First Results from XENON1T

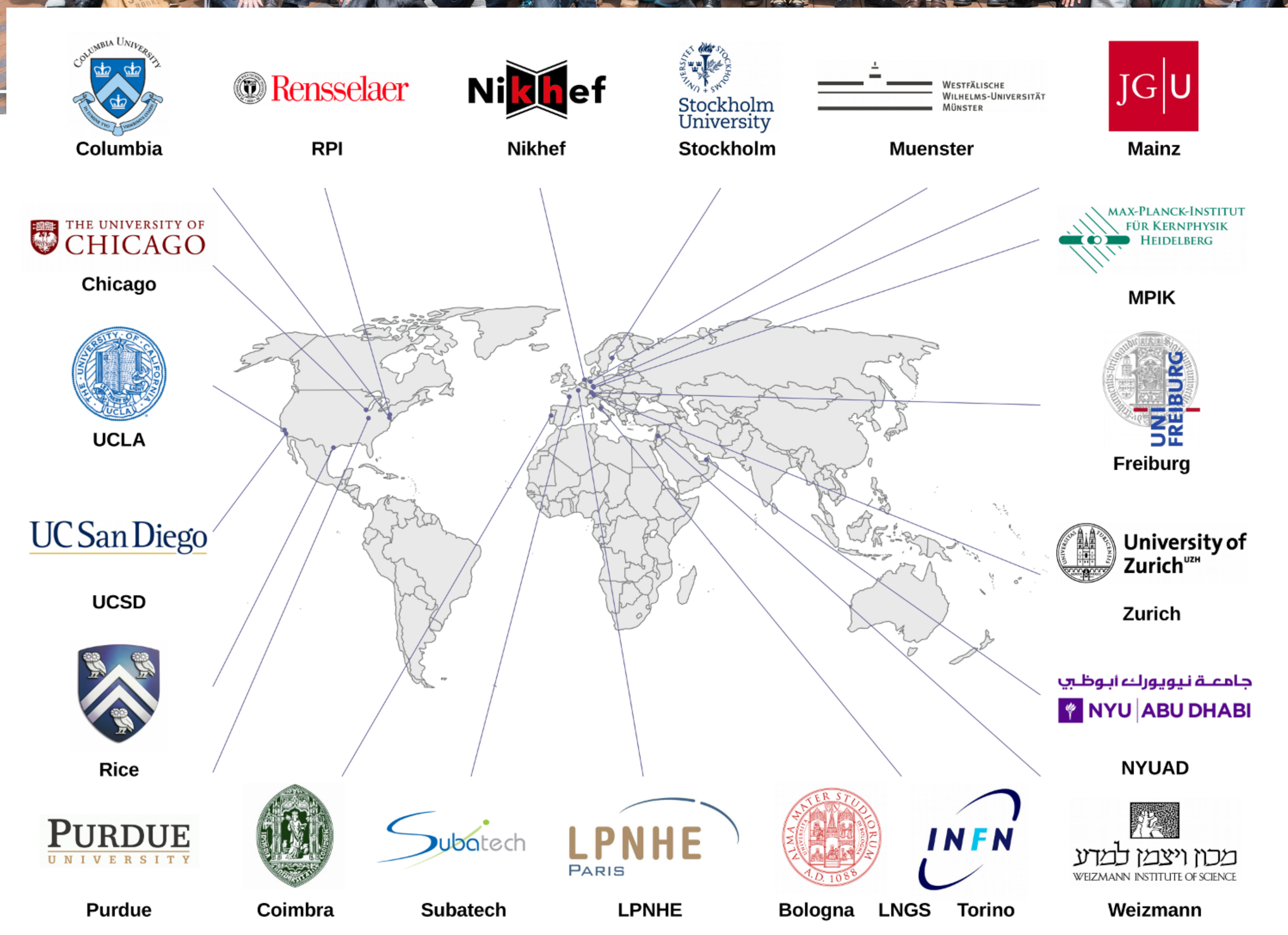
(arXiv:1705.06655)

Qing Lin
Columbia University

Aug. 8th, 2017
TeVPA, Columbus

XENON World


~130 scientists from 22 institutions
PUPIN PHYSICS LABORATORIES


Columbia
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Nikhef
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UCSD
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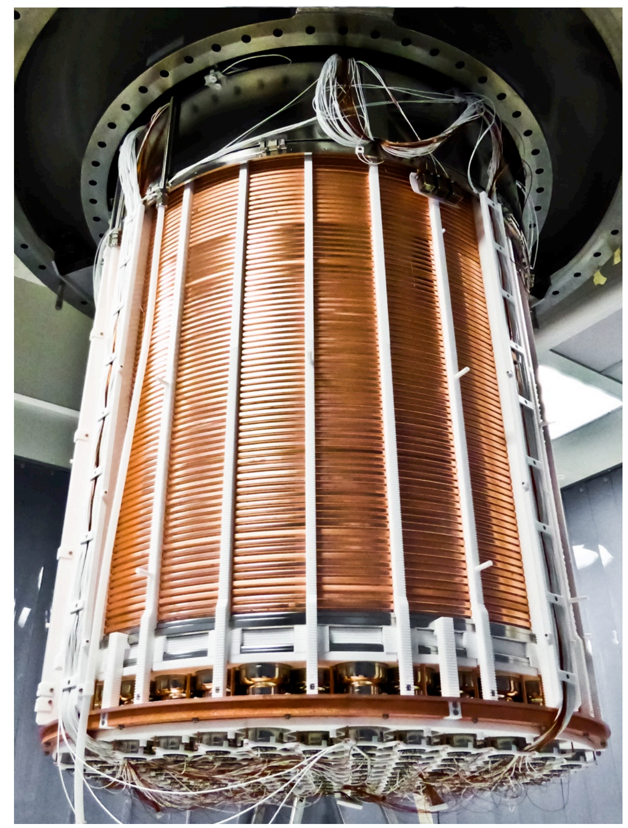
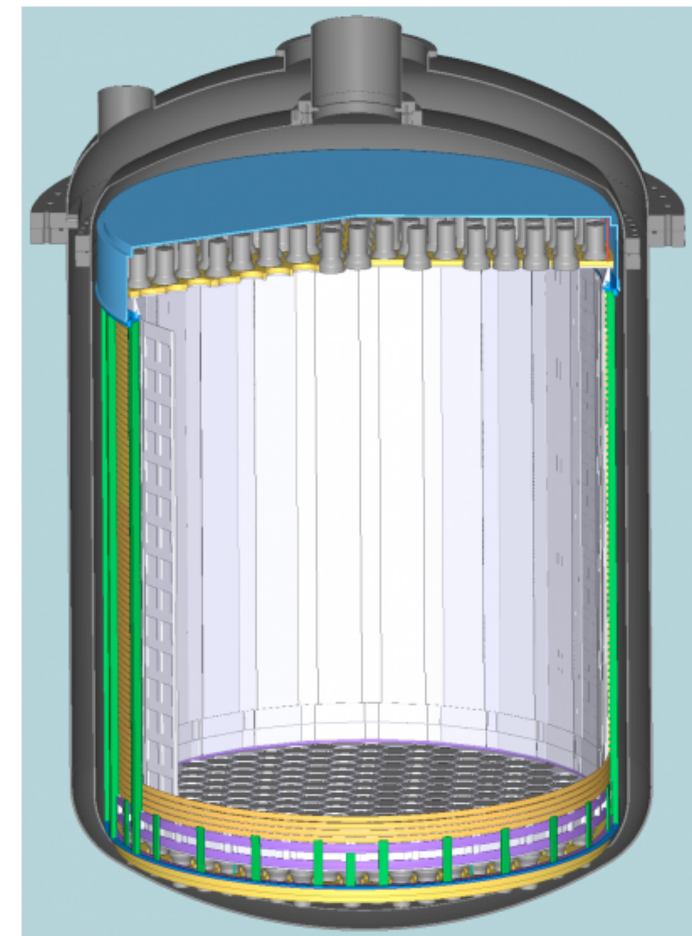
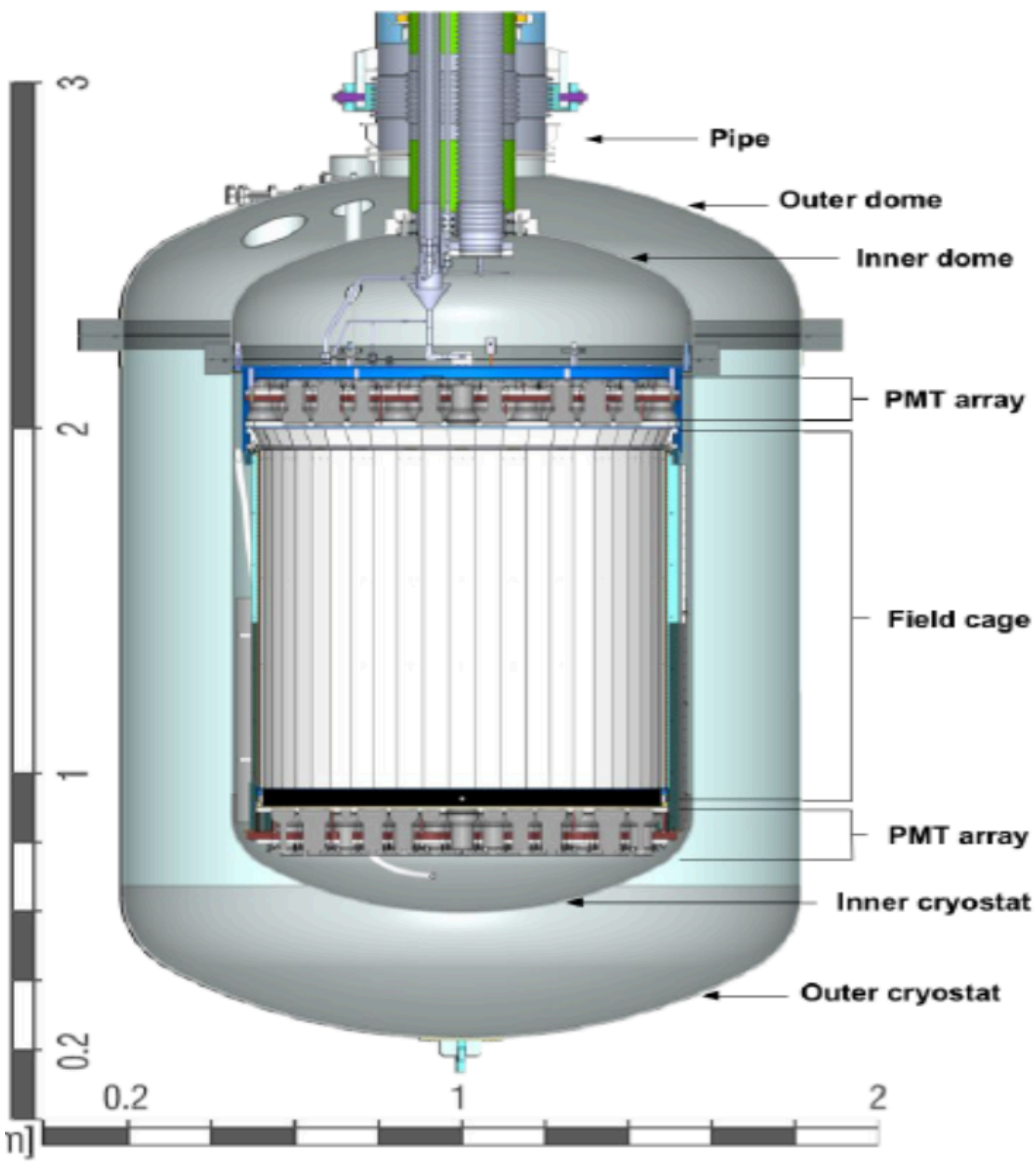
Purdue
Coimbra
Subatech
LPNHE
Bologna
LNGS
Torino
Weizmann

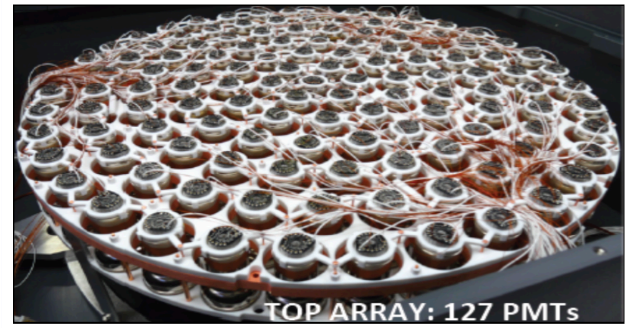

Laboratori Nazionali del Gran Sasso (LNGS), Italy
XENON1T

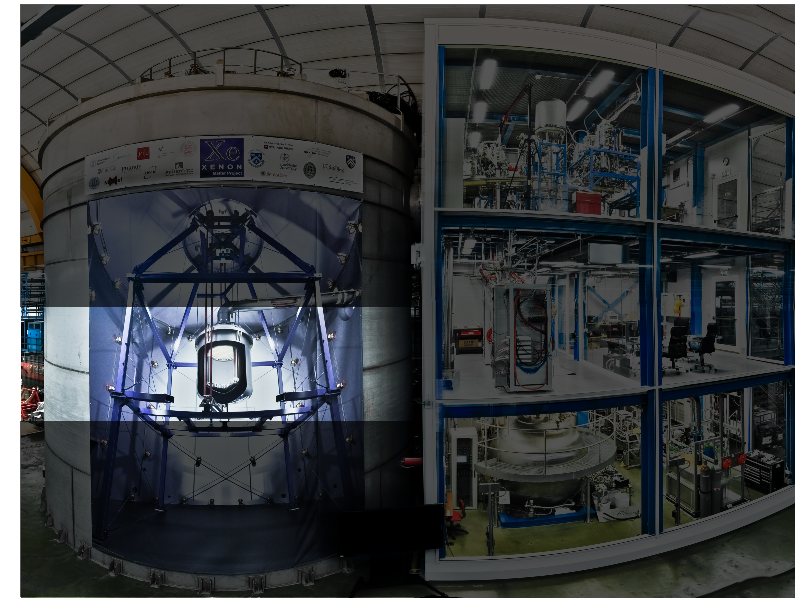
Phases of the XENON program

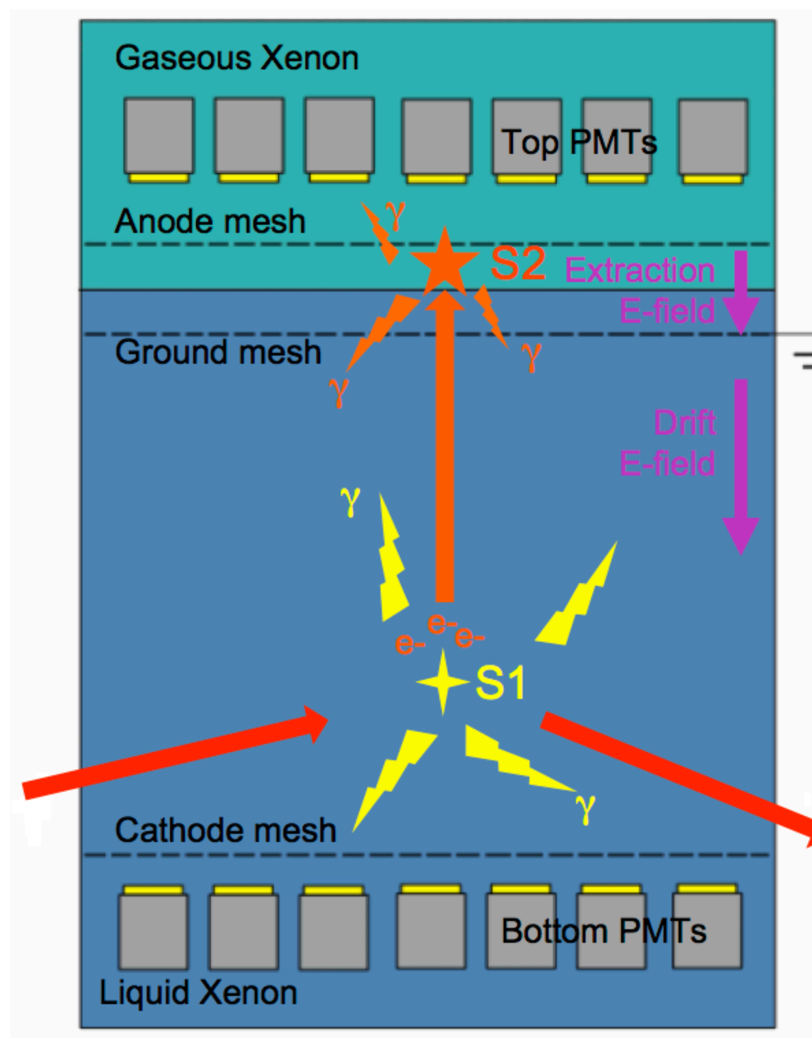
XENON10	XENON100	XENON1T / XENONnT
		 
2005-2007 15 cm drift TPC – 25 kg	2008-2016 30 cm drift TPC – 161 kg	2013-2018 / 2019-2023 100 cm / 144 cm drift TPC - 3200 kg / ~8000 kg
Achieved (2007) $\sigma_{SI} = 8.8 \times 10^{-44}$ cm^2	Achieved (2016) $\sigma_{SI} = 1.1 \times 10^{-45}$ cm^2	Projected (2018) / Projected (2023) $\sigma_{SI} = 1.6 \times 10^{-47}$ cm^2 / $\sigma_{SI} = 1.6 \times 10^{-48}$ cm^2

Time Projection Chamber



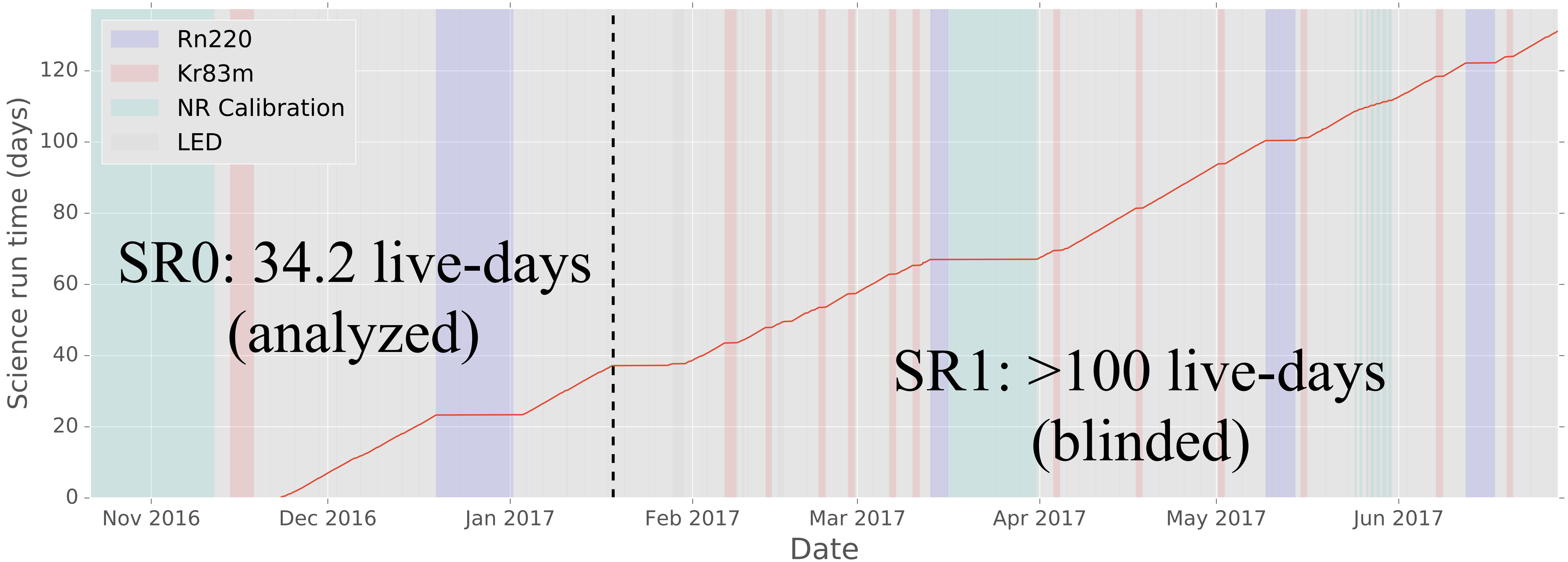






Eur. Phys. J. C 75, no. 11, 546 (2015)

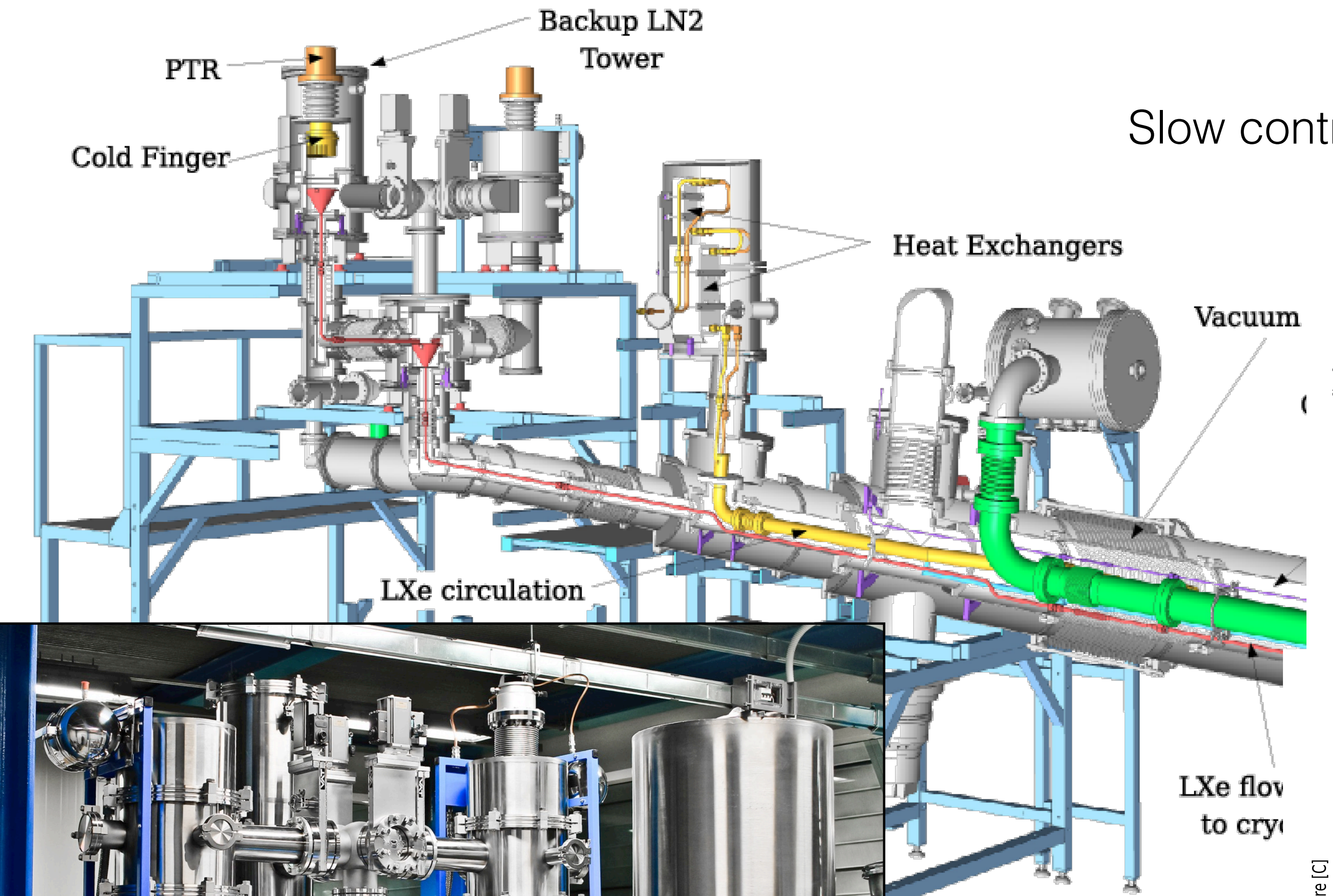
Science Run: Exposure



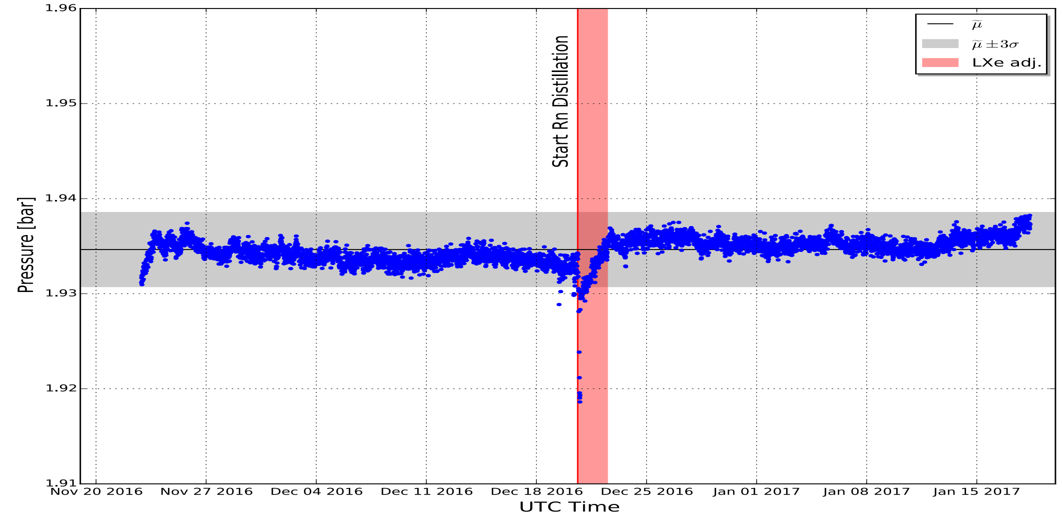
- This talk highlights the analysis of the first science run (SR0)
- We continue to take data after the earthquake and analyzing SR1 now

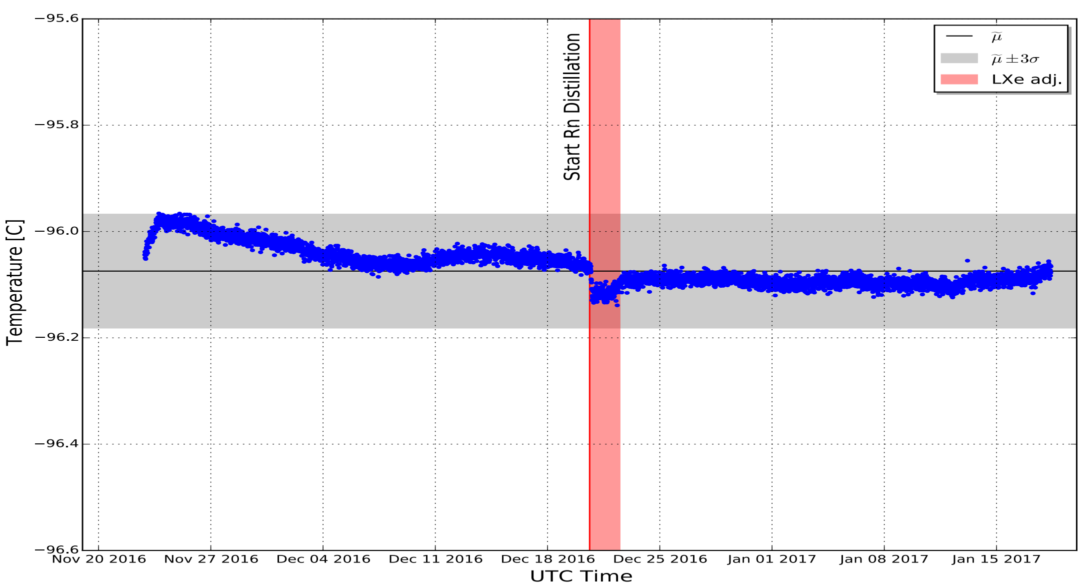
Detector Stability

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



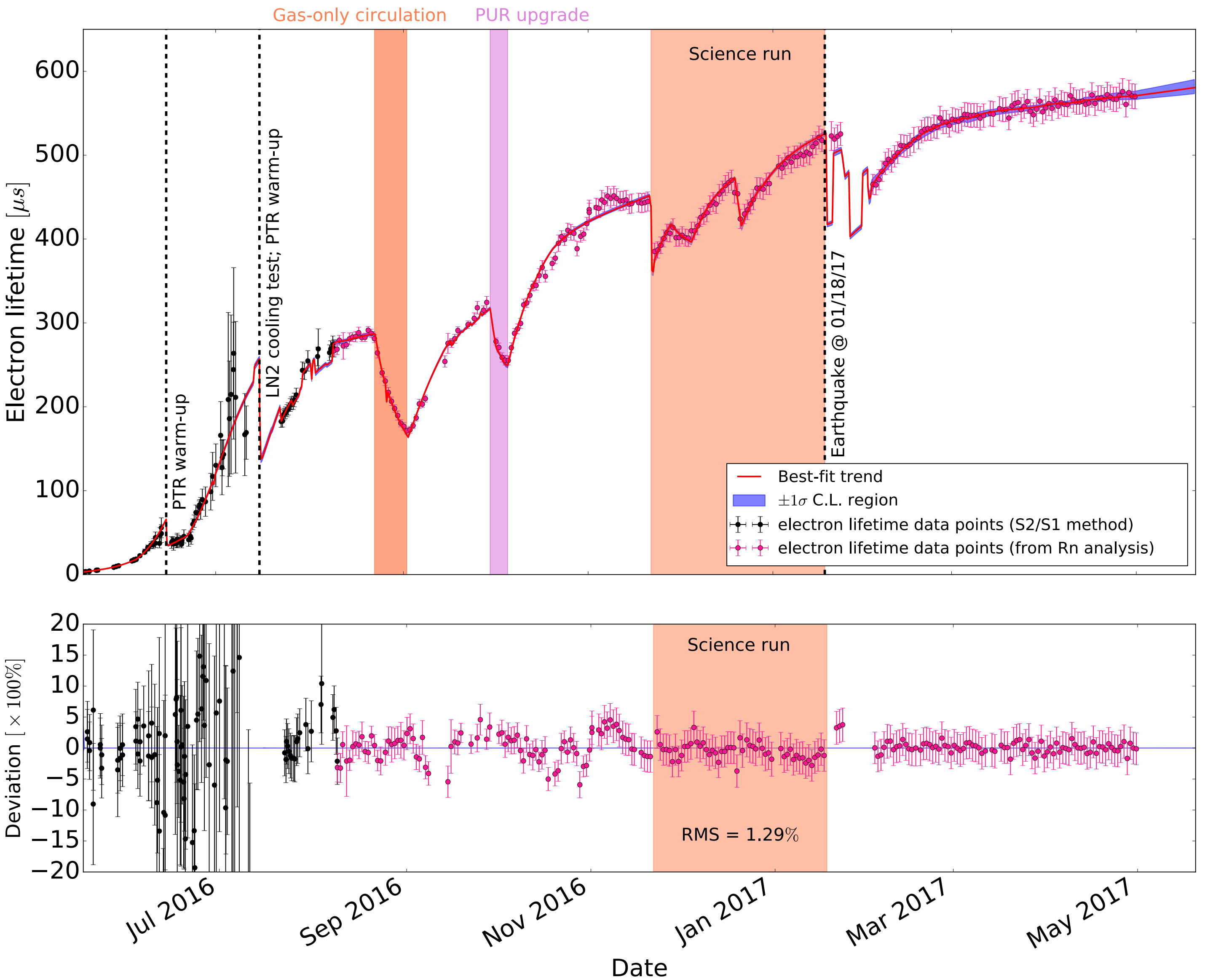
Slow control/Historian monitoring





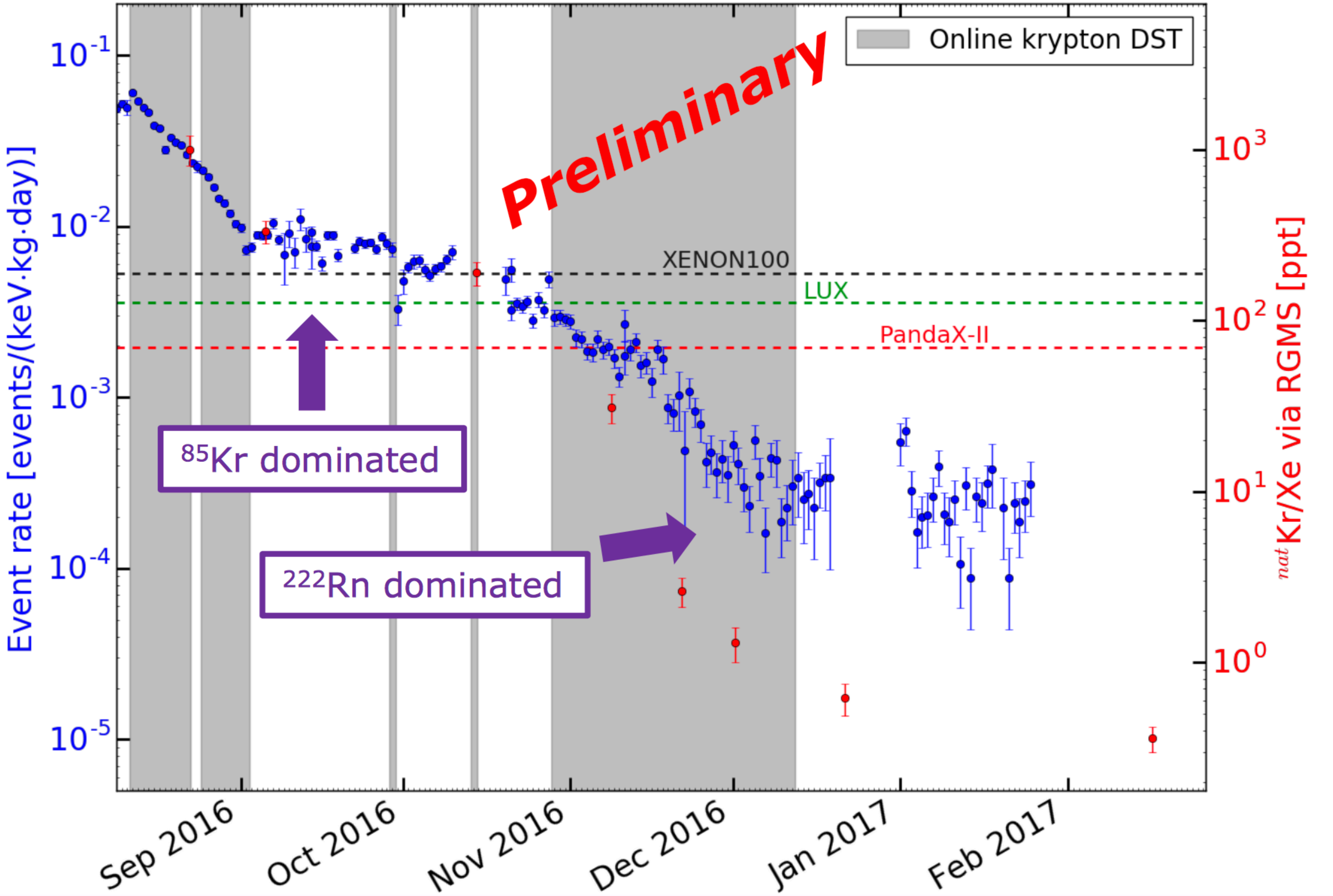
Xe Purification

Goal: remove electronegative impurities below 1 ppb (O2 equivalent) in the Xe gas fill and from outgassing of detector's components with continuous circulation of Xe gas at high speed through hot getters



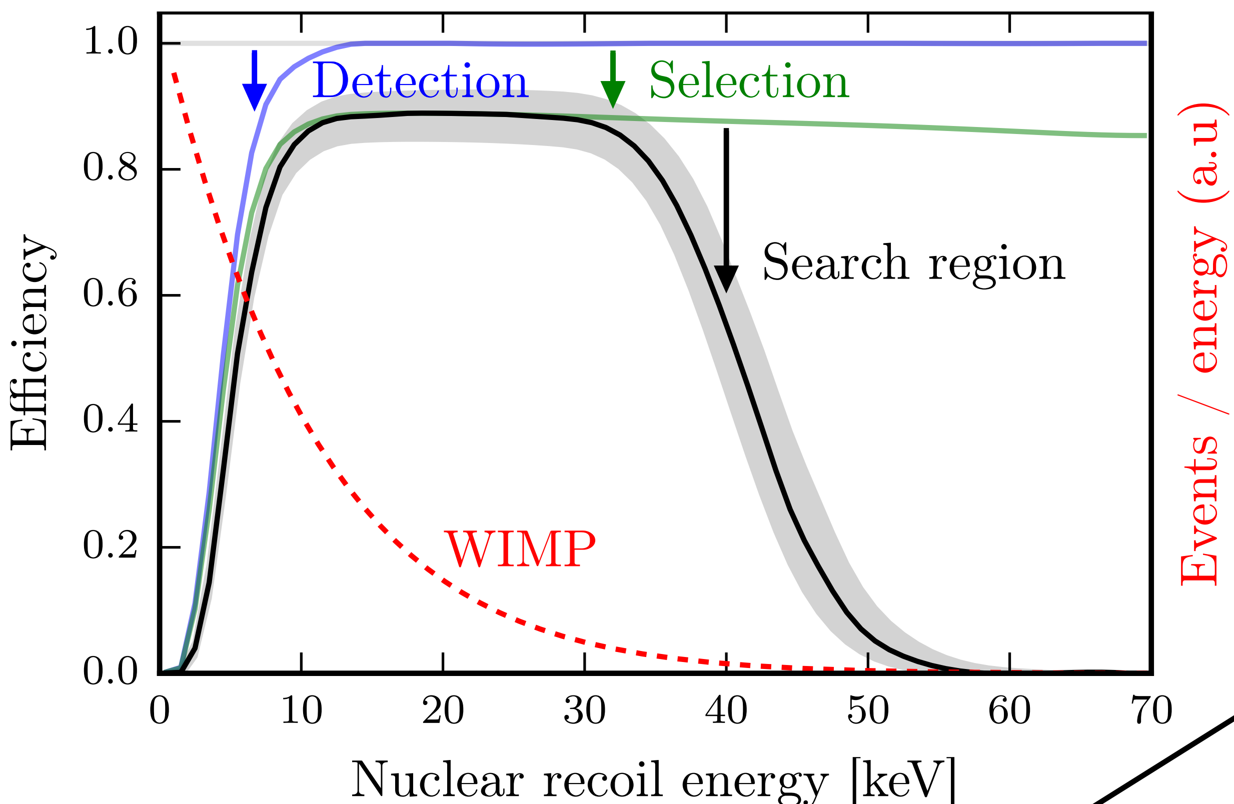
Performance: evolution of e-lifetime, monitored regularly with ERs calibration sources, well described by physical model. Current value approaching the max drift time of the LXeTPC.

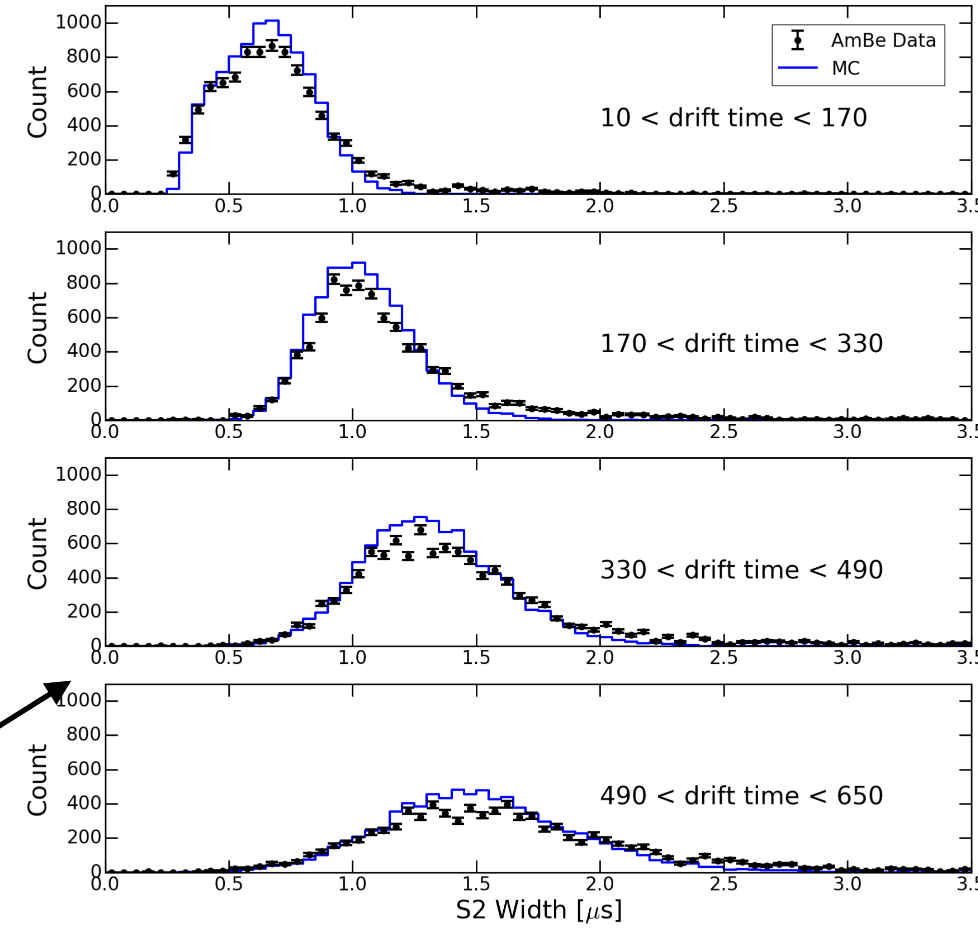
Kr Reduction



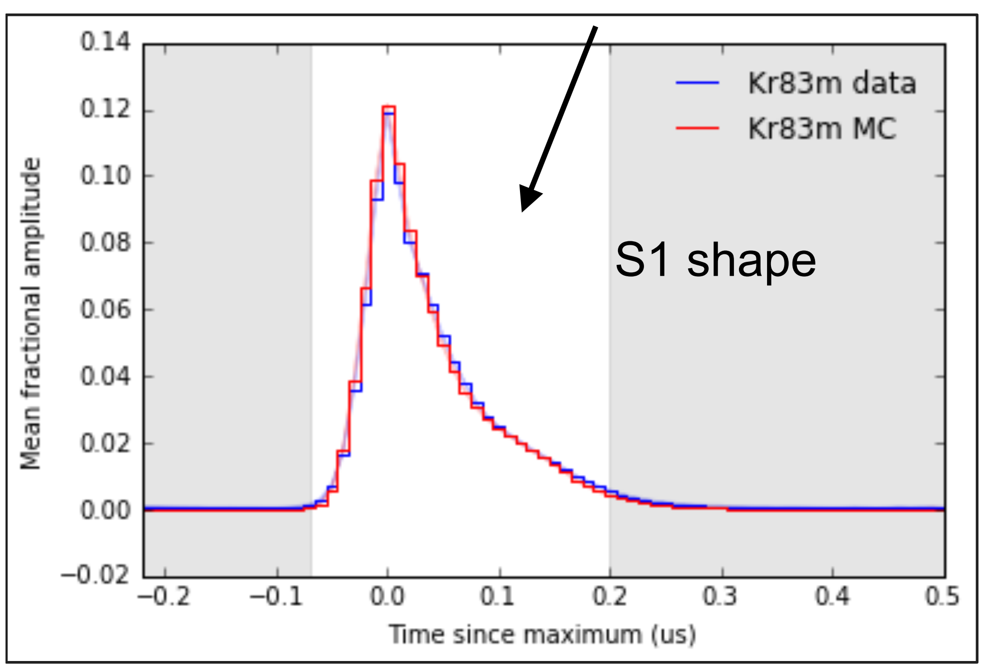
Eur. Phys. J. C77 (2017) no.5, 275 & Eur. Phys. J. C77 (2017) no.6, 358

Efficiencies





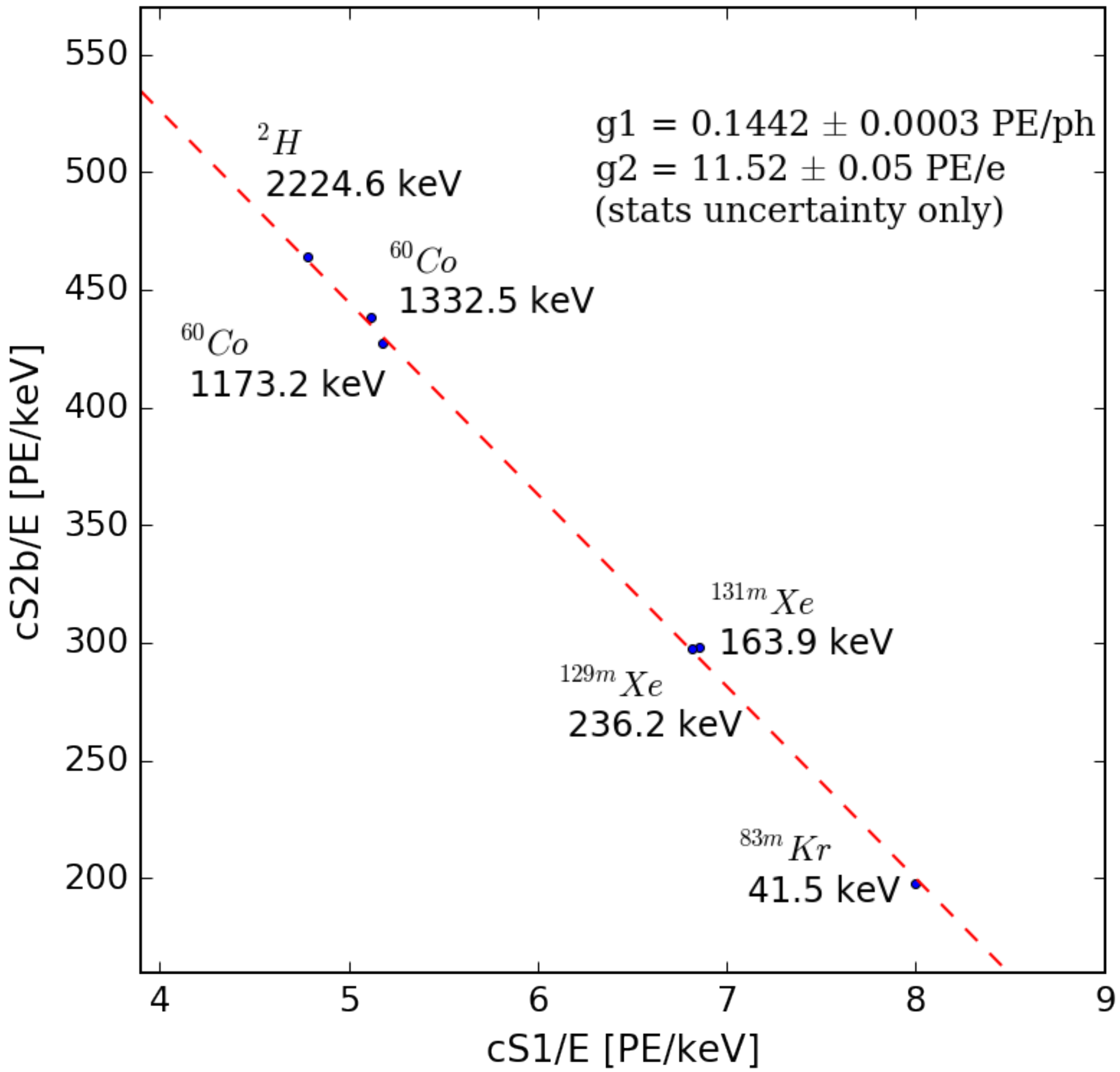
Waveform simulation tuned to match data



- 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

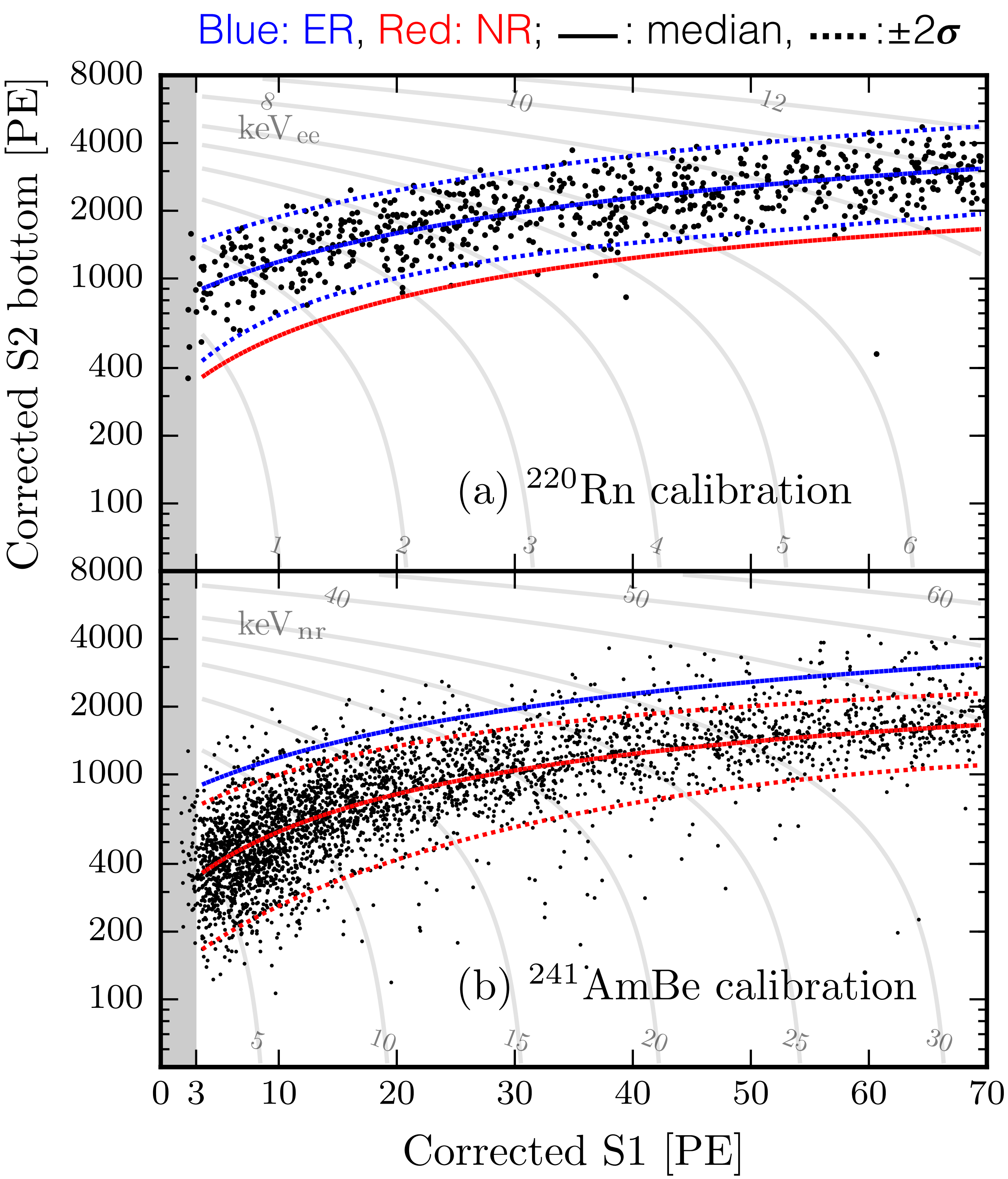
Energy response

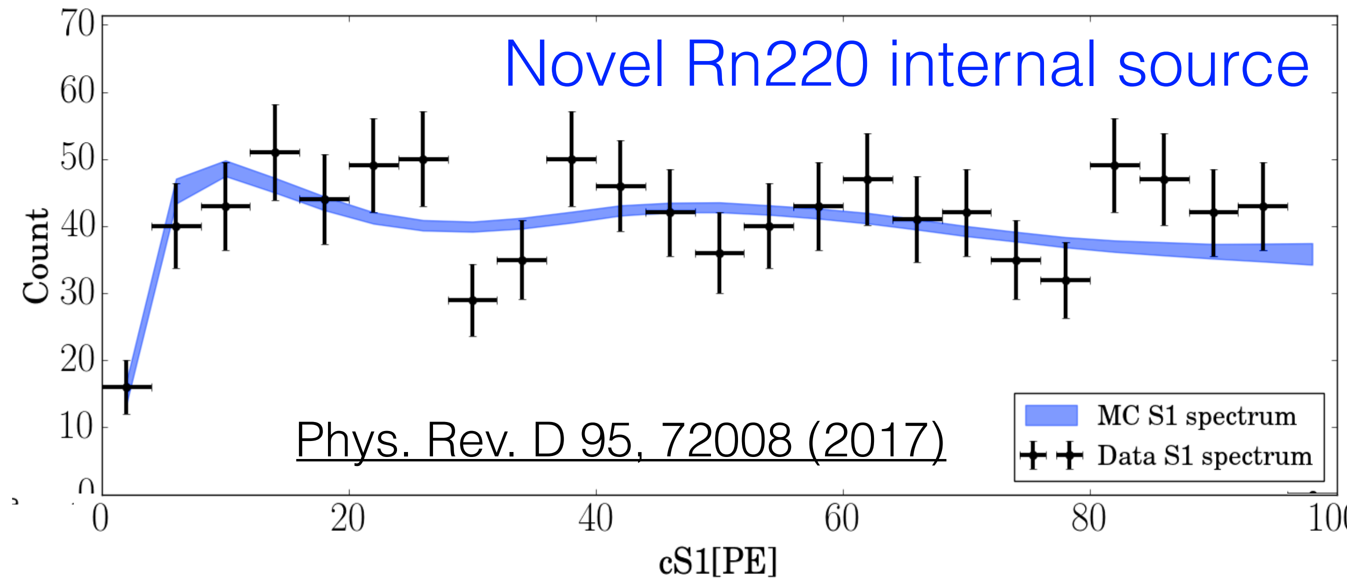
$$E = (n_{ph} + n_e) \cdot W = (\frac{S1}{g1} + \frac{S2}{g2}) \cdot W$$



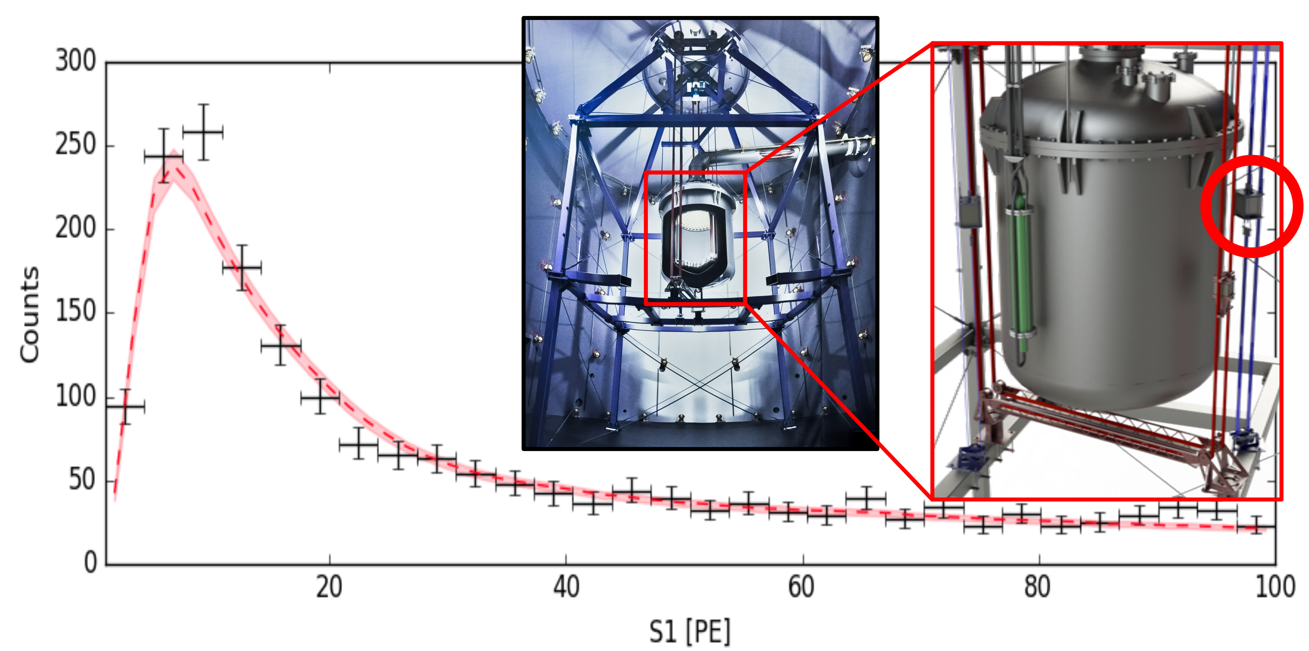
- Excellent linearity with electronic recoil energy from 40 keV to 2.2 MeV
- g1 = **0.1442 ± 0.0068** (sys) PE/photon corresponds to a photon detection efficiency of 12.5 ± 0.6% (taking into account double PE emission)
  - Assumptions of past MC sensitivity projected 12.1%.
- g2: the amplification of charge signal corresponds to near full extraction of charges from the liquid.

Fitting Models to Calibration



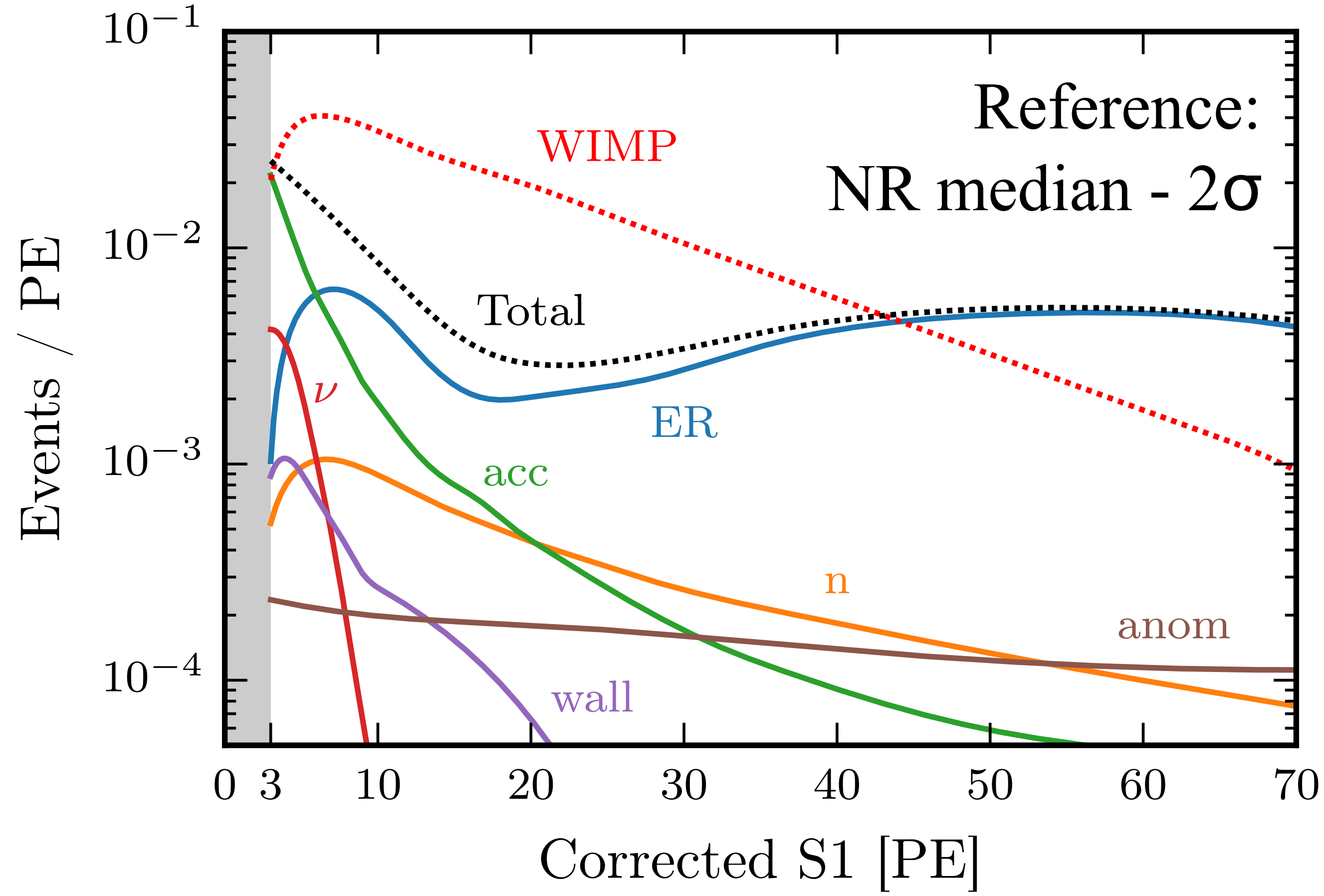


- Full modeling of LXe and detector response in $cS2_b$ vs cS1 space
- All parameters fitted with no significant deviation from priors



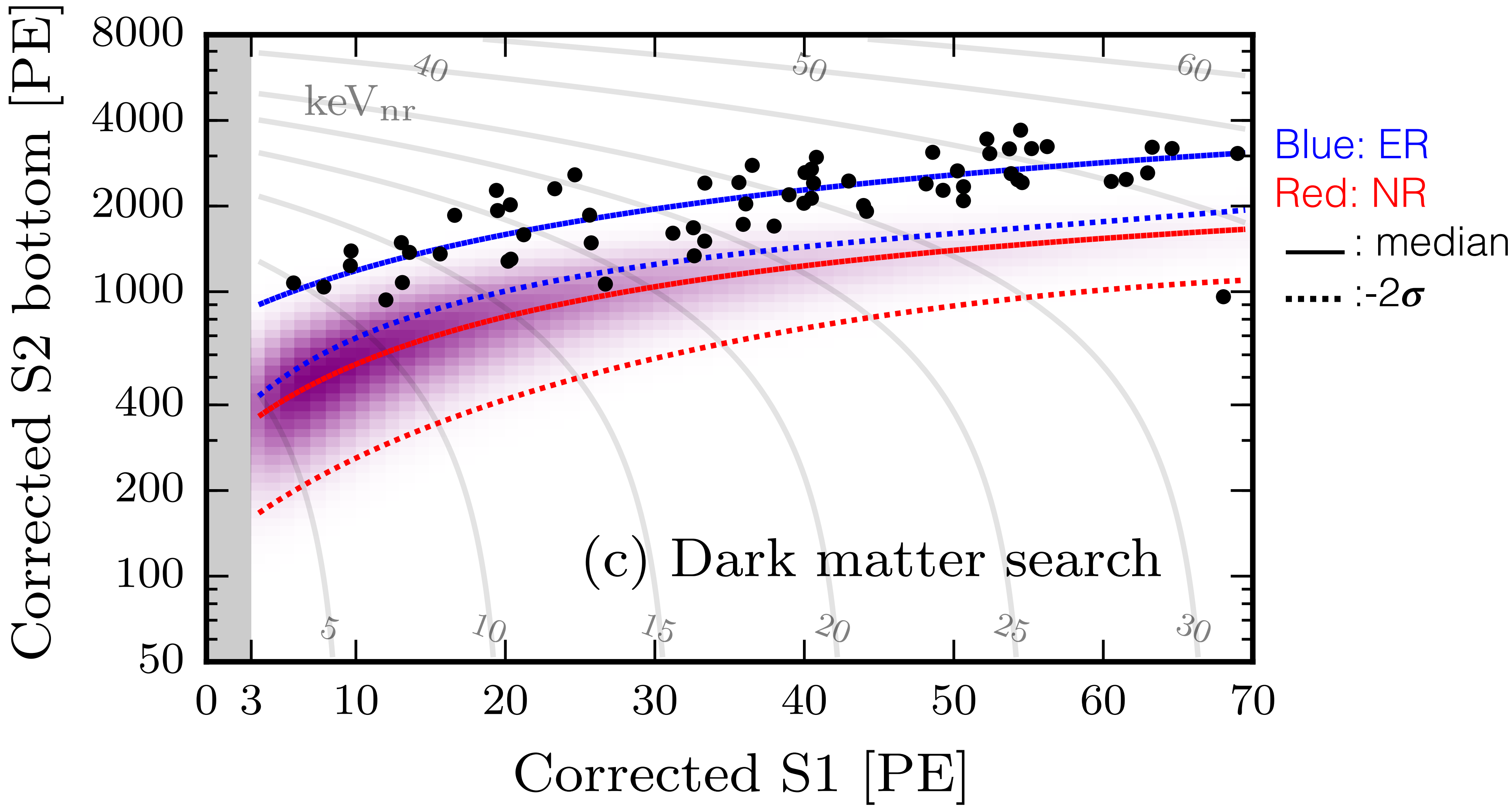
Background model

- ER and NR spectral shapes derived from models fitted to calibration data
- Other background expectations are data-driven, derived from control samples



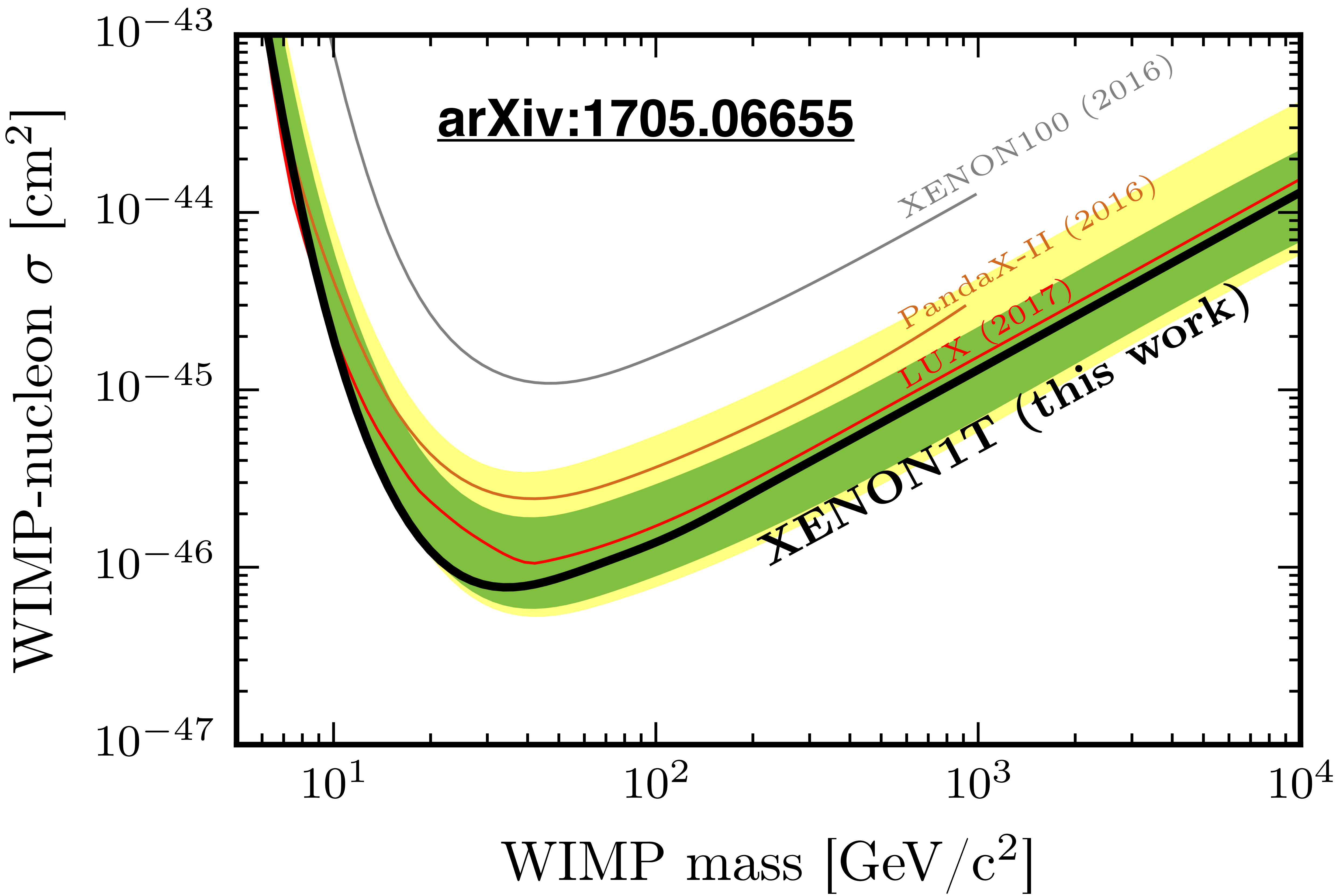
Background & Signal Rates	Total	Reference
Electronic recoils *(ER)*	62 ± 8	0.26 (+0.11)(-0.07)
Radiogenic neutrons *(n)*	0.05 ± 0.01	0.02
CNNS (ν)	0.02	0.01
Accidental coincidences (*acc*)	0.22 ± 0.01	0.06
Wall leakage (*wall*)	0.52 ± 0.32	0.01
Anomalous (*anom*)	0.09 (+0.12)(-0.06)	0.01 ± 0.01
Total background	**63 ± 8**	**0.36 (+0.11)(-0.07)**

Dark Matter Search



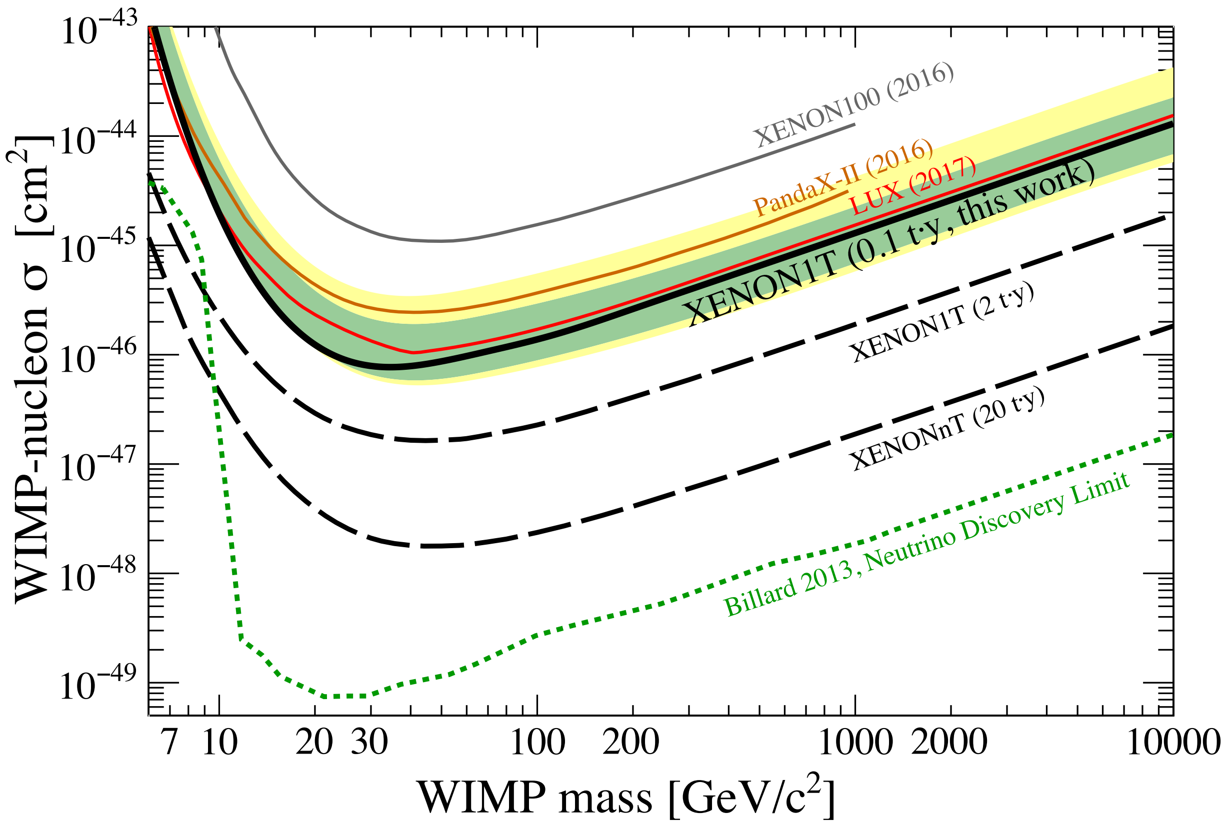
- Extended unbinned profile likelihood analysis
- Most significant ER & NR shape parameters included from cal. fits
- Normalization uncertainties for all components
- Safeguard to protect against spurious mis-modeling of background

XENON1T Results

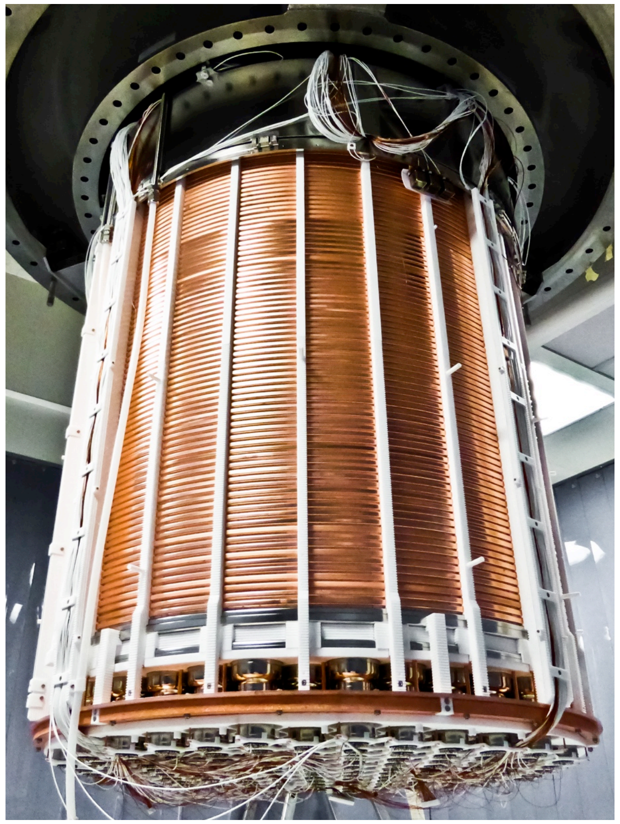


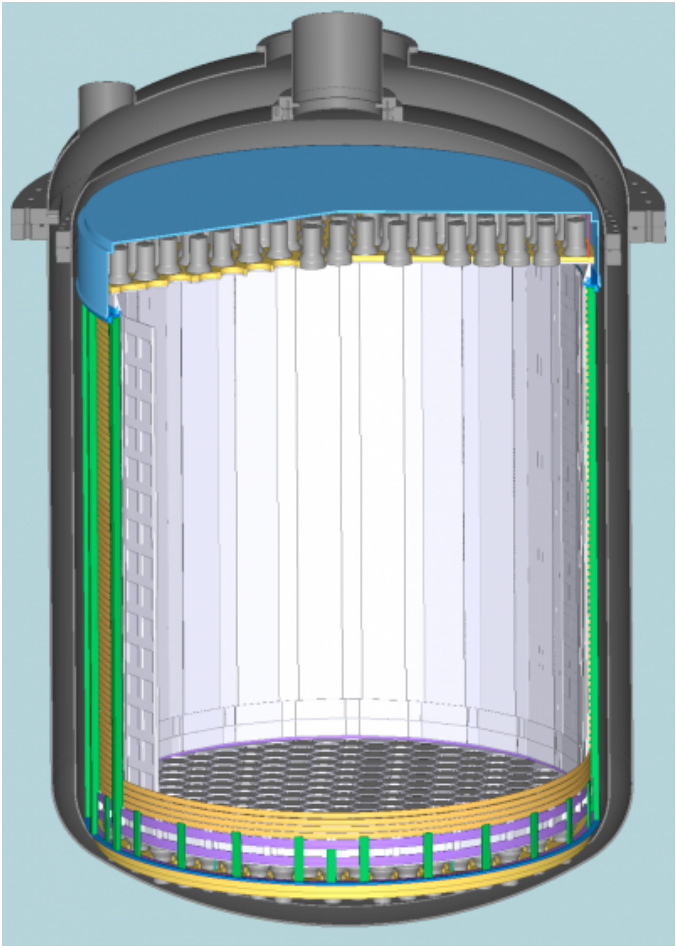
XENON1T Summary

- The world's largest LXe dark matter detector is taking data!
- Lowest ER background achieved!
- >100 ton-days of **new** data accumulated and being analyzed!
- Stay tuned!!!



XENON1T / XENONnT





2013-2018 / 2019-2023

100 cm / 144 cm drift TPC - 3200 kg / ~8000 kg

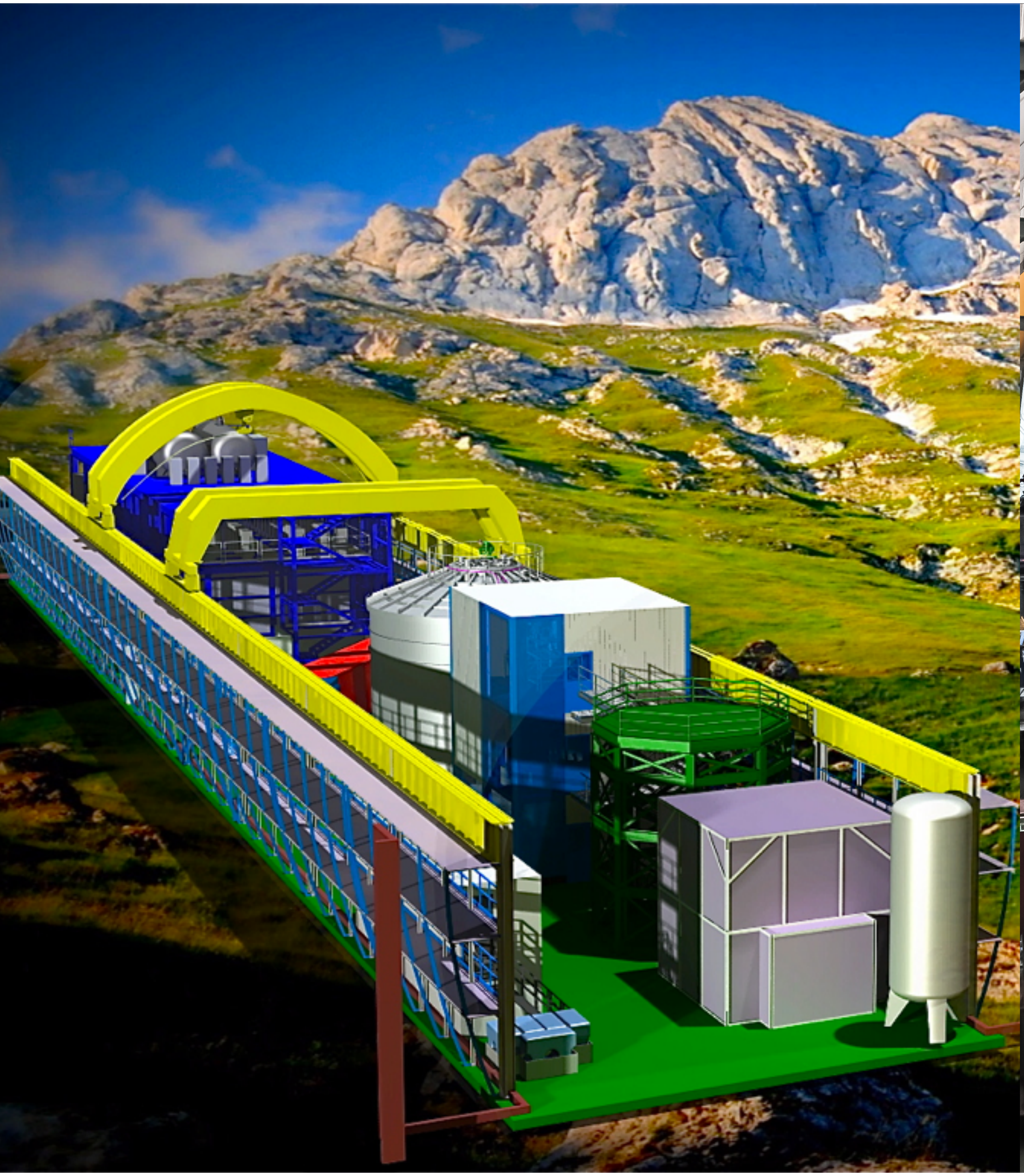
Projected (2018) / Projected (2023)

$\sigma_{SI} = 1.6 \times 10^{-47}\ cm^2$ / $\sigma_{SI} = 1.6 \times 10^{-48}\ cm^2$

Thank you!

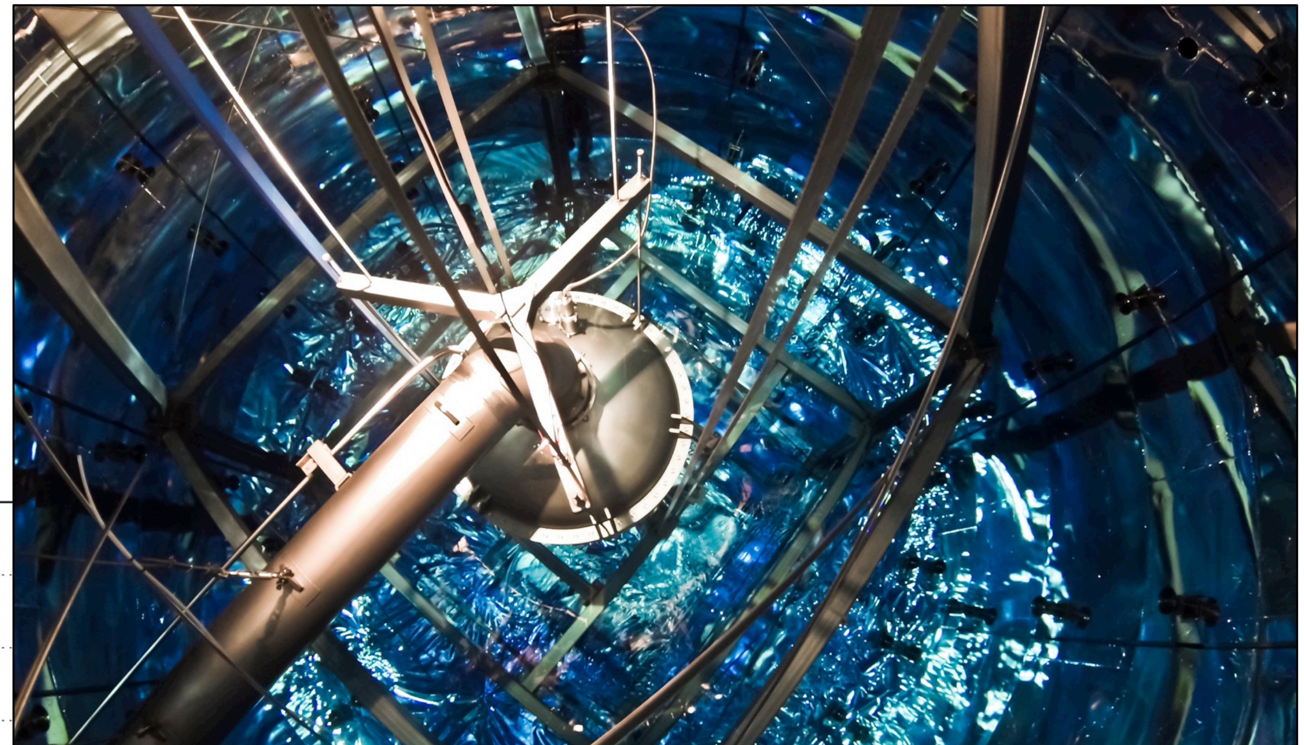
Appendix

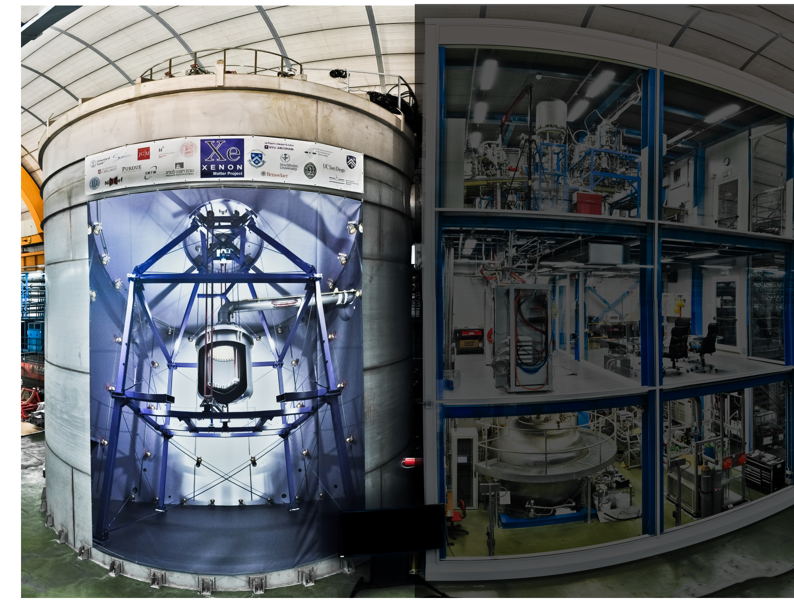
The XENON1T Experiment

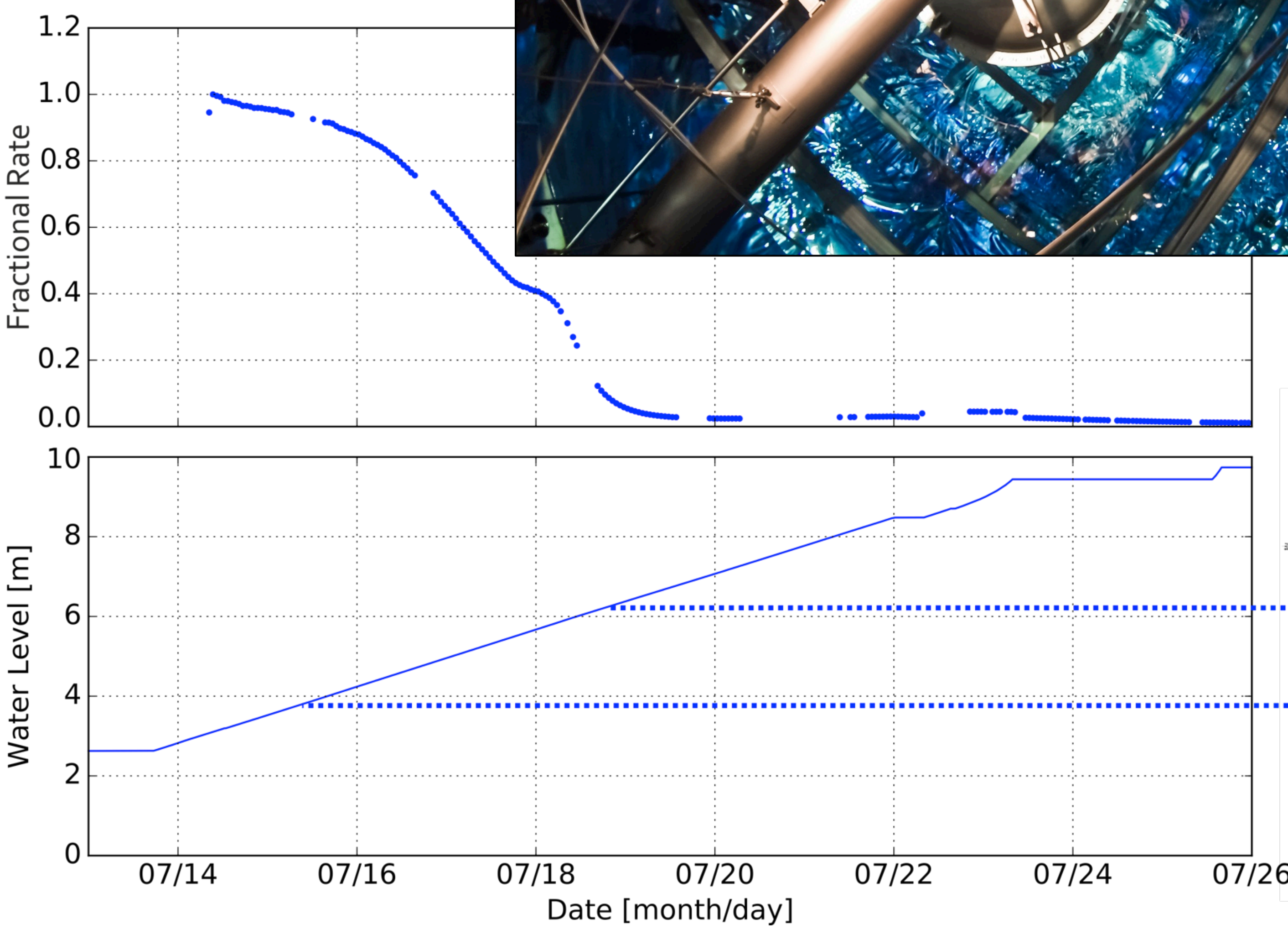


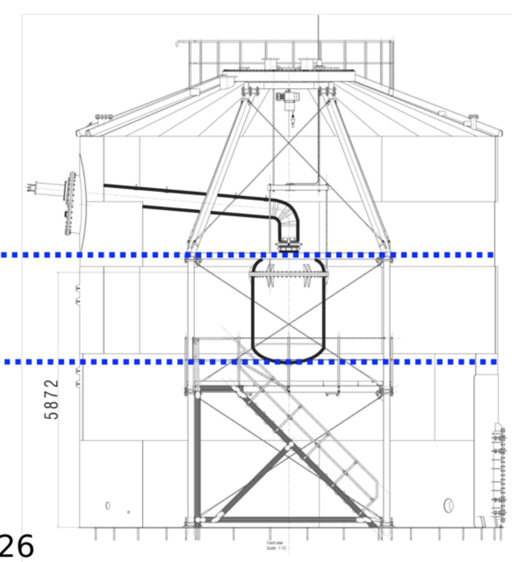

XENON
enlighten
Aug. 2014

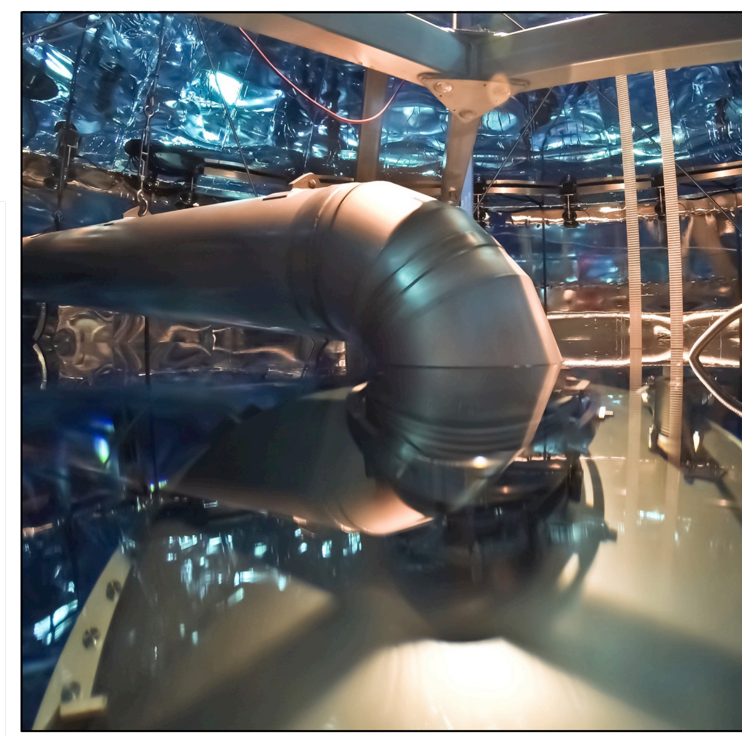
Cryostat in the Water Tank



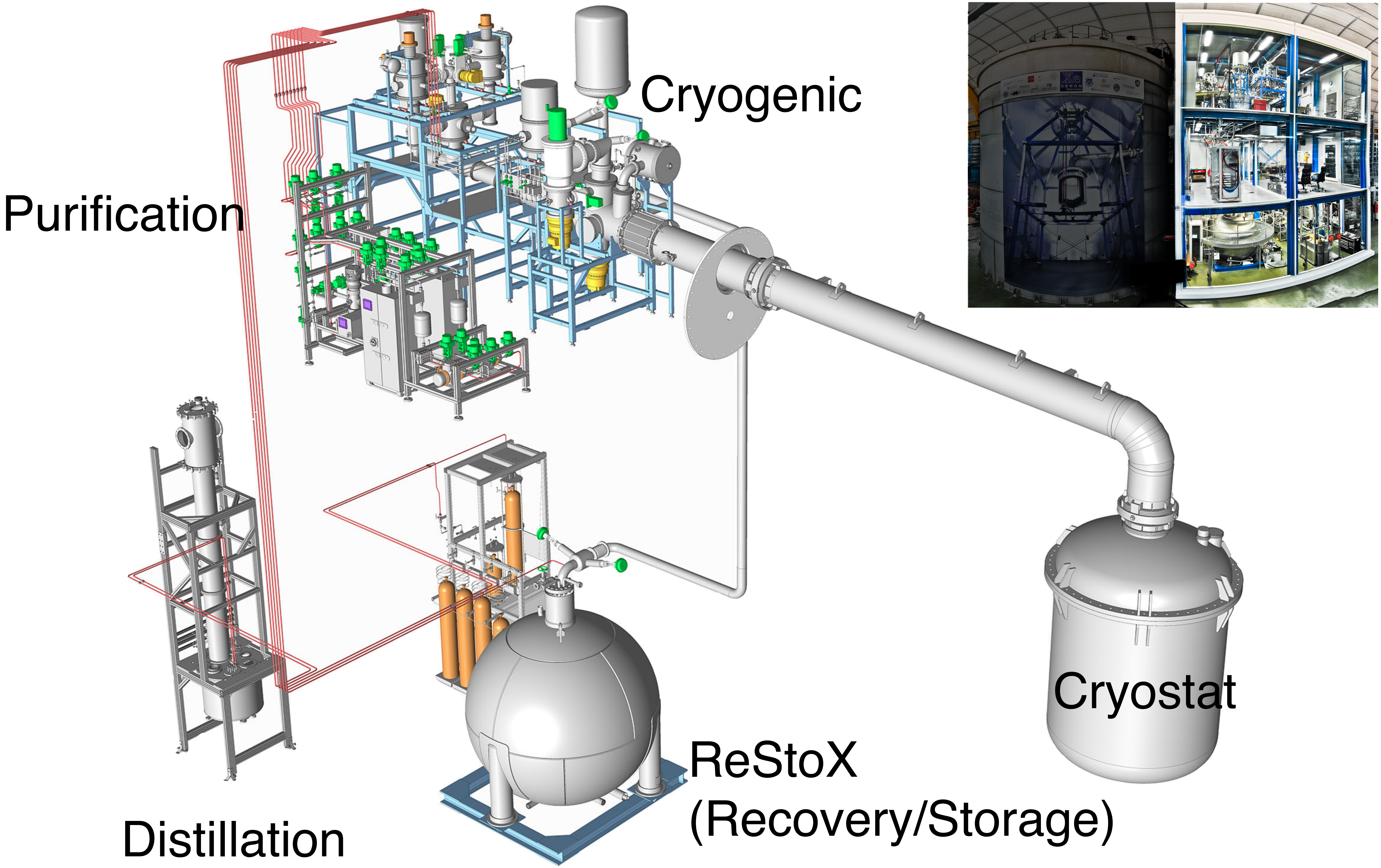






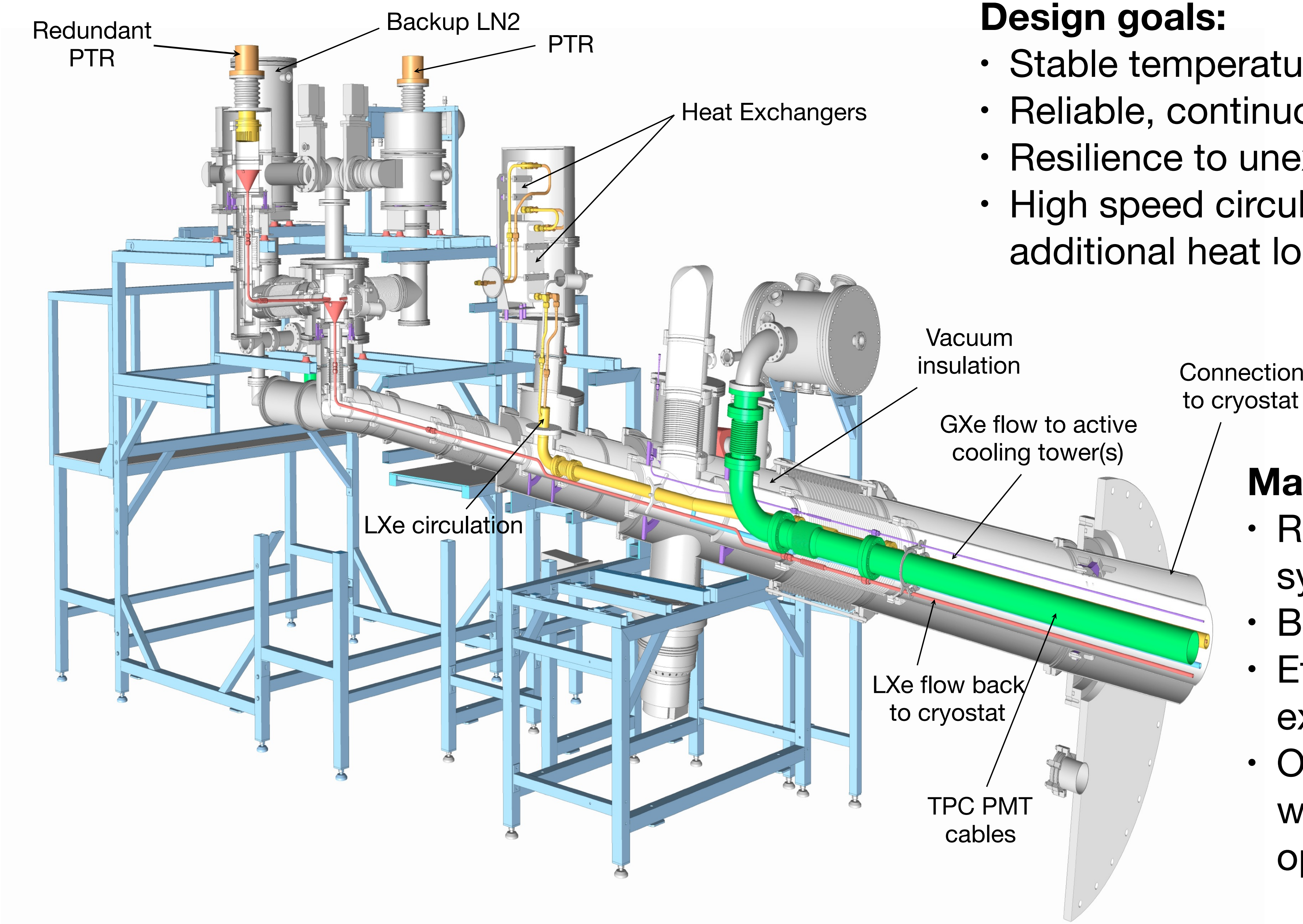


Xenon Plants



Xe Cooling System

Goal: liquefy 3300 Kg of Xe and maintain the xenon in the cryostat in liquid form, at a constant temperature and pressure, and so for years without interruption.



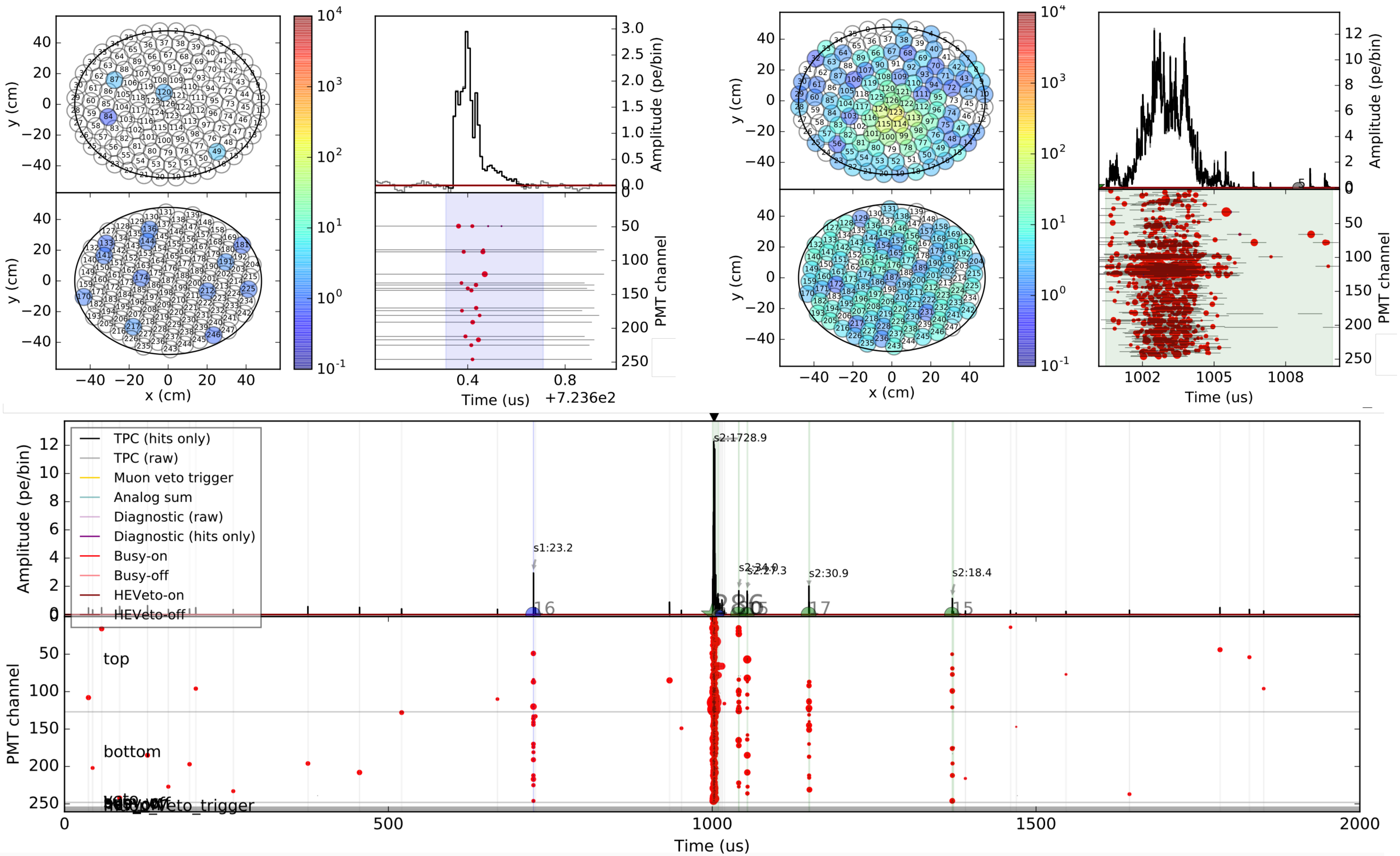
Design goals:

- Stable temperature and pressure control
- Reliable, continuous, long term operation
- Resilience to unexpected failures
- High speed circulation with low additional heat load

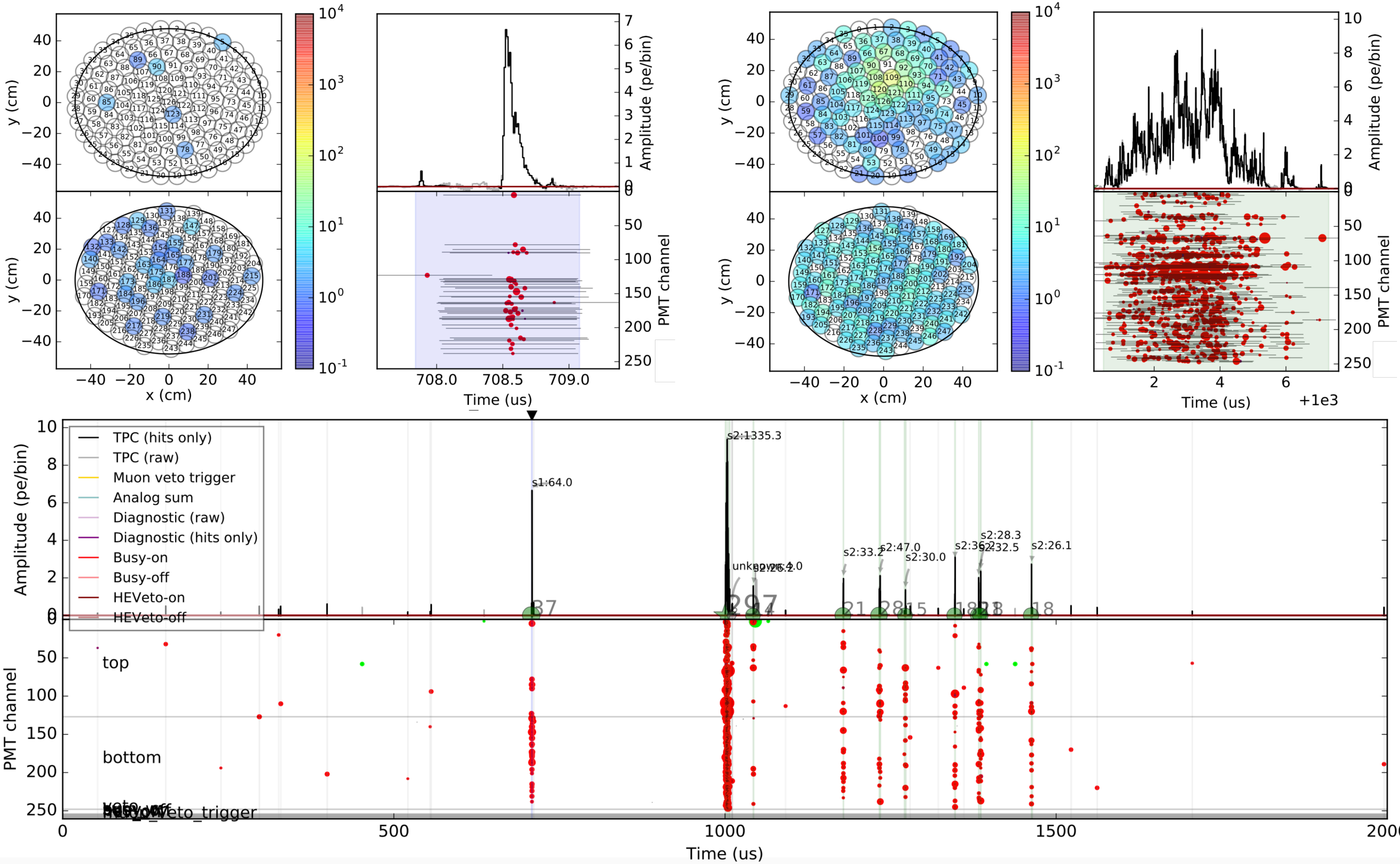
Main features:

- Redundant PTR cooling systems
- Backup LN2 cooling tower
- Efficient two-phase heat exchangers
- One PTR can be serviced while the other is in operation

Real Waveform Example 1

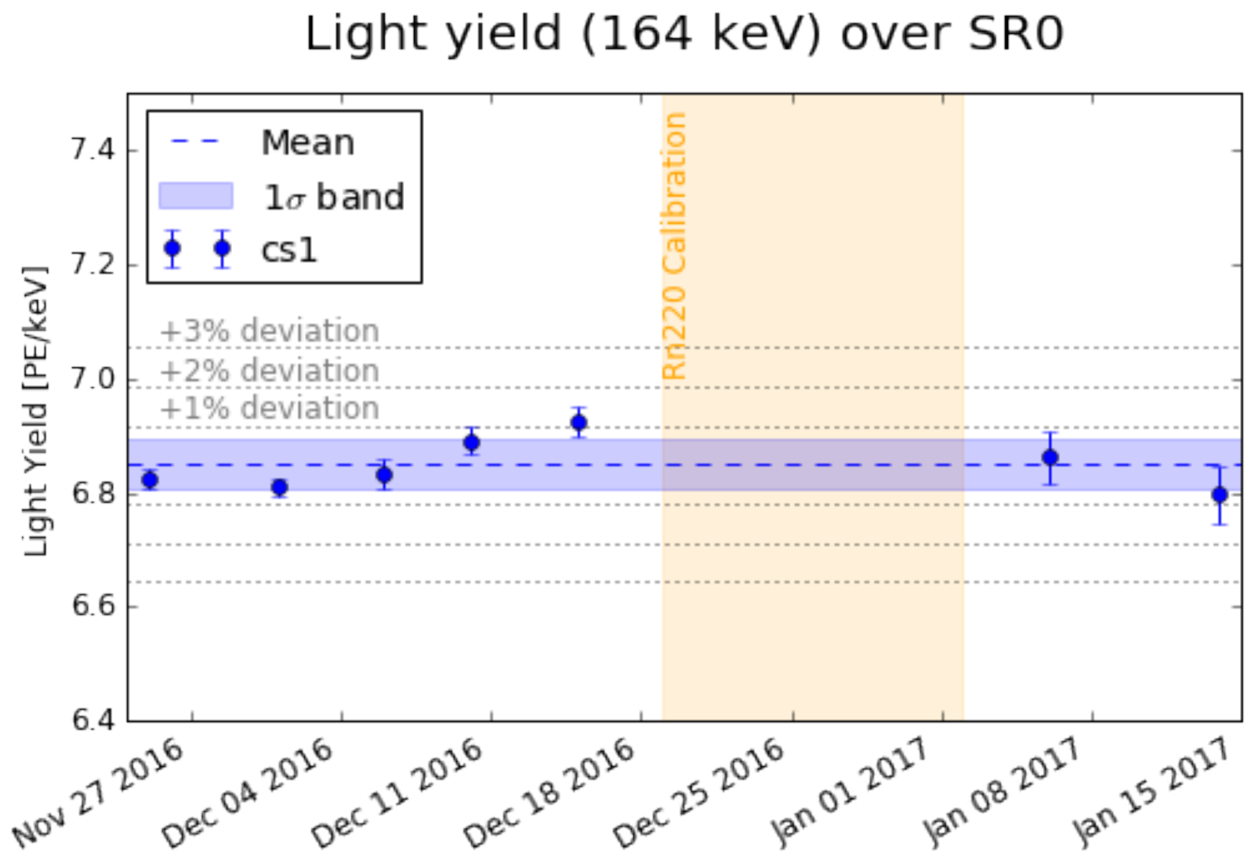


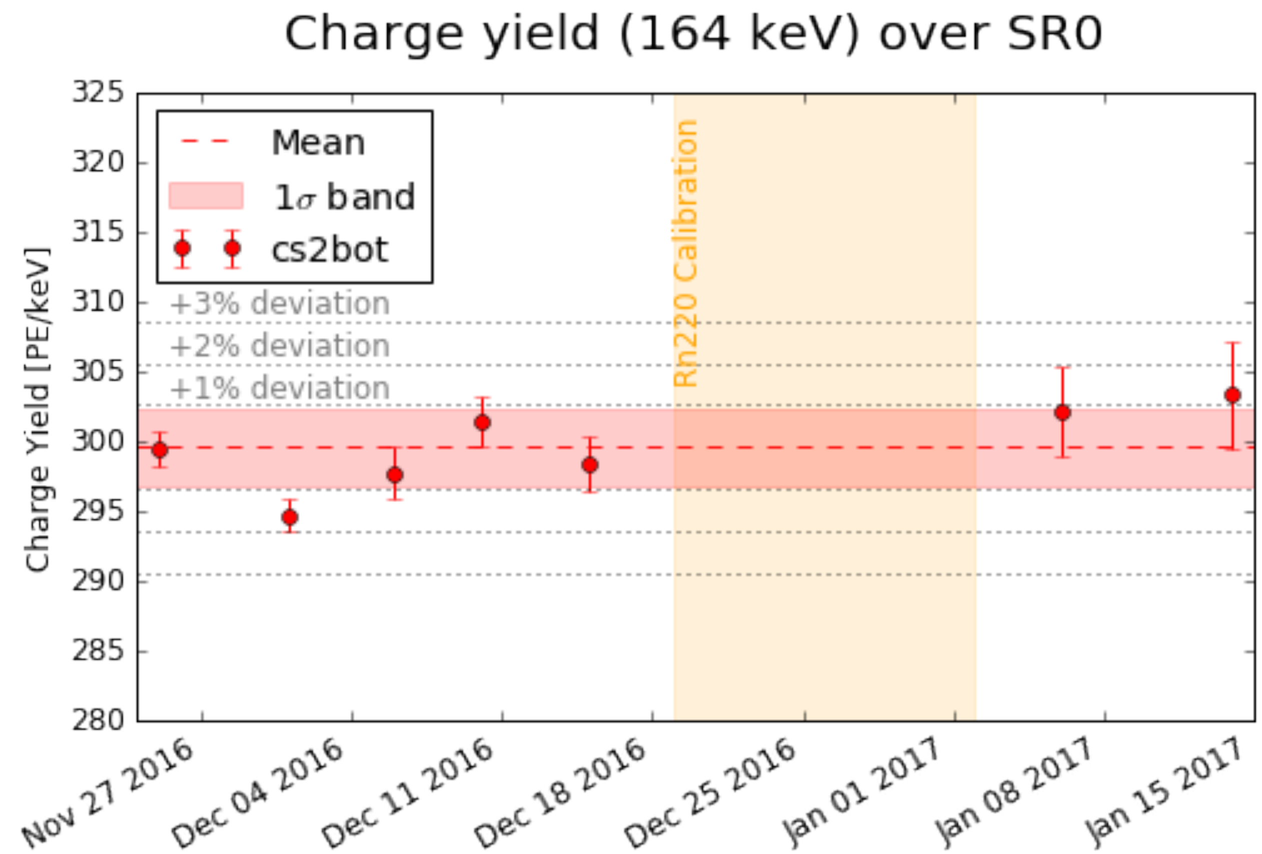
Real Waveform Example 2

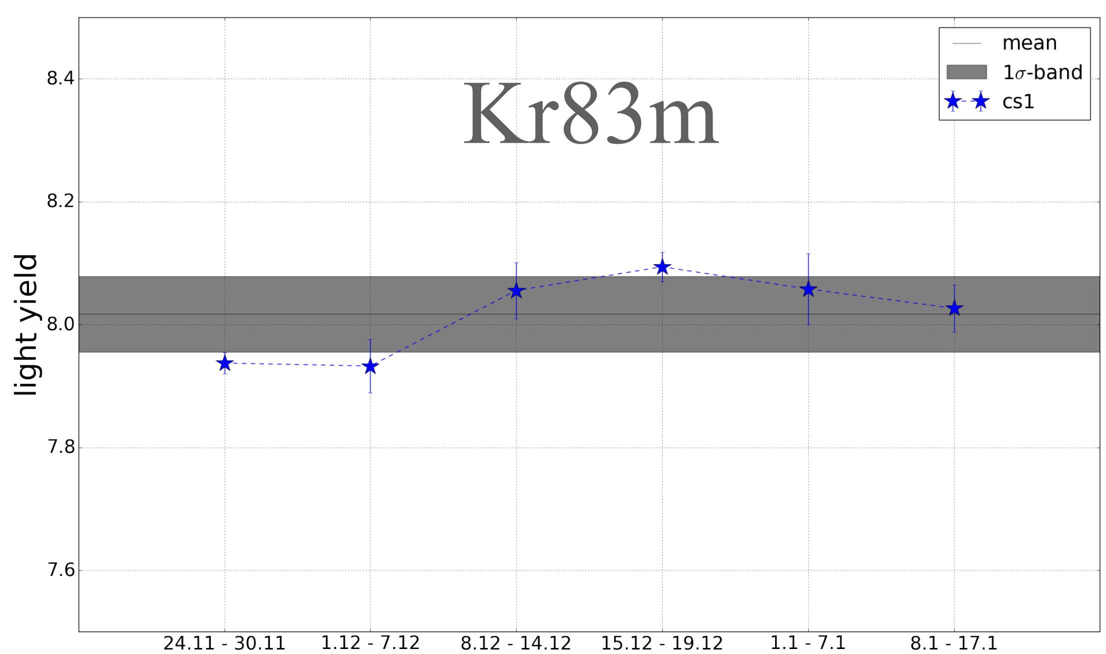


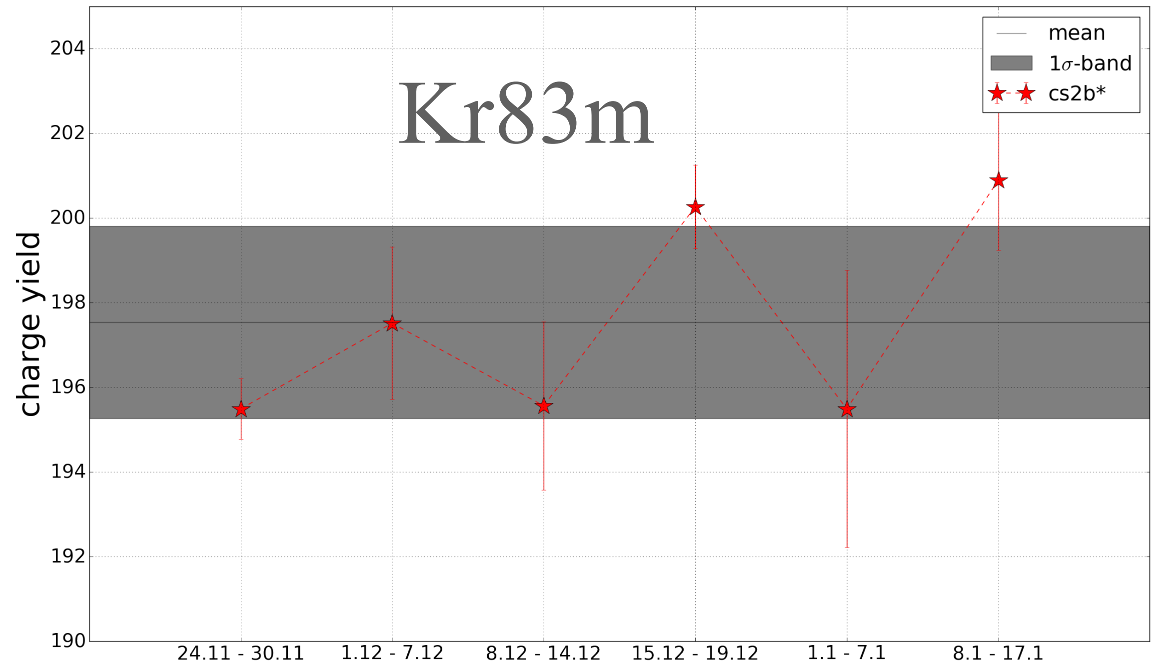
Light/Charge Yield Stability

From Kr83m and activated Xe131m, variation in LY and CY is at ~1% level.

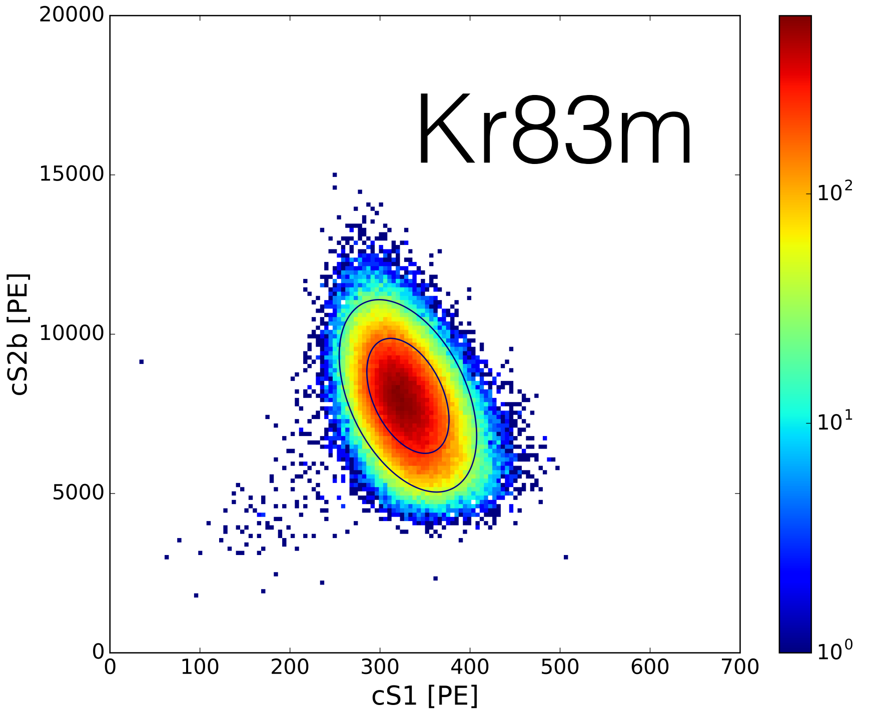


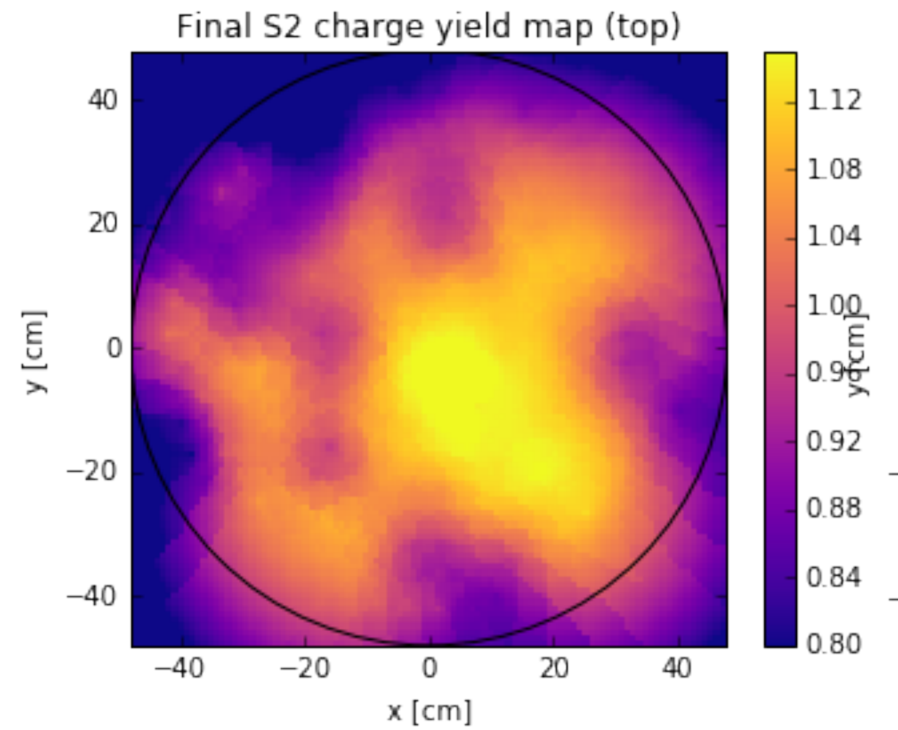


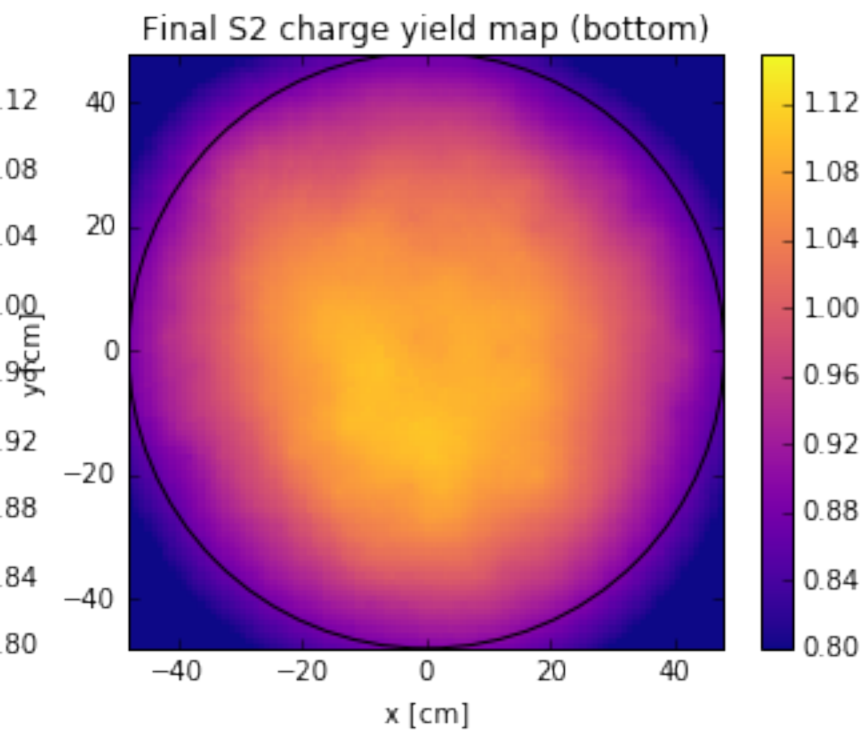




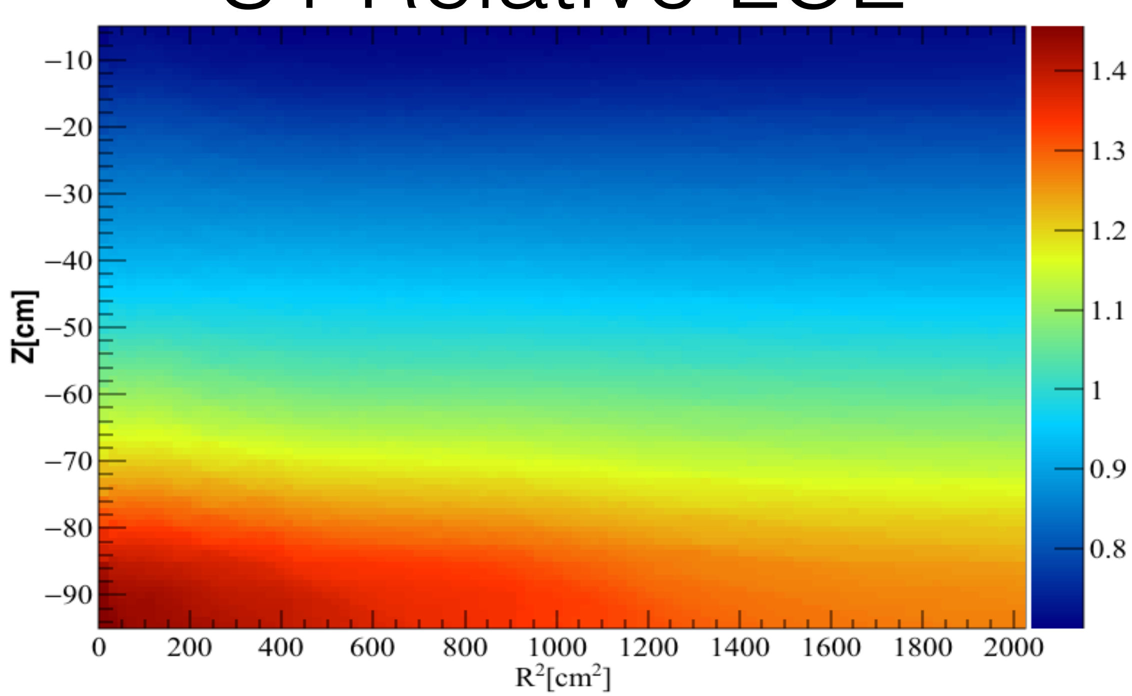
Signal Corrections



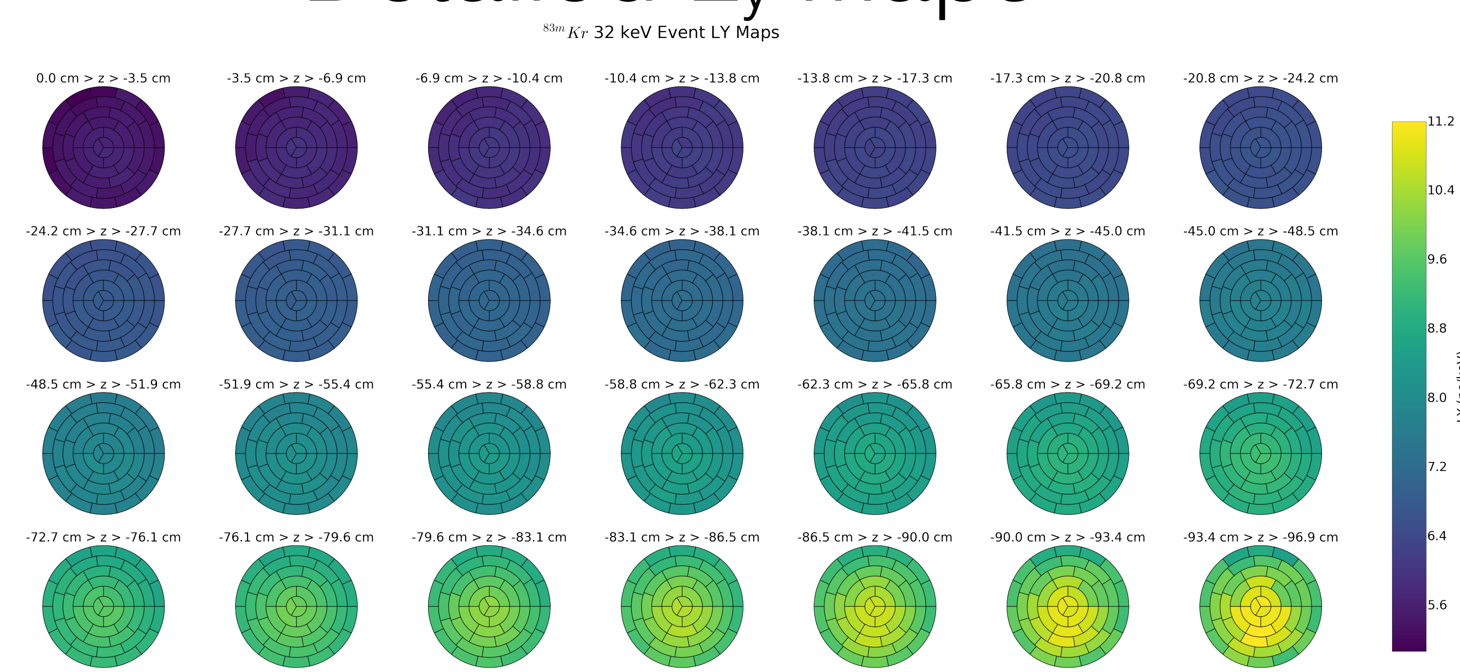




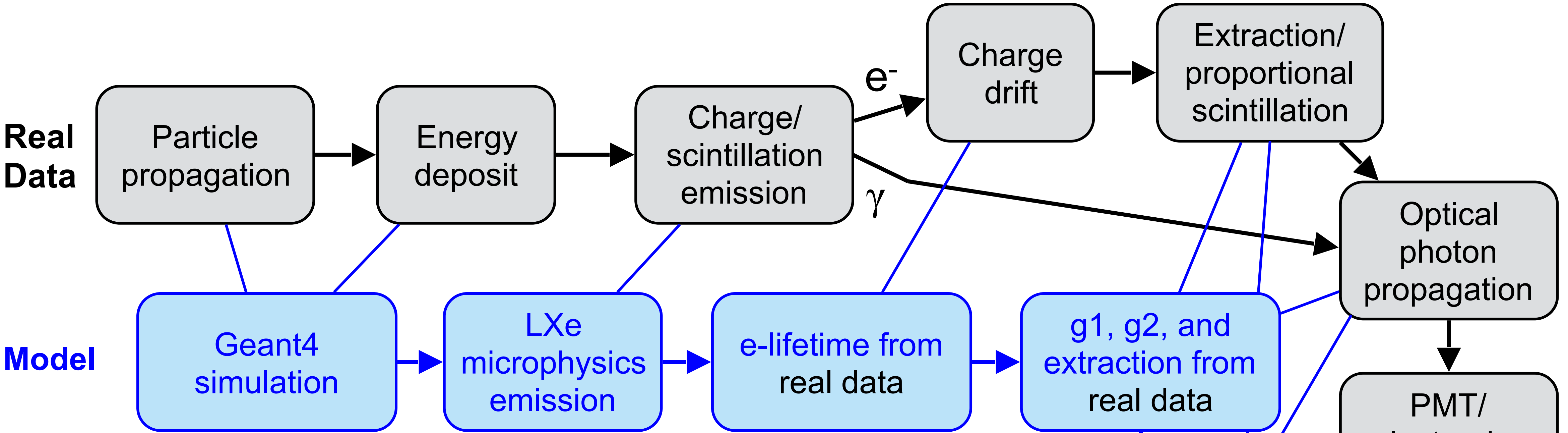
S1 Relative LCE

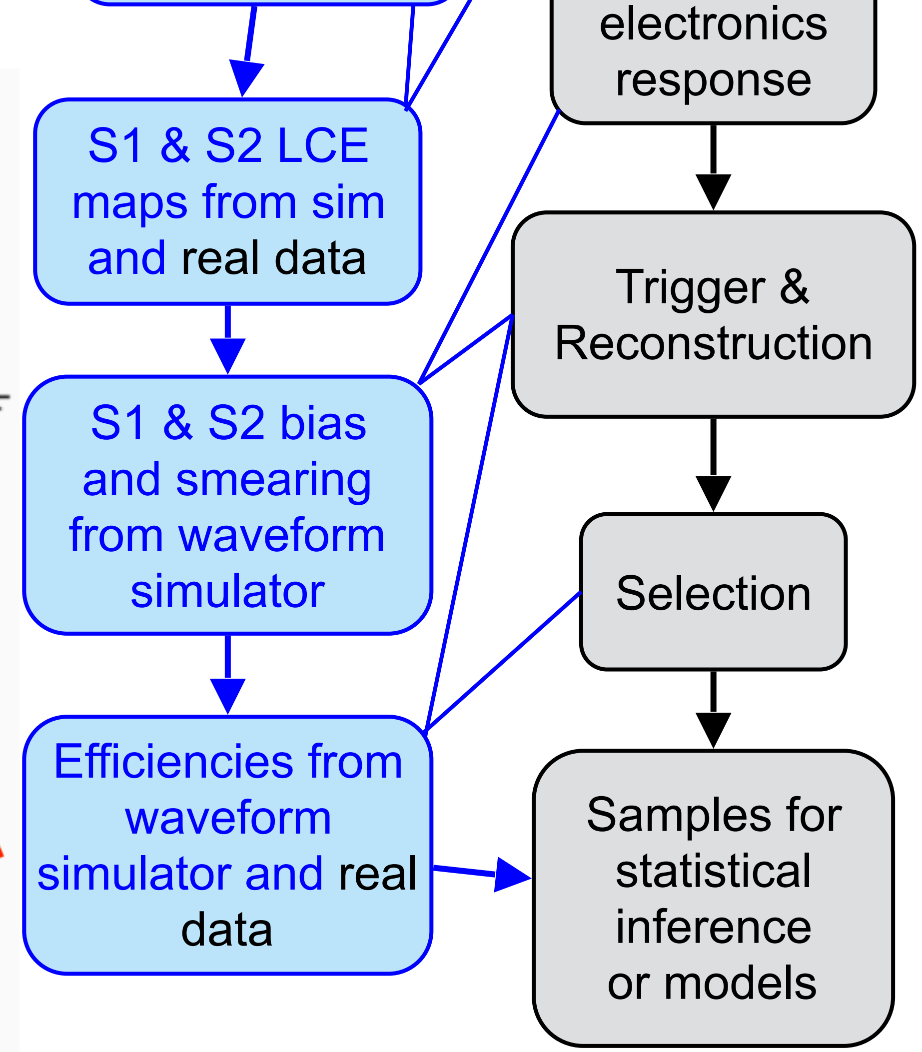


Detailed L_y Maps



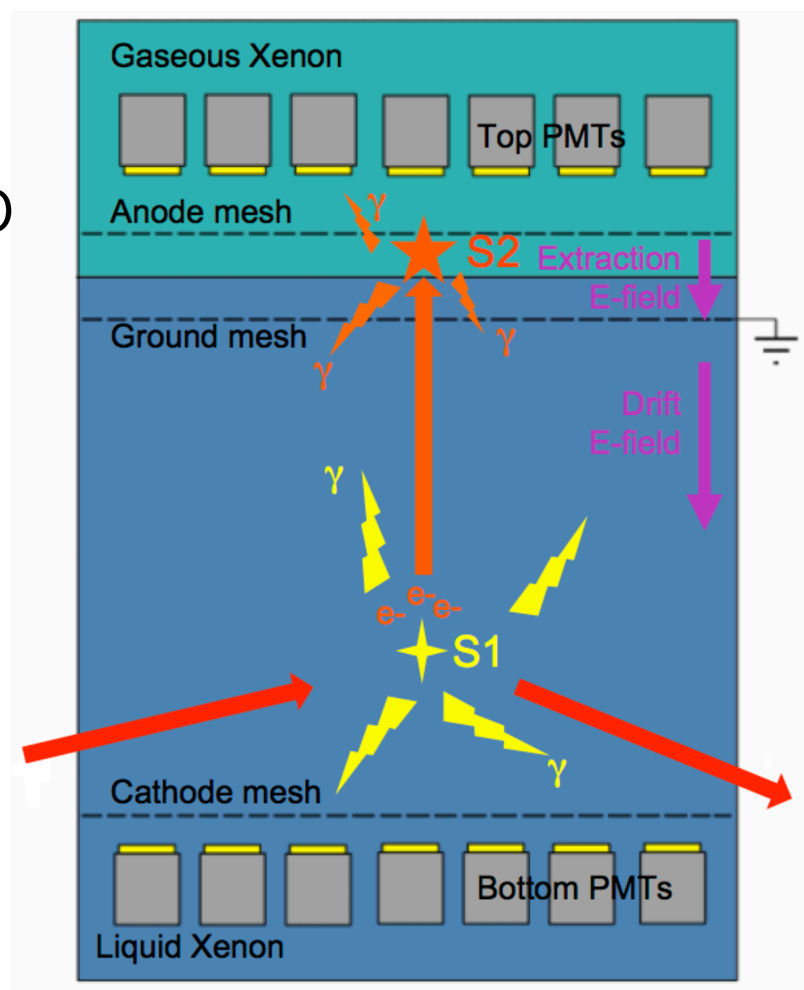
The ER and NR Models





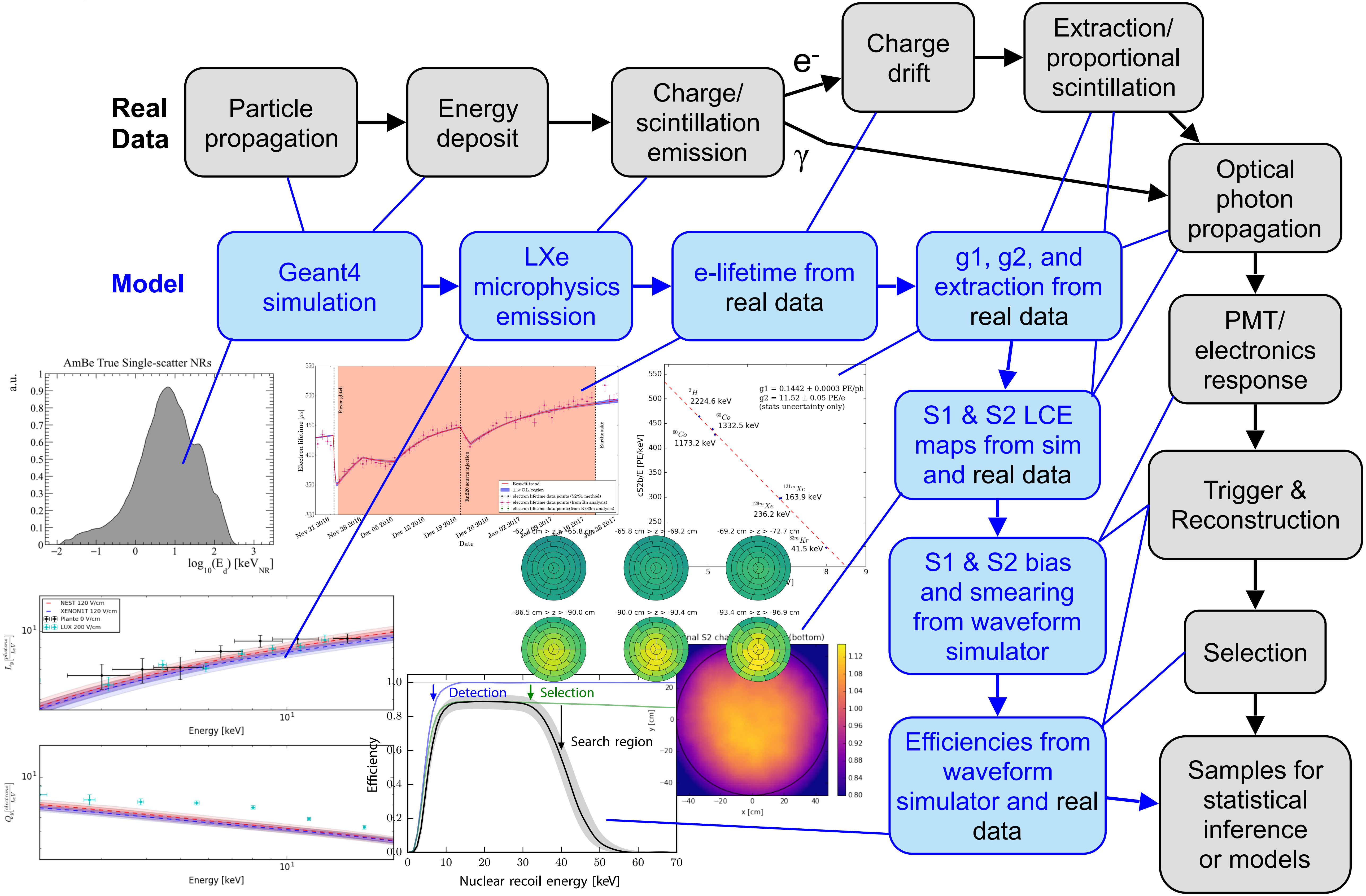
- Simulate LXe microphysics & detector response to fit Rn220 and AmBe calibration data

- Background and signal predictions from tuned models

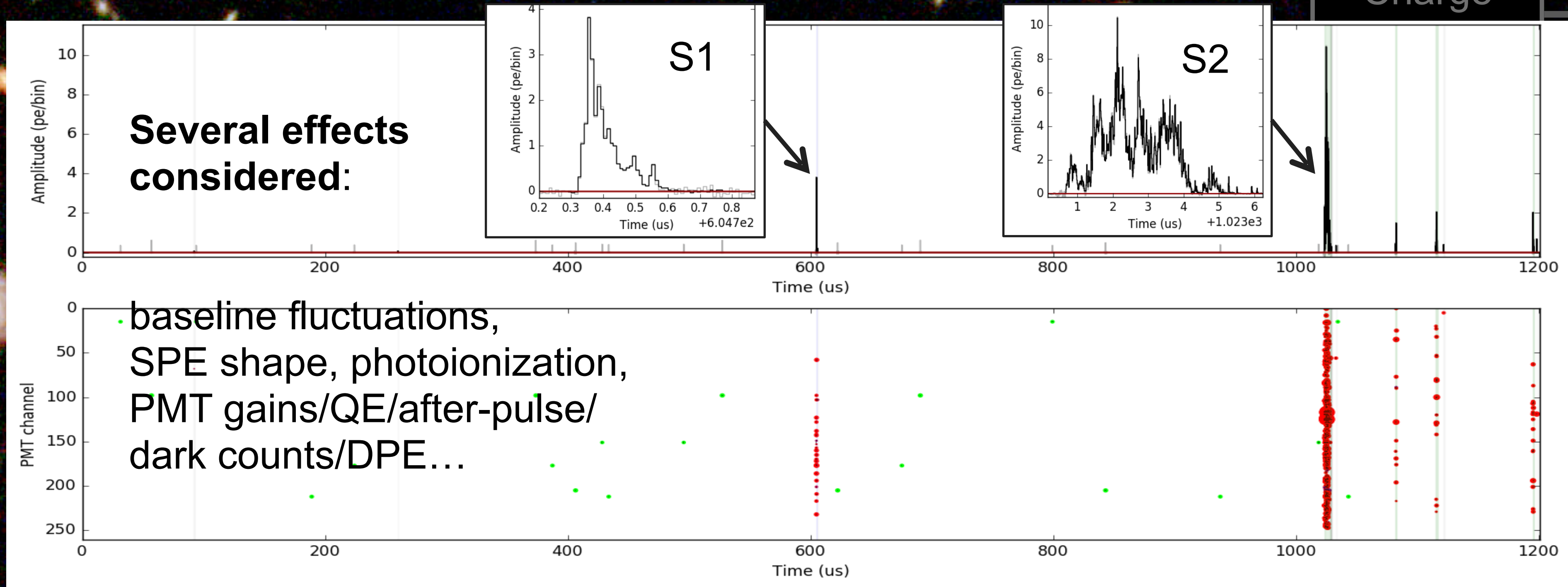


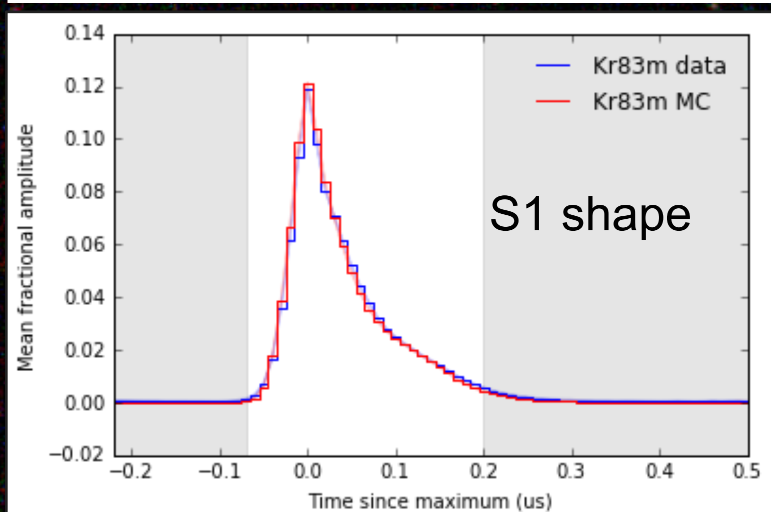
JCAP 1604 no. 4, 027 (2016)

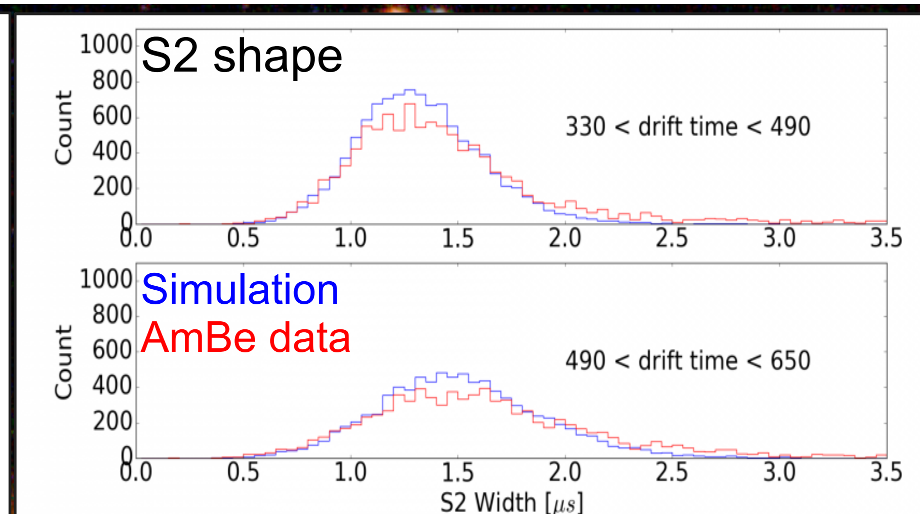
The ER and NR Models

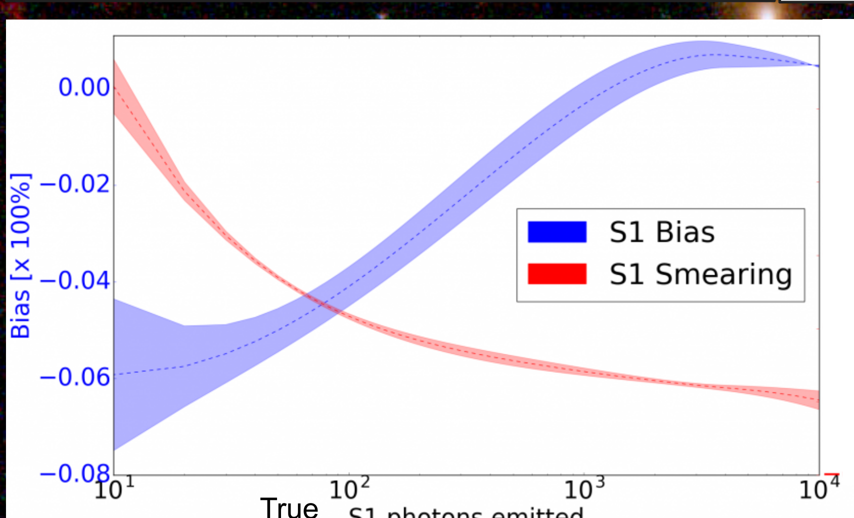


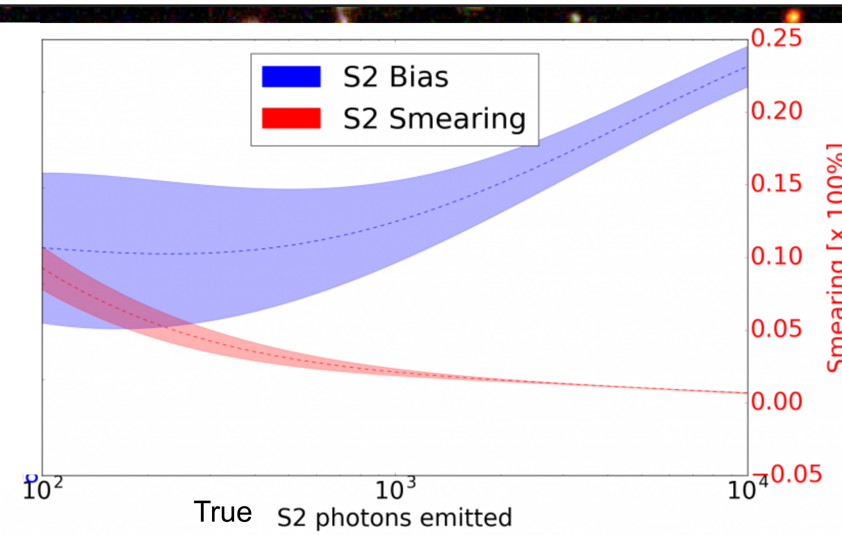
Waveform Simulation (more details)

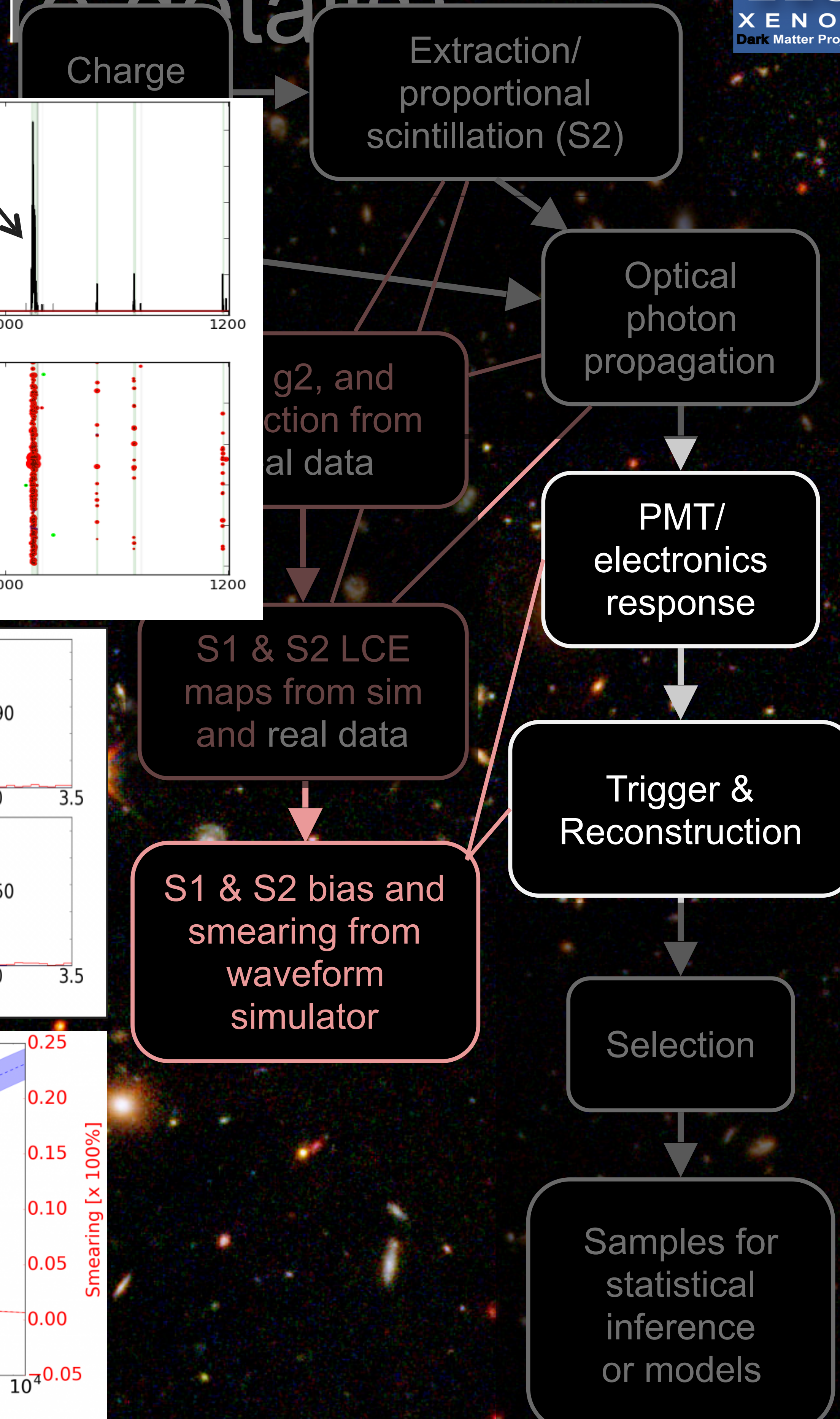




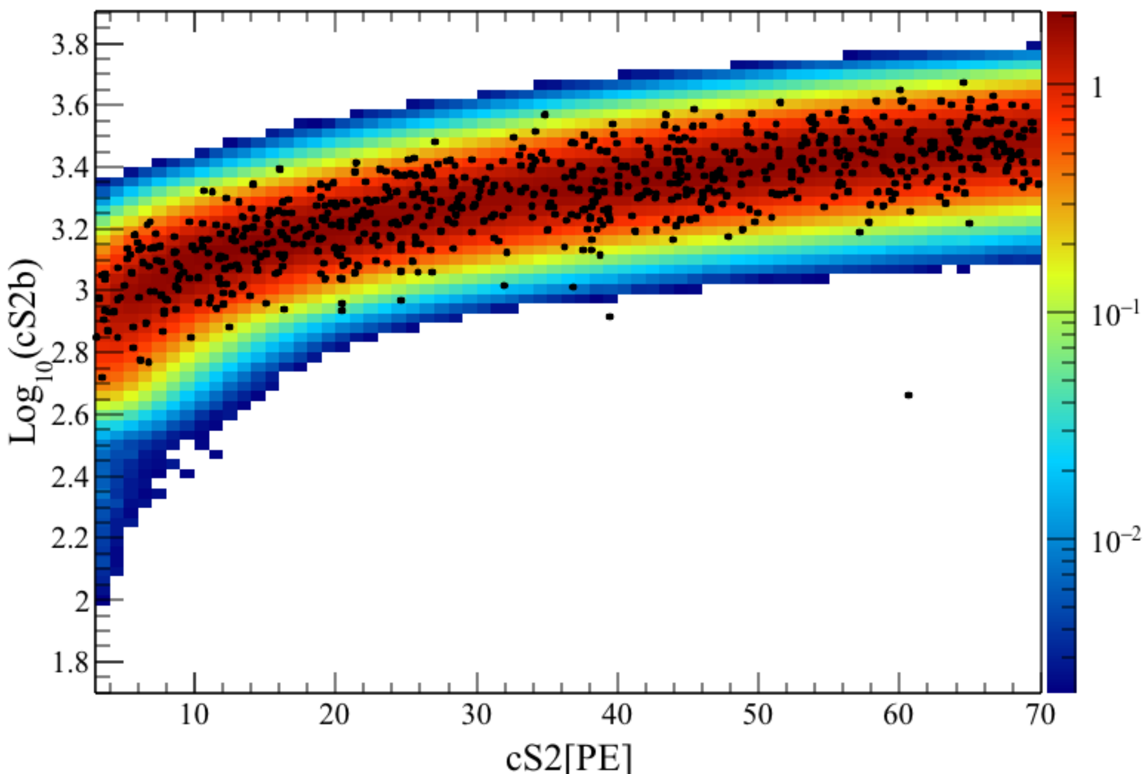




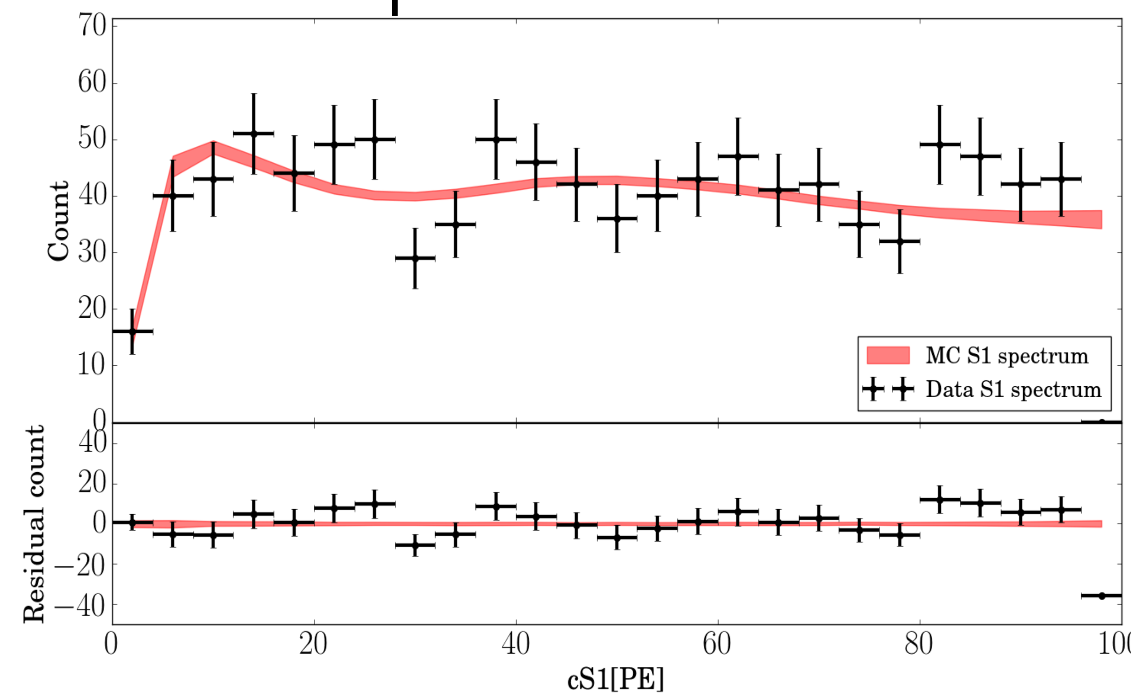




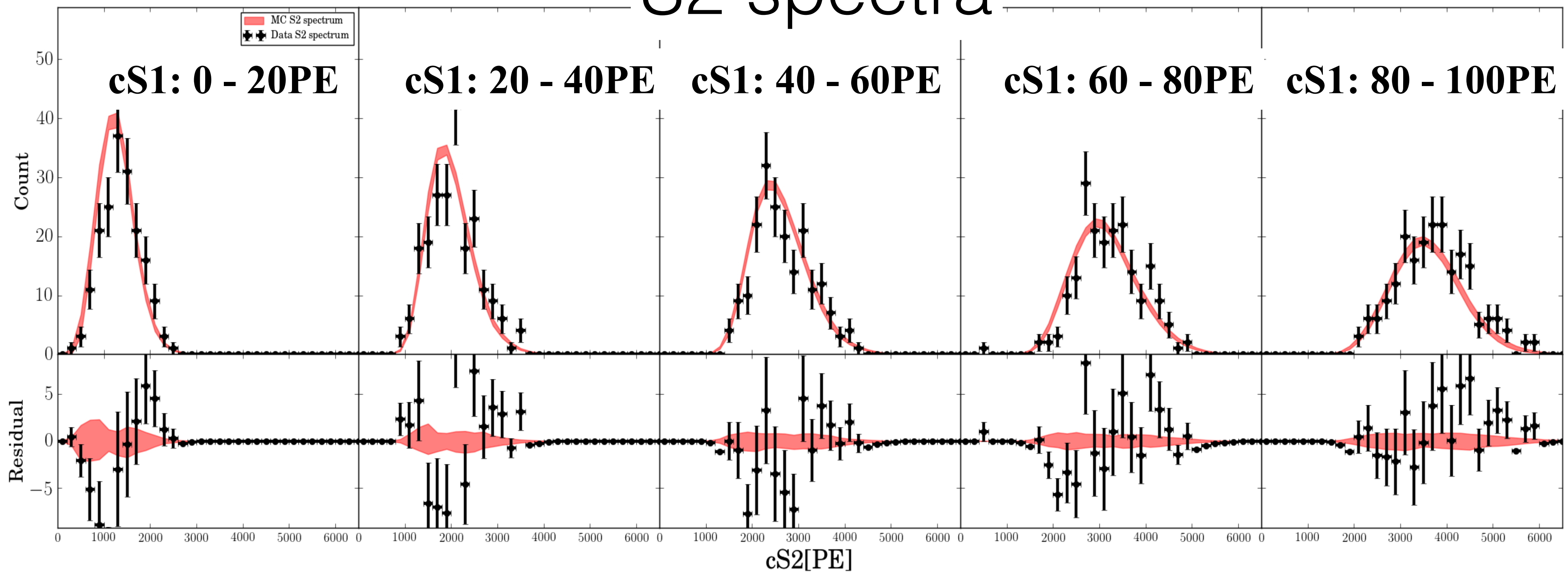
Rn220 Calibration



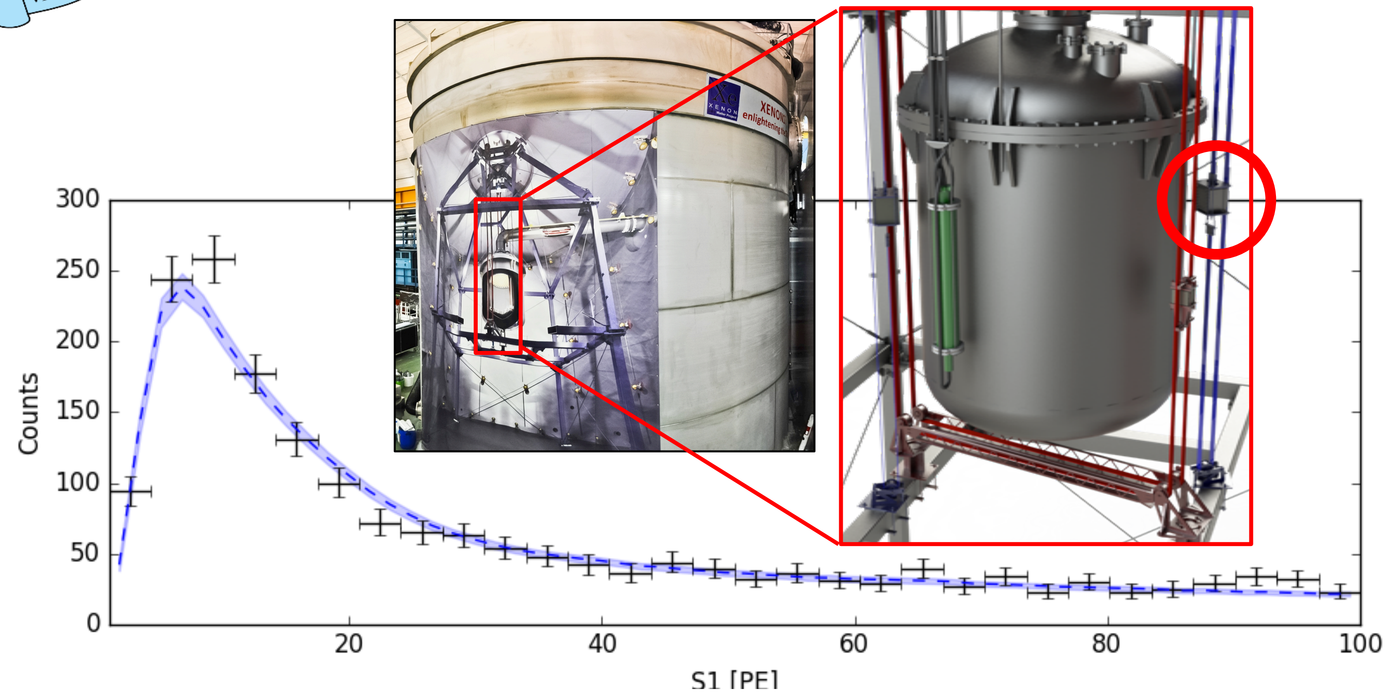
S1 spectrum

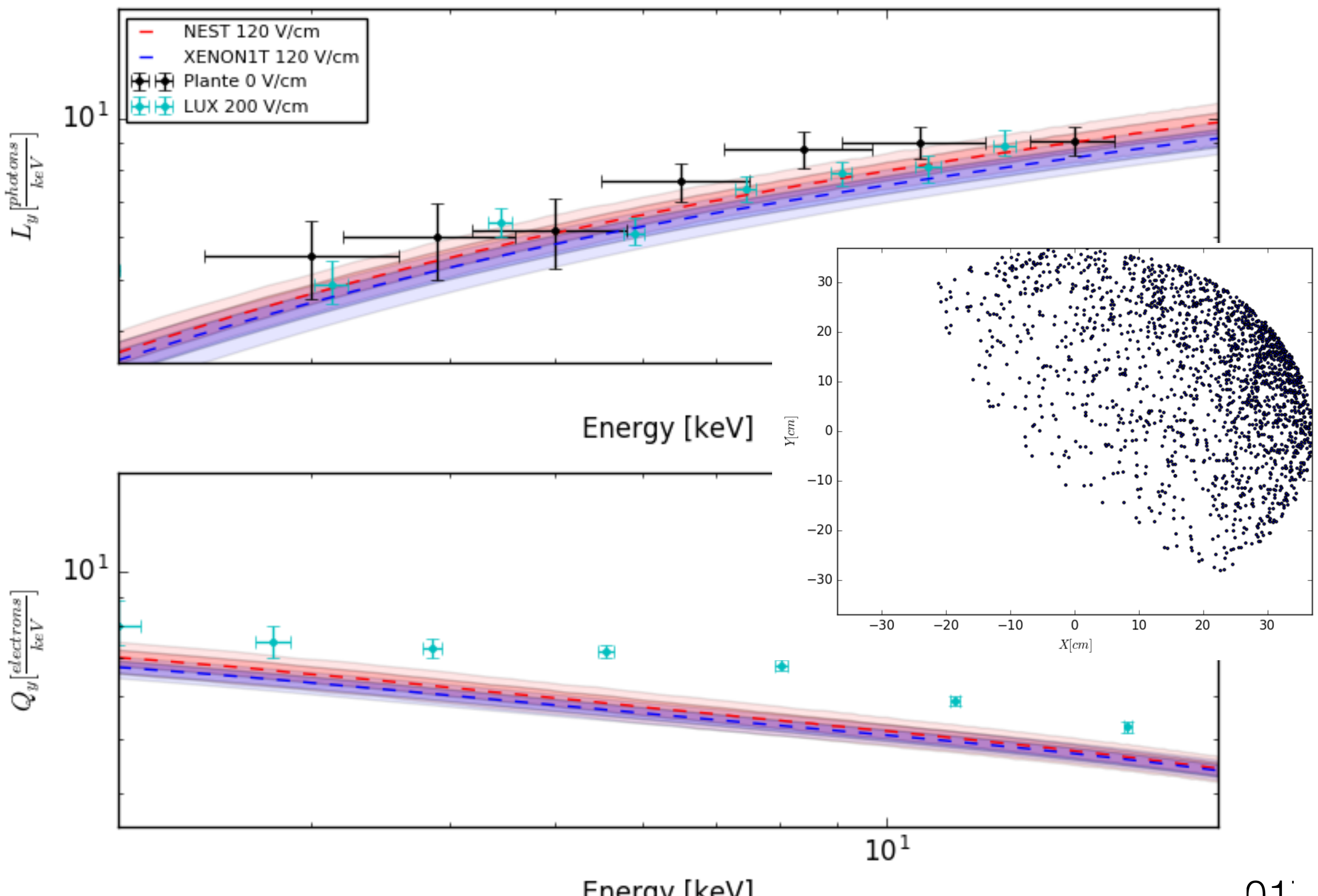


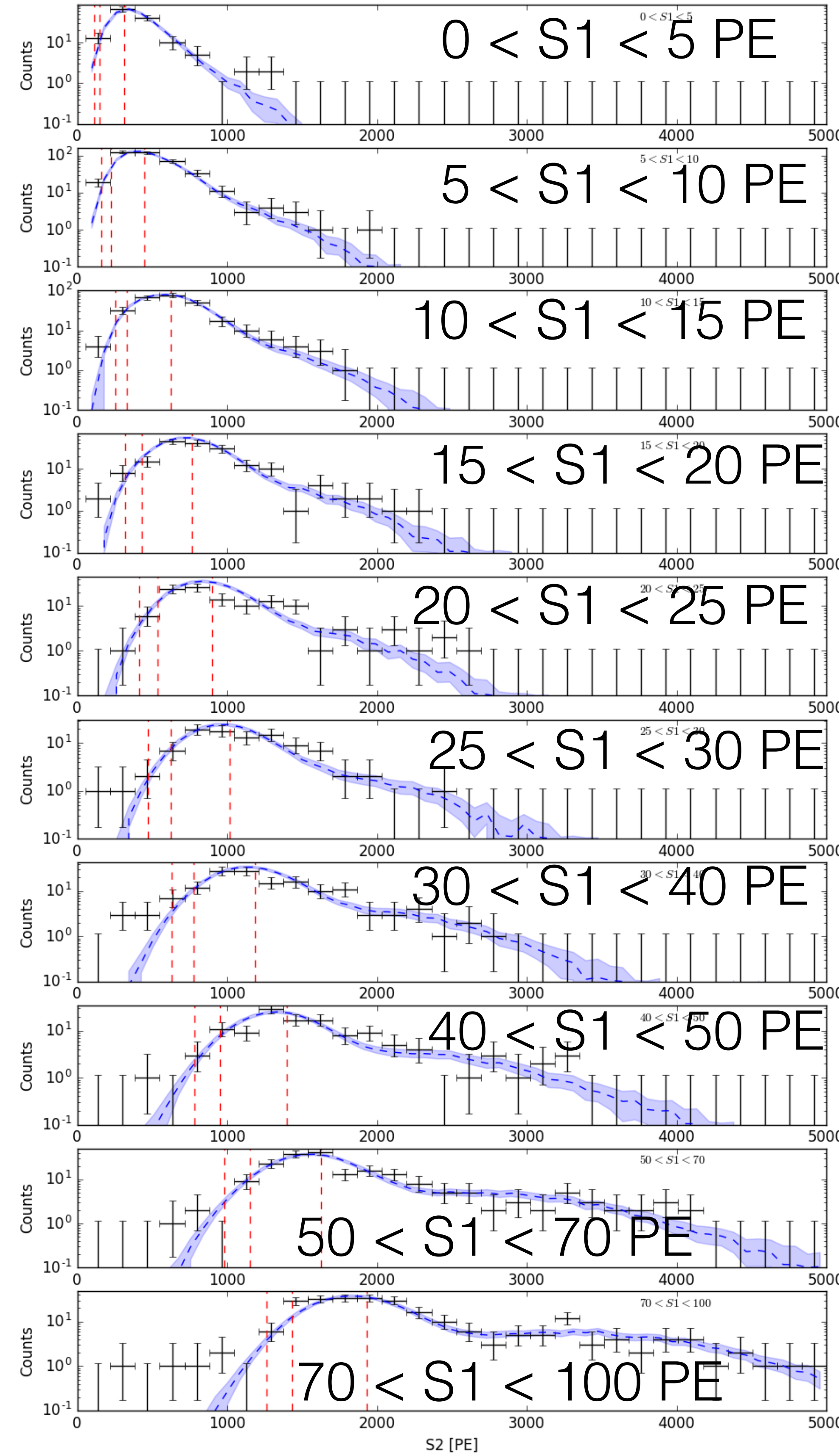
S2 spectra



AmBe Calibration

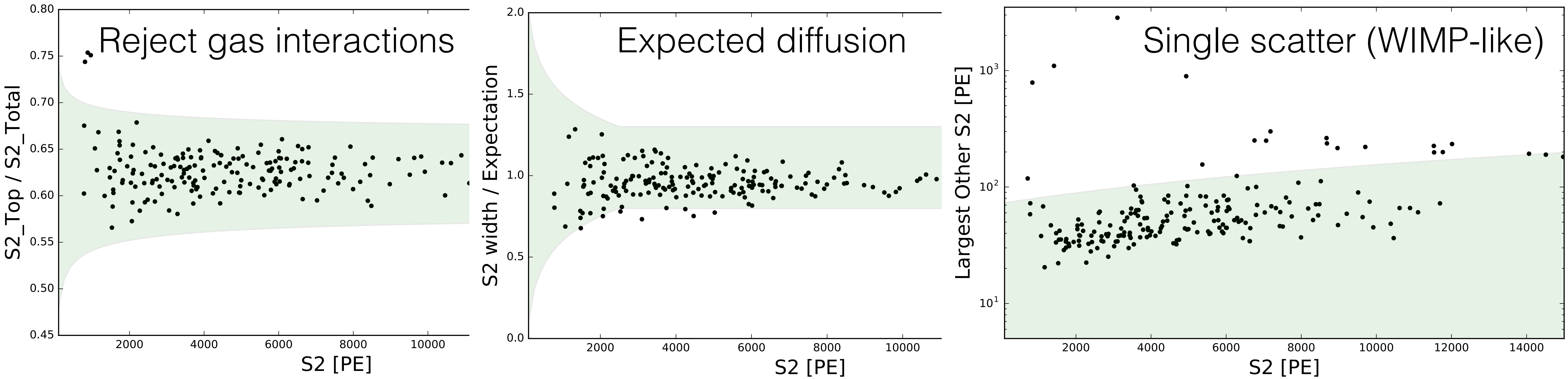


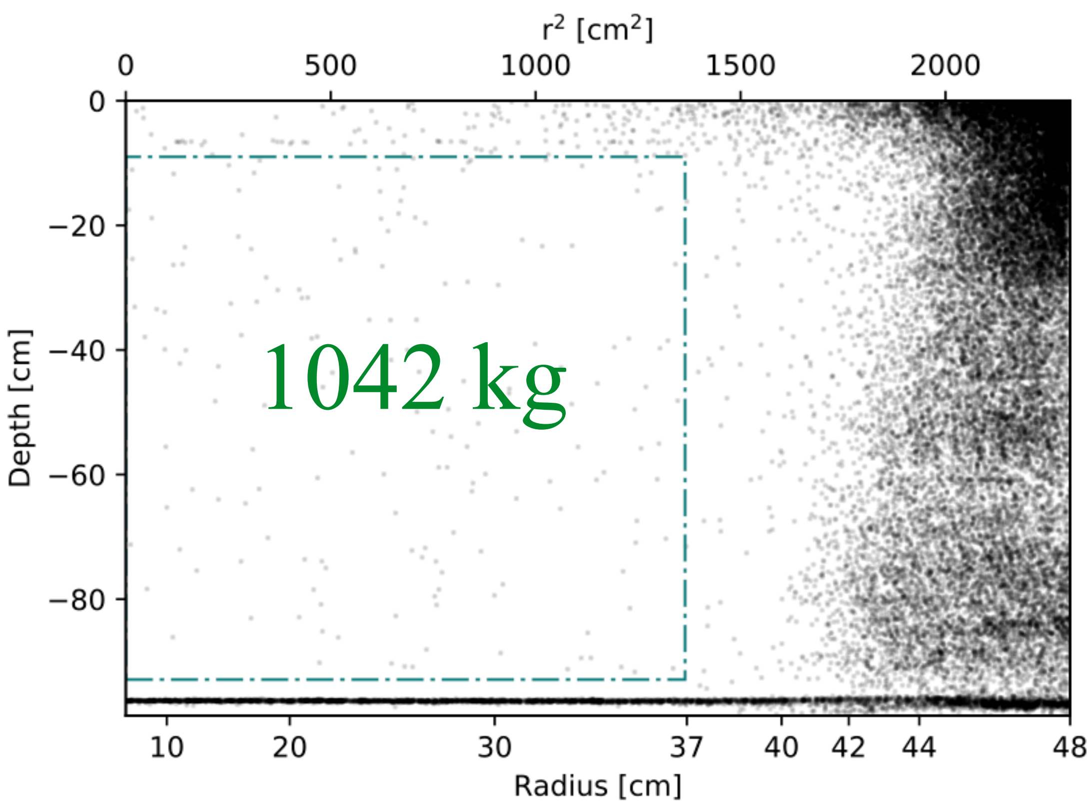




Event Selection

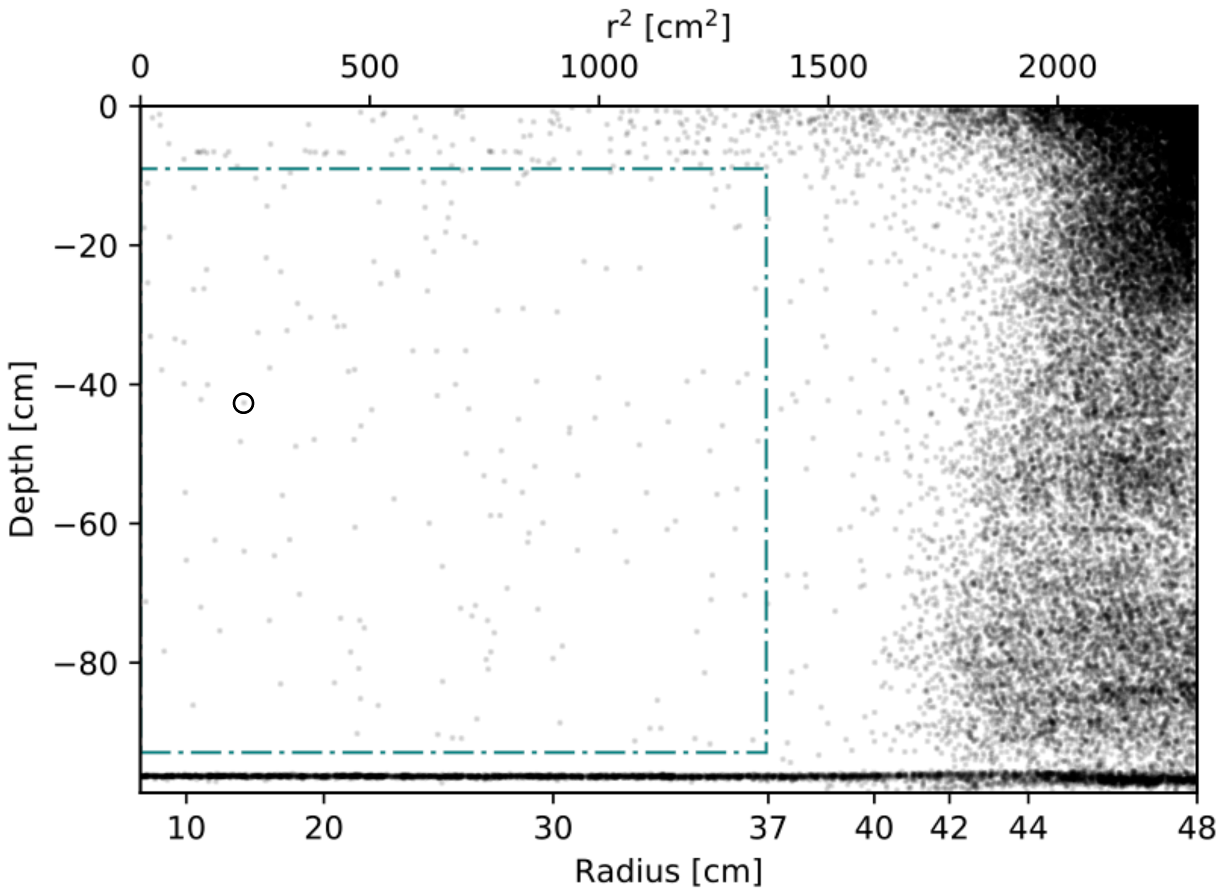
- Data quality and selection cuts tuned to calibration data

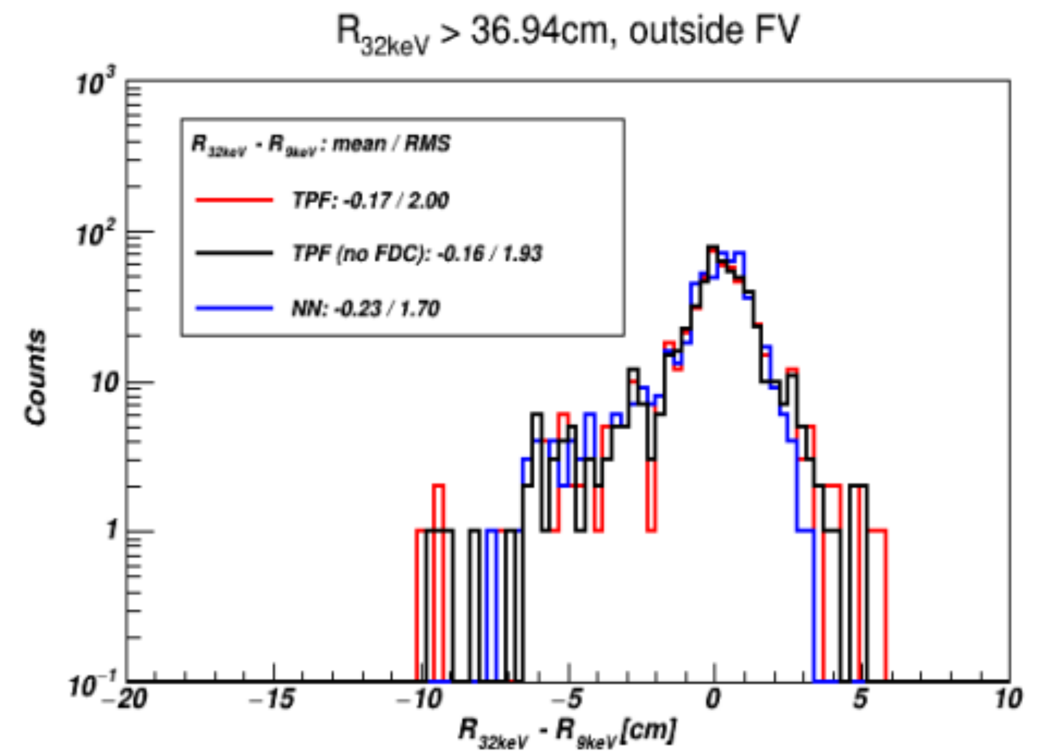


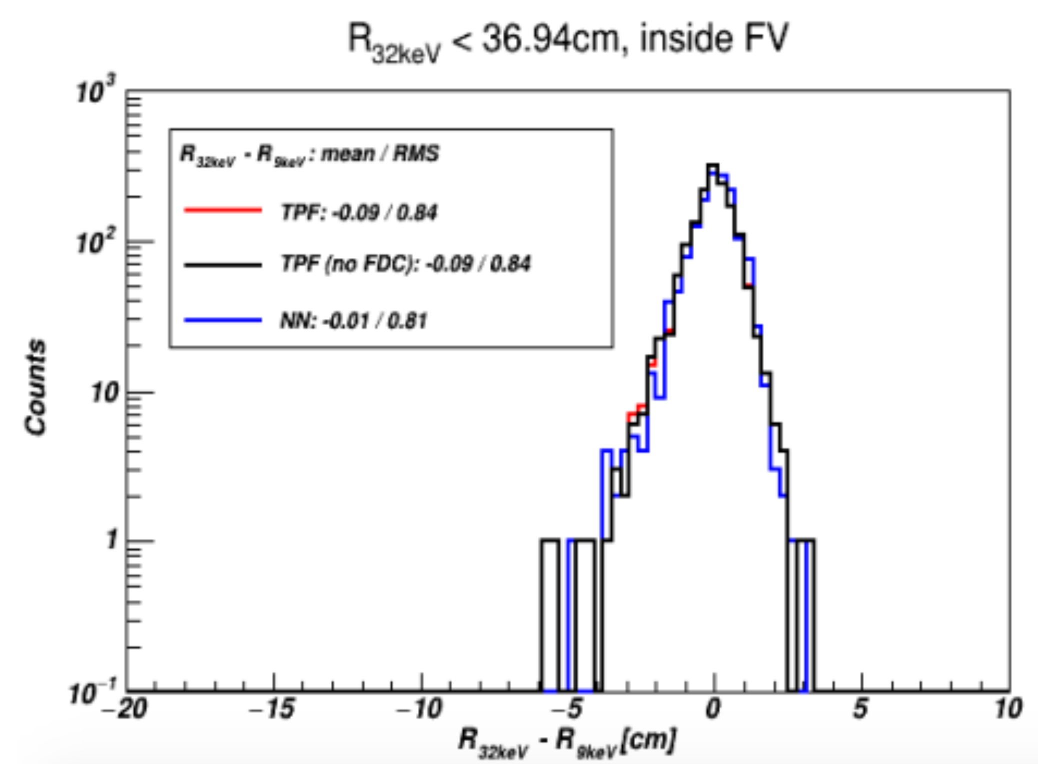


Cut	Events remaining
All Events (cS1 < 200 PE)	128144
Data Quality and Selection	48955
Fiducial Volume	180
S1 Range (3 < cS1 < 70 PE)	63

Position Reconstruction



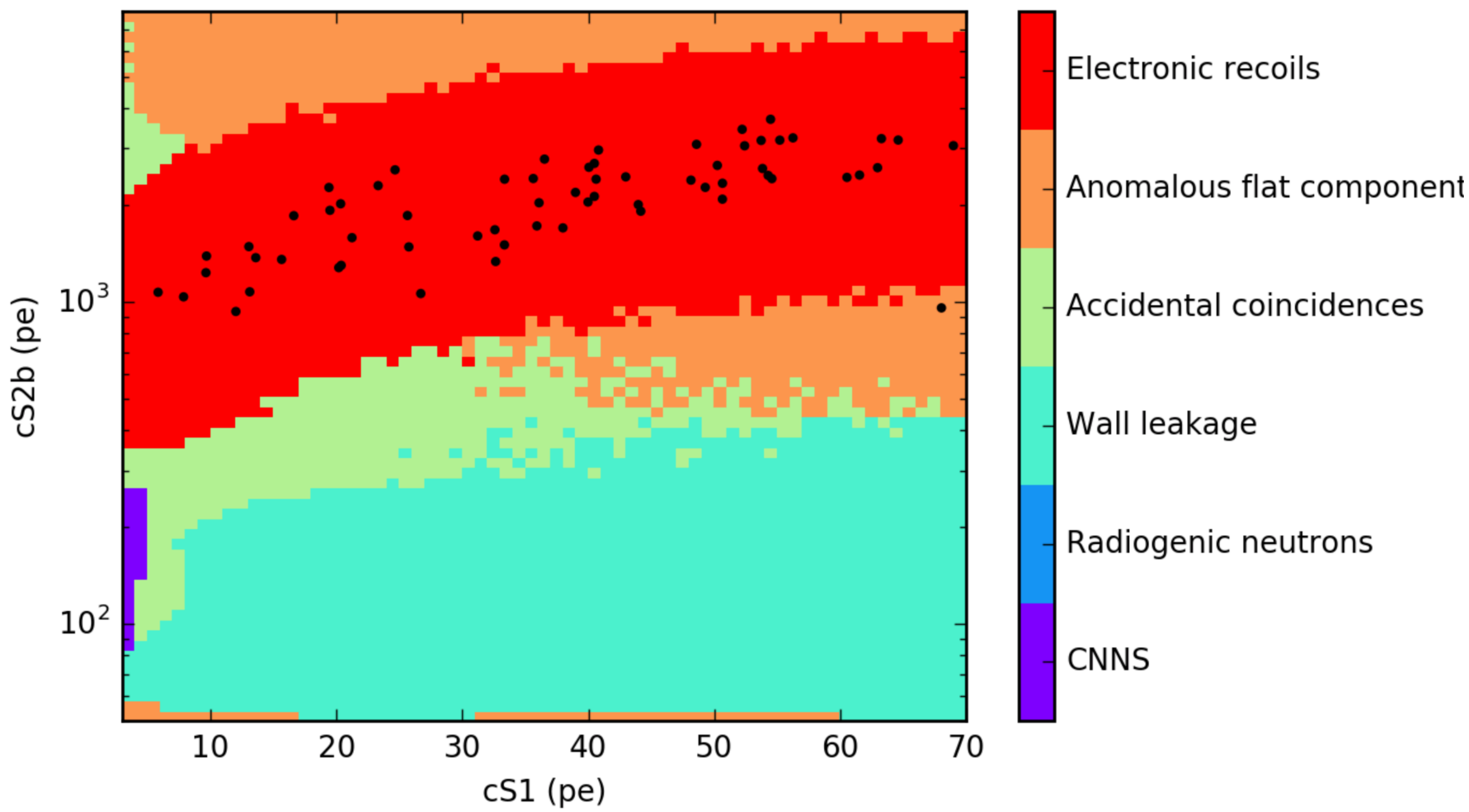


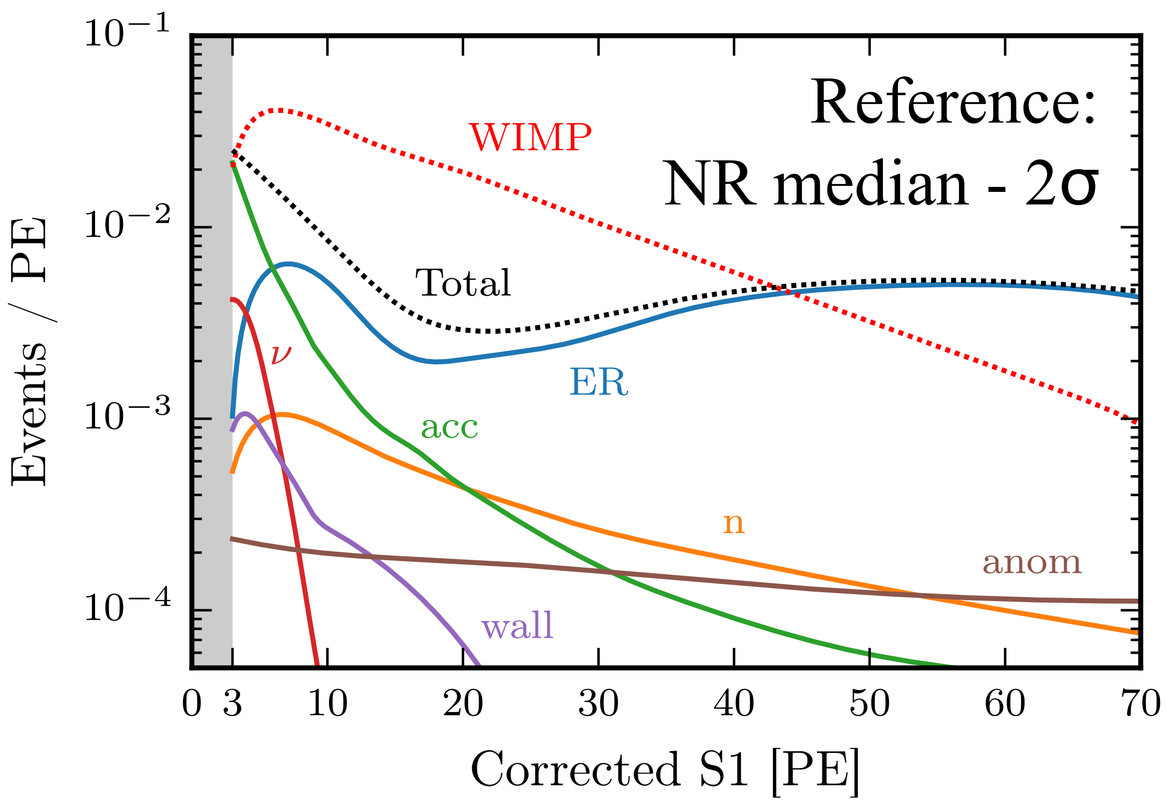


- Position resolution (RMS) is less than 1 cm inside the FV, and ~2 cm outside the FV, estimated using the difference from two peaks (32 keV and 9 keV) from Kr83m events.

Predicting Backgrounds

Most dominant component





- ER/NR background predictions from fitted models.
- Other background predictions are data-driven, derived from control samples
- Correlated shape and normalization uncertainties including prior constraints