Measurement of the branching ratio of radiative muon decay at the Fermilab Muon g-2 experiment

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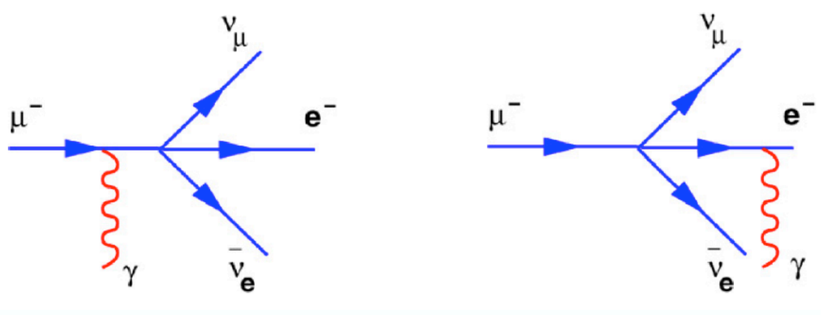
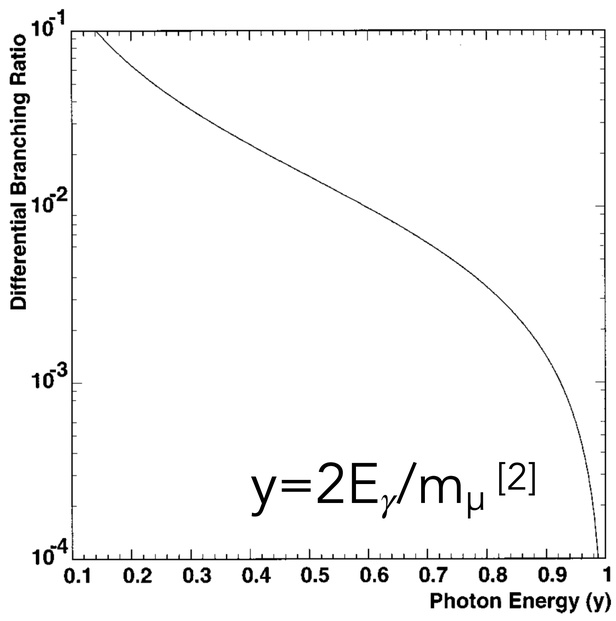
I. Radiative decay of muon



- Branching ratio from PDG[1]
  - $\mathcal{B}(\mu^+ \to e^+ \nu_e \bar{\nu}_\mu) \approx 1$,
  - $\mathcal{B}_{\mathrm{RMD}} = \mathcal{B}(\mu^+ \to e^+ \nu_e \bar{\nu}_\mu \gamma) = 0.014\ (E_\gamma > 10\ \mathrm{MeV})$
  - $\mathcal{B}(\mu^+ \to e^+ \nu_e \bar{\nu}_\mu e^+ e^-) = 3 \times 10^{-5}$



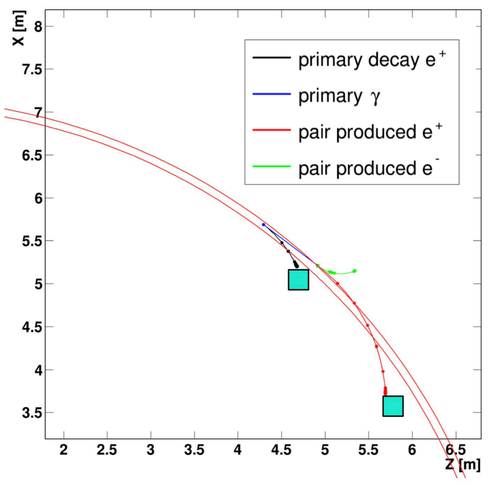
- **Precision test of the Standard Model (SM):**
  - One of the Michel parameters[3], the eta (η) parameter, can be measured ***only*** via RMD[4,5,6].
  - Deviation from the SM prediction hints at new physics
- **Current status of RMD measurements**
  - PIBETA[7] and MEG[8] experiments - muons decay at **rest**
  - Difficulties in detecting the soft photon
  - Only **a tiny phase space** of RMD is probed

II. G-2 Muon storage ring[9] and RMD

- **Relativistic** muons (3.1 GeV/c) constrained to a circular orbit by the 1.5-T of magnetic field

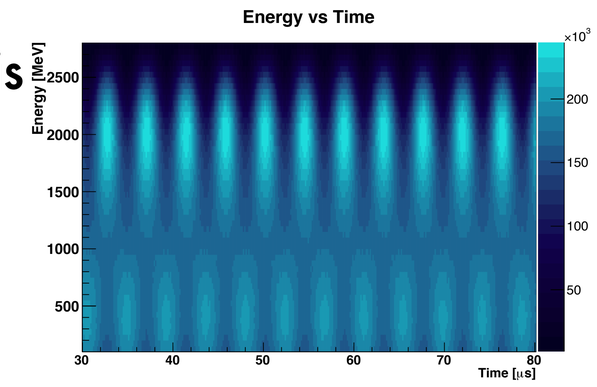
  The maximum RMD Photon energy boosted from 52.8 MeV in rest frame to **3 GeV** in lab frame
- **24 electronmagnetic calorimeters** distributed in the interior of the storage ring

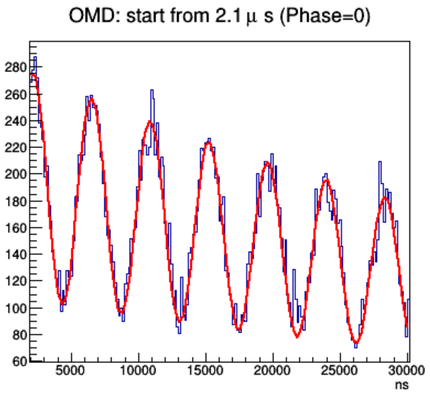
  Discriminant variables can be constructed

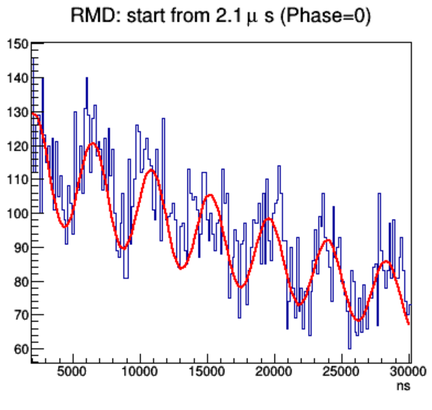


III. Geant4 simulation

- **Simulation-based analysis**
  - Pseudo data constructed as a mixture of RMD and OMD events

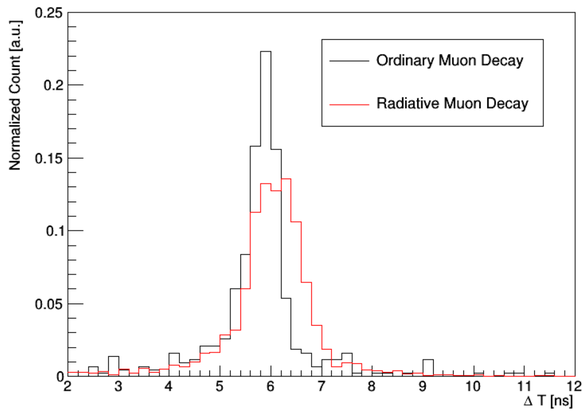


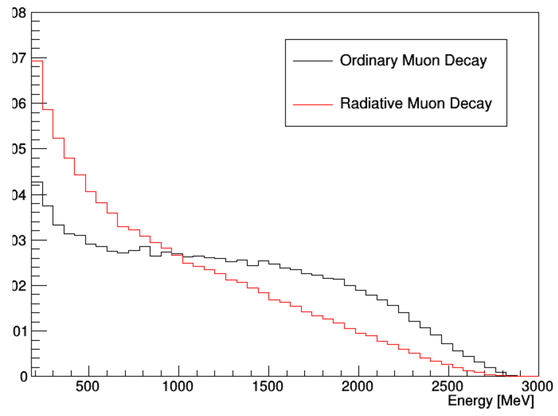




IV. Event topology and data analysis

- **Energy spectrum and ΔT distribution**



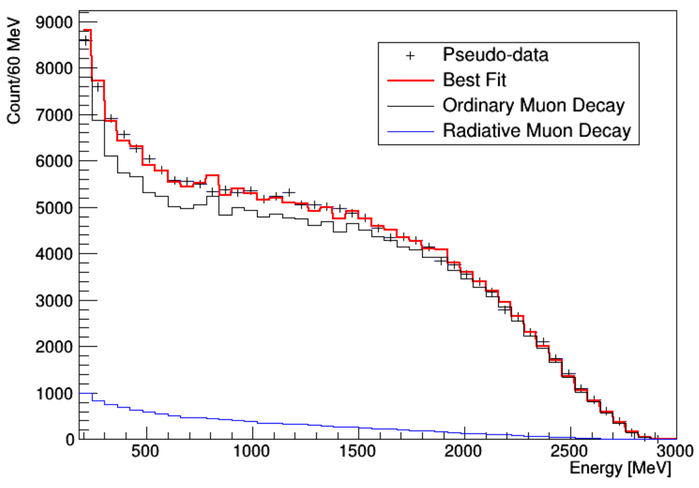


Discriminant	Selections	ϵ_{OMD}	ϵ_{RMD}
ΔT	2 consecutive calos E≥200 MeV	0.14%	0.14%
E	E≥200 MeV	57.0%	33.3%

- **Template fitting strategy**

$$f_{\mathrm{fit}}(x) = a \times f_{\mathrm{RMD}}(x) + (1-a) \times f_{\mathrm{OMD}}(x)$$

$$\mathcal{B}_{\mathrm{RMD}} = \frac{a/\epsilon_{\mathrm{RMD}}}{(1-a)/\epsilon_{\mathrm{OMD}} + a/\epsilon_{\mathrm{RMD}}}$$



- From ***E*** fit

  Br = (8.9±1.3)%
- From ***ΔT*** fit

  Br = (18±8)%

Pseudo-data	$\mathcal{B}_{\mathrm{RMD}}$ [%]
10% RMD	8.9 ± 1.3
20% RMD	19.4 ± 1.1
30% RMD	29.3 ± 0.9
40% RMD	39.4 ± 0.8
50% RMD	49.6 ± 0.6

- The energy method is also validated with several pseudo-data
- With more statistics, the results could be further improved

Scan of pseudo data

References

[1] Particle Data Group, Prog. Theor. Exp. Phys. (2020)
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[7] VanDevender, Brent Adam, An experimental study of radiative muon decay, PhD thesis
[8] A. M. Baldini et al. (MEG), Eur. Phys. J. C 76, 108 (2016)
[9] J. Grange et al. Muon (g-2) Technical Design Report (2015)