Searches for Lepton Flavor Violation

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BLV17
May 15, 2017
Charged lepton flavor violation

- The existence of neutrino oscillations is proof of the violation of lepton flavor conservation in the $\nu$ sector, as well as evidence for BSM physics (e.g., see-saw).
- Is there also observable charged lepton flavor violation (CLFV)?
  - In the Standard Model (+ heavy neutrinos), CLFV is very small, e.g.,

$$B(\mu \rightarrow e\gamma) = \frac{3\alpha}{32\pi} \left| \sum_{i=2,3} U_{\mu i}^* U_{ei} \frac{\Delta m_{1i}^2}{M_W^2} \right|^2 < 10^{-54}$$

- Thus CLFV searches are a clean probe of new physics
- Many models predict CLFV processes to occur in an observable regime
- Sensitivity to CLFV in loop processes can exceed that in direct production
  - There are many distinct experimental probes and a rich phenomenology, leading to a robust experimental scene
  - The form of the CLFV Yukawa coupling matrix is model-dependent, e.g., it could be PMNS-like or CKM-like?
  - Different theories predict distinct correlations between CLFV processes
    Should, for example, $\mu \rightarrow e\gamma$ decay be observed, it is important to understand the rate of $\mu$ to $e$ conversion or $\tau \rightarrow \mu\gamma$ decay
CLFV Processes

- Low energy probes: rare $\mu$, $\tau$ and $h$ decays, $\mu \rightarrow e$ conversion, CLFV in meson decay

$\mu^+ \rightarrow e^+\gamma$

$\tau \rightarrow \mu\gamma, e\gamma$

$(g-2)_\mu$

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

$\mu, \tau \rightarrow 3\ell$

$B \rightarrow \ell\ell'$

$B \rightarrow X_s\ell\ell'$

Higgs decay: $h^0 \rightarrow \tau\mu$ (also $\tau e, \mu e$)
The new CLFV physics

\[ \mu^+ \rightarrow e^+ \gamma \]
\[ \mu^- N \rightarrow e^- N \]
\[ \mu^+ \rightarrow e^+ e^+ e^- \]

\[ \mu \rightarrow e \quad \gamma, Z, h \]
\[ q \rightarrow q \quad \gamma, Z, h \]

\[ \mu \rightarrow e \quad Z' \]
\[ q \rightarrow q \quad LQ \]

+ analoguous \( \tau \) decay processes

CLFV rates and ratios are sensitive probes of underlying model
New Physics contributions to $\mu \rightarrow e$ conversion

$\mu N \rightarrow e N$ is sensitive to a wide variety of New Physics models, e.g., SUSY, 2HDM, Extra Dimensions, LeptoQuarks, GUTs, LHT,…
Model-independent Effective Lagrangian

\[ \mathcal{L}_{\text{CLFV}} = \frac{m_\mu}{(1 + \kappa)\Lambda^2} \bar{\mu}_R \sigma_{\mu\nu} e_L F^{\mu\nu} + \frac{\kappa}{(1 + \kappa)\Lambda^2} \bar{\mu}_L \gamma_\mu e_L (\bar{u}_L \gamma_\mu u_L + \bar{d}_L \gamma_\mu d_L) + h.c. \]

\[ \mu \rightarrow e\gamma \]

\[ \mu \rightarrow eee \]

\[ \mu - e \text{ conversion} \]

CLFV processes have unique sensitivity to New Physics at high mass scales

Derived from A. de Gouvêa, P. Vogel, Prog.Part.Nucl.Phys 71, 75 (2013)
Purely leptonic case: $\mu \rightarrow e\gamma$, $\mu \rightarrow 3e$

$$L_{\text{CLFV}} = \frac{m_\mu}{(1+\kappa)^2} \mu_R \sigma_{\mu\nu} e_L F_{\mu\nu} + \frac{\kappa}{(1+\kappa)^2} \mu_L \gamma_\mu e_L (\bar{e}_L \gamma_\mu e_L) + h.c.$$
• Bounds on CLFV couplings to the Higgs can be derived from LHC limits as well as conventional leptonic processes.
## Current CLFV limits

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<th>Process</th>
<th>Current Limit</th>
<th>Next Generation exp</th>
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<td>( \tau \rightarrow \mu \eta )</td>
<td>( \text{BR} &lt; 6.5 \times 10^{-8} )</td>
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<td>( \tau \rightarrow \mu \gamma )</td>
<td>( \text{BR} &lt; 6.8 \times 10^{-8} )</td>
<td>( 10^{-9} - 10^{-10} ) (Belle II)</td>
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<td>( \tau \rightarrow \mu \mu \mu )</td>
<td>( \text{BR} &lt; 3.2 \times 10^{-8} )</td>
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<td>( \tau \rightarrow eee )</td>
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<td>( K_L \rightarrow e\mu )</td>
<td>( \text{BR} &lt; 4.7 \times 10^{-12} )</td>
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<td>( K^+ \rightarrow \pi^+e^-\mu^+ )</td>
<td>( \text{BR} &lt; 1.3 \times 10^{-11} )</td>
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<td>( B^0 \rightarrow e\mu )</td>
<td>( \text{BR} &lt; 7.8 \times 10^{-8} )</td>
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<td>( B^+ \rightarrow K^+e\mu )</td>
<td>( \text{BR} &lt; 9.1 \times 10^{-8} )</td>
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<tr>
<td>( \mu^+ \rightarrow e^+\gamma )</td>
<td>( \text{BR} &lt; 4.2 \times 10^{-13} )</td>
<td>( 10^{-14} ) (MEG Upgrade)</td>
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<tr>
<td>( \mu^+ \rightarrow e^+e^-\nu )</td>
<td>( \text{BR} &lt; 1.0 \times 10^{-12} )</td>
<td>( 10^{-16} ) (Mu3e)</td>
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<td>( \mu N \rightarrow eN )</td>
<td>( R_{\mu e} &lt; 7.0 \times 10^{-13} )</td>
<td>( 10^{-17} ) (Mu2e, COMET)</td>
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### Limits on Higgs CLFV couplings

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<tr>
<th>Channel</th>
<th>Coupling</th>
<th>Bound</th>
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<td>$\mu \to e\gamma$</td>
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<td>Y_{\mu e}</td>
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<td>$\mu \to 3e$</td>
<td>$\sqrt{</td>
<td>Y_{\mu e}</td>
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<tr>
<td>electron $g - 2$</td>
<td>Re($Y_{e\mu} Y_{\mu e}$)</td>
<td>$-0.019 \ldots 0.026$</td>
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<td>electron EDM</td>
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<td>$\mu \to e$ conversion</td>
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<td>Y_{\mu e}</td>
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<td>$M - \tilde{M}$ oscillations</td>
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<td>Y_{\mu e} Y_{\mu e}^*</td>
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<td>$\tau \to e\gamma$</td>
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<td>Y_{\tau e}</td>
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<td>$\tau \to e\mu\mu$</td>
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<td>Y_{\tau e}</td>
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<tr>
<td>electron $g - 2$</td>
<td>Re($Y_{e\tau} Y_{\tau e}$)</td>
<td>$[-2.1 \ldots 2.9] \times 10^{-3}$</td>
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</tr>
<tr>
<td>muon $g - 2$</td>
<td>Re($Y_{\mu \tau} Y_{\tau \mu}$)</td>
<td>$(2.7 \pm 0.75) \times 10^{-3}$</td>
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<tr>
<td>muon EDM</td>
<td>Im($Y_{\mu \tau} Y_{\tau \mu}$)</td>
<td>$-0.8 \ldots 1.0$</td>
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<tr>
<td>$\mu \to e\gamma$</td>
<td>$(</td>
<td>Y_{\tau \mu} Y_{\tau e}</td>
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Higgs Yukawa coupling limits
Model discrimination through correlations

Calibbi et al 1408.0754

A. Vicente & C.E. Yaguna - Scotogenic model, N_1-N_1 annihilation region

Rate \mu N \rightarrow e N

B(\mu \rightarrow e\gamma)

Model discrimination through correlations

There are correlations in the $\tau \rightarrow \mu \gamma$ and $\ell \ell \ell$ branching fractions.

$\mathcal{B}(\tau \rightarrow \mu \gamma)$ vs. $\mathcal{B}(\tau \rightarrow e \gamma)$ in a general fourth generation scenario (Buras)

$\mathcal{B}(\tau \rightarrow \mu \gamma)$ vs. $\mathcal{B}(\tau \rightarrow e \gamma)$ are anticorrelated. Seeing both modes would be evidence against a fourth generation.
Chronology of $\mu$ and $\tau$ CLFV searches

![Chronology of $\mu$ and $\tau$ CLFV searches](image)

- **Cosmic $\mu$**
- **$\pi$ Beam**
- **$e^+e^-\rightarrow\tau^+\tau^-$**
- **$\mu$ Beam**
- **$\mu \rightarrow e\gamma$**
- **$\mu \rightarrow 3e$**
- **$\mu N \rightarrow eN$**
- **$\tau \rightarrow \mu\gamma$**
- **$\tau \rightarrow 3\mu$**

- **SINDRUM**
- **SINDRUM II**
- **MEG**

Year:
- 1940
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010
- 2020
- 2030

Limit (90% CL):
- $10^{-18}$
- $10^{-16}$
- $10^{-14}$
- $10^{-12}$
- $10^{-10}$
- $10^{-8}$
- $10^{-6}$
- $10^{-4}$
- $10^{-2}$
- $10^{0}$
Chronology of $\mu$ and $\tau$ CLFV searches

- Mu3e I
- Mu3e II
- Year
- $\tau \rightarrow \mu \gamma$
- $\tau \rightarrow 3\mu$
- $\mu \rightarrow e\gamma$
- $\mu \rightarrow 3e$
- $\mu N \rightarrow eN$
- $\pi$ beam
- $e^+e^- \rightarrow \tau^+\tau^-$
- $\mu$ beam
- SINDRUM
- SINDRUM II
- MEG
- MEG Upgrade
- DeeMe
- Mu3e I
- Mu3e II
- Mu2e/COMET II
- Mu2e II/PRIME
- Caltech
- David Hitlin
- BLV17
- May 15, 207
Limits on CLFV $\tau$ decays
Backgrounds: the name of the game

• At the sensitivities required to advance the state of the art in both $\tau$ decays and muon experiments, the primary issue is control of backgrounds in a high rate environment
  • Irreducible backgrounds
  • Accidental backgrounds

• Problematic backgrounds are specific to the type of experiment

• Handles on background control are
  • Charged particle energy resolution
  • Neutral energy resolution
  • Time resolution
  • Particle identification
  • Prompt beam particle rejection
  • Cosmic ray rejection

• New muon experiments
  • MEG upgrade
  • Mu3e
  • DeeMe, Mu2e, COMET

• New $\tau$ decay experiments
  • Belle II
  • LHCb
Belle II $\tau$ CLFV limits

- The target integrated luminosity of 50 ab$^{-1}$ ($\sim$5x10$^{10}$ $\tau\bar{\tau}$) will be reached in ~2025
- The improvement in sensitivity to CLFV $\tau$ decays depends on whether or not a particular mode has backgrounds
  - e.g., limits on $B(\tau \rightarrow \ell\ell\ell)$ improve as $1/\int \mathcal{L} dt$ if there is no background, but more slowly, as $\sim (1/\int \mathcal{L} dt)^{1/2}$, if there is background
Muon experiments: CW vs pulsed beams

- Muon decay experiments $\mu \rightarrow e\gamma, \mu \rightarrow eee$ need a continuous $\mu^+$ beam, such as the PSI synchrocyclotron surface muon beam
- The dominant backgrounds come from accidental coincidences of two decays
  - $\text{bkg} \propto (\text{rate})^2$
  - $\text{signal} \propto \text{rate}$

- $\mu \rightarrow e$ conversion experiments need a pulsed $\mu^-$ beam, such as FNAL or J-PARC
  - many (prompt) pion-induced backgrounds immediately after the proton pulse
  - Use the muon/pion lifetime difference to reduce background

CW operation optimizes the S/N

Pulsed operation optimizes the S/N
Muon experiments: CW vs pulsed beams

- Muon decay experiments $\mu^{-} \rightarrow e\gamma, \mu^{-} \rightarrow eee$ need a continuous $\mu^{+}$ beam, such as the PSI synchrocyclotron surface muon beam.

- The dominant backgrounds come from accidental coincidences.
  - Background: $bkg = \mu^{-} \text{rate}^2$
  - Signal: $\mu^{-} \text{rate}$

Muons decay into charged leptons and gamma-rays. The muons decay into $e\gamma$ and $eee$ channels.

- CW operation optimizes the S/N
- Pulsed operation optimizes the S/N

The graph shows the distribution of events over time, with peaks corresponding to different decay channels. The live window is highlighted to denote the optimal timing for signal detection.
MEG upgrade signal and backgrounds

\[ \mu^+ \rightarrow e^+ \gamma \]
\[ \mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e \gamma \]
\[ \mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e \gamma \]

CLFV signal \( \propto R_\mu \)
Radiative muon decay correlated \( \propto R_\mu \)
Accidental background uncorrelated \( \propto R_\mu \)

Events are described by five variables: \( E_\gamma, E_e, t_{e\gamma}, \theta_{e\gamma}, \phi_{e\gamma} \)
MEG backgrounds

• Backgrounds are proportional to:

\[
\left( \frac{R_\mu}{D} \right) (\Delta t_{e\gamma}) \left( \frac{\Delta E_e}{m_\mu / 2} \right) \left( \frac{\Delta E_\gamma}{15 m_\mu / 2} \right)^2 \left( \frac{\Delta \theta_{e\gamma}}{2} \right)^2
\]

• uncorrelated backgrounds \( \propto \) instantaneous rate
• electron-photon time resolution
• electron momentum resolution
• square of photon energy resolution, since background due to integral of photon spectrum of \( \mu \rightarrow e \nu \nu \gamma \sim (1 - 2E_\gamma/m_\mu) \)
• Square of electron-photon angular resolution

• These considerations dictated original MEG design and the improvements incorporated in the upgrade

Stop \( 10^7 \) muons/sec in 150\( \mu \) kapton target
MEG result and upgrade goal

- MEG has the best current limit on $\mathcal{B}(\mu^+ \rightarrow e^+ \gamma)$
- Uses a surface muon beam: DC, $|p_\mu| 28$ Mev/c, $10^8 \mu/s$
- With a total of $7.5 \times 10^{14}$ stopped muons, gathered in runs from 2009 through 2013, they set a 90% CL limit of $< 4.2 \times 10^{-13}$ (Baldini et al., Eur.Phys.J. C76434, 2016)
- The MEG Upgrade will improve the detector to achieve a 90% CL limit of $< 5 \times 10^{-14}$ in a three year run

- Upgrade schedule
  - Engineering Run 2017 to test LXe modifications and timing
  - Full Engineering Run July 2018
  - Data Fall 2018
  - Upgrades to PSI to modify the surface beam target station
MEG upgrade

Liquid Xenon Gamma-ray Detector

COBRA Superconducting Magnet

Gamma ray

Drift Chamber

single-volume He:iC$_4$H$_{10}$
small stereo cells

Positron Timing Counter

30ps resolution w/ multiple hits

Radiative Decay Counter

better uniformity w/ VUV-sensitive 12x12mm$^2$ SiPM

x2 resolution everywhere

full available intensity 7x10$^7$/s

Muon

Positron

further reduction of radiative BG
MEG upgrade

MEG: 216 PMTs on inner face

Upgrade: ~4000 MPPCs on inner face
Mu3e

- **Current limit:** $1.0 \times 10^{-12}$ (SINDRUM at PSI, 1988)
- Mu3e at PSI will provide substantial improvement
  - Phase I 2018 - $\pi E5$ beamline $10^8 \mu^+/s$
    - Sensitivity $10^{-15}$
  - Phase II - HIMB $10^9 \mu^+/s$
    - Sensitivity $10^{-16}$
Mu3e sensitivity

Mu3e Phase I

$10^{15}$ muon stops at $10^8$ muons/s

$\mu \rightarrow eee$ at $10^{-12}$

$\mu \rightarrow eee$ at $10^{-13}$

$\mu \rightarrow eee$ at $10^{-14}$

$\mu \rightarrow eee$ at $10^{-15}$

Events per 0.2 MeV/c$^2$

$m_{rec}$ [MeV/c$^2$]
Mu3e sensitivity

Mu3e Phase I

10^{15} muon stops at 10^{8} muons/s

μ → eee

μ → eee at 10^{-12}

μ → eee at 10^{-13}

Bhabha Michel

Events per 0.2 MeV/c^2

Mu3e Phase I

10^8 muon stops/s

18.4% signal efficiency

SINDRUM 1988

SES

90% C.L.

95% C.L.

2 \times 10^{15}

BR(μ → eee)

Data taking days

Caltech

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BLV17

May 15, 207
### $\mu$ to $e$ conversion experiments

- Signal is a single monoenergetic electron
- If $N = \text{Al}$, $E_e \sim 105\text{ MeV}$
  - Electron energy depends on $Z$, due to atomic binding energy
- Coherent nuclear recoil

- There are four experiments in various stages of preparation
  - DeeMe
  - COMET Phase I and Phase II
  - Mu2e
  - PRISM/Prime

} Origins trace to MELC and MECO proposals

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

- High rates to achieve required sensitivity
- Prompt and delayed beam-related backgrounds
- Cosmic ray backgrounds
1) Generate a beam of low momentum muons
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2) Stop the muons in a target (C, SiC, Al, Ti, …..)
1) Generate a beam of low momentum muons
2) Stop the muons in a target (C, SiC, Al, Ti, …..)
   • In orbit around nucleus: $\tau_{\mu}^{\text{Al}} = 864 \text{ ns}$
   • Large $\tau_{\mu}^{\text{N}}$ is important for discriminating background
1) Generate a beam of low momentum muons
2) Stop the muons in a target (C, SiC, Al, Ti, ……)
3) Search for events consistent with $\mu N \rightarrow eN$
4) Discriminate against backgrounds from pion decays and interactions, muon decays in orbit (DIOs), radiative decays and cosmic rays
Decay-in-Orbit Shape

\[ \frac{1}{E_{\text{max}}} \frac{dN}{dE} \]

\[ E_e (\text{max}) = 52.8 \text{ MeV} \]
With $\mu$-$\text{Al}^{27}$ binding energy and radiative corrections
Decay-in-Orbit Shape

With $\mu$-Al$^{27}$ binding energy and radiative corrections

\[ \frac{1}{E_{\text{max}}} \frac{dN}{dE} \]

\[ \left( E_{\text{conversion}} - E \right)^5 \]

Czarnecki Szafron

David Hitlin BLV17 May 15, 207
DeeMe

• Directly search for $\mu \rightarrow e$ conversion in a high power target
  • High power, high purity proton beam from MLF at J-PARC
  • Initially a graphite target, then a rotating SiC target
  • Production and conversion target are the same

• Single event sensitivity (1 year = $2 \times 10^7$ sec) with 1MW beam
  • $1.2 \times 10^{-13}$
  • $2.5 \times 10^{-14}$ (4 years)

Upgrade to SiC
  • $2.1 \times 10^{-14}$
  • $5 \times 10^{-15}$ (4 years)
DeeMe status

- Will start with graphite target
- Detector components built
- Beamline (to be shared with other experiments such as g-2) scheduled for 2018
- PACMAN spectrometer magnet moved from TRIUMF
- The Mu2e sensitivity goal $2.6 \times 10^{-17}$ demands a total of $\sim 6 \times 10^{17}$ stopped muons in a 3 year run of $\sim 6 \times 10^7$ sec

- This requires a muon stopping rate of $10^{10}$/sec

### Experimental design

- Pulsed proton beam produce pions, which are captured in the backward direction
- Transport muons from pion decay, with momentum and sign selection
- Since electron backgrounds are at lower momentum than the sought conversion electrons, confine lower momentum particles to smaller helical radii in a solenoid and provide hole in tracker and calorimeter for them to pass through
- Reject cosmic ray events
What happens during a microbunch?

Use of pulsed proton beam and a delayed live gate allows suppression of prompt backgrounds by many orders of magnitude.

Proton pulses must be narrow.

Out-of-time protons must be suppressed by $O(10^{10})$.

Simulations encompass a full ~1 µs, including all the background overlays from the beam flash, $\mu$ capture products, neutrons, etc. and properly accounts for contributions from previous bunches.
What happens during a microbunch?

• Simulations encompass a full ~1µs, including all the background overlays from the beam flash, μ capture products, neutrons, etc., and properly accounts for contributions from previous bunches.

Use of pulsed proton beam and a delayed live gate allows suppression of prompt backgrounds by many orders of magnitude.

Proton pulses must be narrow.

Out-of-time protons must be suppressed by $O(10^{10})$.

(particles with hits within +/-40 ns of signal electron $t_{\text{mean}}$)

• Simulations encompass a full ~1µs, including all the background overlays from the beam flash, μ capture products, neutrons, etc., and properly accounts for contributions from previous bunches.
Cosmic ray veto (four layers)

Covers as much of the transport and detector solenoids as possible. Nonetheless, timing properties of the calorimeter are required to achieve required cosmic ray rejection.
Signal sensitivity for a three year run

Stopped $\mu$: $5.8 \times 10^{17}$

For $R = 10^{-16}$

$N_{\mu e} = 3.94 \pm 0.03$
$N_{DIO} = 0.19 \pm 0.01$
$N_{Other} = 0.19$

$SES = (2.5 \pm 0.1) \times 10^{-17}$

Errors are statistical only
Mu2e progress

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COMET Phase I

SES  \(3 \times 10^{-15}\)

or \(< 6 \times 10^{-15} \) @ 90% CL

for 150 days at 3.2 kW
COMET Phase II

SES (1.0 – 2.6) x 10^{-17} for 2 x 10^7 s at 56kW
### COMET Schedule

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**COMET Phase-I:**
- 2018 ~
- S.E.S. ~ $3 \times 10^{-15}$
- (for 150 days with 3.2 kW proton beam)

**COMET Phase-II:**
- 2022 ~
- S.E.S. ~ $(1.0-2.6) \times 10^{-17}$
- (for $2 \times 10^7$ sec with 56 kW proton beam)
Z dependence of mu to e conversion

Cirigliano, Kitano. Okada, Tuzon

Z

1. CR(\(\mu \rightarrow e, Z\))/CR(\(\mu \rightarrow e, Al\))
2. Z penguin
3. V(Z)
4. Z penguin

\(V(\gamma)\)

D SUSY GUTS
S SUSY
Seesaw
PIP2/Mu2e II

- PIP2 is an 800 MeV, 120 kW superconducting linac for LBNF and the muon campus
  - Currently under design
- There is also an active study of an upgrade of Mu2e
  - An order of magnitude increase in muon stops, but only a x3-5 increase in instantaneous rate
  - Detector systems must be upgraded
- Goals:
  - If $\mu \rightarrow e$ conversion has been found, use heavier targets to ascertain the $(A, Z)$-dependence of conversion rate
  - If conversion is not seen, improve sensitivity by an order of magnitude
Phase Rotated Intense Slow Muon source
PRISM Muon Electron conversion

- A muon storage ring, feeding a COMET-like channel and detector
- High muon intensity:
  - $(10^{11}-10^{12} \mu\text{-}s)$:
    - large 6D acceptance (FFAG),
- Pulsed beam >100 Hz,
- Low momentum, quasi-monoenergetic muons
- Pion contamination <10$^{-18}$
- Requires a multi-GeV 1-4 MeV proton driver
- Aims for SES- $3 \times 10^{-19}$
- Time scale beyond 2030
\( R_K \) and \( R_{K^*} \)

\[
R_K = \frac{\int_{q_{\text{min}}^2}^{q_{\text{max}}^2} d\Gamma[B^+ \to K^+ \mu^+ \mu^-] dq^2}{\int_{q_{\text{min}}^2}^{q_{\text{max}}^2} d\Gamma[B^+ \to K^+ e^+ e^-] dq^2}
\]

also \( R_{K^*} \), with \( B^0 \to K^{*0} \ell^+ \ell^- \)

\( Z' \) leptoquark

![Graphs and figures showing the relation between different decay modes and the leptons.]

LHCb

\[
R_K = 0.745^{+0.090}_{-0.074} \text{(stat.)} \pm 0.036 \text{(syst.)}
\]

![Graphs showing the comparison of \( R_K \) with the Standard Model predictions.]
Outlook

- Current limits on charged lepton flavor violation provide useful constraints on New Physics models
- Over the next decade, improved $\tau$ decay, $\mu$ decay, leptonic and semileptonic meson decay and $\mu \rightarrow e$ conversion experiments will have the sensitivity to probe the regime predicted by many New Physics models
  - Sensitivities reach beyond what is possible in direct production of new particles at the LHC
  - Should evidence for CLFV be found, comparison of branching ratios and conversion rates would be diagnostic of specific models