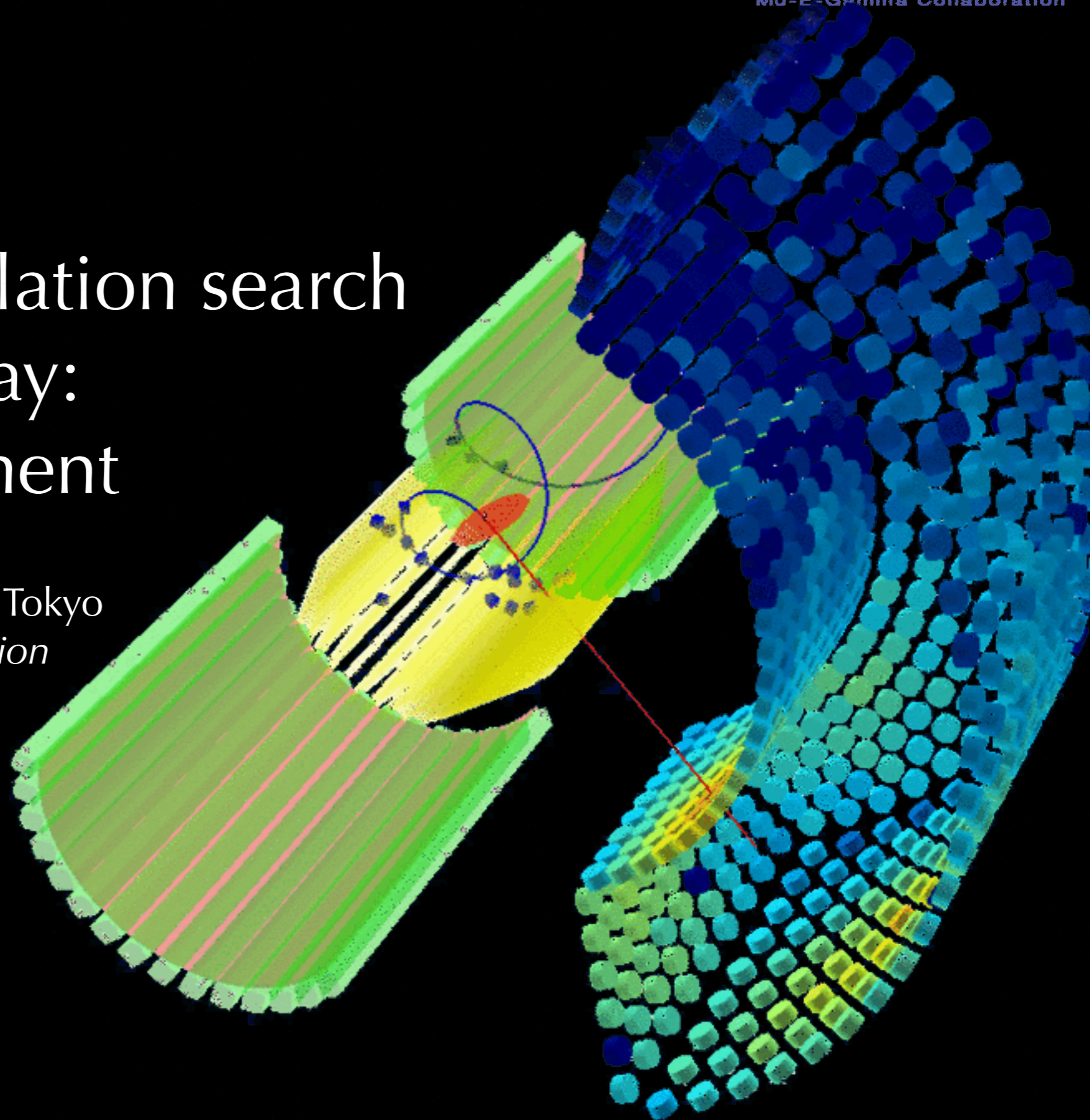


Lepton flavor violation search with $\mu \rightarrow e \gamma$ decay: the MEG experiment

Hiroaki Natori The University of Tokyo
on behalf of the MEG collaboration



The MEG Collaboration



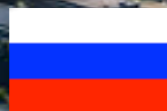
U.Tokyo,
Waseda,
KEK



INFN & U,
Pisa,
Rome,
Genova,
Pavia,
Lecce



PSI



JINR Dubna,
BINP Novosibirsk



UCIrvine

PSI

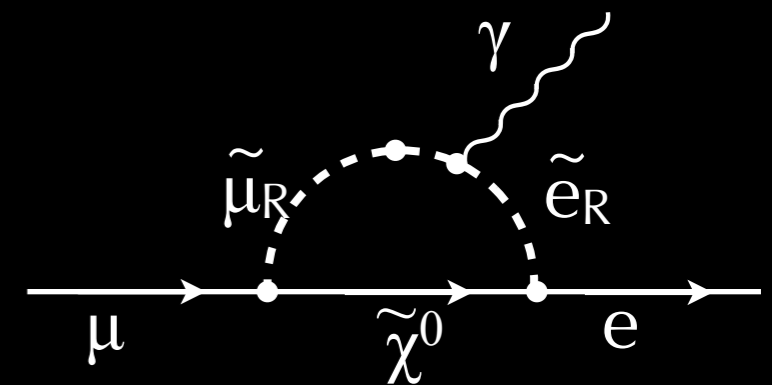
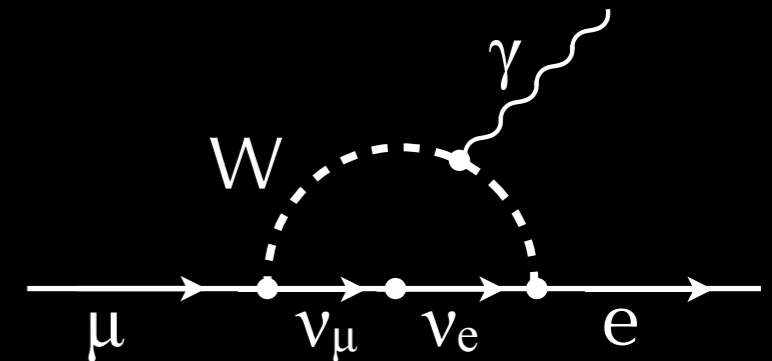


Outline

- Physics motivation for $\mu \rightarrow e \gamma$
- MEG experiment
- Analysis of 2008 data
- 2009 data taking and prospects for future

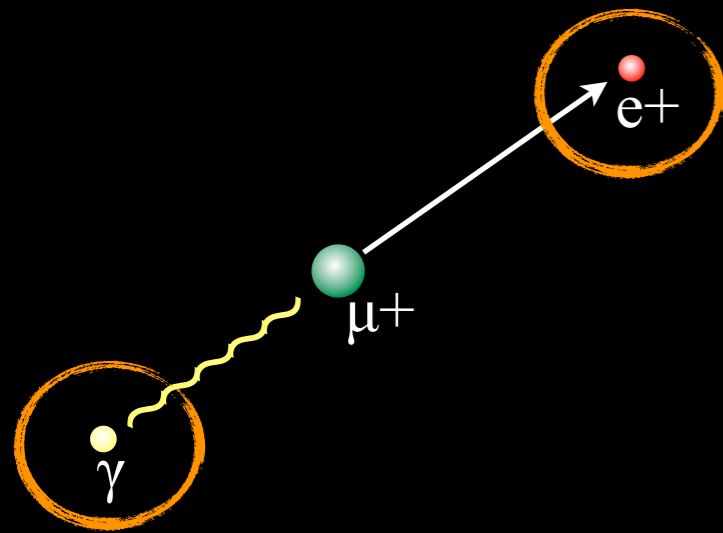
Physics Motivation for $\mu \rightarrow e \gamma$

- cLFV, Clear evidence of new physics beyond the *SM*
- Beyond experimental reach with *SM* with neutrino oscillation extension :
 $\text{Br}(\mu \rightarrow e \gamma) \sim 10^{-54}$
- New physics, e.g. *SUSY-GUT* theories predict observable branching ratio:
 $\text{Br}(\mu \rightarrow e \gamma) \sim 10^{-14}$ to 10^{-11} , just below the current upper limit 1.2×10^{-11} (MEGA)

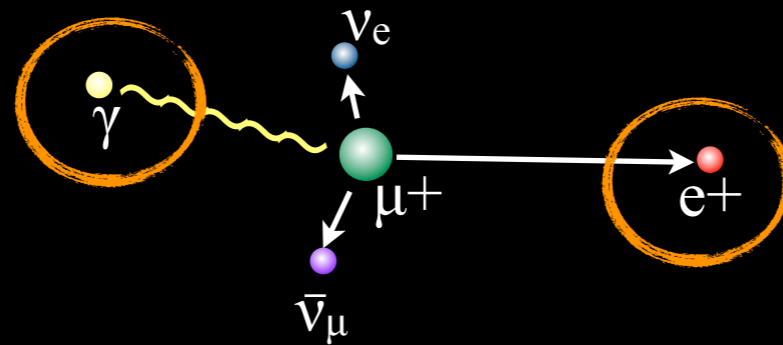


$\mu \rightarrow e \gamma$ decay and B.G.

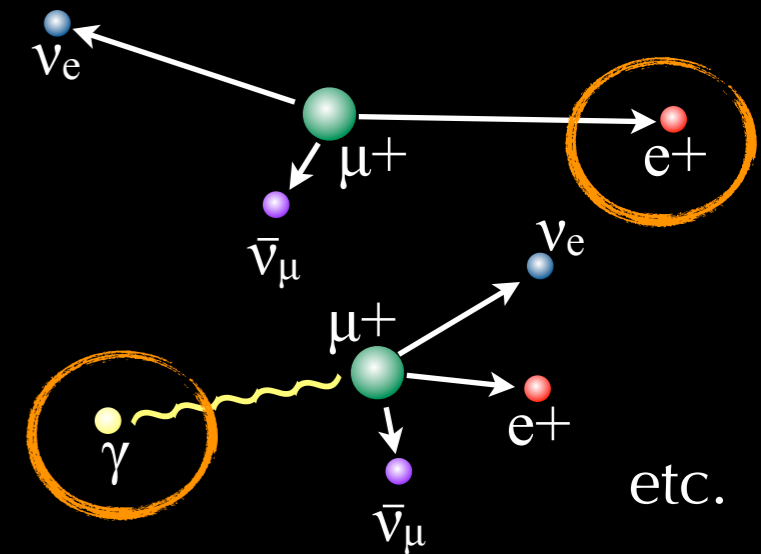
Signal



Prompt B.G.



Accidental Pileup



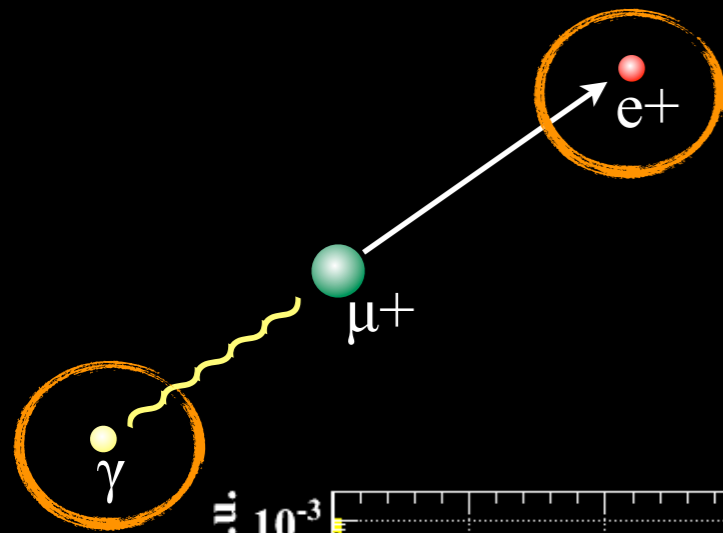
$\mu \rightarrow e \nu \bar{\nu} \gamma$
Radiative muon decay (RMD)

e^+ from
 $\mu \rightarrow e \nu \bar{\nu}$ (Michel decay)
+
 γ from RMD, AIF, etc.

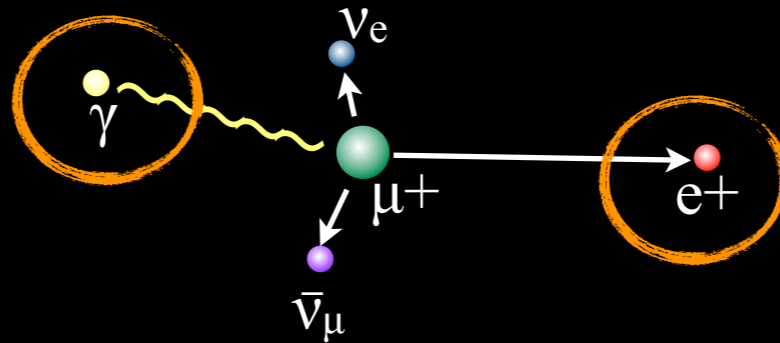
Dominant

$\mu \rightarrow e \gamma$ decay and B.G.

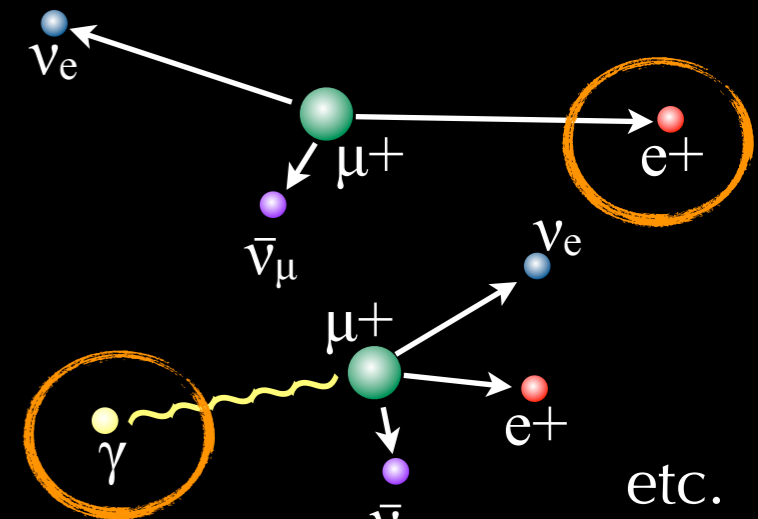
Signal



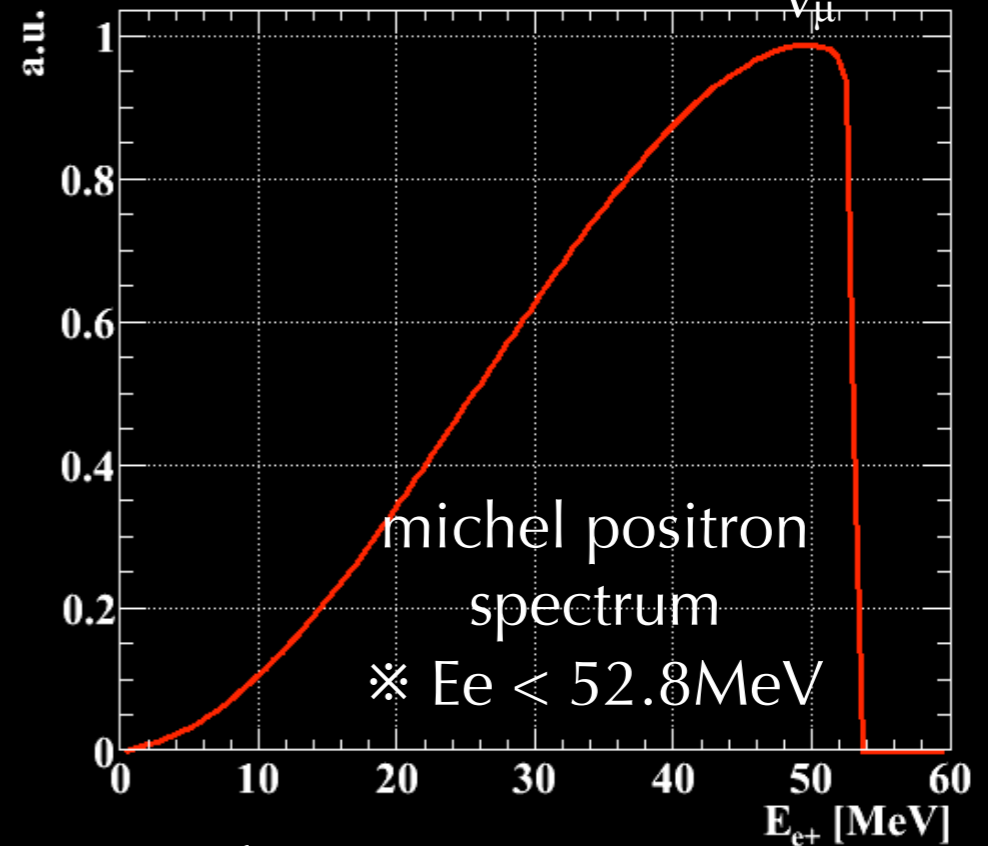
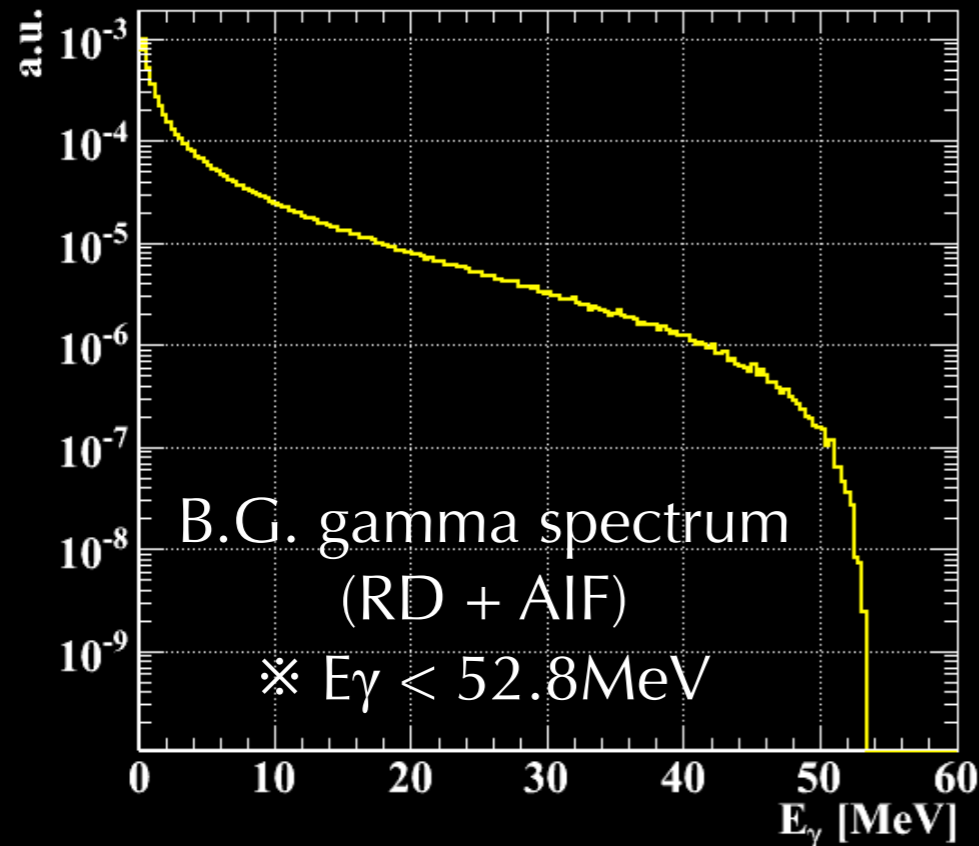
Prompt B.G.



Accidental Pileup

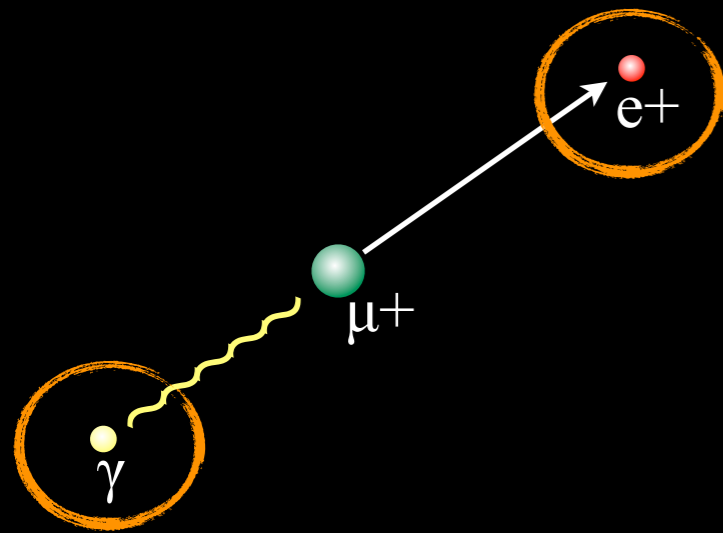


etc.



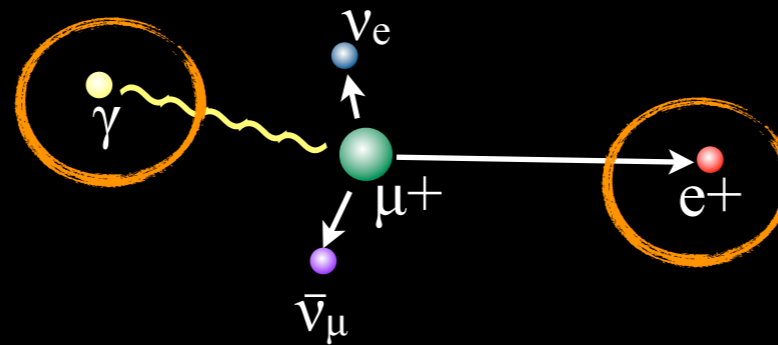
$\mu \rightarrow e \gamma$ decay and B.G.

Signal



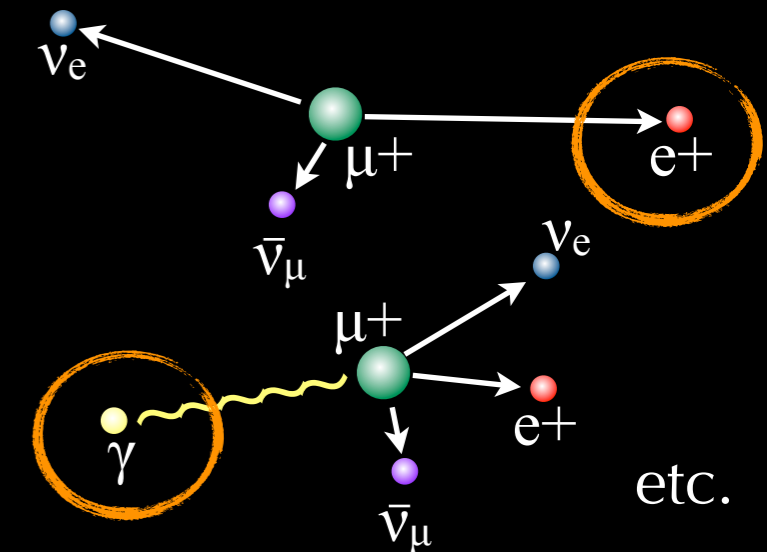
- 2 body decay
 - Back to back
 - Monochromatic
 - $E_e = E_\gamma = 52.8 \text{ MeV}$
 - $T_e = T_\gamma$

Prompt B.G.



- Any angle
(energy correlated)
- $E_e, E_\gamma < 52.8 \text{ MeV}$
- $T_e = T_\gamma$

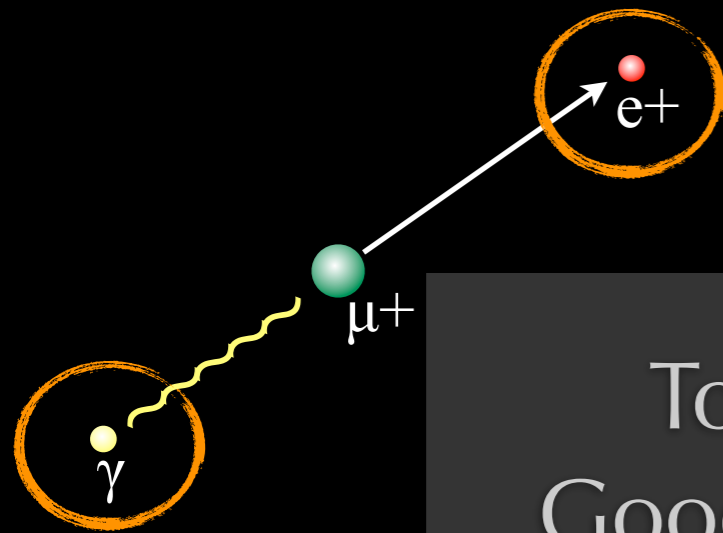
Accidental Pileup



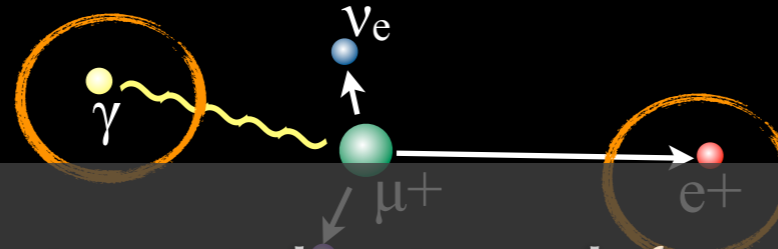
- Any angle
- $E_e, E_\gamma < 52.8 \text{ MeV}$
- Flat time difference

$\mu \rightarrow e \gamma$ decay and B.G.

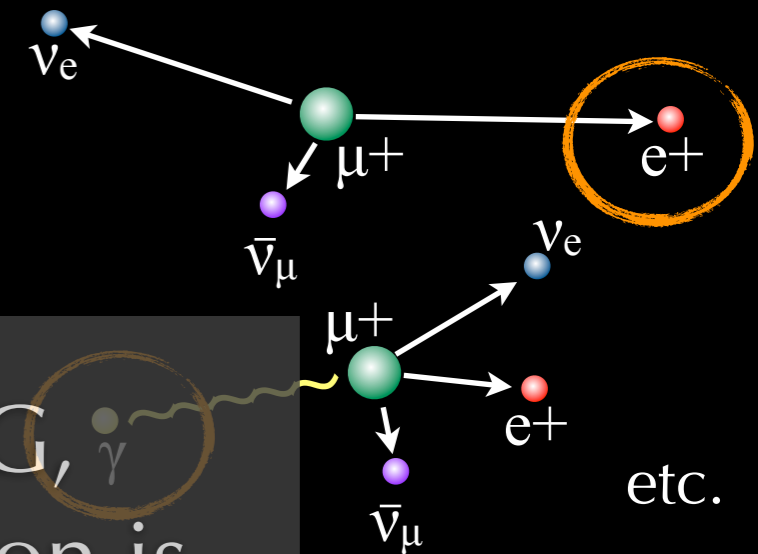
Signal



Prompt B.G.



Accidental Pileup



To distinguish signal from B.G.,
 Good E_γ , E_e , $\theta_{e\gamma}$, $\phi_{e\gamma}$, $T_{e\gamma}$ resolution is important

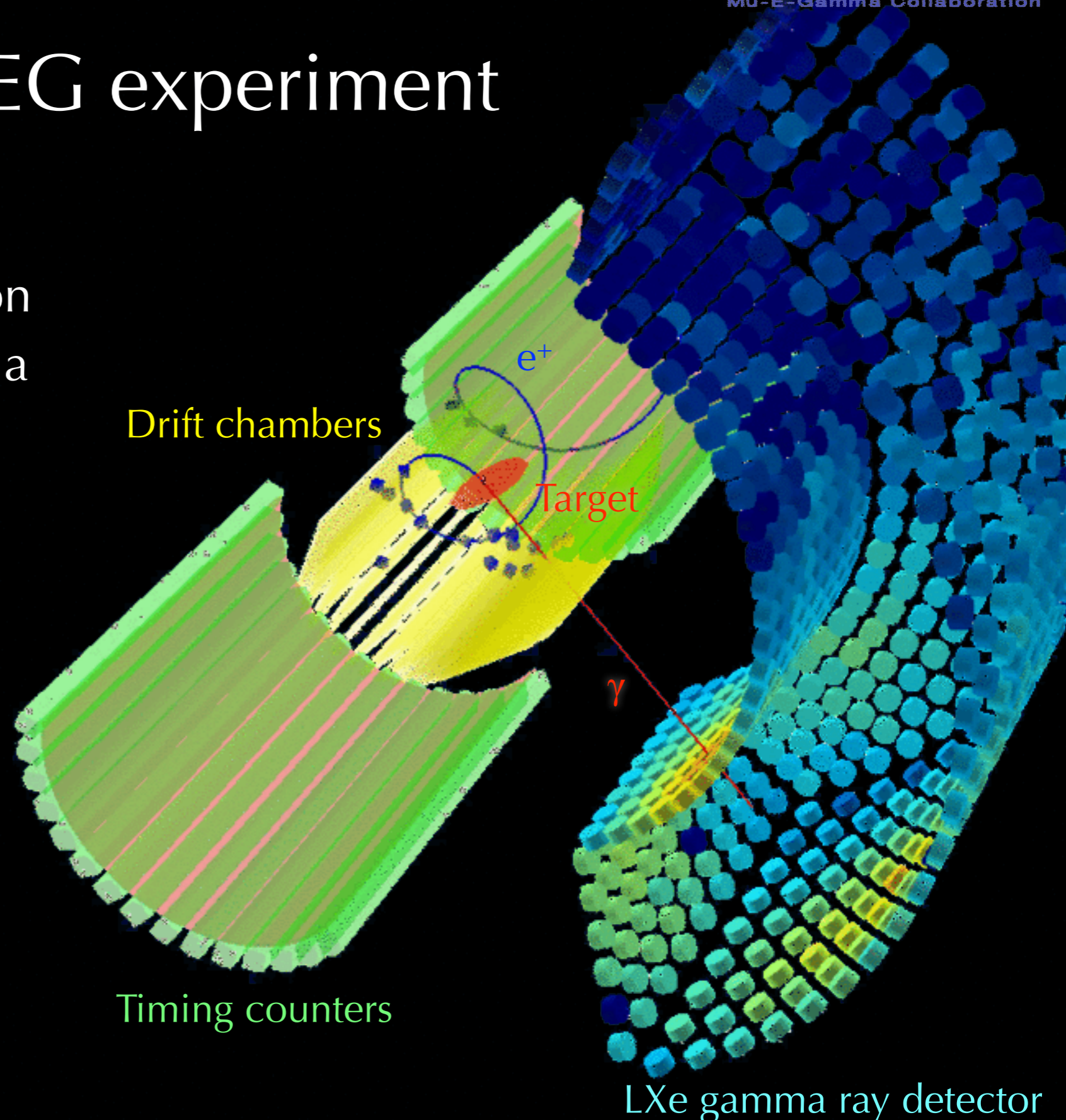
- 2 body decay
- Back to back
- Monochromatic
- $E_e = E_\gamma = 52.8 \text{ MeV}$
- $T_e = T_\gamma$

- Any angle (energy correlated)
- $E_e, E_\gamma < 52.8 \text{ MeV}$
- $T_e = T_\gamma$

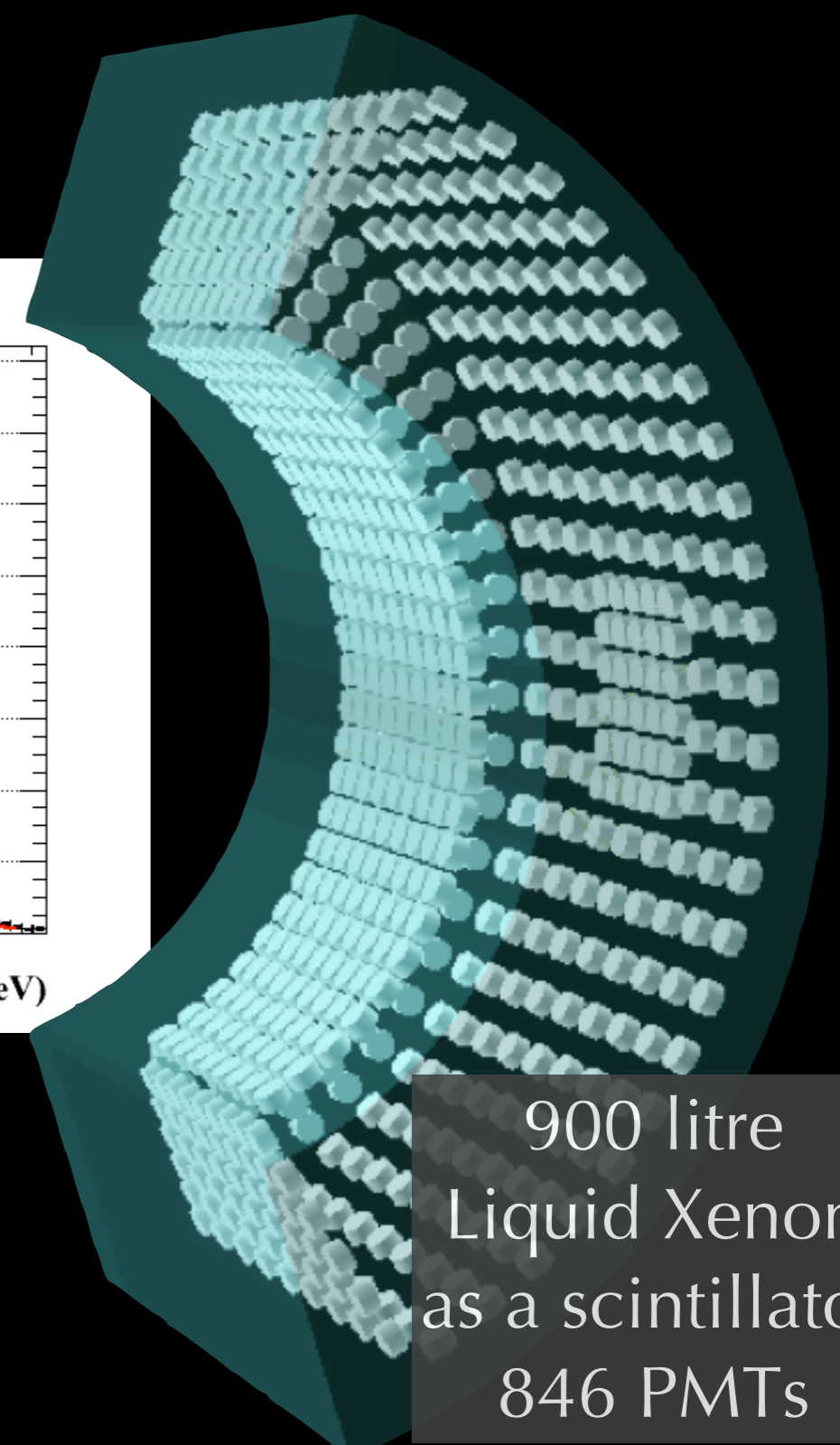
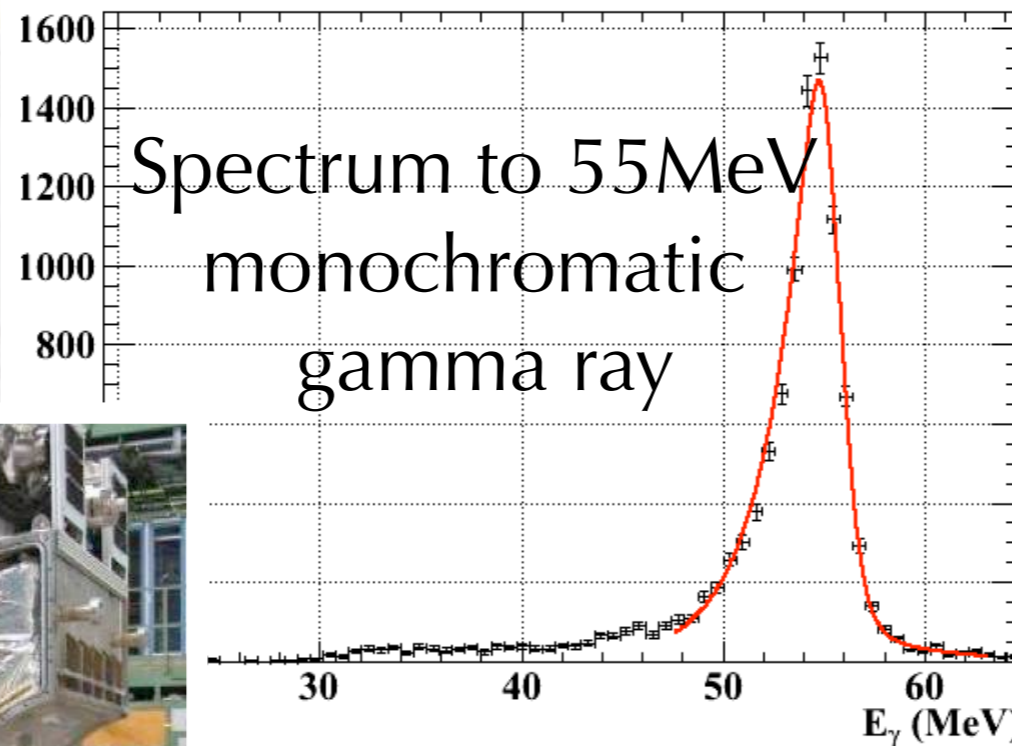
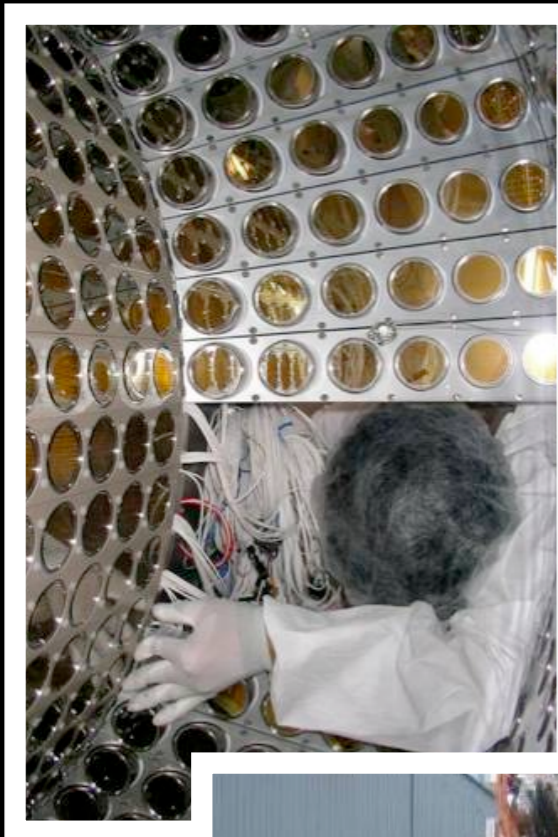
- Any angle
- $E_e, E_\gamma < 52.8 \text{ MeV}$
- Flat time difference

MEG experiment

- Large intensity DC muon beam: $3 \times 10^7 \mu^+$ stop in a $205 \mu\text{m}$ target
- Liquid Xenon γ -ray detector
- Positron spectrometer
 - Gradient B-field SC Solenoid magnet
 - Drift chamber
 - Plastic Scintillator timing counter

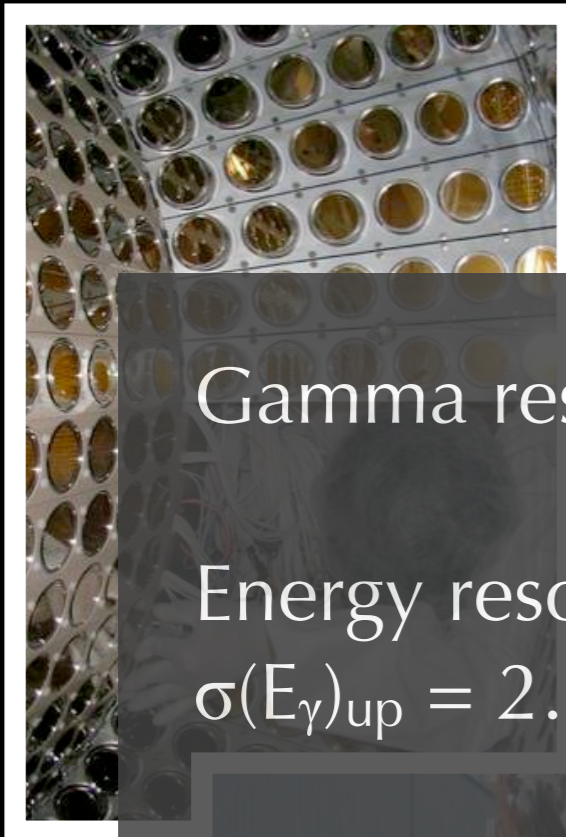


LXe gamma detector



900 litre
Liquid Xenon
as a scintillator
846 PMTs

LXe gamma detector



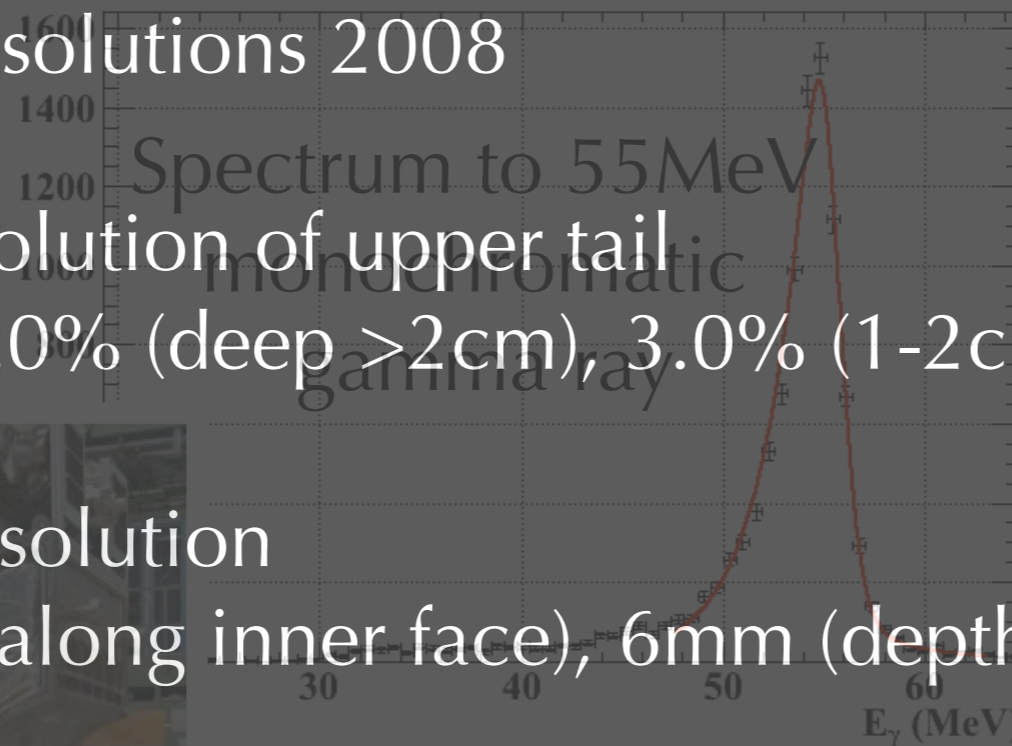
Gamma resolutions 2008

Energy resolution of upper tail

$\sigma(E_\gamma)_{up} = 2.0\%$ (deep >2cm), 3.0% (1-2cm), 4.2% (0-1 cm)

Position resolution

$\sigma = 5\text{mm}$ (along inner face), 6mm (depth)



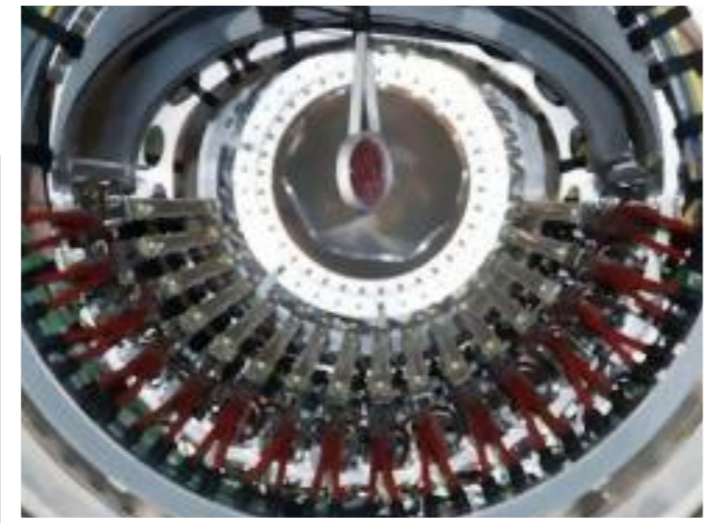
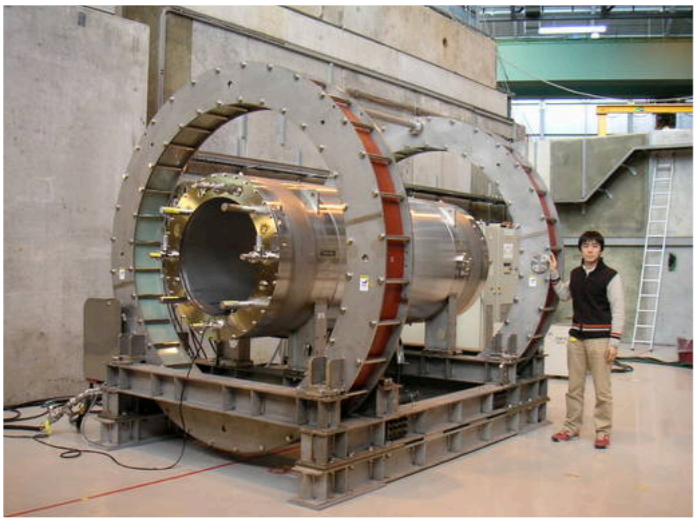
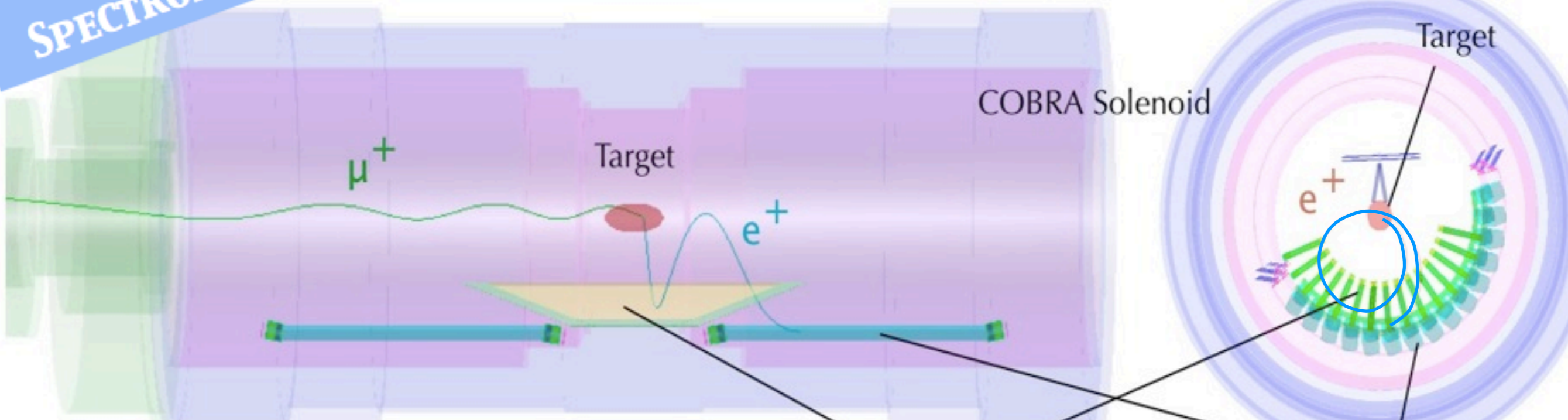
900 litre
Liquid Xenon
as a scintillator
846 PMTs

Positron spectrometer

COBRA SPECTROMETER

- Lateral View -

- Cross-sectional View -



Drift Chamber

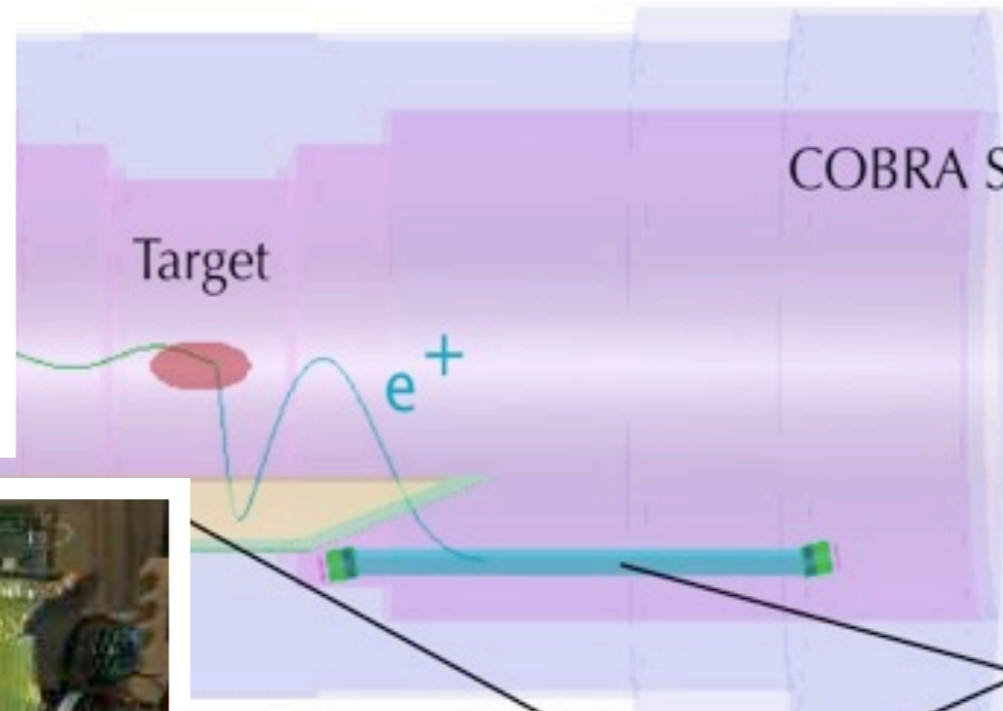
Timing Counter

Positron spectrometer

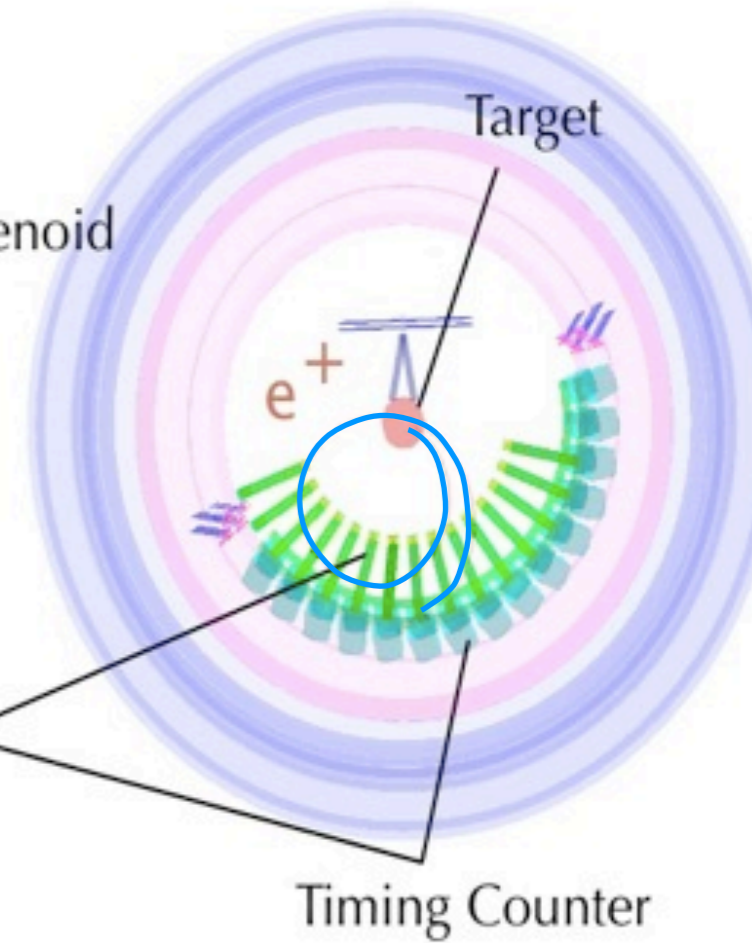
TC Z counter



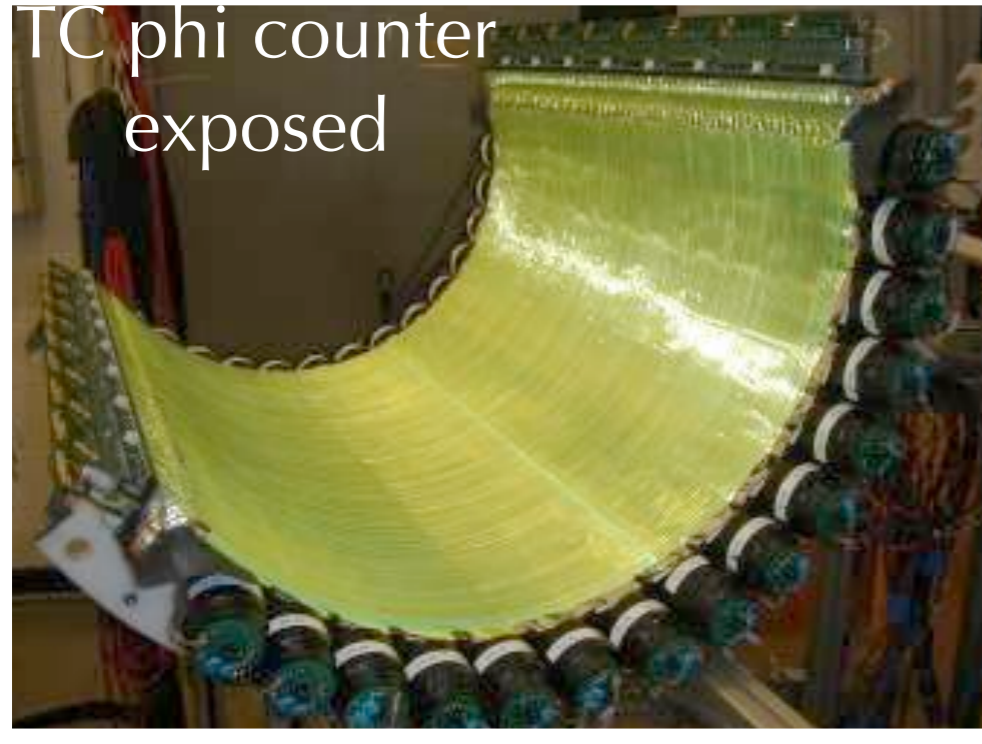
Lateral View -



- Cross-sectional View -



TC phi counter exposed

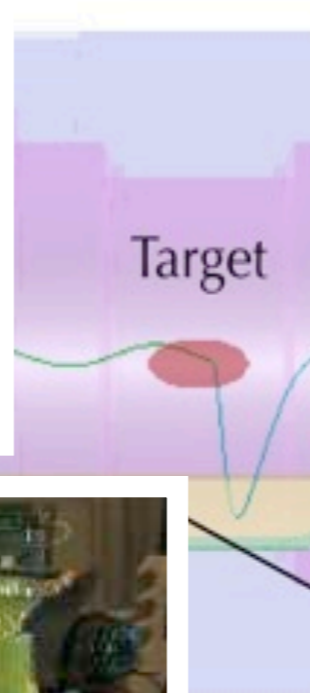


Positron spectrometer

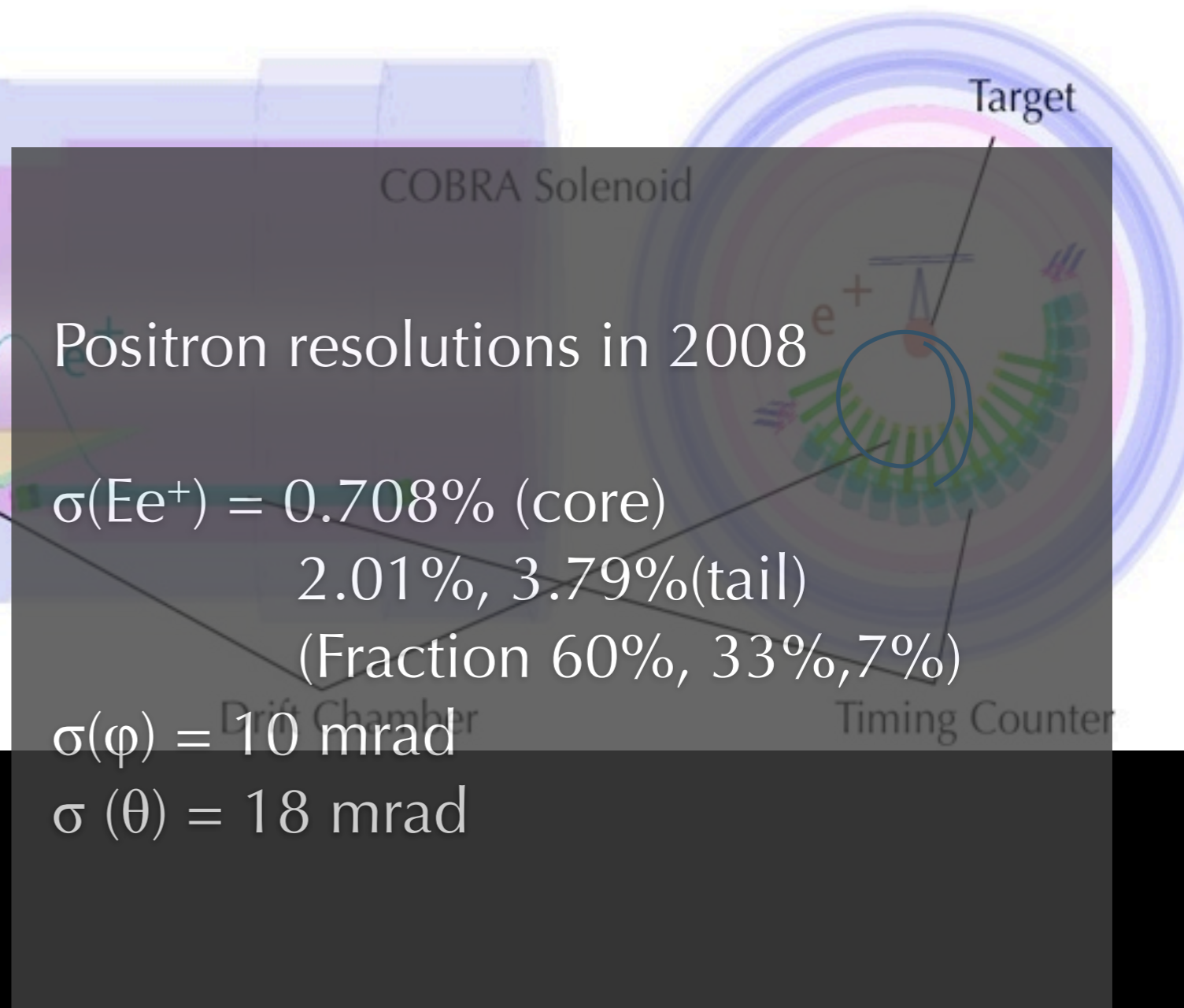
TC Z counter



Lateral View -



- Cross-sectional View -

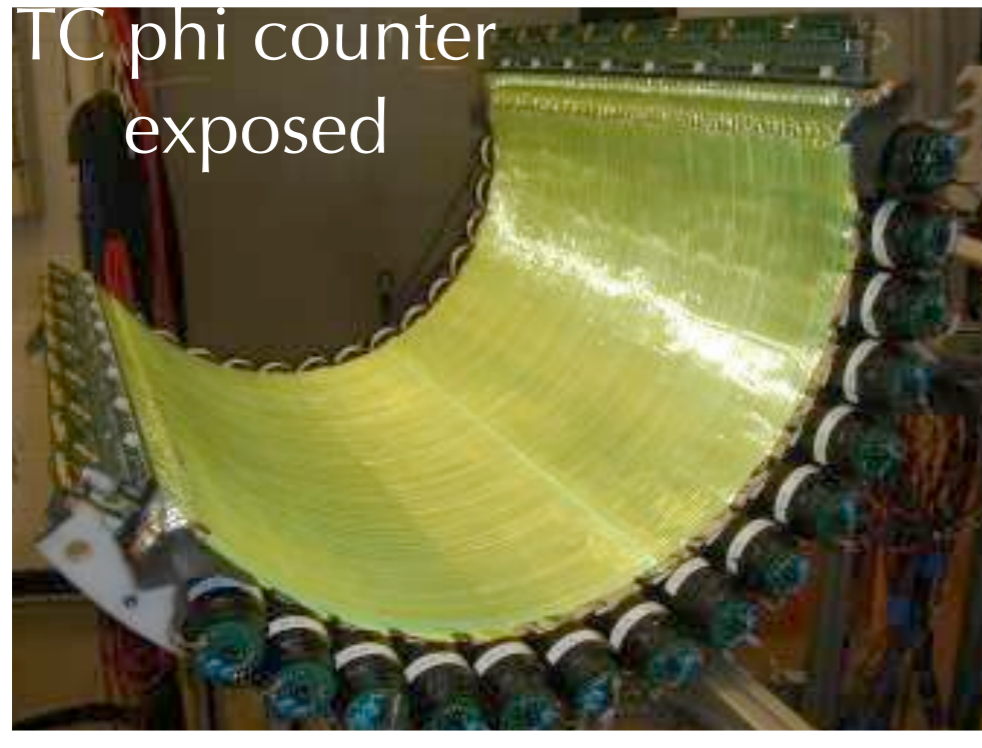


Positron resolutions in 2008

$\sigma(Ee^+) = 0.708\%$ (core)
 2.01%, 3.79% (tail)
 (Fraction 60%, 33%, 7%)

$\sigma(\varphi) = 10$ mrad
 $\sigma(\theta) = 18$ mrad

TC phi counter exposed

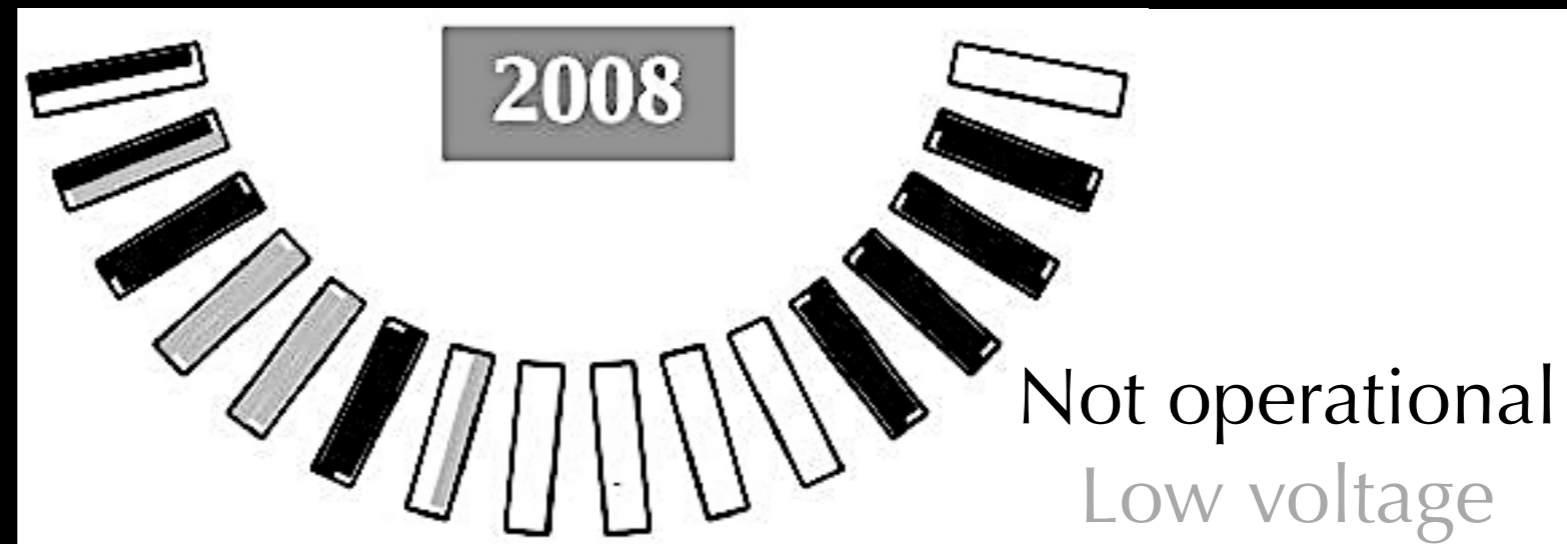
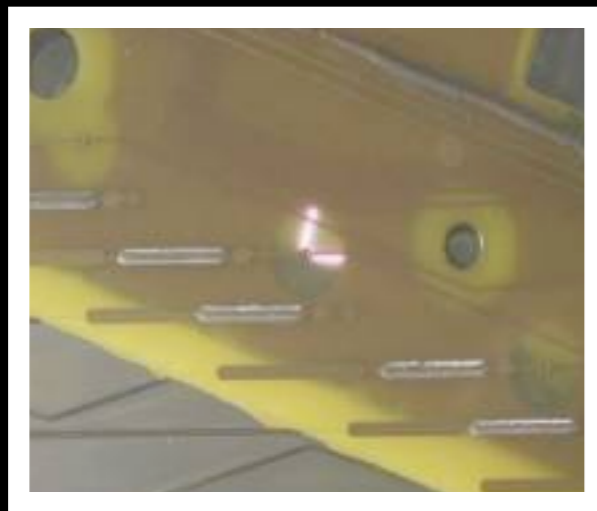


2008 run

- We started physics data taking from 2008
- The first three months of physics data taking (09/08 - 12/08)
- 3×10^7 muons/sec rate, in total 9.5×10^{13} muons stopped on the target

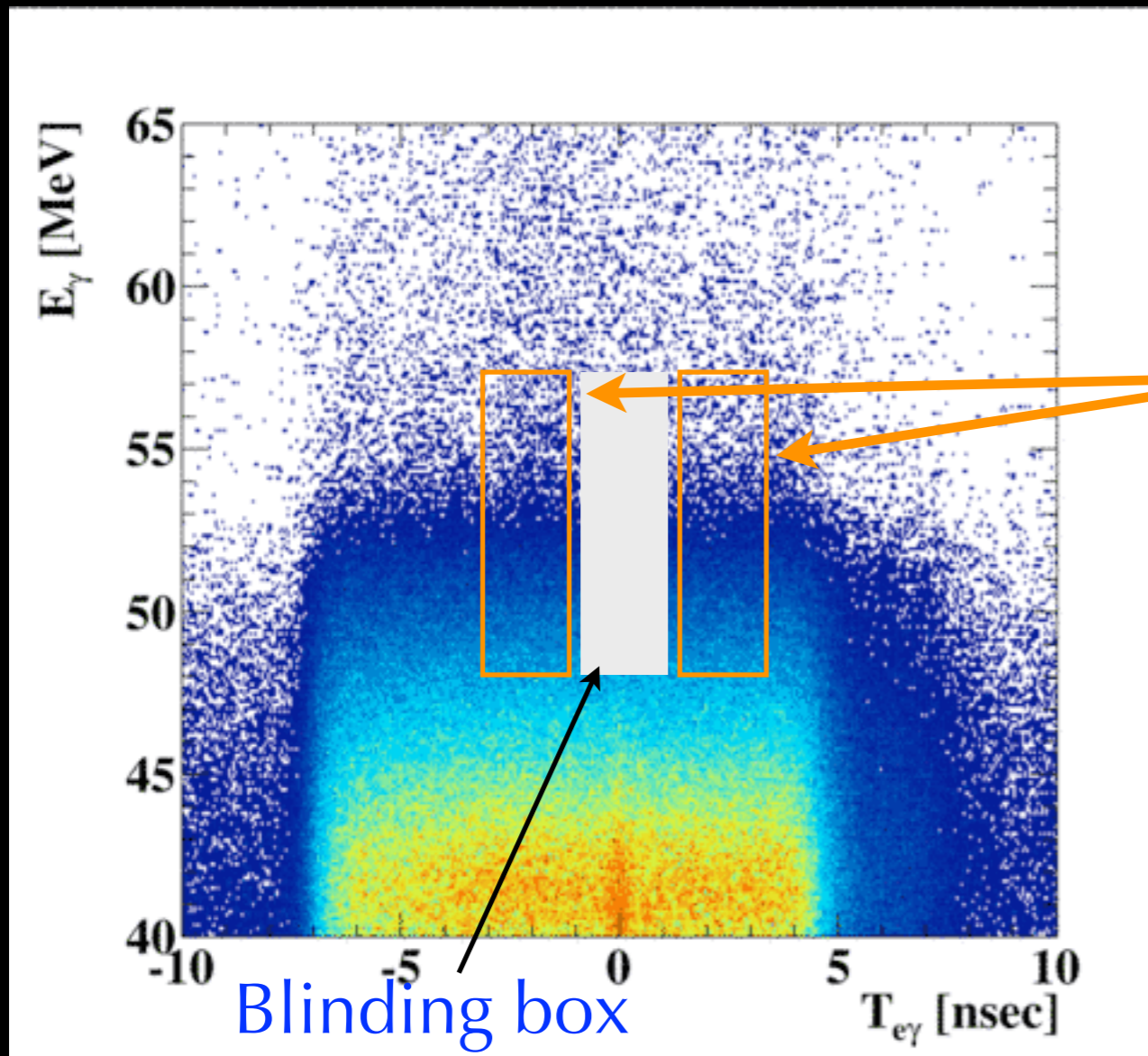
2008 run

- We started physics data taking from 2008
- The first three months of physics data taking (09/08 - 12/08)
- 3×10^7 muons/sec rate, in total 9.5×10^{13} muons stopped on the target



- Unfortunately, **Low statistic** because of DC discharge problem ($\epsilon(e^+) \sim 14\%$, 1/3 of expected)

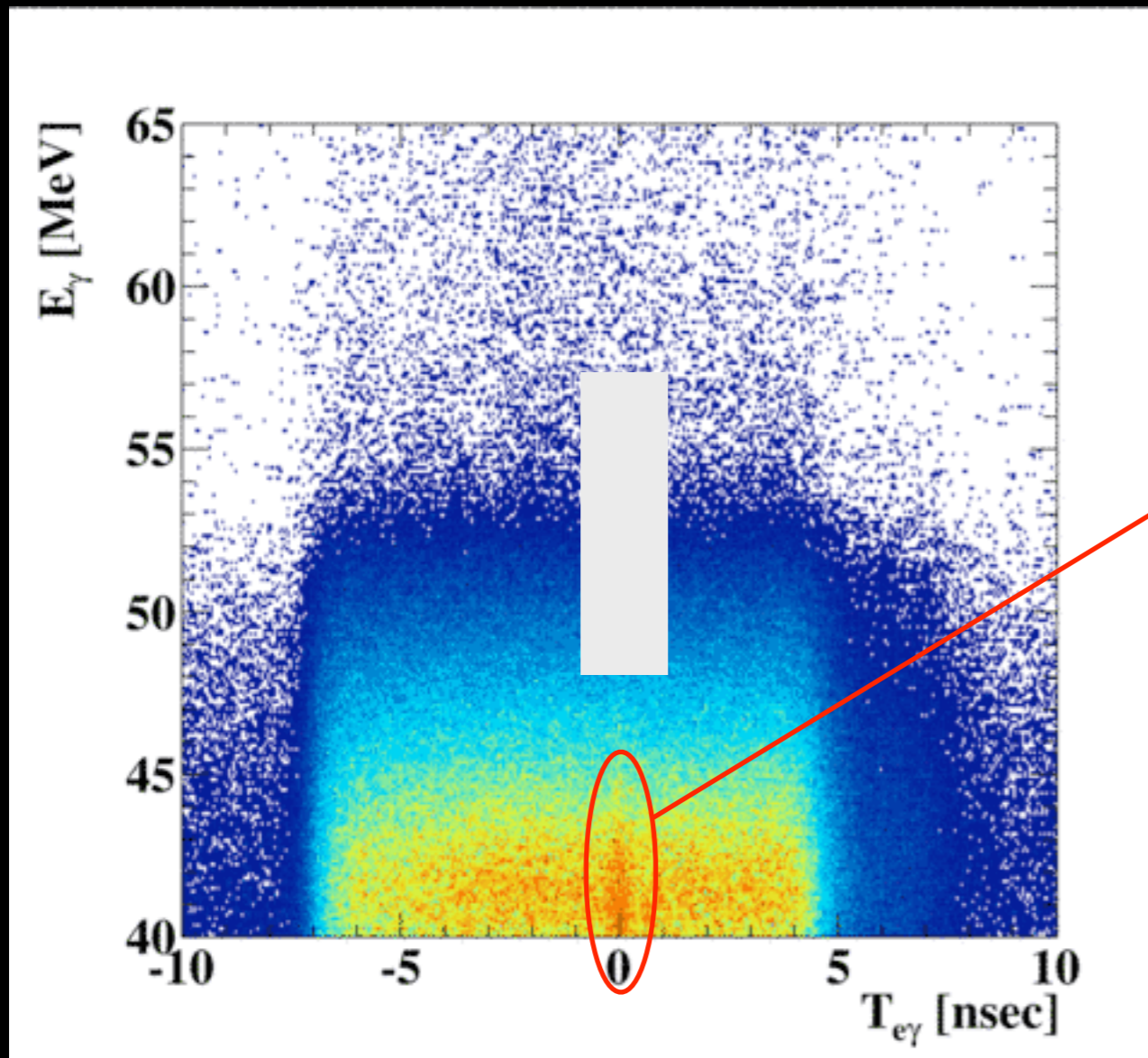
2008 data analysis



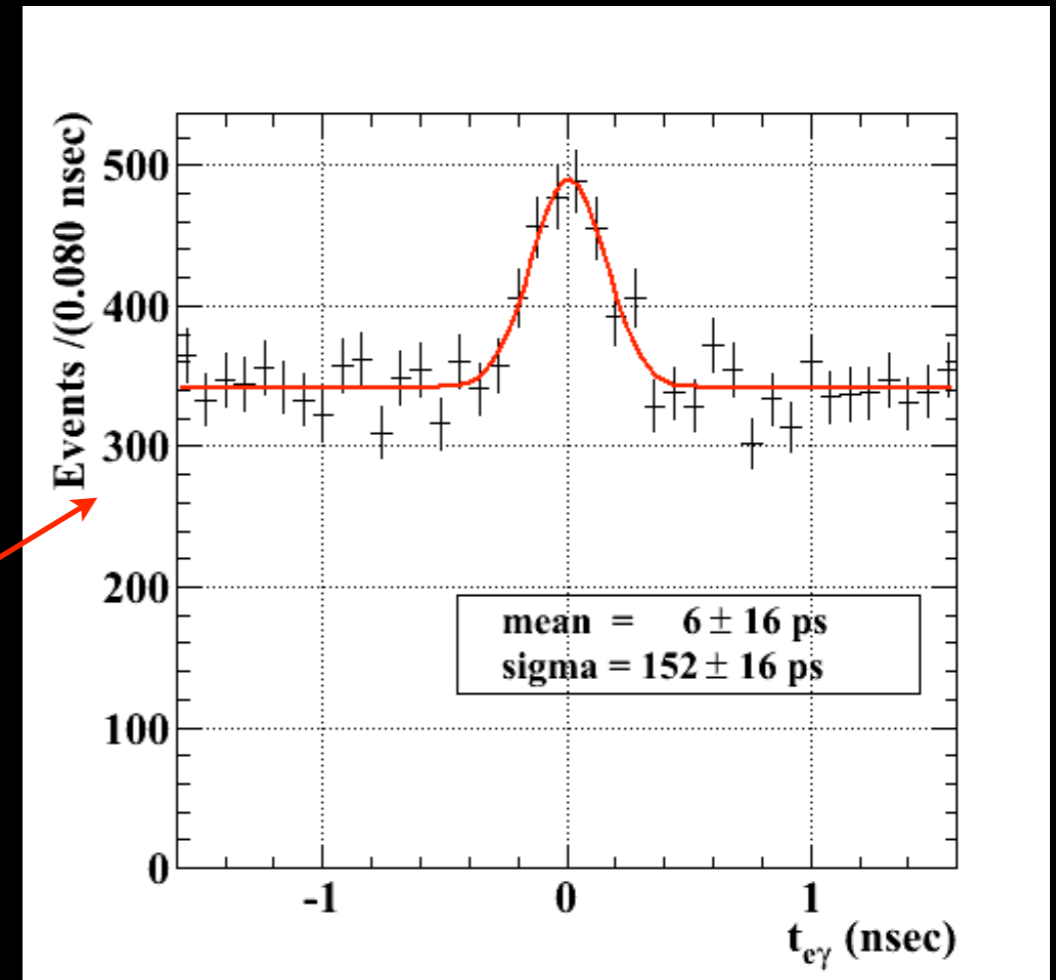
- Blind-box likelihood analysis was adopted
- Accidental background study using side-band
- Prepared PDFs for signal, RMD, and accidental B.G.

※No E_{e^+} , direction cut

2008 data analysis



※No Ee^+ , direction cut

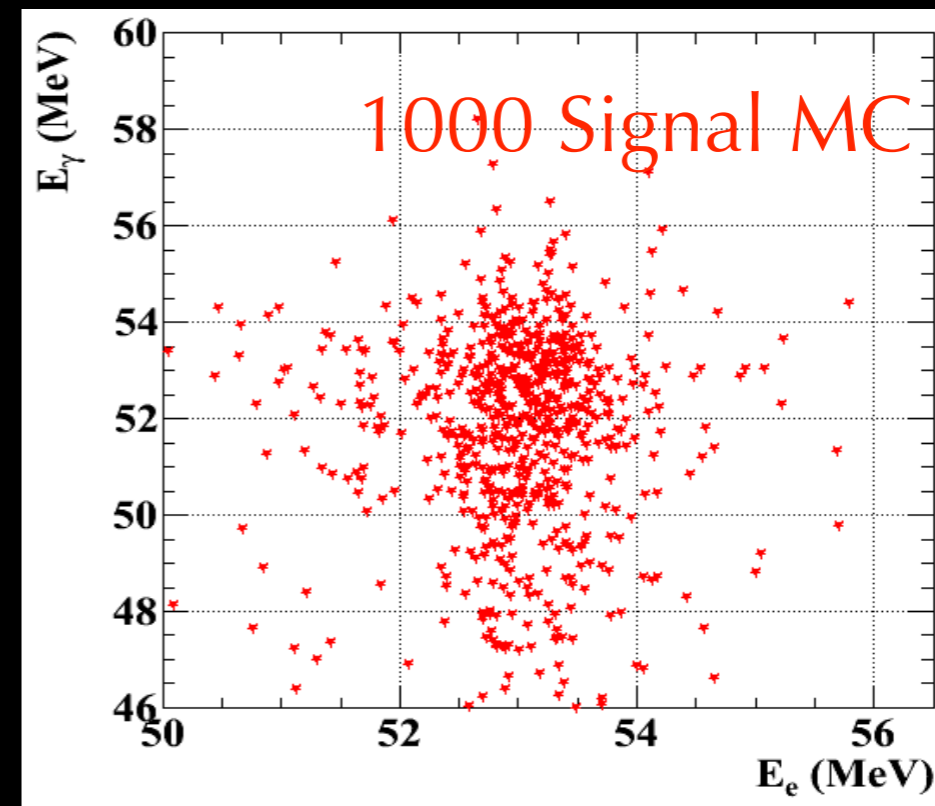
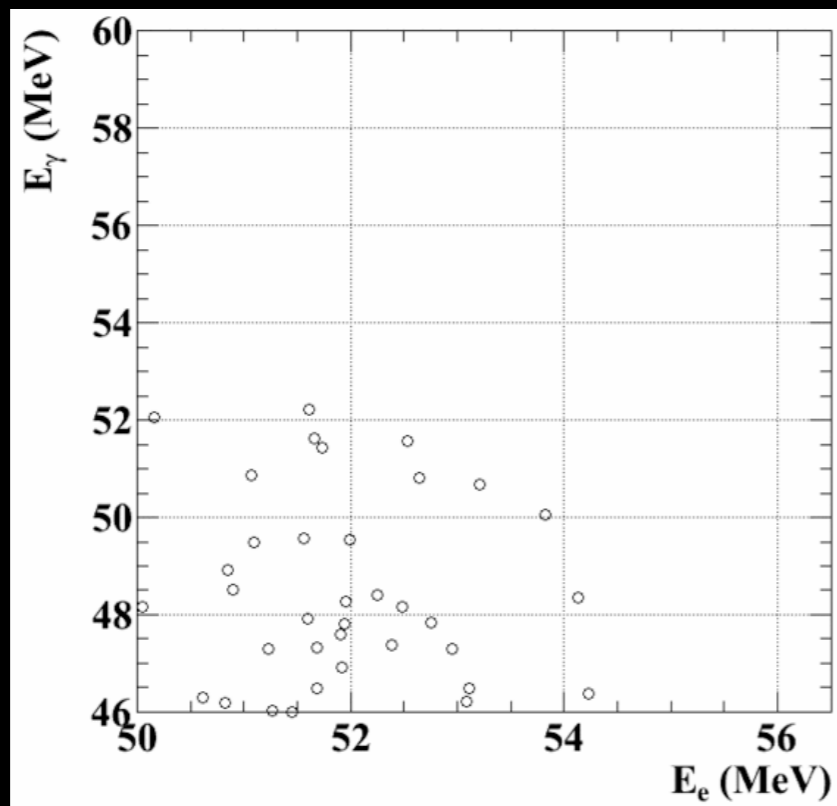


RMD in normal physics run
 $\sigma(t_{e\gamma}) = 148 \pm 17$ psec
 (energy dependence correction done)

Result 2008

$N_{\text{sig}} < 14.7 @ 90\% \text{ CL}$

$\text{Br}(\mu \rightarrow e\gamma) < 2.8 \times 10^{-11} @ 90\% \text{ CL}$



Note: all the other parameters are cut to select $\sim 90\%$ of signal events in these plots

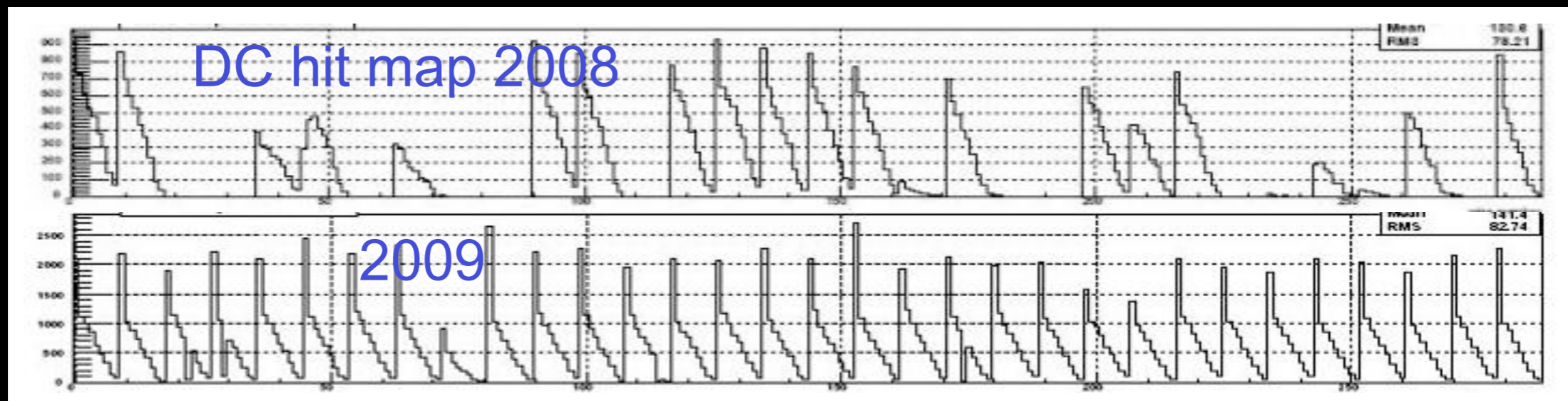
Expected 90% CL UL on BR(no signal) $\sim 1.3 \times 10^{-11}$

90% CL UL from sideband data (no signal): $(0.9-2.1) \times 10^{-11}$

Probability of getting this result by statistical fluctuations is $\sim 5\%$

Main news about 2009 run

- 2 months of physics data taking, total 6.5×10^{13} muon stop
- All DC modules worked
 - efficiency 14% \rightarrow 40%, resolution improved



Performances 2009

	2008	2009(preliminary)
Gamma Energy (%)	2.0 (w>2cm)	←
Gamma Timing (psec)	80	>67
Gamma Position (mm)	5 /6(depth)	←
Gamma Efficiency (%)	63	←
e ⁺ Timing (psec)	<125	←
e ⁺ Momentum (%)	1.6	0.85
e ⁺ angle (mrad)	10(φ)/18(θ)	8(φ)/11(θ)
e ⁺ efficiency (%)	14	40
e ⁺ -γ timing (psec)	148	<180
Muon Decay Point (mm)	3.2(R)/4.5(Z)	2.2(R)/3.1(Z)
Trigger efficiency (%)	66	88
Stopping Muon Rate (sec ⁻¹)	3x10 ⁷	2.9x10 ⁷
DAQ time/Real time (days)	48/78	35/43
S.E.S @90% box	5x10 ⁻¹²	2.3x10 ⁻¹²
Expected N _{BG}	0.5	0.7
Sensitivity	1.3x10 ⁻¹¹	6.6x10 ⁻¹²
BR upper limit (obtained)	2.8x10 ⁻¹¹	-

- Beam time was short, but efficiency improvement made statistics bigger
- With the improvement of e⁺ resolutions, Expected N_{BG} is 0.7
- We expect to renew the current limit from 2009 data
- We will release result of 2009 in this summer

2010 run

- APD will be operational and it will help us to improve trigger efficiency 88% → 94%
- Data statistics will be about 10 times higher than 2008, and sensitivity is estimated to be 1.3×10^{-12}
- We continue to improve reconstruction algorithm and calibration methods

Summary and prospect

- The first 3 months of MEG was taken in 2008
 - Unfortunately, statistic is small, but we could get data in good quality
 - Result was good enough to show we will renew the current limit soon
- We could get more statistic in 2009 in more stable condition, and we will release the result soon
- We will continue running until 2012 to reach our goal sensitivity of $\sim 10^{-13}$ level

Thank you