Material screening and Background expectation for the Xenon100 experiment

Alfredo Davide Ferella
University of Zurich

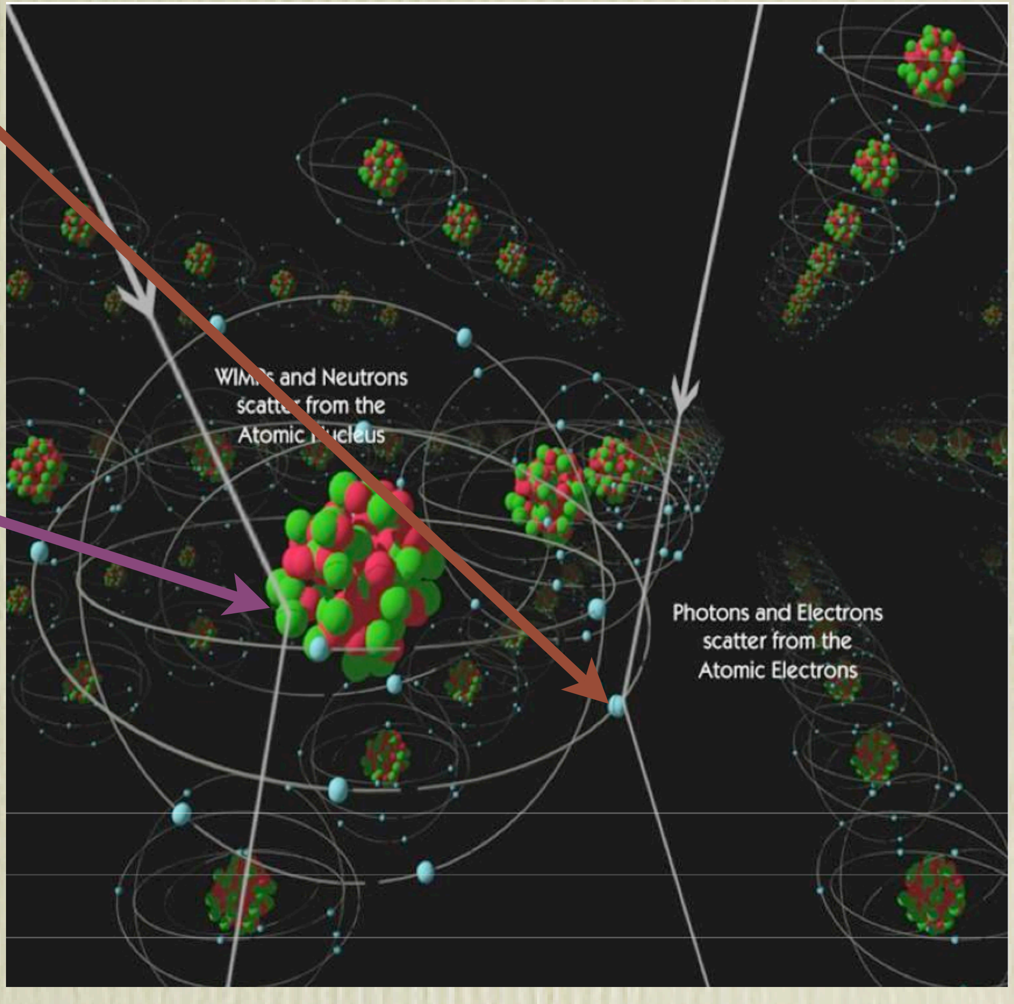
Dark Matter at the crossroad (2008) - DESY, Hamburg 2008, 29 Sep - 2 Oct 2008

What's the Background we are afraid of?

NATURE:

Gamma particles

Neutrons



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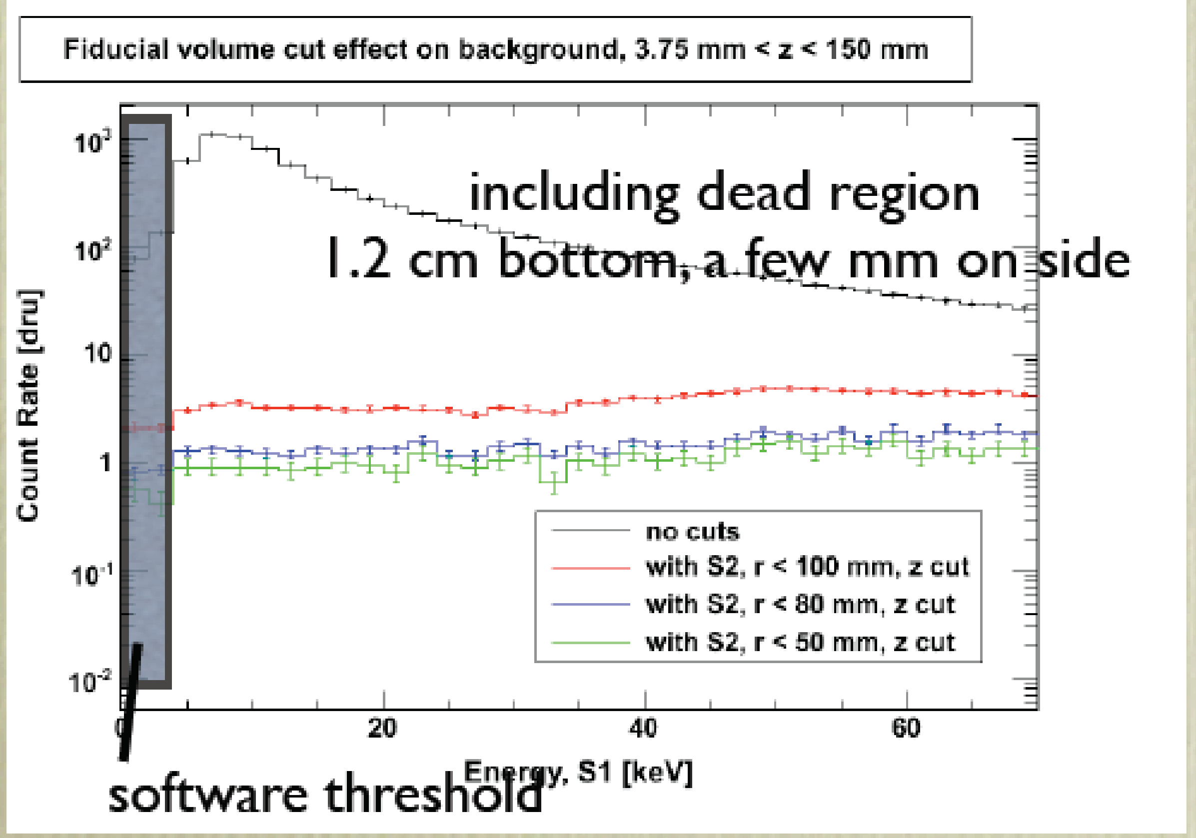
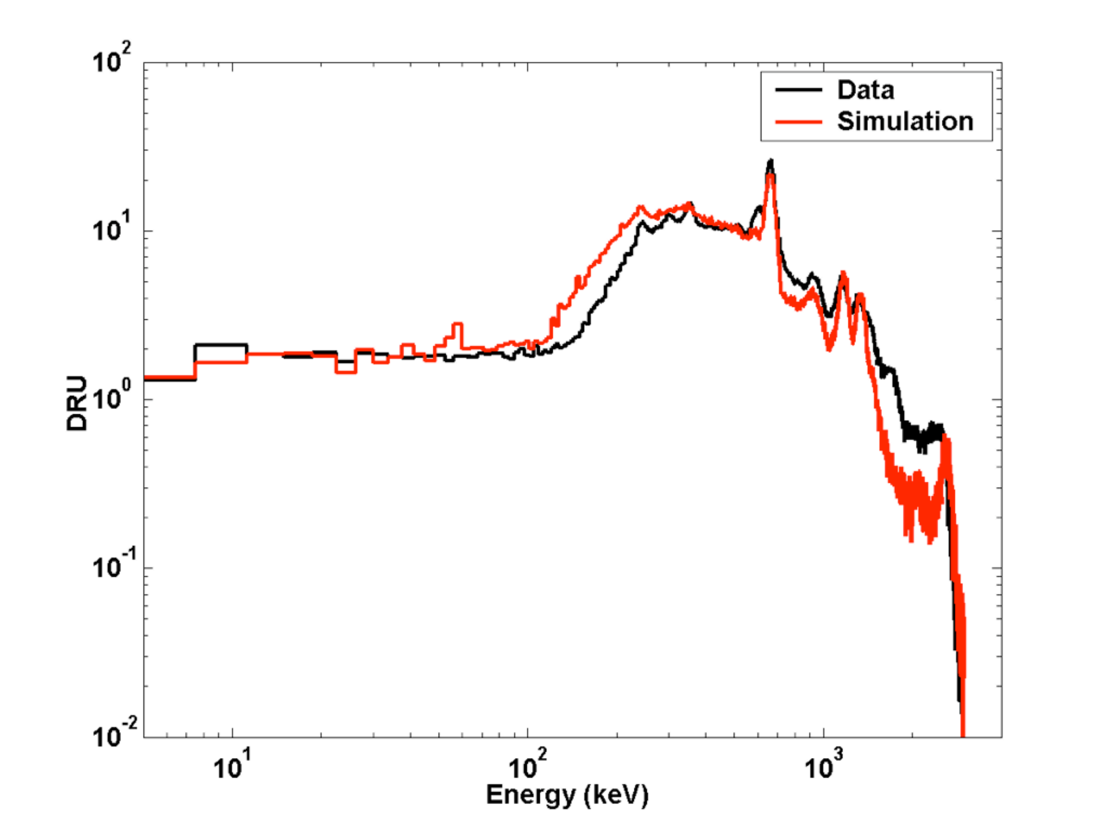
Cosmic muons - Neutrons

"History of the background" in Xenon10

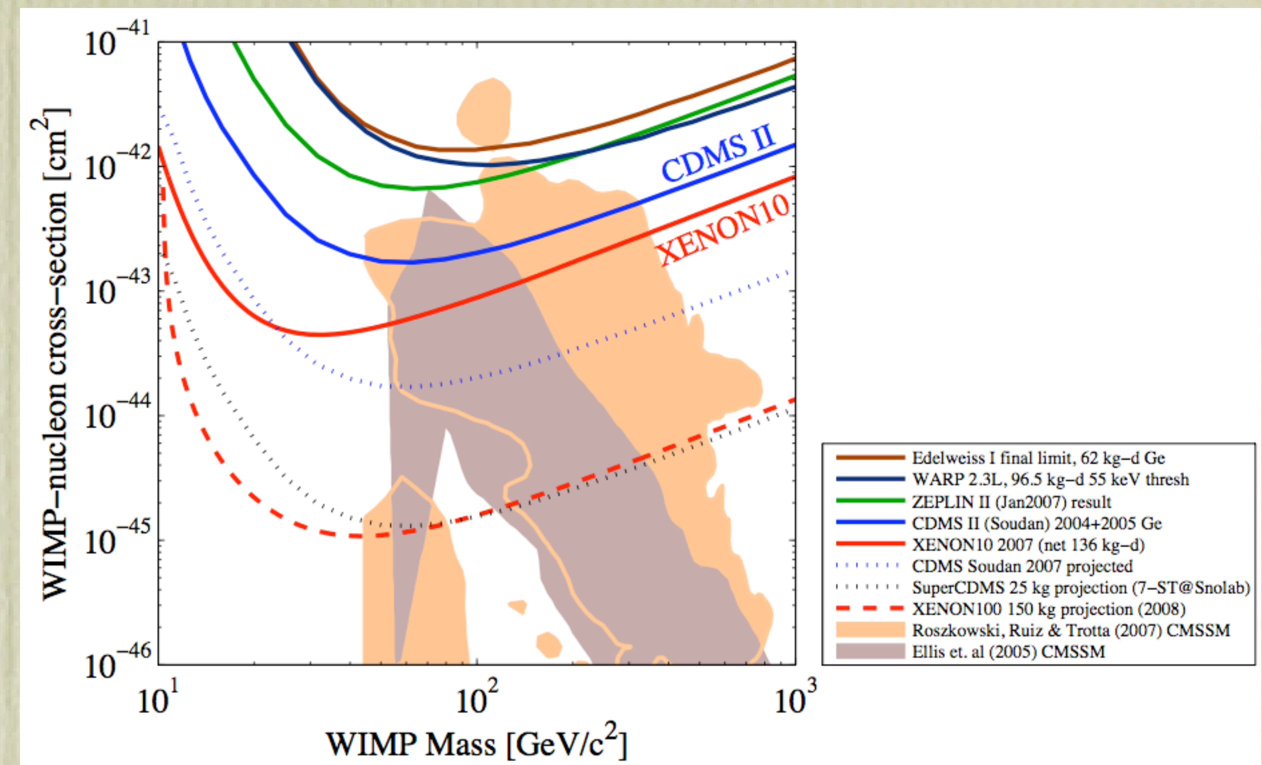
- Xenon10 (prototype):
  - Detector operated for more than 1 year
- Some screening has been done.
- A Background estimation based on GEANT4 has been done.
- The desired sensitivity was < 10^{-43} cm^2 @ ~100 GeV
- To reach such sensitivity, assuming a rejection power of 99.5%, the gamma background had to be kept at the level of ~1 DRU in the ROI (0-40 keV)





The Xenon100 Goals

Improve the sensitivity almsot 2 orders of magnitude over XENON10.



Assuming same energy threshold and same discrimination power as XENON10, the required background in the sensitive volume needs to be 100 times lower with a mass increasing of a factor 10.

In order to fulfill completely these requirements we:

- ✶made an extensive screening campaign in order to select the right materials.
- ✶Add a veto region around the TPM to shield the inner part
- ✶Design the cryogenics and the electronics to be outside the shield
- ✶The existent Xenon10 shield has been improved in order to reduce the external BG
- ✶We used a distillation column to reduce the 85Kr contained in the commercial Xe

Xenon100 Design

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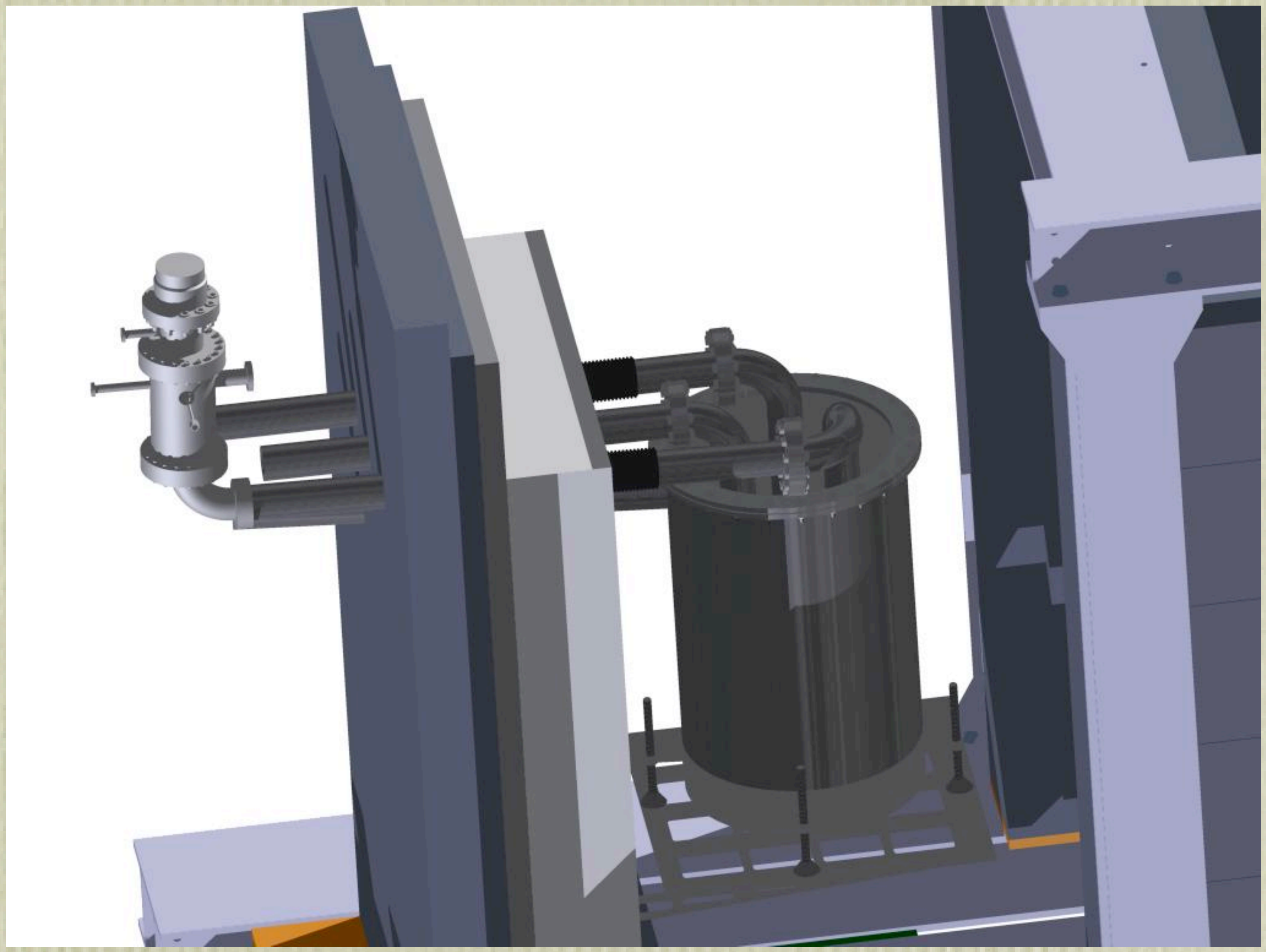
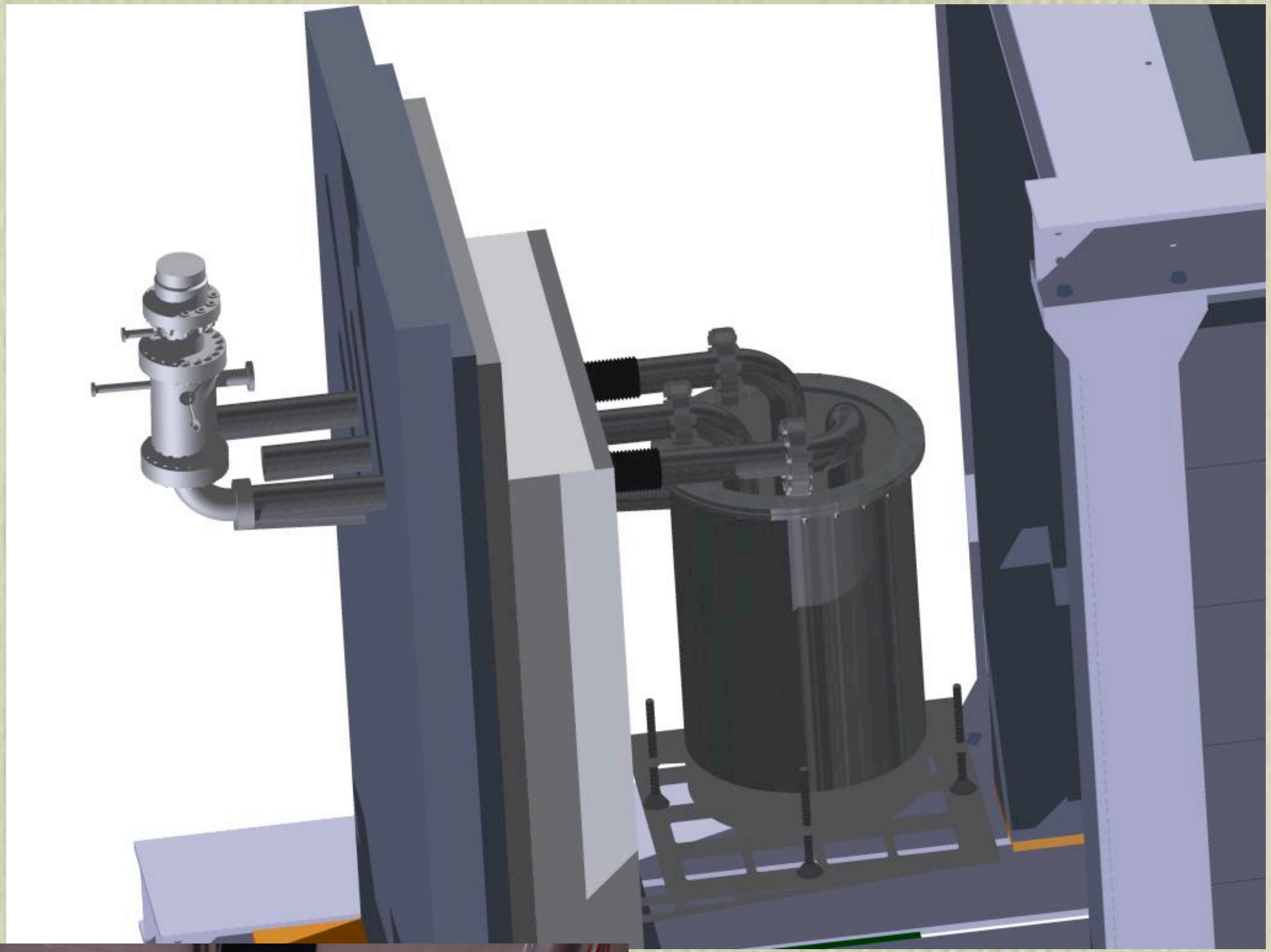
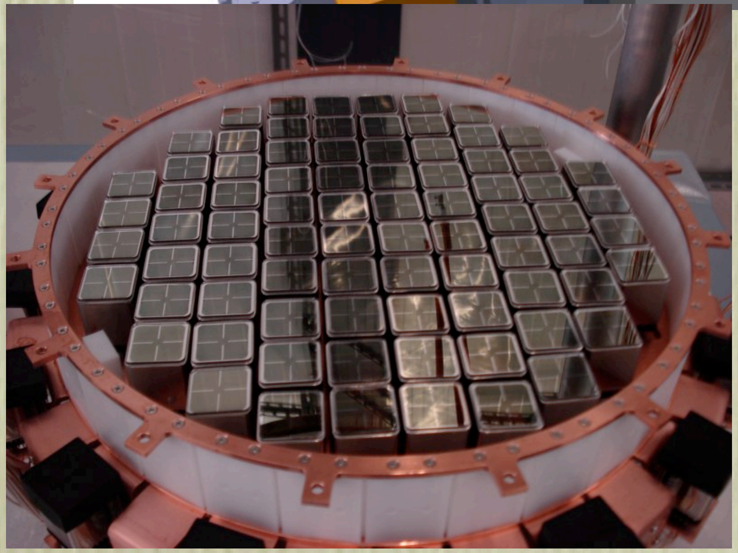
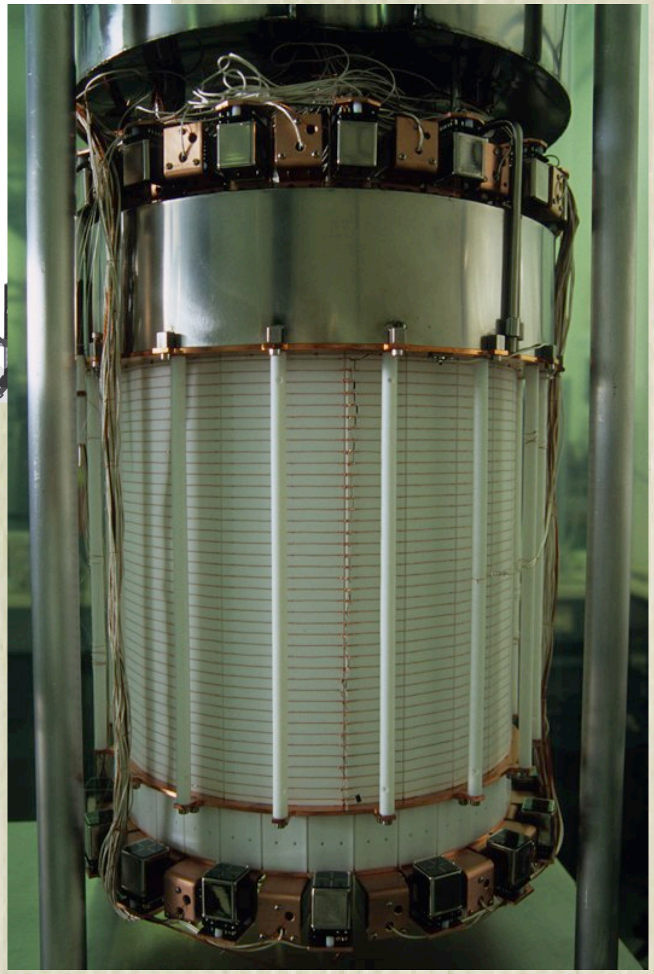


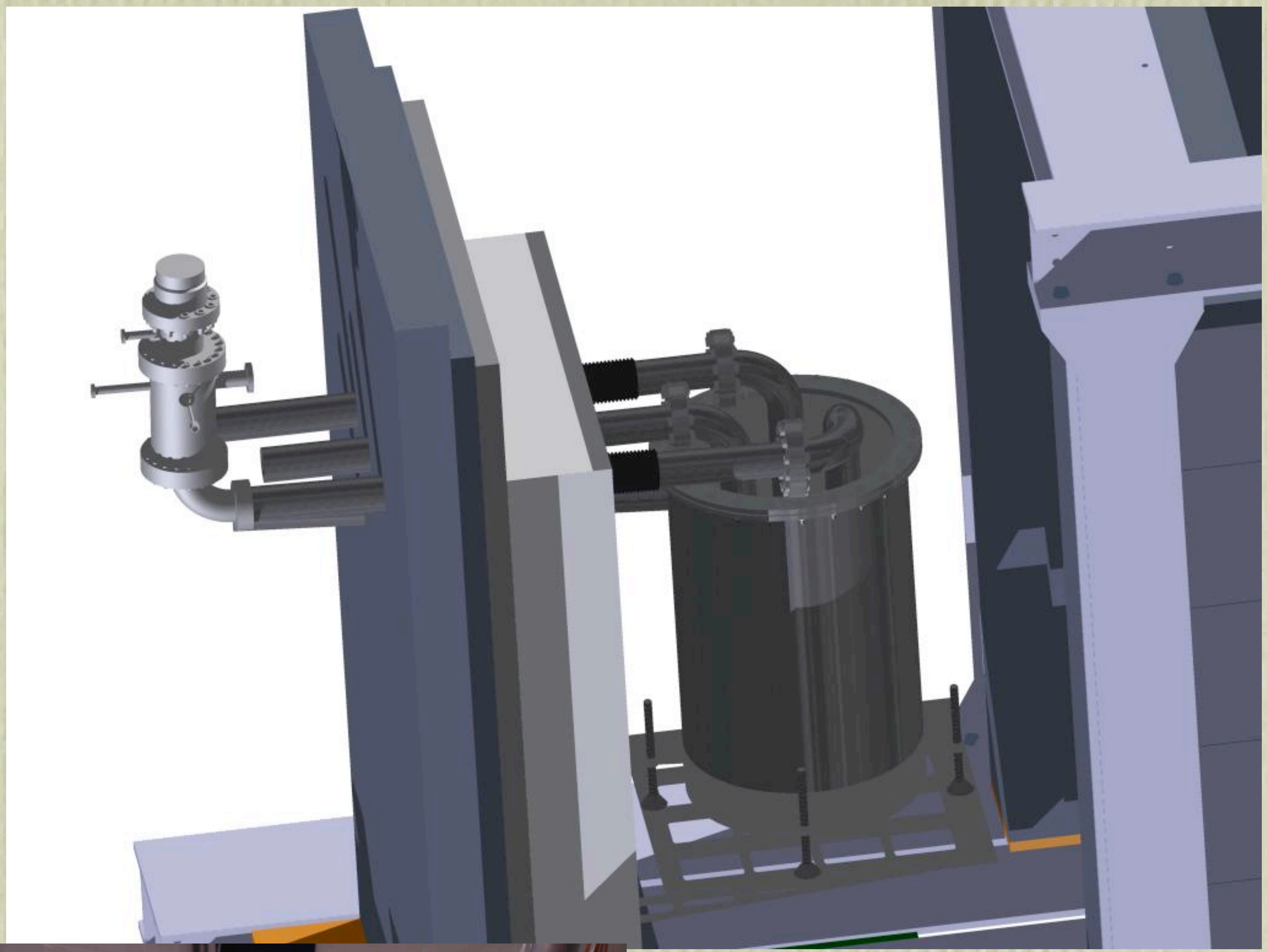
Xenon100 Design

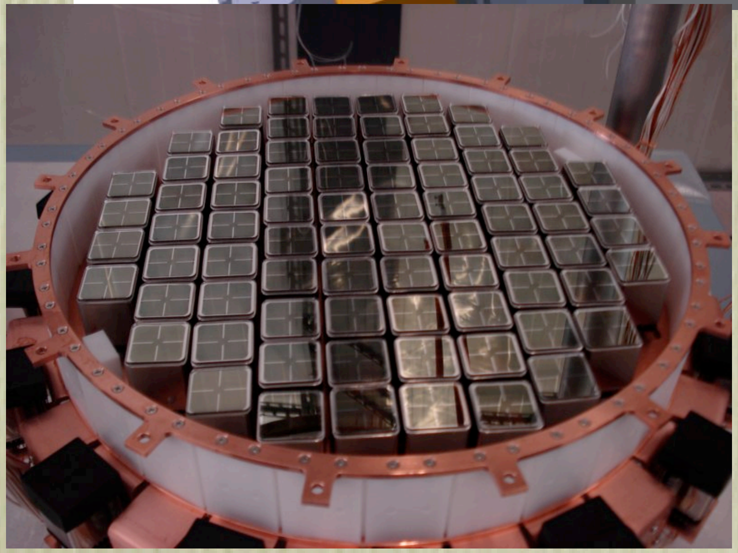






Xenon100 Design

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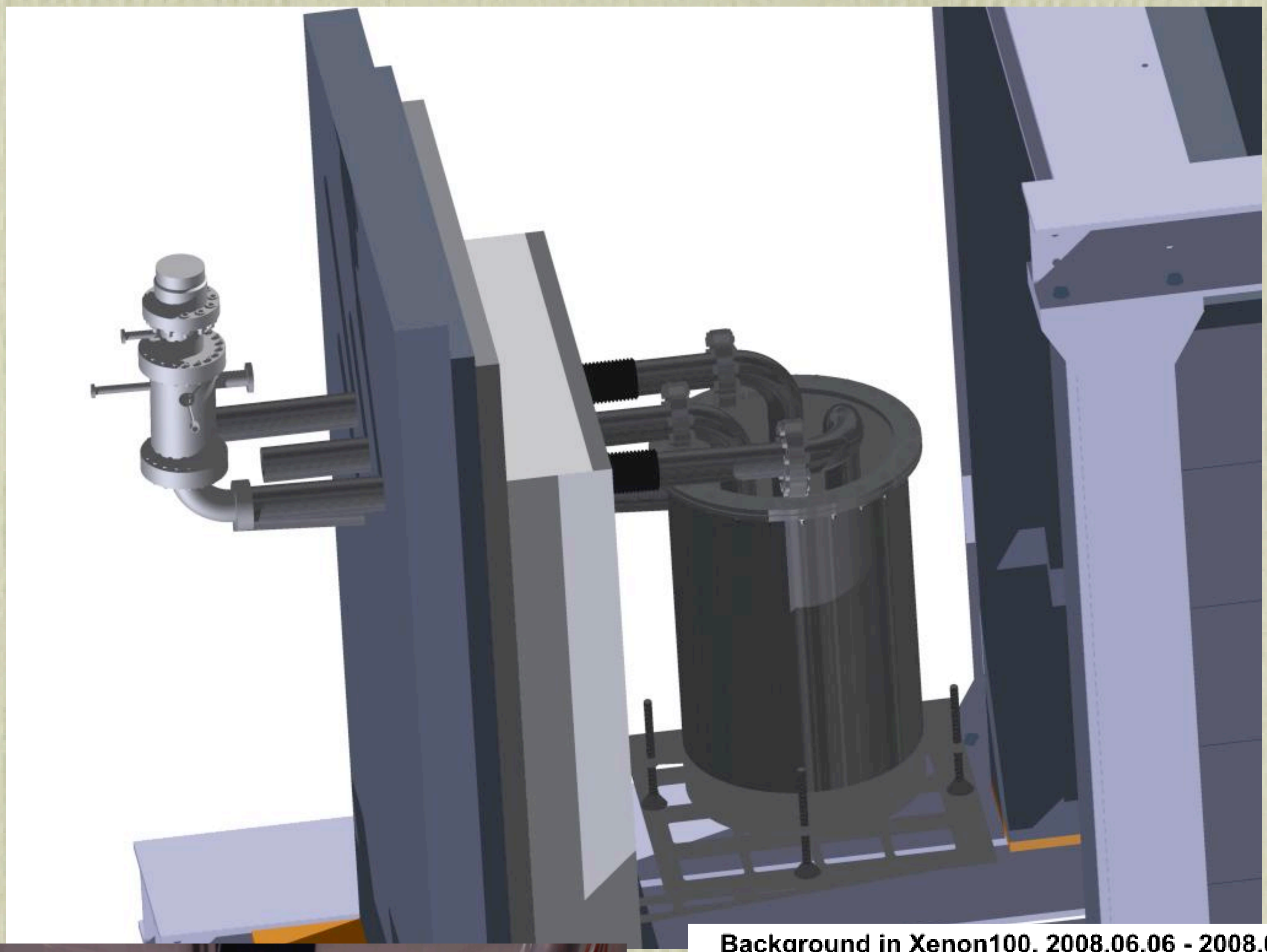
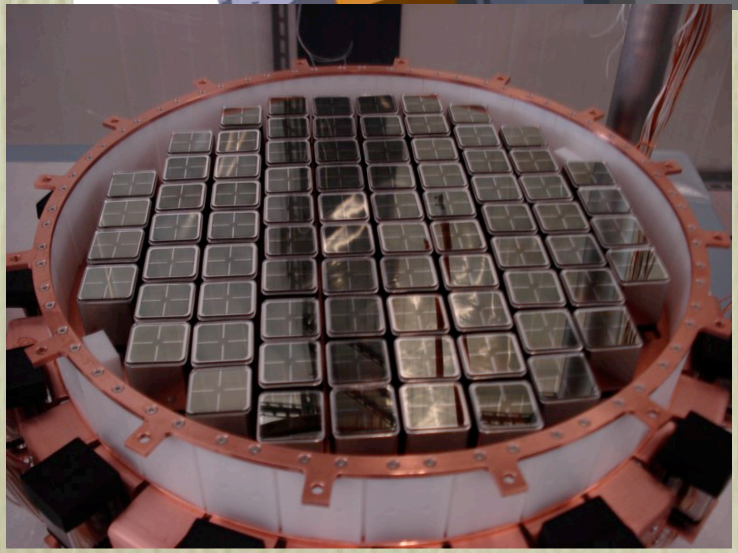
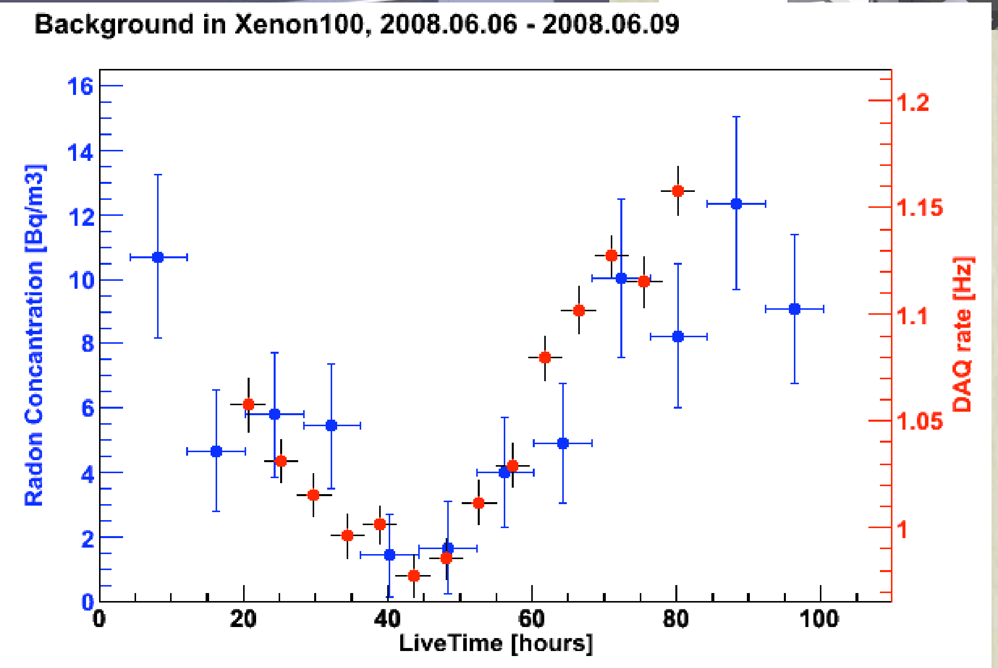






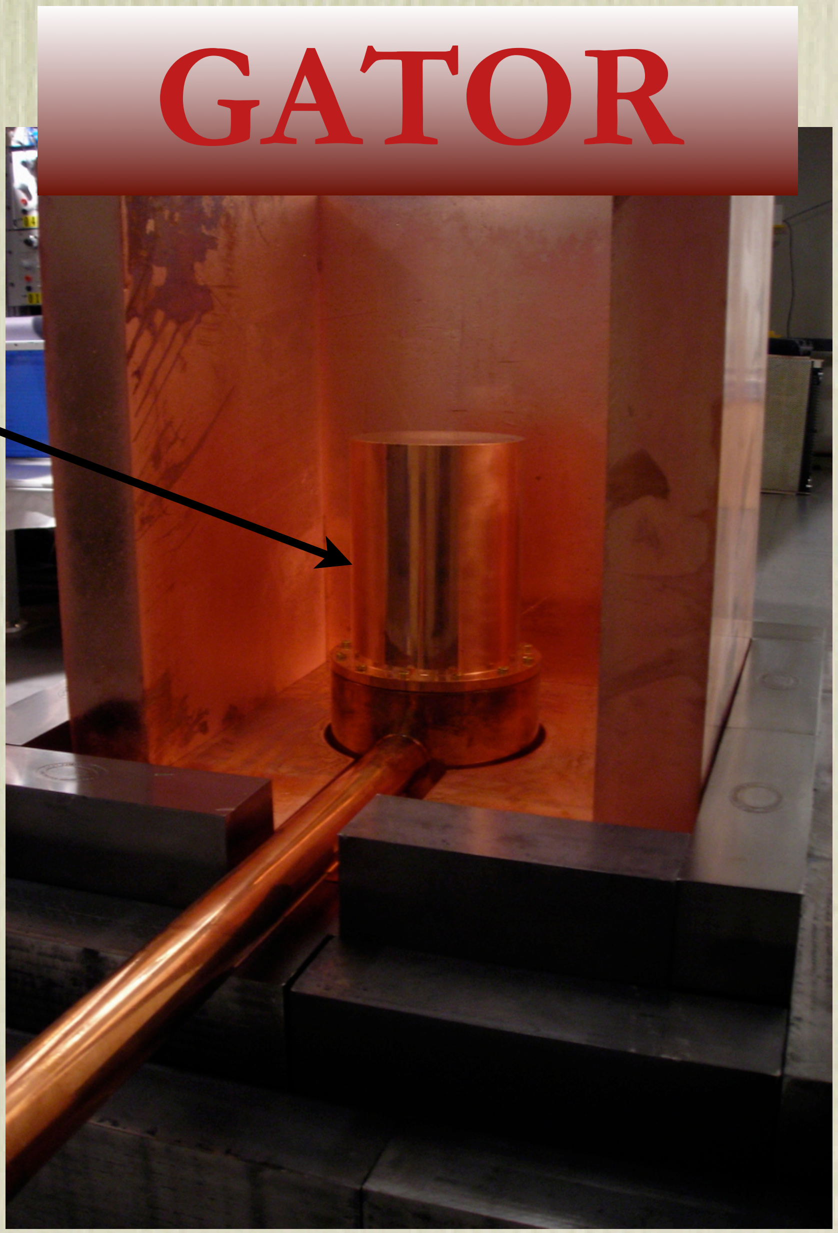
High Purity Germanium Detector for gamma spectroscopy

HPGe detector produced by Canberra

- ✓2.2 kg HPGe crystal
  - ✴ coaxial crystal: 82 mm diameter, 81.5 mm height.
- ✓Ultra Low Background Cu housing

Physical Characteristics

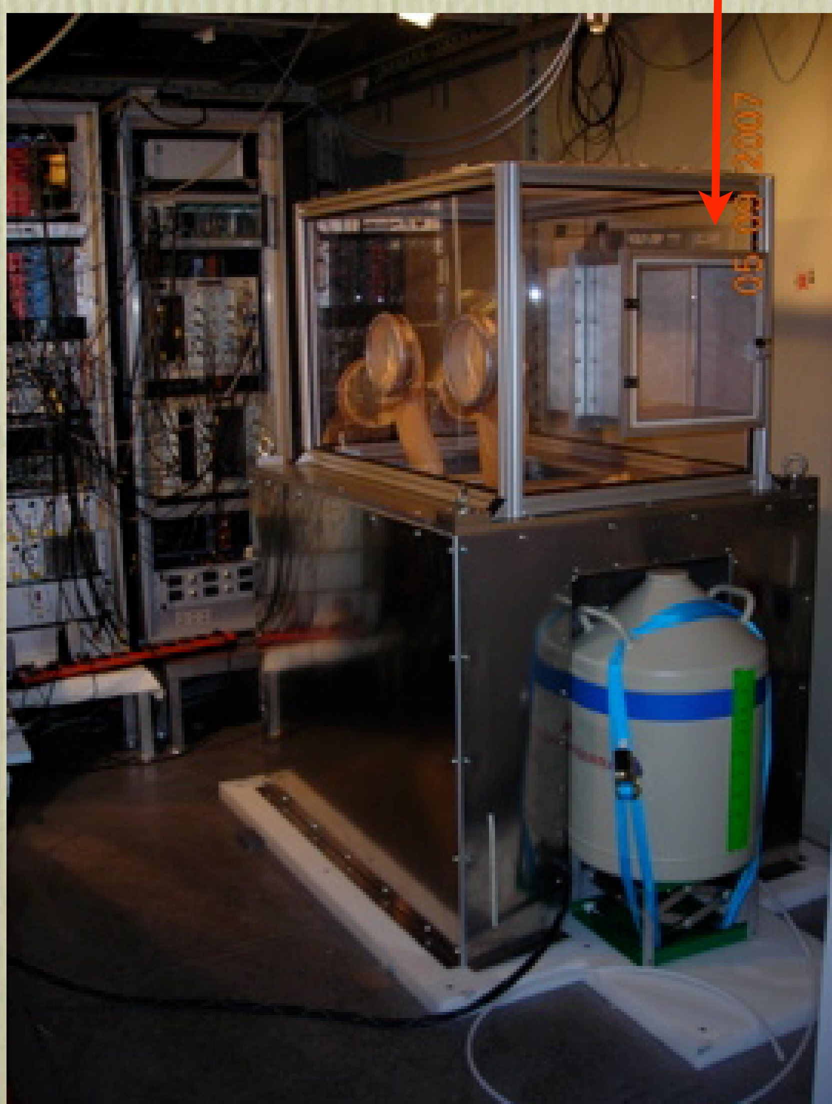
Source (isotope)	^{57}Co	^{60}Co
Energy (keV)	122	1332
FWHM (keV)	1.09	2.06
FWTM (keV)		4.04
Peak/Compton		76.0 : 1
Rel. Efficiency		100.5 %



High Purity Germanium Detector for gamma spectroscopy

- ✓N2 Atmosphere
- ✓Located @ LNGS
- ✓Started taking data on september 2007

Glove box on top for sample purging

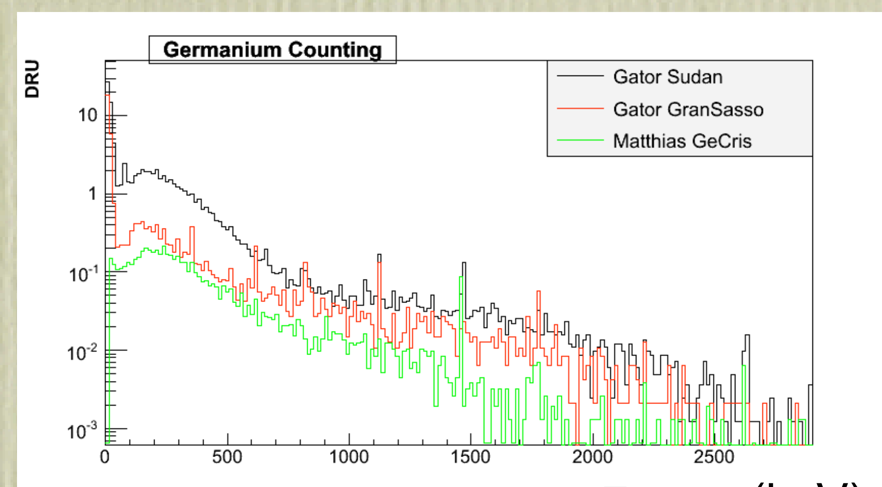


Detector in the shield

Gator at Soudan

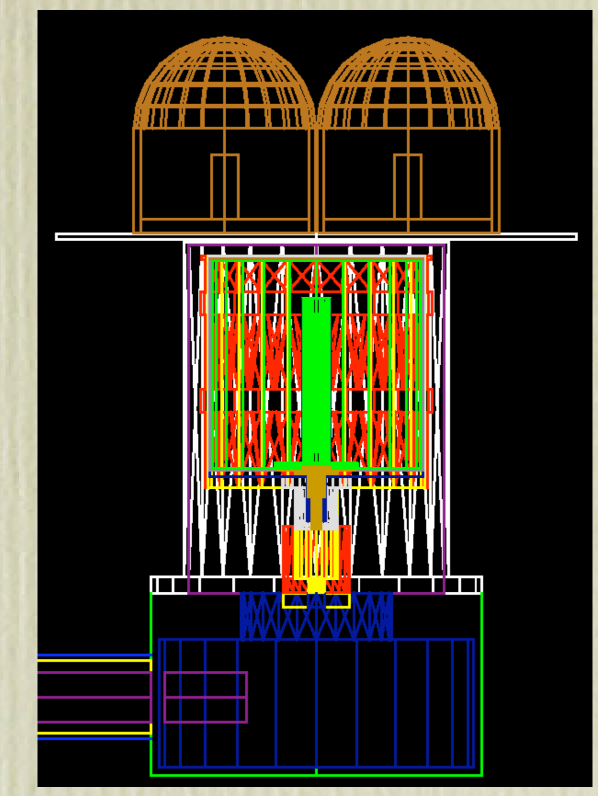
Gator @ Gran Sasso

LNGS 2.47 kg HPGe)

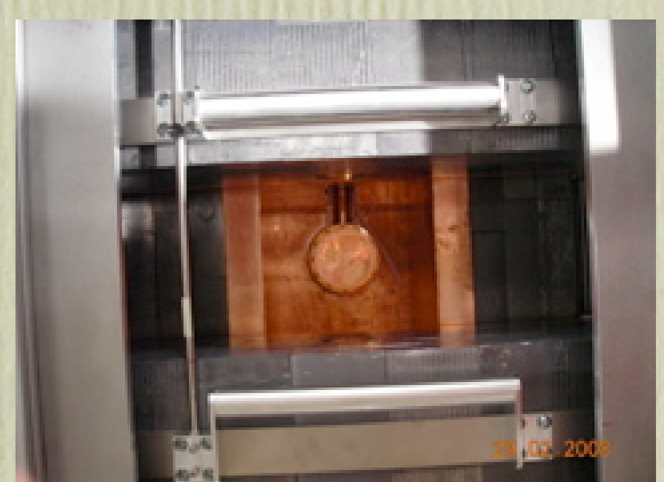


Energy (keV)

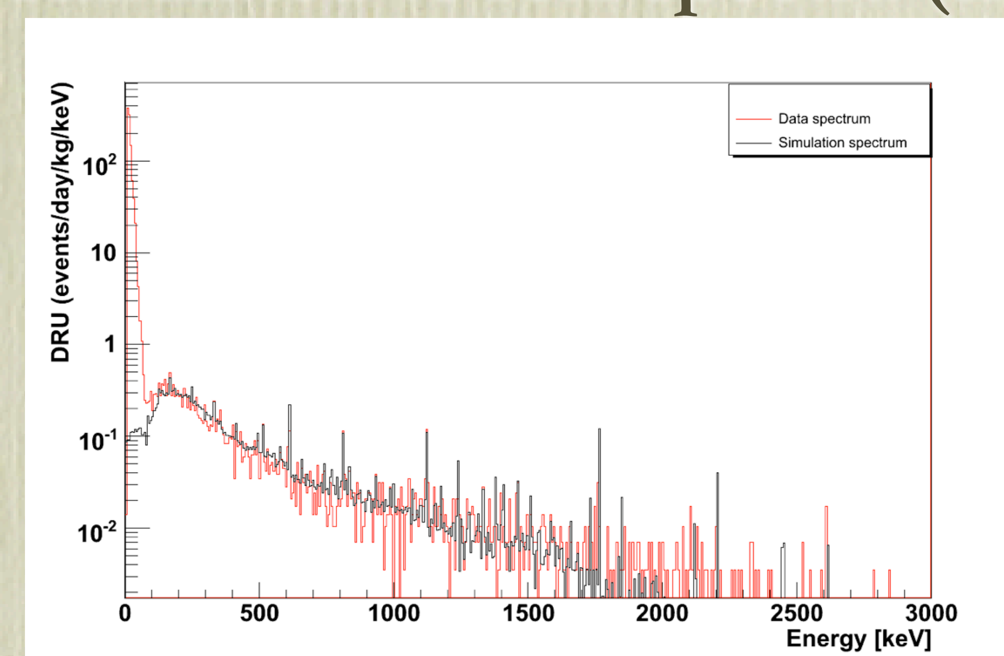
GEANT4 simulation for efficiency estimation



21 Liters cavity



Simulated vs real spectra (fit)



The Xenon100 Material screening

Stainless Steel

Material	238U [mBq/kg]	232Th [mBq/kg]	60Co [mBq/kg]	40K [mBq/kg]
25 mm SS Nironit (flange)	< 1.3	2.9 ± 0.7	1.4 ± 0.3	< 7.1
2.5 mm SS Nironit (bottom cryo)	< 2.7	< 1.5	13 ± 1	< 12
3 mm SS Nironit (ring for the grid)	3.6 ± 0.8	1.8 ± 0.5	7 ± 1	< 4.92
1.5 mm SS Nironit (cryostat)	<0.13	< 1.0	8.5 ± 0.9	10.5 ± 4.2

Inner detector materials

PMT Bases (Cirlex)	65 ± 8	31 ± 10	< 3.6	< 66
PTFE from APT (planned)	< 0.16	< 0.13	< 0.11	2.9 ± 1.1
PTFE from Zurich (in use)	< 0.31	< 0.16	< 0.11	< 2.25
Copper (TPC inner structure)	< 0.22	< 0.21	0.21 ± 0.07	< 1.34
Field shaping resistors [uBq/pc]	590 ± 180	14 ± 3	< 3	190 ± 30
Small Screws (SS)	< 9.2	16 ± 4	9 ± 3	< 46.4

Special thanks to Matthias Laubenstein (LNGS screening facility)

The Xenon100 Material screening

Shield (to be measured again)

Sample	^{238}U (mBq/kg)	^{232}Th (mBq/kg)	^{60}Co (mBq/kg)	^{40}K (mBq/kg)
Outermost Lead (shield)	< 5.7	< 1.6	< 1.1	14 ± 6
Innermost Lead (shield)	< 6.8	< 3.9	<0.19	< 28
Inner Poly from Shield	< 3.54	< 2.69	< 0.77	< 5.88
Outer Poly from Shield	< 5.76	<6.54	< 12.7	< 1.70

PMTs

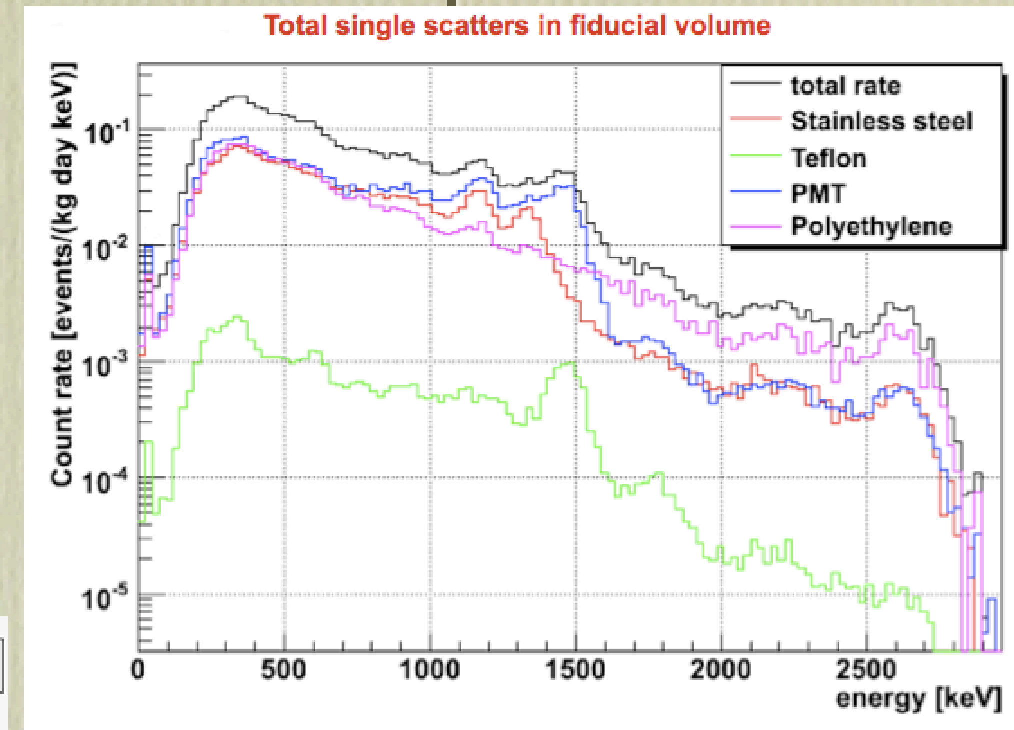
	238U [mBq/PMT]	232Th [mBq/PMT]	60Co [mBq/PMT]	40K [mBq/PMT]
39 PMTs	0.12 ± 0.01	0.11 ± 0.01	1.5 ± 0.1	6.9 ± 0.7
48 PMTs	0.11 ± 0.01	0.12 ± 0.01	0.56 +/- 0.04	7.7 +/- 0.8
22 HQE PMTs	< 0.64	0.18 ± 0.06	0.6 ± 0.1	12 ± 2
23 HQE PMTs	0.16 ± 0.05	0.46 ± 0.16	0.73 ± 0.07	14 ± 2
12 HQE PMTs	< 0.23	0.13 ± 0.05	0.7 ± 0.1	13 ± 2
15 PMTs	0.20 ± 0.03	0.20 ± 0.03	2.8 ± 0.2	11 ± 1
4 HQE PMTs	< 0.15	0.14 ± 0.07	0.57 ± 0.09	5.8 ± 1.5
7 HQE PMTs	0.23 ± 0.12	<0.25	0.7 ± 0.2	12.7 ± 2.5
11 PMTs	0.30 ± 0.19	0.21 ± 0.13	0.76 ± 0.19	12.1 ± 2.5

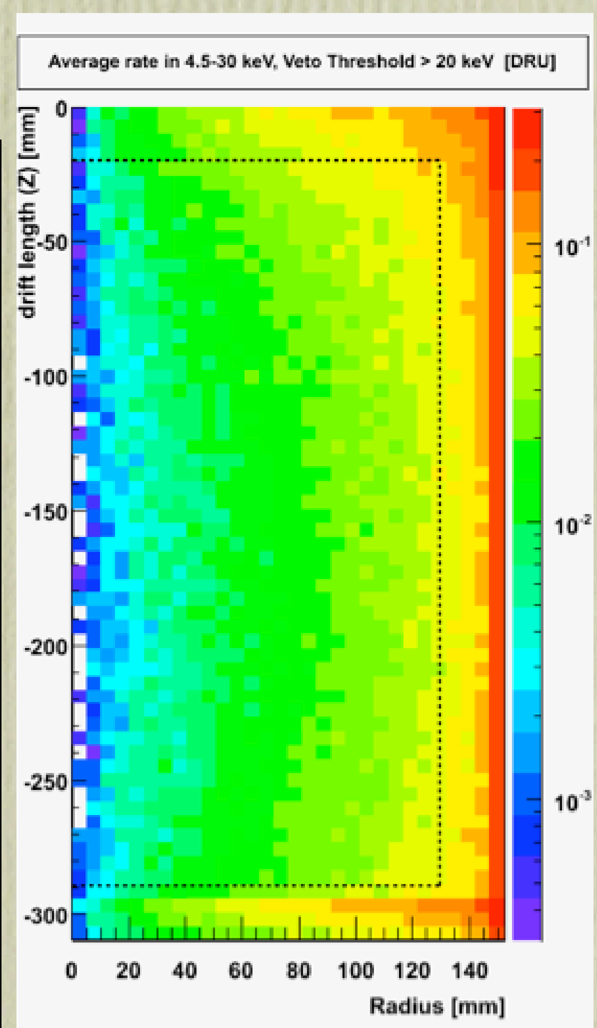
The Xenon100 Background expectation

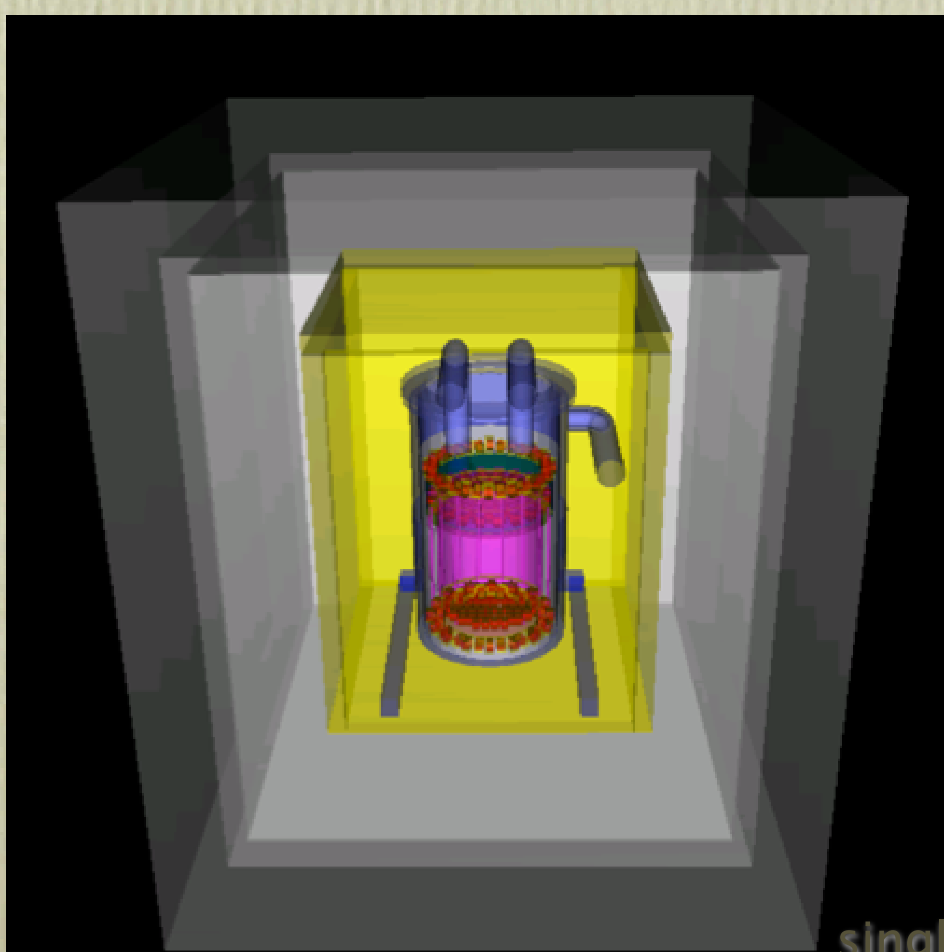
GEANT4 Simulation includes:

- Inside detector geometry
- Outer shield

Simulated gamma and neutron background from all the materials







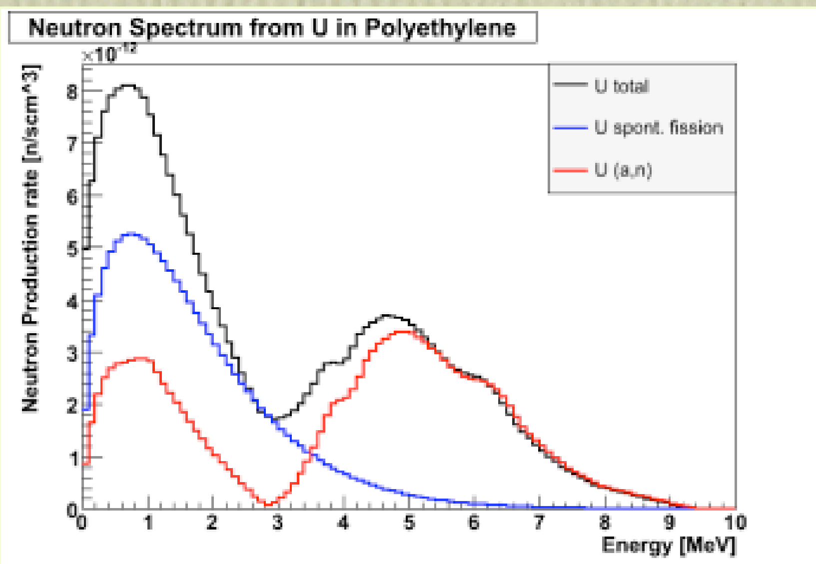
single scatter events distribution in the fiducial volume

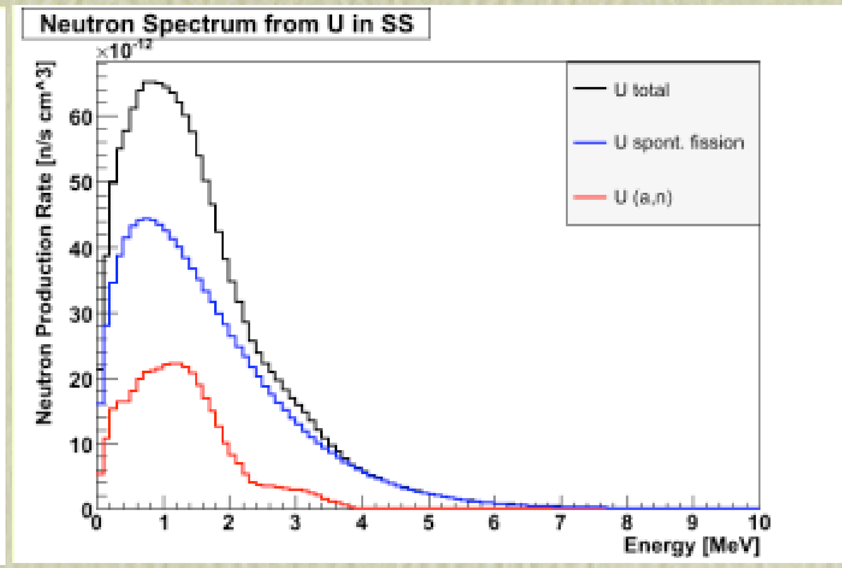
Gammas

Material	Rate of single scatters [mDRU] in the ROI [0,30] keV_{ee}
Stainless Steel	2.01 ± 0.22
Teflon	0.18 ± 0.02
PMTs	4.91 ± 0.60
Polyethylene	3.09 ± 0.29
Copper shield	0.026 ± 0.002
Xenon*	1.03 ± 0.02
Total	**11.25 ± 0.70**

The Xenon100 Background expectation

Neutrons   Detector and shield





Material	Rate of single scatters [μDRU] in the ROI [0,26.5] keV$_r$
Stainless Steel	0.293 ± 0.003
Teflon	0.584 ± 0.003
PMTs	0.318 ± 0.002
Polyethylene	0.49 ± 0.01
Copper shield	0.110 ± 0.002
Lead	0.38 ± 0.02
Xenon	0.07 ± 0.001
Total	**1.74 ± 0.01**

The Xenon100 Background expectation

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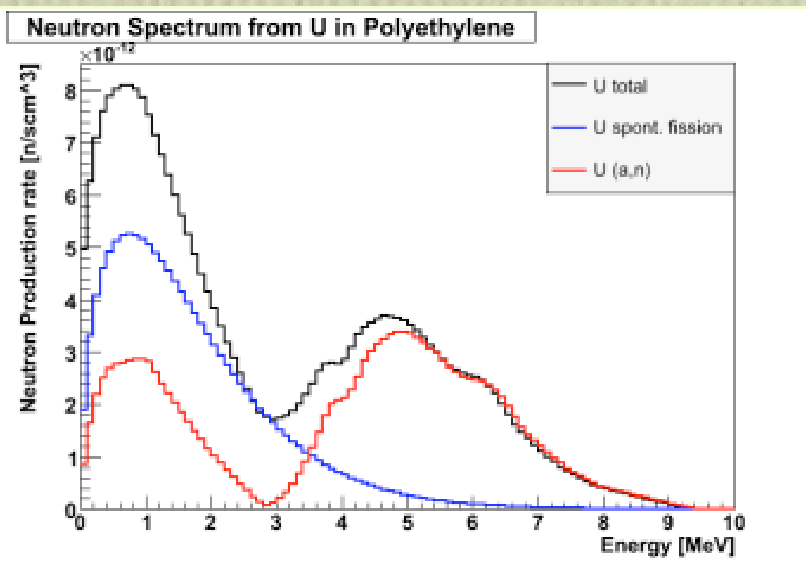

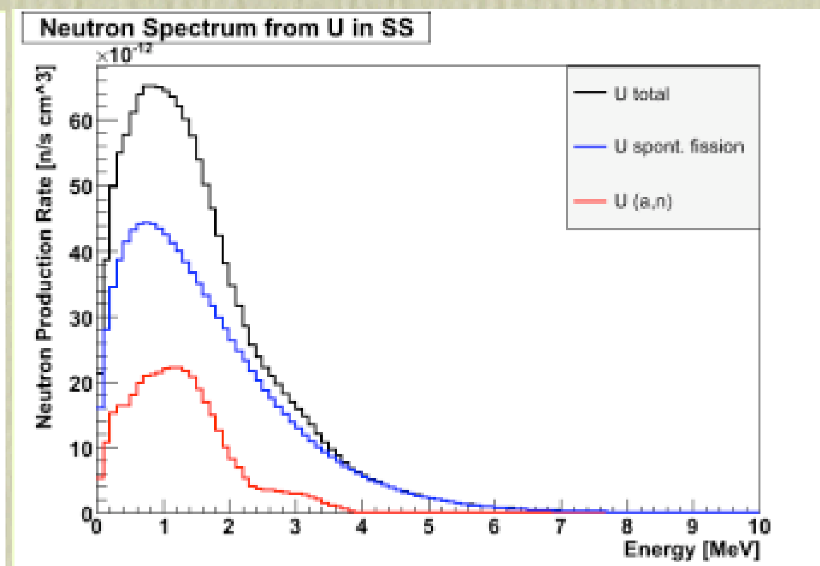

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0.6 single scatter events / year

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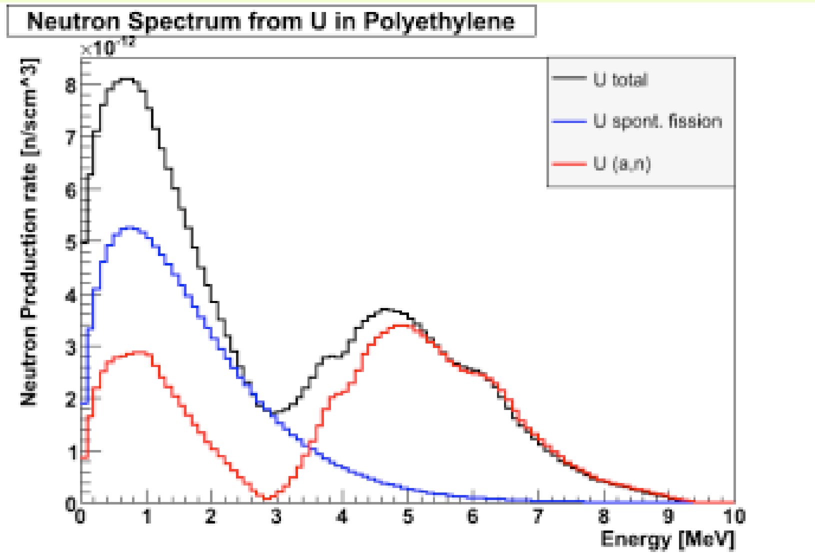

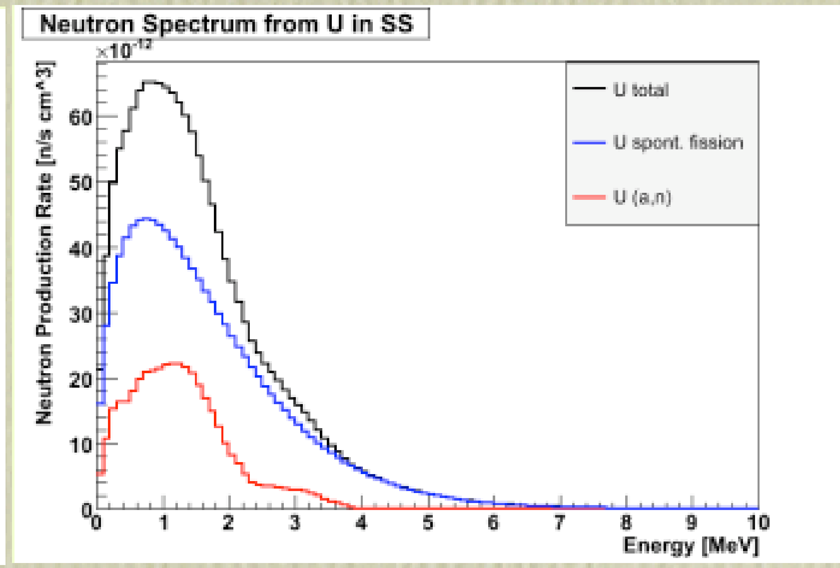

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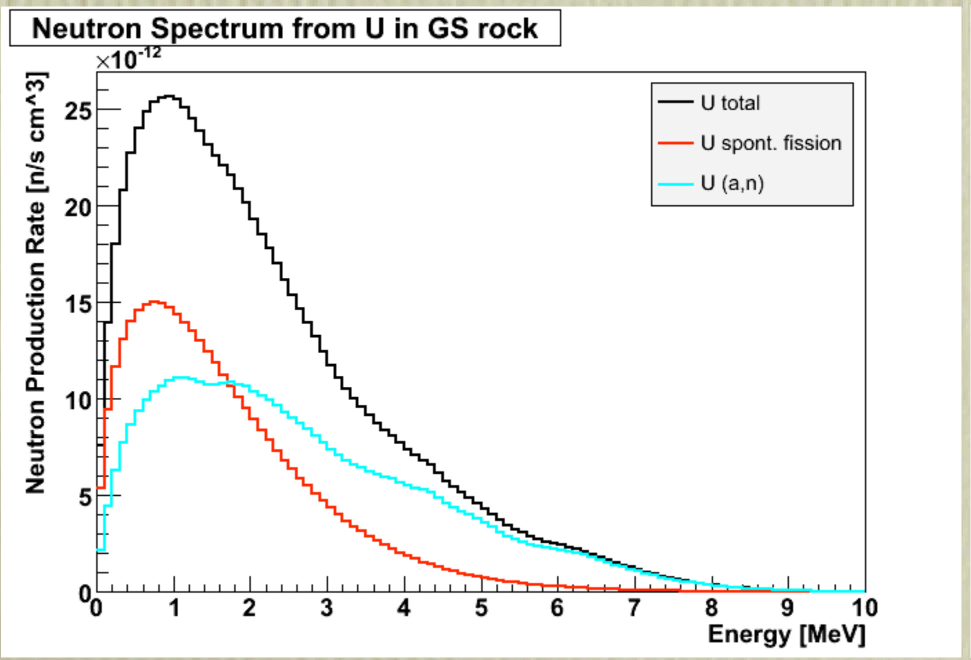
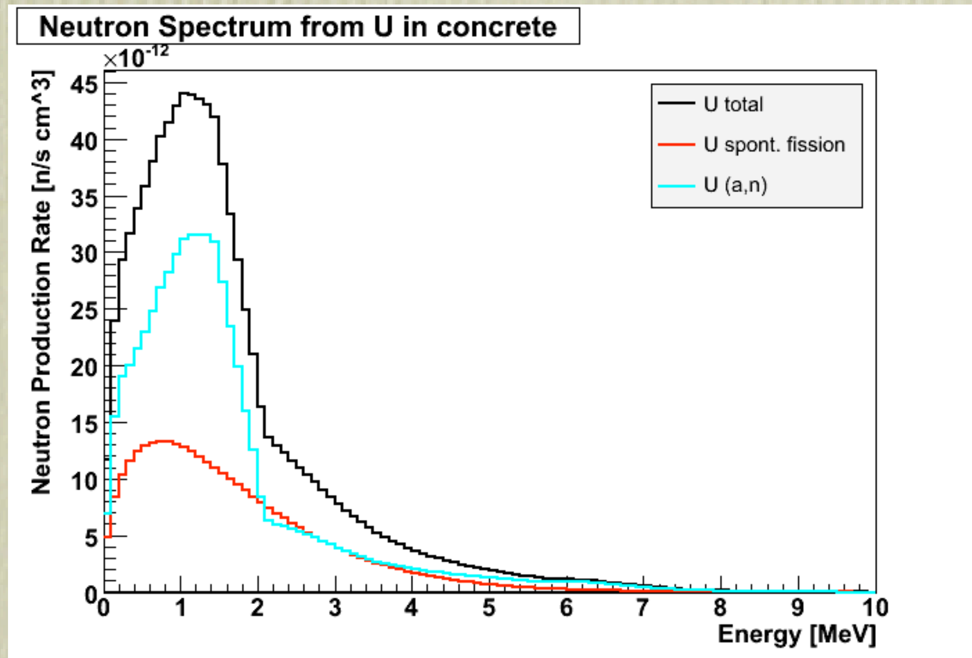
Rock and concrete

0.6 single scatter events / year

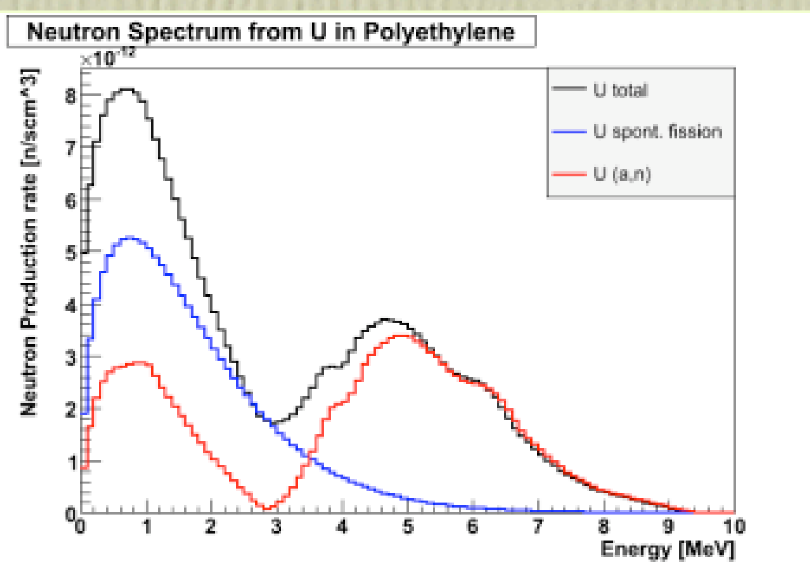


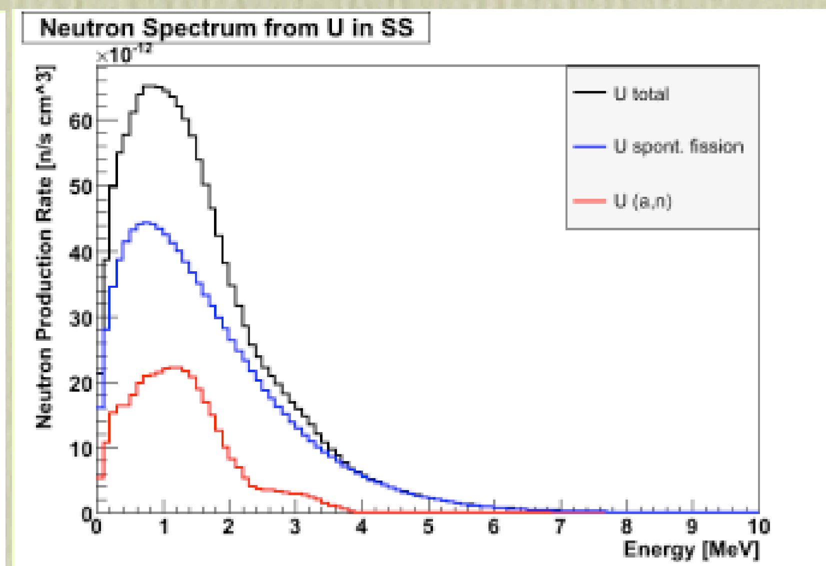


The Xenon100 Background expectation

Neutrons

Detector and shield





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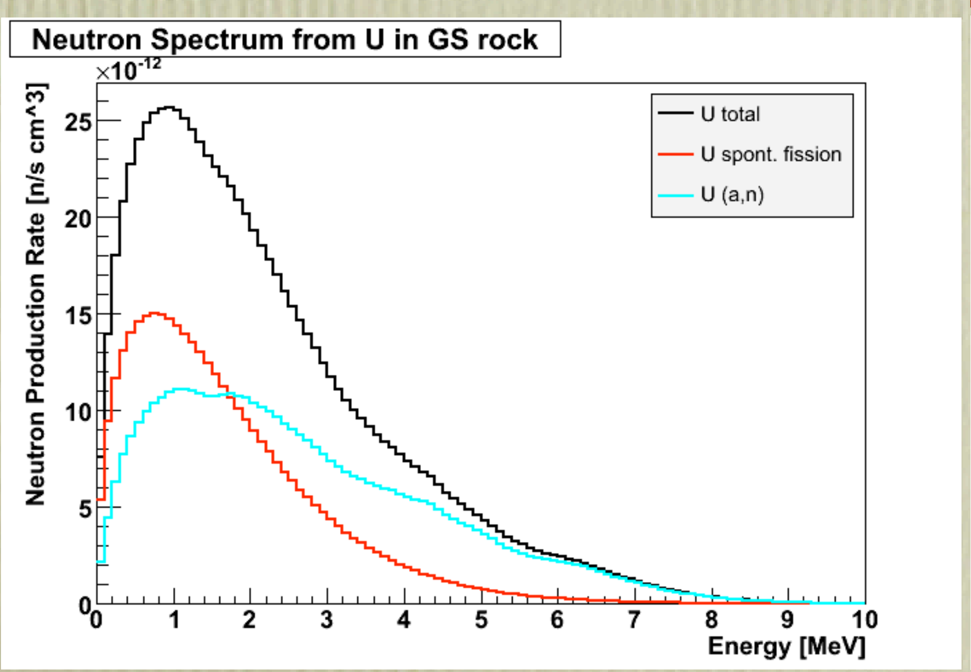
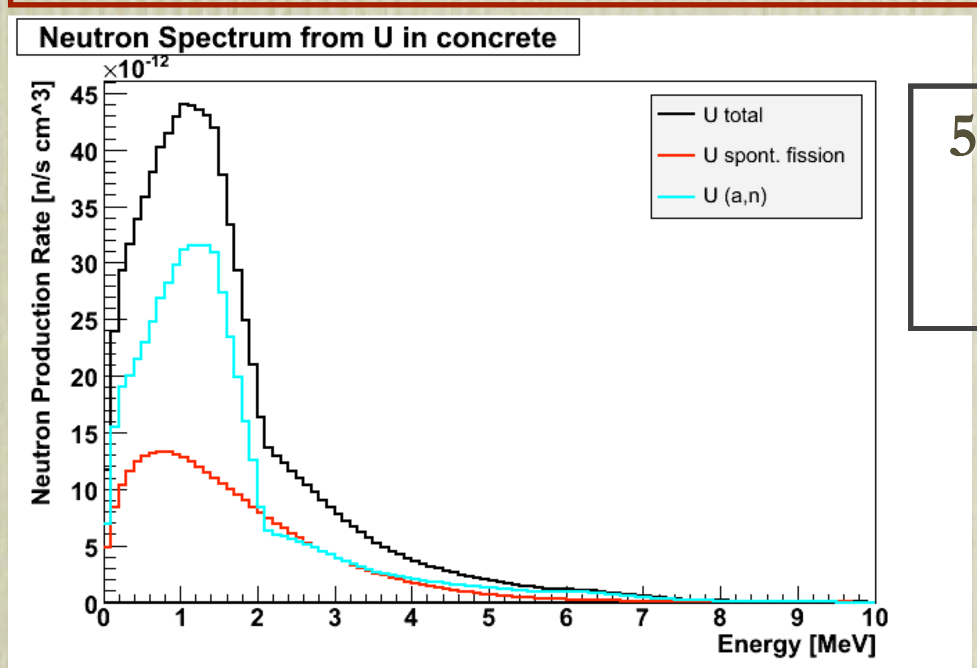
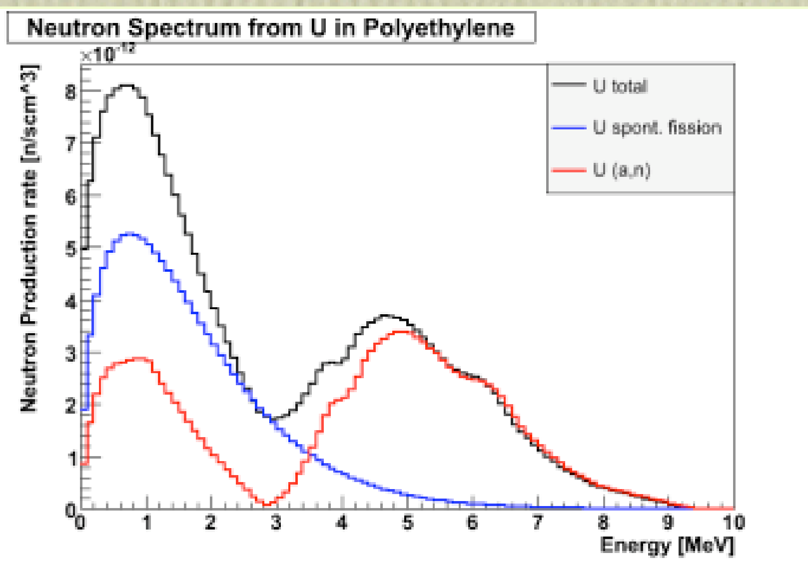


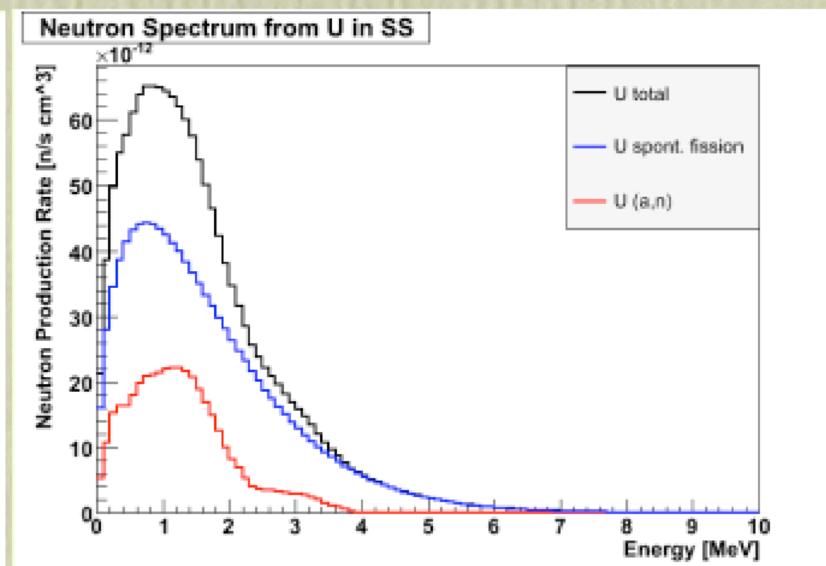


5.0 ± 1.0 Single recoils per 63 kg/y are expected
2.9 ± 0.9 in 46 kg/y fiducial

The Xenon100 Background expectation

Neutrons   Detector and shield





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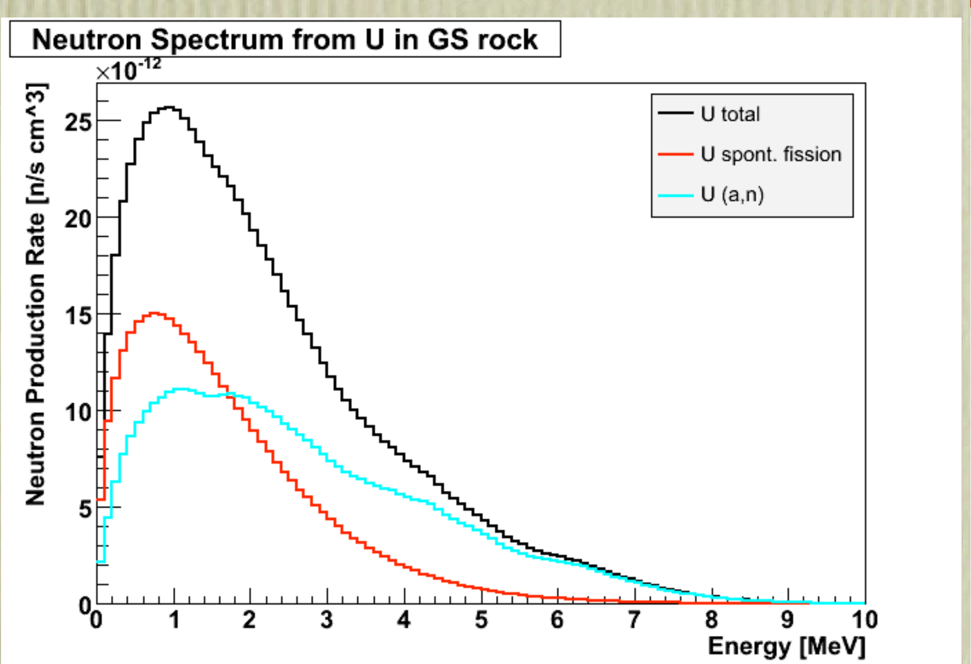
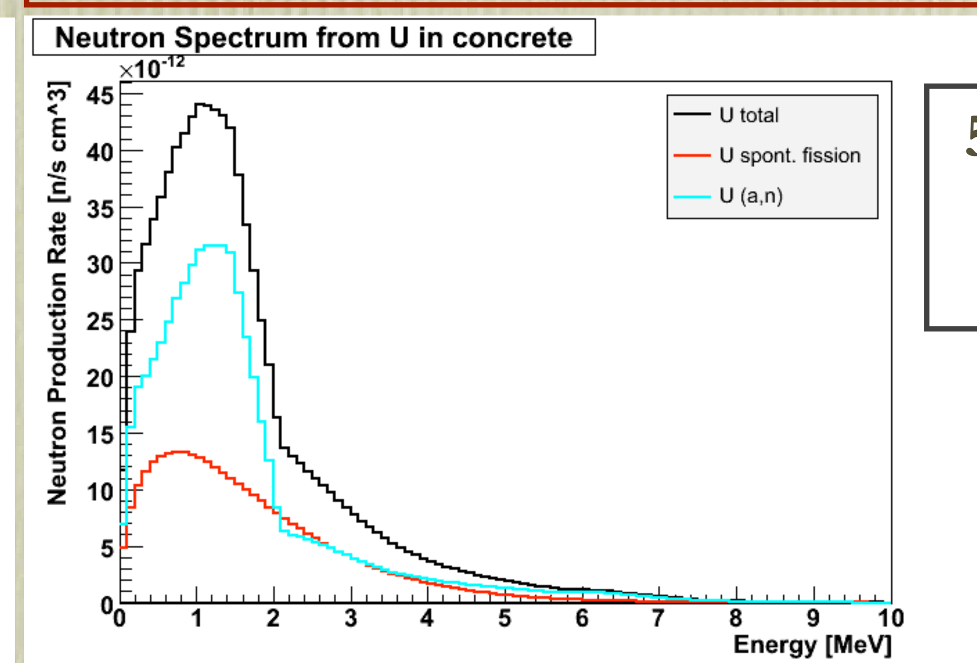
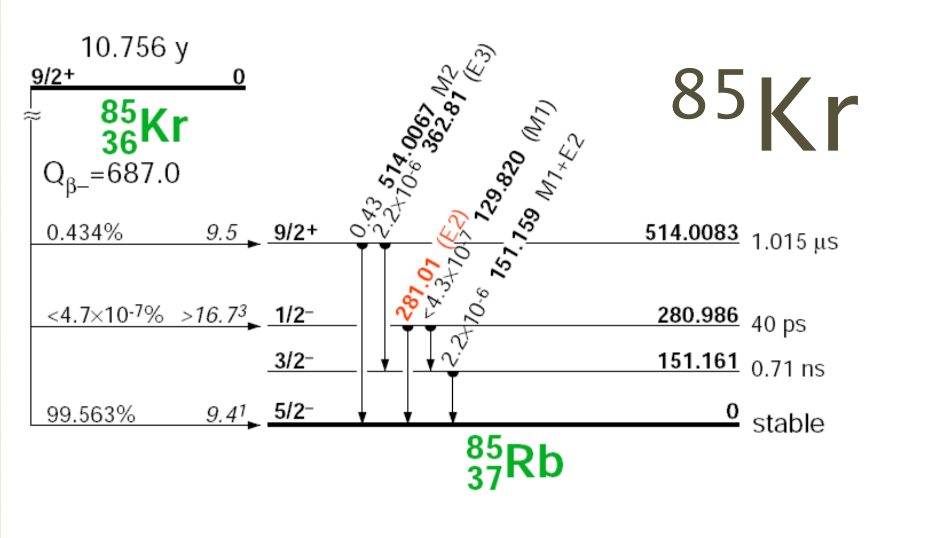




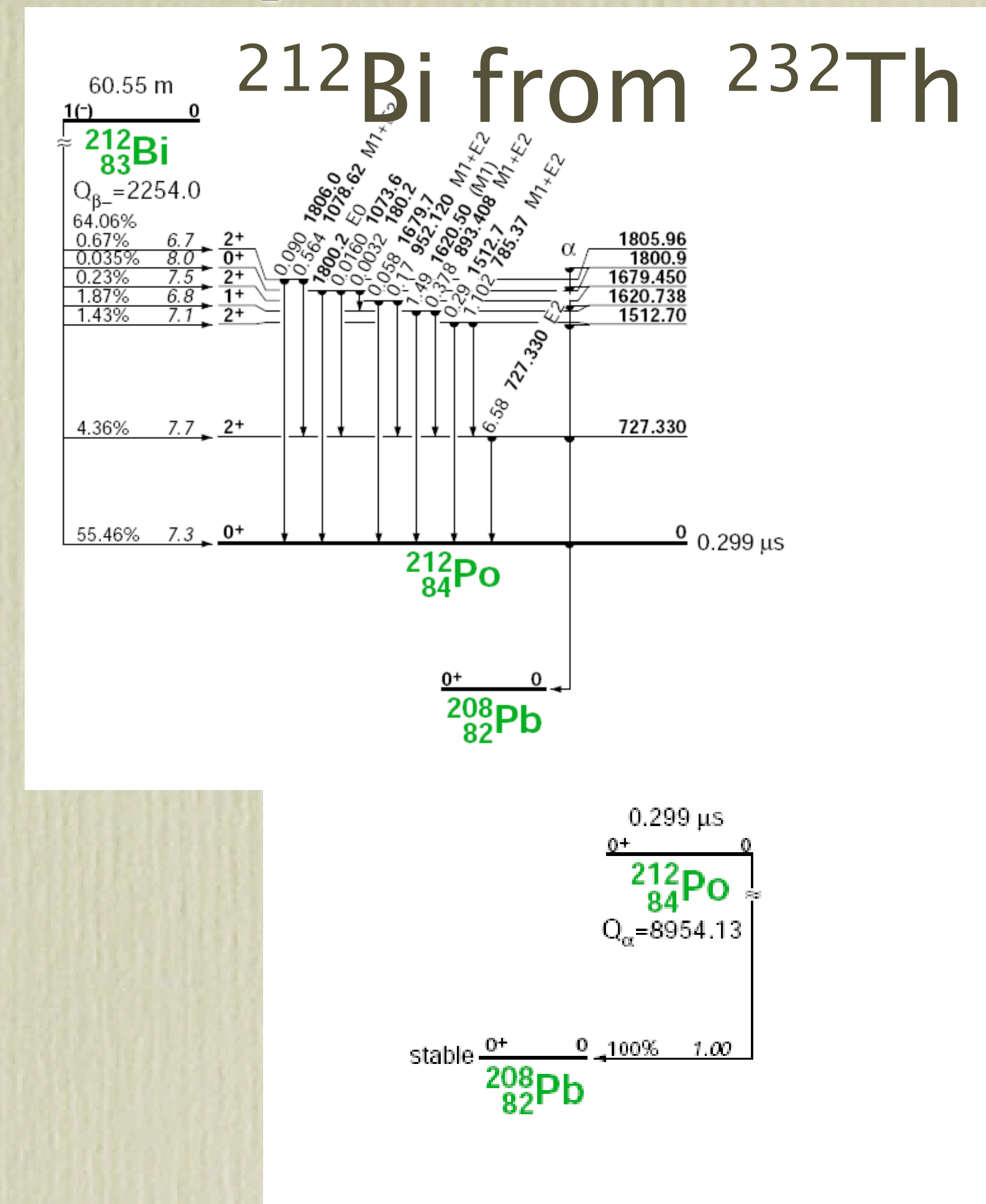
5.0 ± 1.0 Single recoils per 63 kg/y are expected
2.9 ± 0.9 in 46 kg/y fiducial

Additional 20 cm of water shield outside the lead are being used

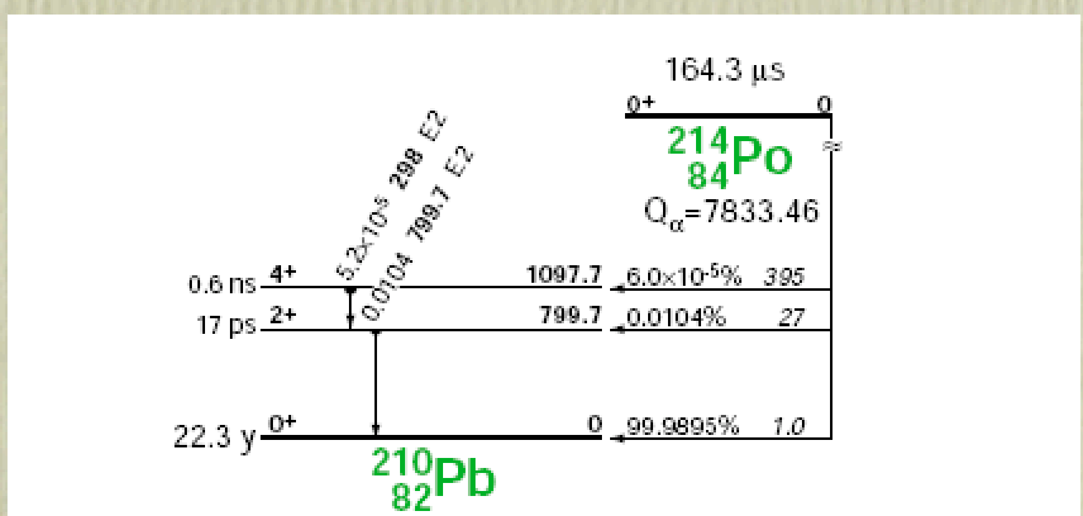
The Xenon10 Delayed Coincidence analysis



^{85}Kr



^{212}Bi from ^{232}Th



^{214}Bi from ^{226}Rn (^{238}U)

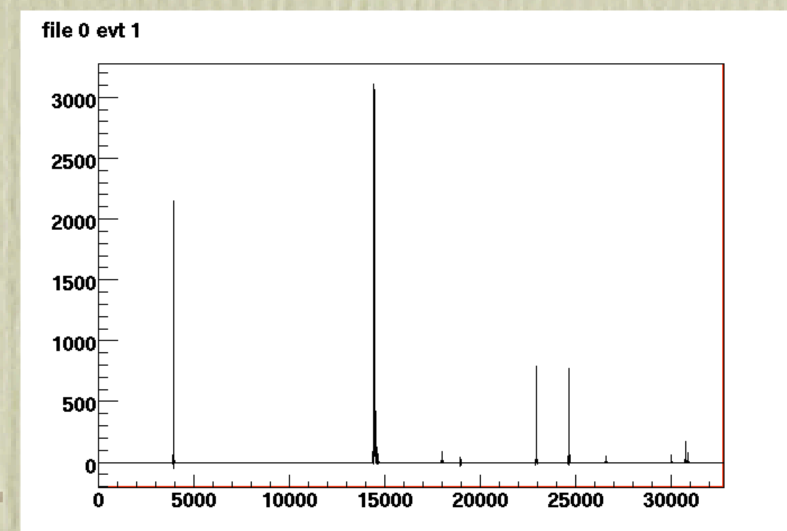
The Xenon10-100 Delayed Coincidence analysis

Xenon10

[^{212}Bi] = 44.2 ± 5.4 μBq/kg
[^{232}Th] = (11 ± 1) x 10-12 g Th g^{-1}

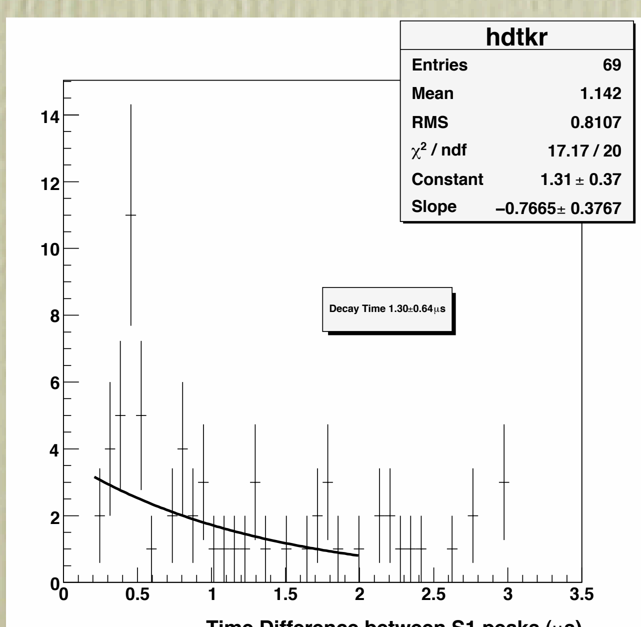
[^{214}Bi] = 25 ± 4 μBq/kg
[^{238}U] = (2.0 ± 0.3) x 10^{-12} g U g^{-1}

[85Kr] = 0.35 ± 0.04 mBq/kg
[^{85}Kr] = 3.4 ± 0.6 ppb

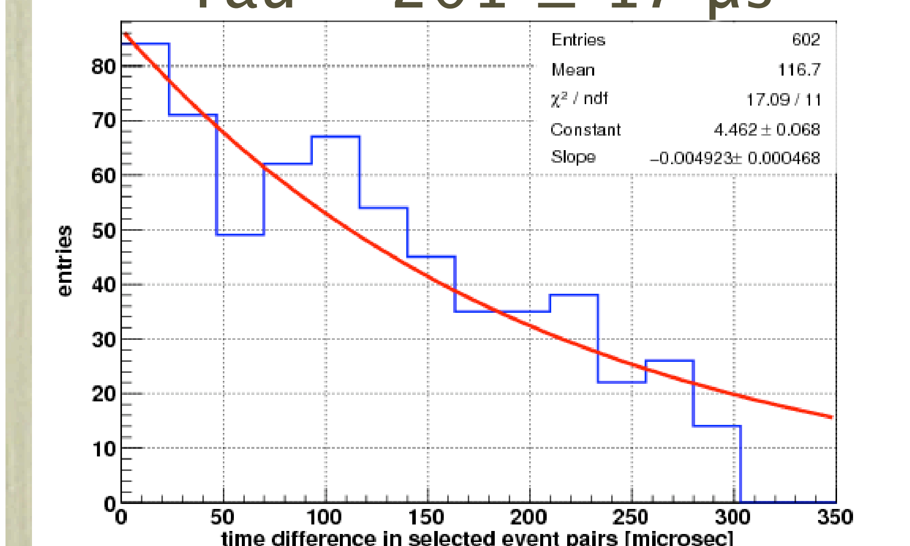


Taking into account the efficiency of all the cuts applied in the analysis, it's possible to estimate the content of 85Kr, 212Bi and 214Bi and thus of 232Th and 238U (if sec. equilibrium):

Xenon100



Tau = 201 ± 17 μs

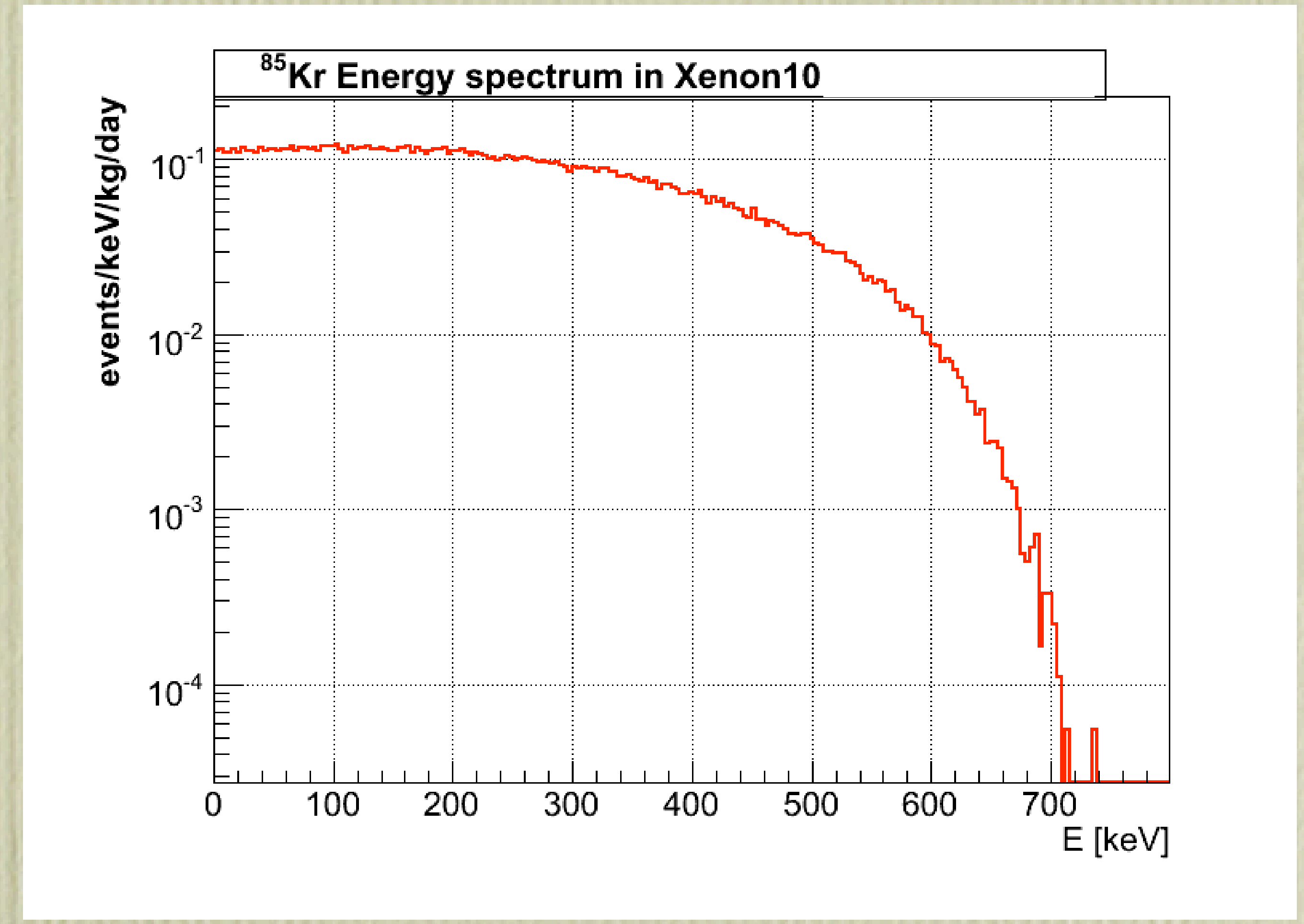


[^{212}Bi] = 1.8 ± 0.5 μBq/kg
[^{232}Th] = (0.4 ± 0.1) x 10-12 g Th g^{-1}

[^{214}Bi] = 53 ± 3 μBq/kg
[^{238}U] = (4.3 ± 0.2) x 10^{-12} g U g^{-1}

[85Kr] = 0.31 ± 0.6 mBq/kg
[^{85}Kr] = 4.0 ± 0.9 ppb

The Xenon100 purification from ^{85}Kr

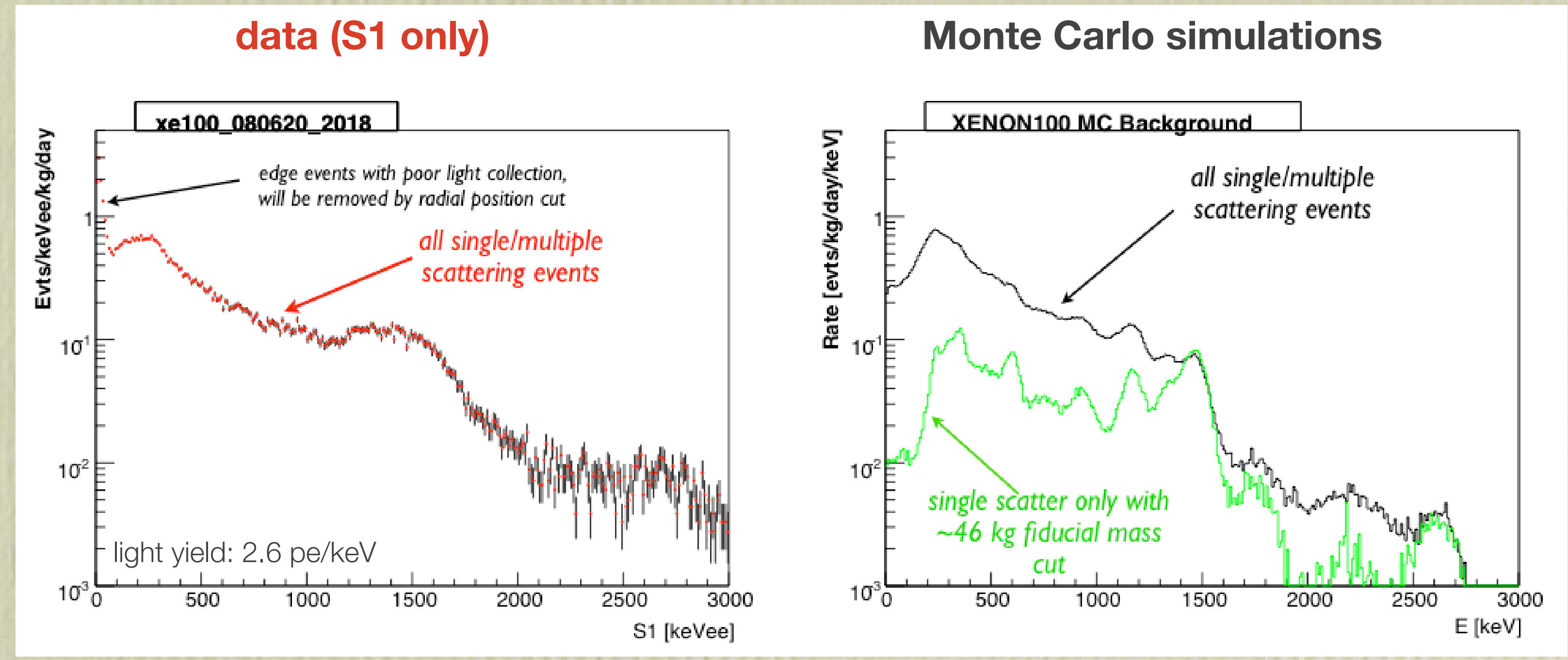


All the xenon has been processed through the column (finished on monday night). Wait for 3 weeks of data taking in order to verify the purification efficiency of the column (ppt level) with the delayed coincidence analysis.

Conclusions

The Xenon100 detector is fully operating underground ready to take Dark Matter data

The background of the experiment is very similar to the expectation

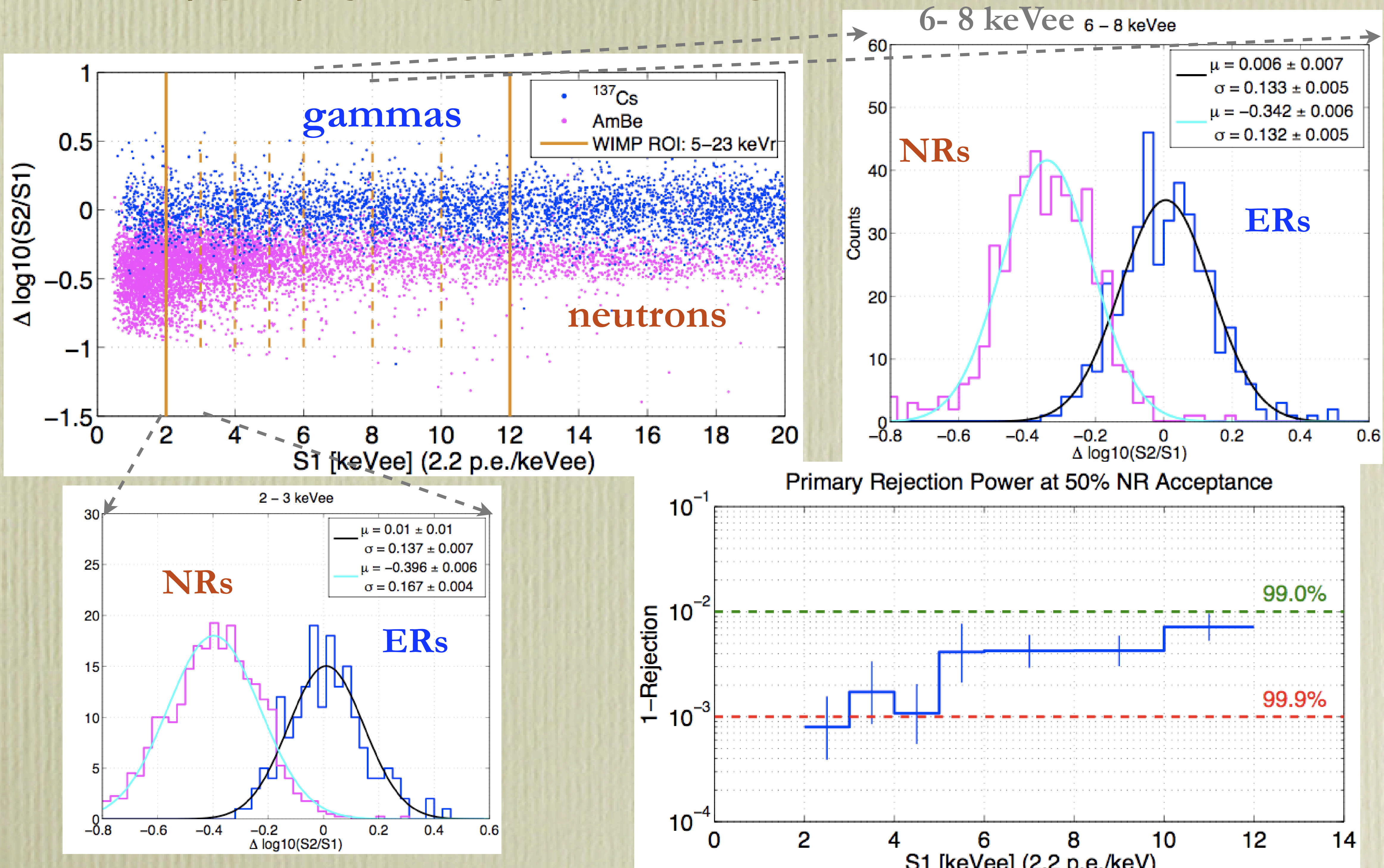


The Xenon has been purified from the Kr.

By November 2008 we plan to start the Dark Matter search run

Thank you

XENON10 Discrimination



- Rejection is > 99.6% for 50% Nuclear Recoil acceptance
  - ➡ Cuts: fiducial volume (remove events at teflon edge where poor charge collection)
  - ➡ Multiple scatters (more than one S2 pulse)