The LUX-ZEPLIN (LZ) Experiment

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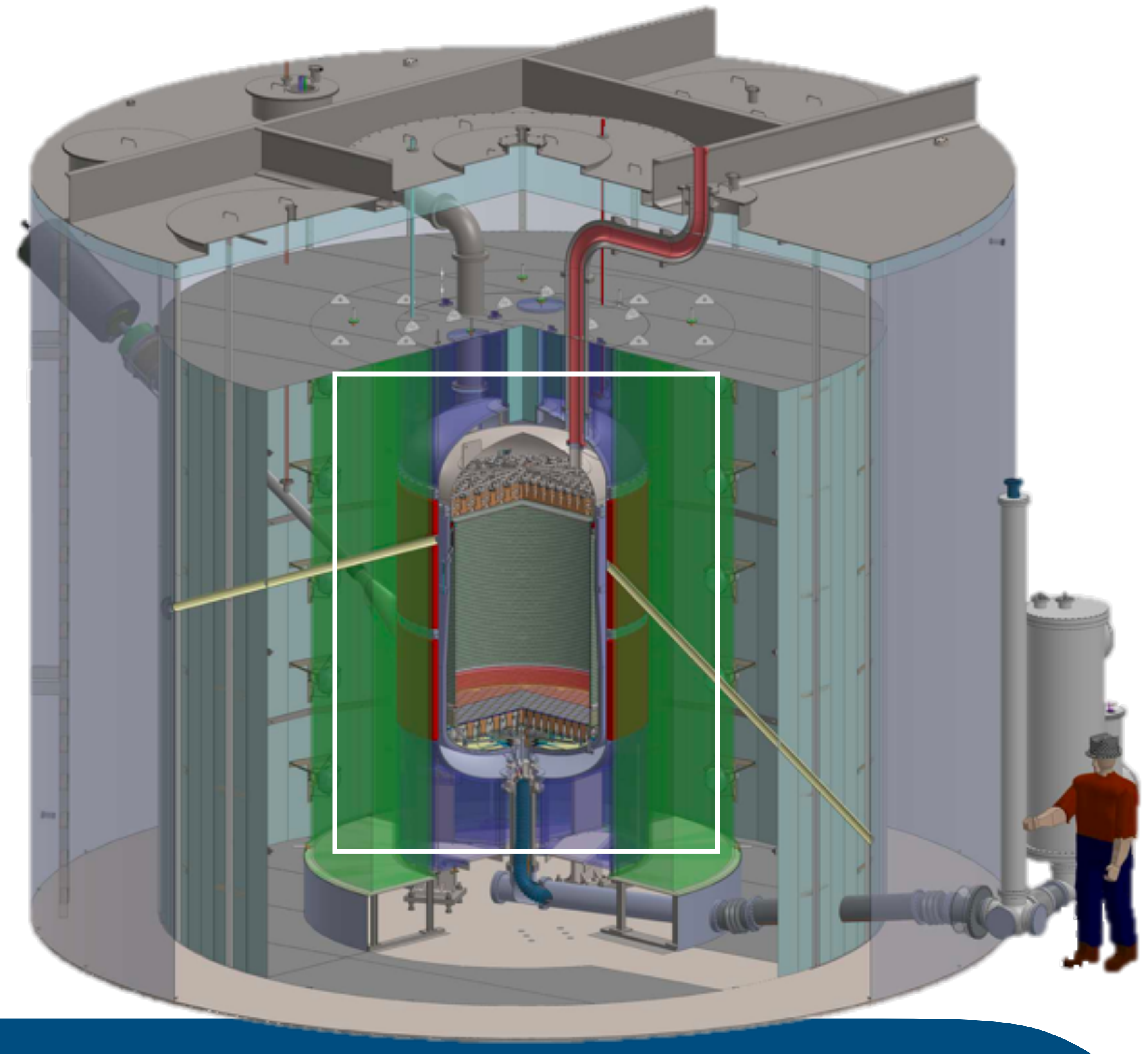
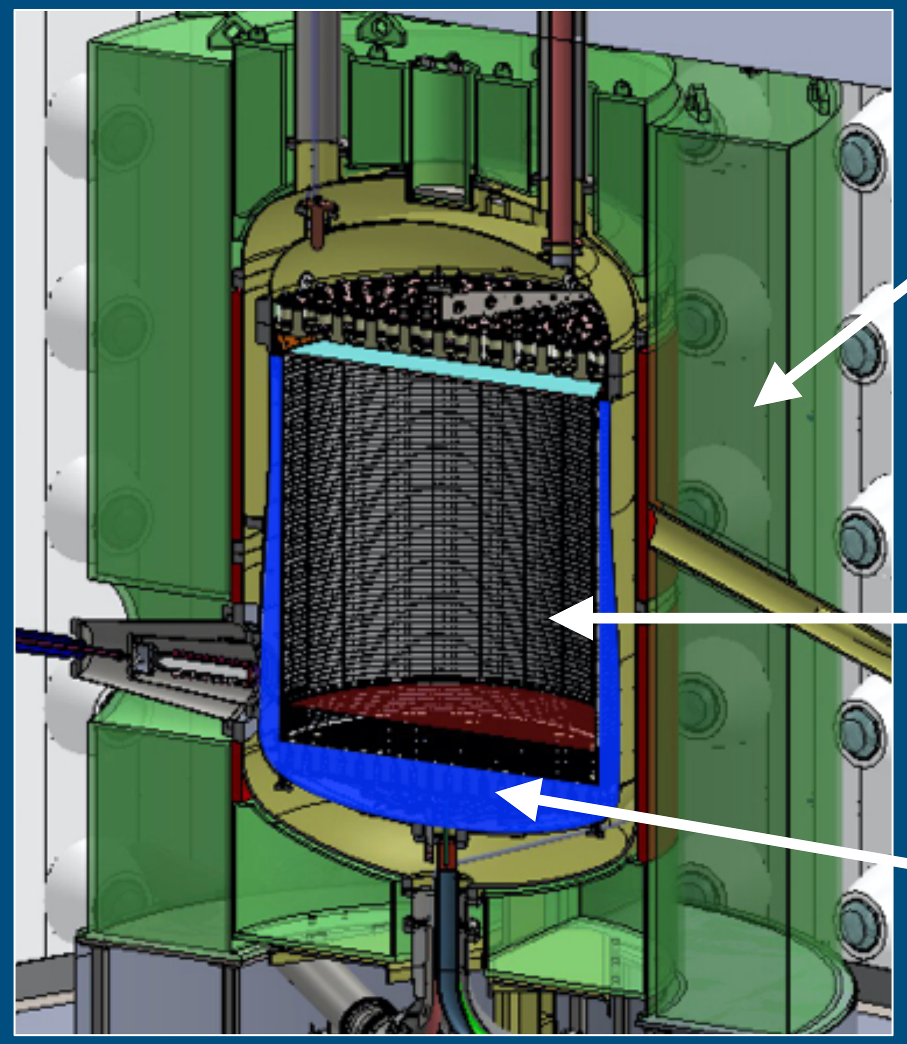
IOP HEPP 2022

Introduction to LZ

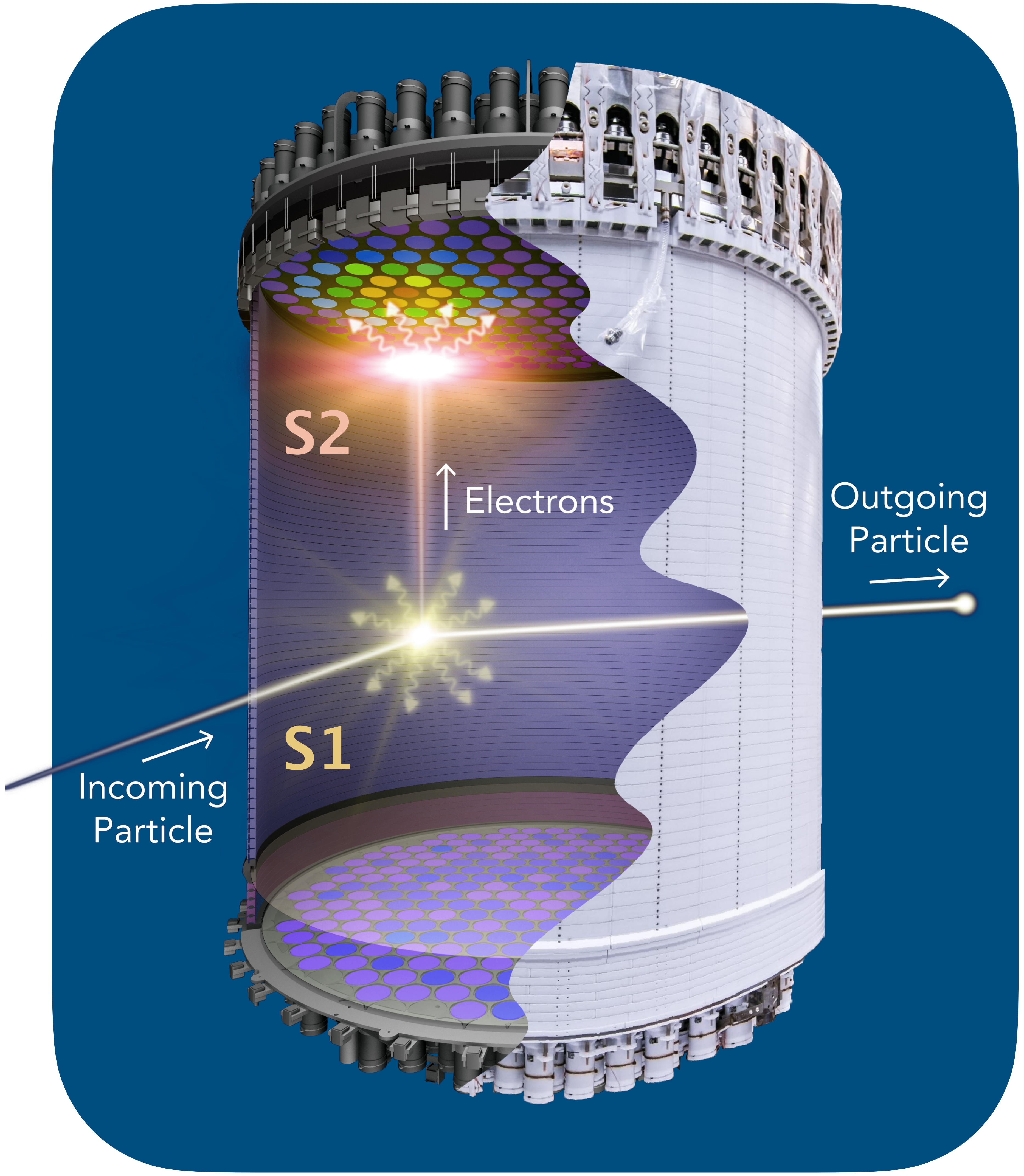
j.nima.2019.163047

- LZ is based 4850 ft underground at the Sanford Underground Research Facility (SURF) in Lead, SD
- LZ is a dark matter direct detection experiment
  - Primarily designed for WIMPs, but has considerable sensitivity to other new physics
- Central detector: dual-phase xenon time projection chamber (TPC) with 7 t active xenon
- "Skin" & outer detector (OD) active vetoes
- The detectors have been commissioned and science data-taking is underway





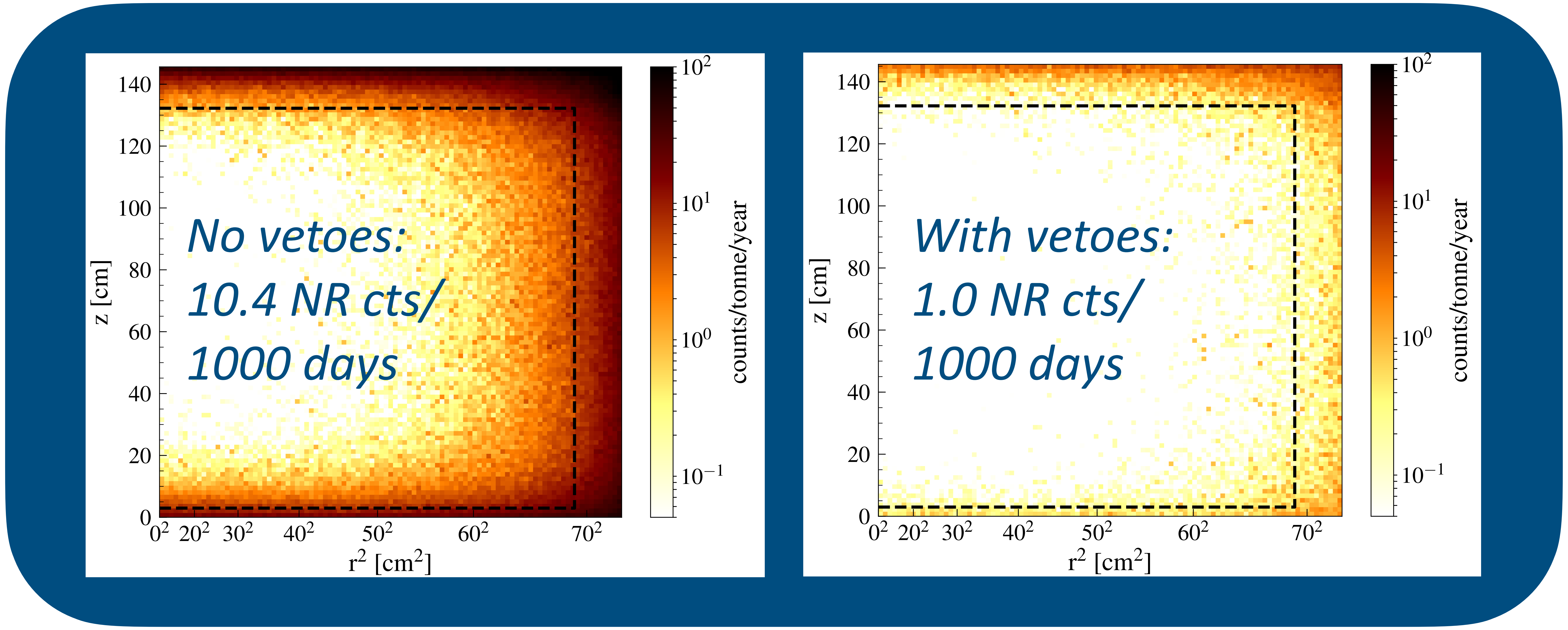
TPC Detection Principle



- Interactions in the xenon create
  - Light – prompt scintillation – S1
  - Charge – electrons drifted and extracted into gas -> proportional scintillation – S2
- Excellent 3D position reconstruction (~mm)
  - Z from time difference between S1 and S2
  - XY from S2 hit pattern on top PMT array
- S2:S1 ratio – discriminate electronic recoils (ERs) from potential WIMP nuclear recoils (NRs)

Background Mitigation

[EPJC, Vol 80: 1044 (2020)](#)



- Material selection – ~2000 assays; radon emanation & neutron activation analysis
- Cleanliness protocols – Rn-reduced cleanroom assembly -> limit surface contamination
- Xenon purification – charcoal chromatography; online radon reduction & getter usage
- Analysis cuts – fiducialisation, single scatter, energy ROI, veto anti-coincidence

WIMP Sensitivity

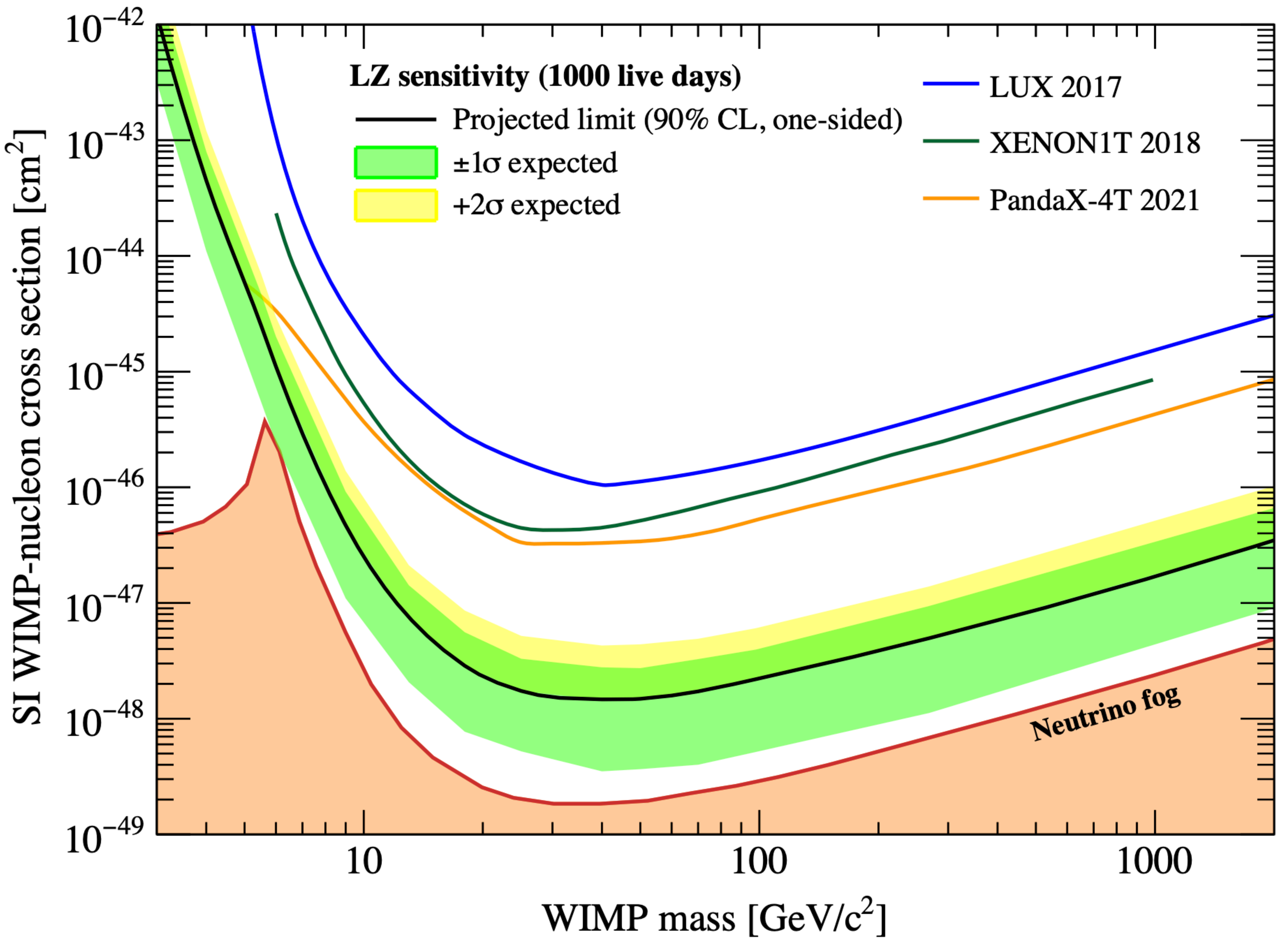
PRD 101, 052002 (2020)
j.astropartphys.2020.102480

*For full exposure (1000 days * 5.6 t):*

Background counts after analysis cuts in the 40 GeV/c^2 WIMP ROI

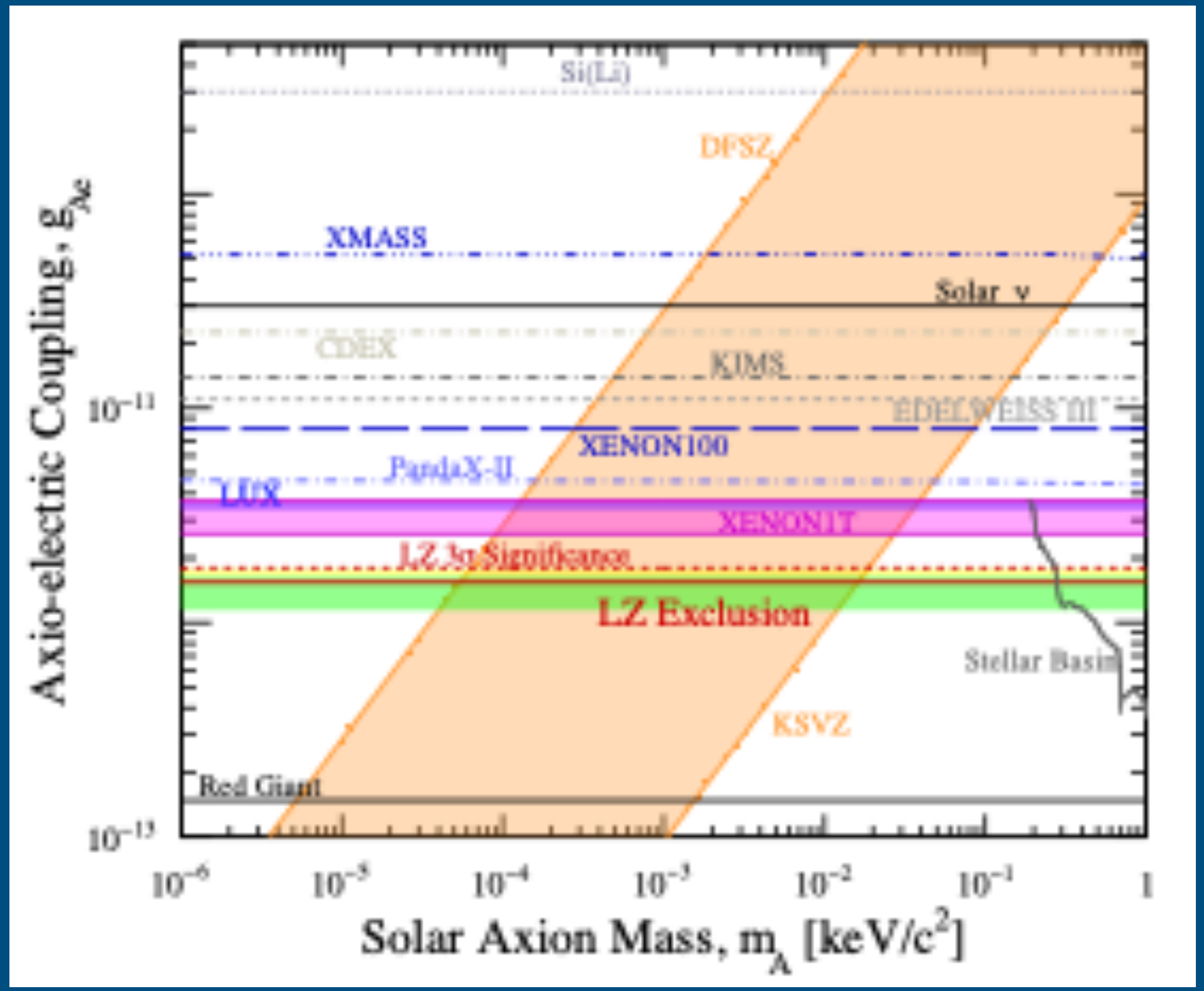
Source	ER [cts]	NR [cts]
Total	1131	1.03
+ 99.5% ER discrimination, 50% NR efficiency	**5.66**	**0.52**

90% CL minimum:
1.4×10^{-48} cm^2 at 40 GeV/c^2

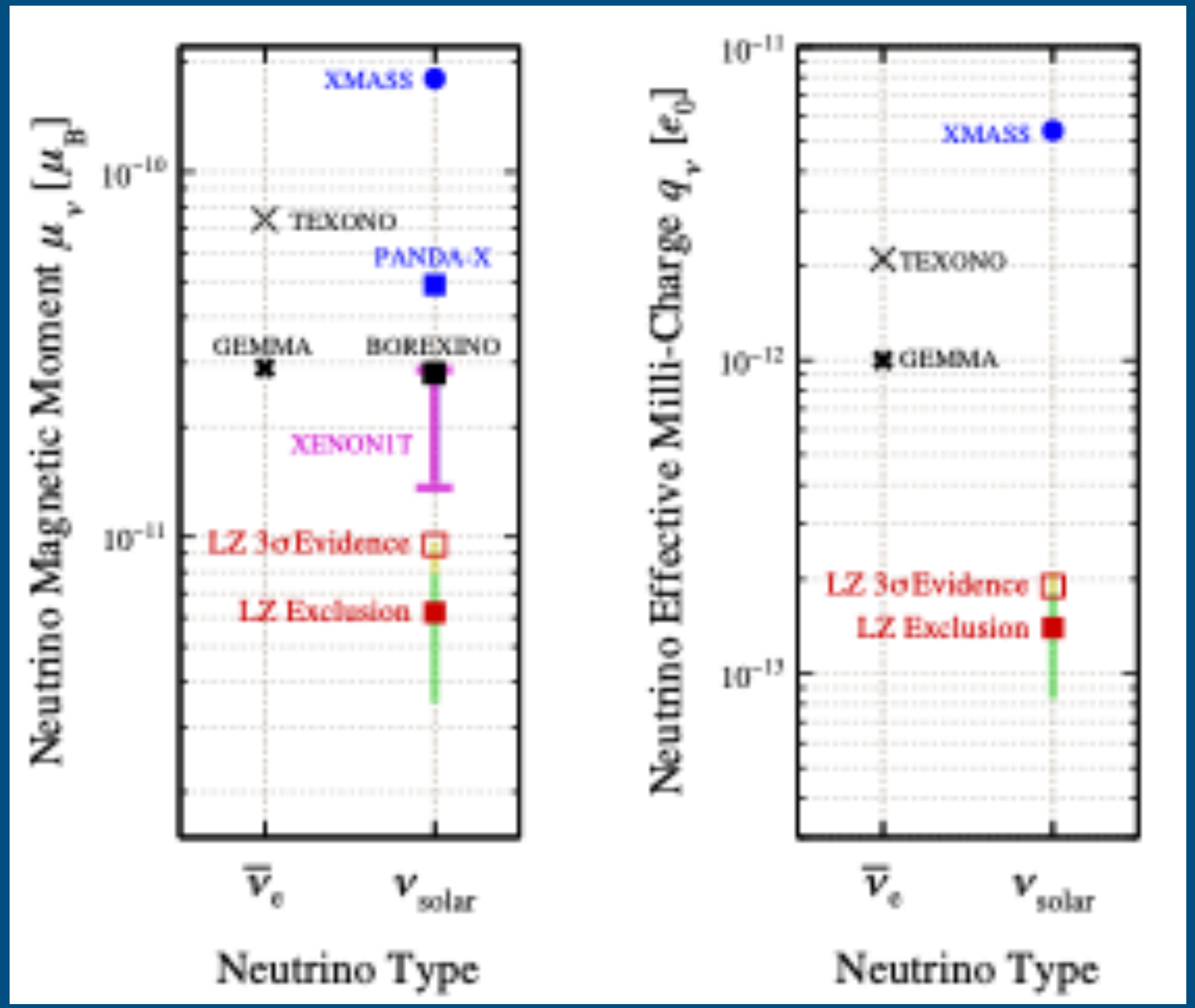


Physics Reach Beyond WIMPs

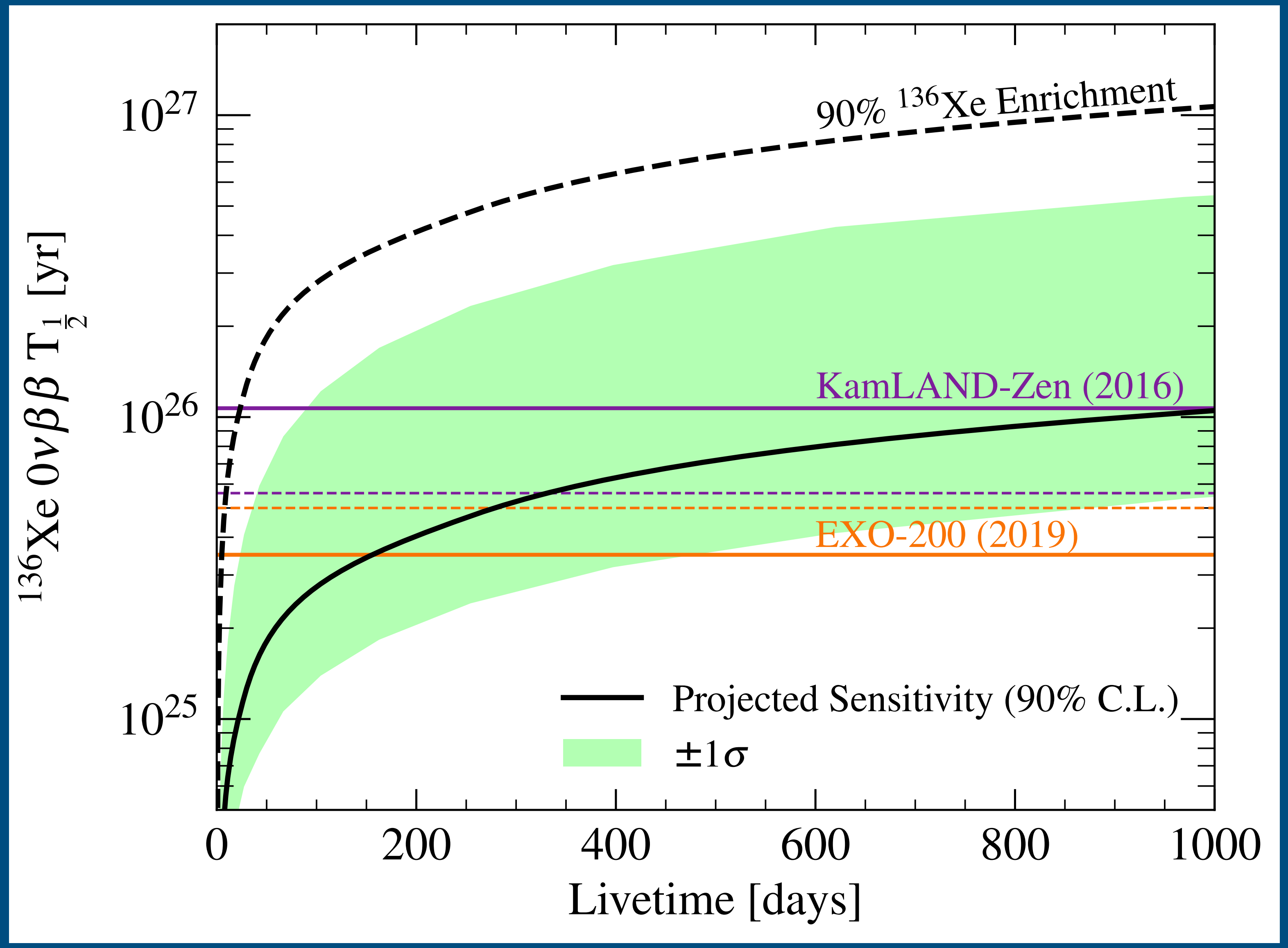
Solar Axions



Neutrino Magnetic Moment & Effective Millicharge



^{136}Xe Neutinoless Double Beta Decay



- Low energy ER – competitive for solar axions; neutrino μ_ν, q_ν; axion-like particles + more
- High energy ER – ^{134}Xe 2νββ & 0νββ ,^{136}Xe 0νββ + exotic decay modes (see Z. Tong's talk)

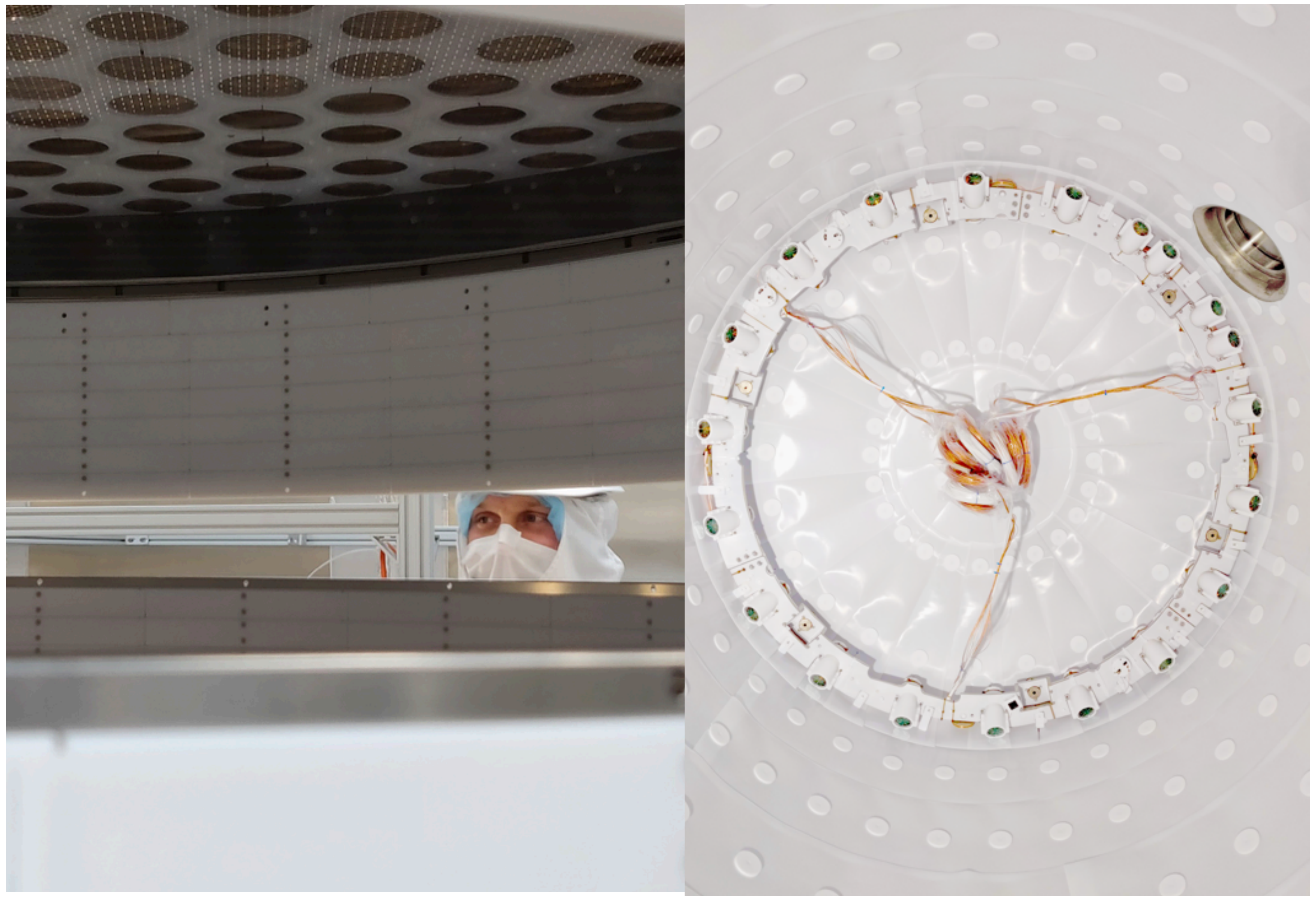
PRD 104, 092009 (2021), *PRC 102, 014602 (2020)*, *PRC 104, 065501 (2021)*

Construction & Commissioning Timeline

TPC & Skin integration in the Surface Assembly Laboratory (SAL)

OD acrylic tanks underground

Inner cryostat vessel (ICV), housing TPC, underground



2018

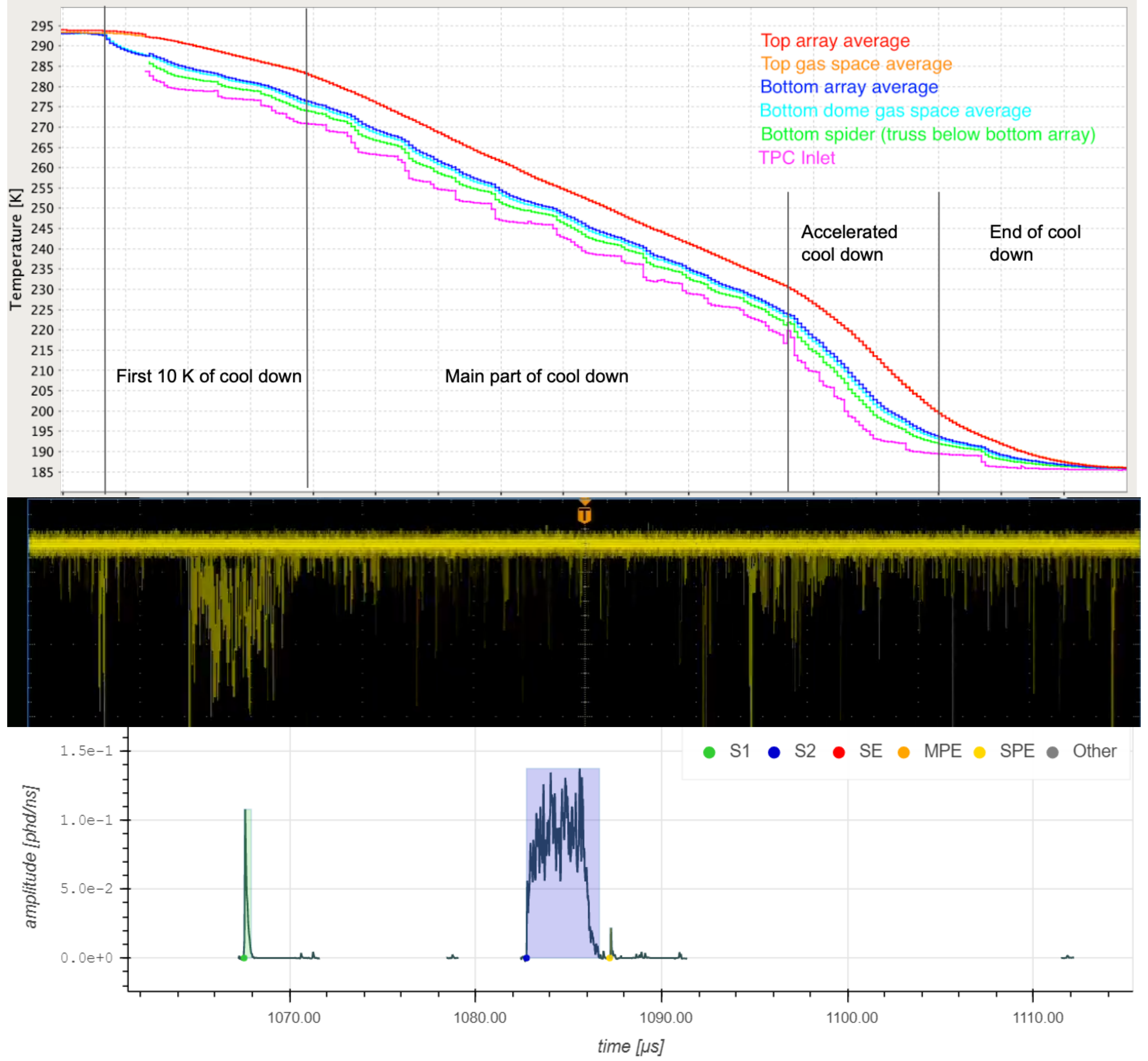
2019

Construction & Commissioning Timeline

High voltage installed; ICV sealed & under vacuum

OD PMT & Tyvek Installation

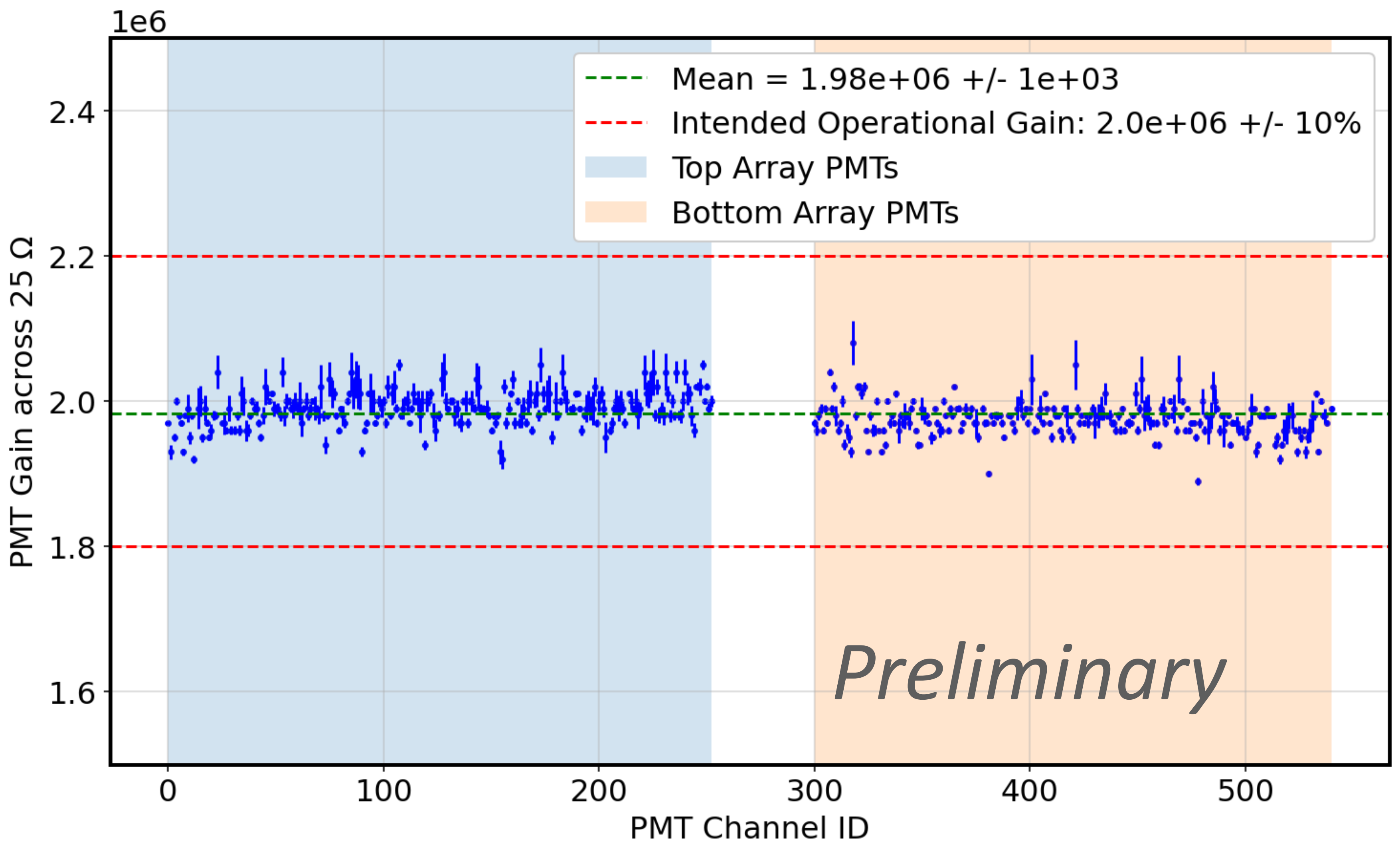
Detector Commissioning

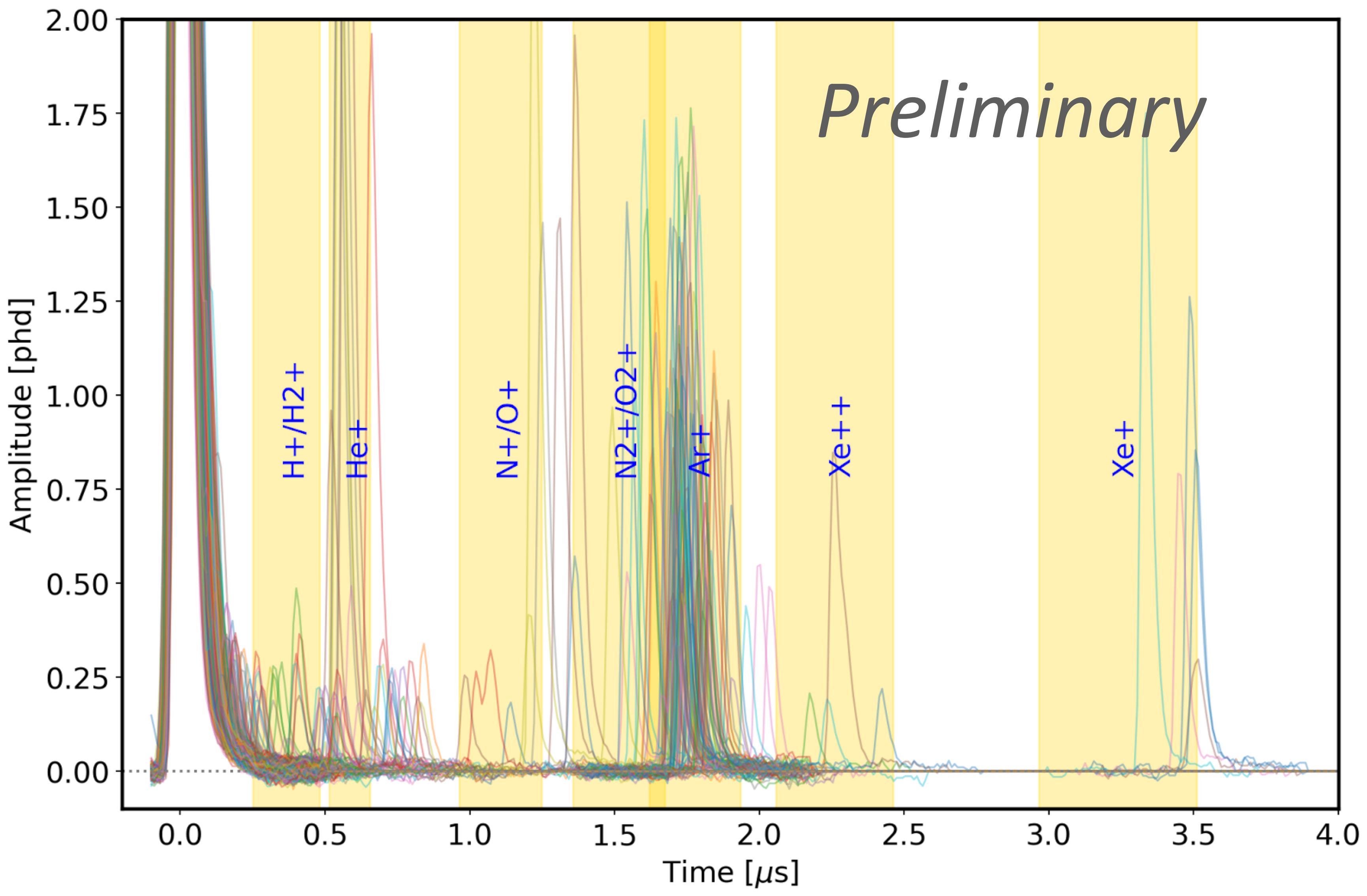


2020

2021

Commissioning Activities

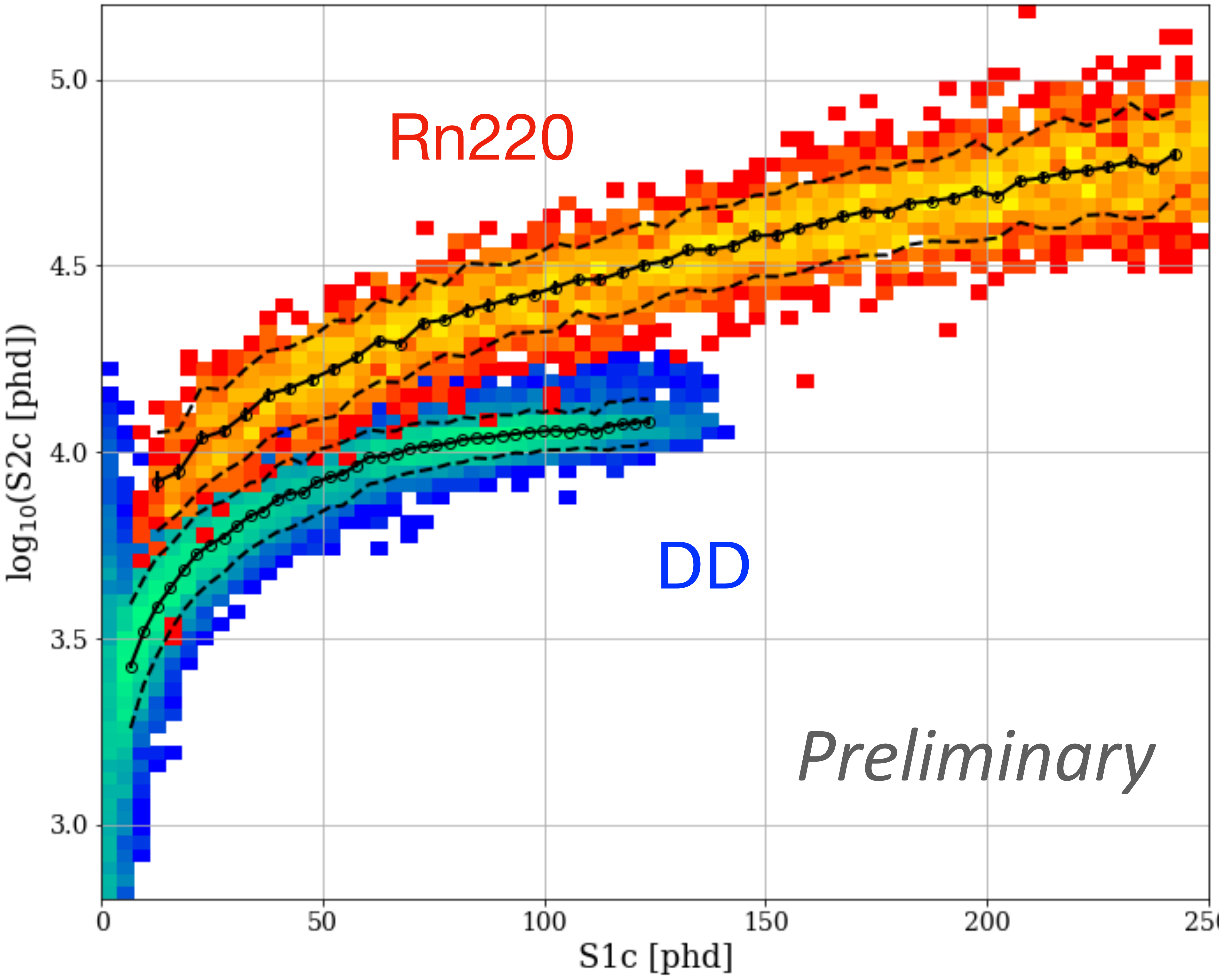




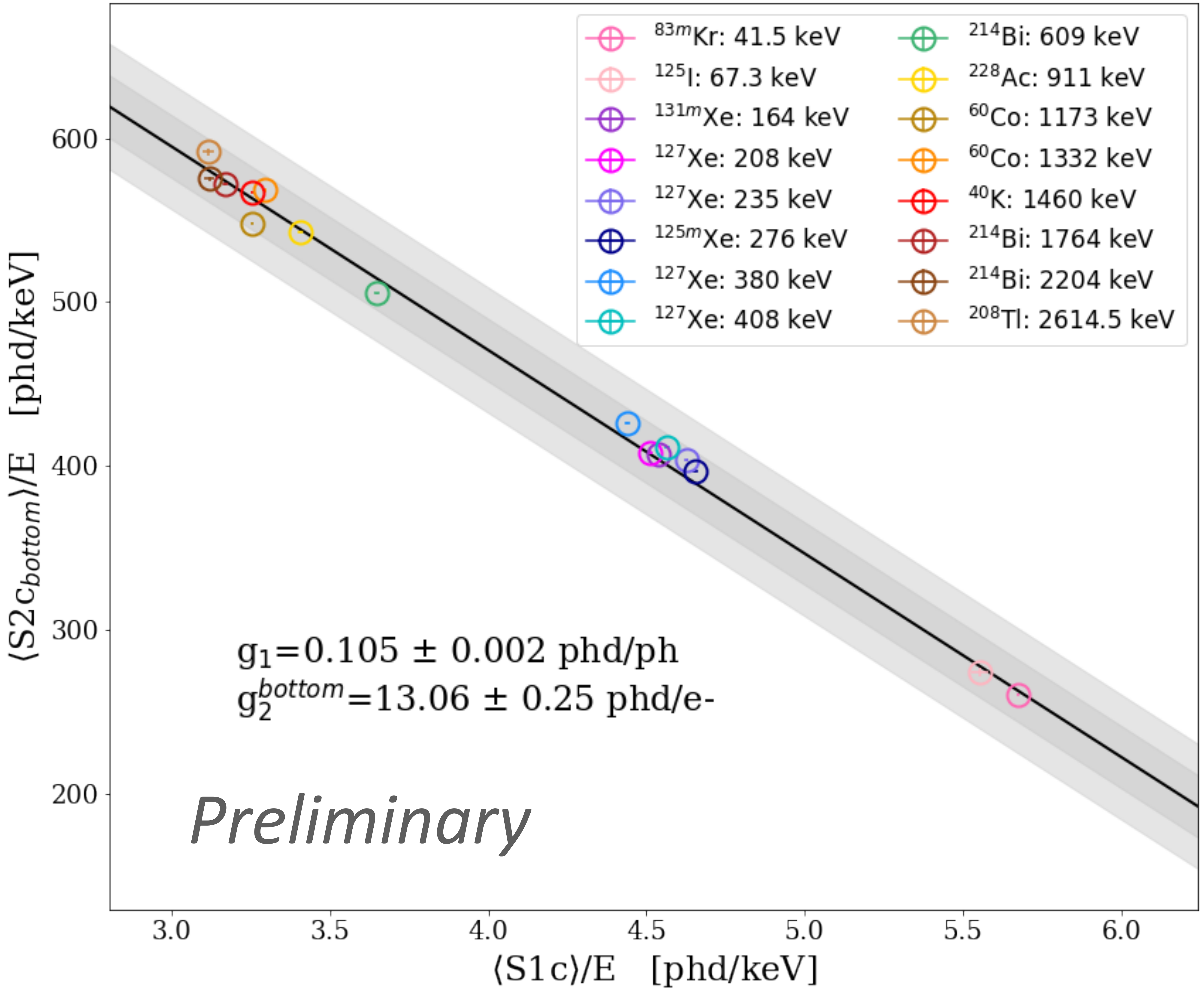
- TPC detector levelled & grids biassed in liquid
  - ~190 V/cm drift & ~7.5 kV/cm gas fields established
- Data processing chain exercised with first S1+S2s
- Data acquisition & trigger settings tuned
- PMT operations & characterisation
  - LED measurements for e.g. afterpulsing and single photoelectron (SPE) studies
  - PMTs gain-matched and gain drifts monitored
  - Dark count & DPE analyses (see A. Baker's talk)

Calibrations

- Different deployment systems available
  - Circulation panel for injection into Xe
  - Vertical source tubes between TPC & Skin for commercial rod sources
  - DD neutron generator + TPC conduits (see J. Orpwood's poster)
- Calibrations can be used to inform
  - Energy scale in all three detectors
  - Inter-detector timings
  - NR & ER bands in the TPC



Detector Response Characterisation



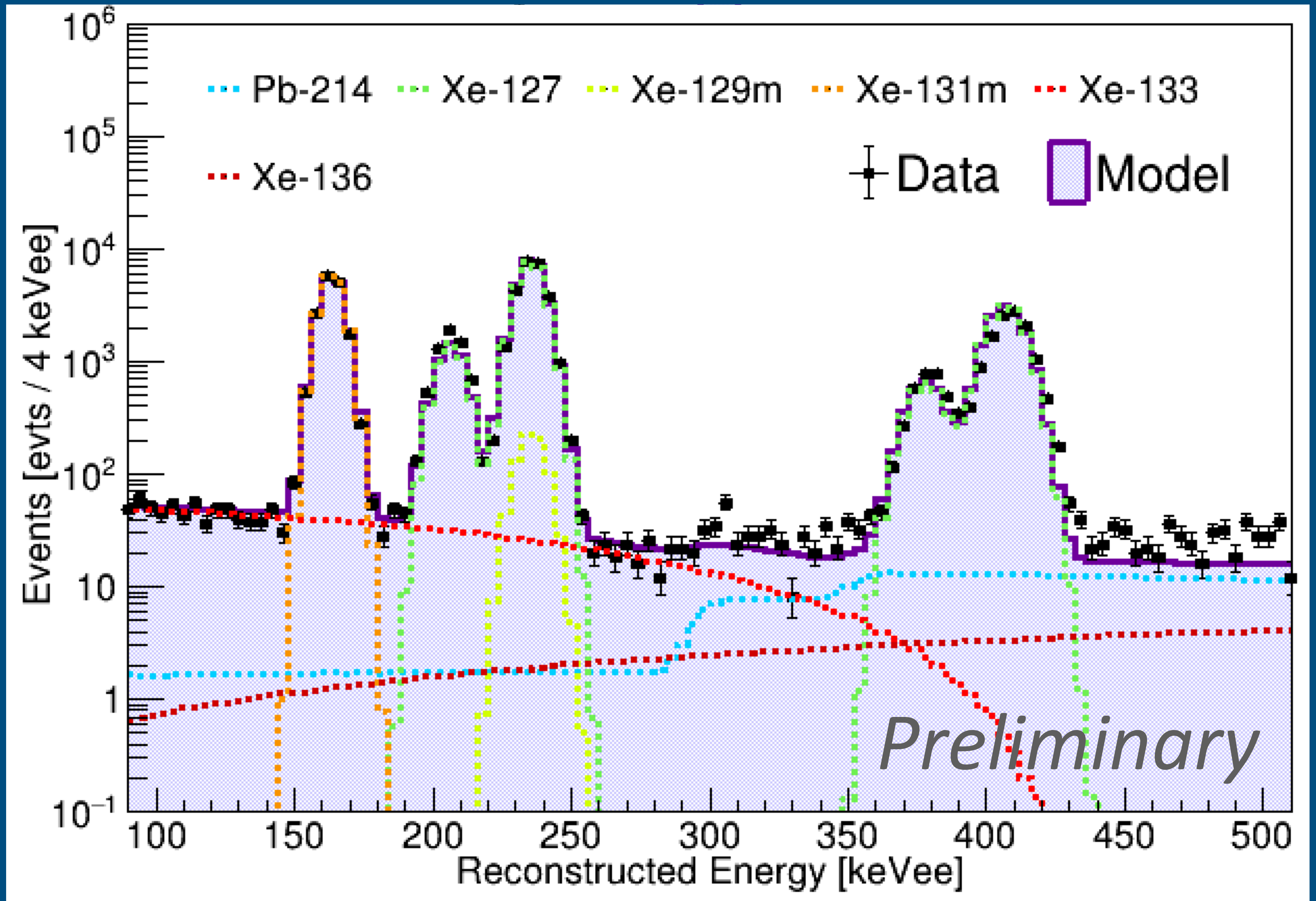
- Mono-energetic ER peaks can be used to find
  - g1, photons detected (phd) per prompt scintillation photon
  - g2, phd per ionisation electron

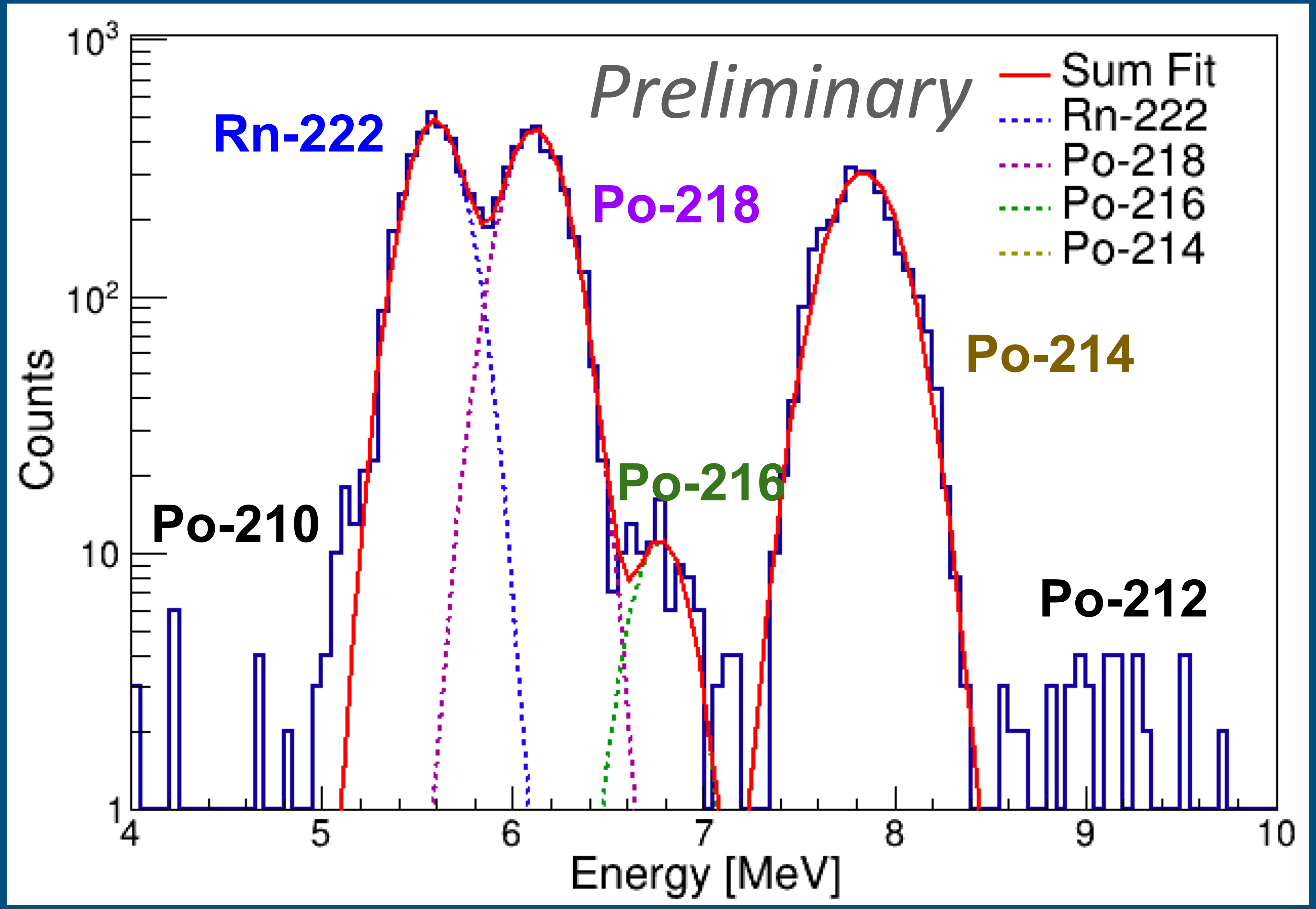
  via the relation $E = W\left(\frac{S1_c}{g1} + \frac{S2_c}{g2}\right)$,

  where E = energy, W= W-value

  c denotes position-corrected signals
- Saturation of higher energy signals problematic (see A. Al Musalhi's talk)

Background Analyses





- Trial fits of background simulations to data attempted, matching mono-energetic peaks
- Rn222 & Rn220 chain alpha populations identified & constrained (see N. Angelides' talk)
- Investigating non-xenon sources of charge/light e.g. Cherenkov (see I. Khurana's talk)

Conclusions

- LZ is a multi-physics experiment, primed for the detection of WIMPs
- The experiment has started taking science data, and extensive analyses are underway

- Radon in LZ – N. Angelides
- Saturation corrections – A. Al Musalhi
- VUV detection – A. Baker
- Majoron searches – Z. Tong
- Cherenkov backgrounds – I. Khurana
- Multiple scatter studies in DD data – J. Orpwood

Acknowledgements

@lzdarkmatter
https://lz.lbl.gov/

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Sanford Underground Research Facility
South Dakota Science and Technology Authority

UKRI Science and Technology Facilities Council

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

ibs Institute for Basic Science

LZ (LUX-ZEPLIN) Collaboration
34 Institutions: 250 scientists, engineers, and technical staff