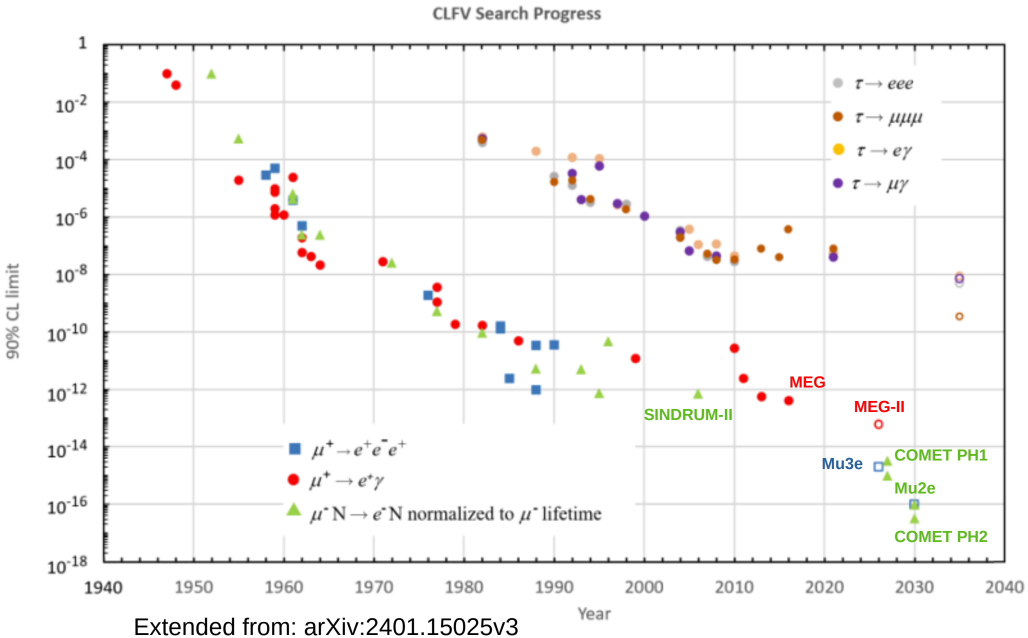
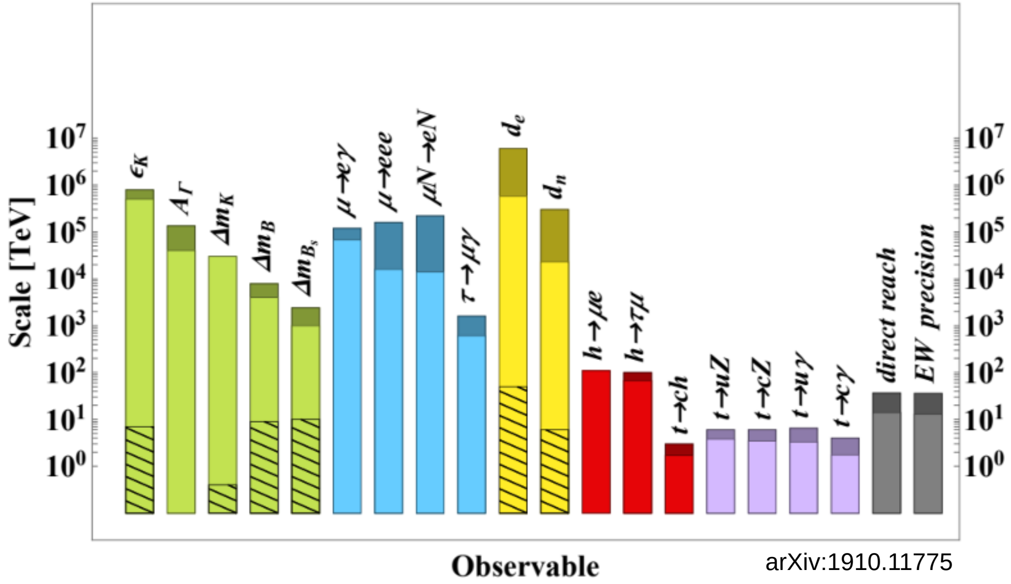
# Overview and status of COMET experiment

George Adamov (SOKENDAI, KEK) on behalf of COMET Collaboration
24th Conference on Flavor Physics and CP Violation
2026.05.21

# CLFV search



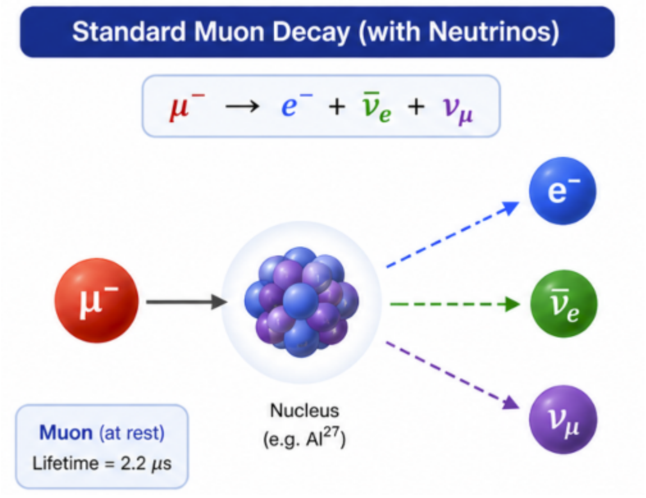

Extended from: arXiv:2401.15025v3




arXiv:1910.11775

- Over the past ~70 years, experiments improved sensitivity demonstrating enormous technological progress in rare-event searches.
- Muon-to-electron conversion experiments are sensitive to many BSM models like SUSY-GUT, Heavy neutrinos,Z' and being good probes in high scale NP.
- The overall trend shows that CLFV searches are evolving into ultra-high precision probes of new physics at energy scales far beyond direct collider reach

# Theory

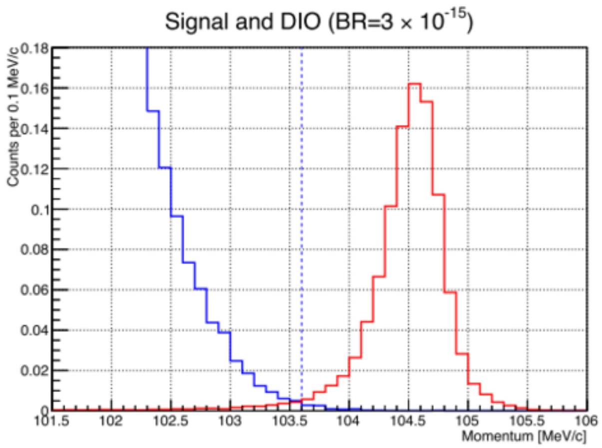


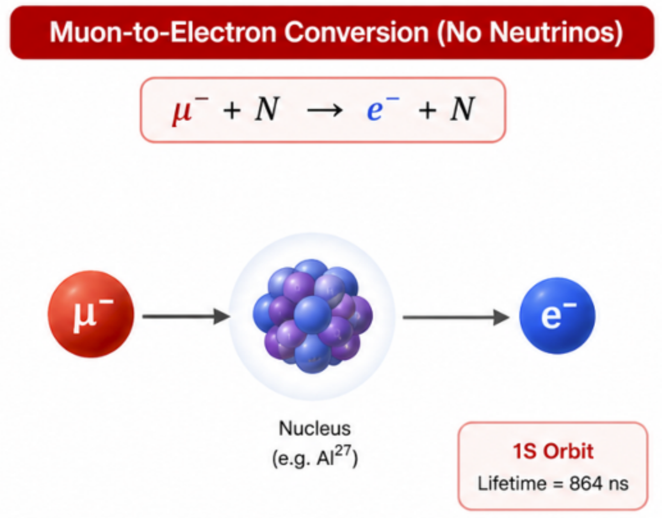

- Energy and momentum are shared among electron and neutrinos
- Broad spectrum due to present neutrinos with pick ~52.8 MeV

Best cutrrent limit for the $\mu^- \rightarrow e^-$ is $7\text{x}10^{-13}$ Au target by SINDRUM-II 2006

Goal is to achieve single event sensitivity of much higher magnitude of $10^{-17}$

Precise momentum resolution is a key to separate signals



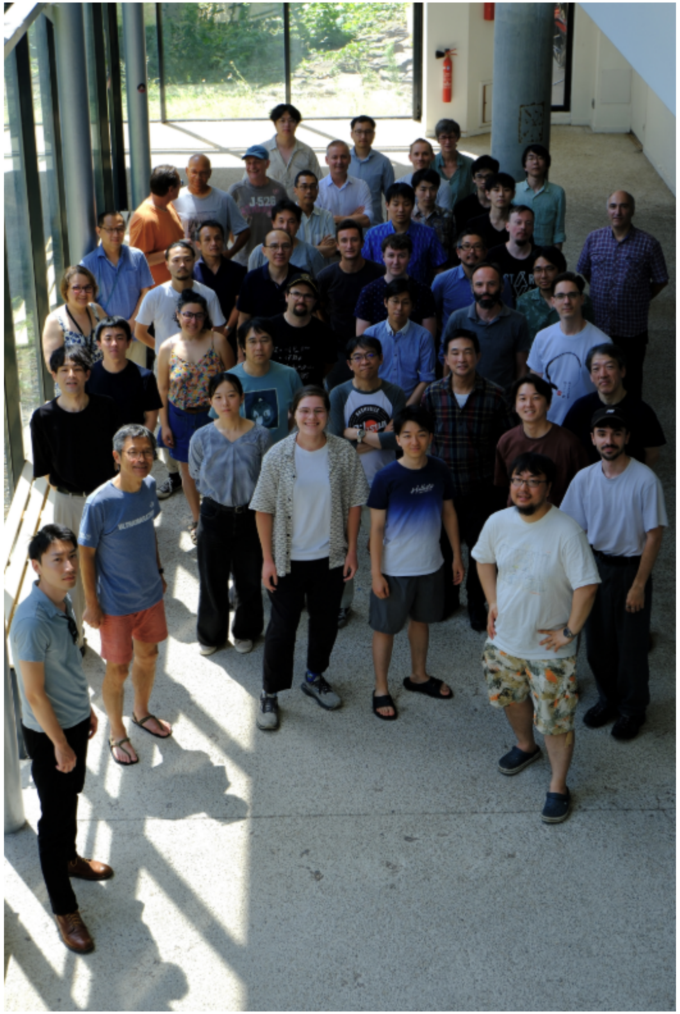




- All energy (minus binding and recoil) carried by electron
- Mono-energetic electron with fixed energy ~105 MeV

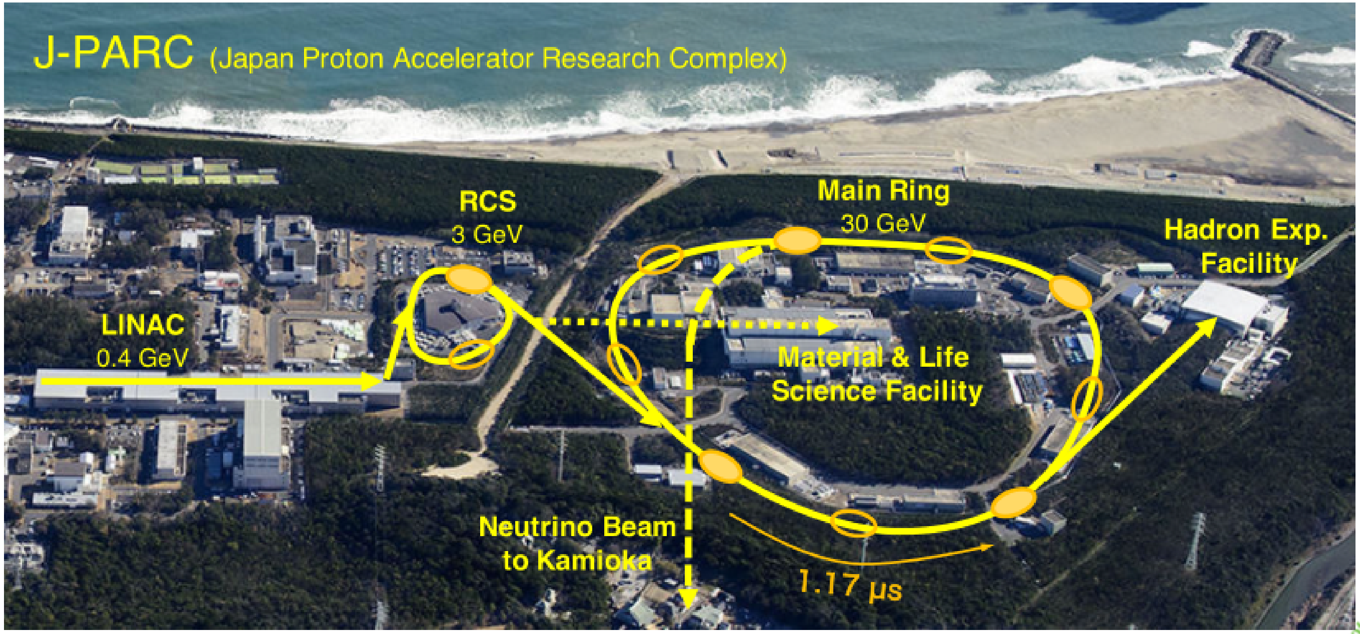
Observation of monochromatic electron signal would proves the CLFV possibility

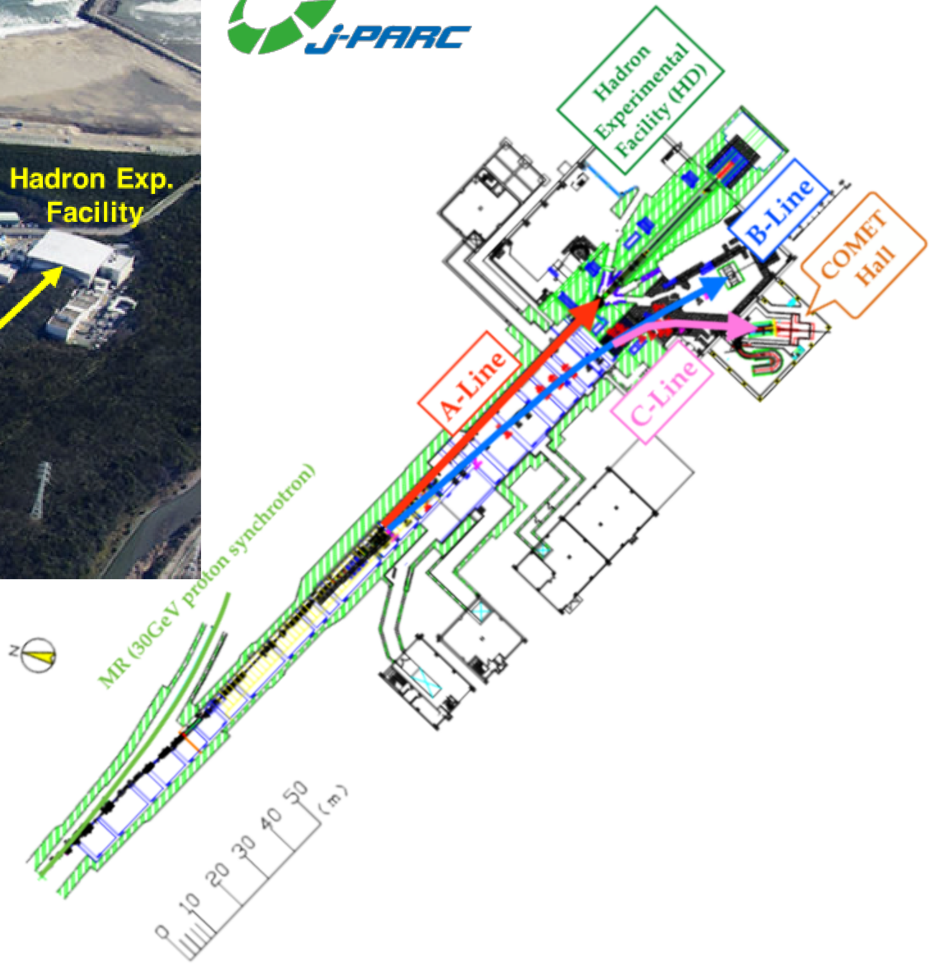
# Collaboration

A collaboration of >200 people from >10 countries
>50 institutes

# Location



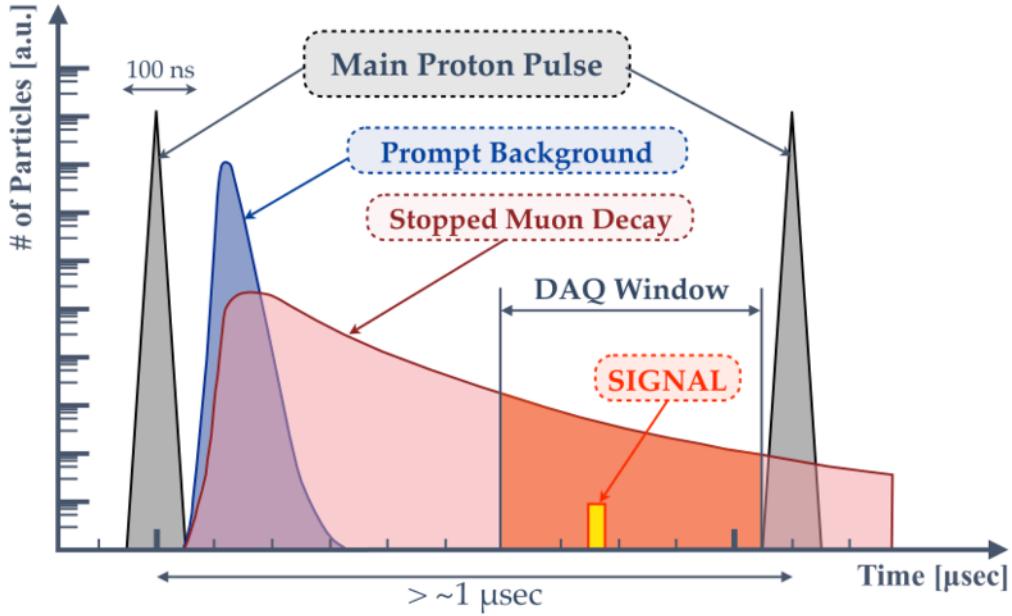



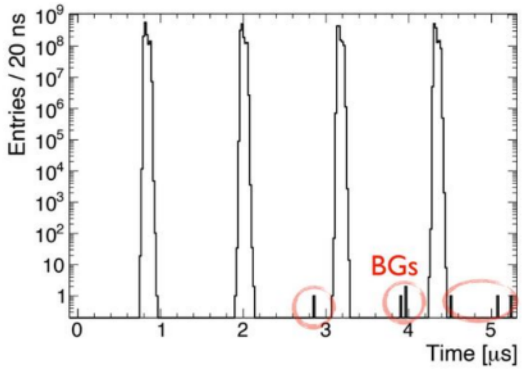

Located at the hadron experimental facility in J-PARC

J-PARC accelerator provides a high quality pulsed proton beam

Dedicated beam transport C-Line for 8 GeV proton beam from Main Ring (MR) to experimental area

# Beam properties




**Beam structure**

- Pulsed proton beam with 100ns narrow pulse
- Protons/Pulse: ~$2\times10^{14}$ at MR
- Bunch spacing: ~1.17 μs between proton pulses
- Extinction factor of $10^{-10}$

**Measure strategy:**

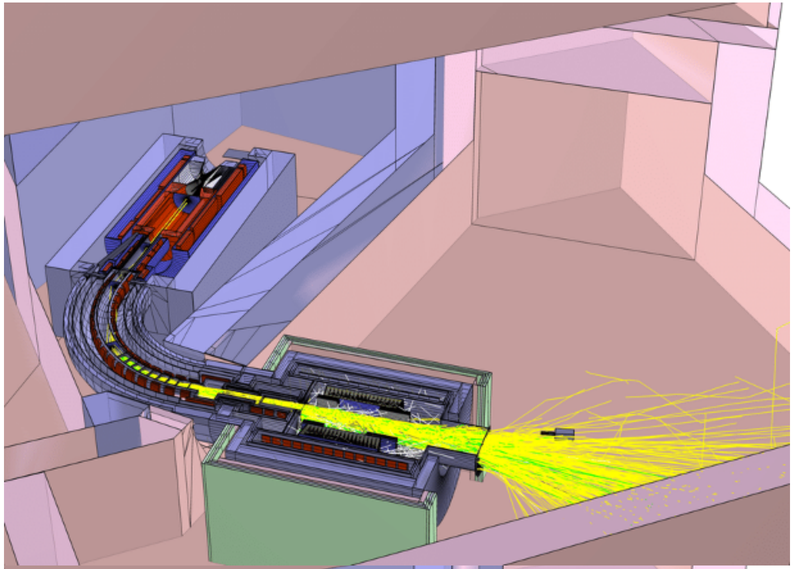
- Aluminium target for longer muonium lifetime
- Delayed readout window (700-1100ns) away from prompt background and around muonic atom lifetime

# Conceptual design

**Phase-I:**

**Proton Target:** Graphite
**Beam power:** 3.2kW
**Physics detector:** CyDet

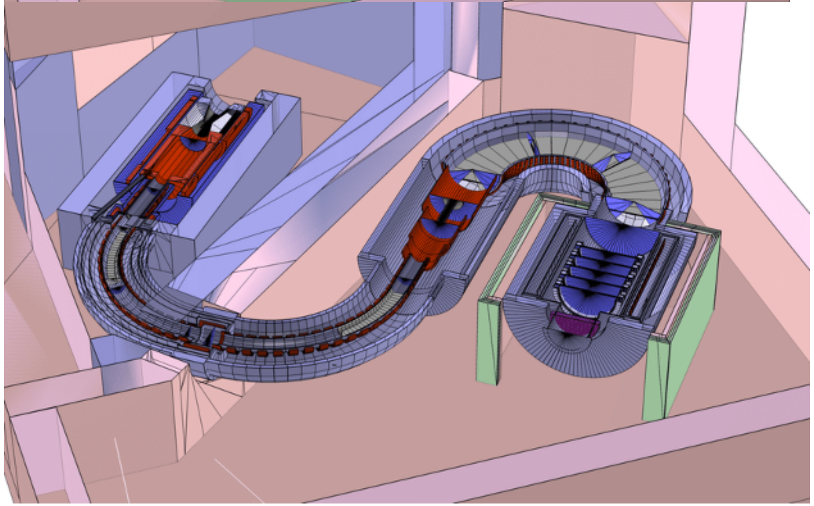
- Direct beam measurement and validation of detector systems
- Perform μ-e search with intermediate sensitivity $O(10^{-15})$



**Phase-II:**

**Proton Target:** Tungsten
**Beam power:** 56kW
**Physics detector:** StrawECAL

- Additional $90^0$ transport solenoid and electron spectrometer.
- Perform μ-e search with final sensitivity $O(10^{-17})$



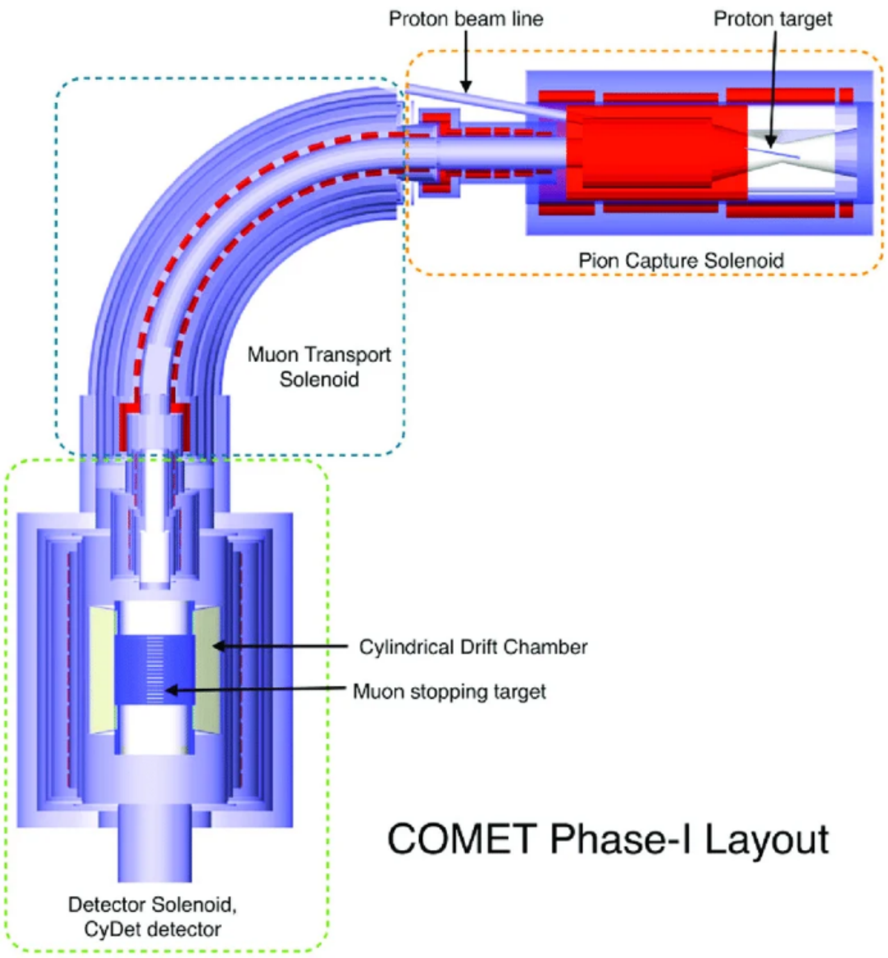
1. Proton beam hits the production target, generated pions are captured by the strong magnetic field of the pion capture solenoid (PCS) and guided into the muon transport solenoid (MTS).

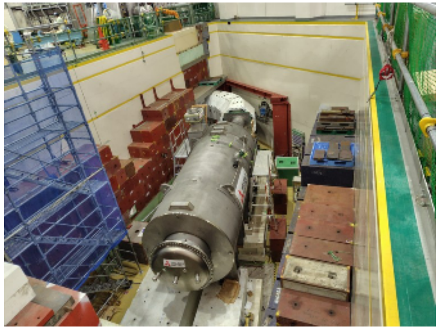
2. During transport, pions decay into muons $\pi^- \rightarrow \mu^- + \nu^-_\mu$ , MTS selects low-momentum muons, removes many unwanted particles, suppresses backgrounds.

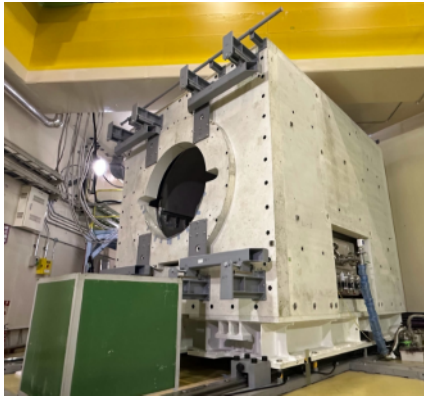
3. Muons reach the detector solenoid (DS) and stop inside thin aluminium target disks, muonic atoms created.

4. Detector systems reconstructs the electron trajectory, momentum and energy to determine distinguish the required energy electron

# Experimental setup - magnets





**PCS**

- Surrounds the production target ~5T.
- Captures pions and muons produced by the proton beam hitting prod. target and guides them into the transport beamline.

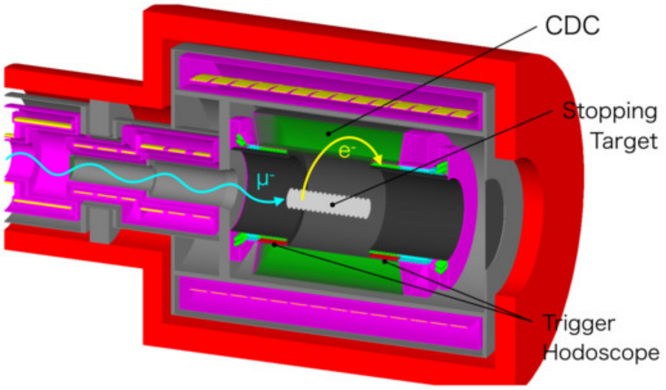
**MTS**

- Curved superconducting solenoid system ~3T.
- Transports low-momentum negative muons while removing unwanted particles and suppressing direct beam-related backgrounds.

**DS**

- Contains the aluminum stopping target and the CyDet detector systems.
- Bends electron trajectories, allowing their momentum to be measured from track curvature.

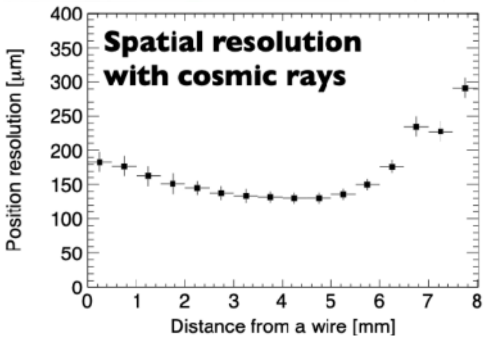
# Detectors – CDC (Cylindrical Drift Chamber)

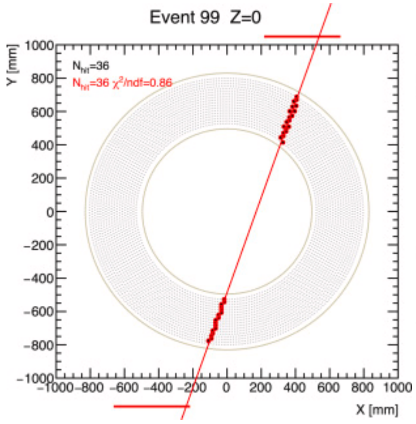


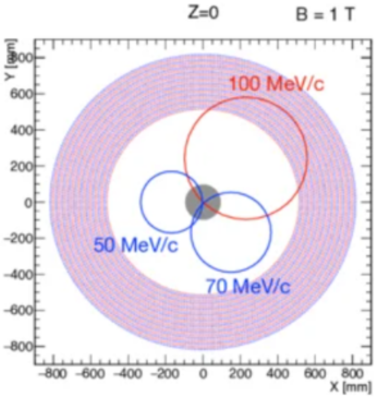

**Goal:**
- Separate signal electrons from the high-energy tail of decay-in-orbit (DIO) background.
- Provide charged-particle tracking inside the Detector Solenoid magnetic field.

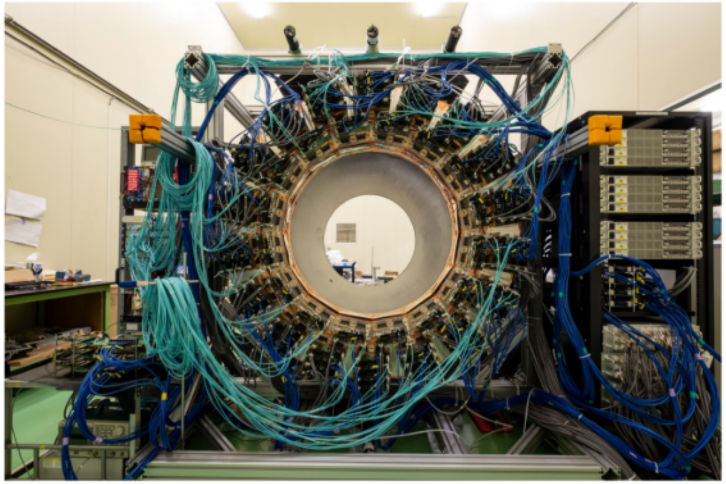
**Design:**
- 20 concentric layers with ~5000 sense wires.
- 2084L filled with inner gas of He/iC4H10 (9:1) to reduce multiple scattering effects.

**Status:**
- System test with cosmic ray completed.
- Construction of the final gas system and detector reassembly ongoing.



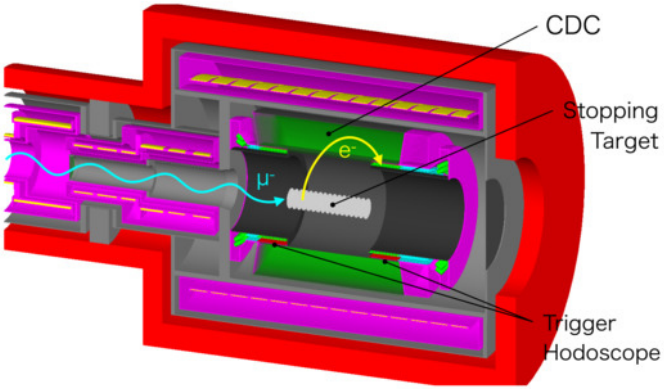



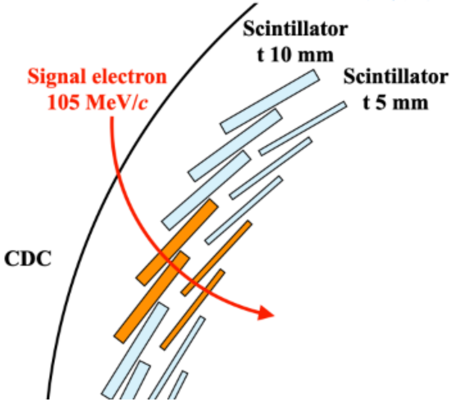
# Detectors - CTH (Cylindrical Trigger Hodoscope)

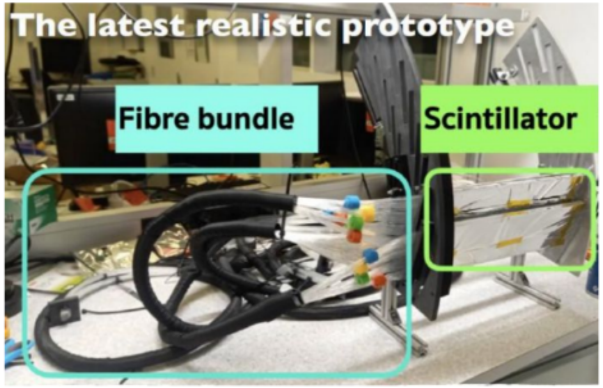
**Goal:**
- Provide the primary trigger for conversion-electron candidate events in COMET Phase-I.
- Deliver precise timing measurement for charged particles emerging from the stopping target region.

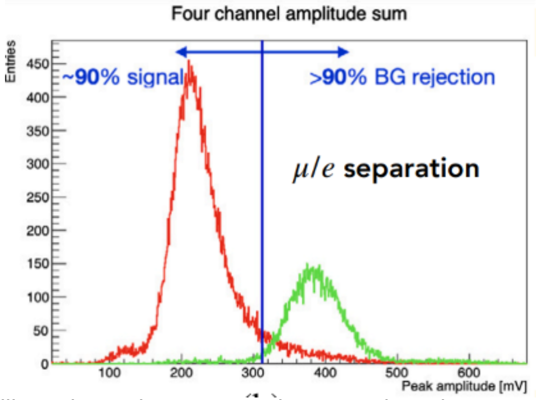



**Design:**
- Built from segmented plastic scintillator counters arranged in azimuthal sectors.
- 2 wheels of 2×64 plastic scintillators + fibre + MPPCs.
- 4-fold coincidences for trigger rate <100kHz.

**Status:**
- Design and FEE commissioned with prototype.
- Fibre bundles being prepared and mass production to start soon.

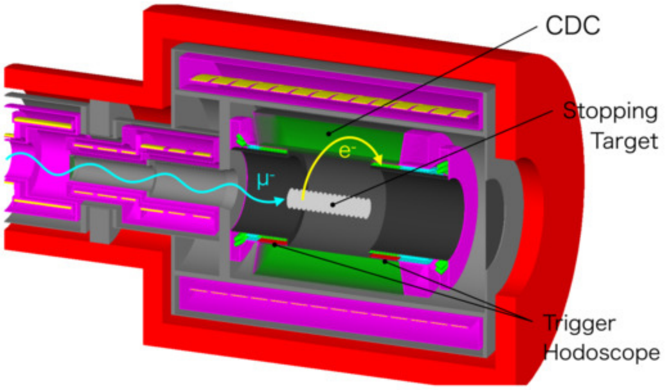


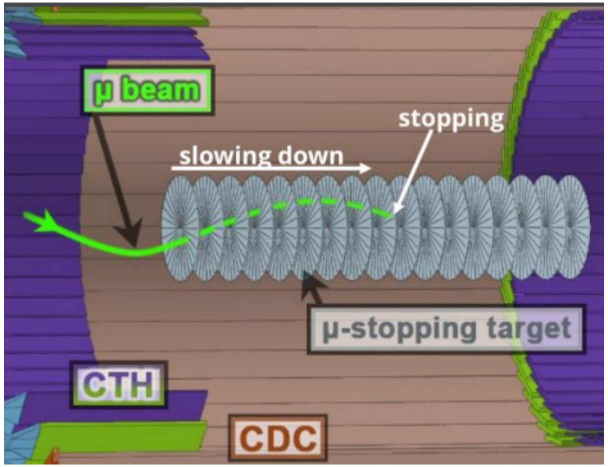

Y. Fujii, et al., Nucl.Instrum.Meth.A 1067 (2024) 169665

# Detectors – CyDet Target

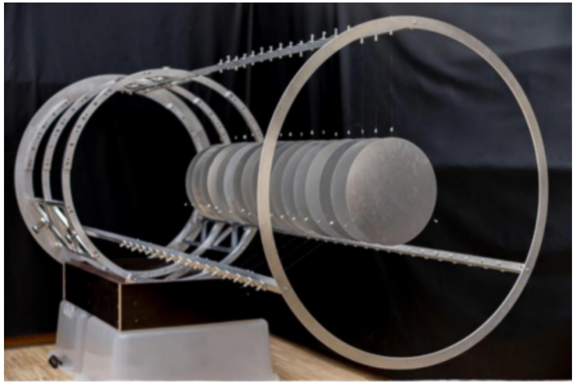



**Goal:**
- Form muonic aluminium atoms where possible $\mu^- + N \rightarrow e^- + N$ conversion can occur.
- Provide a well-understood stopping medium with suitable muon lifetime and low background contribution.

**Design:**
- 17 aluminium discs, R=10 cm, 200um thick, 50mm apart.
- Positioned along the detector axis inside the Detector Solenoid inside CyDet detector volume.
- Thin low-mass disks reduce material interactions that could degrade electron tracking performance.
- Disk spacing is optimized to maximize muon stopping efficiency while maintaining good detector acceptance.




**Status:**
- Target design was optimized through simulation studies for maximum muon stopping efficiency and minimal momentum spread of conversion electrons.
- Final cradle construction is ongoing.



# Detectors - CRV

**Goal:**

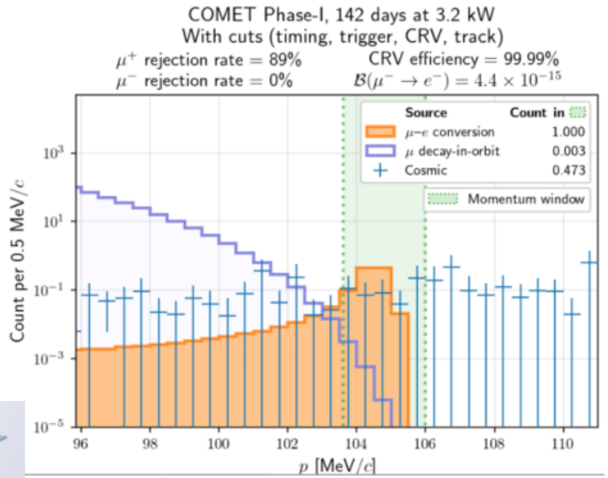
- Suppress cosmic ray muons by a factor of $10^{-4}$
- Installed in the detector zone to separate cosmic ray muons from incident muons.

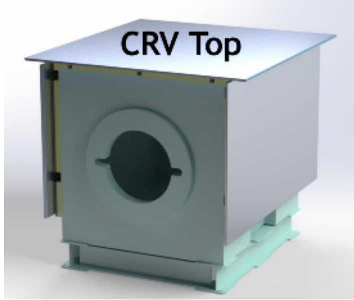
**Design:**

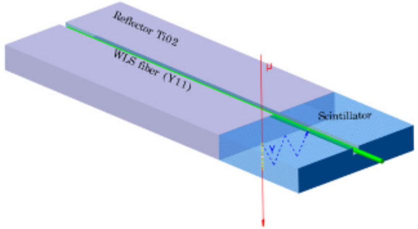
- Top: Plastic scintillation with Wavelength Shifting fiber.
- Sides: Scintillator or ARGO-RPC based on performance.
- Upstream/Downstream: iRPC modules.

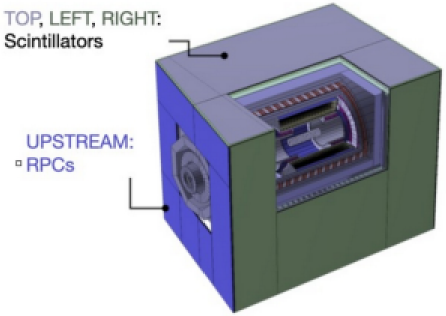
**Status:**

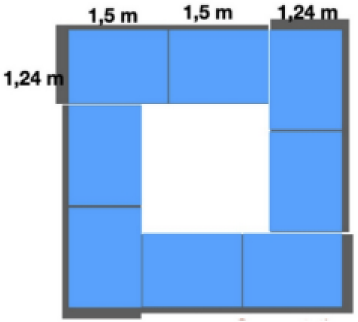
- Top under construction with first module undergoing cosmic test.
- iRPC ongoing evaluation of expected performance.

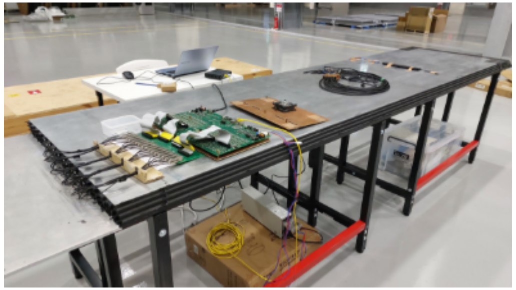


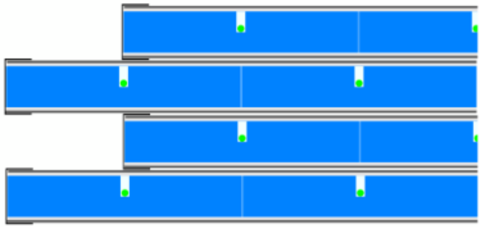



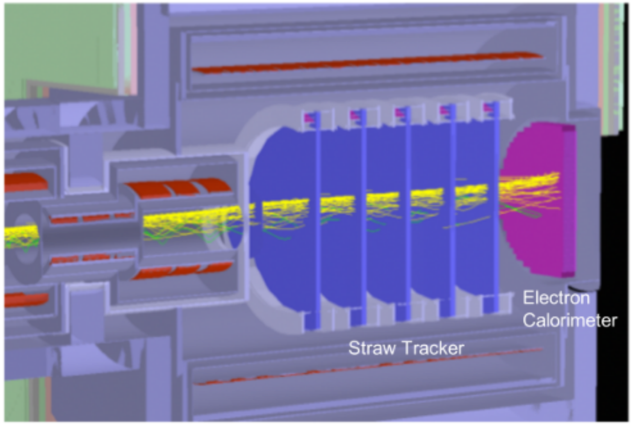





# Detectors - StrawECAL




## Goal:

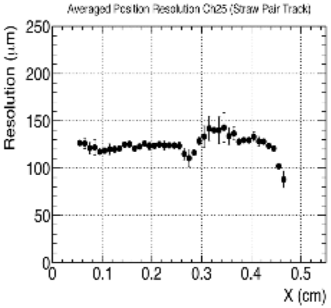
- Aims to measure the particle momentum with high resolution in order to identify the incoming particles.
- Beam measurement in Phase-I, primary detector in Phase-II.

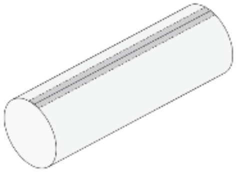
## Design:

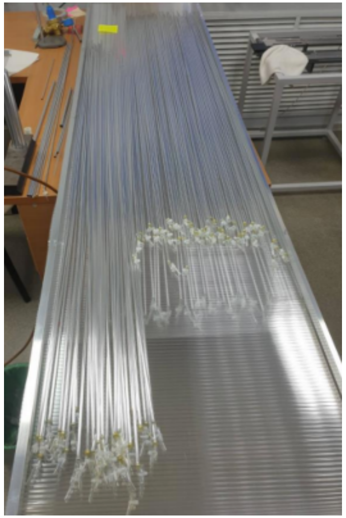
- Single seam welded straw tubes with 20um thin walls filled with gas mixture are utilized to reduce the material amount on the particle path.
- 5 stations with 10 mm straw tubes Phase-I, 5mm straw tubes in Phase-II.
- Placed inside a vacuumed vessel.

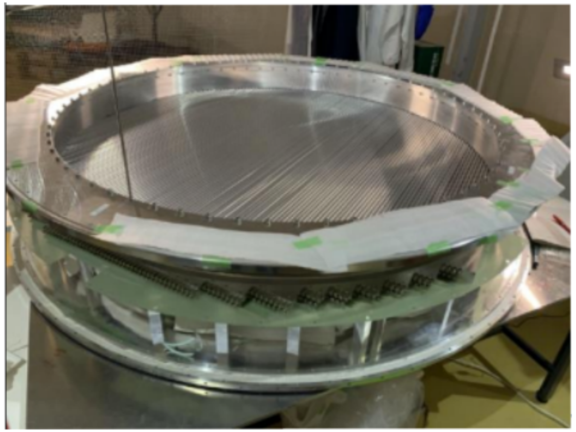
## Status:

- Beam testing achieved 110 μm spatial resolution.
- Momentum resolution <200 keV/s possible.
- 3 stations constructed, with last 2 construction ongoing.







# Detectors - StrawECAL

## Goal:

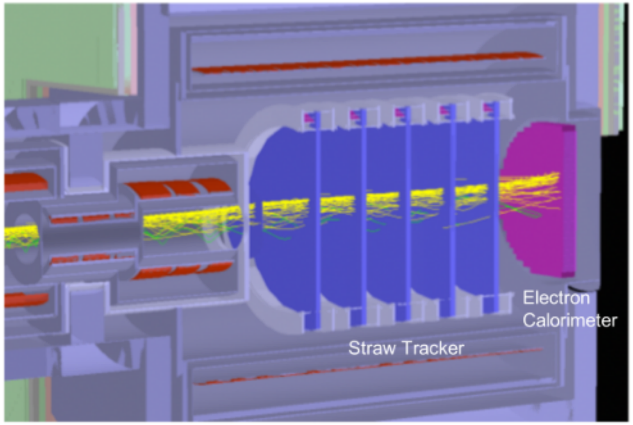
- Measure deposited energy, particle position and timing.
- Provides trigger.
- Complements the Straw Tracker by improving particle identification.

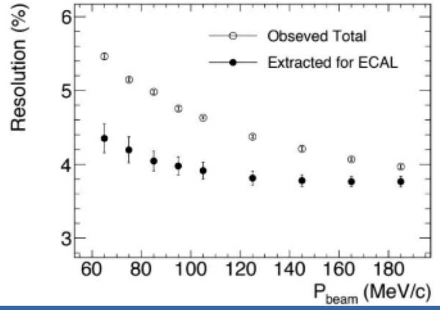
## Design:

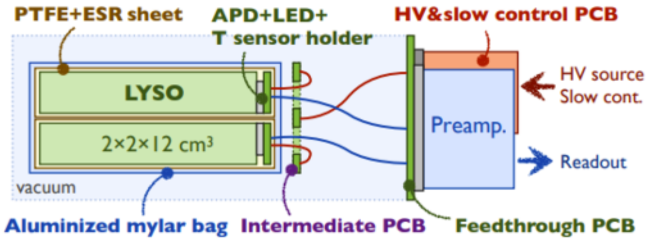
- Scintillator cells based on high density, high light yield and fast LYSO crystals.
- Assembly of 2×2×12 cm scintillators into a detector cell.
- Overall energy resolution is 4.4%, overall position resolution is found to be 5.8 mm (below 5% requirement).

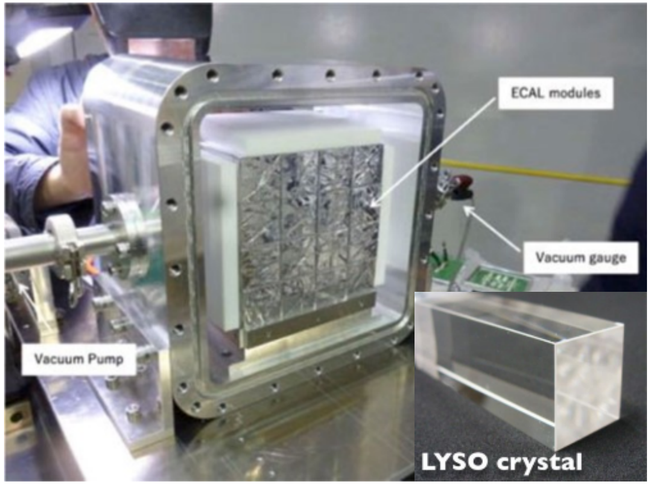
## Status:

- 8x8 Cell prototype tested with electron beam.
- LYSO QC and detector construction ongoing.



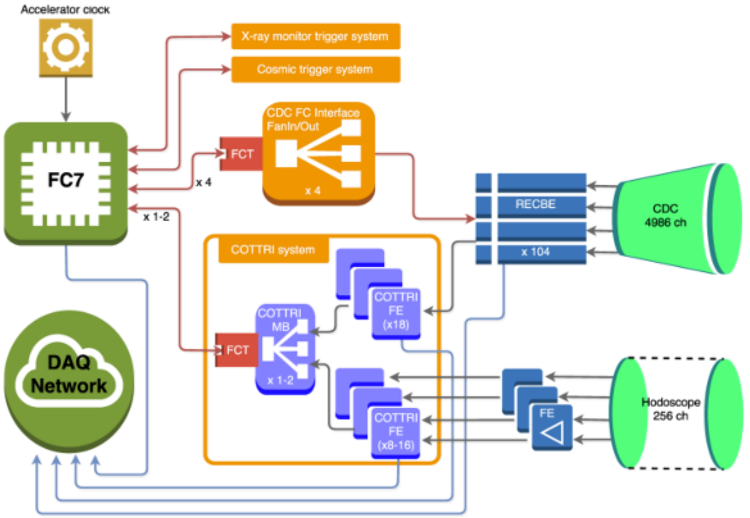
# Trigger & DAQ

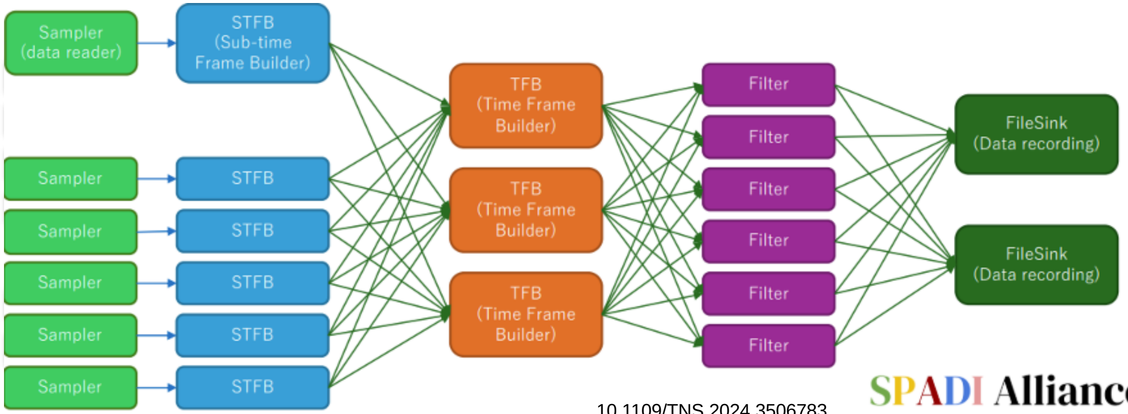
**FC7** FMC carrier board for trigger control & timing distribution:
Distributes accelerator clock for trigger front-ends
Level-0 trigger processor

**COTTRI (COmeT TRIgger)** front-end + back-end hardware trigger system with independent CTH and CDC pipeline

Phase-I - CyDet based trigger
CTH - Primary trigger generated by 4-fold coincidence with trigger rate ~ 200 kHz

Phase-II - StrECAL based trigger
ECAL trigger based on total deposited energy to cell groups of 2 × 2 crystals



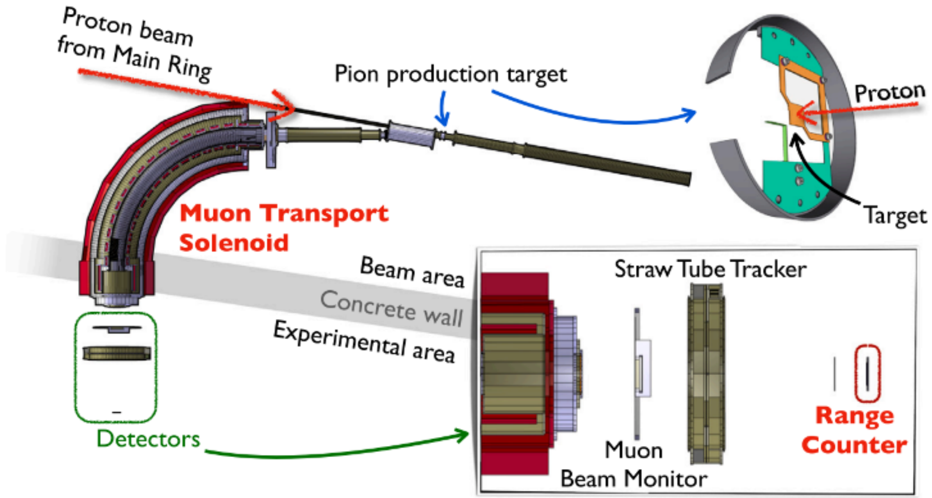

10.1109/TNS.2024.3506783

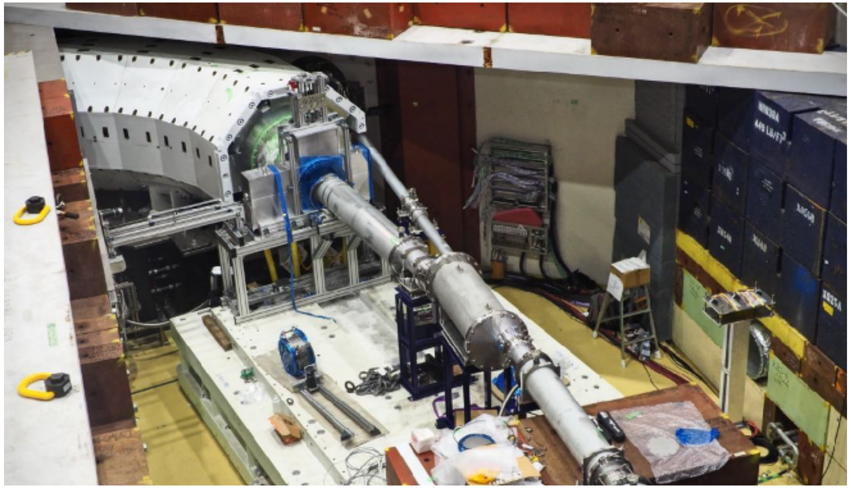
SPADI Alliance
Signal processing and data acquisition infrastructure alliance

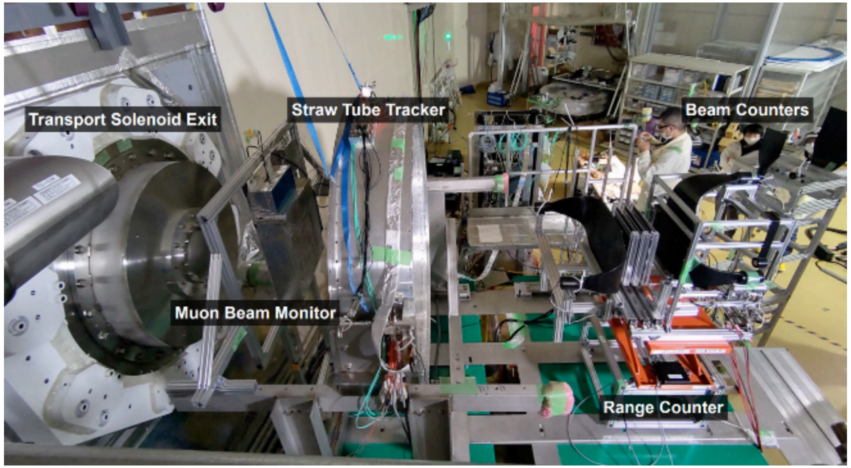
**NestDAQ**

- Custom streaming DAQ based on the FairMQ message queing framework by GSI
- Distributed messaging allowing flexible processing setup
- Relative ease of front-end inclusion
- Large throughput due to the distributed nature
- Up to 10 Gbps transfers (limited by hardware)
- Custom dashboard for DQM and control

# Phase Alpha






**Setup:**

- Slowly-extracted pulsed 8 GeV proton beam at 260 W to thin graphite pion production target.
- Muon Beam Monitor, Straw Tube Tracker, Range Counter- position measurement, decay time, momentum reconstruction and identification of muons
- Validation against simulated expectation

**Results:**

- Beam turning and beam profile measurements
- Muon momentum spectrum measurements
- Successful muon transportation to detector area corresponding with simulation expectations

# Summary and Plan

- COMET experiment at J-PARC is a searching for $\mu^- \rightarrow e^-$ conversion with a sensitivity of $O(10^{-17})$.
- COMET Phase-I targets intermediate sensitivity of $O(10^{-15})$ which is a factor of 100 better than the current limit
- COMET Phase-II intends to achieve single event sensitivity $O(10^{-17})$ and can potentially probe new physics scale up to $\sim 10^5$ TeV
- Construction and detector study is ongoing for all the involved systems in preparation for the physics run and future upgrade.
- Physics run scheduled to be performed during the beam operation windows in early 2028.

COMETちゃん

Thank you.