Shielding and active veto for EURECA

Vitaly A. Kudryavtsev

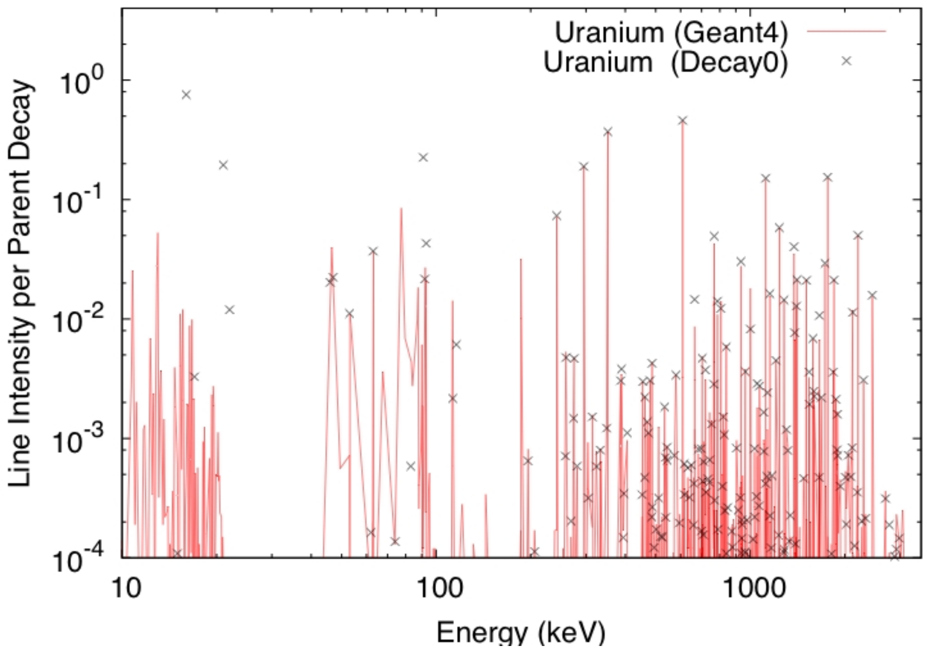
University of Sheffield

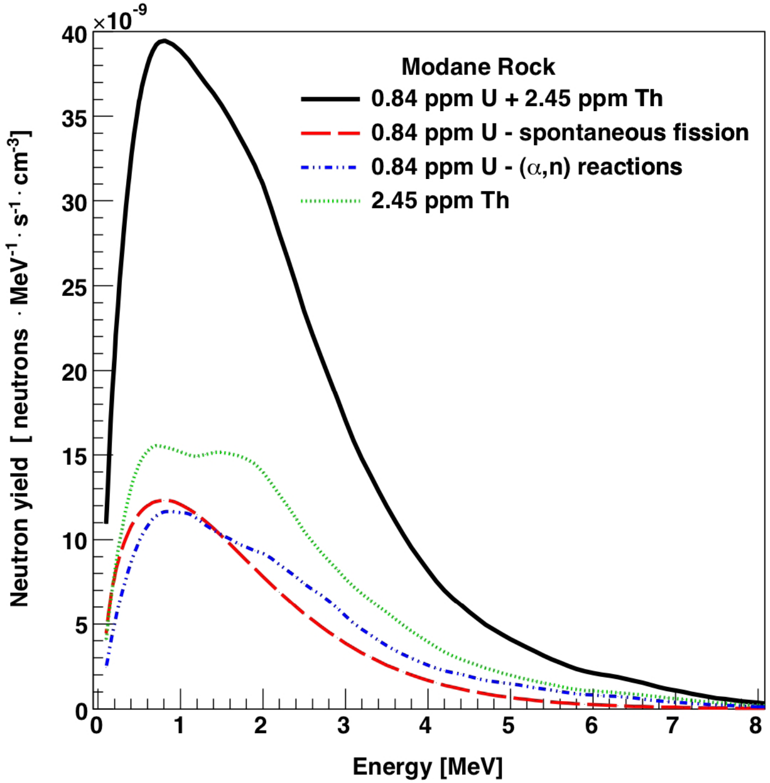
Contributions from many others

Outline

- Spectra of gamma-rays and neutrons.
- Gamma-ray and neutron transport through the shielding:
  - Water shielding against high-Z/low-Z combination.
  - ‘Submarine’ against ‘swimming pool’.
- Water Cherenkov muon veto for EURECA: how efficient will it be?

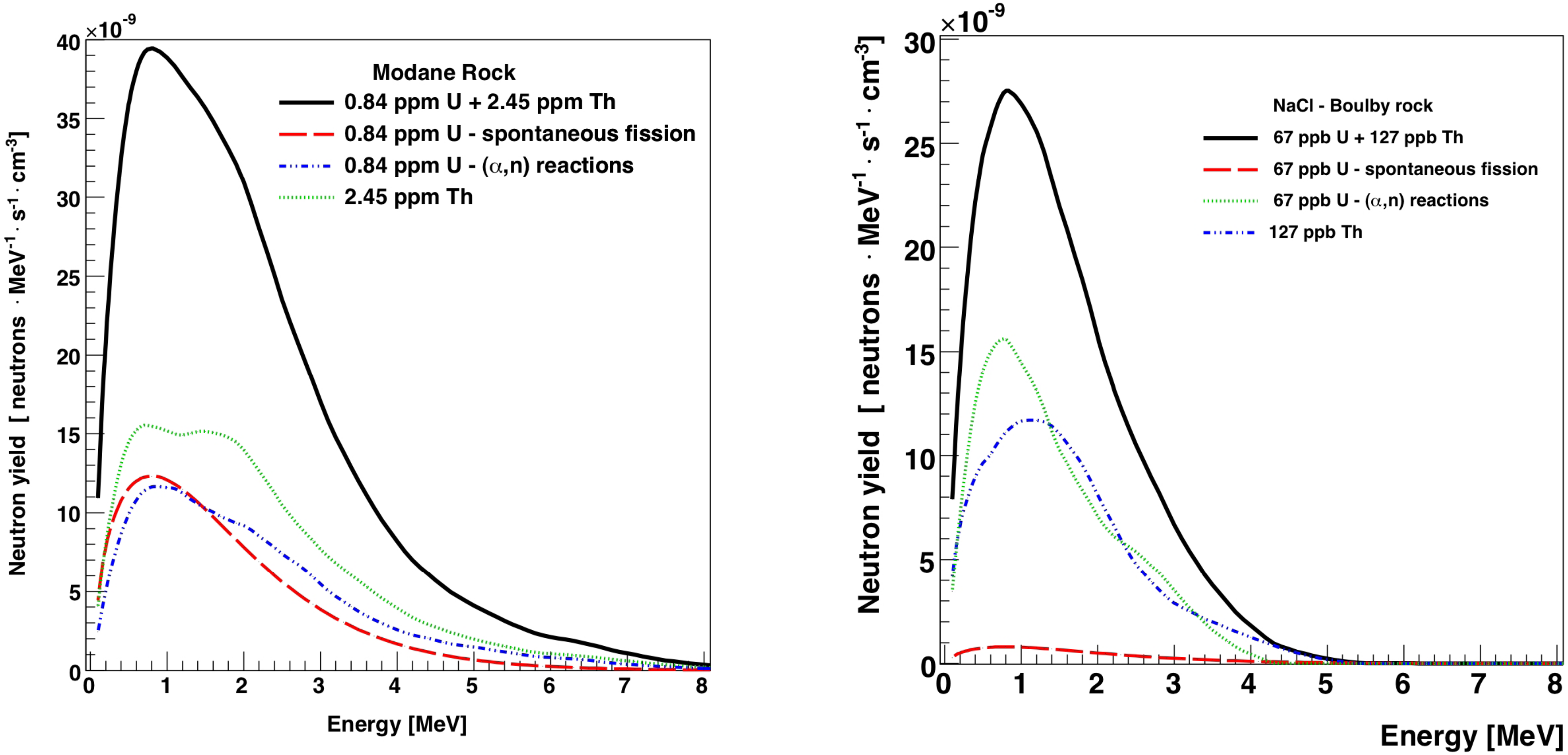
Gamma-ray and neutron production





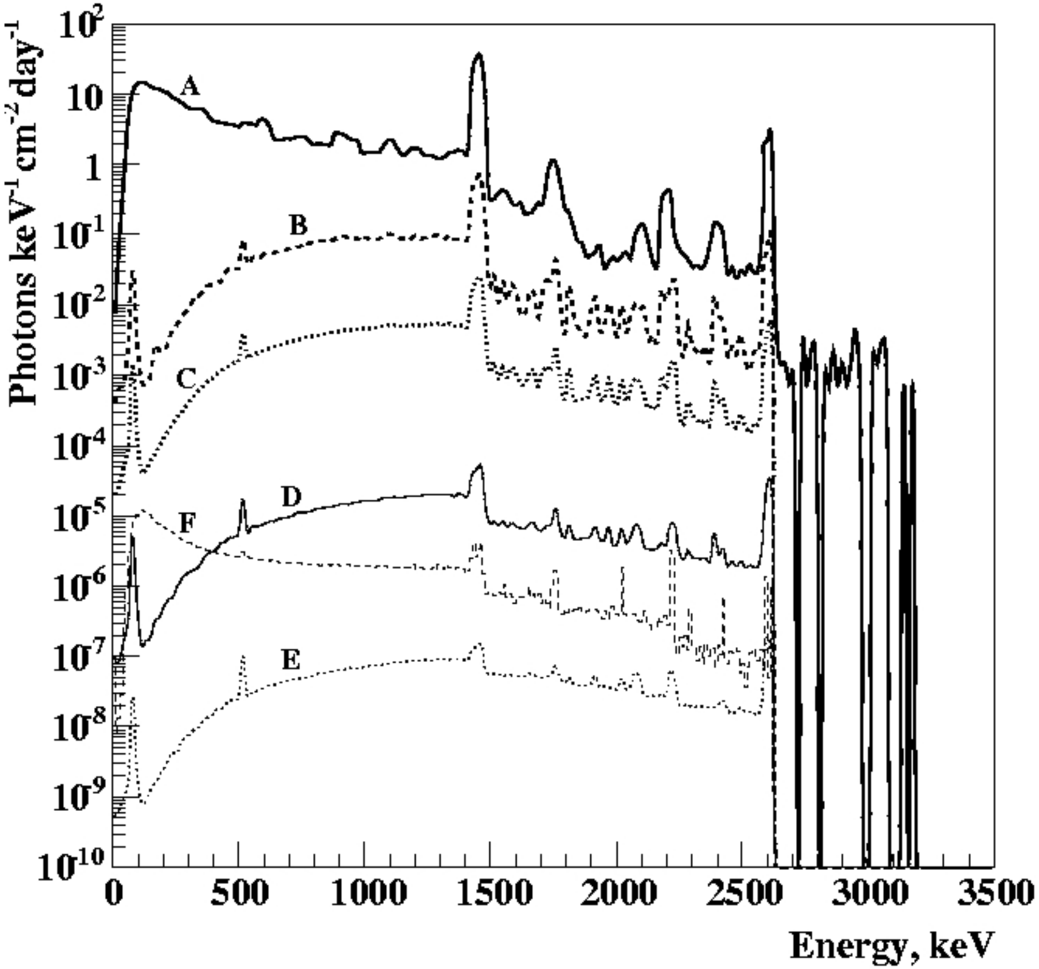
- Gamma-ray spectra from GEANT4 (L. Pandola). When simulating the whole decay chain be careful with timing precision.
- Neutron spectra from modified SOURCES4A (Wilson et al. Sources4A. Technical Report, LA-13639-MS (1999); Carson et al. Astropart. Phys. 21 (2004) 667).

Neutron spectra in different rocks



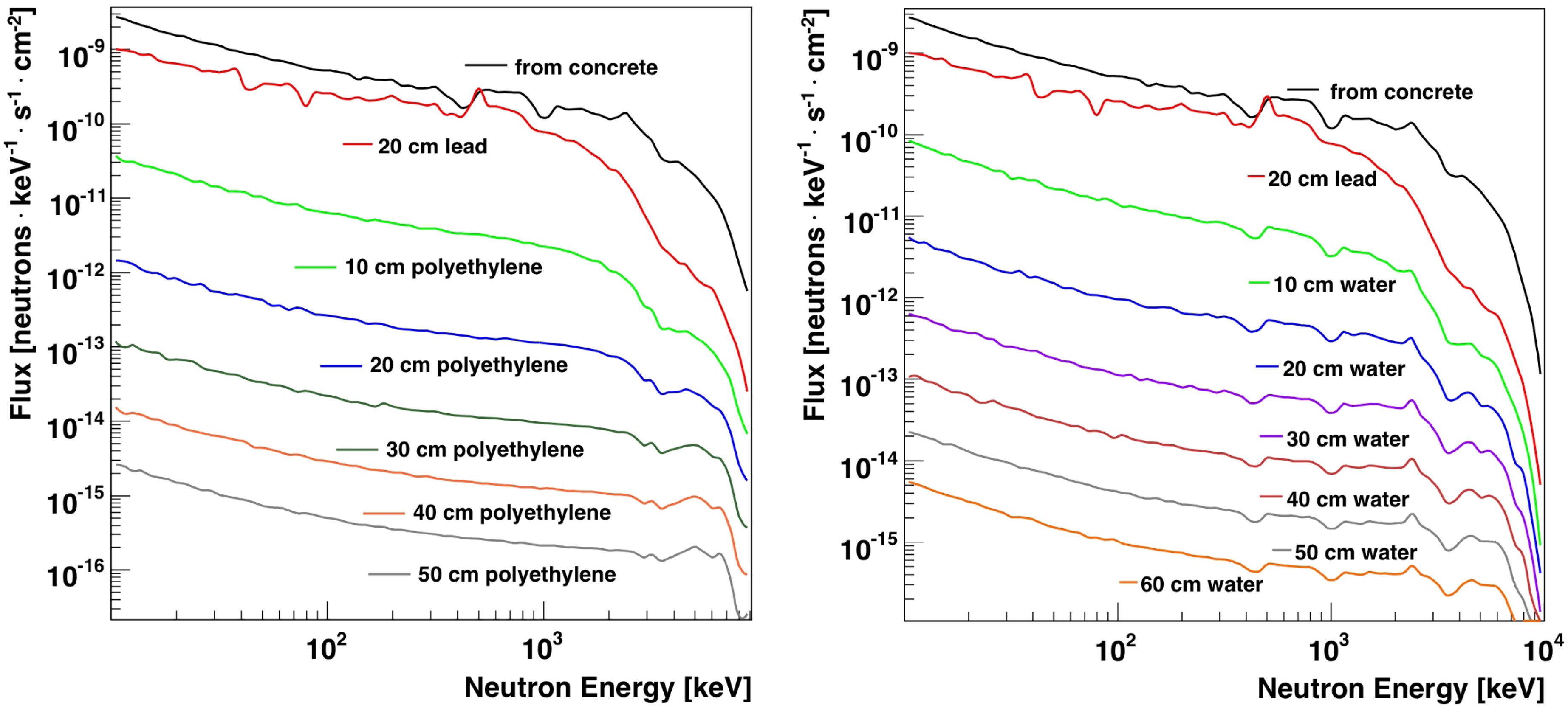
- **Spectra strongly depend on the material (composition).**
- **Hydrogen reduces neutron flux on the rock face (after transport) by a factor 4.7 (1.8) above 100 keV (1 MeV).**

Gamma-ray attenuation in lead



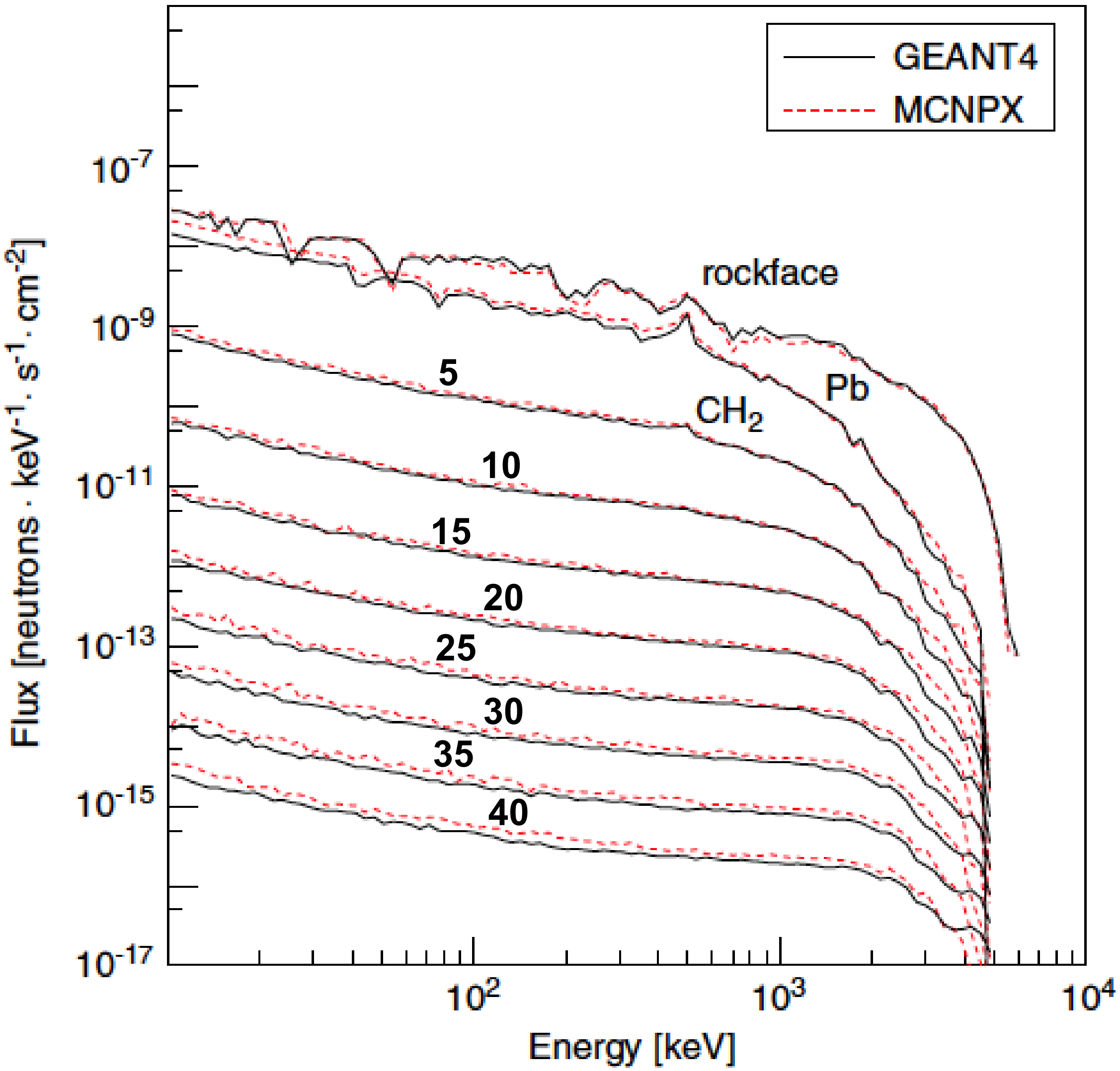
- A - spectrum at Boulby (from rock);
- B - behind 5 cm of lead;
- C - 10 cm of lead;
- D - 20 cm of lead;
- E - 30 cm of lead;
- F - 20 cm of lead and 40 g/cm^2 of CH_2.
- From M. J. Carson et al., Nucl. Instrum. and Meth. A 548 (2005) 418.

Neutrons in water and CH_2



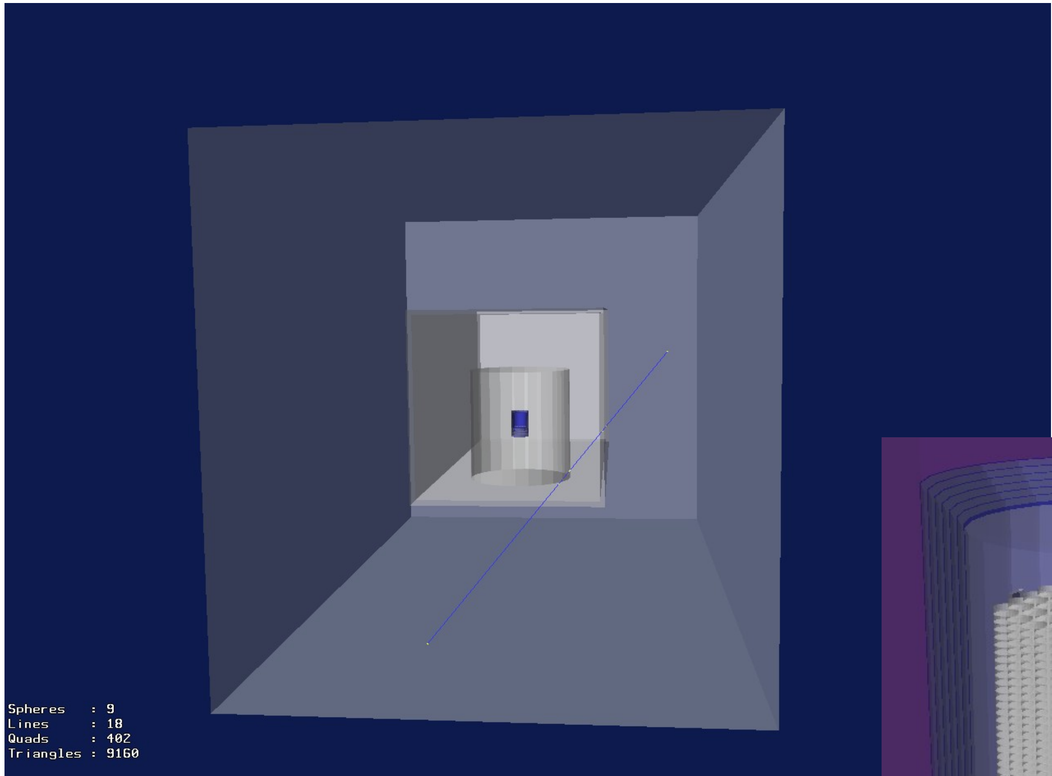
- Neutron attenuation in water and CH_2 - V. Tomasello, PhD Thesis, University of Sheffield (2009).
- Inelastic scattering in lead helps with neutron attenuation at E > 1 MeV.

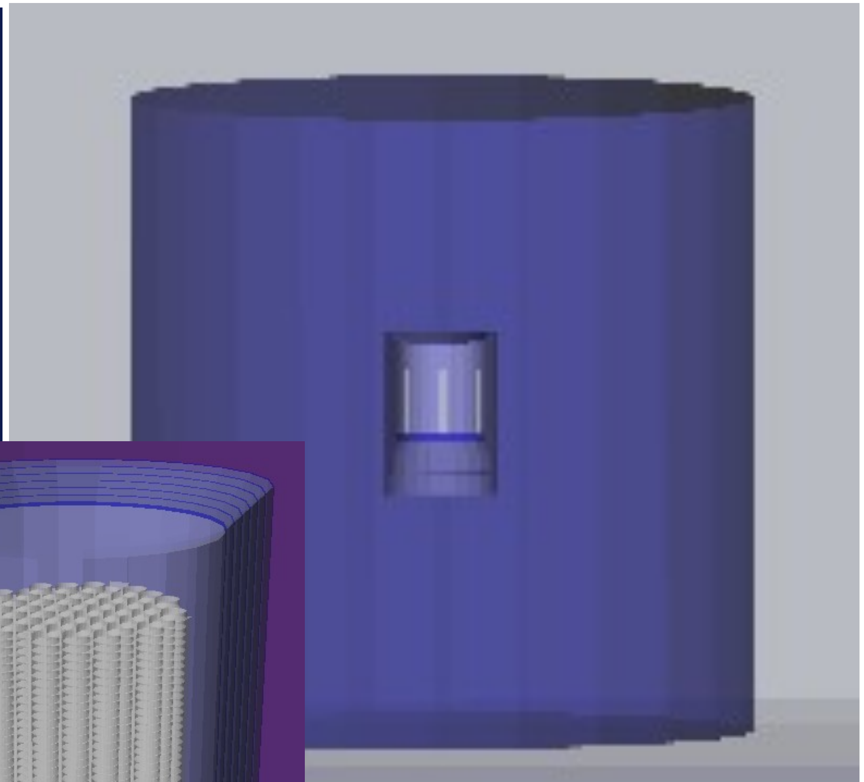
GEANT4 vs MCNPX

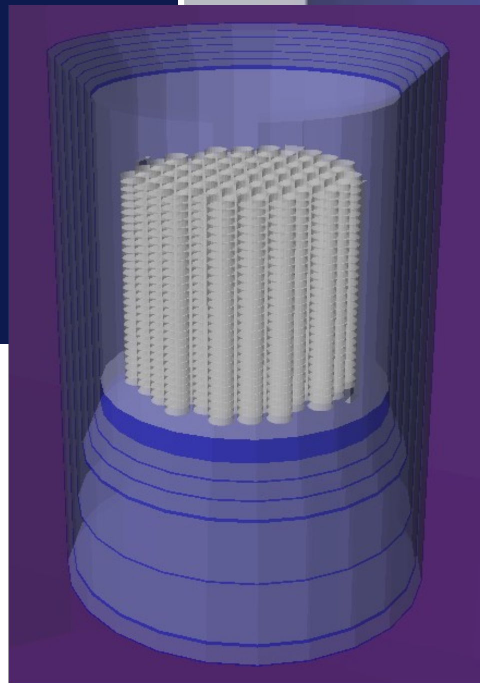


- Neutron fluxes behind shielding.
- 50% higher flux in MCNPX than in GEANT4 after 30 cm of lead and 40 g/cm^2 of CH_2.
- From R. Lemrani et al. Nucl. Instrum. and Meth. A 560 (2006) 454.

ULISSE and EURECA

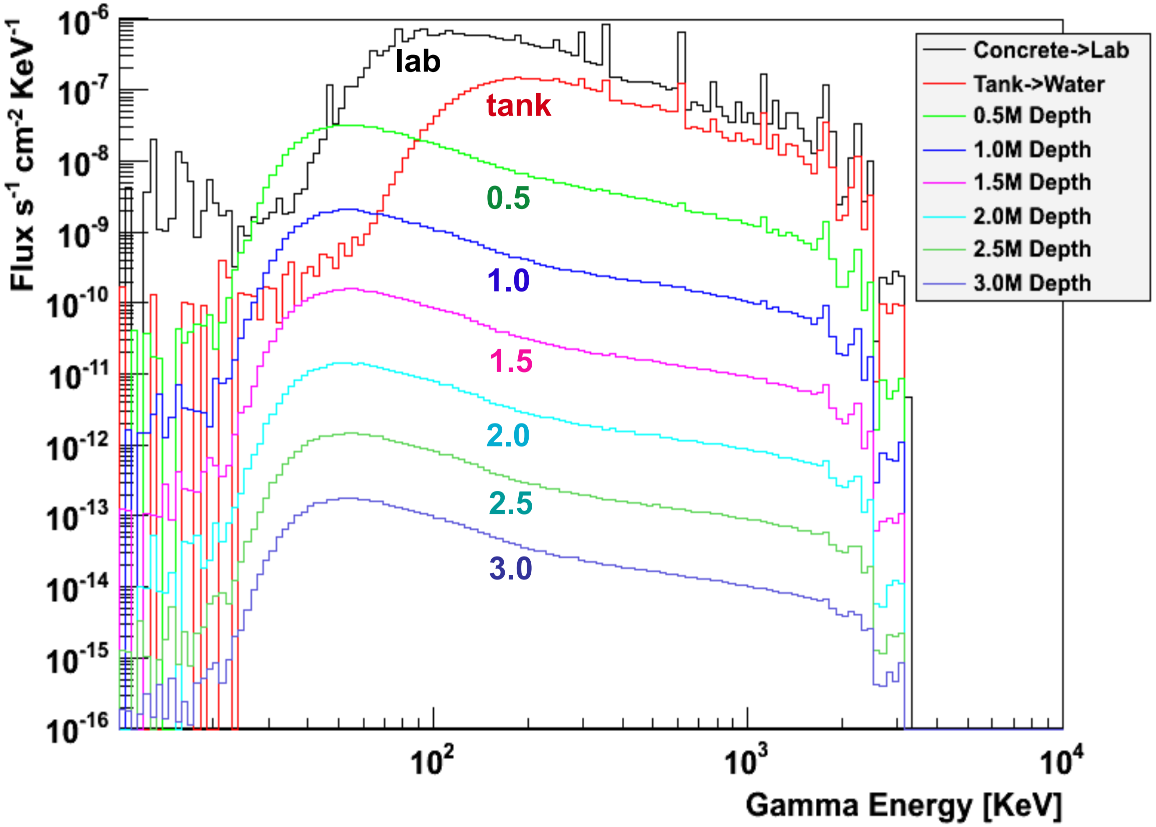






- Lab: 12 m × 30 m × 12 m;
- 30 cm of concrete.
- 3 metres of rock.

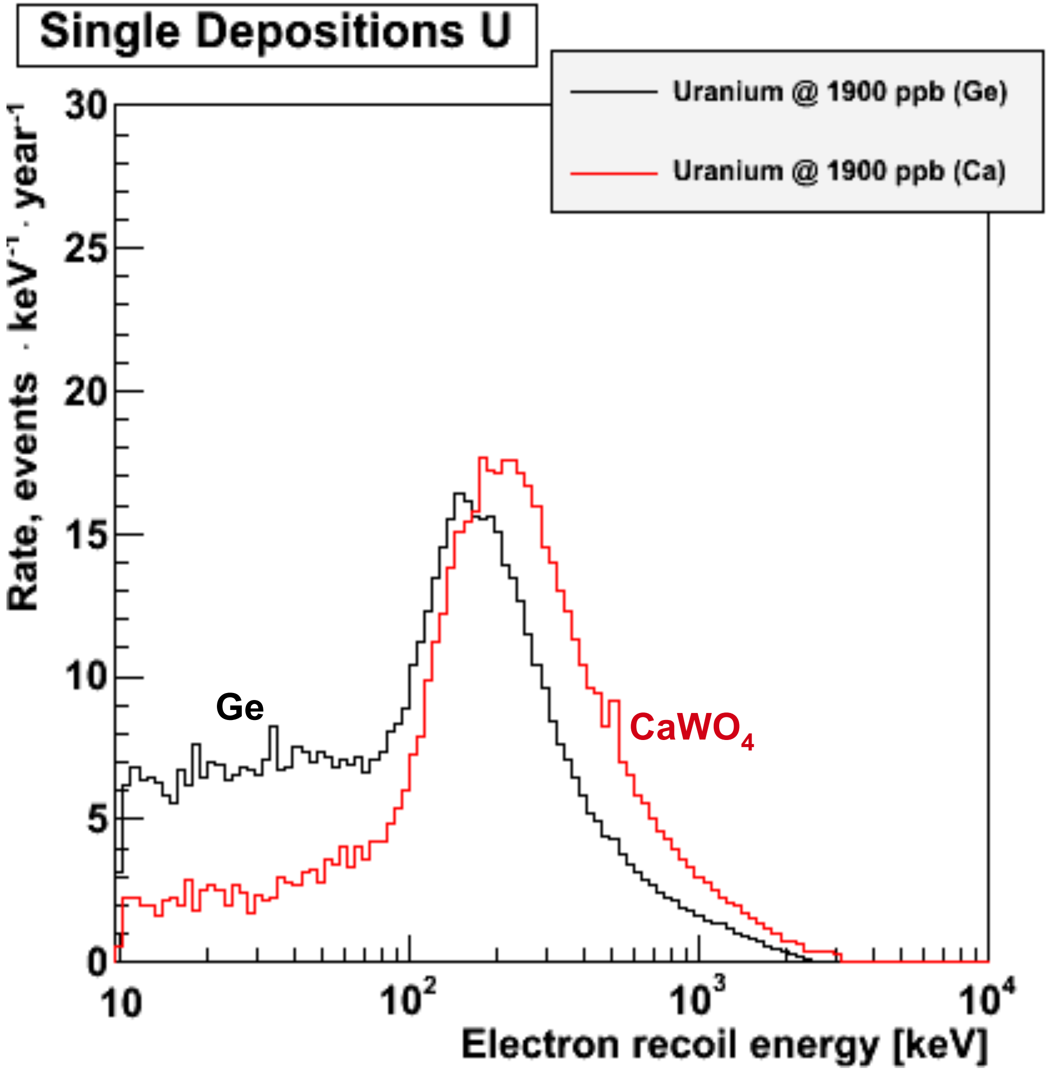
Attenuation in water



Spectra of gamma-rays from U in concrete.

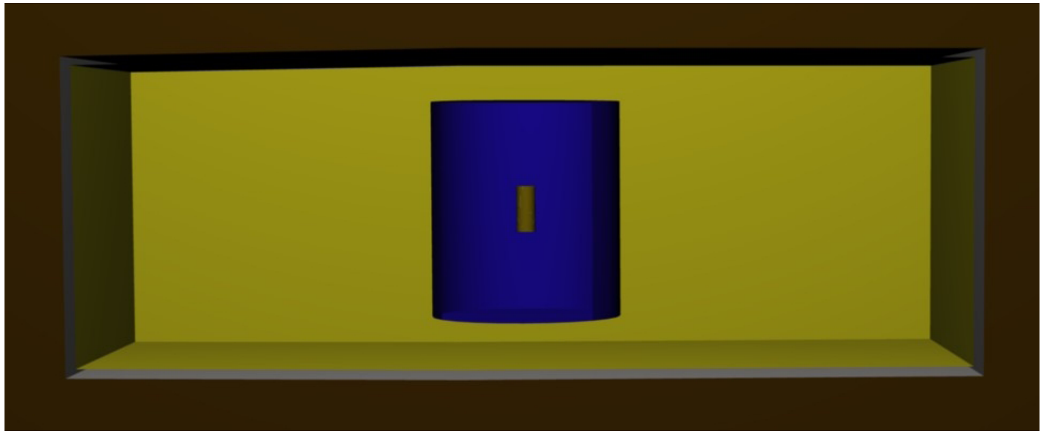
- Fluxes of gammas and neutrons from concrete (30 cm) dominates over that from rock (only <5% of neutrons are coming from rock);
- Intensities and spectra from rock and concrete are very similar;
- If there were no concrete, the flux from rock would be attenuated in almost exactly the same way.

Spectra in EURECA



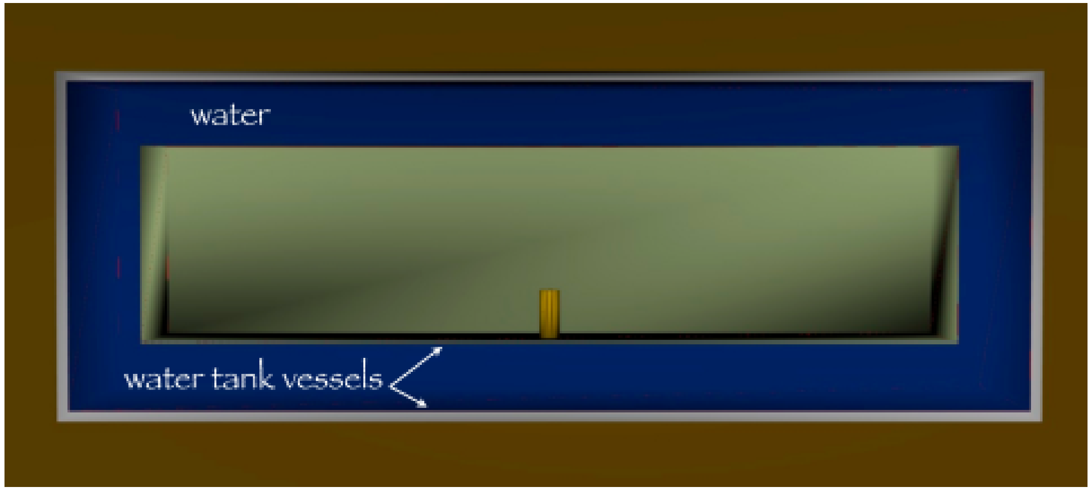
- Rate of electron recoils at 10-50 keV per year behind 3 m of water (2 cm thick vessel of the water tank + ~2 cm thick copper cryostat).
  - 785 in Ge (506 kg);
  - 274 in $CaWO_4$ (577 kg).

Submarine vs swimming pool



Swimming pool

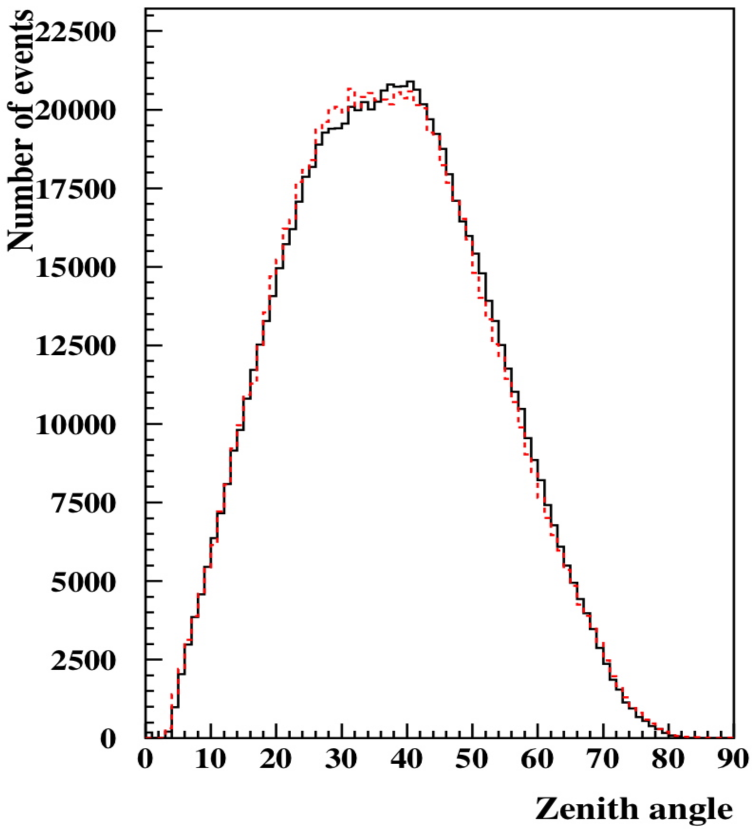
Submarine

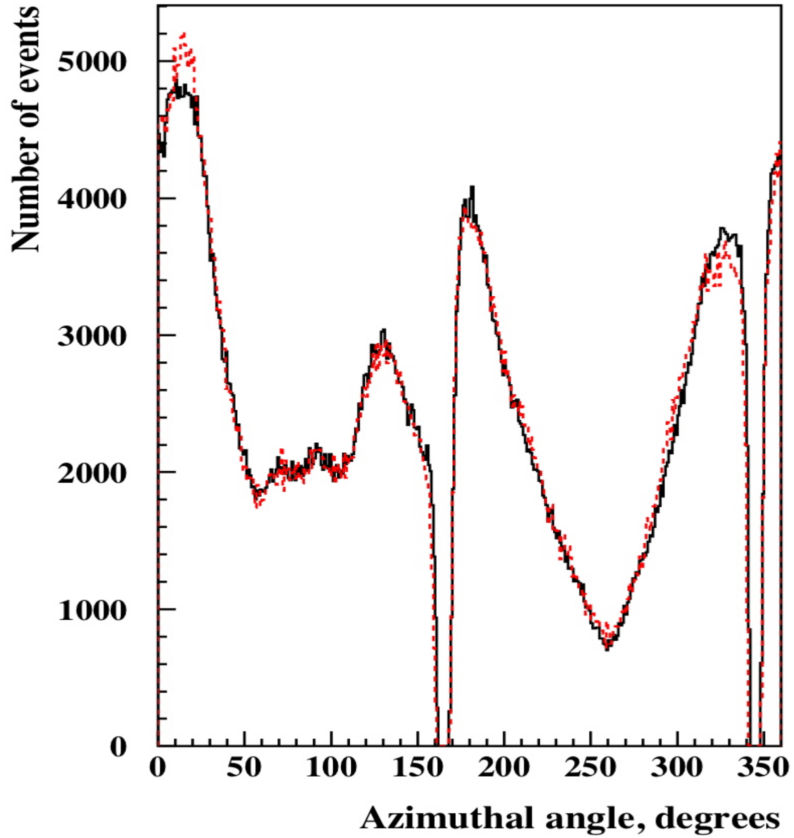


- About 17 nuclear recoils per year at 10-50 keV in 100 kg of Ge from the water tank stainless steel vessel (2 cm thick) along the walls.

- About 10^6 electron recoils per year at 10-50 keV in 100 kg of Ge from the water tank stainless steel vessel (2 cm thick) along the walls.

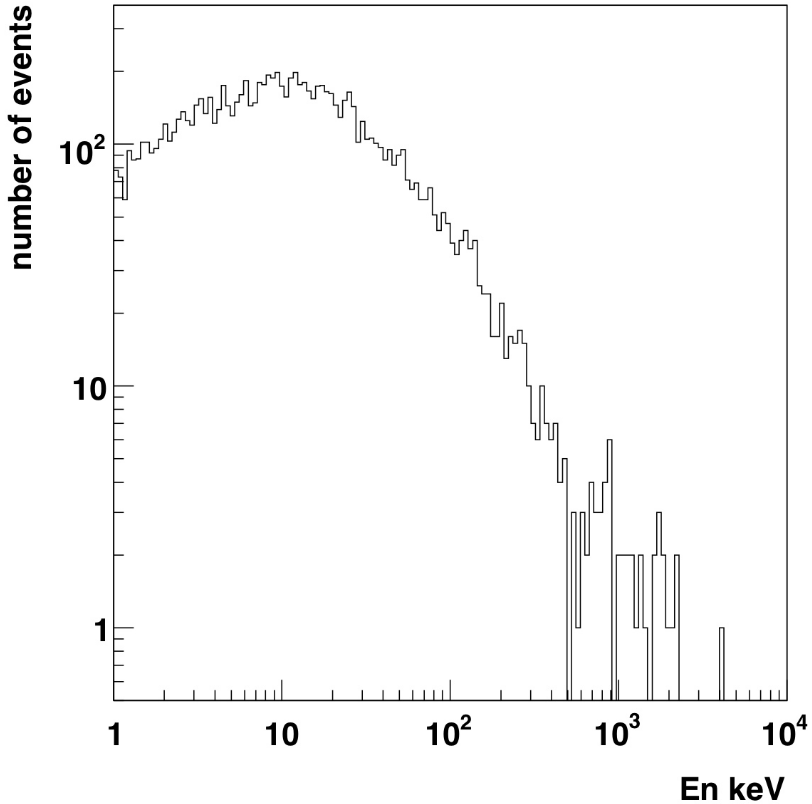
Muon generator: MUSUN

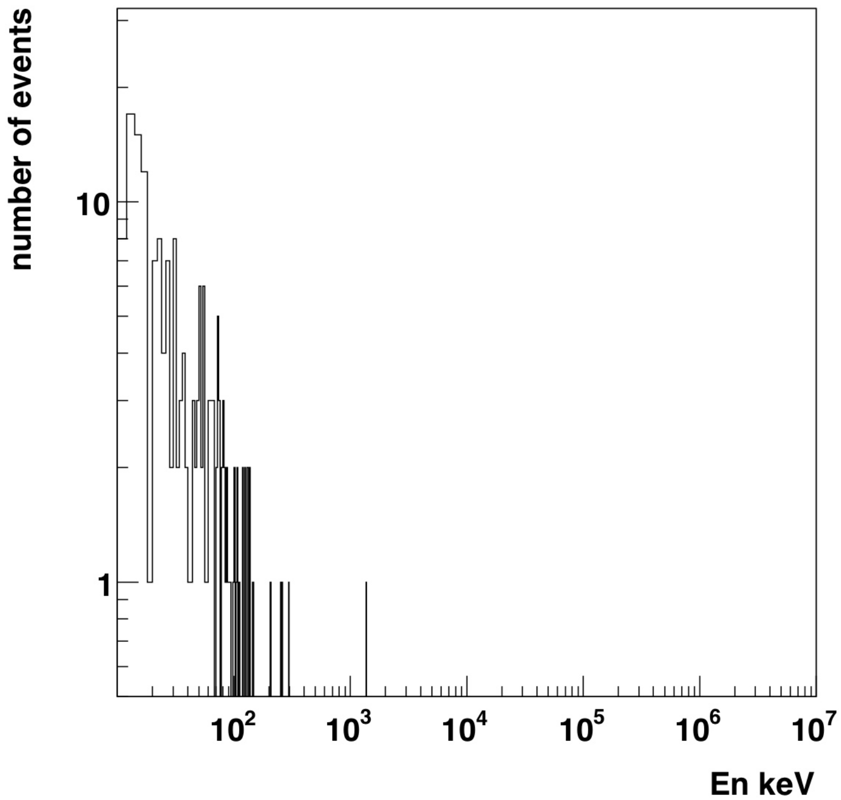




- Zenith and azimuthal angular distribution of muons as generated by MUSUN in comparison with the data from the Frejus proton decay experiment.

Muon-induced neutrons: Ge target





Spectrum of nuclear recoil energy depositions in individual crystals - all multiplicities. Other energy depositions are assumed to be not seen.

Spectrum of single nuclear recoils. Other energy depositions are assumed to be not seen in the detector. The energy threshold was assumed to be 10 keV.

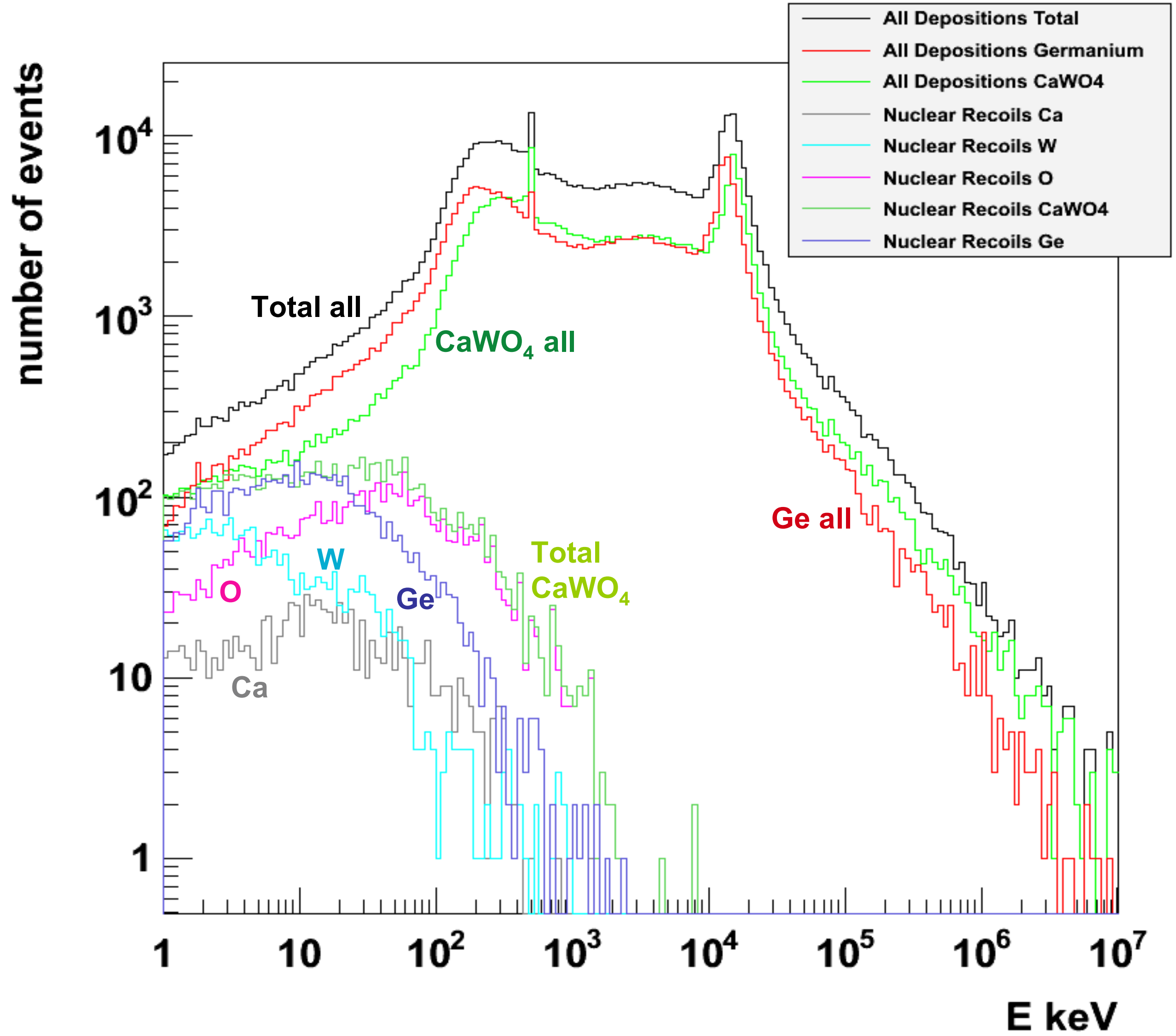
Muon-induced neutrons: Ge target

- **Only single nuclear recoils (without any other energy deposition):**
- **Only 12 events in 7.4 years.**
- **1.6 ± 0.5 events/year at 10-50 keV (2 runs). This is under the assumption that the water tank does not have PMTs or veto is not switched on.**
- **No events in anticoincidence with veto.**
- **One event with energy deposition in veto of only 0.278 GeV. Others - with E_{dep} > 1 GeV.**

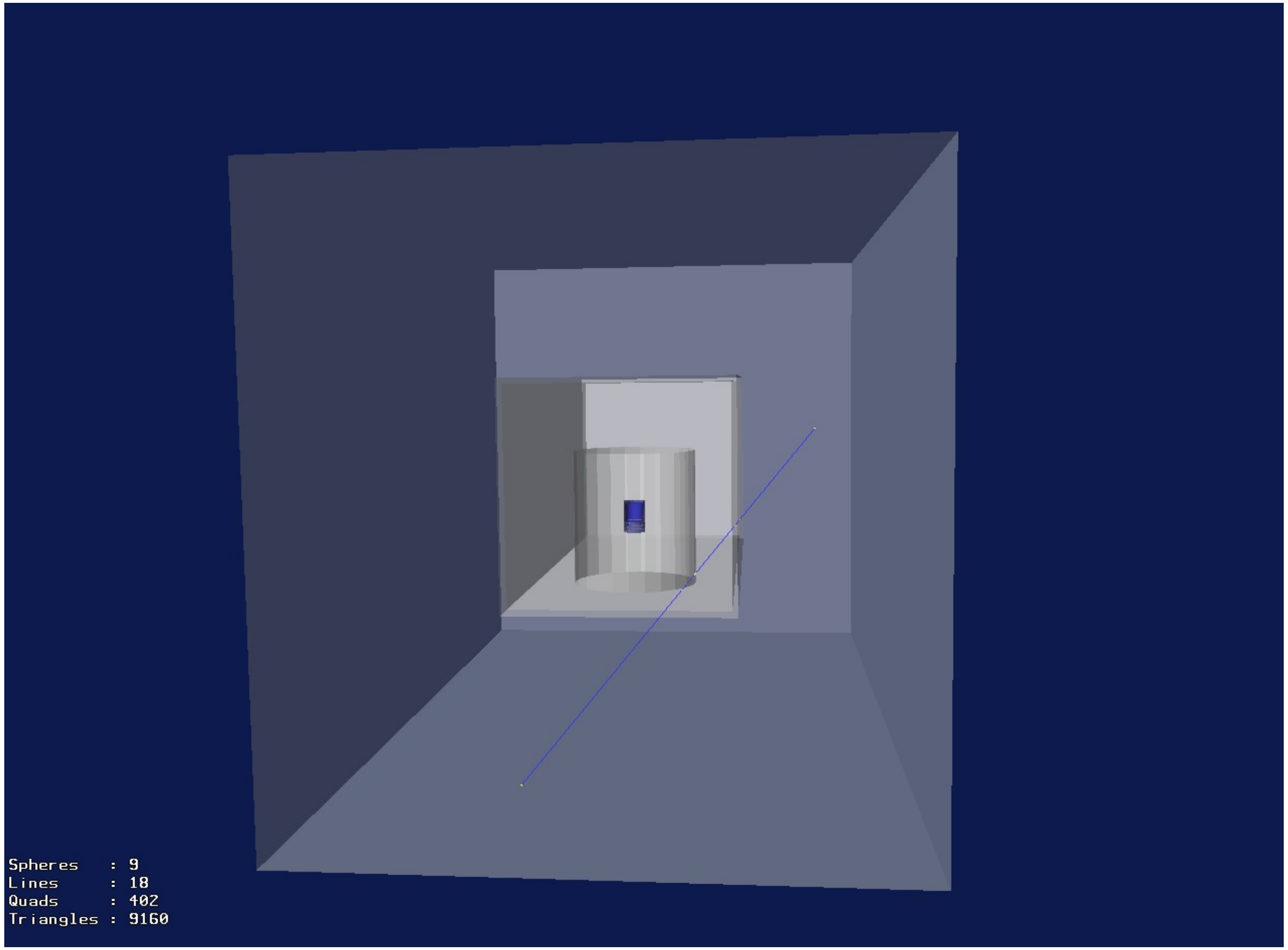
Run 2: single nuclear recoil events

event	tot veto deposition [GeV]					detector deposition [keV]			incident neutron	
	tot em	tot μ	tot hadr	tot nRecol	**TOT**	nR >10keV	nR<10 keV	TOT	volume	process
1	0.270	0.146	91.6×10^{-3}	187×10^{-6}	0.278	16.0	-	16.0	rock/vessel	p-In/n-In
2	0.491	1.26	0.629	0.115×10^{-6}	1.89	27.4	-	27.4	vessel	ph-In/n-In
3	2.63×10^{-3}	0.923	0.127	69.1×10^{-6}	1.05	14.3	9.66	35.7	vessel	Mu-CapAtRest/n-In
4	0.592	1.36	62.7	10.4×10^{-3}	64.6	16.4	-	16.4	water/vessel	ph-In/n-In
5	2.25	1.47	-	-	3.72	17.5	0.392	17.9	vessel	ph-In
6	0.180	1.29	31.4	4.21×10^{-3}	32.8	12.3	-	32.8	water/vessel	ph-In/n-In(no sec n)

Spectra from run 3: Ge + $CaWO_4$



Interesting event



High-energy neutron (~230 MeV) was produced in rock together with other neutrons. It was able to pass through water producing other neutrons and finally hit one crystal.

Conclusions

- **Shielding for 1 tonne scale experiment:**
  - **20 cm of lead + 40-50 g/cm^2 of CH_2 or**
  - **3 m of water.**
- **Optimistic results for muon-induced neutrons.**
- **1.6 ± 0.5 events/year/tonne - single Ge recoils at 10-50 keV; similar rate in $CaWO_4$ but mainly O recoils at high energies.**
- **No event survives veto cut (*E* > 0.2 GeV) in 11.1 years of simulated statistics. One event: *E* (veto) ~ 0.28 GeV. Others: *E* (veto) > 1 GeV.**