

Recent Results from MEG Experiment

W. Ootani on behalf of MEG collaboration
ICEPP, University of Tokyo

Rencontres de Moriond EW 2012, March 3rd-10th, 2012, La Thuile - Aosta Valley, Italy

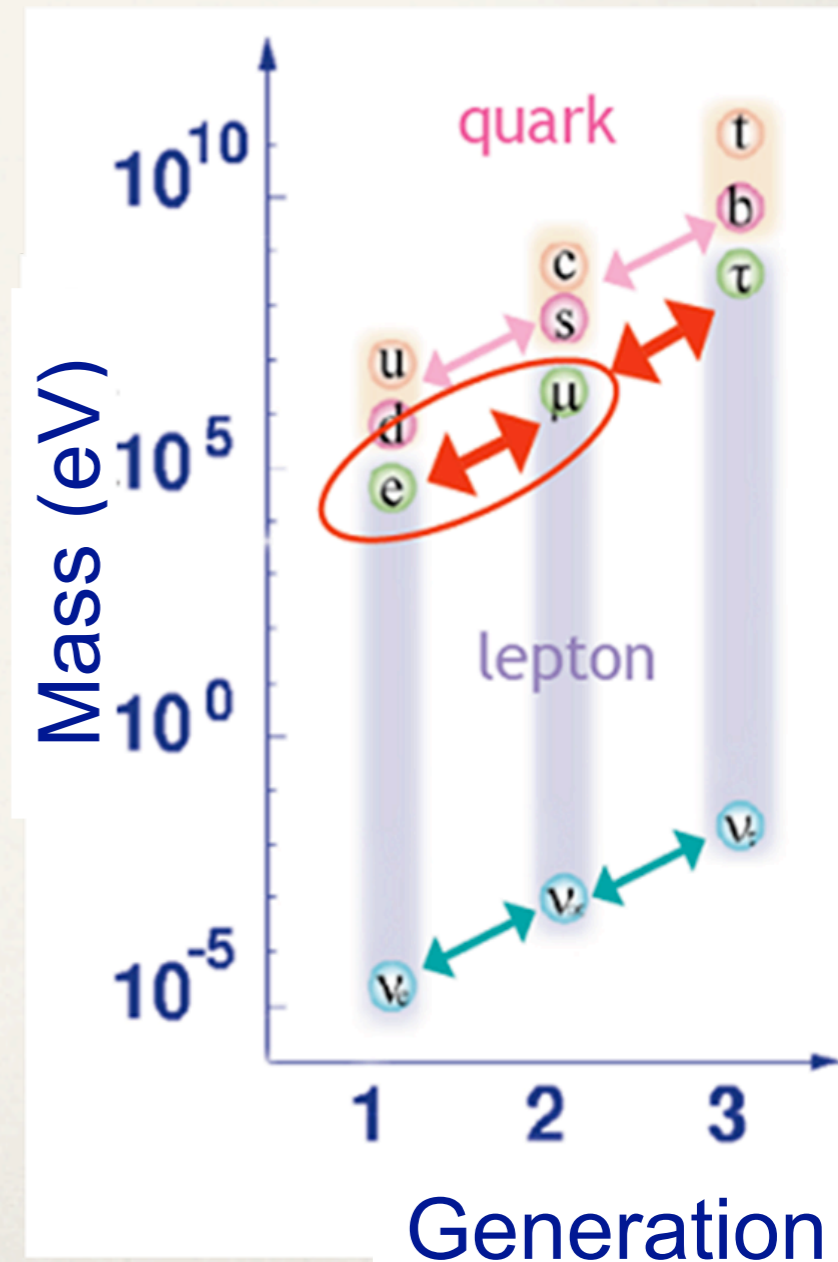
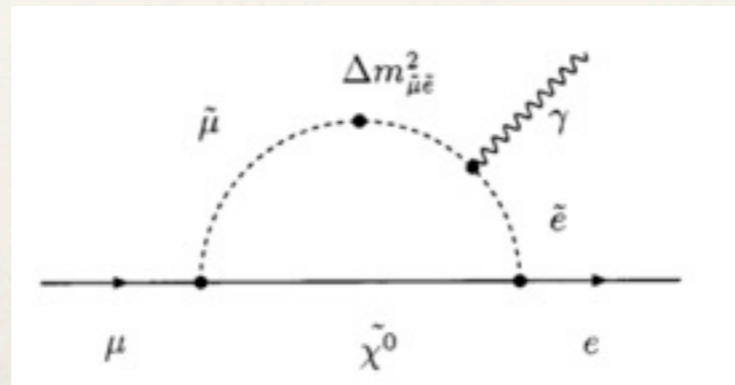
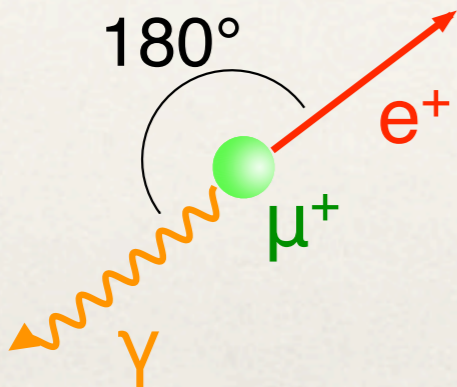
Contents

- ❖ MEG Experiment
- ❖ Recent Results from Data 2009 / 2010
- ❖ Status and Prospects
- ❖ Summary

MEG Experiment

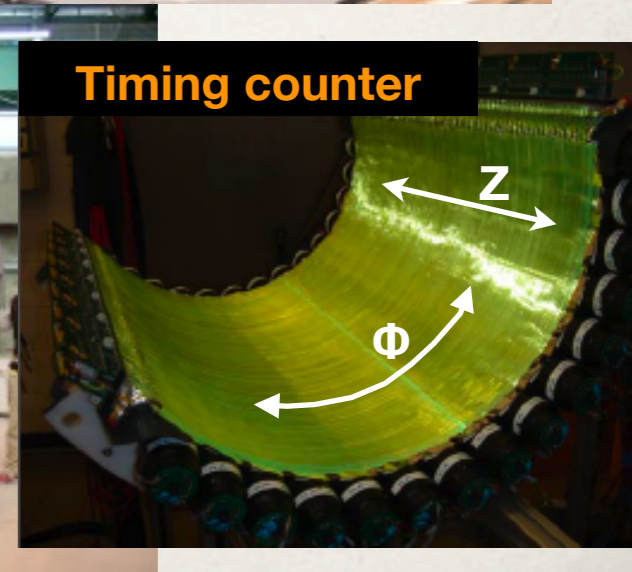
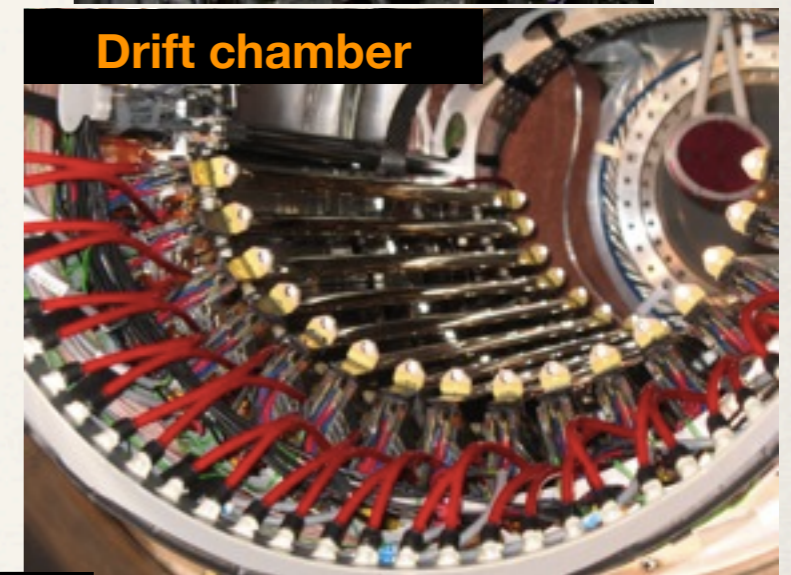
MEG Experiment

- ❖ MEG searches for lepton flavor violating decay, $\mu^+ \rightarrow e^+ \gamma$ with an unprecedented sensitivity
 - ❖ Target sensitivity: $\mathcal{O}(10^{-13})$
- ❖ No background from SM, while many “positive” predictions in new physics.
- ❖ Unambiguous evidence for new physics if discovered!
- ❖ Physics data taking in progress since September 2008.

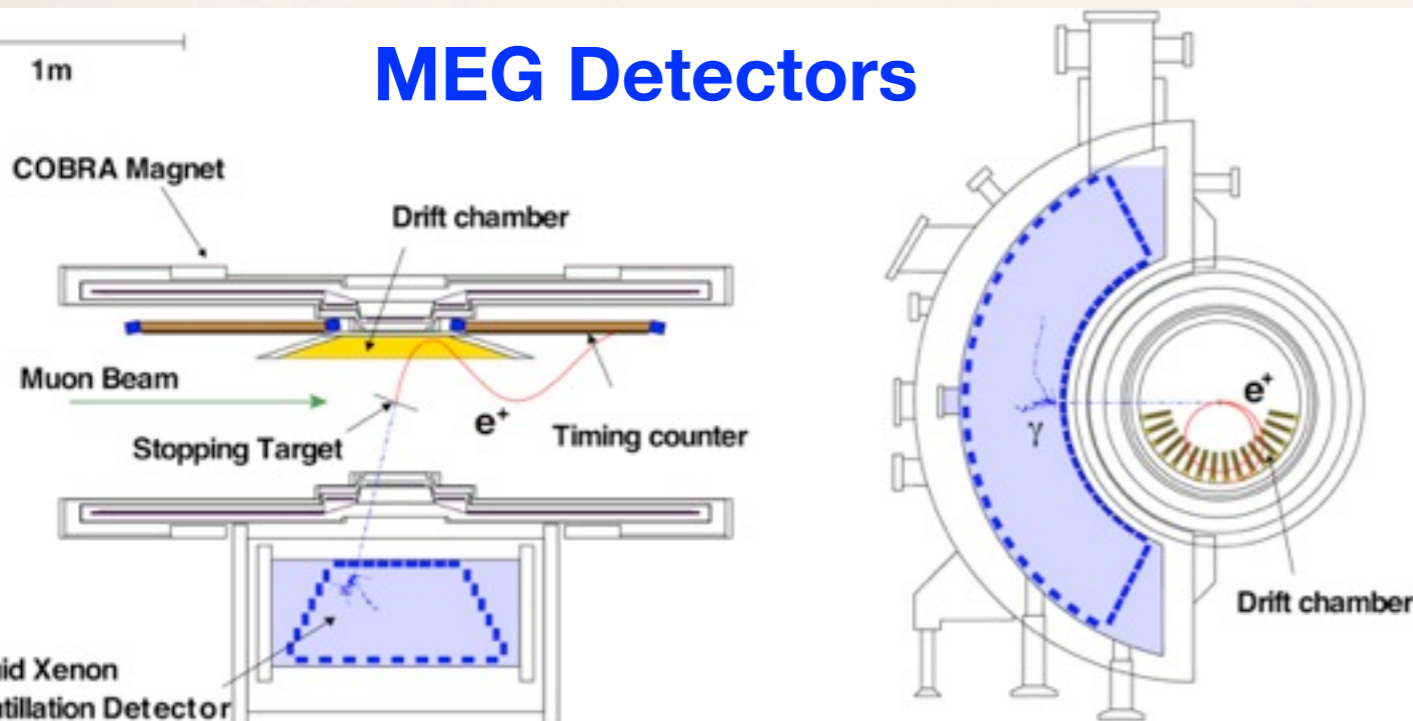


Detectors

- ❖ World's largest LXe γ -detector (900L-LXe)
- ❖ Positron spectrometer
 - ❖ Low-mass drift chamber system
 - ❖ Fast timing counters
 - ❖ Thin-wall superconducting magnet generating special gradient magnetic field (COBRA magnet)
- ❖ World's most intense DC muon beam at PSI ($\approx 10^8 \mu^+ / s$)



MEG Detectors

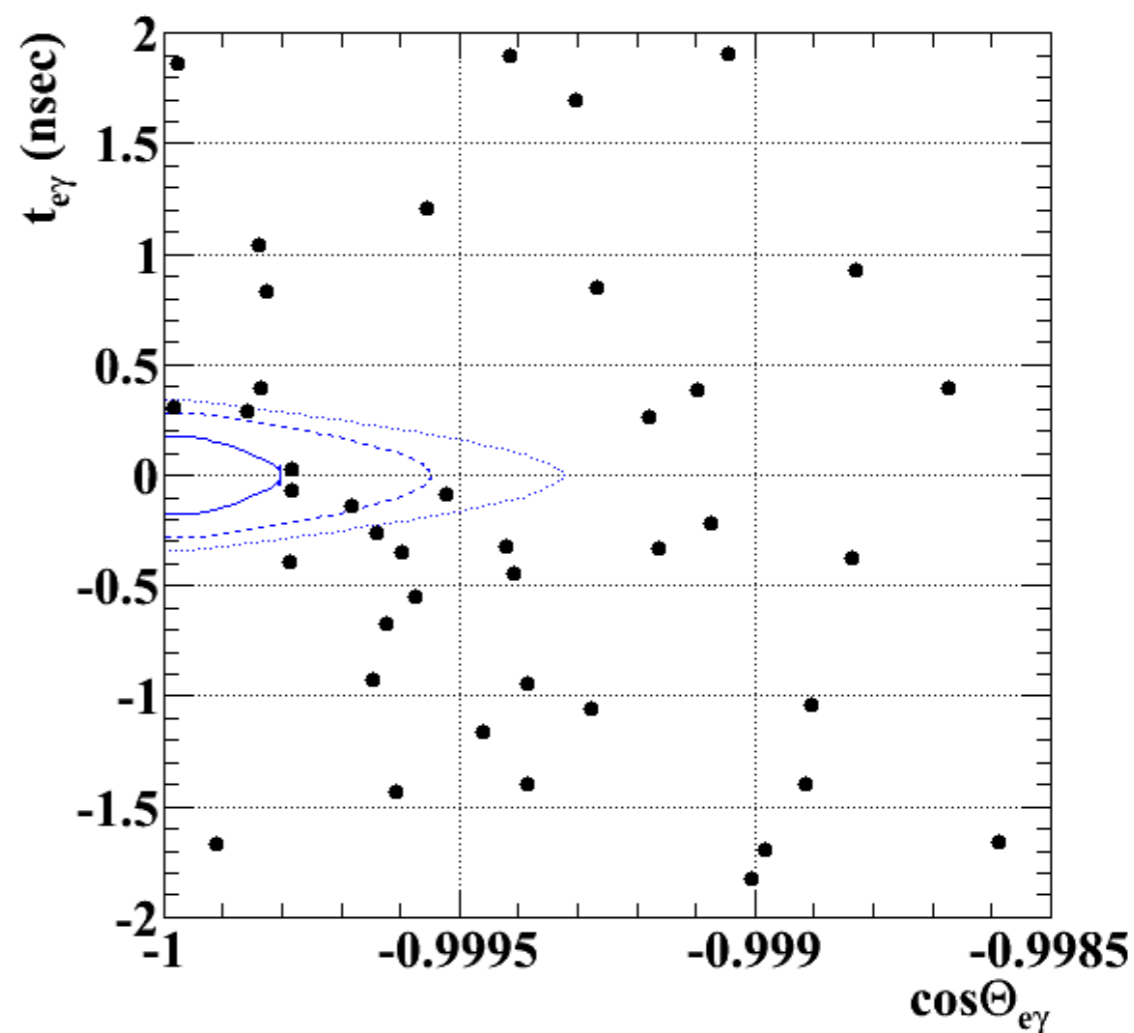
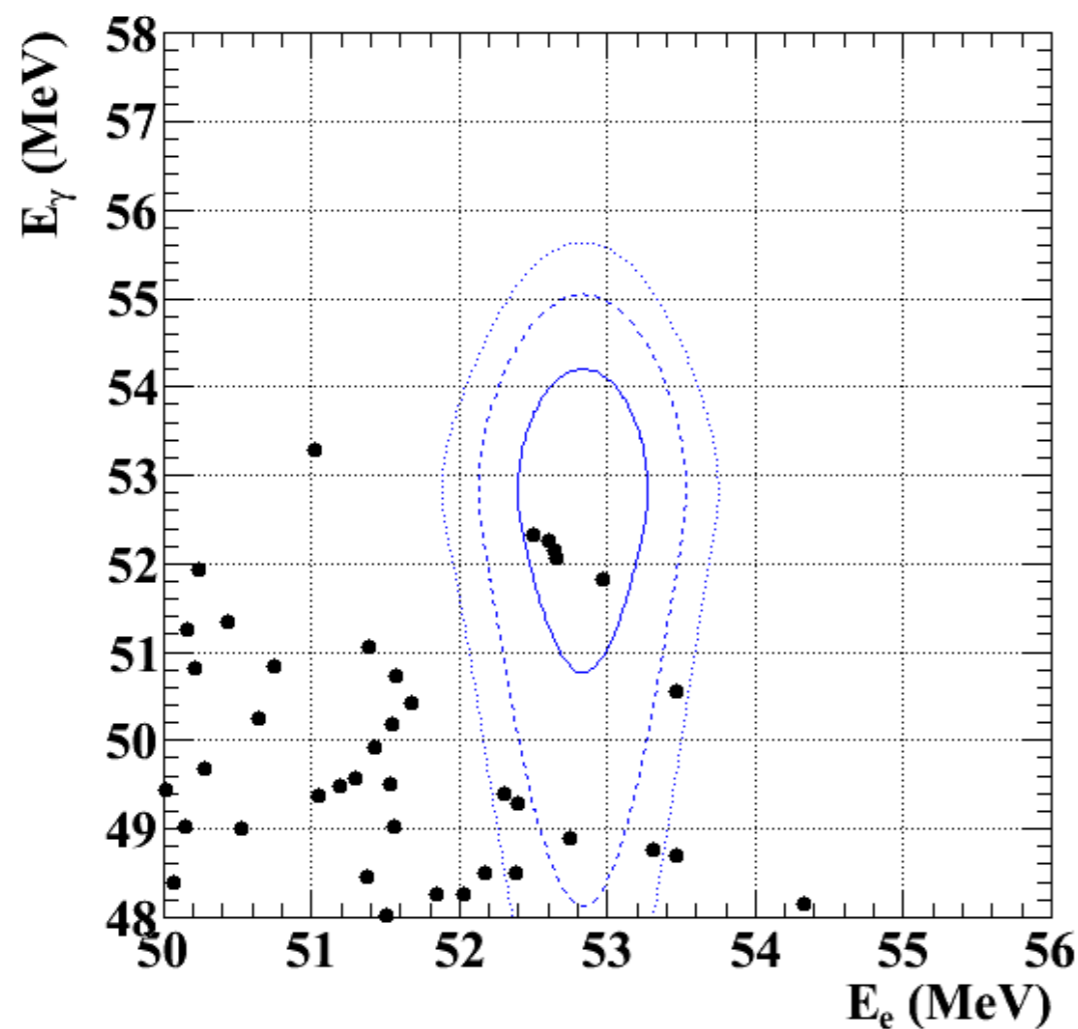


Recent Results from Data 2009/2010

New Result from Data 2009/2010

- ❖ Preliminary result on data 2009 was presented in ICHEP2010 showing a small excess.
- ❖ Updates with new data (from run2010) and new analysis
 - ❖ Data 2010 (data statistics = $2 \times$ data 2009)
 - ❖ Improve detector alignment
 - ❖ More detailed implementation of correlations in positron observables
 - ❖ Improve magnetic field map
 - ❖ Improve likelihood analysis tool
- ❖ New result from analysis on combined data sample for run 2009+2010 was published in Oct.'11.

Preliminary results from data 2009 shown at ICHEP2010



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.

ICHEP, Palais des Congrès, Paris, July 22-28, 2010 R.Sawada for MEG collaboration

|| 2010

was published in Oct. 11.

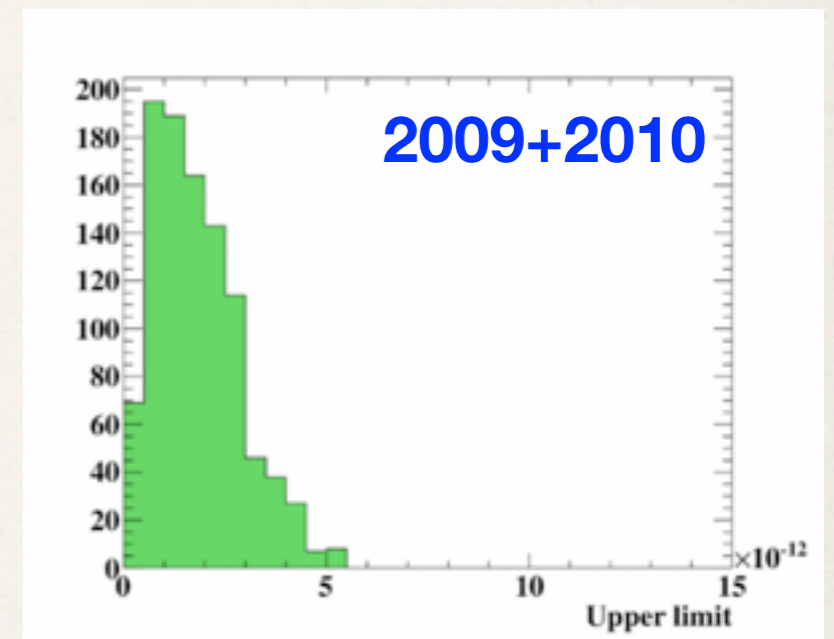
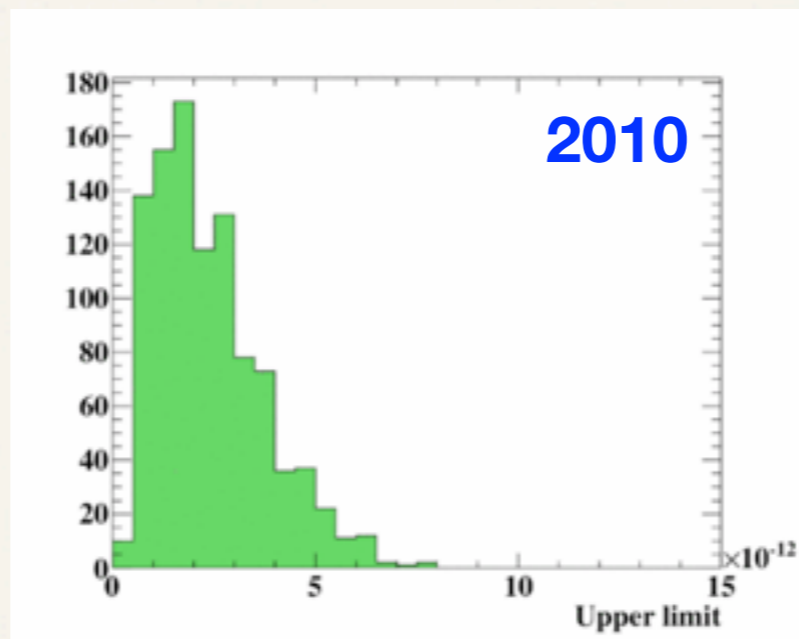
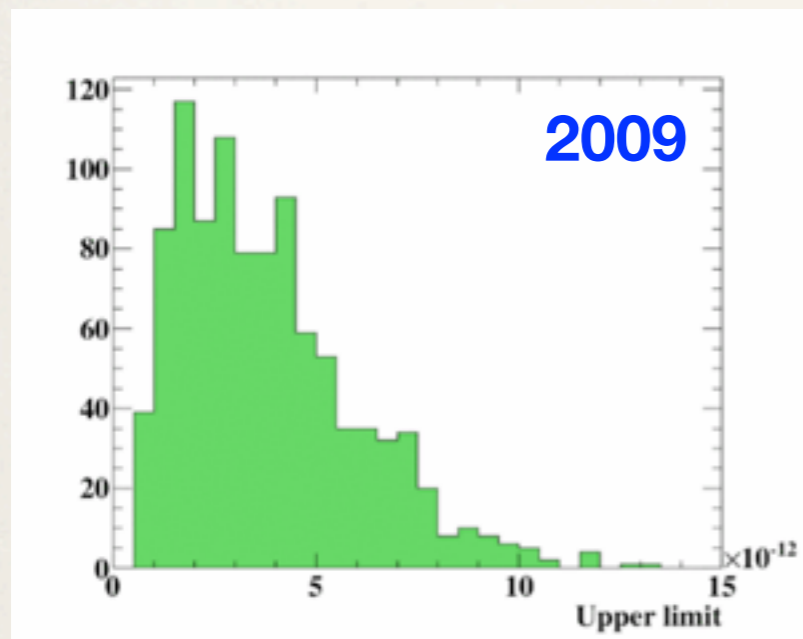
New Result from Data 2009/2010

- ❖ Preliminary result on data 2009 was presented in ICHEP2010 showing a small excess.
- ❖ Updates with new data (from run2010) and new analysis
 - ❖ Data 2010 (data statistics = $2 \times$ data 2009)
 - ❖ Improve detector alignment
 - ❖ More detailed implementation of correlations in positron observables
 - ❖ Improve magnetic field map
 - ❖ Improve likelihood analysis tool
- ❖ New result from analysis on combined data sample for run 2009+2010 was published in Oct.'11.

Sensitivity (data 2009+2010)

❖ Sensitivity

≡ Upper limit averaged over an ensemble of many toy MC experiments with BG only hypothesis with BG rate measured in side-bands



$\mathcal{B} = 3.3 \times 10^{-12}$ (median) $\mathcal{B} = 2.2 \times 10^{-12}$ (median) $\mathcal{B} = 1.6 \times 10^{-12}$ (median)

Sensitivity(2009+2010) is **x8 better** than previous best upper limit ($\mathcal{B} < 1.2 \times 10^{-11}$ (90%C.L.) MEGA 1999)

Side-band Analysis

- ❖ Same analysis performed in fictitious windows in side-bands before unblinding.
 - ❖ $T_{e\gamma}$ sideband (off-time)
 - ❖ Angle sideband (off-angle)
- ❖ **Observed branching ratio upper limits consistent with sensitivity**
- ❖ We got ready to open the blind box...

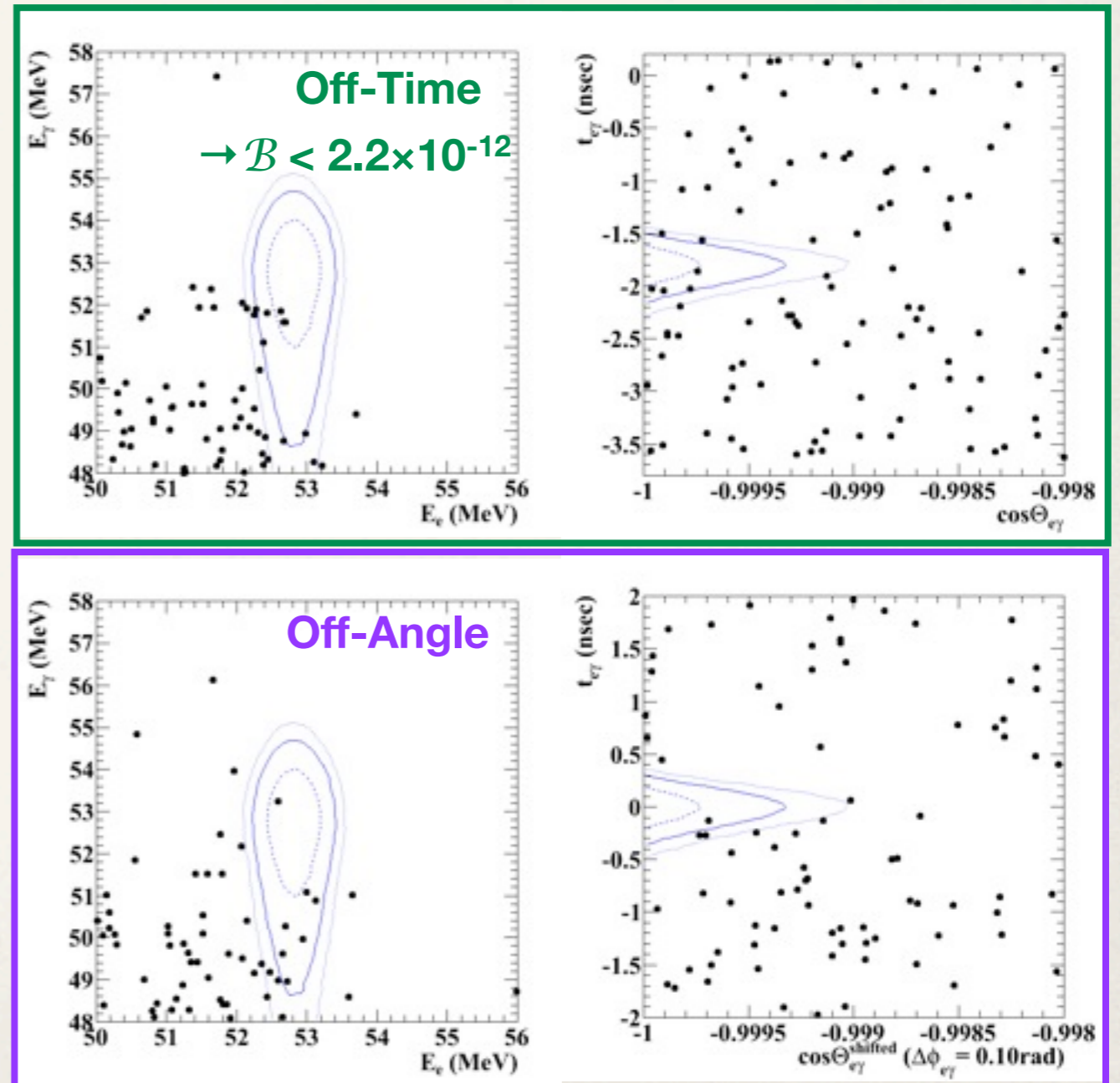
Selection

$(E_e - E_\gamma): \Theta_{e\gamma} < 178.4^\circ \quad |T_{e\gamma}| < 0.278 \text{ ns}$

$(\cos\Theta_{e\gamma} - t_{e\gamma}): 51 < E_\gamma < 55 \text{ MeV} \quad 52.34 < E_e < 55 \text{ MeV}$

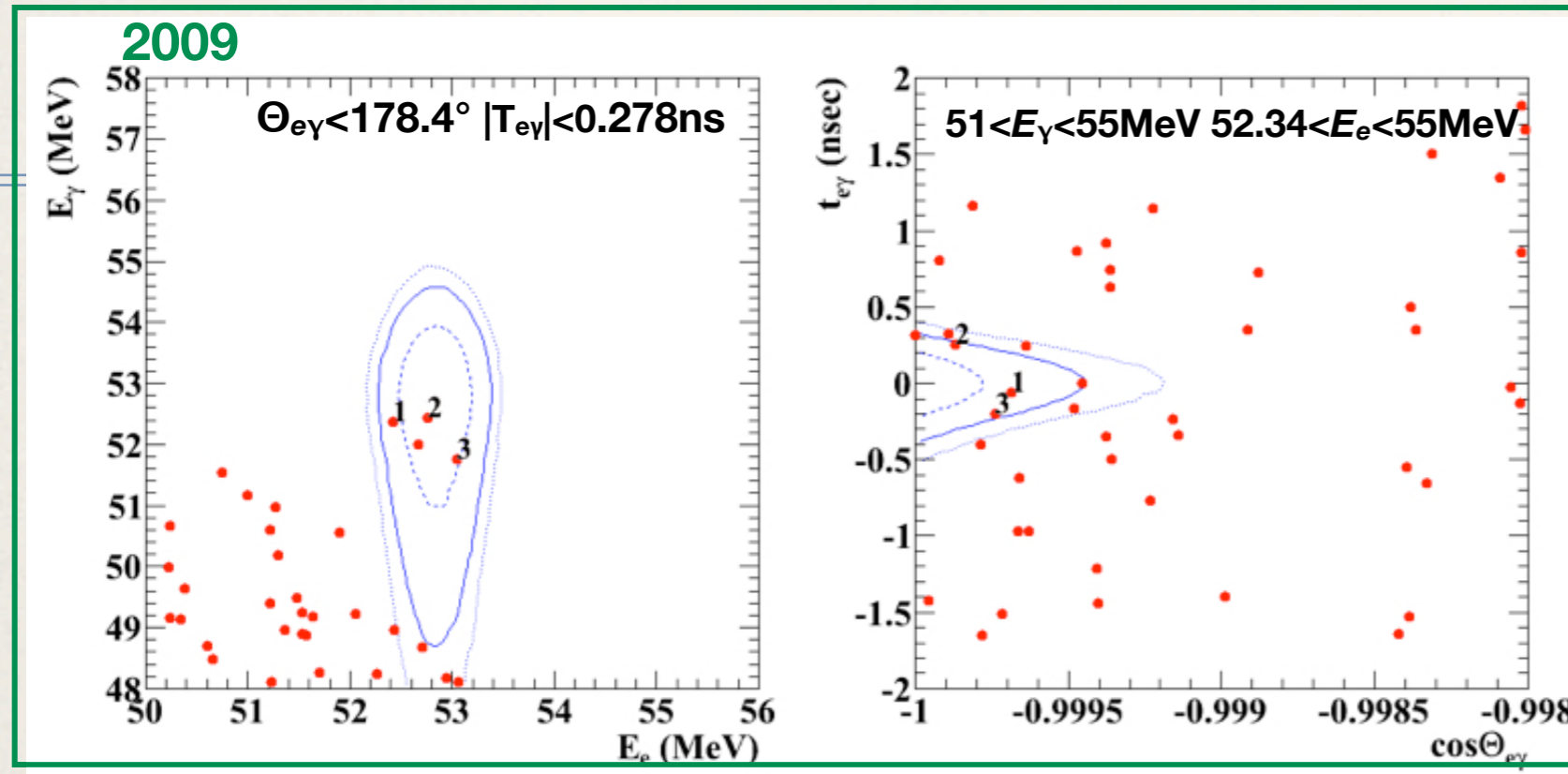
Blue curves:

PDF contour (1, 1.64, 2- σ)

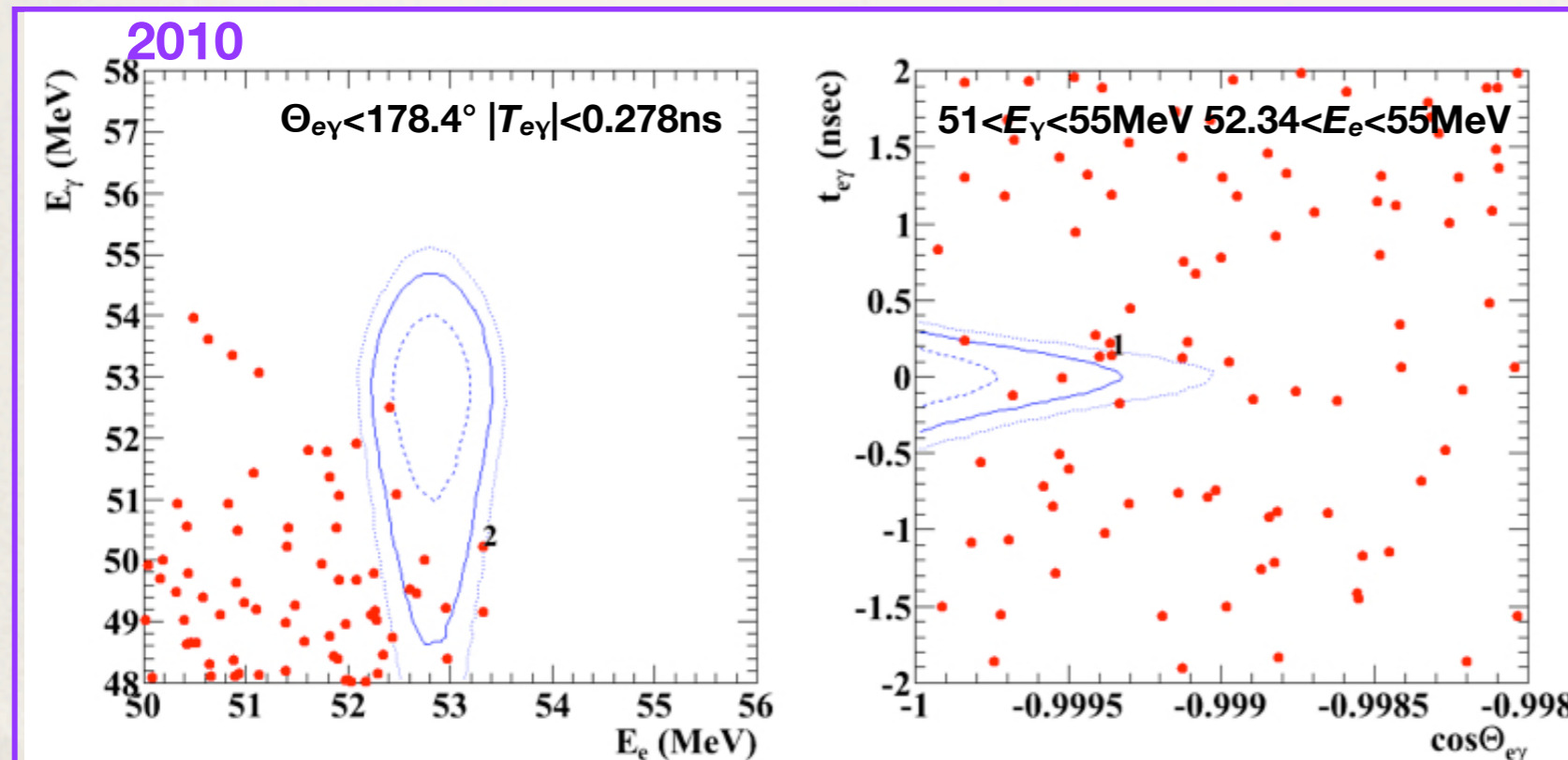


N.B.: These plots are just for reference, not used in the analysis

Event Distribution



Event distribution is not changed much compared to ICHEP10 presentation

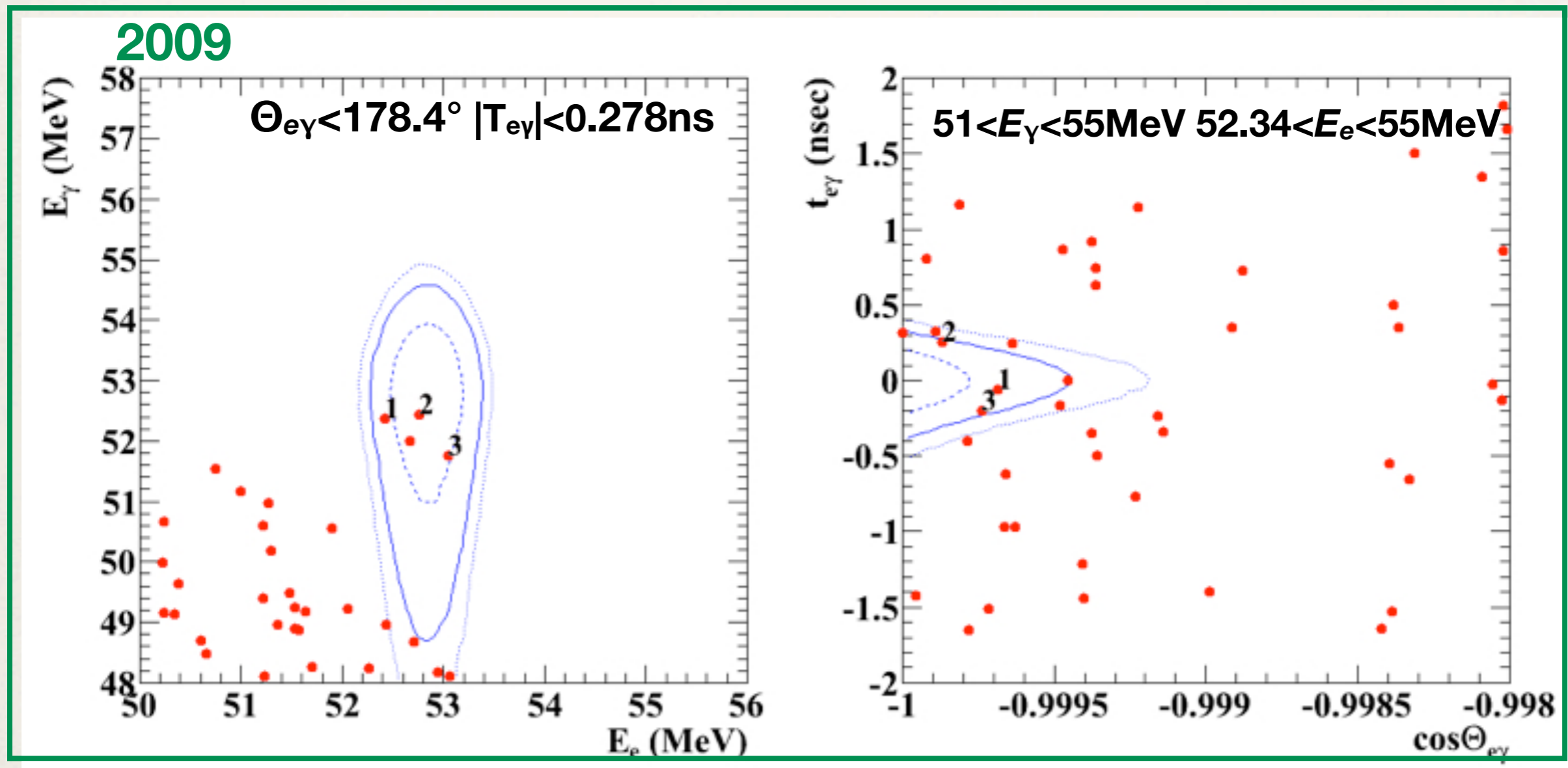


Blue curves: signal PDF contour (1, 1.64, 2- σ)

Events with highest signal likelihood ($S/(0.1R+0.9B)$) are numbered.

N.B.: These plots are just for reference, not used in the analysis

Event Distribution



is not
compared
to
simulation

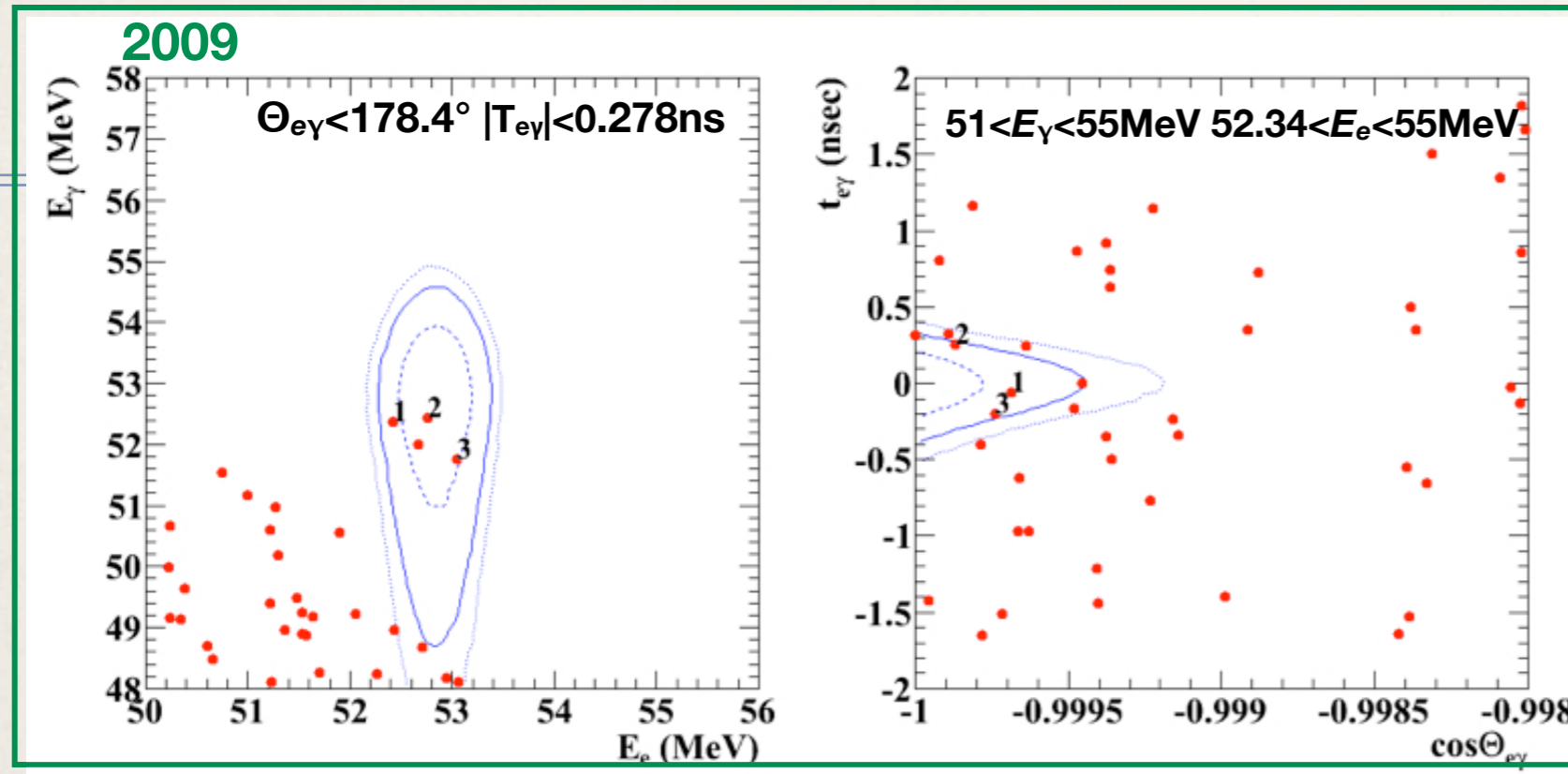
contour

are

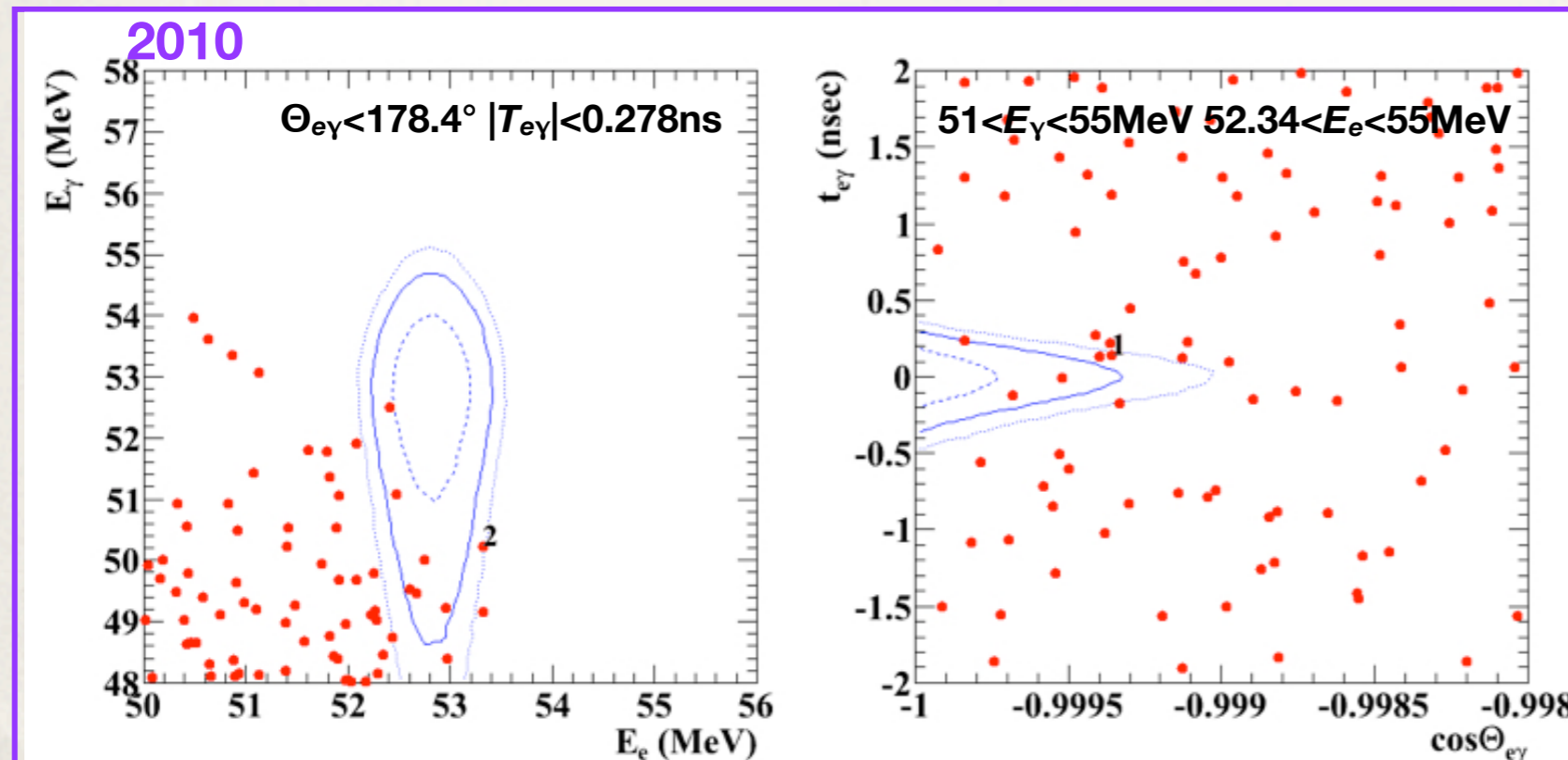
numbered.

N.B.: These plots are just for reference,
not used in the analysis

Event Distribution



Event distribution is not changed much compared to ICHEP10 presentation

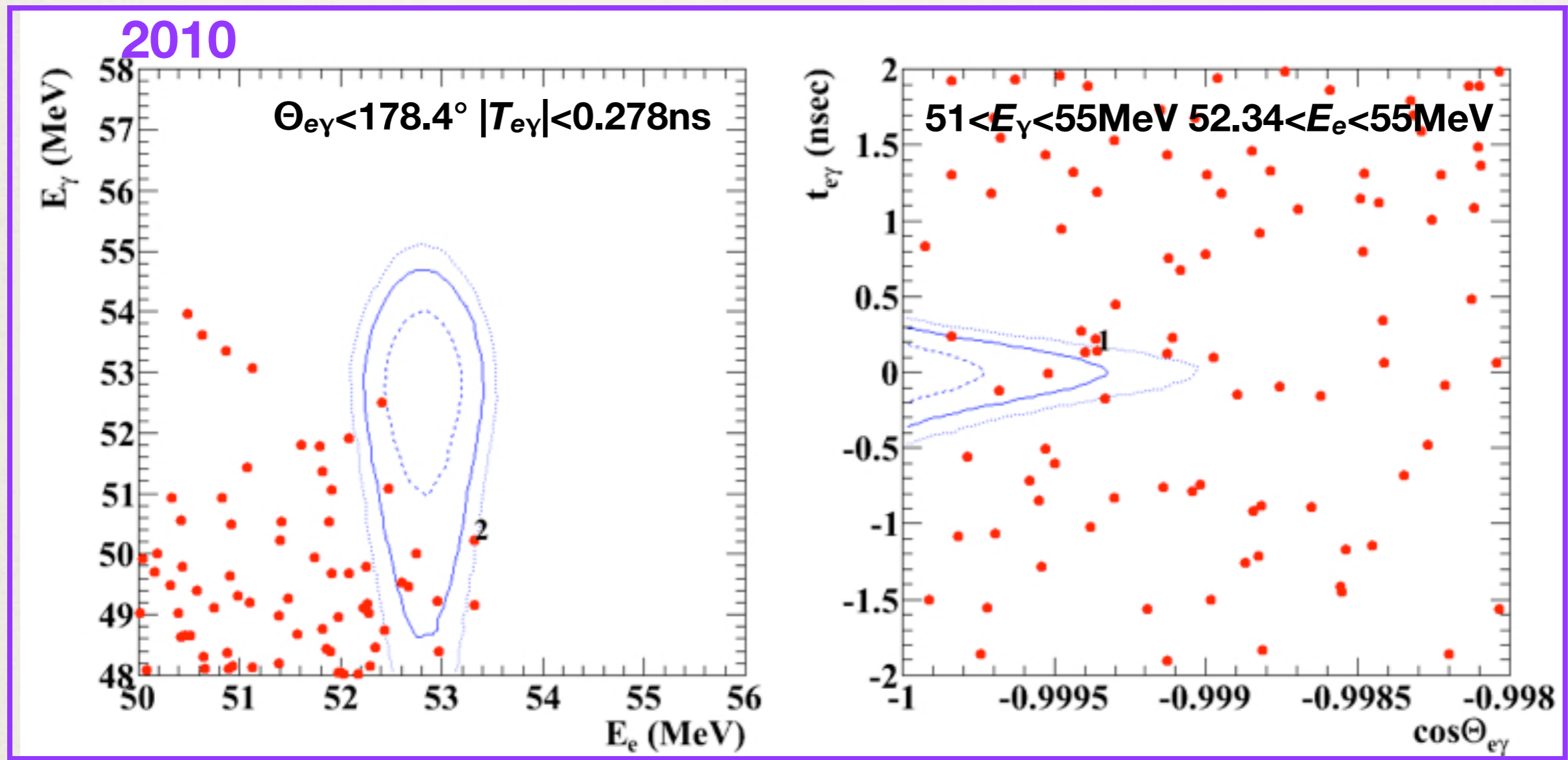


Blue curves: signal PDF contour (1, 1.64, 2- σ)

Events with highest signal likelihood ($S/(0.1R+0.9B)$) are numbered.

N.B.: These plots are just for reference, not used in the analysis

Event Distribution



is not
compared
to
simulation

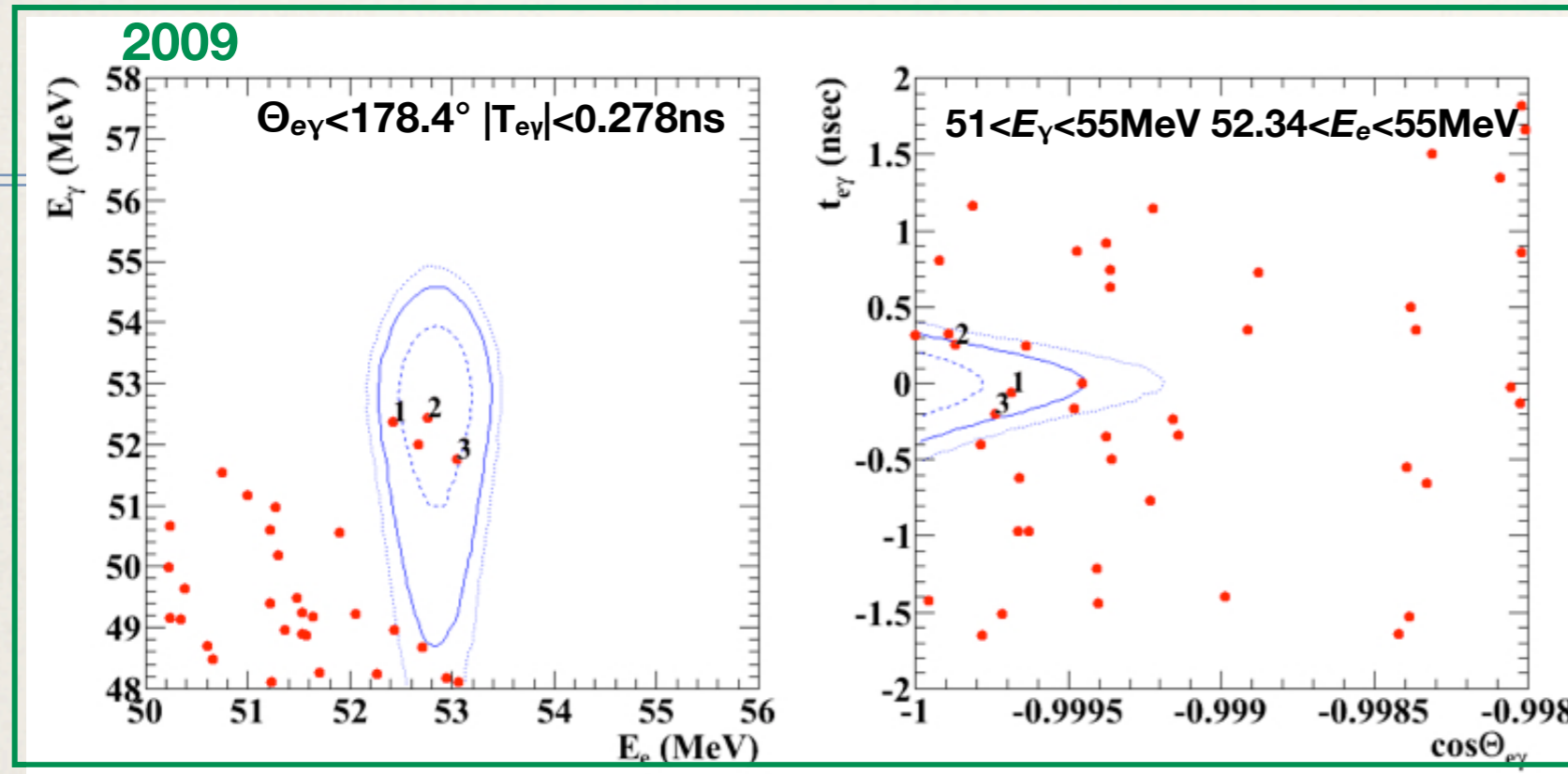
contour

are

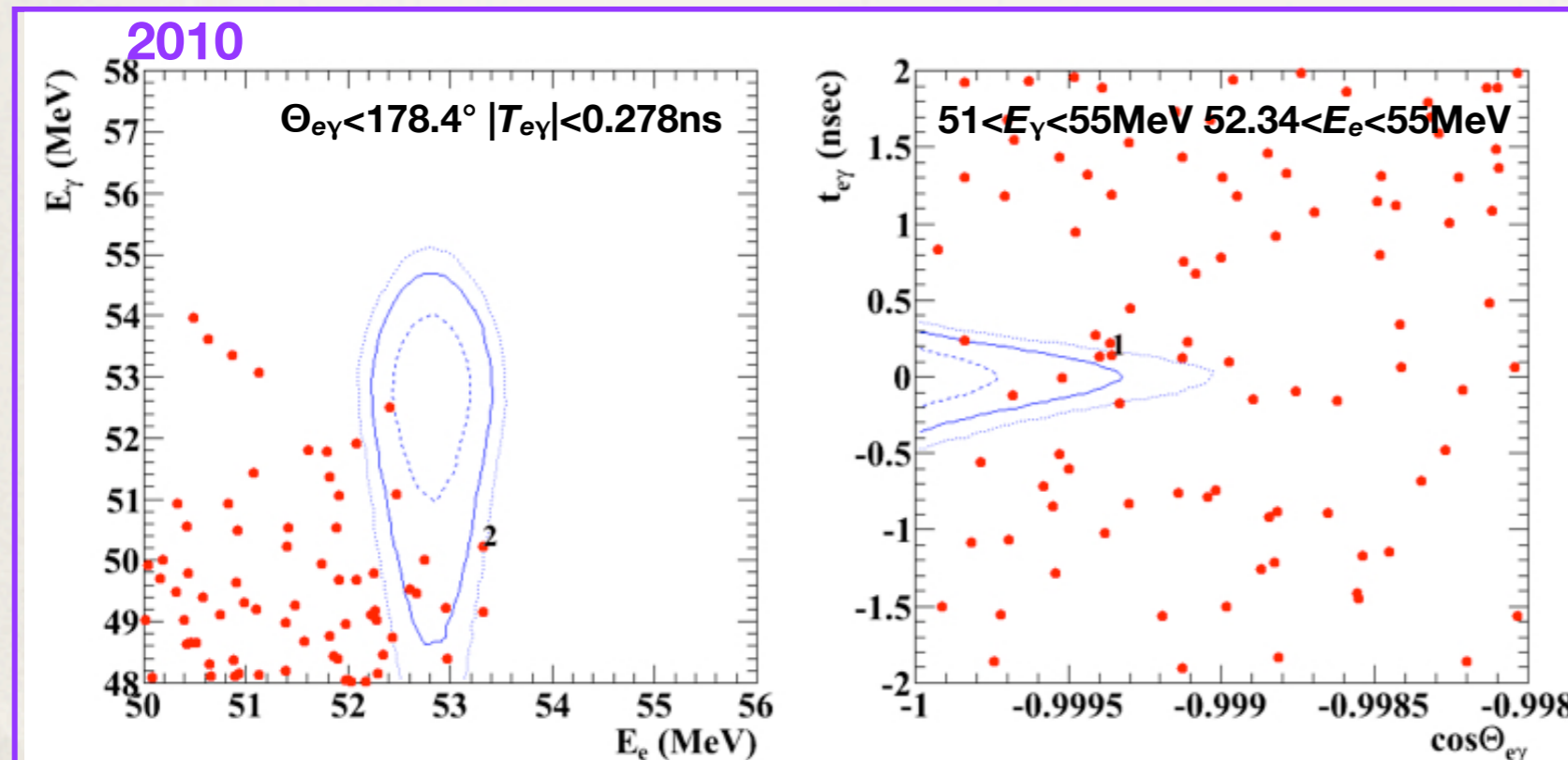
numbered.

N.B.: These plots are just for reference,
not used in the analysis

Event Distribution



Event distribution is not changed much compared to ICHEP10 presentation

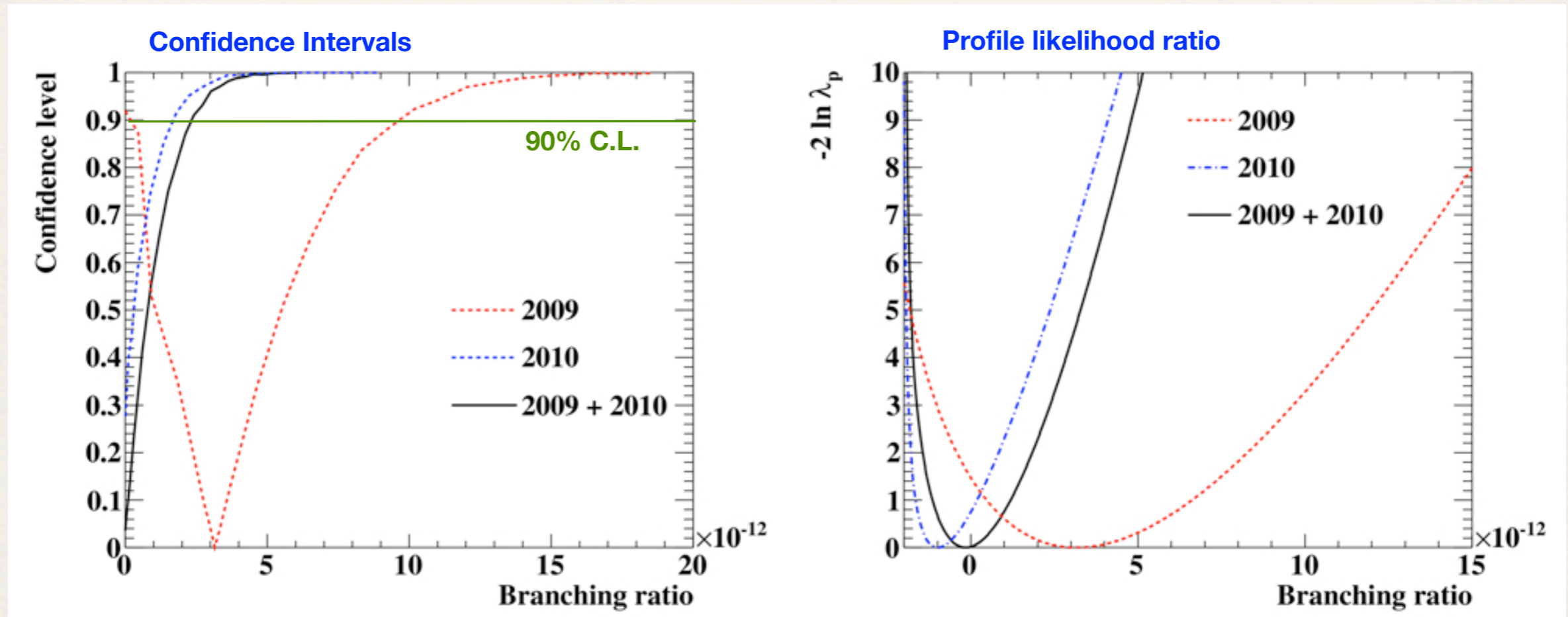


Blue curves: signal PDF contour (1, 1.64, 2- σ)

Events with highest signal likelihood ($S/(0.1R+0.9B)$) are numbered.

N.B.: These plots are just for reference, not used in the analysis

Confidence Interval (data 2009+2010)

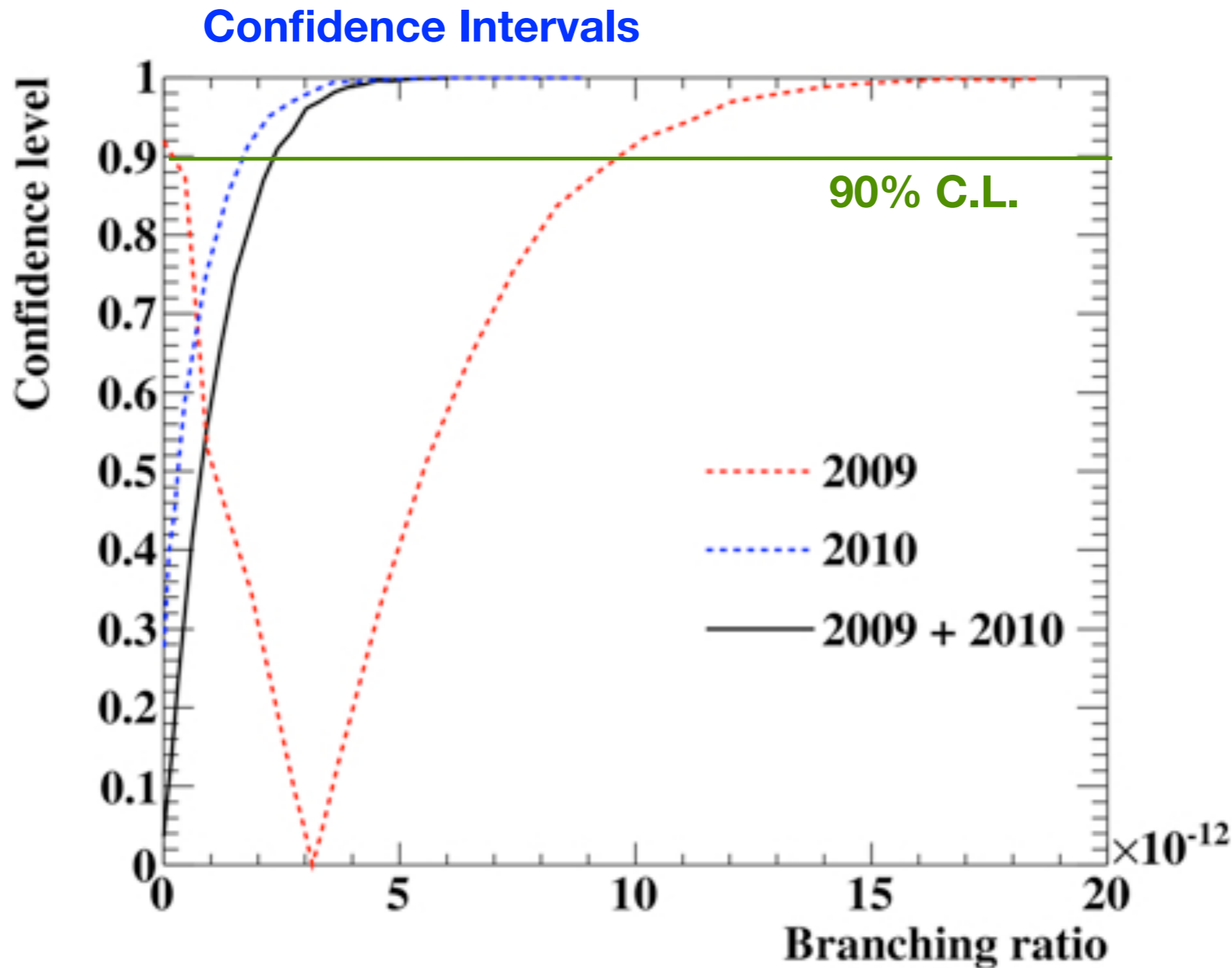


CL curve: Allowed region of branching ratio can be read at any confidence level.

N.B. likelihood curves are not directly used in confidence interval calculation

- ❖ Confidence interval calculated with Feldman-Cousins method + profile likelihood ordering
- ❖ **Run2009 marginally excludes $\mathcal{B} = 0$, but significance is not high. (p-value $\sim 8\%$)**
- ❖ Compatibility bw / 2009 and 2010 $\sim 15\%$

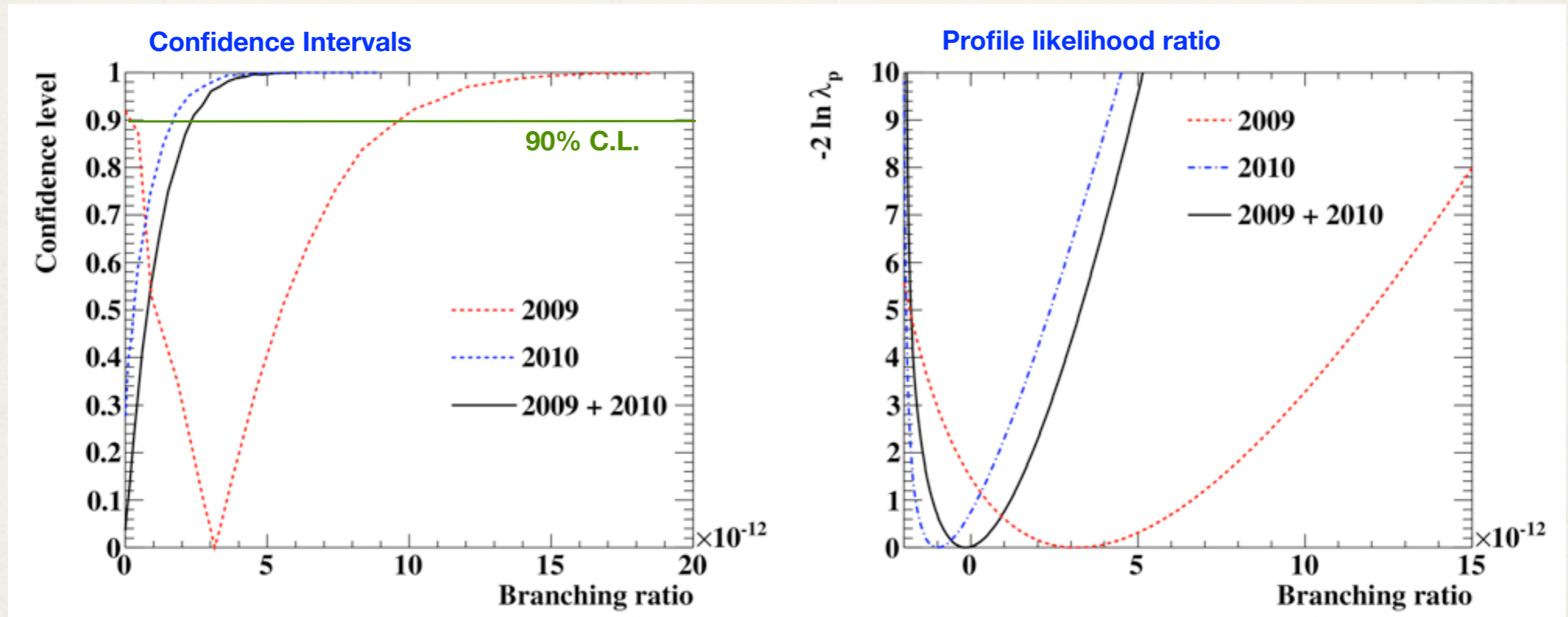
Confidence Intervals (2009 + 2010)



CL curve:
read at any

- ❖ Confidence
- ❖ **Run2009 marginally excludes $\mathcal{B} = 0$, but significance is not high. (p-value $\sim 8\%$)**
- ❖ Compatibility bw / 2009 and 2010 $\sim 15\%$

Confidence Interval (data 2009+2010)



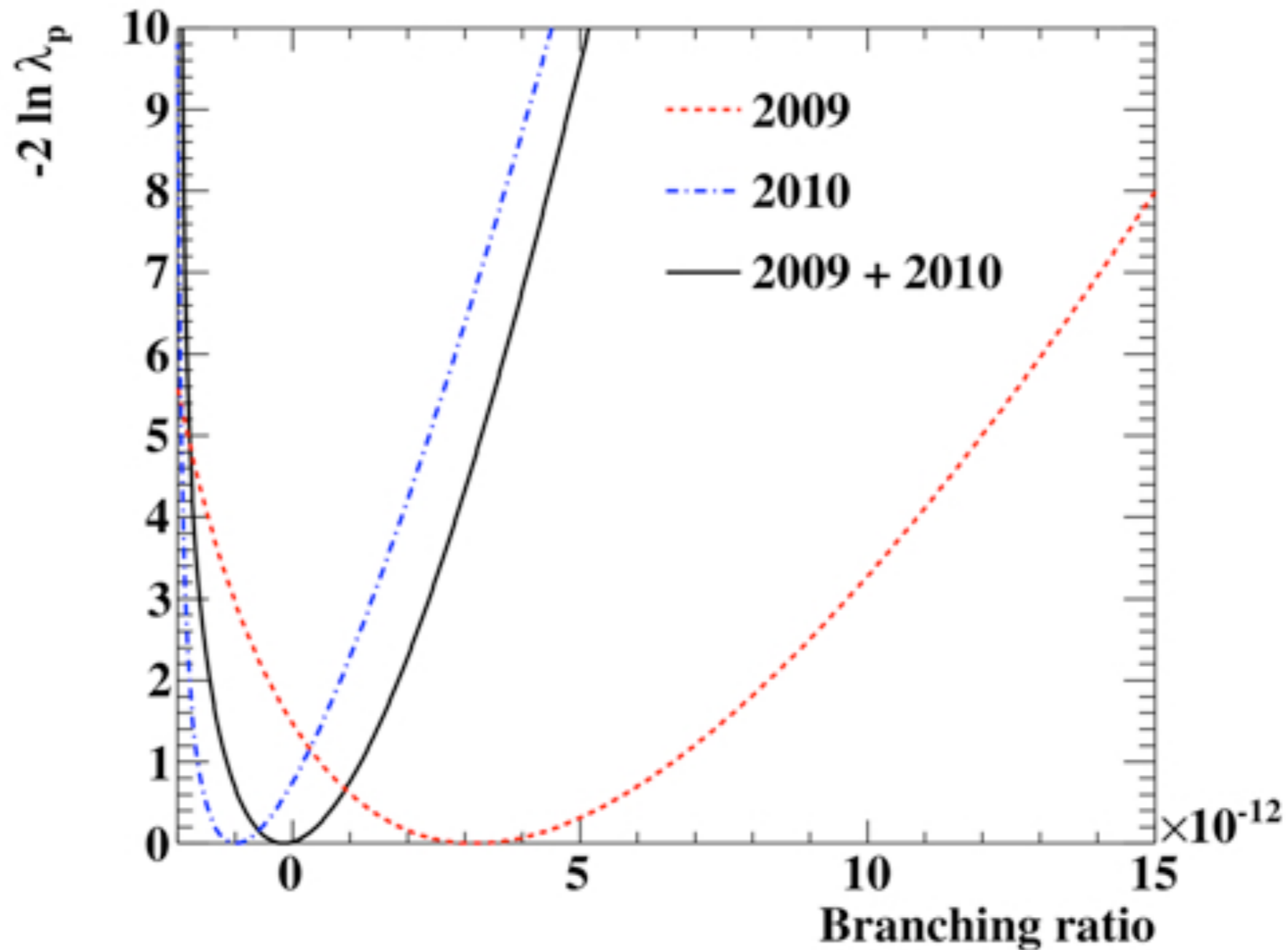
CL curve: Allowed region of branching ratio can be read at any confidence level.

N.B. likelihood curves are not directly used in confidence interval calculation

- ❖ Confidence interval calculated with Feldman-Cousins method + profile likelihood ordering
- ❖ **Run2009 marginally excludes $\mathcal{B} = 0$, but significance is not high. (p-value $\sim 8\%$)**
- ❖ Compatibility bw / 2009 and 2010 $\sim 15\%$

Confidence Intervals (1 / 1 . 2000 . 2010)

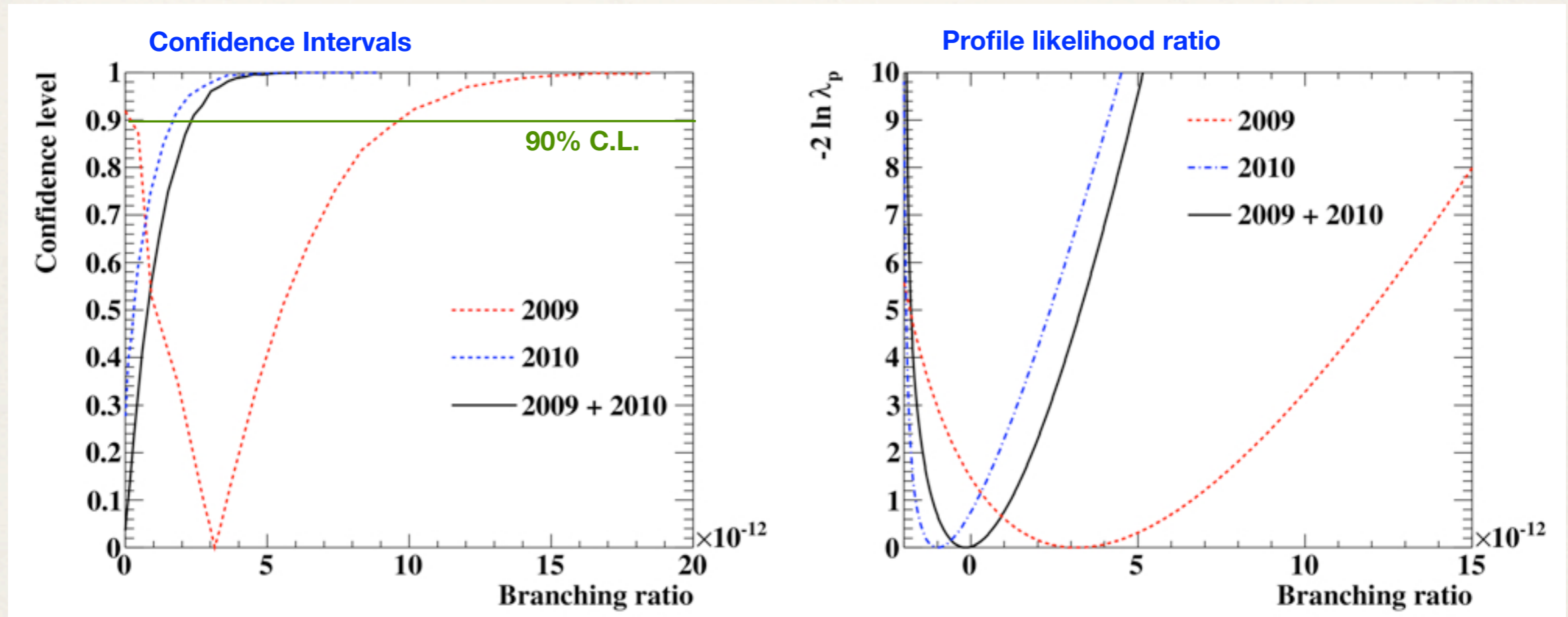
Profile likelihood ratio



CL curve:
read at any

- ❖ Confidence interval
- ❖ Run2009 marginally excludes $\mathcal{B} = 0$, but significance is not high. (p-value $\sim 8\%$)
- ❖ Compatibility bw / 2009 and 2010 $\sim 15\%$

Confidence Interval (data 2009+2010)



CL curve: Allowed region of branching ratio can be read at any confidence level.

N.B. likelihood curves are not directly used in confidence interval calculation

- ❖ Confidence interval calculated with Feldman-Cousins method + profile likelihood ordering
- ❖ **Run2009 marginally excludes $\mathcal{B} = 0$, but significance is not high. (p-value $\sim 8\%$)**
- ❖ Compatibility bw / 2009 and 2010 $\sim 15\%$

New Result Summary

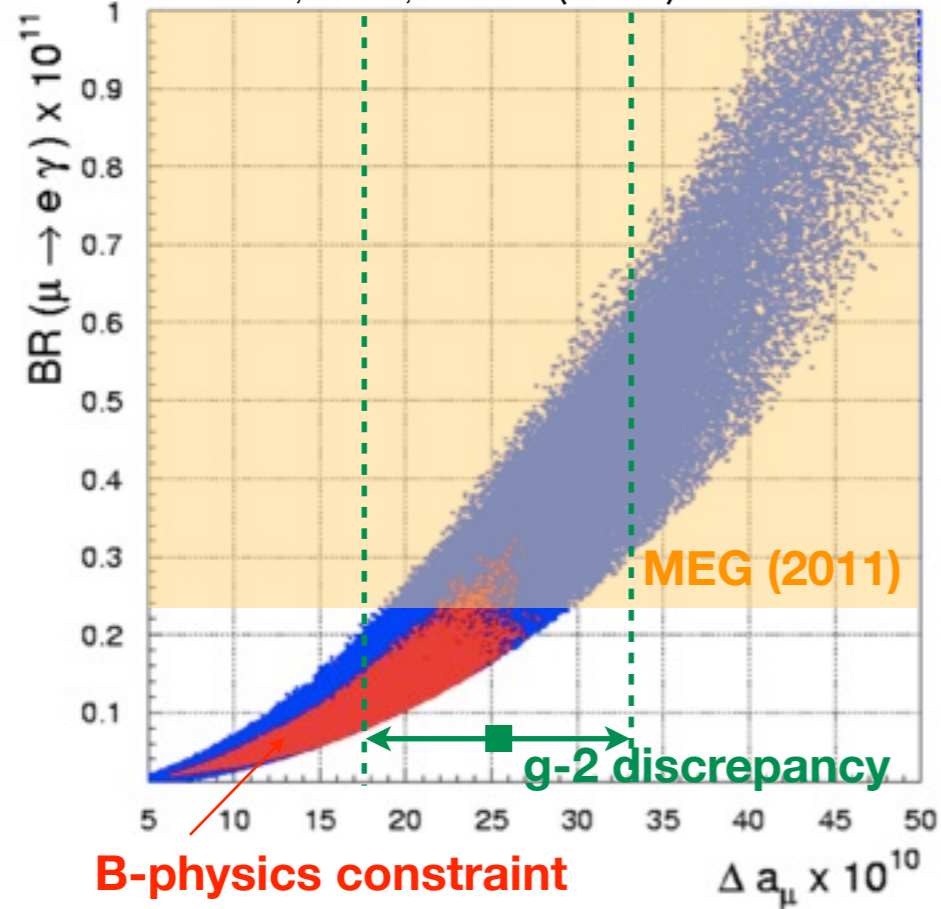
Data set	\mathcal{B}_{fit}	Sensitivity	LL	UL
2009	3.2×10^{-12}	3.3×10^{-12}	1.7×10^{-13}	9.6×10^{-12}
2010	-9.9×10^{-12}	2.2×10^{-12}	-	1.7×10^{-12}
2009+2010	-1.5×10^{-12}	1.6×10^{-12}	-	2.4×10^{-12}

- ❖ New upper limit: $\mathcal{B}(\mu^+ \rightarrow e^+ \gamma) < 2.4 \times 10^{-12}$ (90% C.L.)
 - ❖ $\times 5$ more stringent than previous limit ($\mathcal{B} < 1.2 \times 10^{-11}$, MEGA 1999)
 - ❖ Published in Oct. '11 (Phys. Rev. Lett. 107, 171801(2011))

MEG Constrains New Physics

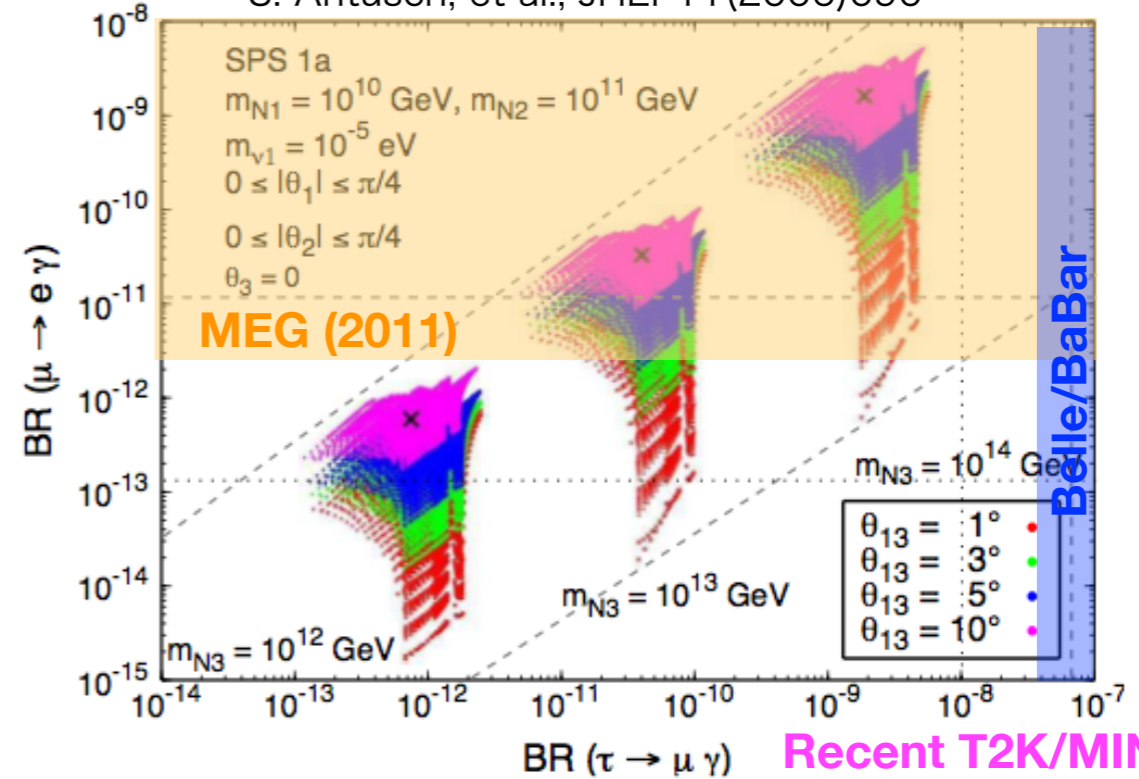
SUSY-GUT

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



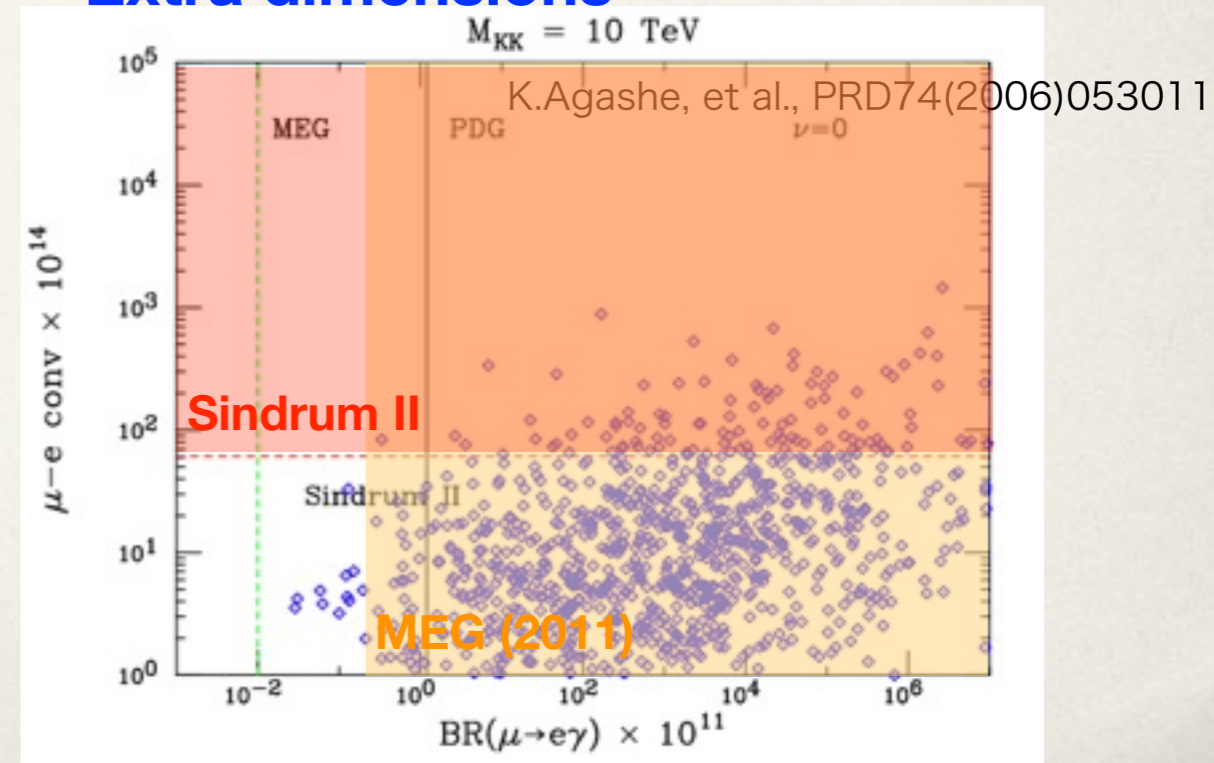
SUSY-Seesaw

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

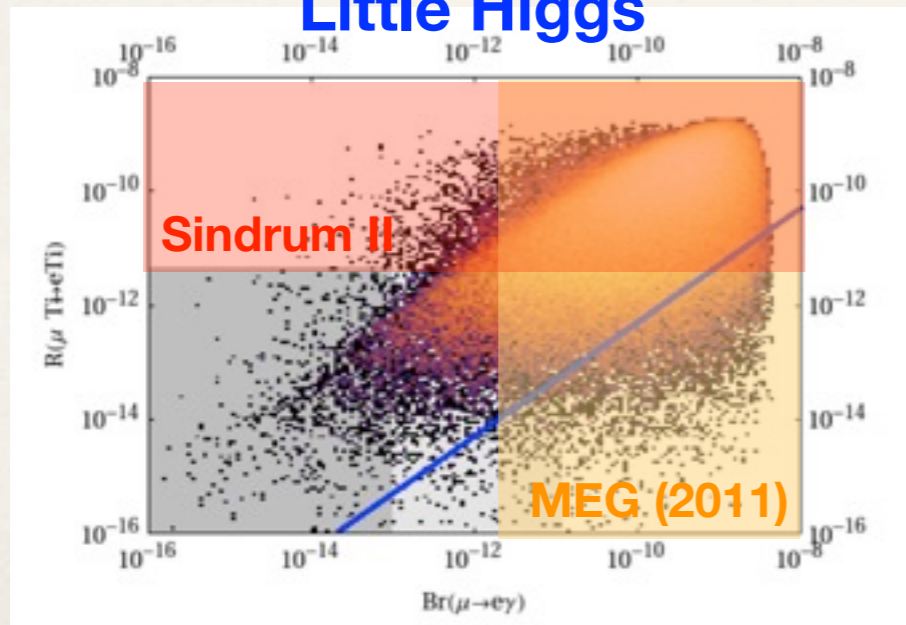


Recent T2K/MINOS/
Double Chooz results
favors large θ_{13} !

Extra dimensions



Little Higgs

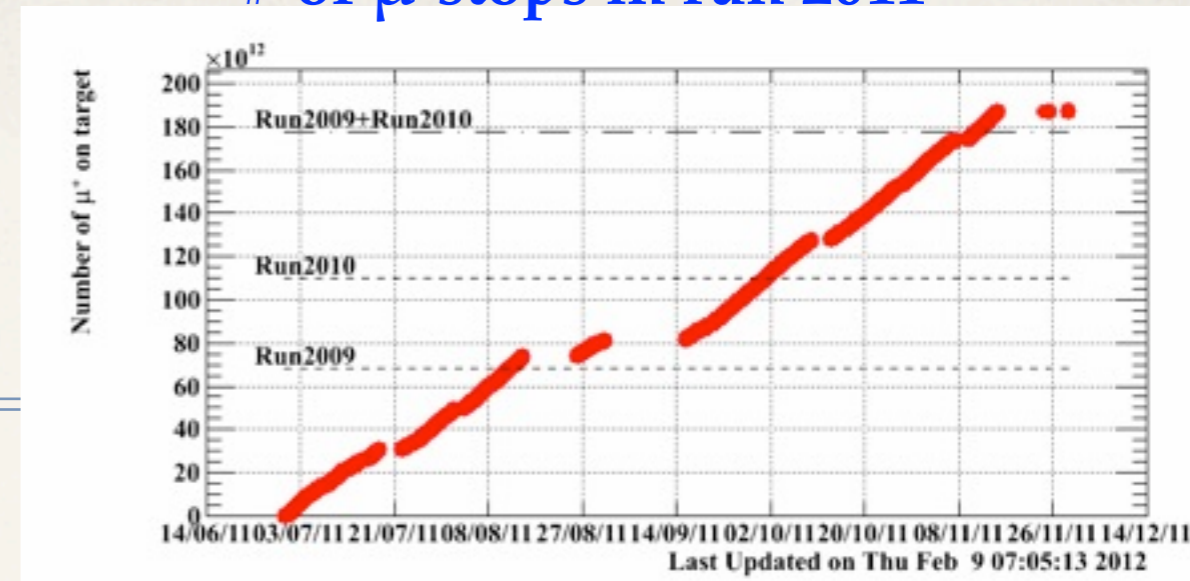


M.Blanke et al., Acta Phys.Polon.B41(2010)657

Status and Prospects

Run 2011 Overview

of μ -stops in run 2011



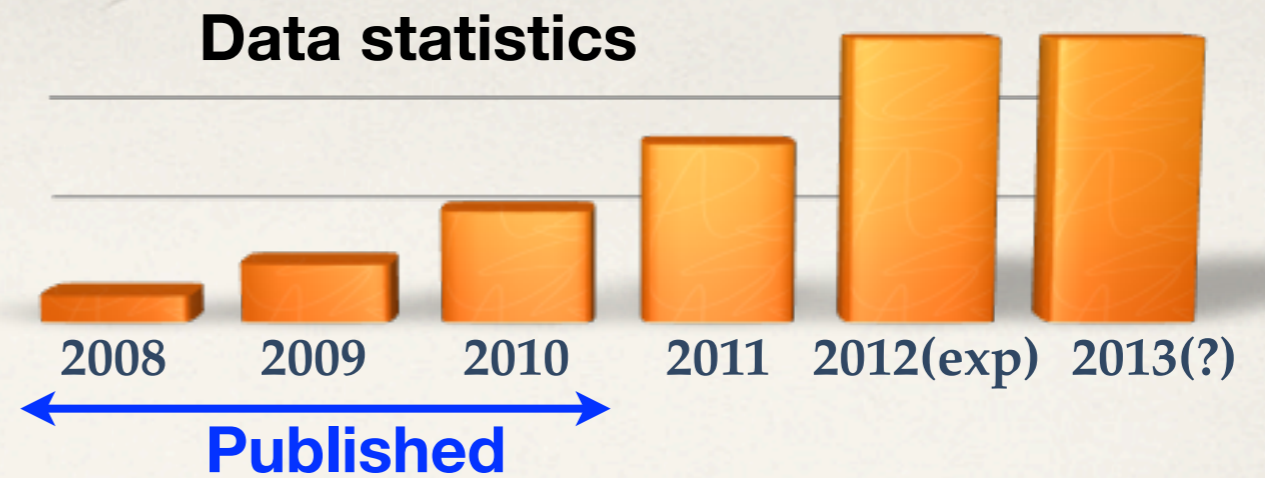
- ❖ Run 2011 was successful.
- ❖ All subdetectors were operational with reasonable performance for whole period.
 - ❖ New DC HV-system (reduced noise)
 - ❖ New DC alignment system
 - ❖ More efficient LXe calibration (CEX with new BGO detector)
 - ❖ Slow LXe light yield degradation (well monitored and corrected)
 - ❖ Higher DAQ efficiency with multi-buffer scheme
 - ❖ DAQ had to stop in beg-Nov due to damage of cryo-plant caused by power outage.
- ❖ Data statistics doubled. **run2011 ~ (run2009+run2010)**

Performance for Run 2011 (Preliminary)

- * Analysis on data 2011 is in a good shape.
- * Calibration and optimization of analysis are going smoothly.
- * Detector performance preliminarily estimated is already comparable to previous years.

	2009	2010	2011 (preliminary)
Gamma energy (%)	1.9% (w>2cm)	1.9% (w>2cm)	1.7% (w>2cm)
Gamma position (mm)	5 (u,v) / 6 (w)	5 (u,v) / 6 (w)	←
Positron momentum (%)	0.59 (core 80%)	0.61 (core 79%)	0.61 (core 86%)
Positron angle (mrad)	6.7 (Φ ,core), 9.4 (θ)	7.2 (Φ ,core), 11.0 (θ)	6.5 (Φ ,core), 10.8 (θ)
Vertex position (mm)	1.5 (Z), 1.1(Y)	2.0 (Z), 1.1(Y)	1.9 (Z), 1.0(Y)
Gamma-positron timing (ps)	146 (core)	126 (core)	133
Gamma efficiency (%)	58	59	←
Trigger efficiency (%)	91	92	95
Data statistics (k-factor)	1.1×10^{12}	2.1×10^{12}	3.4×10^{12}

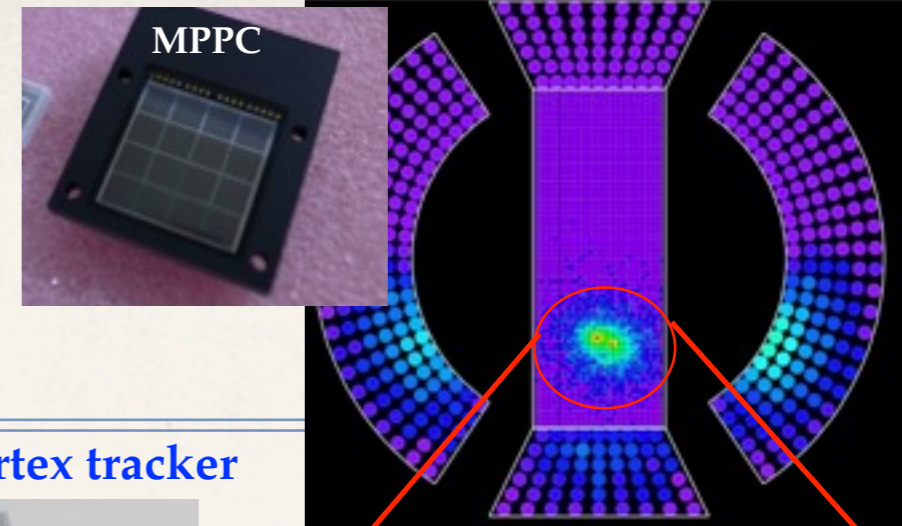
Perspectives



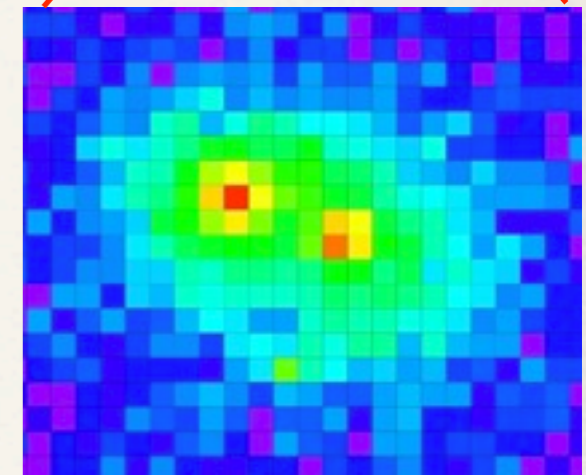
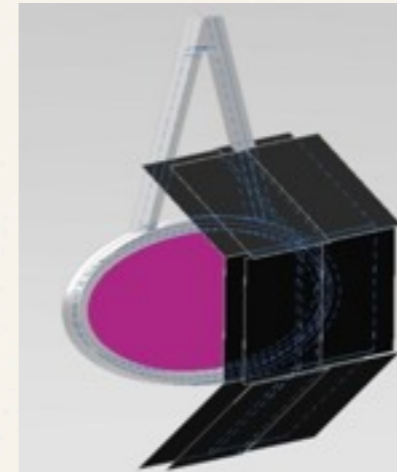
- ❖ We will hopefully be ready for unblinding data 2011 in few months.
- ❖ Run 2012 is in preparation.
 - ❖ Increased beam intensity is planned ($\times 1.15$, $\sim 3.5 \times 10^7$ μ -stops/sec).
 - ❖ Some improvements in resolutions and efficiencies anticipated.
- ❖ **We expect to explore the branching ratio region $\sim O(10^{-13})$ with data 2011 + 2012.**
 - ❖ Still 3σ -discovery potential if $\mathcal{B} \gtrsim 10^{-12}$
- ❖ Sensitivity improvement is starting to slow down due to BG with current detector performance.
- ❖ **It's time to consider a next (big) step...**

MEG Upgrade

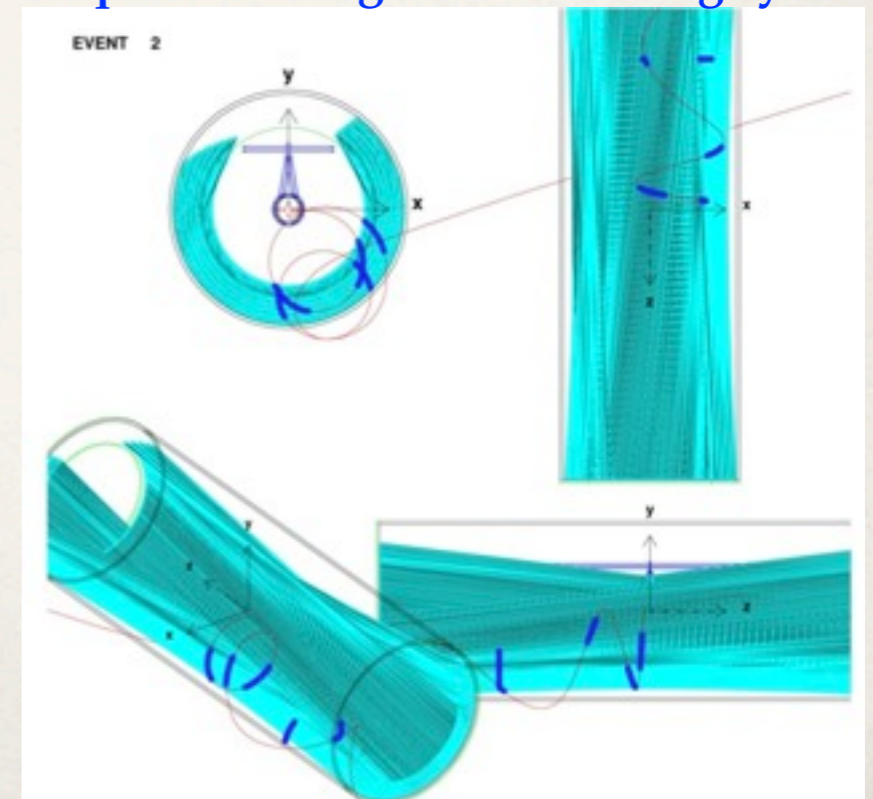
- ❖ Upgrade of MEG experiment under consideration, aiming at sensitivity $\sim O(10^{-14})$
 - ❖ Better resolutions
 - ❖ Better efficiencies
 - ❖ Higher beam intensity ($\sim 10^8 \mu^+ / \text{sec}$)
- ❖ R&D have started based on various ideas on new detectors.
 - ❖ LXe detector with fine-grain scintillation readout by small photo-sensors (UV sensitive MPPC under development).
 - ❖ Unique-volume gaseous tracking system
 - ❖ Active target
 - ❖ Thin silicon vertex tracker
 - ❖ Tracker with scintillating thin sheets
 - ❖ ...



Thin Si vertex tracker



Unique-volume gaseous tracking system



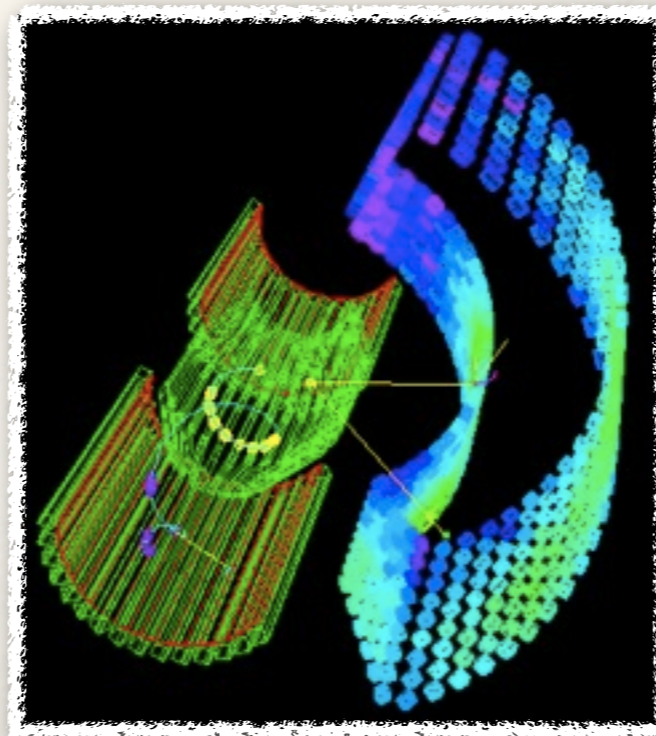
Other Physics in MEG

- ❖ Measurement of radiative muon decay (RMD) branching ratio and Michel parameters

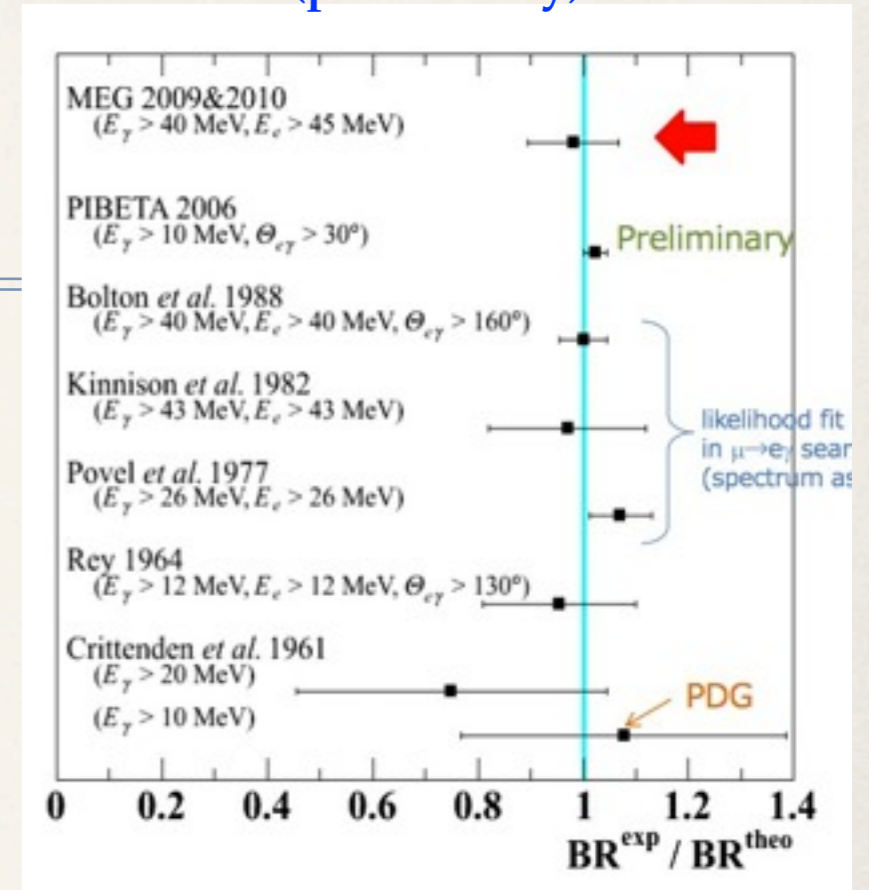
- ❖ Exotic physics searches

- ❖ Search for muon decay mediated by very light pseudo scalar particle, $\mu^+ \rightarrow \phi e^+, \phi \rightarrow \gamma\gamma$
- ❖ Search for muon decay with massless Majoron, $\mu \rightarrow e^+ J$

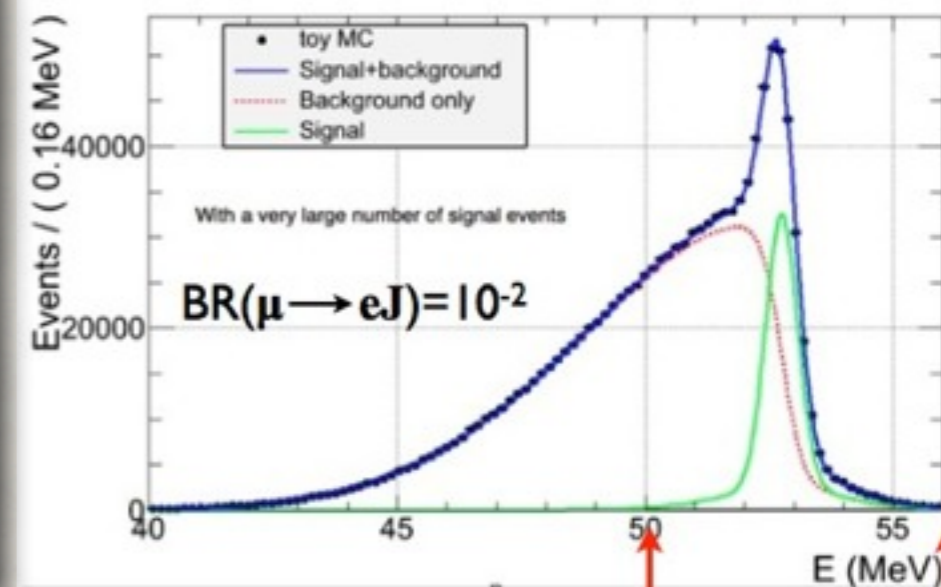
$\mu^+ \rightarrow \phi e^+, \phi \rightarrow \gamma\gamma$ (MC)



RMD BR measured in MEG
(preliminary)



Possible signature of $\mu \rightarrow e J$ in
positron spectrum (toy MC)



Summary

- ❖ MEG searches for $\mu^+ \rightarrow e^+ \gamma$ with an unprecedented sensitivity.
- ❖ Five times tighter upper limit on $\mathcal{B}(\mu^+ \rightarrow e^+ \gamma)$ was set with data 2009+2010.
 - ❖ New limit: $\mathcal{B}(\mu^+ \rightarrow e^+ \gamma) < 2.4 \times 10^{-12}$ (90% C.L.)
- ❖ MEG will be exploring the branching ratio region of $O(10^{-13})$ with data 2011 and 2012.
- ❖ Other physics analyses besides $\mu^+ \rightarrow e^+ \gamma$ search analysis are also in progress.
- ❖ R&D work on MEG upgrade aiming at sensitivity of $O(10^{-14})$ is in progress.

Thank You for Your Attention!



MEG collaboration

~60 physicists from 12 institutes from 5 countries

