Backgrounds and Sensitivity Expectations for XENON100

IDM08, Stockholm, August 19, 2008

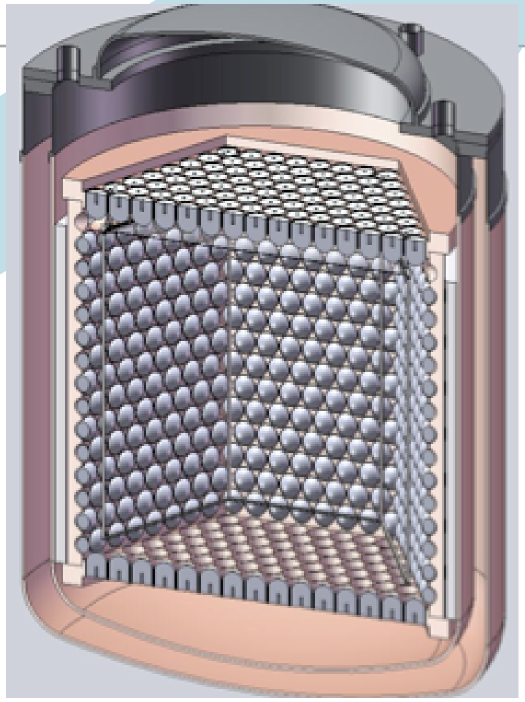
Laura Baudis
University of Zurich
For the XENON100 Collaboration

LNGS collaboration meeting, Oct. 2007

The XENON Program

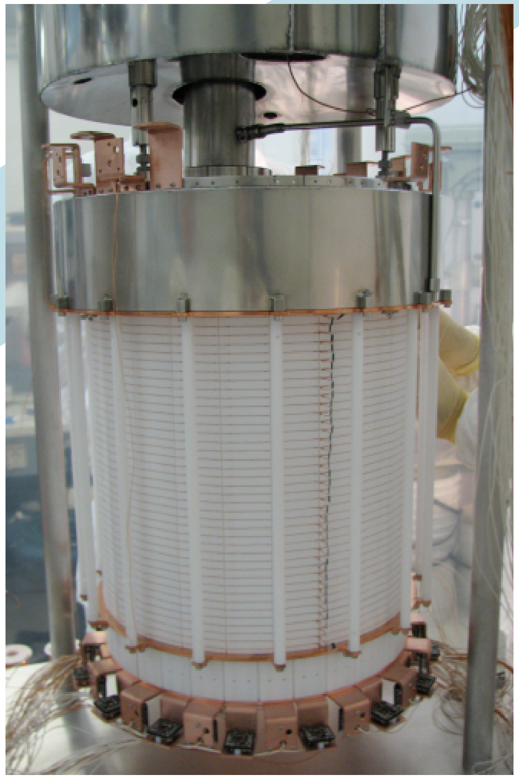
???

XENON1t



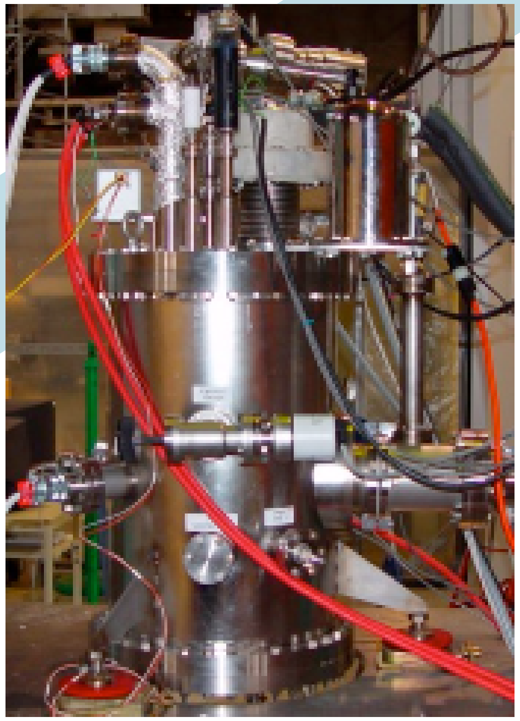
2009-2013

XENON100



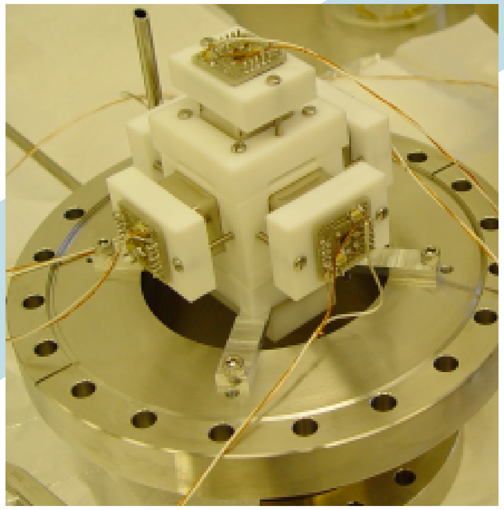
in progress

XENON10



2006-2007

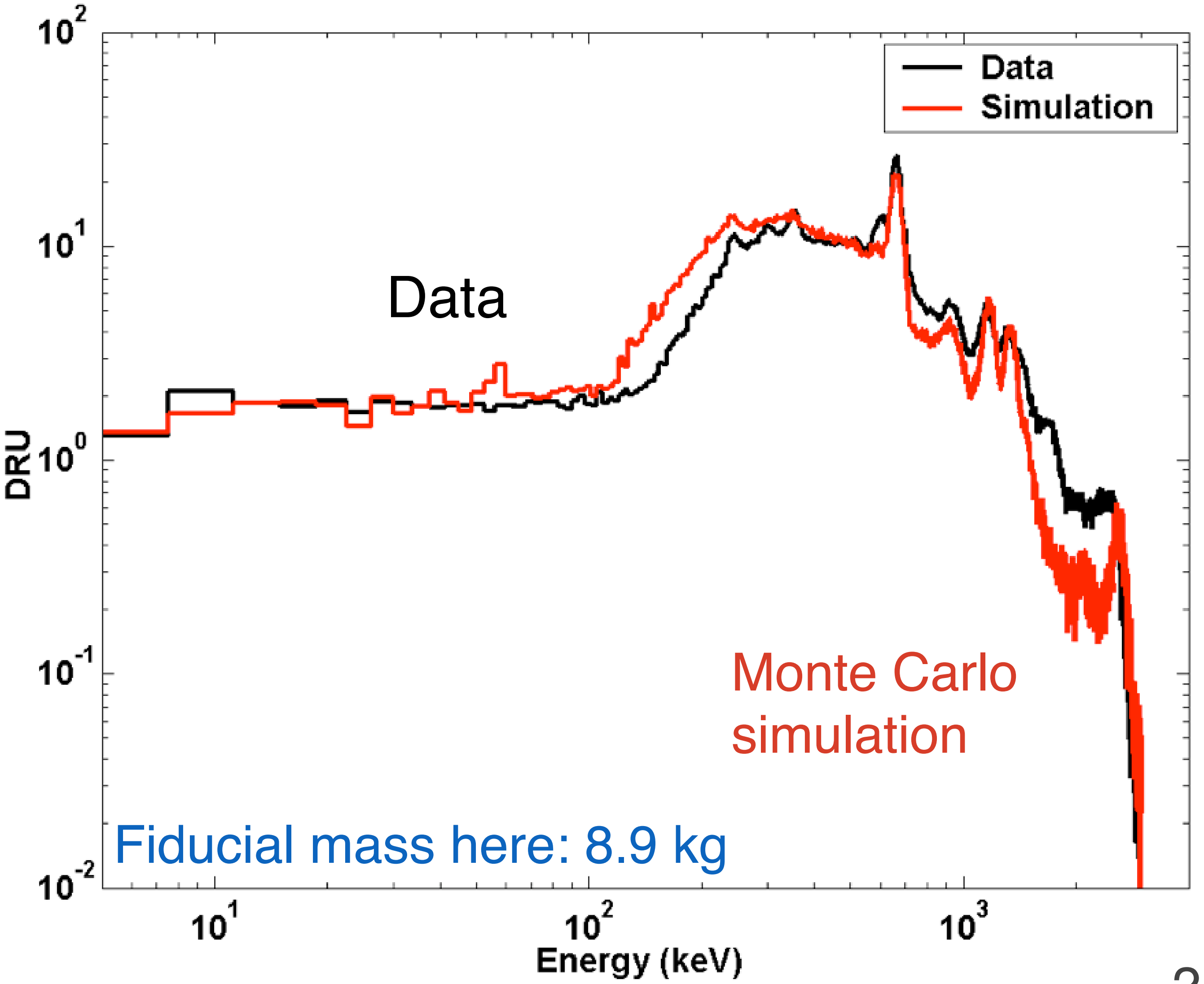
XENON R&D

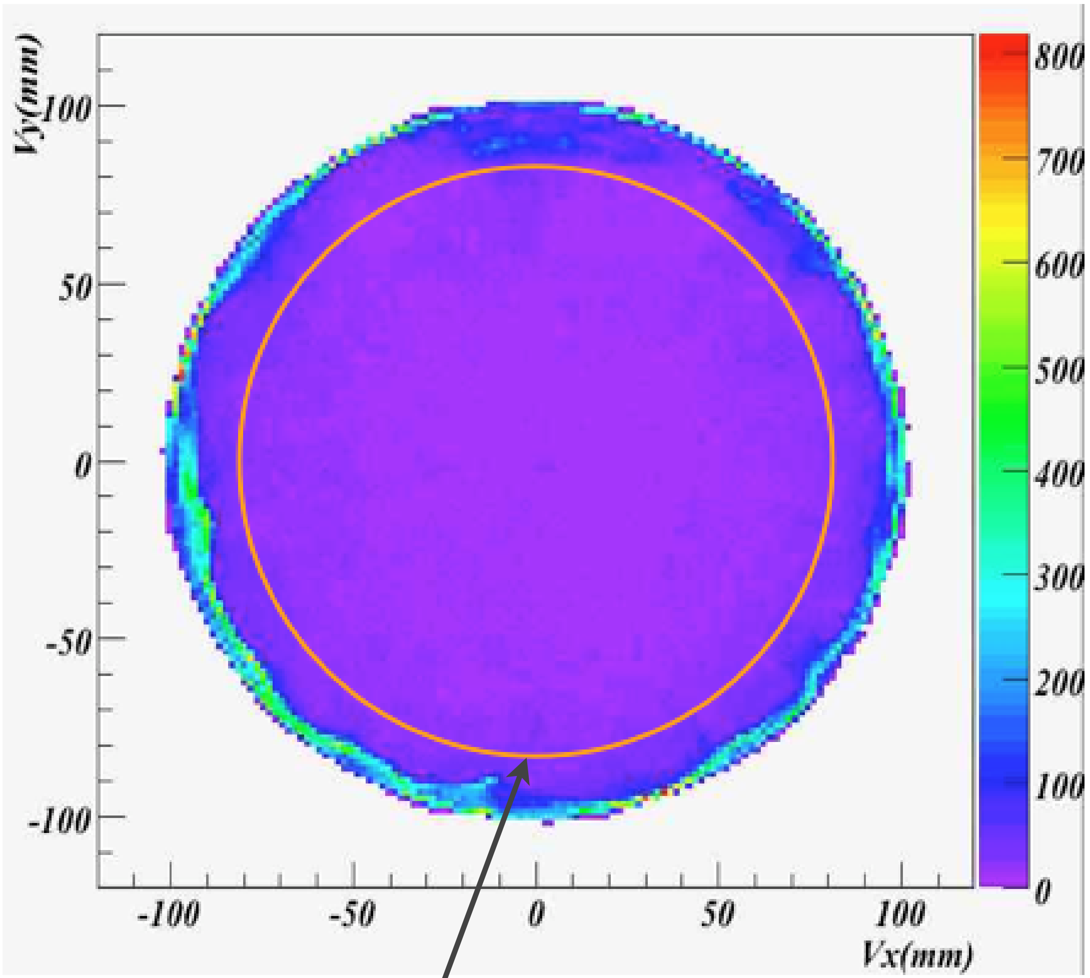


ongoing

Reminder: Backgrounds in XENON10

- Dominated by contribution from detector materials:
- steel (~ 180 kg, ^{60}Co), PMTs (89 R8520, U/Th/K/Co) and ceramic HV feed-throughs (U/Th/K)





dru = events/(kg day keV)

2 cm radial cut (+ z-cut) → 5.4 kg LXe mass

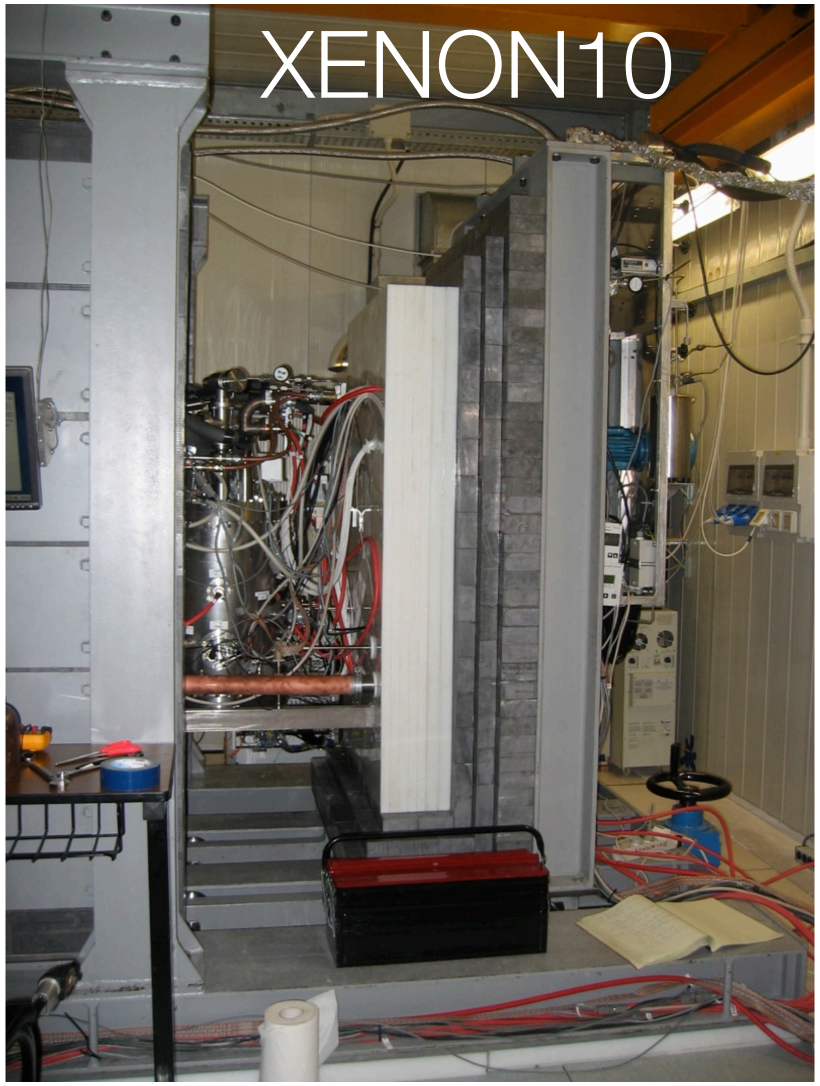
=> background rate of 0.6 events/(kg d keV)

The XENON100 Detector and Background Goals

- Factor ~100 reduction compared to XENON100:
- 1 dru -> 10 mdru raw gamma BG

How?

- selection of ultra-low background materials for detector components and shields
- active LXe veto shield (100 kg) surrounding target on all sides
- reduce intrinsic ^{85}Kr contamination to the required level (50 ppt)
- detector design: place cryogenics and feed-throughs outside the Pb/Poly shield



The XENON100 Detector and Background Goals

- Factor ~100 reduction compared to XENON100:
- 1 dru -> 10 mdru raw gamma BG

How?

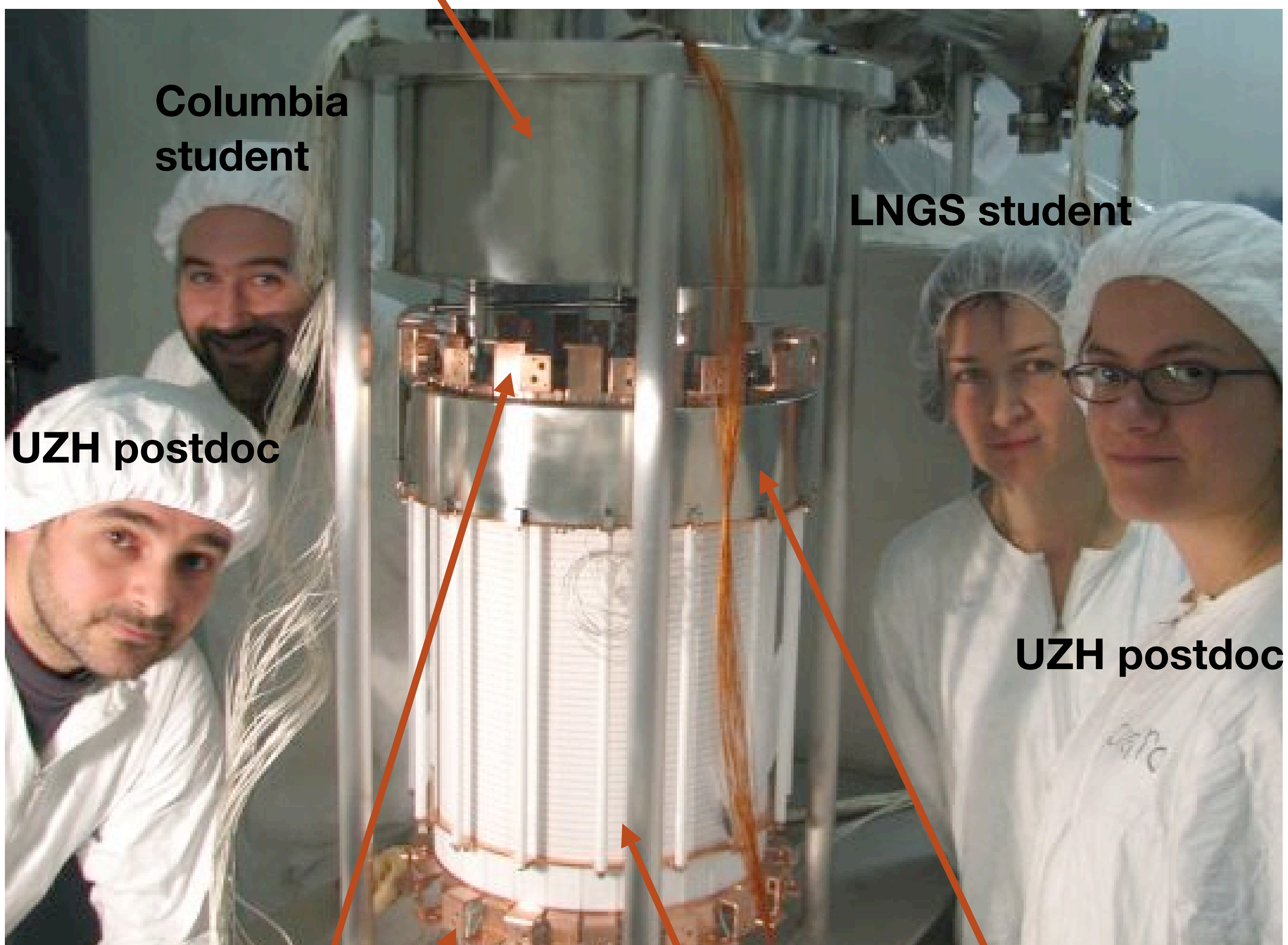
- selection of ultra-low background materials for detector components and shields
- active LXe veto shield (100 kg) surrounding target on all sides
- reduce intrinsic ^{85}Kr contamination to the required level (50 ppt)
- detector design: place cryogenics and feed-throughs outside the Pb/Poly shield
- improve shield by reducing poly activity with 5 cm of OFRP Cu

5 cm Cu on door

5 cm Cu top/sides

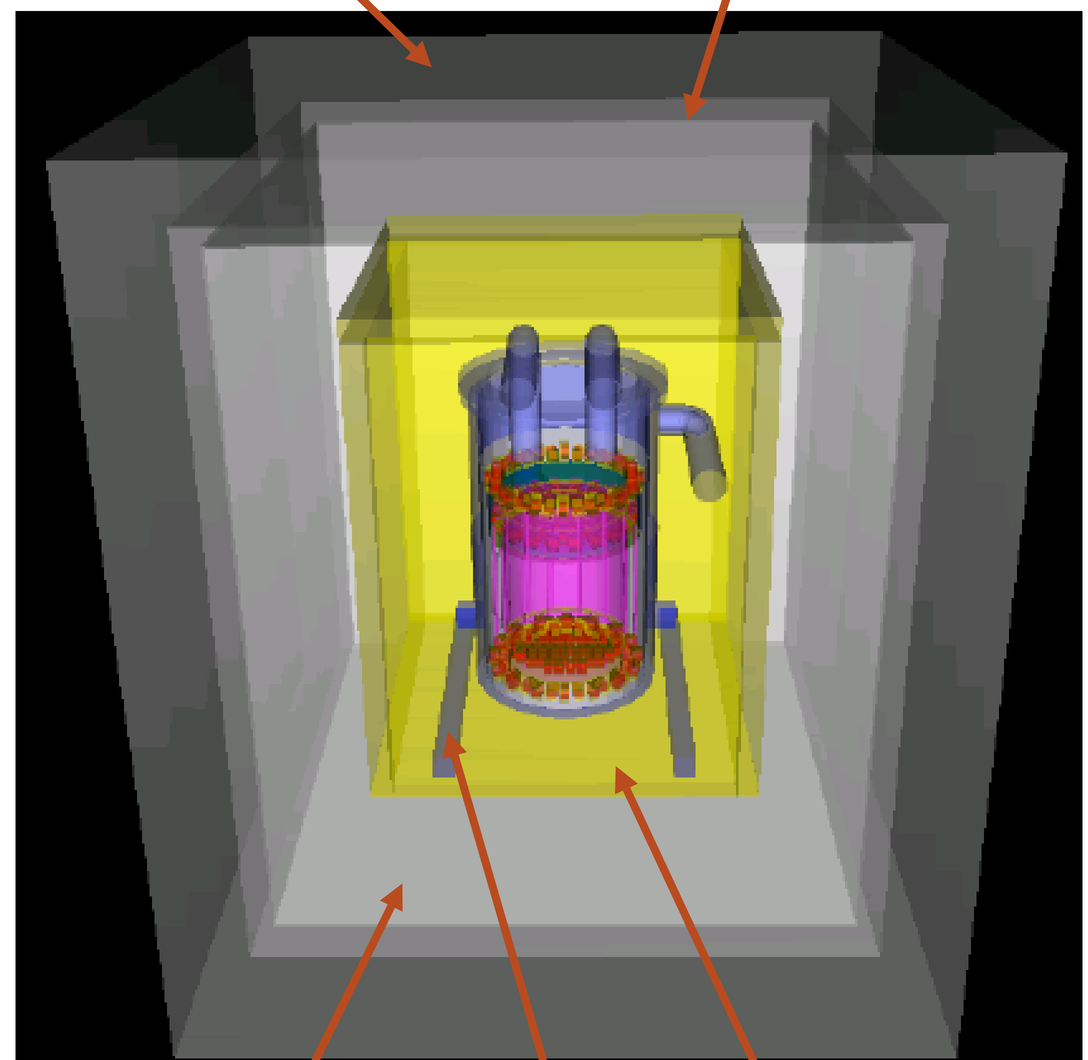
Xenon100 Materials and Shields

Cryostat (stainless steel)



Polish Lead:
15 cm, 27 t

French Lead:
5 cm, 6 t



Bell (stainless steel)

TPC structure (PTFE)
(and PMTs inside)

Veto PMTs and holders (Cu)

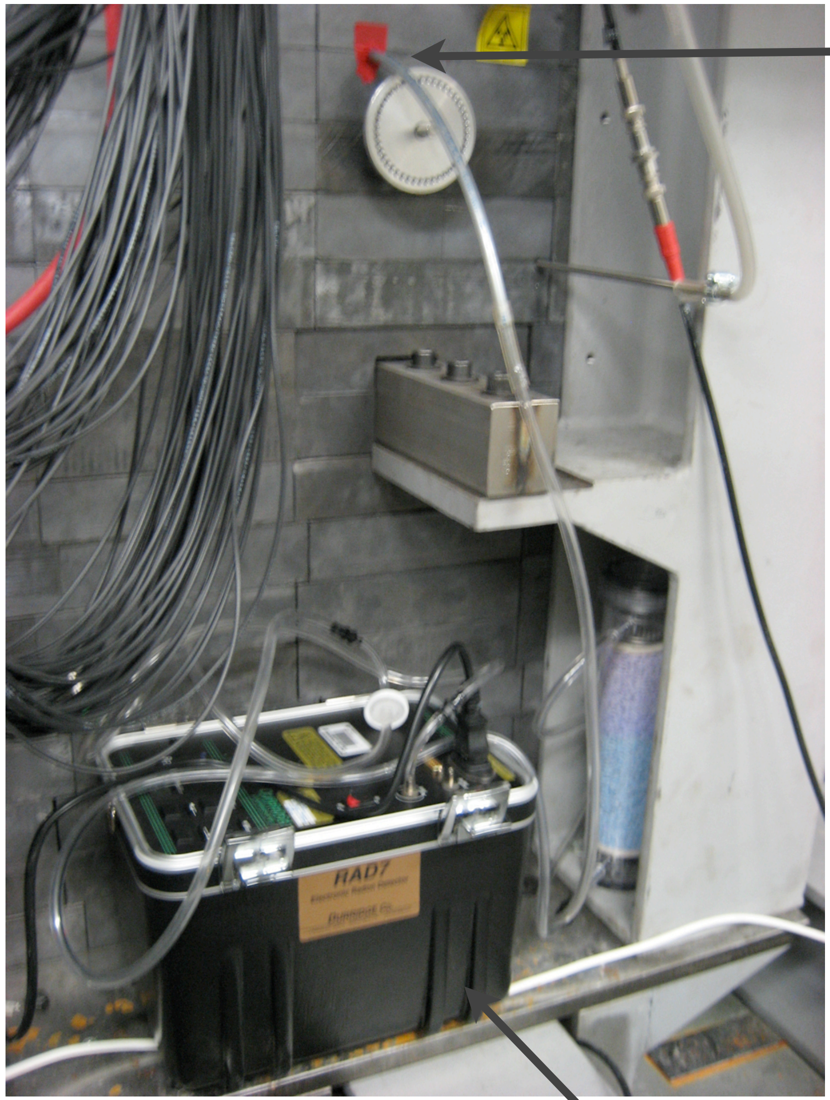
Polyethylene:
20 cm, 2 t

Copper:
5 cm, 2 t

Support bars:
stainless steel

Xenon100 Materials and Shields

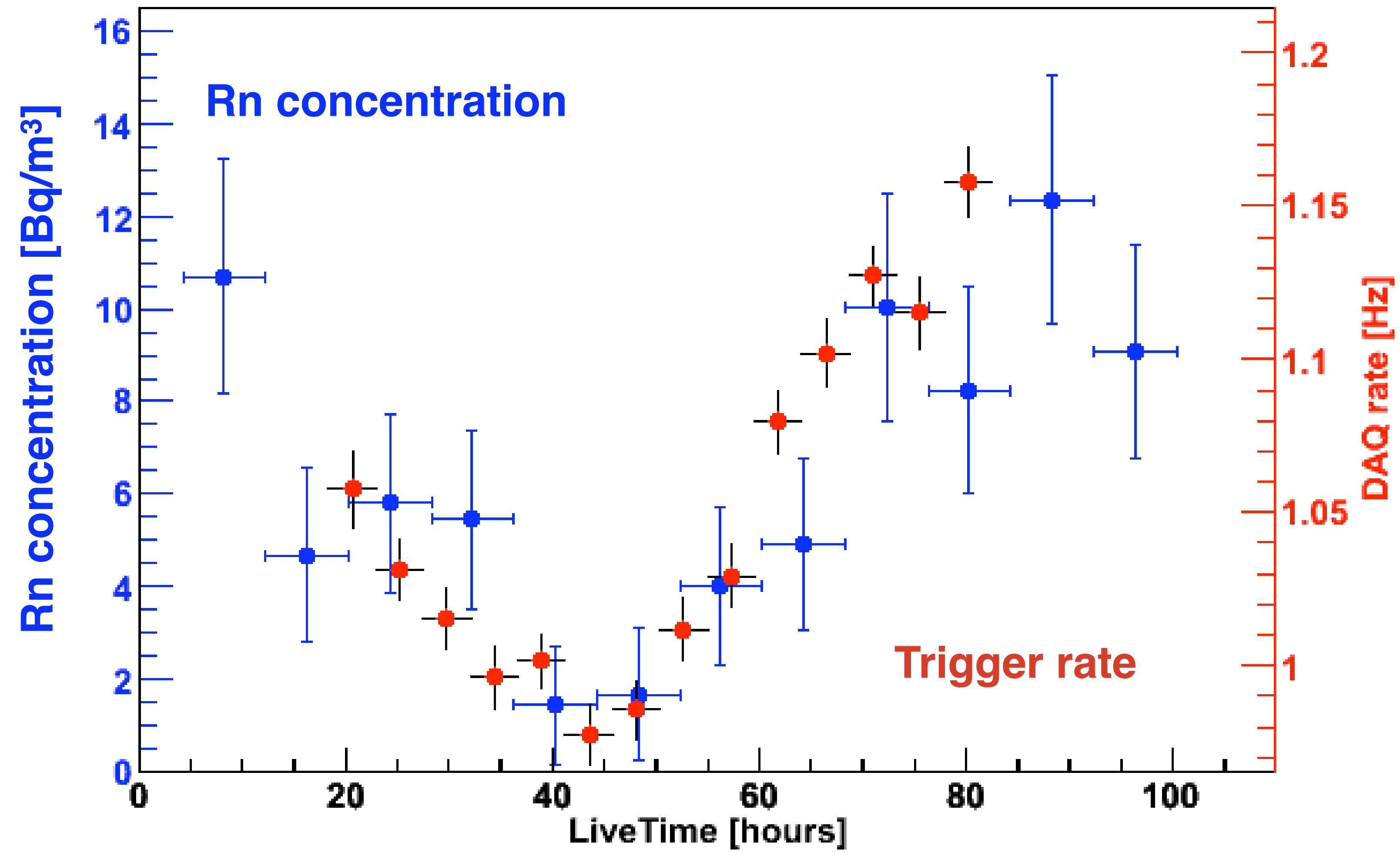
- The shield is continuously flushed with N_2 to avoid events related to radon decays inside it
- The radon levels are continuously monitored (all written out to slow control)



inlet

radon detector (RAD7)

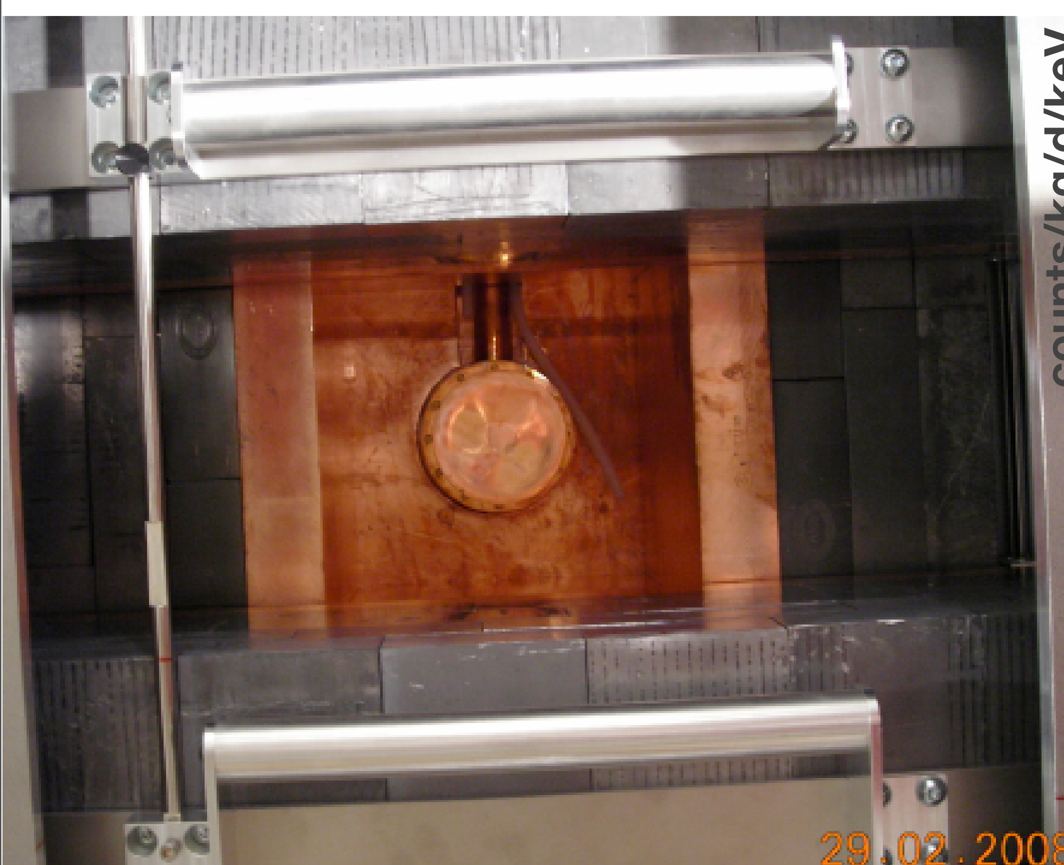
Correlation between Rn values and DAQ rate

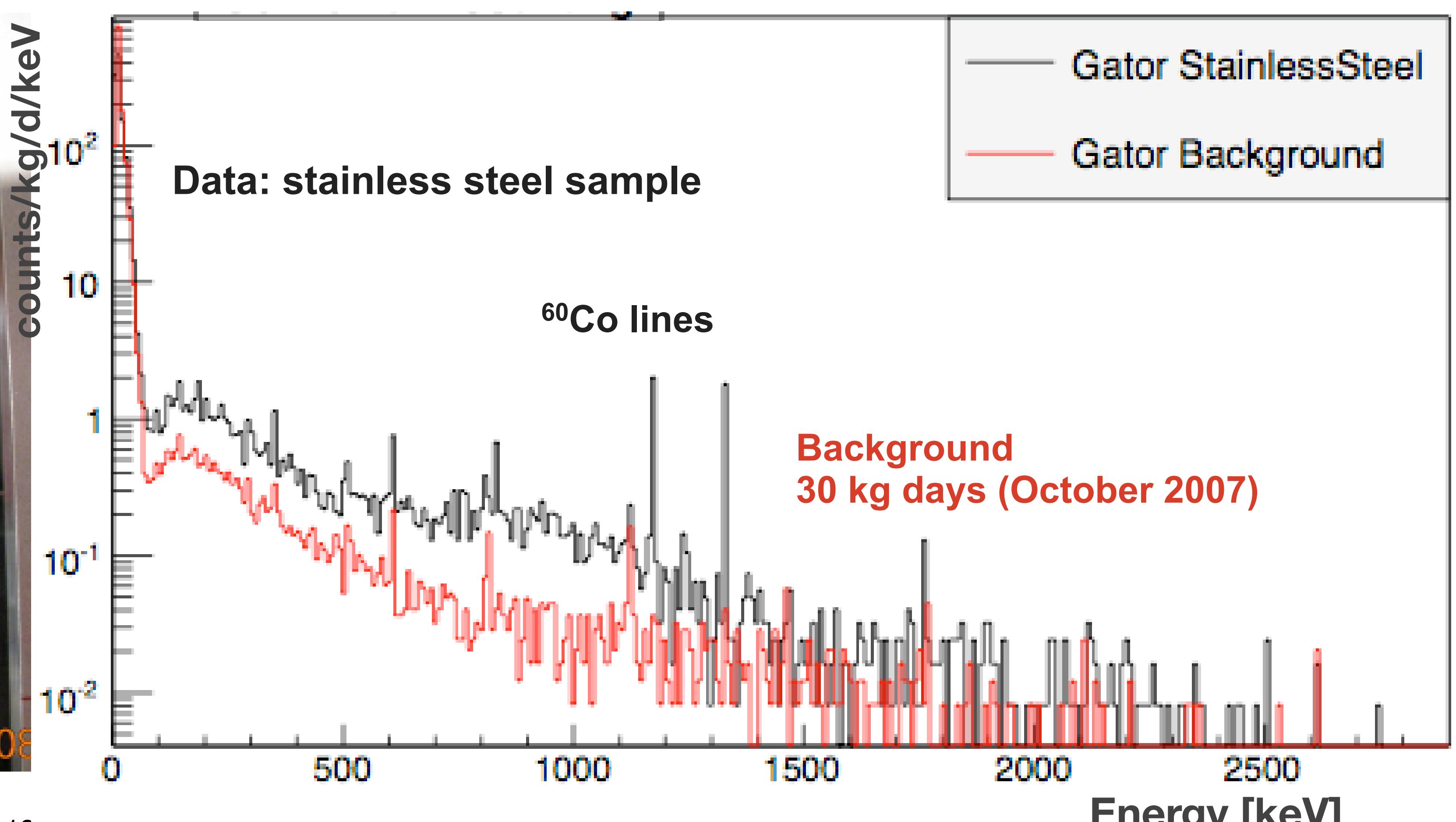


Xenon100 BG rate, June 6-9, 2008

XENON100 Material Screening

- Ultra-low background, 100 % efficient (2 kg) HPGe-spectrometer, operated at LNGS (plus detectors from LNGS screening facility)
- **Shield**: 5 cm of OFRP Cu (Norddeutsche Affinerie); 20 cm Pb (Plombum, inner 5 cm: 3 Bq/kg ^{210}Pb), air-lock system and nitrogen purge against Rn, slow control for online monitoring of HV, N_2 flow rate, leakage current and LN level
- **Background spectrum: < 1 event/(kg d keV) above 40 keV**
- **Screened all XENON100 detector/shield components for a complete BG model**





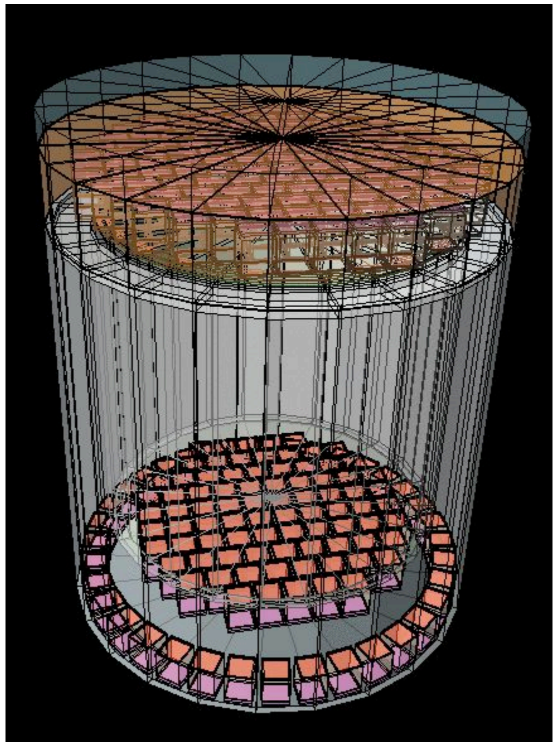
XENON100 Material Screening

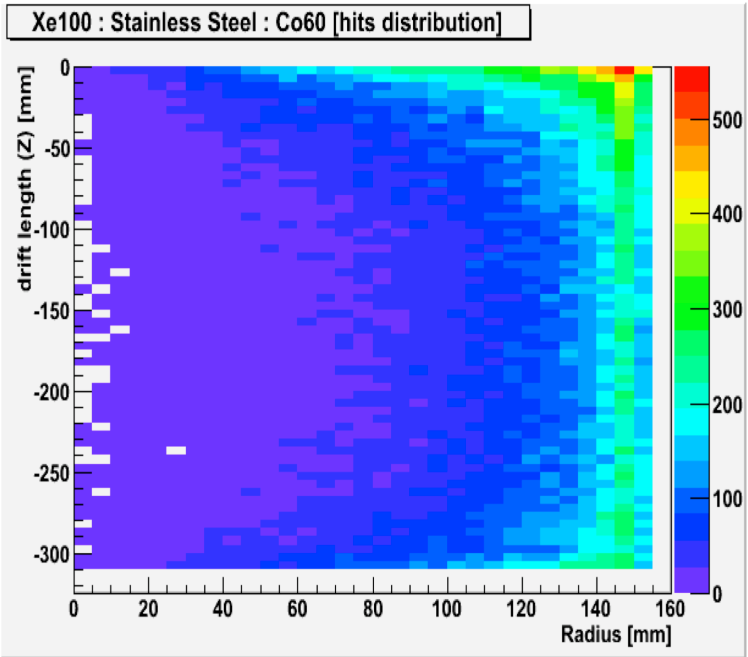
Material*	^{238}U	^{232}Th	^{40}K	^{60}Co
Stainless Steel 1.5 mm (316Ti, Nironit; cryostat)	<2 mBq/kg	<2 mBq/kg	10.5 mBq/kg	8.5 mBq/kg
Stainless Steel 25 mm (316Ti, Nironit, cryostat)	<1.3 mBq/kg	<0.9 mBq/kg	<7.1 mBq/kg	1.4 mBq/kg
PMTs (R8520-AL)	< 0.24 mBq/PMT	0.18 mBq/PMT	7.0 mBq/PMT	0.67 mBq/PMT
PMT Bases	0.16 mBq/pc	0.10 mBq/pc	<0.16 mBq/pc	<0.01 mBq/pc
Teflon (TPC)	< 0.3 mBq/kg	<0.16 mBq/kg	< 2.3 mBq/kg	--
Poly I (shield)	< 3.8 mBq/kg	< 2.7 mBq/kg	< 5.88 mBq/kg	--
Poly II (shield)	2.43 mBq/kg	< 0.67 mBq/kg	<4.66 mBq/kg	--
Polish Pb (outer shield)	< 5.7 mBq/kg	< 1.6 mBq/kg	14 mBq/kg	< 1.1 mBq/kg
French Pb (inner shield)	< 6.8 mBq/kg	< 3.9 mBq/kg	< 28 mBq/kg	< 0.19 mBq/kg

*** only a selection is shown here, all PMTs are screened and show consistent values; also screened: copper, cables, screws, ...**
**** thanks also to Matthias Laubenstein (LNGS screening facility)**

Gamma Background Predictions from MC Simulations

Material	Rate [mdru]
Stainless steel (cryostat, 65 kg)	2.01 ± 0.22
Teflon (TPC, 10.7 kg)	0.18 ± 0.02
PMTs (including bases, 242)	4.91 ± 0.60
Polyethylene (shield, 2t)	2.50 ± 0.29
Copper (shield, 2t)	0.026 ± 0.002
Total*	9.63 ± 0.70



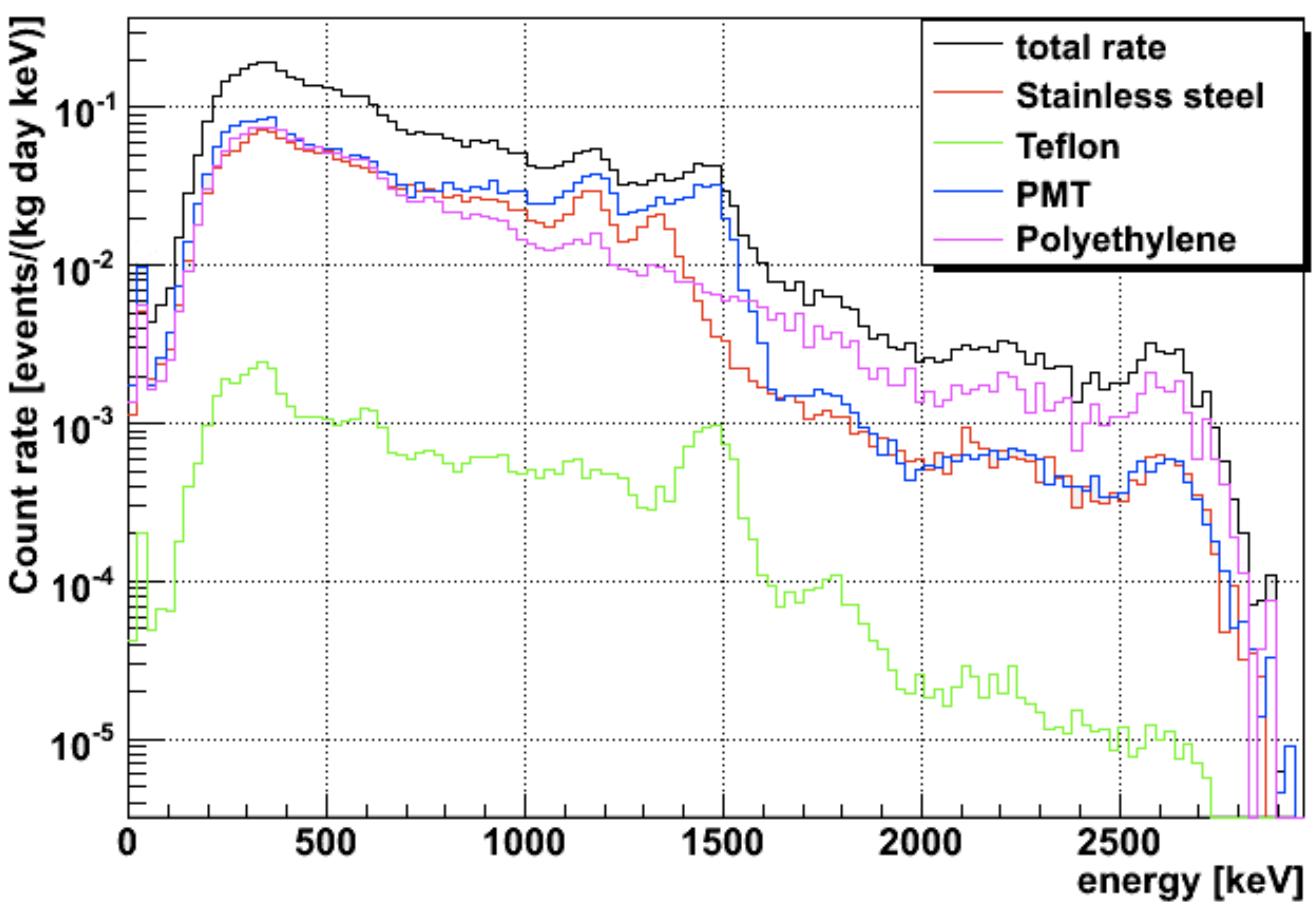


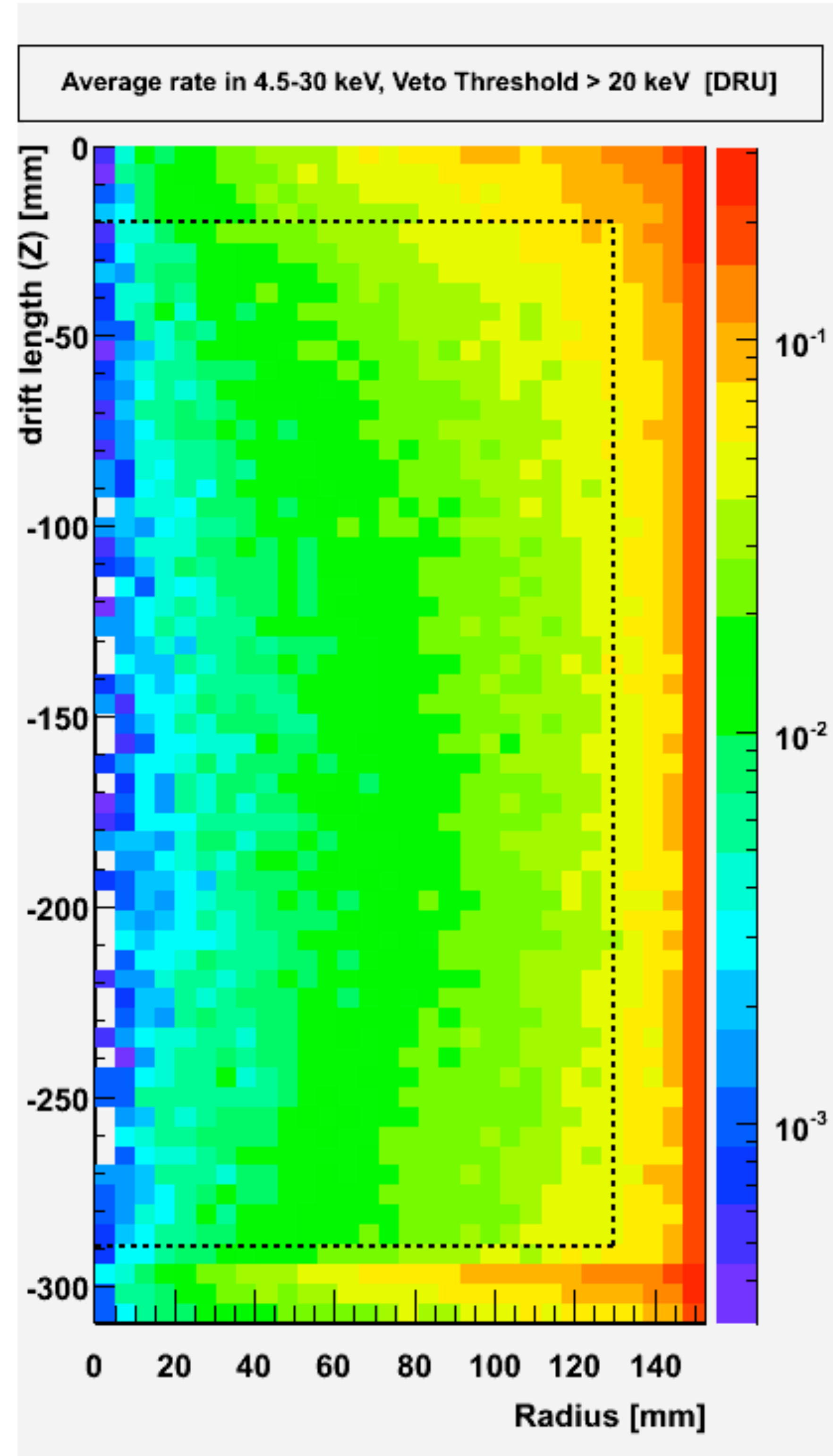
*** dominant background rate before S2/S1 discrimination in fiducial mass**

dru = events/(kg day keV)

Gamma Background Predictions from MC Simulations

Total single scatters in fiducial volume



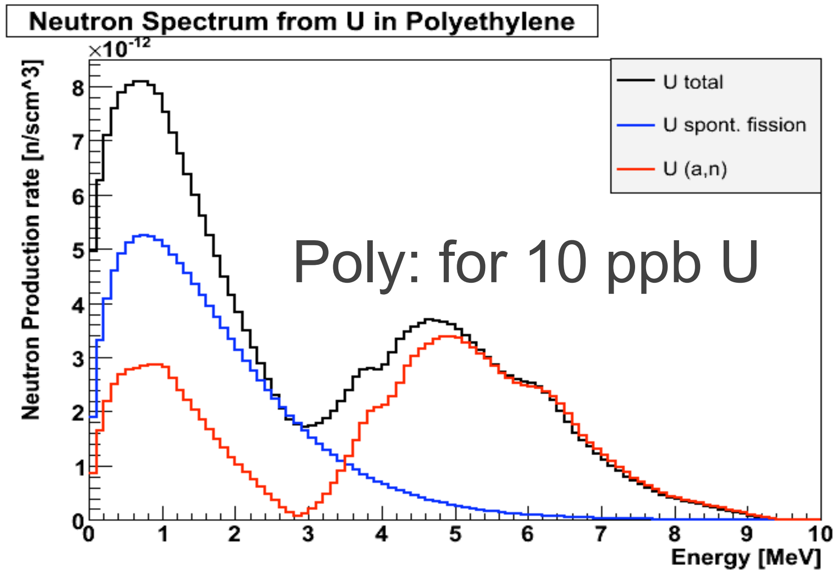


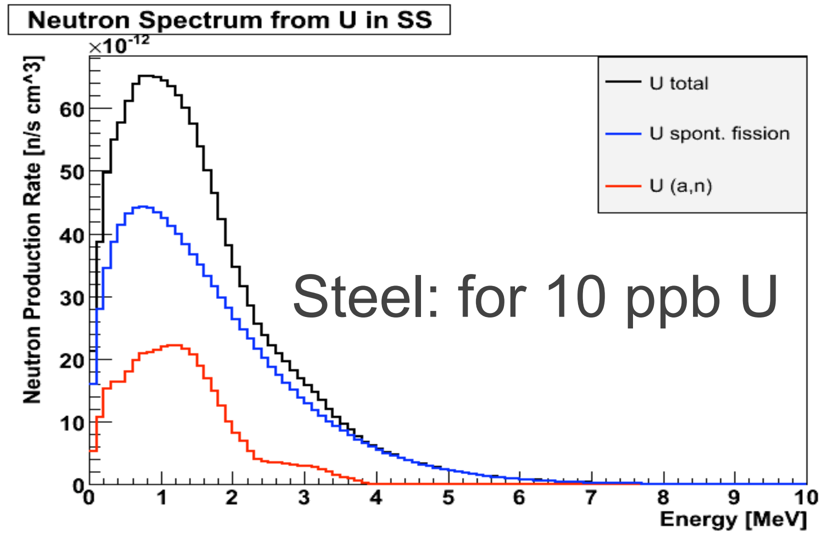
Neutron Backgrounds: MC Simulations

- Internal neutron BG from detector materials + shield, from (α,n) and fission reactions
- Numbers based on detailed MC, with measured U/Th activities of all materials

Material	Total n-rate [yr^{-1}]	Single NR rate [μdru]
Stainless steel	15.0	0.18
Teflon	10.1	0.58
PMTs	7.0	0.32
LXe	0.81	0.007
Copper	1.6	0.01
Poly shield	416.3	0.49
Polish Pb	5805	0.38
French Pb	1579	
Total		~ 1.6

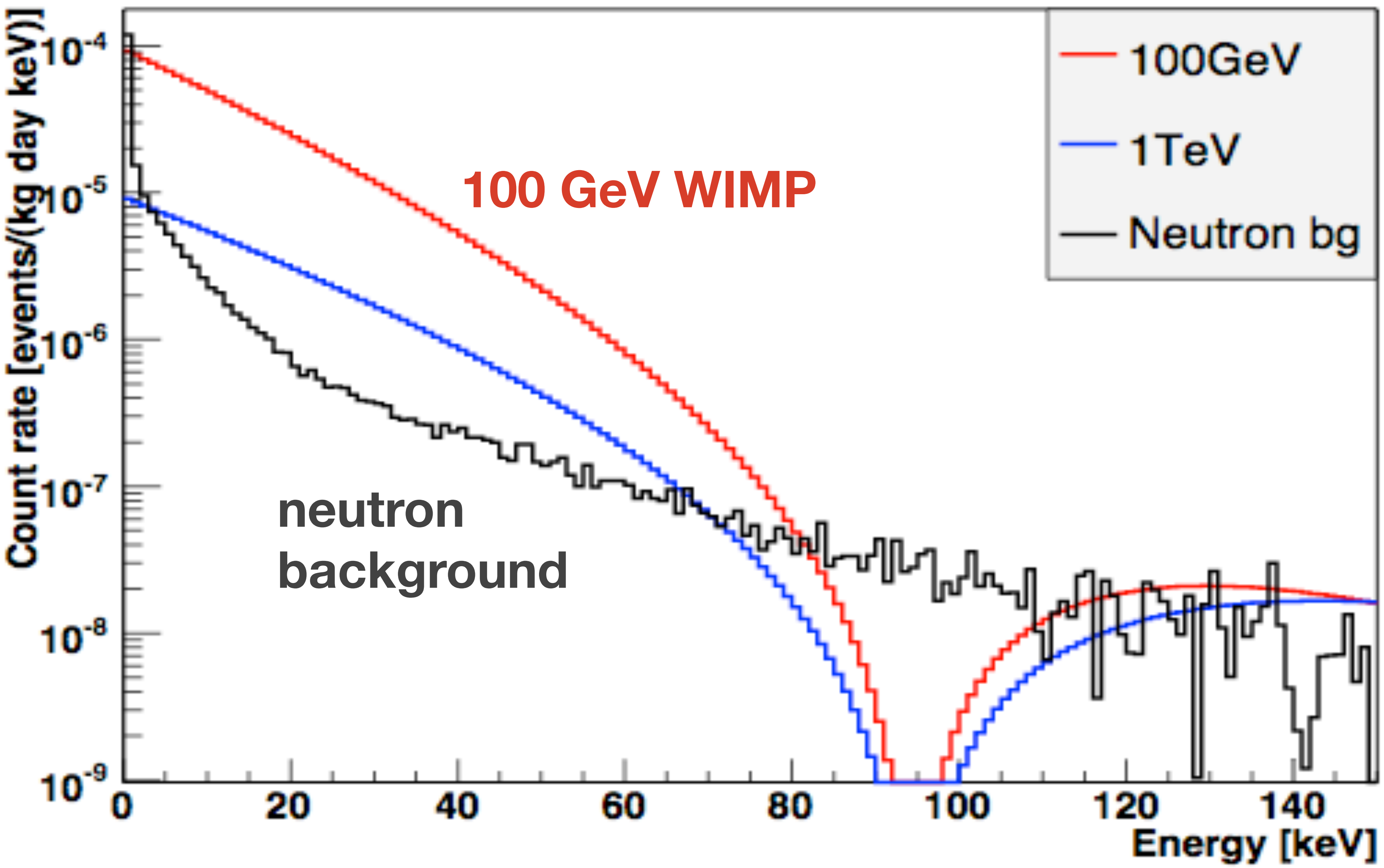
=> ~ 0.6 single NRs/year in FV
(~ 44% of events are singles)





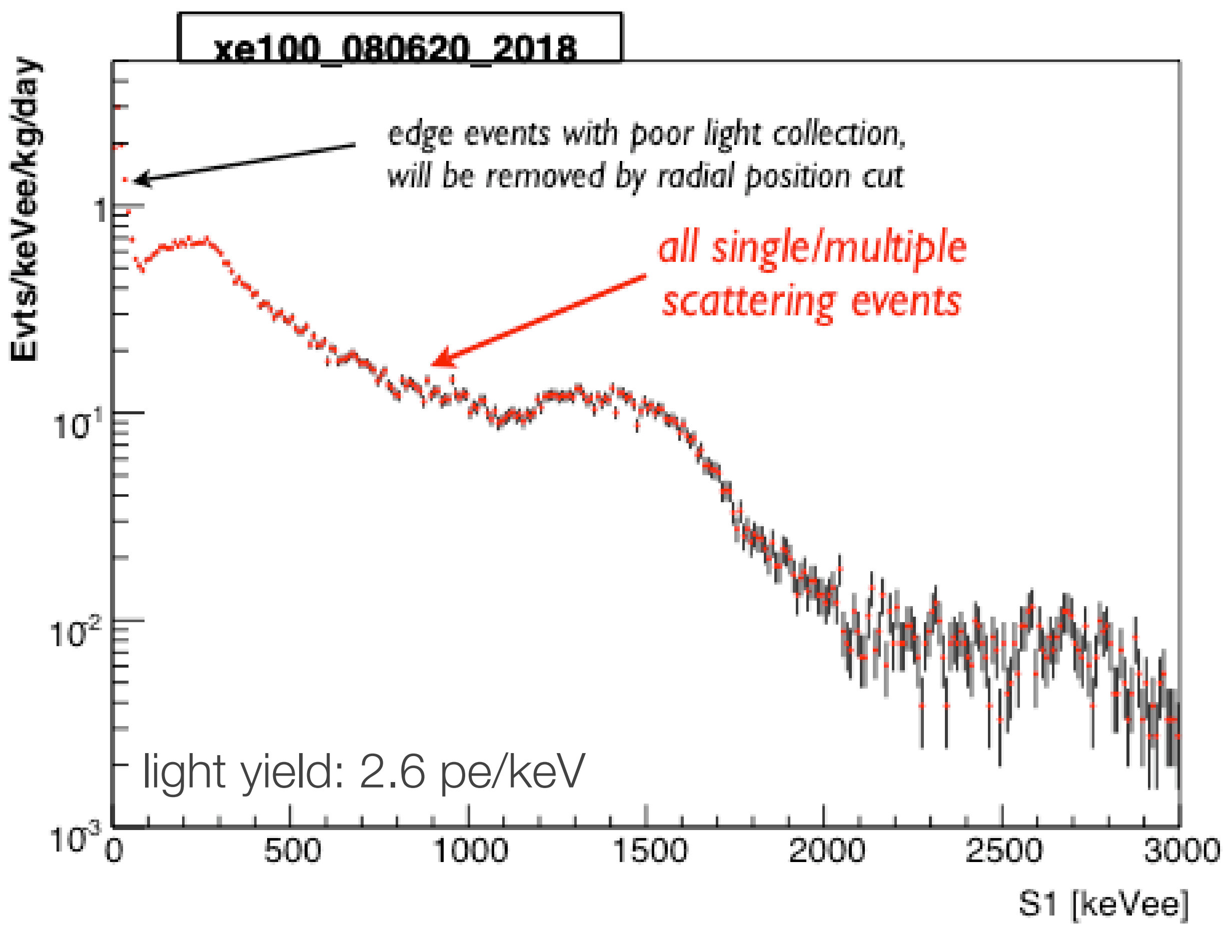
WIMP rate versus neutron background

- assumptions:
  - ➡ spin-independent WIMP-nucleon cross section: **2x10^{-45} cm^{2}**
  - ➡ local WIMP densitv: **0.3 GeV/cm^{3}**

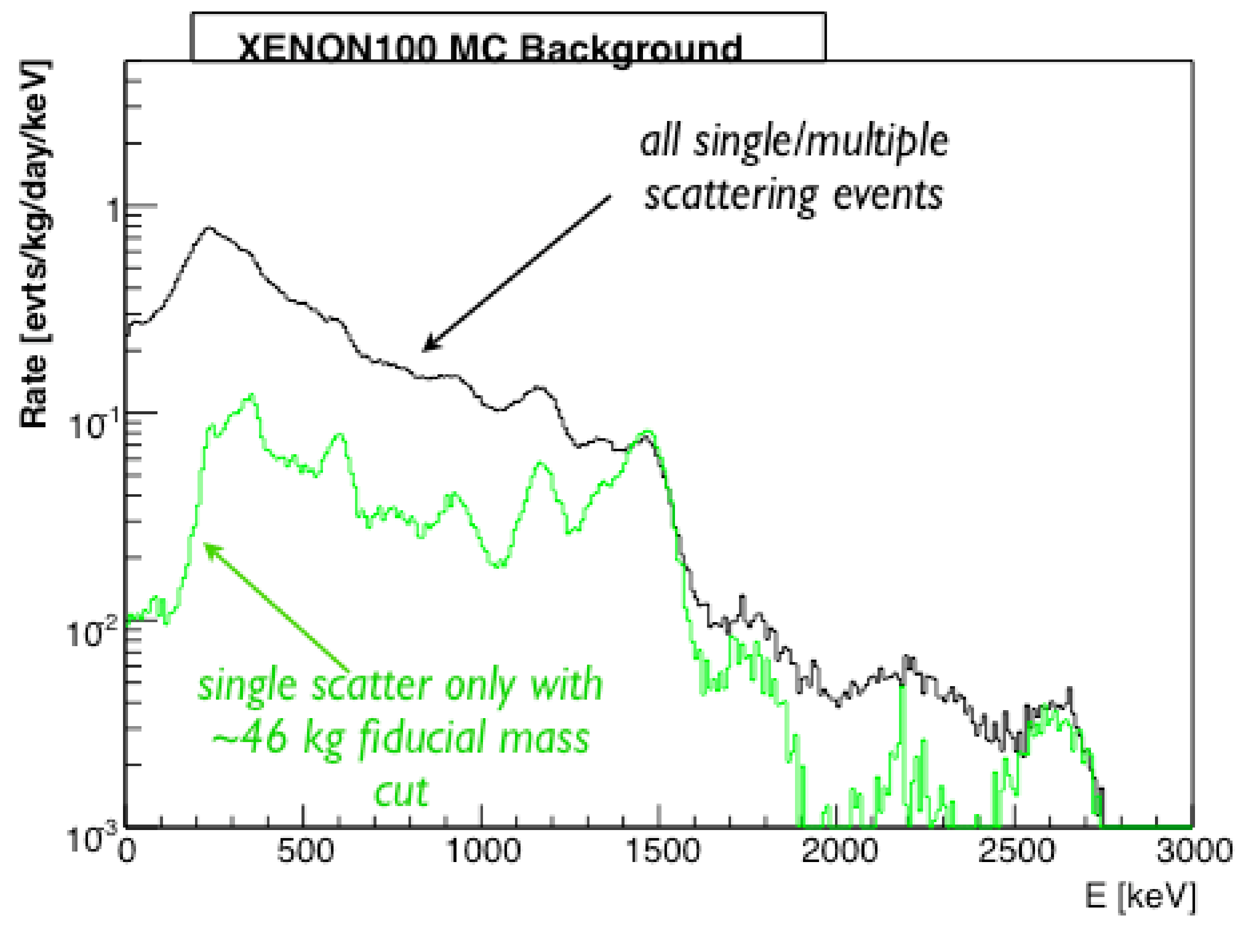


Preliminary Background from XENON100 Data

data (S1 only)



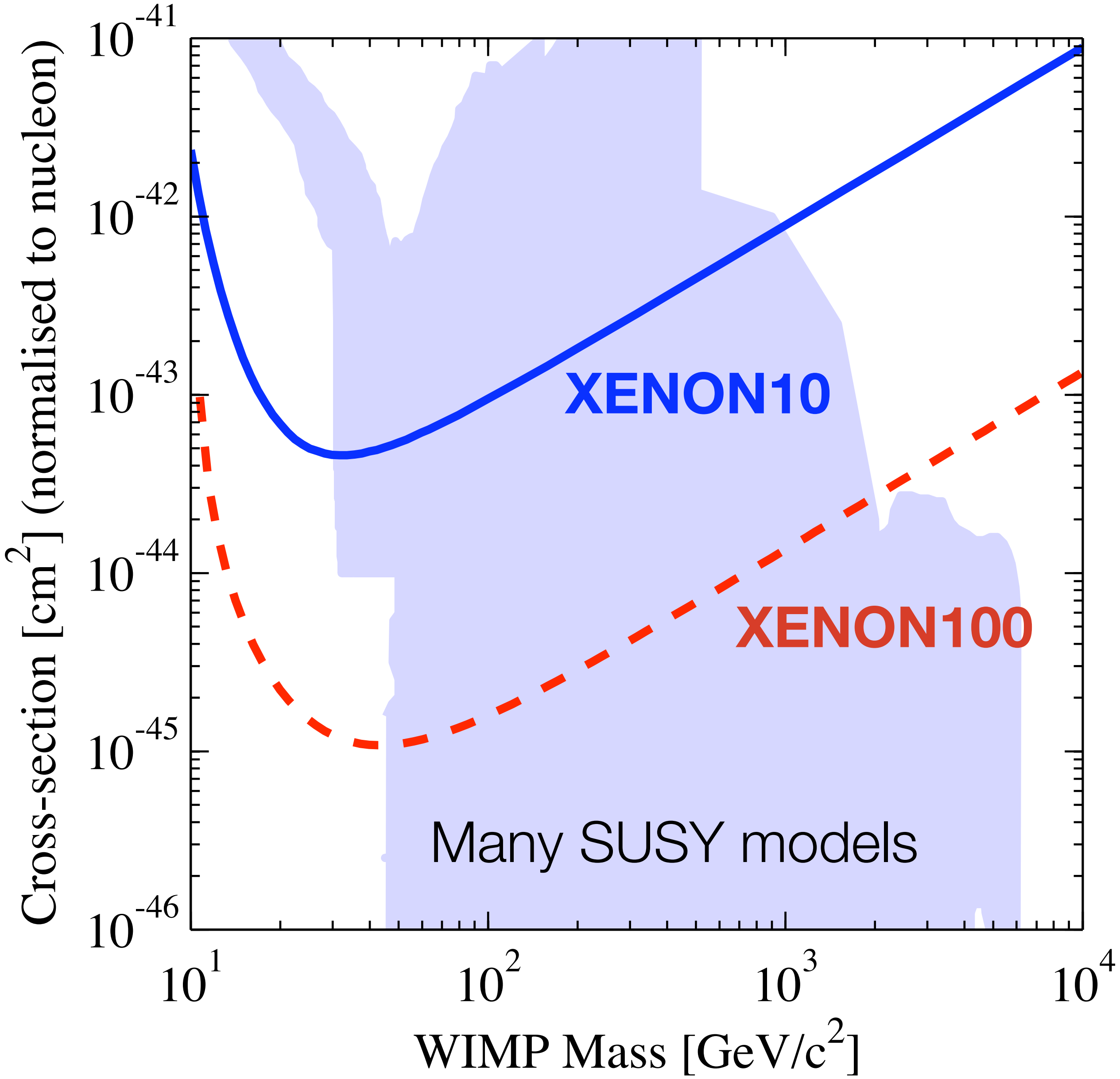
Monte Carlo simulations



Data and Monte Carlo predictions are in good agreement for overall rate

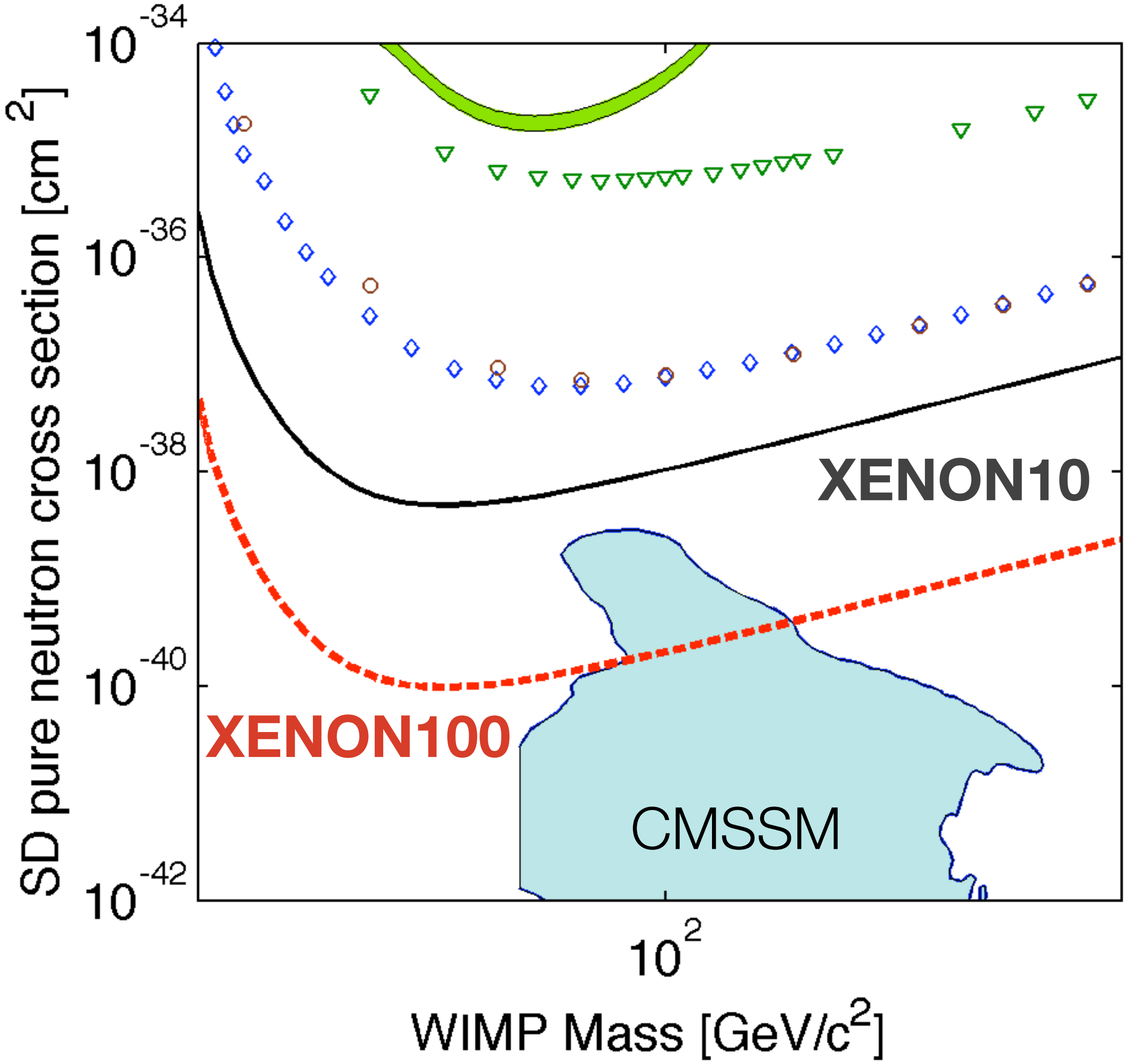
Expected Sensitivity for WIMPs and SUSY Predictions

Spin-independent



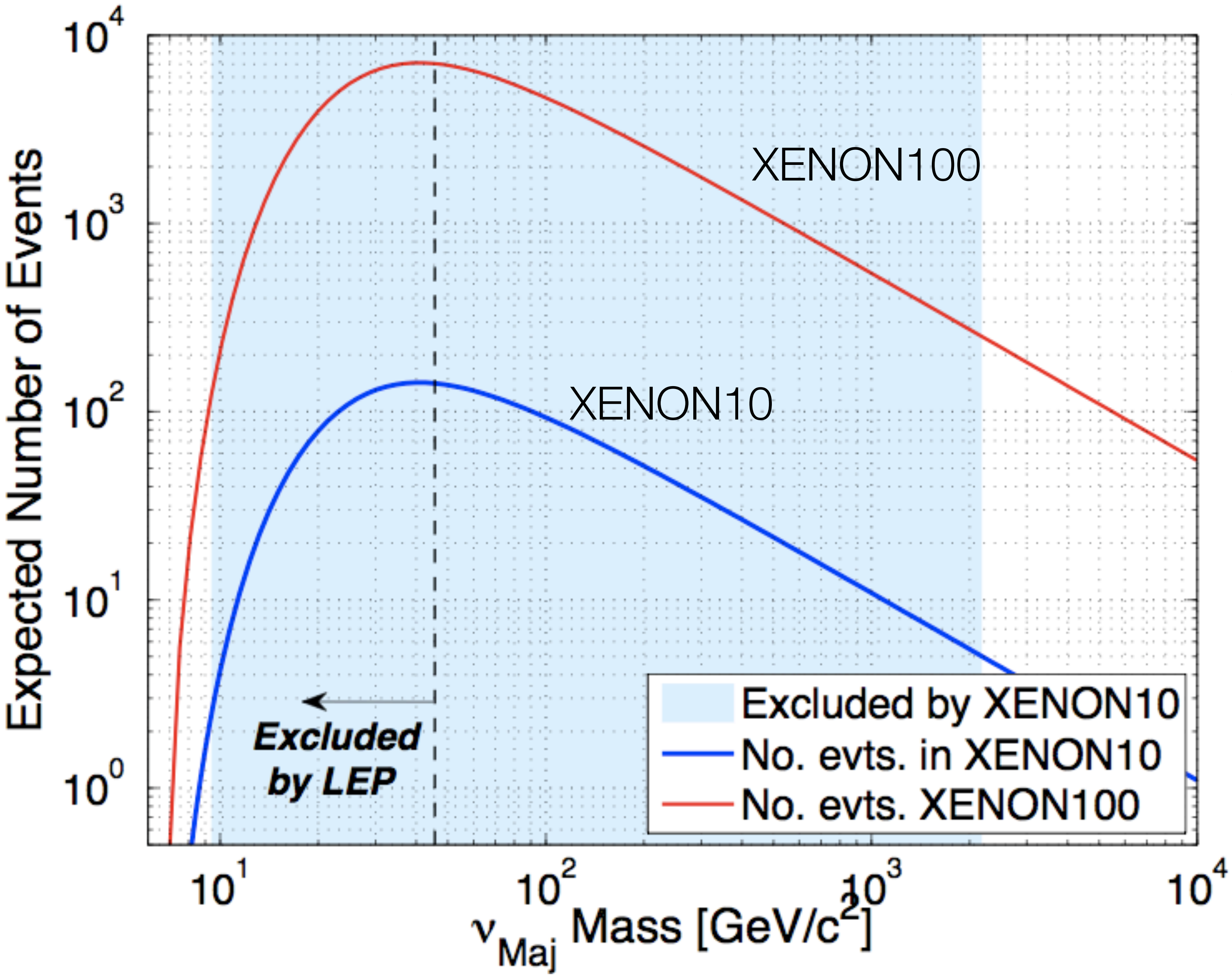
XENON10 limit: PRL100, 021303 (2008)

Spin-dependent (pure n-couplings)



XENON10 limit: arXiv: 0805.2939 accepted in PRL08

Expected sensitivity for heavy Majorana Neutrinos



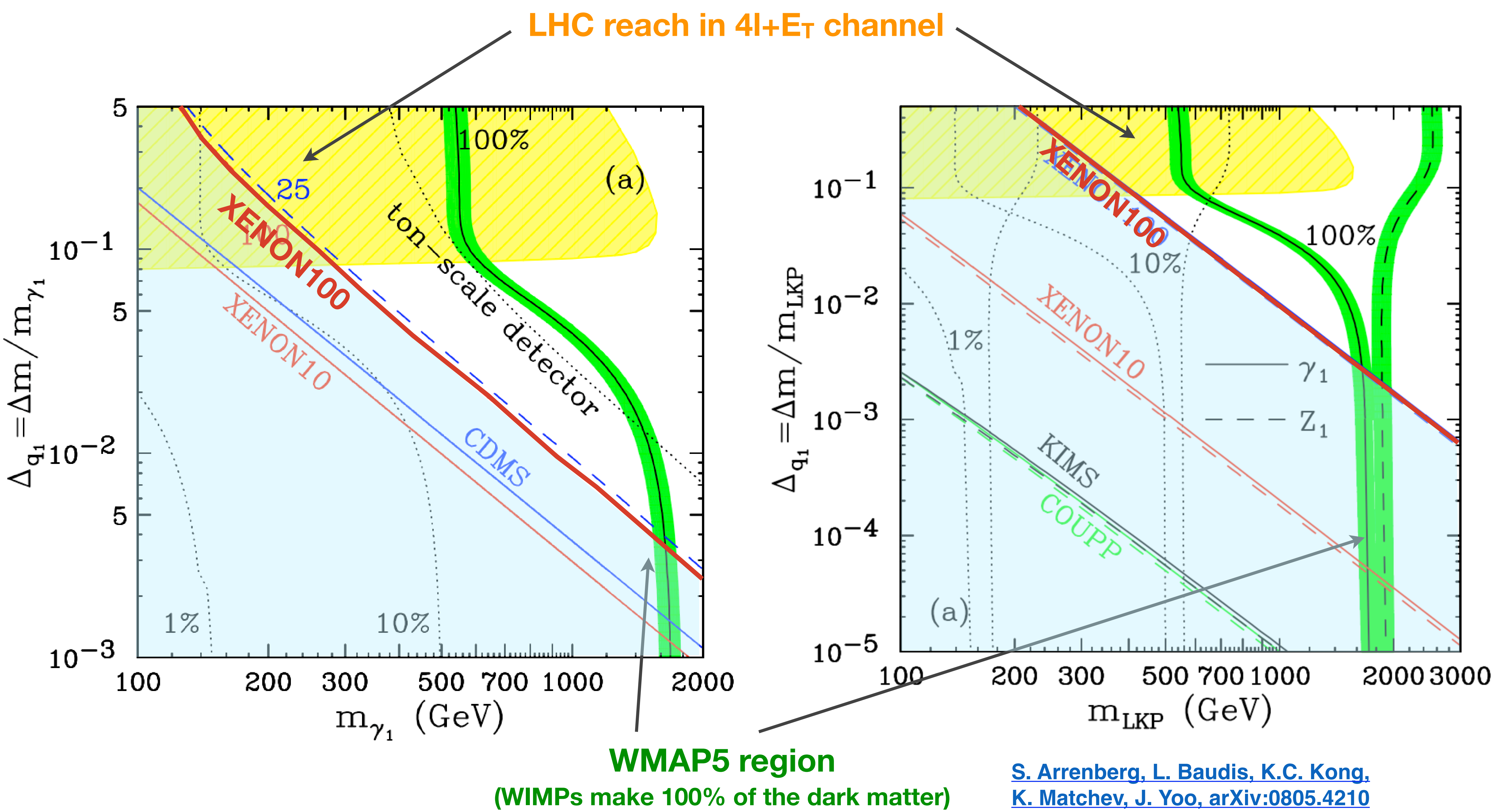
XENON100:
expected number of events
in **50 kg x 300 days**

XENON10:
expected number of events
in **5.4 kg x 58.6 days**
$\Rightarrow M_{\nu M} < 9.4$ GeV and > 2.2 TeV

arXiv: 0805.2939
accepted in PRL08

Expected Sensitivity for WIMPs and UED Predictions

Spin-independent | Spin-dependent



S. Arrenberg, L. Baudis, K.C. Kong, K. Matchev, J. Yoo, arXiv:0805.4210 accepted in PRD08

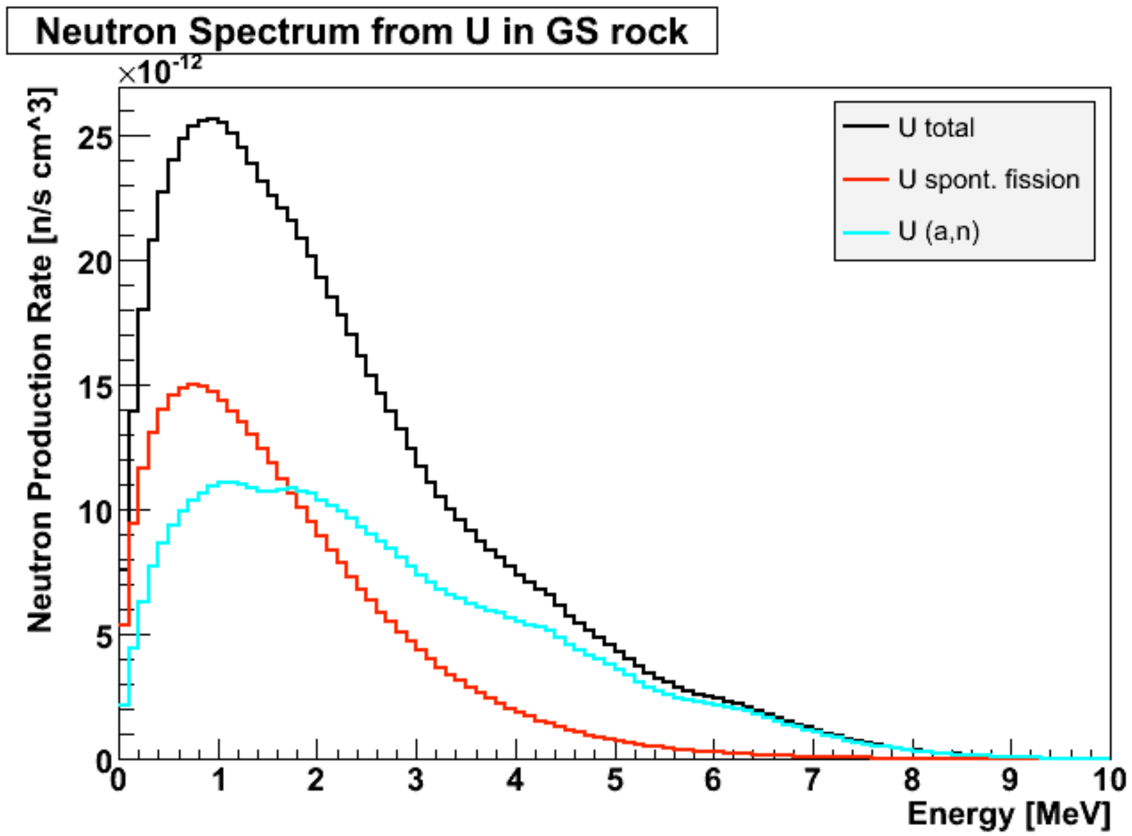
see talk by S. Arreberg

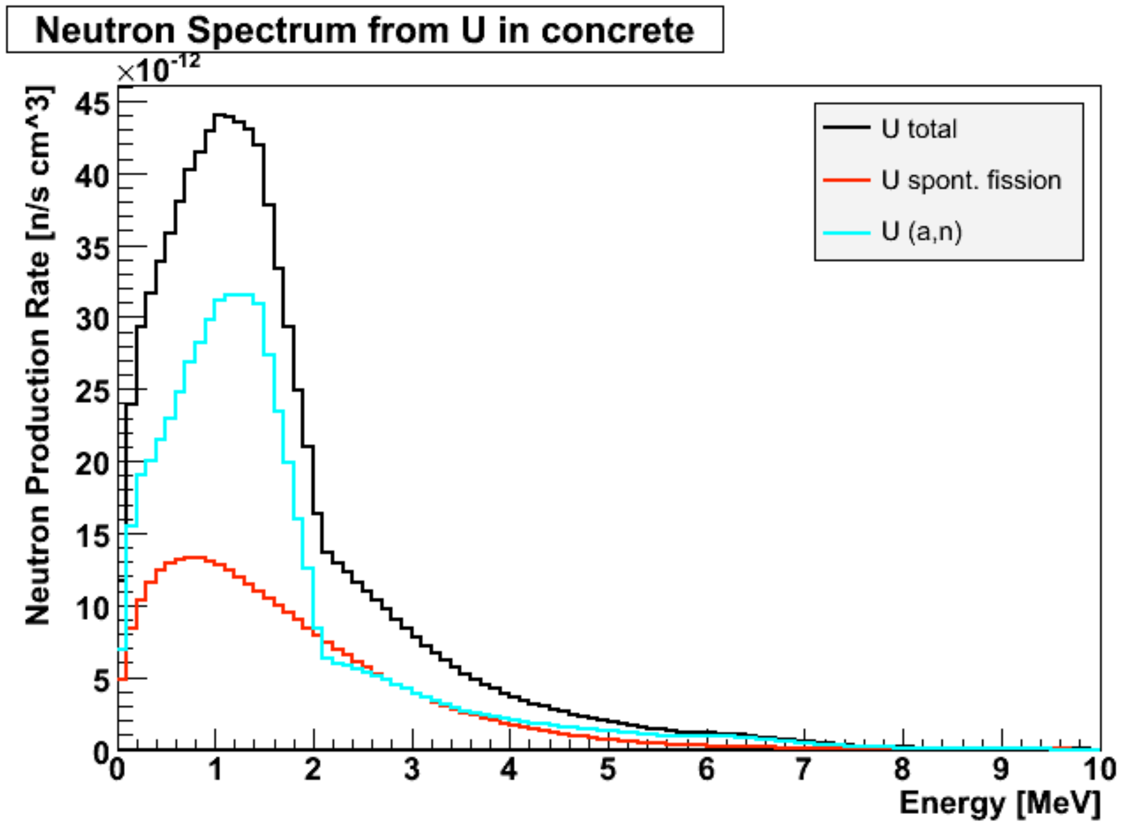
Conclusions and Outlook

- XENON100 is in commissioning phase at LNGS
  - ➡ strong effort to reduce backgrounds by factor 100 compared to XENON10
- electromagnetic background: dominated by PMTs, stainless steel cryostat and poly shield
  - ➡ room for improvement (lower-activity poly, Cu cryostat, lower BG PMTs)
- nuclear recoil background dominated by internal neutrons from material
  - ➡ less than 1 single NR/year predicted for ~ 46 kg fiducial mass
  - ➡ muon induced NR background under study (expected to be negligible)
- preliminary data from XENON100 => overall background as expected based on MCs
- extrapolated sensitivity to WIMPs is ~ 2×10^{-45} cm^2 for SI couplings for ~7 months exposure
- XENON100 has a fantastic discovery potential for dark matter particles of galactic origin and can test many theoretical models of particle physics beyond the Standard Model

End

Neutron background from the rock and concrete





U/Th activities taken from measurements of LNGS Hall A (similar to XENON10 location)

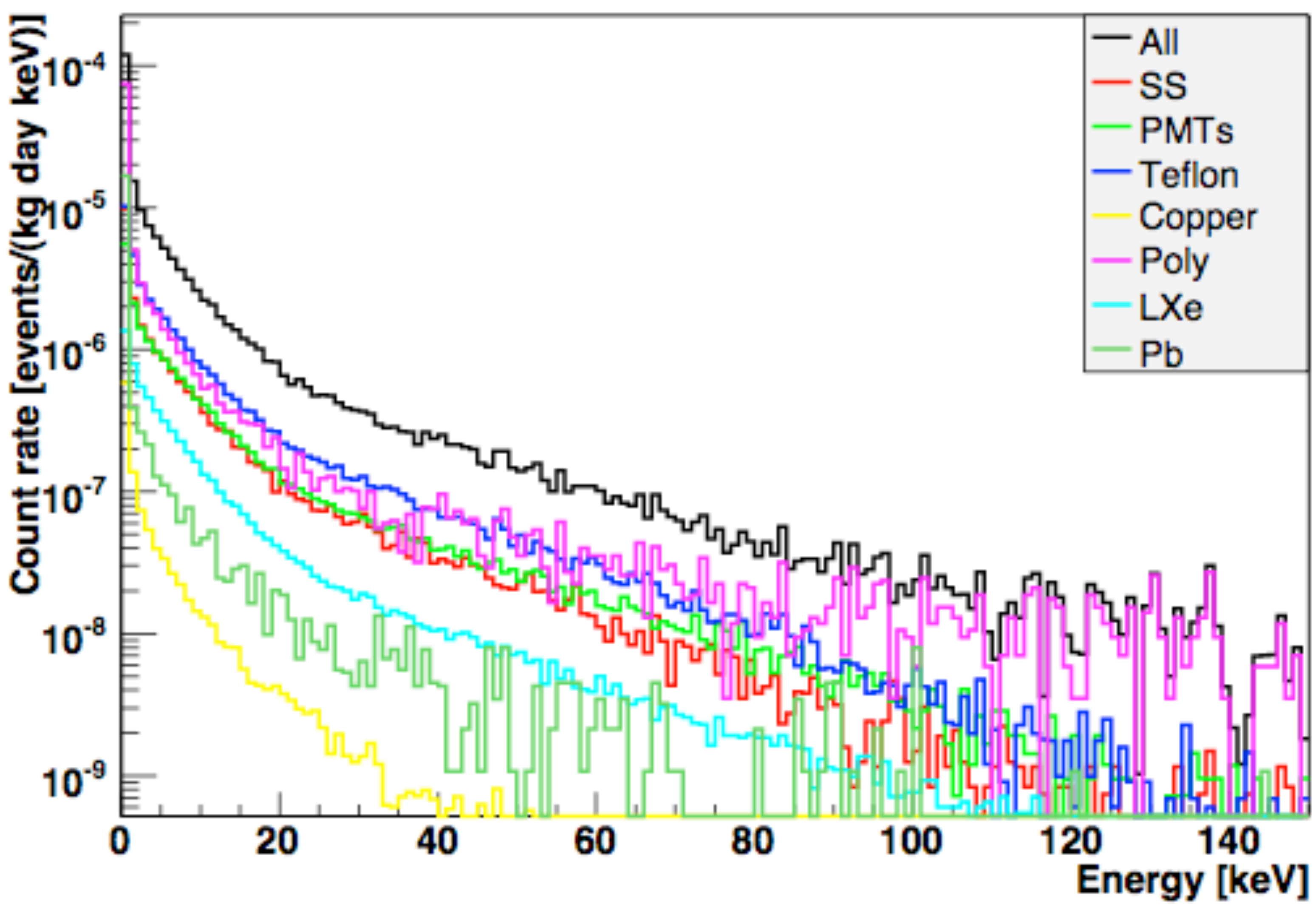
⇒ (5.0 ± 1.0) single nuclear recoils/year in 63 kg LXe

⇒ (2.5 ± 0.9) single nuclear recoils/year in 46 kg LXe

additional water/PE shield outside the Pb is being added to reduce this background component to negligible levels

Neutrons from Materials

- single nuclear recoils from neutrons generated by (alpha,n) and fission reactions in detector and shield materials



Next Step: XENON1t

- Studies in progress for 3 ton (1 ton fiducial) LXe detector
- Possible location: inside LVD SN neutrino detector at LNGS -> active veto for μ-induced neutrons
- Gamma flux inside LVD structure: 10-20 times lower than in main halls (detailed mapping of gamma and neutron background in progress)