Introduction of the COMET Experiment

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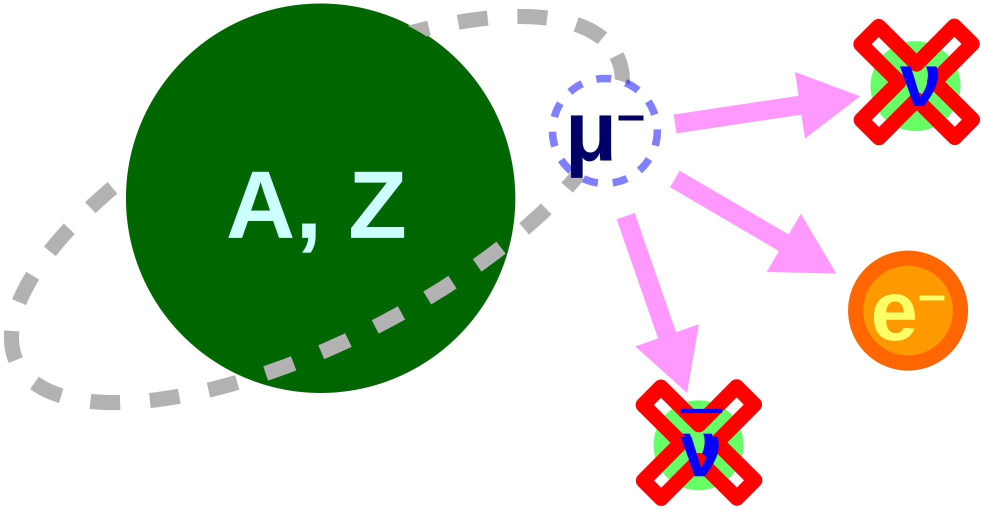
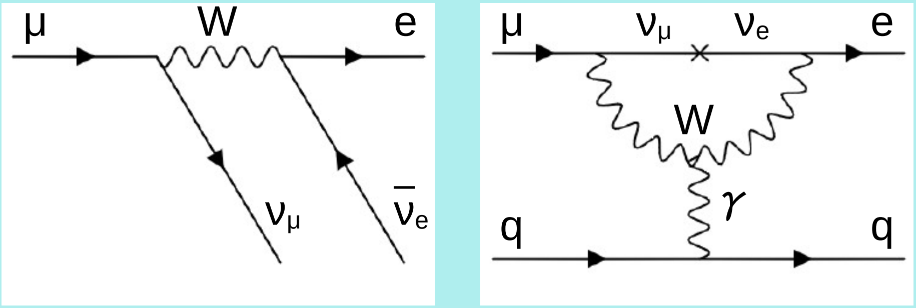
The μ-e Conversion



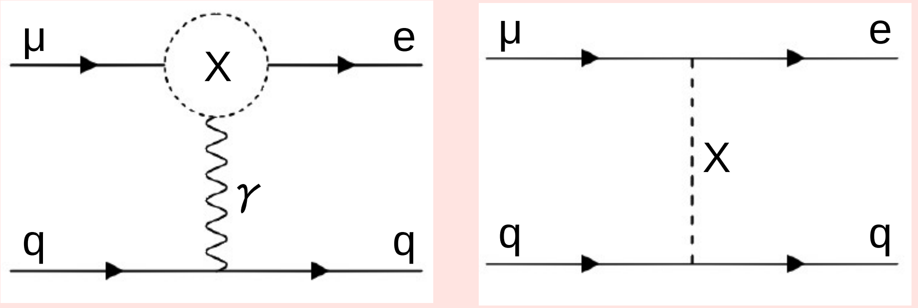
- Conversion of a muon to an electron is "Charged Lepton Flavor Violation" process and strongly prohibited in the Standard Model.
- Its discovery is an evidence of the new physics.

Standard Model



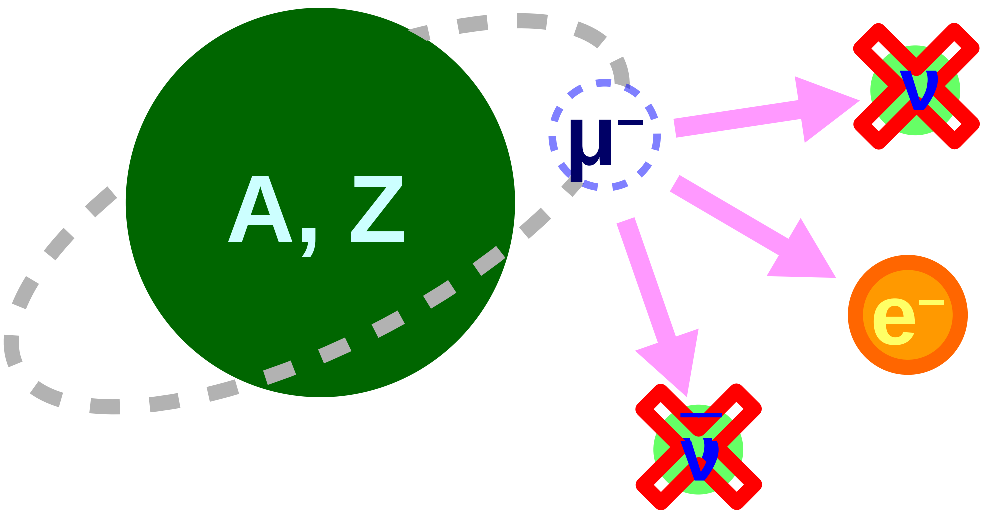
- Muon can decay to electron with neutrinos.
- μ-e conversion via neutrino oscillation is <O(10^{-54}).

New Physics

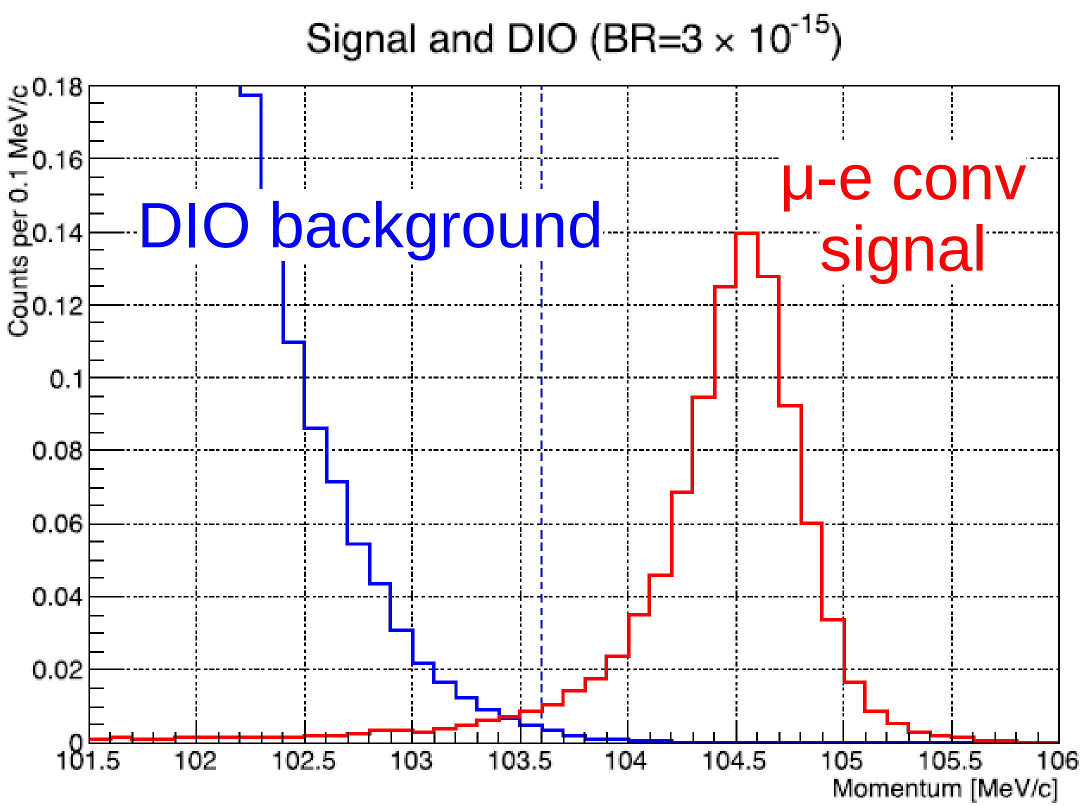


- Sensitivity for the new physics scale is >1000TeV.
- μ-e conversion has sensitivity to both photonic and non-photonic interaction.

The μ-e Conversion

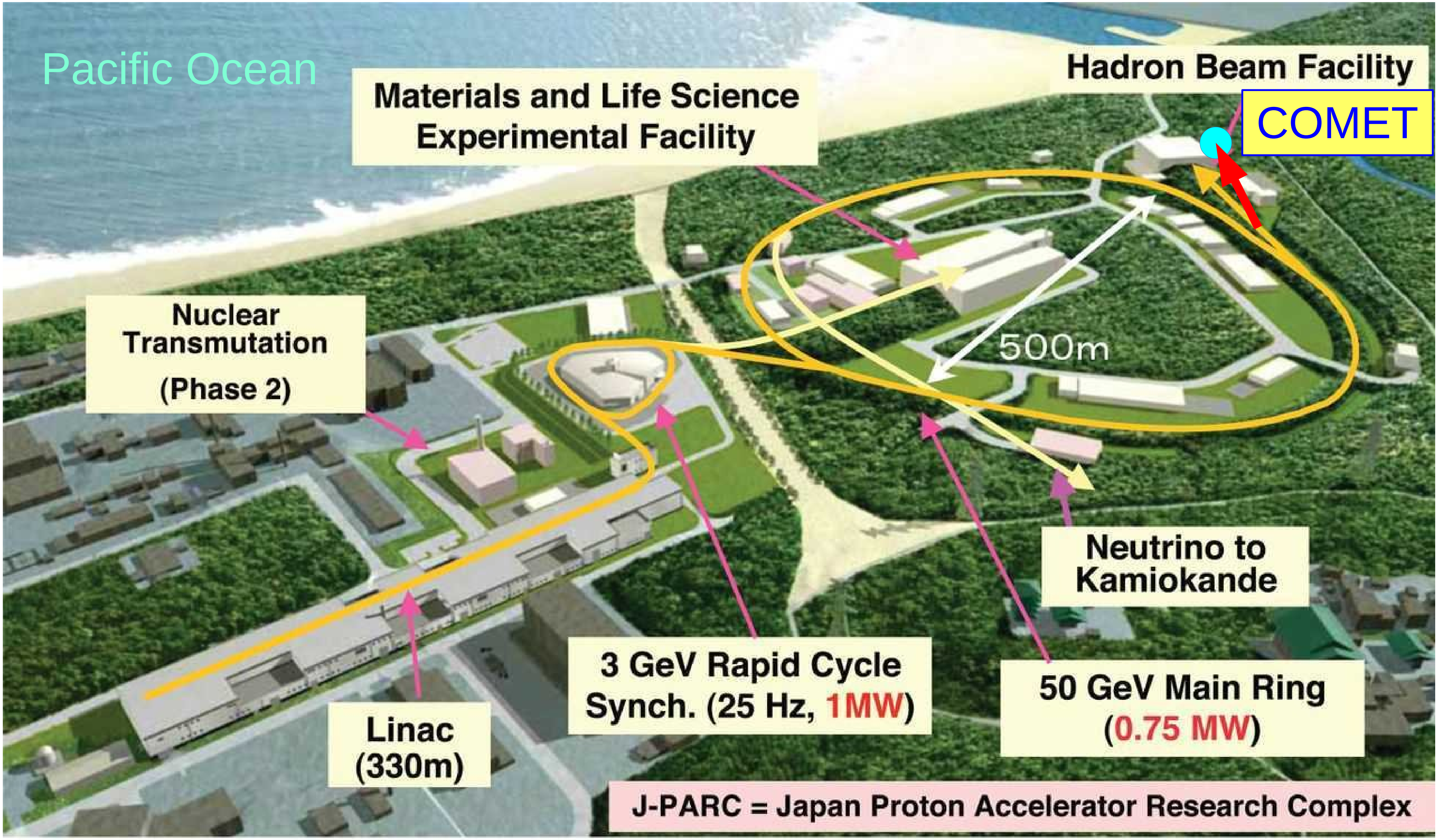


- Current world record of the μ-e conversion is 7×10^{-13} by SINDRUM-II experiment. The COMET experiment aim to reach $O(10^{-17})$ at Phase-II.

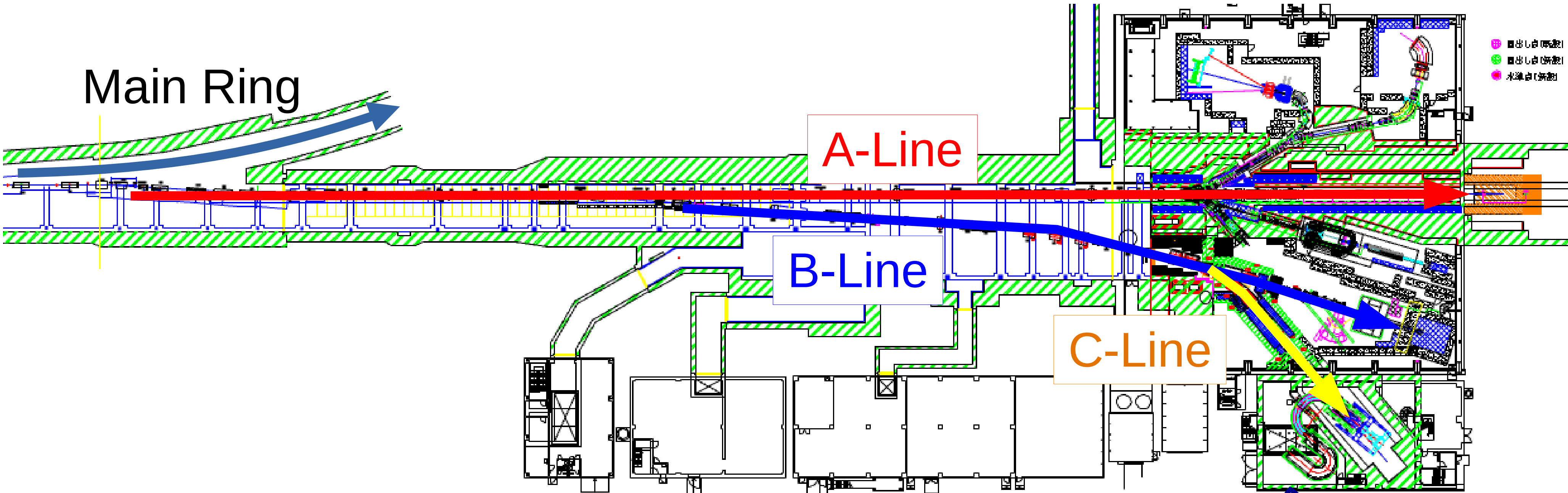


- The signal of μ-e conversion is single electron with energy of about muon mass.
- Electrons from muon decay-in-orbit (DIO) is a major background. It emits a high-energy electron due to recoil of a nucleus.

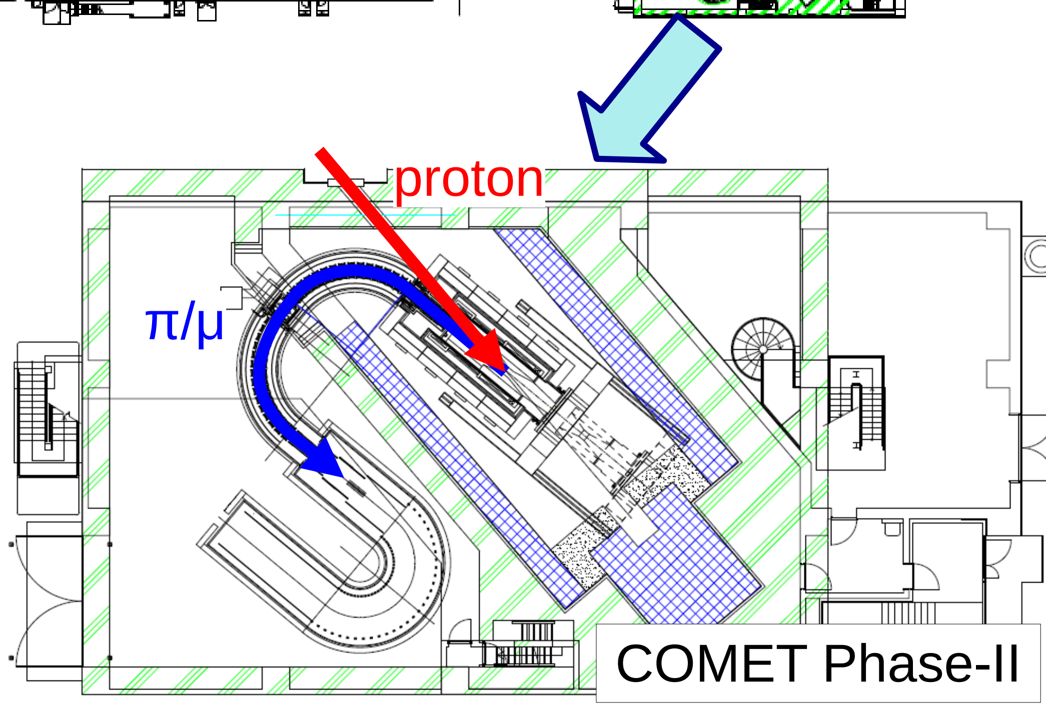
COMET in J-PARC



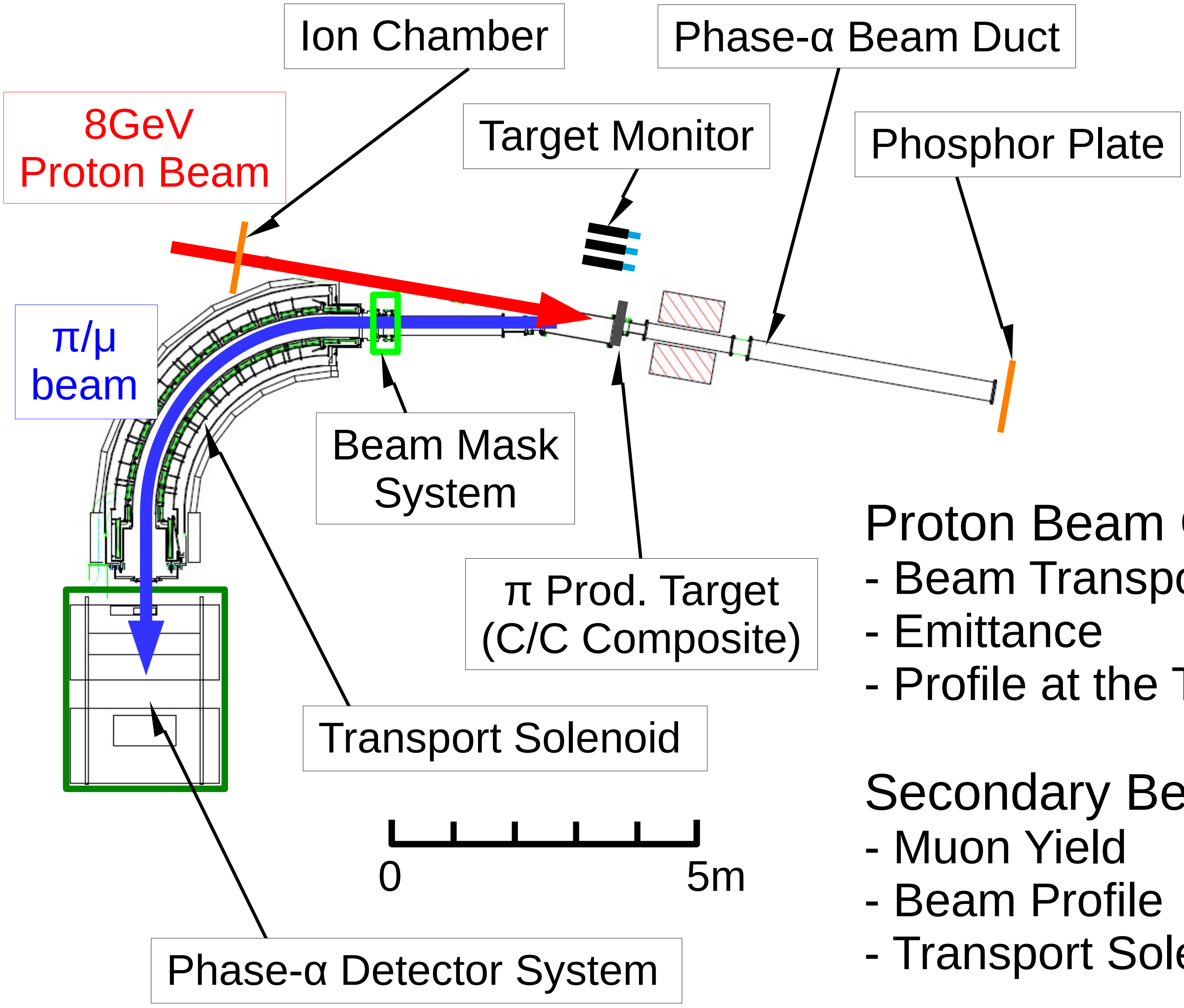
COMET in Hadron Facility



1. J-PARC 8GeV proton beam (56kW max) is injected to the pion production target to generate high-intensity muon beam.
2. Muon beam is stopped at Al target to form muonic atom.
3. Search for high-momentum electrons of the μ-e conversion signal.



COMET Phase-α : Pilot Run

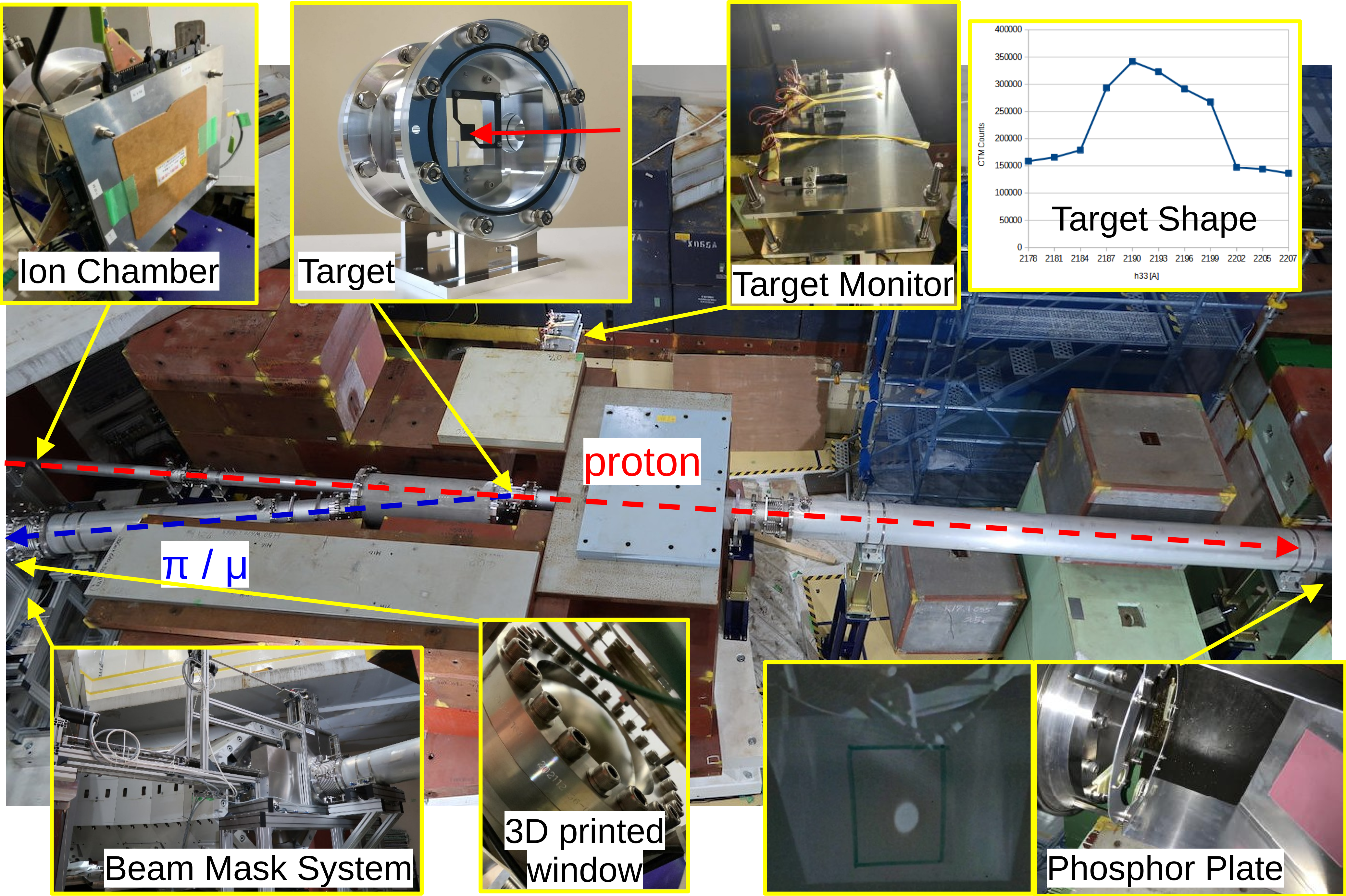


Proton Beam Commissioning
- Beam Transportation
- Emittance
- Profile at the Target

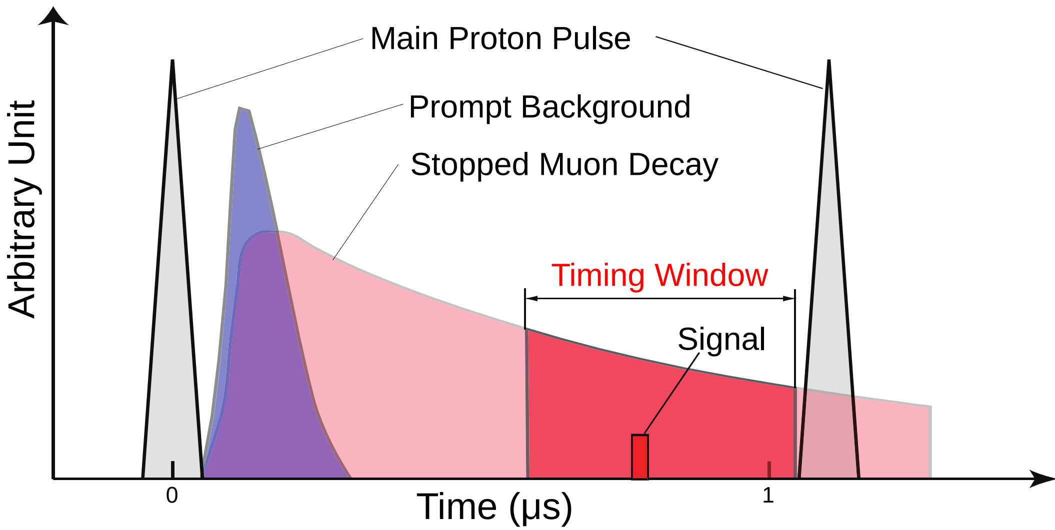
Secondary Beam Commissioning
- Muon Yield
- Beam Profile
- Transport Solenoid Performance

Proton Beam Commissioning

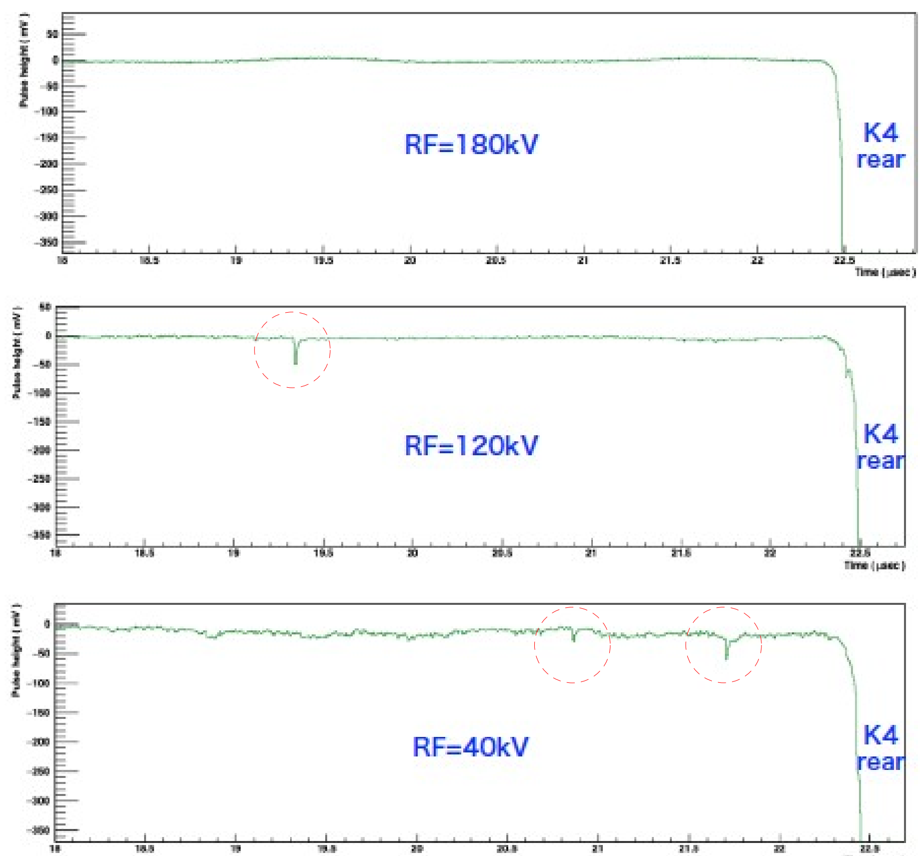
Proton Beam Commissioning



Extinction Measurements



Measurement time window will be set ~700ns after proton pulse to avoid prompt background.
→ Remaining protons between bunches can generate background in the window.



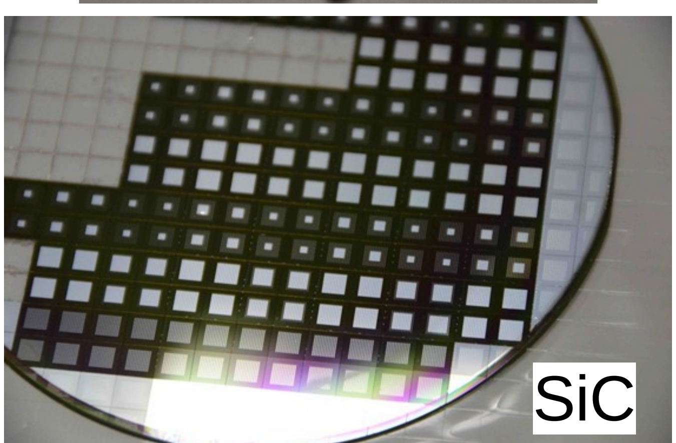
Extinction (=remaining proton between beam bunches) was measured at the MR Abort Line during the COMET Phase-alpha.

Increasing voltage of RF cavity will reduce the extinction to be sufficient level for the COMET experiment.

Beam Extinction Monitor

Protons remaining between bunches (Beam Extinction) can generate background in mu-e conversion measurements.
We are trying direct detection of the Extinction.

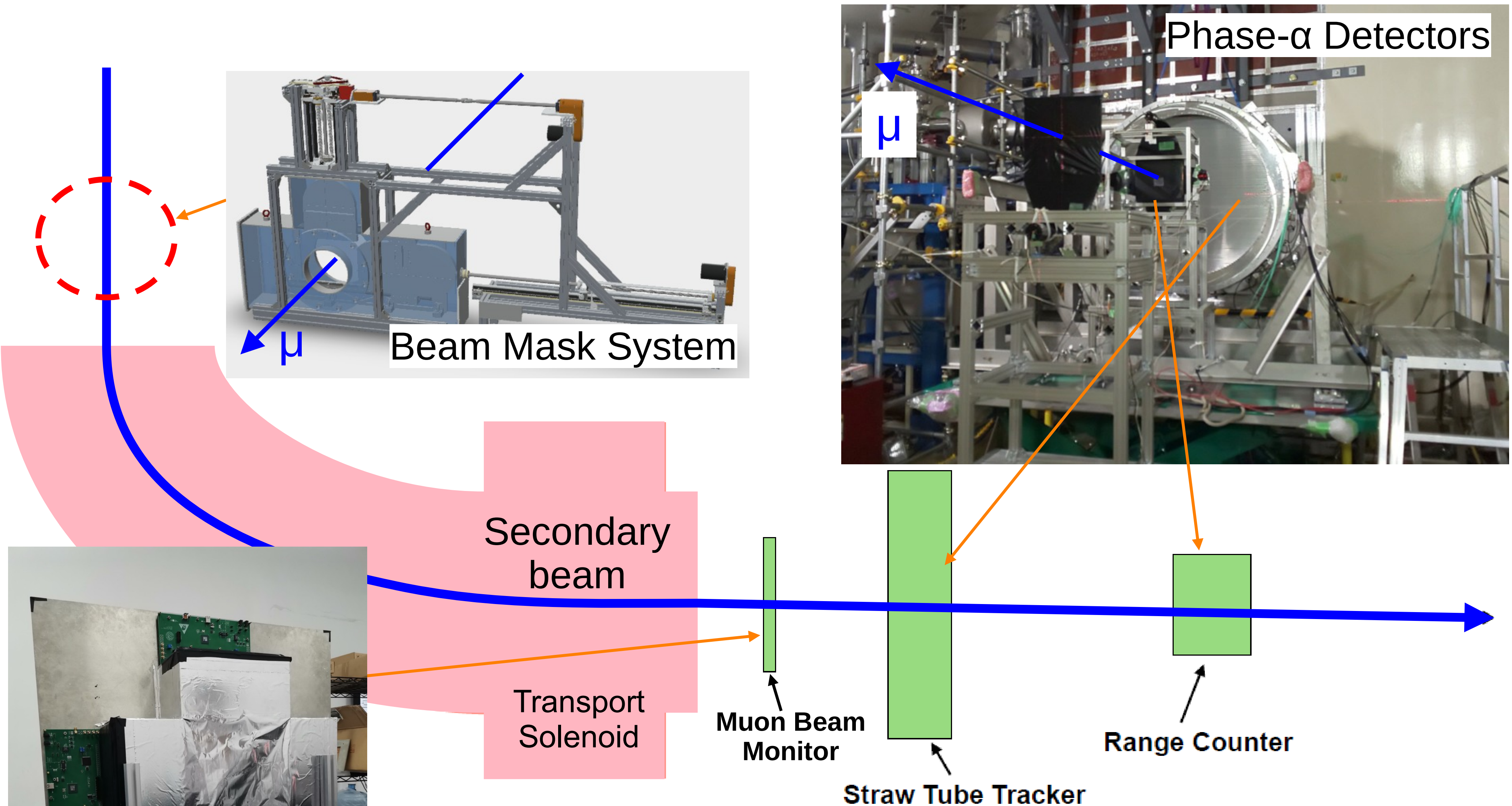
- The detector must detect single proton.
- The detector should have sufficient radiation tolerance.



Wide Band-gap Semiconductor Detector

- **Diamond**
  - High radiation tolerance
  - Expensive
- **TiO_2**
  - New technology
  - Cheap
- **SiC**
  - Better radiation tolerance than Si
  - Cheap

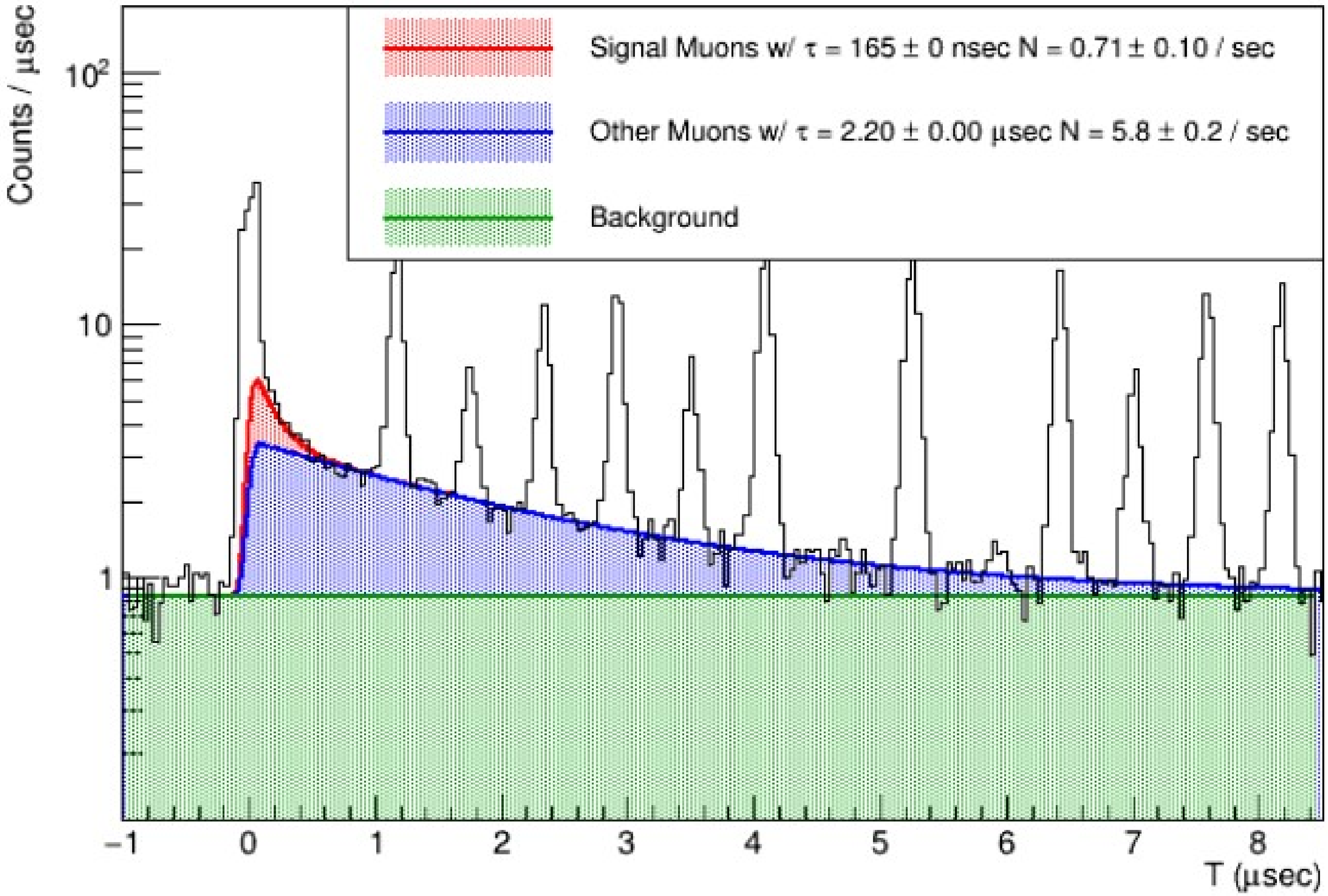
Muon Beam Measurements



Beam operation was performed for ~14 days from 2/10 to 3/15.

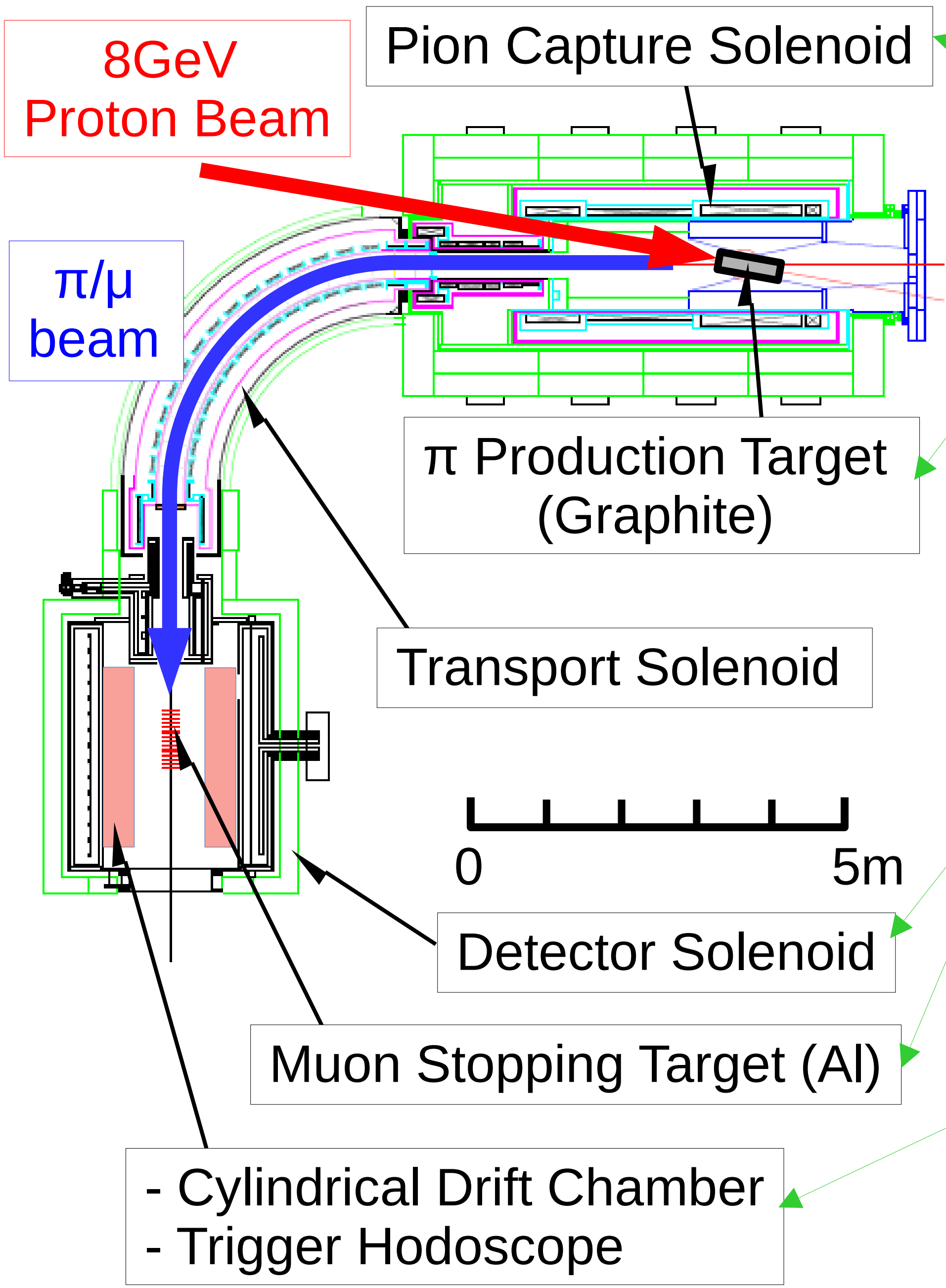
- Muon beam profile / yield, background particles
- Transfer matrix of the Transport Solenoid

Preliminary Muon Data



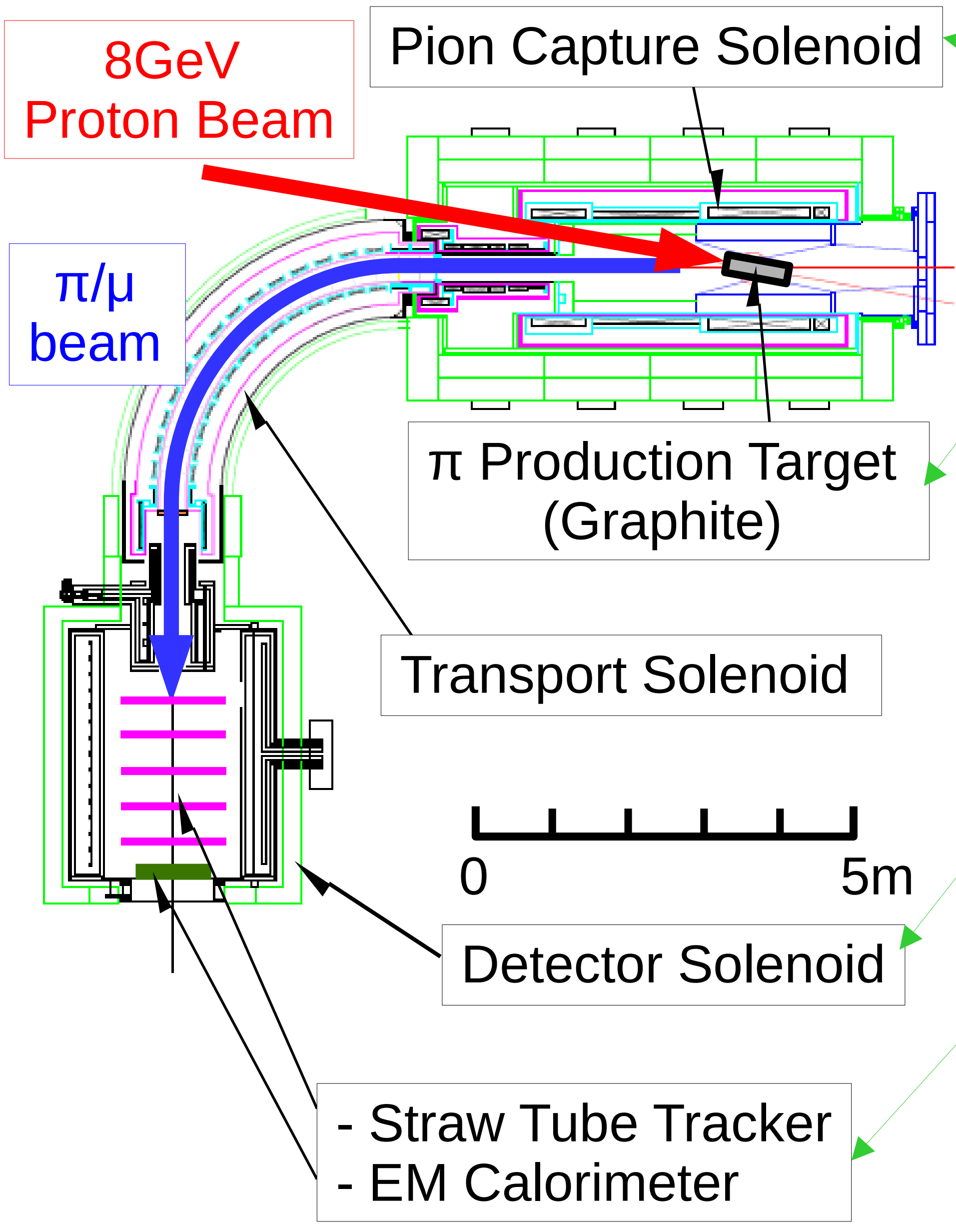
Muon life time is normally ~2.2 usec. It becomes short in the heavy material; 165 nsec in Copper.
(Please ignore many peaks at > 1usec)

COMET Phase-I : Physics Run



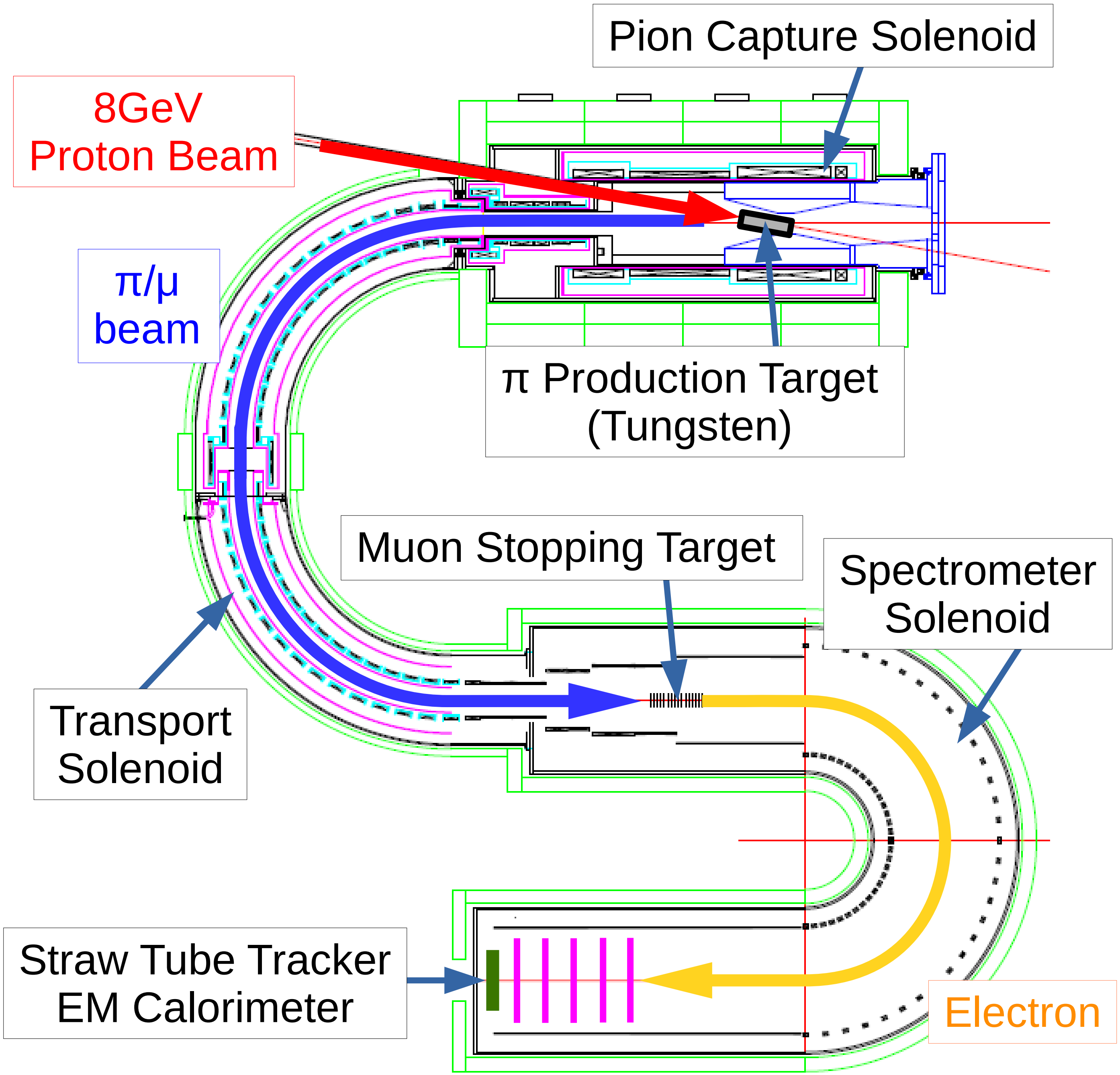
- Pion Capture Solenoid will be installed. It will enhance muon yield by an order of 1000.
- Pion production target will become 700mm long to increase muon yield.
- Expected sensitivity at COMET Phase-I is 7×10^{-15}.
- Detector Solenoid and aluminum muon stopping target will be installed to measure momentum of decay electrons.
- Main detector at Phase-I is Cylindrical Drift Chamber.

COMET Phase-I : BG Study



- Pion Capture Solenoid will be installed. It will enhance muon yield by an order of 1000.
- Pion production target will become 700mm long to increase muon yield.
- Expected sensitivity at COMET Phase-I is 7×10^{-15}.
- Muon stopping target and CDC are removed.
- Straw Tube Tracker and EM Calorimeter are installed to detect secondary beam itself towards COMET Phase-II.

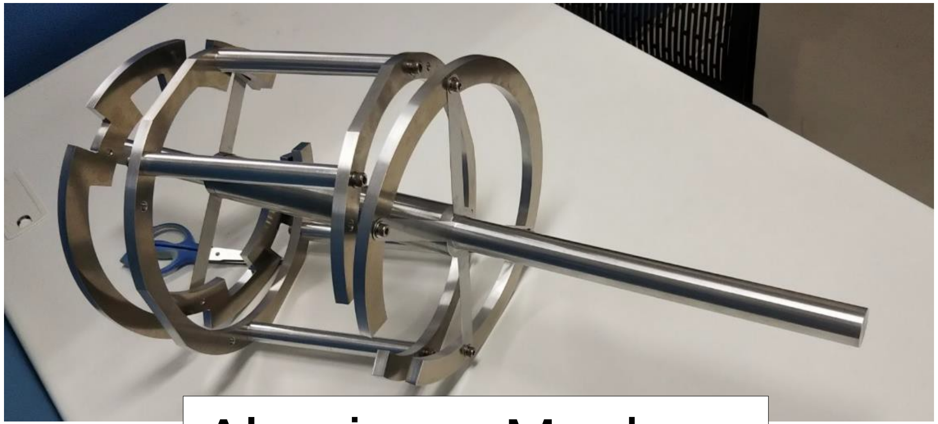
COMET Phase-II : Final Setup



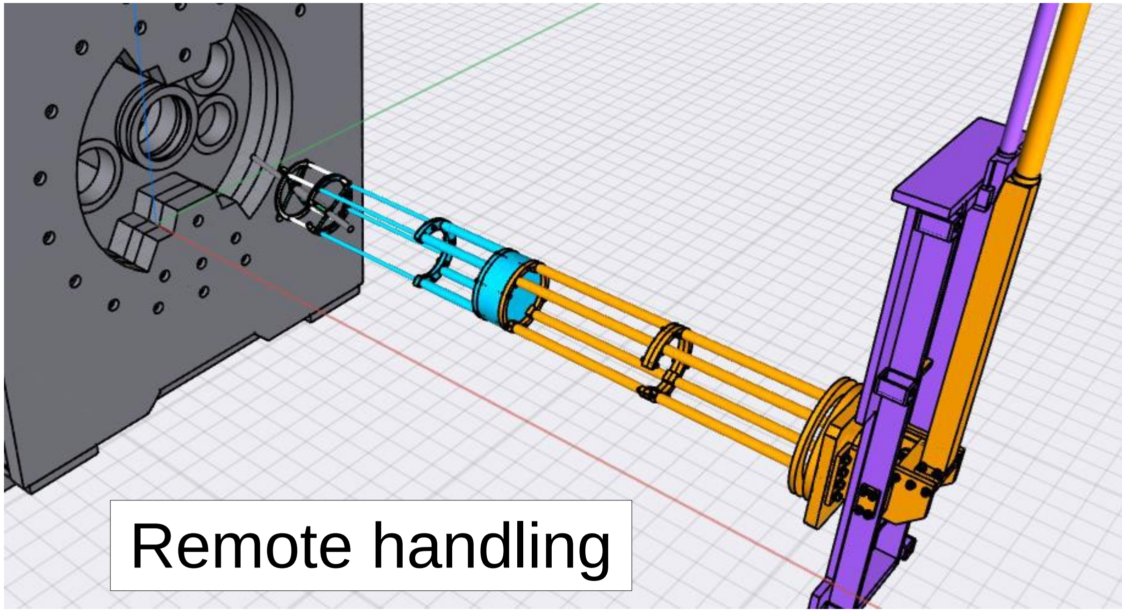
After Phase-I completed, significant upgrade is planned to achieve further sensitivity of a factor of 100.

1. Proton beam intensity will become 20 times higher.
2. Production target will be replaced to tungsten.
3. Transport Solenoid will be extended twice longer.
4. Electron spectrometer will be installed.
5. Straw tube tracker with EM calorimeter will be installed.

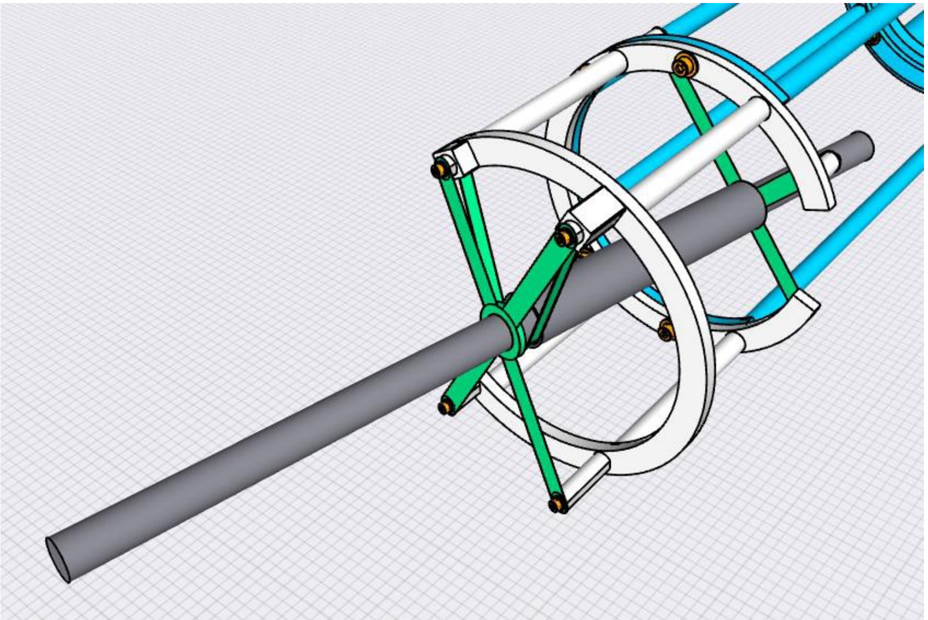
Graphite Target @ Phase-I



Aluminum Mock-up

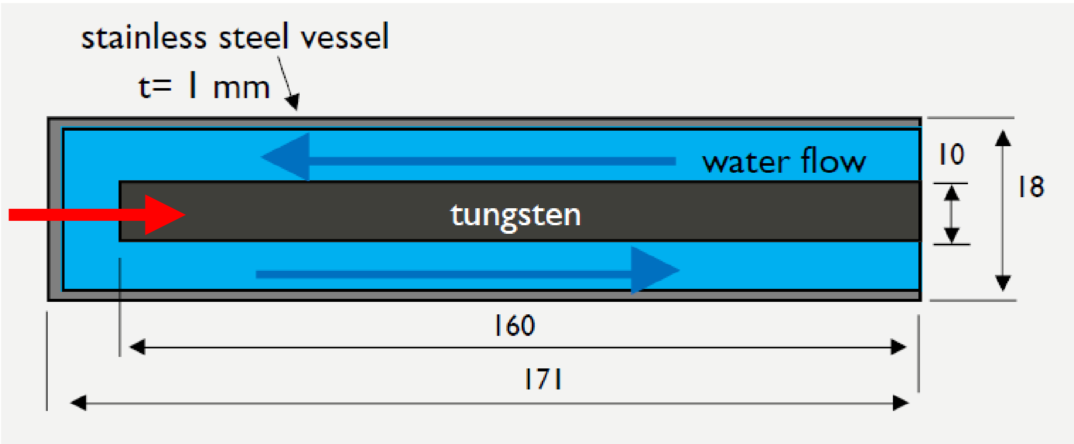


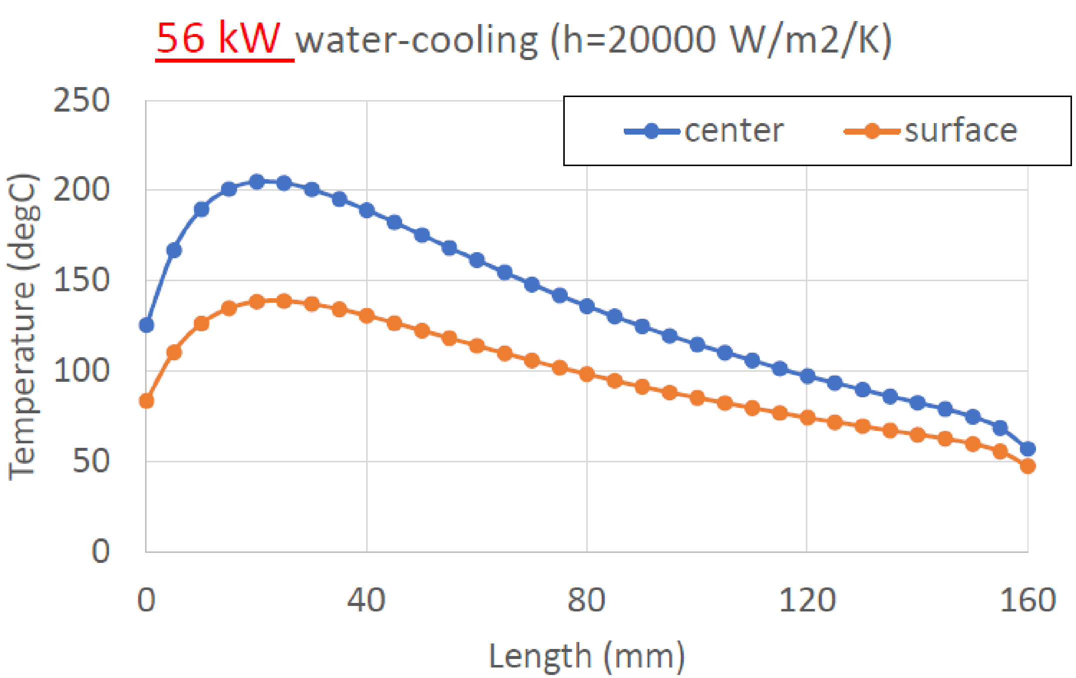
Remote handling



- Graphite is enough strong for 3.2kW beam injection at Phase-I.
- Radiation cooling keeps temperature sufficiently low.
- Target will be highly radio-activated after the beam operation.
- Remote handling scheme is necessary to replace the target.

Tungsten Target @ Phase-II





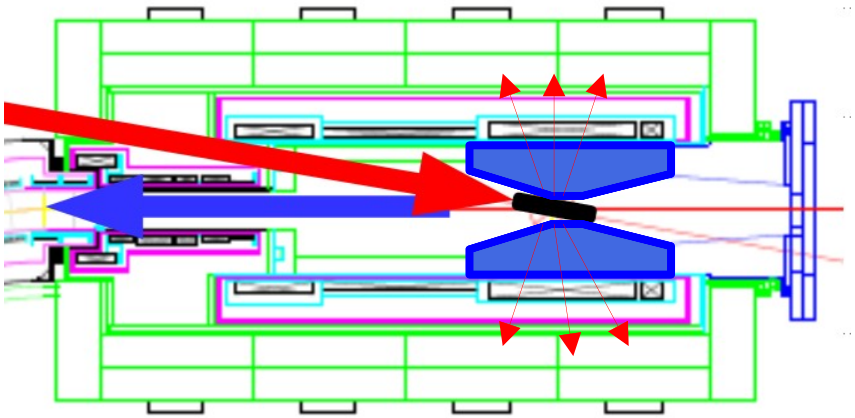
To yield more muons, upgrade of the target material from graphite to tungsten is needed.

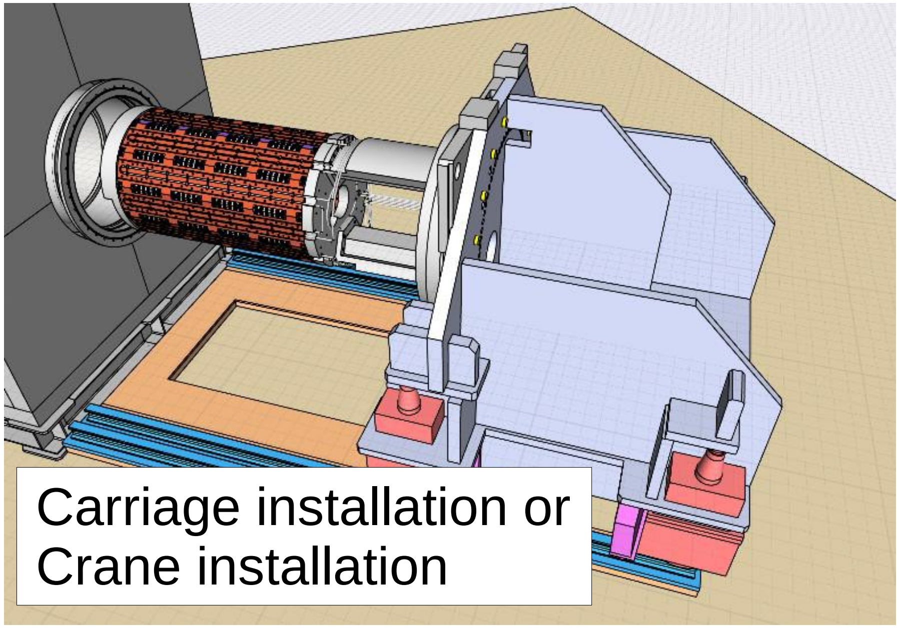
Radiation cooling is not enough with tungsten target and 56kW beam power. Water cooling is needed.

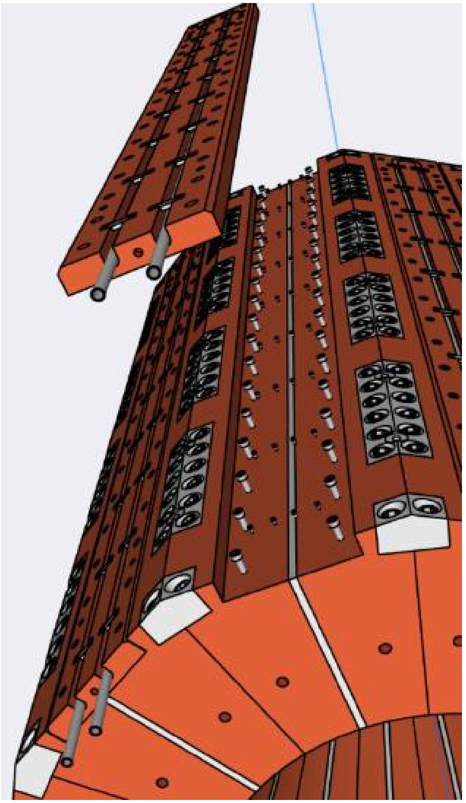
Simple model shows realistic results. But further optimization is needed.

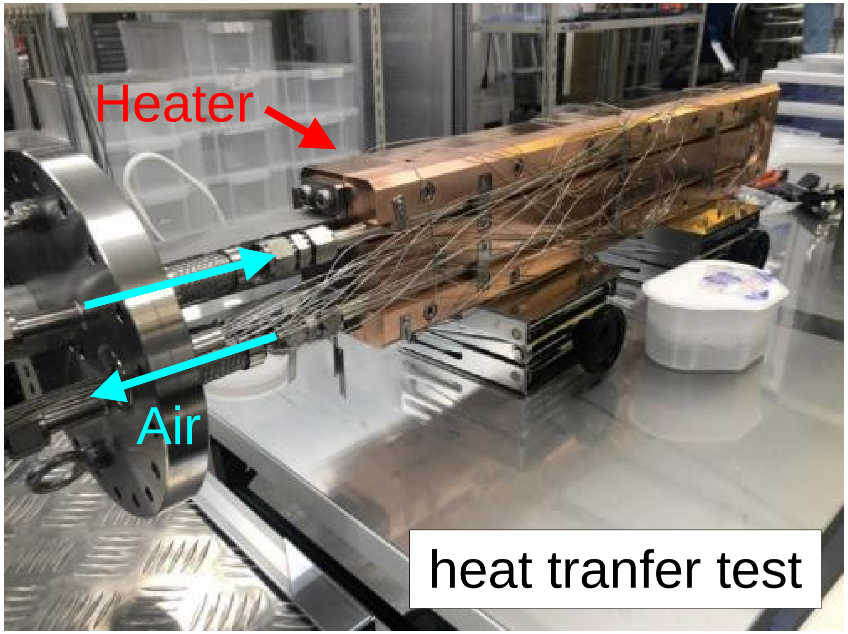
- Tungsten material itself
- Water flow
- Target dimension
- Remote handling

Radiation Shield in Capture Solenoid









Copper / Stainless Steel will be used at Phase-I.

Further R&D is needed towards Phase-II where heavier material will be favored (tungsten, Pb).

Other Progress

5T large-aperture super-conducting magnet is used to capture pions from target. Manufacturing is ongoing in a company.

Radiation Hardness Study

Experimental equipment must be designed / selected to satisfy requirements of radiation hardness.
 - Non-ionizing damage > 1e+12 n/cm2
 - Ionizing damage : 1 kGy ~ 1 MGy

- Target, Radiation Shield
- Superconducting Coil
- Beam Monitor
  - High intensity charged particles hit Sensor
- Readout Electronics
  - Frontend electronics must be installed near the sensors
  - Various kinds of ICs were tested with neutron/gamma beam.

Summary

- Construction of the COMET experiment is ongoing in the J-PARC Hadron Facility. COMET aims to search for the μ-e conversion that is an evidence of the new physics.

- The pilot run, Phase-α, was performed from Feb.10 to Mar. 15 for the commissioning of the proton beam and the secondary beam.

- Further development for the Phase-I and -II are necessary and ongoing.

  - Target, Radiation Shield, Beam Extinction Monitor