Background radiations at LSM

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Outline

- **Background radiation from rock:**
  - Radio-isotope concentrations;
  - Gamma-rays and neutron fluxes;
  - Suppression of background from rock by passive shielding.
- **Muon-induced background:**
  - Muon flux and spectrum;
  - Measurements of neutron yield and flux;
  - Neutron event rate (EURECA);
- **Summary.**

Radio-isotope concentrations

From V. Chazal et al. Astroparticle Physics, 9 (1998) 163.

Element	U	Th	K
Rock	(0.84 ± 0.20) ppm	(2.45 ± 0.20) ppm	$(6.8 \pm 0.8) \times 10^3$ ppm
Concrete	(1.9 ± 0.2) ppm	(1.4 ± 0.2) ppm	$(2.5 \pm 0.4) \times 10^3$ ppm

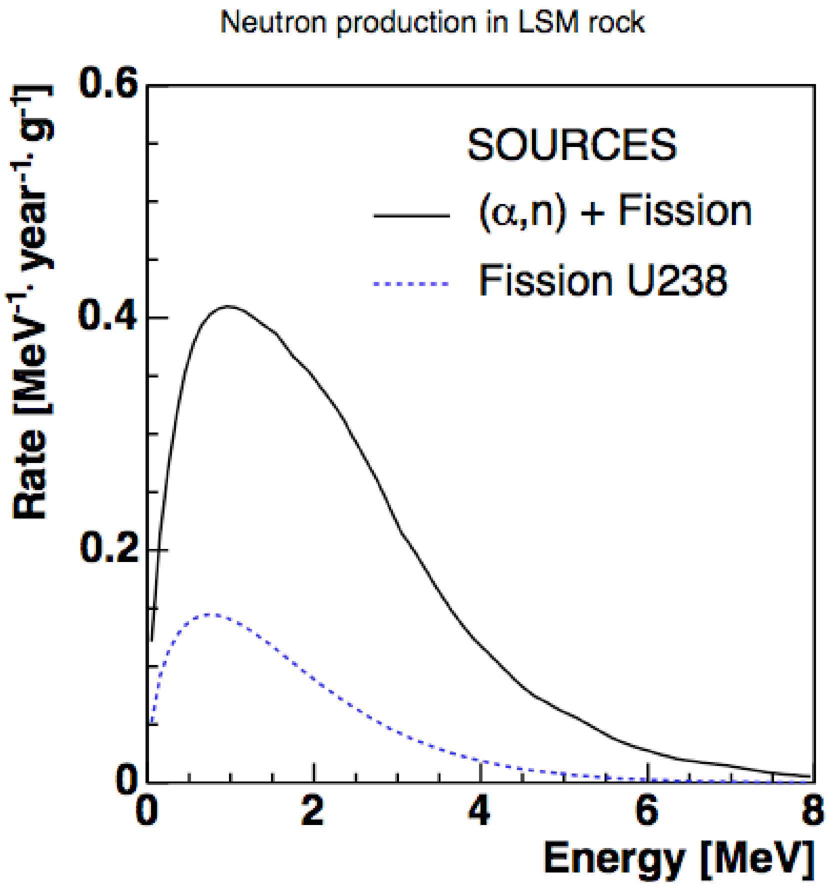
From J. Kisiel et al. (see talk by D. Malczewski at BUS-2006)

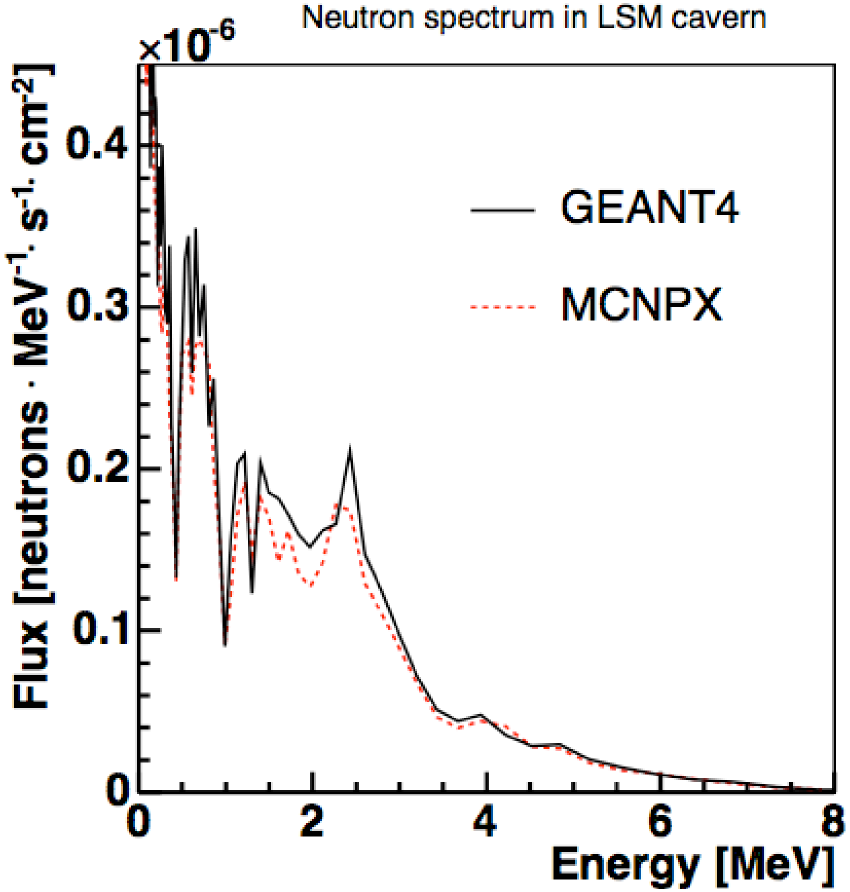
^{226}Ra: 12.3 ± 1.4 Bq/kg (≈ 1.0 ppm of ^{238}U),
^{228}Ac: 4.8 ± 0.9 Bq/kg (≈ 1.2 ppm of ^{232}Th),
^{40}K: 92 ± 22 Bq/kg (≈ 3.0×10^3 ppm of natural K).

Rock and concrete composition in % (from V. Chazal et al. Astroparticle Physics, 9 (1998) 163, also later measurements):

Element	H	C	O	Na	Mg	Al	Si	P	K	Ca	Ti	Mn	Fe
Rock	1	5.94	49.4	0.44	0.84	2.58	6.93	0.06	0.21	30.6	0.07	0.03	1.9
Concrete	1.09	7.78	49.68	0.01	0.78	0.48	2.69	0.07	0.02	36.78	0.09	0.01	0.52

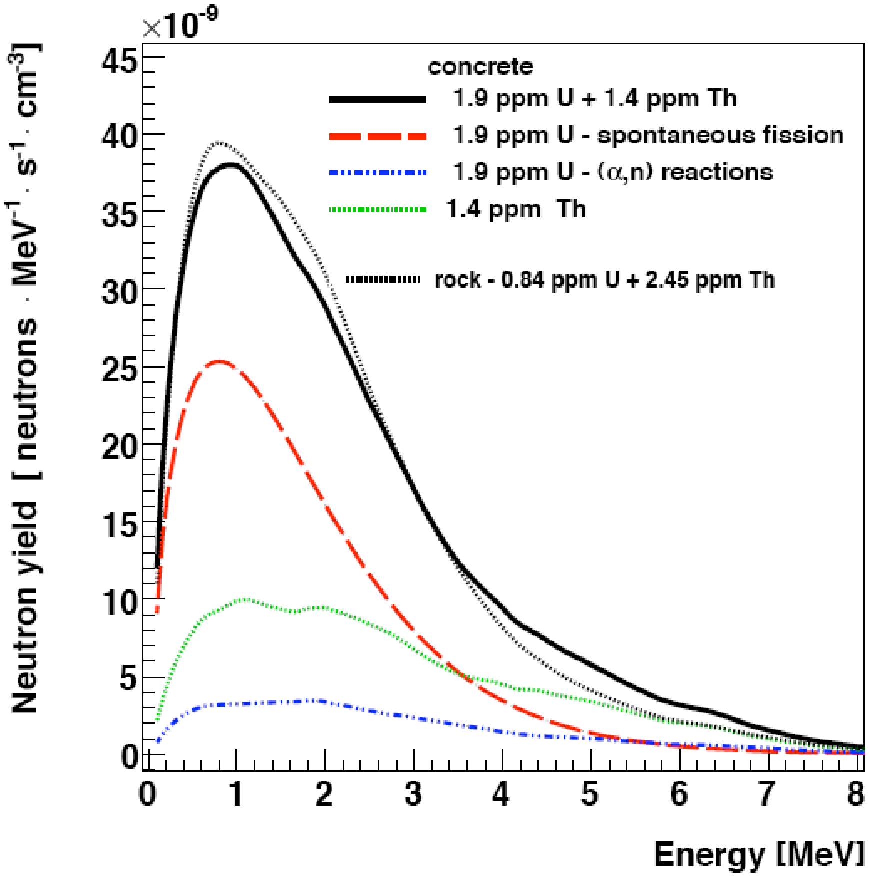
Neutron flux

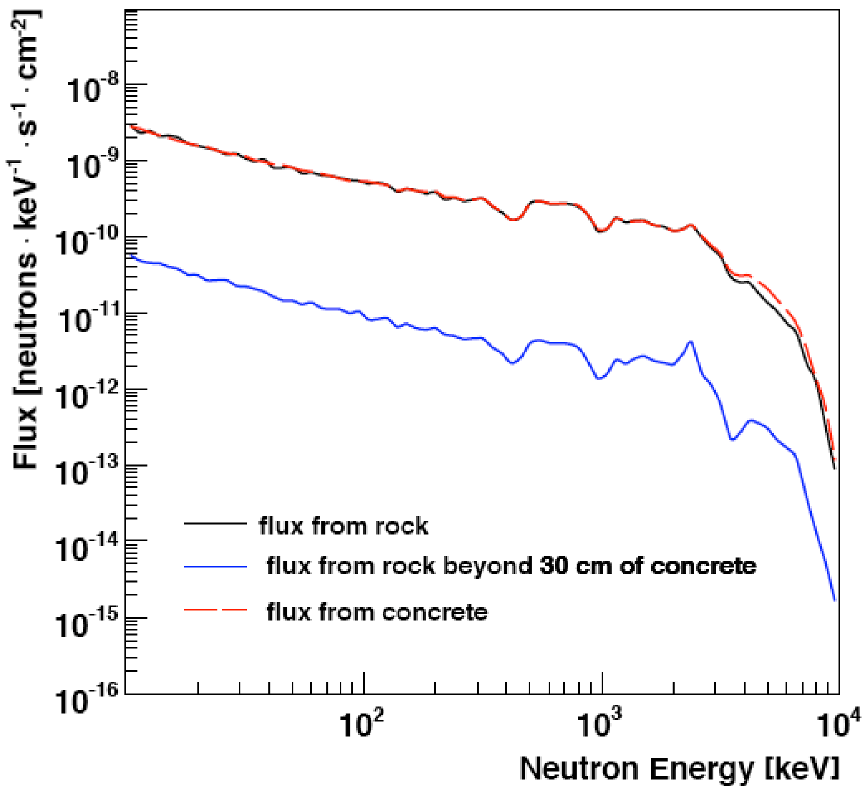




- **R. Lemrani et al. NIMA, 560 (2006) 454.**

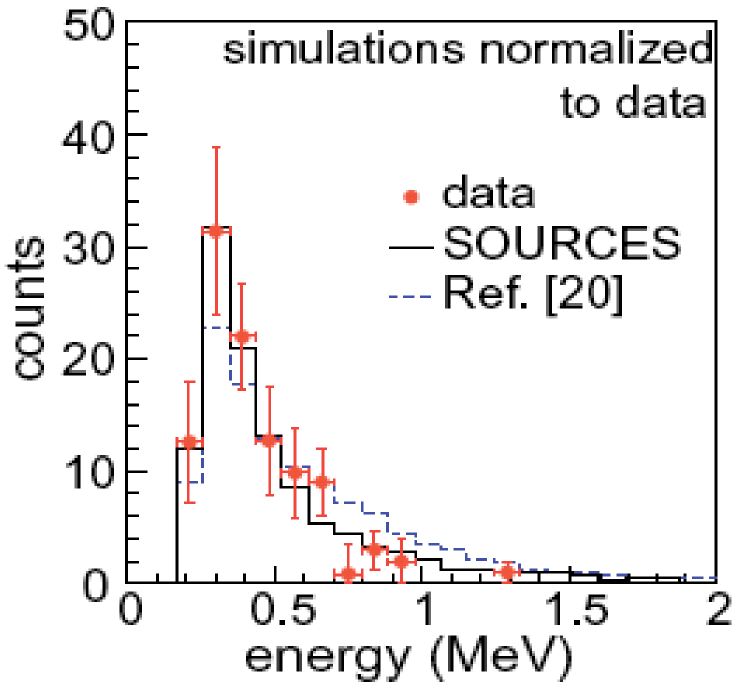
Neutron flux from concrete

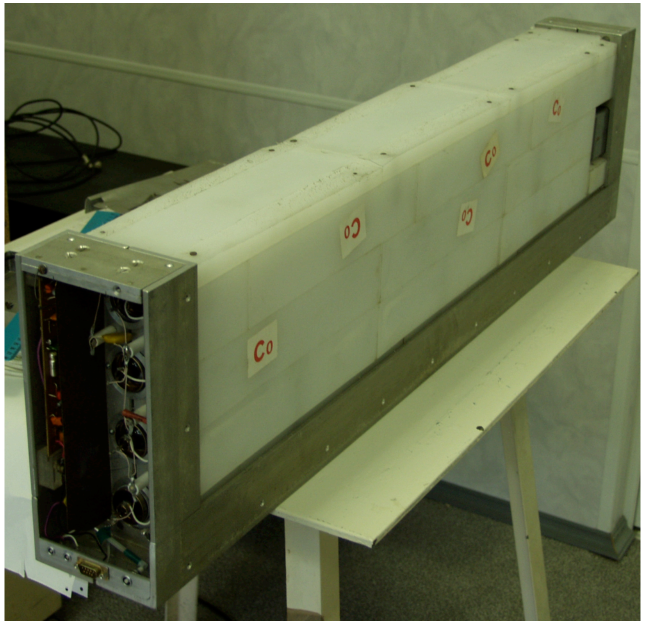




- V. Tomasello et al., in preparation.
- Neutrons and gamma-rays from concrete (30 cm) dominate over those from rock.

Neutron flux measurements



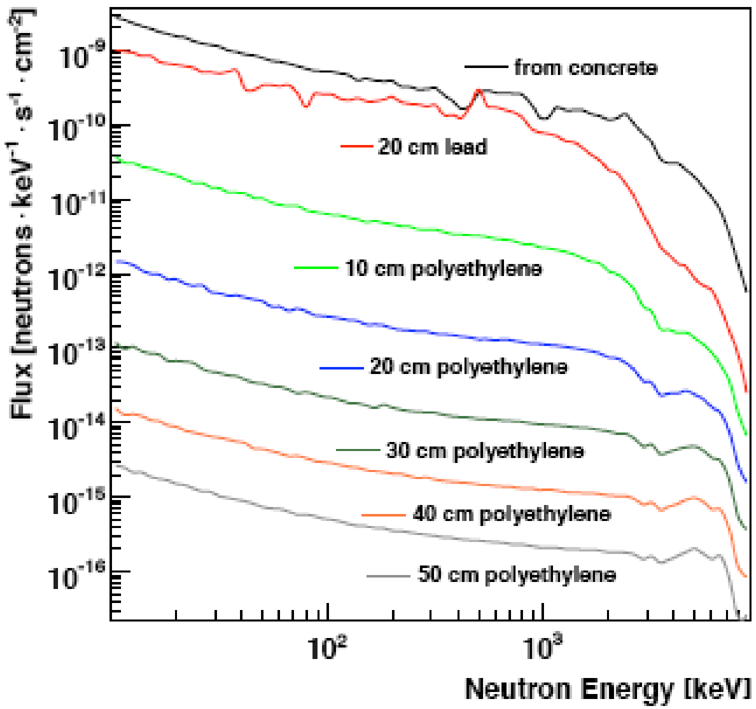


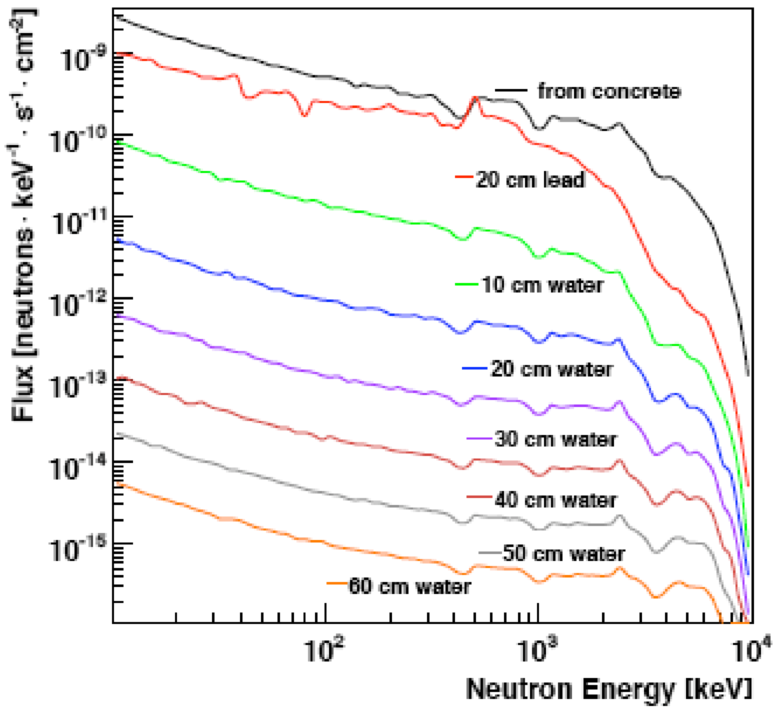
- **Measured neutron flux: (1.06 ± 0.10 (stat) ± 0.59 (syst)) $\times 10^{-6}$ n/cm^2/s above 1 MeV (from Chazal et al., re-analysed in S. Fiorucci et al. Astroparticle Physics, 28 (2007) 143).**
- **New thermal neutron detectors (^{3}He): total neutron rate 150 counts/day, flux ~2×10^{-6} n/cm^2/s (thermal + fast) (talks by the EDELWEISS-II Collaboration).**

External radiations: summary

- **Radio-isotope concentrations are typical for rock.**
- **Neutron flux is relatively small because of:**
  - **The absence of the isotopes with low threshold for (α,n) reactions;**
  - **1% of hydrogen (neutron moderation) and absorption.**
- **Neutron and gamma-ray fluxes from concrete dominate over those from rock. Making concrete radio-pure would help with reducing background radiation from walls.**

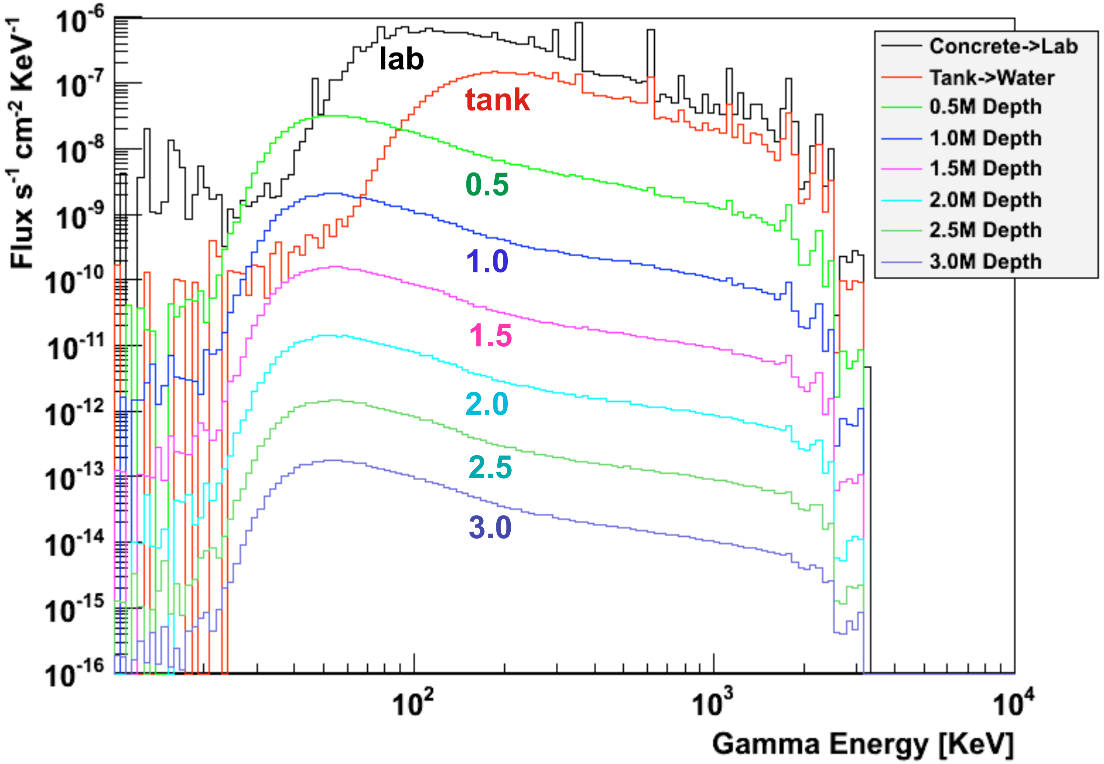
Passive shielding





- **Spectra of neutrons from Th decay chain beyond shielding.**
- **Option 1: lead (~20 cm against gamma-rays) + polyethylene (50 cm) or water (60 cm) (against neutrons).**

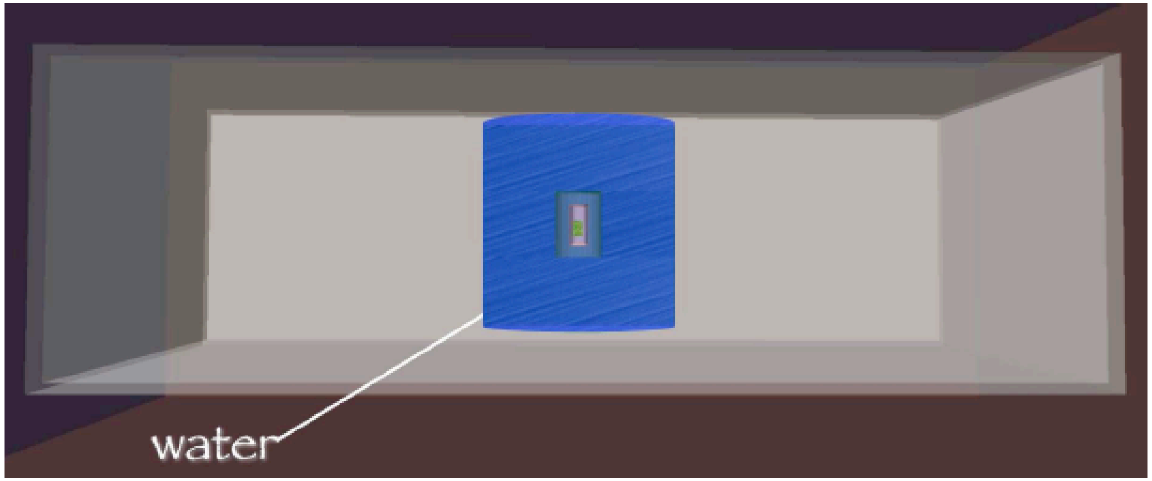
Attenuation in water



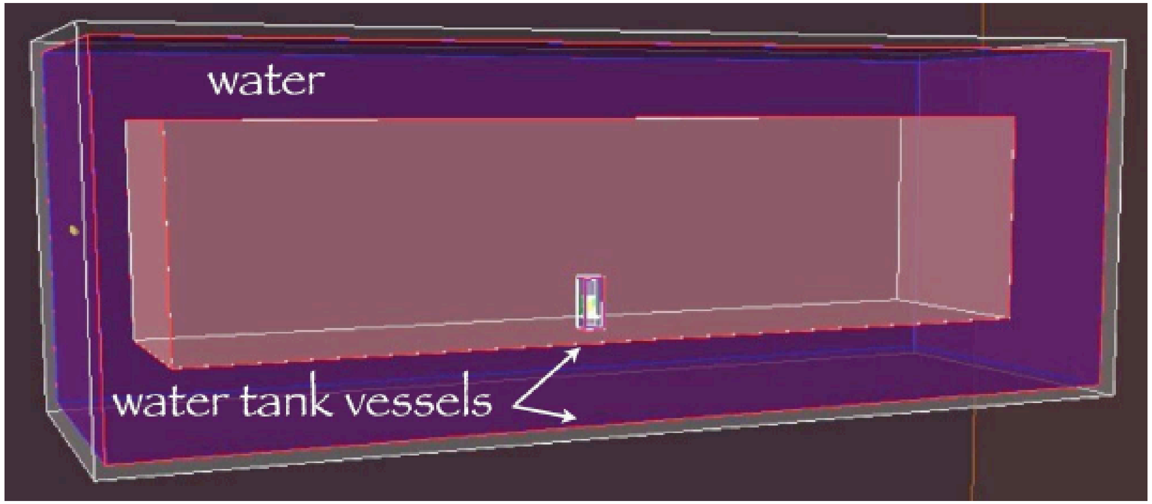
- **Option 2: 3 m of water against neutrons and gamma-rays.**

Spectra of gamma-rays from U decay chain in concrete.

‘Submarine’ versus ‘pool’



(a)



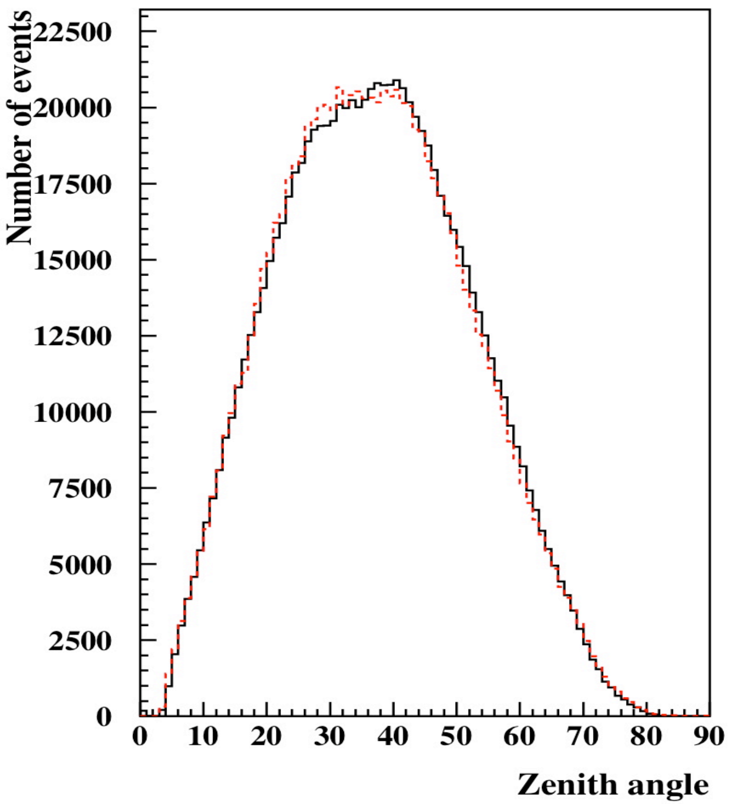
(b)

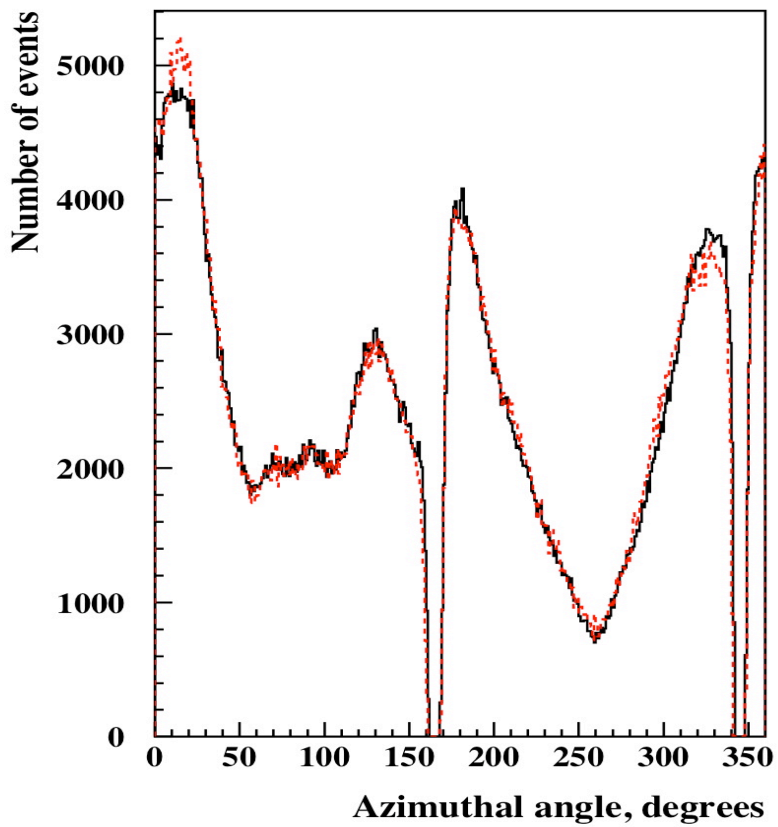
- Study for EURECA.
- Too high background from the stainless steel of the water tank in the ‘submarine’ option -> will require additional inner shielding.
- ‘Pool’ is better.
- All detector components have to be ultra-radio-pure.

Muon-induced events

- **LSM is the deepest lab in Europe: a factor of 3×10^{6} attenuation of the muon flux relative to the surface.**
- **Muon flux: 0.23 m^{-2} hour^{--1} through a sphere with unit cross-sectional area.**
- **<E$_{\mu}$> = 302 GeV, <θ> = 37.5^{o}, <φ> = 167^{o}, <depth> = 4814 m w.e.**

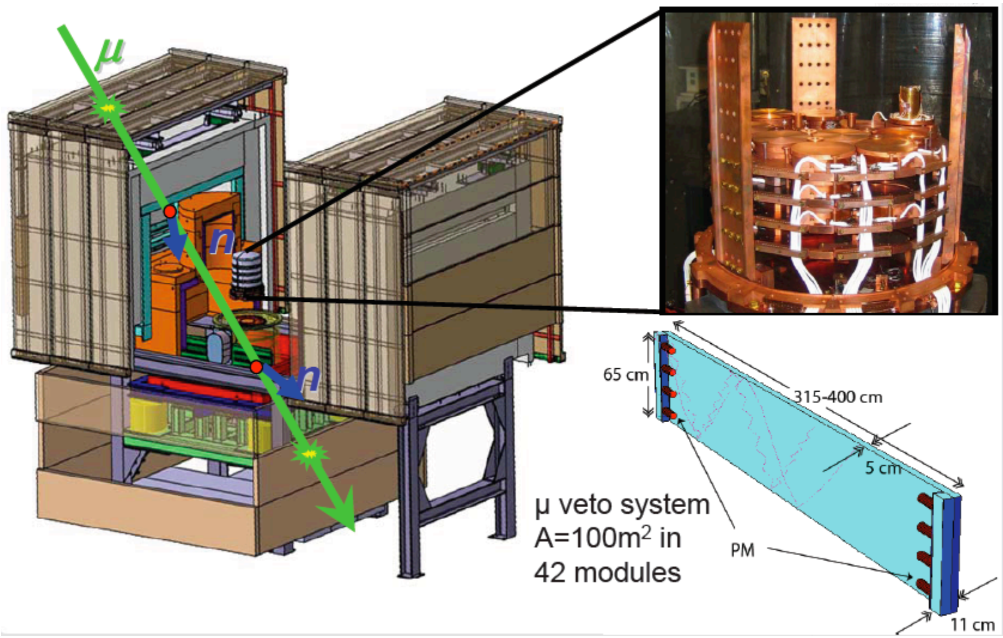
Muon generator: MUSUN

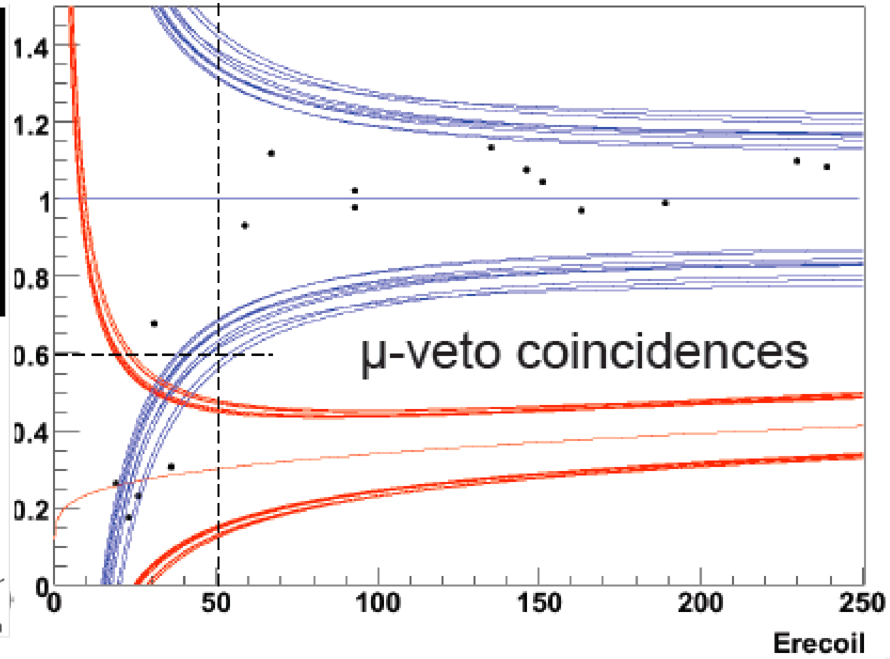




- Zenith and azimuthal angular distribution of muons as generated by MUSUN in comparison with the data from the Frejus proton decay experiment.
- MUSIC and MUSUN, V. Kudryavtsev, Comp. Phys. Comm. 180 (2009) 339;
- Another muon generator: M. Horn, PhD Thesis, Univ. of Karlsruhe (2007).

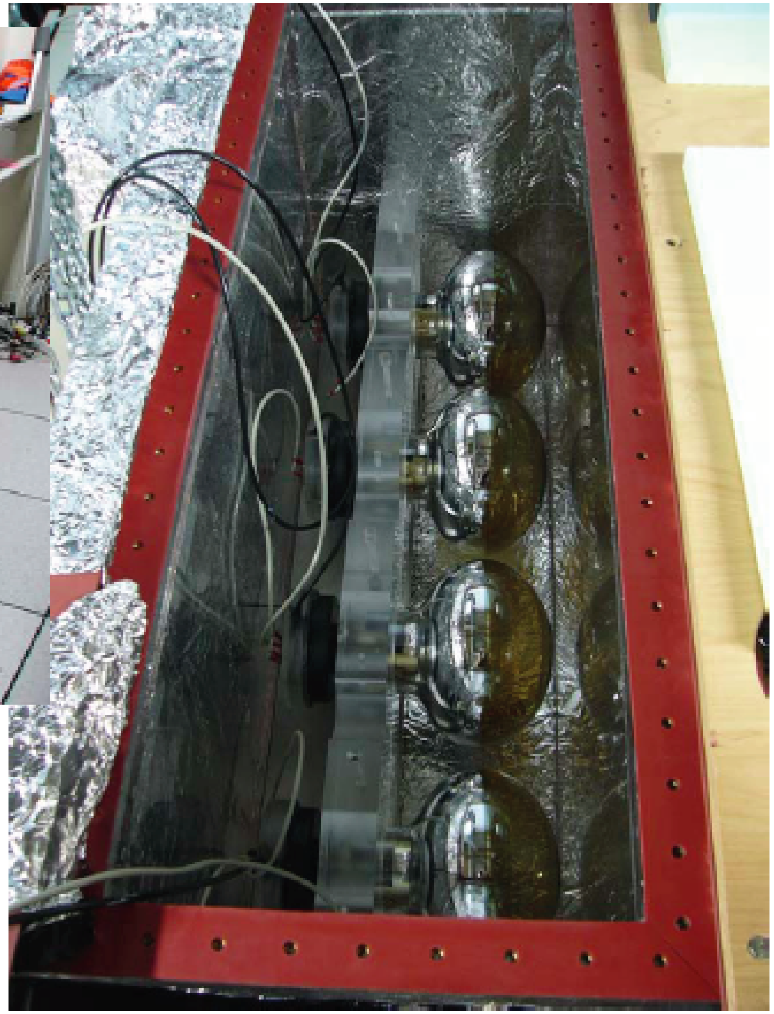
Muon-induced neutrons





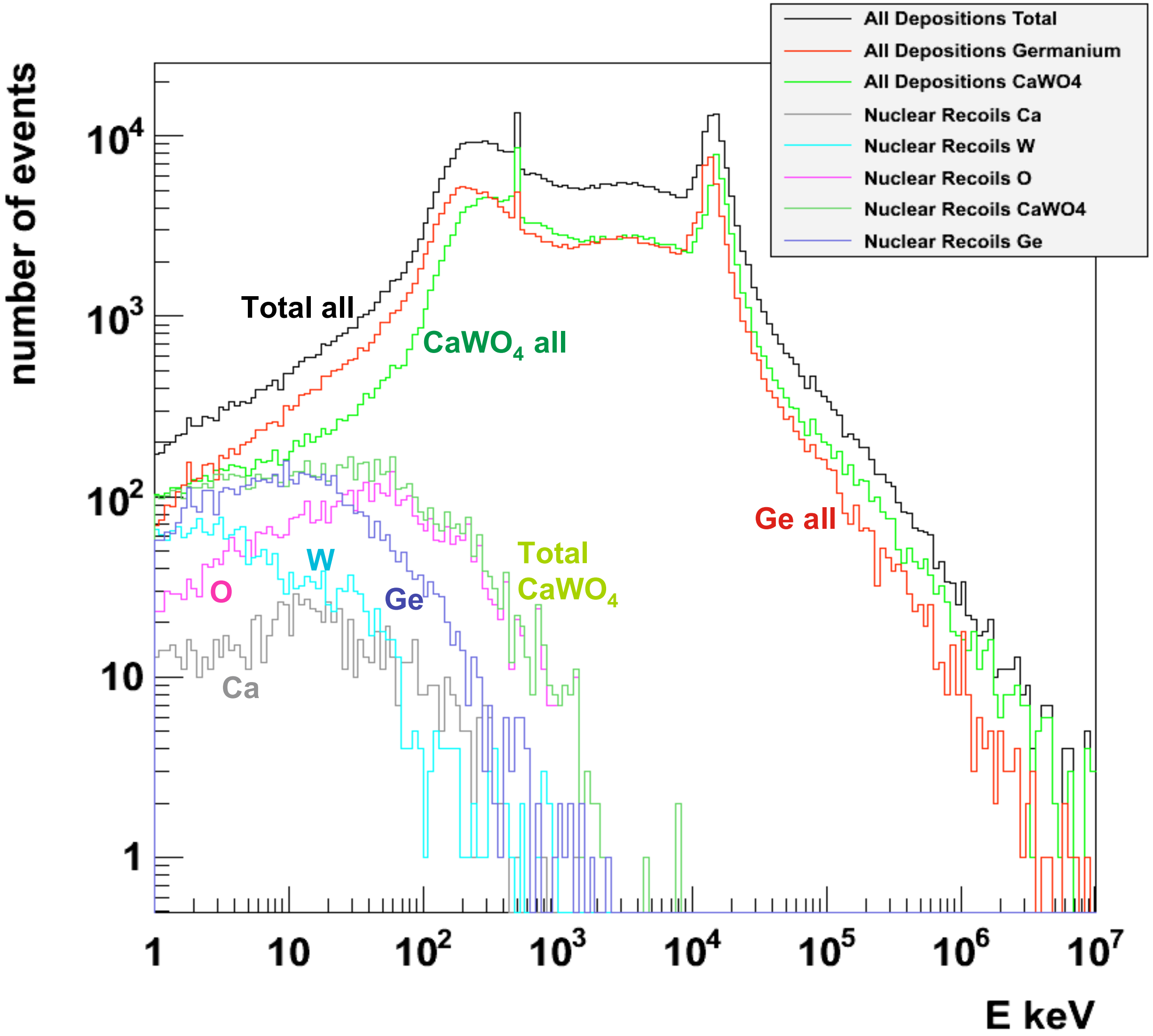
- **Recent measurements:**
  - **Boulby, target: lead, less neutrons observed (56%) compared to GEANT4 predictions (H. Araujo et al. Astroparticle Physics, 29 (2008) 471);**
  - **KamLAND, target: CH_2, agreement between measurements and simulations (S. Abe et al. ArXiv:0907.0061v1 [hep-ex]);**
  - **LSM, EDELWEISS-II, target: everything; preliminary: agreement between measured rate of neutron + gamma events, and simulations at low energies (V. Kozlov, K. Eitel, talks at IDM2008, TAUP2009).**

Muon-induced neutrons



- **New measurements are in progress by the EDELWEISS Collaboration.**
- **Talks by V. Kozlov (IDM2008), K. Eitel (TAUP2009).**

Spectra in EURECA: Ge + CaWO4



- **Only 1.6±0.4 single nuclear recoils per year per tonne of target above 10 keV.**
- **Significant suppression due to anticoincidence between different crystals.**
- **If water is instrumented with PMTs (active veto), then <0.2 ev/year with a threshold of 0.2 GeV for veto.**

Summary

- Extensive measurements have been performed and rock composition and radioactivity levels are well known.
- Radio-isotope concentrations are typical to rocks.
- Monitoring of gamma-ray and neutron fluxes is on the way.
- Neutron and gamma-ray flux attenuation has been studied. External backgrounds is not a huge problem for high-sensitivity experiments and we know how to deal with them.
- LSM is the deepest lab in Europe. Large attenuation of the muon flux by rock above the lab ensures that the muon-induced background can be kept to the minimum.
- We can model the muon-induced background with an accuracy of better than a factor of 2.
- Additional suppression of the muon-induced event rate is achieved by the anticoincidence between different detectors (crystals) and active veto system (90% efficiency is sufficient).
- Internal backgrounds are detector specific and are under study.