MEG II

Satoshi MIHARA

On behalf of the MEG II collaboration

MIP2024 2024/04/20

Outline

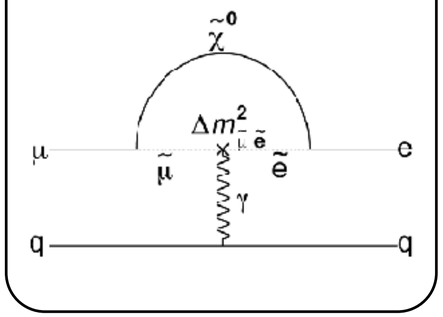
- Introduction
- MEG result
- MEG to MEG II
- Status of MEG II
- Recent result and future prospect of MEG II
- Summary

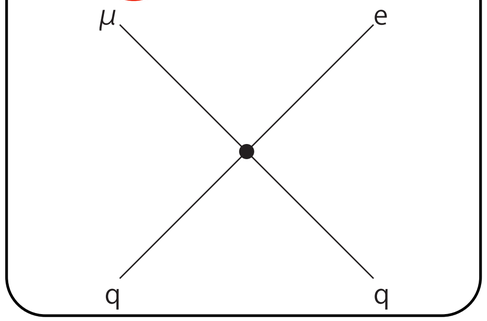
Introduction
cLFV physics with muons

- $\mu \to e\gamma$
- $\mu \to eee$
- $\mu + A \to e + A$

- SUSY-GUT, SUSY-seesaw
  - higgs mediated processes
- Doubly Charged Higgs Boson (LRS *etc.*)
- Randall-Sundrum Models
- SUSY with R-parity Violation
- Leptquarks
- Heavy Z'
- Multi-Higgs Models
- Little Higgs Models

$$\mathcal{L} = \frac{m_\mu}{(\kappa+1)\Lambda^2}\bar{e}\sigma^{\mu\nu}F_{\mu\nu}\mu + \frac{\kappa}{(1+\kappa)\Lambda_F^2}\bar{e}\mu(\bar{q}q + \bar{e}e)$$

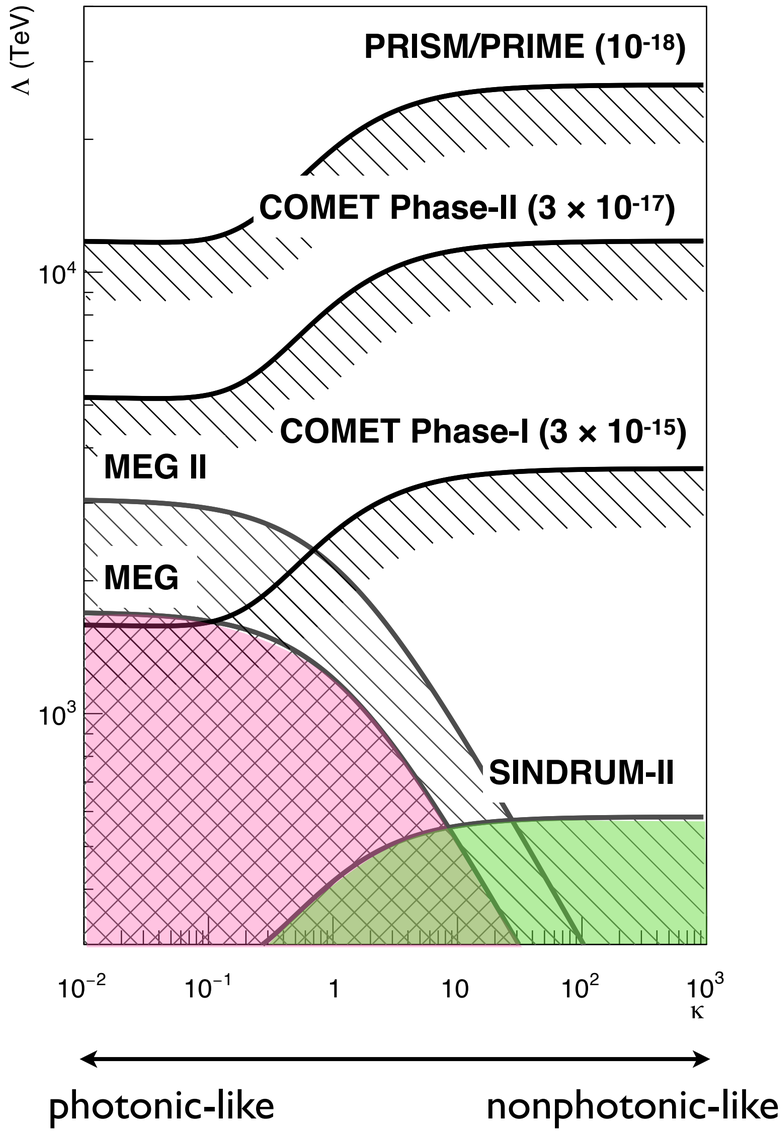




photonic

non-photonic

New physics scale



μ→eγ: MEG

COMET, Mu2e

Introduction

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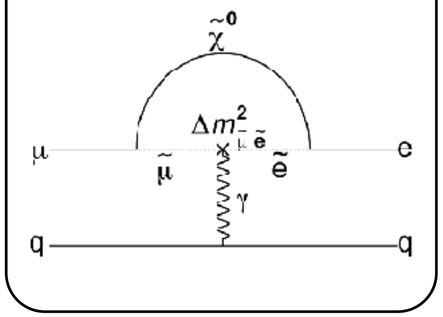

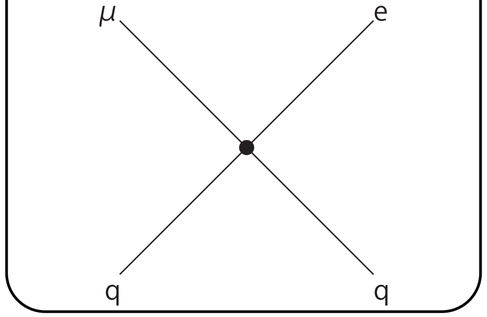

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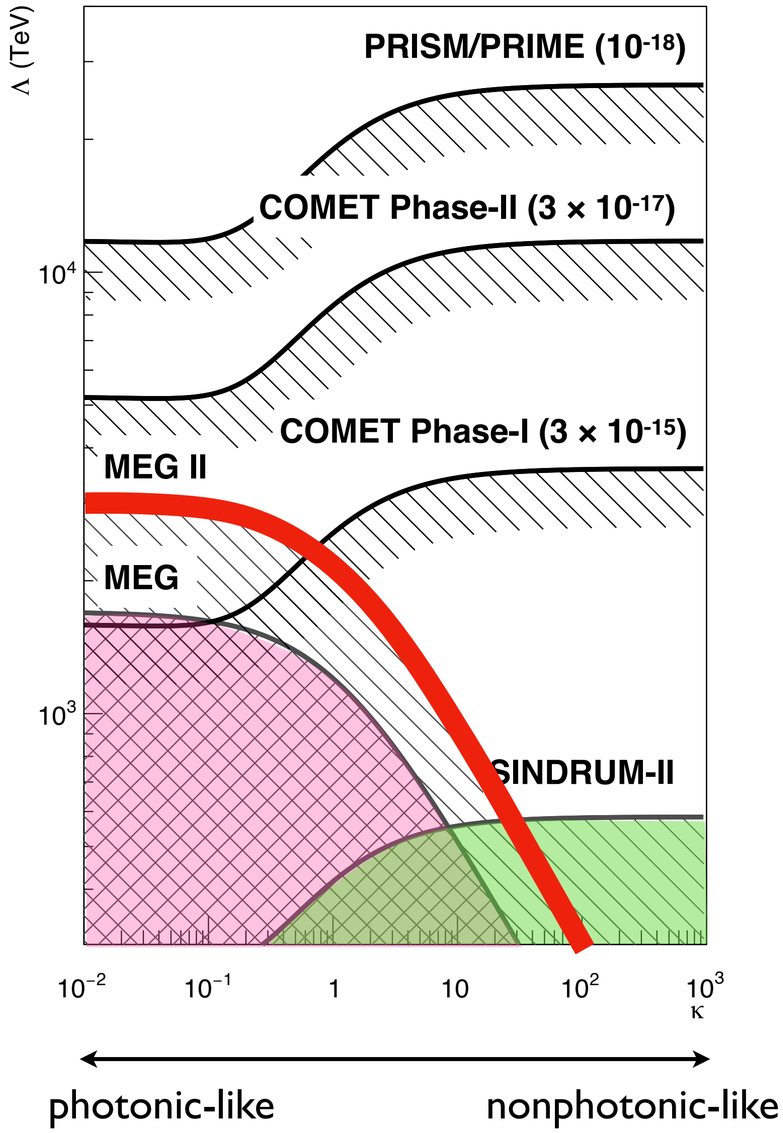
non-photonic

New physics scale



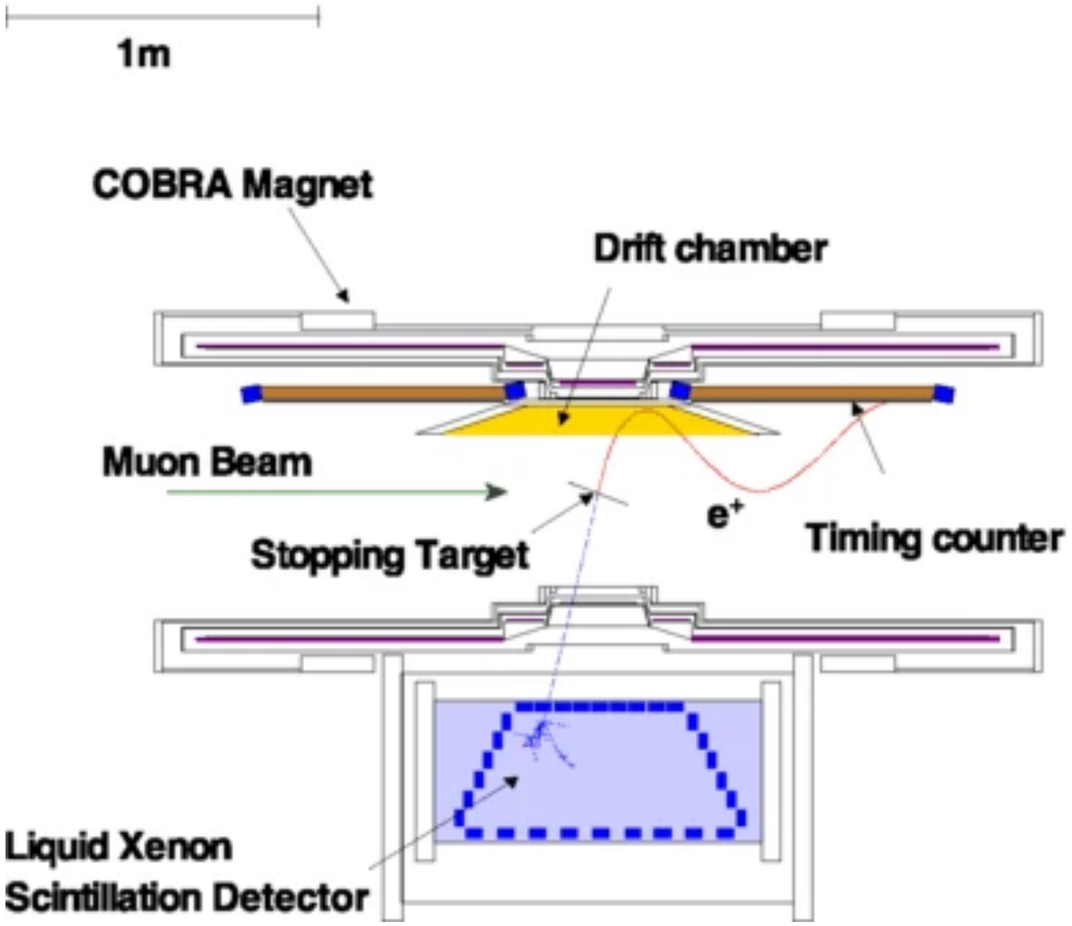
μ→eγ: MEG

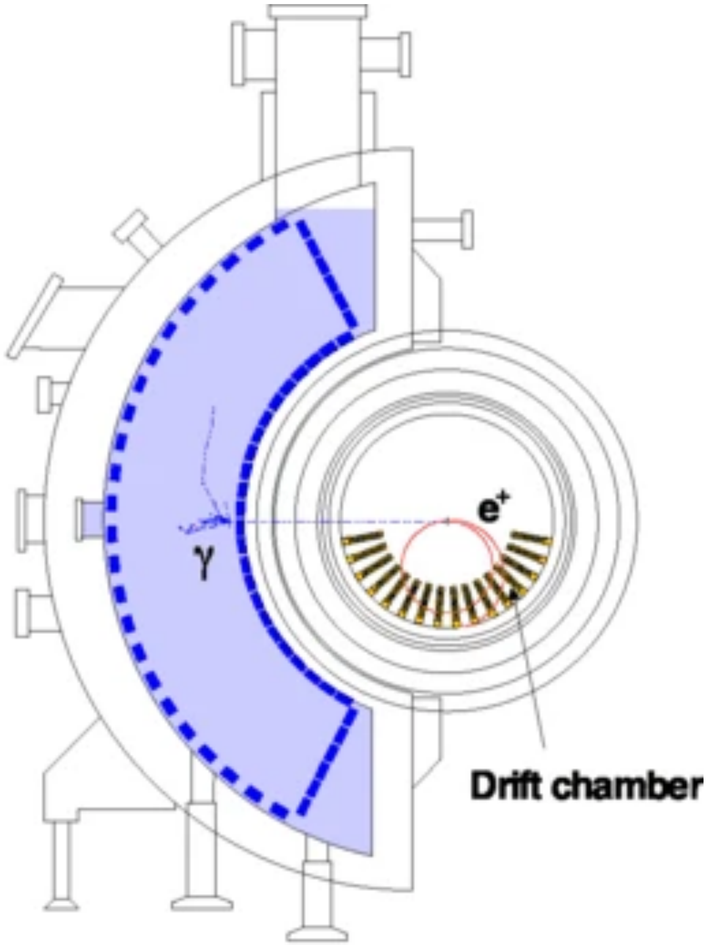
COMET, Mu2e

MEG

$\mu \rightarrow e\gamma$ search at PSI

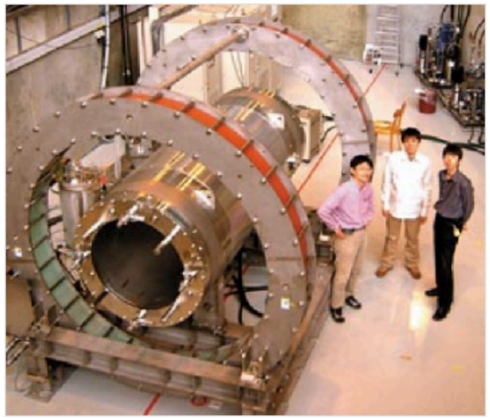
- PSI DC muon beam
- LXe photon detector
- COBRA spectrometer
- Wave forms of all channels are recorded with PSI in-house WFD





MEG
History

- Proposal submitted in 1998 and approved in 1999
- Detector design finalization and construction for almost 10 years
- Engineering run in 2008 followed by Physics until 2013
- Final result published in 2016
  - 4.2×10^{-13} at 90% C.L.



Members of the University of Tokyo with the COBRA magnet in the experimental zone at PSI, after a successful full-excitation test that proved a journey from Japan across three oceans and a trip up the Rhine to Basle could be mastered. The two large compensation coils visible at either end serve to reduce the stray magnetic field at the position of the liquid xenon calorimeter.

The gradient magnetic field of the COBRA (Constant Bending-Radius) spectrometer allows the decay positrons to execute spiral paths of constant projected bending radius and increasing axial pitch, which depend entirely on the particle's total momentum while being independent of its emission angle. This allows a background of lower energy Michel positrons to be swept away more effectively from the fiducial tracking volume of the azimuthally spaced, staggered-cell drift chambers. Timing information and hence trigger information for events is provided by a set of fast, double-layered, orthogonally placed timing-counter arrays, positioned at either end of the magnet.

CERN Courier 27 July 2004

Eur. Phys. J. C (2016) 76:434
DOI 10.1140/epjc/s10052-016-4271-x

THE EUROPEAN PHYSICAL JOURNAL C

CrossMark

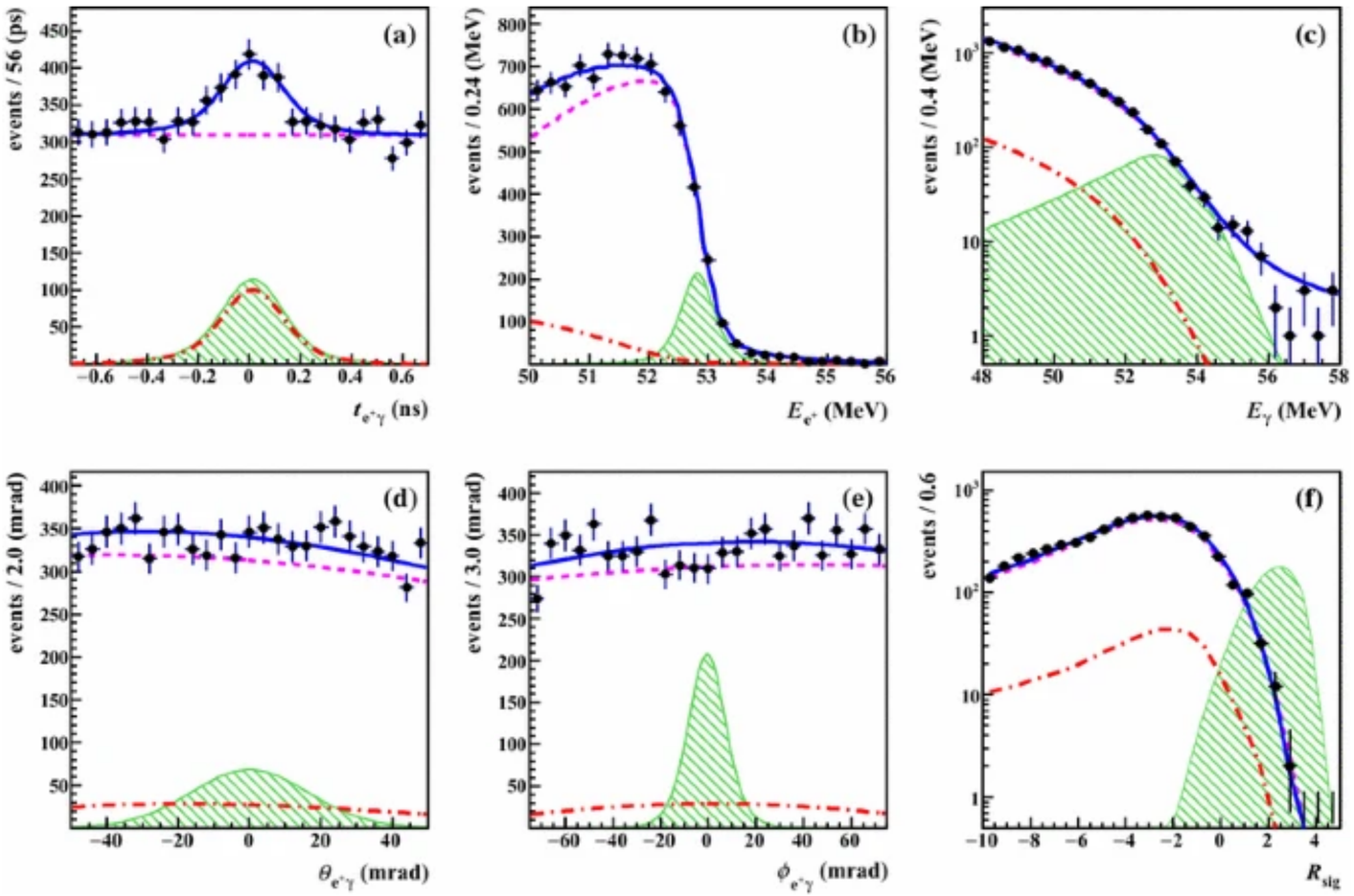
Regular Article - Experimental Physics

Search for the lepton flavour violating decay $\mu^+ \to e^+\gamma$ with the full dataset of the MEG experiment

MEG Collaboration

MEG analysis and result

- Blind analysis in $t_{e\gamma}$ & E_{γ} plane
- Evaluation of detector responses using data only!
- Likelihood analysis to obtain the limit
  - **4.2×10^{-13} at 90% C.L.**

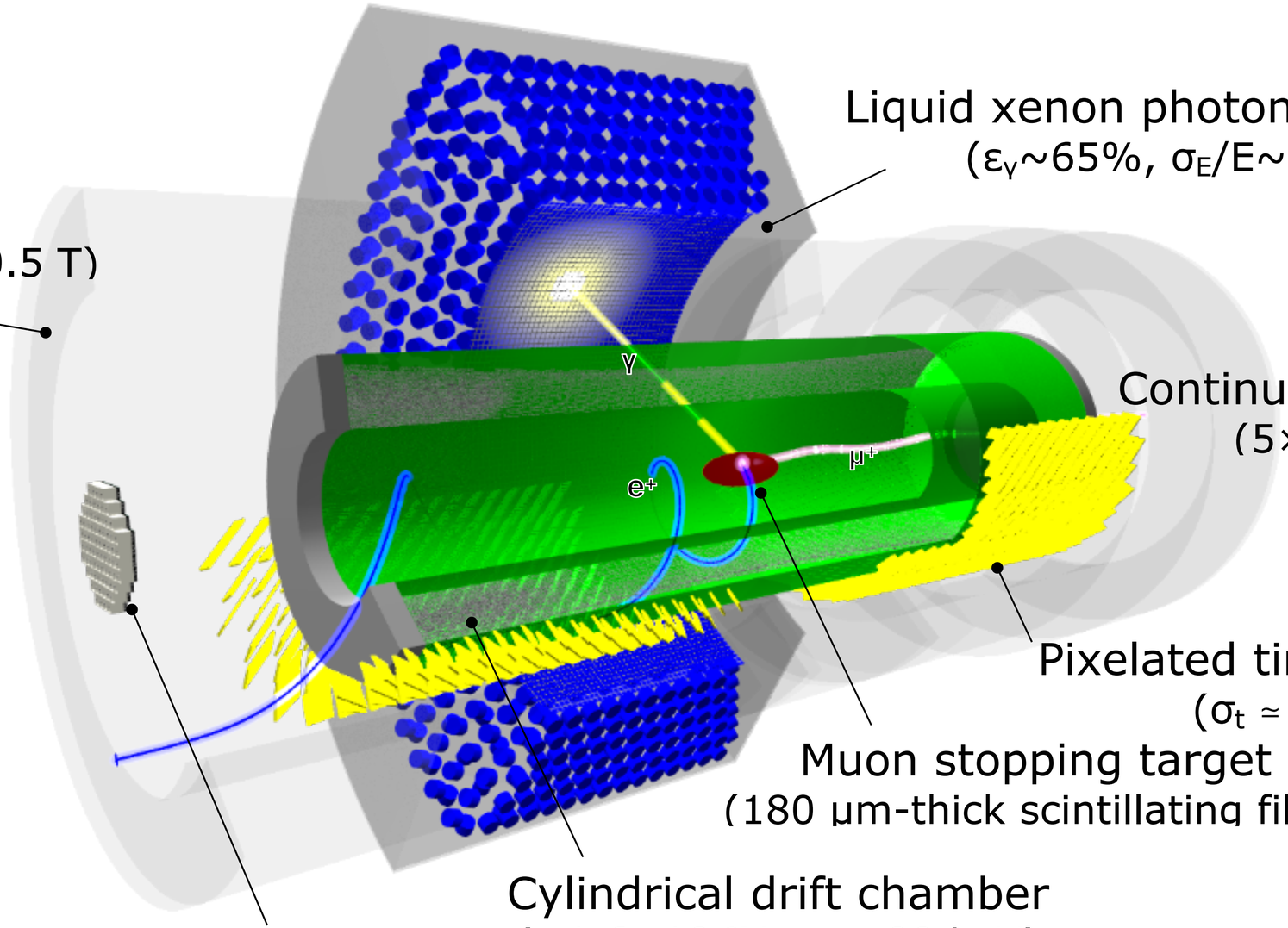


R_{sig} : Signal likelihood

MEG II

x10 better sensitivity than MEG

MEG II



Liquid xenon photon detector
(ε_γ~65%, σ_E/E~2%)

Thin-wall SC solenoid
(gradient B-filed: 1.3→0.5 T)

Continuous μ^+ beam
(5×10^7 s^{-1})

×10
improvement
from MEG

Pixelated timing counter
($\sigma_t \simeq$ 35 ps)

Muon stopping target
(180 μm-thick scintillating film)

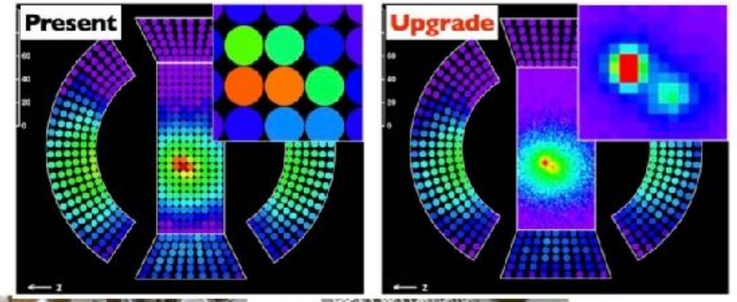
Cylindrical drift chamber
(~$1.6\times10^{-3}X_0$, σ_p~90 keV)

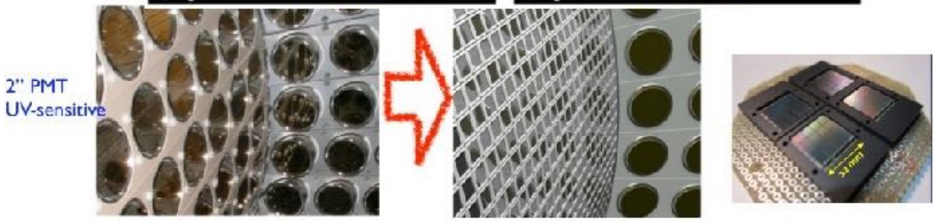
Radiative decay counter
(identify high-energy BG γ events)

Design: EPJ-C **78** (2018) 380
Performance: EPJ-C **84** (2024) 190

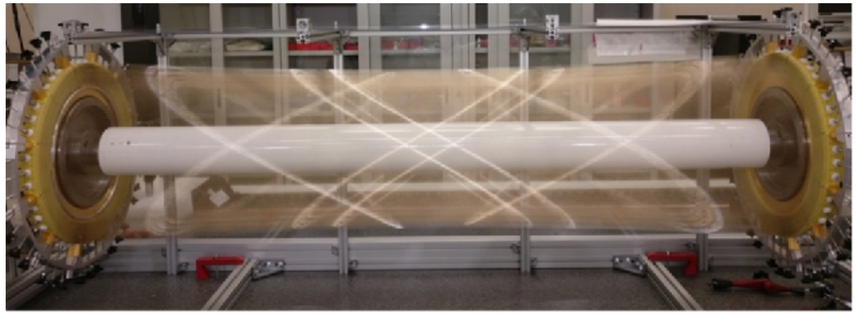
Toward realizing MEG II

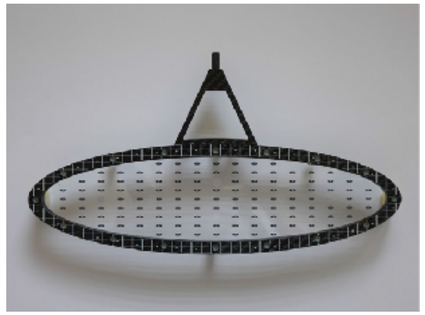
Lessons from MEG

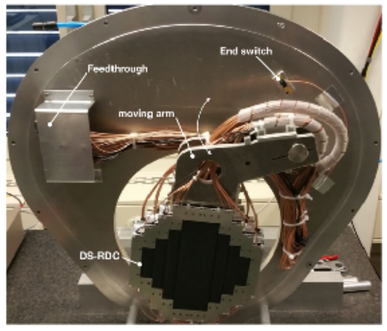


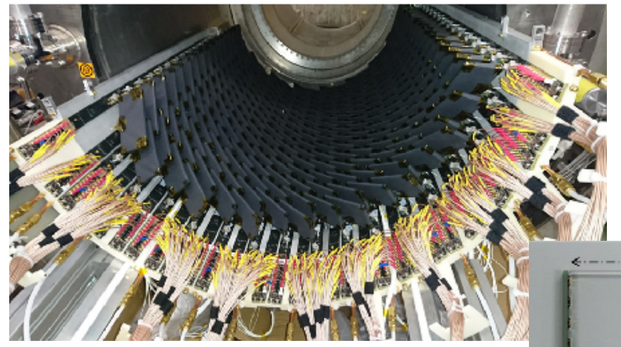


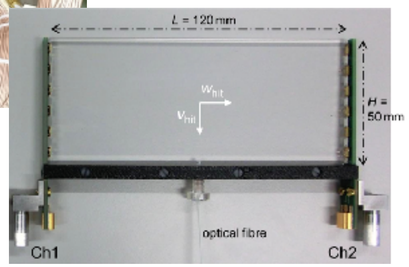
- Aiming at twice better resolutions in all detector components
- Improving the detection efficiencies
- New detector to identify the radiative muon decay
- Alignment of the muon stopping target



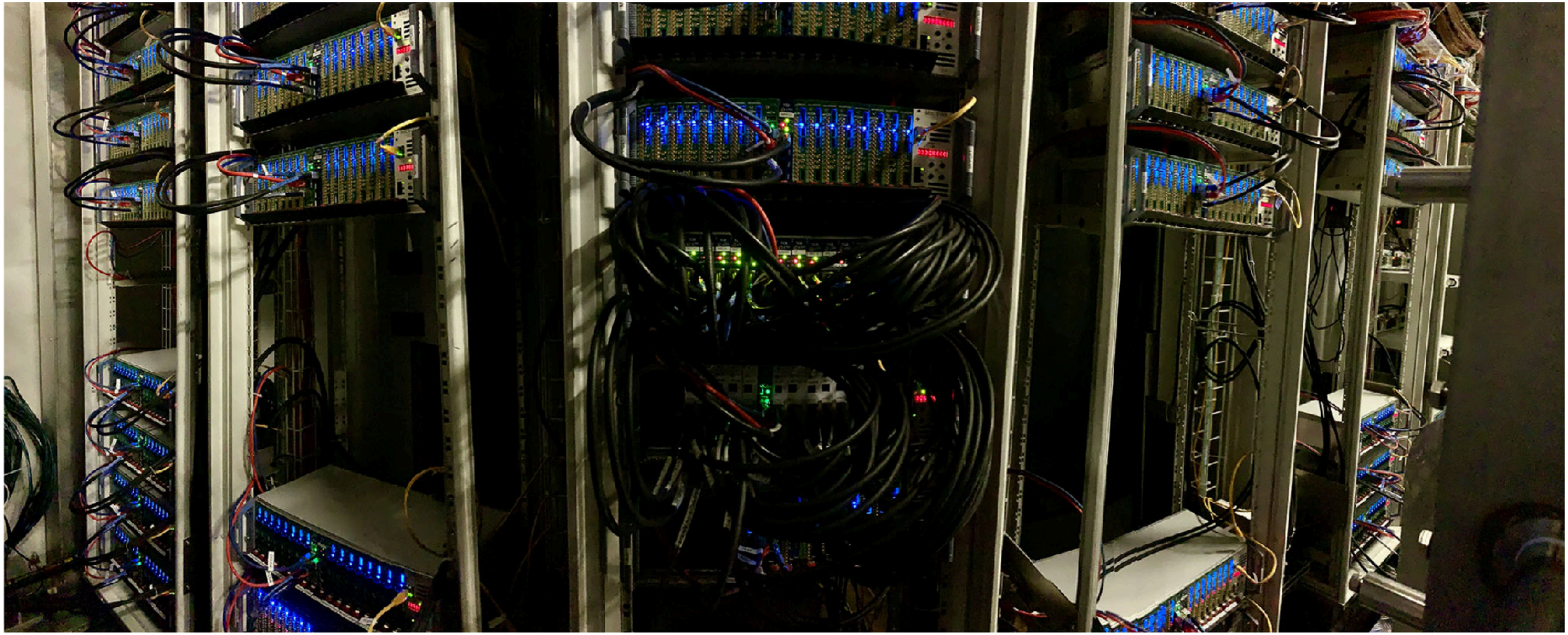






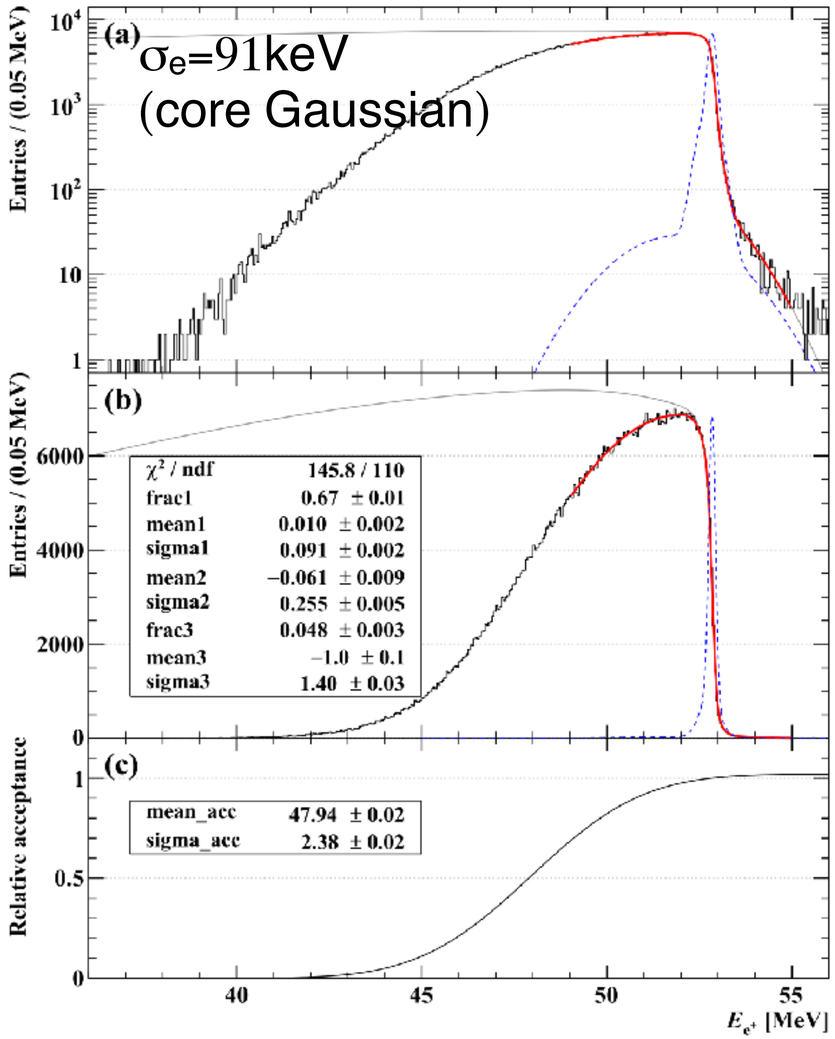


DAQ upgrade

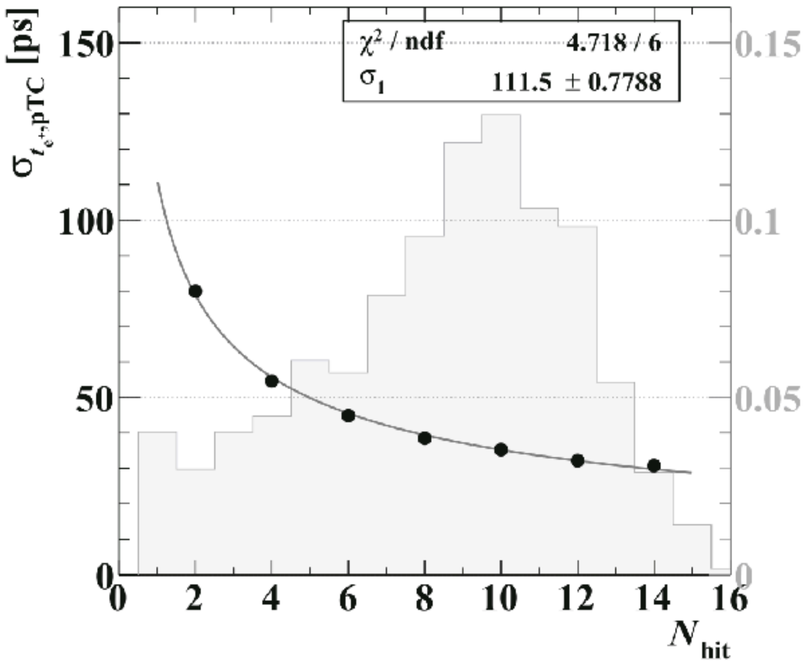


MEG II performance

More details in EPJ-C 84 (2024) 190



Ee+



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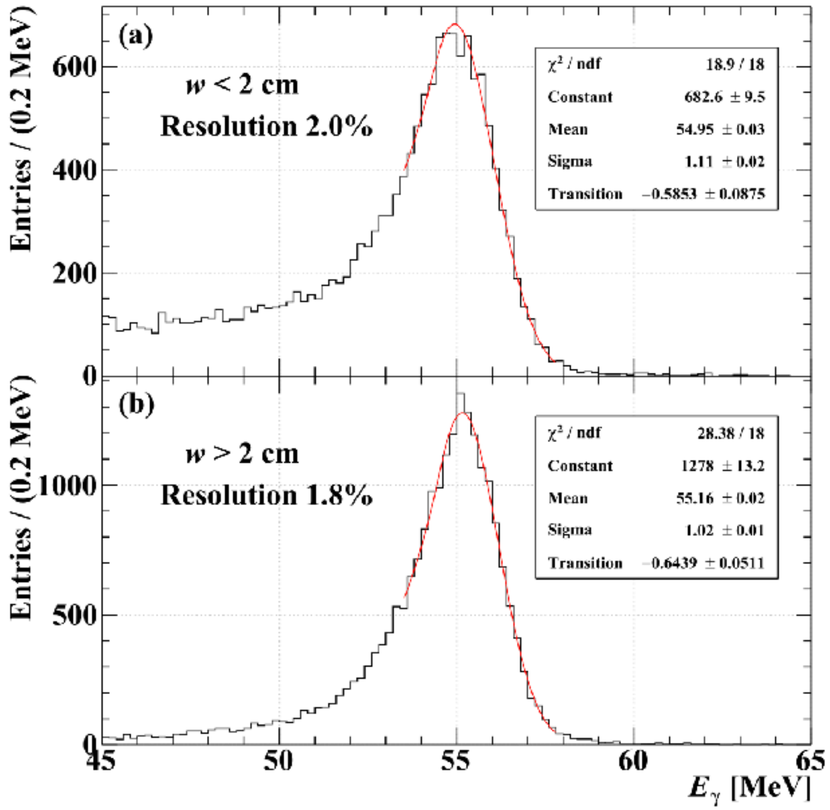
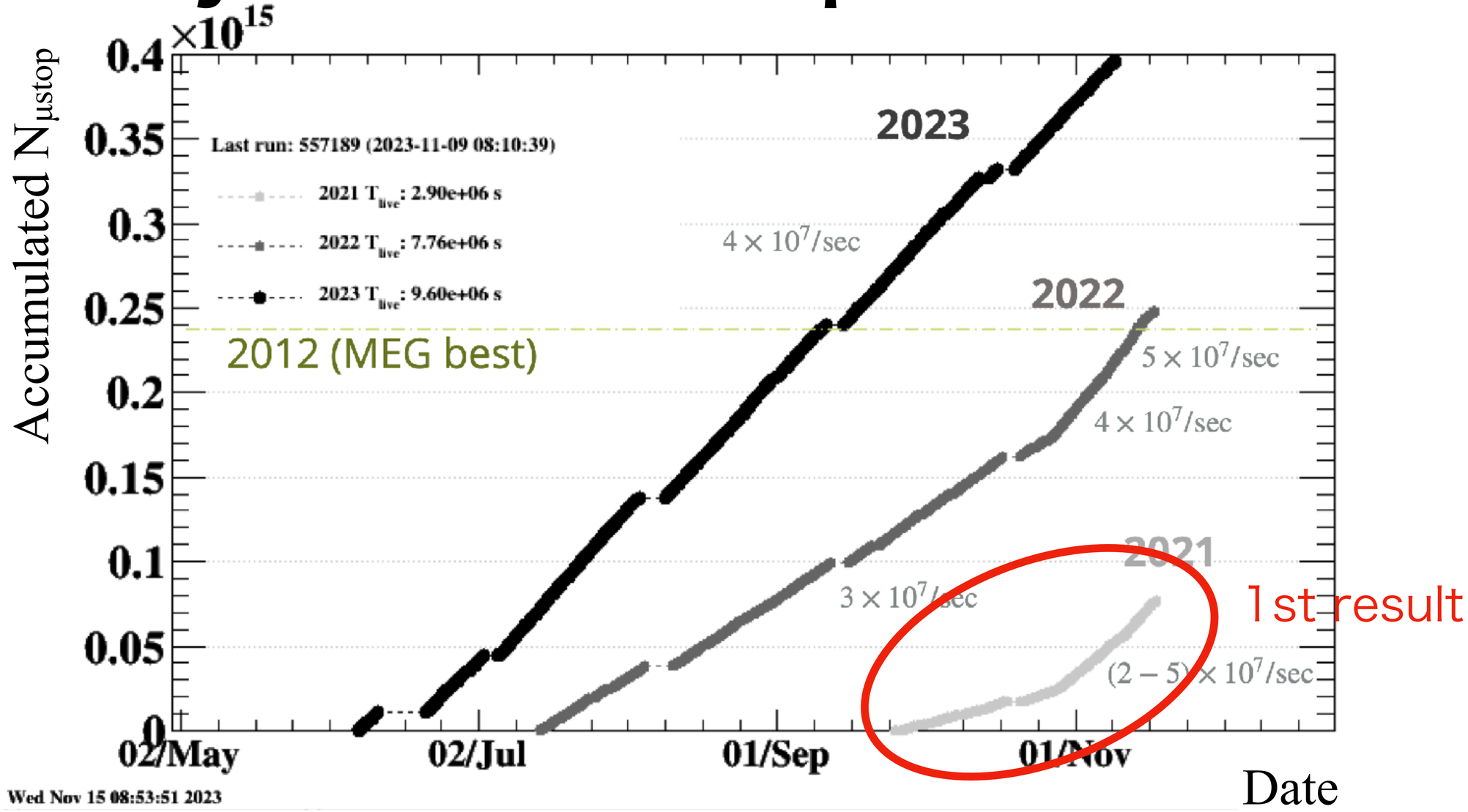


E_γ

MEG II Physics Data Acquisition

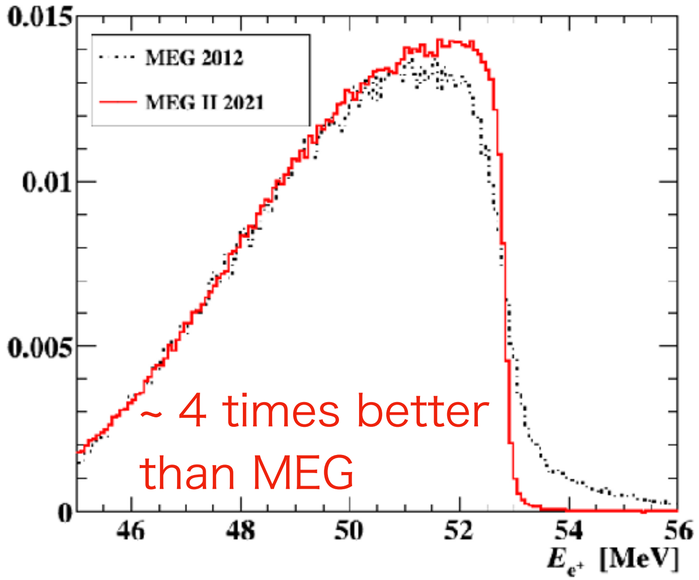


MEG II sensitivity

2021 data set only

	N_μ^{stop}	SES	$S_{90\%CL}$
MEG	7.5×10^{14}	5.8×10^{-14}	5.3×10^{-13}
2021	7.7×10^{13}	3.9×10^{-13}	8.8×10^{-13}
R(2021/MEG)	0.10	6.6	1.7

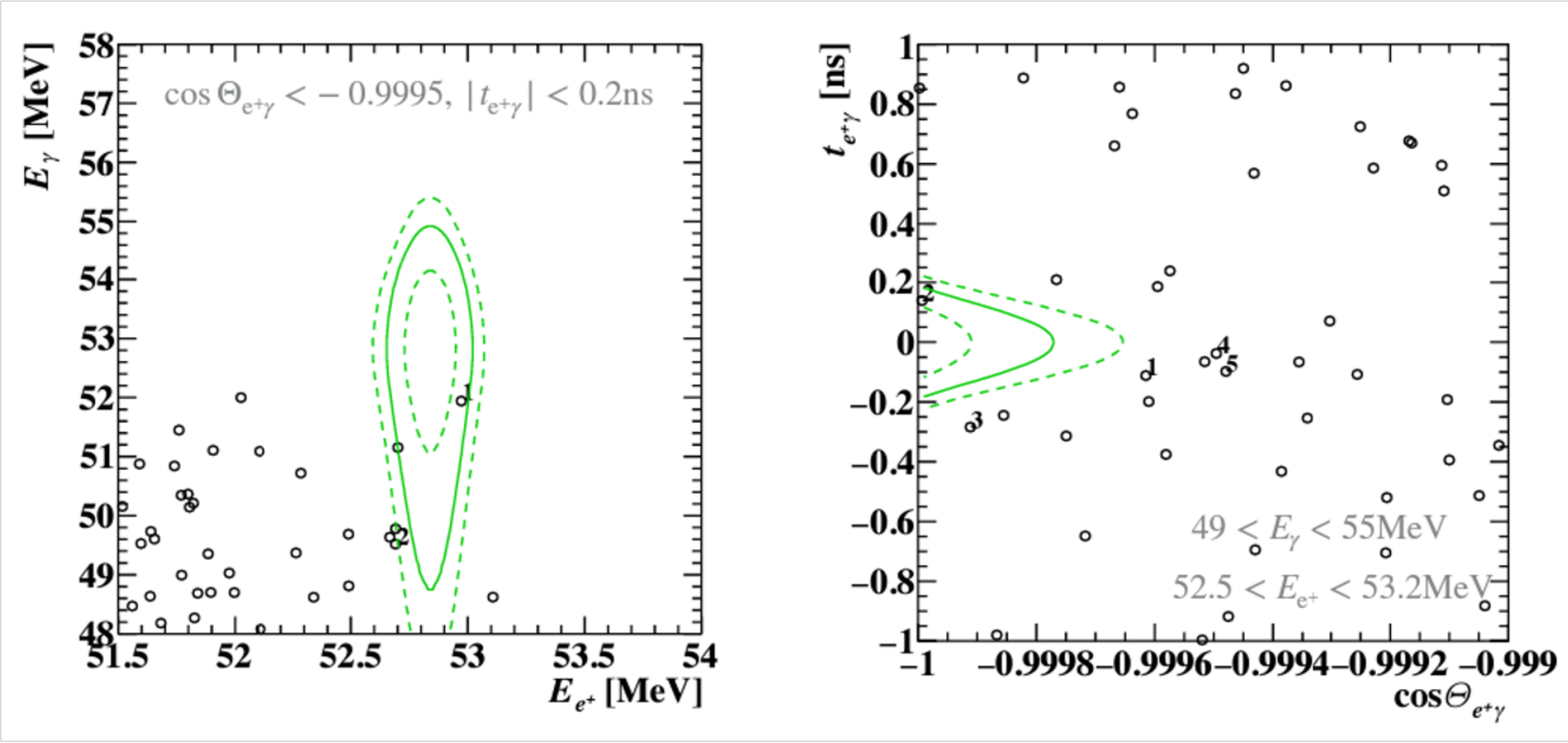
(Expected)



60% of MEG sensitivity (2009-2013) is already achieved with 10% data statistics (accumulated in 7 weeks) !

MEG II result

2021 data set, details
in Eur. Phys. J. C (2024) 84: 216



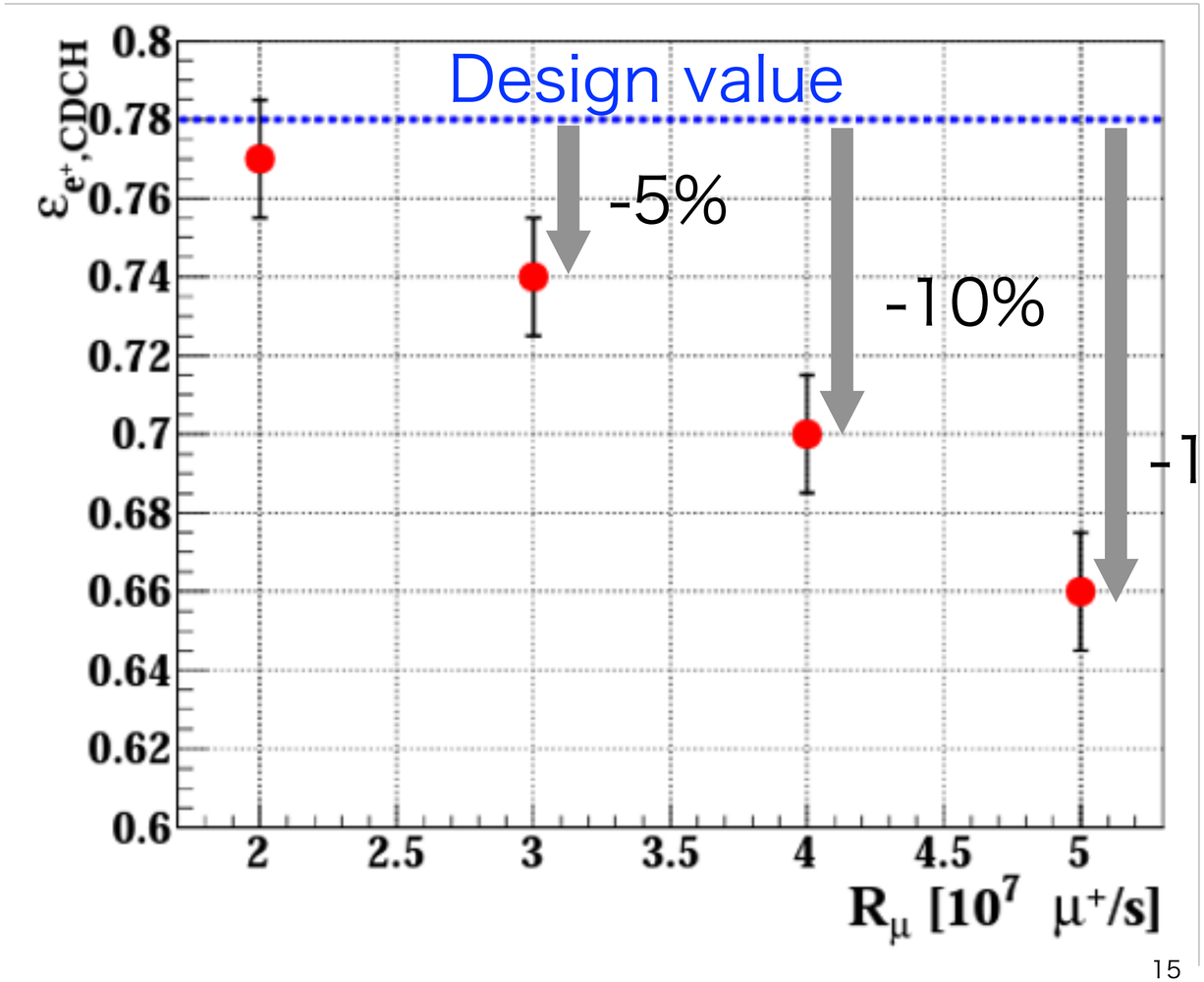
- **No excess**

U.L. by a frequentist approach: **B($\mu \to e\gamma$) < 7.5×10^{-13}**

2021 + MEG combined: **B($\mu \to e\gamma$) < 3.1×10^{-13}**

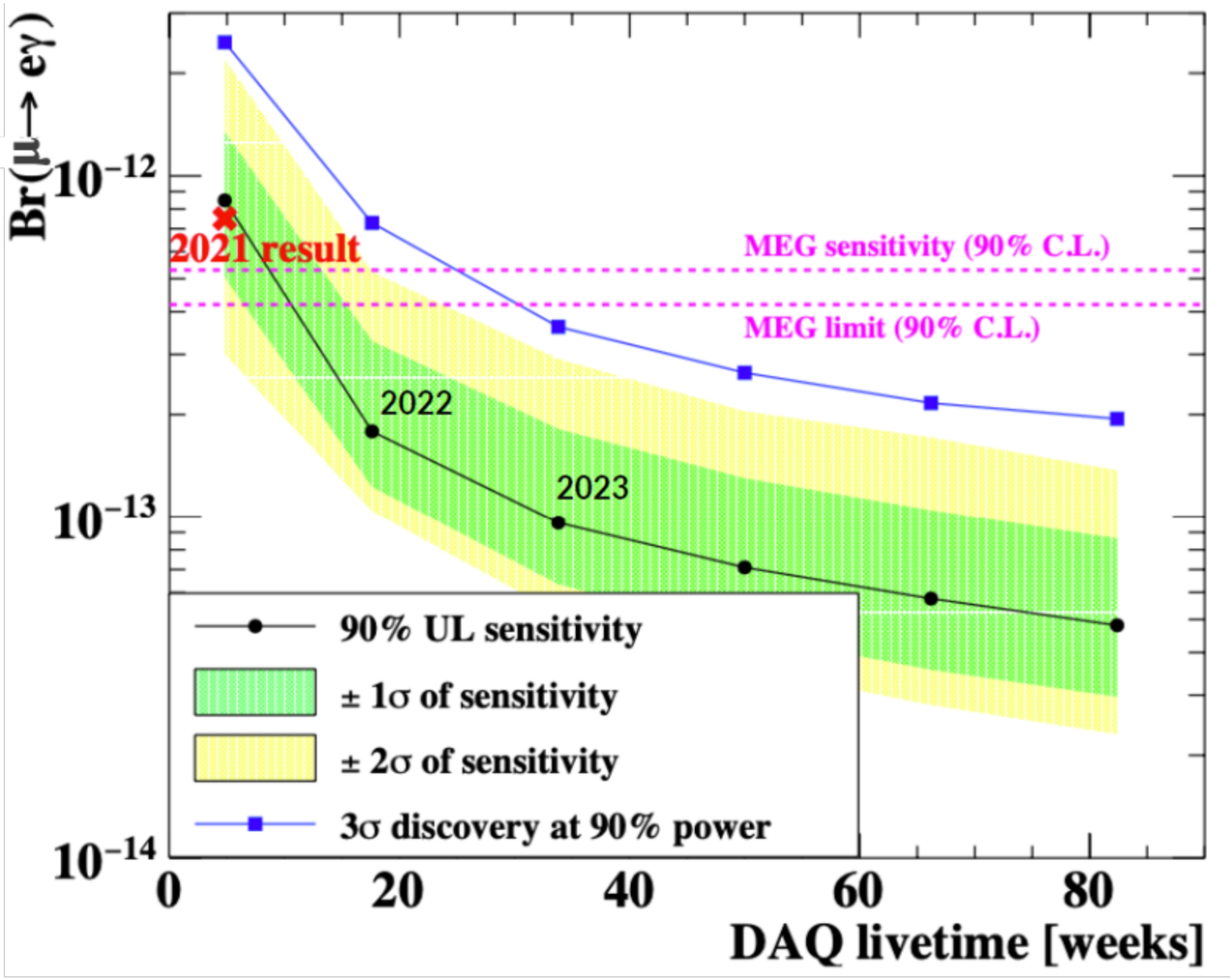
MEG II performance

Optimization of the muon beam rate



- **Higher Beam Rate**
  - Good for
    - Statistics
  - Not good for
    - BG by accidental overlaps
    - Detector performance
- **Optimal at 4x10^7 μ^+/sec**

Prospects

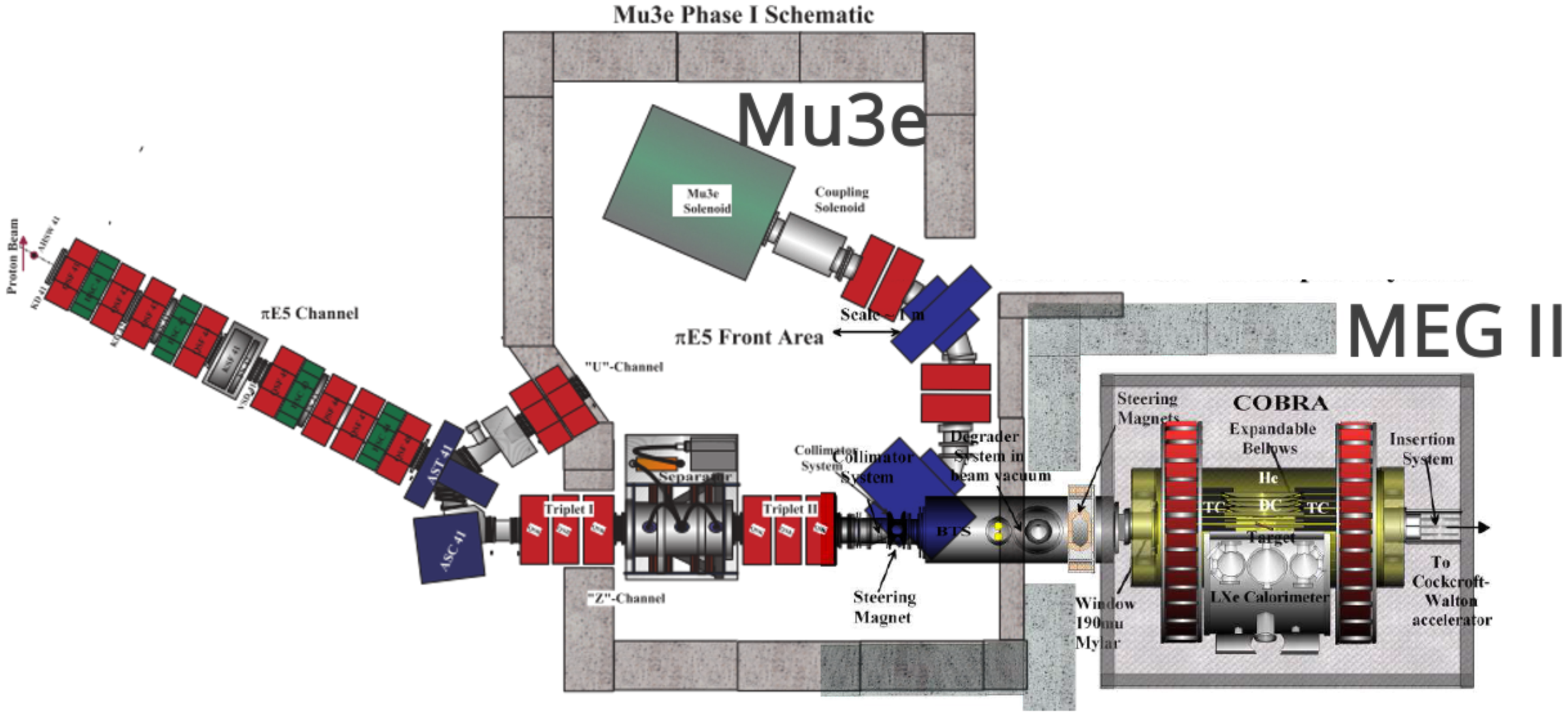


- 2024 run in preparation
- 3 more years (including 2024) to reach the goal of 6×10^{-14}
- 3σ discovery if the BR is above $\sim 2 \times 10^{-13}$
- [Remarks]
  - PSI long shutdown in 2027-2028
  - Mu3e Phase I

Summary

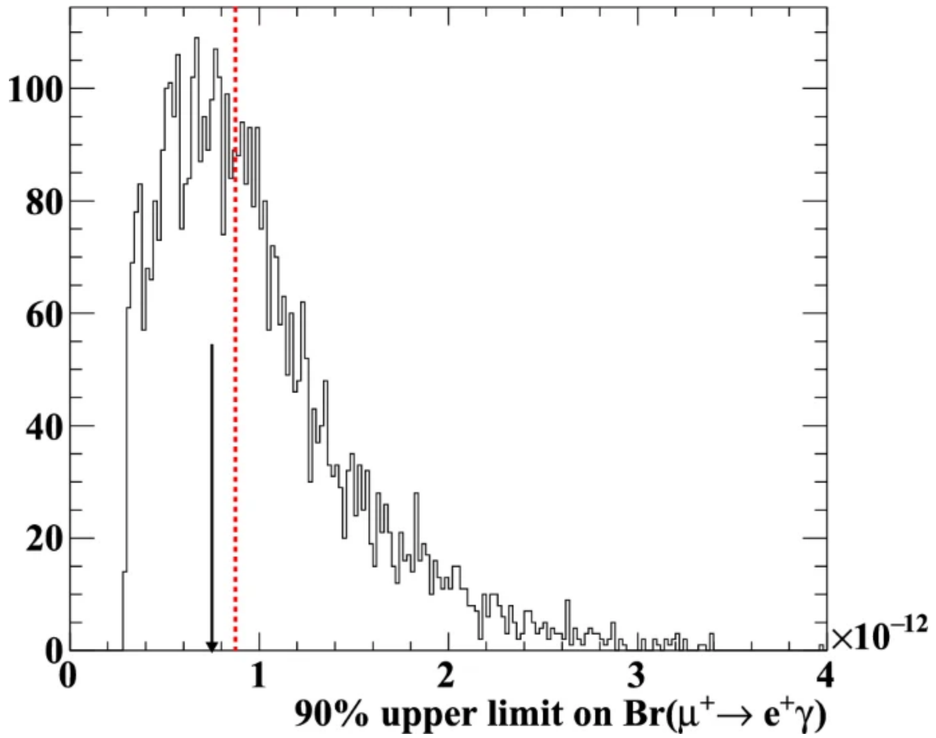
- MEG II started physics data acquisition in 2021 and continued stable operation for more than two years
- The 1st physics result is released,
  - 7.5×10^{-13} at 90% C.L. with MEG II 2021 data only
  - 3.1×10^{-13} at 90% C.L. with MEG + MEG II 2021
- 3 more years data acquisition is scheduled to reach the goal of 6×10^{-14} (if no candidate events)
  - 3σ discovery potential if $\mathrm{Br}(\mu \to e\gamma) > 2 \times 10^{-13}$

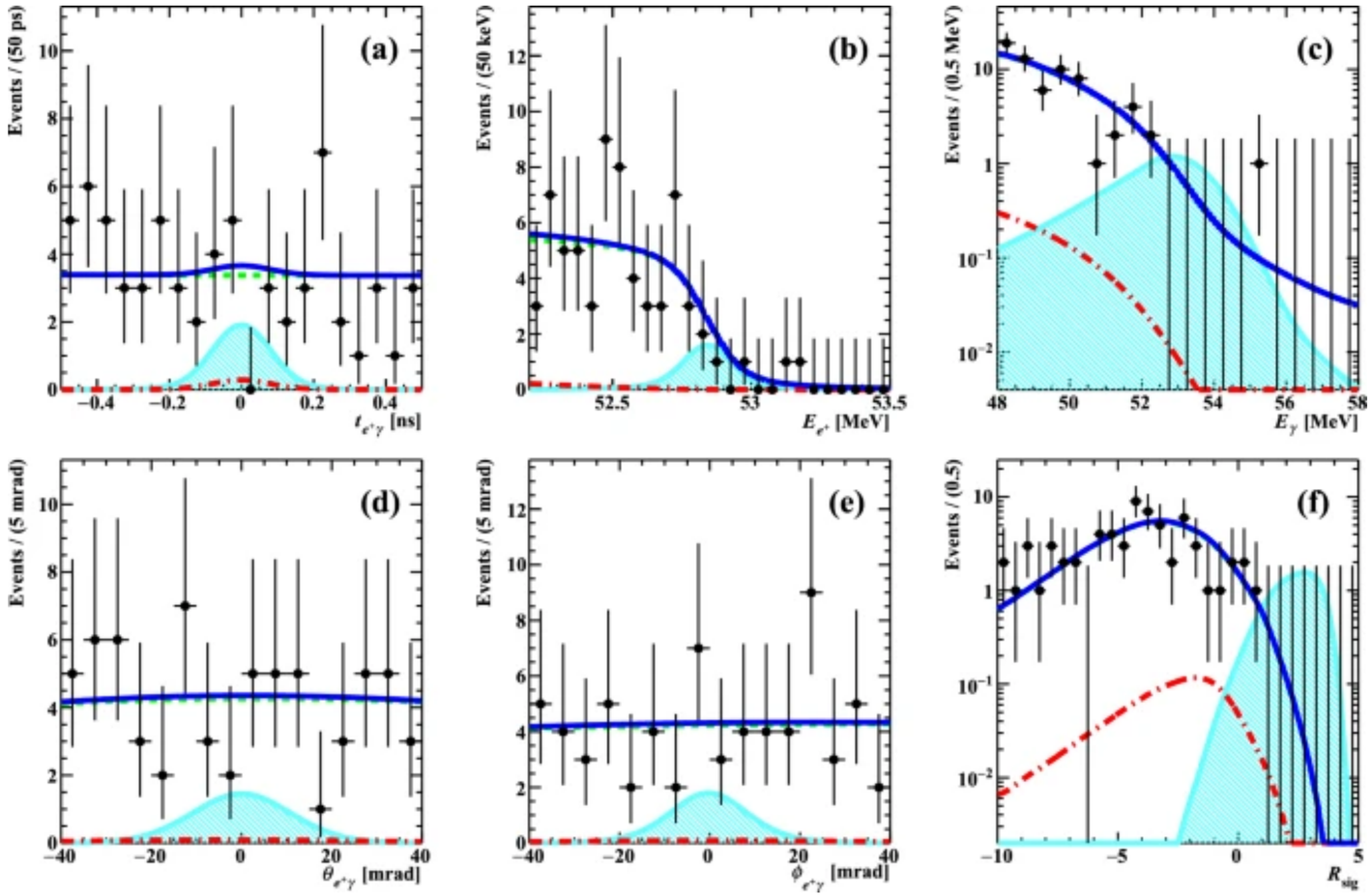
PiE5 beam line



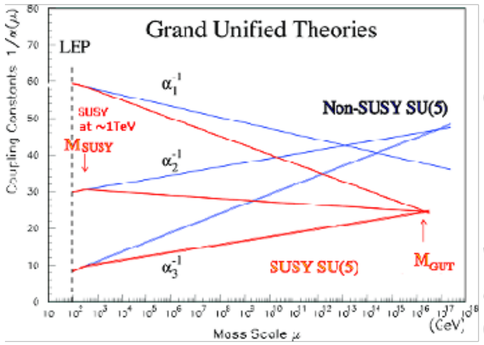
MEG II result

2021 data set only





MEG 30-years history



'Indication' of SUSY-GUT by LEP.
ICEPP LEP-group physicists started to consider experiments to prove it.

Proposal to PSI by JP & RU

Workshop on $\mu \rightarrow e\gamma$ at PSI with different designs by different groups → LOI

IT joined.
Proposal to INFN

Start of MEG physics run

End of MEG physics run

Start of MEG II physics run

Begin of conception of 'MEG' experiment.

1990 1995 2000 2005 2010 2015 2020

Theoretical study shows $\mu \rightarrow e\gamma$ is signal for SUSY-GUT, considering large top mass.

Establishment of neutrino oscillation.
→ Many theoretical studies for $\mu \rightarrow e\gamma$.

(g − 2) anomaly by Brookhaven E821.
→ raised anticipation for $\mu \rightarrow e\gamma$.

Final result on $\mu \rightarrow e\gamma$ from MEGA

Termination of MECO (together with KOPIO)
→ US group joined

Discovery of Higgs.

Large θ_{13} by T2K, later DayaBay and RENO

1st result of MEG

Final result of MEG

MEG II proposal

1st result of MEG II

By Y. Uchiyama