Next-generation $0\nu\beta\beta$ searches with xenon gas TPCs

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Montreal, 14 November 2025

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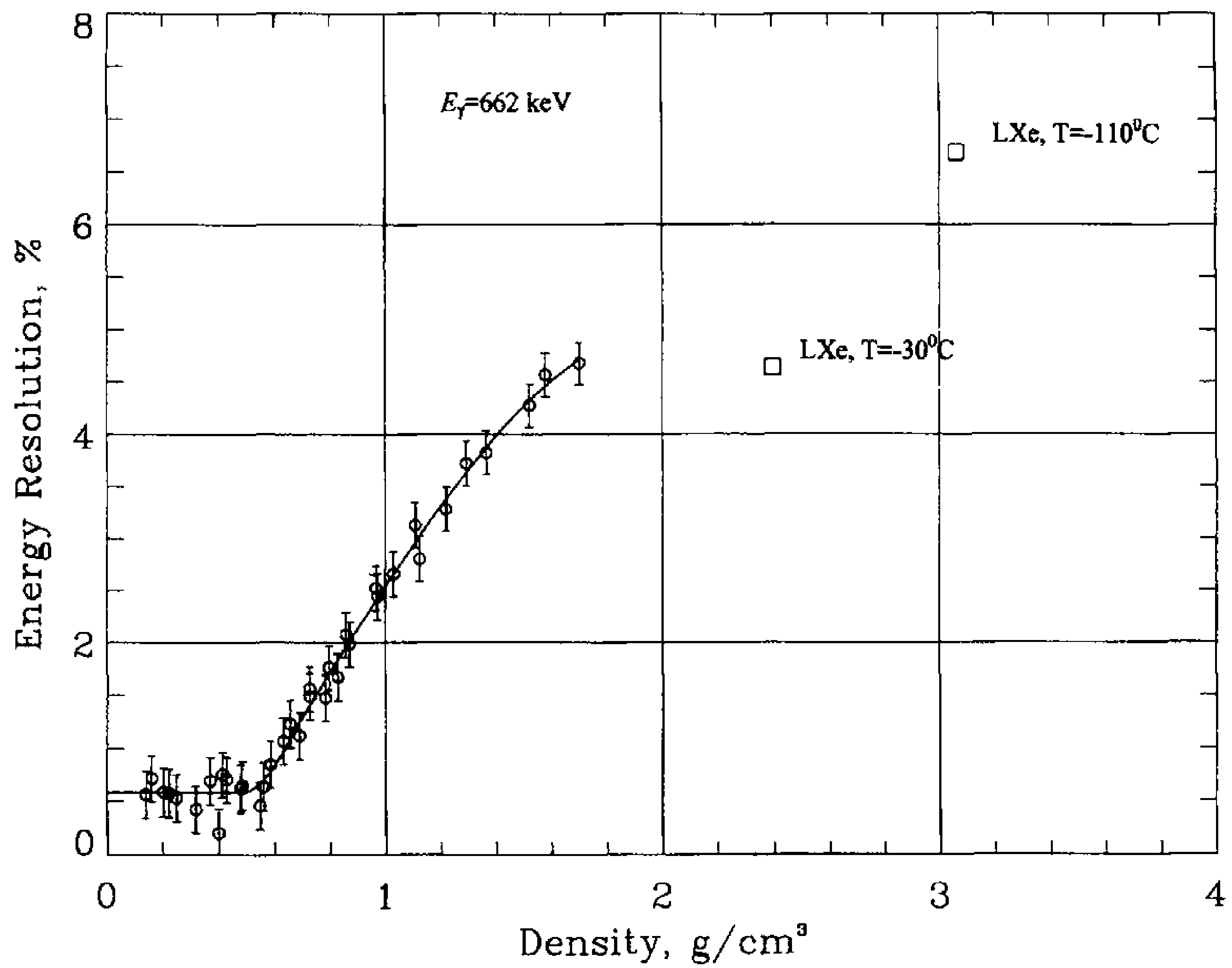
Excelencia Severo Ochoa

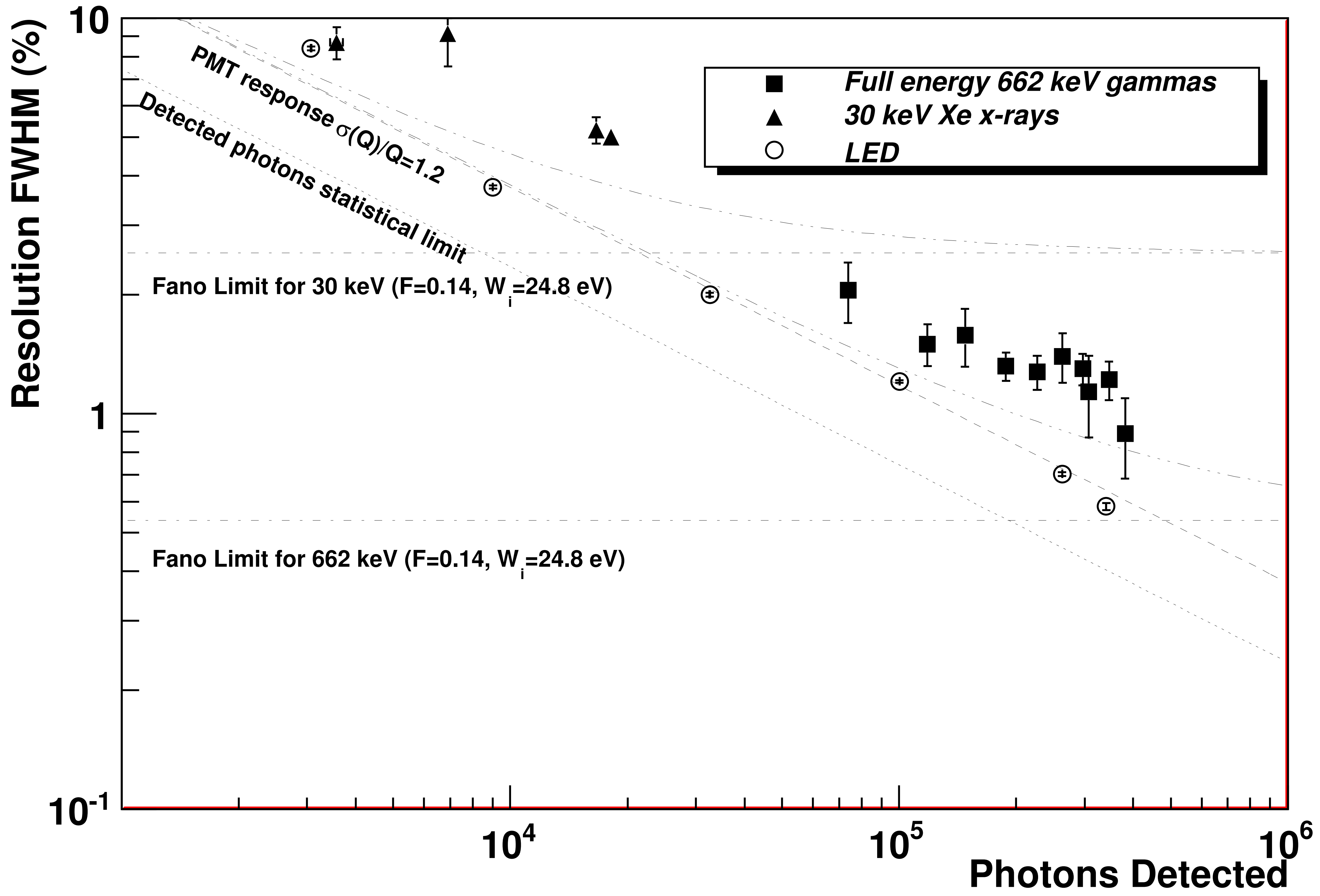
Why xenon gas?
Key advantages for 0νββ searches

ENERGY RESOLUTION

Bolotnikov and Ramsey, NIM A **396** (1997) 360–370



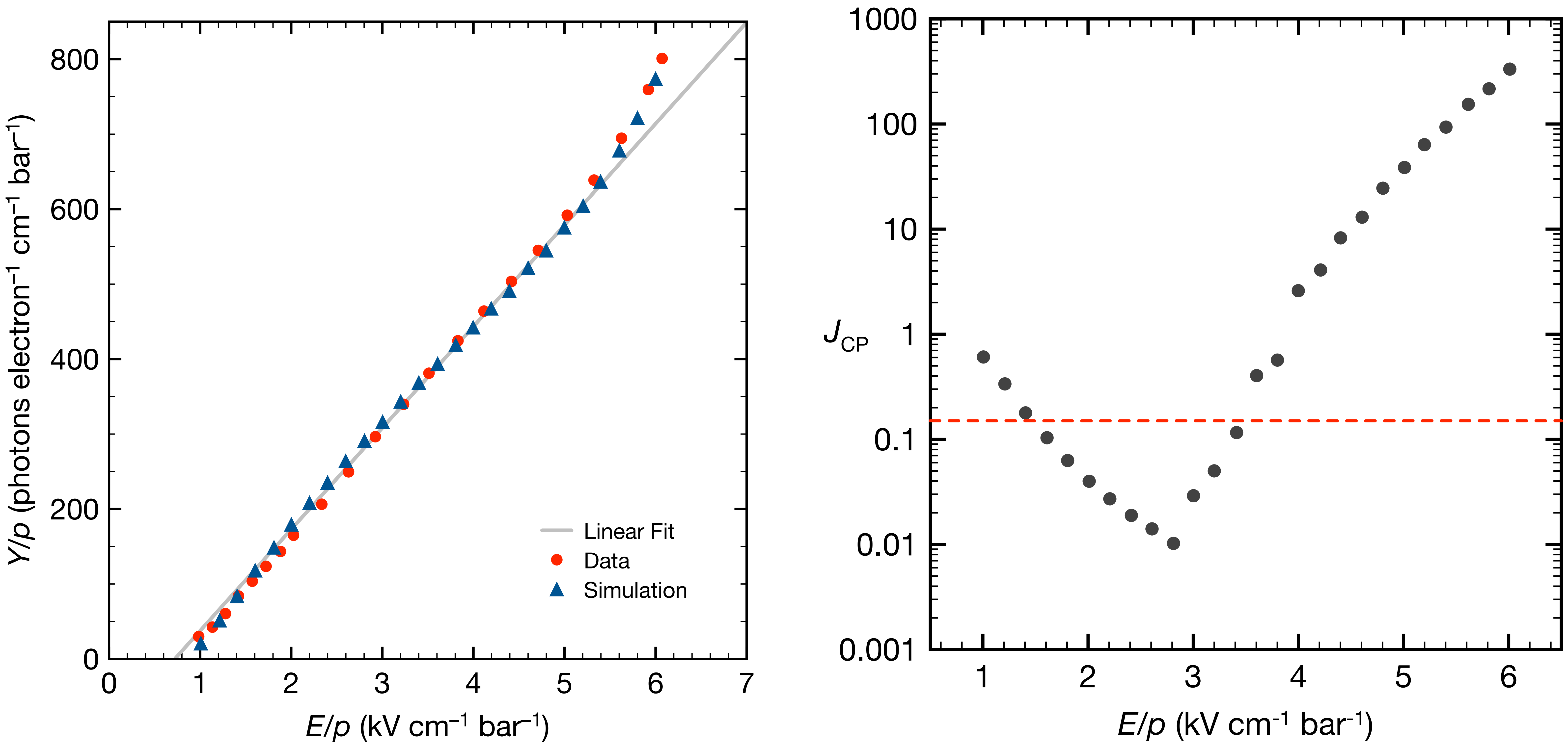
NEXT Collaboration, NIM A **708** (2013) 101-114



Intrinsic resolution of xenon gas close to **0.3% FWHM at 2.5 MeV**.

ENERGY RESOLUTION: ELECTROLUMINESCENCE

C. Oliveira et al., JINST **6** (2011) P05007

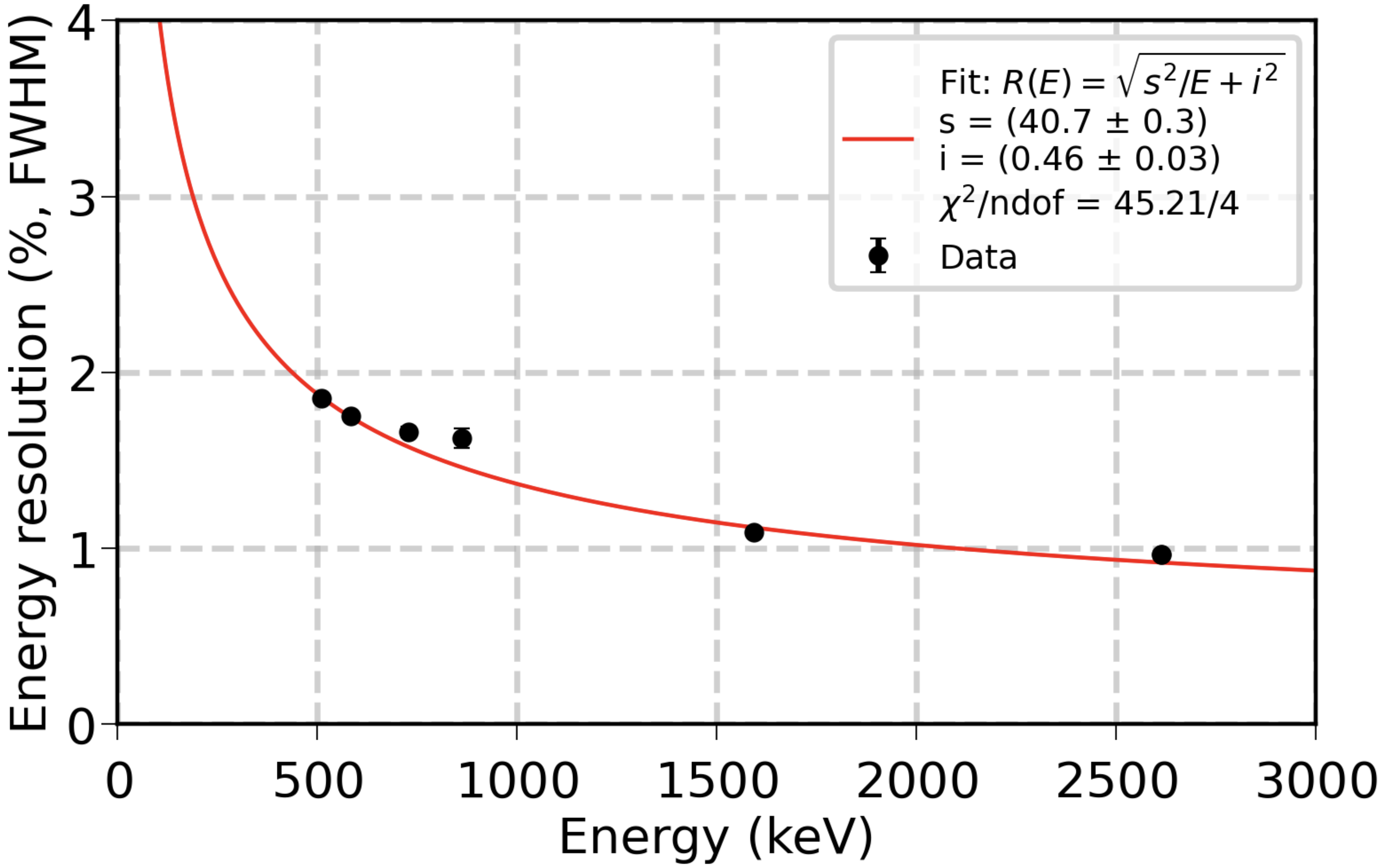


Electroluminescence (EL): ionization charge ➜ vacuum-ultraviolet photons

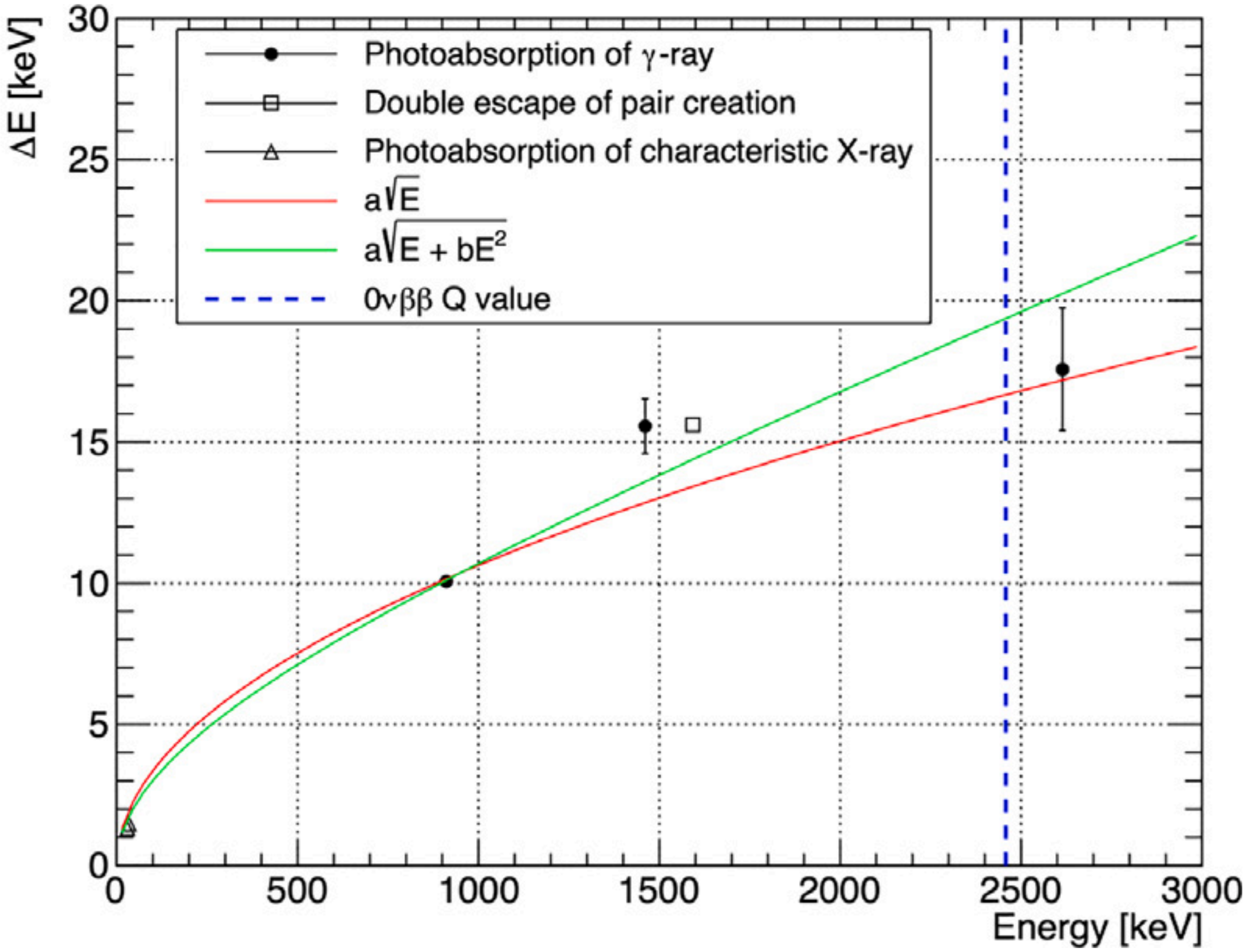
High-gain, low-noise amplification for optimal energy measurement.

ENERGY RESOLUTION: RECENT RESULTS

NEXT Collaboration, arXiv:2511.02467 (2025)



J. Hikida et al., NIM A **1080** (2025) 170706

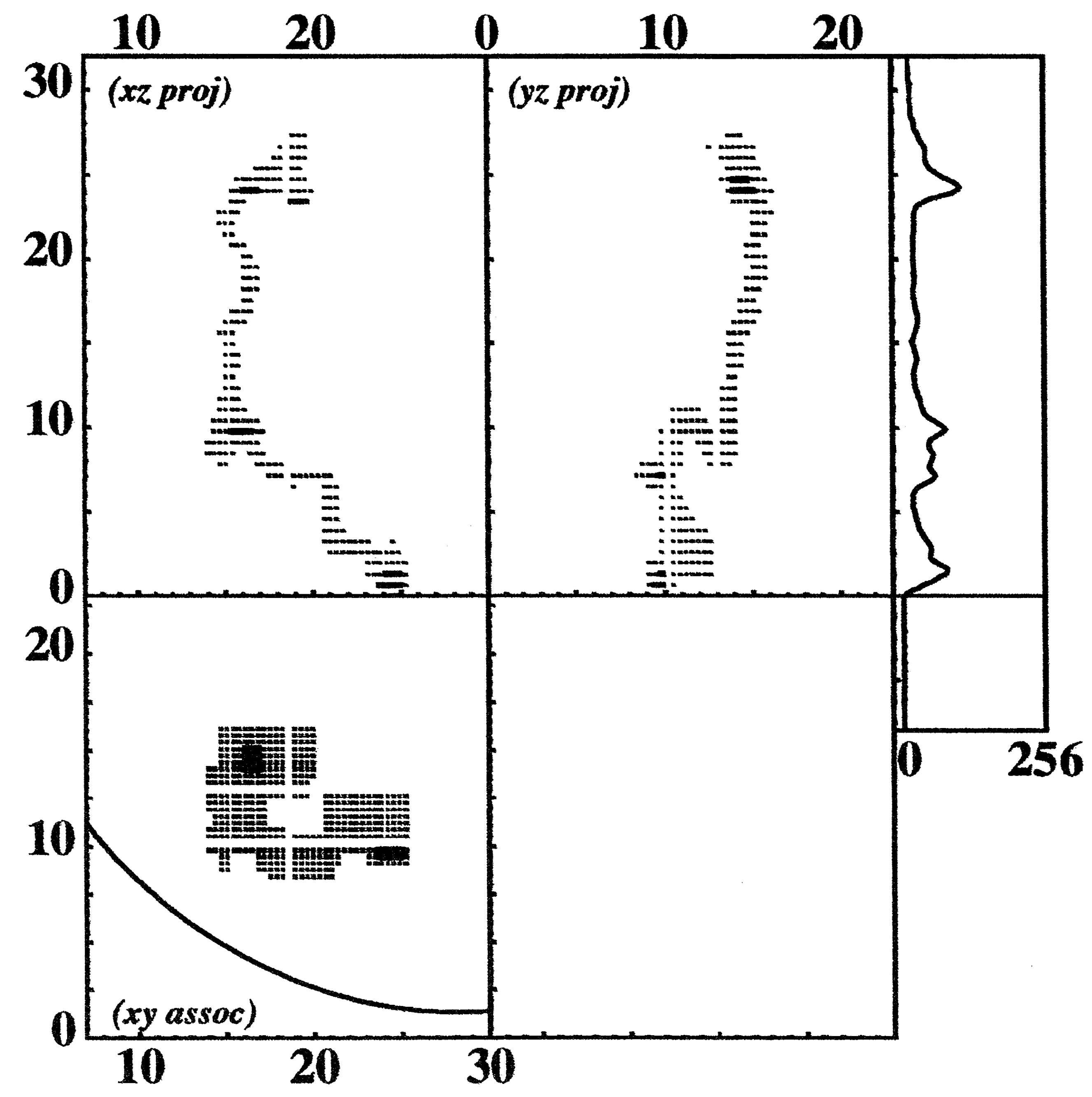


<1% FWHM at $Q_{\beta\beta}$ achieved in large detectors.

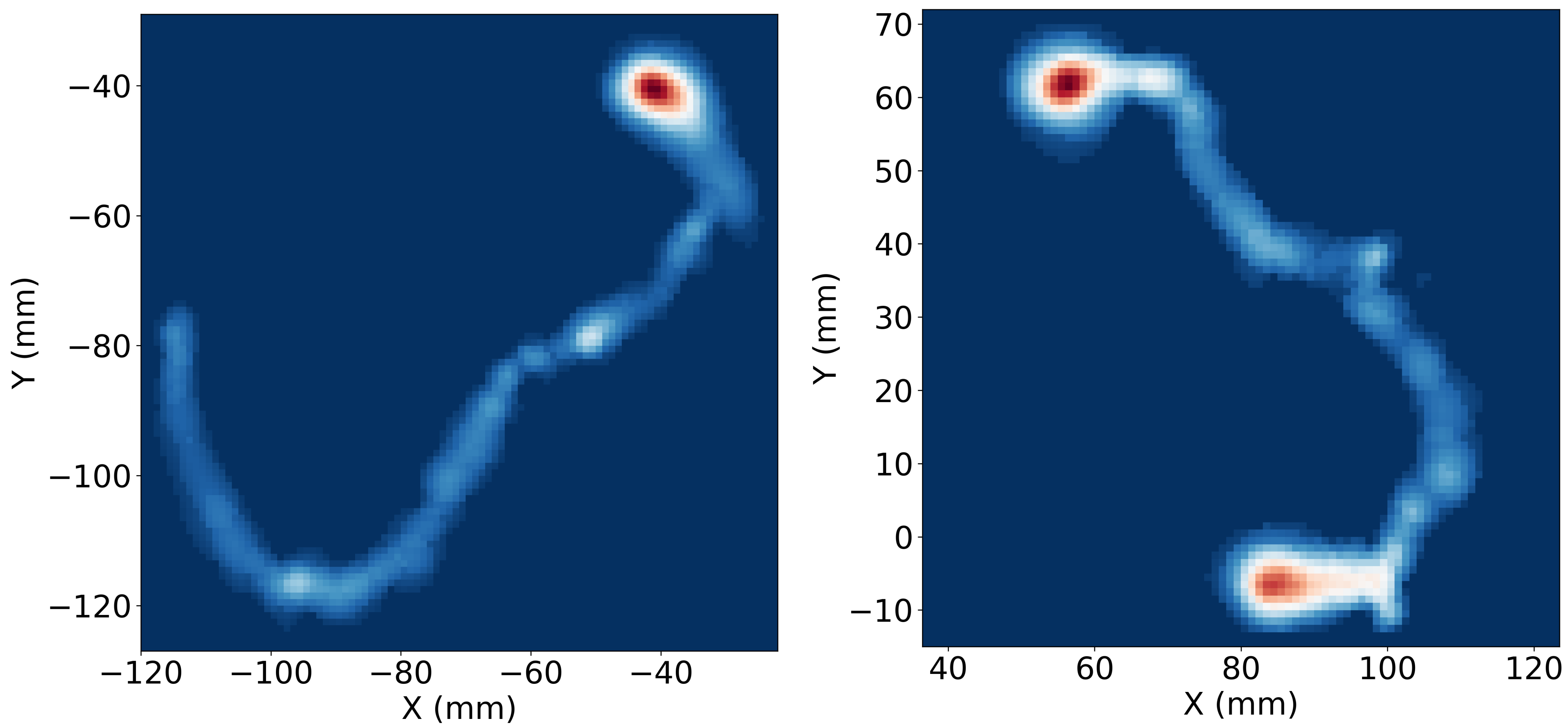
Performance validated across full energy range.

TRACKING: 1 ELECTRON VS 2 ELECTRONS

R. Luescher et al., Phys. Lett. B **434** (1998) 407–414

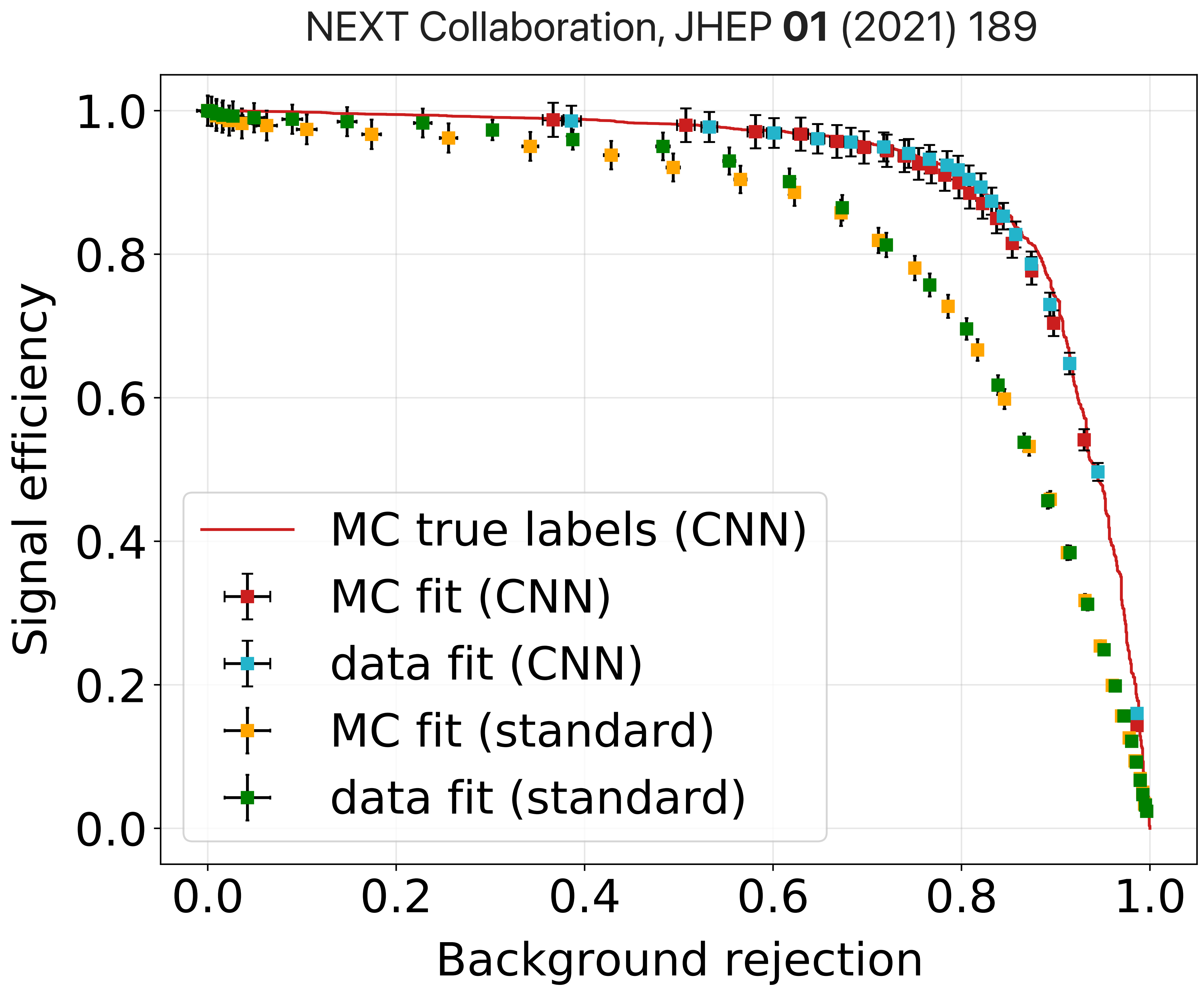


NEXT Collaboration, JHEP **07** (2021) 146



Track topology: two blobs vs one → powerful background rejection

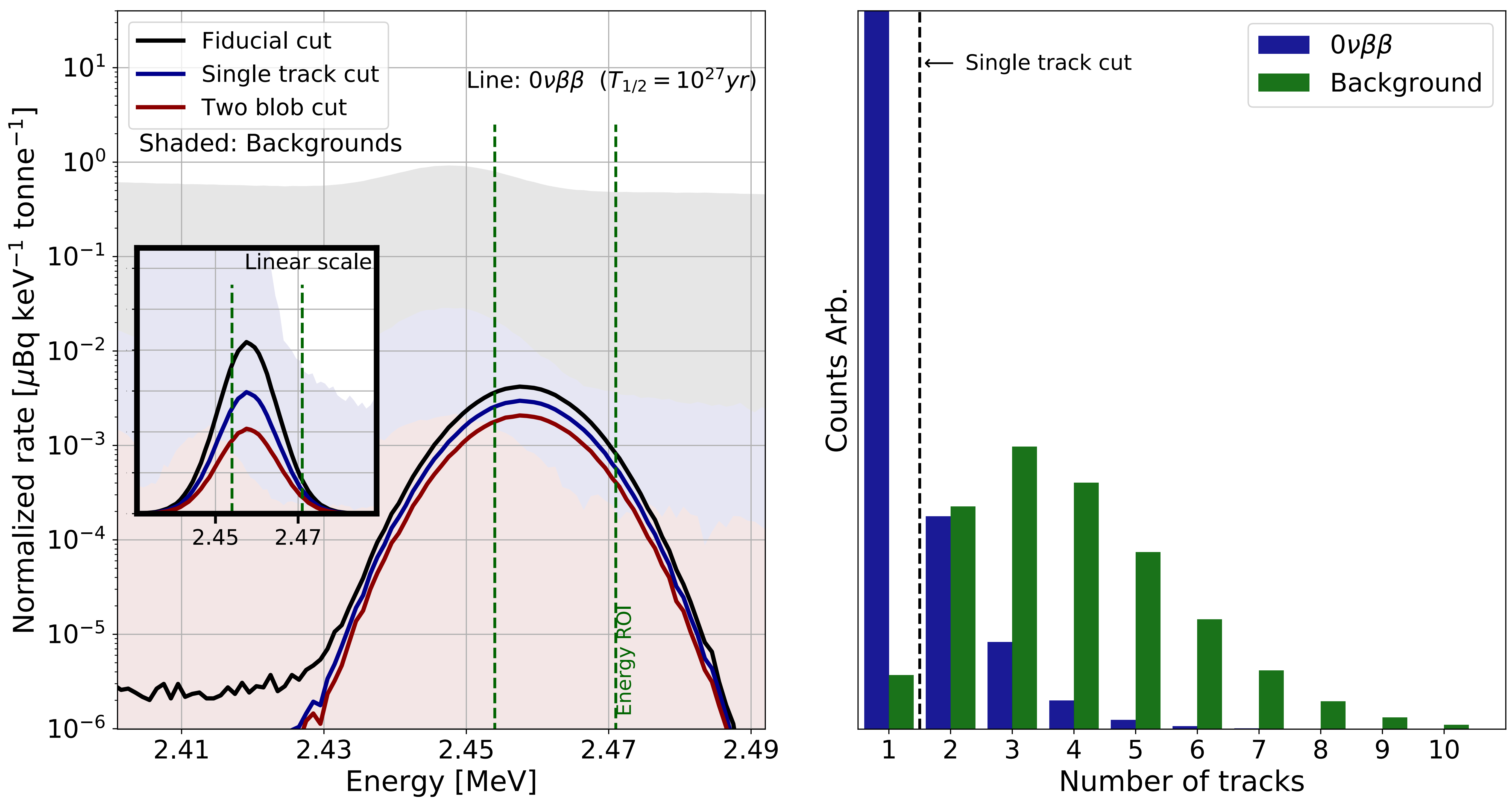
TRACKING: 1 ELECTRON VS 2 ELECTRONS



ML algorithms: **92% background rejection** at 80% signal efficiency

TRACKING: EVENT POSITION AND TRACK MULTIPLICITY

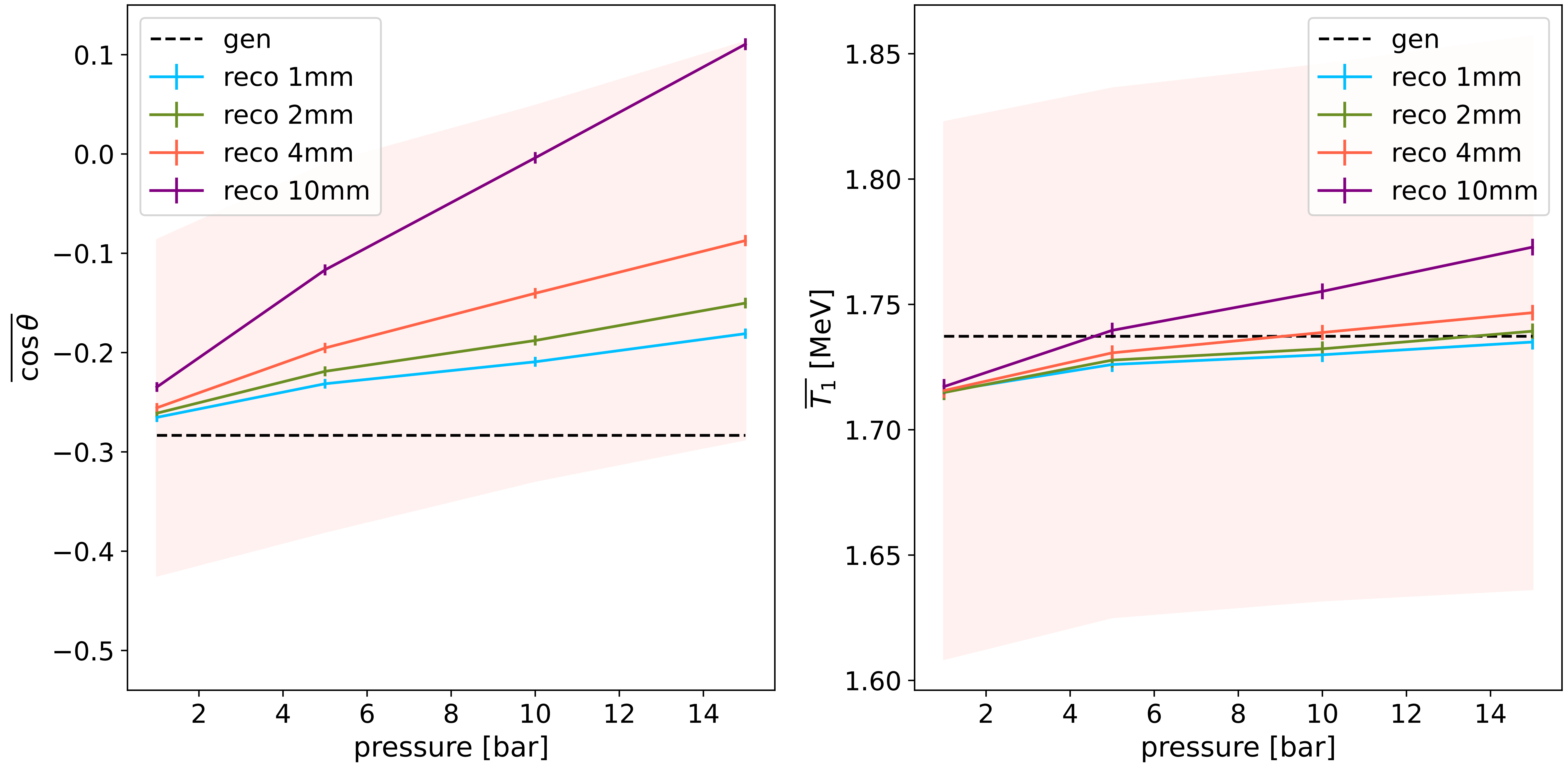
NEXT Collaboration, JHEP **2021** (2021) 08, 164



Tracking also enables background suppression through fiducialization and multiplicity cuts.

TRACKING: EVENT KINEMATICS

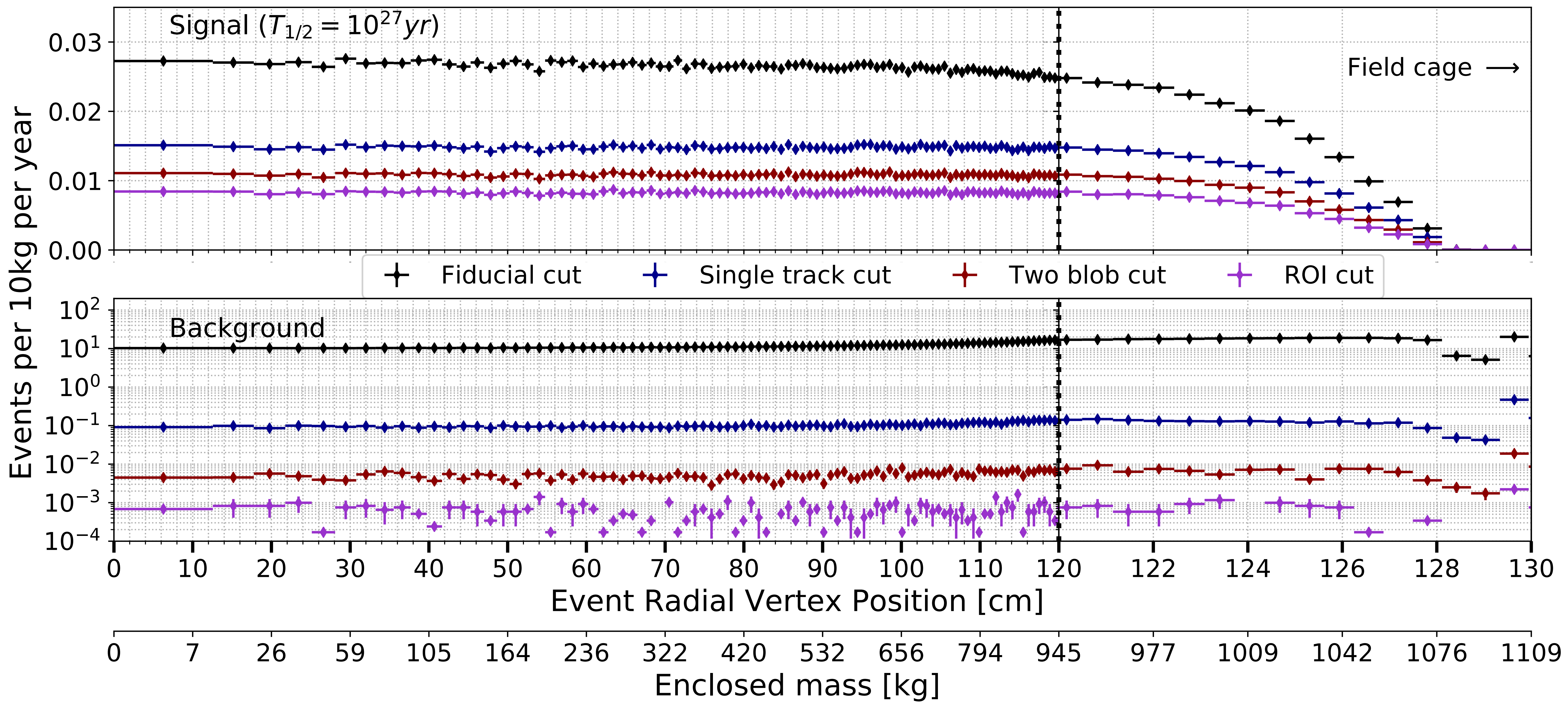
NEXT Collaboration, JHEP **07** (2025) 170



Gas TPCs reconstruct electron kinematics ➜ probe decay mechanism in case of discovery

TRANSPARENCY TO HIGH-ENERGY GAMMA RAYS

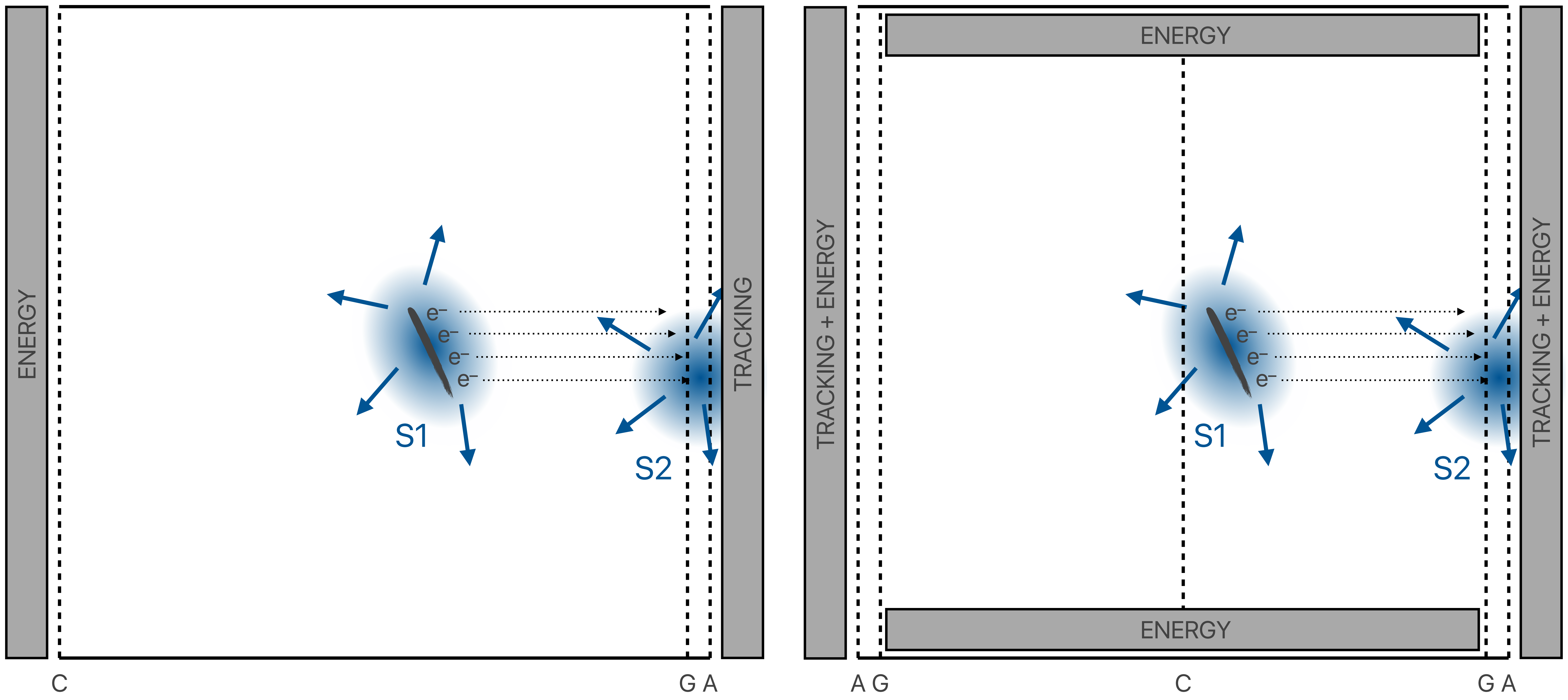
NEXT Collaboration, JHEP **2021** (2021) 08, 164



Background rejection strategy does not rely on self-shielding ➜ No dependence of background index on detector size. Allows a scalable/modular approach.

Technical aspects

DETECTOR CONCEPT



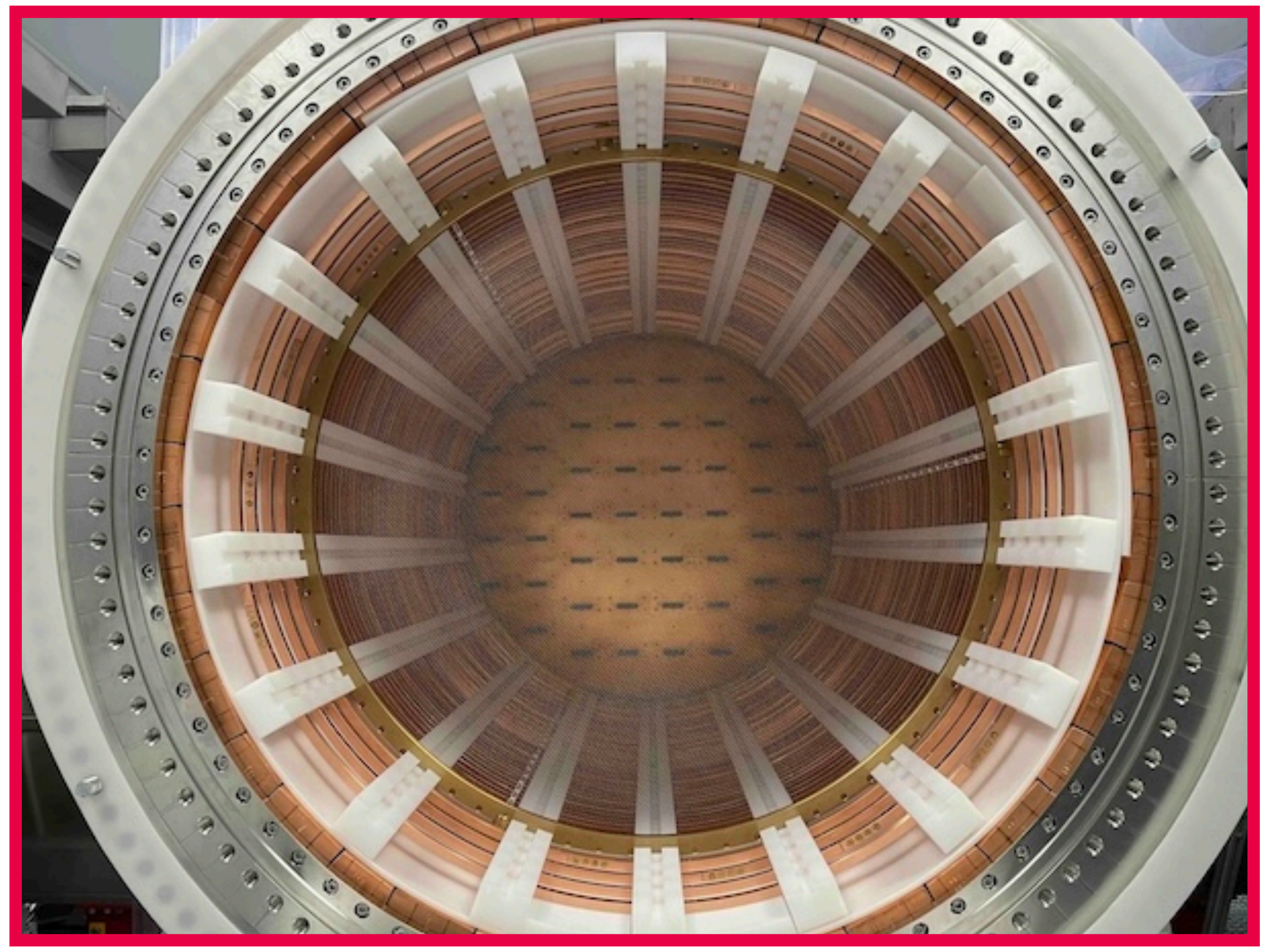
Current (left): asymmetric TPC with single drift volume.

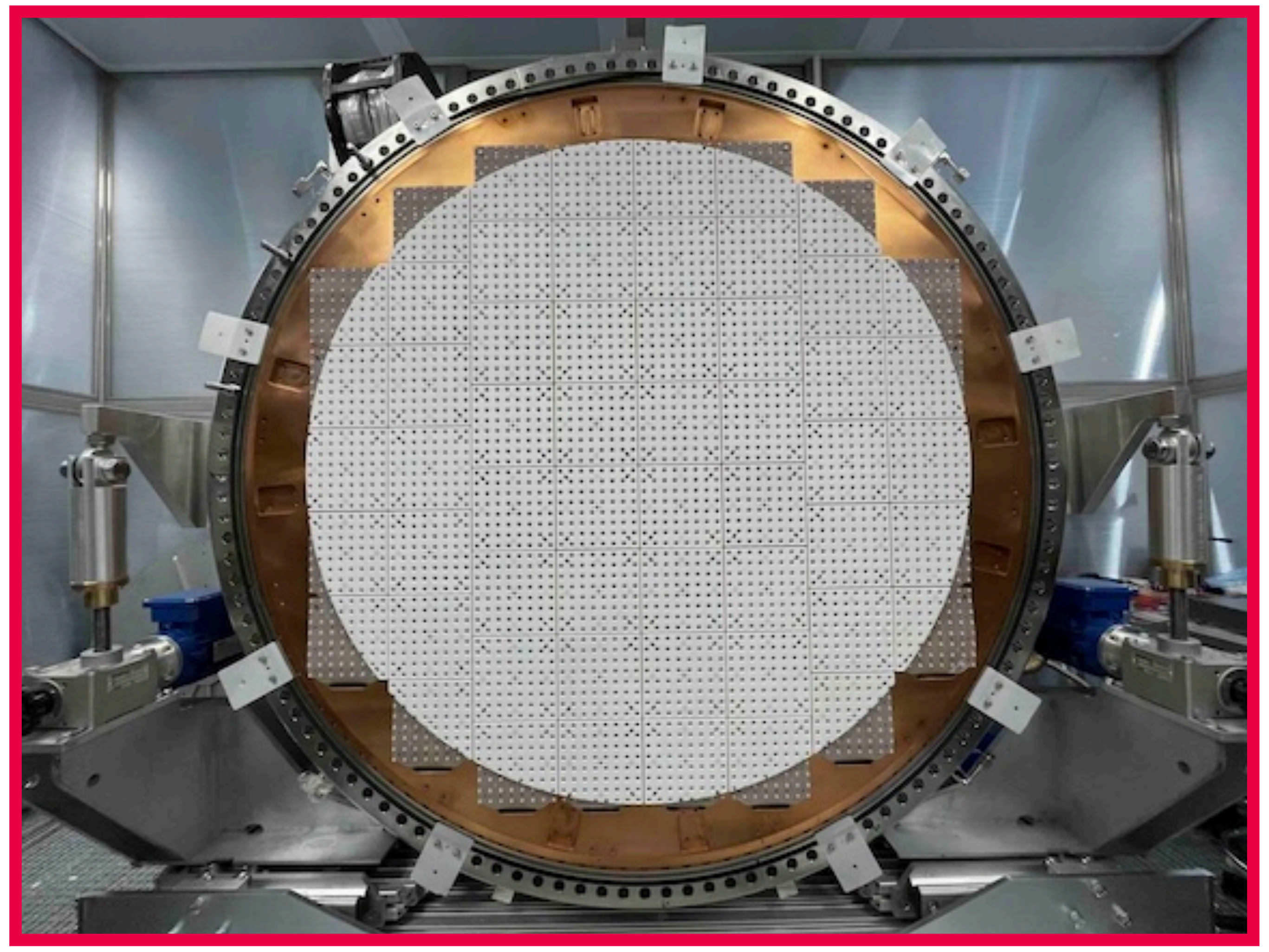
Future (right): symmetric layout with central cathode and two drift volumes.

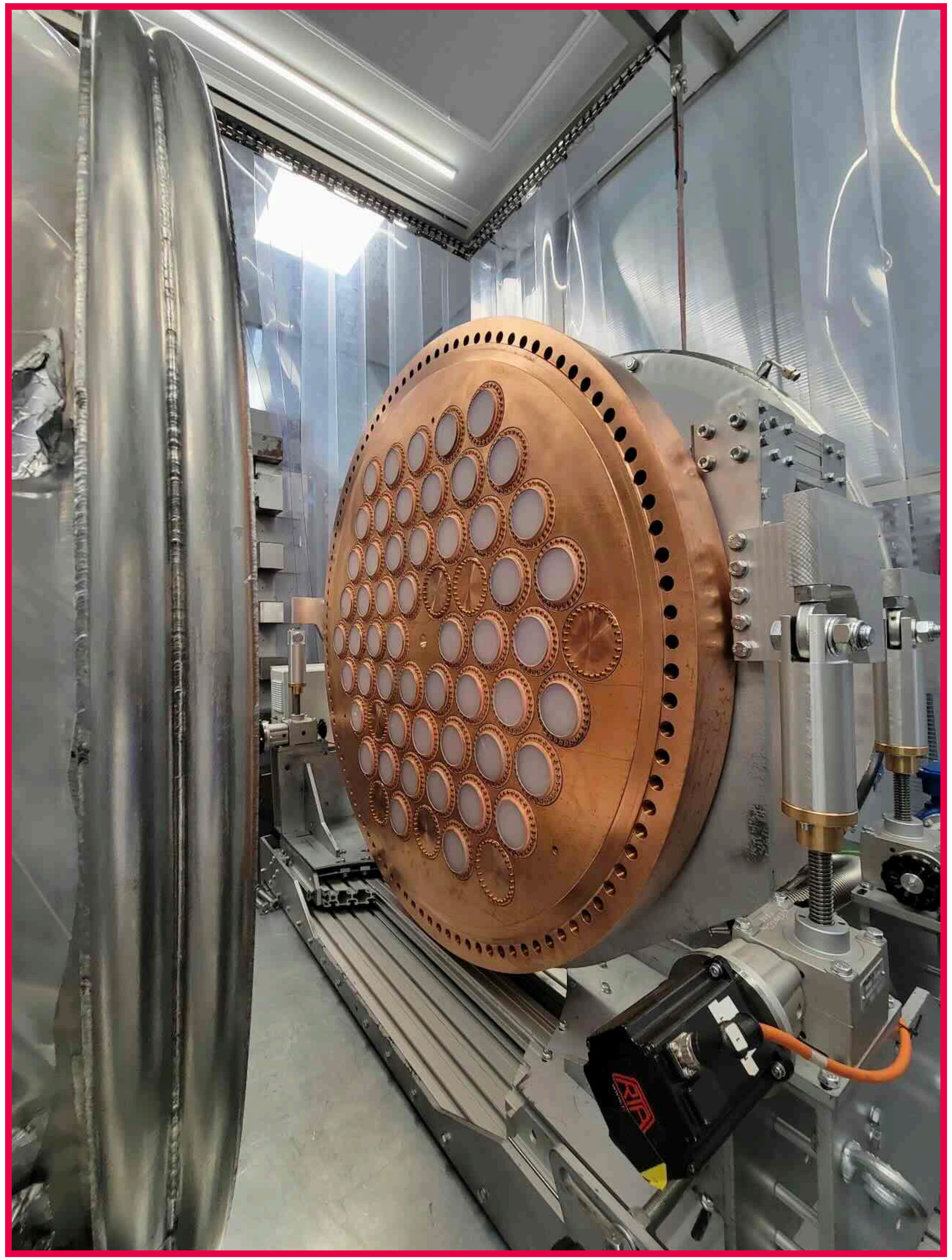
NEXT-100

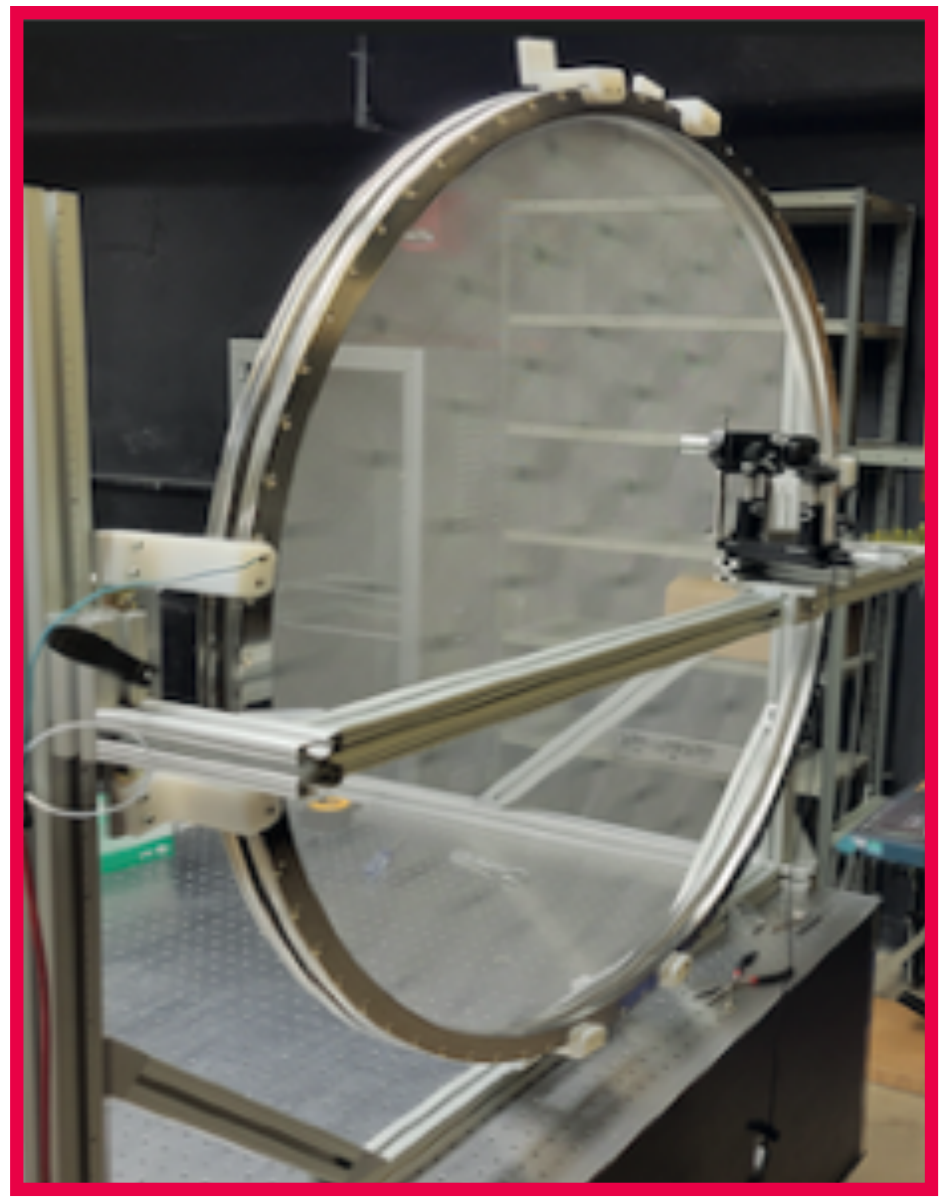
Operating at the Laboratorio Subterráneo de Canfranc since 2024.
Foundation for scaling to tonne scale.

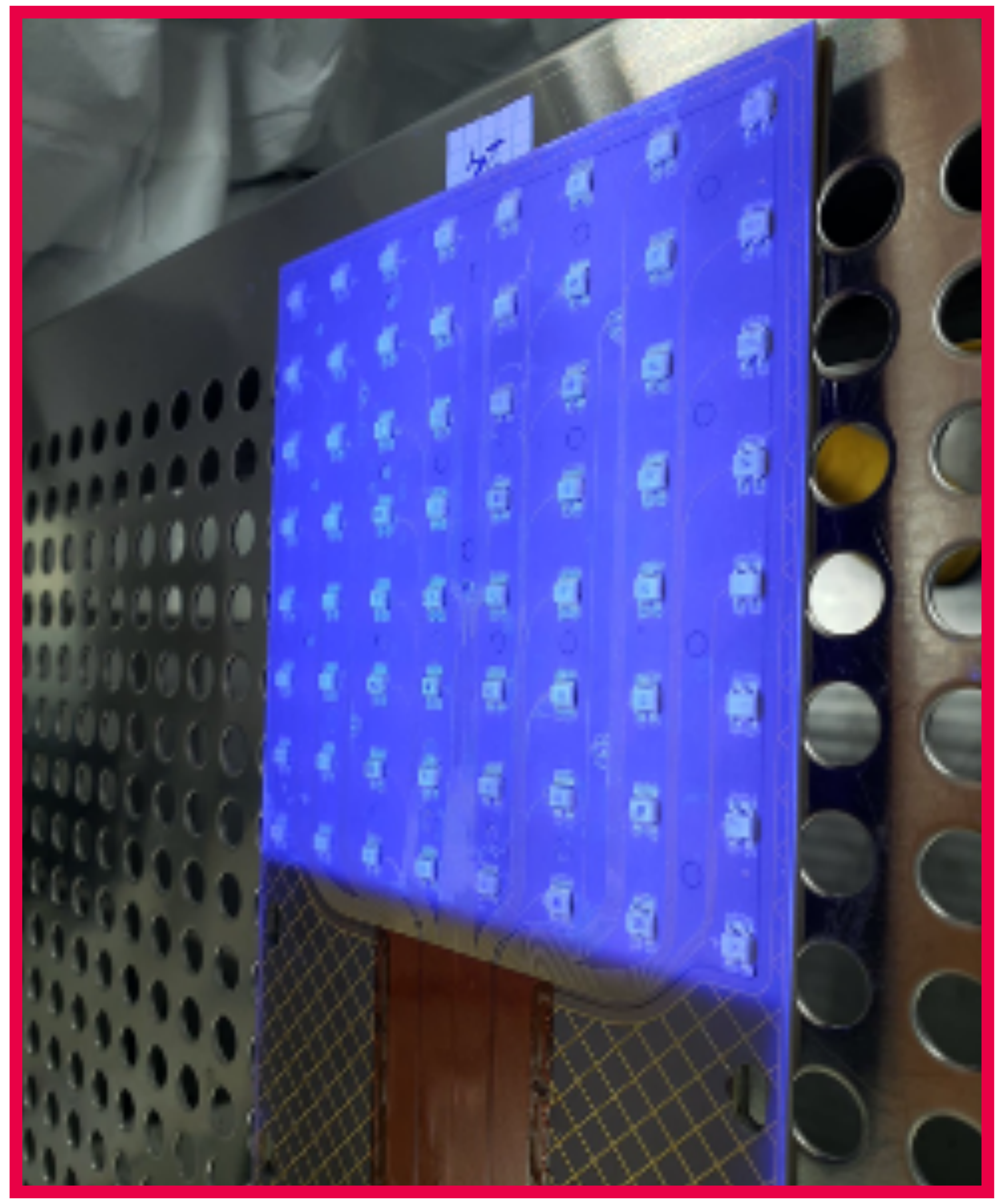
NEXT-100









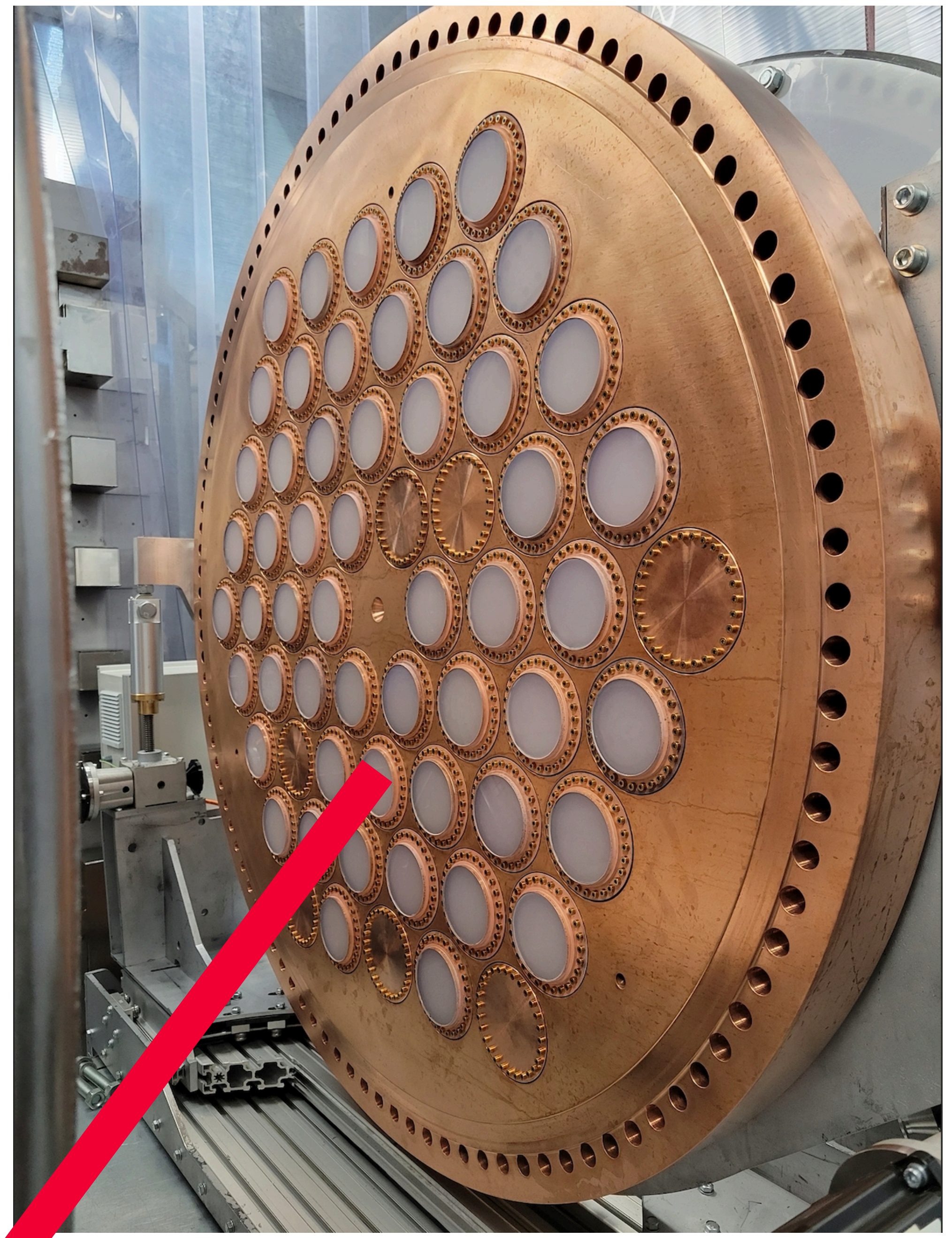


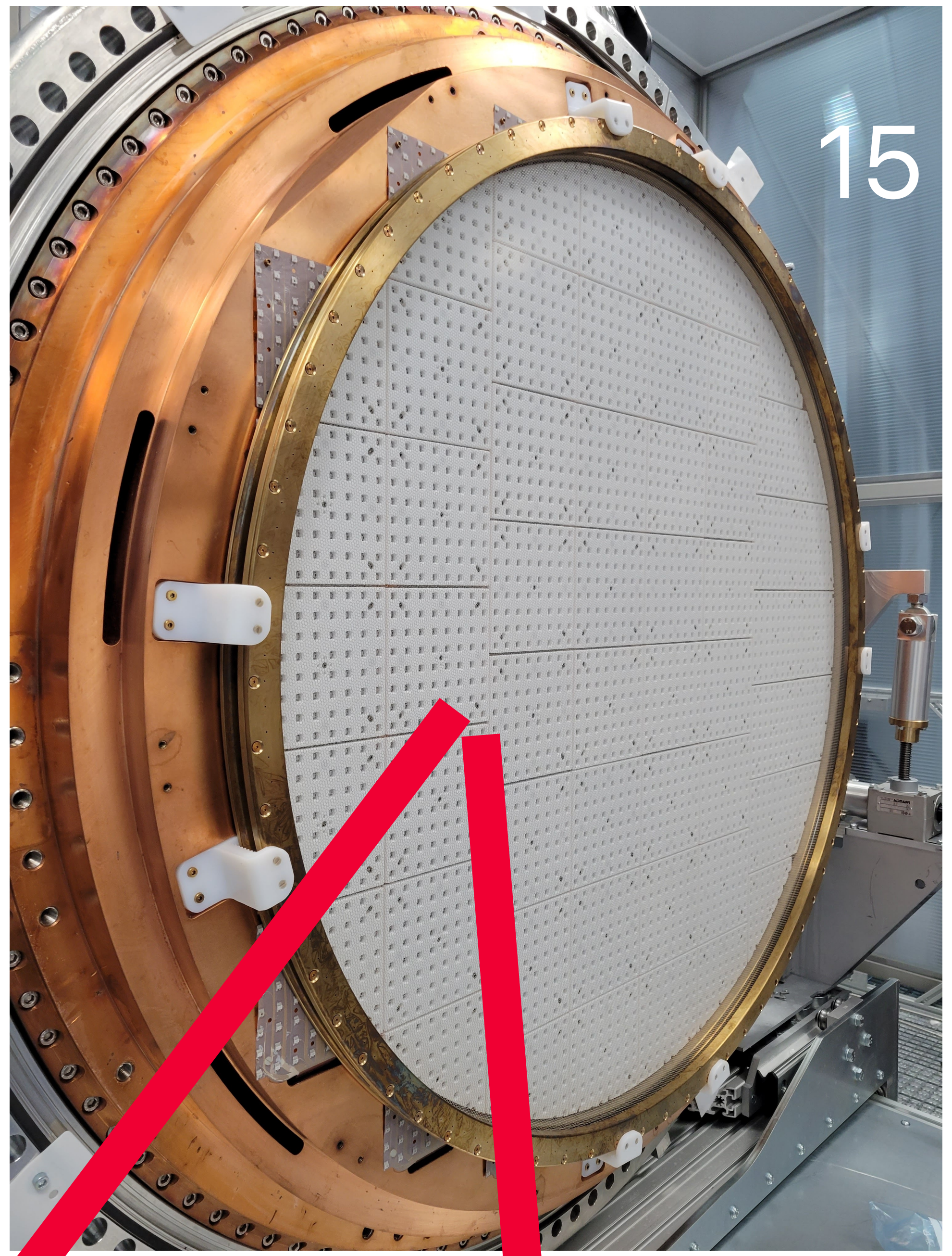
NEXT Collaboration, arXiv:2505.17848

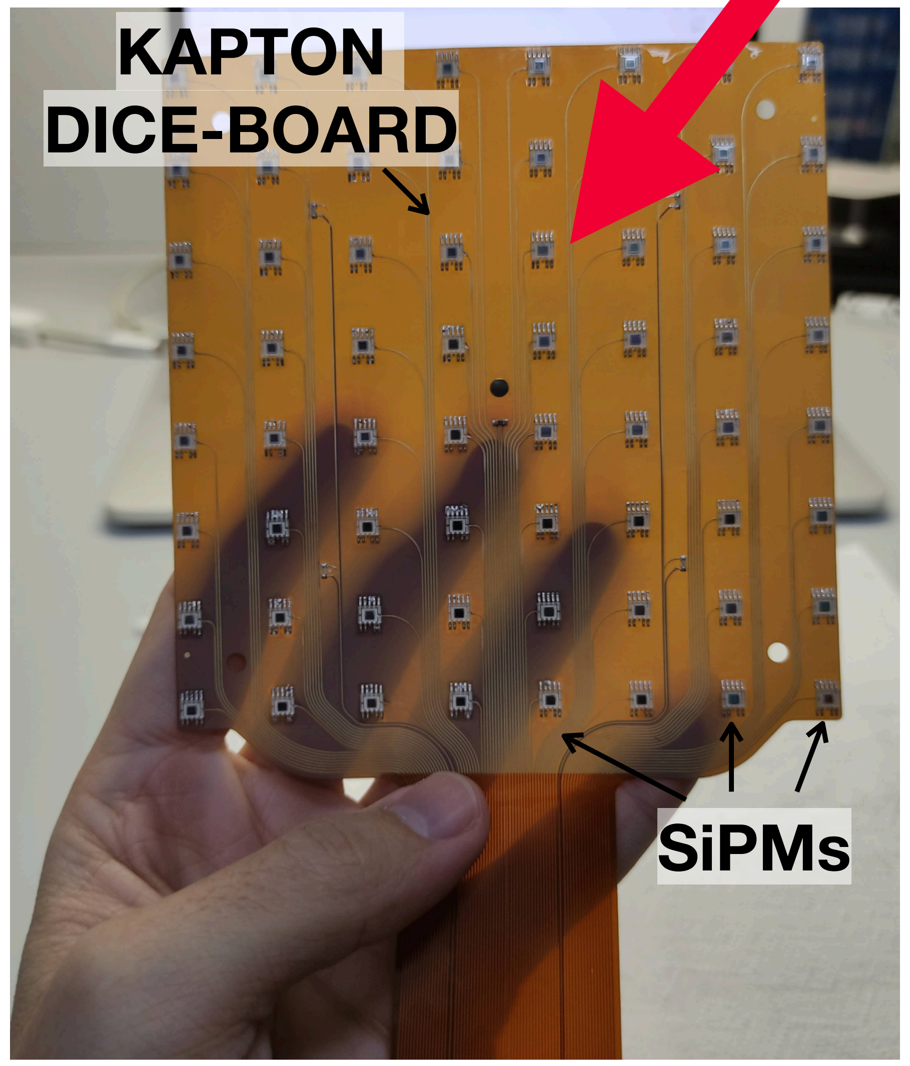
PHOTOSENSORS

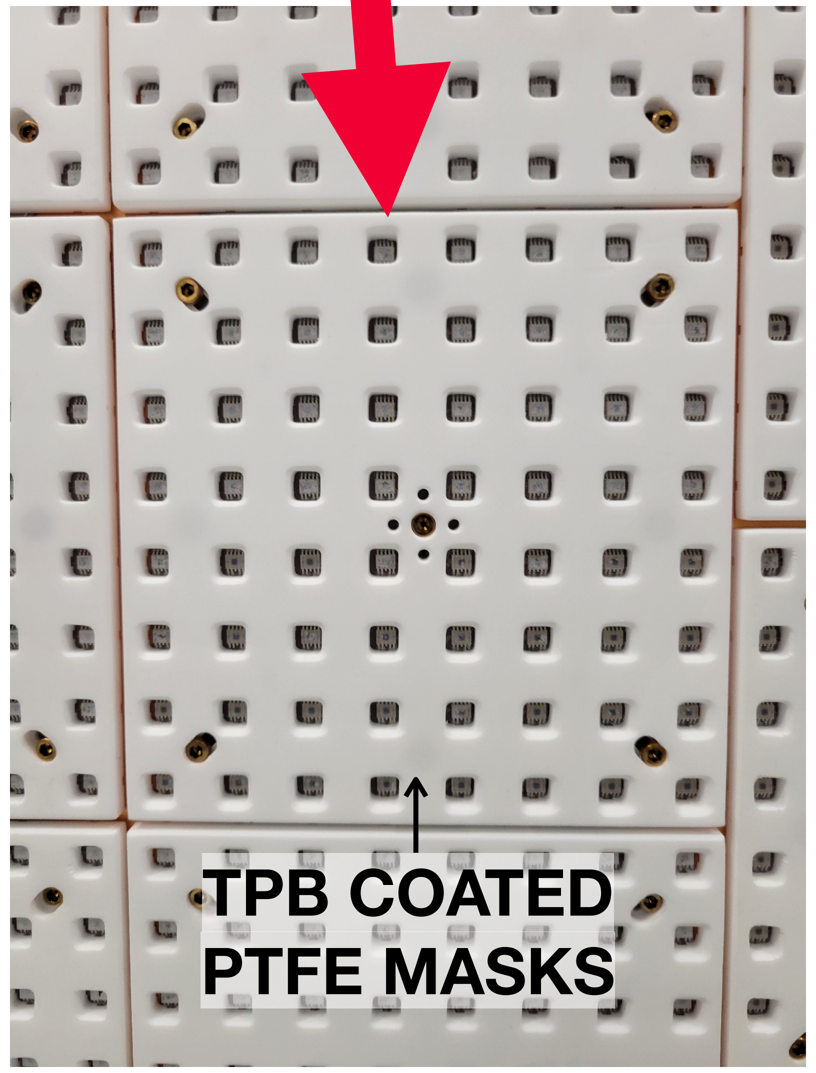
PMTs behind cathode ➜ currently used for t_0 and energy measurement; high radioactivity

SiPMs behind anode ➜ track reconstruction; higher coverage would enable energy measurement

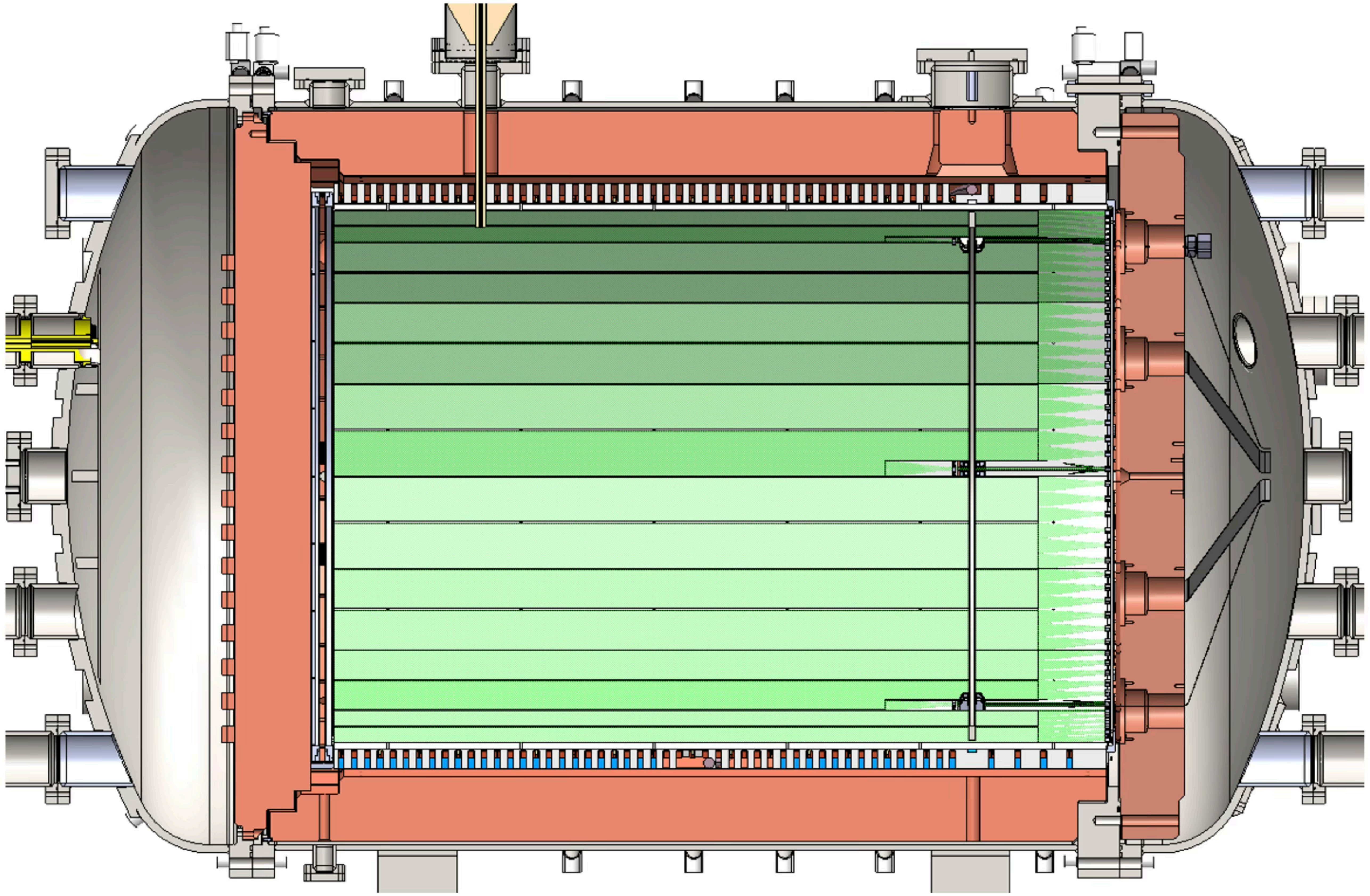






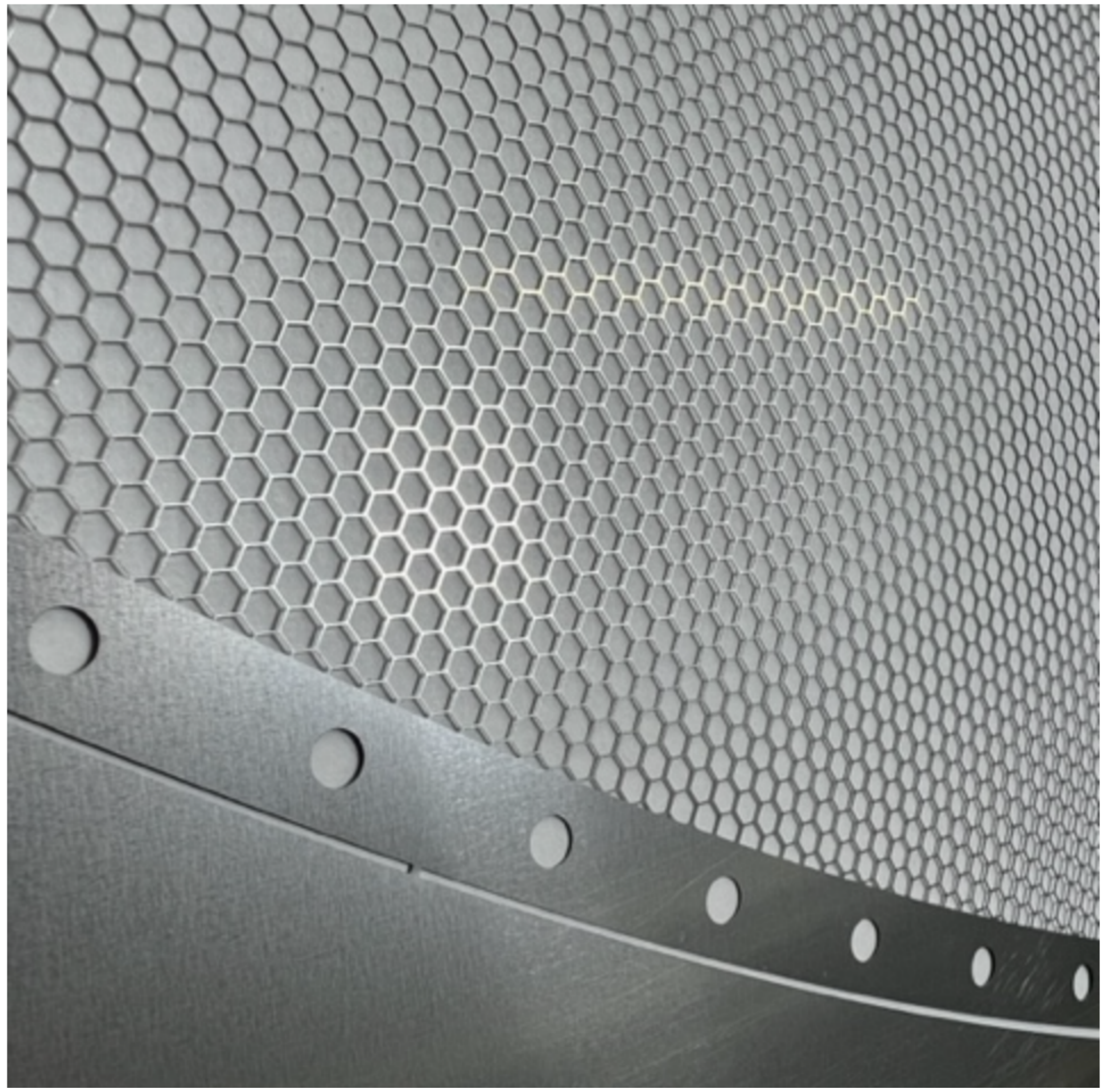


PHOTOSENSORS

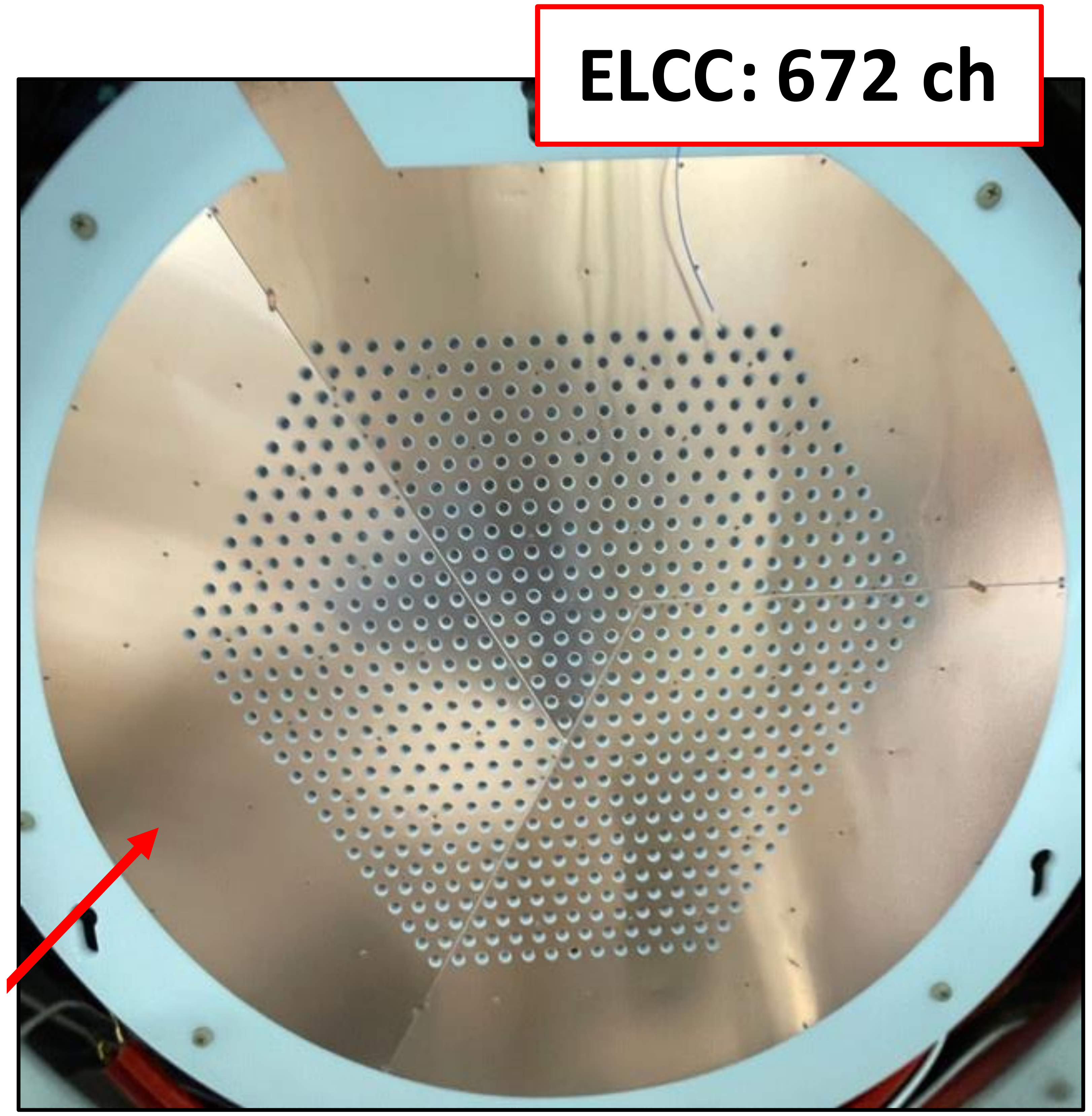


Replace PMTs with WLS fiber panels ➜ reduce background
Increase SiPM coverage ➜ dual energy + tracking capability

AMPLIFICATION STRUCTURES



NEXT Collaboration, JINST **19** (2024) 02, P02007



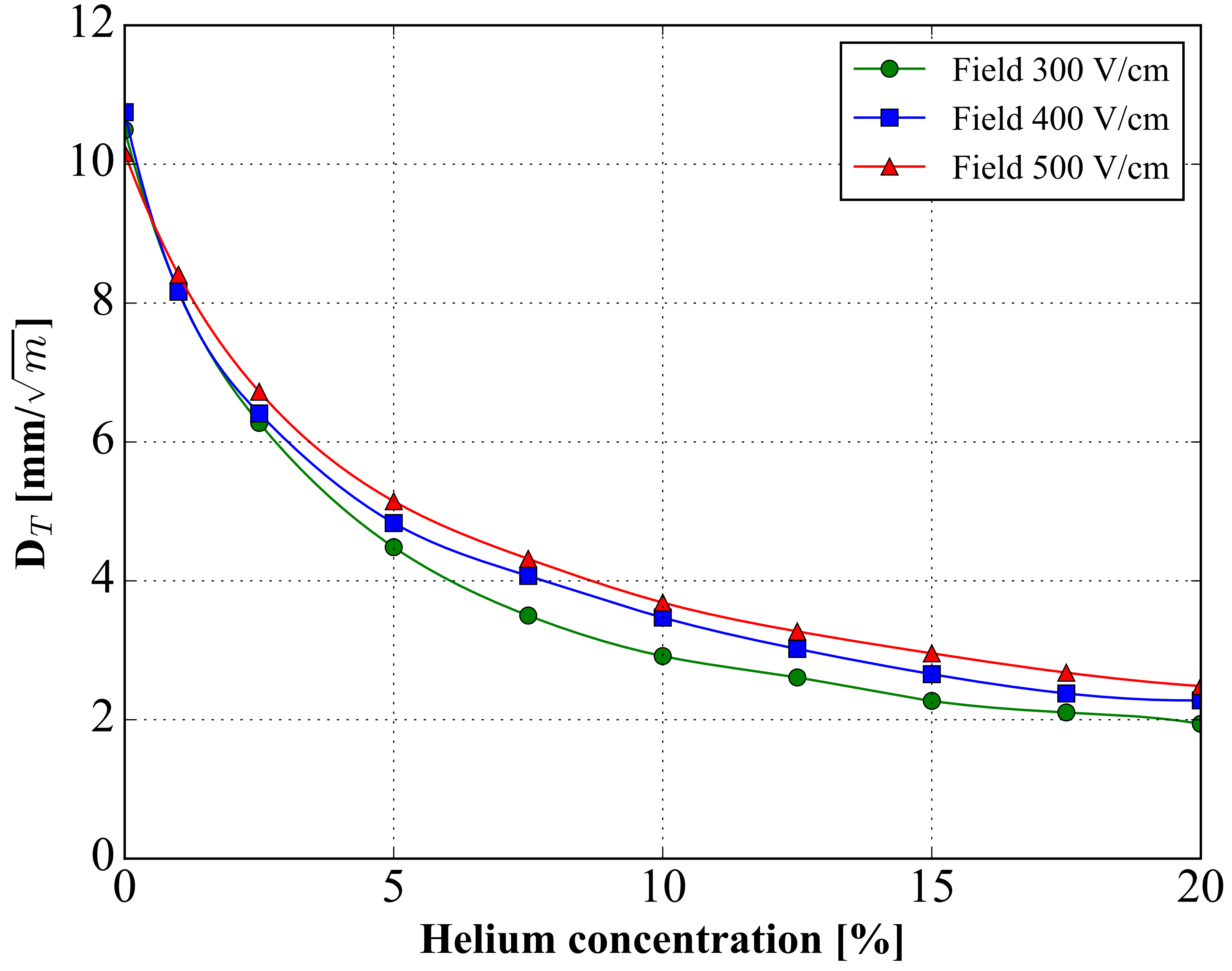
J. Hikida et al., NIM A **1080** (2025) 170706

NEXT-100 uses photo-etched hexagonal stainless steel meshes.

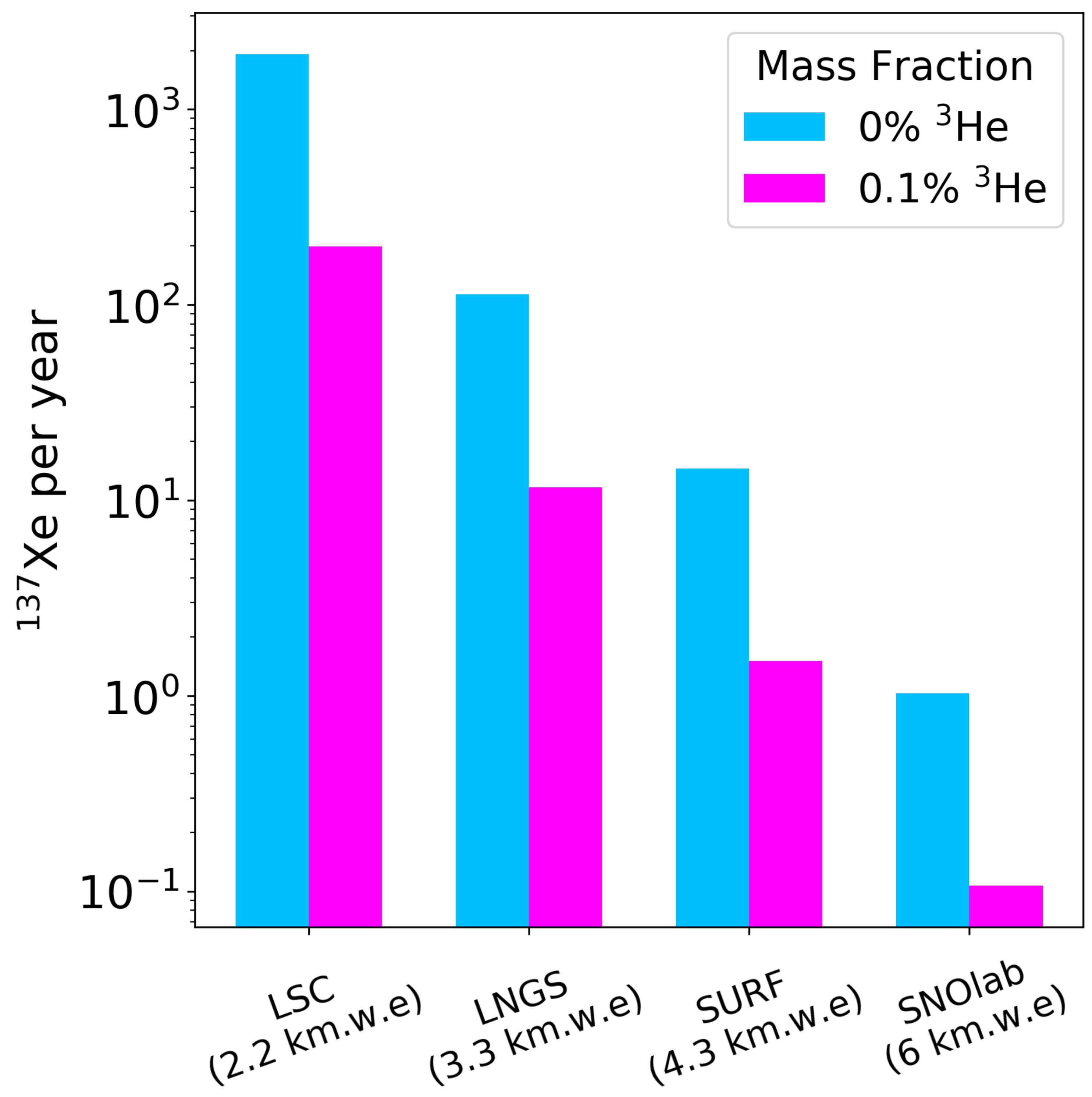
Large diameters require mechanically robust alternatives, such as the ELCC concept (AXEL).

GAS MIXTURES

NEXT Collaboration, NIM A **905** (2018) 82–90



NEXT Collaboration, J. Phys. G **47** (2020) 7, 075001



Helium admixtures reduce diffusion ➜ better tracking

^{3}He offers potential to mitigate main cosmogenic background (^{137}Xe)

Key Takeaways

SUMMARY

Gas TPCs: unmatched resolution + topology ➜ powerful background rejection

Technical maturity supports next-generation sensitivity

Active R&D on scalability and background control:

- Photon detection
- Gas mixtures
- Ba tagging and ion track detection