Latest result and future prospect of MEG

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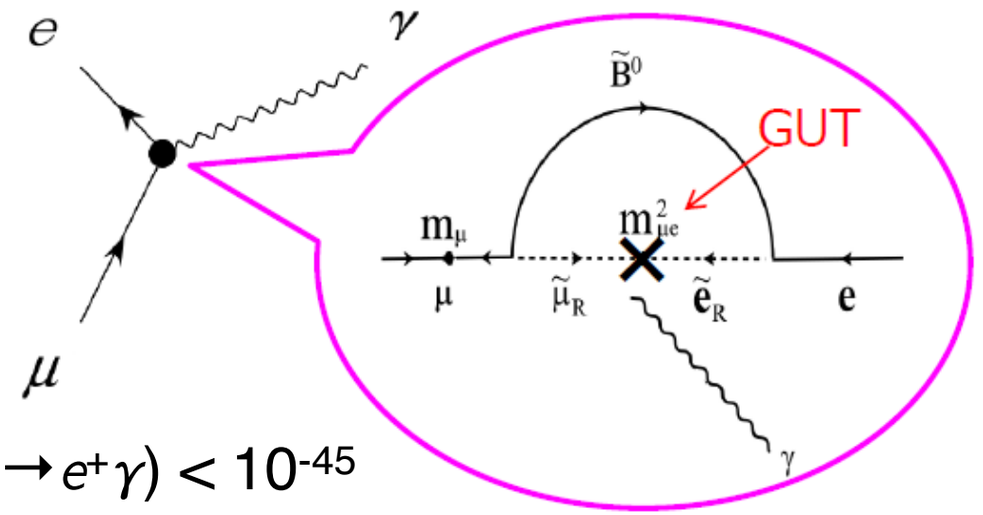
on behalf of the MEG and MEG II collaboration
ICEPP, the University of Tokyo

SUSY 2014
Manchester, 25 July 2014

$\mu^+ \rightarrow e^+\gamma$



- CLFV Forbidden in SM
  - Little SM background through ν oscillation : Br($\mu^+ \rightarrow e^+\gamma$) < 10^{-45}
- So far, no CLFV signal has been observed.
- Many new physics beyond SM (e.g. SUSY, Extra dimensions etc.) predict observable Br (10^{-14} — 10^{-11})
  - Discovery will be an unambiguous evidence of new physics.

- Observed 3.5σ discrepancy of the anomalous magnetic moment of the muon could be due to new physics
  - Strong correlation with $\mu^+ \rightarrow e^+\gamma$
- Complementary search of new physics,
  - LHC Run 2
  - New experiments to search for other muon channels (μ-e conversion, $\mu \rightarrow eee$)

Signal and background

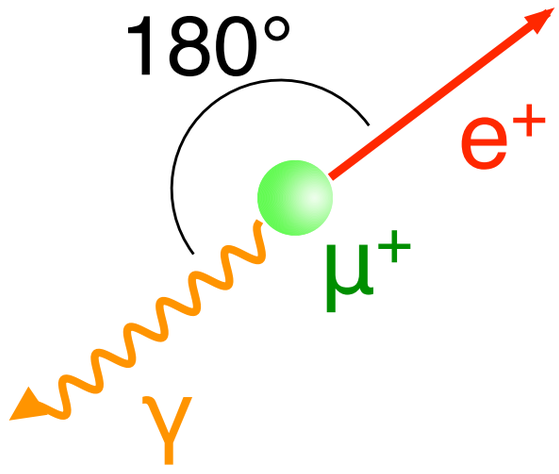
Signal

μ^+ decay at rest

52.8MeV (half of M_μ) (E_γ,E_e)

Back-to-back ($\theta_{e\gamma}$,$\varphi_{e\gamma}$)

Timing coincidence ($T_{e\gamma}$)

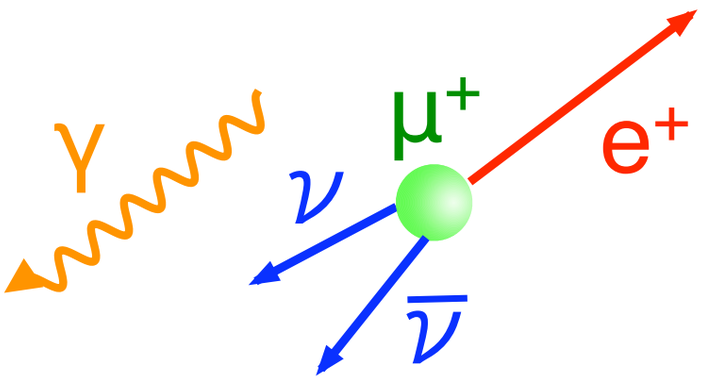


Dominant BG

Accidental background

Michel decay e^+ + random γ

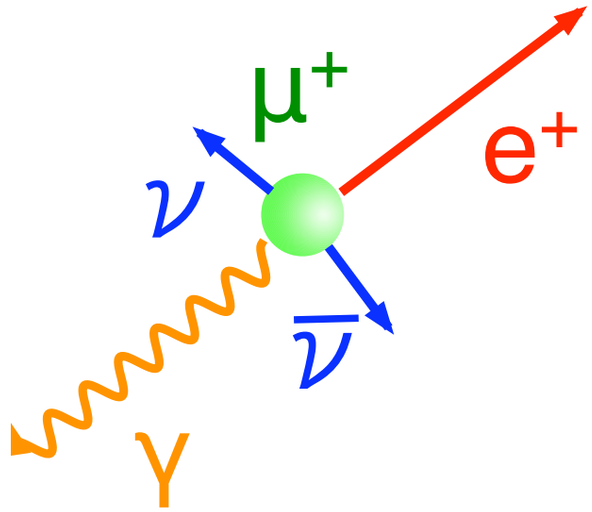
Random timing, angle, E < 52.8MeV



Radiative muon decay

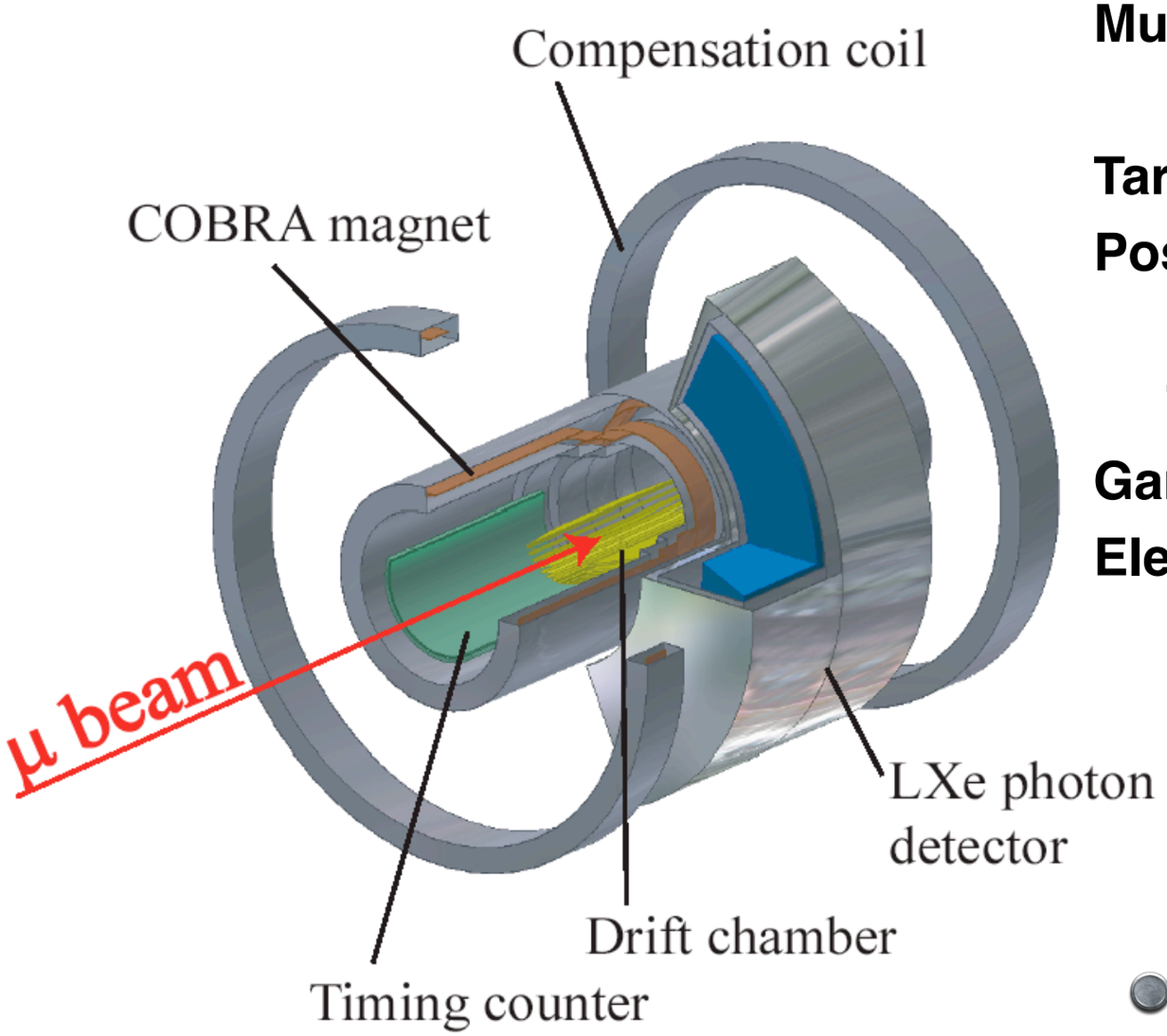
$\mu^+ \rightarrow e^+\nu\nu\gamma$

Timing coincident, not back-to back, E <52.8MeV



MEG Experiment

Searching for the cLFV rare decay $\mu^+ \to e^+ \gamma$ with the highest sensitivity.



Muon beam : Most intense DC beam at PSI
3×10^7 s^{-1} for MEG

Target : 205 μm plastic target

Positron detector :

Drift chamber : Low-mass (2×10^{-3} X_0) chambers

Timing counter : Fast plastic scintillator bars

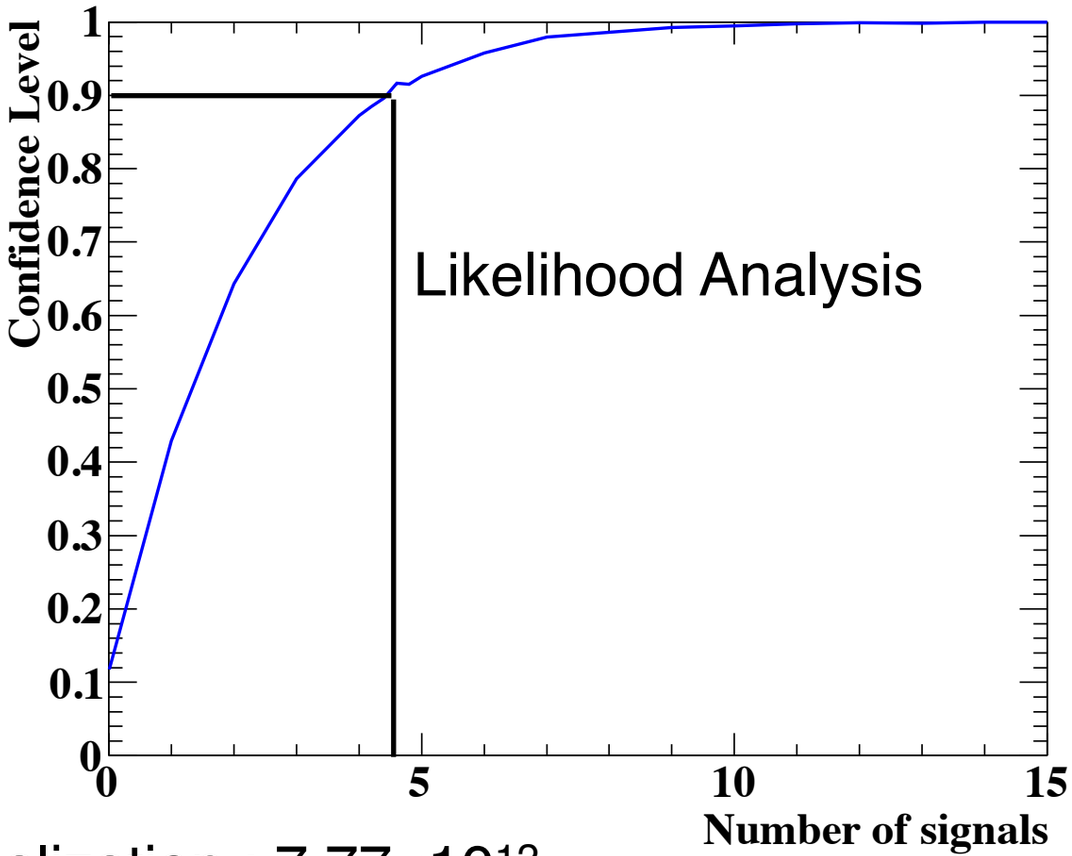
Gamma detector : 900 litter LXe calorimeter

Electronics : FPGA based trigger system
Waveform digitizer (DRS)

- 1999 : Proposal to PSI
- 2009-2013 : Physics run
- The latest result with 2009-2011 data

Latest result

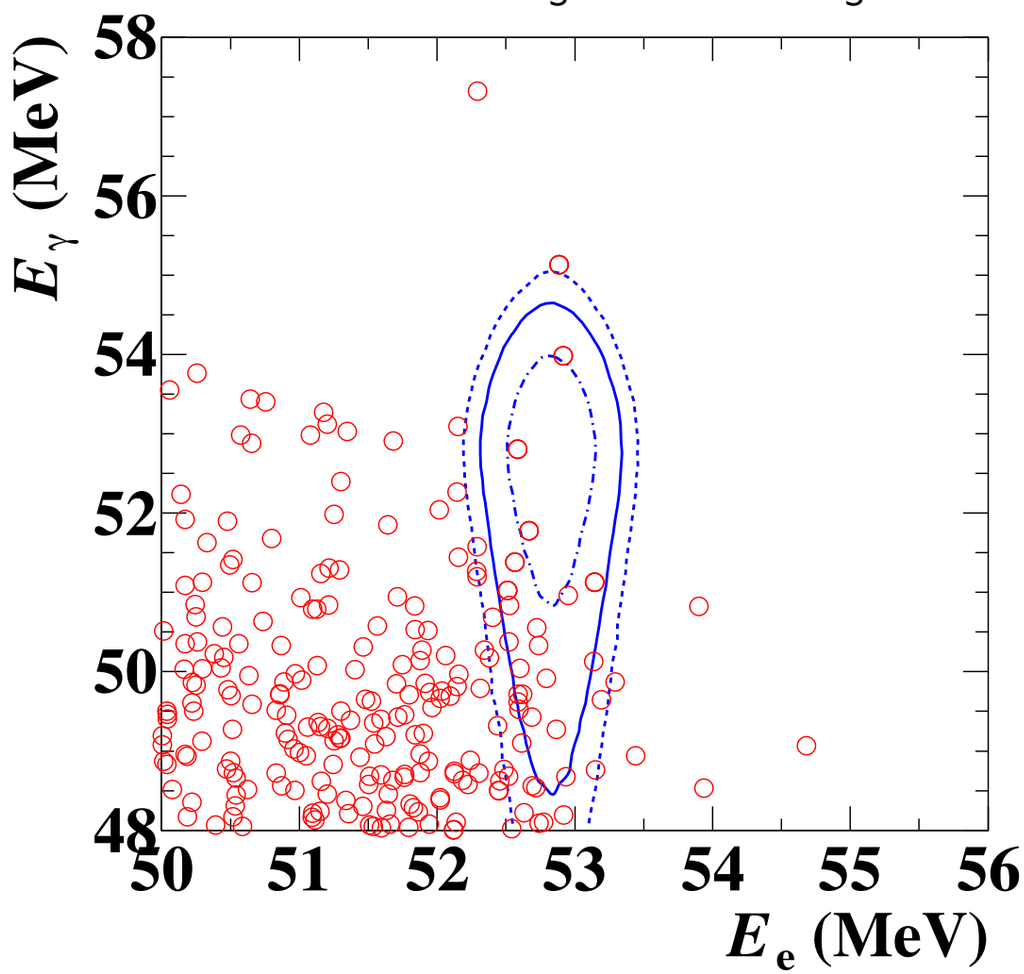
Confidence level



normalization : 7.77×10^{12}

Event distribution

Blue lines : 68, 90 and 95% region of the signal PDF



arXiv:1303.0754 [hep-ex]
Phys. Rev. Lett. 110, 201801 (2013)

$Br(\mu^+ \to e^+\gamma)$

Sensitivity	7.7×10^{-13}
Best fit	-0.6×10^{-13}
Uppler limit @ 90% C.L.	**5.7×10^{-13}**

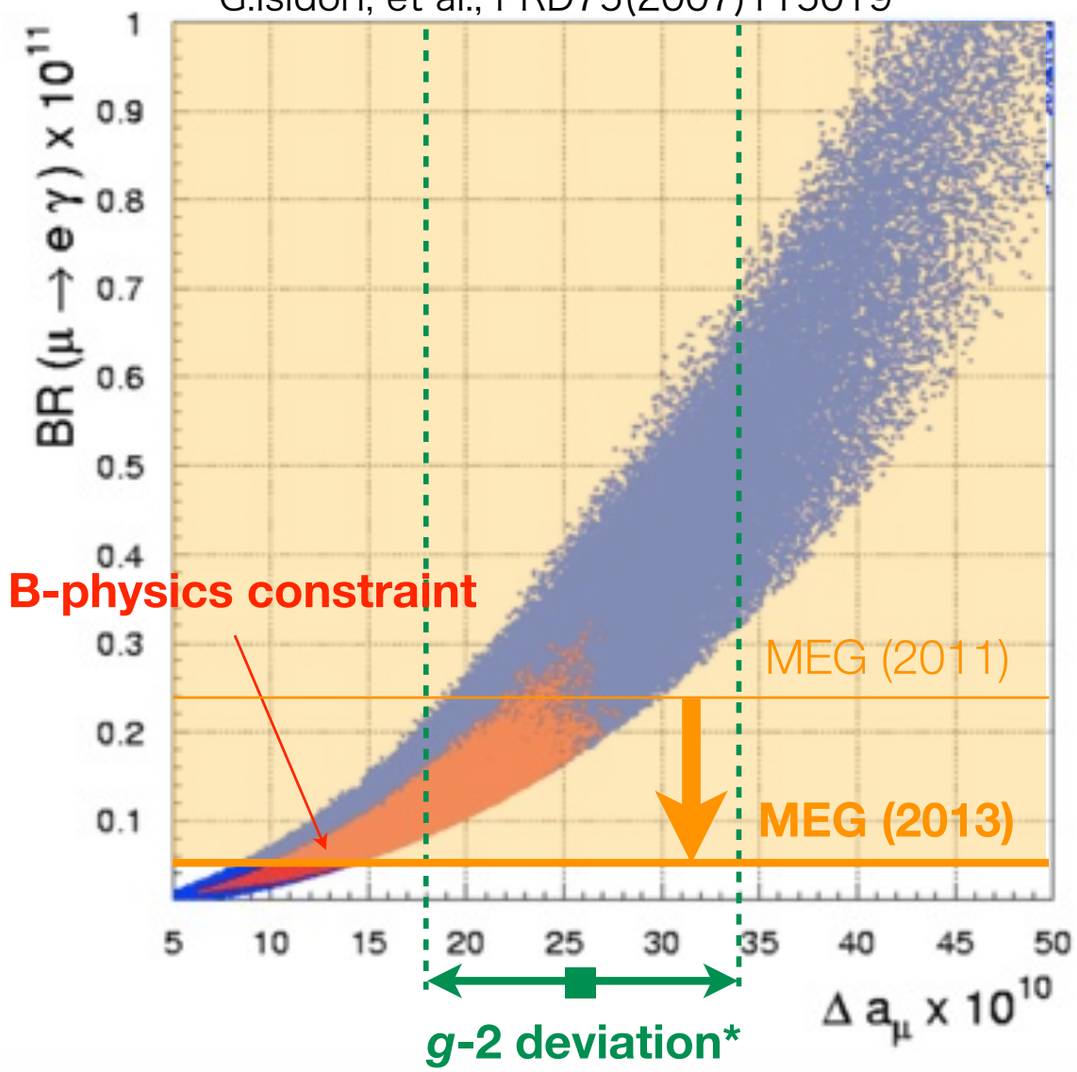
Systematic uncertainties (in total 1% in UL)

- relative angle offsets
- correlations in e^+ observables

New Physics constraints

SUSY-GUT

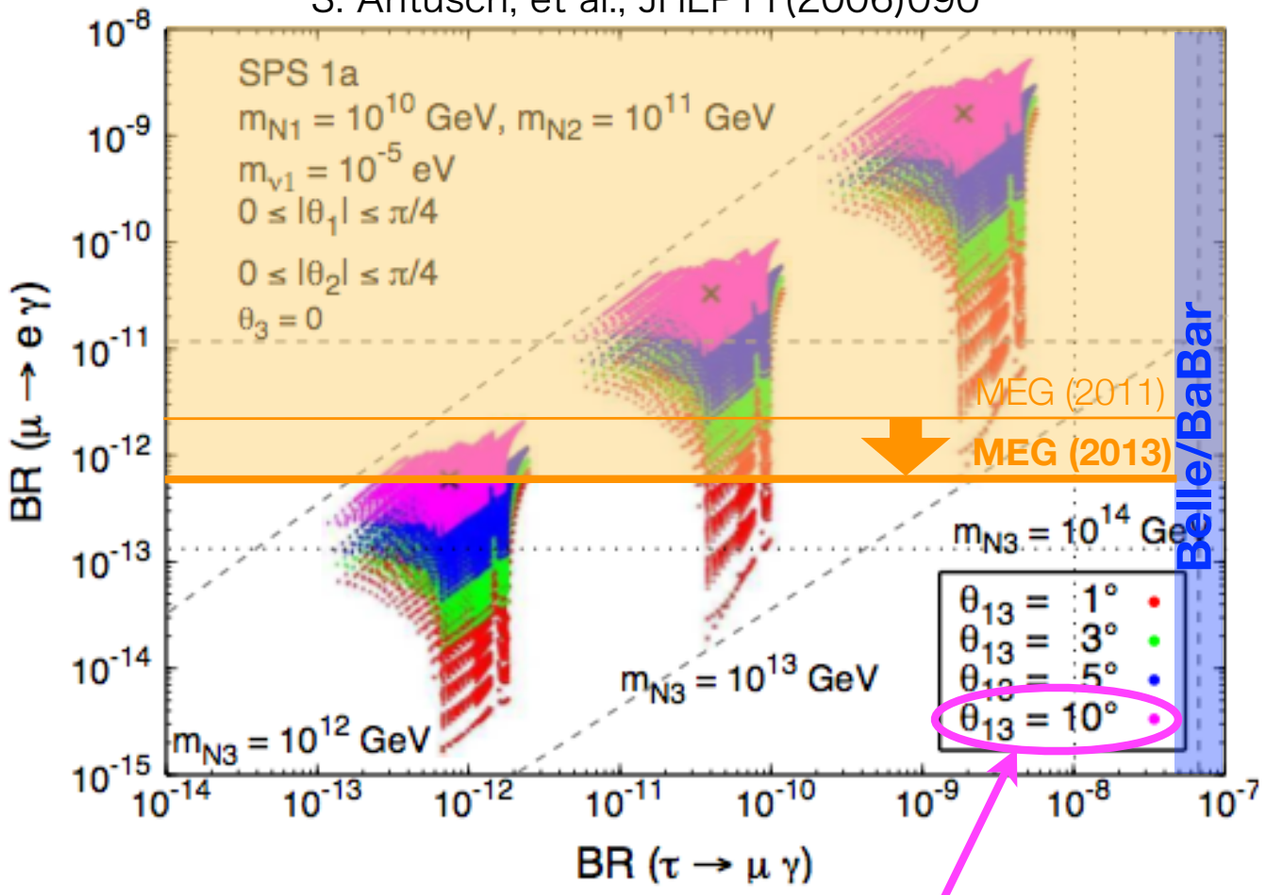
G.Isidori, et al., PRD75(2007)115019



* a_μ(EXP):PRD73(2006)072,
a_μ(SM):Hagiwara et al., JPG38(2011)085003

SUSY-Seesaw

S. Antusch, et al., JHEP11(2006)090



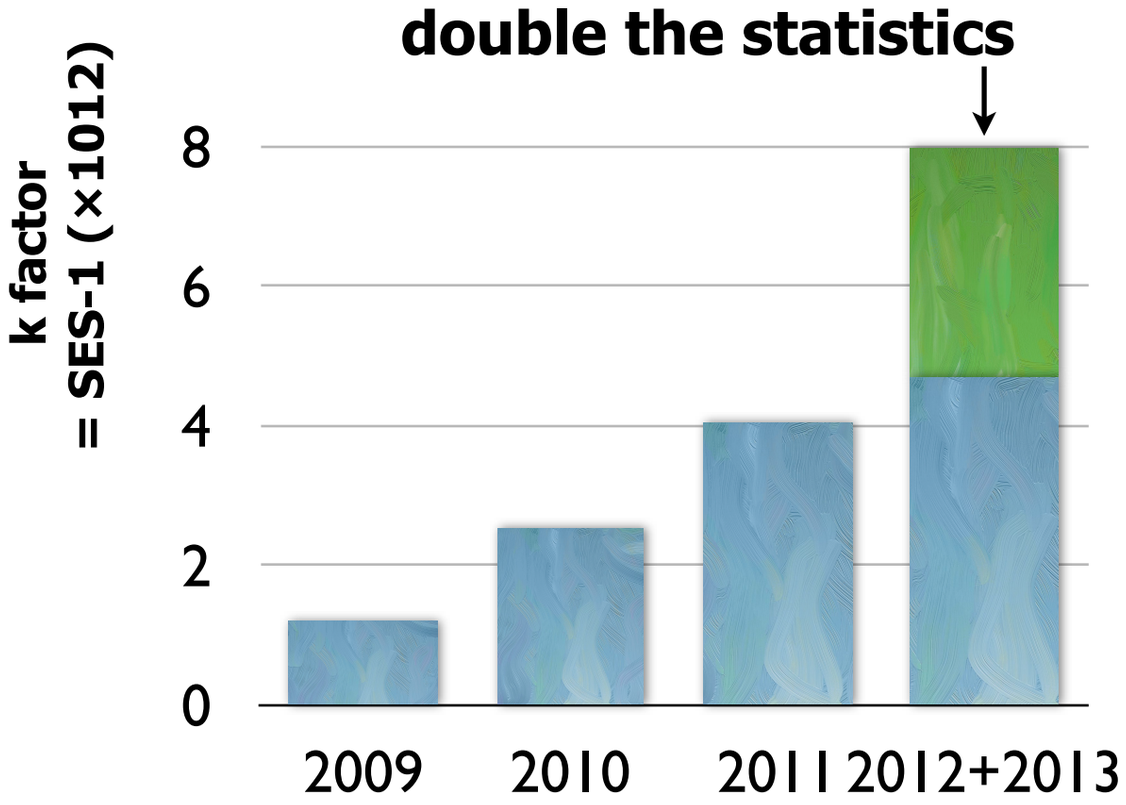
Large θ_{13} measured (~9°)!

New data

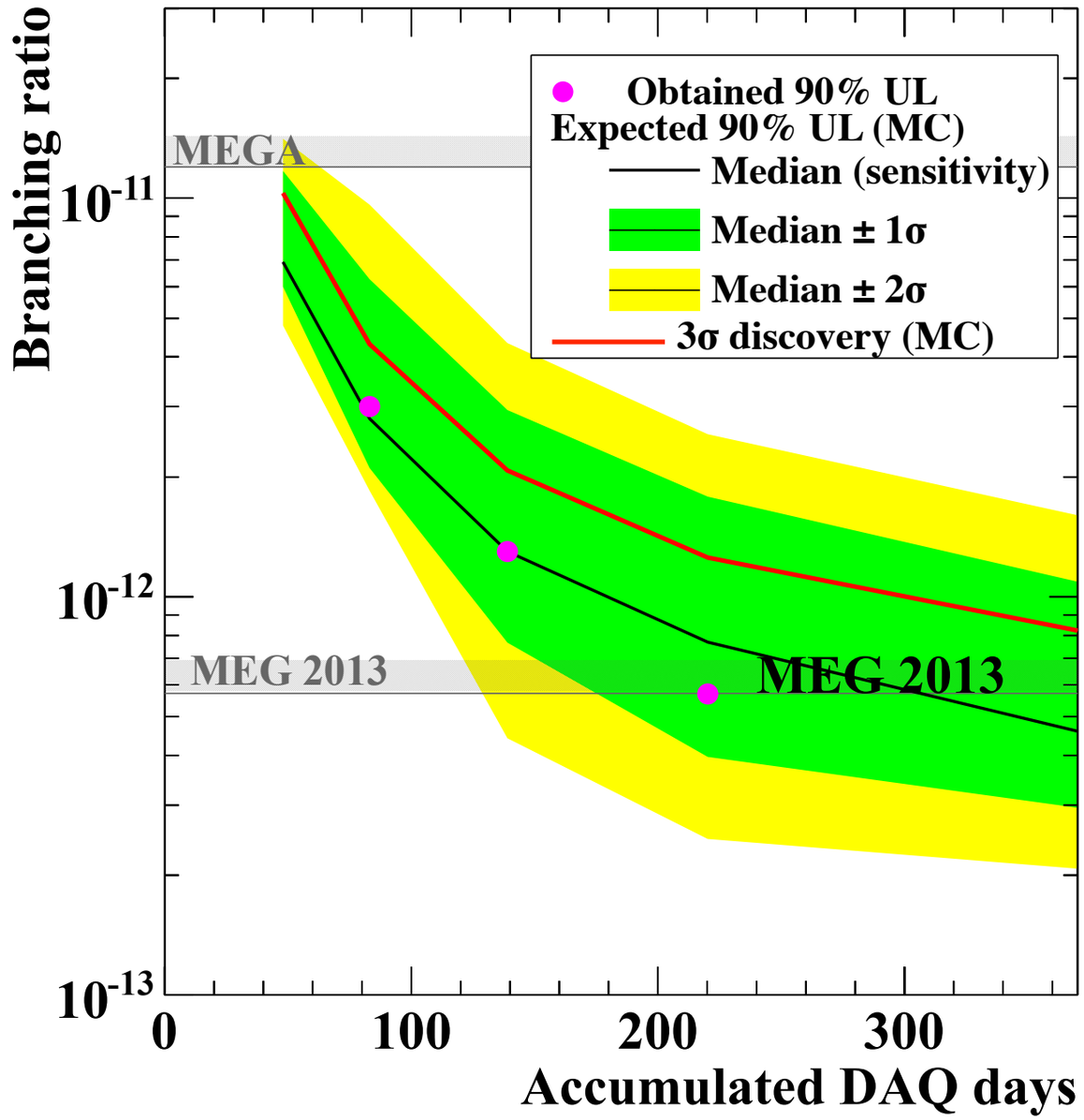
2009-2011data sensitivity
7.7×10^{-13}

Expected 2009-2013 data sensitivity
$\sim5\times10^{-13}$

Even further improvement is expected

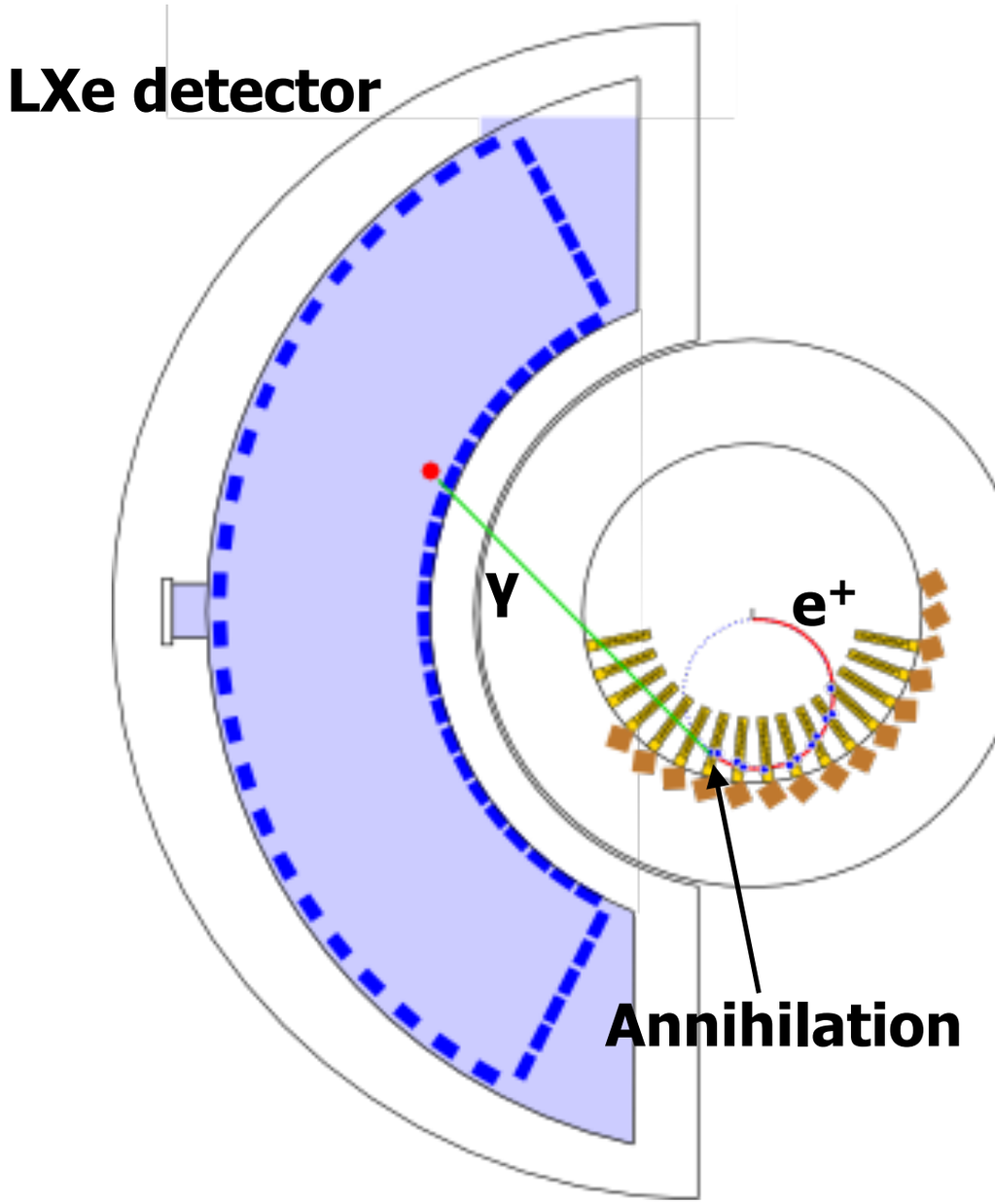


Observed limits and sensitivity



Status and future

- Data process status
  - Calibration of new data is finished.
- Further improvements and crosschecks.
  - New analysis for identifying gamma rays from positron annihilation-in-flight.
    - ~15% improvement of sensitivity is expected.
  - Re-measuring magnetic fields with a new device.



Final analysis of the full dataset by the end of 2014

MEG II

— Upgrade —

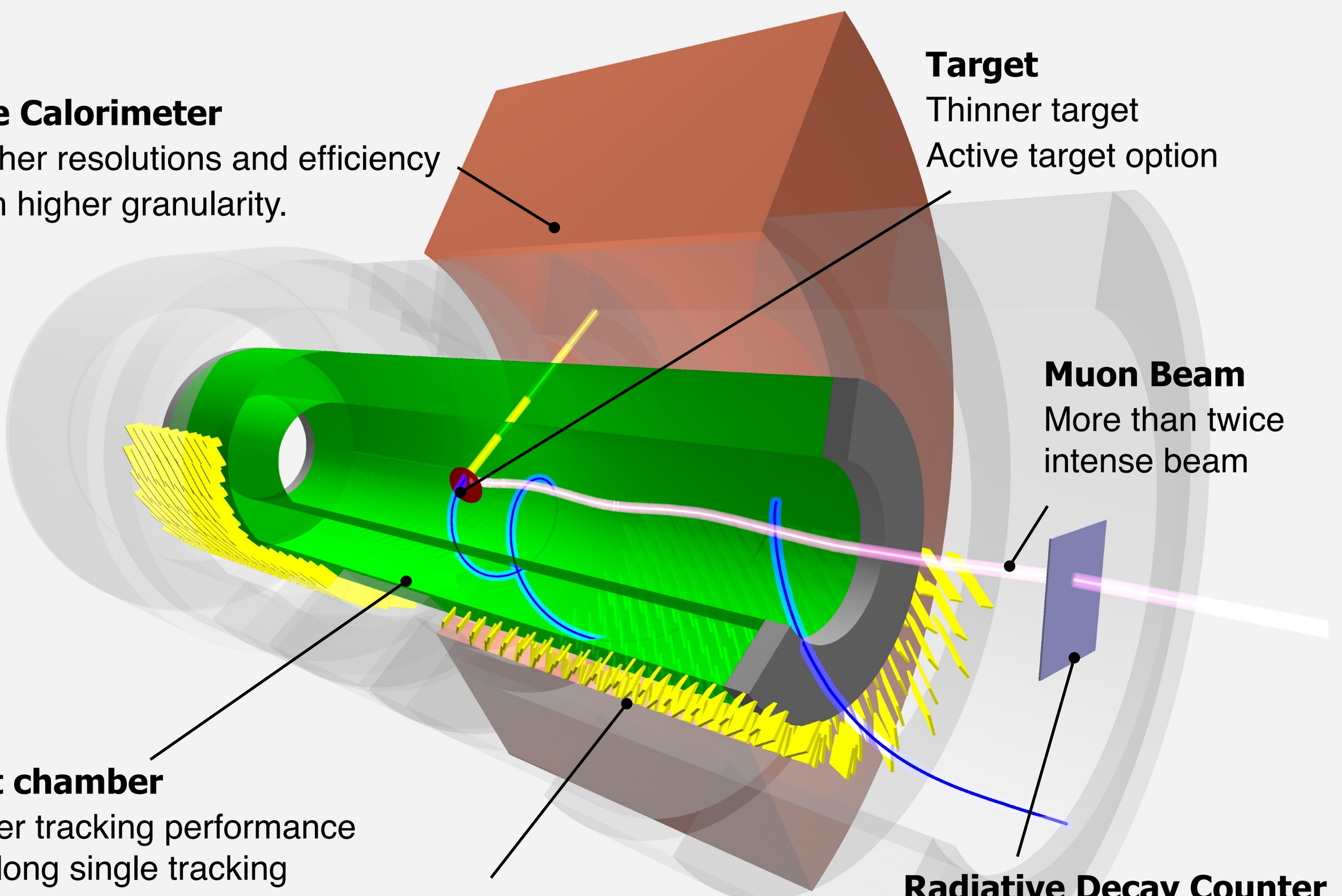
MEG II

- Major upgrade of the experiment for 10 times higher sensitivity.
- Upgrade concept
  - Double beam intensity
  - Double detector efficiency
  - Factor ~30 background suppression
    - Improved detector resolutions
    - Possibility to add a new detector to identify background events
- Start the new experiment from 2016

LXe Calorimeter
Higher resolutions and efficiency with higher granularity.

Target
Thinner target
Active target option

Muon Beam
More than twice intense beam



Drift chamber
Higher tracking performance with long single tracking volume

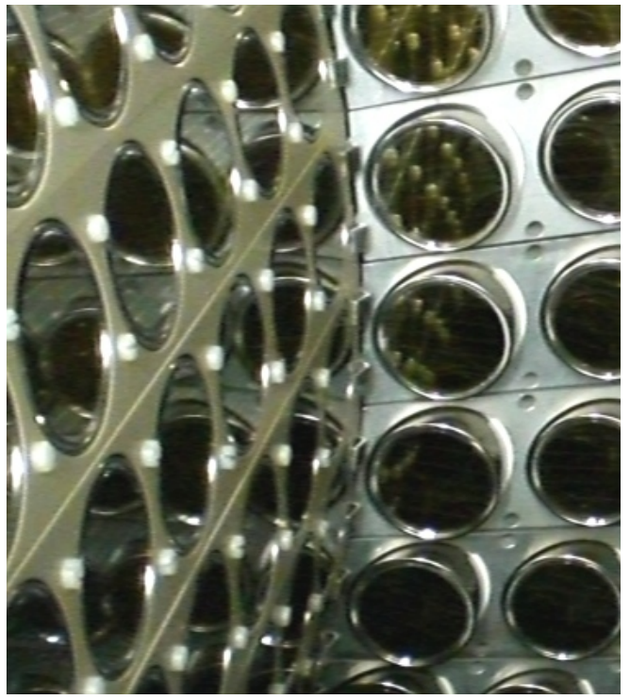
Timing Counter
Higher time resolution with highly segmented detector

Radiative Decay Counter
Identify gammas from muon radiative-decays (optional)

Calorimeter upgrade concept

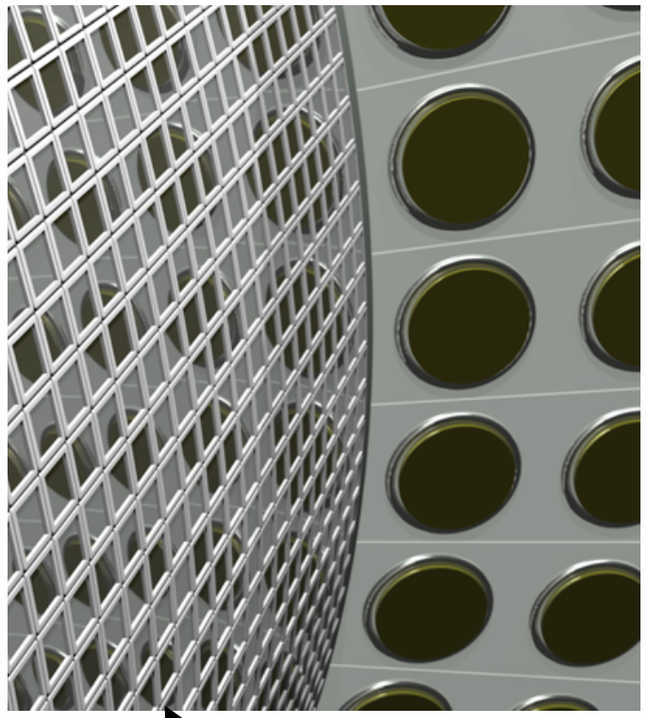
- Improved layout of PMTs
- Replace 2” PMTs on inner face with newly developed VUV-sensitive SiPMs

Present



2 inch PMT
216 ch

Upgraded



computer graphics

12×12 mm² SiPM
~ 4000 ch

	Present	Upgraded
Energy resolution [%]	2.4 / 1.7	1.1 / 1.0
Position resolution [mm]	5 / 5	2.6 / 2.2
Detection Efficiency	63	69

shallow / deep events
(d = 2cm)

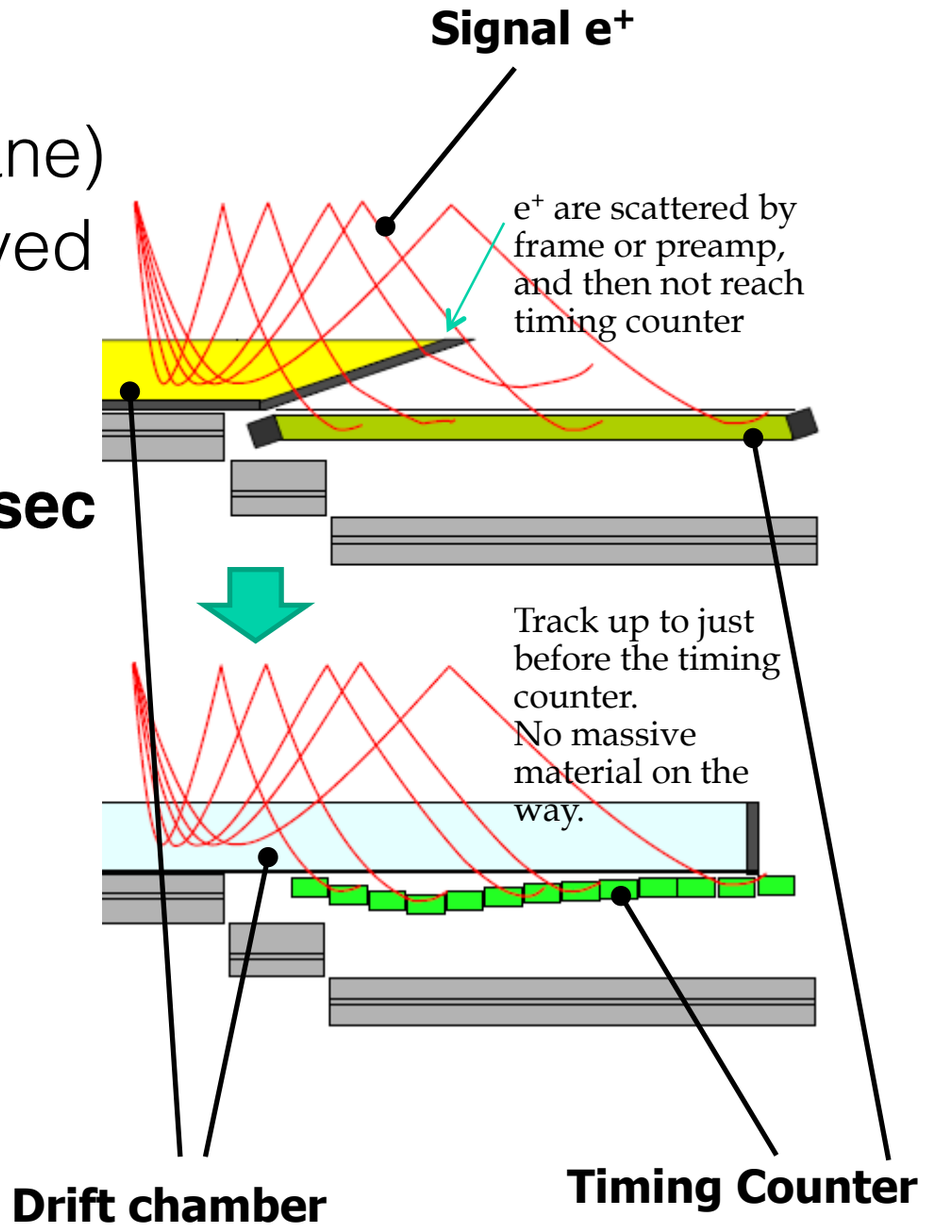
horizontal / vertical

16 times granularity

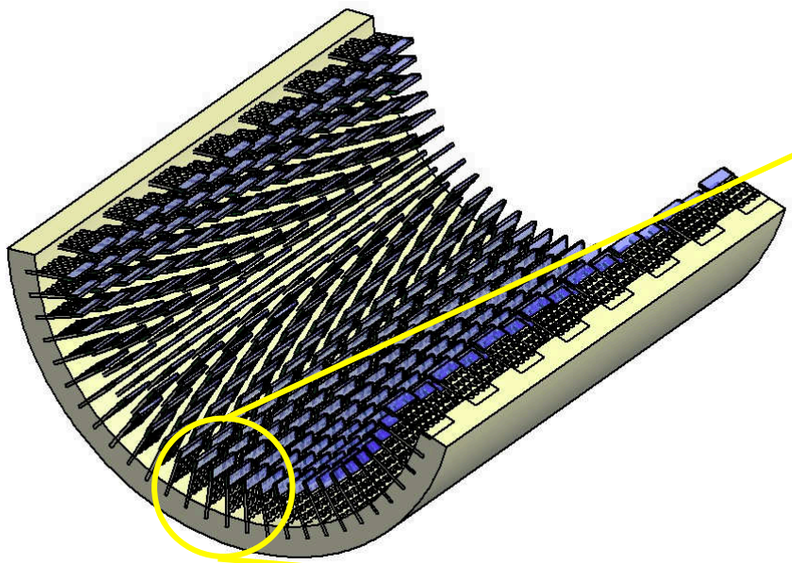
Factor 2 better energy and position resolutions
10% higher efficiency

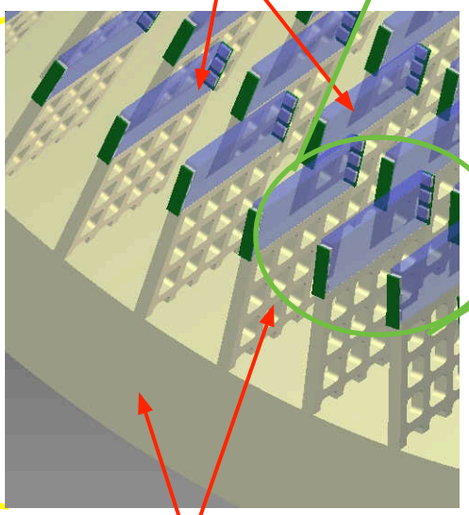
Cylindrical drift chamber

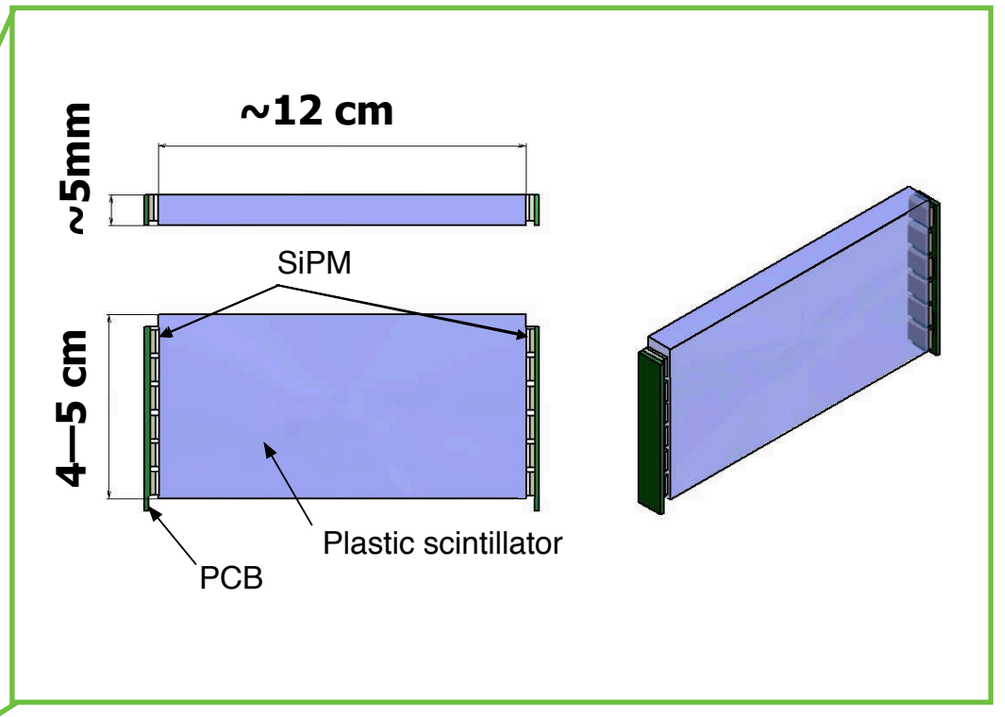
- Gas volume
  - Lower Z gas mixture (85% He + 15% iso-butane)
  - Unique 2m-long chamber-gas volume, improved transparency to timing-counters.
    - **Double** the detection efficiency
    - Improve the Time-Of-Flight error down to **10 psec**
- Wire configuration
  - Stereo-angle configuration for longitudinal position
  - Single hit spacial resolution of **120 μm**
  - Finer granularity (7 mm cell) and higher multiplicity (15 → 60 hits per track)



Timing Counter



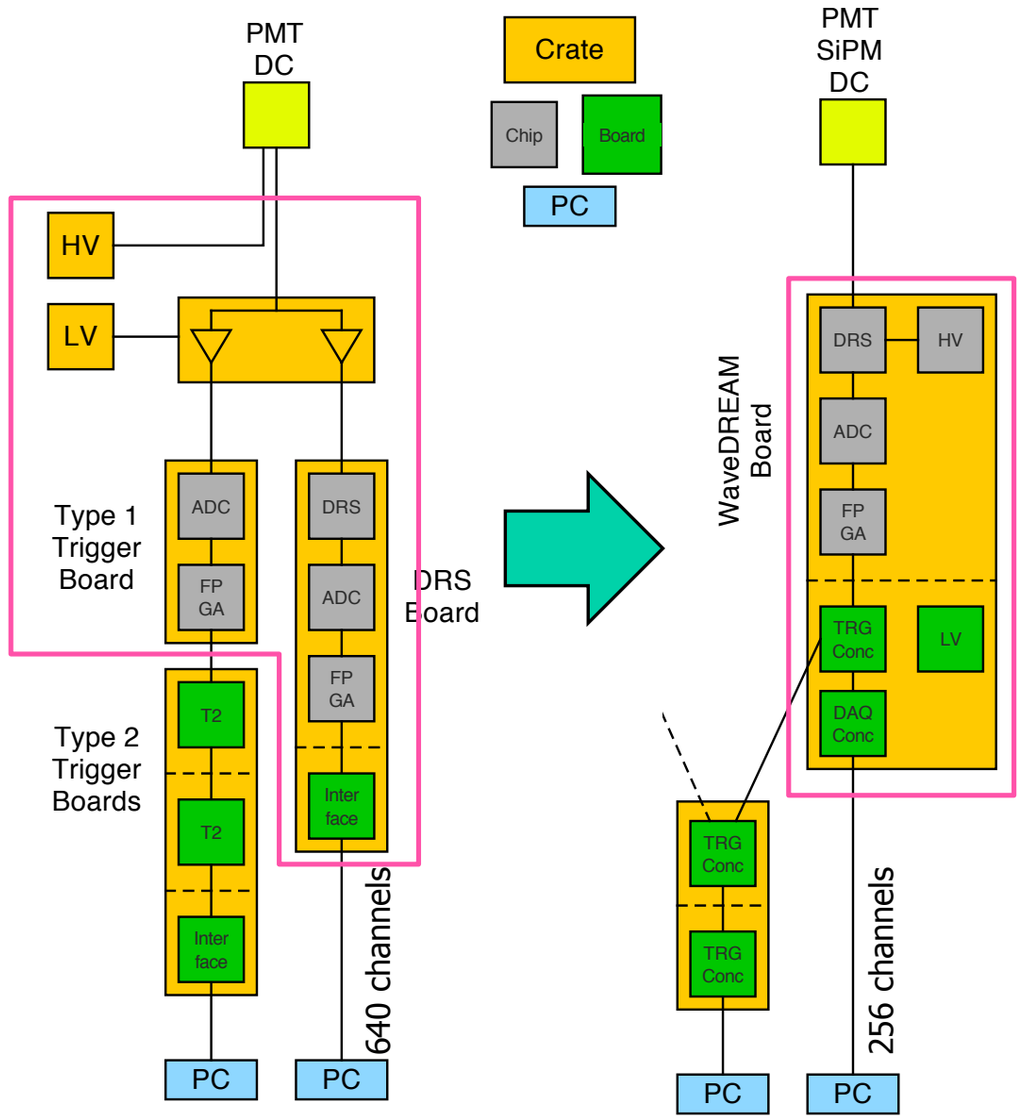




- Many small plastic counters.
- Six SiPMs are directly attached on both sides for high light-collection efficiency.
  - SiPMs on the same side are attached in series to read with a single channel.
- In average, ~8 counters hit by a signal positron.
  - **30 psec** time resolution by averaging the hit-times

Electronics and Trigger

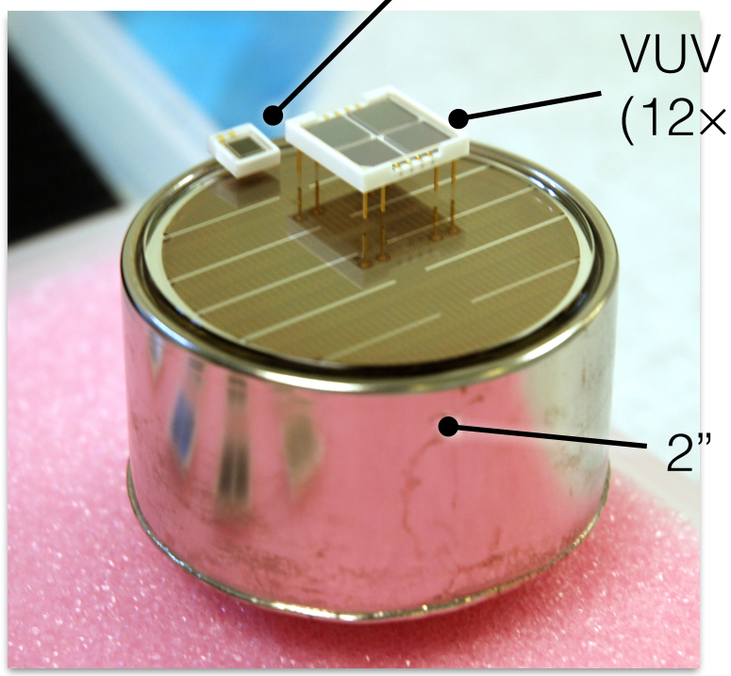
- Much more number of channel of waveform digitizer
  - 3U Eurocard crate (instead of VME)
- We will use many SiPMs, for LXe, TC and optional detectors.
  - Newly developed **WaveDREAM** board contains HV, amplifier and waveform digitizers for trigger and offline analysis.
- Data transmission
  - Serialization protocol with GB capability (possible with on-board FPGAs)



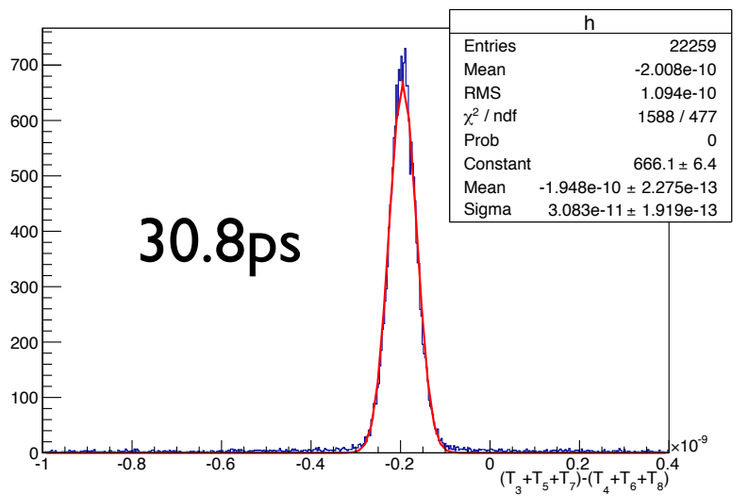
Detector R&D highlights

- LXe calorimeter
  - New type of VUV-sensitive SiPM with 15% PDE for LXe light was developed.
- Drift chamber
  - Good (~110 μm) spacial resolution for cosmic-rays was confirmed with a prototype chamber.
  - Long term stability against aging was confirmed to be ok.
- Timing counter
  - Good resolution (30 psec) was measured in a electron beam test

Photo sensors for LXe



Result of TC beam test



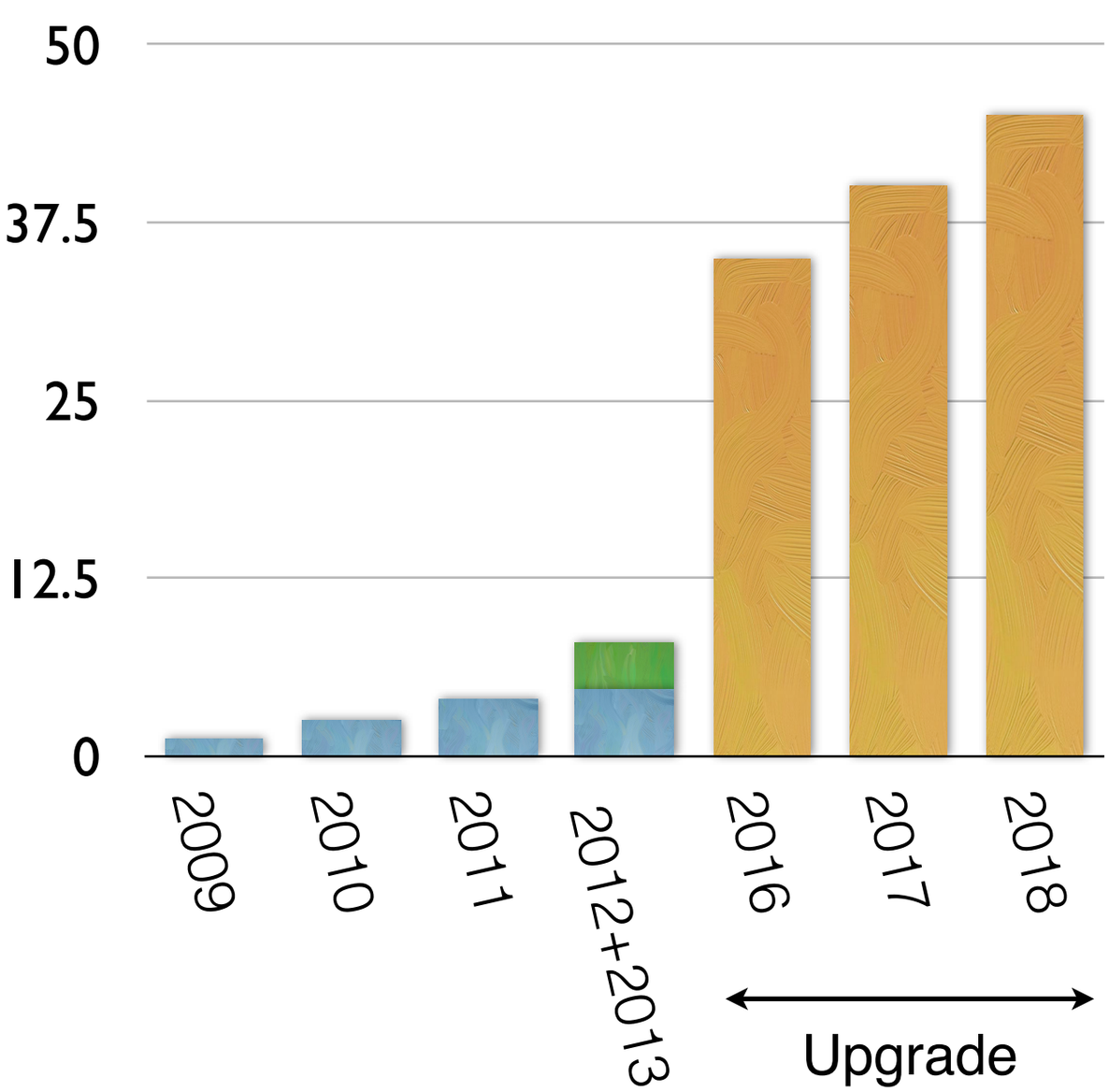
MEG II performance

Resolution (Gaussian σ) and efficiencies for MEG upgrade

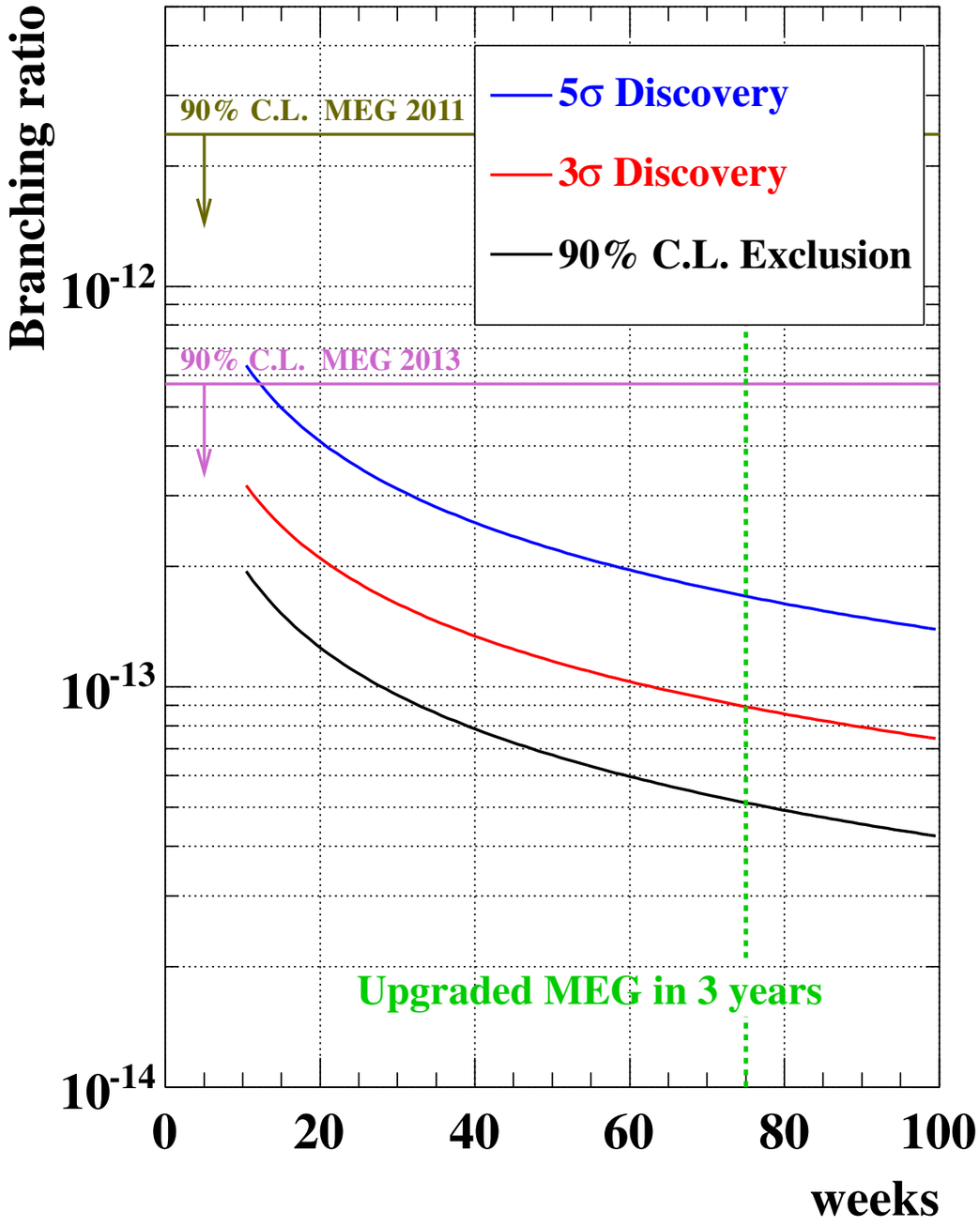
PDF parameters	Present MEG	Upgrade scenario
e^+ energy (keV)	306 (core)	130
e^+ θ (mrad)	9.4	5.3
e^+ ϕ (mrad)	8.7	3.7
e^+ vertex (mm) Z/Y(core)	2.4 / 1.2	1.6 / 0.7
γ energy (%) (w <2 cm)/(w >2 cm)	2.4 / 1.7	1.1 / 1.0
γ position (mm) $u/v/w$	5 / 5 / 6	2.6 / 2.2 / 5
γ-e^+ timing (ps)	122	84
Efficiency (%)		
trigger	$\approx$ 99	$\approx$ 99
γ	63	69
e^+	40	88

MEG II sensitivity

Statistics



Sensitivity prospect



5×10^{-14} sensitivity with 3 years DAQ

Summary

- For the **final result of phase I**, MEG will double the data
  - Further improvement of analysis is expected.
  - Trying to finish analysis in this year.

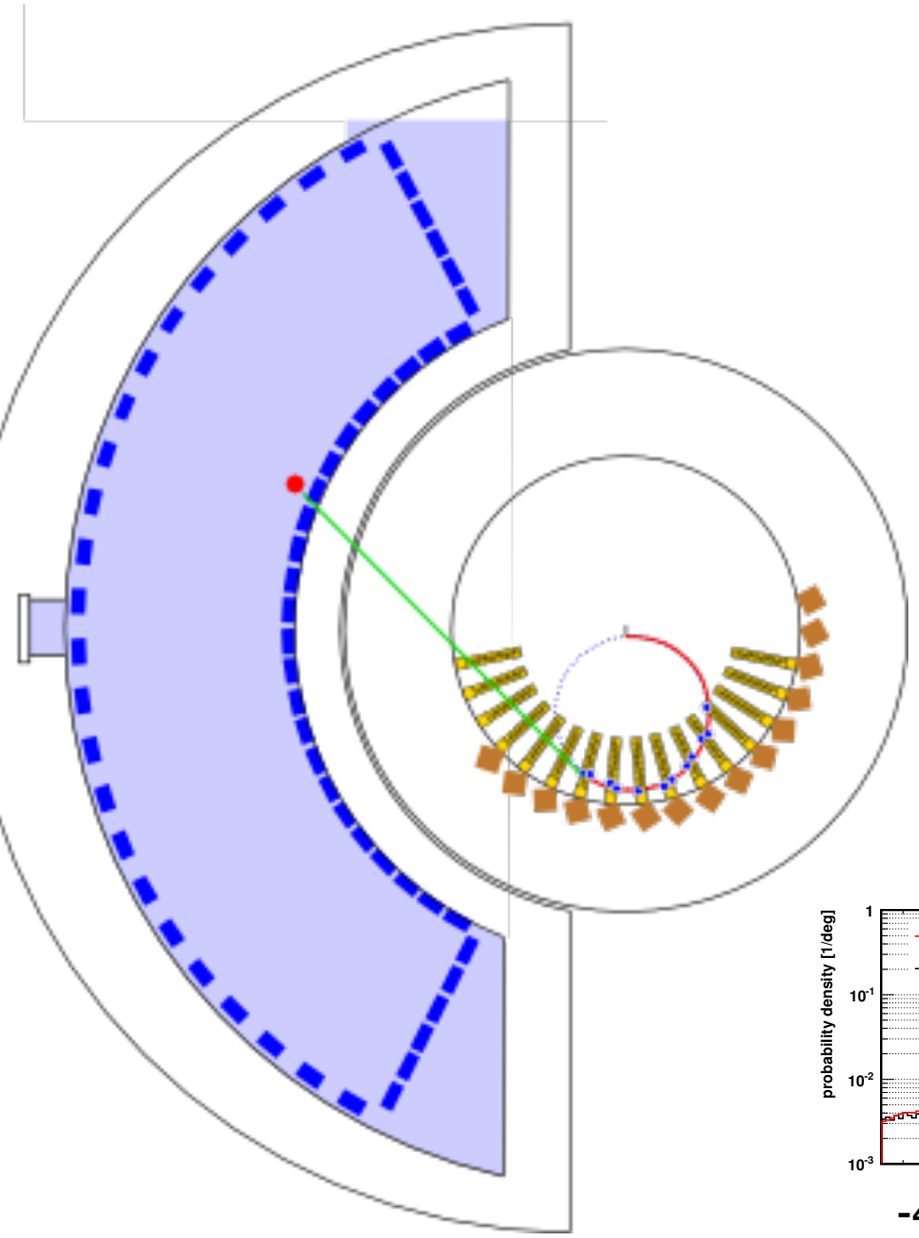
Br ($\mu^+ \to e^+\gamma$) sensitivity × 10^{13}

MEG I	Latest publish	7.7
	Expectation	5
MEG II	Expectation	0.5

- **MEG II** is planned for reaching 10 times higher sensitivity
  - Starting new measurements from 2016, three years data-taking.
  - Design sensitivity of **5×10^{-14}** on Br($\mu^+ \to e^+\gamma$)

Backup

AIF Analysis

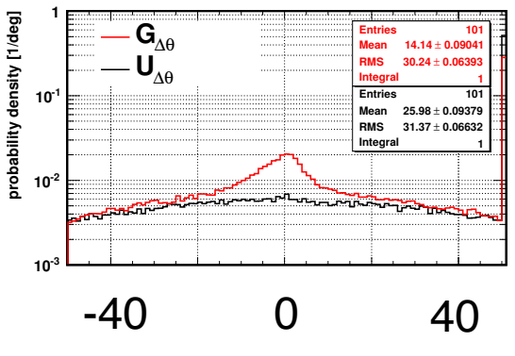


Annihilation in flight (AIF) is one of the main BG γ source.
Mainly come from the target and drift-chamber.

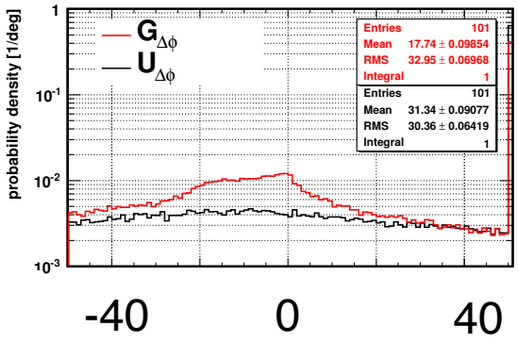
New analysis was developed to match a vanished positron and a hit in LXe detector

The matching variable will be used in the physics analysis as PDFs

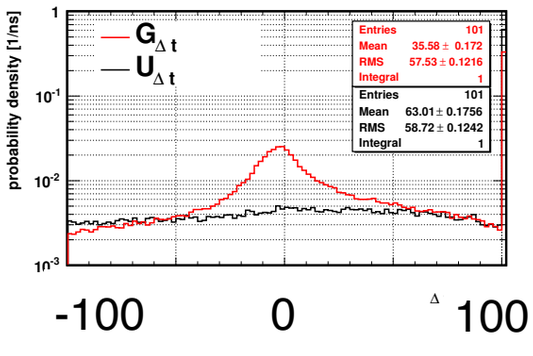
Δθ PDF



Δφ PDF



Δt PDF



Correlated e+,γ pairs
Uncorrelated e+,γ pairs

16% improvement of the sensitivity is expected.

VUV-sensitive MPPC

We developed **VUV-sensitive MPPC** with Hamamatsu
model : S10943-3186(X)

- **Sensitive to LXe scintillation light**, λ~175 nm
  - No protection layer, thinner insensitive layer
  - Optimized optical property of the surface
- **Large sensitive area, 12×12 mm²**
- **50 μm** pixel pitch : **~47–56k pixels** in each package
- Metal quench resister suitable for the low temperature use
- **Four segments** in each package
  - Possible to read each segment separately or to connect them outside of the package
- Thin **quartz window** for protection
  - Open space between the window and MPPCs to allow LXe enter the space
- Different gaps (0.5, 1 or 1.5 mm) to test possibility of discharge due to some conductive dusts floating in LXe.

The first batch of the product delivered in this March