Expected background for the XENON 100 experiment

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Background sources

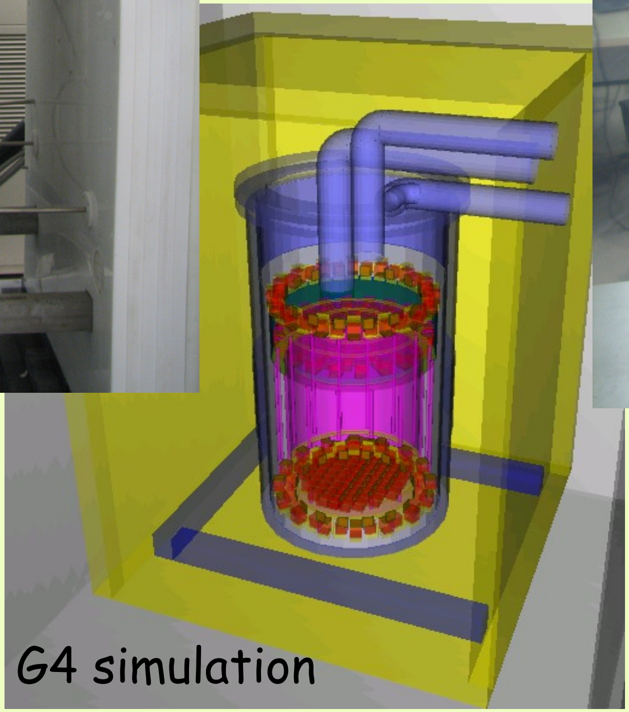
Radioactivity from U, Th, K, Co produces: → Gammas (electron recoils); → Neutrons (nuclear recoils)

High energy cormic ray muons produce: → Neutrons (nuclear recoils)

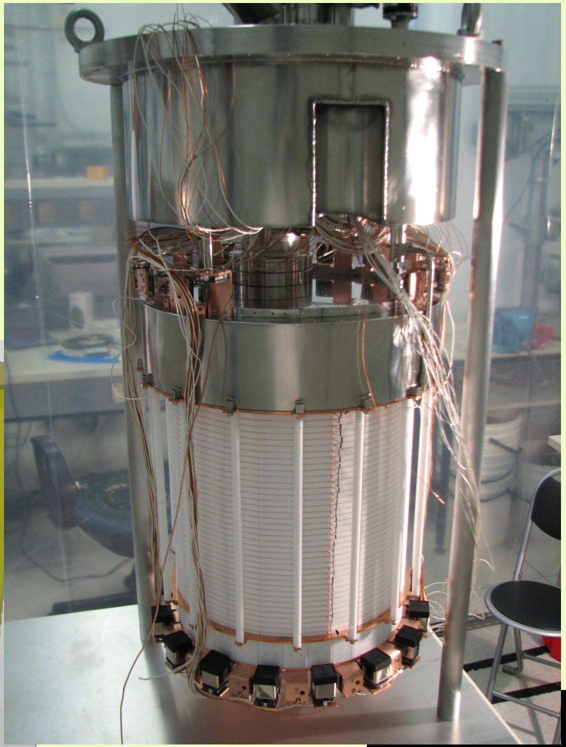
Goal:
to reduce background by a factor of 100 comparing with Xenon 10 (0.6 DRU) through:

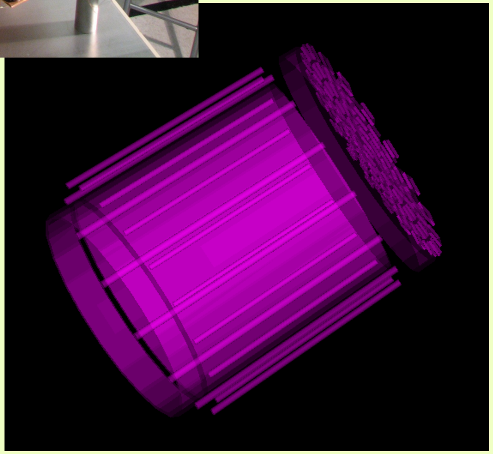
- careful selection of ultra-low background materials
- placing of known hot-materials outside the shield
- using 100kg of active LXe shield

The XENON 100 detector



G4 simulation





242 PMTs
in total
30 cm drift length

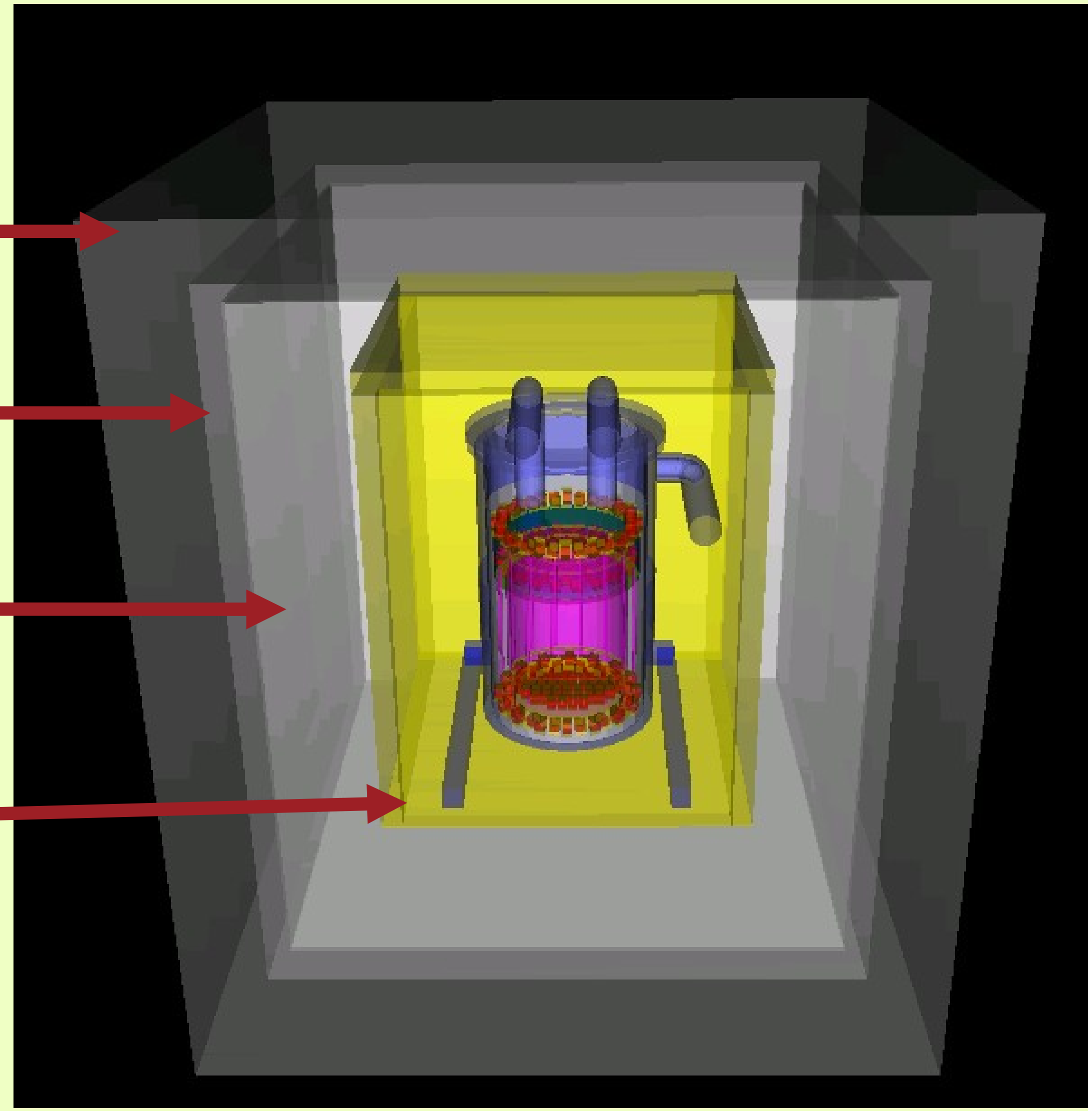
The XENON 100 detector inside the shielding

Lead:
15 cm, 27 t

French Lead:
5 cm, 6 t

Polyethylene:
20 cm, 2 t

Copper:
5 cm, 2 t



Material Screening at LNGS with several HP Ge detectors

- 2.2 kg HP Ge crystal
  coaxial crystal: d=82mm, h=81.5mm
- Ultra low background Cu housing
- Low Background shielding:
  5cm Cu
  low activity Pb (3Bq/kg ^{210}Pb)
- N2 atmosphere

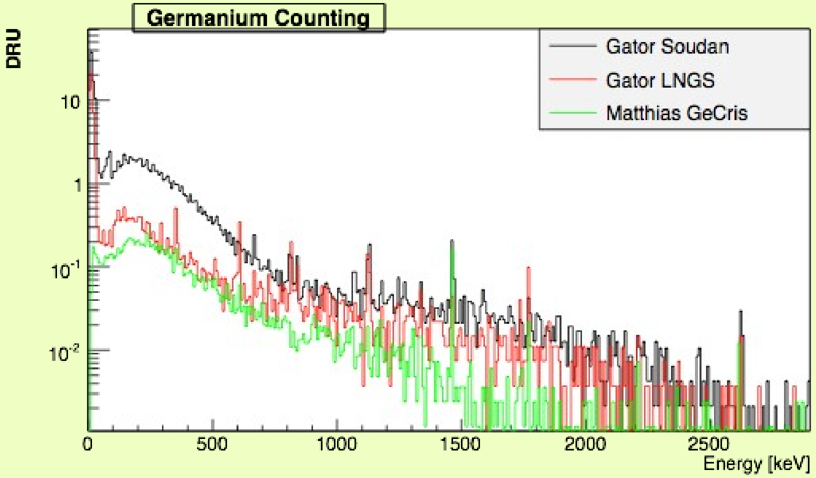
XENON 100's HPGe detector

LNGS HPGe detectors

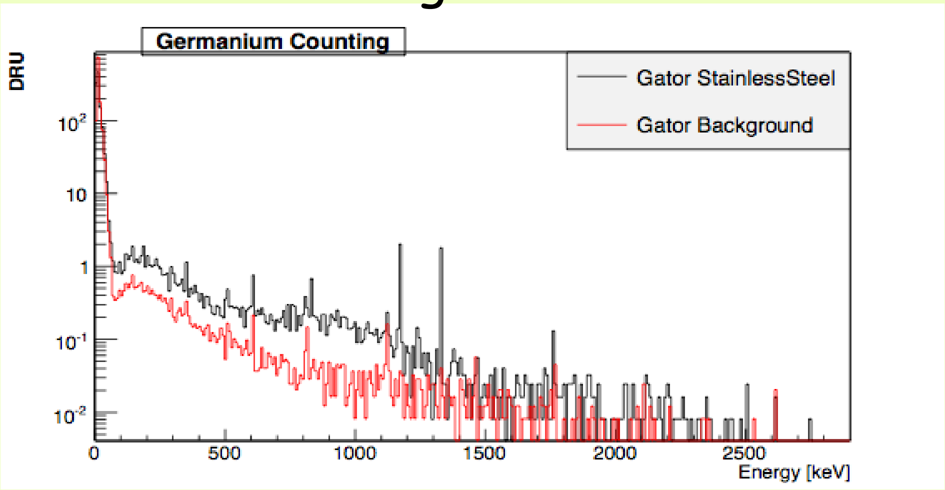
Different HPGe detectors,
2 of them are the most sensitive detectors in the world

Material Screening

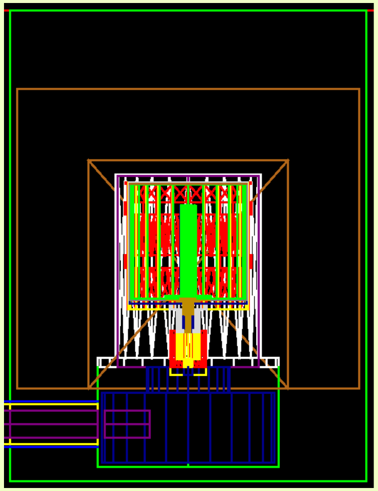
Background rate



Rate with the sample in place vs background rate



GEANT4 simulations with the exact geometry are performed to calculate detector's efficiency



Materials screened with the Ge detectors at LNGS

Material	U-238 [mBq/Kg]	Th-232 [mBq/Kg]	Co-60 [mBq/Kg]	K-40 [mBq/Kg]
PTFE	< 0.31	< 0.16	< 0.11	< 2.25
Stainless steel, 1.5mm*	< 0.13	< 1.0	8.5 ± 0.9	10.5 ± 4.2
PMT bases	0.16 ± 0.02 mBq/pc	0.10 ± 0.02 mBq/pc	< 0.01 mBq/pc	< 0.16 mBq/pc
22 High QE PMTs*	< 0.24 mBq/PMT	0.18 ± 0.06 mBq/PMT	0.50 ± 0.11 mBq/PMT	11.5 ± 2.0 mBq/PMT
Screws for PMT bases**	< 9.2	16 ± 4	9 ± 3	< 46.4
Feedthrough	13 ± 3	13 ± 6	21 ± 2	< 49

It was placed outside the shield

**total mass of screws 300g

*All PMTs and all the different SS pieces were screened

Shielding materials screened with the Ge detectors at LNGS

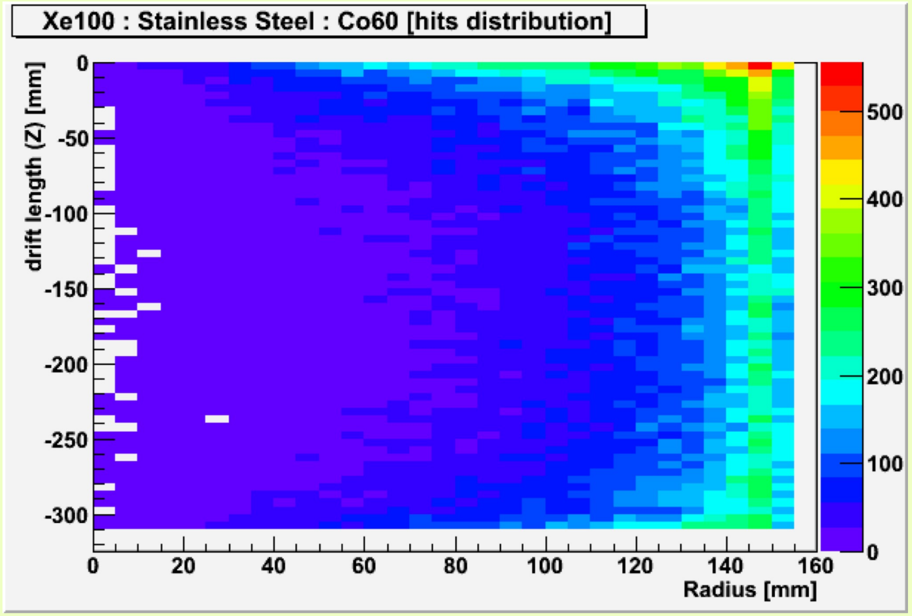
Material	U-238 [mBq/Kg]	Th-232 [mBq/Kg]	Co-60 [mBq/Kg]	K-40 [mBq/Kg]
Copper	< 0.020	< 0.023	NA	NA
Polyethylene	< 3.80	< 2.69	< 0.68	< 5.88
Lead	< 5.7	< 1.6	< 1.1	14 ± 6
French Lead	< 6.8	< 3.9	< 0.19	< 28

To be screened: Cu used for TPC, screws for PTFE rods

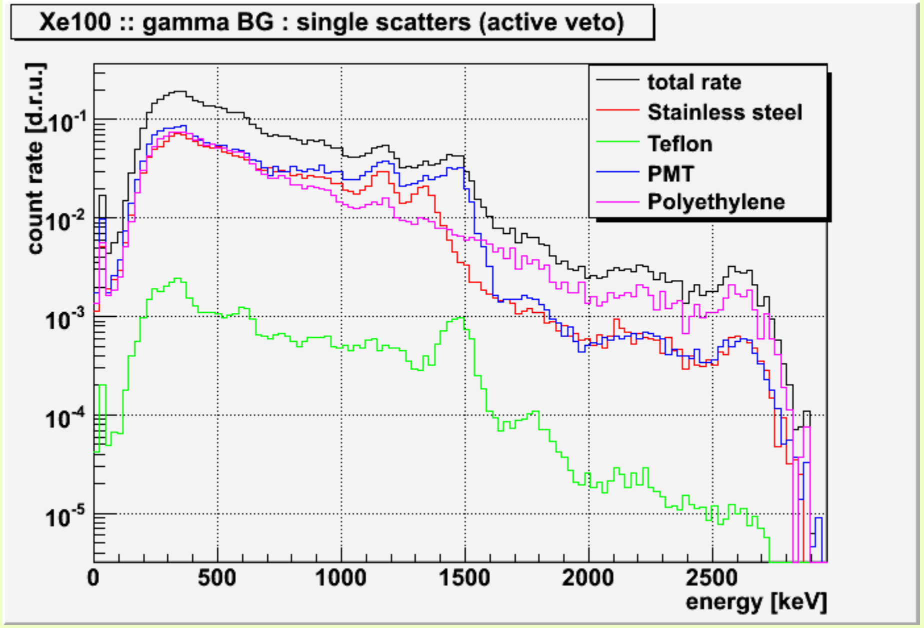
Gamma simulations

Gammas from U-238, Th-232, K-40 and Co-60 were simulated with G4

Position distribution to define FV cuts



Rate of single scatters, with an active veto threshold of 20keV



Predicted gamma background

Material	Rate of single scatters [mDRU] in the energy region 1-30 keV
Stainless Steel	2.01 ± 0.22
PTFE	0.18 ± 0.02
PMTs	4.91 ± 0.60
Liquid Xenon*	1.03 ± 0.02
Polyethylene	3.09 ± 0.29
Copper shield	0.026 ± 0.002
Total	**11.25 ± 0.70**

*Assuming the distillation column will purify the xenon down to the level of 10^{-12} g/g U and Th (A level of 10^{-13} g/g was achieved by XMASS)

Sources of neutrons

1. Local Radioactivity: (α,n) reactions from ^{238}U, ^{235}U, ^{232}Th
spontaneous fission from ^{238}U

Neutron energy few MeV

2. Cosmic ray muons: μ^- capture (important at shallow depths)

μ's in rock and in shielding (Pb, Cu):
- μ spallation
- Hadronic cascades (contribute most)
- E/M cascades

Neutron energy few GeV

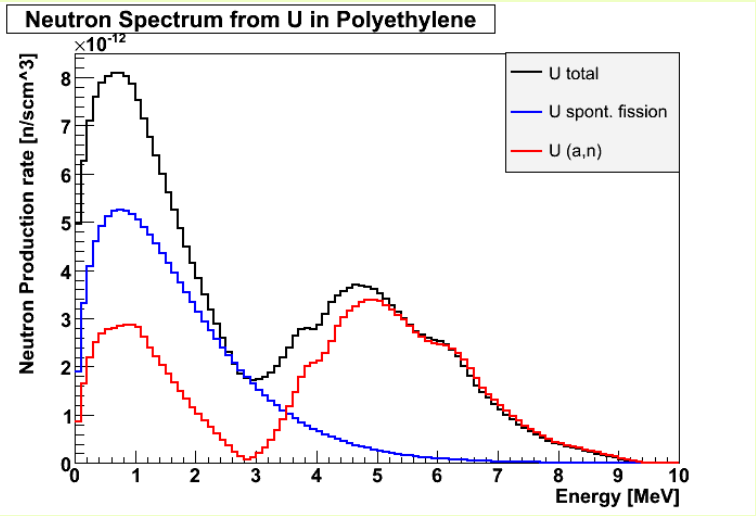
The modified code **SOURCES-4A*** used to calculate **neutron fluxes** and **energy spectra** from U/Th contamination in several materials.

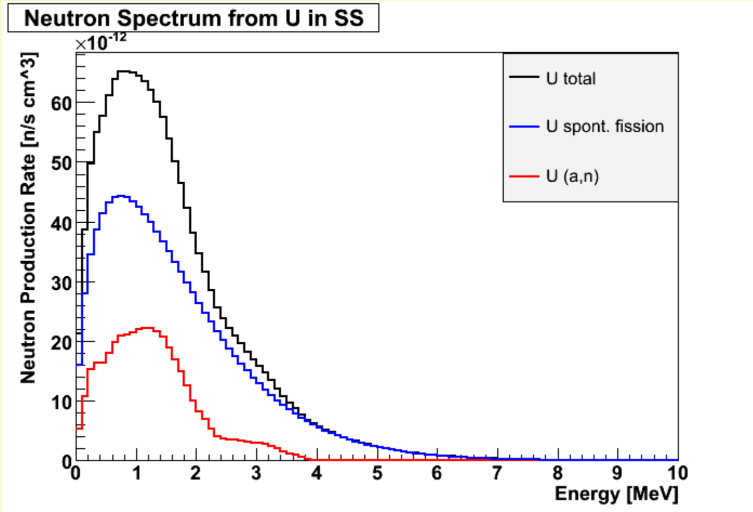
- Alpha energy range extended beyond 6.5MeV upper limit
- The cross-sections of (α,n) reaction updated to recent experimental results.

Main feature of SOURCES:

Takes into account transitions of the final nucleus to the excited states – reduced neutron energy

*Wilson et al., Carson et al., Lemrani et al.



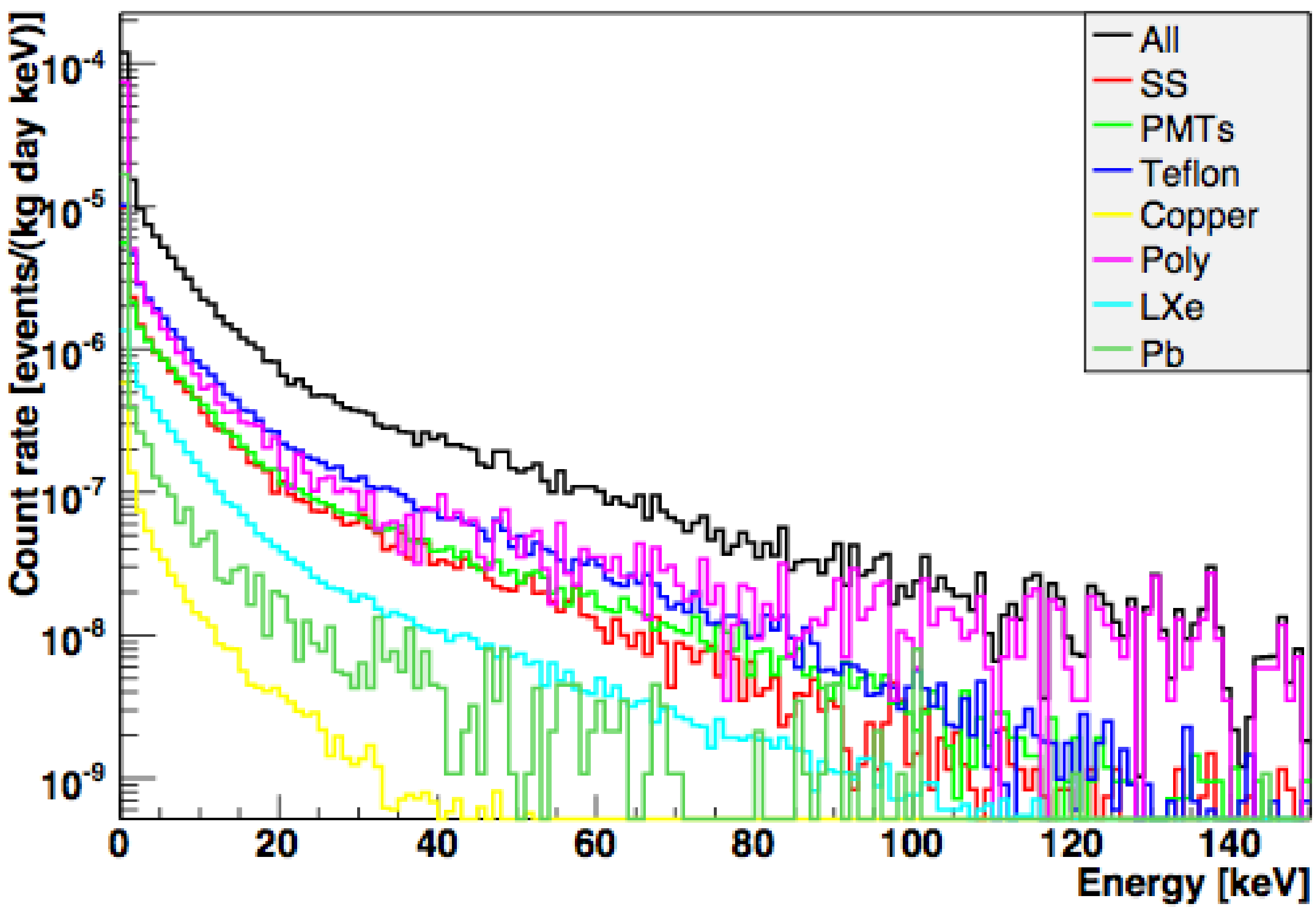


Assuming 10 ppb U

Neutron production rate per year

Material	neutrons/yr
Stainless steel	17.66
PTFE	28.02
LXe	0.814
PMTs	7.018
Copper	1.582
Lead- French	1578.8
Lead – Polish	5805.8
Polyethylene	416.26

Neutron simulations



Predicted neutron background from detector and shielding materials

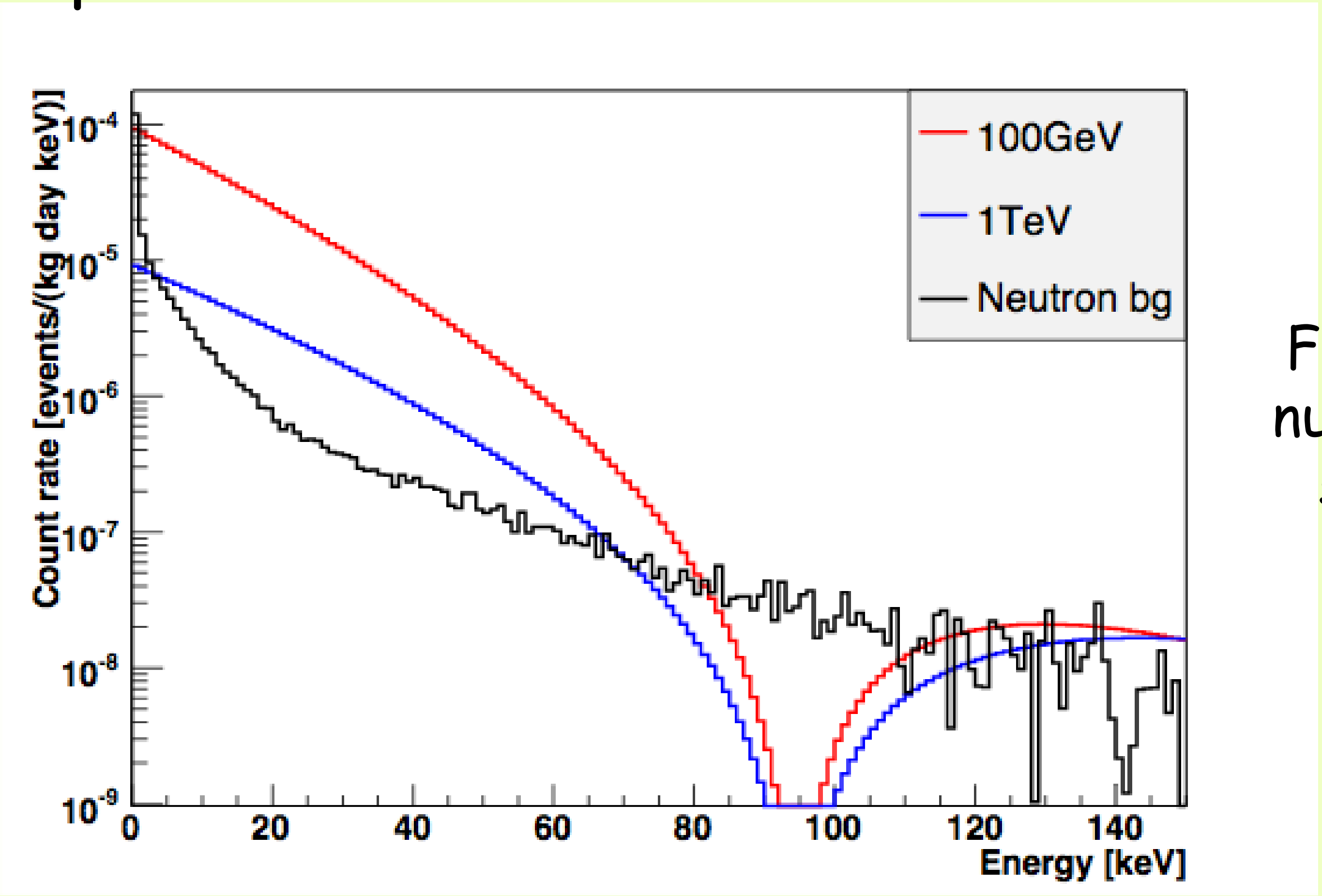
Material	Rate of single scatters [10^{-7}DRU] in the WS region, 4.5-26.9 keV	% singles
SS	2.93 ± 0.03	44
PTFE	5.84 ± 0.03	46
LXenon*	0.07 ± 0.01	49
PMTs	3.18 ± 0.02	47
Copper	0.11 ± 0.002	35
Total Lead	0.38 ± 0.02	43
Polyethylene	4.87 ± 0.10	44
Total	**17.38 ± 0.11**	**44%**

*Assuming the distillation column will purify the xenon down to the level of 10^{-12} g/g U and Th

Total neutron rate = 1.7 μDRU

=> 0.6 single nuclear recoils/year

Expected WIMP rate in XENON 100 vs neutron background

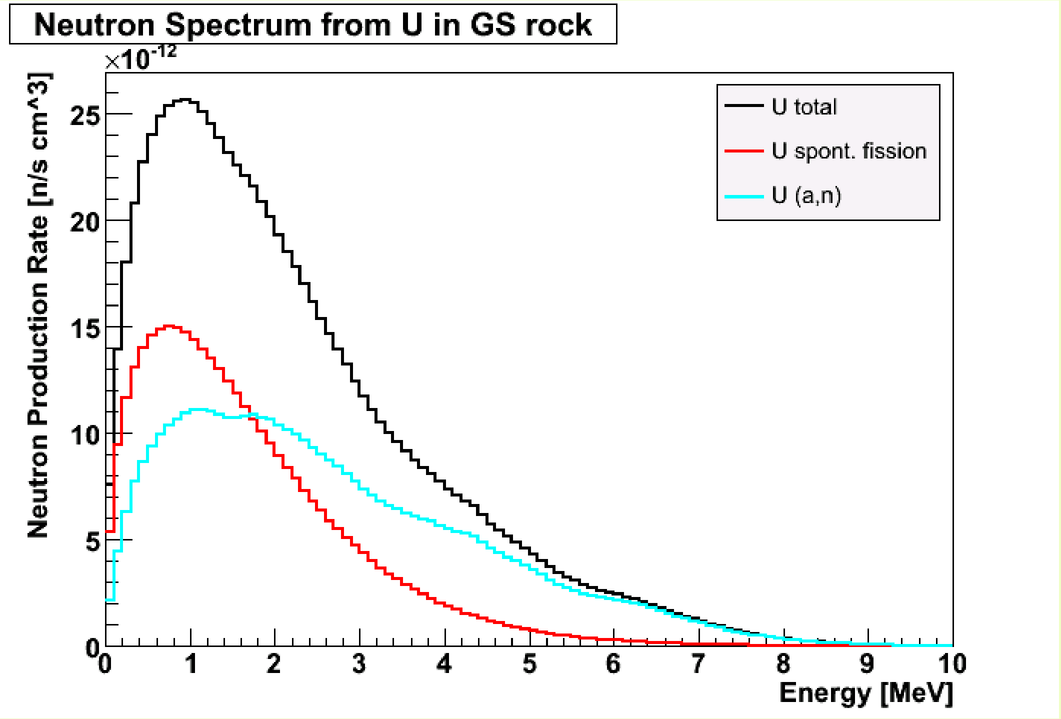


For a WIMP-nucleon cross-section of $2\times10^{-45}cm^2$

Neutrons from local radioactivity of the concrete and rock caverns are in progress

Cavern	Thickness	ρ (g/cm³)	U* (ppm)	Th* (ppm)	neutrons/yr/g
Concrete	30cm	2.4	1.05	0.656	1.7
Rock	3m	2.7	6.80	2.167	7.1

*Activities in rock refer to Hall A (Wulandari et al)
Composition of rock and concrete was taken from Wulandari et al.
However the flux is dominated by neutrons from concrete, therefore doesn't
vary much from hall to hall



Muon-induced neutron simulations

Simulation procedure:

1. Muons are propagated from sea-level down to GS lab : MUSIC code (data already exist)

2. Energy and angular distribution of muons in the XENON Hall and the absolute μ intensity are calculated with the MUSUN code

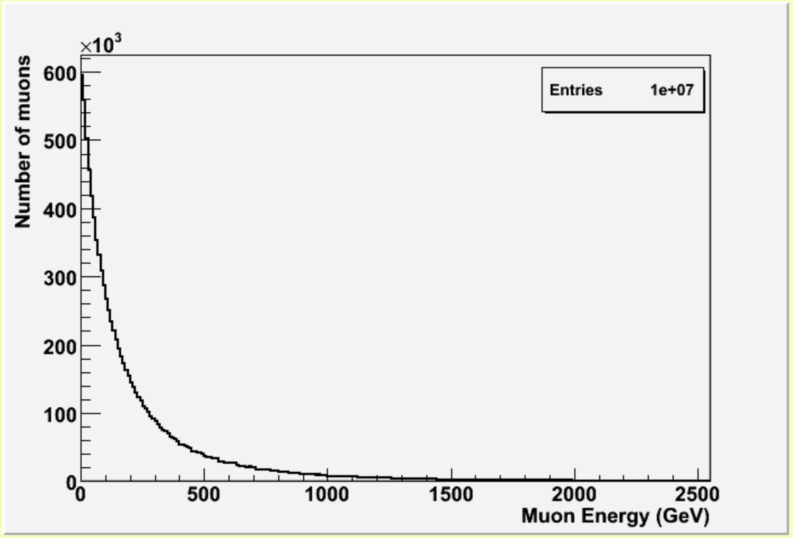
3. Muons are propagated through the rock (rock thickness = 6m) and the shielding producing neutrons with the GEANT4 code

From MUSUN:

μ flux = 1.17/m²/h
Mean μ energy = 270 GeV

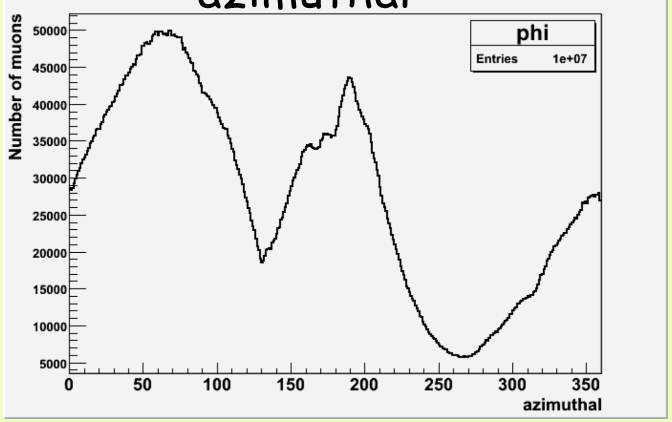
Muons in a parallelepiped
inside the rock (6m thick)

Energy spectrum

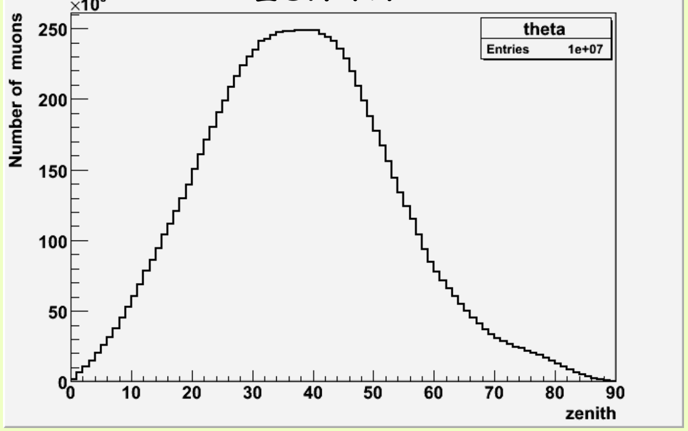


Angular distribution

azimuthal



zenith



Simulation is in progress...

Conclusions

• Background rates due to the detector and shielding materials in the WS region:

Gamma rate = 11.25 mDRU !!! prior to S1/S2 discrimination

Neutron rate = 1.8 μDRU

=> 0.6 single nuclear recoils/year

• Neutron background from rock and concrete cavern:

Simulation in progress... collecting stats

• Neutron flux from muons:

is typically 0.1% or less of the neutron flux from the rock activity

Simulation in progress...

XENON 100 is expected to have 100 times lower background than XENON 10, probing WIMP-nucleon SI cross sections down to $2x10^{-9}$pb