



高圧キセノンガス検出器を用いた ニュートリノレス二重ベータ崩壊探索

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For the AXEL collaboration

今年度はコロナ禍ということもあり、神岡への出張などを行うことができなかったため、利用はありませんでした。

今年度分(10万円)は返却致します。

来年度も引き続き共同利用の申請はさせて頂きたいと思っております。

将来、神岡で物理測定ができないかなどの相談や放射能測定に伺うための利用を予定しております。

Neutrinoless double beta decay

AXEL experiment

Prototype detector

R&D for more sensitivity

Summary

Neutrinoless double beta decay

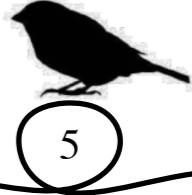
AXEL experiment

Prototype detector

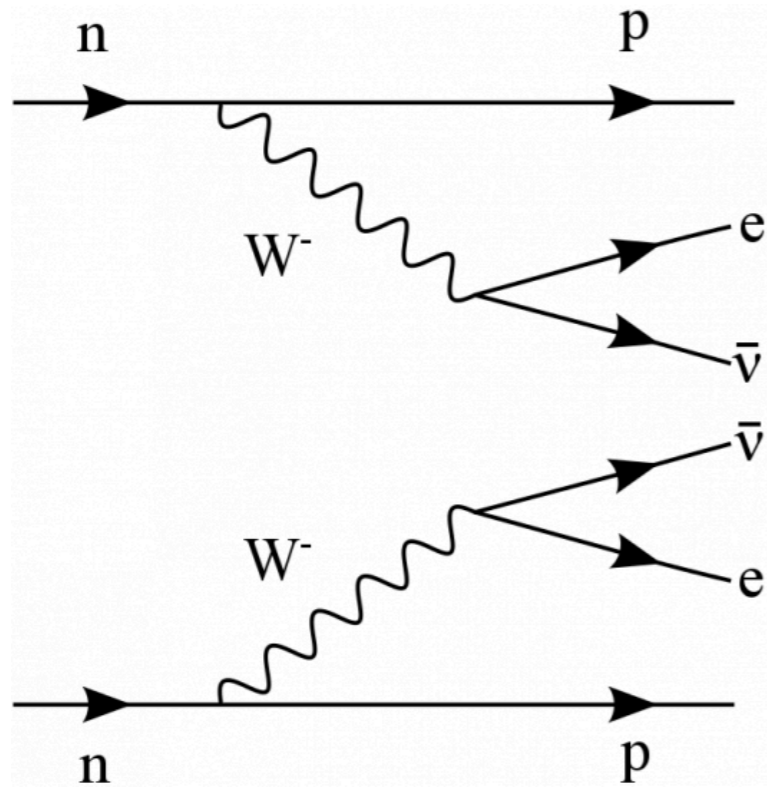
R&D for more sensitivity

Summary

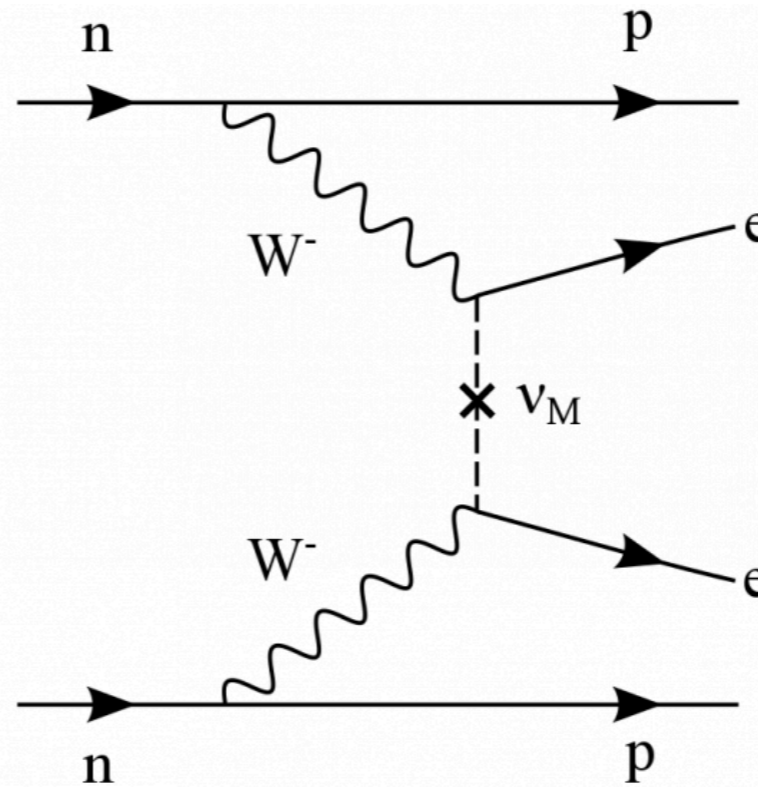
Neutrinoless double beta decay



It occurs only if the neutrino has Majorana mass term



$2\nu\beta\beta$ decay

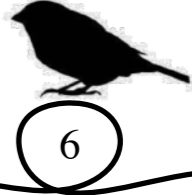


$0\nu\beta\beta$ decay

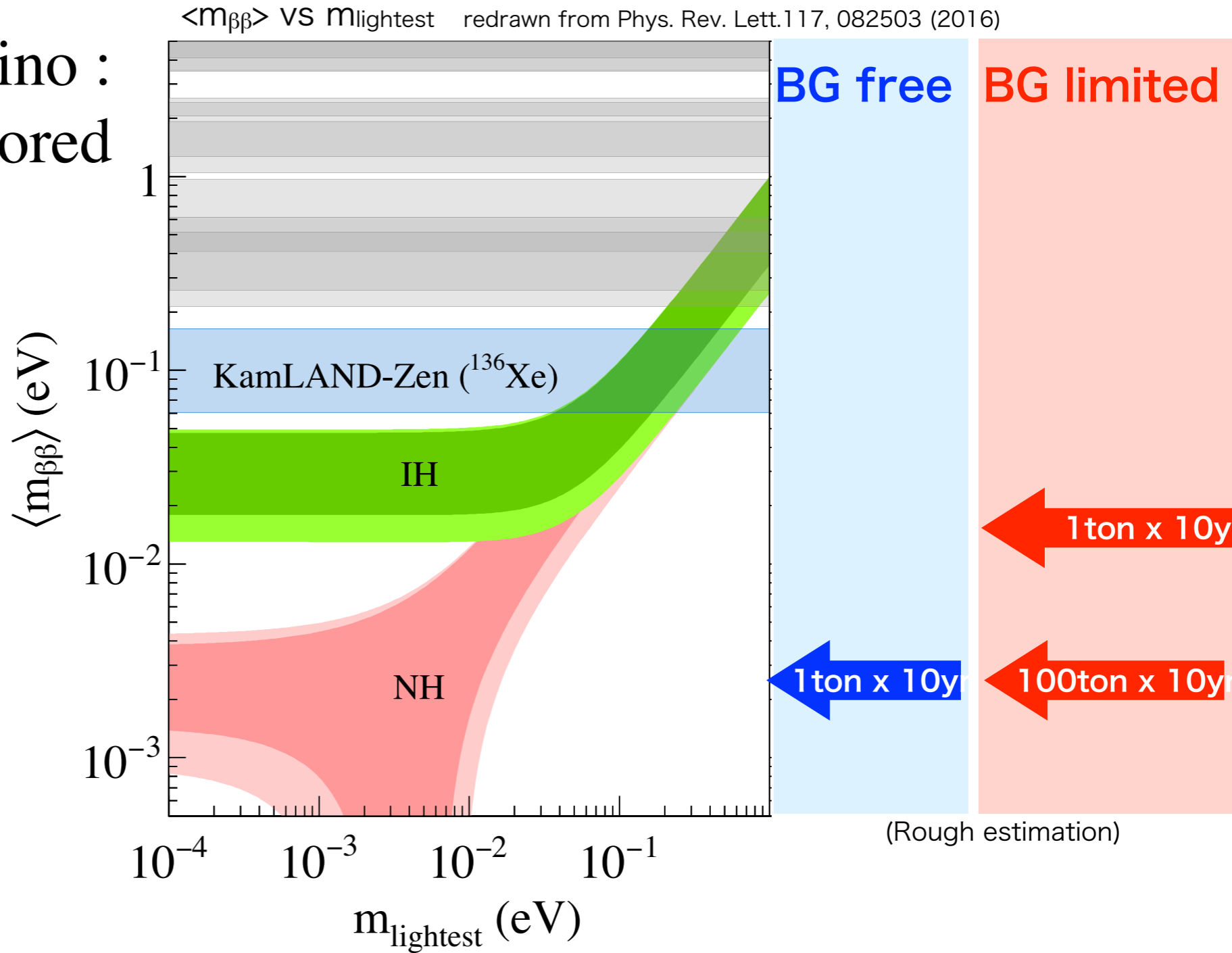
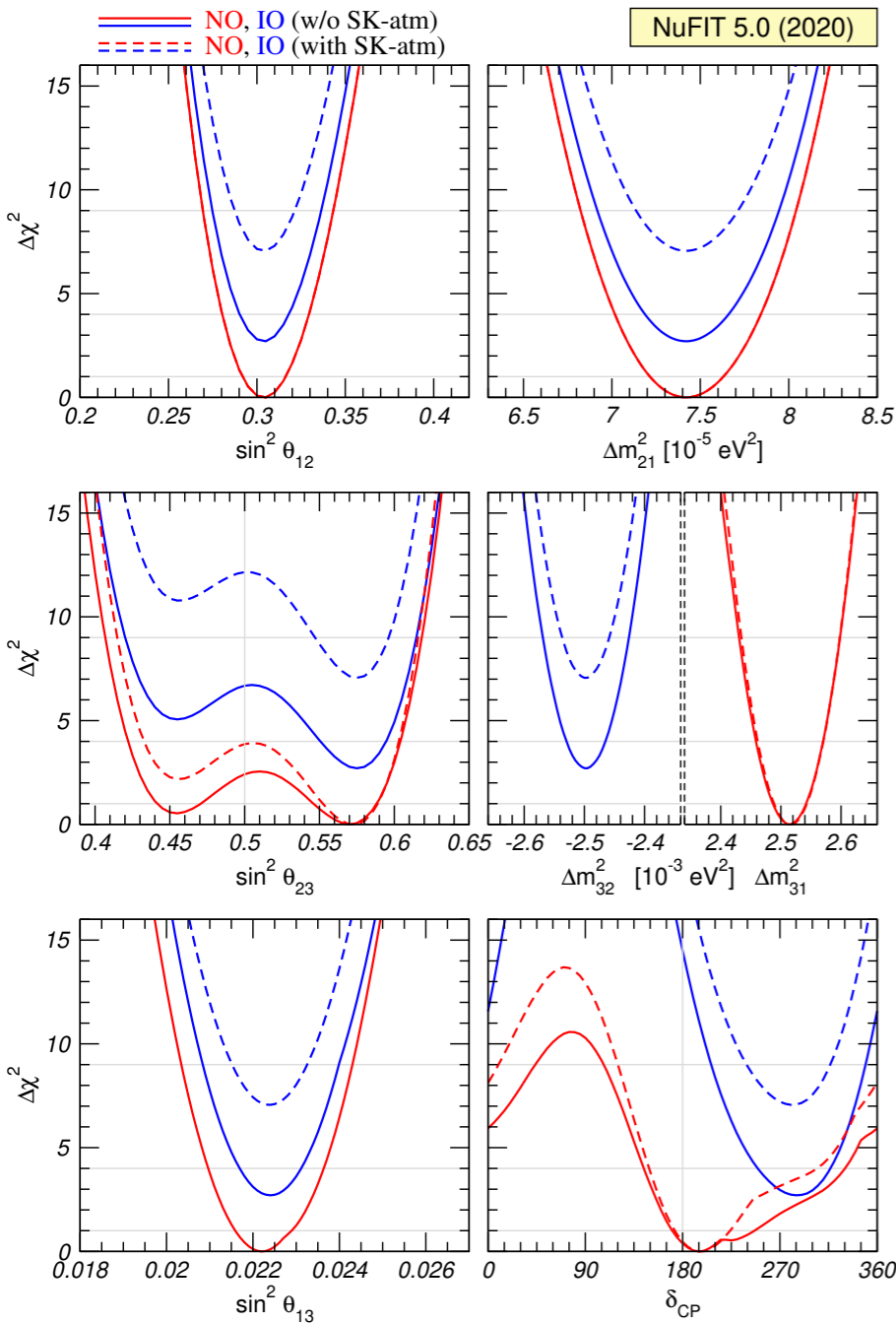
If the neutrino is Majorana

- naturally explains the smallness of the neutrino mass
- One of the conditions of Leptogenesis scenario

Neutrinoless double beta decay



Mass ordering of neutrino :
normal ordering is favored



Ton scale & background free are required
→ high pressure xenon gas TPC

Neutrinoless double beta decay

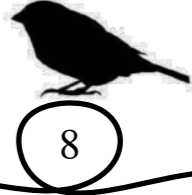
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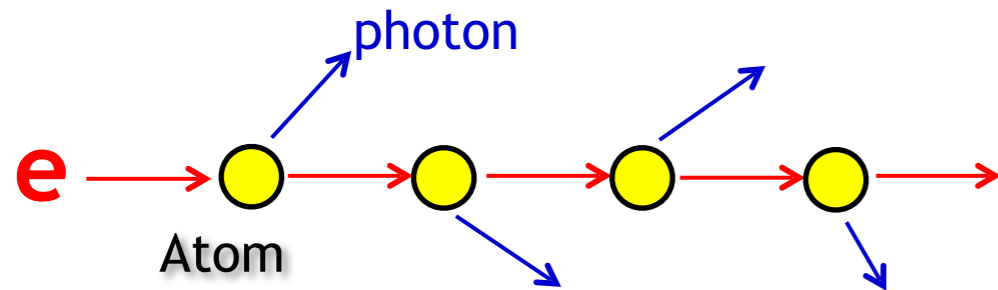
A Xe ElectroLuminescence : AXEL



High pressure Xe gas TPC with unique cell readout structure for $0\nu\beta\beta$ decay search

Detection of Ionization signals

- Electroluminescence (EL) process



Linear response to applied electric field

Without avalanche process
→ less fluctuation of multiplication

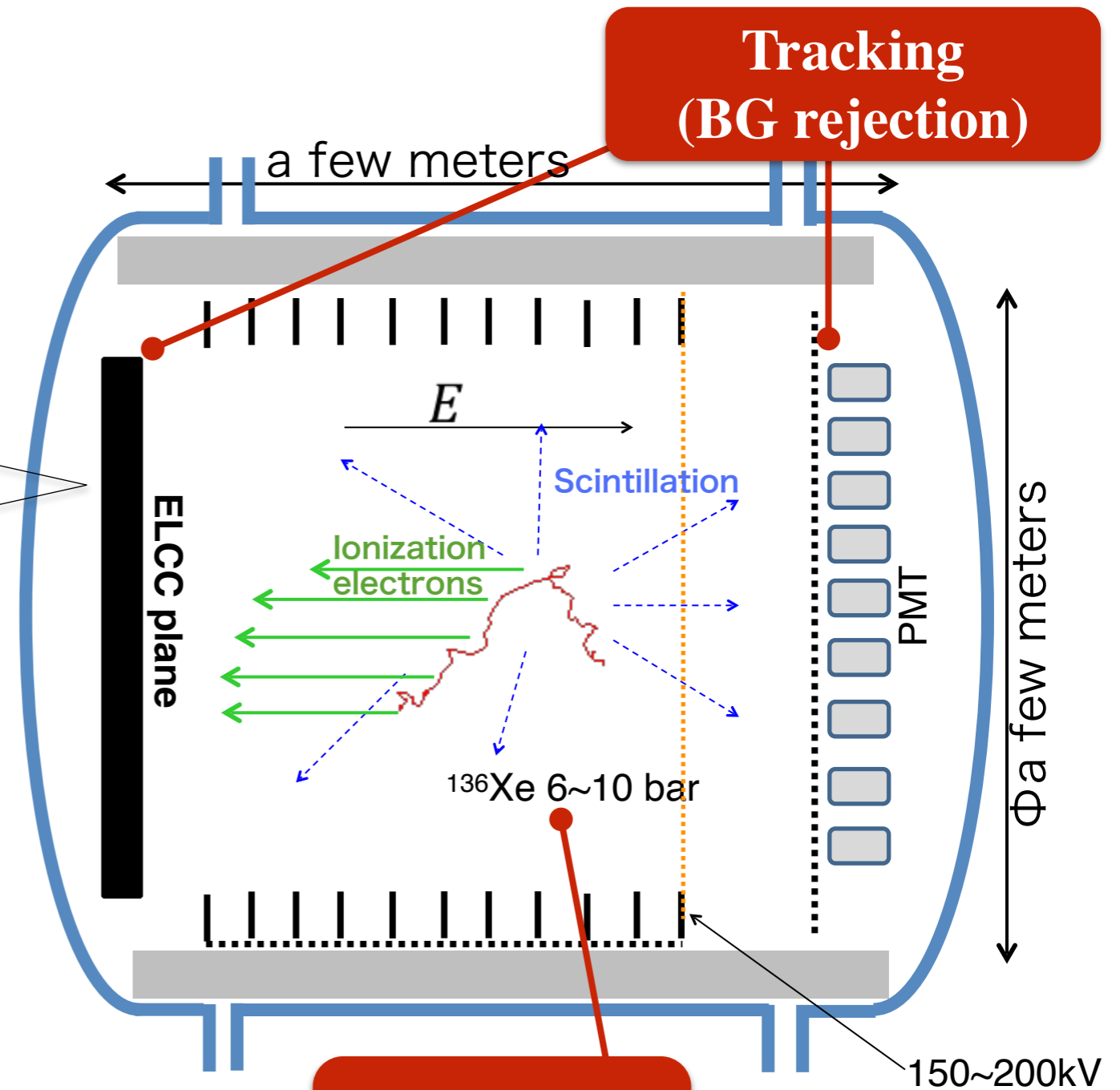
Detail is in the next page

Good energy resolution

→ goal : **0.5%FWHM @ Q-value**

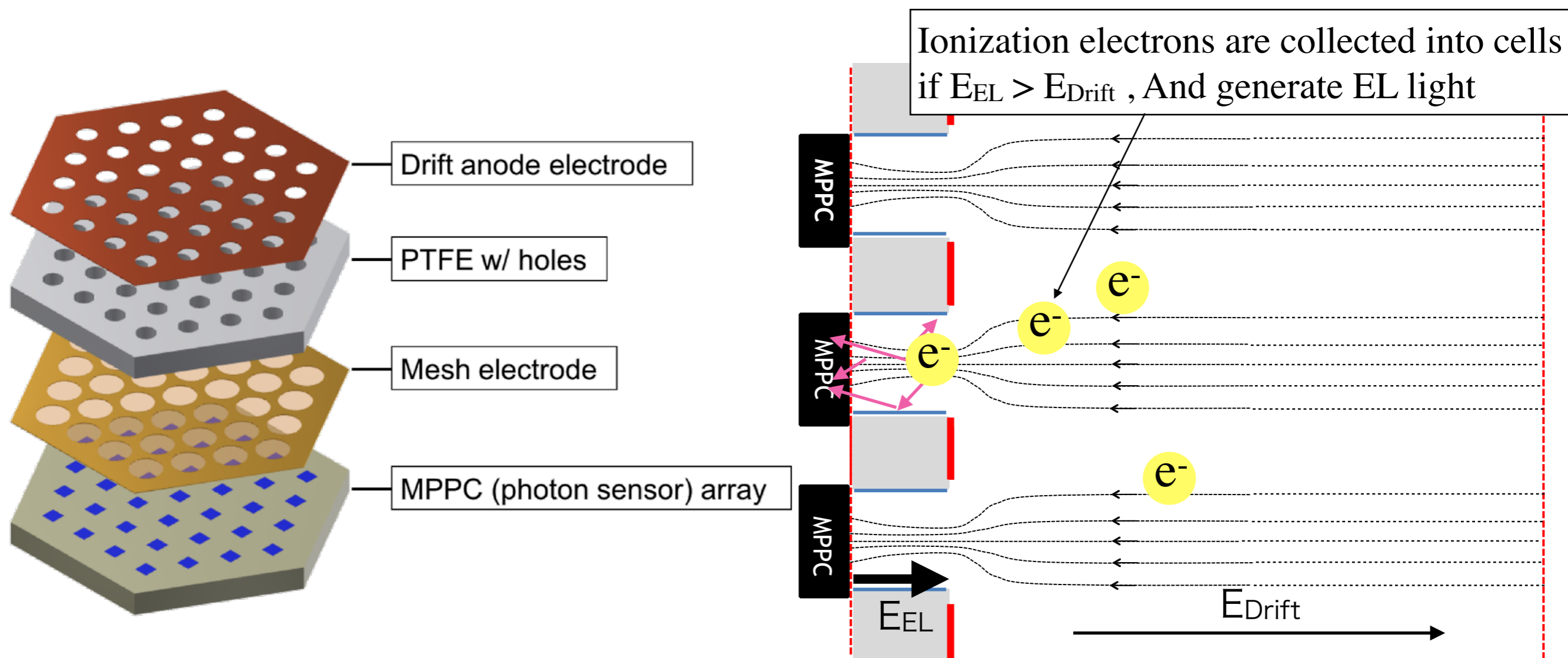
Large mass

→ ton scale ^{136}Xe ($\beta\beta$ -decay nucleus)

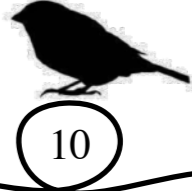


Electroluminescence Light Collection Cell : ELCC

- Energy measurement and Tracking
- Uniform response regardless of event position
- Extendable to large size thanks to its rigid structures



A Xe ElectroLuminescence : AXEL



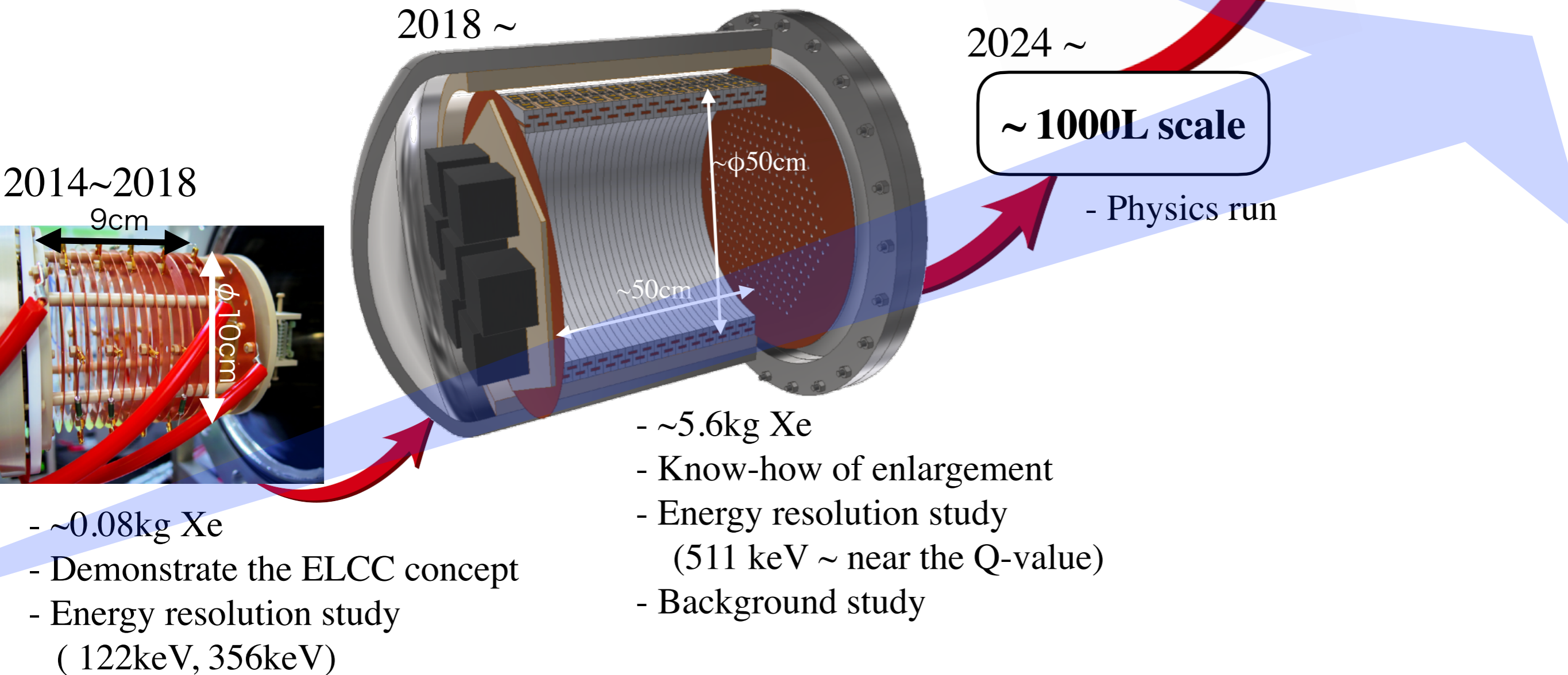
202X ~

ton scale

- sweep out NO

Road map of the AXEL experiment

- Finish evaluation of the prototype detectors until 2021
- aiming to start physics run from 2024



Neutrinoless double beta decay

AXEL experiment

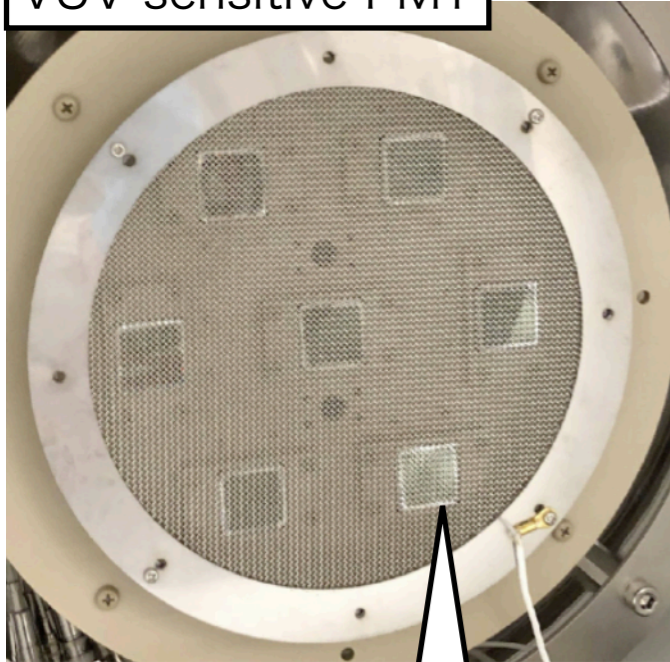
Prototype detector

R&D for more sensitivity

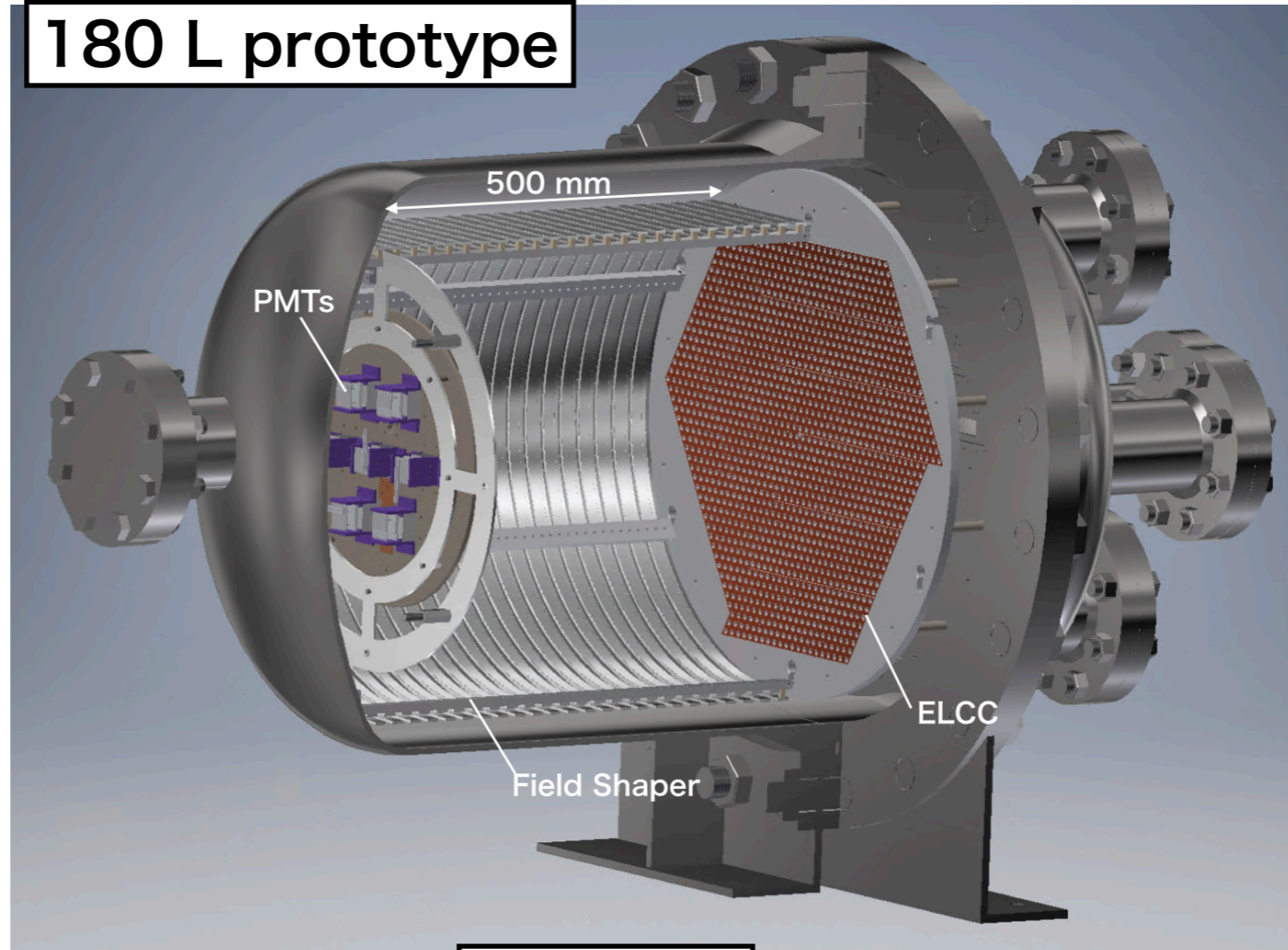
Summary

Prototype detector

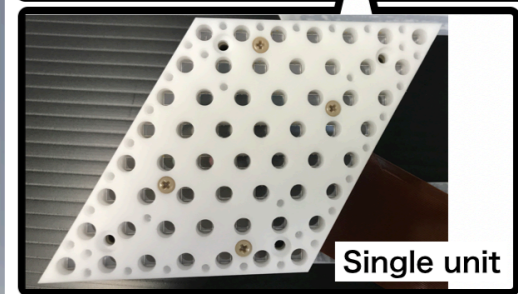
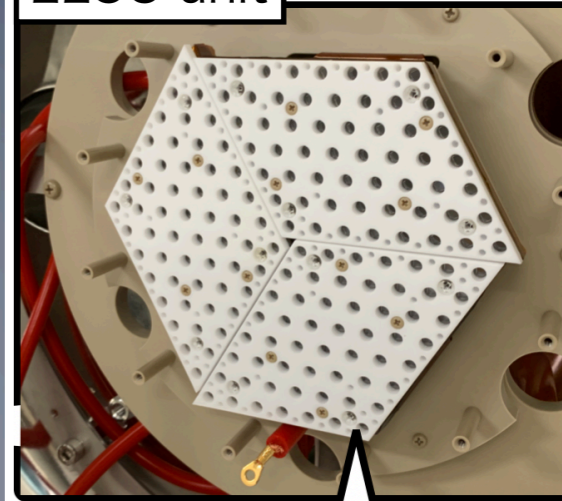
VUV-sensitive PMT



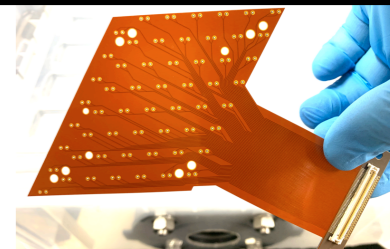
180 L prototype



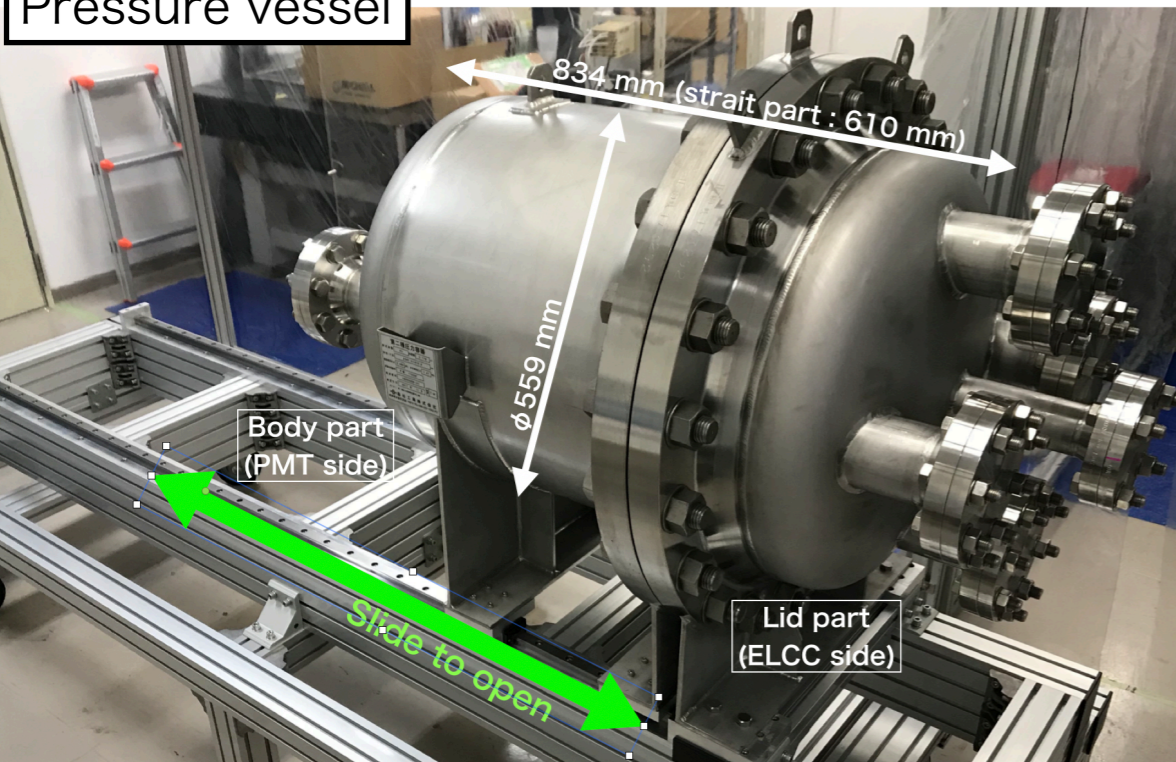
ELCC unit



Flexible Printed Circuit



Pressure vessel

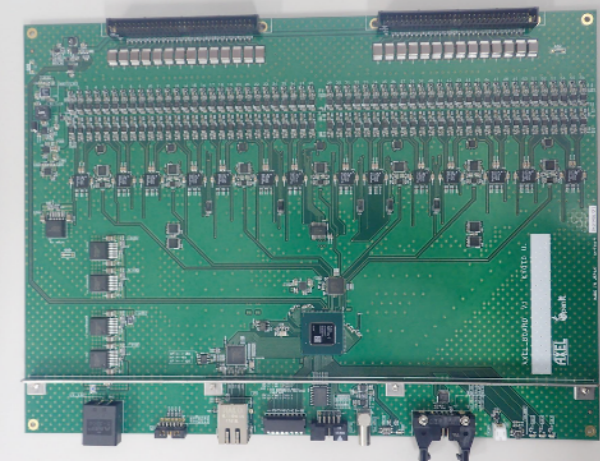


Field shaper



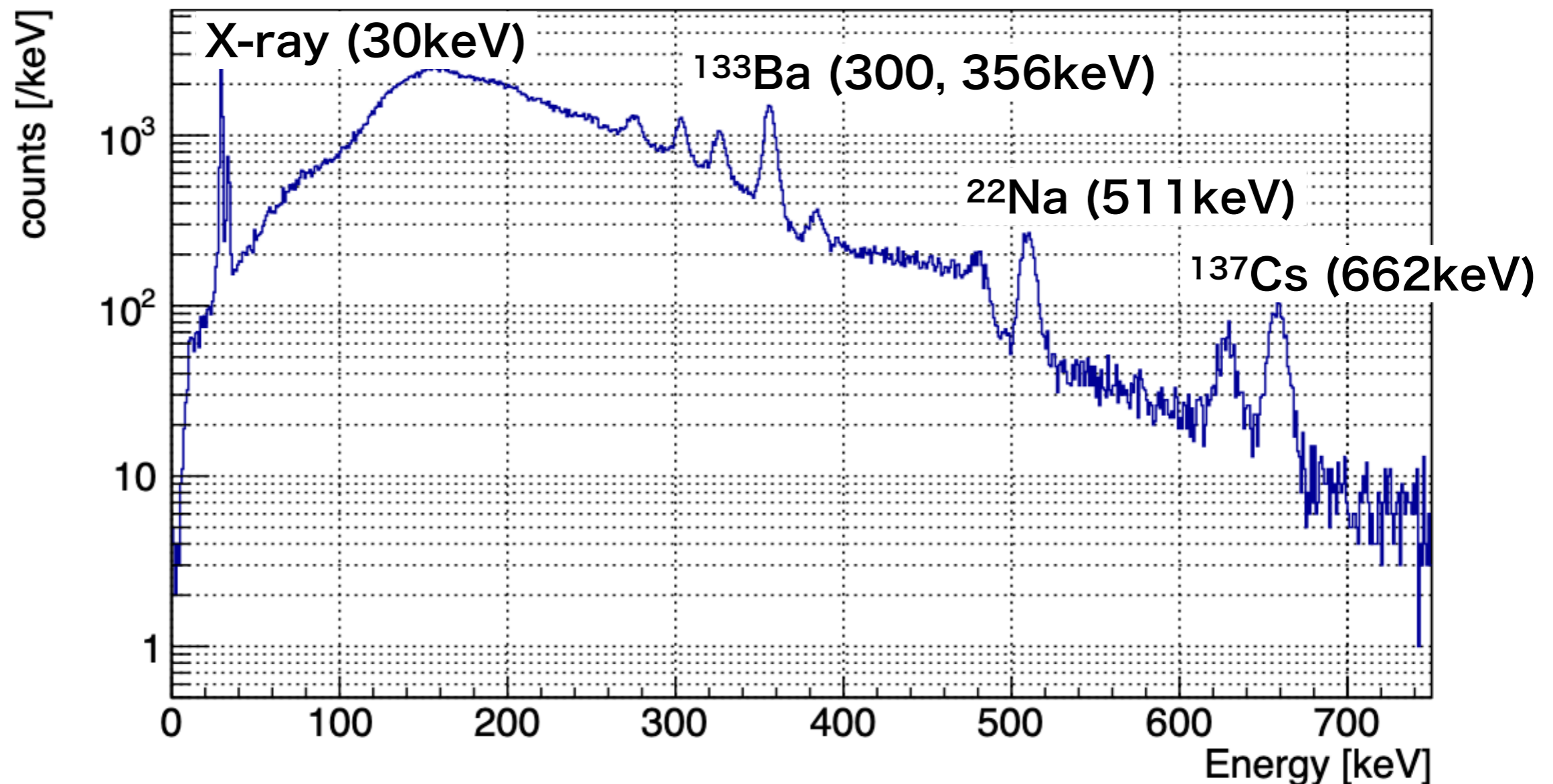
Front-end Electronics Board

ref: arXiv:2001.02104



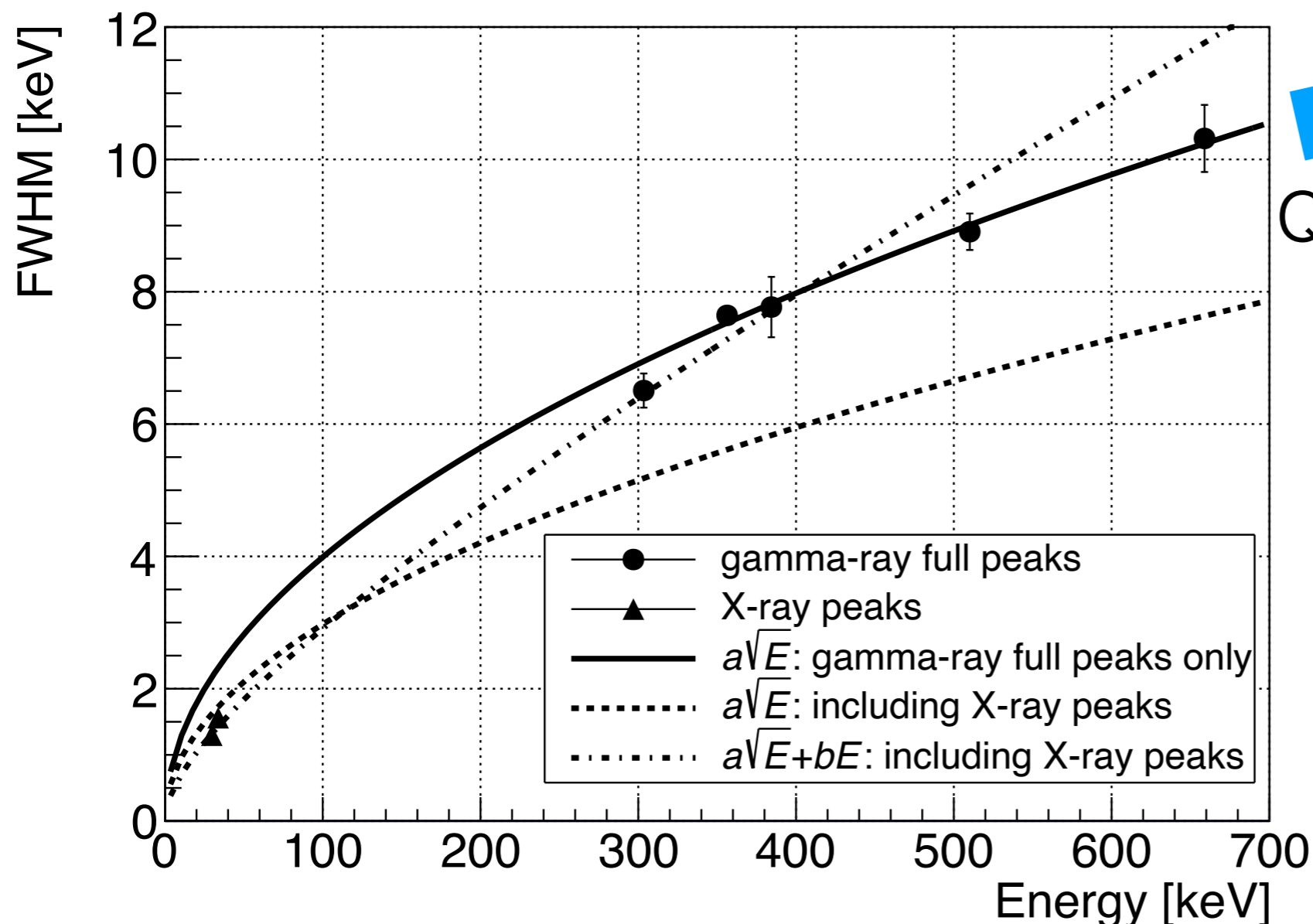
性能評価 @4気圧

- 各種カット、補正後のエネルギースペクトラム
- ^{133}Ba , ^{22}Na , ^{137}Cs 由来のピークがはっきり見える
- Energy resolution is evaluated by Gaussian fitting
- **1.57 %** at 662 keV \rightarrow **0.81 %** at Q-value by \sqrt{E} (FWHM)



Q値(2458keV)での性能の見積もり

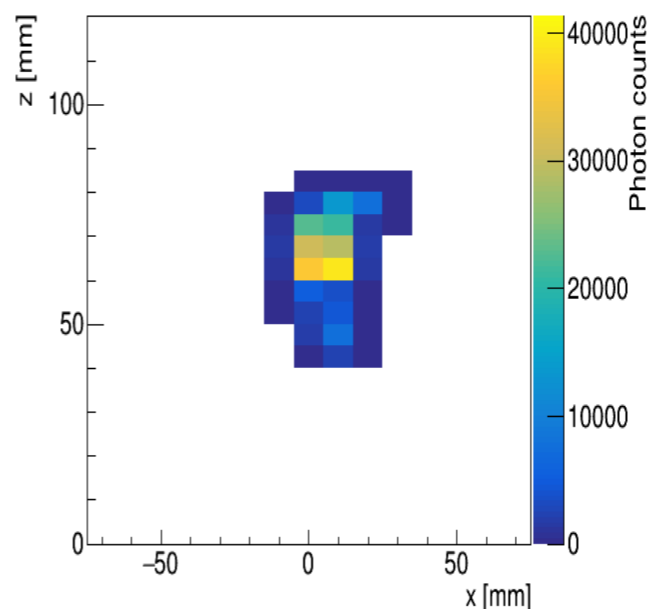
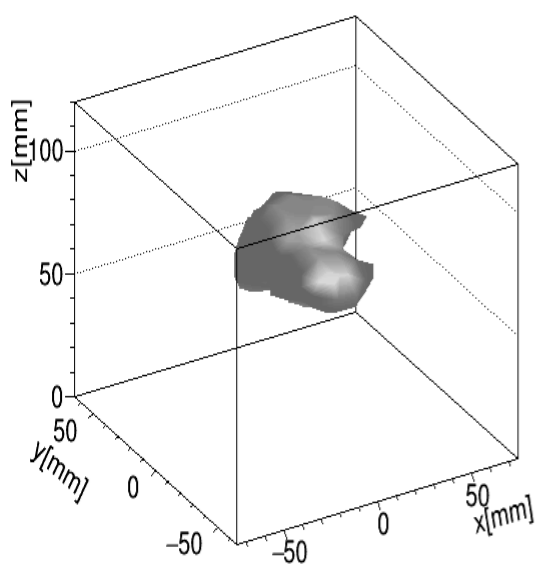
- 2通りの仮定をおいて外挿： $\Delta E \propto A\sqrt{E}$ or $A\sqrt{E + BE^2}$
- Q値でのエネルギー分解能：**0.81~0.84 % (FWHM)**
- Eの1次の寄与はほとんど無い



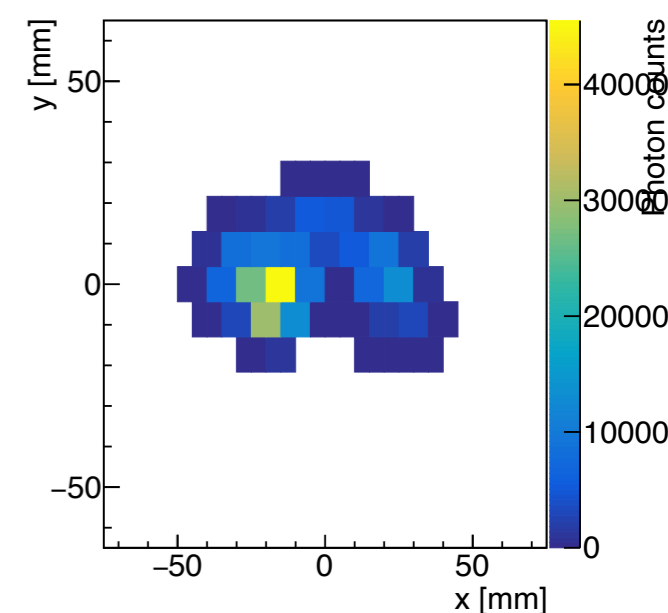
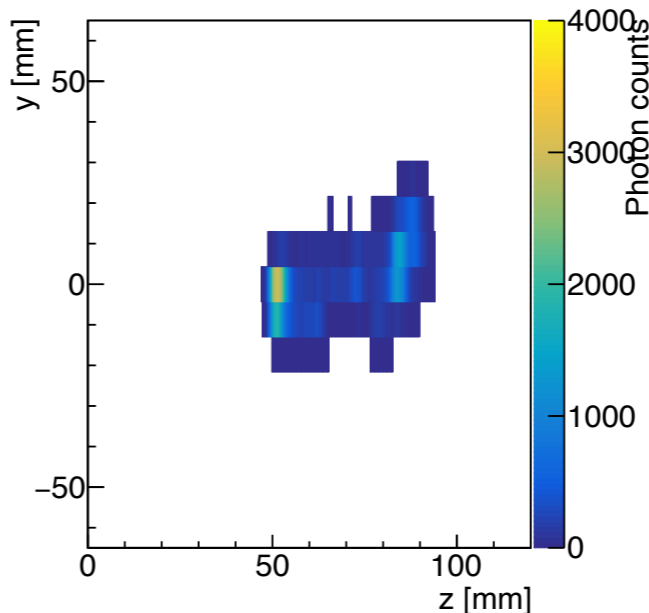
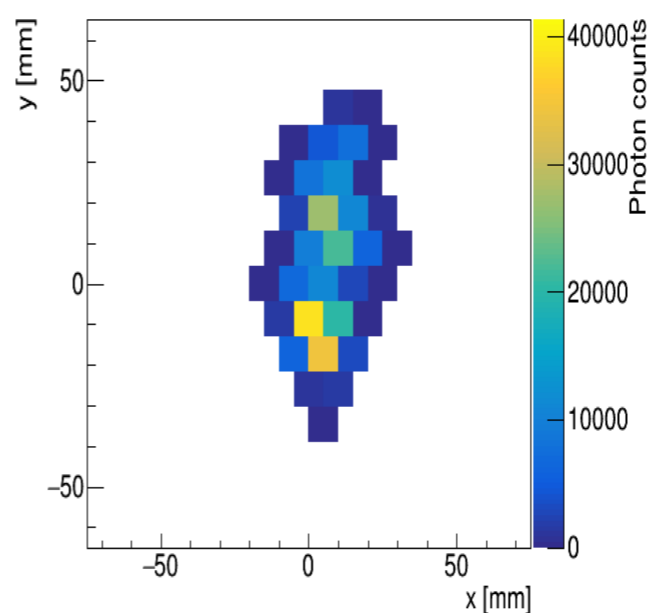
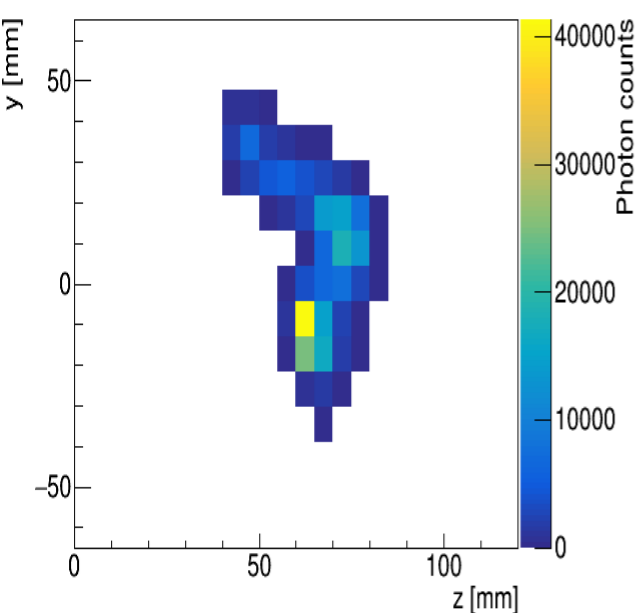
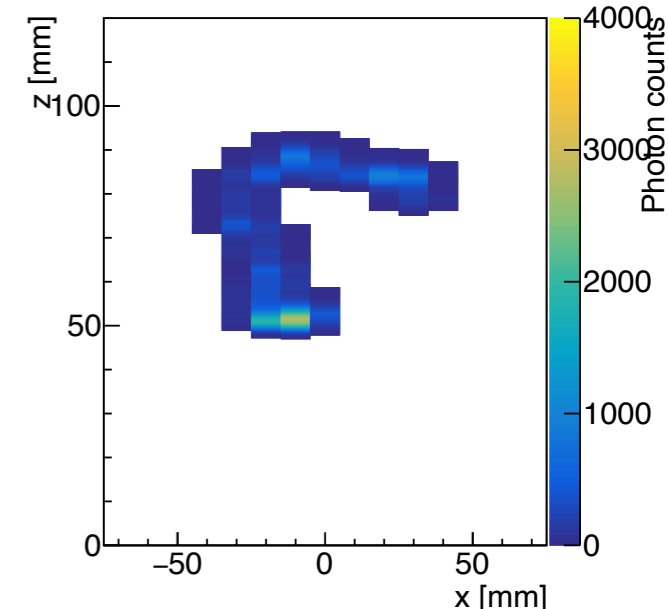
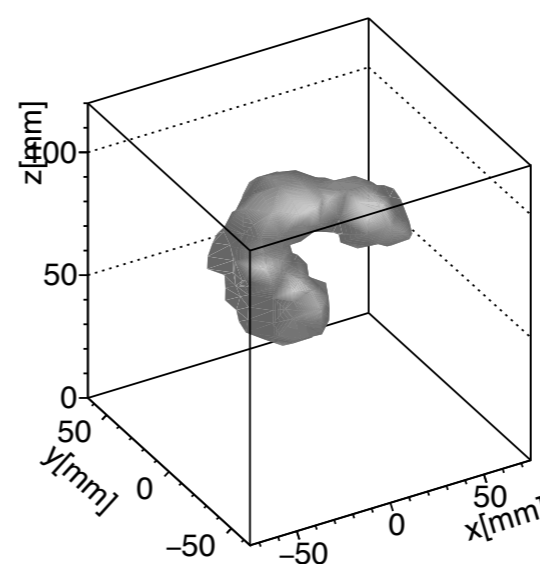
Q値(2458 keV)に外挿

イベントディスプレイ

511 keV



662 keV



Neutrinoless double beta decay

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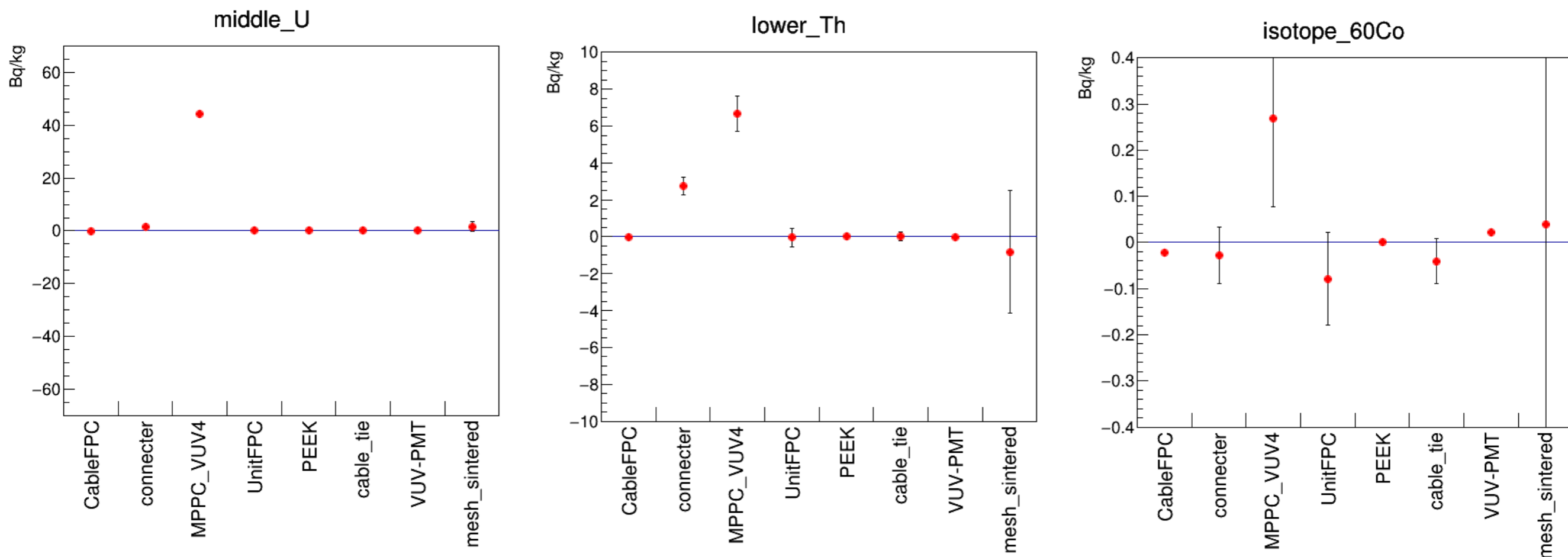
R&D for more sensitivity

Summary

背景事象削減のため極低放射能素材を用いる必要がある
検出器に用いる素材の放射能を調べている

→ 調査の結果を見て、バックグラウンド源になり得る素材の見直しを行っていく

- MPPCのパッケージが汚いことが判明したので、PEEKパッケージのMPPCを浜ホトと開発している



Ba⁺⁺ tagging

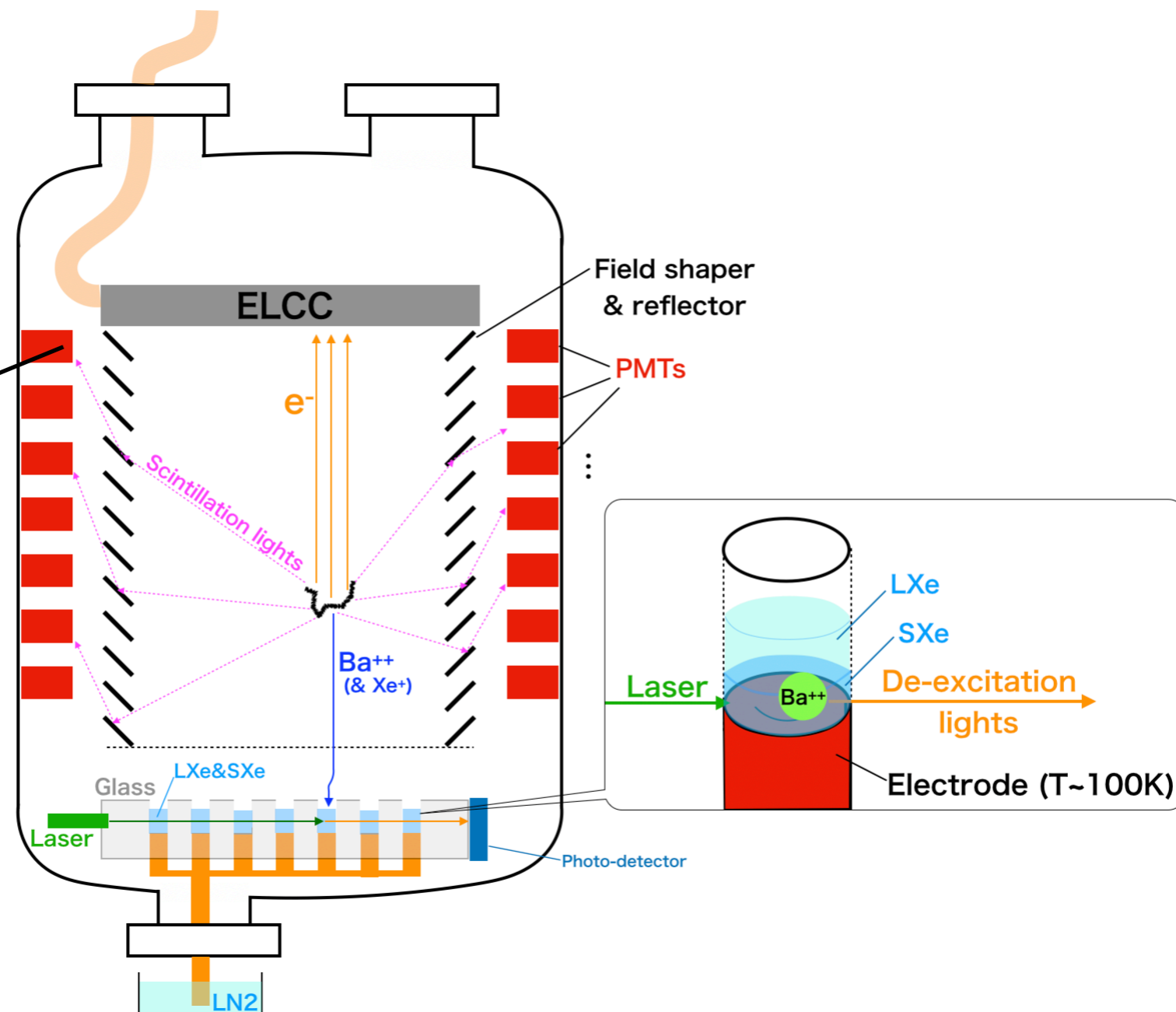
(¹³⁶Ba⁺⁺) : daughter nuclei of ¹³⁶Xe ββ decay

→ **tagging Ba⁺⁺ is a strong evidence of 0νββ decay**

Our strategy : drift Ba⁺⁺ ion → trap in solid xenon (Ba⁺⁺ → Ba⁽⁺⁾?)

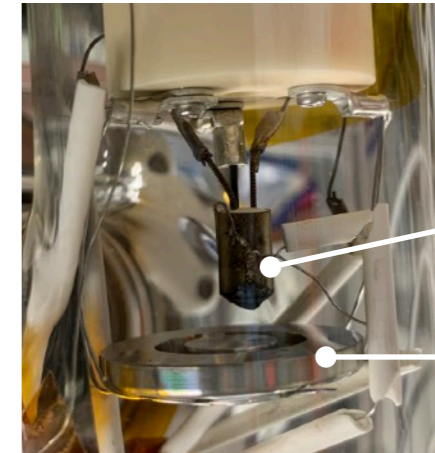
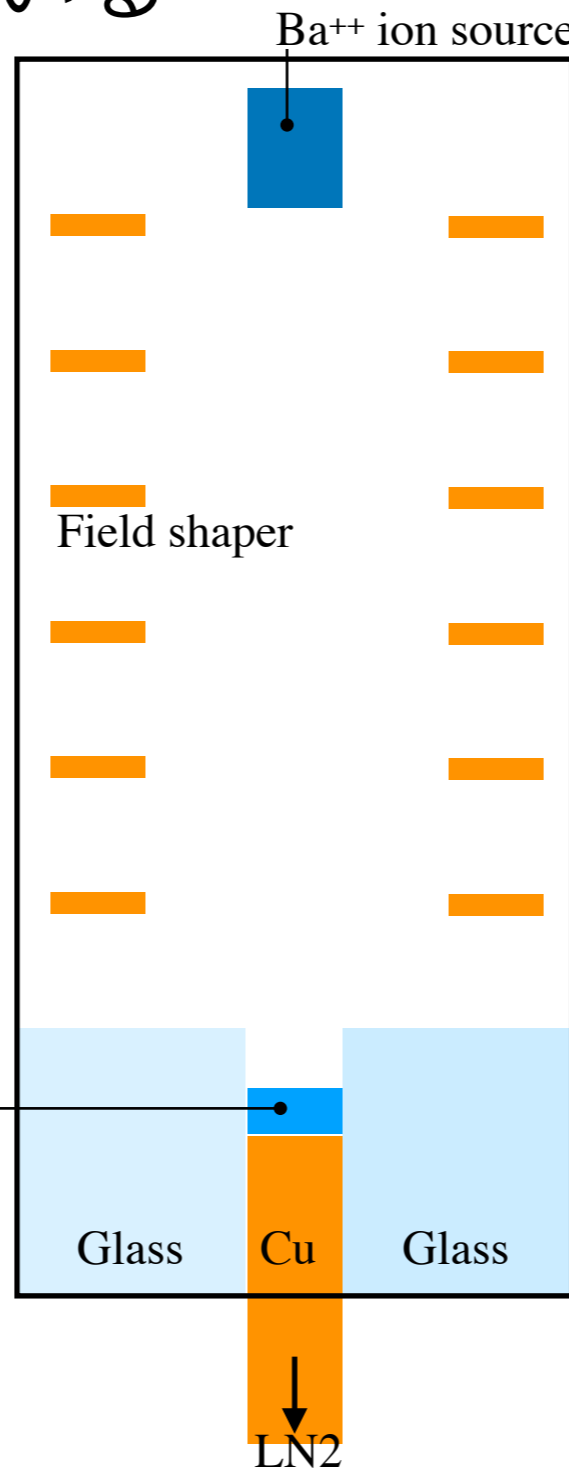
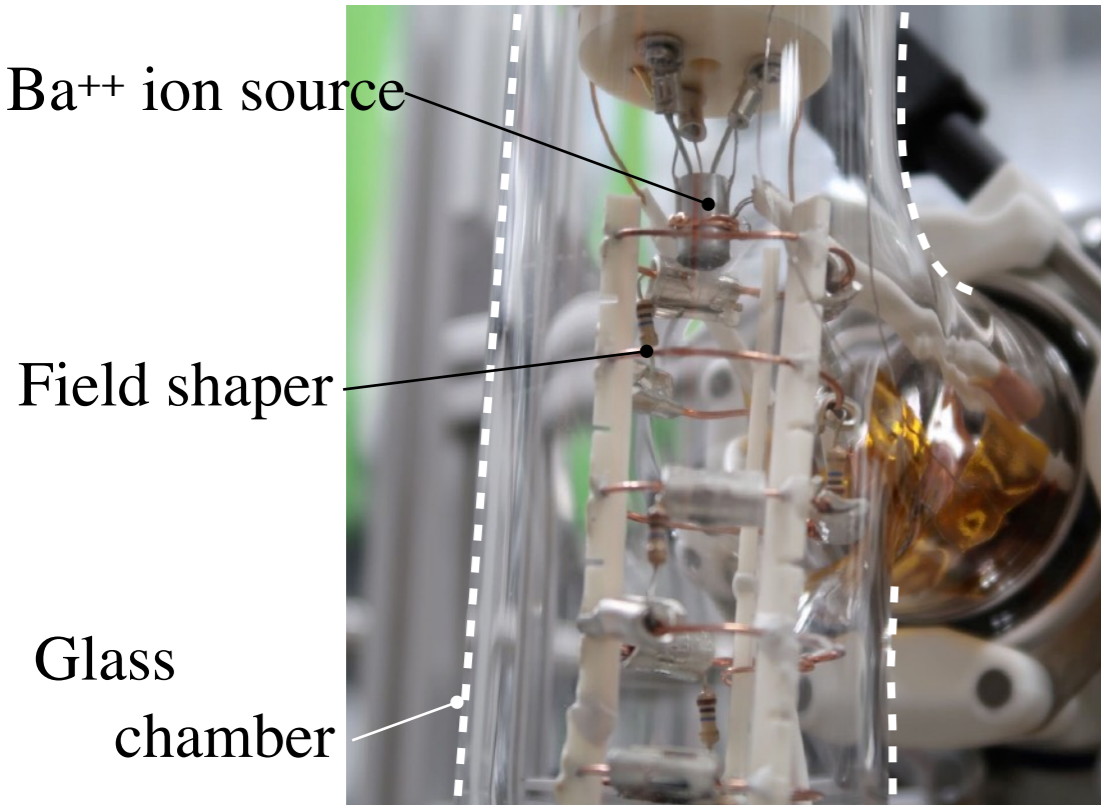
→ excite it by laser → detect the de-excitation light

PMTs are placed
at the side wall

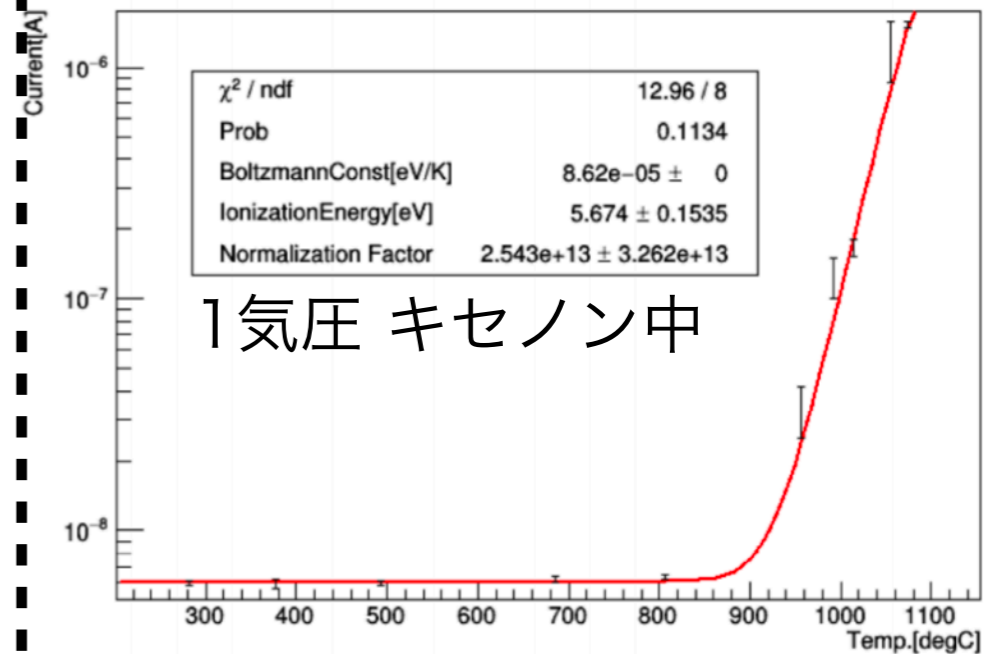


Ba⁺⁺ tagging : R&D

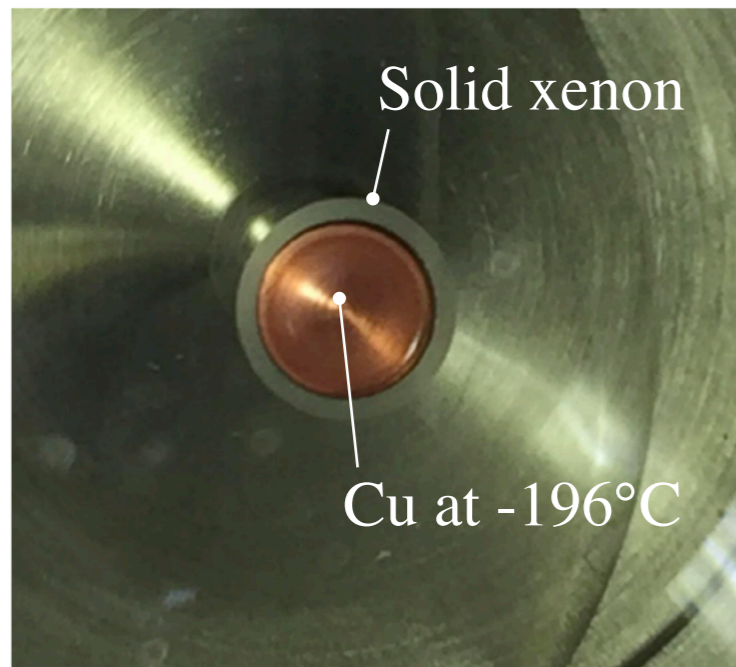
Ba⁺⁺ イオン源からイオンを生成し、銅電極にトラップする試験をテストチェンバーで行っている



イオン源からイオンが放出されているか、ファラデーカップで検証



電流がバリウムイオン由来かどうか、確認をしている



Neutrinoless double beta decay

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R&D for more sensitivity

Summary

AXEL is a high pressure xenon gas TPC for neutrinoless double beta decay search

- High energy resolution with EL and cellular detection scheme
- Topological information

Performance evaluation with prototype detector is ongoing

- estimated $\Delta E : 0.81 \sim 0.84 \%$ (FWHM) at Q-value

Background rejection strategy for future measurement

- Choice of materials : low radioactive materials
- Ba^{++} tagging \rightarrow Ba^{++} tagging and detection system