The COMET Experiment

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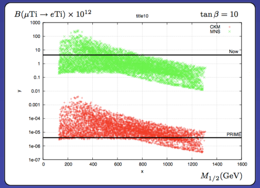
ABSTRACT

The COherent Muon to Electron Transition (COMET) experiment aims to measure muon to electron conversion with an unprecedented sensitivity of less than 1 in 10 million billion. The COMET experiment was given stage 1 approval by the J-PARC Program Advisory Committee in July 2009 and work is currently underway towards preparing a technical design report for the whole experiment. The need for this sensitivity places several stringent requirements on the beamline, such as, a pulsed proton beam with an extinction level between pulses of 9 orders of magnitude; a 5T superconducting solenoid operating near a high radiation environment; precise momentum selection of a large emittance muon beam and momentum selection and collimation of a large emittance electron beam. This paper will present the current status of the various components of the COMET beamline.

PHYSICS MOTIVAION

Charged lepton flavor violation (cLFV) has not been observed yet, and highly suppressed in the Standard Model. But it is predicted to occur in the extension of the Standard Model, in particular SUSY-GUT and SUSY-Seesaw models. The prediction is just below the present experimental limits. COMET plans to search for a muon to electron conversion, which is one of the the process of charged lepton flavor violation with muons ßat a sensitivity of 10^{-17}.



PROTON BEAM

COMET plans to use an 8 GeV, 7 μA, slow-extracted proton beam from the J-PARC main ring (MR). Currently, there are two bunching configuration options for the operation of the RCS and M

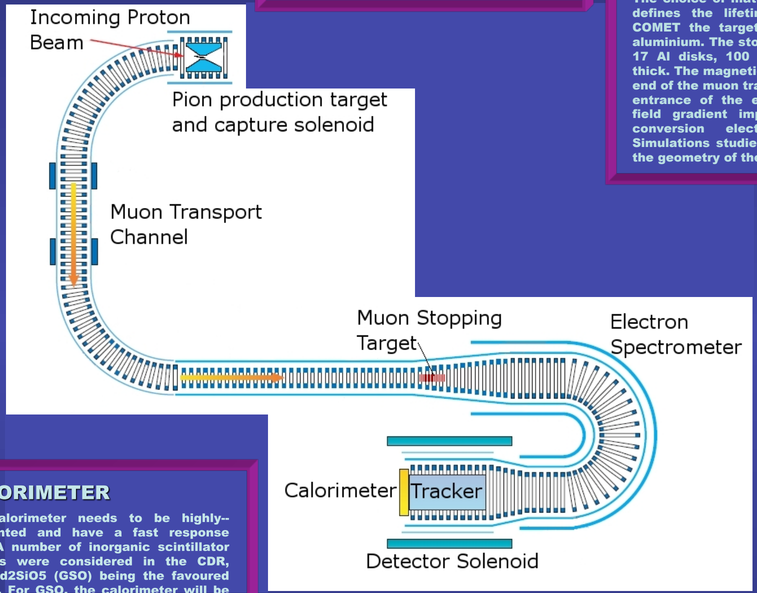
Recent work has focussed on the development of the proton extinction device used to reduce the fraction of protons outside of the pulse to 10^{-9}. The instrinsic extinction of the J-PARC MR is 10^{-7}, which means an additional device is needed to reduce this further by a factor of 10^{-2}. The design described in the CDR consists of two AC dipole magnets with a collimator between them. The magnets have a peak field of 600 G and oscillate at a frequency of 385 MHz. The development of this AC dipole extinction device was done in collaboration with the Mu2e experiment.

MUON TRANSPORT CHANNEL

The dispersive drift of the bent solenoid channel allows charge and momentum selection. In order to keep particles with the reference momentum in the centre of the transport channel an additional vertical dipole field is required. This can be done in a cost–effective way by tilting the solenoid coils. However, post–manufacturing tuning of the dipole field is restricted with this method. An alternative technology choice for producing the dipole field is to use an additional winding on top of the solenoid windings that has a current distribution that follows cos(θ). A prototype of this design has been constructed for the MUSIC project at Osaka University. The design presented in the CDR uses 2 T superconducting solenoids for the muon transport channel. However, this leads to a rise in the magnetic field just before the stopping target. The current design uses a field of 3 T, which eliminates this bump and increases the number of stopped muons. The results of this study is presented in WEPE046.

PION CAPTURE SOLENOID

See THPEC030



CALORIMETER

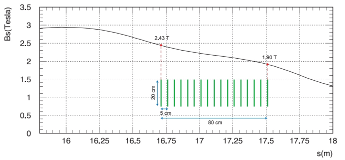
The calorimeter needs to be highly--segmented and have a fast response time. A number of inorganic scintillator crystals were considered in the CDR, with Gd2SiO5 (GSO) being the favoured choice. For GSO, the calorimeter will be segmented into 3x3x15 cm^3 crystals (about 11 radiation lengths long) covering a total area of $55^2\pi$ cm^2, which requires 1056 crystals. Recent studies have looked at using Cerium-doped Lutetium Yttrium Orthoscilicate (LYSO) instead of GSO. The readout of the calorimeter also needs to operate in a 1 T magnetic field, which excludes the use of low-noise, high-gain phototubes. Multi–pixel photon counters are best suited for this application as they offer the benefits of high gains and fast response times and can operate in magnetic fields.

TRACKER

The purpose of the tracker is to measure the momentum of electrons with high precision, in order to distinguish those that come from conversion and those that come from a background process, e.g. DIO. These are relatively low momentum particles and are easily scattered so the amount of material the electrons see has to be as low as possible. The tracker also needs to withstand a charged particle rate of 800 kHz and a photon rate of 8 MHz. In order to meet these requirements, a straw–tube tracker was proposed in the CDR. This consists of five transverse straw planes 48 cm apart, operating in a 1 T solenoid field. Each plane has two (x, y) arrays of straws, rotated by 45°, to provide a redundant measurement.

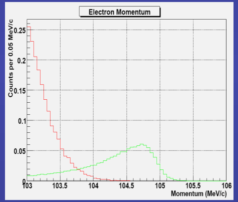
MUON STOPPING TARGET

The choice of material for the stopping target defines the lifetime of muonic atoms. For COMET the target material is chosen to be aluminium. The stopping target is composed of 17 Al disks, 100 mm in radius and 0.2 mm thick. The magnetic field varies from 3 T at the end of the muon transport channel to 1 T at the entrance of the electron spectrometer. This field gradient improves the acceptance of conversion electrons in the detector. Simulations studies are underway to optimise the geometry of the stopping target.

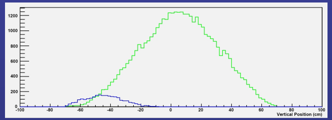


ELECTRON SPECTROMETER

The electron spectrometer is designed to transport electrons from muon conversion or normal decay. The main source of background electrons is from muons that decay after nuclear capture. These are called decay in orbit (DIO) electrons. Electrons from muon conversion have a momentum around 104.7 MeV/c whereas DIO electrons have a range of energies with a tail that extends up to around 104.3 MeV/c



The vertical dispersion of the toroidal field of the electron spectrometer allows lower momentum DIO electrons to be removed by placing an aluminium collimator at the end of the channel. The figure below shows the vertical position of electrons from muon conversion and DIO electrons after passing through the electron spectrometer.



By placing a collimator that extends from 20 cm below the median plane it is possible to remove electrons that have a momentum < 60MeV/c, thus reducing the rate in the detector systems.