

Status of the COMET Experiment at J-PARC

Chen Wu (CSNS, IHEP)
on behalf of the COMET collaboration

MIP2026, Huizhou, April 25th, 2026



- Introduction
- Design of the COMET Experiment
- Preparation for COMET Phase-I
- Summary & Schedule



The COMET Experiment



COMET μ e

The COMET experiment

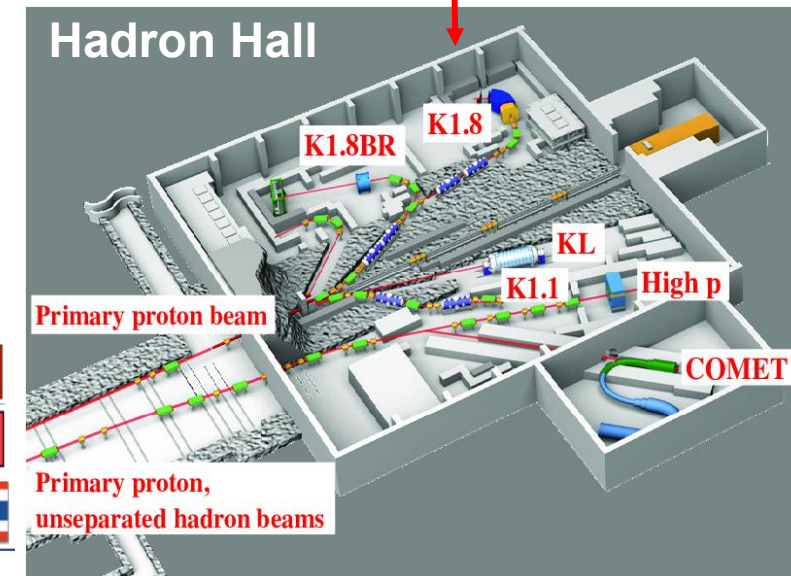
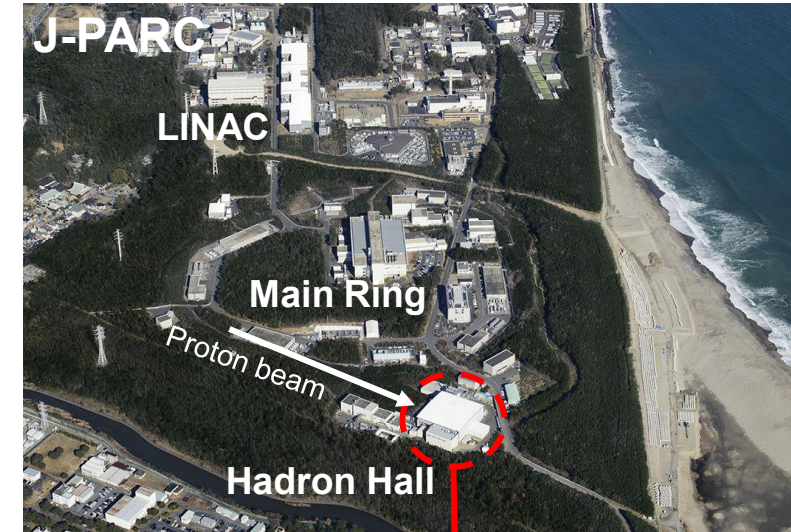
- Utilizing the proton beam from the J-PARC main ring, COMET searches for the **muon to electron conversion** process, which violates charged lepton flavor conservation, with an unprecedented sensitivity.

Spokes person: Masaharu Aoki (The University of Osaka)

Co-spokes person : Yuan Ye (IHEP)

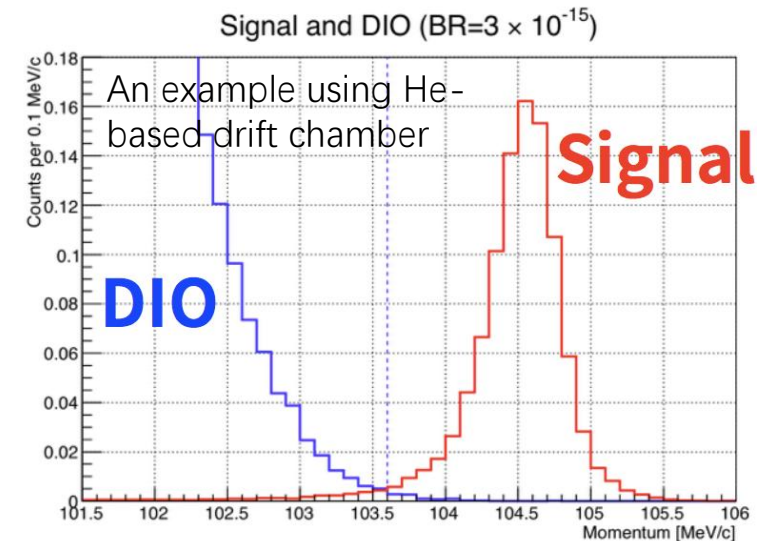
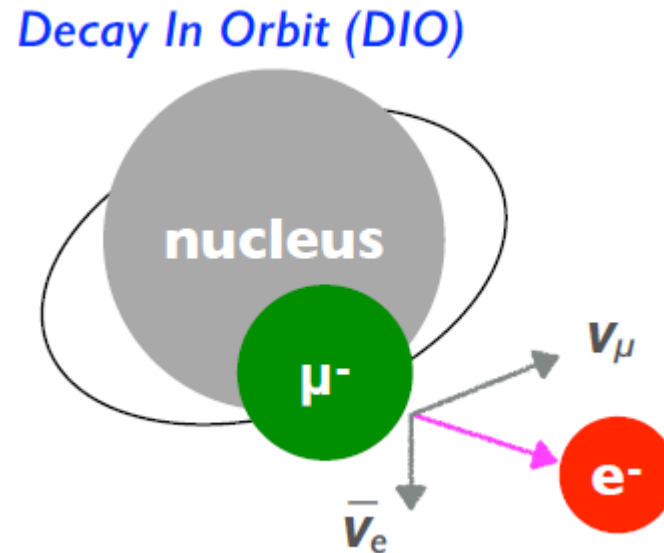
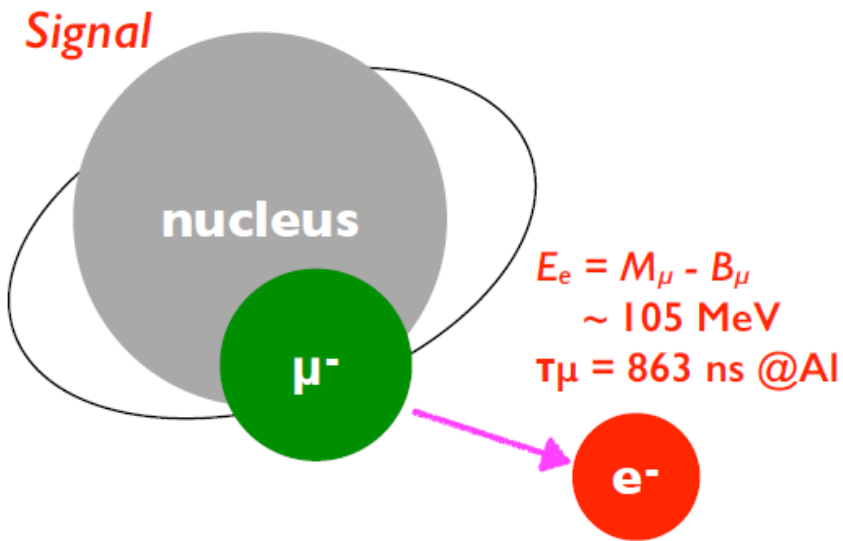


19 countries,
>200 collaborators



Muon-to-electron conversion ($\mu N \rightarrow e N$)

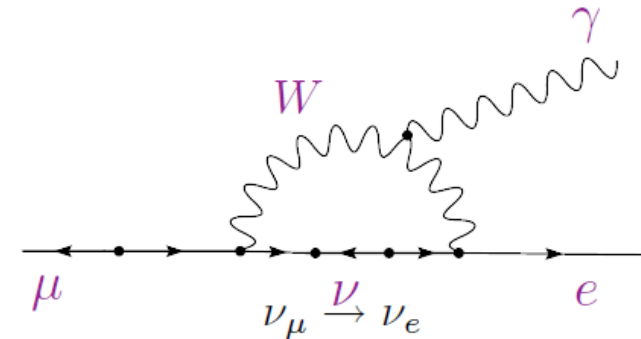
- **Signal:** 1 mono-energetic electron: $E_e = M_\mu - B_\mu - E_{recoil} \sim 105 \text{ MeV}$
- **Background:** intrinsic, beam related, cosmic ray
 - The intrinsic background, from muon Michel decay in orbit, has an end point energy near half muon mass, but



Charged Lepton Flavor Violation (CLFV)

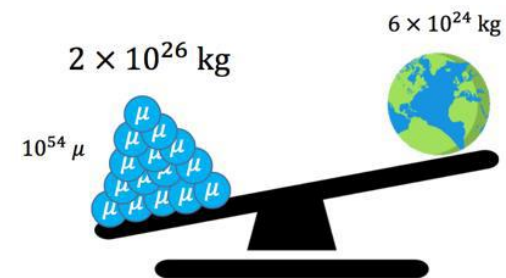
- The quest of CLFV started from searching for $\mu \rightarrow e\gamma$ since 1940s.
 - The null result led to the concept of flavor conservation.
- Neutrino oscillations demonstrates that neutrinos are massive, and lepton flavor conservation is violated (PMNS matrix).
- However, CLFV is still practically forbidden in SM+ m_ν due to GIM
 - 40 orders of magnitude lower than current limit: Clean field to search for new physics!

Highly suppressed in SM+ m_ν by GIM due to the smallness of m_ν



$$\mathcal{B}(\mu \rightarrow e\gamma) = \frac{3\alpha}{32\pi} \left| \sum_{i=2,3} U_{\mu i}^* U_{ei} \frac{\Delta m_{i1}^2}{M_W^2} \right|^2 \sim 10^{-54}$$

S.T. Petcov, Sov.J. Nucl. Phys. 25 (1977) 340

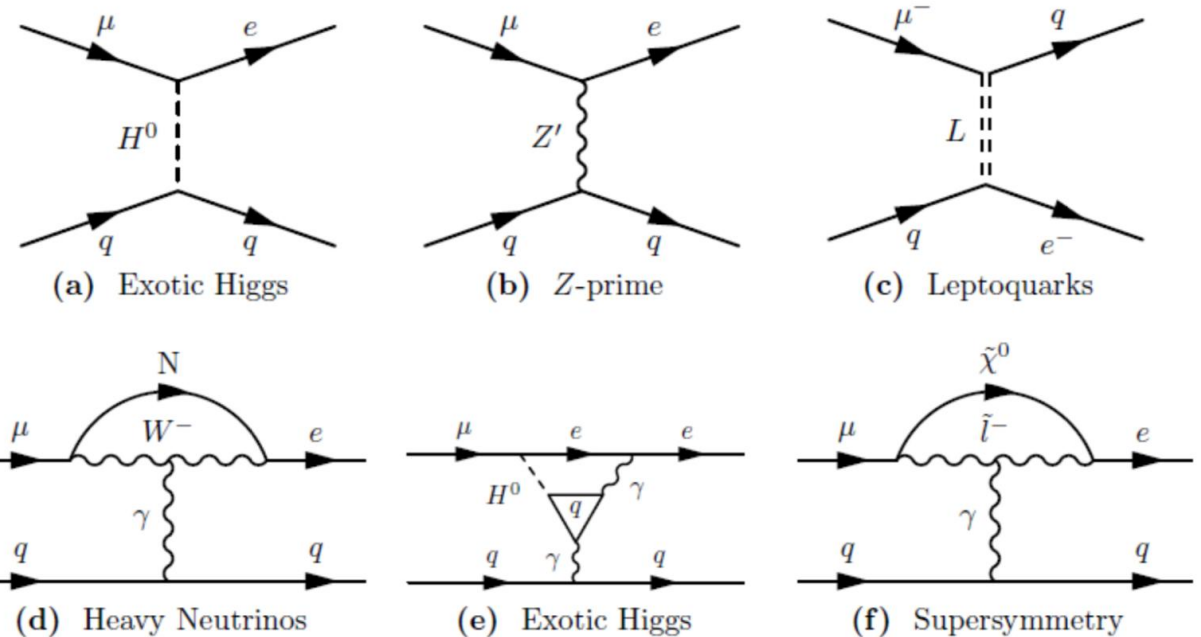


M.J.Lee, NuFACT2023

Charged Lepton Flavor Violation (CLFV)

- Neutrino mass requires new physics: scale is unknown, but can be probed from intensity frontier.
- There is no fundamental law to prevent CLFV.
 - Naturally exists in new physics

CLFV Widely predicted in NP models



Model independent approach: EFT

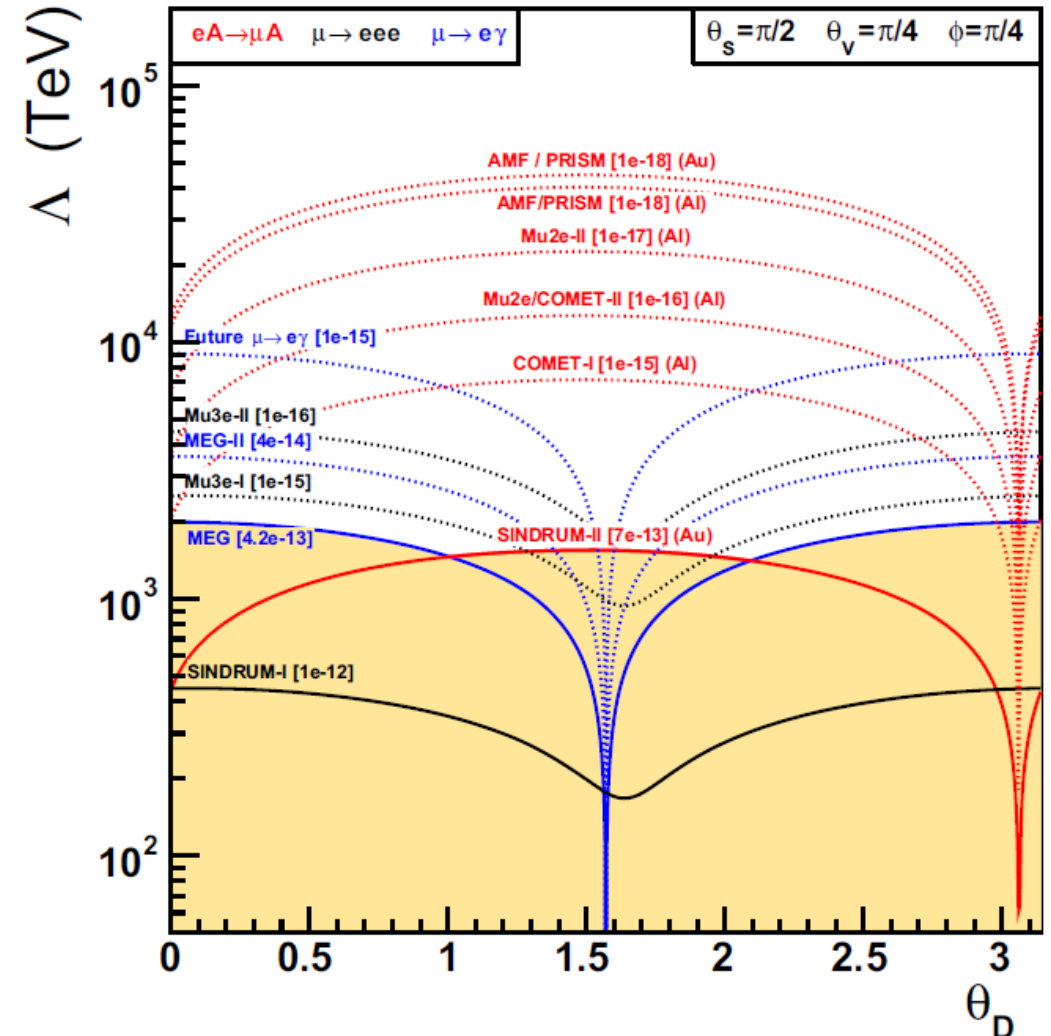
- Extend SM in effective field theory with higher dimension operators:

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{n \geq 1} \frac{C_{ij}^{4+n}}{\Lambda^n} \mathcal{O}^{4+n}$$

- CLFV can be introduced from dim-6:

$$Br \sim \frac{1}{\Lambda^4}$$

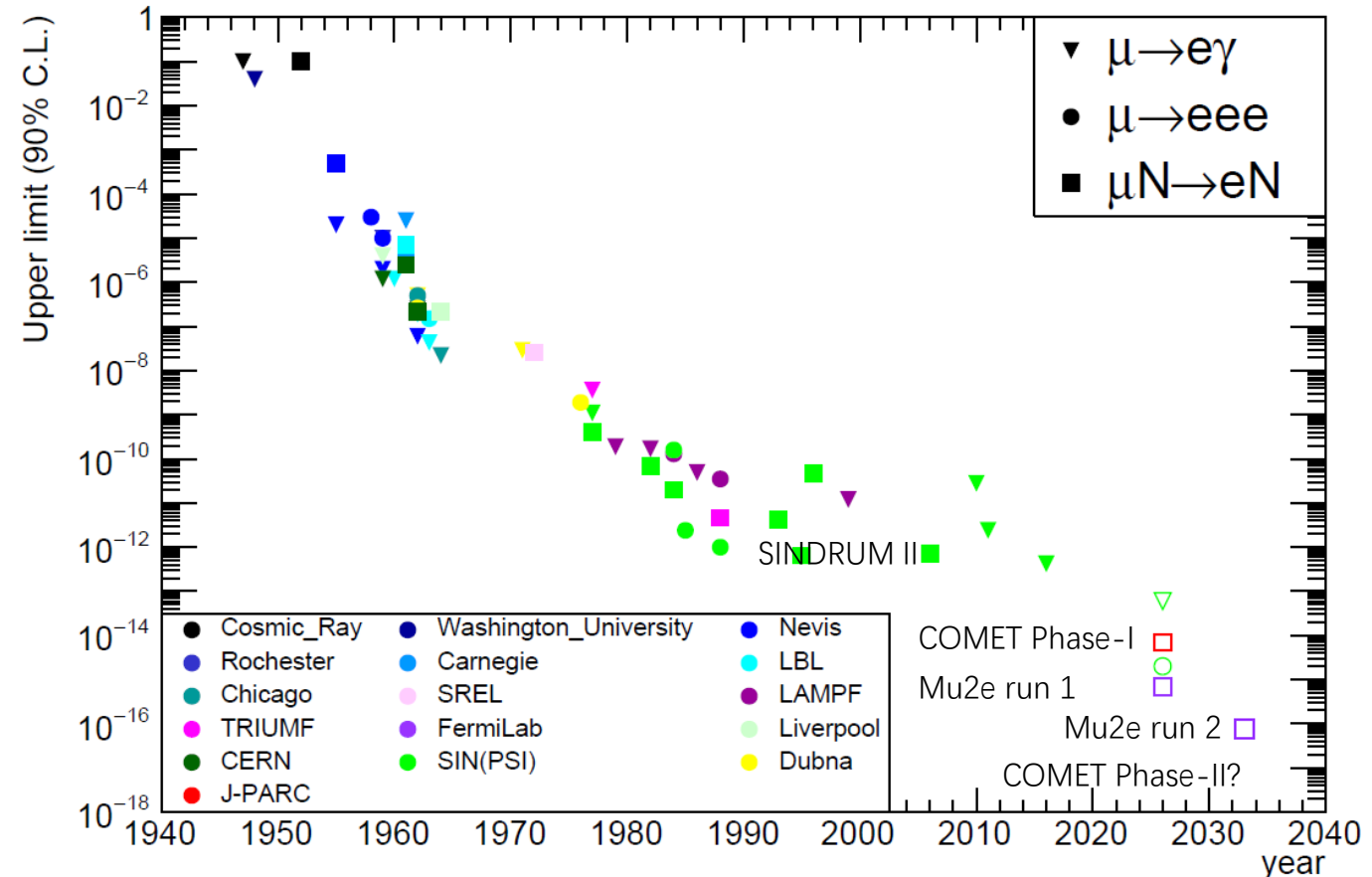
- Λ can reach $\mathcal{O}(10^3 \sim 10^4)$ TeV!
 - Good complementation to direct searches for new physics.



θ_D parameterizes the relative magnitude of dipole and four-fermion coefficients

History of CLFV experiments

- In the near future
 - Already data taking: MEG-II
 - Under construction: COMET Phase-I, Mu2e, Mu3e
- In the far future
 - PSI muon facility upgrade plan (HiMB) will make Mu3e Phase-II and next stage $\mu \rightarrow e\gamma$ possible to improve by x10.
 - COMET Phase-II and Mu2e-II are seeking to be approved: aiming at 10^{-18} , an improvement by x10.
 - In the far future, AMF/PRISM may bring the sensitivity to $< 10^{-19}$





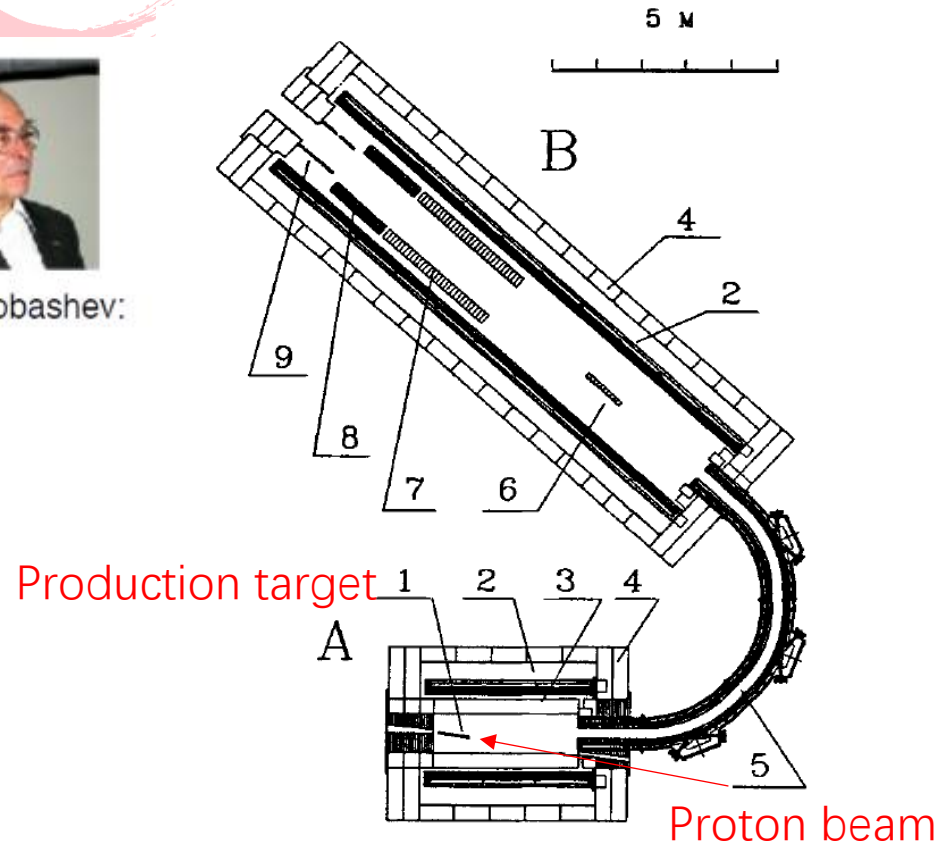
The Design of COMET



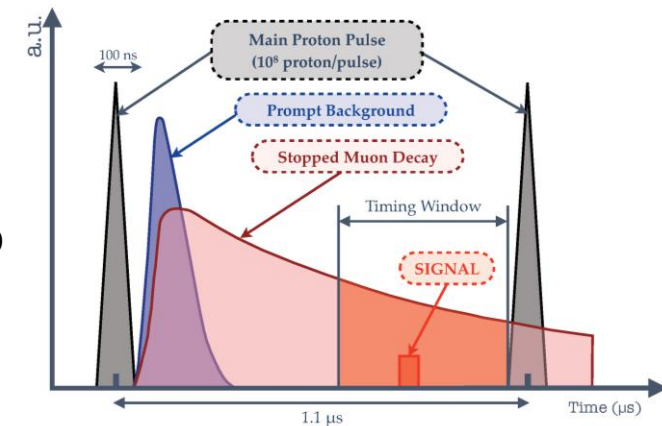
“New muon sources”: the Lobashev scheme



V.M. Lobashev:



- To get much more muons
 - Thick target:**
~1 hadron interaction length.
 - Superconducting magnetic field:**
>2.5 T, adiabatically dropping
- To control radiation
 - Accept backward beam
 - Bending solenoid to select low energy beam particles.
- To suppress beam induced background
 - Pulsed beam (MHz). Wait for beam flash to pass and pions to decay.



Djilkibaev R.M. and Lobashev V.M., Sov.J.Nucl.Phys. 49(2), 384, (1989).

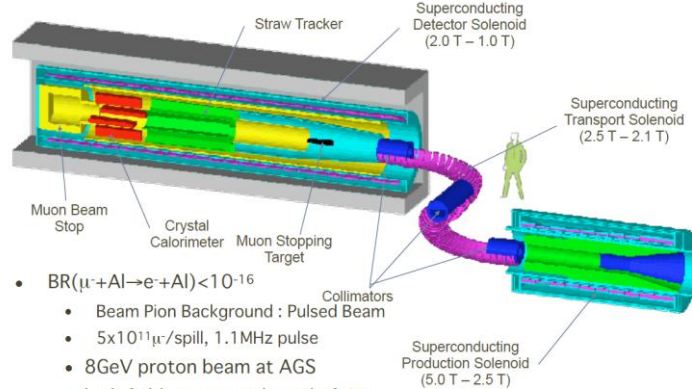
> 10^{10} muons/sec is achievable. Toward $< 10^{-16}$ sensitivity!

Realizing the Lobashev scheme muon sources



Proposed in 1999.
Canceled in 2005

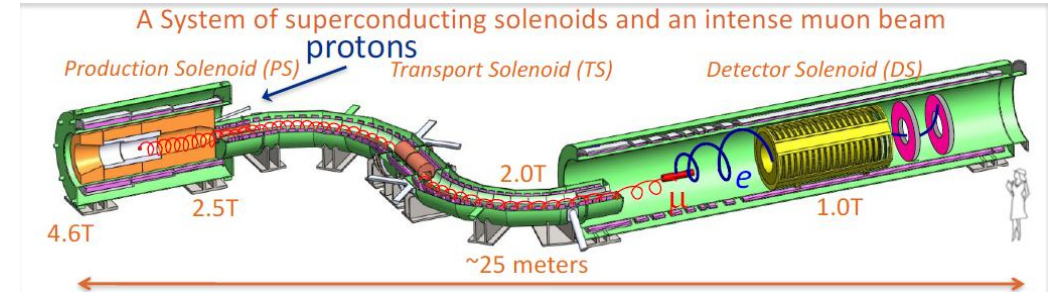
MECO @BNL/AGS



- $BR(\mu + Al \rightarrow e + Al) < 10^{-16}$
 - Beam Pion Background : Pulsed Beam
 - $5 \times 10^{11} \mu^- / \text{spill}$, 1.1 MHz pulse
 - 8 GeV proton beam at AGS
 - high field capture solenoid of 4 T
- ~ 2005, and cancelled

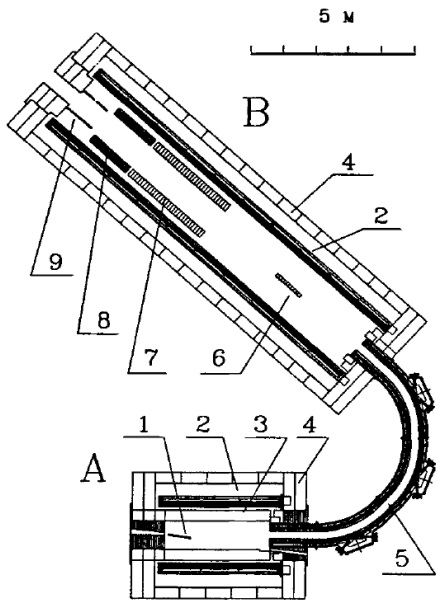
Revived at FermiLab.

Proposed in 2007. **Under construction**

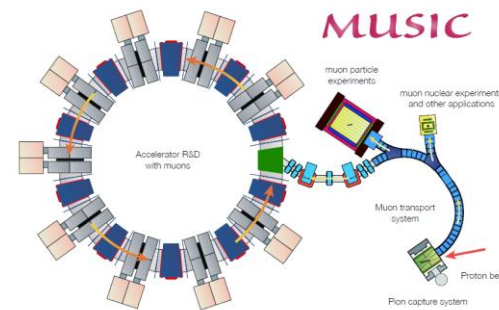
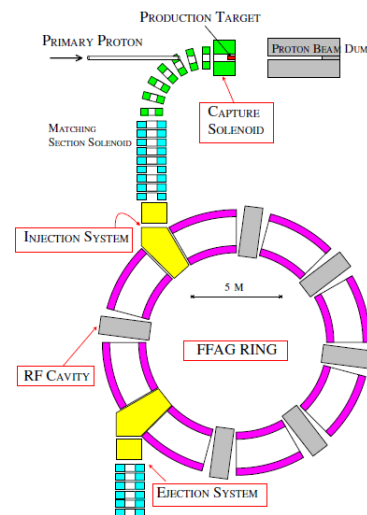


COMET, Phase-I of PRISM/PRIME.
Proposed in 2007. Phase-I **Under construction**

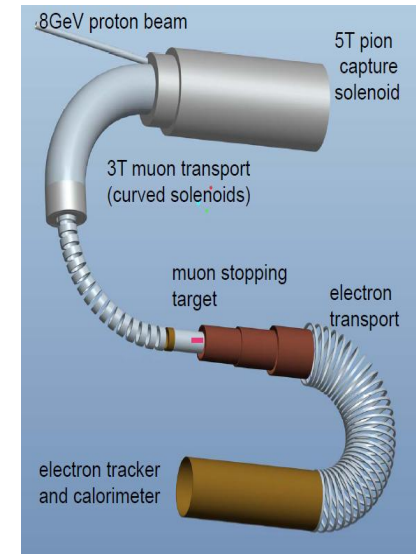
Proposed in 1989.
No budget support.



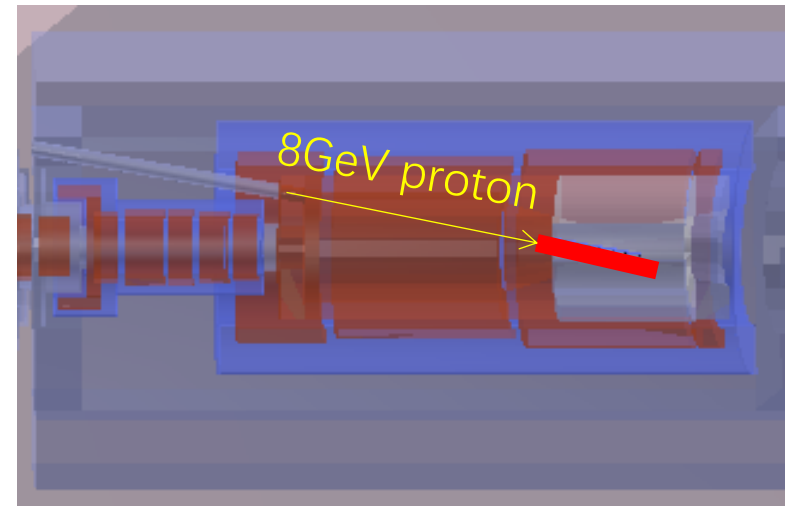
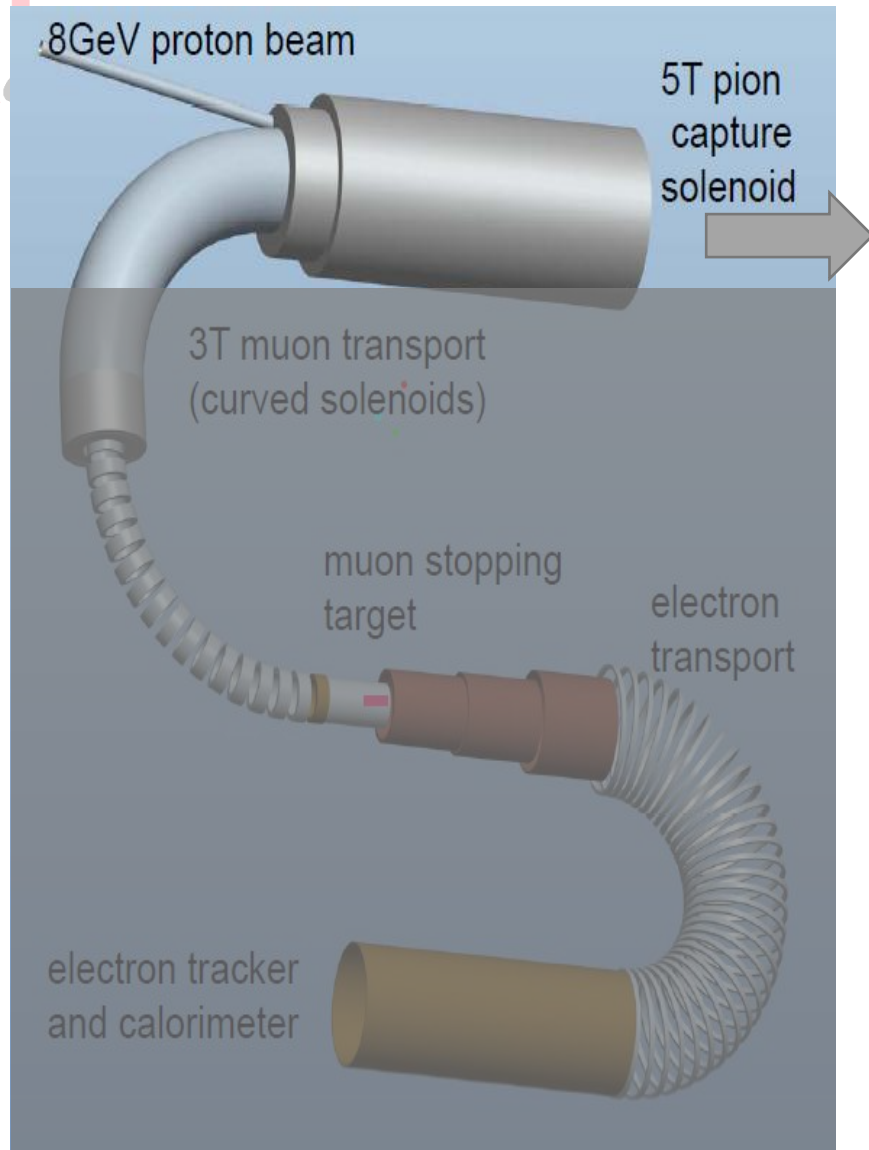
PRISM/PRIME
Conception started ~ 2003



MuSIC, proposed in 2010
Under construction

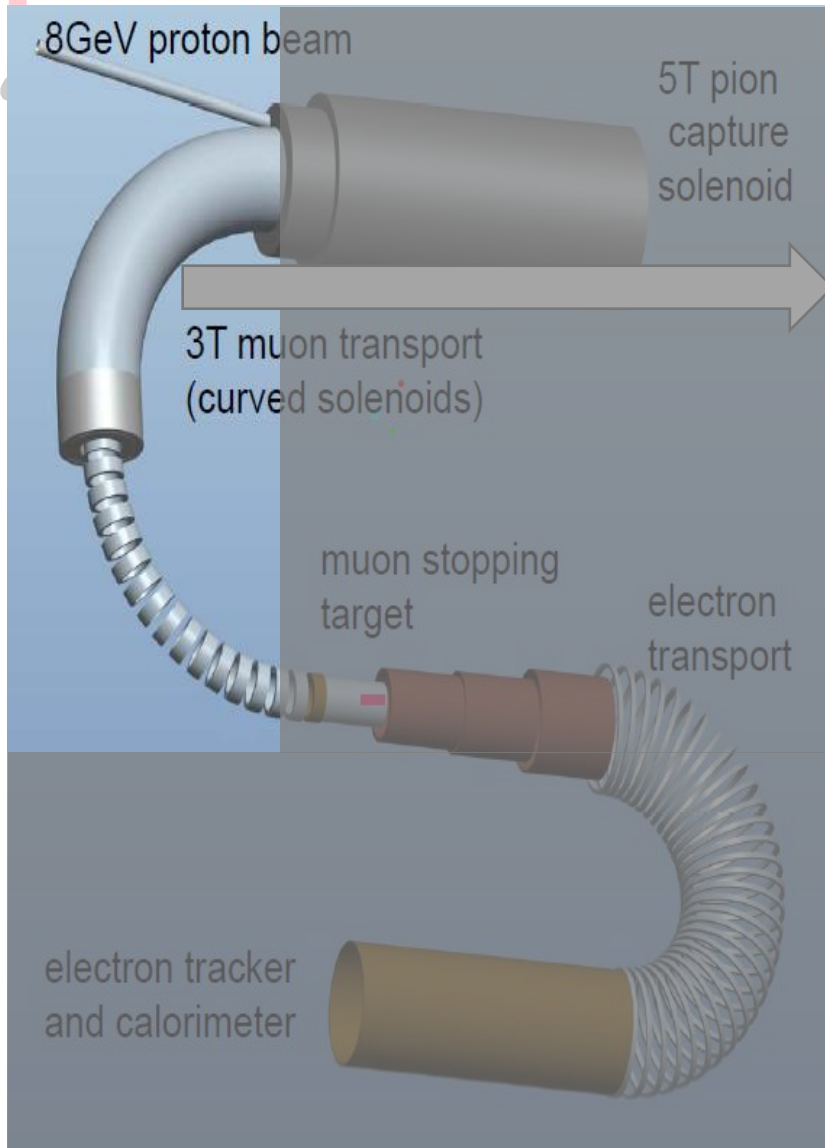


Production target and the capture magnet



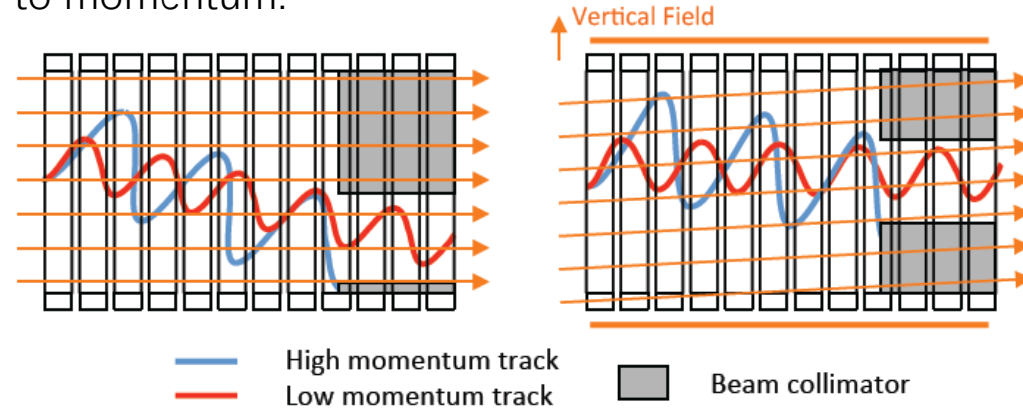
- 8 GeV 56 kW proton beam
- Thick target with **1~2 hadron interaction length**
- Powerful capture magnet: **5 T**
 - Large inner bore to fit in the shielding
 - **Adiabatic decreasing** field: focusing and mirroring
- Expected muon yield: **10^{11} muon/sec!** (10^8 @ PSI)

Transportation solenoid



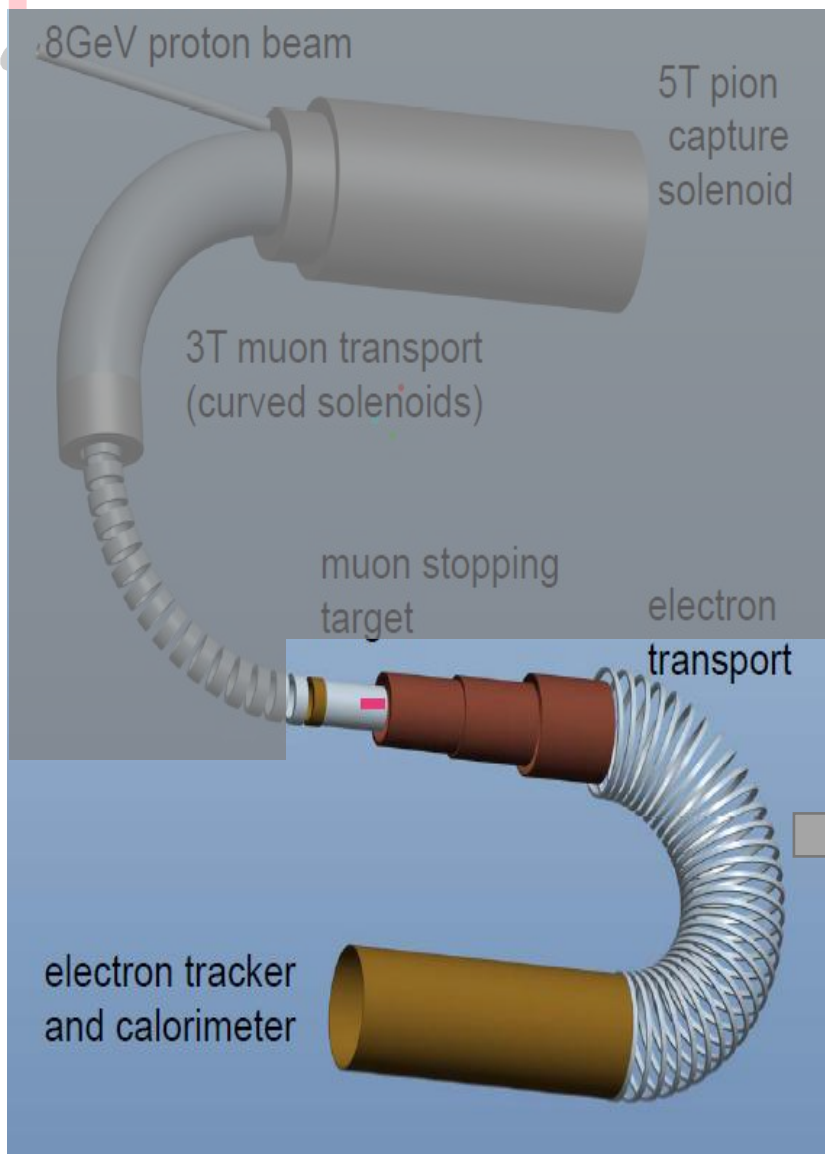
Drift vertically, proportional to momentum.

Vertical field as "correction"

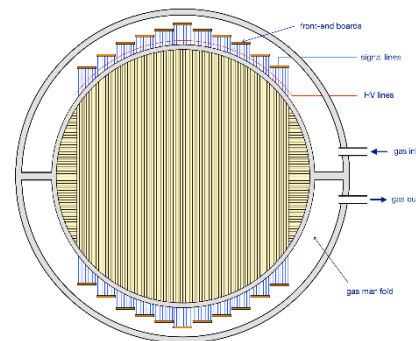


- Use **C shape** curved solenoid
 - Beam gradually disperses
 - Charge & momentum
 - **Dipole field** to pull back muon beam
 - Can be used to tune the beam
- Collimator placed in the end
 - Utilize the dispersion in **180** degrees

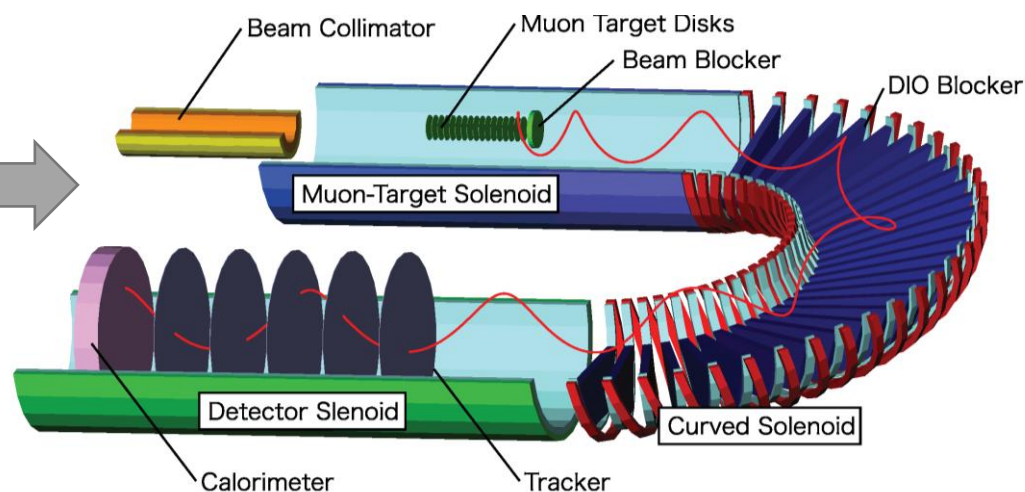
Stopping target and detector system



- Use **straw tracker** to measure the momentum
 - Really light: put in vacuum, 12 micro meter thin straw



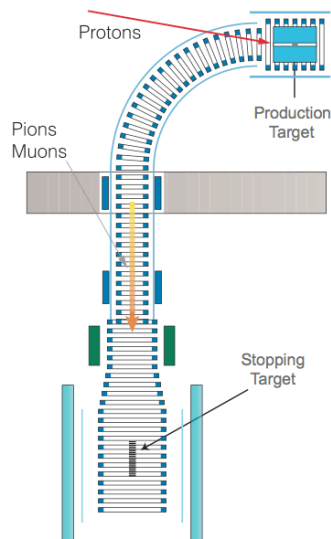
- **Electromagnetic calorimeter**
 - Providing trigger, TOF and PID



Phased Approach for COMET

COMET Phase-I

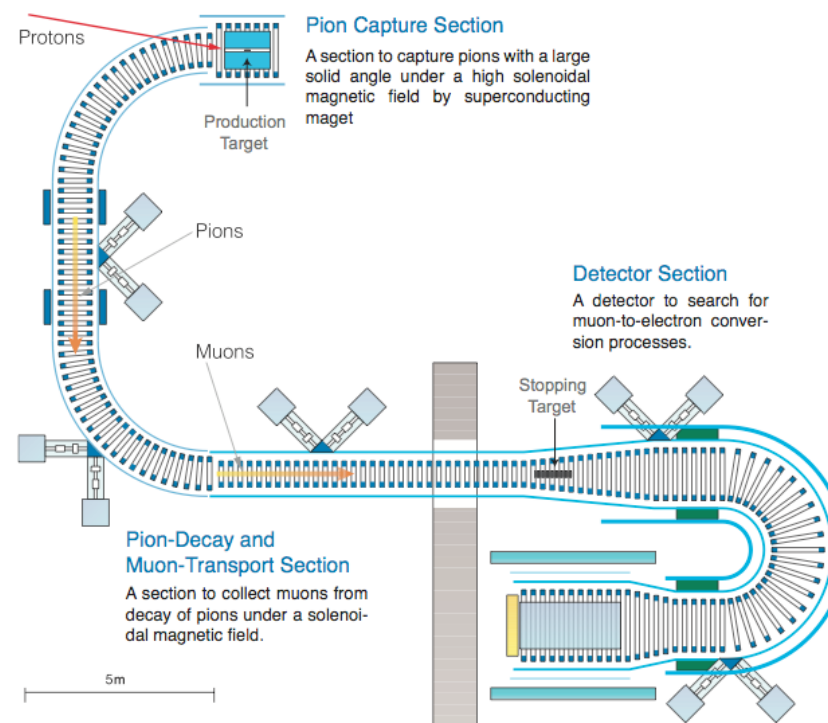
- Directly measure the muon beam with prototypes of Phase-II detector.
- Search for $\mu - e$ conversion with factor of 100 improvement* $O(10^{-15})$
- 8 GeV, 3.2 kW, graphite target



- Upstream part same as Phase-II
 - Except production target and part of shielding

COMET Phase-II

- Search for $\mu - e$ conversion with full sensitivity: factor of 10,000 improvement $O(10^{-17})$
- CDR submitted in 2009
- 8 GeV, 56 kW, tungsten target





Preparation for Phase-I

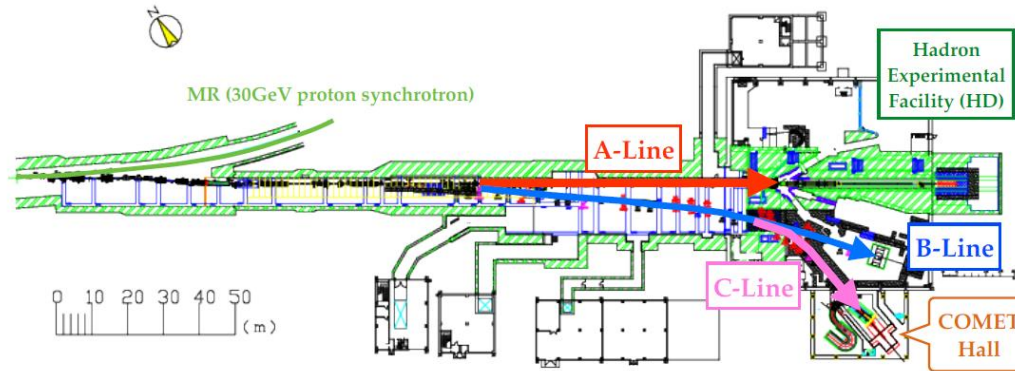
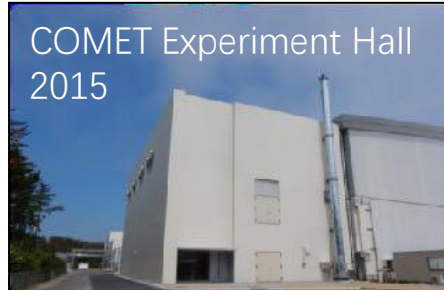


COMET Facility

COMET

e

C-line ready. Proton beam came to COMET for the first time.



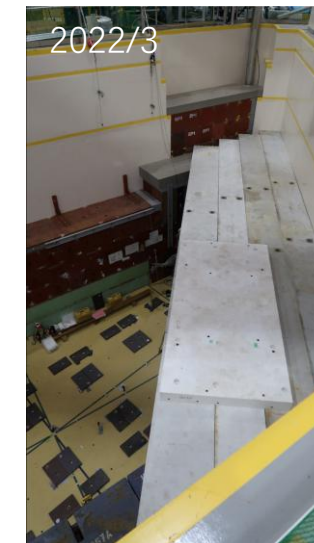
Detector area prepared in 2022.



MTS (muon transportation solenoid) in position.

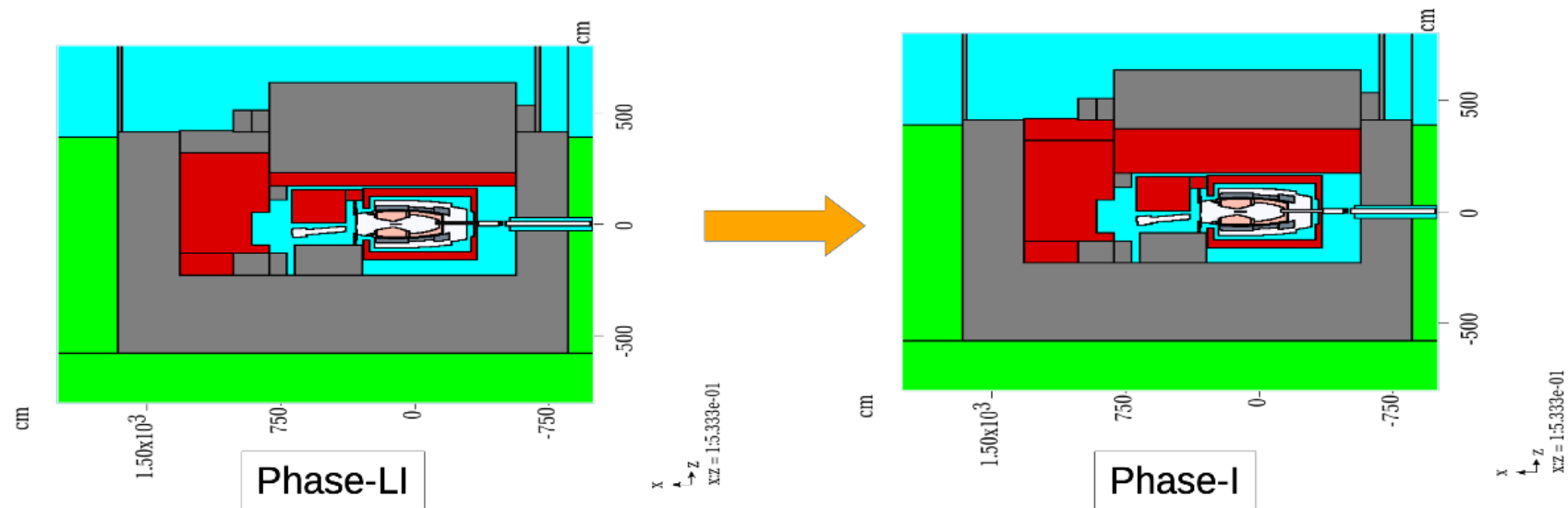


Shielding added.



COMET Facility

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)

Finished in 2023!

Aiming at 2028

COMET Facility

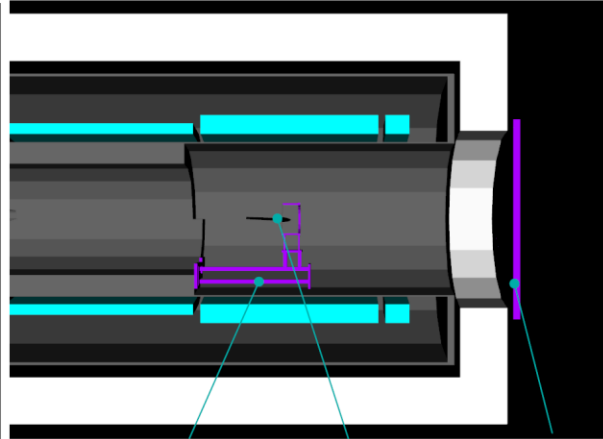
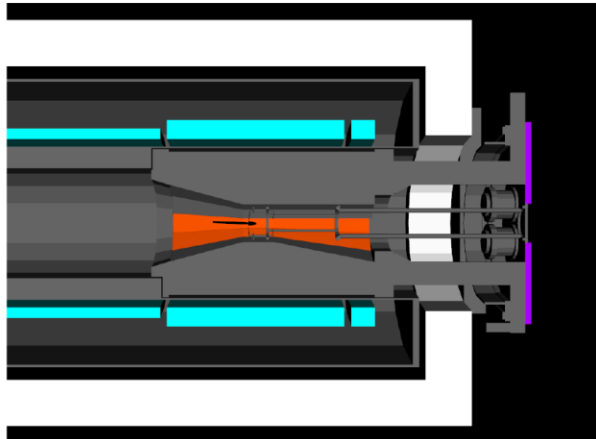
Commissioning run planned with 32 W, with minimal ceiling shielding, without CS inner shielding

We've decided to start experiment w/o installing CS inner shield.

Prompt Dose Estimation

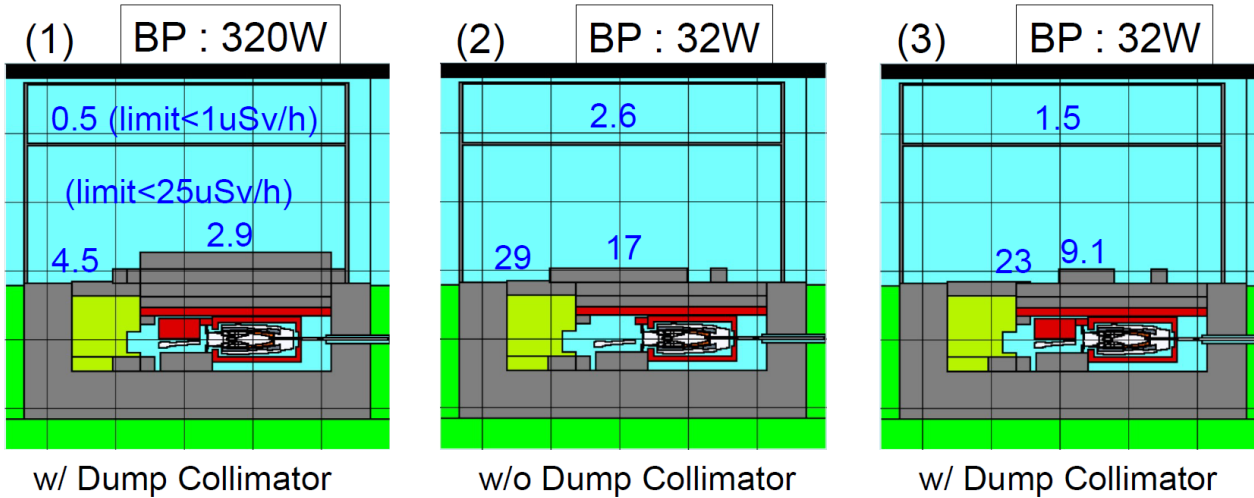
Phase-I configuration

Commissioning configuration



Stainless steel, aluminum, copper, graphite, superconductor

Newly designed target support, mounted/dismantled manually
Dedicated flange with beam window
Target itself is supposed to be final one



Ceiling Shield
• Iron : 73 m³
• Concrete : 521 m³

Ceiling Shield
• Iron : 73 m³
• Concrete : 296 m³
(-35%)

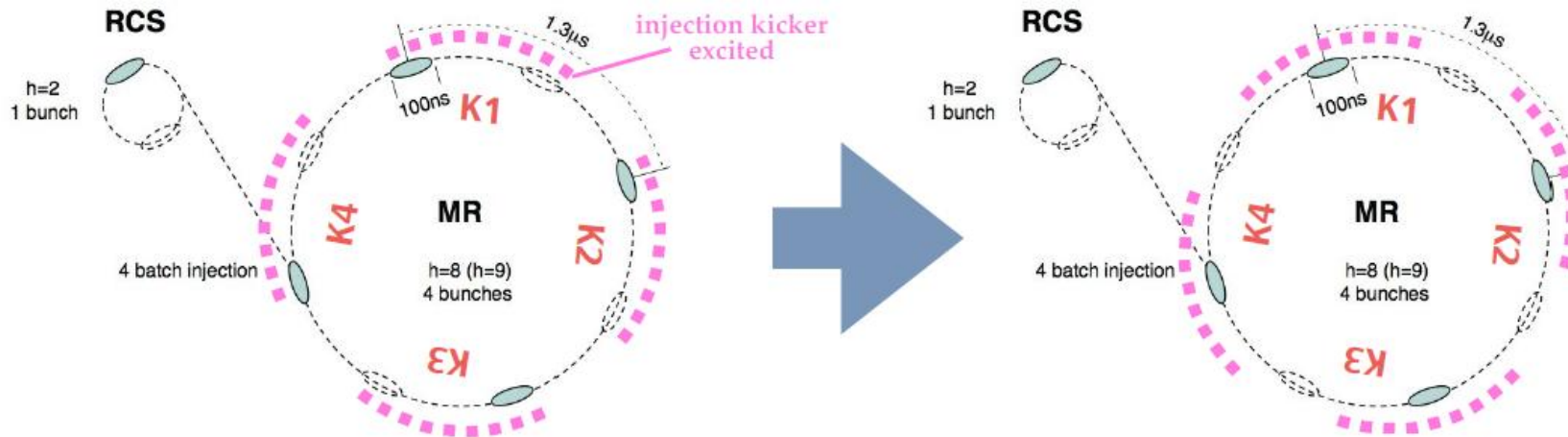
Ceiling Shield
• Iron : 73 m³
• Concrete : 238 m³
(-45%)

Current our proposal is Option (3)
(a little more shield is required though).

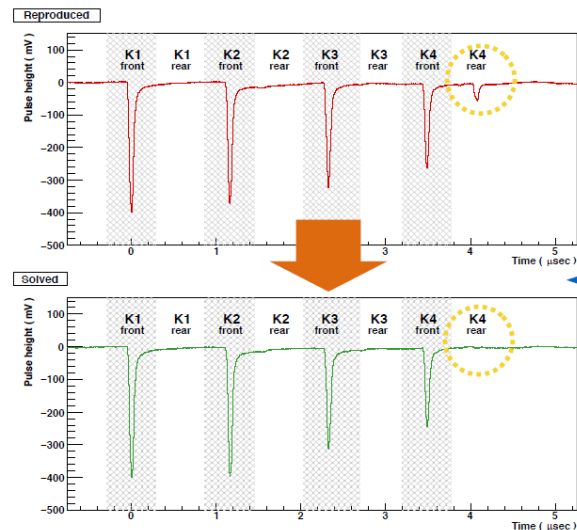
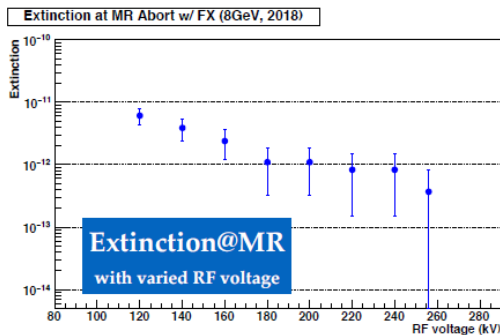


Proton beam from J-PARC

- To make the proton extinction factor: $R (N_{leak}/N_{pulse}) < 10^{-10}$
 - Shift the kicker phase by half period to avoid residual protons in the empty bucket.



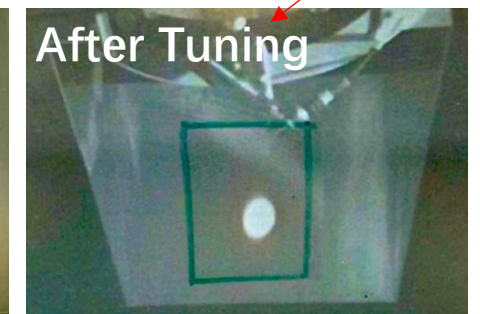
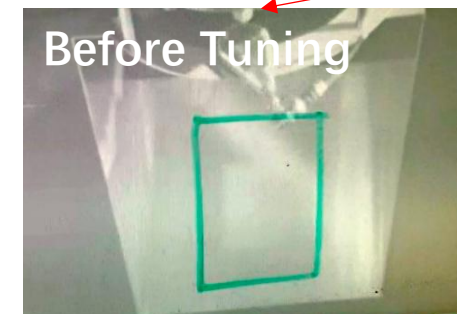
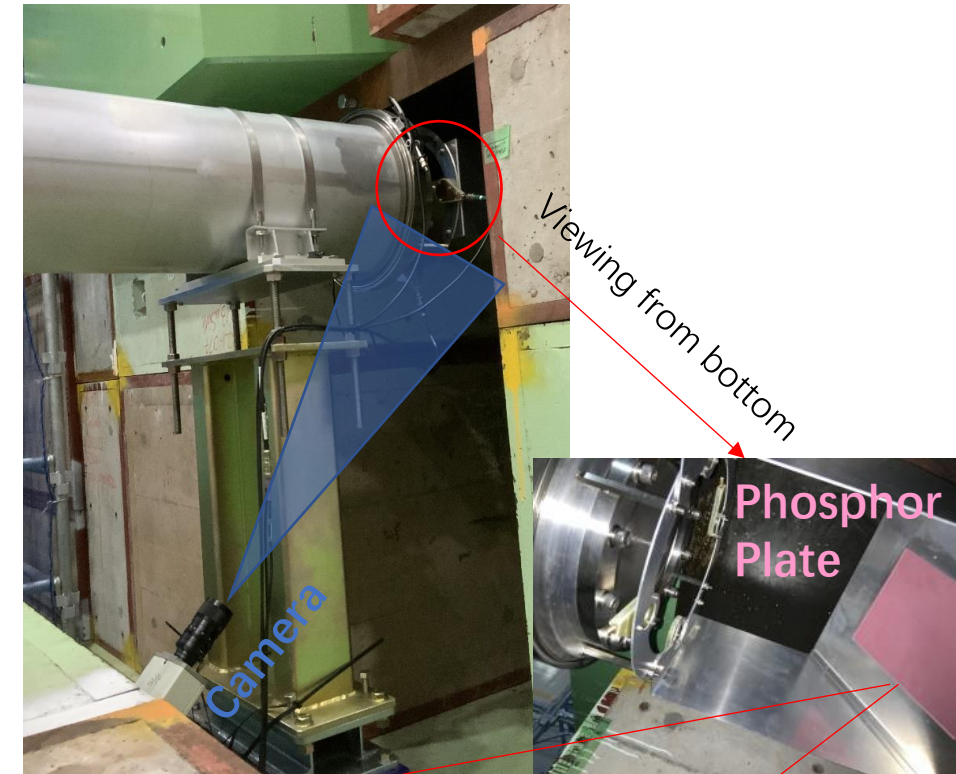
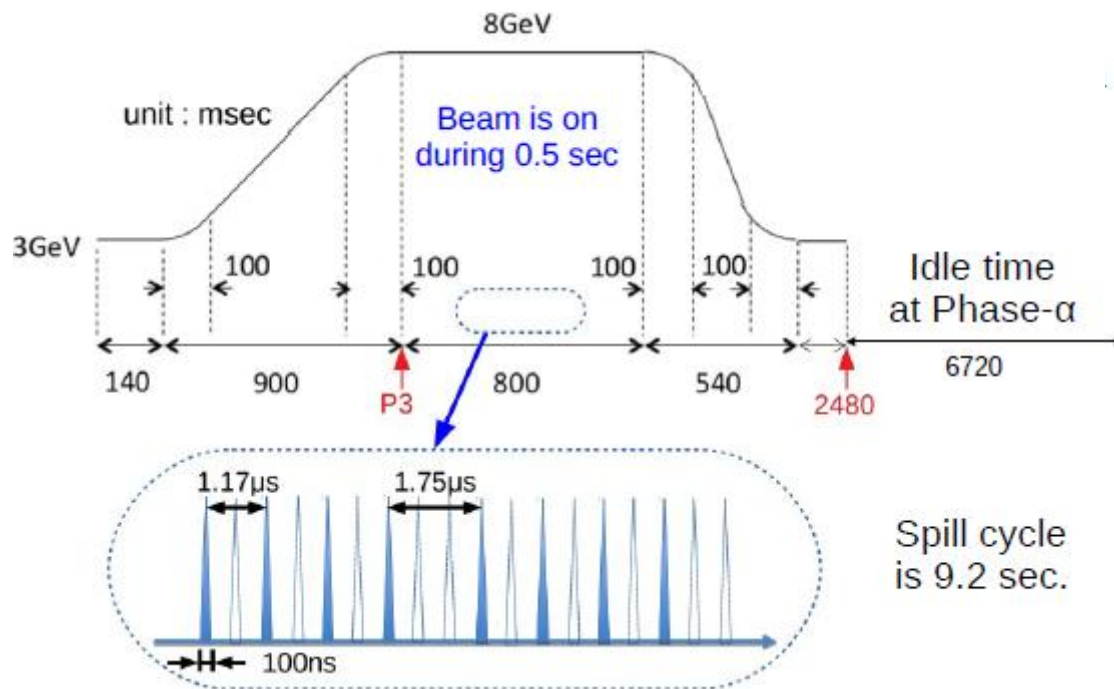
Measurement at main ring:
proton leak $< 10^{-12}$



2018: Observed K4 rear leak.
2021: T78 at hadron hall, solved the leak by shifting the kicker further:
 $< 3.2 \times 10^{-12}$
2023: Confirmed same performance after the power upgrade in the J-PARC main ring.

COMET Phase- α in 2023: Proton Beam Commissioning

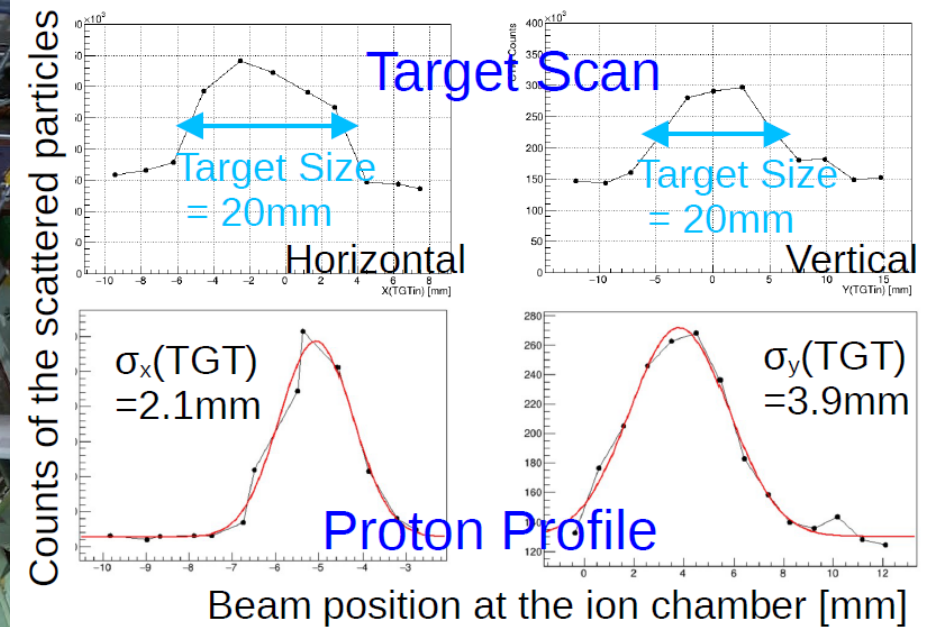
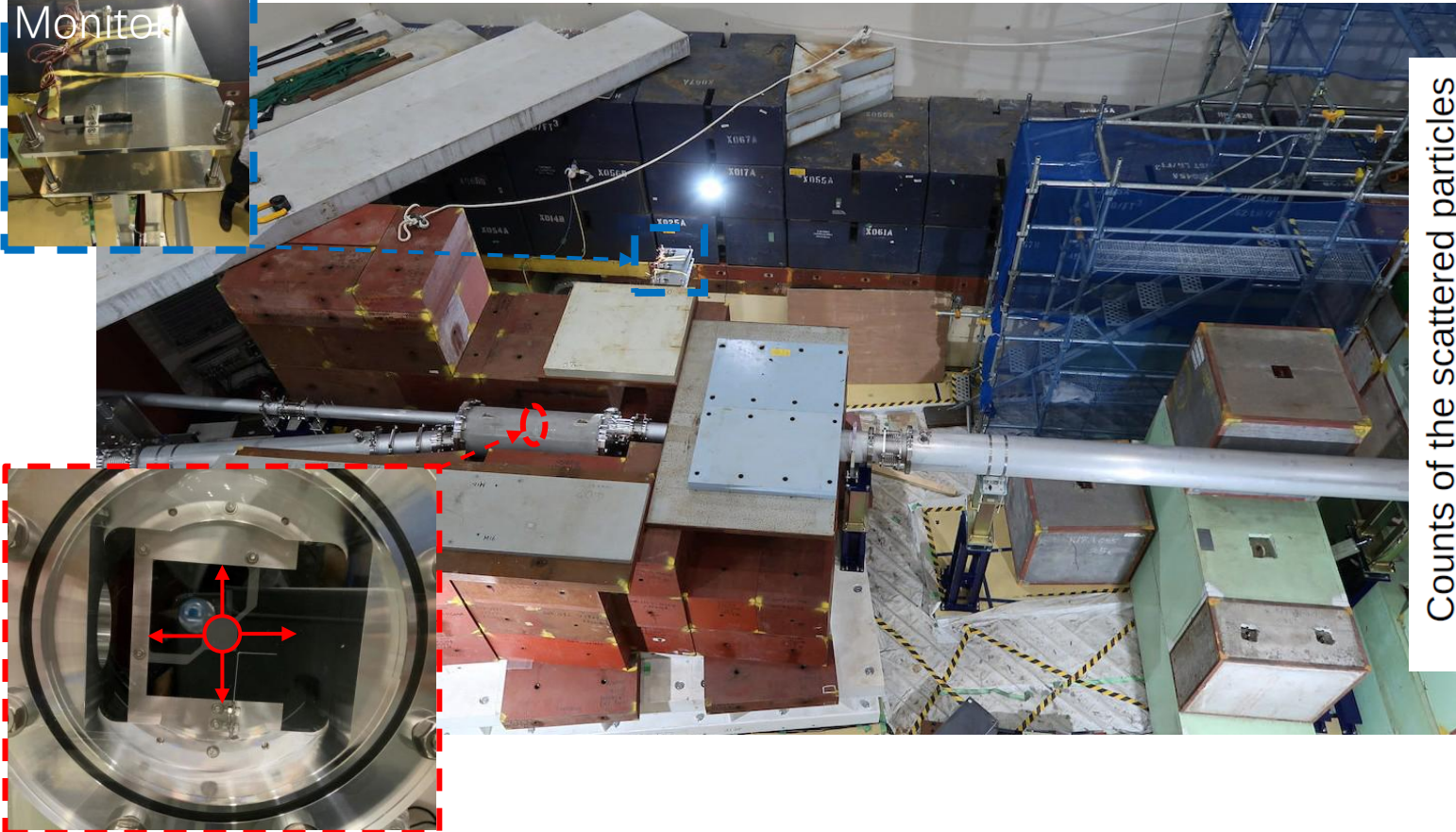
- Slow extraction with the COMET proton beamline (C-Line) was commissioned for the first time!
 - Same bunch filling structure as COMET Phase-I, but longer accelerator cycle
 - Lower beam power: 260 W (3.2 kW in Phase-I)



COMET Phase- α in 2023: Proton Beam Commissioning

Sweeping bending magnet and measuring target monitor counts, center and profile of the target was determined.

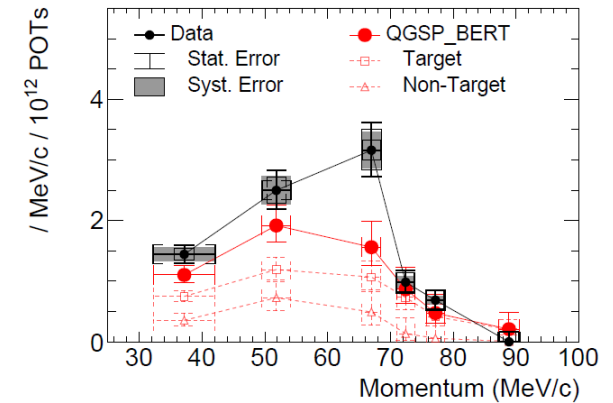
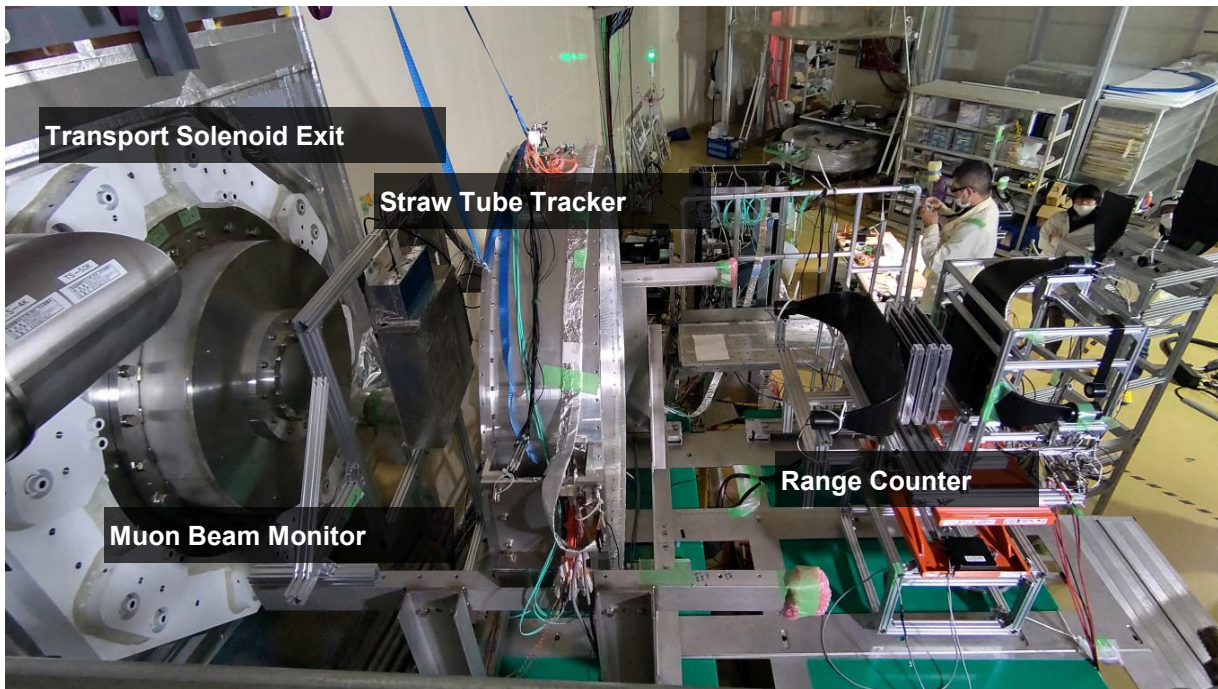
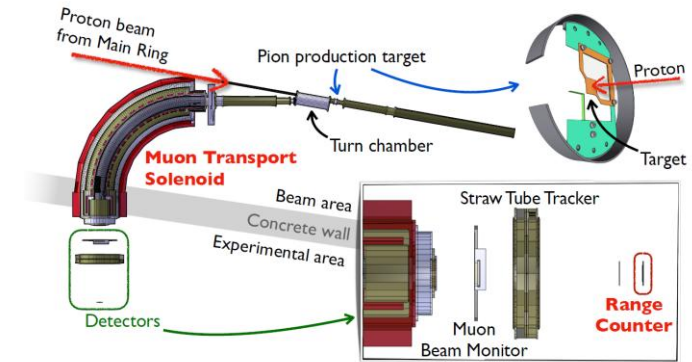
Target Monitor





COMET Phase- α in 2023: Muon Beam Measurement

- The muon beam was successfully transported to detector area.



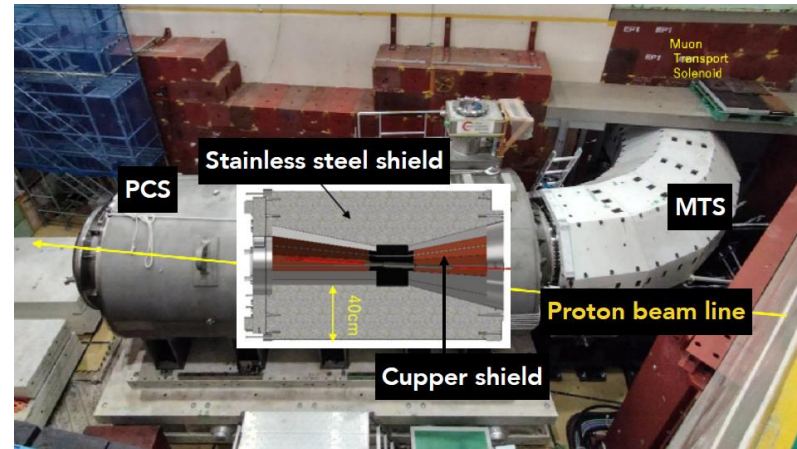
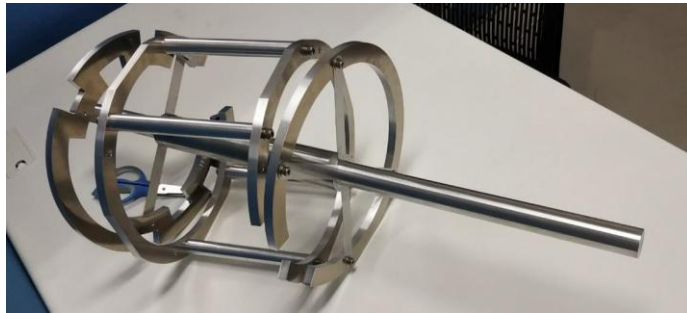
(b) dN_{μ}/dp : Momentum spectrum at the RC

Internal Review finished.

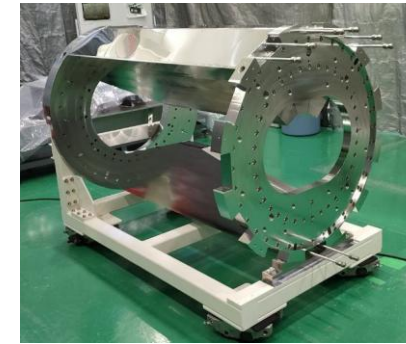
COMET Production Target System



Prototype of target station for Phase-I



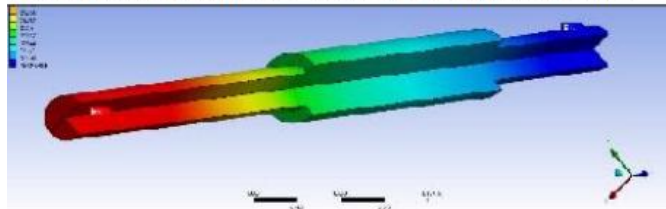
Cooling test of shielding (Cu for Phase-I)



Graphite target for Phase-I: radiation cooling, $T < 245$ degree

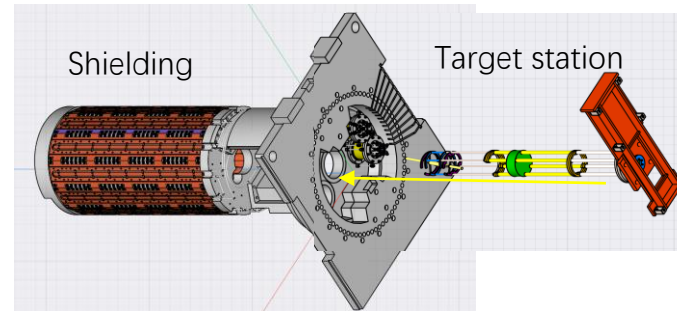
Graphite

Diameter: 26 mm and 40 mm, Length: 700 mm

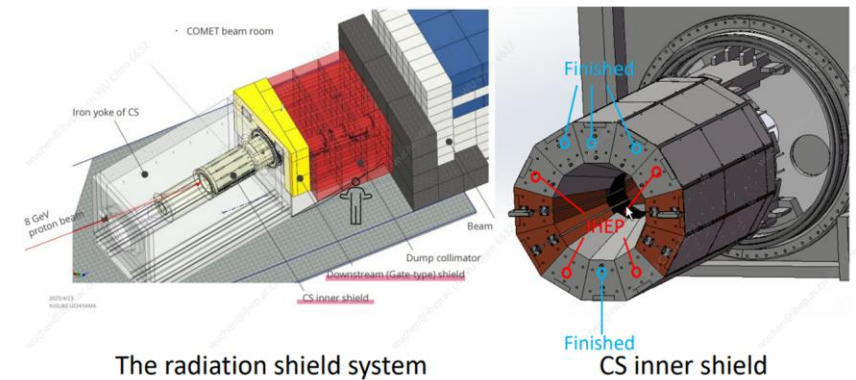


FEM simulation is completed. Max. temp. 245 degC.

Target station with remote control



PCS inner shield being purchased
Postpone installation until physics run



The radiation shield system

CS inner shield

COMET Super Conducting Solenoids

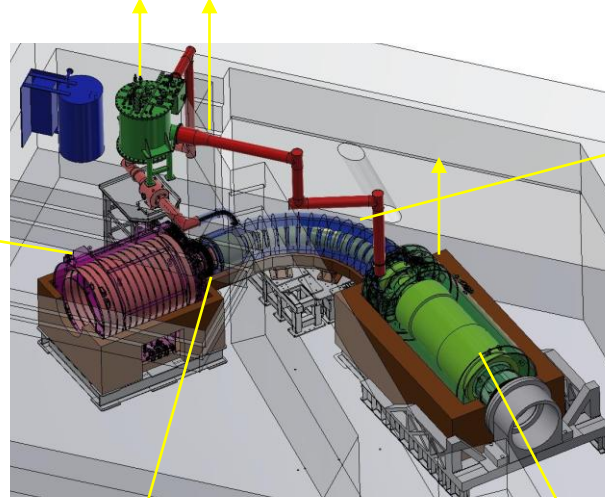
COMET

All the magnets are now in place in the COMET hall!!

DS delivered to Tsukuba in Oct. 2024



Successfully tested the cooling system with $I=3000$ A in 2021



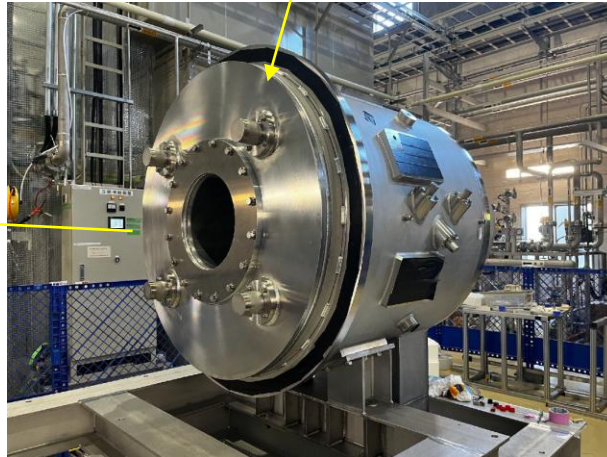
Installed in 2015. Tested in 2022. Field map measured in 2022. Commissioned in 2023



DS moved to J-PARC in 2025, combined with BS



BS magnet delivered March 2022.

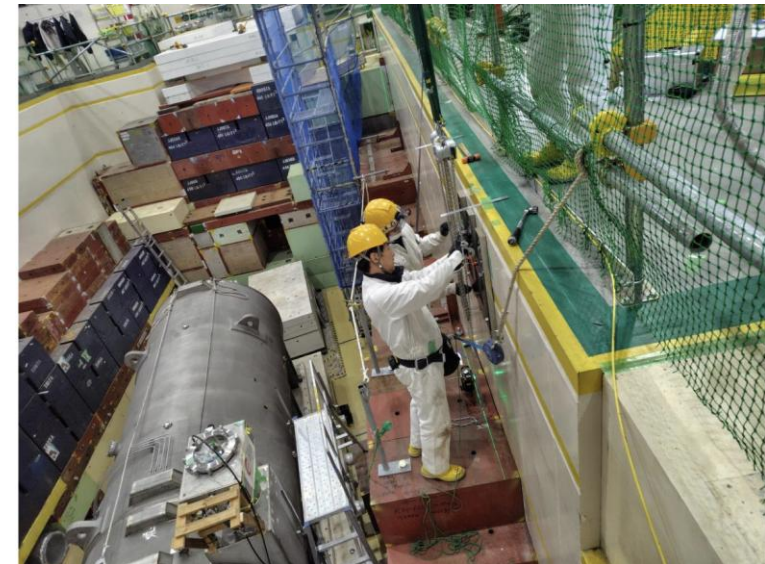
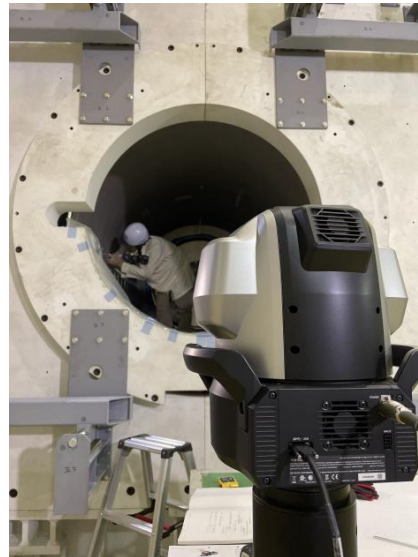


CS delivered and installed in Nov. 2024!



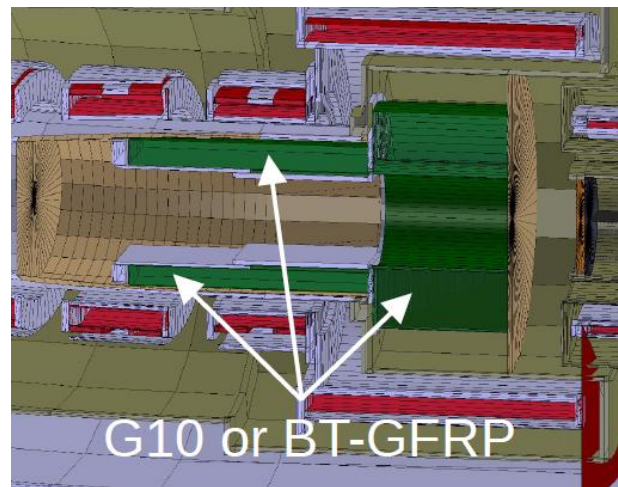
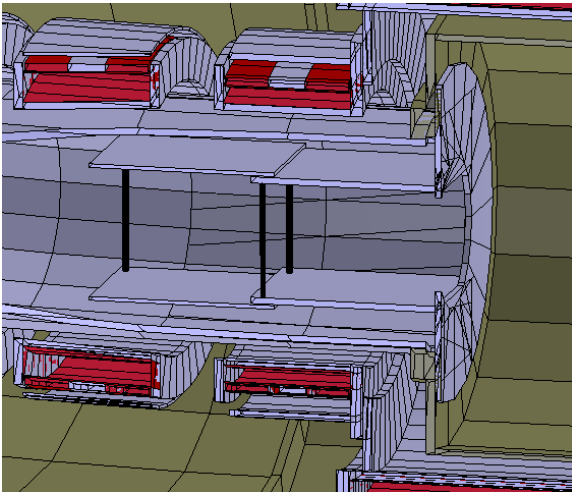
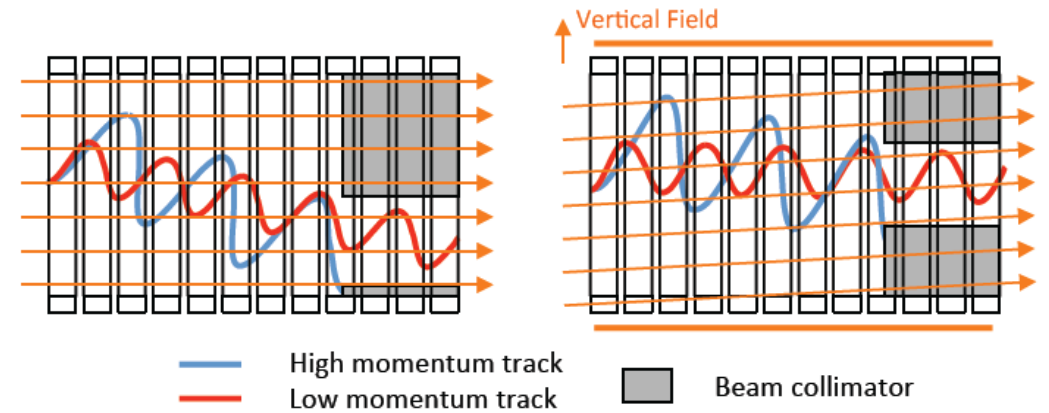
Recent Highlights:

- 1 T DS: Basic performance was tested in 2024 and successfully
 - Cooled to within 14 days (with N₂ cooling)
 - Ramped up to the rated current without any training quenches
- Installation to the COMET hall is finished in 2026
- DS/BS/TS magnet excitation tested in March 2026
- Field measurement started in April 2026
- 4.4 T PCS: installed in Nov. 2024
 - Vacuum test : good
 - Coil resistance : good
 - Sensors : good
- Installing the helium transfer tube (TRT) and iron return yoke of PCS
- Plan to start cooling in October 2026.



Muon Beam Collimator

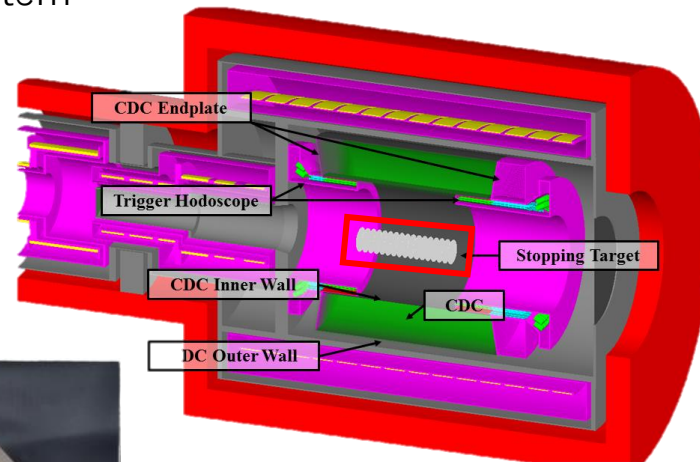
- Beam collimator designed for charge and momentum selection.
- G10 or BT-GFRP are candidates to suppress outgas due to the radiation damage.
- Collimator was constructed based on the optimization.
- Installation of the collimator was completed.



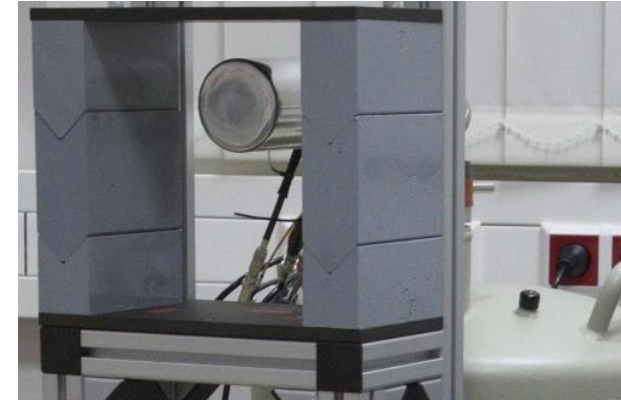
CyDet: Stopping Target System

The stopping target system is under optimization by the Dresden group.

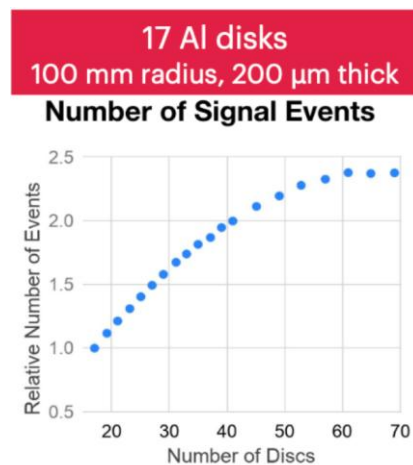
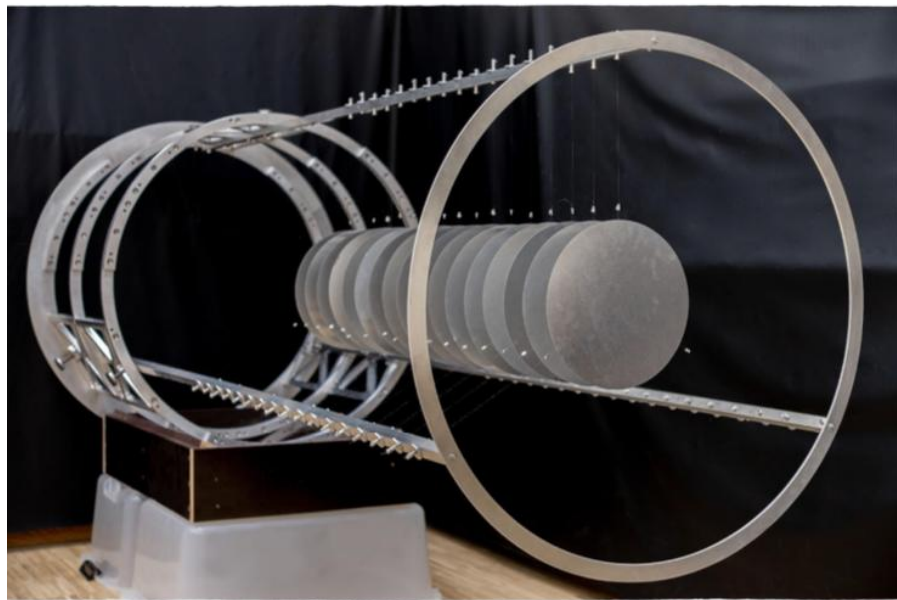
- Number of plates, thickness, etc.
- Prototypes including supporting system produced.



HPGe detector (to calibrate # stopped muons) placed a few meters away from the target. Dresden group is optimizing the shielding design.



Ongoing tests to choose specific material



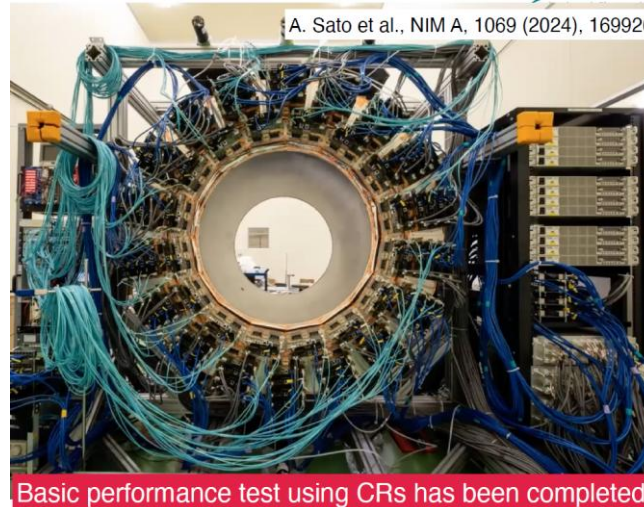
CyDet: Cylindrical Drift Chamber (CDC)



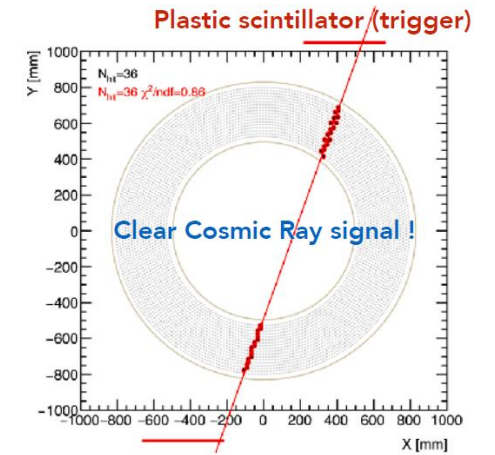
- ~5000 cells in 20 layers
- All stereo type layers
- Filled with He:isobutane=90:10 gas.

All the 128 boards produced by IHEP group before 2015. All mounted in 2019.

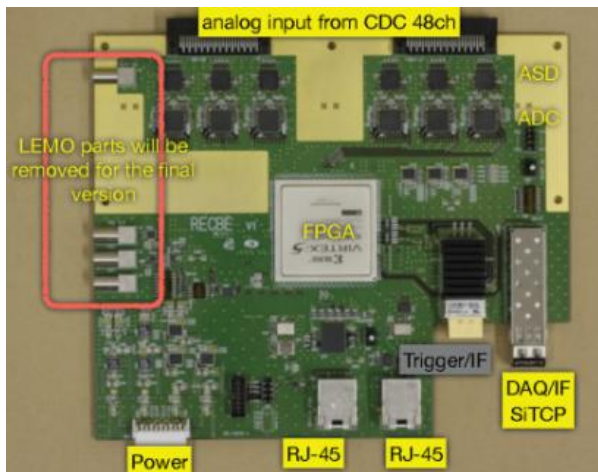
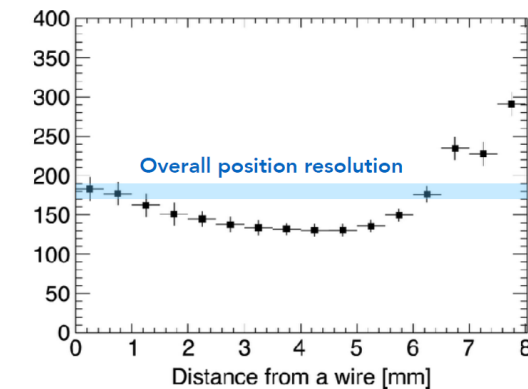
CDC was constructed in 2016 and still working stably. Moved to J-PARC in 2022.



Cosmic ray test shows spatial resolution~165 um



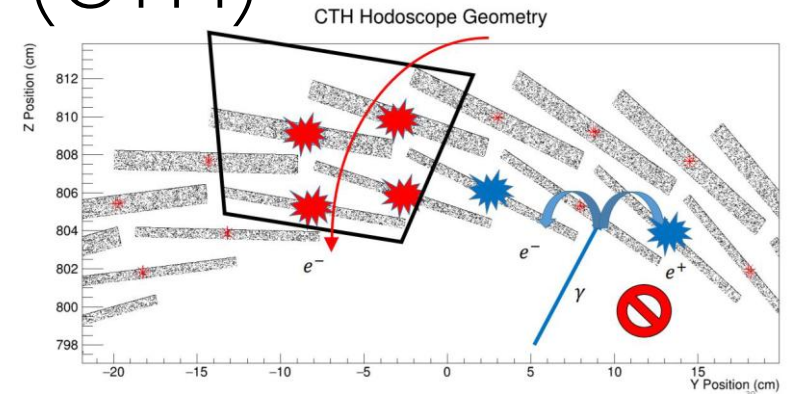
Plan to move to R&D building in May 2026.



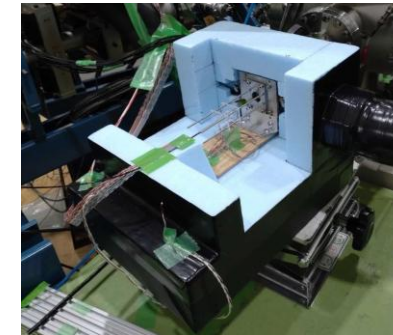
CyDet: Cylindrical Trigger Hodoscope (CTH)

To provide trigger signal and t_0 for tracking

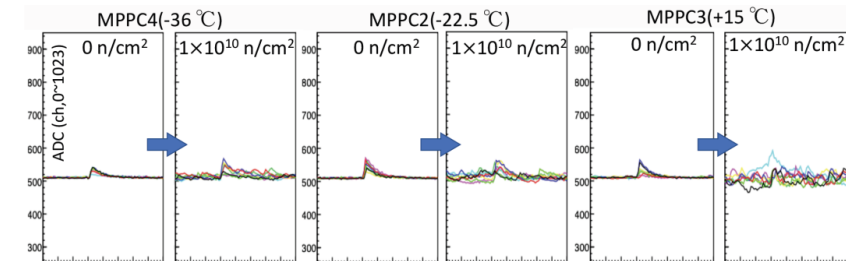
- 64 scintillators, x2 layers, x2 hodoscopes
- Timing measurement < 1 ns & Four-fold coincidence to suppress accidental trigger rate < 100 kHz
- W/ the realistic prototype, < 1 ns time resolution was obtained and the particle identification capability was tested
- Partial ($\sim 1/3$) readout of CTH will be installed first for commissioning run



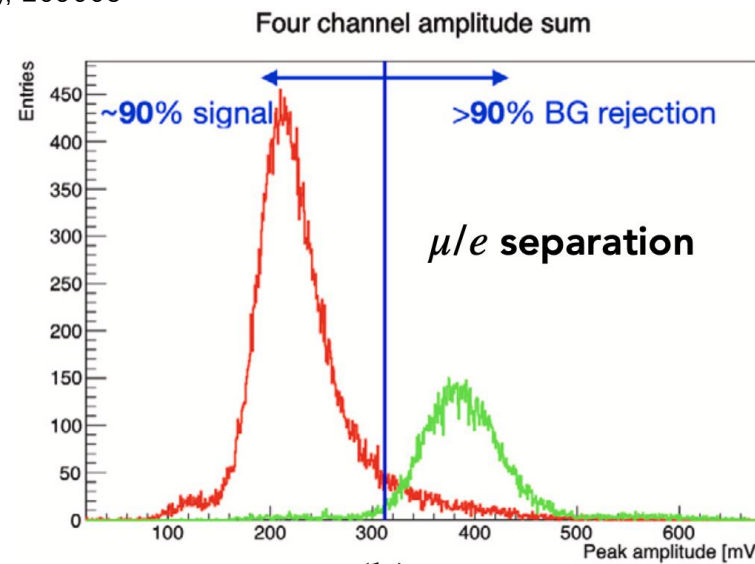
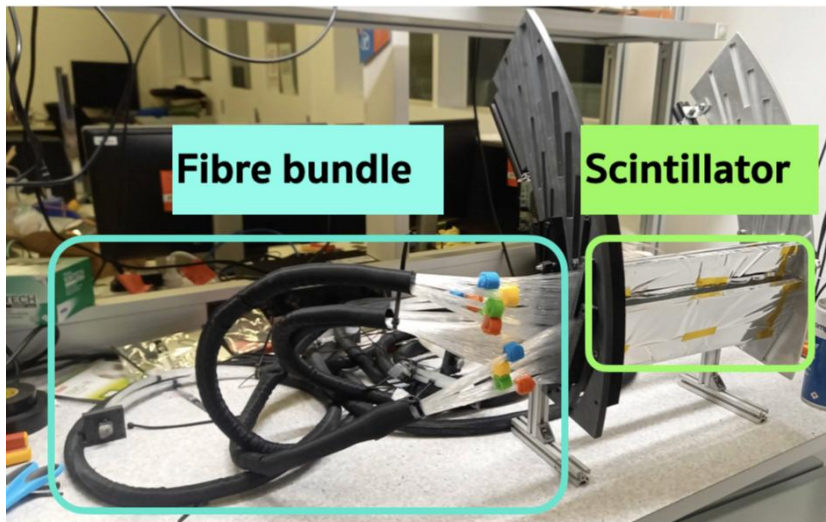
Readout cooled by N₂.



Successfully reduced the noise by cooling



Y. Fujii, et al., Nucl. Instrum. Methods Phys. Res. A, 1067 (2024), 169665

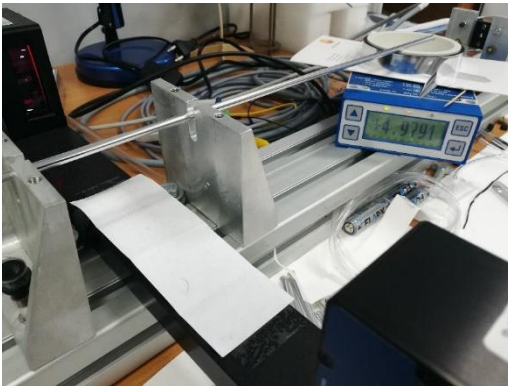
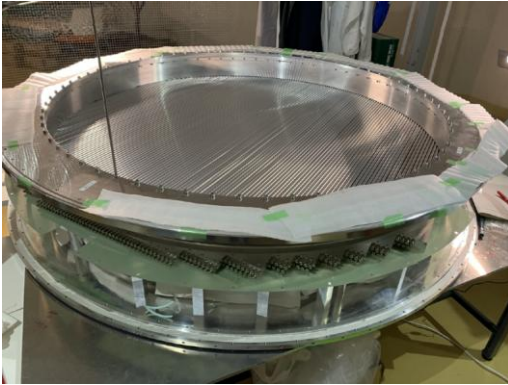


CTH prototype

StrEcal: Straw Tube & Electromagnetic Calorimeter

First station for COMET Phase-I ready. Others being constructed

- 10 mm diameter, 20 μm thickness

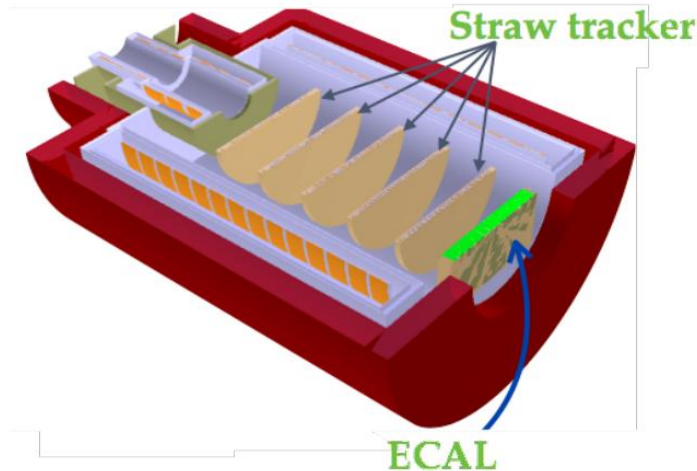


Constructed 5 mm diameter, 12 μm thickness straws for Phase-II

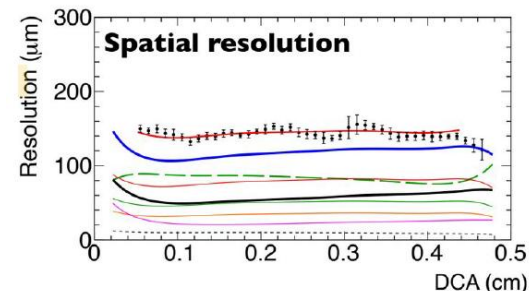
- Pressure tests with 4 bar successful.
- Diameter variation within 120 μm
- Further investigations on the way.

StrEcal system in phase-I: 5 straw tracker stations and ~ 500 LYSO crystals.

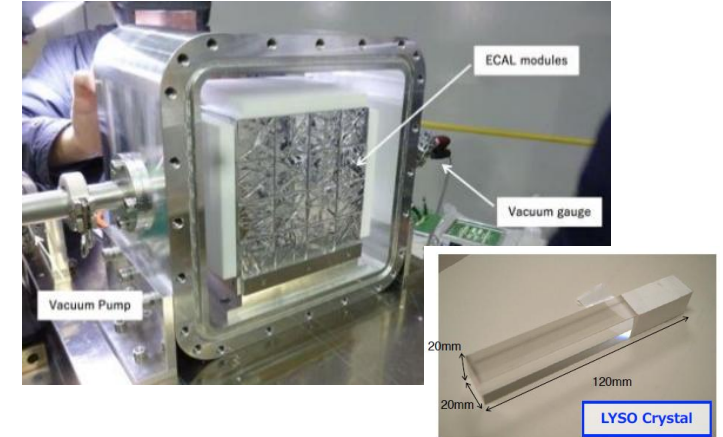
- In phase-II: more stations, 1920 LYSO crystals



Straw filled with Ar:Ethane=50:50 gas.
Beam test shows spatial resolution $\sim 150 \mu\text{m}$

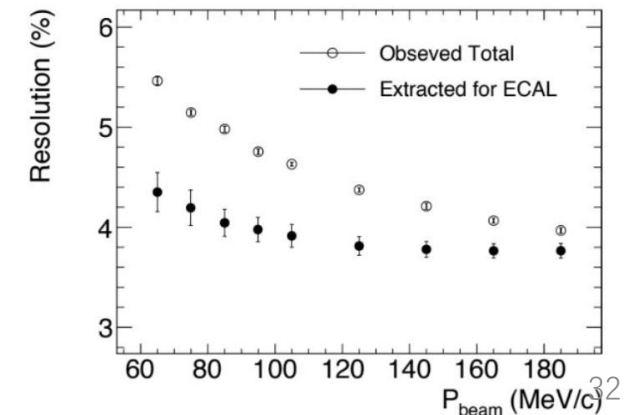


H. Nishiguchi, et al., Nucl.Instrum.Meth.A 958 (2020) 162800



Successful prototype test for LYSO in vacuum.

- $\sigma_E/E = 4\%$, $\sigma_{x/y} = 6 \text{ mm}$, $\sigma_t = 0.5 \text{ ns}$
- Phase-I support structure completed.
 ~ 500 LYSO crystals mounted.



Cosmic ray Veto (CRV)

COMET_e

CRV to suppress cosmic ray background

- One of the most crucial

Top : plastic scintillator(JINR/GTU)

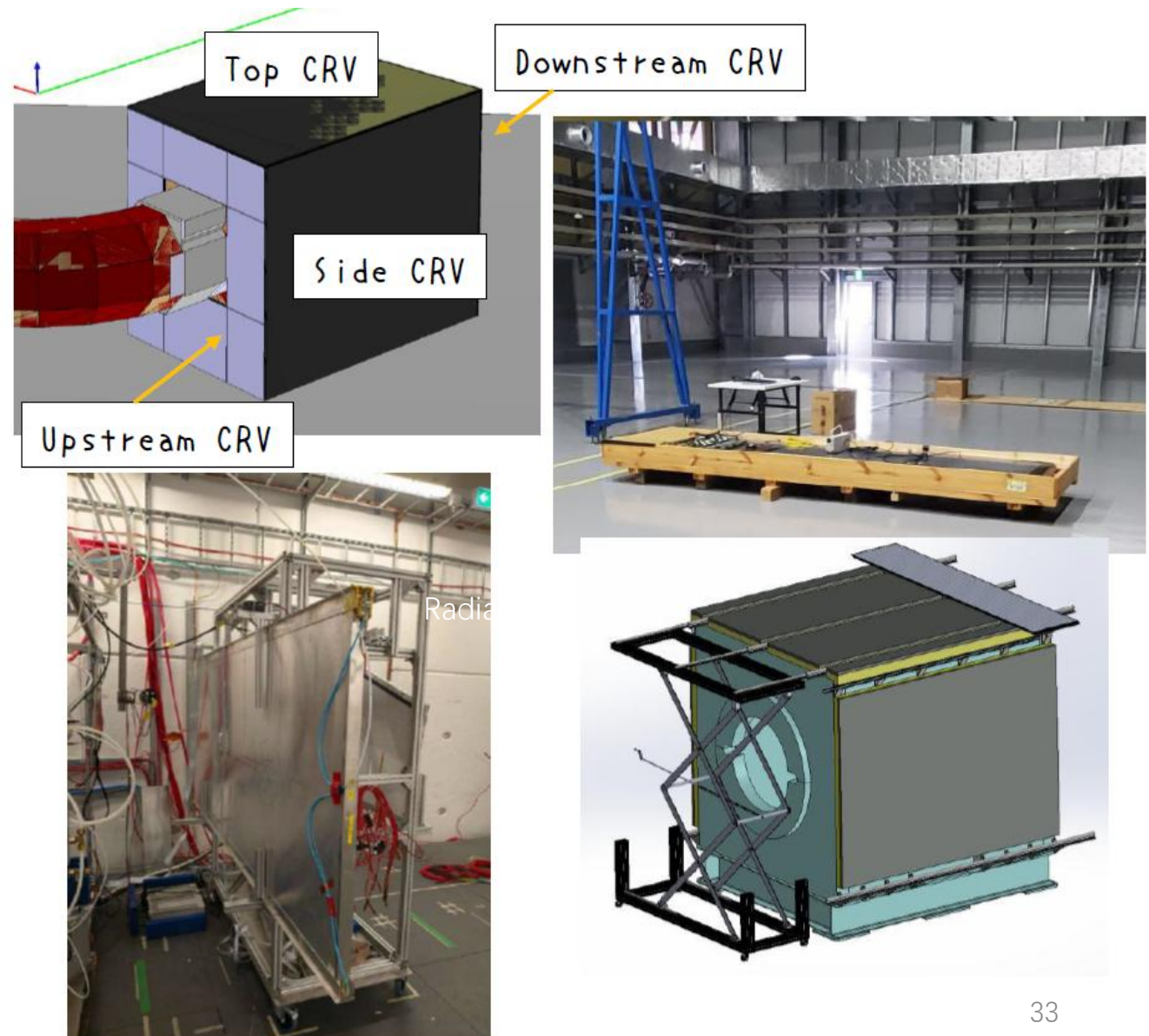
- Preparation in J-PARC R&D building is ongoing.
- Discussion on installation scheme is ongoing.

Side : ARGO-RPC(IHEP)

- Irradiation test at GIF++ @CERN was performed.
- Analysis is ongoing.

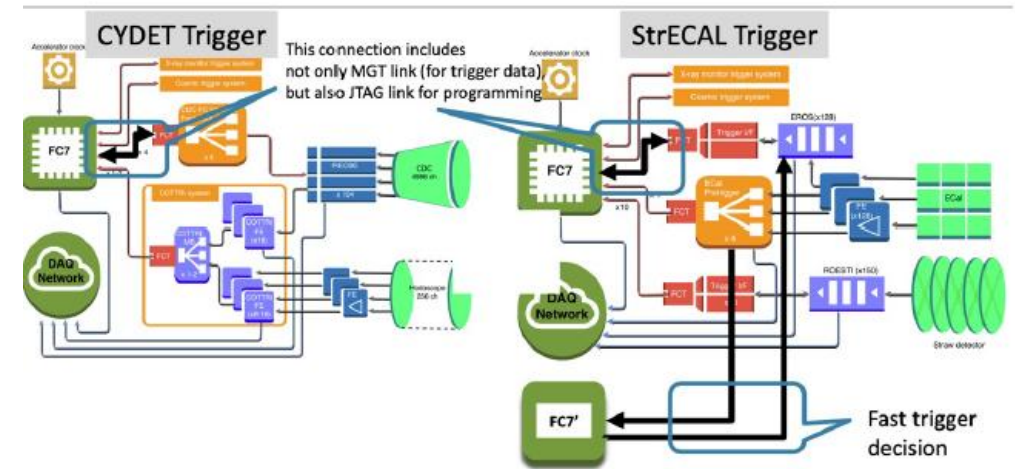
Upstream/Downstream : iRPC(IP2I/LPCA)

- Discussion on integration plan is ongoing.



Trigger & DAQ system for COMET Phase-I

- High trigger rate (20-30 kHz) for DAQ
 - Mostly background hits
 - Beam electron, secondary from capture neutron/gamma
 - Online trigger suppress BG hits
- A configurable and flexible Trigger system
 - Central system based on commercial CERN product and a custom interface board
 - Ensuring commonality in interfacing with different systems.
- Online BG hit/event classification using charge and layer features
 - Trigger board implementation to the LUT of FPGA
 - Trigger rate reduced from 91 kHz to 13 kHz, 96% efficiency and $3.2\mu\text{s}$ latency.



FC7 (CMS)



FCT



COTTRI



Summary & Schedule

- COMET is an experiment at J-PARC searching for muon to electron process.
 - Aims at single event sensitivity (S.E.S) = 2.6×10^{-17} (x10000 better) with 1 year beam time using 56 kW 8 GeV proton beam.
- COMET will be carried out in two phases and Phase-I is under construction.
 - Aims at S.E.S = 3×10^{-15} (x100 better) with 150 days beam time using 3.2 kW 8 GeV proton beam.
 - Will directly measure the muon beam.
- COMET Phase-I is expecting its beamtime in 2028

	2025												2026												2027												2028		
	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3			
DSBS installation / commissioning																																							
Refrigerator Overhaul / Compressor motor																																							
DSBS+MTS commissioning / field measurement																																							
Detector, beam window installation																																							
CyDet trigger test / cosmic-ray test																																							
PCS power supply installation																																							
PCS yoke const., TRT installation																																							
Refrigerator Overhaul / Oil separator																																							
PCS cooldown / commissioning																																							
Magnet integration test / field measurement																																							
Refrigerator maintenance																																							
Beam Dump Reconstruction																																							
CS inner Shiled																																							
Pion Production Target																																							
Equipment in Beam Room																																							
Ceiling Shield / Air tightness																																							
Beam Operation																																							

Y.Fujii, COMET run coordinator: **We will not delay this schedule no matter what**

Thank You!



COMET ちゃん
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