MEG II 実験による$\mu^+ \to e^+\gamma$探索の最新結果と現状

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日本物理学会第80回年次大会

2025年9月16日(火)-19日(金)

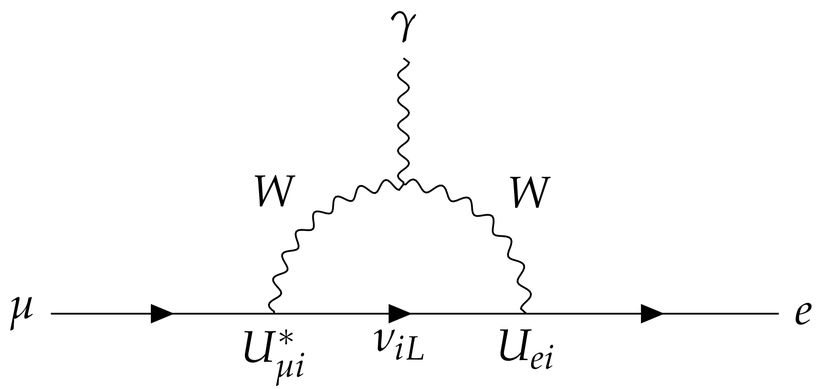
16aEK108-13

$\mu \to e\gamma$ as a probe for new physics

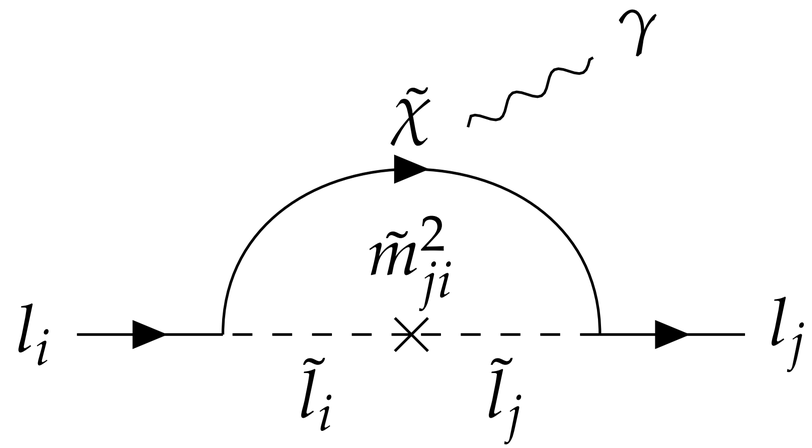
- Lepton flavour conservation is an accidental symmetry in the SM

- **The charged-lepton-flavour-violating decay $\mu \to e\gamma$ is an interesting probe to search for new physics beyond the SM**
  - **Its discovery would be clear evidence of new physics**

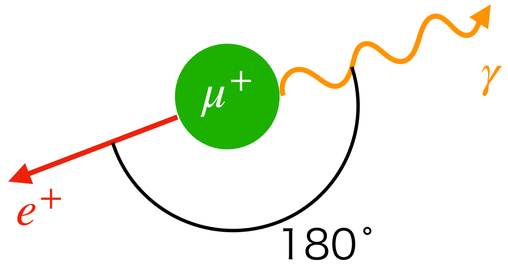
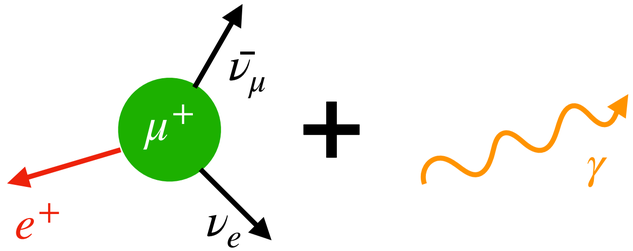
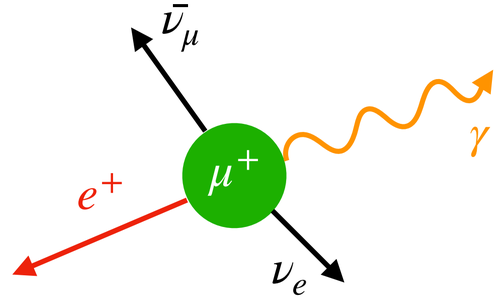
$\mathcal{B}(\mu \to e\gamma) \sim 10^{-54}$ SM + ν oscillation



BSM models (e.g. SUSY) $\mathcal{B}(\mu \to e\gamma) \sim 10^{-14} - 10^{-12}$

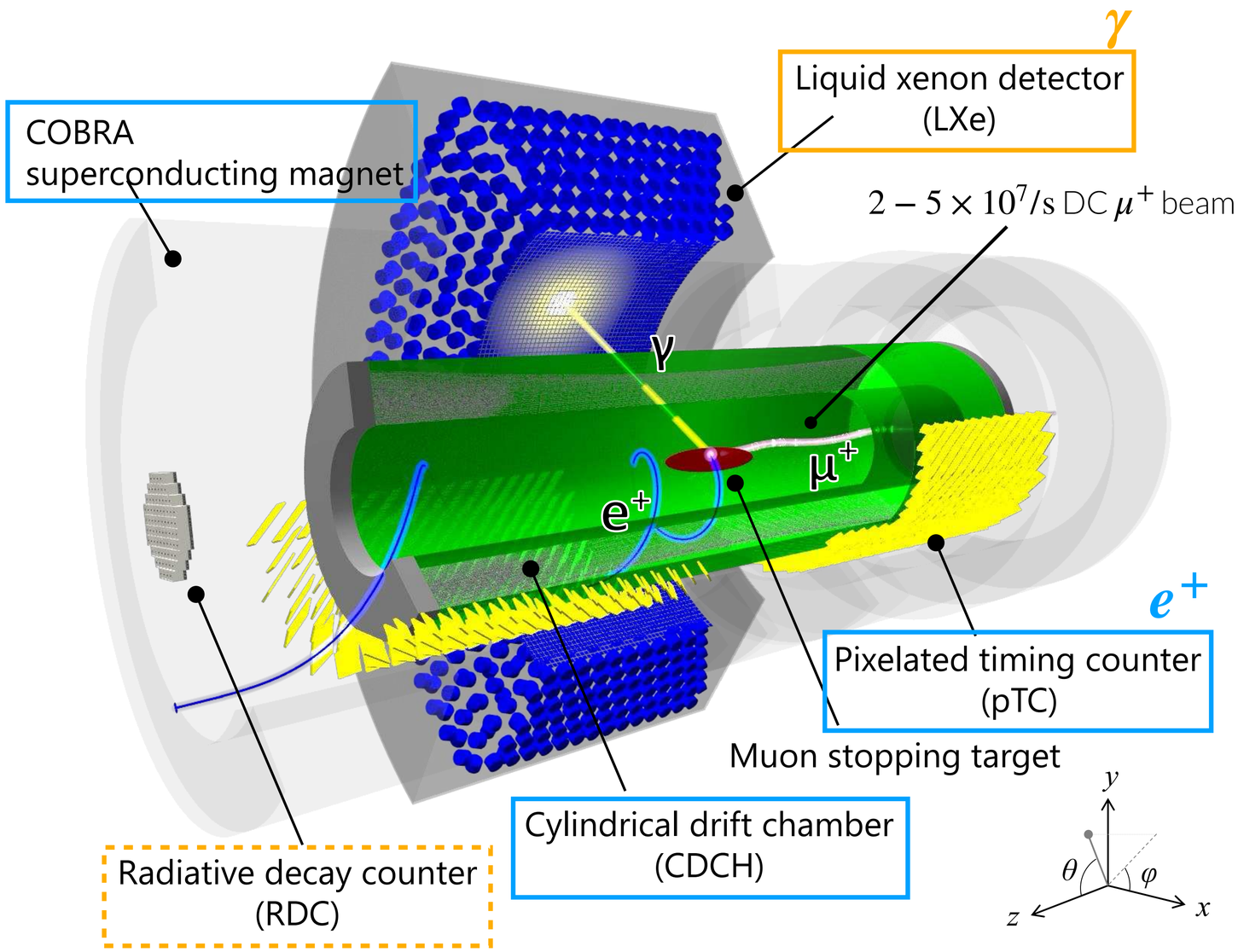


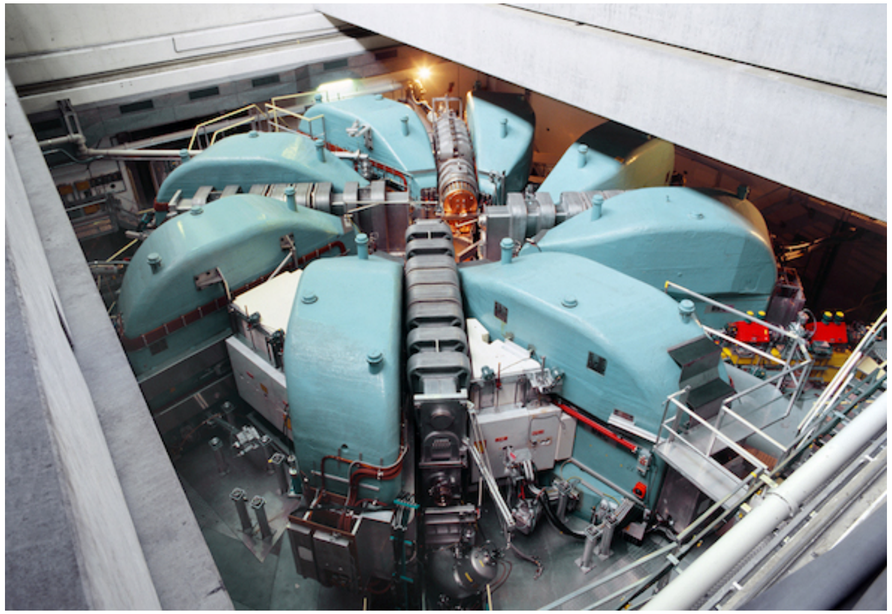
$\mu \to e\gamma$ signature and background

	Signal	Accidental background ≫ RMD background	
			
E_γ	52.8 MeV	<52.8 MeV	<52.8 MeV
E_e	52.8 MeV	<52.8 MeV	<52.8 MeV
$t_{e\gamma} = t_\gamma - t_e$	0 s	Flat	0 s
Opening angle	180°	<180°	<180°

Precise kinematics measurement required to distinguish signal from backgrounds

MEG II experiment in search of $\mu^+ \to e^+\gamma$





World's most intense proton cyclotron (1.4 MW)
@Paul Scherrer Institut in Switzerland

High-intensity DC muon beam

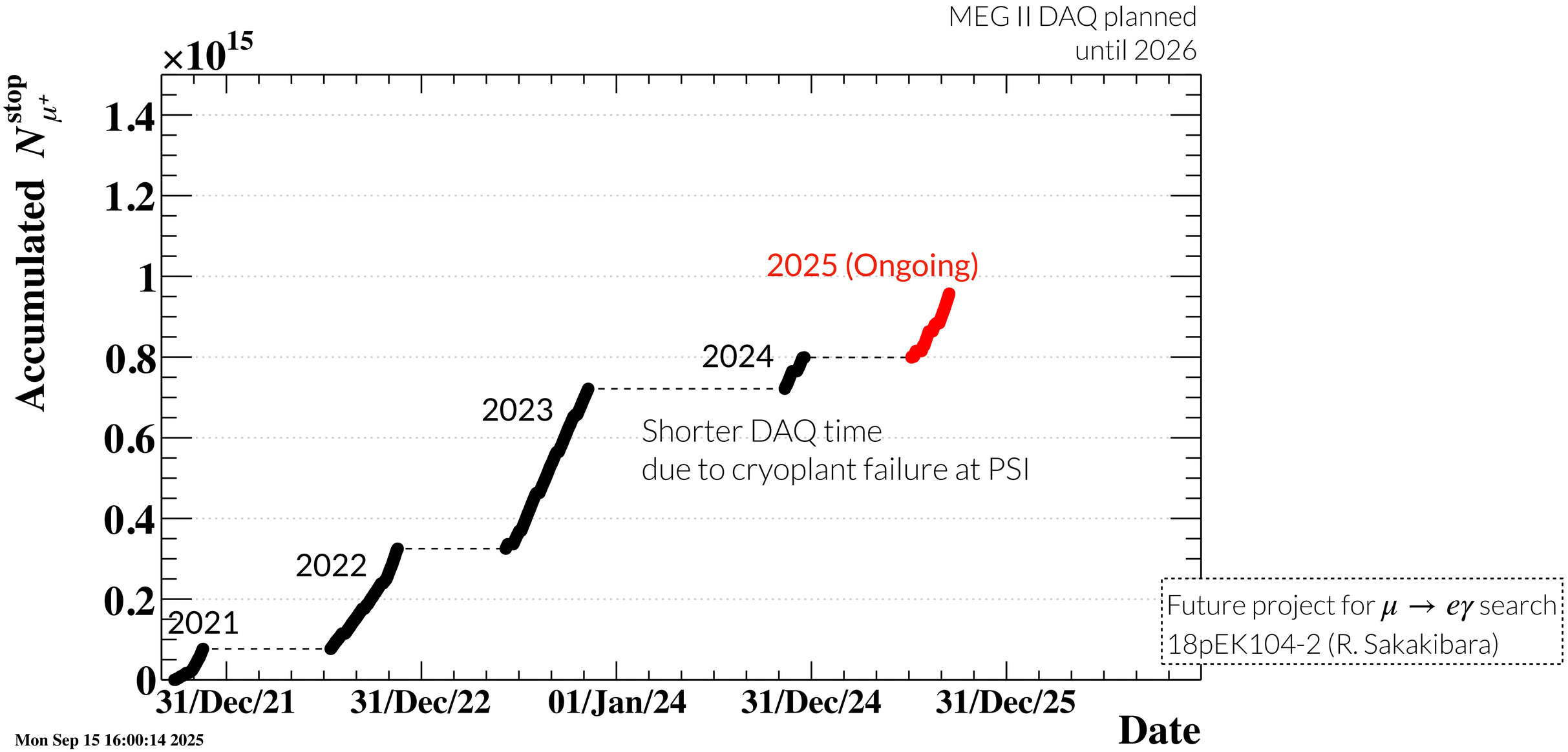
×

Innovative high-resolution detector

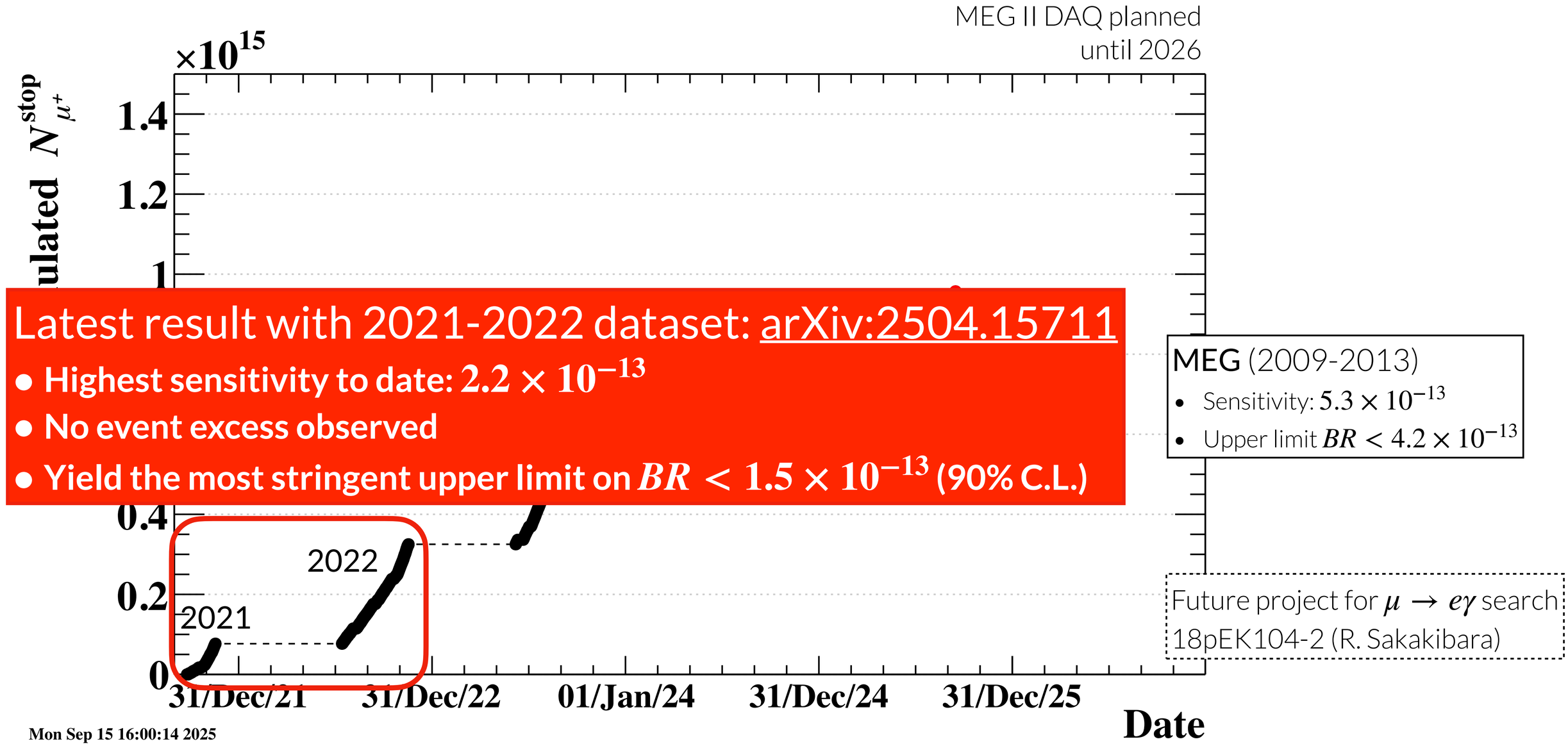
Eur. Phys. J. C 84 (2024), 190

→ Target sensitivity of 6×10^{-14}

DAQ timeline

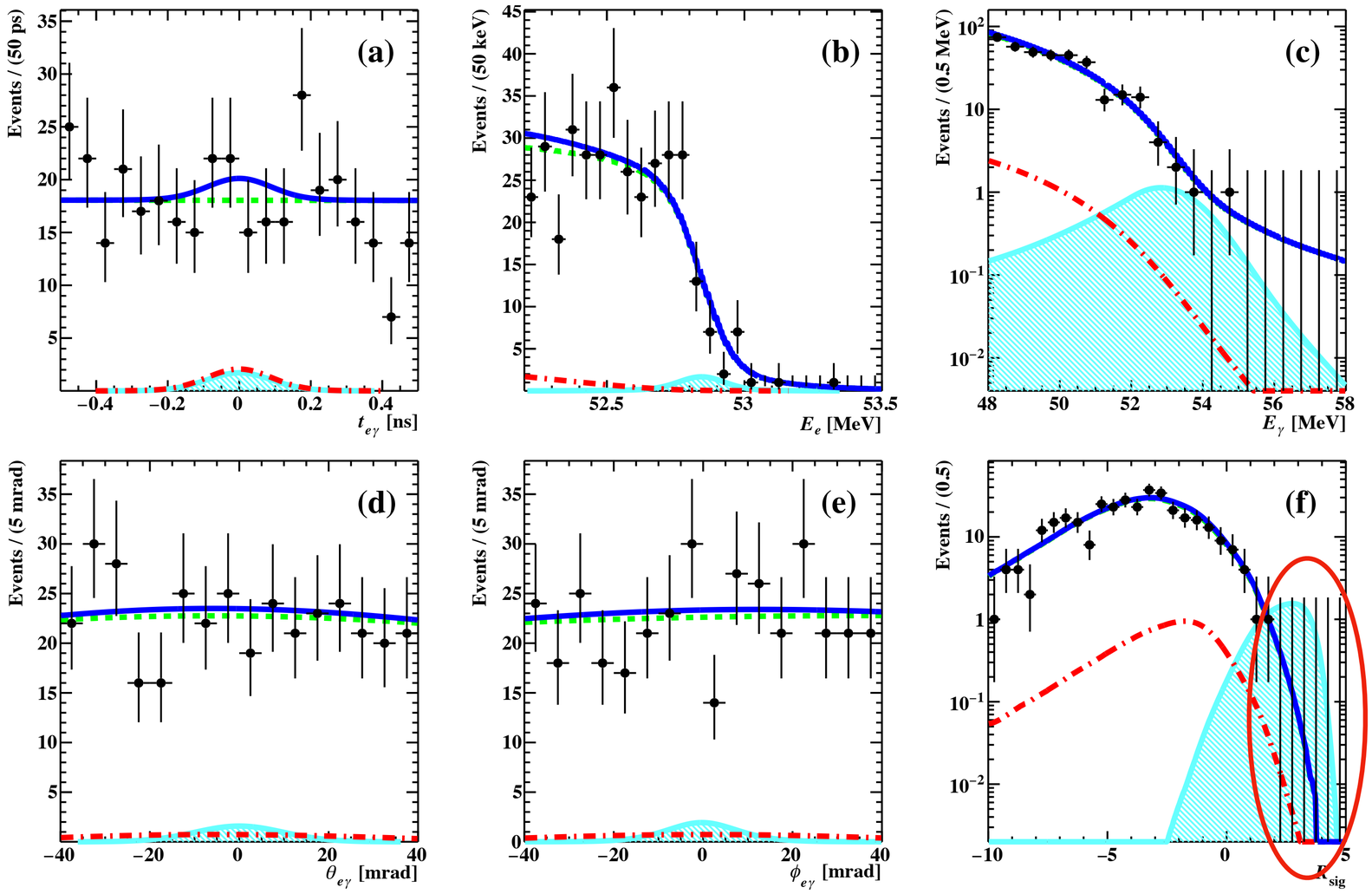


DAQ timeline

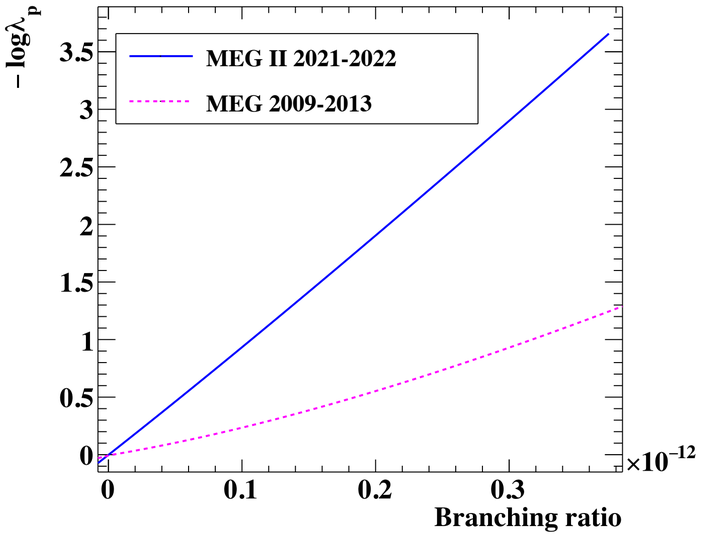


Results

Data (357 events), N_{sig} upper limit (2) x 4, N_{ACC} (360.9), N_{RMD} (9.7)



- $\boldsymbol{BR(\mu \to e\gamma) < 1.5 \times 10^{-13}}$ (90% C.L.)
  - Most stringent to date
  - MEG: 4.2×10^{-13}



No event excess observed

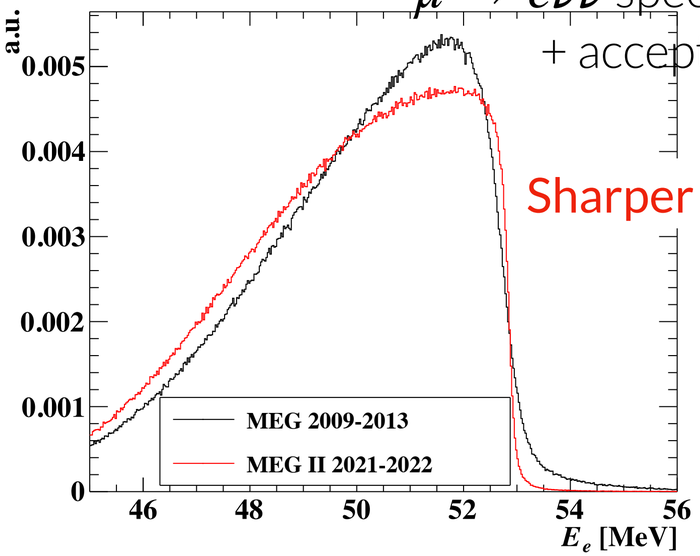
Relative signal likelihood

$$R_{\mathrm{sig}}(\vec{x}_i) = \log_{10}\left(S(\vec{x}_i)/B(\vec{x}_i)\right)$$

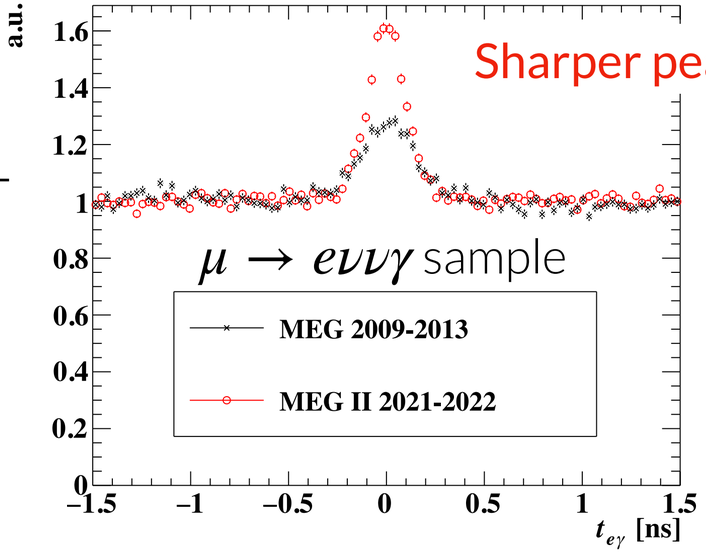
Detector improvement from MEG

	MEG [44]	MEG II achieved in this work
Resolutions		
E_γ (%) $(w_\gamma < 2\,\mathrm{cm})/(w_\gamma > 2\,\mathrm{cm})$	2.4/1.7	2.4/1.9
u_γ, v_γ, w_γ (mm)	5, 5, 6 →	2.5, 2.5, 5
t_γ (ps)	67 [43]	63
E_e (keV)	380 →	89
θ_e, ϕ_e (mrad)	9.4, 8.7	6.2, 5.2
z_e, y_e (mm)	2.4, 1.2	1.76, 0.61
t_e (ps)	102 [43] →	~40
$t_{e\gamma}$ (ps)	122 →	78
Efficiencies		
ε_γ (%)	63	63
ε_e (%)	30 →	67
ε_{TRG} (%)	≈99	91

$\mu \to e\nu\nu$ spectrum + acceptance



Sharper edge

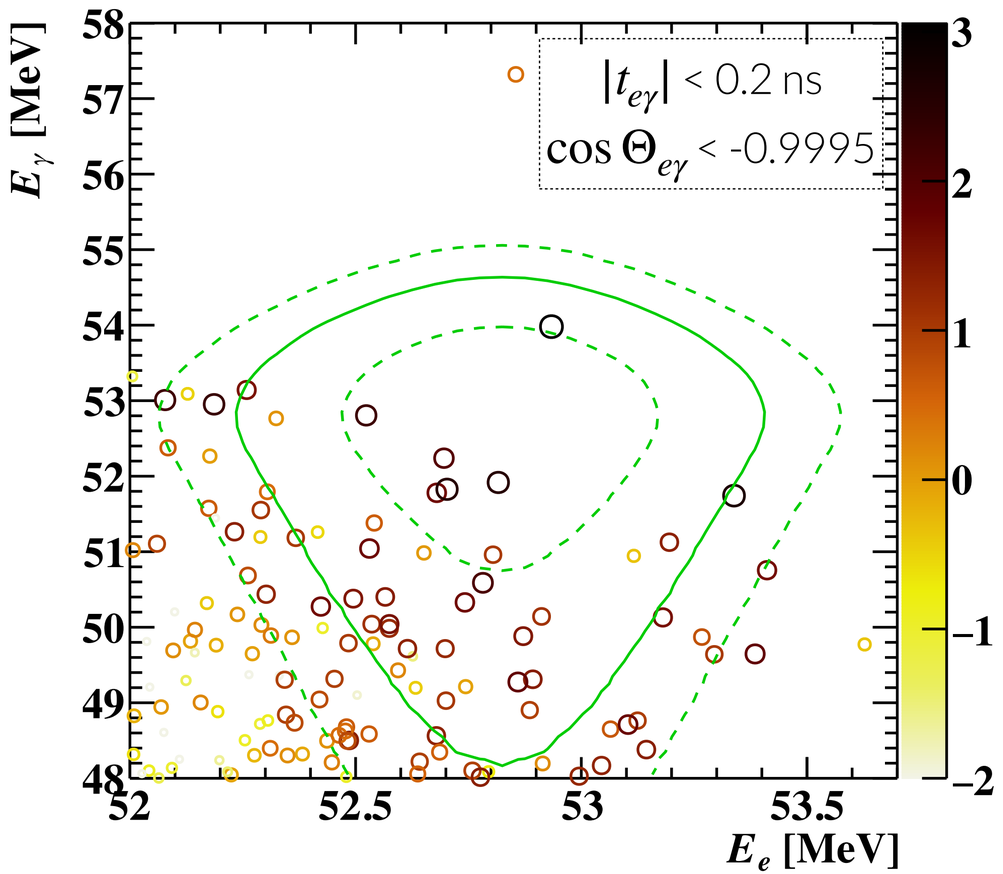


Sharper peak

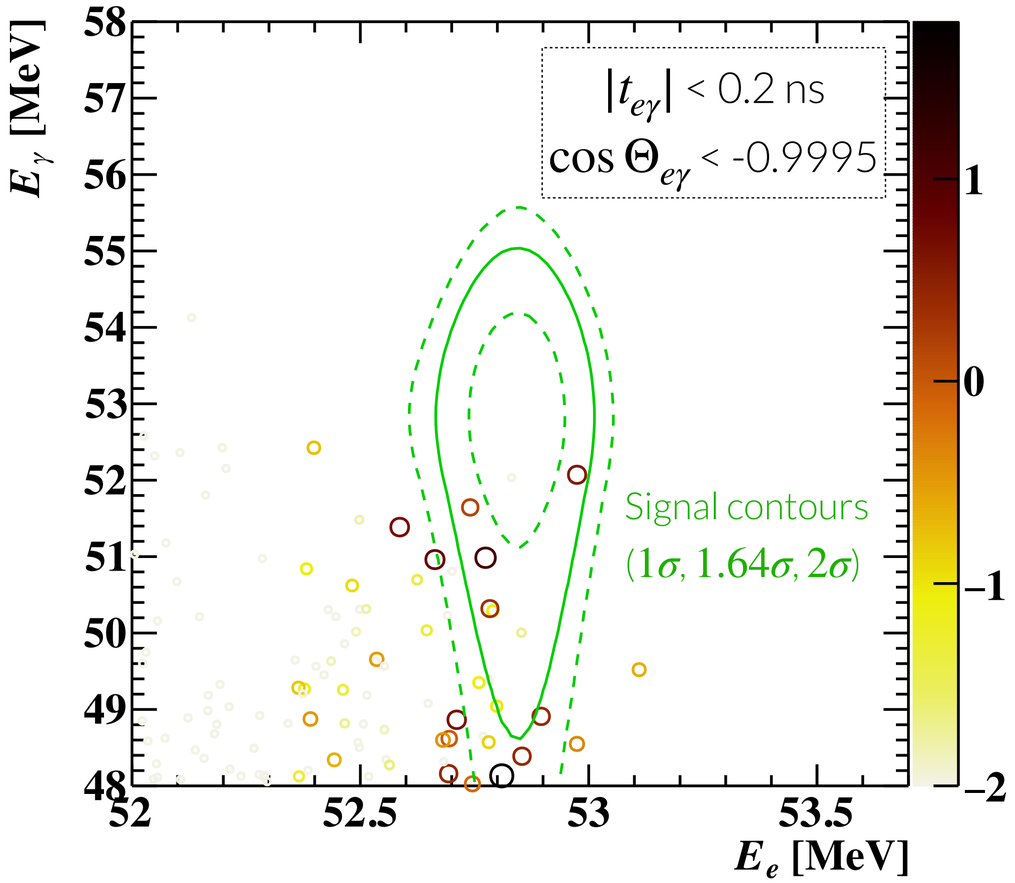
Background much reduced w.r.t. MEG

- Detector performance improvement → **x2.4 sensitivity improvement**
  - Comparable statistics: 1.71×10^{14} in MEG full dataset vs 1.34×10^{14} in MEG II 2021-2022

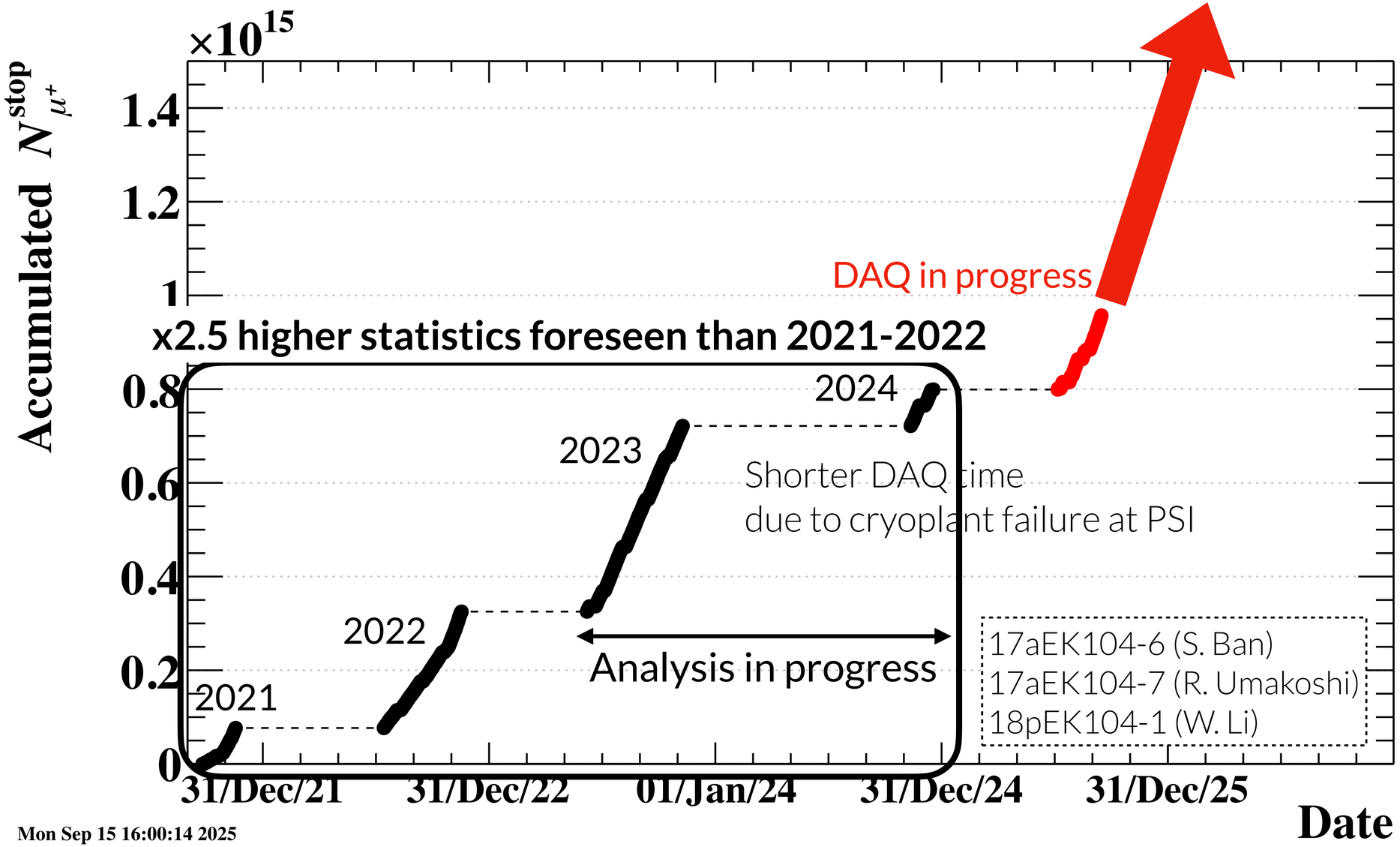
MEG 2009-2013



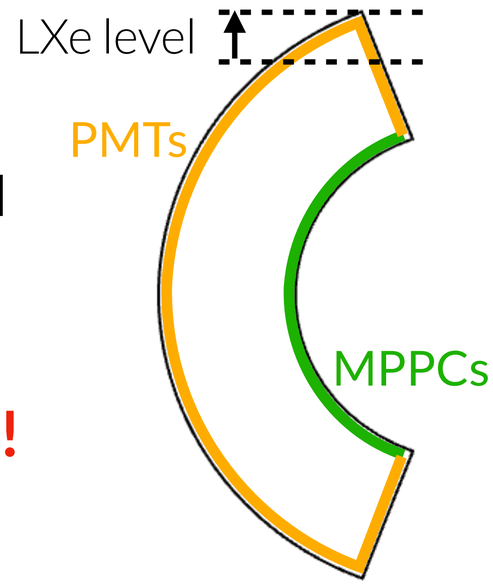
MEG II 2021-2022



Towards next searches



Run 2025 with issues in 2024 resolved

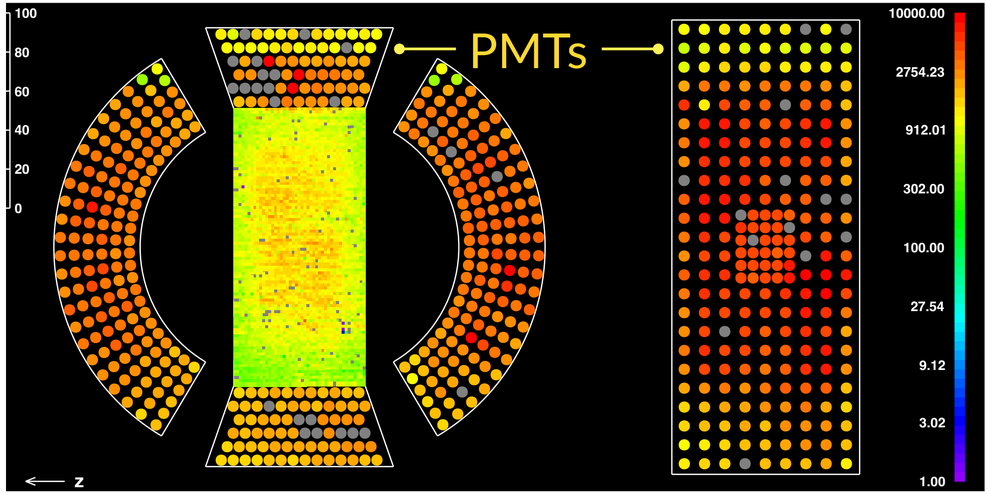


- Two big challenges in run 2024
  - A magnet for μ beam could not be operated due to no LHe supply from PSI
  - Xe leak in LXe photon detector

- Both solved → **Statistics have been stably accumulated in run 2025!**

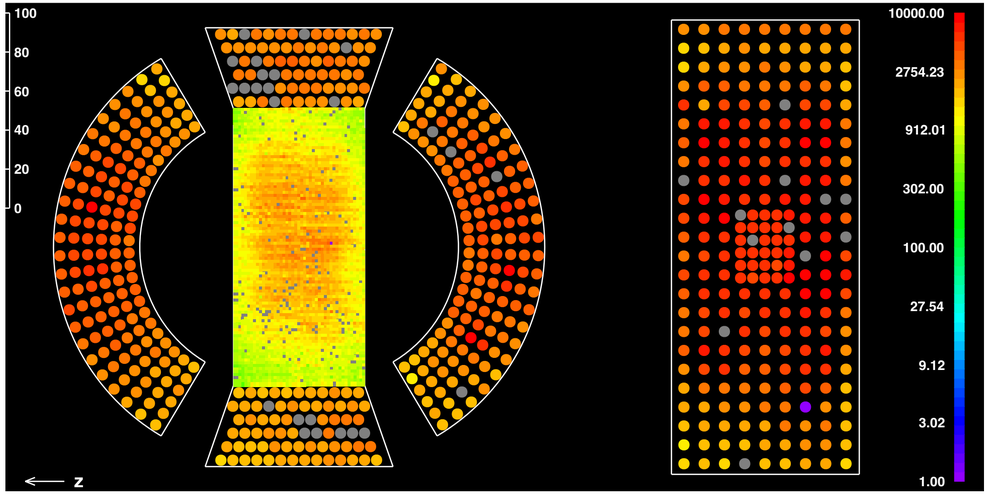
Light distribution for LED

14/Dec./2024



- New Xe added
- No more leak

8/Sept./2025

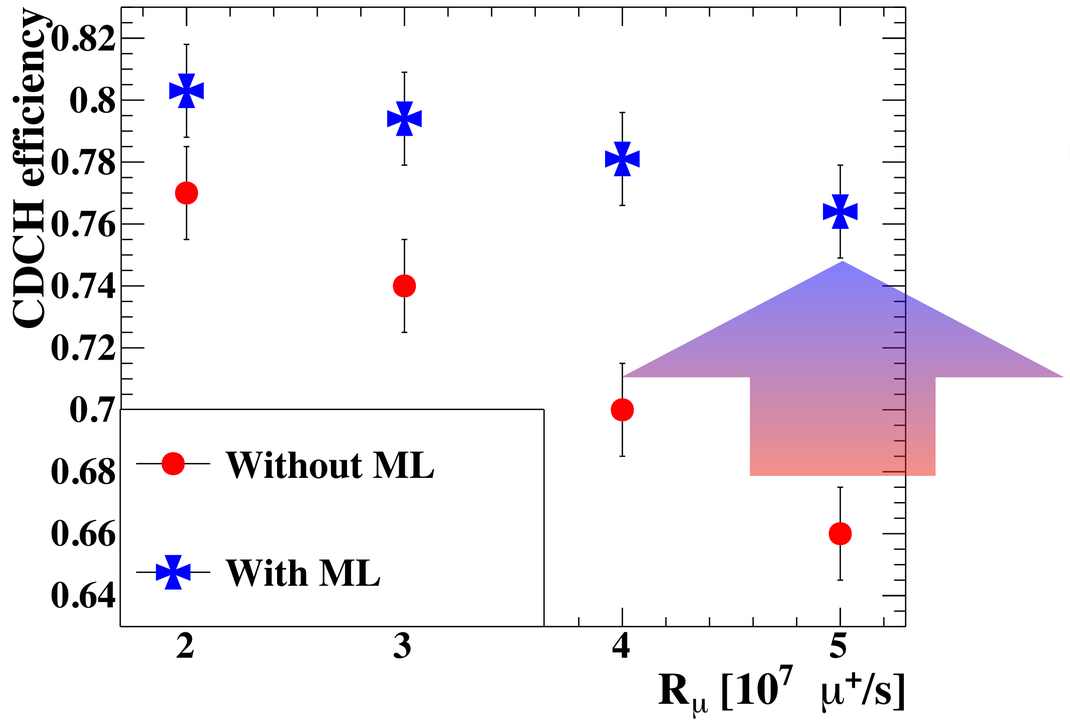


Positron efficiency & beam intensity

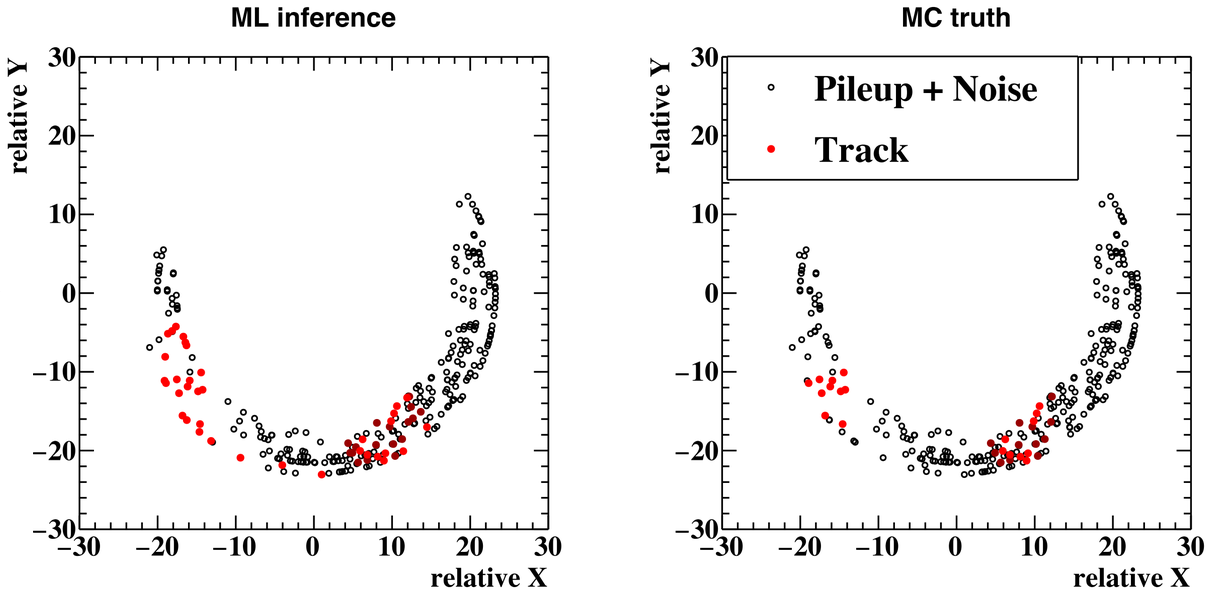
- Transformer-based positron track finding developed

➡ Positron efficiency improved by $\mathcal{O}$(10%), especially at higher beam intensity

➡ DAQ at higher beam intensity ($4 \rightarrow 5 \times 10^7\ \mu/\mathrm{s}$) since this year's run



Filter out pileup hits

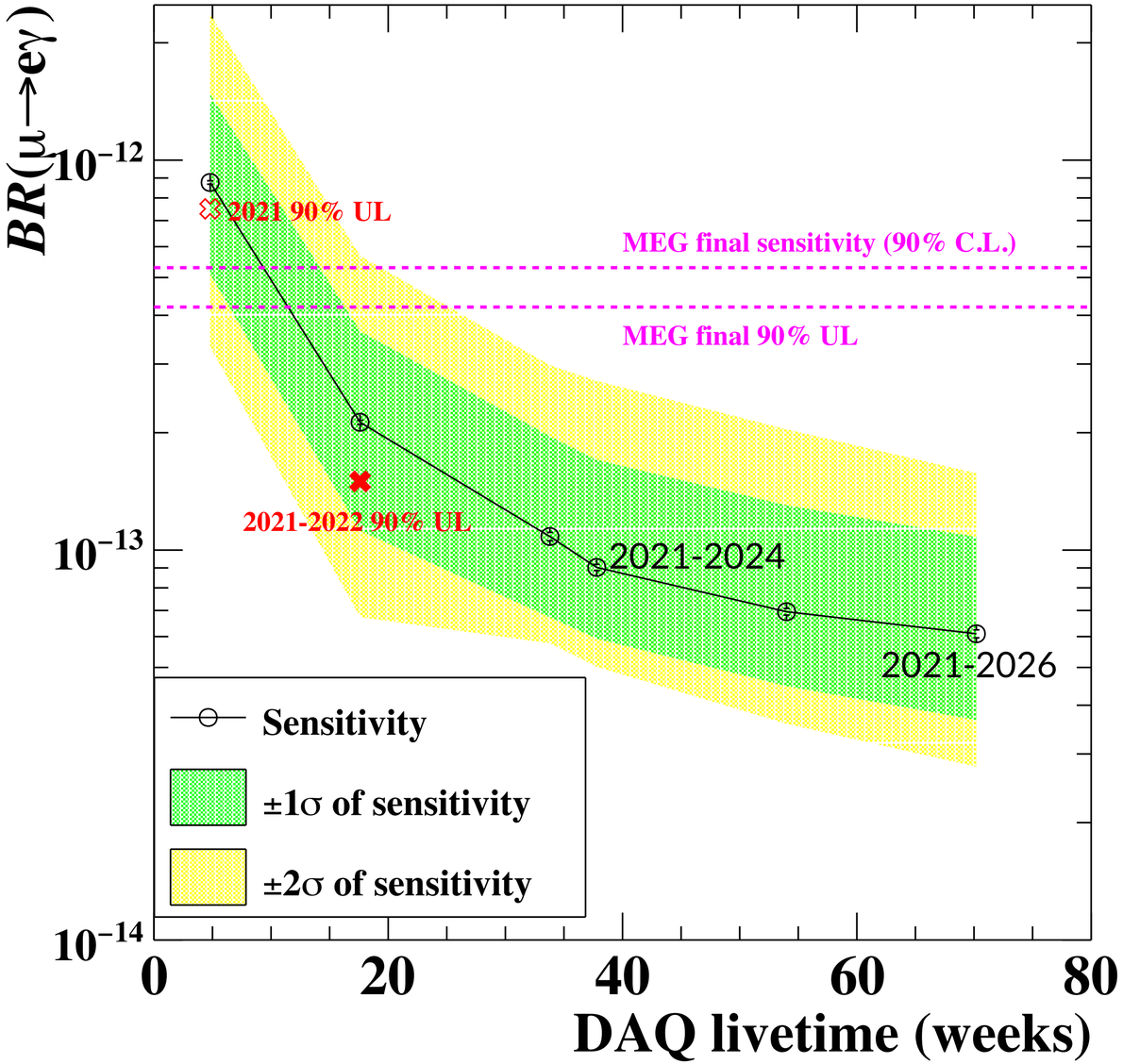


Conclusion & prospects

- The MEG II experiment has been taking physics data since 2021

- The latest result based on 2021-2022 dataset:
  - $BR(\mu \to e\gamma) < 1.5 \times 10^{-13}$ (90% C.L.)
  - Most stringent upper limit to date

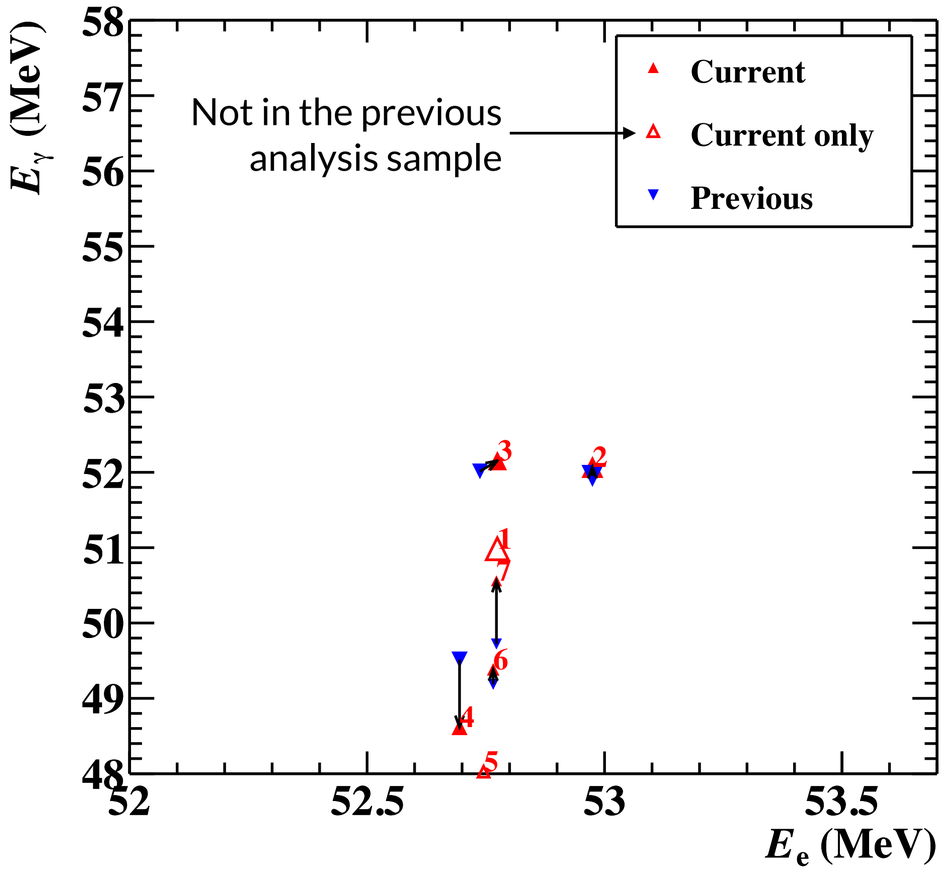
- DAQ will continue until 2026, reaching a target sensitivity of 6×10^{-14}
  - Not only taking data, but also further improving analysis methods for better sensitivity than 6×10^{-14}

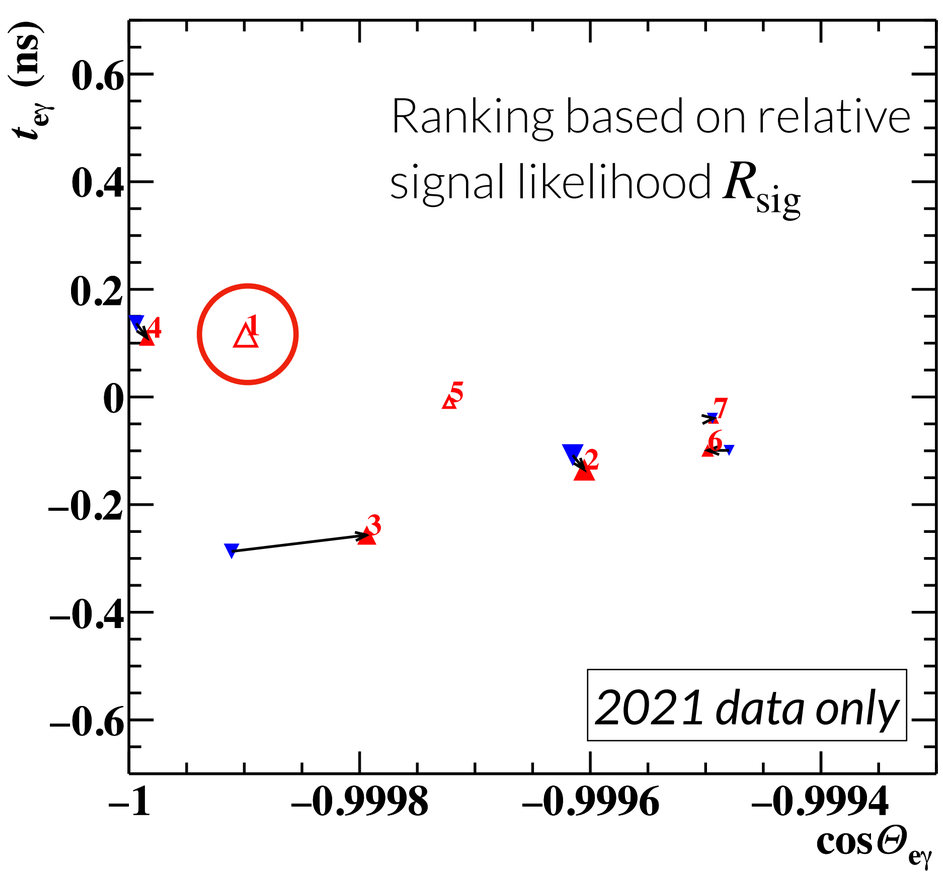


Backup

Event-by-event examination for the 2021 data

- 2021 data reanalysed with new reconstruction algorithms and calibration
- Confirm *this update improved our sensitivity*

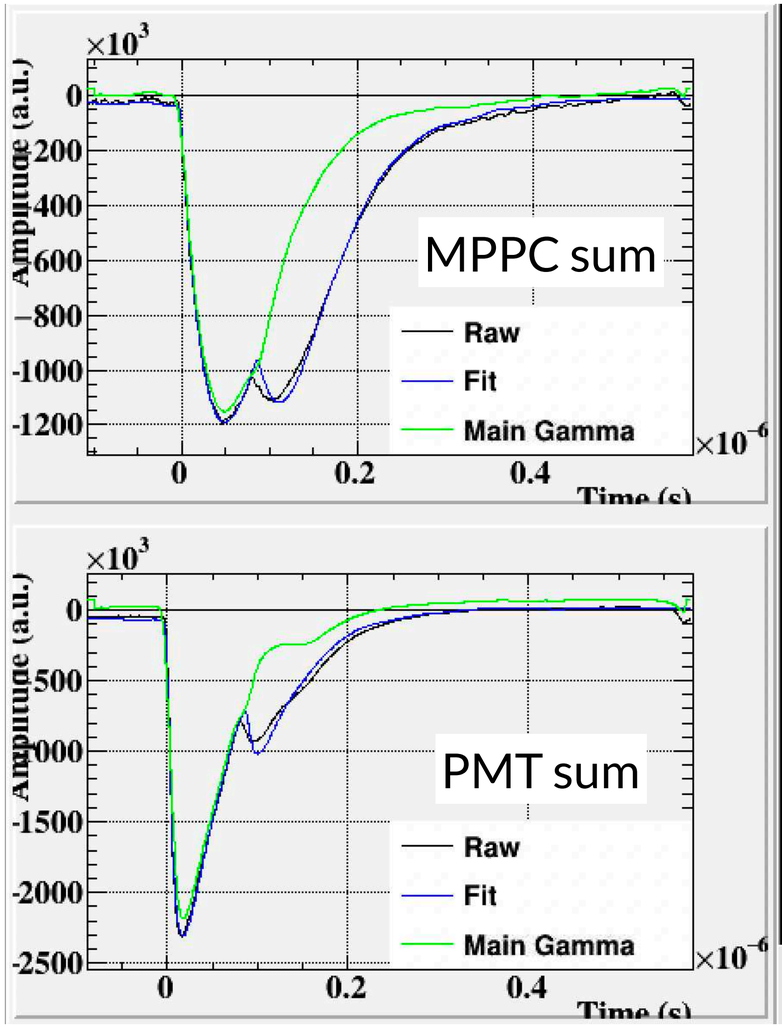


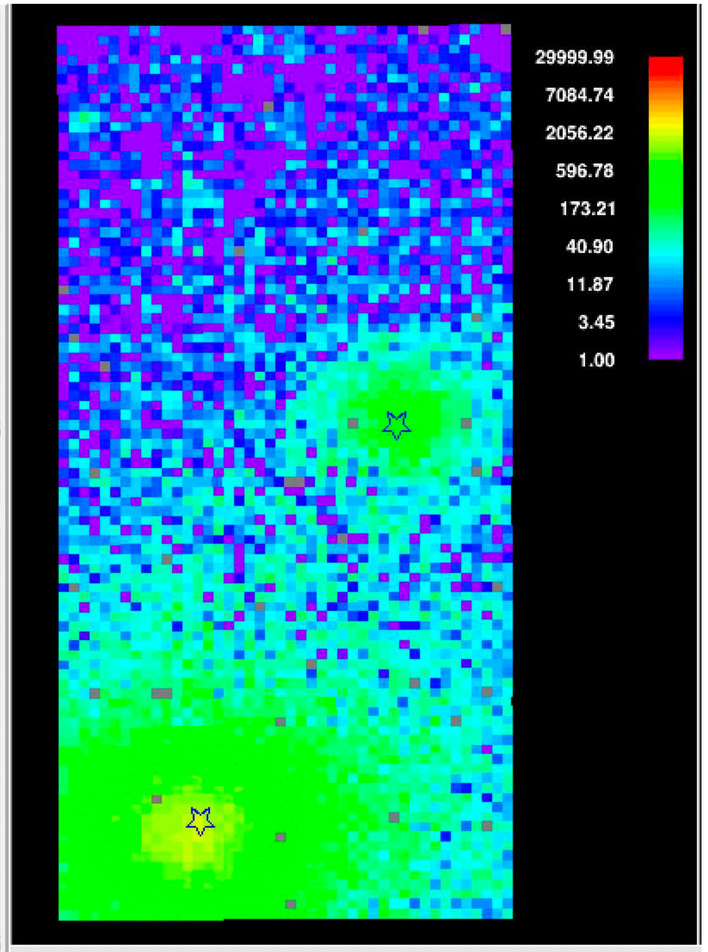


Improve t_γ resolution for pileup events

- Pileup photon made the main photon timing be reconstructed later by 1.8 ns

- **Photon timing reconstruction improved for pileup events**
  - Limited # photosensors used for t_γ reconstruction
  - Update photosensor selection



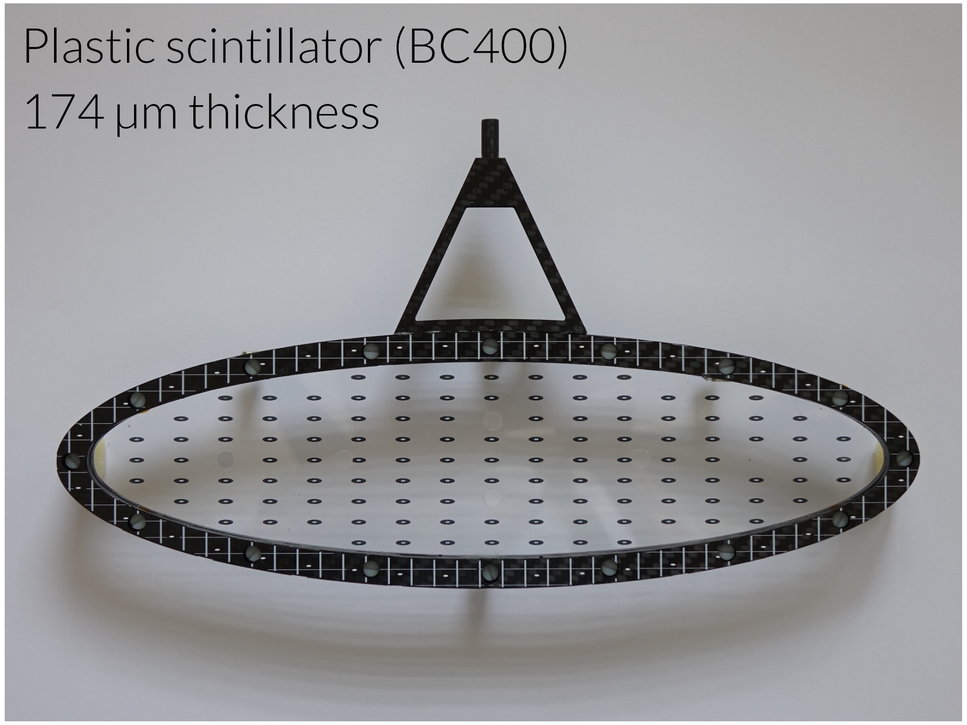


Scintillation light distribution in MPPCs

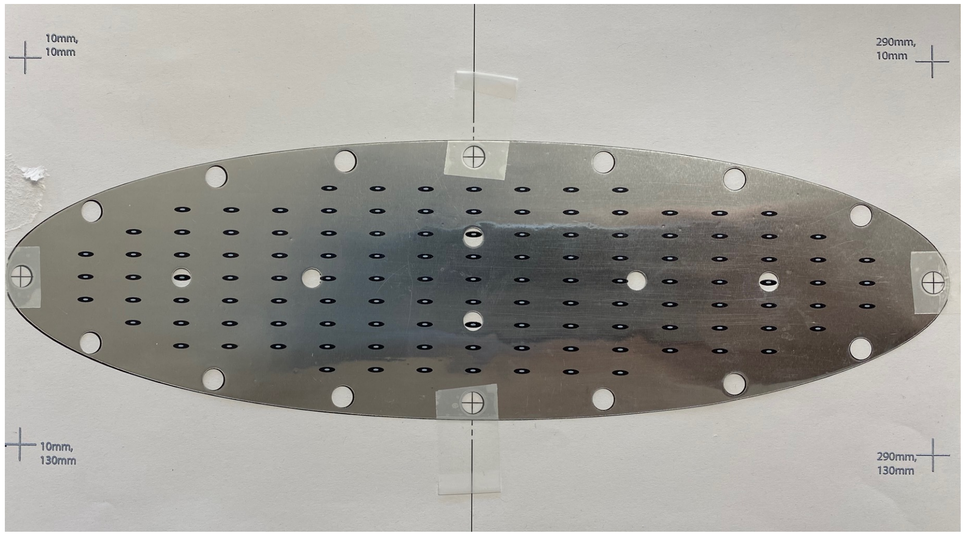
Exchange muon stopping target in 2025

- A source of systematic uncertainty: **Temporal variation of target deformation**
  - Another observation: Degree of deformation increased over the years

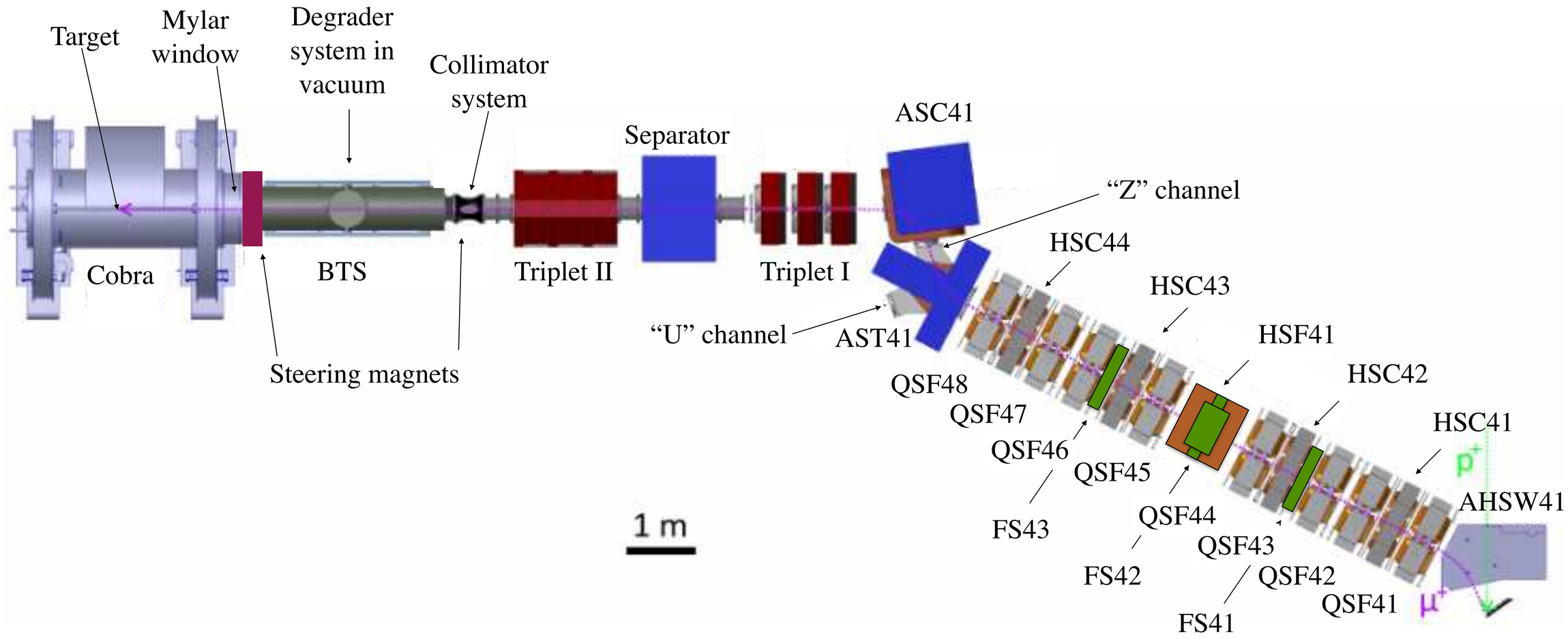
- **More rigid Beryllium target installed since run 2025**



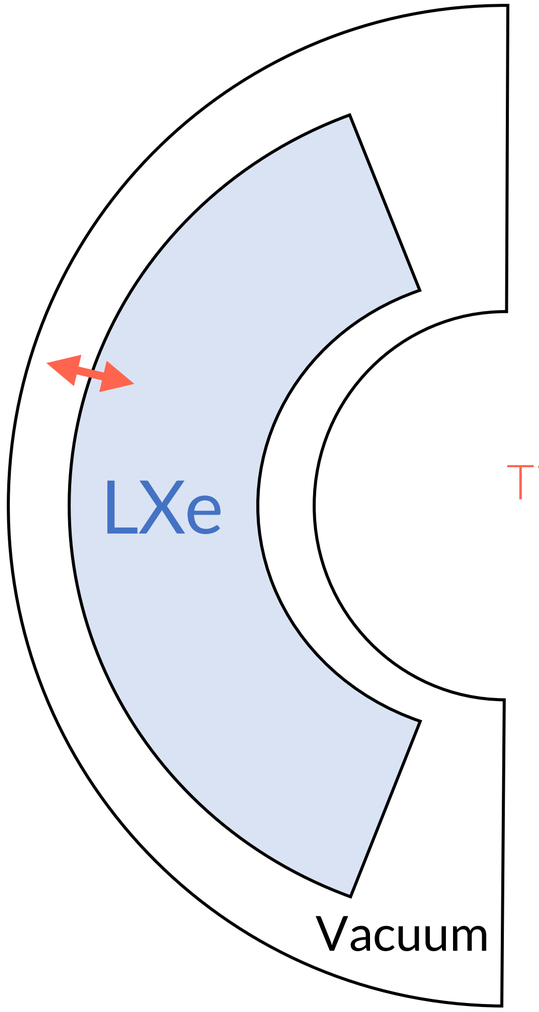
Beryllium with a thickness of 93-95 μm



Beamline components



Fixing liquid xenon leakage



Tighten inner vessel nuts