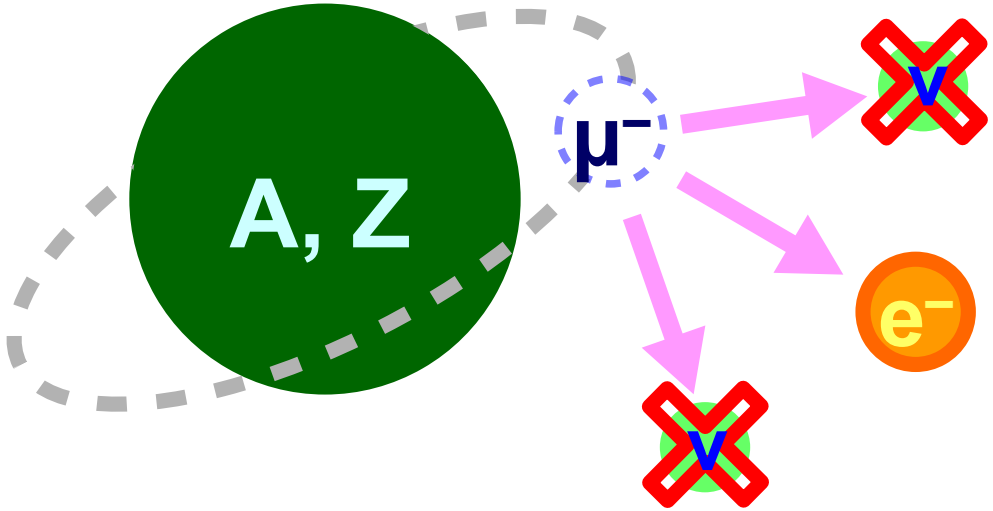
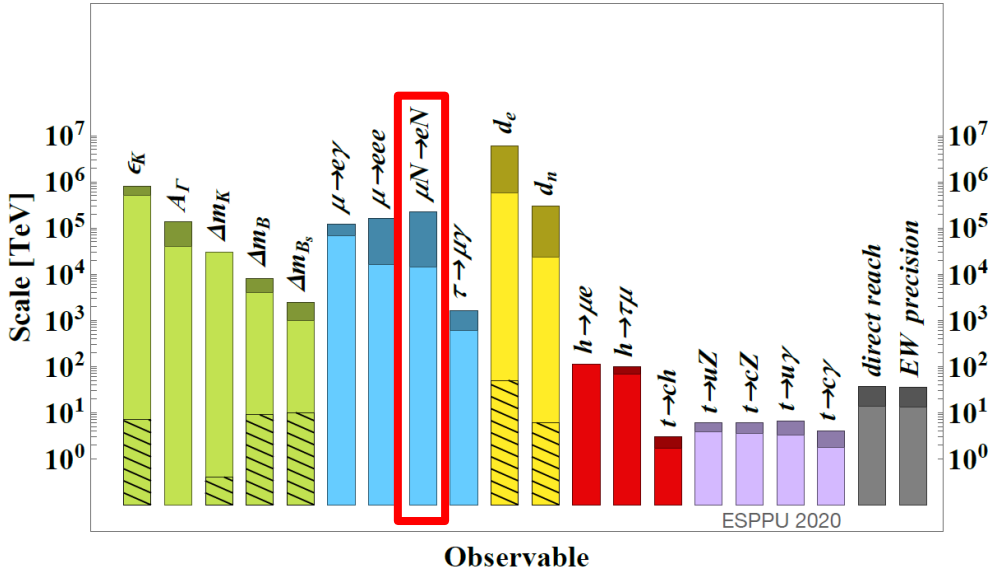
The COMET Experiment for the Search of Muon-to-Electron Conversion

Lepton Photon 2025

KEK / J-PARC
Yoshinori Fukao
for the COMET Collaboration

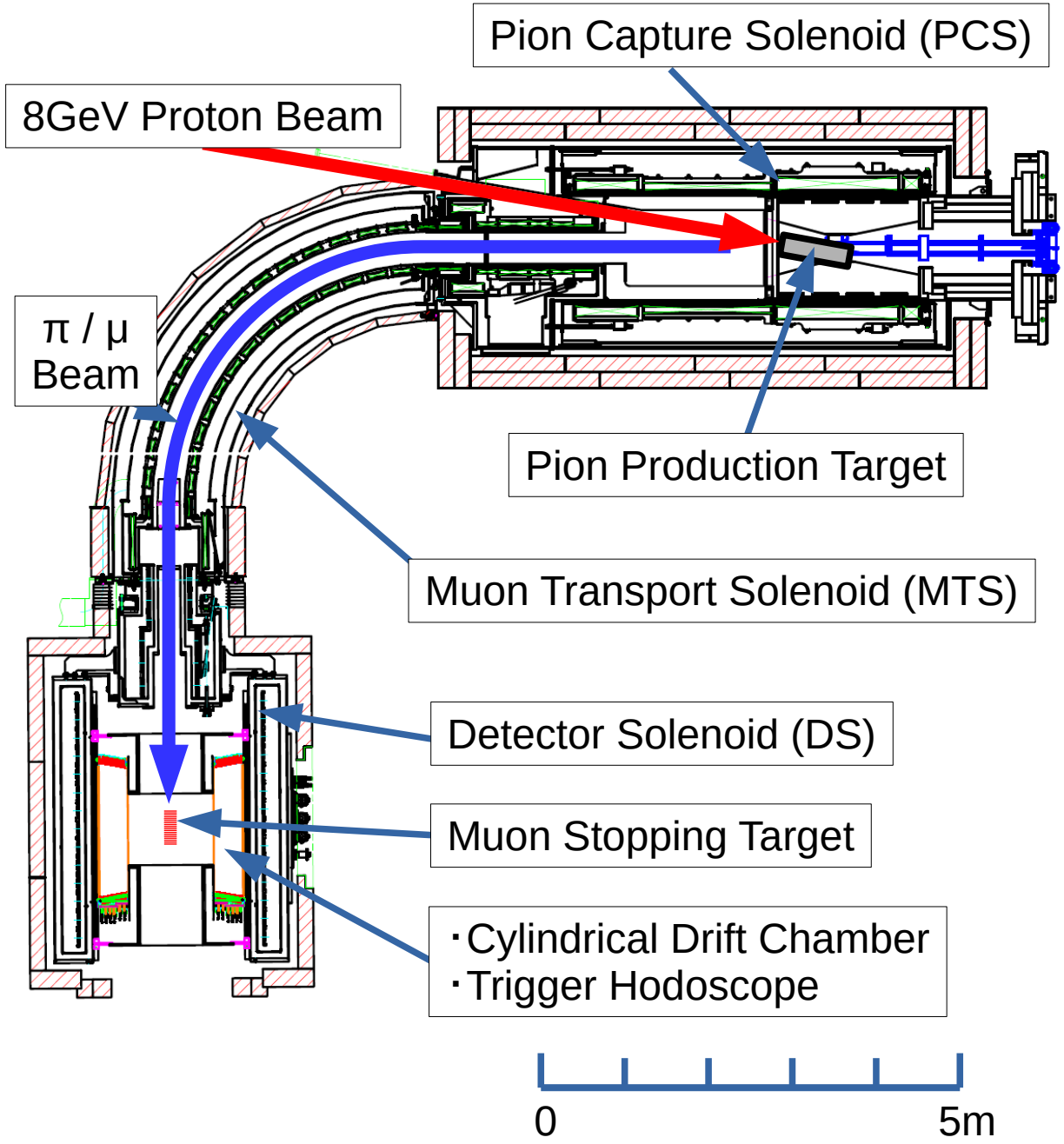
The μ-e Conversion





- Conversion of a muon to an electron violates Charged Lepton Flavor Conservation, which is accidentally conserved in the Standard Model. Its discovery is clear evidence of the New Physics.
- The μ-e conversion search can indirectly probe the NP of orders of magnitudes higher energy scale than the direct measurements.
- The current upper limit of 7×10^{-13} is obtained by SINDRUM-II. Goal of COMET is to achieve x100 higher sensitivity at Phase-I and x10000 at Phase-II.

COMET Phase-I Setup

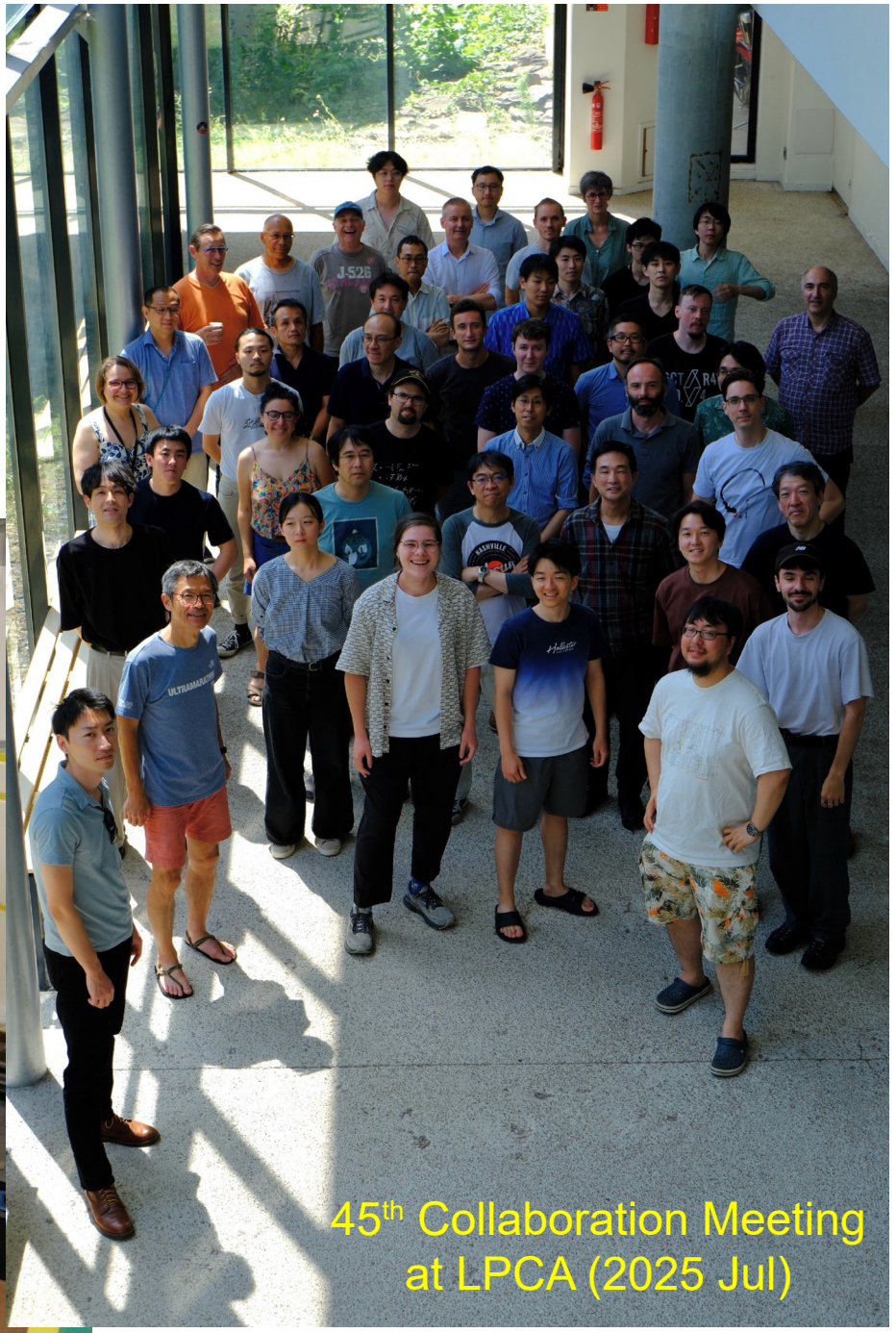


1. Proton beam (8GeV, 3.2kW) is injected to the Pion Production Target
2. Generated pions are captured and transported by the superconducting solenoid magnets, decaying to muons.
3. Muon beam is stopped at Aluminum target to form muonic atom.
4. Search for ~105MeV electrons of the μ-e conversion signal.

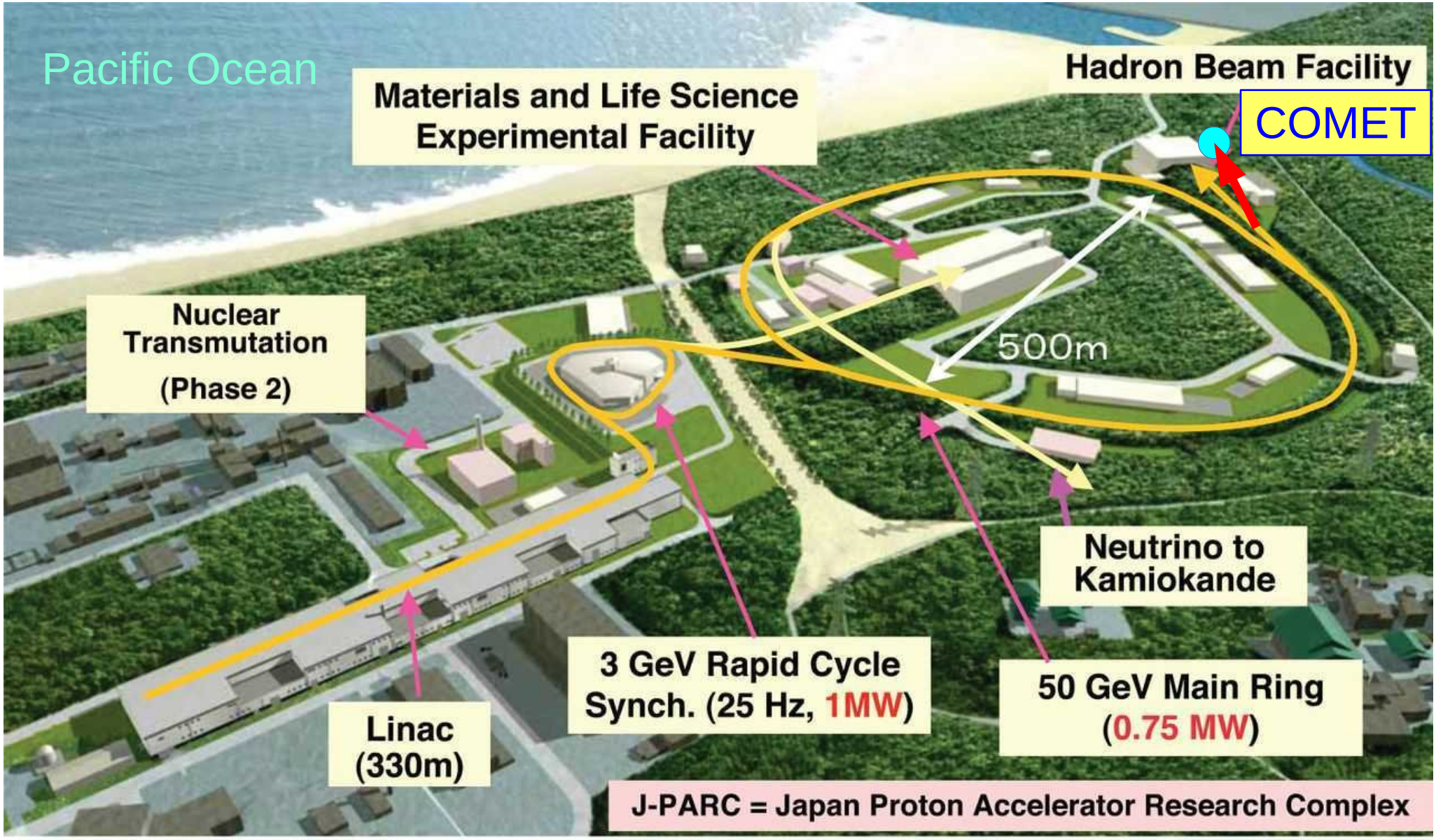
The COMET Collaboration

> 200 collaborators from
>10 countries.

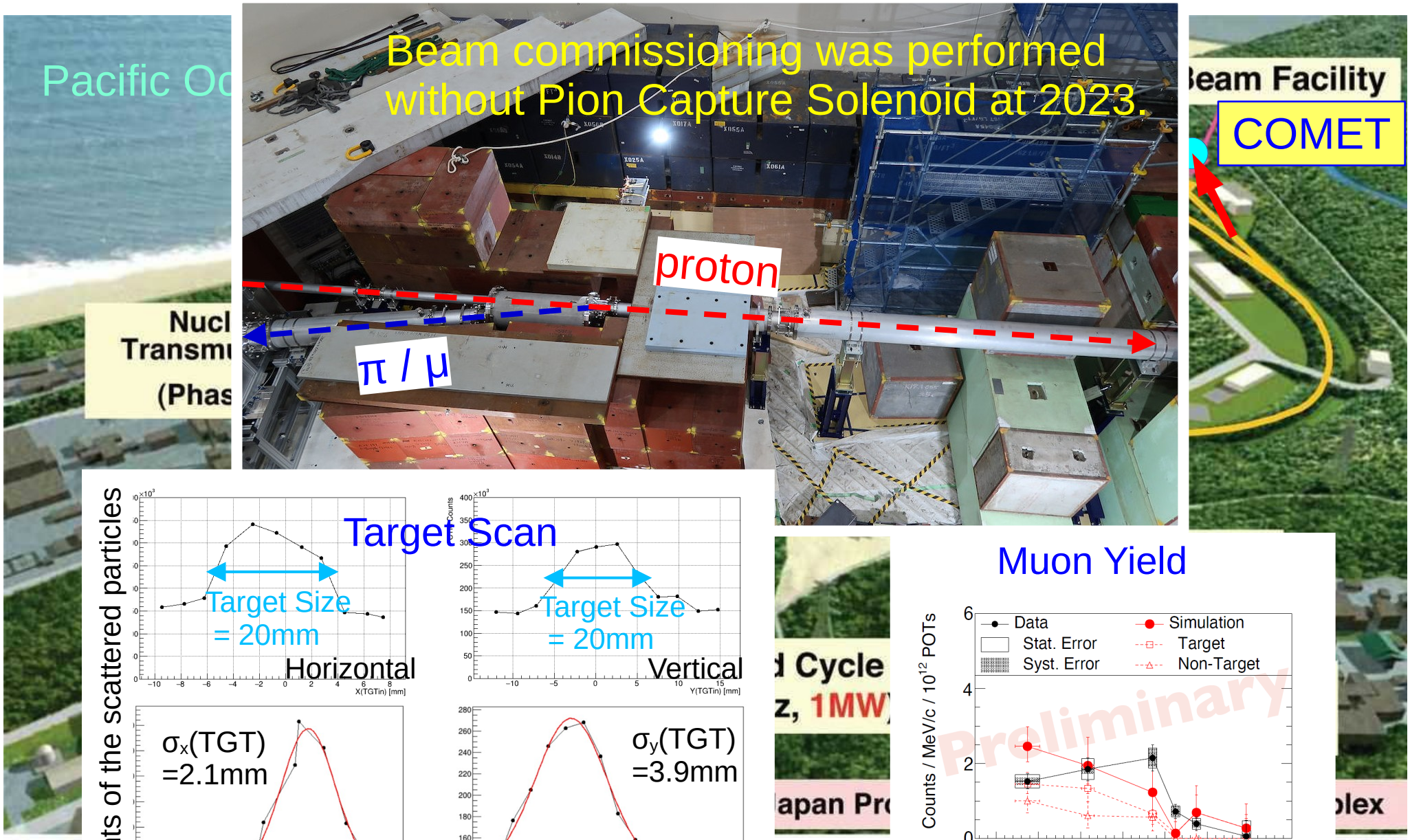

44th Collaboration Meeting
at J-PARC (2024 Nov)


45th Collaboration Meeting
at LPCA (2025 Jul)

J-PARC

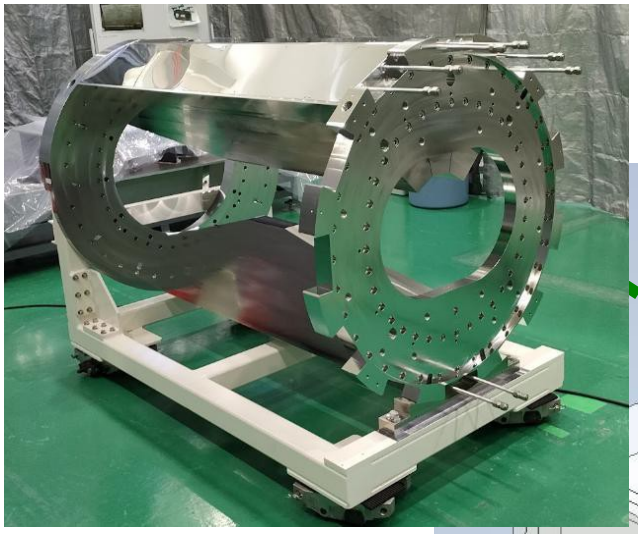

Pacific Ocean
Materials and Life Science Experimental Facility
Hadron Beam Facility
COMET
Nuclear Transmutation (Phase 2)
500m
Neutrino to Kamiokande
3 GeV Rapid Cycle Synch. (25 Hz, 1MW)
50 GeV Main Ring (0.75 MW)
Linac (330m)
J-PARC = Japan Proton Accelerator Research Complex

J-PARC

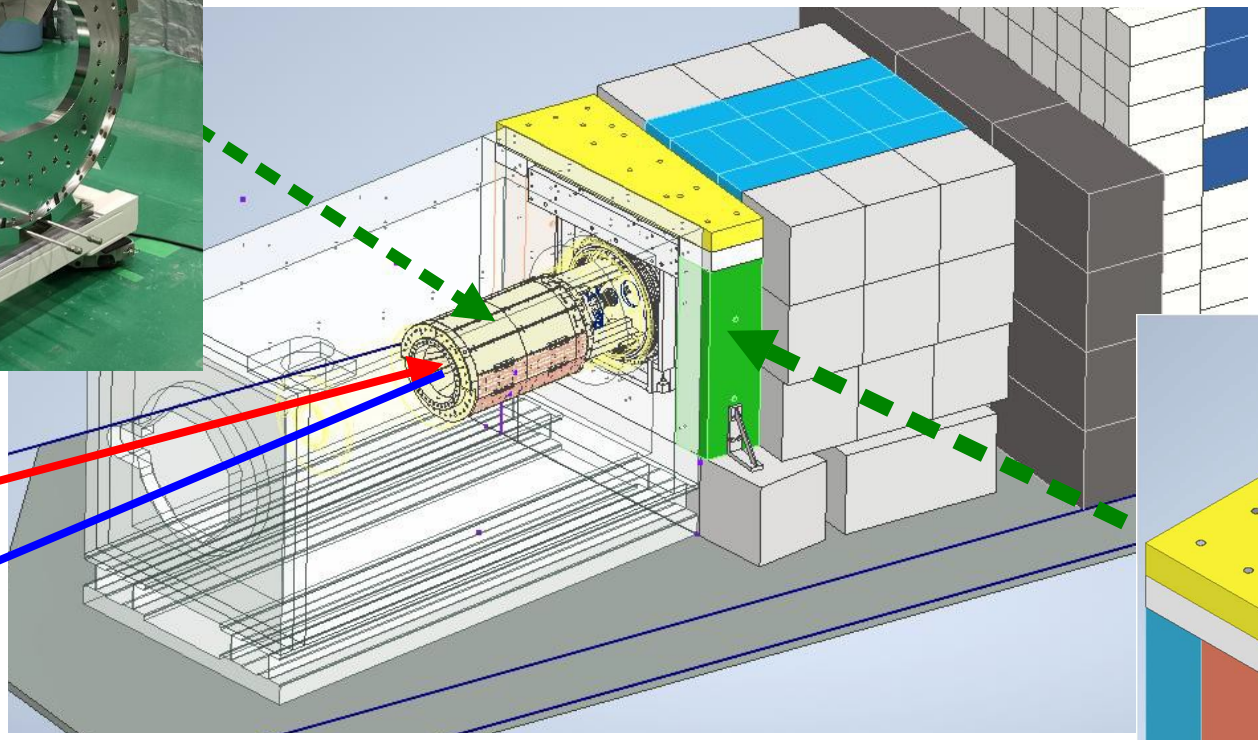

Pacific Oc
Nucl
Transmu
(Phas
Beam commissioning was performed
without Pion Capture Solenoid at 2023.
proton
π / μ
Beam Facility
COMET
Target Scan
Target Size
= 20mm
Horizontal
Target Size
= 20mm
Vertical
X(TGTin) [mm]
Y(TGTin) [mm]
Counts of the scattered particles
σx(TGT)
=2.1mm
σy(TGT)
=3.9mm
Proton Profile
Beam position at the ion chamber [mm]
d Cycle
z, 1MW
apan Pro
Muon Yield
Data
Stat. Error
Syst. Error
Simulation
Target
Non-Target
Counts / MeV/c / 10^12 POTs
Momentum (MeV/c)
Preliminary
olex

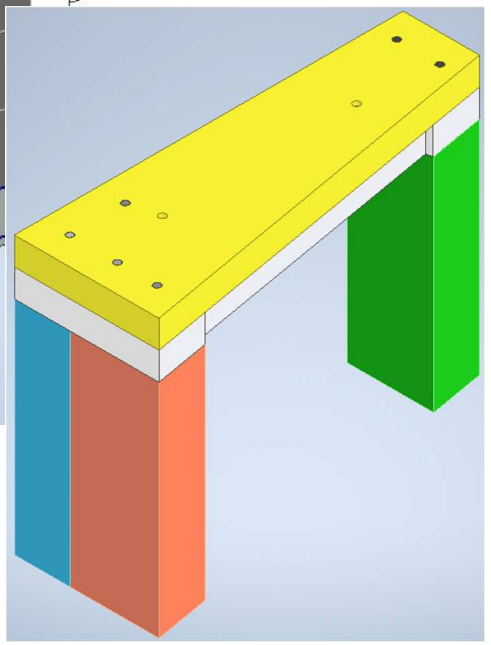
Facility Construction

As we once performed the beam operation, many items for the facility infrastructure is existing, though we need additional radiation shields etc.



Part of the PCS inner Shield was manufactured.
Remaining is being manufactured soon.

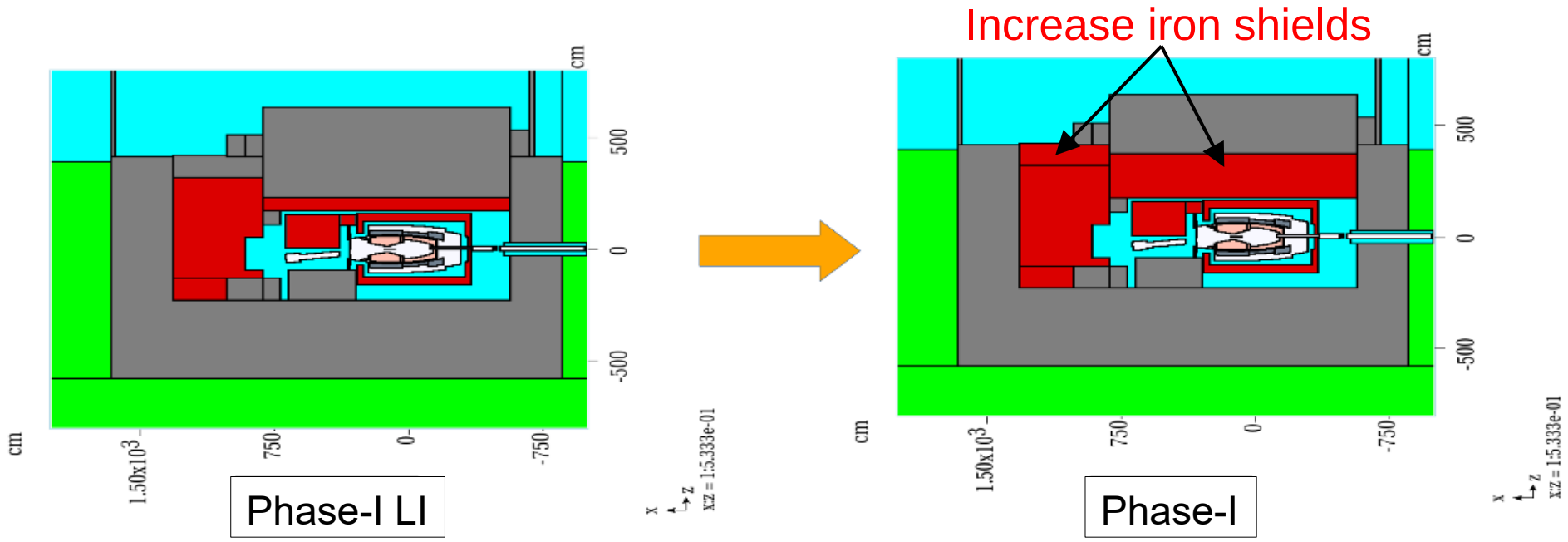




Manufacturing of the radiation shield downstream of PCS is starting.

Facility Construction

For the earliest physics measurements, we plan to start the beam operation with minimum shield (Low Intensity, LI), and increasing them toward the full beam intensity.



Phase-α (0.26kW) → PCS, DS, Detector system, minimum shielding → Phase-I LI (0.3kW) → additional shielding on beam room ceiling → Phase-I (3.2kW)

We aim to achieve the Phase-I LI during 2027.

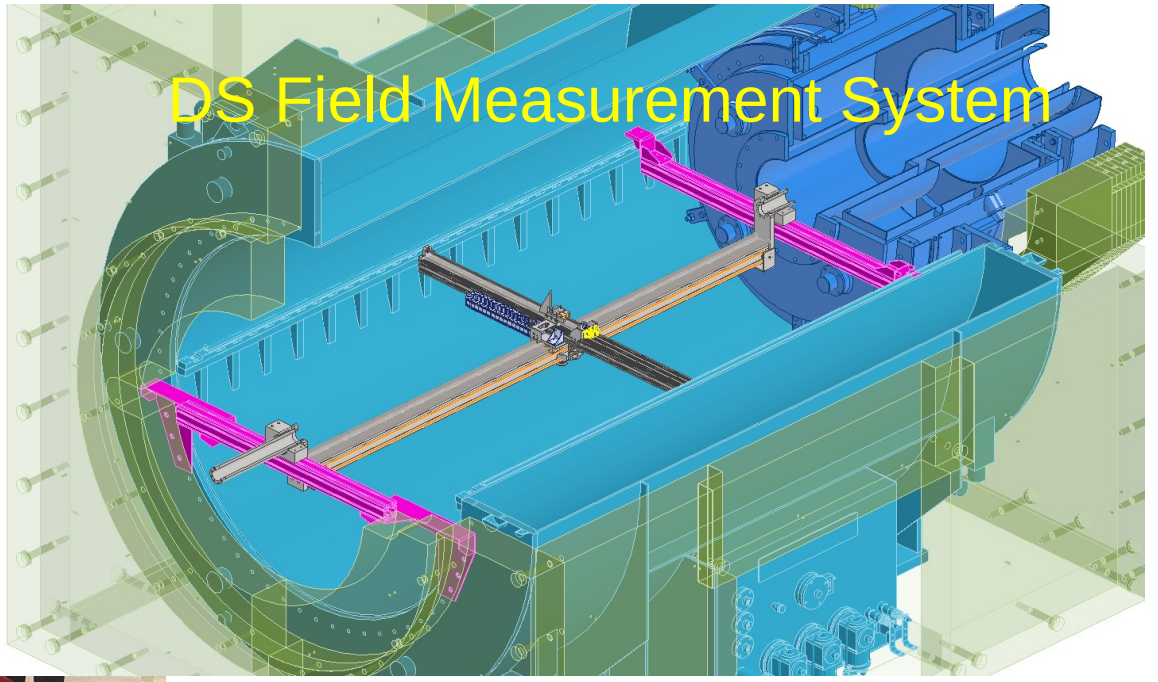
Pion Capture Solenoid

PCS was installed at the last November.

- Vacuum test : good
- Coil resistance : good
- Sensors : good

The next task is to connect Transfer Tube to the cryogenic system.

Detector Solenoid, Bridge Solenoid

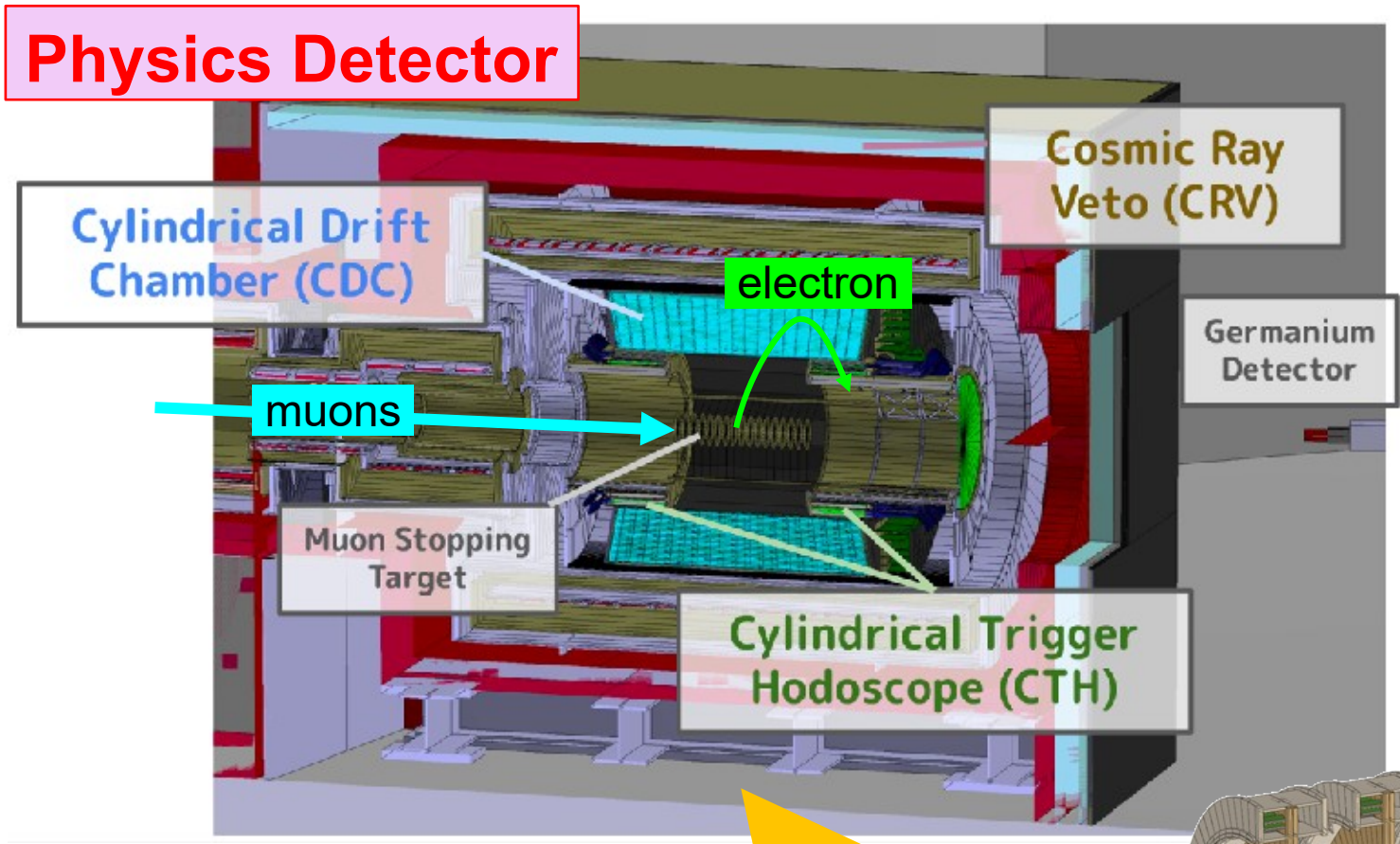


- DS was delivered to KEK Tsukuba Campus in 2024.
- BS (between MTS and DS) was delivered to J-PARC in 2022.

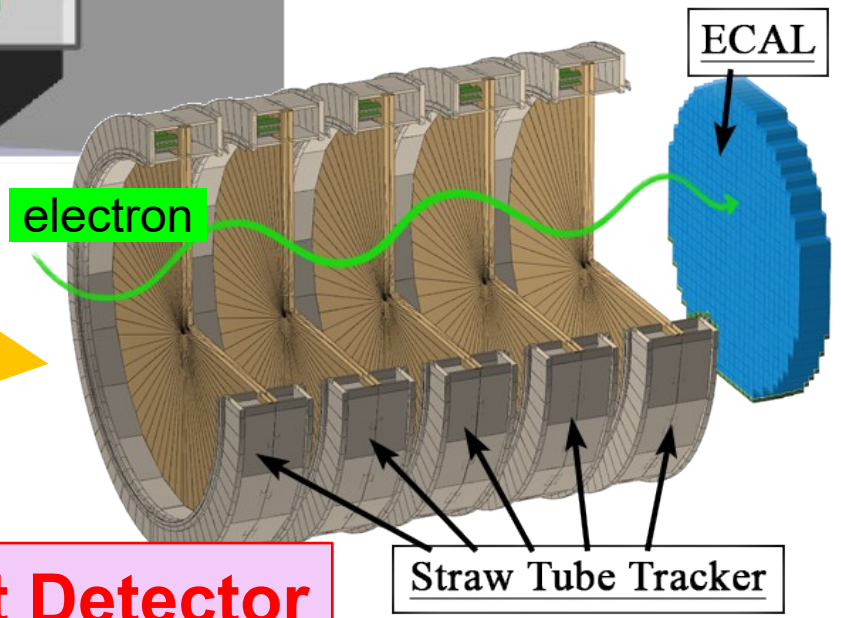
- Preparation is ongoing for the installation, which will start this September. Field measurements is scheduled in March 2025, followed by the detector installation.

Detector System

Physics Detector



Exchange Inner Detectors

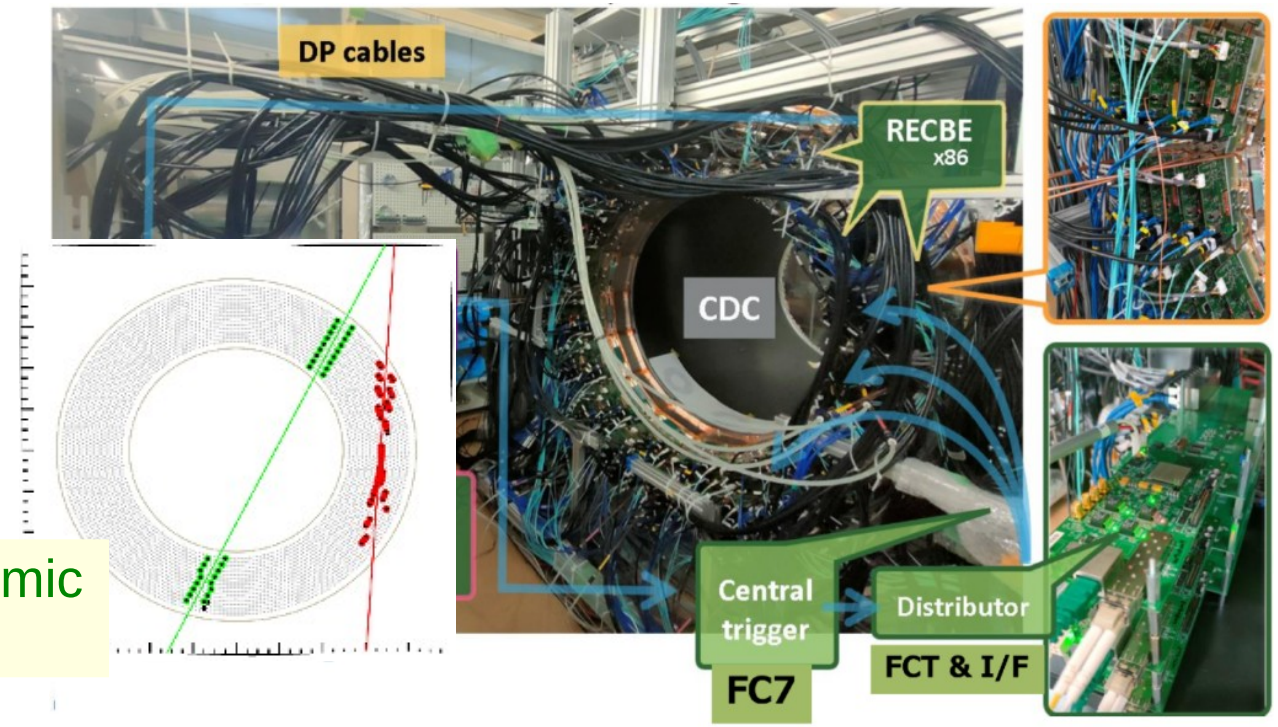


Beam Measurement Detector

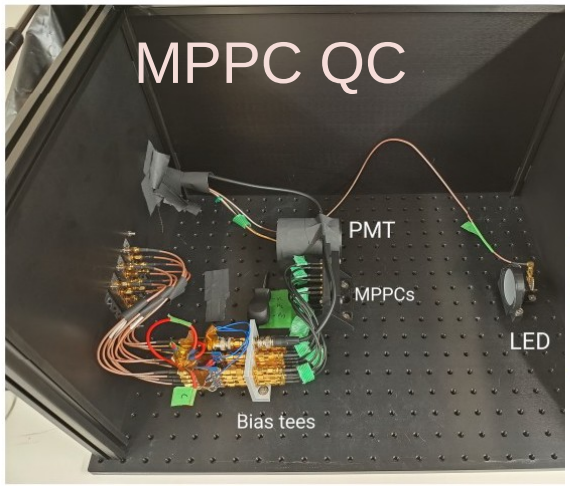
Physics Detectors

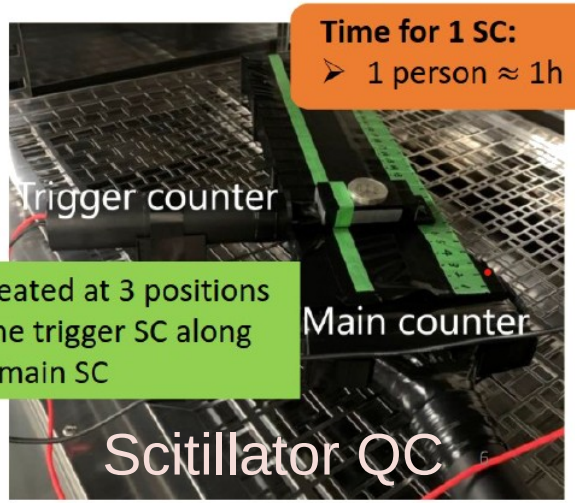
Cylindrical Drift Chamber

- Operation test of Cylindrical Drift Chamber is ongoing at J-PARC.
- A water cooling system for the electronics and a closed gas circulation system will be upgraded for the working condition.



Measured cosmic ray tracks





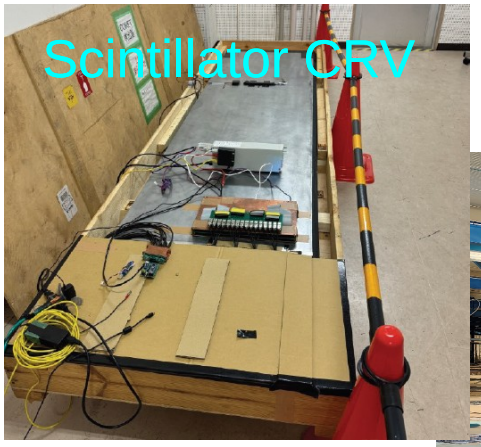
Repeated at 3 positions of the trigger SC along the main SC

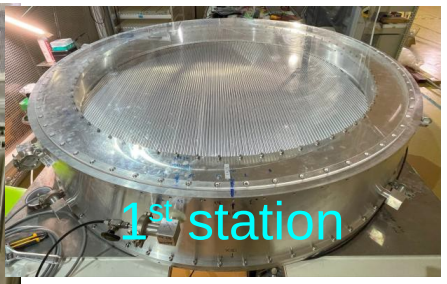
Trigger Hodoscope

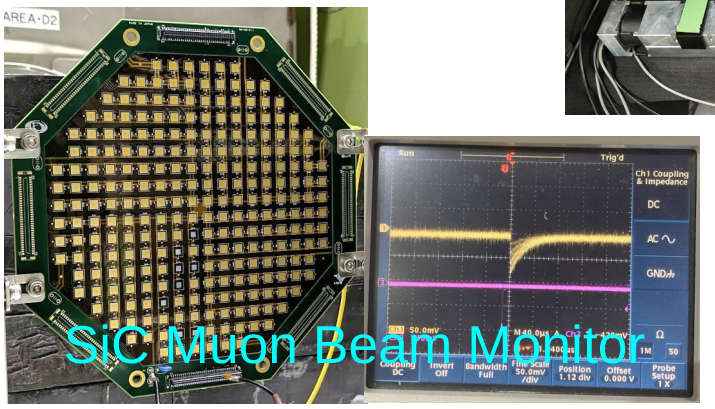
- QC for the scintillators and MPPC was completed at J-PARC.
- Light yield degradation was observed in some scintillators. Solutions are in discussion.
- Upstream supporting structure has been manufactured.

Other Detectors

- **Cosmic Ray Veto detector** system will be constructed in combination of scintillators and existing RPCs for quick completion.
- Three stations (out of five) of **Straw Tube Tracker** has been produced. The performance test is ongoing.
- QC/QA of crystals and electronics of **Electromagnetic Calorimeter** is ongoing.
- Testing TiO2 and SiC semiconductor sensors for the development of the **proton and muon beam monitor**.



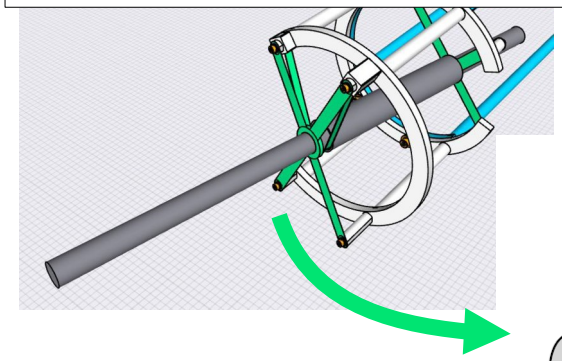




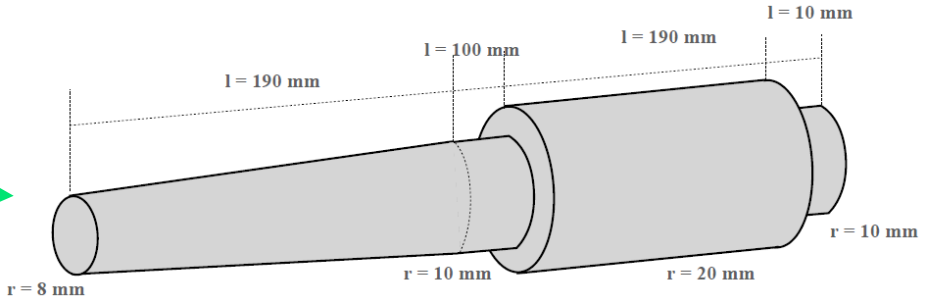
Simulation Study

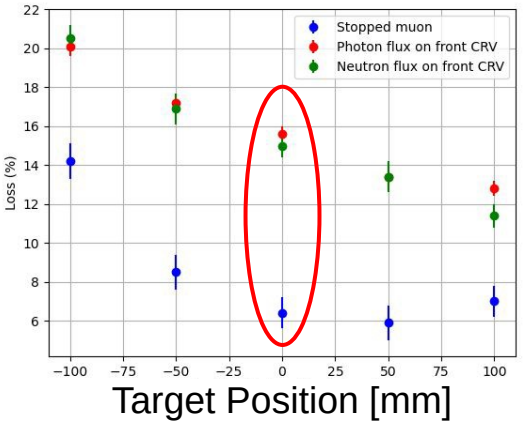
As the installation of magnets and detectors is starting, an intensive simulation study is ongoing to finalize the design of the beam line.

Pion Production Target

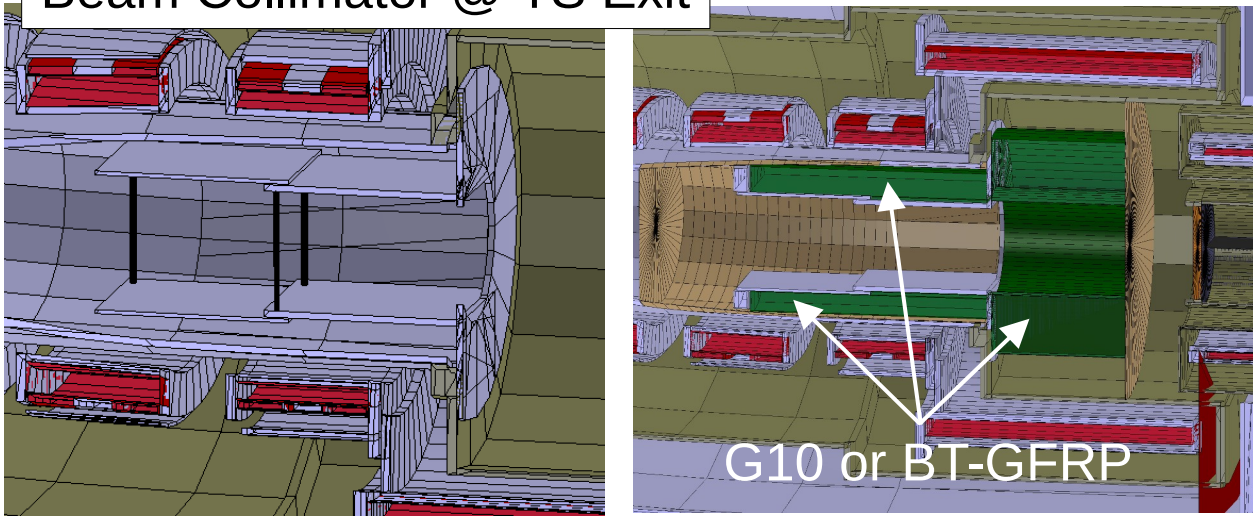


Optimized target shape will suppress BG radiation to the detectors (~15% less at CRV), keeping the muon yield.





Beam Collimator @ TS Exit



- Installing additional material in a space at the exit of the Transport Solenoid will suppress background radiation at the detectors (>50% reduction is expected).
- G10 or BT-GFRP are candidates to suppress outgas due to the radiation damage.

Summary

The COMET experiment is being constructed at J-PARC.

The first beam commissioning at the COMET experimental hall was performed in 2023. The measured results is being published soon.

For the earliest physics measurements, we plan to start the beam operation with minimum facility configuration.

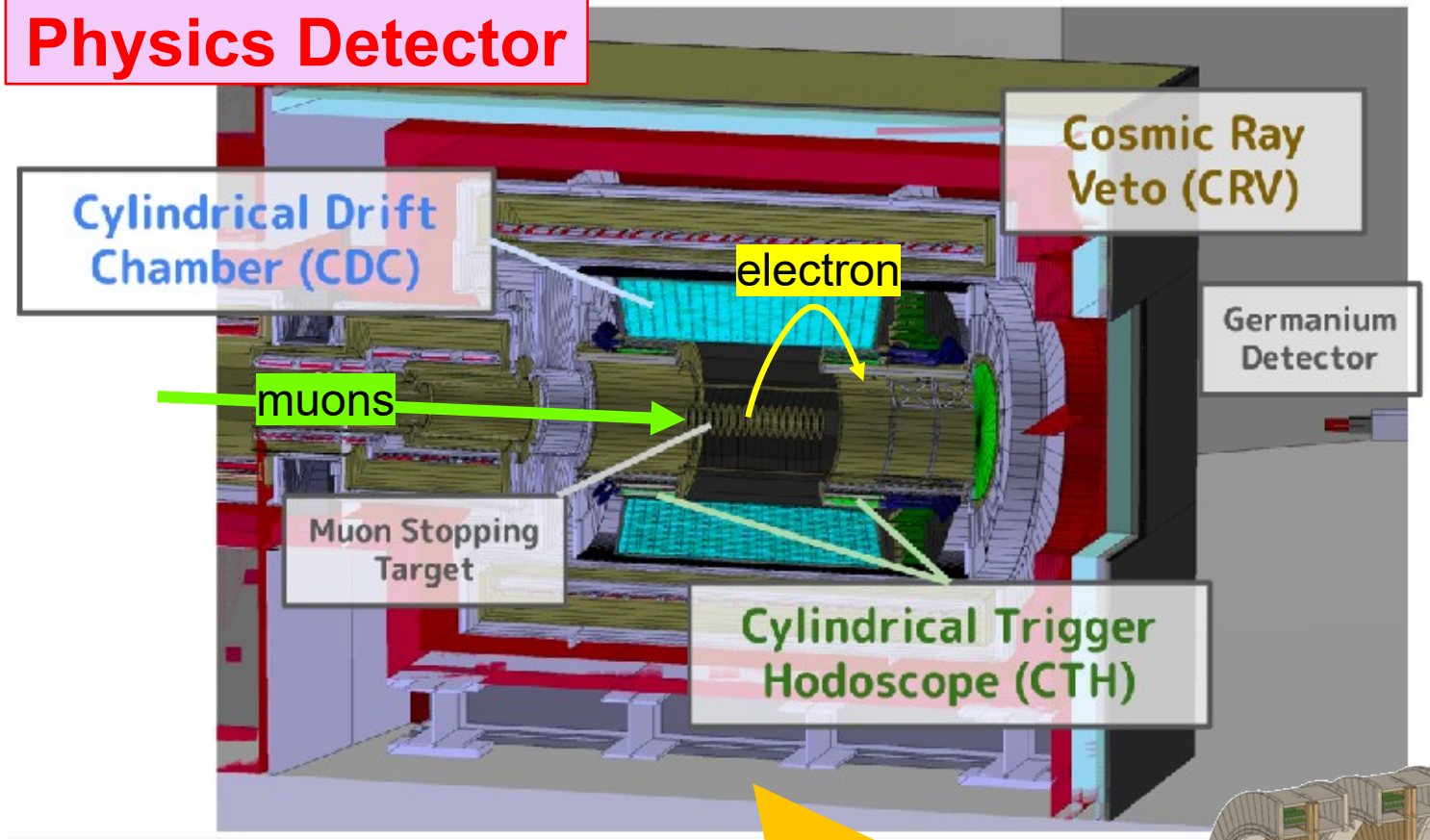
Pion Capture Solenoid has been installed at the last November. The remaining Bridge Solenoid and Detector Solenoid will be installed soon, followed by the installation of the physics detectors.

Ongoing intensive simulation study finalizes the design of the beamline equipment as the installation work begins.

Backup

COMET Detector System

Physics Detector



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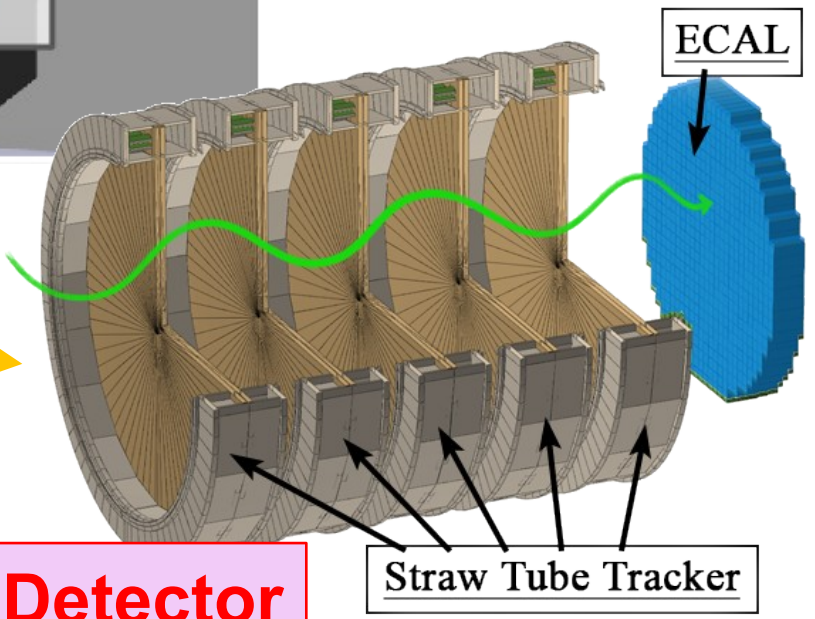

Beam Measurement Detector

DAQ System

COMET DAQ : MIDAS → NestDAQ

- **Scalable system** : Performance can be improved by adding multiple computers.
- **Software trigger** : Originally designed to include the software trigger.

Improvement has been confirmed

- with CDC readout electronics.
- with single PC