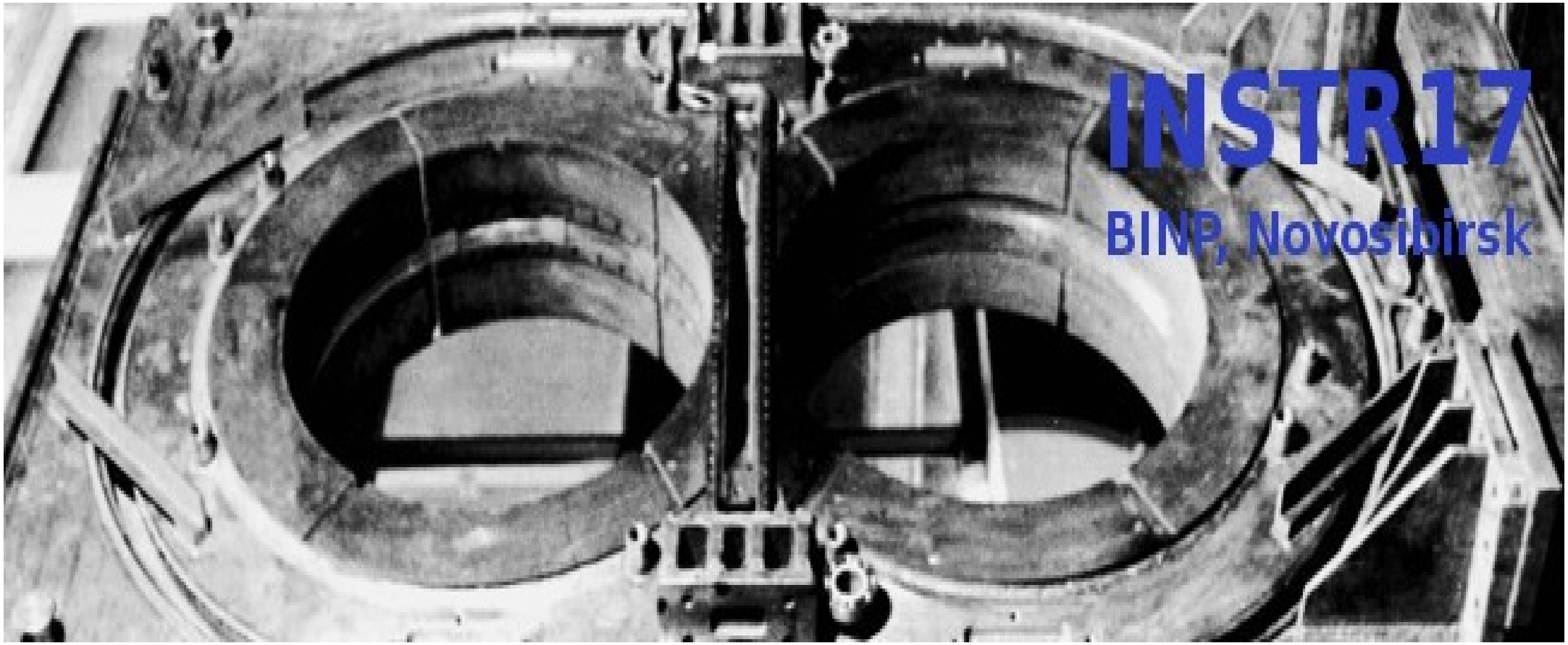
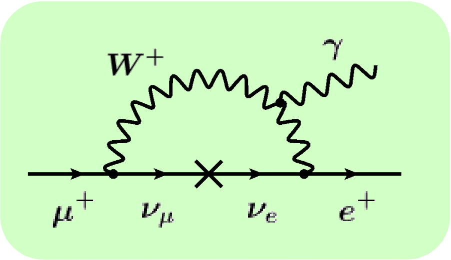


The MEGII detector

Paolo W. Cattaneo (INFN Pavia)
on behalf of MEGII collaboration

$\mu \rightarrow e\gamma$

Standard Model incl. Dirac ν's:

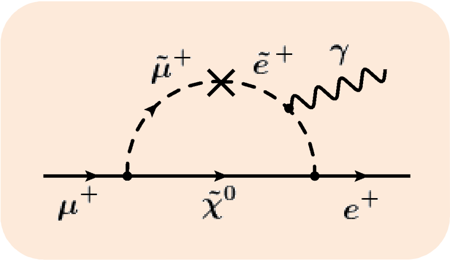


$$\mathrm{Br}(\mu \to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=2,3} U^*_{\mu i} U_{ei} \frac{\Delta m^2_{1i}}{m^2_W}\right|^2$$

$$< 10^{-54}$$

Impossible to detect

New Physics (e.g. SUSY):



$$\mathrm{Br}(\mu \to e\gamma) \approx \frac{\alpha^3}{G_F^2} \frac{(\delta_{\mathrm{LL}})^2_{e\mu}}{m^4_{\mathrm{SUSY}}} \tan^2(\beta)$$

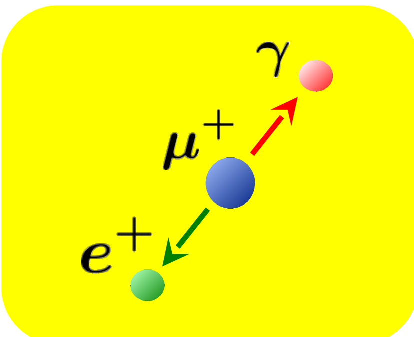
$$\approx 10^{-11} \sim 10^{-14}$$

Small but not impossible!

$\mu \rightarrow e\gamma$ and other CLFV processes have never been observed $\Rightarrow$ Observation of CLFV is clear evidence of new physics!

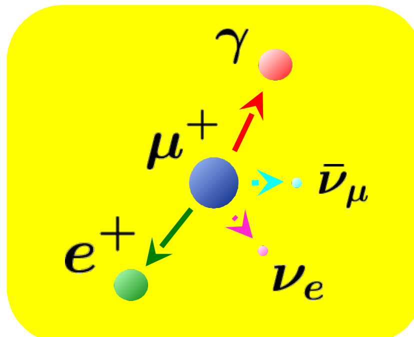
Detection principle

Signal:

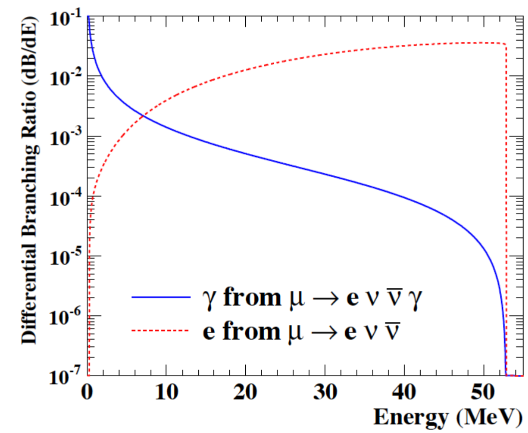


$E_\gamma = 52.8$ MeV
$E_e = 52.8$ MeV
$\Theta_{e\gamma} = 180^\circ$
$T_{e\gamma} = 0$ s

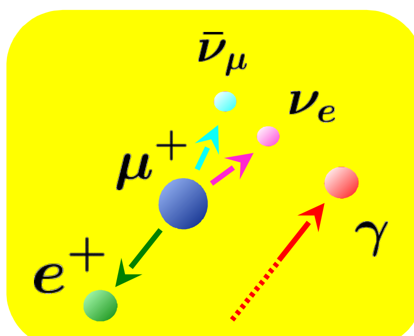
BG 1: Radiative muon decay



$E_\gamma < 52.8$ MeV
$E_e < 52.8$ MeV
$\Theta_{e\gamma} < 180^\circ$
$T_{e\gamma} = 0$ s



BG 2: Accidental coincidences



Positron from Michel decay

Photon can come from:

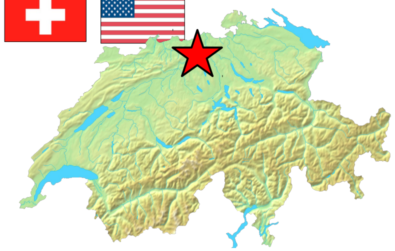
1. *Radiative muon decay*
2. *Positron annihilation in flight*
3. *Positron Brehmsstralung*

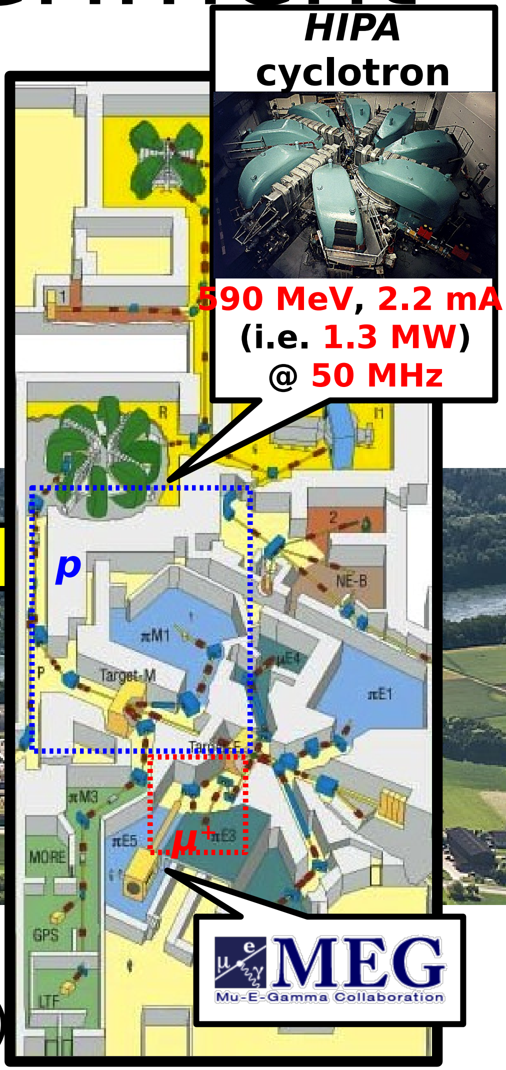
$E_\gamma < 52.8$ MeV
$E_e < 52.8$ MeV
$\Theta_{e\gamma} < 180^\circ$
$T_{e\gamma} \sim$ flat

$$N_{\mathrm{acc}} \propto R_\mu^2 \cdot (\sigma_{E_\gamma})^2 \cdot \sigma_{E_e} \cdot (\sigma_{\Theta_{e\gamma}})^2 \cdot \sigma_{T_{e\gamma}}$$

The MEG/MEGII experiment

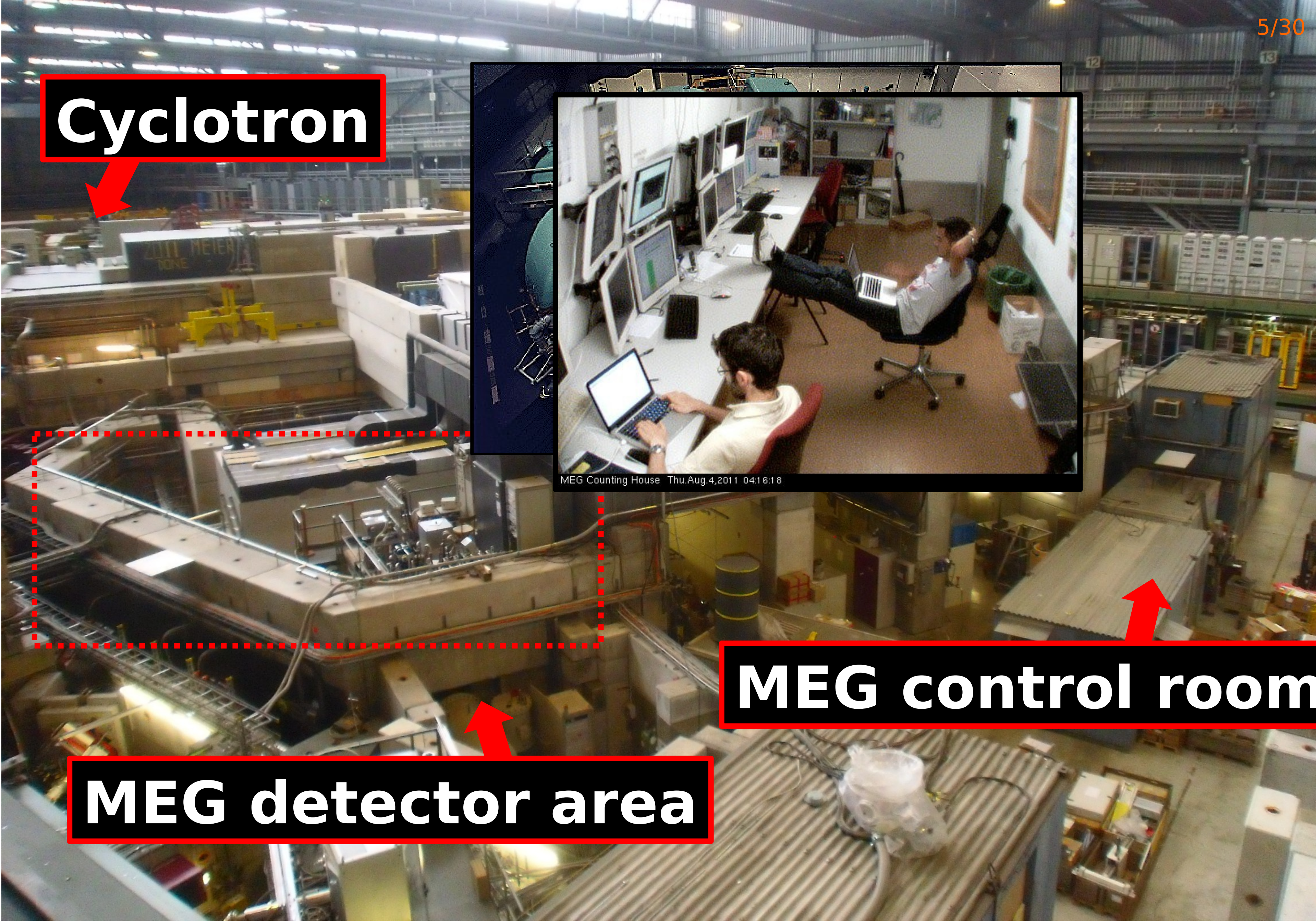
- The MEGII Collaboration: ~60 physicists, 12 institutes
- Detector location: The *Paul Scherrer Institut* Zürich, Switzerland





- The world's highest intensity muon & pion beams

($\pi E5$: DC surface muons, $R_\mu > 10^8\,\mu^+/s, \;\; |p_\mu| \approx 28\ \mathrm{MeV}/c$)


Cyclotron
MEG Counting House Thu.Aug.4,2011 04:16:18
MEG control room
MEG detector area

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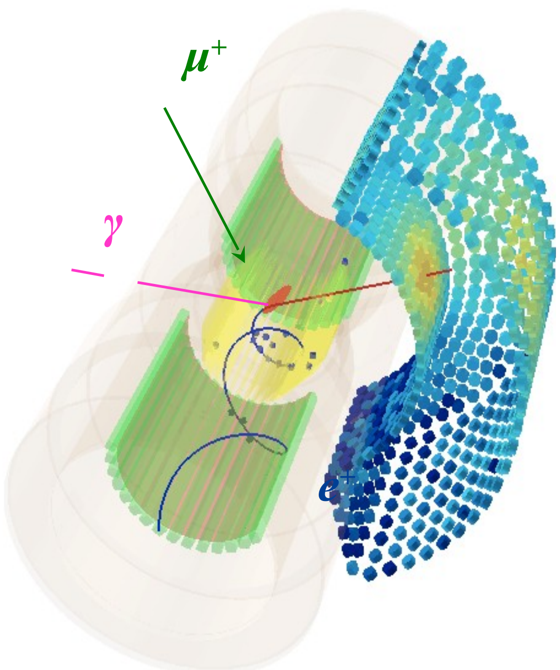
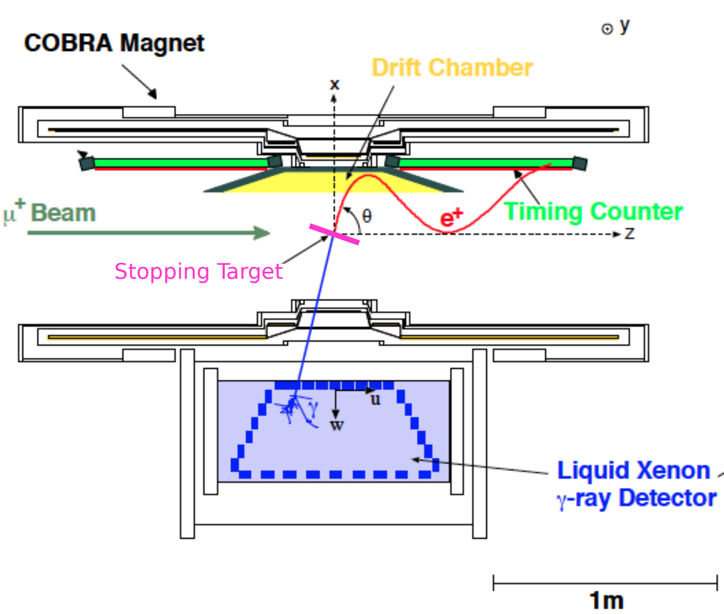
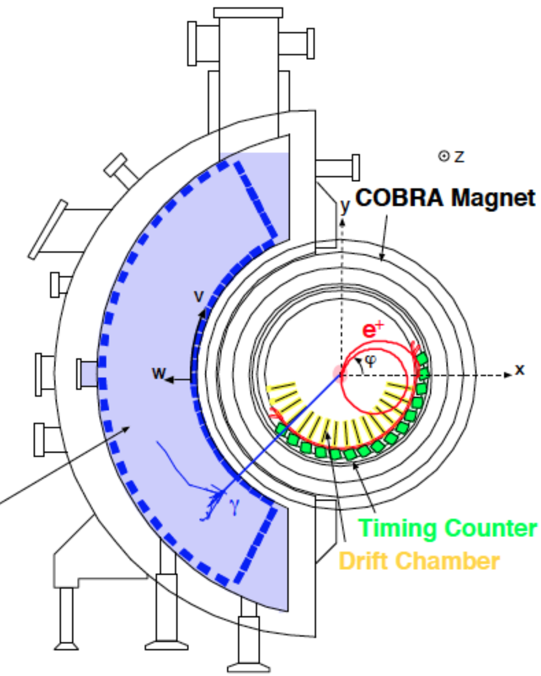
The MEG detector







Dedicated detector with asymmetric coverage ($\Omega_{MEG}/4\pi = 11\%$):

1. Low-mass positron spectrometer with gradient B-field to reconstruct the positron track
2. Innovative liquid Xenon detector to measure the gamma position, time and energy
3. High performance DAQ system: multi-GHz waveform digitization of all 3k channels
4. Arsenal of calibration & monitoring tools to make sure we understand our detector

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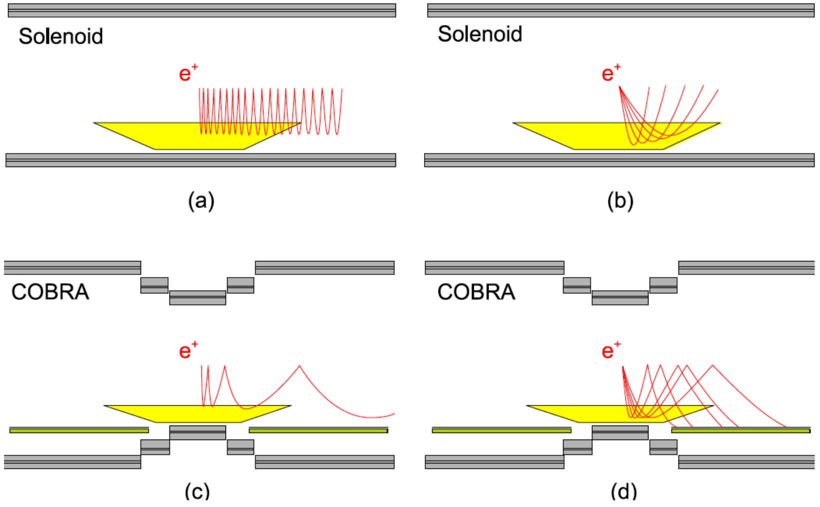
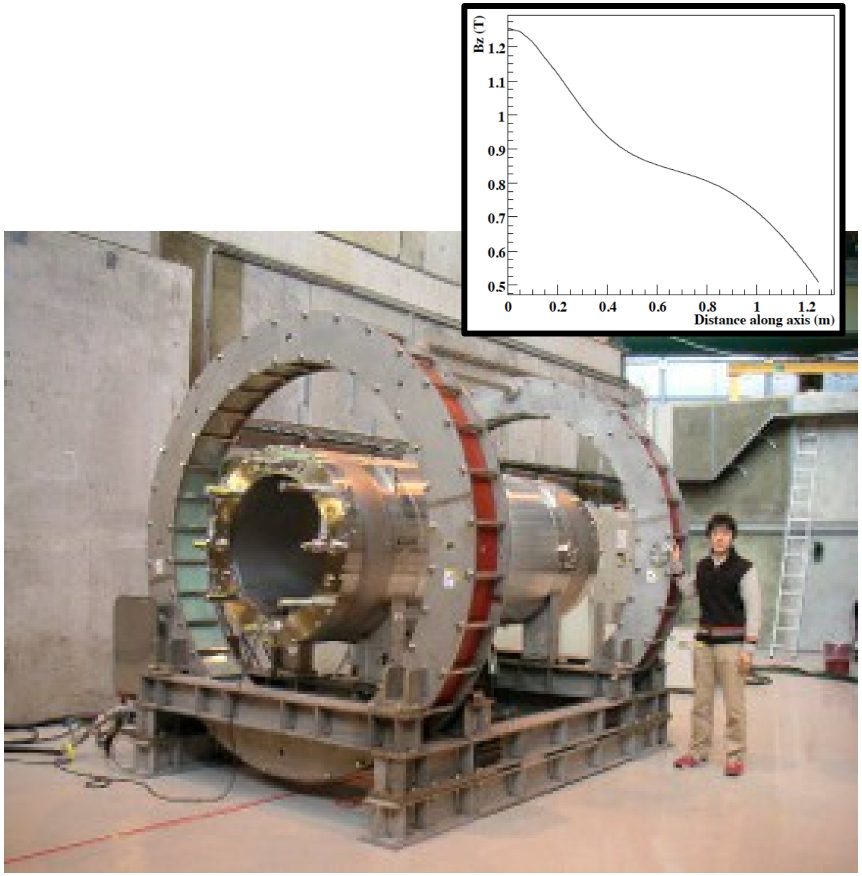
The MEG/MEGII COBRA magnet

Superconducting COBRA magnet:

- Solenoidal gradient B-field: 0.5 - 1.3 T (COnstant Bending RAdius, quick



- 0.2 X_0 fiducial thickness



arXiv:1301.722

MEG-II

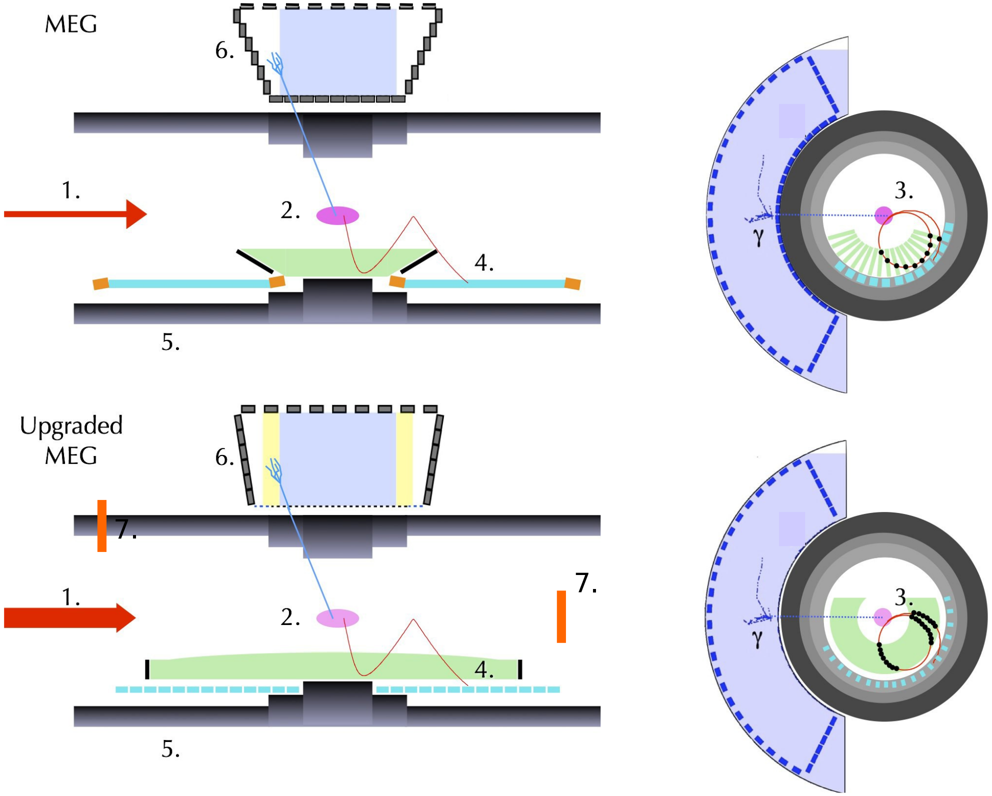
Goal: 10x improvement in sensitivity (**~5×10^{-14}**)

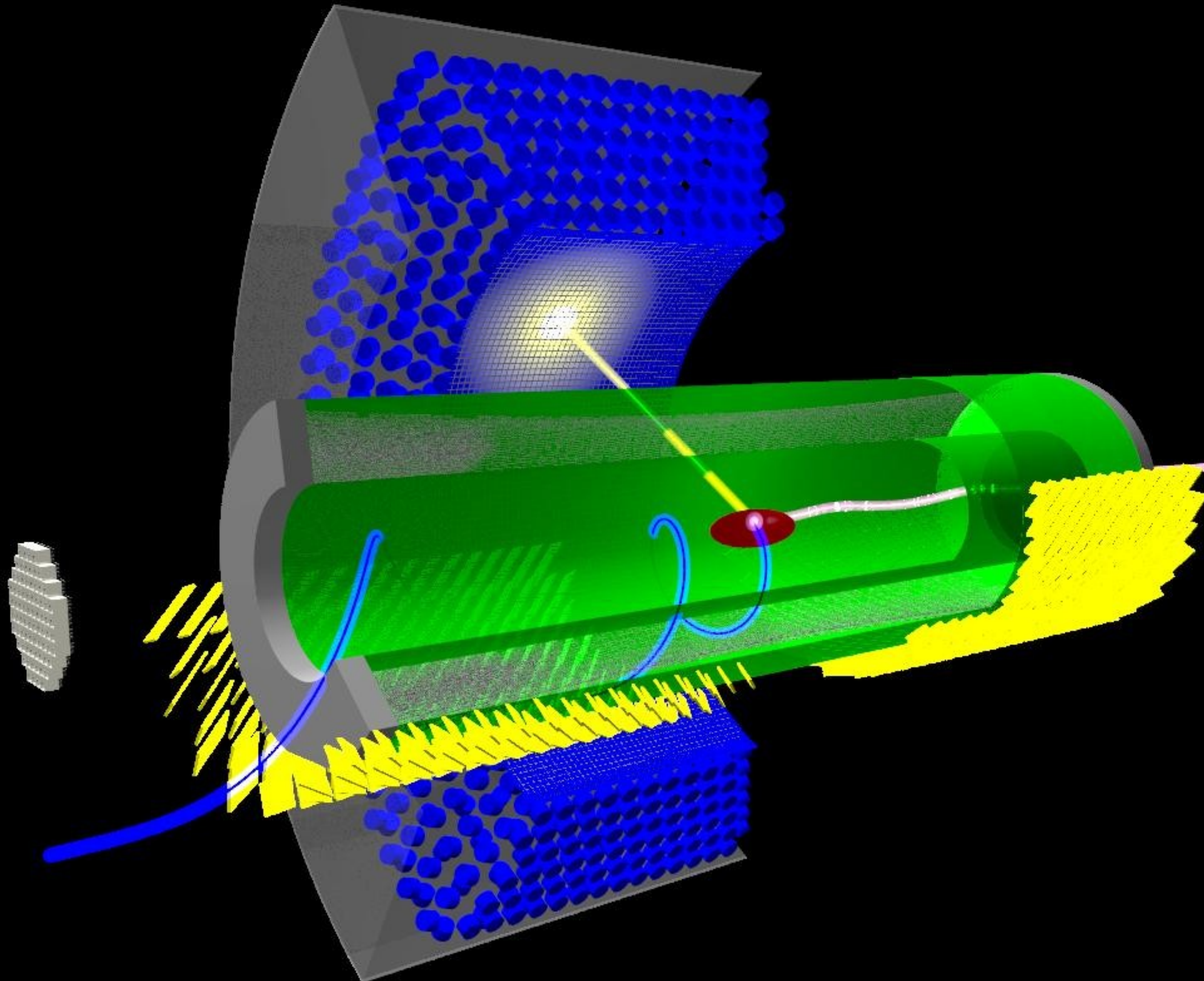
How?

- Higher beam rate & efficiencies
- Improved detector resolutions
- Moderate costs (~5 M$)

Upgrades:

1. **Increased beam intensity (7×10^{7} μ^{+}/s)**
2. **Thinner (140 µm) or active target**
3. **Enlarged cylindrical single-volume DC**
4. **Pixelated TCs with SiPM readout**
5. **New high-bandwidth DAQ boards**
6. **Enlarged LXe volume, SiPM readout**
7. **RMD counters**

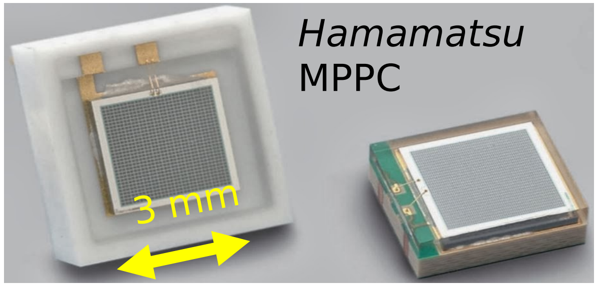


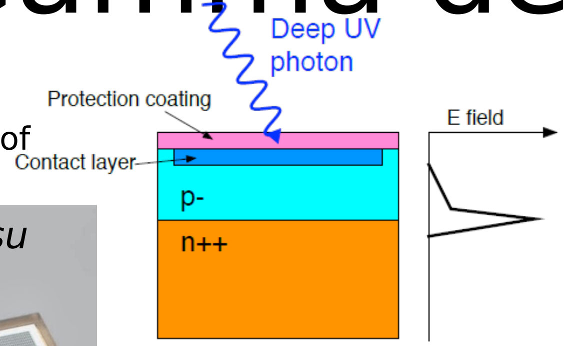


Gamma detector

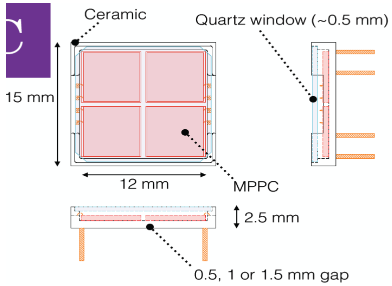
Upgrade:

- Replace PMTs on inner face of detector by MPPCs (SiPMs)





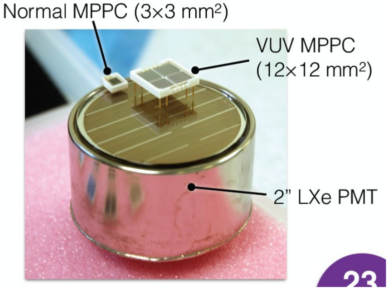
- Remove protective layer
- Fit anti-reflective coating to LXe refraction index
- Protect with quartz

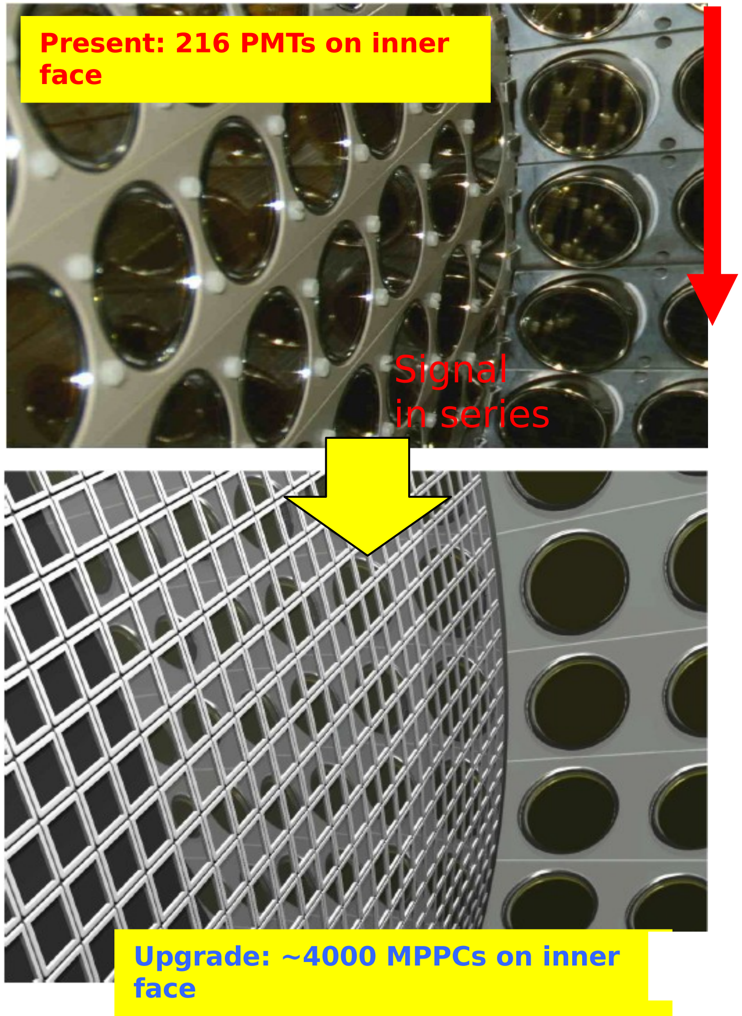


- Extend inner face along z-direction and modify PMT layout at lateral faces

MPPC development:

✓ VUV sensitive (PDE > 15%)
✓ Large area sensor(12×12 mm²)
✓ Fast response (short pulse using novel SiPM connection method)





Gamma detector

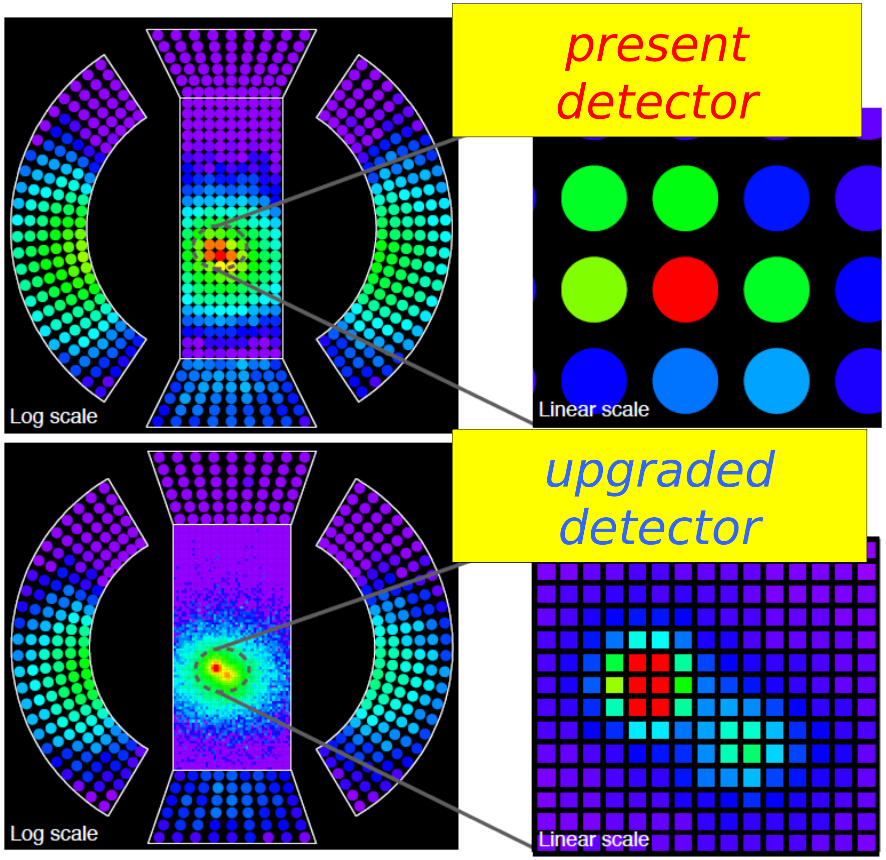
Improvements:

- Improved detector response at sides
- Improved detection efficiency (+10%)
- Improved position and energy resolutions
- Improved pile-up handling

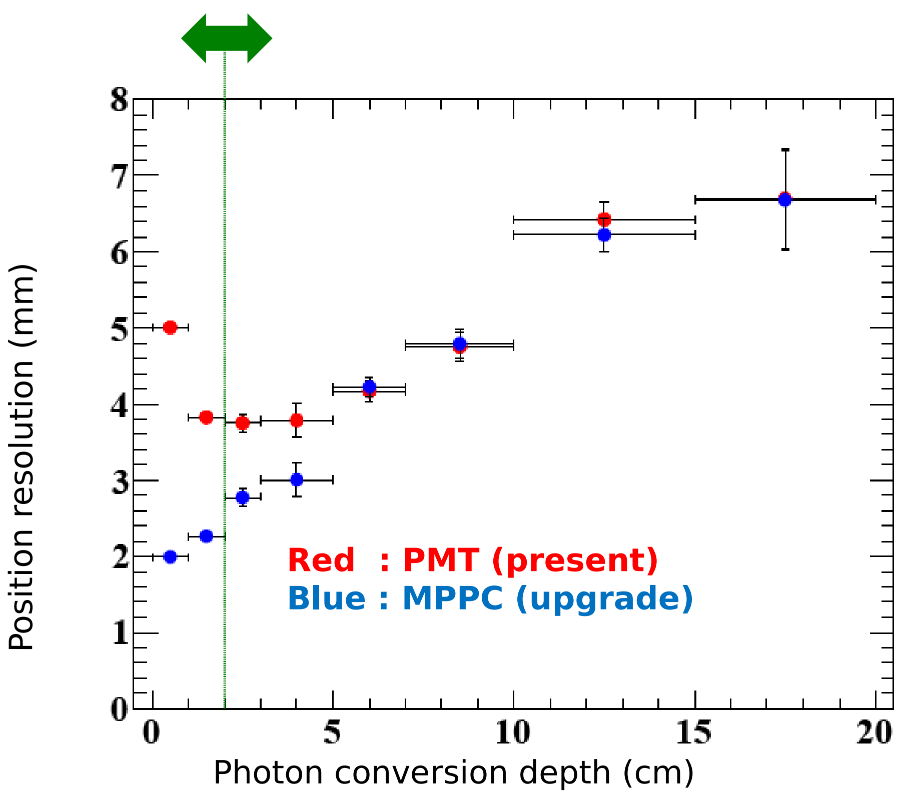
Status:

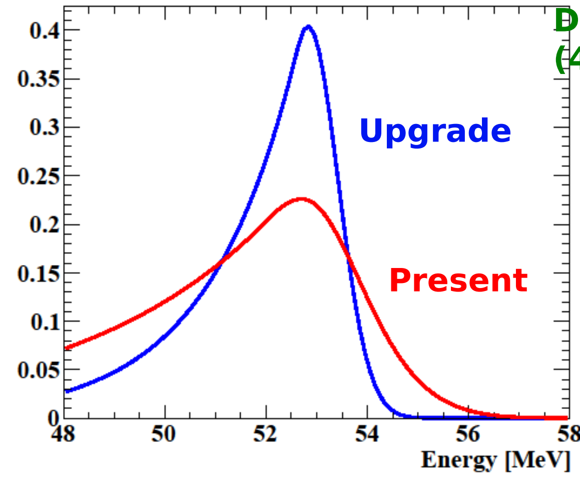
- Ready to be installed this summer

Pile-up MC event (28 + 25 MeV):



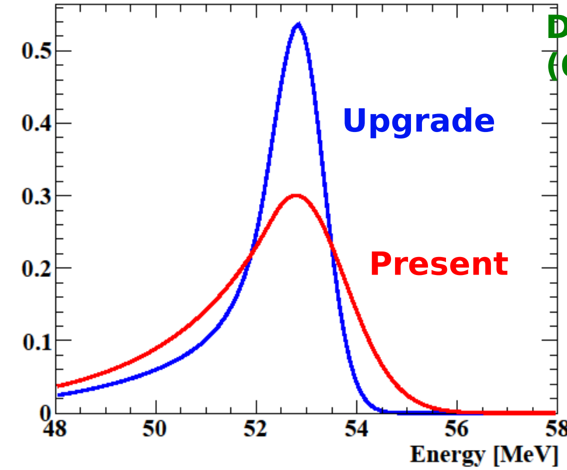
Gamma detector





Depth < 2 cm
(40% of all events):

σ_E
2.4%
↓
1.1%

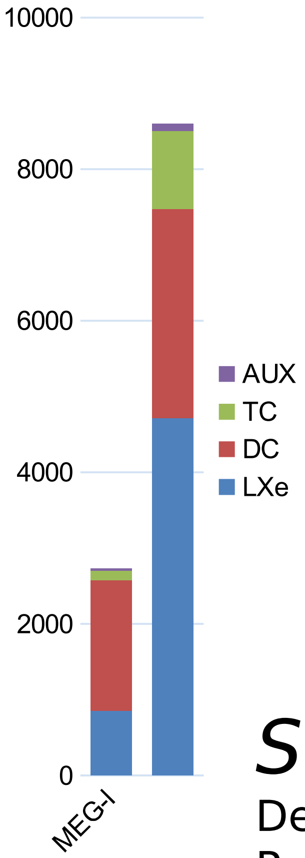


Depth ≧ 2 cm
(60% of all events)

σ_E
1.7%
↓
1.0%

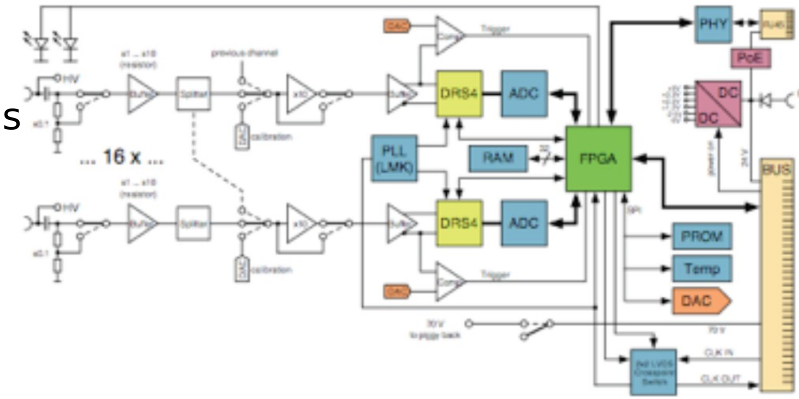
Electronics

\# of readout channels:



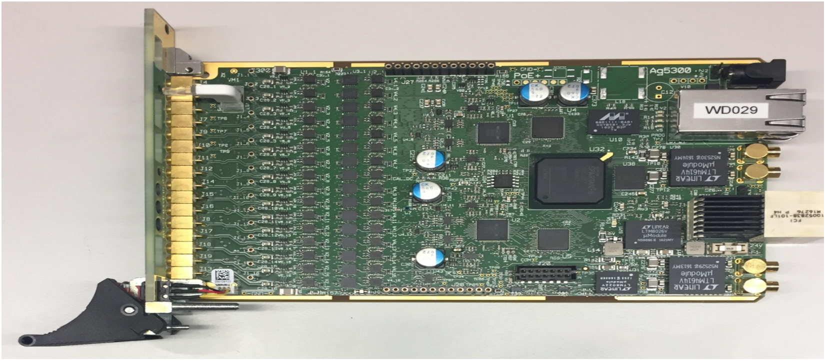
Motivation:

- Increased # of readout channels
- Higher bandwidth to preserve full waveform digitization
- Higher event rate → faster readout



WaveDREAM board:

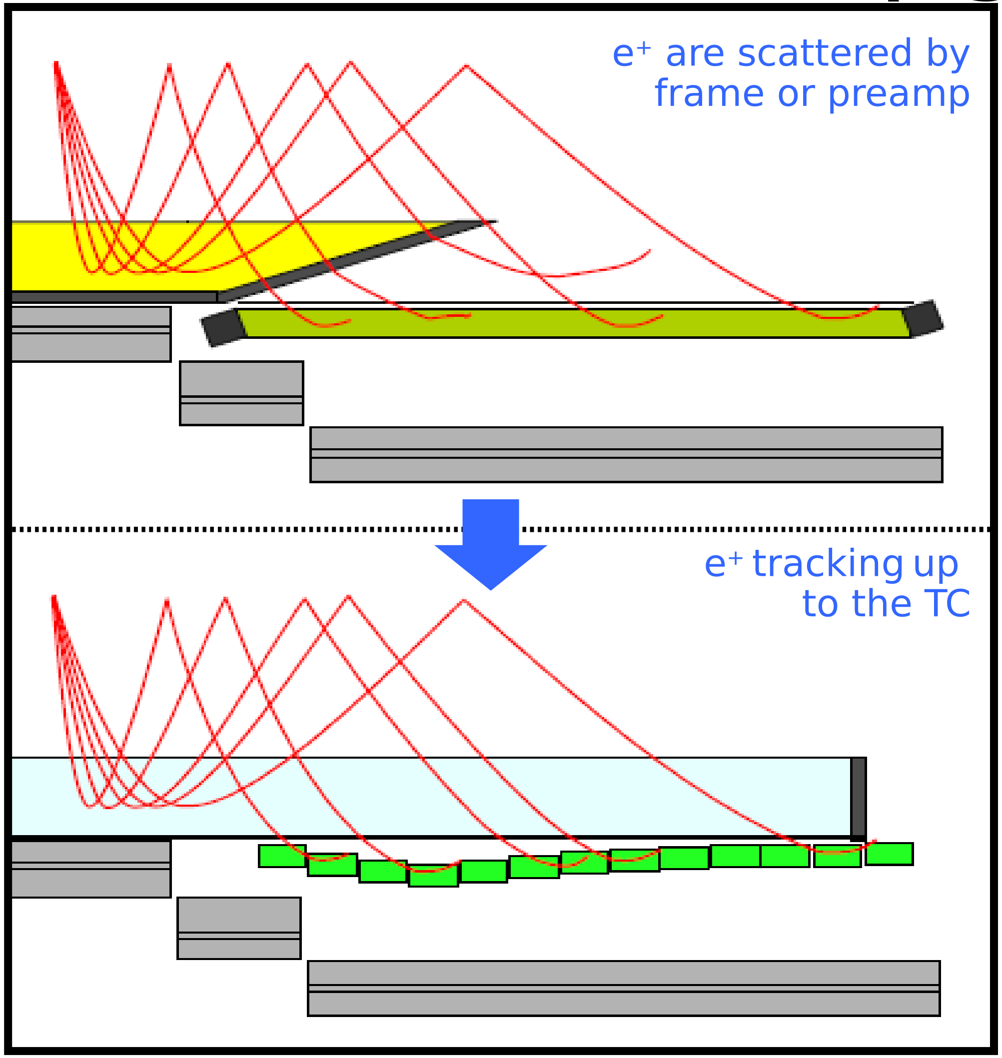
Multi-functional purpose board that integrates analog frontend, trigger, digitization (*DRS4* chips, 2 GHz sampling) and HV supply on a single board



Status:

Design finished
Production between end 2017 and begin 2018

Positron detector upgrade



Positron detector

Cylindrical DC:

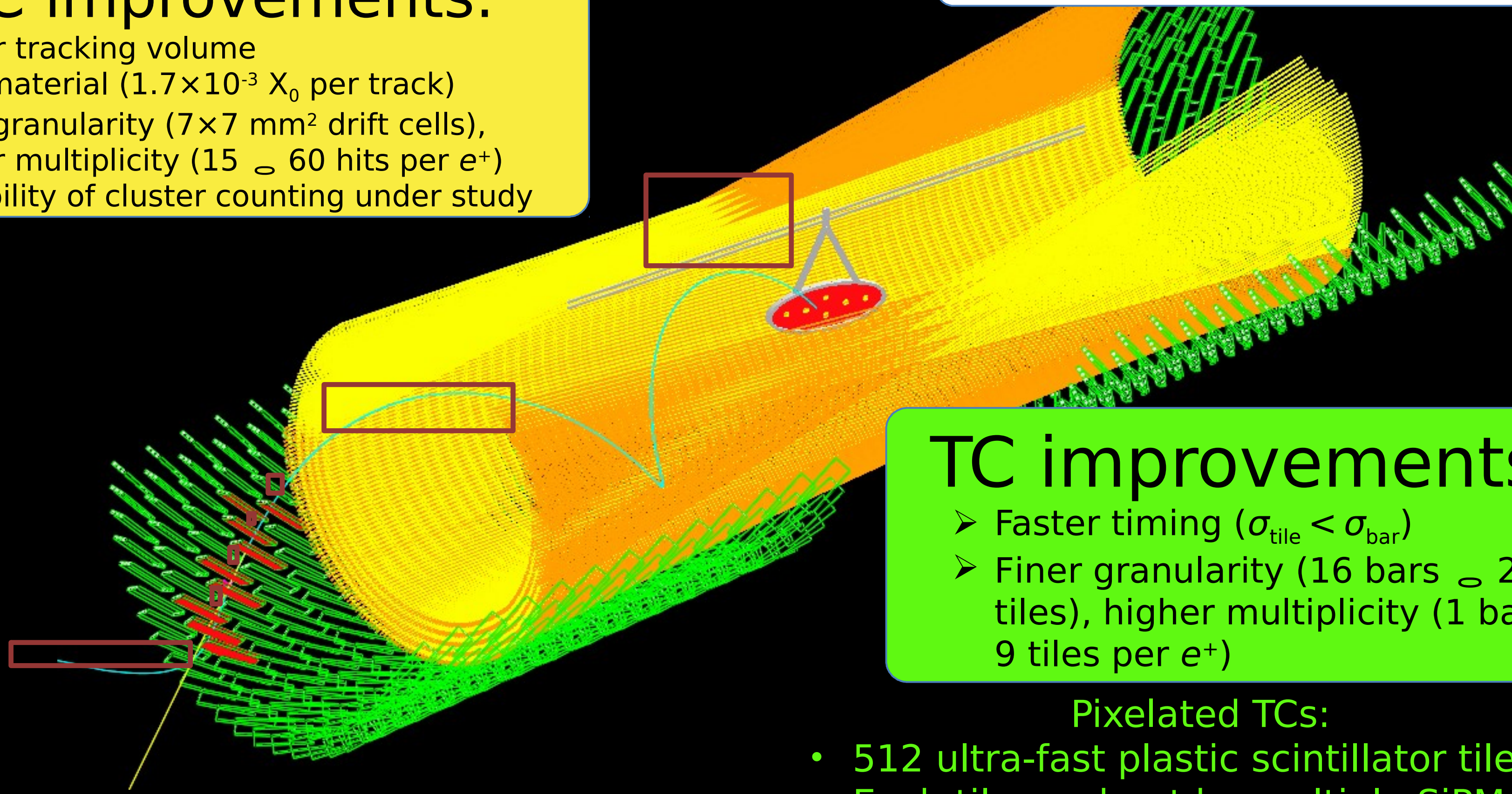
- Single-volume, low-Z gas mixture (He:iC_4H_{10} = 85:15)
- 1200 sense wires (2 m long, 20 µm diameter) with stereo angle (7°) configuration

DC improvements:

- ➢ Larger tracking volume
- ➢ Less material (1.7×10^{-3} X_0 per track)
- ➢ Finer granularity (7×7 mm^2 drift cells), higher multiplicity (15 → 60 hits per e^+)
- ➢ Possibility of cluster counting under study

Improvements:

- ➢ Improved detection efficiency (x2)
- ➢ Improved timing resolution (eliminates 75 ps contribution to σ_t)



TC improvements:

- ➢ Faster timing ($\sigma_{tile} < \sigma_{bar}$)
- ➢ Finer granularity (16 bars → 256 tiles), higher multiplicity (1 bar → 9 tiles per e^+)

Pixelated TCs:

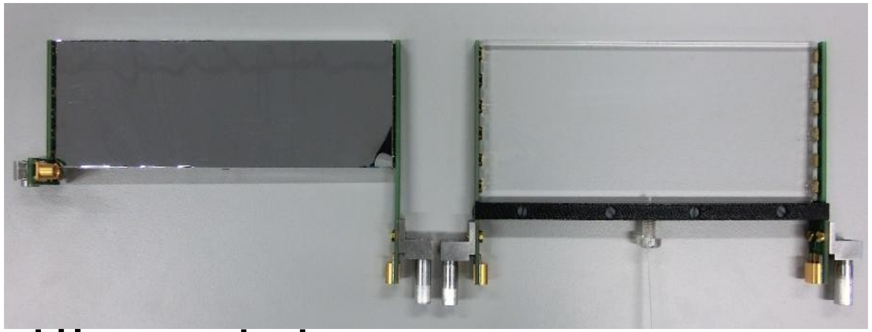
- 512 ultra-fast plastic scintillator tiles
- Each tile read-out by multiple SiPMs

Cylindrical Drift Chamber

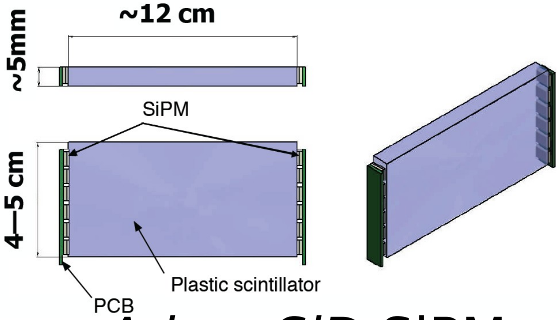
Long R&D to optimize a chamber design able to stand the design higher rate and improve resolution.
Described in detail in the next talk:
G.Tassielli “The construction technique of high granularity and high trasparency Drift Chamber for MEGII upgrade“

Pixelated Timing counter

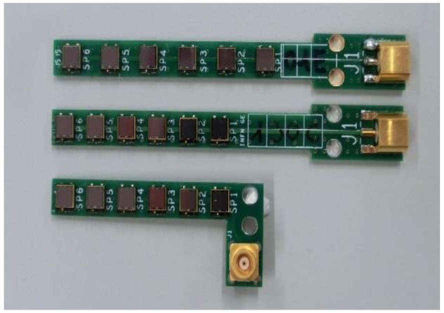
Long R&D to optimize scintillator,
SiPM, Connection, bias, wrapping etc.



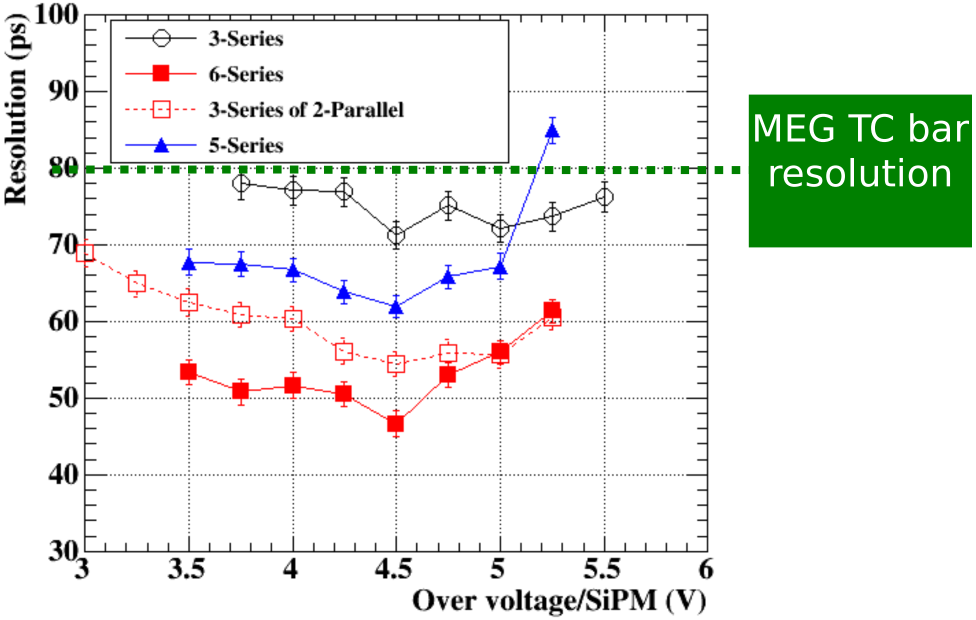
Single tile:



AdvanSiD SiPM
(6-series):



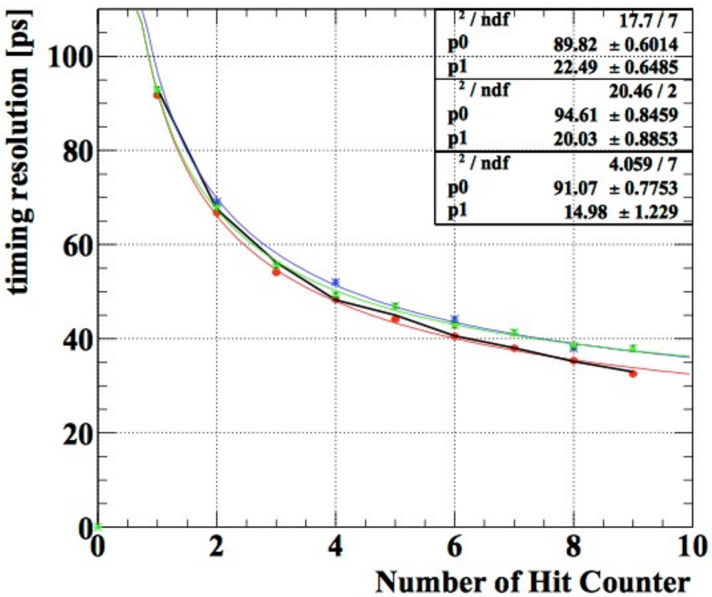
Single tile prototype
tests using ^{90}Sr source:

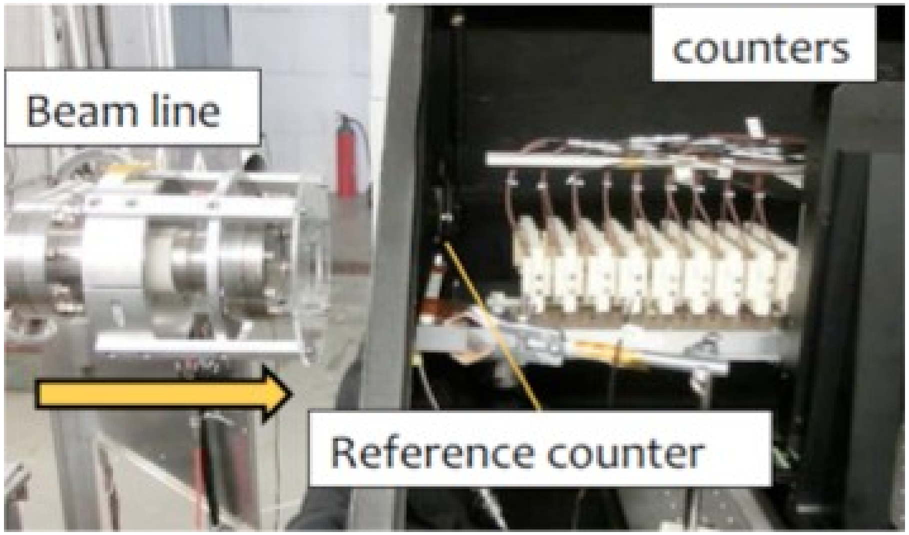


Pixelated Timing counter

Multi hit counters exploited to improve resolution
Tested at BTF (LNF) and PSI with magnetic field.

Beam test @ LNF:

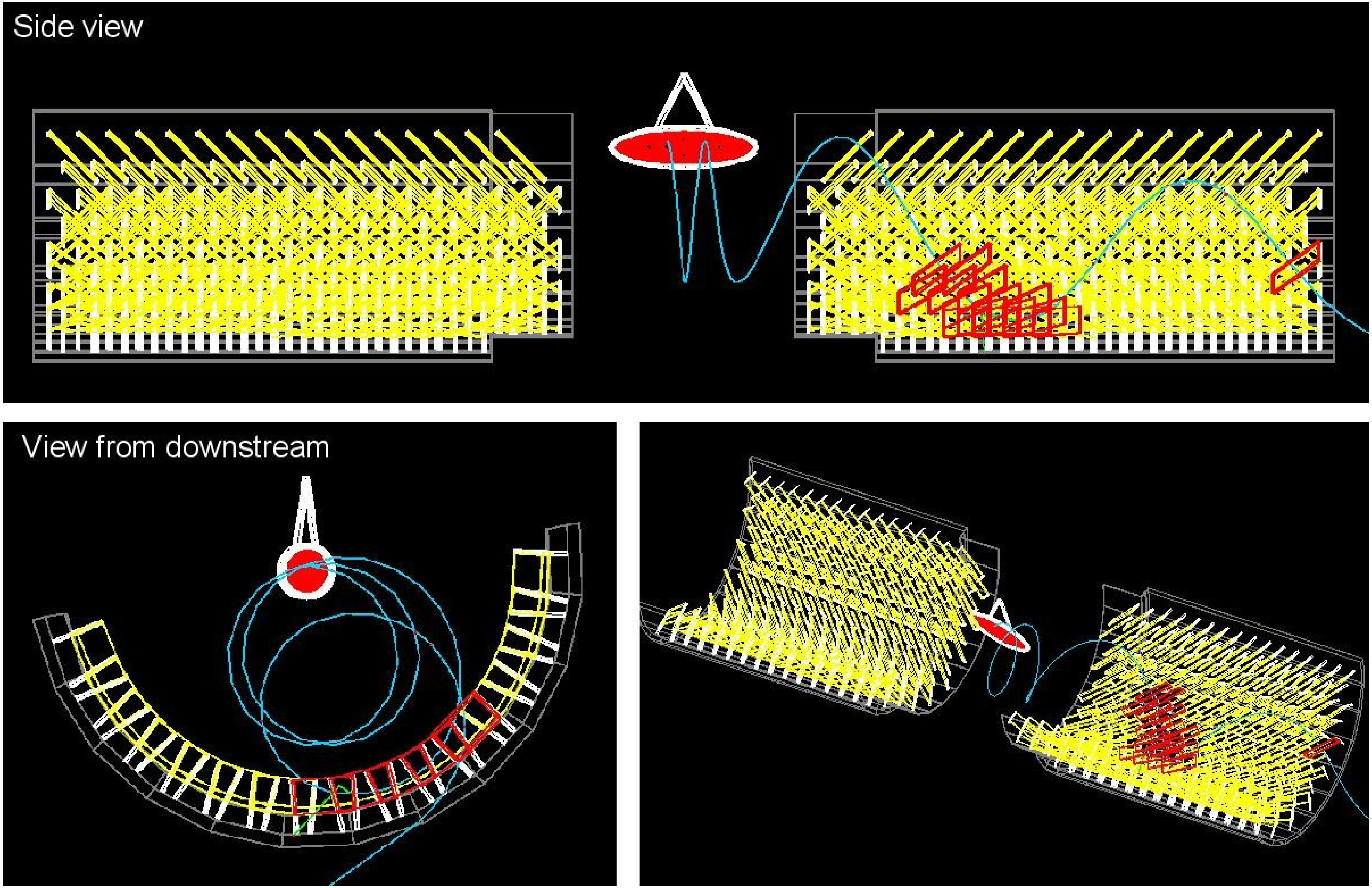




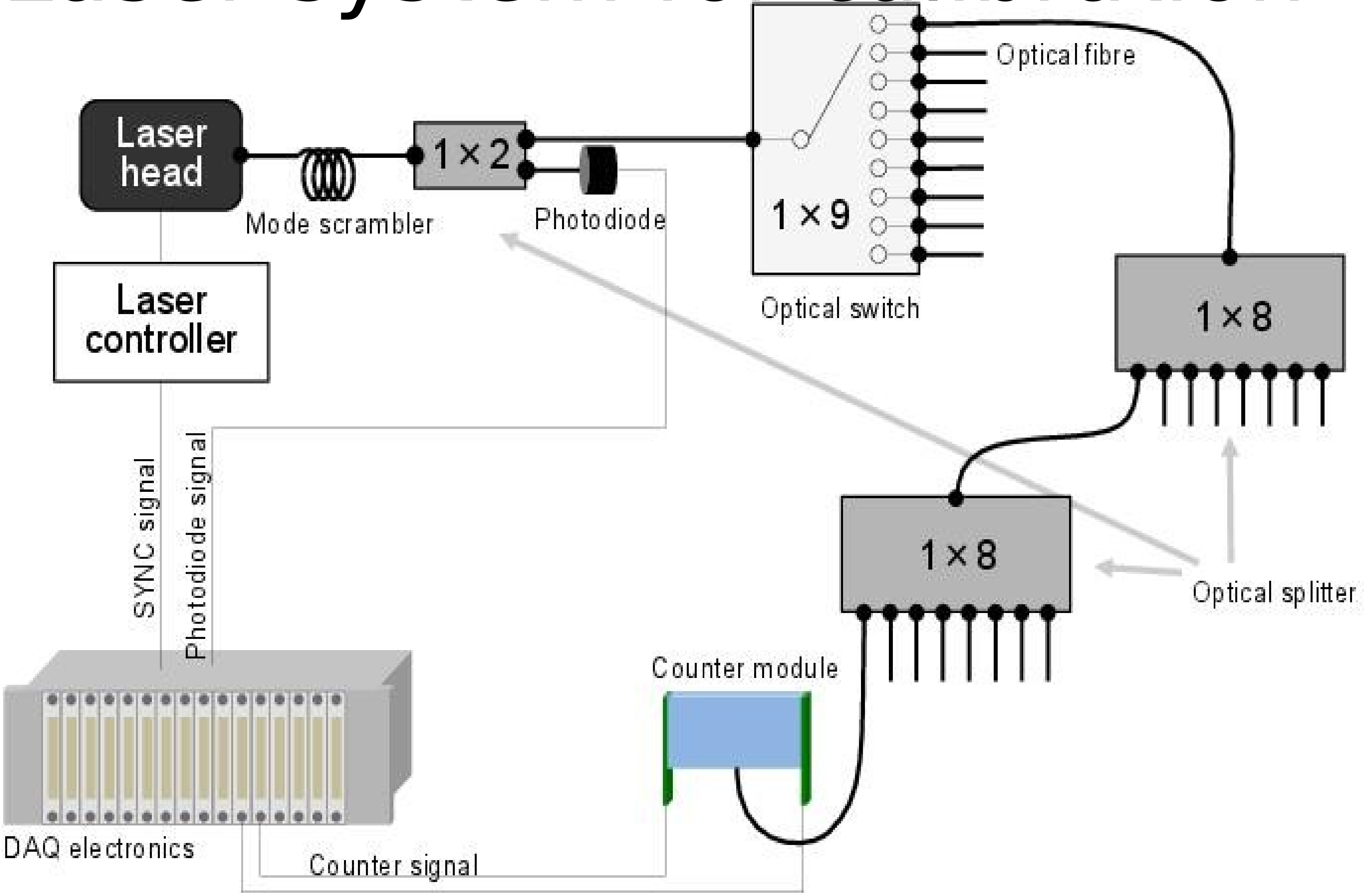
$\langle N_{tiles} \rangle$ per track = 9 $\sigma_t \propto 1/\sqrt{N_{tiles}}$

Status:

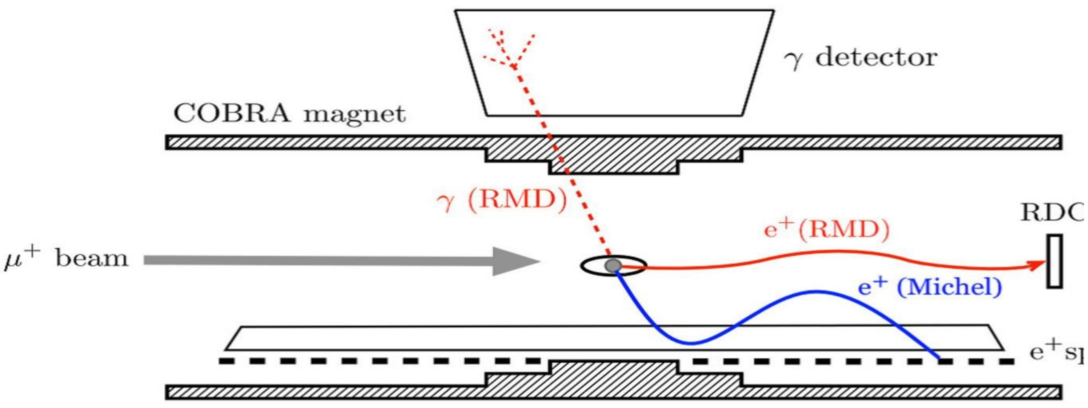
- Excellent resolution achieved with single tile prototypes
- Resolution improvement using multiple tiles confirmed at BTF and PSI (pre-engineering run)
- Tile configuration and detector layout finalized
- All detector ready this fall

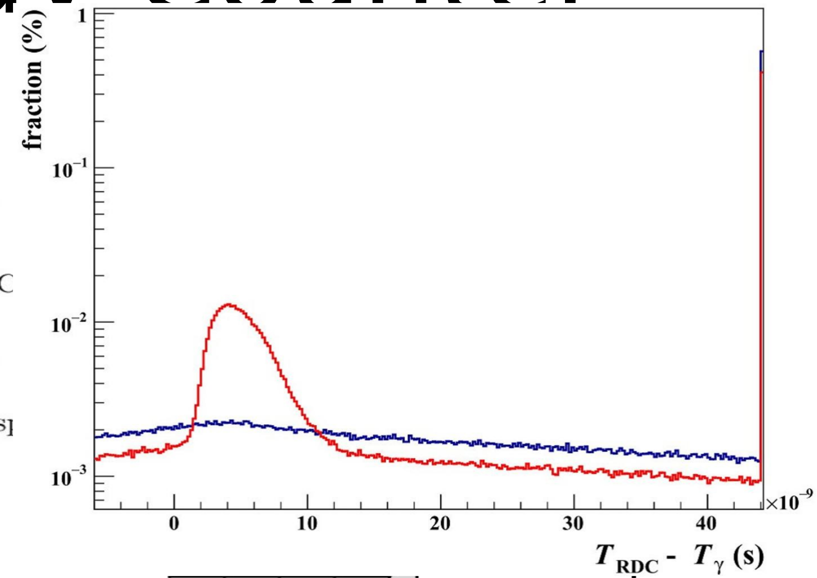

Side view
View from downstream

Laser system for calibration

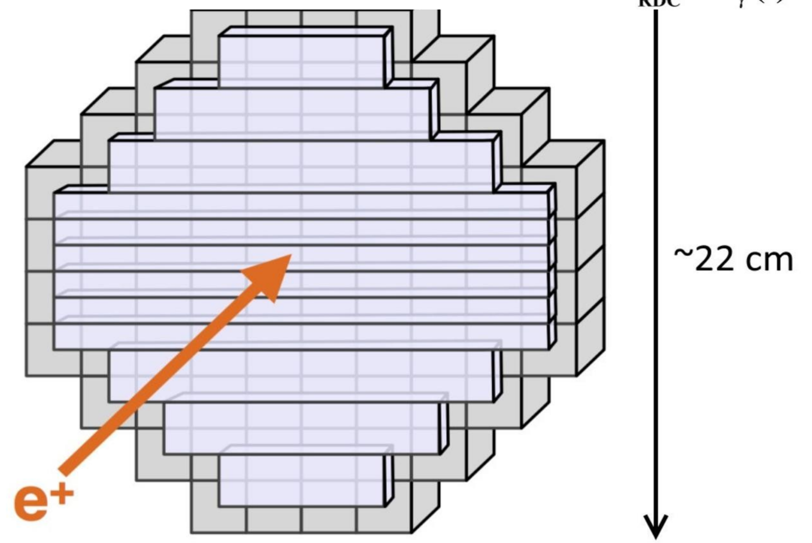


Radiative Decay Counter





The RDC detect low momentum positrons time-correlated with high energy photons (>48MeV).
These photons are a major source of accidental background when associated to positron from different muon decay.



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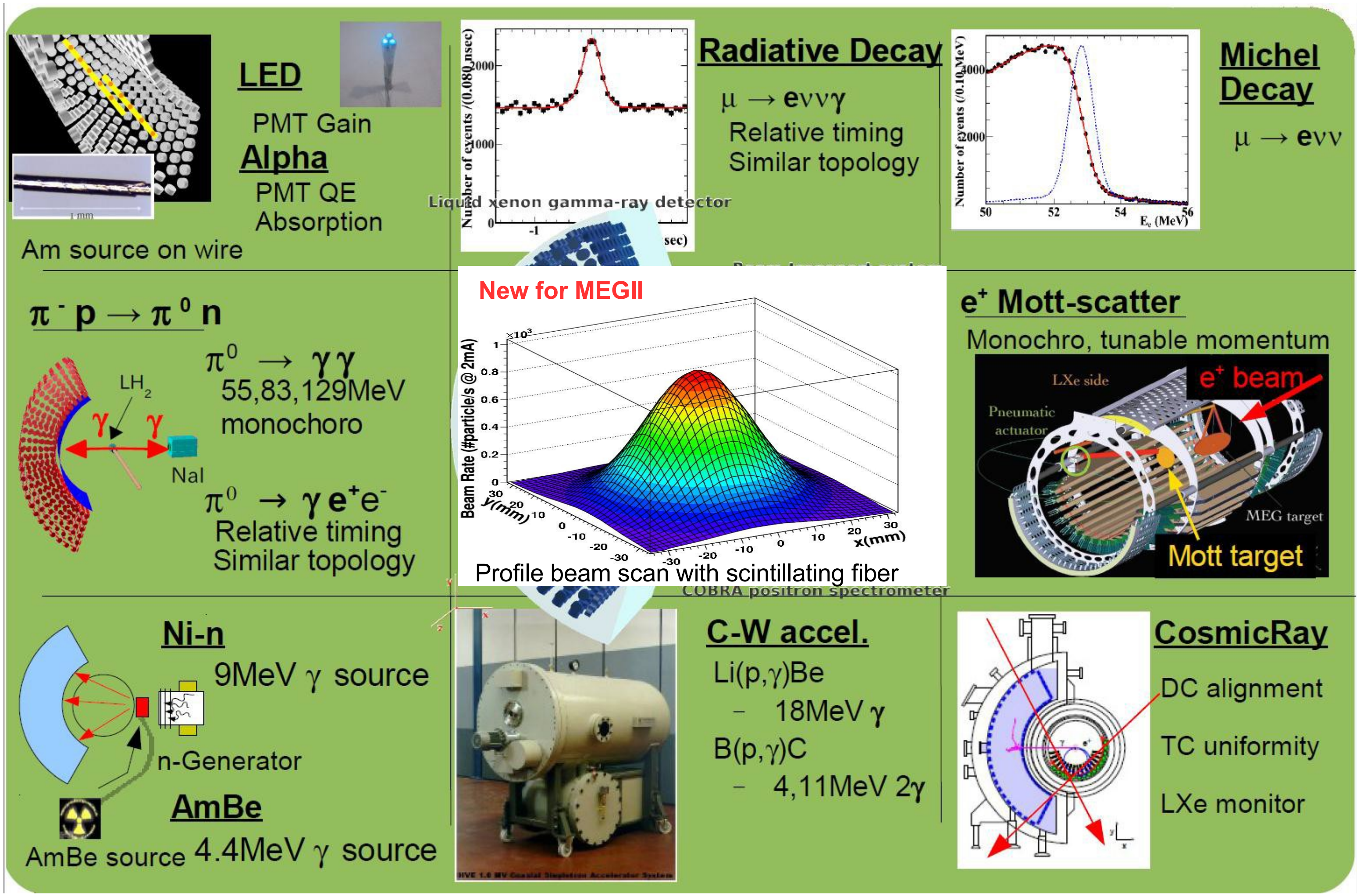
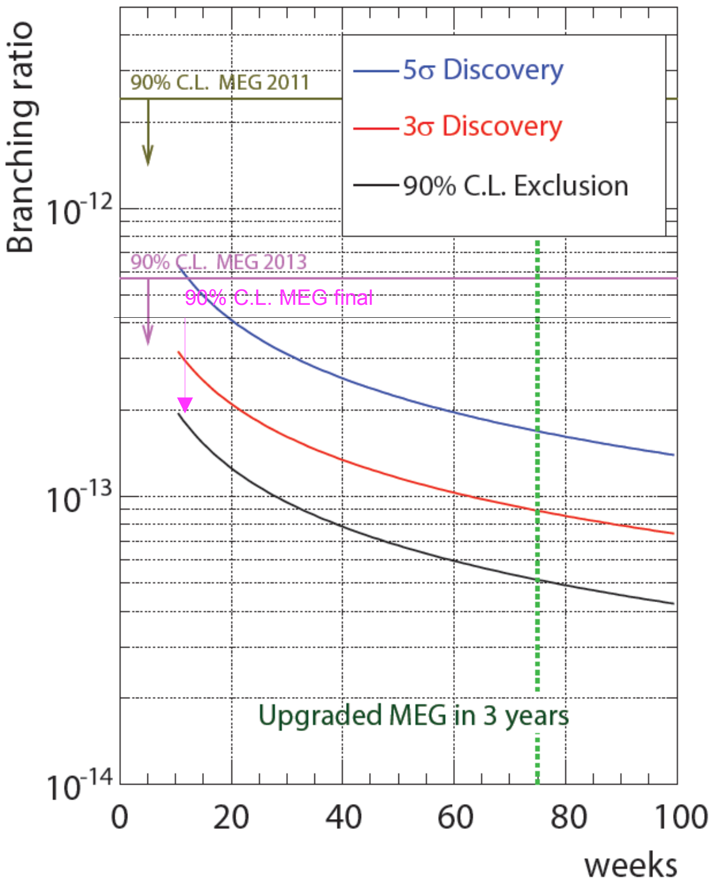
Calibration & Monitoring



arXiv:1301.722

MEG-II outlook

Resolution	MEG I	MEG II
e^+ momentum	0.31 MeV	0.13 MeV
e^+ angle	8.7 / 9.4 mrad	3.7 / 5.3 mrad
e^+ vertex	2.4 / 1.2 mm	1.6 / 0.7 mm
e^+ time	107 ps	33 ps
γ energy	1.27 / 0.9 MeV	0.58 / 0.53 MeV
γ position	5 / 5 / 6 mm	2.6 / 2.2 / 5 mm
γ time	67 ps	76 ps
Efficiency		
trigger	$\approx$ 99%	$\approx$ 99%
γ	63%	69%
e^+	40%	88%



Engineering run end of 2017

Physics run end of 2018

On behalf of the MEGII Collaboration

Thank you for your attention!

MEG-I conclusion

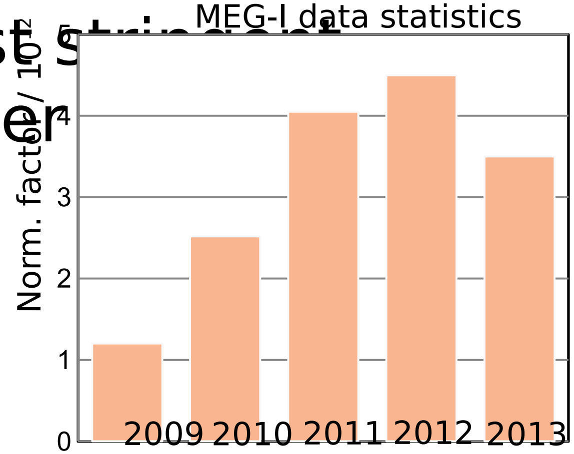
Most recent analysis:

Combined 2009-2011 analysis did not show a significant excess of signal over background, resulting in a factor 4 improvement of the world's most s… BR($\mu \to e\gamma$) upper

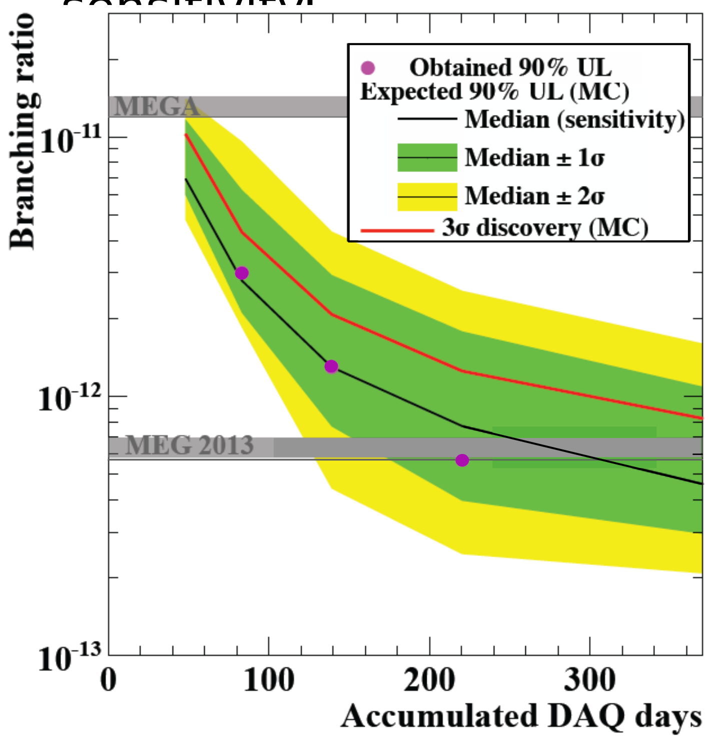
$\mathrm{Br}(\mu^+ \to e^+\gamma) < 5.7 \cdot 10^{-13}$ (90% C.L.)

MEG-I outlook:

- MEG-I data taking finished in 2013
- Total statistics incl. 2012+2013 data is expected



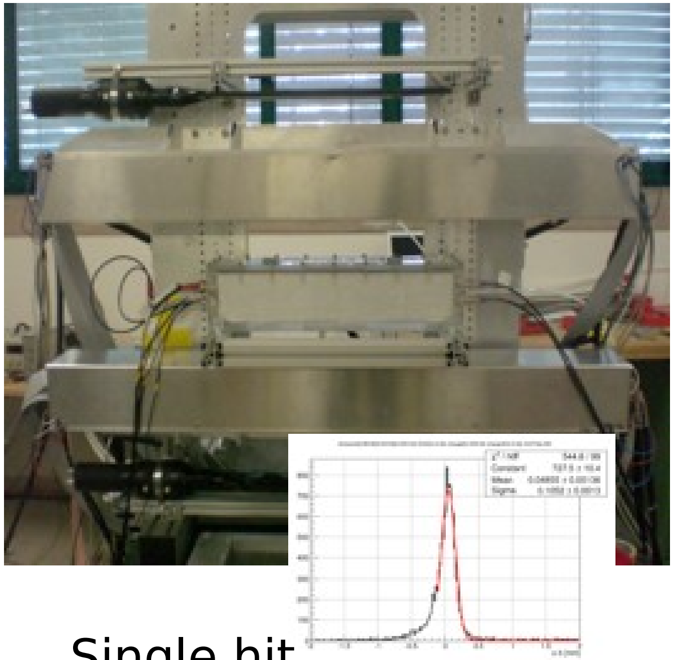
- Observed BR limits & sensitivity:



arXiv:1301.722

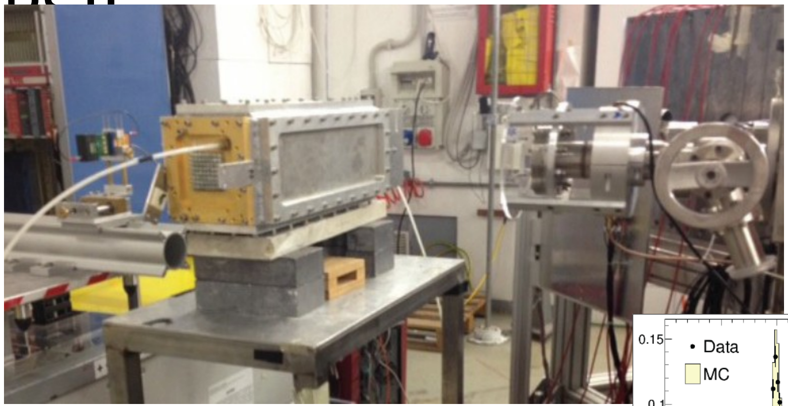
Drift chamber R&D

Cosmic ray telescope:

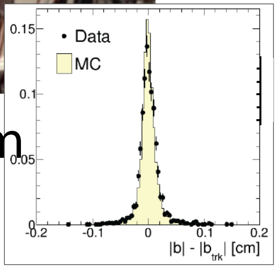


Single hit resolution: 105 µm

Beam tests @ LNF and PSI:



Single hit resolution: 125 µm



Status:

- Prototypes successful, resolution and ageing better than design specs
- Chamber design finalized
- Mock-up chamber with full sector of wires to be tested at PSI this fall