# Recent Results from XENON1T

(arXiv:1705.06655)

Qing Lin
Columbia University

Oct. 4th, 2018
Brookhaven National Laboratory

# XENON Collaboration

XENON Dark Matter Project

170 scientists

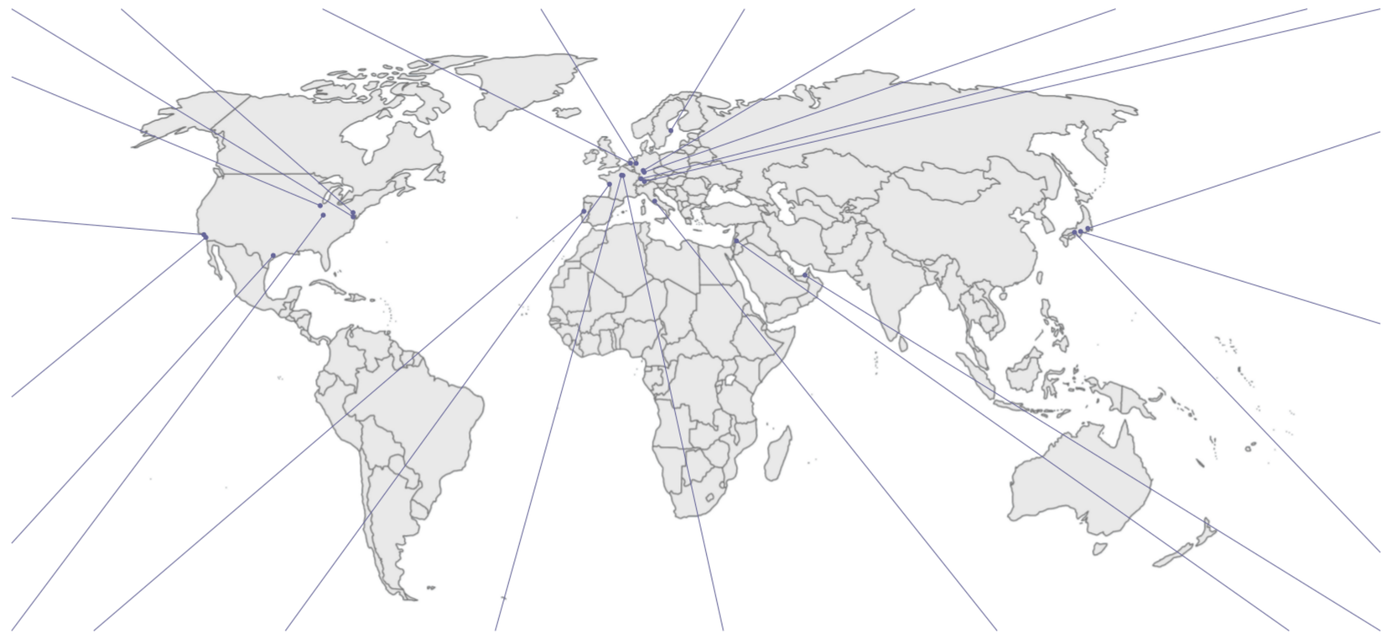
25 institutions

11 countries

Columbia · RPI · Nikhef · Muenster · Stockholm · Mainz · MPIK, Heidelberg · Freiburg · Zurich

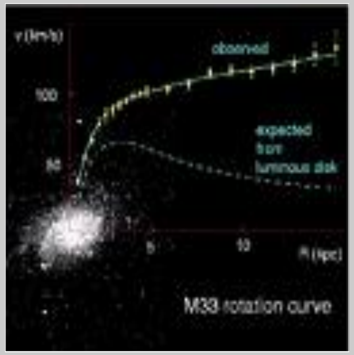
Chicago · UCLA · UCSD · Rice

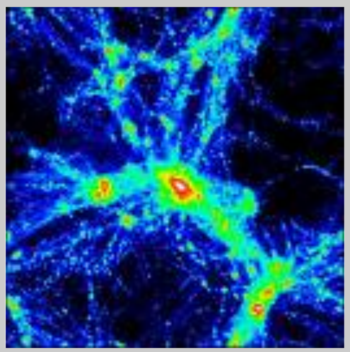
Tokyo · Nagoya · Kobe

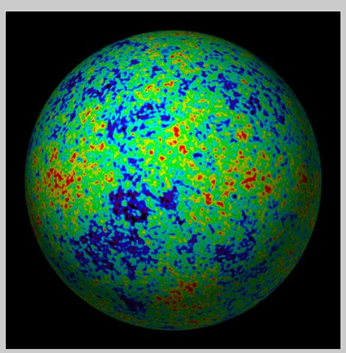


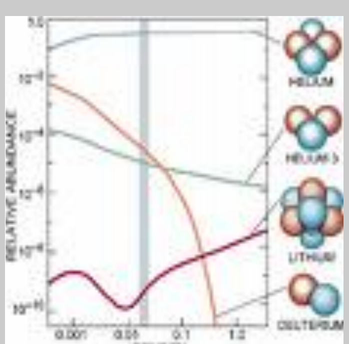
Purdue University · Subatech · LPNHE Paris · LAL Laboratoire de l'Accélérateur · Alma Mater Studiorum · INFN · מכון ויצמן למדע · جامعة نيويورك ابوظبي NYU ABU DHABI

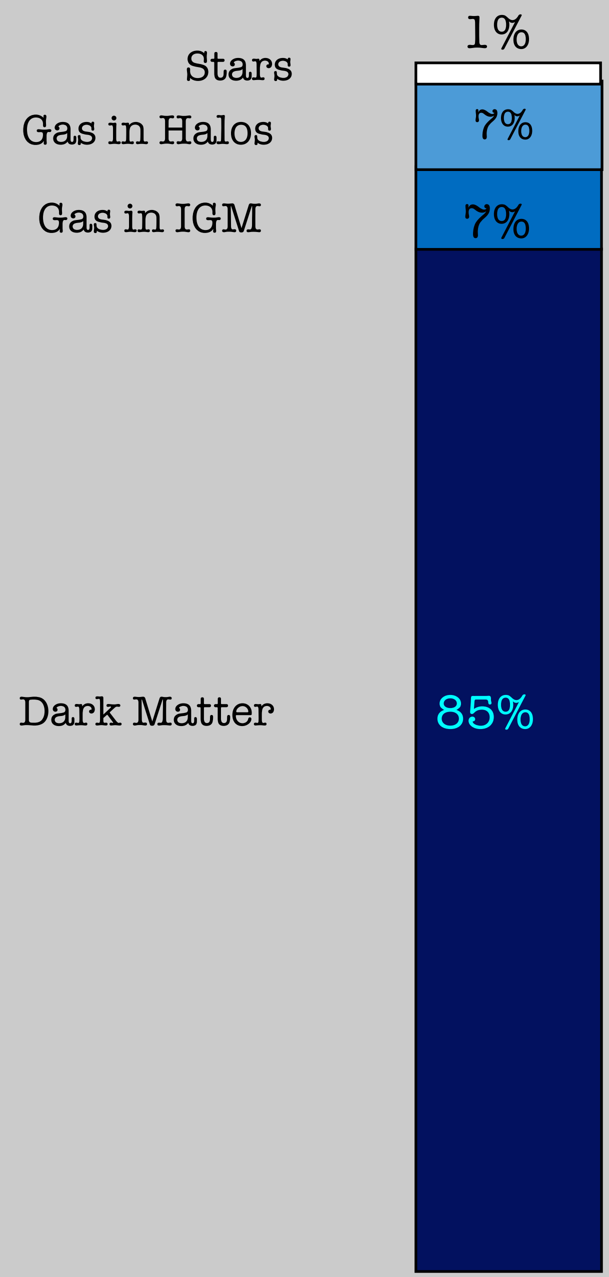
# 85% of matter in Universe invisible

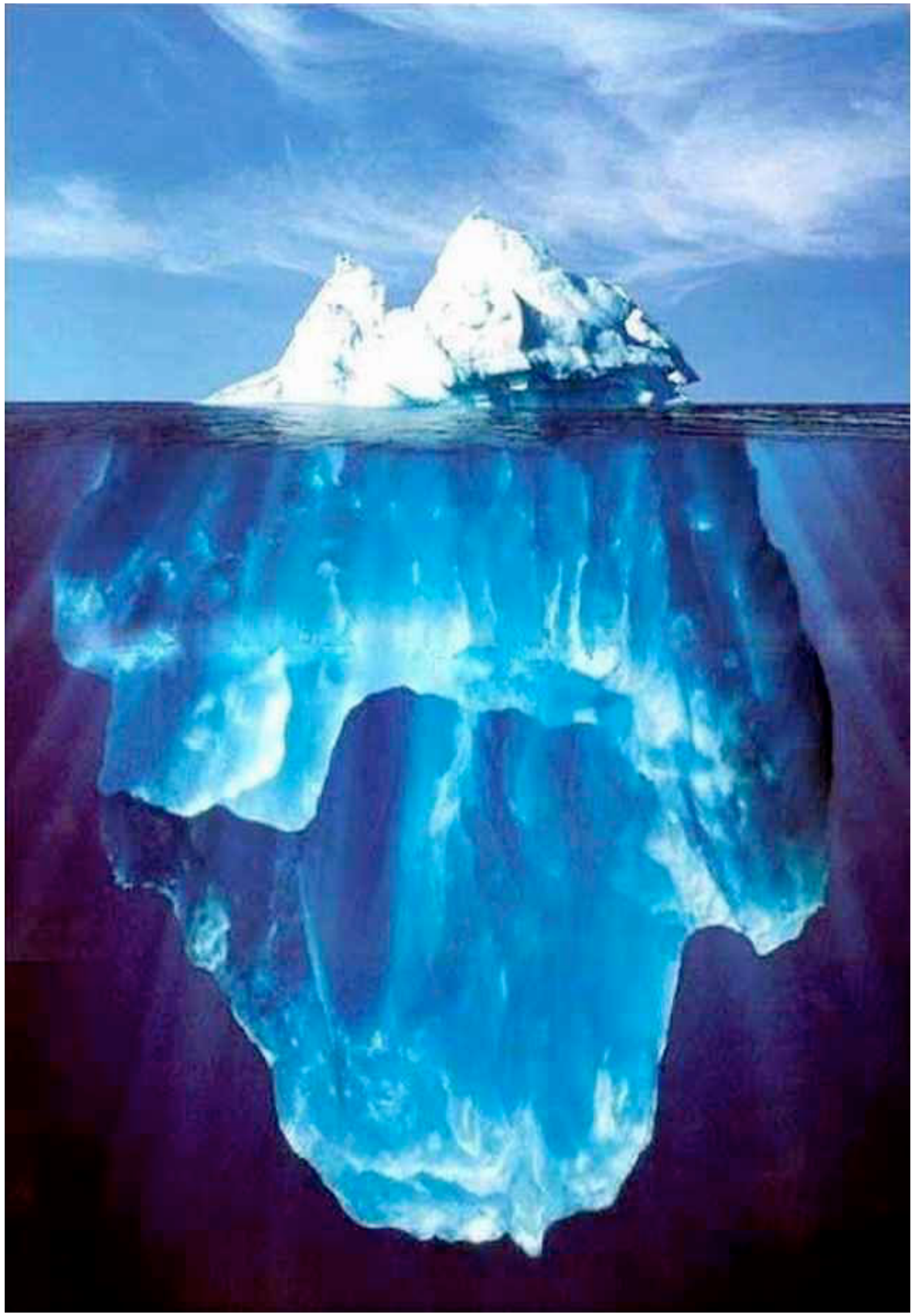


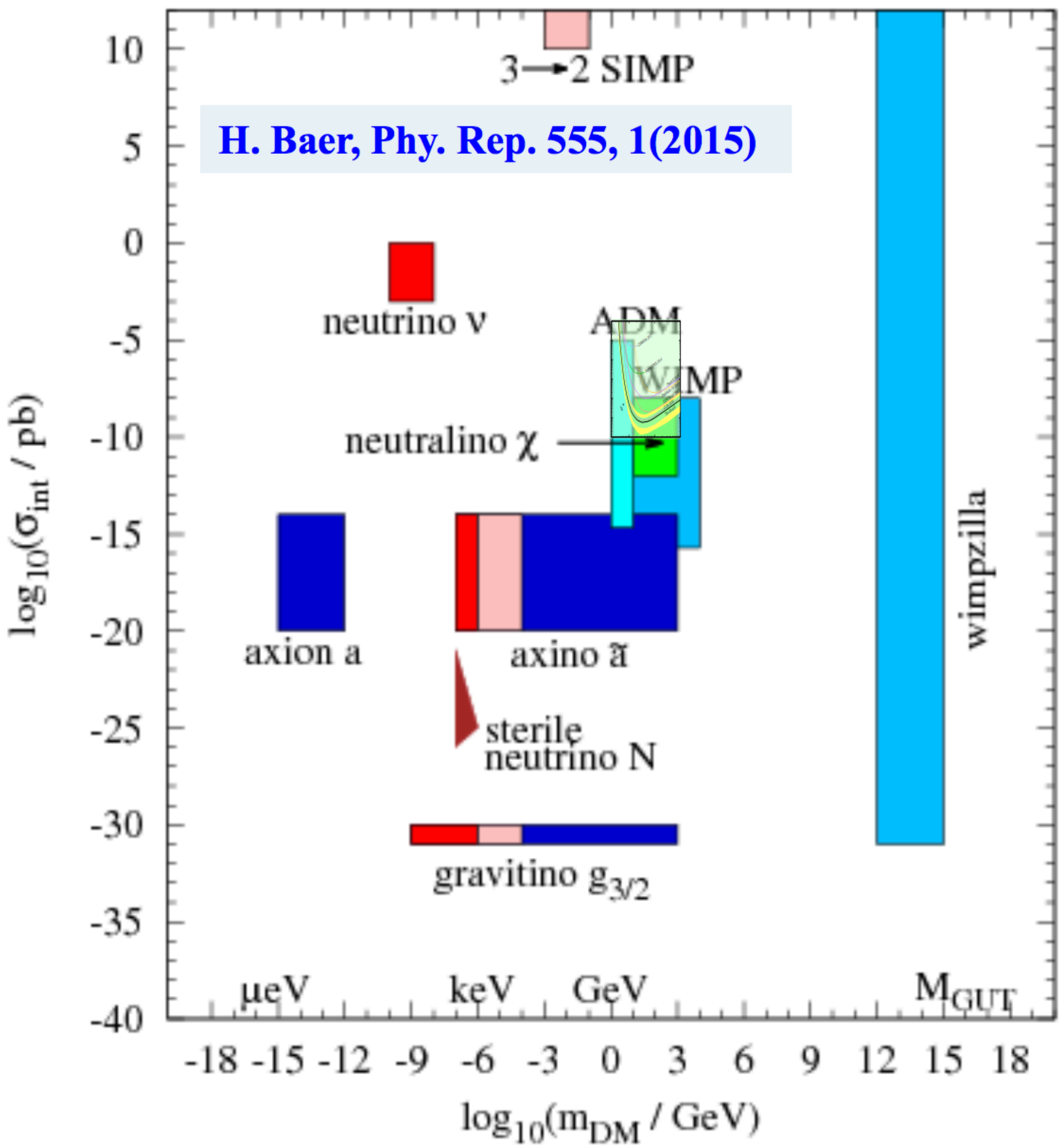






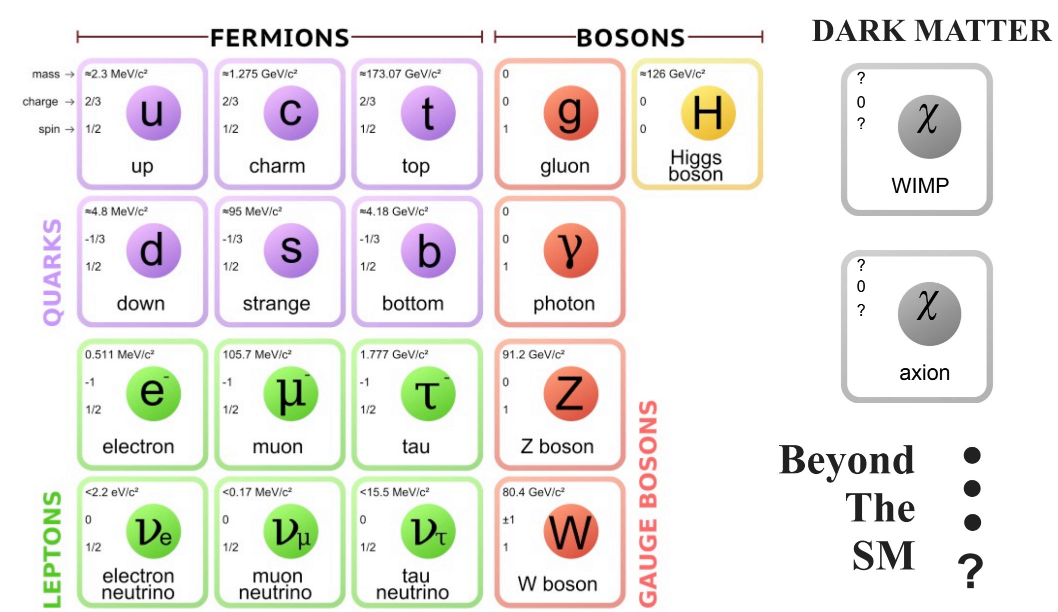



# Dark Matter Candidates



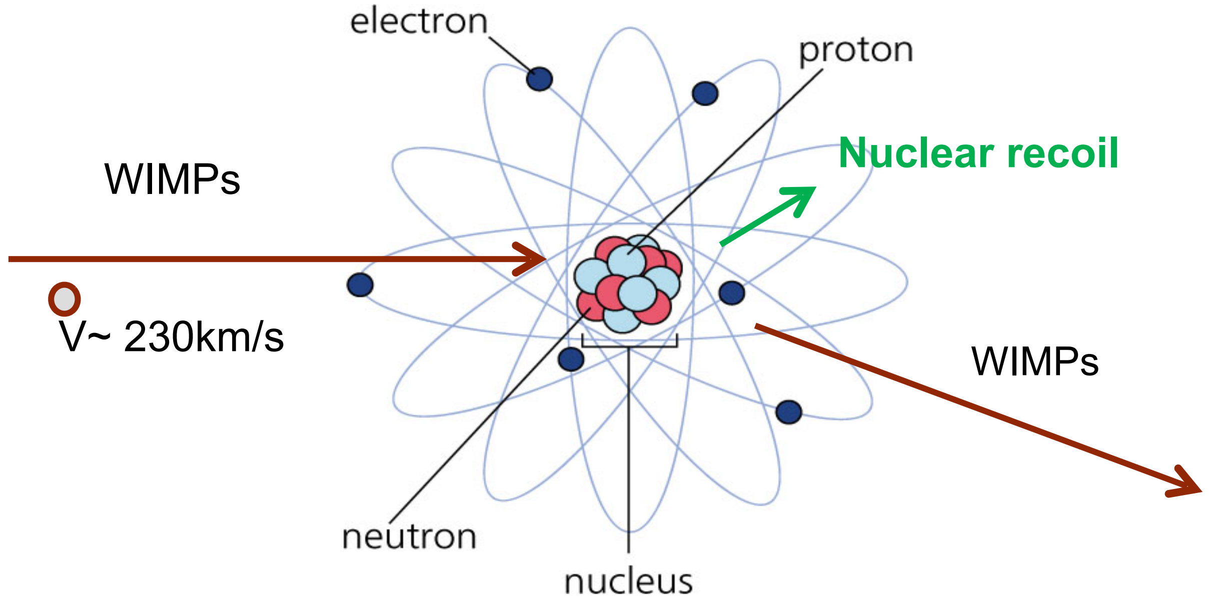

- Neutral (no EM interactions)
- Stable (or lifetime longer than that of the universe)
- Massive (for structure formation)

- tens of DM models, each with its own phenomenology
- models span 90 orders of magnitude in DM candidate mass
- WIMPs by far the most studied class of DM candidates



# Direct Search for WIMPs

**Elastic Scattering of WIMPs off target**



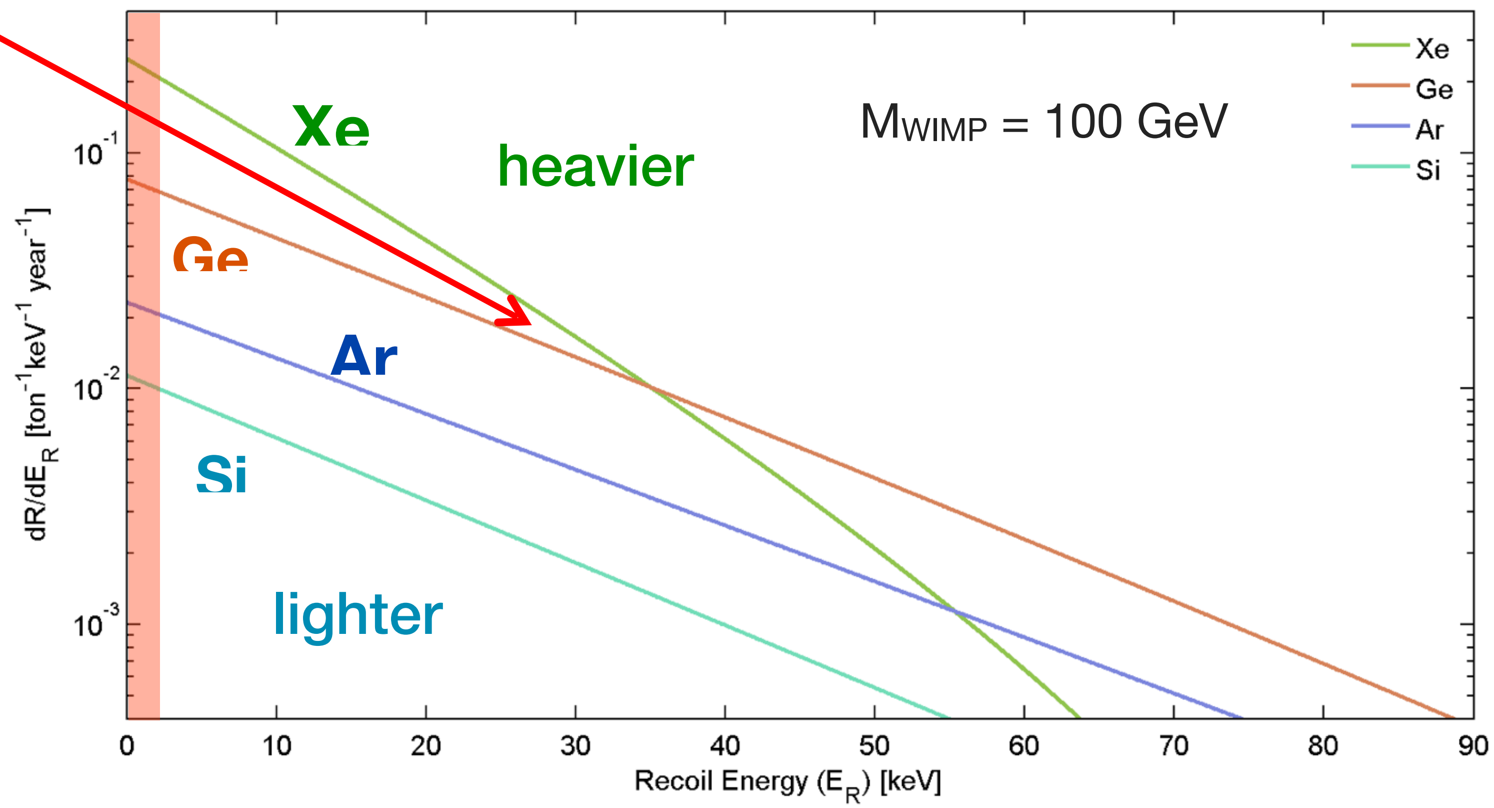

**Recoil Energy:**

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

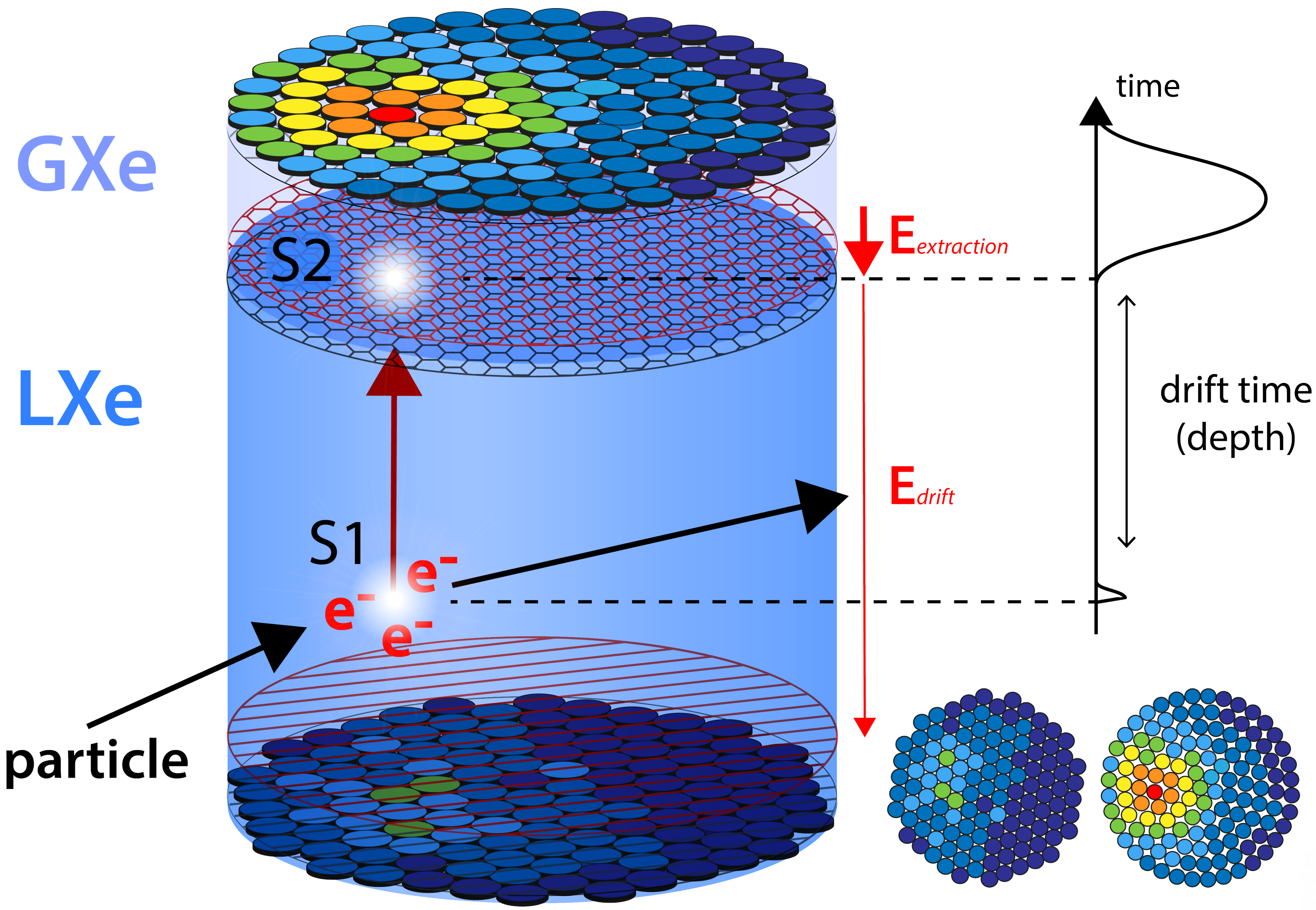
$$R \propto N \frac{\rho_\chi}{m_\chi} < \sigma_{\chi \leftrightarrow N} >$$

**Requirements for WIMPs detectors**

- Large target mass
- Low energy threshold
- Ultra-low background
- Interaction type discrimination

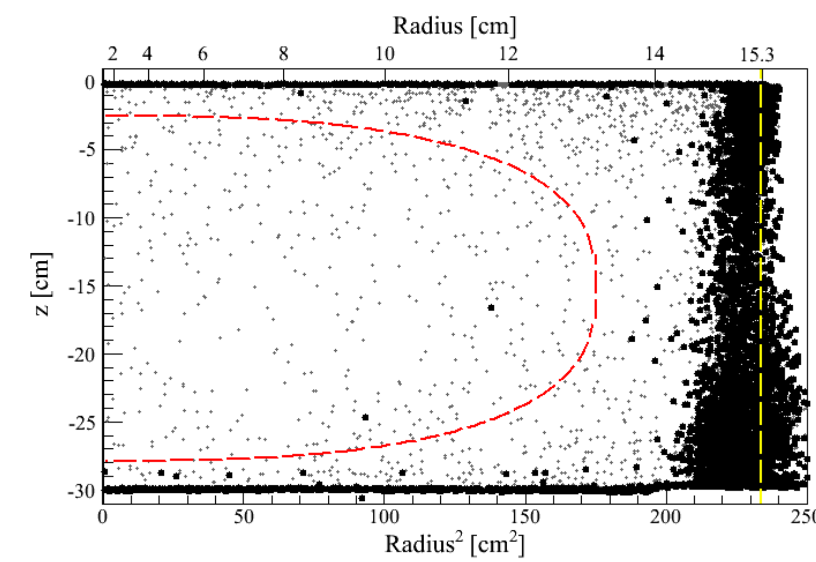


# Dual phase xenon TPC

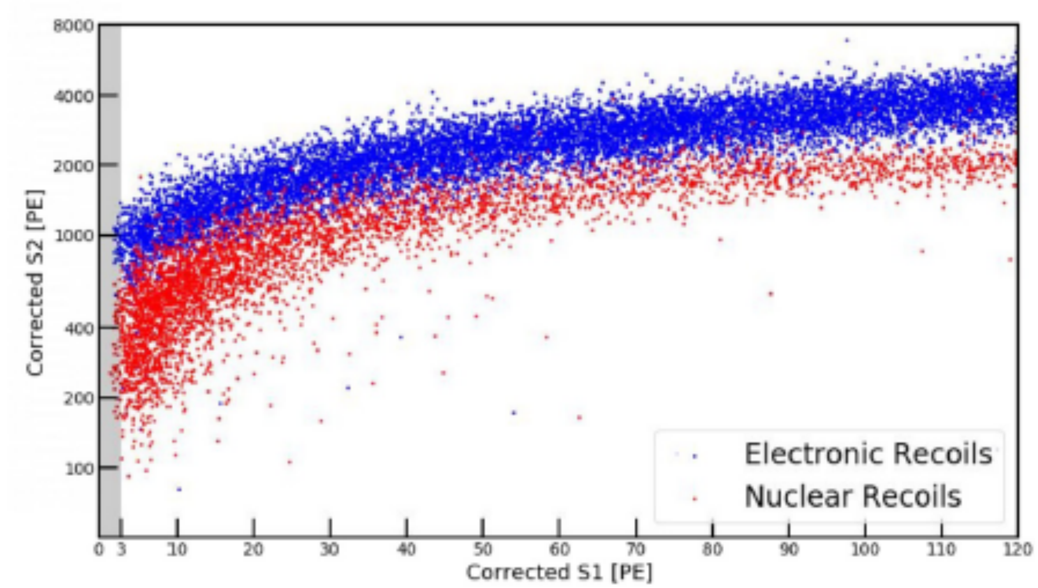



## Why xenon?

Strong self shielding to gamma



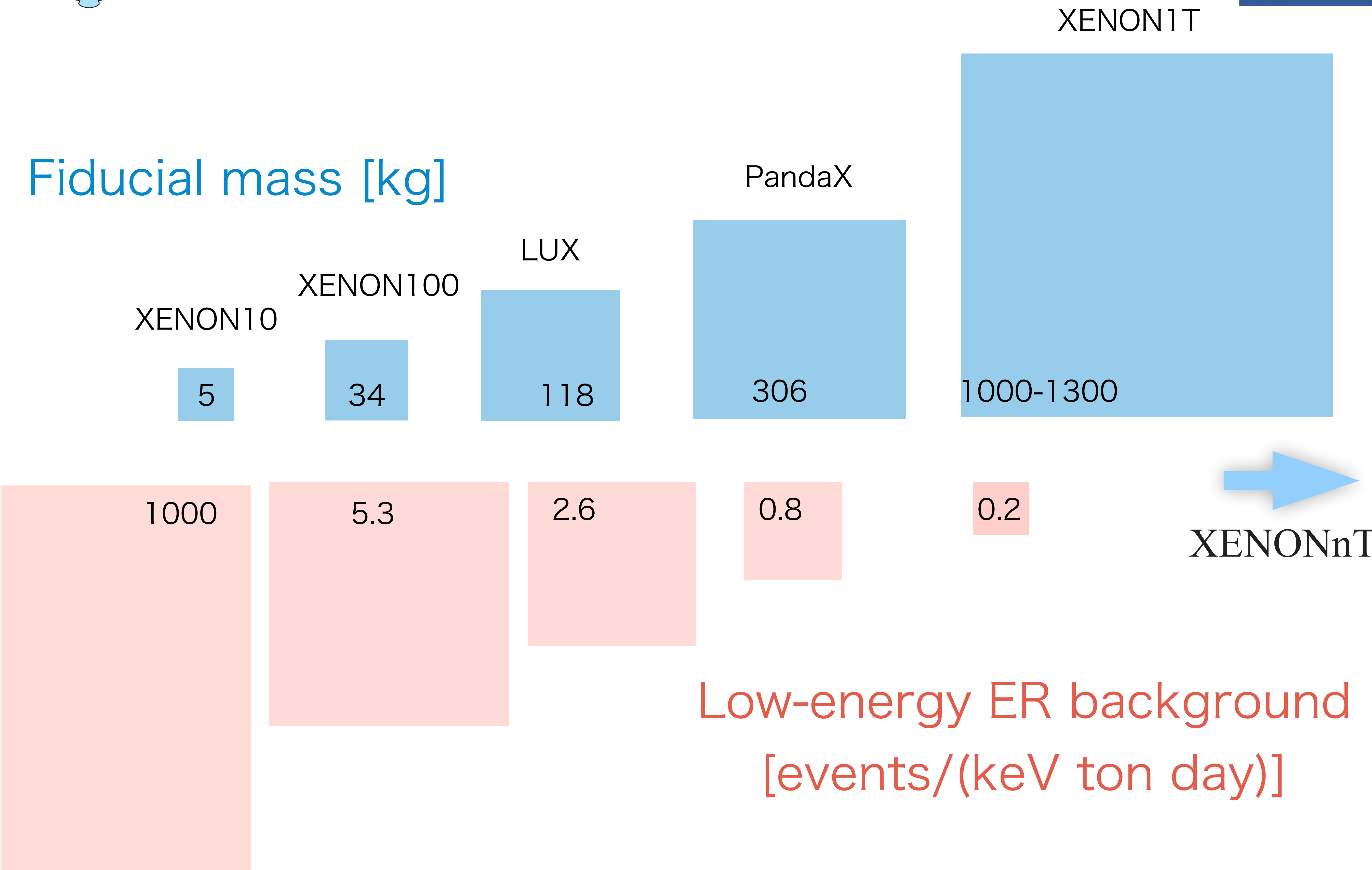

NR/ER Discrimination
>99.5% gamma & beta rejection




## Why TPC?

Excellent position reconstruction resolution ~ cm

# Detector Mass & Background



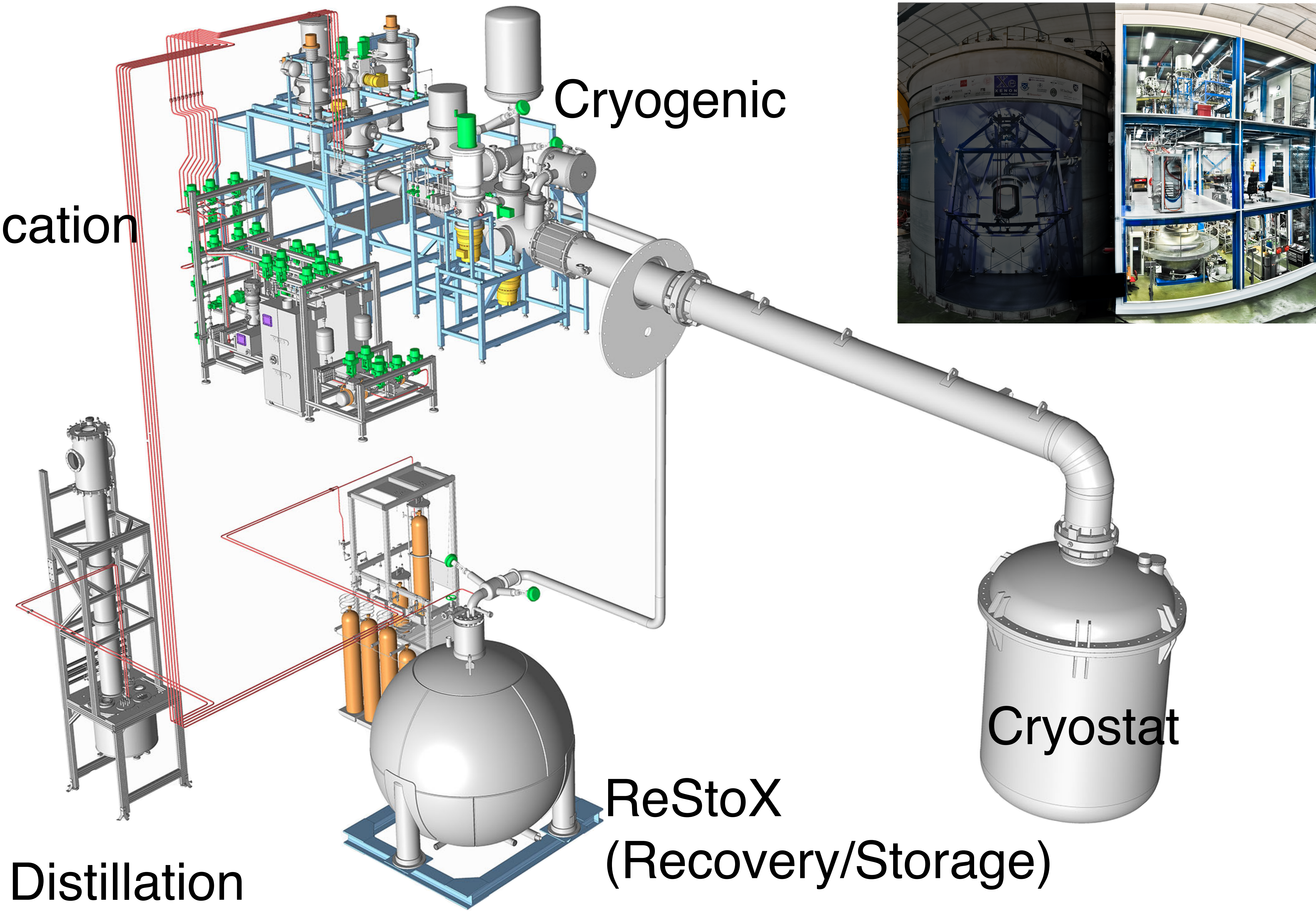
# Outline

- XENON1T Detector
- Understanding the Detector
- XENON1T Results
- Next step: XENONnT

# XENON1T Detector

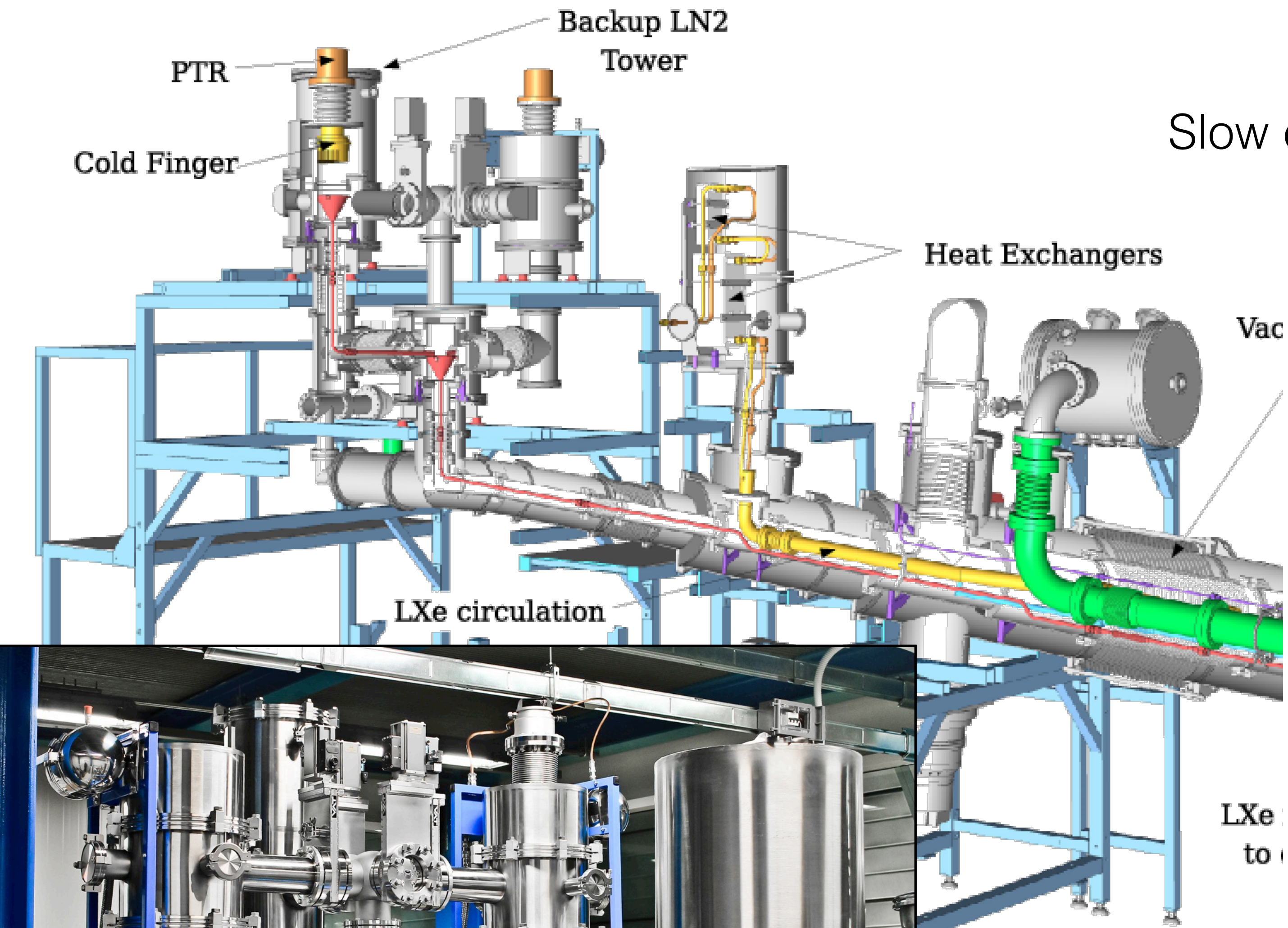
# XENON1T @ LNGS

# Xenon Plants

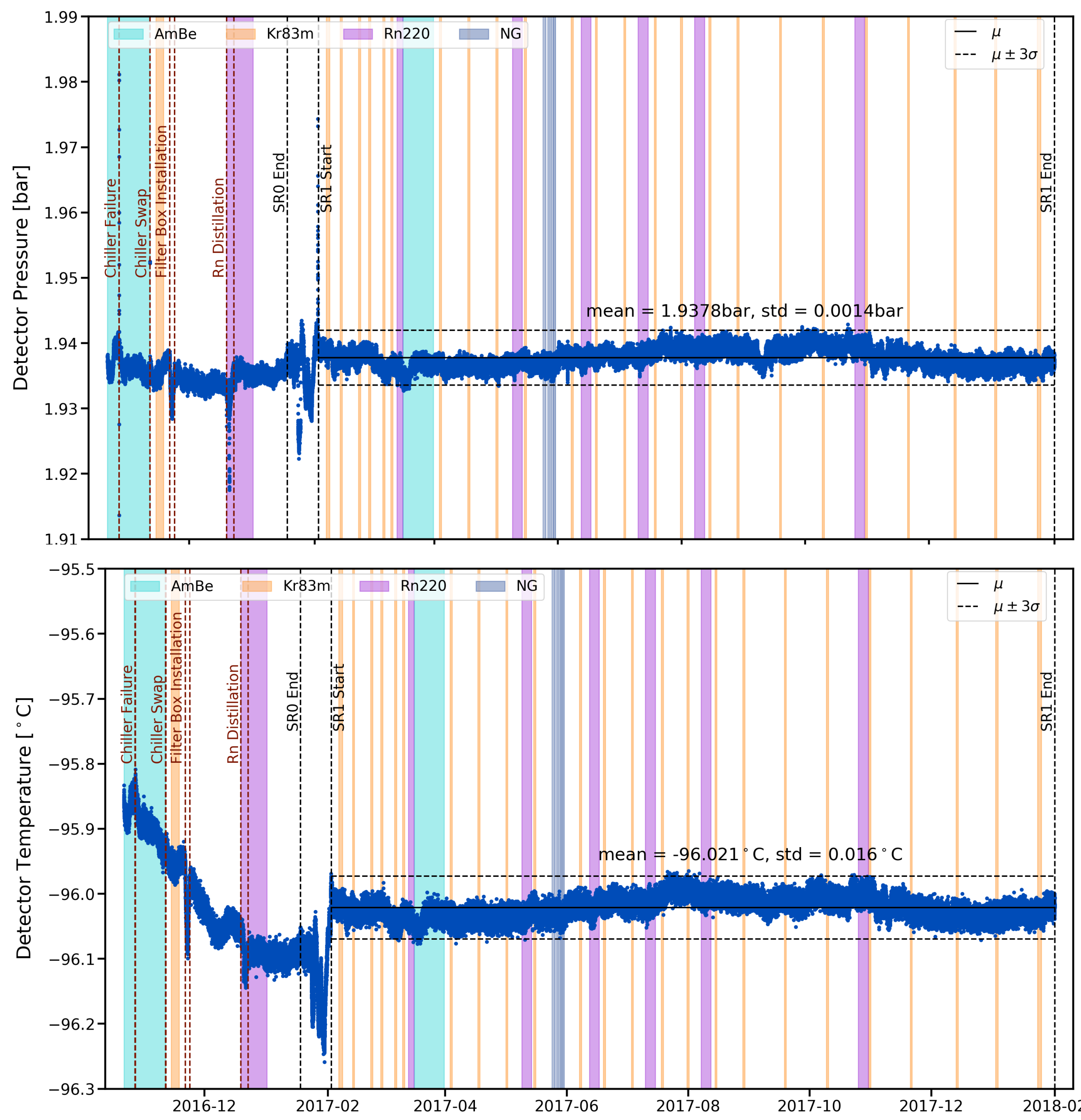


# Detector Stability

- LXe temperature stable at -96.02 °C, RMS 0.02 °C
- GXe pressure stable at 1.938 bar, RMS 0.001 bar



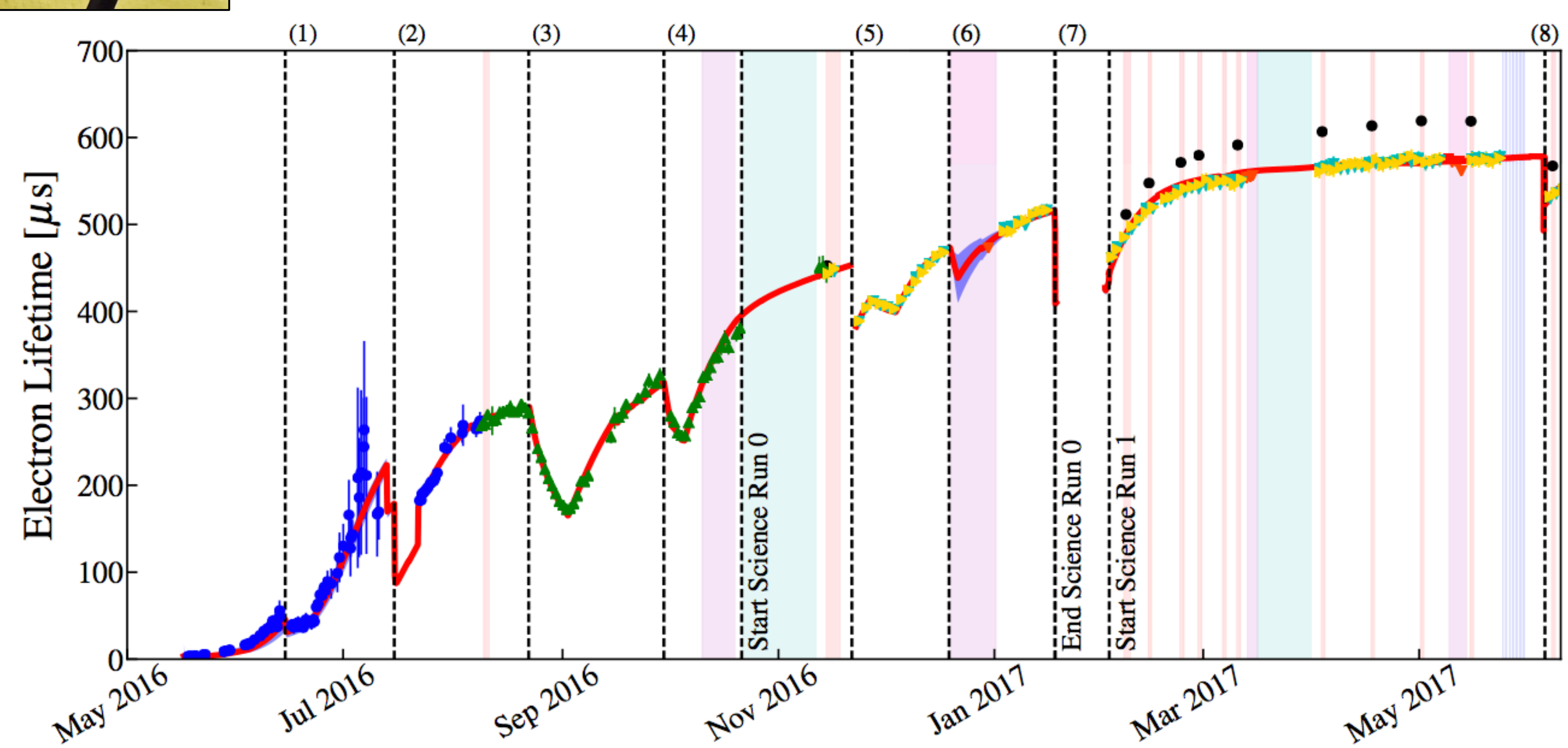

Slow control/Historian monitoring



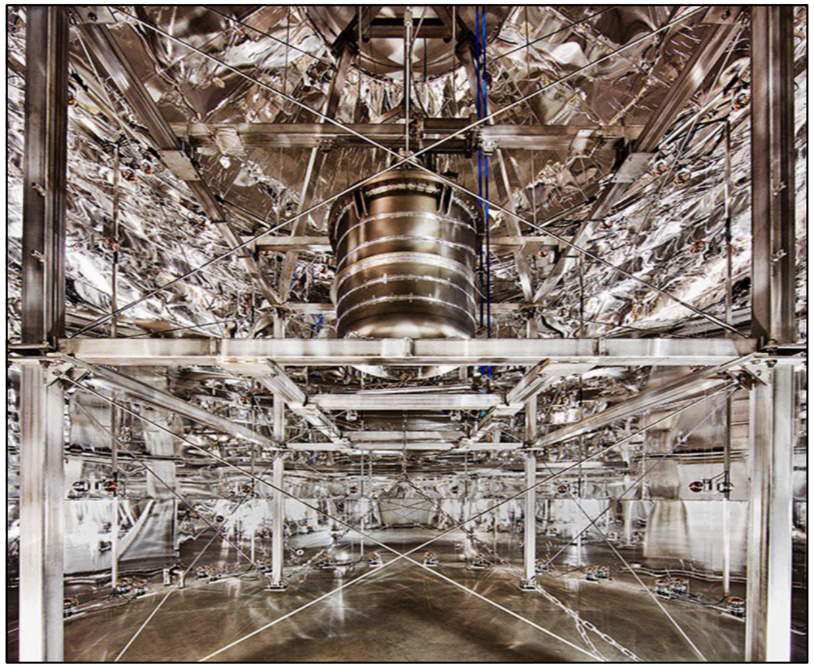
# Xe Purification

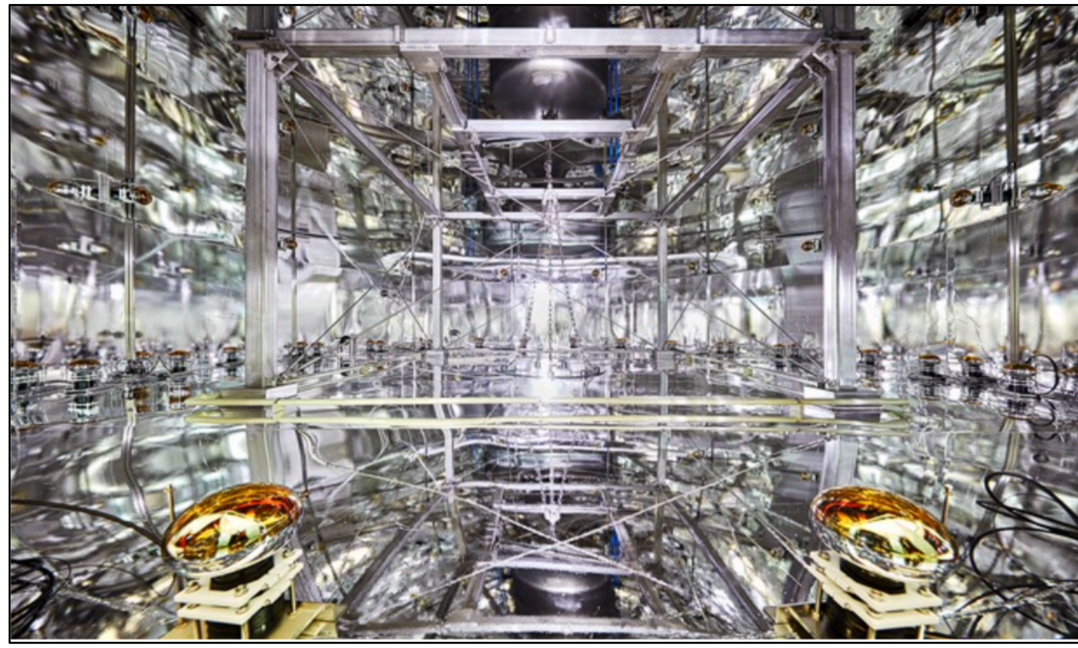
**Goal**: remove electronegative impurities below 1 ppb (O2 equivalent) in the Xe gas fill and from outgassing of detector's components with continuous circulation of Xe gas at high speed through hot getters

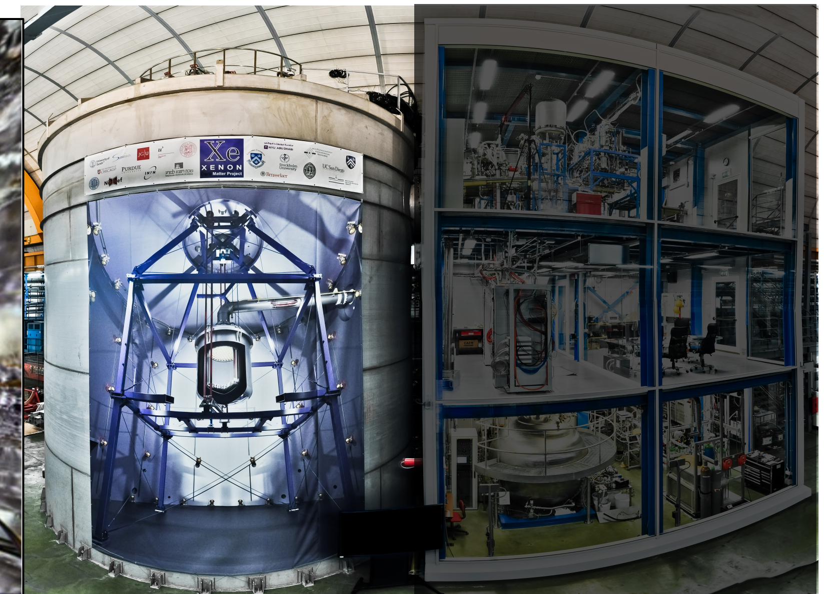
**Performance:** evolution of e-lifetime, monitored regularly with ERs calibration sources, well described by physical model. Current value approaching the max drift time of the LXeTPC.



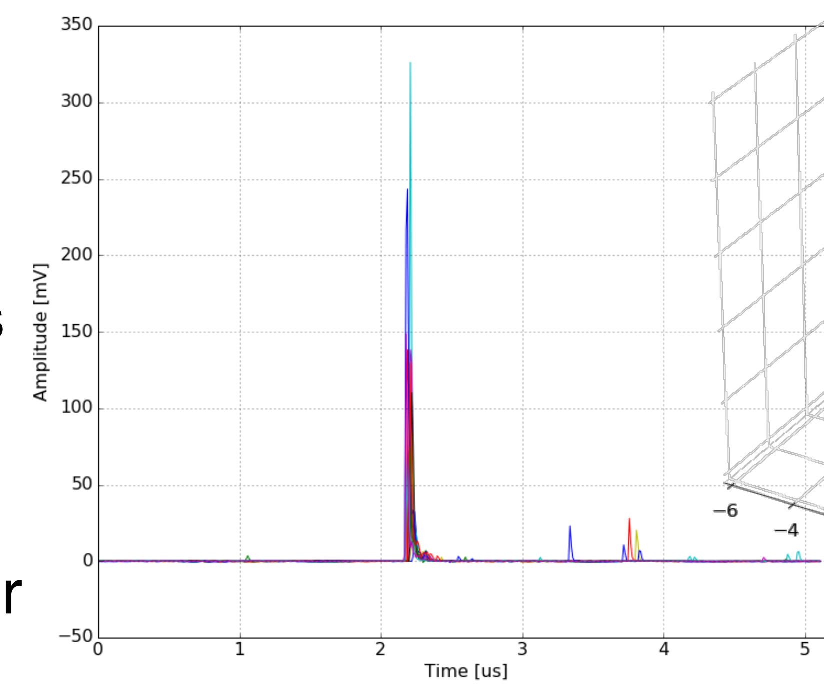
# Cherenkov Muon Veto

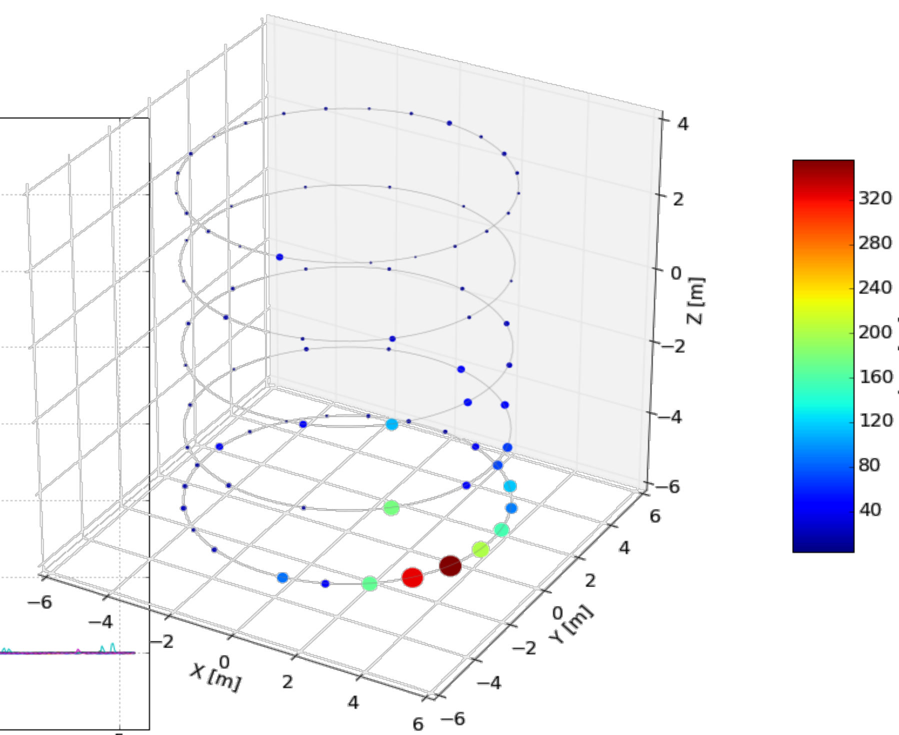






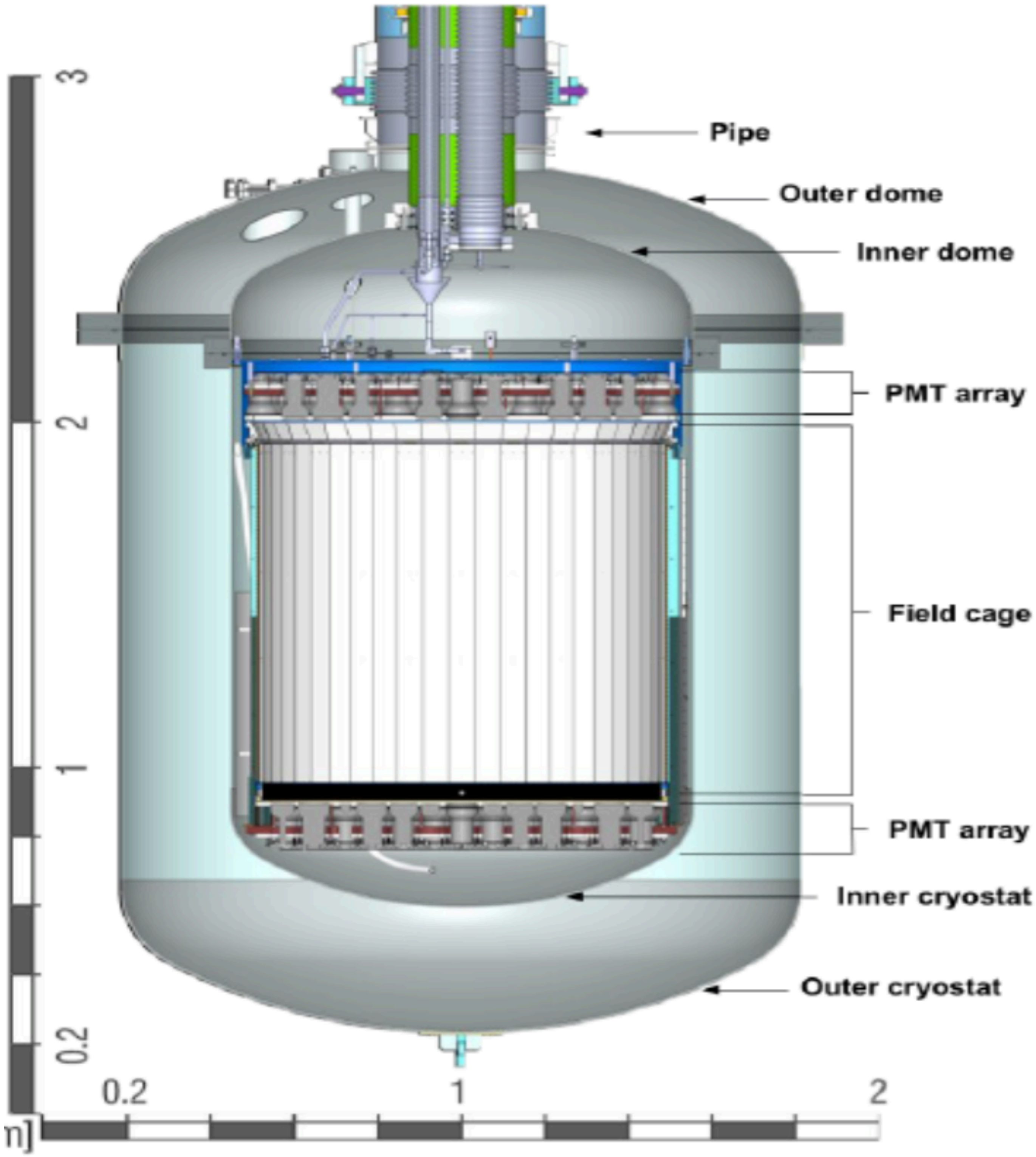
- Active shield against muons
- 84 high-QE 8" Hamamatsu R5912 PMTs
- Trigger efficiency > 99.5% for muons in water tank
- Can suppress cosmogenic neutron background to < 0.01 events/ton/year
- No coincidences with TPC found in this science run

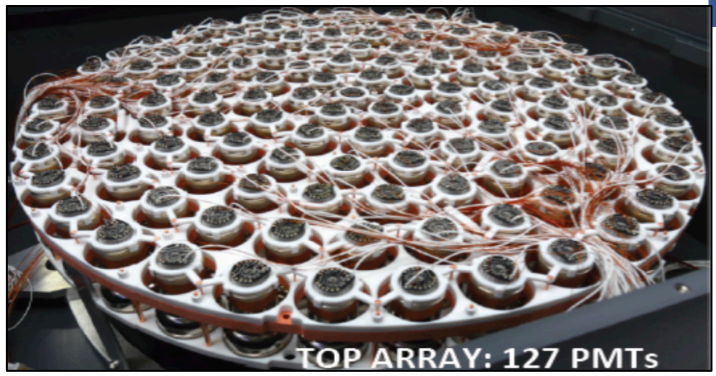


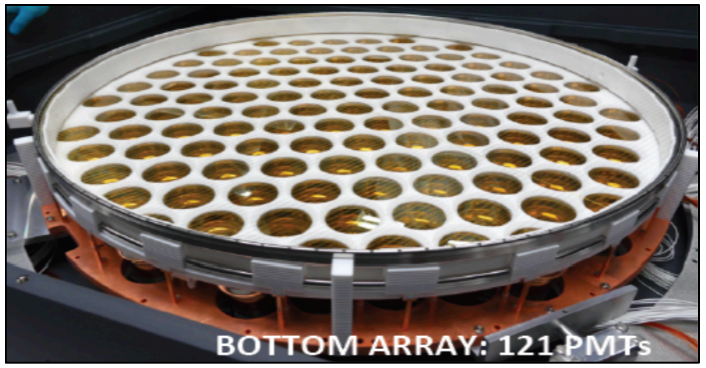




JINST 9, 11007 (2014)

# XENON1T TPC

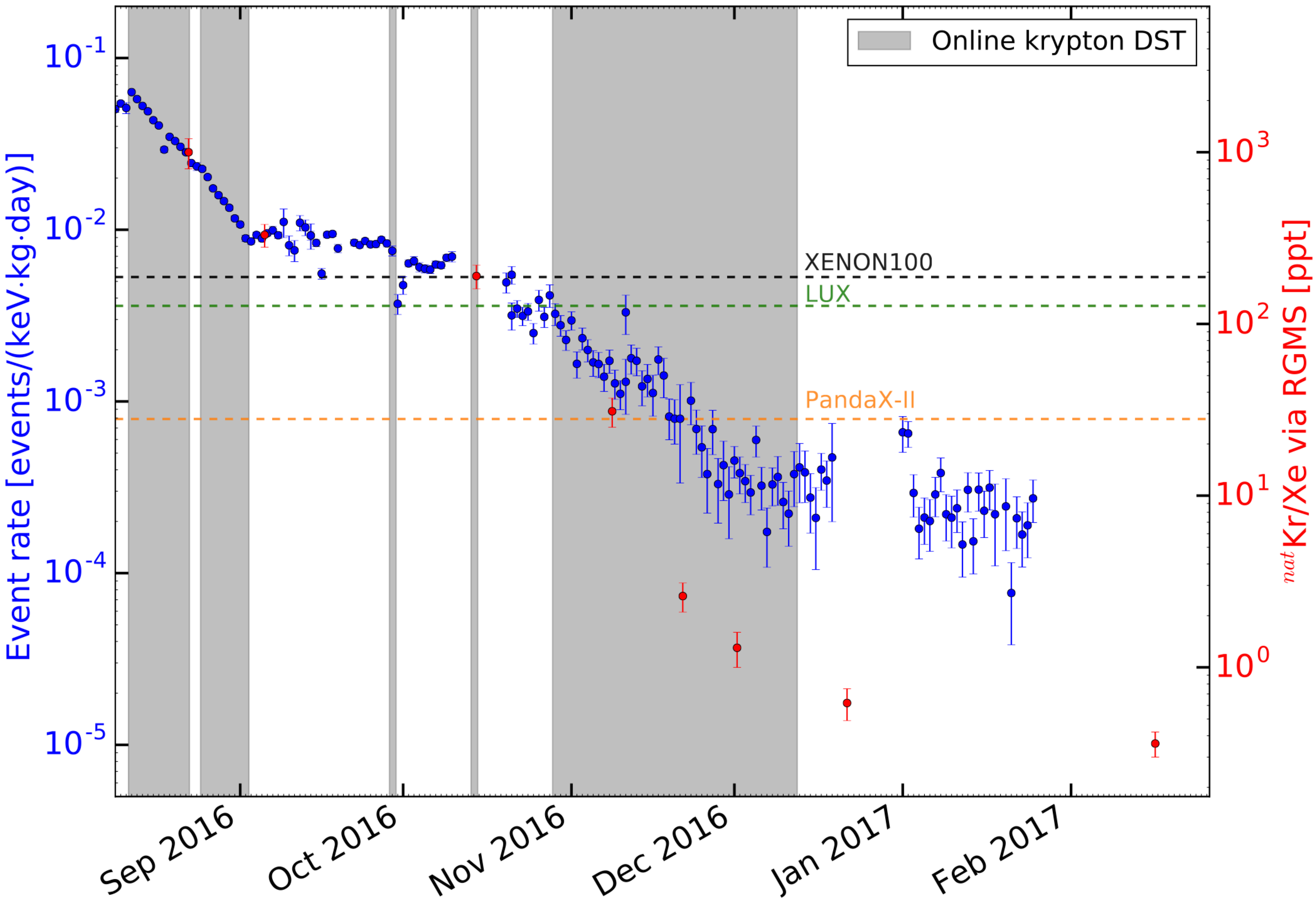


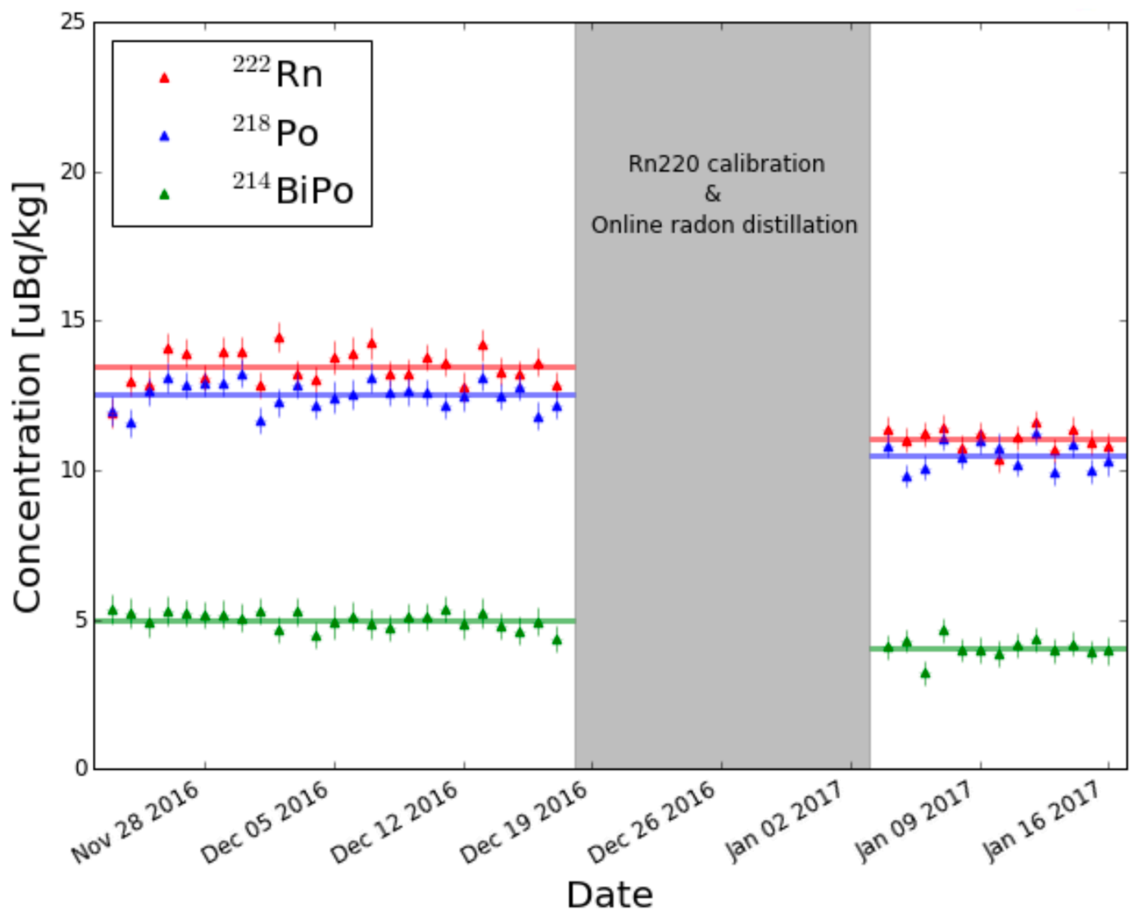

Eur. Phys. J. C 75, no. 11, 546 (2015)

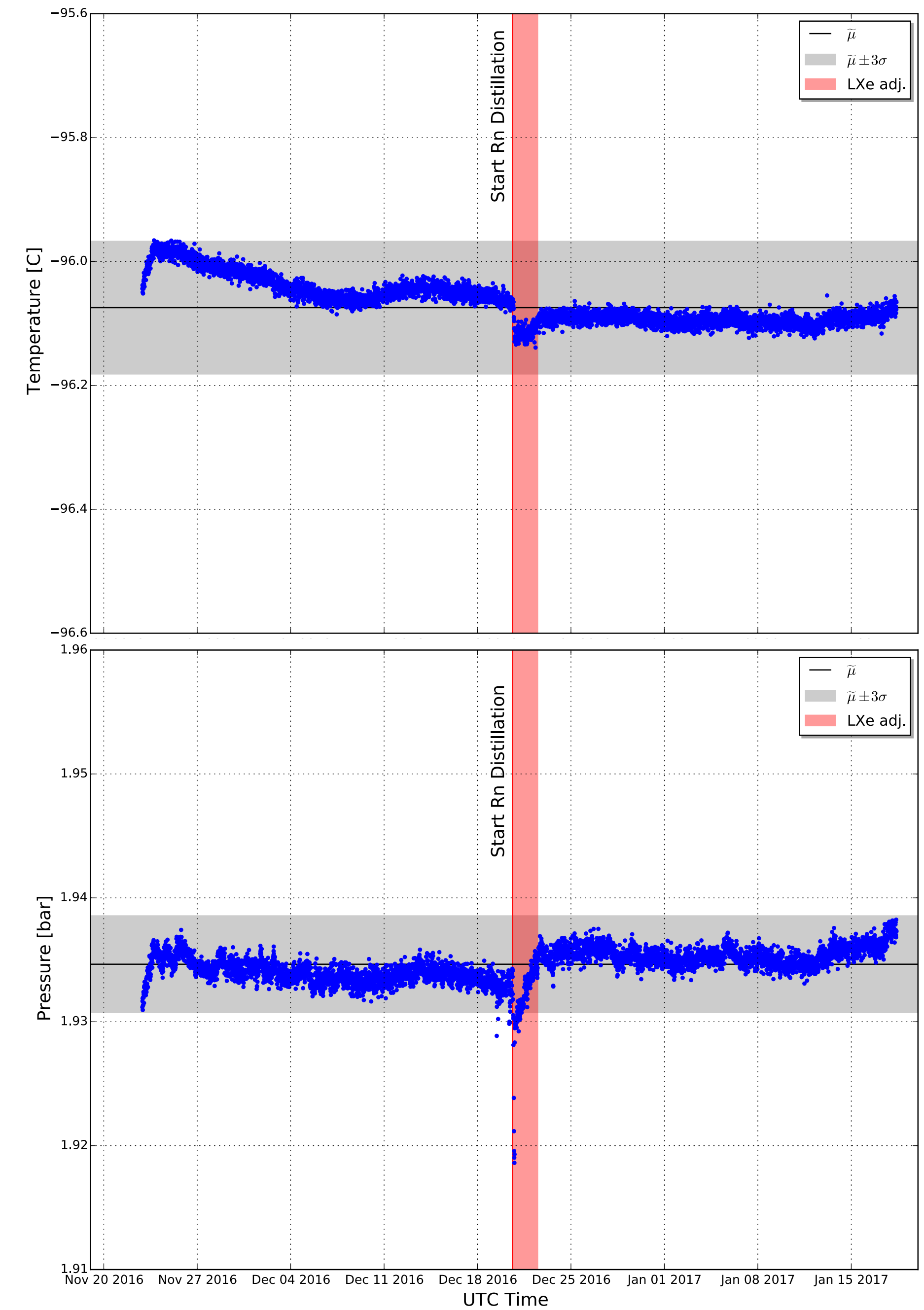
# Kr Reduction




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

- Online Rn distillation does not affect data taking
- Reduction of ~20%



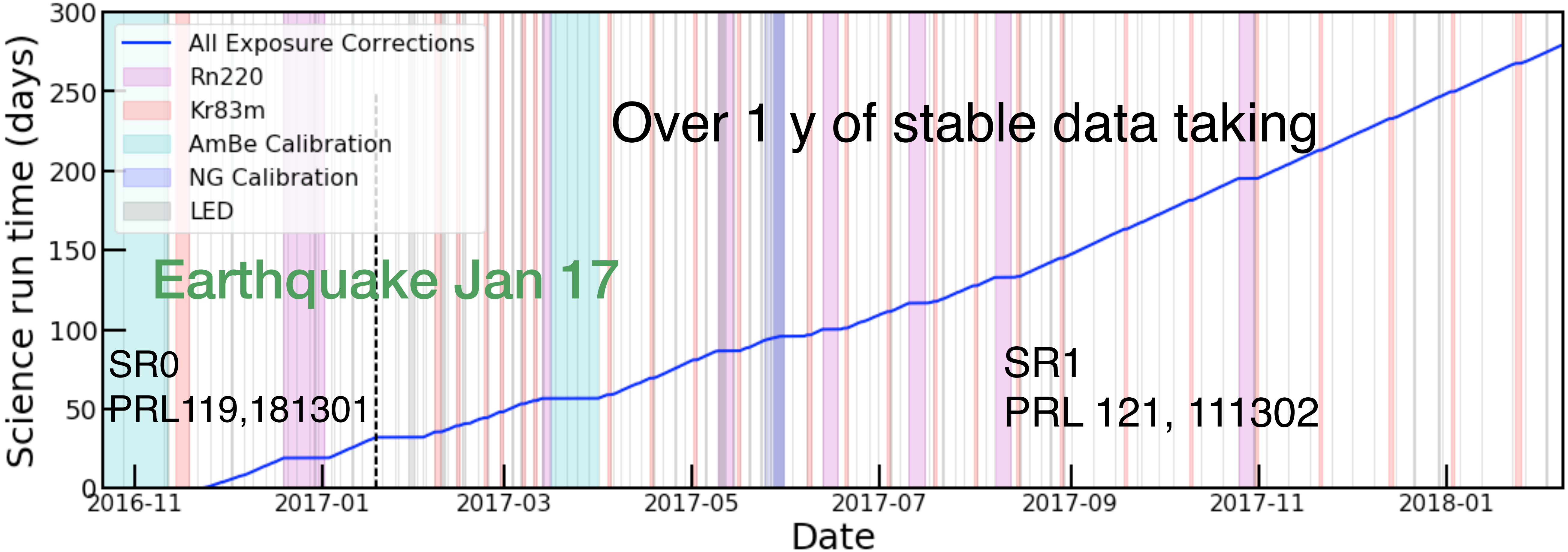




Eur. Phys. J. C77 (2017) no.5, 275 & Eur. Phys. J. C77 (2017) no.6, 358

# Understanding Detector

# XENON1T: Science and calibration data

- 279 days high quality data (livetime-corrected) spanning more than 1 year of stable detector's operation. The LXeTPC has been "cold" since Summer 2016
- 1 tonne x year exposure given 1.3 tonne fiducial volume- the largest reported to-date with this type of detector
- Experiment still running smoothly and collecting more data



# Overview of Data Analysis

**XENON1T (real waveforms)**

**Geant4 + waveform simulation**

**Raw data Processor (PAX)**

- peak-finding
- S1, S2 identification
- Interactions Reconstruction
    - position
    - energy
    - interaction type
    - …

**Selection & Correction**

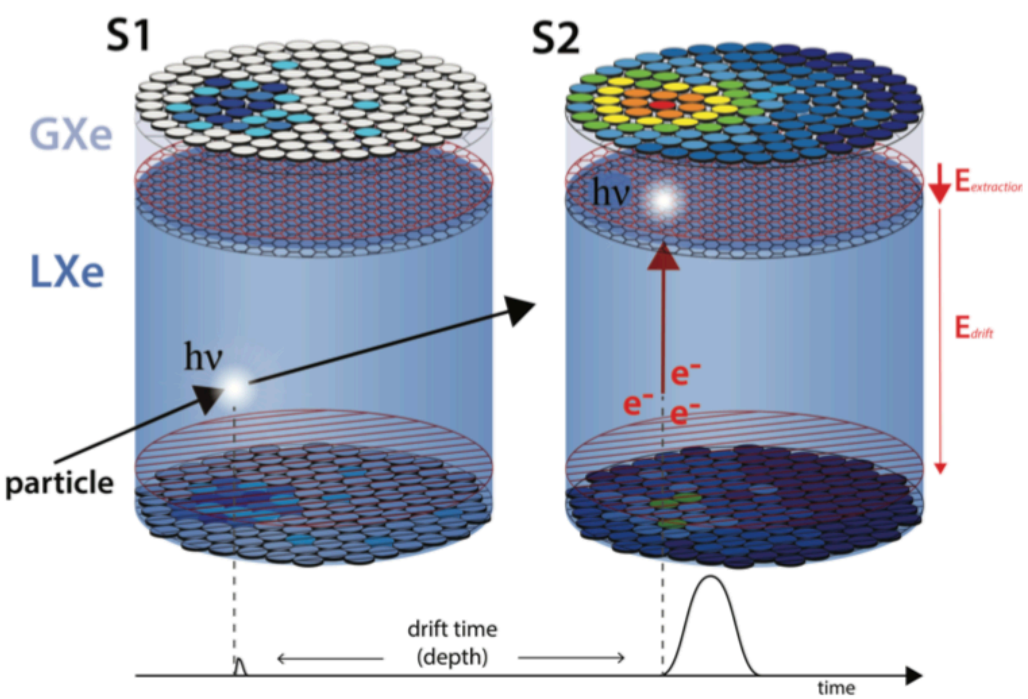
- Noise rejection
- Field distortion
- Signal correction
    - Spatial dependence
    - Field non-uniformity

**Detector Calibration**

**Background Modeling**

**Statistical Interpretation**

**Physics Results**



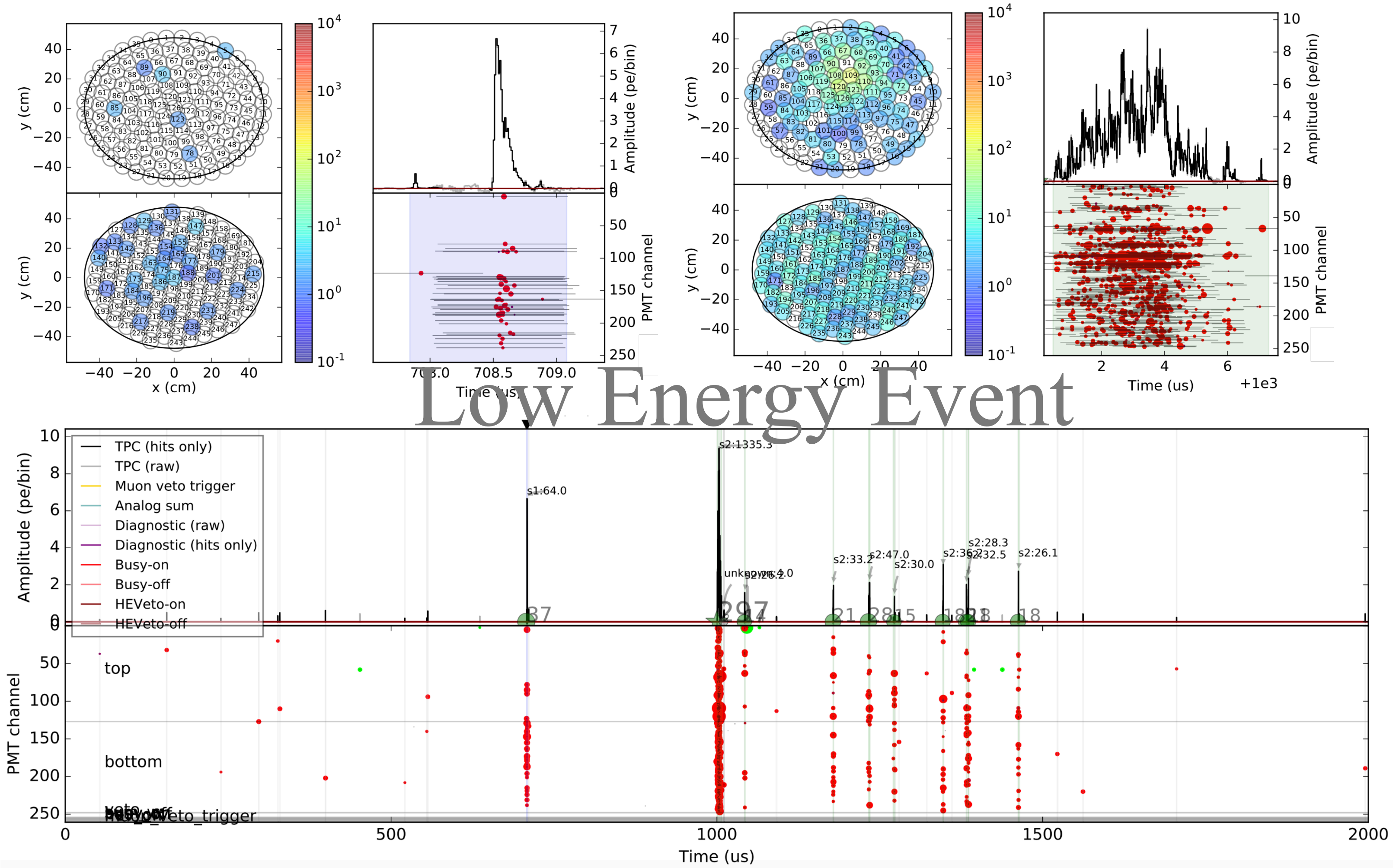

PAX

Processor for Analyzing XENON

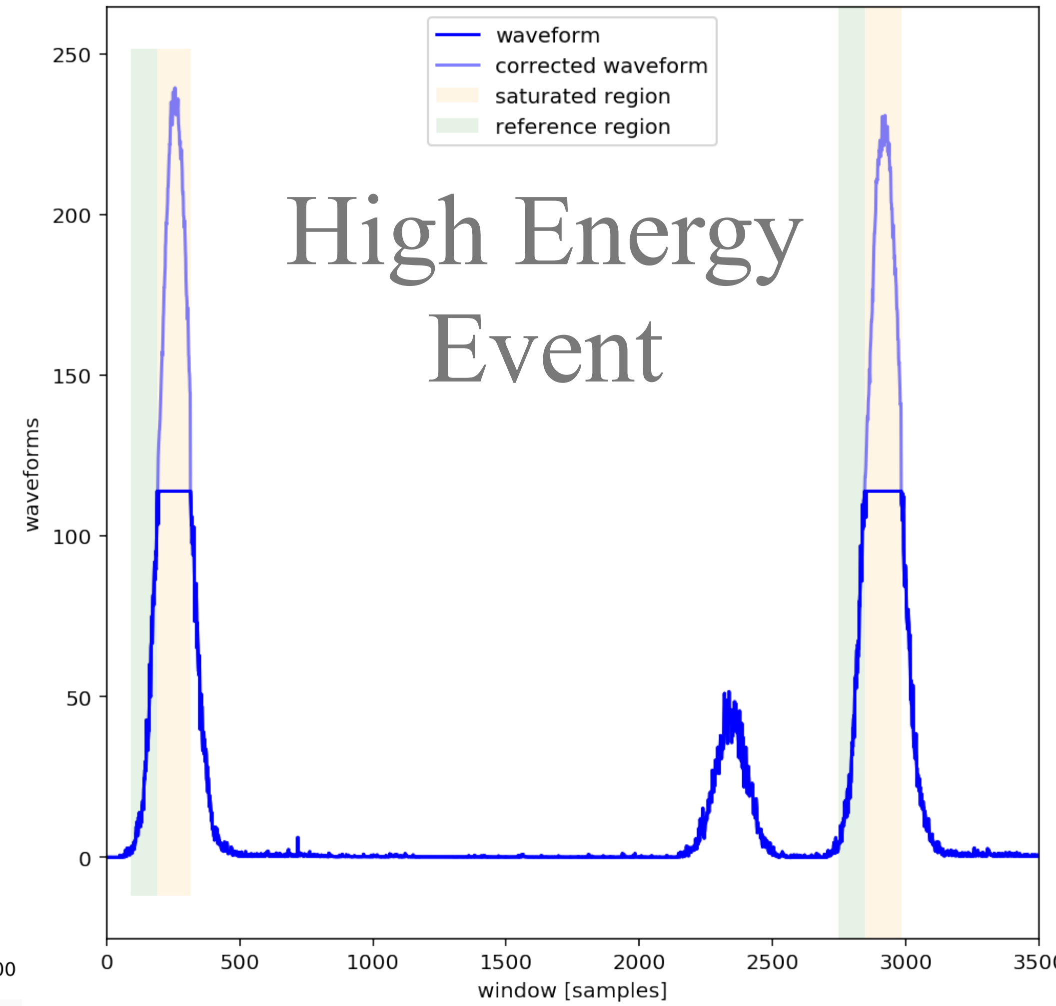
Developed by the XENON collaboration Publicly available to the community

https://github.com/XENON1T/pax

# Raw data process




Low Energy Event




High Energy Event

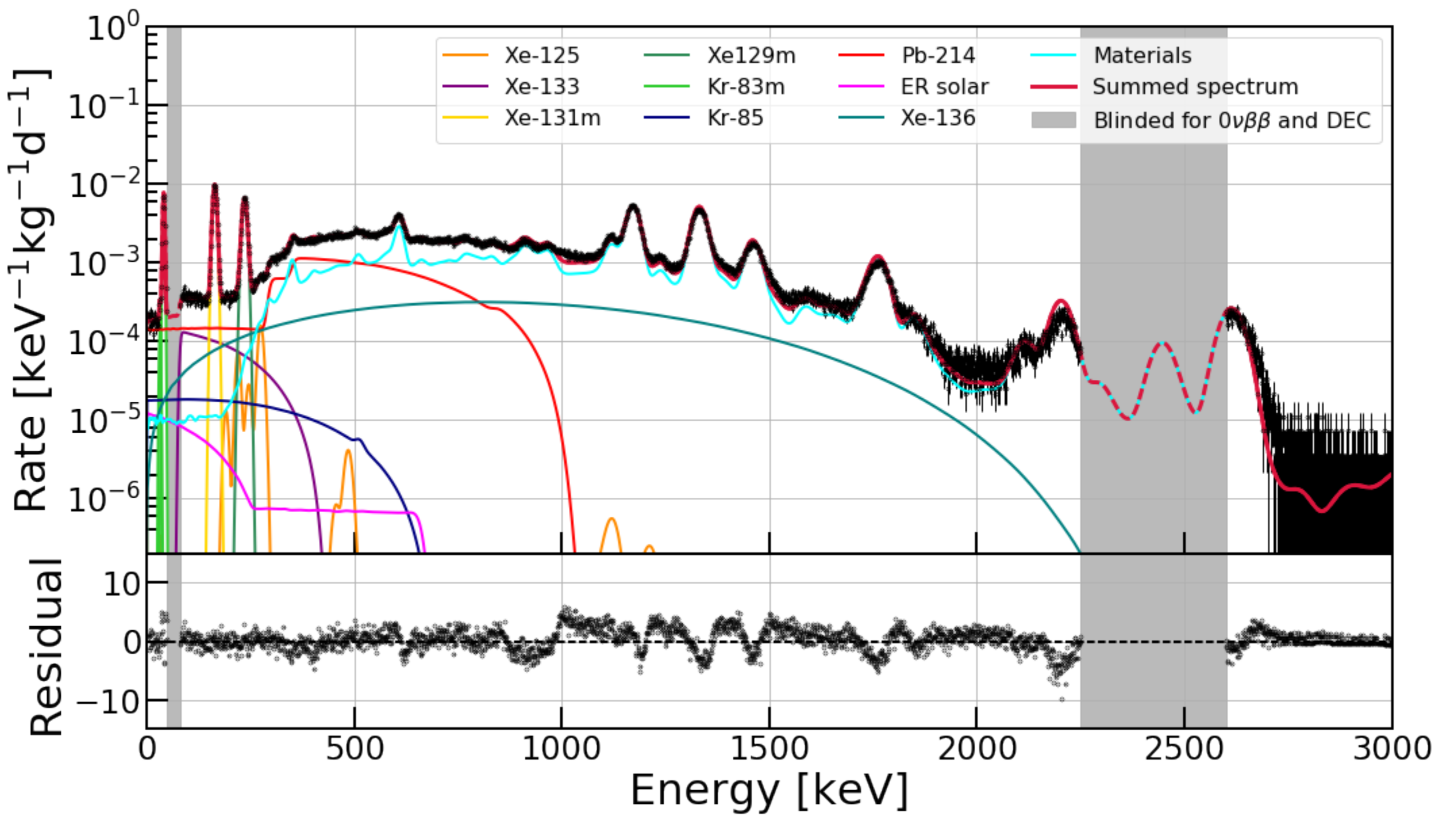
Challenges:

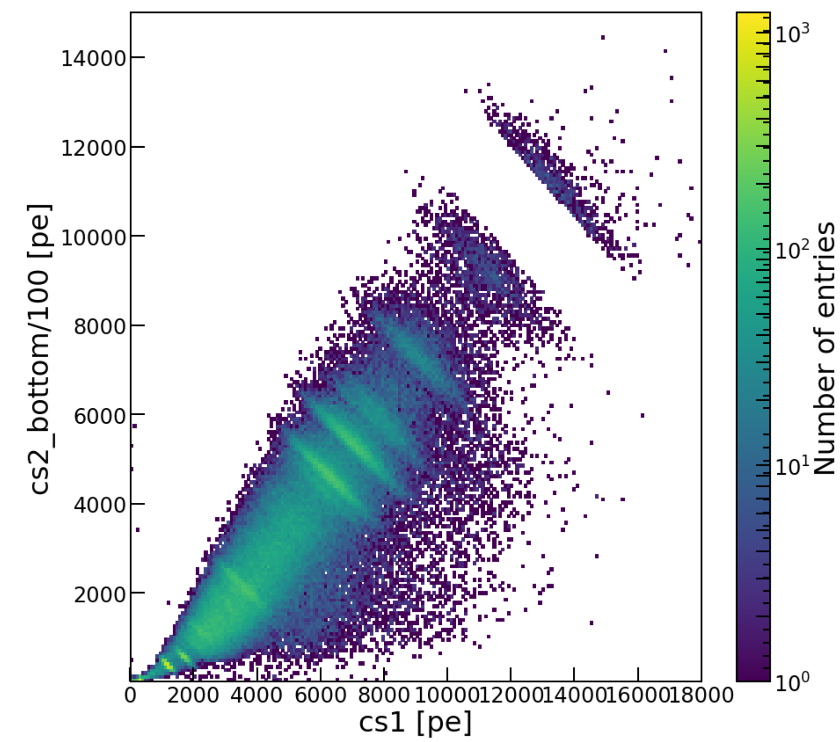
Contamination from electronic noise, PMT after pulses and impurity photo-ionization.

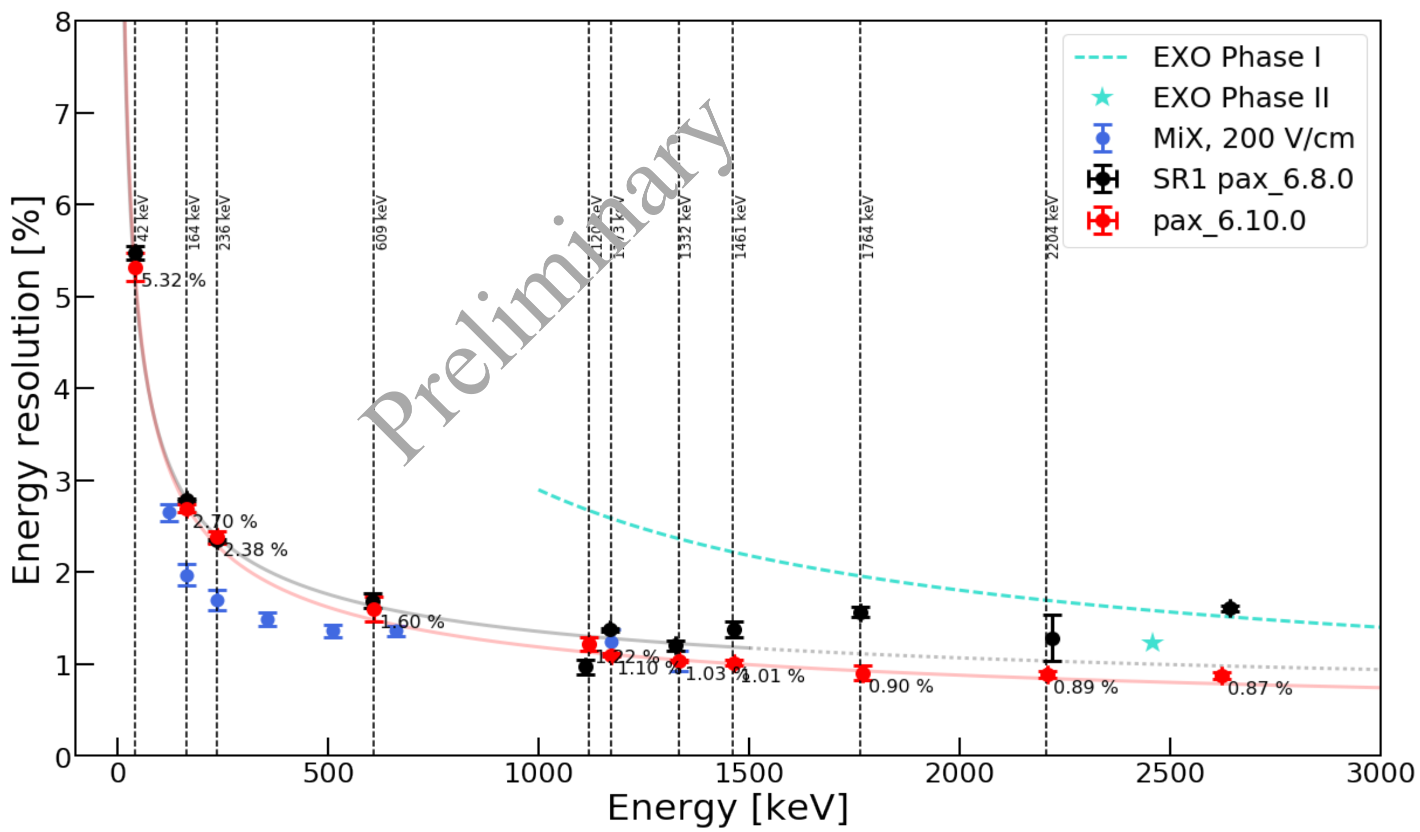
Need to distinguish between single and multiple scatters

Digitizer & PMT saturation at high energy

# Energy Linearity



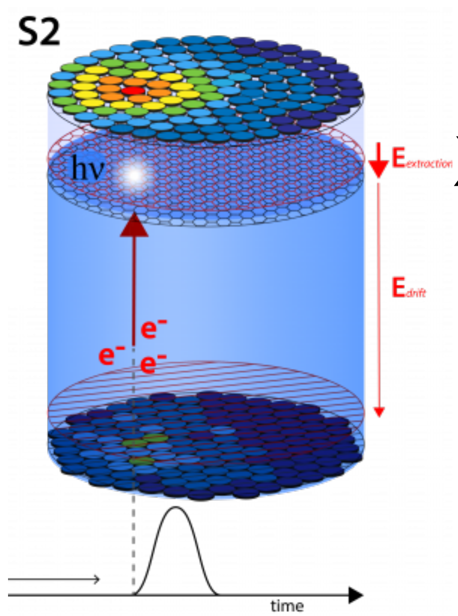




Linear energy reconstruction from **0 to 3 MeV**

Energy resolution @ 2.5MeV is **<1%**

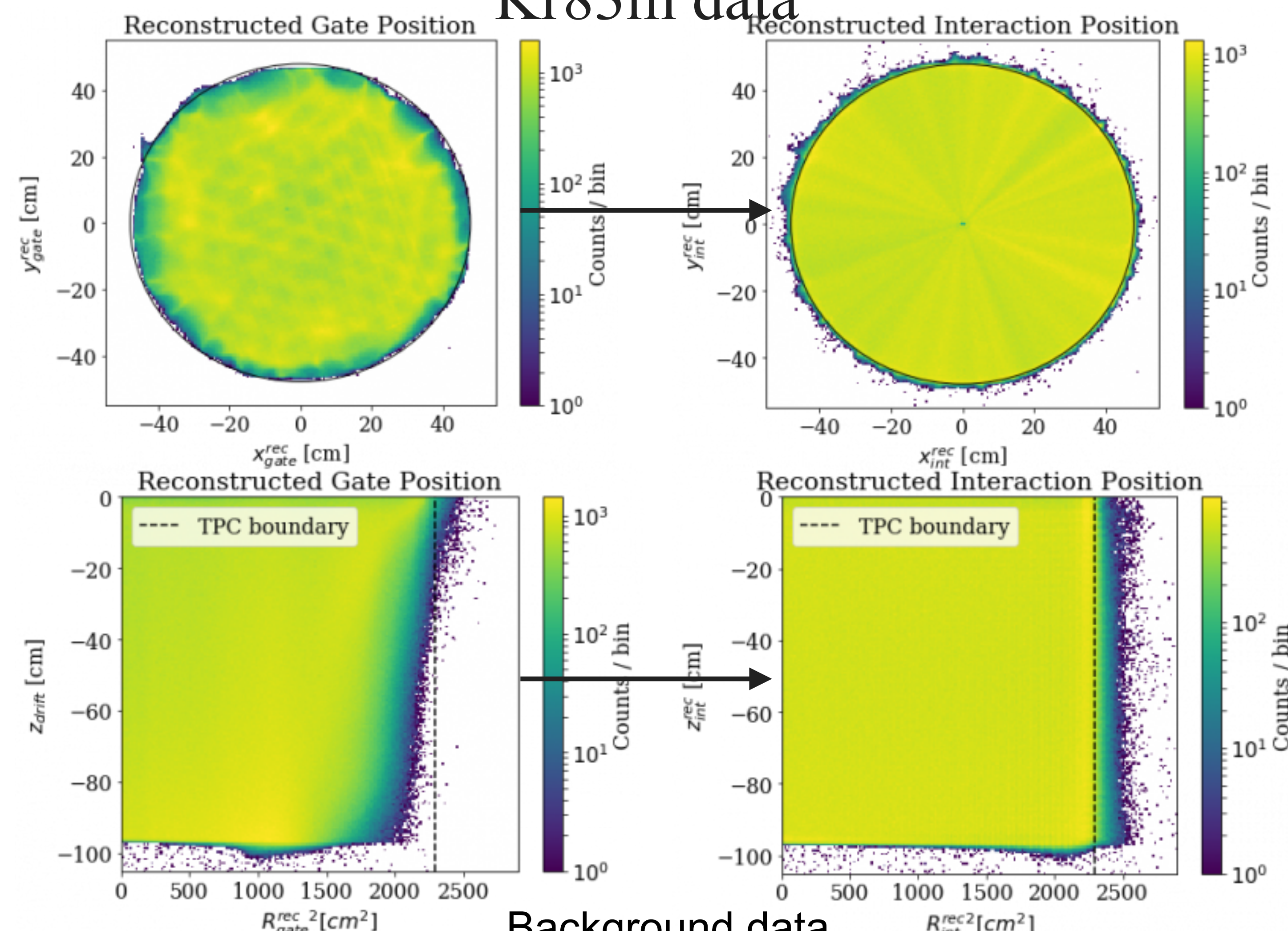
# Position Reconstruction & Correction




X-Y reconstruction via **neural network**:

- **Input:** charge/channel top array
- **Training:** Monte Carlo simulation

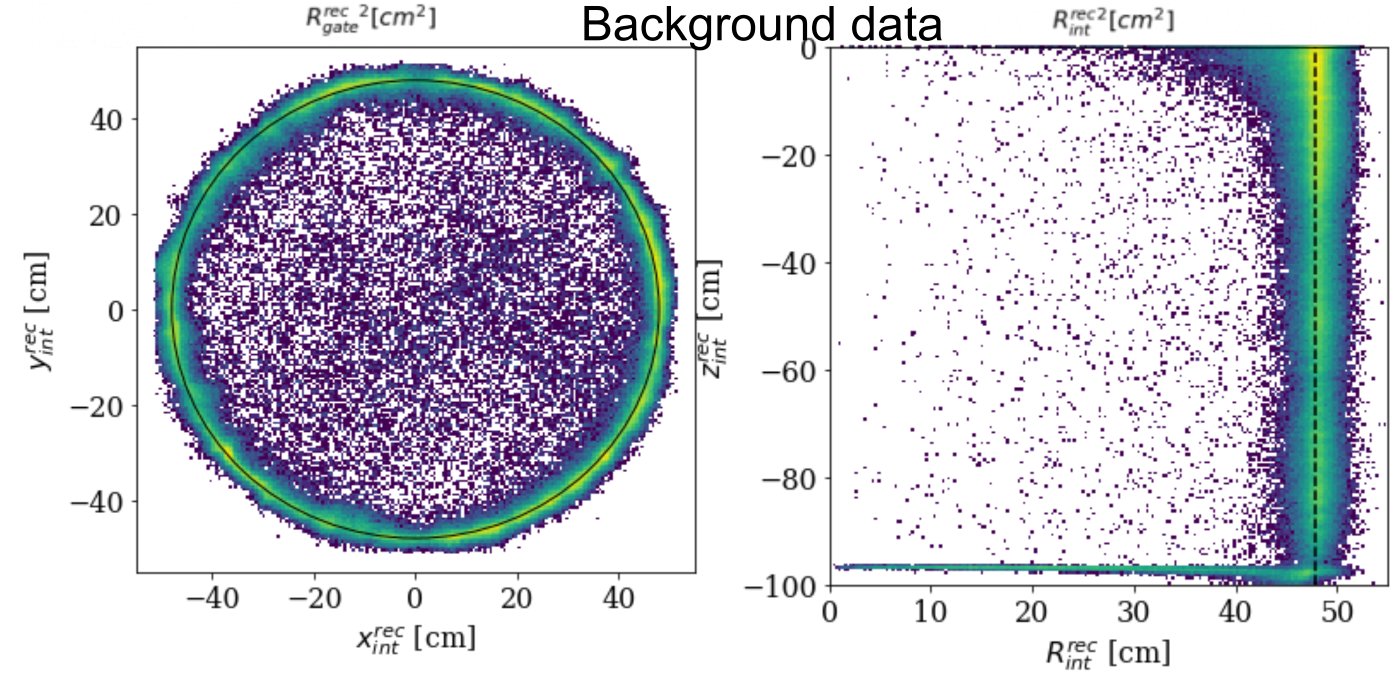
Kr83m data




**Position corrections** using $^{83m}$Kr

- **Drift field distortion**
- Localized inhomogeneities from inactive PMTs
- Data-derived correction verified by comparison to MC with several event sources

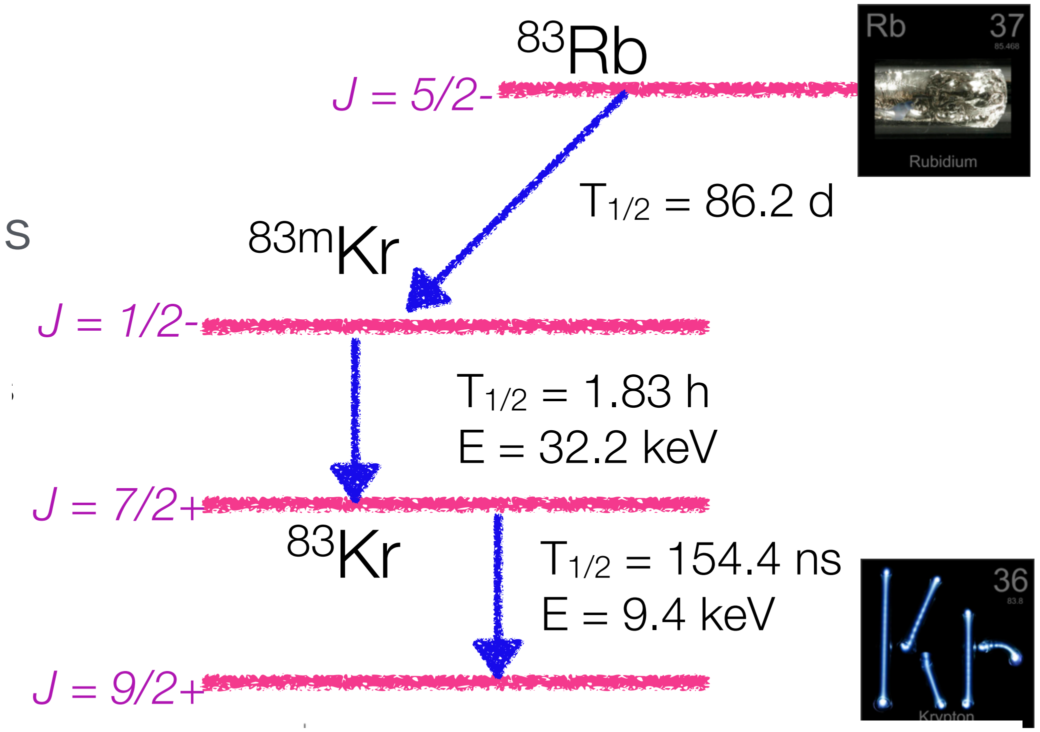
Background data



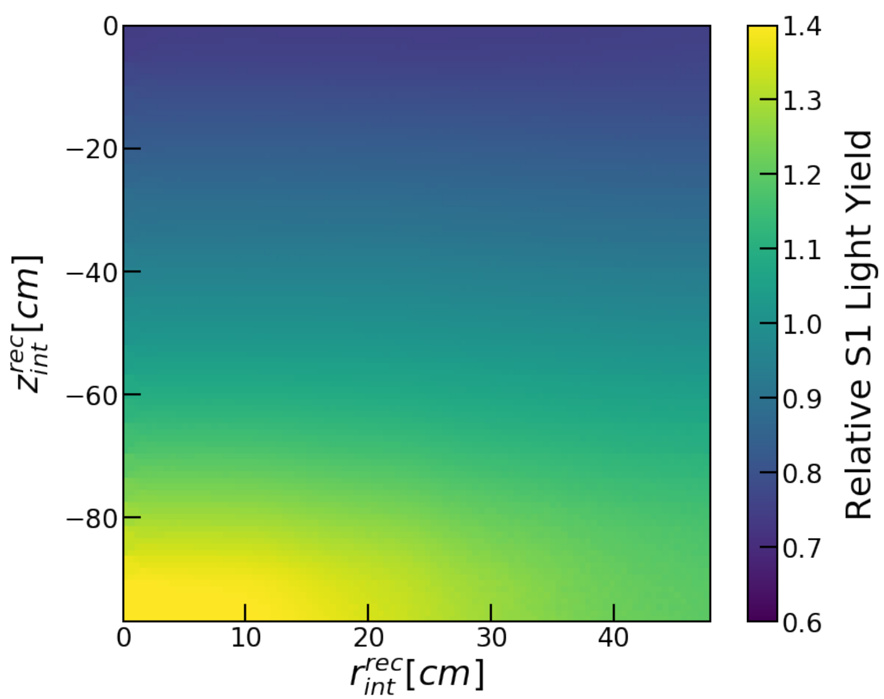
# Signal Correction

### Spatial signal corrections with $^{83m}$Kr source

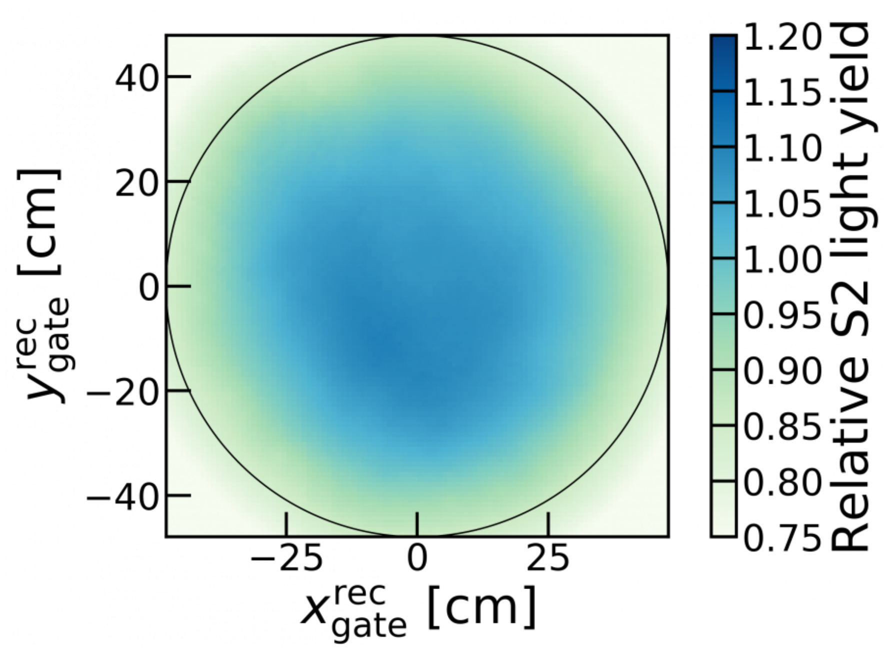
- Internal source (injected directly into LXe)
- 32.2 keV and 9.4 keV emissions separated by $T_{1/2}$ =154 ns
- Used for several corrections
  - Position dependent light collection efficiency
  - Position dependent S2 amplification
  - Electron lifetime correction



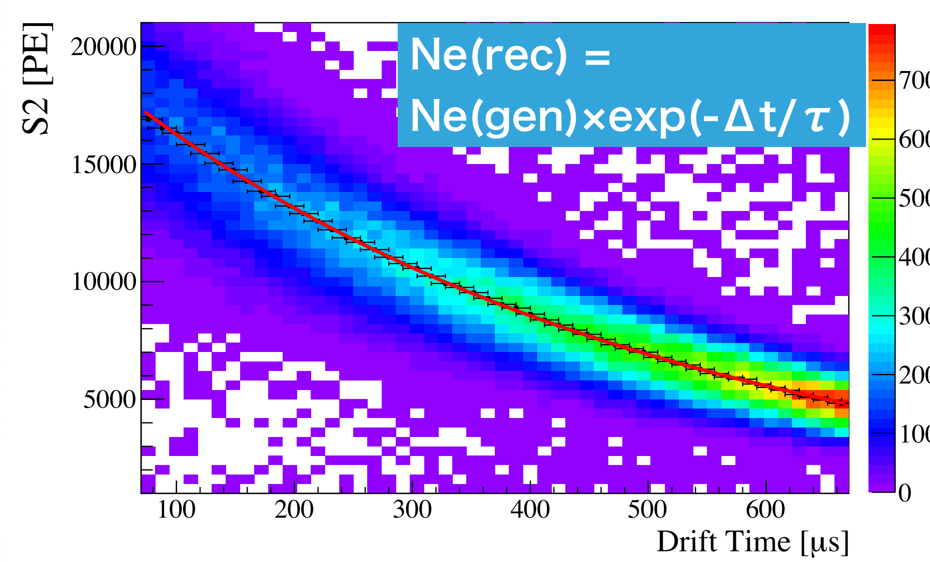

### Relative S1 light yield



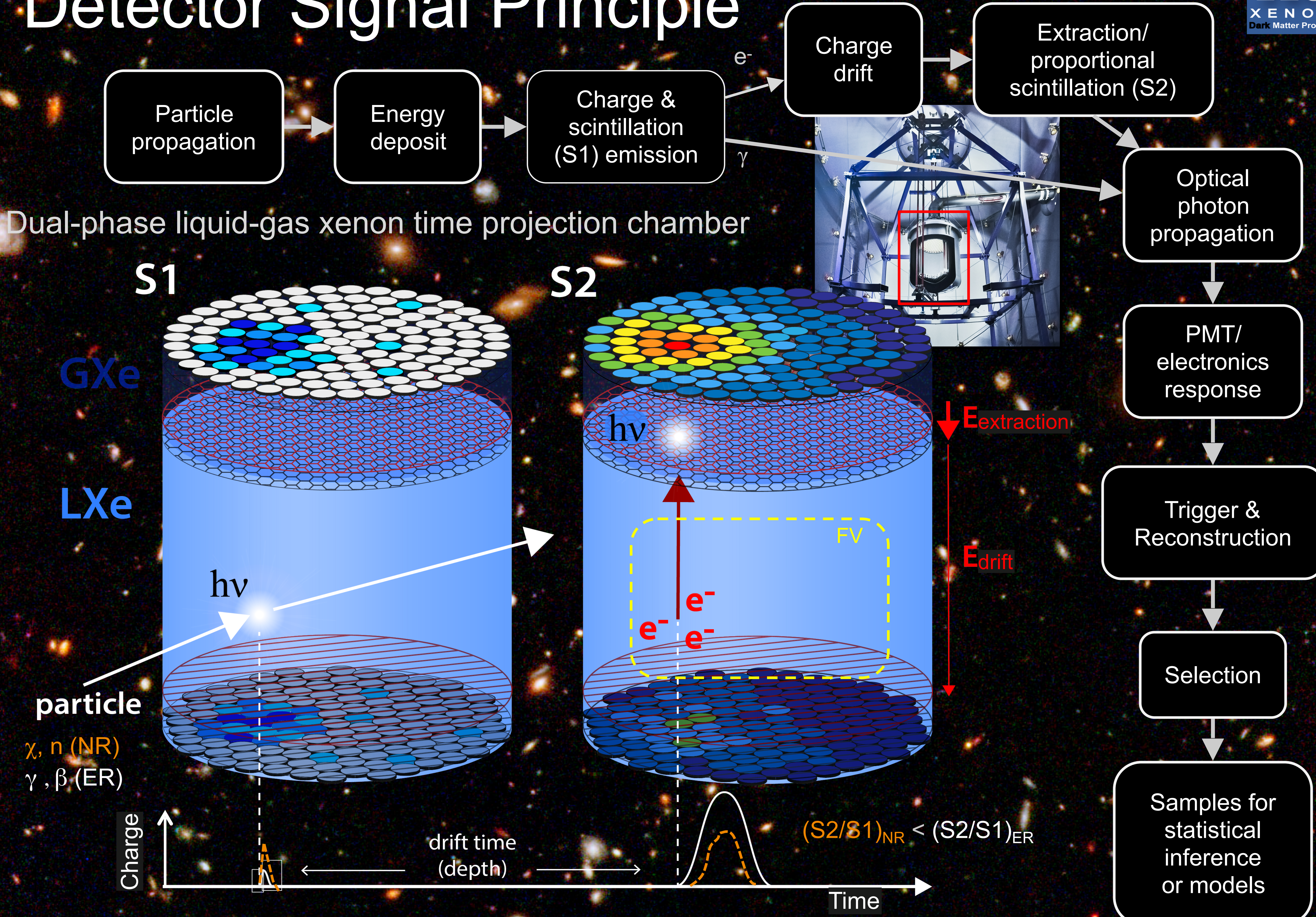

### Relative S2 light yield



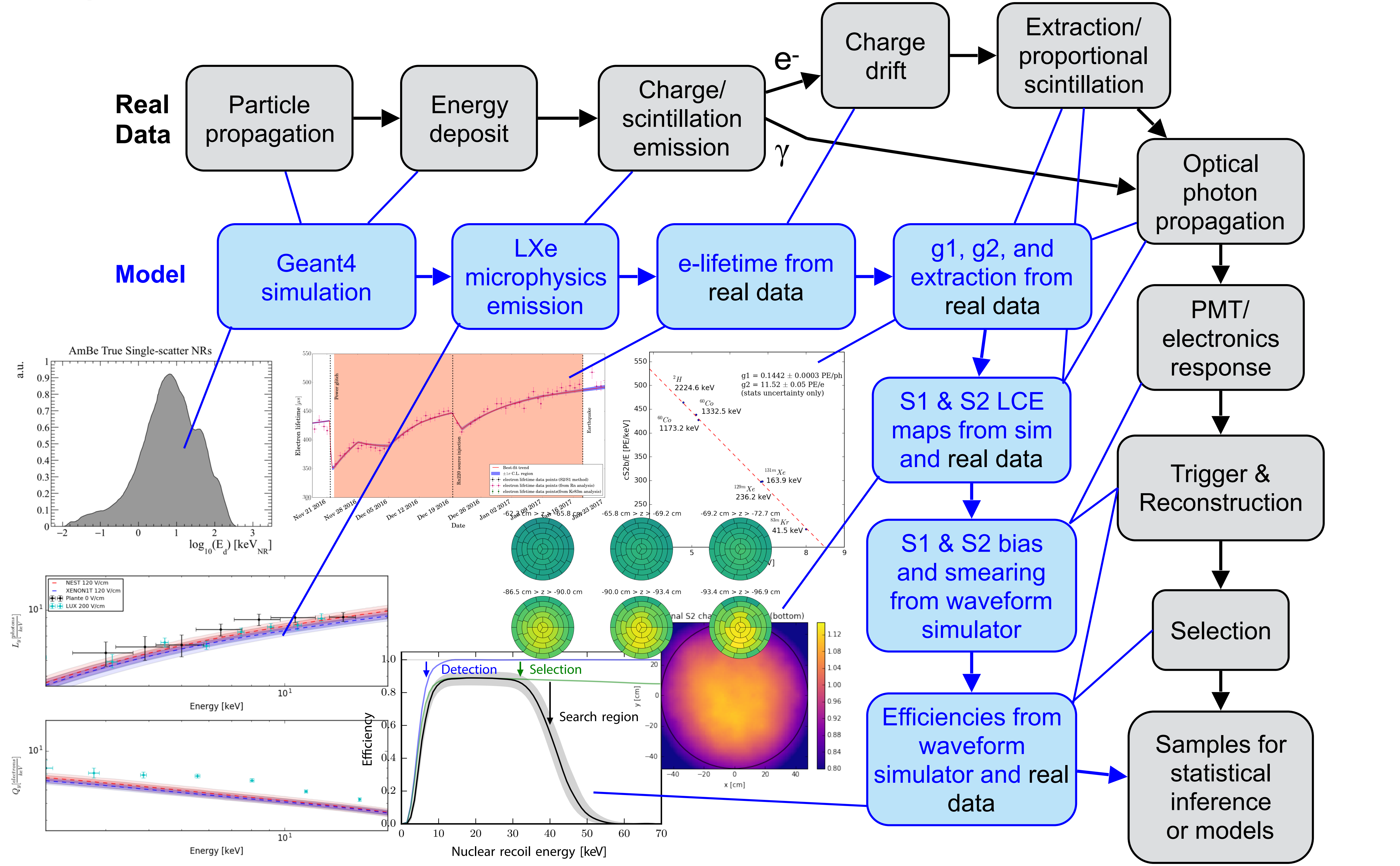

### S2 electron lifetime vs dt



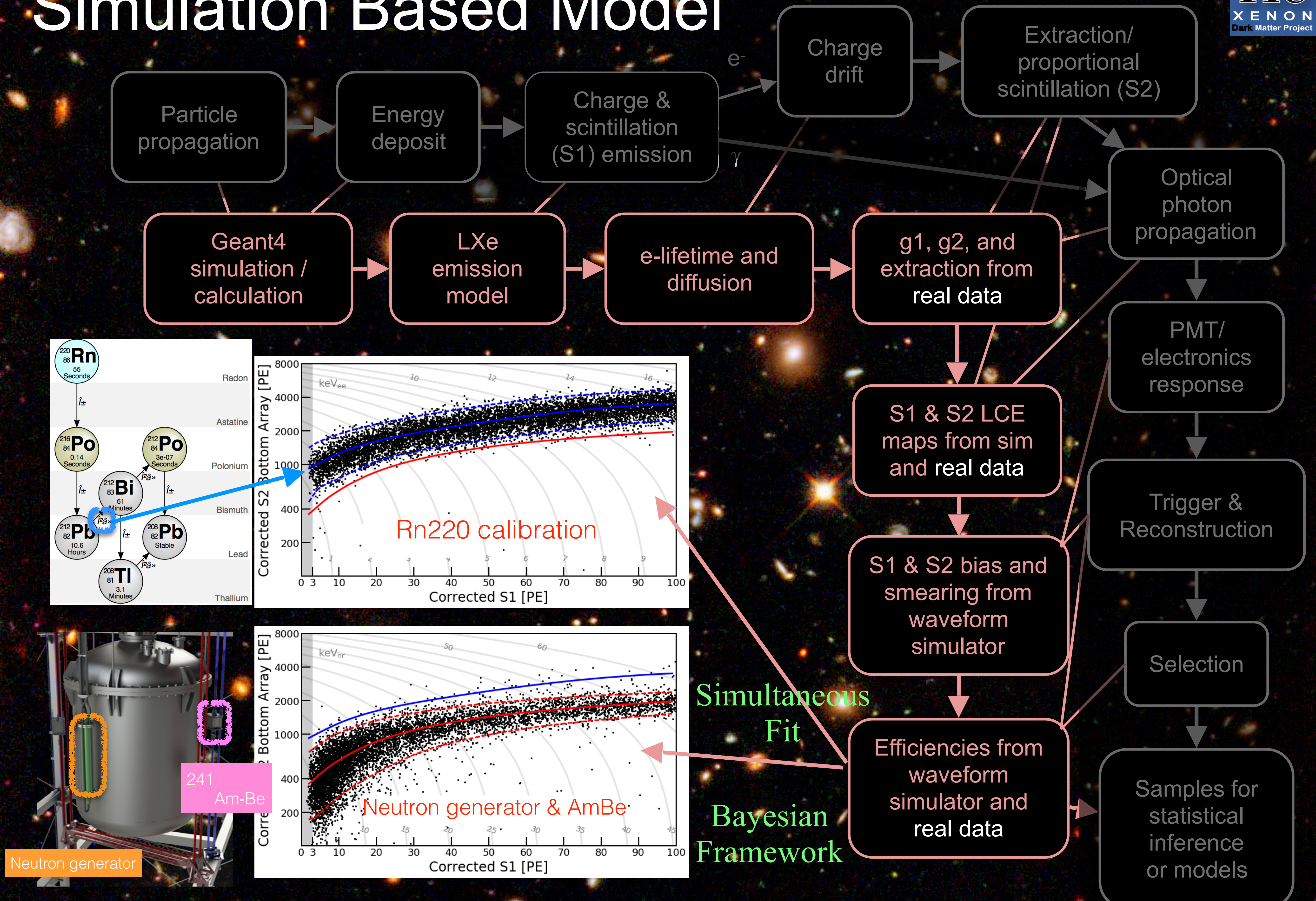
# Detector Signal Principle



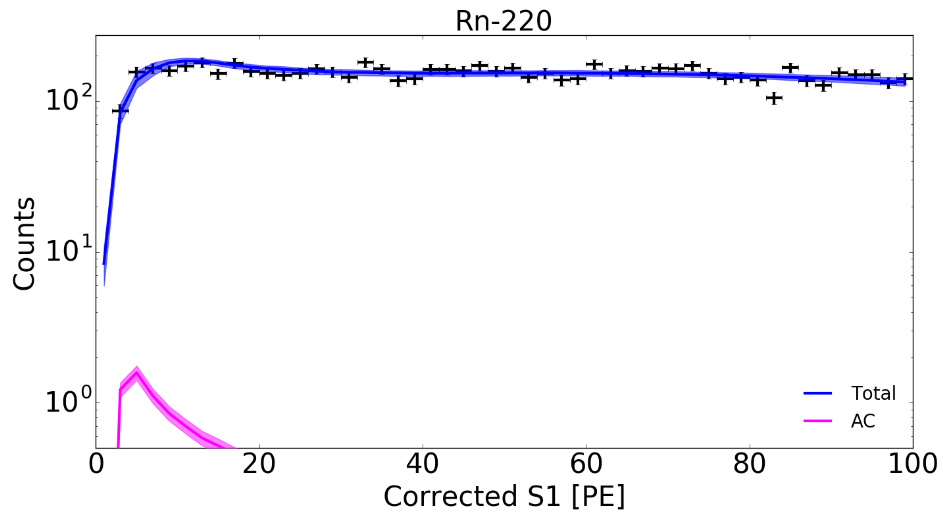
# The ER and NR Models



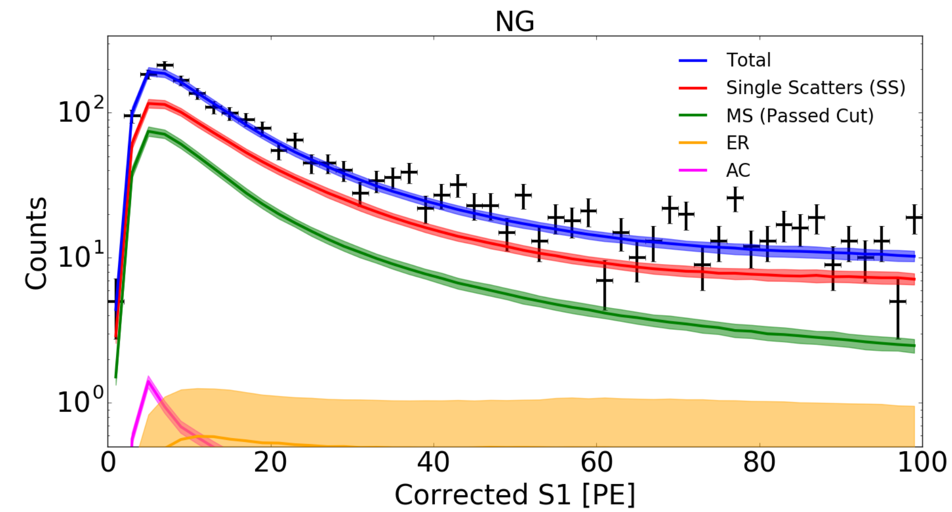
# Simulation Based Model

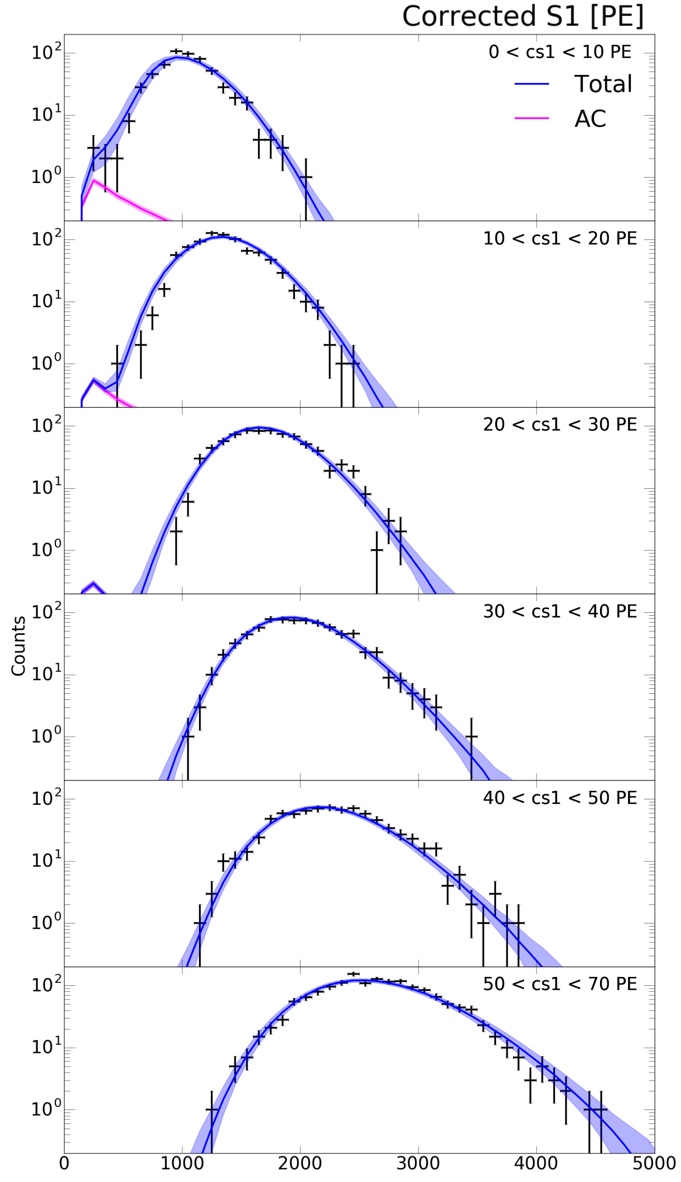


# Good matching to data

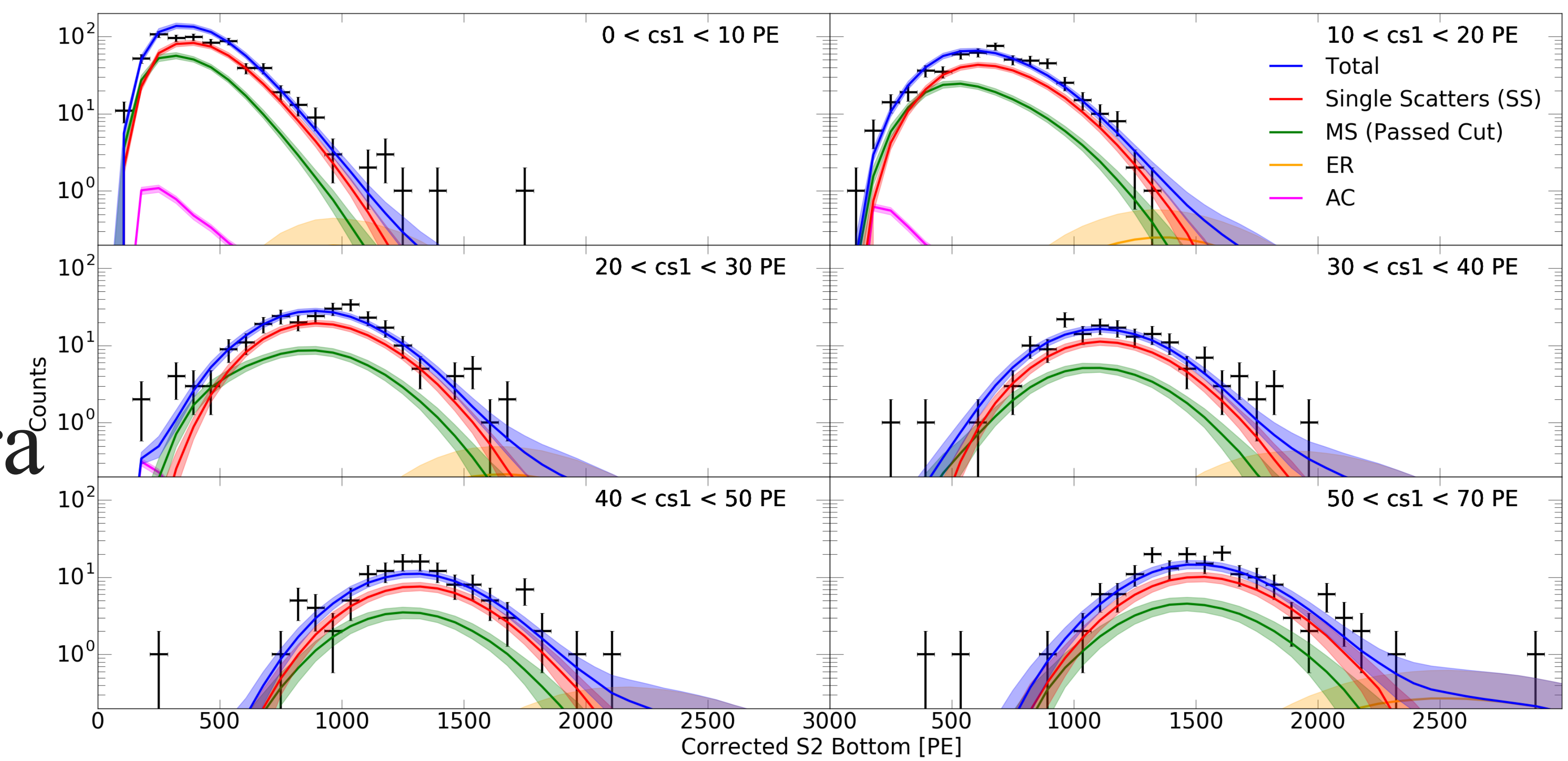



cS1 spectra



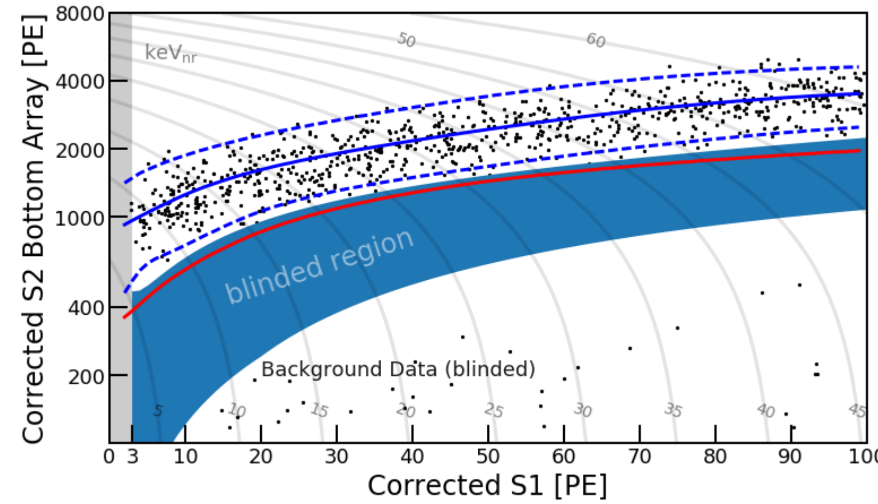

cS2 spectra

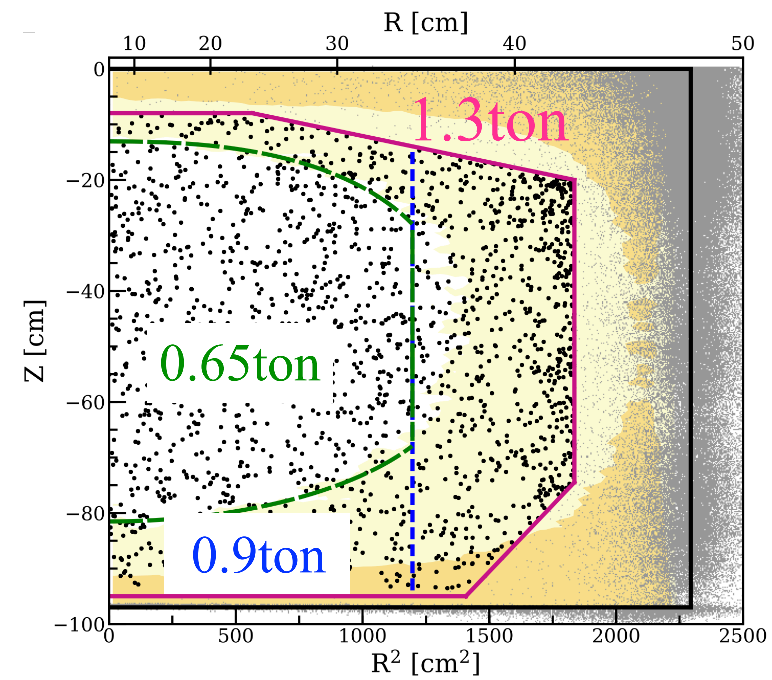



More challenging for NR: Need to model the multiple scatters

# Backgrounds

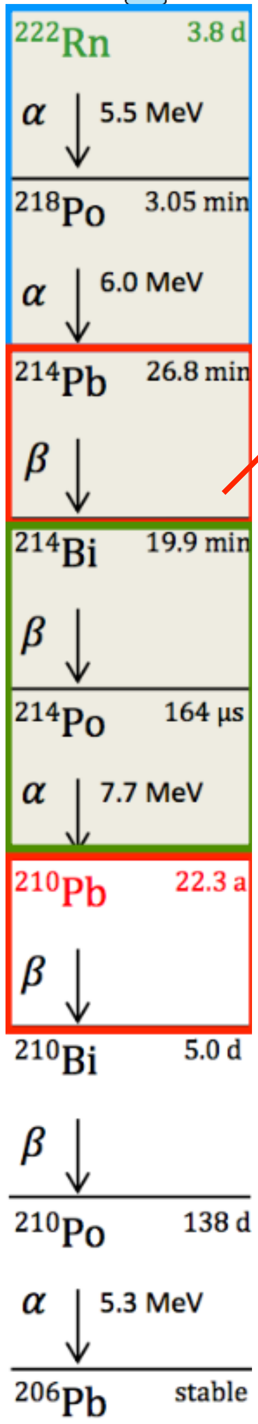
| Mass | 1.3t | 1.3t | 0.9t | 0.65t |
|---|---|---|---|---|
| (S2, S1) | Full | Reference | Reference | Reference |
| ER | 627±18 | 1.6±0.3 | 1.1±0.2 | 0.6±0.1 |
| Neutron | 1.4±0.7 | 0.8±0.4 | 0.4±0.2 | 0.14±0.07 |
| CENNS | 0.05±0.01 | 0.03±0.01 | 0.02 | 0.01 |
| AC | 0.47±0.15 | 0.10±0.03 | 0.06±0.02 | 0.04±0.01 |
| Surface | 106±8 | 4.8±0.4 | 0.02 | 0.01 |
| BG | 735±20 | 7.4±0.6 | 1.6±0.3 | 0.8±0.1 |
| Data | **739** | **14** | **2** | **2** |



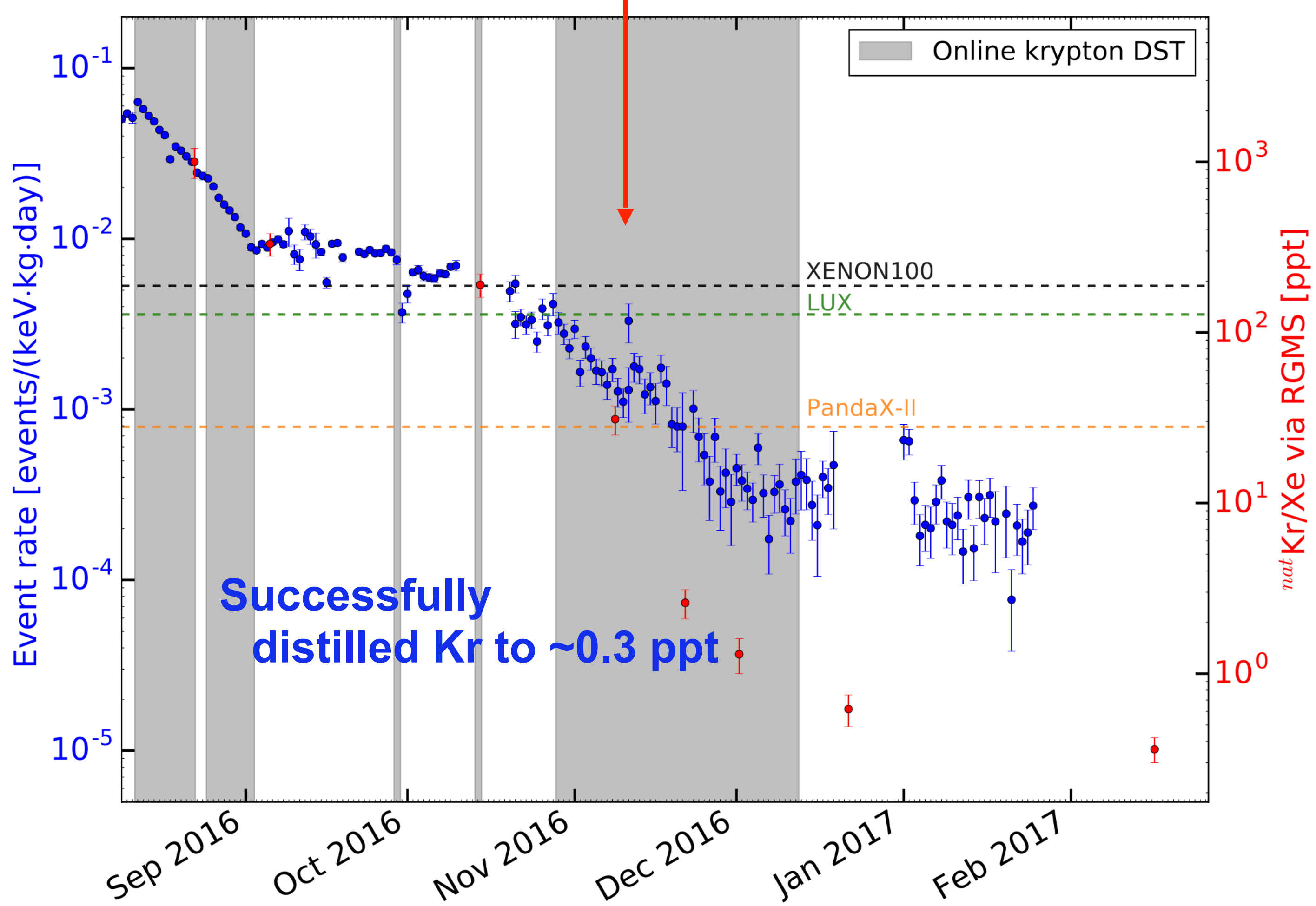




- ER is the dominant background
- Surface background & neutron distribution are not uniform. Spatial likelihood is taken into consideration.

# Electronic recoil background




- **Rn222 : 10 uBq/kg**
  - **Achieved with careful surface emanation control and measurements**
  - **Further reduction with online cryogenic distillation**
- **Kr85 : sub-ppt Kr/Xe**
  - **Achieved with online cryogenic distillation**
- **Materials radioactivity (HPGe gamma screening): subdominant**




| Source | Rate (1.3t) [$t^{-1}$ $y^{-1}$ $keV^{-1}$] | Fraction [%] |
|---|---|---|
| 222Rn | 56 ± 6 | 74.7 |
| 85Kr | 7.7 ± 1.3 | 10.3 |
| Materials | 8 ± 1 | 10.7 |
| Solar ν | 2.5 ± 0.1 | 3.3 |
| 136Xe | 0.8 ± 0.1 | 1.1 |
| Total | **75 ± 6** | |
| Measured | 82±5(sys)±3(stat) | |

# Nuclear recoil background

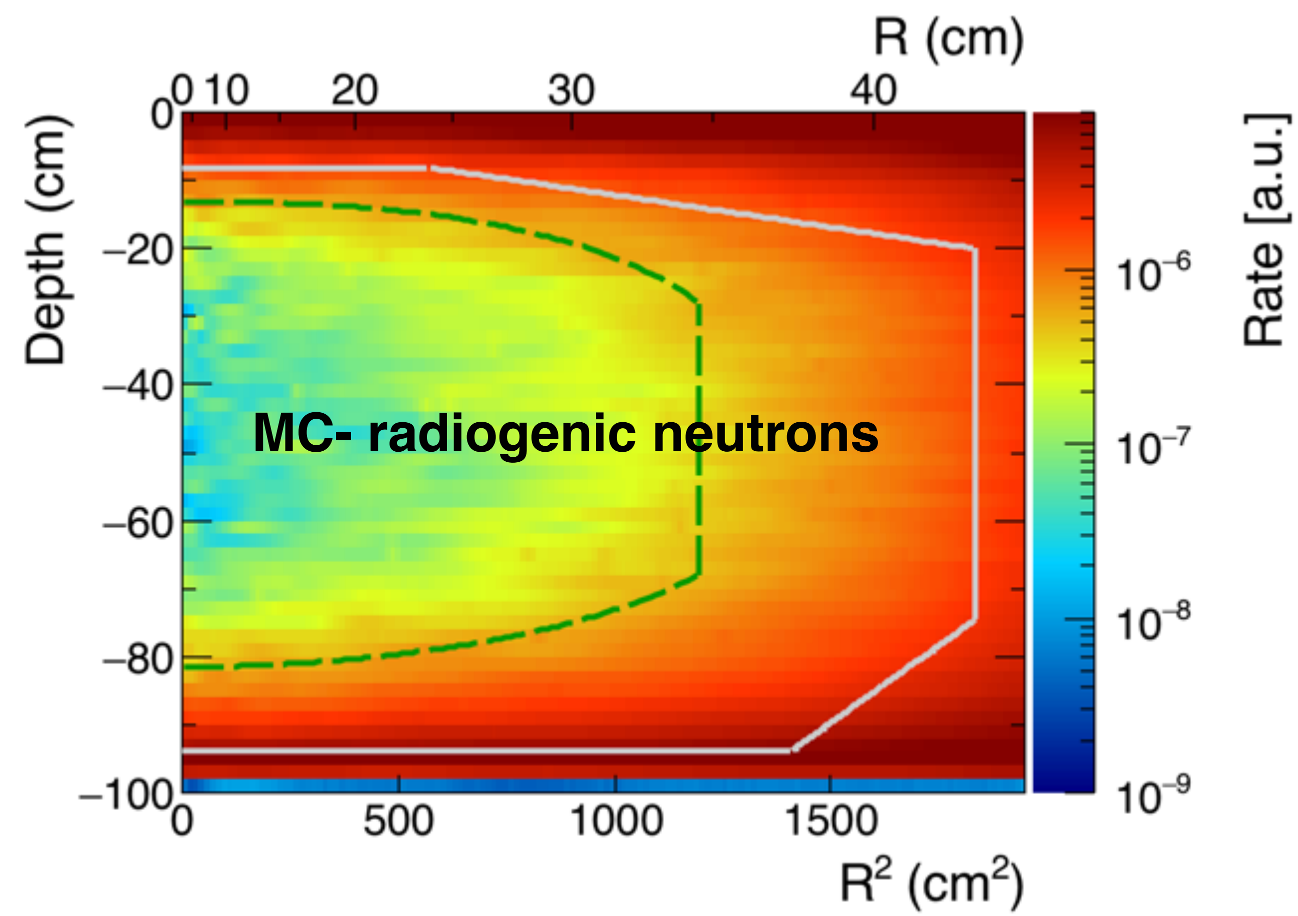
Cosmogenic μ-induced neutrons significantly reduced by rock overburden and muon veto

Coherent elastic ν-nucleus scattering, constrained by **$^{8}$B** neutrino flux and measurements, is an an irreducible background at very low energy (1 keV)

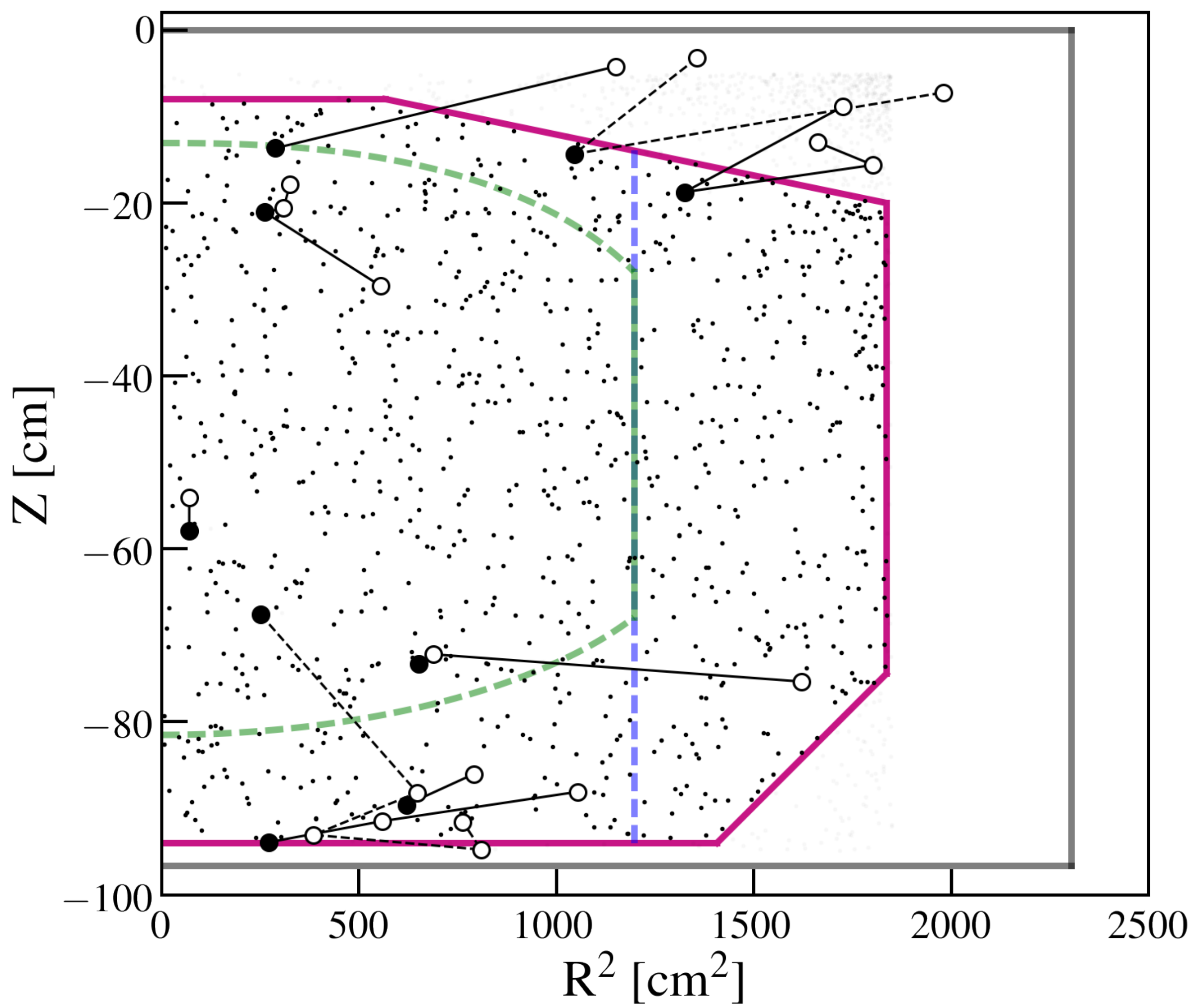
Radiogenic neutrons from (α, n) reactions and fission from $^{238}$U and $^{232}$Th: reduced via careful materials selection, event multiplicity and fiducialization

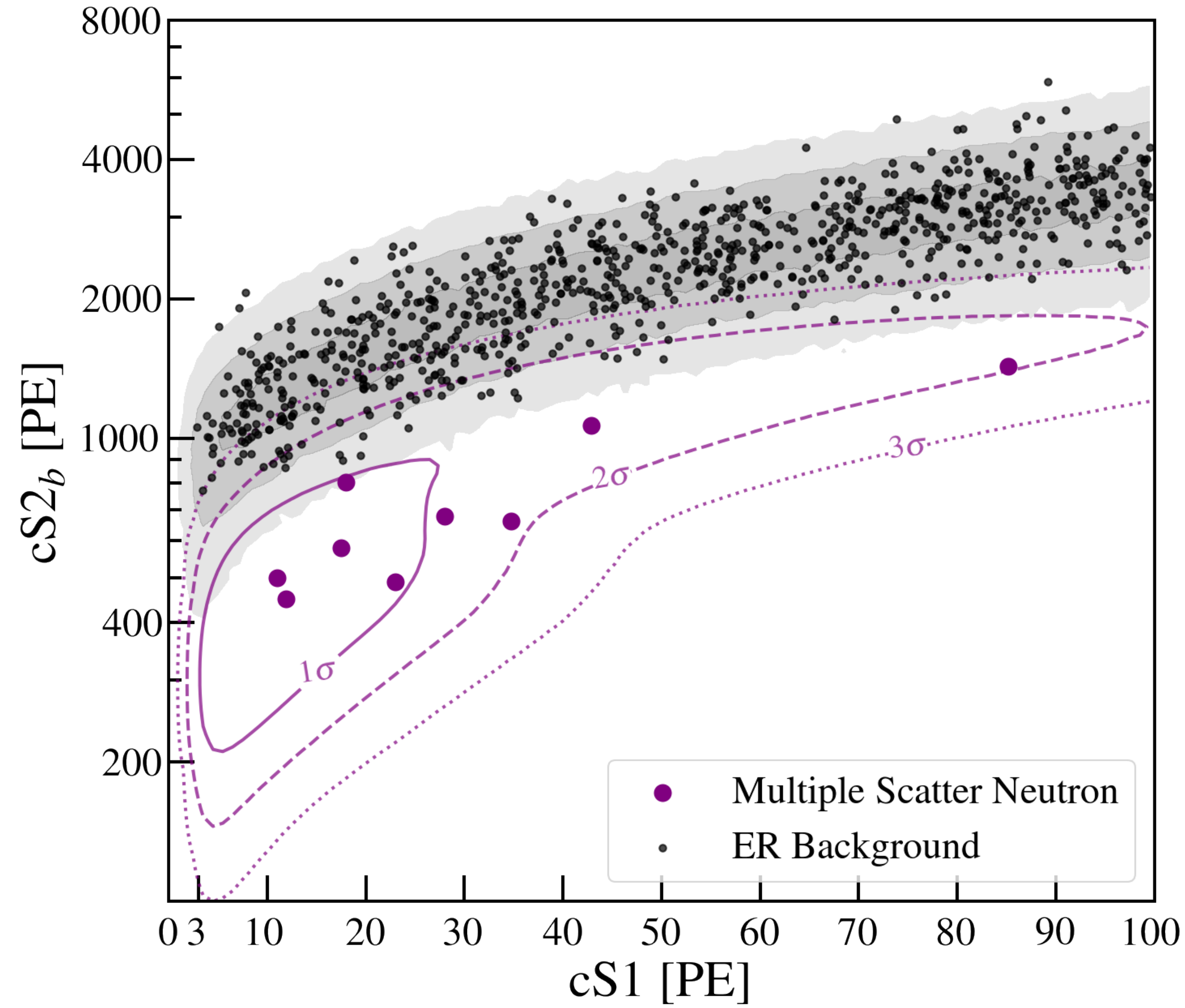
(Expectations in 4-50 keV search window, 1t FV, single scatters)

| Source | Rate [$t^{-1}$ $y^{-1}$] | Fraction [%] |
|---|---|---|
| **Radiogenic n** | 0.6 | 96.5 |
| **CEνNS** | 0.012 | 2.0 |
| **Cosmogenic n** | < 0.01 | < 2.0 |



# Constraint from multiple scatters

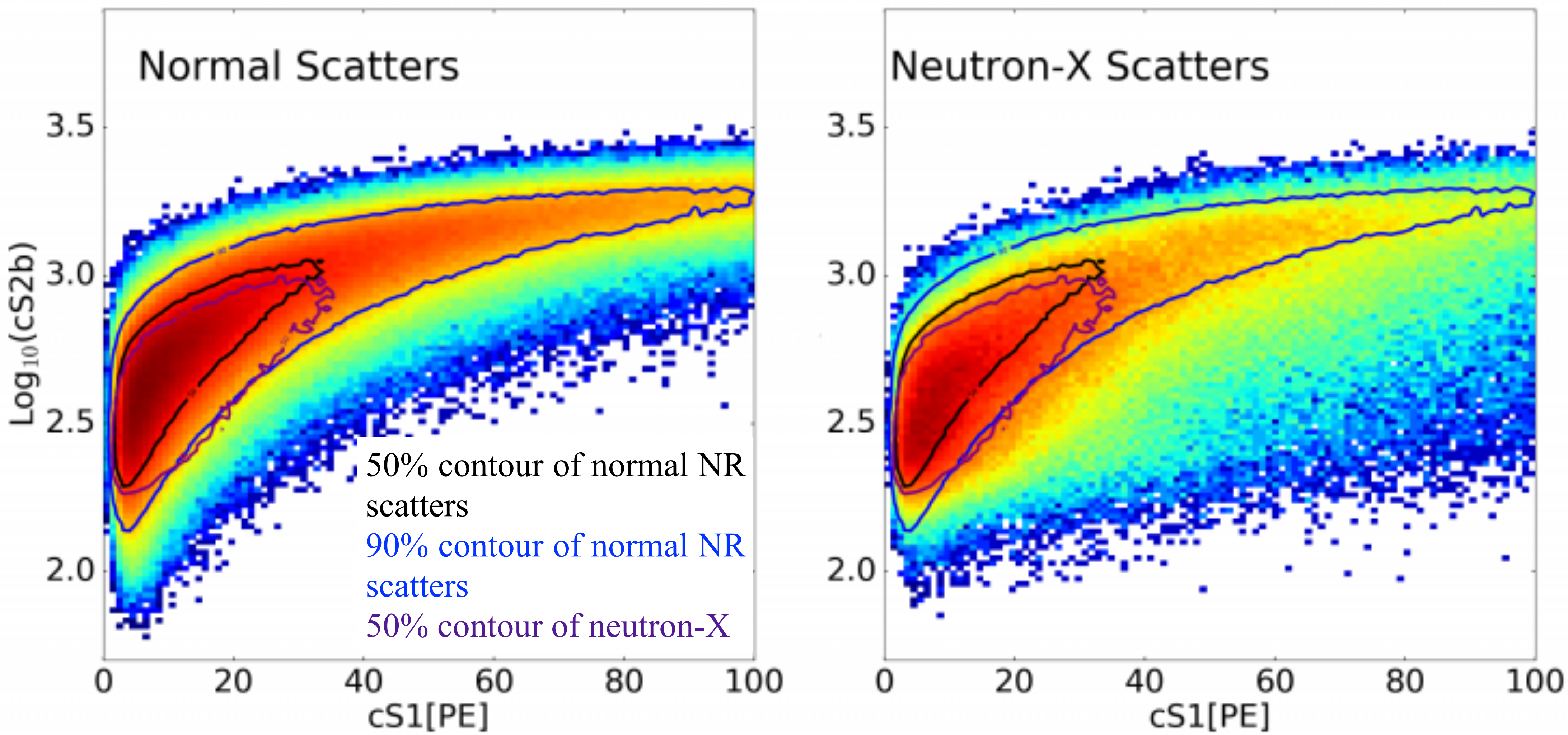


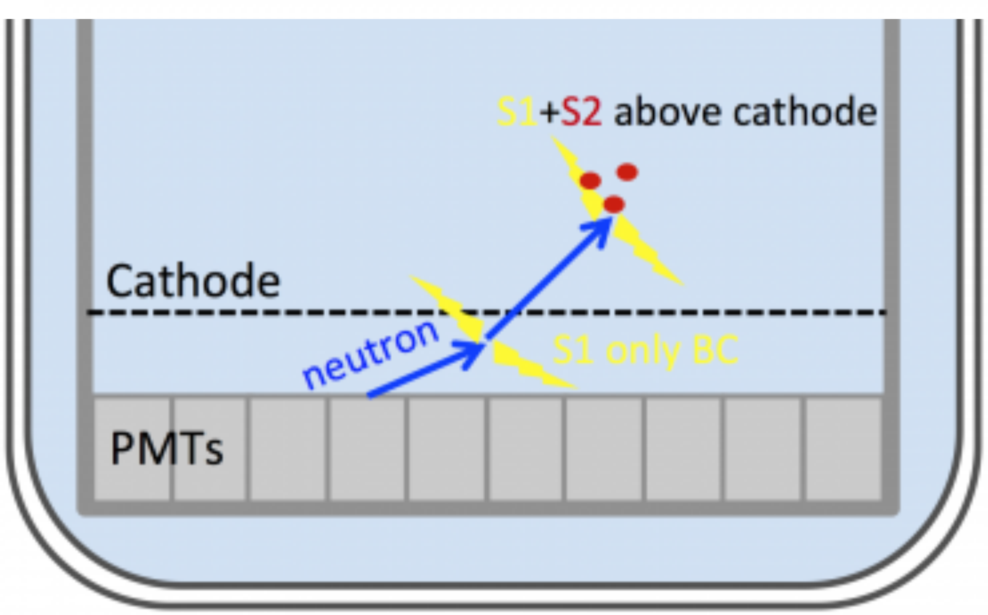




Multiple neutron scatters are good samples for constraining the radiogenic neutron models because no other background has multiple scatters in low energy region.

Nine events are identified.

# Neutron-X

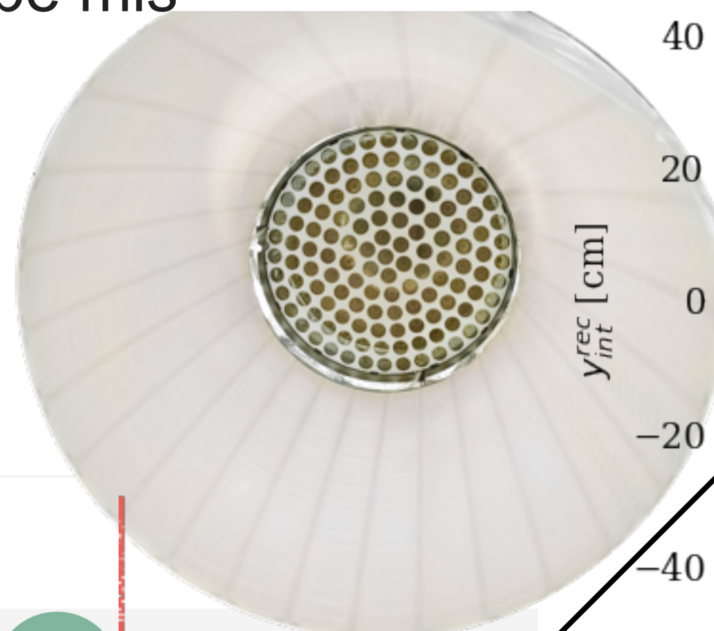


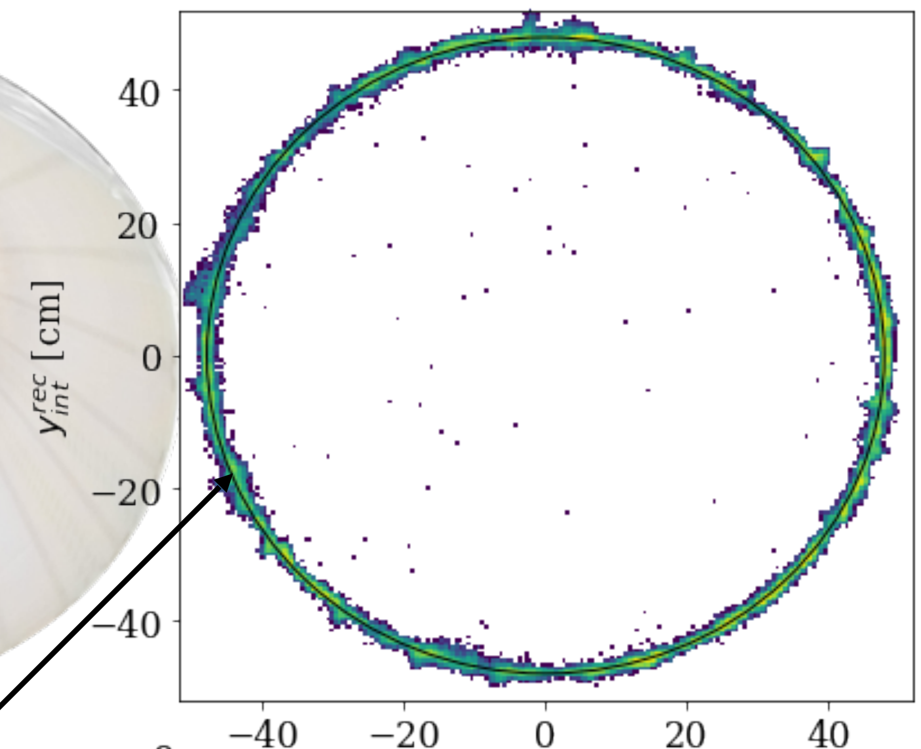



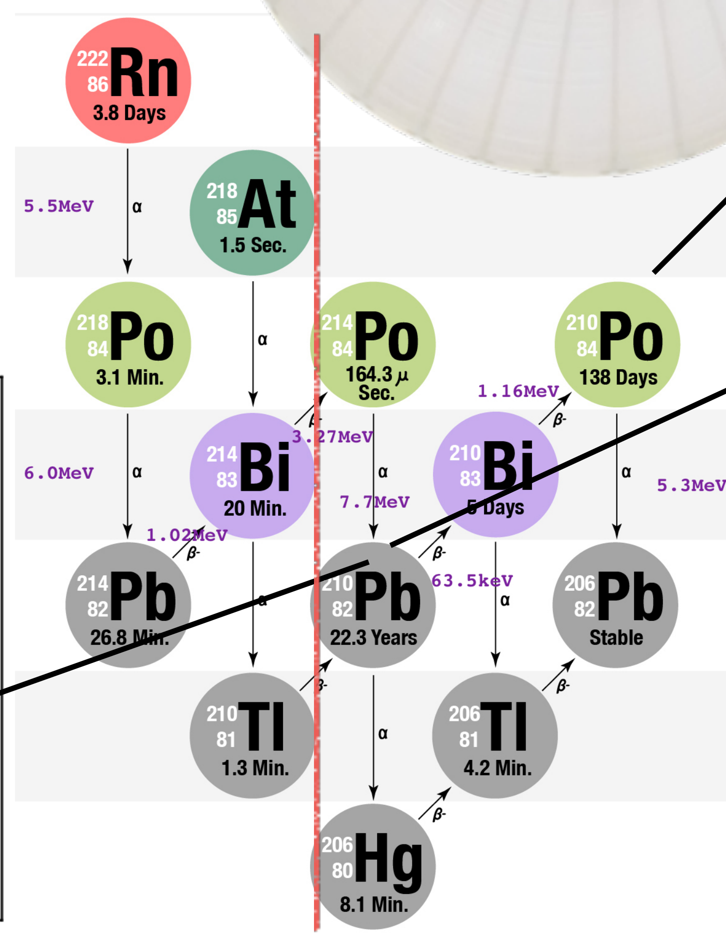

Scintillation signal of the non-active energy deposition is lost, leading to smaller S2/S1 ratio.
The shape variation is important in the likelihood analysis.

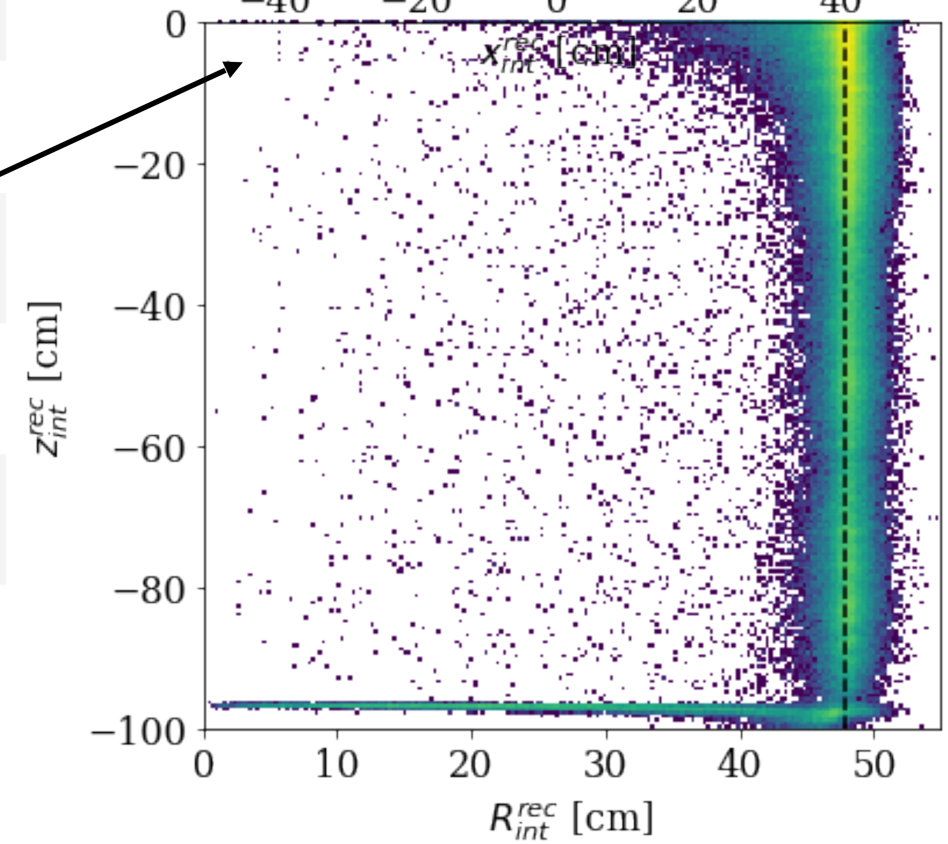
# Surface Background

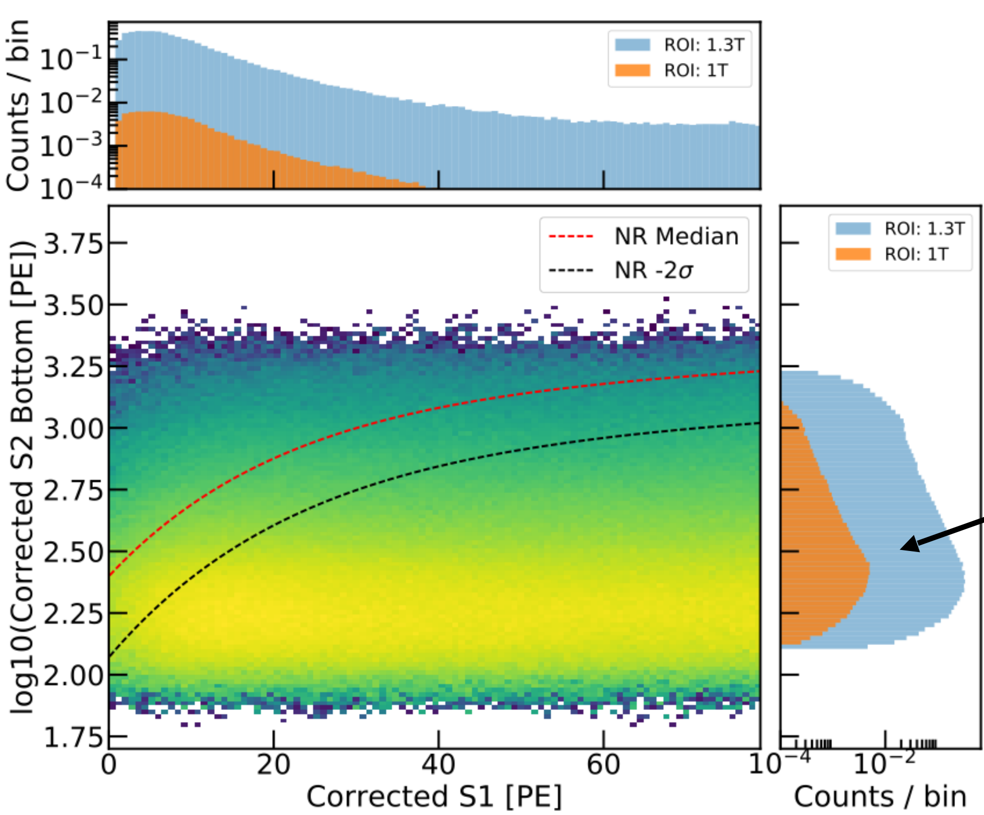
- Pb210 and Po210 plate-out on PTFE surface produce events with reduced S2 -> can be mis-reconstructed into NR signal region
- Suppressed by fiducialization of volume
- Data-driven model derived from surface event control samples





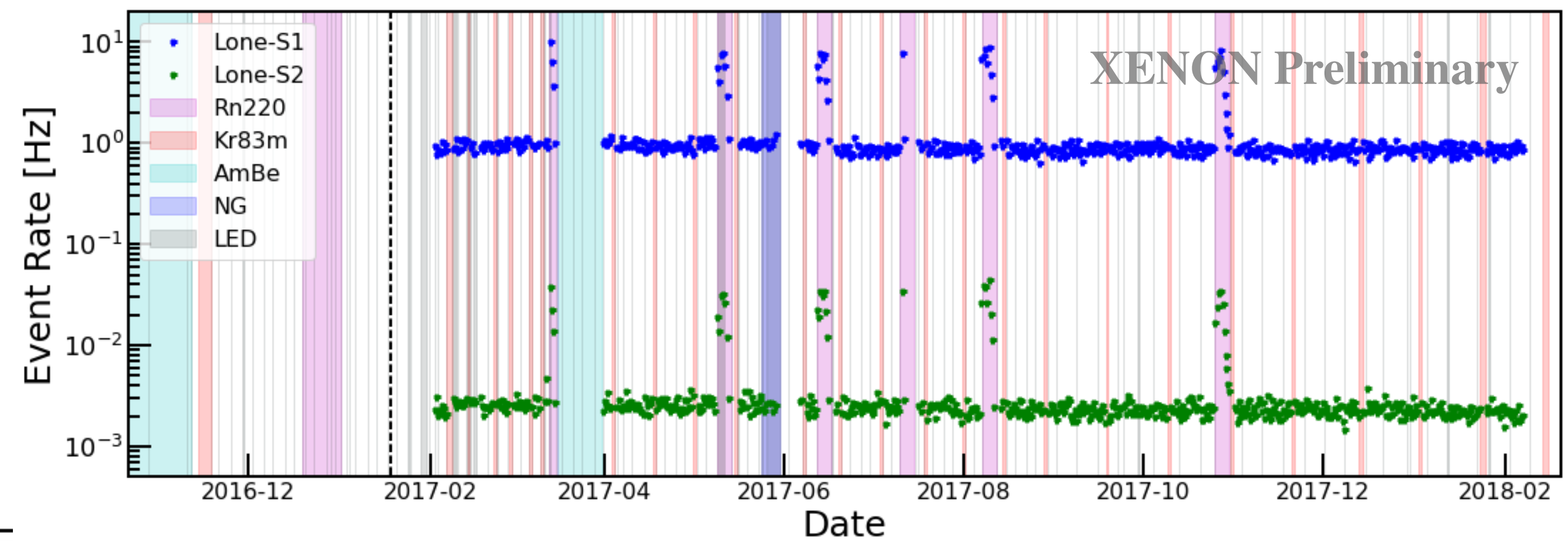



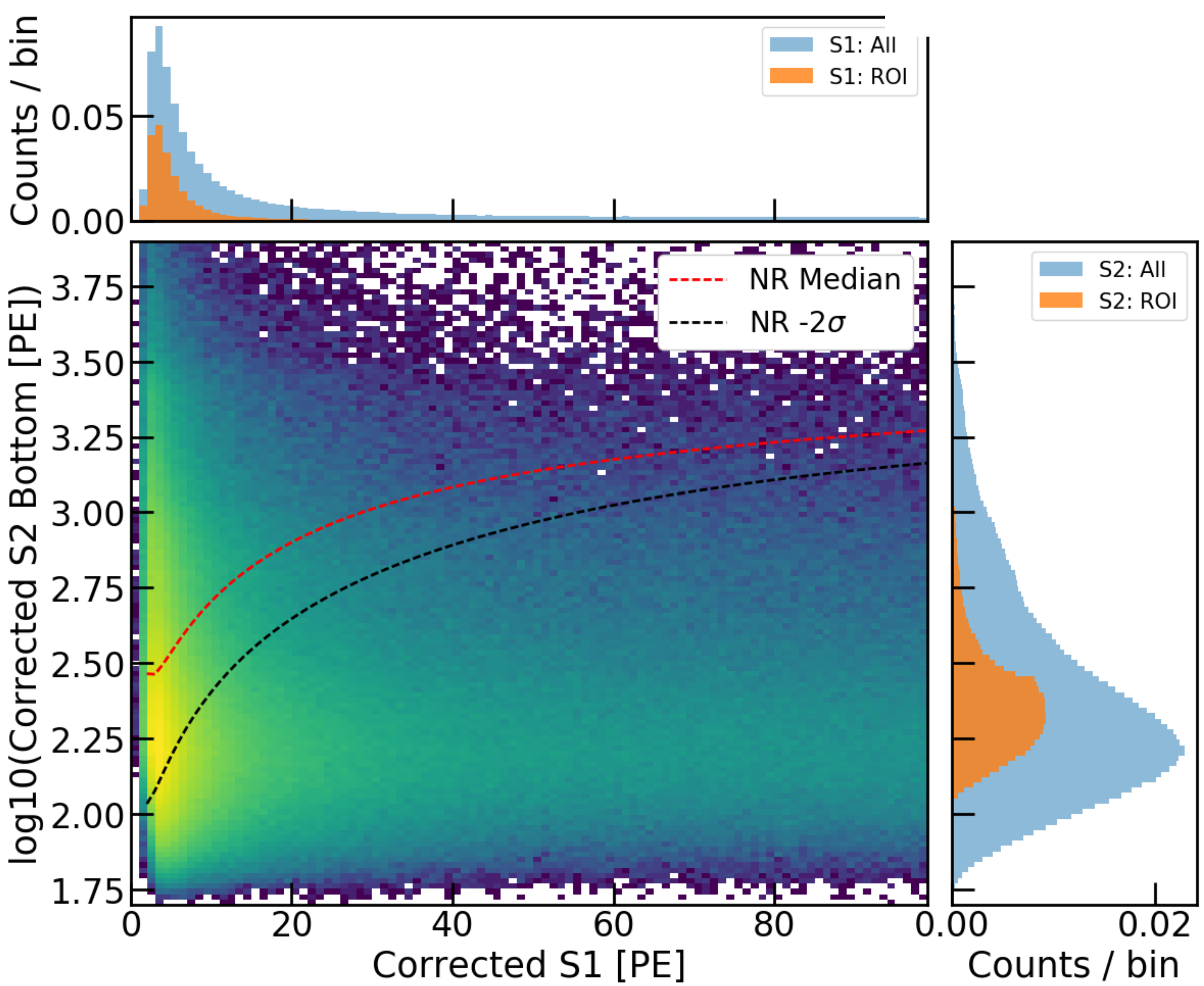



# Accidental Coincidence Background

A “lone” S1 or S2 signal produced in light and charge insensitive regions of the TPC may be accidentally combined to produce fake events in signal region



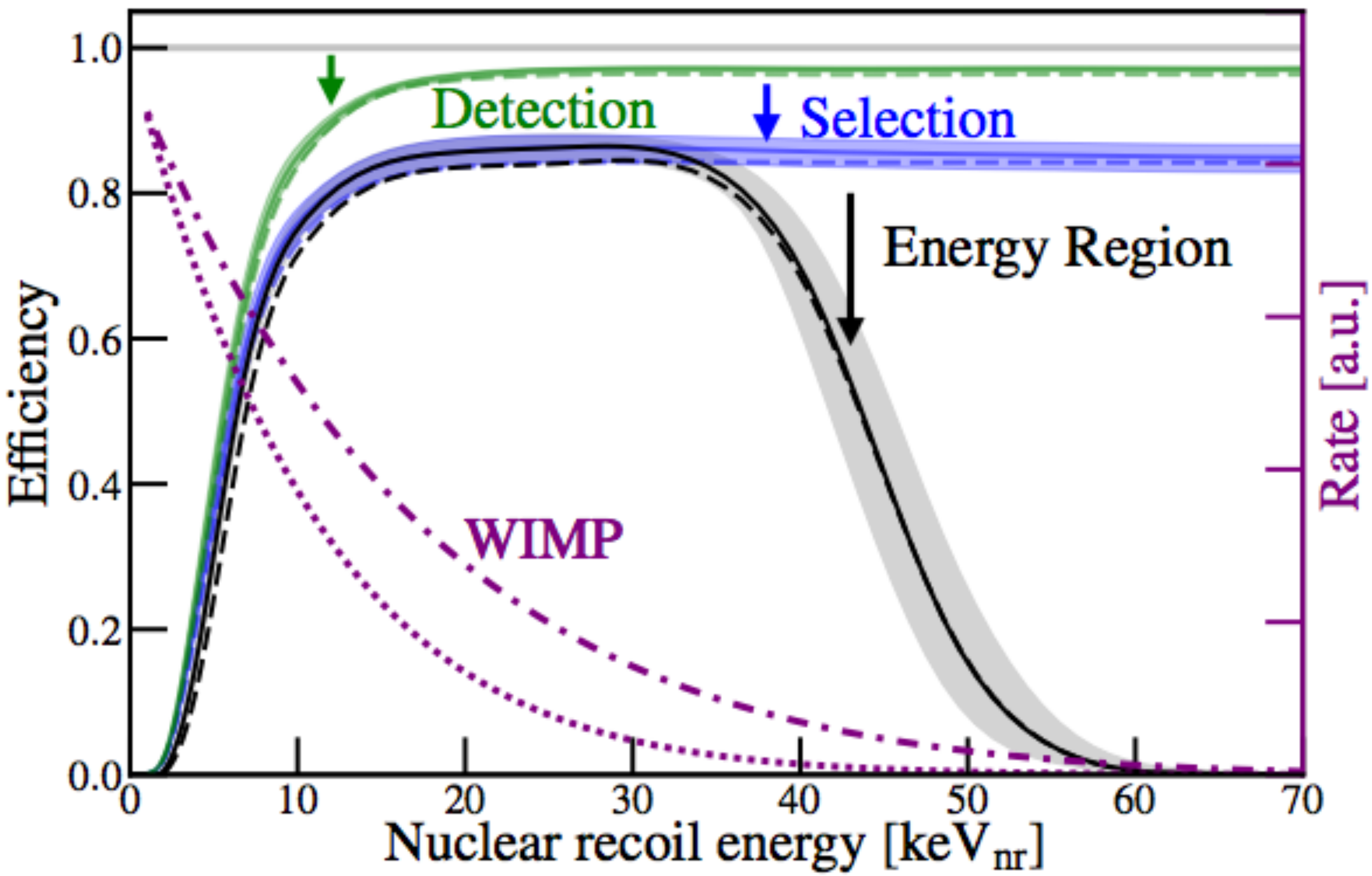




Empirical model shows an overall small rate in the ROI for NRs

- Select unpaired S1/S2 from data
- Randomly pair to form events
- Apply selection conditions from analysis
- Performance verified with $^{220}$Rn data and background sidebands

# XENON1T Results

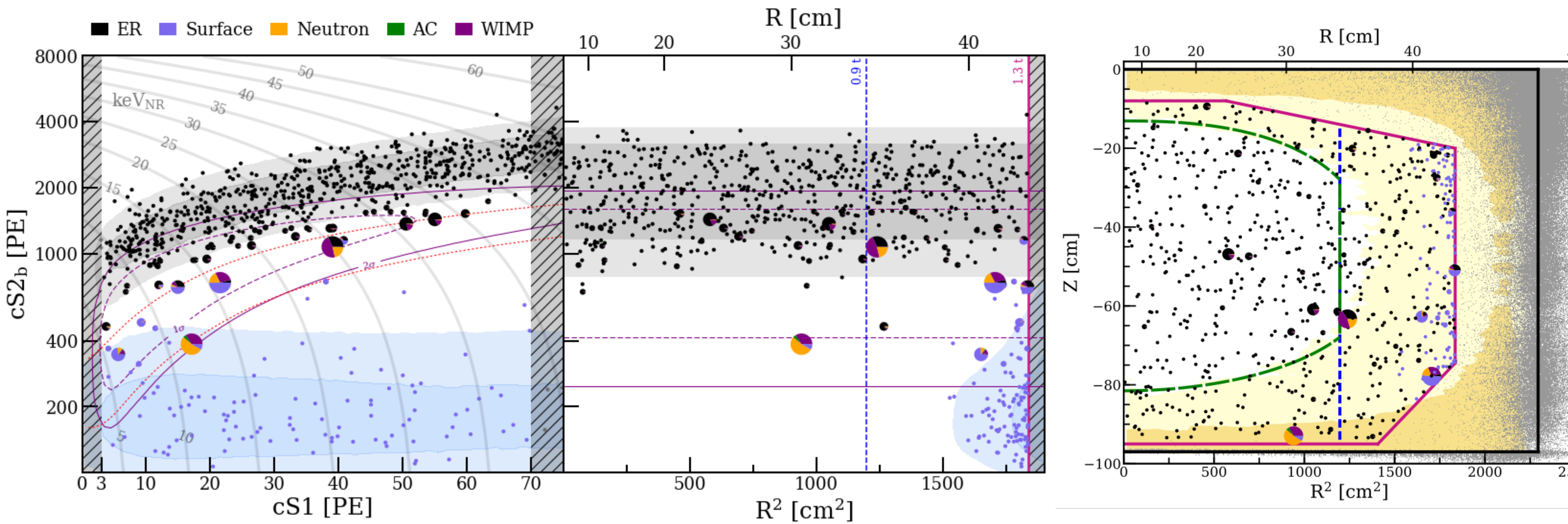
# Efficiency



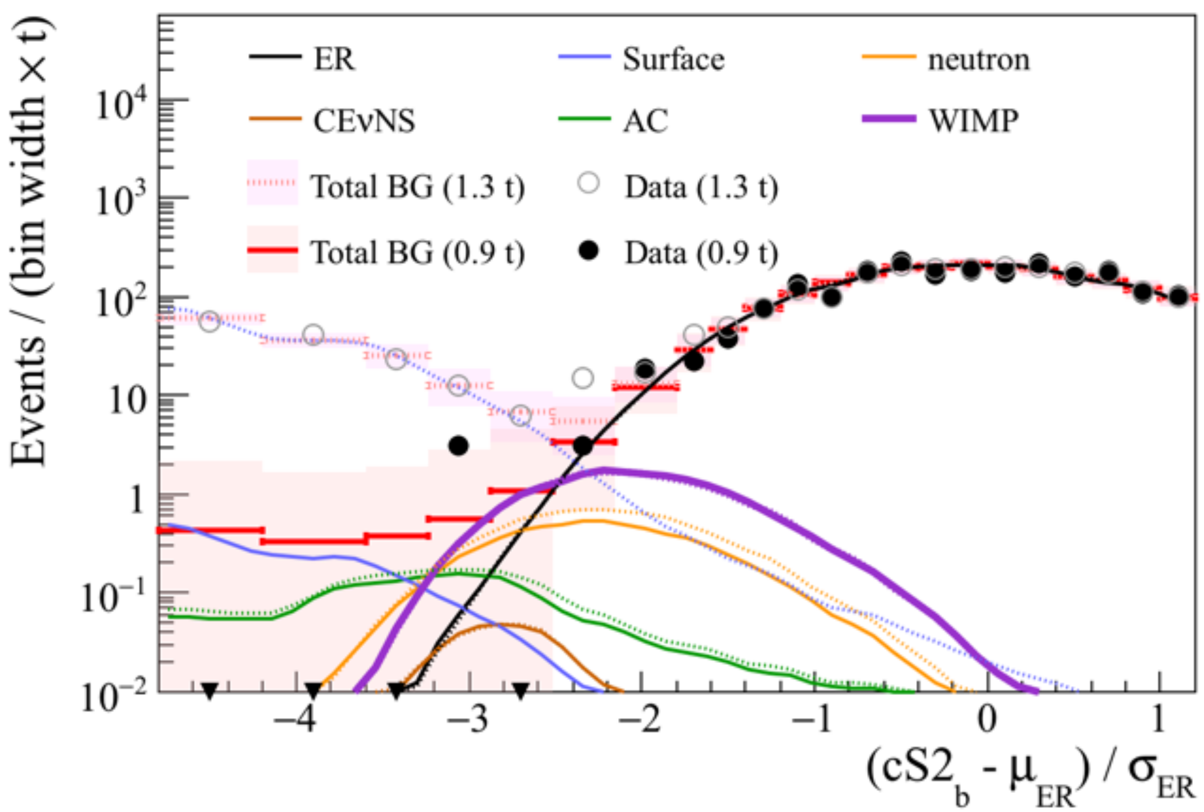

- Detection efficiency dominated by 3-fold coincidence requirement
  - Estimated via novel waveform simulation including systematic uncertainties
- Selection efficiencies estimated from control or MC data samples
- Search region defined within 3-70 PE in cS1
- 50 GeV (dotted) and 200 GeV (dashed and dotted) WIMP spectra shown

# Dark Matter Search Results

- Results interpreted with unbinned profile likelihood analysis in cs1, cs2, r space
- piechart indicate the relative PDF from the best fit of 200 GeV/c² WIMPs with a cross-section of $4.6 \times 10^{-47}$ cm²

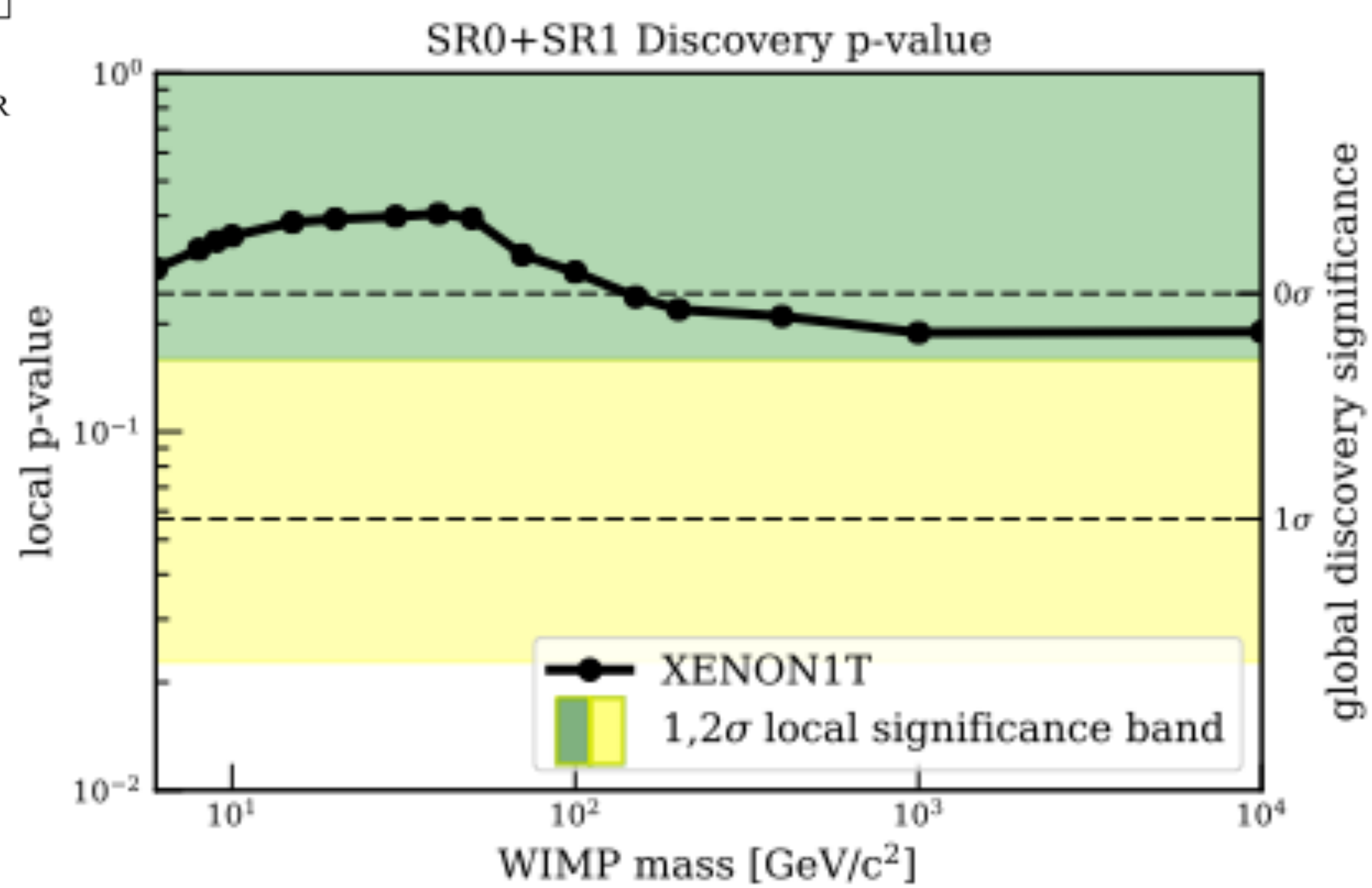


# Statistical Interpretation

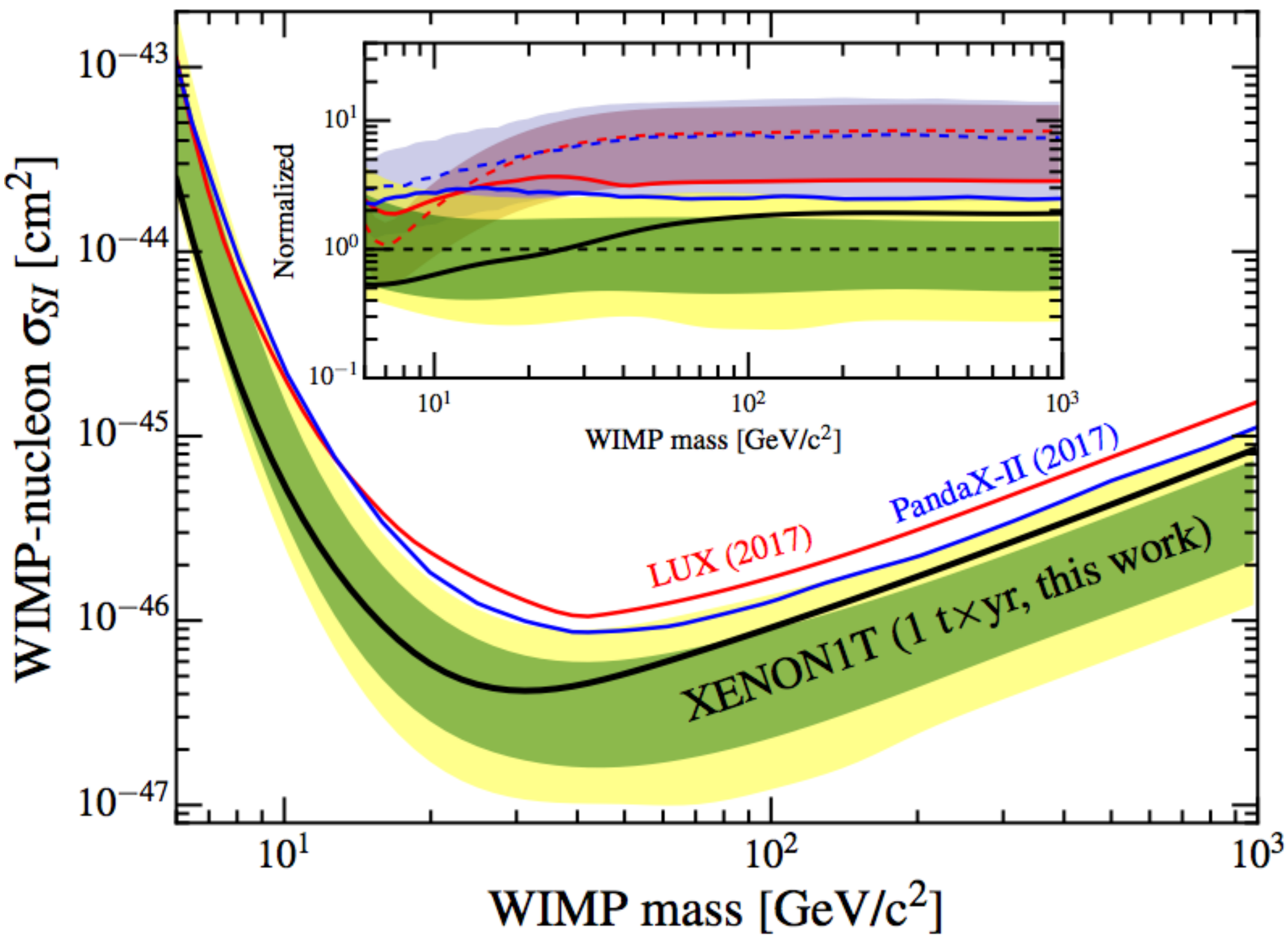



- Extended unbinned profile likelihood analysis
- Example left: Background and 200 GeV WIMP signal best-fit predictions, assuming 4.7 x $10^{-47}$ $cm^2$, compared to data in 1.3T and 0.9T
- Most significant ER & Surface backgrounds shape parameters included
- Safeguard to protect against spurious mis-modeling of background

- No significant (>3 sigma) excess at any scanned WIMP mass
- Background only hypothesis is accepted although the p-value of ~0.2 at high mass (200 GeV and above) does not disfavor a signal hypothesis either



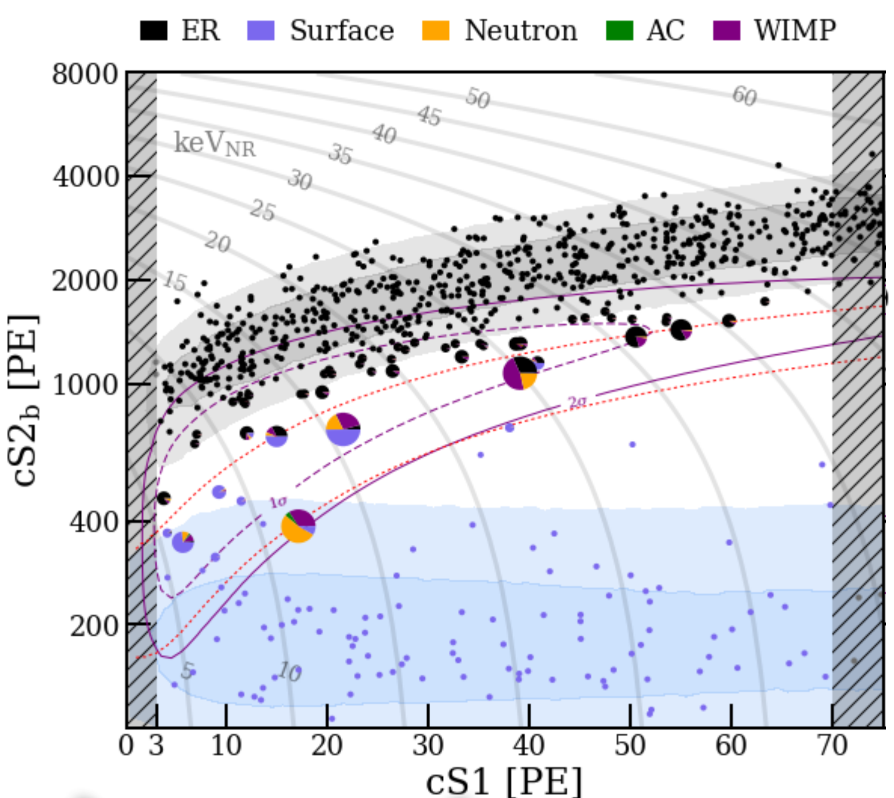
# Constraint on SI WIMP

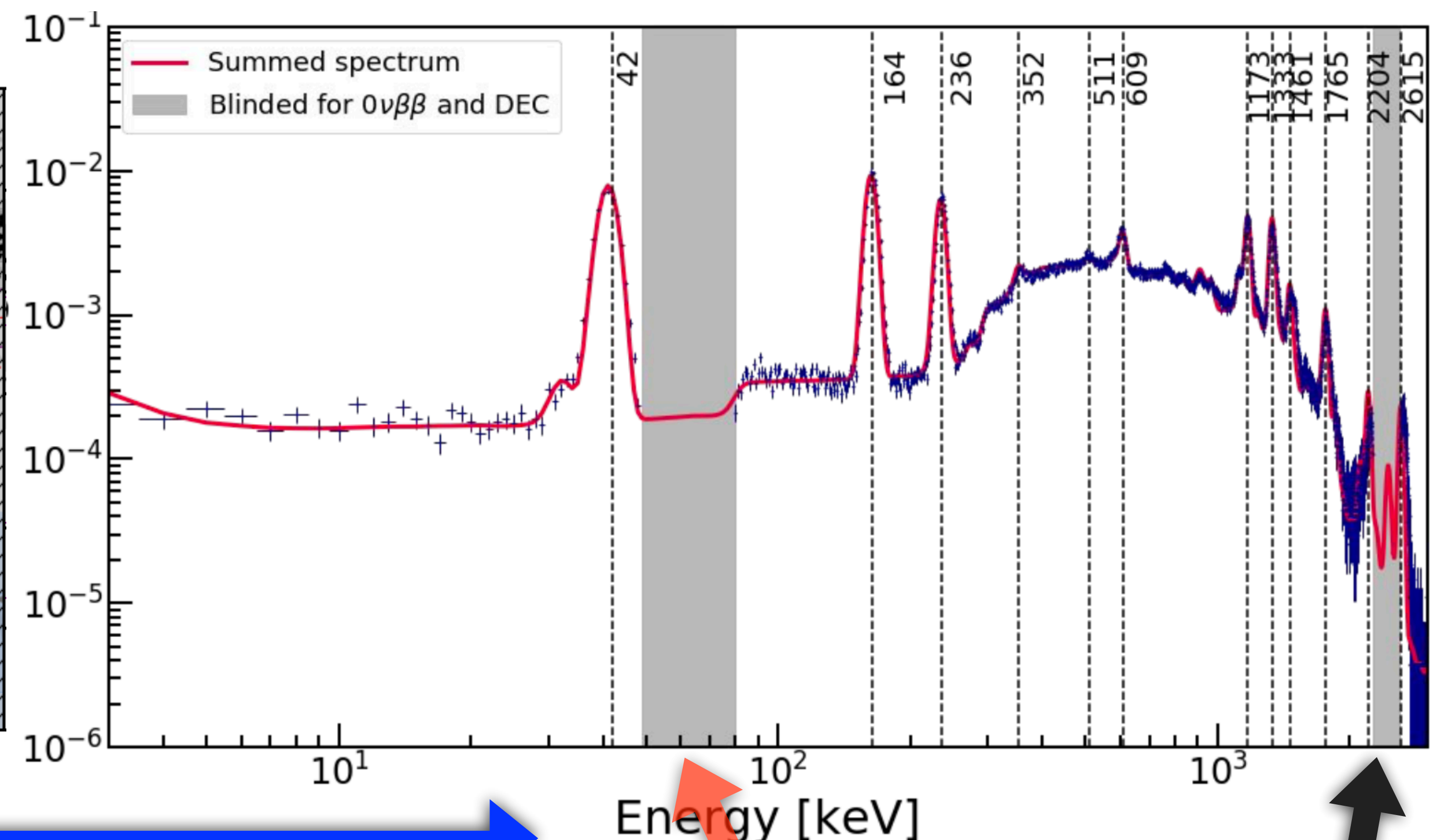



- Most stringent 90% CL upper limit on WIMP-nucleon cross section at all masses above 6 GeV
- Factor of 7 more sensitivity compared to previous experiments (LUX, PandaX-II)
- ~ 1sigma upper fluctuation at high WIMP masses, could be due to background or signal

**Minimum at 4.1x10$^{-47}$ cm$^2$ for a WIMP of 30 GeV/c$^2$**

# Alternative searches




Light WIMPs through:
- S2 only
- Single-electrons

- EFT search using high energy NR
- dark photon, superWIMP, Axion-like particle search using ER

Double electron capture of Xe124

Neutrino less double beta decay (0νββ) of Xe136

# Next step: XENONnT

# XENONnT

## Minimal Upgrade

The XENON1T infrastructure and sub-systems were originally designed to **accommodate a larger LXe TPC**.




## Fiducial Xe Target

**XENONnT TPC** features:

total Xe mass = 8 t

target mass = 5.9 t

**fiducial mass = ~4 t**


## Background

Record low-back levels in XENON1T dominated by $^{222}$Rn-daughters.

Identified strategies to effectively **reduce $^{222}$Rn by ~ a factor 10**.

## Fast Turnaround

Use **XENON1T sub-systems,** already tested

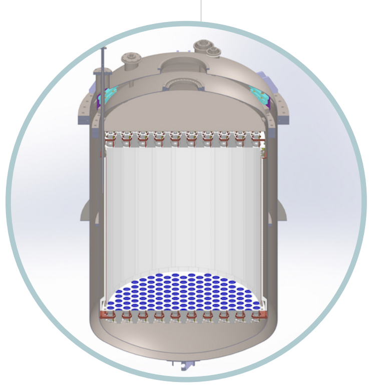
Fast pace:

**Installation starts in 2018**

**commissioning in 2019**

# XENONnT: what's new

**New**



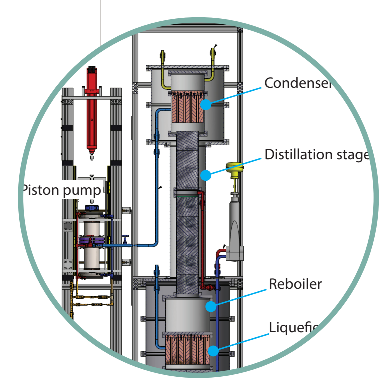
## New TPC

5.9-ton Time Projection Chamber

## LXe Purification

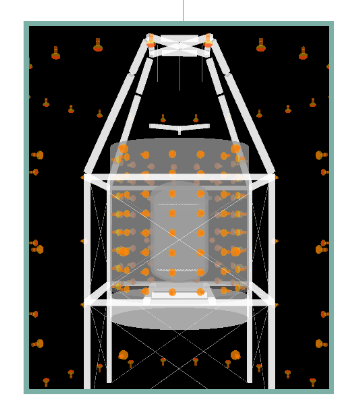
To achieve fast cleaning of the large LXe volume (5L/min LXe, 2500 SLPM)

↕ GXe purification (120 SLPM)




## Radon Distillation

To online remove the $^{222}$Rn emanated inside the detector



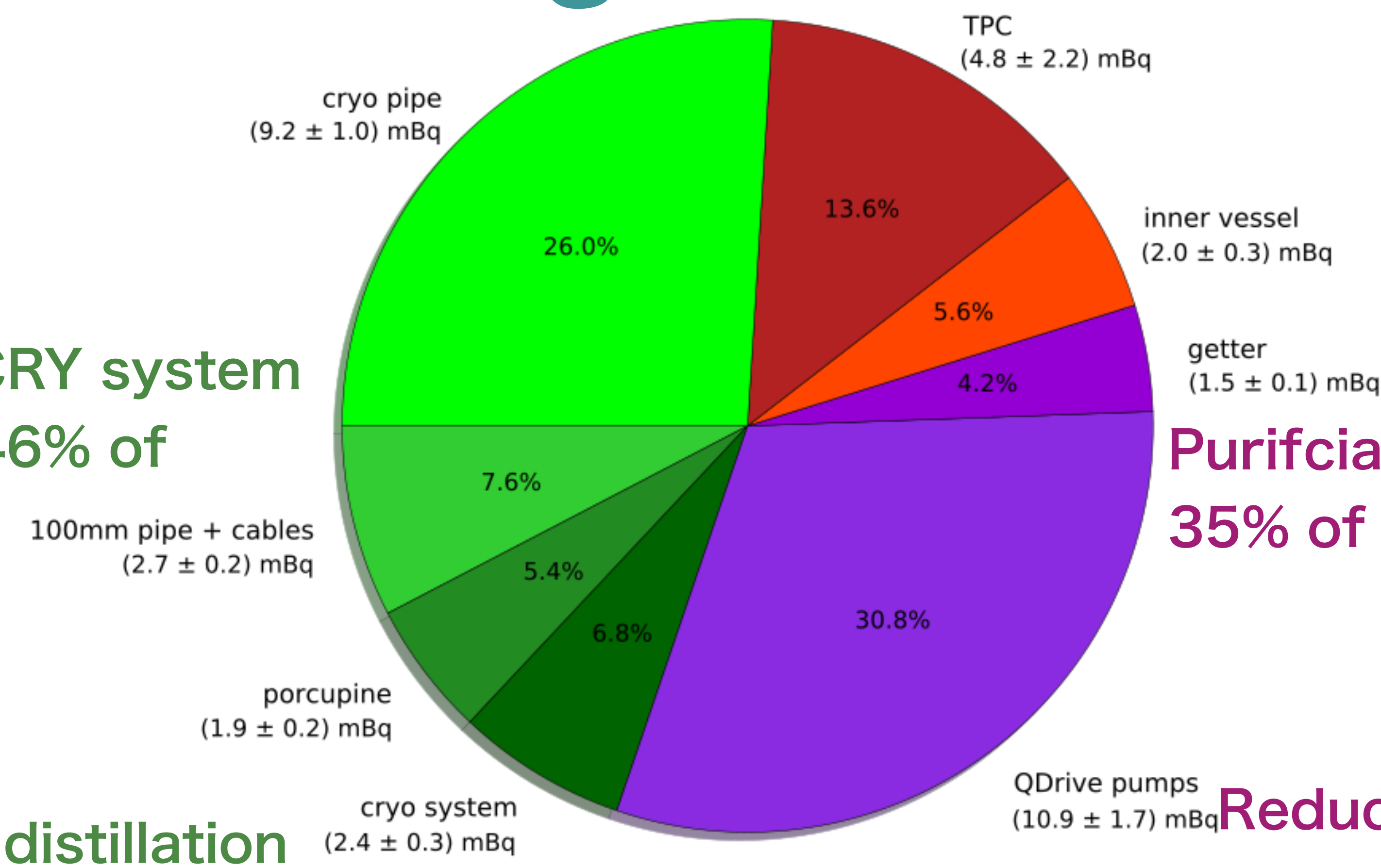
## Neutron Veto

To tag and measure in situ neutron-induced background

**Gd-loaded Water Cherenkov detector**

# Purification upgrade & Rn reduction

## Rn budget@XENON1T




Cryo pipe/cables/CRY system system emanates 46% of total budget

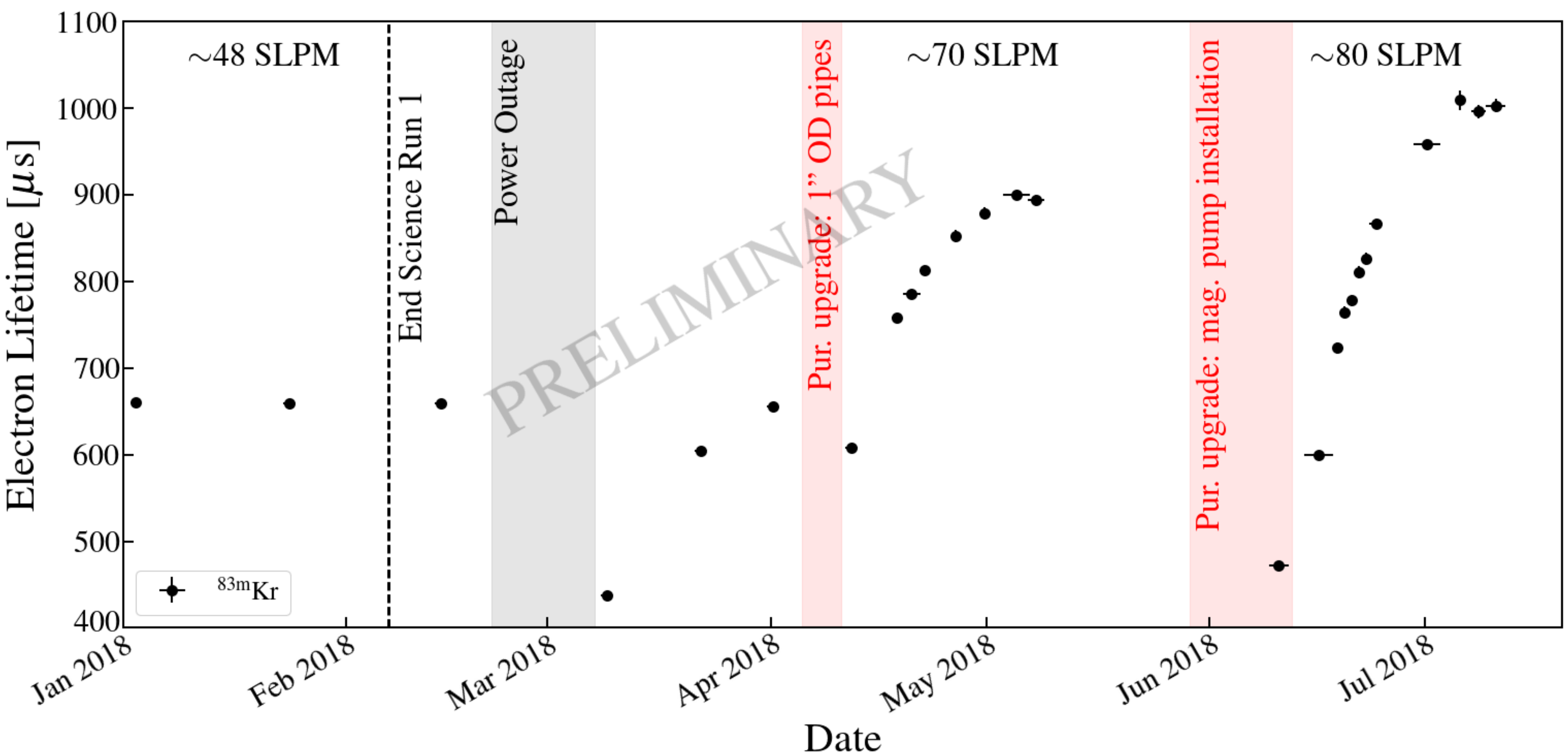
Reduce with online distillation

Purifciation system emanates 35% of total budget

Reduce by pump exchange

# Switch to magnetic pump

- Q-Drive pumps: dominant Rn-source (3 pumps)
- Replaced by magnetically-coupled piston pump
  - Installed at PUR system in May/June 2018
- Running since 12.06.2018 ( > 3 months)
- Flow: 75 slpm (54 slpm with 3 Q-drive)
- Inlet pressure: 1.6 bar, compression: 1.5 bar
- **Now electron lifetime reaches ~1ms**

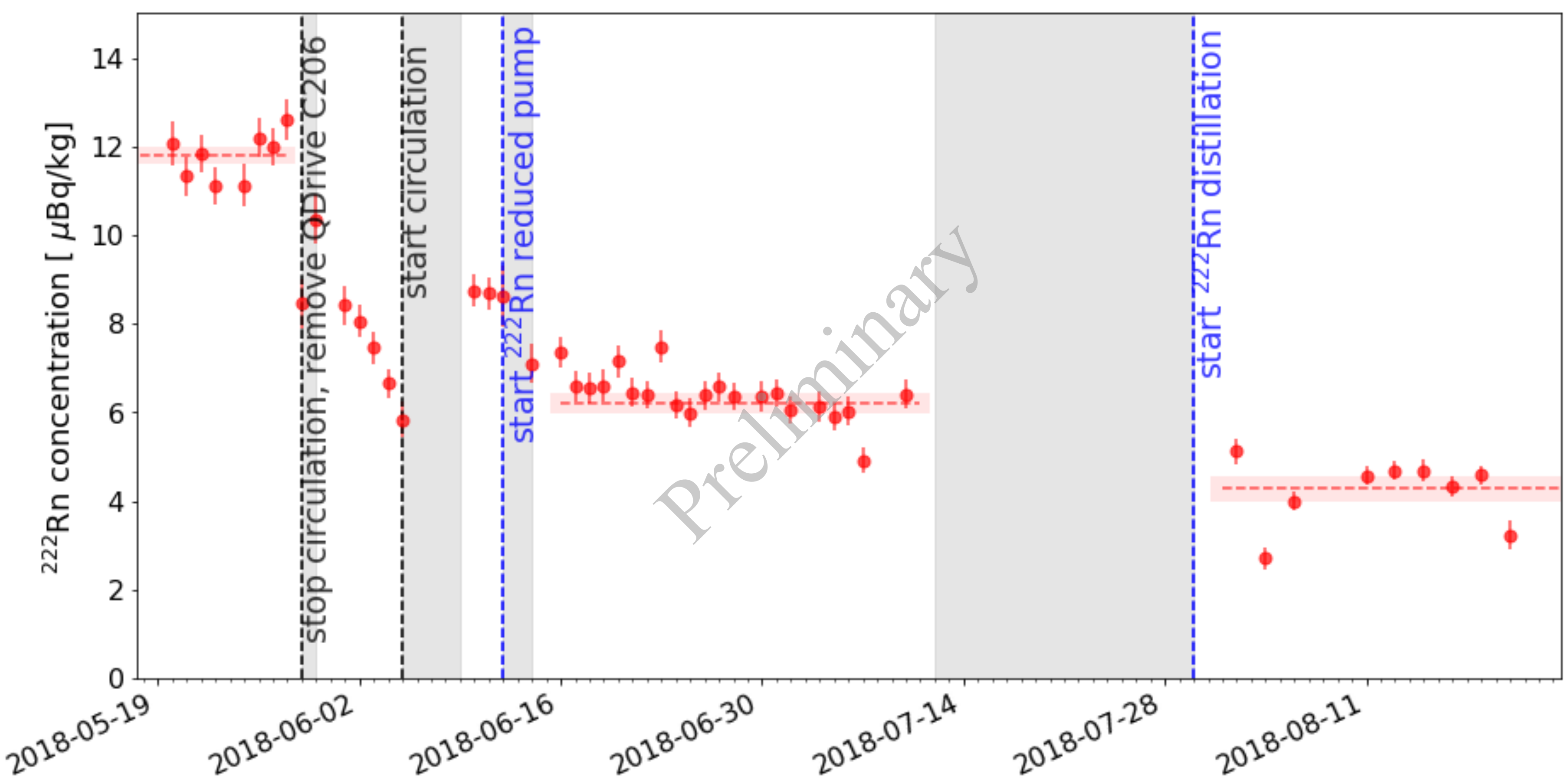



Eur .Phys. J. C (2018) 78: 604

# Rn reduction

- Extract and remove radon from GXe of CRY emanated by cryo-pipe and cables
- Less Rn can enter TPC
  - Total radon activity concentration inside TPC reduced without xenon loss

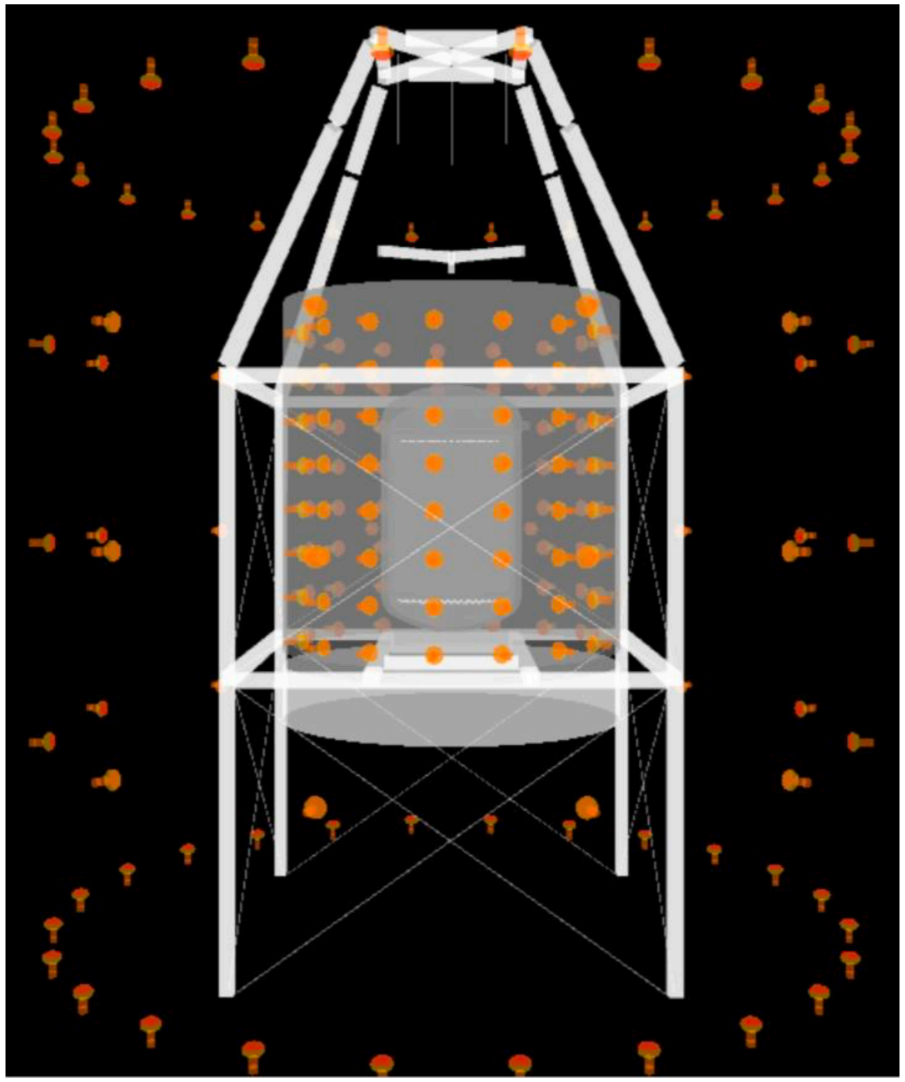
| Period | Conc. [$\mu$Bq/kg] |
|---|---|
| SR1 | 11.8 ± 0.2 |
| + MagPump | 6.3 ± 0.1 |
| +Online Distillation | 4.3 ± 0.2 |

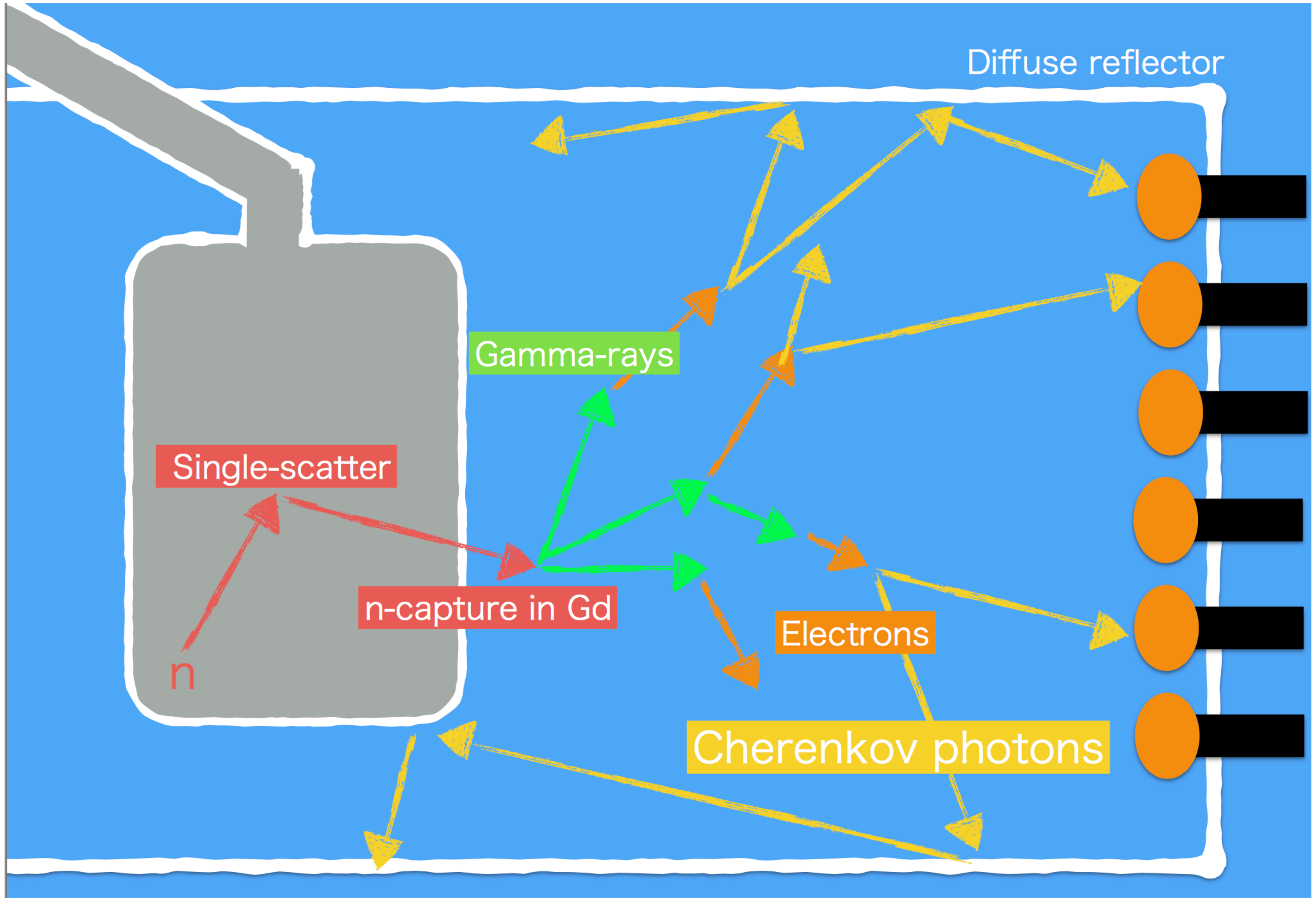



- Magnetically-coupled piston pump reduces 45% w.r.t SR1
  - Online DST reduces 20% w.r.t SR1
  - Reduction by 65 % w.r.t SR1 (factor 2.7)

**Promising results for XENONnT!**

# Neutron Veto

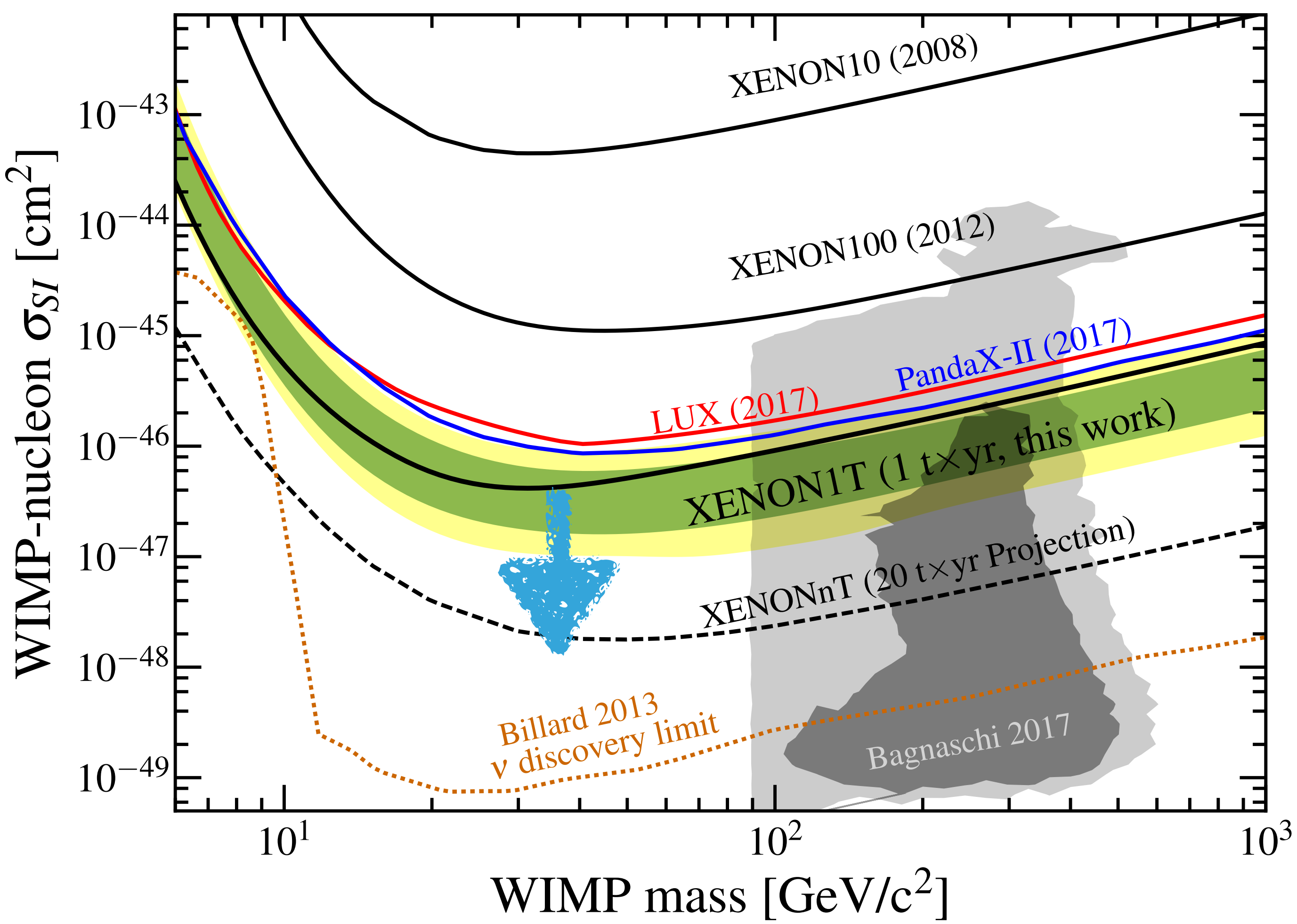


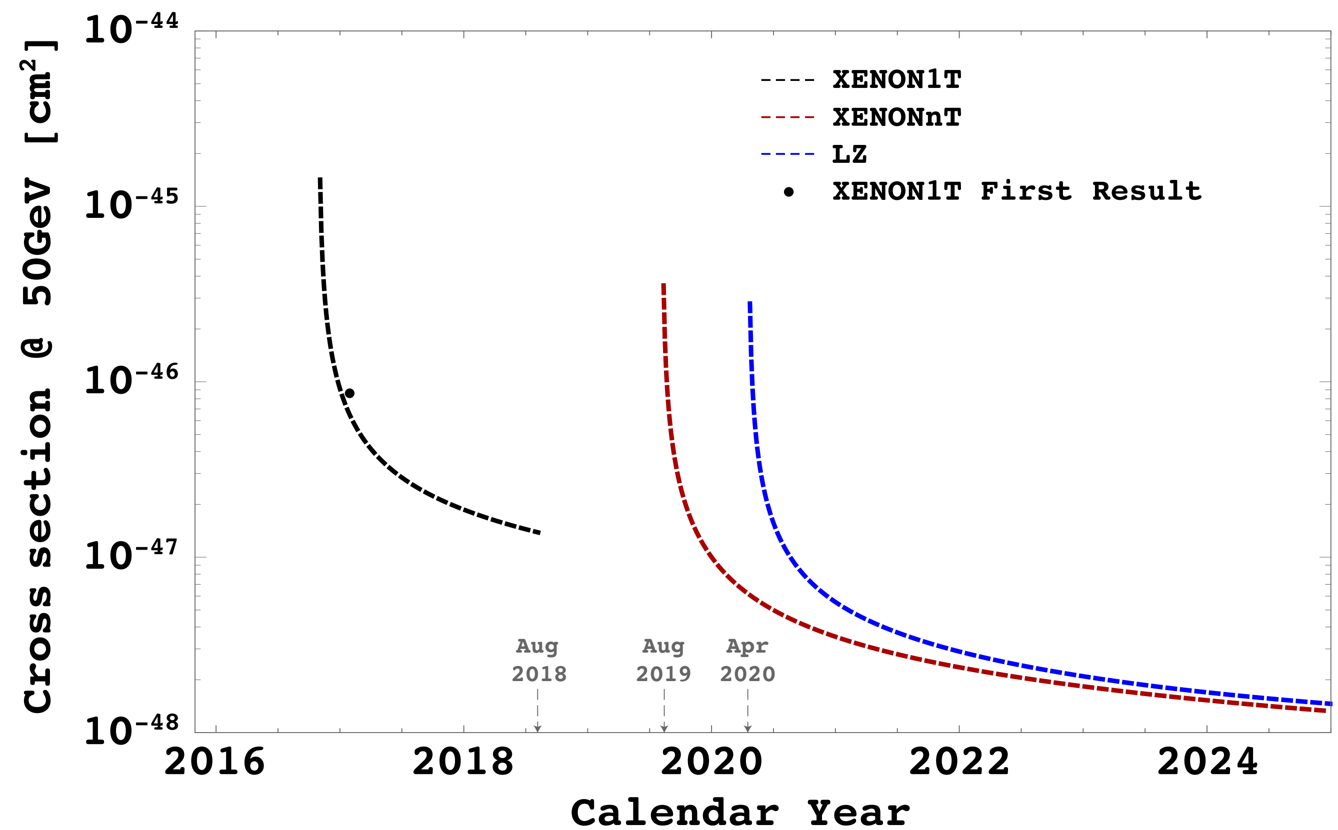



Gd-Water Cherenkov veto detection is going to be deployed as neutron veto

>85% tagging efficiency is expected.

# Fast upgrade to XENONnT

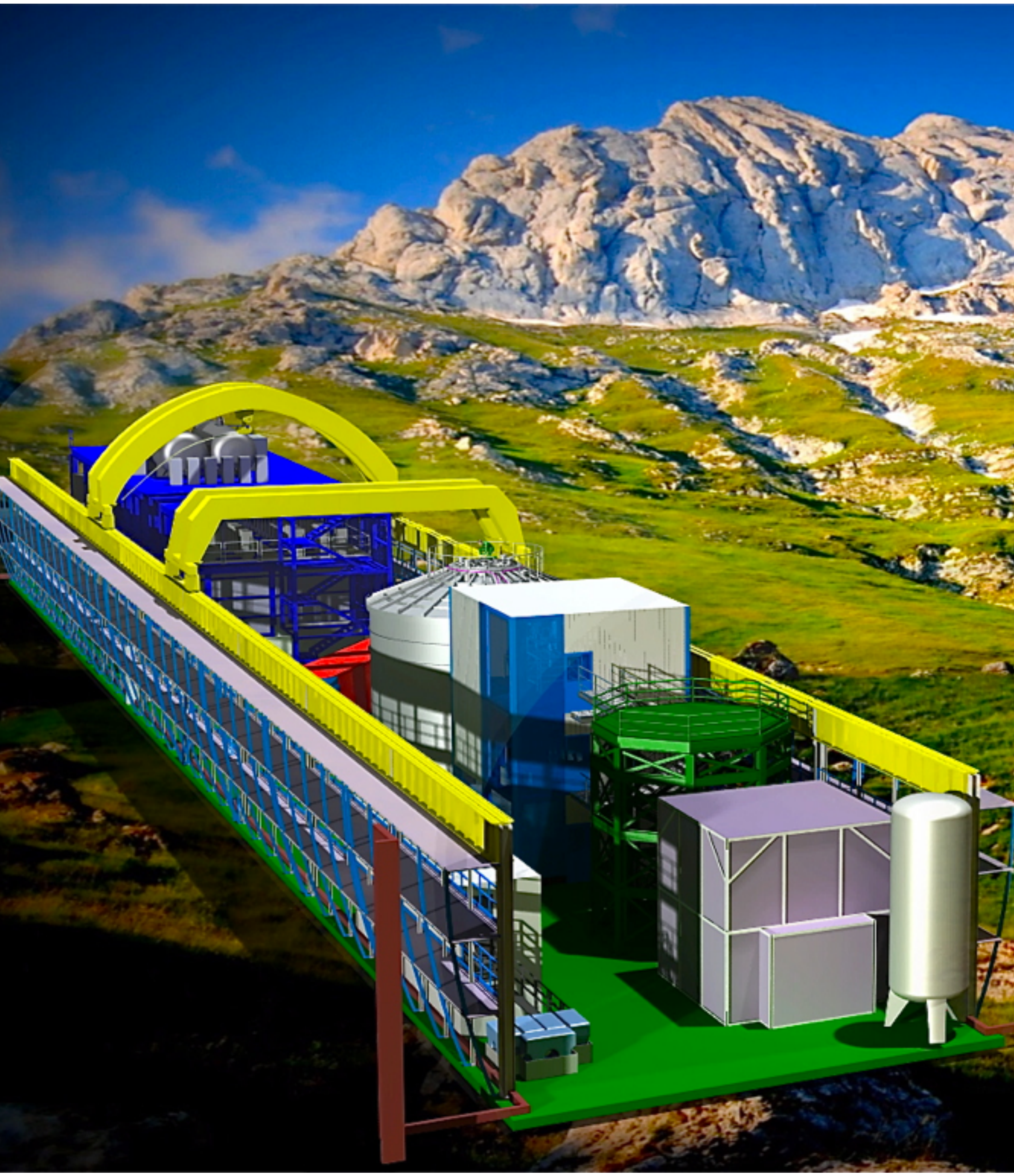


Thank you!

# Backup

# The XENON1T Experiment




XENON
Aug. 2014

# Phases of the XENON program

XENON10

2005-2007
15 cm drift TPC – 25 kg

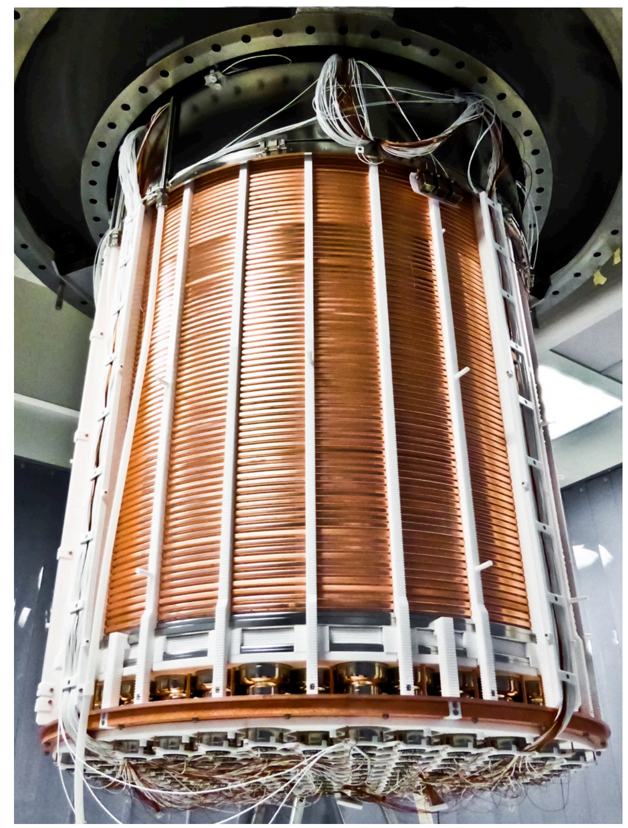
Achieved (2007)
$\sigma_{SI} = 8.8 \times 10^{-44}$ cm$^2$

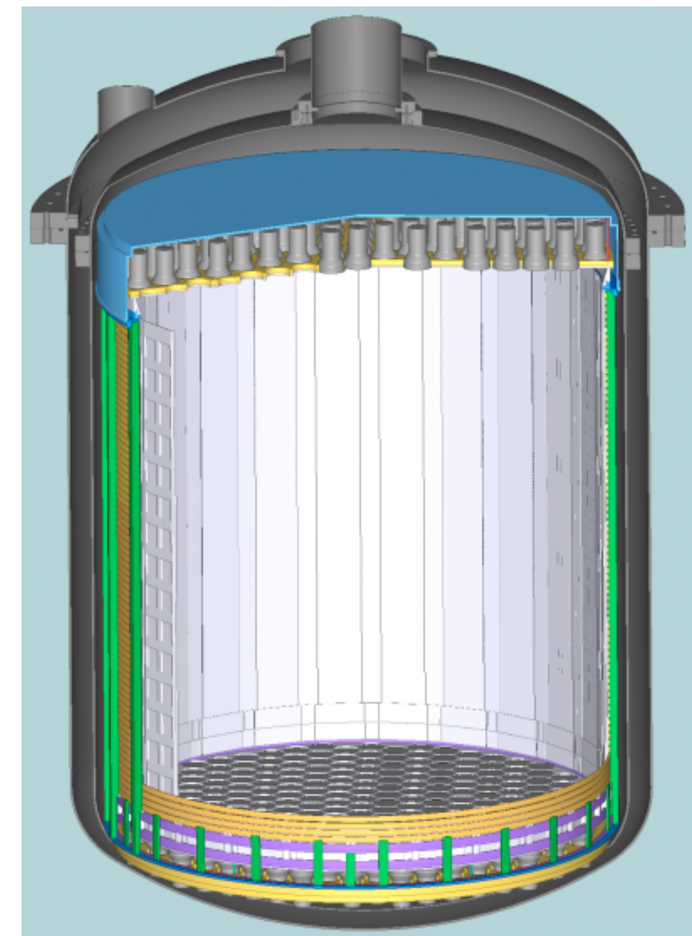
XENON100

2008-2016
30 cm drift TPC – 161 kg

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

XENON1T / XENONnT

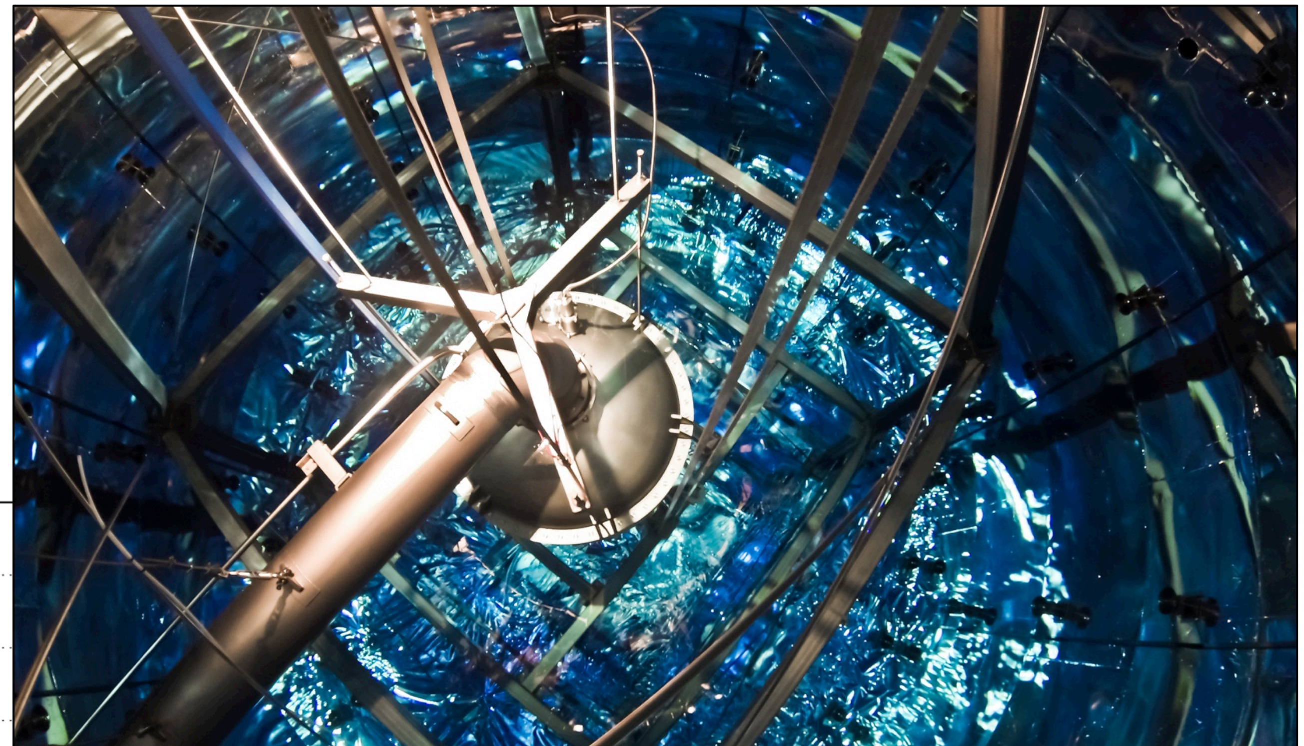


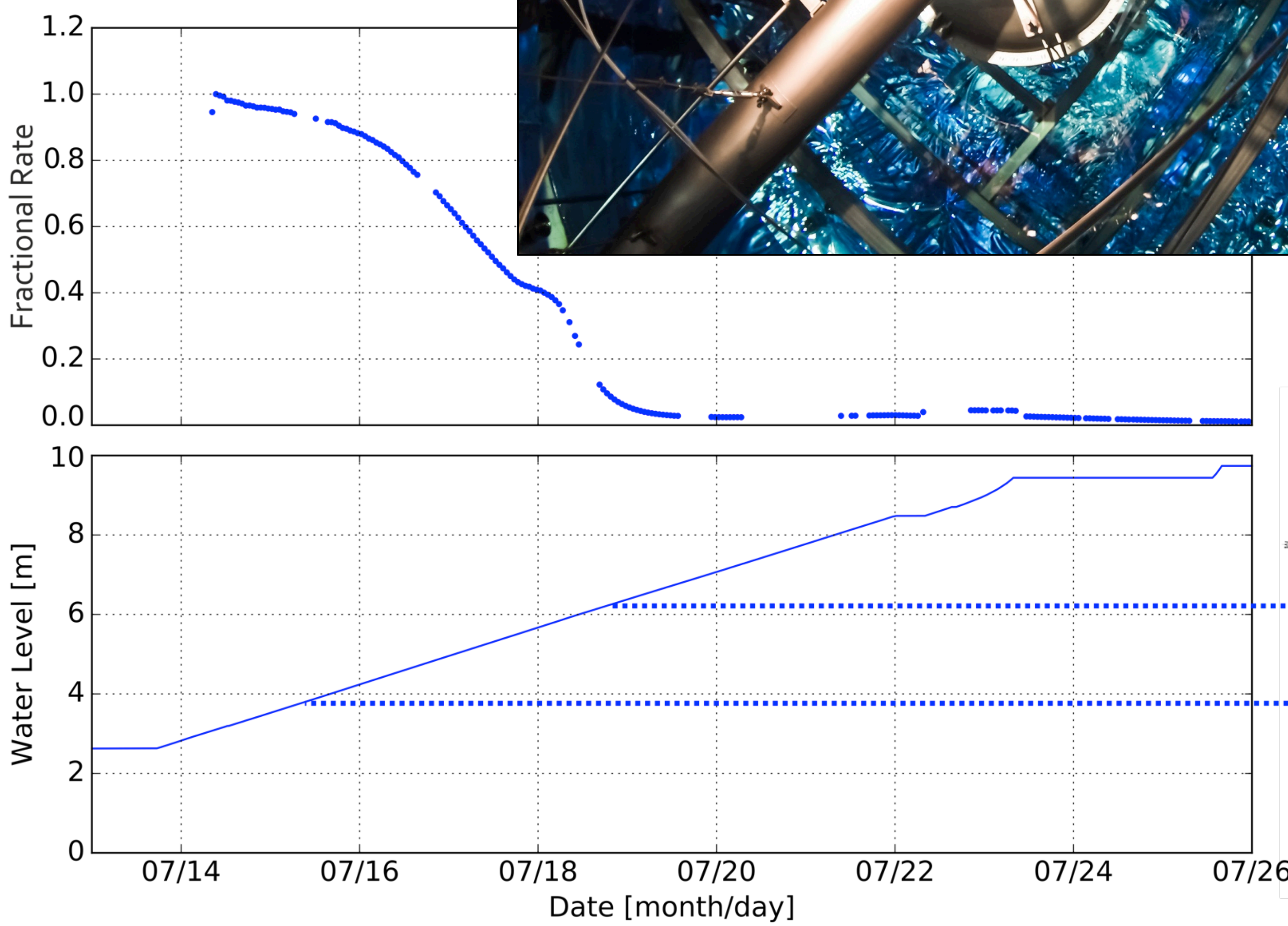


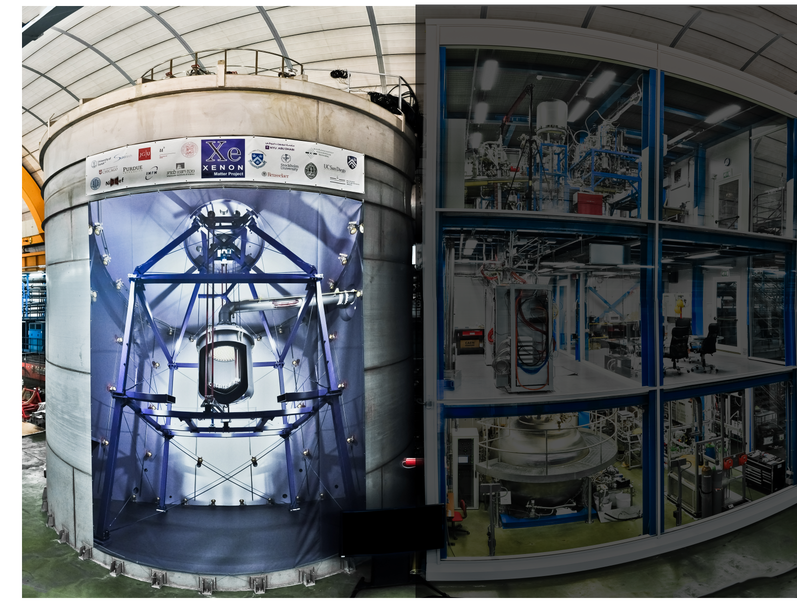
2013-2018 / 2019-2023
100 cm / 144 cm drift TPC - 3200 kg / ~8000 kg

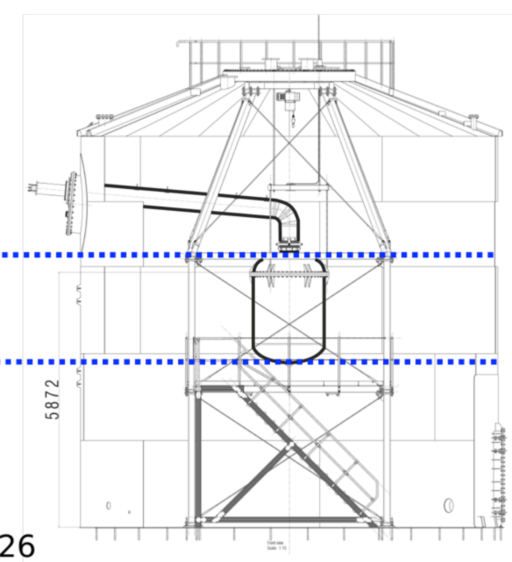
Projected (2018) / Projected (2023)
$\sigma_{SI} = 1.6 \times 10^{-47}$ cm$^2$ / $\sigma_{SI} = 1.6 \times 10^{-48}$ cm$^2$

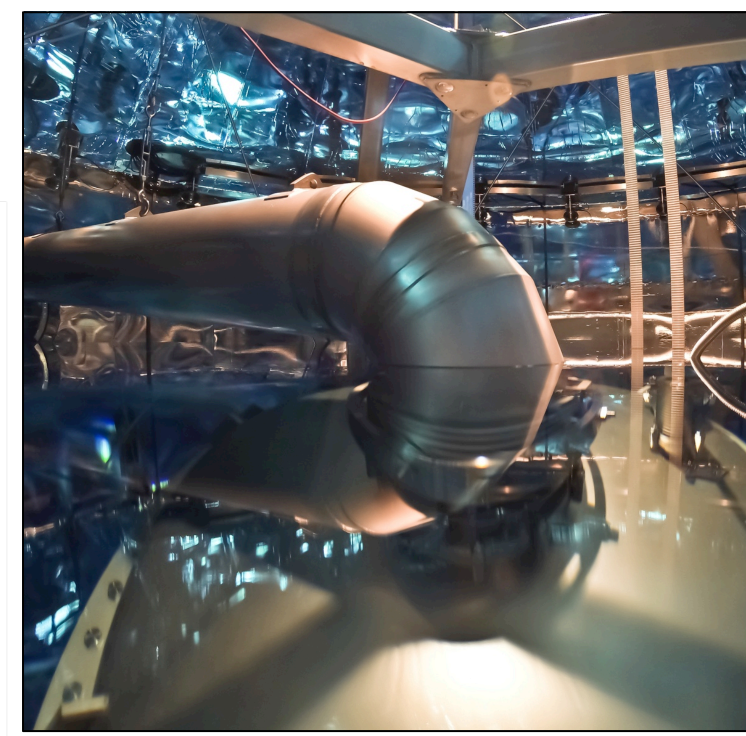
# Cryostat in the Water Tank





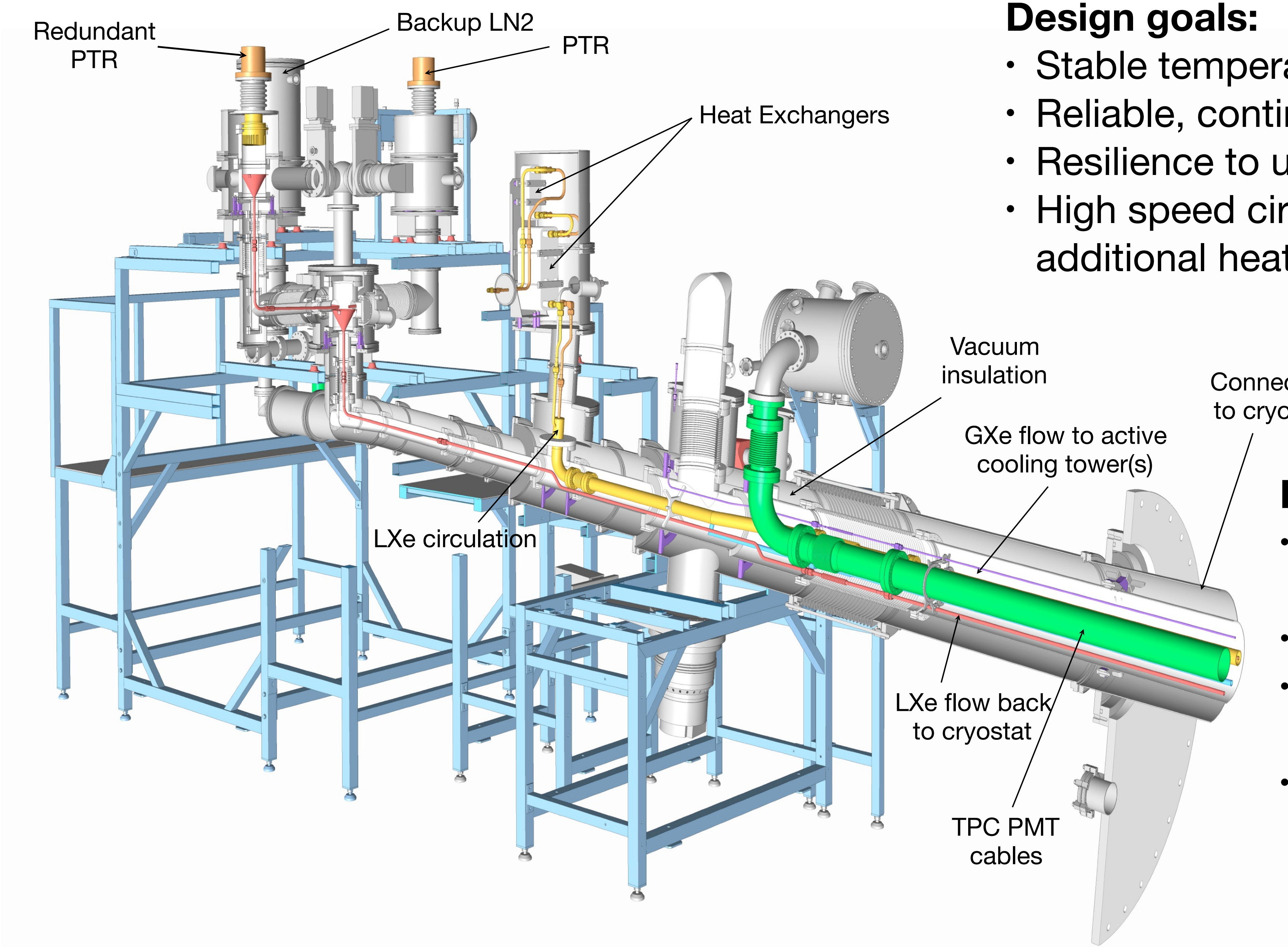





# Xe Cooling System

**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

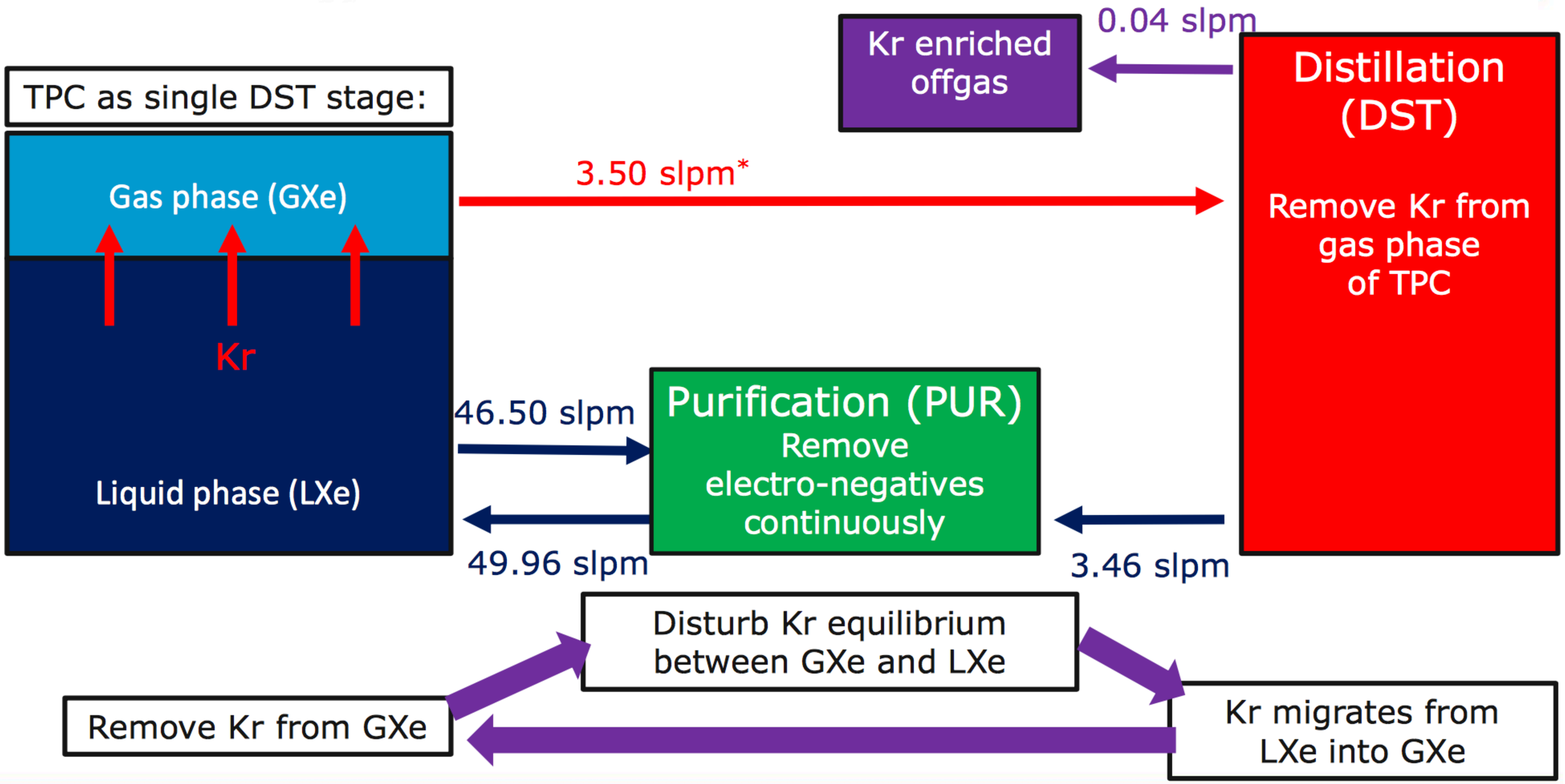
**Main features:**

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

# Online Kr/Rn distillation

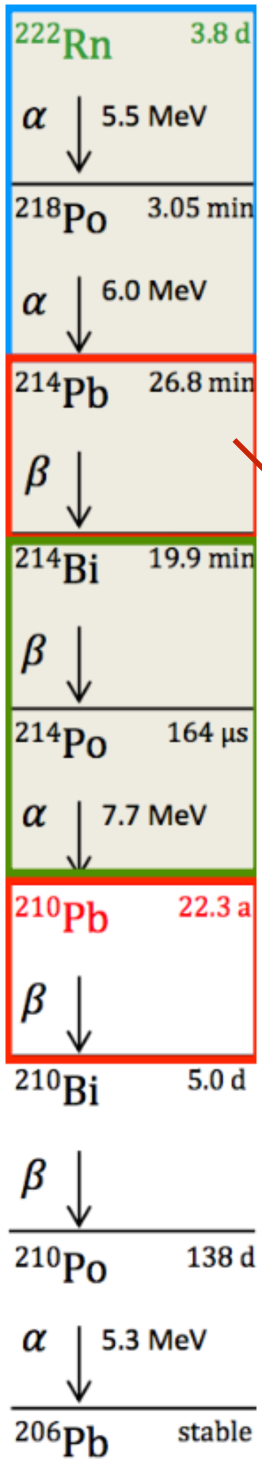
Online distillation does not affect data taking

The same column is used for both Kr/Rn removal




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

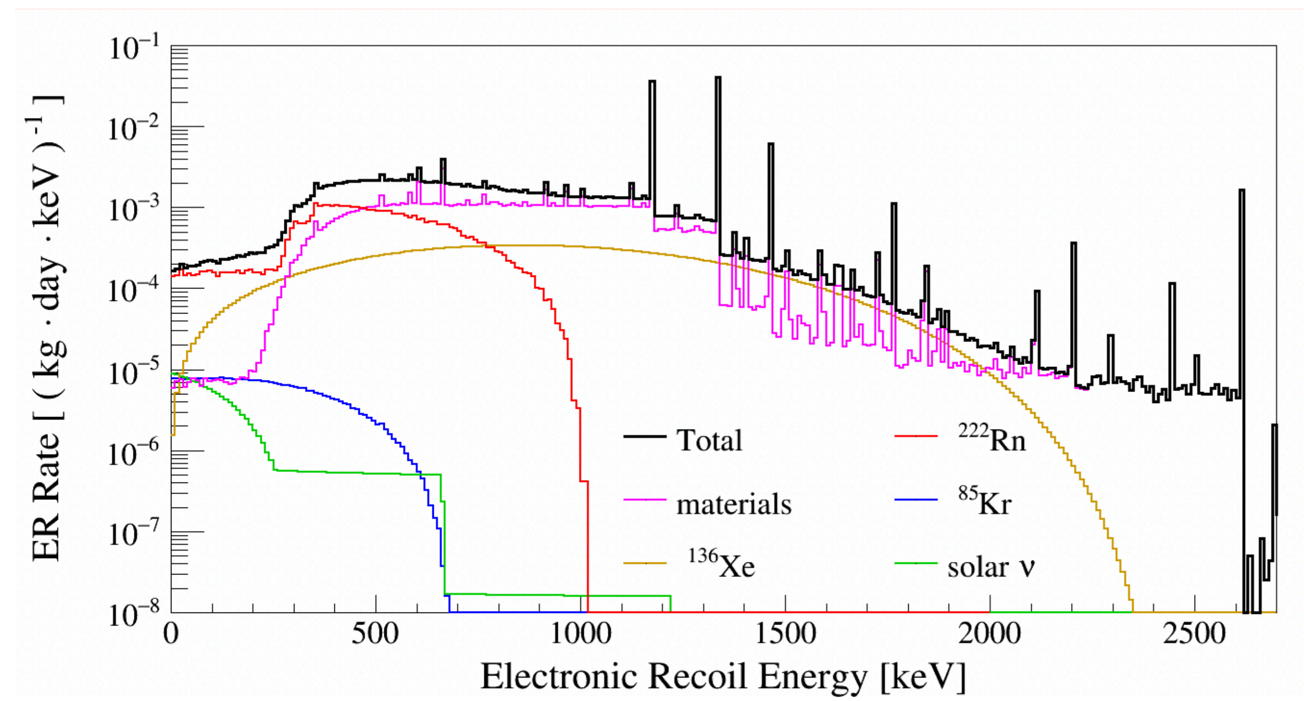
# Background budget



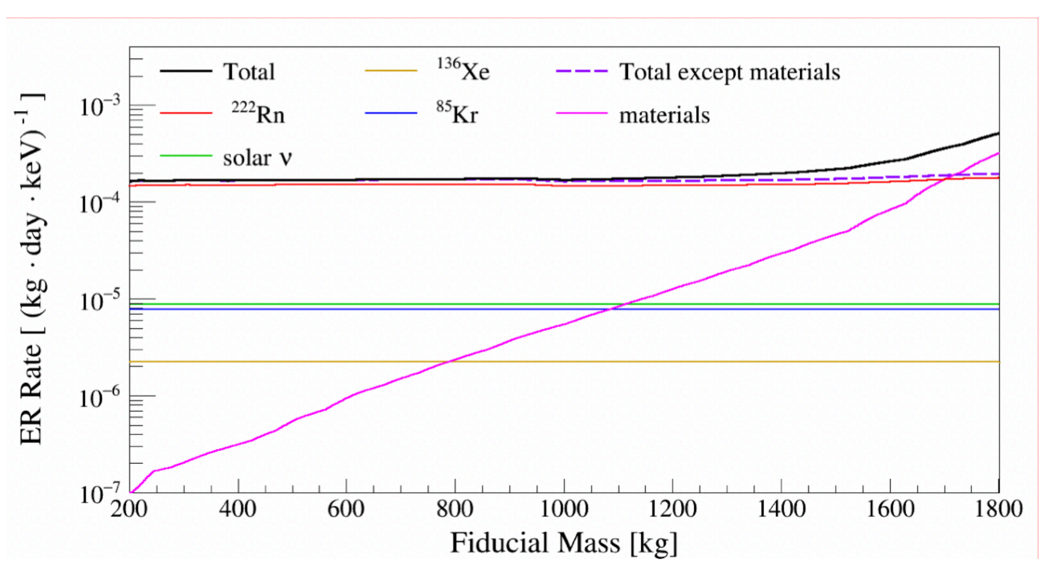

**Internal beta backgrounds:**

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

**Dominating backgrounds**



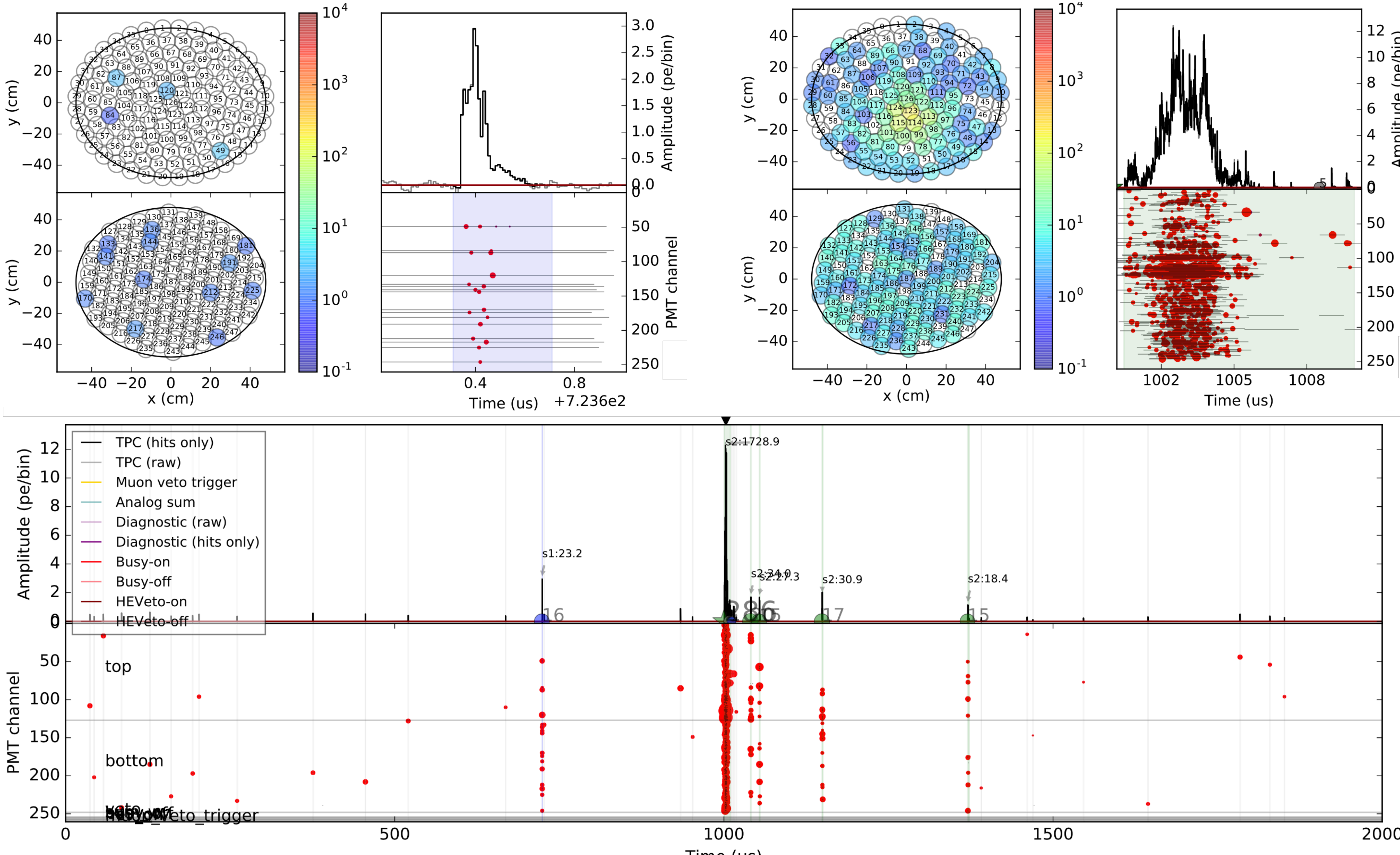

**JCAP04(2016)027**



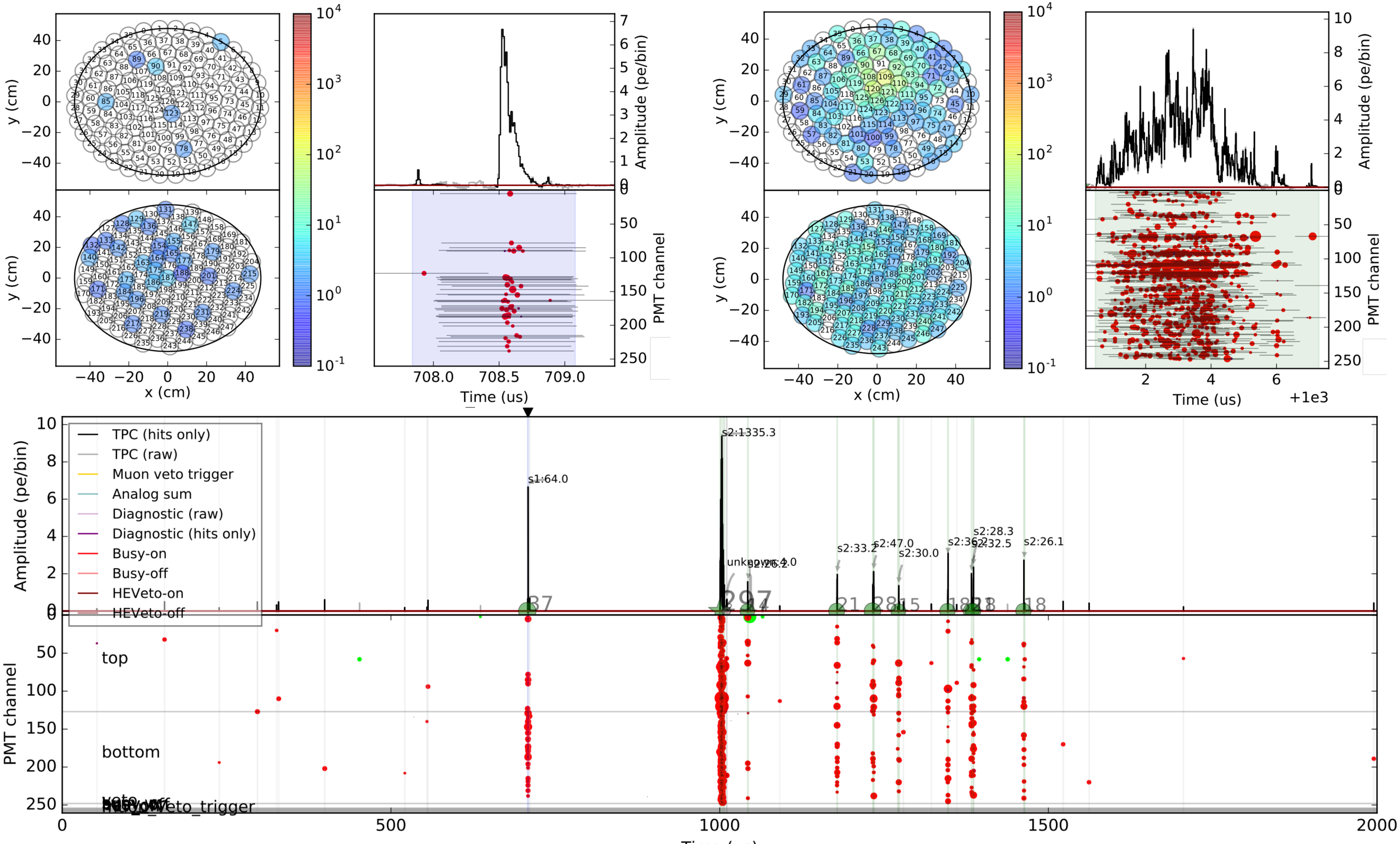

**In 1 ton FV, gamma bkg from materials is of the same order as the one from Kr85**

| Source | Background [(kg · day · keV)$^{-1}$] | Background [y$^{-1}$] | Fraction [%] |
|---|---|---|---|
| Materials | $(7.3 \pm 0.7) \cdot 10^{-6}$ | $29 \pm 3$ | 4.1 |
| $^{222}$Rn | $(1.54 \pm 0.15) \cdot 10^{-4}$ | $620 \pm 60$ | 85.4 |
| $^{85}$Kr | $(7.7 \pm 1.5) \cdot 10^{-6}$ | $31 \pm 6$ | 4.3 |
| $^{136}$Xe | $(2.3 \pm 1.1) \cdot 10^{-6}$ | $9 \pm 4$ | 1.4 |
| Solar neutrinos | $(8.9 \pm 0.2) \cdot 10^{-6}$ | $36 \pm 1$ | 4.9 |
| **Total** | $(1.80 \pm 0.15) \cdot 10^{-4}$ | **$720 \pm 60$** | **100** |

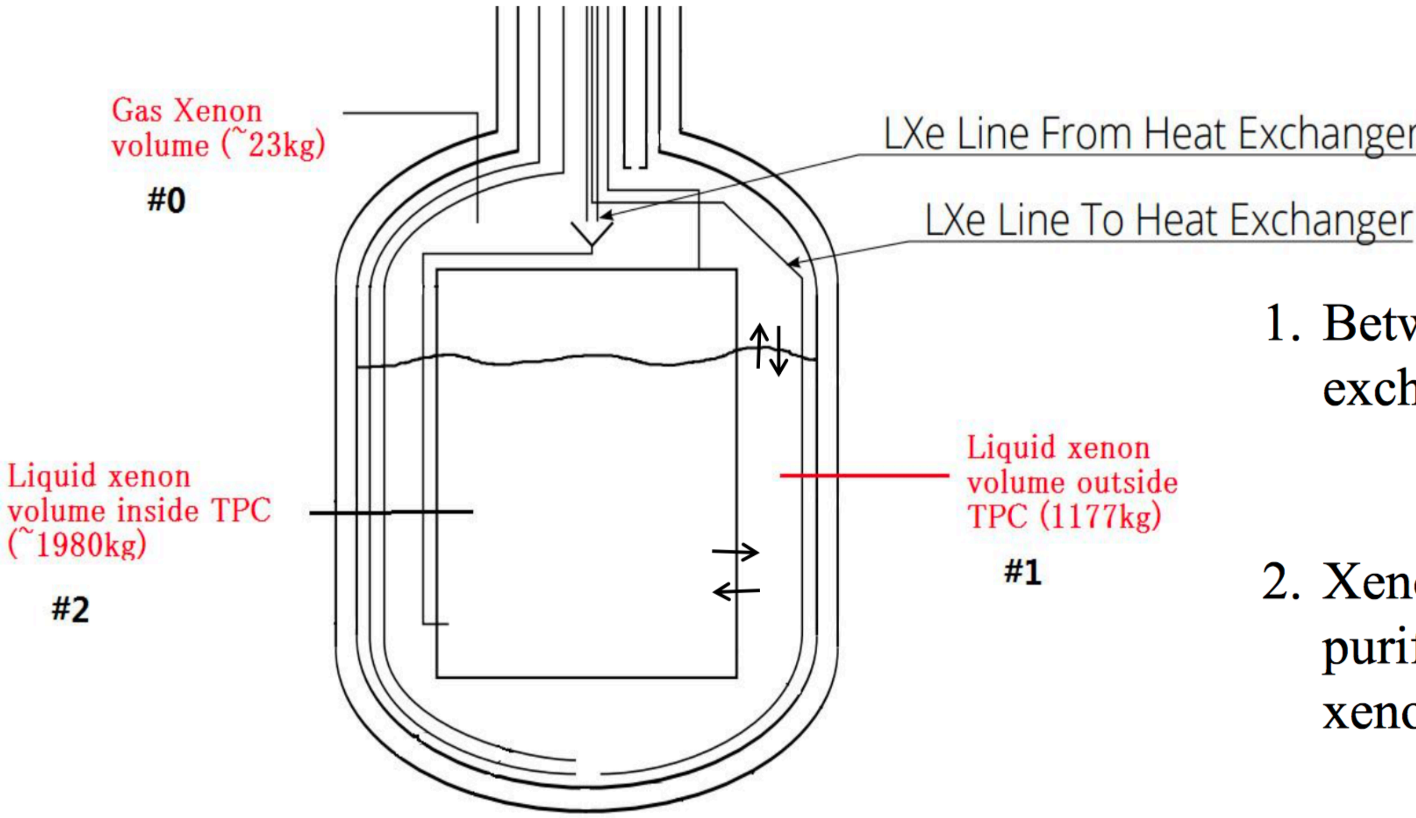
# Real Waveform Example 1



# Real Waveform Example 2



# Electron lifetime evolution model




1. Between volumes, there're xenon exchange also impurity exchange.
2. Xenon is taken from Volume#1 to purification system, and clean xenon comes back to Volume#0.

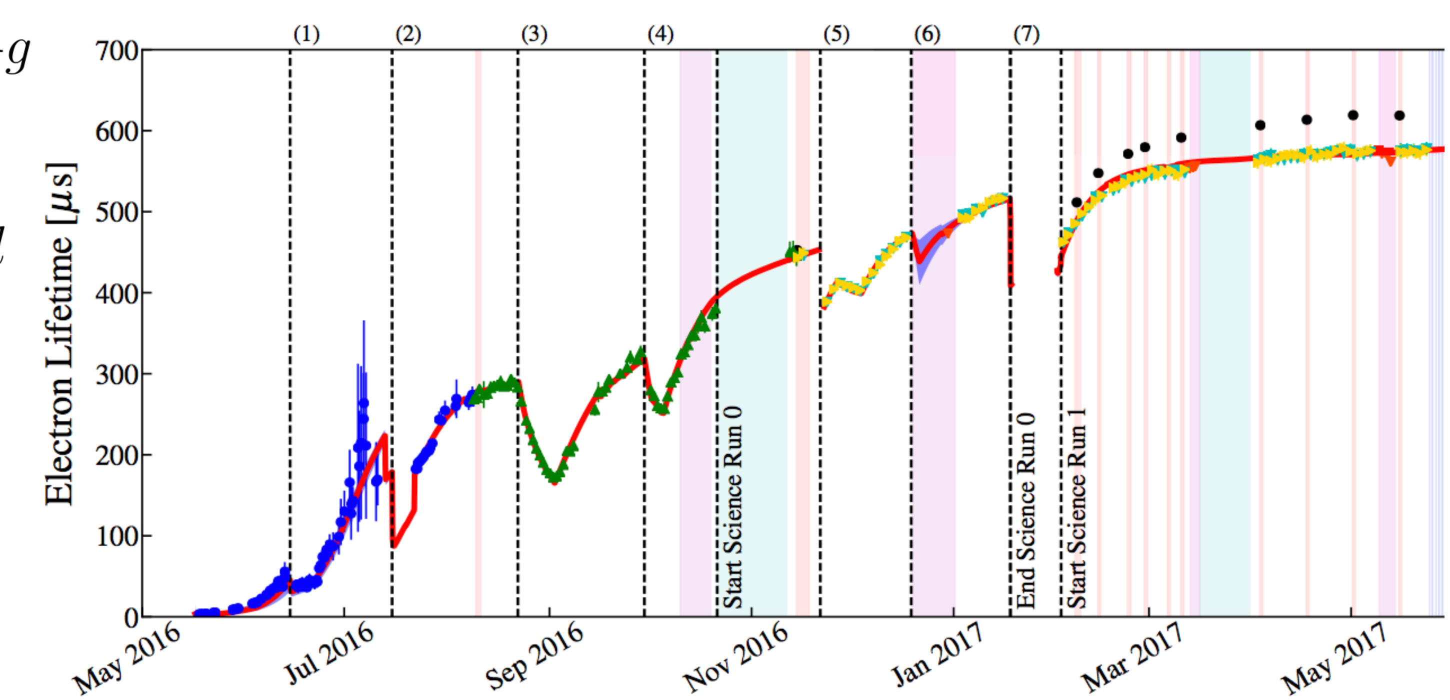
$$
\begin{cases}
M_g \frac{dI_g}{dt} = -F_g \rho I_g + \frac{\epsilon_1 P_C I_l}{h} - \frac{\epsilon_2 P I_g}{h} + \Lambda_g \\
M_l \frac{dI_l}{dt} = -F_l \rho I_l - \frac{\epsilon_1 P_C I_l}{h} + \frac{\epsilon_2 P I_g}{h} + \Lambda_l
\end{cases}
$$

$P$ - cooling power

$P_c$ - cooling power with no flow

$\epsilon_1$ - probability of impurity to migrate from liquid xenon to gaseous xenon

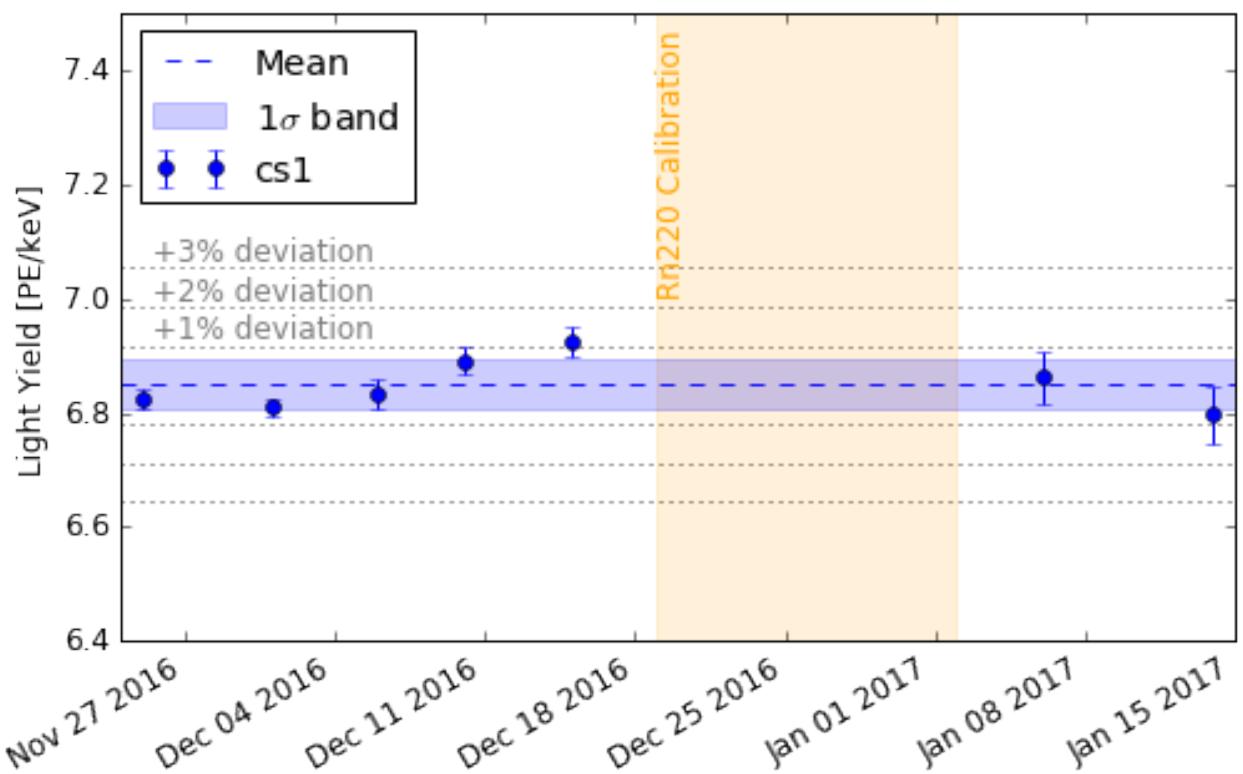
$\epsilon_2$ - probability of impurity to migrate from gaseous xenon to liquid xenon



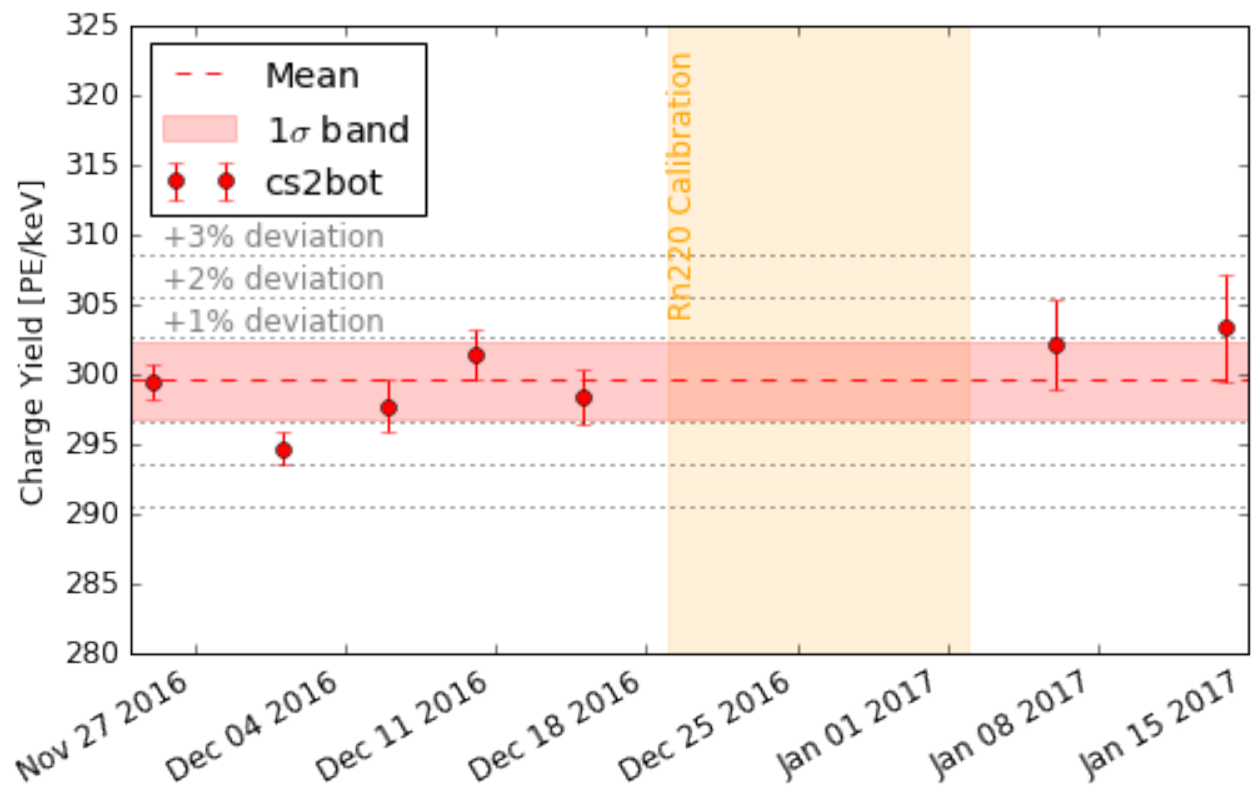
# Light/Charge Yield Stability

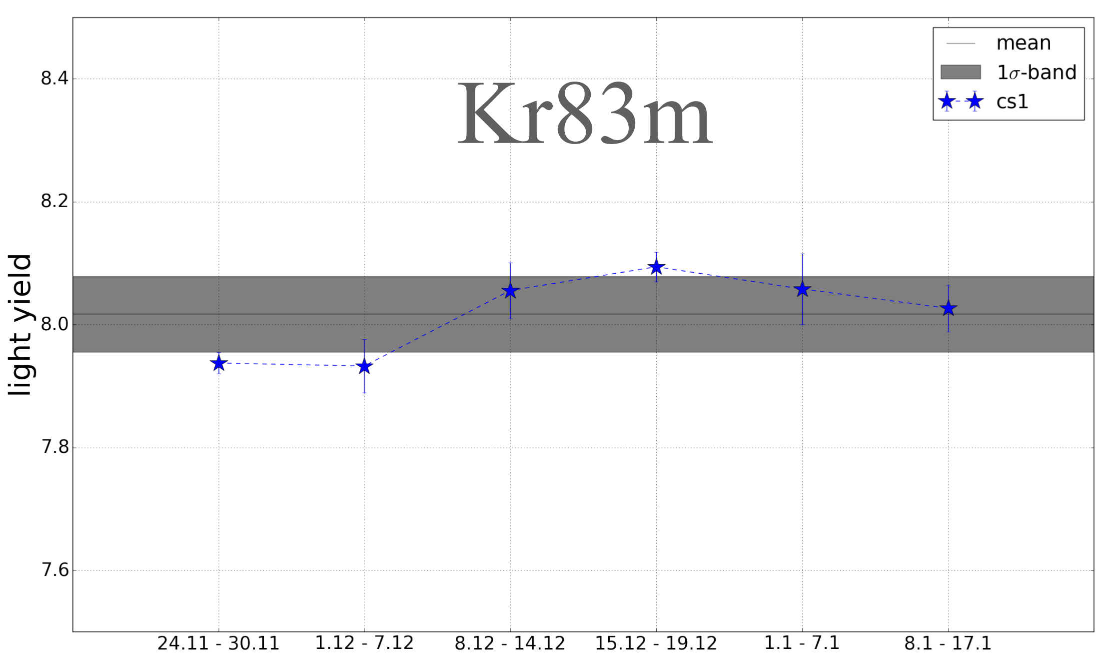
From Kr83m and activated Xe131m, variation in LY and CY is at ~1% level.

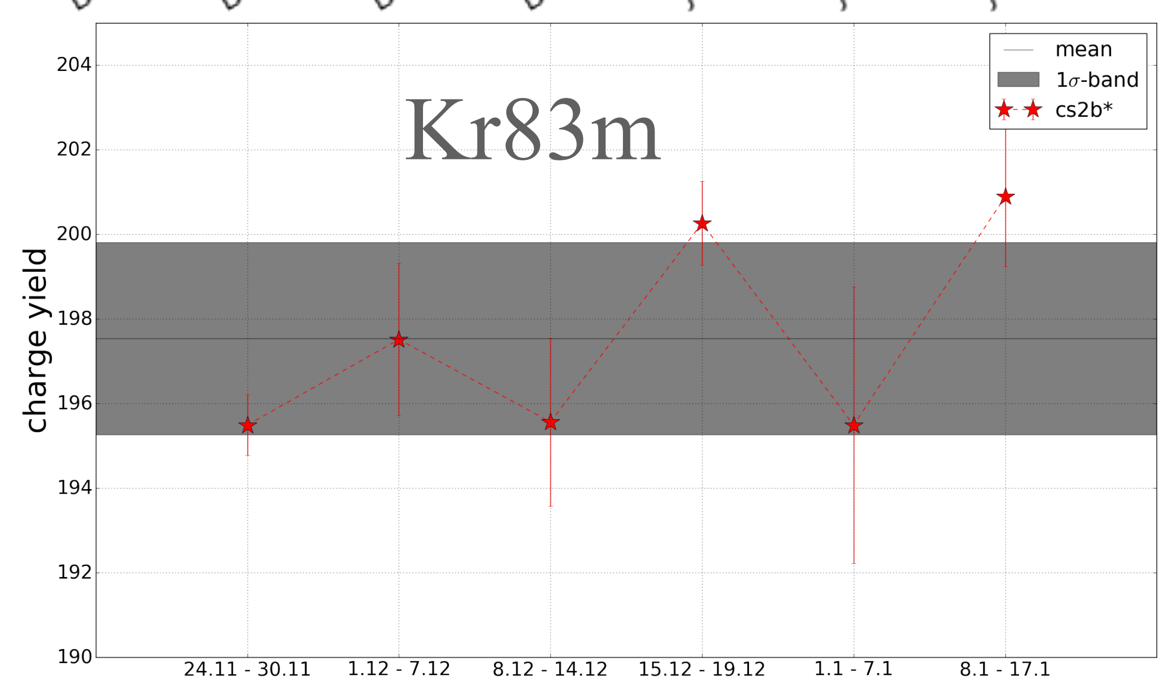
Light yield (164 keV) over SR0



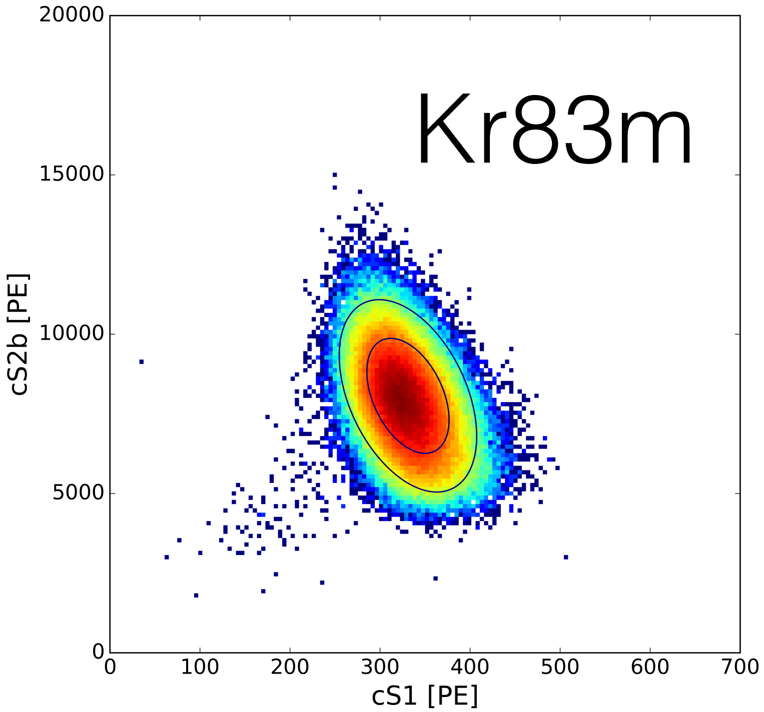

Charge yield (164 keV) over SR0

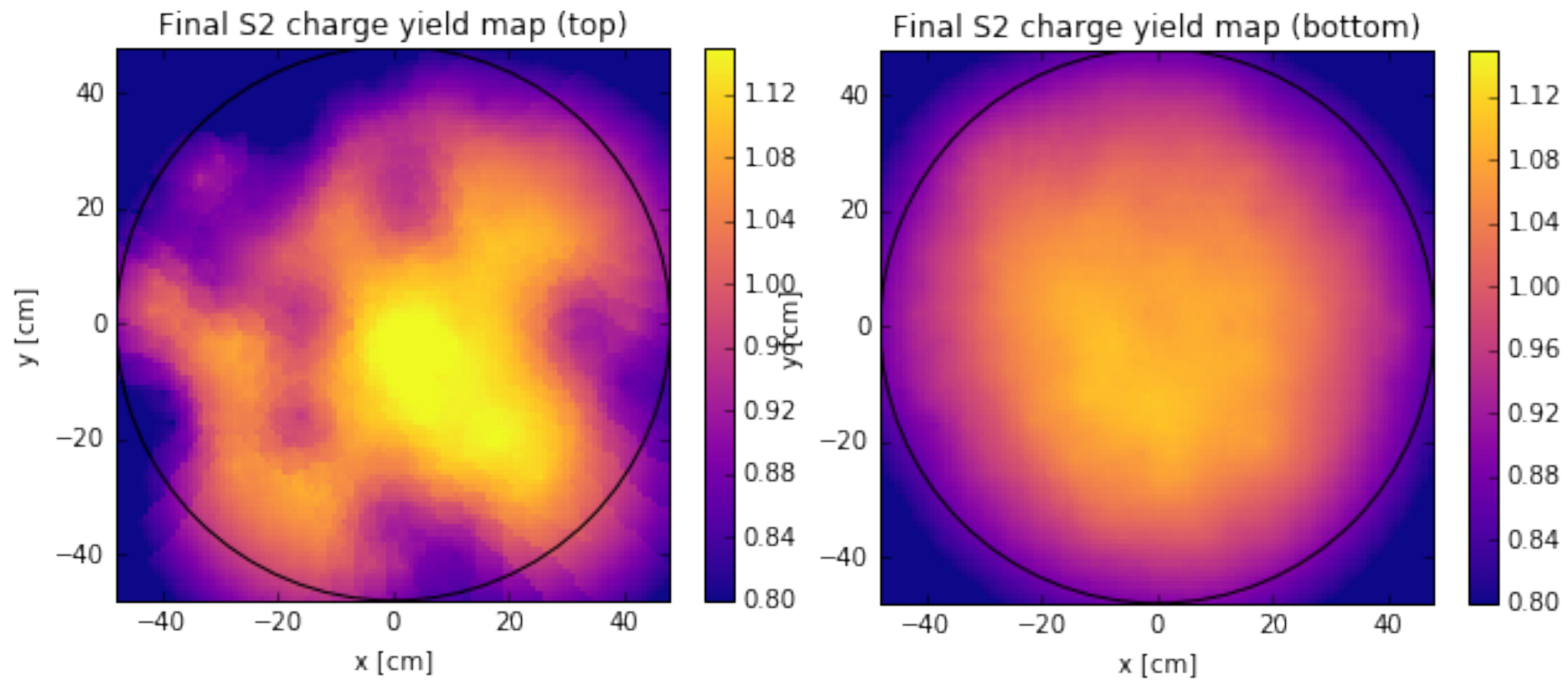


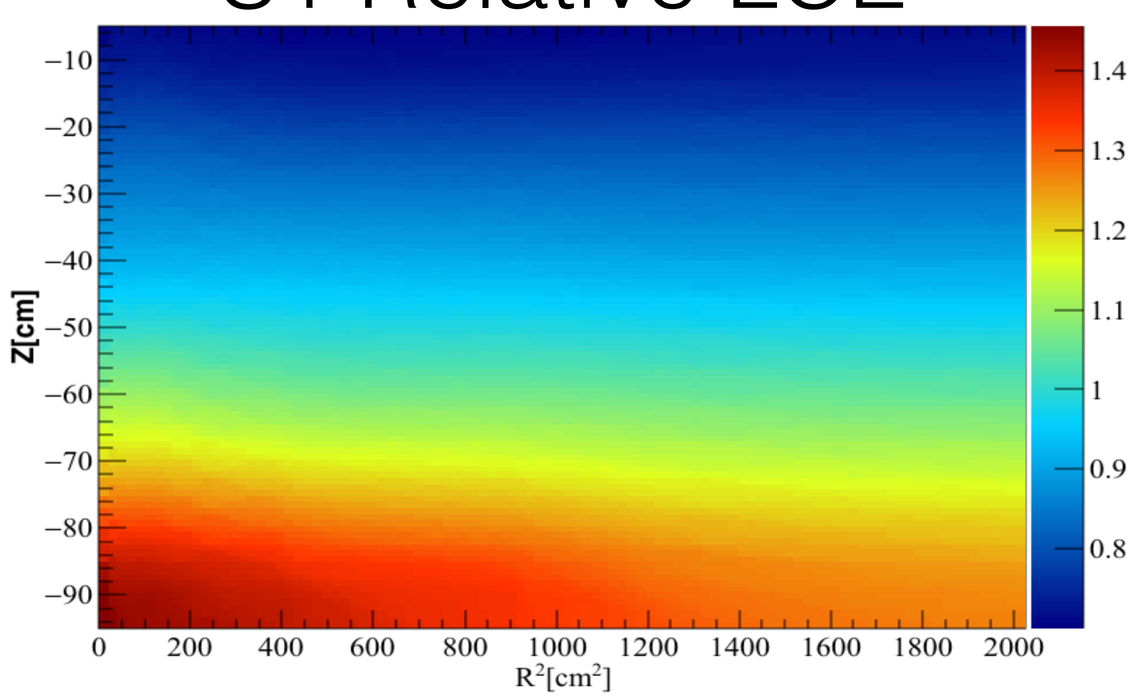



# Signal Corrections

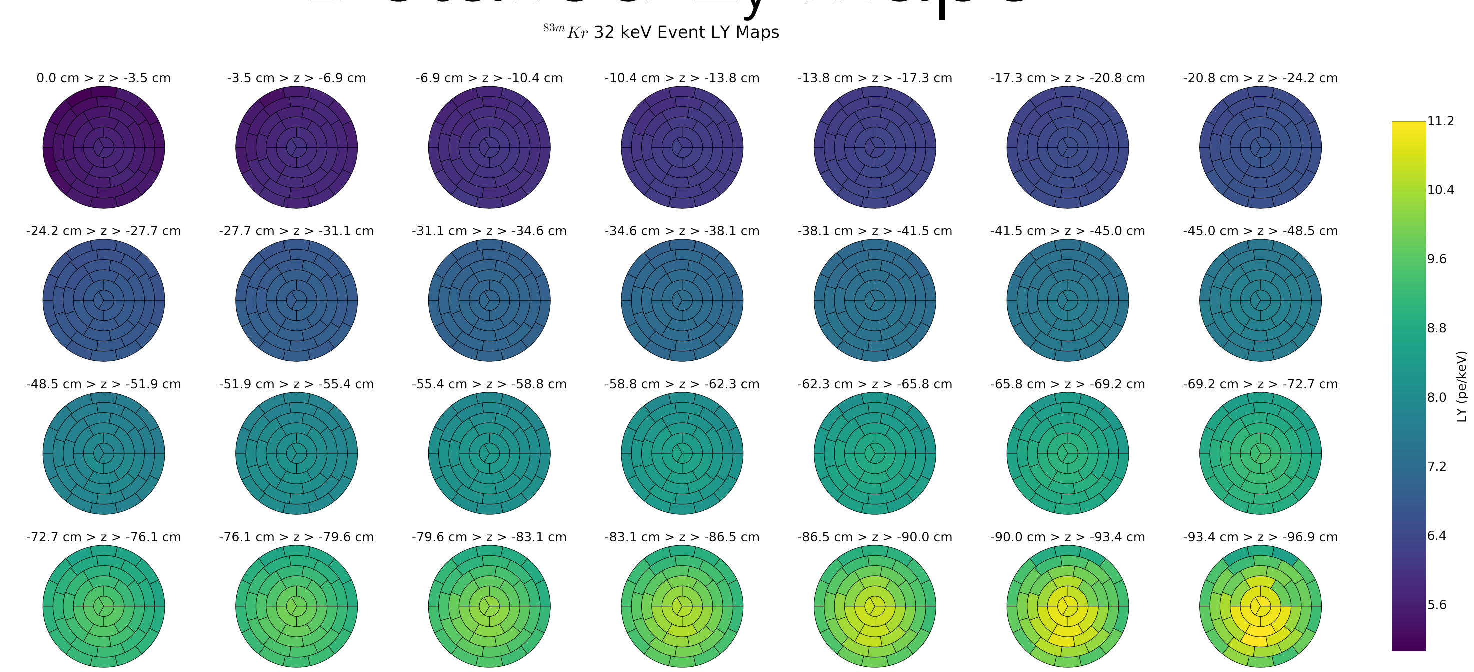


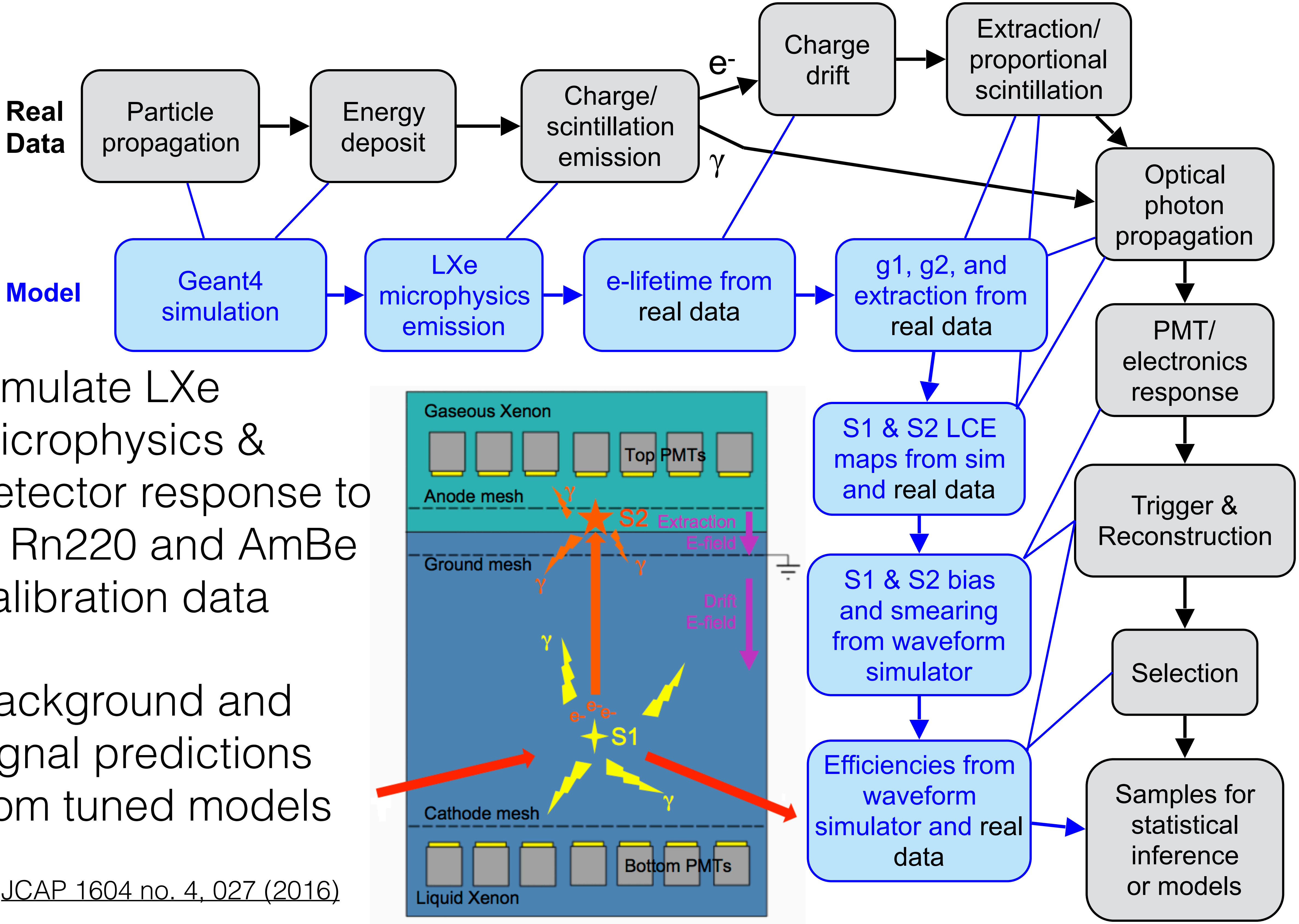

## S1 Relative LCE




## Detailed $L_y$ Maps



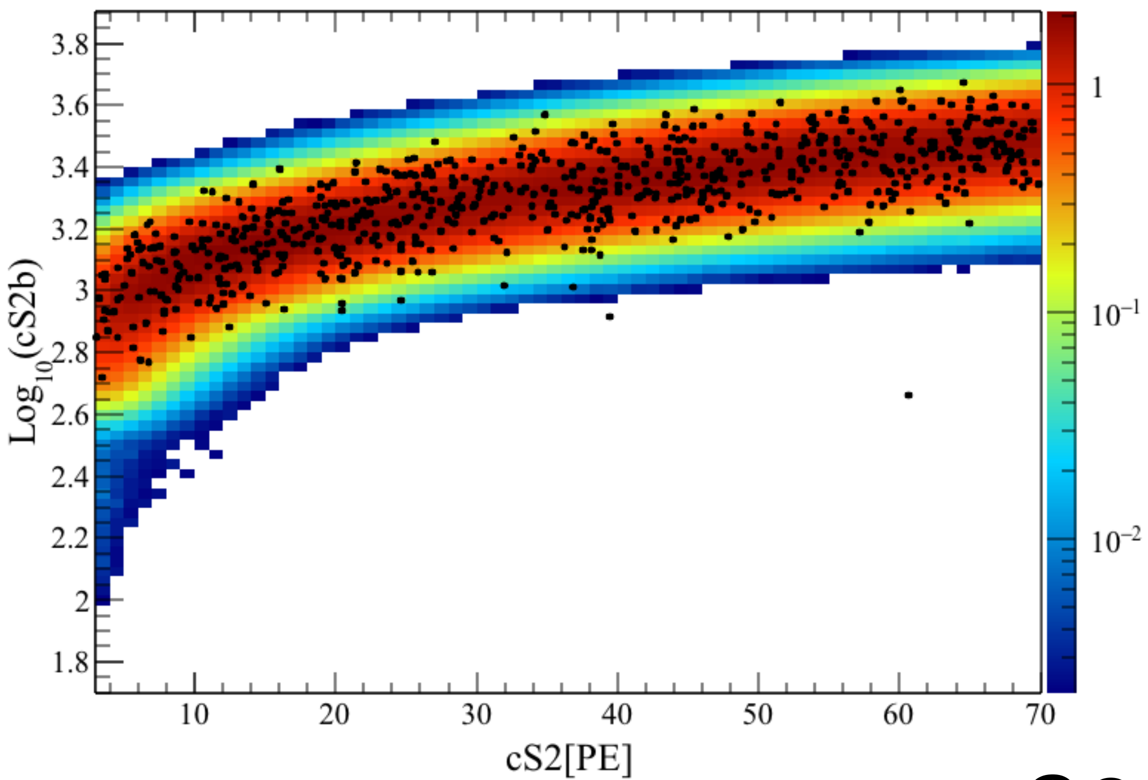
# The ER and NR Models



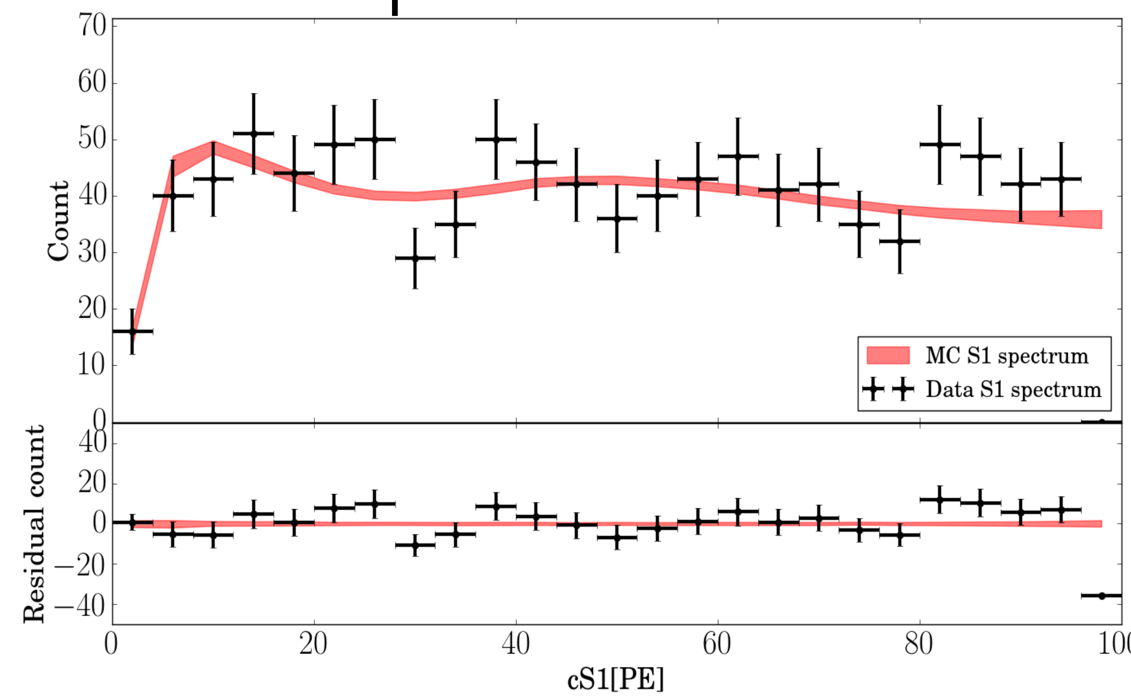

- Simulate LXe microphysics & detector response to fit Rn220 and AmBe calibration data
- Background and signal predictions from tuned models

JCAP 1604 no. 4, 027 (2016)

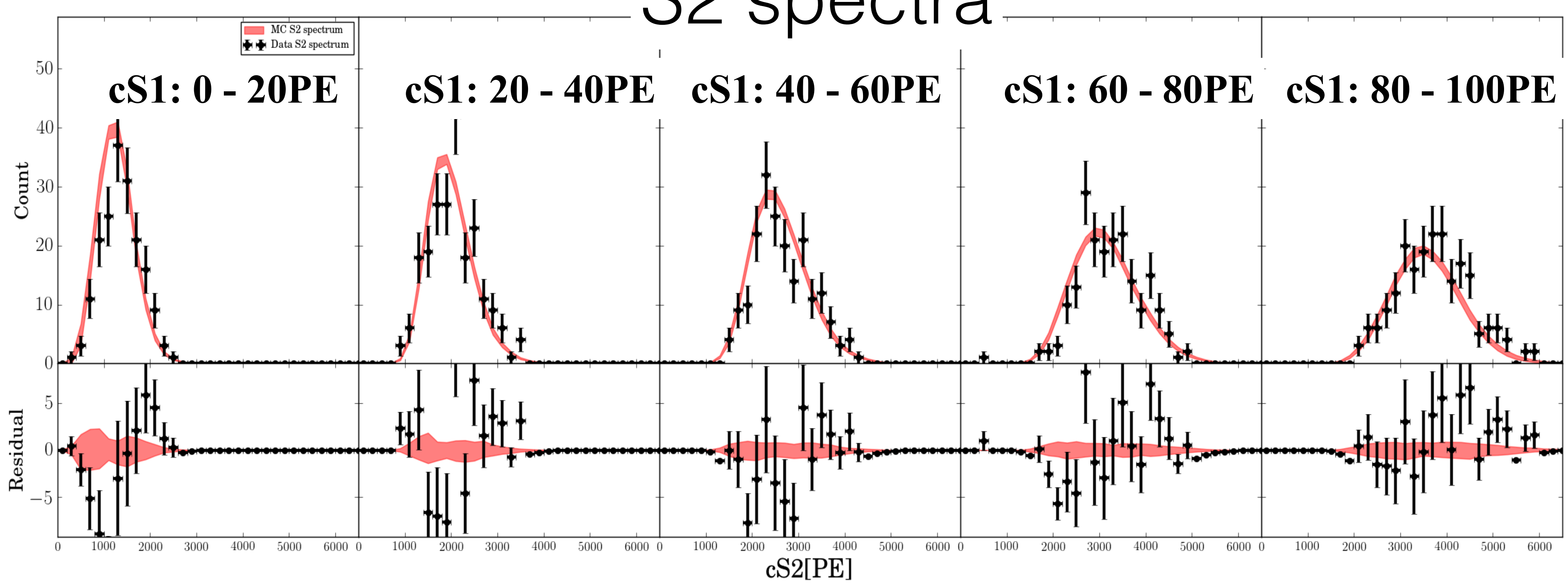
# Rn220 Calibration



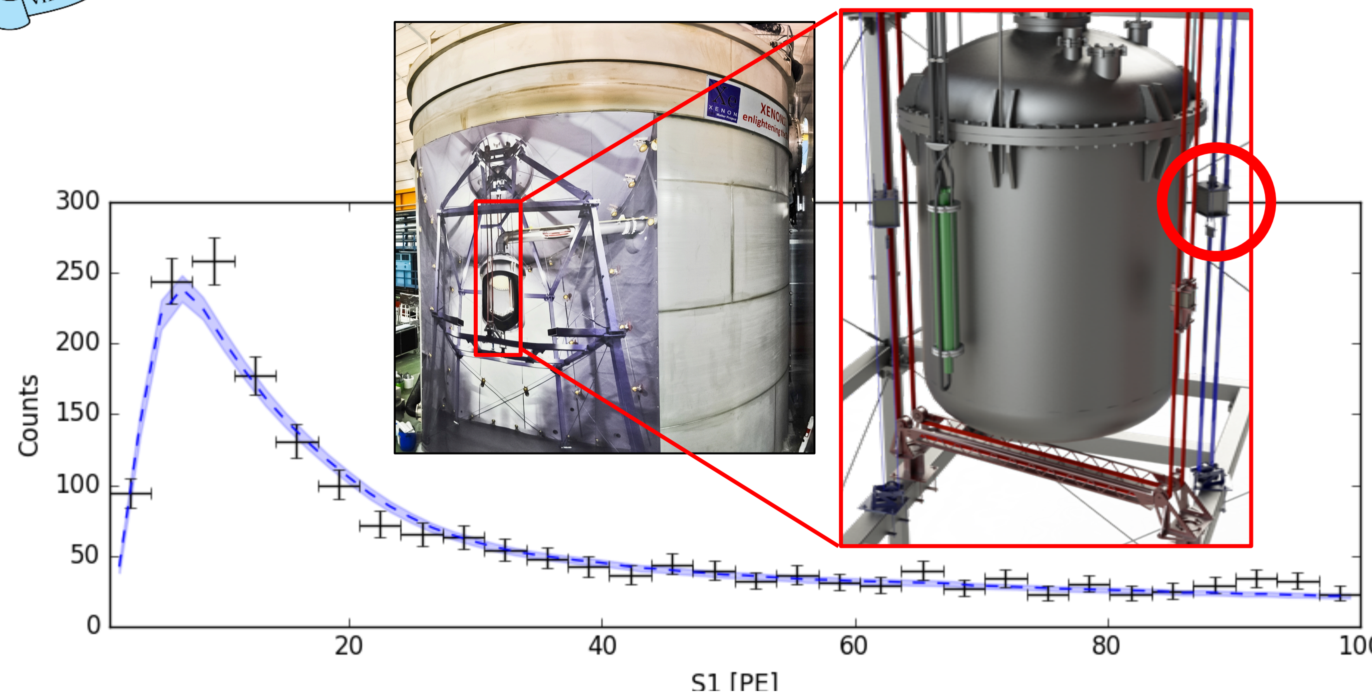

## S1 spectrum

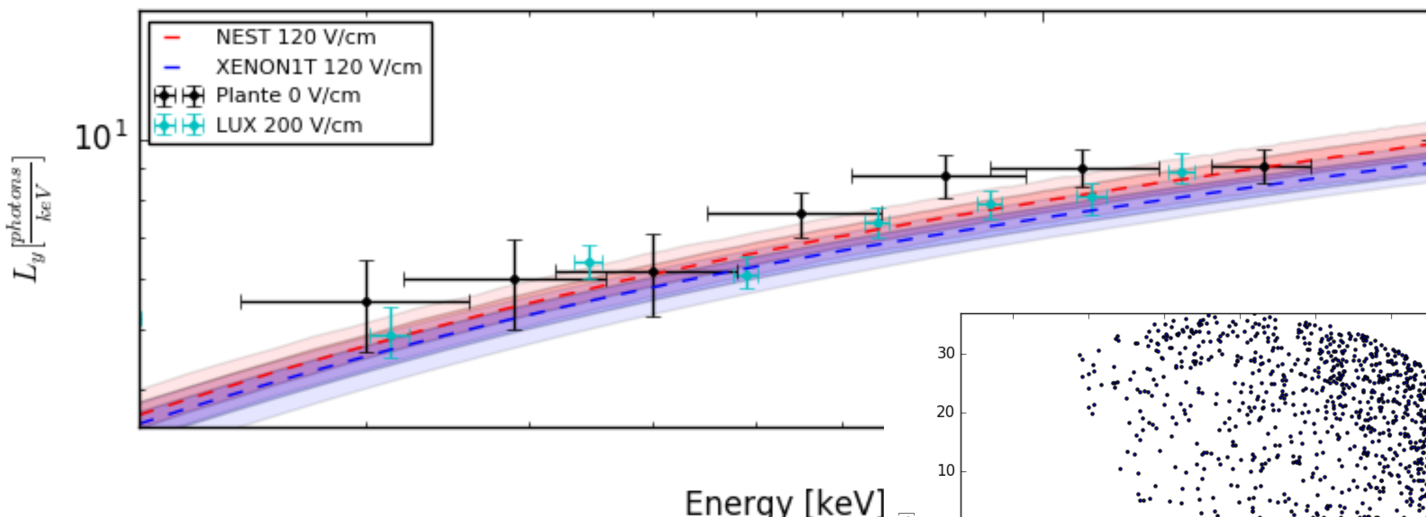


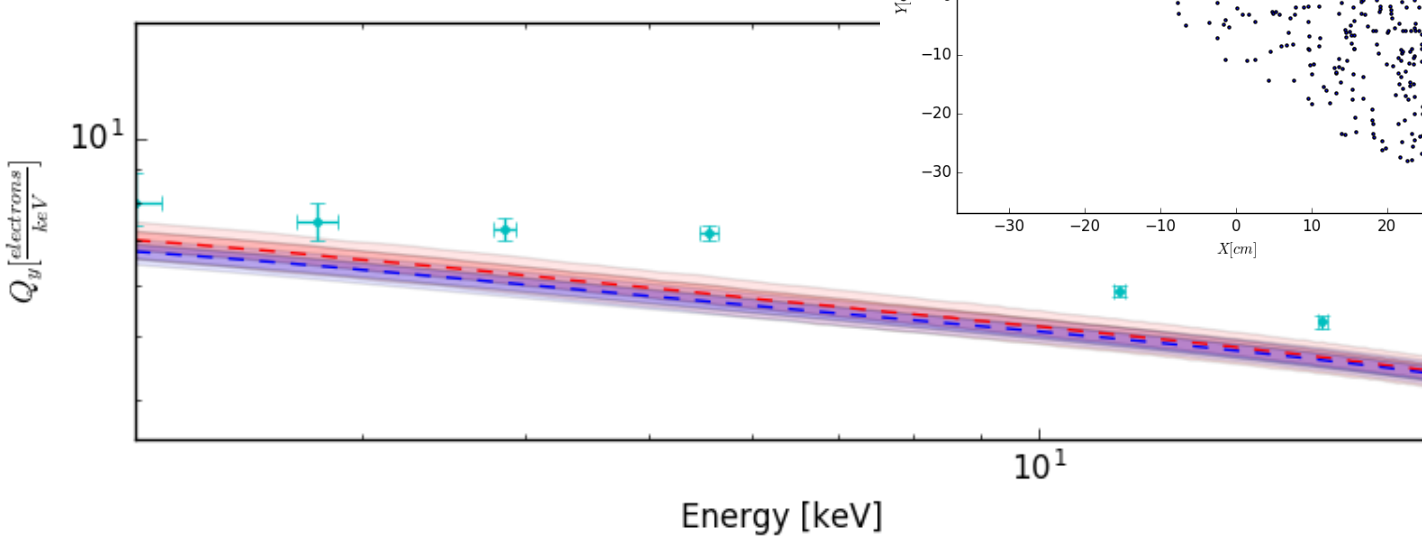

## S2 spectra

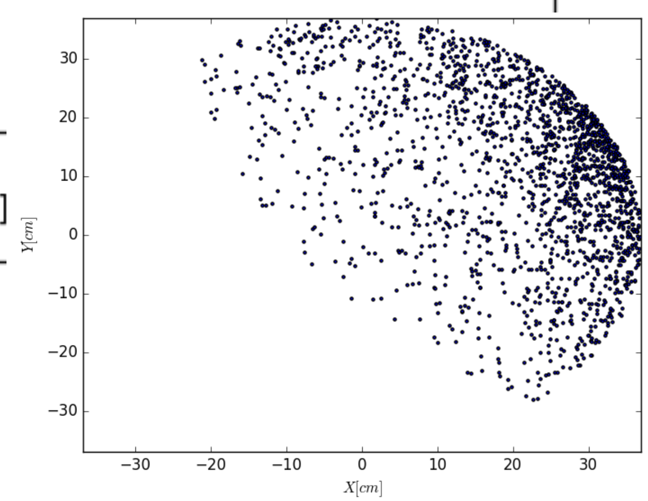


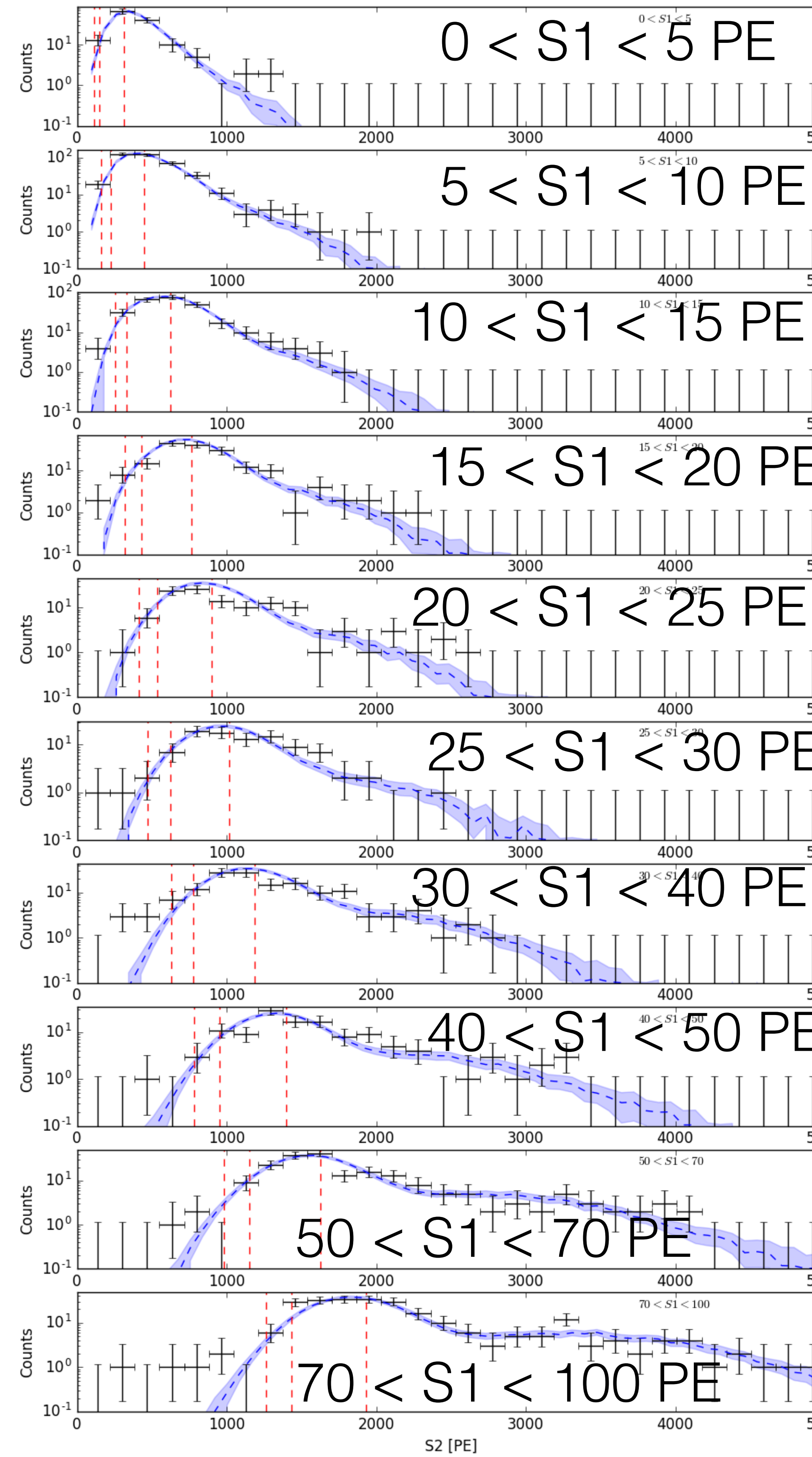
# AmBe Calibration



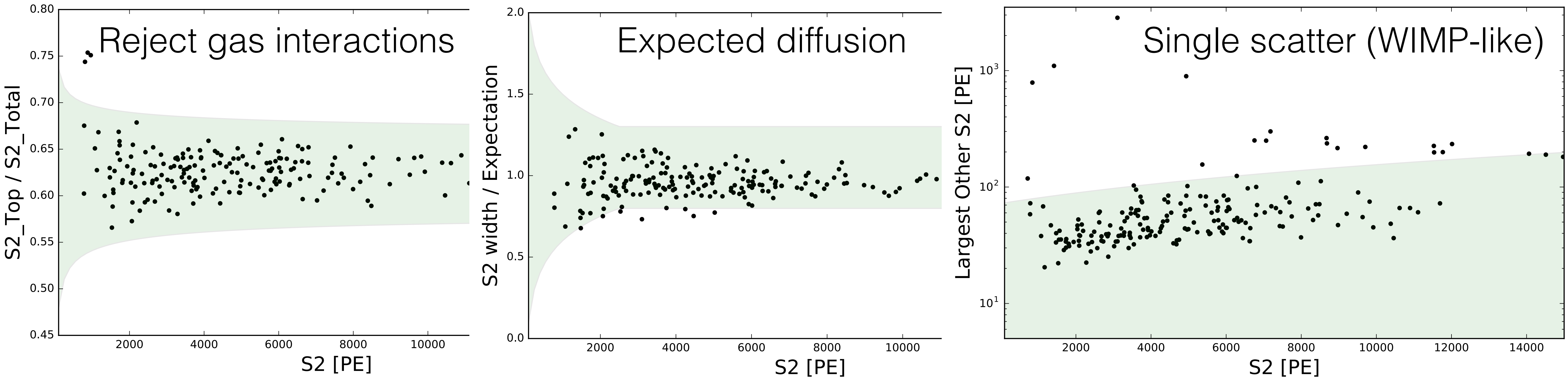



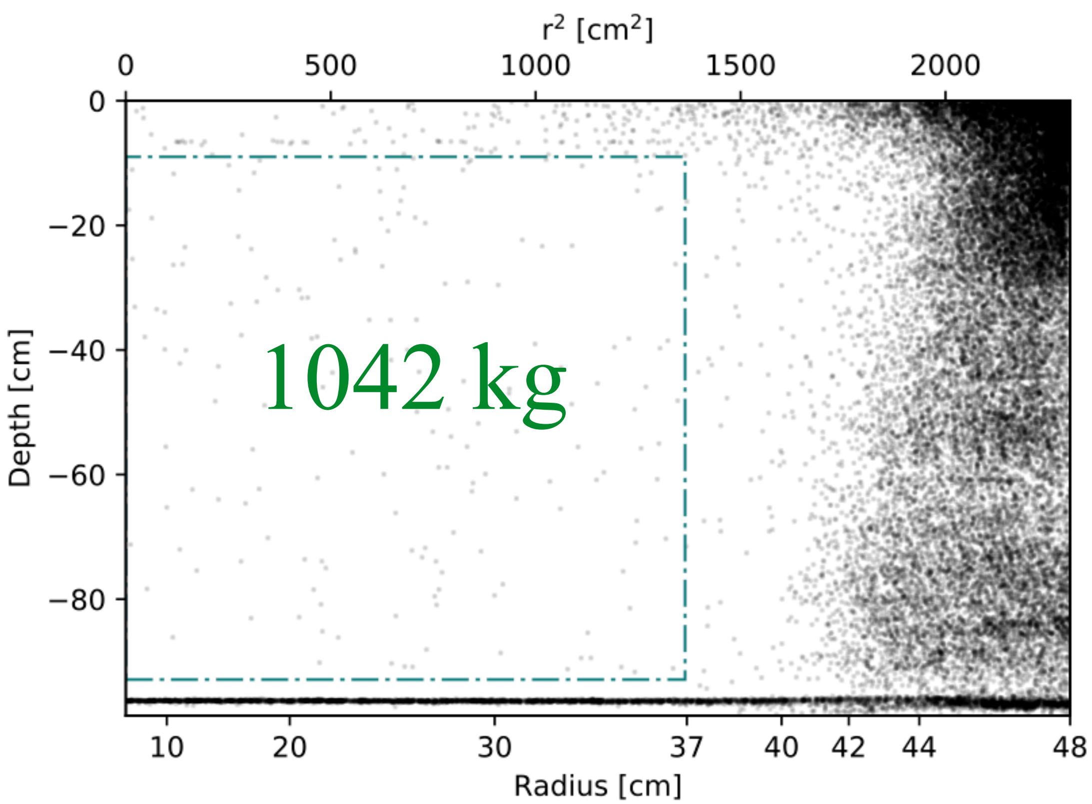



# Event Selection

- Data quality and selection cuts tuned to calibration data

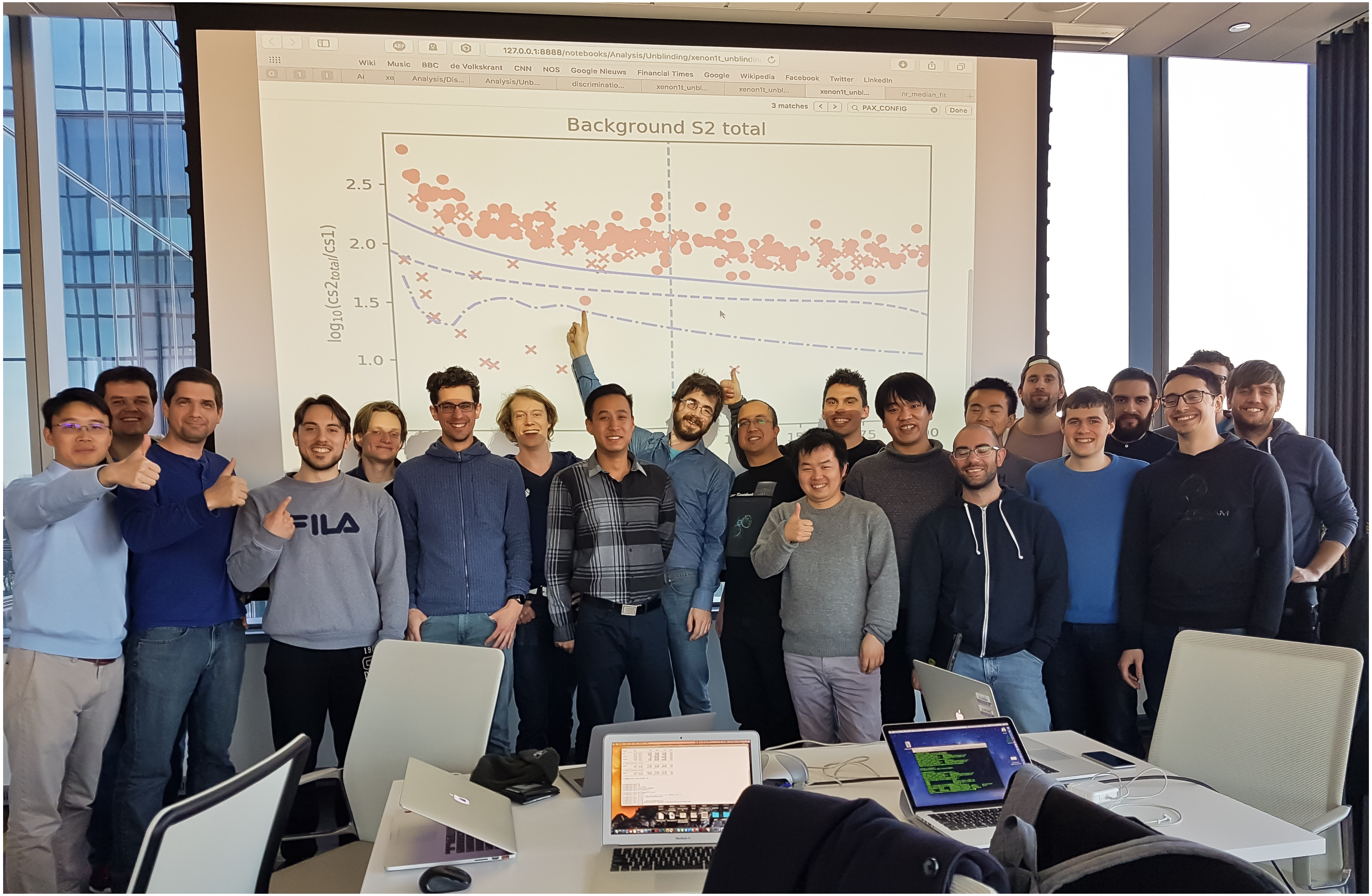


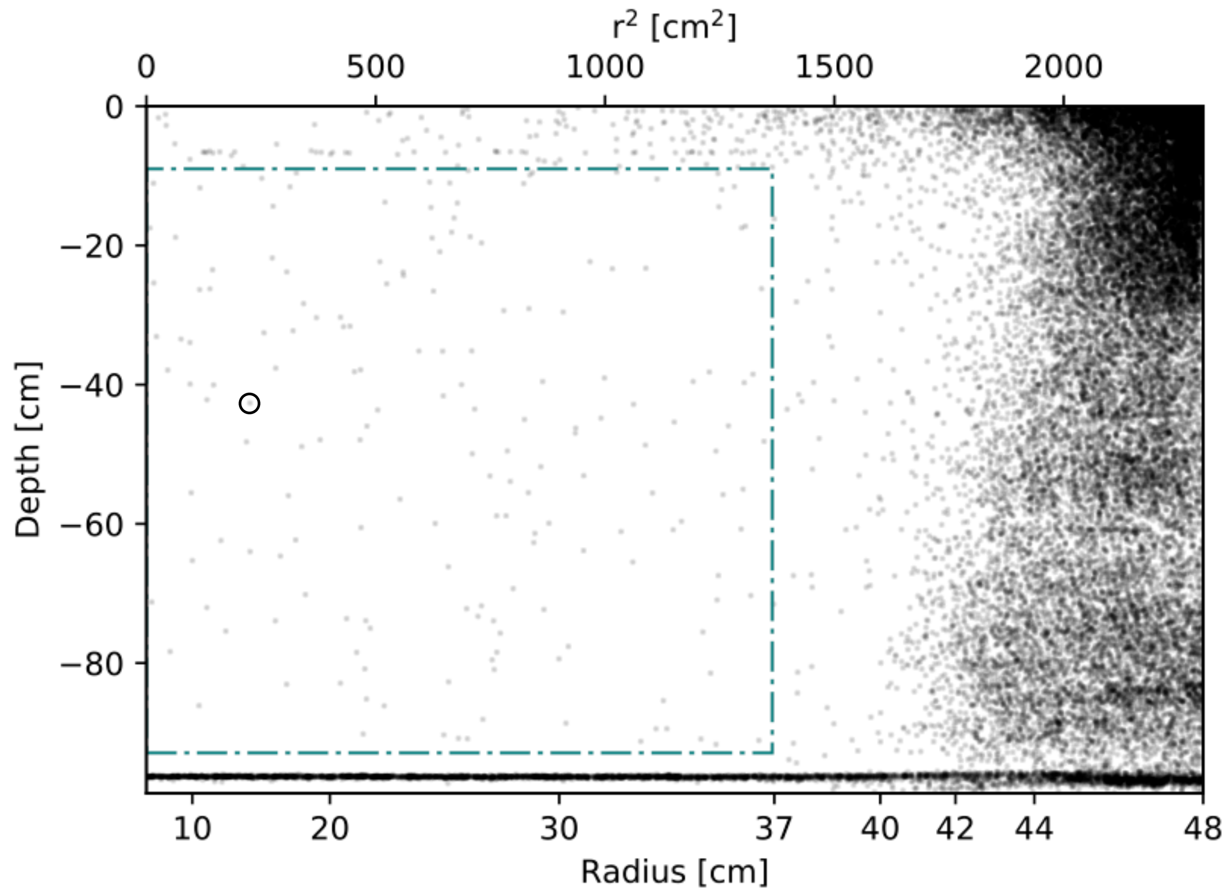

| Cut | Events remaining |
|---|---|
| **All Events (cS1 < 200 PE)** | 128144 |
| **Data Quality and Selection** | 48955 |
| **Fiducial Volume** | 180 |
| **S1 Range (3 < cS1 < 70 PE)** | 63 |

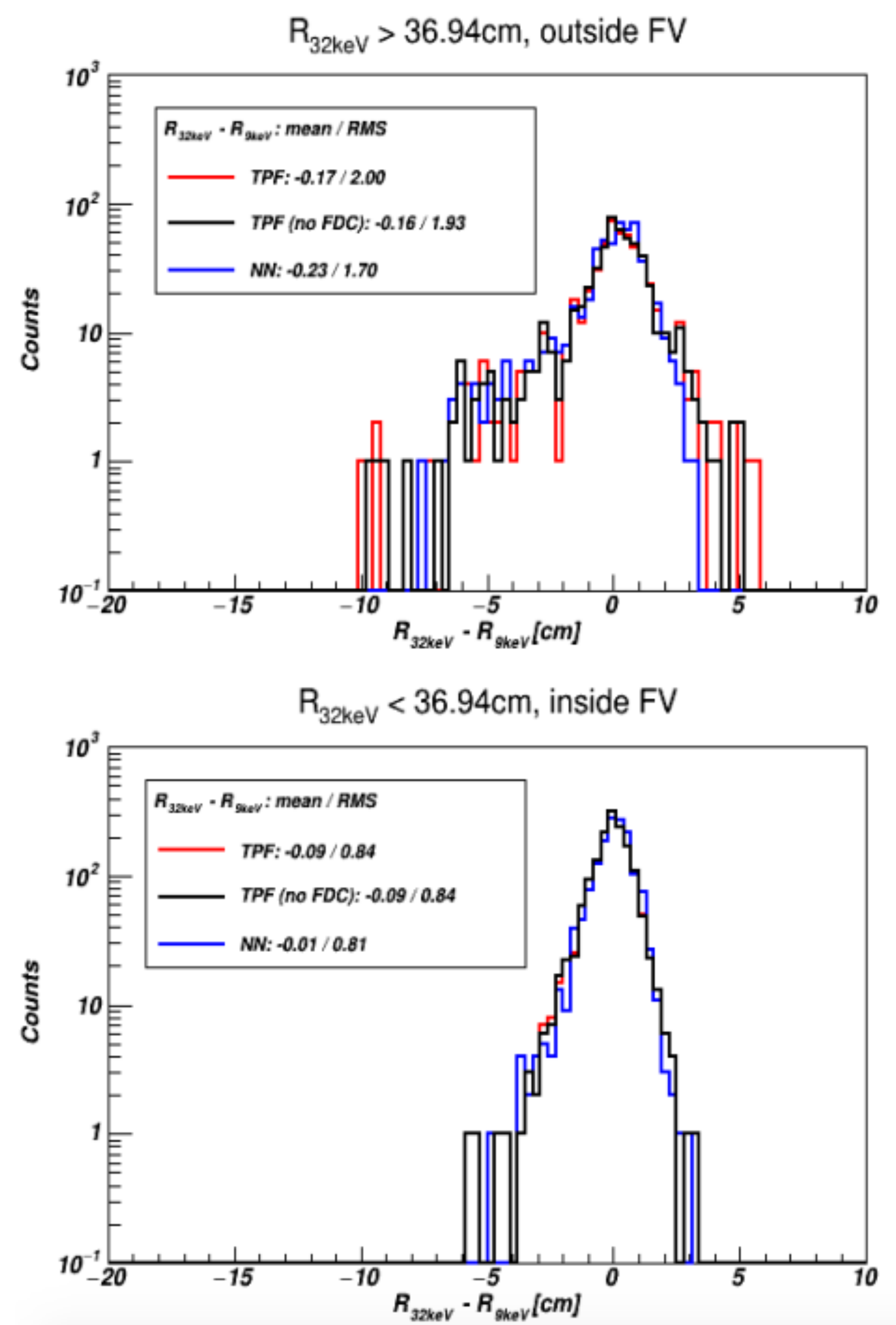
# Before Unblinding

# And after



# Position Reconstruction

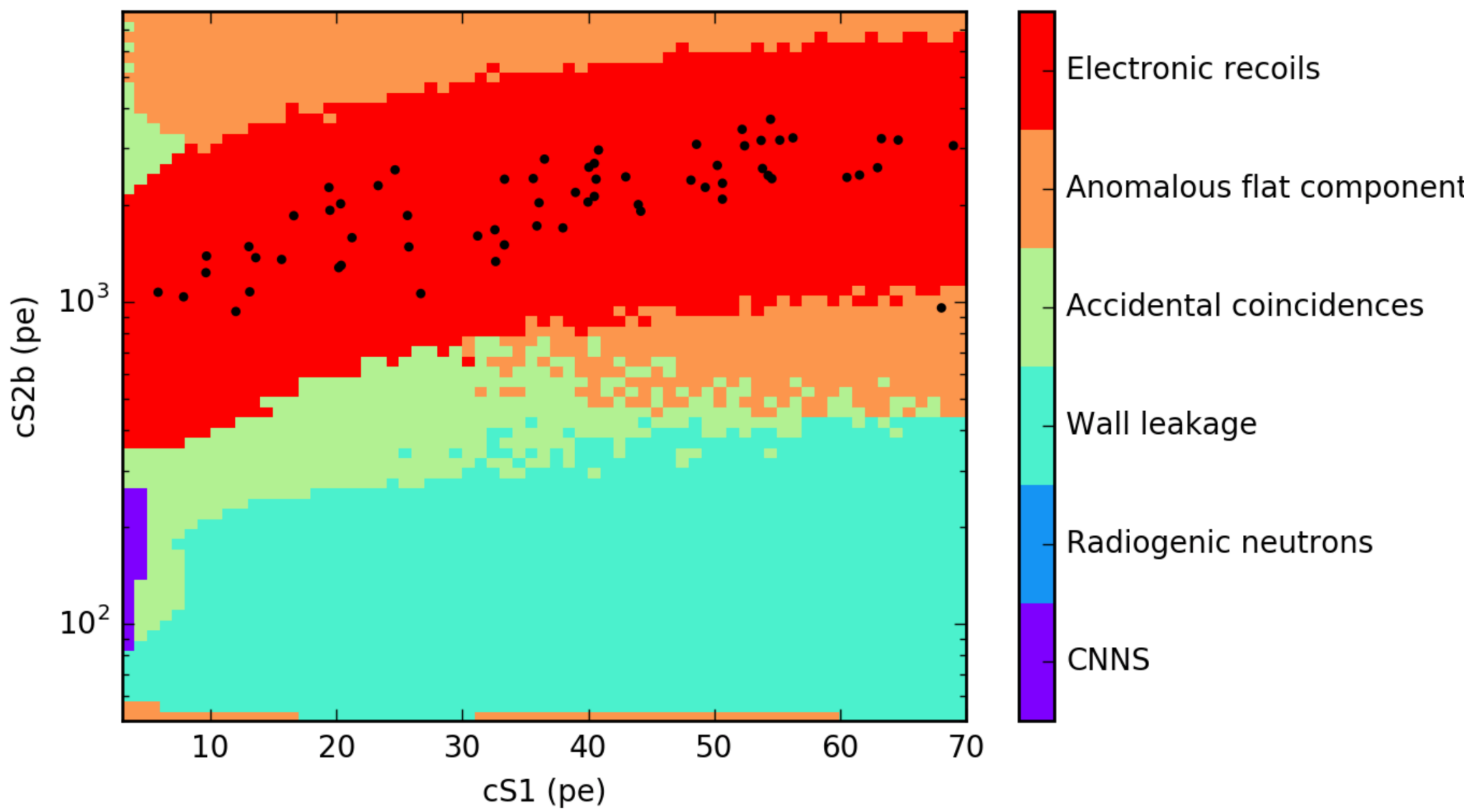


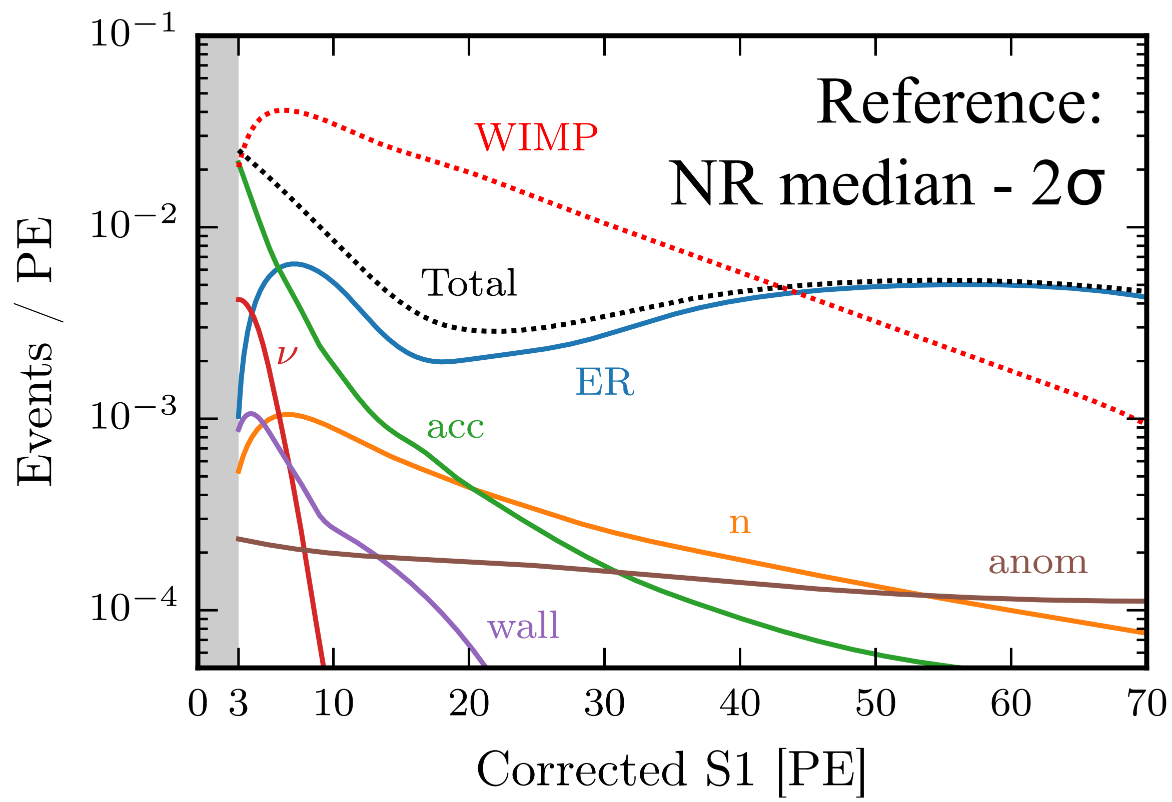




- Position resolution (RMS) is less than 1 cm inside the FV, and ~2 cm outside the FV, estimated using the difference from two peaks (32 keV and 9 keV) from Kr83m events.

# Predicting Backgrounds

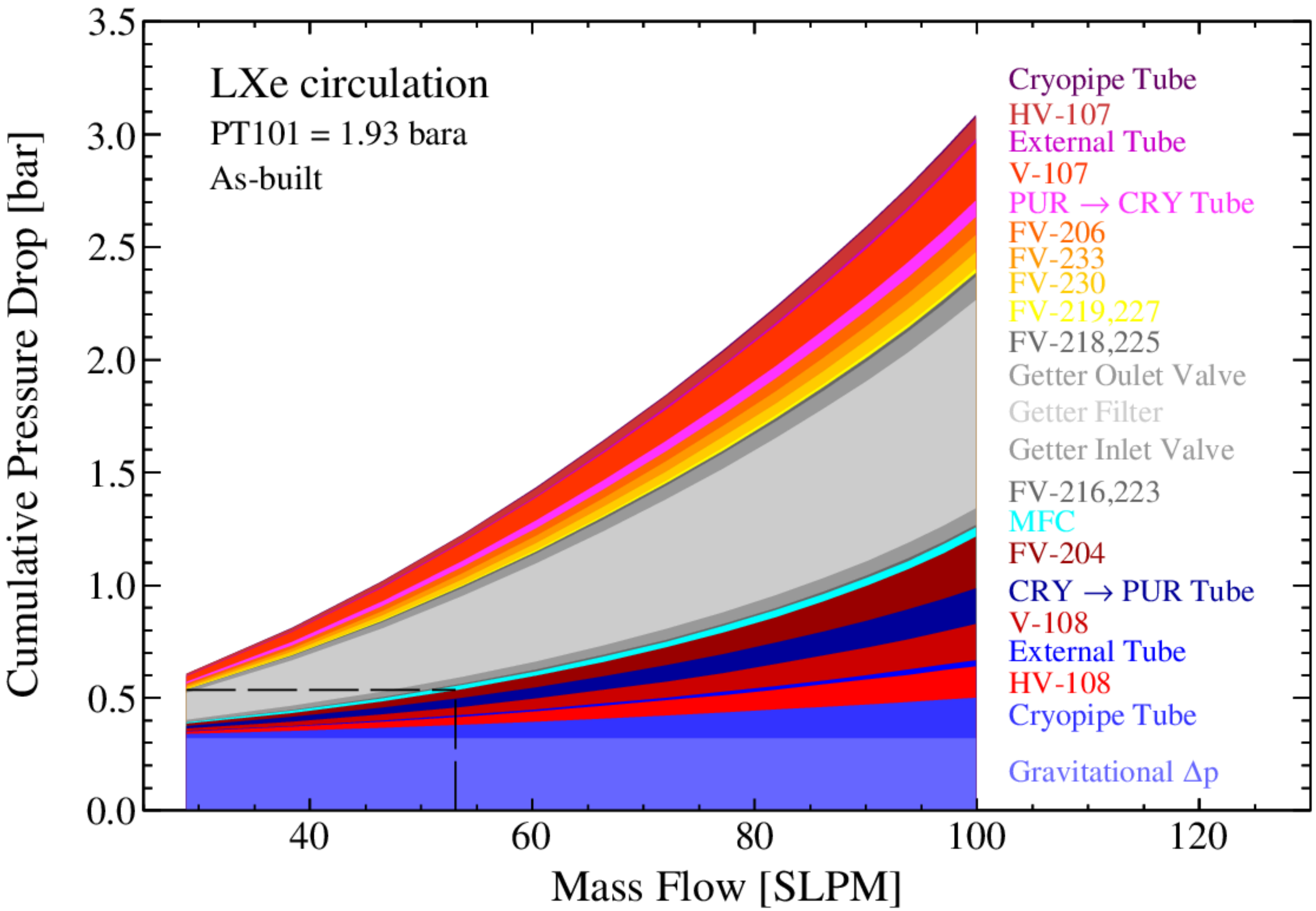
Most dominant component




- 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

# Lessons from XENON1T

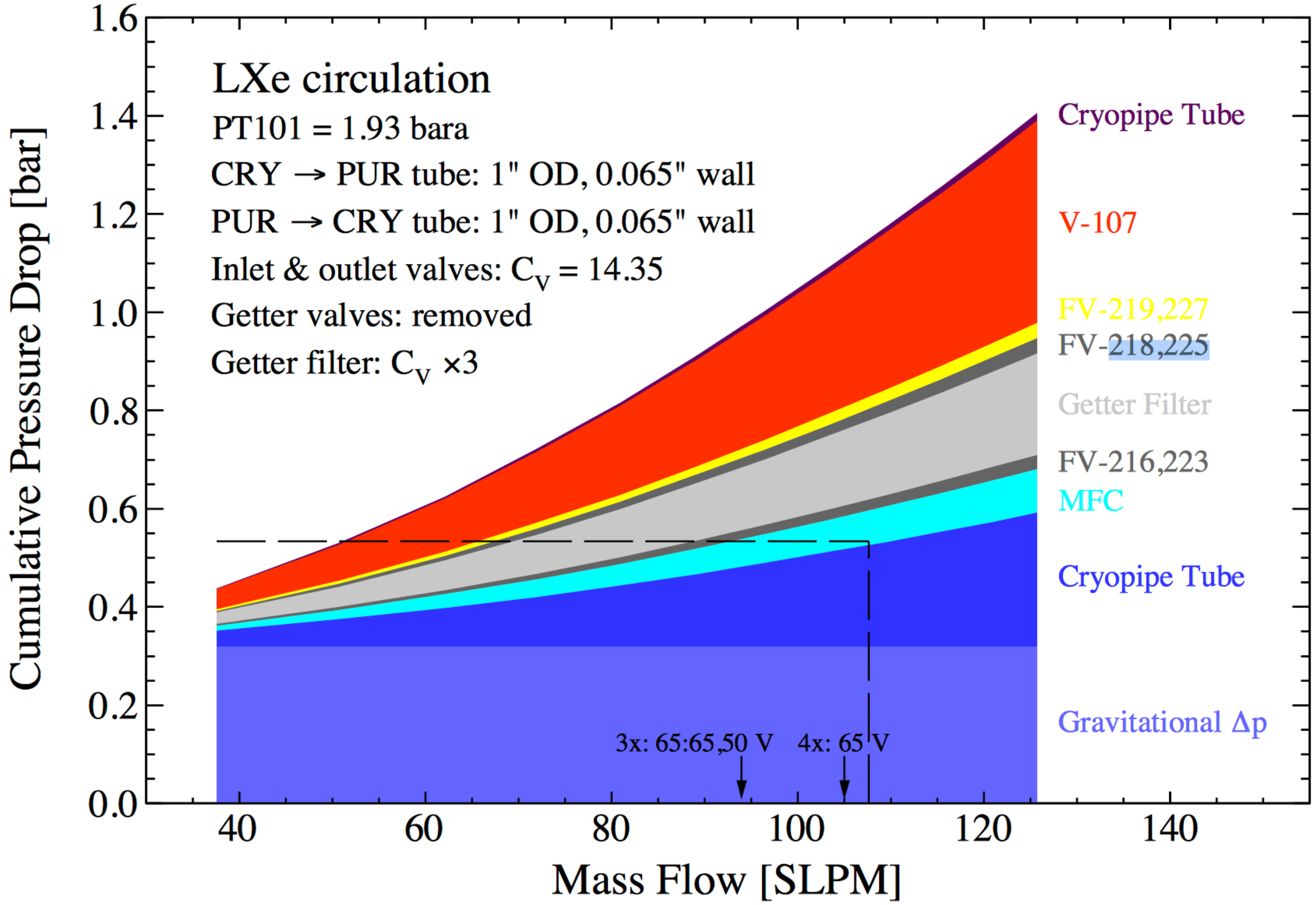



Pressure threshold at Q-drive inlet (~1.45bara) is the limitation for higher flow in Xe1T.

# XENONnT Purification

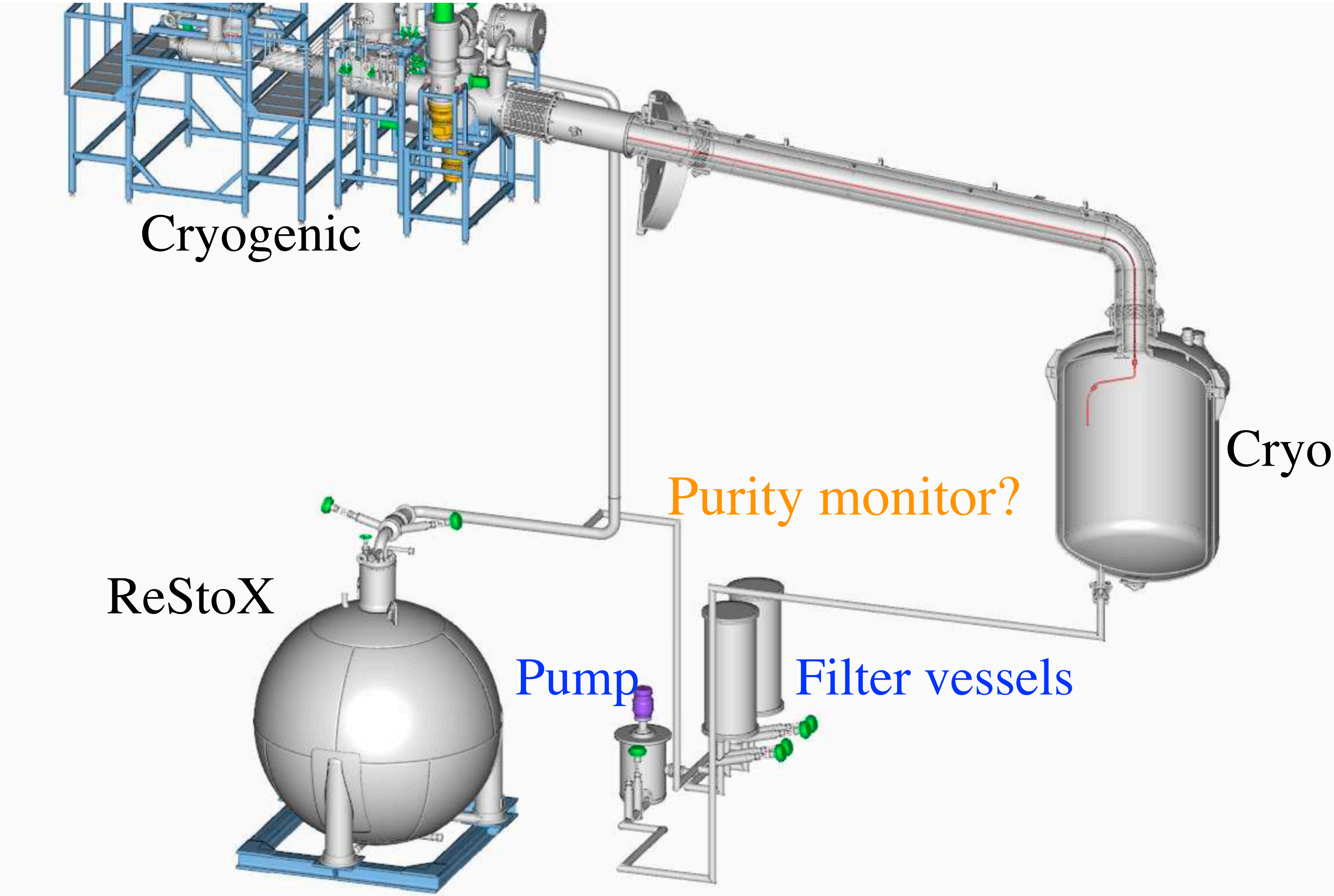
- Gas phase LXe/GXe purification
  - With our current understanding, using the XENON1T purification system as-is for XENONnT would roughly mean:
    - Bulk cleaning (exponential) phase would end after ~6 months when the electron lifetime is about $100\,\mu s$, when outgassing is in equilibrium with the removal rate
    - Slow decrease with time of outgassing leads to an increase of the electron lifetime to about $300\,\mu s$ after ~1.5 years
  - This comes from assuming 8000 kg LXe, that most impurities are released from materials in the LXe, and an increase in outgassing of a factor of $3^{2/3} \approx 2$ with respect to XENON1T
  - Planning to upgrade current XENON1T purification flow path to reduce the flow resistances in the circulation path considerably
- Cryogenic LXe purification
  - Attractive since easier to achieve large flows but no turn-key solutions for $O_2$ removal to sub-ppb levels in LXe
  - Some reagents tested in LAr can probably work but have large Rn emanation rates
  - About to start R&D with demonstrator facility at Columbia University

# XENONnT GXe Purification

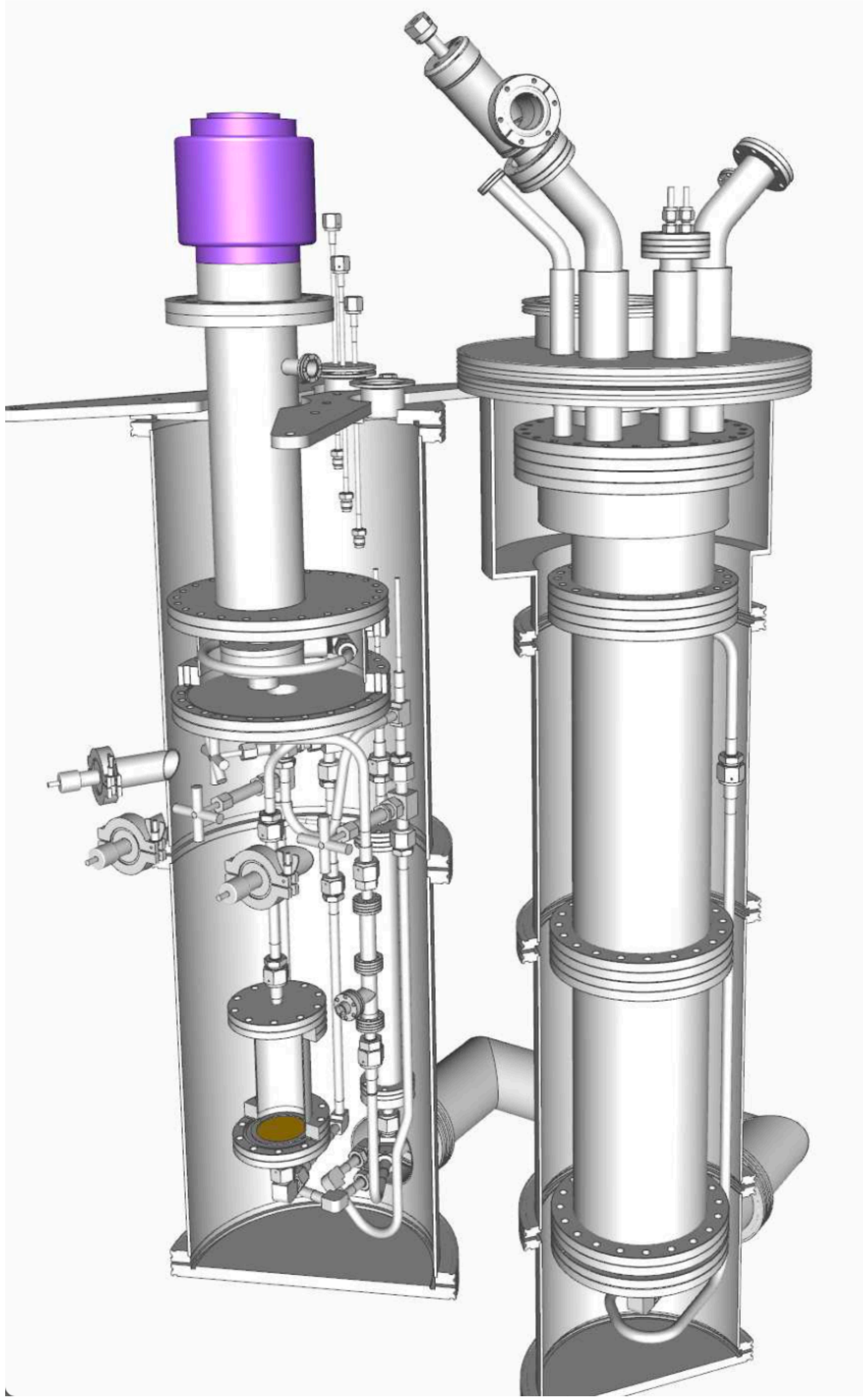



- ~120SLPM is achievable with the magnetically-driven piston pump.
- Flows much larger than that will be difficult with the 0.5 in tube inside the cryopipe.
- Also, getters are limited to about 60SLPM each so we would likely need additional getters
- With the previous assumptions, a purification flow of 120 SLPM for XENONnT would mean an electron lifetime roughly equivalent to that of XENON1T.
- An acceptable fallback plan if cryogenic LXe purification is not useable in XENONnT.

# XENONnT: Cryogenic LXe Purification



# XENONnT: Cryogenic LXe Purification: Test Facility



- Design of system completed, fabrication started
- Use XENON1T demonstrator cryostat with a "purity monitor"-type detector to measure electron lifetime for ultra-fast response
- Use cryogenic LXe pump with $100\,\mathrm{L/h}$ capacity and $2\,\mathrm{bar}$ pressure differential from Muenster
- Regenerate the $O_2$ filter while detector is operating
- Change $O_2$ filter type or geometry with detector operating
- Three types of $O_2$ reagents procured, can be tested for Rn emanation
- Strategy is to test filter $O_2$ absorption capacity and efficiency of different reagents under similar flow conditions and $O_2$ concentration as in XENONnT
- Given large Rn emanation rate from $O_2$ reagents identified, goal is to find minimum amount that can be used for purification

# XENONnT: Cryogenic LXe Purification: Test Facility