A Search for Muon to Electron Conversion at J-PARC

Ye Yuan, Tran Hoai Nam, on behalf of the COMET Collaboration
Experimental Physics Center, Institute of High Energy Physics
Department of Physics, Graduate School of Science, Osaka University

Introduction

Charged lepton flavor violation (cLFV) has yet to be observed and is known to be sensitive to new physics beyond the Standard Model (SM). Various extensions of the SM predicts that cLFV occurs at some detectable branching ratio. Therefore, from experimental point of view, it is very attractive to search for cLFV with more powerful beams and better detection techniques.

Among the cLFV processes, $\mu - e$ conversion, a coherent neutrino-less conversion of muon to electron in the presence of a nucleus: $\mu^- + N(A,Z) \rightarrow e^- + N(A,Z)$, is our interest. We have proposed a new search for $\mu - e$ conversion at J-PARC, the E21 experiment - COMET(COherent Muon to Electron Transition). The single event sensitivity (SES) of the COMET will be 2.6×10^{-17}, which is 10,000 times better than that of the current experimental limit set by SINDRUM II at 7×10^{-13}.

Staging approach of the COMET

The layout of COMET is shown in Fig 1, high field pion capture solenoid, C-shaped muon transport and C-shaped electron spectrometer are key points.

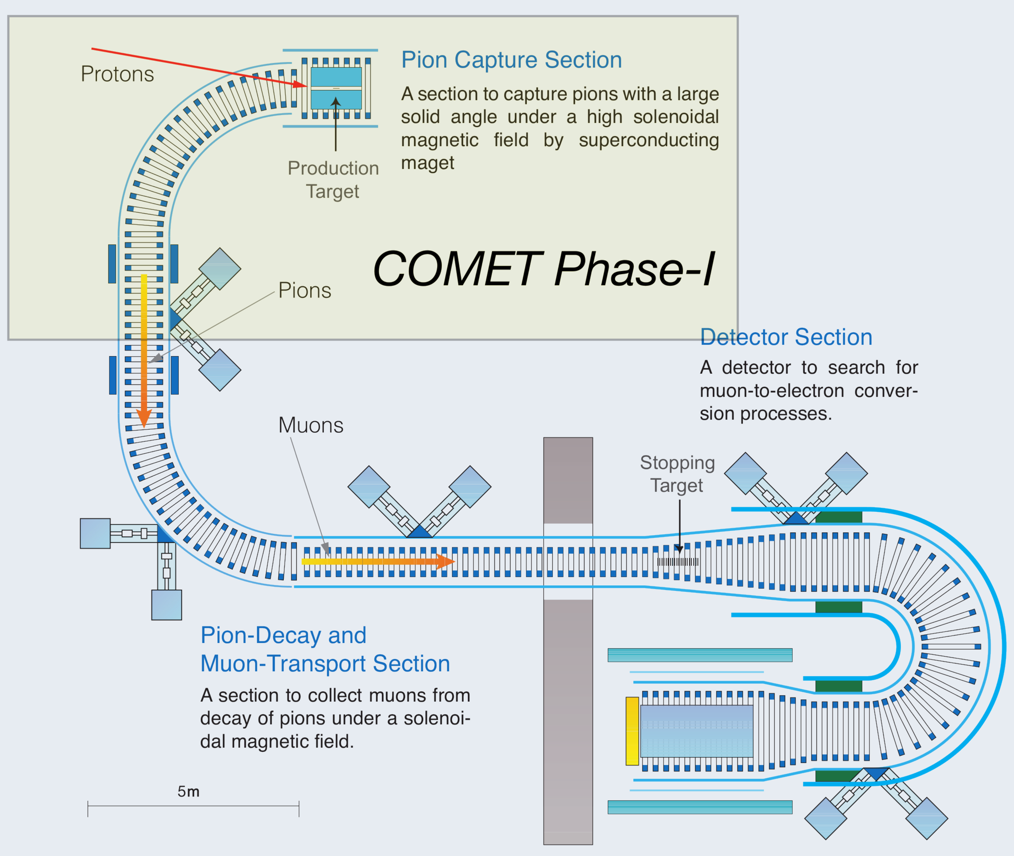


Figure 1: Schematic layout of the COMET

In order to realize the COMET experiment, a two-stage approach has been taken. The first stage, COMET Phase-I will construct the first 90 degrees of the muon beam line as shown in Fig 3, it has two major goals:

1. Search for $\mu - e$ conversion: we aim at an intermediate SES of 3×10^{-15}, which is an improvement of a factor of 100 compares to SINDRUM II.
2. Background measurements for full COMET: make direct measurement of the proton beam extinction and other potential background sources, using the actual COMET beam line.

Layout of the COMET experiment at Hadron Hall, J-PARC is shown in Fig 2. The COMET Phase-I funding has been approved by KEK.The construction is expected to finish in 2015, then data taking would start around 2016.

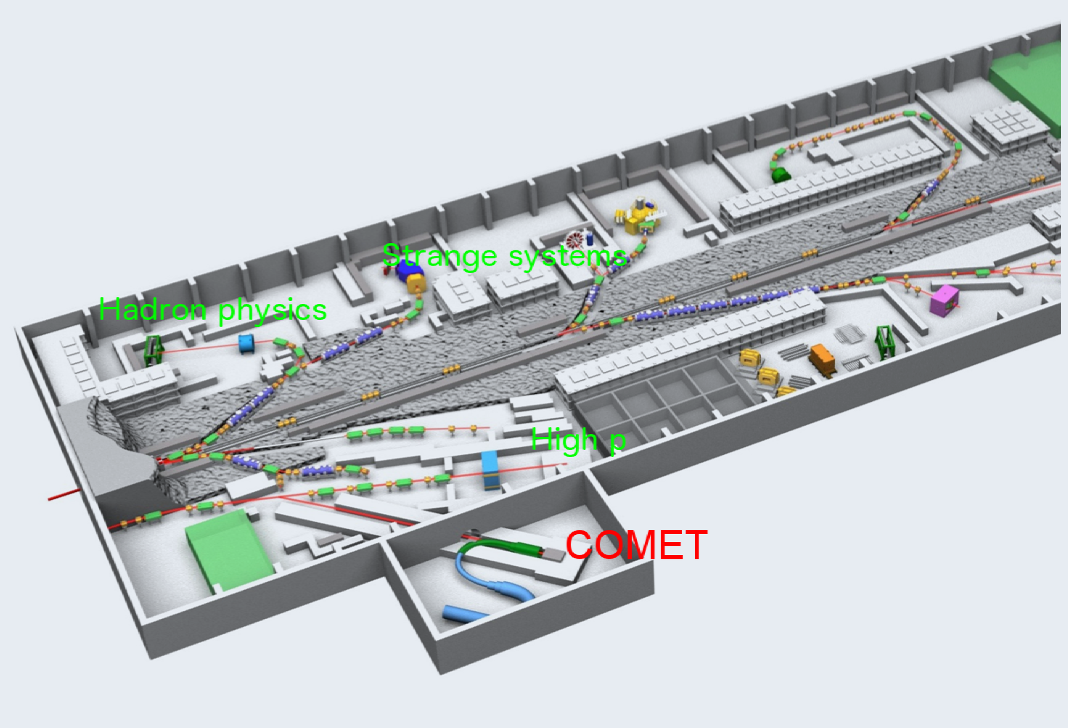


Figure 2: COMET beam line in the Hadron Hall extension plan

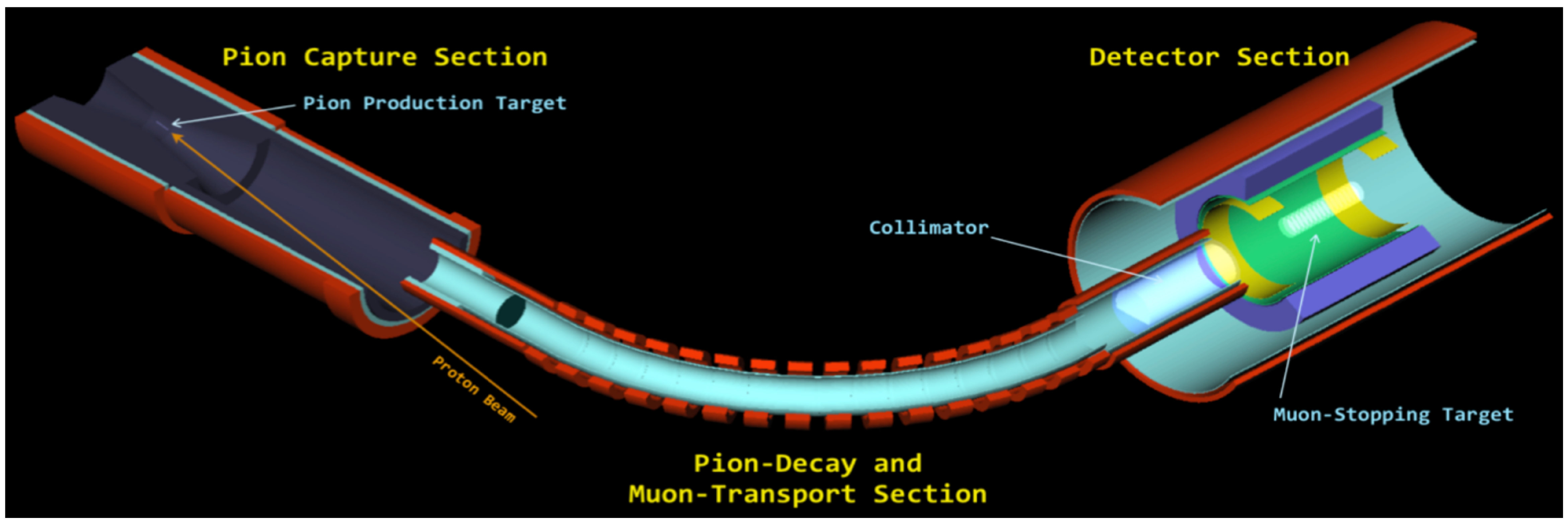


Figure 3: Concept of the COMET Phase-I

Proton beam

COMET Phase-I will use an 8 GeV, 0.4 μA $(2.5 \times 10^{12}$ protons/sec), slowly extracted proton beam from the J-PARC main ring (MR). One proposed configuration for the bunch structure of the proton beam is shown in Fig 4.

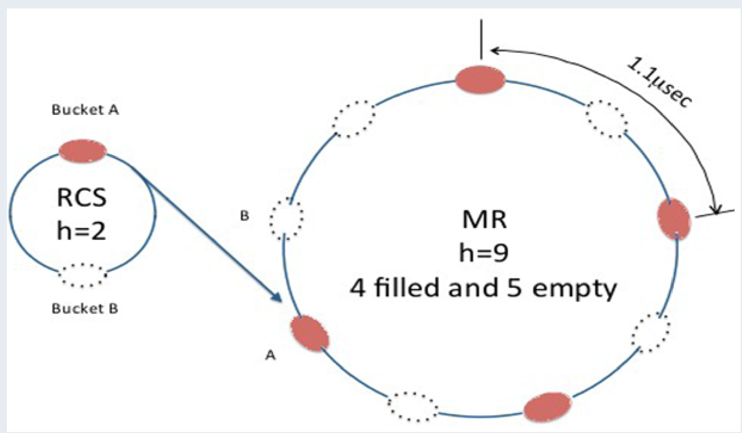


Figure 4: COMET proton beam acceleration bunch configuration

Muon transportation

The muon beam line of COMET Phase-I includes the pion capture section and the muon transport section up to the end of first 90^o bend. The field in the superconducting pion capture solenoid is 5 T. Pions and muons - produced when pions decay in flight - goes to a matching section, before going to the transport solenoid with a 3 T field. A prototype of this system has been built and operated successfully at Osaka University.

Negative muons are selected by a dipole field, which is created by an additional winding on top of the solenoid windings. A collimator is placed in front of the detector section to eliminate high momentum muons (and survival pions).

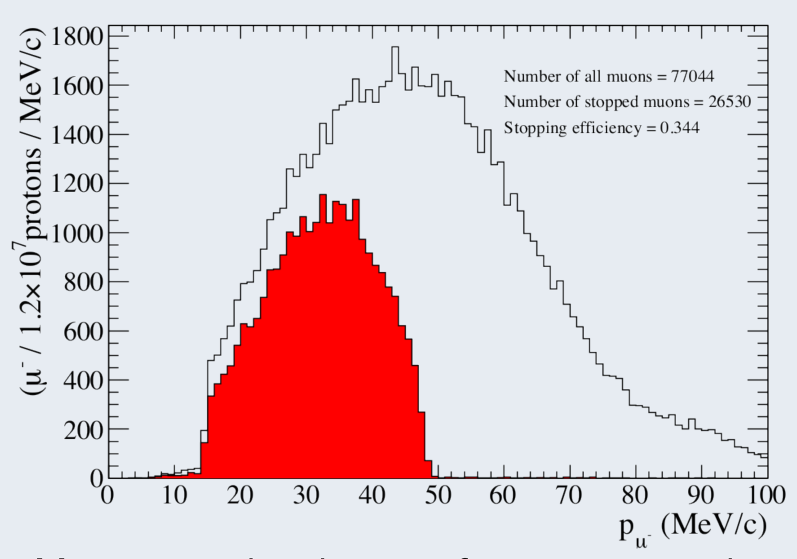
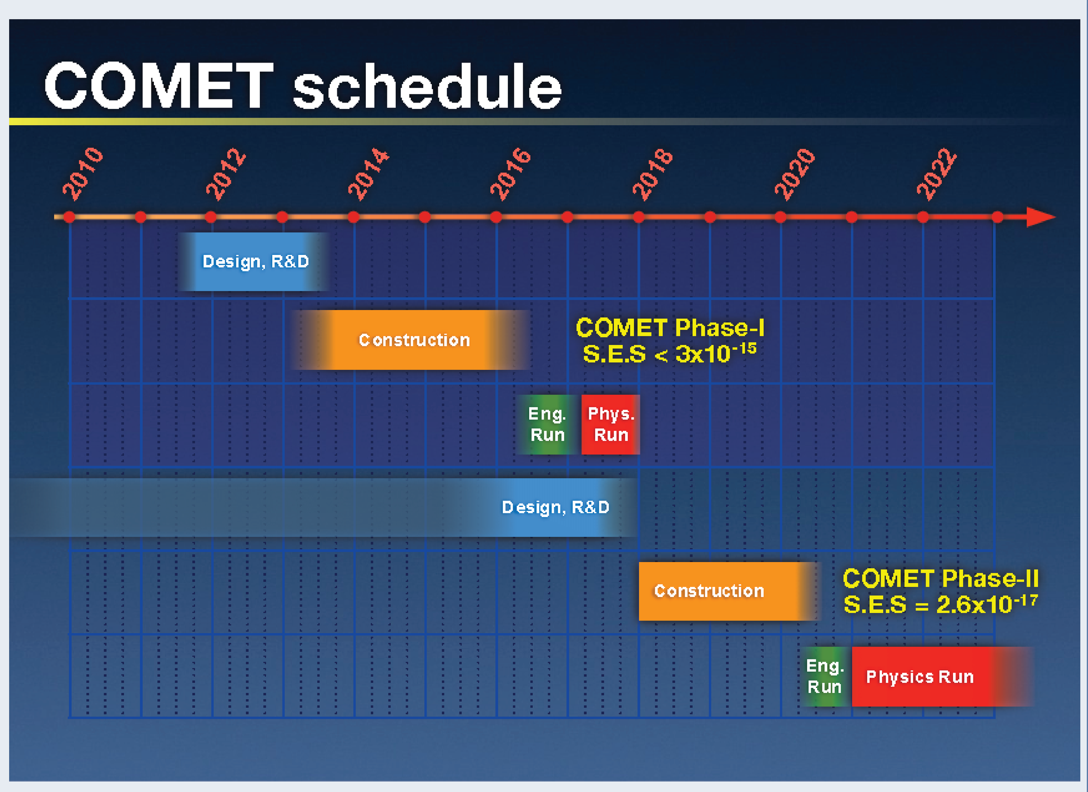


Figure 5: Momentum distribution of muons approaching the target (open histogram) and those stopped by it (red)

Schedule



Detectors for COMET Phase-I

There will be two detectors for two goals of COMET Phase-I: physics measurements and background measurements.

1. $\mu - e$ conversion search: There are two candidates for the detector for the search. Baseline detector is a cylindrical drift chamber (CDC), shown in the detector section in Fig 3. The CDC is chosen because it would help reducing background rate and hit rate. The alternative option is using the same detector for background measurements: a tranverse tracker, which is decribed below.
   The CDC is placed inside a magnetic field of 1T. It is tuned to accept particles with momentum larger than 70 MeV/c. Segmented triger hodoscope is located before the drift chamber, provides timing signal and reduces protons hit rate on the chamber. In order to reach the goal SES, energy resolution requirement for the CDC is 400 KeV at 105 MeV/c.

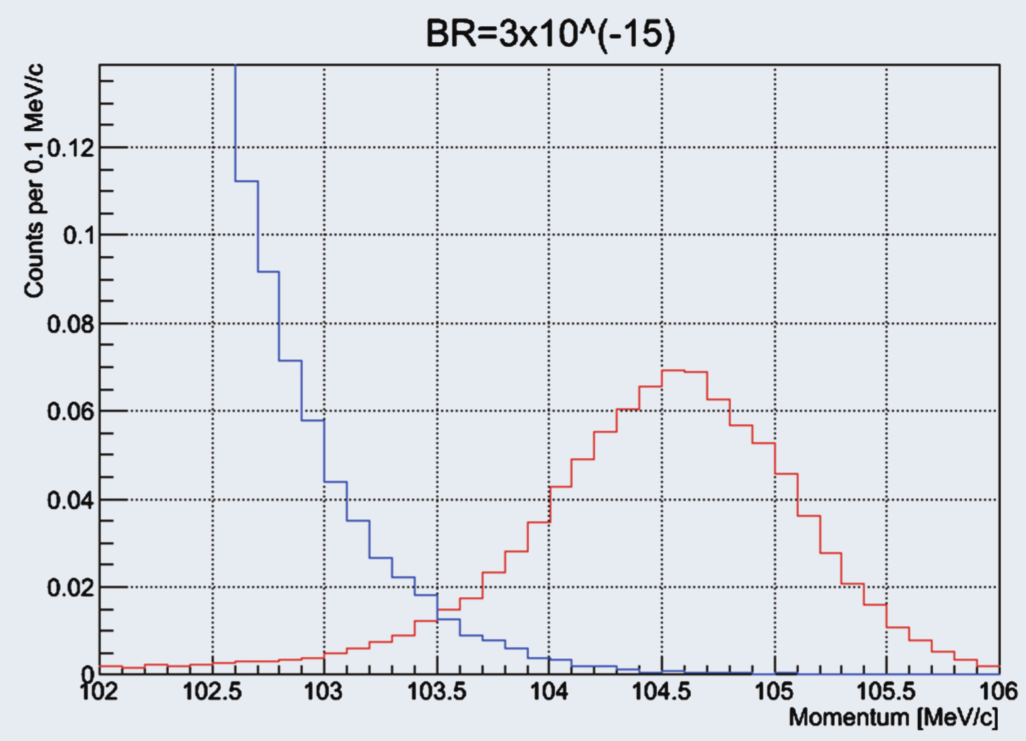


Figure 6: Signal of $\mu - e$ conversion, electron with momentum of about 105 MeV/c (red); and background from electron from muon decay in orbit (blue).

2. Background measurements: A tranverse tracker will be used. It consists of a solenoid magnet, 0.8 - 1 T, 5 straw tube tracker layers and a crystal calorimeter. This is regarded as a final prototype for Phase-II detector.

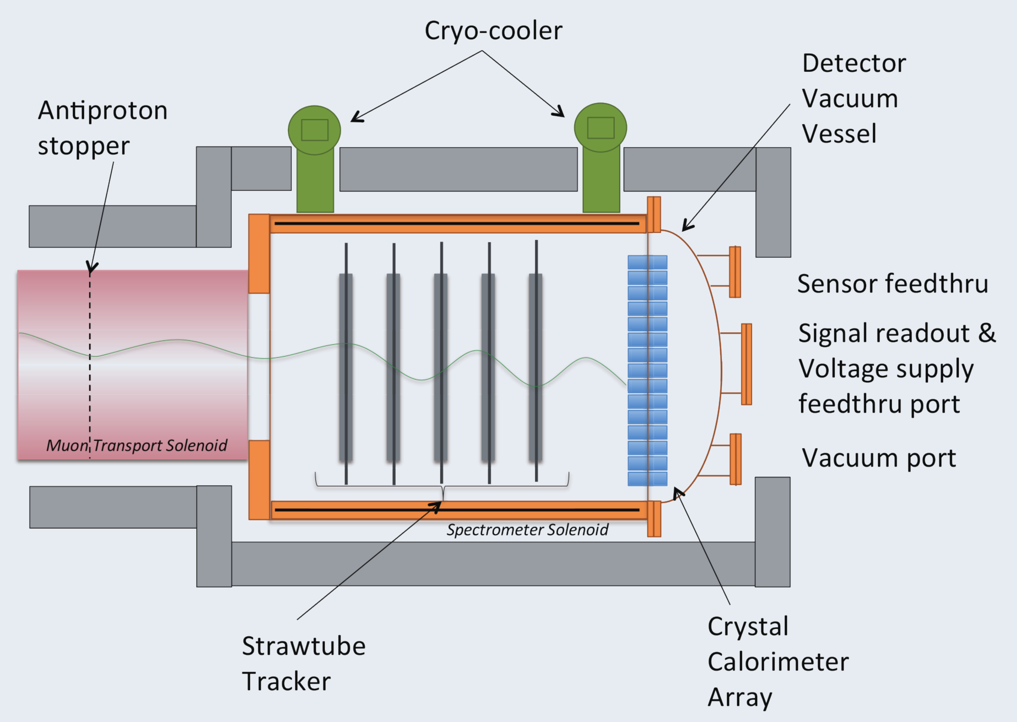


Figure 7: Concept of the detector for background measurements

A lot of detector R&D activities are ongoing: ECAL with GSO/LYSO crystals and APD readout; prototype of straw tube tracker; front end electronic board; calculation and wire chamber test for CDC; . . .