Search for Muon to Electron Conversion at J-PARC: COMET **Phase-I** Experiment

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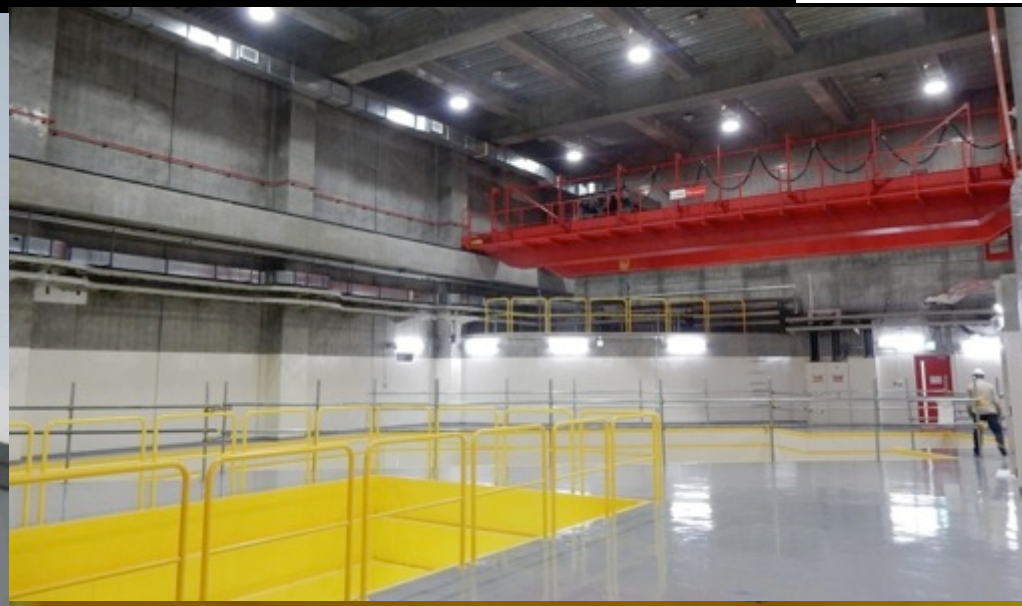
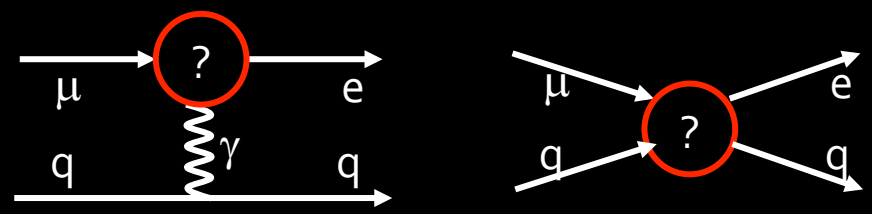
Aug 5, 2016, ICHEP

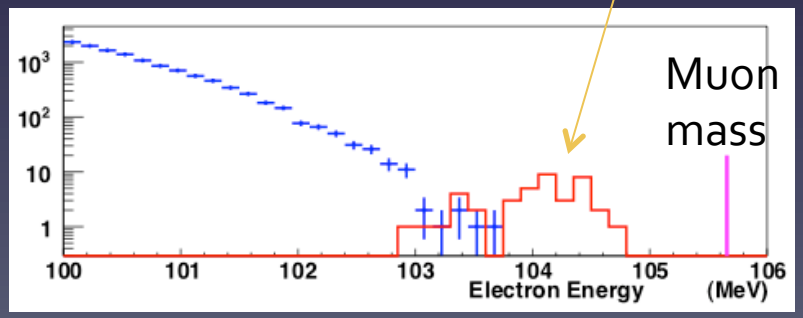


Muon Conversion: $\mu^- N \rightarrow e^- N$



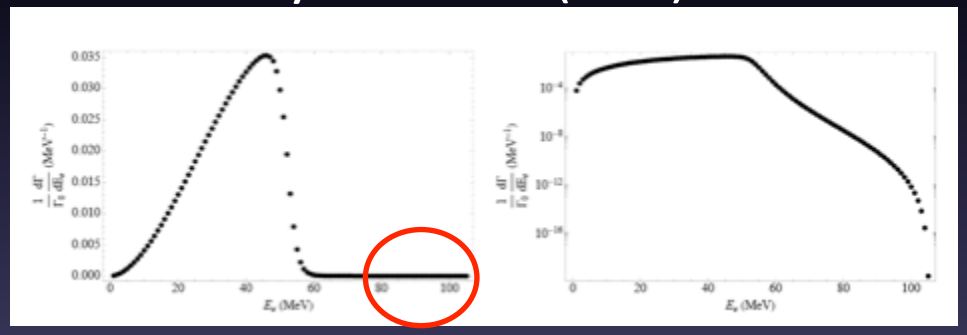
Signal

- Muon stops at Al (or Ti) target, captured in 1s orbit
- Decay with mono-energetic electron
  - $E = m_\mu - E_{rec} - E_B \sim 105\text{MeV}$



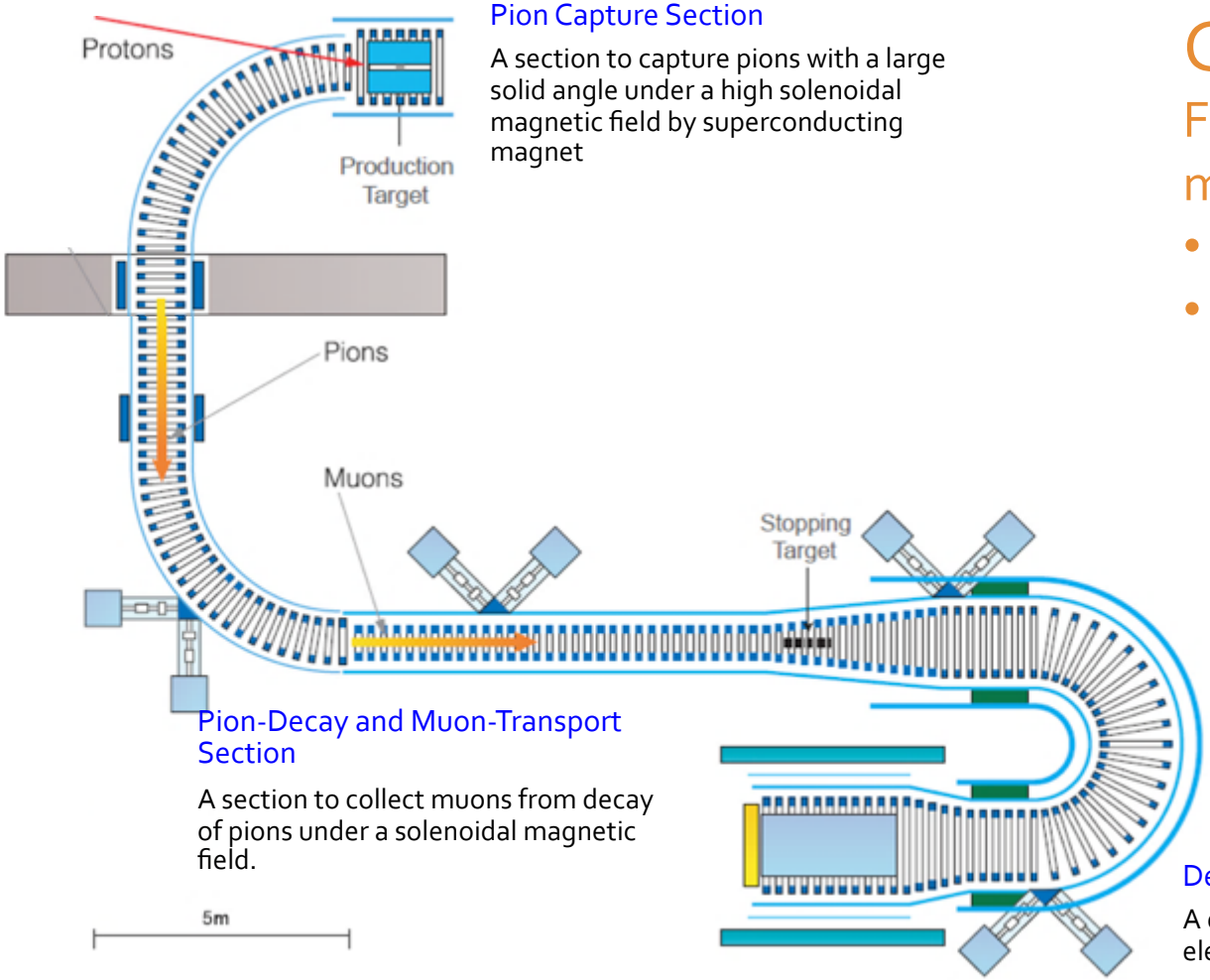
Background

- Decay-In-Orbit (DIO)



- Prompt background (to beam arrival)
  - Muon/pion decay in flight
  - Radiative pion capture: $\pi N \rightarrow \gamma X$; $\gamma \rightarrow e^+e^-$
  - Cosmic, Anti-proton…

COMET Experiment



Pion Capture Section

A section to capture pions with a large solid angle under a high solenoidal magnetic field by superconducting magnet

Pion-Decay and Muon-Transport Section

A section to collect muons from decay of pions under a solenoidal magnetic field.

Detector Section

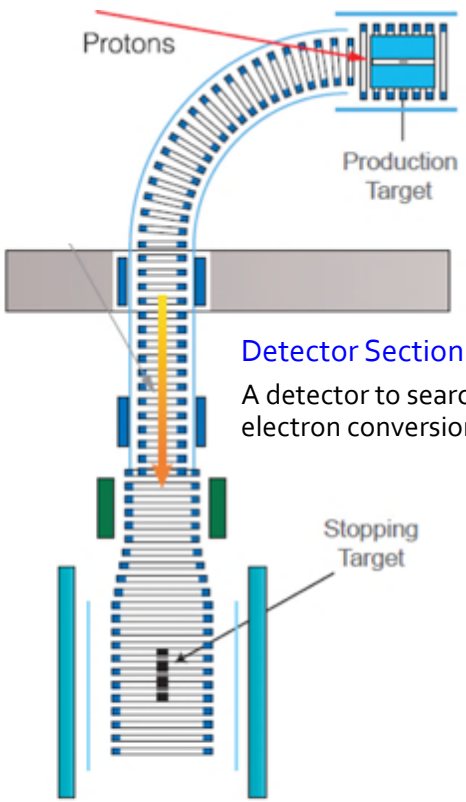
A detector to search for muon-to-electron conversion process

COMET Phase-II

For R~10^{-17} muon conversion measurement

- 56 kW proton beam
- 1 year DAQ

COMET Experiment



Pion Capture Section

A section to capture pions with a large solid angle under a high solenoidal magnetic field by superconducting magnet

Detector Section

A detector to search for muon-to-electron conversion process

COMET Phase-II

For R~10^{-17} muon conversion measurement

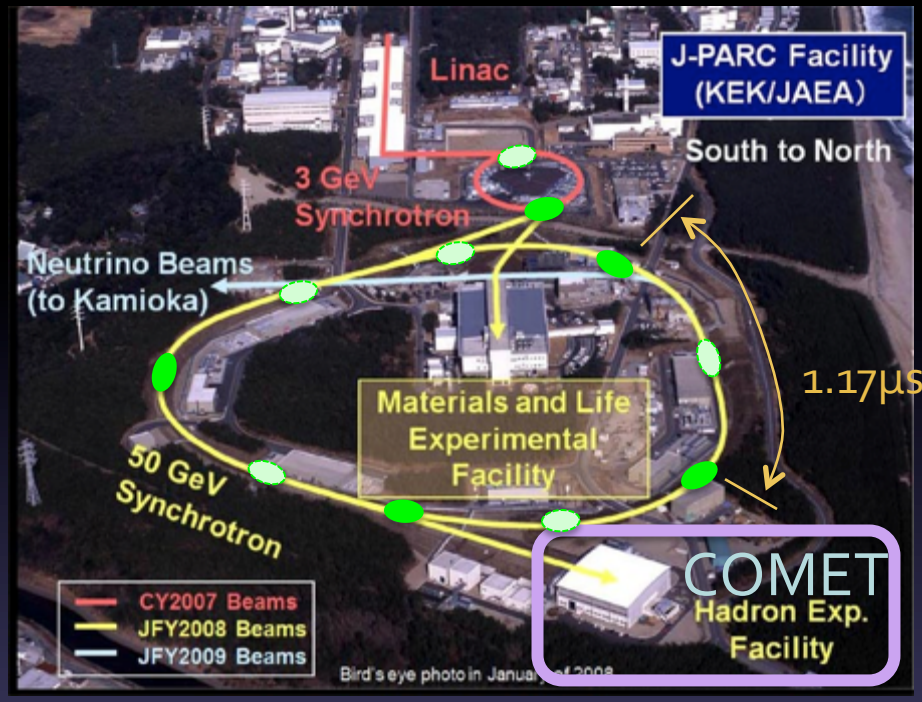
- 56 kW proton beam
- 1 year DAQ

COMET-Phase-I

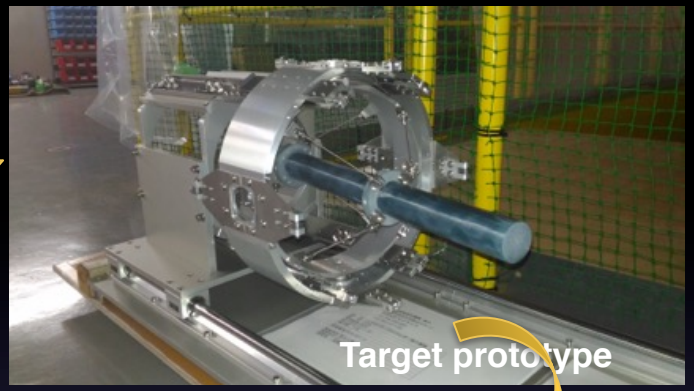
For BG measurement, R~10^{-15} muon conversion

- 3kW proton beam
- Half year DAQ

Facility / Beams

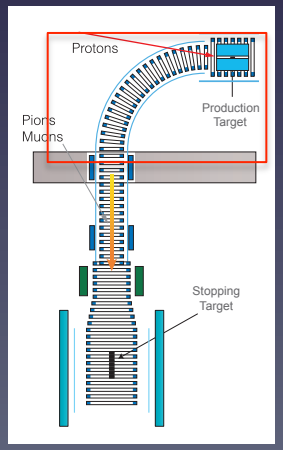


proton



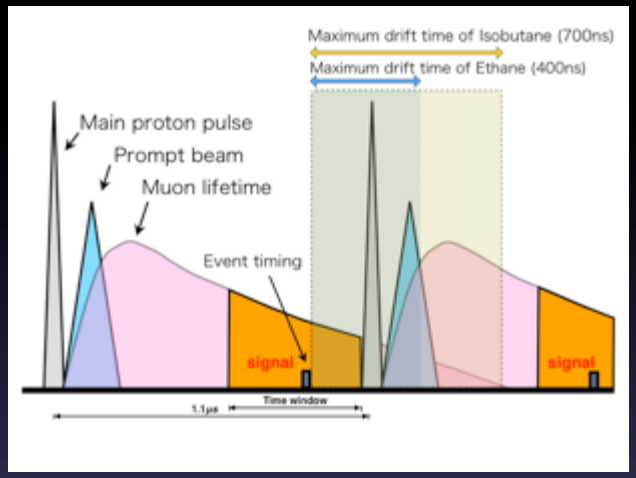
pion

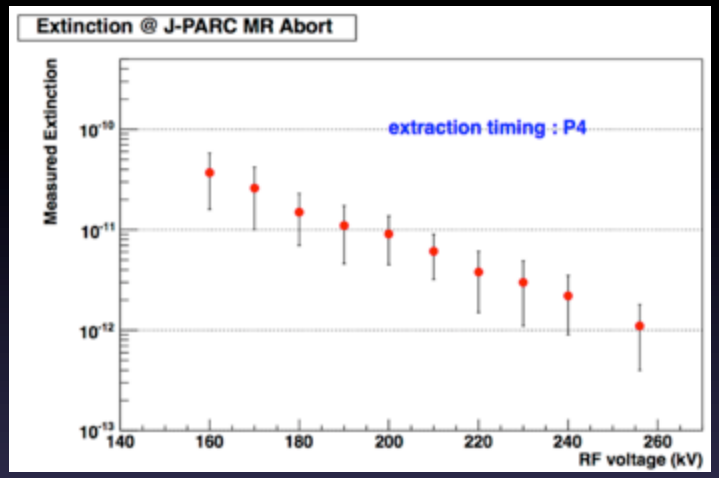
- 8GeV, 3.2kW pulsed proton beam
- 4/9 (or 3/9) buckets filled in MR

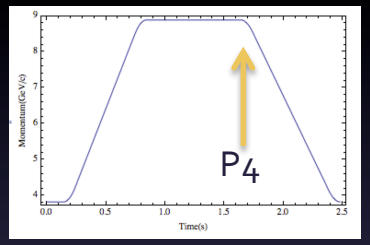


Pion/Muon to detector

Pulsed proton beam



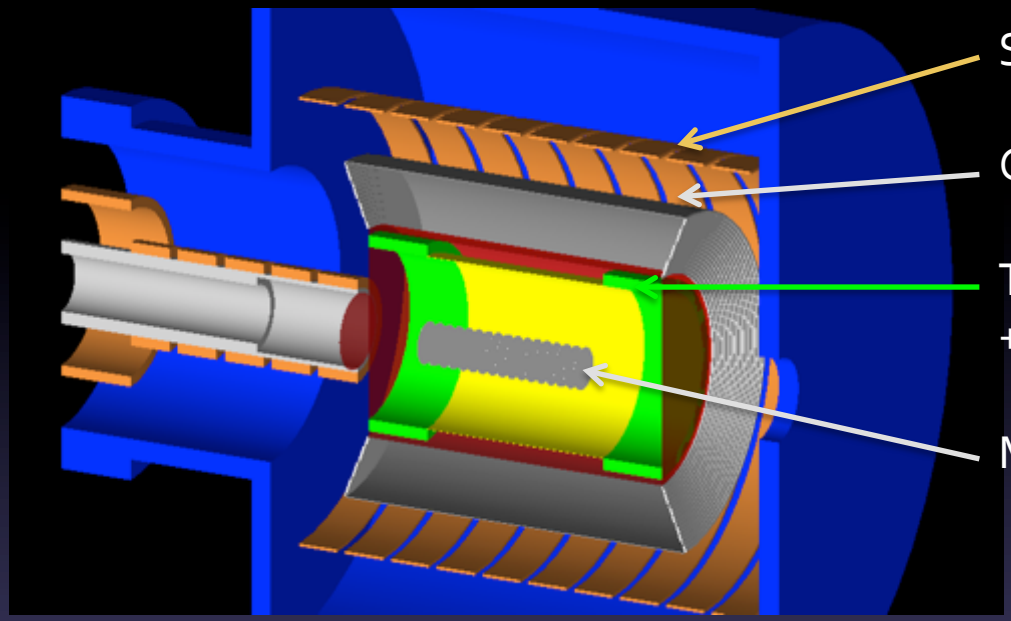


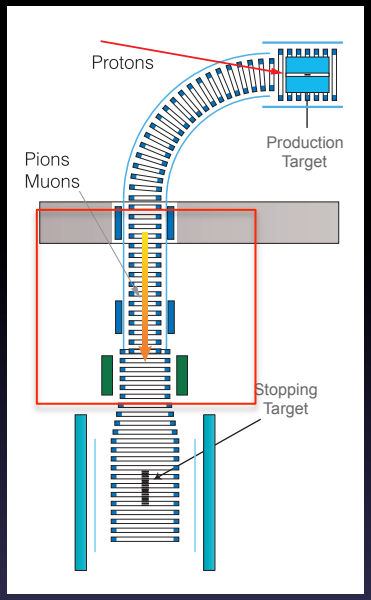


One MR cycle : 2.48sec

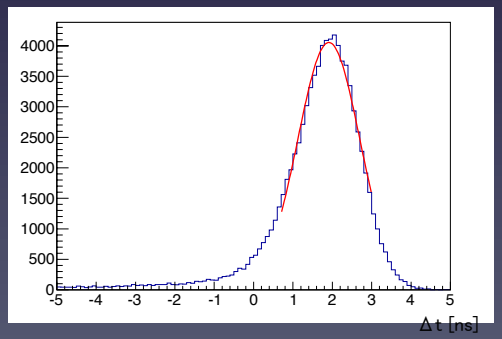
- Pulsed proton beam
  - Beam background with proton pulse is major BG hit source
  - High extinction between beam enables localizing signal event in time
- $<10^{-9}$ extinction factor achievable by increasing MR RF voltage (May 2014), both at 8GeV and 30GeV

Cylindrical Detector system



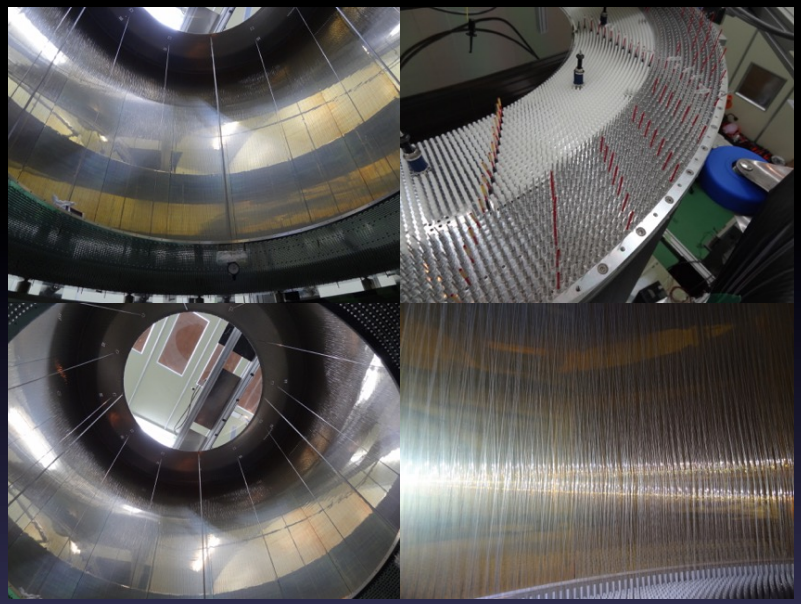


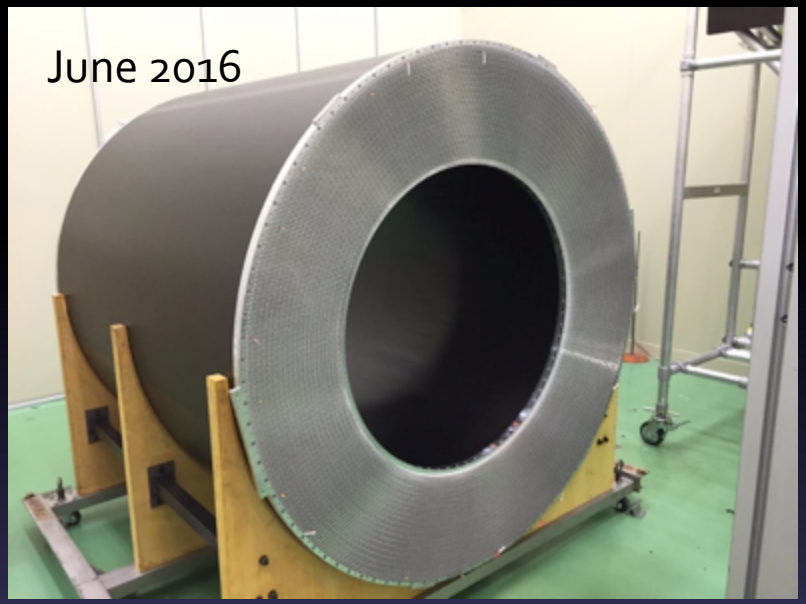
- All stereo-wire drift chamber, 20 layers, ~5000 sense wires
- Hodoscope for timing and trigger
  - Trigger : see page 8
  - Timing requirement 1ns, <0.8ns could be achieved



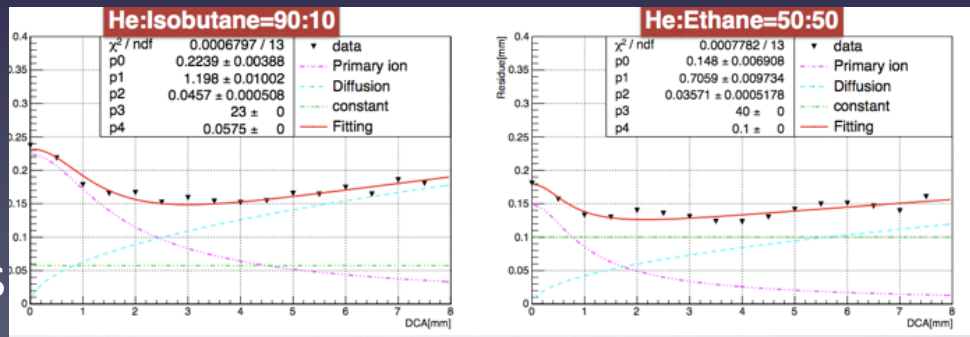
Distribution of Timing difference between Cerenkov and Scintillator

CyDet construction



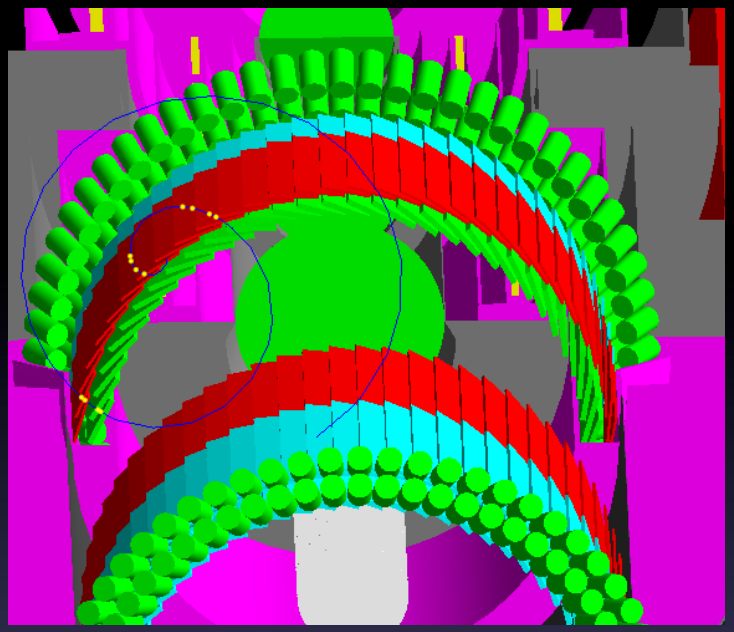


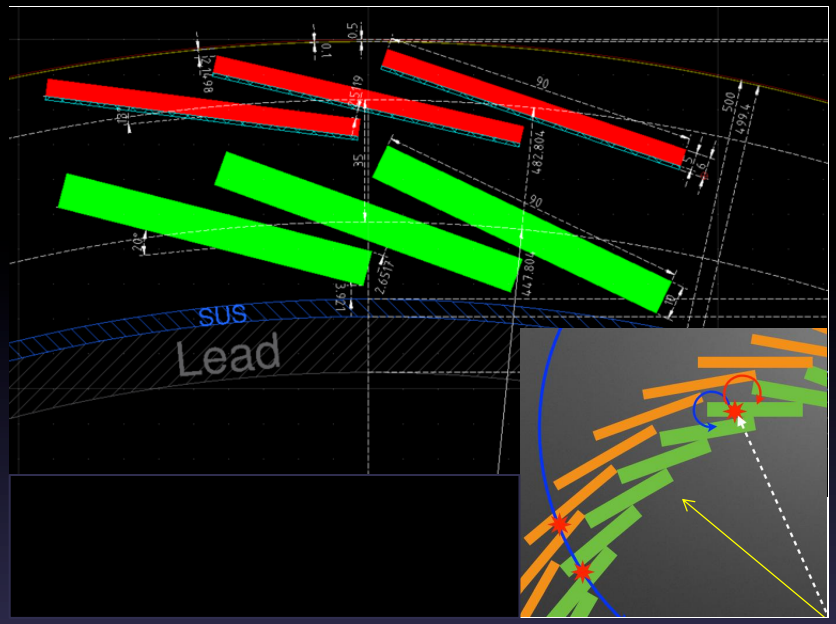
- Construction completed June 2016, Cosmic ray test from August 2016
- Spatial resolution requirement 200μm can be possible both gas mixture



Position resolutions of CDC prototype obtained in the beam test @Spring-8

CTH: Trigger Hodoscope





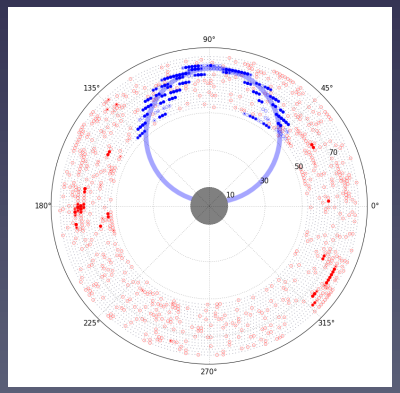
- Twisted, overlapped two scintillators + two Cerenkov detectors
- Primary hit rate too high for trigger

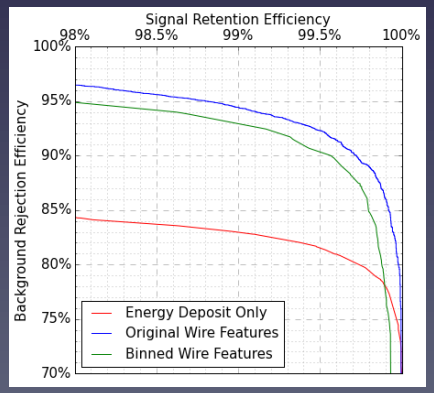
	Upstream Scintillator	Upstream Cherenkov	Downstream Scintillator	Downstream Cherenkov
Average rate @200 ~ 1170 ns (MHz)	3.5	1.5 - 2	4	3

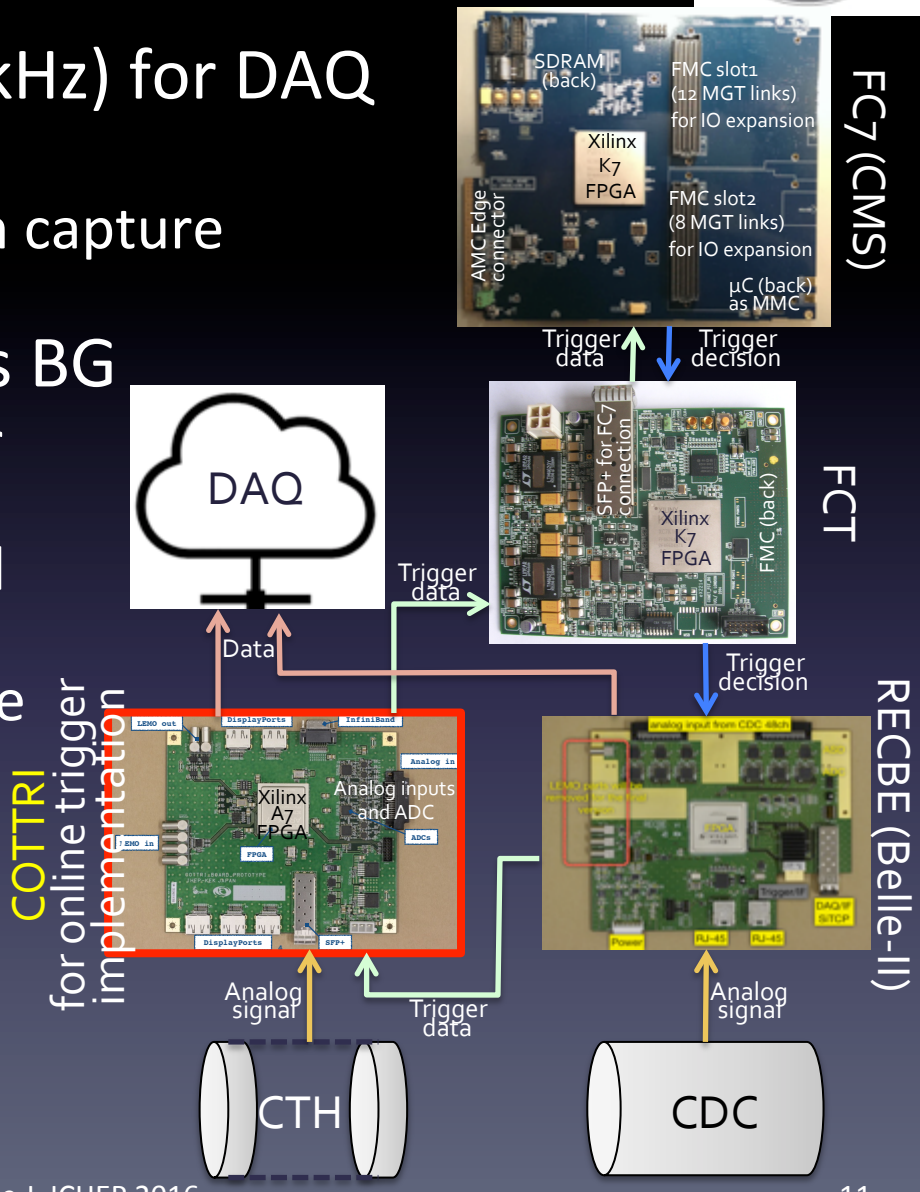
- Adding lead shielding, require 4-fold coincidence for trigger : primary trigger rate 20 – 30 kHz

Trigger / DAQ

- Still high trigger rate (20-30 kHz) for DAQ
  - Mostly background hits
  - Beam electron, secondary from capture neutron/gamma
- Using online BDT to suppress BG
  - Energy deposition in CDC, layer information as input to BDT
  - 95% BG suppressed, 99% signal electron retains
  - 1 – 2 kHz trigger rate achievable

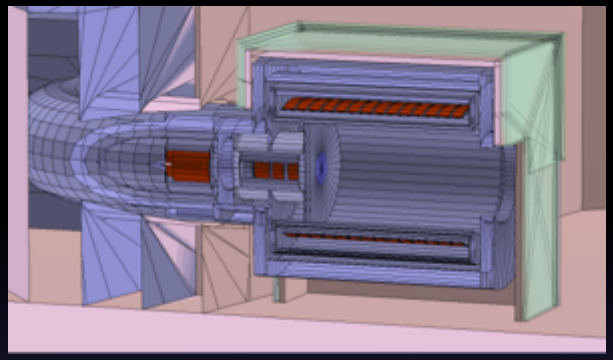


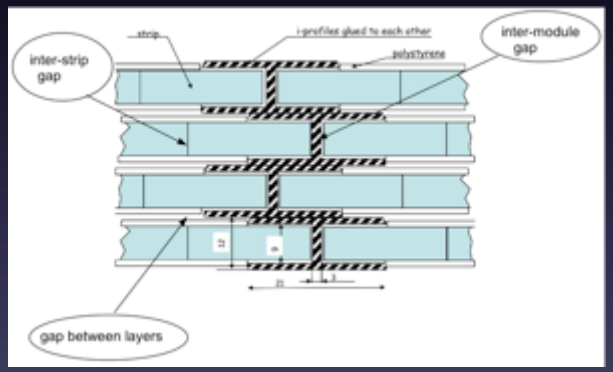


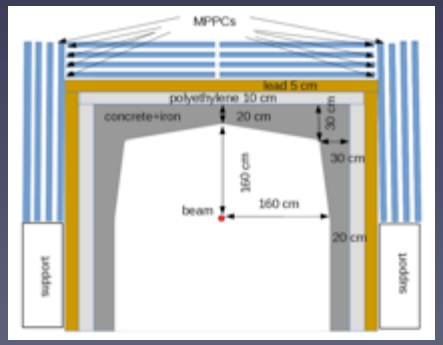


Cosmic ray / Neutron

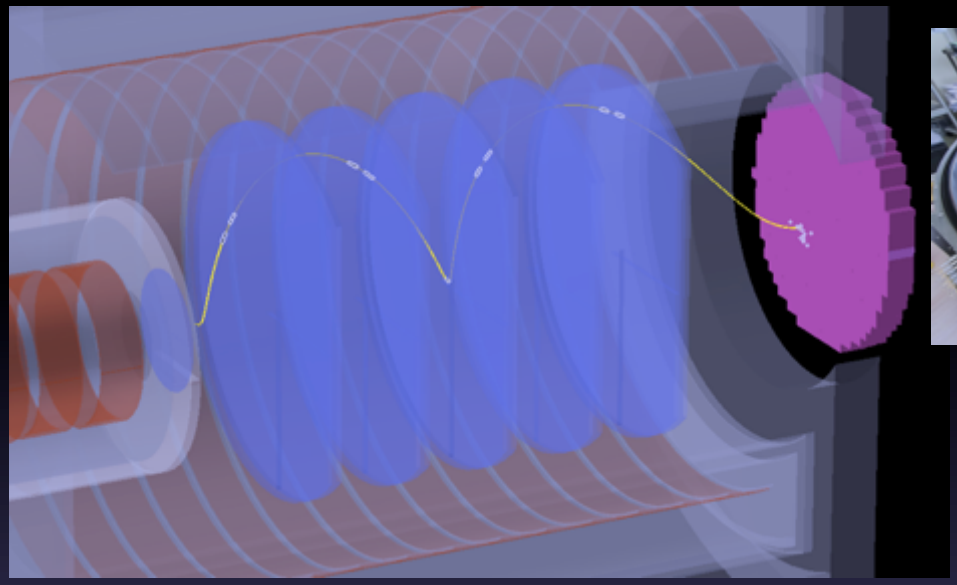
- To suppress Cosmic Ray muon to factor of 10^{-4}
  - Decay in flight, interaction with detector material
  - Note: CDC can full-reconstruct CR
- Neutron issue
  - SiPM weak to neutron irradiation, generates noise at Strip sensor
  - Internal Neutron Shield reduces neutron from stopping target
  - Similar neutron flux expected from proton target, shielding around beamline under study

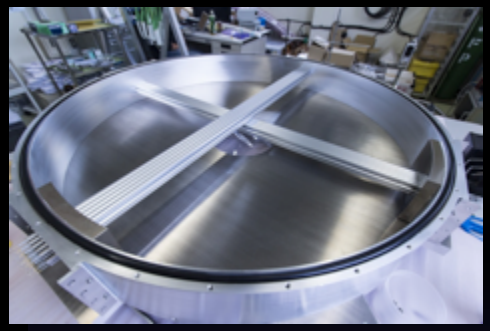


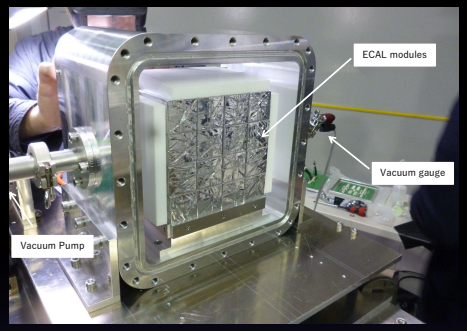


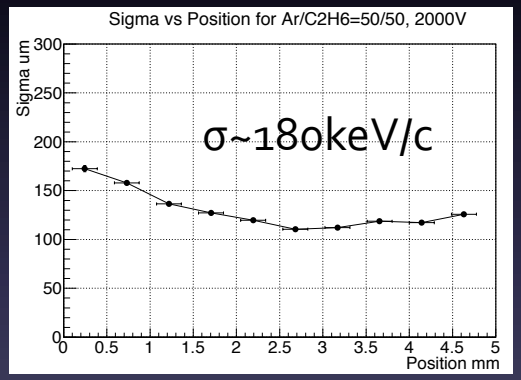


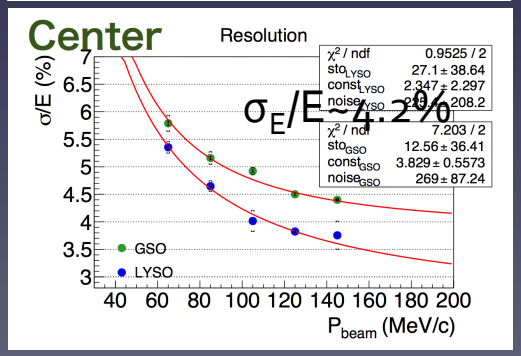
Background measurement







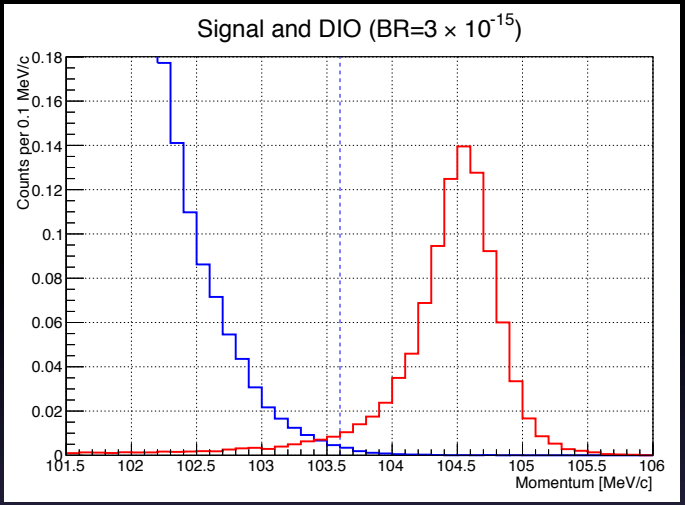




- StrEcal
  - Detector for Phase-II
  - 5 station of straw detectors+ ~2000 LYSO calorimeter
- Beam measurement program at Phase-I
  - Particle composition, beam profile
  - 1/1000 reduced beam
    - no radiation tolerance, pile-up issue.
  - CyDet rolls out and StrEcal installed

Physics sensitivity

- Net acceptance = 4.1%
  - Online efficiency ~0.99
  - Geometric acceptance + track quality ~0.18
  - 103.6 MeV < p < 106MeV : 0.93
  - 700ns < t < 1170 ns : 0.3
- Background = 0.032
  - RPC ~ 0.003
  - DIO ~ 0.01
  - Cosmic <0.01
- SES(Phase-I) ~ 3.1×10^{-15}
  - SES(Phase-II) ~ 2.5×10^{-17}

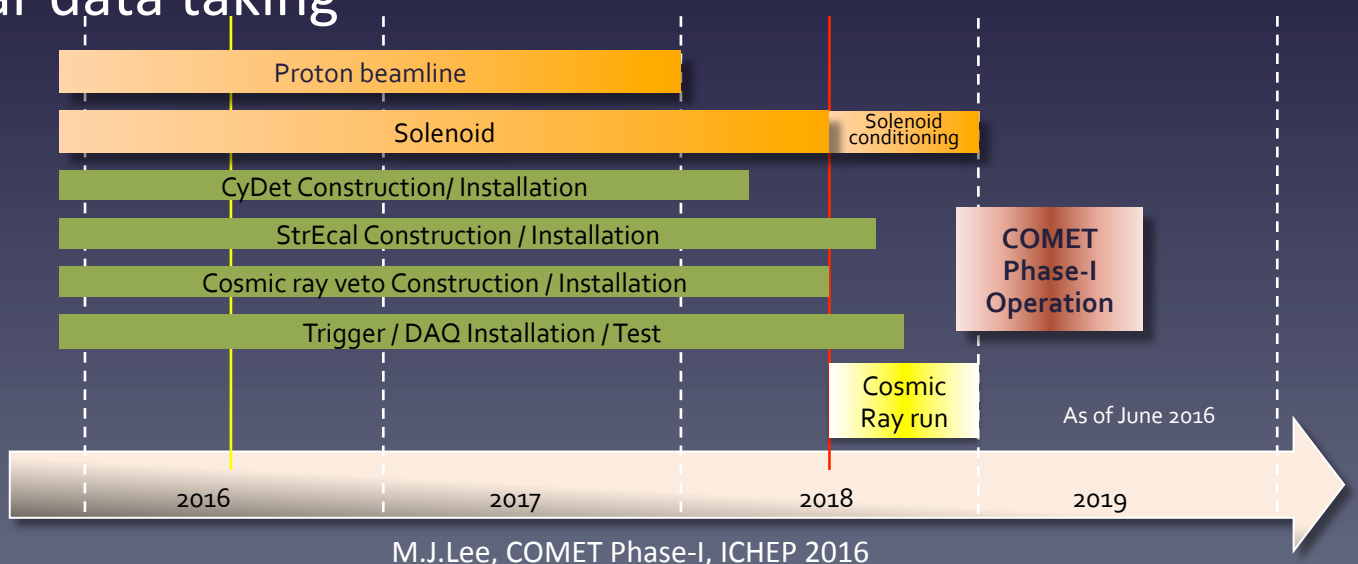


Type	Background	Estimated events
Physics	Muon decay in orbit	0.01
	Radiative muon capture	0.0019
	Neutron emission after muon capture	< 0.001
	Charged particle emission after muon capture	< 0.001
Prompt Beam	* Beam electrons	
	* Muon decay in flight	
	* Pion decay in flight	
	* Other beam particles	
	All (*) Combined	≤ 0.0038
	Radiative pion capture	0.0028
	Neutrons	$\sim 10^{-9}$
Delayed Beam	Beam electrons	~ 0
	Muon decay in flight	~ 0
	Pion decay in flight	~ 0
	Radiative pion capture	~ 0
	Anti-proton induced backgrounds	0.0012
Others	Cosmic rays†	< 0.01
Total		0.032

† This estimate is currently limited by computing resources.

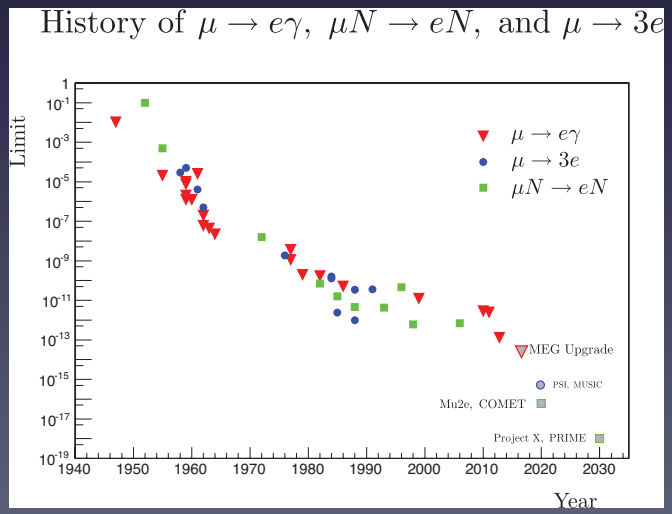
Schedules

- Highly recognized by KEK IPNS, ready for stage-2 approval
- Proton beam line construction complete in 2017
- Phase-I physics data taking in 2018 or 2019
  - Cosmic run at 2018, 4 weeks of engineering run
  - 5 month data taking
- Phase-II R&D in parallel with Phase-I R&D and data taking
- Phase-II physics data taking in 2021
  - 1 year data taking



Summary

- SES : 3.1 x 10^{-15}
  - SES (Phase-II): 2.5 x 10^{-17}
- Start data taking at 2018
- Half year data taking for
  - Muon conversion measurement
  - Beam measurement



176 collaborators,
33 institutes, 15 countries