Exploration of New Physics —
Muon to positron transition at COMET experiment

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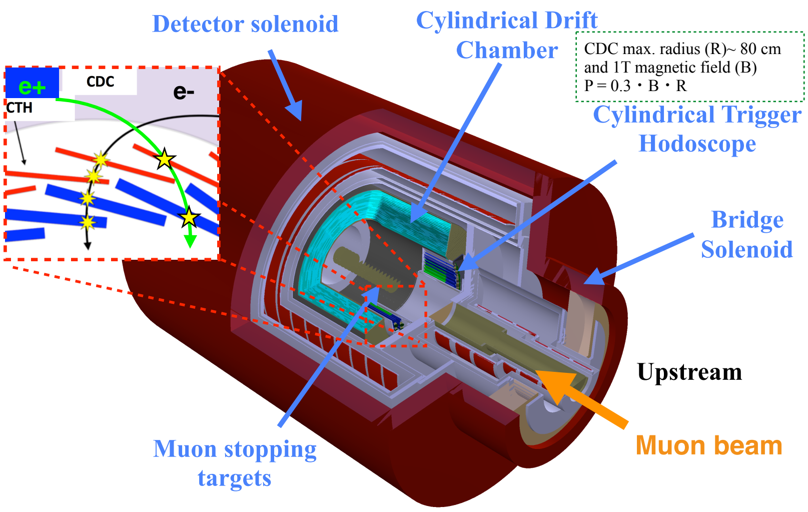
Muon positron transition and COMET experiment

The violation of lepton number is known to be one of the sources of neutrino mass generation in the physics beyond the Standard Model. Another promising channel for searching CLFV is $\mu^- + N(Z) \rightarrow e^+ + N(Z-2)$ (hereafter μ^-e^+ conversion), which both *flavour* and *lepton number (L)* are not conserved. This process with $\Delta L=2$ can be mediated by Majorana neutrinos through type-1 seesaw mechanism or new particles appearing at a high energy scale (> TeV).

The **CO**herent **M**uon **E**lectron **T**ransition (**COMET**) Phase-I experiment is not only capable of searching for CLFV process via the $\mu^- + Al \rightarrow e^- + Al$ but also the μ^-e^+ conversion process with approximately O(10^{15}) muons captured in the stopping target. In principle, both μ^-e^+ and μ^-e^- conversion process should have similar Single Event Sensitivity (S.E.S), however S.E.S$_{\mu\text{-}e+}$ depends highly on the end point energy of Radiative Muon Capture (RMC$_{max}$) which depends on nucleus. Therefore, choosing the right material of muon stopping target can directly suppress the background level for searching of μ^-e^+ conversion. According to our previous studies, **^{32}S, ^{40}Ca and ^{40}Ti** are shown to be three potential candidates for future CLFV experiment. [1]



Can we see μ^-e^+ conversion in COMET?

$$E_{\mu\text{-}e+} = m_\mu + M(A,Z) - M(A,Z-2) - B_\mu - E_{recoil}$$

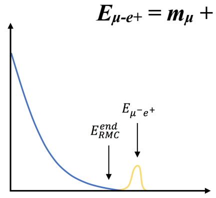
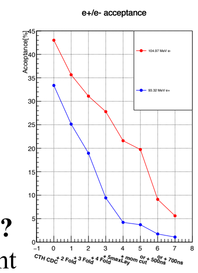


Illustration of energy distribution of μ^-e^+ conversion

➡ Mono-energetic positron signal @ 92.32 MeV easy to find supposedly !



Signal acceptance for e^+ and e^- with different cut conditions in the case of Al stopping target

① **Why is e^+ signal acceptance so low?**

➡ Low signal acceptance due to current design of Cylindrical Trigger Hodoscope

② **Radiative Muon Capture (Al target)**

External RMC : $\mu^- + Al \rightarrow \nu_\mu + Mg + \gamma$

Internal RMC : $\mu^- + Al \rightarrow \nu_\mu + Mg + e^+ + e^-$

➡ RMC$_\gamma$ Spectrum : $P(x) = C(1-2x+2x^2)x(1-x)^2 \, , \, x = \frac{E\gamma}{E\gamma_{end}}$ [2]

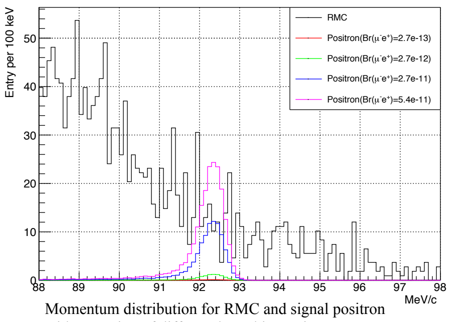
➡ End point energy of electron/positron from pair production is **101.34 MeV**

③ **Muon Decay In Orbit (DIO)**

DIO : $\mu^- + Al \rightarrow \nu_\mu + Al + \bar{\nu}_e + e^-$

➡ Br(DIO) electron at 90-105 MeV is 6.77×10^{-10}

➡ Mis-Identification of e^+ e^- could be problematic, currently the estimated rate is O(10^{-4})



Momentum distribution for RMC and signal positron with assuming of different branching ratio

④ **Estimated rate of RMC$_{e+}$**

➡ Expected RMC events are huge, which is fatal for converted signal e^+

➡ With momentum window cut, still ~100 events are expected from RMC

➡ With Likelihood analysis one can still measure

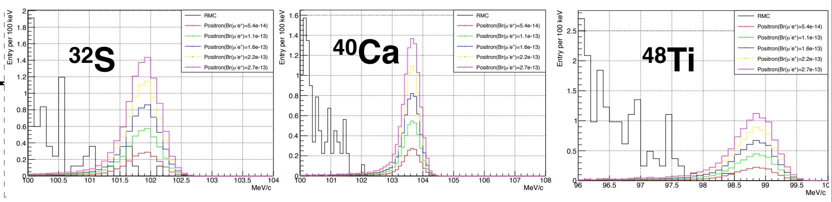
Muon Stopping Target candidates

Atom	$E_{\mu^- e^+}$ (MeV)	$E_{\mu^- e^-}$ (MeV)	E^{end}_{RMC} (MeV)	N.A. (%)	f_{cap} (%)	τ_{μ^-} (ns)
^{27}Al	92.30	104.97	101.34	100	61.0	864
^{32}S	101.80	104.76	102.03	95.0	75.0	555
^{40}Ca	103.55	104.39	102.06	96.9	85.1	333
^{48}Ti	98.89	104.18	99.17	73.7	85.3	329

Potential candidates for searching of μ^-e^+ conversion process. $E_{\mu\text{-}e\text{-}}$ and $E_{\mu\text{-}e+}$ are ground state energy of converted e^- and e+, respectively. E_{RMC} is the end point energy of RMC. N.A. is the natural abundance. f_{cap} is the capture rate and τ_μ is the life time of negative muon. These numbers are from [1]

Momentum distribution of signal and RMC$_{e+}$

Preliminary results



Momentum distribution for RMC$_{e+}$ and different branching ratio of converted signal e+ for ^{32}S, ^{40}Ca and ^{48}Ti

➡ Clear separation are observed with these candidates using COMET Phase-I setup assuming number of muons stopped O(10^{15})

How to select?

➡ Clear separation between end point energy of RMC and conversion signal

➡ Long $\tau_{\mu\text{-}}$ for suppressing Radiative Pion Capture

➡ High Natural abundance to avoid having different mono peaks for $E_{\mu\text{-}e+}$

Summary and prospective

➡ In COMET, with current stopping target (^{27}Al), it is hard to achieve high Br(μ^-e^+ conversion)

➡ Simulation results shows that **^{32}S, ^{40}Ca, ^{48}Ti** are promising candidates

➡ Further investigation for background (<1 events) should be carried out (e.g. RPC, Cosmic Ray, Beam prompt and anti-protons e.t.c.)

[1] Yeo, Beomk *et al.* "Future experimental improvement for the search of lepton-number-violating processes in the eμ sector", Phys. Rev. D **96**, 075027 (2017)
[2] Hwang, W-YP. "Radiative muon capture." Physical Review C 22.1 (1980): 233