ICRM-LLRMT 2022

Report of Contributions

https://icrm2022.lngs.infn.it/

Contribution ID: **1** Type: **Oral Presentation**

Evolution of traceable Radon emanation sources from MBq to few Bq

Friday, 6 May 2022 09:00 (20 minutes)

In the framework of the EMPIR project traceRadon[1] stable atmospheres with low-level, activity concentrations of radon have to be produced for calibration of radon detectors capable of measuring outdoor air activity concentrations. The traceable calibration of these detectors at very low activity concentrations is of special interest, for the radiation protection community, as well as the climate observation community.
Because radiation protection networks (like the EUropean Radiological Data Exchange Platform (EURDEP)) and climate observation networks (like the Integrated Carbon Observation System (ICOS)) need reliable, accurate radon activity concentration measurements, either for identification of Radon Priority Areas (RPA), for false alarm prevention or to apply the Radon Tracer method (RTM) for the estimate of greenhouse gas (GHG) emissions.
To achieve this goal, low activity sources of radium have been produced with different methods and different characteristics. Sources from MBq Ra-226 down to several Bq Ra-226 have been developed and characterized during this evolution and uncertainties below 2 % (k=1) have been reached through dedicated detection techniques, even for the lowest activity sources. The uncertainty of the lowest activity sources is improved by a new online technique, a combination of the source and the detector in the same device. This device named IRSD, reaches a counting efficiency approaching 50 % through detection under quasi 2π sr solid-angle. It is produced with Ra-226 activities between 2 Bq and 440 Bq, already.
To compare the performance of the sources in application, e.g., to establish a reference atmosphere, as well as to study the stability of the sources and to establish traceability to national standards an intercomparison exercise was carried out at the PTB facility.
The different source production techniques, the determination of the radium activity, as well as the radon activity (emanation) and assigned uncertainties are presented. The implementation details of the intercomparison set-up are shown and the results of the characterization of the sources are discussed.

[1]: This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. 19ENV01 traceRadon denotes the EMPIR project reference.

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Presenter: RÖTTGER, Stefan (Physikalisch-Technische Bundesanstalt)

Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **2** Type: **Oral Presentation**

A XENON RADIONUCLIDES DETECTOR FOR NUCLEAR EXPLOSION MONITORING

Tuesday, 3 May 2022 14:30 (20 minutes)

The Comprehensive nuclear Test Ban Treaty (CTBT) is an international effort started in 1996 to stop all nuclear tests. To ensure that the treaty is respected, an International Monitoring System (IMS) has been globally deployed to measure seismic, hydro-acoustic, infrasound and radionuclide signals (particulate and gaseous) from potential nuclear events. The typical signature for such events is the presence of xenon radionuclides in the air.

The Mobile Analyzer of Radioactive Gases OuTflows (MARGOT) is a spectrometer developed to measure trace amounts of ^{131m}Xe, ^{133m}Xe, ^{133}Xe, and ^{135}Xe in air samples, with the objective to be integrated to the gas monitoring stations of the IMS. The MARGOT system is based on the coincidental detection of beta and gamma radiation, using silicon detectors for the electrons and inorganic scintillators combined with photomultiplier tubes for the photons. Its design was motivated by the will to obtain a higher detection efficiency than current detectors, which compromise either on detection resolution or on angle of detection.

The MARGOT system is compact, unshielded, relatively low cost and operates at ambient temperature. In this presentation, the performances of the system will be discussed, and the upgrades in terms of detection and data acquisition will be presented.

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Presenter: DER MESROBIAN-KABAKIAN, Anthony (CEA)

Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **3** Type: **Poster Presentation**

Optimization of gamma-ray spectrometry by Monte-Carlo simulation

Thursday, 5 May 2022 12:50 (20 minutes)

The low-level radioanalysis laboratory is performing part of its measurements of environmental samples using high-resolution gamma spectrometry. These samples are of various t ypes: water, soils, plants, biologicals, aerosols. They are held in different containers for liquids and solids (from few milliliters to 500 milliliters), centering devices are used for aerosol filters.
The laboratory is developing numerical Monte-Carlo models of its pool of HPGe detectors (ranging from small 60 cm^3 planar detectors to large coaxial ones with a volume larger than 250 cm^3). The objectives are multiple, for some geometries radioactive calibration standards are no longer available and the simulation makes it possible to generate efficiency curves for which correction factors (self-absorption and coincidence) are derived from these models. First, a presentation of the development and validation of a numerical model and its uncertainties will be presented. Then, three examples of applications will be shown. The first is the simulation of the efficiency curve for a sample of aerosols filter, with the aim to obtain a numerical model with uncertainties lower than 10% (k=2) for energies > 60 keV and 15% (k=2) for lower energies. The second example will be on the study of equivalent heights necessary for the assessment of the self-absorption coefficients according to the formalism of ISO 18589-3 standard. Finally, a study on the variation of summation correction factors as a function of the sample composition will reopen the debate on this complex but essential subject.

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Presenter: Dr CAGNIANT, Antoine

Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **4** Type: **Poster Presentation**

INFLUENCE OF THE SOLAR ACTIVITY ON THE BACKGROUND OF A HIGH-RESOLUTION GAMMA-RAY SPECTROMETER

Thursday, 5 May 2022 12:50 (20 minutes)

Galactic cosmic rays produce neutrons when they interact with the Earth's atmosphere. In gamma-ray spectrometers these neutrons can be scattered and captured in the materials of the shield and the detector, producing signals in the spectrometer's background. By the end of the eighties, at JSI, a new spectrometer was built, housing a germanium detector with a relative efficiency of 36% in a lead shield with the mass of about 4 tons. To reduce the intensity of the signals due to the neutrons in the spectrometer background about 100 kg of paraffin and plates with boron acid were placed in the shield's cavity. As a consequence of that, the only signatures due to the neutrons and recognized in the spectrometer background were the peak at 2223 keV due to their capture on hydrogen and the Doppler broadened peak at 477 keV due to their capture in 10B. The count rate in the peak at 2223 keV amounted about 11 counts per hour.

Since the flux density of neutrons depends on the intensity of primary cosmic rays striking the atmosphere, it is expected that the variability of this intensity due to its moderation by the solar wind causes a variability of the count rate in the peak at 2223 keV. The intensity of solar wind depends on the number of sunspots, which changes with the solar cycle, having a period of 11 years. Therefore the count rate in the peak at 2223 keV exhibits a time dependence, correlated with the number of sunspots. As a consequence of that a negative correlation is expected to occur between the number of sunspots and the count rate.

Since the year 1996 measurements of the background of this spectrometer exist, therefore it is possible to correlate the count rate in the peak at 2223 keV with the number of sunspots over a time interval lasting more than two solar cycles. Because the solar wind takes a few days to reach the Earth, the correlation was investigated as a function of the shift in time between the start of the background measurement with respect to the date of sunspot number.

The dependence of the correlation coefficient on the shift in time has shown a long-term correlation corresponding to the 11-year solar cycle and a short-term correlation corresponding to sunspots. From the position and the width of the minimum of the correlation coefficient corresponding to sunspots it was possible to assess the speed of the solar wind to (870 ± 590) km/s and the mean duration of the phenomena on the Sun driving the solar wind to 6.8 days. The irregular depression in the dependence of the correlation coefficient preceding the drop corresponding to sunspots indicates that the magnetic fields on the photosphere, causing the solar wind, exist before they reveal their presence by cooling the photosphere and causing sunspots.

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **5** Type: **Poster Presentation**

CALCULATION OF DECISION THRESHOLDS ACCORDING TO THE ISO 11929 (2019) STANDARD IN THE PRESENCE OF PEAKED BACKGROUND

Thursday, 5 May 2022 12:50 (20 minutes)

The standard ISO 11929-3:2019 (ISO 2019) warmly recommends the use of the (generalised) least-squares method (LSQ) in the determination of characteristic limits, calculated from gamma-ray spectra. To calculate the decision threshold, it prescribes the analysis of the spectral region, comprising the most prominent peak of the gamma-ray emitter of interest i.e. the measurand. As the decision threshold is determined by the null measurement uncertainty, the spectrum in the absence of the indication must be analysed. To achieve this, the contribution of the indication must be stripped off the spectrum and the decision threshold is calculated from the uncertainties of the difference, i.e. the background. The variance of the content of an individual channel of the background spectrum is then the sum of the variances of the measured channel content, the calculated channel content depending on shape of the response of the spectrometer to the measurand (shape contribution) and the variance due to the uncertainty of the observed value of the measurand (scaling contribution). While the uncertainty matrix of the measured channel contents is diagonal, because the channel contents are statistically independent, the uncertainty matrix due to the uncertainty of the observed value has off-diagonal elements different from zero, since a change of the uncertainty changes the variances of all channel contents subject to the presence of the measurand. The uncertainty matrix of the calculated channel contents of the response may be diagonal or not, depending on how these channel contents were determined.

The construction of the uncertainty matrix of channel contents, described by the Standard, can't be applied directly to the case when the measurand is present in the background. Its presence may be due to the spectrometer background, the interferences with other gamma-ray emitters or the sample blank. In the presence of sources of peaked background, additional contributions to the uncertainty matrix of channel contents have to be taken into account. For each contribution to the peaked background two contributions to the uncertainty matrix must be included: the first one, due to the channel contents given by the height of the peaked background (shape contribution) and the second one, due to the background height uncertainty (scaling contribution).

In the paper the extension of the Standard to the case when the peaked background is present will be described in detail and numerical examples illustrating the calculation of detection limits in the case of various sources of peaked background having different intensities and uncertainties will be presented.

ISO 2019. ISO 11929-3, Determination of the characteristic limits (decision threshold, detection limit and limits of the coverage interval) for measurements of ionizing radiation – Fundamentals and application part 3: Application to unfolding methods, ISO, Geneva.

Primary authors: Dr ZORKO, Benjamin ("Jožef Stefan" Institute); Mr VODENIK, Branko ("Jožef Stefan" Institute); Dr KORUN, Matjaž ("Jožef Stefan" Institute); Dr PETROVIČ, Toni ("Jožef Stefan" Institute)

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **6** Type: **Oral Presentation**

Emergency Unmanned Airborne Spectrometric (HPGe) Monitoring System

Wednesday, 4 May 2022 11:10 (20 minutes)

Following a nuclear or radiological event, radiation protection authorities and other decision-makers need rapid and credible information about the affected areas based on reliable radiological data. However, the potentially large areas and risks to people in the vicinity pose difficult measurement challenges.
Therefore, European joint research project "Metrology for Mobile Detection of Ionising Radiation Following a Nuclear or Radiological Incident" (Preparedness) in the framework of the European Metrology Programme for Innovation and Research (EMPIR) has developed new measurement techniques and traceable calibration methods for determining ground surface activity.
One of the major outcomes of the Preparedness project is the development of unmanned airborne spectrometric system equipped with a high-purity germanium (HPGe) detector. Considering accident conditions, the system must be reliable and heavy-duty. Therefore, an unmanned helicopter with sufficient payload and flying range is used as a carrier. Spectrometric system enables fast and safe identification of released radionuclides and thus the level of technology disruption and the determination of accident zones with specific conditions. The system will support timely and effective measures to protect the population and the environment from the effects of ionising radiation.
The paper describes adaptation of the HPGe detector for airborne use, testing its performance using standard sources and Monte Carlo modelling. Data collected during the initial flight tests are presented and compared to the Monte Carlo simulations. The data obtained was used to calculate minimum detectable activity for several radionuclide sources and different flight altitudes.
This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

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Presenter: ŠURÁŇ, Jiří

Session Classification: Thematic Session 2: Emergency Preparedness

Track Classification: Thematic Session 2 - Emergency preparedness

Contribution ID: **7** Type: **Oral Presentation**

Latest results from the CUORE experiment

Tuesday, 3 May 2022 09:00 (20 minutes)

The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for 0νββ decay that has been able to reach the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO_2 crystals arranged in a compact cylin-drical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and in April 2021 released its 3rd result of the search for 0νββ, corresponding to a tonne-year of TeO_2 exposure. This is the largest amount of data ever acquired with a solid state detector and the most sensitive measurement of 0νββ decay in ^{130}Te ever conducted, with a median exclusion sensitivity of 2.8×10^{25} yr. We find no evidence of 0νββ decay and set a lower bound of 2.2×10^{25} yr at a 90% credibility interval on the ^{130}Te half-life for this process. In this talk, we present the current status of CUORE search for 0νββ with the updated statistics of one tonne-yr. We finally give an update of the CUORE background model and the measurement of the ^{130}Te 2νββ decay half-life, study performed using an exposure of 300.7 kg·yr.

Primary author: DOMPÈ, Valentina

Co-author: CUORE COLL.

Presenter: DOMPÈ, Valentina

Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **8** Type: **Oral Presentation**

A COINCIDENCE BASED (GAMMA-ALPHA/BETA) SYSTEM FOR VERY-LOW BACKGROUND RADIATION MEASUREMENTS

Tuesday, 3 May 2022 14:50 (20 minutes)

High-accuracy measurements of nuclear and related materials are a useful tool in nuclear forensics, in particular, the characterization of investigated radioactive samples, where very low quantities are available. As an example, the detection of certain isotopes may be used as a distinctive signature of the nuclear cycle, irradiation time, fluxes etc. for the attribution of the sample to a particular reactor facility. Low-background measurements are useful for supporting the verification regime of the Comprehensive Test Ban Treaty Organization (CTBTO), where the detection of certain fission (and/or activation) products in air filter samples can indicate the occurrence of nuclear explosions (e.g. 140Ba and 133Xe). Additional applications of low-background measurements can be found in studies involving fundamental physics and environmental radioactivity.
Traditionally, radionuclides are identified and quantified by detecting one type of their radioactive emissions. Gamma/X-rays are usually detected using high-purity germanium (HPGe) or NaI, whereas alpha and beta particles are typically detected by a proportional counter, silicon detector or plastic/liquid scintillator. Systems based on multi-particle detection in coincidence mode (alpha/gamma, beta/gamma and gamma/gamma) hold the potential for providing excellent signal-to-noise ratio, compared to the traditional (single emission-based) systems [1-3]. Another major advantage of coincidence-based systems is their relatively lower cost and competitive sensitivity compared to underground laboratories.
An innovative low-background multi-detector system is being developed in Soreq NRC. The proposed setup comprises a HPGe detector, a liquid scintillator cell read by a photomultiplier tube and plastic scintillator panels (for cosmic radiation reduction). The geometric configuration provides a detection efficiency of nearly 90% for alpha and beta particles and a typical detection efficiency of ~3% for gamma-rays in single-emission mode. Preliminary tests of a prototype system configuration in coincidence mode exhibit a minimal detection activity of 0.1 Bq for Am-241 during a measurement time of 16 hours. By incorporating dedicated electronics and software, it is possible to observe the different data aspects associated with the decay. Energy and timestamp are recorded event-by-event for each particle type, thereby allowing to perform off-line analysis of the entire dataset and make use of the various detection modes. In addition, future developments of the system will include additional features such as alpha/beta discrimination and alpha spectrometry.
Results from first characterization tests of the system will be presented and several potential applications of will be discussed.

[1] J.L. Burnett et al. Journal of Radioanalytical and Nuclear Chemistry 312, 81-86 (2017).

[2] A. Ringbom et al. Nuclear Instruments and Methods in Physics Research A 508, 542-553 (2003).

[3] P.P. Povince. Journal of Radioanalytical and Nuclear Chemistry 316, 893-931 (2018).

Primary authors: Dr ARAZI, Lior (Ben-Gurion University of The Negev); Dr BRANDIS, Michal (Soreq Nuclear Research Center); AVIV, Ofer; Mr NISSIM, Safi (Soreq Nuclear Research Center)

Presenter: AVIV, Ofer

Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **9** Type: **Poster Presentation**

The upgraded low-background germanium counting facility Gator for high-sensitivity γ-ray spectrometry

Thursday, 5 May 2022 12:50 (20 minutes)

The Astroparticle Physics Group at the University of Zurich operates the high-purity germanium (HPGe) γ-ray spectrometer Gator in a low-background environment at the Gran Sasso Underground Laboratory in Italy. It is used to screen and select materials for rare-event search experiments such as XENON, DARWIN, GERDA and LEGEND. The 2.2 kg HPGe crystal is surrounded by a passive shield made of layers of copper, lead and polyethylene, and the sample cavity is purged with gaseous nitrogen for environmental radon suppression. After upgrades of the shield enclosure, the background rate is (82.0 ± 0.7) events/(day kg) in the energy region 100 - 2700 keV. We describe the general facility, the recent upgrades and their impact on the background level. We also demonstrate its sensitivity by presenting the results for several material samples.

Primary author: Mr BISMARK, Alexander (University of Zurich)

Co-authors: Prof. BAUDIS, Laura (University of Zurich); Dr GALLOWAY, Michelle (University of Zurich)

Presenter: Mr BISMARK, Alexander (University of Zurich)

Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **10** Type: **Oral Presentation**

Radionuclides in glaciers: a study of the Adamello ice core

Thursday, 5 May 2022 09:00 (20 minutes)

ABSTRACT
Alpine glaciers are among the most sensible indicators of climate change. Physical changes in glaciers are in fact a direct and visible evidence of a change in temperature and precipitation regime. Glaciers are also natural archives, registering during their lifetime information about past temperature, precipitations, atmospheric composition. Ice cores give the possibility to access this information and thus reconstruct past environmental conditions of the surrounding area. Considering the many chemical and physical parameters that it is possible to study in ice cores, radionuclides play an important role. They are typically transported following atmospheric pathways and deposited on the surface of glaciers. The stratigraphic signal of some radionuclides can be used as an aid to ice core dating, marking temporal horizons. In addition, inventories of anthropogenic radionuclides in glaciers and alpine environments can be used to reconstruct production, diffusion and deposition of such radionuclides in the environment.
The present work was conceived to better understand how radionuclides, and in particular 137Cs and 3H, behave in temperate glaciers. Temperate glaciers experience frequent melting episodes, which occur during summer. For this reason, it is expected to find some level of alteration along the stratigraphy.
The aim of this work is to use a combination of liquid scintillation counting and gamma ray spectroscopy to reconstruct a profile of 137Cs and 3H in the Adamello ice core.
This work focuses on the study of the 45m ice core drilled at Pian di Neve site, Adamello glacier, in the Italian Alps, during summer 2016. Analysis were initially carried out on the chips of the ice core, which were divided in 71 runs covering the entire length of the ice core. Samples were filtrated prior to analysis: the filter was analyzed for radiocaesium, which is mainly bound to particulate matter, with a germanium well detector; the filtrated water was prepared for tritium analysis.
Further analysis on ice core samples were performed on samples corresponding to the depth at which the highest radioactivity peak was found (30-35m). This allowed to improve the temporal resolution of the radioactivity profile.
Measurements show a radioactivity profile along the ice core with distinct peaks of 137Cs and 3H. The main events taken into account to explain the release of radionuclides in the atmosphere and possible subsequent deposition are the nuclear tests that took place before the Partial Test Ban Treaty (PTBT) entered into force in 1963 and the nuclear accident occurred in Chernobyl in 1986. The annual release of megatons due to the nuclear test explosions which were carried out in the year 1963, prior to the PTBT, was compared to the activities measured in the ice core samples, and a correlation was found. A shallower section of the ice core also showed contamination of 137Cs, but not of 3H, compatible with historical data on the Chernobyl accident.
In conclusion, we present a complete radioactivity profile of ice core with an average resolution of 50cm, and a focus for the 30-35 section with a resolution of 5cm. This profile shows that it is indeed possible to extract a readable signal from the stratigraphy of the ice core and allows some considerations on the melting that has occurred on the Adamello glacier in the past decades.

Primary authors: Dr DELMONTE, Barbara (Environmental and Earth Sciences Department, University Milano-Bicocca); DI STEFANO, Elena (Istituto Nazionale di Fisica Nucleare); Dr BACCOLO, Giovanni (Environmental and Earth Sciences Department, University Milano-Bicocca,); CLEMENZA, Massimiliano (Istituto Nazionale di Fisica Nucleare); Prof. MAGGI, Valter (Environmental and Earth Sciences Department, University Milano-Bicocca)

Presenter: DI STEFANO, Elena (Istituto Nazionale di Fisica Nucleare)

Session Classification: Thematic Session 1: Studies of Climate Change

Track Classification: Thematic Session 1 - Studies of climate change

Contribution ID: **11** Type: **Oral Presentation**

SOIL GAMMA-RAY SPECTROSCOPY FOR PRECISION AGRICULTURE WITH HPGE DETECTORS: A FULL METHOD FOR RADIONUCLIDES SPECIFIC ACTIVITY ESTIMATION FOR IN-SITU MEASUREMENTS THROUGH MONTE CARLO SIMULATIONS

Monday, 2 May 2022 10:50 (20 minutes)

Efficient soil exploitation in agriculture has always been a crucial issue. Nowadays, valid results in precision agriculture cannot be pursued without a multi-source analysis of soil properties, which must be carried forward by different and complementary techniques. Indeed, spectroscopy (VNIR-SWIR, gamma), remote-sensing, proximal electromagnetic and geo-chemical analysis are all essential for complete soil characterization. Pignoletto collaboration [1], coordinated by INFN of Milano Bicocca, aims to provide the best tools and guide-lines for precision agriculture, by integrating these parallel efforts and developing methods for the rapid characterization of agricultural terrains through remote and proximal devices (drones and rovers). Soil gamma-ray spectroscopy is particularly suitable since it provides bulk information about radionuclides concentration in the ground, which can be correlated to the presence of soil constituents (like organic matter, clay, silt) [2][3][4]. Measurements are performed with HPGe detectors, since their overall performance in efficiency and resolution allows to take precise measurements on soil samples in laboratory (CANBERRA BEGe detector) and quick acquisitions in the field (portable HPGe ORTEC-DETECTIVE-X). The main goal is to achieve precise in-situ estimations of radionuclide specific activity (Bq/kg) comparable with those achieved in laboratory. In fact, acquiring data on an extended field source makes the estimation of radionuclide concentration trickier, but at the same time it permits faster coverage of large areas and non-invasive soil analysis. Since a portable detector on the ground has a specific field of view, which may be influenced by many factors like soil composition, density and shape, Monte Carlo simulations are essential in order to estimate detector efficiency in different set-ups. MC code Arby, based on Geant4, is employed to estimate detectors efficiency and to take into account how soil source parameters affect the acquisition. Portable HPGe is employed in three main set-ups: lying on the ground, placed on a tripod or suspended few meters above the ground (as it will be implemented on drones). Simulations allow to estimate, in each case, HPGe efficiency and field of view for different emitted gamma energies. Coefficients can be extracted which allow to convert gammas count rate in concentration measurements (Bq/kg). Finally, simulations also suggest the optimal grid which the detector must follow in order to grant complete and rapid soil analysis, depending on detector height, soil density and terrain constituents variability.

[1] https://pignoletto.mib.infn.it
[2] Elejalde C., et al. Correlations between soil parameters and radionuclide c contents in samples from Biscay (Spain). Water, Air, and Soil Pollution, 1996
[3] Claudia Dierke, Ulrike Werban, Relationships between gamma-ray data and soil properties an agricultural test site. Geoderma, 2013
[4] Reinhardt, N. and Herrmann, Gamma-ray spectrometry as versatile tool in soil science: A critical review. J. Plant Nutr. Soil Science, 2019

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **12** Type: **Poster Presentation**

A Radioacitivity Survey of Commercially Available PTFE from European Suppliers

Thursday, 5 May 2022 12:50 (20 minutes)

Due to its optical and electrical properties, polytetrafluoroethylene (PTFE) is an indispensable construction material for many modern rare event searches. Thus, the radioactive contamination of PTFE therein needs to be as low as possible. We present a cross-sectional study investigating the radioactive contamination of PTFE samples from major European suppliers of raw PTFE. The bulk contaminations of the samples were measured utilizing ICP-MS and HPGe gamma spectrometry, and the radon surface emanation was assessed with a recently commissioned electrostatic radon detector.

Primary author: BAUR, Daniel Peter

Presenter: BAUR, Daniel Peter

Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **14** Type: **Oral Presentation**

Sequential analysis of ultra-trace levels of ^{3}H, ^{137}Cs, Pu and U radionuclides in ice samples

Thursday, 5 May 2022 09:20 (20 minutes)

Surface glacier ice maintains historical records of global fallout radionuclides from the atmospheric nuclear weapon testing (NWT) period. These radionuclides have found important applications for developing and/or validating ice core chronologies and ice flow models. Among the artificial radionuclides, plutonium-239 (^{239}Pu, half-life: 24 100 yr), plutonium-240 (^{240}Pu, half-life: 6 561 yr), cesium-137 (^{137}Cs, half-life: 30.05 yr) and tritium (^{3}H, half-life: 12.31 yr) have found important use in dating ice cores with ages up to 70 yr old. Uranium-236 (^{236}U, half-life: 2.3 107 yr) is less reported, mainly due to the high analytical demands to detect it. Pu and U are present typically at very low levels in ice, and needs to be purified from the matrix and potential interferences in order to measure them accurately. ^{137}Cs is as well present at trace levels in ice, and usually needs to be pre-concentrated before any measurement can be done.

We present a radiochemical procedure for the sequential determination of ^{3}H, ^{137}Cs, Pu and U radionuclides in ice samples. The method was validated using in-house spiked water samples and a certified reference material (IAEA-381). After melting, the ice samples are acidified to pH 2. An aliquot of 50 mL is distilled for ^{3}H analysis. The distillate is counted with an ultra-low level LSC Quantulus 1220. A detection limit for ^{3}H of 1.1 Bq kg^{-1} was achieved for a counting time of 1440 min. About 20 mL of the sample is taken to analyze the U content in a sf-ICP-MS Element 2. This information is used to calculate the U separation yield and to quantify ^{236}U in the final U fractions. The remaining water is spiked with stable Cs (about 1 mg) and ^{242}Pu (0.3 pg) as yield tracers. Cs isotopes are extracted on a AMP-PAN resin, then eluted in a 15 mL geometry and finally counted with high-resolution gamma spectrometry using HPGe detectors. The Pu and U radionuclides are concentrated by co-precipitation with $Fe(OH)_3$. After dissolution, Pu and U radionuclides are separated and purified using the extraction chromatography resins TEVA and UTEVA. Pu and U radionuclides are measured with a MC-ICP-MS Neptune.

The results of the method validation, including accuracy and precision for each radionuclide, are presented. We show some results obtained in surface ice samples collected at the Aletsch Glacier, in Switzerland. In this particular study, we aimed at investigating the absolute age of glacier surface ice. For Pu and U radionuclides, the atom ratios $^{240}Pu/^{239}Pu$ and $^{236}U/^{239}Pu$ in glacial ice are also reported.

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Presenter: CORCHO, José

Session Classification: Thematic Session 1: Studies of Climate Change

Track Classification: Thematic Session 1 - Studies of climate change

Contribution ID: **15** Type: **Oral Presentation**

Low-background gamma spectroscopy and neutron diffraction in the study of stony meteorites

Monday, 2 May 2022 11:10 (20 minutes)

The study of the origin of the Solar System can gain significant information from the characterisation of meteorites. However, these samples are quite rare and it is therefore of paramount importance to settle a completely non-destructive analysis procedure to preserve these materials. The idea is to perform a set of bulk and surface analysis in order to identify a rock as a meteorite and to characterise it in terms of its elemental and mineralogical composition.
In this framework, gamma-ray spectroscopy allows to identify the presence of cosmogenic radionuclides which are formed by the exposure to galactic and solar cosmic rays. Particularly important are ^{60}Co (5.27 years) and ^{26}Al ($7 \cdot 10^5$ years). As a consequence, if the meteorite specimens are small or the date of the fall is expected to be more than a few half-lives of ^{60}Co ago, low-background spectroscopy is needed, due to the low radioactivity levels. In our case, low-background gamma spectroscopy has been carried out at the STELLA facility within the LNGS, where we identified an average activity of (0.71 ± 0.05) Bq/kg for ^{26}Al, which is consistent with the meteoric origin of the studied sample.
The great depth of penetration of neutrons in materials can be exploited to perform a bulk non-destructive analysis. In particular, we carried out Time-of-Flight Neutron Diffraction (ToF-ND) at the INES diffractometer at the ISIS Neutron and Muon Source in order to disclose the mineral phases contained in the sample, which can yield important information about the formation of the proto-planet from which the sample originated. The data analysis, performed with the Rietveld refinement procedure, enables to quantify and characterise the mineralogical phases within the sample. In our case, ToF-ND showed the presence of magnesium-based silicate minerals together with some pure and altered iron-based mineral phases.
Finally, by micro-Raman spectroscopy (μRS) and Energy Dispersive X-ray Spectroscopy (EDS), we derived the mineral and elemental composition of the sample, with the benefit of space-resolved measurements. In particular, the combined application of these techniques returned important information about the composition of each structure, including the glass and the iron alloys, which could not be studied with ToF-ND in detail as they are minority phases. Furthermore, these techniques returned important information which helped in the analysis and interpretation of data taken with other techniques.
In conclusion, our protocol has been successful in the characterisation of a stony meteorite and it will be applied to other classes of meteorites in order to verify its range of feasibility.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **16** Type: **Oral Presentation**

RADON CALIBRATION PROCEDURES

Friday, 6 May 2022 09:20 (20 minutes)

The implementation of Directive 2013/59/EURATOM and the related modifications to national laws establishing reference levels of radon activity concentration, contributed to the increased interest in accurate radon measurements. Therefore, there was a need for calibration of radon instruments at reference concentrations below 300 Bq/m^3 with quality assured procedures and uncertainties that provide a reasonable basis for decision-making.

One of the most important aspects of the reliability of radon activity concentration measurements is ensuring traceability by providing regular calibration of the instruments in the region of the activity concentration of its later application. To achieve this, it is necessary to provide a radon chamber to contain the radioactive reference atmosphere for the calibration, a reference instrument (if this reference atmosphere is not a primary one) traceable to the primary or secondary standard, a well-characterized radon source, developed uncertainty budgets, standardized calibration procedures, and a quality assurance program. Though this principle was established during the past decades, the activity concentrations below 100 Bq/m^3 have not been subject to metrological research so far. This situation changed with the EMPIR 19ENV01 traceRadon which started in 2020 because here radon is not only addressed as the largest natural source of public exposure to ionizing radiation but also as a useful tracer for understanding atmospheric processes and estimating greenhouse gas emissions. That is why reliable measurements of low-level radon activity concentrations, such as those found in the environment (<20 Bq/m^3), are important both for organizations responsible for radiation protection and climate research. The general aim of the project is the development of traceable methods and robust technology for measurements of environmental low-level radon activity concentrations and radon fluxes, Both are important to derive information on greenhouse gas fluxes in the environment and therefore important for reduction strategy planning. The following metrological activities have been carried out so far: development of radon activity standards, calibration of low-level atmospheric radon concentration monitors, development of reference infrastructure for radon flux from the soil, calibration of continuous radon flux monitors in the field, and validation of radon flux models and inventories.

The development and implementation of calibration procedures at low-level radon activity concentrations and the improvement of existing solutions is a constant challenge for European laboratories. This study contains the most important information on the existing calibration procedures, an overview of available sources, suitable equipment used for the calibration of radon monitors, as well as future challenges.

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Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **17** Type: **Poster Presentation**

ALGORITHMS DEVELOPMENT FOR LOW LEVEL RADIOXENON SPECTRUM ANALYSIS

Friday, 6 May 2022 10:20 (10 minutes)

Underground or underwater nuclear tests can eventually lead to radioxenon releases in the atmosphere. In this scope, the verification regime of the Comprehensive nuclear Test Ban Treaty installed dedicated noble gas systems for the detection of low-level radioxenon activity in the air. Recent development of these noble gas systems included new detector technologies. They exhibits very low background count rates. In this case, radioxenon signal as low as a few counts per 12h are expected. Therefore, for such low count measurement, classical Currie law estimation for measurement detection threshold and detection limits are not precise enough. To deal with this issue, the CEA/DAM implemented several algorithms (matrix inversion, iterative process, spectral unmixing).
Also, as it is not convenient to test and compare these algorithms on measured low level spectra of radioxenon, a Monte-Carlo simulated database of spectra was generated, for several detection configuration (high resolution beta/gamma spectra, low resolution gamma/high resolution beta spectra, and low resolution beta/gamma spectra).
This work will be presented, and algorithms key performance indicators for each detector configuration will be compared.

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Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **18** Type: **Oral Presentation**

Neutron tagging with gadolinium loaded PMMA

Tuesday, 3 May 2022 09:20 (20 minutes)

DarkSide-20k is a direct dark matter search experiment, that looks for Weakly Interacting Massive Particles (WIMPs) events. The detector is based on an ultrapure liquid Argon double-phase Time Projection Chamber, which will be located at Laboratori Nazionali del Gran Sasso. In the rare event search experiments (like the DarkSide case), it is crucial to keep under control any background sources. In particular, one of the most dangerous background sources are neutrons, which could
induce nuclear recoils, producing a signal indistinguishable from that of the WIMPs. The strategy adopted in the DarkSide-20k experiment is to build a neutron veto detector, made of a thick plastic layer containing gadolinium, which has a high neutron capture cross section. The construction of 17 cm thick plates made of polymethylmethacrylate (PMMA) doped with a compound containing gadolinium was therefore adopted. The choice of PMMA is due to the high hydrogen content of this polymer, to moderate the neutrons. Then thermal neutrons will be captured on the gadolinium nuclei and will be revealed, exploiting the subsequent emission of an easily-detectable high energy γ ray cascade. All the components of the composite material must be screened to identify any traces of elements (such as uranium, thorium and potassium) whose descendant radioactive isotopes could affect the performance of the experiment. The screening is performed with Inductively Coupled Plasma Mass Spectrometry (ICPMS) and with germanium detectors. The DarkSide collaboration foresees two possible strategies for the realisation of gadolinium doped PMMA sheets, using two gadolinium-containing compounds: gadolinium acetylacetonate ($Gd(C_5H_7O_2)_3$) and gadolinium oxide (Gd_2O_3) in the form of nanograins. The two candidates have both positive and negative aspects: for instance the gadolinium acetylacetonate is miscible in MMA (the liquid monomer), but its synthesis on an industrial scale is quite complex and requires particular attention in each step to avoid any contamination. On the other hand, it is possible to easily find gadolinium oxide nanograins at a level of radiopurity that meets the standards required by DarkSide (this aspect has been verified through germanium screening and ICPMS). However, the nanograins are not miscible in MMA, therefore they must be treated with a suitable surfactant that prevents their sedimentation, in order to obtain pieces with a reasonably homogeneous gadolinium dispersion. The surfactant concentration must be kept under control, since each additional material represents a possible source of background. Overall, 20 tons of material are required to build the detector. The R&D projects are almost finalized: laboratory scale samples have been produced with both techniques. At the moment, tests on an industrial scale are ongoing.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **19** Type: **Oral Presentation**

INTERCOMPARISON EXERCISES AS A TOOL FOR IMPROVING THE QUALITY OF RADIOCHEMICAL MEASUREMENTS IN DRINKING WATERS

Monday, 2 May 2022 14:50 (20 minutes)

In last years the demand of radiometric analysis of drinking waters greatly increased due to the transposition of the EU Drinking Water Directive 2013/51/Euratom (E-DWD) into national legislation of EU member states. In order to assess compliance with parametric values given by the Euratom Directive, gross alpha/beta (GAB), ^{3}H and ^{222}Rn measure-ments are basically requested. The number of laboratories providing such analytical services conse-quently increased and, despite the availability of internationally recognized procedures, problems on analytical data reliability emerged, especially for GAB measurements since it is a screening parameter strongly depending on the chosen experimental setups. Results of the interlaboratory comparison on GAB activity run by EC-IRMM in 2012, for example, enlightened an overall critical situation regardless of the techniques used.

A strict cooperation among JRC, ARPA Lombardia and JSI allowed to employ intercomparison results as collaborative studies to define accuracy and reproducibility of results provided by laboratories on the basis of their operational procedures. Firstly, results of an intercomparison of ^{222}Rn in water were analysed with interesting outcomes, secondly the results of a European proficiency test on GAB activity in water were examined at the same purpose. Finally, with the aim to identify and specify the real problems encountered by laboratories in low level GAB measurements, a specific intercomparison has been organised in Italy with the accredited provider UNICHIM. Untreated natural water samples were distributed to approximately 30 laboratories, both public and private, together with a very complete questionnaire which allowed to consider not only the adopted experimental setups but the complete data processing as well. Alpha and beta activity concentrations in the samples were close to those requested by the E-DWD. The evaluation was restricted to the measuring procedure EN ISO 11704 which employs liquid scintillation counting (LSC) for GAB measurements. Reference values were established with the help of 7 expert European laboratories. A careful analysis of provided results, together with questionnaire answers enlightening specific aspects of experimental setups and data processing adopted by laboratories, allowed to get useful information on the reproducibility and the accuracy of the ISO procedure and to identify weak points in its application by laboratories. In a final national workshop, all these items were widely discussed and strategies for improving analytical outcomes suggested as well. Bearing in mind that GAB is a screening parameter, and its determination is inherently affected by unavoidable variability factors, actions based on results of intercomparison exercises are needed to improve reliability and comparability of data relevant to assess compliance to European regulations.

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Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **21** Type: **Oral Presentation**

MACHINE LEARNING IN ENVIRONMENTAL RADON SCIENCE

Monday, 2 May 2022 11:30 (20 minutes)

Acknowledged to be a relevant hazardous agent and the most important contribution to ionizing radiation exposure, in most cases, radon (Rn – mostly referring to 222Rn, but in some context also to 220Rn) has therefore been subject to regulation and to intense scientific interest for many years. Temporal dynamic as well as spatial variability of environmental Rn are controlled by a number of factors such as meteorology, lithology, soil properties, hydrogeology, tectonics and seismicity. In addition, indoor radon concentration and the one of its short-lived progeny (which cause the actual radiological problem) are subject to anthropogenic factors, such as physical characteristics of a building and usage pattern.

The causal relationships between controlling factors and response variables – Rn concentration in an environmental compartment as function of time and long-term mean concentrations as function of geographical location – are mostly complicated and difficult to model, although the underlying physical processes are simple. Predictors are often intercorrelated or badly known. On the other hand, understanding and being able to predict temporal and spatial Rn dynamic are important for these reasons: (1) Rn maps are important tools of decision making in Rn policy and implementing regulation whose objective is reducing Rn exposure; (2) Analysis of Rn time series is a tool to exploit the potential of Rn as tracer of environmental processes which manifest in signals in time series.

Traditional tools are classical geostatistics for spatial analysis and prediction, most commonly methods belonging to the kriging family, and time series analysis methods such as ARMA-type approaches and multivariate linear regression, among other. However, in particular in high-dimensional multivariate settings and complicated dependence structure of covariates, these traditional methods seem to have come to an end or need to be supplemented by new ones.

New tools belong to what is commonly called machine learning (ML). Here, algorithms learn from the data, without need of defining dependence models beforehand, in general. The algorithm establishes a data-driven model which honours the (often partly hidden) dependence structure; this has the disadvantage that it does not yield a physical explanation of the effect. On the other hand, experience shows that the predictive power can be substantially higher than the one of traditional approaches.

We give a short overview on ML methods and discuss their respective merits, their application and ways of validating results. We show examples of 222Rn mapping in Europe based on ML involving a number of geogenic predictors, and of analysis of time series of a long-tem experiment being carried out in Chiba, Japan, involving soil and indoor Rn and thoron (Tn, 220Rn) concentrations and meteorological covariates, whose ultimate target is identifying seismic signals in Rn time series, and even predicting seismicity based on detecting signals of seismic precursors in Rn dynamic.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **24** Type: **Oral Presentation**

Measuring the half-life of Po-215 by low-level liquid scintillation counting

Tuesday, 3 May 2022 15:10 (20 minutes)

The radioactive isotope of ^{215}Po is a part of the decay chain historically known as the actinium series, which starts with the naturally occurring ^{235}U and ends in the stable isotope of ^{207}Pb. When neglecting ^{215}At, which is only present in insignificant amounts, ^{215}Po is the progeny with the shortest half-life (of about 1.8 ms) in the decay chain.
Due to the limited time scale, a simple half-life determination by measuring the diminishing activity of a chemically separated sample as function of time is not feasible. Instead, one has to apply the so-called delayed coincidence method, in which the distribution of the lifetimes of individual ^{215}Po nuclei is measured. In previous experiments, this was achieved by e.g. placing a thin ^{227}Ac sample in between two silicone surface barrier detectors and measuring the elapsed time between the alpha decay of ^{219}Rn and the following alpha decay of ^{215}Po itself.
In this paper, we present an alternative approach using liquid scintillation counting (LSC) in combination with digital data acquisition and offline data an alysis. The use of LSC simplifies sample preparation and handling but provides limited energy resolution compared to silicone surface barrier detectors. However, due to the fact that all other members of the actinium series have half-lives which are several magnitudes longer than the one of ^{215}Po, the discrimination between different alpha energies is not strictly necessary. By limiting the source activity so that the average time gap between two alpha decays becomes considerably longer than the half-life of ^{215}Po, an indirect selection of alpha events can be achieved. On a timescale equivalent to 10-15 half-lives of ^{215}Po, the time difference distribution of event pairs related to the same ^{215}Po nucleus would result in Poisson statistics, whereas uncorrelated alpha decays observed on the same time scale would contribute to a constant background.
For our experiment, a single LS sample was prepared from aqueous solution of ^{227}Ac in standard 20 mL polyethylene vials using Ultima Gold AB scintillator. The initial ^{227}Ac activity was approximately 0.5 Bq. The vial was then measured in a custom-built triple-to-double coincidence ratio (TDCR) counter, equipped with 3 photomultiplier tubes (PMT). During the measurement all observed events were recorded in list-mode format by a fast digitizer. The half-life determination took place offline by studying the time difference distribution of triple coincidence events, where all PMTs fired within 40 ns.
The measurement is still ongoing, but the obtained preliminary half-life of 1.779 (7) ms (based on data taken over a period of 40 days) is in good agreement with the currently recommended value of 1.781 (4) ms for 215Po. This shows the feasibility of the above-described approach. Further details of the measurement and the final result will be presented at the conference.

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Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **26** Type: **Oral Presentation**

AN INNOVATIVE METHOD FOR DETERMINATION OF URANIUM ISOTOPES IN SOILS BY ALPHA-SPECTROMETRY COUPLED WITH MICROTHENE-TOPO COLUMN

Friday, 6 May 2022 12:10 (20 minutes)

Determination of the low-level activity concentrations of uranium isotopes in soil samples are very important in many fields, including nuclear industry, environmental science, radioecology, geology and geochronology. As early as 2002, our laboratory has started to develop a method for determination of uranium isotopes by α-spectrometry in soil samples, which was based on fusion with Na_2CO_3 and Na_2O_2 at 600 ℃, leaching with HNO_3, silicate mineralization with HF, coprecipitation as hydroxides, Microthene-TOPO (tri-octyl-phosphine oxide) column extraction, elution with $(NH_4)_2C_2O$ source preparation by electrodeposition and measurement by α-spectrometry.
An improved method have been published later in 2004.

Experience has shown that whether or not to remove silicates from the leaching solution is very important to the separation and determination of uranium isotopes. Because any silicon gel present in the leaching solution may block the column and make the uranium separation from other interfering α-emitting nuclides less effective, even failed. In fact, the α-particle energy of many natural radionuclides is nearby that of uranium isotopes. The most critical nuclide is ^{210}Po, whose energy (E_α: 5.30 MeV) almost coincides with that of ^{232}U (E_α: 5.32 MeV) that is commonly used as an yield tracer. Therefore, ineffective separations surely interfere with accu-rate determination of uranium isotopes by α-spectrometry.
In the early procedures, the silicates were mineralized with HF. The treatment can remove some part of silicates as volatile SiF_4, and other part still remains in the leaching solution. Although the procedure works well, the treatment with HF is time-consuming and toxic not only for workers but also for environment. In order to further improve the method, a new procedure was developed, in which silica was coated with polyethylene glycol 2000 (PEG) in HNO_3 and the colloidal silica was allowed to settle down and finally was removed from the leaching so-lution through filtration. For method validation, reference materials supplied by the IAEA were analysed based on the new established method. The results showed that all the ^{238}U, ^{234}U and ^{235}U concentrations obtained are in good agreement with the recommended or information values. Therefore, the new method can provide reliable results. The method has also been applied to analyse some different kinds of environmental soils, showing that (1) the yields are high and stable, (2) no ^{210}Po and thorium isotopes are observable in the uranium sources prepared with the recommended procedure, and (3) it is time-saving and has good suitability for soils.

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Session Classification: Radiochemistry

Track Classification: Radiochemistry

Contribution ID: **27** Type: **Oral Presentation**

Low level measurements for rare nuclear transitions in Hf isotopes

Tuesday, 3 May 2022 09:40 (20 minutes)

Recently, efforts have been made to improve the low-level measurements in Hf isotopes. In particular a passive approach, using a gamma-ray spectrometry technique, and active one, using the so-called "source = detector" approach have been adopted and here summarized. Both the techniques are implemented and optimized to investigate rare nuclear decays in Hf nuclides, such as α decay to the ground level and to the first excited state and double β decays of ^{174}Hf. An experiment to measure low-level radioactive contaminants of a Cs_2HfCl_6 (CHC) crystal scintillator has been carried out at the STELLA (SubTErranean Low Level Assay) facility at the Gran Sasso National Laboratory of the INFN, Italy. Such an experiment has preliminary profit of measurements using inductively coupled plasma mass spectrometry (ICP-MS) and HP-Ge diode to estimate the radiopurity level of the CHC. This crystal represents one of the promising new scintillating materials for γ spectroscopy also in the field of low-level measurements. It offers a light output of more than 50000 photons/MeV, high energy resolution and an excellent ability for pulse shape discrimination (PSD) between $\gamma(\beta)$ and α particles. The residual contaminations of the CHC crystal with a mass of 6.90(1) g were estimated using the above-mentioned techniques. The results on rare nuclear transitions in Hf isotopes (mainly in the ^{174}Hf isotope) and the perspectives of such measurements will be presented here.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **28** Type: **Poster Presentation**

Montecarlo simulation of dose contribution from environmental sources to a biological system in the RENOIR Radiobiology Experiment at INFN-LNGS

Monday, 2 May 2022 12:50 (15 minutes)

The RENOIR radiobiology experiment focuses on the study of the underlying biophysical mechanisms that trigger the different biological response observed in external laboratory with respect to the underground LNGS laboratory, where the cosmic ray flux is reduced by a factor of 10^6 and the neutrons flux by a factor of 10^3. A detailed characterization of the radiation spectrum is crucial for this kind of study, as well as an investigation on whether all the components of the natural radiation field weigh in the same or in different way to trigger the biological responses. We apply Montecarlo simulations to the estimate of the dose contribution from different environmental sources (muons, photons, and neutrons) to the biological system under study in the RENOIR project. We use as input particle flux measurements performed above ground and a detailed description of the geometry and of the materials of the experimental setup, to calculate the impact on the dose rate from each particle source. The results will be used to build a careful modeling of the experimental conditions for the RENOIR radiobiology experiment, that will help the interpretation of the biological results.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **30** Type: **Oral Presentation**

Production and characterization of a ^{222}Rn - emanating stainless steel source

Friday, 6 May 2022 09:40 (20 minutes)

Future liquid xenon detectors require unprecedented low levels of intrinsic radioactive backgrounds. Particularly ^{222}Rn and its subsequent decay products represent threatening background sources for the sensitivity of such experiments. Therefore, extensive radon screening campaigns, as well as studies on novel approaches for radon mitigation, need to be carried out. They both crucially depend on infrastructure allowing to measure radon at very low activities. For the correct quantification of detection efficiencies as well as radon mitigation factors, reliable sources of known and stable radon emanation are required.
A new approach to producing clean radon sources by implantation of ^{226}Ra ions into stainless steel has been investigated. In a proof of principle study, two stainless steel plates have been implanted at the ISOLDE facility located at CERN. Results from a complete characterization of the sources will be presented. Each sample provides a radon emanation rate of about 2 Bq which has been measured using electrostatic radon monitors as well as miniaturized proportional counters. Additional measurements using HPGe and alpha spectrometry as well as measurements of the radon emanation rate at low temperatures were carried out. Limitations, improvements and possible applications of this technique will be discussed.

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Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **31** Type: **Oral Presentation**

Rapidly deployable radioactivity-in-air monitoring systems for nuclear and radiological preparedness

Wednesday, 4 May 2022 12:30 (10 minutes)

Following a nuclear or radiological event, fast and appropriate radiation protection measures, based on reliable radiological data, are of high priority for decision makers worldwide. The nuclear accidents in Chernobyl (1986) and Fukushima (2011) are major examples where such protection measures were crucial. During events where a large radioactive plume is released to the atmosphere, it is essential to measure the radioactivity-in-air concentration to monitor the progression of the radioactive cloud. It is also vital, in the immediate and medium term, to monitor the air to ensure the safety of first responders, recovery workers and the local population as resuspension of locally deposited contamination may occur. Transportable air samplers equipped with high-resolution gamma spectrometers offer a flexible and economic solution to this dynamic monitoring requirement. Presented is an overview of three such systems that are being developed through the EMPIR "Preparedness" project. The first system, which utilises a modern co-planar grid CdZnTe detector, is a compact, light-weight system suited for use by first responders. The second system is a rapidly deployable, rugged air sampler with high sensitivity $CeBr_3$ scintillator detector. This instrument is built into a flight case, is easily re-deployed by one person with a car, and is suited for use by recovery workers. The final system is a semi-permeant, high-volume air sampler with electro-mechanically cooled HPGe gamma-spectrometer. The modular design provides benefits through optimised utilisation of expensive components (e.g. HPGe) and rapid commissioning. The system also utilises novel, low-background bricks that can be built around the instrument to provide shielding from ground contamination.

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Presenter: BELL, Steven (National Physical Laboratory)

Session Classification: Thematic Session 2: Emergency Preparedness

Track Classification: Thematic Session 2 - Emergency preparedness

Contribution ID: **32** Type: **Oral Presentation**

Monte Carlo simulation of background components in low level Germanium spectrometry

Thursday, 5 May 2022 11:10 (20 minutes)

This talk presents the decomposition of the background spectra of the 4 screening detectors GeMPI 1 - 4 at the Gran Sasso Underground Laboratory (LNGS) using Monte Carlo simulations in the Geant4 based framework MaGe. The GeMPI detectors are low background Ge spectrometers located at a depth of 3500 m.w.e. and achieve extremely high sensitivities in material screening at a level of µBq/kg. They are used to test material samples on their suitability to use in rare event experiments.

In the simulations muons, neutrons and tiny radioactive contaminations of the detector and shielding materials are investigated as possible sources of background radiation. It was found that the Pb210 contaminations in the detector shield and the neutrons coming from radioactive decays in the surrounding rock have the highest impact on the background spectra.
A detailed understanding of the composition of the background spectra was achieved, allowing for the proposal of two new shield designs for future GeMPI-like detectors. With these new shield designs a reduction of the integrated background count rate to 10 counts/d/kg in the interval [40,2700] keV is possible.

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **33** Type: **Oral Presentation**

COMPARISON OF DIFFERENT APPROACHES OF SOIL SAMPLING UNCERTAINTY DETERMINATION

Monday, 2 May 2022 15:10 (20 minutes)

The ISO/IEC 17025 standard General requirements for the competence of testing and calibration laboratories, issued in November 2017, requires that laboratories must identify, evaluate and appropriately propagate all significant contributions to the measurement uncertainty, including also those arising from sampling. The common praxis with previous version of the standard was that the contributions of the measurement procedure were evaluated in detail and in reports it was stated that the result represent the activity of the sample measured and not of the whole sampled balk material. Based on this new requirement, the contribution of the sampling uncertainty to the total uncertainty budget of the high-resolution gamma-ray spectrometry of environmental samples has to be evaluated properly.

There are different approaches for determination of the sampling uncertainty Commonly recommended method for chemical testing laboratories is the split-sample method, described in the EURACHEM Guide Measurement uncertainty arising from sampling. This method is based on applying the same sampling procedure two or more times on the same target or on different targets and replication of the measurement procedure entirely or partly by splitting the samples. For calculation of the standard deviation or relative standard deviation two methods, range statistics or analysis of variances (ANOVA method), are proposed.

At the Laboratory for Radioactivity Measurements at Jožef Stefan Institute an alternative method for determination of the sampling uncertainty was developed. The determination of sampling uncertainty is based on the evaluation of the standard deviation of the set of measurement results of samples taken from the same target, which includes also the contribution of the sampling uncertainty and the combined uncertainty budget of sample preparation and analysis. From these two uncertainties the contribution of the sampling uncertainty can be extracted.

To properly evaluate the sampling uncertainty we performed statistical analyses of measurements of sets of samples taken from the same target in the same general time period. During an extensive soil sampling campaign we took soil samples at 9 locations performed on a grid of 9 points with the distance of 3 m, at each location the sampling was performed at 3 depths (0–5 cm, 5–10 cm and 10–15 cm). On this set of samples both approaches of evaluation of sampling uncertainty were applied.

In this paper the comparison of these two methods for the evaluation of soil sampling uncertainty will be presented and discussed.

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Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **34** Type: **Poster Presentation**

VALIDATION OF EFFICIENCY TRANSFER FOR HIGH DENSITY MATERIALS IN HPGE SPECTROMETRY

Thursday, 5 May 2022 12:50 (20 minutes)

ABSTRACT
Free release and/or controlled reuse of lead originating from controlled areas of the SCK•CEN requires, amongst other tests, low-level radioactivity measurements of these materials. For that purpose, the lead is collected, characterized for its radioactivity content and segregated in batches with similar destination. Each batch is than melted and poured into ingots. From each batch, several approximately 0.5 cm-thick, cylindrical shaped samples (pucks) with a diameter of 5 cm are also produced during the melting campaign. These pucks are analyzed by high-resolution gamma-ray spectrometry to verify that the limits described in Belgian law for the protection of the public (ARBIS art. 35, 2001) are not exceeded. One or more of the following radionuclides: ^{60}Co, ^{54}Mn, ^{134}Cs, ^{137}Cs, ^{154}Eu and ^{110m}Ag had to be checked in the lead pucks following the origin of the lead. The high density (11.3 g/cm³) of the sample is a challenge for the analyses by high-resolution gamma-ray spectrometry. Moreover, to keep detection limits as low as possible, these samples were measured in close contact with the detector, a configuration that increase the repeatability dispersion and by consequence also the total uncertainty. Experimental calibrations are not readily set up for this high density material samples, since reference sources are generally not available in this configuration. Hence, efficiency transfer with EFFTRAN, referencing regular standard sources available in our laboratory was used to set up calibrations. Since the different pucks have slightly varying heights, sample specific calibrations are computed accounting for the actual height of the sample. Since our routine analyses were only validated for low-density materials (0-3 g/cm³), additional validation was required to prove that the method based on efficiency transfer with EFFTRAN is fit for purpose.
For the validation study, we used thin circular paper reference sources containing ^{60}Co and ^{137}Cs and a set of 5 1 mm lead disks. A paper source was successively measured on top of different piles of lead disks (ranging from 1 to 5 mm), to compose different source configurations representing attenuation as in the actual sample. With these source configurations, we verified efficiency transfer by EFFTRAN with a non-attenuating reference source on top of the end cap for several HPGe detectors. The uncertainty of the reference source in combination with the high correction for self-shielding of the source resulted in a total combined uncertainty of 10 % at coverage factor k = 1 for gamma-ray energies above 600 keV. This uncertainty was considered fit for purpose, for the moment 300 pucks have been analyzed so far. Meanwhile we also measured the EURM 800 and EURM 801 stainless steel disks containing a certified value for the massic activity of ^{60}Co produced by JRC Geel with a zeta score below 2.

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **35** Type: **Oral Presentation**

Cosmogenic activation calculation of experiments with LAr target

Friday, 6 May 2022 10:00 (20 minutes)

In rare event search experiments, activation of detector materials can lead to significant backgrounds. Typically, trace radioactive contaminants are activated by cosmic-ray interactions while the detector materials are being stored or transported above ground. In highly sensitive experiments, these cosmogenic backgrounds can limit sensitivity. It is therefore necessary to determine the cosmogenic activation of detector materials before installation. Liquid Argon (LAr) is used as a target for many future experiments, including DarkSide-20k (DS-20k) and DarkSide-LowMass (DS-LM). The dominant radioactive isotopes produced in LAr include ^{3}H, ^{37}Ar, ^{39}Ar, and ^{42}Ar. Due to its long half-life and the difficulty separating it from ^{40}Ar, ^{39}Ar is especially important for experiments looking for signals below 565 keV, while ^{42}Ar may pose a background to MeV-scale rare event searches. In experiments looking for a rare event like DS-20K and DS-LM, the presence of ^{39}Ar can cause a signal pile up or limiting backgrounds. Atmospheric argon (AAr) has a specific activity of 1 Bq/kg for ^{39}Ar, and DS-50 measured the specific activity of 7.4×10^{-4} Bq/kg in underground argon (UAr). Additional reduction may be achievable through isotopic distillation with the Aria facility. At these levels, cosmogenic activation of radioactive isotopes may pose a significant contribution to the total activity, and achieving high radiopurity requires transportation and storage plans that account for the target's activation in transit and storage. To this end, a software package is being developed for evaluating the activation of radioisotopes in UAr and AAr, based on a compiled selection of reaction cross-section measurements and models, the PARMA and Gordon cosmic-ray flux models, and the user-specified transportation history and initial composition of the target argon. These calculations will be validated for ^{37}Ar activation in DS-50, comparing the software's predictions to the measured activity in DS-50 after the initial UAr fill. This code is designed to be flexible and easily extensible. The flux and reaction cross-section models can easily be changed, different cross-section estimates and scaling factors can be used over different energy ranges, and capabilities for calculating the activation of other target materials may be added in the future. In the talk, I will discuss the importance of cosmogenic activation calculations for low-background experiments, and how this code works.

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Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **39** Type: **Poster Presentation**

Implementation of an active muon veto in an existing low-level γ-ray spectrometer at the underground laboratory Felsenkeller

Thursday, 5 May 2022 12:50 (20 minutes)

For low-level gamma-spectrometers situated at medium deep underground laboratories the cosmic radiation still causes a significant contribution to the background count rate. The cosmic component here mainly consists of muons and neutrons produced by muonic reactions. Our investigations were performed in the underground laboratory Felsenkeller, situated at a depth of 138 m.w.e. At this level the total muon intensity is reduced by a factor of 30...40 compared to the earth's surface [1]. The energy-integrated neutron flux amounts to 0.6 ... $4.6 \cdot 10^{-4}$ cm^{-2} s^{-1}, depending on the location and consists mainly of (μ,n) neutrons [2]. Aiming towards continuously decreasing detection limits, the installation of an active muon veto was a logical conclusion under the given circumstances. The original gamma spectrometer is situated in an accessible shielding and was described in detail in [3]. It consists of a state-of-the-art low-level HPGe detector (92% rel. eff.), a low-level lead shield with a copper inner shield and a nitrogen-flushed casing. The active veto consists of three large plastic scintillator plates of 4.5 and 5.0 cm thickness, respectively, arranged around the outer housing of the lead castle. The data processing and adjustment of time relations for the coincidence circuit is implemented by analogue NIM-modules. Optimizations of the electronics was performed with respect to trigger thresholds, coincidence time interval and gate length. Finally, the muon veto improved the integral background count rate (40...2700 keV), normalized to the Ge-crystal mass down to 424 ± 4 d^{-1} kg^{-1}. This corresponds to a relative reduction of around 85%, exclusively achieved by the active veto. Future investigations will include the analysis of cosmogenic radionuclides in meteorite samples, as well as determining radionuclide contents in low active environmental samples.

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[3] Köhler, M. et al., 2009. A new low-level γ-ray spectrometry system for environmental radioactivity at the underground laboratory Felsenkeller. Appl. Rad. Isot. 67 (2009) 736-740

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **40** Type: **Oral Presentation**

QA/QC AS A TOOL FOR AN IMPROVEMENT OF THE ANALYTICAL PROCESS AND CHARACTERISTIC LIMITS IN THE CASE OF DETERMINATION OF TRITIUM SPECIFIC ACTIVITY BY ELECTROLYTIC ENRICHMENT

Monday, 2 May 2022 15:30 (20 minutes)

In the Laboratory for LSC, we have been measuring tritium in environmental waters since 2009 using the method of electrolytic enrichment of tritium, accredited according to ISO 17025. Each electrolytic set contains a maximum of 15 electrolyzed samples with unknown activity, 5 control - calibration electrolyzed samples and three control non - electrolyzed samples. All measurement data and parameters are collected in control QA / QC charts. In the period of 383 electrolyzes, we collected and edited more than 140 data per each electrolysis, which we used, among other things, to upgrade the analytical process and improve the final results.

For electrolysis we use a device made at the AGH University of Science and Technology, Krakow, with 20 half-litre cells. For the calculation, we follow the papers (Gröning & Rozanski, 2003) and (Rozanski & Gröning, 2004). At the initial implementation of the electrolytic protocol (Q = 1400 Ah) and counting time up to 1000 min on Quantulus 1220, the typical values for the detection limit were around 0.096 Bq/kg according to ISO 11929, for enrichment factors Z = 18.2 ± 1.3 and for enrichment parameters P = 0.889 ± 0.012. We were not satisfied with the scattering of the final masses (~9 %) and consequently the Zs and Ps, so we decided to optimize the whole process.

By measuring the temperatures at typical places in the electrolytic cooling system, we obtained data for modelling the cooling of cells and air currents in the cooling device. Considering the optimal model, we upgraded the electrolytic process by installing spoilers and redirecting fans. This reduced the scatter of the final masses in the cells by roughly 60 %, which allowed us to increase the charge. We extended the duration of electrolysis and thus reduced the currents and heating of the samples during electrolysis. Scatter of Z with the same electrolytical protocol is now around 0.9 (33 % improvement), scatter of P has not changed. At the highest charges (Q_{max} = 1422.41 Ah) we then achieved Z = 33.4 ± 1.5 and P = 0.952 ± 0.007.

In the new modified calculation of specific activity, we consider the cpm of electrolyzed dead water, the individual mass of all samples in each measurands, we updated the uncertainty contributions shown from the control charts and added Bayesian statistics (ISO 11929) for calculation of the best estimate of specific activity and all characteristic limits. After the upgrades of the electrolytic process and calculations, we now reachenter code here the detection limits of around 0.035 Bq/kg. Uncertainties are now roughly 10 % lower.

In this paper, we will show the statistically processed data of the original and new electrolytic runs, explain the optimization process, show which parameters and in what way they affect the quality of the results and support the findings with experimental data. We will explain the changes in the modified calculation and how they affect the final improved result and show new, lower characteristic limits.

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Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **42** Type: **Poster Presentation**

Performance of HPGe Detector (BEGe Crystal)

Thursday, 5 May 2022 12:50 (20 minutes)

In this work we present the characterization of a BEGe (Broad Energy Germanium) type HPGe (High Purity Germanium) detector, with a Carbon Fiber entrance window (typically ~0.6 mm thick) and an active area of 6305 mm^2, operated at shallow depth in Abu Dhabi. The shielding is made of 6 inch lead [5 inch ordinary low-background lead; and 1 inch of low ^{210}Pb content] and a liner composed of 1.5 mm high purity copper and 1 mm low-background tin. For cooling, a hybrid cryostat [CANBERRA CryoCycle II] is used. The detector was calibrated using a NORM sample with known isotopes, and the efficiency curve was obtained using LabSOCS, a 1.6 keV FWHM (Full Width at Half Maximum) was obtained for the 662 keV peak of ^{137}Cs. A muon veto was applied at different gate times, reducing the back-ground by 10% (for energies greater than 100 keV), as well as reducing the area of the 511 keV annihilation peak by 15%. Flushing the detector with nitrogen gas, to remove the radon progeny, further improved the background by ~2-3%. A thorough analysis for the shaping filter parameters, namely, the rise-time and the flattop, showed that the detector had its best resolution at rise-time equal to 4 μs at a flattop value of 1.1 μs, this was true for energies approximately below 1000 keV, with a more significant improvement for less than 511 keV peaks. The analysis was done using REXX code, for energies 30 keV to 2.5 MeV, with ten iterations for each measurement, using point sources, and then repeated with a NORM sample, and the results were in agreement for both.

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **44** Type: **Poster Presentation**

Using a Likelihood Fit to identify Radioactive Background Components in the CRESST Eexperiment

Monday, 2 May 2022 12:50 (15 minutes)

Large efforts are being made to directly detect interactions of dark matter with ordinary matter, including the Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) experiment located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. During the second phase of the experiment, CRESST-II, scintillating CaWO4 target crystals were used to detect nuclear recoils. However, at low energies a distinction between dark matter recoils and beta-particles/gamma-rays is hardly possible. It is therefore vital to understand the composition of ambient radioactive background in the experimental reference data as it can be used in an analysis that allows to check for possible dark matter signals.

Tackling this problem, a first Monte Carlo electromagnetic background model was developed for CRESST-II in a predecessor study, where sources of contamination (radiogenics and cosmogenics) were identified and simulated for the detector module named TUM40. The resulting spectral templates were scaled using parametric Gaussian templates that were fitted to obvious peaks in the experimental data. The remaining flat energy spectra, that lack distinct alpha- or photopeaks, were scaled using a steady-state condition known as secular equilibrium.

The techniques presented in this work aim at improving this fitting method via a likelihood-based application of Bayesian inference and the Metropolis-Hastings algorithm. Several ways of assessing convergence and fit quality are discussed. Then, the results of a fit with 83 free parameters are presented, showing a significant increase of the reproduction in the energy range 1 keV–40 keV from 68% in the predecessor study to over 90% in this work. Finally, an overview of the current developments and considerations to improve upon the predecessor model are presented.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **45** Type: **Poster Presentation**

RADIOPURITY OF MATERIALS IN THE DIRECT DARK MATTER SEARCH CRESST EXPERIMENT

Tuesday, 3 May 2022 10:20 (10 minutes)

CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is a direct dark matter search experiment, located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy, where an overburden of 1400 m of rock (3800 m water equivalent) provides an efficient reduction of the cosmic radiation background.
In the CRESST experiment, ~25 g scintillating $CaWO_4$ crystals are used as target material for elas-tic dark matter nucleus scattering and operated as cryogenic detectors. An intrinsic radioactive contamination of the crystals and surrounding materials of as low as possible is crucial for the sensitivity of the experiment. Since 2011, $CaWO_4$ crystals are grown at the crystal laboratory of the Technische Universität München (TUM) to better meet the requirements of the CRESST experiment. The new generation of TUM-grown crystals are grown using recrystallization and low speed growing.
Furthermore, the result of an extensive screening campaign which is going on to study the level of contamination in parts of the setup will be presented. These results potentially will be used as an input for the simulation of the background of the CRESST experiment.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **46** Type: **Oral Presentation**

COSMOGENIC RADIONUCLIDES IN THE CAVEZZO METEORITE: γ-RAY MEASUREMENT AND DETECTION EFFICIENCY SIMULATIONS

Thursday, 5 May 2022 11:30 (20 minutes)

The Cavezzo meteorite was recovered on January 4^{th}, 2020, just three days after the fall, observed over Northern Italy by the all-sky cameras of the Italian PRISMA fireball network. Two specimens, weighing 3.1 g (F1) and 52.2 g (F2), were collected in the predicted strewn-field and the meteorite was classified as an L5 anomalous chondrite.

The γ-activity of F2 sample was measured at the Monte dei Cappuccini underground Research Station (Torino) with a large-volume HPGe-NaI(Tl) spectrometer. Thanks to the high efficiency, selectivity and low background of the spectrometer, we were able to measure activities below 1 decay per minute (dpm). Many cosmogenic isotopes were revealed: ^{47}Ca, ^{52}Mn, ^{48}V, ^{51}Cr, ^{7}Be, ^{58}Co, ^{56}Co, ^{46}Sc,^{57}Co, ^{54}Mn, ^{22}Na, ^{60}Co, ^{44}Ti and ^{26}Al. The presence of nuclides with half-lives down to few days confirmed the recent fall of the sample. The very low activity of ^{44}Ti and ^{60}Co (⊠ 0.1 dpm) was revealed with a particular coincidence between the HPGe and NaI(Tl) detectors.

To obtain the detection efficiency, we have simulated the response of the detector with the GEANT4 toolkit. The simulations were calibrated with standards of known activity to define the spectrometer's dead layer thickness and validated against the measurement of the Dhajala meteorite (H3-4, fall on January 28^{th}, 1976).

In this contribution, we focus on the coincidence optimization techniques and the detection efficiency computation.

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **49** Type: **Oral Presentation**

RES-NOVA: Archaeological lead-based cryogenic detectors for neutrino astronomy

Tuesday, 3 May 2022 10:00 (20 minutes)

One of the most energetic events in the Universe are core-collapse Supernovae (SNe), where almost all the star's binding energy is released as neutrinos. These particles are direct probes of the processes occurring in the stellar core and provide unique insights into the gravitational collapse and the neutrino properties. Currently, astroparticle physics is in need of SN observations and of a detection technique highly sensitive to all neutrino flavors.
RES-NOVA will revolutionize how we detect neutrinos from astrophysical sources by deploying the first array of cryogenic detectors made from archaeological Pb. Pb is a unique target material, it is the only element that simultaneously offers the highest neutrino interaction cross-section (via coherent neutrino-nucleus scattering, CNNS), for high interaction rates, and the highest nuclear stability, for ultra-low background levels. For the first time, we propose to use archaeological Pb not as detector shielding material, but as sensitive target material.
CNNS enables RES-NOVA to be equally sensitive to all neutrino flavors, without being affected by neutrino flavor oscillations. While, archaeological-Pb allows to deploy an ultra-low background level in the region of interest that lies at the detector energy threshold, $O(1\,\mathrm{keV})$. All these features make possible the deployment of the first cm-scale neutrino telescope for the investigation of astrophysical sources.
In this contribution, we will present the characterization of the radiopurity levels of an archaeological-Pb sample operated as cryogenic detector, and the performance of a small scale proof-of-principle detector of RES-NOVA.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **50** Type: **Oral Presentation**

DOSIMETRIC AND SPECTROSCOPIC CHARACTERIZATION OF THE RENOIR RADIOBIOLOGY EXPERIMENT AT INFN-LNGS: APPLICATION OF LOW BACKGROUND RADIATION DETECTION TECHNIQUES AND MODULATION OF RADIOACTIVE BACKGROUND.

Monday, 2 May 2022 11:50 (20 minutes)

ABSTRACT

An inescapable feature of life on Earth is exposure to ionizing radiation both from space and terrestrial sources. Deep Underground Laboratories (DUL) are research infrastructures built under a layer of rock able to greatly reduce the cosmic ray flux and provide the ideal environment for extremely low dose/dose rate investigations in many different disciplines such as physics and biology. The underground infrastructure of INFN-LNGS in Italy is one of the largest underground laboratories in the world in terms of installations, dimension, complexity and completeness. Starting from the 1990s, alongside astroparticle and neutrino physics experiments, radiobiology studies were performed with the aim of understanding the effects of environmental background radiation on the metabolism of living beings and contributing to the burning open question of the biological effects of very low dose/dose rate radiation and associated health risks.

For these studies, it is mandatory to characterize in detail the environmental and experimental conditions, particularly in terms of dose contributions to the biological model systems coming from the different components of the radiation field. Here we briefly introduce the RENOIR radiobiology experiment and present the dosimetric and spectroscopic characterization of the experimental set up and environments with a focus on the application of Low Background Radiation Detection Techniques and the approach used for radioactive background modulation.

To characterize the environmental low-LET radiation component, thermoluminescent dosimeter (TLD) and NaI scintillator measurements were carried out while the aboveground environmental neutron flux was measured using a DIAMON neutron spectrometer. An improved and efficient air ventilation system keeps the radon concentration underground low, equal to the surface concentration. It is also continuously monitored.

The intrinsic contribution of radioactivity in the experimental set up (caps, vials and culture medium) was measured by gamma-ray spectrometry with a high purity germanium detector and by Inductively Coupled Plasma Mass Spectrometry. Although the two techniques are very different from each other in terms of measured radionuclides (precursors vs daughters), sensitivity and time of measurement, the results are in good agreement with each other, especially for potassium which represents the major contribution.

One of the main objectives of the RENOIR experiment is to obtain information on the involvement of the low-LET component of the radiation field in biological model responses. With the help of simulations, special devices resembling Marinelli beakers have been constructed and filled with tuff to increase the gamma background radiation; to reduce (mitigate) the gamma background radiation we took advantage of a 10 cm thick lead shield, which was adapted to the requirements of the biological samples.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **51** Type: **Poster Presentation**

FAST ANALYSIS OF GROSS ALPHA WITH A NEW PLASTIC SCINTILLATION RESIN

Tuesday, 3 May 2022 15:50 (15 minutes)

The analysis of radionuclides is complex, with high economic and time costs. This is very evident in decommissioning activities and environmental monitoring, for which the obtention of appropriate information requires doing as many analyses as possible. In such situations, the assessment of the sample content through global or screening parameters may be of help to avoid the use of selection procedures for each radionuclide which are usually long and complex.
One parameter of high interest is the gross alpha. This parameter, conformed by the actinides, radium and polonium content, is measured for example in the characterization of radioactivity in water intended for human consumption. If the value of the gross alpha is under 0.1 Bq L^{-1} the water is considered drinkable and the specific analysis of several alpha emitters is not needed. Another example is the nuclear dismantling process, which is used to improve waste management as it permits checking if the sample can be treated as conventional or as radioactive waste.
Although there are several approaches to measuring the gross alpha parameter, there is still a need to simplify the determination by the use of faster methods which could also be capable to reduce the uncertainty associated with such determination.
This work presents a new method to determine gross alpha by using plastic scintillation resin (PSresins) packed in a solid-phase extraction cartridge. PSresins were used previously for the measurement of beta-emitting radionuclides such as ^{90}Sr and ^{99}Tc. In this work, a specific PSresin selective for all actinides, radium and polonium has been developed using P,P′-di[3-(trimethylsilyl)-1-propyl] methylenediphosphonic acid as an extractant. This new PSresin allows the determination of alpha-emitting radionuclides with a detection efficiency above 95%. All alpha emitters studied (^{241}Am, ^{236}Pu, ^{230}Th, ^{238}U, ^{210}Po and ^{226}Ra) presented quantitative retention in moderated nitric acid media (pH 2). This optimum working medium was determined though a batch study of 22 different media in HCl, HNO_3 and H_3PO_4 acids for each radionuclide. The analysis procedure proposed consisted just of passing directly through the PSresin cartridge 100 mL of the sample treated previously during 30' at 50°C with 1% of hydrogen peroxide as a valence adjustment agent. After that, the cartridge is measured in the scintillation detector for 2 hours. Under the correct alpha-beta discrimination parameter (alpha and beta misclassification error around 15%), the gross alpha parameter is determined in less than 4 hours from the sample reception with quantification errors similar to or even lower than the ones obtained with the currently used methods.

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Presenter: GIMÉNEZ GUERRA, Isaac

Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **54** Type: **Poster Presentation**

THE DETERMINATION OF AMERICIUM AND PLUTONIUM ISOTOPES IN ENVIRONMENTAL SAMPLES AND AIR FILTERS IN AUSTRIA

Friday, 6 May 2022 10:30 (10 minutes)

The radiochemical environmental monitoring program in Austria includes the measurement of radiostrontium and of the alpha emitting Plutonium isotopes in soil and vegetation. However, in an emergency situation other radionuclides like Pu-241 or Am-241 may be of interest as well. Moreover, for the evaluation of the exposure situation it is also important to analyze these radionuclides in other samples like aerosols or air filters.
This project belongs to a series of measurement campaigns in which for specific locations a reference value is determined. The focal point of this project is the determination of the reference values in air filters of different locations. Besides this, the within-year variance of these locations should be determined. Additionally soil, vegetation and raw milk was analyzed. Within these samples, we determined the following radionuclides: Pu-238, Pu-239/240, Am-241 and Cm-244 all via alpha spectroscopy and Pu-241 via LSC. In addition, we measured Pu-239 via ICP-MS in soil samples as well. As we focused in this project on air filters, we also measured Sr-90 via LSC for that kind of sample. The radiochemical separation included the combination of SR-Resin® for Pu and Sr and DGA®- and TEVA®-Resin for Am and Cm. Before the measurement we coprecipitated the purified element fractions of Am and Pu with Nd as carrier.
In conclusion, we assume our measured values as reference values for that kind of samples. The details of the method and the results will be presented. This project was funded by the Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology.

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Presenter: KADAN, Rainer

Session Classification: Radiochemistry

Track Classification: Radiochemistry

Contribution ID: **56** Type: **Oral Presentation**

Impact of environmental and materials radioactive contamination on superconducting quantum bits

Monday, 2 May 2022 12:10 (20 minutes)

Environmental radioactivity was recently discovered as a potential limit for superconducting quantum bits. Cosmic rays, but also radioactive isotopes naturally present in the laboratory, can suppress the coherence time of individual qubits and induce correlated errors in quantum processors. In this contribution, we present the effect of "far" radioactive sources (cosmic rays, neutrons, and laboratory radioactivity) and close materials contamination (chip holder, magnetic shield, ...) on a typical qubit developed within the SQMS center. We also study the radioactivity suppression that can be attained with minimal protocols and with more aggressive shielding techniques.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **57** Type: **Poster Presentation**

ELOISE – RELIABLE BACKGROUND SIMULATION AT SUB-KEV ENERGIES

Tuesday, 3 May 2022 10:20 (10 minutes)

$CaWO_4$ is a well-known target material for experiments searching for rare events like coherent elastic neutrino-nucleus scattering with NUCLEUS or hypothetical dark matter-nucleus scattering with CRESST. Pushing the detection threshold down to sub-keV energies, experiments encounter new phenomena like an exponential rise of observed events towards lowest energies of yet unknown origin. This highlights the need for verified and reliable simulations of radioactive background components at sub-keV energies, e.g. based on the widely used Geant4 toolkit.

The ELOISE project aims to tackle this issue for electromagnetic particle interactions in $CaWO_4$ in a two-stage approach: First by a systematic evaluation of the current accuracy by comparing benchmark simulations with data from extended literature research and dedicated measurements. Second, if needed, ELOISE intend to develop bespoken simulation code for $CaWO_4$ to improve the accuracy at the sub-keV energy regime. During a four-year time scale, ELOISE plans to study the accuracy of ionization, photoelectric effect, atomic de-excitation and nuclear stopping. Currently, ELOISE conduct a dedicated measurement of electronic energy loss in $CaWO_4$ via ionization.

In this contribution, we will first motivate the problem and outline the scope of ELOISE. Afterwards, we will report first results of ELOISE's reference measurements. Finally, we will discuss our preliminary findings and its implication for rare event searches with $CaWO_4$.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **59** Type: **Poster Presentation**

Purification technique and radiopurity analyses of YCl_3 for CLYC scintillation crystal growth

Friday, 6 May 2022 10:30 (10 minutes)

ABSTRACT

Detectors needed for rare event search experiments, like neutrinoless double beta decay, neutrino interactions and those searching for direct evidence of dark matter require a high level of radiopurity to minimize background signals thus guaranteeing a high sensitivity.
Therefore, the assessment of chemical and radio-purity of all raw materials and reagents involved in the crystal growth plays a crucial role to ensure a successful outcome. Often, an extremely high radiopure crystal is not an achievable target using raw materials as supplied by the manufacturer: different purification steps have to be developed to reduce chemical and radio-contaminations with the aim to fulfil the requirements of the experiment.
Within this context, a detailed description of all purification steps and radiopurity analyses on YCl_3 (99.99%, Lanhit) to be used for CLYC (Cs_2LiYCl_6:Ce) crystal scintillator production will be reported. Firstly, a double liquid-liquid extraction technique with 0.2 mol l-1 of Trioctylphosphine oxide (TOPO) solution in toluene has been used to remove Th and U impurities from the starting reagent. Then, the radioactive content of all samples was evaluated by high resolution inductively coupled plasma mass spectrometry (HR-ICP-MS) analysis after a solid phase extraction with TRU (TRans Uranian) resin columns to improve detection limits. Finally, the HR-ICP-MS results have been cross-checked with high purity germanium (HPGe) gamma-ray spectroscopy to simultaneously provide complementary information for a complete and accurate overview of each sample. These preliminary analyses, both before and after purification, were performed at the Chemistry Service and at the Low Background Facility STELLA of the Gran Sasso National Laboratory (LNGS), respectively.
As a result of the purification procedure the radioactive contamination of YCl3 decreased by almost two orders of magnitude in ^{232}Th and ^{238}U. On the other hand, the significant activity of some radionuclides belonging to the thorium and uranium (^{238}U, ^{235}U) decay chains such as ^{227}Ac, ^{226}Ra and ^{228}Ra remained nearly unchanged after the purification process, so the impact of these radionuclides in addition to the segregation effect during crystal growth or eventually the application of further chemical purification steps needs to be evaluated in the near future.

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Session Classification: Radiochemistry

Track Classification: Radiochemistry

Contribution ID: **60** Type: **Poster Presentation**

PRELIMINARY STUDY ON THE INFLUENCE OF FE AND NI CONCENTRATIONS ON THE QUANTIFICATION OF ^{55}FE AND ^{63}NI

Friday, 6 May 2022 10:30 (10 minutes)

Decommissioning of nuclear facilities involves the assessment of the radioactivity inventory for, among others, waste classification and temporary storage. For nuclear fission reactors, apart from the reactor core, the main contribution to the radioactivity comes from the graphite, if present, and the construction materials (concrete, metal materials such as aluminium alloy, steel, and lead). For nuclear fusion reactors, the main contribution comes from activation products and tritium. Among the most occurring radionuclides, ^{63}Ni and ^{55}Fe (neutron ac-tivation products) are significant in both fission and fusion reactors and considered as hard-to-measure-radionuclides because of their characteristic emissions.

^{63}Ni is a pure beta emitting radionuclide and can be produced by the following neutron reac-tions: ^{62}Ni (n, ɣ)^{63}Ni and ^{63}Cu (n, p)^{63}Ni. ^{55}Fe decays via electron capture to stable ^{55}Mn with the emission of Auger electrons and low energy X-rays, it is produced by the neutron activation reactions ^{54}Fe (n, ɣ)^{55}Fe and ^{56}Fe(n,2n)^{55}Fe.

Due to their low energy beta particles and electrons, only destructive analysis can be carried out for ^{63}Ni and ^{55}Fe activity determination, in particular, liquid scintilla-tion counting (LSC) is the most suitable method. This work focuses on destructive characterization analysis of steel materials coming from research reactors, in those cases in which the activity level is very low, close to the unconditional release level determined by the Authority. To achieve the minimum detectable activity concentration in accordance with the Authority request in a reasonable time, a preliminary study on the variation of measurement efficiency against the sample concentration is necessary.

The sample concentration in the LSC vial is strictly connected to the quenching, particularly to the colour quenching. Small sample amounts produce a low quenching effect and high detection efficiency. On the other hand, the lower the fraction of the original sample is mixed with the scintillator, the higher the minimum detectable activity concentration, along with the acquisition time. The goal of this study is to quantify the correlation between sample concentration and measurement efficiency with the aim to optimize the measurement time.

In this work, the preliminary results of the study will be illustrated in the case of a steel sample from decommissioning of a research fusion reactor.

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Session Classification: Radiochemistry

Track Classification: Radiochemistry

Contribution ID: **61** Type: **Poster Presentation**

COINCIDENCE SPECTRA EVOLUTION WITH DELAY BETWEEN GAMMA SPECTROMETER AND ITS VETO SHIELD

Thursday, 5 May 2022 12:50 (20 minutes)

Two low-background, digital gamma-ray spectrometers with digital data acquisition systems have been designed and developed in the Department of Nuclear Physical Chemistry, Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), Krakow, Poland.
The first spectrometer is equipped with Broad Energy Germanium detector BE5030 (Canberra, USA), multi-layer passive shield and active shielding which consists of five plastic scintillators (Scionix, Netherlands) with areas in range 0.14 to 0.49 m^2. Data acquisition and initial signal preprocessing are carried out by digital analyzer DT5725 (CAEN, Italy) while data offline analysis is performed with purposely written code VETO (Gorzkiewicz et al. 2019). The second spectrometer, constructed in 2021, consists of coaxial HPGe detector (Baltic Scientific Instruments, Latvia), 10 cm lead shield and five plastic scintillators (all with areas 0.49 m^2) and new version of CAEN DT5725S digitizer. Thanks to the size of the spectrometer chamber (about 60x60x60 cm), 12 containers with water (5 L each) can be placed inside to thermalize background neutrons. Both spectrometers are routinely used in low-background gamma ray spectrometric measurements. However thanks to manifold, off-line data exploration continuous monitoring of the cosmic-ray muon flux is performed (Gorzkiewicz et al. 2021).
Short time resolution of used digitizers (4 ns) enables precise determination of the delays between veto detectors as well as between germanium and each veto detector. In the case of used germanium and scintillation detectors, the delays between coincidence events are at the level of 1 - 3 μs. Such property of devices is the starting point of the presented research project, involving analysis of the changes of germanium detectors spectra as a function of the shift and width of the coincidence windows. Empirical time shift distribution reveals some structure. The gamma spectra corresponding to certain parts of this structure were subject of present study. Conducted analyses showed changes in shape of germanium detector background spectrum with increasing delay of coincidence window which correspond to structure of coincidence events time distribution. In addition, the presence of 511 keV peak and peaks corresponding to the excitation and activation of shielding and detectors materials nuclei, depends on the delay of the coincidence window. Moreover line 692 keV (emitted due to reactions ^{72}Ge(n, n')^{72}Ge*) is observed for coincidence events delayed over 2000 ns.

Gorzkiewicz K. et al., 2019. "Low-background, digital gamma-ray spectrometer with BEGe detector and active shield: commissioning, optimisation and software development". J Radioanal Nucl Chem 322, 1311–1321, https://doi.org/10.1007/s10967-019-06853-7

Gorzkiewicz K. et al., 2021. "Investigations of Muon Flux Variations Detected Using Veto Detectors of the Digital Gamma-rays Spectrometer" Applied Sciences 11, no. 17: 7916. https://doi.org/10.3390/app11177916

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **62** Type: **Poster Presentation**

GRANDSim: a novel Geant 4 based simulation software for HPGe detectors in use at CTBTO monitoring stations

Thursday, 5 May 2022 12:50 (20 minutes)

As part of the CTBTO verification regime, the radionuclide component of the International Monitoring System (IMS) is based on 80 particulate stations and 40 noble gas systems. Daily gamma spectral data are transmitted to the International Data Centre (IDC) in Vienna for automatic processing and interactive analysis.
Data analysis aims at monitoring a list of CTBT relevant radionuclides. These consists of 42 fission products and 41 activation products in aerosols as well as 4 isotopes of radioxenon. The results are made available to authorized users of State signatories through secured access mechanisms, for national implementation of CTBT related measures.
The IDC developed a novel Geant 4 based Monte Carlo simulation software for HPGe detectors in use at IMS particulate stations. The software, dubbed GRANDSim (Geant 4 based RAdioNuclide Detector Simulation software), covers both coaxial and planar detectors, measurement geometries and shielding configuration of the three technologies operated at IMS particulate stations.
The software simulates efficiency calibration, isotopic response function and coincidence summing correction factors for natural and anthropogenic radionuclides of interest. The physical model is automatically optimized by constraining simulation results against experimental calibration for non-summing energies.
Simulated entities are used as support parameters in the automatic processing of daily spectra from IMS for:
- Improving the quality of efficiency calibration (by including coincidence summing corrections).
- Enhancing the nuclide identification results (by including summation peaks) which reduces the workload on analysts in interactive mode.
- Ensuring reliable activity concentration results by including required coincidence summing corrections when applicable.

In addition, GRANDSim simulates gamma spectra for mixtures of radionuclides with any activity concentrations.
The contribution aims at presenting the key features of GRANDSim.

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **63** Type: **Oral Presentation**

Ultra-sensitive measurements of ^{238}U through delayed coincidence analysis on activated liquid samples

Tuesday, 3 May 2022 15:30 (20 minutes)

In rare events physics experiments the background produced by decay of radioactive nuclides in experiment materials could overlap the signals of interest. A big effort is necessary to keep the radioactive contamination under control by selecting the materials used in the construction of the experiment. In this contest it is crucial to develop sophisticated analysis and measurement techniques to achieve the contamination limits of ^{238}U imposed by the experiments.

Neutron activation analysis (NAA) is a good technique for studying trace radioactive contamination of Uranium within the materials. This technique involves exposing the sample to a thermal neutron flux in order to transform the long life nuclide ^{238}U into the radioactive short life ^{239}Np nuclide. The gamma radiations emitted after the beta decay of ^{239}Np are usually measured with an HPGe detector in order to identify the presence of ^{238}U. This technique allows us to achieve sensitivity at the ppt level, but sometimes it is not enough to satisfy the strong demands coming from the requirements.

In order to increase the sensitivity on ^{238}U in liquid samples, a new measurement methodology has been developed. The beta decay of ^{239}Np populates an isomeric state with high probability, the deexcitation of this level can occur in several channels by emission of gammas and internal conversion (IC) electrons in a delayed time ruled by the half-life of the isomeric state. The high probability of IC transition allows to use the emitted electron to obtain a strong marker of this decay by measuring the timing distribution of the delayed events. By measuring in coincidence the beta and IC electrons and the correlated gamma photons with a beta-gamma spectrometer, we obtain a strong reduction of background with a proper time selection. This technique allows us to achieve results with a sensitivity two orders of magnitude better than the standard approach.

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Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **64** Type: **Oral Presentation**

TECHNIQUES OF BACKGROUND SUPPRESSION IN BOREXINO

Monday, 2 May 2022 09:40 (40 minutes)

After more than 14 years of data taking, the Borexino experiment has proven to be a unique tool for studying the interior of the Sun. The key of the success of Borexino is the unprecedented level of the liquid scintillator radiopurity and the overall control of the detector backgrounds, reached after several years of hardware improvements and analysis technique developments. The expected solar neutrino interaction rate of a few tens per day in 100 ton sets the requirements about the needed radiopurity.
In this talk the main components of the background are presented along with the experimental procedures implemented to suppress them or reduce their impact via shielding, purification and data selection. Several methods are used to remove muons and cosmogenics isotopes as well as the external and surface backgrounds. The initial radiopurity of the detector exceeded the design goal for several contaminants, and a series of procedures to purify the scintillator have significantly reduced the internal radioactive contaminants as ^{85}Kr and ^{210}Pb , and allowed to reach currently unequaled levels of ^{238}U and ^{232}Th < 10^{-20} g/g.

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Session Classification: Invited talk

Track Classification: Invited talk

Contribution ID: **65** Type: **Poster Presentation**

NOVEL COMPTON SUPPRESSION EQUIPMENT IN LOW-LEVEL GAMMA-RAY SPECTROMETRY WITH LIST MODE DATA ACQUISITION

Thursday, 5 May 2022 12:50 (20 minutes)

ABSTRACT

COSSU has been developed at the Radiation and Nuclear Safety Authority of Finland to improve the sensitivity of the measurement in the Gamma Laboratory. COSSU is a multi-detector gamma coincidence device that is used for the analysis of routine environmental monitoring samples. In addition, it can be used in the studies of more complex cases, for example, samples that have low activity concentrations of several anthropogenic radionuclides. COSSU has a large coaxial germanium detector with a two-piece scintillator detector surrounding it. The device is enclosed by a heavy-duty lead shield to reduce background.

COSSU is a Compton suppression system utilizing gamma-gamma anticoincidence, but it operates as a full coincidence system. Specific software has been developed for the sorting, visualization and analysis of list mode data produced by the multi-detector list-mode devices in the Gamma Laboratory. By utilizing the software, the coincidence data can be accessed and the true-coincidence losses of photo-peaks of multiple gamma-ray-emitting nuclides restored in the analysis. This simplifies data analysis and further increases the sensitivity of the device in low count-rate gamma spectrometry.

A detailed Geant4 simulation model of the device was developed. Simulations were used to optimize the device as well as to support calibrations and complex analysis tasks.

The setup has been integrated to current laboratory information management system used in the Gamma Laboratory. Compton suppression reduces the continuous background seen by the high-purity germanium detector by a factor of 3 – 10, in addition to comparable reduction in the Compton continuum of any peaks in the spectrum. A comparison with the results of conventional gamma-ray spectrometry is presented.

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Session Classification: Low Level ɣ-ray Spectrometry

Track Classification: Low level ɣ-ray spectrometry

Contribution ID: **66** Type: **Oral Presentation**

HERGA: a High Efficiency fast-Response GAmma detector

Wednesday, 4 May 2022 11:30 (20 minutes)

The detection of natural radio-nuclides is of interest in several applications, for example for monitoring in natural or man-affected environments or for the identification and tracing of illegal radioactive materials. We designed and tested a camera for gamma-ray imaging based on the coded mask technique, able to detect a gamma-ray radioactive source with mrad precision. A first prototype consisting of 16 CsI(Tl) scintillators arranged in a 4x4 matrix and coupled to photo-multiplier tubes (PMTs) with a digital readout. We used a 7×7 mask composed of transparent and opaque tiles to encode and decode a radioactive gamma-ray point source image through a reconstruction algorithm. An upgrade of this detector will employ Silicon Photomultipliers directly coupled to the CsI(Tl) crystals, making the camera more compact and portable. In this contribution we will present the detailed geometry and working principle of the detector, as well as its performance in terms of energy and spatial resolutions and of minimum detectable activity.

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Presenter: Dr DI VENERE, Leonardo (INFN Bari)

Session Classification: Thematic Session 2: Emergency Preparedness

Track Classification: Thematic Session 2 - Emergency preparedness

Contribution ID: **68** Type: **Oral Presentation**

UNCERTAINTY DETERMINATION FOR SCREENING OF RADIOCESIUM IN FOODS WITHOUT SAMPLE PREPARATION PROCEDURE

Wednesday, 4 May 2022 11:50 (20 minutes)

The radioactivity monitoring for foodstuffs has been reinforced since the Fukushima daiichi NPP accident. The sample preparation procedures involving machining shall be required to homogenize radioactivity and fill a sample in the same type of container that is employed for the calibration. The conventional method, however, can be only used radioactivity monitoring by sampling surveys, even if no radioactive materials are detected, the samples cut up for measurement cannot be shipped. In such a situation a new type of device that is named as "Non-destructive radioactivity measurement device (hereinafter NDRMD)" has been developed to measure radioactive cesium in bagged whole samples without sample preparation technique so that all products can be inspected in advance of shipping. In the case of using such a device, it would be important to be determined the approximate detection efficiency for samples having various sizes and shapes with acceptable uncertainty from the information on the weight and type of the sample only, and also to take into account the variation of the detection efficiency due to the heterogeneity of radioactivity in each sample. However, such unexpectable uncertainties arising from these components might not be sufficiently clear to maintain reliability of inspection. In the present study, the uncertainties in the measurement of the radioactivity of whole foods using the NDRMD were determined by comparing the results of the measurement of food samples by the NDRMD with the results by the calibrated Ge detector using the conventional sample machining procedure. Two different models of NDRMDs that have a large (5"φ×5") NaI detector or multiple small (2"φ×2") NaI detectors were employed. In the present study, 36 samples of wild pine mushrooms and 29 of bamboo shoots cultivated Fukushima area were used. Each sample was measured four times by NDRMD, and the samples were shuffled before each measurement to check the reproducibility. After these measurements, individual activity concentrations of these specimens were determined by the conventional gamma-ray spectrometry technique with the sample preparation procedure. The relations between results obtained by each NDRMD and the Ge detector were analyzed by curve fitting with linear regression. As a result, the activity concentration obtained by NDRMDs were proportional to that obtained by the Ge detector, although the results obtained by NDRMDs were tended to be underestimated compared to the results obtained by the Ge detector. In addition, the prediction interval, which could reflect the variability due to counting statistics, reproducibility of placing the bagged sample, heterogeneity or radio-cesium in the sample in the individual values, were determined. The upper limits of prediction interval for 50 Bq/kg with a 95 % level of confidence were below 100 Bq/kg that was the guideline value for general foods in Japan for both pine mushrooms and bamboo shoots in the use of every device. These results represent that screening test of radiocerium in pine mushrooms and bamboo shoots is possible with 50 Bq/kg of screening level with a 95 % level of confidence, which is defined in ISO 19581, by the present three models of NDRMDs with the same measurement condition and procedure that were employed in the present study.

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Presenter: YAMADA, Takahiro (Kindai University)

Session Classification: Thematic Session 2: Emergency Preparedness

Track Classification: Thematic Session 2 - Emergency preparedness

Contribution ID: **69** Type: **Poster Presentation**

DEVELOPMENTS IN SUPPORT OF THE COMPREHENSIVE NUCLEAR-TEST- BAN TREATY - ULTRA SENSITIVE MEASUREMENTS OF AIRBORNE NUCLEAR DEBRIS

Thursday, 5 May 2022 12:50 (20 minutes)

The Comprehensive Nuclear Test-Ban Treaty (CTBT) International Monitoring System (IMS) provides a network of 80 Radionuclide detection systems, strategically positioned around the globe with the aim of detecting particulate radionuclide emissions from nuclear explosions. The authors have undertaken research, with the aim of increasing the overall sensitivity of the monitoring regime both within IMS laboratories and at IMS radionuclide stations.
Comparisons of HPGe based low-level ɣ-ray spectrometry systems at both an IMS laboratory and remotely located at the IMS station on St Helena are assessed, versus a prototype coincidence system based in Vienna.
The coincidence systems are based on dual Broad Energy detectors using the Canberra Lynx MCA to collect data in time-stamped list mode with a 100 ns time resolution. Data is processed using an efficient, custom software chain (available from the authors). Processing of the data is largely automated, streamlining the analysis such that nuclide identification and quantification is a relatively simple task. Analysis is performed in summed singles, coincidence and anti-coincidence modes, maximising the sensitivity of the spectrometer and the robustness of the analysis.
The improvements in detection limits are discussed within the context of the IMS, alongside the additional advantages of coincidence counting in the identification of different treaty relevant radionuclides in a complex air sample.

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Presenters: Mr DAVIES, Ashley (CTBTO); Dr BRITTON, Richard (CTBTO)

Session Classification: Low Level ɣ-ray Spectrometry

Track Classification: Low level ɣ-ray spectrometry

Contribution ID: **70** Type: **Poster Presentation**

JOINT MULTI-TEMPORAL SPECTRUM ANALYSIS FOR LOW-LEVEL RADIOACTIVITY IN GAMMA-RAY SPECTROMETRY

Thursday, 5 May 2022 12:50 (20 minutes)

In the context of environment monitoring, we aim at (i) reducing the time between the sampling and the detection of radionuclides in the samples and (ii) computing a precise estimation of the activity in the sample we analyse, particularly at low-level. To achieve this, we focus on a full spectrum analysis algorithm on gamma-ray spectrum obtained on HPGe detectors.
Full spectrum analysis has proven to perform very well compared to usual peak based analysis as emphasized in Xu et al. (2020, 2022). In fact the information carried in the entire spectrum allows to lower the detection limits and estimate the activity of the radionuclide, even at the mBq level. However, current analysis methods focus on a single spectrum, measured after a long decay time (e.g. days) to limit the impact of short-lived radionuclides. This highly limits the ability of the early detection of artificial radionuclides. For that purpose, we propose to rather rely on multiple measurements of the sample in time and make use of the time decay of the radionuclide's activity in the framework of full spectrum analysis. This is first carried out by taking multiple measurements, integrated on short time intervals. We further introduce a new multi-temporal full spectrum analysis that allows the joint analysis including time-dependency of the spectra. In contrast to standard analysis methods, it models for both the full energy spectrum of the radionuclides to be identified and quantified, as well as their disintegration scheme, including parent-daughter dependencies for radionuclides which belong to radioactive series.
In continuity with these previous works we propose in this paper a novel approach, which performs in an online estimation procedure, allowing to process rapidly the data as they are taken, including in list mode. The algorithm is further based on a multi-temporal multiplicative update algorithm, which allows to precisely account for the Poisson statistics of the data. Numerical experiments and comparisons with standard analysis methods have been carried out on both simulated and real measurements of aerosol samples. Preliminary results show that accounting for temporal information allows for an earlier detection of artificial radionuclides than standard methods.

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Session Classification: Low Level ɣ-ray Spectrometry

Track Classification: Low level ɣ-ray spectrometry

Contribution ID: **71** Type: **Poster Presentation**

LOW ACTIVITY RADON EMANATION SOURCES FOR GREENHOUSE GAS MITIGATION STRATEGY

Thursday, 5 May 2022 10:00 (10 minutes)

ABSTRACT

Atmospheric measurements of radon activity concentration seem to be very useful for the assessment and improvement of atmospheric transport models (ATM). Radon can be used as a tracer to evaluate dispersal models important for identifying successful greenhouse gas (GHG) mitigation strategies. For this purpose, the "traceRadon" (Radon metrology for use in climate change observation and radiation protection at the environmental level) project will provide the necessary measurement infrastructure and use obtained outputs in the Radon Tracer Method (RTM) which is important for GHG emission estimates that support national reporting under the Paris Agreement on climate change. To increase the accuracy of GHG modelling, traceability to SI units for radon release rates from soil, its concentration in the atmosphere and validated methods for its dispersal are needed. There exists correlation between GHG and radon c oncentration. However, traceability to the environmental level does not exist for measurements of radon fluxes and atmospheric radon activity. Therefore, the radon data used for improvement of the ATM and estimation of the GHG emissions needs significant improvement of accuracy of both radon flux measurements and environmental radon activity concentrations in the range from 1 Bq m^{-3} to 100 Bq m^{-3} to be able to provide robust data for use in the RTM. The overall aim of this project is to develop metrological capacity to measure low level of radon in the environments, which can be used to determine remission reduction strategies of GHG. This includes the two new traceable Rn-222 emanation sources (below 100 Bq m^{-3}) for application in climate monitoring and radiation protection networks. Such sources will be used to calibrate a transfer instrument to assure the traceability. The new low level activity emanation sources have been developed and their evaluation is in progress. The first source was created from an emulsion of salts of fatty acids in silicone rubber, formed from the weighed standard solution. Traceability of the Ra-226 activity is established by weighing and gamma spectrometry. Using a stainless-steel cylindrical case with valves and aerosol filters, applying ultra-dried air and a mass flow controller with a humidifier (to control the dilution of the activity concentration) enables to established time-stable radon activity concentration in a low-level radon chamber. The second approach is electrodeposition process of a carrier-free Ra-226 solution on a stainless-steel plate. The emanation of the Rn-222 follows differential equations, by nature, that include the build-up and decay of the Rn-222. Therefore, the measurement of the disequilibrium of the Ra-226 and the Rn-222 progeny is only correct for stable states. In order to overcome this constraint, the project has developed an algorithm using a new statistical method based on Bayes filtering (Kalman filter, assumed density fil tering). With this algorithm the emanated Rn-222 in the unit atoms per second as well as the associated uncertainty is determined online from spectrometric data including the knowledge of the already measured spectra. The outcome will be a new validated radon flux dataset to assist with application of the RTM for GHG flux estimates and will lead to more reliable data for policy and decision markers to use in the combat against climate change. The intercomparison of the two types of emanation sources in the frame of the traceRadon project will be presented and the outcome discuss.

This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States from the European Union's Horizon 2020 research and innovation programme.

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Presenter: MAZÁNOVÁ, Monika

Session Classification: Thematic Session 1: Studies of Climate Change

Track Classification: Thematic Session 1 - Studies of climate change

Contribution ID: **72** Type: **Poster Presentation**

DEVELOPMENT OF LIQUID CERTIFIED REFERENCE MATERIAL FOR NUCLEAR DECOMMISSIONING – HOMOGENEITY EVALUATION

Monday, 2 May 2022 15:50 (10 minutes)

ABSTRACT

A Certified Reference Material (CRM) is defined in ISO Guide 30 as a RM characterised by a metrological valid procedure for one or more specified properties (in this case content of selected radionuclides) accompanied by a certificate that provides the value of a specified properties, their associated uncertainties and statement of metrological traceability. The certificate reports the characterization results and provides information regarding the appropriate use of the material. There are several characteristics that a certificate may contain as outline in ISO Guide 31. The most important are: instructions for the correct use of the RM, level of homogeneity, certified values and their uncertainties (in this case content of the selected radionuclides), uncertified values (like stable elements content) and period of validity (or expire date). Homogeneity and stability are crucial characteristics of any CRM. Great attention must be paid to the production of them. However, careful production is not enough. Homogeneity assessment and stability evaluation is explicitly required by ISO Guide 35. In connection with the INSIDER project, two relevant reference materials have been chosen to be developed. For this purpose liquid material characterised for radionuclide content and based on liquid effluent tank waste from JRC Ispra has been produced by CMI.
For liquid CRM developed at CMI a questionnaire about radionuclide composition, activity ranges, minimum sample mass (volume needed) and homogeneity level has been distributed to the participants of the INSIDER project in order to define materials as useful as possible to assess the laboratories participating in the inter-laboratory comparisons. It was intended to produce 10 L of this liquid material. The main goal was to test measurement methods and to assess the performances of the laboratories. Radioactivity content in Bq.g-1 for the radionuclides defined in the specification has been determined. Because matrix-matching inactive material is not available the fselected stable elements have been added into the liquid solution. Radionuclide content and stable elements content can be closely matched to the tank waste based on the characterization of a real active material already carried out by JRC-Ispra.
Except of the radionuclide content (characteristic values) we also need to know homogeneity of the CRM. In homogeneity testing, there are two types of homogeneity: within-unit homogeneity and between-unit homogeneity. Within-unit homogeneity is an issue that arises when the minimum sample size specified in the instructions for use (in this case 0.5 L) is smaller than the size of the whole RM unit (which is 10 L). According to ISO Guide 35 testing for within-unit heterogeneity should provide at least 5 degrees of freedom. This can be achieved by taking at least 6 subsamples (in this case m = 8) from a whole bottle and measuring each subsample at least 1 time (in this case n = 3). Sampling scheme used to pick up the units for a homogeneity study is typically one of simple random sampling, random stratified sampling or systematic sampling. CMI has decided for random stratified sampling. Random stratified sampling typically divides the unit into a number of segments of equal size. CMI divided 10 litters of RM into 8 equal parts and from each part took one sample (0.5 L) for homogeneity testing. This type of sampling has been chosen to check possible sedimentation. In the case of non-destructive method (e,g. gamma spectrometry), where the sample allows multiple measurements, n can be greater than 1. In those cases, where n

> 1, the data can be evaluated by one-way analysis of variance (ANOVA). The experiment involves two uncertainty components: the repeatability of the experiment (method) and between-sample variation. In the experimental set-up, method repeatability and between-sample heterogeneity of the liquid reference material were estimated by analysing 8 units, 3-times each. The results will be presented. From the results the ANOVA tables were computed and corresponding F-tests were performed to determine ^{241}Am, ^{137}Cs and ^{60}Co homogeneity.

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Presenter: MAZÁNOVÁ, Monika

Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **73** Type: **Oral Presentation**

DETERMINATION OF PO-210 IN DRINKING WATER WITH PLASTIC SCINTILLATION RESINS. DEVELOPMENT AND METHODS COMPARATIVE

Friday, 6 May 2022 12:30 (20 minutes)

Po-210 is a natural occurring radionuclide produced in the decay chain of ^{238}U. Spanish legislation RD 140/2003 establishes that all consumption waters which exceeds fixed parametric values requires the determination of ²¹⁰Po, among other specific radionuclides. In addition, due to its extremely high radiotoxicity the limit activity allowed for ^{210}Po, 0.1 Bq L^{-1}, is the lowest among the radionuclides considered. ^{210}Po is usually analyzed by alpha spectrometry after controlled volume reduction (UNE-EN ISO 13161) or by alpha spectrometry after preconcentration through coprecipitation with MnO_2 and separation from interferences with the SRresin®. Those methods provide good results with very low detection methods. However, both are slow since require from long sample process time and therefore faster methods could be an alternative to increase laboratory productivity. Considering this necessity, this work intends to develop a new method to analyze ^{210}Po in water samples using a selective plastic scintillation resin (PSresin). This resin is made of 50-60 µm polystyrene scintillating microspheres coated with Aliquat-336 as a selective extractant. The advantage of this method with regards alpha spectrometry and liquid scintillation is that unifies separation and measurement steps in the same material, reducing time of analysis and reagents (no elution is required) and avoiding the generation of mixed wastes.
The studies performed have allowed the isolation of ^{210}Po onto PSresin eluting ^{210}Pb and ^{210}Bi, as the main interferences, with hydrochloric acid rinses at 1 mol L^{-1} and 6.25 mol L^{-1}, respectively. In addition, an optimization of rinse volumes was carried out. On the other hand, a research of several chemical analogues to polonium to be used in the whole procedure as chemical tracer was performed. Zinc and cadmium were found to be the most suitable metals reproducing polonium behavior both on the preconcentration step through MnO_2 precipitation and on the PSresin separation.
Finally drinking water samples were analyzed with the PSresins method and also through the reference methods UNE-EN ISO 13161 and IAEA/AQ/12. The comparison showed that PSresin method is faster and provided accurate results, but those based on alpha spectrometry achieved lower detection limits.

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Session Classification: Radiochemistry

Track Classification: Radiochemistry

Contribution ID: **74** Type: **Poster Presentation**

PSKITS FOR FAST AND SELECTIVE ANALYSIS OF ^{99}Tc IN DECOMMISSIONING

Tuesday, 3 May 2022 15:50 (15 minutes)

Many nuclear facilities around the world must be decommissioned in the near future. This process requires the correct management of the samples in order to know which samples need to be stored in a deep geological repository, which ones need to be temporary stored and which ones can be treated as common materials. In order to do that, is necessary the characterization of the radionuclides presents in a high amount of samples. For gamma emitters this measurement is already solved, but for alpha and beta emitters, it is necessary to develop fast and selective methods of analysis. Among the beta emitters, ^{99}Tc is a key element in the characterization of the radioactive wastes, as is a fission product of uranium, present in significant quantity, with a long half-life.

One of the waste management scenarios includes the characterization on the field. In this case, a fast measurement would allow an in situ decision of the classification of the material or if further studies are needed. In this sense, the objective of this work is to develop a fast method for the measurement of ^{99}Tc based on the use of PSkits. The PSkits are scintillation vials that include in its structure, a plastic scintillator foil, coated with a selective extractant, in this case, Aliquat·336. These PSkits allows a fast measurement just shaking the sample in the PSkit, pouring the solution and finally measuring the PSkit directly in a scintillation detector.

For this study, the synthesis of the foils was optimized in terms of vial support, proportion of crosslinker and porogen obtaining that the use of a plastic vial, proportions 32:1 and 2:1 (St:DVB in molls) and the use of heptane as porogen produce the best results in themrs of detection efficiency and also foil synthesis.

Also, the conditions for the PSkit use were also studied. These included the contact time, the shaking method and the rinsing conditions, being a gentle stirring and a contact time of the sample in the PSkit of 10 minutes enough to obtain retentions around 80% and detection efficiencies around 50% with low retentions of the common radiometric interferences of ^{99}Tc.

Finally, the established procedure was applied to the measurement of synthetic samples, that simulates real wastes, to validate the applicability of the method.

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Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **75** Type: **Oral Presentation**

Dark matter direct detection with the XENON experiment

Tuesday, 3 May 2022 11:20 (20 minutes)

Astrophysical observations indicate that a significant fraction of the energy content of the Universe is composed of cold dark matter. The most promising candidates for a particle explanation of dark matter are weakly interacting massive particles (WIMPs). Xe based dual-phase TPC is one of the best technologies in the field of direct dark matter searches, reporting the most stringent upper limit on WIMP-nucleon spin-independent elastic scatter cross-section with the XENON1T experiment at Laboratori Nazionali del Gran Sasso (Italy). The upgraded project XENONnT, utilizing 5.9 t of instrumented liquid Xe, is currently taking data. With the exposure goal of 20 t×y, the new experiment will reach a sensitivity to spin-independent WIMP-nucleon cross-section of 1.4×10^{-48} cm^2 for a 50 GeV/c2 mass WIMP (at 90% C.L.), one order of magnitude beyond XENON1T limit. The results reported by the XENON1T will be presented, as well as the status and the experimental program of XENONnT.

Primary authors: D'ANDREA, Valerio (Università dell'Aquila & LNGS); ON BEHALF OF THE XENON COLLABORATION

Presenter: D'ANDREA, Valerio (Università dell'Aquila & LNGS)

Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **76** Type: **Poster Presentation**

The GeMSE Gamma Spectroscopy Facility for Meteorite and Material Screening

Thursday, 5 May 2022 12:50 (20 minutes)

The GeMSE (Germanium Material and meteorite Screening Experiment) facility operates a low-background HPGe crystal in an underground laboratory in Switzerland, with a moderate rock overburden of 620 m.w.e.. It is devoted to material screening for rare event search experiments in astroparticle physics as well as characterization of meteorites. A multi-layer passive shielding, a muon veto and a boil-off nitrogen purge line inside the measurement cavity minimize the instrument's background rate which decreased by 33% to (164 ± 2) counts/day (100–2700 keV) after five-years of underground operation. A fit to the known background components shows that the GeMSE background is now muon-dominated.

This talk focuses on the upgraded remote operation of the experiment, its background and active mass characterization, and improvements to optimize the efficiency calculation for complex-shaped samples by means of 3d scanning.

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Presenter: LINDEMANN, Sebastian (University of Freiburg)

Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **77** Type: **Poster Presentation**

BALOO, A BASEMENT CdWO4 SCINTILLATION LOW BACKGROUND DETECTOR

Tuesday, 3 May 2022 16:50 (20 minutes)

BALOO (BAsement scintillation LOw-backgrOund detector) is a low-background scintillation set-up constructed in a basement room at the Institute for Nuclear Research of NASU for assessment of materials radiopurity, R&D of radiopure scintillation materials and small scale low counting experiments. A $CdWO_4$ crystal scintillator 7 cm in diameter and 7 cm height is viewed by a low-background photomultiplier through a high-purity quartz light-guide 10 cm length. The detector is shielded by layers of OFHC copper (6-12 cm) and low radioactive lead (15 cm). The set-up construction allows an easy access to the sample volume of the detector by shift of the passive-shield upper part. A plastic scintillator counter 100 × 100 × 12 cm is placed above the set-up to veto cosmic muons. The detector background counting rate is reduced by 3 orders of magnitude in the energy interval 0.5 – 2.6 MeV and by an order of magnitude above 3 MeV in comparison with the unshielded detector at the Earth surface. Thanks to the low level of background and a very high gamma-ray quanta detection efficiency of the CdWO4 scintillator, the sensitivity of the detector is comparable to the characteristics of low-background HPGe detectors located underground: for instance, 90% C.L. activity upper limits are on the level of 5 mBq/kg (^{40}K), 1 mBq/kg (^{137}Cs), 3 mBq/kg (^{226}Ra), and 0.8 mBq/kg (^{228}Th) for a 3-kg titanium sample in the Marinelli geometry over 30 days of measurements. Assembling of anti-radon system and additional muon-veto counters is in progress to improve the set-up sensitivity further.

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Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **78** Type: **Oral Presentation**

CHARACTERIZATION OF AN ULTRA-HIGH PURITY NAI(TL) SCINTILLATOR WITH THE POP-DRY SETUP

Tuesday, 3 May 2022 11:40 (20 minutes)

The SABRE project aims to produce ultra-low background NaI(Tl) scintillating detectors to carry out a model-independent search for dark matter through the annual modulation signature, with an unprecedented sensitivity to confirm or refute the DAMA/LIBRA claim. This means achieving the lowest background rate ever reached for a NaI(Tl) detector, of the order of 0.1 counts/day/kg/keV in the energy region of interest (ROI) for dark matter searches (1-6 keV).
Direct counting of beta and gamma particles with the SABRE Proof-of-Principle detector, equipped with a liquid scintillator active veto and operated at the Gran Sasso National Laboratory (LNGS), has already demonstrated very low internal radioactivity for the so-called NaI-33 crystal. In particular, the amount of ^{nat}K content, determined by direct counting of ^{40}K, is found to be 2.2 ± 1.5 ppb (or < 4.7 ppb at 90% CL), which is the lowest level ever achieved in NaI(Tl) crystals. The liquid scintillator veto was initially proposed to effectively reduce the ^{40}K background from a predicted contamination of ^{nat}K at a level of 10-20 pbb. As presented here, data acquired for about one year with the NaI-33 detector into a purely passive shielding made of copper, polyethylene and water (PoP-dry setup), have shown that liquid scintillator veto is not necessary for NaI(Tl) crystals with a potassium contamination of the order of that of NaI-33. Moreover, preliminary studies of the purification of NaI powder by zone refining demonstrated that such contamination can be further reduced, lowering its contribution in the ROI by about a factor of 10. This is not the case for ^{210}Pb instead, which is reduced by zone refining by only a factor of three and, to date, remains one of the leading background for NaI(Tl) crystals in the ROI for dark matter searches. Starting from the study of the behaviour of the ^{210}Pb contamination during the zone refining process, we are developing a specific method to reduce such contamination to a negligible level.

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Presenter: Dr MARIANI, Ambra (Princeton University, INFN-LNGS)

Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **79** Type: **Oral Presentation**

ESTABLISHING THE CAPABILITY OF INDUCTIVELY COUPLED PLASMA TANDEM MASS SPECTROMETRY FOR LONG HALF-LIFE MEASUREMENTS: A CASE STUDY FOR U-238

Wednesday, 4 May 2022 09:00 (20 minutes)

A number of long-lived radionuclides suffer from half-life measurements that are outdated, have inconsistencies in the values obtained and/or limitations with regards to the uncertainty budget. When used in combination with absolute counting techniques, inductively coupled plasma mass spectrometry (ICP-MS) is increasingly recognised as part of the metrological toolbox for providing updated and precise half-life measurements. This project aims to develop a consistent approach to measurement of the number of atoms using ICP-MS/MS for the first time for this purpose to contribute to updated, precise half-life measurement of long-lived radionuclides. ICP-MS/MS has demonstrated enhanced interference removal capabilities and improved confidence in measurement for a number of long-lived radionuclides, and this can potentially be transferred to half-life measurement for such radionuclides.

This work presents the development of a method for remeasuring the half-life of U-238 using ICP-MS/MS for atom counting. This value is important for geochronological applications over long timescales. Accuracy and precision of the U-238 half-life are of utmost importance and it is therefore necessary to ensure that measurement methods and treatment of uncertainties in its half-life evaluation are up to date. Until recently, the U-238 half-life had not been measured since 1971, where highly enriched uranium underwent alpha counting. This measurement is used as a basis for the currently recommended half-life of 4.468 (5) × 10^9 years. Previous half-life measurements have shown to be outdated or inconsistent in their treatment of uncertainty budgets.

Prior to measurement, a U-238 sample was separated from its daughters using extraction chromatography and standardised for its activity using Defined Solid Angle counting. For ICP-MS/MS measurement, a series of isotope dilutions were prepared using standardised U-238 and U-234. A certified uranium reference material was used to assess the relative performance of different mass bias models, and to optimise the instrument parameters to minimise the uncertainty in the mass measurement. The subsequent derived number of U-238 atoms were combined with its absolute activity value to obtain a remeasured half-life value of 4.516 (58) ×10^9 years. Various parameters, including the sample introduction system, were investigated to improve the precision of the technique. This method can be applied to other isotopes with stable or long-lived analogues, including Sm-151 and Zr-93, using the tandem mass spectrometry capability to reduce problematic interferences.

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Presenter: RUSSELL, Ben

Session Classification: Non-radiometric techniques

Track Classification: Non-radiometric techniques

Contribution ID: **80** Type: **Oral Presentation**

Development of an ultralow-background bolometric alpha detector for the measurement of surface contamination

Tuesday, 3 May 2022 17:10 (20 minutes)

Next-generation experiments searching for rare events must satisfy increasingly stringent requirements on the bulk and surface radioactive contamination of their active and structural materials. The measurement of surface contamination is particularly challenging, as no existing technology is capable of separately measuring those parts of the ^{232}Th and ^{238}U decay chains that are commonly found to be out of secular equilibrium.
We will present the results obtained with a detector prototype consisting of 8 silicon wafers of 150 mm diameter instrumented as bolometers and operated in a low-background dilution refrigerator at the Gran Sasso Underground Laboratory of INFN, Italy.
The prototype was characterized by a baseline energy resolution of few keV and a background of ~60 nBq/cm^2 in the full alpha range, obtained with simple procedures for cleaning of all employed materials and no specific measures to prevent recontamination. Such performances, together with the modularity of the detector design, demonstrate the possibility to realize an alpha detector capable of separately measuring all alpha emitters of the ^{232}Th and ^{238}U chains, possibly reaching a sensitivity of few nBq/cm^2.

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Presenter: CELI, Emanuela (Istituto Nazionale di Fisica Nucleare)

Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **81** Type: **Oral Presentation**

CALCULATION OF CHARACTERSTIC LIMITS FOR GAMMA SPECTROMETRY WITH INFLUENCE OF INTERFERING NUCLIDES

Thursday, 5 May 2022 11:50 (20 minutes)

ABSTRACT

Gamma spectrometry is a widely used technique for the measurement of gamma-emitting nuclides and is used in a wide range of applications in radiation protection, nuclear security and environmental sciences. One of the critical steps in analysing the spectrum includes the decision on which nuclides are present in the sample. Many laboratories report the Minimum Detectable Activity (MDA) as an upper limit for any activity present if a nuclide is determined to be not detectable. Statistical methods for evaluating whether the measurement signal is consistent with background noise or contains a signal were established a long time ago (Currie, 1968). Ignoring complications that may arise from more complicated regions of the spectrum, dedicated commercial gamma-spectrometry software can routinely calculate characteristic limits based on Currie or ISO11929 for the case that the region of interest does not contain a peak. If, however, an interfering peak is present the standard calculations will give incorrect results.
We present results of applying a modified method for determining characteristic limits based on ISO11929:3 (2019) to experimental spectra. The formalism was applied to 13 similar spectra measured on 13 different detectors. The spectra are reasonably complex and contain Eu-155 whose two major lines are heavily affected by interfering nuclides. Standard calculations without interference correction give MDA 10 x lower than the certified activity of Eu-155. ISO11929 formalism gives MDA at the same level as the certified activity. The number of non-detections (2 out of 13) and agreement of calculated activities with reference value support the validity of the approach.

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Session Classification: Low Level ɣ-ray Spectrometry

Track Classification: Low level ɣ-ray spectrometry

Contribution ID: **82** Type: **Oral Presentation**

REVISITING METHODS FOR RADIOLOGICAL ASSESSMENT OF URANIUM-NATURALLY-OCURRING GROUNDWATERS INTENDED FOR HUMAN CONSUMPTION

Thursday, 5 May 2022 14:30 (20 minutes)

A comprehensive radiological characterisation of groundwaters intended for human consumption was addressed between 2017 and 2021 in Castilla y León (Spain) according to the current Spanish regulation (RD 314/2016), transposition of the Council Directive 2013/1/EURATOM. Within this framework, more than three hundred samples were analysed to determine ^{238,235,234}U, ^{228,226,224}Ra, ^{210}Pb, and ^{210}Po using both low-level ɣ–ray and α–particle spectrometry techniques. Their activity concentrations were in the range of 0.231(52)-1349(25), 0.042(14)-68.4(31), 0.40(14)-1865(52), 0.108(72)-76.1(21), 0.24(14)-1162(27), 0.44(28)-268.6(71), 0.88(56)-799(16) and 0.108(20)-55.3(18) mBq·l^{-1}, respectively. Gross alpha and beta activities were also determined with the purpose to study their predictive capability in groundwa-ters with a natural radioactivity content. This is relevant because gross alpha and beta activities are used to control variations in the natural radioactivity of the groundwater bodies once radiologically characterized and it is widely known that traditional methods do not reproduce alpha and beta activities in this instance. Consequently, the methods applied were improved for low-level proportional counting and liquid scintillation techniques. Regarding proportional counting, sources were prepared from variable aliquot volumes to obtain a constant dry mass residue in the planchet reducing the self-absorption alpha particle and direct efficiencies were assessed for each sample using a natural uranium standard solution. Source preparation for liquid scintillation counting (LSC) was according to the ISO 11704:2018 using for alpha and beta efficiencies also the same natural uranium standard solution as for proportional counting. The results obtained using both techniques did not differ statistically and, overall, they were correlated with the sum of the activities corresponding to the natural radionuclides present in the samples. This means that gross activities as determined with the improved procedures can provide us insight into the radionuclide content of the groundwaters. To test it, low-level LSC was also used for the rapid determination of ^{238,235,234}U activity concentrations. Samples were selected according to certain hydrogeochemical conditions that promote the preferential mobilisation of uranium isotopes from bedrock minerals to groundwater, ensuring the presence of other alpha natural emitters (mainly ^{226,224}Ra and ^{210}Po) kept very low and/or below the technique detec-tion limit. The total procedure times were less than 24 hours because source preparation did not require laborious radiochemical procedures and an ultra-low background LSC detector was used for the measurements. The results obtained were compared to the α spectrometric ones and, there-fore, ^{234}U enrichments as measured by the liquid scintillation method proposed were assessed. In this work, LSC for uranium determination constitutes a rapid alternative which together with the high predictive capability improve methods are a clear guideline for laboratories responsible for the environmental radioactivity from given the extensive applicability of the regu-latory framework.

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Session Classification: Thematic Session 3: Future ISO/CEN/IEC standards

Track Classification: Thematic Session 3 - Future ISO/CEN/IEC standards

Contribution ID: **83** Type: **Poster Presentation**

UNDERGROUND RADIOACTIVITY MEASUREMENTS OF METEORITES

Monday, 2 May 2022 12:50 (15 minutes)

Meteoroids are activated by cosmic rays during their travel through space. Formation of specific radionuclides in meteoroids enables nuclear dating of recovered meteorites. It is of interest to determine their (i) formation age, (ii) cosmic age (time since breakup) and (iii) terrestrial age. Furthermore, radionuclides can help to determine the original size of a meteoroid by investigating the different massic activities of recovered individual pieces of meteorites and distribution of radionuclides inside each piece. However, unique nature of meteorites and usually limited amount of material available for studies triggers necessity to apply analytical methods as non-destructive as possible. Gamma-ray spectrometry is therefore a useful tool for investigation, especially applied to meteorites immediately after the fall, when also relatively short-lived radionuclides like Be-7, Na-22, Cr-51, Co-57, Mn-56 and Co-60 can be detected.
In this study a recent stony meteorite found in Libya in the Hammadah al Hamra region (HaH 346) was studied to provide constrains regarding its fall date. The specimen comes from a huge fall that was observed but reports of the date of the fall are ambiguous and differ by almost a year. As an additional complication, the location of fall differs by about 100 km. The specimen measured weighed 498 g and was of irregular shape, to some extent resembling a tetrahedron. Since first, laboratory-based measurements of this piece did not conclusively determine the terrestrial age a high sensitivity measurement was performed in the underground laboratory HADES (EUFRAT).
The low background in HADES enabled long measurement time and allowed to measure the piece at several distances from the detector to minimise systematic uncertainties arising from the irregular shape. Furthermore, a 3D-scanning of the piece was developed and introduced in the Monte Carlo code that calculates corrections for efficiency and coincidence summing.
In the paper we will describe metrological aspects of this particular study to accurately determine the terrestrial age of meteorite. Furthermore, the methodology to introduce adequate correction factors will be described. Also, we will present the methodology for calculating the uncertainty associated with nuclear dating.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **84** Type: **Oral Presentation**

RAPID ASSESSMENT OF ACTINIDES IN EMERGENCY RESPONSE SCENARIOS

Wednesday, 4 May 2022 12:10 (20 minutes)

Following a radiological incident, there is a need to rapidly monitor a range of sample types for multiple radionuclides to assess the risks to the public and the environment. Such rapid measurements will also be beneficial for high throughput routine monitoring of samples in and around nuclear sites.

This study describes the recent developments and comparison of methods for measurement of actinides (Th, U, Pu, Np, Am) following a radiological incident. This contributes to meeting the requirements of the European Metrology Research Programme project Preparedness (2017-2021). The project focused on air filter samples, which were initially treated using microwave digestion. Sample digests were split into two fractions. One half was measured directly by tandem inductively coupled plasma mass spectrometry (ICP-MS/MS) without further treatment. The instruments integrated reaction cell and two quadrupole mass filters were used for online removal of interferences, such as 238U tailing and 238U1H polyatomic overlap on 239Pu. The second half of the samples were taken through a single stage extraction chromatography separation procedure to isolate each actinide prior to measurement using alpha spectrometry. Suitable tracers were added to assess the chemical recovery, and a fraction of each separated fraction was taken for ICP-MS/MS measurement to check the agreement between the two techniques.

Data is presented to show the difference in measurement, procedural and analyst time, as well as the detection limits achievable and number of samples that can be measured within a single batch. The results have implications for deciding on the measurement route required depending on the analyte(s), turnaround time and limit of detection required.

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Session Classification: Thematic Session 2: Emergency Preparedness

Track Classification: Thematic Session 2 - Emergency preparedness

Contribution ID: **85** Type: **Oral Presentation**

Purification and characterization of enriched germanium samples for LEGEND-200 HPGe detectors by ICP-MS

Wednesday, 4 May 2022 09:20 (20 minutes)

The GERDA (Germanium Detector Array) collaboration operates bare high-purity germanium detectors (HPGe) made out isotopically enriched material inside a cryogenic fluid shield to search for the neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge. Its successor, the LEGEND-200 (Large Enriched Germanium Experiment for Neutrinoless ββ Decay) experiment will re-use the GERDA experimental infrastructures at the Gran Sasso National Laboratories. The mass of HPGe detectors will be enlarged up to 200 kg to probe $0\nu\beta\beta$ half-lives beyond 10^{26} years. During detector production a fraction of the enriched germanium remains as kerf and metal resid-uals, which cannot be directly reused for detector production. To recover as much as possible of these residual materials for additional detector production, a very efficient purification process is needed to eliminate most of the impurities. For this reason, a purification plant was designed and built to convert Ge metal to GeO_2 through sequential chemical reactions. Inductively coupled plasma mass spectrometry (ICP-MS) has been used to characterize starting materials, reac-tion products, and the final product, to search for impurities inside the samples and to monitor the contamination level. A quadrupole detector was used to determine the amount of impurities inside the samples through semi-quantitative analysis. Moreover, using high-resolution ICP-MS for some elements found in low resolution (Al, K, Fe, As), lower detection limits were reached improving our analysis. Characterization of the starting material, and the monitoring of the contaminants in the intermediate and final products will be discussed.

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Session Classification: Non-radiometric techniques

Track Classification: Non-radiometric techniques

Contribution ID: **87** Type: **Oral Presentation**

ACTIVITY CALIBRATION OF ^{222}Rn BY LSC AND DETERMINATION OF THE HALF-LIFE OF ^{214}Po

Tuesday, 3 May 2022 17:30 (20 minutes)

Liquid scintillation counting is a well-suited method for the activity calibration of ^{222}Rn sources, as the geometrical efficiency is 4π sr and the detection efficiency is close to 5 at equilibrium with the progenies. In the past we have developed a method to calculate this detection efficiency for the Triple to Double Coincidence Ratio (TDCR) method, considering some simplifications, like assuming 100% detection efficiency of alpha radionuclides and high-energy beta radionuclides of the radon progenies. A correction was applied for the disintegration of ^{214}Po, as its half-life is not negligible versus the counter dead-time and leads to a reduction of its detection probability. In this work we revisited these simplifications in order to develop a more accurate model. In the new model, we did not assume a unity detection efficiency for the high-energy beta radionuclides, but we calculated it using the free parameter model in LSC, by considering the energy spectrum transferred to the scintillator, from up-to-date beta spectra calculation and Monte Carlo simulation of the energy transferred to the scintillator.
Radon in water LS sources were measured using a miniature TDCR counter and an acquisition system based on a fast digitizer. The offline processing of acquisition files was made using several dead-time base duration values from 5 µs to 1000 µs, and the counting rates were corrected for blank measurement, accidental coincidences and dead-time evolution during the measurement. The analysis of the relationship between the triple and double coincidence counting rates versus the base dead-time duration allows a new type of determination of the half-life of ^{214}Po. This half-life was found to be slightly smaller, albeit coherent with the evaluated DDEP value. This new value was integrated to a computer program, allowing an accurate determination of the detection efficiency of ^{222}Rn in equilibrium with its progenies, without the need of an extrapolation to zero dead-time measurement.
The results obtained in this work will largely facilitate the calibration of ^{222}Rn sources and the calibration of LSC counters for ^{222}Rn-in-water measurements.

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Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **89** Type: **Oral Presentation**

CONVERSION FACTOR AND OTHER VARIABLES IN THE INDOOR RETROSPECTIVE RADON CONCENTRATION STUDIES

Friday, 6 May 2022 11:10 (20 minutes)

Estimation of indoor retrospective radon concentration is a subject of primordial interest concerning cause-effect studies on the incidence of radon in public health. These studies can be performed by measuring the surface concentration of the radon progeny implanted on mirrors.
The conversion factor (relationship between the concentration of Po-210 on mirrors and the retrospective concentration of Rn-222 in the air) was analyzed under real environmental conditions in two places in a former work [1]. The Pb-210/Po-210 equilibrium on mirrors, also in two cases: exposure to high and low Rn concentrations, was also studied later [2].
Two new places, and new variables of interest, such as reproducibility, implantation with the exposure time, and cleaning of mirror surfaces, have been now considered. In the reproducibility studies, three mirrors were placed and removed simultaneously, after about two years of radon exposure. For the study of the implantation of radon progeny with the exposure time, five mirrors were placed simultaneously in a cave, and they were removed sequentially. Expositions were performed in places whit moderate concentrations of ^{222}Rn. The effects of cleaning the surface of mirrors have been considered to study the implantation deep of the recoiling nuclei.
The conversion factor Po-210 (Bq/m^2 on mirror surface) / Rn-222 (Bq/m^3 on air) for the four sites studied, has been estimated. Reproducibility of measurements has been proven. Dependence of concentration with exposure time has been checked. The effects of cleaning the surfaces have been studied. The results obtained for the possible ^{210}Pb-^{210}Po equilibrium inside the mirrors have been also analyzed.
Some modelling taking into account theoretical considerations has been proposed in order to understand the mechanisms and variables producing the implantation of radon progeny on indoor mirror surfaces. Experimental results have been compared with those predicted by the model.

[1] Martín Sánchez, A., de la Torre Pérez, J., Ruano Sánchez, A.B. Experimental studies about the ratio between 210Po deposited on surfaces and retrospective indoor 222Rn concentrations. Rad. Prot. Dosim. 160, 206-209 (2014).
[2] Martín Sánchez, A., de la Torre Pérez, J., Ruano Sánchez, A.B. Study about the radionuclides implanted on glass surfaces for the estimation of retrospective indoor radon concentrations. Appl. Rad. Isot. 126, 13-15 (2017).

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Presenter: MARTIN SANCHEZ, Alejandro (Universidad de Extremadura)

Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **91** Type: **Poster Presentation**

Analysis of radioxenon at CTBTO noble gas systems

Friday, 6 May 2022 11:30 (20 minutes)

Noble gas systems were developed for use under the Comprehensive Nuclear-Test-Ban Treaty (CTBT) at 40 of the 80 CTBT-specified radionuclide stations within the International Monitoring System (IMS). Operated technologies use HPGe and beta-gamma coincidence-based detection systems.
Noble gas systems process air to extract and measure the radioactive isotopes of xenon that are most likely to be released after a nuclear explosion (Xe-131m, Xe-133, Xe-133m and Xe-135).
One of the CTBTO achievements over the last decade was the certification of 26 noble gas stations.
Daily spectral data from certified stations are analysed in the International Data Centre (IDC) operations, with dedicated software tools for automatic processing and interactive review.
A 3-level based sample categorization scheme is used as a first screening layer of CTBT relevant xenon isotopes
Automated and reviewed products are generated and made available to Member States via secured access mechanisms.
IDC reviewed results over a long-term period at various locations further contributed to a reliable characterization for better understanding the worldwide background of xenon isotopes.
The presentation aims at presenting data processing pipeline and achieved analysis results.

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Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **92** Type: **Poster Presentation**

Direct measurement of the ionization quenching factor of nuclear recoils in germanium in the keV energy range for the CONUS experiment

Tuesday, 3 May 2022 10:20 (10 minutes)

Recent development of ultra-sensitive particle detectors have opened the possibility to detect the neutrinos via coherent elastic neutrino-nucleus scattering (CEνNS). Having a larger cross-section, this process offers opportunities to further study this elusive particle in rather compact detectors and paves the way for new explorations beyond the Standard Model of particle physics.

The CONUS experiment is located at 17m from the 3.9 GW_{th} core of the nuclear power plant Brokdorf (Germany) and aims to detect CEνNS with four 1 kg-sized high-purity germanium detectors with a sub-keV energy threshold. A deep understanding of the detector response to nuclear recoils is needed for the interpretation of the data and motivated a dedicated measurement of the ionization quenching factor in 2020 at the PTB facility in Braunschweig (Germany), where an HPGe target was irradiated by mono-energetic neutrons. In this talk, the results of this campaign will be presented in details and the most recent results of the CONUS experiment will be exposed, in light of this new knowledge.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **95** Type: **Oral Presentation**

High sensitivity tests of quantum mechanics foundations

Tuesday, 3 May 2022 12:00 (20 minutes)

The VIP experiment, operated at the Laboratori Nazionali del Gran Sasso (LNGS) of INFN, aims to perform high sensitivity tests of the Pauli Exclusion Principle (PEP) for electrons. In the context of Local uantum Field Theories, deviations from PEP are strongly constrained by the Messiah Greenberg Superselection (MGS) rule, which forbids superpositions of states with different symmetry. Such models can then be only tested with open systems. Such a condition is fulfilled in VIP-2 by introducing new electrons in a pre-existing system of electrons, and testing the resulting symmetry state. An overview of the latest VIP-2 Open Systems result will be presented.

PEP violations, transgressing MGS, were recently shown to be induced by space-time non-commutativity, a class of universality for several models of uantum Gravity. High sensitivity tests of PEP vio-lation in closed systems represent the better candidates to test the non-commutativity emergence
in uantum Gravity, at unexpectedly high energy scales. The results of exploratory studies will be shown.

The extremely low background environment of LNGS is also suitable for investigating the measurement conundrum, one of the main mysteries of uantum Mechanics Foundations. Dynamical models of wave function collapse explain the quantum-to-classical transition by a progressive reduction of the superposition, proportional to the increase of the mass of the system. The results of our analyses, setting the strongest bounds on the collapse models, will be presented.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **96** Type: **Oral Presentation**

CALIBRATION FOR GAS CONTAINERS IN GAMMA-RAY SPECTROMETRY

Friday, 6 May 2022 11:50 (20 minutes)

ABSTRACT
To meet the need for rapid monitoring of gas activity in Kr-85, Xe-127, Xe-133 and Rn-222, two gamma-ray spectrometers of LNHB have been specifically calibrated with two types of reference containers with respective volumes 500 cm^3 and 100 cm^3. Two standardization methods were used depending on the radionuclide of interest. For Kr-85, Xe-133 and Xe-127, the reference values were measured by the method of three length-compensated proportional counters, with a relative standard combined uncertainties of about 1.1 % and the reference activity of Rn-222 was obtained from the solid angle measurement of a cryogenic source, with 0.35 % relative standard combined uncertainty. The spectrometers consist of high-purity germanium detectors coupled to conventional electronic modules. The calibration was performed for two container–to-detector distances. Different precautions were taken to process the spectra correctly. For example, the 514-keV peak area of 85Kr may be affected by a significant uncertainty due to the possible interference with the annihilation peak at 511 keV. There is no difficulty in measuring high activities, but for low activities (a few tens of Bq), the case of the 511-514 doublet is more delicate and inappropriate treatment can lead to significant deviations. Spectrometry measurements on 133Xe were performed in two steps. A first step allowed the quantification of the impurities (Xw-131m and Xe-133m), and relevant calibration factors for these xenon impurities were established by computing efficiency transfer factors. These impurities consequently induce corrective factors for the reference activity. In a second step, the calibration factors for Xe133 were established with 10 containers filled with the reference gas. The spectrum of 127Xe shows three main peaks at 172.1 keV, 202.9 keV and 375.0 keV. Three calibration coefficients could be established for each of these main lines. The calibration factors are obtained with a relative standard combined uncertainties of about 1.4 %, 1.1% and 1.1 %, respectively for Kr-85 (514 keV), Xe-133 (79.6 keV-81.0-keV) and the three lines of Xe-127. In the Rn-222 spectra, we observe peaks due to Rn-222 and its progenies (mainly Bi-214 and Pb-214). The only photon emission corresponding to Rn-222 has an energy of 510 keV, interfering with the annihilation peak, with a low emission intensity (0.076%). It, therefore, has two disadvantages. However, it is the only reliable information related to the volume distribution of the gaseous radionuclide, as the progeny in solid form tends to deposit on the walls of the container. The calibration coefficient has been measured, but with a relative standard combined uncertainties of about 5 %. This calibration work for gas containers is directly established with the radionuclides of interest, allowing the activity of containers of the same type to be determined routinely, simply by applying the calibration factors thus established.

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Presenter: LÉPY, Marie-Christine

Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **97** Type: **Oral Presentation**

EXPERIMENTAL DETERMINATION OF SOIL SAMPLING UNCERTAINTY IN THE CONTEXT OF ENVIRONMENTAL RADIOLOGICAL MONITORING.

Monday, 2 May 2022 16:30 (20 minutes)

Uncertainty estimation is an important aspect of method validation. Measurement uncertainty is also to be considered when decisions have to be made based on measurement results. Generally, uncertainty associated with nuclear counting analyses are attributed to two main components of uncertainty; one is related to sampling, the other to sample preparation and the subsequent nuclear counting. The component related to sample preparation and the measurement is commonly also evaluated in proficiency tests and hence allows a laboratory to evaluate its validity (e.g. in a test evaluating the Limit of Acceptable Precision). It is uncommon for radioactivity measurements (except for in-situ analysis) to consider sampling uncertainty in proficiency testing. The recent upgrade of ISO17025 however explicitly requires that testing laboratories determine the uncertainty related to sampling. This new requirement is especially important for laboratories involved in the radiological monitoring of the environment if they carry out their own sampling. In this Framework, this study presents an experimental approach based on a soil samples collection campaign and their analysis by gamma spectrometry with a view to determining the sampling uncertainty of the "soil" matrix.

Uncertainty related to sampling can be determined by evaluating measurement results obtained from controlled repetitive sampling in well-specified conditions e.g. using the dual split concept as described in the Eurachem-Citac guide on "Measurement uncertainty arising from sampling". In order to determine the sampling uncertainty of a gamma spectrometric analysis in soil, three laboratories IRE (BE), SCK-CEN (BE) and IPH (BiH) started a joined initiative with the financial support of the Federal public service economy from Belgium (FPS Economy). The aim of the project was to determine sampling uncertainty for the sampling and analysis of a representative top layer, 1m² surface, of soil with a single sampling as is commonly used in the radiological monitoring programs of soil. This uncertainty estimation requires a well-known sampling target for which radionuclide specific radioactivity can be measured and is well above the detection limits of the analysis. Fallout of the Chernobyl accident in 1986 still gives measurable quantities of Cs-137 in soils in the Balkan peninsula. The sampling site is located in the central part of Bosnia and Herzegovina, 20 km south-west from Sarajevo, at Bjelasnica Mountain, where preliminary investigation showed Cs-137 content of a few hundreds of Becquerels per kg. The site selected for the sampling was subdivided into several adjacent lots according to a sampling scheme in order to obtain a homogeneous distribution between the different laboratories participating in this study. The laboratories used their own materials and methods for taking and analyzing the soil samples. For this study, 16 soil samples and 32 analyzes by gamma spectrometry were carried out by each laboratory.

The dual split sample method in combination with ANOVA was used to evaluate the sampling uncertainty of each participant. The comparison of the results of the different laboratories shows a good agreement between the average of the results of the laboratories. Moreover, it is clear that the uncertainty due to sampling significantly increases the total measurement uncertainty and that the contribution to the total uncertainty due to sampling is larger than the contribution due to the analysis. The results also reveal that there is no significant difference between the sampling uncertainty for the slightly different sampling techniques used by IRE, SCK-CEN and IPH and may be considered as typically for these sampling techniques and this sampling target.

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Presenter: BRUGGEMAN, Michel (SCK-CEN)

Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **98** Type: **Poster Presentation**

Investigations on the detector background estimation in single beta-gamma coincidence measurements at IMS stations using the Monte-Carlo method

Tuesday, 3 May 2022 15:50 (15 minutes)

For beta/gamma coincidence measurements at IMS radionuclide stations, the gross number of counts in a Region of Interest (ROI) is a sum of the net number of counts from a radionuclide, the detector background, interference contributions from other radionuclides, and the activity from previous samples remaining in the detector cell (memory effect). The net numbers of counts and associated uncertainties in ROIs are estimated by the net count calculation (NCC) method generally. The estimation of the detector background using a Monte Carlo method (MCM) that employs a conditional Poisson distribution is investigated in this study. Traditionally, a detector background measurement is carried out at least 6 times longer than routine sample measurements. The numbers of counts of the detector background in ROIs and the associated uncertainties are estimated using a conversion ratio of measurement times between the sample and detector background spectra. In noble gas systems such as SAUNA a gas background measurement takes places prior to each sample measurement routinely. The statistical analysis on the gas background spectra in which the memory effect is not present demonstrates that the gross numbers of counts follow a Poisson distribution, whereby the variance of the number of detector background counts equal to its mean. The estimation of the numbers of counts due to the detector background between the two approaches are consistent, but the associated uncertainty estimated in the traditional approach is underestimated. In the MCM, the likelihood function for the gross number of counts in a ROI assumes that it follows a Poisson distribution with the mean equal to the measured gross number of counts in the spectrum of the single sample measurement. The Poisson distribution for the number of counts due to the detector background is processed in three approaches with the mean equal to: 1) the gross number of counts as observed in the detector background measurement but converted to the sample measurement time; 2) the statistical mean of the numbers of counts in the gas background spectra; 3) the same statistical mean as in the case 2) but under the condition that the sampled number of detector background counts is less than or equal to the sampled gross number of counts, resulting in a non-negative net number of counts. The mean value as well as the standard deviation of the net numbers of counts in each ROI are estimated using the distribution derived through the procedure of the NCC method. The decision thresholds are estimated accordingly by applying the same Poisson distribution for both sample and detector background spectra. The impacts of the three MCM approaches on the net numbers of counts and decision thresholds are compared. In conclusion, the detector background needs to be subtracted using the statistical results of the gas background spectra.

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Session Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Track Classification: Techniques for low-level α-particle, β-particle and γ-ray measurements

Contribution ID: **99** Type: **Oral Presentation**

TESTING OF CONTAINER SEALING METHODS FOR RA-226 MEASUREMENTS USING HPGE DETECTORS

Thursday, 5 May 2022 12:10 (20 minutes)

The measurements of Ra-226 are often performed using gamma-ray spectrometry. These measurements are however usually not direct. In most cases, progeny radionuclides, such as Bi-214 and Pb-214 are used to calculate the Ra-226 activity. An important condition ensuring accuracy of these measurements is the secular equilibrium between Rn-222 and its progenies. This condition can be met by the use of tight containers or application of appropriate sealing methods. The tightness of the containers should be tested and the leakage rate should be included in the uncertainty budget of each Ra-226 measurement result.

A proficiency testing exercise on measurements of naturally occurring radionuclides (including Ra-226) in building materials was organised by the EC JRC-Geel. Laboratories participating in the study were asked to fill in a registration survey. In total, 108 answers were collected. Out of the 103 laboratories who reported using gamma-ray spectrometry, 72 indicated using a container sealing method. Among the most popular methods were sealing with different types of tape and parafilm. Only 25 laboratories confirmed testing the radon tightness of the containers used.

In order to assess the performance of some of the reported sealing methods a series of tests was conducted using Rn-222 gas. Two types of containers were used - a wide-mouth polypropylene container (Nalge Nunc International, USA) and a custom-made Teflon container with a rubber o-ring. The Rn-222 gas was transferred into the containers using a syringe. The polypropylene containers were sealed using three different methods – with an insulation tape, with parafilm and with paraffin disc topped with liquid paraffin. Measurements were performed using a radon chamber connected to an Alpha-Guard and high-purity germanium (HPGe) detectors.

The results show that the tape or parafilm sealing, if applied alone, does not stop the Rn-222 leakage. The best method out of the ones tested was use of Teflon containers or polypropylene containers and paraffin disc with liquid paraffin. The latter method is used routinely at the SCK CEN (Belgium) and was retained as the best option for use with relatively large volume samples in which, next to Ra-226, also other gamma emitters have to be measured with a requested sensitivity. The sealing with paraffin was also introduced as an alternative for mixing the sample with active charcoal, another method used to trap Rn-222 in the sample material and counting beaker. The method with active charcoal however is not applicable to liquid samples.

To promote the use of a method for testing Rn-tightness to monitoring laboratories it should be simple and easy to apply. The recommended method, which will be described, consist of following the decay of Rn-222 in a water sample using an HPGe detector. The radon-rich water can either come from a natural source or be induced by placing a water-tight Ra-226 source in the water for some time.

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Presenter: SOBIECH-MATURA, Katarzyna

Session Classification: Low Level ɣ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **100** Type: **Poster Presentation**

CONRAD – A low level germanium test detector for the CONUS experiment

Thursday, 5 May 2022 12:30 (20 minutes)

We describe the development and construction of the high-purity germanium detector setup CONRAD (CONus RADiation) to characterize and monitor background radiation over a wide energy range.
The CONUS experiment is measuring coherent scattering of reactor anti neutrinos on Ge nuclei at the nuclear power plant at Brokdorf, Germany. CONRAD has been used for background studies inside the CONUS shield during the commissioning phase of the experiment at the underground laboratory of the Max-Planck-Institut für Kernphysik. It resulted in a total (40-2700 keV) background count rate of (350±2) $d^{-1}kg^{-1}$. The CONUS shield is adapted to the shallow depth location of the experiment and in the talk it will be shown how this low count rate in combination with CONRAD was achieved.
In its cryostat, the high-purity Ge crystal of 1.9 kg active mass was originally cooled with liquid nitrogen and was upgraded to an electric cryo-cooling system. This enabled to operate CONRAD also at the CONUS experimental site at distance of about 17m from the reactor core of the commercial nuclear power plant. The conversion succeeded without any deterioration either in spectral nor in background quality of CONRAD. The large diode makes the detector especially suitable to study the unshielded background at site and to validate Monte Carlo simulations of gamma radiation and neutron fluence measurements. These measurements along with further application of CONRAD for background studies will be discussed in the talk.

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Session Classification: Low Level γ-ray Spectrometry

Track Classification: Low level γ-ray spectrometry

Contribution ID: **101** Type: **Oral Presentation**

IN-HOUSE VALIDATION OF GAMMA-RAY SPECTROMETRY METHOD FOR I-131, CS-134, AND CS-137 IN ANIMAL FEED

Thursday, 5 May 2022 14:50 (20 minutes)

The aim of this study was testing of performance characteristics and single laboratory validation of a method for measuring I-131, Cs-134 and Cs-137 using high resolution gamma-ray spectrometry with High Purity Germanium (HPGe) detectors. This was the first out of two validation steps for the draft European documentary standard for measurement of I-131, Cs-134 and Cs-137 in animal feed. Development of this standard was requested from European Committee for Standardisation by European Commission (EC) Directorate General for Health and Food Safety (DG SANTE). The EC Joint Research Centre in Geel was given the task to prepare and validate this standard. The main reason for this request from DG SANTE was a concern about the accuracy of low-level measurements that laboratories will have to carry out while testing animal feed originating from Japan as required by the Commission Implementing Regulation 2017/2058.

These three anthropogenic radionuclides can appear in the environment (e.g. water, air, soil). From there, they can be absorbed by plants intended for both human consumption and animal feed. The activity of these radionuclides is therefore being monitored in the environment as elevated levels can be an indication of an emergency situation. One of these radionuclides, namely I-131, is very short-lived (around 8 days half-life) and reaches quickly very low levels of activity. This is the reason for the lack of readily available certified reference materials containing all three radionuclides of interest. Therefore all tests were conducted using spiked reference materials. The spiking method was first tested and proven to provide homogeneous samples [1]. Three different matrices (poultry feed pellets, maize and hay) were first characterised for their original content of radionuclides. Afterwards they were spiked with known amounts of certified radioactive solutions of I-131, Cs-134, and Cs-137 at three activity levels. The homogeneity of the spiked materials was also assessed. The measurements were performed with two HPGe detectors. The measurement protocol described in the "CEN/TC 327/WG 6 N 24" draft standard was followed strictly.

The pre-established in-house validation criteria tested in this study included detection limit calculation, determination of trueness, linearity, range, uncertainty, precision under repeatability conditions, intermediate precision and robustness of the method. All of the criteria were met, which confirms that the method described in this draft standard is fit for the purpose of accurate detection and determination of I-131, Cs-134 and Cs-137 in animal feed.

[1] K. Sobiech-Matura, B. Máté, T. Altzitzoglou. Appl. Radiat. Isot 109 (2016) 126-128

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Presenter: SOBIECH-MATURA, Katarzyna

Session Classification: Thematic Session 3: Future ISO/CEN/IEC standards

Track Classification: Thematic Session 3 - Future ISO/CEN/IEC standards

Contribution ID: **102** Type: **Poster Presentation**

JUNO physics and background control strategy

Tuesday, 3 May 2022 10:20 (10 minutes)

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton multi-purpose liquid scintillator detector currently being built in a dedicated underground laboratory in China, expected to start taking data in 2023. JUNO's primary physics goal is the determination of the neutrino mass ordering, with an expected significance of 3-4 sigma in about six years of data taking, by measuring the oscillation pattern of electron antineutrinos coming from two nuclear power plants at a baseline of 53 km. Besides the main physics goal, JUNO will have a very rich physics program including the measurement of neutrino oscillation parameters with a sub-percent precision, and the detection of solar and galactic core-collapse supernova neutrinos among others. To reach the proposed goals an unprecedented energy resolution of 3% at 1 MeV as well as a comprehensive energy calibration program are needed. The collaboration has also developed a strategy to keep all the radiogenic backgrounds under control before and during the construction of the detector. In this talk, the relevance of the JUNO detector design and background control strategy to the physics goals will be presented and discussed as well as the status of the construction.

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Presenter: BARRESI, Andrea

Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **103** Type: **Poster Presentation**

High sensitivity Rn measurements at Canfranc

Friday, 6 May 2022 10:20 (10 minutes)

At Laboratorio Subterraneo de Canfranc (LSC, Spain) are working two detectors designed to precisely measure low concentrations of Rn. The Electrostatic Rn Monitor (ERM) can measure Rn at a level of 1 mBq/m^3. Right now, it is measuring the air coming from the Radon Abatement System. The Cryogenic Radon Detector is a detector designed to detect the emanated Rn with a precision in the order of tenths of μBq.

Description of both detectors and results will be presented in this conference. Additionally, future plans will be shown.

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Session Classification: Noble gases

Track Classification: Noble gases

Contribution ID: **104** Type: **Poster Presentation**

ON THE APPLICATION OF AUTOMATED FUSION TO TOTAL DISSOLUTION OF DIFFERENT MATERIALS

Friday, 6 May 2022 10:30 (10 minutes)

Fusion flux dissolution is a powerful technique for the complete dissolution of solid inorganic materials. Different automated fusion devices such as Katanax (Katanax, Canada) or Claise LeNEO (Malvern Analytical, United Kingdom) have demonstrated their successful applicability for the complete dissolution of solid materials prior to analysis e.g. by ICP MS or alpha spectrometry. In this study, ^{243}Am, uranium, thorium and plutonium isotopes were investigated in different types of samples, such as soil/sediment, calcinated fucus and building materials (cement and expanded clay blocks) and using a Katanax K3 (Katanax, Canada). It is a well-known phenomenon that the uranium and thorium isotopes can be incorporated into refractory parts of these samples and that other dissolution techniques (e.g. by microwave) do not succeed in completely setting free these isotopes. In order to optimise the radiochemical separation following fusion, for a nuclide selective interference free analysis by alpha spectrometry, two different approaches are compared - direct pouring of the melted sample after fusion into the corresponding media and evaporation to half of the volume in order to be compatible with the radiochemical separation. The chemical recovery in both cases was evaluated and compared. The applied separation methods using the melt poured directly in the needed media for the separation were: (1) anion exchange together with UTEVA resin for Pu, U and Th isotopes and (2) sequential separation using TEVA-TRU resins of Pu, Th, U and ^{243}Am.

In the building materials analysed, chemical recovery of thorium isotopes was very low when microwave digestion was applied. A substantial higher recovery was obtained when Li-based flux fusion was used. Repeatability of the results was also investigated and it will be discussed in this paper. Unbiased assay, in which the radionuclides of interest are completely dissolved from the matrix material, was especially important for these building materials as they will become a reference material for a proficiency test and a method validation study.

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Presenter: VASILE, Mirela

Session Classification: Radiochemistry

Track Classification: Radiochemistry

Contribution ID: **106** Type: **Oral Presentation**

Material assay campaign of the DarkSide-20k experiment

Tuesday, 3 May 2022 12:20 (20 minutes)

The DarkSide-20k experiment will search for dark matter in the form of WIMPs and has potential to set the most stringent limits for the spin-independent interaction of heavy WIMPs with nucleons. The central detector will be a dual-phase time projection chamber with an Ar target. The background requirement is 0.1 events in 200 tonne years, which is the most stringent one ever set so far in the field of rare event searches. In order to fulfill it a thorough assay campaign that has been running for five years to assess the radiopurity of the detector materials, its translation into background in the region of interest for WIMP searches and informing the design for best detector performance.

In this talk, we will first present the organization of the assay campaign, which was developed paying special attention to the decay chains of U and Th. Several assay techniques are combined in order to be sensitive to the chain parents (ICPMS), the different gamma emitters through the chain (HPGe) and the often ignored Po-210 content in the bulk of the materials. Such measurements are not redundant since breaking of the secular equilibrium is observed in a large proportion of the materials assayed and the Po-210 in the bulk can be up to two orders of magnitude more abundant than its precursors.

We will discuss the translation of such backgrounds into trigger rate and background in the region of interest for the WIMP searches, giving details of the procedure to do so. Neutrons are the main background induced from detector materials in Ar TPCs, so special attention is payed to their estimates. SaG4n is a Geant4-based open code developed within the framework of DarkSide and is used for calculating the neutron yield induced by (a,n) reactions, with alphas coming mainly from the mentioned radioactive chains.

A specific mass spectrometry campaign has been added to the radioassay campaign in order to find out the chemical composition of critical components and minimize the uncertainty of the (a,n). This is specially indicated in the case of heterogeneous components, materials with relatively high activity or potential presence of isotopes with high (a,n) cross section.

The details on the assay campaign and its results to date will be presented together with an overview of the status of the DarkSide-20k experiment.

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Presenter: PESUDO, Vicente (CIEMAT)

Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **107** Type: **Poster Presentation**

A LOW RADIOACTIVITY HE:CF4 TPC WITH OPTICAL READOUT FOR THE CYGNO EXPERIMENT

Tuesday, 3 May 2022 12:40 (20 minutes)

Innovative experimental techniques are needed to further search for dark matter (DM) weakly interacting massive particles. The ultimate limit is represented by the ability to efficiently construct and identify nuclear and electron recoil events at the experimental energy threshold. Gaseous Time Projection Chambers (TPC) with optical readout are very promising candidates thanks to the 3D event reconstruction capability of the TPC technique and the high sensitivity and granularity of last generation scientific light sensors. The CYGNO experiment is pursuing this technique by developing a TPC operated with He:CF4 gas mixture at atmospheric pressure equipped with a Gas Electron Multipliers (GEM) amplification stage that produces visible light collected by scientific CMOS camera. A fast photodetector is used to measure the drift time of the primary ionization electrons and thus reconstruct the third coordinate of the ionization track. Events are reconstructed with an innovative multi-stage pattern recognition algorithm based on advanced clustering techniques. The detailed reconstruction of the event topology allows to infer the direction of the recoils and it also gives a powerful tool to discriminate DM signal from radioactivity background.

A 50-liter demonstrator (LIME) was successfully operated at the Frascati National Laboratories and it will be commissioned at the Gran Sasso Underground Laboratories (LNGS) in 2022. Tracking performances, directionality, and energy measurements down to few KeV have been evaluated with radioactive sources. A detailed assessment of the internal background due to radioactive contamination of the detector's components has been conducted. These measurements together with estimates of LNGS cavern background are used in an advanced Monte Carlo simulation to evaluate the demonstrator sensitivity to DM. Data from the underground campaign of LIME will be essential to characterize the detector in a low background environment demonstrating the scalability of such a detector concept to larger apparatus to significantly extend our knowledge about DM and neutrinos.

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Session Classification: Fundamental physics

Track Classification: Fundamental Physics

Contribution ID: **109** Type: **Poster Presentation**

A comparison of 238U radioactivity level using HPGe and ICP-MS at CUP

Monday, 2 May 2022 15:50 (10 minutes)

Two flagship experiments at the Center for Underground Physics (CUP), AMoRE searching for neutrinoless double beta decay and COSINE for WIMP (Weakly Interaction Massive Particle) dark matter, are rare-event search experiments running at the Yangyang underground laboratory (Y2L). It is critical to know radioactivity levels of respective detector materials to control the experiment sensitivities. Inductively coupled plasma mass spectrometry (ICP-MS) and high-purity germanium (HPGe) detector are widely used for radioactivity assay, however, their levels of ^{238}U are quite different in many sample measurements. High intensity gammas in ^{238}U decay chain are from ^{226}Ra, ^{214}Pb and ^{214}Bi in the lower decay chain, and generally only these activities are reported from the ^{238}U chain for HPGe measurement. In contrast, ICP-MS's result is sensitive only to ^{238}U itself. The upper and lower chain activities can be different because of a breakage in chain equilibrium. Using the 63.29 keV and 93.40 keV gammas from ^{234}Th decay and 1001.03 keV gamma from ^{234m}Pa, upper chain radioactivity levels for two samples (A: Na_2CO_3 and B: $CaCO_3$) were recently analyzed and compared with ICP-MS results. Because of the short half-lives of ^{234}Th and ^{234m}Pa, which are directly below ^{238}U in the decay chain, these activities must be in equilibrium and representative of the ^{238}U concentration. Radioactivity levels of ^{234}Th, ^{234m}Pa and ^{226}Ra decay chains in sample A using the HPGe detector are 162.55 ± 19.24 mBq/kg, 115.02 ± 48.74 mBq/kg and 451.29 ± 41.00 mBq/kg respectively. The ^{238}U level using ICP-MS was reported as 14 ppb which is converted to 168 mBq/kg. The levels of ^{234}Th and ^{234m}Pa in sample B with the HPGe detector are 13.85 ± 0.83 Bq/kg and 9.03 ± 0.92 Bq/kg respectively. The ^{238}U level by ICP-MS was reported as 878 ppb (10.5 Bq/kg). These results show HPGe and ICP-MS measurements of ^{238}U concentration are well matched.

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Presenter: LEE, Eunkyung (Center for Underground Physics, IBS)

Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **110** Type: **Poster Presentation**

PRODUCTION OF LOW BACKGROUND SCINTILLATING CRYSTALS FOR UNDERGROUND EXPERIMENTS IN KOREA

Monday, 2 May 2022 12:50 (15 minutes)

There are two major underground experiments in Korea, AMoRE and COSINE, searching for neutrinoless double beta decay and WIMP (Weakly Interacting Massive Particle) type dark matter respectively. The Advanced Molybdenum based Rare process Experiment (AMoRE) is searching for the neutrinoless double beta ($0\nu\beta\beta$) decay of ^{100}Mo isotopes in molybdate crystals using high-resolution cryogenic detectors in milli-kelvin temperatures.
The AMoRE phase-II (AMoRE-II) is going to have ~100 kg of ^{100}Mo isotopes in crystals to study the $0\nu\beta\beta$ decay in the inverted mass hierarchy region of neutrino mass. Various molybdate crystals such as $^{48dep}Ca^{100}MoO_4$, $Li_2{}^{100}MoO_4$, $Na_2Mo_2O_7$, and $PbMoO_4$ for the AMoRE-II have grown and tested for their performances including background radiation levels. For the COSINE experiment, a mass-volume ultra-radio-pure NaI(Tl) crystal growth are currently under development at the Center for Underground Physics (CUP) of the Institute for Basic Science (IBS) in Korea. Both experiments require quite challenging low background levels in the crystals being developed.
There are number of radioassay devices in the CUP to measure radiation levels in all steps of crystal development. The argon gas ionization alpha counter and HPGe detectors are running at Yangyang underground laboratory which is located underground with ~700 m overburden to increase their sensitivities by reducing cosmic radiation background. An ICP-MS machine is at IBS-HQ where the purification and crystal growing R&D are taking place.
A review on the production of the ultra-low background crystals together with their extremely low background radiation measurements is going to be presented.

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Presenter: GILEVA, Olga

Session Classification: Applications

Track Classification: Applications

Contribution ID: **111** Type: **Poster Presentation**

Production and characterization of ultra-pure copper for low background applications

Monday, 2 May 2022 12:50 (15 minutes)

About two tons of ultra pure copper has been produced as a material for construction of an internal shield of a low-background gamma spectrometer. In the process several companies were involved. Aurubis A.G. (Germany) has prepared a dedicated casting mould, selected the best possible raw material (Cu cathodes) with respect to chemical composition and cast the 2-ton block. In order to minimize the cosmic exposure the block was immediately transported and stored underground, 150 m below the surface in the Wieliczka Salt Mine (Poland). It was taken out only for short time for forging (Zarmen S.A., Poland), cutting and fabrication of the shield components.
The radio-purity level of the coper was determined by analyzing: the long lived U/Th isotopes with an ICP mass spectrometer, Ra-226 and other gamma emitters by high-sensitivity germanium spectrometry and Pb-210 by a dedicated technique based on Po-210 separation from Cu and determination of its activity. The results showed very high purity of the material and, as expected, disequilibrium between different parts of the U-chain.
In the presentation the details of the production and analysis of the material will be given.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **112** Type: **Oral Presentation**

THORIUM AND URANIUM TRACE ICP-MS ANALYSIS FOR AMoRE PROJECT

Wednesday, 4 May 2022 09:40 (20 minutes)

The AMoRE (Advanced Mo based Rare process Experiment) is an international collaboration for the neutrinoless double-beta (0v⊠⊠) decay of the ^{100}Mo isotope with cryogenic detectors using molybdate (100MoO4)-based scintillation crystals. The process requires that the detector apparatus and its components, scintillating crystals and initial materials used for the crystal growth be extremely low in radioactive isotopes whose decays may generate background noise signals in the region of interest.

The present study summarizes an ICP-MS analysis program conducted for the AMoRE experiment. All the tests were performed at class 1000 clean rooms in the Center for Underground Physics (CUP) at IBS, Korea. An ICP-MS machine, Agilent 7900, was used for the trace analysis.

Firstly, the $^{100}MoO_3$ powder as one of two main initial materials for the crystal growth was studied in the analysis. Prior to a usage enriched $^{100}MoO_3$ powder was deeply purified at the CUP and to ensure its ultra-radio-purity, a sample preparation technique with a UTEVA resin was developed for Th and U analysis with ICP-MS. The technique proved the detection limit down to a few ppt by means of high separation of Mo-matrix and efficient analyte's recovery.

Copper is another important sample to be tested because Cu is used in the detector unit assembly frame and shielding components for the AMoRE detector. To determine the most appropriate one, several types of high purity Cu were measured: Cu-OFE (Aurubis and Mitsubishi Materials) and Cu-NOSV (Aurubis). To avoid a matrix effect, a solid phase extraction with UTEVA resin was applied for accurate and sensitive Th and U analysis through the efficient Cu-matrix separation. Such a technique allowed to reach the detection limit below 0.5 ppt.

Indeed, the closest part to the scintillating crystal in the detector assembly is the 3M Vikuiti ESR film used as a light reflector. Two types of the Vikuiti film, a roll and a sheet, were checked for the radiopurity. Polymeric matrix of the film was decomposed in a microwave ashing machine. The dry ash was dissolved and subjected for Th and U measurements. The analysis has shown low contaminations of Th and U in the film at about 10 ppt.

In conclusion, ICP-MS in tandem with suitable sample preparation method is a powerful technique which can support a big part of radioassay program for a project like the AMoRE. In some cases, it may give much better sensitivity than the other methods like HPGe or NAA.

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Presenter: GILEVA, Olga (CUP, IBS)

Session Classification: Non-radiometric techniques

Track Classification: Non-radiometric techniques

Contribution ID: **114** Type: **Oral Presentation**

Proficiency Test Data Interpretation and Data Rejection

Monday, 2 May 2022 16:50 (20 minutes)

The interpretation, evaluation and visualisation of radioactivity proficiency test exercises (PTEs) are presented in this paper.
Data submitted as part of NPL radioactivity measurement PTEs between 1989 and 2018 represents a useful resource for gauging current capabilities for radioactivity measurement since it includes ~14 000 individual reported measurements; since this programme was started in 1989 the submitted data have been of varying quality.
The extant data has been analysed, using the steps laid out in this paper; the data are tested via the ζ-test, z-test and a relative uncertainty test, the R-test. The outcomes from the three tests may be used to assign an overall score to a particular laboratory's reported result for a given measurement. Assigning priority to the tests in this order; ζ-test > z-tests > R-test, with the z- and R-tests subdivided into pass or fail at the lower limit and pass and fail at the upper limit, each test returns a simple binary result. These are combined to generate the overall score; in addition, the individual test results may be combined to give a performance comparator.
The z-test and R-test rely on an assessment of the quality of reported data. Results reported without an uncertainty are excluded from further analysis. Furthermore, data that are 'obviously' wrong (possibly a 'blunder', according to ISO 13528:2015) are identified. What may constitute 'obviously wrong' (termed an 'improbable deviation' in this paper) may be debated, but for the purposes of this work, these are data that are quite clearly far away from the assigned value, and are identified using an objective treatment. and outliers are identified in the remaining data. Outlier identification is an area of much debate, and differing methods for identifying outliers have been employed, such as Dixon's Q outlier test; Grubbs outlier test; Chauvenet's Criterion. For this work the use of Peirce's Criterion was selected; the advantage of using Peirce's Criterion is that it is based on finding the most probable distribution of data by rejecting one or more contributing values, and then using the culled data to determine overall performance, median relative uncertainty and acceptability limits on relative uncertainties.
Apart from the common visualisations of proficiency test data, an additional graph is used. This is an adaption of the Naji- and Pom- plots, and presents the data by using the relative deviation as the abscissa and the relative reported uncertainty as the ordinate. This plot is bounded by the limits of the ζ-test, z-test and R-test, resulting in a defined area for results that are acceptable, according to the outcomes of the three tests.
The use and interpretation of these tests and scores will be described in detail in the paper and illustrated with a selection of data from past NPL proficiency tests.

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Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **115** Type: **Oral Presentation**

Updating property values for IAEA reference materials 384, 385, 410, 412 and 414

Monday, 2 May 2022 17:10 (20 minutes)

The IAEA Environment Laboratories produce reference materials that may be used by laboratories world-wide for quality assurance and quality control purposes, as well as for method development, validation of analytical procedures and for training. The materials are certified and focus on the measurement of radionuclides in the marine environment, and include marine sediment, seawater, mussels and fish.

These reference materials are a vital resource for laboratories making environmental measurements, and in the past year efforts have been made to re-evaluate existing material in line with current practice at the BIPM. This approach also provides a framework for future characterisation of new reference materials.

This paper presents work on five existing reference materials where the property values for these materials have been re-evaluated. The approach taken was to:

• Assess the original data for further data analysis,
• Identify outlier values and reject them,
• Consolidate data from short-lived natural decay series radionuclides,
• Correct long-lived natural decay series radionuclides for ingrowth from parent radionuclides,
• Correct ^{241}Am values to take account of ingrowth from ^{241}Pu,
• To determine reference values by calculating power moderated means, and
• To accept certified values only where there were at least four degrees of freedom and where the relative uncertainty was <7.5% (k = 1)

Data will be presented for selected radionuclides from the cohort of five reference materials identified in the title of this abstract, and comments for future characterisation of reference materials by the IAEA.

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Session Classification: Quality and Intercomparisons

Track Classification: Quality and Intercomparisons

Contribution ID: **116** Type: **Oral Presentation**

ICPDR JOINT DANUBE SURVEY 4 – METHODS AND RESULTS

Monday, 2 May 2022 12:30 (20 minutes)

This low-level radionuclide metrology research work was carried out within the Joint Danube Survey 4 (JDS4), coordinated in 2018-2020 by the International Commission for the Protection of the Danube River (ICPDR). The ICPDR (http://www.icpdr.org) is a transnational body, which has been established to implement the Danube River Protection Convention. The Joint Danube Survey is carried out every six years. JDS1 was held in 2001, JDS2 in 2007, and JDS3 in 2013. JDS4 completed the sampling campaign in summer 2019 to start an extensive ecological, biological, chemical and radionuclide analysis stage
1) to collect information on parameters not covered in the ongoing monitoring,
2) to acquire data that are readily comparable for the entire river, and
3) to promote the work of the ICPDR and raise awareness of water management.
First, the gamma-emitting nuclides of the sediment samples (grain size fraction <63 µm; dried at 105℃) were analysed by low-level gamma-spectrometry. Then the activity concentration of ^{90}Sr was determined by liquid scintillation counting (LSC) after isolating the radiostrontium using a new radiochemical separation method, which was developed in another project at AGES on behalf of the federal ministry of sustainability and tourism. Due to the simplicity and fastness of the novel method a high sample throughput was achieved.
The paper focusses mainly on the development of methods, application, validation and the uncertainty calculation. The impact of essential influencing factors on the radiometric and radioanalytical methods has been investigated, discussed and considered in the uncertainty budget. Furthermore, the influence of the applied methods on the calculation of detection limits and decision thresholds have been explored.
The results of the radiometric analysis of ^{90}Sr, ^{137}Cs and naturally occurring radionuclides (eg. ^{40}K, ^{210}Pb, ^{226}Ra, ^{228}Ra) in recent riverbed sediment are presented and discussed. 33 years after the environmental contamination due to the Chernobyl accident, a significant long-term decrease in activity concentration of sediment along the river was observed.
This up-to-date radionuclide data set is of great importance since it covers the complete analysis of riverbed sediments along the entire length of the Danube. Notably, the chronological development of the radionuclides' activity concentration levels gives insight into the long-term ecological decay/transport of the nuclides and makes it possible to apply a radioecological environmental model that gives a projection for possible future developments and river management requirements.

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Presenter: MARINGER, Franz Josef (BOKU - University of Natural Resources and Life Sciences, Vienna)

Session Classification: Applications

Track Classification: Applications

Contribution ID: **117** Type: **Oral Presentation**

RESEARCH SUMMARY OF THE EMPIR METRORADON PROJECT

Monday, 2 May 2022 14:30 (20 minutes)

The aim of this joint research project – carried out in the frame of the European Metrological Programme for Innovation and Research (EMPIR) coordinated by EURAMET – is to develop reliable techniques and methodologies to enable SI traceable radon activity concentration measurements and calibrations at low radon concentrations including geographical radon mapping beyond the state of the art. The results of the project will be targeted at the implementation of the European Council Directive 2013/59/EURATOM (EU BSS), one aim of which is to reduce the risk of lung cancer for European citizens due to high radon concentrations in indoor air. The calibration and measurement techniques and radon mapping methods developed in the project will assist EU member states in the establishment of their national radon action plan, which is required under the EU-BSS.

The scientific outcome of this research will help to establish a basic European metrological infrastructure for radon measurements enabling sound monitoring of radon and radon protection in Europe. In addition to the 17 European consortium members the project currently has 9 collaborators representing academic and public organisations. The strong engagement of about 150 stakeholders from manufacturers of radon monitoring equipment, companies offering radon measurements, calibration facilities, national authorities charged with the implementation of the EU Basic Safety Standards into national law, and international bodies is key to the successful implementation of the project's results.

In this paper, a comprehensive overview on the generated research results beyond the state of the art is given based on the working structure of the joint research project: (1) procedures for traceable calibration of ^{222}Rn instruments at low activity concentrations, (2) reducing the influence of ^{220}Rn on ^{222}Rn measurements and calibrations, (3) comparison of existing radon measurement procedures in different European countries and optimisation of the consistency of indoor radon measurements and soil radon exhalation rate measurements, (4) methodologies for the identification of radon priority areas and investigation of the relationship between soil radon exhalation rates and indoor radon concentrations, (5) validation of the traceability of European radon calibration facilities, and guide-lines on calibration and measurement procedures for the determination of radon concentration in air.

The project's outputs and data will benefit European and international standards on radon monitoring, radon measurement and calibration, geographical radon mapping, and guidelines on radiological protection, construction products, radiation instrumentation and nuclear data.

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Session Classification: Applications

Track Classification: Applications

Contribution ID: **121** Type: **Oral Presentation**

The traceRadon project

Thursday, 5 May 2022 09:40 (20 minutes)

Accurate knowledge of the low-level atmospheric radon activity concentration and radon fluxes are key parameters in the evolution of climate observations as well as radiation protection.
The need for traceable low-level atmospheric radon concentration measurement of two communities – climate observation and radiation protection – are joined under the EMPIR project traceRadon[1].
This project includes the development of a metrological capacity to measure low levels of radon in the environment (new sources, reference monitors, transfer instruments and robust methodology), and the validation of process-based maps for radon flux from the soil.
For the first time ever traceable methods for measuring low-level atmospheric radon activity concentrations in the range of 1 Bq·m-3 to 100 Bq·m-3 with uncertainties below 10 % applying traceable radon emanation sources as well as transfer standard instruments, are available.
Development of a radon flux calibration infrastructure, along with a transfer standard for radon flux, is another important aim of the project. This calibration infrastructure provides traceability from the laboratory to field measurements of radon fluxes, which is an essential step before applying the Radon Tracer Method (RTM) for indirect greenhouse gases fluxes retrieval.
Traceable measurements of atmospheric radon and radon fluxes are combined to validate current radon flux maps and inventories and to improve process-based radon flux models. This validation is further extended by using dosimetric and spectrometric data from the radiological early warning networks in Europe.
The use of reliable radon flux data and maps for the identification of Radon Priority Areas (RPA) has never been attempted before, due to a lack of robust data. It will therefore be possible to support the European member states in the identification of RPA, for example by extending the Radon Hazard Index through inclusion of dynamic data. This data will be available online for scientists, policy makers and end users. By this EURAMET is supporting regulation with metrology according to the EURAMET strategy 2030.
The concept and aims of the traceRadon project are presented, achieved results for traceability chains, uncertainties and data evaluation are discussed and the transfer of results from lab to field at the mid-term of the project is sketched.

[1]This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. 19ENV01 traceRadon denotes the EMPIR project reference.

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Session Classification: Thematic Session 1: Studies of Climate Change

Track Classification: Thematic Session 1 - Studies of climate change

Contribution ID: **122** Type: **Poster Presentation**

Research Project on the development of evaluation methods for inspection systems OF radioactive materials in foods

Wednesday, 4 May 2022 12:30 (10 minutes)

Monitoring and inspection of radioactivity in foods resulting from the nuclear accident at Fukushima Daiichi NPS in 2011 have been reinforced by local governments based on an inspection plan in accordance with the guidelines decided by the Nuclear Emergency Response Headquarters. The guidelines have been reviewed as necessary to ensure rational and efficient inspections with considering trends in monitoring, new scientific findings, or the lifting of shipping restrictions and other restrictions. In this research project, we are developing evaluation methods for the inspection system regarding radioactivity in foods and obtaining scientific knowledge for revising the guidelines.
The conventional test method for radioactive materials in foods using gamma-ray spectrometry using Ge-detector ensures reliability by homogenizing food samples and filling them into a set measuring container and making the conditions as identical as possible to those of a reference source to be compared. As alternative scintillation spectrometer using NaI(Tl) or CsI detectors are also widely used for screening test of radio-cesium in foods. In both cases, however, even if no radioactive materials are detected, the samples cut up for measurement cannot be shipped. In such a situation a new type of device that is named as "Non-destructive radioactivity measurement device (hereinafter NDRMD)" has been developed to measure radioactive cesium in bagged whole samples without sample preparation technique so that all products can be inspected in advance of shipping. However, in order to ensure reliability as one of the food inspection systems, it is necessary to conduct a detailed analysis of each individual sample for which testing efficiency can be improved by adopting this method.
In order to make it clear, following tasks are carried out in this project:
1) Uncertainty determination for screening of radio-cesium in foods without sample preparation procedure: The uncertainties in the measurement of the radioactivity of whole foods using the NDRMDs were determined by comparing the results of the measurement of food samples by the NDRMDs with the results by the calibrated Ge detector using the conventional sample machining procedure. Details will be shown in another presentation #68.
2) Determination of radioactivity distribution in foodstuffs: To evaluate effect of localization of radioactivity in samples on activity measurement without sample preparation procedure, radioactivity distribution in foodstuffs were determined by the imaging plate technique with a special sample treatment procedure and the conventional gamma-ray spectrometry.
3) Uncertainty evaluation in gamma-ray spectrometry arising from heterogeneity of radioactivity in foods: Uncertainties arising from heterogeneity of radioactivity in sample on the conventional gamma-ray spectrometry were determined by use of a Monte Carlo simulation with data of activity distribution obtained from real food samples.

In our presentation, outline of our whole research project for food monitoring post Fukushima accident situation will be represented.

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Session Classification: Thematic Session 2: Emergency Preparedness

Track Classification: Thematic Session 2 - Emergency preparedness