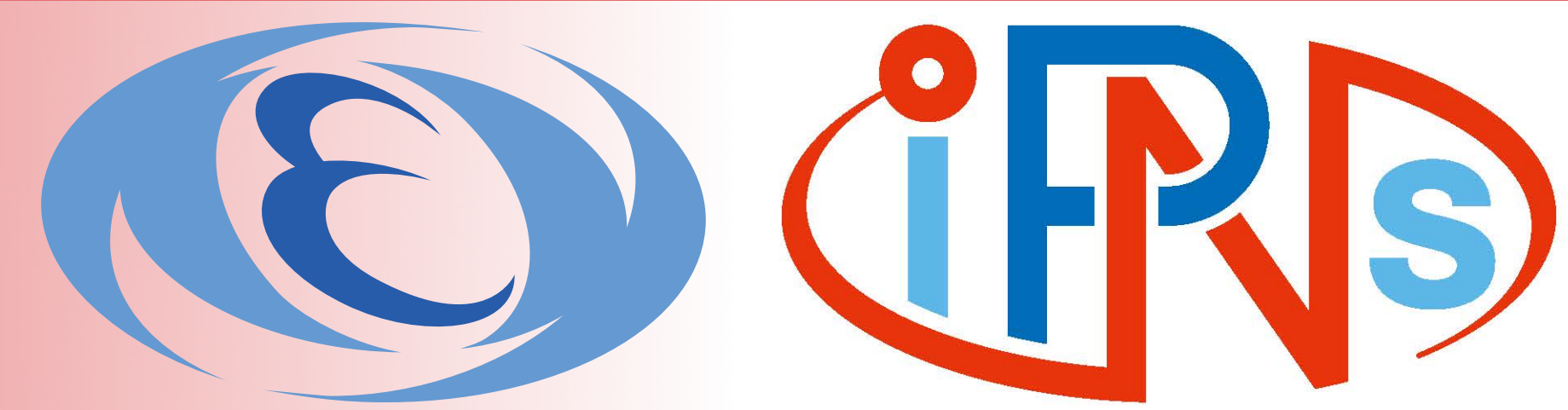




THE COMET EXPERIMENT

Searching for Muon-to-Electron Conversion at J-PARC

Kou Oishi

*Institute of Particle and Nuclear Studies (IPNS),
High Energy Accelerator Research Organization (KEK), Japan*

On behalf of the COMET Collaboration

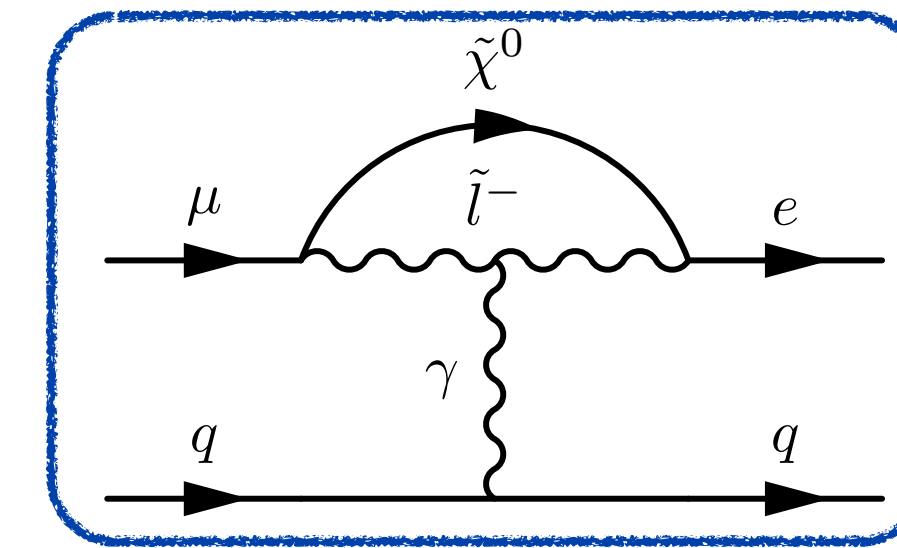
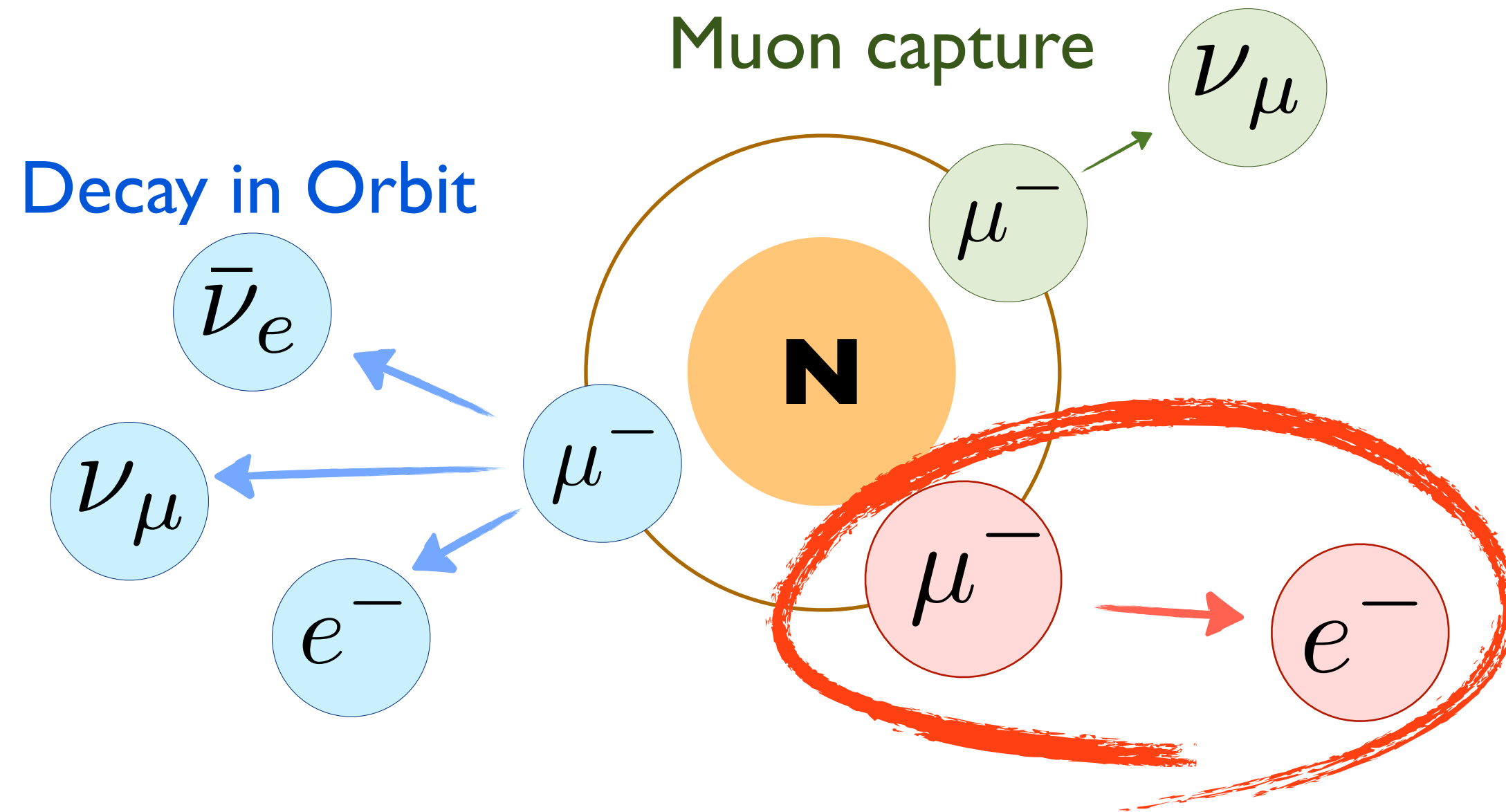


**XV International Conference
on New Frontiers in Physics**

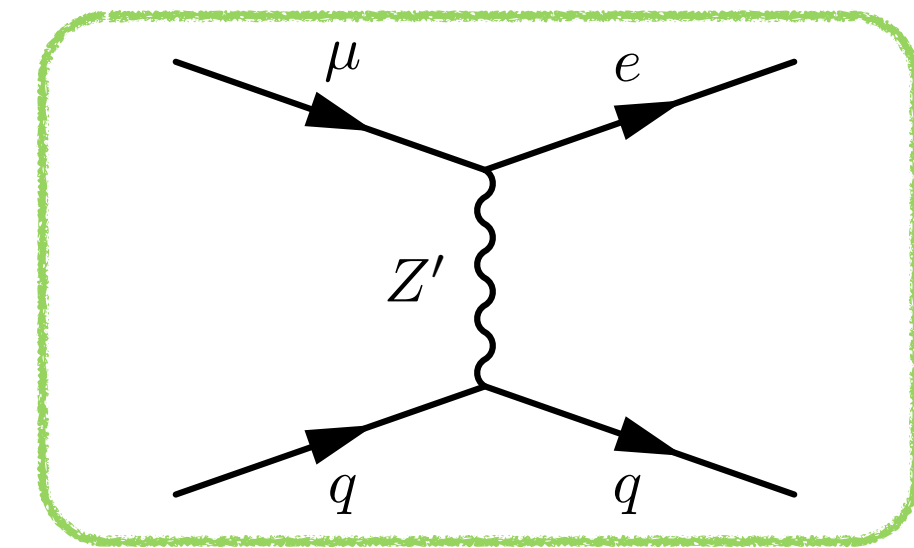
19 - 30 August 2026, OAC, Kolymbari, Crete, Greece



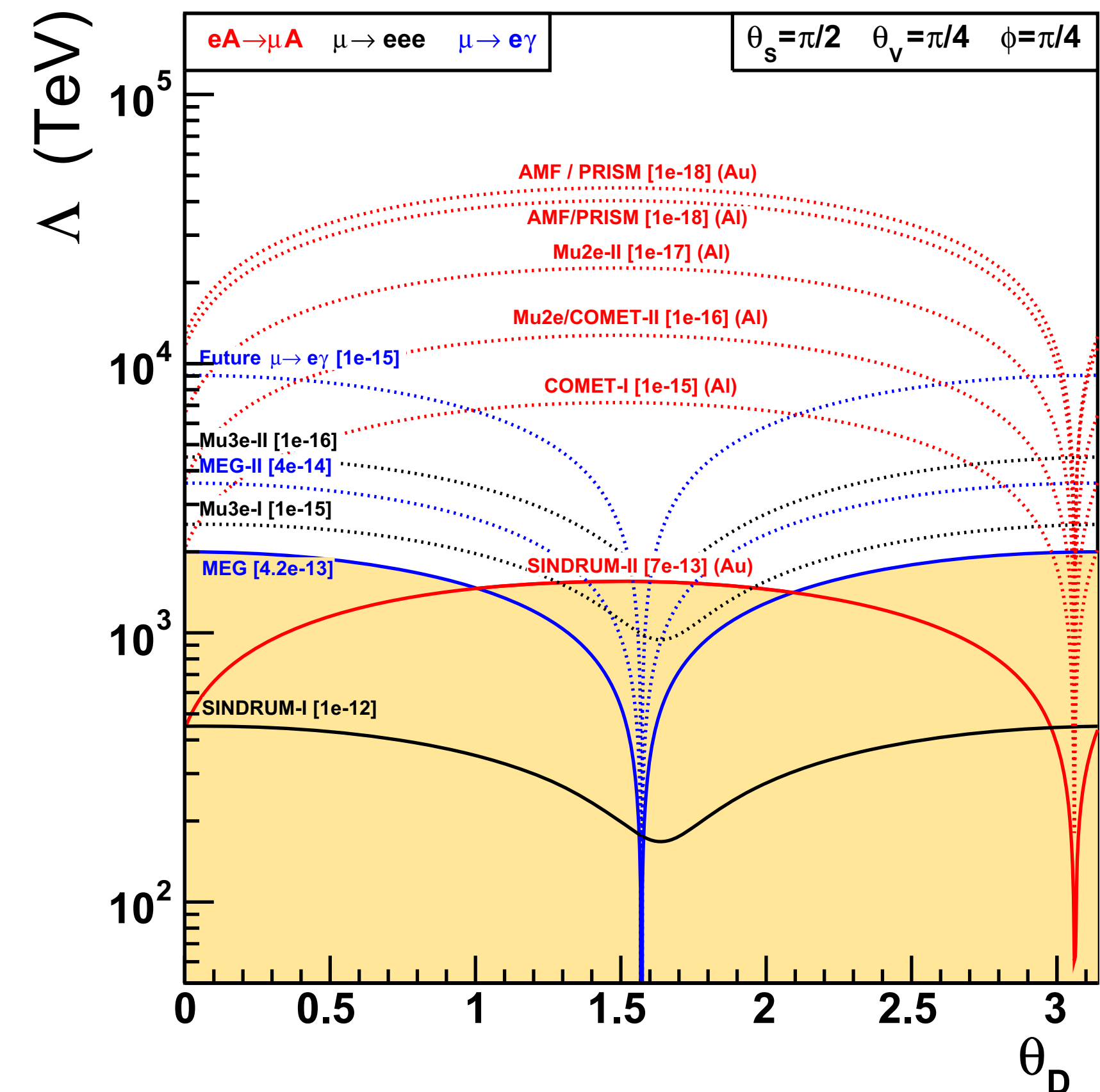
MUON-TO-ELECTRON CONVERSION



Photonic process



Four-fermion process



A charged lepton flavour-violating process

- ✦ Muon decays to single electron with no neutrino.
 - ★ Strongly suppressed in the SM including the neutrino oscillation.
 - ★ Branching ratio: $\text{BR}(\mu N \rightarrow e N) \sim \text{BR}(\mu \rightarrow e \gamma) < 10^{-54}$
- ✦ Reach up to $\sim 10^{-15}$ in several Beyond SMs.
 - ★ Z' , leptoquarks, heavy right-handed neutrinos, etc
- ✦ **Observation indicates new physics!**
- ✦ Model discrimination with $\mu \rightarrow e \gamma$ (MEG/MEG II) and $\mu \rightarrow eee$ (Mu3e)

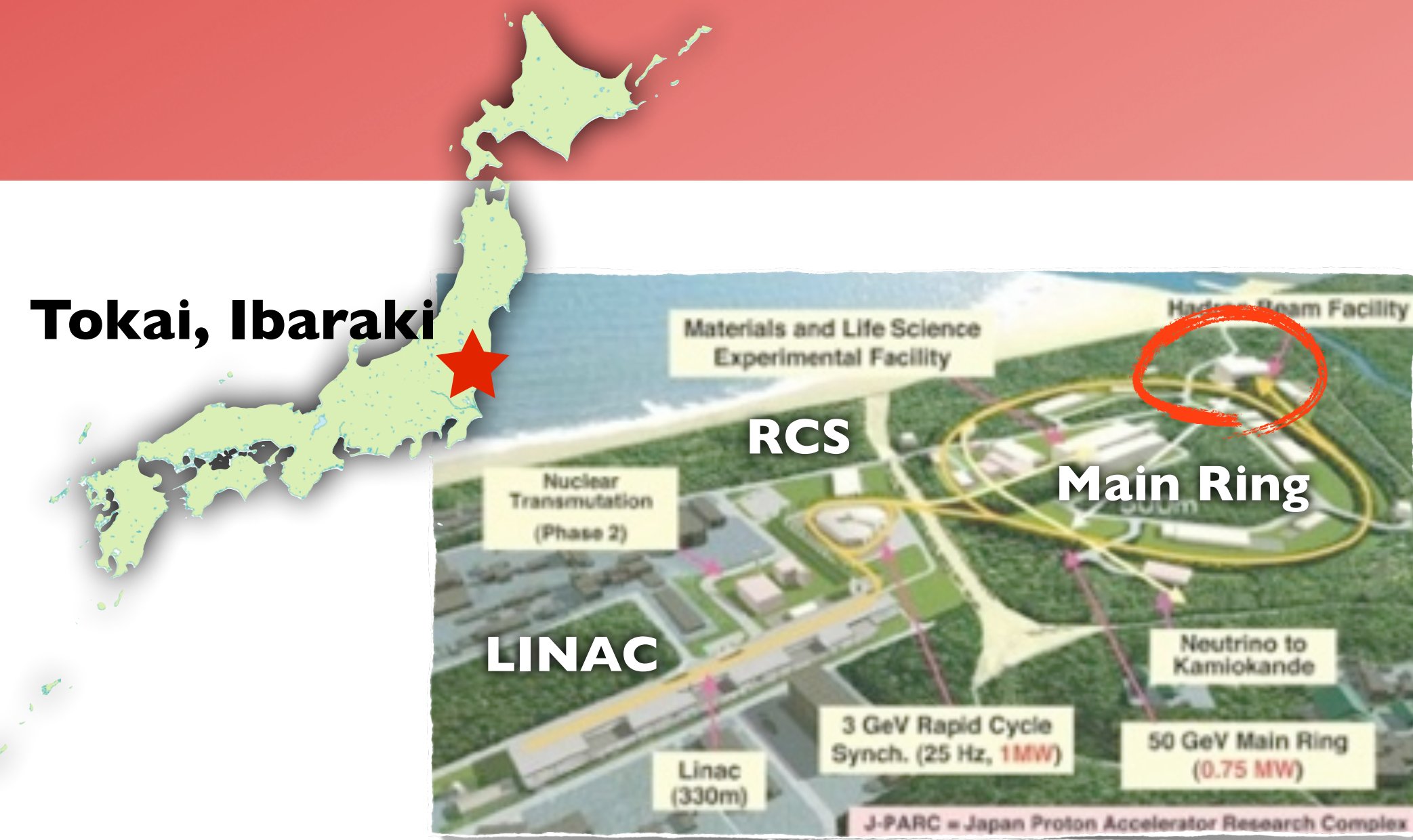


COMET EXPERIMENT

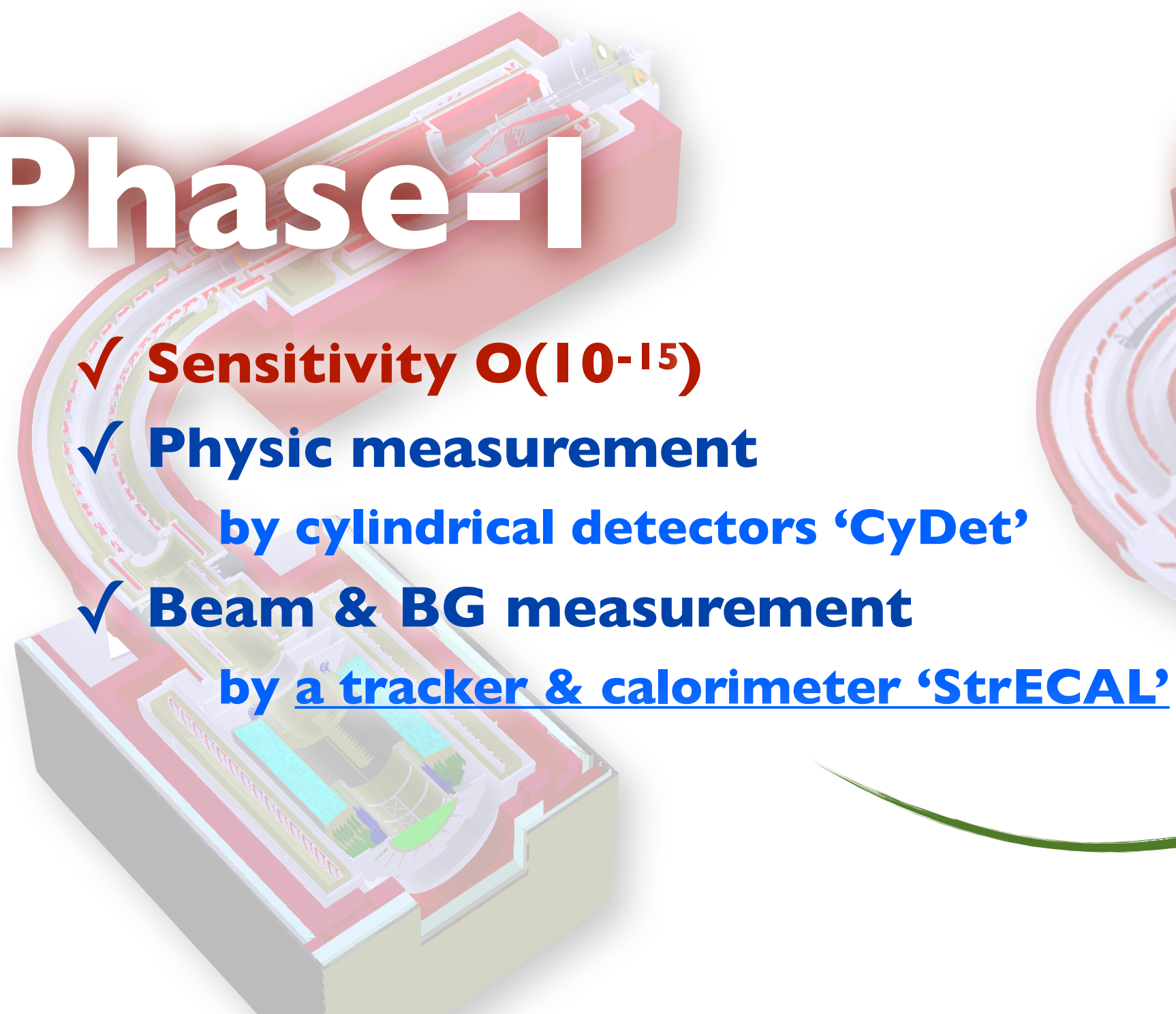
Searching for μ -e conversion in aluminium at J-PARC

- ✦ The final single event sensitivity: $\mathcal{O}(10^{-17})$ 10,000 $\times$ improvement from
 - ★ $R(\mu^- + \text{Au} \rightarrow e^- + \text{Au}) < 7 \times 10^{-13}$ by SINDRUM II @ PSI, Switzerland
 - ★ Bertl, W., et al. Eur. Phys. J. C 47, 337–346 (2006). DOI: 10.1140/epjc/s2006-02582-x
- ✦ Dedicated facility and muon transport line being constructed.
- ✦ Two-staged plan: Phase-I and Phase-II

Tokai, Ibaraki

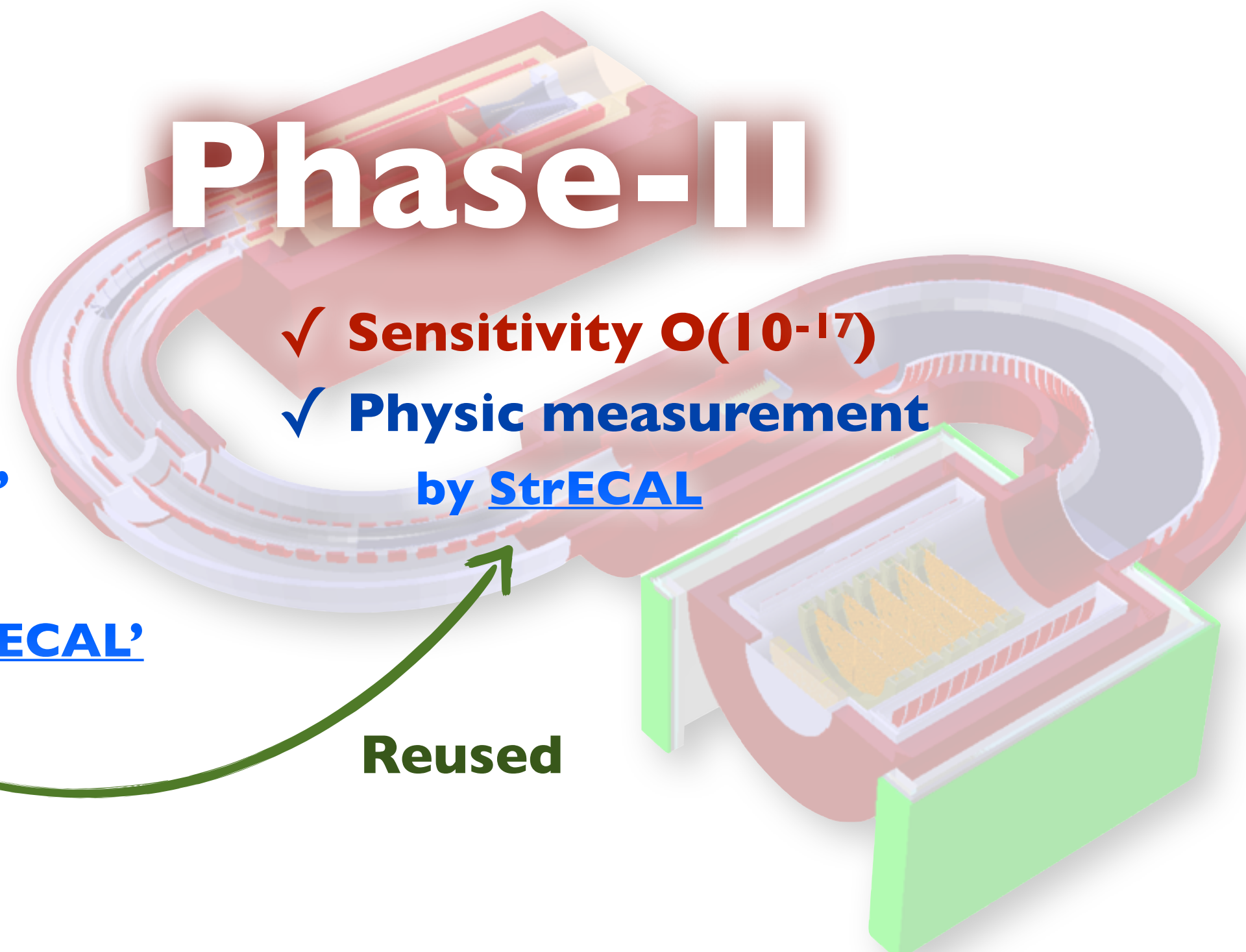


Phase-I



- ✓ Sensitivity $\mathcal{O}(10^{-15})$
- ✓ Physic measurement by cylindrical detectors ‘CyDet’
- ✓ Beam & BG measurement by a tracker & calorimeter ‘StrECAL’

Phase-II



- ✓ Sensitivity $\mathcal{O}(10^{-17})$
- ✓ Physic measurement by StrECAL

Reused





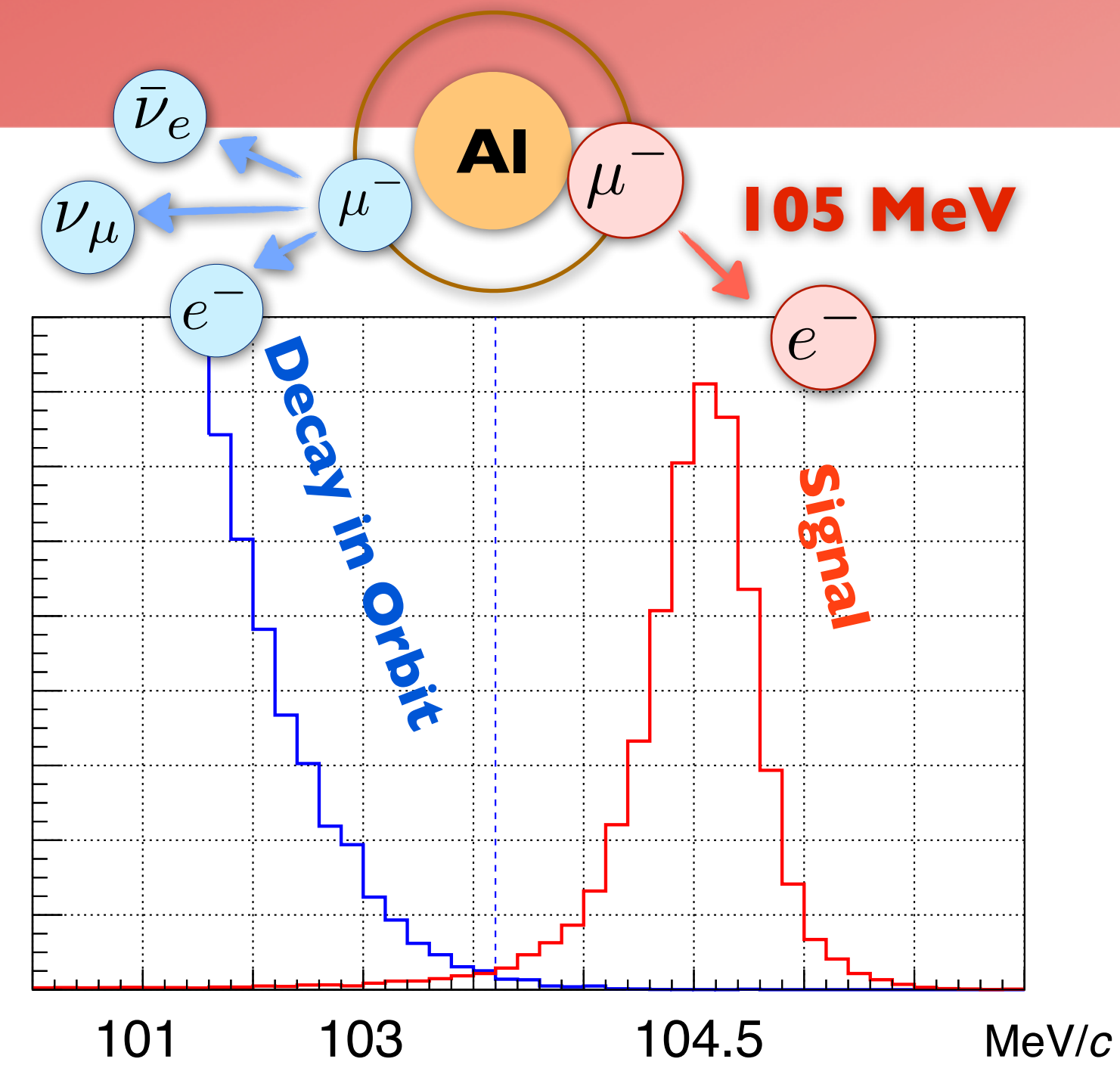
EXPERIMENTAL PRINCIPLE

I. Signal & Background

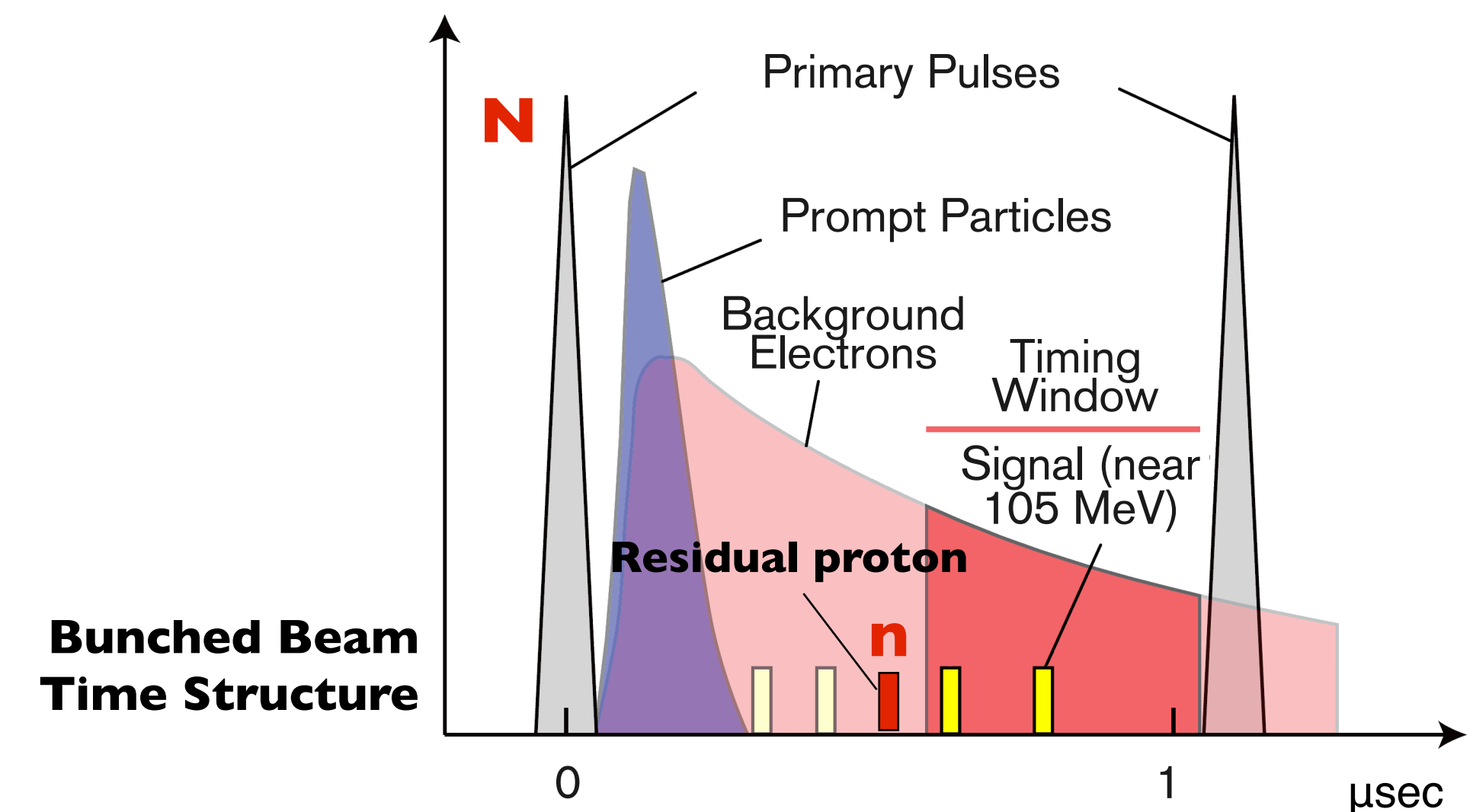
- Signal: $\mu^- + N \rightarrow e^- + N$
 - Monochromatic energy of **105 MeV** (Al used in COMET)
- Irreducible BG: **decay-in-orbit (DIO)**
 - Contaminate the signal region w/ a finite resolution.
 - Momentum resolution < 200 keV/c** is required.

II. Intense bunched muon beam

- World-class intensity proton beam @ J-PARC.
 - To gain high statistics of muons.
 - Effective transport beamline** is essential.
 - Backgrounds arise from the proton and its secondaries.
 - Antiproton, radiative pion capture, muon decay in flight, etc...
- Bunched beam structure
 - Delayed timing window** for masking the beam BGs.
 - The fraction of residual protons between the bunches (**extinction** = n/N in the right fig.) $< 10^{-10}$



Electron momentum spectrum
w/ $BR(\mu N \rightarrow eN) = 10^{-15}$



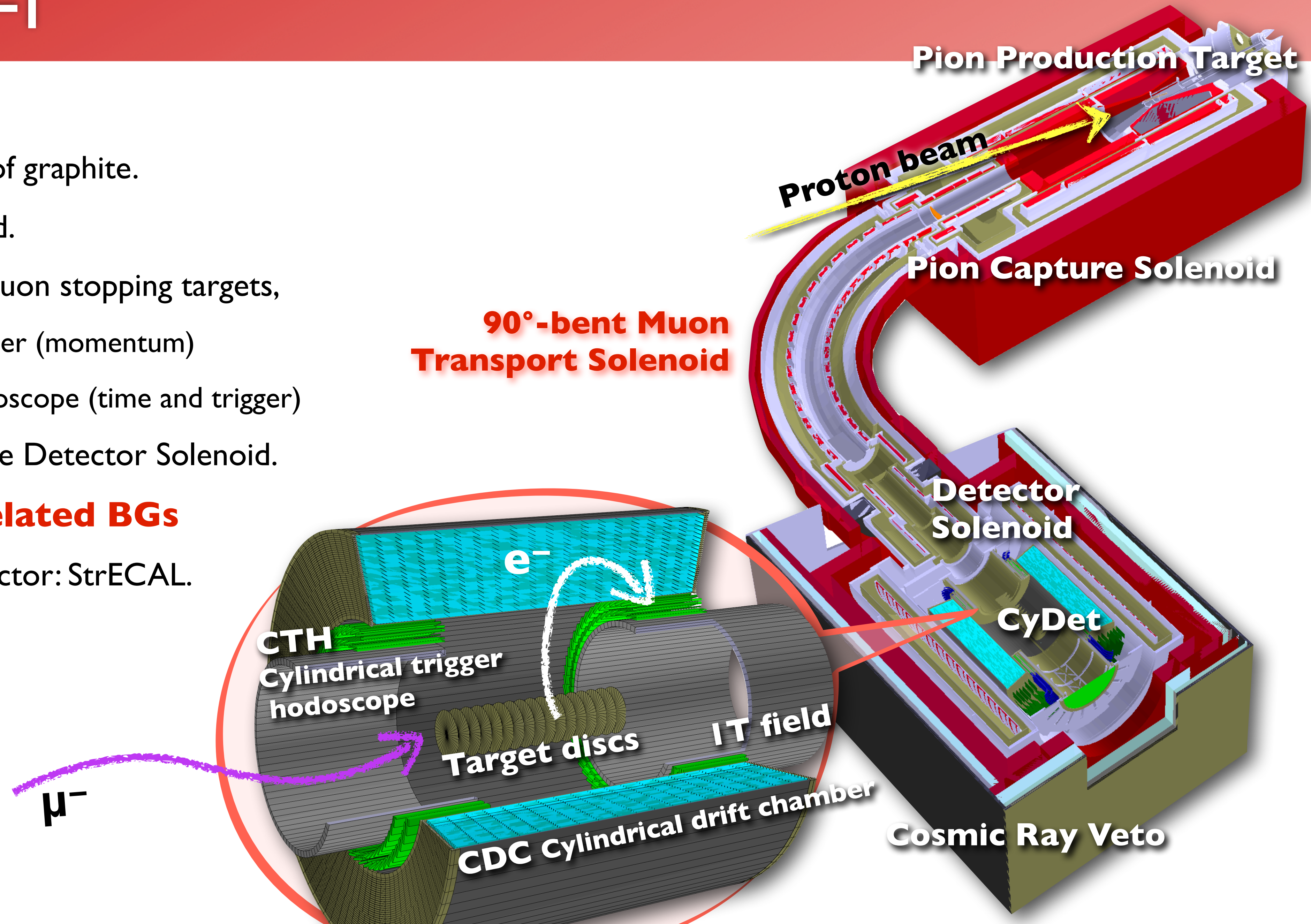
PHASE-I

Sensitivity $O(10^{-15})$

- ✦ Pion production target made of graphite.
- ✦ $\pi \rightarrow \mu$ in the transport solenoid.
- ✦ **CyDet** combining with the muon stopping targets,
 - ★ **CDC**: Cylindrical Drift Chamber (momentum)
 - ★ **CTH**: Cylindrical Trigger Hodoscope (time and trigger)
- ✦ Cosmic Ray Veto surrounds the Detector Solenoid.

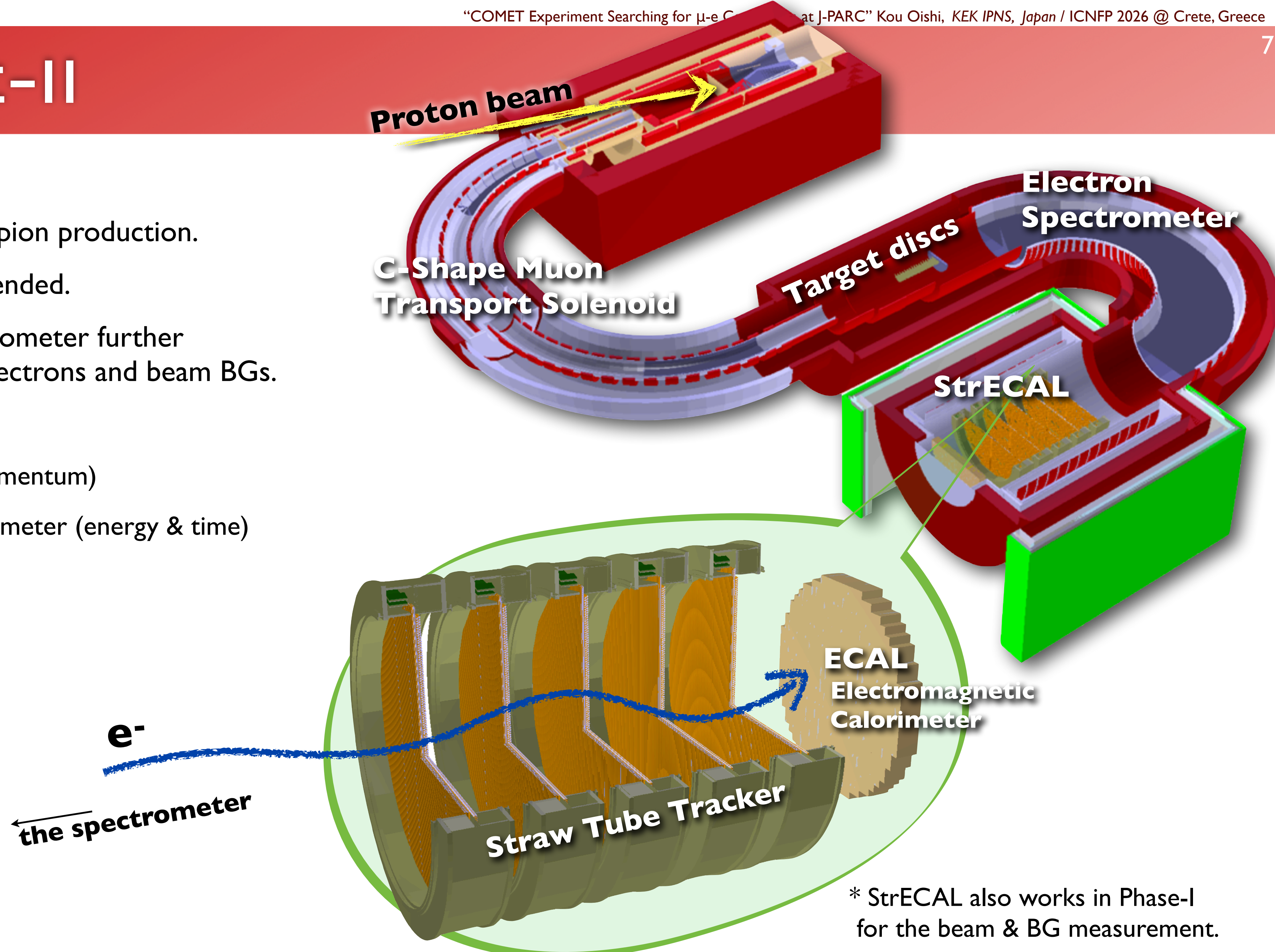
Beam profile & beam-related BGs

- ✦ Measured by the Phase-II detector: StrECAL.



Sensitivity $O(10^{-17})$

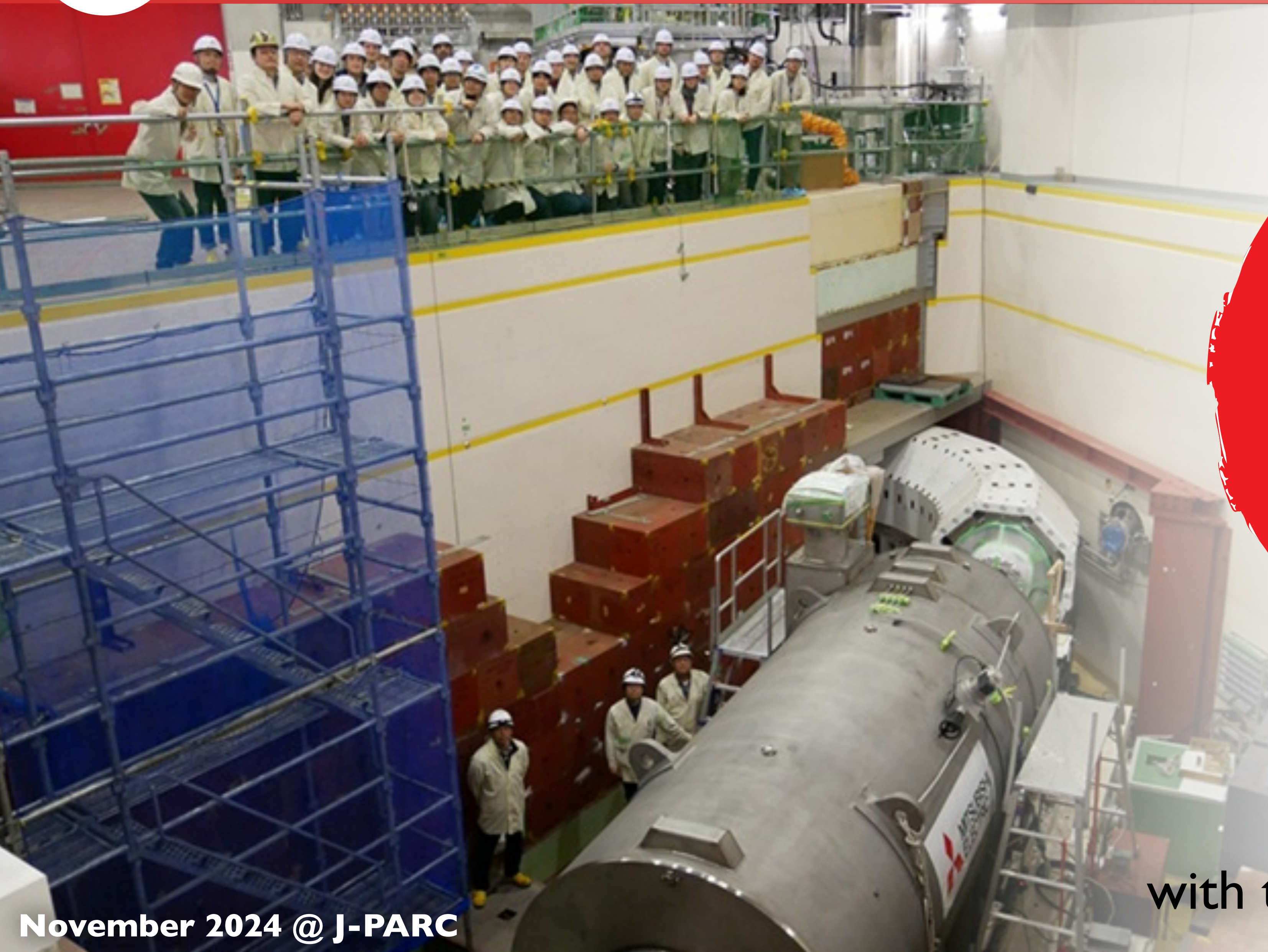
- ✦ Tungsten target for enhanced pion production.
- ✦ The transport line will be extended.
- ✦ The additional electron spectrometer further suppresses low momentum electrons and beam BGs.
- ✦ **StrECAL** combining
 - ★ **Straw Tube Tracker** (momentum)
 - ★ **ECAL**: Electromagnetic calorimeter (energy & time)
 - ❖ Provides trigger signals.



* StrECAL also works in Phase-I for the beam & BG measurement.



COMET COLLABORATION



Our Collaborators

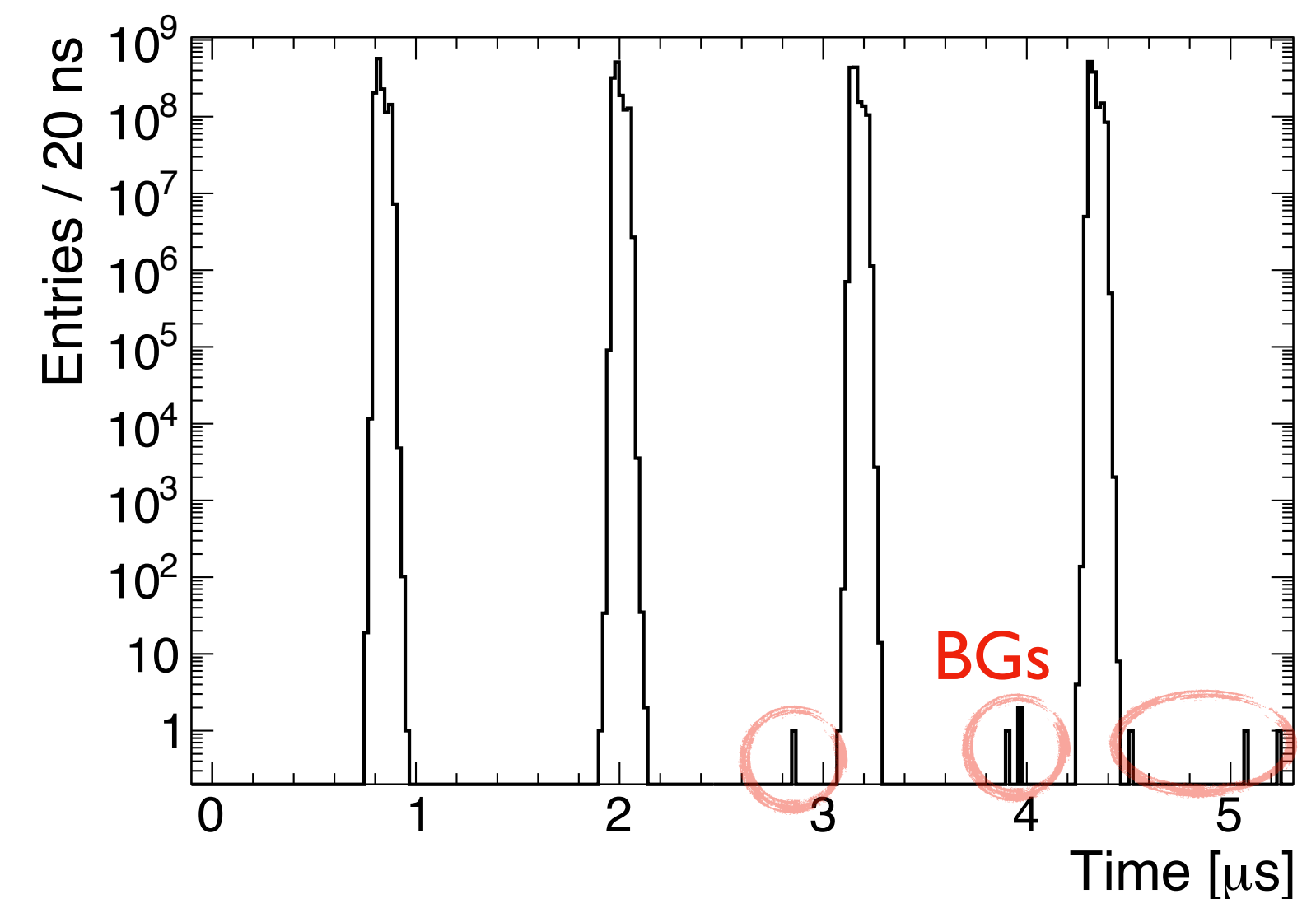
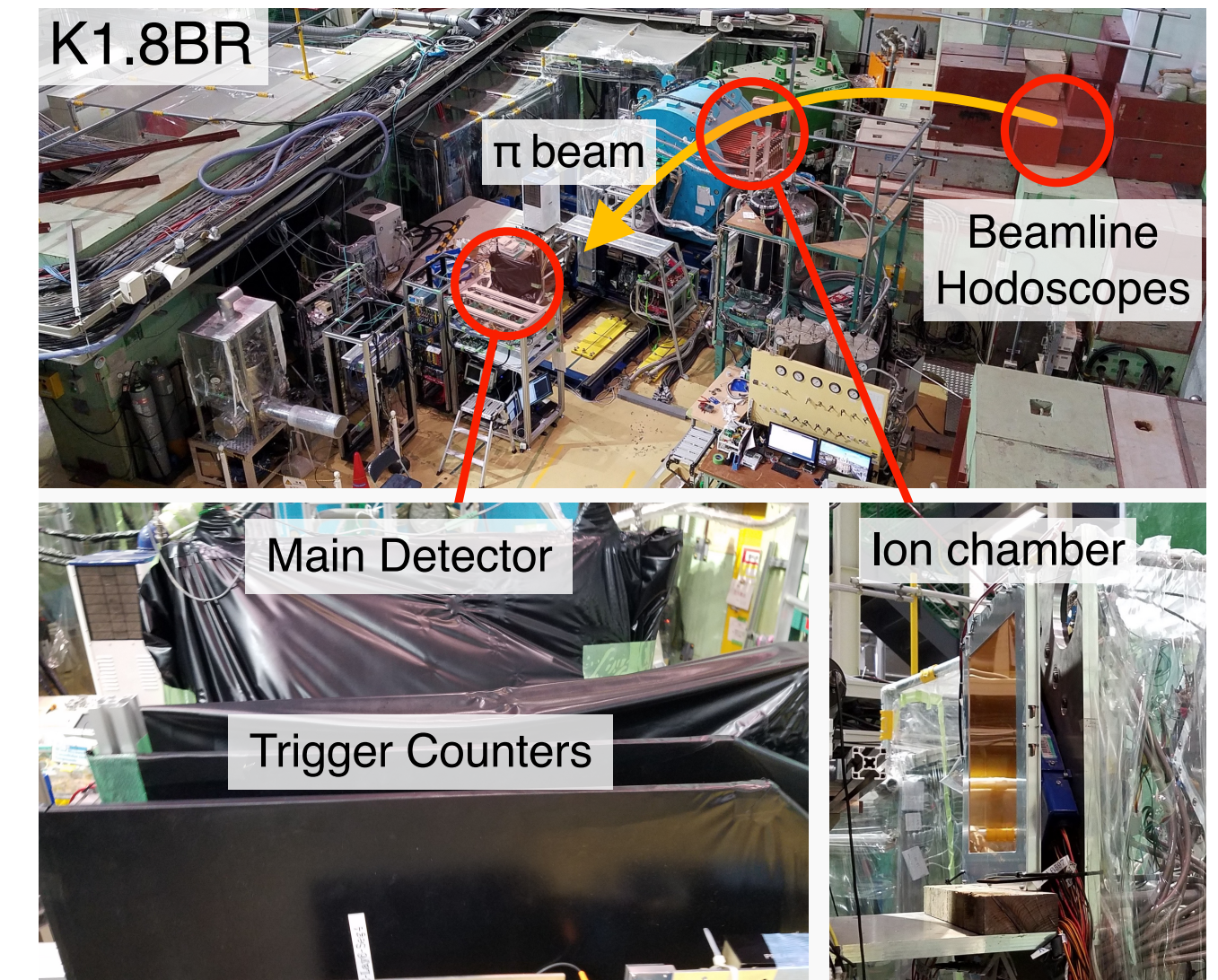
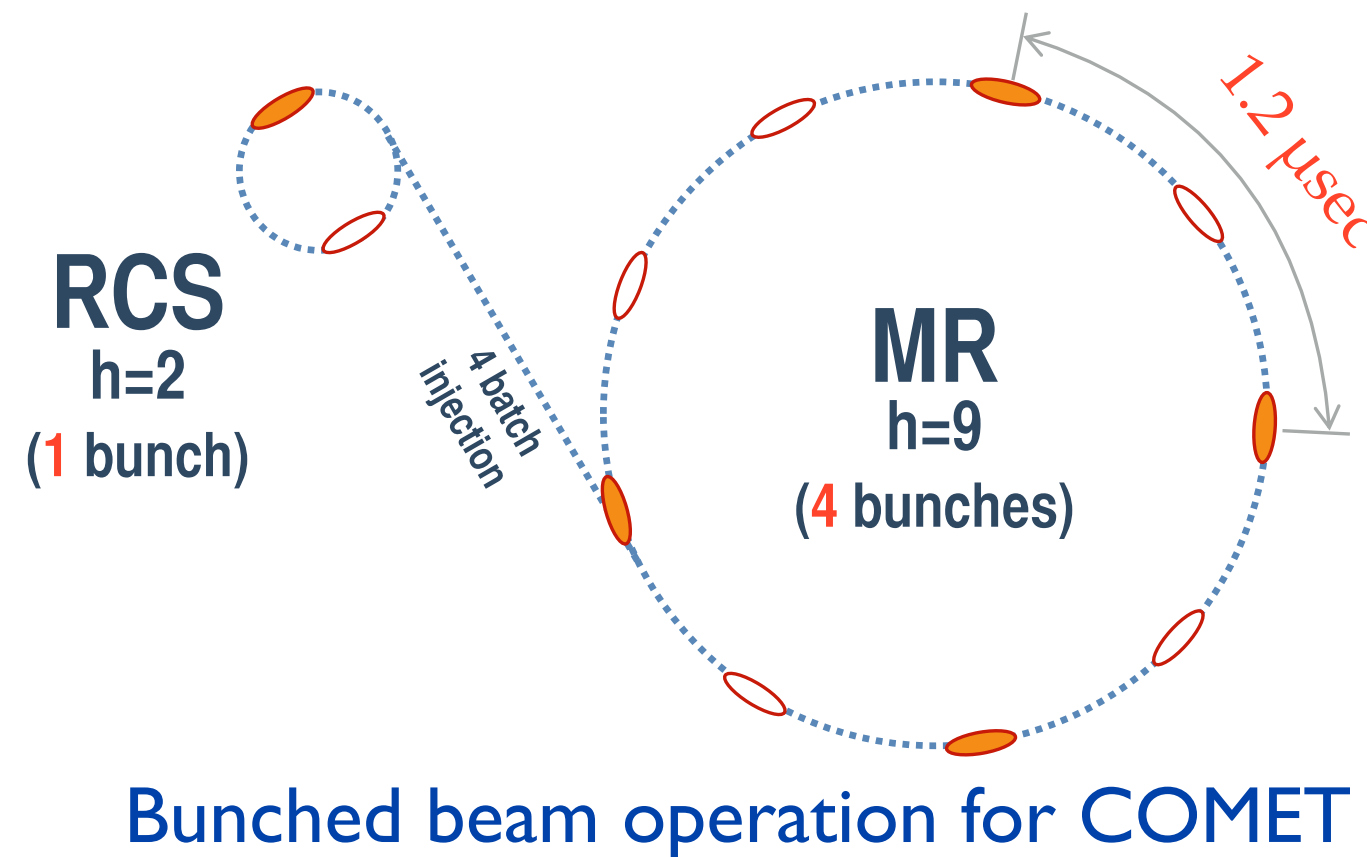
with the delivered solenoid magnet

November 2024 @ J-PARC

COMET ^{μ} _e PROTON BEAM

J-PARC Proton Beam for COMET

- ◆ (1) Accelerated up to 8 GeV (vs. 30 GeV)
 - ★ to minimise antiprotons.
 - ★ 3.2 (56) kW for Phase-I (Phase-II)
 - ◆ (2) Bunched slow extraction (SX) for timing-window measurement
 - ★ Only 4 out of 9 buckets will be filled for 1.2 μ s intervals.
 - ★ **‘Proton extinction’** $< 10^{-10}$
- The proton extinction was measured $< 1.0 \times 10^{-10}$**
- ◆ @ K1.8BR of the Hadron Facility (T78 exp. in 2021)
 - ★ Near to the COMET facility.
 - ◆ High inter-bunch residual proton suppression has been confirmed.



No inter-bunch contaminations in T78 exp.



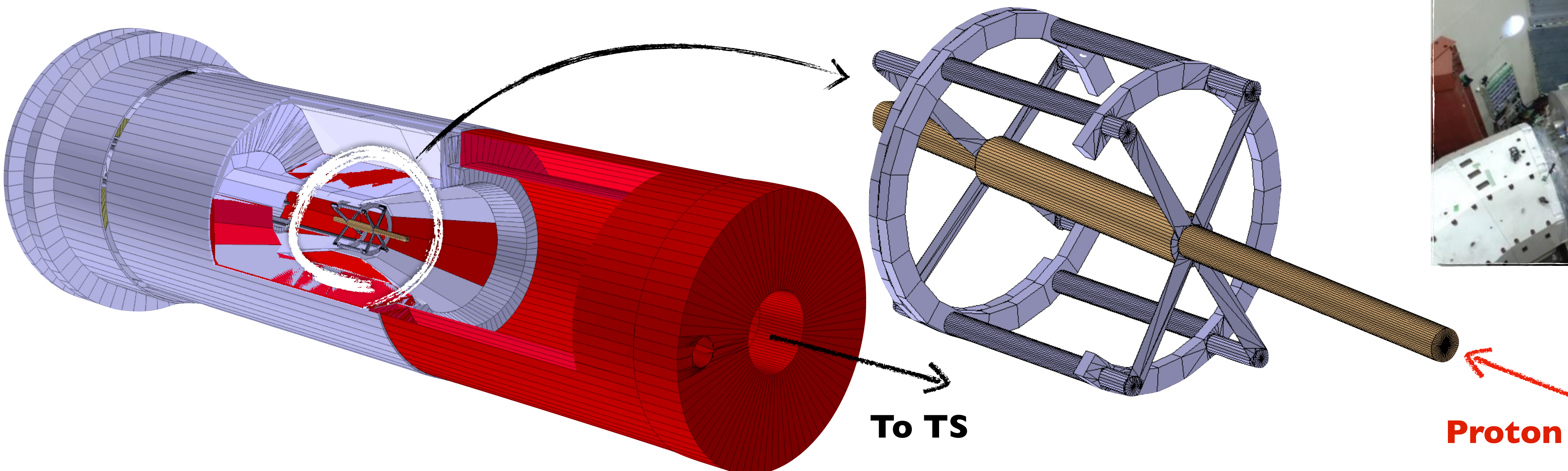
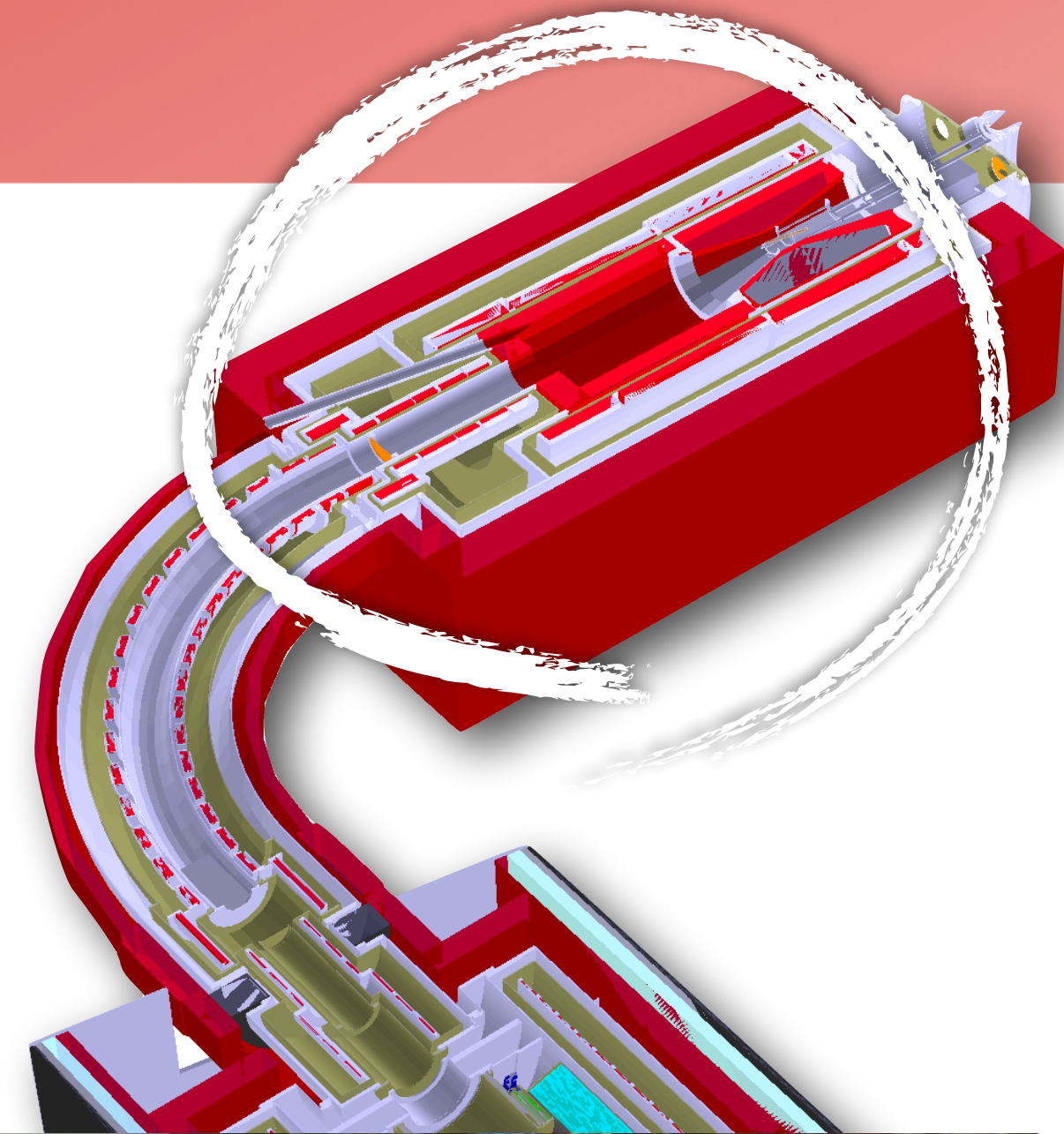
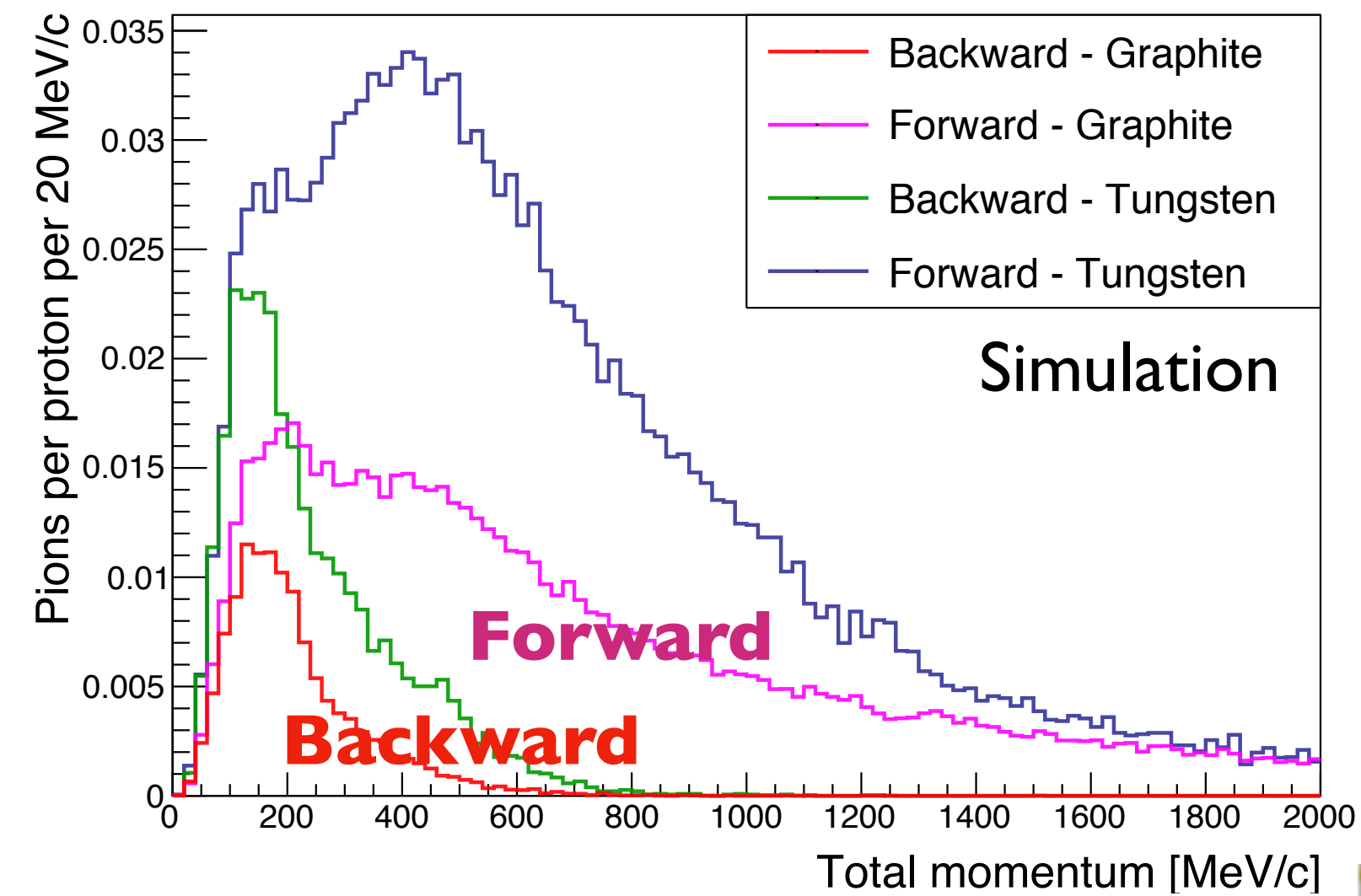
PION PRODUCTION SECTION

Pion Production Target

- ♦ Graphite (Tungsten) for Phase-I (II).

Pion capture solenoid

- ♦ 4.4 T superconducting magnet
- ♦ Pions extracted in the backward direction.
 - ★ Better exclusive collection of low-momentum pions
- ♦ Delivered and installed in 2024!

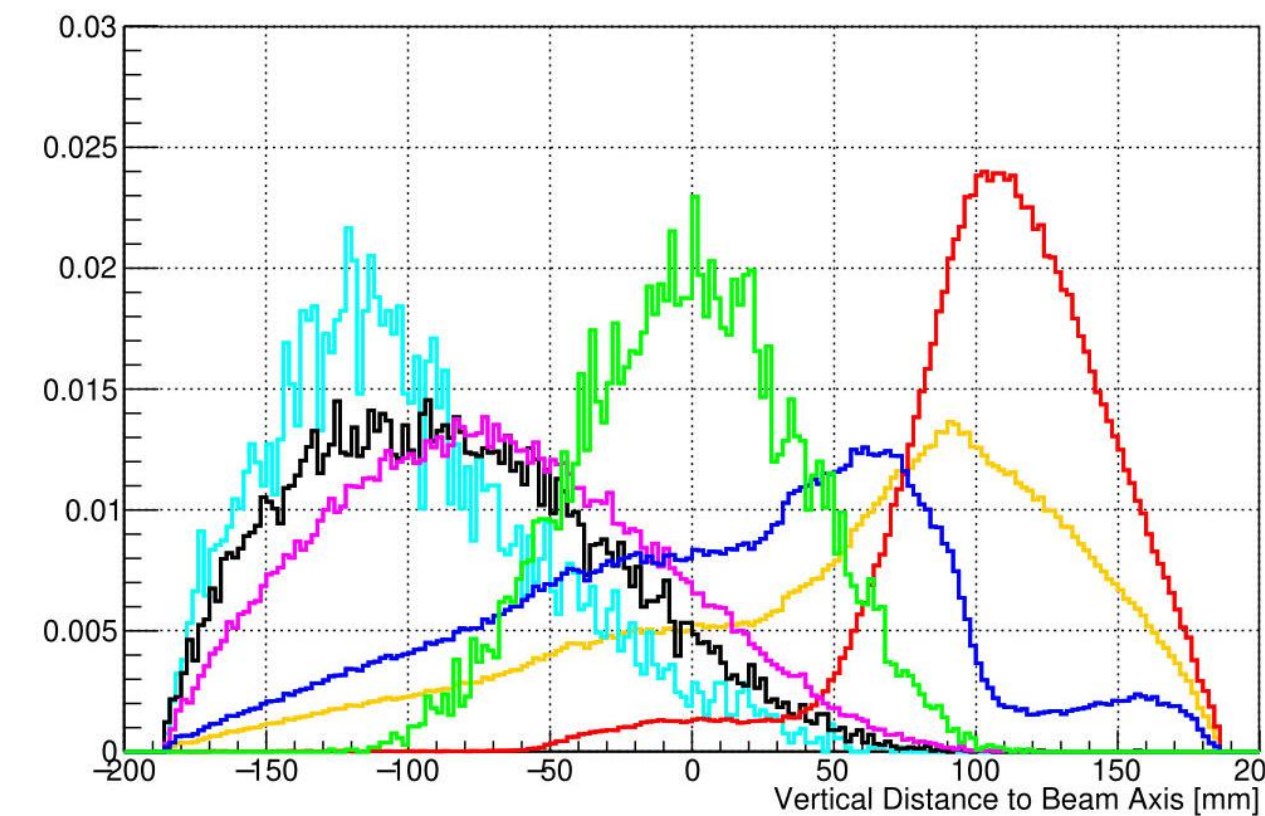
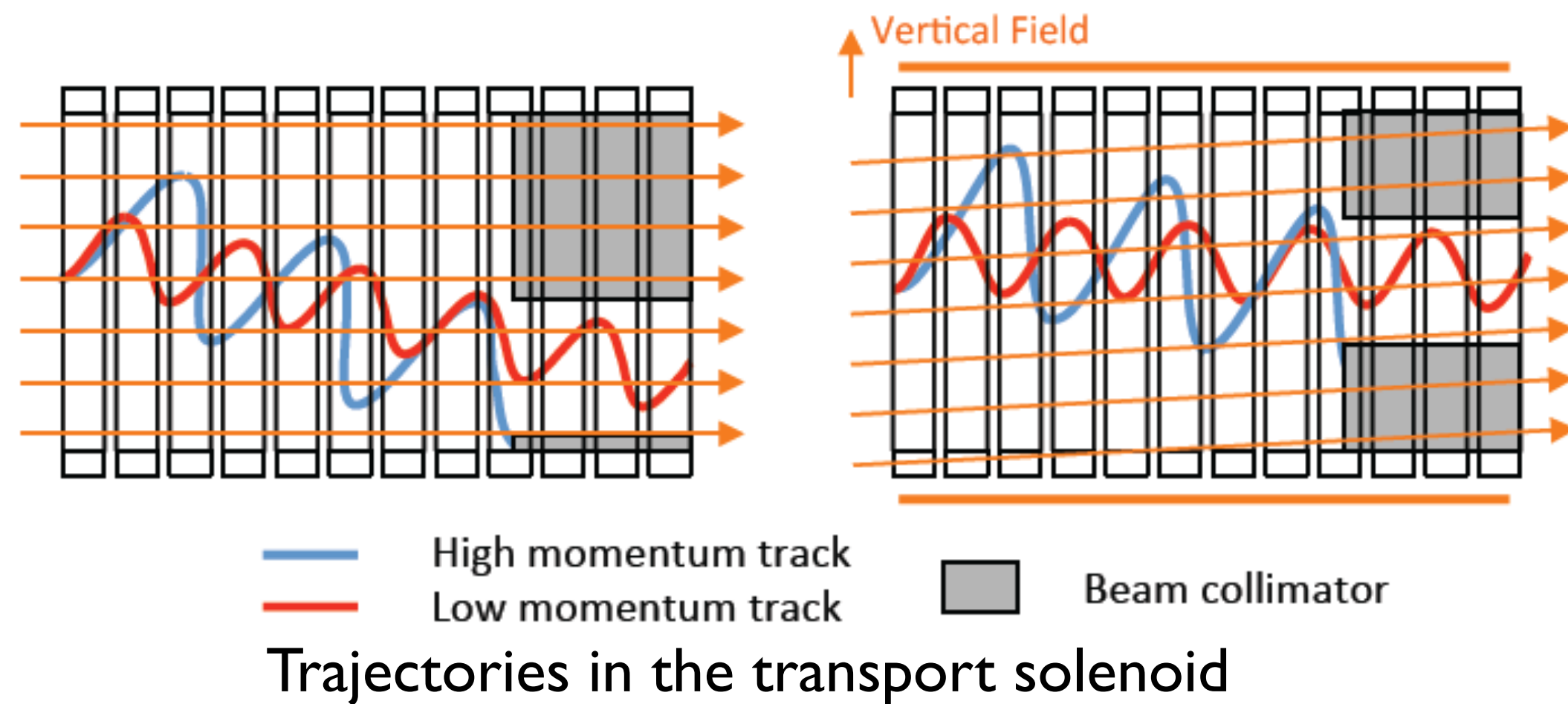




MUON TRANSPORT SOLENOID

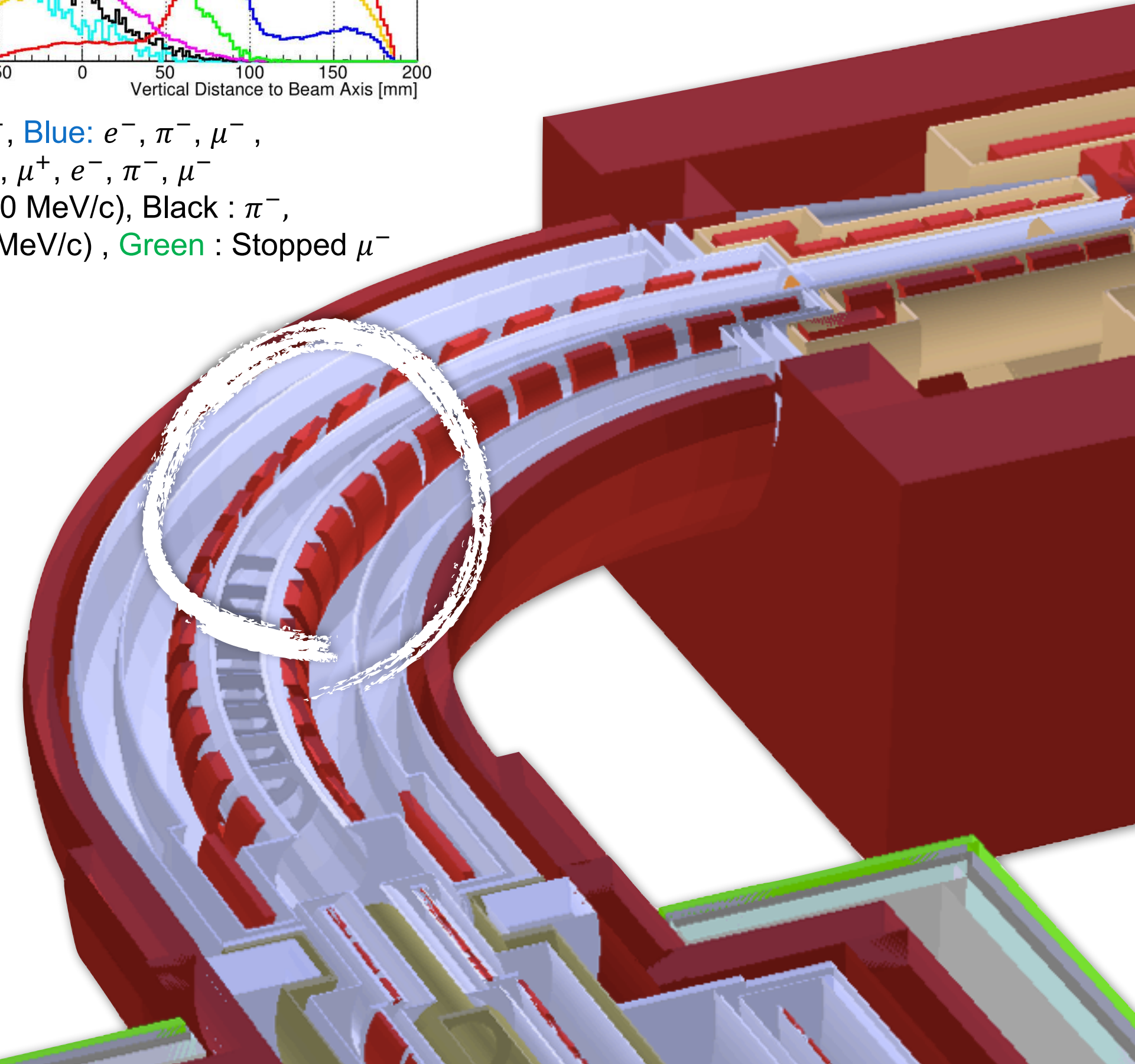
Characteristic 90°-bent solenoid

- ✦ The centre of the helical trajectories drifts vertically.
 - ★ Additional dipole magnetic field for compensation
 - ★ Charge and momentum selection with optimum collimators.
- ✦ The magnet and beam collimator are designed to select the target low-momentum μ^- .
 - ★ μ^- of 30–50 MeV/c tend to stop in the aluminium target.



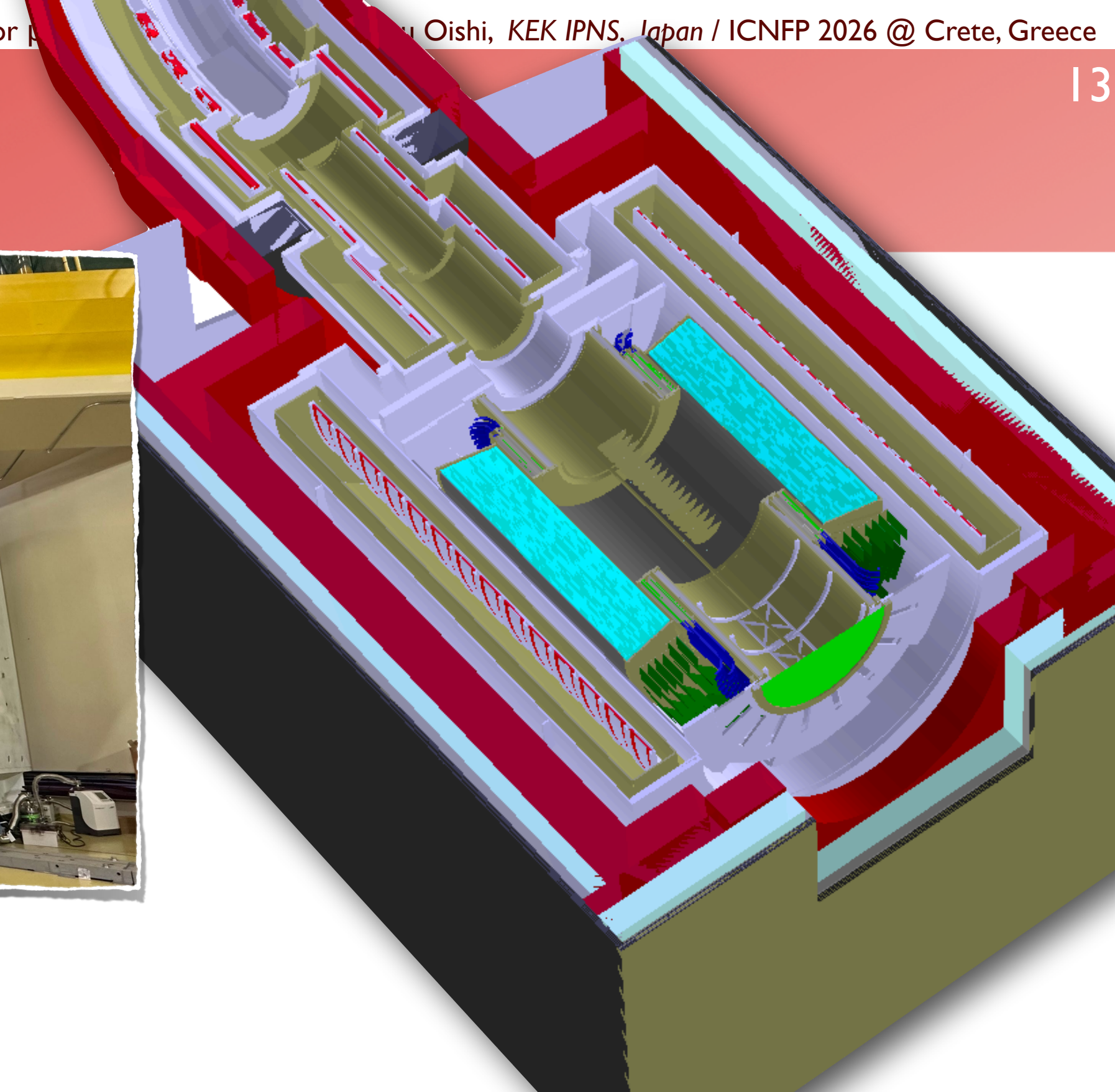
Vertical positions of different particle types before the collimator

Red : p, e^+, π^+, μ^+ , Blue: e^-, π^-, μ^- ,
 Orange : $p, e^+, \pi^+, \mu^+, e^-, \pi^-, \mu^-$
 Magenta: $\mu^- (p > 70 \text{ MeV/c})$, Black : π^- ,
 Cyan: $e^- (p > 100 \text{ MeV/c})$, Green : Stopped μ^-



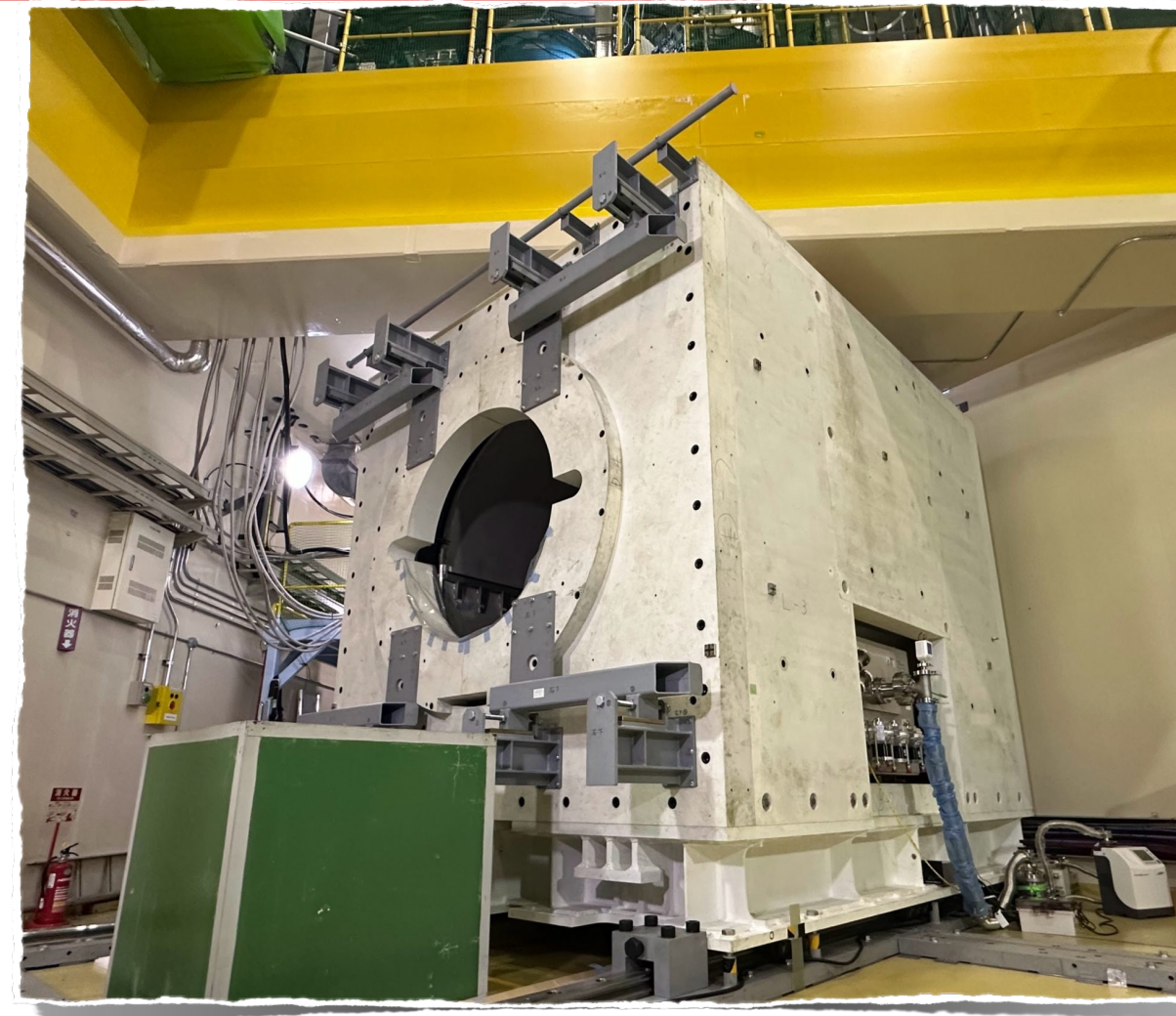


DETECTOR SOLENOID



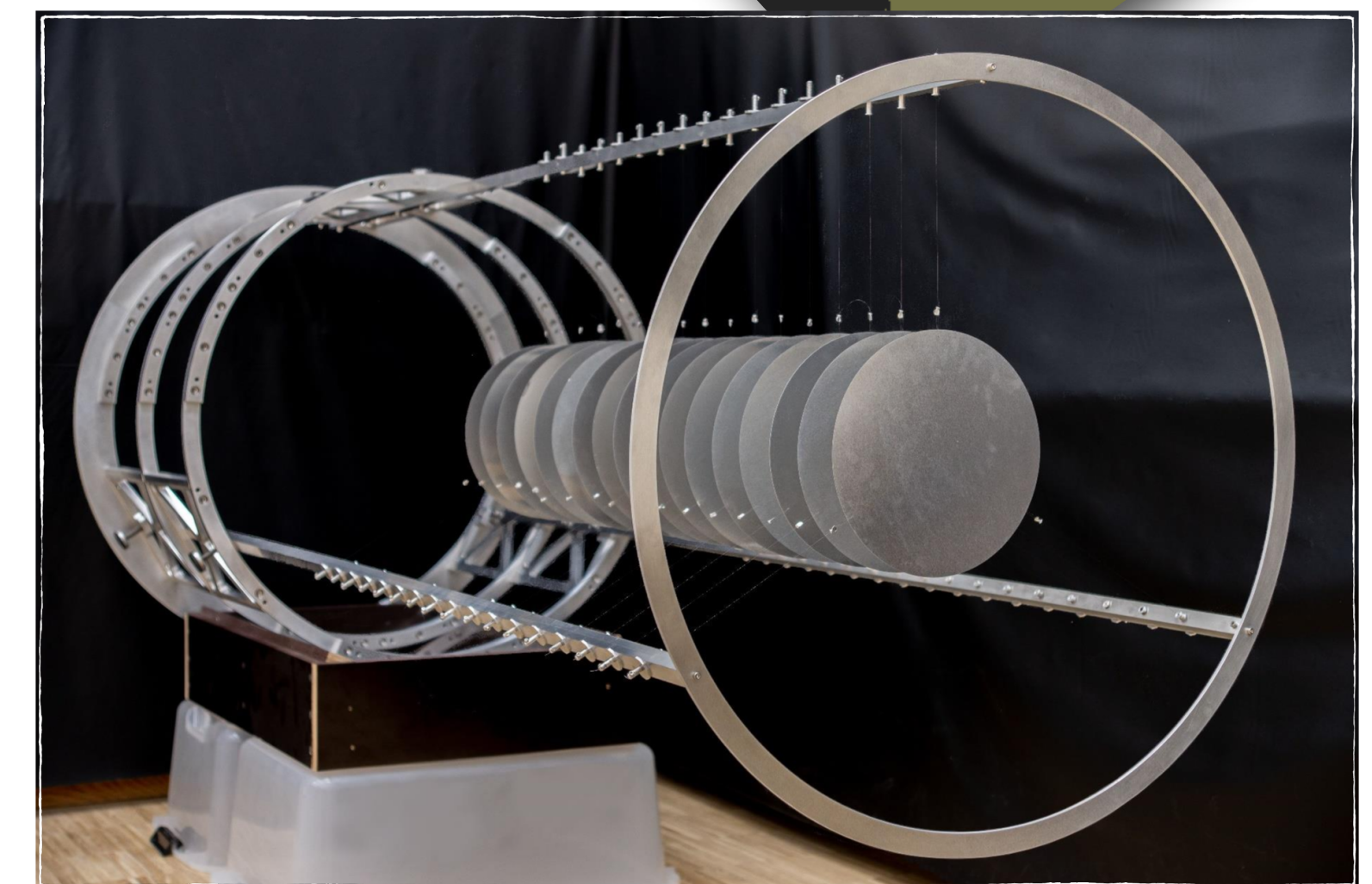
The most important magnet

- ♦ 1 T solenoidal magnetic field
- ♦ Installed in December 2025
 - ★ Watch the [YouTube video](#) !
 - ★ All magnets installed for Phase-I!
- ♦ The commissioning is under preparation.
 - ★ Detailed field measurement will be performed.



Aluminium muon-stopping target

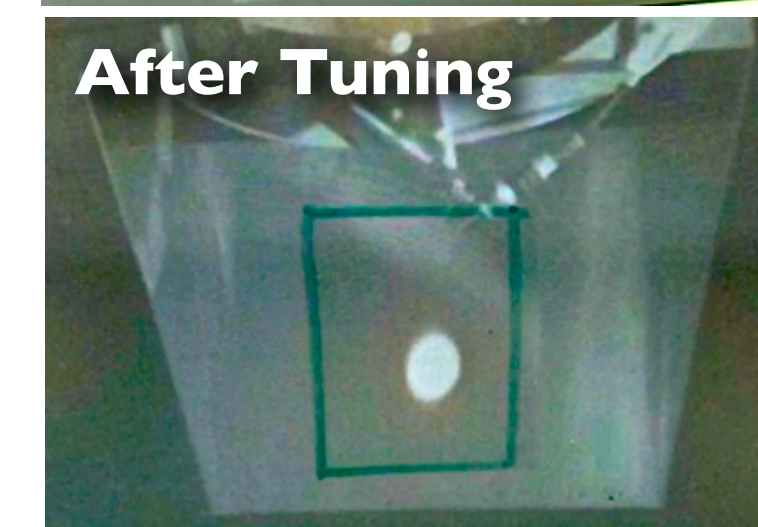
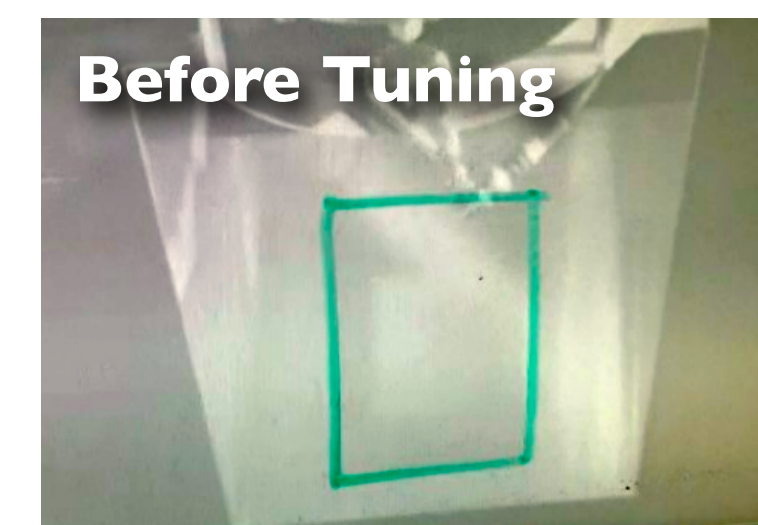
- ♦ 17 discs of R10 cm & $200 \mu\text{m}^T$, 50 mm spacing.
- ♦ High-density Ge detector will measure muonic X-rays from them for normalisation.



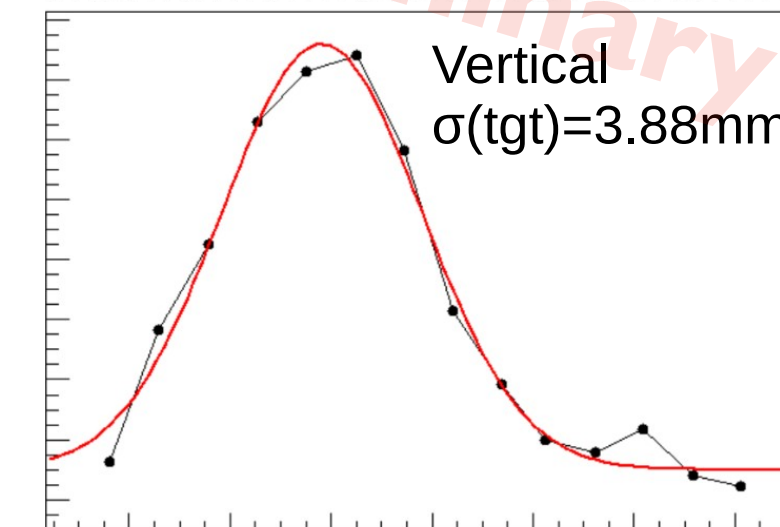
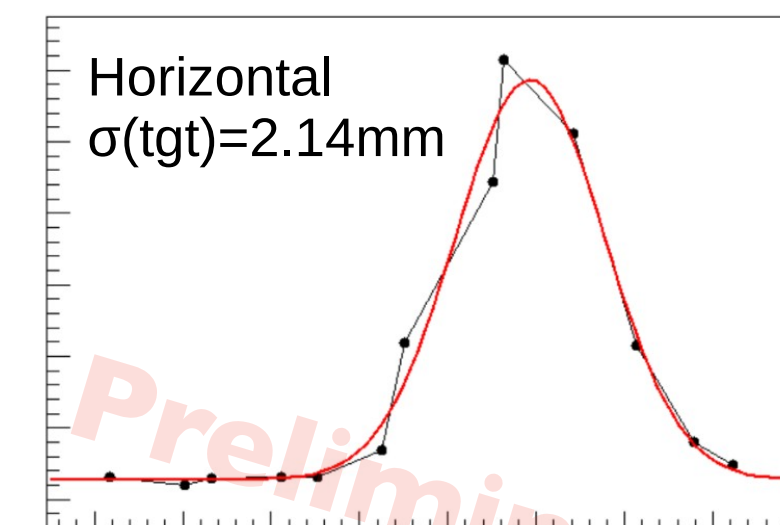
COMET ^{μ} _e PHASE- α

The 1st Commissioning of the COMET facility in 2023

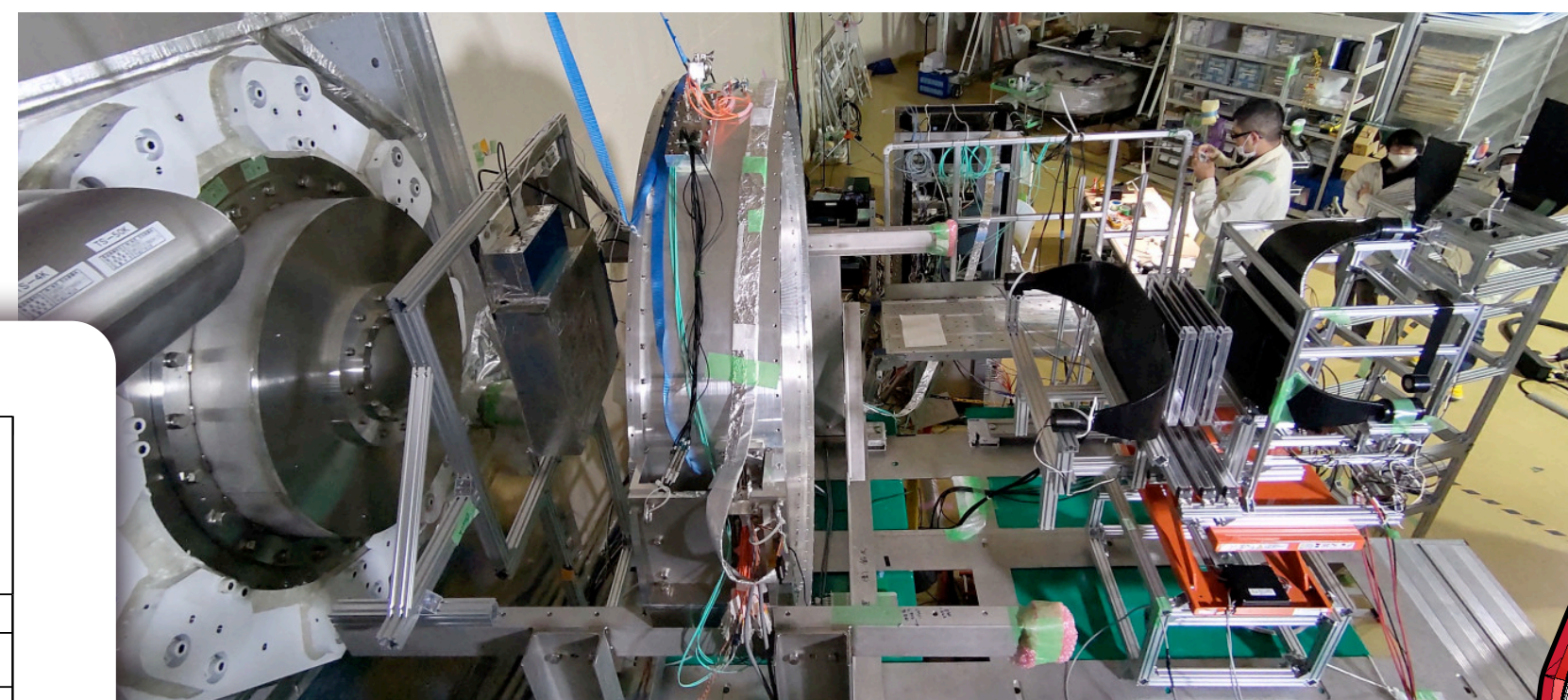
- ✦ The first proton beam injection to the COMET facility.
 - ★ Slow-extracted pulsed 8 GeV proton beam at 260 W ($\sim 1/10$ of Phase-I)
 - ★ Beam tuning and profile measurement were well performed.
- ✦ The muon beam was successfully transported by the TS.
 - ★ Muon momentum spectrum was measured for the first time!
 - ★ A paper will be soon submitted.



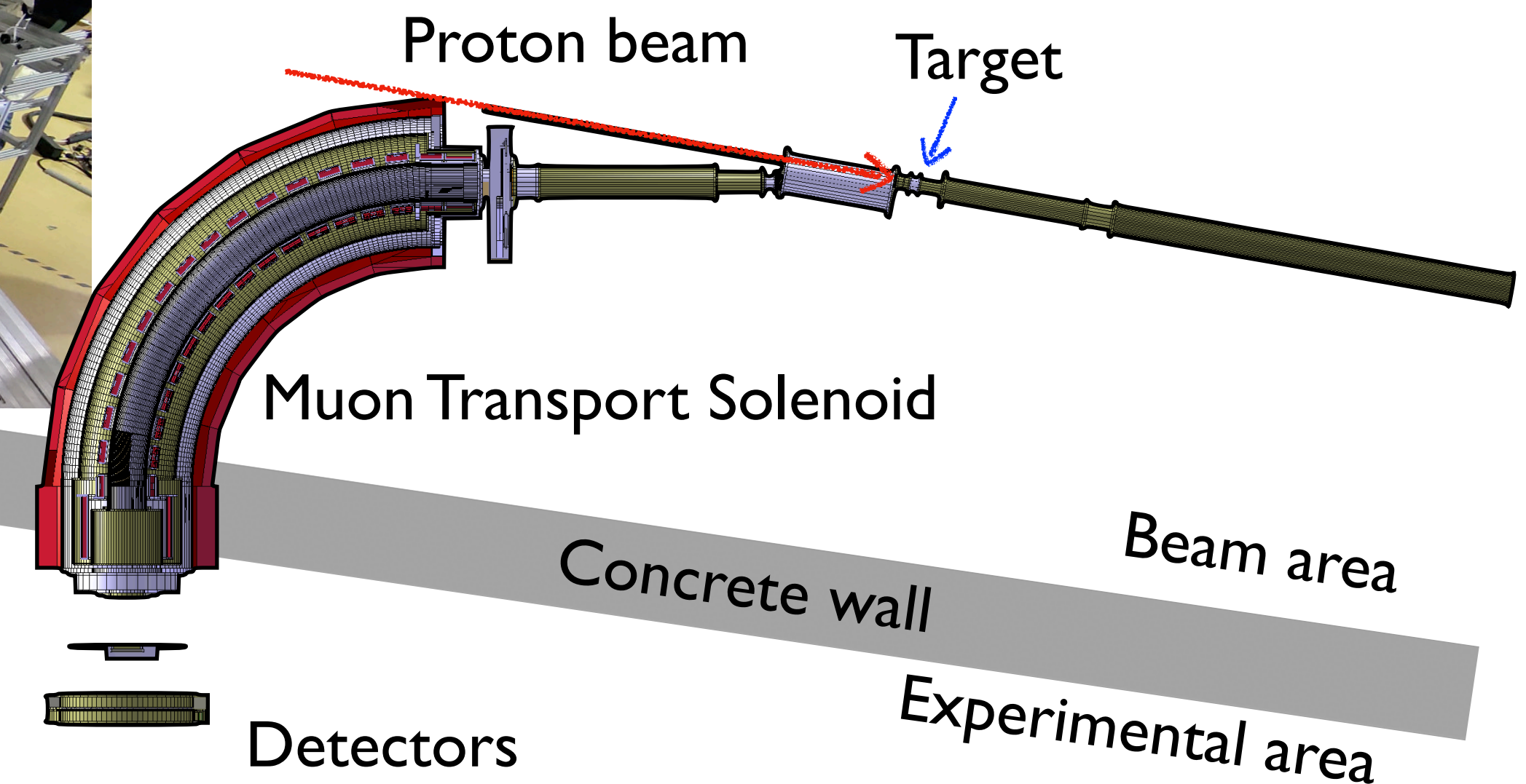
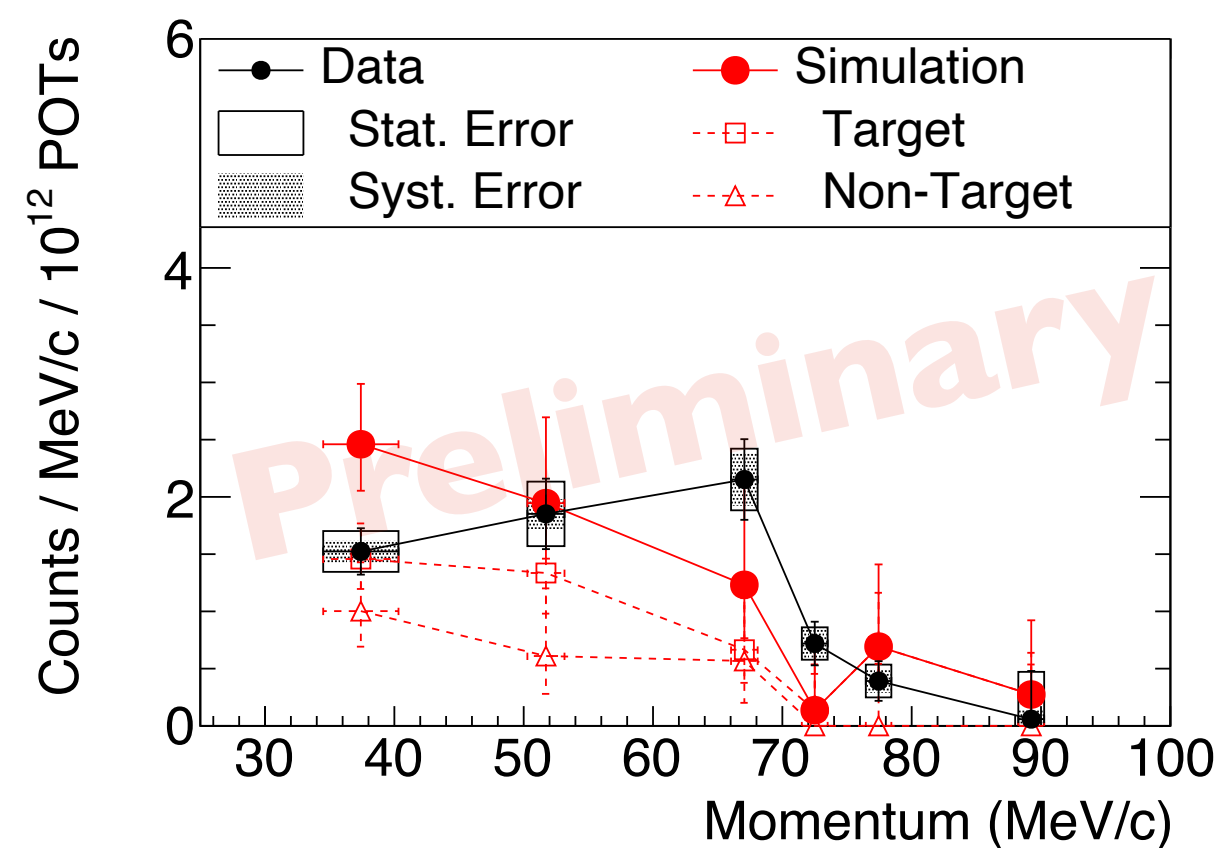
Phosphor plate response
before and after beam tuning



Measured beam size



Phase- α Detectors



CYLINDRICAL DRIFT CHAMBER

Requirements

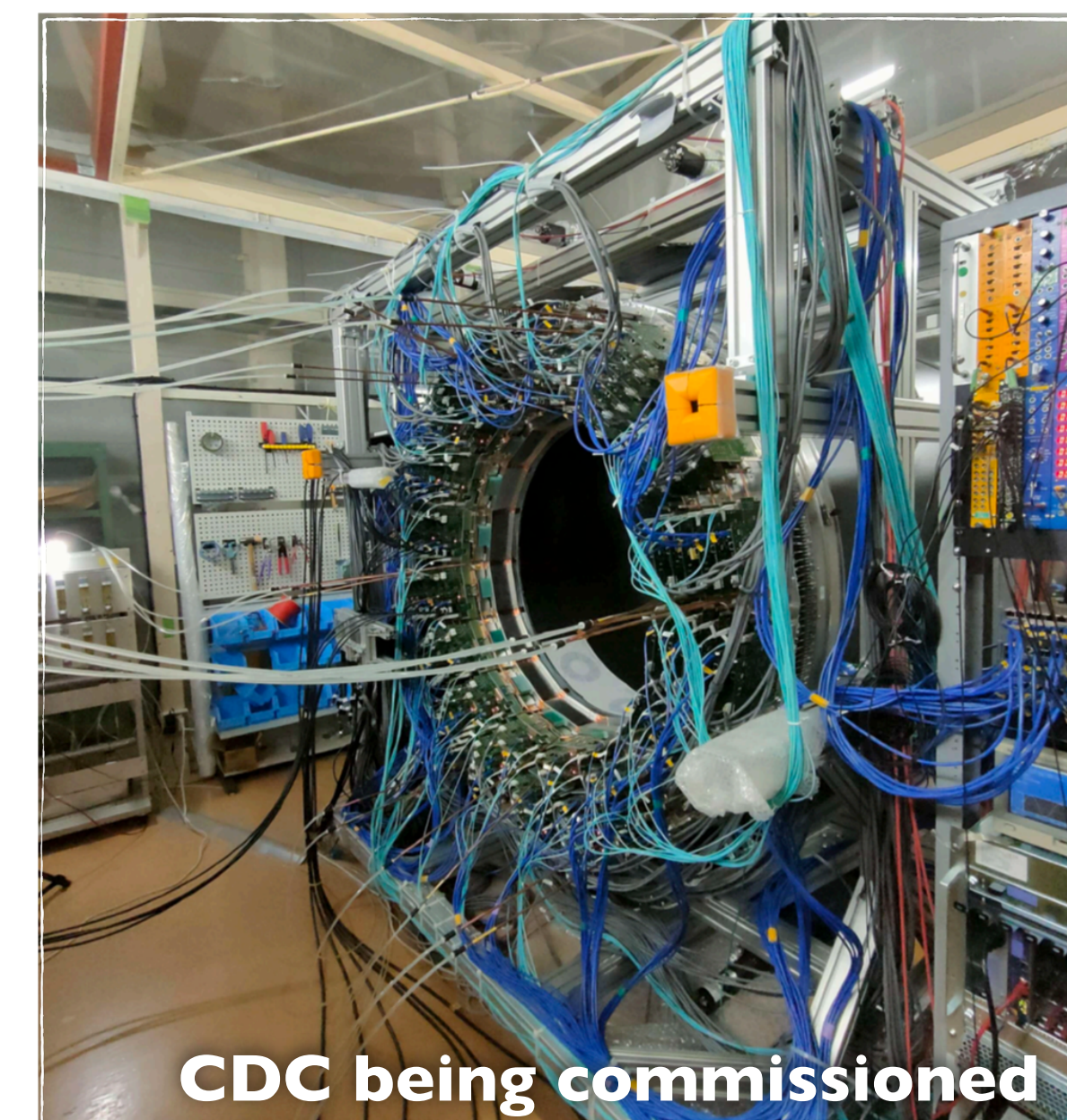
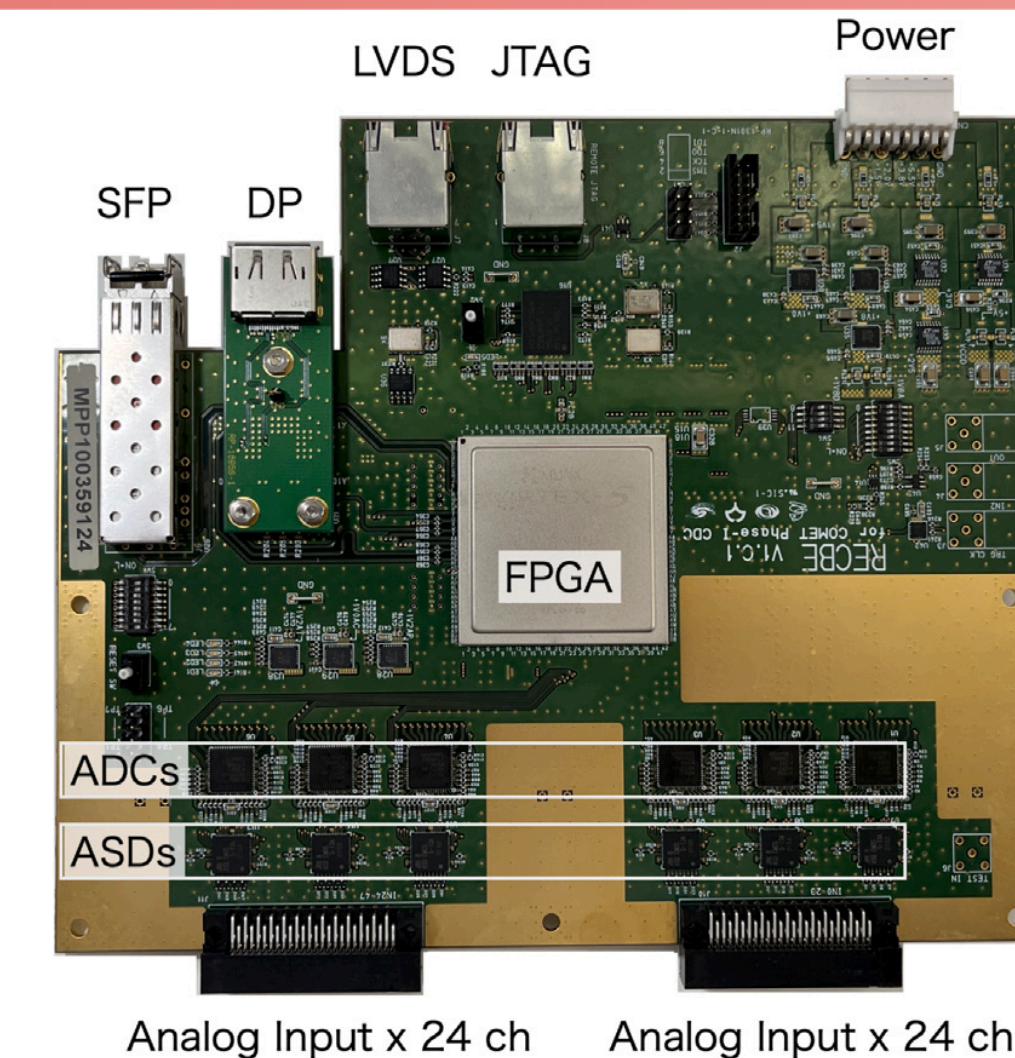
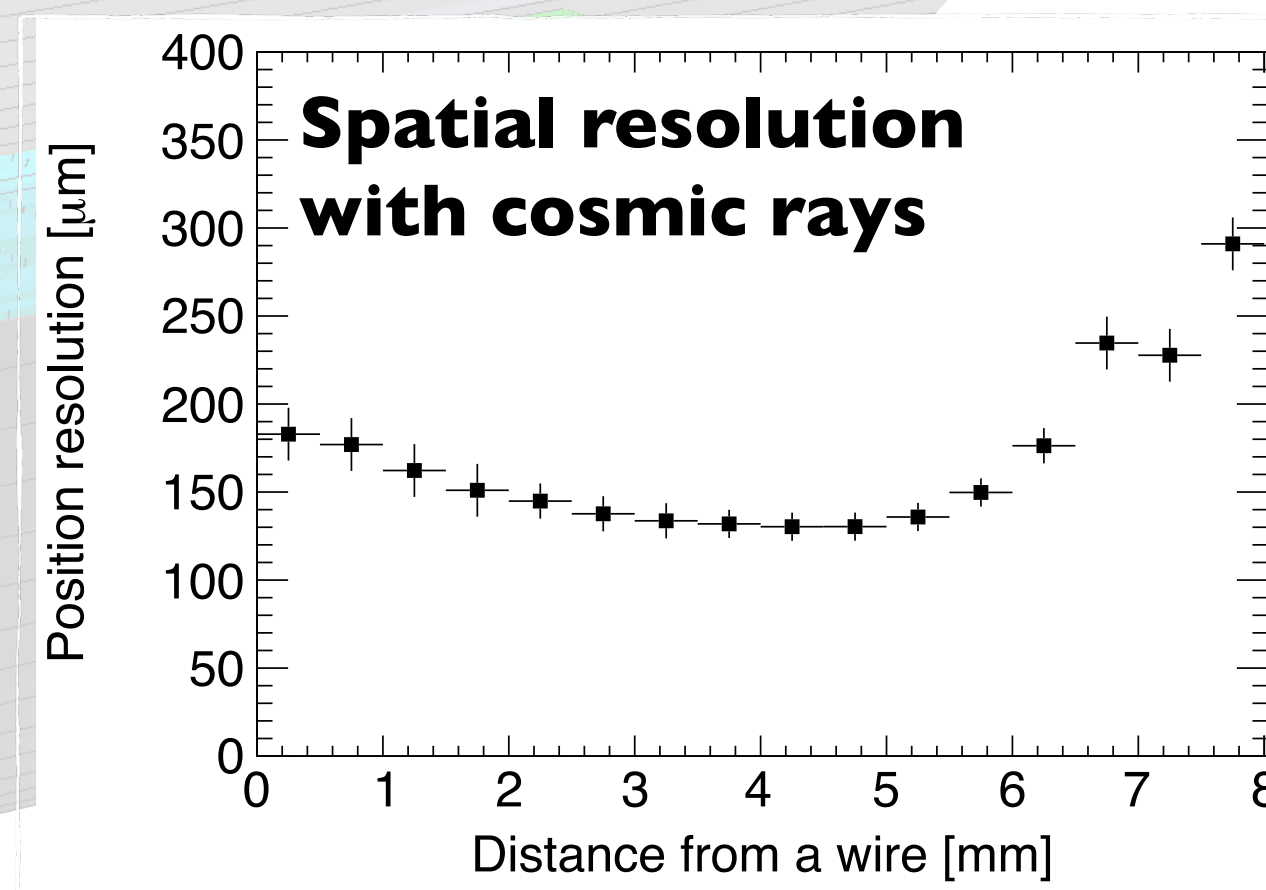
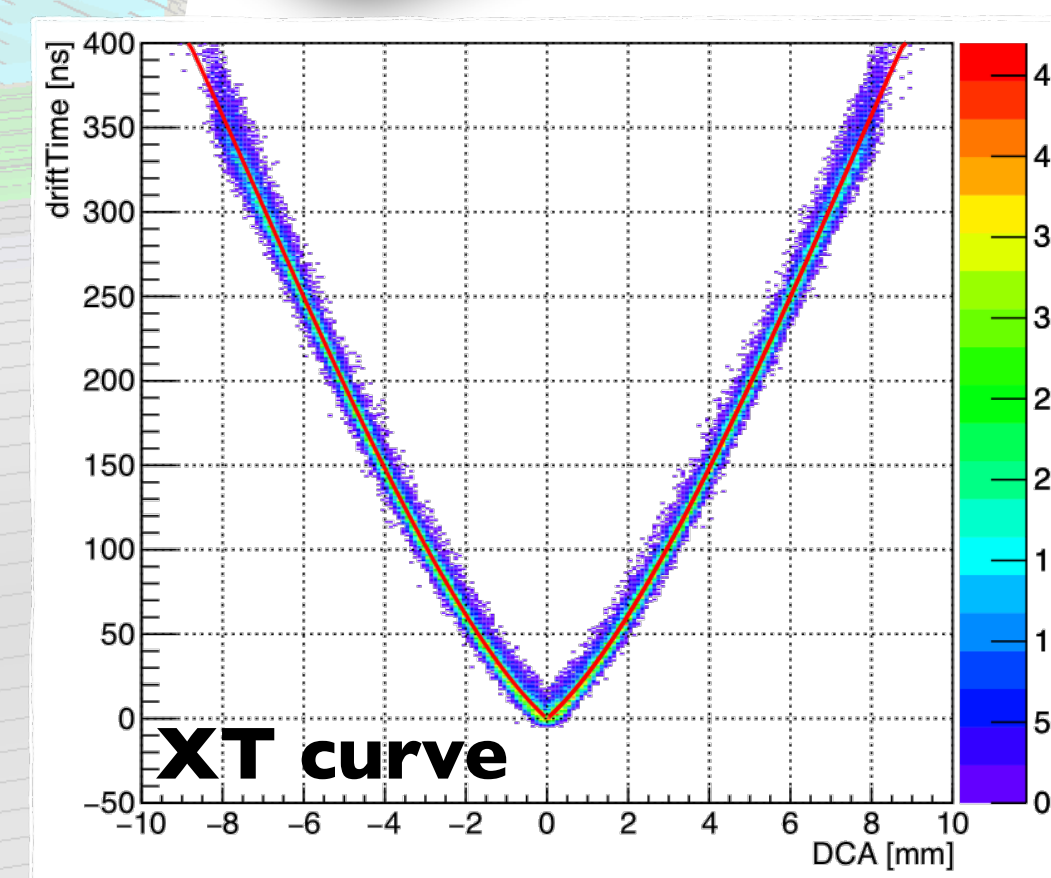
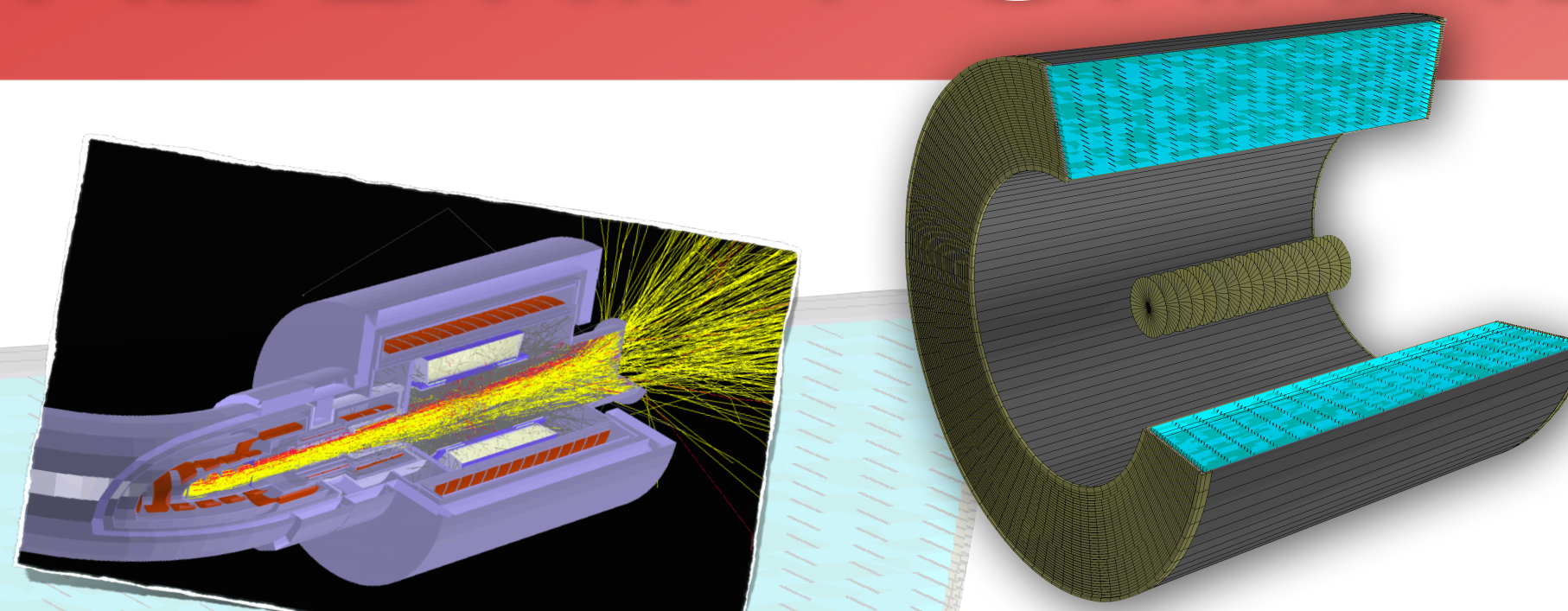
- Measure signal electrons' momentum avoiding beam particles.
- Spatial resolution $< 200 \mu\text{m}$

Design

- ~ 5000 (Au plated W) sense wires in 20 layers
 - Stereo wire configuration for **3-dimensional position measurement**
- Chamber radius: 496 mm to 840 mm
 - Suppress hits by DIO electrons $< 60 \text{ MeV}/c$
- Gas: **He : iso-C₄H₁₀ = 90:10**

Commissioning is carrying on.

- Performance evaluation with cosmic rays
- Chain test of the front- and back-ends electronics including the trigger system.



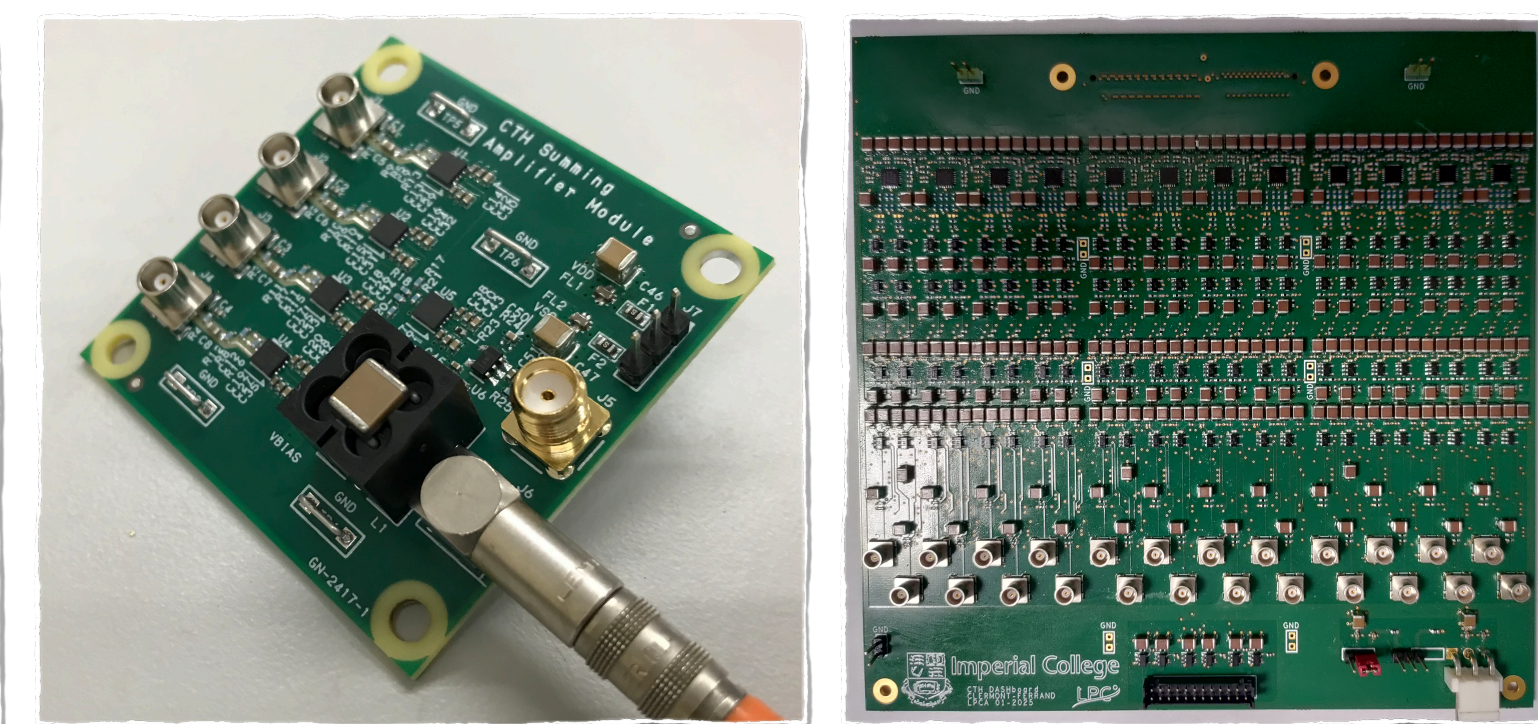
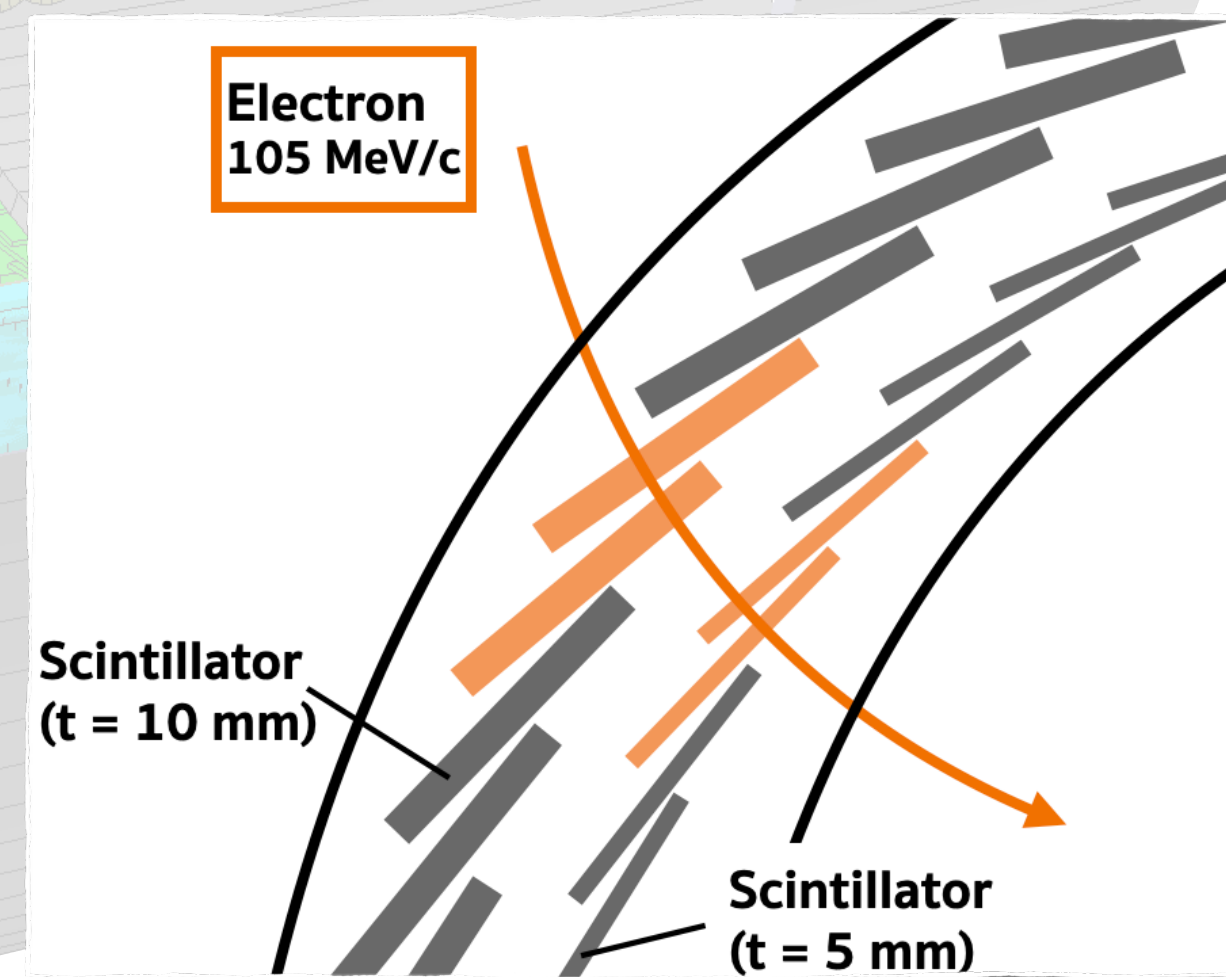
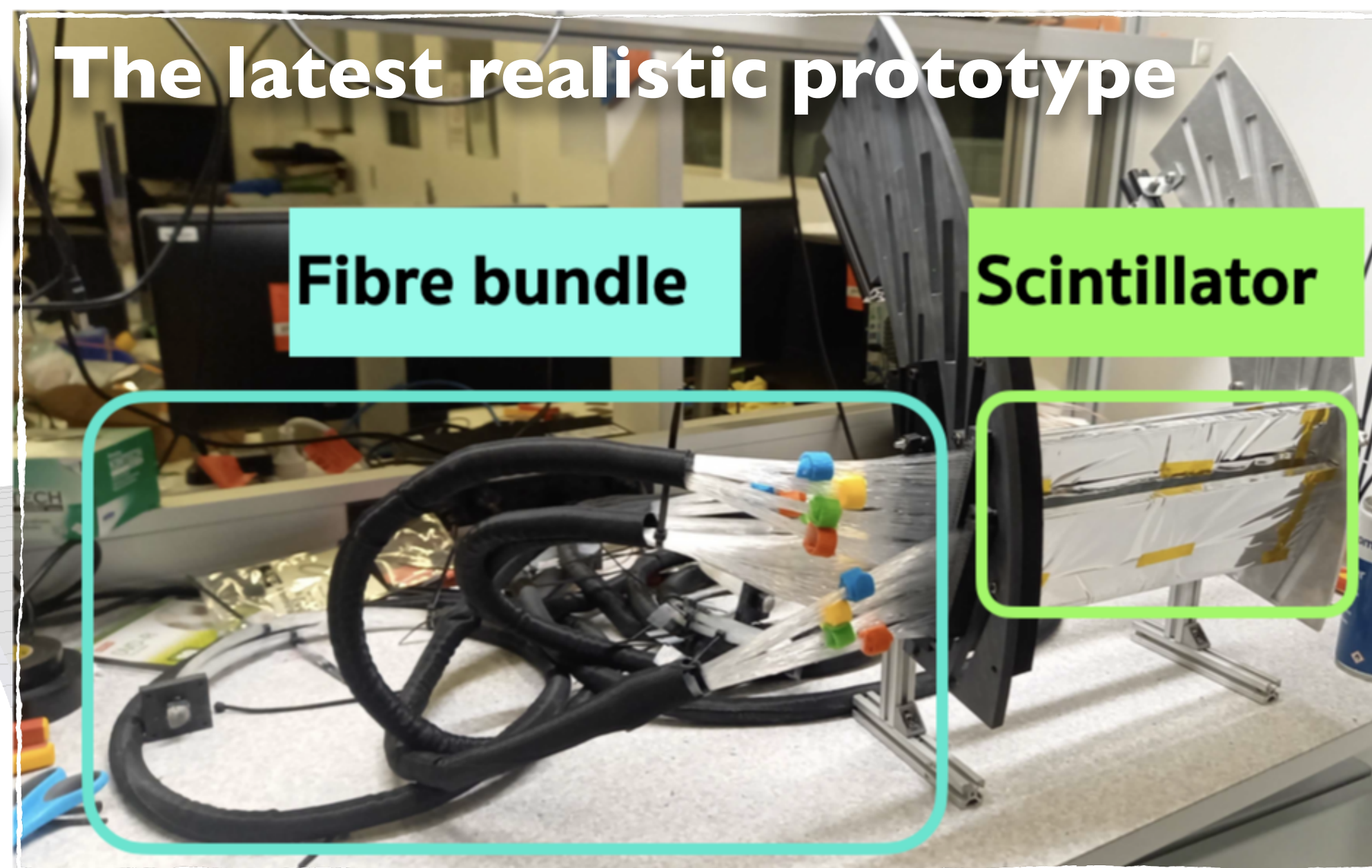
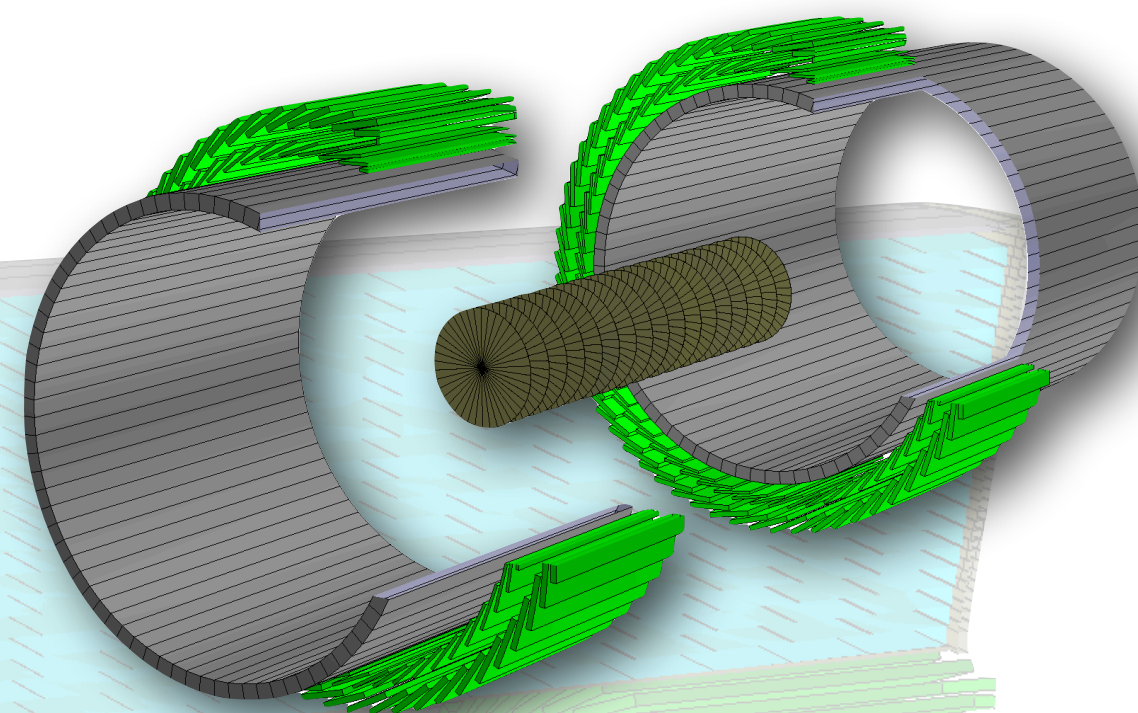
CYLINDRICAL TRIGGER HODOSCOPE

Requirements

- ✦ (Primary) trigger decision
- ✦ T_0 measurement for tracking

Design

- ✦ 2×64 plastic scintillators installed at each end
 - ★ Readout by MPPCs through a plastic fibre bundle.
 - ★ > 40 p.e. for a detection efficiency $> 99\%$
- ✦ MPPCs operated $< -36^\circ\text{C}$ (for radiation damages)
- ✦ For reasonable trigger rate,
 - ★ 4-fold coincidence
 - ★ Inner lead shield to block gamma rays from inside.
- ✦ Mass production is ongoing.



Frontend electronics

Lateral view

COMET μ COSMIC RAY VETO

Rejecting cosmic ray-induced fake signals

✦ The most significant background source for COMET

★ ~0.5 events estimated for Phase-I (~150 days operation)

✦ Required to have detection efficiency $> 99.99\%$.

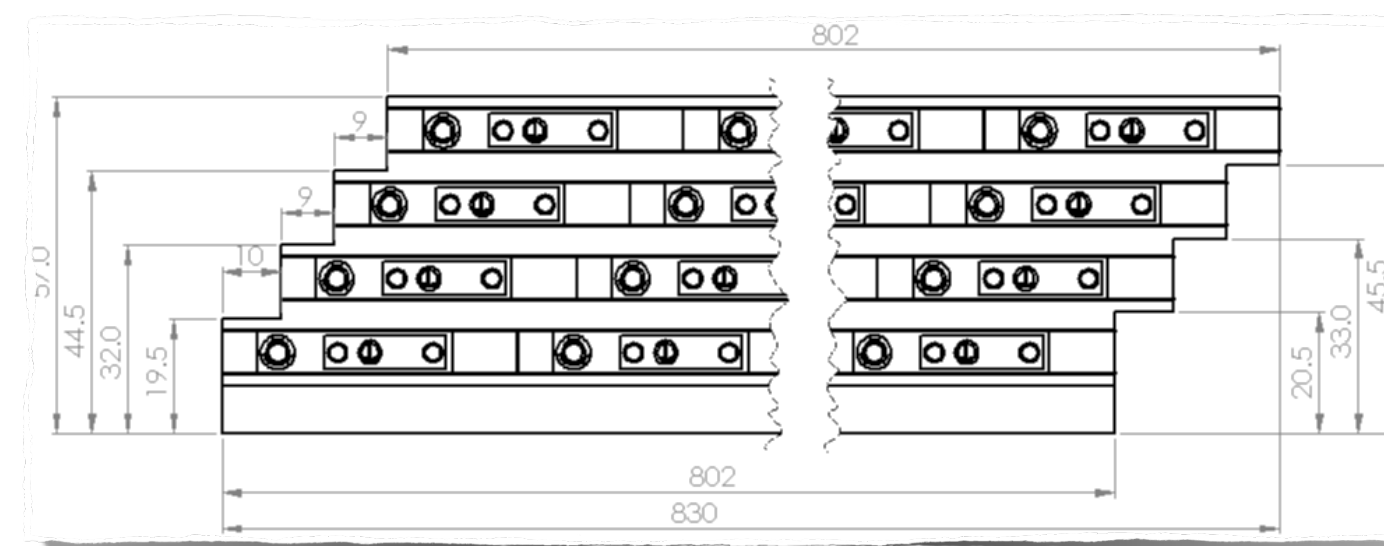
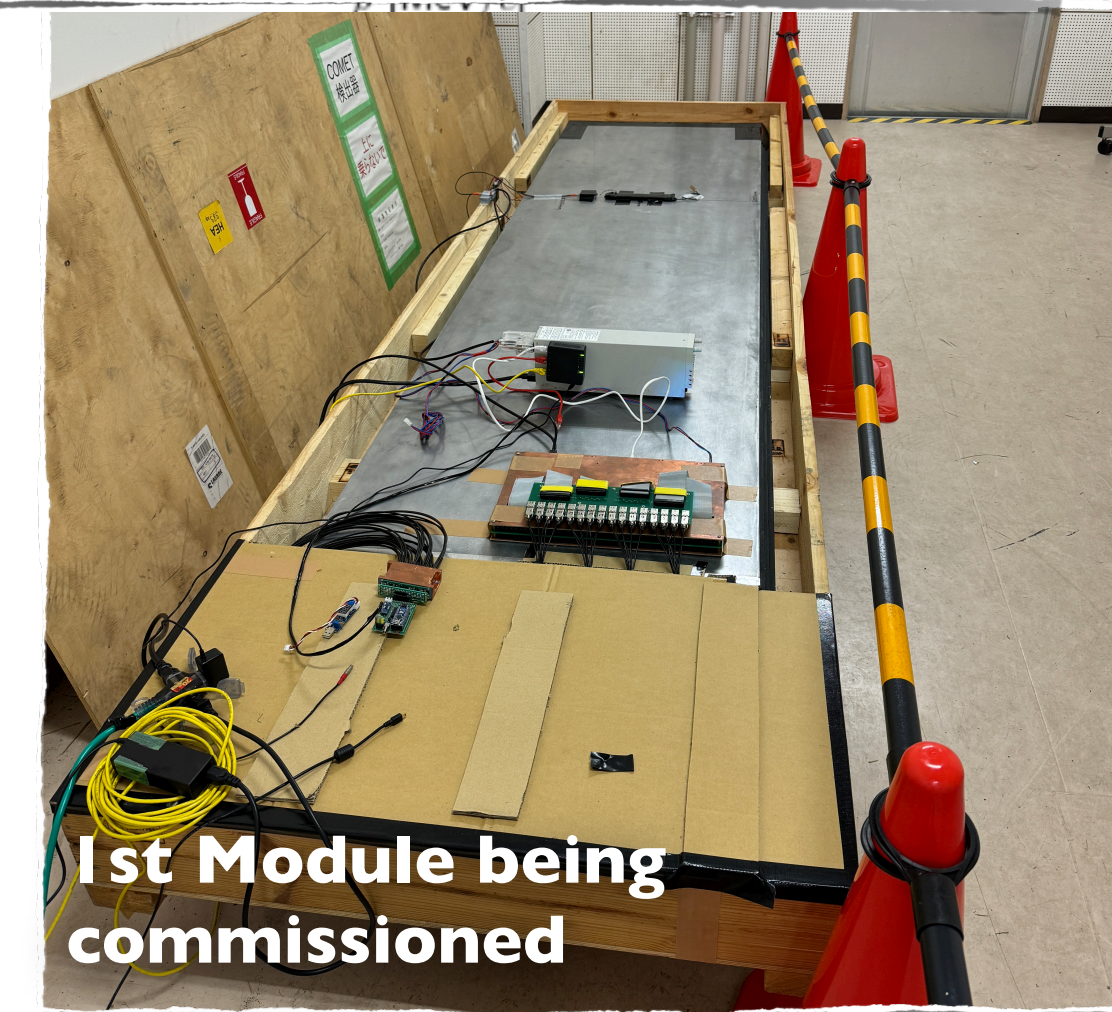
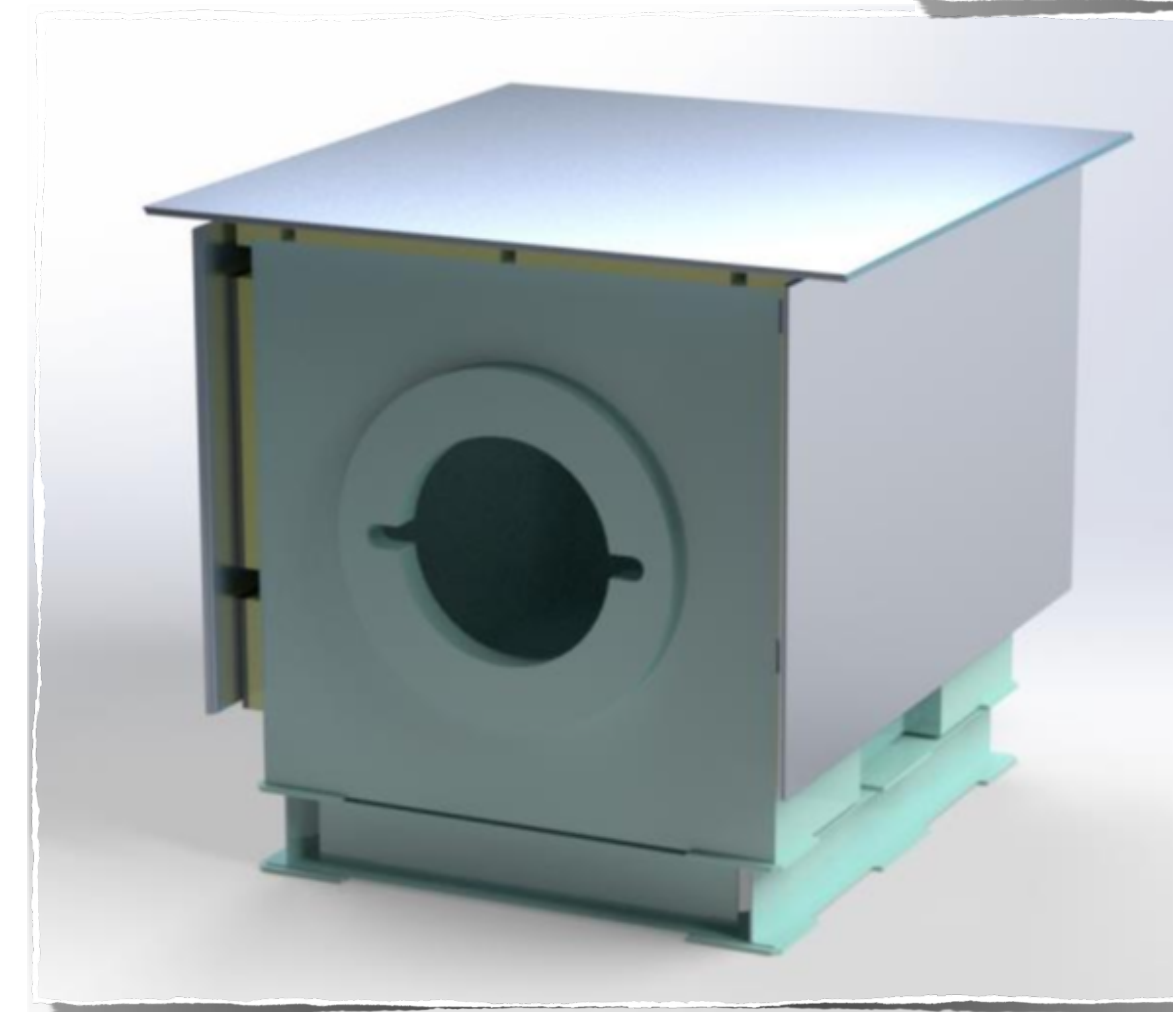
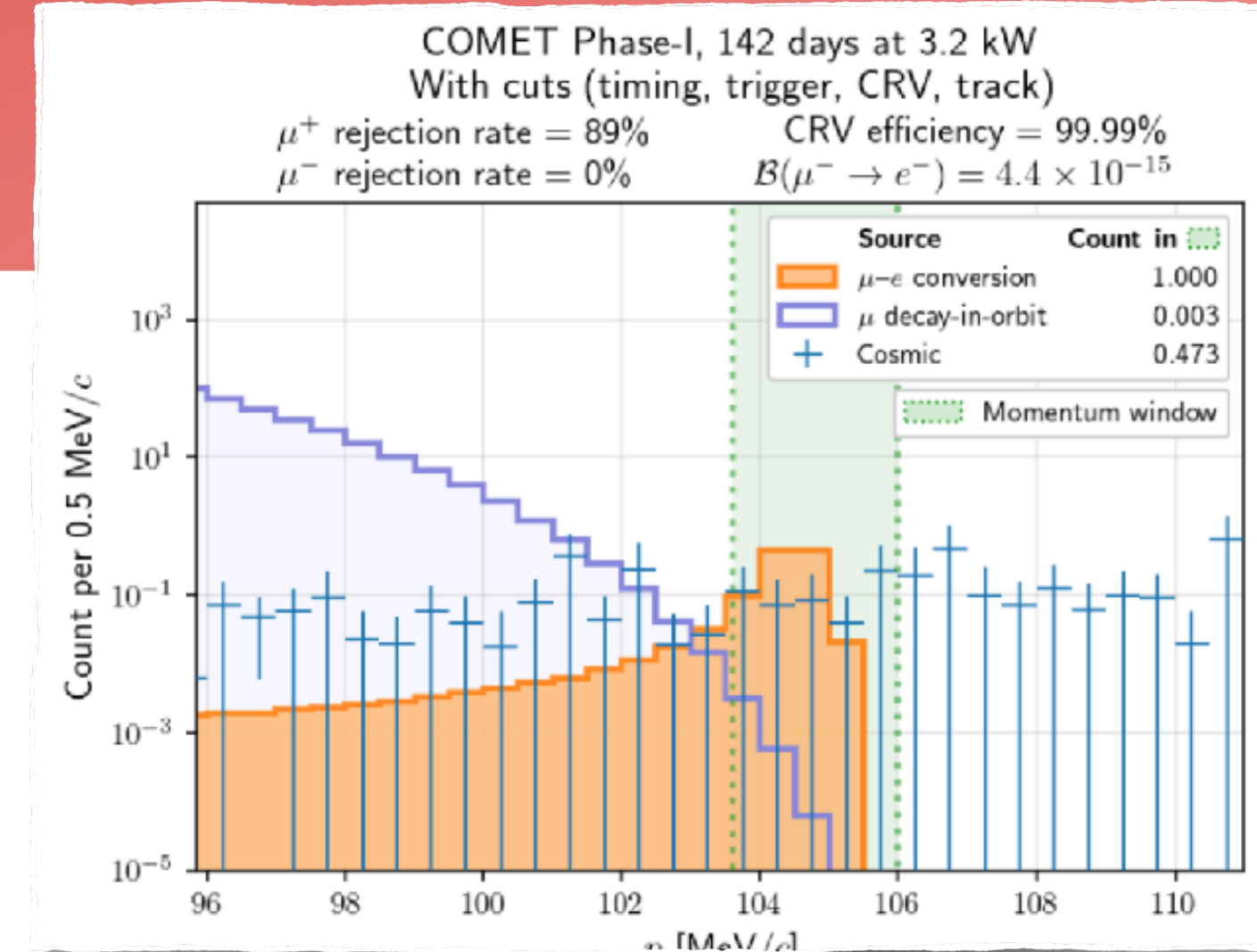
Design

✦ Plastic scintillator strips

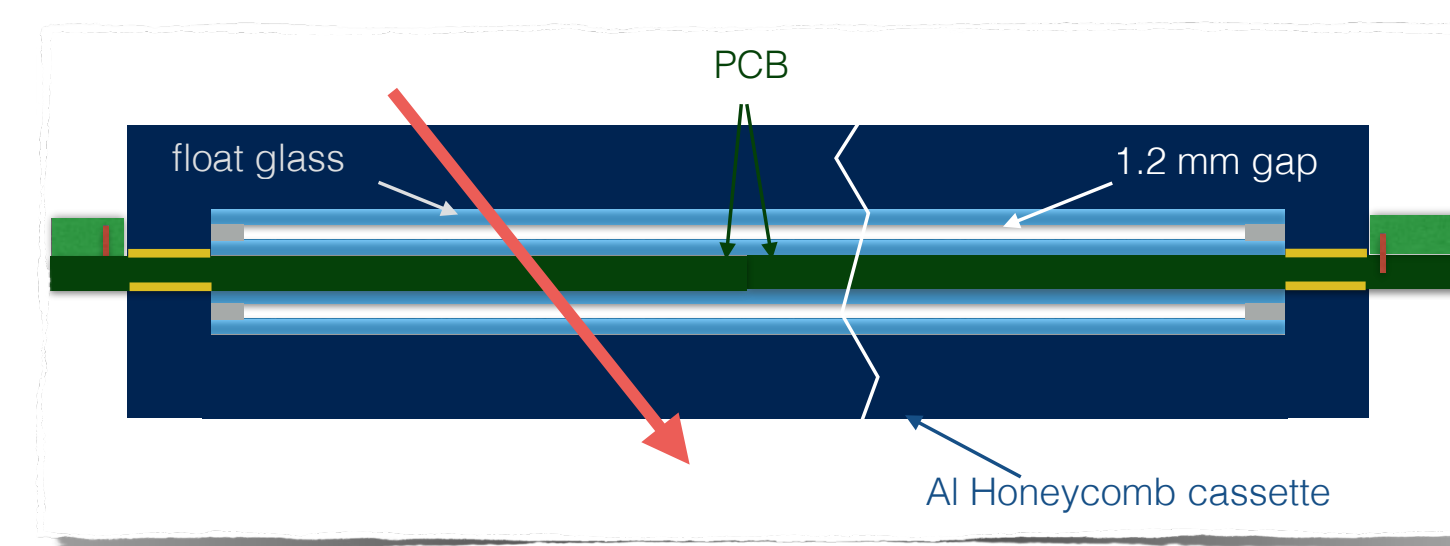
★ Four layers + SiPM readout

✦ Resistive Plate Chamber (RPC)

★ Five–seven layers



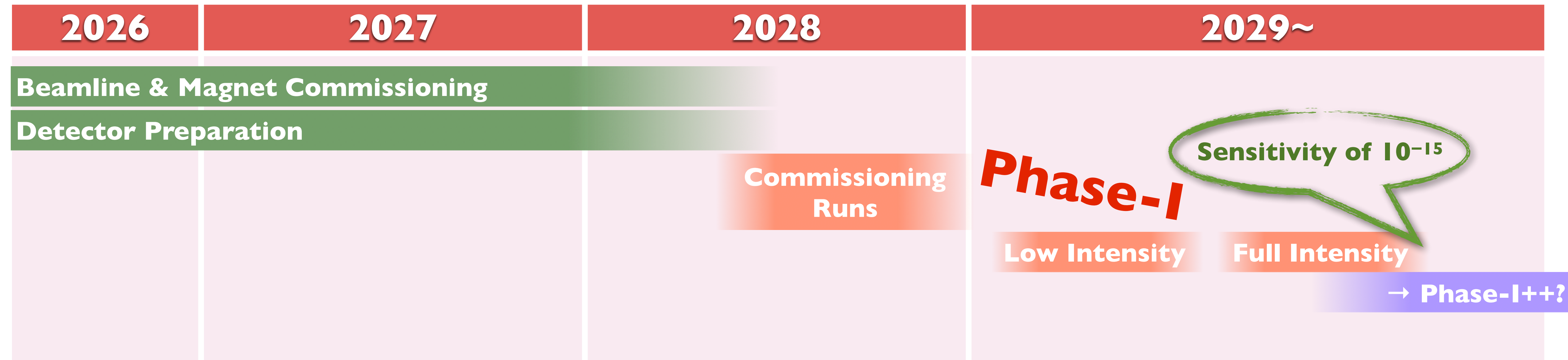
Scintillator module



RPC module

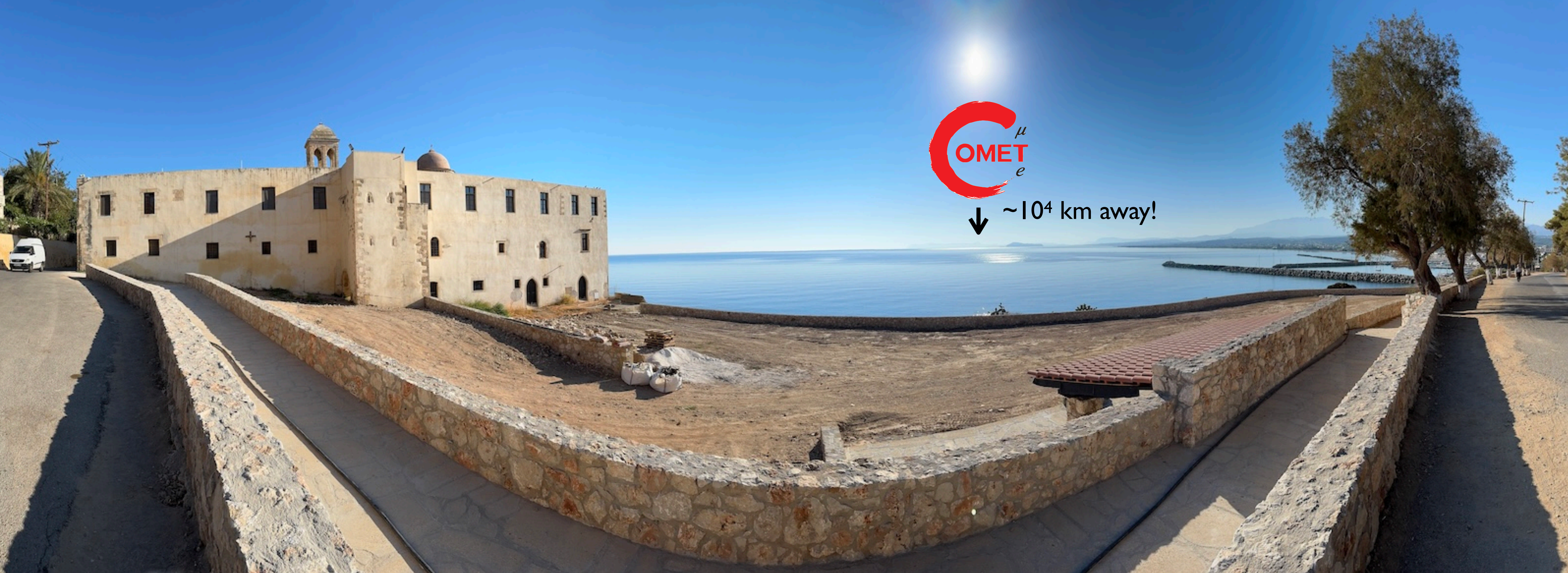


SUMMARY & SCHEDULE



COMET experiment will search for μ -e conversion at J-PARC.

- ✦ Aims at single event sensitivity: $O(10^{-15})$ (Phase-I) and $O(10^{-17})$ (Phase-II).
- ✦ The facility & beam line construction is almost completed.
- ✦ The detector construction is also progressing.
 - ★ CyDet, StrECAL, and Cosmic Ray Veto
- ✦ We will start with commissioning runs in 2028 with low beam intensity, followed by physics data taking runs.



↓ $\sim 10^4$ km away!



THANK YOU FOR LISTENING

COMET ちゃん

COMET chan: official mascot character