AXEL: high-pressure Xe gas TPC for neutrinoless double beta decay search

Hayato SASAKI, High energy physics laboratory, Kyoto University, 6/23/2026

Neutrinoless double beta decay($0\nu\beta\beta$)

- Evidence of neutrino's majorana nature
  - Matter-antimatter asymmetry of the universe
  - Origin of neutrino's low mass
- Very rare(> 3.8×10^{26} year for half-life from ^{136}Xe[1])
  - High energy resolution
  - Environmental radiation discrimination
  - Large mass of decay nuclei

AXEL experiment

- High-pressure Xe gas TPC
  - **BG rejection with track pattern**(Fig4,5)
- Electroluminescence Light Collection Cell(ELCC)
  - **High energy resolution** due to low-fluctuation amplification process(electroluminescence)
  - **Scalability** with rigid cell structure

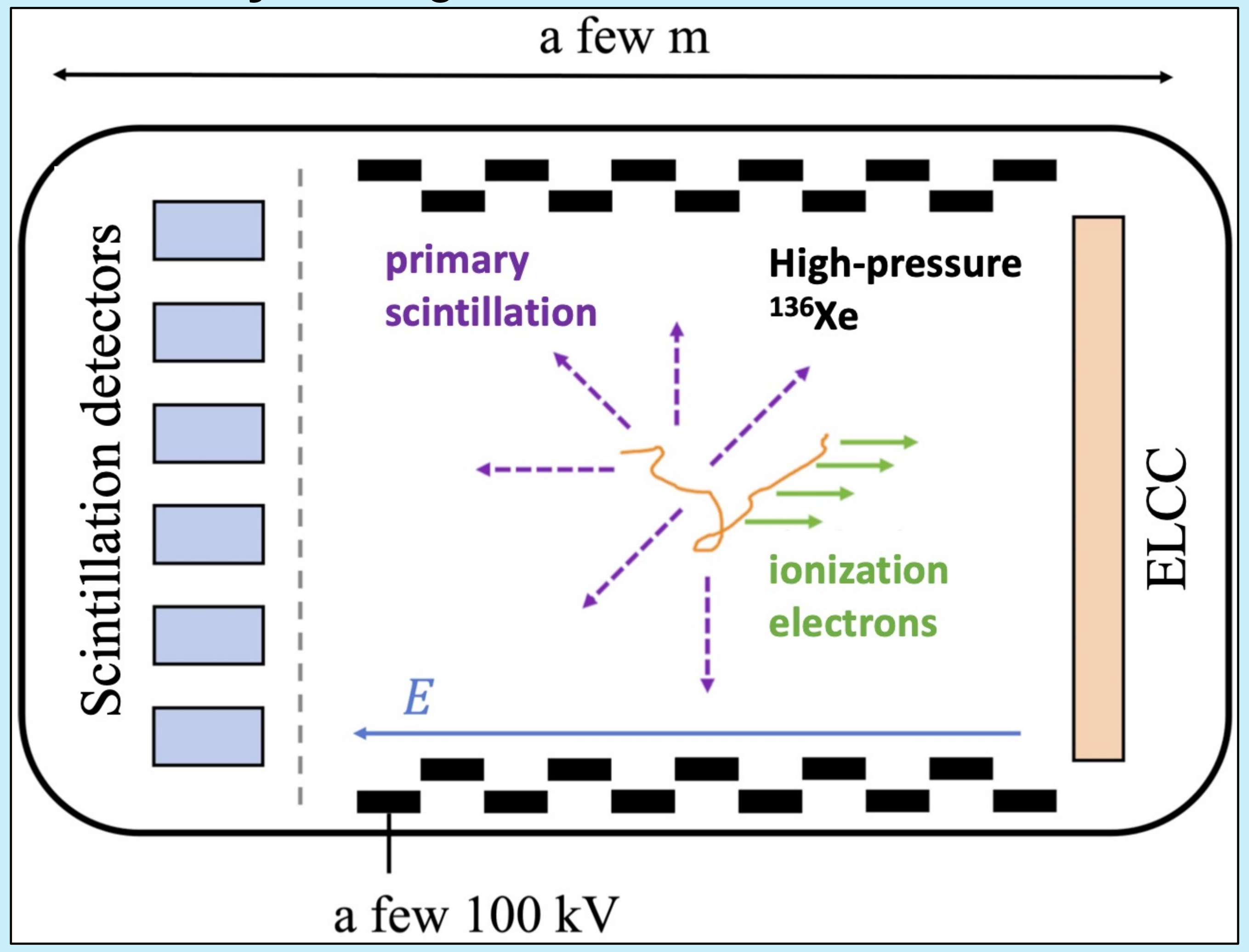

Fig1: Schematic view of AXEL detector

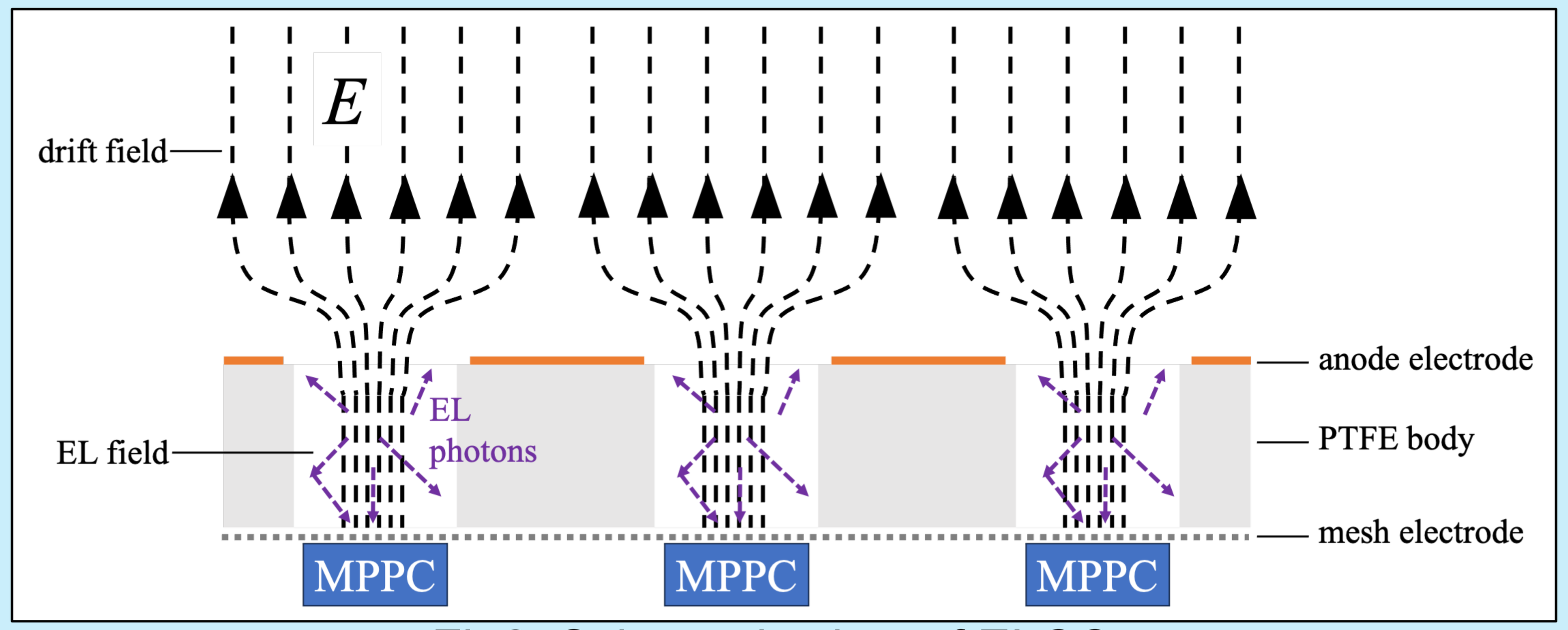

Fig2: Schematic view of ELCC

- Performance evaluation with 180L-size prototype
  - Achieved energy resolution: **0.66%**(FWHM) @ 2615 keV
- Constructing next 1000L-size (20kg ^{136}Xe) detector
  - First $0\nu\beta\beta$ search of AXEL

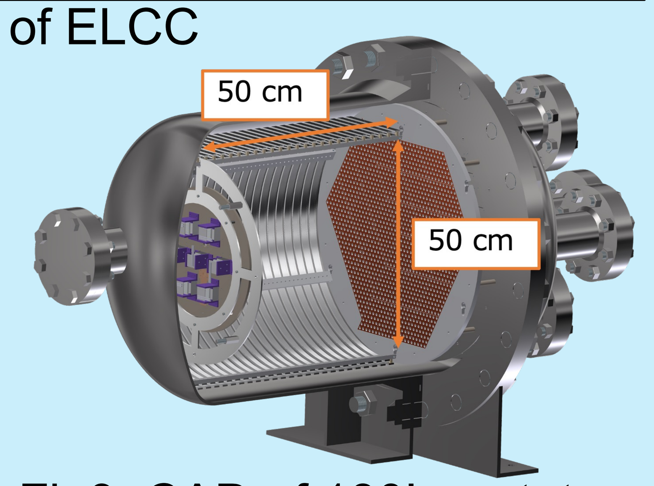

Fig3: CAD of 180L prototype

Track pattern recognition with machine learning

- Machine learning to discriminate track topology was developed with Geant4 simulated tracks.
  - 95% BG rejection with 60% signal efficiency
- Richardson-Lucy deconvolution to subtract the effect of diffusion
  - Expected to enhance the discrimination efficiency

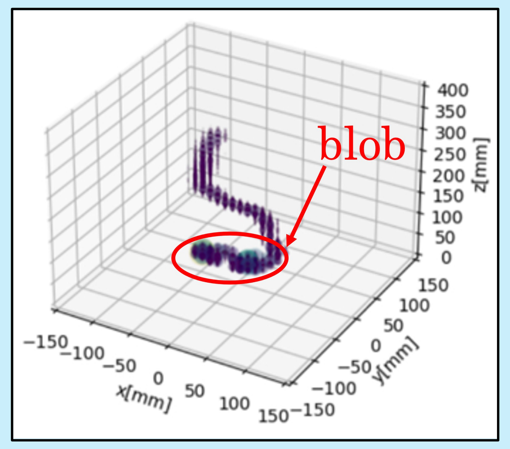

Fig4: Measured track from γ-ray

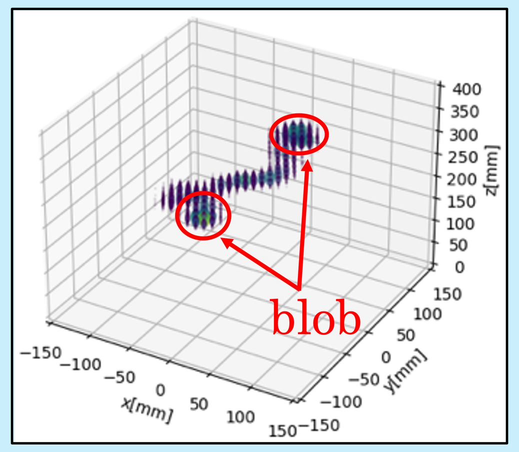

Fig5: Simulated track of $0\nu\beta\beta$

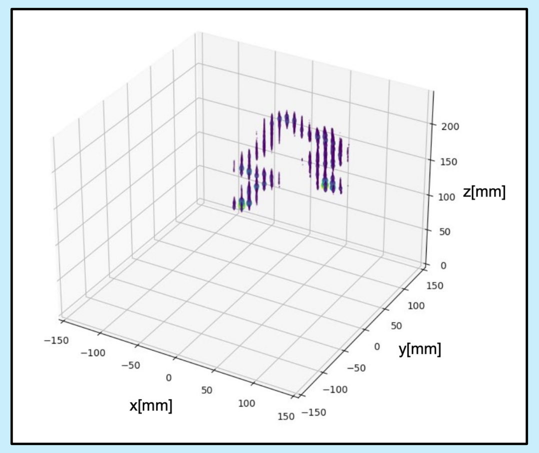

Fig6: Before RL deconvolution

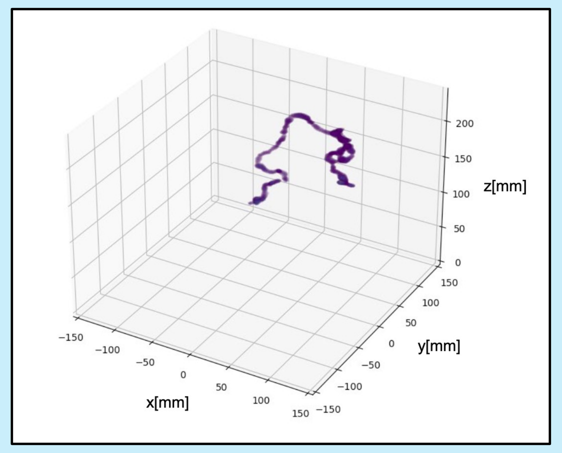

Fig7: After RL deconvolution

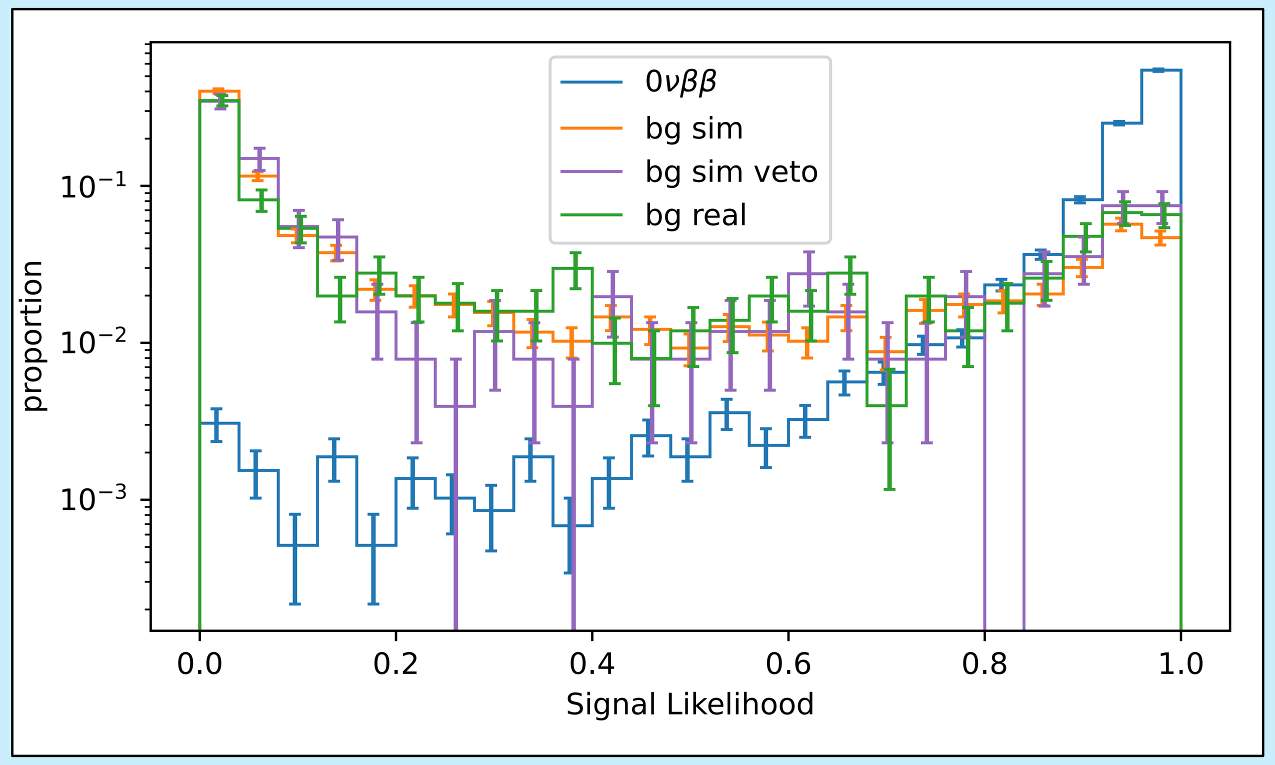

Fig8: Signal likelihood distribution

Cockcroft-Walton generator

- High DC voltage generation with low(~1 kV) AC input
  - No need to develop HV endurance feedthrough
- Achieved voltage
  - -34.3 kV in 6.0 bar xenon
  - -76.4 kV in air

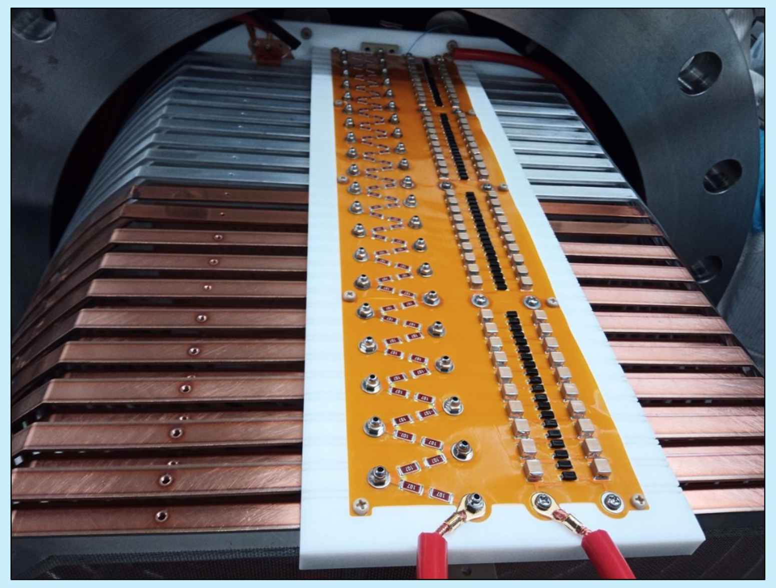

Fig9: 40-step CW in 180L prototype

Fig10: 80-step CW

Discharge-resistive ELCC

- Target field of ELCC: 3 kV/cm/bar -> ~10 kV supplied on the anode electrode
  - Creeping discharge along the cell
- Countermeasures for the discharge
  - Step around the cell
  - Anode made of Flexible Printed Circuit(FPC) with Kapton covering around the cell
  - Both achieved the target field.

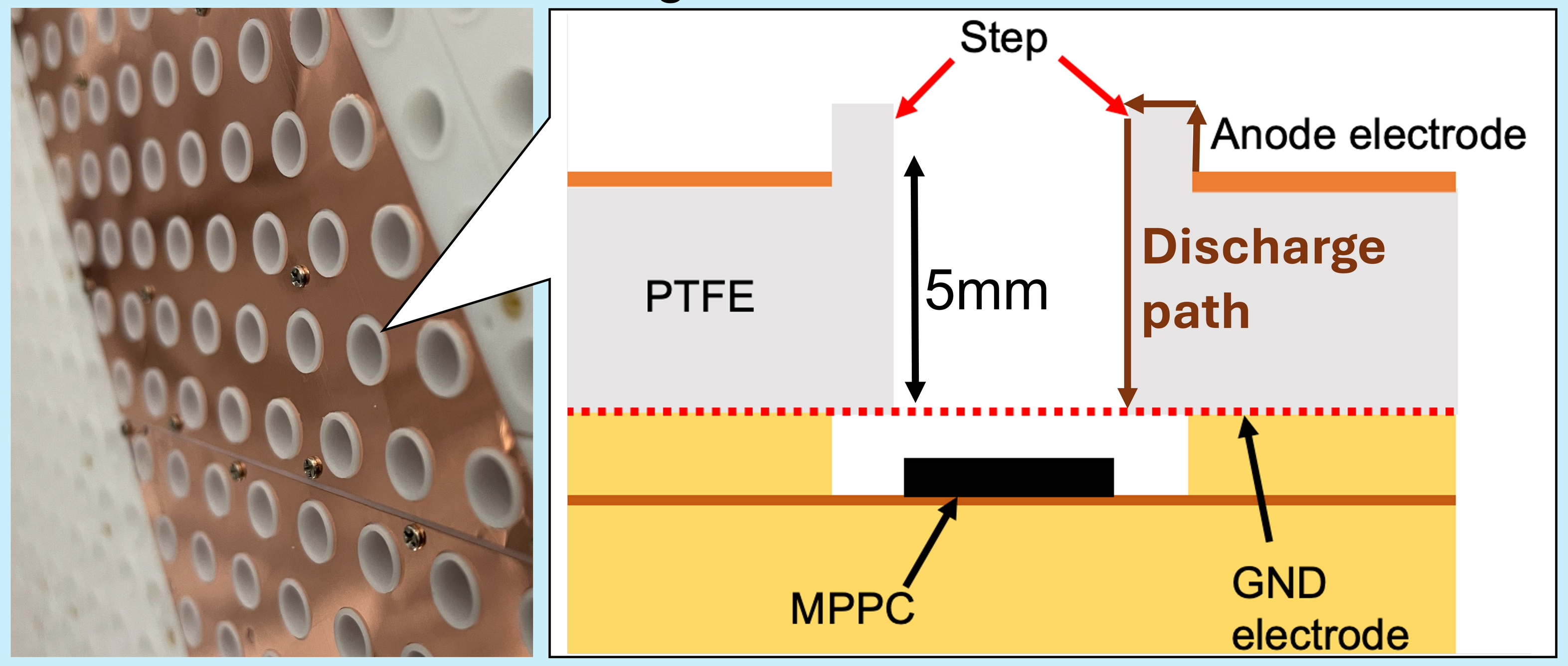

Fig11: Step around the cell to suppress creeping discharge

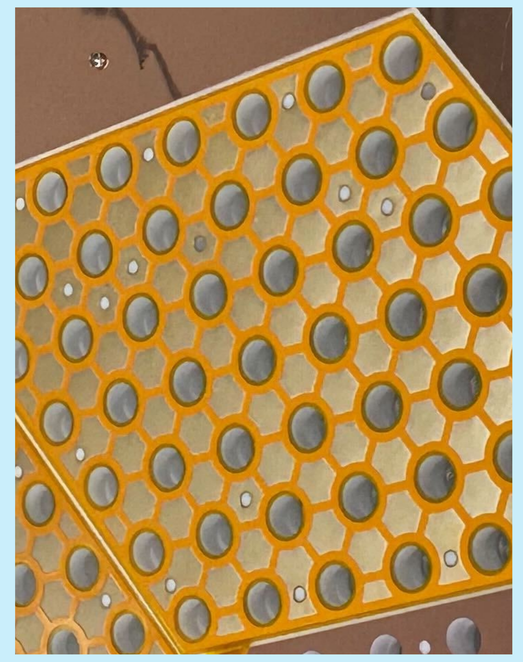

Fig12: FPC anode

Low radiation field cage

- Reducing contamination in field cage with FPC-made electrodes
- FPC design for suppressing creeping discharge and charging-up on its surface
- Achieved voltage:
  -31.2 kV in 6.0 bar xenon, 98.1% for target drift electric field

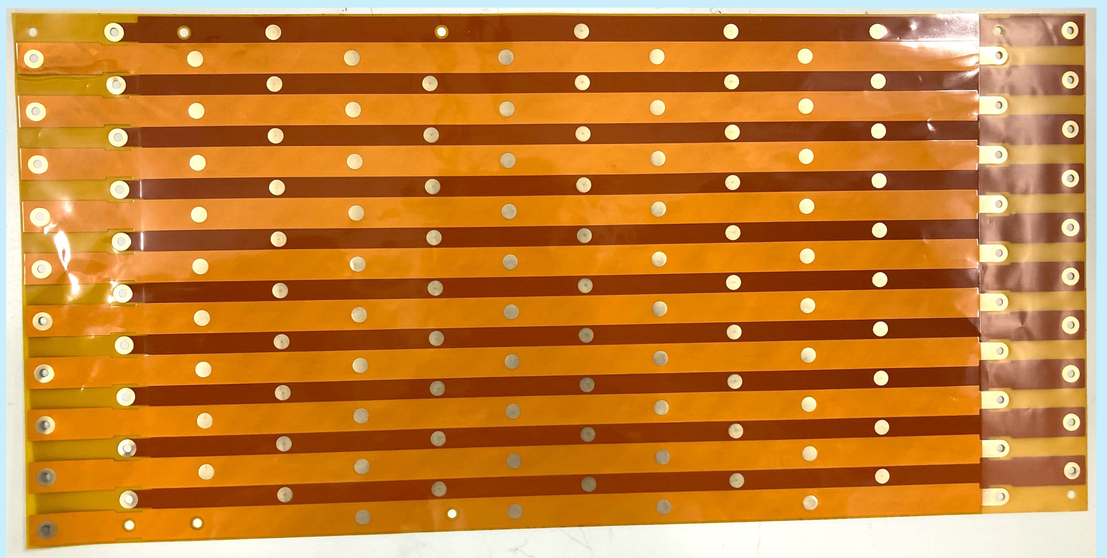

Fig13: FPC for field cage

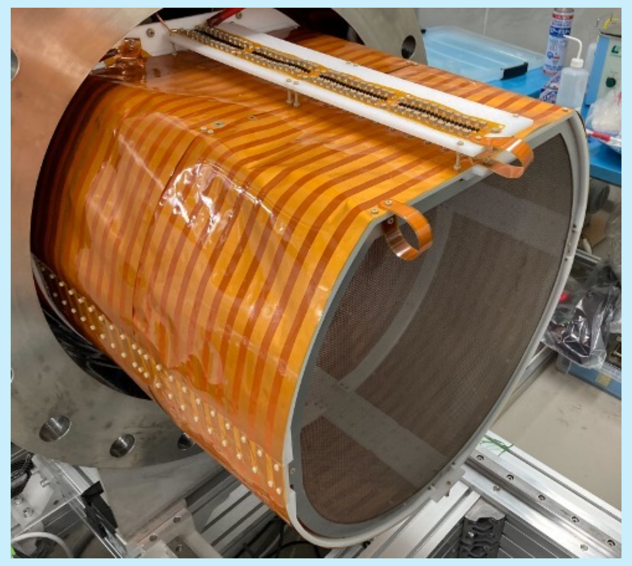

Fig14: Assembled field cage

High voltage supply on ELCC

- Supplying high voltage separately on each unit
  - Suppressing the power of discharge
  - Lowering the voltage only for units prone to discharge
- Structure for supplying voltage from the rear of the units
  - Dividing PTFE to two parts with countermeasures for creeping discharge
  - Confirmed 3 kV/cm/bar in 7.0 bar xenon

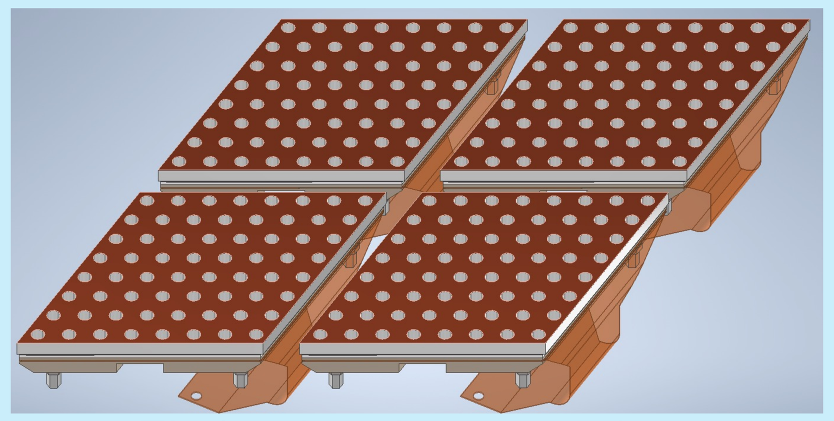

Fig15: Anode separation

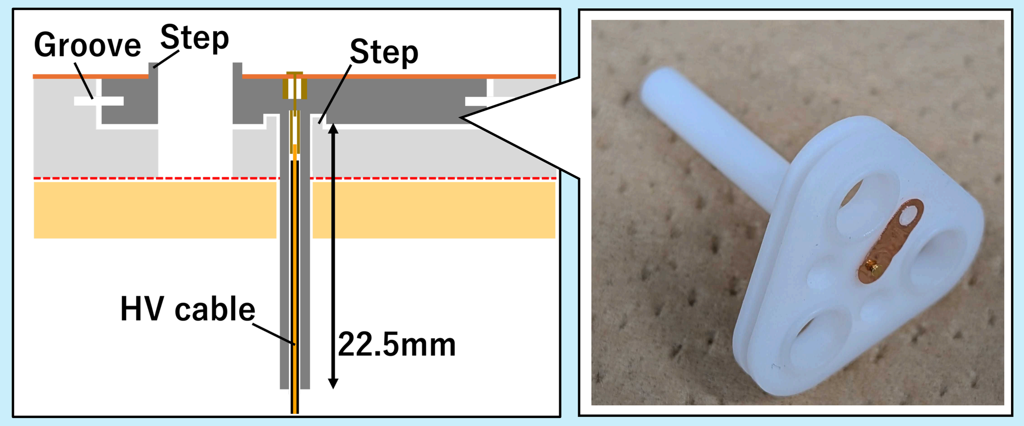

Fig16: Structure for unit-by-unit HV supply