SIDERALIS
cosmic SIlence in Deep underground Environments for RAdiation and LIfe Studies

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On behalf of the SIDERALIS collaboration
INFN-CSN5 experiment proposal

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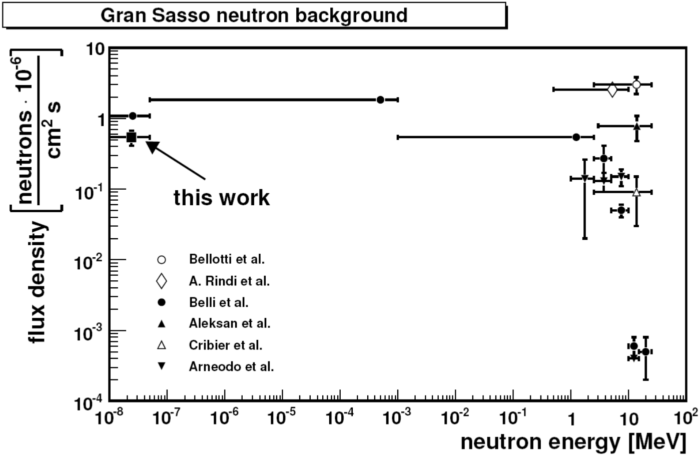
The scientific case

- Many modern Physics experiments challenge the measurement of very small event rates ($\lesssim$ *few events/year*)$\Rightarrow$ equipments location deep underground
- Deep underground experiments are sensitive to background neutrons:
    - I Elastic scattering of neutrons affects signals from WIMP interactions
    - II Inelastic scattering of neutrons or neutron capture produce γ rays influencing $0\nu\beta\beta$ decay
- Previous results from radiobiology studies have indicated that the neutron component, among the other radiation field's contributions, most likely could be the best candidate responsible of the observed effects (less efficient DNA repair mechanisms and ROS scavenging processes) on cells *in-vitro*, hosted in Deep Underground Environment (LNGS bypass tunnels)
- An evident lack of coherent data does exist in literature on the topic of neutron background in underground labs (LNGS in particular), because the direct comparison of the results obtained by experiments carried out in the past is made difficult, due to the wide variety of experimental setups and detected neutron energy ranges. Moreover, simulations of underground environments' neutron background have shown results affected by several uncertainties, relying on different assumptions on material compositions (e.g. the rocks), physical models and cross sections libraries available in Monte Carlo codes, different codes used.
- Cosmic rays induced outdoor neutron background is another issue, nowadays attracting interest among the scientifc community because of its impact on experiments at high latitudes and altitudes, for which high sensitivity neutron spectrometer are being demanded

An example: *n* background measurements @ LNGS



Z. Debicki *et al.*, Nuclear Physics B (Proc. Suppl.) 196 (2009) 429-432

The experiment proposal I

The neutron background needs to be understood in detail, in order to:

- limit its impact on fundamental physics experimental sensitivity (thus allowing more accurate VETO systems)
- discriminate its role in previous radiobiology experimental results and in future studies on more complex living organisms

SIDERALIS experiment proposal relies on:

1. Extensive simulations campaign, by means of benchmarks with MCNP6 and FLUKA Monte Carlo codes, aimed at
   - I Simulating the neutron background in LNGS halls and bypass tunnels
   - II Studying the response matrix of a novel high sensitivity neutron compact macro-detector, based on BF_3 proportional counters
2. Prototype and calibration of the new detector, in strong collaboration with the industrial partner, involving the development of dedicated electronics and innovative moderating materials (doped flexible rubber sheets)
3. Test of the detector at LNGS and detailed characterization of the LNGS neutron flux and spectrum, in the different halls and bypass tunnels

The experiment proposal II

5. Completing the characterization of the underground radiation field by means of
   - I gamma spectroscopic measurements with HPGe spectrometers
   - II evaluations of the contributions from the different families of radionuclides to the detected gamma dose rates with TLD detectors
   - III measurements of radon activity concentrations in air with Radon Daughter Monitor
6. Set of biological measurements, complementary to the physical ones, addressed at discriminating the relative contribution of the different radiation components, by means of *in-vivo* experiments on the fruit fly *Drosophila Melanogaster*

The collaboration

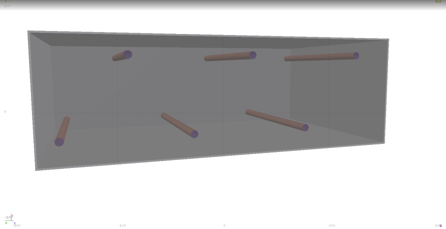
The SIDERALIS experiment will join together the collaboration and expertise of several Italian research institutes and one industrial partner, namely:

- INFN, within its laboratories and sections
  1. INFN-LNF
  2. INFN-LNGS (hosting lab)
  3. INFN-RM1
  4. potential collaboration with INFN-TO and Argentine Antarctic Institute (IAA)
- ISS
- ELSE nuclear (industrial partner)
- Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi
- ENEA
- INAIL
- Università degli Studi de L'Aquila
- Università degli Studi di Roma “La Sapienza”

Neutron detector design and development (LNF-ELSE)

- BF_3-filled proportional counters constitutes a valuable alternative to ^{3}He-filled ones, given the known issue of the ^{3}He shortage and the series of advantages and disadvantages of BF_3 gas
- It has already been shown in the past that BF_3 counters are a reliable tool for low level neutron backgrounds in underground laboratories, but...
  - I No experimental assessment of the detector efficiency in underground environmental conditions has been performed. Efficiency has always been calculated by means of MC simulations, without any benchmark
  - II Detected neutron energy spectrum has always been somehow "inferred" from the neutron cross sections of the various moderators used and from the mixing of experimental and MC calculations

Thus an inconsistency in the various approaches used does exist, probably leading to the inconsistency of the results gained. What we want to measure is not just $\phi^{(i)}(n)$, but $\frac{\mathrm{d}\phi(n)}{\mathrm{d}E}$!



What SIDERALIS proposes is a compact ($\sim$3x2x1.5 m^3) Multi Cylinder Neutron Detector (MCND), following a different approach relying on

- Increasing the efficiency of a single tube increasing the number of tubes in the array (non linear dependence!)
- Employing different types and thickness of moderators (standard Cd or $(C_2H_4)_n$ and new doped flexible rubber sheets) - Bonner spheres method
- Using MC codes to
  1. calculate the response function of the new detector
  2. perform theoretical estimations of the expected neutron fluxes experimental results will be compared to
  3. benchmark theoretical predictions between two of the most widely used codes in neutron physics, MCNP6 and FLUKA

γ rays dosimetry and spectroscopy (ISS-Roma1-ENEA-INAIL)

- HPGe spectroscopic measurements will allow to gain precious informations on
  1. γ fluxes populating the experimental sites
  2. activity concentration ratios between the ^{238}U and ^{232}Th radioactive series and their decay disequilibrium (useful also for accurate MC simulations!)
- γ dose rates measurements will be performed with high pressure ionization chambers and TLDs
- Ionization chamber and scintillation cell will allow monitoring of hourly and daily variation of indoor ^{222}Rn activity concentratoin in air
- Average Rn concentrations in experimental sites evaluations by means of passive Rn dosimeters

Radiobiology (ISS-Roma1-Centro Fermi-UNIVAQ)

- *In-vivo* measurements on living organism fruit-fly *Drosophila Melanogaster* will study the effect of acute exposures to genotoxic agents on the genome stability in terms of chromosome break frequency and expression of DNA repair genes both in
    1. underground PULEX/Cosmic Silence facility at LNGS
    2. reference laboratory at University of L'Aquila/University of Rome "La Sapienza"
    3. LIBIS facility at ISS - LIBIS allows to expose biological samples at dose rates ranging from few $\mu Gy/h$ to few tens of mGy/h
- Genotoxic effects will rely on γ dose rate modulation and specific drugs after different periods of chronic low dose rate exposures
- The aim is to increase knowledge about the role of the radiation spectrum component(s) triggering the molecular mechanisms involved in the biological response to environmental radiation

People involved in SIDERALIS I
INFN personnel and associates

The SIDERALIS experiment does estimate the following service request to LNF:

- 3 months of man equivalent for engineering mechanical design
- Radiation protection group (FISMEL) support according to the following table:

People	INFN section/LAB	FTE
Adolfo Esposito (technologist executive)	LNF	0.3
Oscar Frasciello[1] (technologist)	LNF	0.7
Maurizio Chiti (technician)	LNF	-
Giuseppe Carinci (technician)	LNF	-
Alfonso Gentile (technician)	LNF	-
Total	LNF	1.0
Emanuela Bortolin (researcher)	ISS-Roma 1	0.2
Cinzia De Angelis (senior researcher)	ISS-Roma 1	0.2
Giuseppe Esposito (researcher)	ISS-Roma 1	0.3
Maria Antonella Tabocchini[2] (senior researcher)	ISS-Roma 1	0.3
Maria Cristina Quattrini (technician)	ISS-Roma 1	-
Total	ISS-Roma 1	1.0
Total	INFN	2.0

[1] National and LNF local SIDERALIS responsible

[2] Roma 1 local SIDERALIS responsible

People involved in SIDERALIS II

Other institutions' personnel

People	Institution
Cristina Nuccetelli (senior researcher)	ISS
Giacomo Manessi (R&D engineer)	ELSE Nuclear
Marcello Ballerini (R&D engineer)	ELSE Nuclear
Rosabianca Trevisi (researcher)	INAIL
Federica Leonardi (researcher)	INAIL
Francesco Cardellini (researcher)	ENEA
Francesca Cipressa (research fellow)	Centro Fermi
Patrizia Marciano (researcher)	University of L'Aquila
Giovanni Cenci (Associate Professor)	University of Rome "La Sapienza"

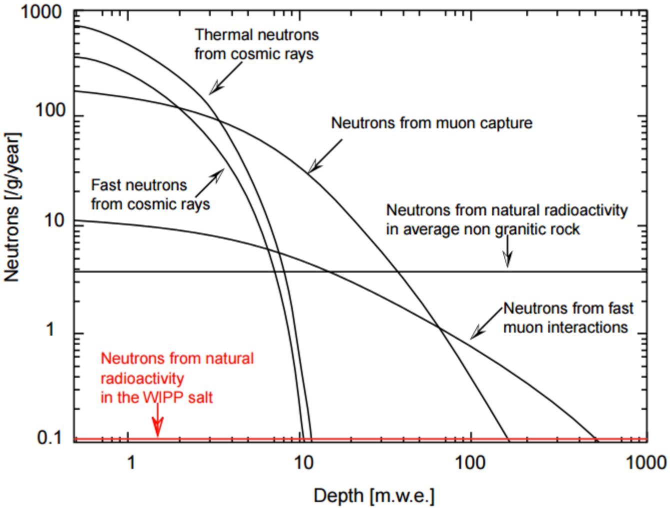
Cost estimates

Item	Cost estimate (k€)
Detectors	25.0
MCND Electronics & moderators	90.0
Other consumption goods	8.0
External services	7.0
Travels	30.0
Research Fellow	19.5
Total	**179.5**

Thanks for your kind attention!

Backup slides

Underground *n* background sources



E.-I. Esch, *"Detector Development for Dark Matter Research"*, PhD thesis