MEG実験の最新結果

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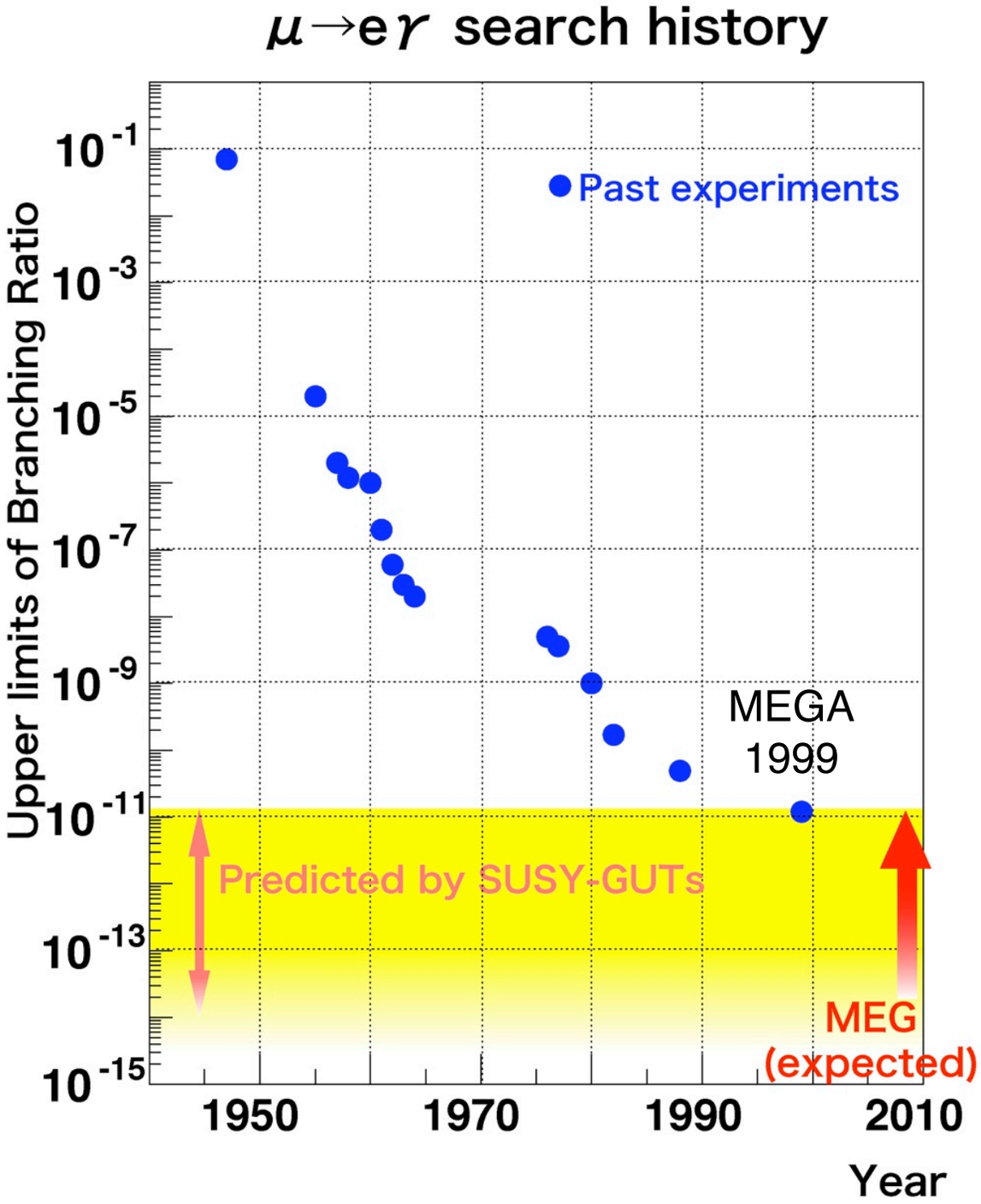
17th ICEPP Symposium

MEG collaboration : ~60 physicists from 13 institutes

Japan : *ICEPP U. of Tokyo, Waseda U., KEK*
Italy : *INFN&U.Genova, INFN&U.Lecce, INFN&U.Pavia INFN&U.Pisa, INFN&U.Roma*
U.S. : *UC Irvine*
Switzerland : *PSI, ETH*
Russia : *JINR Dubna, BINP Novosibirsk*

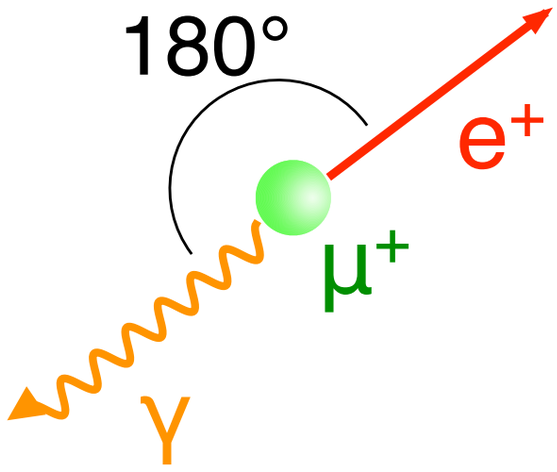
Physics Motivation

- Forbidden in the standard model
- New physics predict B.R. from 10^{-14} to 10^{-11}.
- Current upper limit (1.2×10^{-11}) is close to prediction.
- Discovery => evidence of new physics.
- MEG goal : ~10^{-13}

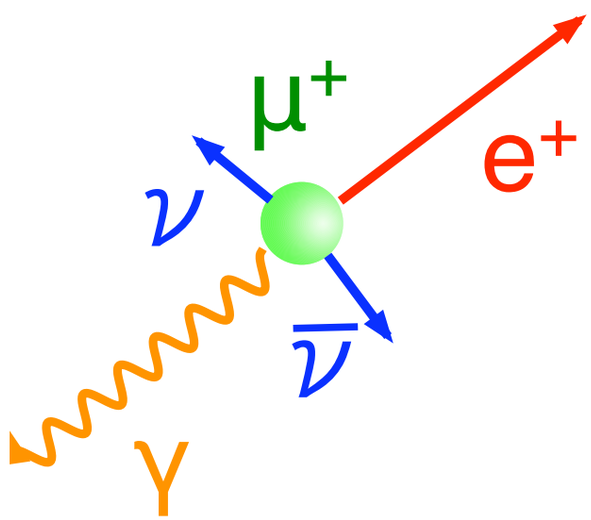


Signal and Background

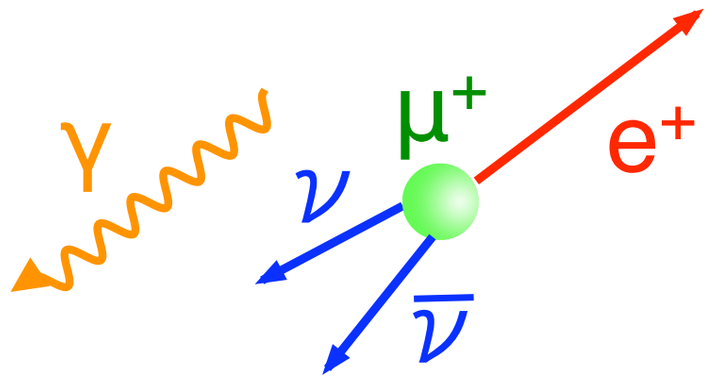
Signal



Prompt Background



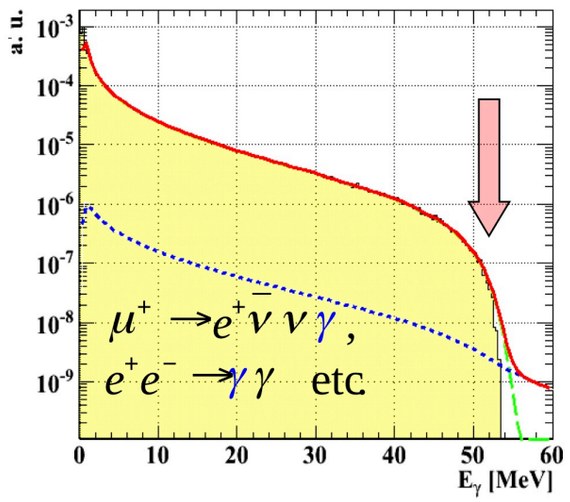
Accidental Background



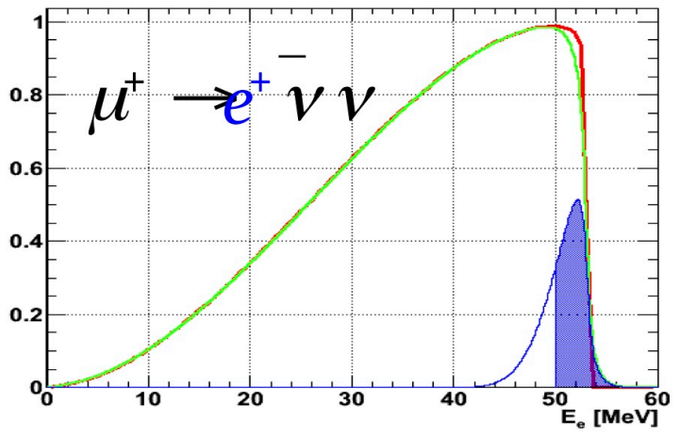
Dominant background is accidental.

Detector resolution is crucial.

γ BG

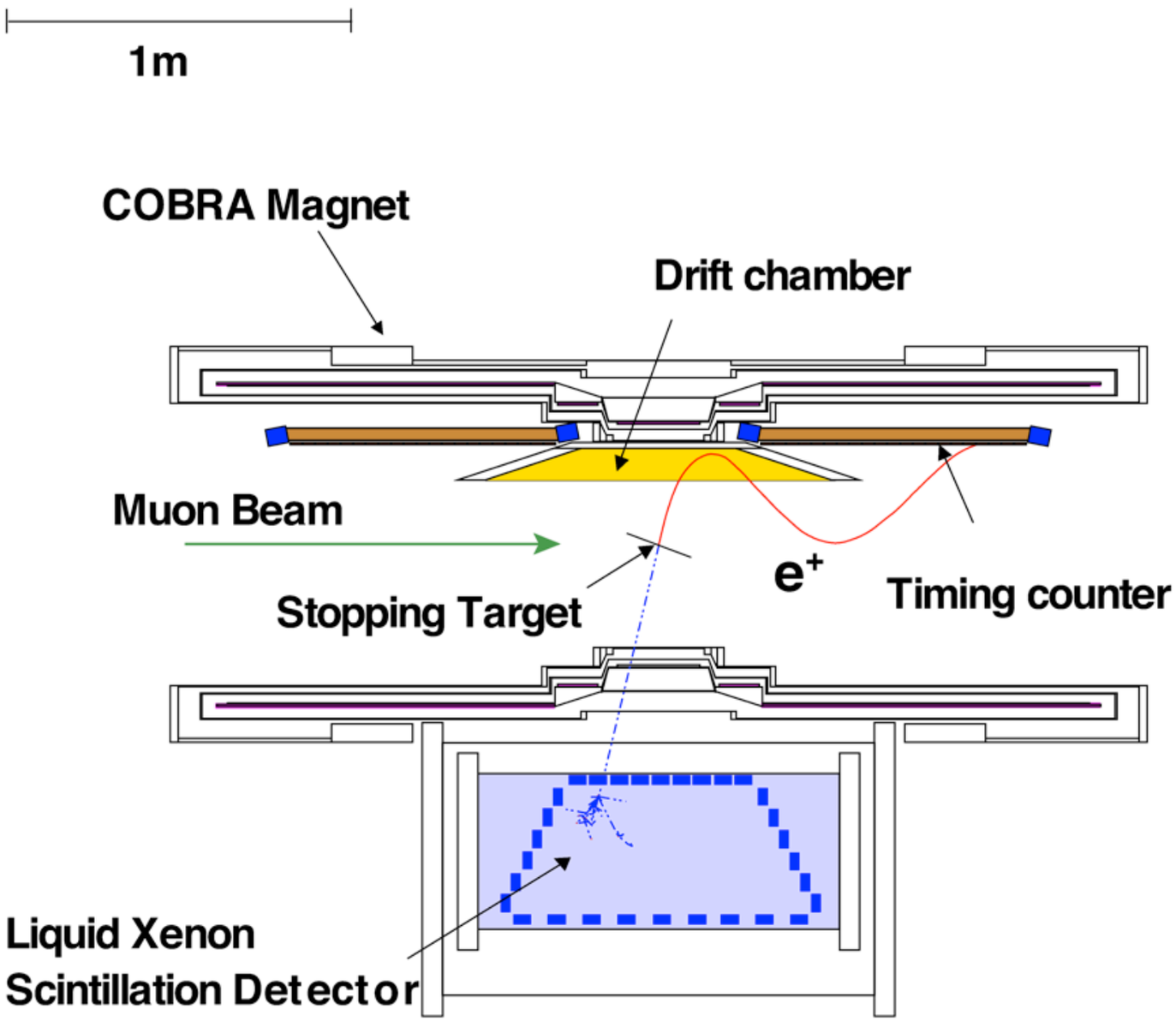


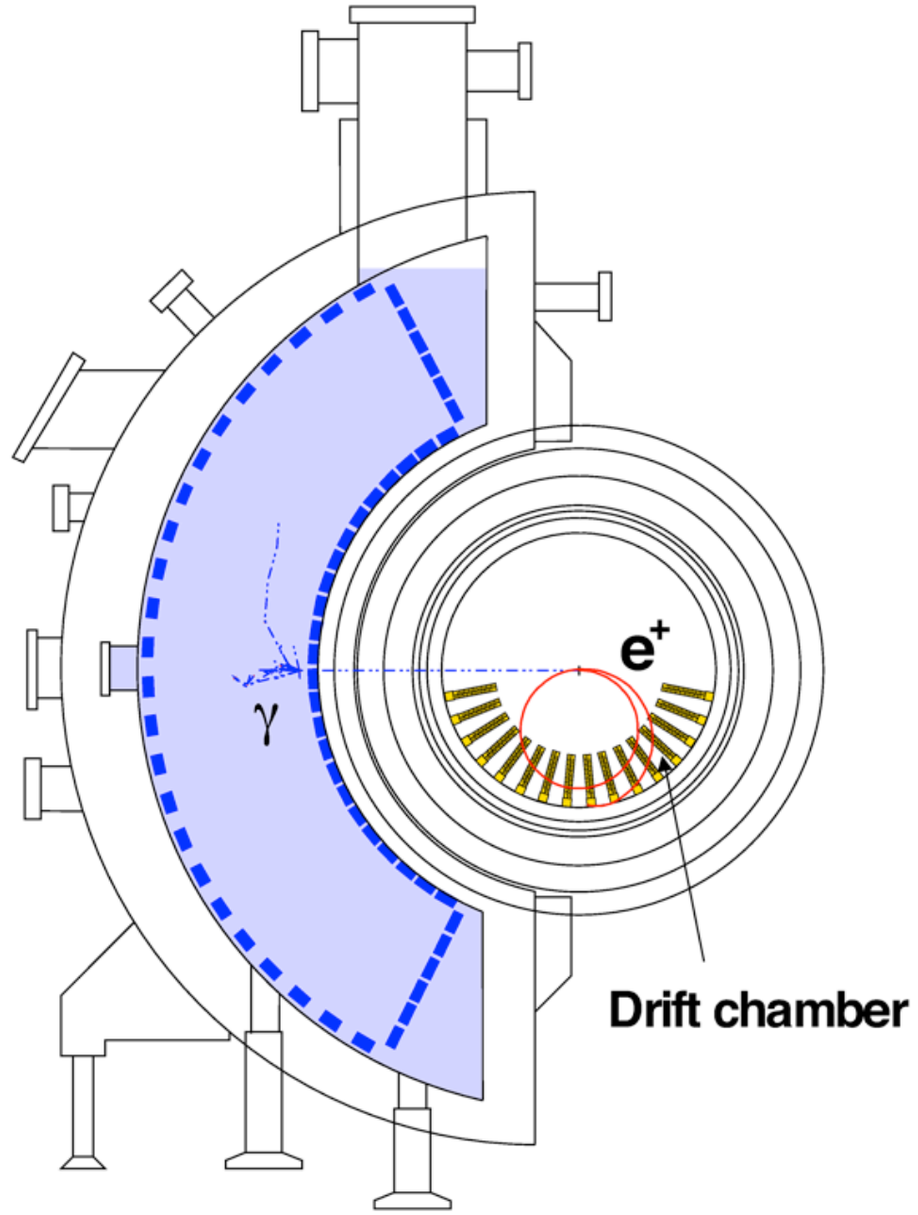
e+ BG



The Experiment

PSI : most intense DC muon





Time line

2008

Physics data taking

(lower efficiency and resolutions due to hardware problem)

2008 run result : Sensitivity = 1.3×10^{-11}
90% U.L. = 2.8×10^{-11}

2009

Physics data taking

This talk

2010

← Preliminary 2009-run result

Physics data taking

← Final 2009-run result

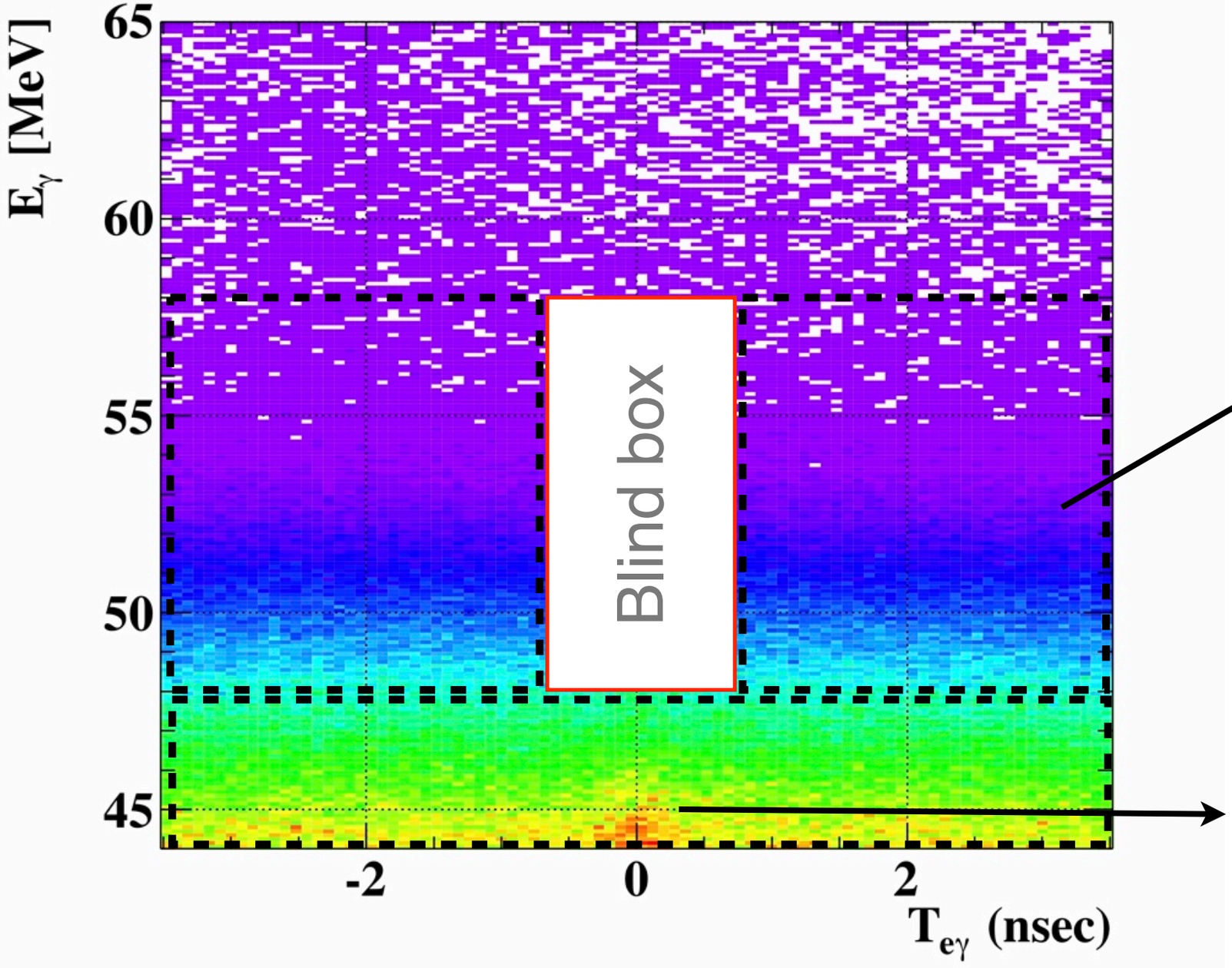
2011

2009 run

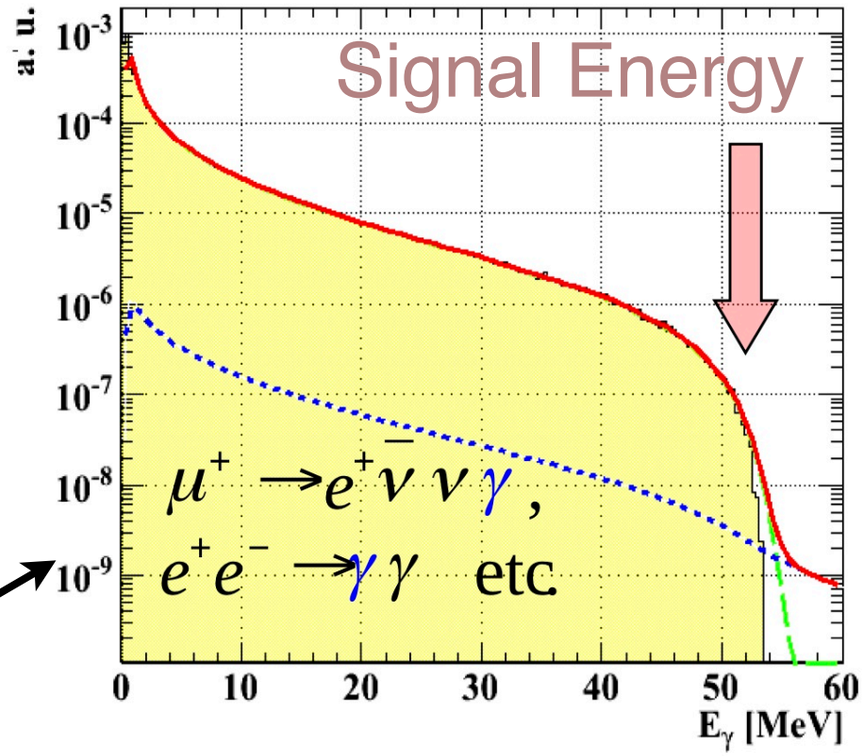
stopping rate 2.9×10^{7} μ s^{-1}
93 TB data taken
22.3 M Triggers
43 days physics data taking

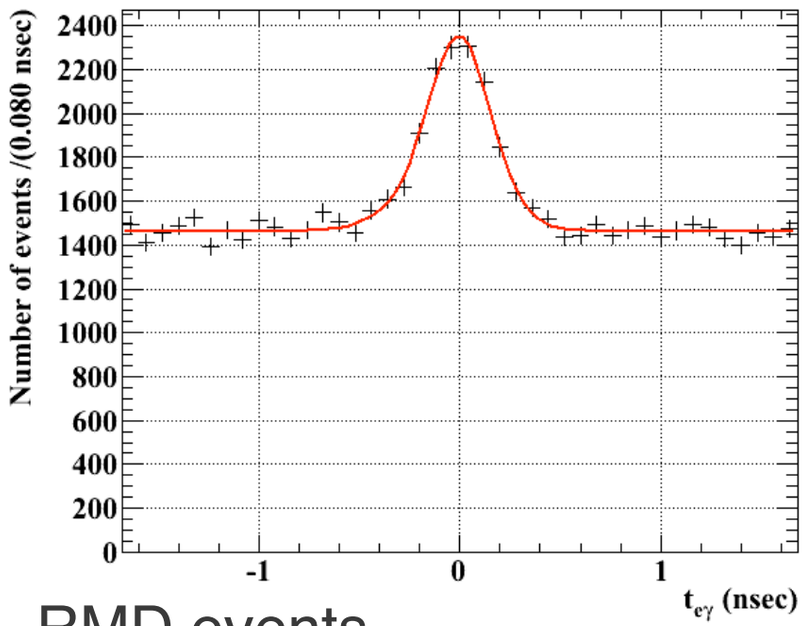
Data samples

E_γ vs T distribution without any selection.



γ BG





RMD events

Analysis Method

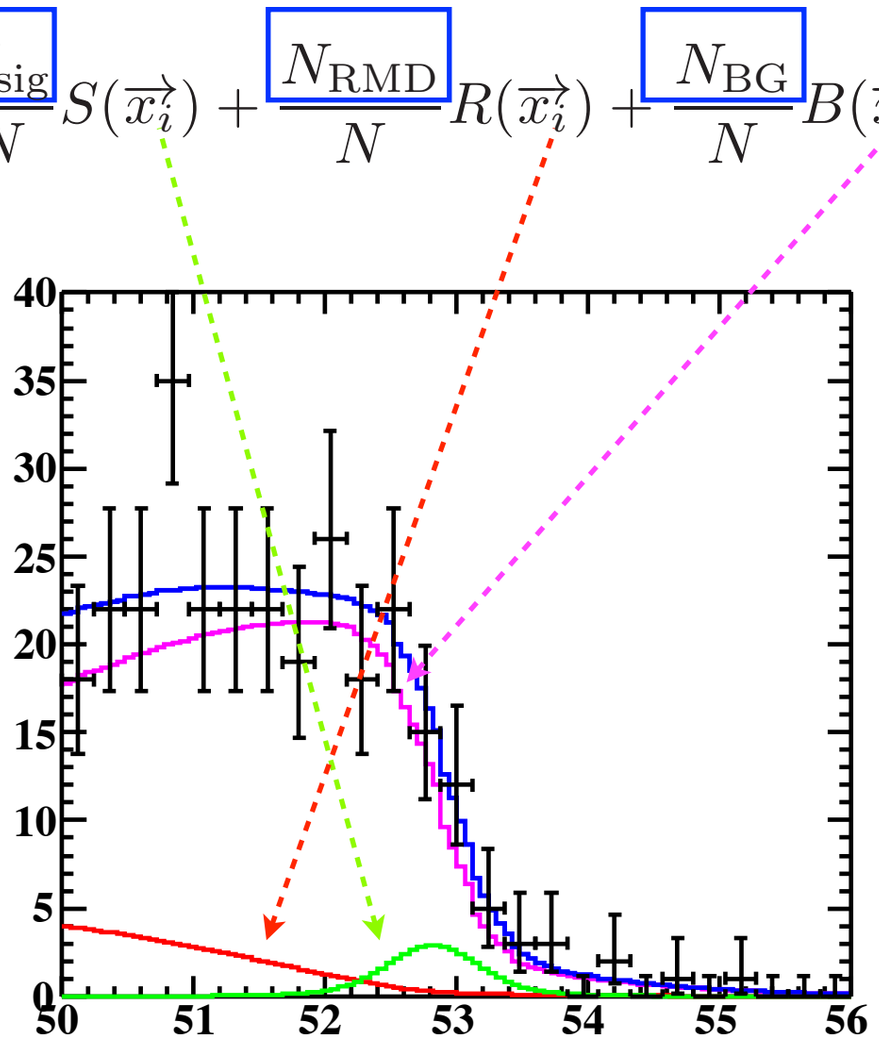
Extended unbinned maximum likelihood analysis on number of events

$$\mathcal{L}\left(N_{\rm sig}, N_{\rm RMD}, N_{\rm BG}\right)$$

$$= \frac{N^{N_{\rm obs}}\exp(-N)}{N_{\rm obs}!} \times$$

$$\prod_{i=1}^{N_{\rm obs}}\left[\frac{N_{\rm sig}}{N}S(\vec{x_i}) + \frac{N_{\rm RMD}}{N}R(\vec{x_i}) + \frac{N_{\rm BG}}{N}B(\vec{x_i})\right]$$

Parameters : N_{sig}, N_{RMD}, N_{BG}
Observables : $\vec{x_i} = E_\gamma, E_e, T_{e\gamma}, \theta_{e\gamma}, \varphi_{e\gamma}$
Event-by-event PDF



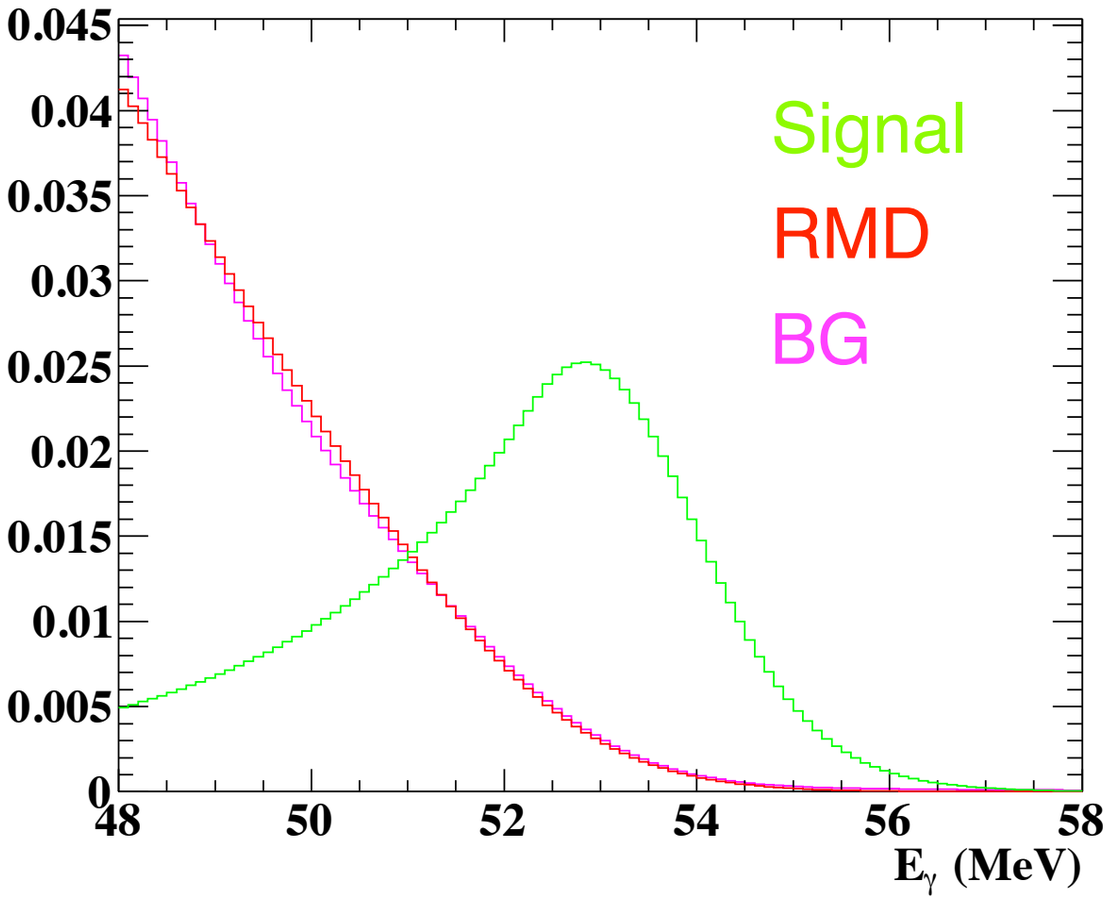
Toy MC
Projection to a parameter

BG : Accidental
RMD : Radiative muon decay

- Fit is done by independent likelihood analysis tools to check possible systematic effects.

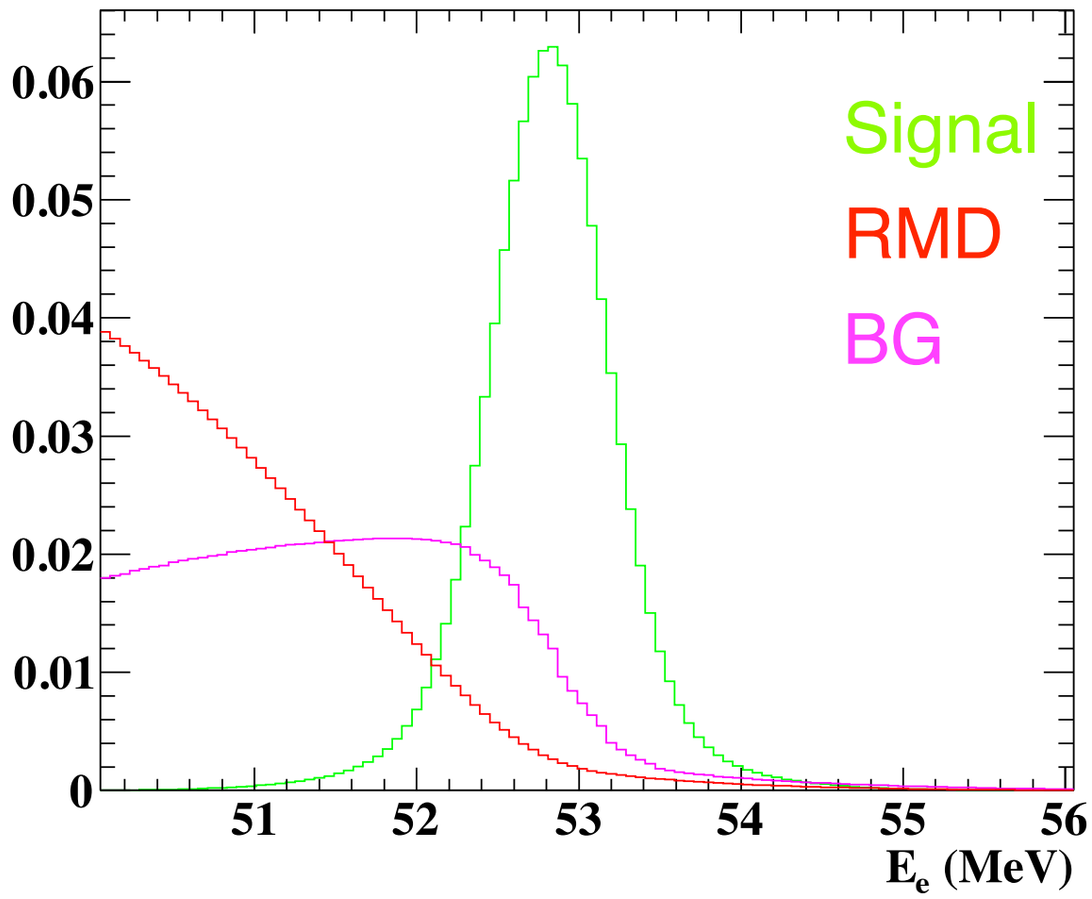
PDFs

Gamma Energy



Signal : 55MeV calibration gamma (π^0 decay)
BG : Measured in sideband
RMD : Theoretical shape folded with resolution

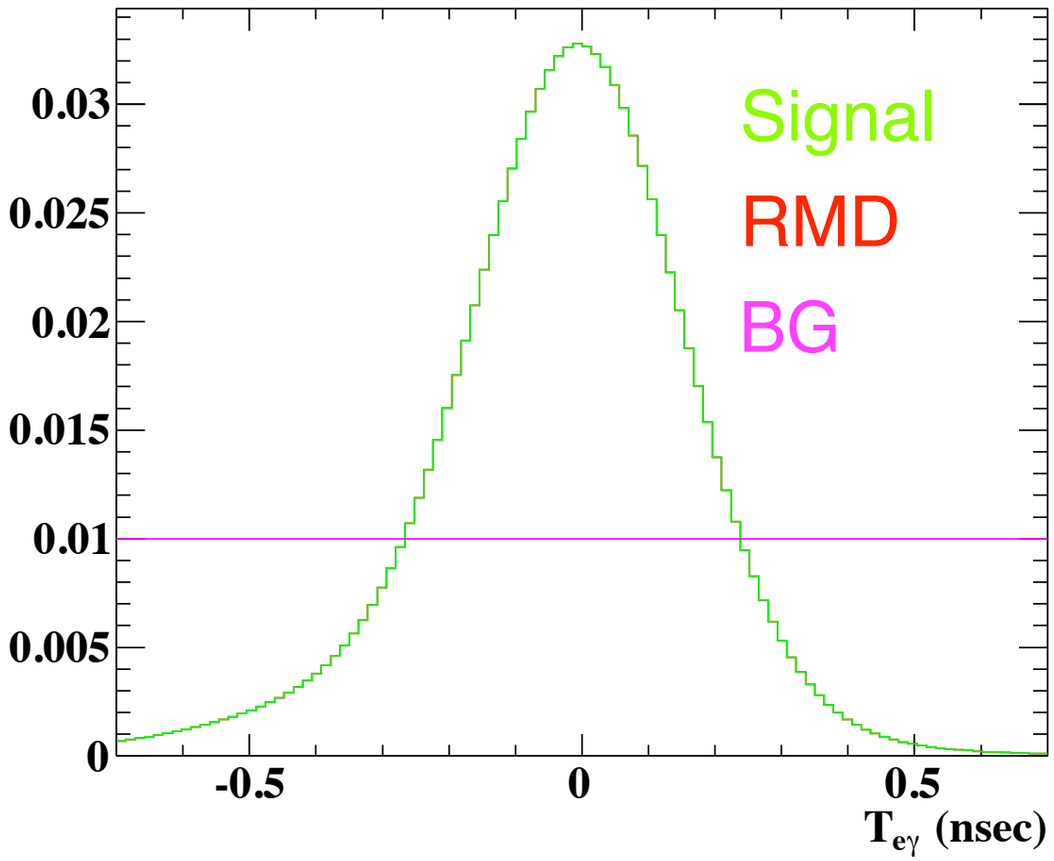
Positron Energy



Signal : Measured resolution
BG : Measured in sideband
RMD : Theoretical shape folded with resolution

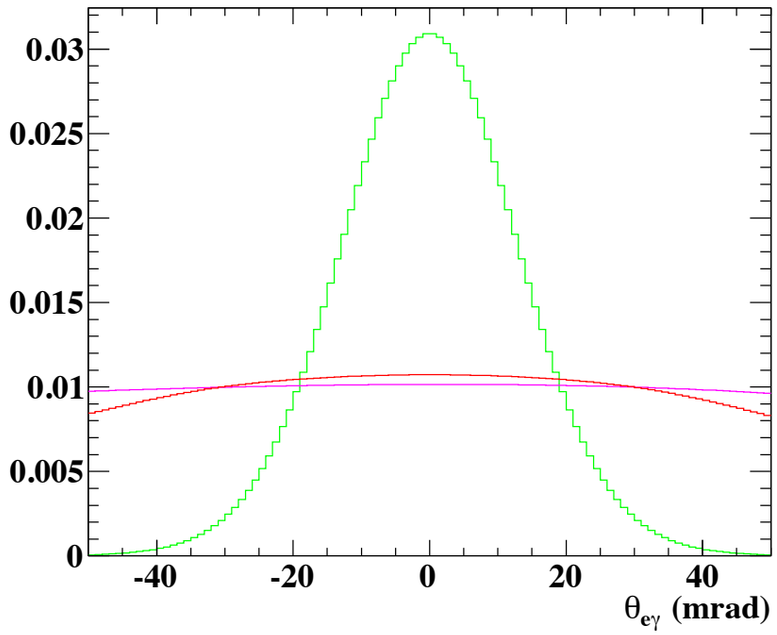
PDFs

Relative time

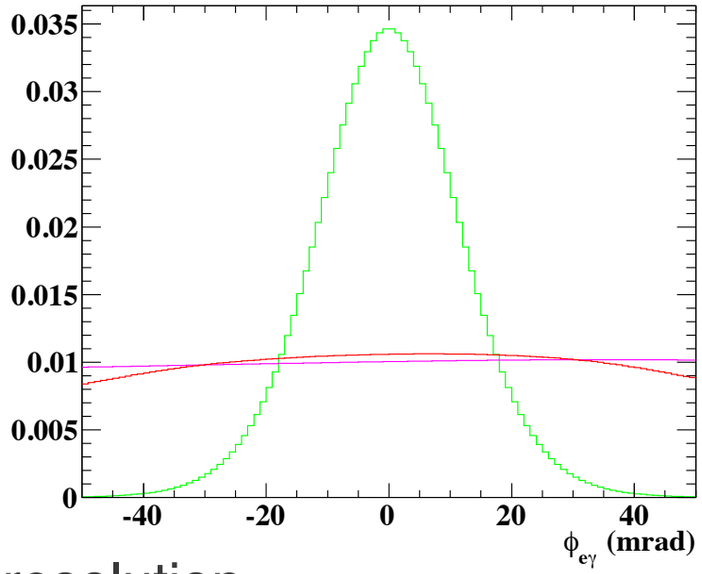


Signal : Measured RMD peak
BG : Flat
RMD : Theoretical shape folded with resolution

Relative angle



Signal
RMD
BG



Signal : Measured resolution
BG : Measured in sideband
RMD : Theoretical shape folded with resolution

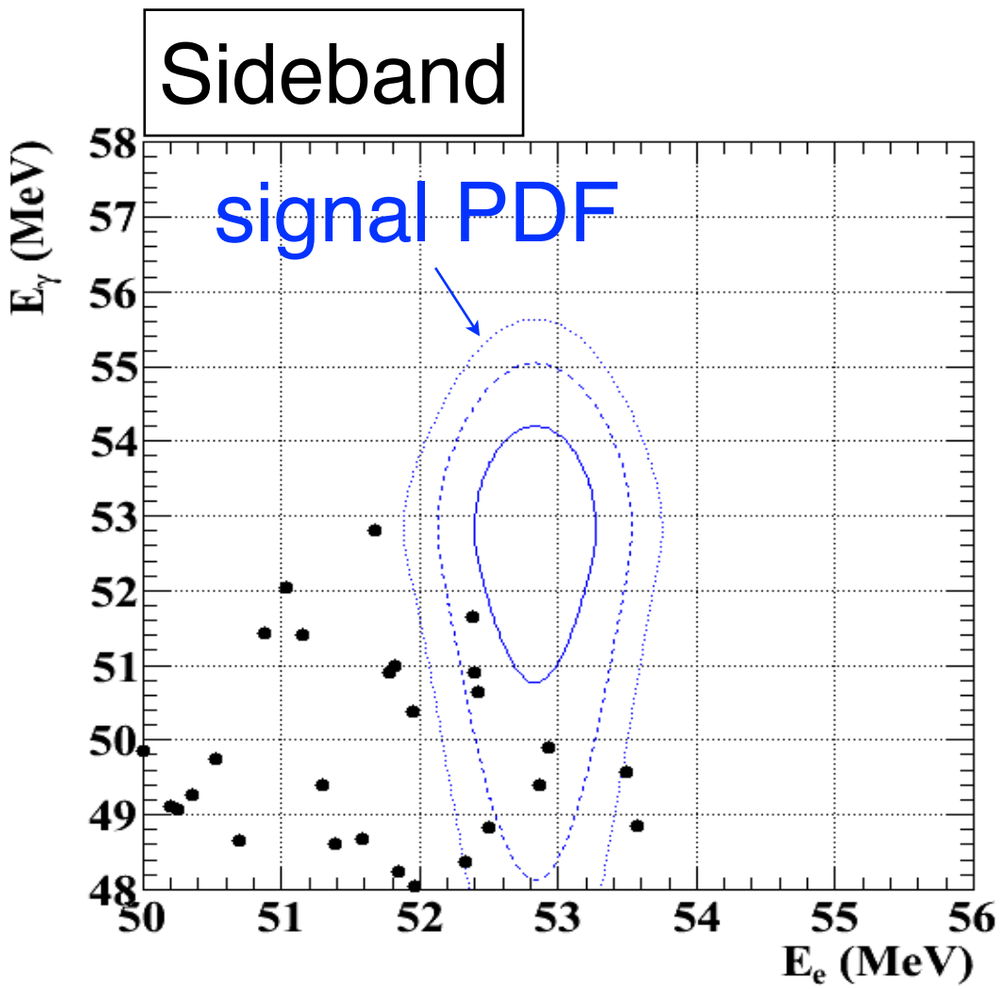
2009 Run Sensitivity

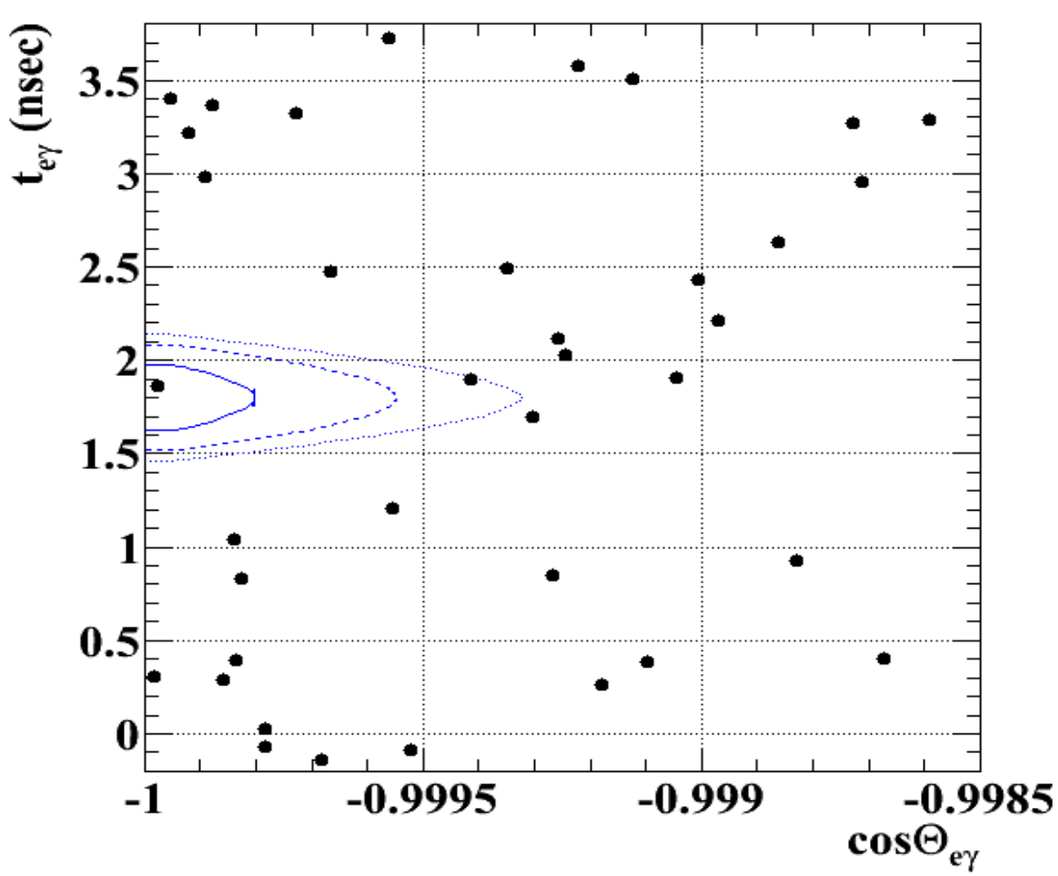
Average 90% C.L. upper limit of toy MC with null signal.

Sensitivity : 6.1×10^{-12}

Sideband fit result is consistent. Br < $4\text{-}6\times10^{-12}$

前の実験のUL (MEGA $1.2\text{x}10^{-11}$) よりも二倍良い実験感度



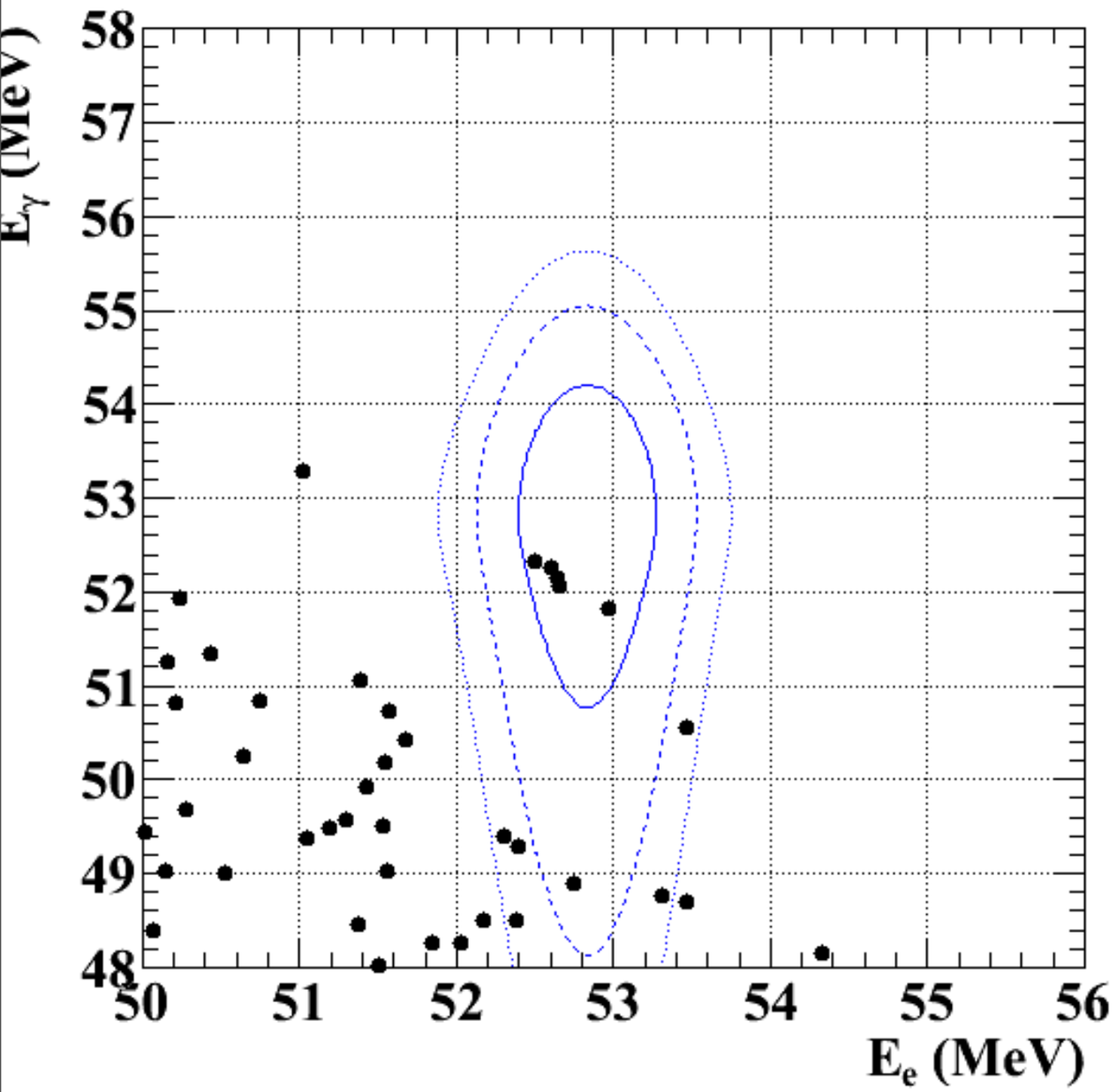


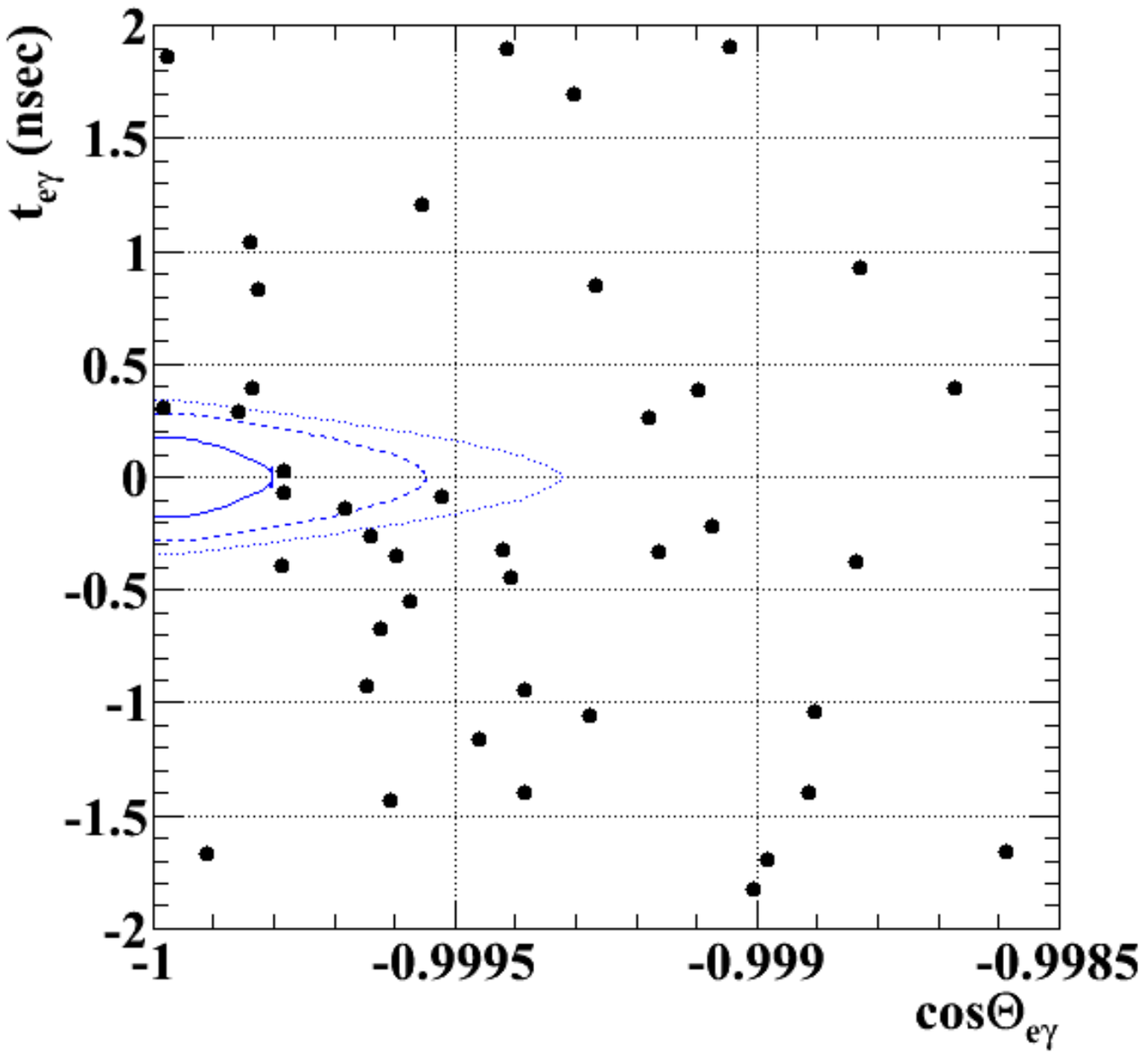
Positive $T_{e\gamma}$ sideband

Blue lines are 1(39.3 % included inside the region w.r.t. analysis window), 1.64(74.2%) and 2(86.5%) sigma regions.

2009 Preliminary Result

Event distribution after unblinding

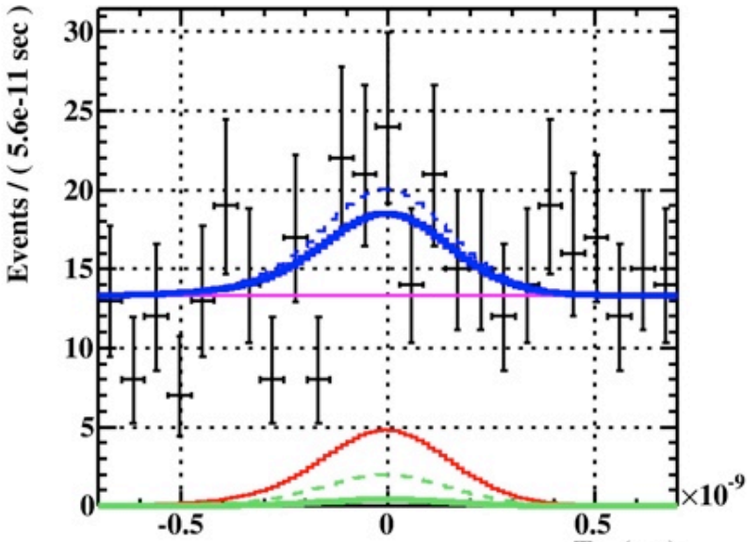




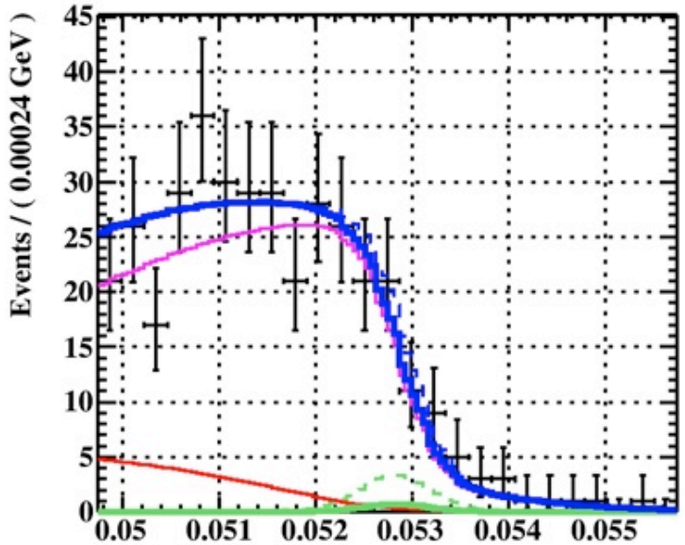
Blue lines are 1(39.3 % included inside the region w.r.t. analysis window), 1.64(74.2%) and 2(86.5%) sigma regions.

For each plot, cut on other variables for roughly 90% window is applied.

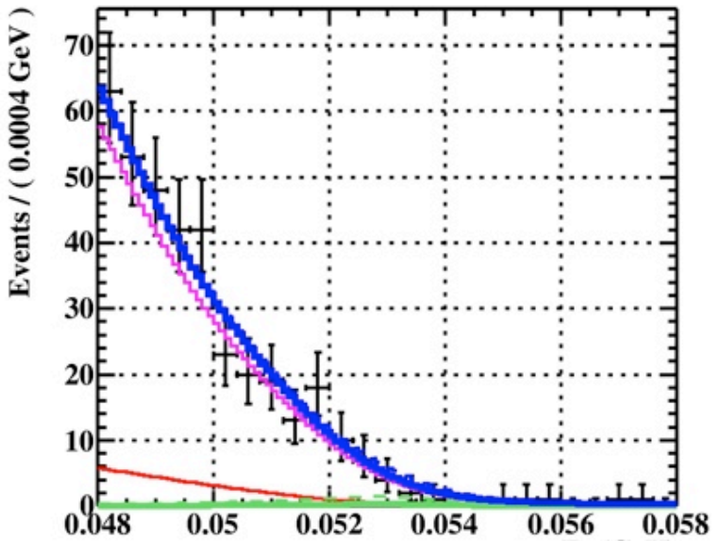
Fit Result



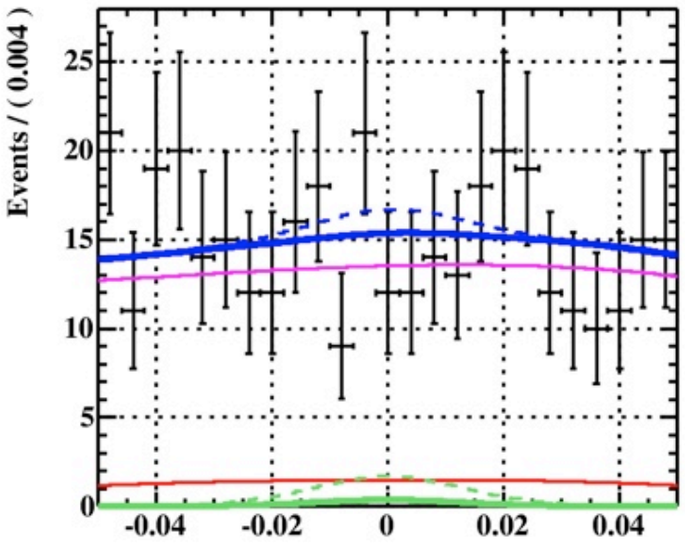
$T_{e\gamma}$ (psec)



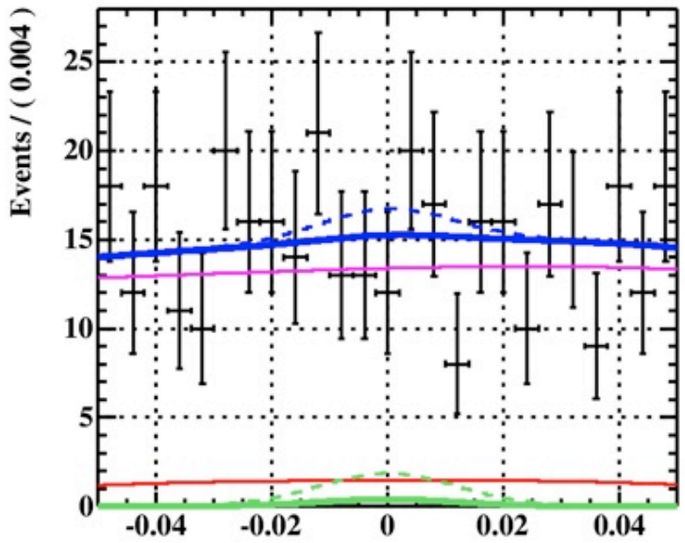
E_e (MeV)



E_γ (MeV)



$\theta_{e\gamma}$ (mrad)



$\phi_{e\gamma}$ (mrad)

Accidental BG

RMD

Signal

Total

$N_{RMD}=35^{+24}_{-22}$
(Expectation from sideband = 30±2)

Dashed lines : 90% C.L. UL of Nsig

Nsig best fit = 3.0

Nsig < 14.5 @ 90% CL

Nsig=0は90%CL範囲内 (excludeされていない)

B.R. = Nsig / 1.0 ± 0.1 × 10^{12}

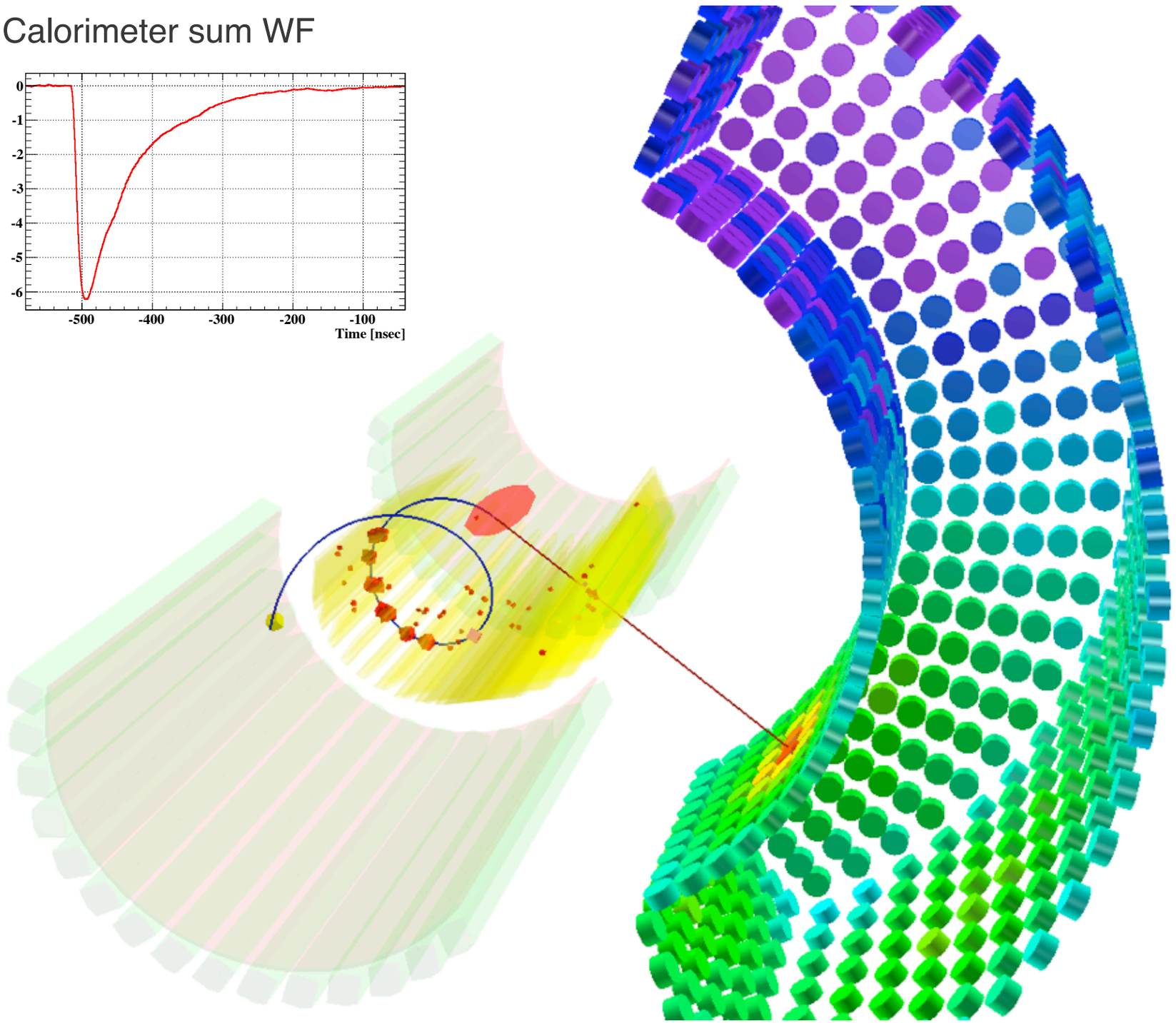
Fitting was done by three groups with different parametrization, analysis window and statistical approaches, and confirmed to be consistent (Nsig best fit = 3.0-4.5, UL = 1.2-1.5×10^{-11})

Event display

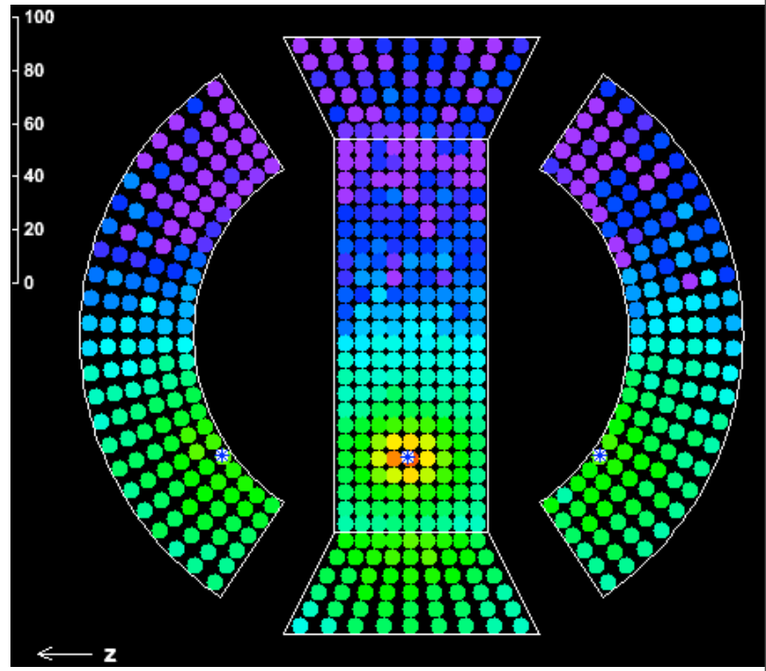
One of the most signal-like events.

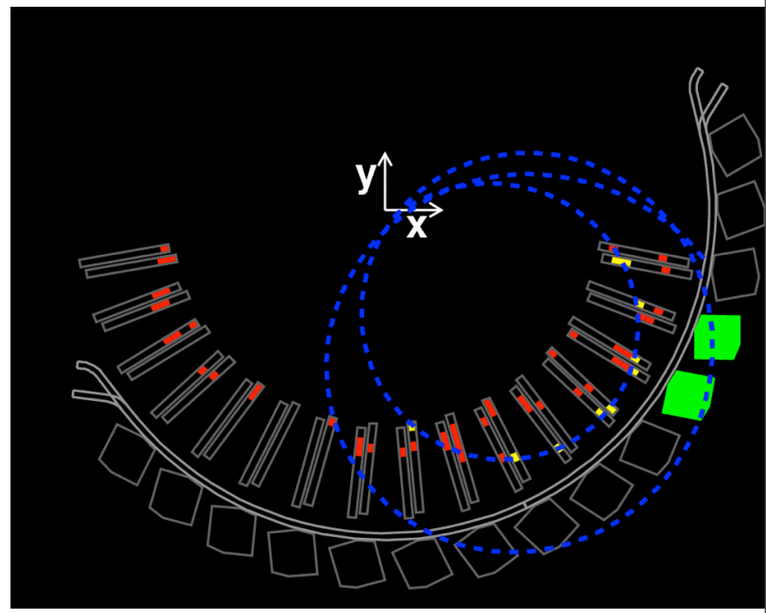
E_γ = 52.25 MeV
E_{e+} = 52.84 MeV
$\Delta\theta$ = 178.8 degrees
$\Delta T = 2.68 \times 10^{-10}$ s

Calorimeter sum WF



Calorimeter PMT hit map





Spectrometer hits and a track

Final analysis of 2009 run *to be in public soon*

After the preliminary analysis, we understood several sources of uncertainties better. **Sensitivity is therefore better than the preliminary result**.

- Treatment of **magnetic field**.
  - Resulted in a better resolutions and smaller systematic uncertainties

- **Relative alignment** between photon and positron detectors.
  - Several measurements were carried out
    - Cosmic rays
    - Calibration 17.6 MeV gamma ray with putting small lead cubes in front of the photon detector
    - AmBe source scan in front of the photon detector
  - Resulted in a smaller uncertainty.
  - In this year, we may take dedicated RMD data for the purpose

Perspective

- 2010 DAQ is finished; x1.9 times data statistics compared to 2009 run.
  - Better time resolution is expected thanks to upgrade of DRS
- 2011 is the first long-term physics run
- Possible improvements
  - Hardware
    - DAQ and trigger efficiency improvement with multiple event buffer
    - Positron detection efficiency improvement with thinner cables and layout.
    - New HV modules to reduce noise
  - Analysis
    - Positron
      - Software noise filtering
      - Use scintillation fiber data (not used so far)
      - Calibration with monochromatic calibration positrons (Mott scattering)
      - Improvement of magnetic field systematics
      - Time reconstruction
    - Gamma
      - Improvement of energy reconstruction algorithm

Performance summary and prospect

	2008	2009	2010 (preliminary)	2011 (preliminary)	2012 (preliminary)
Gamma Energy (%)	2.0(w>2cm)	←	1.5-2.0	1.2-2.0	←
Gamma Timing (psec)	80	>67	←	←	←
Gamma Position (mm)	5(u,v)/6(w)	←	←	←	←
Gamma Efficiency (%)	63	58	58-60	←	←
e^+ Timing (psec)	<125	←	←	←	←
e^+ Momentum (%)	1.6	0.61(core)	←	0.55-0.61(core)	←
e^+ Angle (mrad)	10(ϕ)/18(θ)	6.2(core)/9.4	←	← / 7-9.4 (θ)	←
e^+ Efficiency (%)	14	40	←	←	40-55
e^+-gamma timing (psec)	148	151(core)	120-130	100-130	←
Muon Decay Point (mm)	3.2(Y)/4.5(Z)	3.3(Y)/3.3(Z)	←	2.8-3.3/3.0-3.3	←
Trigger efficiency (%)	66	91	92	92-98	←
Stopping Muon Rate (sec^{-1})	3×10^7	2.9×10^7(300μm)	2.9×10^7	←	←
DAQ time/ Real time (days)	48/78	35/43	56/67	135/161	←

Sensitivity Prospect

2008,2009(preliminary) ML analysis UL

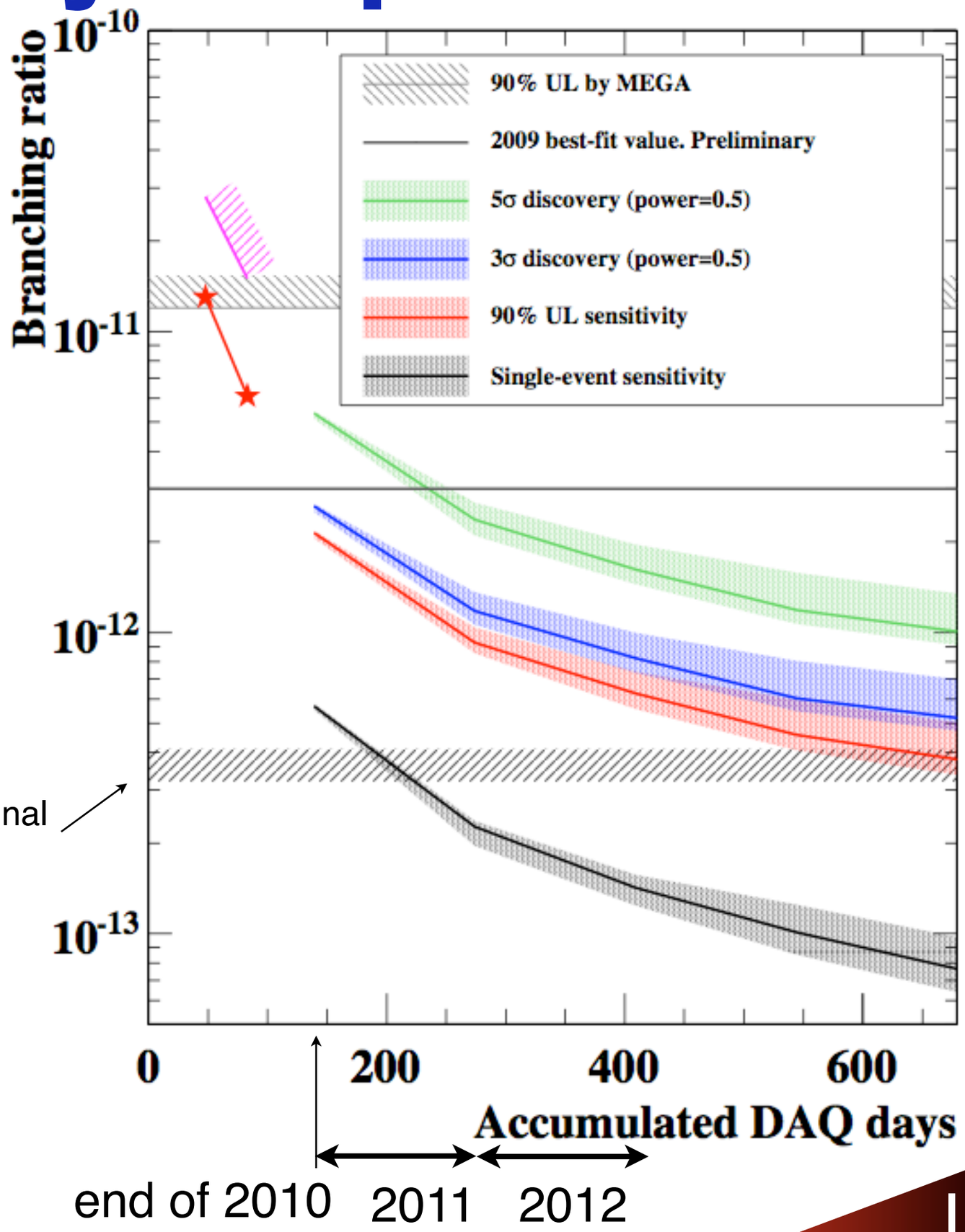
★ 2008,2009(preliminary) ML analysis sensitivity

Based on cut analysis (lower sensitivity than maximum likelihood)

Band shows different scenarios of detector resolutions

BG BR in a optimized signal box for this cut analysis

Possible major upgrades after 2012 are not included in the calculation



Conclusion

- Preliminary results from 2009 data,
  - Sensitivity : 6.1×10^{-12}.
  - 90 % C.L. upper limit : 1.5×10^{-11}
  - Nsig=0 is in 90% C.L. region.
- 2010 run is finished and being analyzed.
- We will take data for another 2 years at least.
- We can clarify the result with a much better sensitivity.
  - If it was due to BG fluctuation : it would be excluded at >90%CL already with 2010 data
  - If it was due to signal : we would discover

2009年ランの最終結果は来週発表

詳しくは春の学会でお話しします