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Preliminary study of Phase-II of the COMET Experiment

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The observation of charged Lepton Flavor Violation (CLFV) would be a clear indicator of physics beyond the Standard Model (BSM). The COMET experiment will study CLFV for a neutrinoless μ→ e conversion with a sensitivity on nuclei improved by four order of magnitude, using the intense pulsed muon beam at J-PARC. The COMET apparatus, Phase I, is under construction, the branching ratio of the μ→ e conversion is expected to be 3.1×10^{-15} (90% Confidence Level), the data taking is foreseen to start within the next two years. The second stage of the experiment, Phase II, will increase sensitivity to the μ→ e conversion by two order of magnitude within one year of data taking. In this paper the updated study of Protons target and Muons target will be introduced, a further improvement in sensitivity can be foreseen.

Contents and Discussions

1. Proton beam

The J-PARC main ring will provide a pulsed 8GeV proton beam, which is slowly-extracted. The pions yield produced by a proton beam is proportional to the proton beam power. The beam power for Phase-II is 56 kW

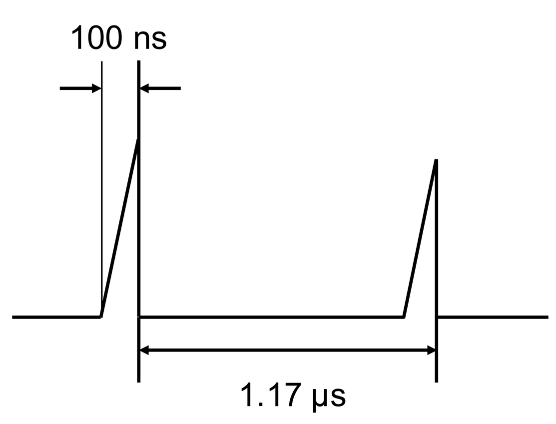

Fig.3. Proton time structure

2. Introduction to Sensitivity

The Single-Event Sensitivity (SES) can be defined as:

$$S.E.S(\mu^- N \to e^- N) = \frac{1}{N_\mu B_{capture} A_{\mu\to e}}$$

Pulling running time into above equation, the following relationship has been given:

$$S.E.S \cdot t_{run} = \frac{1}{(I_p/e) R_{\mu/p} B_{capture} A_{\mu\to e}}$$

Where Branching ratio for muon nuclear capture in Al ($B_{capture}$) is 61%, the proton beam current I_p is 7μA, in this paper, Muon stopped rate per Proton on Target (POT) ($R_{\mu/p}$) and the Total signal acceptance of Phase-II ($A_{\mu\to e}$) have been optimized

3. Optimization: Proton target and muon target

In the COMET experiment, the muon beam is produced from the decay of secondary pion beam created by protons striking a proton target. A heavy metal target with high-melting point have been selected. In Phase-II, tungsten would be used. To collect as many low-energy components of muon and pion as possible, the maximum magnetic field of 5T will be used. In this study, the length, the radius and the location have been optimized to obtain the maximum muon stopped rate. The muon target is required to collect the low momentum muons, the magnetic field is graded from 3T to 1T. In this study, the magnetic field and the muon target disks have been optimized to improve the muon yield.

4. Signal acceptance

Acceptance was estimated from simulation study. The electrons are generated in stopping target, The beam blocker and DIO blocker have been optimized to remove the high-energy muons, pions and to remove the low-energy DIO background respectively.

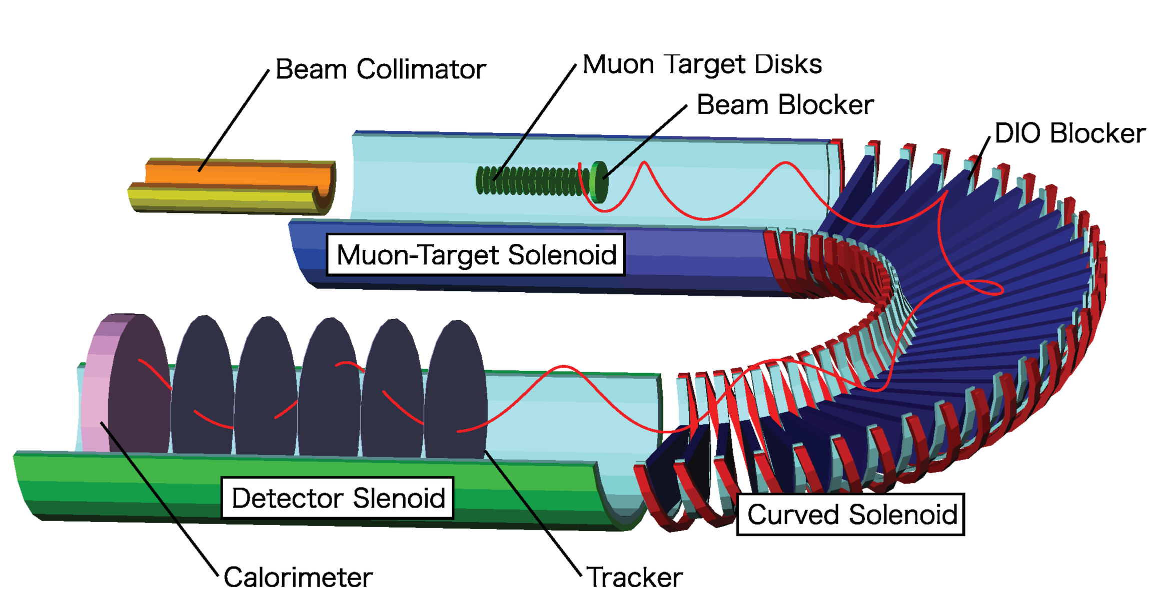

Fig.4. The process to detect the signal electron

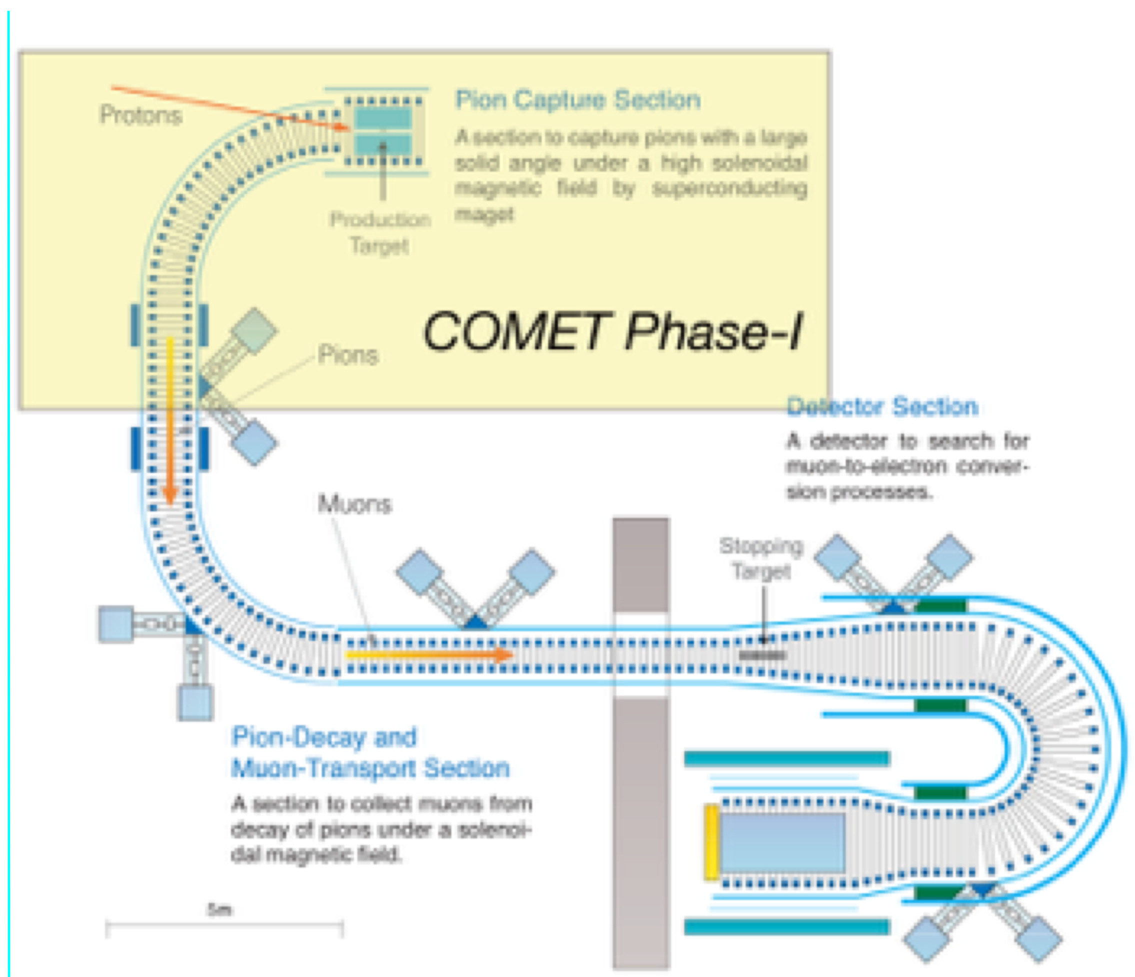

Fig.1. Schematic layout of COMET (Phase-II) and COMET Phase-I. The sensitivity to Phase-I and Phase-II will be 3.1×10^{-15} and 2.6×10^{-17} respectively.

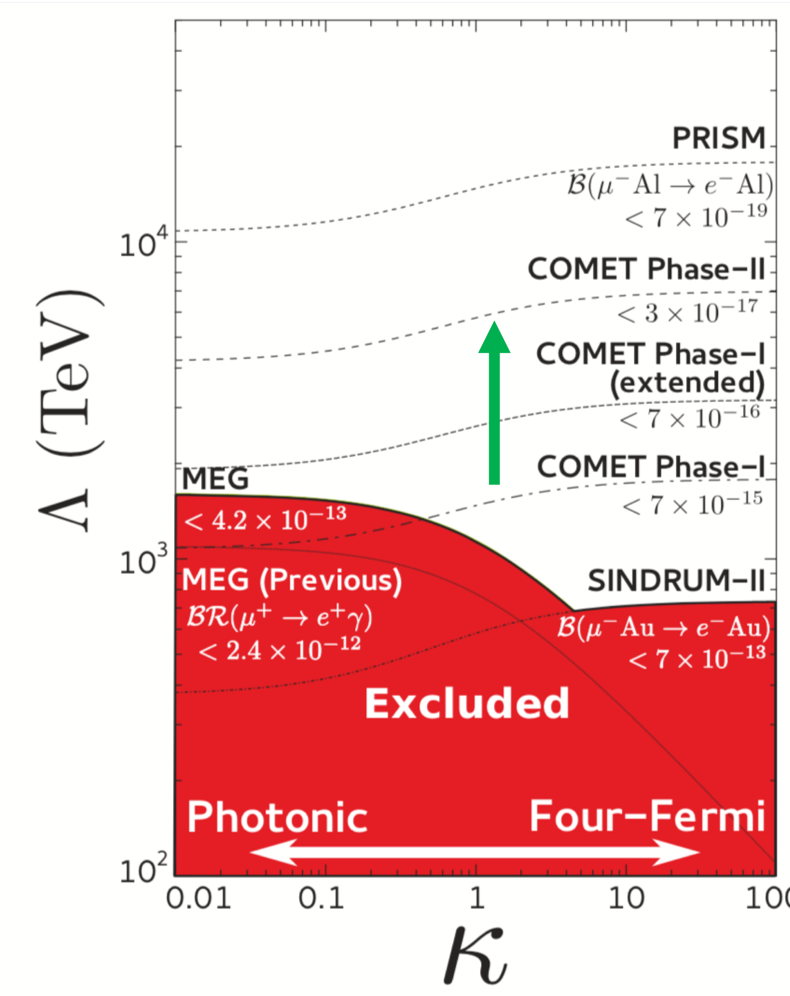

Fig.2. The sensitivity to Λ as a function of κ for μ→eγ and μ→e conversion efforts . The new degree of freedom Λ is a mass-dimension parameter, which represent the effective mass scale; the dimensionless parameter κ, which governs the relative size between the dipole-type operator and the four-fermion operator.

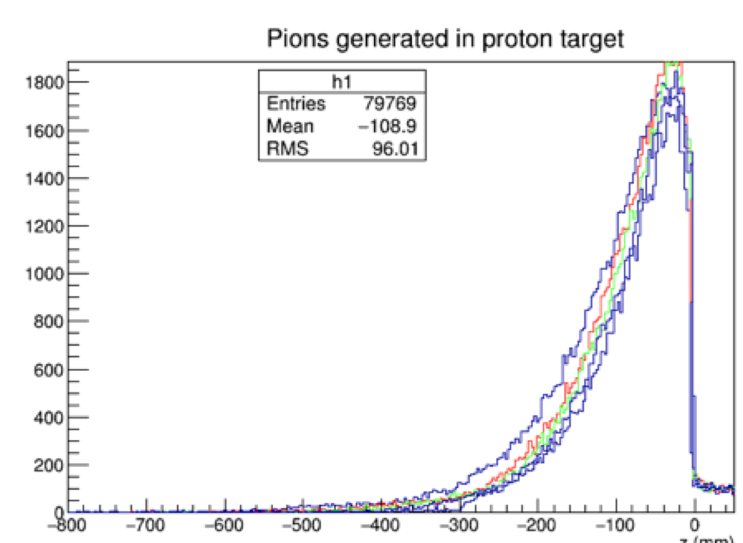

Fig.5. The distribution of generated pions in proton target

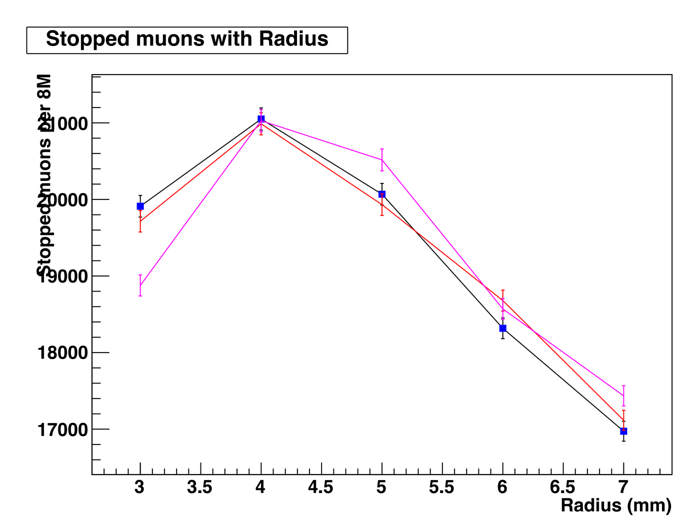

Fig.6. Integrated muon yields as a function of target radius

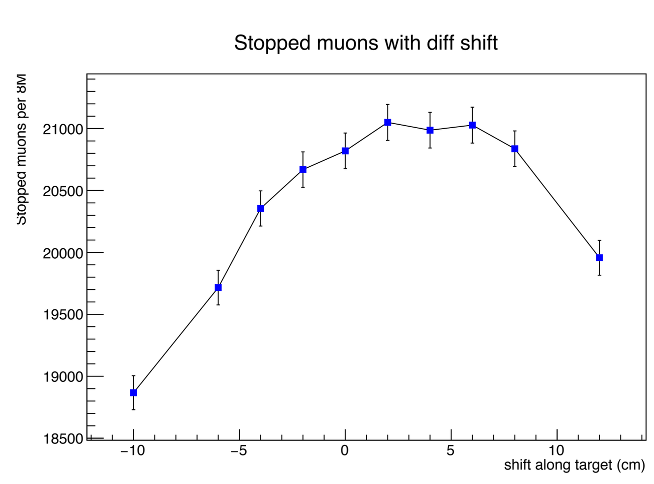

Fig.7. Integrated muon yields as a function of target location

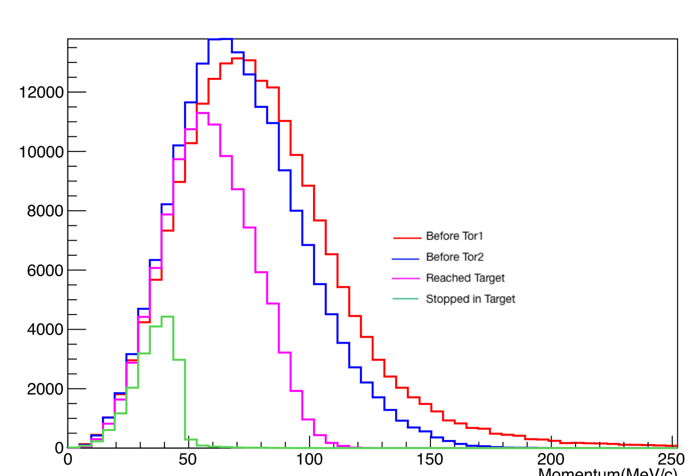

Fig.8. The distribution of muon in in each section.

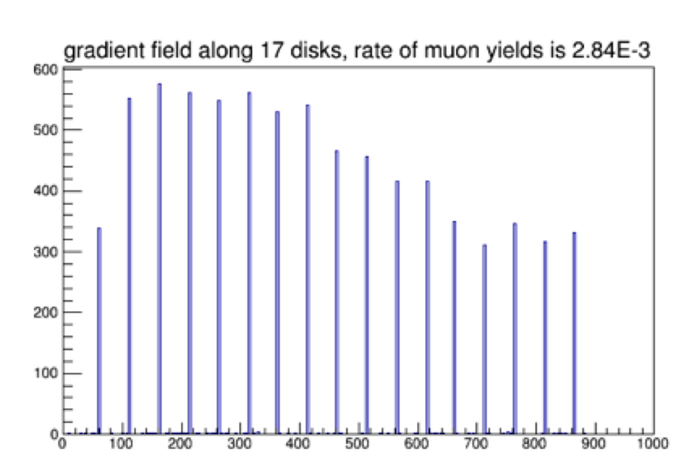

Fig.9. The distribution of stopped muon on target disks with gradient Field.

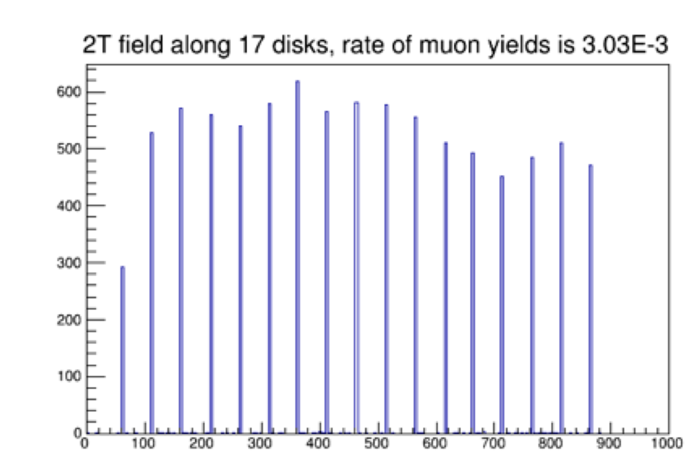

Fig.10. The distribution of stopped muon on target disks with uniform Field.

Table.1. Comparing acceptance based on different beam blocker and DIO blocker

	Radius of Beam blocker	High of top edge of DIO blocker	Geometrical acceptance	DIO hit rate	Running time
Previous study	250mm	-350mm (within whole electron spectrum)	22%	4×10^{-5}	1.57×10^{7}
This study	100mm	-450mm (within part of electron spectrum)	55%	4.1×10^{-4}↑	2×10^{7}

With the improvement of signal acceptance, the DIO hit rate will increase. The signal acceptance could be increased by a factor of 2.3 with new design of DIO and beam blockers. Even in this case, the DIO hit rate per straw within 50 nsec gate is 2%.

Summary

The COMET experiment, which has very high sensitivity, is promising to search the CLFV. In this study, the optimization of proton target, muon target have been done, the muon rate per POT will be increased by a factor of 1.7 and 2.2 respectively, also the signal acceptance will be improved by a factor of 2.3 by the optimization of beam blocker and DIO blocker. In addition, using the running time of 2×10^{7}, which would be increased by a factor of 1.27. Finally, the SES could be increased by a factor of 11. Above is preliminary study, further study will be completed in the future.