A New Idea of the Experiment Searching for μ-e Conversion --- DeeMe ---

M. Aoki (Osaka University) on behalf of DeeMe Working Group
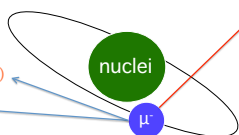aokim@phys.sci.osaka-u.ac.jp, http://deeme.hep.sci.osaka-u.ac.jp/

What is μ-e Conversion?

- μ- in material → Muonic Atom (1S)
- Standard Model: Two allowed processes

$$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$$ Muon Capture (MC)

$$\mu^- \rightarrow e^- \nu \bar{\nu}$$ Muon Decay in Orbit (MDO)

— MC:MDO = 1:1000(H), 3:2(Al), 13:1(Cu)   - τ(free μ-) = 2.2 μs, τ(μ⁻;Al) = 0.88 μs

nuclei

μ⁻
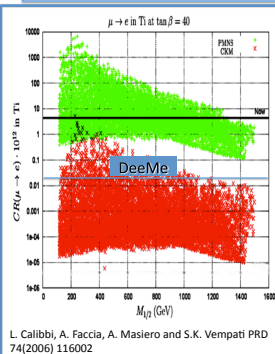
- Beyond the Standard Model:

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$ μ-e Conversion
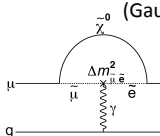
- It violates charged-lepton flavor invariance.
- It is therefore forbidden in the Standard Model.
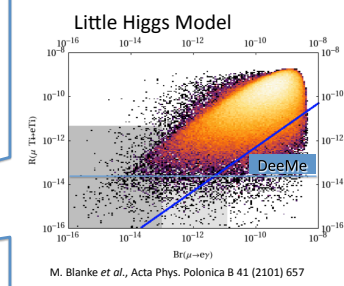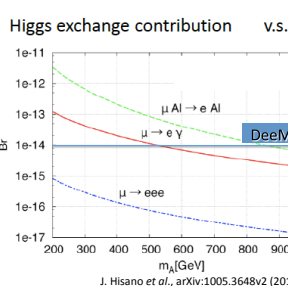
μ-e Conversion → physics beyond the Standard Model

New physics and μ-e conversion

μ → e in Ti at tan β = 40

L. Calibbi, A. Faccia, A. Masiero and S.K. Vempati PRD 74(2006) 116002

- SUSY-GUT, SUSY-seesaw (Gauge Mediated process)

  - BR = 10^{-15} = BR(μ→eγ) × O(α)
  - Other related processes: τ→lγ

- SUSY-seesaw (Higgs Mediated process)

  - BR = $10^{-12} \sim 10^{-15}$
  - Other related processes: τ→lη

- Many Other Processes

Higgs exchange contribution   v.s.

μ Al → e Al
μ → e γ
DeeMe
μ → eee

J. Hisano et al., arXiv:1005.3648v2 (2010)

Little Higgs Model

DeeMe

M. Blanke et al., Acta Phys. Polonica B 41 (2101) 657

μ-e conversion may be observed at BR ~ 10^{-14}, or give a stringent constraint on many models.

Signal and Backgrounds

SINDRUM II   run2000: μe conversion on gold
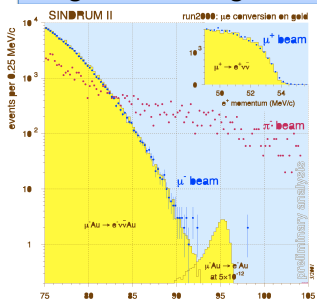
- Signal : μ⁻ +(A,Z) → e⁻ +(A,Z)
  - A single mono-energetic electron
    - Energy: 105 MeV
    - Timing: delayed about μS

- Physics backgrounds
  - Muon Decay in Orbit (MDO)
    - Energy < 105 MeV
      Prob.(> 102.5 MeV) < 10^{-14}
  - Beam Pion Capture
    π⁻+(A,Z) → (A,Z-1)* → γ+(A,Z-1): γ → e⁺ e⁻
    - Timing: Prompt

Think Different

Ordinary Method

- Primary beam line for proton transport.
- π production target.
- Secondary beam line for π-μ transport.
- μ⁻ stopping target.
- Tertiary beam line for e⁻ transport
  - It will be a complicated Setup.

105 MeV/c Spectrometer
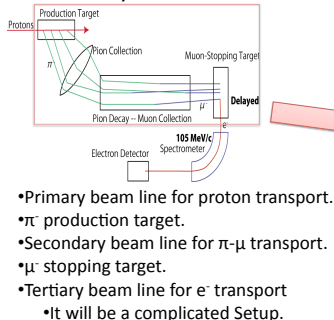
μ-e Conversion electrons may directly come from a proton target.

New Method

- Primary beam line for proton.
- π⁻ production/μ⁻ stopping target.
- Secondary beam line for e⁻.
  - Simpler than the ordinary method.

Proton
Muon Target
π Pion Capture
Pion -> Muon
μ Muon Stop
e

105 MeV/c
Prompt BG
low Momentum BG   Delayed   Kicker   Electron Spectrometer

DeeMe

- A test experiment at J-PARC MLF in 2009 showed very large yield of μ⁻ stops in the present target.
  - 8 × 10^9 /sec/MW
  - in good agreement with Geant4 MC calculation.

- DeeMe Stage1 (result < 2015)
  - Use the existing beam line.
  - Place an Al plate near the target.
    - Muonic Al Formation: 4 × 10^9/sec
  - Single Event Sensitivity: ~ 5 × 10^{-14} for Al

- DeeMe Stage2
  - Build a multipurpose large acceptance beam line.
  - Single Event Sensitivity: < 10^{-14} for Al.
  - Time-share with other muon-physics experiments
    - muon g-2, muonium HFS.

- Backgrounds
  - MDO will be suppressed by momentum spectroscopy by the DeeMe Detector. The momentum resolution Δp/p=1% is enough.
  - Beam Pion Capture background will be suppressed in the delayed timing since the primary proton from J-PARC RCS to MLF is highly pulse structured.

DeeMe Stage2

DeeMe Detector

g-2 Beamline
muonium HFS
- Multi Purpose Facility

DeeMe Kicker
320 mmH × 320 mmW
BL = 500 G·m

Large Acceptance e⁻ Collection
- 105-MeV/c electrons
- > 120 msr

DeeMe Target
Carbon Disk + Al μ-stopper

Site

J-PARC

Neutrino beams to SK
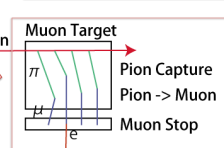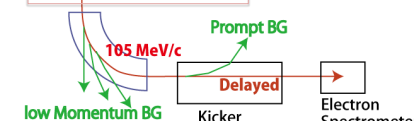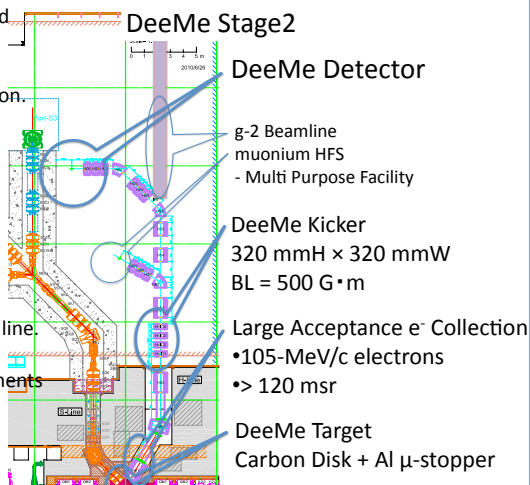
JFY 2006 / 2007
JFY 2008
JFY 2009

Hadron experimental hall

J-PARC MLF
- 3 GeV, 333 μA = 1 MW
- 25 Hz (Fast Extraction from RCS)
- Muon target + Neutron Target

Summary

- Physics of μ-e Conversion is very important.
- There is a rather simple way to do the experiment.
- DeeMe at J-PARC can improve the current limit by two orders of magnitudes (BR < 10^{-14}).
- The detailed design of DeeMe is on-going.