II South American Dark Matter Workshop

22nd November 2018

Status and Results from the XENON1T Dark Matter Experiment

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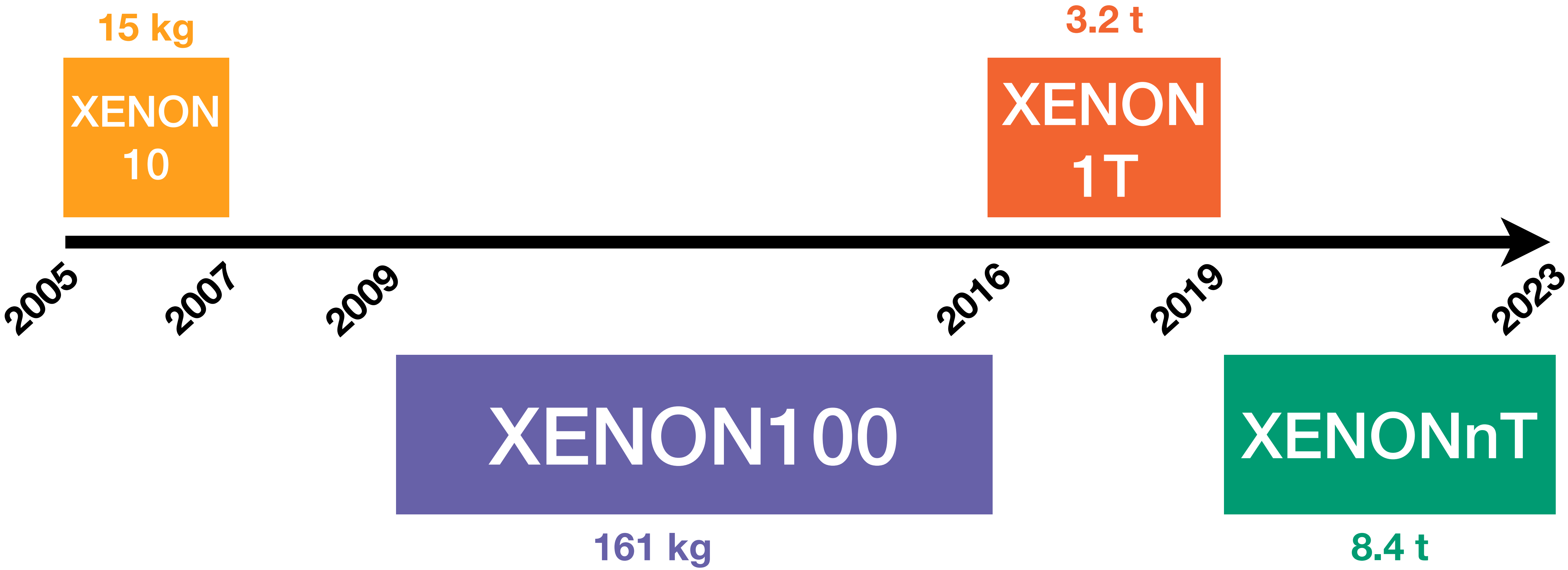
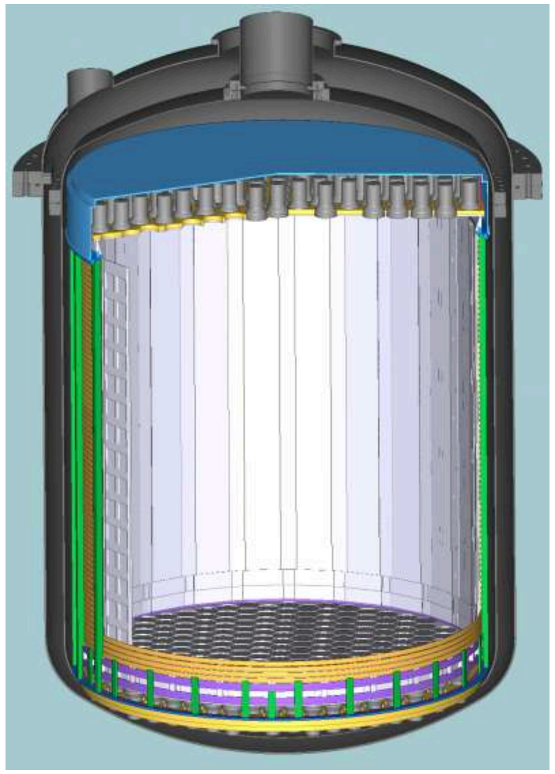
University of Zurich UZH

on behalf of the XENON Collaboration

XENON Dark Matter Project

Evolution of the XENON TPCs

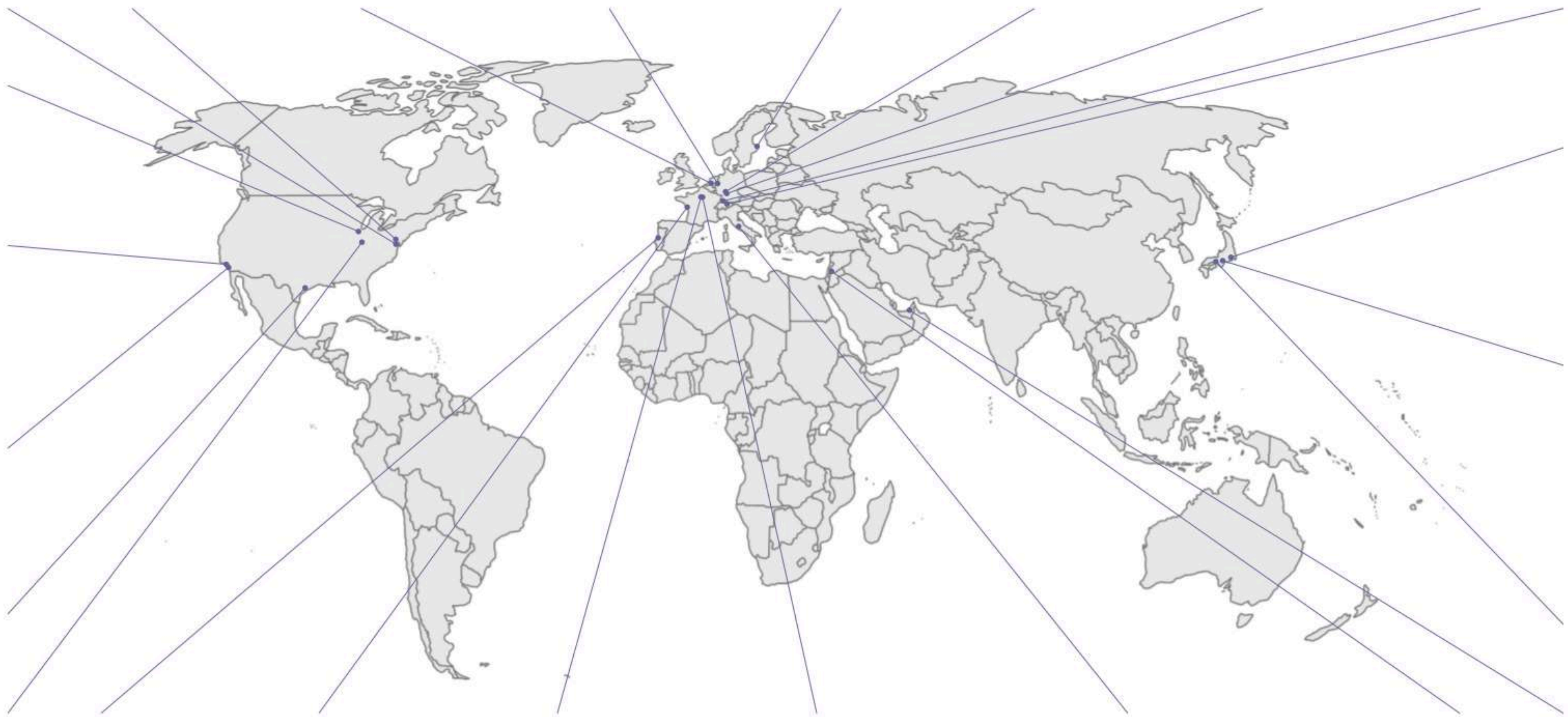




The XENON collaboration

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

Chicago | UCLA | UCSD | Rice



Tokyo | Nagoya | Kobe

Purdue | Coimbra | Subatech | LPNHE | LAL | Bologna | LNGS | Torino | Napoli | Weizmann | NYUAD

160 scientists

27 institutes

11 countries

XENON1T at LNGS

700 t
pure water

84
8-inch PMTs

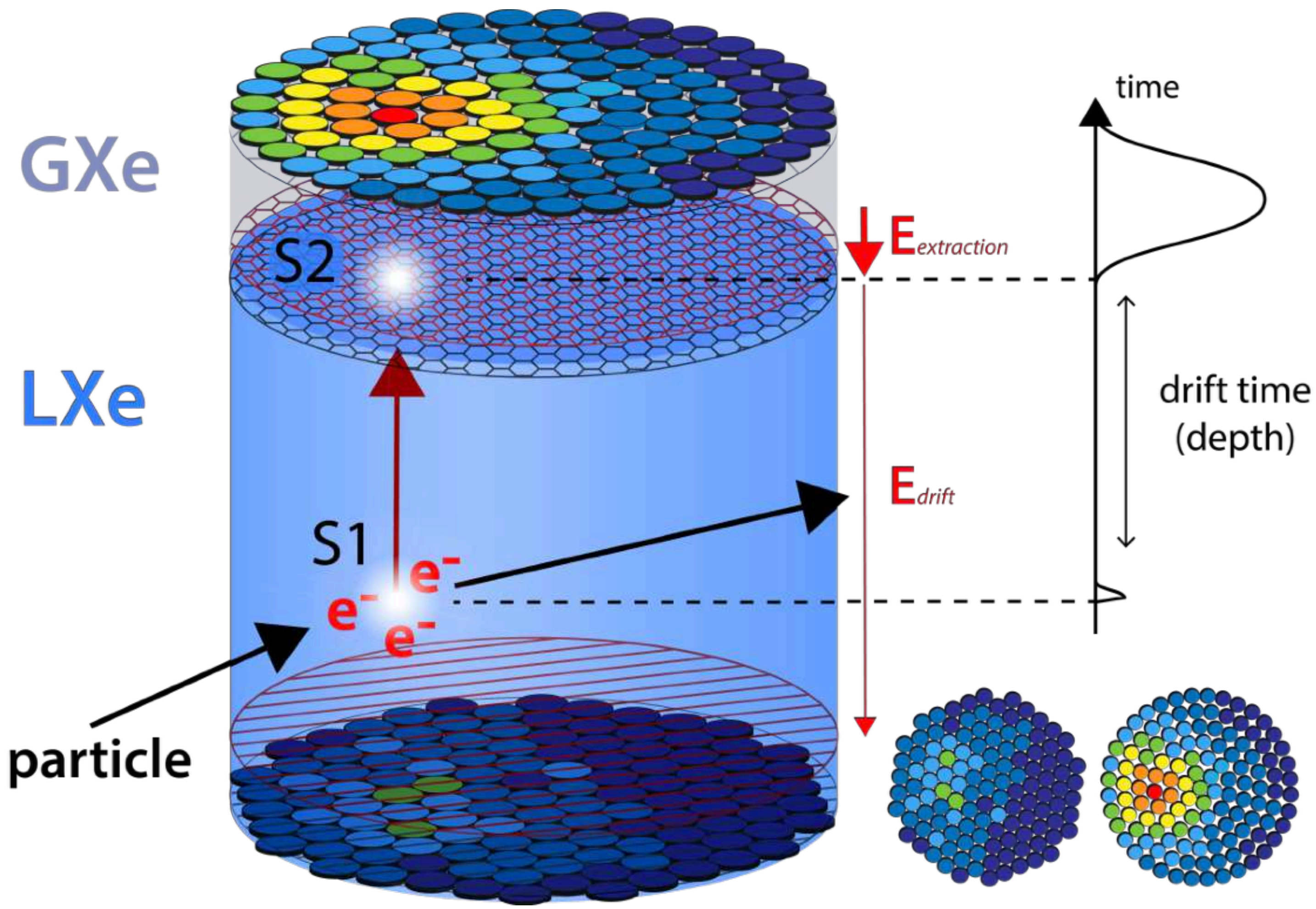
Cryostat

TPC

Google street view: tinyurl.com/lngstour

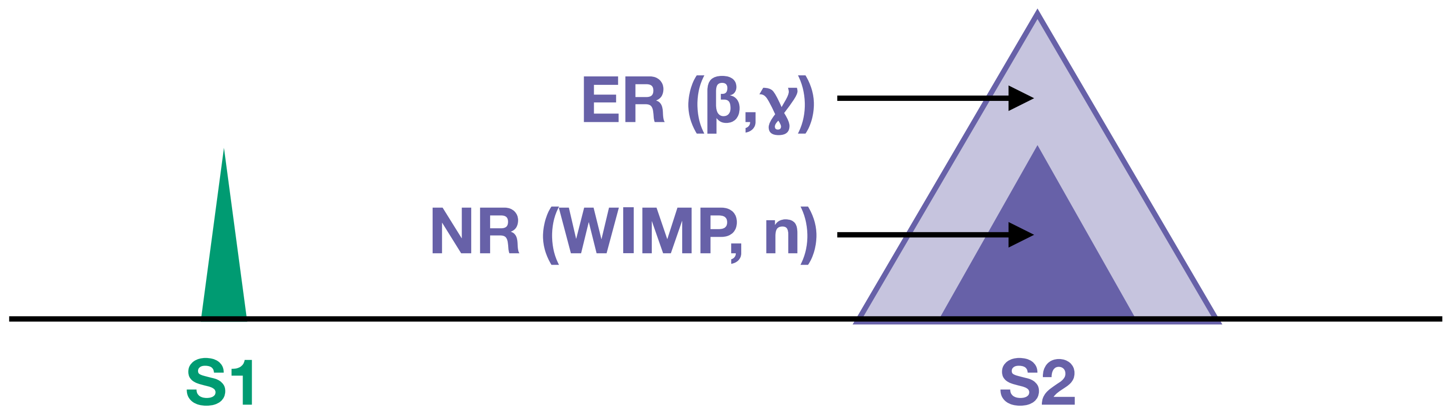
EPJ C 77:881 (2017)

Dual-phase time projection chamber



Particle interacts in liquid xenon
- S1: prompt scintillation signal
- S2: electrons drifted to gas produce proportional scintillation signal
- Heat

Position reconstruction
- (*x*, *y*) from S2 pattern on top PMTs
- *z* (depth) from S1 – S2 delay



Particle type identification
- S2:S1 ratio different for electronic recoils (β, ɣ) and nuclear recoils (WIMP, n)

TPC in XENON1T

TPC

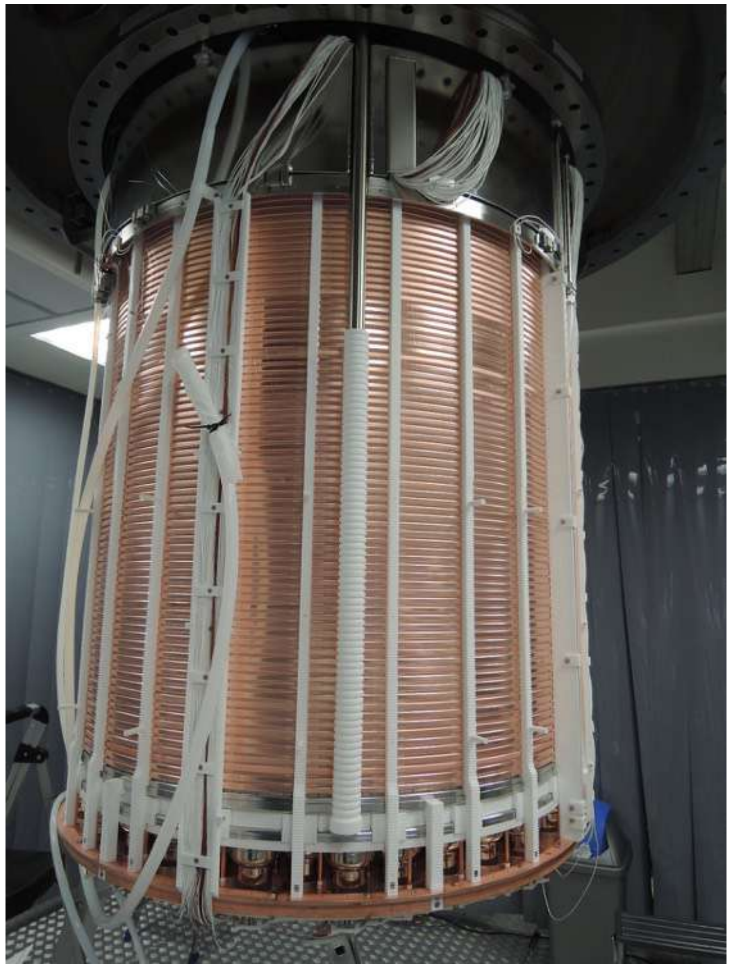
holding 2 t
liquid xenon

~ 1 m diameter
~ 1 m length

Highly reflective
PTFE walls

74 copper field
shaping rings

Five high-transparency
electrodes

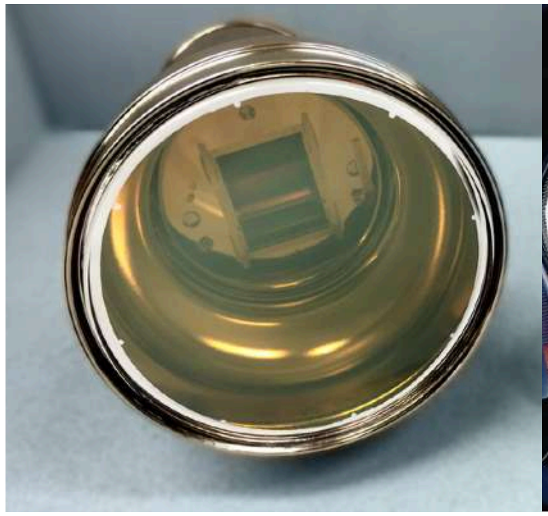


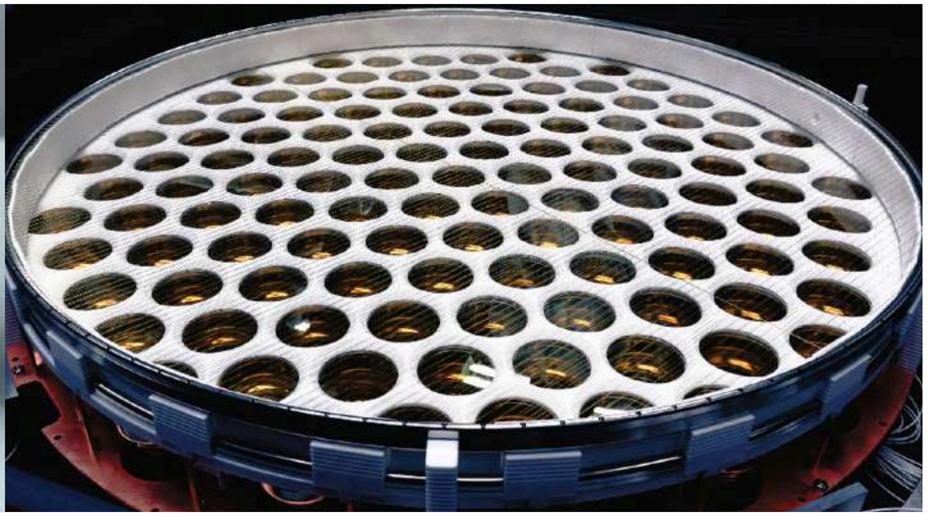
PMTs

Hamamatsu R11410-21

248 3-inch PMTs in XENON1T
low radioactivity & VUV-sensitive
QE ~ 35% at 175 nm

EPJ C 11:546 (2015)

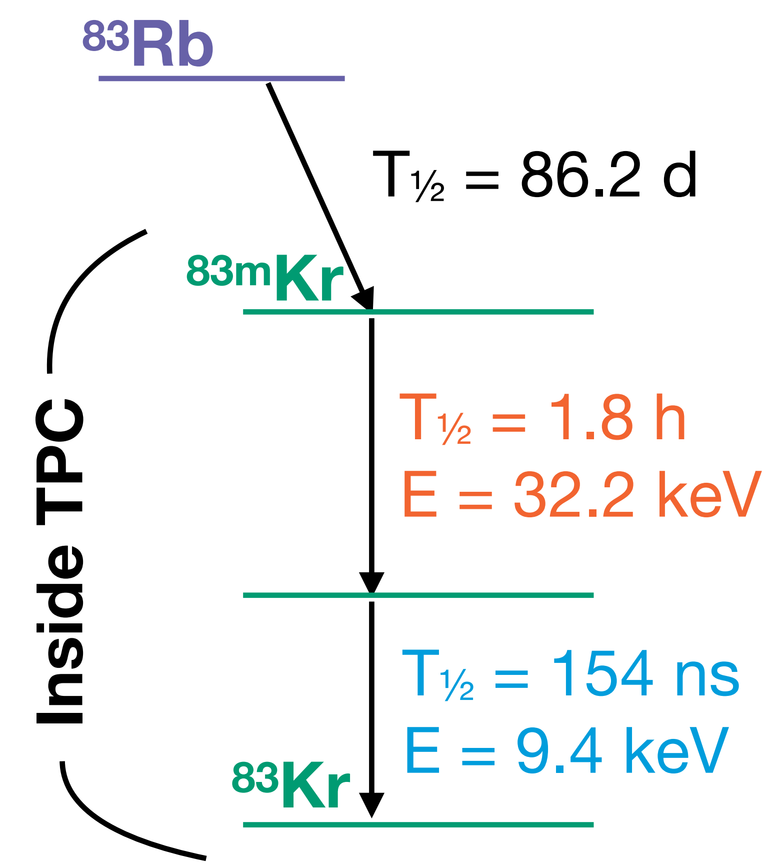




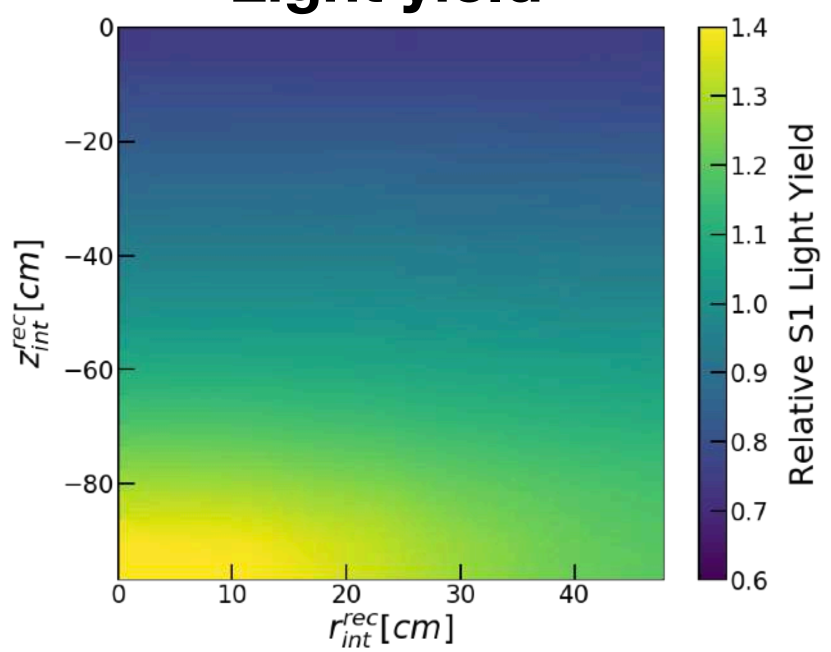
Detector response

83mKr as calibration source

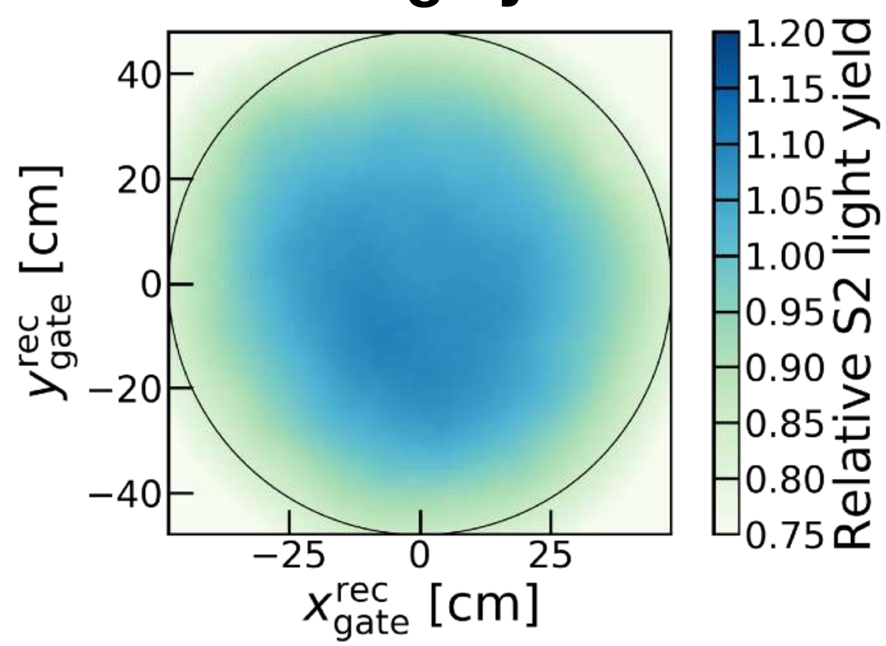
- Injected into LXe
- Double emission allows very pure identification
- Used to correct spatially varying detector response:
    - S1: light collection efficiency (x, y, z)
    - S2: electron lifetime (z), charge amplification (x, y)
    - Position: due to non-uniform field (x, y, z)



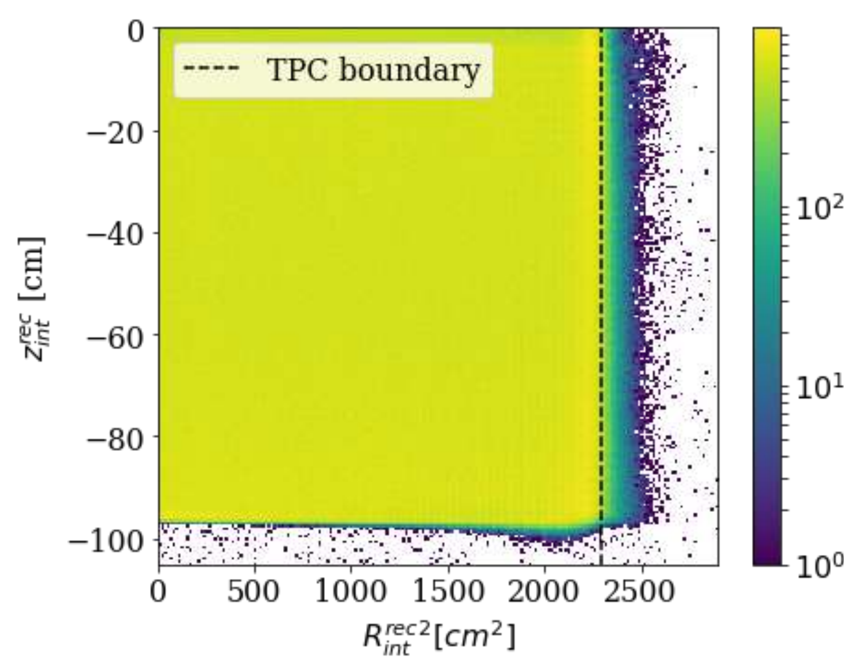
Light yield



Charge yield



Field uniformity

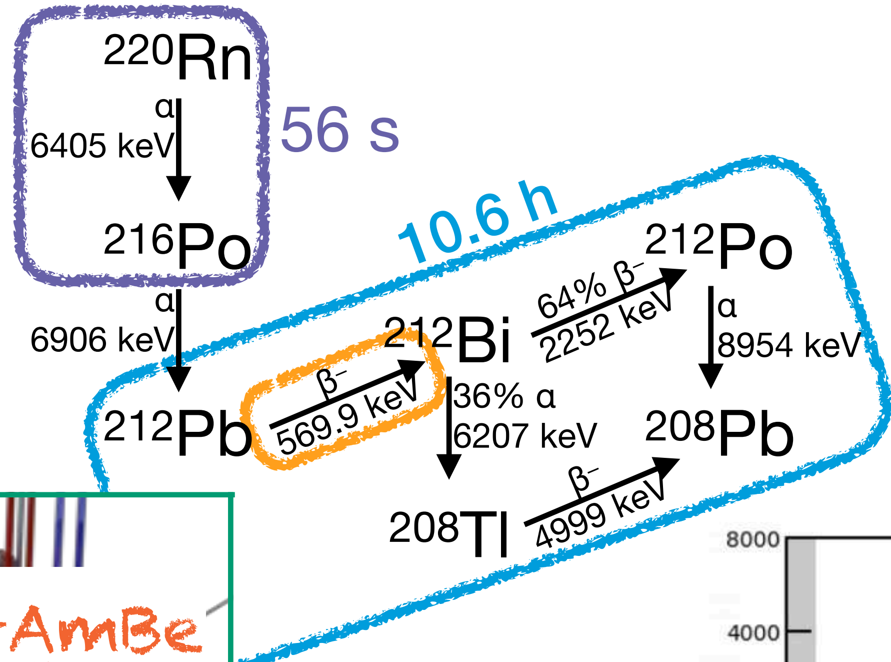


Calibration of ER / NR bands

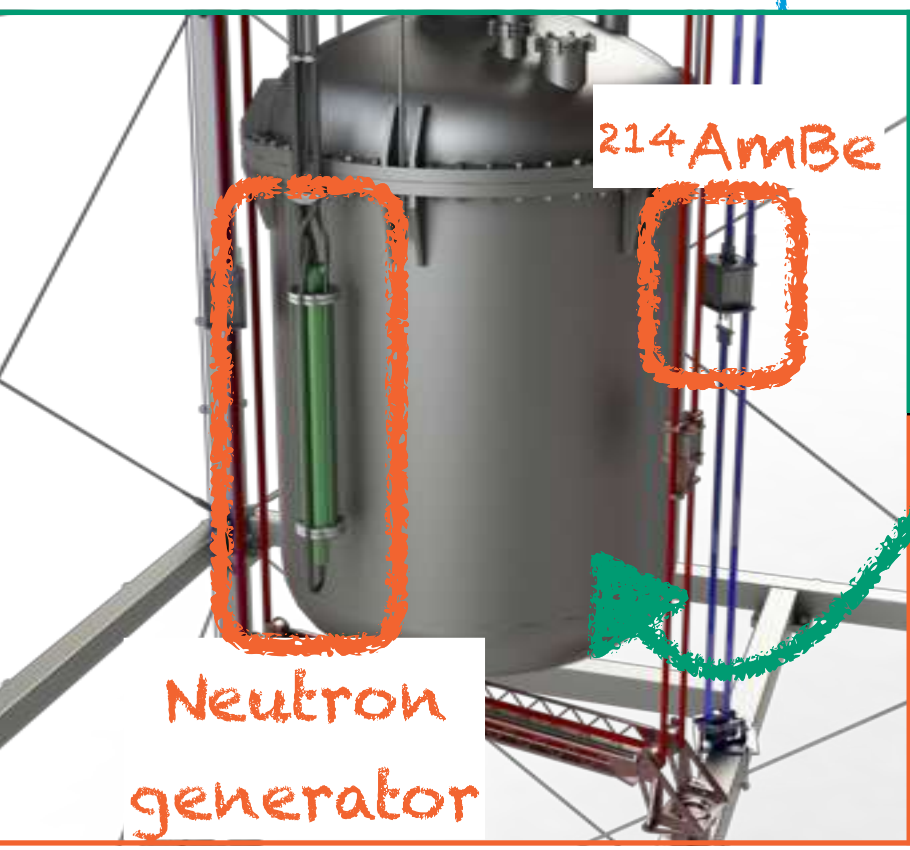
JINST 11:P04004 (2016)

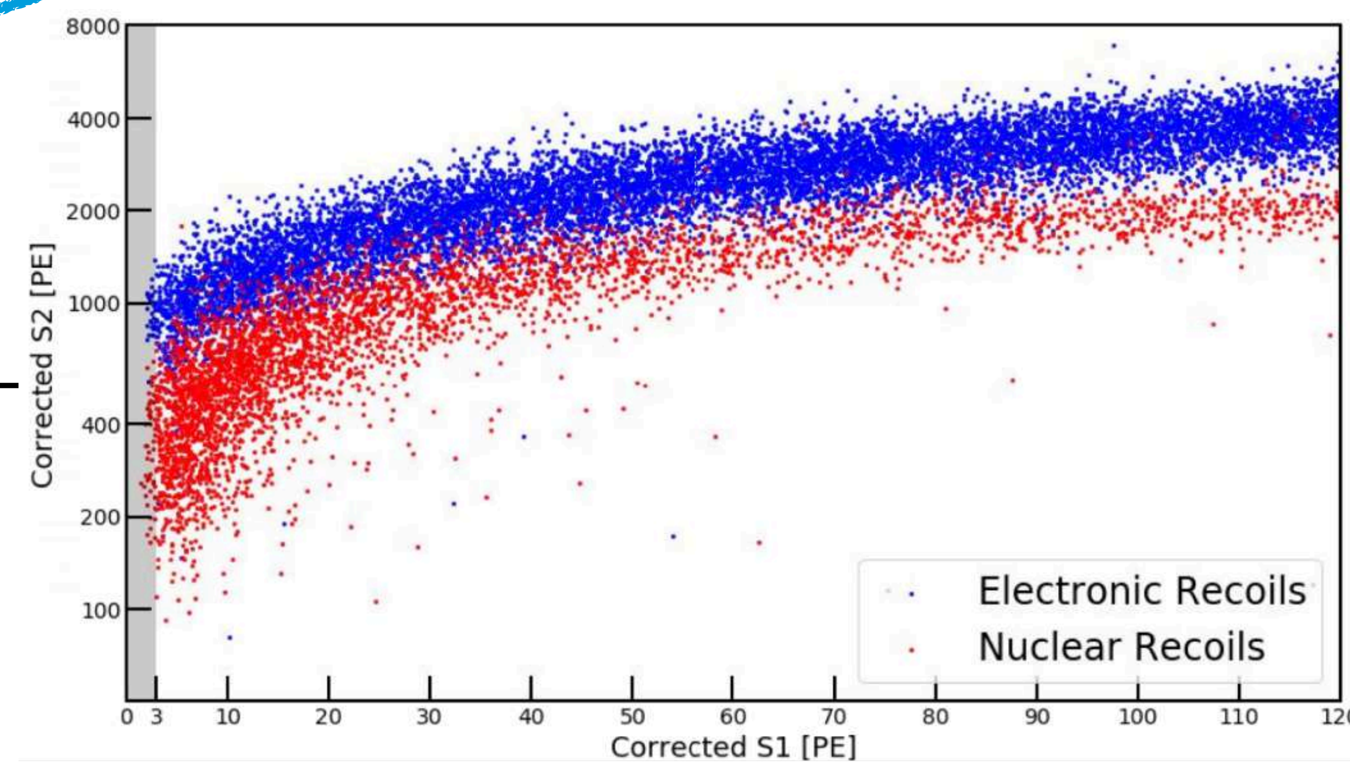
Electronic recoils

^{220}Rn injected
into liquid xenon
Decays away
in few days



^{212}Pb β^- decay:
continuous low E spectrum





External sources mounted on belt system
D-D fusion generator

High neutron flux (2000 n/s)
Reduce calibration weeks → days
compared to AmBe source

Nuclear recoils

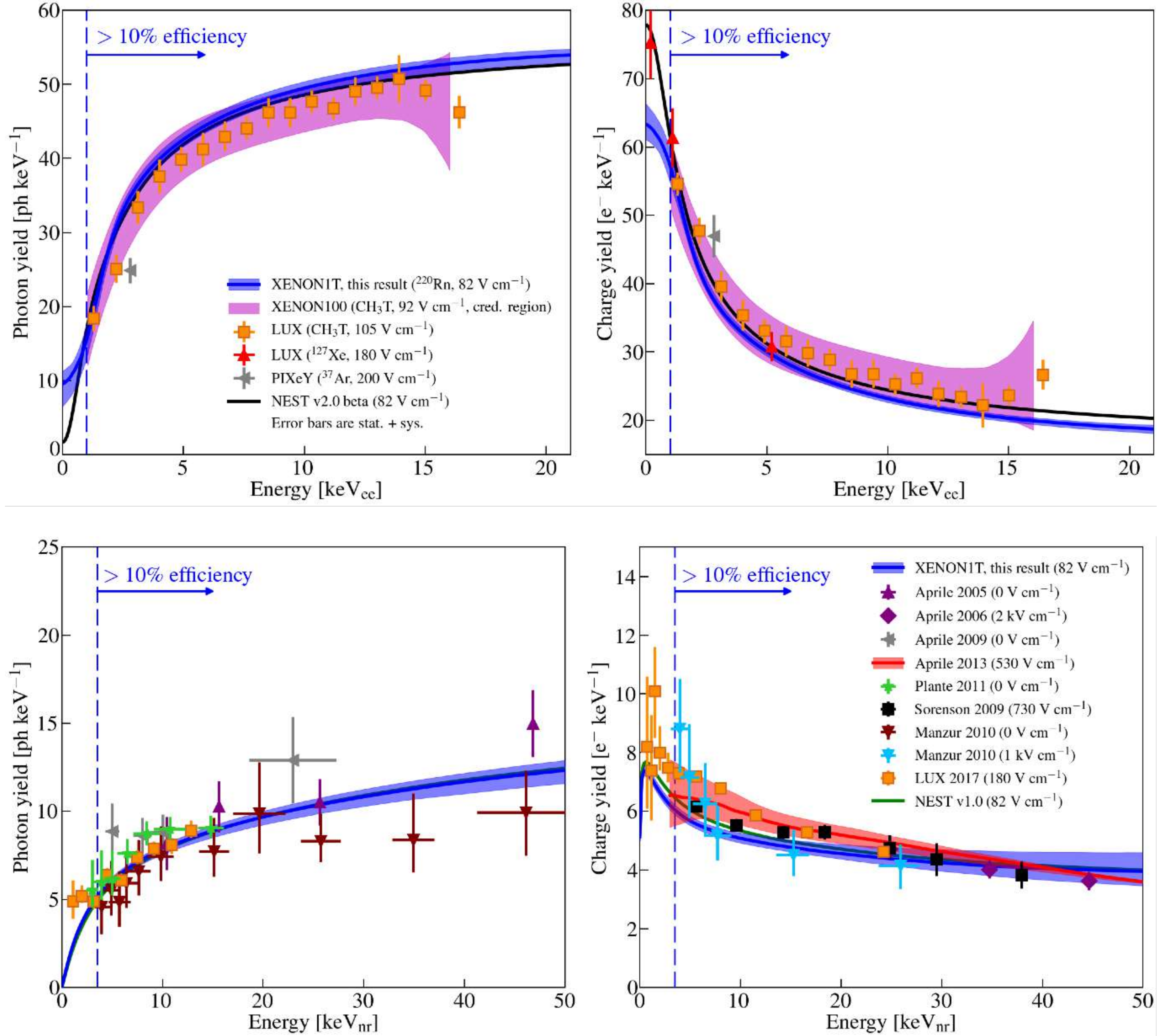
Nucl. Inst. Meth. A 879:31 (2018)

Calibration of ER / NR bands

Models for detector response physically motivated from LXe microphysics
Fit with the calibration data

ER

NR



ER backgrounds

4.1% Materials

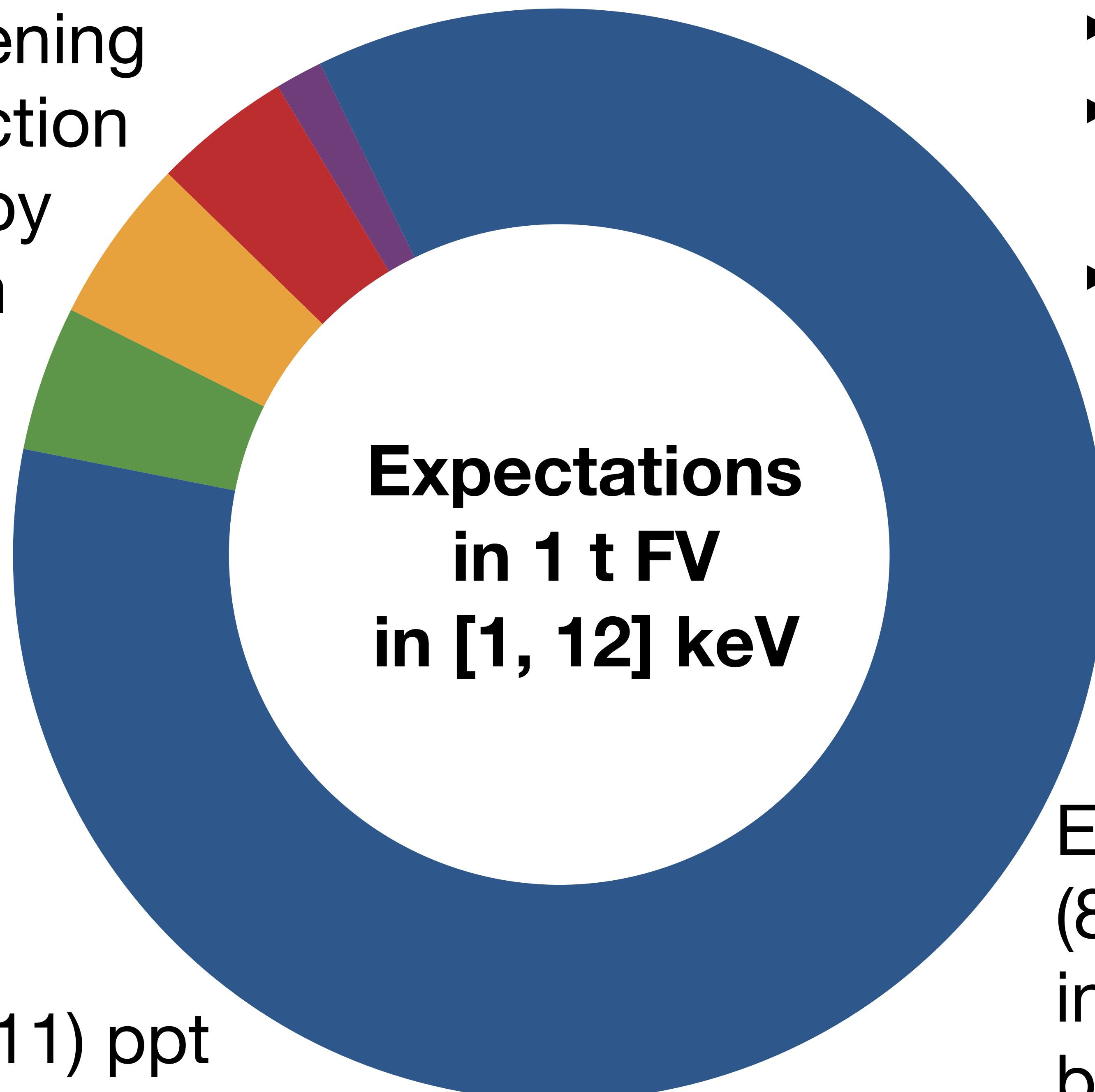
- HPGe γ screening
- Material selection
- Suppressed by fiducialisation

1.4% ^{136}Xe

85.4% ^{222}Rn

- ~ 10 μBq/kg
- Control surface emanation
- Further reduction by online distillation (more later)

4.9% Solar ν



4.3% ^{85}Kr

- Cryogenic distillation
- ^{nat}Kr (0.66 ± 0.11) ppt

EPJ C 77:275 (2017)

ER Rate
(82 ± 5) ev/(keV t y)
in 1.3 t
below 25 keV_{ee}

Lowest ER background ever achieved in DM detector

JCAP 04:027 (2016)

NR backgrounds

< 0.01 ev Cosmogenic n

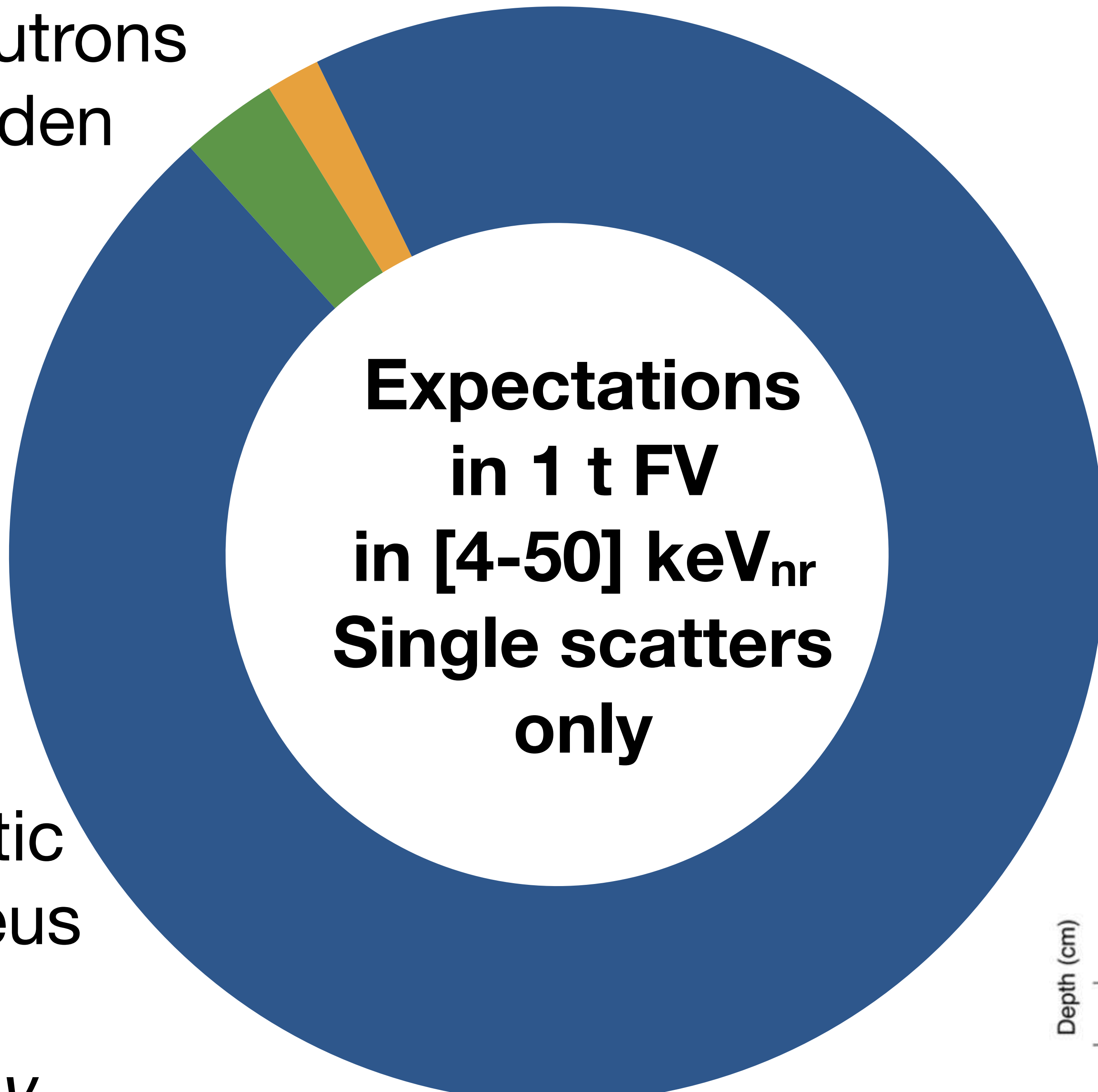
- μ-induced neutrons
- Rock overburden
- Muon veto

JINST 9:P11006 (2014)

0.6 ev Radiogenic n

- From (α, n) and spontaneous fission
- Material selection
- Mostly multiple scatter
- Fiducialisation

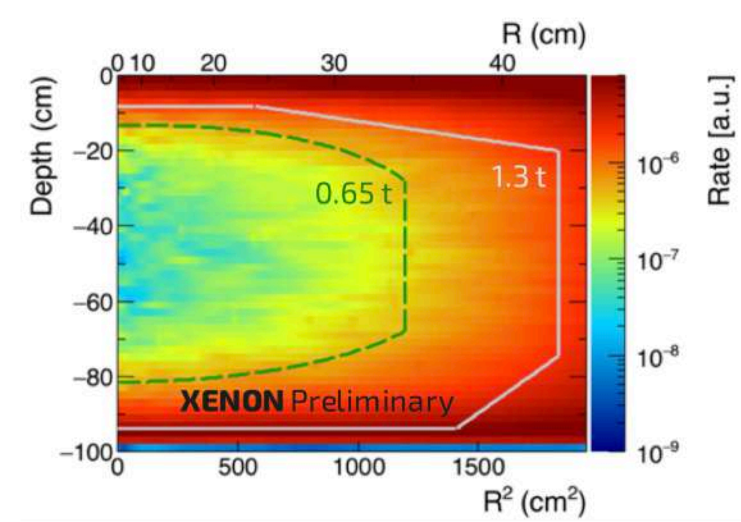
EPJ C 77:890 (2017)



0.02 ev CEνNS

- Coherent elastic neutrino-nucleus scattering
- From ^{8}B solar ν
- Irreducible, very low energy (< 1 keV)

JCAP 04:027 (2016)



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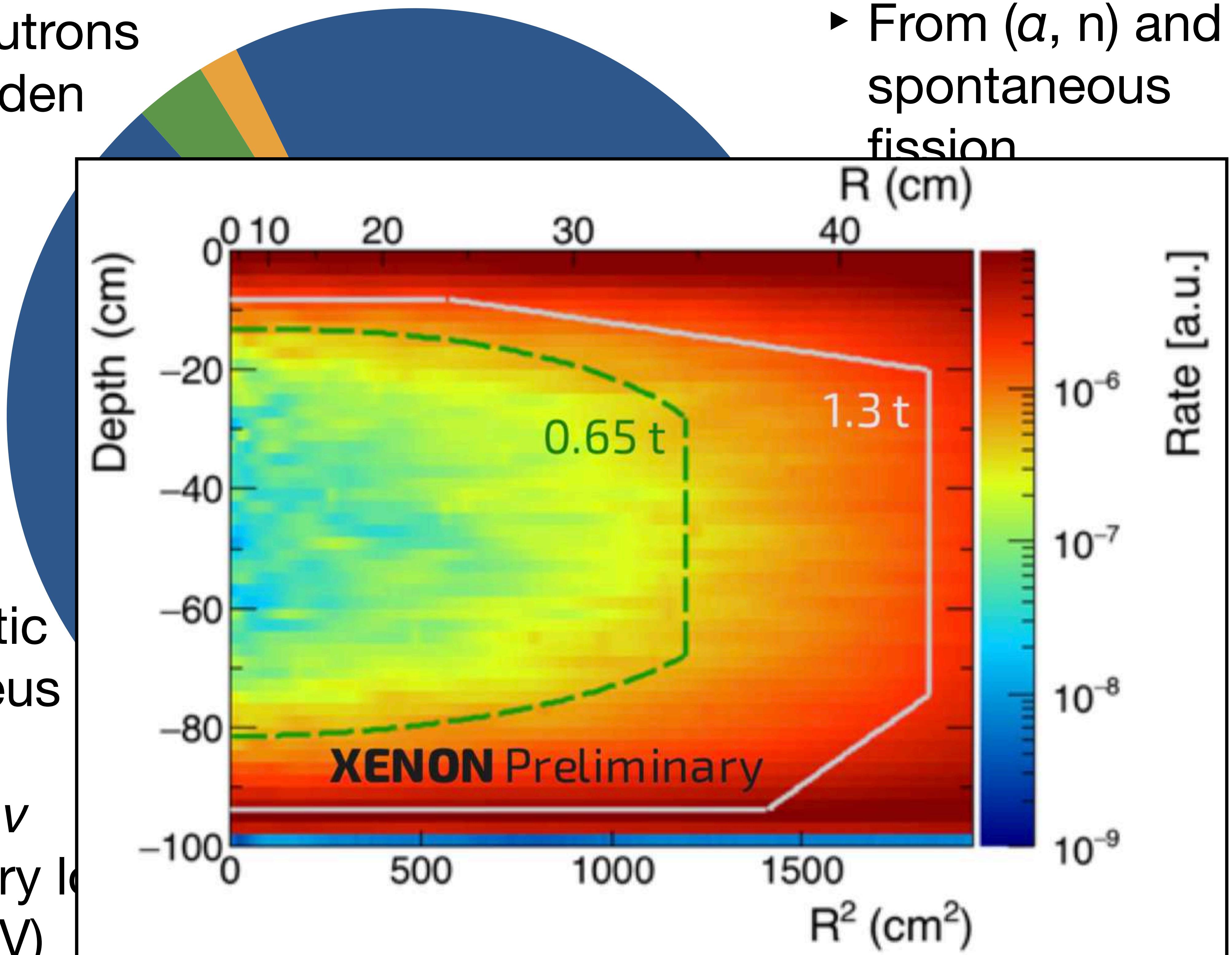

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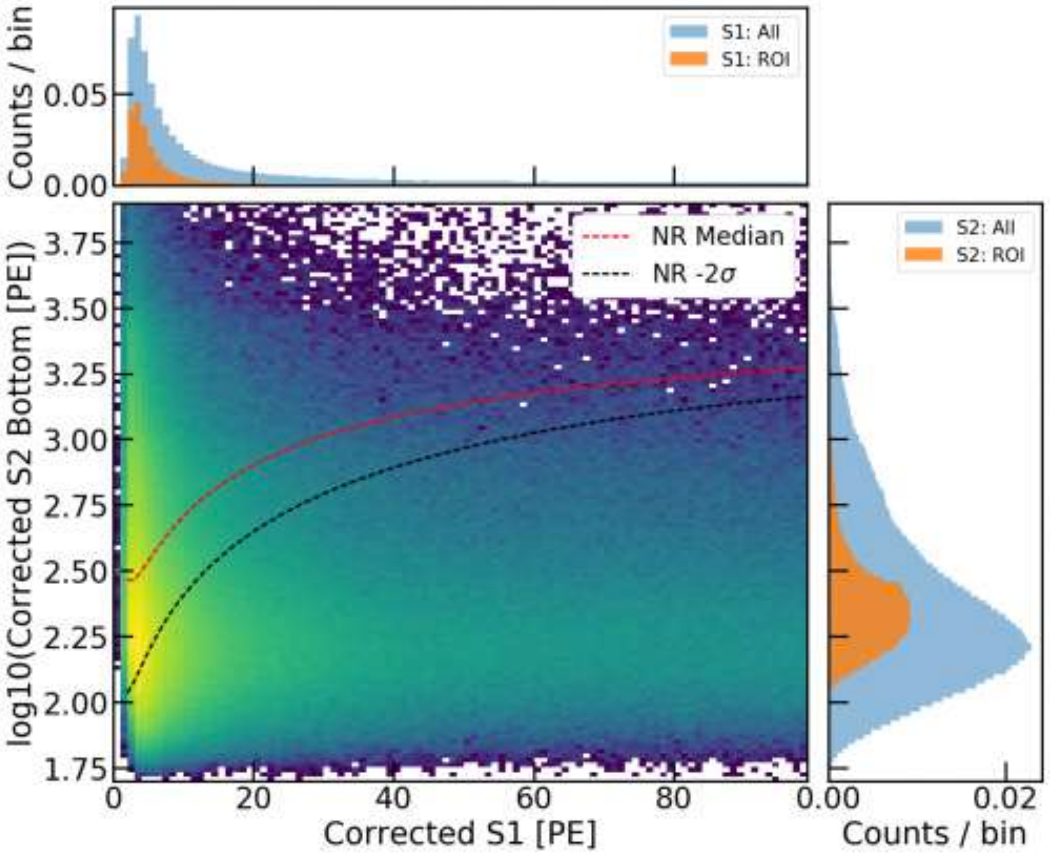
- Irreducible, very l… energy (< 1 keV)

Other backgrounds

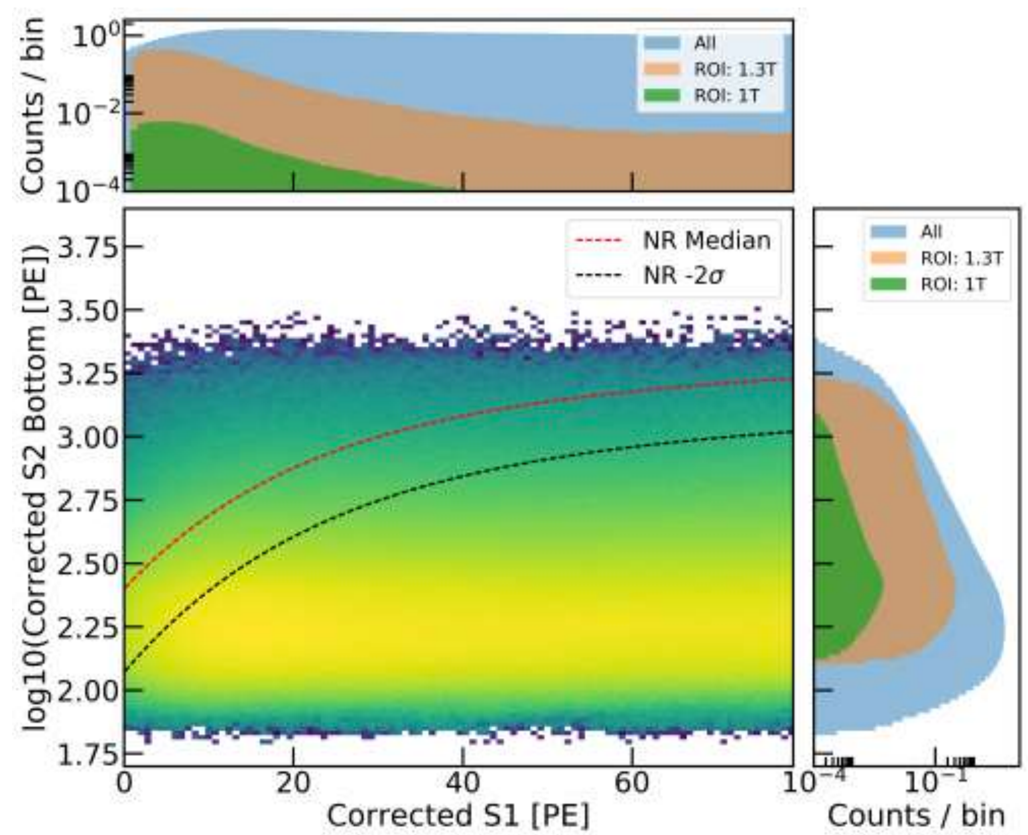


Accidental coincidence

- Random pairing of S1-like and S2-like lone signals

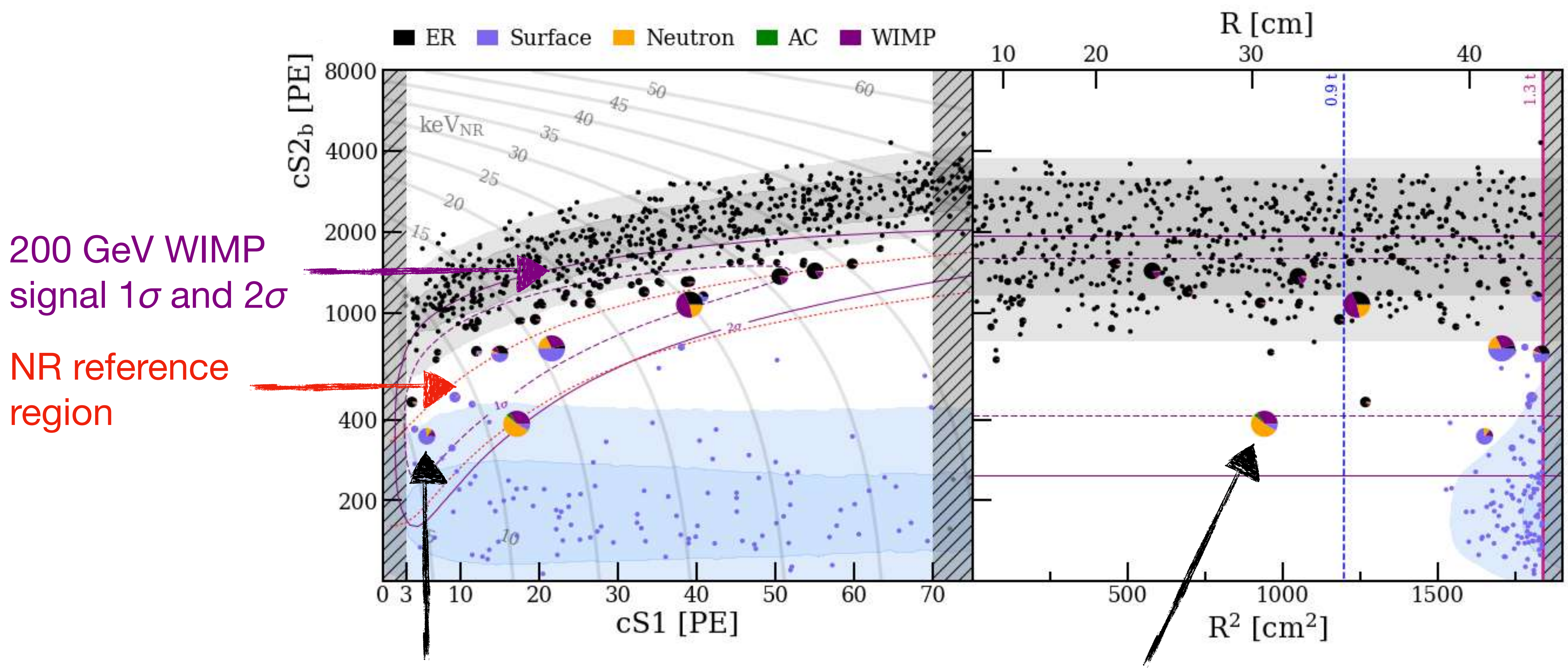
Surface events

- Events at outer edge of TPC
- Position reconstruction trickiest here
- Charge loss on walls



Dark matter search results

- Results interpreted with **profile likelihood analysis**
- 4 dimensions:
  3 unbinned: cS1, $cS2_{bottom}$, R
  1 binned (binary): core 0.65 t volume with low radiogenic n rate



Pie charts show relative contribution of each component to that event's PDF

Large pie charts have more WIMP probability

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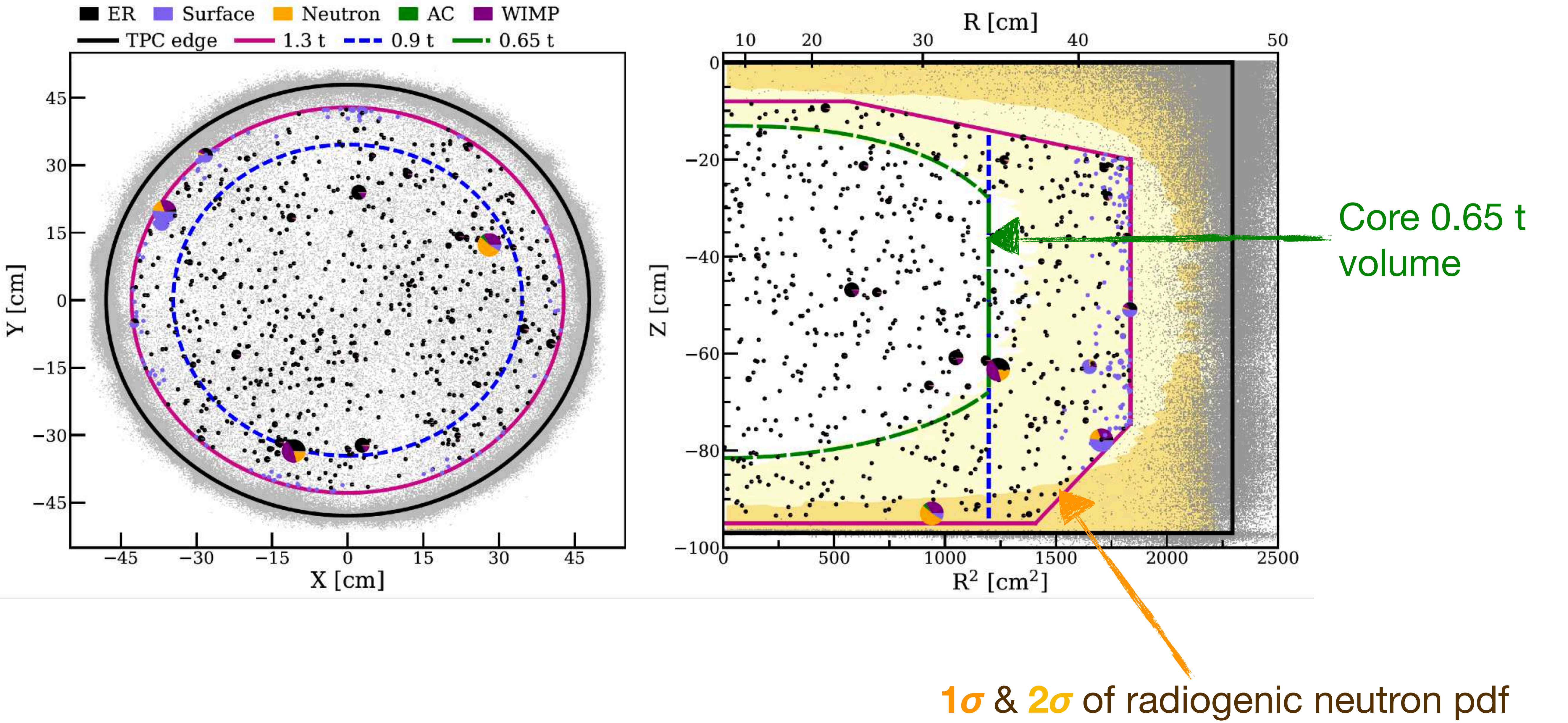


Limit on WIMP cross-section

Sensitivity

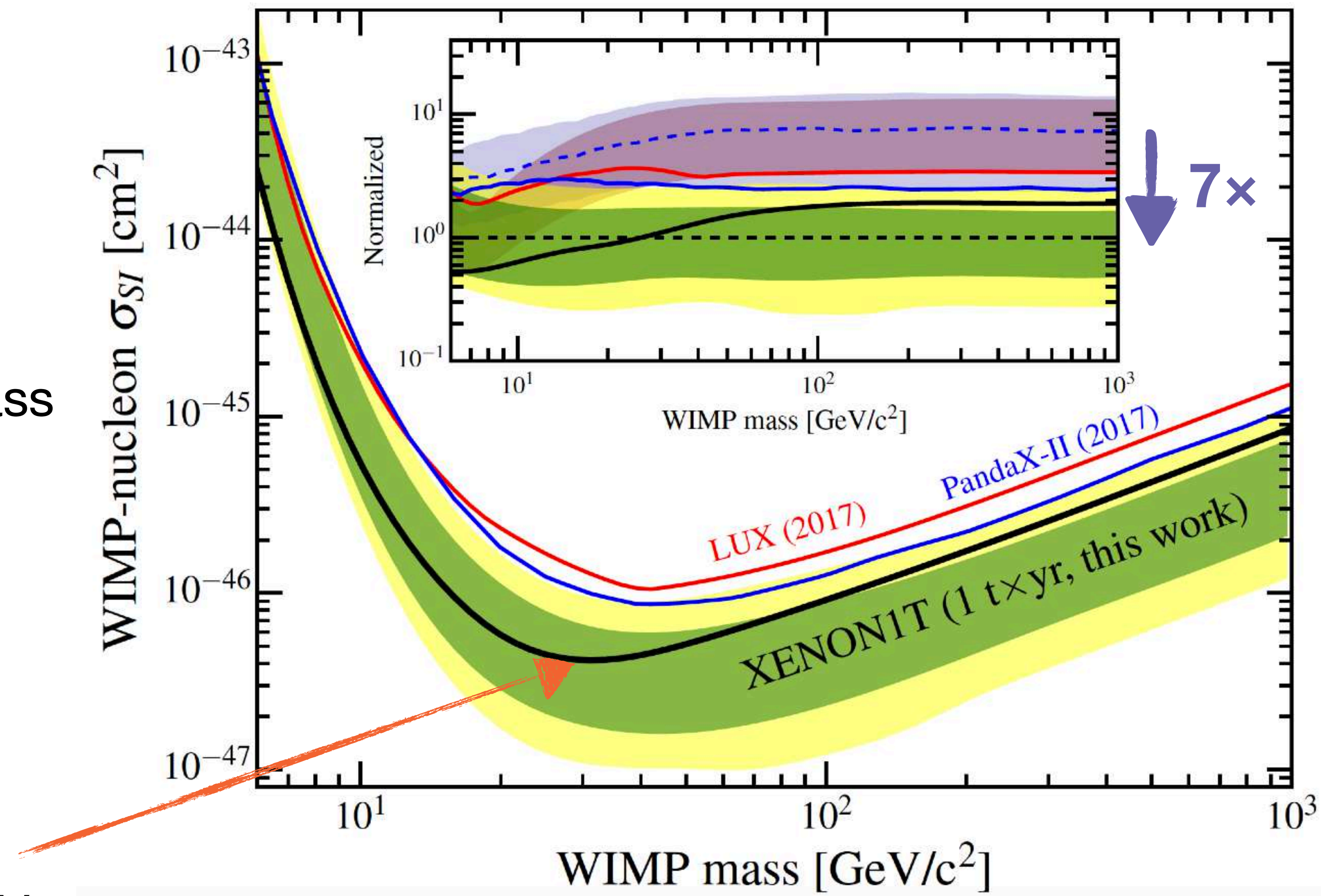
- 7-times improvement of previous-generation experiments

Limit

- Strongest exclusion limits for WIMPs above 6 GeV
- Under fluctuation < 8GeV
  Over-fluctuation for higher mass

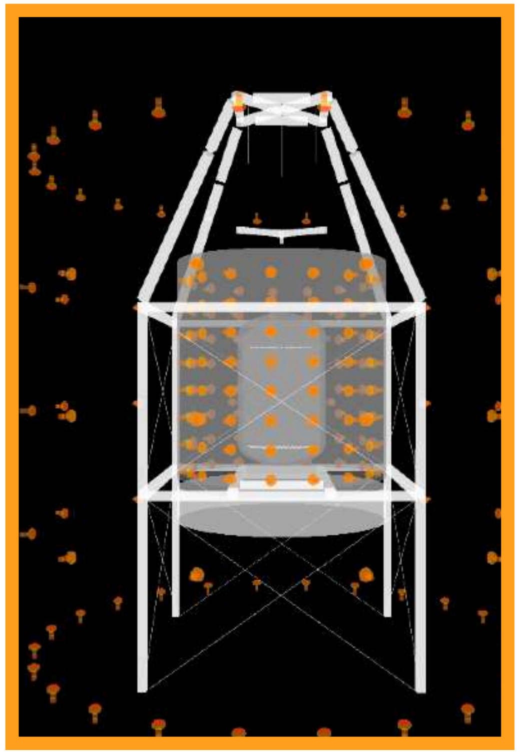
Minimum

$\sigma_{SI} < 4.1 \times 10^{-47}$ cm^2 at 30 GeV



Phys. Rev. Lett. 121, 111302 (2018)

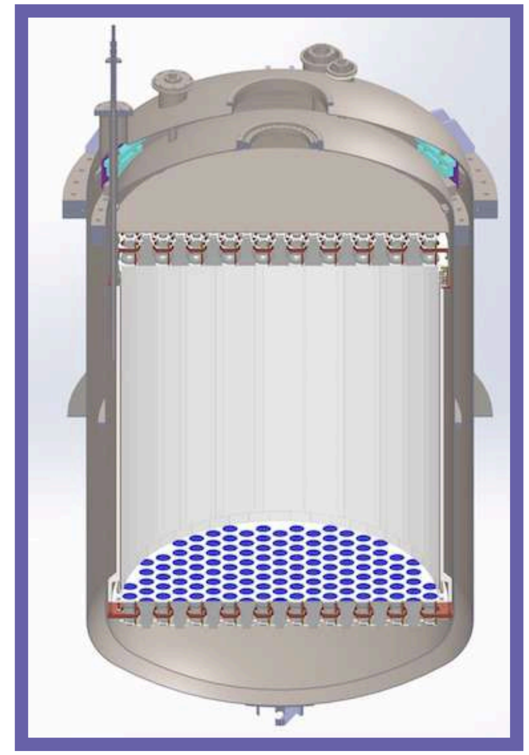
Outlook: XENONnT



neutron veto

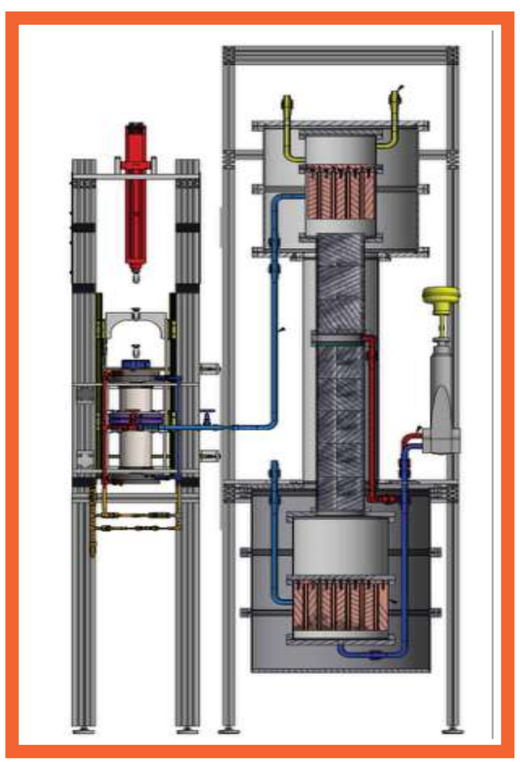
- Inner region
- optically separate
- extra PMTs

- Gd in the water tank
- 0.5% $Gd_2(SO_4)_3$



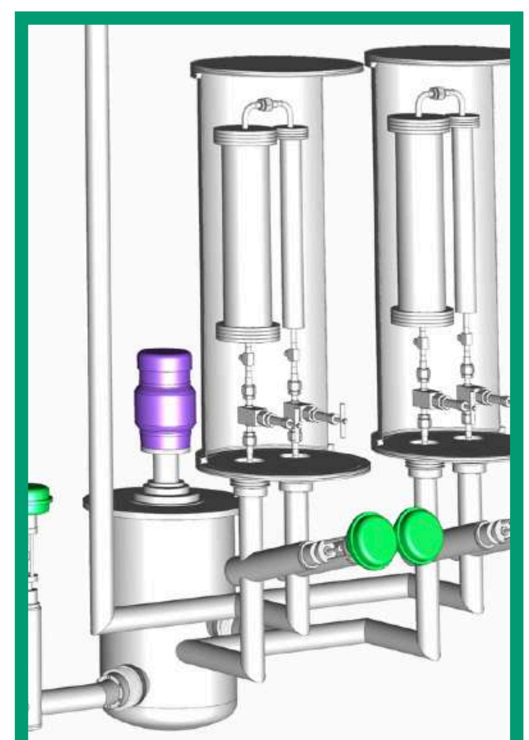
larger TPC

- Total 8.4 t LXe
- 5.9 t in TPC
- ~ 4 t fiducial



^{222}Rn distillation

- Reduce radon from pipes, cables, cryogenic system



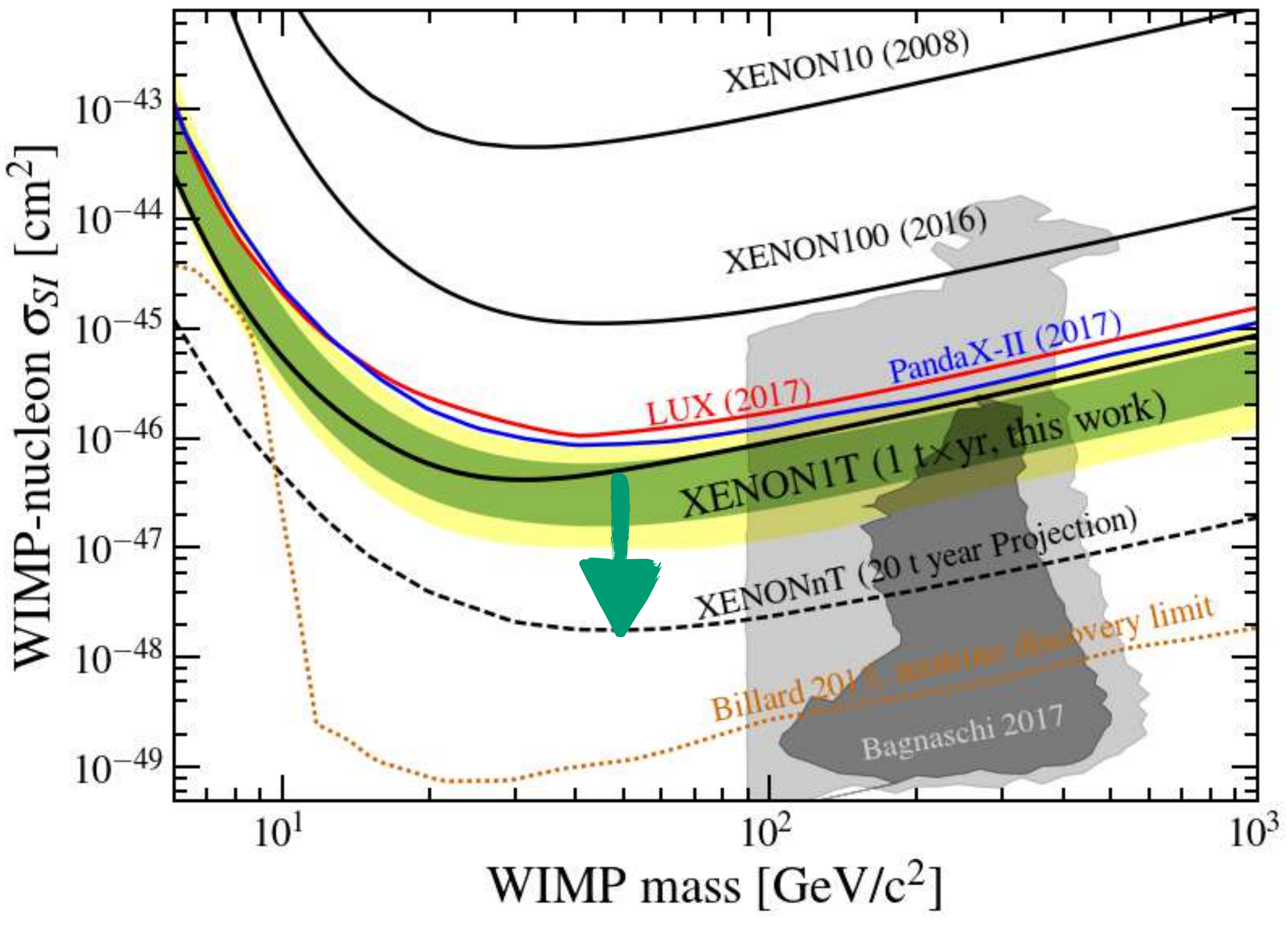
LXe purification

- Faster xenon cleaning
- 5L/min LXe (2500 slpm)
- Now: 120 slpm

Summary

XENON1T

- First multi-ton scale LXe TPC
- Stable operation > 1 year
- More results on the way: annual modulation, low-mass WIMP, 0νββ, solar axions, dark photons



XENONnT

- 4–5× bigger fiducial mass
- 10× better sensitivity
- Preparations and tests underway
- Construction starting early next year
- Commissioning 2019

Stay tuned for more exciting results

contact@xenon1t.org

www.xenon1t.org

@xenon1t

XENON Dark Matter Project

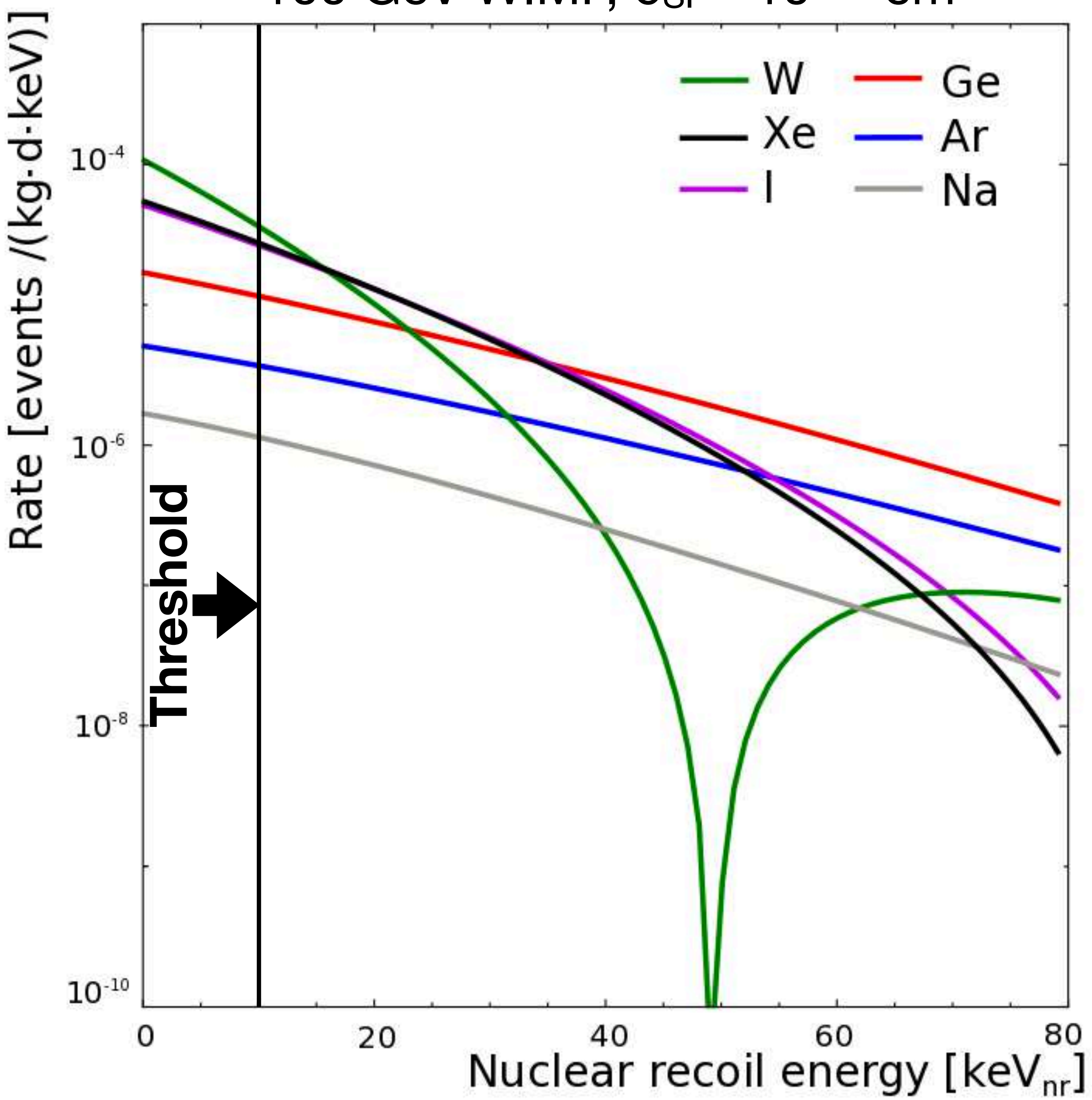
University of Zurich UZH

Backup slides

Why xenon as a target?

- High atomic mass
- Self-shielding
- ~ 50% odd-nucleon isotopes
- 178 nm scintillation light detectable directly — no wavelength shifters
- Radioactively pure: all isotopes either stable, short lifetime (≤36 d), or long lifetime (^{136}Xe: 2.2×10^{21} y)
- High charge & light yield
- High boiling point (~ –100 °C)

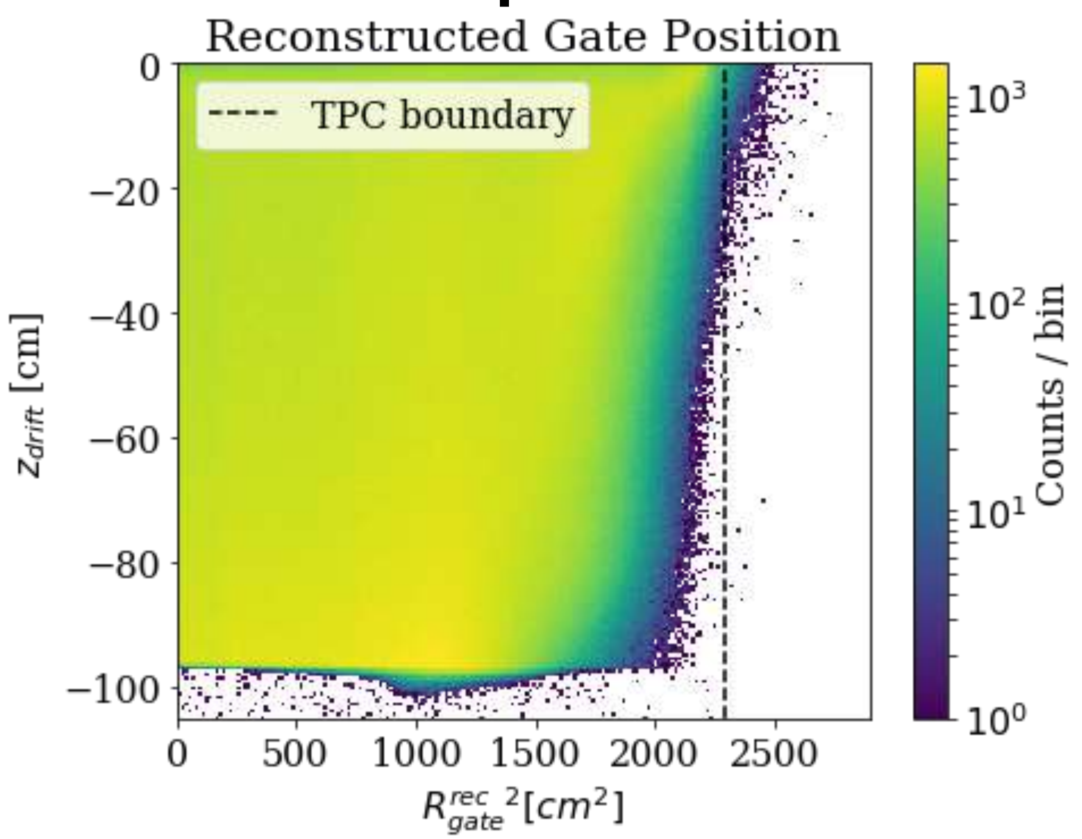
100 GeV WIMP, $\sigma_{SI} = 10^{-45}$ cm^2



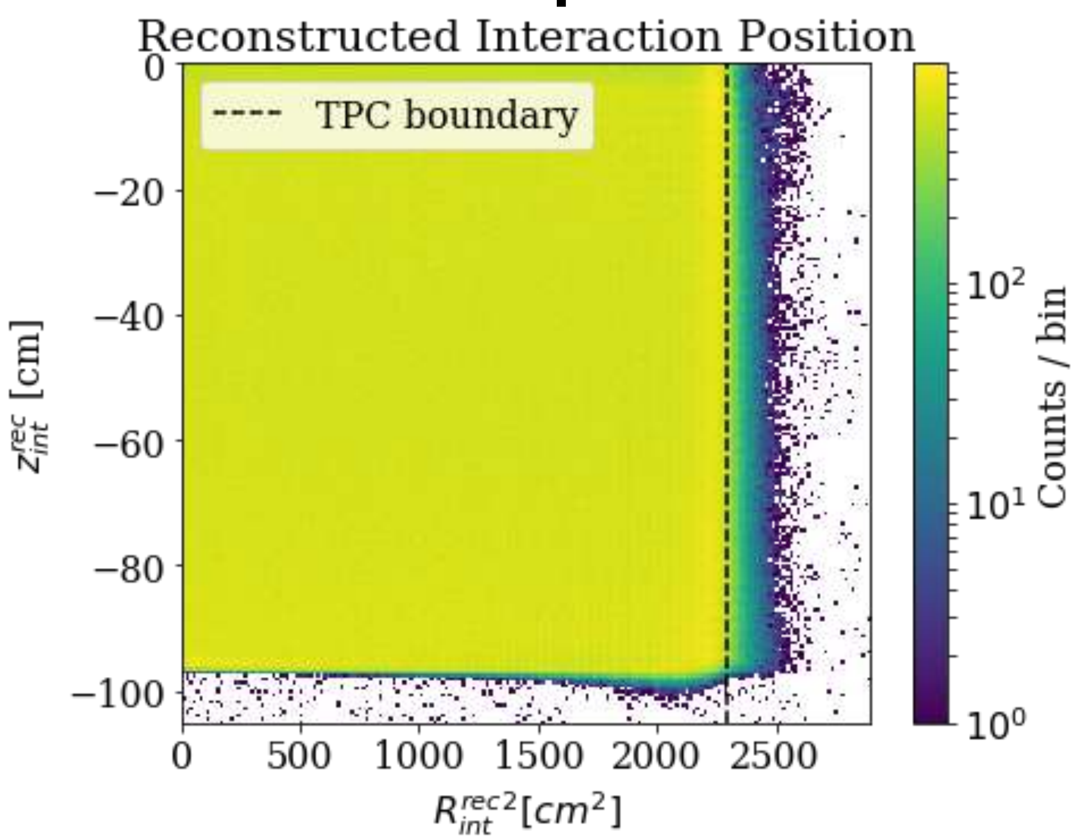
J. Phys. G 43:013001 (2016)

Field non-uniformity correction

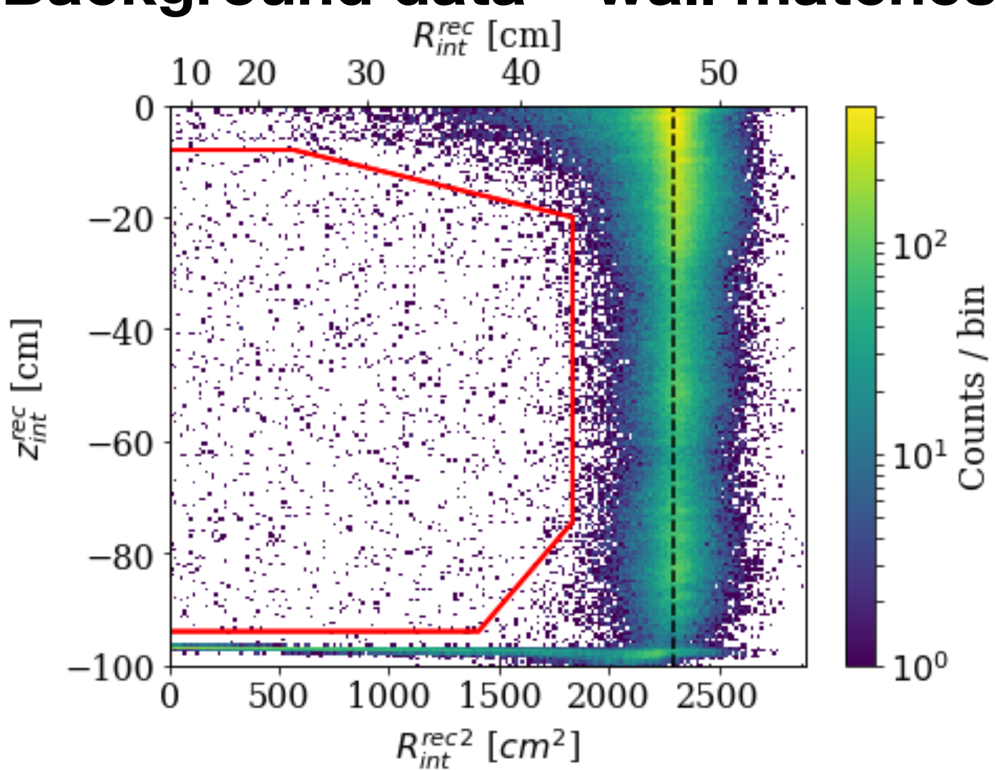
“Raw” position



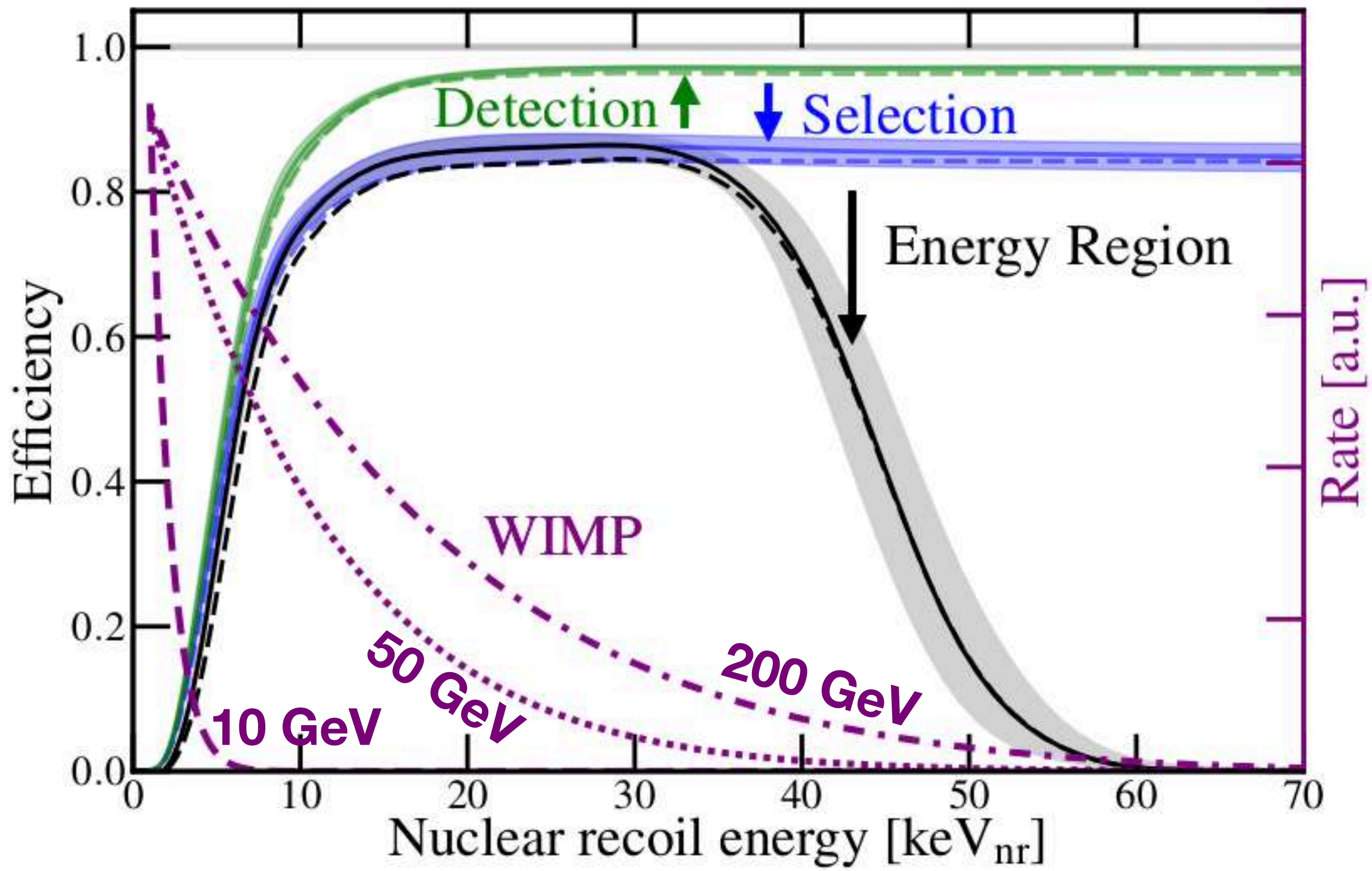
Corrected position



Background data – wall matches



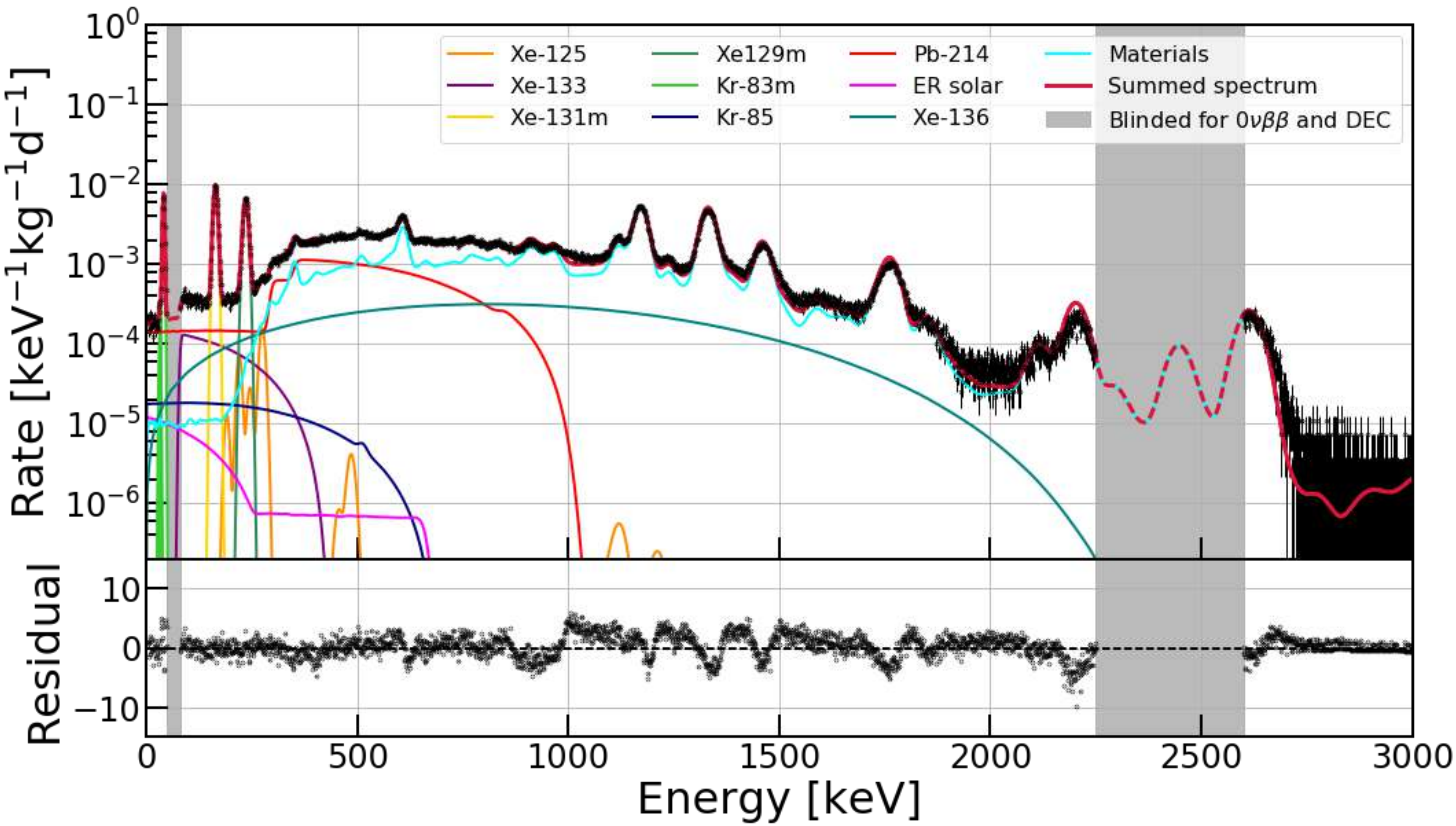
Detection and selection efficiency



- Dominant detection efficiency loss:
  3 PMTs must contribute to S1 (so S1 > 3 pe)
- Selection efficiencies estimated from calibration or MC data
- Search region defined as 3–70 pe in cS1

Energy spectrum matching

In 1 t volume



XENON1T Cryogenic systems

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