BSM search with high intensity muon beam in MEG II experiment

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on behalf of MEG II collaboration

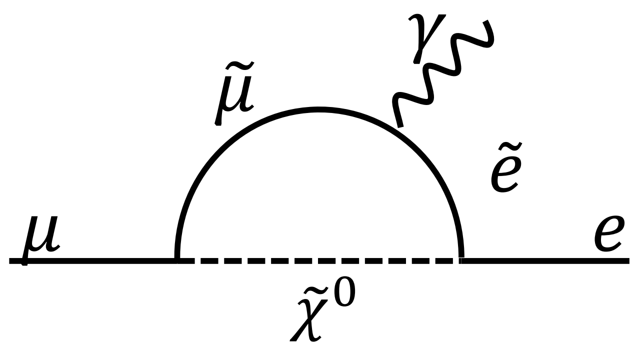
EPS-HEP conference 2019

ICEPP
The University of Tokyo

MEG II
Mu - E - Gamma collaboration

JSPS
Core-to-Core
Program

Why search $\mu \to e\gamma$?

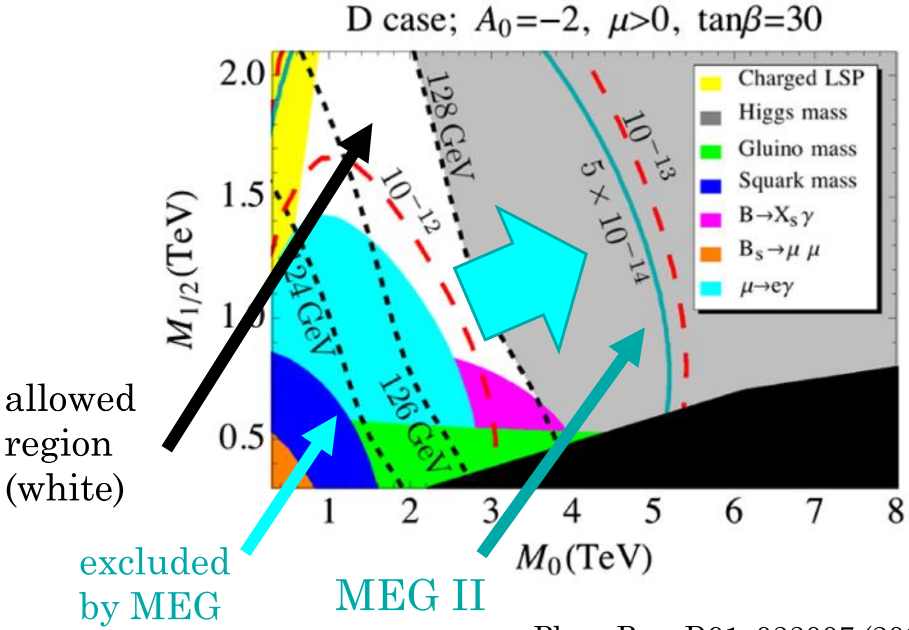


- LFV is predicted by many BSMs
  $Br(\mu \to e\gamma) \sim O(10^{-14})$ (e.g. SUSY-seesaw)

- Experimental bound is already close to BSM prediction
  $Br(\mu \to e\gamma) < 4.2 \times 10^{-13}$ (90% C.L., MEG)

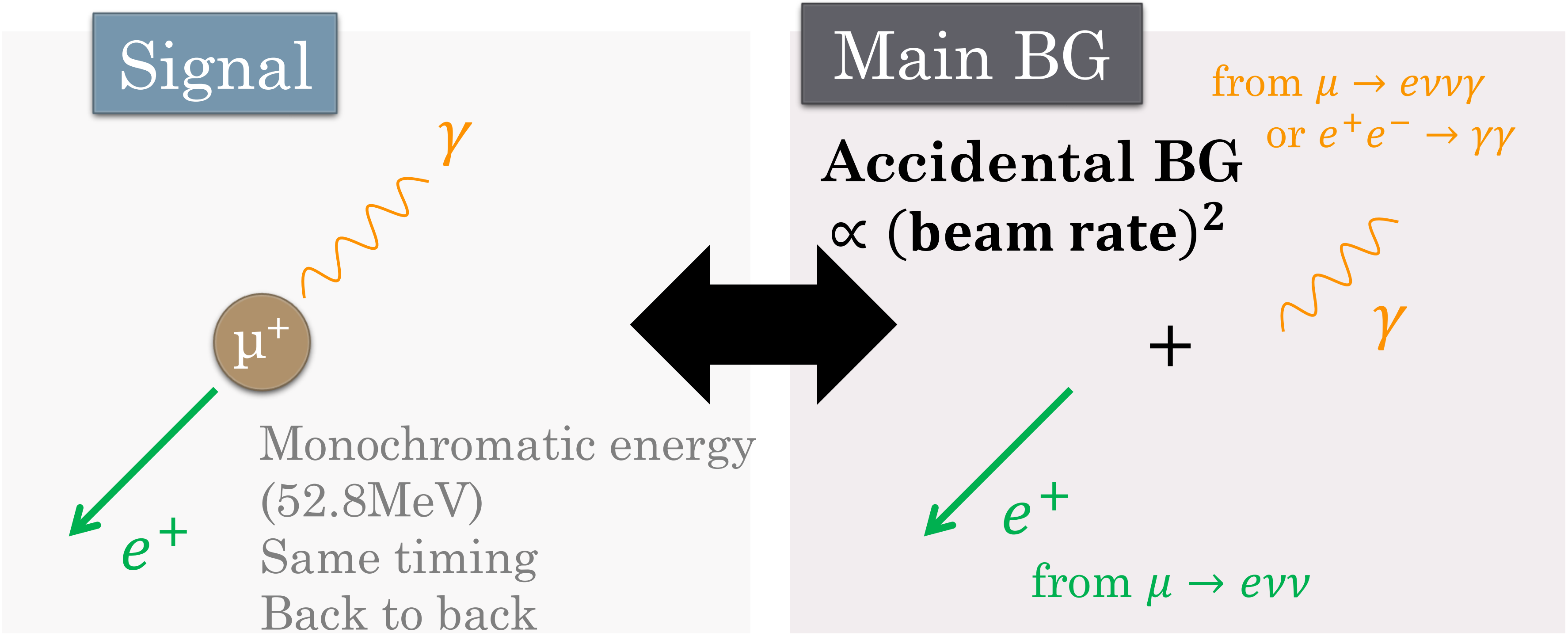
$\mu \to e\gamma$ is a powerful tool to probe BSM!

Example: $\mu \to e\gamma$ contour in SUSY parameter space



Phys. Rev. D91, 033007 (2015)

Signal and BG of $\mu \to e\gamma$

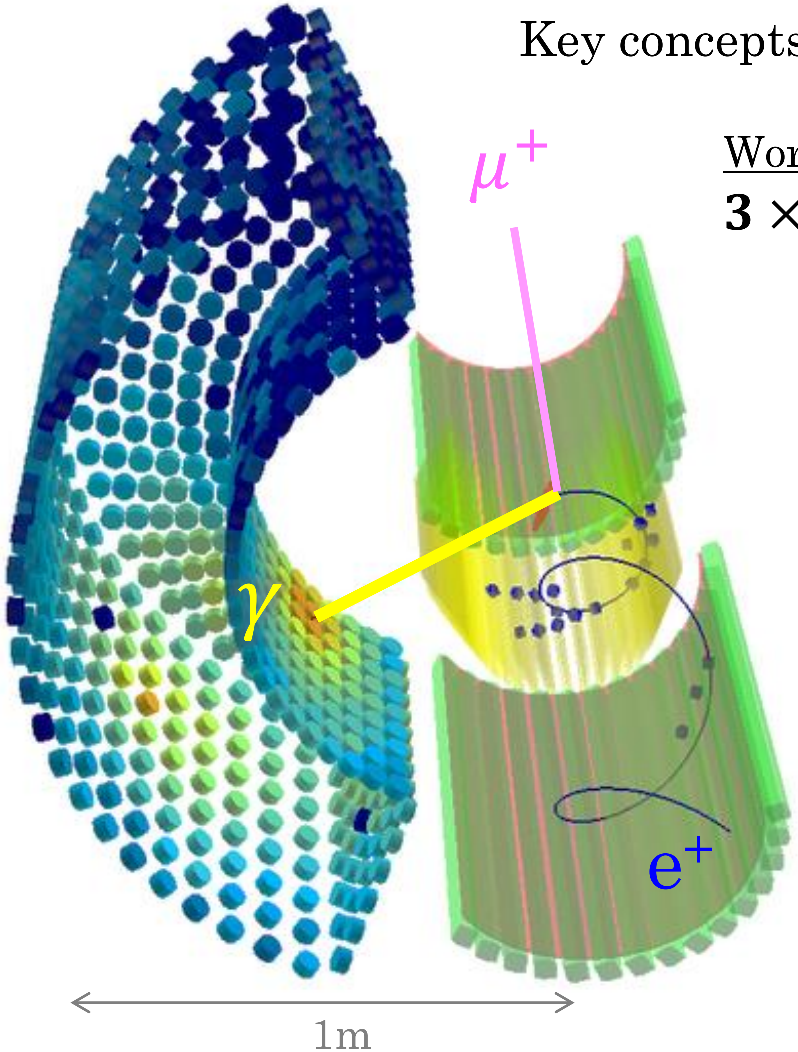


What we need for $\mu \to e\gamma$ search:

- **e^+, γ detector with good energy, time, position resolution**
- **High intensity μ beam**

MEG (2009-2013)

Key concepts in MEG:



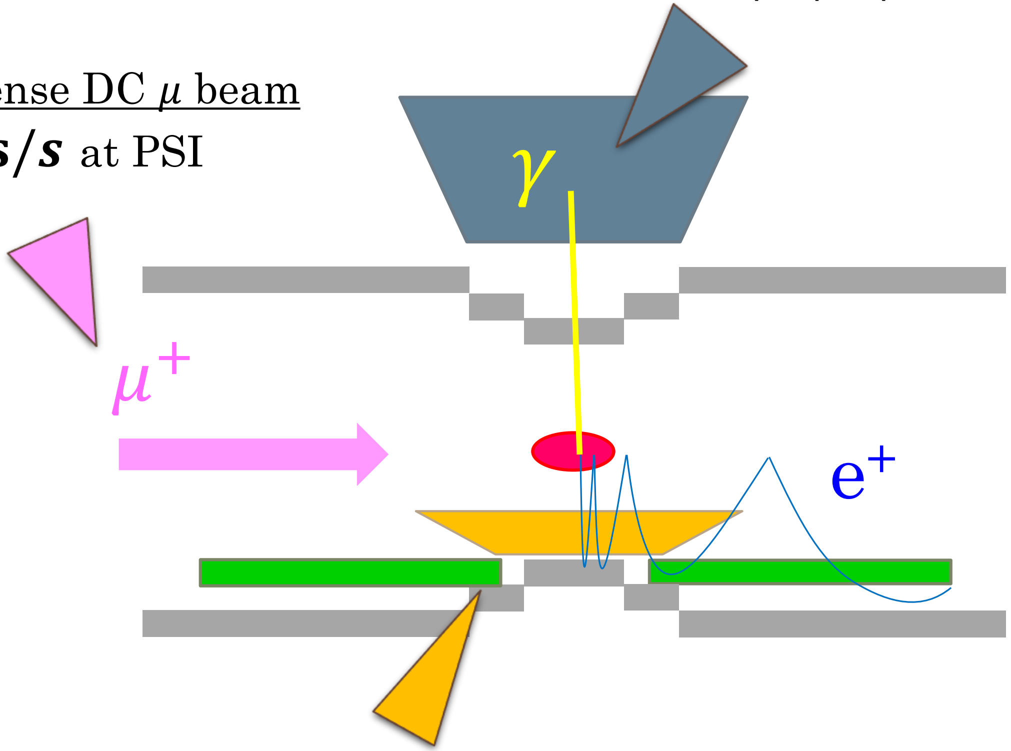
World's most intense DC μ beam

$\mathbf{3 \times 10^7 muons/s}$ at PSI

900L **liquid Xe** detector

→ High light yield etc.

→ Good $E_\gamma, t_\gamma, x_\gamma$ resolution



Low mass drift chamber

→ less multiple scattering

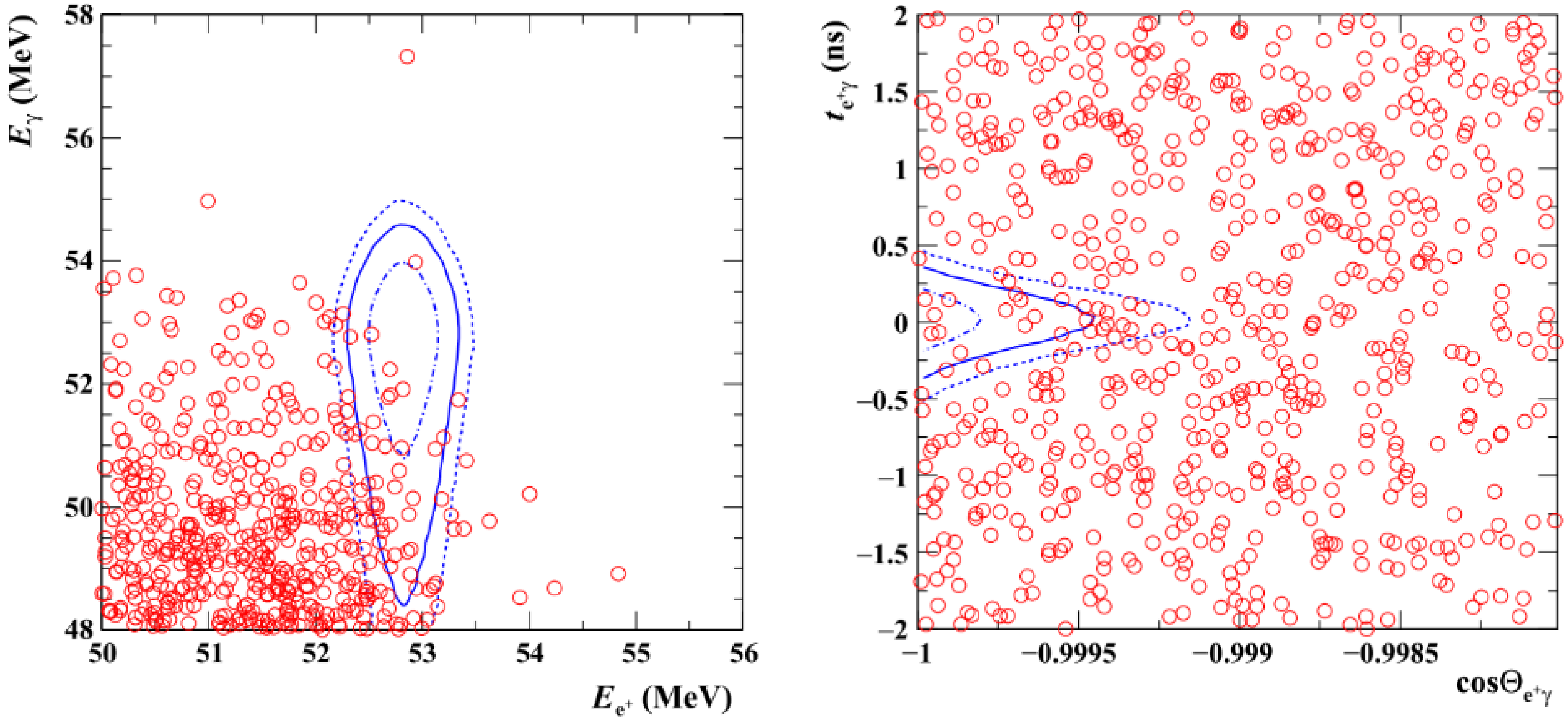
→ good p_e, x_e resolution

Gradient B-field

→ reduce BG hits from low momentum e+

MEG result (2016)

Event distribution ($E_\gamma, E_{e^+}, t_{e\gamma}, \theta_{e\gamma}$)



7.5×10^{14} stopped muons were used. No excess of events observed.

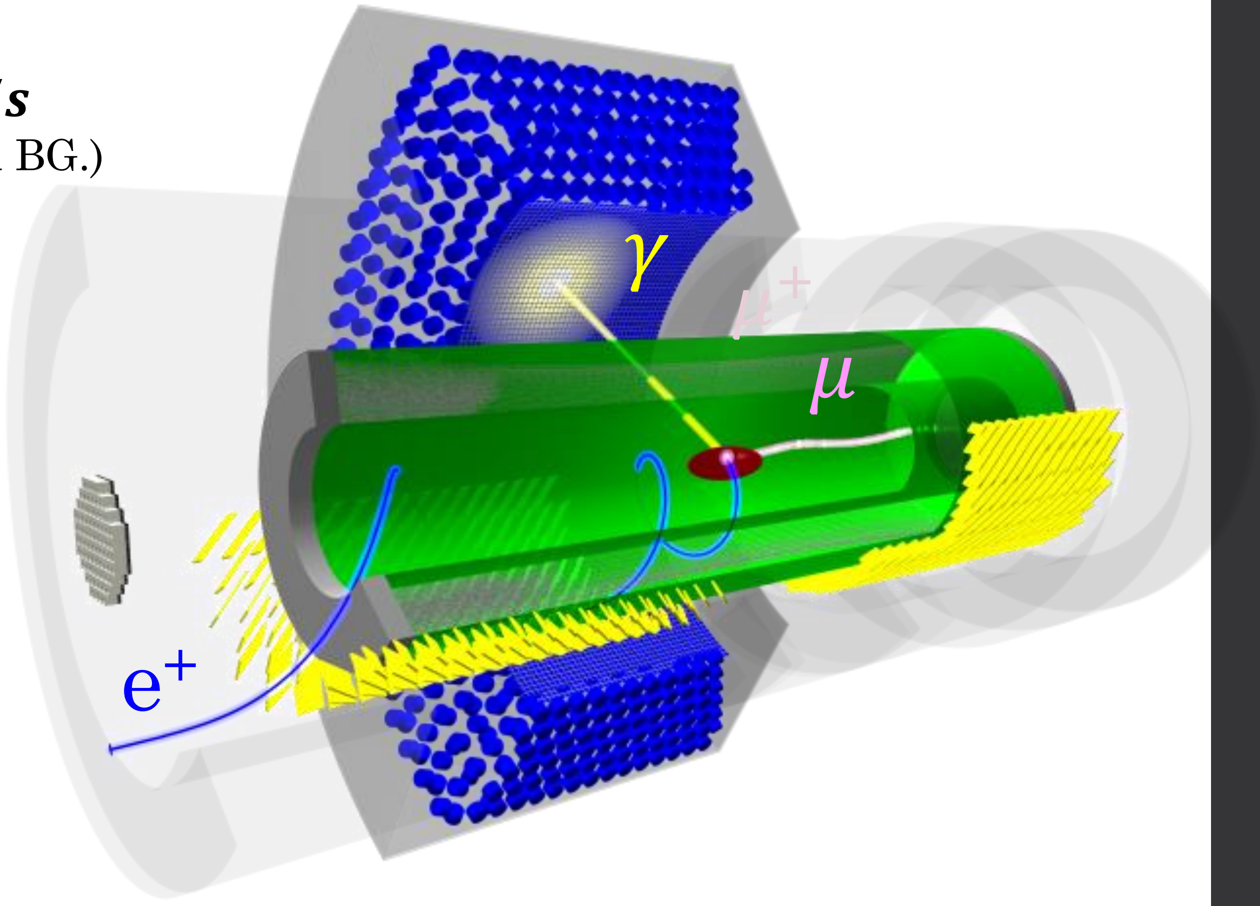
$\boldsymbol{Br(\mu \to e\gamma) < 4.2 \times 10^{-13}}$ **(90% C.L.)**

Eur. Phys. J. C (2016) 76:434

MEG II upgrade

With same concept as in MEG, upgrade the beam and detectors.

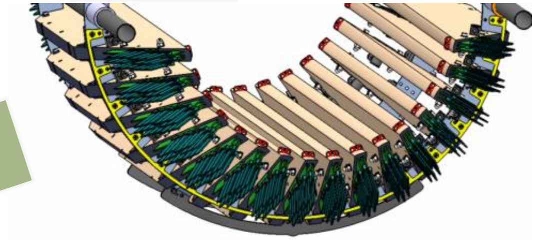
- μ beam rate increase: $\mathbf{3 \times 10^7 \rightarrow 7 \times 10^7 \mu/s}$
  (It was reduced in MEG to cope with accidental BG.)
- Detector **resolution** $\times$ **2** improvements
  (energy, timing, position)
  Efficiency $\times$ **2** increase
- Additional detector to identify BG γ



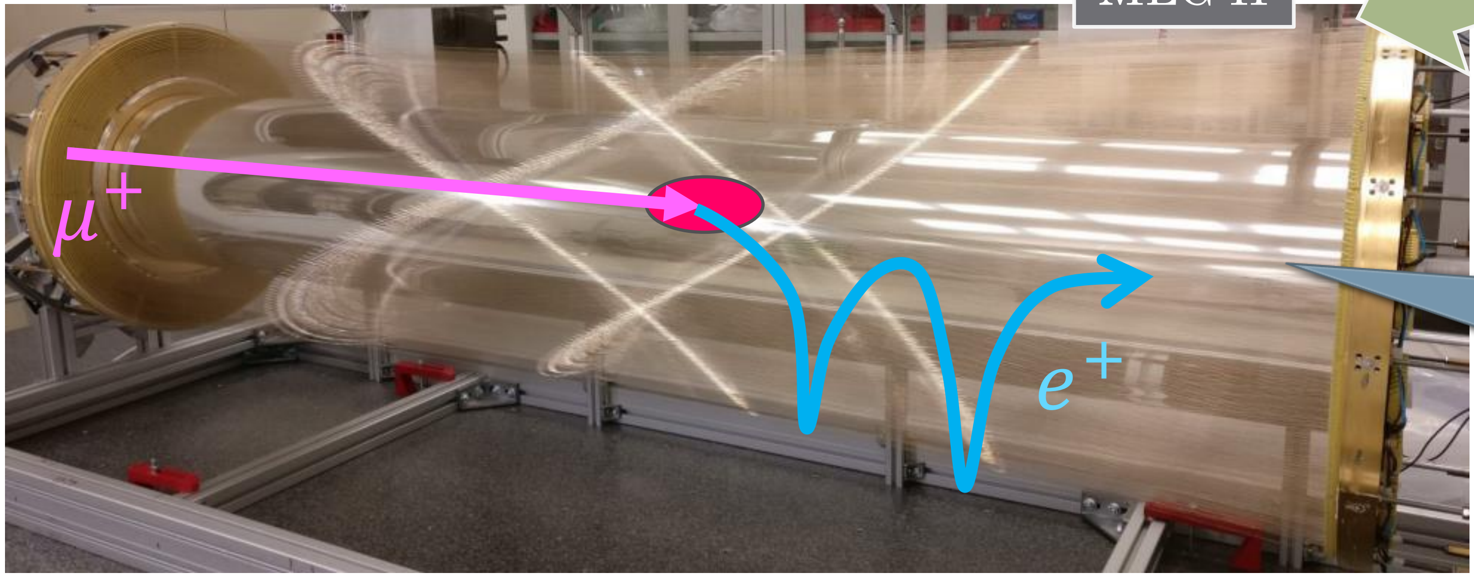
Target sensitivity:
$\mathbf{6 \times 10^{-14}}$ $\mathbf{(90\%\ \mathit{C.L.})}$ in 3 years
→ 10 times improvement from MEG

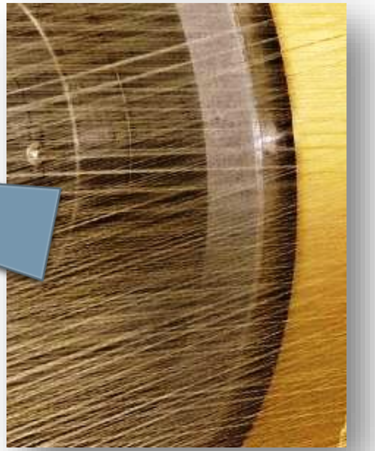
e^+ : drift chamber

MEG module chambers



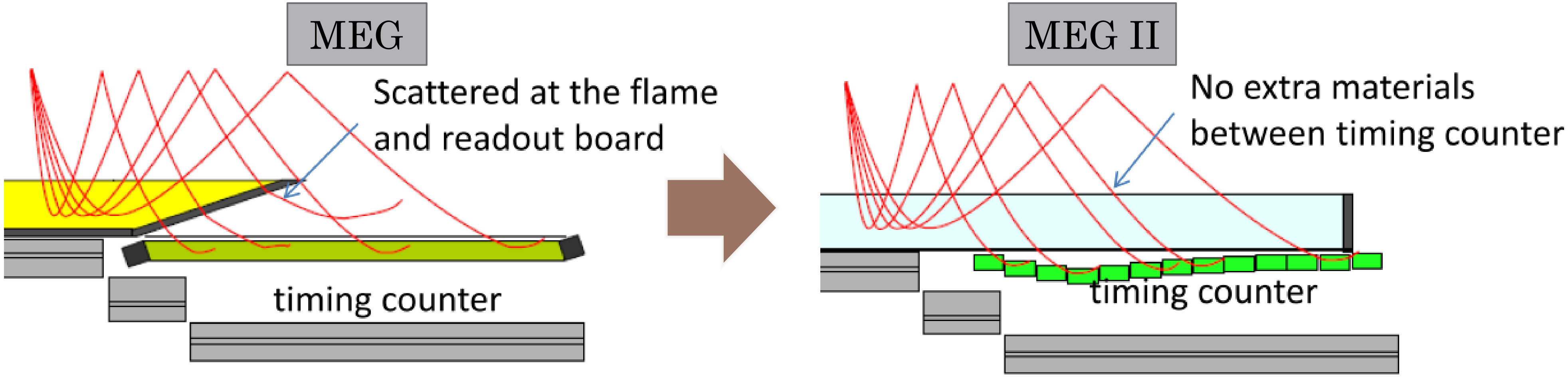
single volume chamber MEG II





- Cylindrical stereo wire chamber (stereo angle: 6 – 8.5°)
- **Low mass (1.58×10^{-3} X_0** along track**)** → low multiple scattering → good resolution
  Gas: He(85%)+iC_4H_{10}(15%), Wire: 20μm W for anode, 40 or 50μm Al for cathode
- 1920 anode wires in 6-8mm interval, 9 layers
  → many hits per track → good resolution (σ_E ~ 130 keV, σ_{angles} ~ 5 mrad expected)
- No extra material between timing counter → efficiency ×2

e^+ : drift chamber



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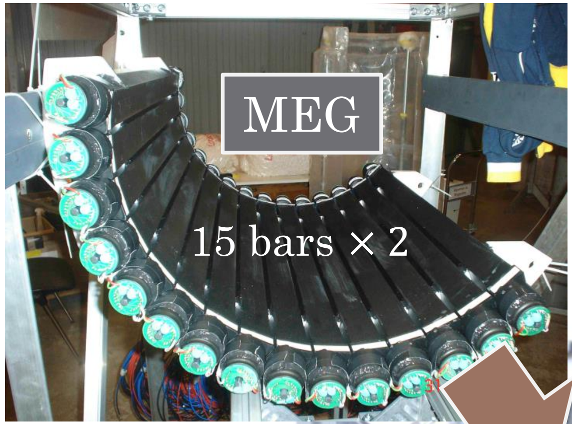
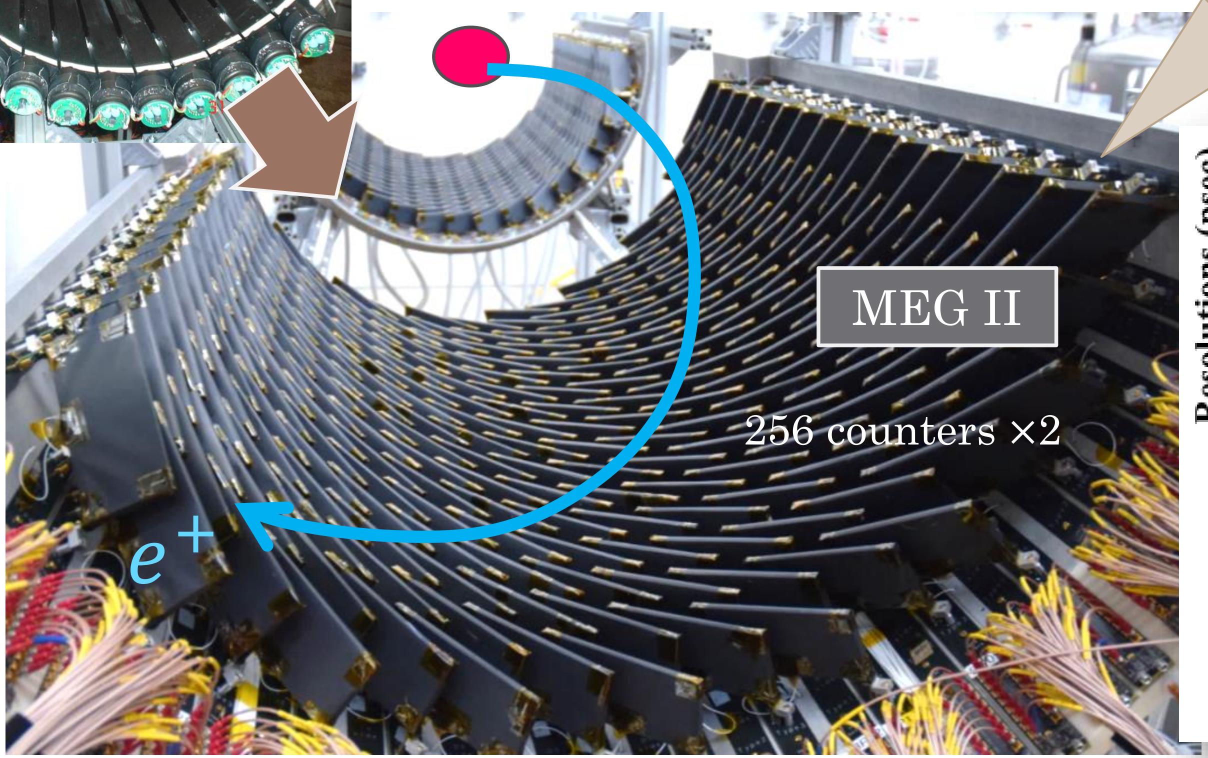
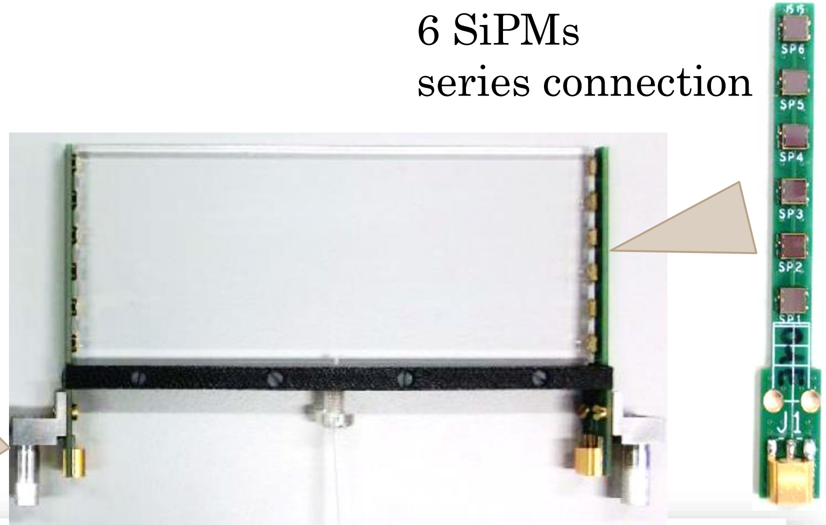
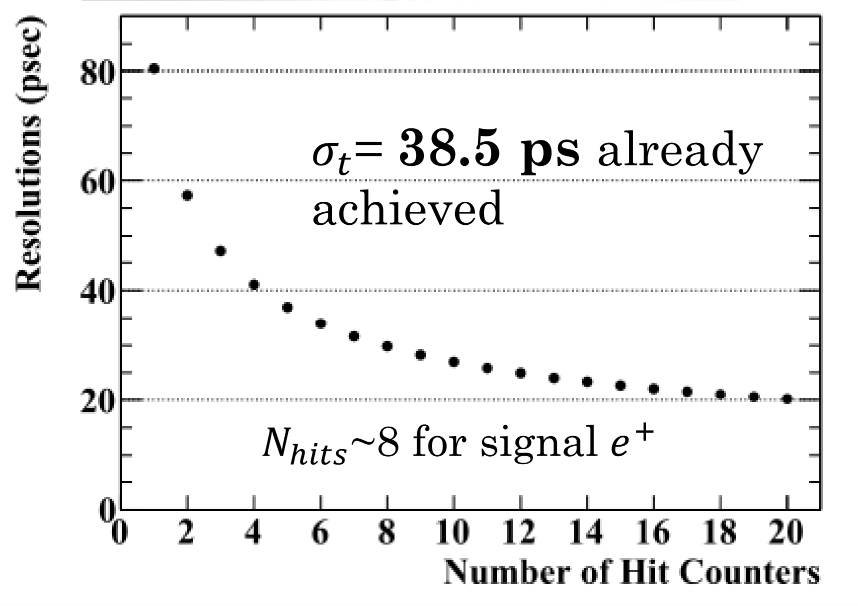
e^+ : timing counter



- Fast plastic scintillator + SiPM
- **Increased segmentation**
  → many hits per track
  → good resolution







e^+ : timing counter

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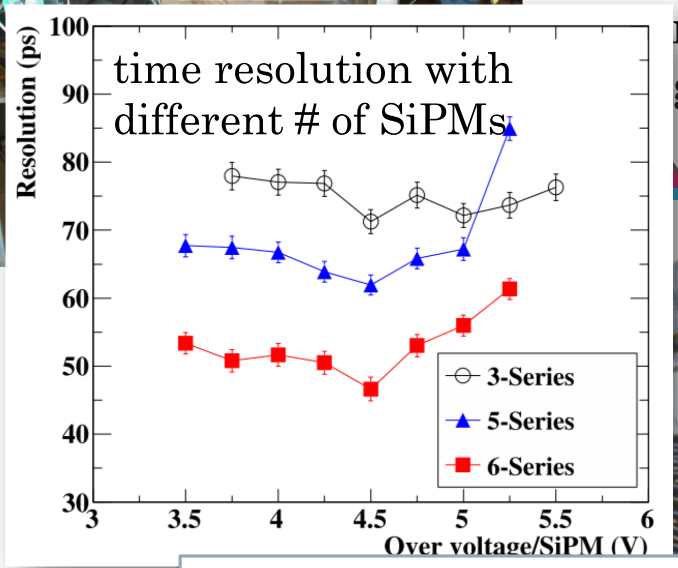
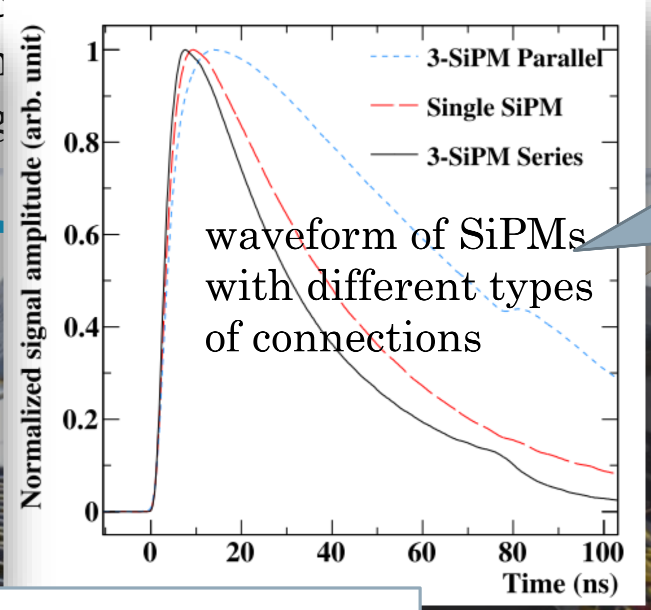
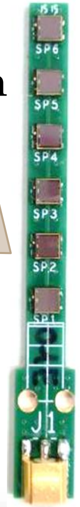
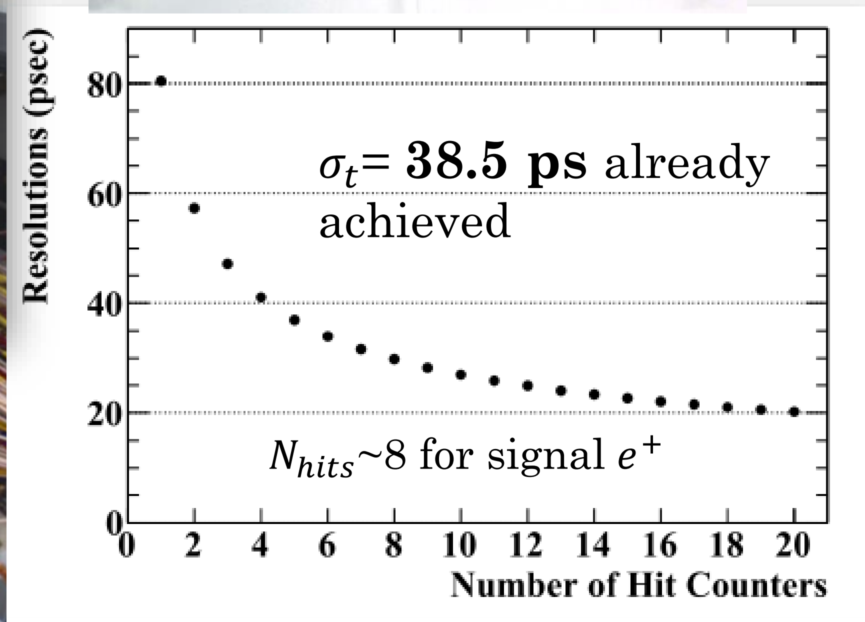
- **Increased segmentation**

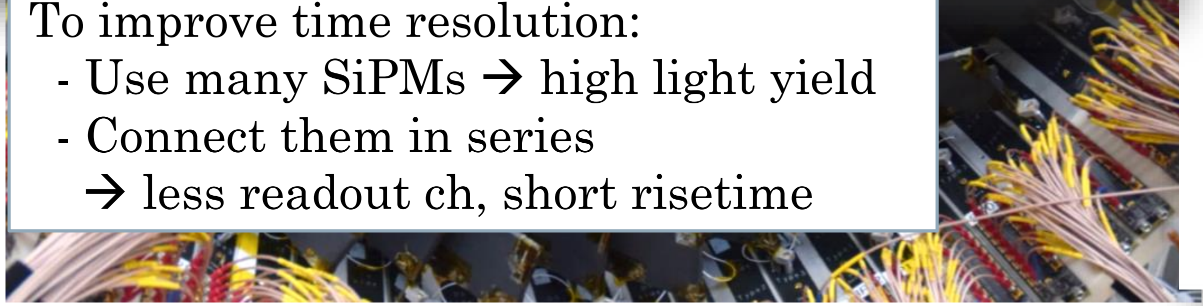




6 SiPMs
series connection

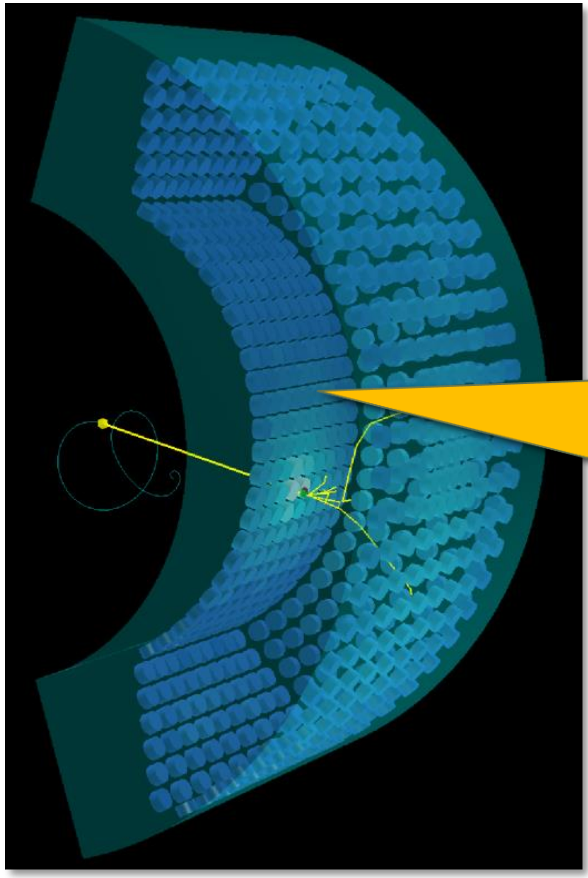






To improve time resolution:
- Use many SiPMs → high light yield
- Connect them in series
  → less readout ch, short risetime

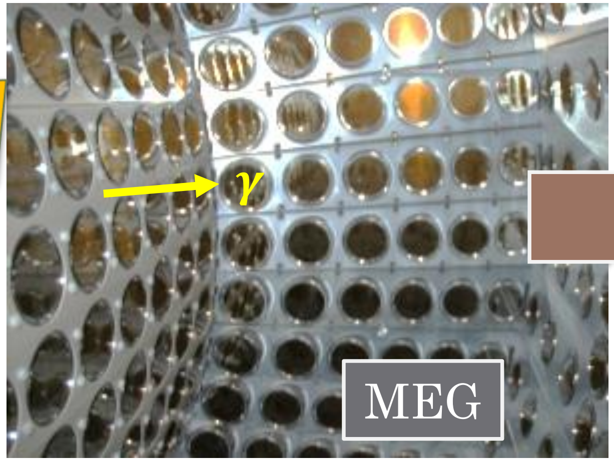
γ: liquid Xe detector

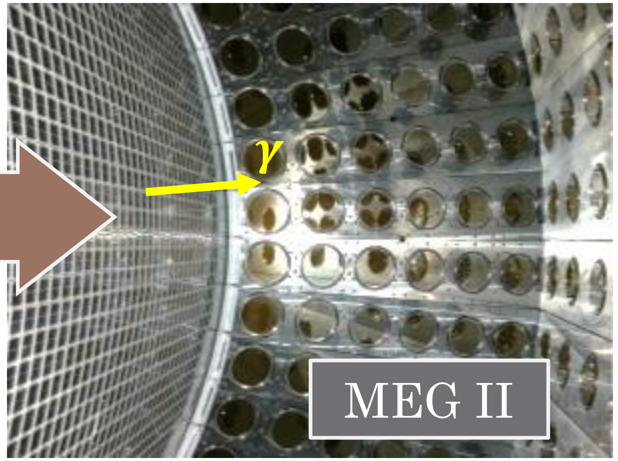


Reuse LXe from MEG

- Large light yield (~75% of NaI)
- Fast (τ_{decay} = 45ns)
- High stopping power (X_0=2.8cm)
- Uniform (liquid)

→ good $E_\gamma, x_\gamma, t_\gamma$ resolution



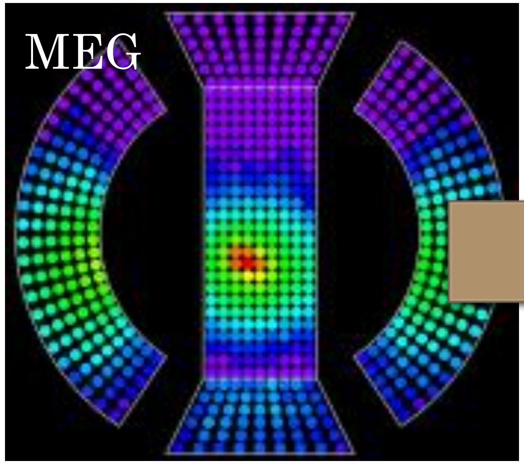


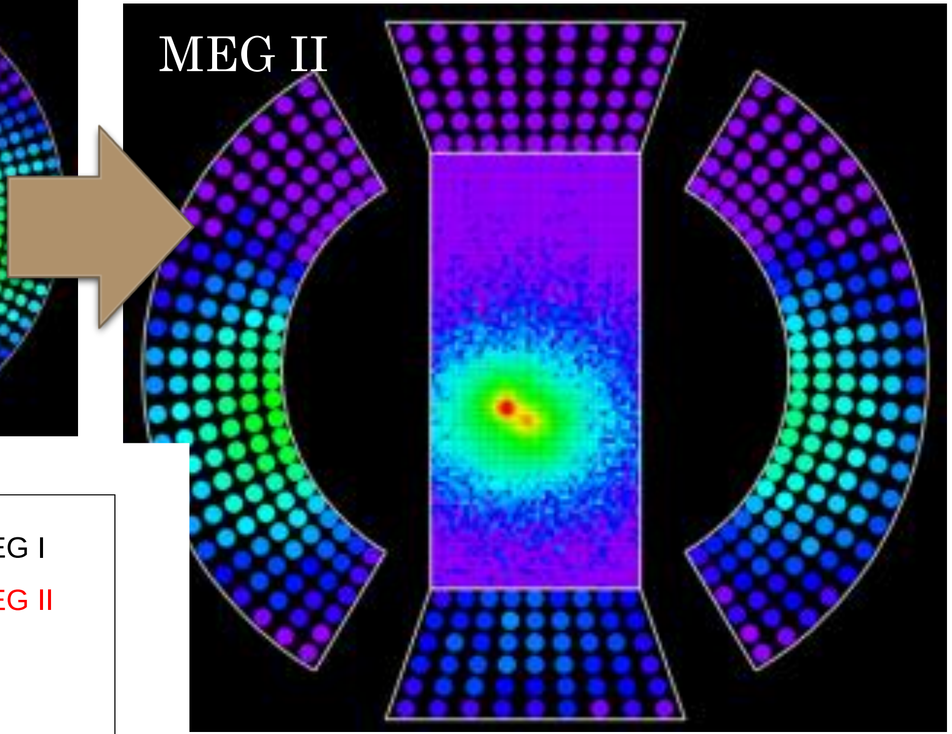
Replaced 216 PMTs (2-inch) to 4092 SiPMs (12mm)

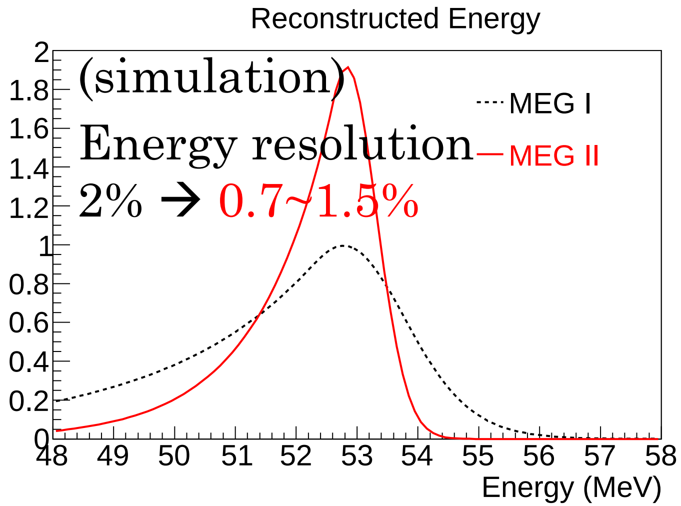
→ Uniformity of sensor coverage and granularity improved!

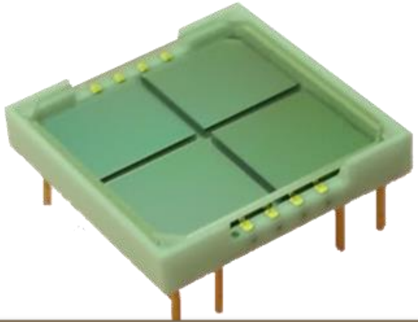
→ E_γ and x_γ are expected to improve by factor of 2

γ: liquid Xe detector









VUV-scintillation light sensitive large SiPM is successfully developed

Replaced 216 PMTs (2-inch) to 4092 SiPMs (12mm)

→ Uniformity of sensor coverage and granularity improved!

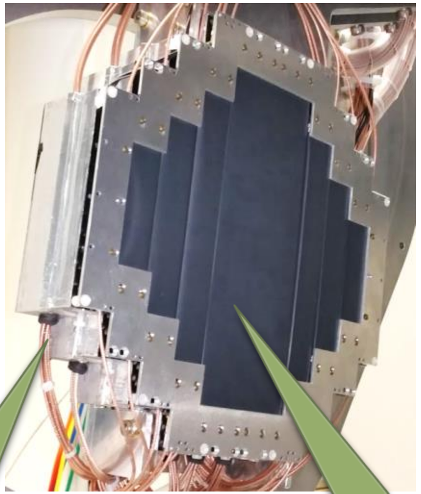
→ E_γ and x_γ are expected to improve by factor of 2

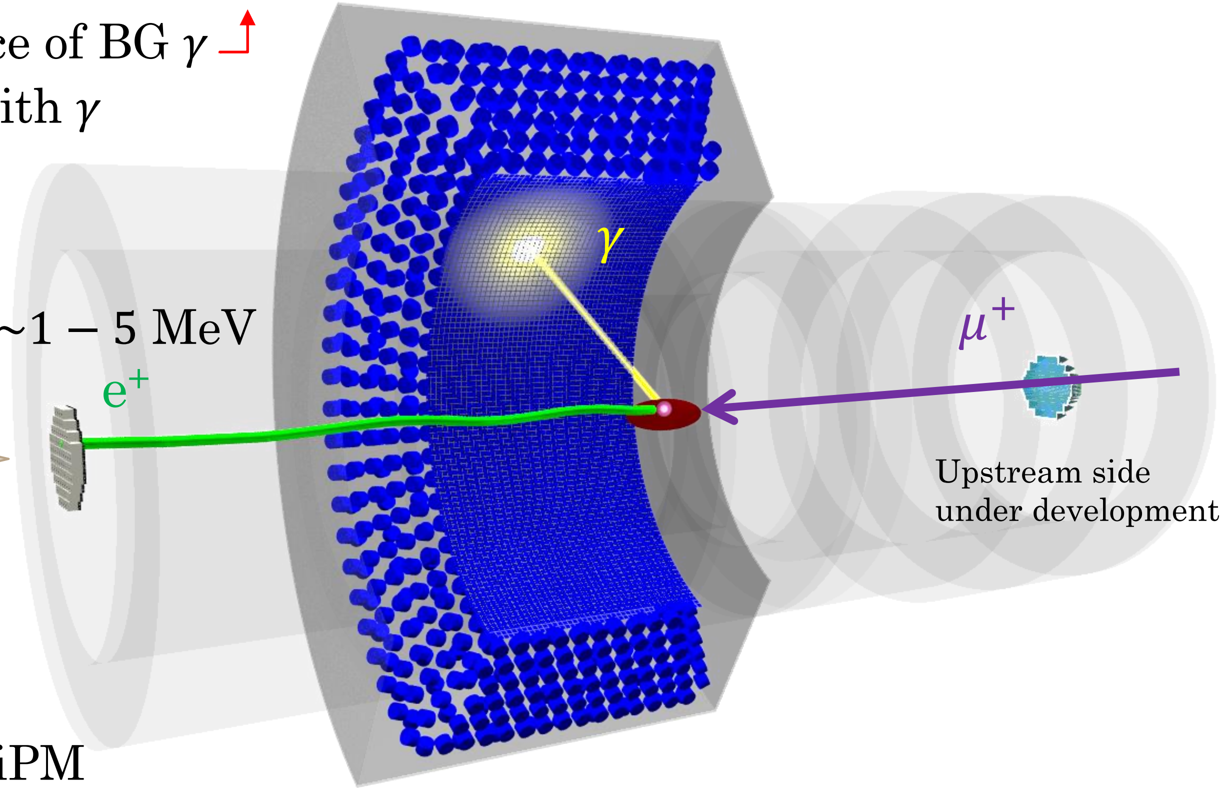
Background identifying detector

New detector to identify radiative μ decay $\mu \rightarrow e\nu\nu\boldsymbol{\gamma}$

main source of BG γ

Detects low momentum e^+associated with γ





LYSO crystals + SiPM
→ measure E_e (to distinguish e from normal μ decay)

Plastic scintillator + SiPM
→ measure T_e

Sensitivity improvement expected (DS only):
7.0×10^{-14} → $\mathbf{6.0\times10^{-14}}$

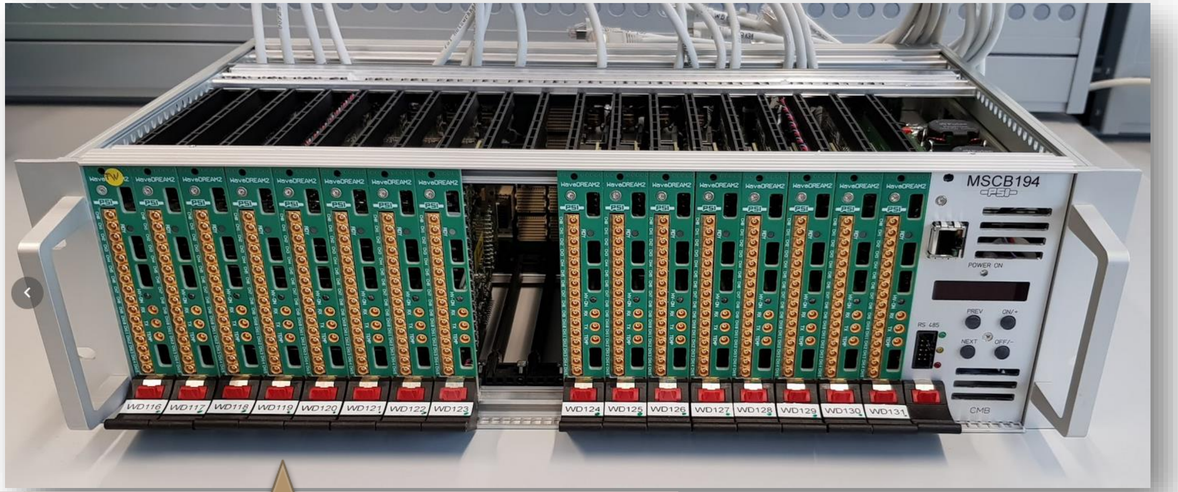
DAQ, trigger

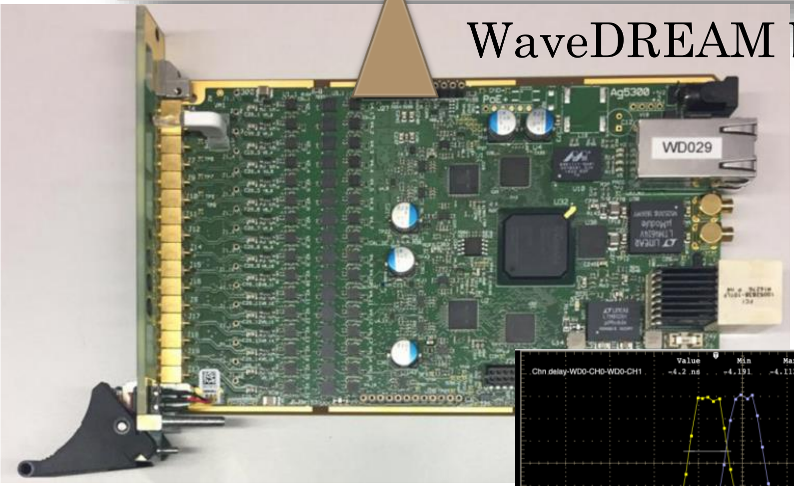
New DAQ + trigger system developed by PSI+INFN: WaveDAQ

- Waveform (1-2 GHz) readout of ~9000 channels with DRS chip (Domino Ring Sampler)

- Trigger is integrated
  → Reduced rack space,
  Sophisticated trigger
  (High energy γ, coincidence with e^+ back-to-back)

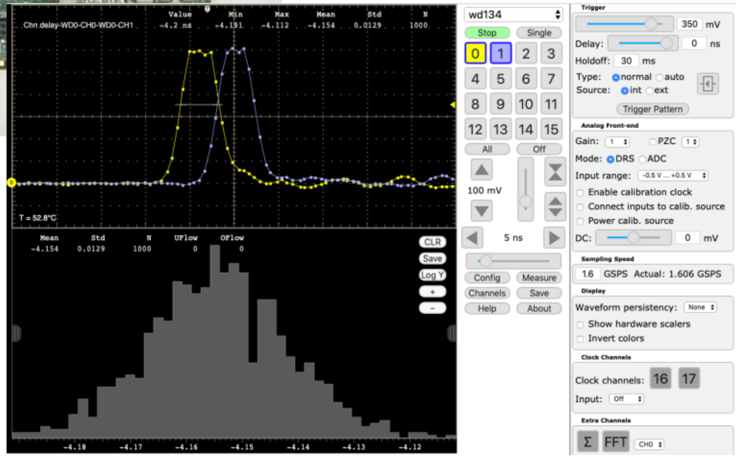
- Amplifier, shaper and HV supply for SiPMs





WaveDREAM board

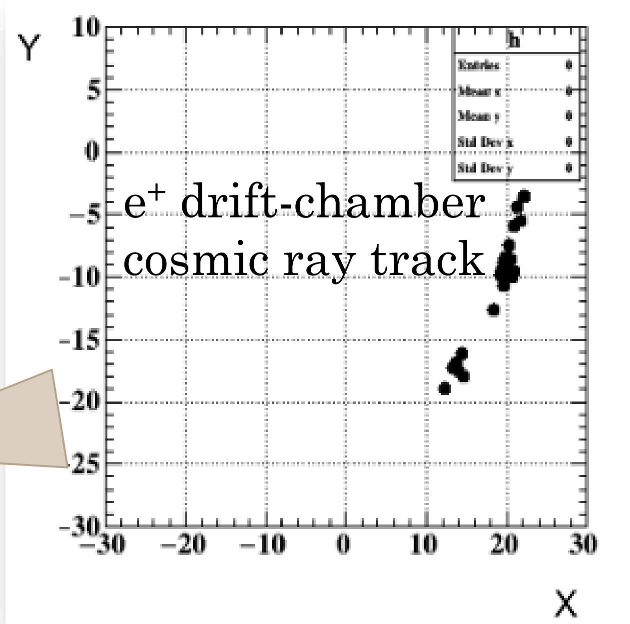
oscilloscope mode

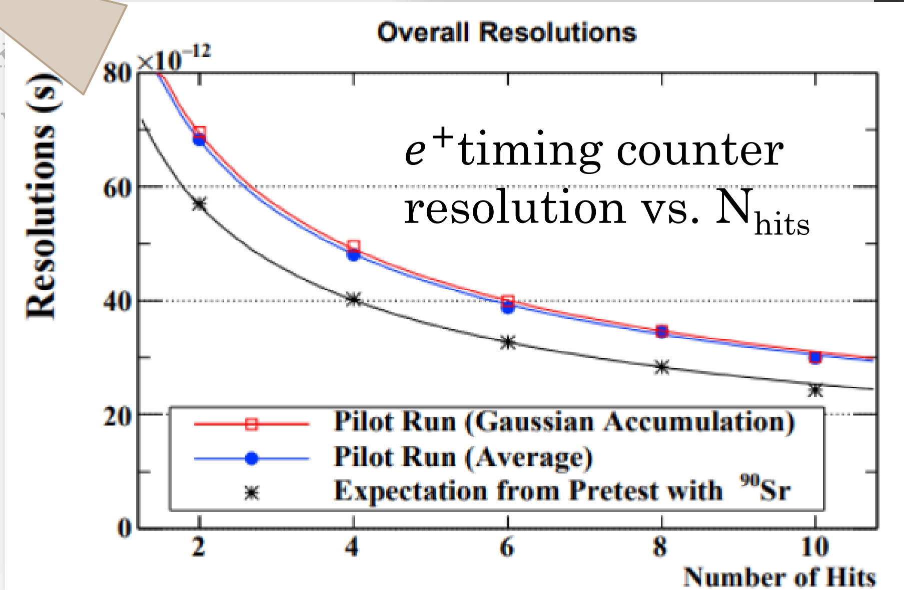


Overall status

Pre-engineering run with **all** detectors installed was done in 2018.

- e^+ drift chamber
  Partial operation due to electrostatic instability problem
  → Fixed by elongation of wires. Broken wires are removed.
- e^+ timing counter already achieved 38.5 ps resolution
- γ liquid Xe detector
  Successfully observed γ events. T_γ resolution look
  → next: measure energy and position resolution
  ~50 MeV γ from π^0 decay
- Background identifying detector
  Successfully demonstrated BG γ identification
- Electronics
  Part of the channels were available in 2018
  → Start mass production soon





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- e^+ drift chamber
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  → Fixed by elongation of wires. Broken
- e^+ timing counter already achieved 38.5 ps resolution
- γ liquid Xe detector
  Successfully observed γ events. T_γ resolution looks good (44ps).
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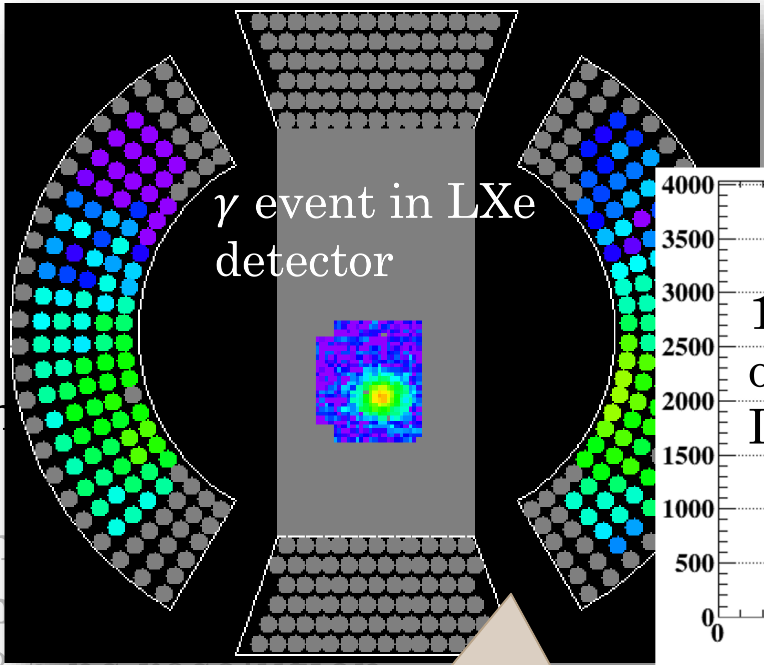

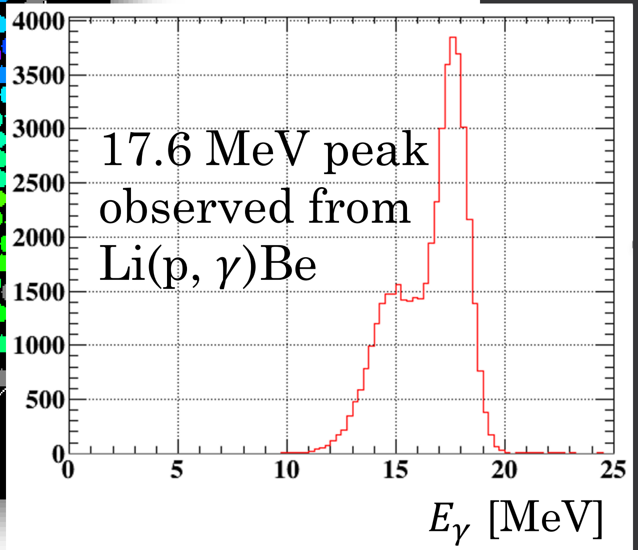

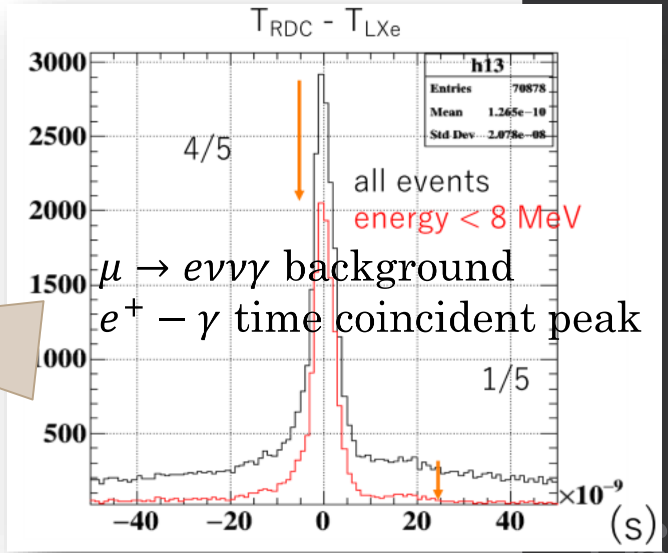

Summary

- $\mu \to e\gamma$ is a golden probe for searching BSM physics.
- MEG II utilizes high intensity μ beam at PSI to search $\mu \to e\gamma$ aiming at $Br(\mu \to e\gamma) < 6\times10^{-14}$, which is 10 times better than MEG.
- All the detectors are upgraded to cope with increased background. Resolutions are expected to improve by factor of 2.
- Detector construction is completed except for readout electronics. Commissioning runs with μ beam will continue in 2019-2020, followed by physics run (~3 years).

Backup slides