The development of hermetic quartz chamber for future low background liquid xenon detectors

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DMNet

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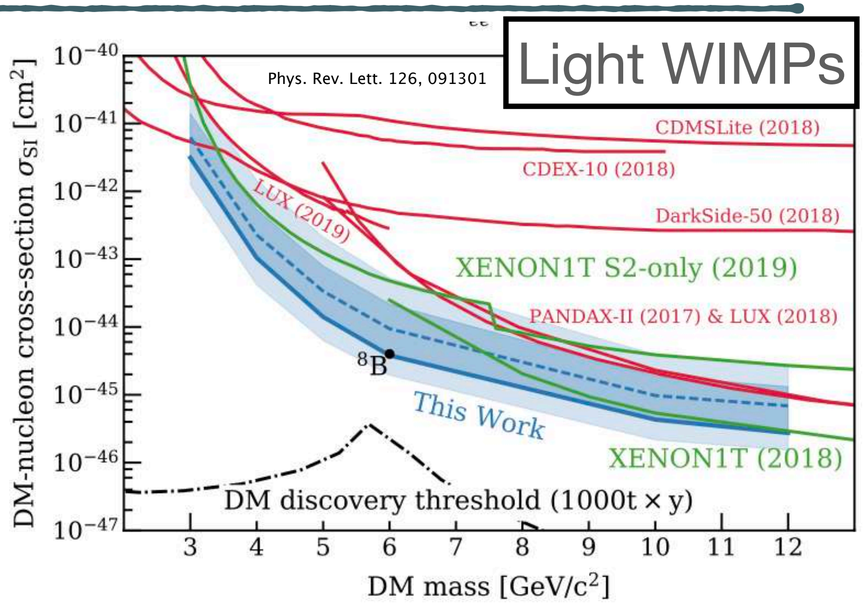
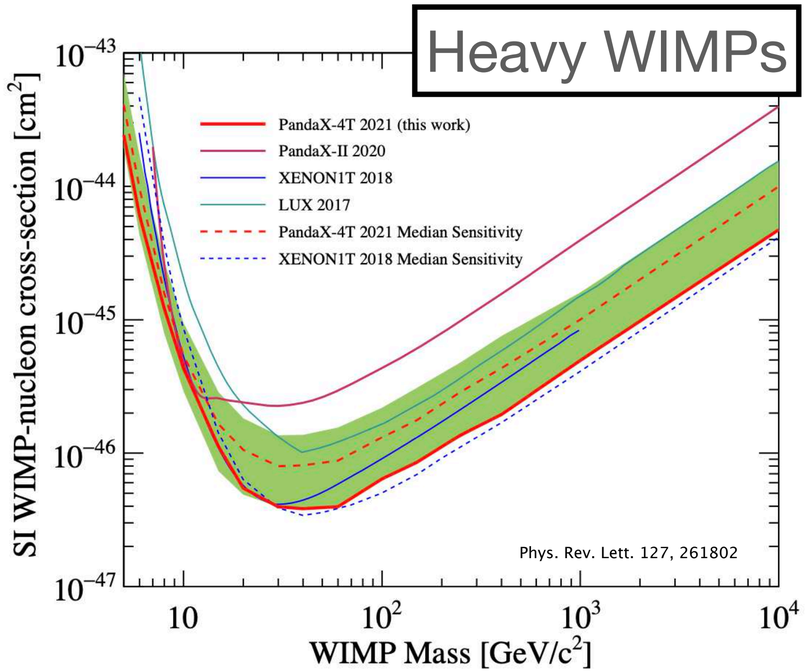
ISEE Institute for Space-Earth Environmental Research

Introduction: future DM direct detection with ^{2} LXe

- Currently, world limit for WIMPs are achieved by liquid xenon detectors: **XENON1T** and **PandaX-4T.**
  - Achieved: 10^{-46} - 10^{-47} cm^2
- Also larger scale detectors, **XENONnT** and **LZ** are running
  - Target: ~10^{-48} cm^2
- For future DM search, **G3 detector (DARWIN/LZ)** is planned with ~50 tons.
  - Target: ~10^{-49} cm^2





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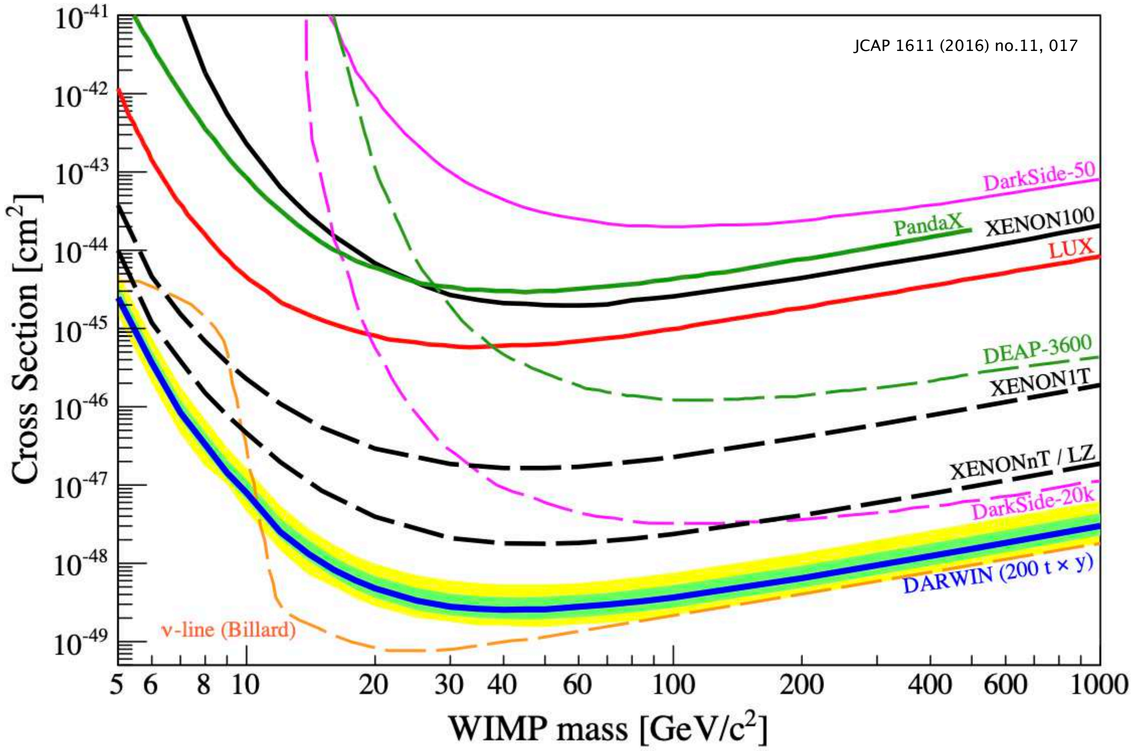
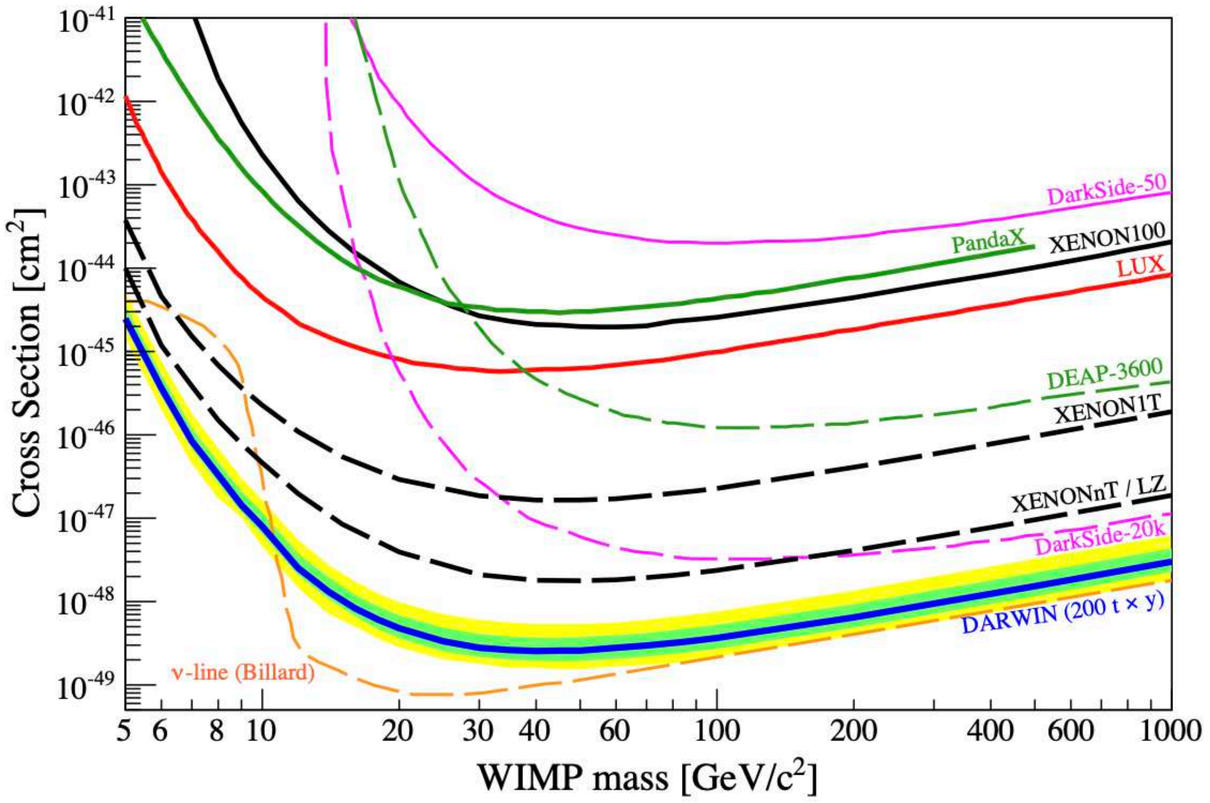
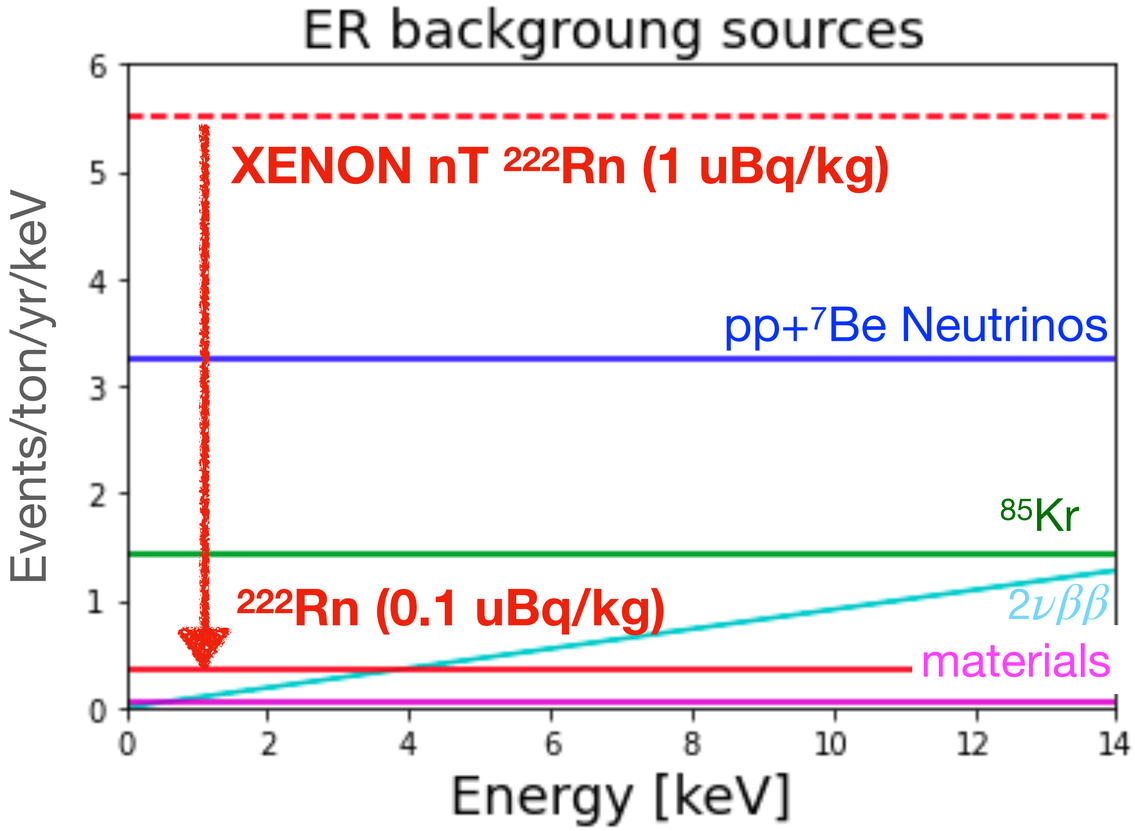


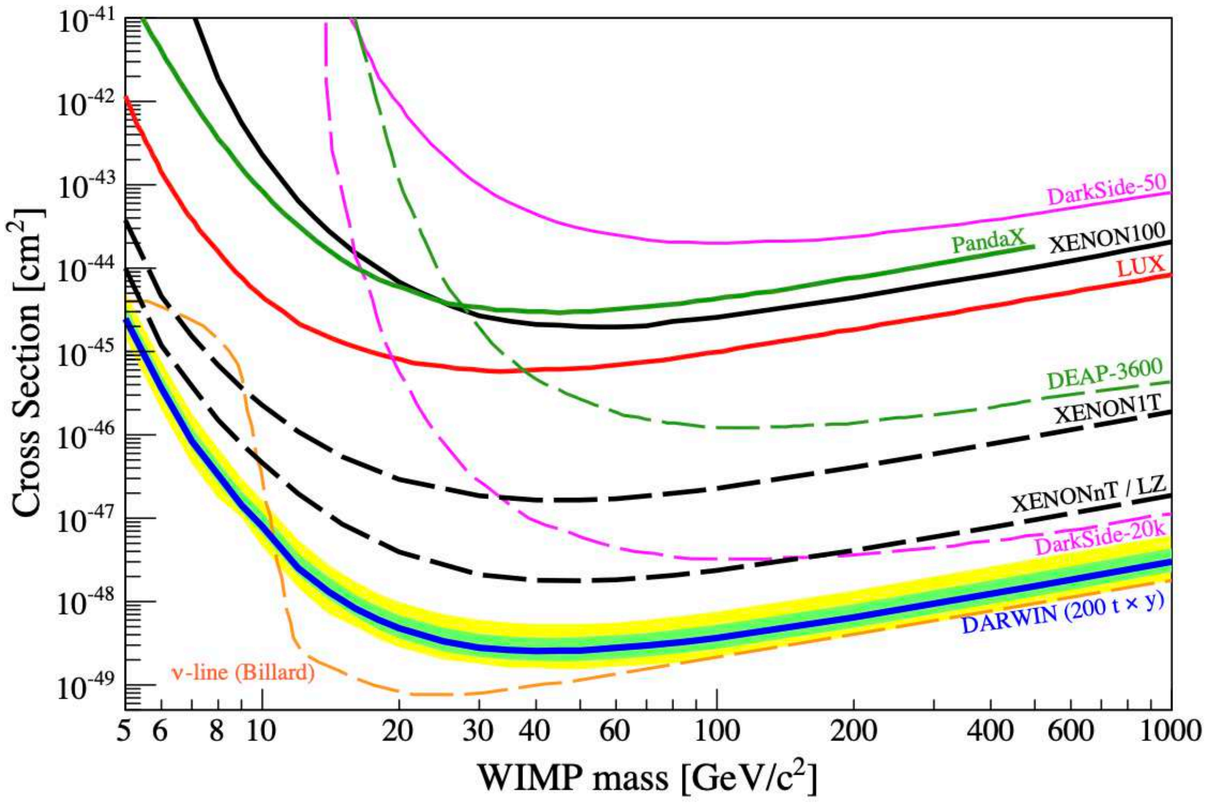
Rn BG target for future detector

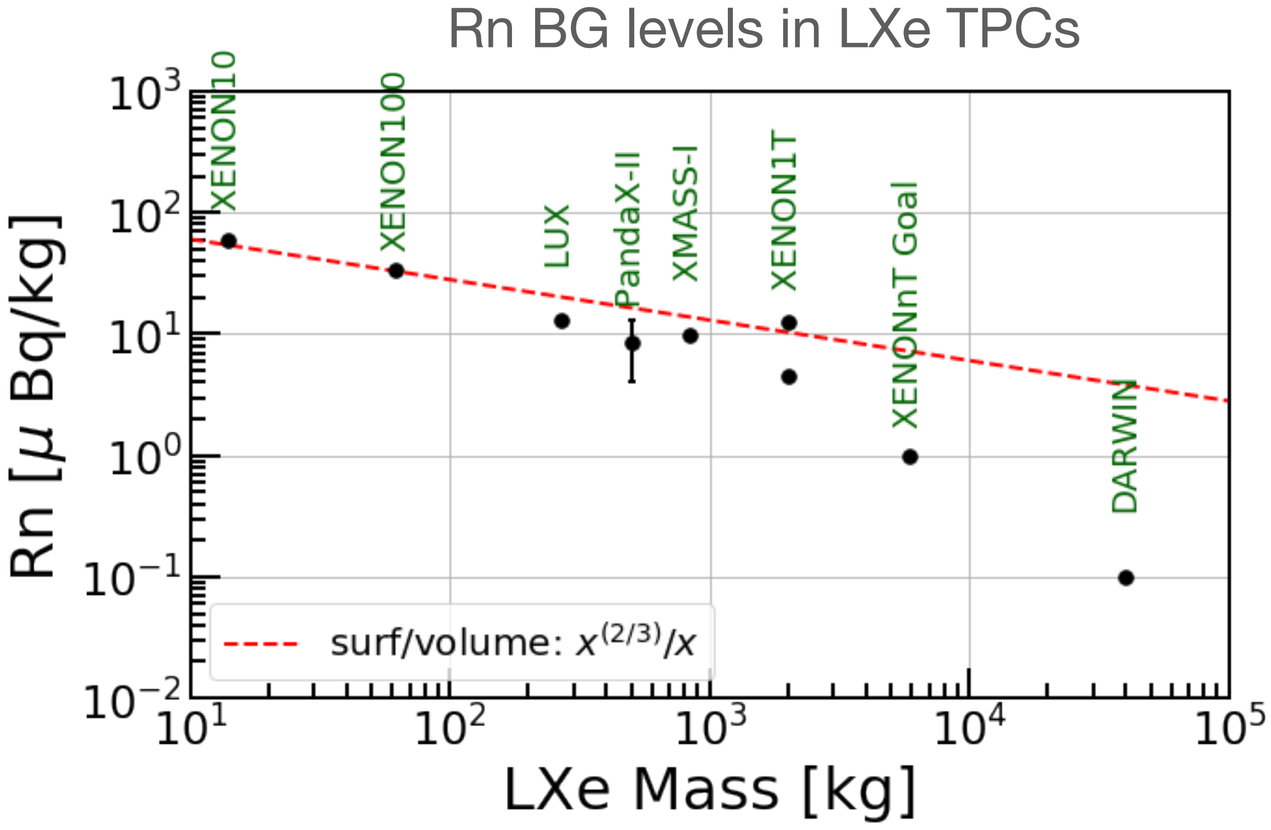




- To achieve the sensitivity ~10^{-49} cm^2, ^{222}Rn is the most serious background source
- We need **~1/10** of XENONnT target level -> How to achieve?

Rn BG target for future detector

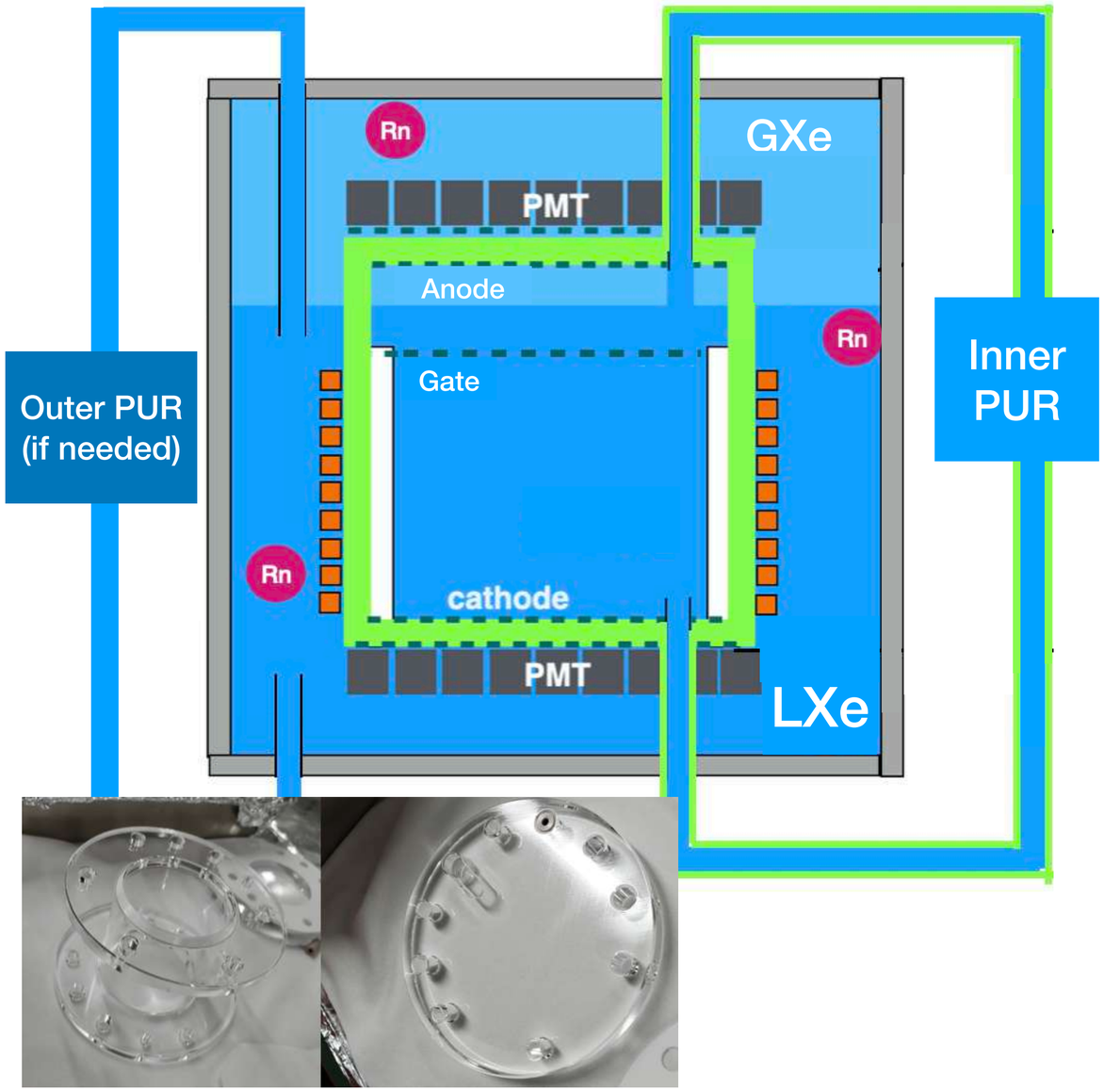




Yamashita,Dark Matter searches in the 2020s at the crossroads of the WIMP

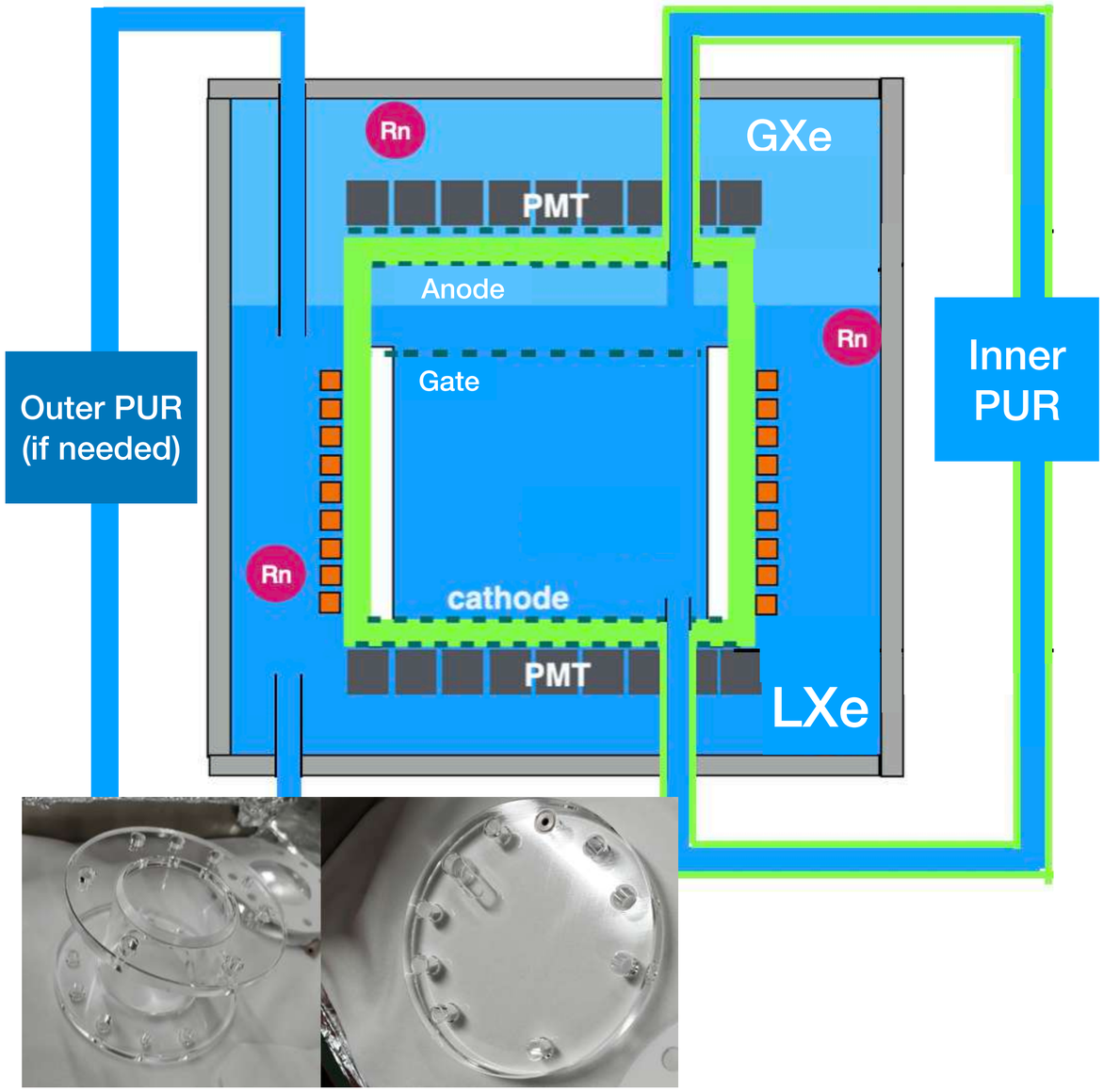
- Improvement by surface-volume ratio is not enough:
  - Additional Rn reduction is required !

Hermetic Quartz TPC: Concepts



- To solve this issue, we are studying about **Heretic Quartz TPC.**
  - Fully Isolating the TPC volume using Quartz
  - VUV transparent quartz with low radio-activity
- Non-hermetic quartz TPC has been tested**:** PTEP, 2020, 113H02
  - Good performance as TPC
- Next step: fully hermetic TPC

Hermetic Quartz TPC: Concepts



Advantages

- Almost no Rn222 emanation
- Less O_2/H_2O outgassing
- Coating electrode (no sagging)
  - -Dedicated study ongoing too

Challenges

- How tightly can we close?
- How to stabilize the detector?

R&D Steps

Current Status

1. **Characterization of sealing properties with Rn-emanation detector and GN2**
   - Flange, Gasket, Torque, Piping conditions vs Leak Rate
   - Rn-shielding test
2. **Characterization with GXe & S1-only setup**
   - Reproduce the results of step1 with Xenon
3. **Rn shielding test with LXe TPC (~0.3 kg)**
   - Shielding performance in cryogenic temperature
   - Detector stability (level, pressure...)
   - Optimization of electrode design with COMSOL

1: Characterization of sealing properties with GN2

Acknowledgement: SCREEN SPE Quartz

Test for Quartz flange conditions

Conditions of Quartz flange:

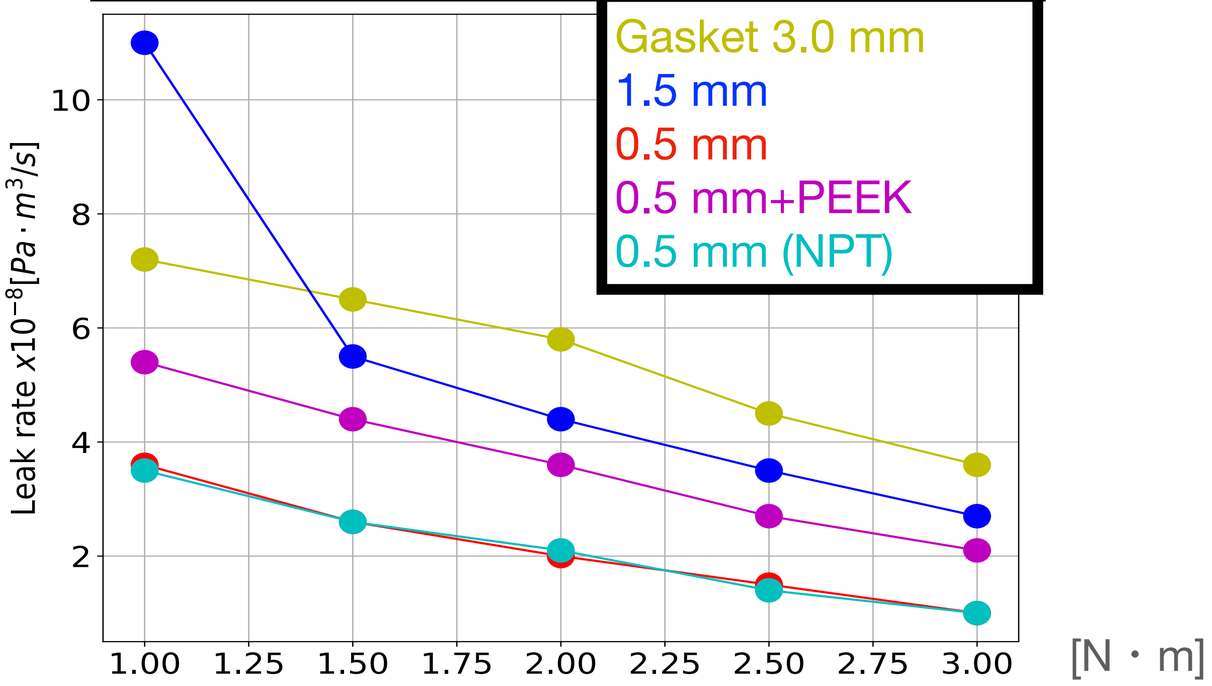
NPT screw or Branch-arm?

Gasket thickness?

With/Without spacer?

Torque?

Leak rate vs torque at each conditions



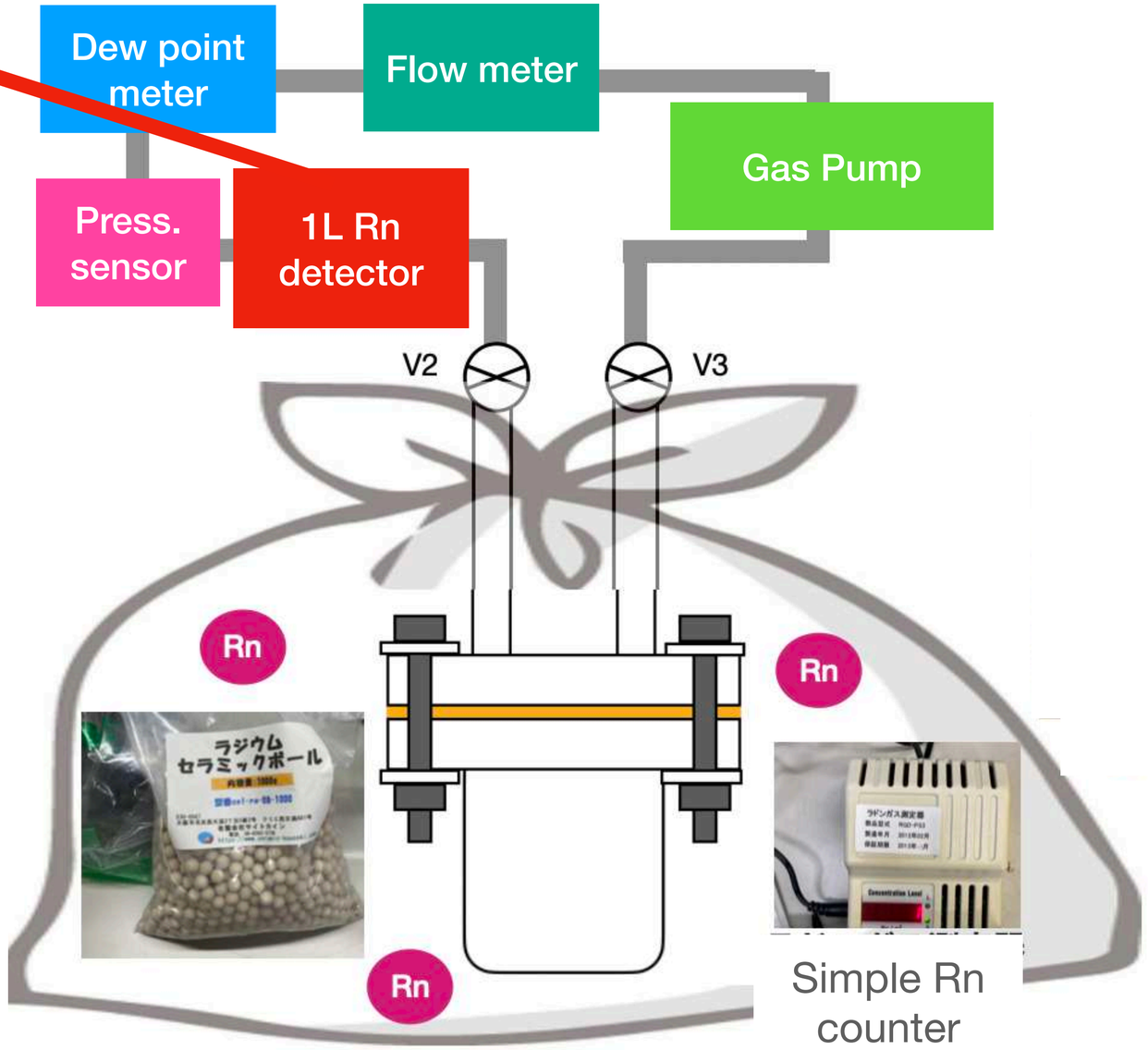
For TPC design:

- Piping: NPT screw
- Gasket material: ePTFE
- Gasket thickness: 0.5 [mm]
- Use PEEK spacer

But: How about Rn shielding vs Leak rate?

Vacuum leak rate vs Rn shielding

- 1L Rn detector developed by SuperK group
  - PTEP Volume 2018, Issue 9, Sep 2018, 093H01



Simple Rn counter

- Measurement done with GN2
- Inner Rn concentration was measured
  - BG run: without Rn source outside Quartz
  - Rn run: with Rn source outside Quartz

Vacuum leak rate vs Rn shielding

Rn reduction factor: $R_{in/out} = \dfrac{^{222}\mathrm{Rn}\text{ concentration inside quartz}}{^{222}\mathrm{Rn}\text{ concentration outside quartz}}$

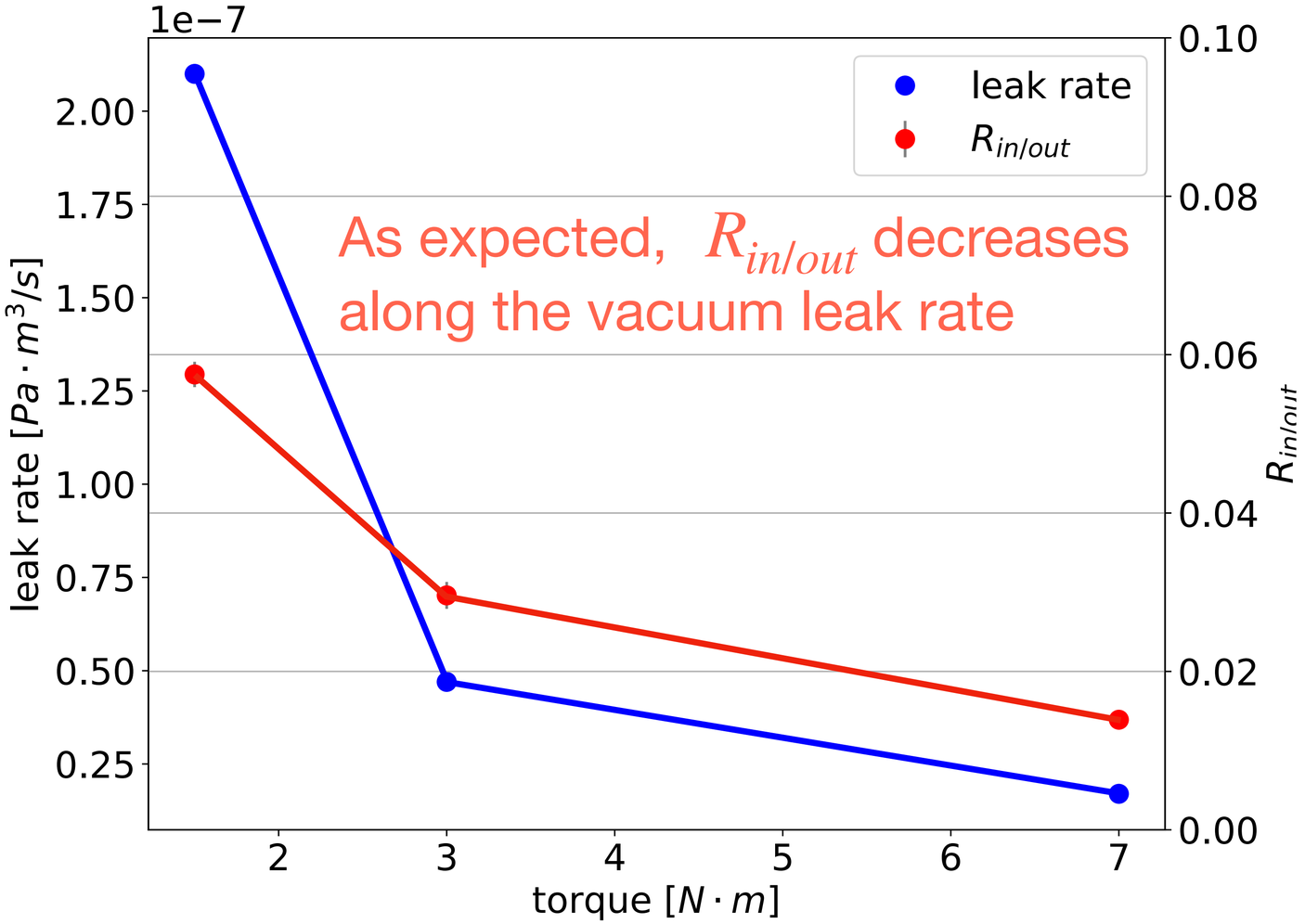
@Torque 7.0 [N · m]:

Leak rate:

$$1.7 \times 10^{-8}\ [\mathrm{Pa \cdot m^3/s}]$$

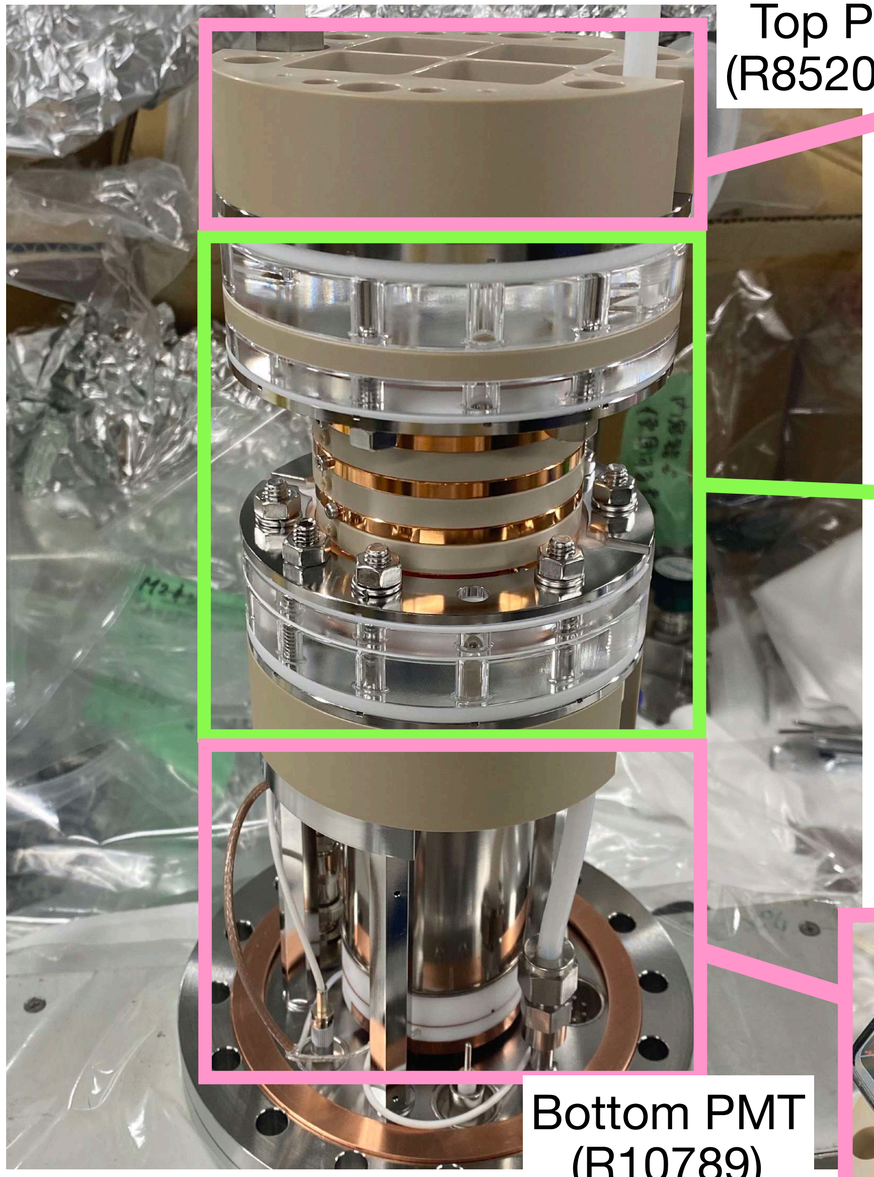
$R_{in/out}$:

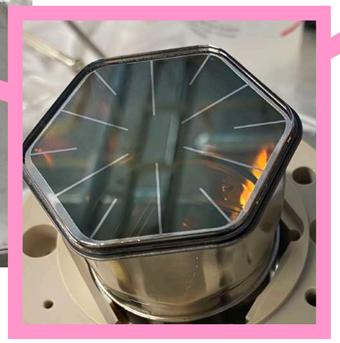
$$(1.39 \pm 0.03) \times 10^{-2}$$

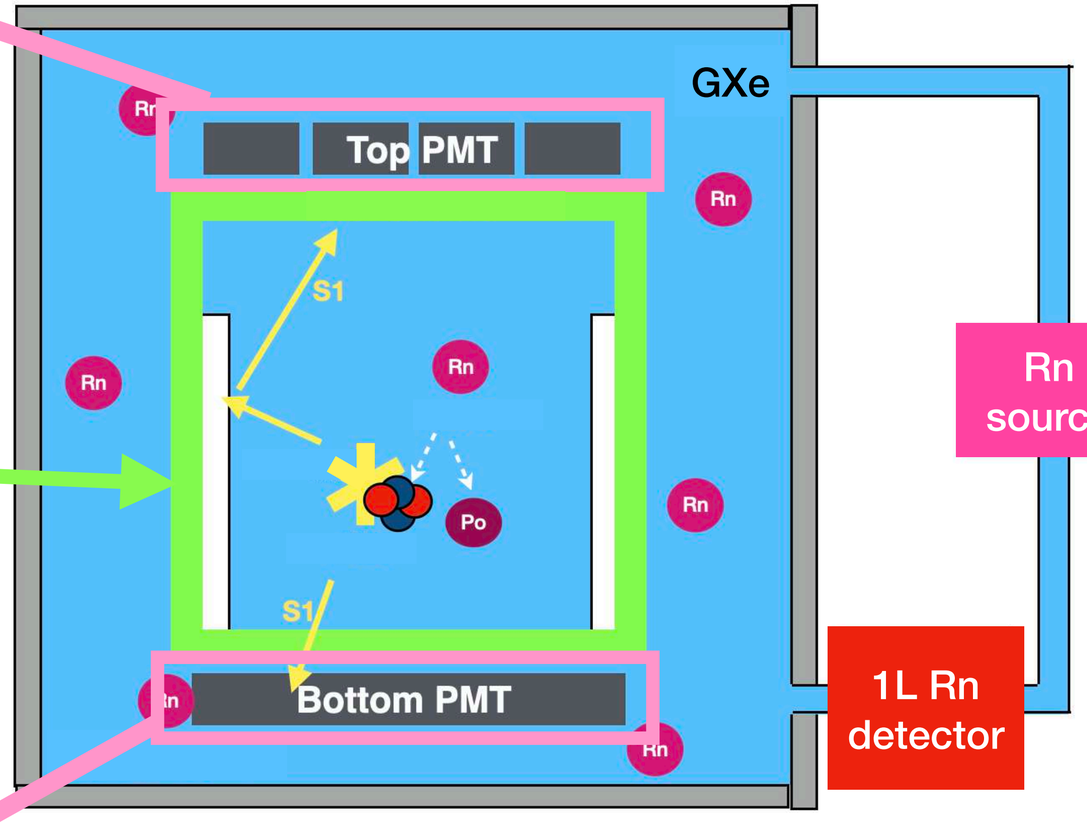


2: Characterization with GXe & S1-only setup

Rn shielding with GXe detector



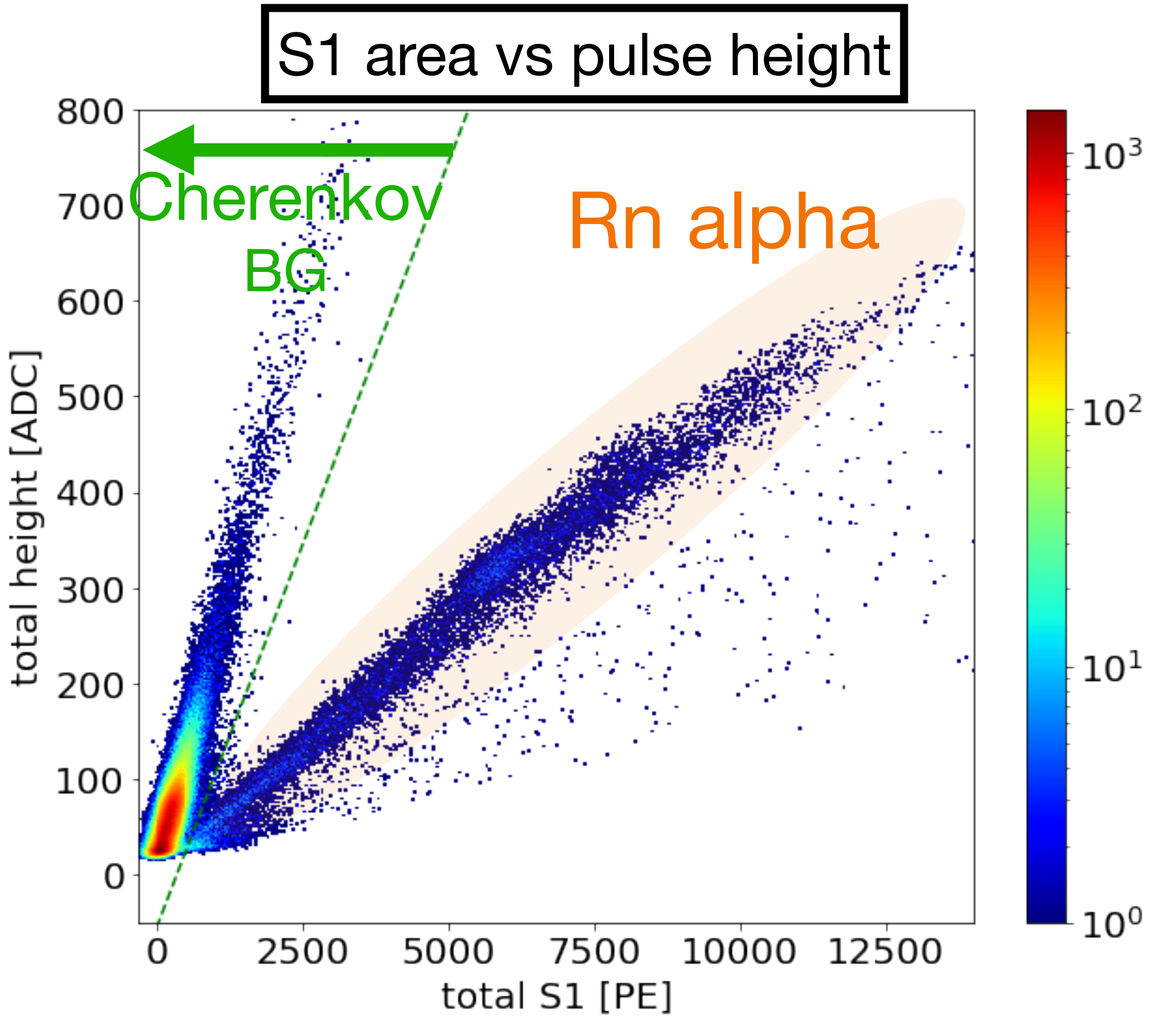




- Small hermetic TPC was designed based on the test results.
- For 1st step, test with GXe is ongoing
  - Artificially add Rn source outside Quartz chamber

Analysis for Rn alpha signals

- Rn S1 spectrum was measured using Rn source
- Count alpha rates with S1, and compare the one outside Quartz Chamber
- The test is ongoing:
  - First test showed clear Rn alpha inside quartz
    - Estimated R: ~50%
  - Leak found at NPT screw, under investigation



Conclusions and future plans

- Hermetic quartz TPC: Rn reduction for future liquid xenon detectors
- Test of the quartz flange was performed and achieved:
  - Suppressing the Rn concentration to ~1.4%
- GXe run with small detector is ongoing:
  - Successfully manage to observe sufficient S1 signals with GXe S1-only setup
  - Difficulty with NPT screw: under investigation
- LXe run in this year
  - Run as S1 detector at first, then apply HV to test as TPC

BACK UP