# Overview of the COMET Phase-I experiment

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## Motivation

The purpose of the COMET (COherent Muon to Electron Transition) experiment is to discover physics Beyond the Standard Model(BSM) via muon to electron conversion and pushing the intensity frontier at J-PARC. It is an effort to observe the conversion of muon bound to an atomic 1s ground state of an aluminium atom.

$$\mu^- + Al \rightarrow e^- + Al \quad (1)$$

This process is very suppressed with a branching ratio of $10^{-54}$ in Standard Model physics. However, in some BSM theories, a branching ratio of $10^{-15}$ is suggested. COMET is organized in two phases. Phase-I studies the proton beam extinction and other potential background sources, in addition to searching for the $\mu \rightarrow e$ signal with the CyDet. Phase-II will be a much more sensitive version of the experiment.

## BSM predictions

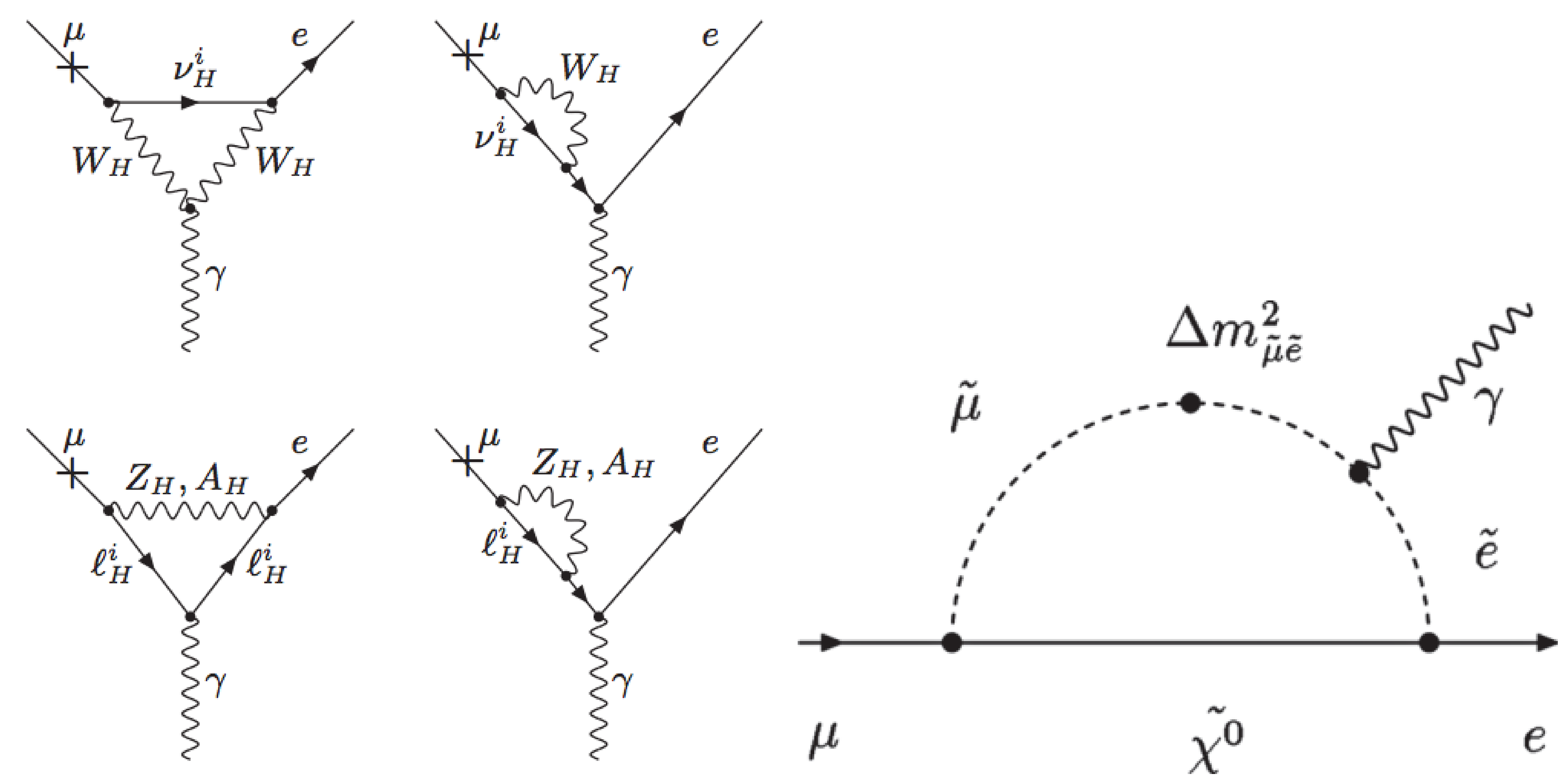

Figure: (Left) Littlest Higgs model with T-Parity diagrams contributing to the $\mu \rightarrow e$ process. H-subscripted particles represent the heavy 'partners' of their SM particles. (Right) A SUSY loop diagram for a $\mu \rightarrow e$ process with the $\gamma$ possibly captured by the nucleus. $\Delta m^2_{\tilde{\mu}\tilde{e}}$ represents the magnitude of slepton mixing.

## Experimental method

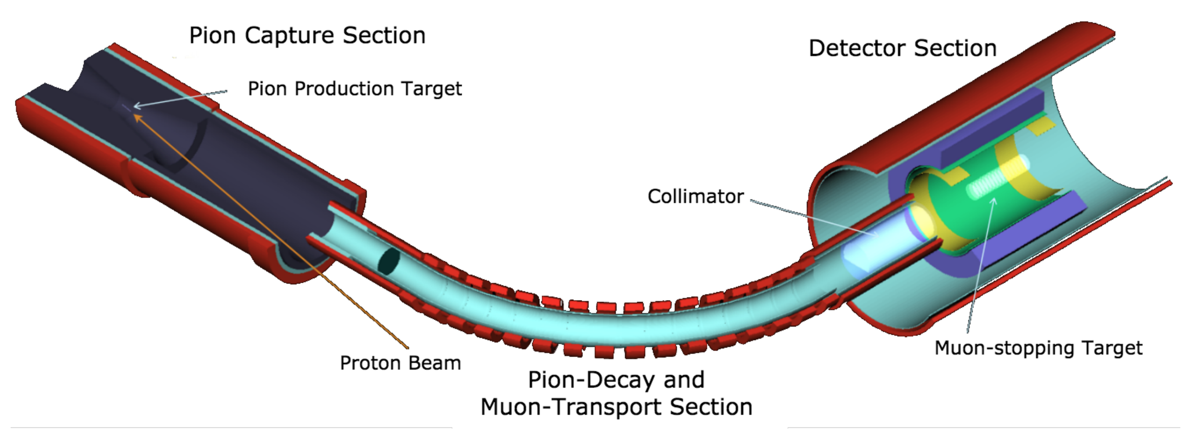


Figure: Schematic layout of COMET Phase-I. Goals of the first phase include measurement of proton beam extinction factors and other potential background sources to prepare for COMET Phase-II and to search for the $\mu^- - e^-$ conversion with a SES of better than $3.1 \times 10^{-15}$. Beam characterization will be done by prototype sections of the Phase-II detectors.

- A pulsed proton beam power of $\sim$ 8kW is directed at a graphite target to produce short-lived pions. They travel along the curved superconducting solenoid. They quickly decay into $\mu^-$ and $\bar{\nu}_\mu$.
- $\mu^-$ continue travelling and they get momentum selected due to the curved trajectory. It hits the Al target inside the Cylindrical Detector (CyDet), creating muonic atoms.
- The $\mu^-$ in the 1s-shell converts into an $e^-$, gains energy and leaves the Al atom. The CyDet records a signal during the timing window.

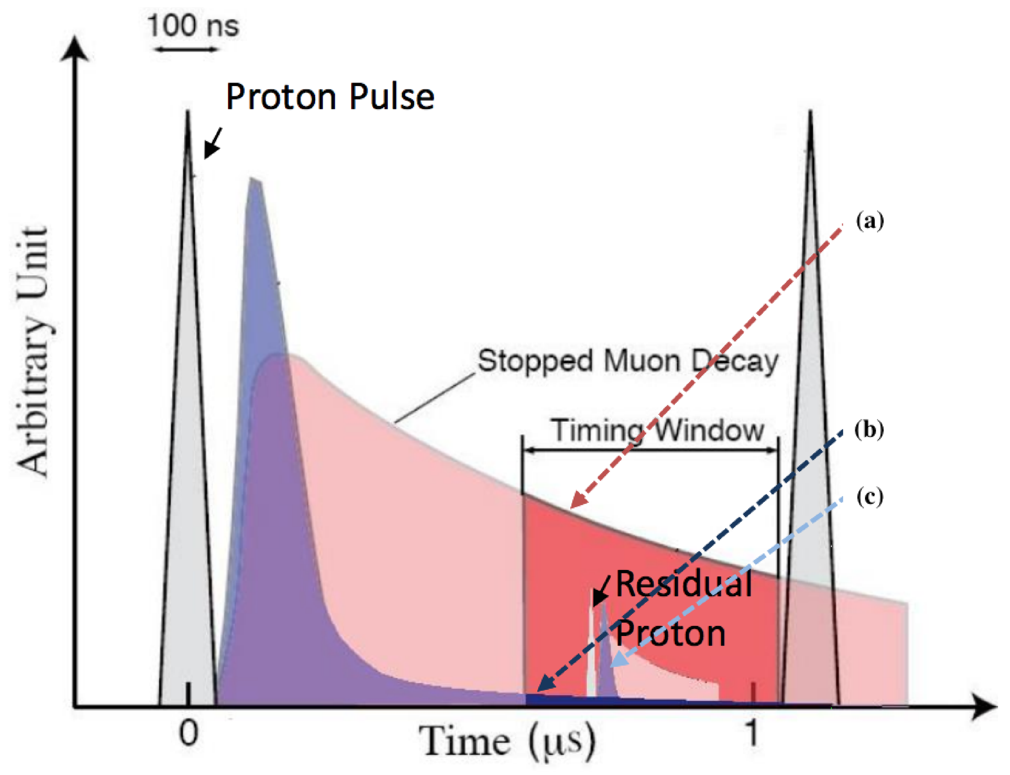


Figure: Timing window where measurement can be taken with an acceptable level of background. (a) Intrinsic physics backgrounds, (b) Beam related backgrounds (delayed), (c) Beam related backgrounds (prompt).

## Event candidate

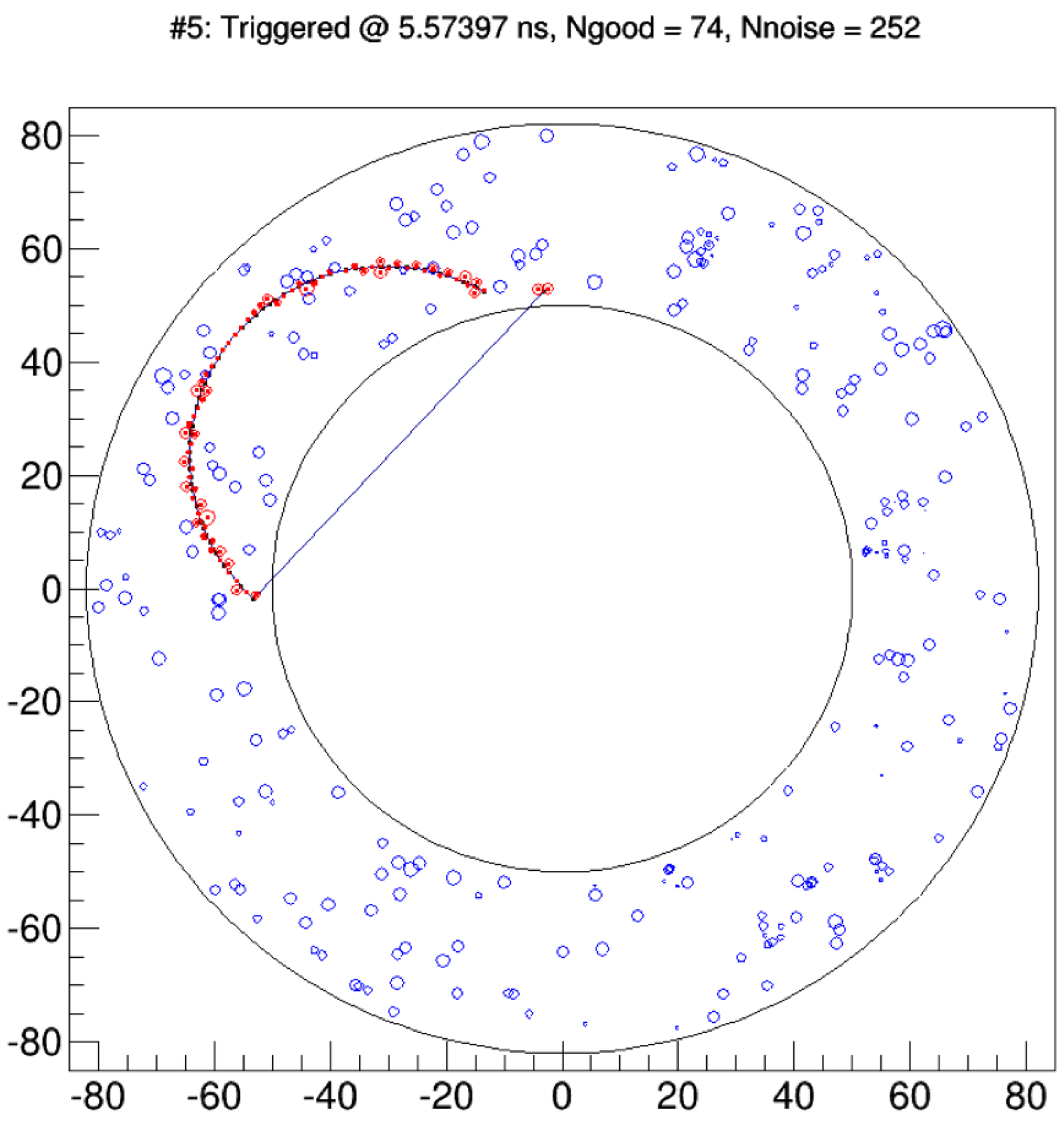


Figure: Simulation result of signal and accidental hit detector occupancy for the CyDet. (Red) Signal hits created by the converted electron that passed the energy deposit cut. (Blue) Noise hits that passed the energy deposit cut. The event signature is from a mono-energetic single electron emitted from the conversion with an energy of $E_{\mu e} = m_\mu - B_\mu - E^0_{rec} \sim 105$ MeV. There is another poster on the COMET Phase-I CDC in this conference.

## Background sources

DIO is a major contributor to background in the search for $\mu^- e^-$ conversion in a muonic atom. Other background sources are listed below.

| Background | Estimated events |
|---|---|
| Muon decay in orbit | 0.01 |
| Radiative muon capture | $5.6 \times 10^{-4}$ |
| Neutron emission after muon capture | $<$ 0.001 |
| Charged particle emission after muon capture | $<$ 0.001 |
| Beam electrons (prompt) | $8.3 \times 10^{-4}$ |
| Muon decay in flight (prompt) | $2.0 \times 10^{-4}$ |
| Pion decay in flight (prompt) | $\leq 2.3 \times 10^{-4}$ |
| Other beam particles (prompt) | $\leq 2.8 \times 10^{-4}$ |
| Radiative pion capture (prompt) | $\leq 2.3 \times 10^{-4}$ |
| Anti-proton induced backgrounds | 0.007 |
| Electrons from cosmic ray muons | $<$ 0.0001 |
| Total | 0.019 |

Table: Phase-I expected beam-related, intrinsic physics and cosmic ray backgrounds per single event.

## Signal Sensitivity

Single event sensitivity (SES) is the experimental sensitivity to observe one event. It is defined by the number of muons stopping in the muon target, $N_\mu = 2.0 \times 10^{18}$, the fraction of captured muons in Al, $f_{cap} = 0.6$, and the detector acceptance, $A_e = 0.04$, as follows.

$$BR(\mu^- + Al \rightarrow e^- + Al) = \frac{1}{N_\mu \cdot f_{cap} \cdot A_e} = 3.1 \times 10^{-15} \quad (2)$$

The upper limit is $7.2 \times 10^{-15}$ (90% C.L.) which is about 100 times better than the current published limit of $7 \times 10^{-13}$ (90% C.L.) by SINDRUM-II at PSI.

## Timeline for Phase-I and Phase-II

- **Now** Construction of the Cylindrical Detector (CDC).
- **end 2015** Completion of the CDC.
- **mid 2016** Completion of the detector, DAQ electronics and solenoids.
- **end 2016** CDC calibration and testing completed.
- **2017** Phase-I data taking for 100 days and analysis.
- **$\sim$2020** COMET Phase-II begins operation.

Phase-II will add a $180^\circ$ C-shape bend to the muon transport solenoid and more advanced detectors such as a straw tracker and a electron calorimeter. This improves the momentum resolution to reach the ultimate SES of $3 \times 10^{-17}$.