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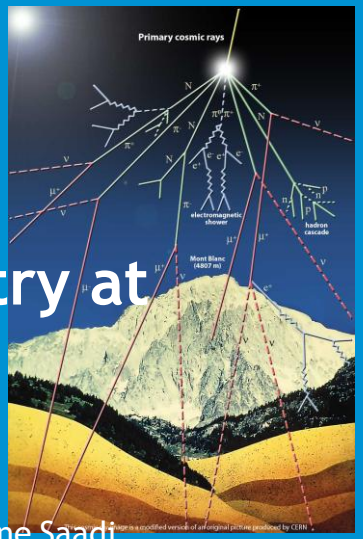
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Bonner Spheres Neutron Spectrometry at Mountain Altitude and Underground at LSBB



Véronique Lacoste, Valérian Lalucaa, Alain Martin, Michel Pépino, Caroline Saadi
Institut de Radioprotection et de Sûreté Nucléaire, BP3,
Saint-Paul-lez Durance 13115, Cedex FRANCE

Daniel Boyer, Alain Cavaillou, Julien Poupeney, Christophe Sudre
Laboratoire Souterrain à Bas Bruit de Rustrel, Observatoire de la Côte d'Azur,
Rustrel 84400, FRANCE

i-DUST
INTER-DISCIPLINARY UNDERGROUND SCIENCE AND TECHNOLOGY

9 – 11 June 2010, Apt (France)

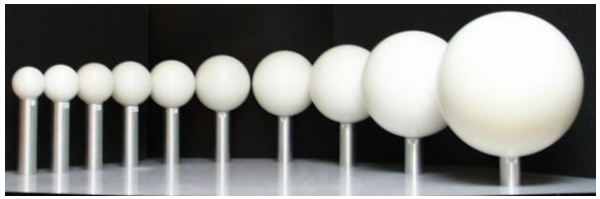
Système de management
de la qualité IRSN certifié

Outline

- The Neutron Metrology and Dosimetry Laboratory of IRSN
- Context and motivations for spectrometry of high energy neutrons
- The IRSN Bonner spheres spectrometer extended to high energy neutrons
- Tests underground at LSBB
- First measurement campaign at the LSBB altitude experimental site
- Conclusions and perspectives

Main tasks of the Neutron Metrology and Dosimetry Laboratory

- Radiological Protection and Human Health Division / External Dosimetry Department (located in Paris)
- LMDN located in Cadarache, ~70 km from Apt
- Provision of services and expertise for the qualification of radiation protection instruments and for workplaces characterization
  - Neutron spectrometry and dose assessment (nuclear industry, medical facilities, etc)
- Development and operation of reference neutron facilities (available for external customers)
  - Mono-energetic neutron fields (2 keV – 20 MeV)
  - Standard Radionuclides sources (^{241}Am-Be, ^{252}Cf)
  - Realistic neutron fields (simulating workplaces of PWR)
- Development of neutron devices for metrology (own needs) and expertise
  - **Bonner spheres systems adapted to various environments (NPP, medical LINAC, high energy accelerators)**



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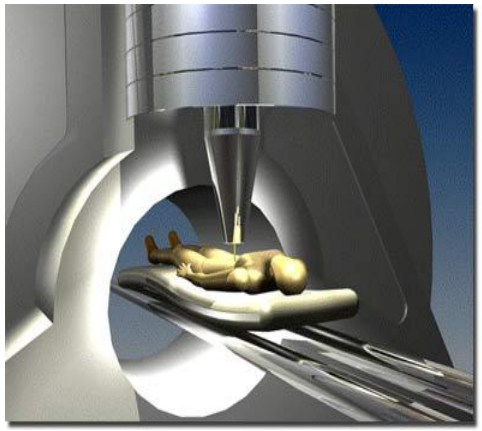
Context and motivations for spectrometry of high energy neutrons

Medical dosimetry
Emerging of high energy cyclotron facilities for hadron-therapy

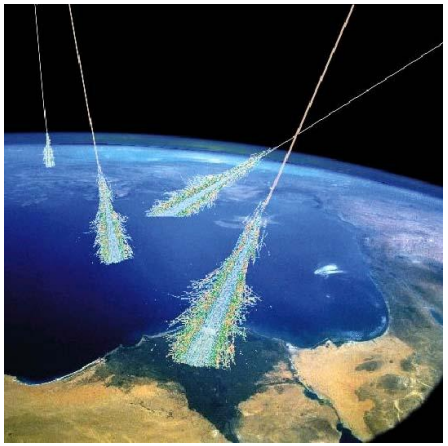


- Additional doses to patients
- Input or comparison data for simulation codes
- Check the response of neutron monitor in treatment rooms
- Design of screens and shieldings
- etc

Production of secondary neutron fields with high energy components (> 20 MeV)

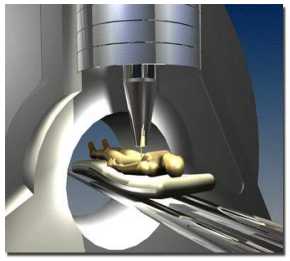
Development of a new IRSN system for the characterization of high energy fields, with high or weak neutron fluence rates

Characterization of the natural radiative environment

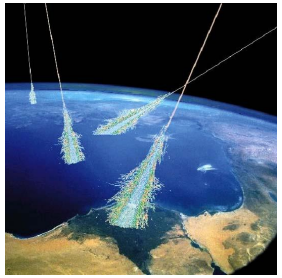


- SEE (Single Event Effects) studies in the aeronautics and aerospace domains
- Aircrew dosimetry
- Study of the « Space Weather »
- etc

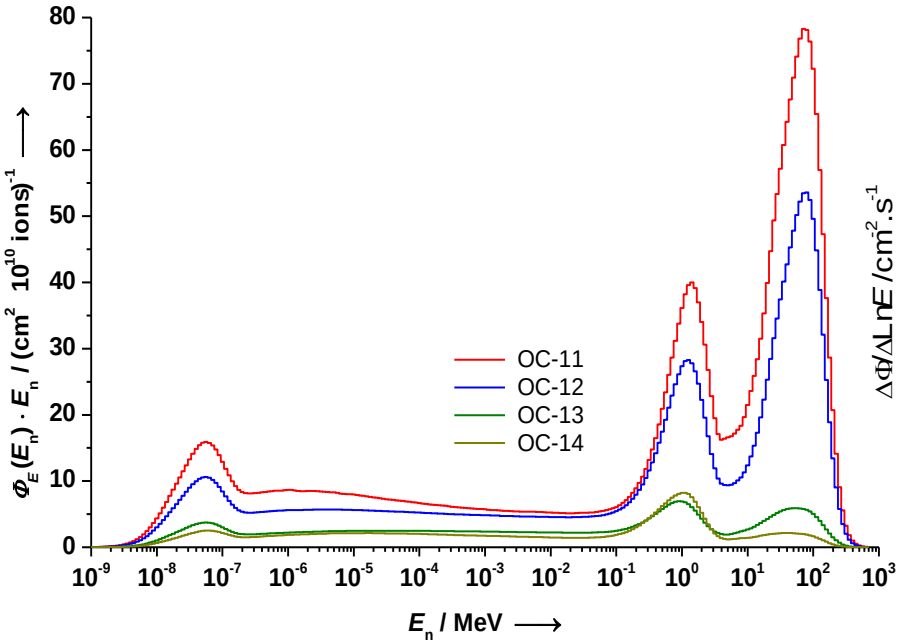
Examples of neutron fluence energy distributions

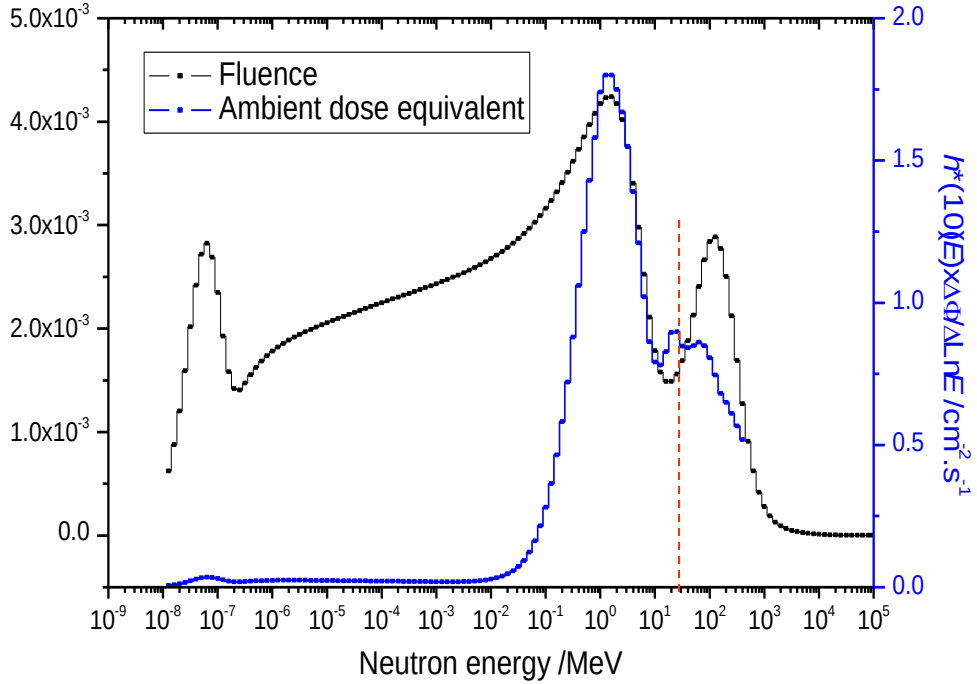


Hadrontherapy with ^{12}C
(@ GSI - Germany)



Cosmic neutrons
(ex @ LSBB altitude site)

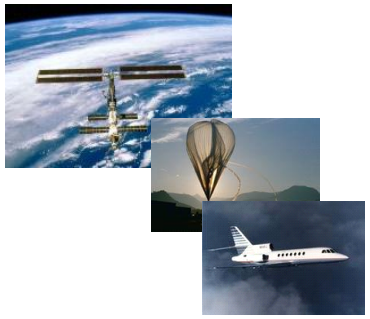




Context and motivations for spectrometry of high energy neutrons

New working group ONERA – IRSN – LSBB – OMP

- Office National d'Etudes et de Recherches Aérospatiales (French Aerospace Lab)
  - Measurement and modeling of the Natural Radiative Environment
  - Studies and modeling of the SEE (for space, atmospheric and ground environments)



- IRSN - LMDN
  - Reference neutron facilities
  - Neutron instruments (spectrometers) and measurements

- LSBB
  - Involved in SEE studies (Xilinx)
  - Experimental sites for testing ONERA and IRSN devices dedicated to the Natural Radiative Environment characterization
    - low-noise underground sites
    - mountain altitude site (+ 1000 m above sea level)

- Observatory of Midi-Pyrénées
  - Mountain altitude site : « Pic du Midi » - 2885 m

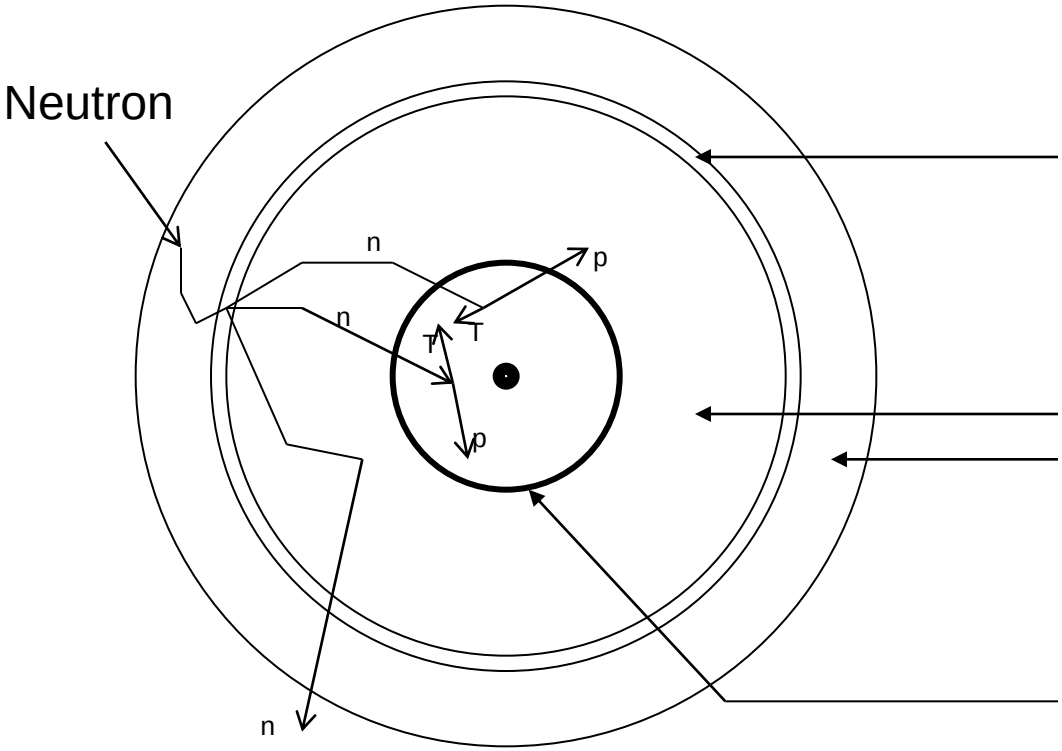
Platform for long-term measurement of the natural radiative environment

The IRSN Bonner sphere spectrometer extended to high energy neutrons

- **Developed and optimized for the detection with high efficiency of the high energy neutrons**
- **A Helium-3 proportional counter**
  - Detection of neutrons with the reaction n +^{3}He -> p +T
  - Spherical: 2" (~5 cm) diameter
  - 10 bars ~ 145 psi
- **13 moderator spheres between 3 and 12 inches**
  - 10 spheres of Polyethylene

  3 - 3.5 – 4 - 4.5 – 5 – 6 – 7 – 8 – 10 and 12 inches
  - 2 spheres with a tungsten shell
  - 1 sphere with a lead shell
- **Tests “of performances” at LSBB**
  - Intrinsic electronic noise
  - Ability for low neutron fluence rate detection

Principle of detection



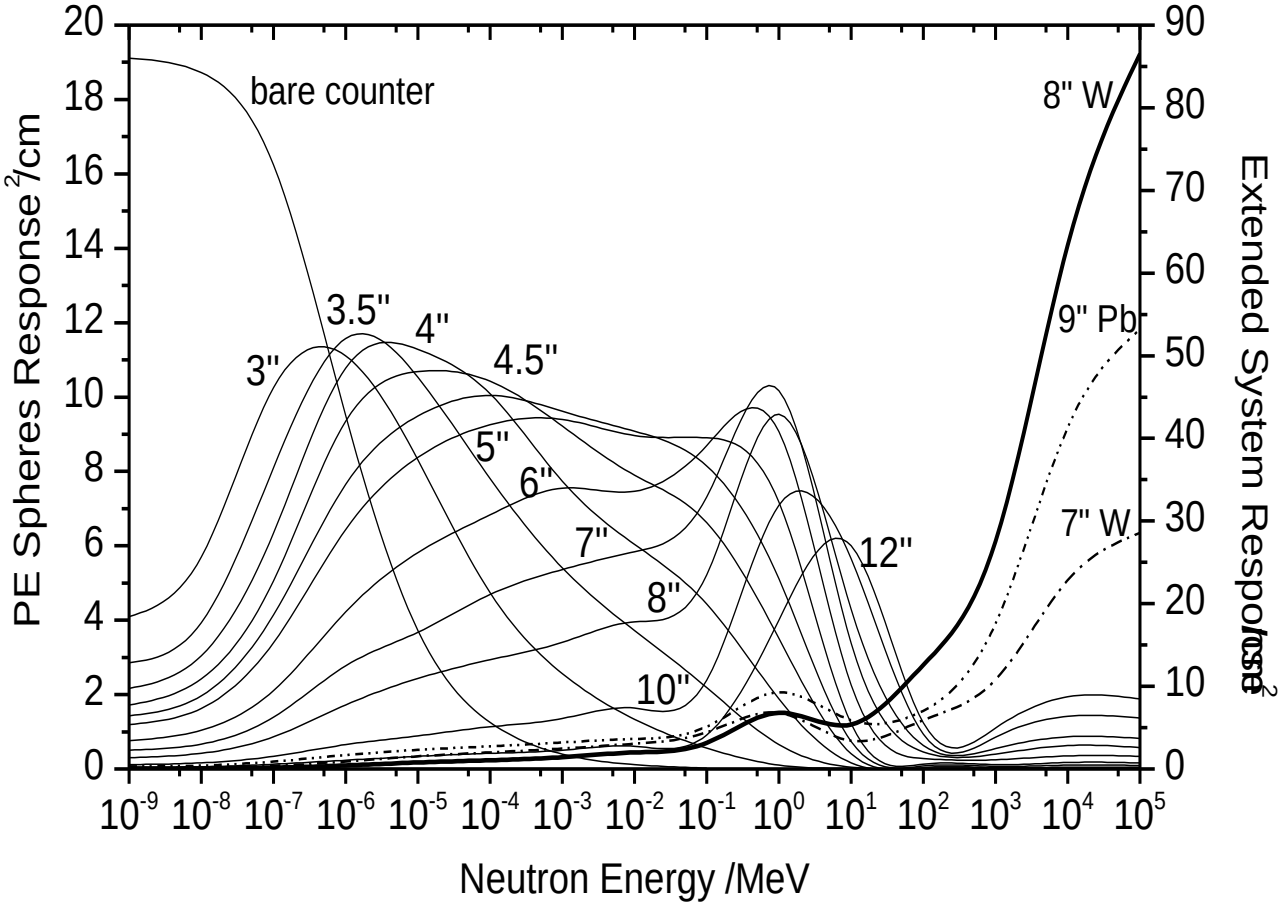
Metallic shell (Tungsten or Lead)
(n, xn) reactions on high energy neutrons

High density polyethylene (PE)
0.95 g/cm^2
Slow down neutrons by elastic scattering

He-3 proportional counter
n + ^{3}He -> p + T (Q = 764 keV)

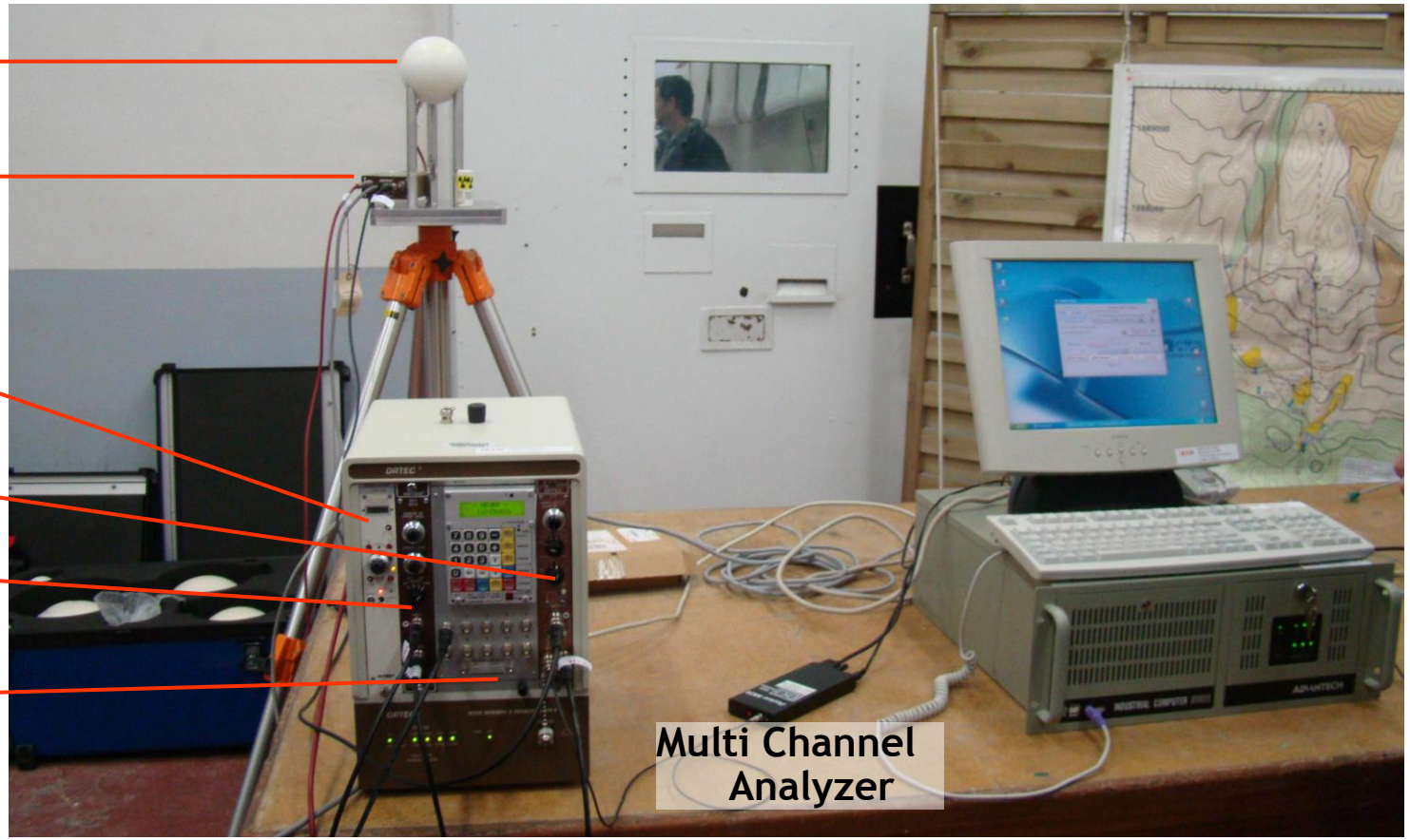
The MCNPX calculated response functions

- Response functions calculated with MCNPX Monte Carlo simulation code
- Experimental characterization on fall 2010, at the IRSN reference facilities



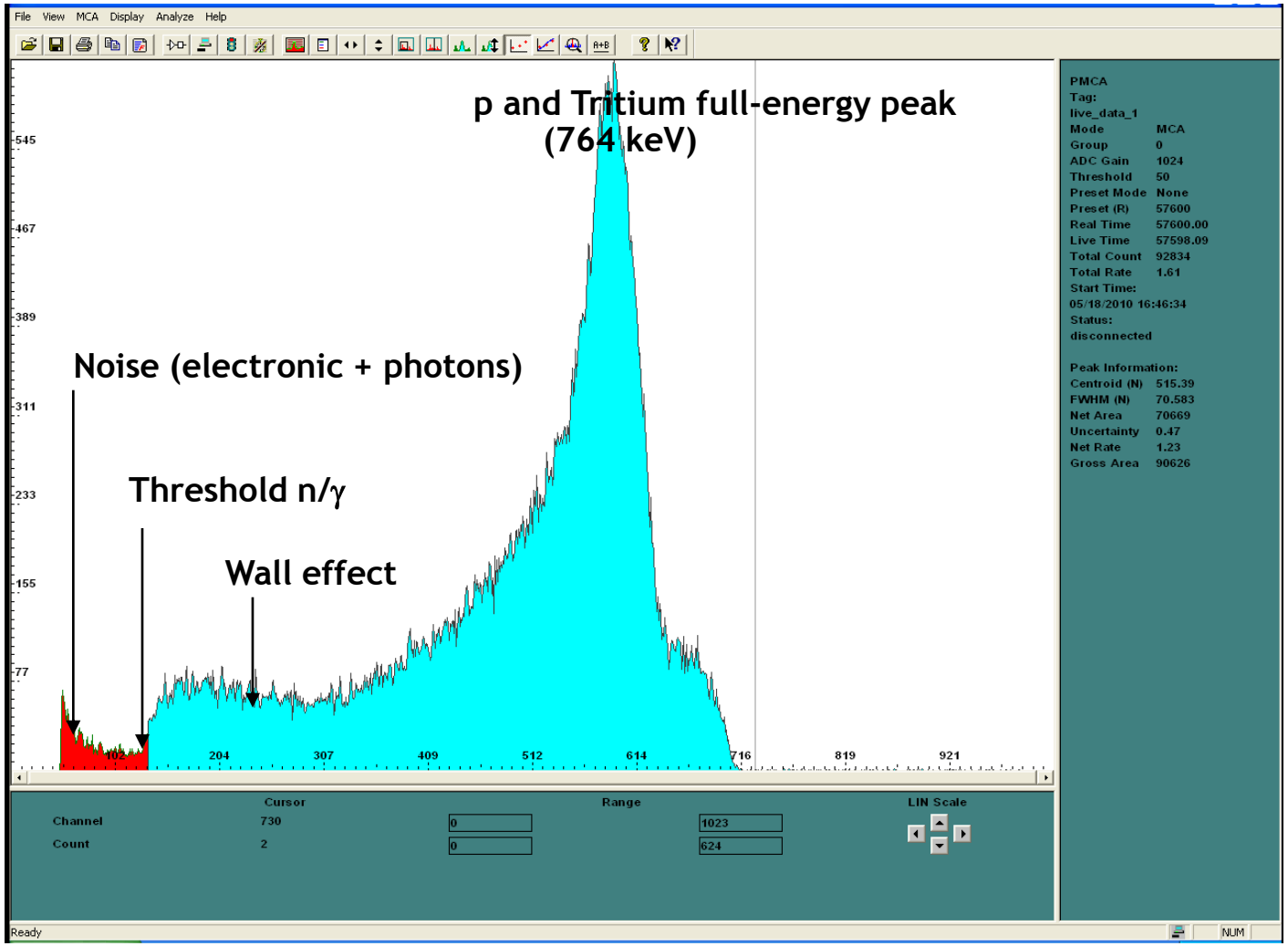
Acquisition setup

- Similar to gamma spectrometry
- Both records of the pulse height spectrum from MCA and counts from SCA



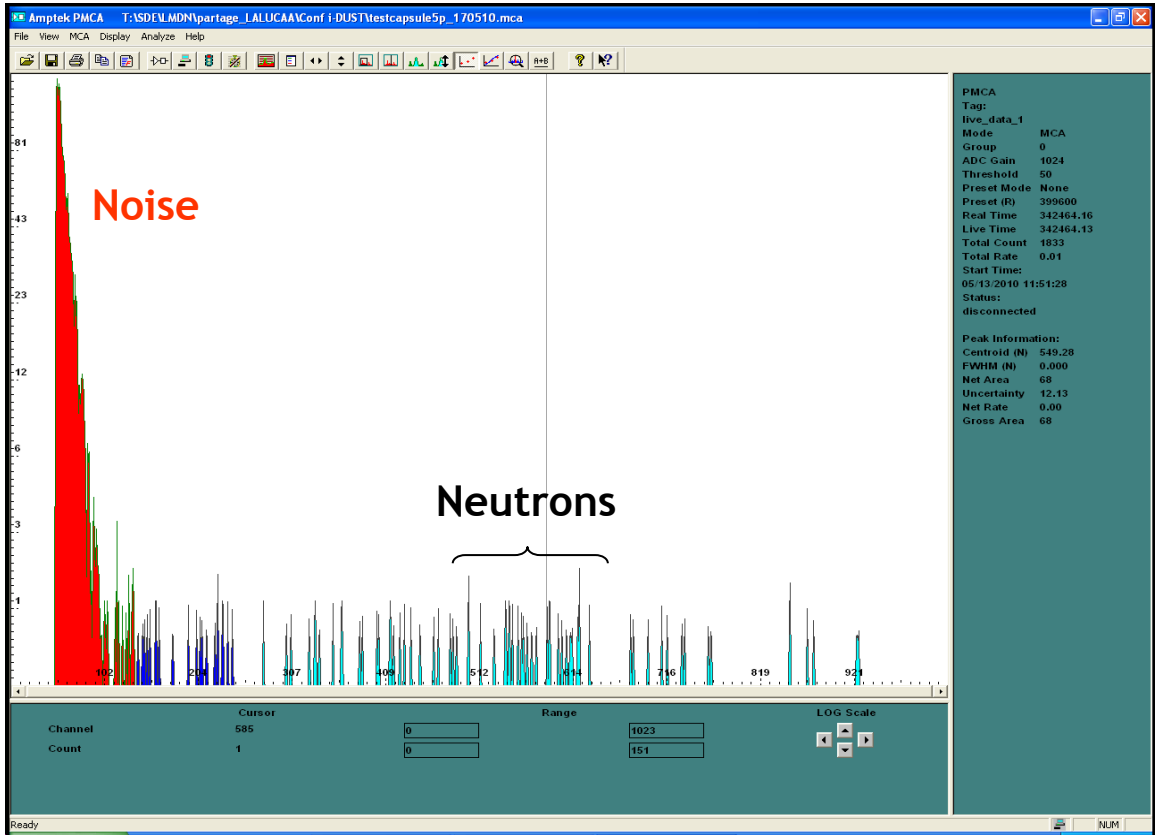
Pulse height spectrum from the MCA

Ex : Radioactive source (^{241}Am-Be) DAQ time ~16hours



Tests underground at LESA (-500 m)

"Background measurement" DAQ time ~4 days
Capsule switched-off



- First results show few events (2×10^{-4} cts/s) in the region of interest.
- Mean expected count rate at +1000 m : ~ 0.10 cts/s -> 0.2% "background contribution" (worst case)
- Necessity of longer acquisition time (at least 30 days) for ~ 5% statistical unc.
- A second measurement campaign will be started in summer in the LSBB capsule switched-off

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Estimated neutron fluence energy distribution

- Estimation of the neutron fluence at the top of the "Grande Montagne" (for the corresponding expected solar activity)

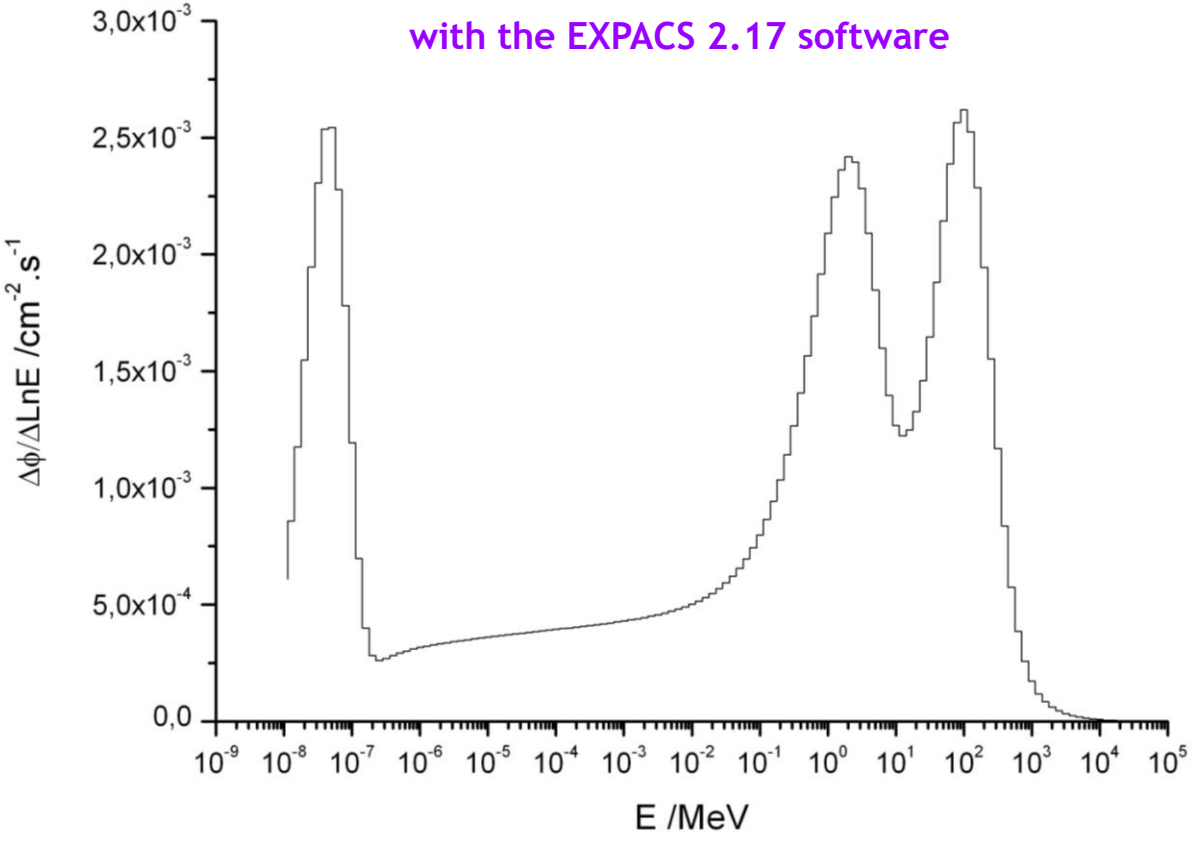
  Latitude : 43° 56' 26.04 N

  Longitude : 05° 29' 04.11 E

  Altitude : + 1000 m (above sea level)

- Estimated count rate of each sphere is given by folding the response function with the neutron fluence energy distribution

Neutron fluence energy distribution calculated with the EXPACS 2.17 software



Estimated time of measurement @ LSBB altitude site

	cts/s	Tacq (h)
3p	0,07	39
3,5p	0,08	34
4p	0,09	31
4,5p	0,10	29
5p	0,10	27
6p	0,10	27
7p	0,10	28
8p	0,09	32
10p	0,07	40
12p	0,05	54
7p-W	0,10	28
8p-W	0,15	18
9p-Pb	0,14	20

- T_{acq} estimated to reach 10000 counts
- 400 hours in total (17 days)
- Acquisition of all spheres in parallel
  - 54 hours (~2 days)
  - study of the variation of the neutron fluence energy distribution with
    - SPE (solar Particle Event)
    - GCR events (Galactic Cosmic Rays)
    - Solar activity (11 year cycles)

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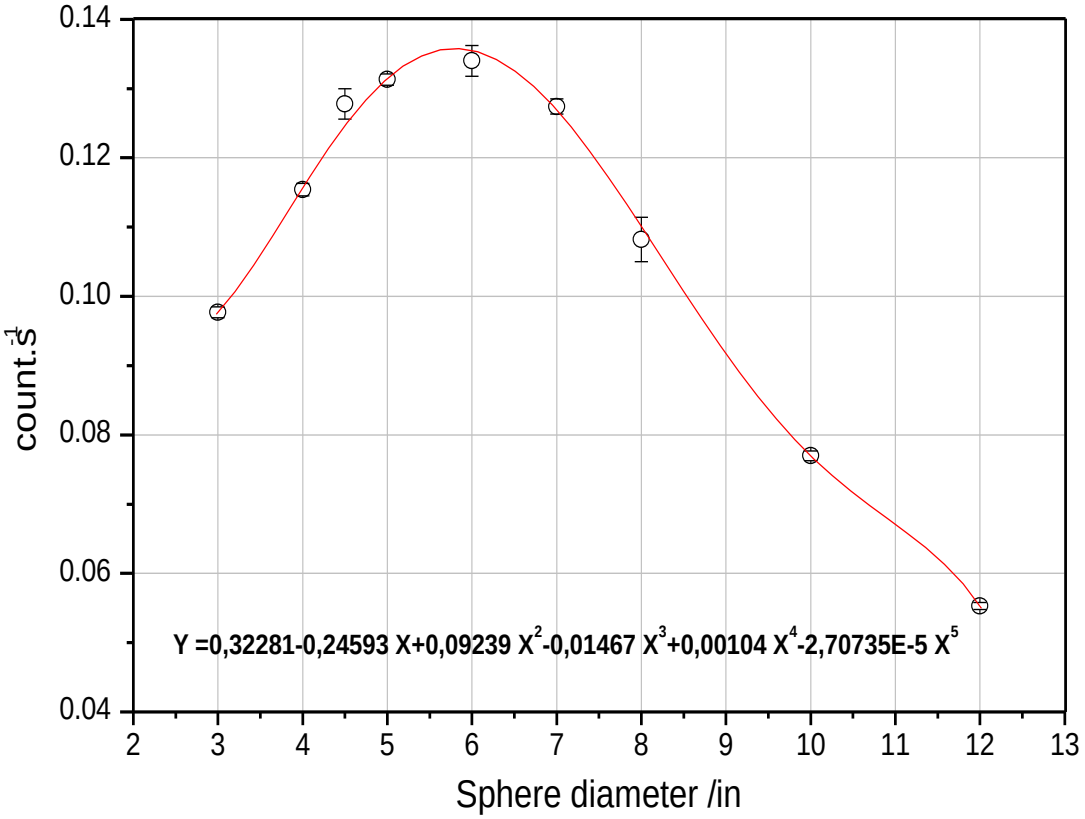
Preliminary first results !

- Measurement campaign started in May, 19 - Still running
- Experimental count rates comparable to the calculated ones
- Check of the coherence of the data (count rates) with a polynomial function



Conclusions and perspectives

- **First tests of the IRSN BSS-HE in natural environment performed at the LSBB experimental sites**
- **Underground measurements showed that the intrinsic electronic noise not disturbing for altitude low rates detection**
  - Further tests needed to check noise vs radioactivity neutrons (in GESA)
  - If neutrons - Long-period data acquisition necessary for radioactivity neutron measurements (several weeks – use of the system in parallel)
- **Measurements of cosmic neutrons at + 1000 m (above sea level)**
- **Experimental data seem correct and reliable for further analysis**
- **Additional measurement campaigns foreseen in summer 2010**
- **Unfolding of the data and determination of the "LSBB-Vestale" neutron spectrum**
- **Validation of the response functions at the reference neutron facilities Autumn 2010.**