Muon & Tau Physics

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HEC sub-committee for future planning

Opening Remark

- Many people say LHC will find NP, and our future plan depends on results there.

It is not all !

- There may be new findings in the charged lepton sector ! (maybe already…)

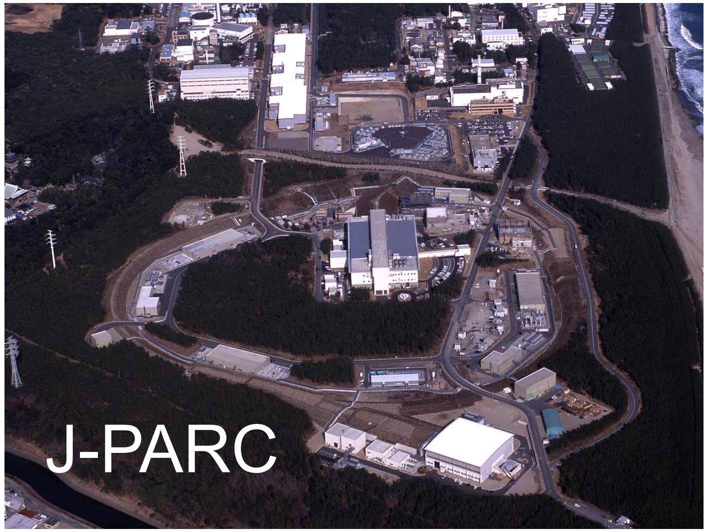
3.4 σ deviation in muon g-2

MEG ($\mu \rightarrow e \gamma$) is in progress and may find…

Contents

Special thanks to:
Mihara-san, Saito-san, Mori-san

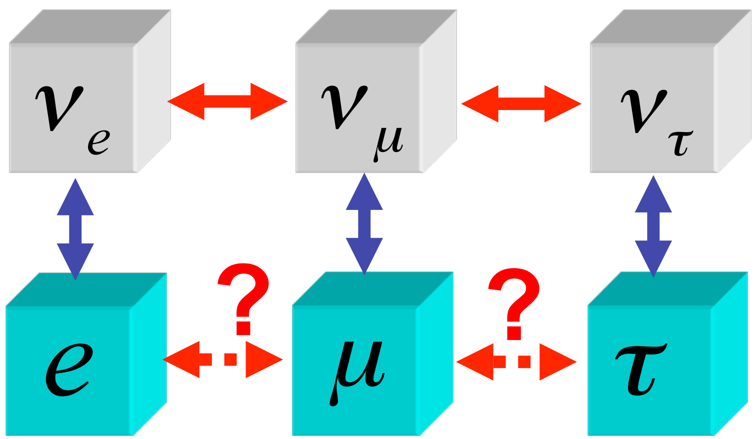
- Muon LFV
  - $\mu \rightarrow e \gamma$
    - MEG (+upgrade)
  - $\mu \rightarrow$ e conversion
    - DeeMe
    - COMET
    - More…
- Muon g-2/EDM
- Tau Physics @ Belle II



Quest on Lepton Flavor Physics

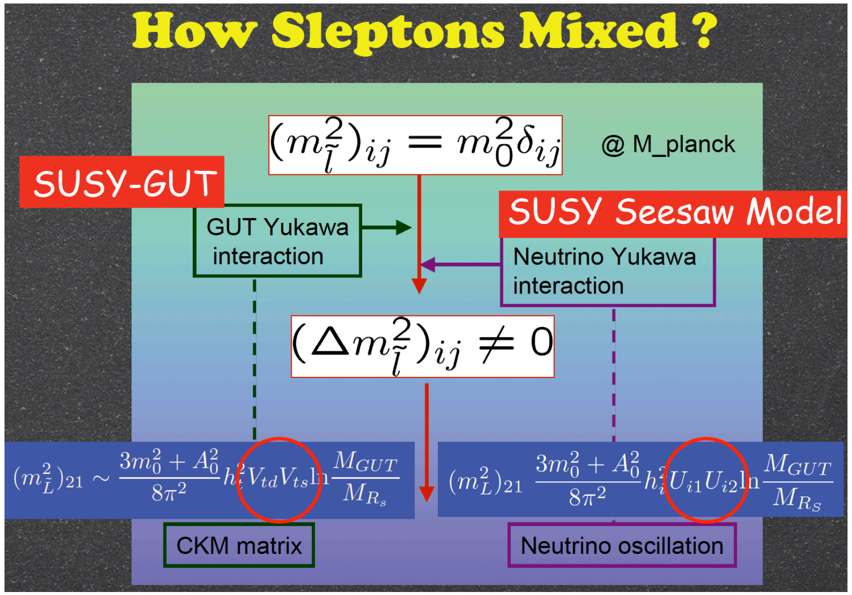
- Quarks have flavor mixing & CPV.
- Neutrinos have flavor mixing ➡ CPV?
- What about charged leptons ?

Discovered already and getting matured
(the final angle θ_{13} being measured…)



Not discovered yet !

Kuno-san

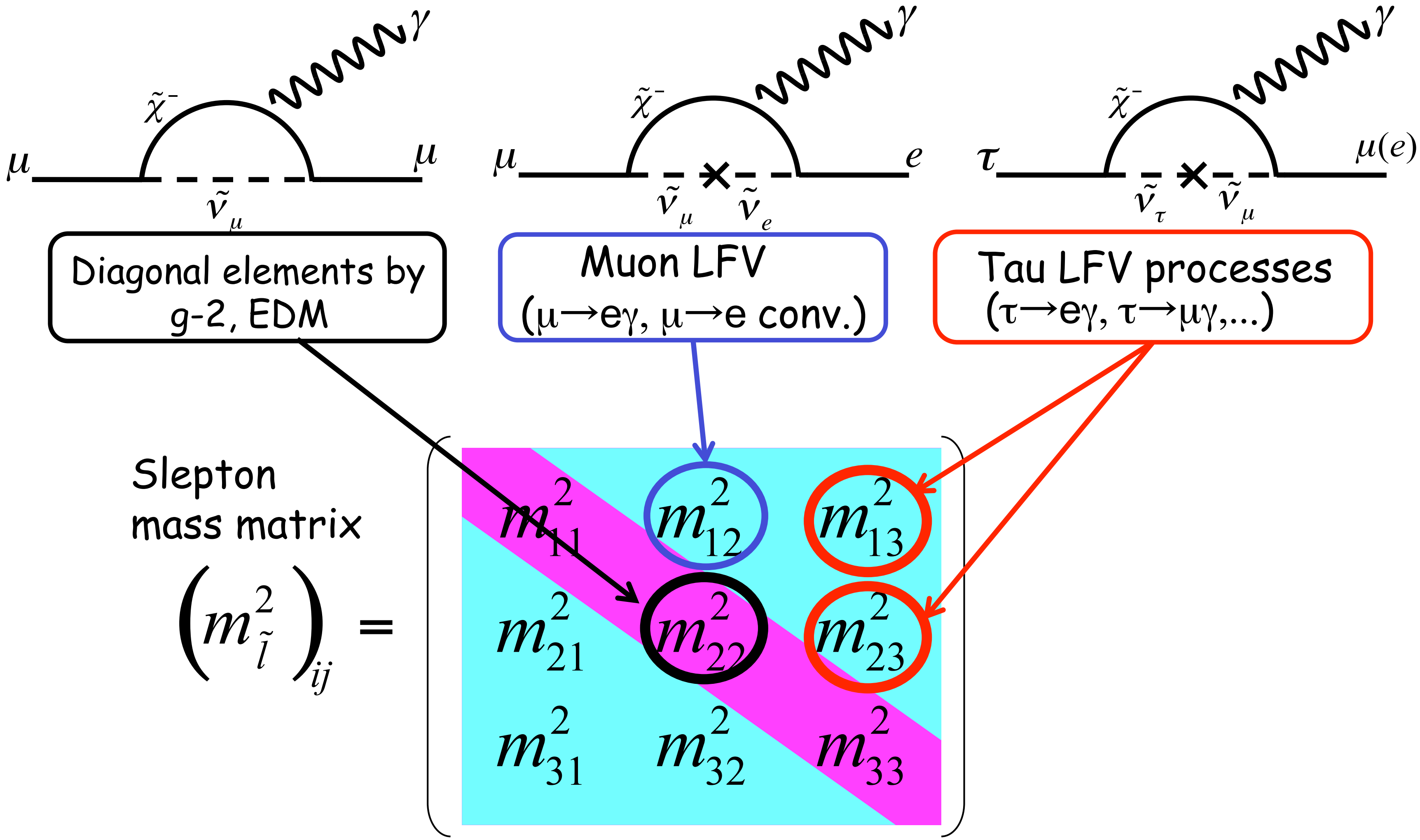


Very interesting to know how the charged lepton mixing matrix looks like !

Routes to Slepton Mass Matrix

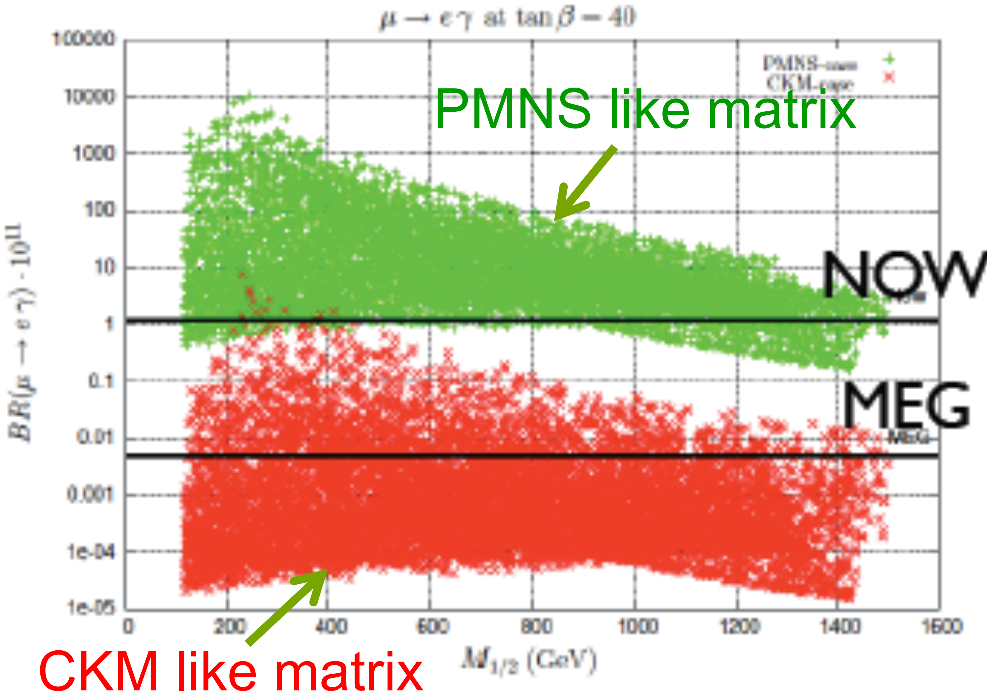
- In case of SUSY, LFV processes are induced by off-diagonal elements of the slepton mass matrix.

Sensitive to the SUSY breaking mechanism



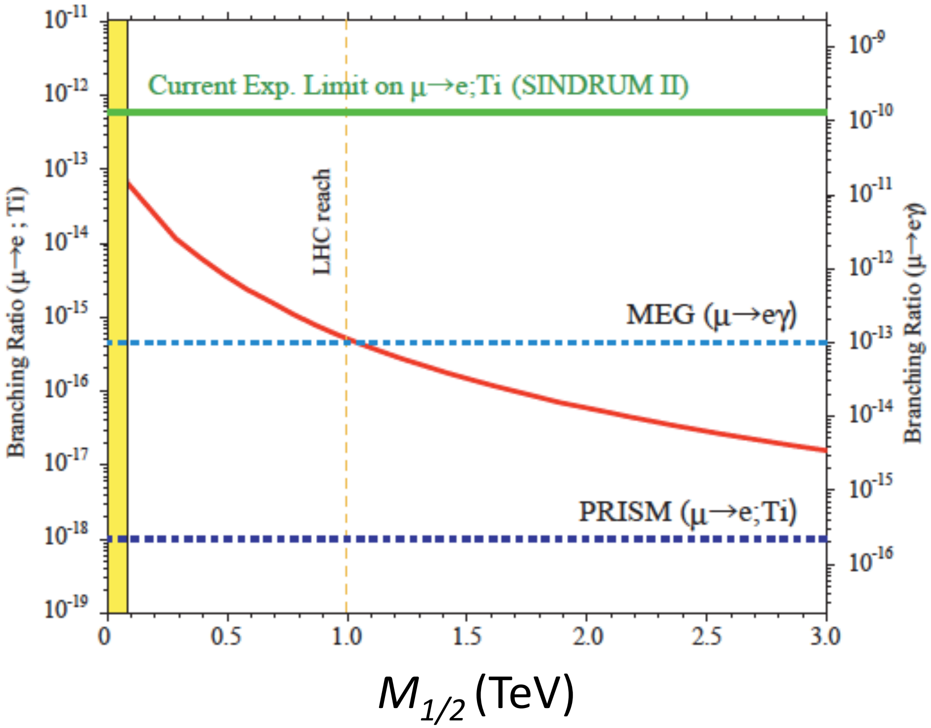
Sensitivity to New Physics

- Good chance to see the signal.
- Sensitivity exceeds the limit at LHC.



L. Calibbi et al., PRD74,116002(2006)

SO(10) SUSY GUT



A. Masiero et al., arXiv:0401138

CMSSM w/ ν_R

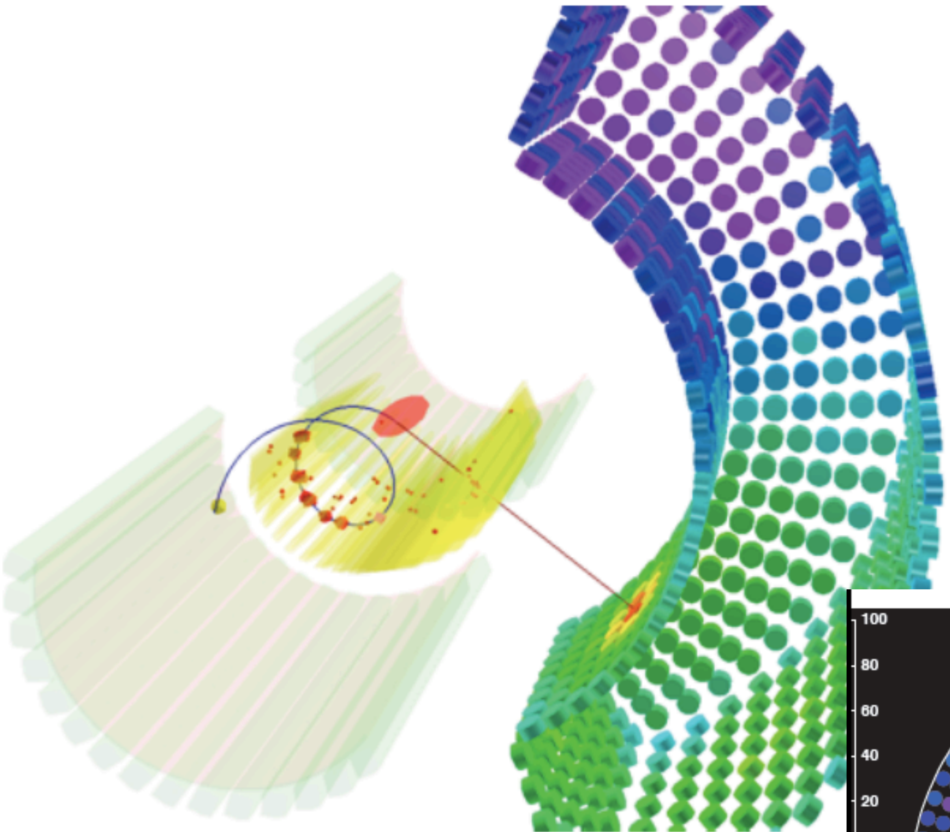
Rating of DNA of New Physics

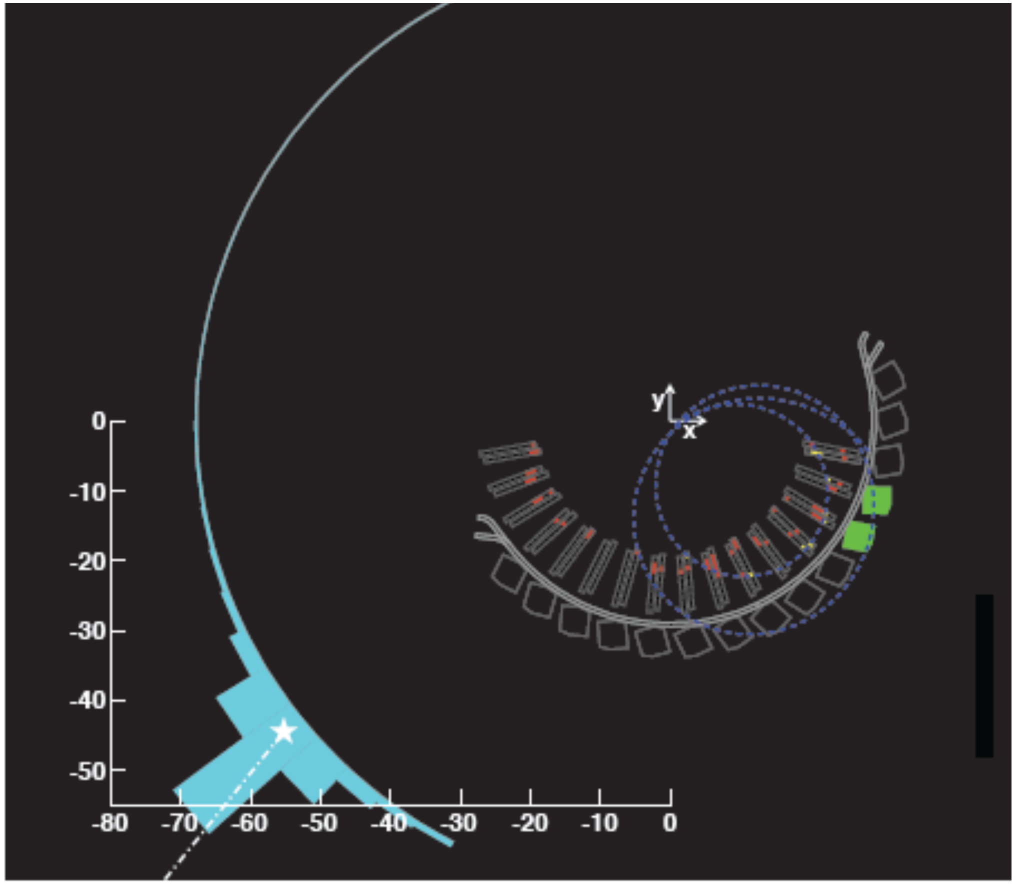
W. Altmannshofer, A. J. Buras、S. Gori, P. Paradisi, D. M. Straub, Nucl. Phys. B830, 17-94, 2010.

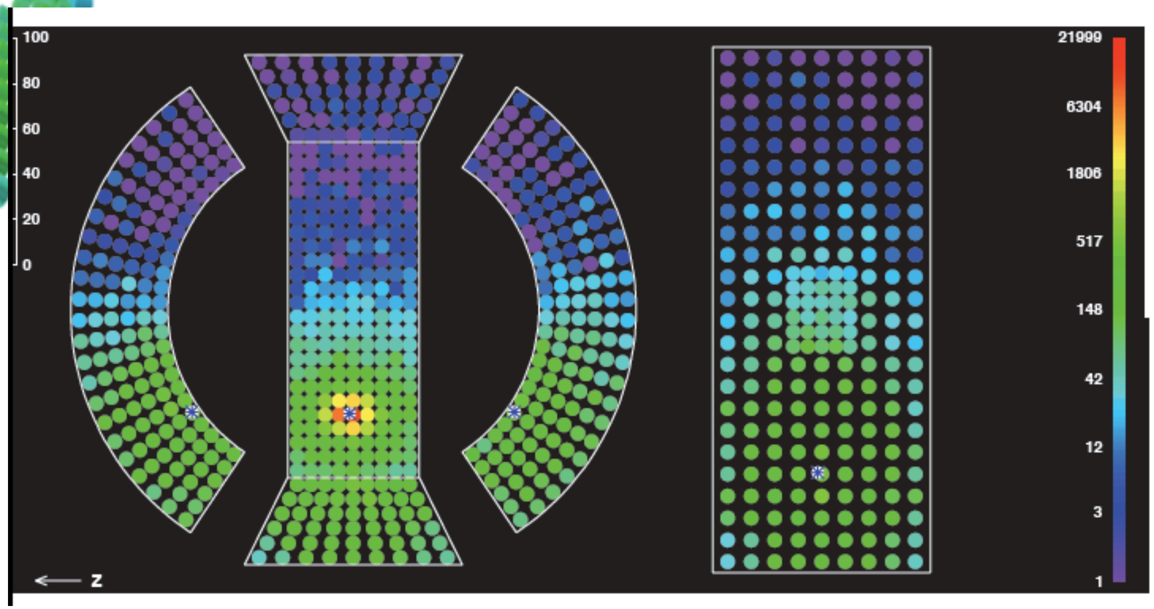
	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{\rm CP}(B \to X_s \gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B \to K^* \mu^+ \mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B \to K^* \mu^+ \mu^-)$	★	★	★	★	★	★	?
$B \to K^{(*)} \nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s \to \mu^+ \mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+ \to \pi^+ \nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L \to \pi^0 \nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?

Table 8: "DNA" of flavour physics effects for the most interesting observables in a selection of SUSY and non-SUSY models ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

μ→e γ search
MEG at PSI



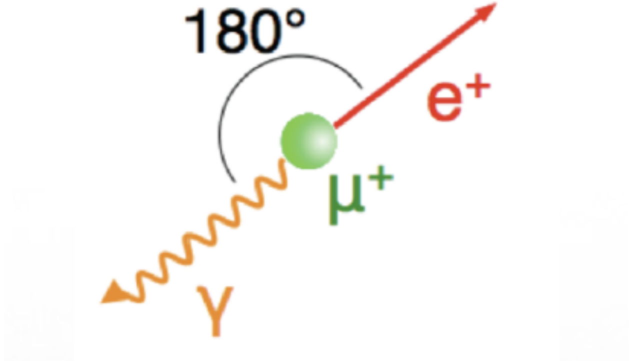




A signal candidate event

μ → e γ : Signal & Background

Signal



$$E_\gamma = E_e = \frac{m_\mu}{2} = 52.8\,\mathrm{MeV}$$

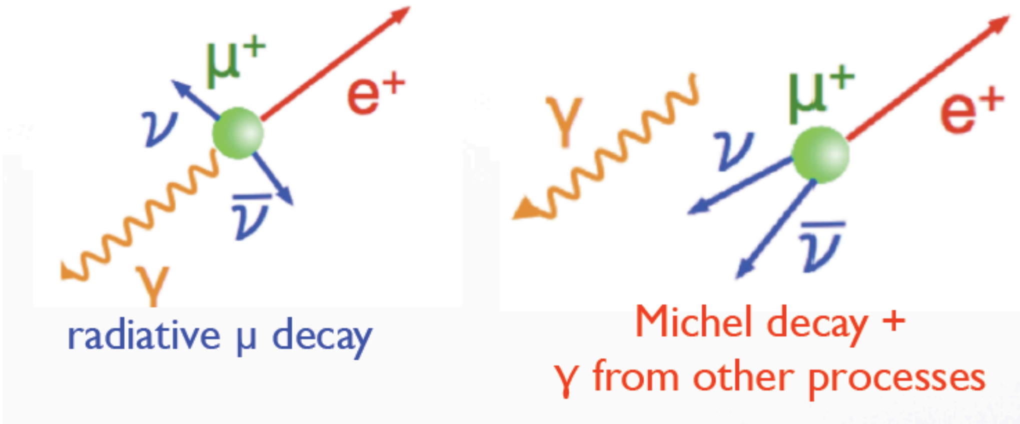
$$\Delta t_{e\gamma} = 0$$

$$\theta_{e\gamma} = \phi_{e\gamma} = 180^\circ$$

Background

Correlated

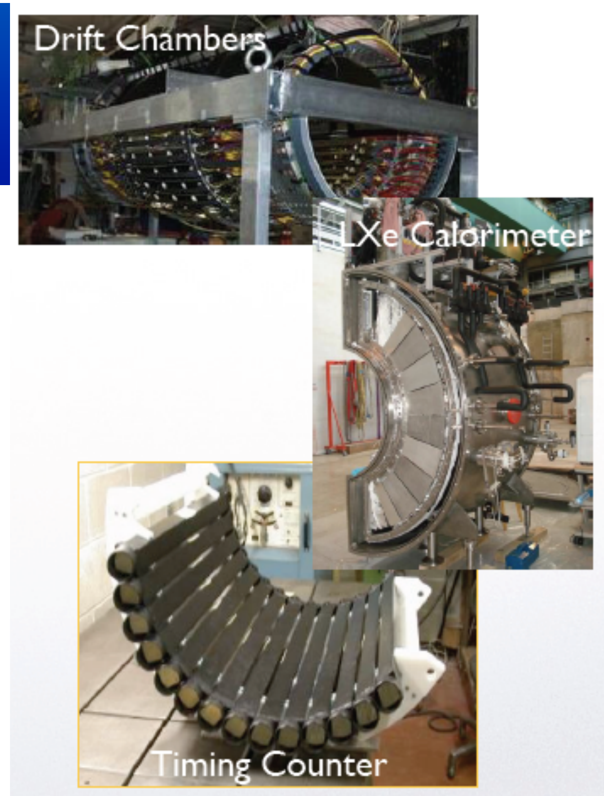
Accidental



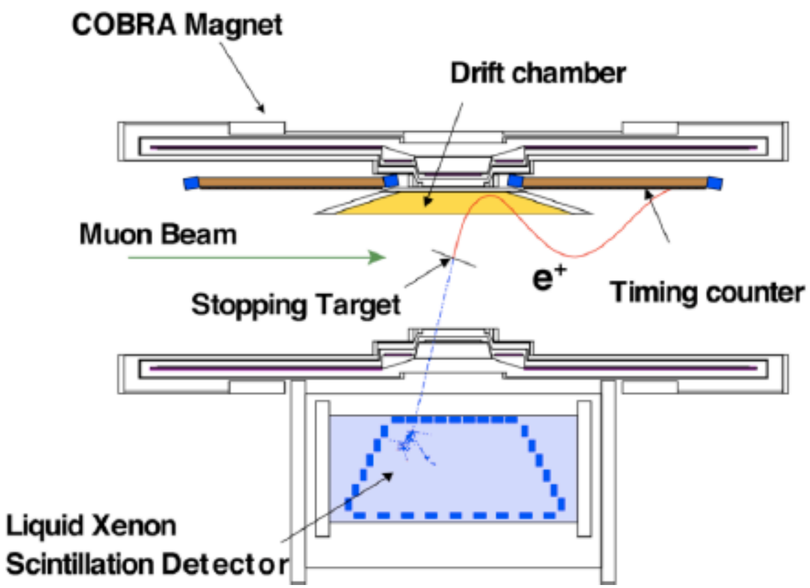
$$B_{acc} \propto \delta E_e \cdot \delta t_{e\gamma} \cdot (\delta E_\gamma)^2 \cdot (\delta\theta_{e\gamma})^2$$

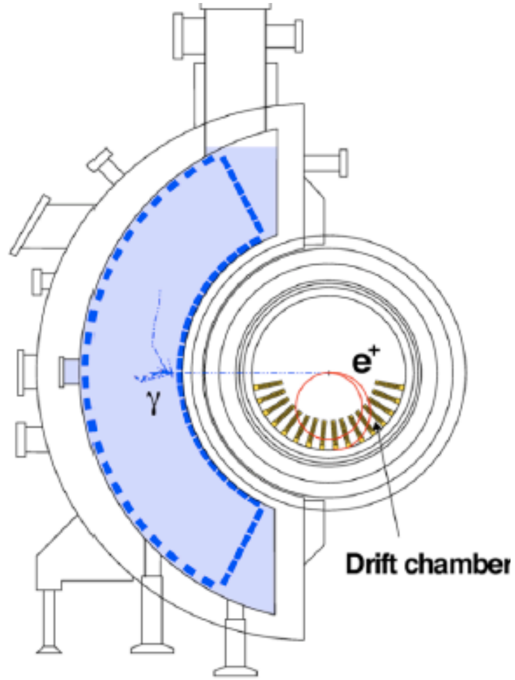
Accidentals are dominant background at $O(10^{-13})$ sensitivity

MEG Experiment at PSI



- High rate μ^+ beam: 3×10^7/s on a thin stopping target.
- e^+ detection
  - Gradient B-field to sweep μ^+ quickly and keep bending radius constant.
  - Low mass drift chamber to measure (E_e, θ_e).
  - Timing counter for precision timing.
- γ detection
  - liquid Xe detector to measure $(E_\gamma, \theta_\gamma, t_\gamma)$
  - Fast response, high light yield.

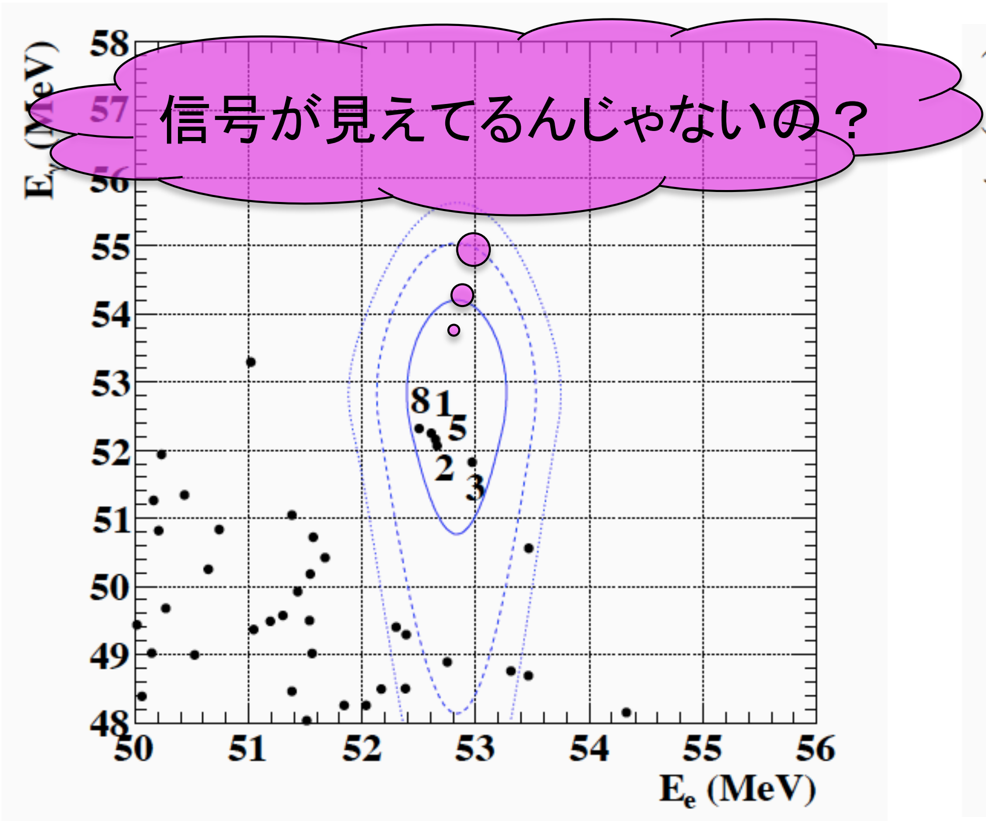


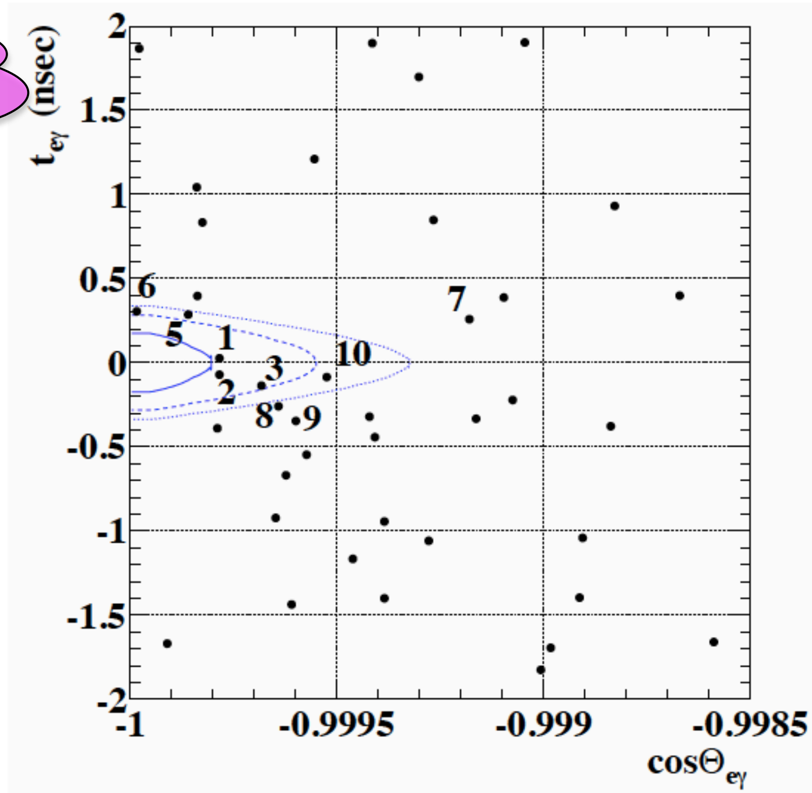


MEG 2009 Result (preliminary)

- BR(μ→eγ) < 1.5×10^{-11} (90% C.L.)
- Sensitivity at 6.1×10^{-12} (average 90%C.L. UL from null signal toy MC)

c.f.) The best UL (MEGA): BR(μ→eg)<1.2×10-11 (90% C.L.)
PRD65,112002 (2002)



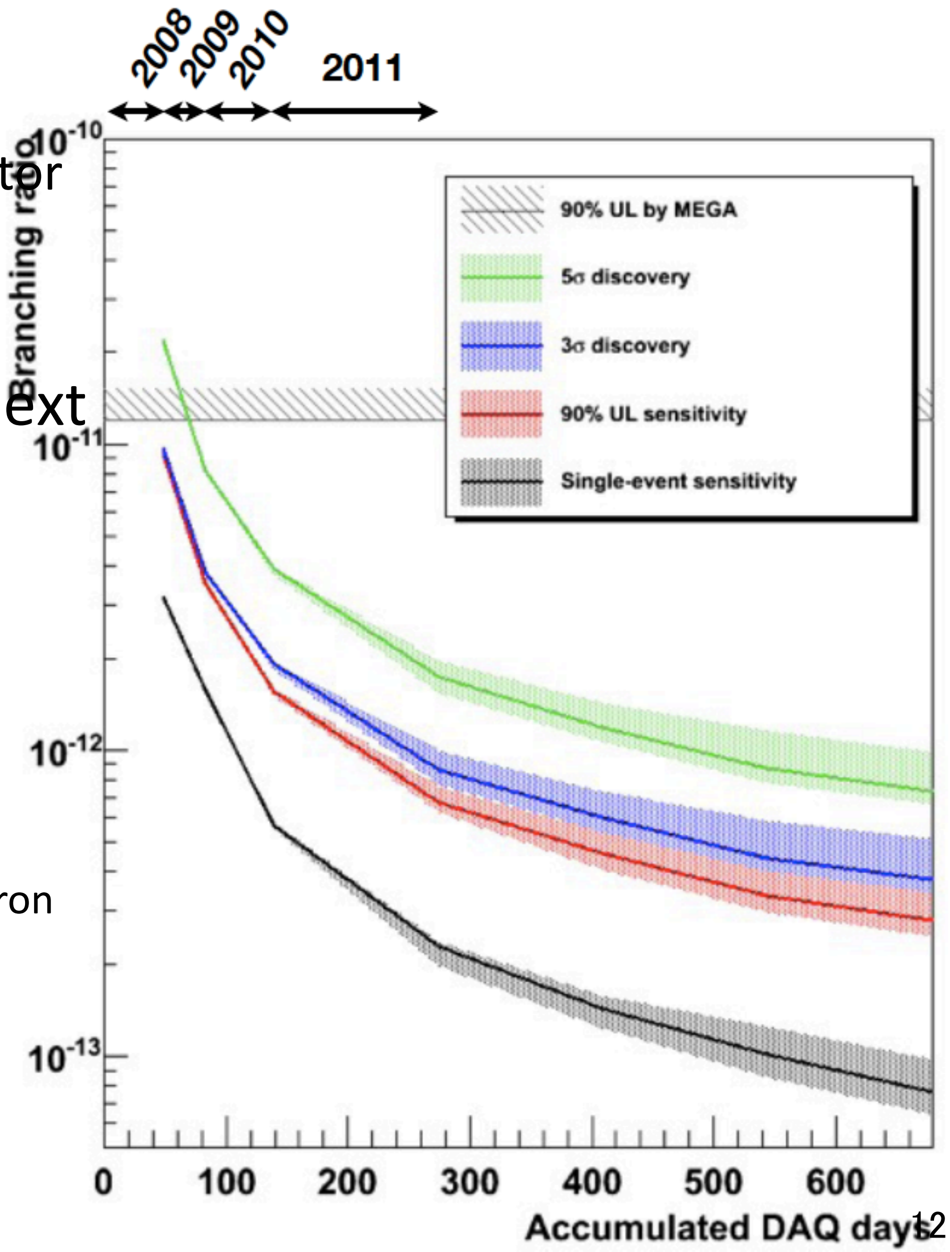


Solid/dashed/dotted lines correspond to 1/1.64/2 σ regions.

MEG Prospect

- Coming soon:
  - 2009+2010 result in summer

    (2010 run x ~2 stat. w/ some detector improvement)
  - 2011 run is starting
- Possible improvements for the next few years:
  - Improved DAQ & trig. Eff.
  - Improved e^+ detection eff.
  - Better e^+ reconstruction:
    - Reduced noise
    - Z-measuring fiber counters
    - Calibration with monochromatic positron beam (Mott scattering)
  - Better dE_γ with precise calibration and better reconstruction algorithms
  - Improvement of magnetic field map
  - Beam intensity optimization



Possible Improvements for Future Upgrade

Future upgrade for x10 better sensitivity

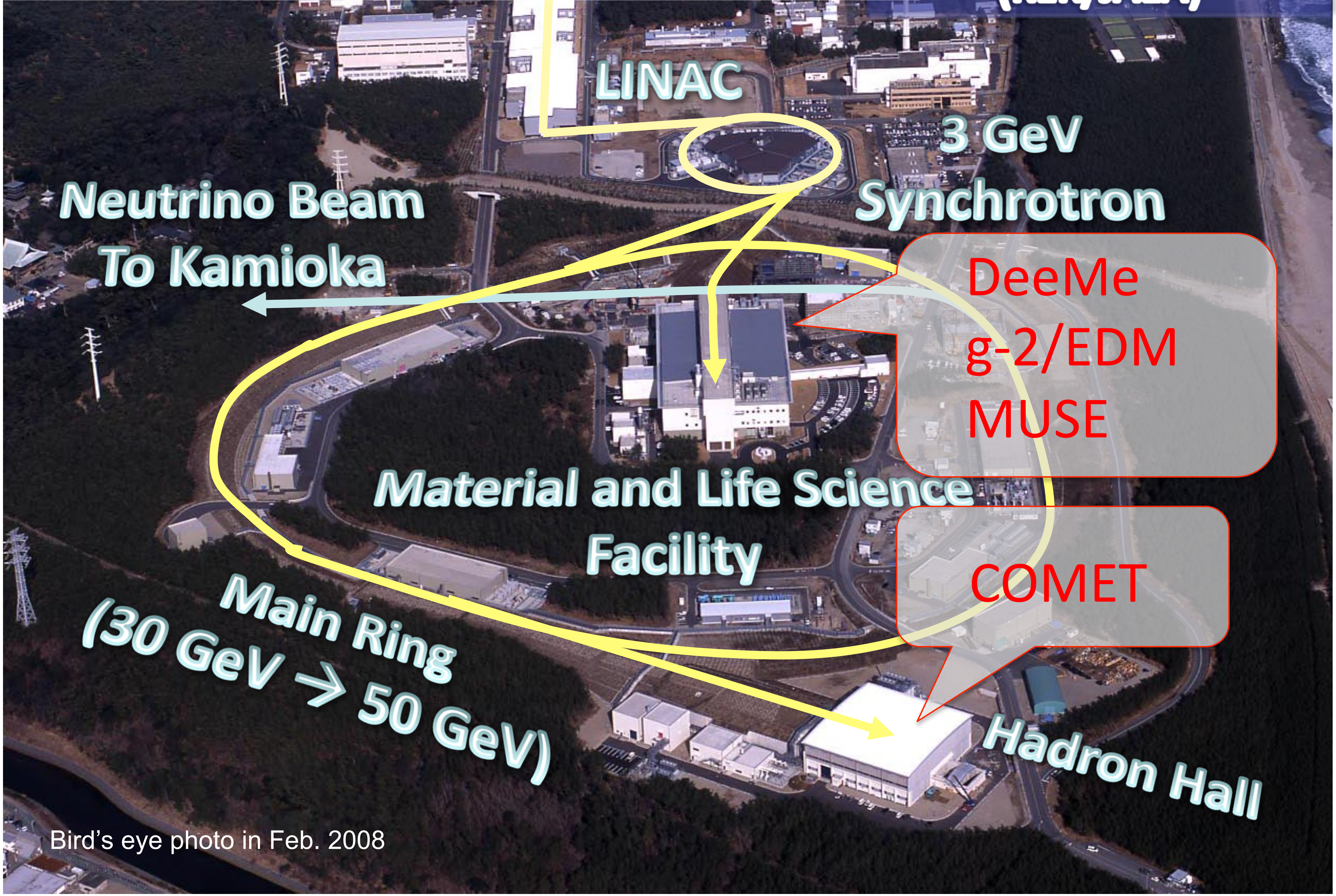
- Detector upgrade
  - LXe g-Detector
    - New photon sensor w/ higher QE
    - Finer granularity w/ smaller sensor
  - Positron spectrometer
    - Reduction of material
    - Increase acceptance
    - Improve resolution and background

$$B_{acc} \propto \delta E_e \cdot \delta t_{e\gamma} \cdot (\delta E_\gamma)^2 \cdot (\delta\theta_{e\gamma})^2$$

Improvement	
LXe detector	
Higher QE PMT + coverage	δE_γ x 0.65, $\delta t_{e\gamma}$ x 0.77
Finer granularity with smaller PMT	$\delta\theta_{e\gamma}$ x 0.72, B_{acc} x 0.6
Drift chamber	
Reduce material	δE_e x 0.8
General	
Double acceptance	B_{acc} x 0.5

- Polarized μ^+ beam → Angular distribution measurement
  - Testing different SUSY-GUT models
  - Reduce background

Muon programs at J-PARC

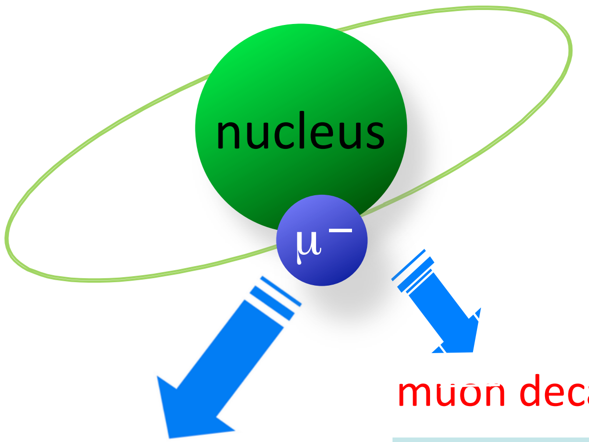


μ-e Conversion

Neutrino-less muon nuclear capture
(=μ-e conversion)

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

1s state in a muonic atom



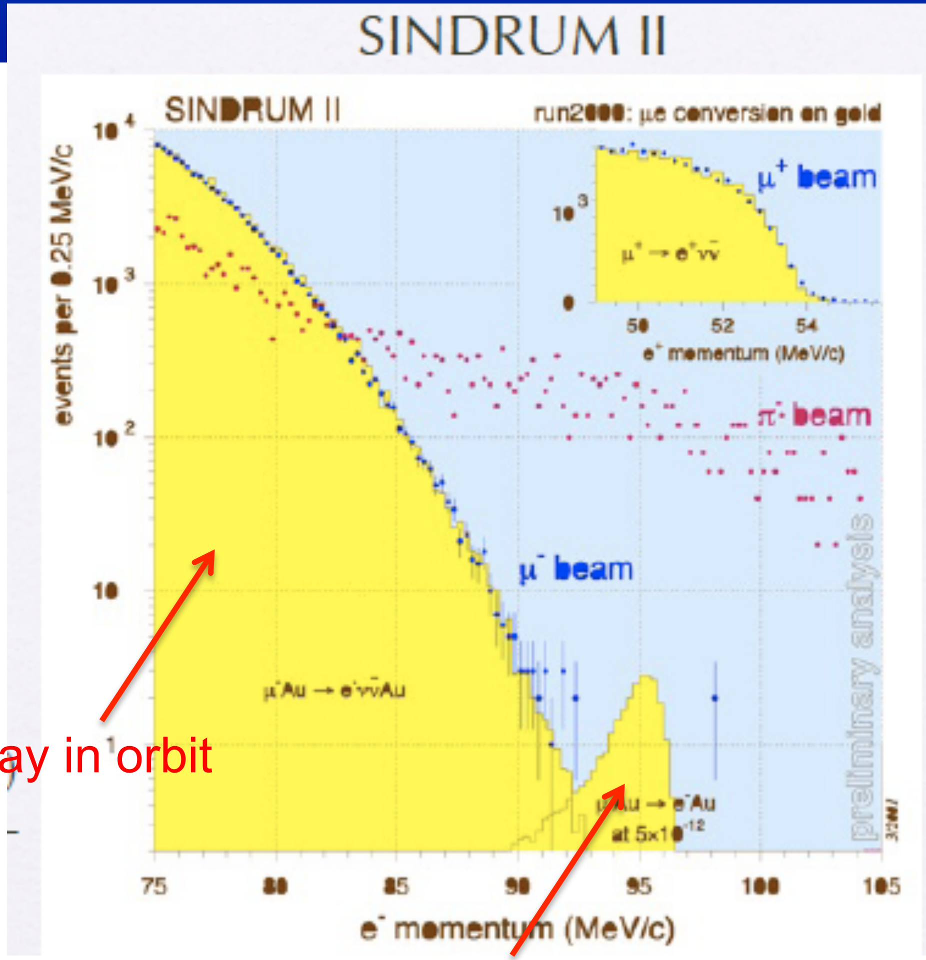
muon decay in orbit

$$\mu^- \rightarrow e^- \nu \bar{\nu}$$

nuclear muon capture

$$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$$

$$B(\mu^- N \rightarrow e^- N) = \frac{\Gamma(\mu^- N \rightarrow e^- N)}{\Gamma(\mu^- N \rightarrow \nu N')}$$



Decay in orbit

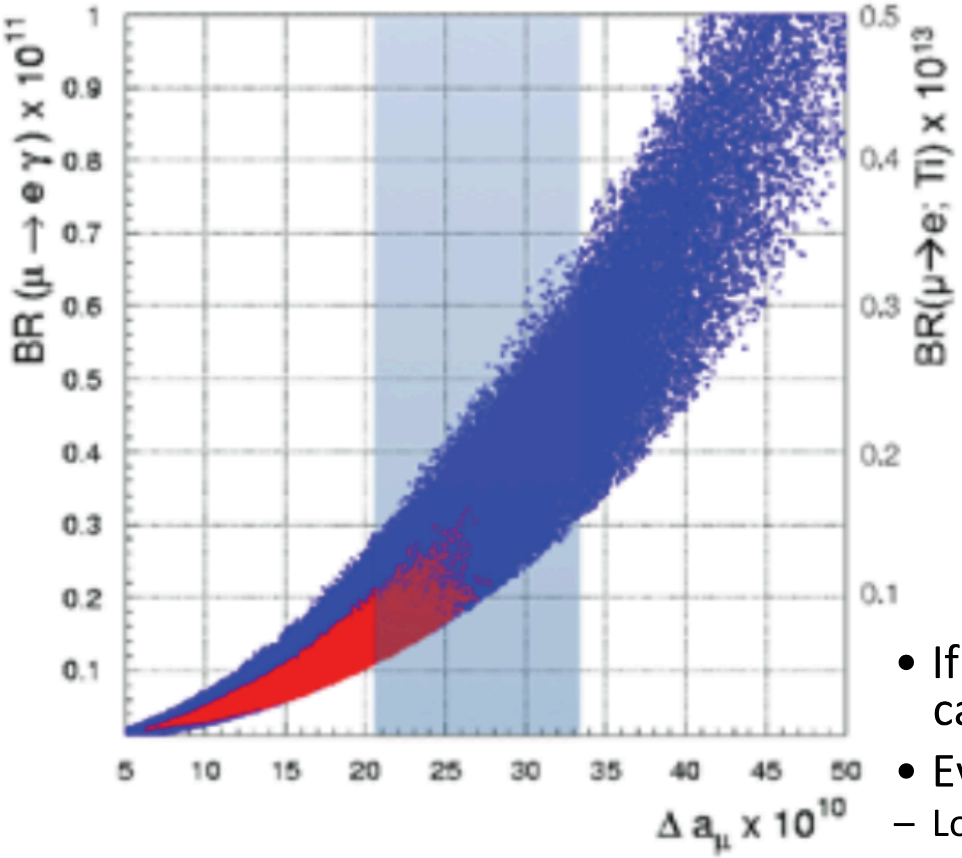
Siganl E_e = 105MeV, 1μs delay

Previous result (SINDRUM II)

$$BR[\mu^- + Au \rightarrow e^- + Au] < 7 \times 10^{-13}$$
$$BR[\mu^- + Ti \rightarrow e^- + Ti] < 4.3 \times 10^{-12}$$

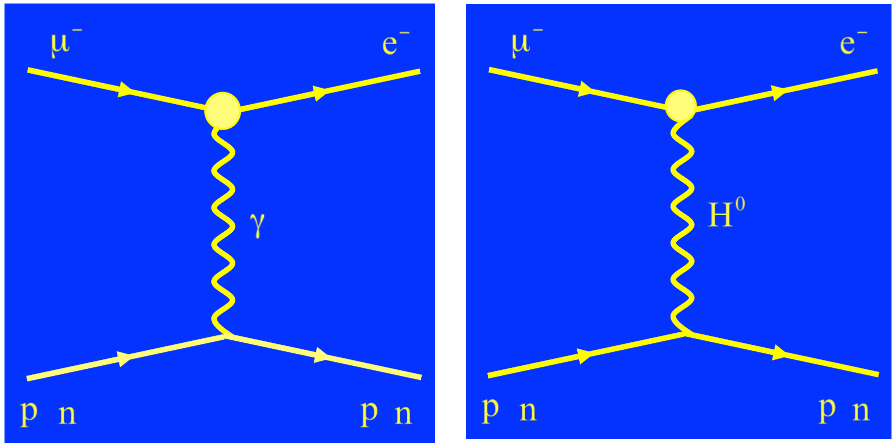
μ-e Conversion: Sensitivity to NP

Relation to g-2 (Δa_μ)



G. Ishidori *et al.*, PRD 75 (2007) 115019

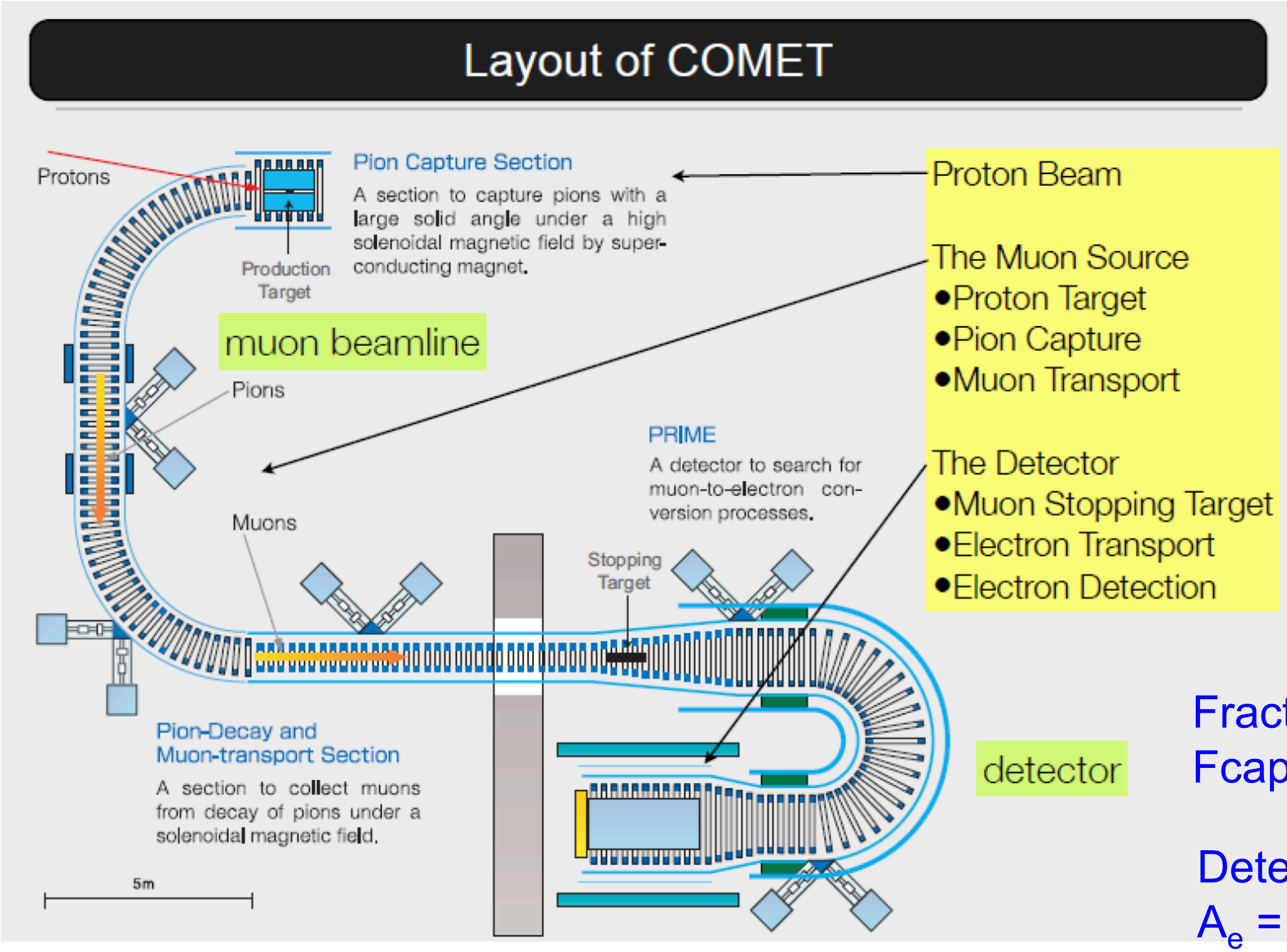
μ→e γ and μ → e conversion



$$\frac{B(\mu N \to eN)}{B(\mu \to e\gamma)} \sim \frac{1}{100}$$

- If μ→eγ exits, μ-e conv must be (except rare case of cancellation)
- Even if μ→eγ is not observed, μ-e conv may be
  - Loop vs Tree
  - Searches at LHC
- Important to measure both μ→eγ and μ-e conv with similar sensitivities

COMET



$Np = 8.5 \times 10^{20}$

0.0035 μ/proton

0.66 stop/μ

$N\mu = 2.0 \times 10^{18}$

Fraction of μ capture
Fcap = 0.6

Detector acceptance
$A_e = 0.031$

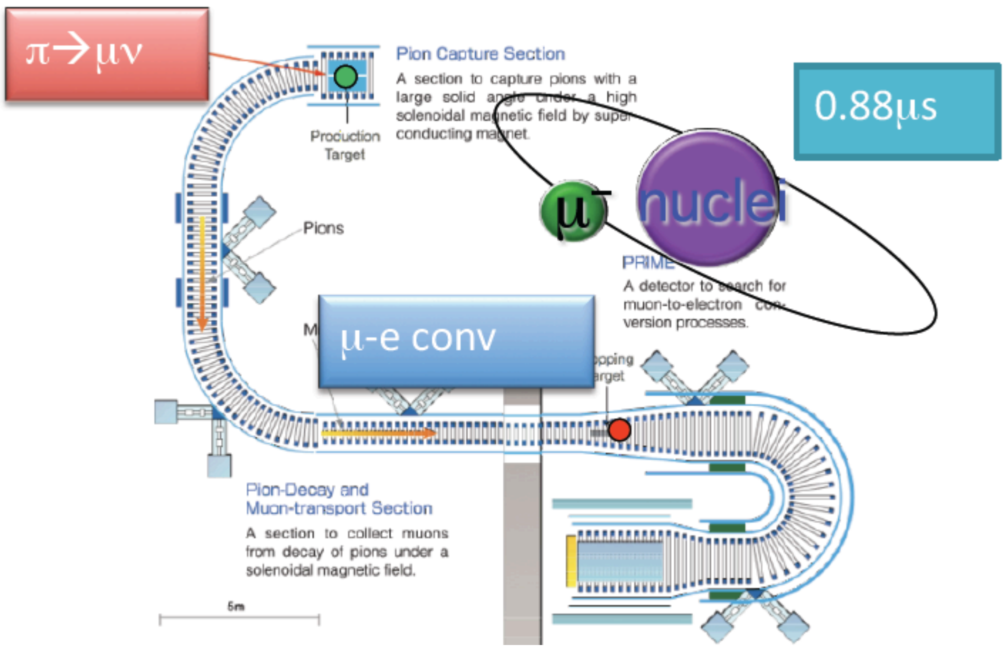
Sngle event sensitivity

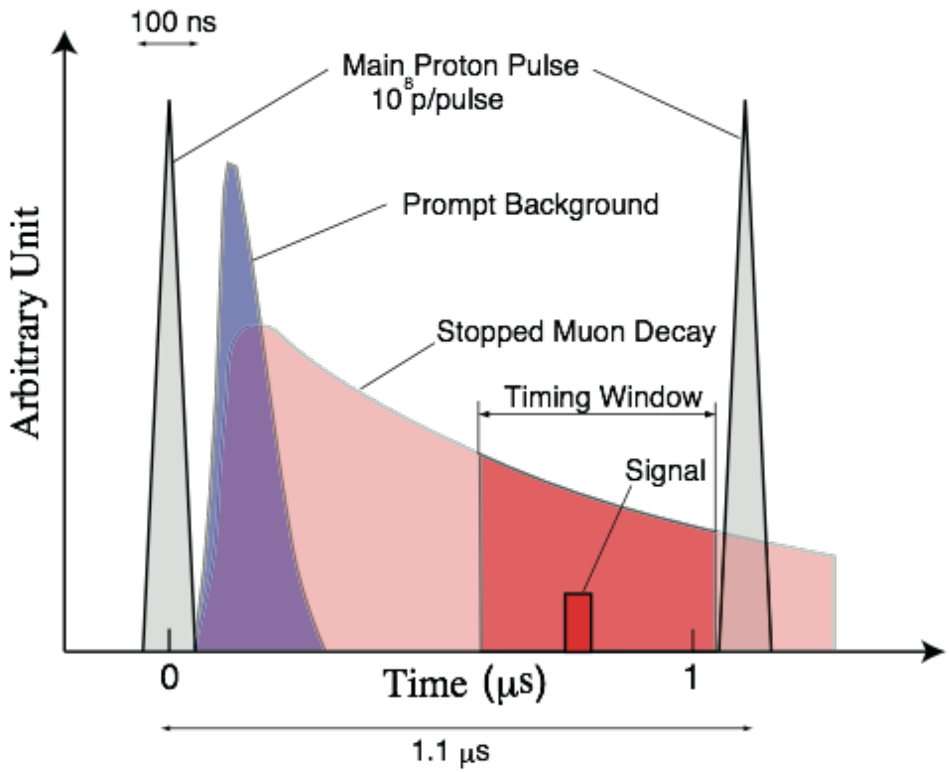
$$B(\mu^- + Al \to e^- + Al) \sim \frac{1}{N_\mu \cdot f_{cap} \cdot A_e},$$

Single event sensitivity
2.6×10^{-17}

Requirements for the Beam

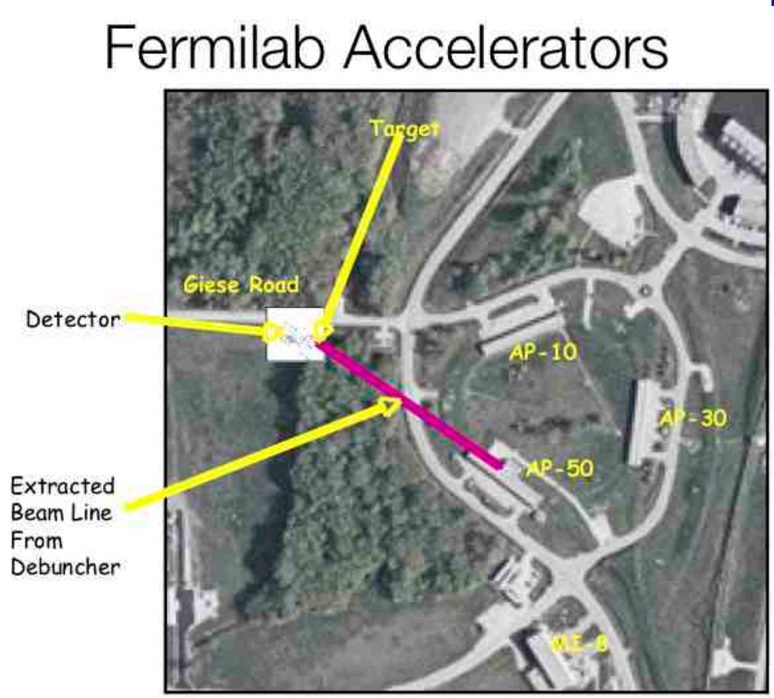
- Backgrounds
  - Beam Pion Capture
    - $\pi^- + (A,Z) \rightarrow (A,Z-1)^* \rightarrow \gamma + (A,Z-1)$ $\gamma \rightarrow e^+ e^-$
    - ***Prompt timing → good Extinction!***
  - μ^- decay-in-flight, e^- scattering, neutron streaming
- Requirements from the experiment
  - Pulsed
  - High purity
  - Intense and high repetition rate

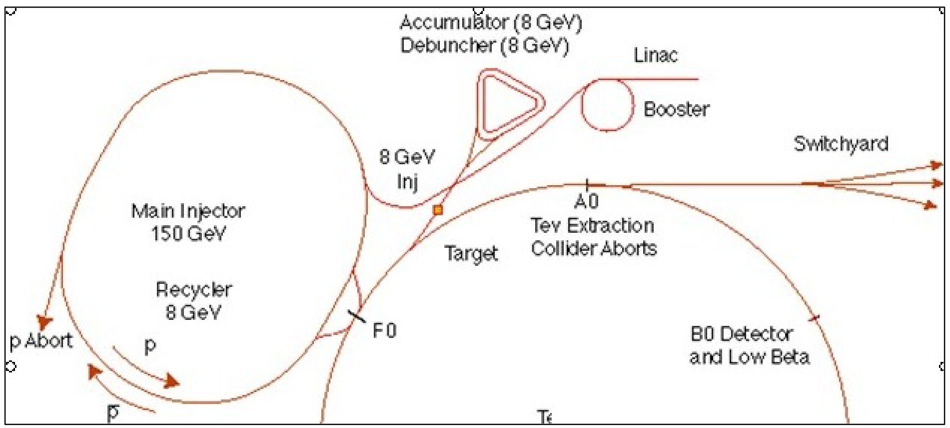


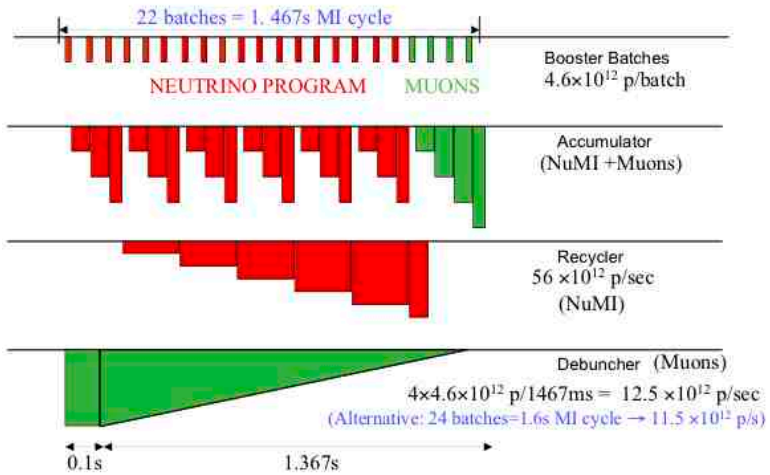


Mu2e @ FNAL

- The mu2e Experiment at Fermilab.
  - Proposal has been submitted.
    - Received CD-0 in Nov. 2009
    - In a process to obtain CD-1
    - Anticipated DAQ start in 2017
  - After the Tevatron shut-down
    - uses the antiproton accumulator ring
    - the debuncher ring to manipulate proton beam bunches
- Compatible target sensitivity to COMET

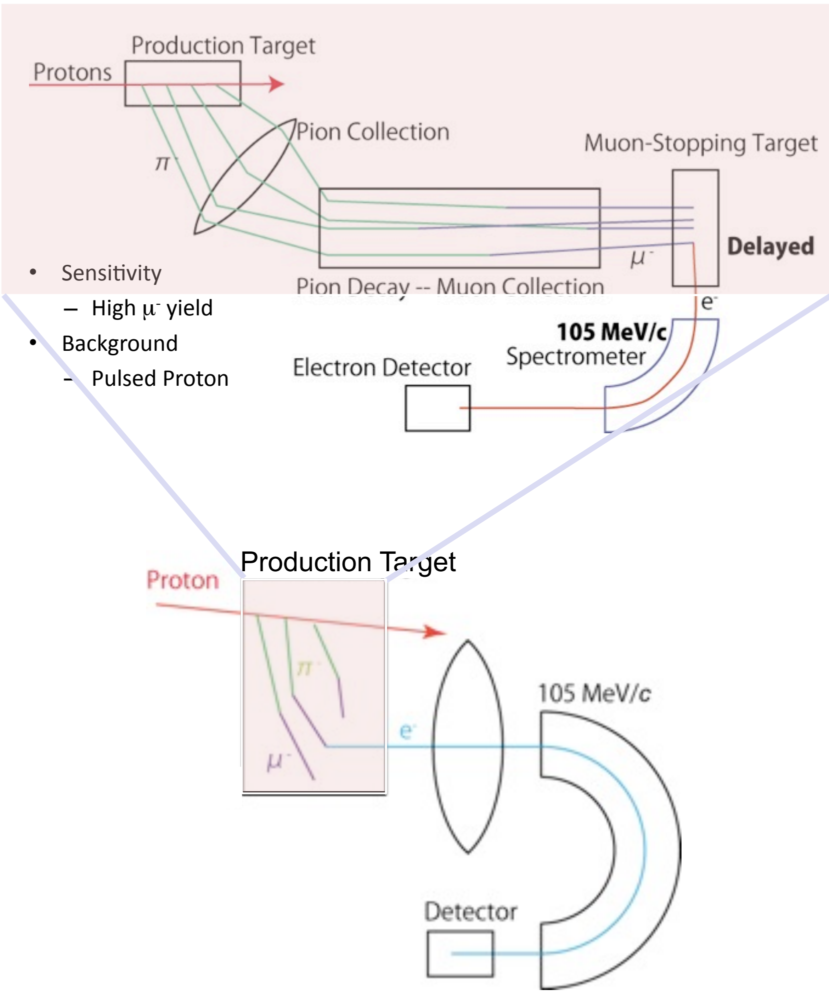






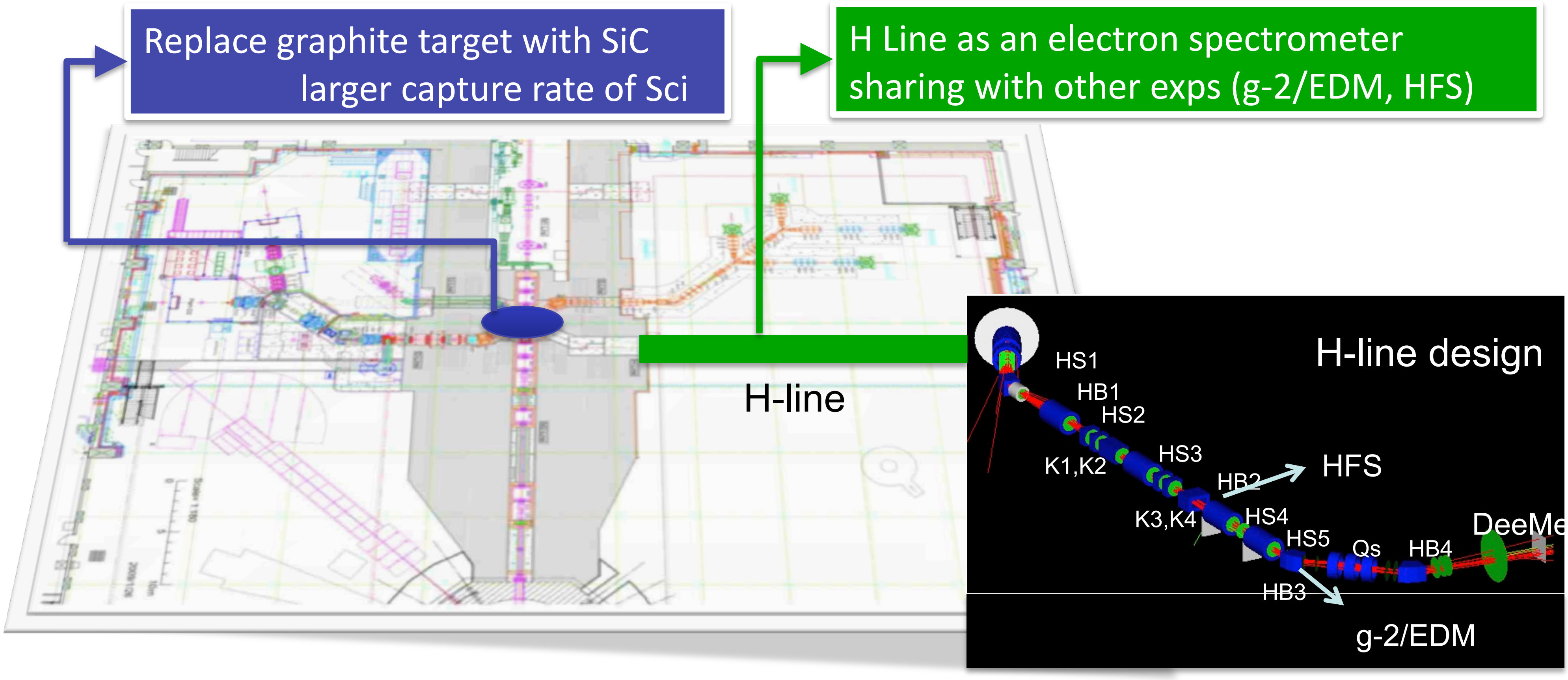
DeeMe

- It may be worth to search for μ-e conv. with a sensitivity around 10^{-14} because
  - $Br(\mu \rightarrow e\gamma)/Br(\mu\text{-}e) \sim \alpha$
- DeeMe at J-PARC aims at 10^{-14} sensitivity for μ-e conv. using
  - MLF pulsed proton beam
  - Beam line as a spectrometer
- Proposal submitted both to
  - IPNS PAC
    - Physics merit and experiment feasibility under discussion
  - MUSE PAC
    - Approved



DeeMe at MLF

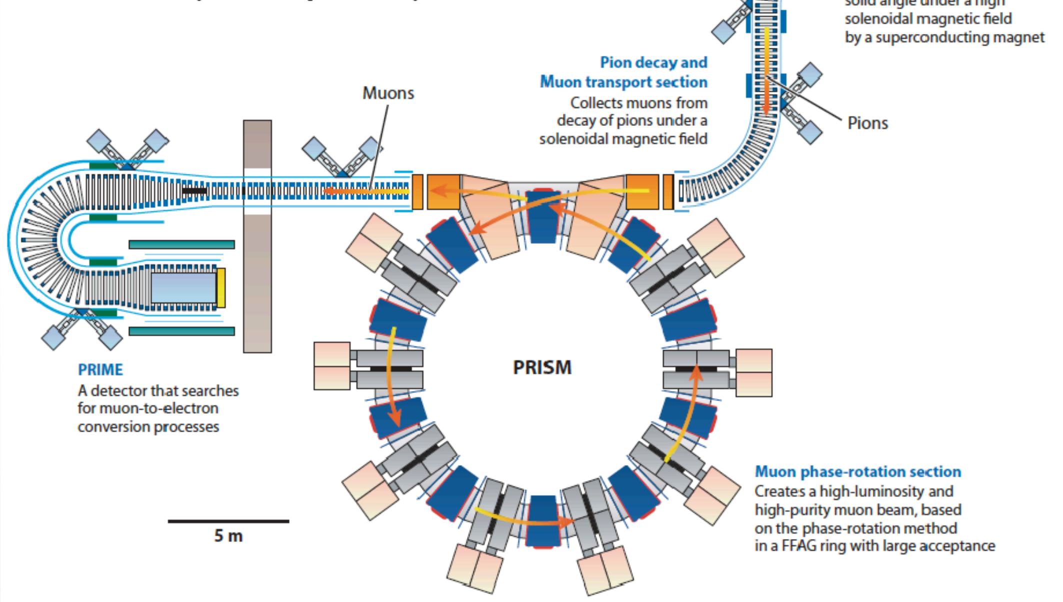
- Beam line as an electron spectrometer
  - Kicker magnets to sweep prompt background
  - Conventional spectrometer to measure electron momentum
- S.E.S. 1.5×10^{-14} for 2×10^{7} sec DAQ



More

Aiming for a 10^{-18} search with an extreme high intensity ($10^{11} \div 10^{12}$ μ/s) beam with μ storage ring.

PRISM at J-Parc
(R&D phase)



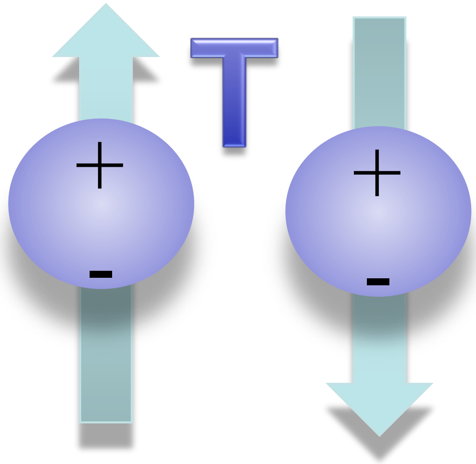
Fixed-field alternating gradient synchrotron perform conversion from original short-pulse beam with high momentum spread (30%) into a long pulse beam with narrow momentum spread (3%).

μ beam production studies at MUSIC@RCNP in progress.

Muon g-2 / EDM

- Magnetic and Electric Dipole Moments are related to Spin of the Particle: axial vector

$$\vec{\mu} = g\left(\frac{e}{2m}\right)\vec{s} \qquad \vec{d} = \eta\left(\frac{e}{2mc}\right)\vec{s}$$



$$a = \frac{g-2}{2}$$

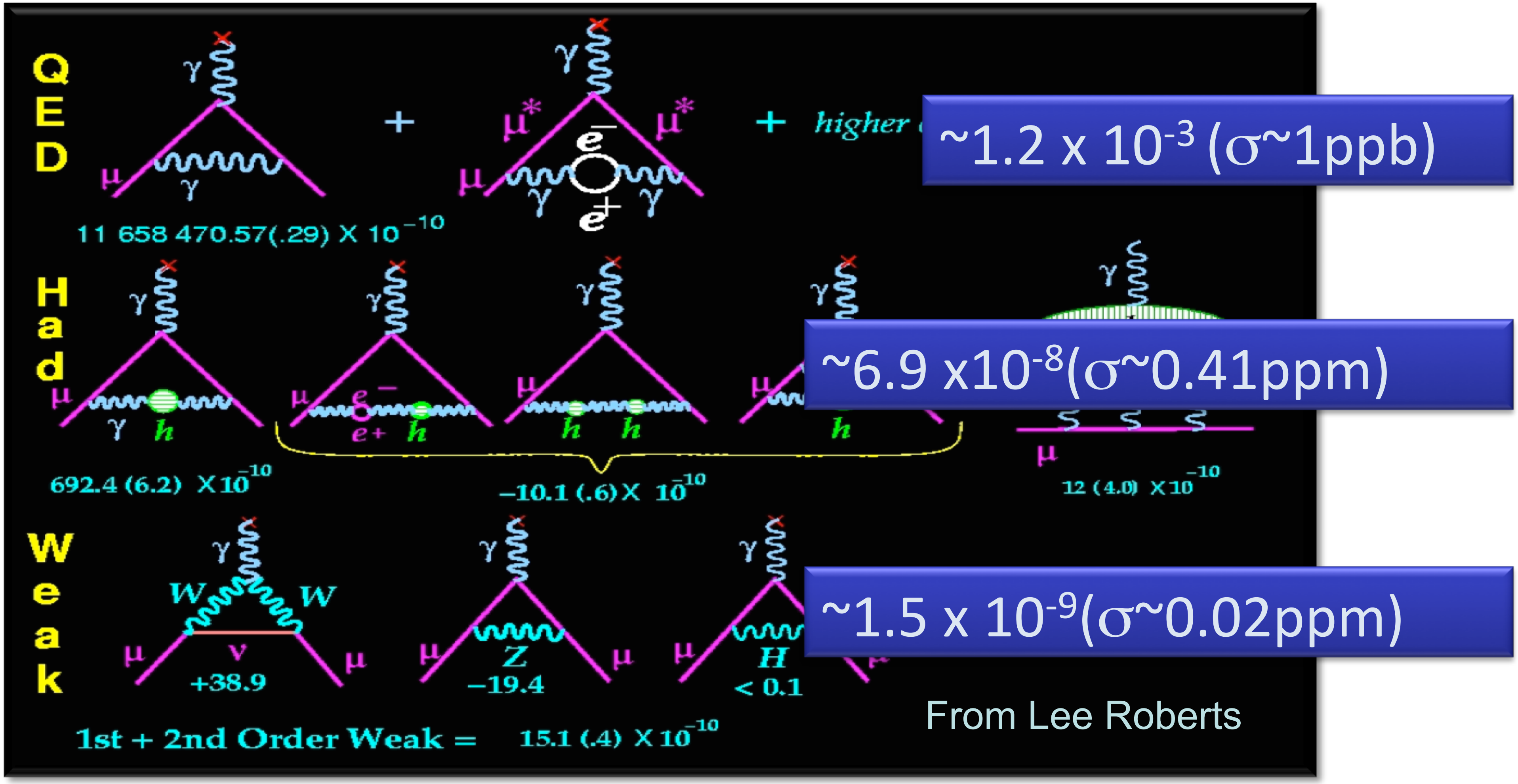
$$H = -\vec{\mu}\cdot\vec{B} - \vec{d}\cdot\vec{E}$$

MDM (Magnetic Dipole Moment)
Contains contributions from ALL PHYSICS!
- EW, QCD, and New Physics
⇒ precision test of the SM
⇒ the most precise determination of α_{EM} from electron g-2 (0.37 ppb)

EDM (Electric Dipole Moment)
If EDM nonzero, T is violated
⇒ CP violation in the lepton sector (under CPT)
⇒ leptogenesis?
⇒ Baryon Asymmetry in the Universe

SM Contribution to $a \neq 0$

- Any particle which couples to muon/photon would contribute : QED >> Hadron > Weak

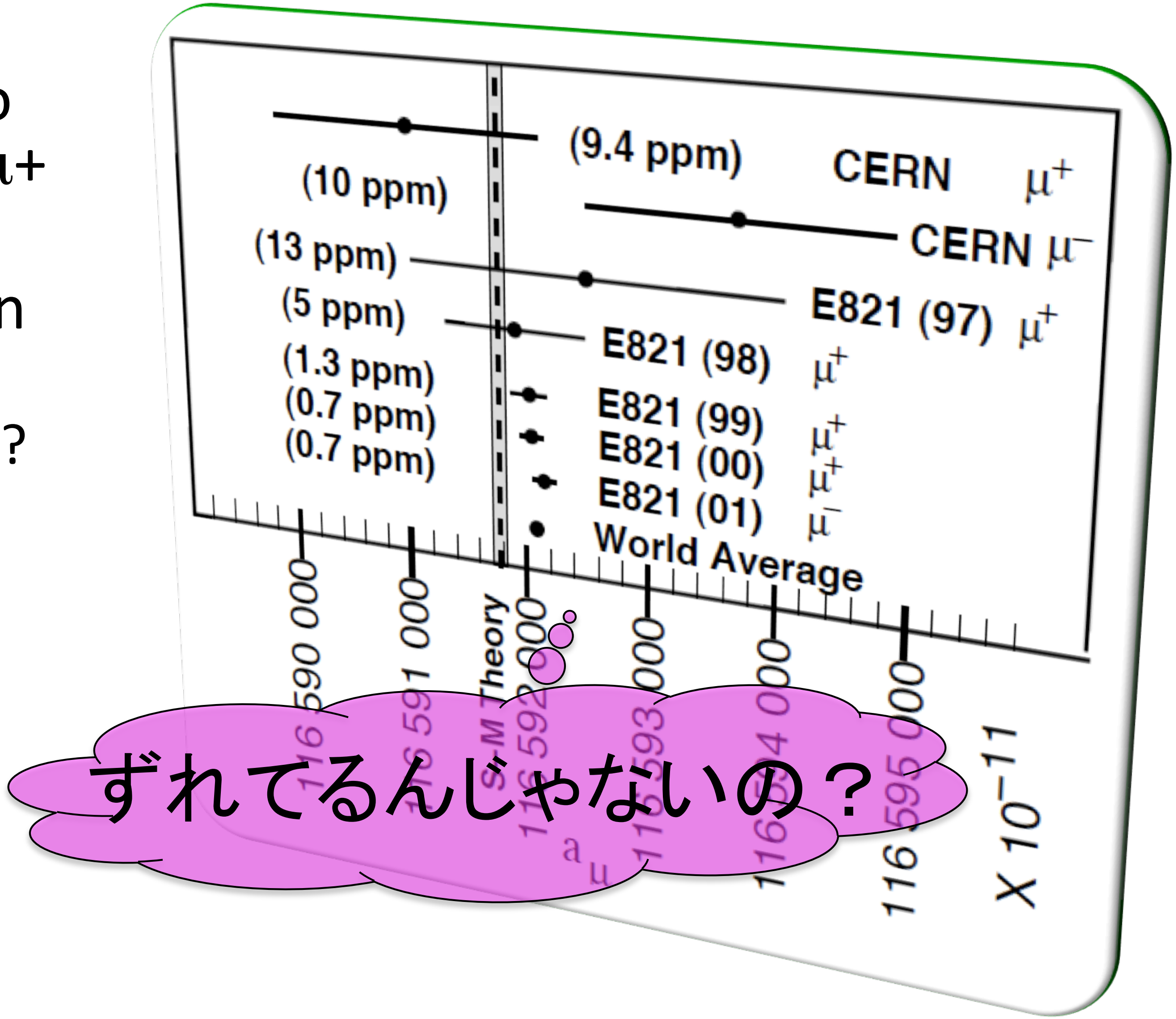


"Final Report" from BNL E821

$$\Delta a_\mu^{(\text{today})} = a_\mu^{(\text{Exp})} - a_\mu^{(\text{SM})} = (295 \pm 88) \times 10^{-11}$$

- E821 at BNL-AGS measured down to 0.7 ppm for both μ+ and μ−
- 3.4 sigma deviation from the SM
  - SM prediction OK?
  - New Physics?
- Need to explore further
- Preferably

NEW METHOD!



Muon Spin precession

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} - \quad + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} \quad \right)\right]$$

$$\eta : \ d_\mu = \frac{\eta}{2}\left(\frac{e}{2m}\right)$$ Electric Dipole Moment

$$d_e = (6.9 \pm 7.4)\times 10^{-28}\, e\cdot\mathrm{cm}$$

Expected to be

$$d_\mu < (1.5 \pm 1.4)\times 10^{-25}\, e\cdot\mathrm{cm}$$

Measured to be

$$d_\mu = (0.0 \pm 0.9)\times 10^{-19}\, e\cdot\mathrm{cm}$$

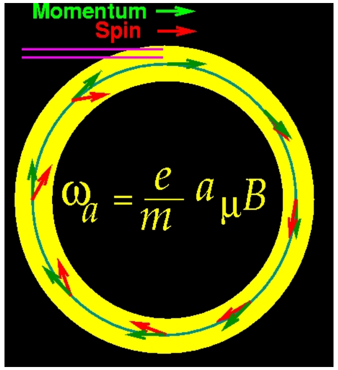
G.W.Benett et al. Phys.Rev.D80:052008,2009

$$a_\mu - \frac{1}{\gamma^2 - 1} = 0$$

$$\gamma_{\mathrm{magic}} = 29.3$$

$$p_{\mathrm{magic}} = 3.09\ \mathrm{GeV}/c$$

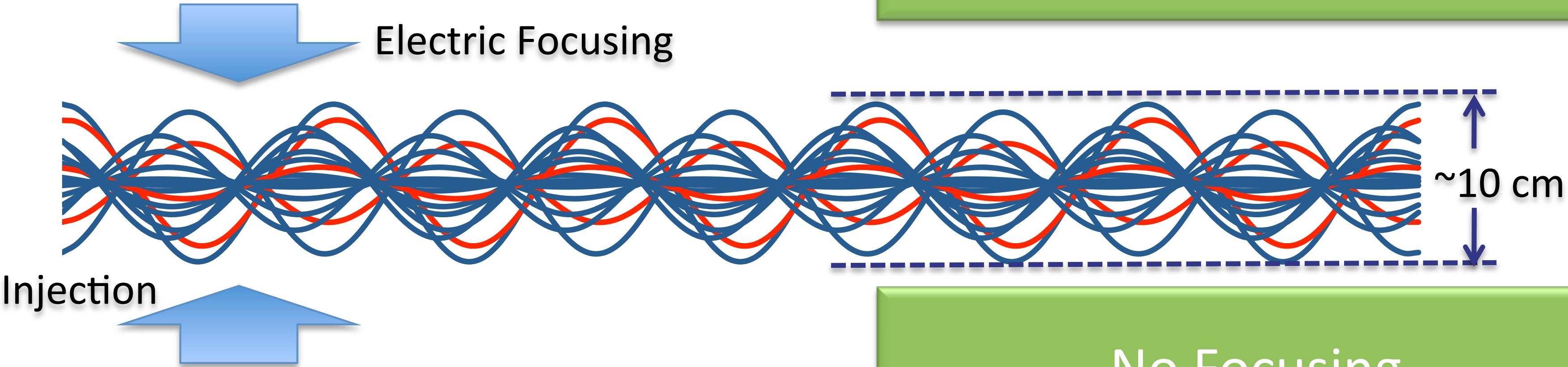
$$\vec{\omega}_a = -\frac{e}{m} a_\mu \vec{B}$$



Off Magic Momentum?

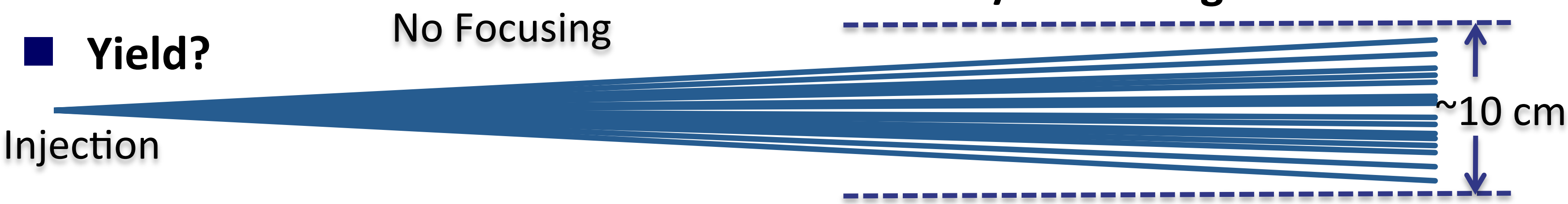
- Tertiary Muon Beam
  - Widely spread over phase space
  - Contamination of pion

Electric Field for Focusing ⇒ Magic Momentum

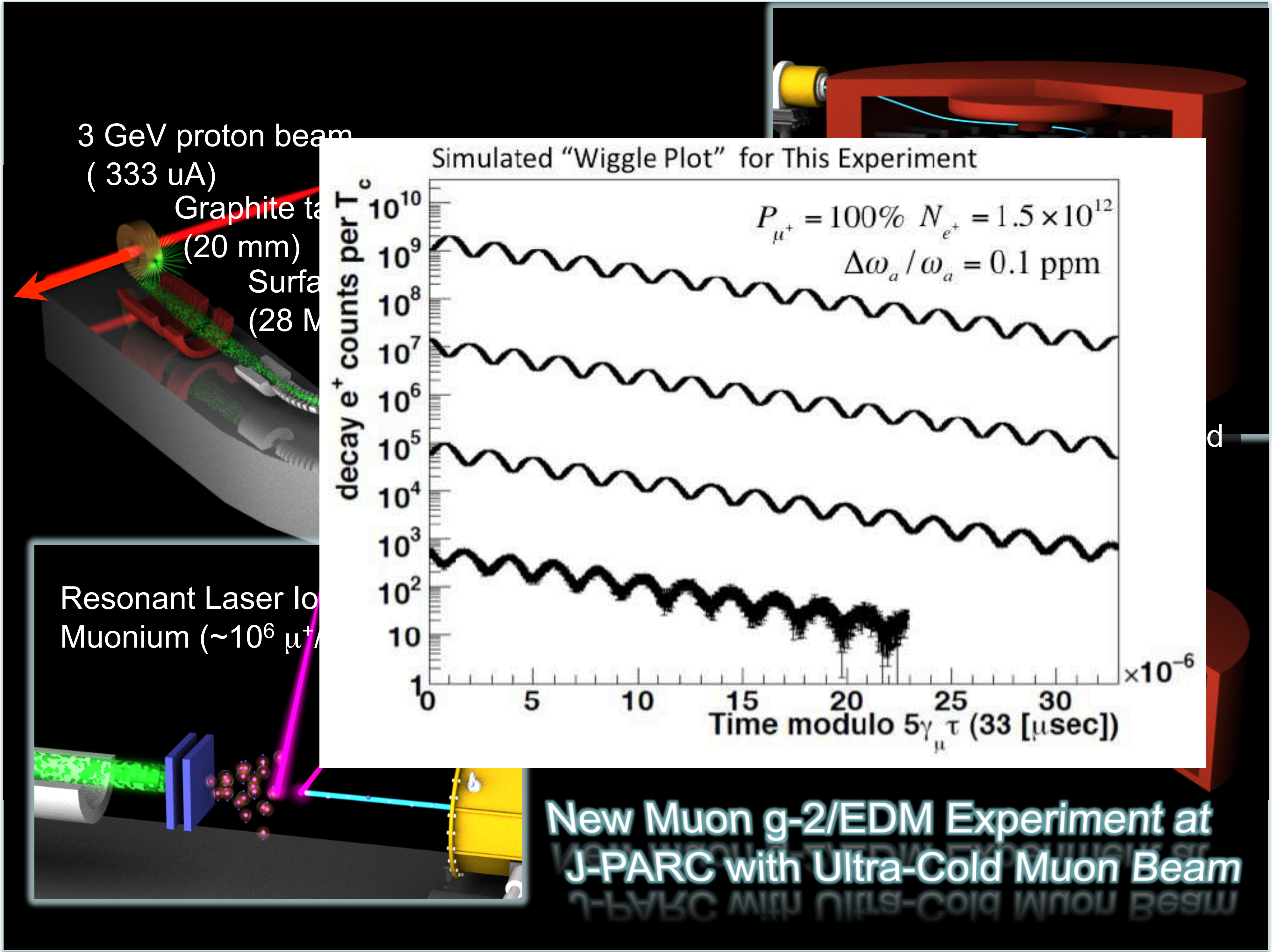


No Focusing ⇒ Any Momentum

- **Ultra-Cold Muon Beam**
  - **Can be contained in the detection volume w/o focusing**
  - **Yield?**



$\sigma(p_T)/p_L \le 10^{-5}$ ⇒ < 10 cm spread over 10 km travel


3 GeV proton beam
(333 uA)
(20 mm)
Simulated “Wiggle Plot” for This Experiment
$P_{\mu^+} = 100\%$ $N_{e^+} = 1.5 \times 10^{12}$
$\Delta\omega_a / \omega_a = 0.1$ ppm
decay e+ counts per T_c
Time modulo $5\gamma_\mu\tau$ (33 [μsec])
$\times 10^{-6}$
New Muon g-2/EDM Experiment at
J-PARC with Ultra-Cold Muon Beam

BNL / FNAL / J-PARC

	BNL-E821	Fermilab	J-PARC
Muon momentum	3.09 GeV/c		0.3 GeV/c
gamma	29.3		3
Storage field	B=1.45 T		3.0 T
Focusing field	Electric quad		None
# of detected m+ decays	5.0E9	1.8E11	1.5E12
# of detected m- decays	3.6E9	-	-
Precision (stat)	0.46 ppm	0.1 ppm	0.1 ppm

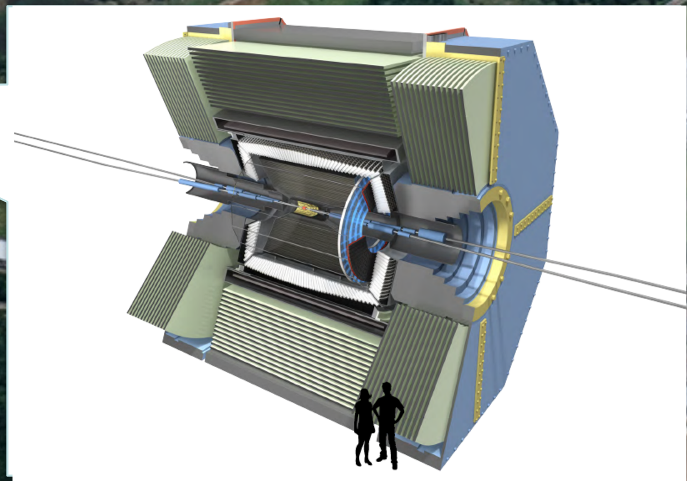
Tau Physics at SuperKEKB

Super B factory $\sigma(e^+e^- \to B\overline{B}) \approx 1.1\,\mathrm{nb}$

is also a

Super Tau Factory $\sigma(e^+e^- \to \tau^+\tau^-) \approx 0.91\,\mathrm{nb}$

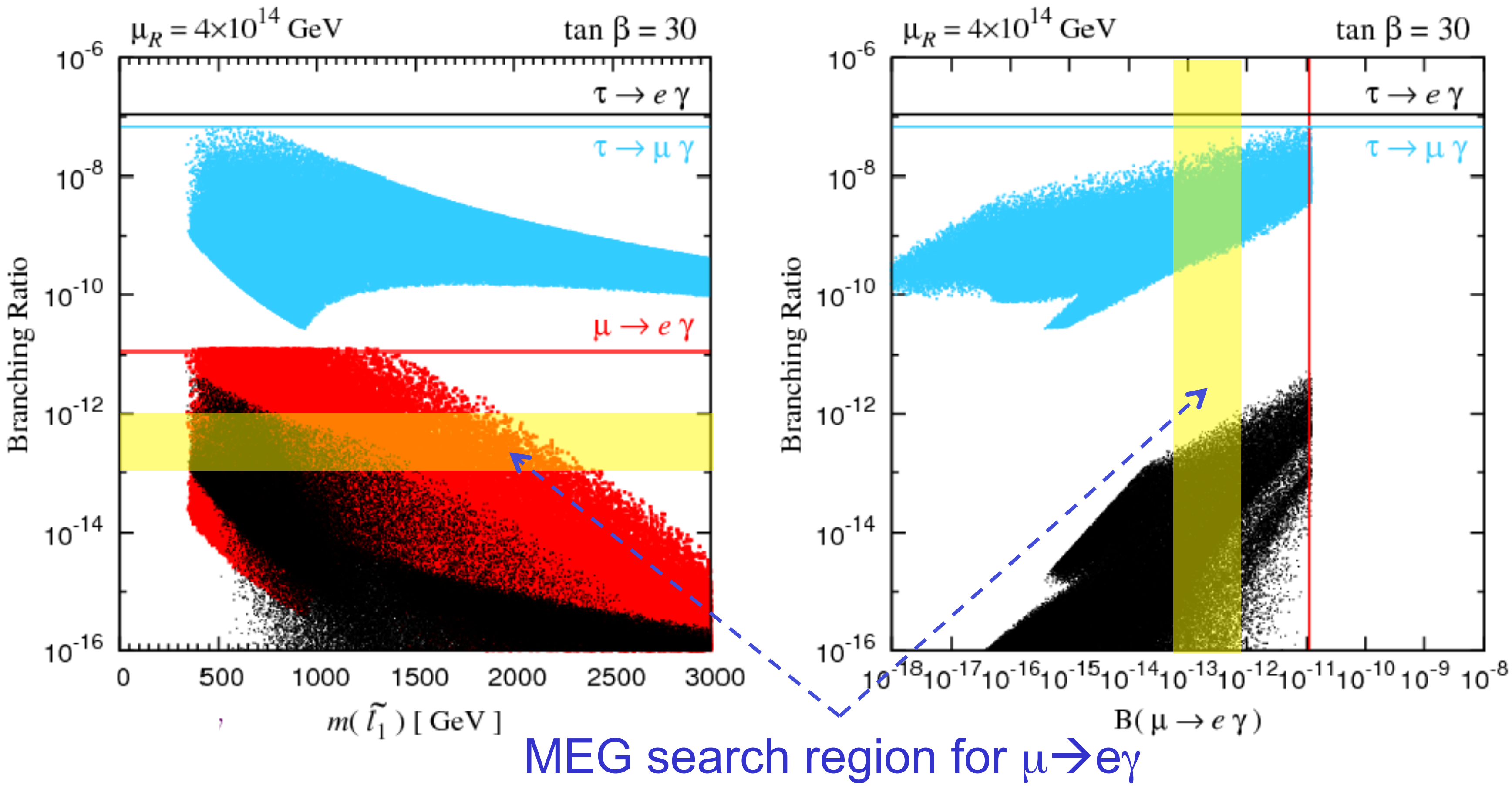
Physics with $O(10^{10})$ τ / year



SUSY-GUT

Goto, Okada, Shindou & Tanaka
PRD77, 095010 (2008)

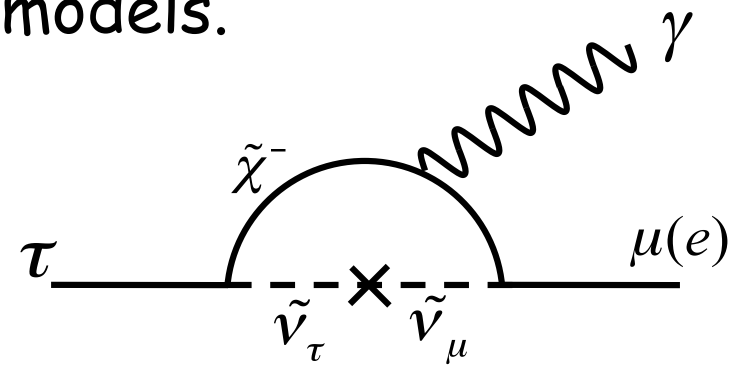
- SU(5)+ν_R, non-degenerate ν_R(I), normal Hierarchy

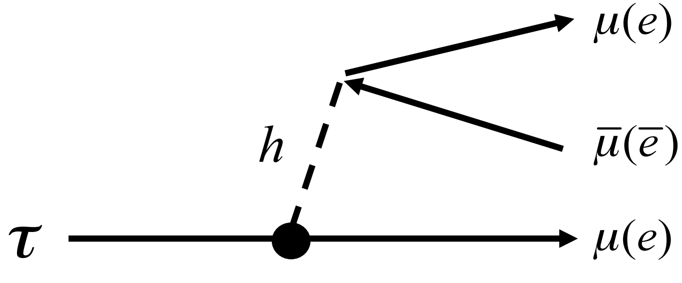


If MEG find μ→eγ at ~$10^{-12\to13}$, good chance to see also τ→μγ at $10^{-8\to-10}$
Even if MEG does not, still important to search for τ→μγ.

NP signature in $\tau \to \ell\gamma, \ell\ell\ell$

- The two decays have different sensitivity for different NP models.



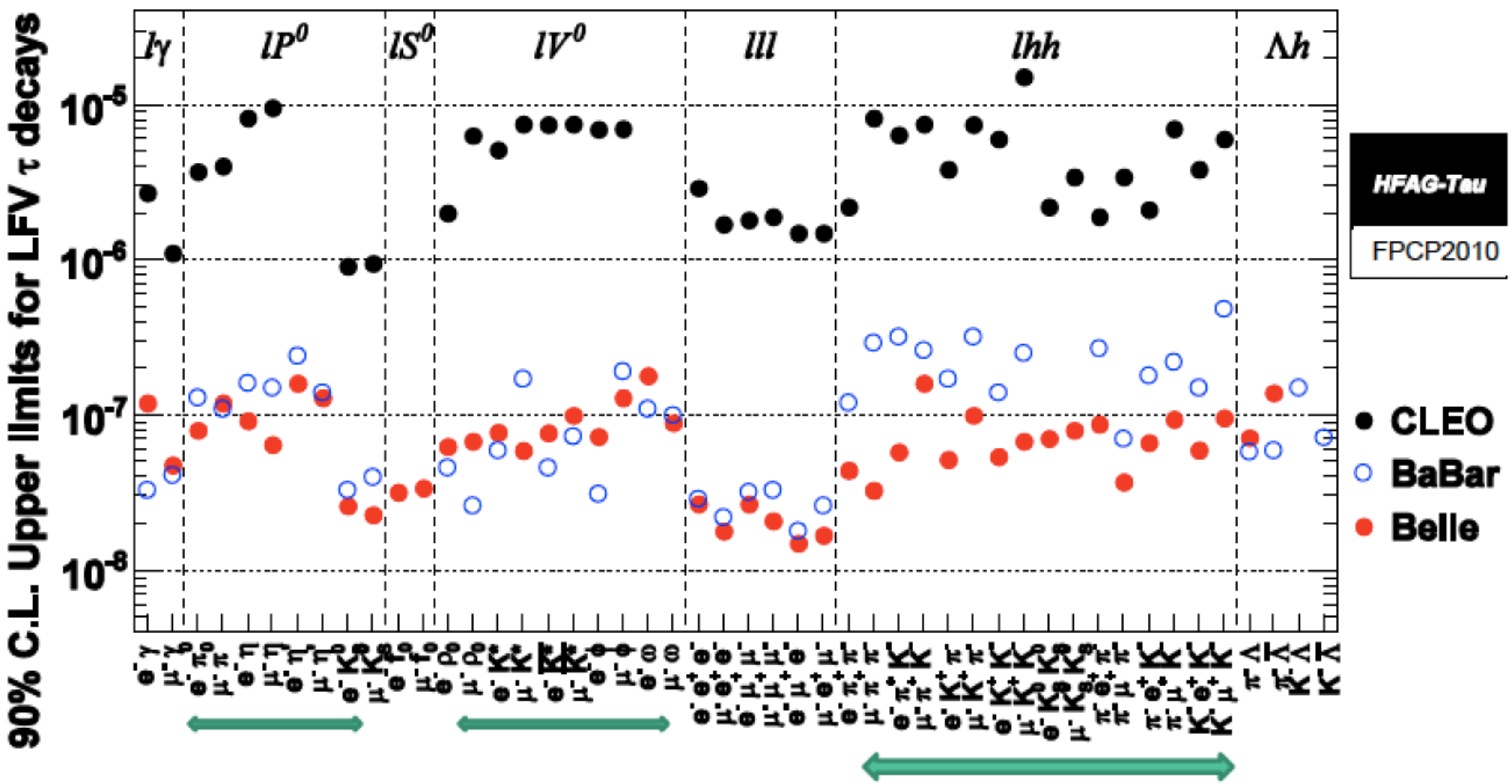


	Reference	τ◊μγ	τ◊μμμ
SM + heavy Maj ν_R	PRD 66(2002)034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547(2002)252	10^{-9}	10^{-8}
SUSY SO(10)	PRD 68(2003)033012	10^{-8}	10^{-10}
mSUGRA+seesaw	PRD 66(2002)115013	10^{-7}	10^{-9}
SUSY Higgs	PLB 566(2003)217	10^{-10}	10^{-7}

Searches in various LFV modes help to discriminate NP models.

LFV results

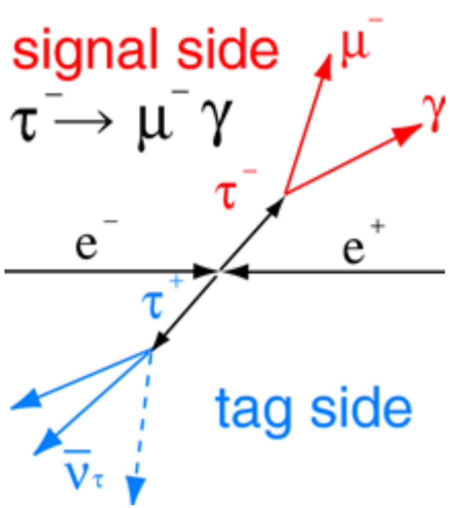
The present B-factories reach the sensitivity of O(10^{-8})



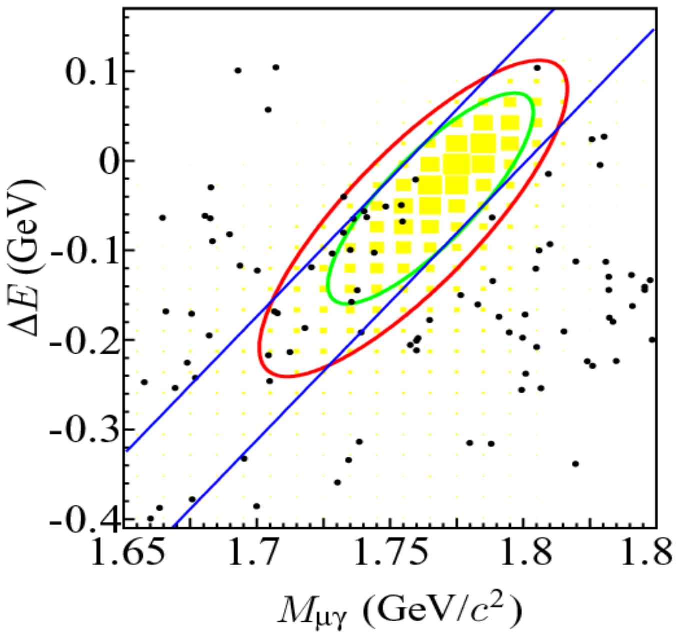
$\tau \to \mu\gamma$, $e\gamma$

535 fb^{-1}

PLB666, 16(2008)

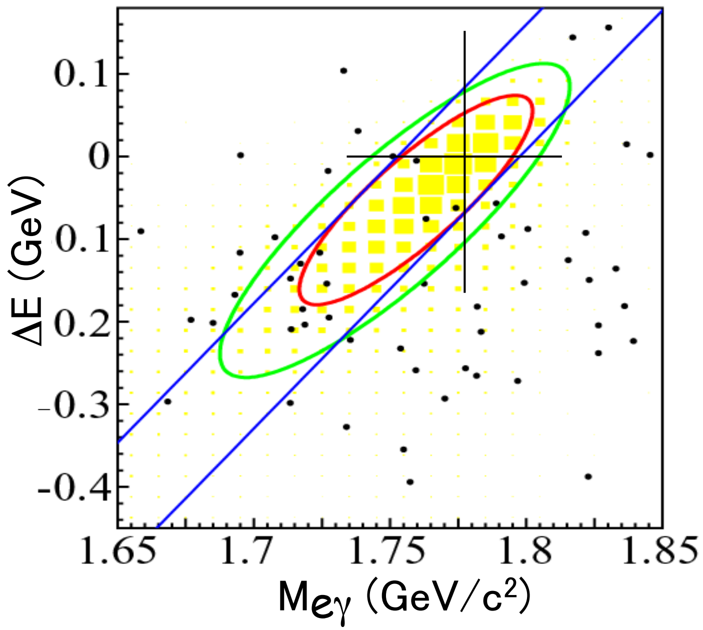


$\tau \to \mu\gamma$



Br<4.5x10^{-8} at 90%C.L.

$\tau \to e\gamma$

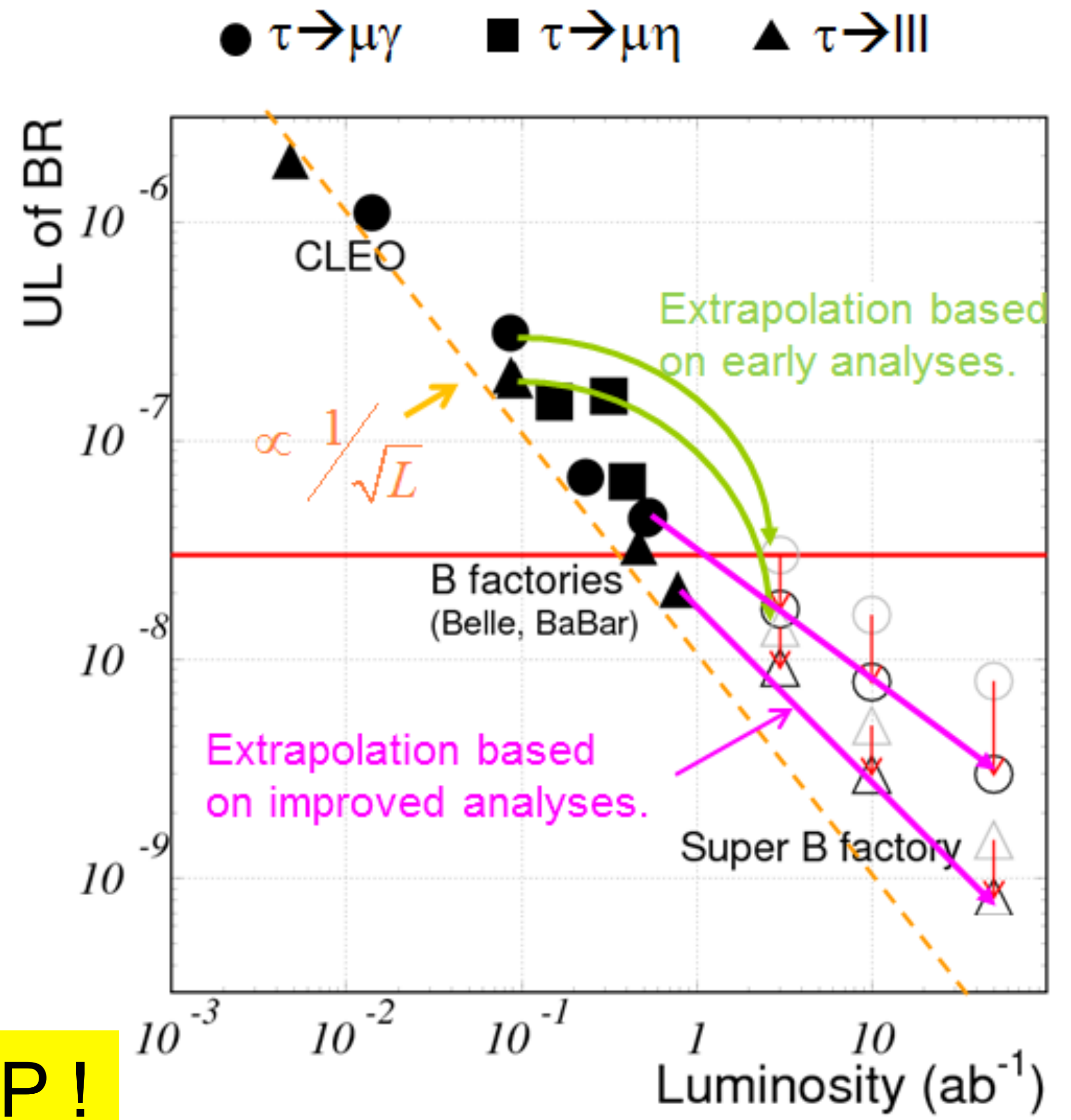


Br<1.2x10^{-7} at 90%C.L.

- Background: $\tau \to \mu\nu\nu/e\nu\nu$ + ISR (or beam background)
- Small amount of $\mu\mu$ events in $\Delta E>0$

Future prospects

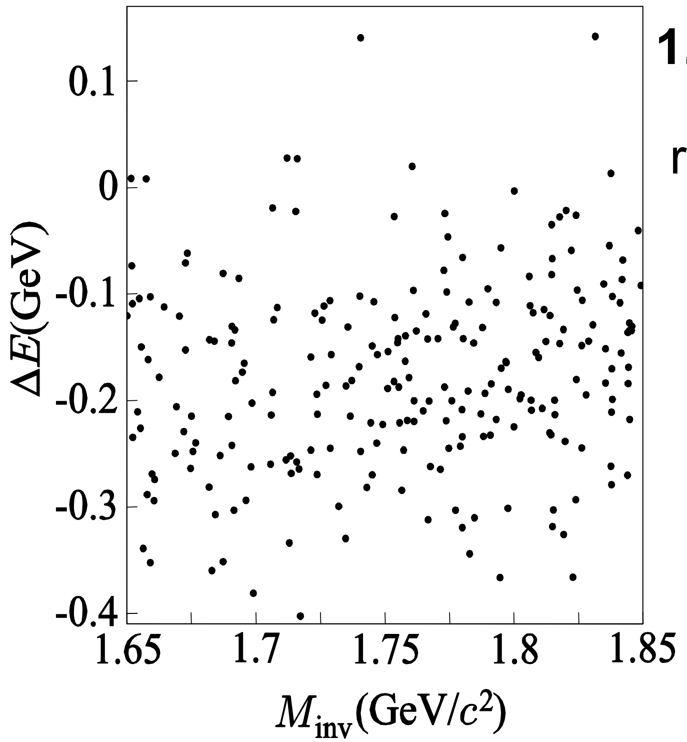
- Super B-factory:
  L_{int} = 10→50ab^{-1}
  N_τ = (1→5) x 10^{10}
- Recent improvement in the analysis
  - BG understanding
  - Intelligent selection
- At 50 ab^{-1}
  Br(τ→μγ) < O(10^{-9})
  Br(τ→lll < O(10^{-10})



Good chance to see NP !

Background in $\tau \to \mu\gamma$ analysis

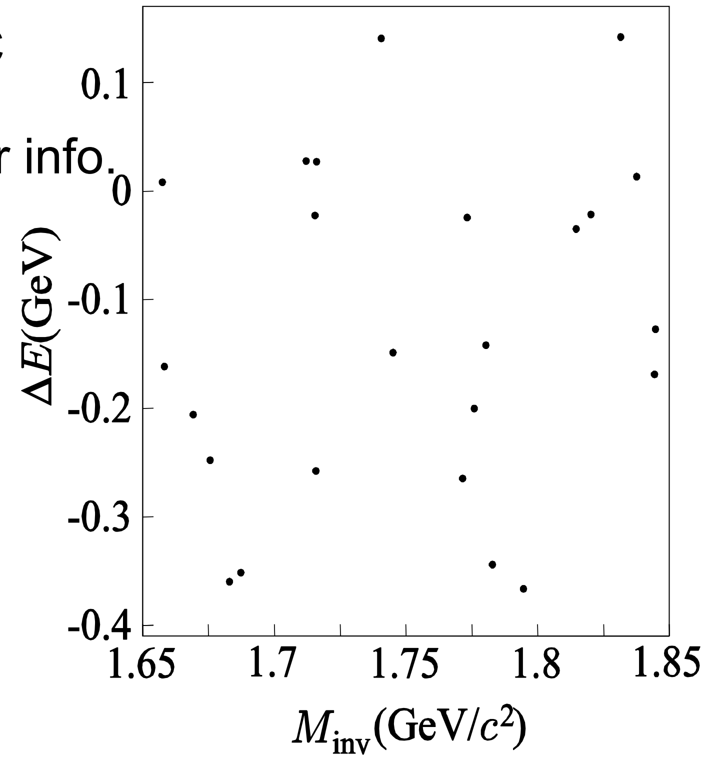
If we can remove BG events caused by ISR completely···



1.5 ab^{-1} generic $\tau\tau$ MC

removed by generator info.

90% events removed!



In order to improve:

- Better γ resolution
- Optimization of accelerator energies & asymmetry.

Summary

- Muon and Tau physics:
  - Good probe for high energy scale (beyond LHC)
  - No SM background, No hadronic uncertainty

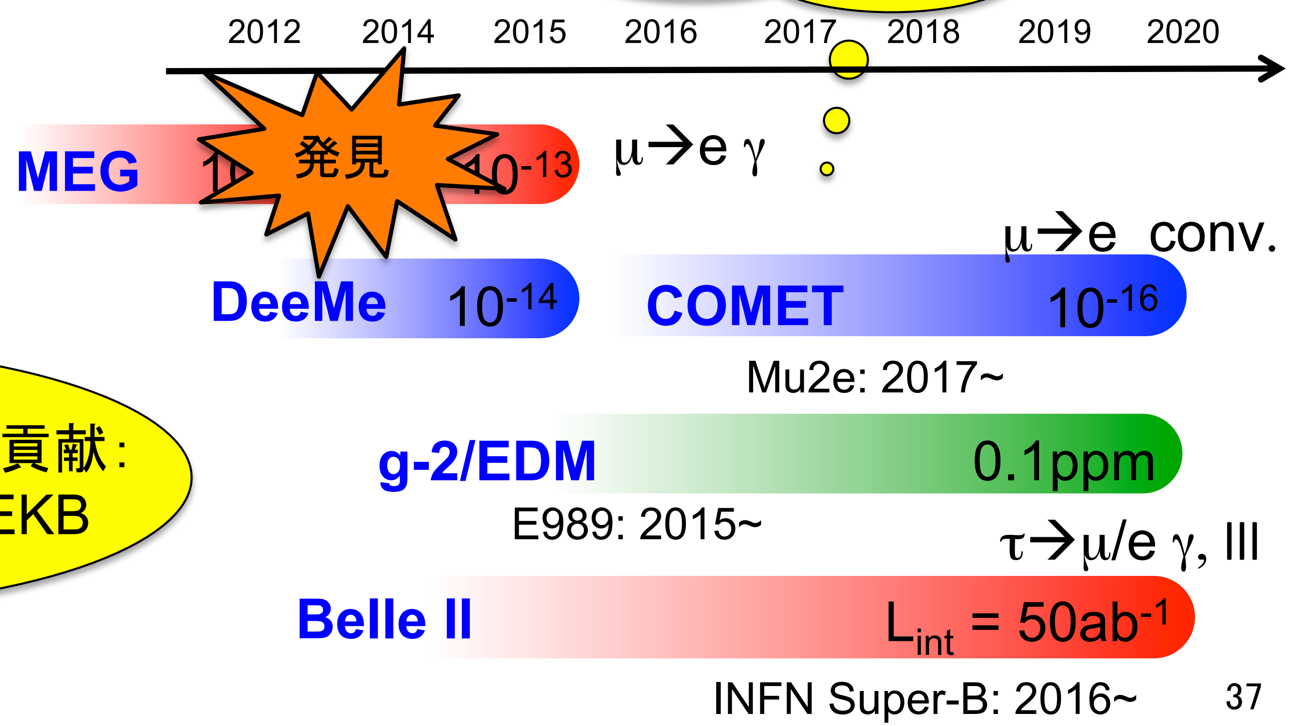
- Muon g-2: 3.4σ deviation now. → Important to test w/ the new experiment

- MEGで早期発見に期待：O(10^{-12})
  発見なら他実験で見ることが最重要
  - μ→e conversion at < O(10^{-14})
  - τ LFV at <O(10^{-9})

  が encouraging !

荷電レプトンセクターが新たな研究のパラダイムに

日本のアドバンテージ/貢献：
J-PARC & Super KEKB

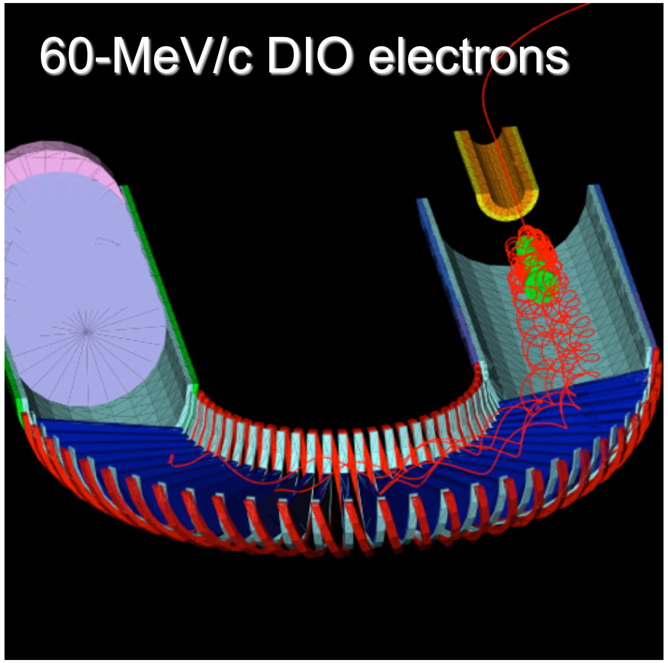


Backup

Peformance prospect for next few years

	2008	2009 (preliminary)	2010 (preliminary)	2011 (preliminary)	2012 (preliminary)
Gamma Energy (%)	2.0(w>2cm)	←	1.5-2.0(w>2cm)	1.2-2.0(w>2cm)	←
Gamma Timing (psec)	80	>67	←	←	←
Gamma Position (mm)	5(u,v)/6(w)	←	←	←	←
Gamma Efficiency (%)	63	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(Φ)/9.4(θ)	←	6.2(Φ)/(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(Y)/3.0-3.3(Z)	←
Trigger efficiency (%)	66	91	92	92-98	←
Stopping Muon Rate (sec^{-1})	3×10^7	2.9×10^7	2.9×10^7	←	←
DAQ time/ Real time (days)	48/78	35/43	56/67	135/161	←

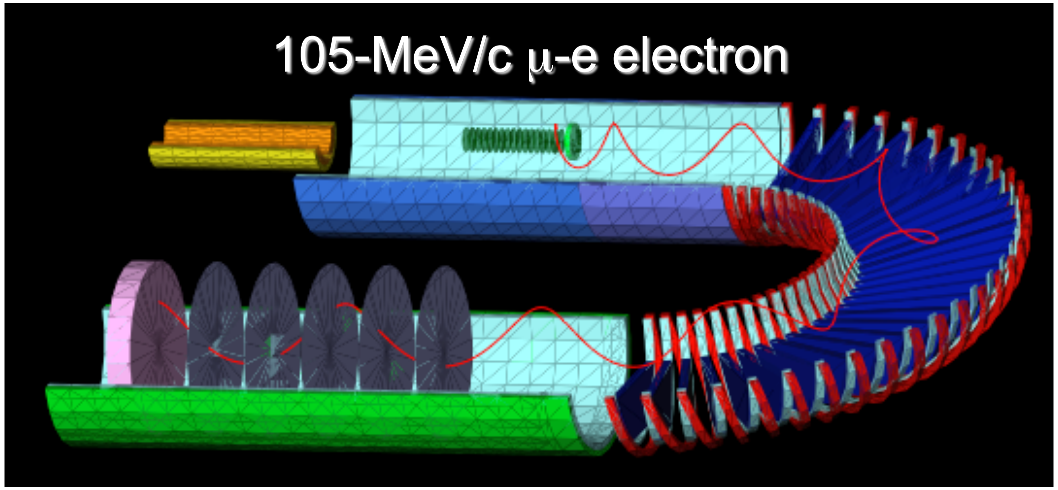
COMET Curved Solenoid Spectrometer

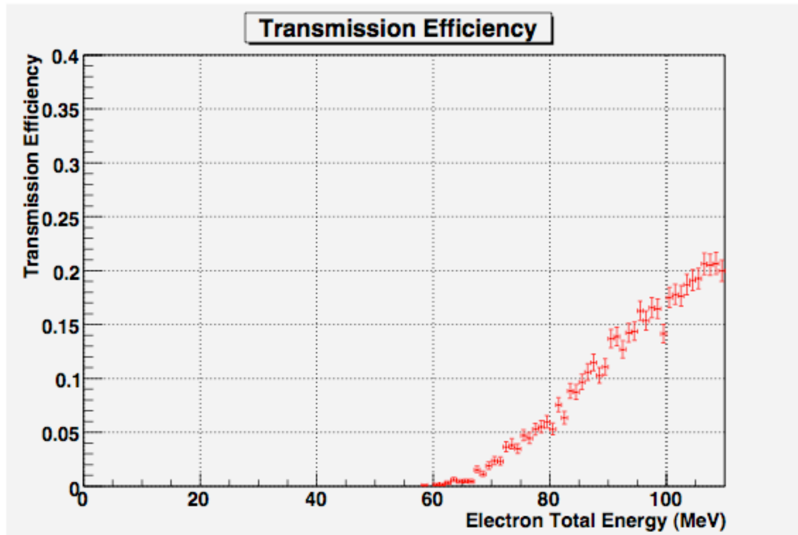


- Select electron momentum with large acceptance
  - Same technique in muon transport
- Torus drift for rejecting low energy DIO electrons.

$$D[m] = \frac{1}{0.3 \times B[T]} \times \frac{s}{R} \times \frac{p_l^2 + \frac{1}{2}p_t^2}{p_l}$$

  - rejection ~10^{-6}: < 10kHz
- Good acceptance for signal electrons (w/o including event selection and trigger acceptance)
  - 20%





COMET: Background Estimation Summary

Background	Events	Comments
Radiative Pion Capture	0.05	
Beam Electrons	<0.1	MC stat limited
Muon Decay in Flight	<0.0002	
Pion Decay in Flight	<0.0001	
Neutron Induced	0.024	For high E n
Delayed-Pion Radiative Capture	0.002	
Anti-proton Induced	0.007	For 8 GeV p
Muon Decay in Orbit	0.15	
Radiative Muon Capture	<0.001	
Muon Capture with n Emission	<0.001	
Muon Capture with Charged Part. Emission	<0.001	
Cosmic-Ray Muons	0.002	
Electrons from Cosmic-Ray Muons	0.002	
Total	0.34	

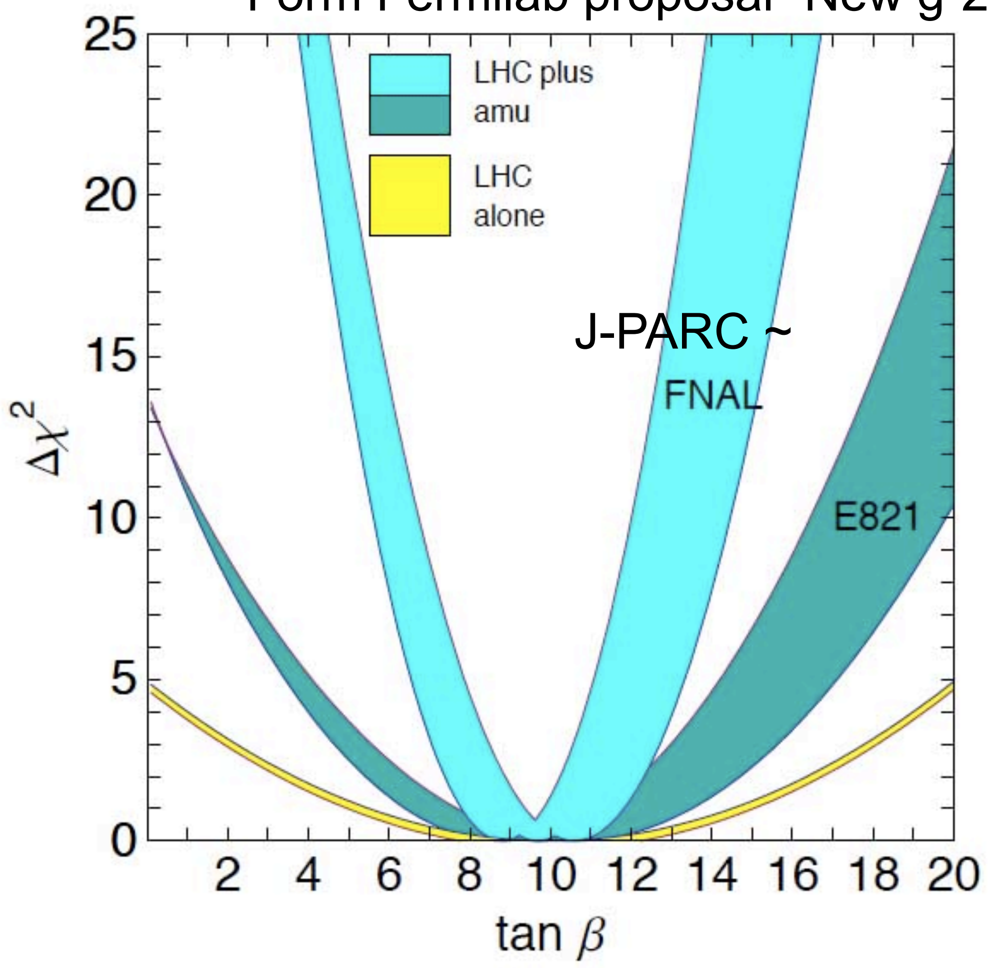
Assuming proton beam extinction < 10^{-9}

Muon g-2 in the LHC era

- Even the first SUSY discovery was made at LHC, the muon g-2 measurement remains unique to determine SUSY parameters:

μ and tan β

Form Fermilab proposal "New g-2"

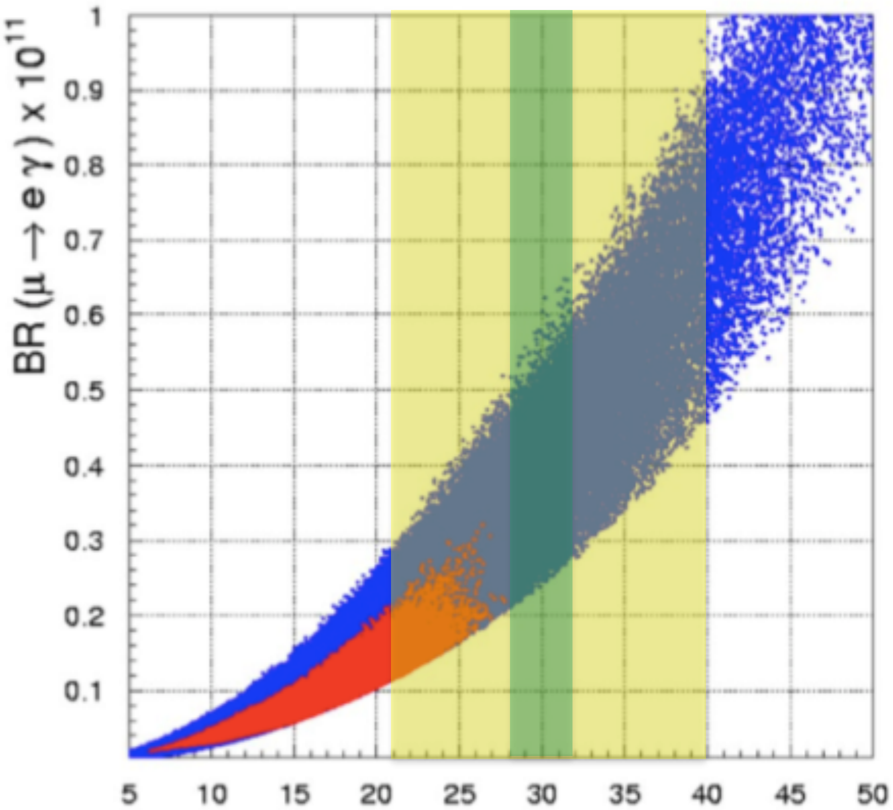


$$a_\mu(\mathrm{SUSY}) \approx (\mathrm{sgn}\,\mu) 13 \times 10^{-10} \tan\beta \left(\frac{100\ \mathrm{GeV}}{\tilde{m}}\right)^2$$

g-2, EDM and cLFV

- Large g-2 → Large cLFV → Large EDM

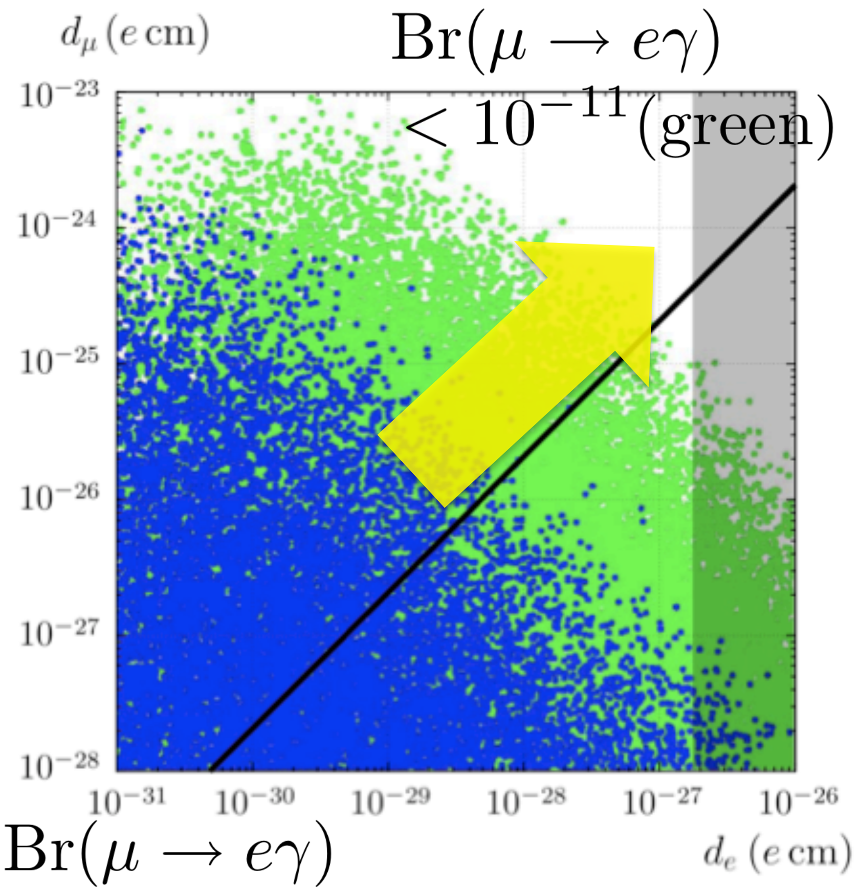
G. Isidori, F. Mescia, P. Paradisi, and D. Temes, PRD 75 (2007) 115019



Current limit by MEGA 1.2 x 10^{-11}

To be superseded by MEG soon

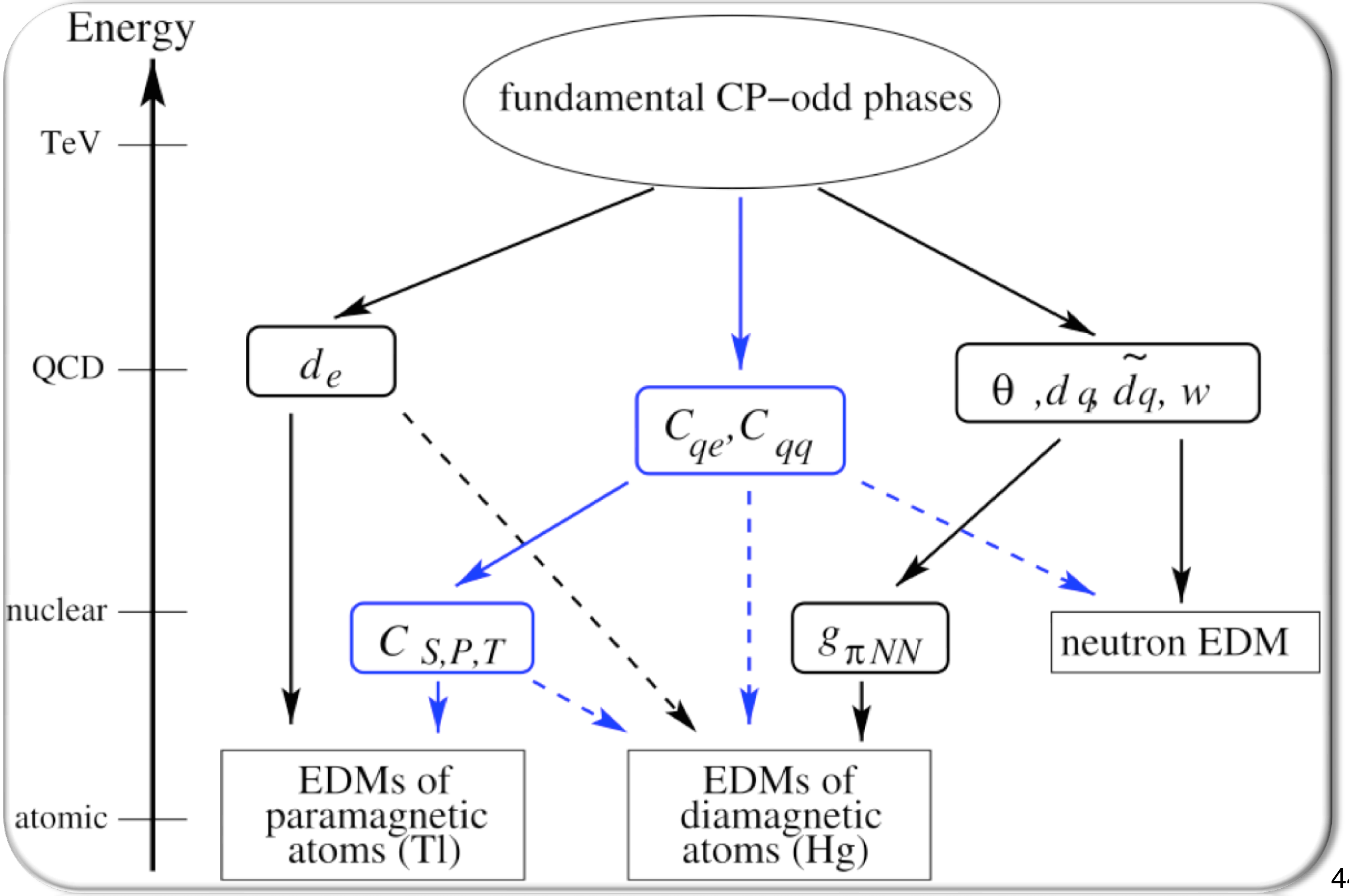
J. Hisano, Nagai, Paradisi



$\mathrm{Br}(\mu \to e\gamma) < 10^{-13}$(blue)

Origin of EDM

M.Pospelov and A.Ritz, Ann.Phys. 318 (2005) 119



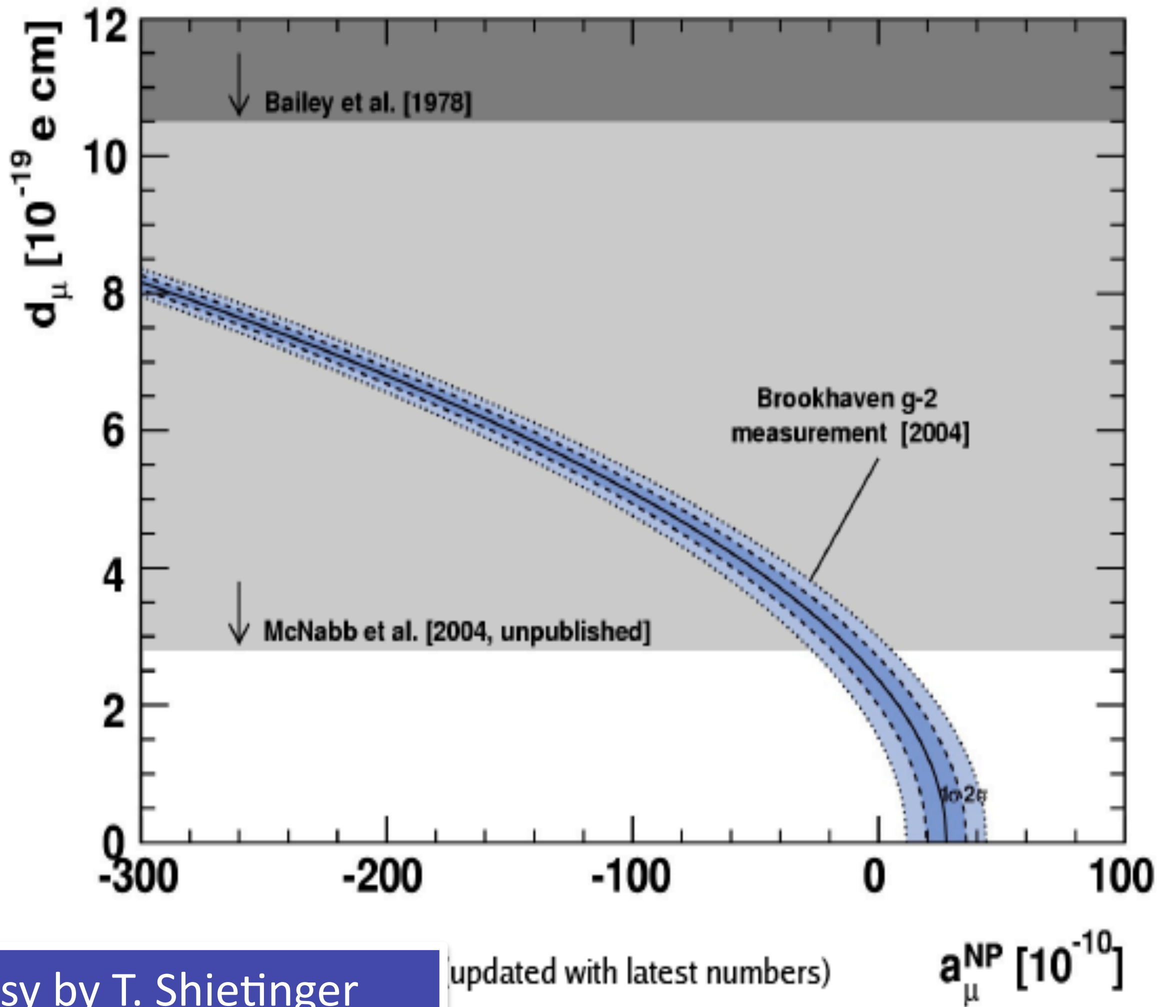
Measured in g-2 experiment

- "Inclusive" precession frequency

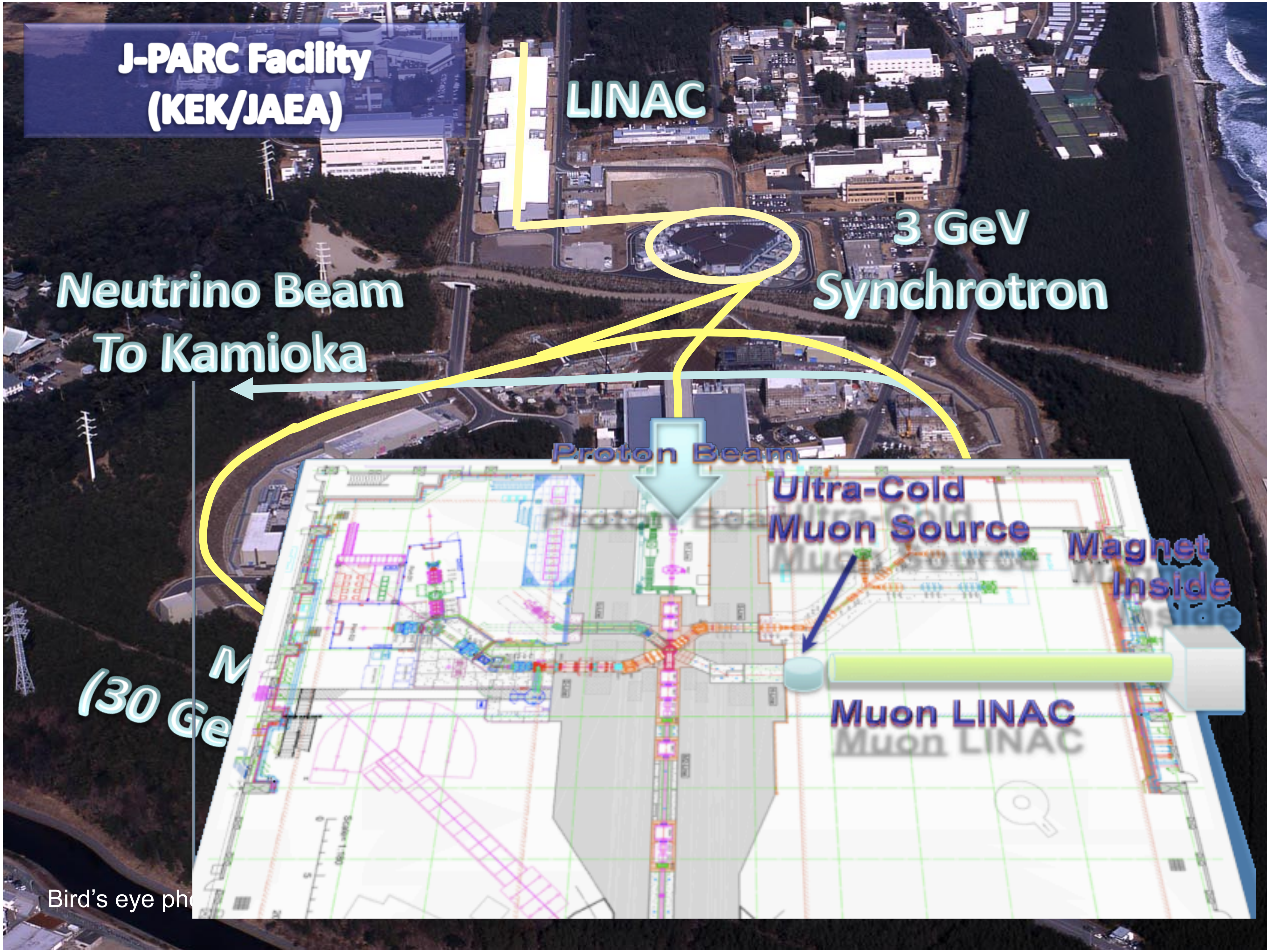
$$\omega = \sqrt{\omega_a^2 + \omega_\eta^2}$$

$$\Leftrightarrow \quad \vec{\omega}_a = -\frac{e}{m} a_\mu \vec{B}$$

- Experimental limit of EDM is in the similar range!



Courtesy by T. Shietinger



J-PARC Facility
(KEK/JAEA)
LINAC
3 GeV
Synchrotron
Neutrino Beam
To Kamioka
Proton Beam
Ultra-Cold
Muon Source
Magnet
Inside
Muon LINAC
(30 Ge
Bird's eye ph

Muon magnetic moment

- Magnetic moment and spin can be related as

$$\vec{\mu} = g\left(\frac{e}{2m}\right)\vec{s}$$

$\vec{\mu}$: magnetic moment
$\vec{s}$: spin
g : gyromagnetic ratio

- Dirac equation predicts g=2 → a=0

$$\mu = (1+a)\left(\frac{e\hbar}{2m}\right) \qquad a = \frac{g-2}{2}$$

a=1.2e-3 for e, μ, …
a=1.8 for proton

- Radiative corrections (including NEW PHYSICS) would make g≠2 → a≠0

$$\left(\frac{m_\mu}{m_e}\right)^2 \sim 40{,}000 \qquad \left(\frac{m_\tau}{m_\mu}\right)^2 \sim 290$$

Magic vs "New Magic"

- Complimentary!

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} \ldots + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} \ldots\right)\right]$$

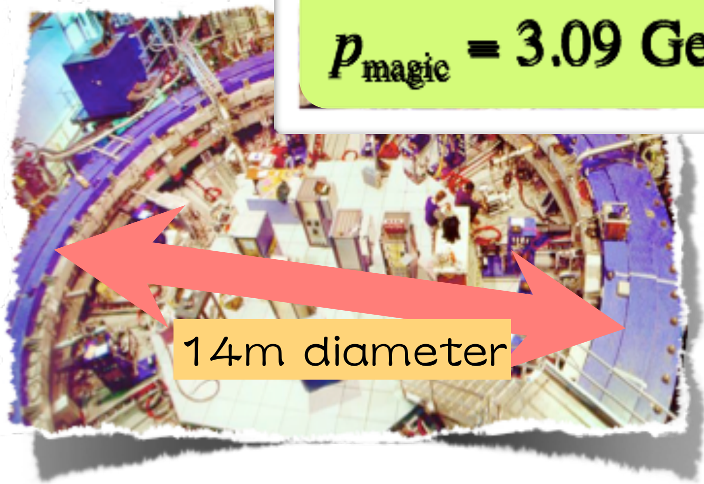
BNL/Fermilab Approach

$$a_\mu - \frac{1}{\gamma^2 - 1} = 0$$

$$\eta \approx 0$$

$$\gamma_{\text{magic}} = 29.3$$

$$p_{\text{magic}} = 3.09\ \text{GeV}/c$$

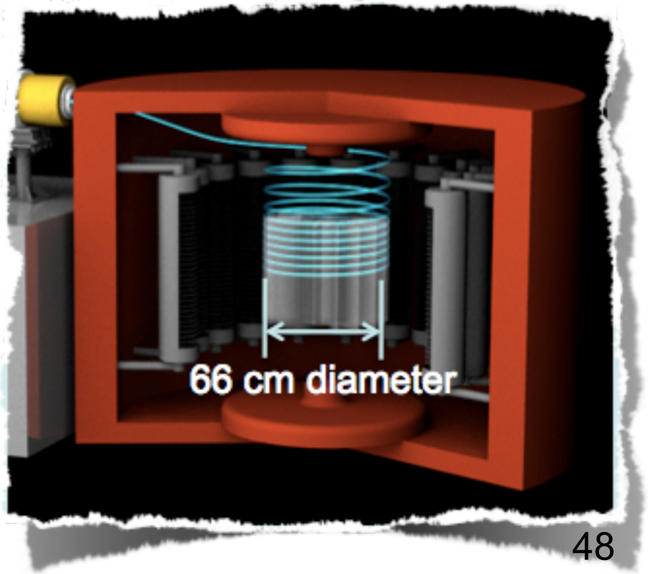


$$\vec{\omega}_a = -\frac{e}{m} a_\mu \vec{B}$$

J-PARC Approach

$$\vec{E} = 0$$

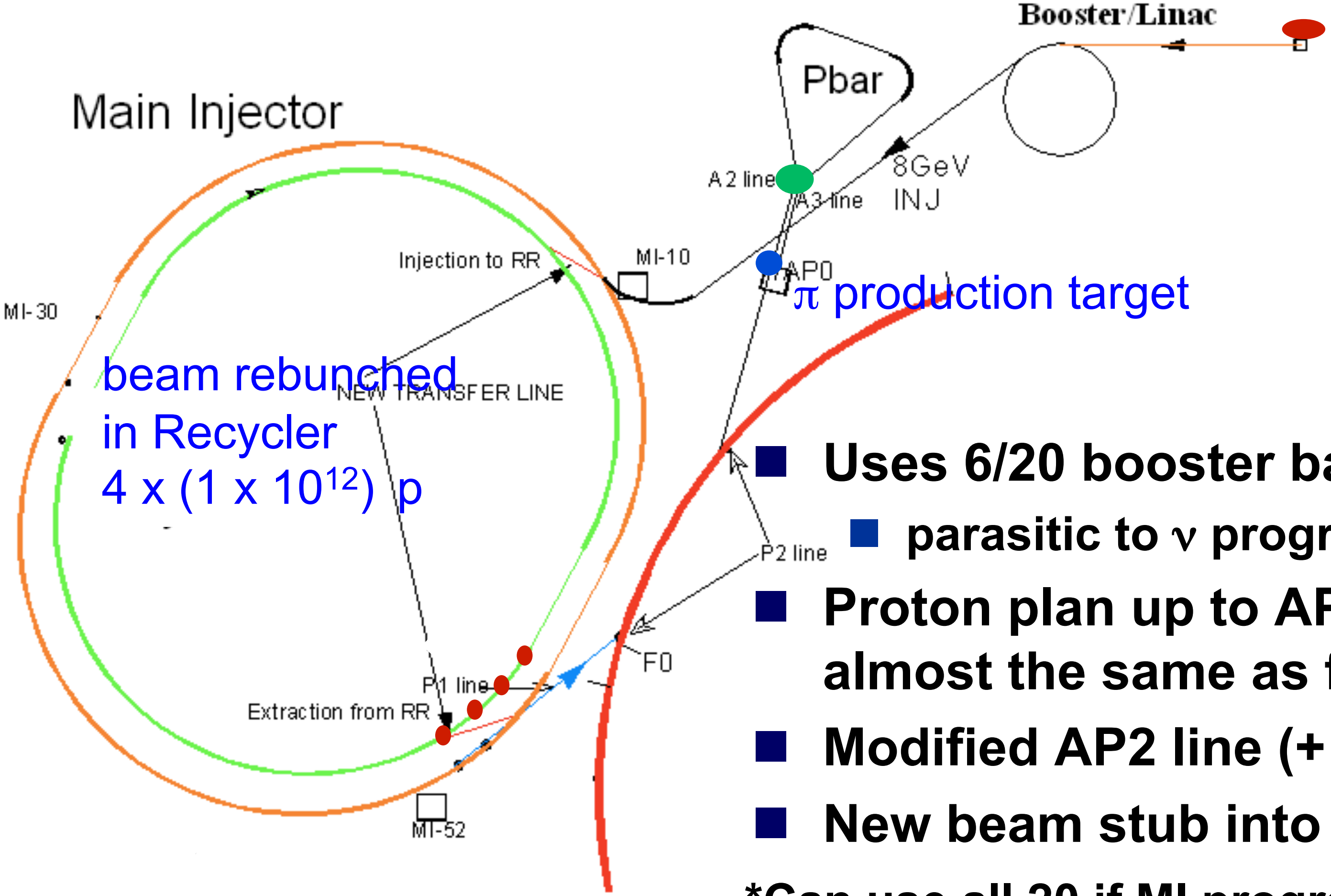
$$\vec{\omega} = \vec{\omega}_a + \vec{\omega}_\eta$$



Fermilab (g-2) Experiment: E989 Goal ± 0.14 ppm (BNL E821 ÷ 4)

- Approval and funding
  - Stage 1 approval: January 2011
  - First Funding from DOE: June 2011
  - Funding profile for FY2012 and later being determined
- Uses:
  - the existing storage ring relocated to Fermilab
  - 8 GeV booster to provide proton batches that are rebunched in the Recycler ring
  - p-bar Debuncher ring is a 900m pion decay line
- Permits X 21 the statistics of BNL E821

Polarized muons delivered and stored in the ring at the magic momentum, 3.094 GeV/c



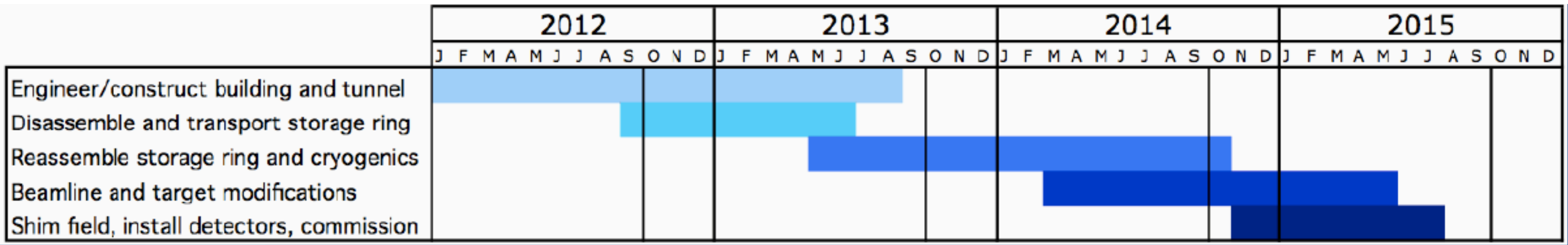
- Uses 6/20 booster batches*
  - parasitic to ν program
- Proton plan up to AP0 target is almost the same as for Mu2e
- Modified AP2 line (+ quads)
- New beam stub into ring

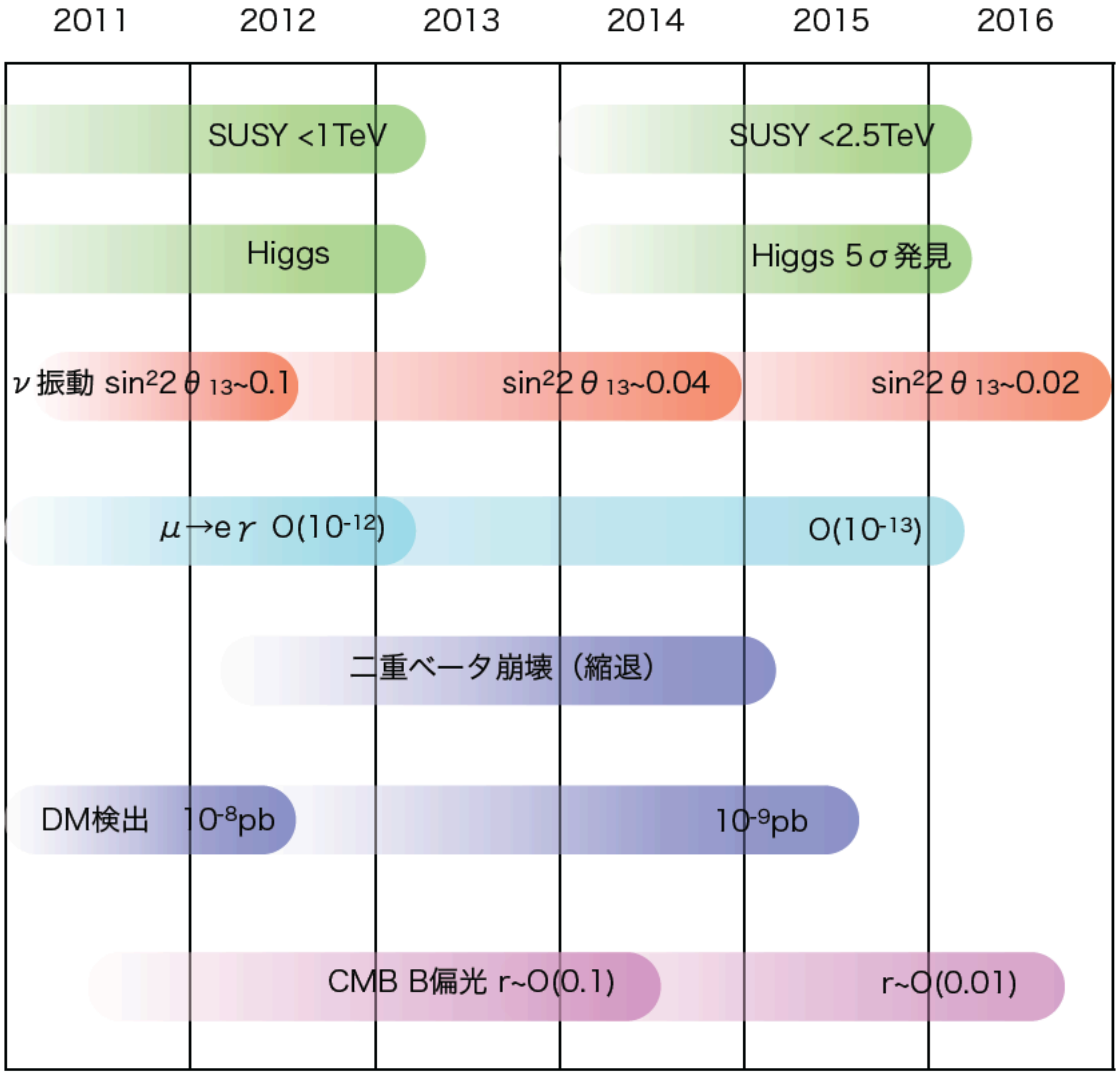
*Can use all 20 if MI program is off

Fermilab (g-2) Experiment: E989
Goal ± 0.14 ppm (BNL E821 ÷ 4)

- **Total project cost ~$42M**
  - **CD0 expected this fall**
  - **Conceptual Design Report being prepared**
- **FY2011 Funding began this June**
- **FY2012 and beyond is being discussed between DOE and Fermilab**

Technically driven schedule:





2011
2012
2013
2014
2015
2016
SUSY <1TeV
SUSY <2.5TeV
Higgs
Higgs 5σ発見
ν振動 sin²2θ13~0.1
sin²2θ13~0.04
sin²2θ13~0.02
μ→eγ O(10-12)
O(10-13)
二重ベータ崩壊（縮退）
DM検出 10-8pb
10-9pb
CMB B偏光 r~O(0.1)
r~O(0.01)