Improving the Sensitivity to Low-Mass WIMPs with XENON Detectors

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Liquid Xenon TPCs

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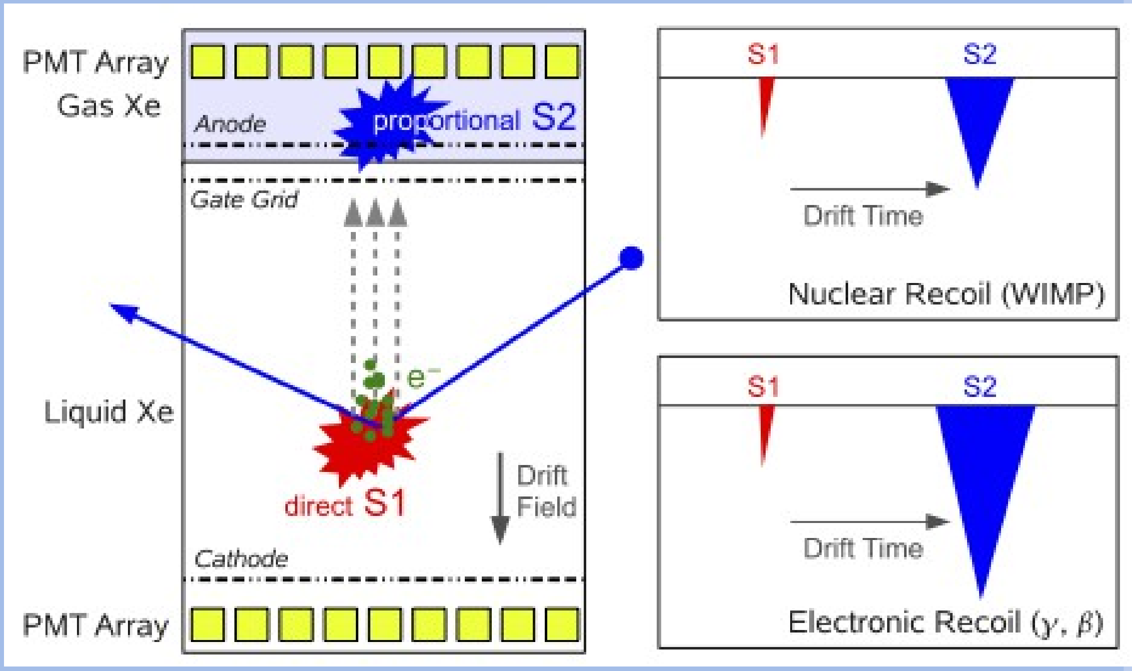
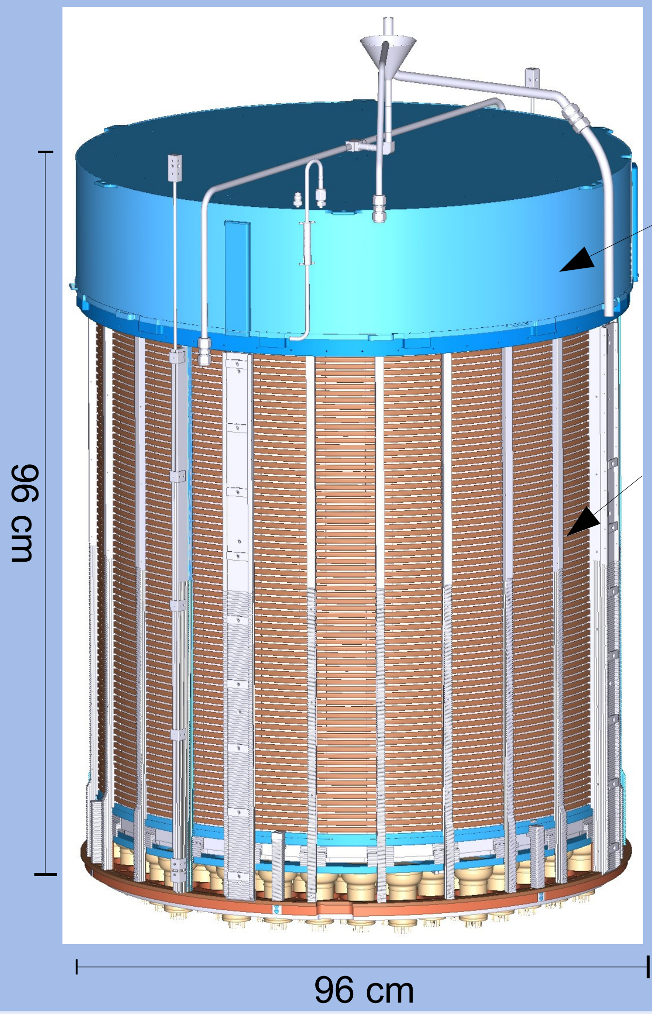
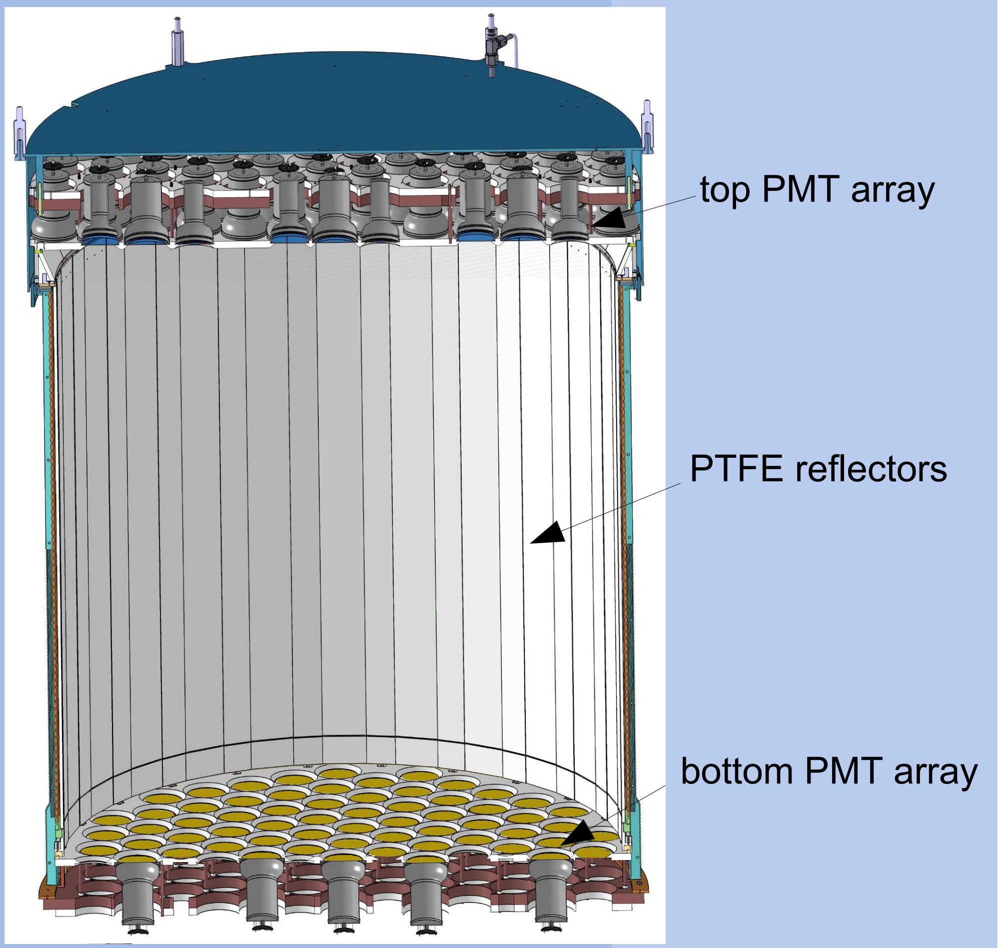
- 3D position reconstruction → fiducialization
- ER/NR discrimination
- Removal of double scatters



The XENON1T Experiment

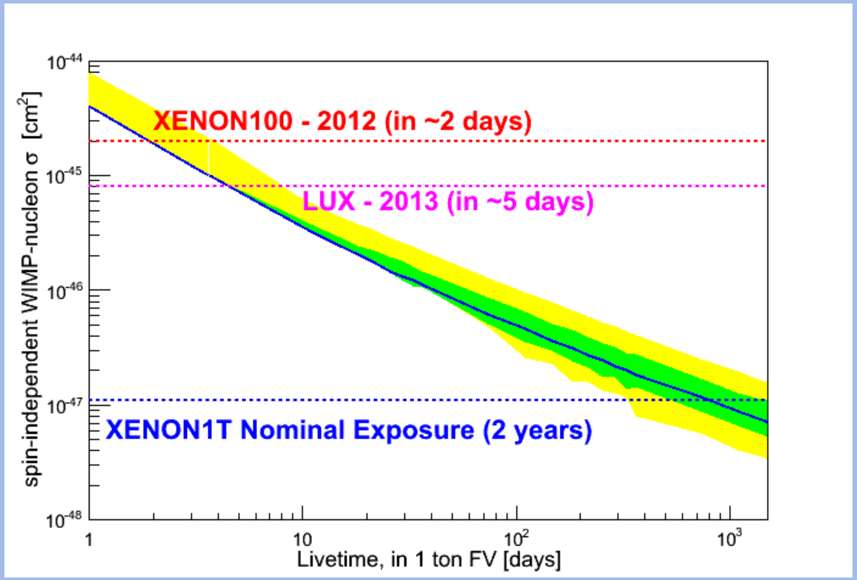
The XENON1T TPC

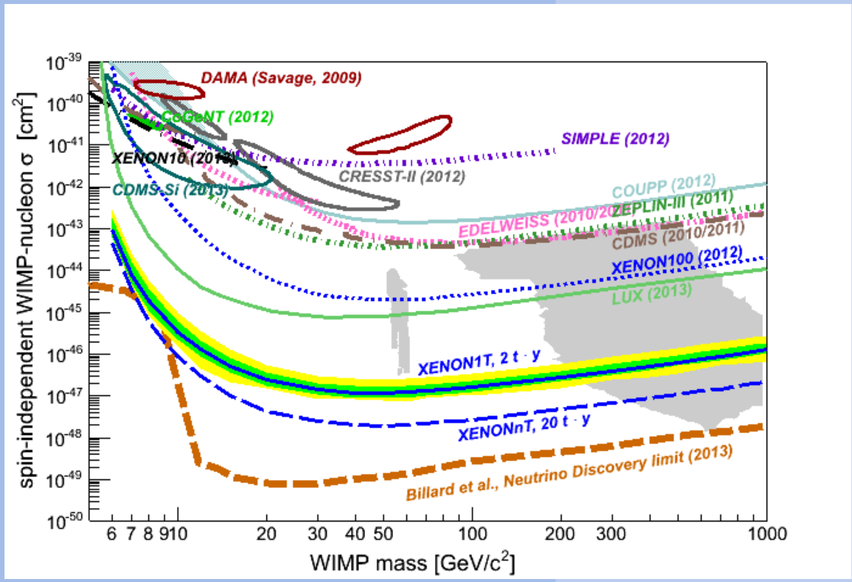




Projected Sensitivity

> $1.2 \cdot 10^{-47}$ cm^2 at 50 GeV after 2 t·y exposure



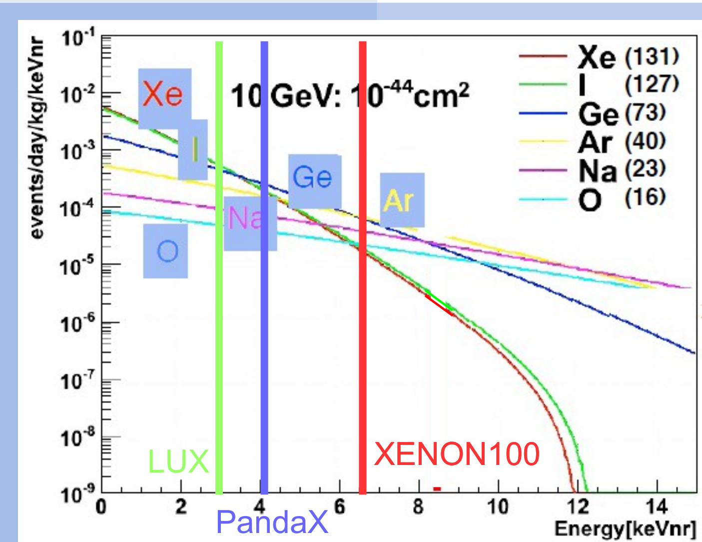


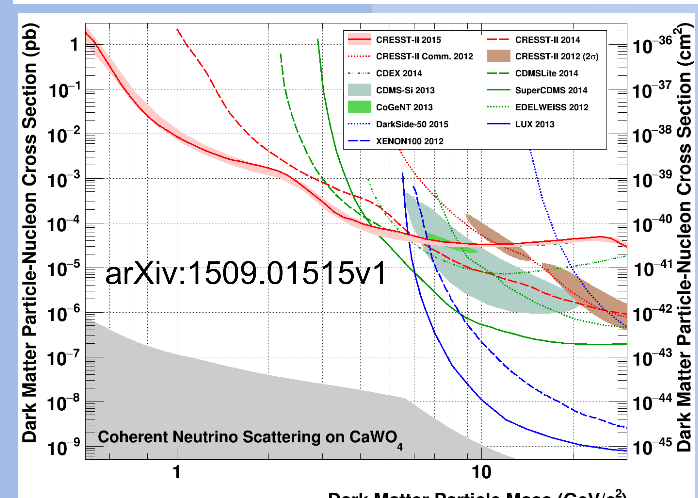
Current Status of XENON1T

- TPC: Preparation for comissioning and first data
- Cryogenics: Filling of 3.5 t LXe into ReStoX

Sensitivity to Low-Mass WIMPs

- High atomic mass of Xe (A=131)
- Energy threshold 3~6 keV
  - Currently sensitivity limited to m_χ > 6 GeV
- Strategies towards lower thresholds
  - Increase light collection efficiency (LCE)
  - Using S2 signal for energy scale





What can we do about backgrounds?

Backgrounds

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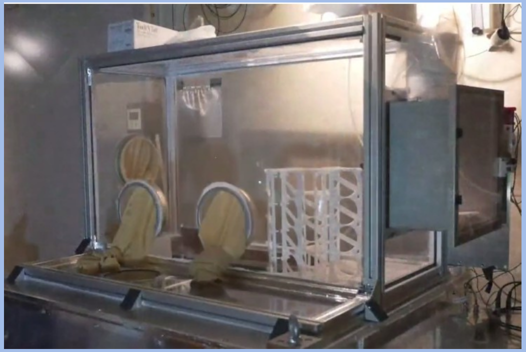
- Extensive material screening campaings
  - HPGe detectors
  - ICP-MS
  - Rn emanation

GeMPI, LNGS

Gator, LNGS

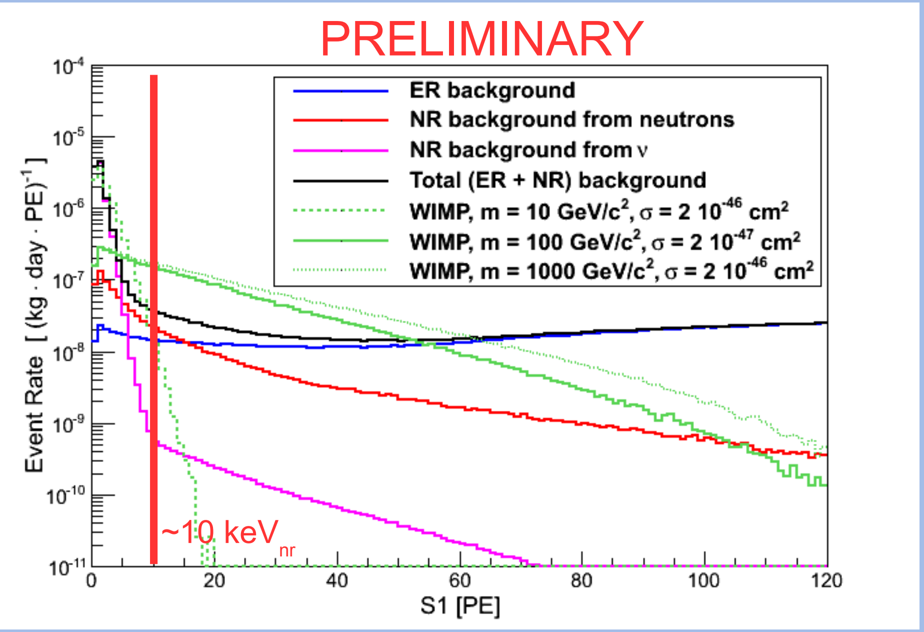


GIOVE, MPIK

GeMSE, Bern

XENON1T Background

> XENON1T: Irreducible background at low energies from CNNS



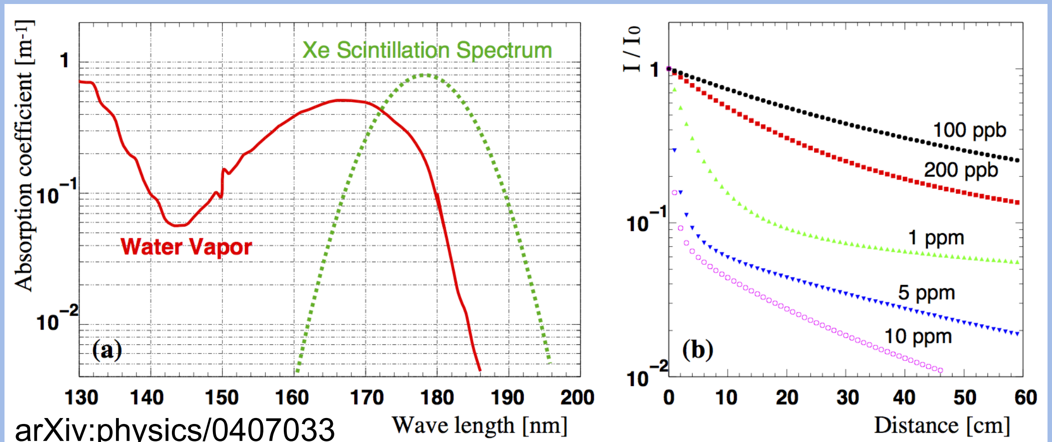
2 t·y exposure, 3-70 PE

	99.75% ER discrimination
Total ER	0.76
NR from neutrons	0.44
NR from CNNS	0.47

What can we do to improve the LCE?

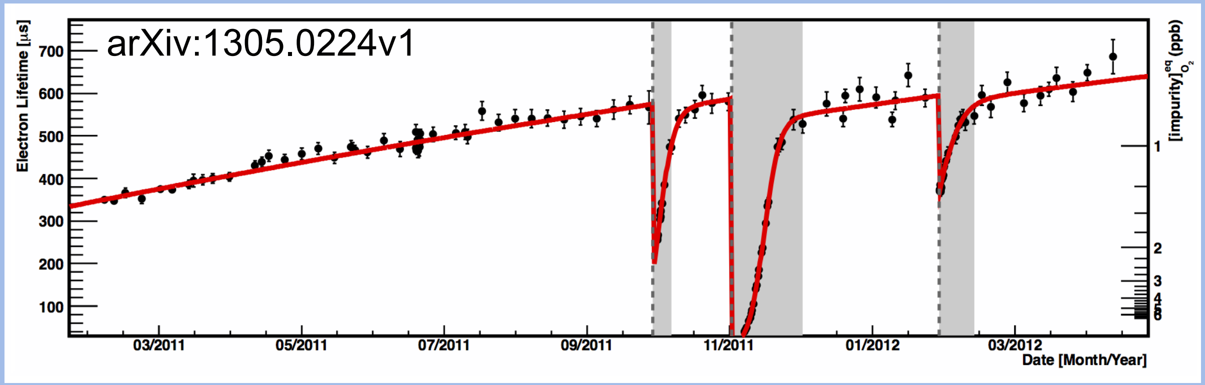
Light Attenuation

> Absorption length diminished by H_2O and O_2 impurities
> Impurity concentration <1ppb reached in XENON100



arXiv:physics/0407033

XENON1T purification system



PTFE Reflectors

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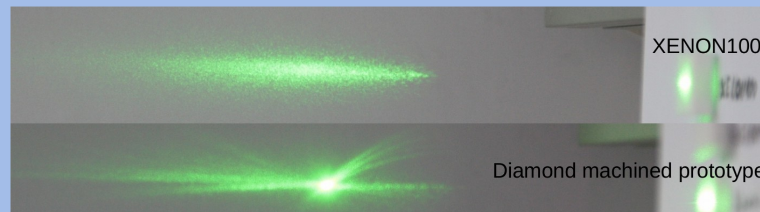
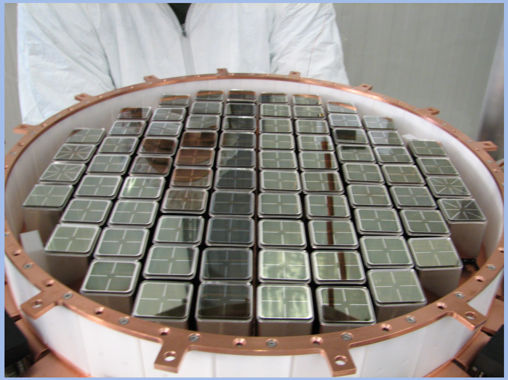
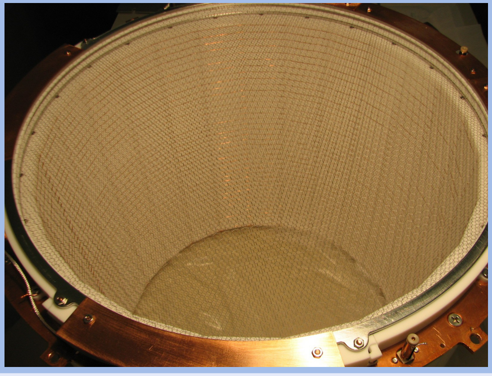
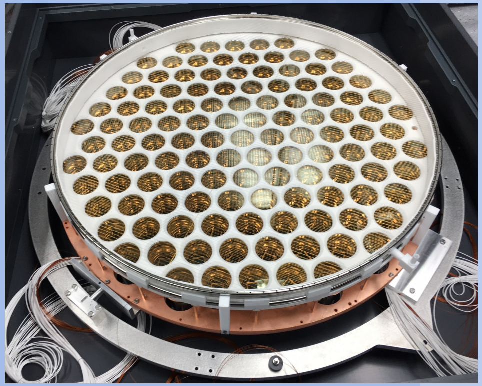


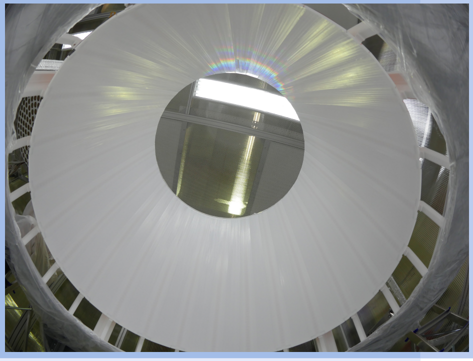
XENON100





XENON1T





Electrodes Transparency

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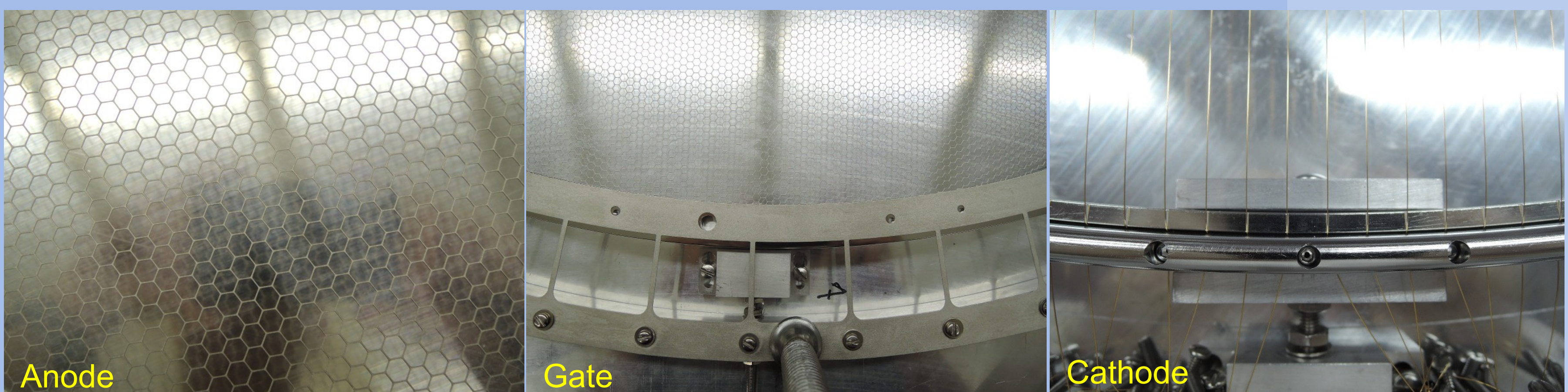
	XENON100	XENON1T
Top meshes	47.7%	87.9%
Cathode	83.4%	96%

XENON1T electrodes



PMTs

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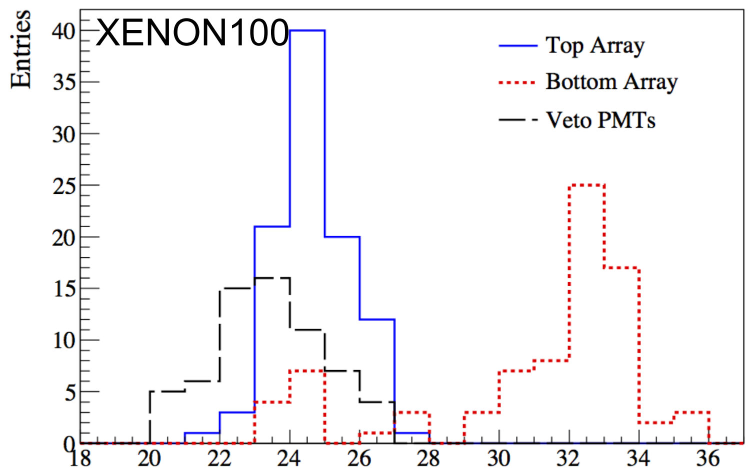
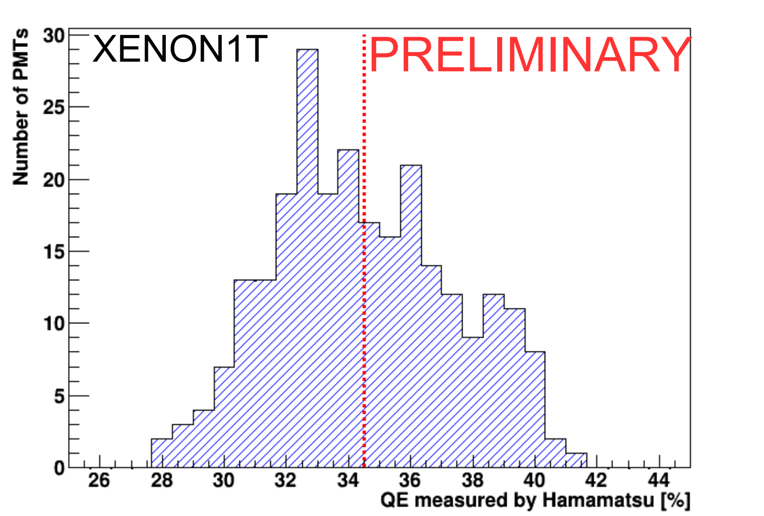
	XENON100	XENON1T
PMT Model	Hamamatsu R8520-06-Al	Hamamatsu R11410
Diameter	1“	3“
Top array	98	127
Bottom array	80	121
Coverage (bottom array)	52%	76%



arXiv:1107.2155v2

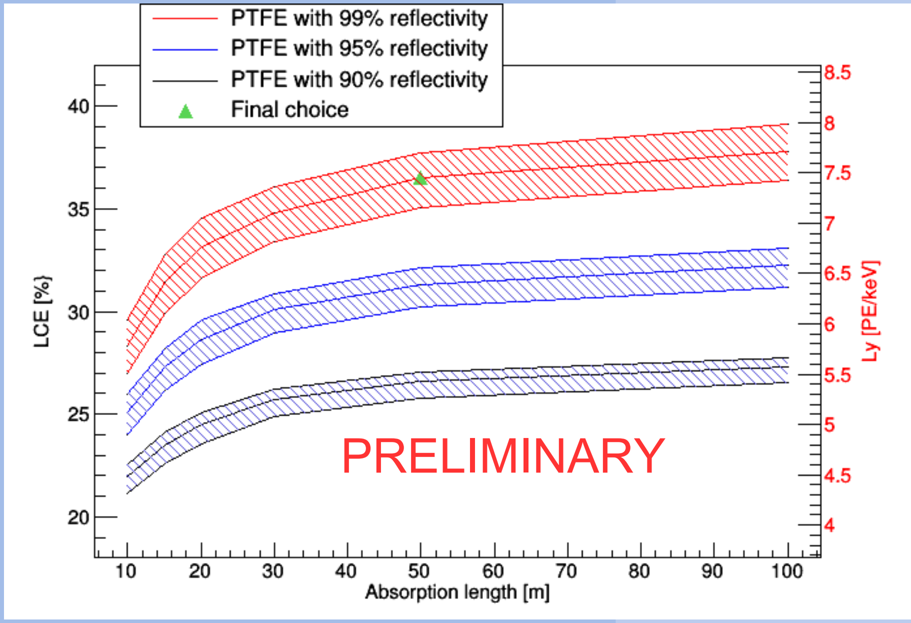


Light Collection Efficiency

> L_y: Average Light Yield for 122 keV γ at zero field

	L_y (PE/keV)
XENON100	3.8
PandaX-I	7.3
LUX	8.8
XENON1T	7.7 (simulation)

LCE simulation XENON1T



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What else can we do to lower the threshold?

„S2-only“ Analysis

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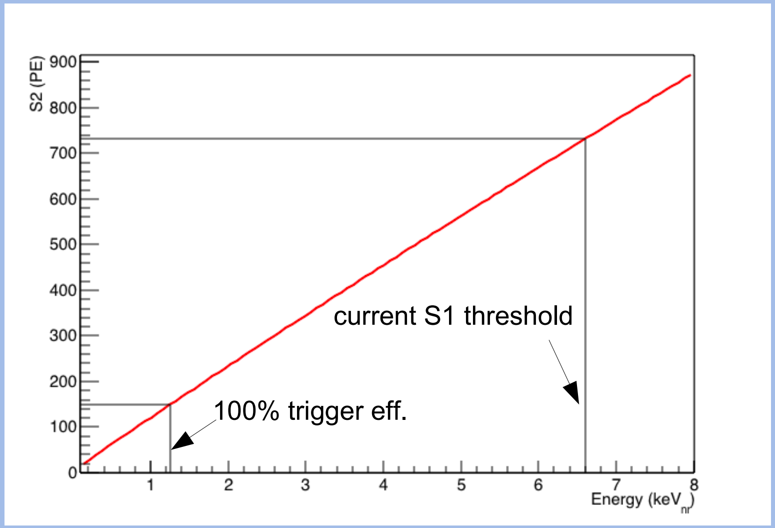
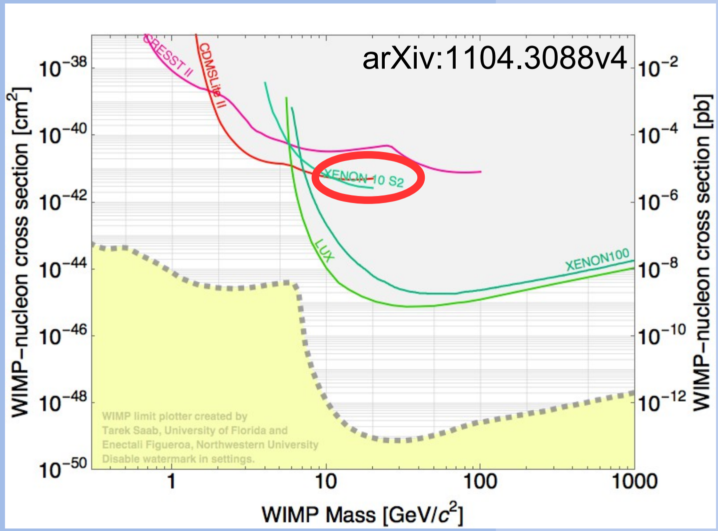
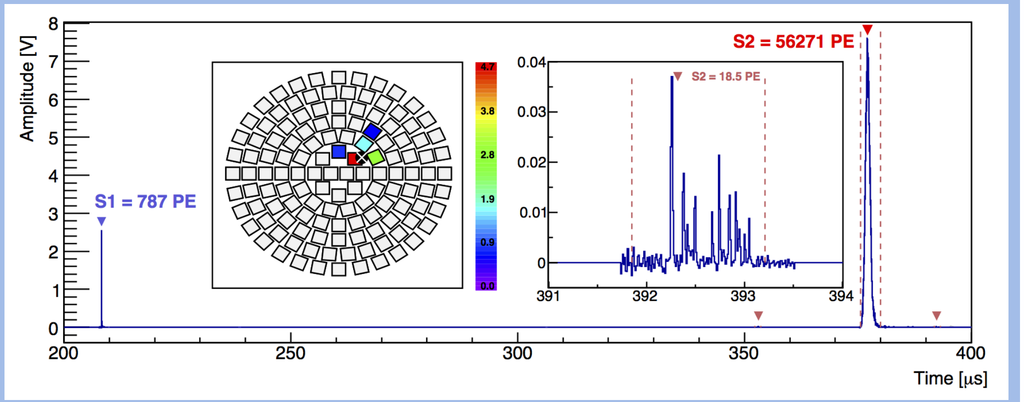
- Take S2 signal for energy scale
  - Lower threshold from 6.6 keV to ≈1.5 keV
  - No determination of z-position
  - No NR/ER discrimination
  - No background model

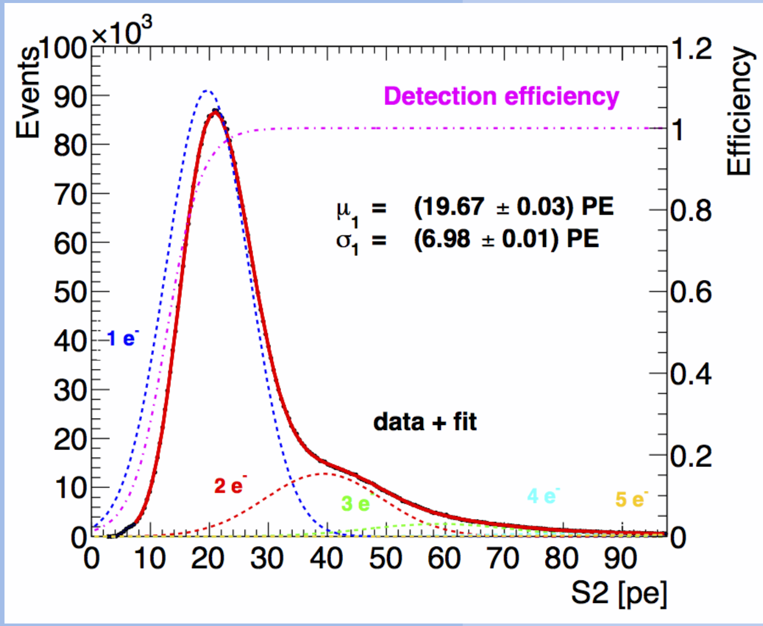




Single Electron Background

- Single electrons generated by photoionization on impurities and metallic surfaces (cathode, field shaping rings)
- Peaks at multiples of 20 PE in low-energy S2 spectrum





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How do we determine the energy scale?

Determining the Energy Scale

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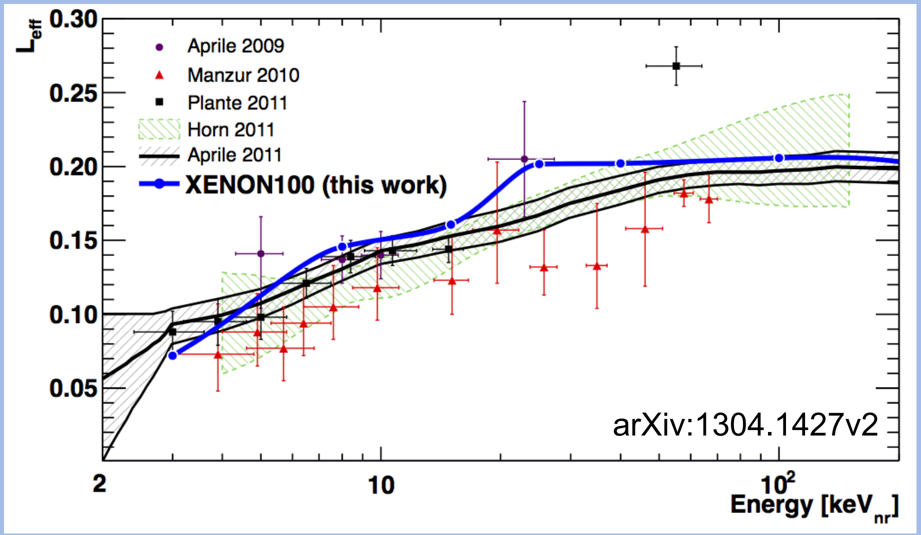
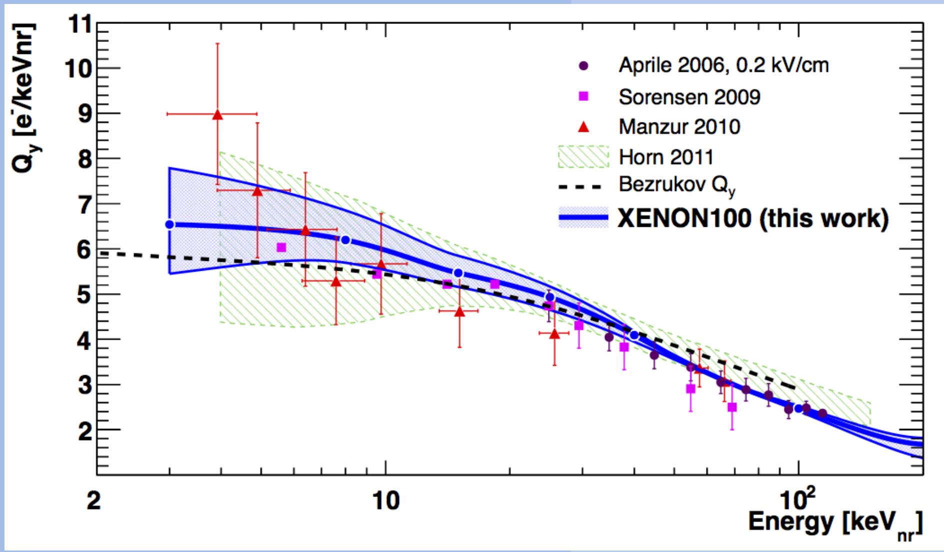
- L_{eff}: Relative light yield of nuclear recoils
- Q_y: Charge yield of nuclear recoils
- Currently no published measurements below 3 keV

$$E = \frac{cS1}{L_y}\frac{1}{\mathcal{L}_{eff}(E)}\frac{S_{ee}}{S_{nr}}$$

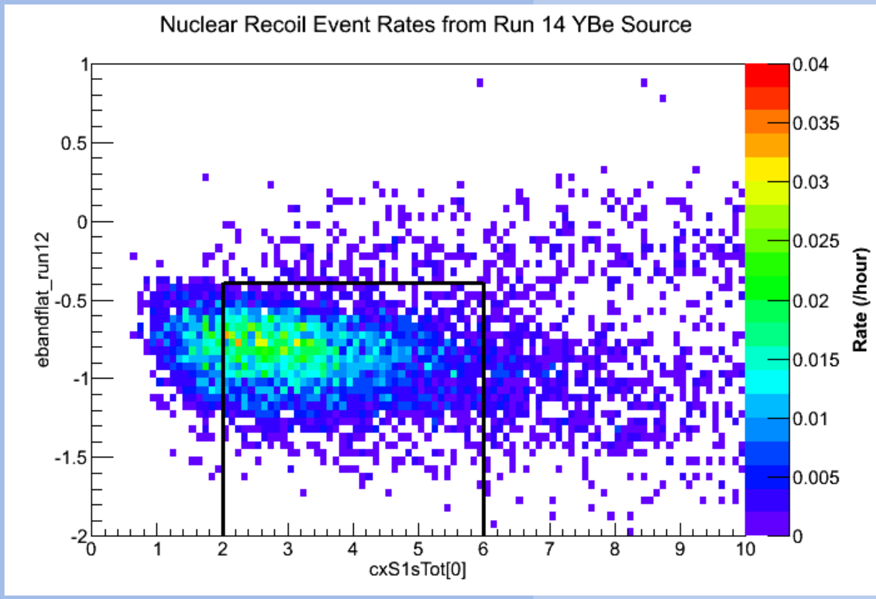
$$E = \frac{cS2}{Y}\frac{1}{\mathcal{Q}_y(E)}$$





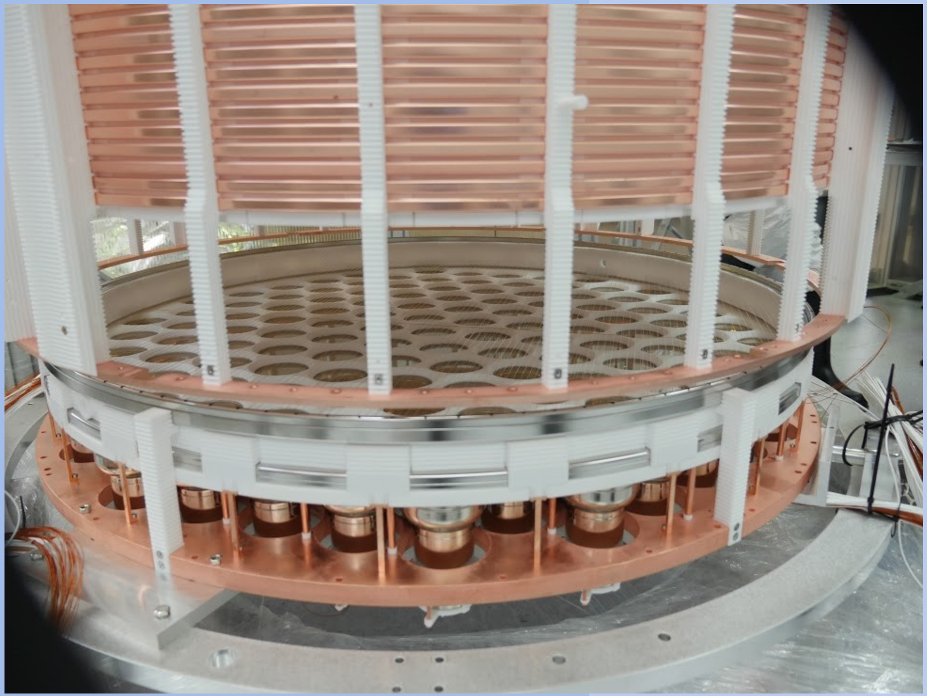
XENON100 ^{88}Y/Be Photo-Neutron Source Measurement

- 152 keV mono-energetic neutrons
  - Nuclear recoils below 4.5 keV
- Observation of NR events due to Poisson upward fluctuations
- Goal: Decrease uncertainties of L_{eff}/Q_y at low energies



Summary

- LXe TPCs have currently best sensitivity for m_x > 6 GeV
- R&D towards lower masses
  - Increase LCE
  - „S2-only“ analysis
- Requirements
  - Decreasing uncertainties in L_{eff} and Q_y



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Backup Slides

ER Background XENON1T

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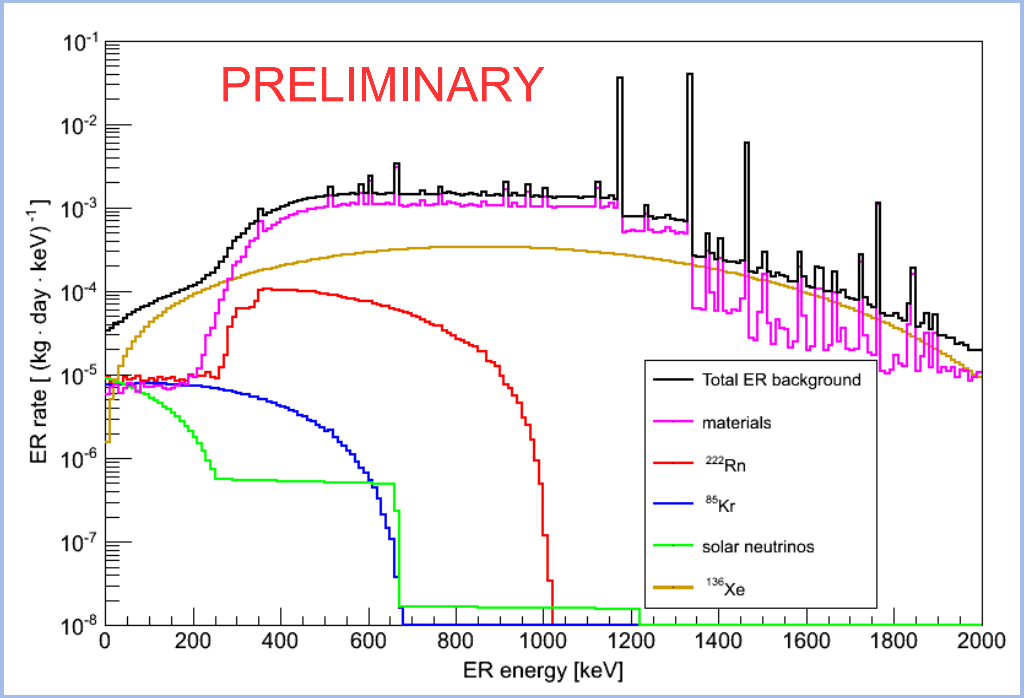

1 t FV, 2-12 keV

	Events (y^{-1})
Materials	27 ± 3
^{222}Rn	56 ± 11
^{85}Kr	28 ± 6
Solar ν	32 ± 1
^{136}Xe	9 ± 5

Trigger Efficiency XENON100

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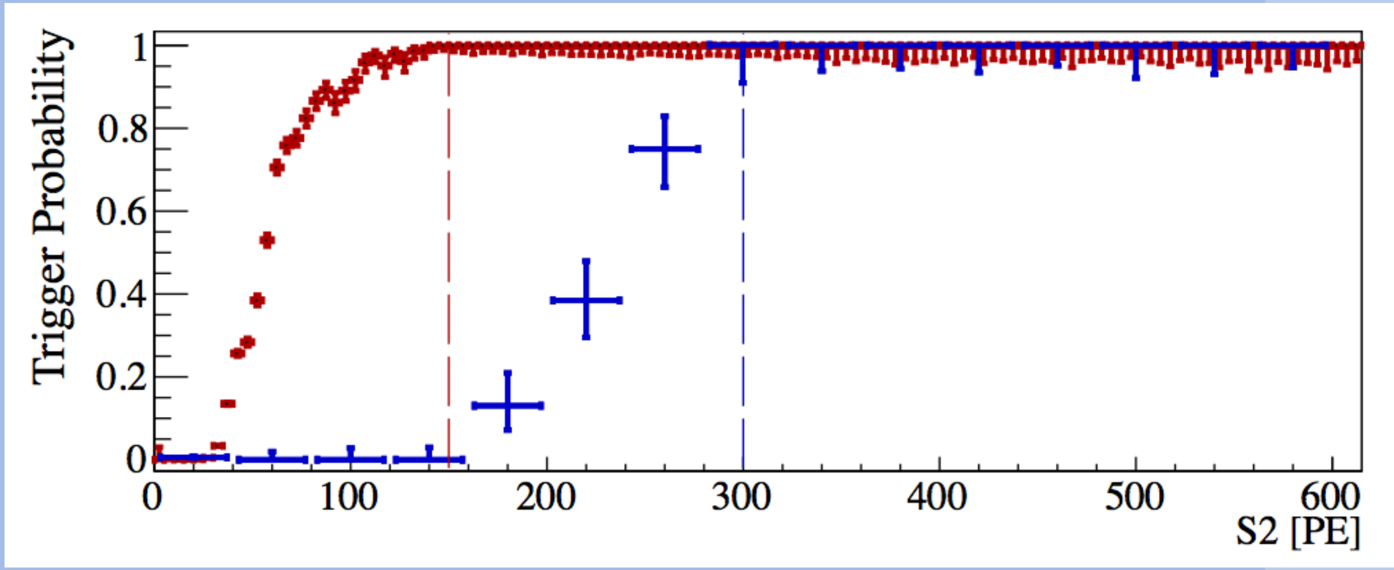

XENON1T Energy Scale

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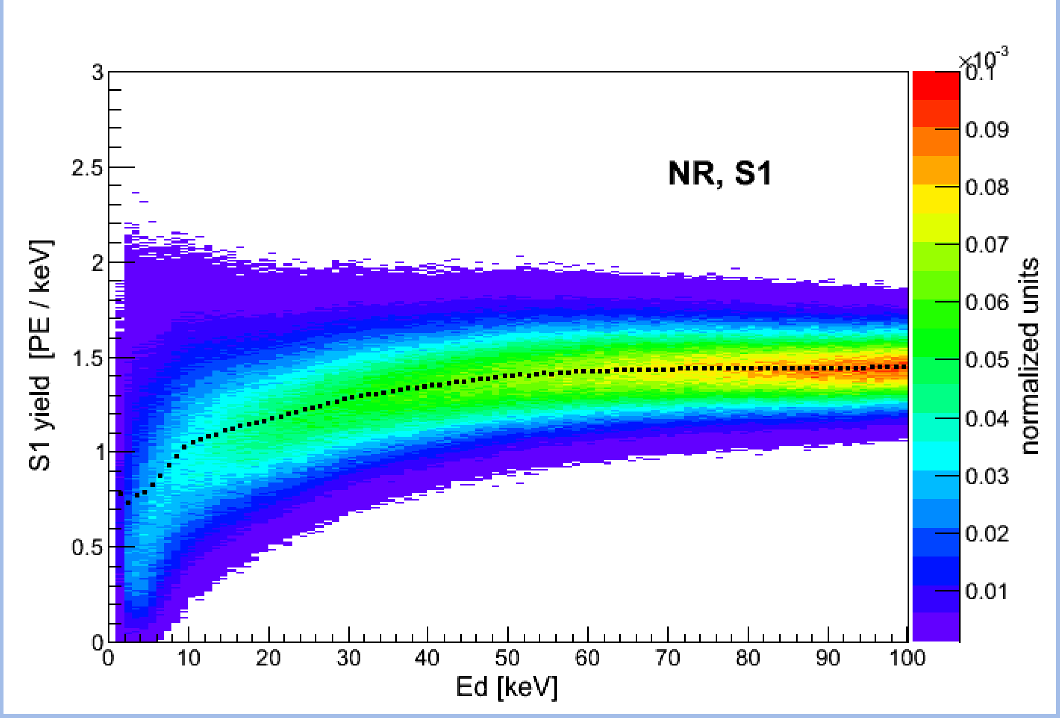

LCE XENON100

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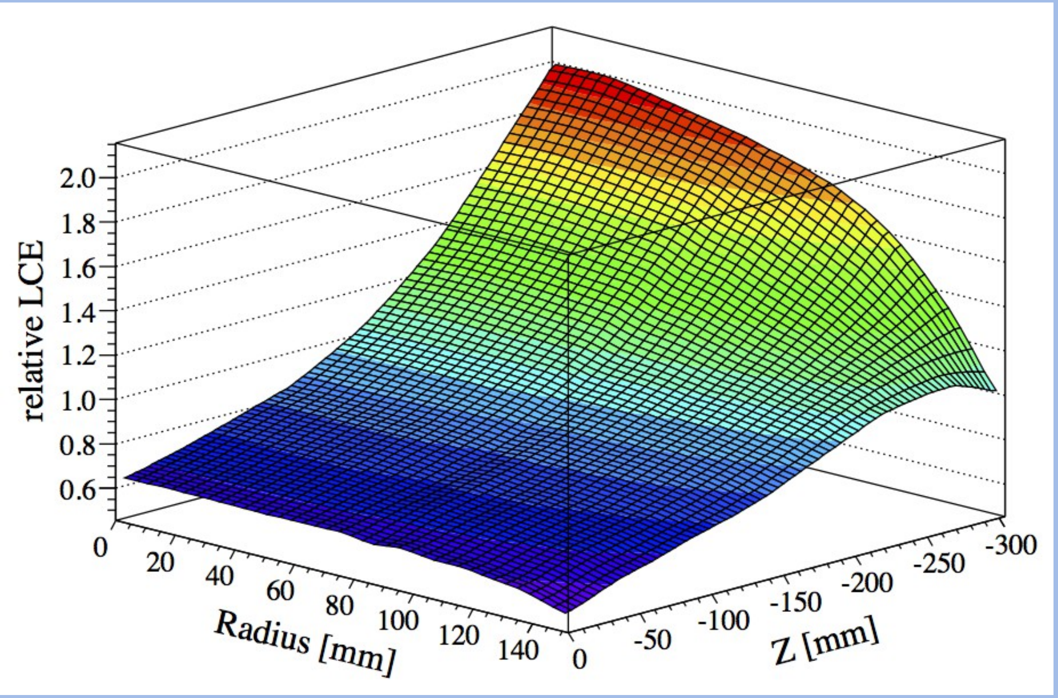

Double Photoelectron Emission

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