Joint Year-end Meeting - Welcome

Yoshitaka Kuno
Department of Physics
Osaka University

December 19th, 2011
from Tsukuba, Japan

Welcome !

Elementary Particle Physics in 2011

- LHC starts...
  - A hint for Higgs
    - but not conclusive yet!
  - No sign of new physics beyond the Standard Model
- Neutrinos
  - A hint for neutrino mixing parameter of large θ^{13} from T2K and Double Chooz (and Minos)
    - but not conclusive yet!

Elementary Particle Physics in 2012

- Wish some impacts from LHC
- Wish some impacts from Neutrino experiments

- Wish some impact realized in rare processes such as in flavor physics.

2012 could be an exciting time

Search for $\mu^- + e^- \rightarrow e^- + e^-$ in a muonic atom

What is Lepton Flavor Violation of Charged Leptons (cLFV) ?

What is Lepton Flavor Violation of Charged Leptons (cLFV) ?

LFV of neutrinos is confirmed.

LFV of charged leptons (cLFV) has not been observed.

Charged Lepton Flavor Violation with Muons

current future

ΔL=1

- $\mu^+ \to e^+\gamma$
- $\mu^+ \to e^+e^+e^-$
- $\mu^- + N(A,Z) \to e^- + N(A,Z)$
- $\mu^- + N(A,Z) \to e^+ + N(A,Z-2)$

ΔL=2

- $\mu^+e^- \to \mu^-e^+$
- $\mu^- + N(A,Z) \to \mu^+ + N(A,Z-2)$
- $\nu_\mu + N(A,Z) \to \mu^+ + N(A,Z-1)$
- $\nu_\mu + N(A,Z) \to \mu^+\mu^+\mu^- + N(A,Z-1)$

Charged Lepton Flavor Violation with Muons

ΔL=1

- $\mu^+ \to e^+\gamma$
- $\mu^+ \to e^+e^+e^-$
- $\mu^- + N(A,Z) \to e^- + N(A,Z)$
- $\mu^- + N(A,Z) \to e^+ + N(A,Z-2)$

ΔL=2

- $\mu^+e^- \to \mu^-e^+$
- $\mu^- + N(A,Z) \to \mu^+ + N(A,Z-2)$
- $\nu_\mu + N(A,Z) \to \mu^+ + N(A,Z-1)$
- $\nu_\mu + N(A,Z) \to \mu^+\mu^+\mu^- + N(A,Z-1)$

	current	future
$\mu^+ \to e^+\gamma$	$<10^{-11}$	$<10^{-14}$
$\mu^+ \to e^+e^+e^-$	$<10^{-12}$	$<10^{-14}$
$\mu^- + N(A,Z) \to e^- + N(A,Z)$	$<10^{-12}$	$<10^{-18}$
$\mu^- + N(A,Z) \to e^+ + N(A,Z-2)$		
$\mu^+e^- \to \mu^-e^+$	$<10^{-3}G_F$	$<10^{-4}G_F$
$\mu^- + N(A,Z) \to \mu^+ + N(A,Z-2)$		
$\nu_\mu + N(A,Z) \to \mu^+ + N(A,Z-1)$		
$\nu_\mu + N(A,Z) \to \mu^+\mu^+\mu^- + N(A,Z-1)$		

A new CLFV process in a muonic atom

A new CLFV process in a muonic atom

- $\mu^+ \rightarrow e^+e^+e^-$ is hard to detect since it is a 3-body decay and the spectrum fraction to be measured is limited

A new CLFV process in a muonic atom

- $\mu^+ \rightarrow e^+e^+e^-$ is hard to detect since it is a 3-body decay and the spectrum fraction to be measured is limited
- A muonium CLFV decay such as $\mu^+e^- \rightarrow e^+e^+$ is a 2-body decay having a larger phase space, but the overwrap of μ^+ and e^- is small.

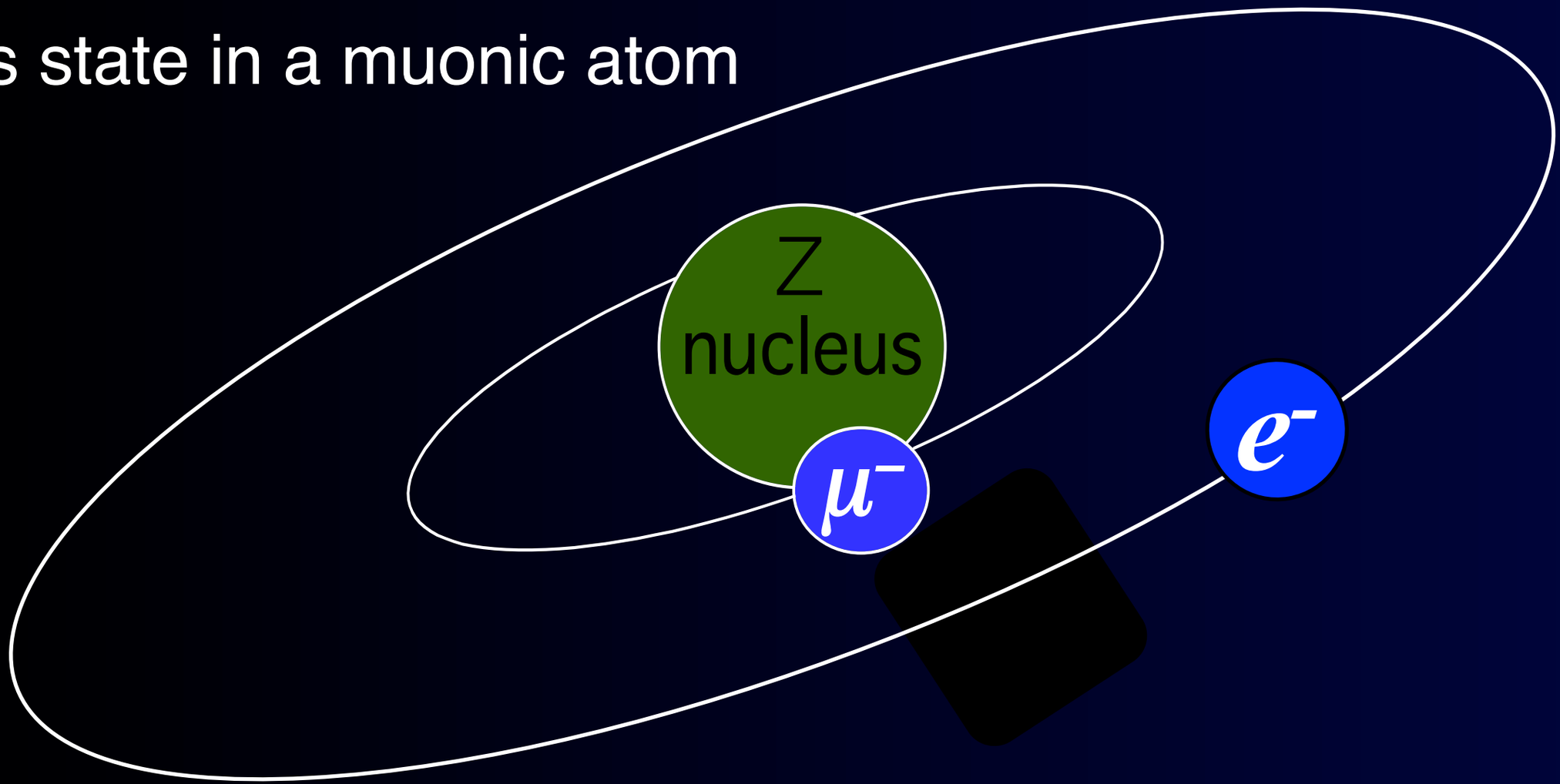
A new CLFV process in a muonic atom

- $\mu^+ \rightarrow e^+e^+e^-$ is hard to detect since it is a 3-body decay and the spectrum fraction to be measured is limited
- A muonium CLFV decay such as $\mu^+e^- \rightarrow e^+e^+$ is a 2-body decay having a larger phase space, but the overwrap of μ^+ and e^- is small.

how to improve the overwrap of μ and e ?

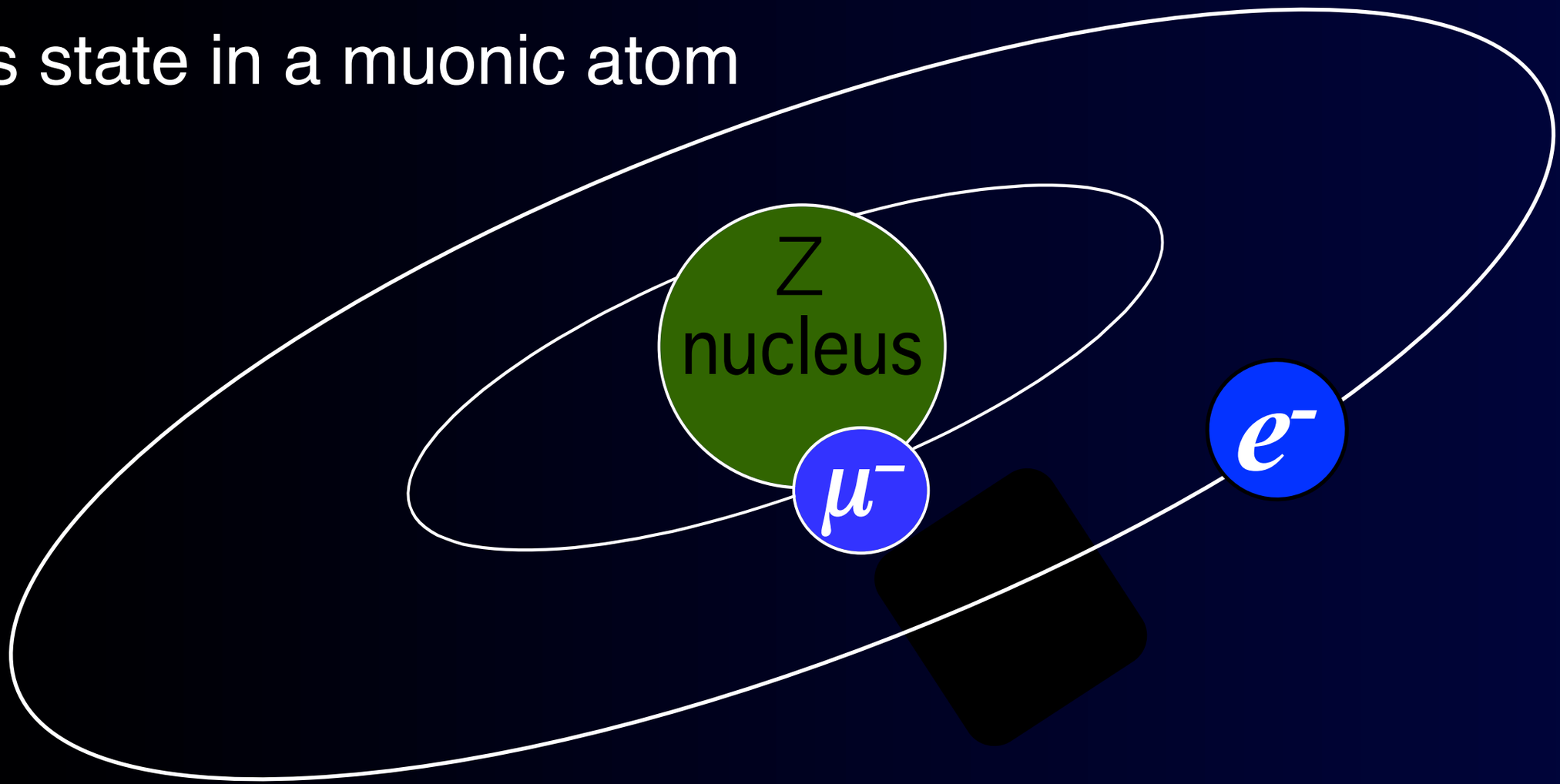
$\mu^- + e^- \rightarrow e^- + e^-$ in a Muonic Atom

1s state in a muonic atom



$\mu^- + e^- \rightarrow e^- + e^-$ in a Muonic Atom

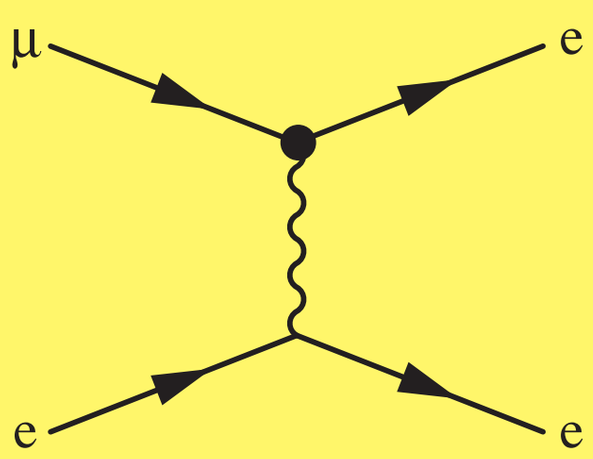
1s state in a muonic atom

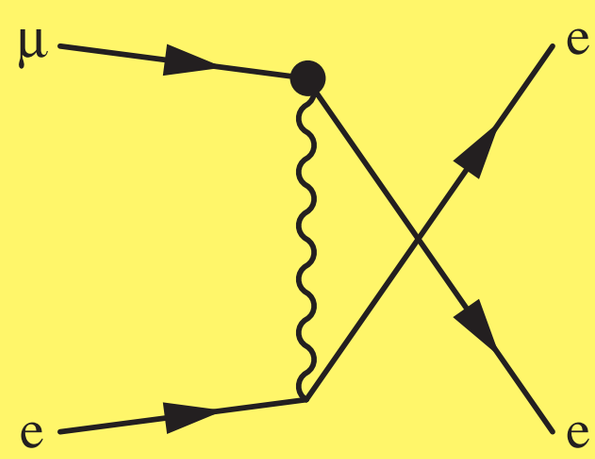


The overwrap between μ^- and e^- is proportional to Z^3.
For example, Z=82 (Pb), the overwrap increases by a factor of 5×10^5.over the muonium. The rate is 10^{-17} to 10^{-18}.

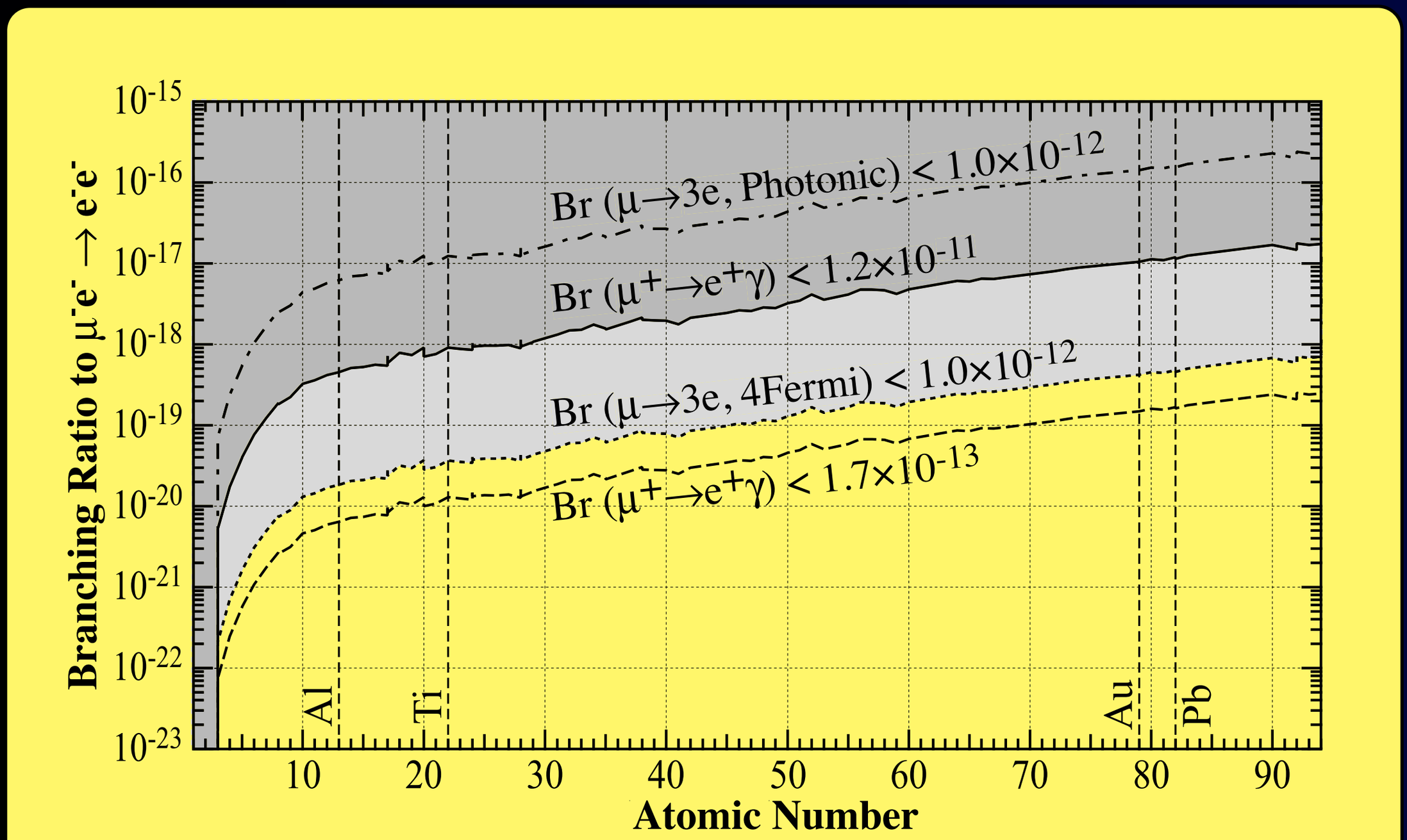
Lagrangian and Diagram

$$\mathcal{L}_{\mu^-\mathrm{e}^-\to\mathrm{e}^-\mathrm{e}^-} = -\frac{4G_\mathrm{F}}{\sqrt{2}}\Big[m_\mu A_\mathrm{R}\,\overline{\mu_\mathrm{R}}\sigma^{\mu\nu}e_\mathrm{L}F_{\mu\nu}$$
$$+ m_\mu A_\mathrm{L}\,\overline{\mu_\mathrm{L}}\sigma^{\mu\nu}e_\mathrm{R}F_{\mu\nu}$$
$$+ g_1(\overline{\mu_\mathrm{R}}e_\mathrm{L})(\overline{e_\mathrm{R}}e_\mathrm{L}) + g_2(\overline{\mu_\mathrm{L}}e_\mathrm{R})(\overline{e_\mathrm{L}}e_\mathrm{R})$$
$$+ g_3(\overline{\mu_\mathrm{R}}\gamma^\mu e_\mathrm{R})(\overline{e_\mathrm{R}}\gamma_\mu e_\mathrm{R}) + g_4(\overline{\mu_\mathrm{L}}\gamma^\mu e_\mathrm{L})(\overline{e_\mathrm{L}}\gamma_\mu e_\mathrm{L})$$
$$+ g_5(\overline{\mu_\mathrm{R}}\gamma^\mu e_\mathrm{R})(\overline{e_\mathrm{L}}\gamma_\mu e_\mathrm{L}) + g_6(\overline{\mu_\mathrm{L}}\gamma^\mu e_\mathrm{L})(\overline{e_\mathrm{R}}\gamma_\mu e_\mathrm{R})$$
$$+ (\mathrm{H.c.})\Big]\,.$$





Saturated Branching Ratios



Publication

M. Koike, M. Yamanaka, Y. Kuno and J. Sato, Phys. Rev. Lett. 105 (2010) 121601

PHYSICAL REVIEW LETTERS

New Process for Charged Lepton Flavor Violation Searches: $\mu^- e^- \to e^- e^-$ in a Muonic Atom

Masafumi Koike,[1,*] Yoshitaka Kuno,[2,†] Joe Sato,[1,‡] and Masato Yamanaka[3,§]

[1]*Physics Department, Saitama University, 255 Shimo-Okubo, Sakura-ku, Saitama, Saitama 338-8570, Japan*
[2]*Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[3]*Institute for Cosmic Ray Research, University of Tokyo, Kashiwa 277-8582, Japan*
(Received 8 March 2010)

Summary and Outlook

- This process has good features.
  - two charged particles (electrons) in the final state.
  - both may have 52 MeV
  - both may be back-to-back in the same time.
- This process may not be the first one to search for CLFV.
- This would be useful to pin down the physics of CLFV, together with other processes.

Wish you make your best
on your presentations
in the whole today.