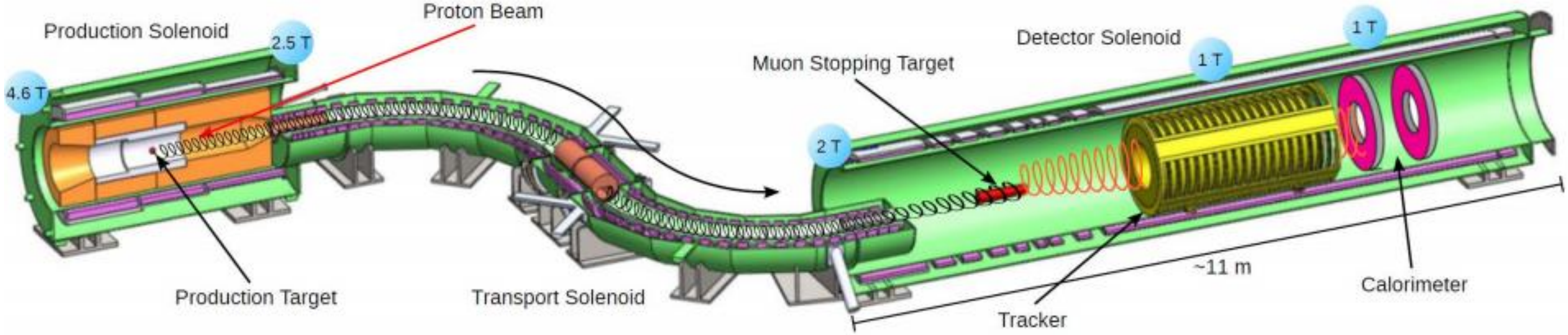


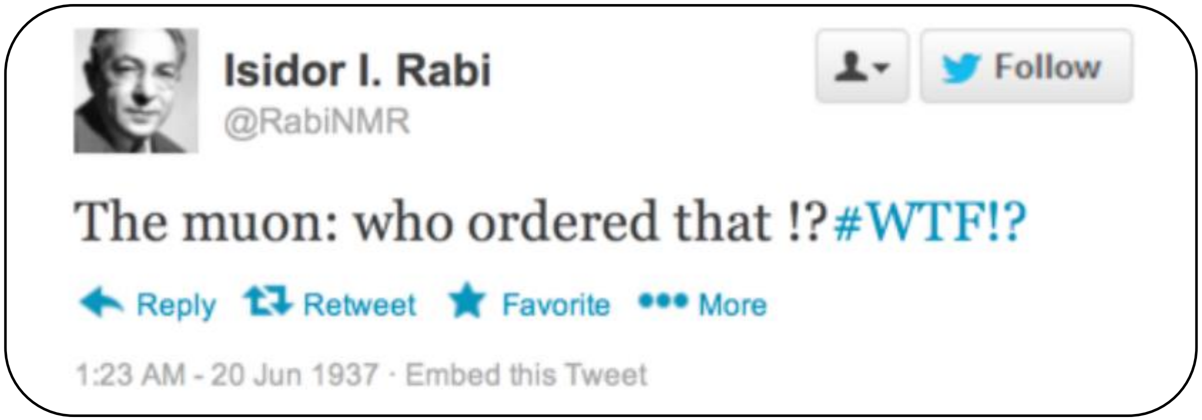
Mu2e Physics

Dan Ambrose
University of Minnesota
May 31, 2016

What’s up with the Muon?

1936: Anderson and Neddermeyer discover the muon

Which led Rabi to take to social media:



*Taken from a talk by Roni Harnik

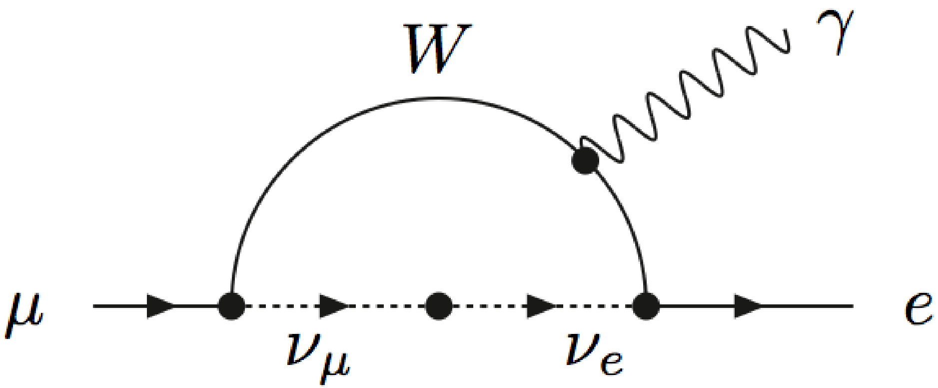
Many mysteries still surrounded the muon:

- Anomalous magnetic dipole moment deviation from theory > 3σ
- Quarks mix, Neutrinos mix, charged Leptons???

Charged Lepton Flavor Violation(CLFV)

With neutrino mass, we know that lepton flavor is not conserved.

The SM CLFV process would be :



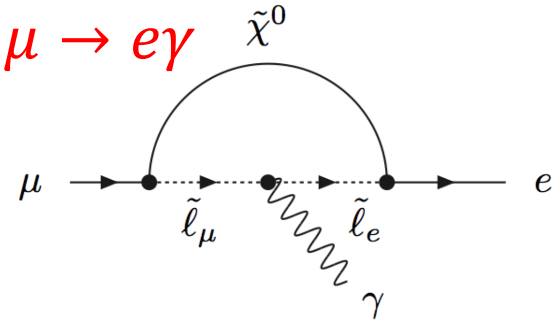
$$\mathcal{B}(\mu \to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=2,3} U^*_{\mu i} U_{ei} \frac{\Delta m^2_{1i}}{M^2_W}\right|^2 < 10^{-54}$$

*Physically unobservable

Any observation of CLFV must be new physics!

Current Constraints on CLFV

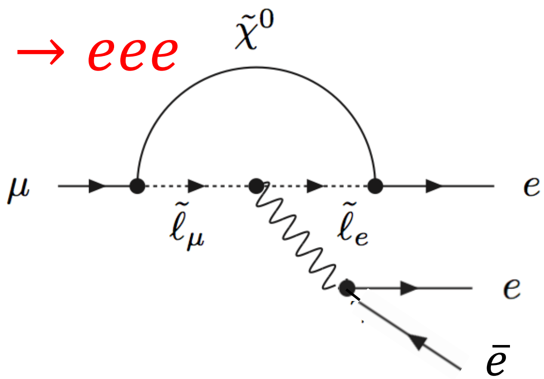
$\mu \rightarrow e\gamma$



MEG: $\mathcal{B}(\mu \rightarrow e\gamma) < 5.7 \times 10^{-13}$

PRL **110**, 201801 (2013)

$\mu \rightarrow eee$

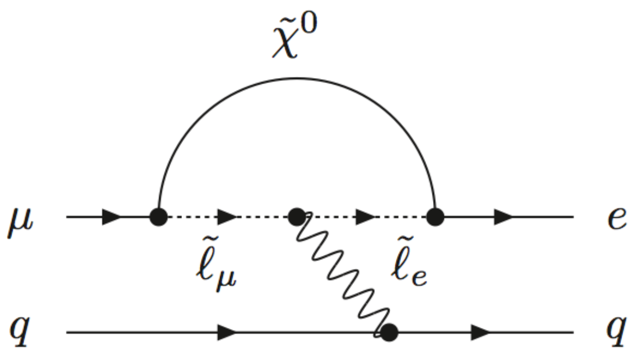


SINDRUM-I: $\mathcal{B}(\mu \rightarrow 3e) < 1 \times 10^{-12}$

Nucl. Phys., B **299**, 1 (1988)

$\mu N \rightarrow eN$

Muon conversion in the field of a nucleus

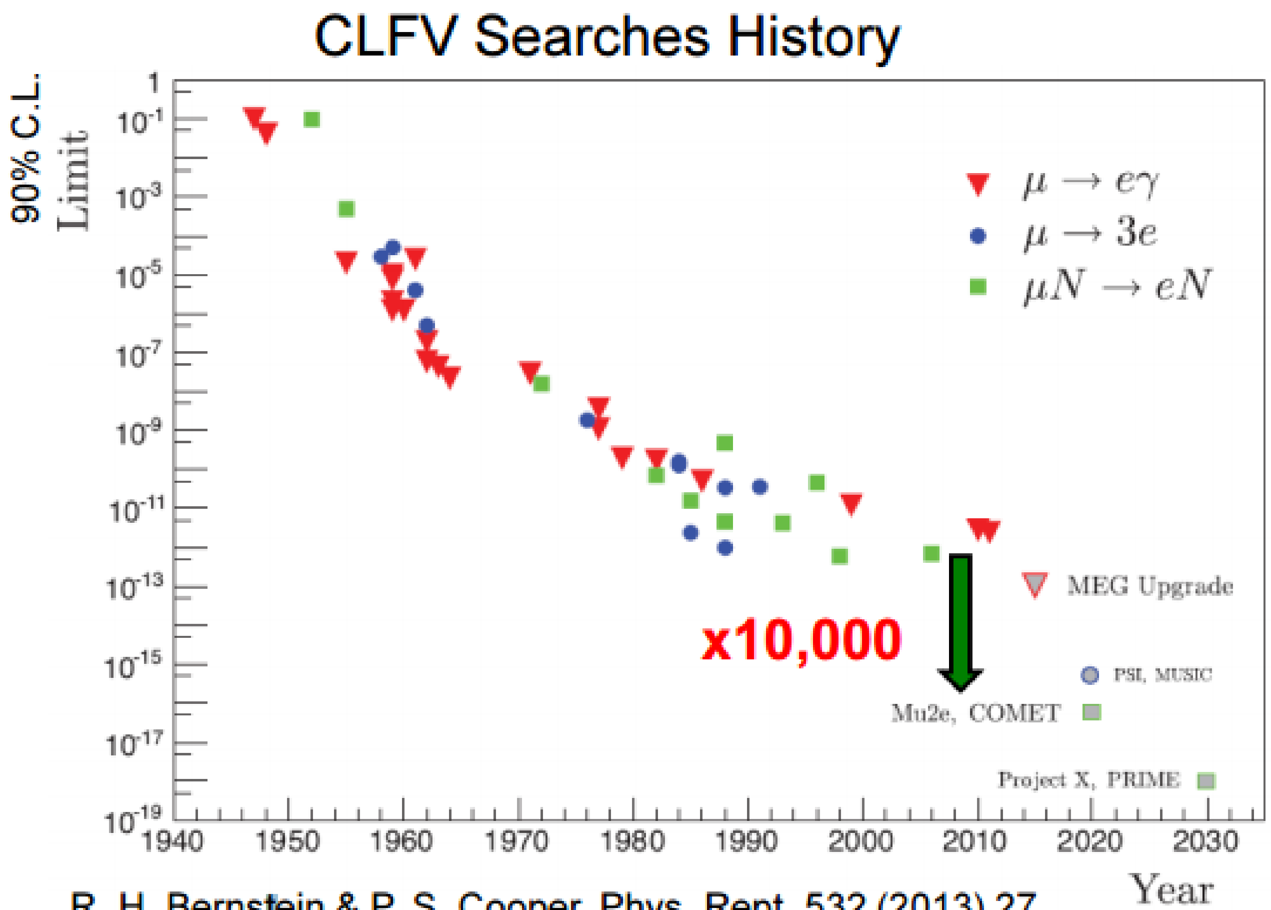


SINDRUM-II:

$$R_{\mu e}(\mu N \rightarrow eN \text{ on Au}) < 7 \times 10^{-13}$$

EPJ C **47**, 337 (2006)

Long History of Searches for CLFV

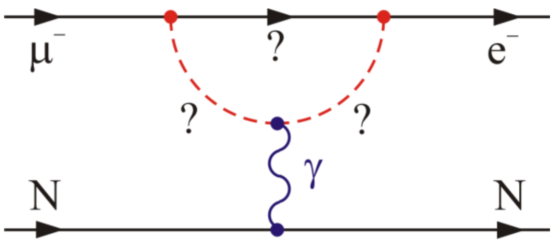


R. H. Bernstein & P. S. Cooper, Phys. Rept. 532 (2013) 27

Sensitivity to High Mass Scales

$$L_{CLFV} = \frac{m_\mu}{(\kappa+1)\Lambda^2}\bar{\mu}_R\sigma_{\mu\nu}e_L F^{\mu\nu} + \frac{\kappa}{(1+\kappa)\Lambda^2}\bar{\mu}_L\gamma_\mu e_L(\bar{u}_L\gamma^\mu u_L + \bar{d}_L\gamma^\mu d_L)$$

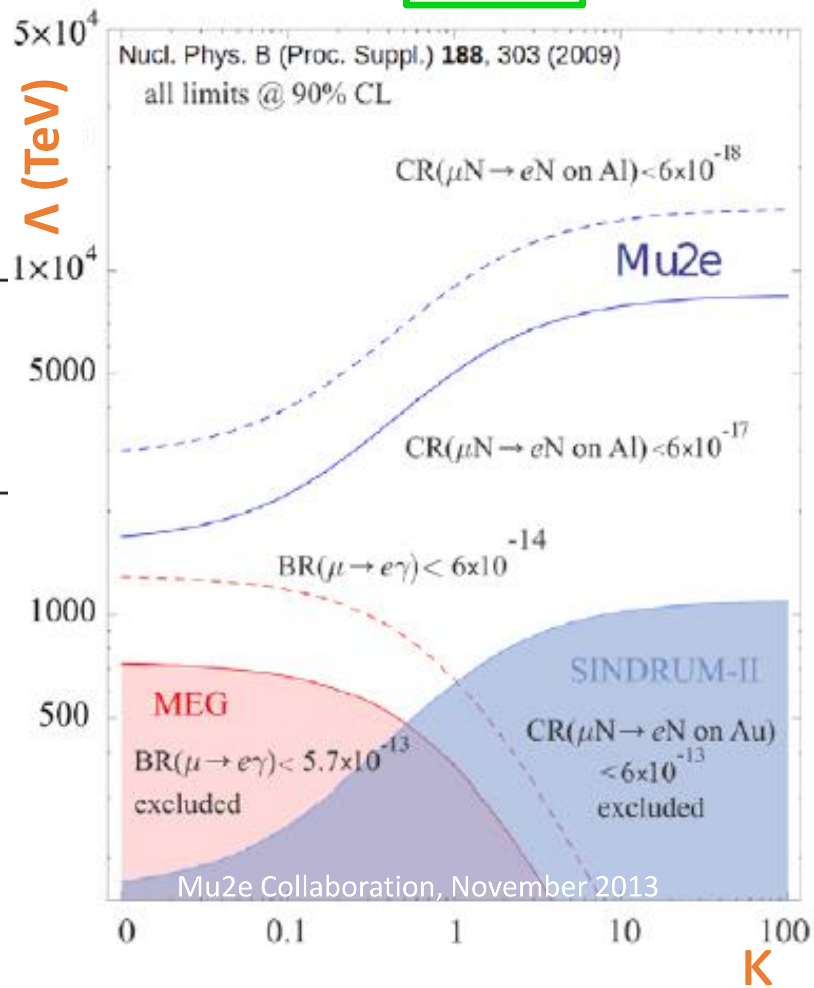
Loops dominate for κ << 1



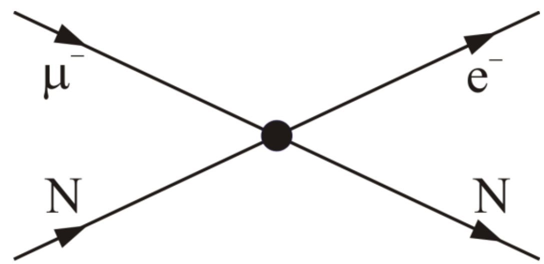
μ→eγ

μN→eN

μ→eee



Contact terms dominate for κ >> 1



~~μ→eγ~~

μN→eN

μ→eee

Can we test many models?

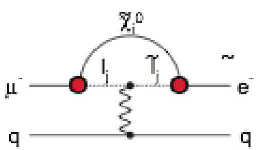
Mu2e's Capacity:

2.5×10^{-17} single event sensitivity

Λ_c between 2000 to 7000 TeV

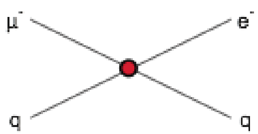
Supersymmetry

rate ~ 10^{-15}



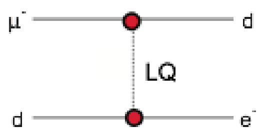
Compositeness

Λ_c ~ 3000 TeV



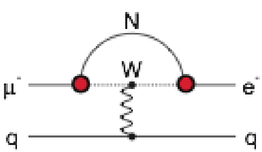
Leptoquark

M_{LQ} = $3000\ (\lambda_{\mu d}\lambda_{ed})^{1/2}$ TeV/c²



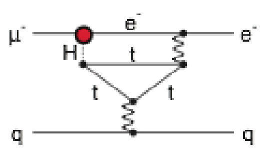
Heavy Neutrinos

$|U_{\mu N}U_{eN}|^2$ ~ 8×10^{-13}



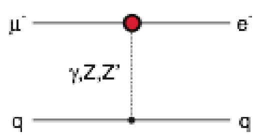
Second Higgs Doublet

$g(H_{\mu e})$ ~ $10^{-4} g(H_{\mu\mu})$



Heavy Z' Anomal. Z Coupling

$M_{Z'}$ = 3000 TeV/c²



YES!

Mu2e is sensitive to many new physics processes

Estimates from Flavour Physics of Leptons and Dipole Moments, Eur.Phys.J.C57:13-182,2008

arXiv:0909.1333 **[hep-ph]**

W. Altmannshofer, A.J.Buras, S.Gori, P.Paradisi, D.M.Straub

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

Mu2e Concept

- Generate a beam of low momentum muons (μ^-)
- Stop the muons in an Aluminum target
- The stopped muons are trapped in orbit around the nucleus
- Look for events consistent with $\mu N \rightarrow eN$
- We measure : $$R_{\mu e} = \frac{\mu^- + N(A,Z) \rightarrow e^- + N(A,Z)}{\mu^- + N(A,Z) \rightarrow \nu_\mu + N(A,Z-1)}$$

Numerator:

Muon to electron conversion in the presence of a nucleolus

Denominator:

Nuclear captures of muonic Al atoms

Creating and Decaying Muonic Atom

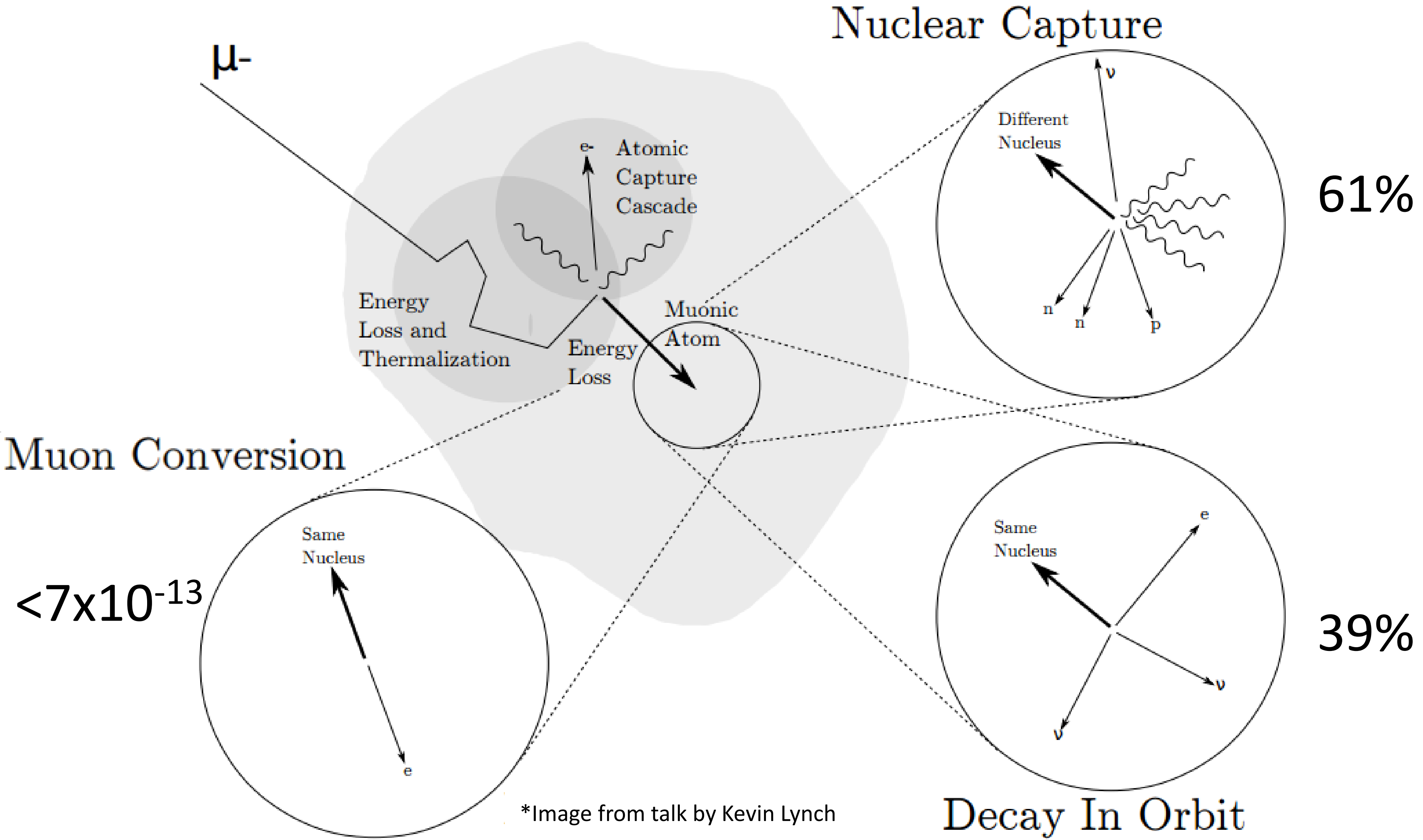
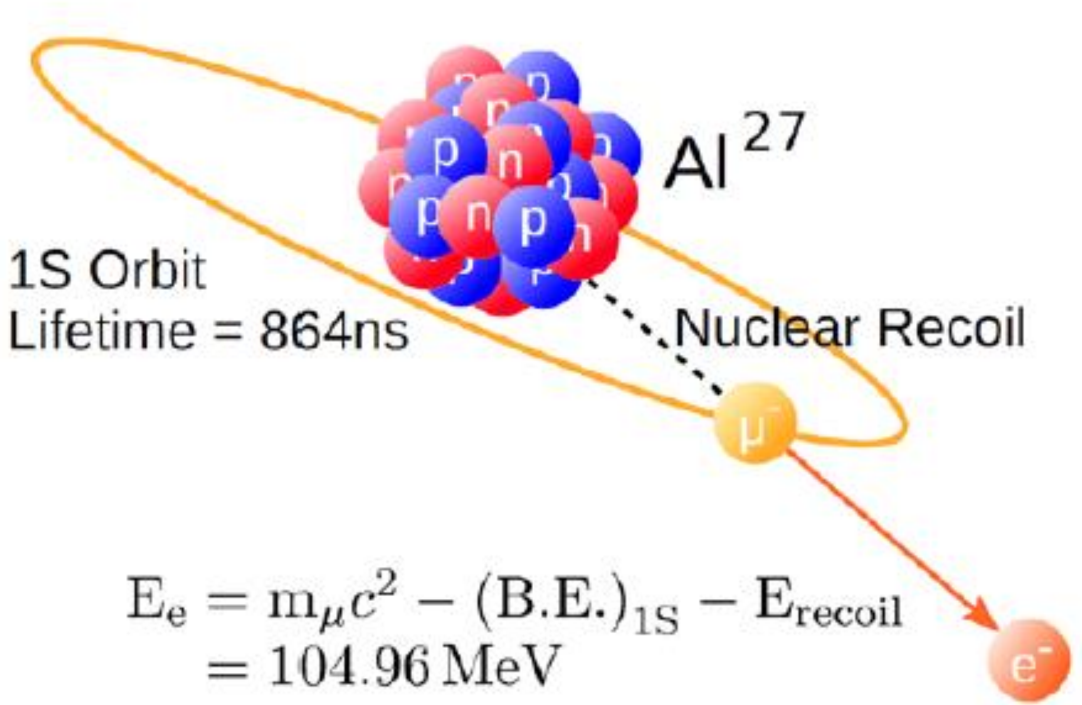


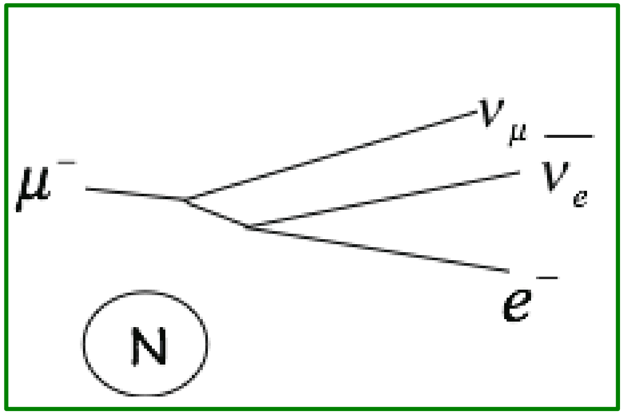
*Image from talk by Kevin Lynch

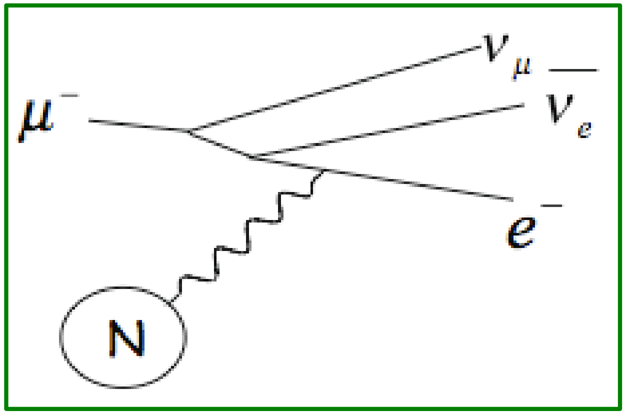
Experimental Signature

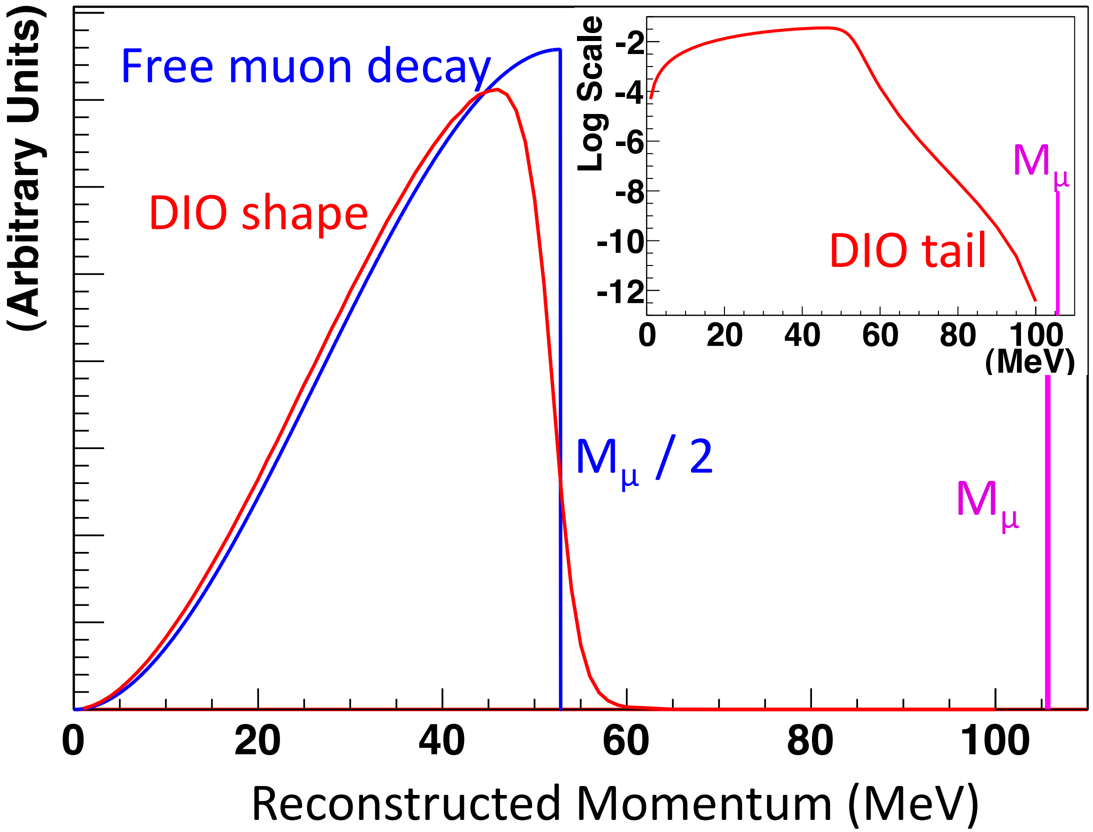


- When captured by a nucleus, a muon will have an enhanced probability of exchanging a virtual particle with the nucleus.
- This reaction recoils against the entire nucleus, producing a *mono-energetic* electron carrying most of the muon rest energy.

Decay–in-Orbit: Dominant Background

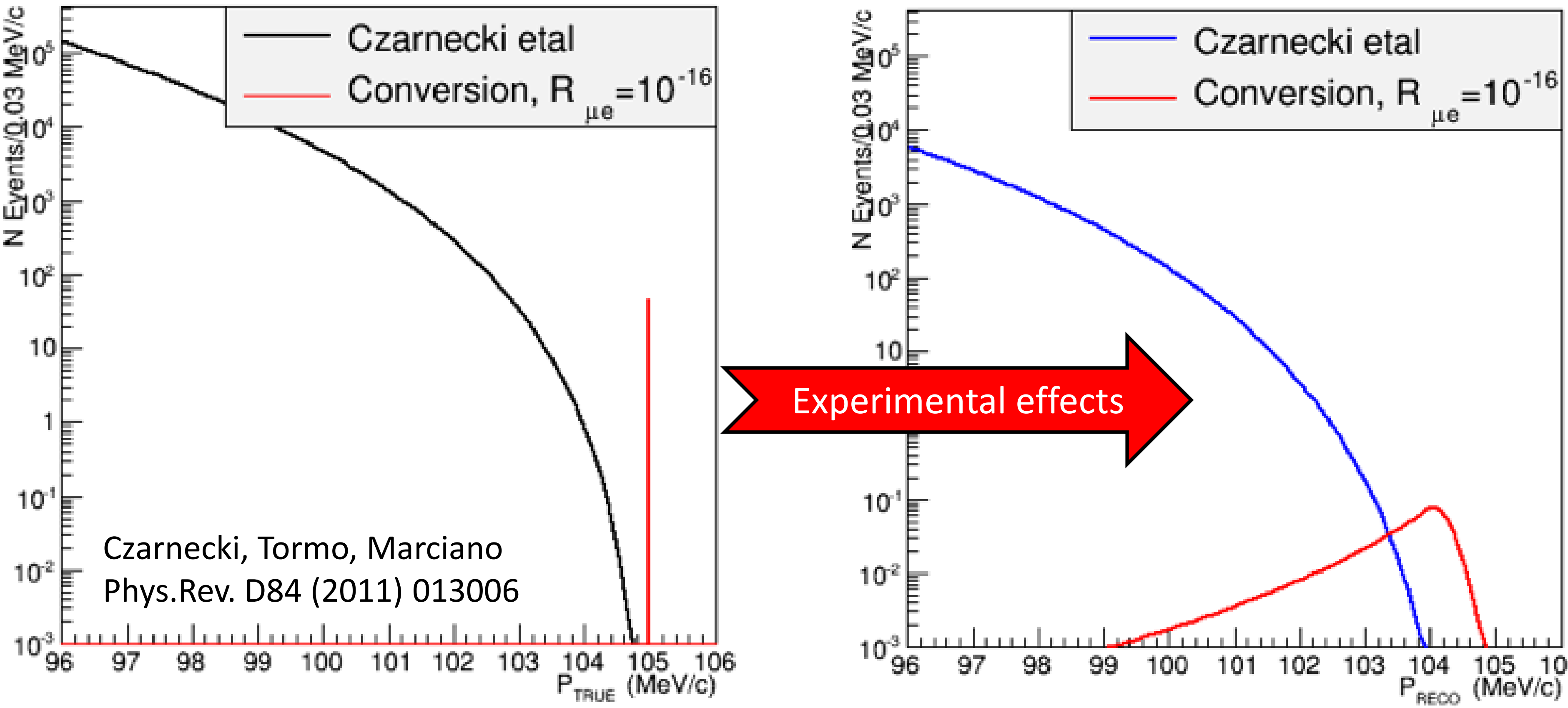






DIO Endpoint

- Tail of DIO falls as $(E_{Endpoint} – E_e)^5$
- Separation of ~few 100 keV for $R_{\mu e} = 10^{-16}$



Summary

- There is a lot of excitement about theoretical model discrimination afforded with a 4 orders of magnitude improvement on muon conversion sensitivity.

Thank you