A New Charged Lepton Flavor Violation Experiment: Muon-Electron Conversion at Sensitivity < 10^{-16}

for the Mu2e Collaboration

What is μe Conversion?

muon converts to electron in the field of a nucleus

$$\mu^- N \rightarrow e^- N$$

$$R_{\mu e} = \frac{\Gamma(\mu^- + N(A,Z) \rightarrow e^- + N(A,Z))}{\Gamma(\mu^- + N(A,Z) \rightarrow \text{all muon captures})}$$

- Standard Model Background of 10^{-54}
- Charged Lepton Flavor Violation (CLFV)
  - can measure a signal with SES of ~3 x 10^{-17}
- Related Processes: μ or $\tau \rightarrow e\gamma, \tau \rightarrow 3l, K_L \rightarrow \mu e$ and more

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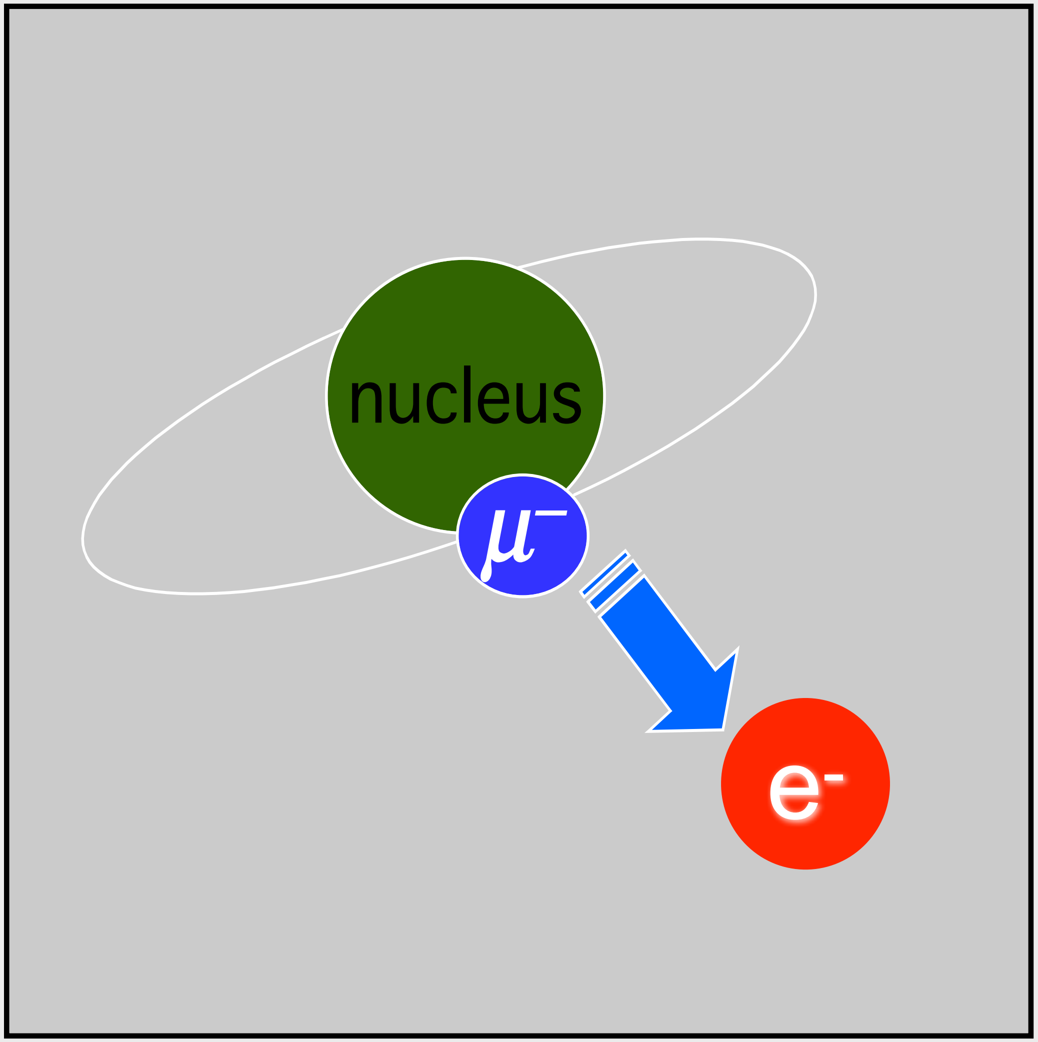
Experimental Signal

$$\mu^- N \rightarrow e^- N$$

- A Single Monoenergetic Electron
- If *N* = Al, E_e = 105. MeV
  - electron energy depends on Z
- Nucleus coherently recoils off outgoing electron, no breakup



“Who ordered that?”

– I.I. Rabi

After the μ was discovered, it was logical to think the μ is just an excited electron:

- expect BR($\mu \rightarrow e\gamma$) ≈ 10^{-4}
- Unless another ν, in Intermediate Vector Boson Loop, cancels (Feinberg, 1958)

➡ same as GIM mechanism!

-

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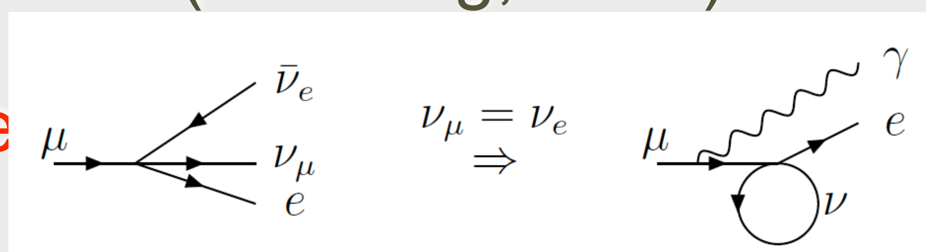
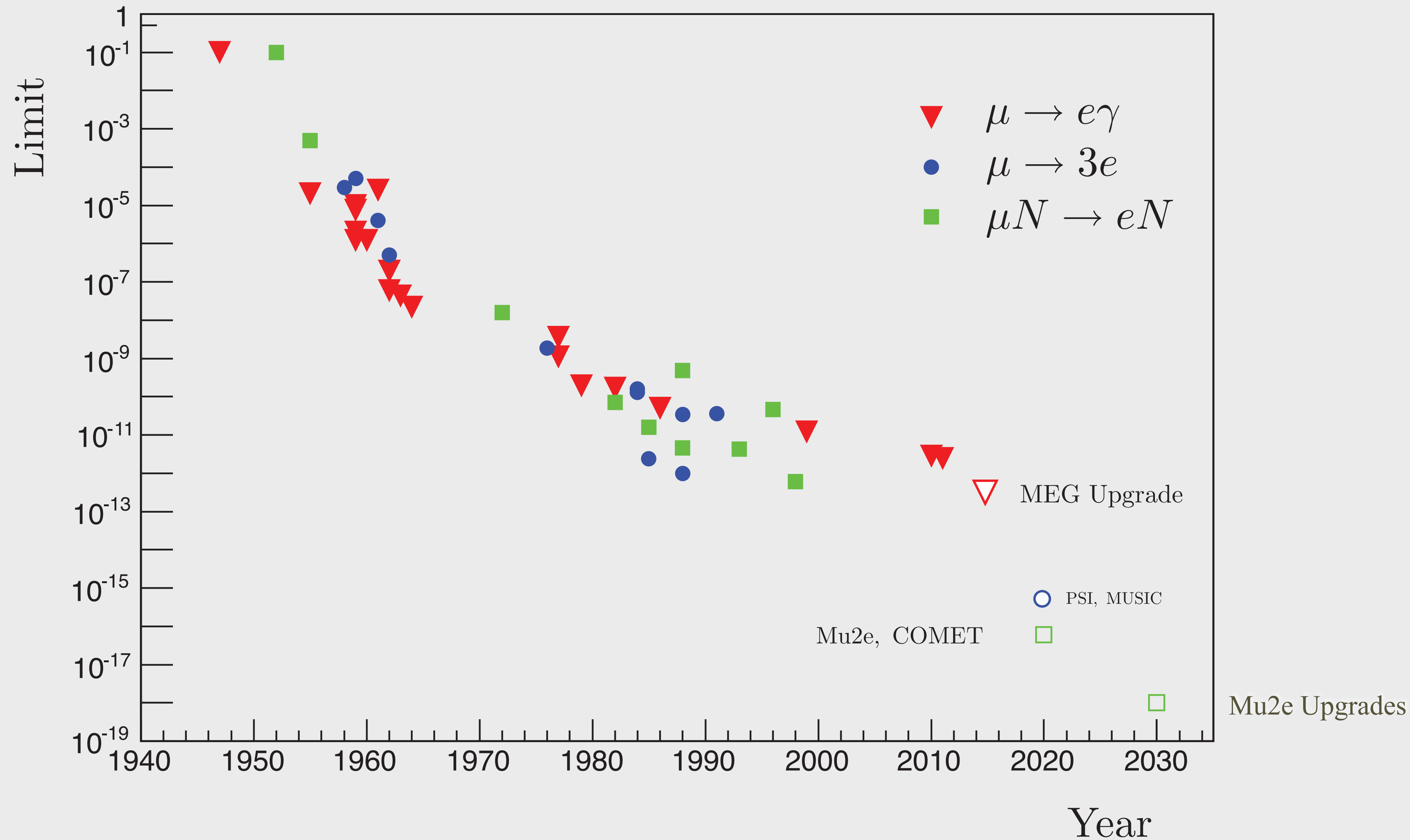


[1]Unless we are willing to give up the 2-component neutrino theory, we know that $\mu \rightarrow e + \nu + \bar{\nu}$.

History of $\mu \to e\gamma$, $\mu N \to eN$, and $\mu \to 3e$



RHB and P.S. Cooper, Phys Rept C (1307.5787)

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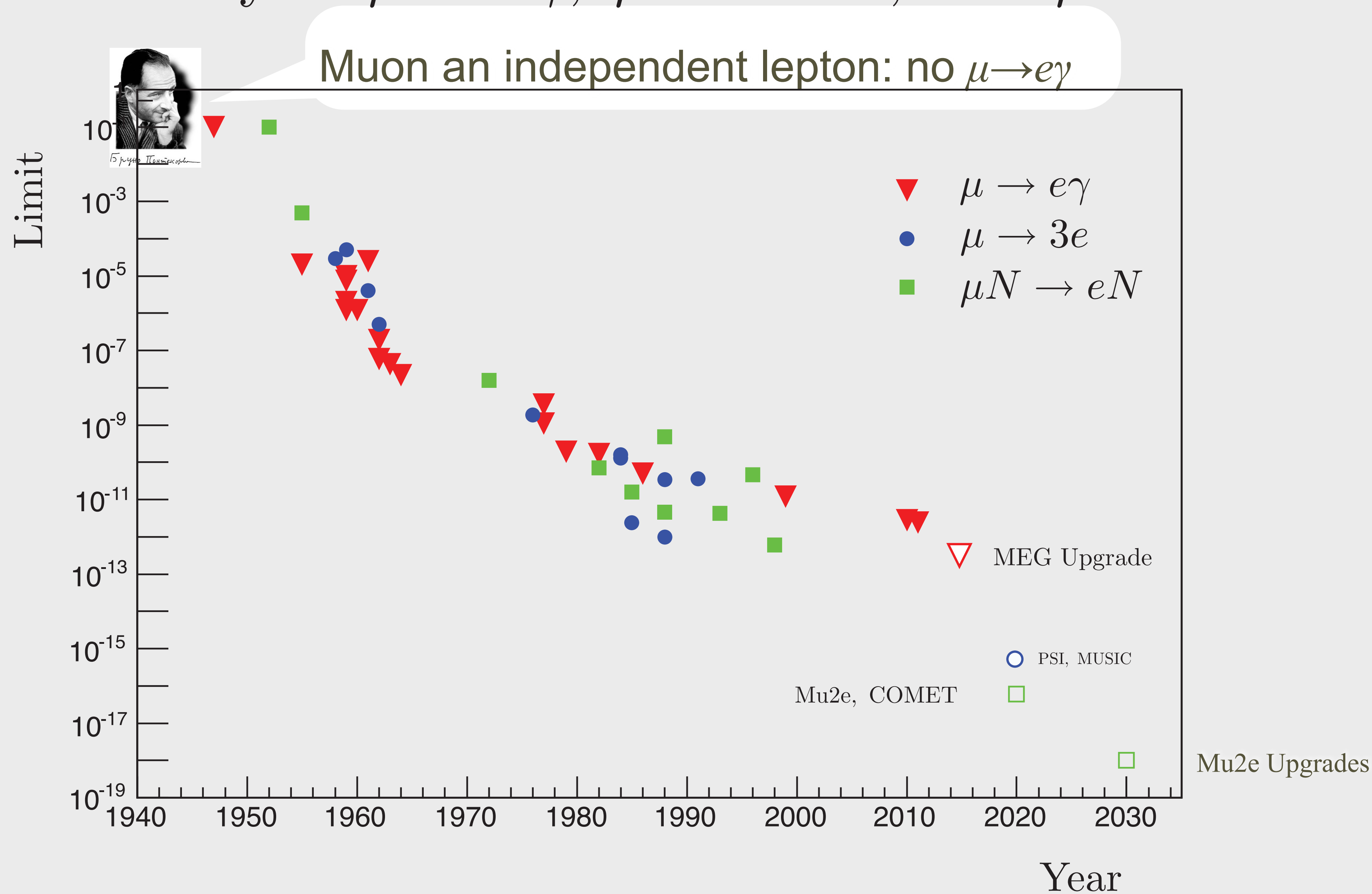

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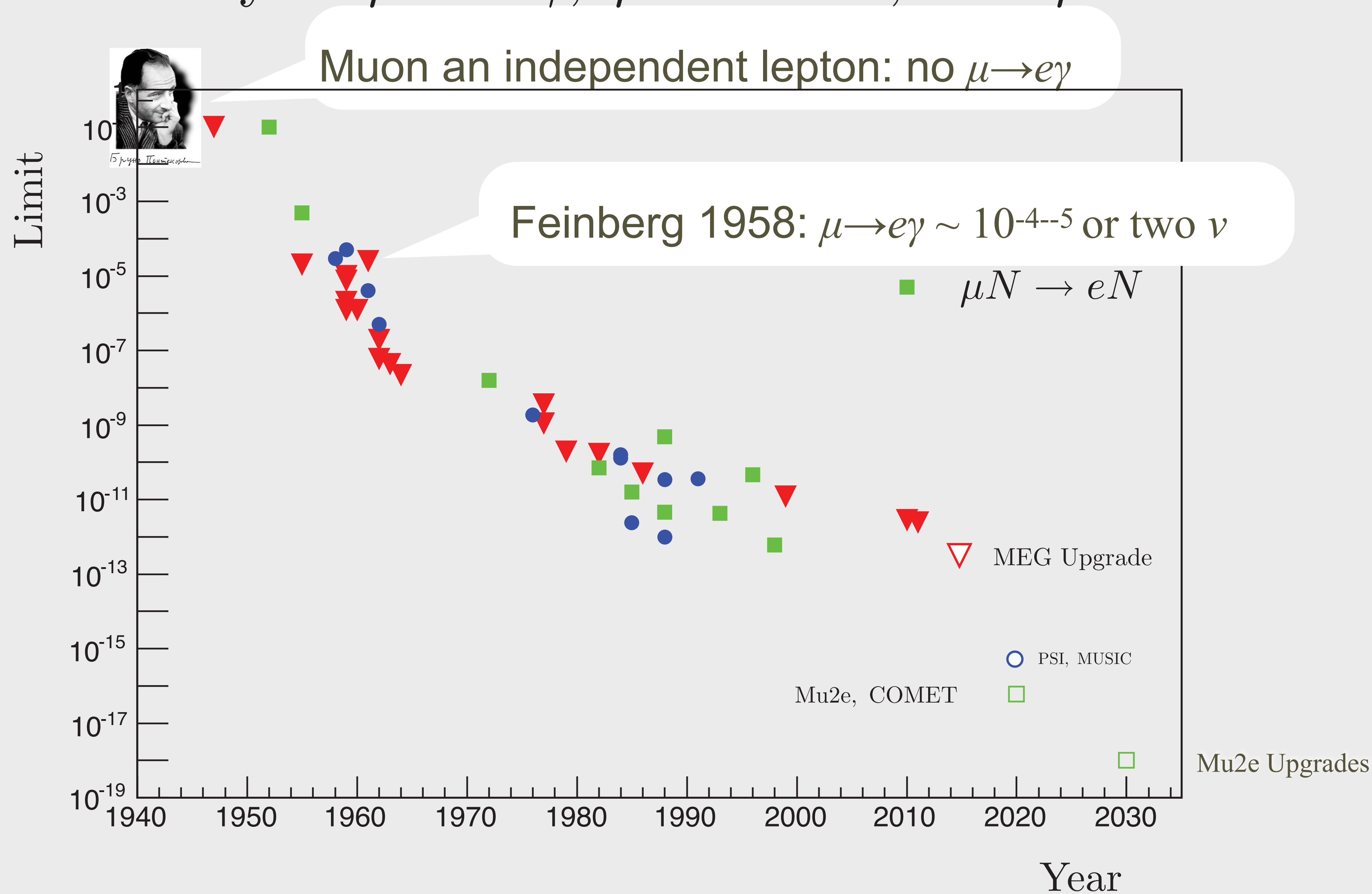

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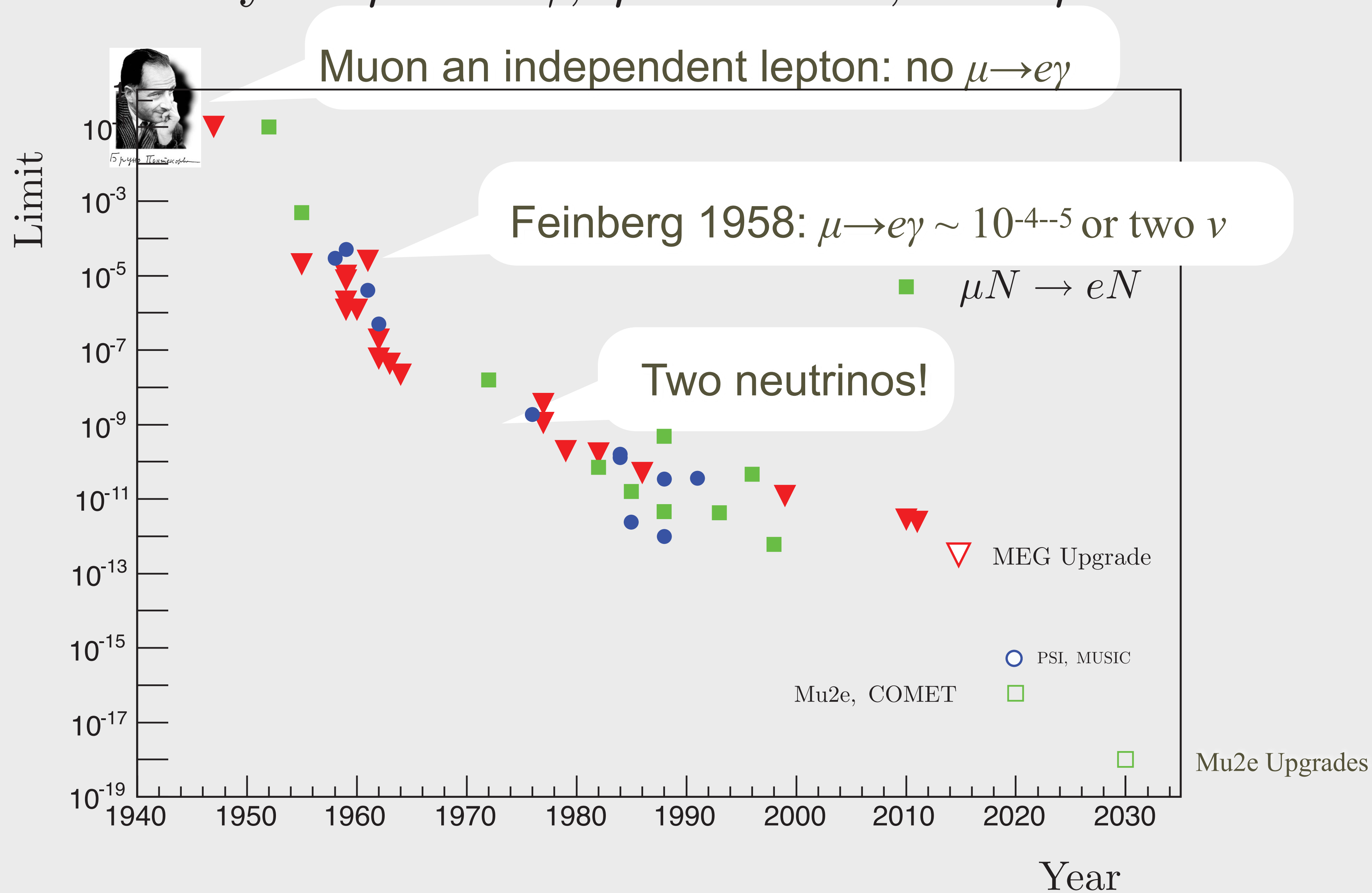

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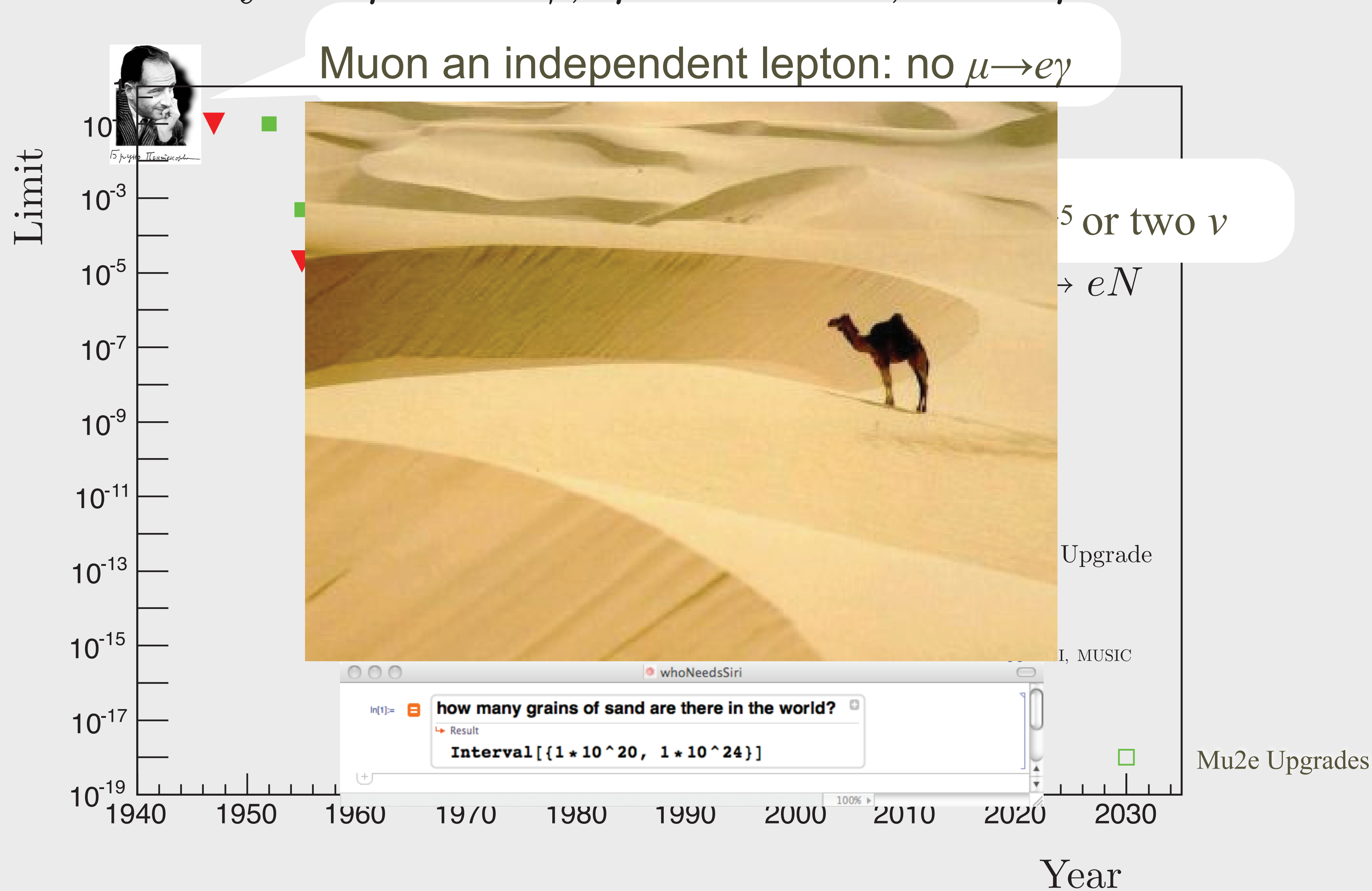


RHB and P.S. Cooper, Phys Rept C (1307.5787)

How Rare is That?

- Pretty Rare: let us know if this happens to you!

Probability of...	
rolling a 7 with two dice	1.67E-01
rolling a 12 with two dice	2.78E-02
getting 10 heads in a row flipping a coin	9.77E-04
drawing a royal flush (no wild cards)	1.54E-06
getting struck by lightning in one year in the US	2.00E-06
winning Pick-5	5.41E-08
winning MEGA-millions lottery (5 numbers+megaball)	3.86E-09
your house getting hit by a meteorite this year	2.28E-10
drawing two royal flushes in a row (fresh decks)	2.37E-12
your house getting hit by a meteorite today	6.24E-13
getting 53 heads in a row flipping a coin	1.11E-16
your house getting hit by a meteorite AND you being struck by lightning both within the next six months	1.14E-16
your house getting hit by a meteorite AND you being struck by lightning both within the next three months	2.85E-17

thanks to Eric Prebys

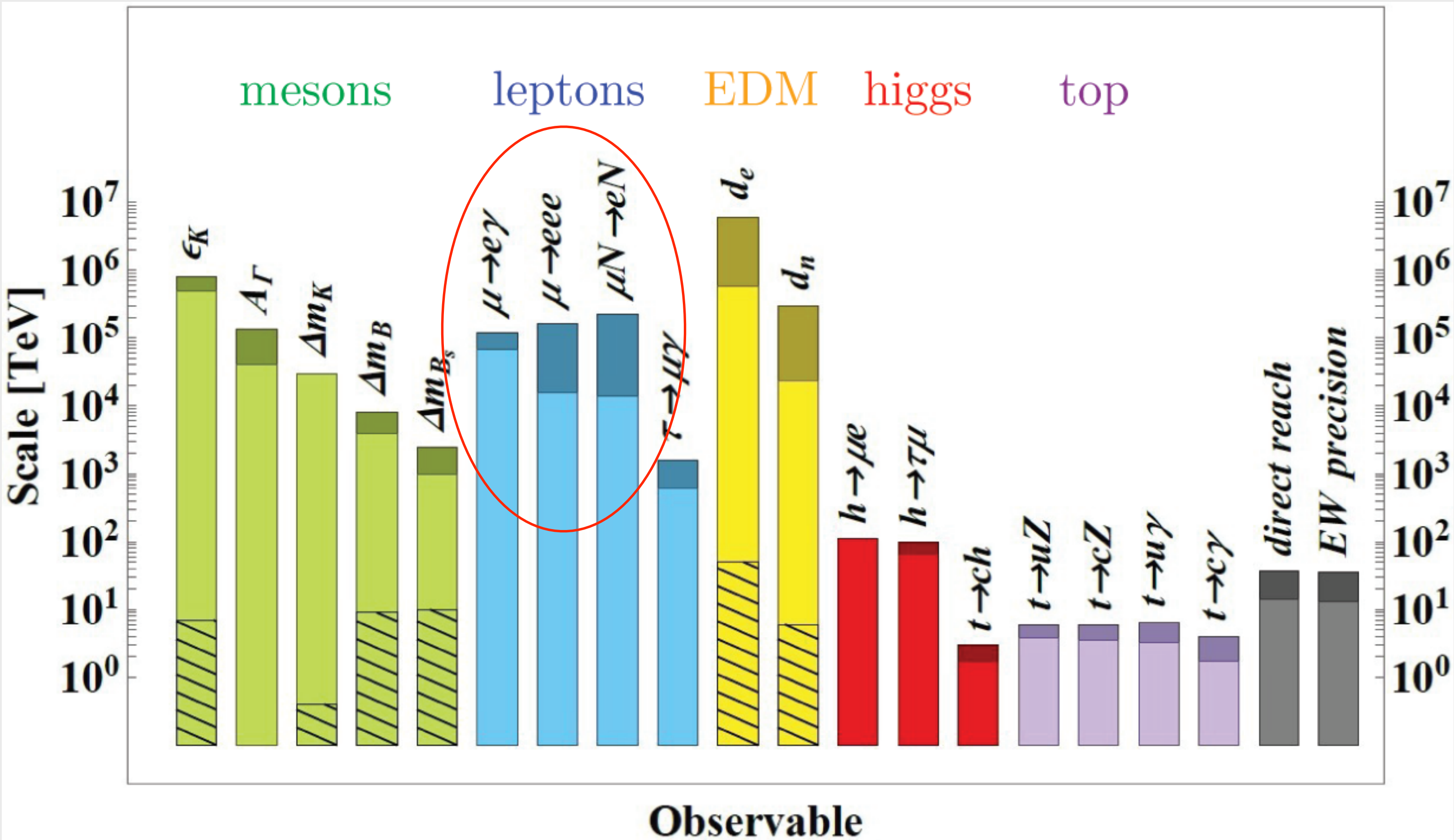
CLFV Muon Processes

- $\mu \to e\gamma$
  - oldest studied, most powerful limits, and the best experiment so far: MEG at PSI
- $\mu N \to eN$
  - muon to electron conversion: muon converts in field of nucleus, leaving nucleus unchanged

$$R_{\mu e} = \frac{\Gamma(\mu^- + N(A,Z) \to e^- + N(A,Z))}{\Gamma(\mu^- + N(A,Z) \to \text{all muon captures})}$$

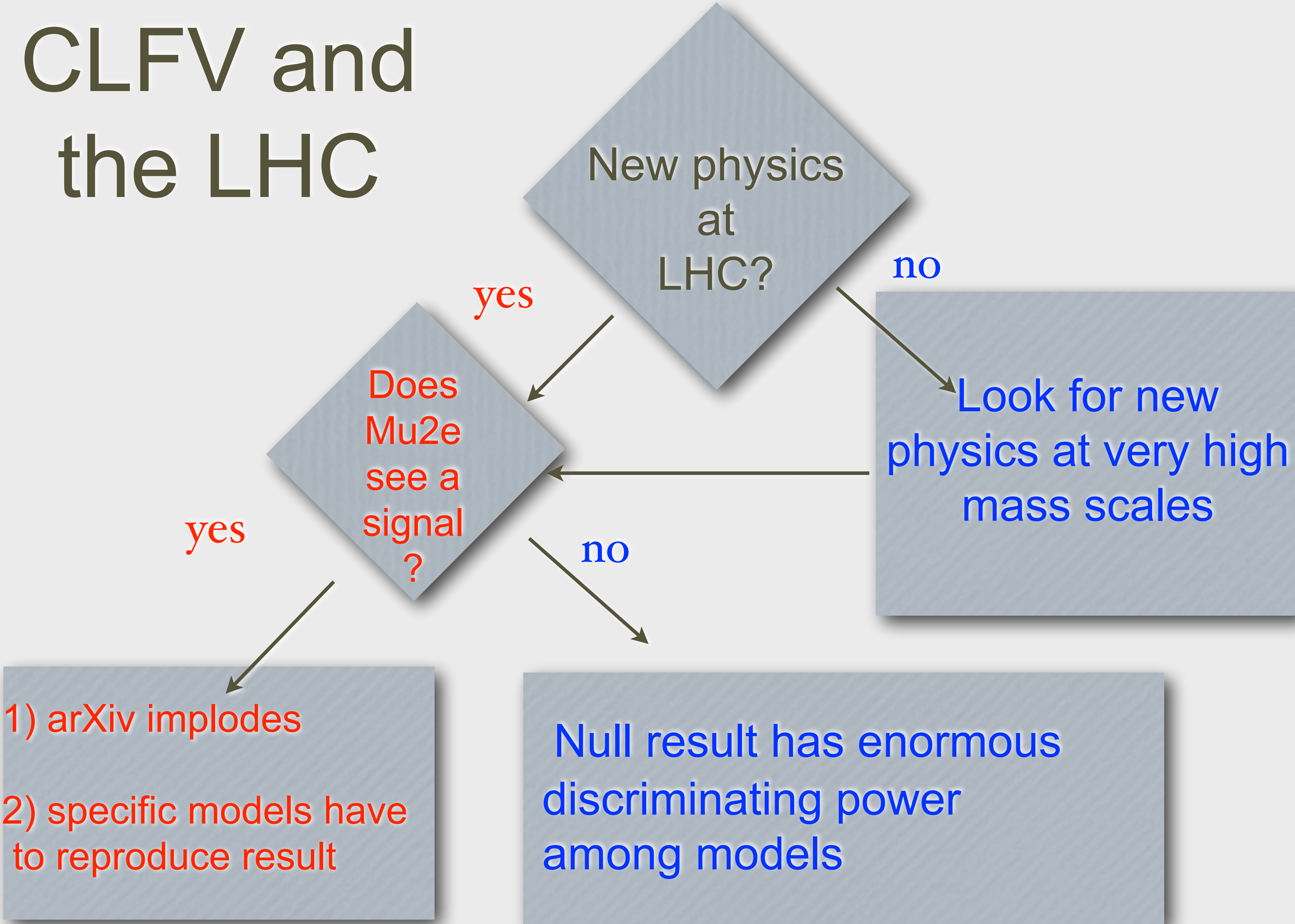
  - two experiments upcoming at FNAL and JPARC
- $\mu \to eee$
  - ambitious and unique, excellent partner to other two (at PSI)

Mass Scales of Muon CLFV Searches



operator coefficients =1, from Physics Briefing Book, 1910.11775

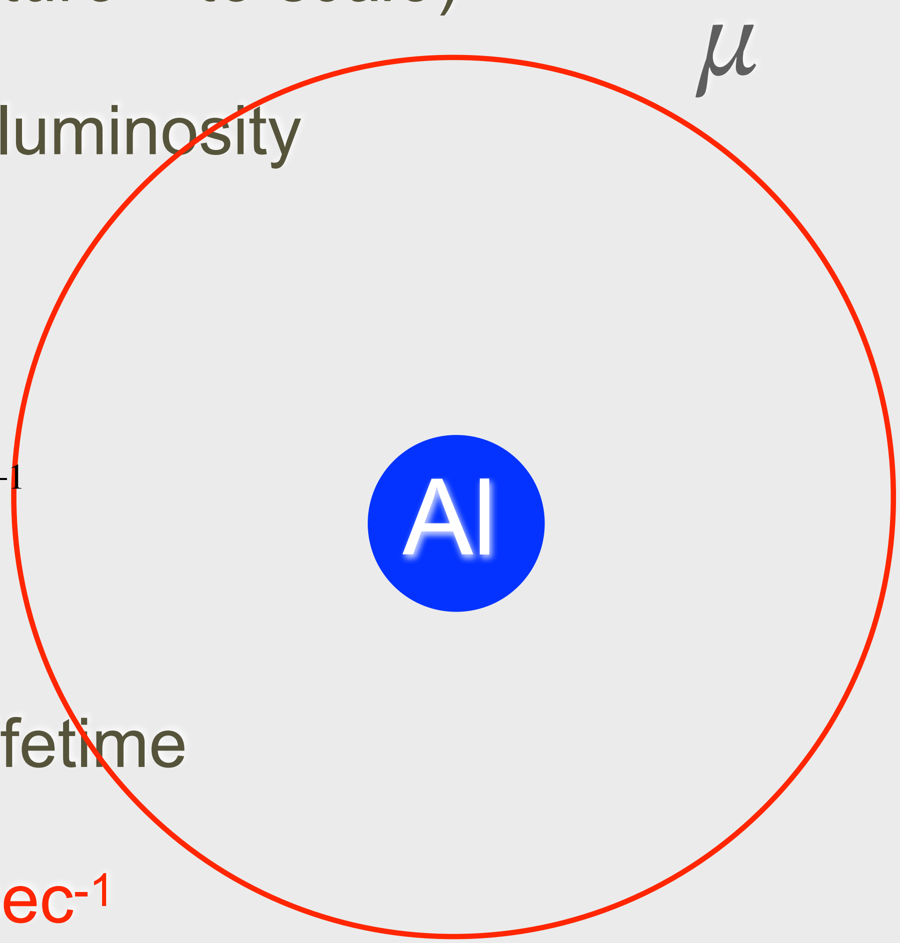
CLFV and the LHC



Measuring 10^{-17} in Collider Units

- The captured muon is in a 1s state and the wave function overlaps the nucleus (*picture ~ to scale*)
- We can turn this into an effective luminosity
- Luminosity = density x velocity

$$|\psi(0)|^2 \times \alpha Z = \frac{m_\mu^3 Z^4 \alpha^4}{\pi} = 8 \times 10^{43}\,\mathrm{cm}^{-2}\,\mathrm{sec}^{-1}$$



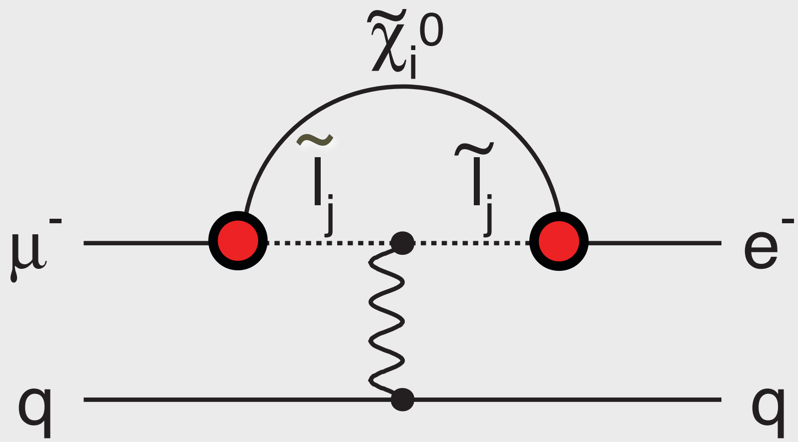
- Times 10^{10} muons/sec X 2 μsec lifetime
- Effective Luminosity of 10^{48} $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$

Andrzej Czarnecki

LFV, SUSY and the LHC

Supersymmetry

rate ~ 10^{-15}

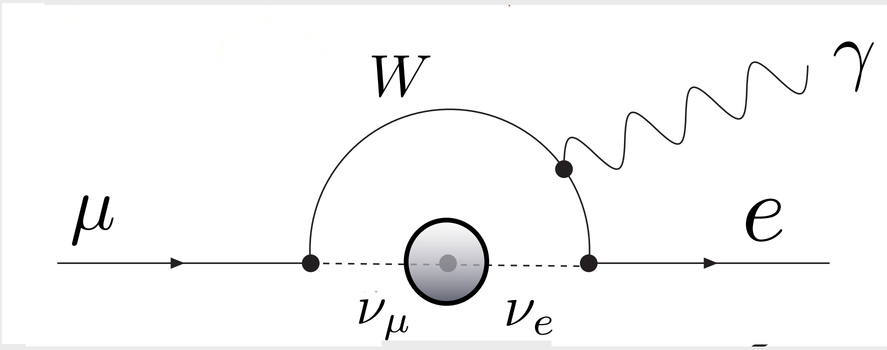


Access SUSY through loops:

signal of Terascale at LHC implies ~40 event signal / <0.5 bkg in this experiment

Neutrino Oscillations and Muon-Electron Conversion

- ν's have mass! *individual lepton numbers are not conserved*
- Therefore Lepton Flavor Violation occurs in Charged Leptons as well



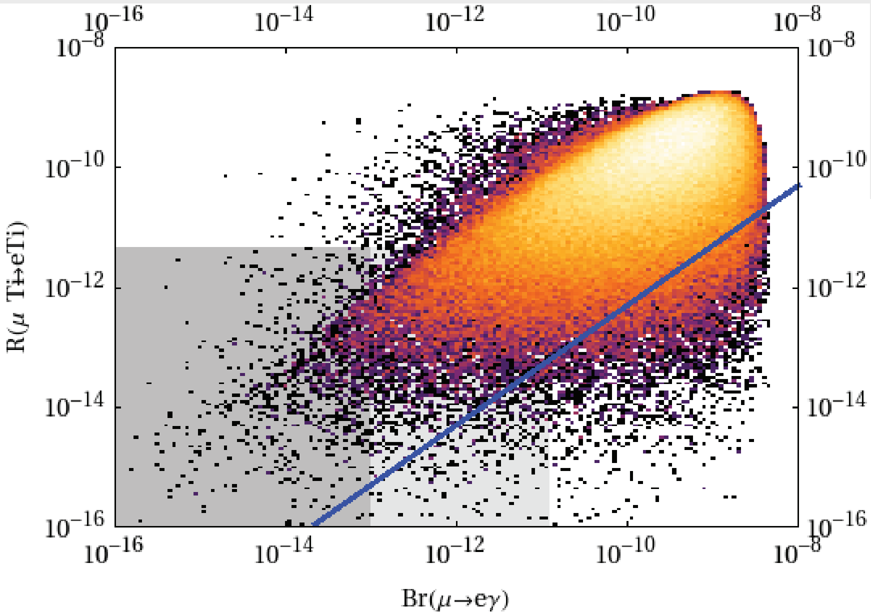
NO STANDARD MODEL BACKGROUND

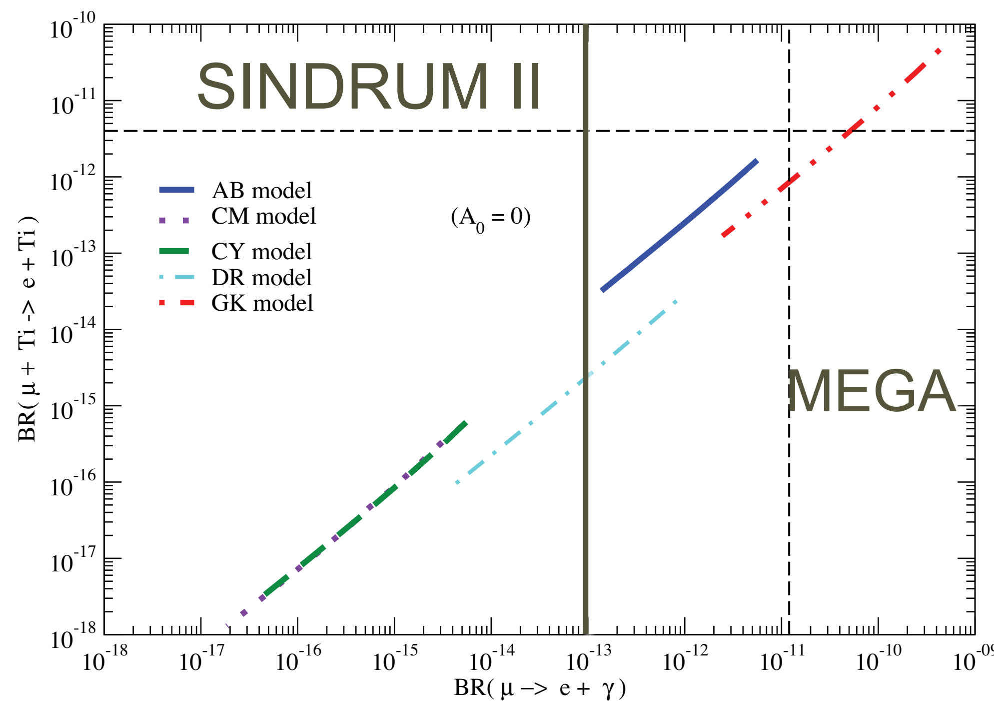
$$\mathrm{BR}(\mu \to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=2,3} U^*_{\mu i} U_{ei} \frac{\Delta m^2_{1i}}{M^2_W}\right|^2 < 10^{-54}$$

Combining μ→eγ with μ→e Conversion

Littlest Higgs

Monika Blanke, Andrzej J. Buras, Bjoern Duling, Stefan Recksiegel, Cecilia Tarantino, Acta Phys.Polon.B41:657,2010,arXiv:0906.5454v2 [hep-ph]





SO(10) models:

C. Albright and M. Chen, arXiv:0802.4228, PRD D77:113010, 2008.

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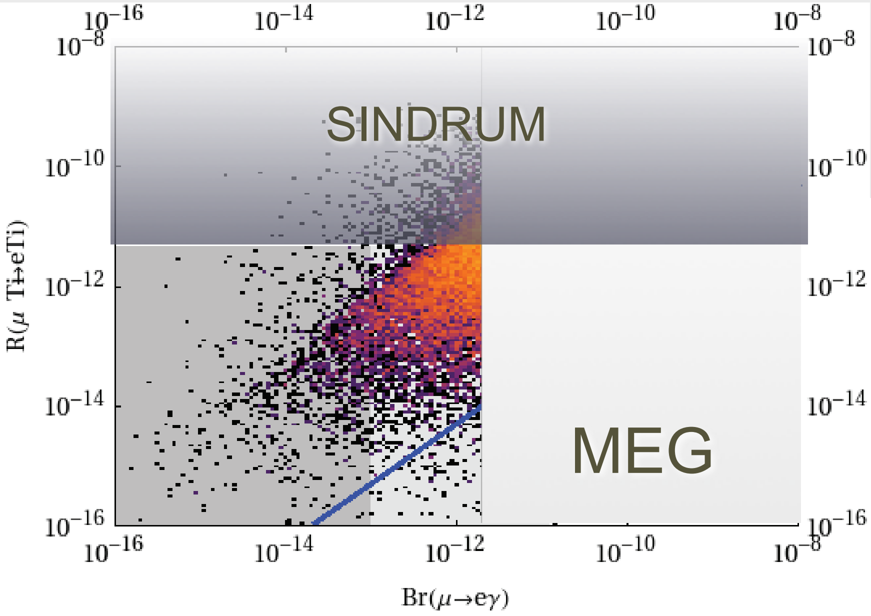

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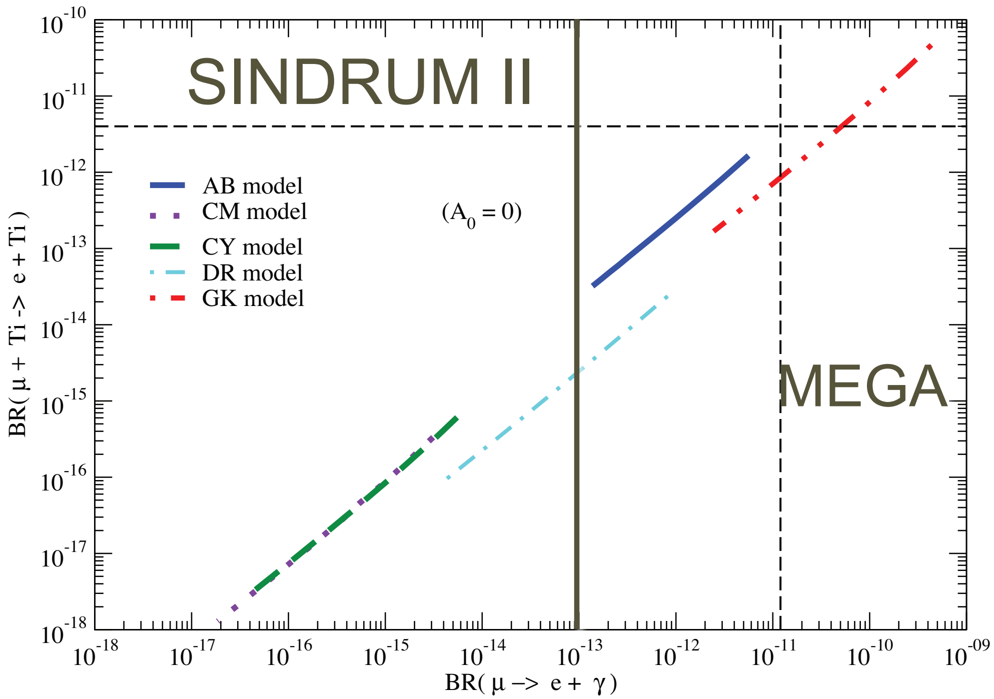

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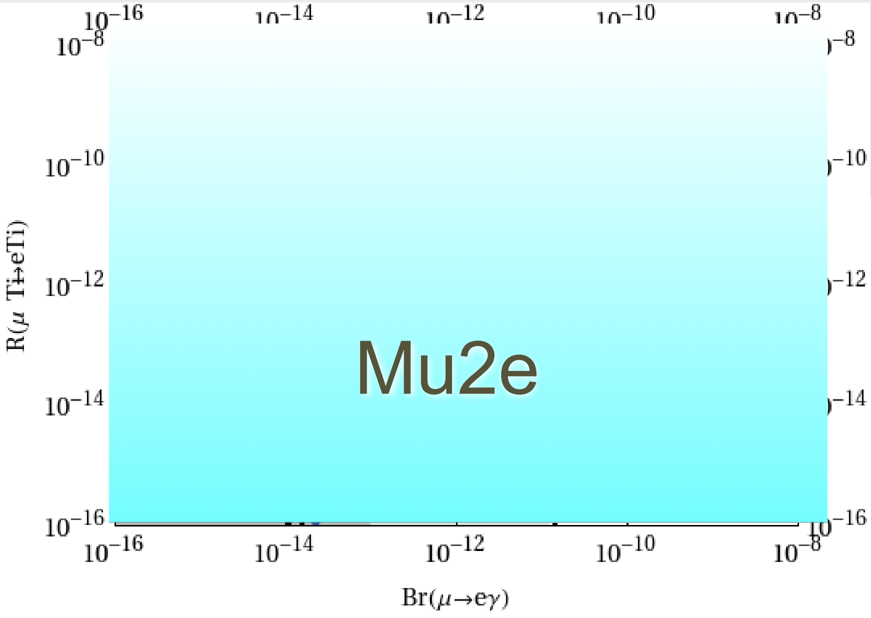

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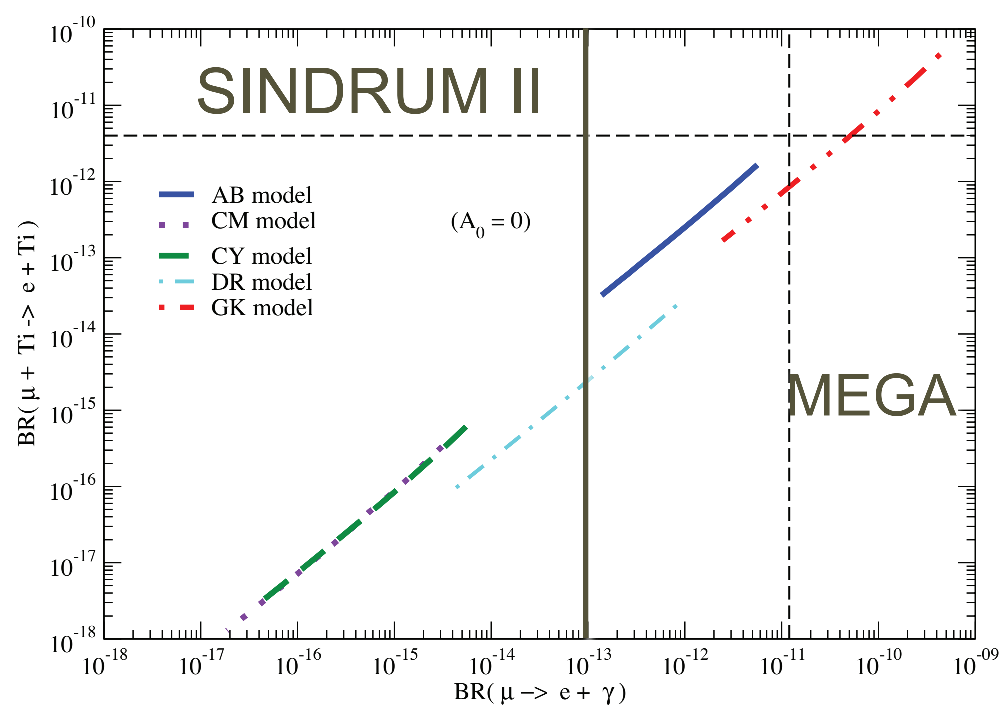

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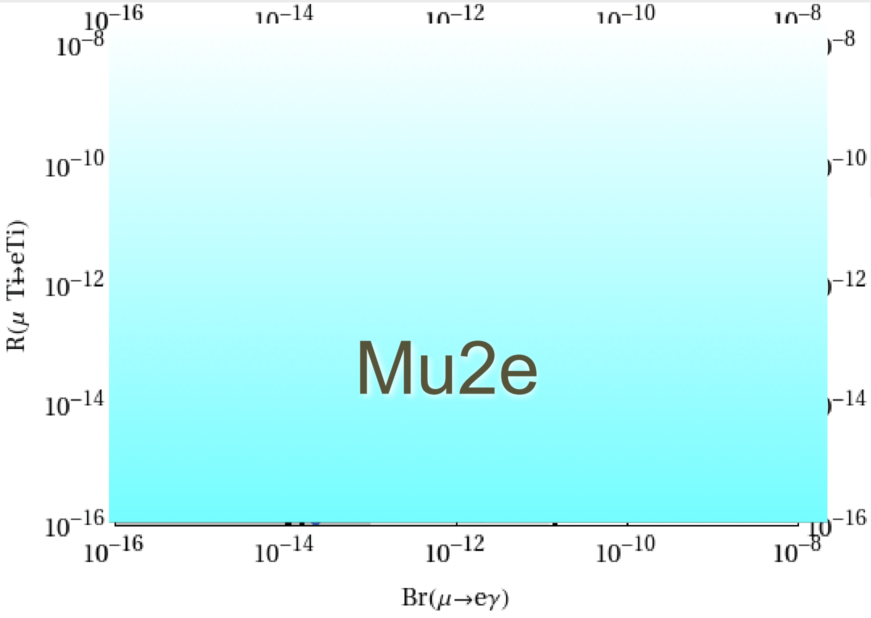

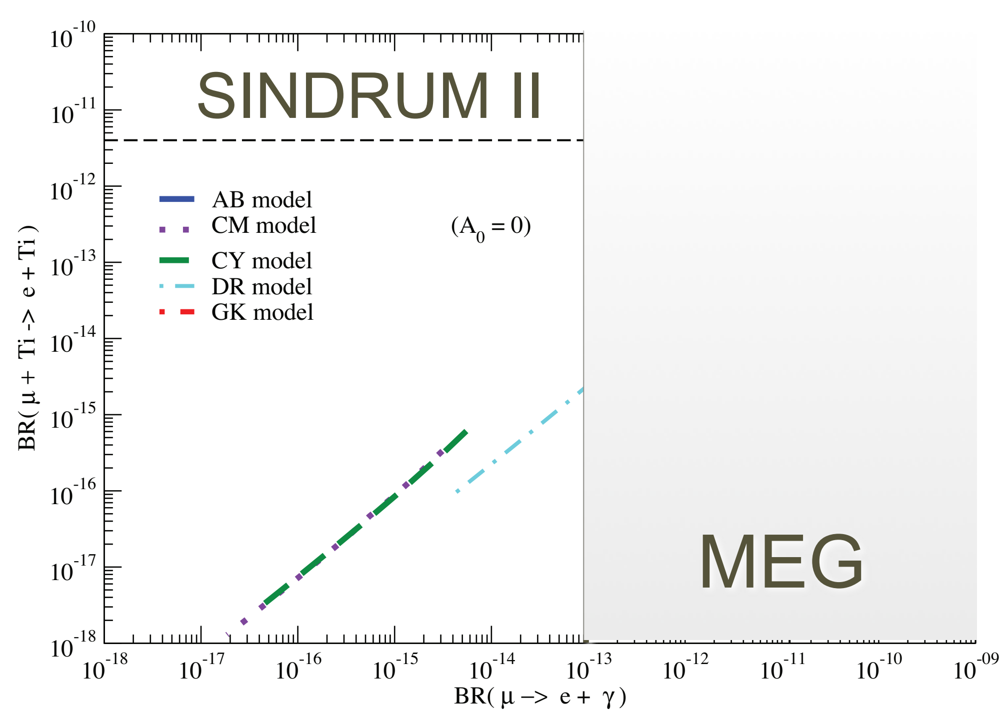

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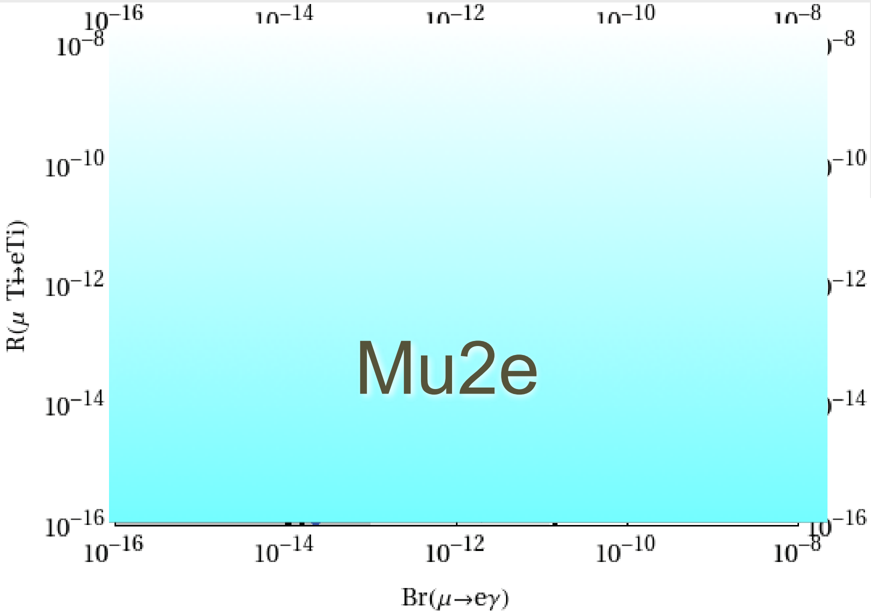

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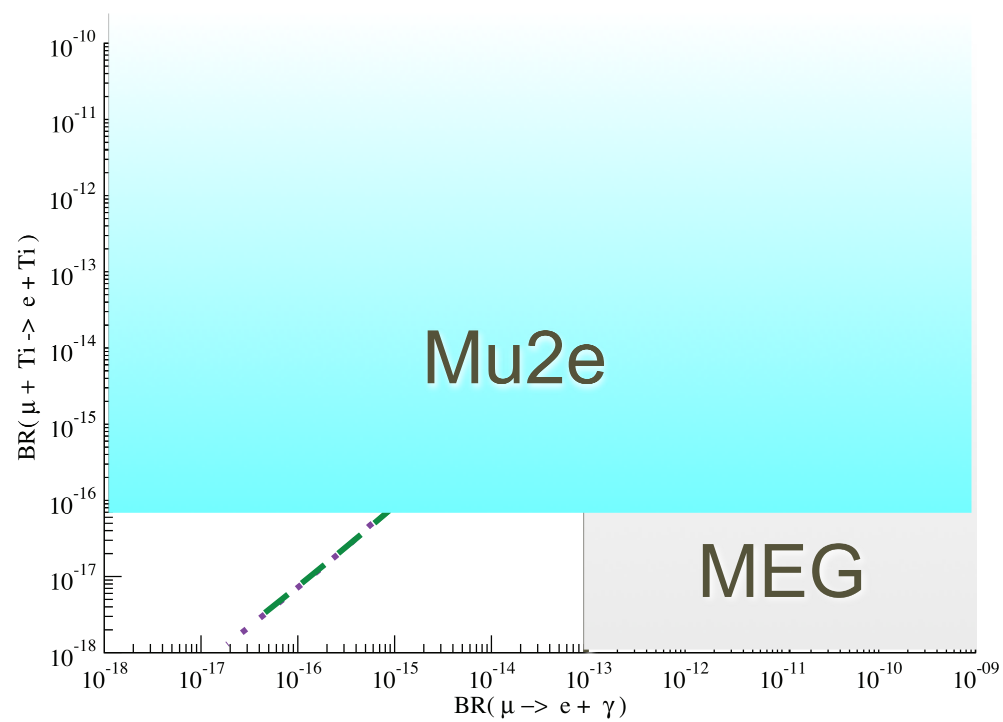
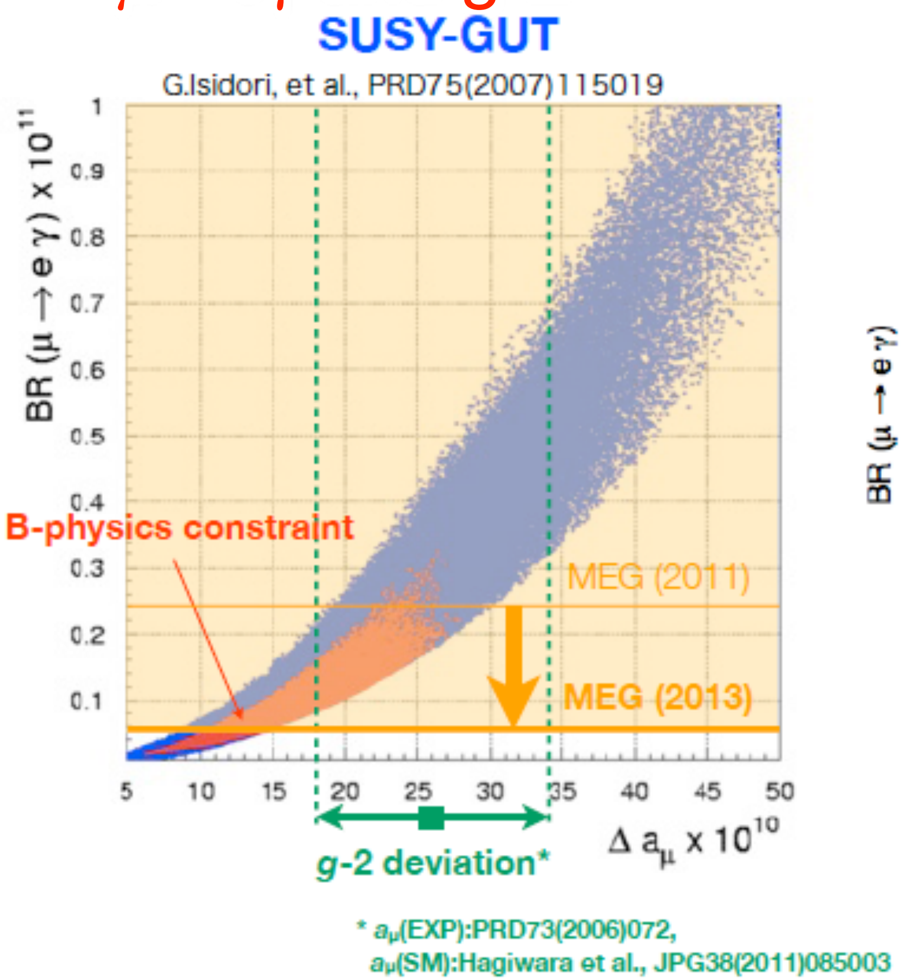
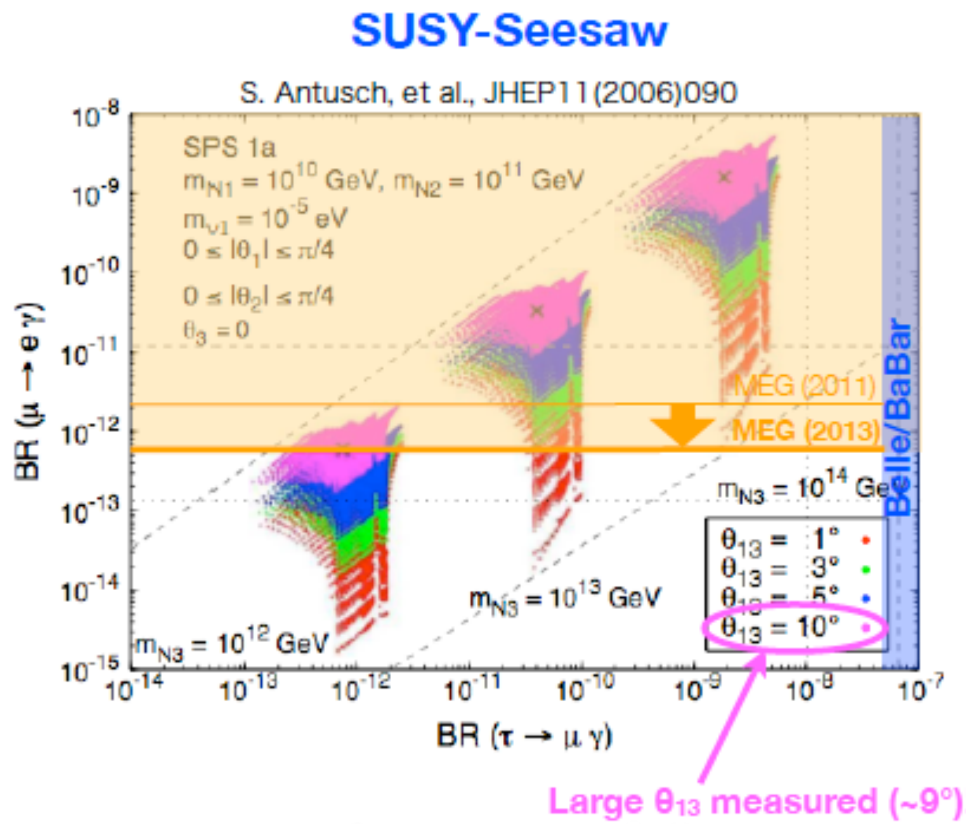


Outside of CLFV As Well

$\mu \to e\gamma$ and g-2



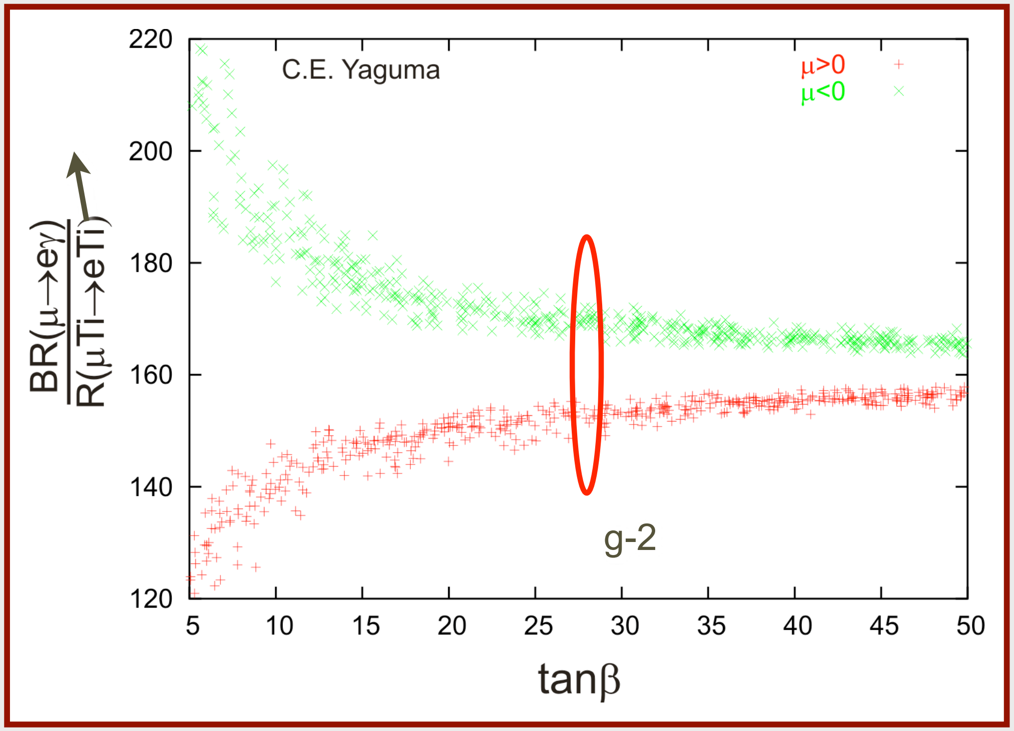


$\mu \to e\gamma$ and $\tau \to \mu\gamma$ and θ_{13}

Mu2e, g-2, and $\mu \rightarrow e\gamma$

Yaguna,
hep-ph/0502014v2

MSSM w mSUGRA



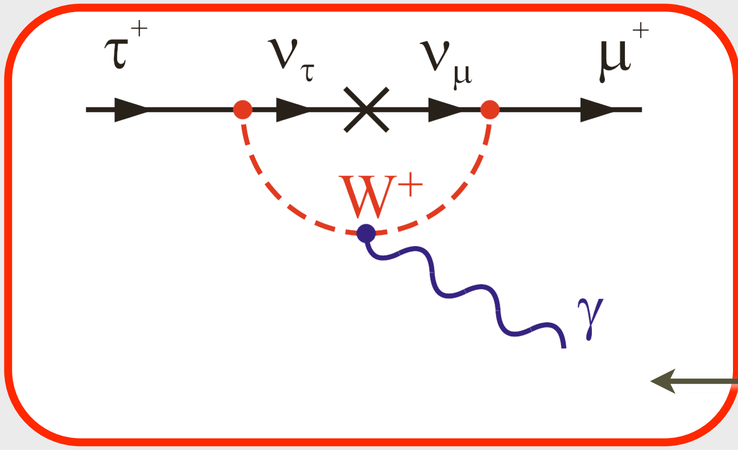
- Need:
  - observation of CLFV in more than one channel, and/or
  - evidence from LHC, g-2, or elsewhere

to allow discrimination among different models

CLFV and Tau Decays

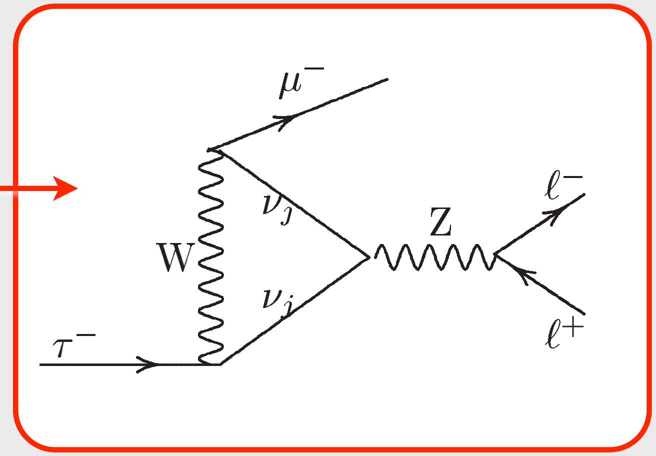
τ processes also suppressed in Standard Model but less:

Lee, Shrock
Phys.Rev.D16:1444,1977



$$\ln\left(\frac{m_3^2}{M_W^2}\right)^2$$

$$\left(\frac{\Delta m_{23}^2}{M_W^2}\right)^2$$



Pham, hep-ph/9810484

SM ~ 10^{-49}

SM ~ 10^{-14} ?

Good News:

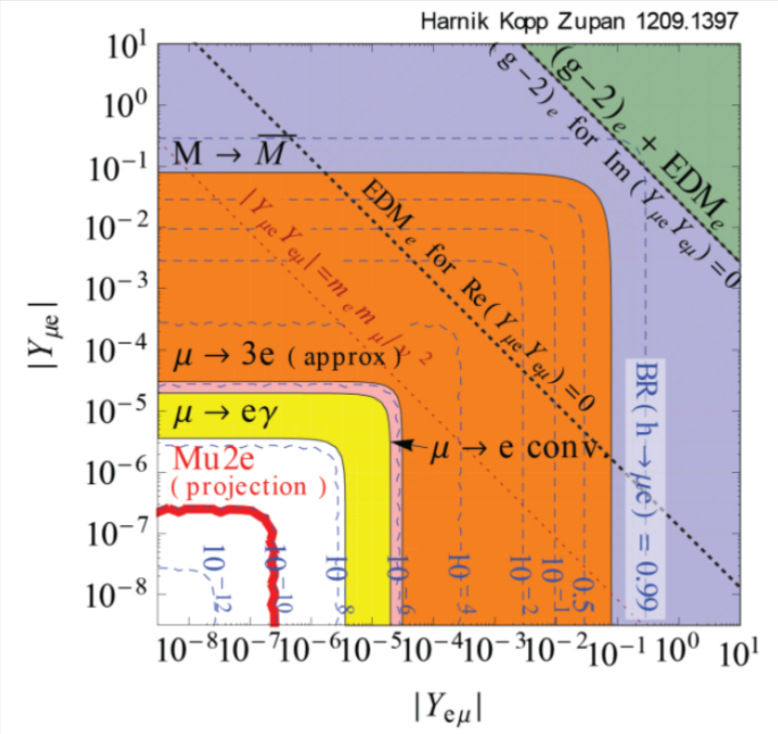
Beyond SM rates can be orders of magnitude larger than in associated muon decays

Bad News:

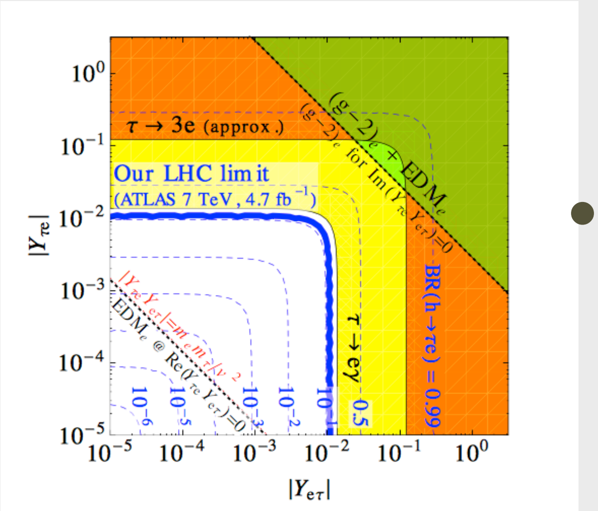
τ's hard to produce: ~10^{10} τ/*yr* vs ~10^{11} μ/*sec* in upcoming muon experiments

τ's help pin down models and sometimes biggest BR

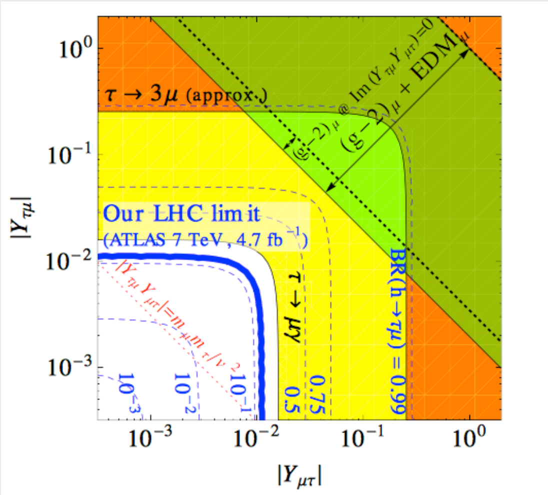
Constraints on Higgs:



- Very strong limits on LFV Higgs decays for 1st-2nd generation



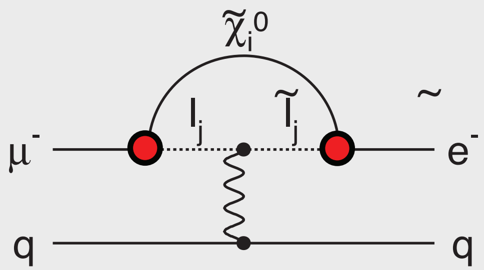
- But not if τ involved: 1st-3rd or 2nd-3rd



Contributions to $\mu \rightarrow e$ Conversion

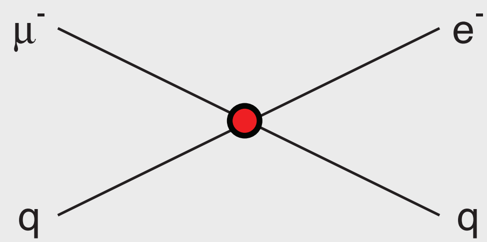
Supersymmetry

rate ~ 10^{-15}



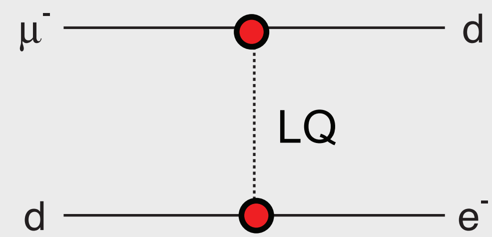
Compositeness

Λ_c ~ 3000 TeV



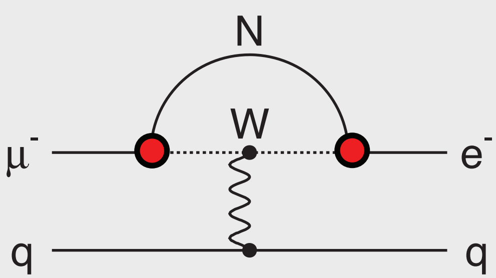
Leptoquark

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



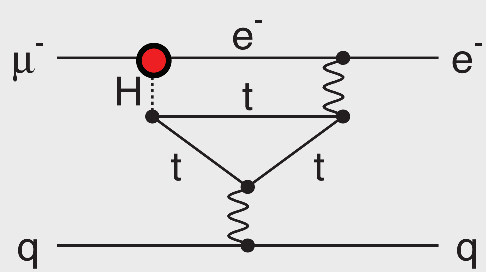
Heavy Neutrinos

$|U_{\mu N}U_{eN}|^2$ ~ 8×10^{-13}



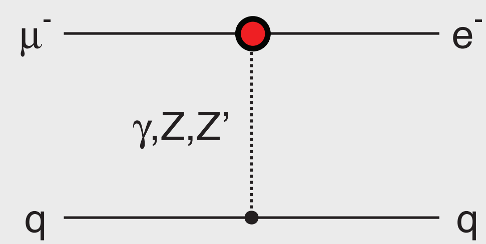
Second Higgs Doublet

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



Heavy Z' Anomal. Z Coupling

$M_{Z'} = 3000$ TeV/c^2

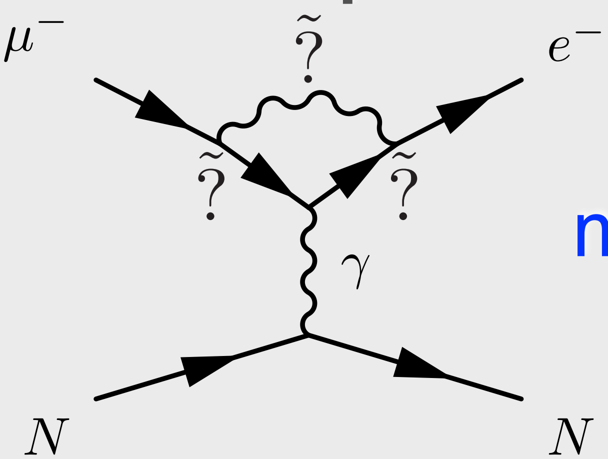


also see Flavour physics of leptons and dipole moments, arXiv:0801.1826 ;
Marciano, Mori, and Roney, Ann. Rev. Nucl. Sci. 58, doi:10.1146/annurev.nucl.58.110707.171126 ;

De Gouvea Lagrangian

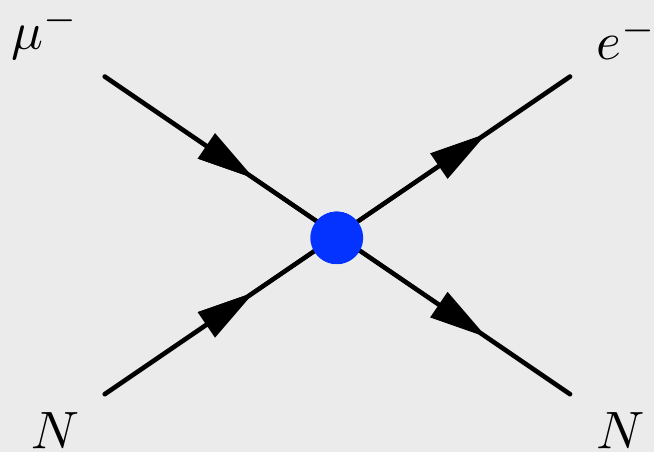
$$\mathscr{L}_{\mathrm{CLFV}} = \frac{m_\mu}{\Lambda^2}\,\bar{\mu}_R\,\sigma_{\mu\nu}\,e_L\,F^{\mu\nu} \quad + \frac{1}{\Lambda^2}\bar{\mu}_L\gamma^\mu e_L(\bar{u}_L\gamma_\mu u_L + \bar{d}_L\gamma_\mu d_L)$$

"Loops"



Supersymmetry and Heavy Neutrinos

"Contact Terms"



New Particles at High Mass Scale (leptoquarks, heavy Z,...)

mass scale Λ

Contributes to $\mu\to e\gamma$
(just imagine the photon is real)

Mu2e/COMET/MEG/Mu3e at 10^3 TeV

Does not produce $\mu\to e\gamma$

Mu2e/COMET at 10^4 TeV

EFT: Beyond Λ and κ

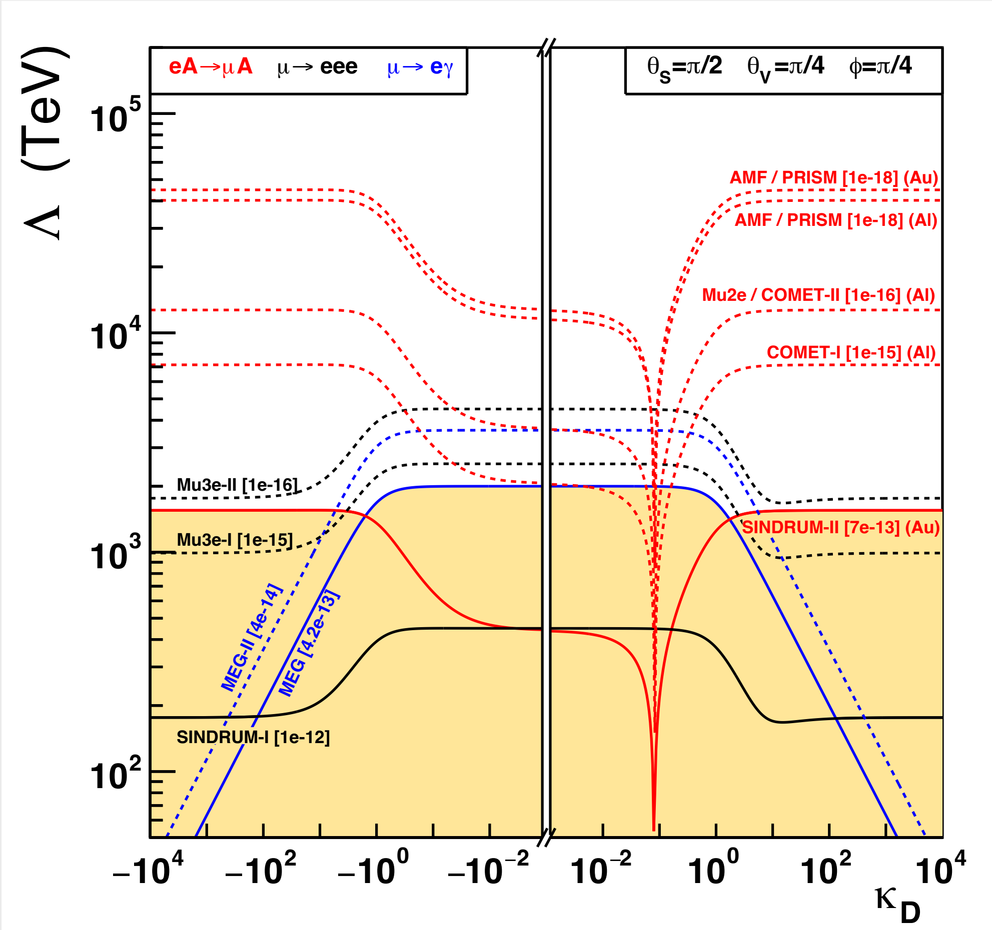
S. Davidson and B. Echenard, 2010.00317 [hep-ph]

- Write EFT Lagrangian:
  - Dipole ($\mu \to e\gamma$) +
    Contact Scalar ($\mu \to 3e$)$_L$ +
    Contact Vector ($\mu \to 3e$)$_R$ +
    Contact $\mu N \to eN$ (light nuclei) +
    Contact $\mu N \to eN$ (heavy nuclei)
- Parameterize coefficient space with spherical coordinates: *lets you express constraints on all three processes simultaneously*
- Will show you “slices” in the multi-dimensional space

Complementarity

S. Davidson and B. Echenard, 2010.00317 [hep-ph]

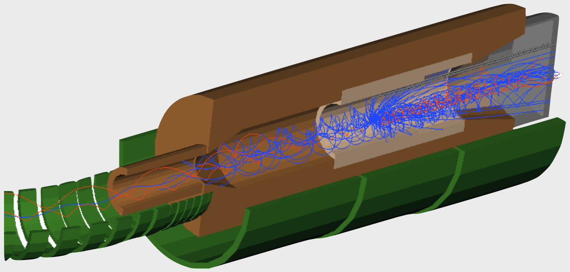
- All three channels have strengths; we need the combination

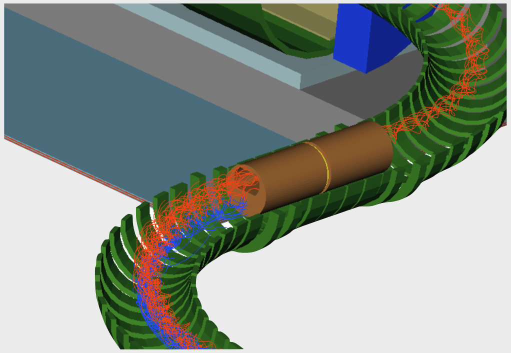


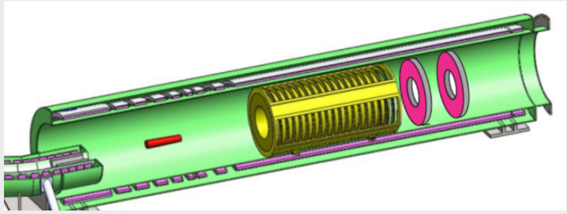
- $\mu \to e\gamma$ and $\mu \to 3e$ at $\mathcal{O}(10^{-15})$ are a next-gen target

Next Part

- *An overview of experiment and walk you through the solenoids*





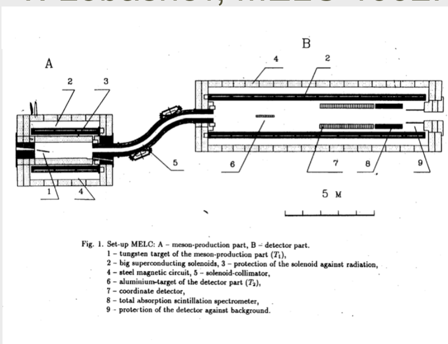


- Describe what happens when muons reach the stopping target

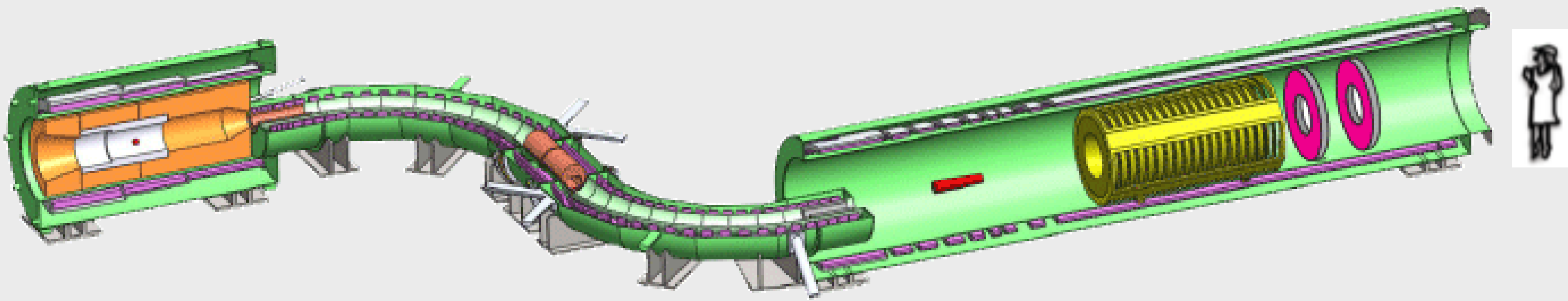
- Explain detector, signal, and backgrounds

Mu2e Overview

V. Lobashev, MELC 1992:



- Production: protons hit a target, making π's, which decay into accepted μ's



- *Transport:* S-curve eliminates backgrounds and sign-selects μ^- vs. μ^+

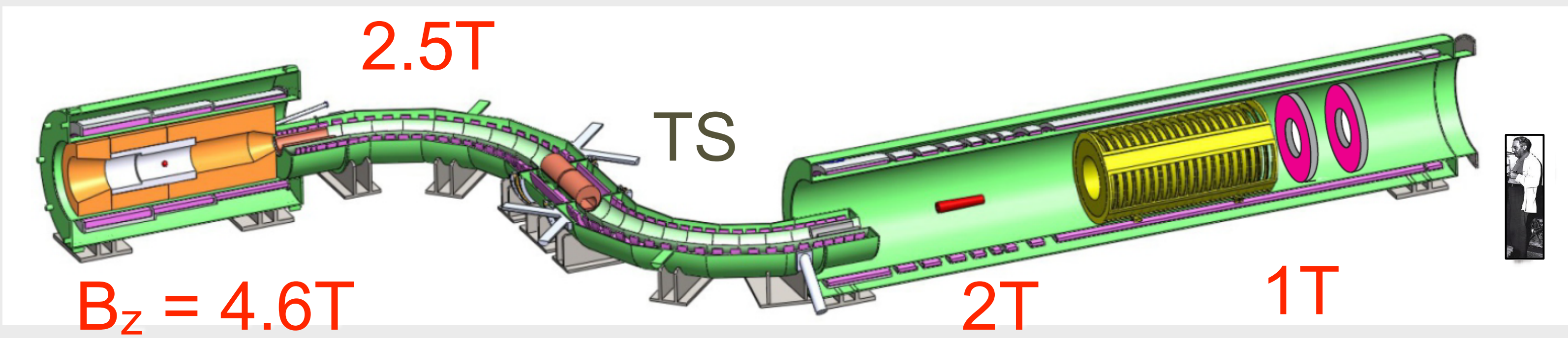
entire system in vacuum < 10^{-4} torr

- *Detector:* Stopping Target, Tracking and Calorimeter

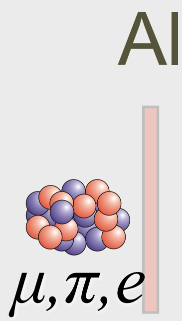
Mu2e Muon Beam: Three Solenoids and Gradient

4.6T ⟶ B-field gradient ⟶ 1T

PS DS

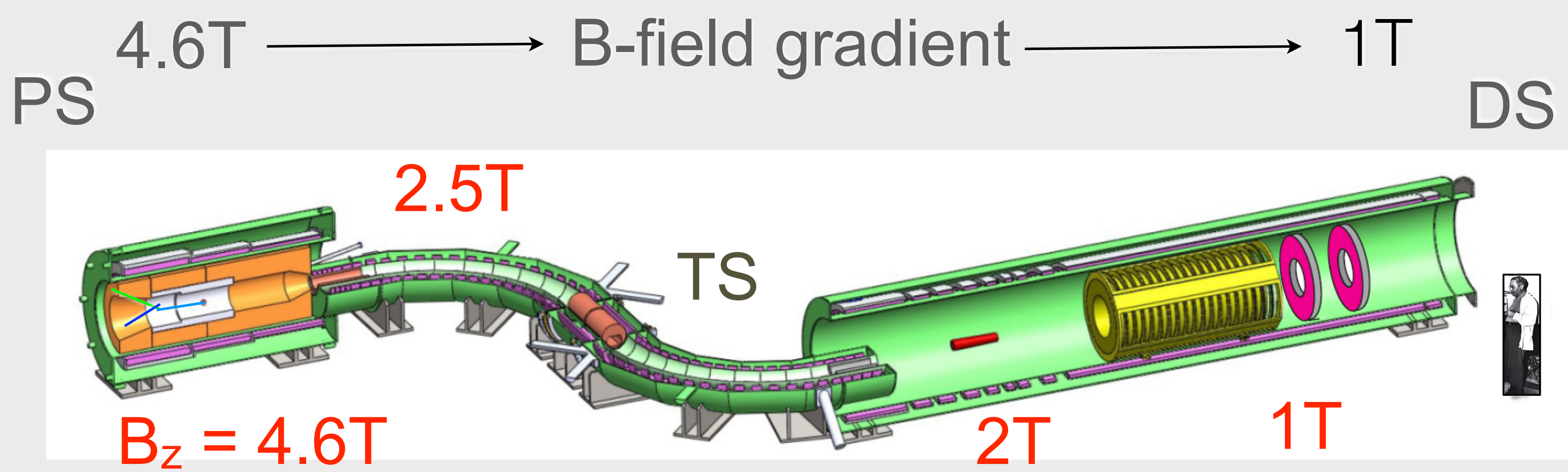


- Target protons at 8 GeV inside superconducting solenoid
- Capture muons and guide through S-shaped region to Al stopping target
- Gradient fields used to collect and transport muons



Muon K.E ~ 7 MeV
muons range out by dE/dx in Aluminum

Mu2e Muon Beam: Three Solenoids and Gradient



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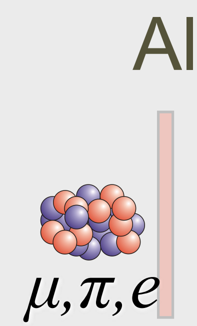

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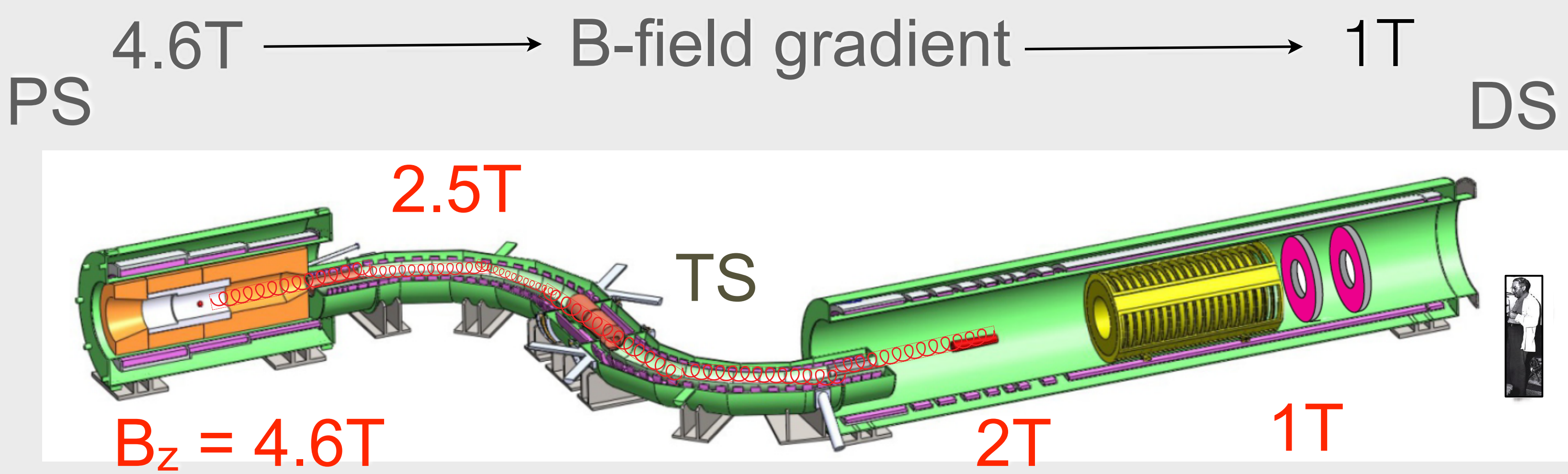

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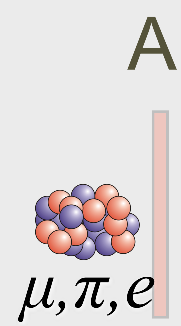

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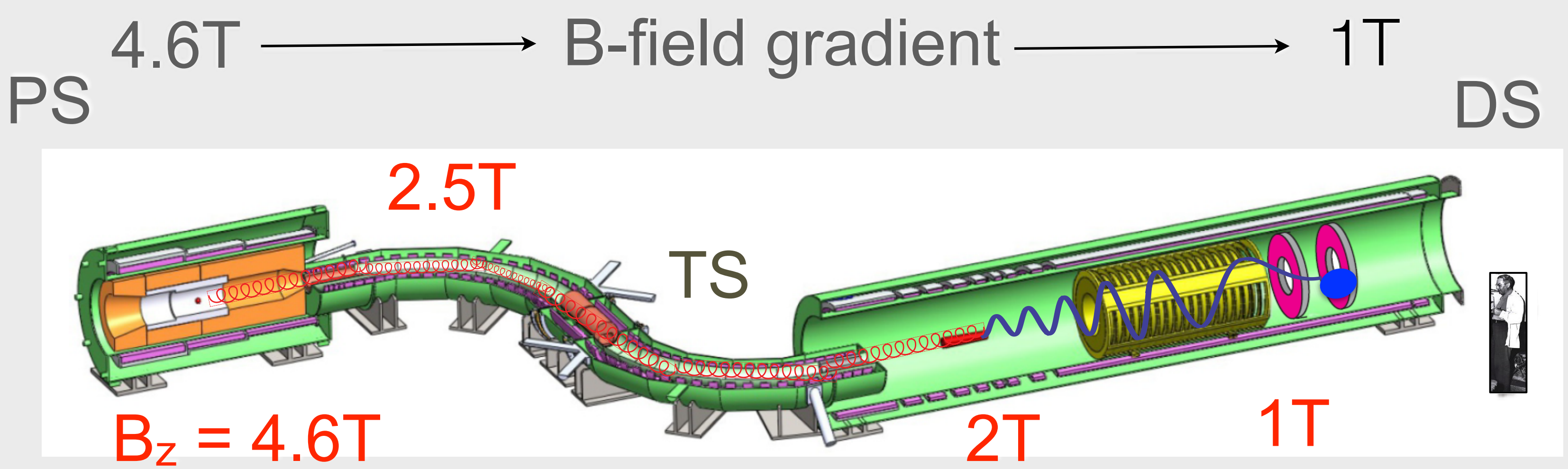

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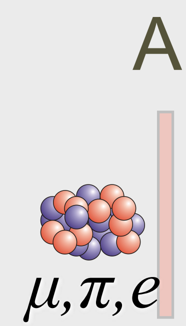
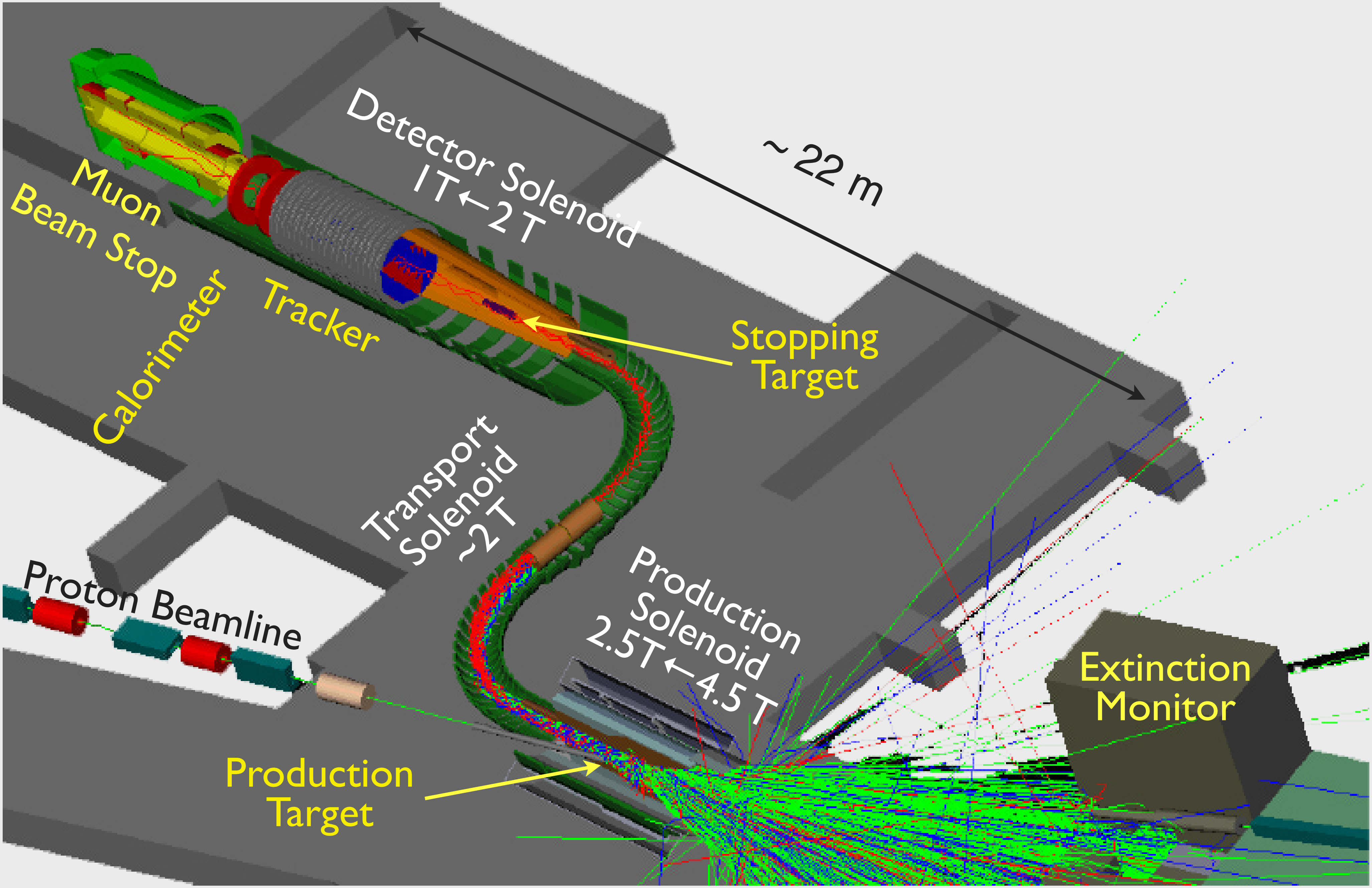


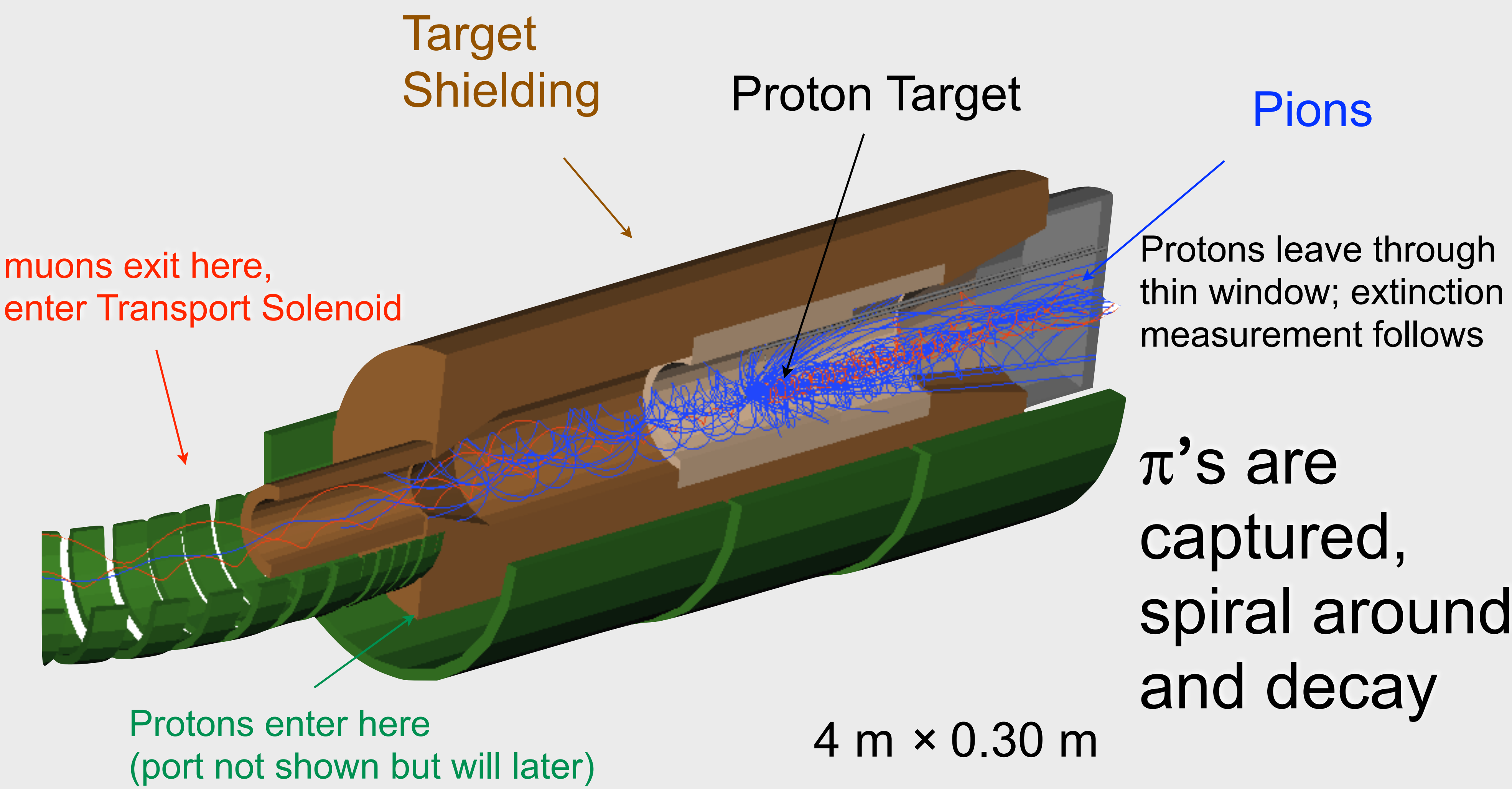
Muon K.E ~ 7 MeV
muons range out by dE/dx
in Aluminum

Beam's Eye View



Production Solenoid:

Protons enter opposite to outgoing muons



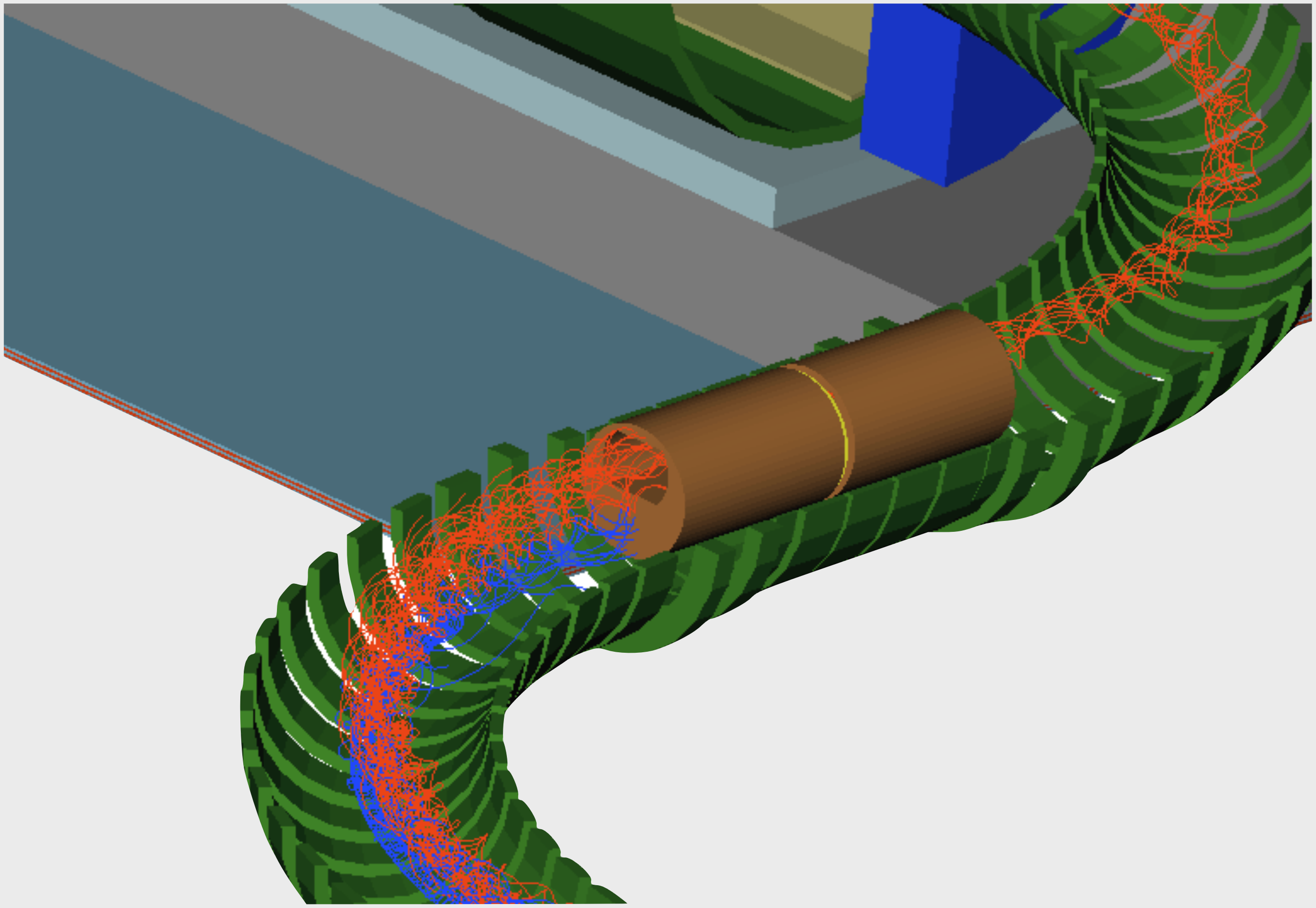
π's are captured, spiral around and decay

4 m × 0.30 m

Transport Solenoid

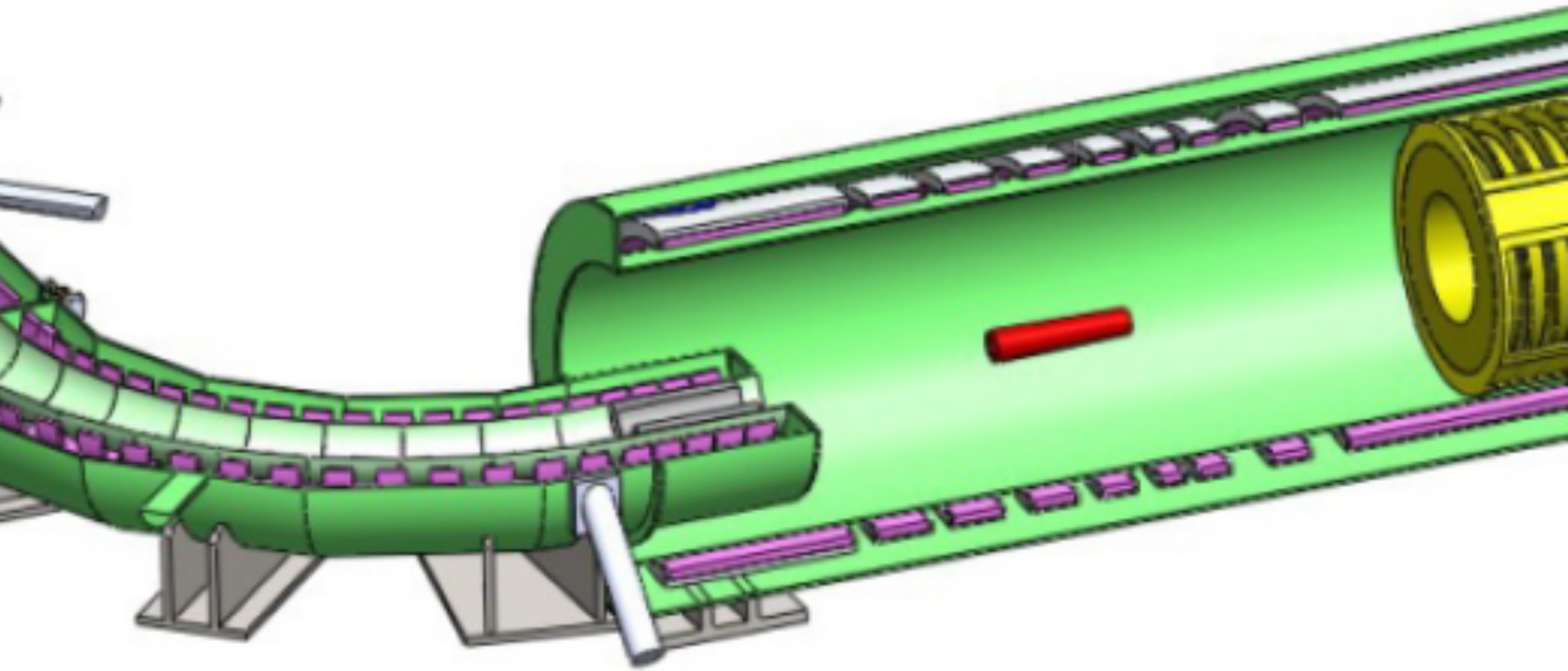
- Curved solenoid eliminates line-of-sight transport of photons and neutrons

- Curvature drift and collimators sign and momentum select beam



13.1 m along axis × ~0.25 m

Now Enter Detector Solenoid



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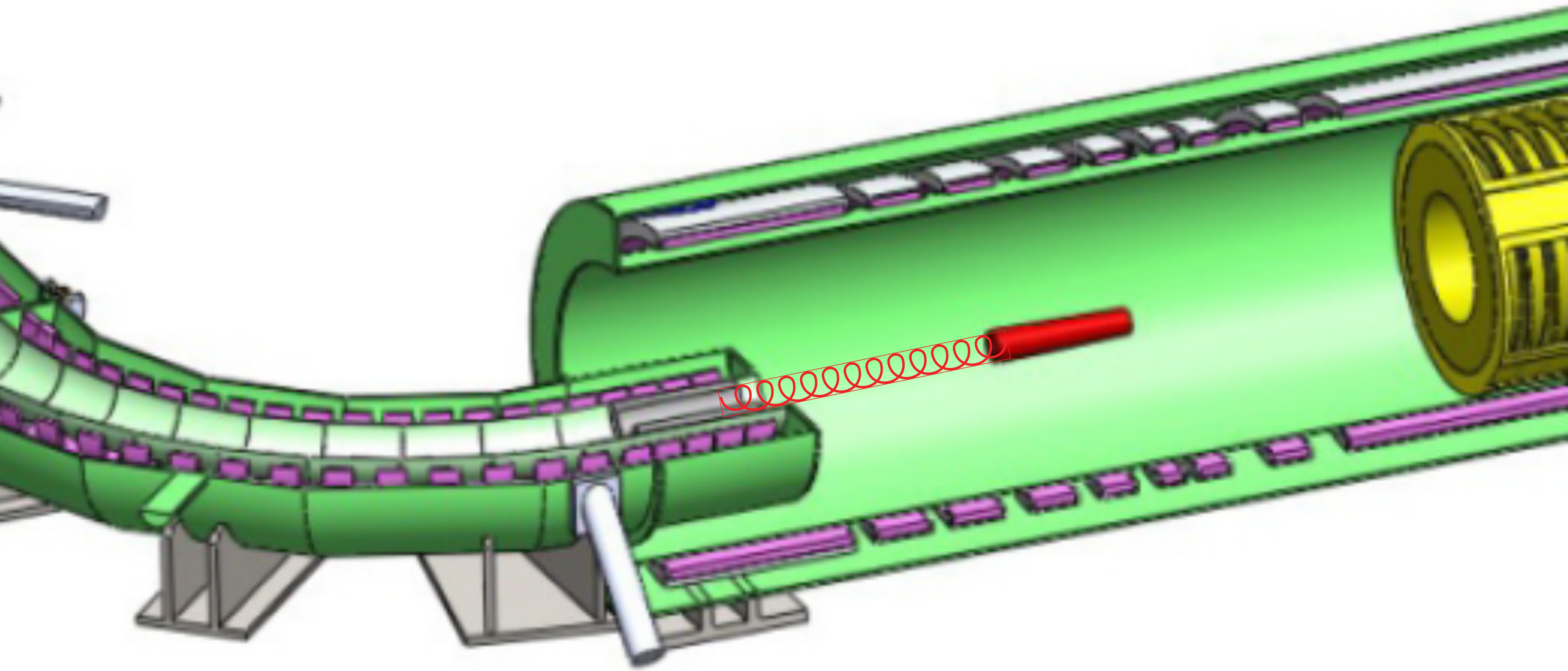
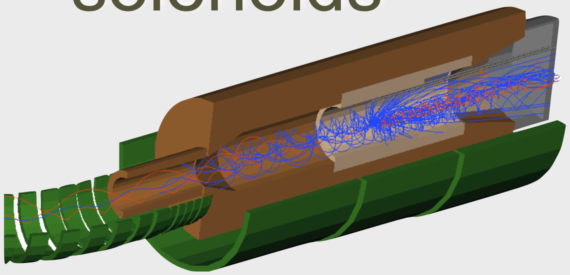
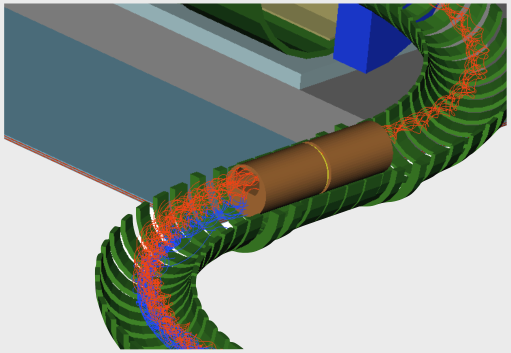
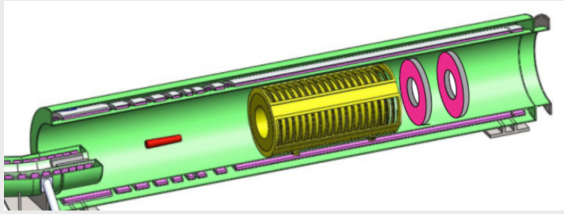


Next Part

- An overview of experiment and walk you through the solenoids







- *Describe what happens when muons reach the stopping target*

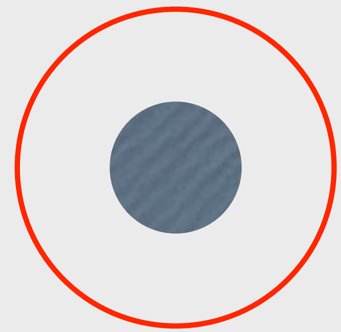
- Explain detector, signal, and backgrounds

Overview Of Processes

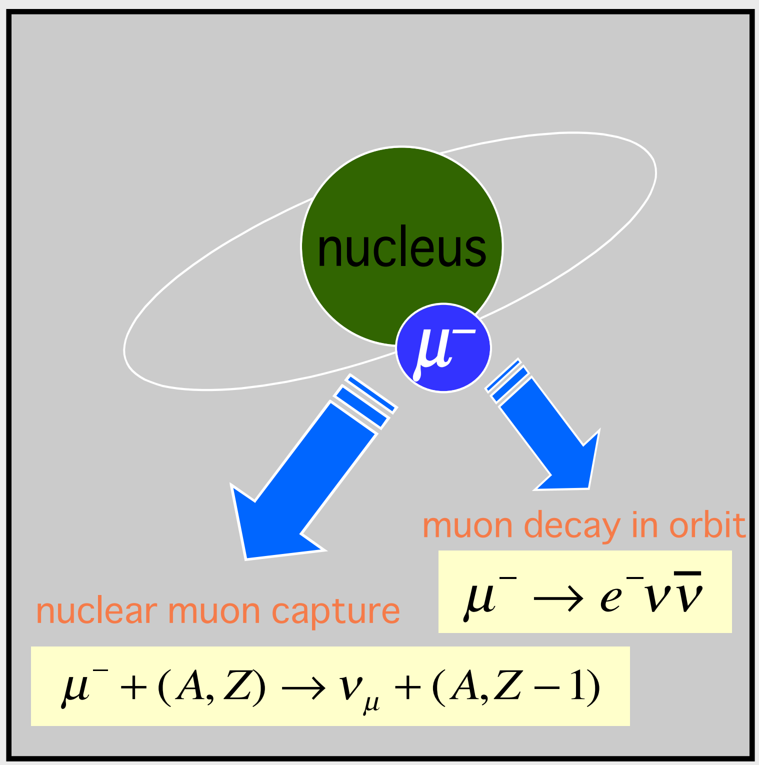
μ^- stops in thin Al foil

the Bohr radius is ~ 20 fm,
so the μ^- sees the nucleus

μ^- in 1s state



Al Nucleus
~4 fm

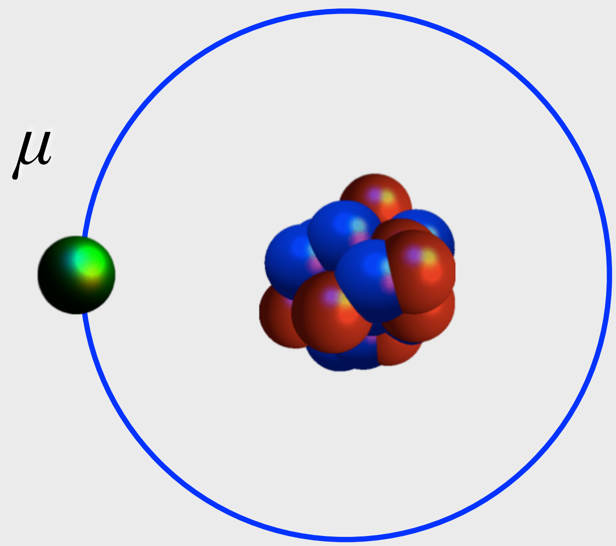


60% capture
40% decay

muon capture,
muon “falls into”
nucleus:
normalization

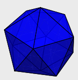
Decay in Orbit:
background

Decay-in-Orbit (DIO) Background



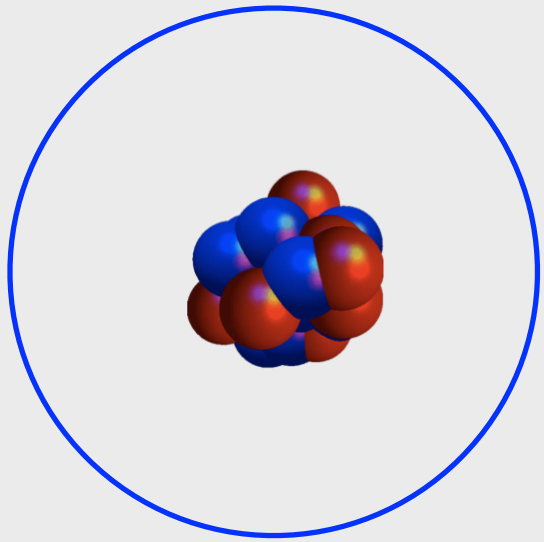
Decay-in-Orbit (DIO) Background

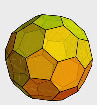
this electron can be background;
let's see how



e

ν_μ





$\bar{\nu}_e$

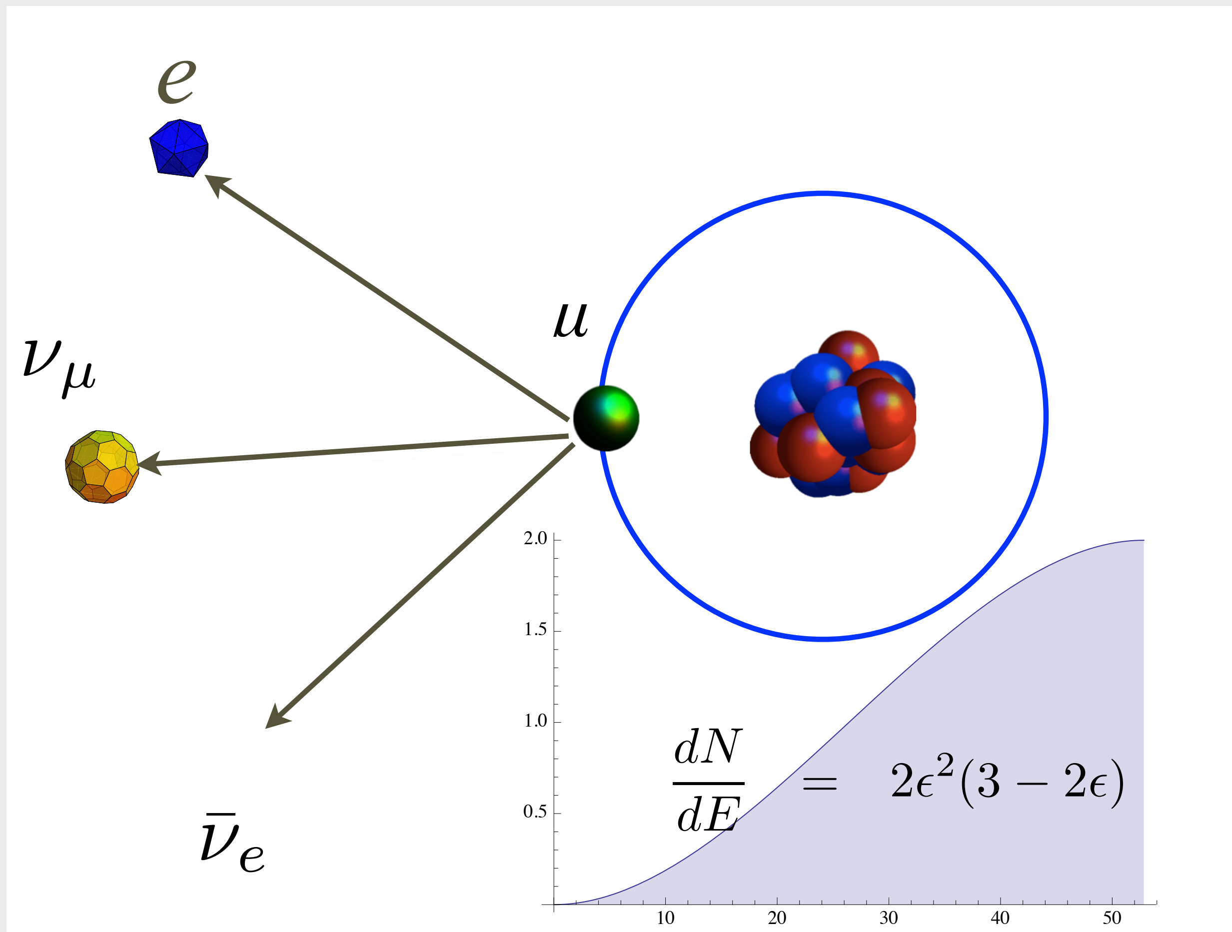
DIO: usually not background

- Peak and Endpoint of Michel Spectrum is at

$$E_{\max} = \frac{m_\mu^2 + m_e^2}{2m_\mu} \approx 52.8\ \text{MeV}$$

- Detector will be insensitive to electrons at this energy

- Recall *signal* at 105 MeV>>52.8 MeV



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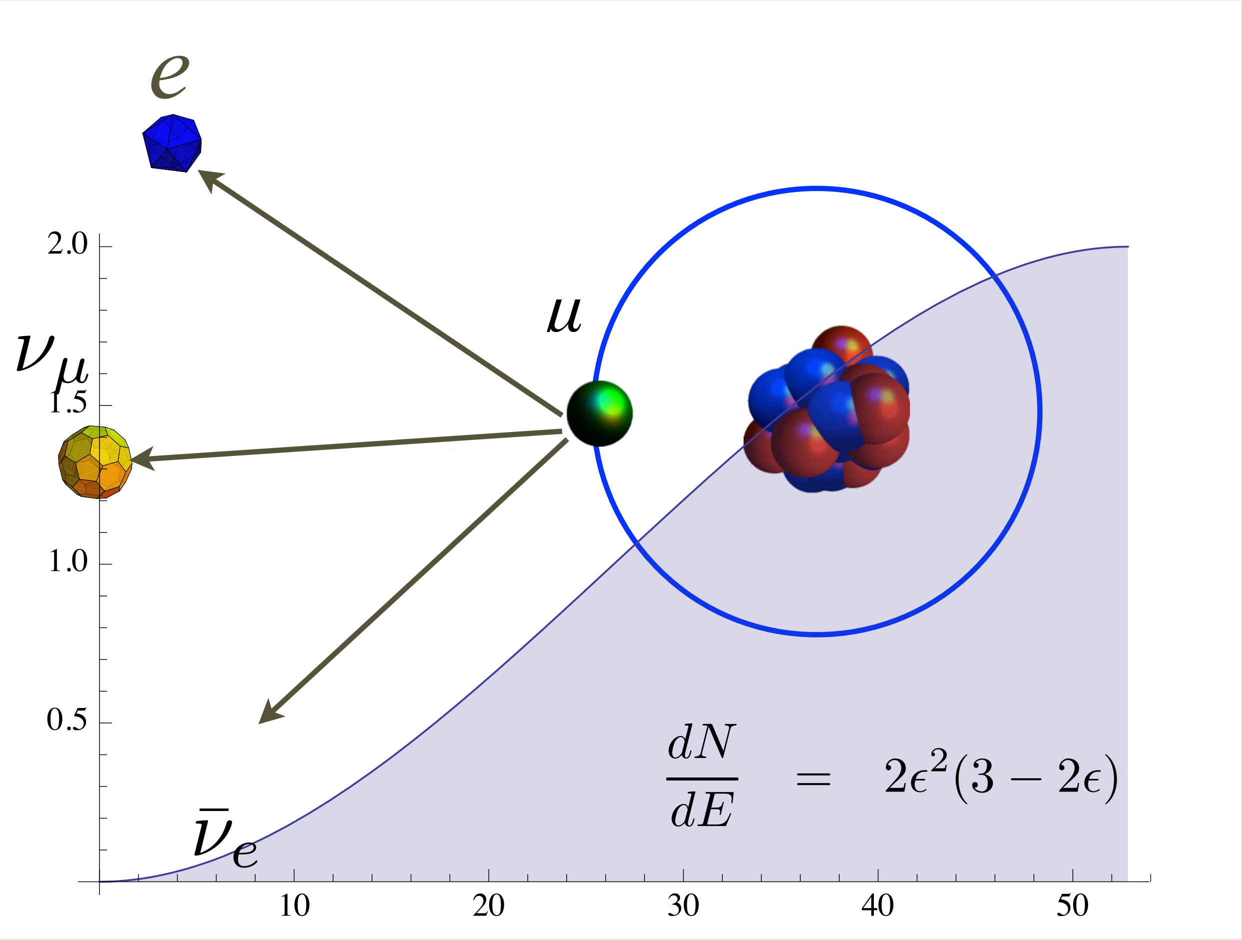
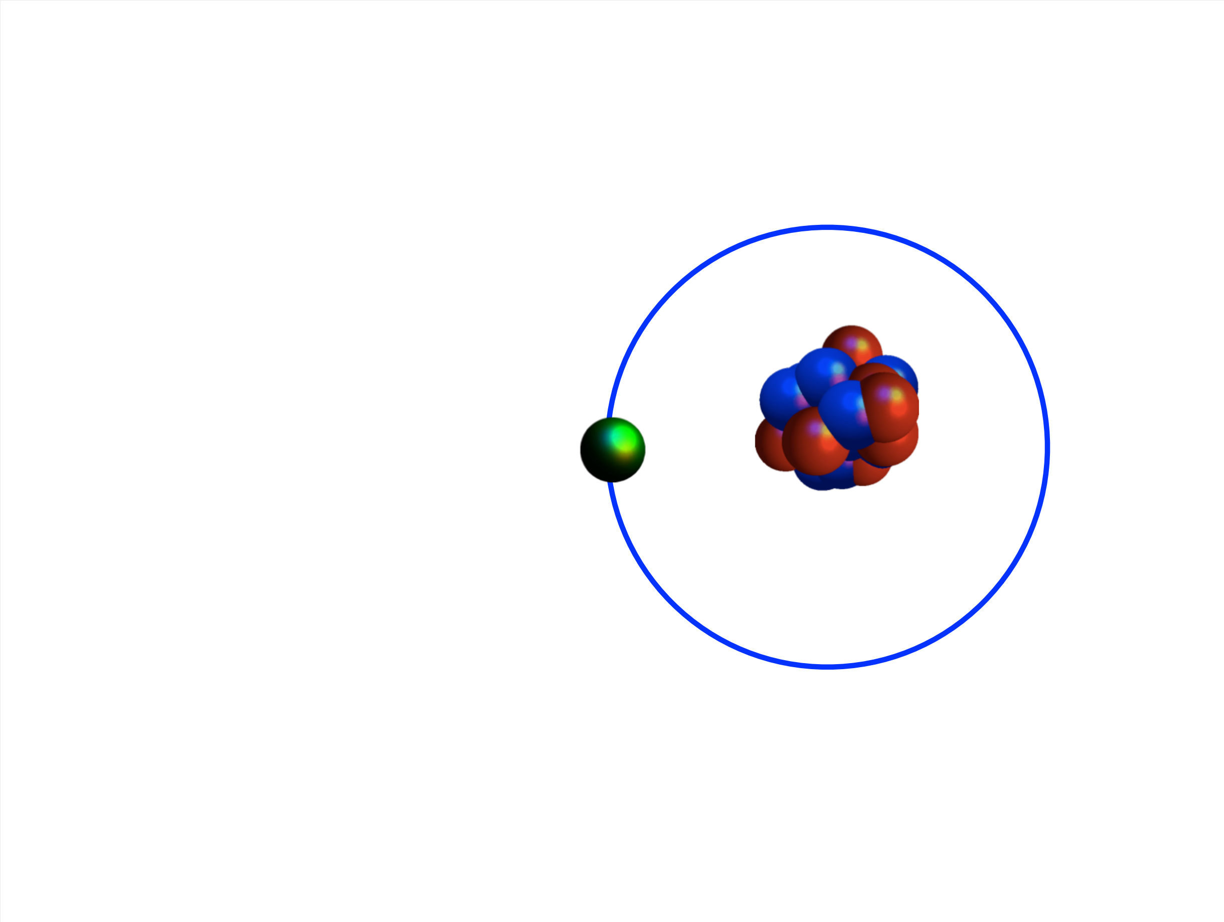


Decay-In-Orbit Background

- Same process as before
- But this time, include electron recoil off nucleus
- If neutrinos are at rest, the DIO electron can be exactly at conversion energy (up to neutrino mass)



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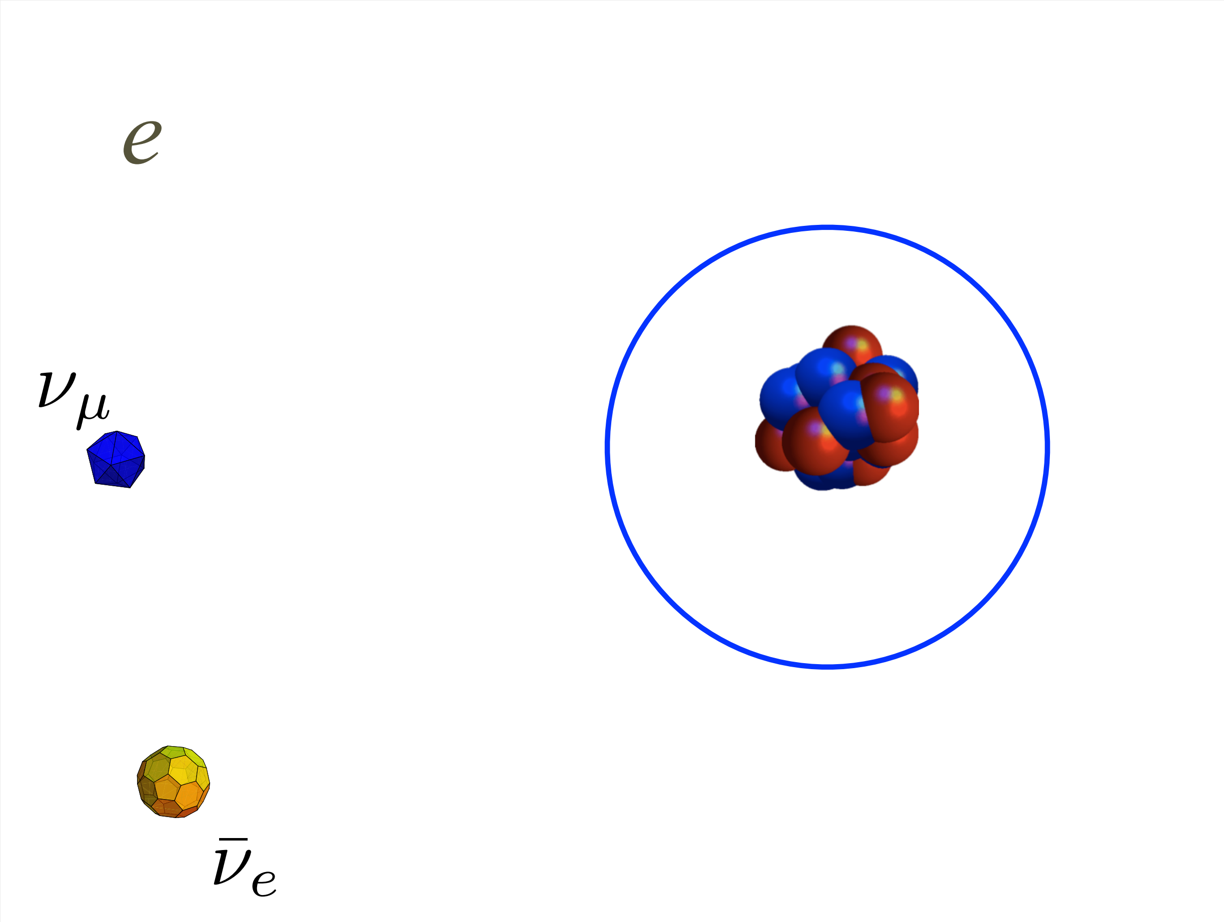

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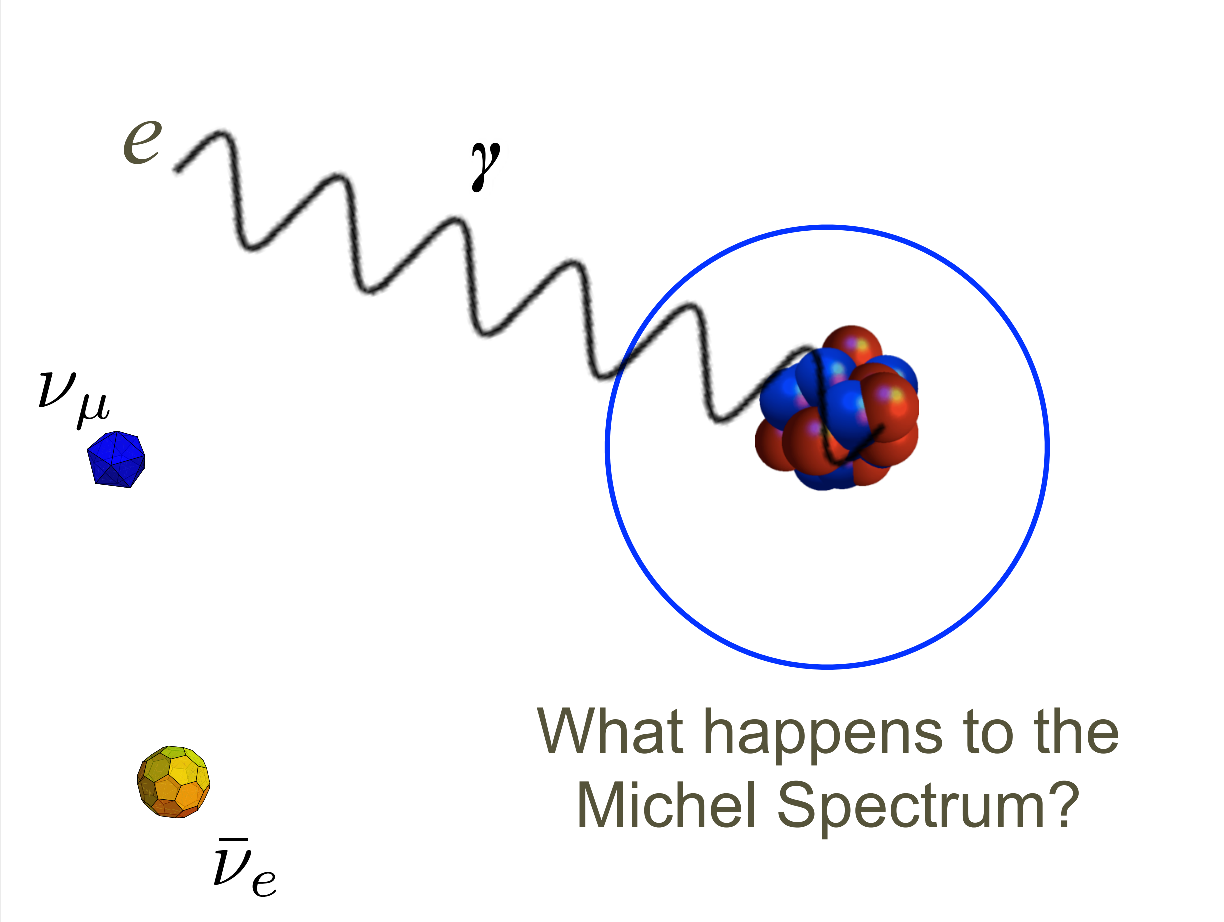
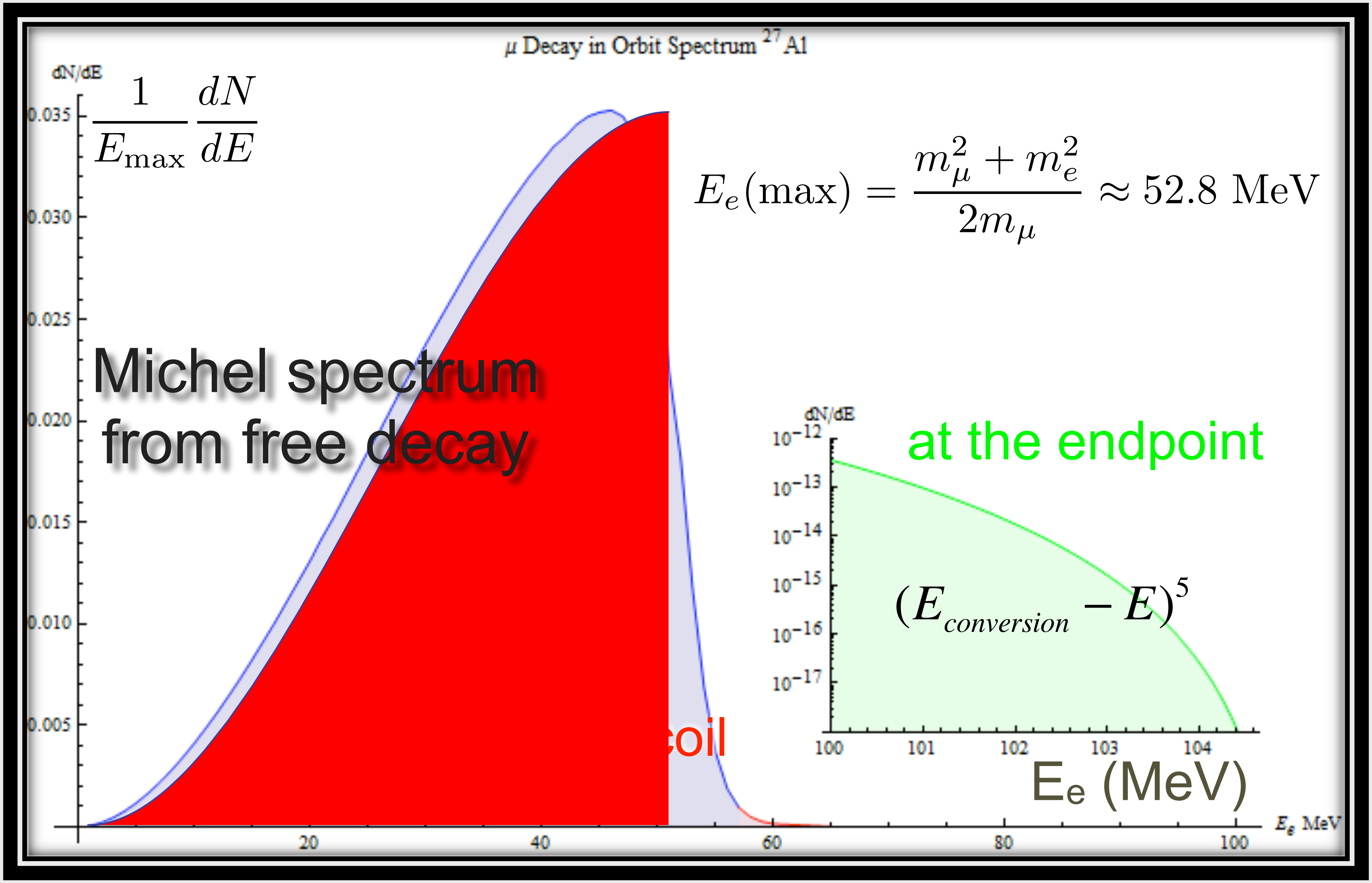


Decay-in-Orbit Shape

Szafron and Czarnecki , 1608.05447[hep-ph] 10.1103/PhysRevD.94.051301



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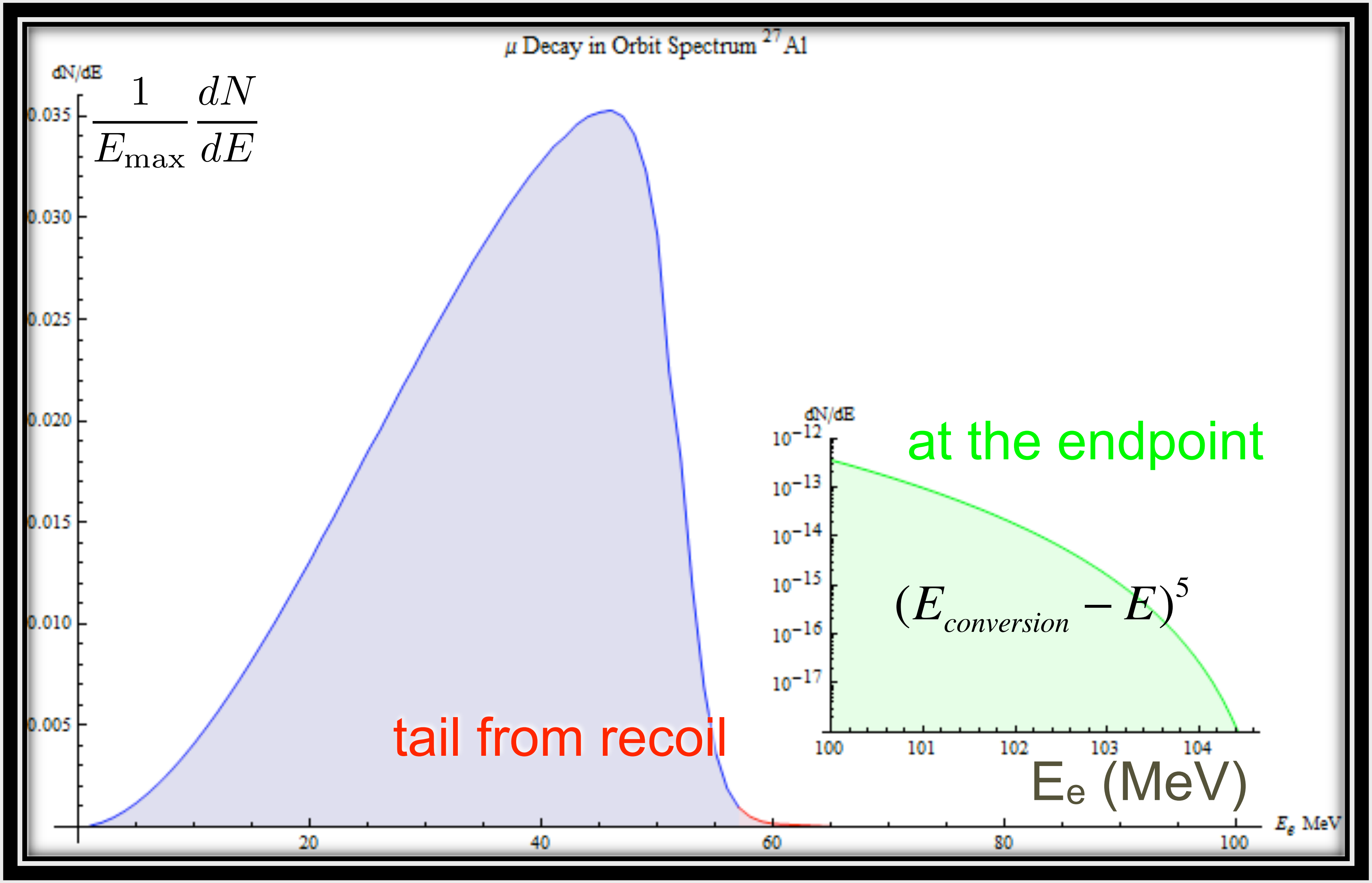

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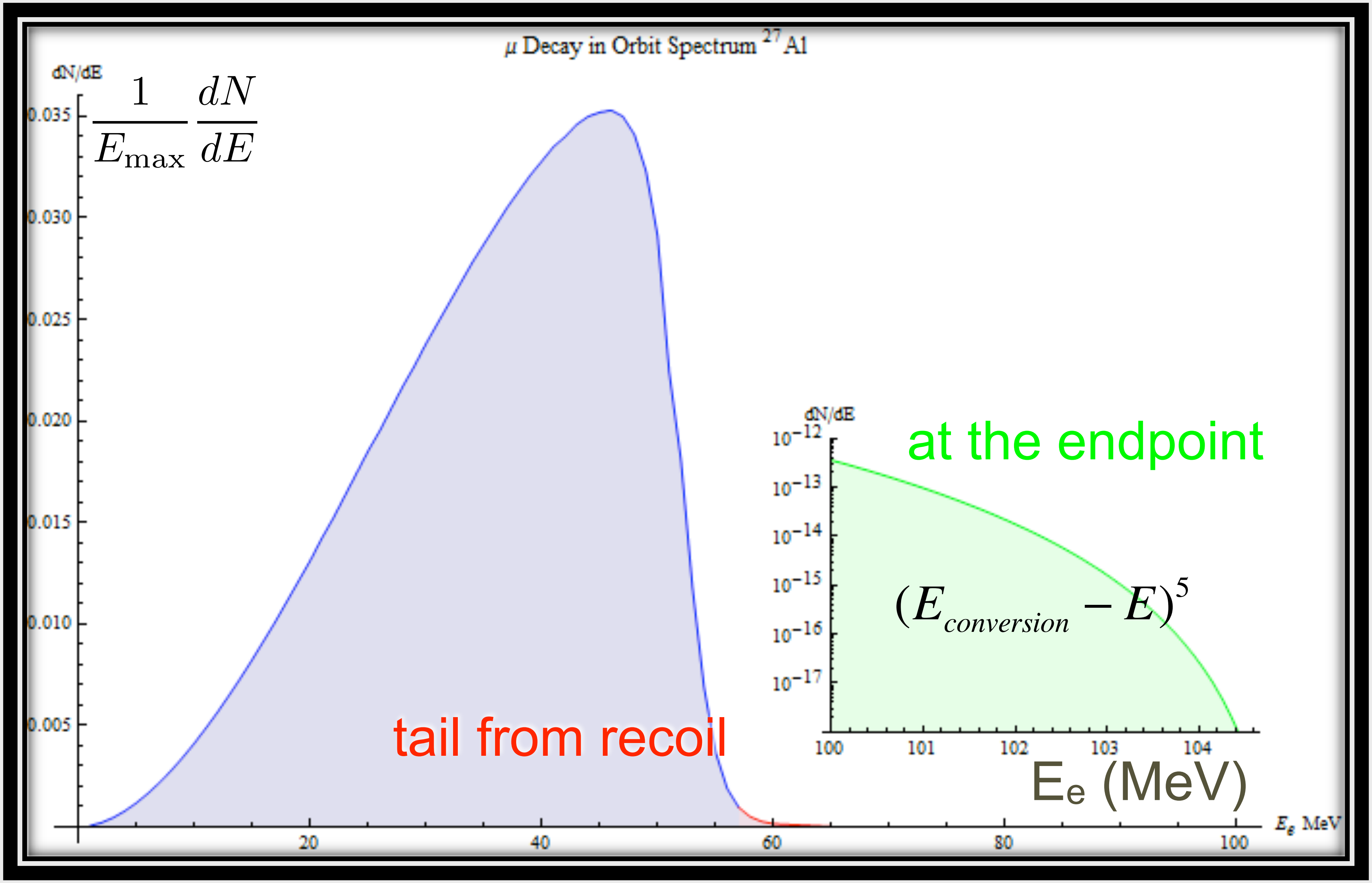


How Do We Suppress DIO?

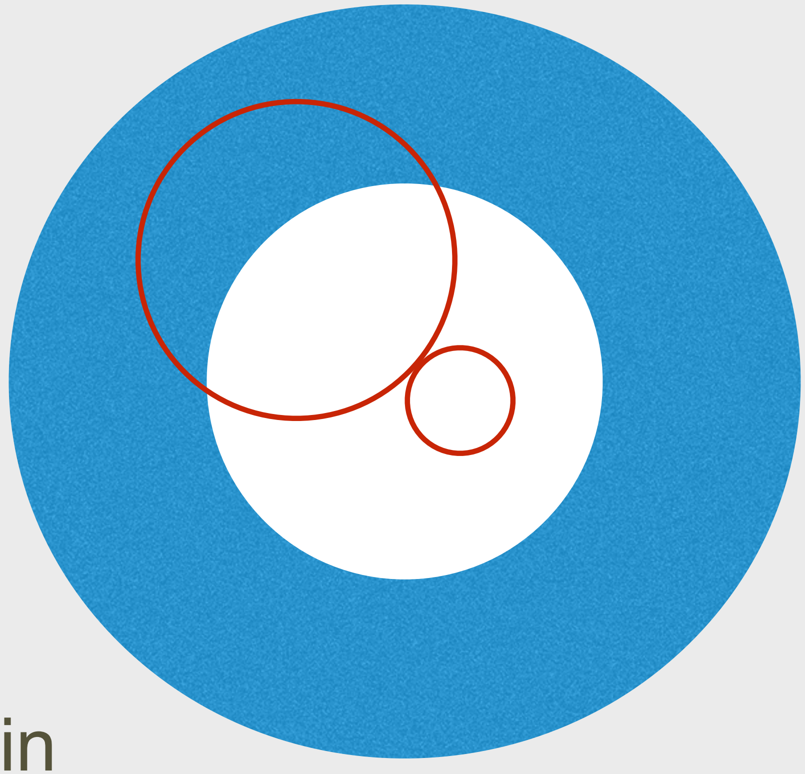
- Best possible energy resolution: we do not want DIO events near the endpoint resolution smeared upwards and promoted into the signal region, so we are sensitive to both the “gaussian width” and especially to “high side tails”
- We use a solenoidal field and annular detectors
  - $p=qBR$; p for Michel edge at 52.8 MeV is about 1/2 of conversion energy of 105 MeV.

Annular Detectors

Looking along detector axis

105 MeV signal

- This design gives us a few 10^5 muons to reconstruct instead of ~ 10^{18} from the distorted DIO spectrum
- Making it possible to have a small DIO background



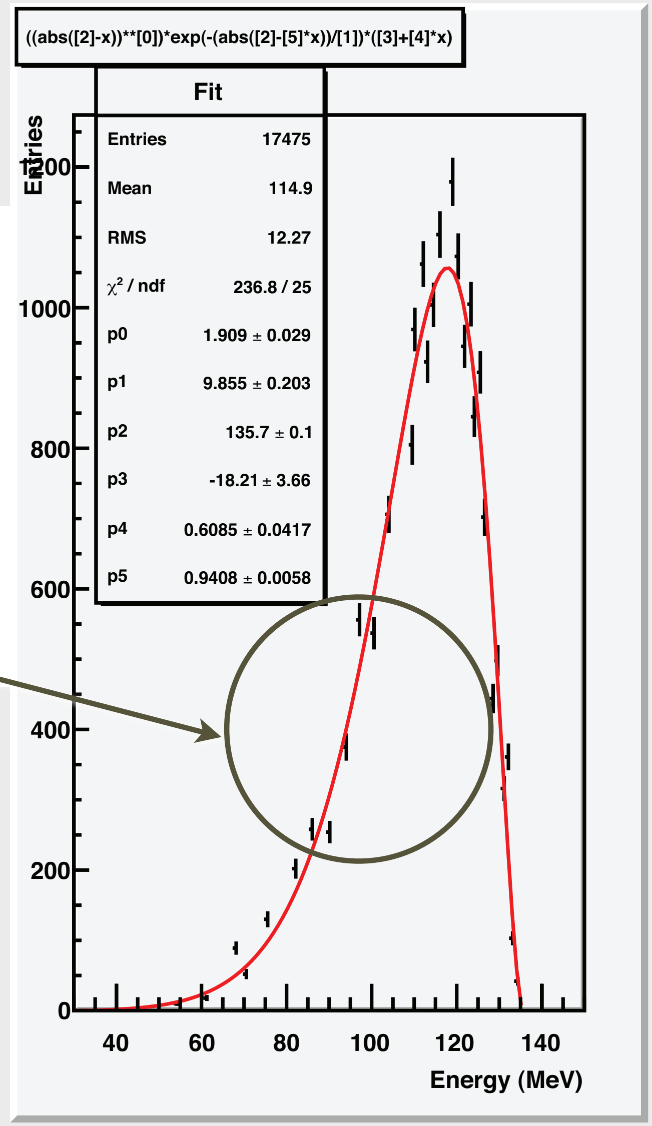
p=qBR again

52.8 MeV/c background

Prompt Backgrounds

Particles produced by proton pulse which interact almost immediately when they enter the detector: π, neutrons, pbars

- **Radiative pion capture**, π-+A(N,Z) $\rightarrow \gamma$ +X.
  - γ up to m_π, peak at 110 MeV; $\gamma \rightarrow$ e+e- ; if one electron ~ 100 MeV in the target, looks like signal: ***limitation in best existing experiment, SINDRUM II?***



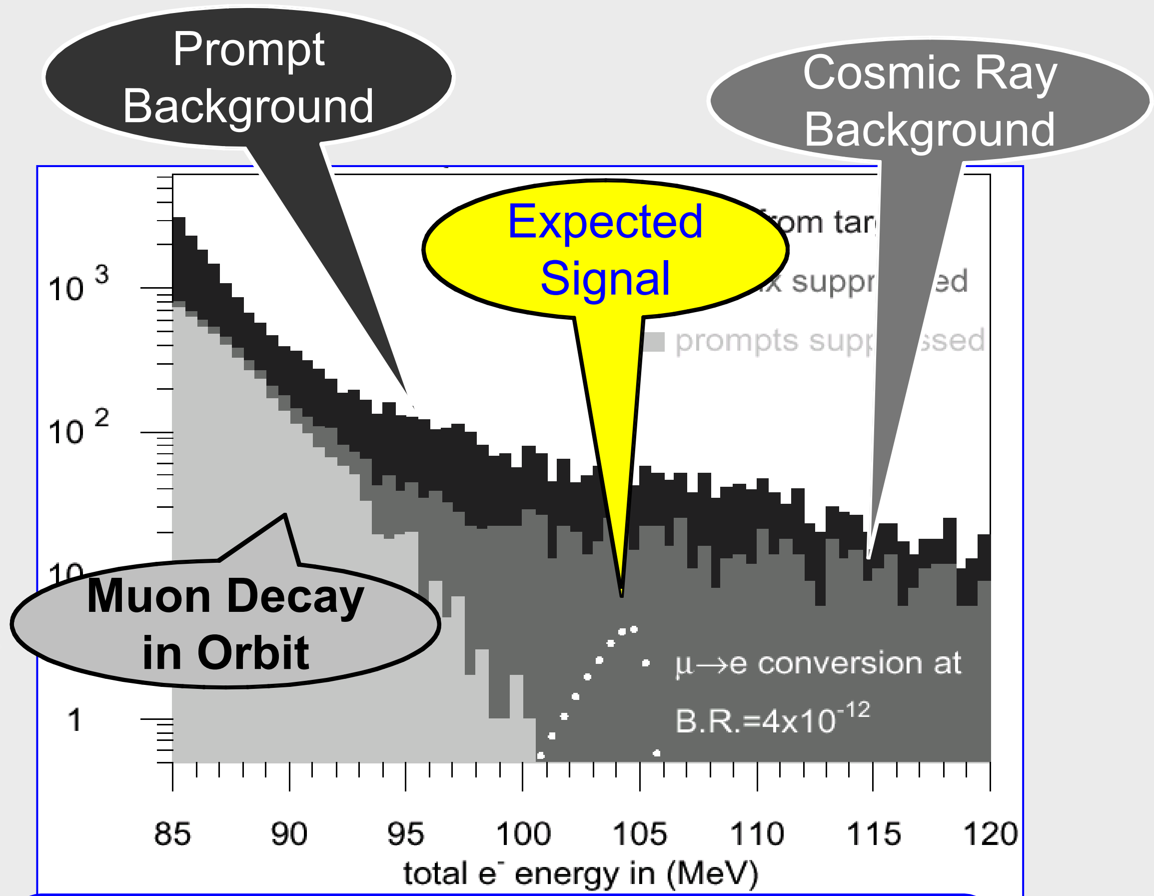
energy spectrum of γ measured on Mg
J.A. Bistirlich, K.M. Crowe et al., Phys Rev C5, 1867 (1972)

also included internal conversion, $\pi^- N \rightarrow e^+ e^- X$

Previous Best Experiment

SINDRUM-II

- $R_{\mu e} < 6.1 \times 10^{-13}$ in Au
- Want to probe to 6×10^{-17}
- $\approx 10^4$ improvement



Experimental signature is 105 MeV e^- originating in a thin Ti stopping target

SINDRUM-II Results

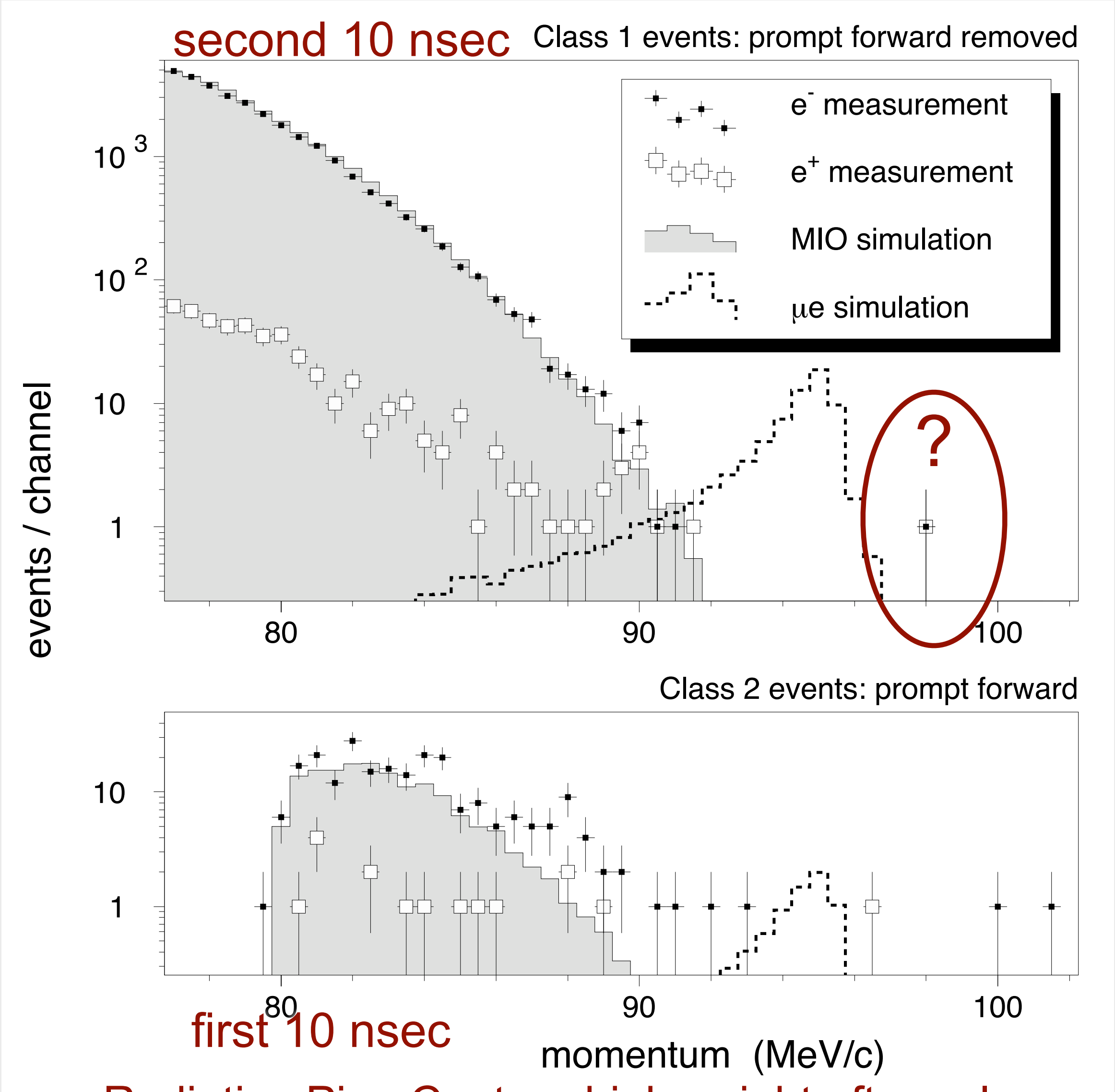
- Final Results on Au:

$$B_{\mu e}^{\rm Au} < 7 \times 10^{-13} \text{ @ } 90\% \text{ CL}$$

51 MHz (20 nsec) repetition rate, width of pulse ~0.3 nsec

not enough time separation between
signal and prompt
background:
can't scale this method up
10^4

W. Bertl et al., Eur. Phys. J. C 47, 337–346 (2006)



Radiative Pion Capture higher right after pulse

How Can We Do Better?

>10^3 increase in muon intensity from SINDRUM

Requiring

Pulsed Beam to Eliminate prompt backgrounds like radiative π capture and CR

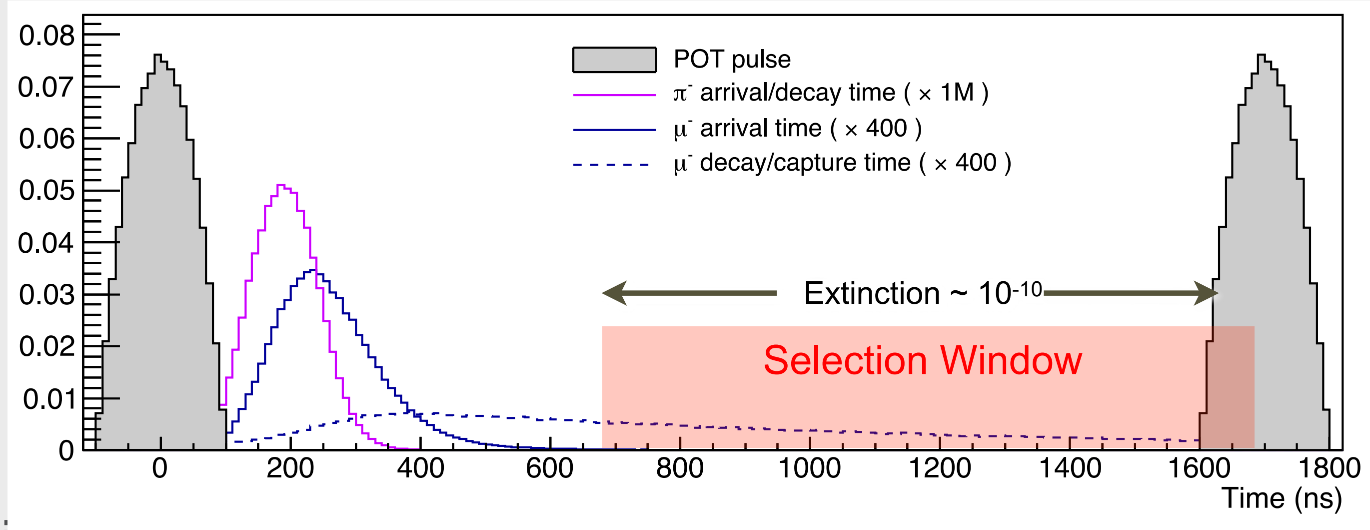
wait for pions to decay after pulse

protons out of beam pulse/ protons in beam-pulse < 10^{-10}
and we must measure it

Pulsed Beam Structure

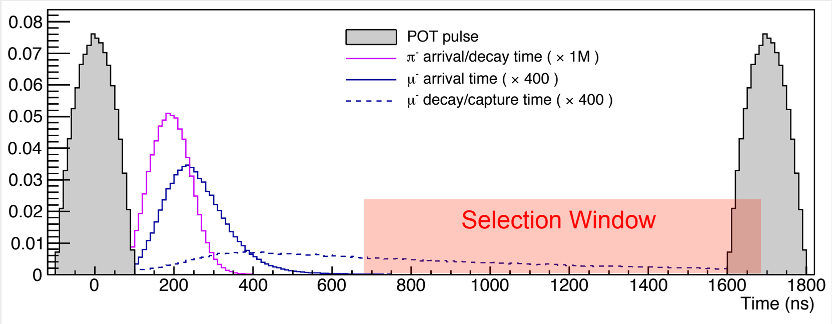
- Tied to prompt rate and machine: FNAL "perfect"
- Want pulse duration << τ_μ^{Al}, pulse separation ≈ τ_μ^{Al}
  - FNAL Ring has circumference 1.7μsec , $\sim \times 2\tau_\mu^{\text{Al}}$
- Extinction between pulses $\leq 10^{-10}$ needed

  = # protons out of pulse/# protons in pulse



Prompt Background and Choice of Z

choose Z based on tradeoff between rate and lifetime: longer lived reduces prompt backgrounds



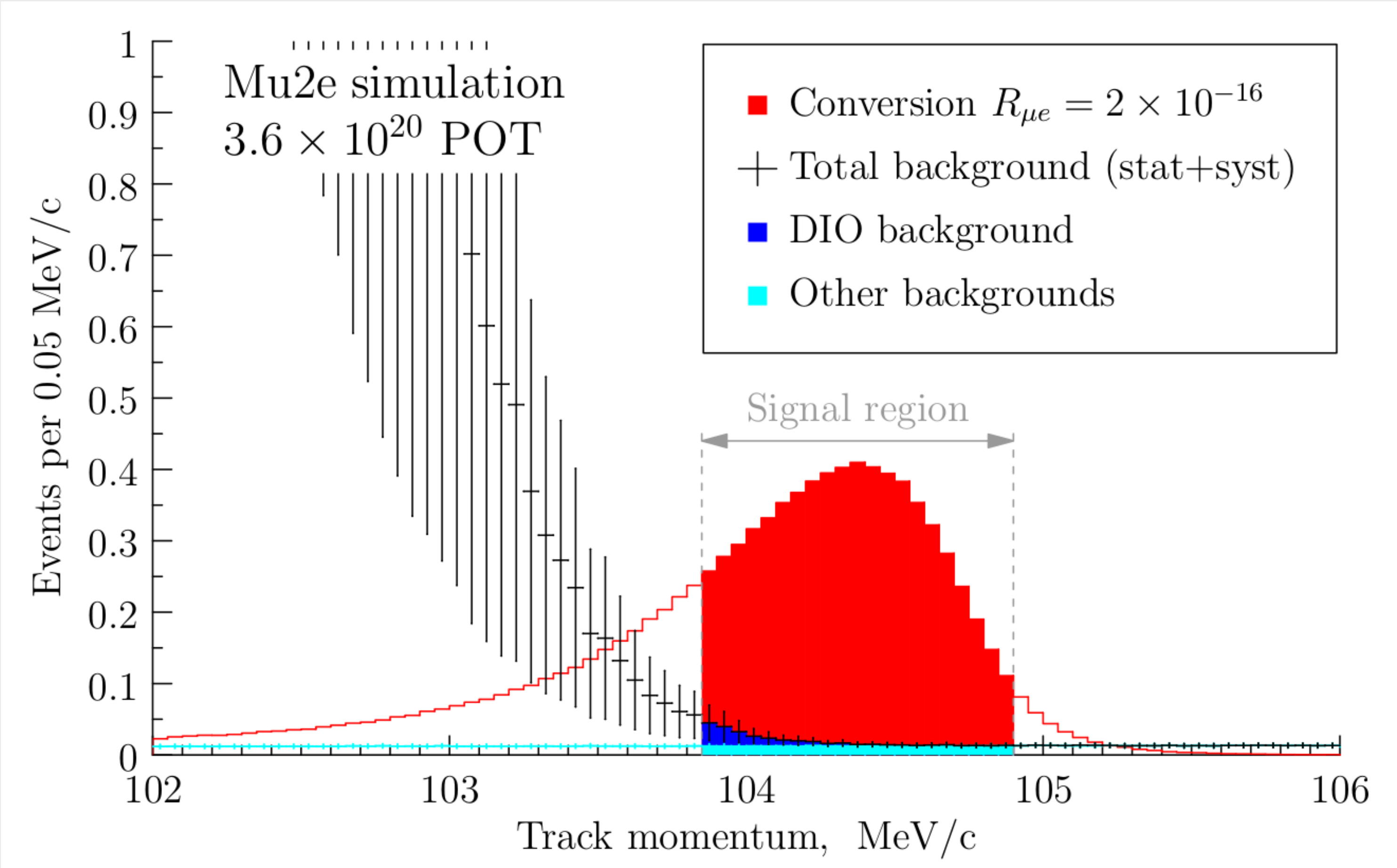
Nucleus	$R_{\mu e}(Z)$ / $R_{\mu e}(Al)$	Bound Lifetime	Conversion Energy
Al(13,27)	1	864 nsec	104.96 MeV
Ti(22,~48)	1.7	328 nsec	104.18 MeV
Au(79,~197)	~0.8-1.5	72.6 nsec	95.56 MeV

Signal and Background

- Full GEANT4 modeling and reconstruction without any truth input

$5\sigma \sim 2 \times 10^{-16}$

90% CL $\sim 8 \times 10^{-17}$



typical SUSY at 10^{-15}: 40 events vs 0.4 bkg

Final Backgrounds

- For $R_{\mu e}$ = 10^{-15}
  ~40 events / 0.40 bkg
- For $R_{\mu e}$ = 10^{-16}
  ~4 events / 0.40 bkg

Process	Expected event yield
Cosmic ray muons	$0.21 \pm 0.02(\text{stat}) \pm 0.06(\text{syst})$
DIO	$0.14 \pm 0.03(\text{stat}) \pm 0.11(\text{syst})$
Antiprotons	$0.040 \pm 0.001(\text{stat}) \pm 0.020(\text{syst})$
Pion capture	$0.021 \pm 0.001(\text{stat}) \pm 0.002(\text{syst})$
Muon DIF	< 0.003
Pion DIF	$0.001 \pm < 0.001$
Beam electrons	$(2.1 \pm 1.0) \times 10^{-4}$
RMC	$0.000^{+0.004}_{-0.000}$
Total	$0.41 \pm 0.13(\text{stat+syst})$

Outline

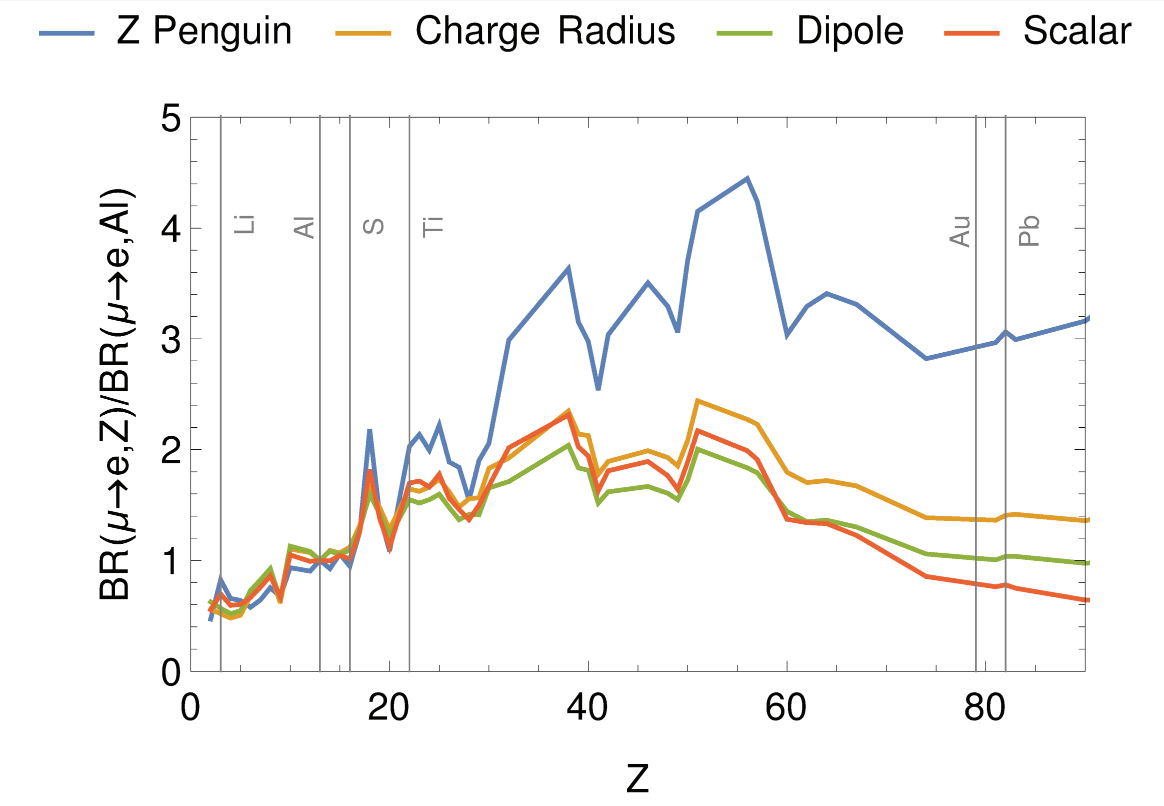
- The search for muon-electron conversion
- Experimental Technique
- *Mu2e Upgrades*
- Conclusions

Mu2e Upgrades

- Next Step in cLFV Program:

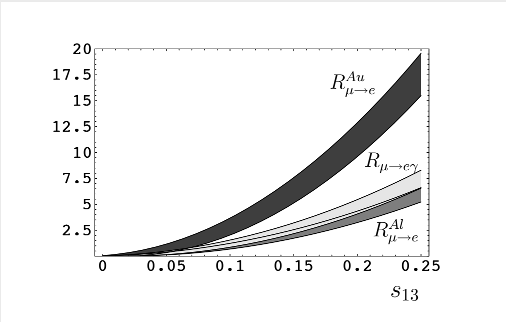
Conversion at Higher Atomic Number

- Model Discrimination and Possibly Larger Signal at high Z
- if Mu2e sees a signal, this is the obvious next step
- if not, we should try for another x10-100 better constraints



adapted from V. Cirigliano, B. Grinstein, G. Isidori, M. Wise **Nucl.Phys.B728:121-134,2005**

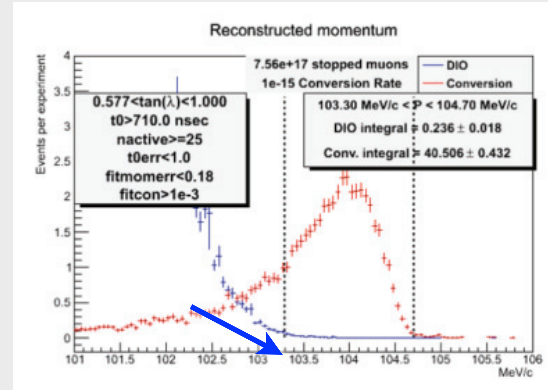
Upgrade Plans...



Signal?

Yes

No



1. Change Z of Target to determine source of new physics

2. Prompt Rates will go up at higher Z, have to redesign detector and muon transport

1. Both Prompt and DIO backgrounds must drop to measure $R_{\mu e} \sim 10^{-18}$

2. Detector, Muon Transport, Cosmic Ray Veto, Calorimeter

Mu2e-II

- x10 upgrade of Mu2e, probably with Ti target
- Task Force formed
  - LOIs at Snowmass (13 on various aspects)
    - new calorimeter, tracker, upgraded CRV
- And LOIs for a muon program post Mu2e-II with PSI and FNAL experiments

https://www.snowmass21.org/docs/files/summaries/RF/SNOWMASS21-RF5_RF0_Frank_Porter-106.pdf

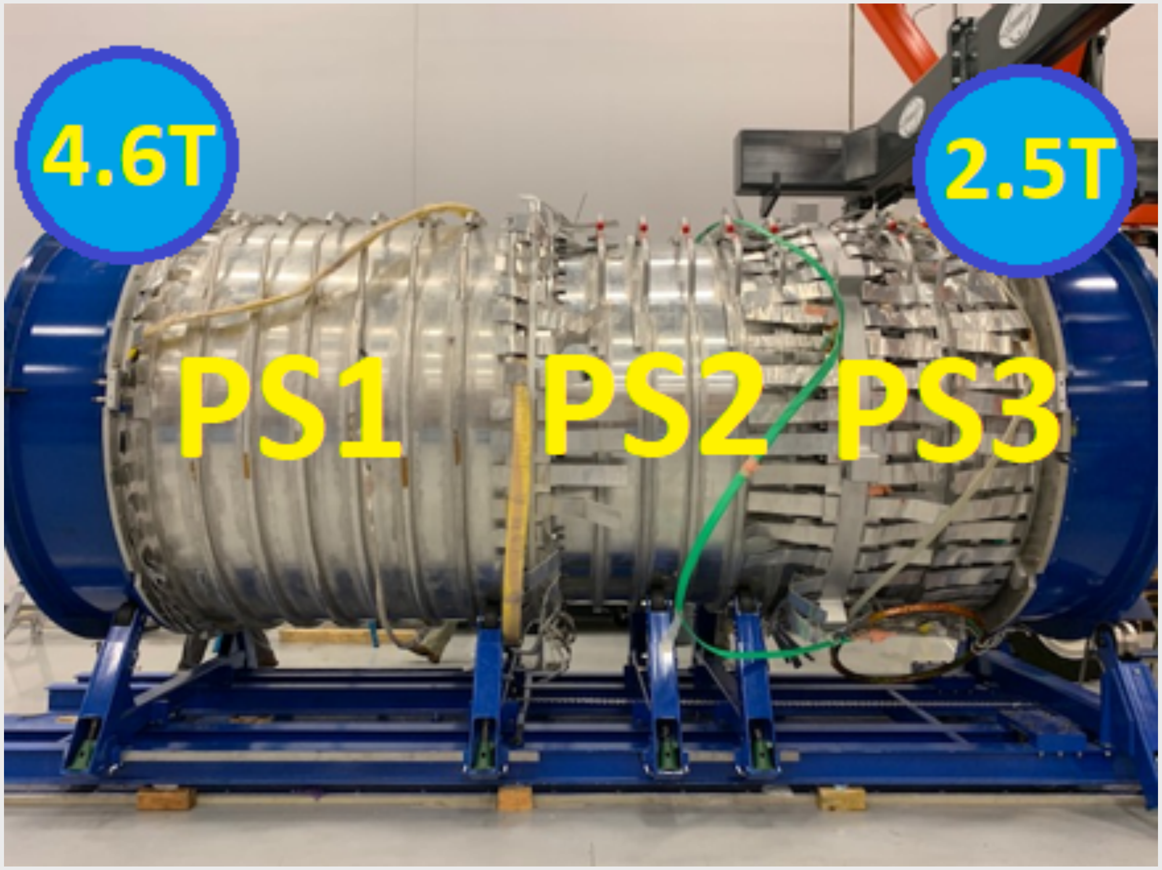
https://www.snowmass21.org/docs/files/summaries/RF/SNOWMASS21-RF5_RF0-AF5_AF0_Robert_Bernstein-027.pdf

Solenoid Status

- Transport Solenoid: about ready to go in Hall

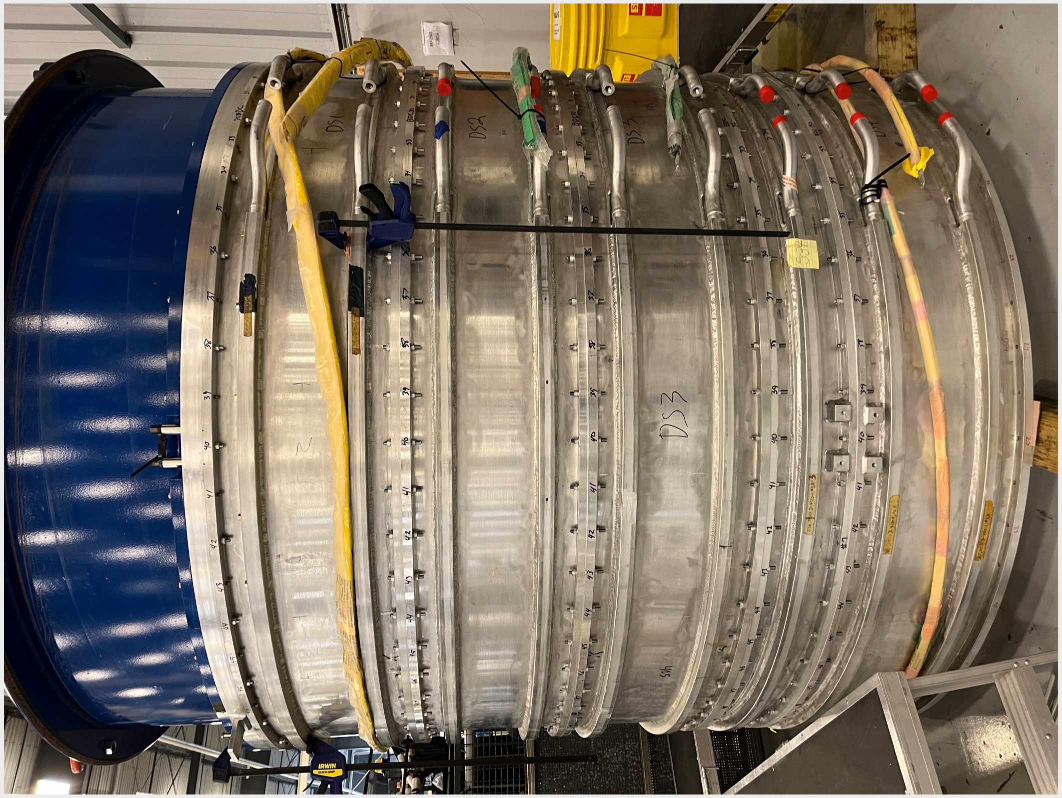
Solenoid Status

- Production Solenoid



Detector Solenoid

- Coils wound, in assembly (3 like this): tracker, calorimeter will fit inside this

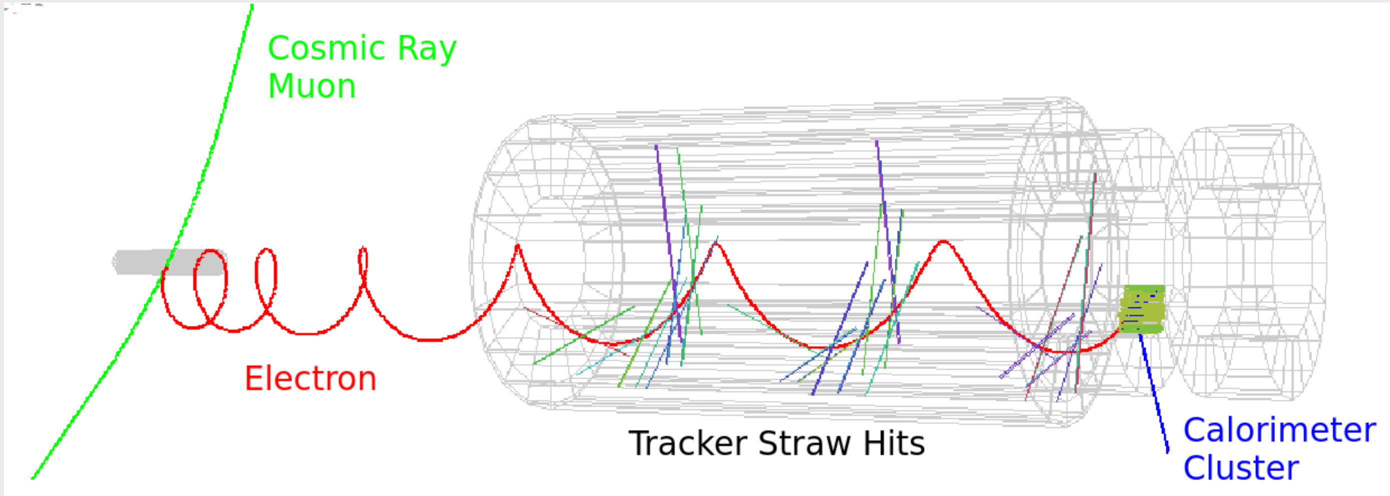


Calorimeter

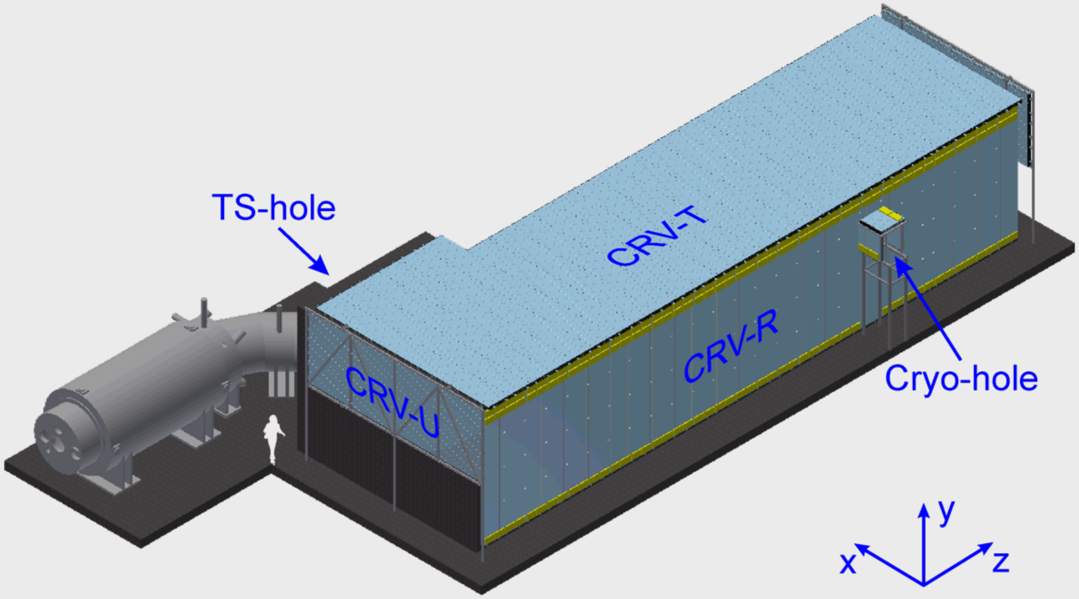
- Two disks, each 674 CsI crystals
- Fast energy measurement
  - for the trigger
  - combined with tracker momentum for PID
  - clusters can be used to seed track fit

Cosmic Ray Veto

- Would expect ~1 background/ day from cosmic muons; CRV must be 99.99% efficient



finished and shipped to FNAL; debugging readout



Tracker

- High Resolution (180 keV FWHM) momentum measurement
  - minimize energy loss with low mass straws
  - dual-end readout for location along straw

5mm diameter, 15 μ thick

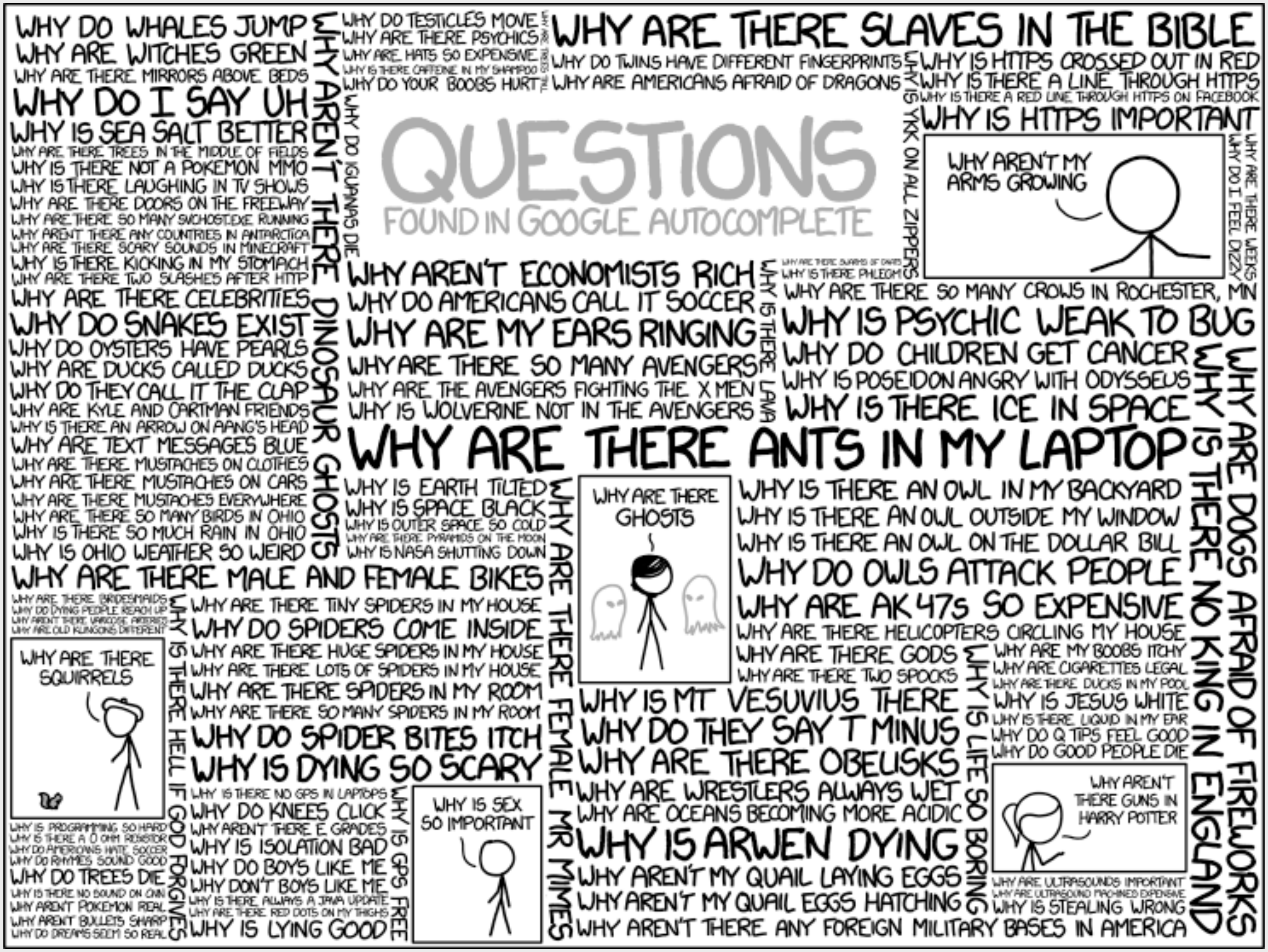
36 planes = 216 panels

Schedule

- Data-taking 2025-6
- x100 existing in a few weeks of running
- x1000 in under a year before LBNF/PIP-II Shutdown
- 4-5 years of running for full data set

Conclusions

- Mu2e will:
  - Reduce the limit for $R_{\mu e}$ by more than four orders of magnitude, x10 in mass reach ($R_{\mu e} < 8 \times 10^{-17}$ @ 90% C.L.)
  - Discover unambiguous proof of new physics or
  - Set powerful constraints on a wide variety of models
- Mu2e will therefore both complement LHC results and independently probe up to 10^4 TeV/c^2
- With upgrades, we could extend the limit by up to two additional orders of magnitude, study the details of new physics, and build a new rare muon process program


QUESTIONS
FOUND IN GOOGLE AUTOCOMPLETE
WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SVCHOST.EXE RUNNING
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES ON CARS
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY AREN'T THERE DINOSAUR GHOSTS
WHY DO TESTICLES MOVE
WHY ARE THERE PSYCHICS
WHY ARE HATS SO EXPENSIVE
WHY IS THERE CAFFEINE IN MY SHAMPOO
WHY DO YOUR BOOBS HURT
WHY DO IGUANAS DIE
WHY ARE THERE SLAVES IN THE BIBLE
WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY IS YKK ON ALL ZIPPERS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT
WHY AREN'T MY ARMS GROWING
WHY ARE THERE WEEKS
WHY DO I FEEL DIZZY
WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS
WHY IS THERE LAVA
WHY IS THERE PHLEGM
WHY ARE THERE SO MANY CROWS IN ROCHESTER, MN
WHY IS PSYCHIC WEAK TO BUG
WHY DO CHILDREN GET CANCER
WHY IS POSEIDON ANGRY WITH ODYSSEUS
WHY IS THERE ICE IN SPACE
WHY ARE THERE ANTS IN MY LAPTOP
WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN
WHY ARE THERE GHOSTS
WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOCKS
WHY ARE MY BOOBS ITCHY
WHY ARE CIGARETTES LEGAL
WHY ARE THERE DUCKS IN MY POOL
WHY IS JESUS WHITE
WHY IS THERE LIQUID IN MY EAR
WHY DO Q TIPS FEEL GOOD
WHY DO GOOD PEOPLE DIE
WHY AREN'T THERE GUNS IN HARRY POTTER
WHY ARE ULTRASOUNDS IMPORTANT
WHY IS STEALING WRONG
WHY IS THERE NO KING IN ENGLAND
WHY ARE DOGS AFRAID OF FIREWORKS
WHY ARE THERE MALE AND FEMALE BIKES
WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY ARE OLD KLINGONS DIFFERENT
WHY ARE THERE SQUIRRELS
WHY IS THERE HELL IF GOD FORGIVES
WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY
WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A JAVA UPDATE
WHY ARE THERE RED DOTS ON MY THIGHS
WHY IS LYING GOOD
WHY IS GPS FREE
WHY IS SEX SO IMPORTANT
WHY IS PROGRAMMING SO HARD
WHY IS THERE A 0 OHM RESISTOR
WHY DO AMERICANS HATE SOCCER
WHY DO RHYMES SOUND GOOD
WHY DO TREES DIE
WHY IS THERE NO SOUND ON CNN
WHY AREN'T POKEMON REAL
WHY AREN'T BULLETS SHARP
WHY DO DREAMS SEEM SO REAL
WHY ARE THERE FEMALE MR MIMES
WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA
WHY IS LIFE SO BORING