Spin-dependent muon to electron conversion and muon to positron conversion

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Spin dependent muon to electron conversion

Introduction

muon to electron conversion in a muonic atom

$$\mu^- + N \to e^- + N$$

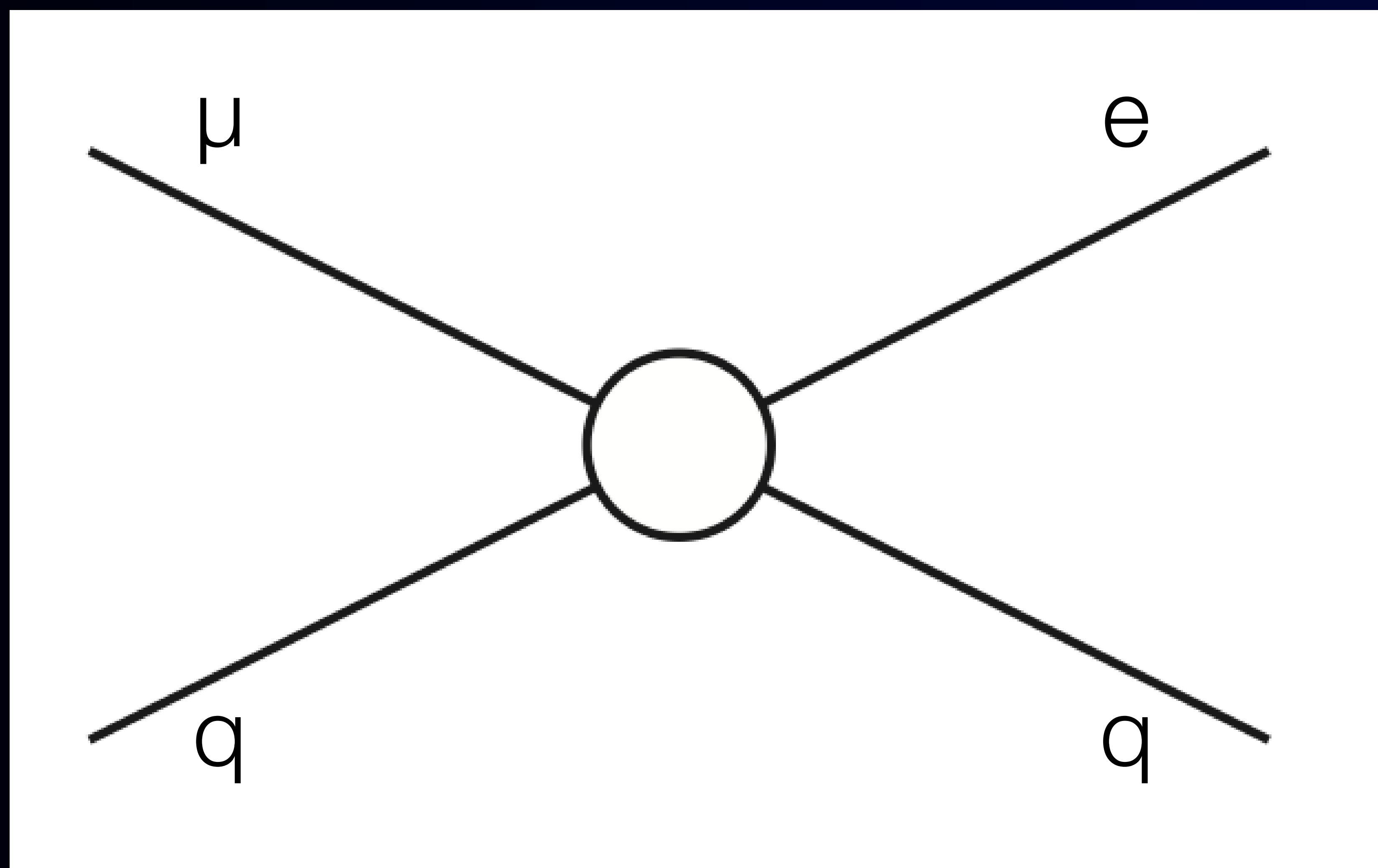
(charged lepton flavour violation)

Lepton flavour

	electron number	muon number	tau number
e generation	1	0	0
μ generation	0	1	0
τ generation	0	0	1

If found …

μ□ □ □□□ □□□□ □□□□□



CLFV Effective Interactions

Dipole interaction

Four Fermi interaction

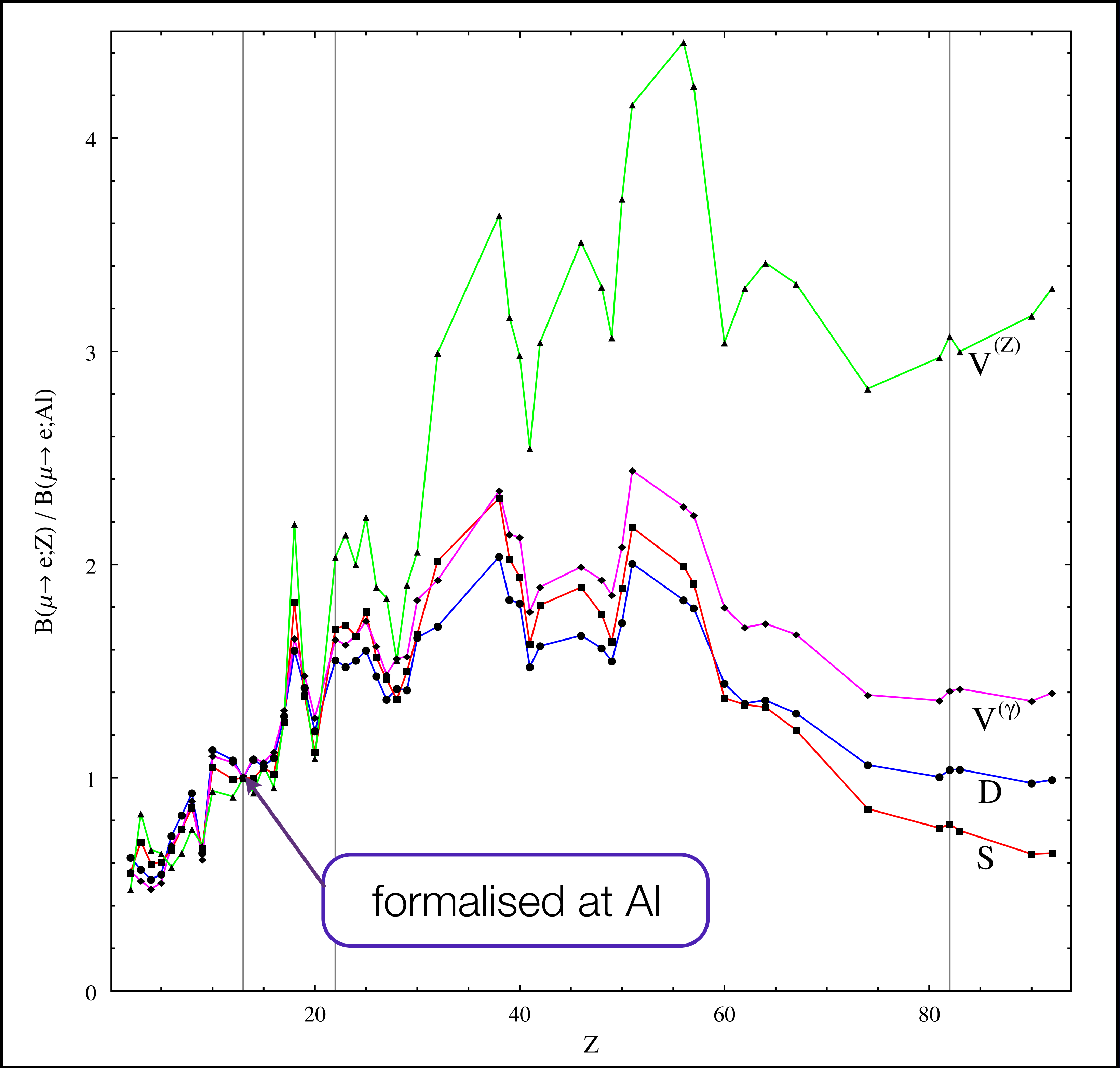
dipole interaction

vector interaction

scalar interaction

Coherent
μ-e Conversion
(spin independent)

μ-e Conversion : Target dependence (discriminating effective interaction)



V. Cirigliano, R. Kitano, Y. Okada, and P. Tuzon, Phys. Rev. D80, 013002 (2009)

vector interaction (with Z boson)	with Z penguin
vector interaction (with photon - charge radius)	left-right models
dipole interaction	SUSY-GUT
scalar interaction	SUSY seesaw

Effective Lagrangian for μ→e Conversion

$$\delta\mathcal{L} = -2\sqrt{2}G_F \sum_{q=u,d,s} \sum_{Y} \sum_{O} C^{qq}_{O,Y} \mathcal{O}^{qq}_{O,Y} + h.c. \qquad (1)$$

where $Y \in \{L, R\}$ and $O \in \{V, A, S, T\}$ and the operators are explicitly given by $(P_{L,R} = 1/2(I \mp \gamma_5))$

$$\begin{aligned}
\mathcal{O}^{qq}_{V,Y} &= (\bar{e}\gamma^{\alpha} P_Y \mu)(\bar{q}\gamma_{\alpha} q) \\
\mathcal{O}^{qq}_{A,Y} &= (\bar{e}\gamma^{\alpha} P_Y \mu)(\bar{q}\gamma_{\alpha}\gamma_5 q)
\end{aligned}$$

$$\mathcal{O}^{qq}_{S,Y} = (\bar{e}P_Y\mu)(\bar{q}q) \qquad \mathcal{O}_{D,Y} = m_{\mu}(\bar{e}\sigma^{\alpha\beta}P_Y\mu)F_{\alpha\beta}$$

$$\mathcal{O}^{qq}_{T,Y} = (\bar{e}\sigma^{\alpha\beta} P_Y \mu)(\bar{q}\sigma_{\alpha\beta} q)\ . \qquad (2)$$

CLFV Effective Interactions

Dipole interaction

Four Fermi interaction

dipole interaction

vector interaction

scalar interaction

Coherent
μ-e Conversion
(spin independent)

axial vector interaction

tensor interaction

Incoherent
μ-e Conversion
(spin dependent)

Spin dependent μ-e conversion (Model Independent) - first ariticle

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Spin-dependent $\mu \to e$ conversion

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ABSTRACT

The experimental sensitivity to $\mu \to e$ conversion on nuclei is expected to improve by four orders of magnitude in coming years. We consider the impact of $\mu \to e$ flavour-changing tensor and axial-vector four-fermion operators which couple to the spin of nucleons. Such operators, which have not previously been considered, contribute to $\mu \to e$ conversion in three ways: in nuclei with spin they mediate a spin-dependent transition; in all nuclei they contribute to the coherent (A^2-enhanced) spin-independent conversion via finite recoil effects and via loop mixing with dipole, scalar, and vector operators. We estimate the spin-dependent rate in Aluminium (the target of the upcoming COMET and Mu2e experiments), show that the loop effects give the greatest sensitivity to tensor and axial-vector operators involving first-generation quarks, and discuss the complementarity of the spin-dependent and independent contributions to $\mu \to e$ conversion.

Spin dependent μ-e conversion (Model Independent) - second preprint

"Spin-dependent" $\mu \to e$ Conversion on Light Nuclei

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Abstract

The experimental sensitivity to $\mu \to e$ conversion will improve by four or more orders of magnitude in coming years, making it interesting to consider the "spin-dependent" (SD) contribution to the rate. This process does not benefit from the atomic-number-squared enhancement of the spin-independent (SI) contribution, but probes different operators. We give details of our recent estimate of the spin dependent rate, expressed as a function of operator coefficients at the experimental scale, and explore the prospects for distinguishing coefficients by using different targets. For this purpose, a geometric representation of different targets as vectors in coefficient space is introduced. It is found that comparing the rate on isotopes with and without spin could allow to detect spin dependent coefficients that are at least a factor of few larger than the spin independent ones. Distinguishing among the axial, tensor and pseudoscalar operators that induce the SD rate would require calculating the nuclear matrix elements for the second two. Comparing the SD rate on nuclei with an odd proton vs odd neutron could allow to distinguish operators involving u quarks from those involving d quarks; this is interesting because the distinction is difficult to make for SI operators.

Muon to positron conversion

μ- to e+ conversion

$\mu^- + \mathrm{Ti} \rightarrow e^+ + \mathrm{Ca(gs)}$ 1.7×10^{-12}
$\mu^- + \mathrm{Ti} \rightarrow e^+ + \mathrm{Ca(ex)}$ 3.6×10^{-11}

$\mu^- + N(Z) \rightarrow e^+ + N^*(Z-2)$

Lepton number violation (LNV) and CLFV = CLNLFV

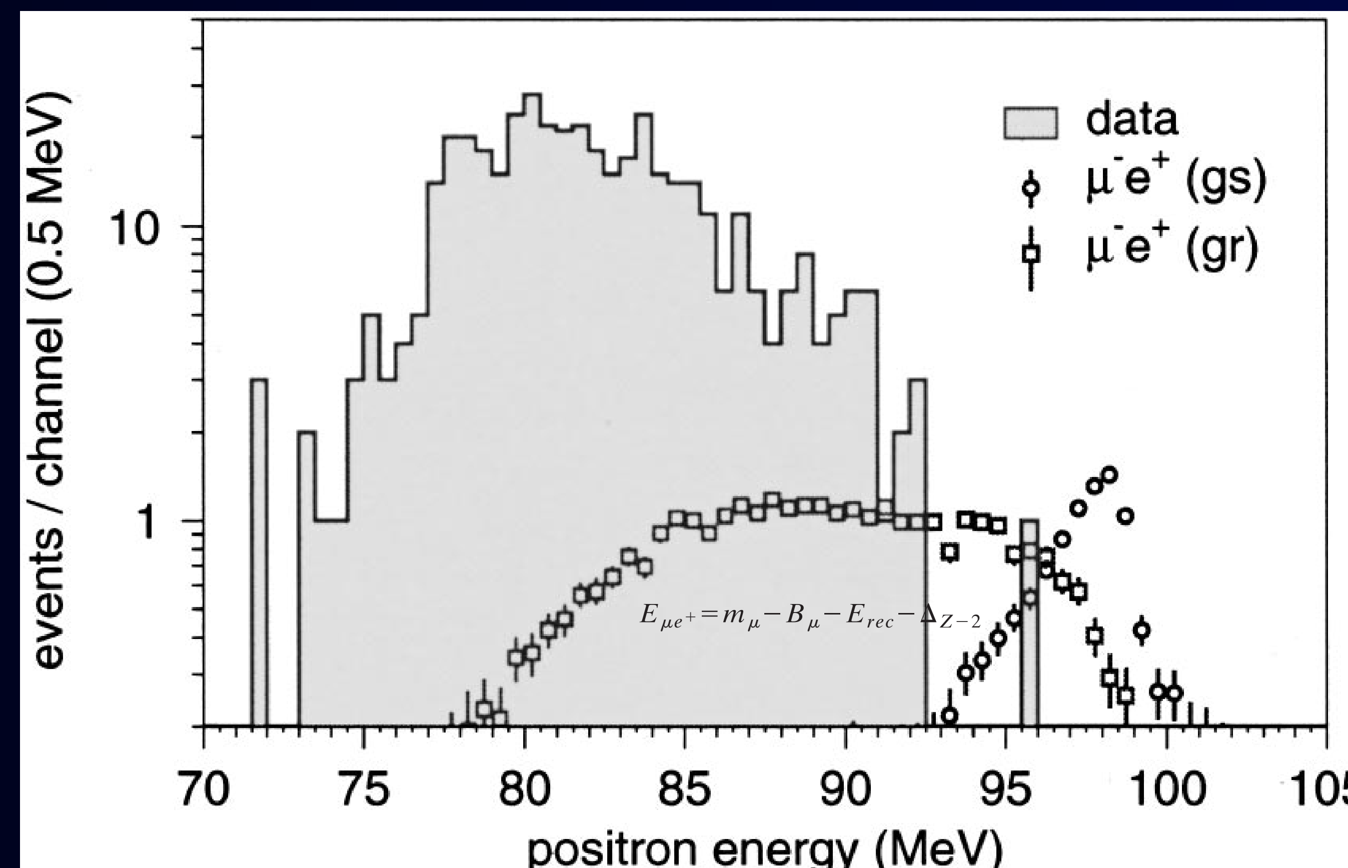
signal signature

$$E_{\mu e^+} = m_\mu - B_\mu - E_{rec} - \Delta_{Z-2}$$

backgrounds

positrons from photon conversion after radiative muon/pion nuclear capture

previous measurements at PSI



$\mu^- + \mathrm{Ti} \rightarrow e^+ + \mathrm{Ca(gs)}$	1.7×10^{-12}
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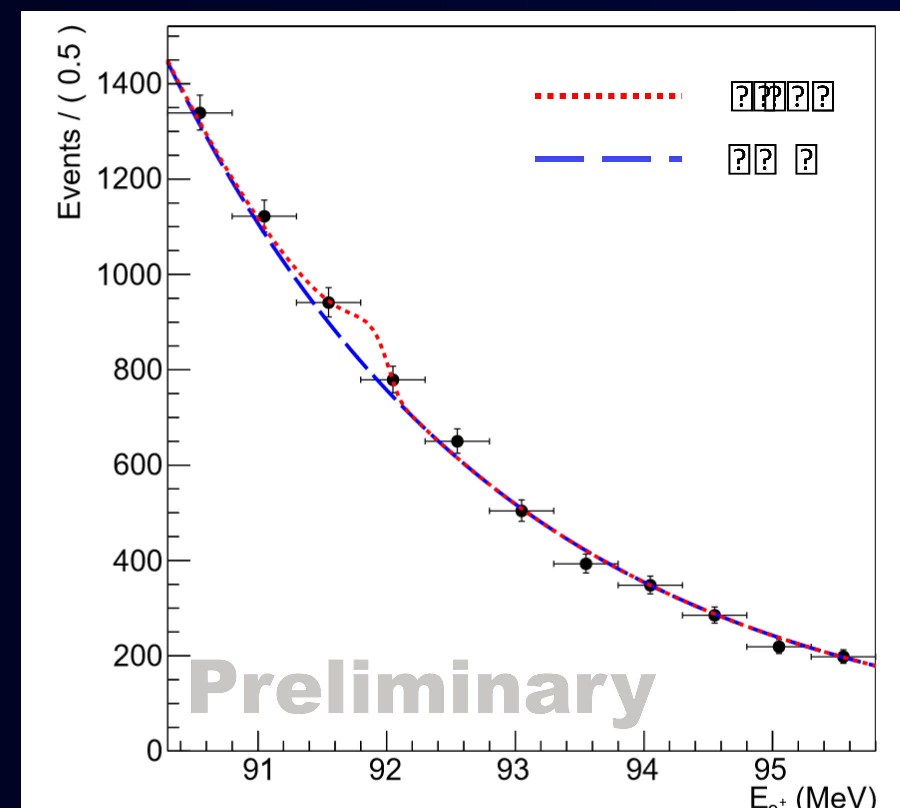
positrons from photon conversion after radiative muon/pion nuclear capture

$$\mu^- + \mathrm{Ti} \rightarrow e^+ + \mathrm{Ca(gs)} \qquad 1.7\times10^{-12}$$
$$\mu^- + \mathrm{Ti} \rightarrow e^+ + \mathrm{Ca(ex)} \qquad 3.6\times10^{-11}$$

showing that aluminium is not a good target



mass relation for target selection

$M(A, Z-1) > M(A, Z-2)$
for $M(A, Z)$

μ- to e+ conversion
- PRD paper

PHYSICAL REVIEW D **96,** 075027 (2017)

Future experimental improvement for the search of lepton-number-violating processes in the *eμ* sector

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The conservation of lepton flavor and total lepton number are no longer guaranteed in the Standard Model after the discovery of neutrino oscillations. The $\mu^- + N(A,Z) \to e^+ + N(A,Z-2)$ conversion in a muonic atom is one of the most promising channels to investigate the lepton number violation processes, and measurement of the $\mu^- - e^+$ conversion is planned in future $\mu^- - e^-$ conversion experiments with a muonic atom in a muon-stopping target. This article discusses experimental strategies to maximize the sensitivity of the $\mu^- - e^+$ conversion experiment by introducing the new requirement of the mass relation of $M(A,Z-2) < M(A,Z-1)$, where $M(A,Z)$ is the mass of the muon-stopping target nucleus, to eliminate the backgrounds from radiative muon capture. The sensitivity of the $\mu^- - e^+$ conversion is expected to be improved by 4 orders of magnitude in forthcoming experiments using a proper target nucleus that satisfies the mass relation. The most promising isotopes found are ^{40}Ca and ^{32}S.

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Thank you!

COMET character