Application to Life Sciences and other societal challenges
Poster session summary
May 24th 2022

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Life Sciences

Spinning of nuclear and particle physics technologies to the benefit of medicine

• Increasing accuracy in external and internal radiotherapy
• Novel implant technologies
• Improving cancer diagnostics tools
QuARC – A quality assurance range Calorimeter

Saad Shaikh, Raffaella Radogna, Fern Pannell, Ruben Saakyan, Spyros Manolopoulos, Derek Attree, Connor Godden, Simon Jolly

Detector able of fast **real-time range measurements** without compromising accuracy to determine range of protons in proton beam therapy.

- Stack of **water-equivalent** polystyrene plastic scintillator sheets [1] that **sample proton energy deposition** along path.
- Each coupled to a photodiode to measure **light output** proportional to proton energy (with quenching corrections).
- Modular 32-channel ADCs for **zero-deadtime measurements at over 5 kHz**, read-out by an FPGA.
- **Fit of depth-light curve to reconstruct Bragg curve** and recover proton range.
Morphological changes in proton therapy are source of range uncertainty.

INSIDE
Bi-modal imaging system for in-vivo range monitoring in particle therapy.

Our purpose is to assess the sensitivity of the INSIDE IB-PET system in detecting anatomical changes.

Eight proton treated patients: six patients without and two patients with morphological changes.

RANGE VARIATION ANALYSIS
The Most-Likeljy-Shift (1st time applied to IB-PET images) was compared with the Beam-Eye-View.

The sensitivity was evaluated by the standard deviation of the range difference distributions in unchanged patients (squares). It was found to be larger for the changed patients (triangles).

The range differences obtained were superimposed on the CT scan as colorized maps.

CHANGES DETECTED
Were localized in the same zones as the one observed with the control CT scans.
A novel detection system dedicated for personalised radiation therapy planning designed to have:

- a detection head allowing for changes in geometry dependant on patient’s needs;
- a scalable Data Acquisition (DAQ) system supporting reconfigurability;
- a high-level software package using machine learning techniques to analyse medical imaging and generate needed detector geometry for the configuration and simulations.
ORIGIN, an EU project targeting real-time 3D dose imaging and source localization in brachytherapy: commissioning and first results of a 16-sensor prototype

A. Giaz, N. Ampilogov, M. Caccia, S. Cometti, W. Kam, S. O’Keefee, M. Martyn and R. Santoro

- The ORIGIN project addresses the urgent need to deliver more precise and effective Brachytherapy treatments
- Development of innovative optical fibre dosimeters with inorganic scintillators on the tip.

### BRACHYTHERAPY

<table>
<thead>
<tr>
<th>Source</th>
<th>Activity</th>
<th>Implantation</th>
<th>$E_Y$</th>
<th>$\lambda$ @ $E_Y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDR $^{125}\text{I}$</td>
<td>15 MBq</td>
<td>Permanent</td>
<td>35 keV</td>
<td>3 cm</td>
</tr>
<tr>
<td>HDR $^{192}\text{Ir}$</td>
<td>$\sim$100 GBq</td>
<td>Temporary</td>
<td>380 keV</td>
<td>10 cm</td>
</tr>
</tbody>
</table>

### HDR MEASUREMENTS

Before channel equalization

After channel equalization

Source Position at (0,0,0)

Sensor position

Cylindrical source pos.

True source pos.

5 cm

1.5 cm

4 cm
Astroparticle experiments to improve the biological risk assessment of exposure to ionizing radiation in the exploratory space missions

Alessandro Bartoloni, Nan Ding, Gianluca Cavoto, Cristina Consolandi, Lidia Strigari

The research topic initiative was launched in November 2021:
- > 1500 views (topic & articles)
- > 20 expected contributions
- > 5 abstracts received
- 1 published manuscript

Open for articles submissions!

Contributors from different research areas:
- Radiation Detection 18%
- Particle & Astroparticle Physics 11%
- Radiotherapy 21%
- Life Science 21%
- Astrophysics & Astroparticle 8%
- Medical Physics & Radiobiology 23%
- Radiobiology 21%

Frontier Detectors for Frontier Physics
15th Pisa Meeting on Advanced Detectors
May 22 - 28 2022 • La Sapienza, Isola d’Elba (Italy)
Visual prosthesis based on Silicon PhotoMultiplier: the SPEye project

P.W. Cattaneo on behalf of the SPEye Collaboration

Abstract: Several retinal degenerative diseases like age-related macular degeneration (AMD) and retinitis pigmentosa (RP) cause total or partial blindness to about 1 over 4000 people in the world for a total of ~1.5 million. Those diseases cannot be cured, the only possible improvement of life quality for the people affected is a visual prosthesis compensating the retinal damage. Such devices have been developed with interesting but limited results. We suggest an improved version based on subretinal implantation of SiPM arrays which should be able to stimulate the healthy part of the retina at low power and high visual acuity.
Fast Timing MPGD for ToF-PET
Filippo Errico, Anna Colaleo, Marcello Maggi, Antonello Pellecchia, Raffaella Radogna, Piet Omer J. Verwilligen

PET is an effective functional imaging technique especially for cancer diagnosis. Its performance is strictly connected to the ability to detect and reconstruct photons emitted by the positron - electron annihilation. Its sensitivity is enhanced when time information are included (ToF-PET). The measure of the detection time difference between the two photons leads to a higher contrast image and more accurate diagnoses.

Studies for a possible development of a ToF-PET based on MPGD will be shown. MPDG has a very good spatial and time resolution and very low price, making it suitable for a full-body scanner.

Further improvement in the time precision (suitable goal is to achieve values of the order of 100 ps) could be reached thanks to the FTM design, where multiple layers of MPGD compete in better measuring time information.
Performance of monolithic BGO crystals as gamma detectors using a Neural-Network event decoding algorithm

G. Sportelli, M. Morrocchi, M. G. Bisogni, P. Carra, E. Ciarrocchi, V. Rosso, N. Belcari

BGO has been the preferred scintillating material in PET applications for decades, until the need for time-of-flight acquisitions moved the preference to LYSO a faster, but more expensive and less versatile scintillator. In this work we demonstrate experimentally and in simulation that with the use of AI decoding algorithms, BGO can comply with time-of-flight speed requirements and thus become a competitive candidate for gamma ray detection.

Achieved performance (experimental data)

<table>
<thead>
<tr>
<th></th>
<th>CTR (ps)</th>
<th>SR (mm)</th>
<th>Energy Res. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2 mm LYSO</td>
<td>160</td>
<td>0.8</td>
<td>12.7</td>
</tr>
<tr>
<td>3.2 mm BGO</td>
<td>320</td>
<td>0.8</td>
<td>20.2</td>
</tr>
</tbody>
</table>

DAQ based on the HRFlexToT ASIC

Energy spectra (top left), CTR (top right) and flood maps (bottom)

The research leading to these results has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement n. 688735 (Photonics Based Sensing ERA-NET Cofund), Regione Toscana (PRSE 2012-2015 approval n. 11131/2016) and VLAIO.
Characterisation of a scintillating fibre-based hodoscope exposed to the CNAO low-energy proton beam

Riccardo Rossini, Roberto Benocci, Roberto Bertoni, Maurizio Bonesini, Massimiliano Clemenza, Alessandro Menegolli, Erik Vallazza, Gian Luca Raselli, Ludovico Tortora, Marco Prata, Marco Pullia, Massimo Rossella

- Beam hodoscope, active area 6x6 cm², 64 scintillating 1x1 mm² fibres, to be used in the FAMU experiment as a muon beam monitor (at RAL, UK), aimed to perform a precision measurement of the proton Zemach radius in muonic hydrogen atoms
- Calibration with at the CNAO synchrotron in Pavia (Italy) with proton beams at 125, 150 and 175 MeV with very low rate (50 Hz)
- Protons at 150 MeV are chosen as their \(-dE/dx\) curve is similar to the one of the 60 MeV/c negative muons in the FAMU experiment
- The single proton signal at 150 MeV allows to calibrate the detector in order to enable muon counting at the high rate RAL muon beam
Characterization of charge sharing and fluorescence effects by multiple counts analysis in a Pixie-II based detection system.

P. Delogu, V. Di Trapani, D. Dreossi, B. Golosio, R. Longo, L. Rigon, P. Oliva

- The imaging performance of X-ray Photon Counting Detectors (XPCD) based on high Z crystal sensors is mainly affected by the simultaneous detection of a single interacting photon by different pixels. Such multiple counts worsen the spatial resolution and cause loss of spectral resolution.
- In this work we presents an experimental study for the systematic characterization of multiple counts detection in a Pixirad-I/Pixie-II system.

**The detection system:** Pixirad/Pixie II

An interacting photon releasing all its energy can be registered by a single pixel a) or by a “cluster” of different adjacent pixels due to charge sharing b). Fluorescence can lead to multiple counts, even from disjointed clusters c).

Using photons of energy below the Cd K-edge and relative threshold (Threshold/Energy) set to 0.1, the relative frequencies of clusters corresponding to single, double and triple counts are respectively of 0.4, 0.4 and 0.2. Choosing appropriate values of the discrimination thresholds, multiple counts can be avoided with no loss in detection efficiency.

When imaging with photons having energy above Cd K-edge, clusters of more than 4 pixels are observed. In this case the threshold can be set to record only “primary” events, at the cost of a reduction in the detection efficiency.

We acquired large stacks of images, for each of which only few photons interact in the whole sensor.

- We observed, in single images, the presence of “clusters” of different size
- By counting the clusters of different size, we studied the dependence of the multiple counts on the energy of the impinging photons and on the discrimination threshold
Other societal challenges

Spinning of nuclear and particle physics technologies to the benefit of society

• Homeland security
• Environmental sustainability
• Cultural Heritage
• Novel science divulgation
• Instrumentation on the crossroads between nuclear and applied physics and beyond
Performances of scintillators applied to Special Nuclear Material (SNM) measurements in the field of Nuclear Safeguards, material verification and Nuclear Security

M. Morichi, M. Corbo, G. Mangiagalli

SCENARIO:

- nuclear threats are still an actual problem for homeland security and for counter terrorism agency as reported by IAEA through the ITDB (3497 incidents from 1993 to 2018)
- SNM out of regulatory control can be used by terrorists to produce dirty bombs (conventional explosive coupled to radioactive material) to contaminate national strategic areas and to rise panic in the common people

METHOD:

- Innovative scintillators coupled to digital electronics with pulse shape processing (PSP) firmware allow to new measurements method that are step-change respect the current detection systems.
- EJ309 liquid scintillator is used for detect both gamma and fast neutrons (allowing energy measurement of the neutrons) with a double integration charge gate to perform PSP
- CeBr₃ is used for gamma spectroscopy as a tradeoff between good resolution plus low intrinsic background and easiness of use

SOLUTION:

- SNIPER-GN is a Backpack Radiation Device (BRD) designed by CAEN and equipped with EJ309 and CeBr₃. It can perform gamma and neutron counting, gamma spectroscopy identification and is the only instrument in the world that performs neutron source identification in less than 1 min through the neutron measurement
- SNIPER-GN patented algorithm allows for discrimination between Cf-252, Am/Be, Am/Li, U and Pu with. In less than 1 min can also determine the measurement condition indicating the presence of masking source, moderators or lead shielding
- It exceed international standards like: IEC62327, ANSI N42.34, ANSI N42.53
uRANIA: a micro-Resistive WELL for neutron detection

Matteo Giovannetti LNF-INFN on behalf of the uRANIA-V project

**10B neutron converter**

Due to the He shortage a call for alternative solutions for thermal neutron detection arise. A 10B conversion stage facing the gas gap, through nuclear capture, transforms a standard µ-RWELL in a thermal neutron detector, reaching efficiency up to 10% for single detector plane.

Different converter geometries are accessible:

- Planar cathodes
- Grooved cathodes
- Metallic meshes

**HOTNES ENEA test facility**

**Summary and results**

- For the planar cathode a scan for different 10B thickness has been performed in current mode, measuring an efficiency $\approx 1.5 \pm 2.0\%$
- The planar 10B-coated cathode + 10B-coated mesh configuration characterized in current mode exhibits an efficiency of $4.6 \pm 1.0\%$
- The counting mode measurements, performed for the 10B-coated planar and grooved cathode layouts show the following results:
  - Planar $\rightarrow 2.19 \pm 0.05\%$
  - Grooved $\rightarrow 2.61 \pm 0.06\%$
A novel concept of a Single Plane Compton Gamma Camera based on scintillator pixels read out on only one side by SiPMs. The scatterer layer made of 8x8 array of 3 x 3 x 3 mm³ GaGG scintillators, with a 3.2 mm pitch. Matching plexiglass lightguides connect the scatterer layer to another 8x8 array of 3 x 3 x 3 mm³ GaGG scintillators which serves as the absorption layer. The latter is coupled to a matching array of 8x8 silicon photomultipliers. The scatterer and the absorber pixels in one column are read out by the same SiPM thus minimizing the number of readout channels.
Open-Sky muon tomography for Glacier Monitoring

A. Cervelli (INFN-Bologna), S. Rabaglia (Universitá di Bologna), M. Sioli (Universitá di Bologna)

The project goal is to achieve an ice thickness resolution of O(5m) that corresponds to an angular resolution on the incoming muon tracks of O(7mrad).

Open-sky operations need fast detector to reduce to negligible level background tracks not passing through the target.

Detector requirements: reduced number of channels, low maintenance needs, able to operate in adverse weather with simple powering scheme.

Detector Design:
- 5 pairs of plastic planes with embedded scintillating fibers bundles, running on orthogonal axes
- Plane dimensions 1mx1m
- Fiber bundle diameter 6cm
- One photodetector per bundle: number of channels O(2000)

Optimization was done with different configurations in terms of detector length and plane spacings.

Glacier melting is one of the most visible effects of global warming. Muon tomography can shed light on glacier thickness and their melting processes. Only few glaciers have underground access to open-sky detectors.

Measuring muon fluxes with good angular resolution allow for glacier-bedrock interface depth.

Only assumption is made on the overall bedrock+ice thickness T.

\[ \Phi(\rho, \theta, \lambda) = \Phi_0 e^{-\frac{\rho}{\lambda}} \]

\[ X = L_1 \rho_1 + L_2 \rho_2 \quad ; \quad T = L_1 + L_2 \]

A first simulation with reduced statistics showed first results for a direct measurement of bedrock-glacier interface, and a higher statistics simulation is in preparation to understand the exposure time needs for the detector.
The ANET Compact Neutron Collimator

Valeria Monti on behalf of the ANET collaboration
{Università degli studi di Torino and INFN Torino, Italy

Development and construction of a **compact multichannel collimator** for neutron imaging

**CONCEPT** → Compact scalable structure alternating B₄C and air channels. Dynamic continuous path for a homogeneous irradiation of the sample.
**RESULTS** → Improvement of the resolution measured at two different neutron imaging beams (BOA @ PSI Swiss, PAVIA LENA reactor Italy). First tomography examples.

*Resolution at different distances of the sample from the scintillator at BOA neutron beam with and without the ANET CNC.*

Tomography of a Dane iron fibula (circa X century d.C.). Red areas show a higher attenuation w.r.t green areas and are associated with hydrogen-rich mineral phases, which implies an advanced corrosion stage.
The Cosmic Ray Cube is a portable tracking device conceived for outreach activities.

- It consists of 48 scintillating bars with WLS fibres coupled to SiPMs.
- Its operation requires only the standard electrical power.

The detector was used to measure the differential muon flux inside the bunker of Monte Soratte (Italy) a suitable location for the Ptolemy experiment.

The differential muon flux $\Phi_\mu$ scan highlights the details of the mountain above the bunker:

- providing a map of the rock thickness that surrounds the detector.
Qualification of New Companies for the Production of Resistive Plate Chambers

O. Kortner, H. Kroha, D. Soyk, T. Turković, MPI for Physics, Munich, Germany

- Resistive plate chambers (RPCs) with subnanosecond time resolution and mm spatial resolution are cost-effective charged particle detectors for the instrumentation of large areas.
- 1000 Thin-gap RPCs will be installed in the phase-II upgrade of the ATLAS muon spectrometer and experiments searching for long-lived charged particles like ANUBIS plan to use RPCs.
- Huge demand for RPC for future experiments and tight mechanical constraints require new production capacities in industry and industry-style quality assurance.
- The production procedure for thin-gap RPCs was optimized at MPI for Physics and is currently transferred to 4 companies in Germany.

Optimized spacer design / New assembly and gluing template / Successful functional test
The use of Low-temperature Cofired Ceramics technology in Gas Electron Multiplier Microstructures

Piotr Bielówka, Waclaw University of Science and technology

Foreseen advantages of LTCC-GEM structures over polyimide-based ones:
- low outgassing
- low coefficient of thermal expansion
- excellent dielectric properties
- a high amplification
- a high density of vias
- robustness and durability
- many types of conductive layers can be used
- low production costs of prototypes

The first LTCC-GEM prototypes were investigated, and the R&D work is ongoing.

A GEM made on the basis Low-Temperature Cofired Ceramics technique.

LTCC-GEM microstructure made with LTCC substrate covered by a conductive substrate. Vias were fabricated by a laser beam.
Beam monitoring detectors for High Intensity Muon beams

Giovanni del Maso, PSI

Currently PSI delivers the most intense continuous muon beam in the world with up to few $10^8 \mu^+/s$, and aims at reaching $10^{10} \mu^+/s$ within the High Intensity Muon Beam (HIMB[1]) project. Usual beam monitoring tools are not suited for $\mu^+$ beams as it is necessary to distinguish $\mu^+$ from the particles contaminating the beam, such as $e^+$ and $\pi^+$. The performances of these detector as measured along the beamline, their detailed MC simulations and the beam characteristics are presented.

The SciFi detector

It is a grid of scintillating fibers coupled to plastic scintillators divided in two layers each measuring one transverse direction.

- It can operate in vacuum under high magnetic field conditions.
- It is non-invasive: 80% of the beam is not affected by the detector. Can be run together with data taking to monitor beam properties.

Can perform particle ID through energy deposition and time of flight with respect to the proton beam RF.

Coincidences between fibers can be exploited to measure a 2D beam profile.

The MatriX detector

The matriX detector is a matrix of plastic scintillators coupled to SiPMs. It can operate in vacuum under high magnetic field conditions. Can perform particle ID through energy deposition.

It measures by construction a full 2D beam profile.

A plexiglass light-guide is placed in between the scintillator and the SiPM to increase separation between $e^+$ and $\mu^+$.

200 $\mu$m BC400