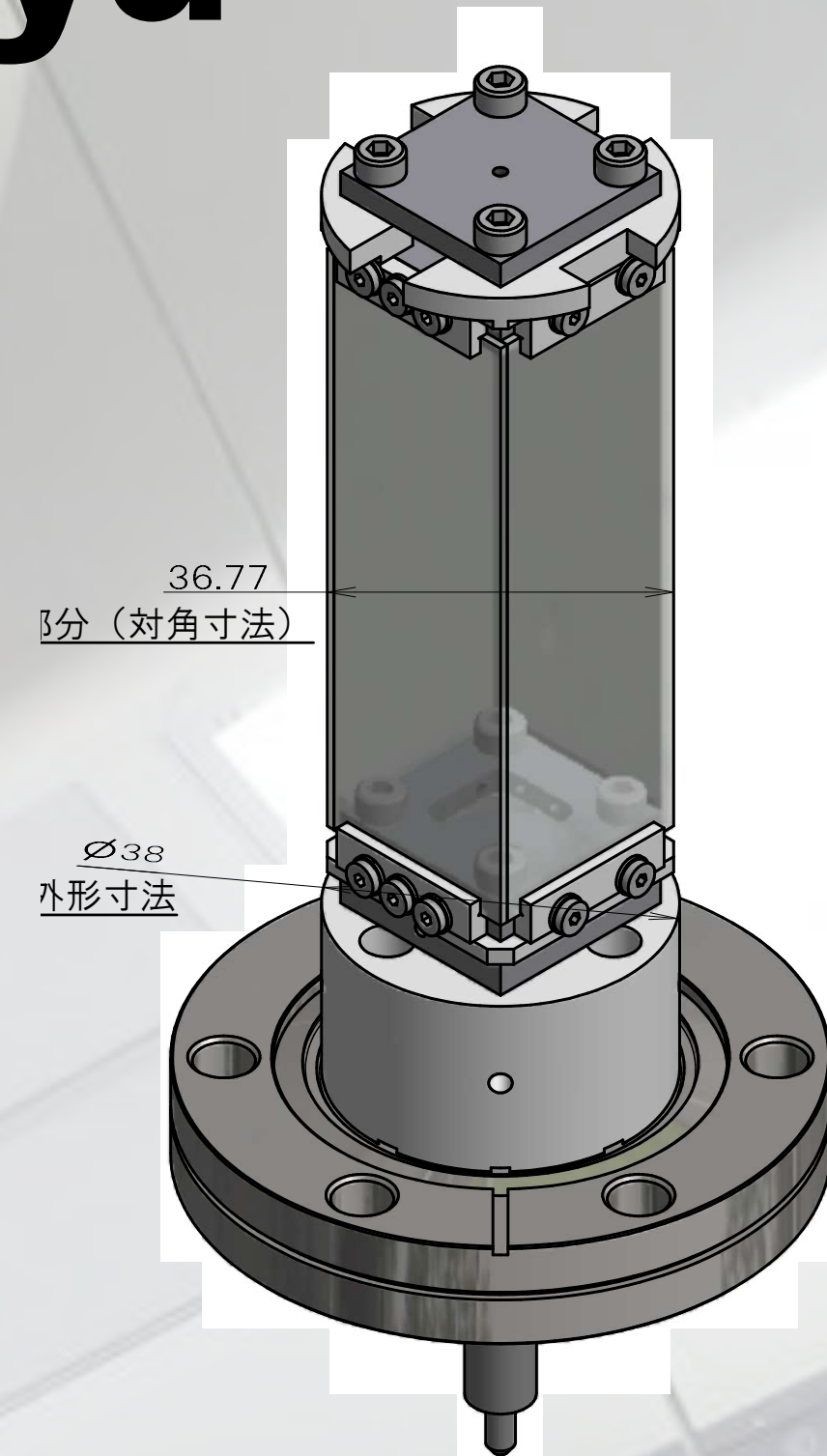
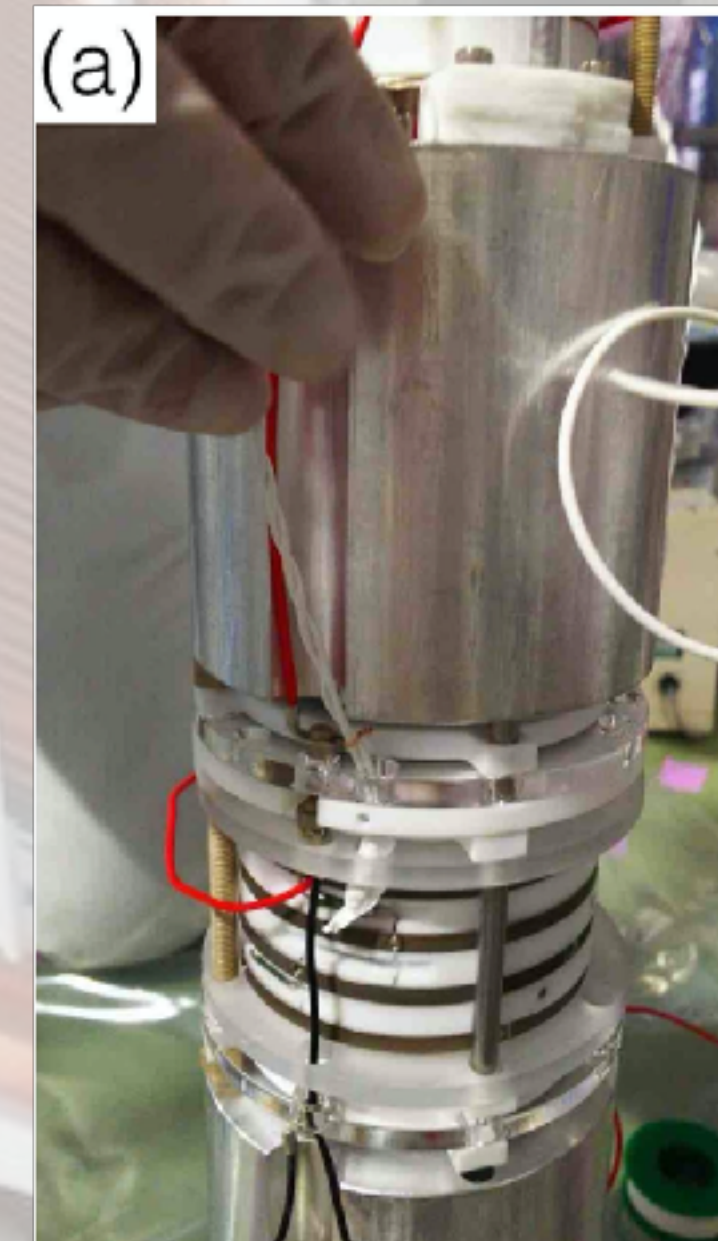


LXe DM search activity at Nagoya

Masaki Yamashita
ISEE, Nagoya University

2020/08/26
IBS and KMI Joint Workshop 2020



Outline

- XENON experiment at Gran Sasso
 - XENON1T Recent Result
 - XENONnT Status
- Liquid XENON detector R&D at Nagoya

XENON1T Recent Result



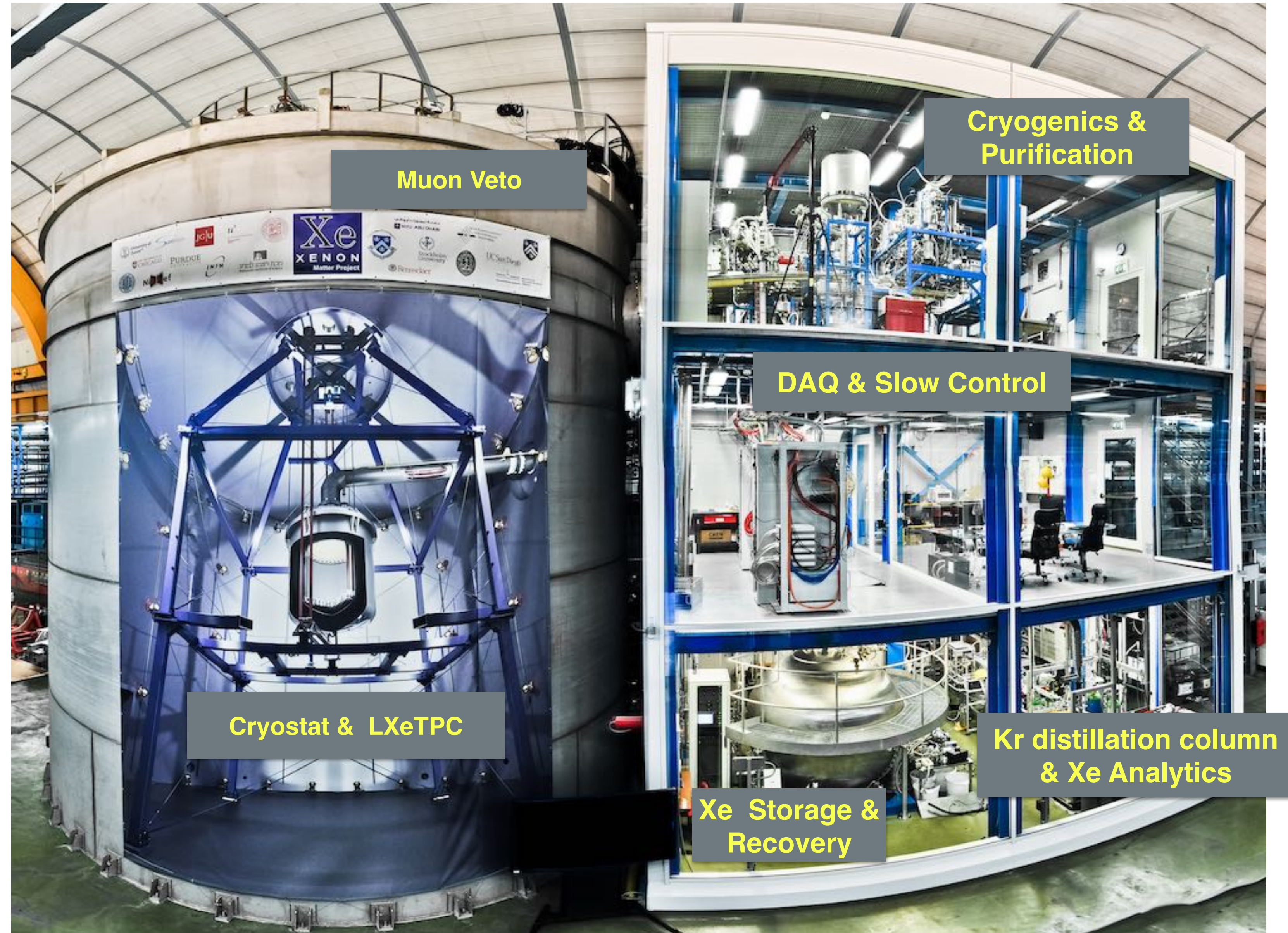
The XENON Collaboration: ~170 scientists

3 researchers
Yoshitaka Itow, Masaki Yamashita, Shingo Kazama
+ 4 graduate student from Nagoya



XENON1T Detector

- Direct Dark Matter (WIMP) search detector
- 3.2 tonne total/ 1 tonne fiducial LXe
- Two phase Xe TPC
- ~250 x 3 inch PMTs
- **2012-2018 (terminated)**

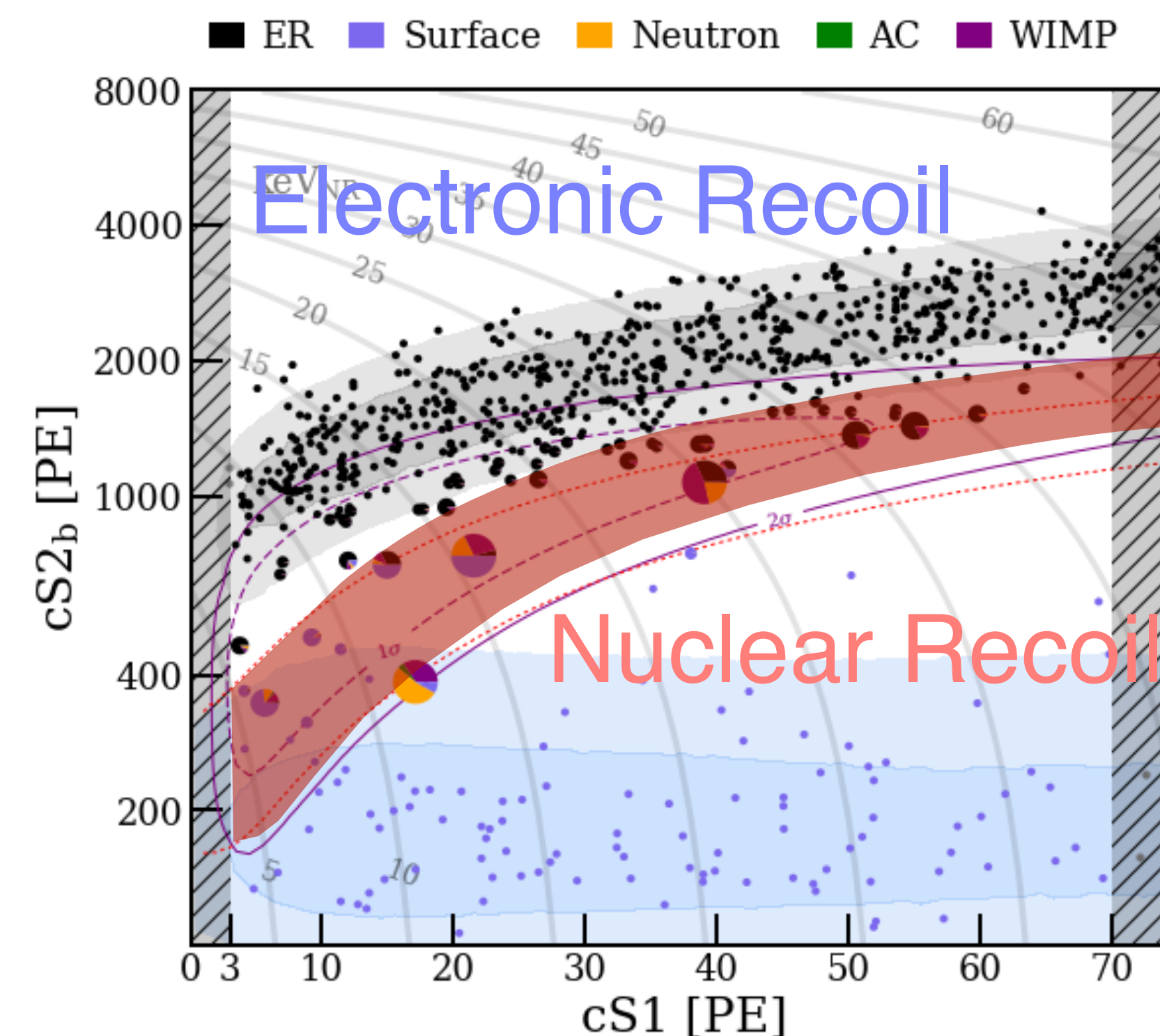
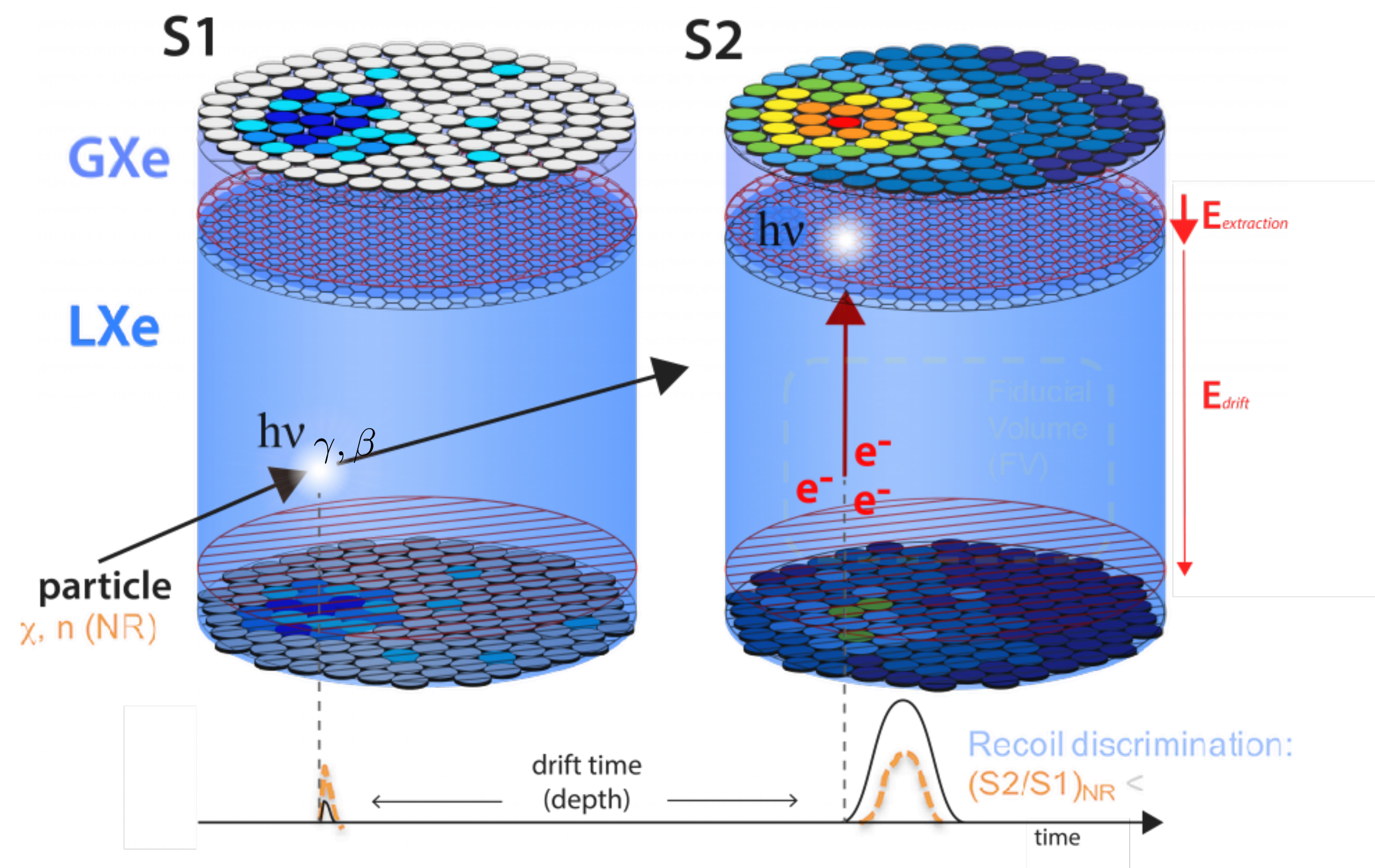


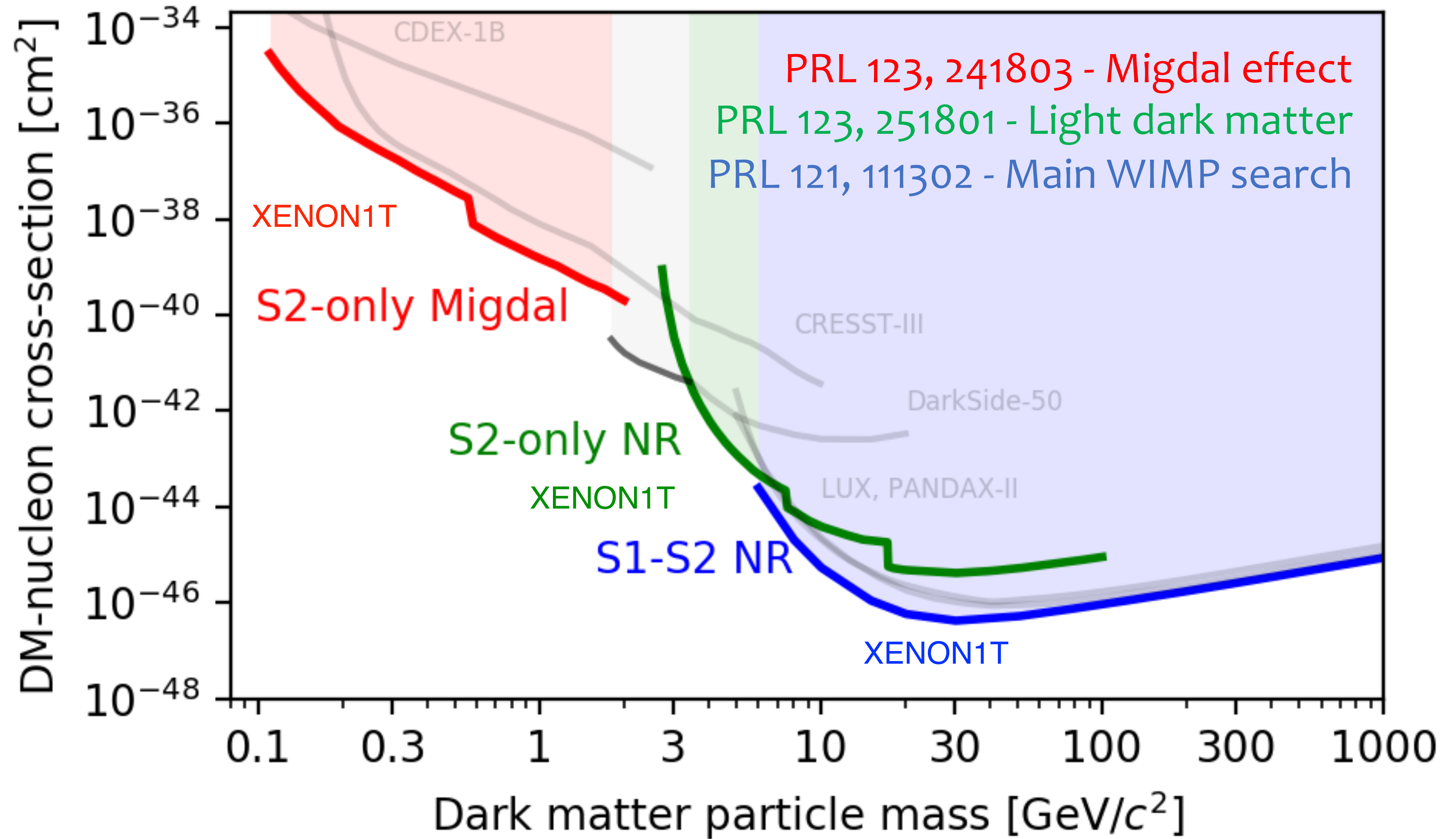
Two-phase Xe Time Projection Chamber

- **Scintillation light - S1**
- **Ionization electron -S2**

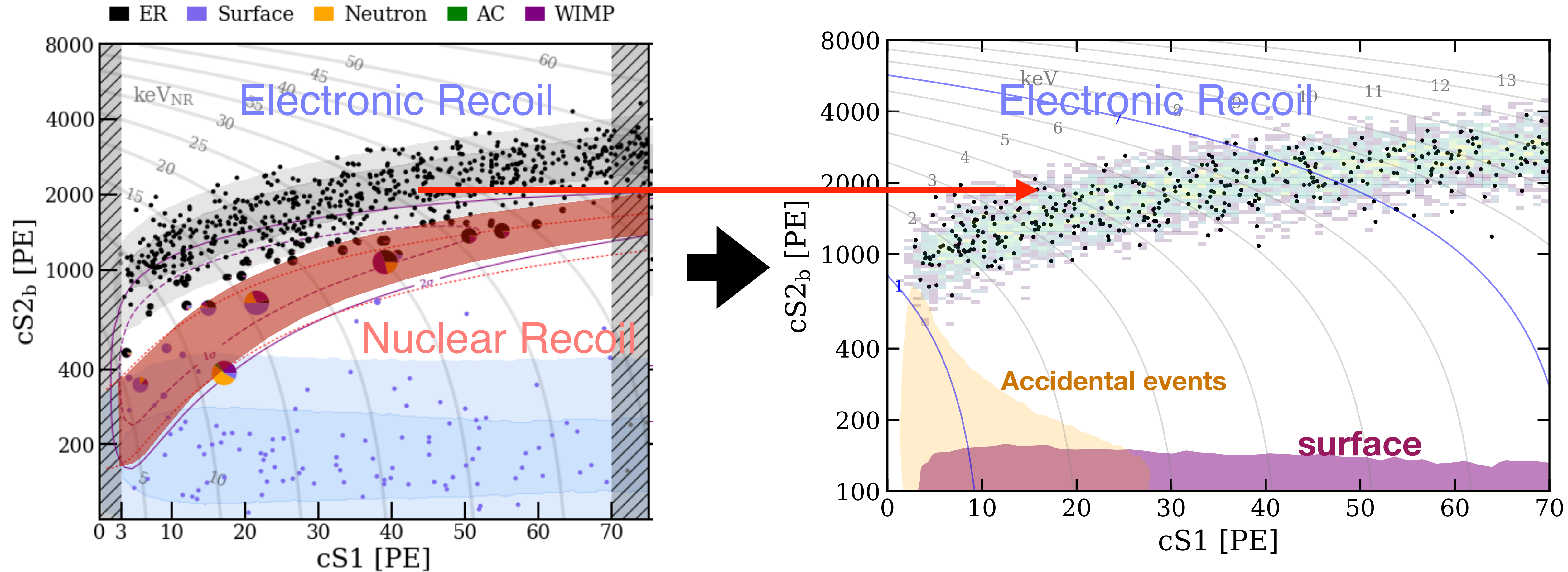
Two signals for each event:

- 3D event imaging: x-y (S2) and z (drift time)
- self-shielding, surface event rejection, single vs multiple scatter events
- Particle identification using S2/S1 ratio (nuclear recoil vs beta, gamma)



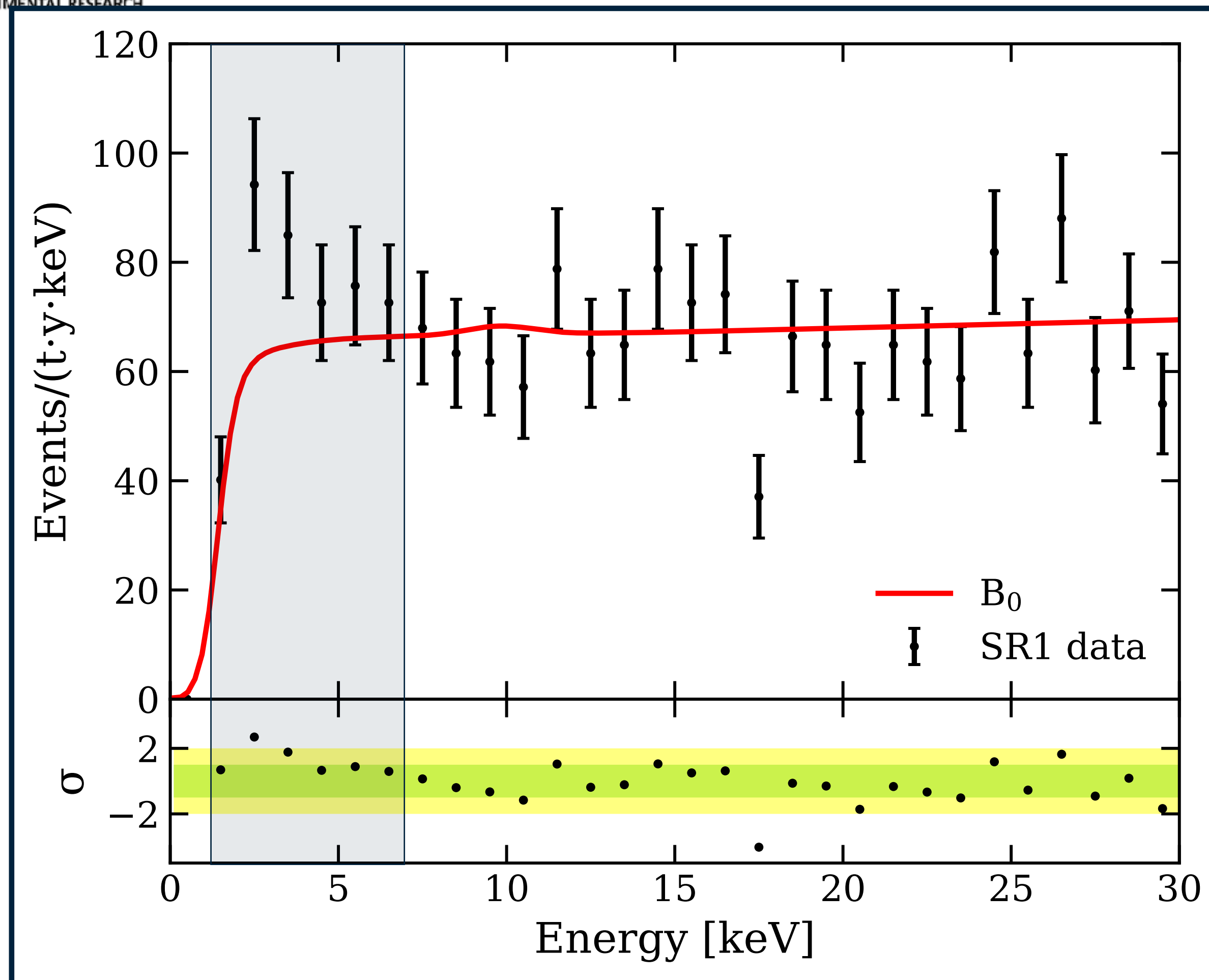


XENON1T Electronic Recoil band band



Nuclear recoil energy scale -> Electronic recoil energy scale

The Low Energy Excess (ER)



Excess between 1- 7 keV!

Expectation: 232 ± 15

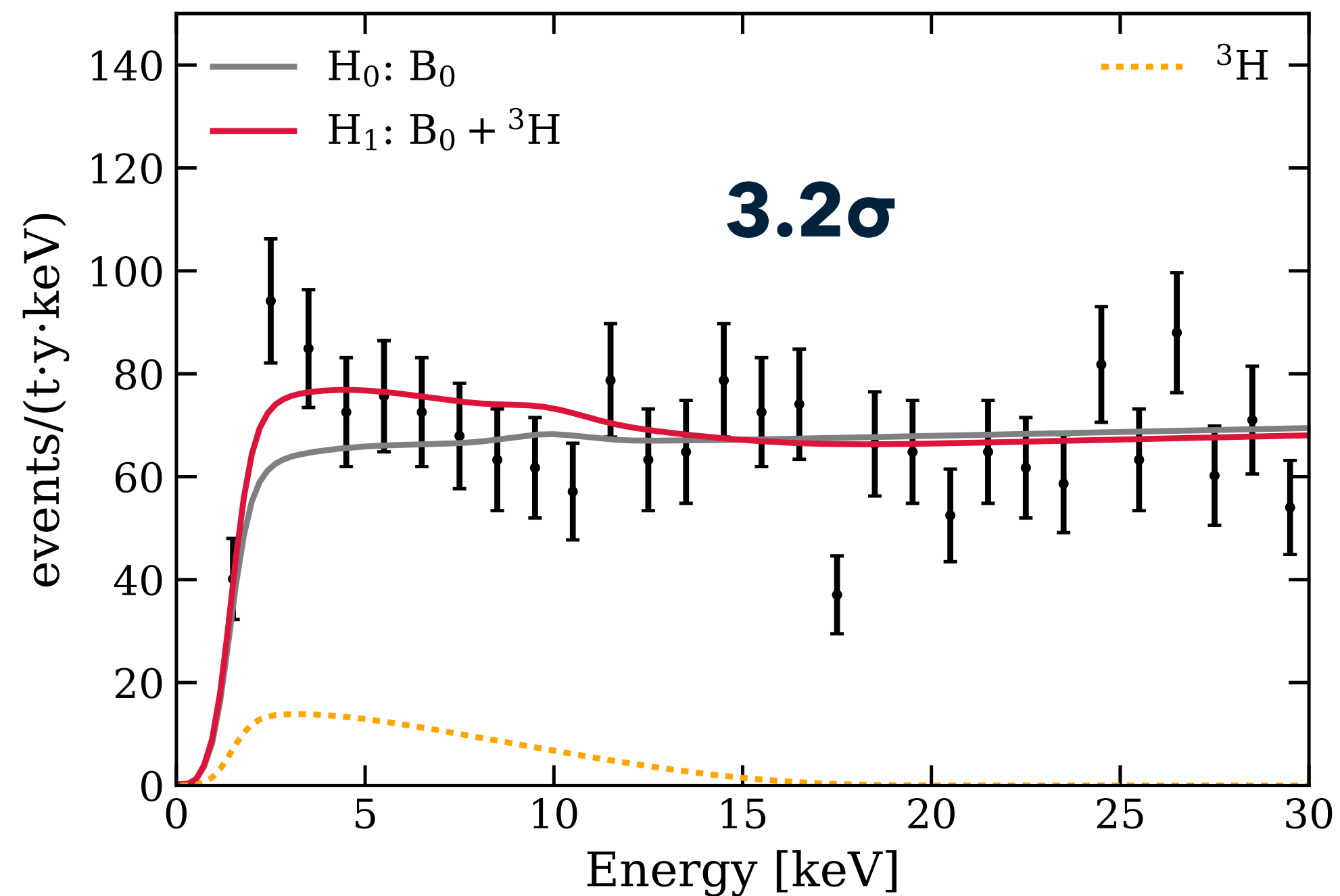
Observation: **285**

Excess is most abundant between 2-3 keV

Tritium and Solar axion Fit

Unbinned profile likelihood analysis

Tritium



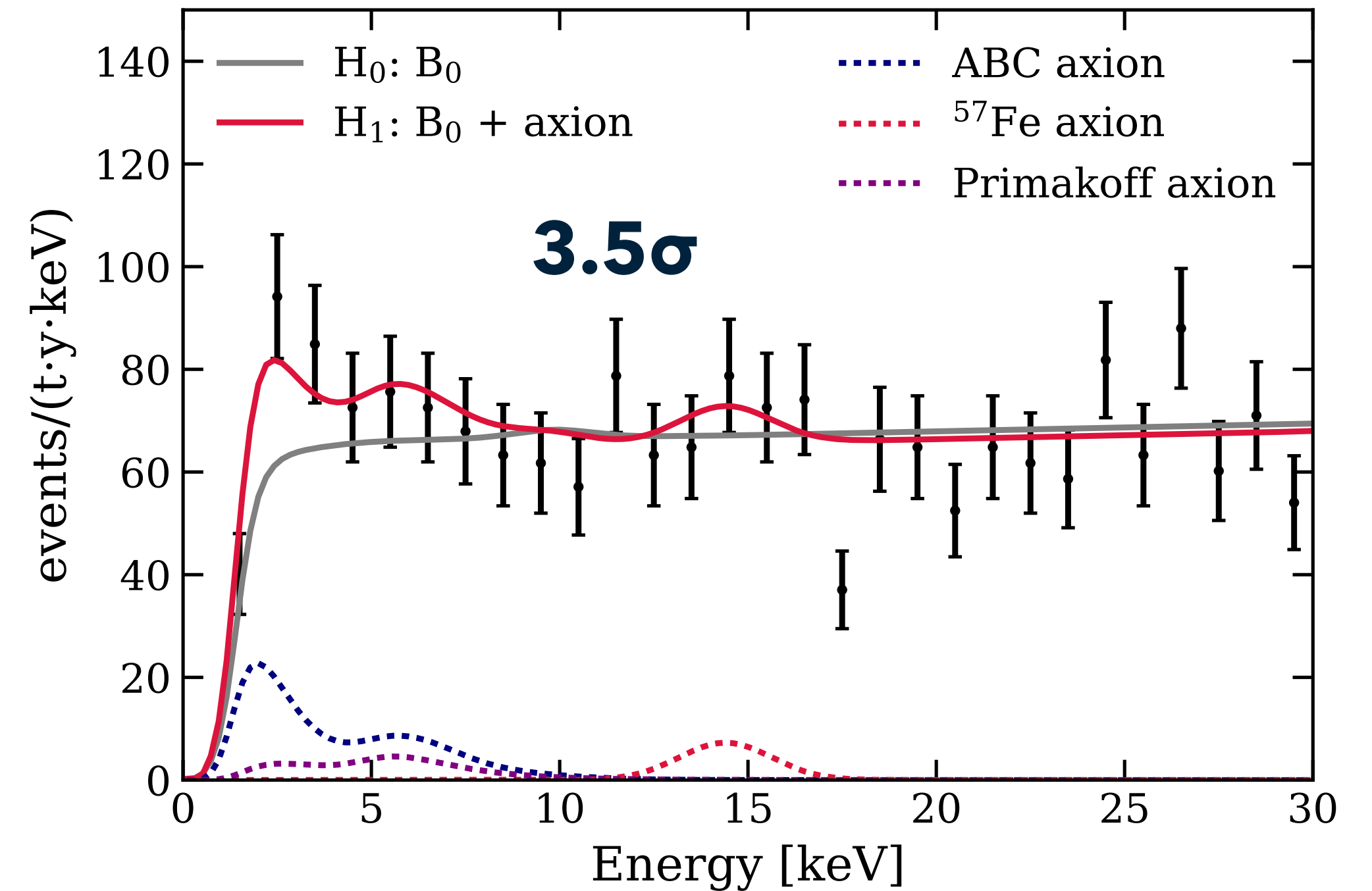
Tritium Rate

$$159 \pm 51 \text{ events}/(\text{t} \cdot \text{y})$$

${}^3\text{H}:\text{Xe}$ concentration

$$6.2 \pm 2.0 \times 10^{-25} \text{ mol/mol}$$

Soar Axion



XENON1T BG + Axion (ABC, Primakov, ${}^{57}\text{Fe}$)

Excludes one of:

- $g_{ae} = 0$
- $g_{a\gamma} = g_{an}^{eff} = 0$

$$g_{ae} < 3.7 \times 10^{-12}$$

$$g_{ae}g_{an}^{eff} < 4.6 \times 10^{-18}$$

$$g_{ae}g_{a\gamma} < 7.6 \times 10^{-22} \text{ GeV}^{-1}$$

strong tension from stellar cooling

XENON1T results are ...
inconclusive.
Then?

Next Step: XENONnT

Sensitivity Paper :arXiv:2007.08796

3x

Larger active volume

~1/6

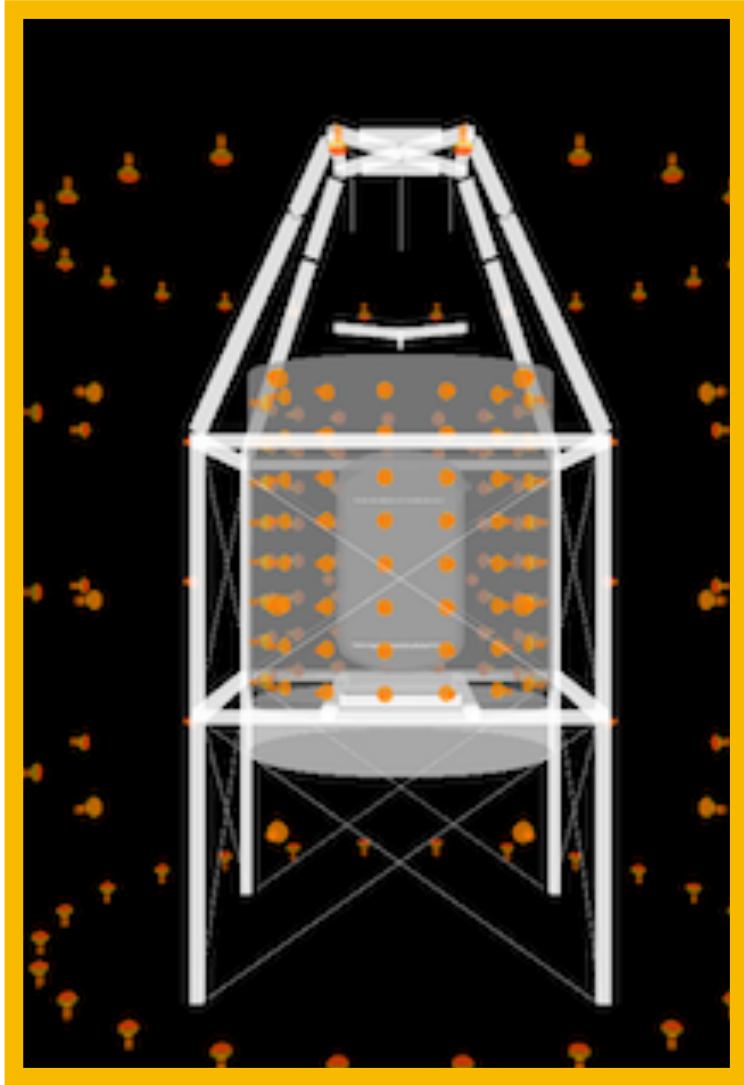
Reduced background level



Commissioning ongoing



New Apparatus in XENONnT



Neutron veto

- Inner region of existing muon veto
- optically separate
- 120 additional PMTs
- Gd in the water tank
- 0.5 % $\text{Gd}_2(\text{SO}_4)_3$



LXe purification

- Faster xenon cleaning
- 5 L/min LXe (2500 slpm)
- XENON1T ~ 100 slpm



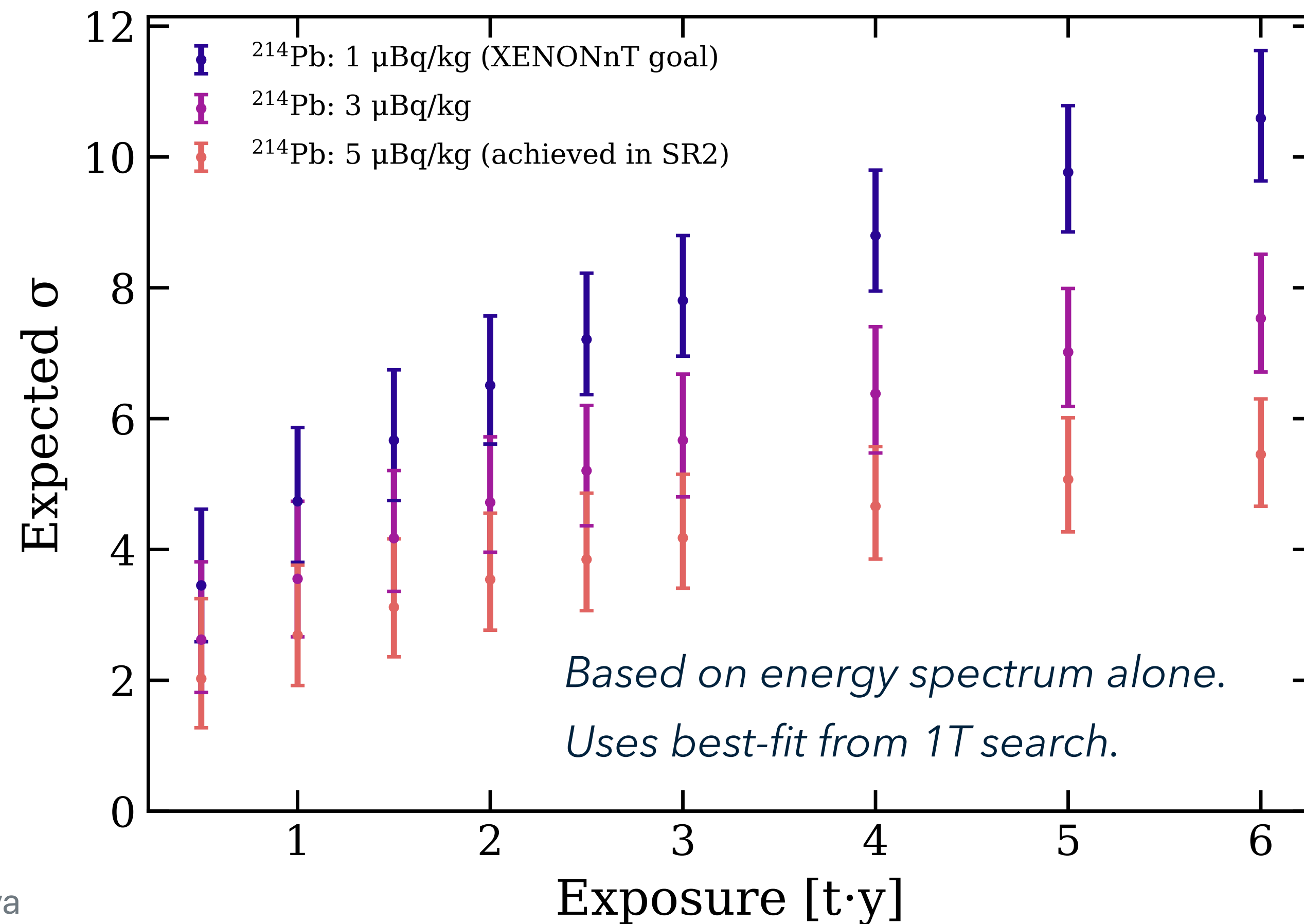
^{222}Rn distillation

- Reduce Rn (^{214}Pb) from pipes, cables, cryogenic system
- New system, PoP in XENON1T

- Nagoya group contribute
 - Neutron Veto (Gd Water)
 - identify single neutron scatter in TPC
 - LXe Purification
 - Rapid recirculation in liquid phase

Next Steps: XENONnT

XENONnT will discriminate axions from tritium
 with $\sim$ few months of data

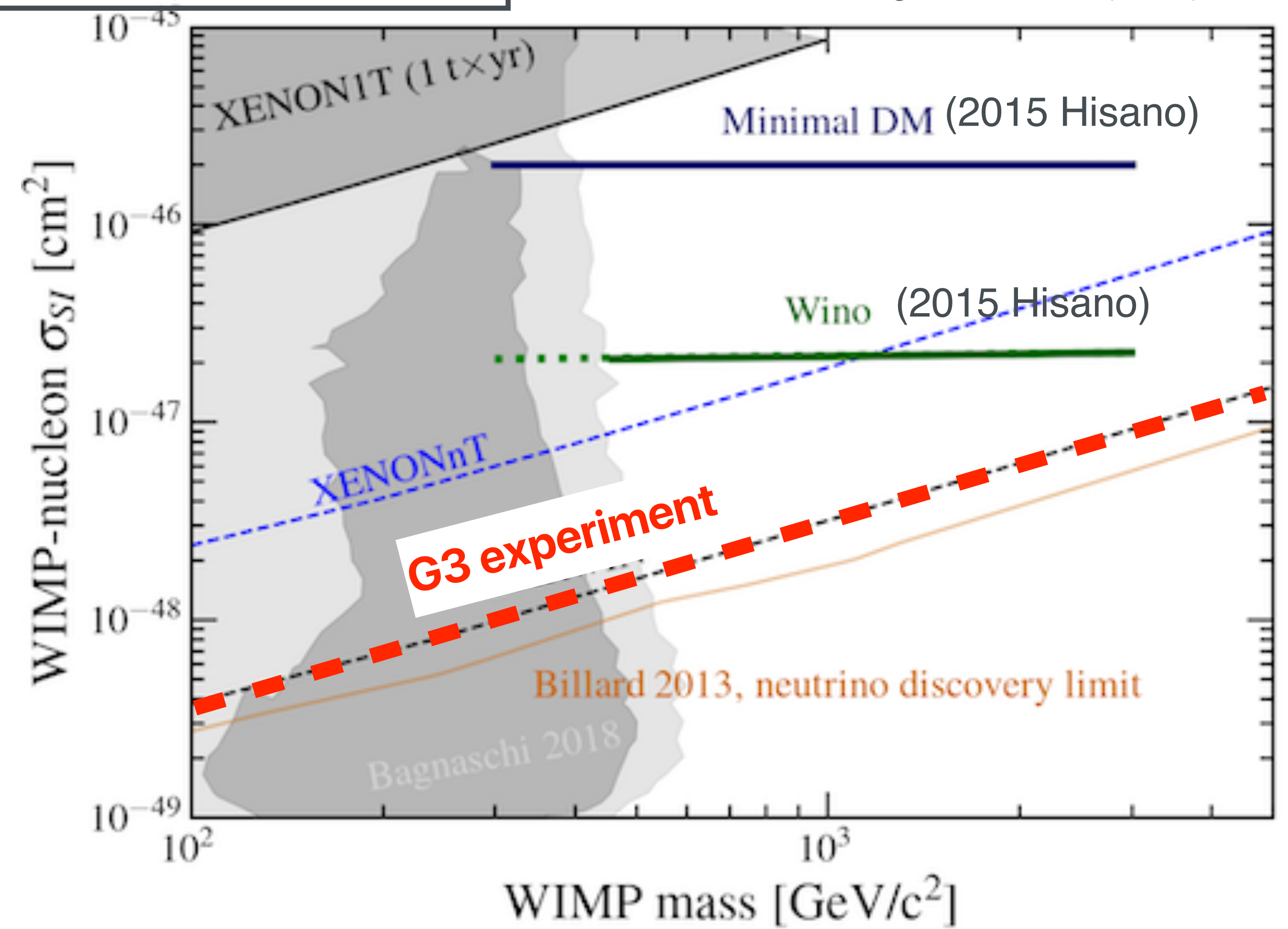
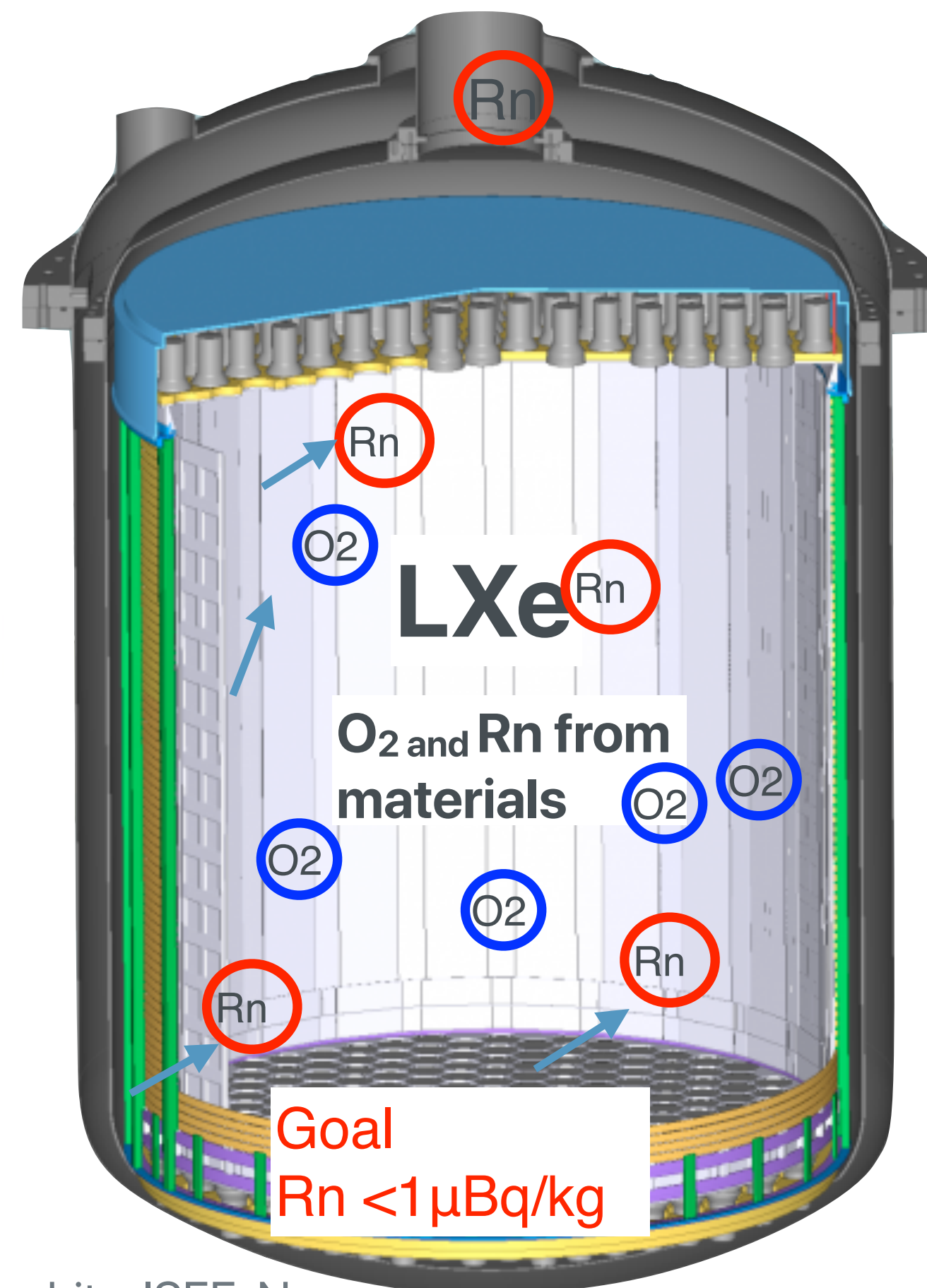


LXe detector R&D at Nagoya (+DM group in Japan (g3c))

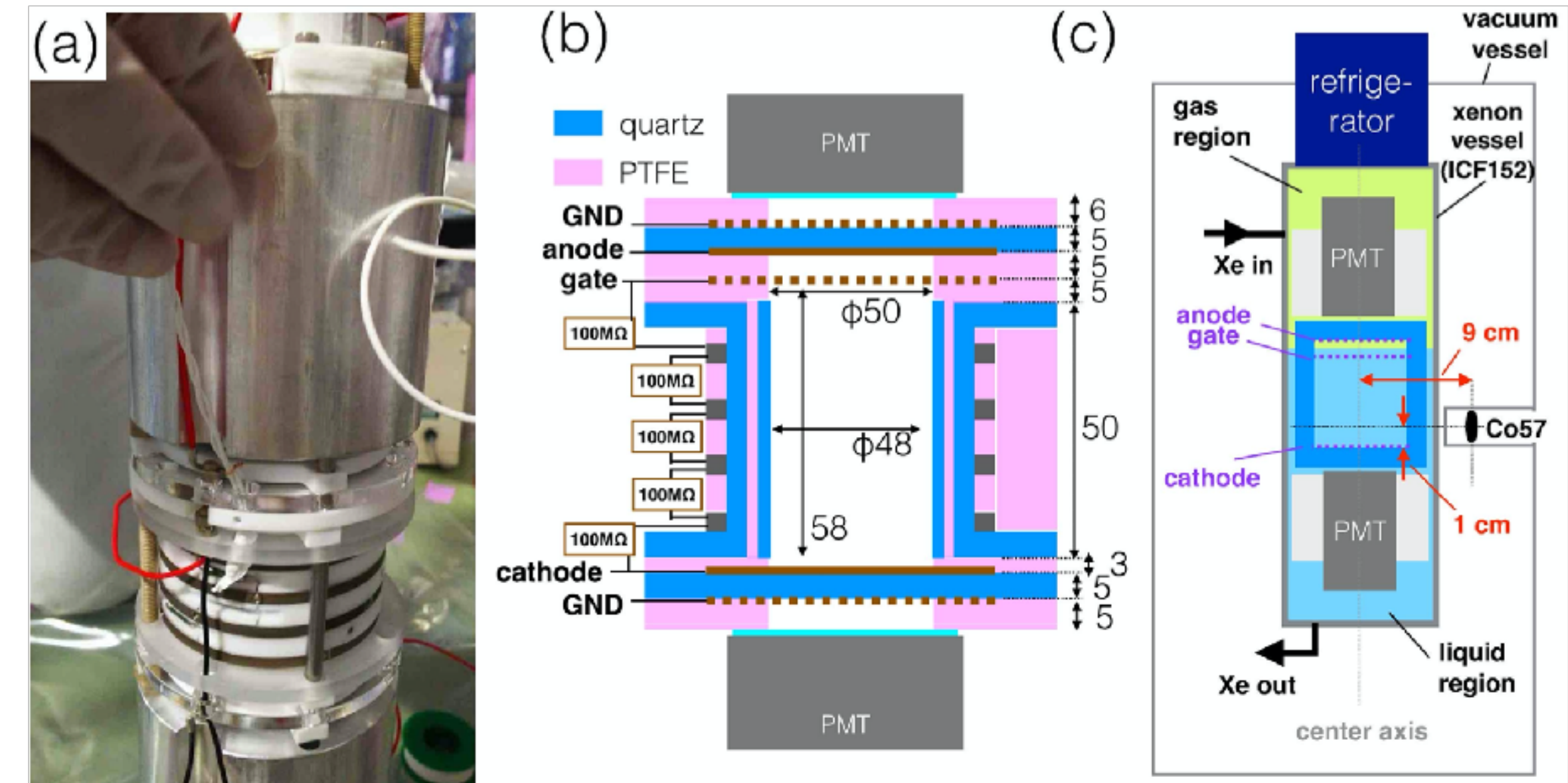
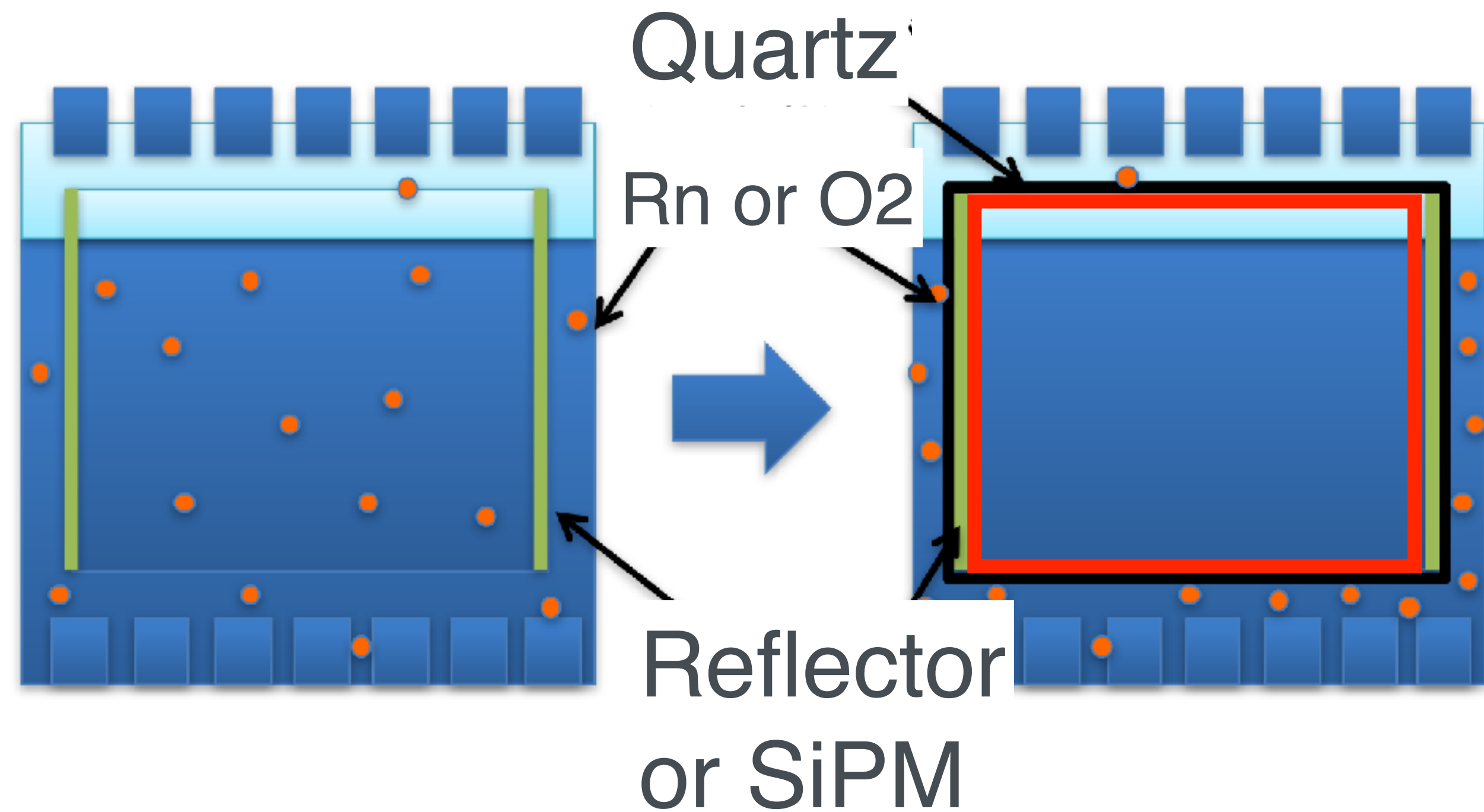
LXe detector R&D at Nagoya

- 50 tonne LXe (such as DARWIN, XENONnT 8.4 tonne)
- Main background Rn daughter (^{214}Pb)
- drift ionized electron $\sim 3\text{m}$ (XENONnT 1.5m)
- Lower BG for double beta decay, ^{136}Xe (light sensor etc)

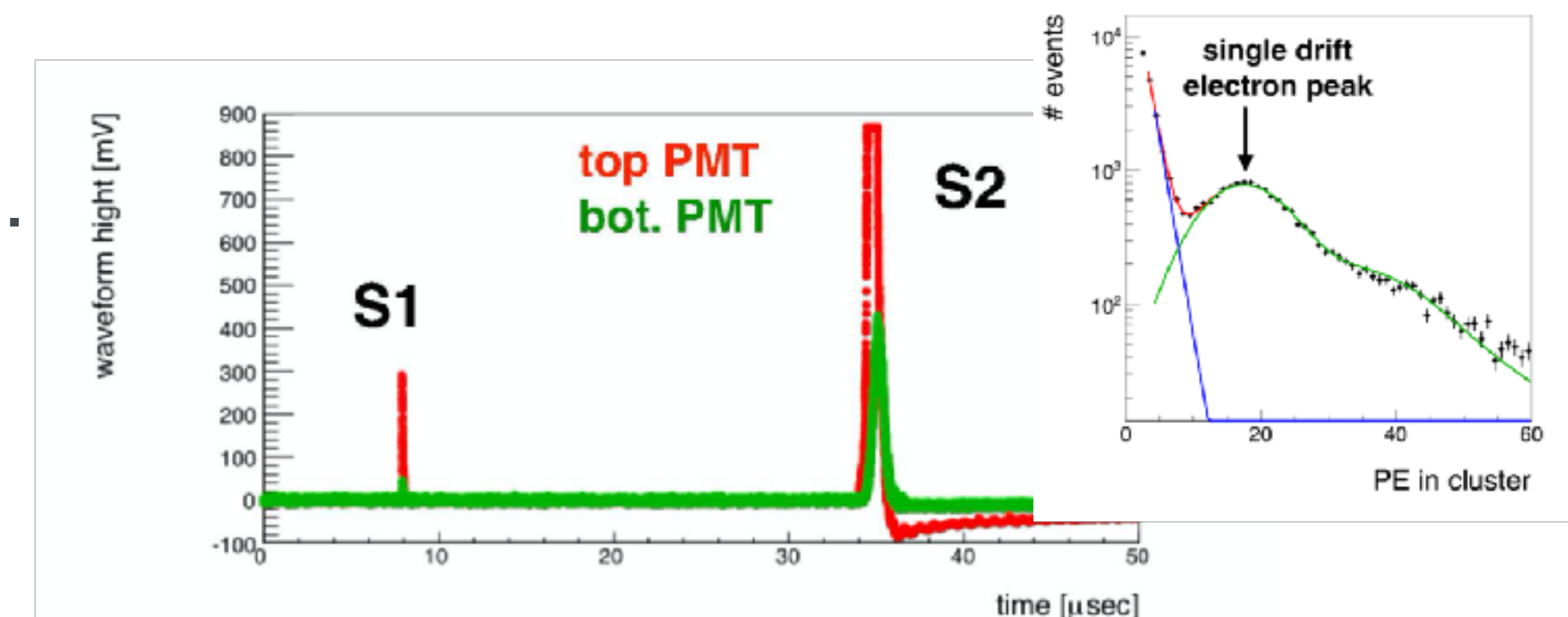
Hisano, Ishiwata, Nagata JHEP06(2015)097



Hermetic TPC R&D (arXiv 1910.13831.)

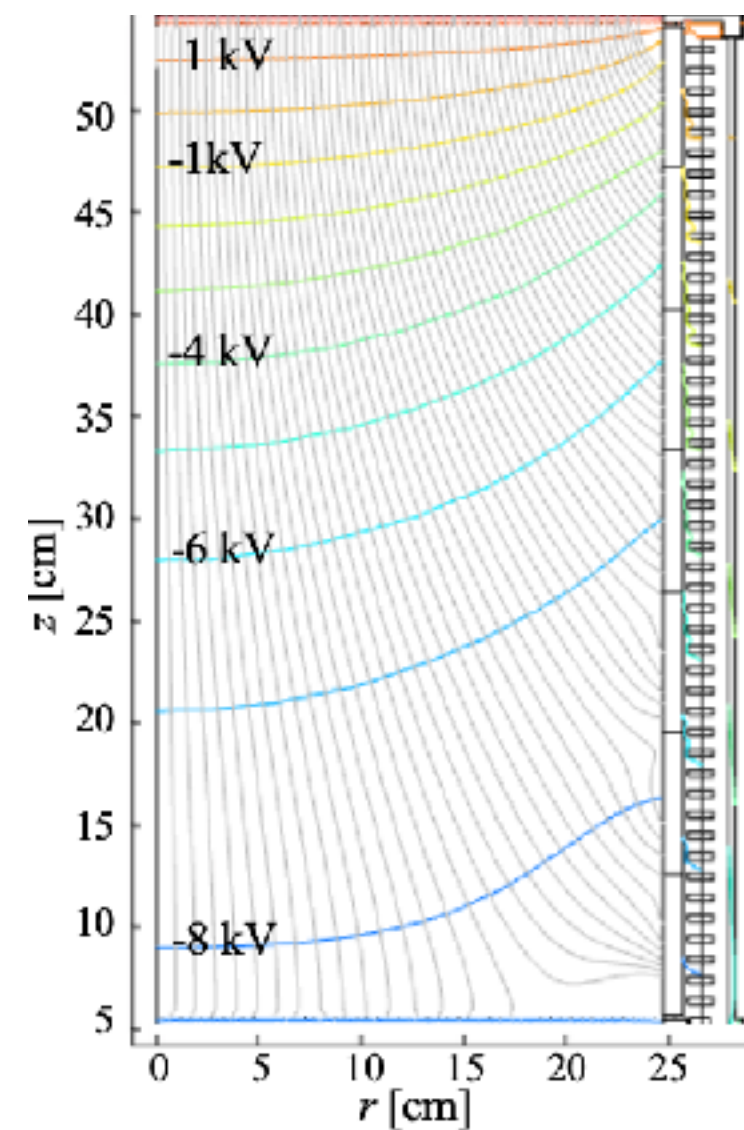


- Separate sensitive volume from outside to reduce Rn and Oxygen.
- Possible light read out from side.
- We demonstrated small quartz chamber prototype detector.
 - Light yield, drift electron lifetime/velocity etc.



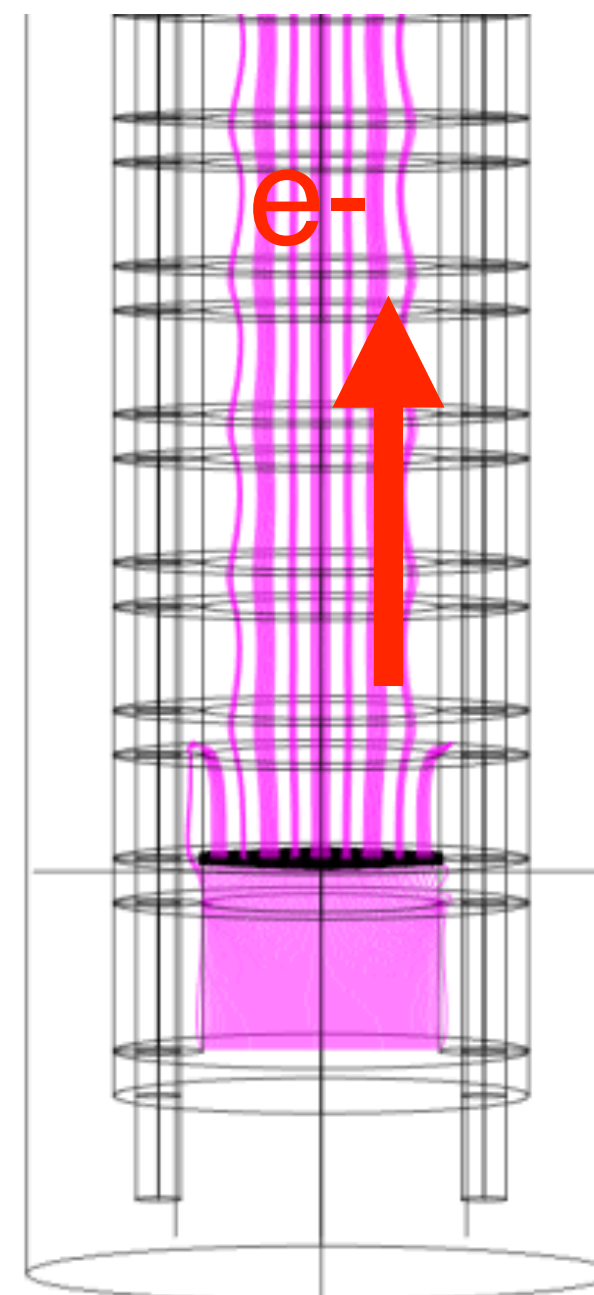
Transparent resistivity electrode

- Uniform electric field near the wall.
- Avoid charge up.
- Candidate (SiO₂ doped ITO, graphene etc)
 - sputtering on SiO₂ palte
- test chamber is under construction.

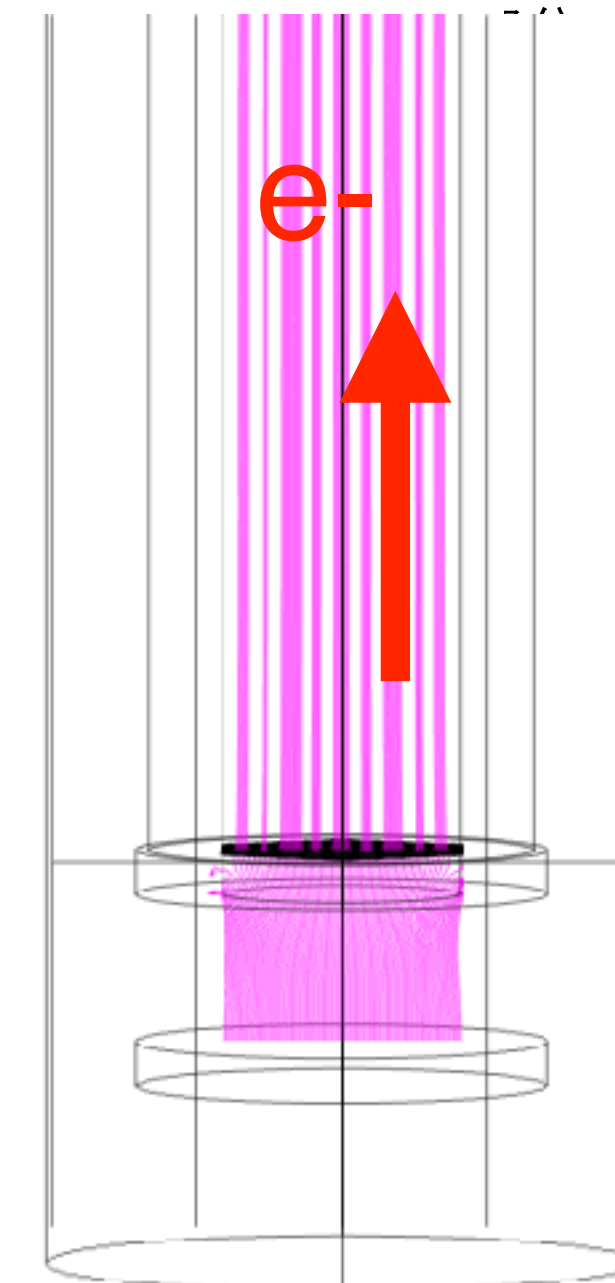


JINST 12 P11022 (LUX collaboration)

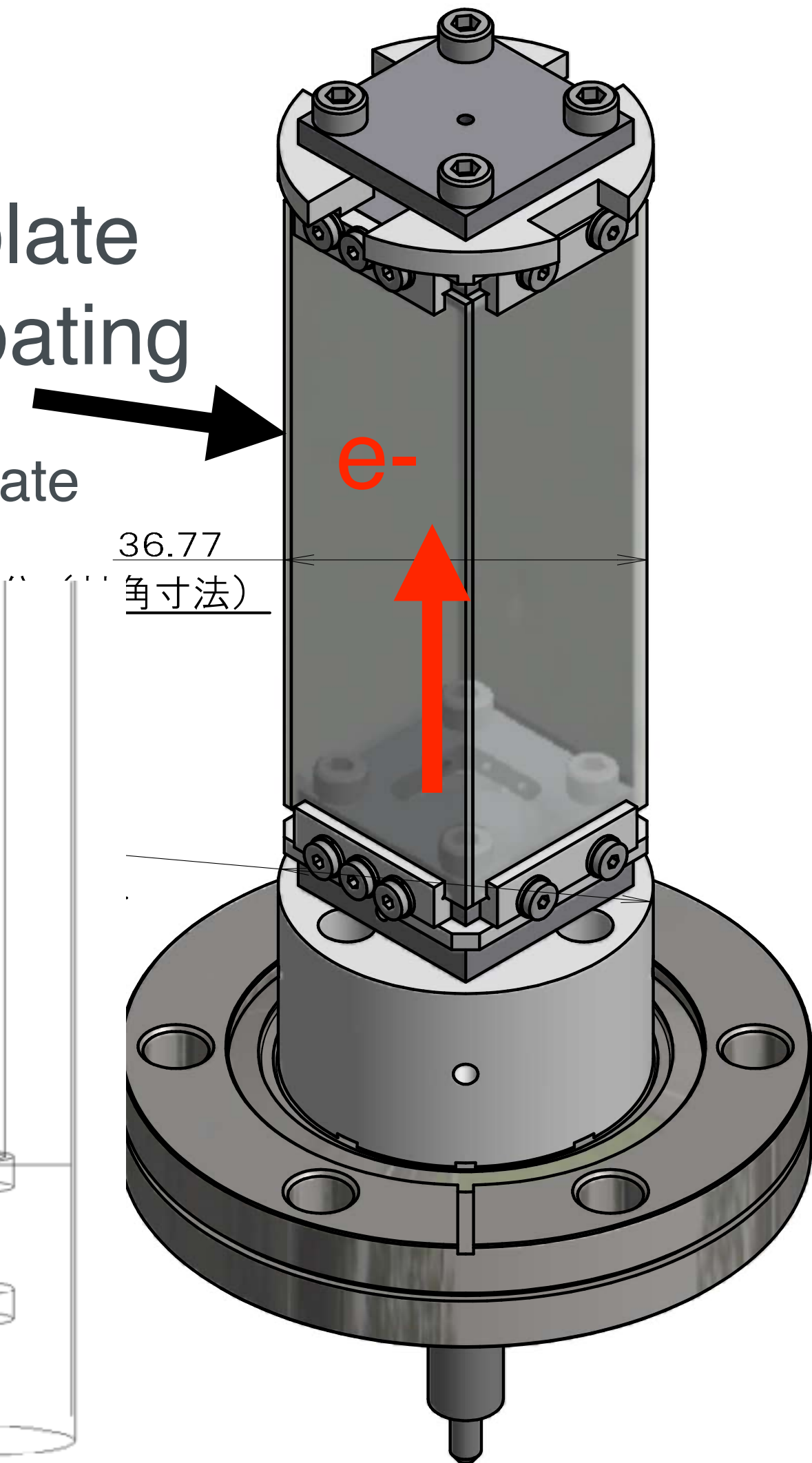
Shaping ring



Resistivity plate



SiO₂ plate
with coating



Development of Low dark rate SiPM(arXiv:2007.13537)

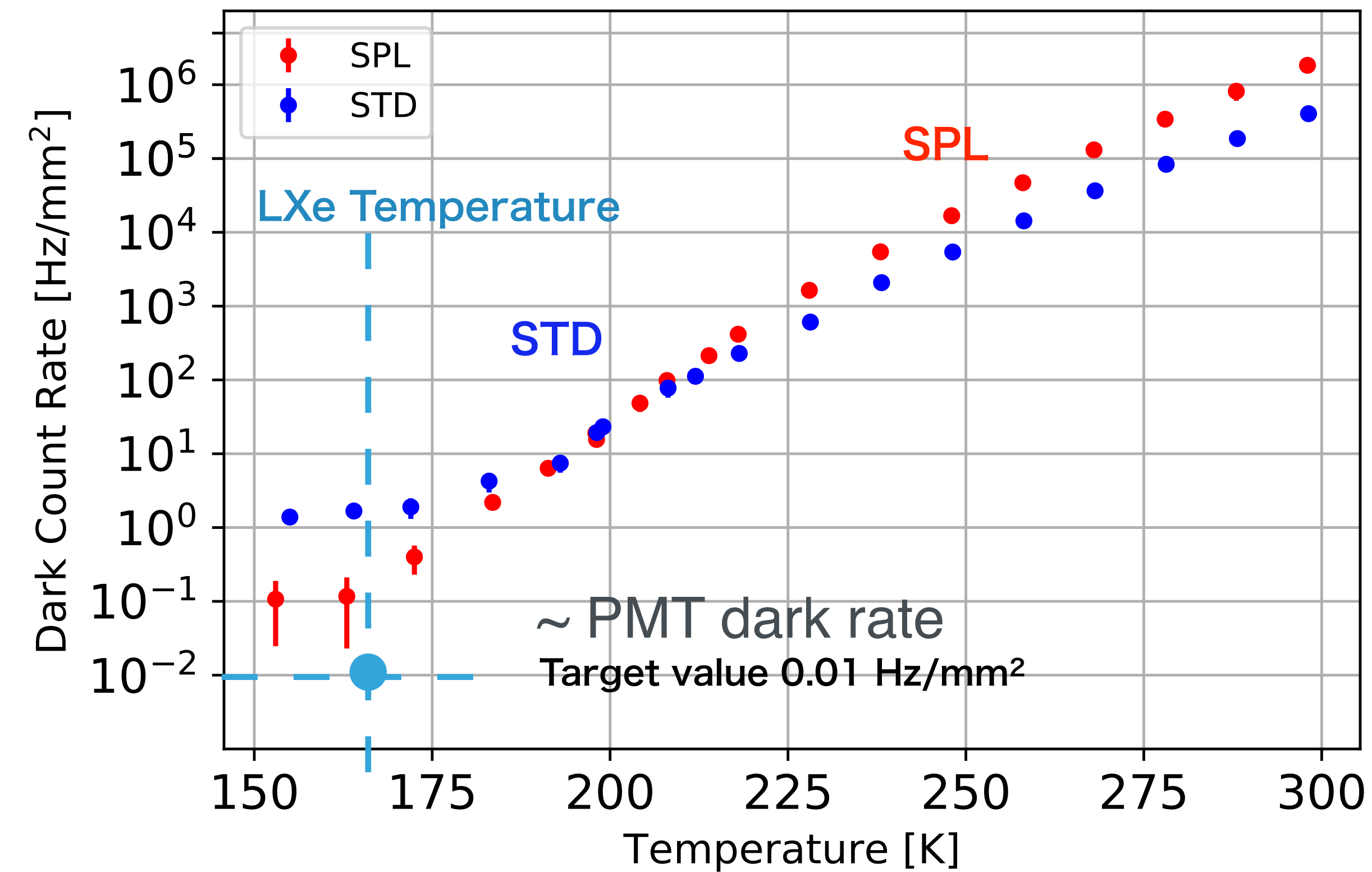
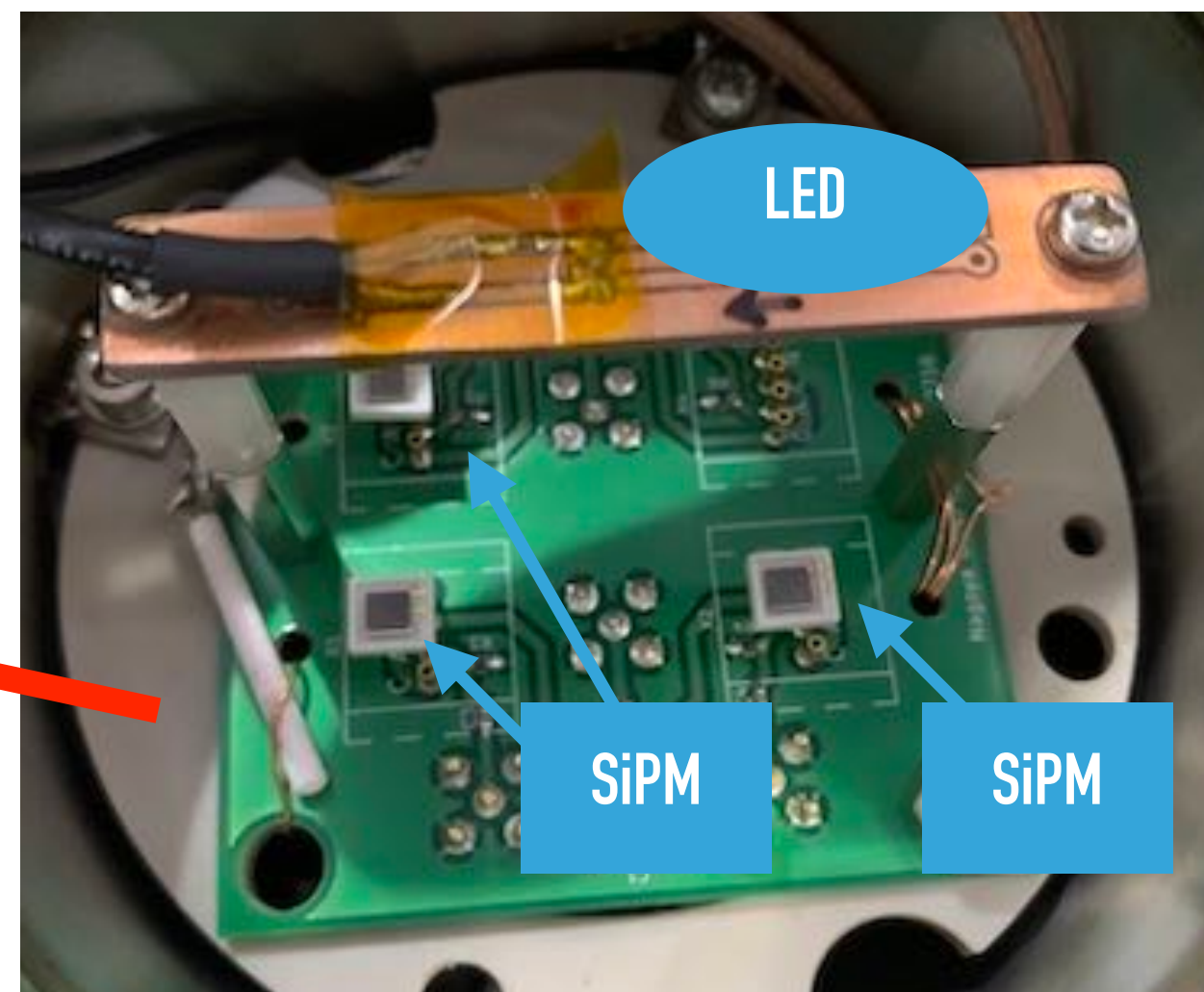
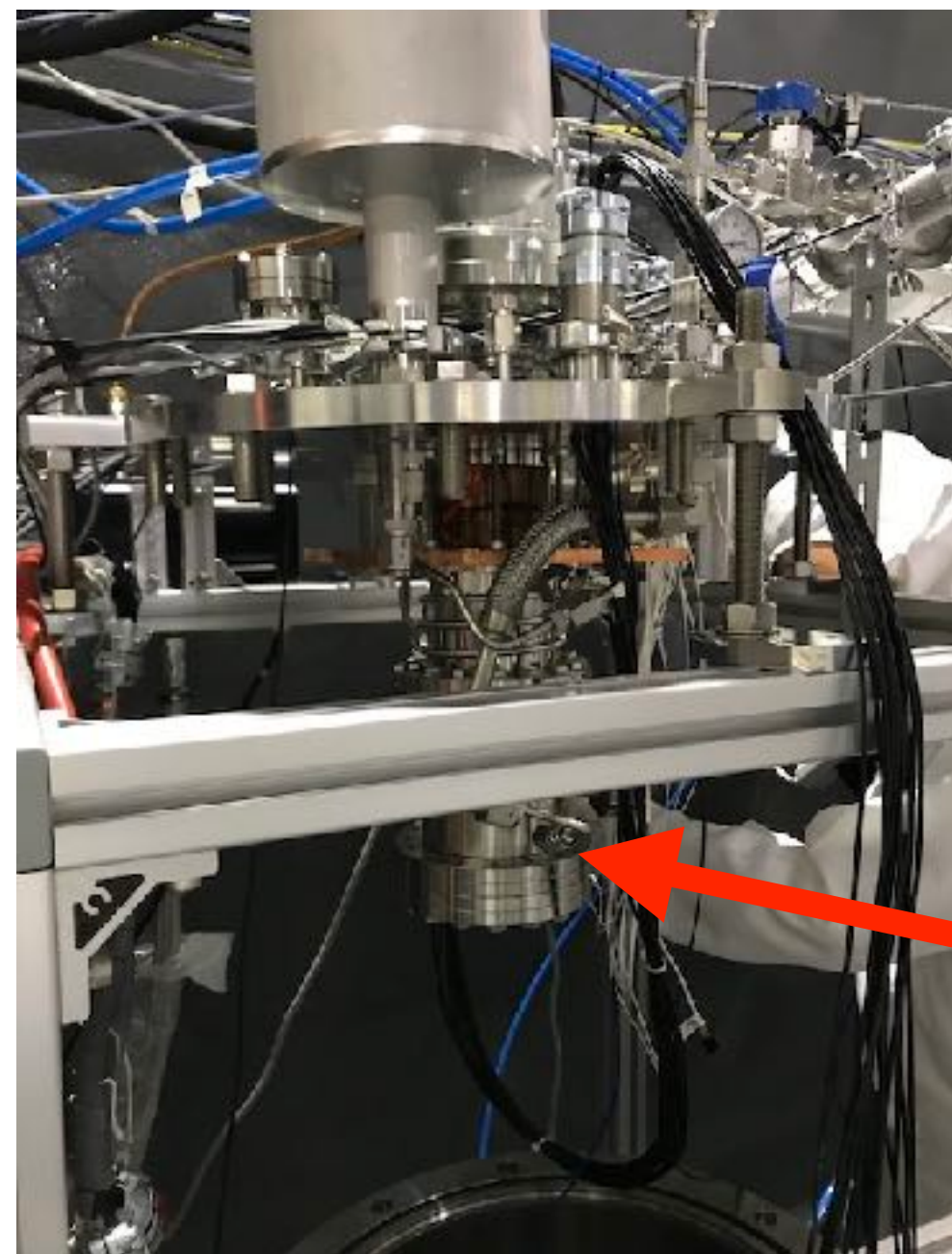
S12572 (Hamamatsu)



SPL SiPM

STD SiPM

- Inner field modification to reduce the dark rate at low temperature.
- Development with Hamamatsu
- Test the proof of principle.
 - This is not for LXe light.
- VUV version for future.



Summary

- XENON1T
 - world best sensitivity for WIMP search
 - ER Excess in low energy (1-7 keV)
 - Solar Axion (3.5σ)
 - Neutrino Magnetic Moment (3.2σ)
 - Bosonic Dark Matter (3.0σ)
 - Tritium Background (3.0σ)
- XENONnT under commissioning phase now and will tell us more about ER excess.
- LXe detector R&D at Nagoya for future DM experiment
 - Hermetic TPC
 - low dark rate SiPM
 - resistivity electrode