First Dark Matter Search Results from XENON1T

(arXiv:1705.06655)

Fei Gao
Columbia University

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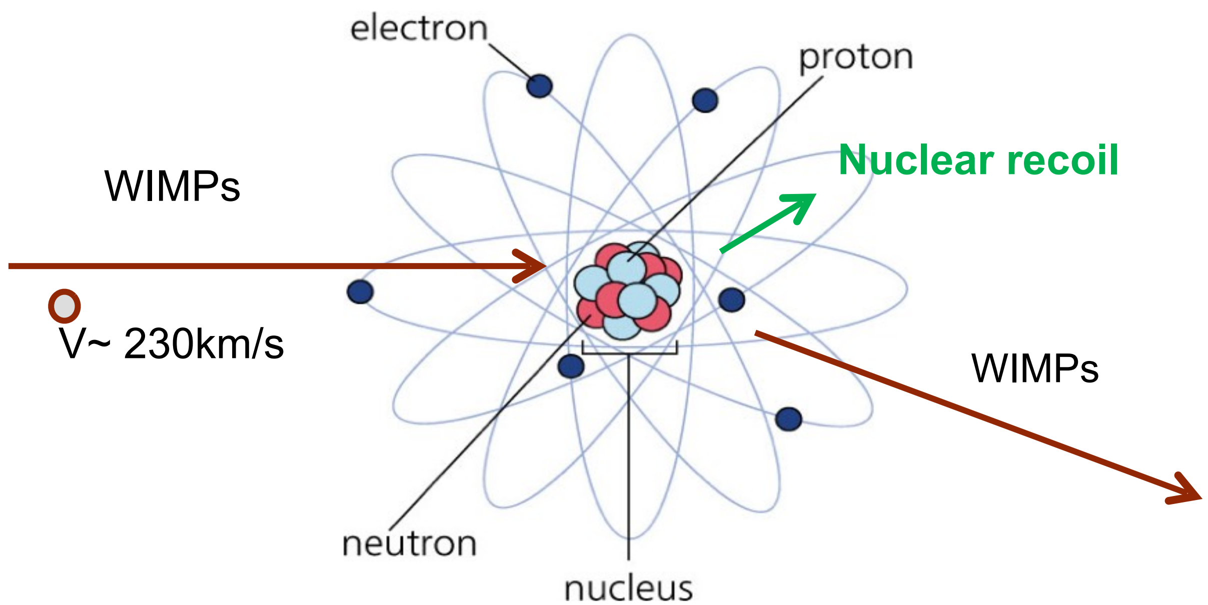
PANIC2017

Direct Search for WIMPs

Elastic Scattering of WIMPs off target



Recoil Energy:

$$Er = \frac{\mu^2 v^2}{m_N}(1 - cos\theta) \sim 10keV$$

$$R \propto N \frac{\rho_\chi}{m_\chi} < \sigma_{\chi \leftrightarrow N} >$$

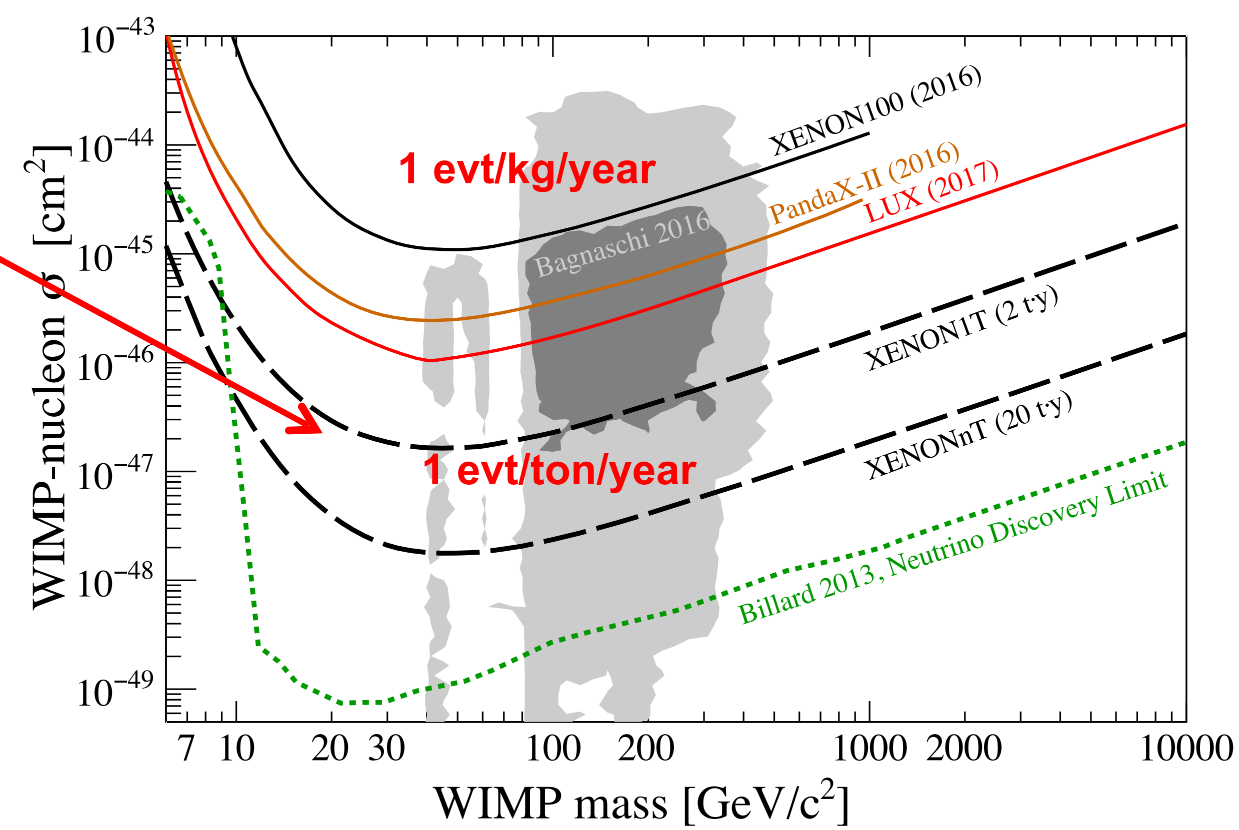
Requirements for WIMPs detectors

Large target mass

Low energy threshold

Ultra-low background

Interaction type discrimination

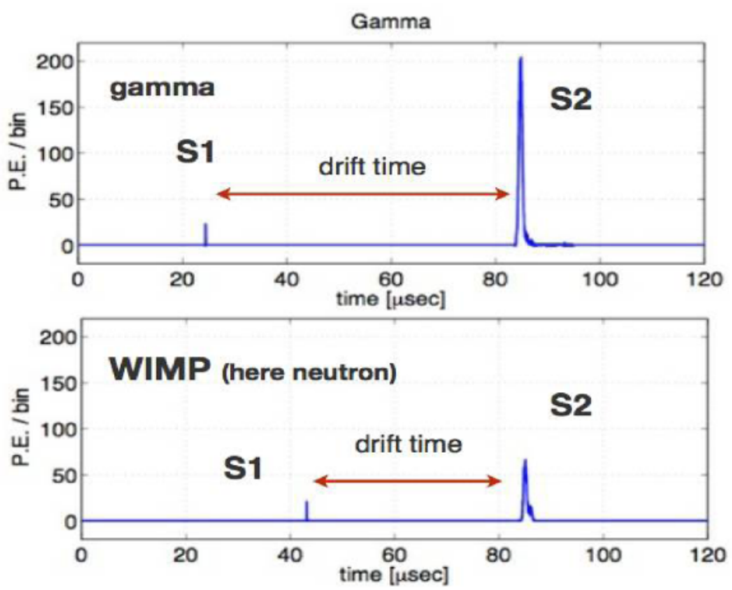


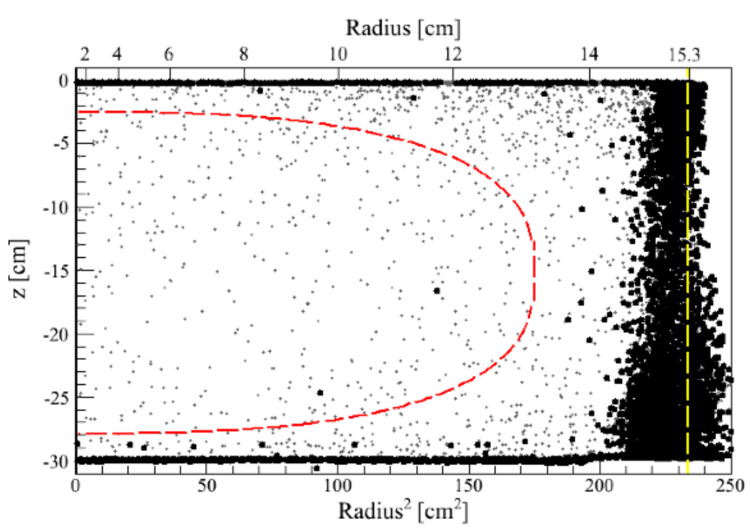
IN LVMINE TVO VIDEBIMVS LVMEN

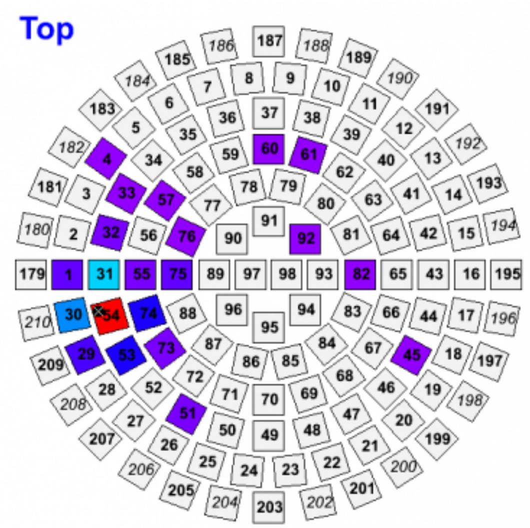
Dual phase xenon TPC

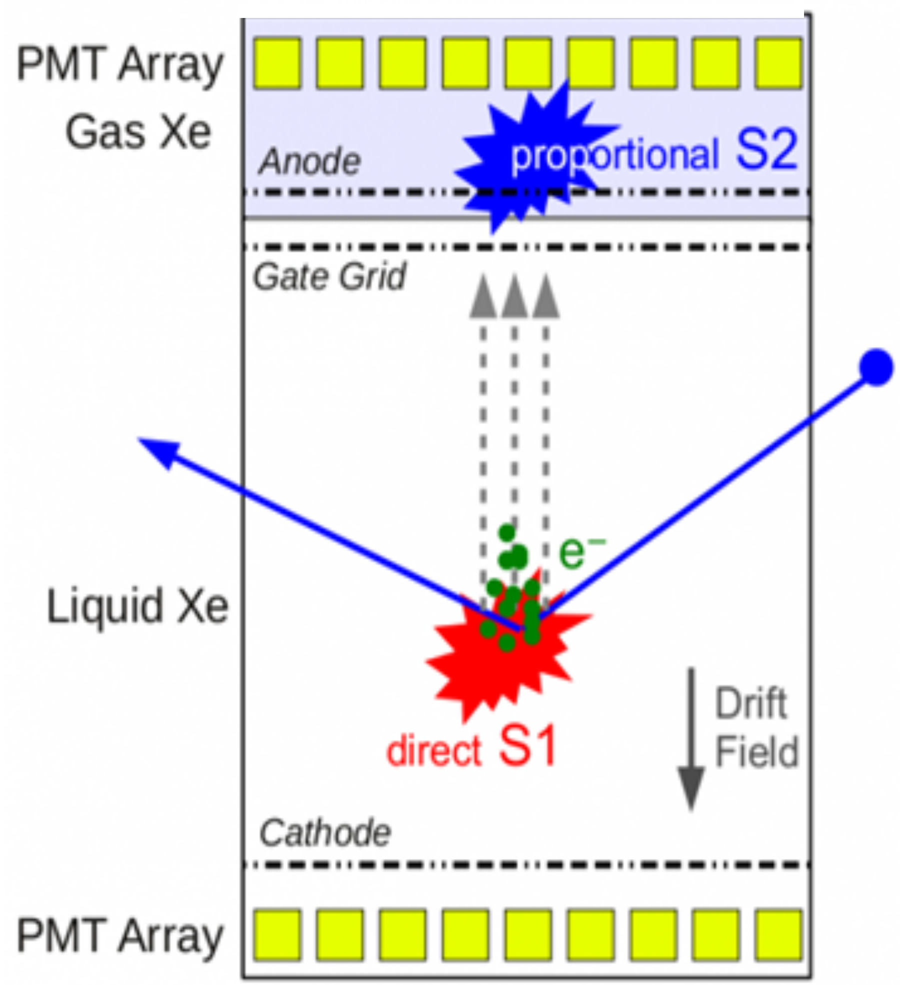
Xe XENON Dark Matter Project

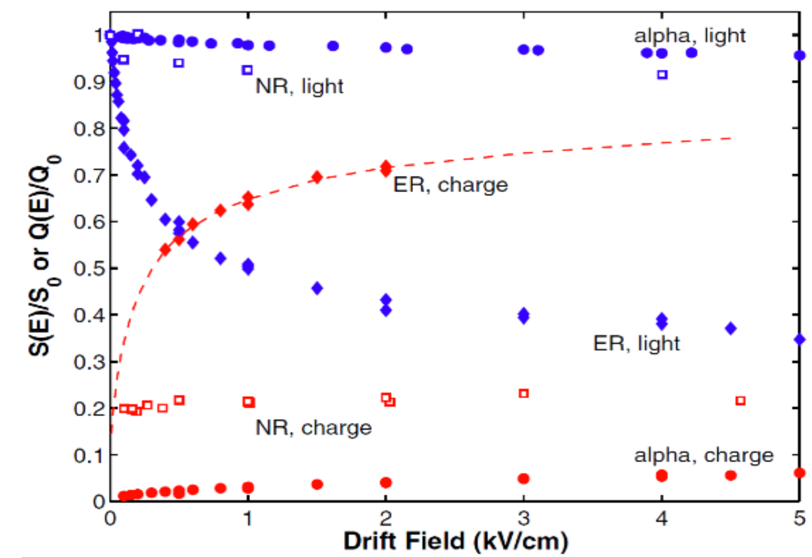
3-D position reconstruction



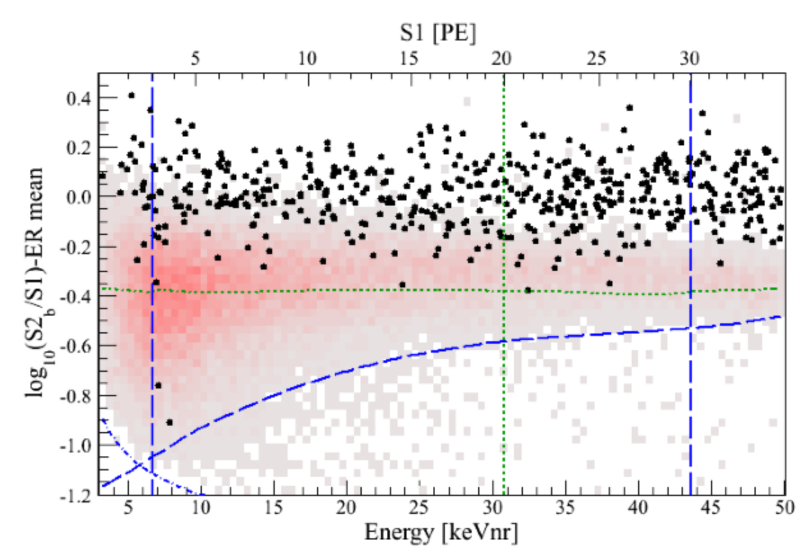




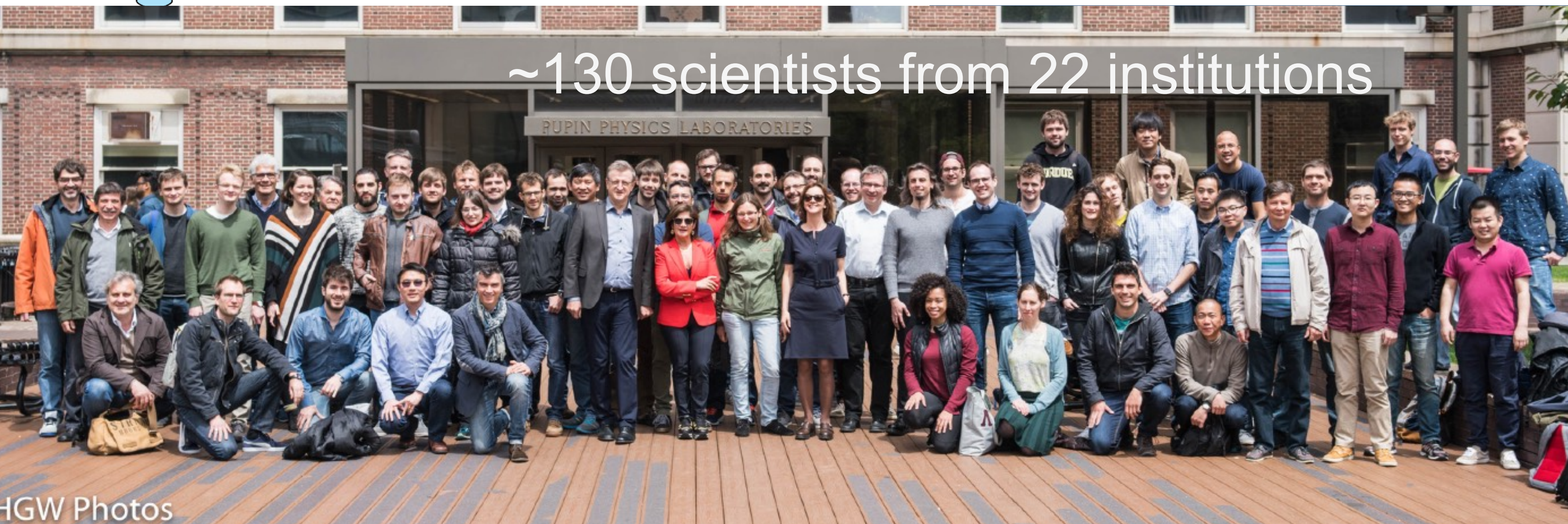


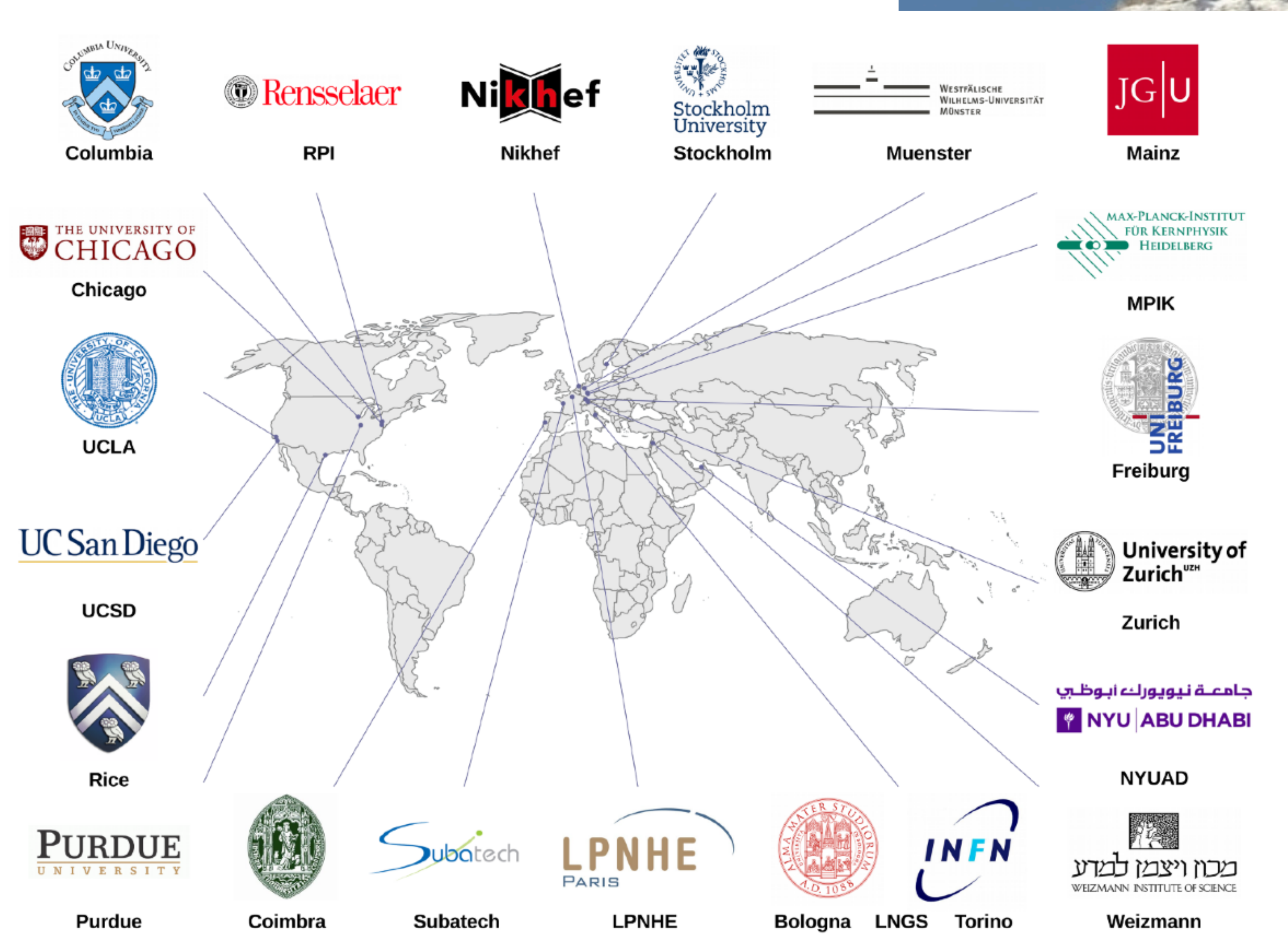


NR/ER Discrimination



XENON World


~130 scientists from 22 institutions
PUPIN PHYSICS LABORATORIES
HGW Photos


Columbia
Rensselaer
RPI
Nikhef
Nikhef
Stockholm University
Stockholm
Westfälische Wilhelms-Universität Münster
Muenster
JG|U
Mainz
The University of Chicago
Chicago
UCLA
UC San Diego
UCSD
Rice
Max-Planck-Institut für Kernphysik Heidelberg
MPIK
UNI FREIBURG
Freiburg
University of Zurich
Zurich
جامعة نيويورك ابوظبي
NYU ABU DHABI
NYUAD
Purdue University
Purdue
Coimbra
Subatech
Subatech
LPNHE Paris
LPNHE
Bologna
INFN
LNGS
Torino
מכון ויצמן למדע
Weizmann Institute of Science
Weizmann


Laboratori Nazionali del Gran Sasso (LNGS), Italy
XENON1T

Phases of the XENON program

XENON10

2005-2007
15 cm drift TPC – 25 kg

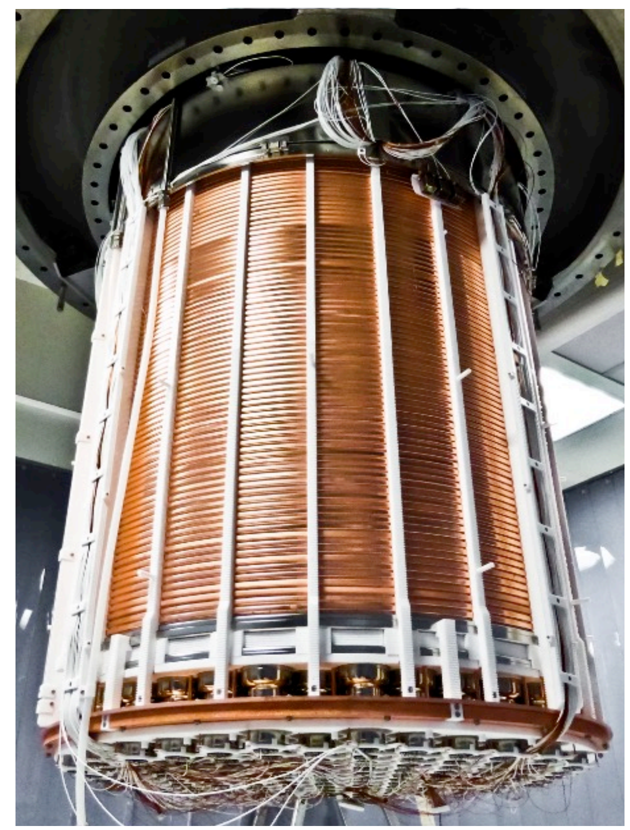
Achieved (2007)
$\sigma_{SI} = 8.8 \times 10^{-44}$ cm^2

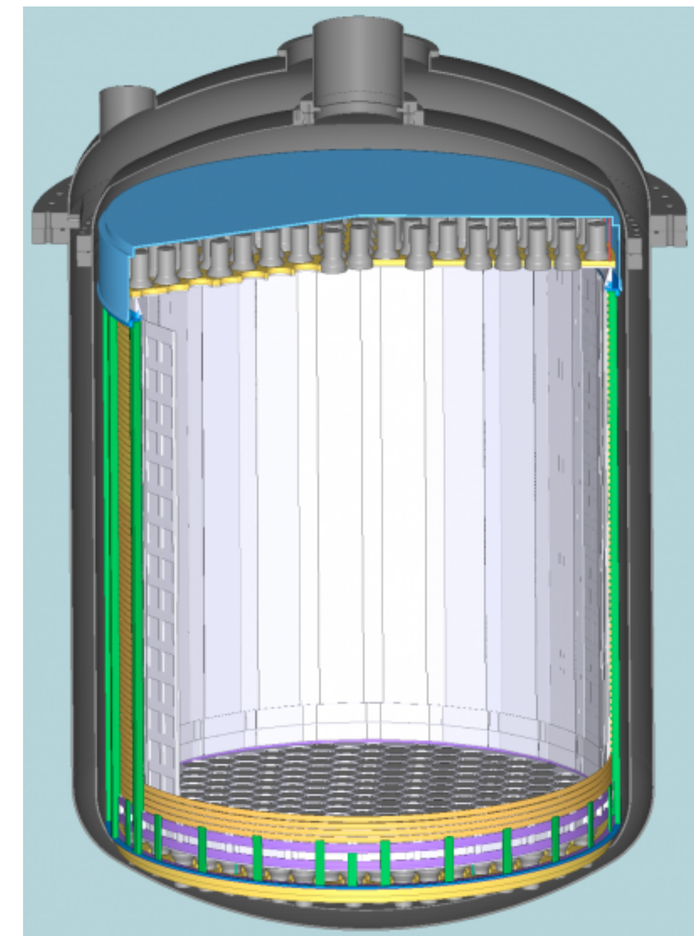
XENON100

2008-2016
30 cm drift TPC – 161 kg

Achieved (2016)
$\sigma_{SI} = 1.1 \times 10^{-45}$ cm^2

XENON1T / XENONnT





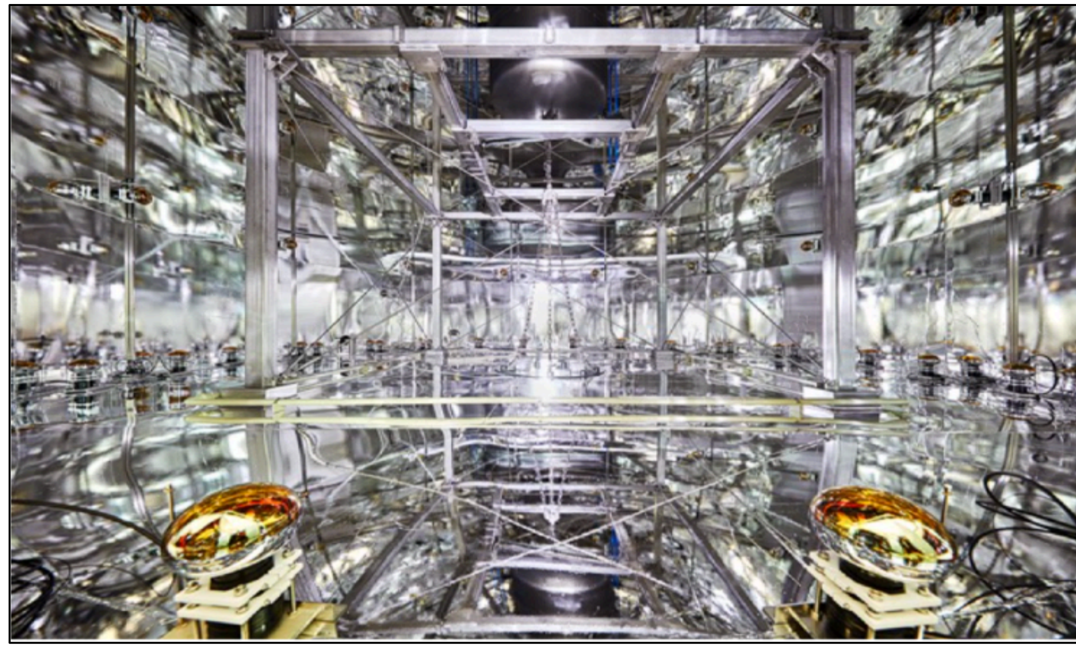
2013-2018 / 2019-2023
100 cm / 144 cm drift TPC - 3200 kg / ~8000 kg

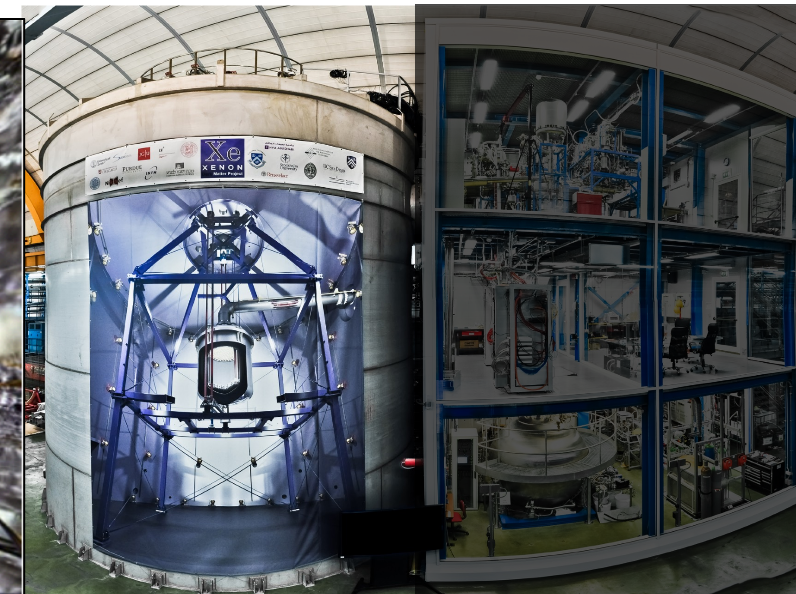
Projected (2018) / Projected (2023)
$\sigma_{SI} = 1.6 \times 10^{-47}$ cm^2 / $\sigma_{SI} = 1.6 \times 10^{-48}$ cm^2

XENON1T: All Systems

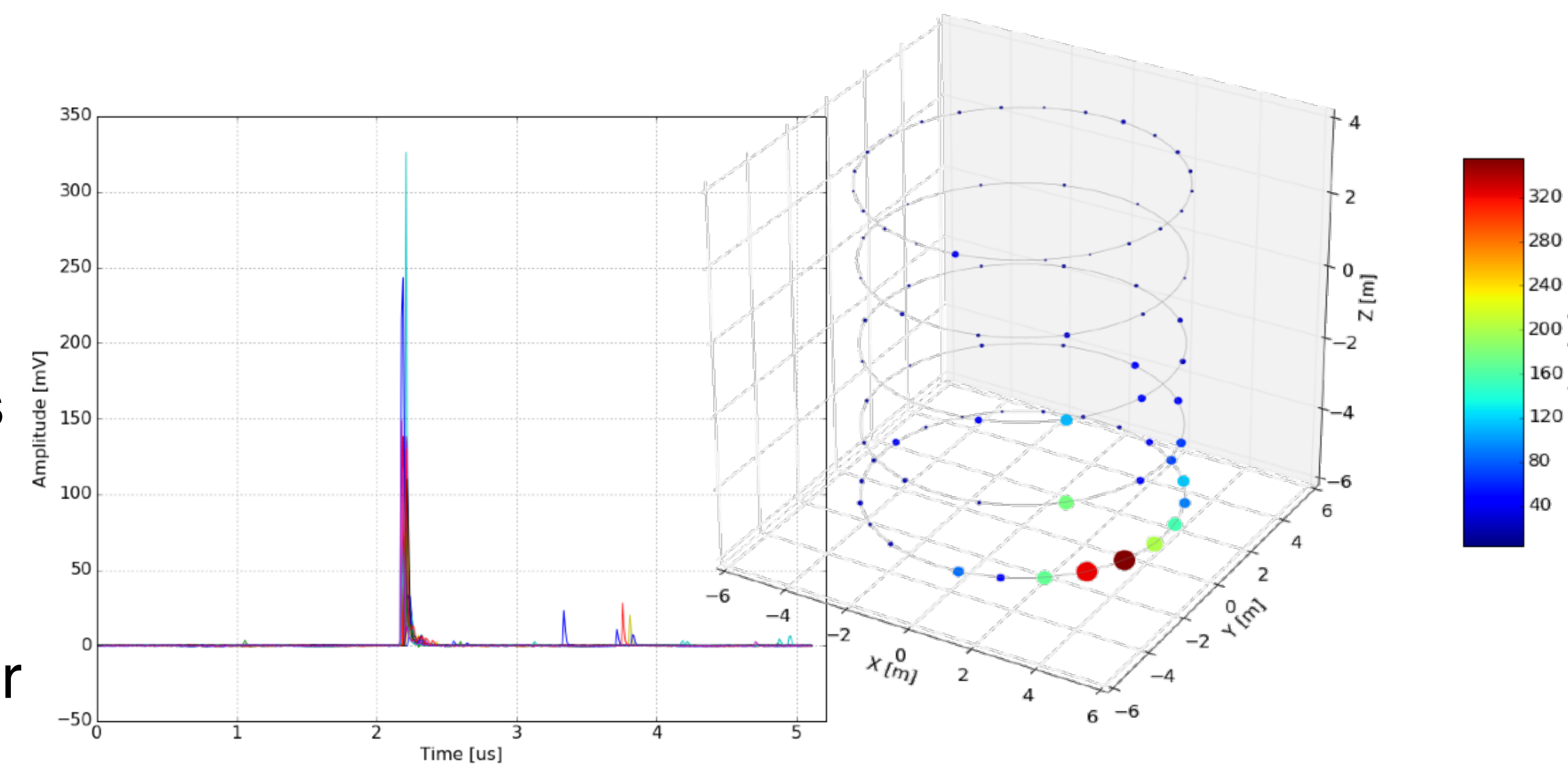
arXiv:1708.07051

Cherenkov Muon Veto



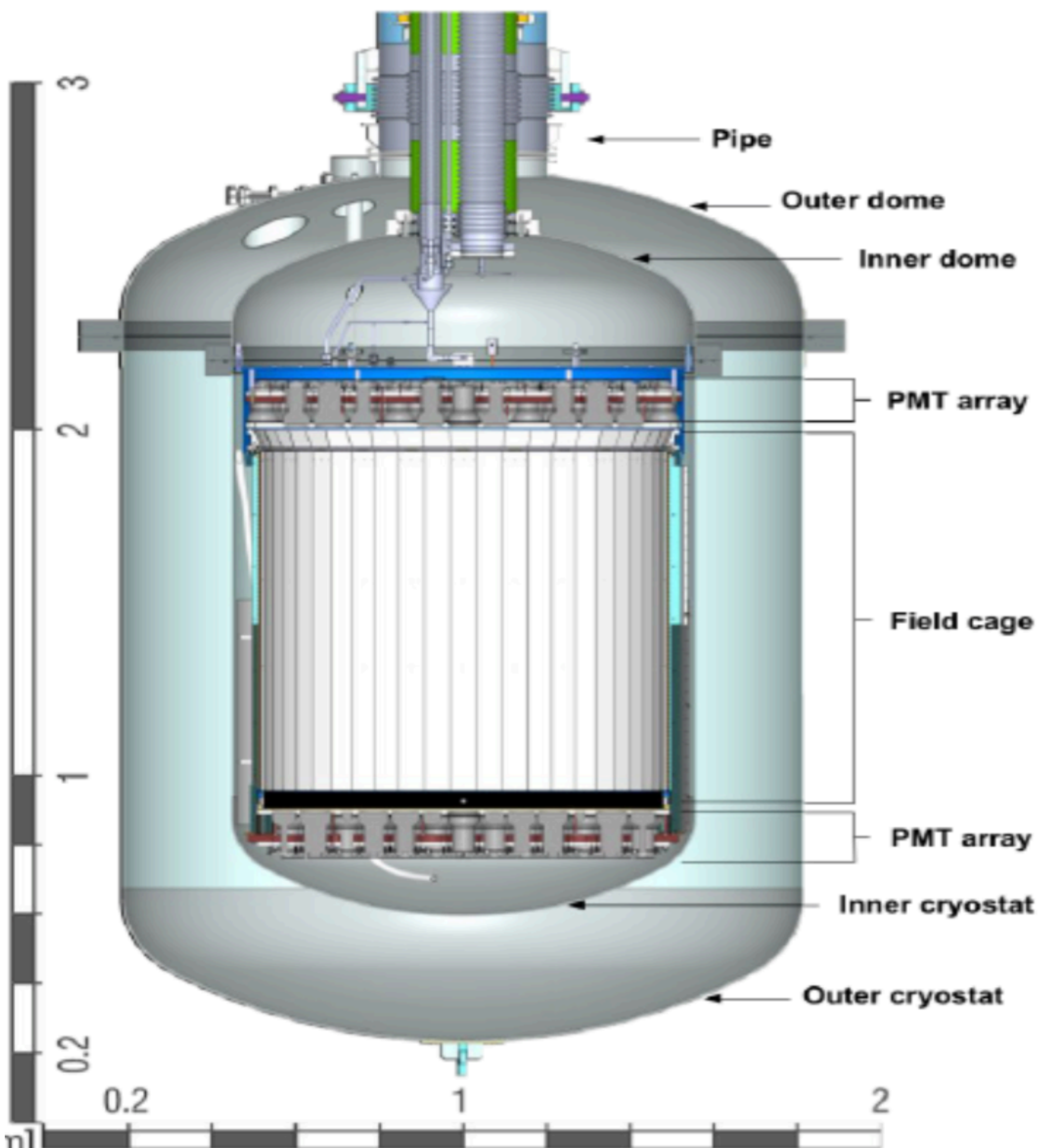


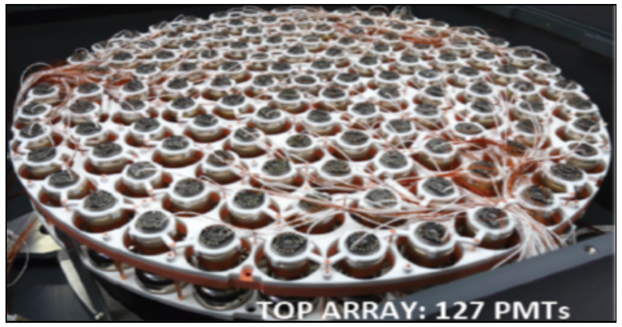
- Active shield against muons
- 84 high-QE 8'' Hamamatsu R5912 PMTs
- Trigger efficiency > 99.5% for muons in water tank
- Can suppress cosmogenic neutron background to < 0.01 events/ton/year
- No coincidences with TPC found in this science run

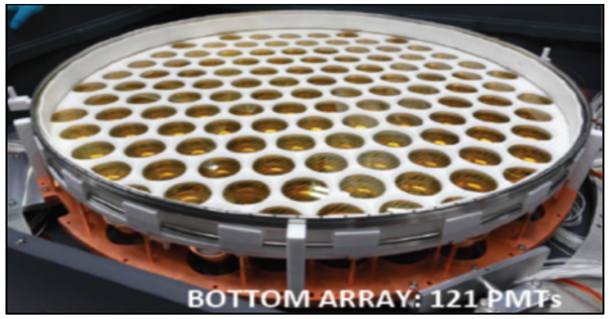


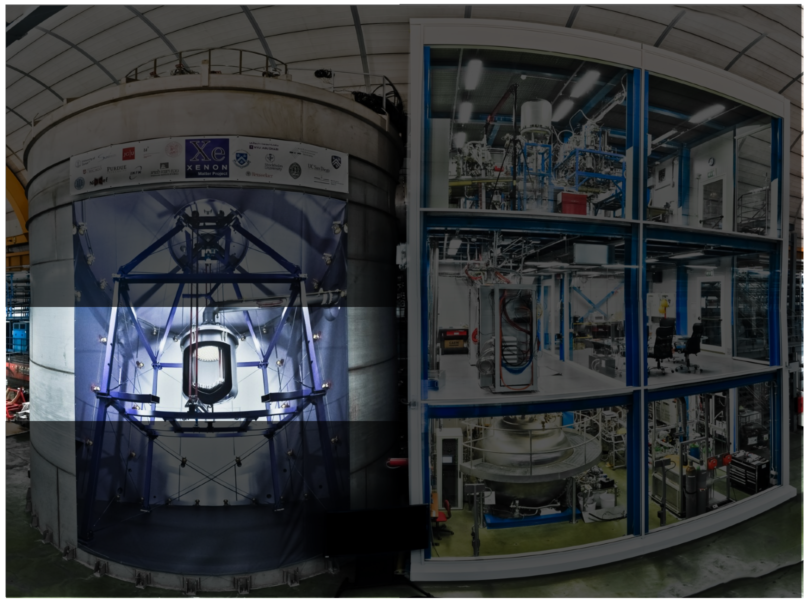
JINST 9, 11007 (2014)

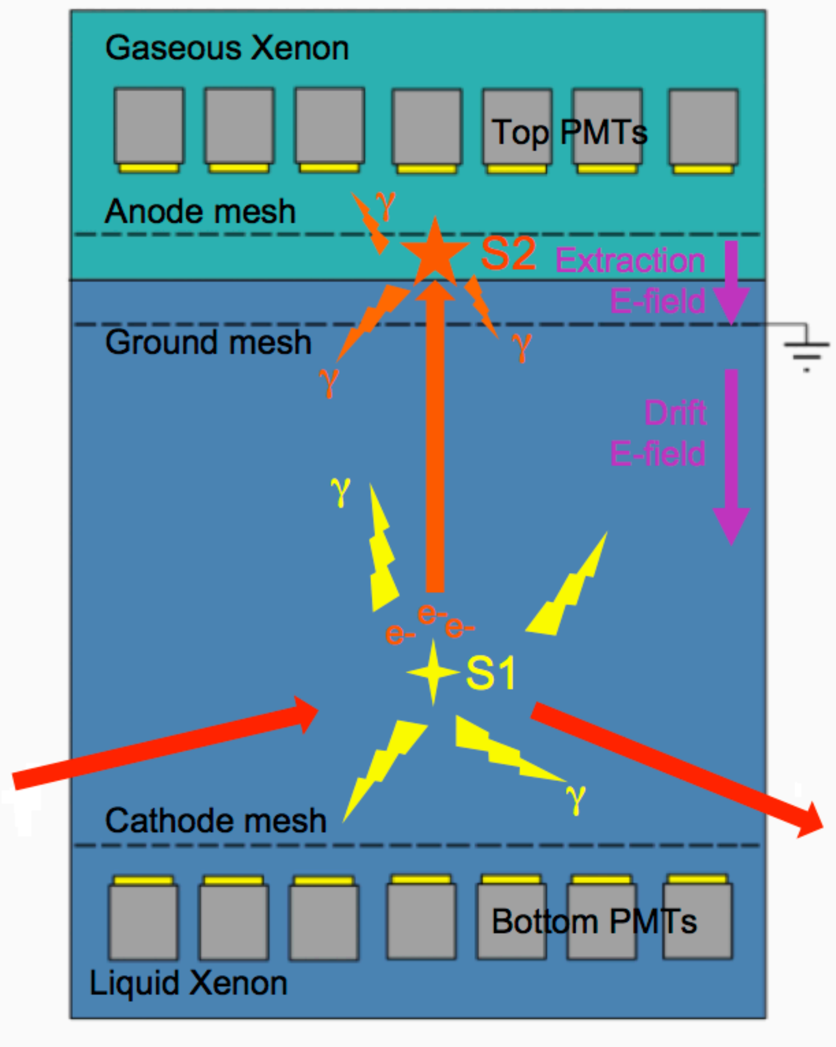
Time Projection Chamber







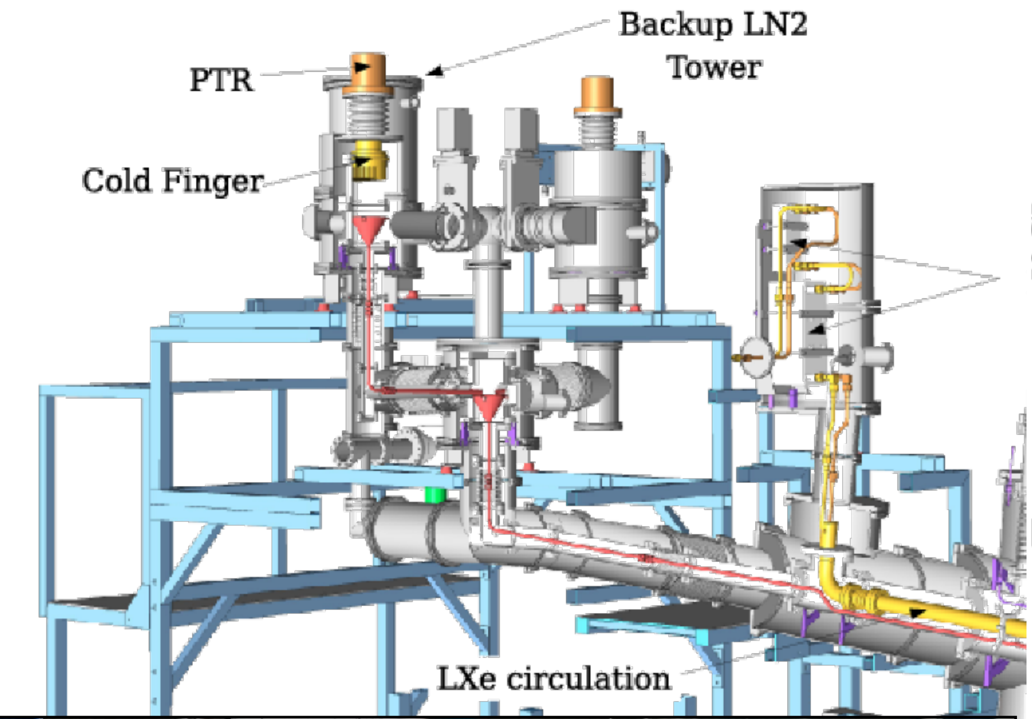




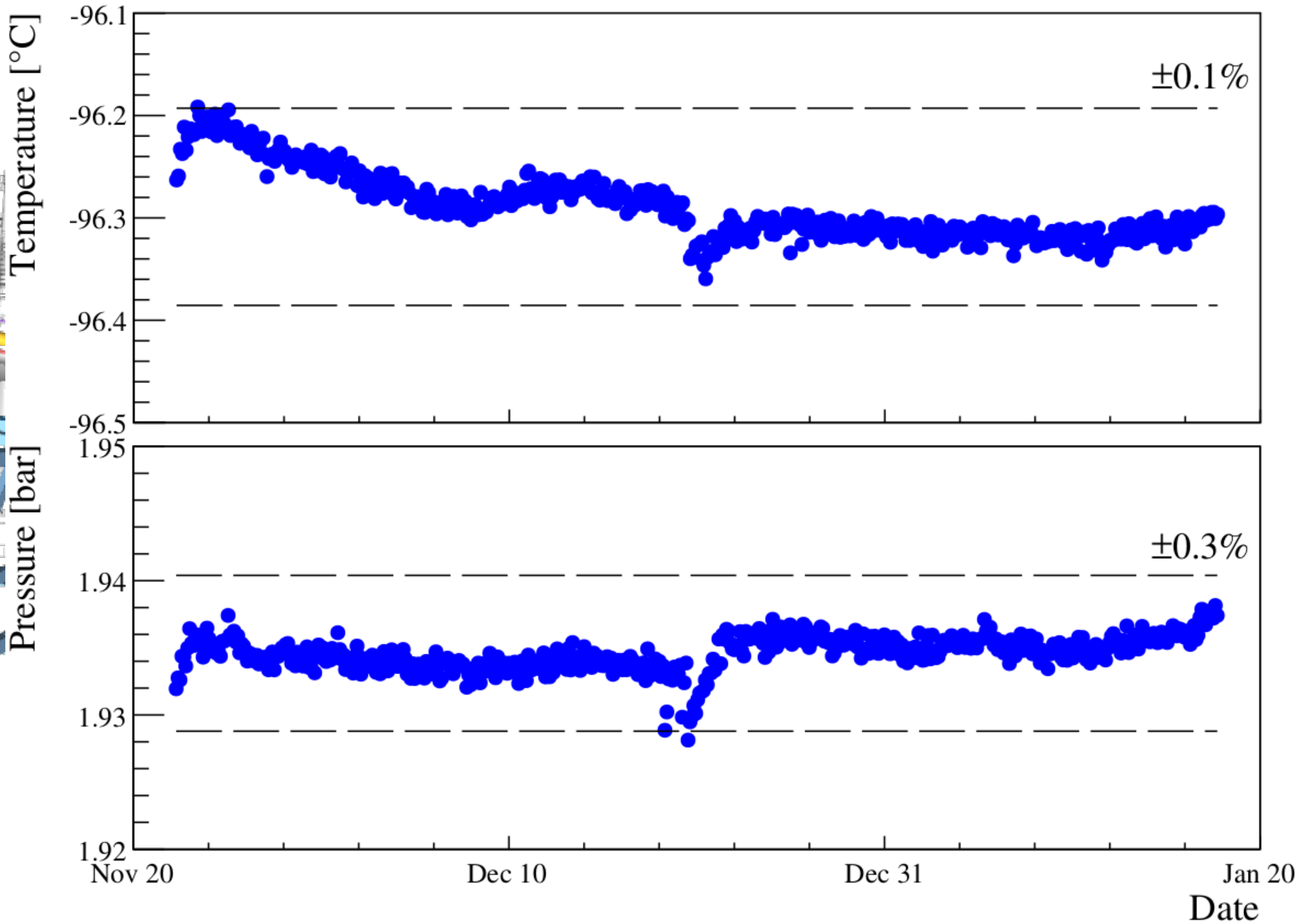
Eur. Phys. J. C 75, no. 11, 546 (2015)

Detector Stability

- LXe temperature stable at -96.07 °C, RMS 0.04 °C
- GXe pressure stable at 1.934 bar, RMS 0.001 bar

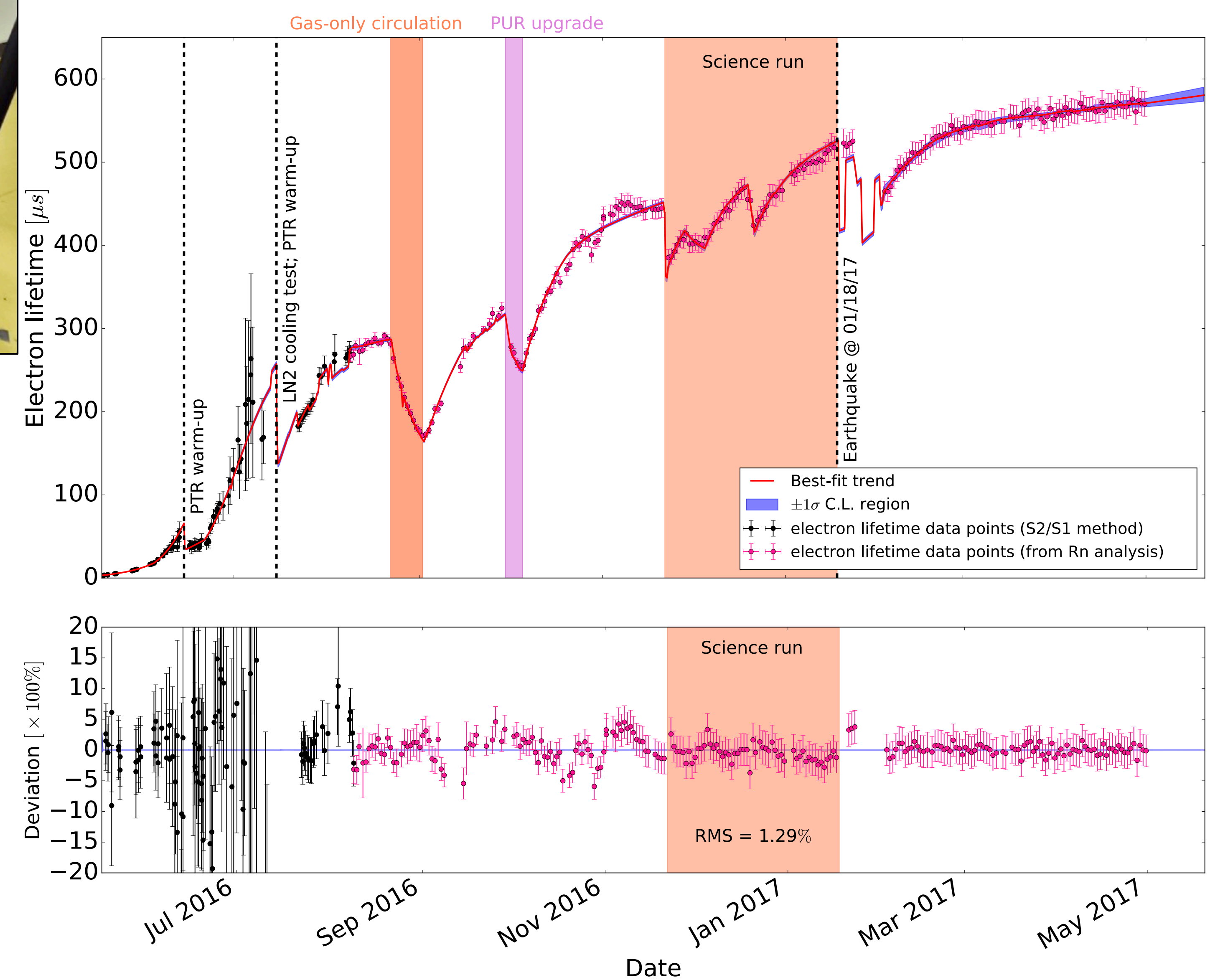


Slow control monitoring



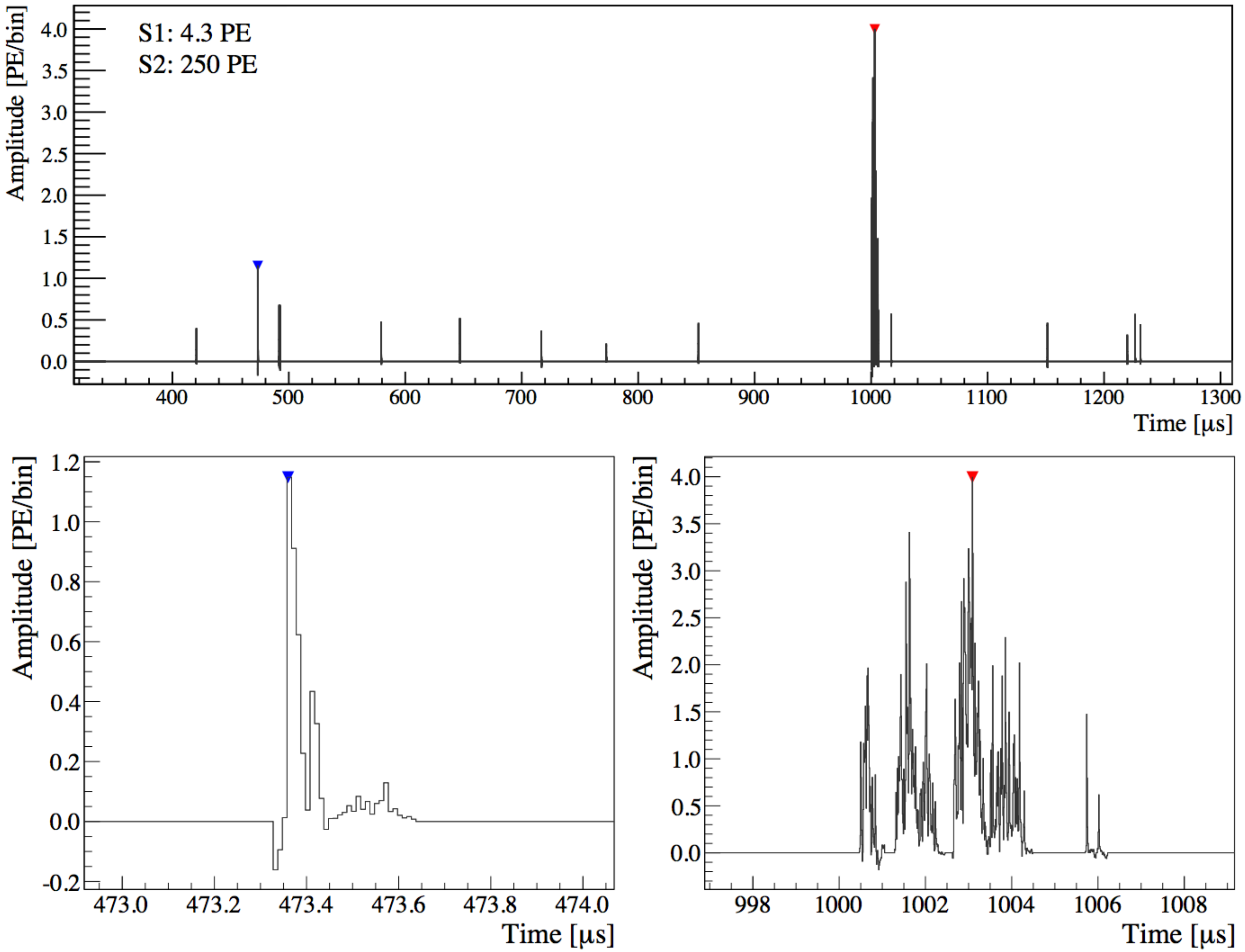
Xe Purification

Goal: remove electronegative impurities below 1 ppb (O2 equivalent) in the Xe gas



Performance: evolution of e-lifetime, monitored regularly with ERs calibration sources. Current value approaching the max drift time of the LXeTPC.

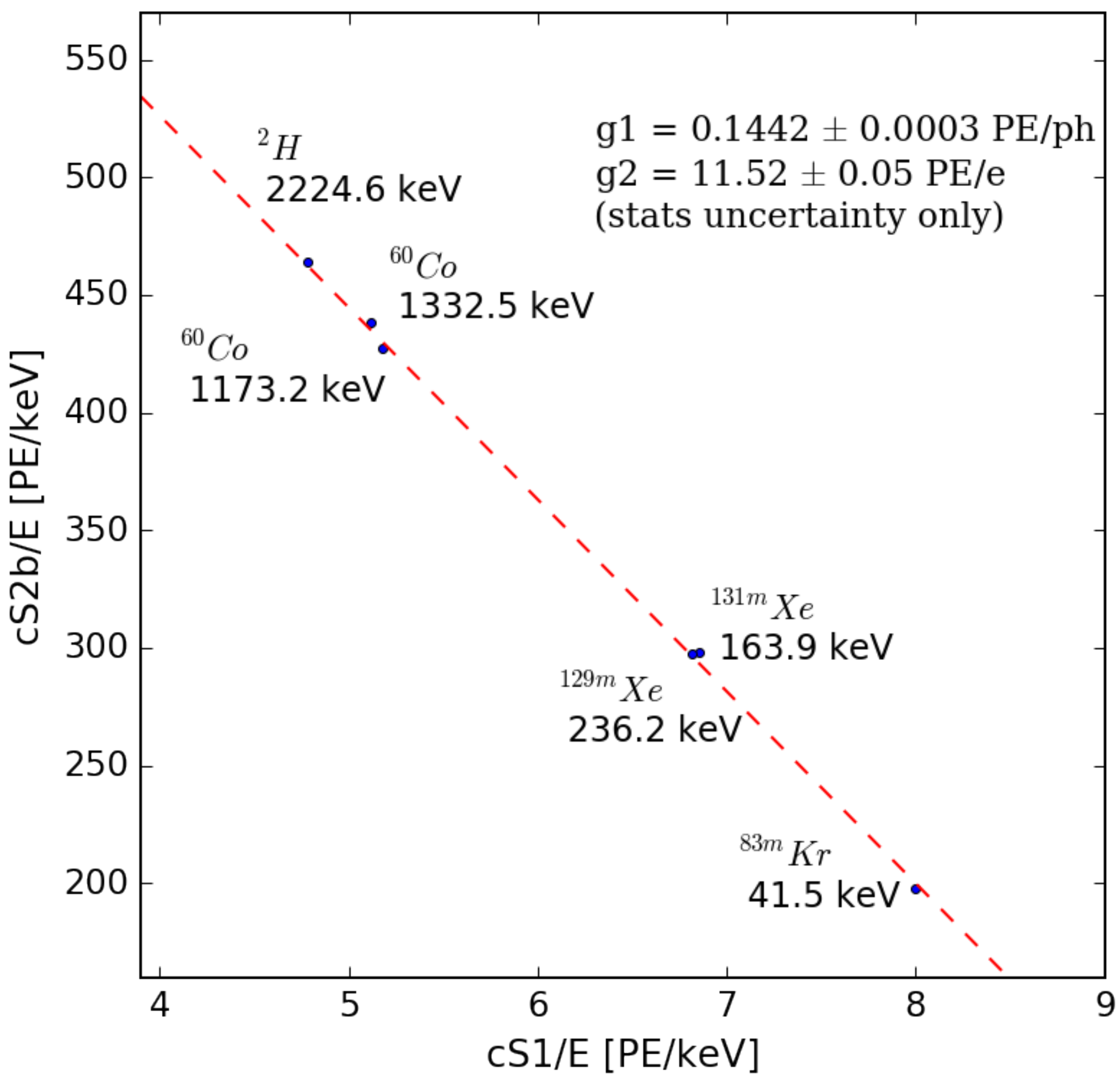
Real Waveform Example



arXiv:1708.07051

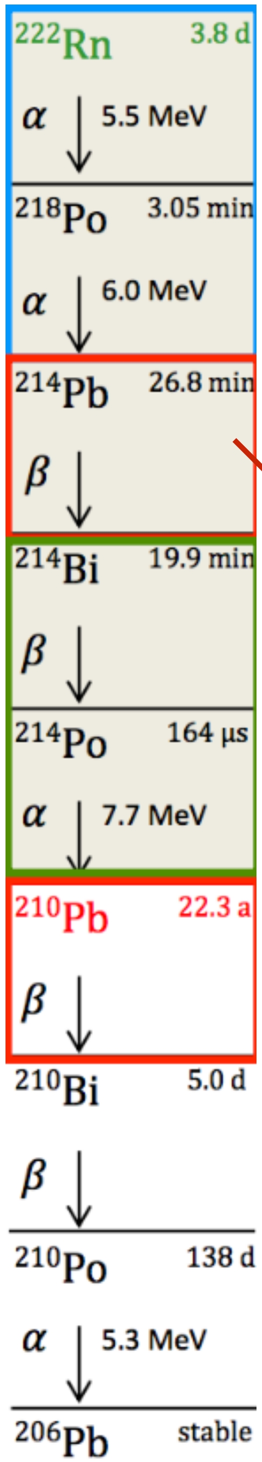
Energy response

$$E = (n_{ph} + n_e) \cdot W = (\frac{S1}{g1} + \frac{S2}{g2}) \cdot W$$



- Excellent linearity with electronic recoil energy from 40 keV to 2.2 MeV
- g1 = 0.144 ± 0.007 (sys) PE/photon corresponds to a photon detection efficiency of 12.5 ± 0.6% (taking into account double PE emission)
  - Assumptions of past MC sensitivity projected 12.1%.
- g2: the amplification of charge signal corresponds to near full extraction efficiency

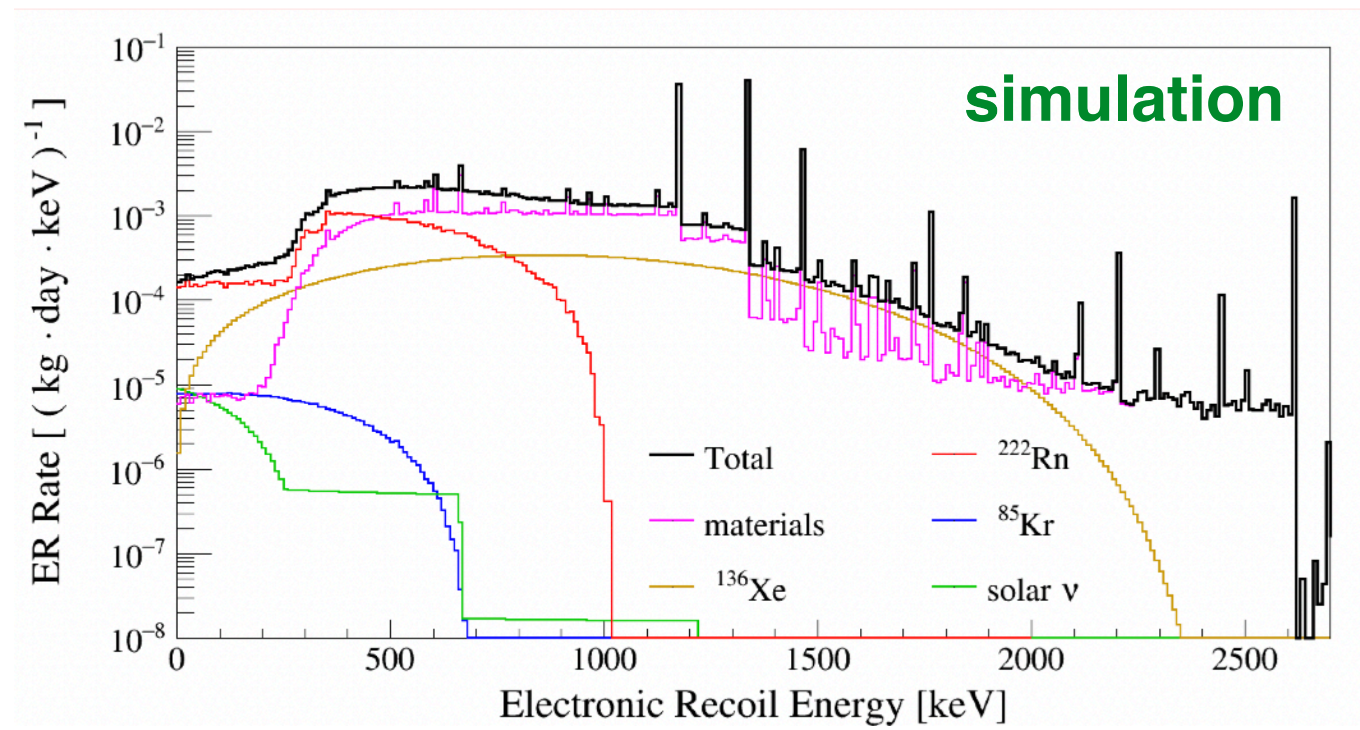
Background budget



Internal beta backgrounds:

- **Bkg goal for Kr85: 0.2 ppt Kr/Xe**
- **8.9% of Xe136 abundance**
- **Bkg goal for Rn222: 10 uBq/kg**

Dominating backgrounds



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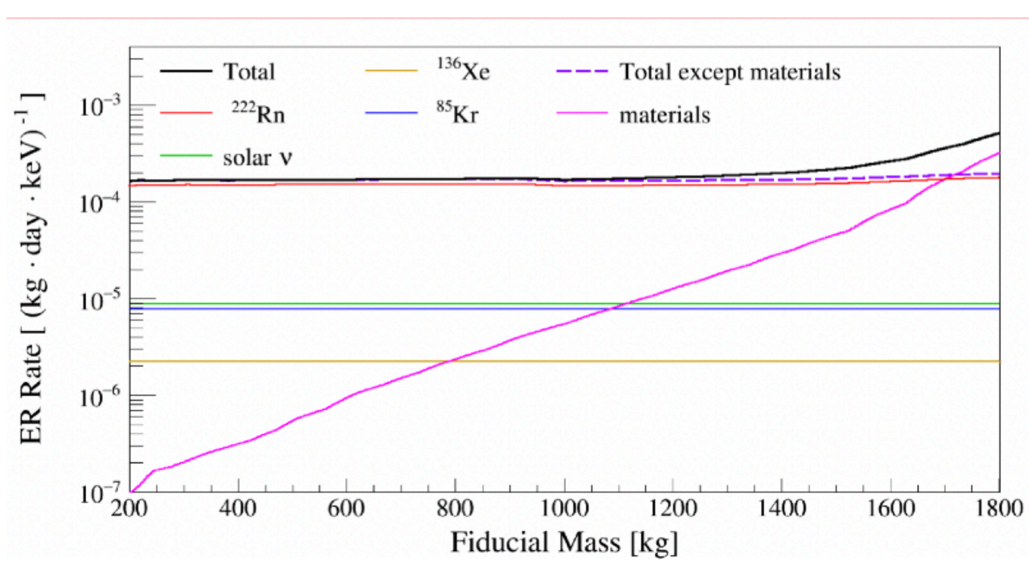
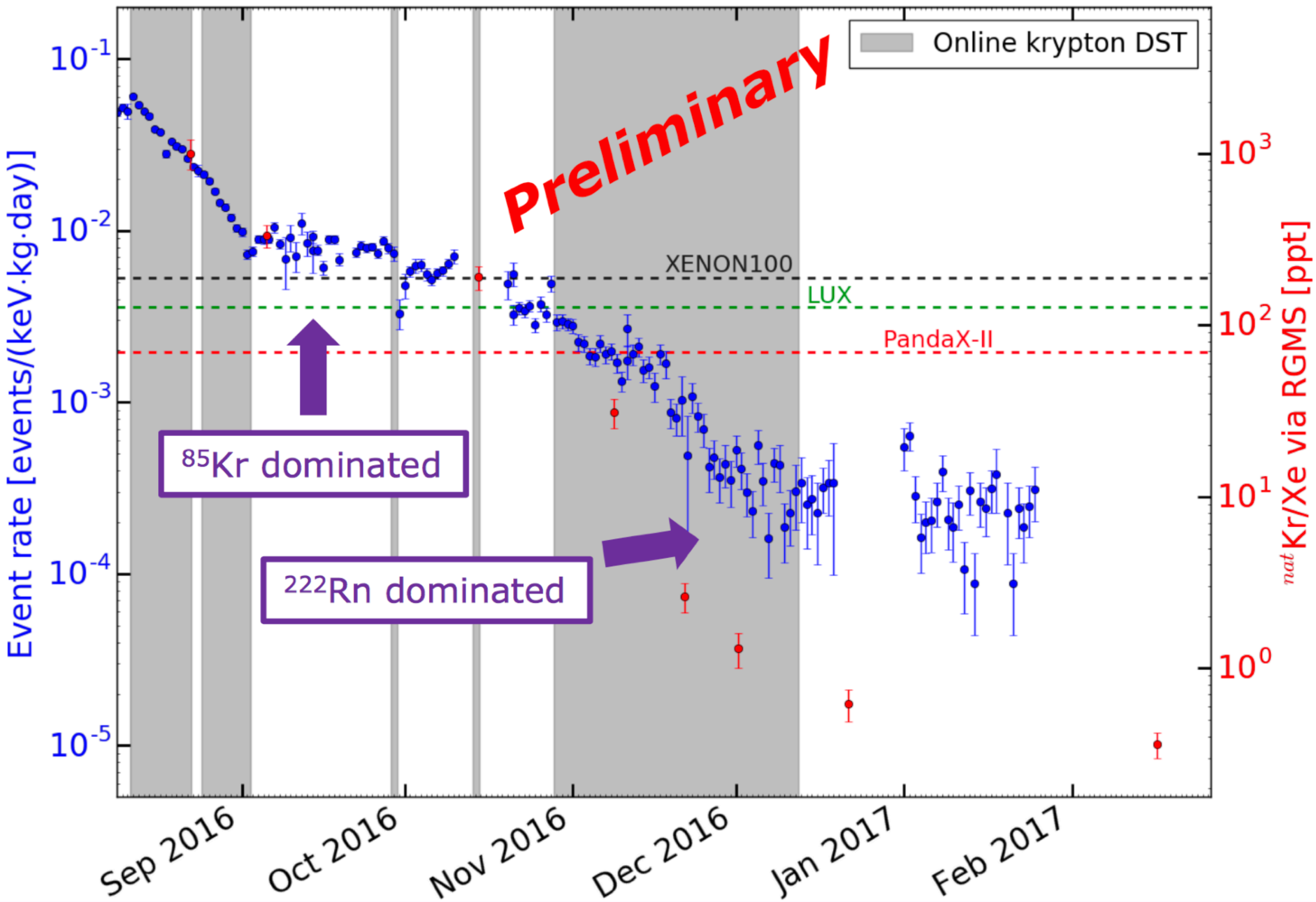


In 1 ton FV, gamma bkg from materials is of the same order as the one from Kr85

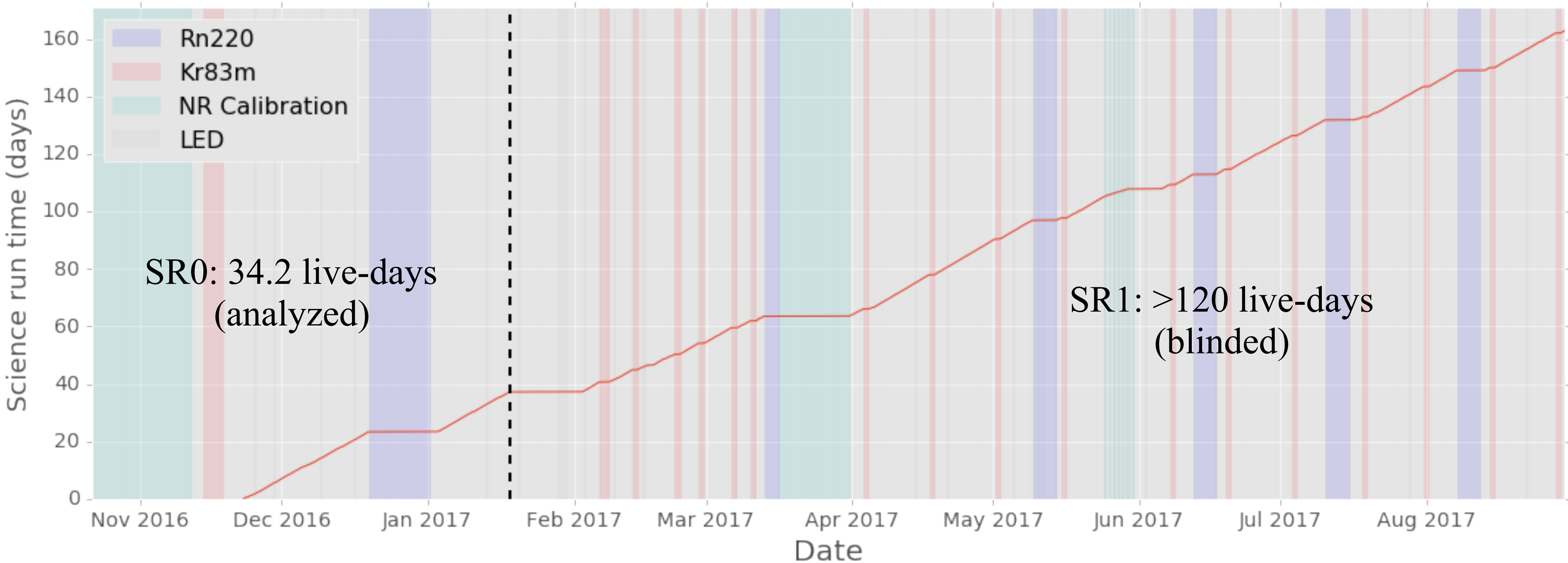
Source	Background $[(\text{kg}\cdot\text{day}\cdot\text{keV})^{-1}]$	Background $[\text{y}^{-1}]$	Fraction [%]
Materials	$(7.3\pm0.7)\cdot10^{-6}$	29 ± 3	4.1
^{222}Rn	$(1.54\pm0.15)\cdot10^{-4}$	620 ± 60	85.4
^{85}Kr	$(7.7\pm1.5)\cdot10^{-6}$	31 ± 6	4.3
^{136}Xe	$(2.3\pm1.1)\cdot10^{-6}$	9 ± 4	1.4
Solar neutrinos	$(8.9\pm0.2)\cdot10^{-6}$	36 ± 1	4.9
Total	$(1.80\pm0.15)\cdot10^{-4}$	720 ± 60	100

Online Kr distillation



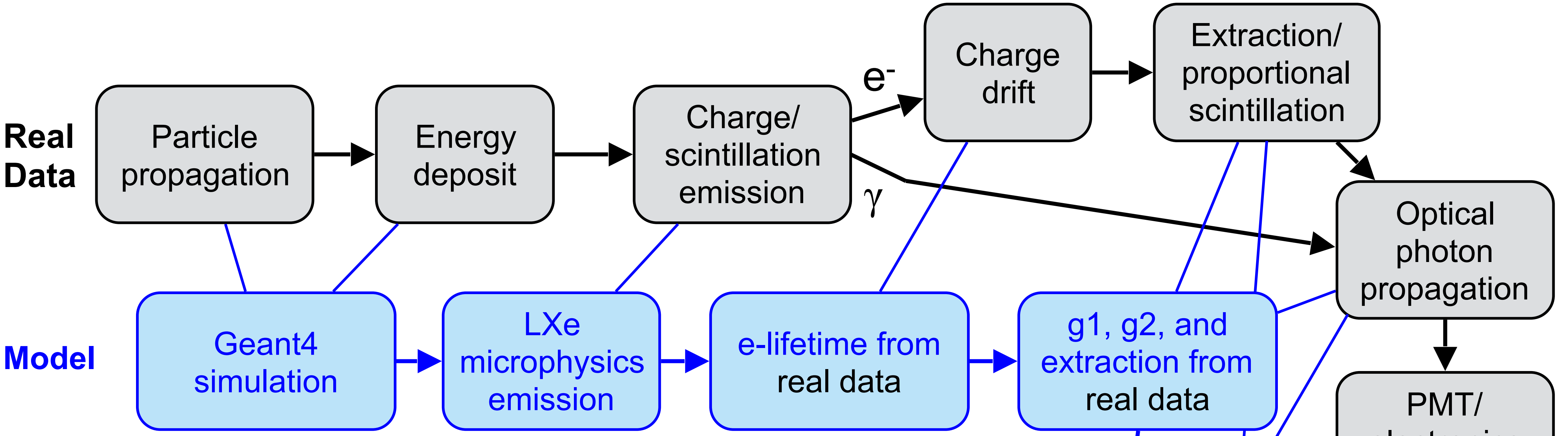
Eur. Phys. J. C77 (2017) no.5, 275 & arXiv:1702.06942

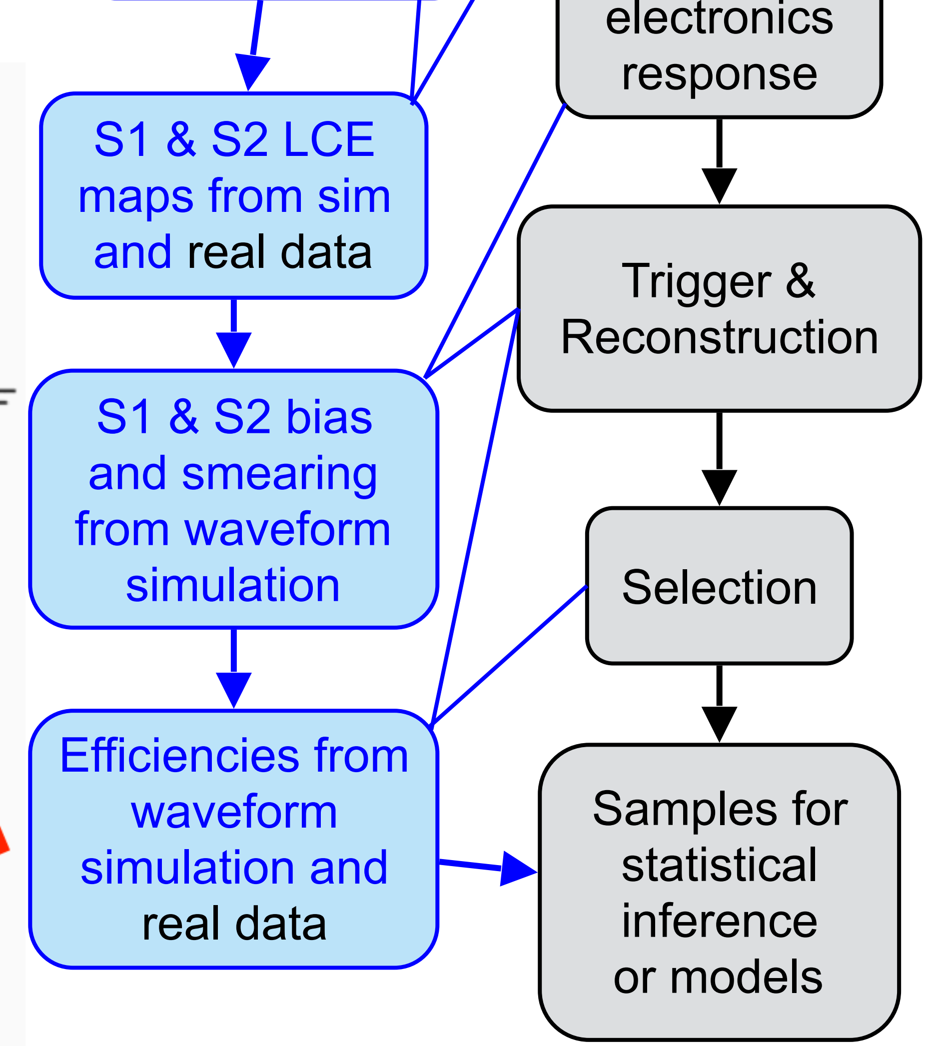
Dark Matter Exposure



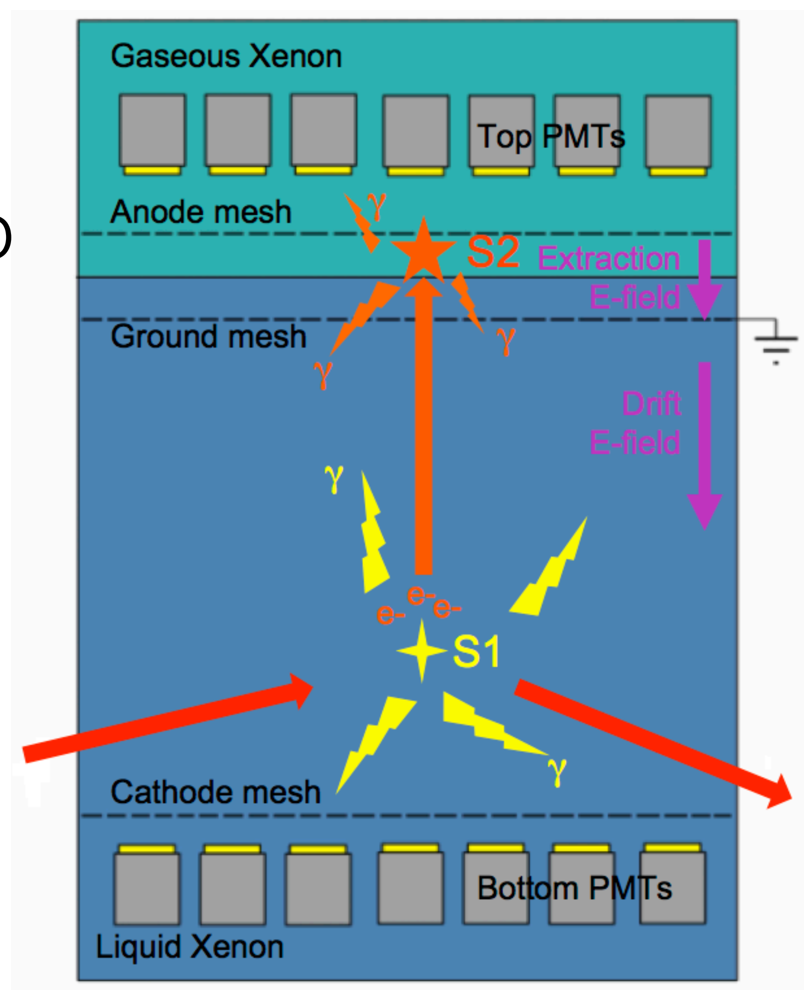
- This talk highlights the analysis of the first science run (SR0)
- We continue to take data after the earthquake and analyzing SR1 now

The ER and NR Models



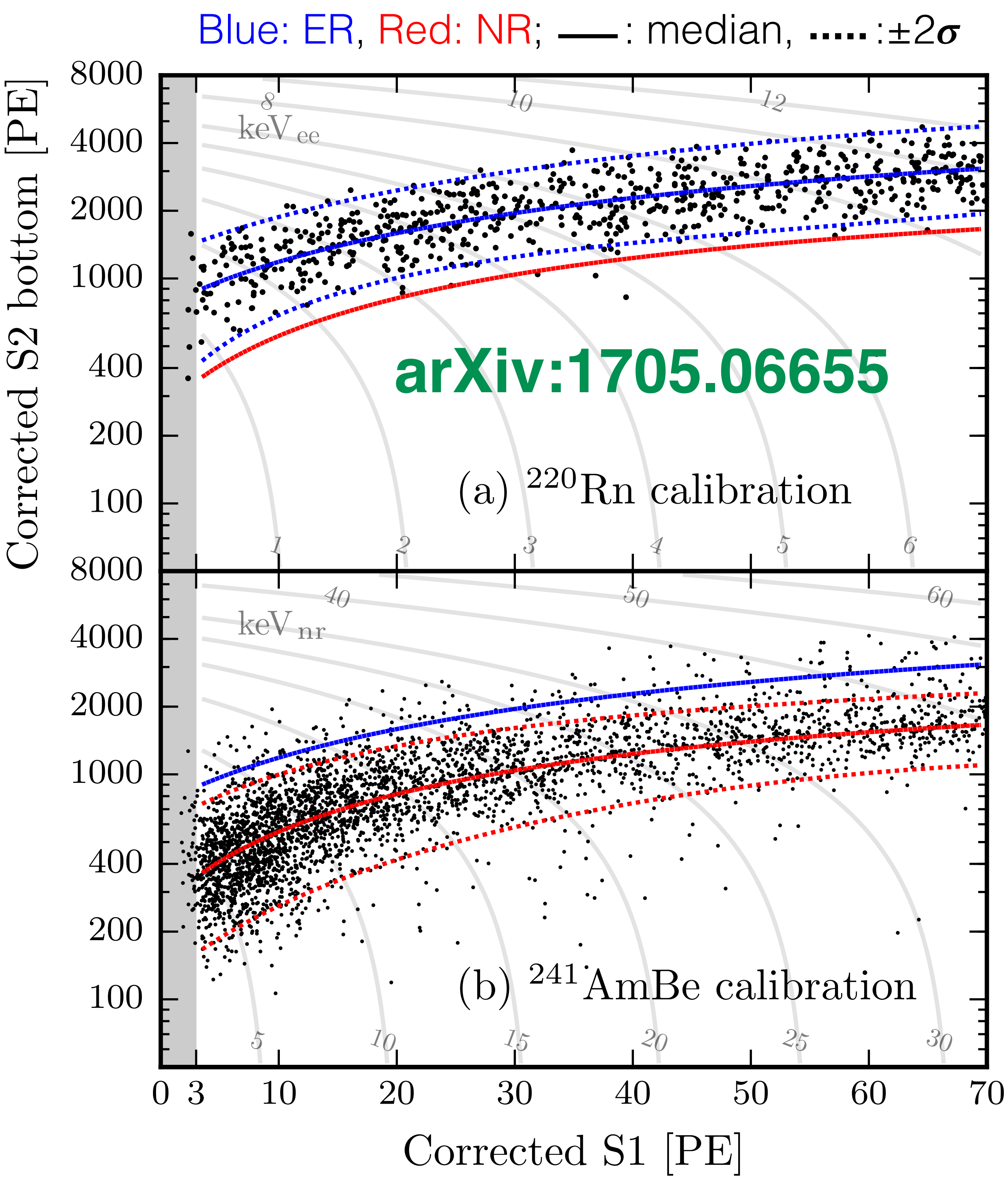


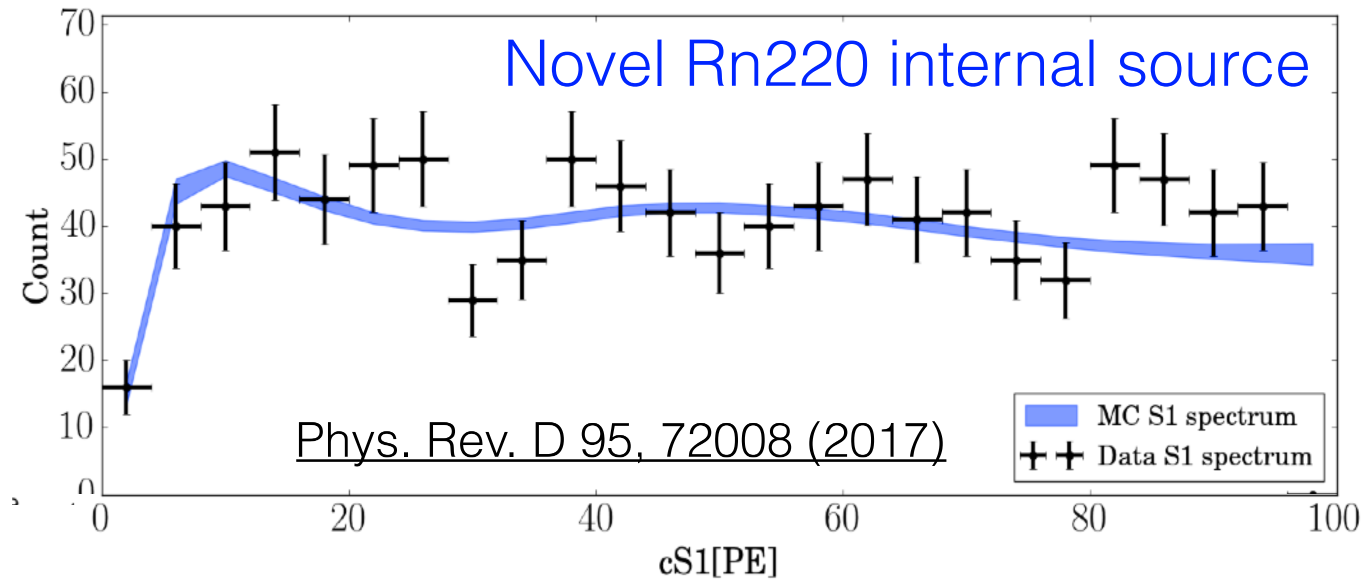
- Simulate LXe microphysics & detector response to fit Rn220 and AmBe calibration data
- Background and signal predictions from tuned models



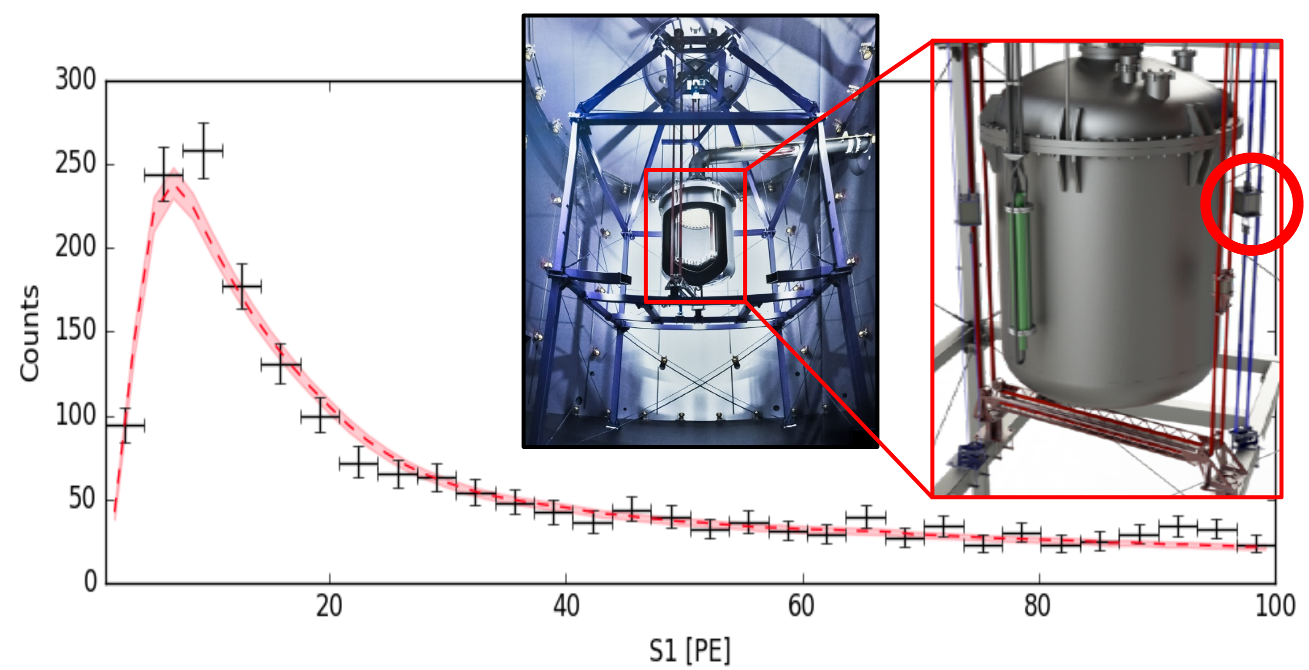
JCAP 1604 no. 4, 027 (2016)

Fitting Models to Calibration



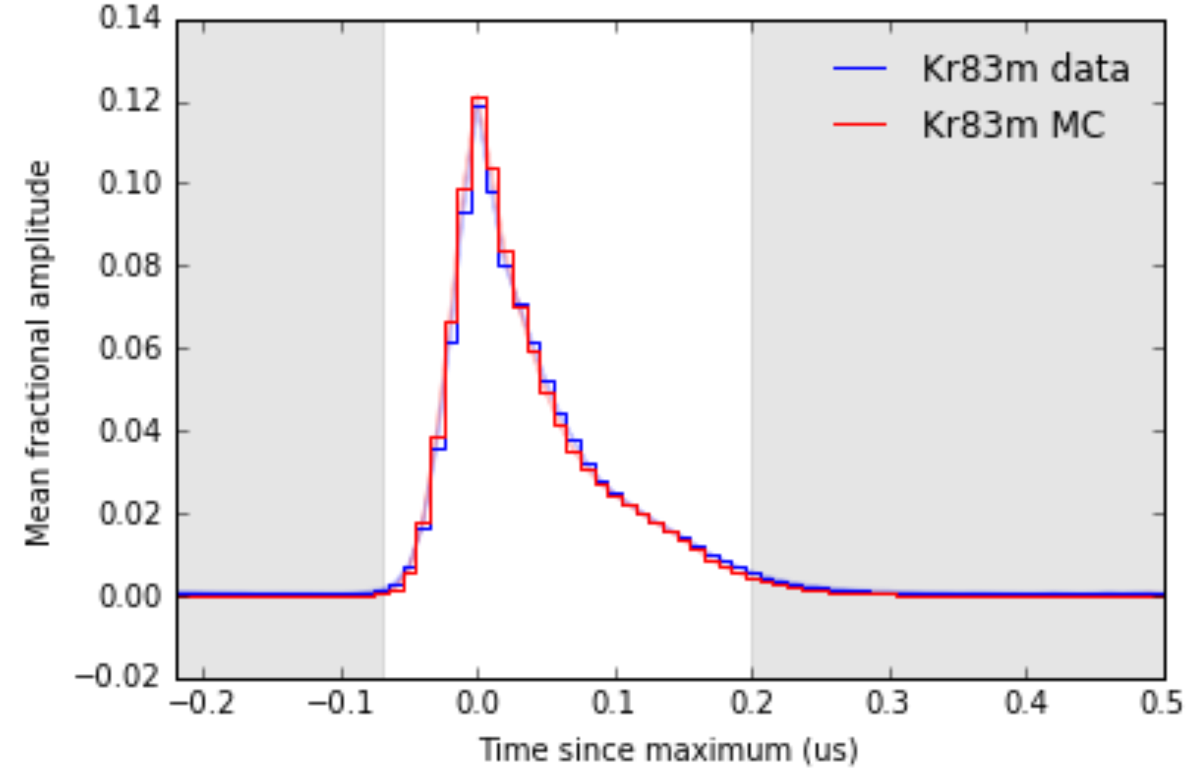


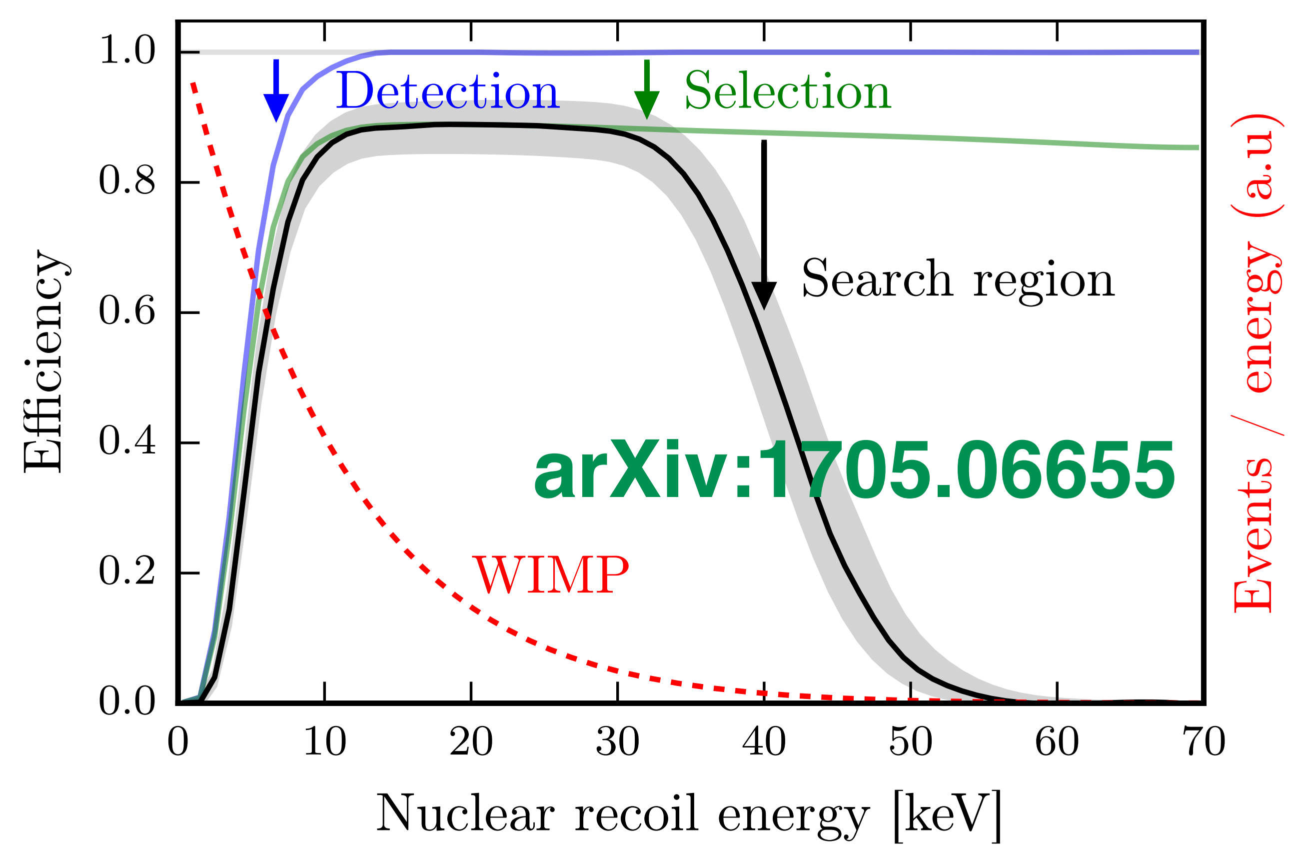
- Full modeling of LXe and detector response in $cS2_b$ vs cS1 space
- All parameters fitted with no significant deviation from priors



Efficiencies

- Detection efficiency dominated by 3-fold coincidence requirement
  - Estimated via novel waveform simulation including systematic uncertainties
- Selection efficiencies estimated from control samples or simulation
- Search region defined within 3-70 PE in cS1

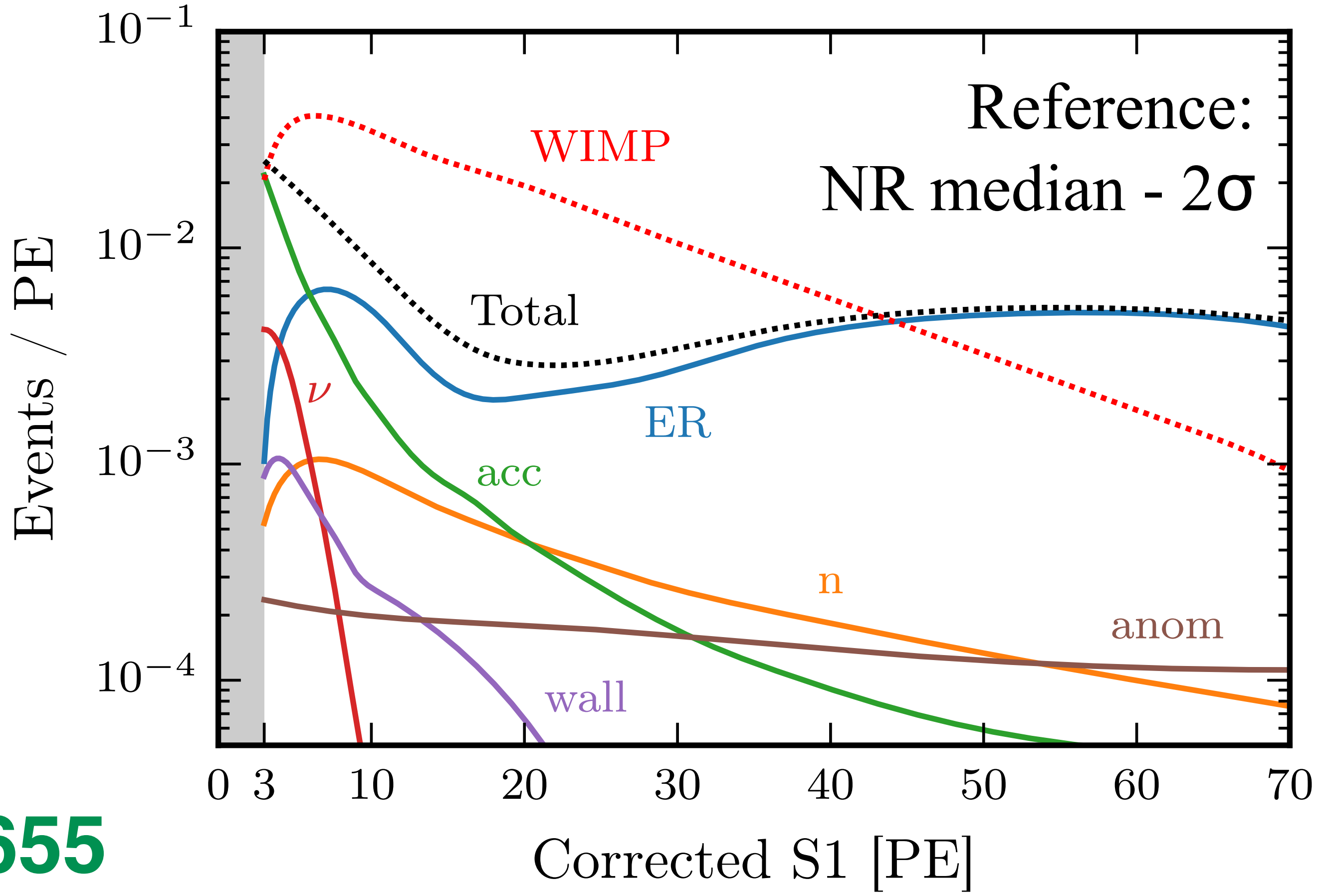




Background model

- ER and NR spectral shapes derived from models fitted to calibration data

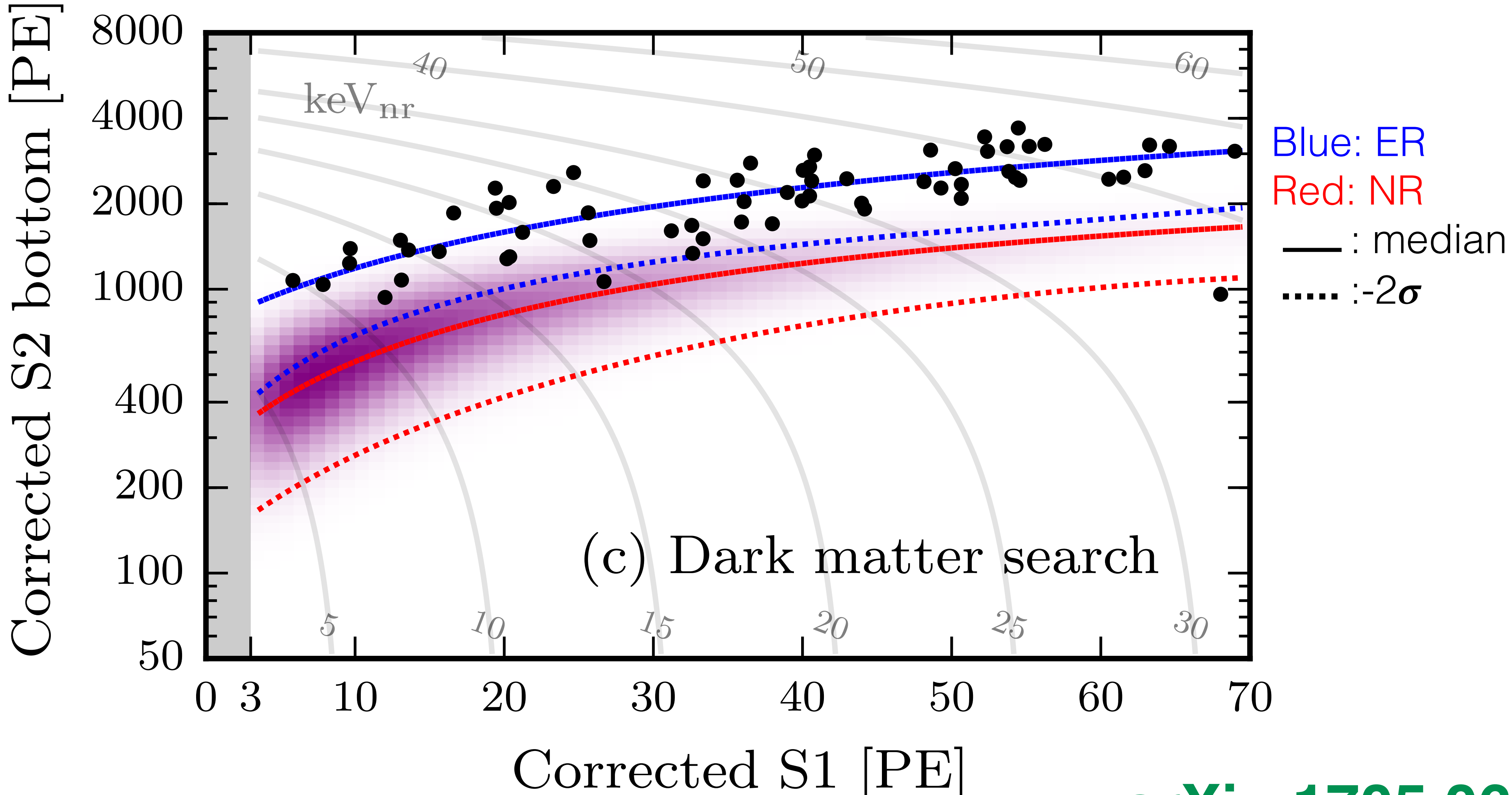
- Other background expectations are data-driven, derived from control samples



arXiv:1705.06655

Background & Signal Rates	Total	Reference
Electronic recoils *(ER)*	62 ± 8	0.26 (+0.11)(-0.07)
Radiogenic neutrons *(n)*	0.05 ± 0.01	0.02
CNNS (ν)	0.02	0.01
Accidental coincidences (*acc*)	0.22 ± 0.01	0.06
Wall leakage (*wall*)	0.5 ± 0.3	0.01
Anomalous (*anom*)	0.09 (+0.12)(-0.06)	0.01 ± 0.01
Total background	**63 ± 8**	**0.36 (+0.11)(-0.07)**

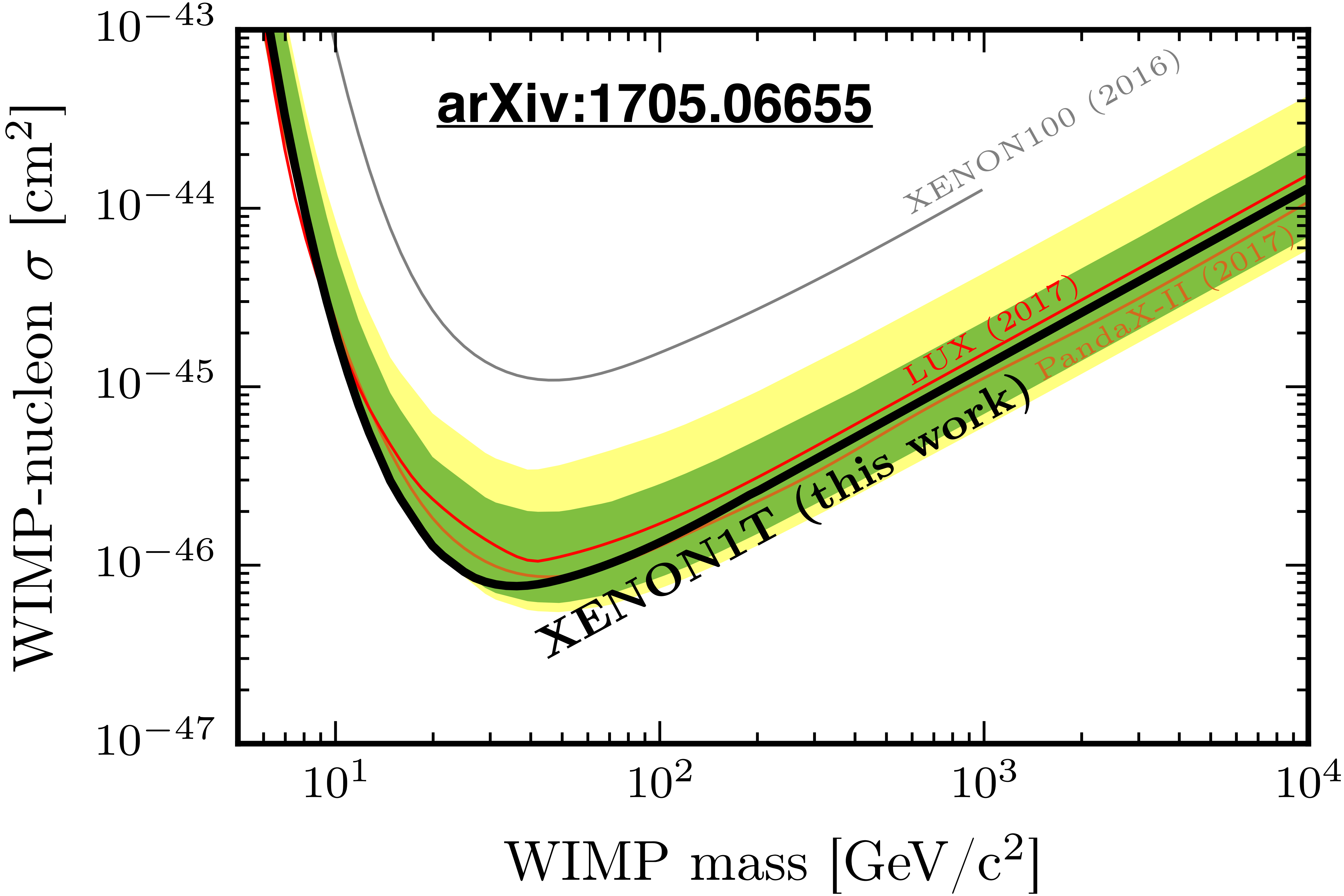
Dark Matter Search



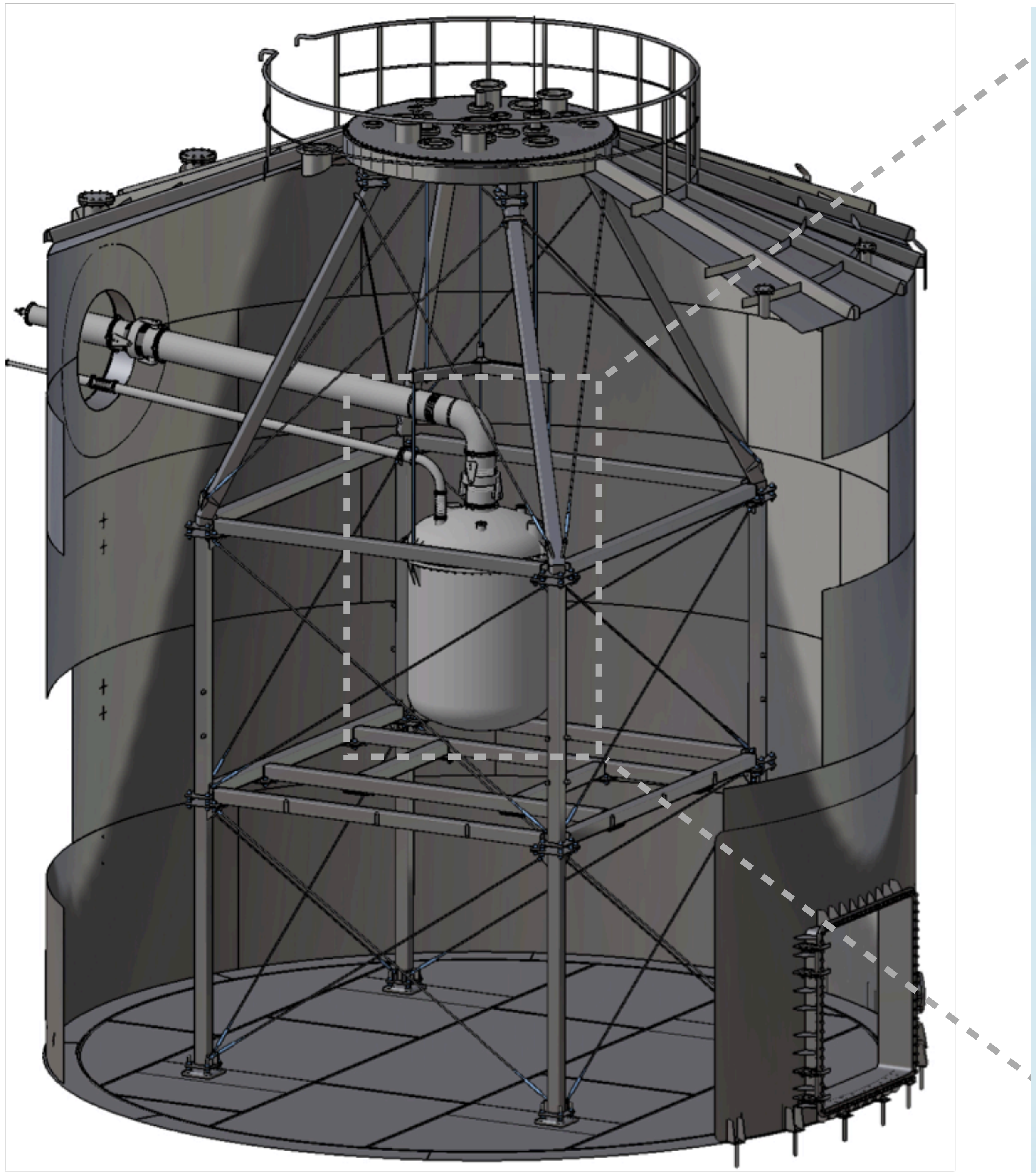
arXiv:1705.06655

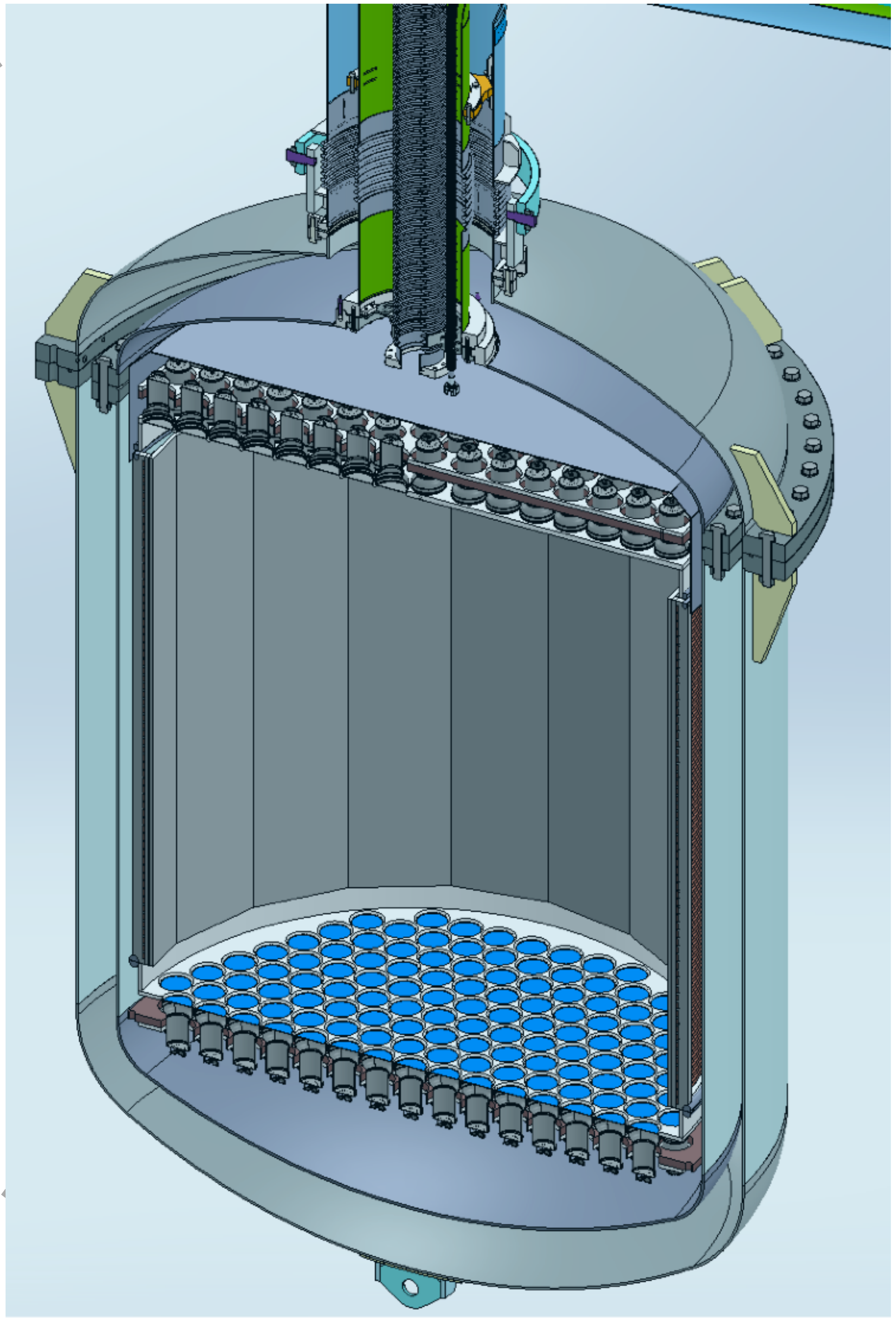
- Extended unbinned profile likelihood analysis
- Most significant ER & NR shape parameters included from cal. fits
- Normalization uncertainties for all components
- Safeguard to protect against spurious mis-modeling of background

XENON1T Results



From XENON1T to XENONnT





- start XENONnT in early 2019

Summary

- First multi-ton-scale LXe detector in operation for dark matter search!
- Great discovery potential in XENON1T and XENONnT
- Stay tuned!