A Search for a Charged Lepton Flavour Violating Process; Muon to Electron Conversion in COMET

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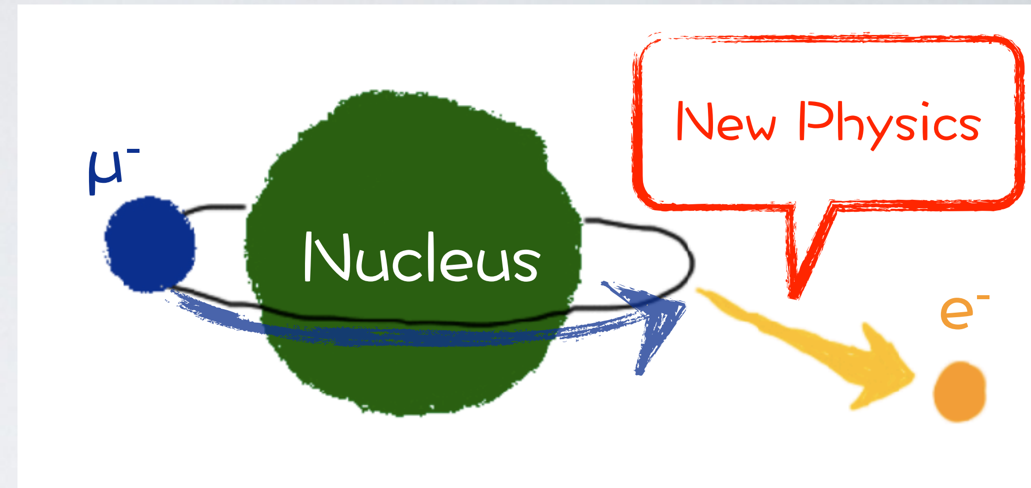
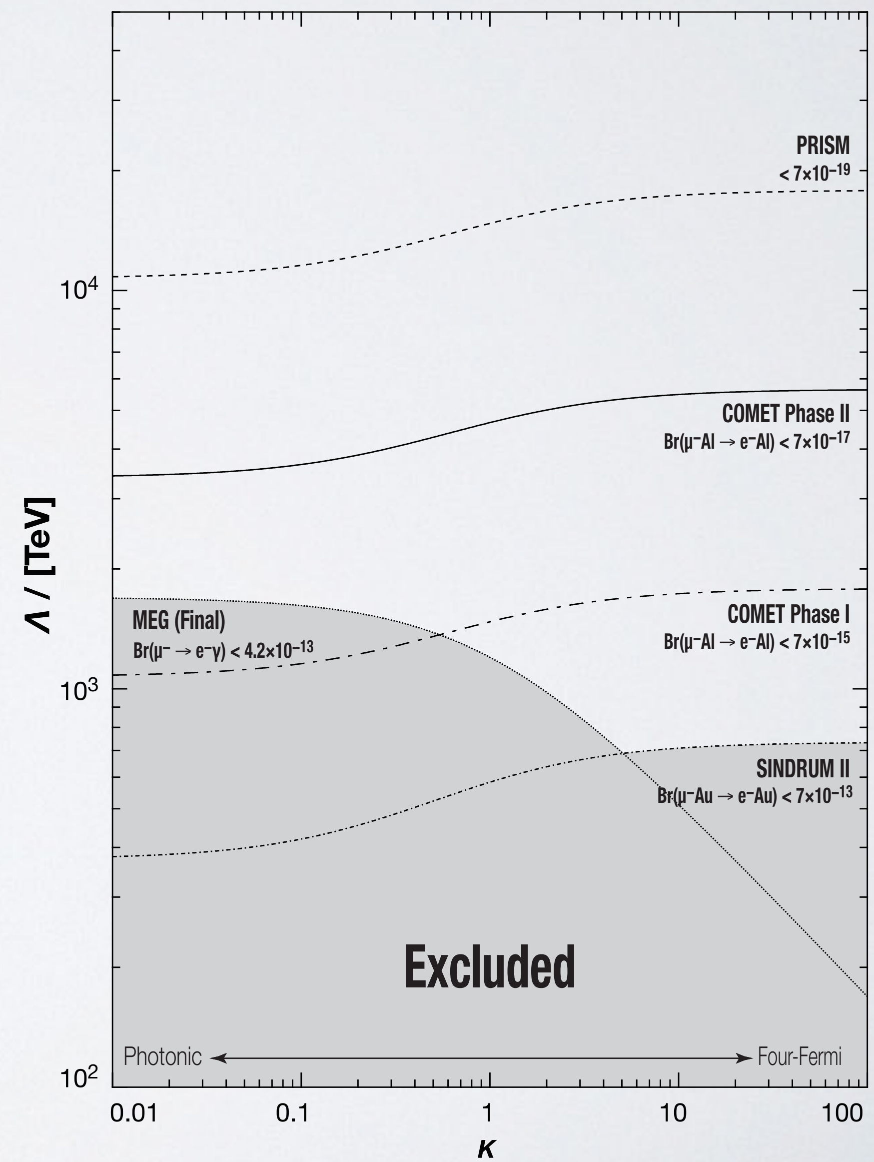
EPS-HEP 2019, Ghent, Belgium

The μ-e Conversion



- A flavour violating process in a muonic atom
  - Strongly suppressed in the SM $<10^{-50}$

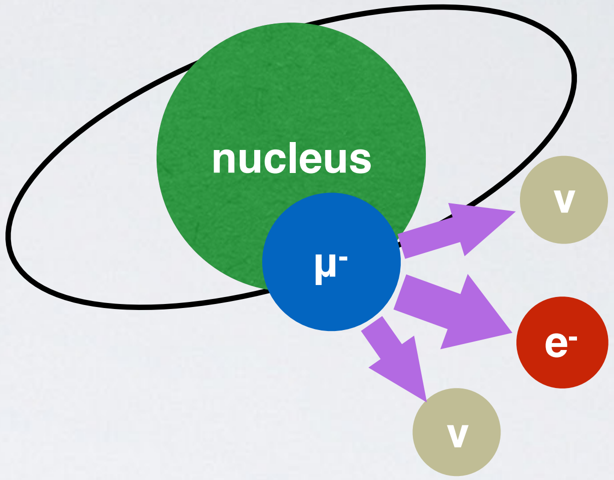
  ⇔New physics allow the detectable conversion rate up to 10^{-14}
  - Clear signal of new physics
- Simple kinematics
  - $\mathbf{E_{\mu e}=M_\mu-E_B-E_{recoil}\sim105MeV}$
- Current Upper Limit: 7×10^{-13} by SINDRUM-II (2006)
  - New physics may be almost there
- COMET aims **100** & **10,000** times better sensitivity in Phase-I & Phase-II

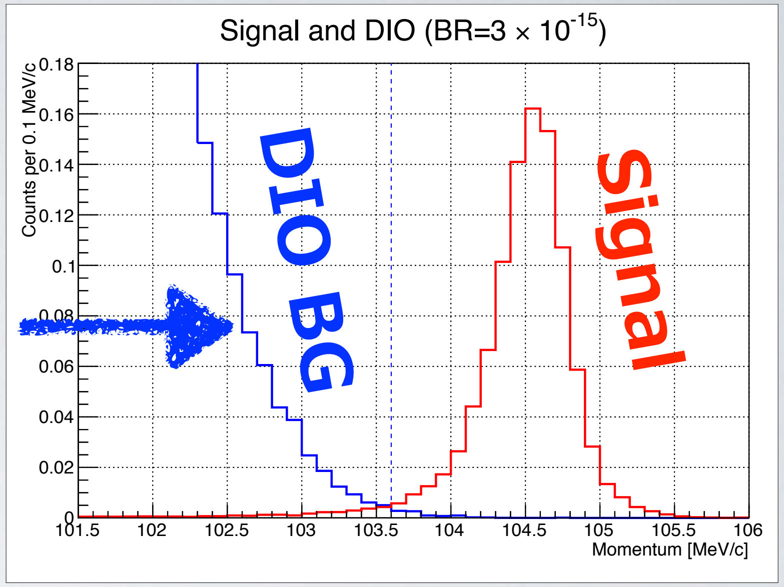


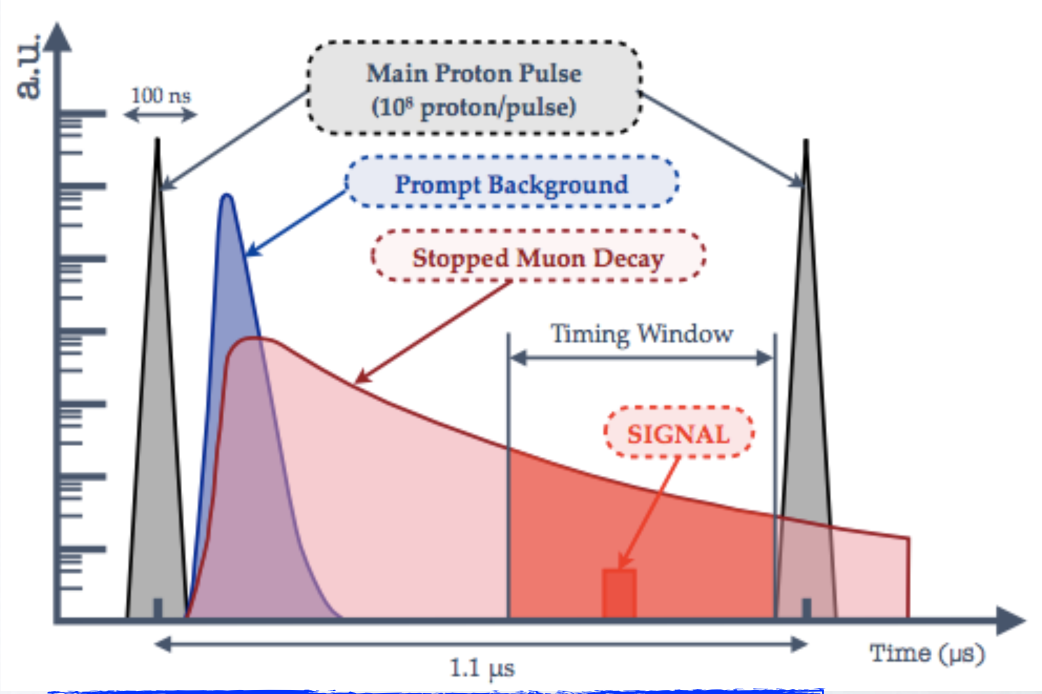
Y. Fujii, EPS-HEP2019@Ghent

Key Challenges

- **Statistics**
  - Require >10^{17} of stopping muons
    - ➡Powerful beam
- **Background reduction**
  - Decay In Orbit (DIO)
    - ➡Good momentum resolution
  - Beam related BG
    - ➡Pulsed beam
  - Cosmic-ray BG
    - ➡Veto detector
- **Technical issues**
  - High radiation environment
    - ➡Rad-hard electronics/detectors
  - High rate (hit/trigger/DAQ)
    - ➡Trigger system, offline pileup rejection, etc



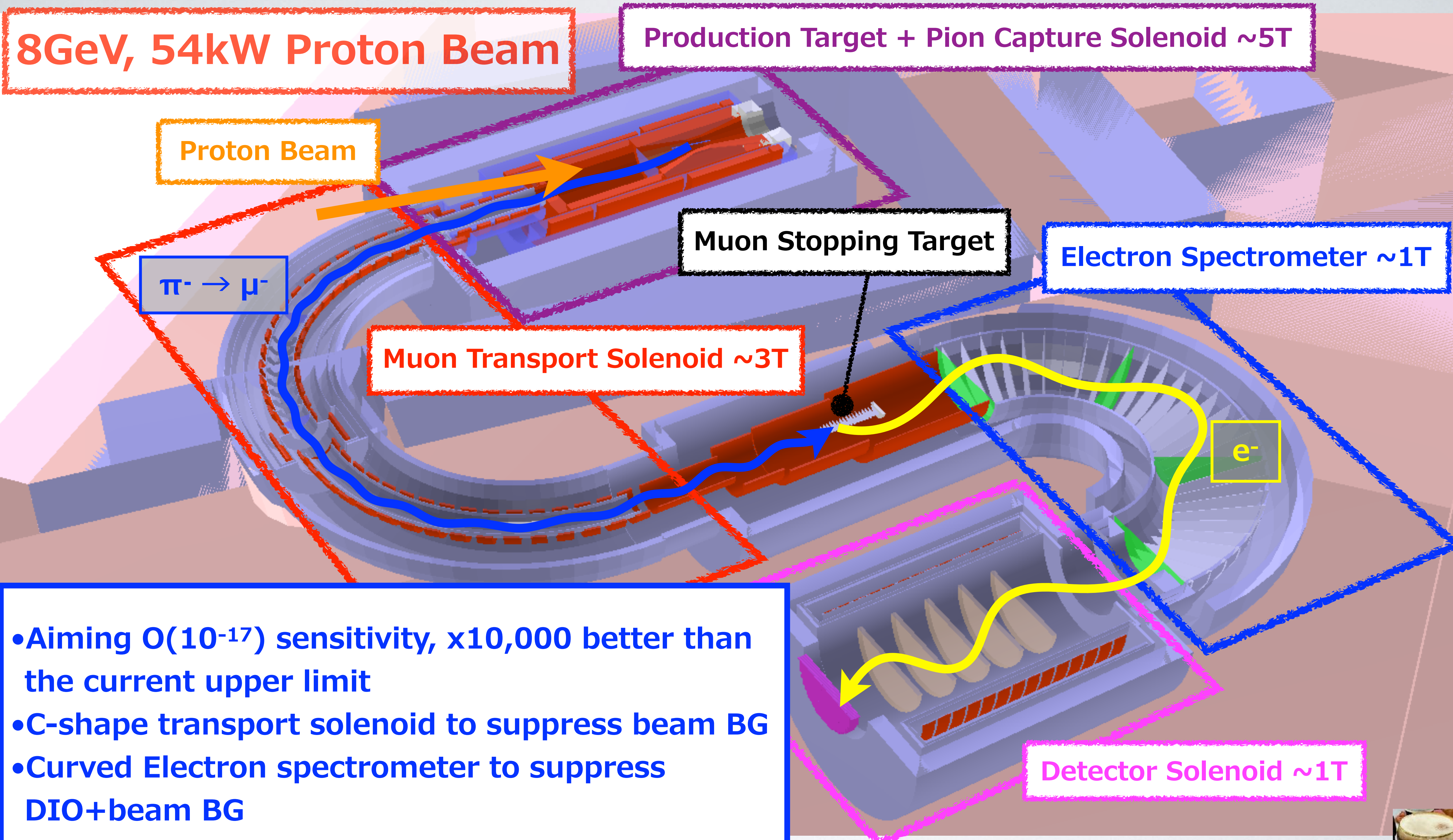




details in K. Ueno's poster

details in Y. Nakazawa's slides

COMET Overview

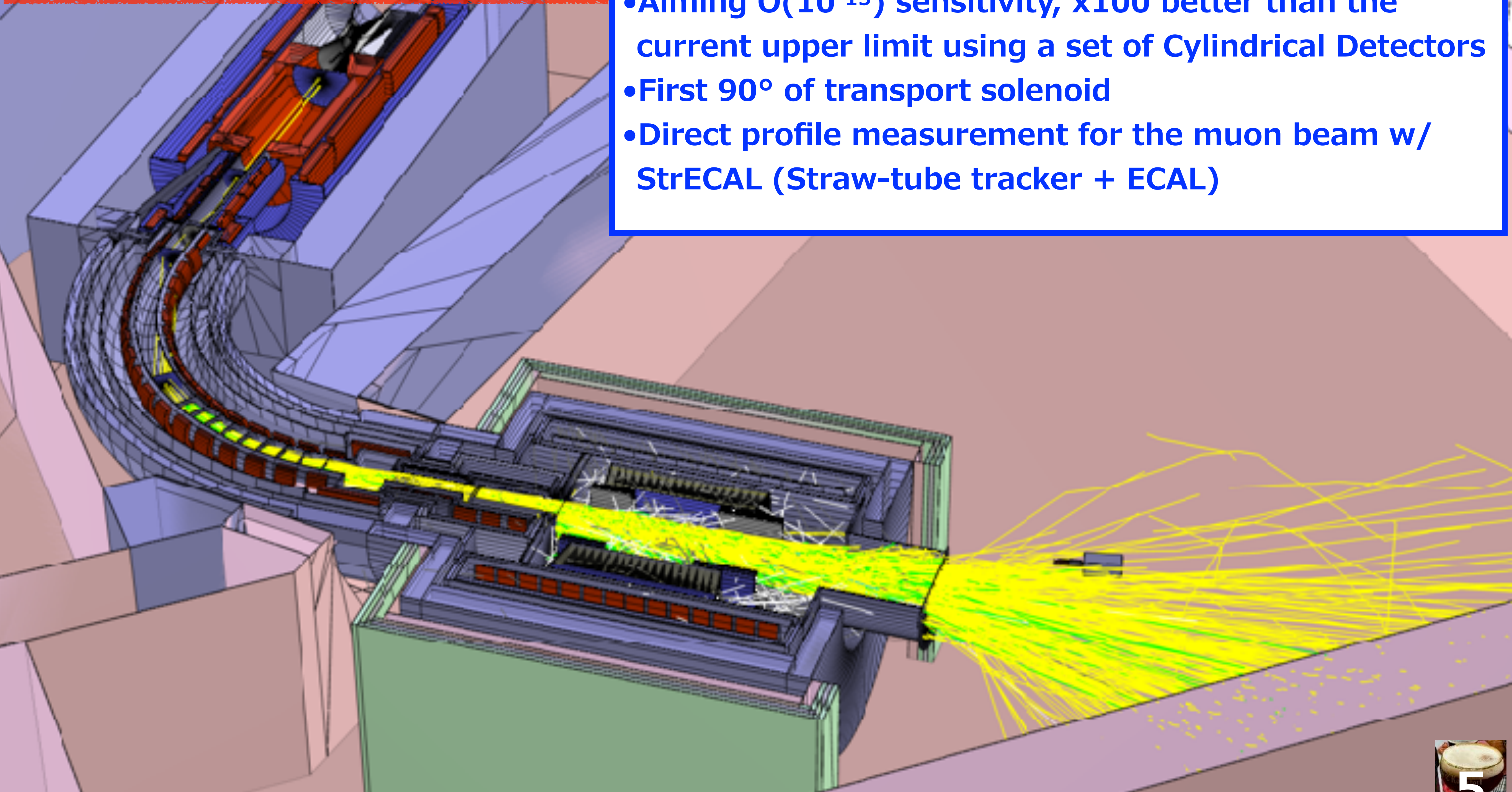


- Aiming O(10^{-17}) sensitivity, x10,000 better than the current upper limit
- C-shape transport solenoid to suppress beam BG
- Curved Electron spectrometer to suppress DIO+beam BG

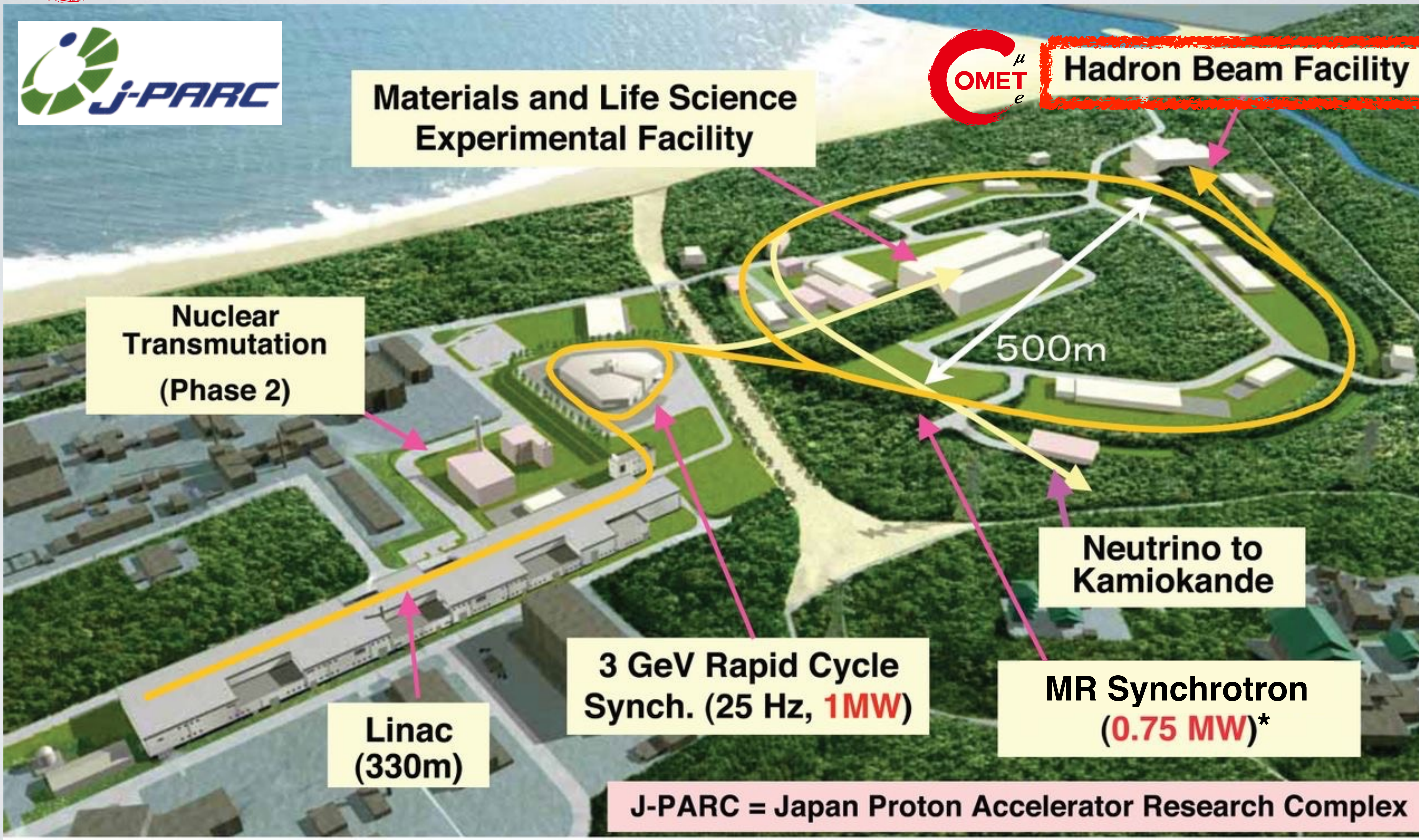
COMET Phase-I

8GeV, 3.2kW Proton Beam

- Aiming O(10^{-15}) sensitivity, x100 better than the current upper limit using a set of Cylindrical Detectors
- First 90° of transport solenoid
- Direct profile measurement for the muon beam w/ StrECAL (Straw-tube tracker + ECAL)



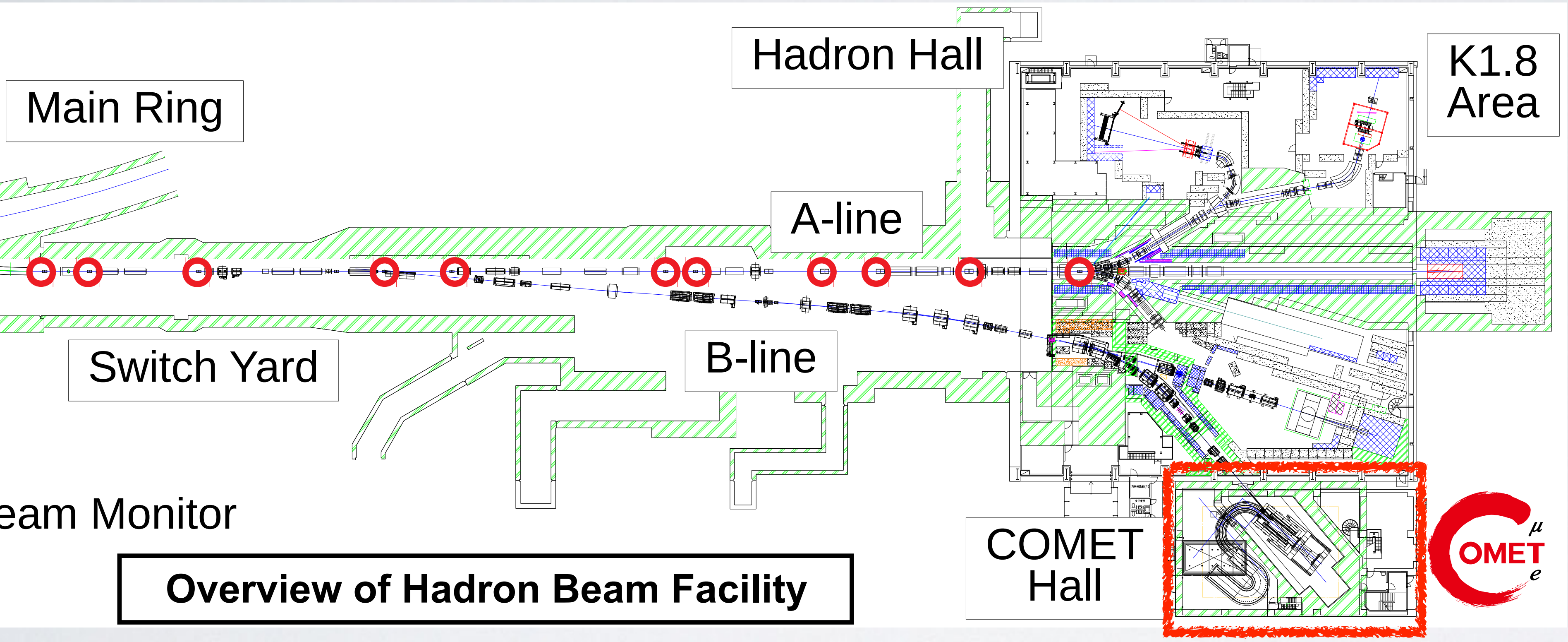
J-PARC

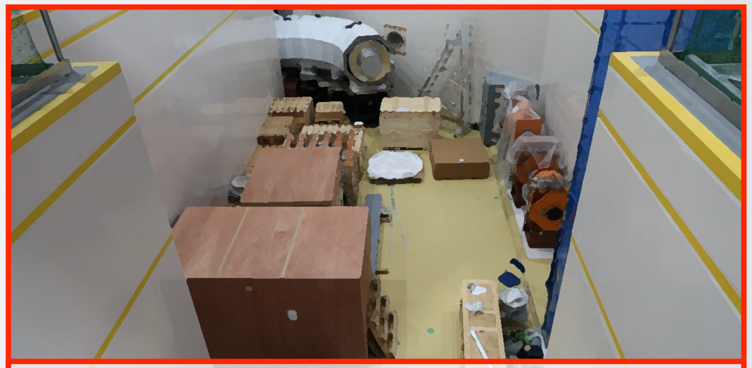


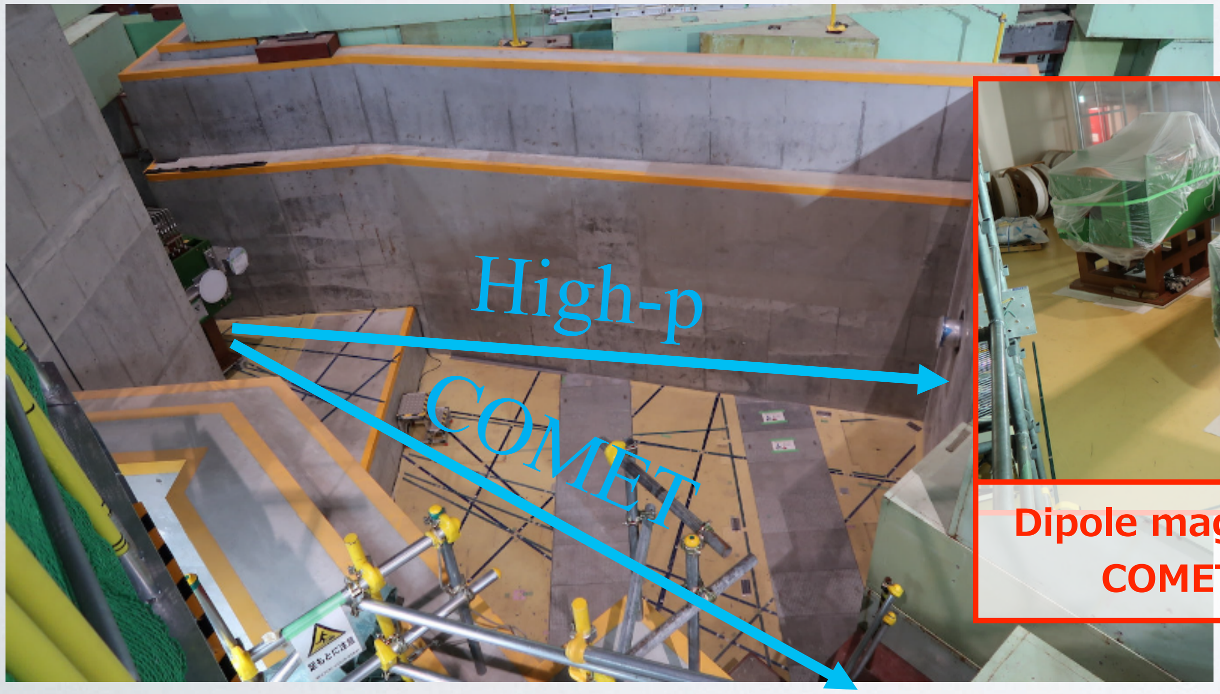
Joint Project between KEK and JAEA

*design value

Experimental Facility



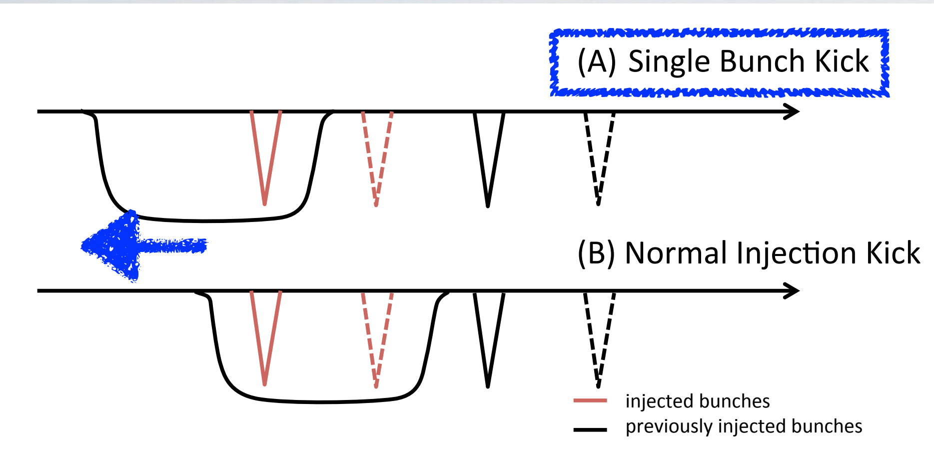

COMET Experimental floor

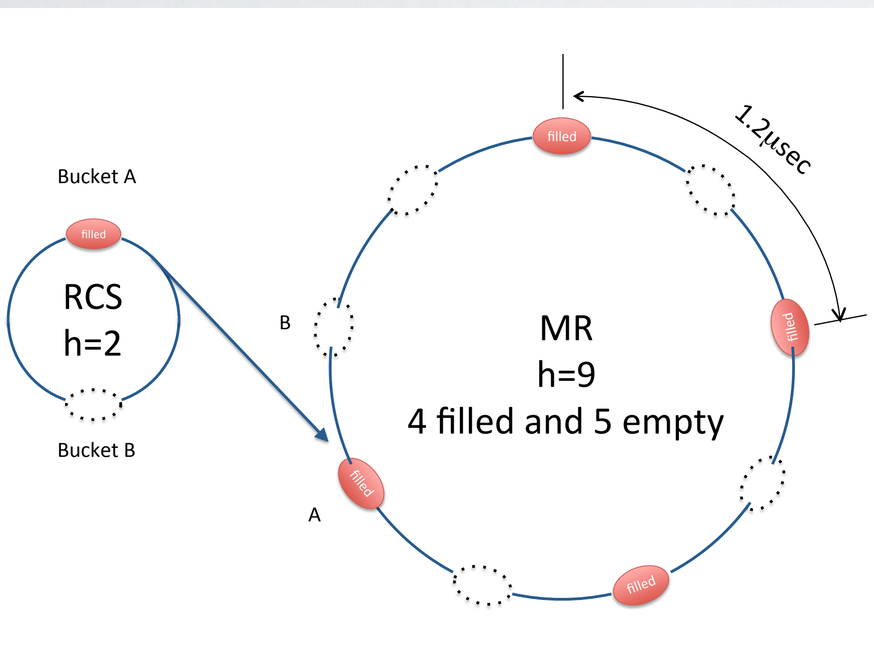


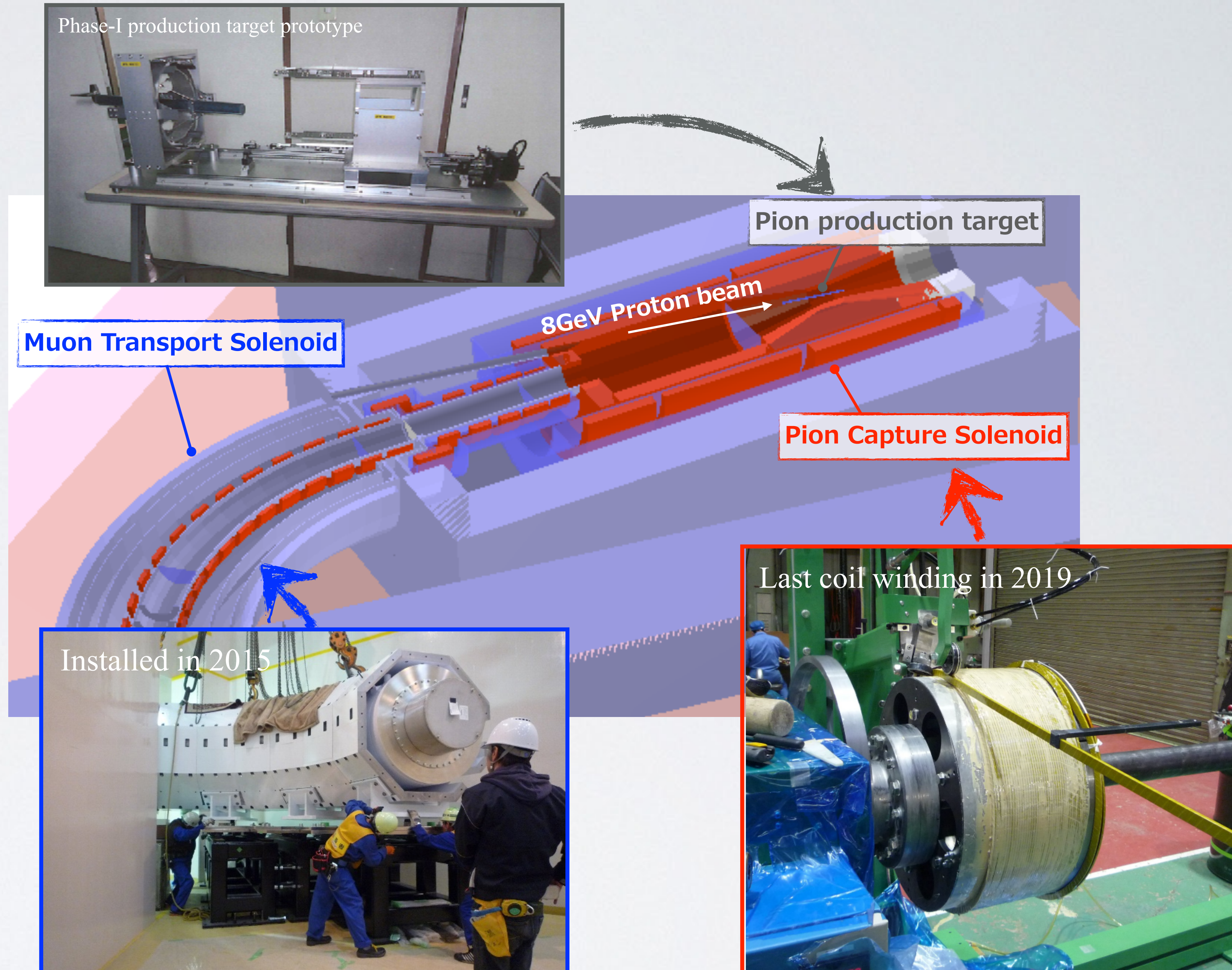

Dipole magnets for High-p/
COMET beam-lines

- COMET building, beam-line shields are almost completed
- Beam-line and magnets are under construction

Proton/Muon Beam



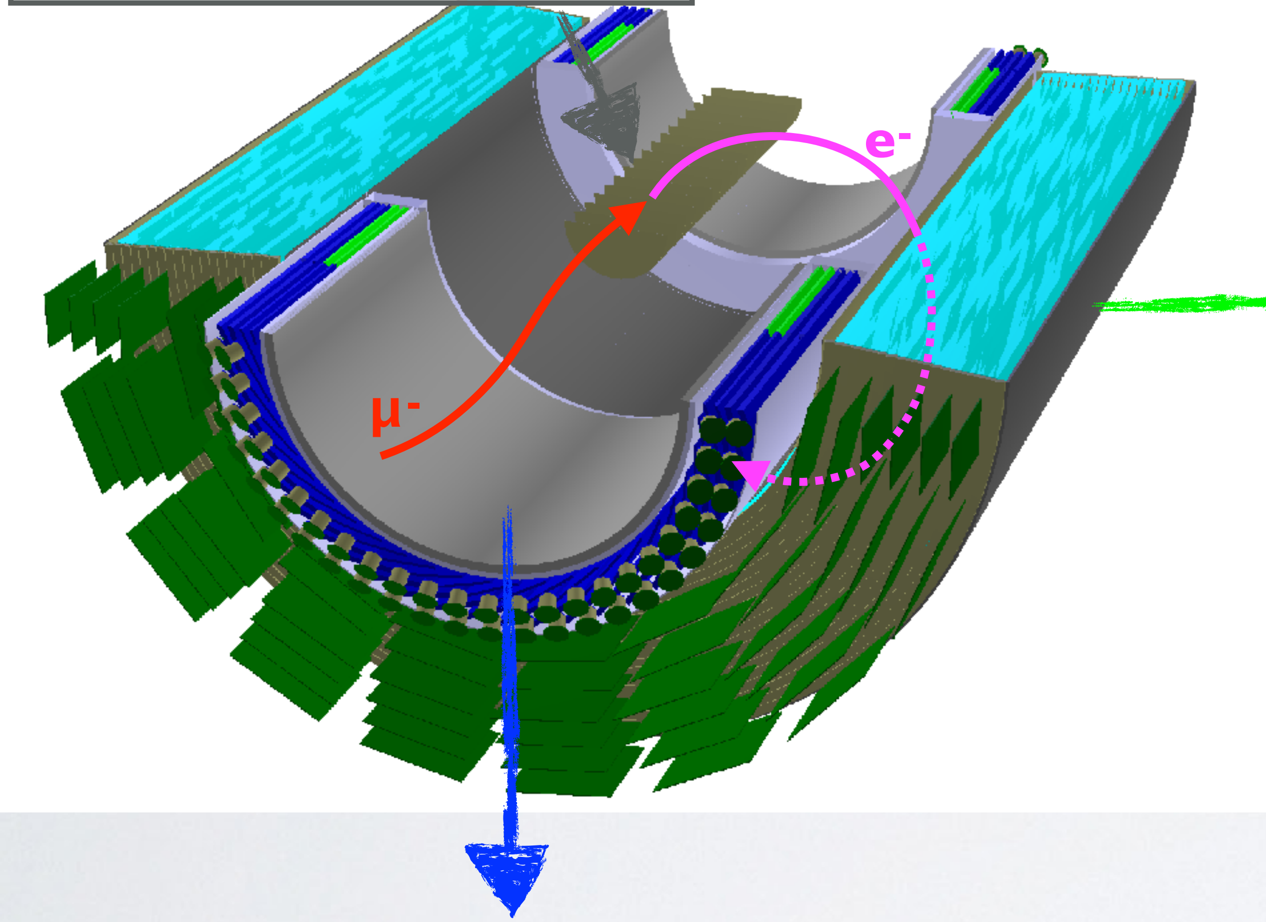




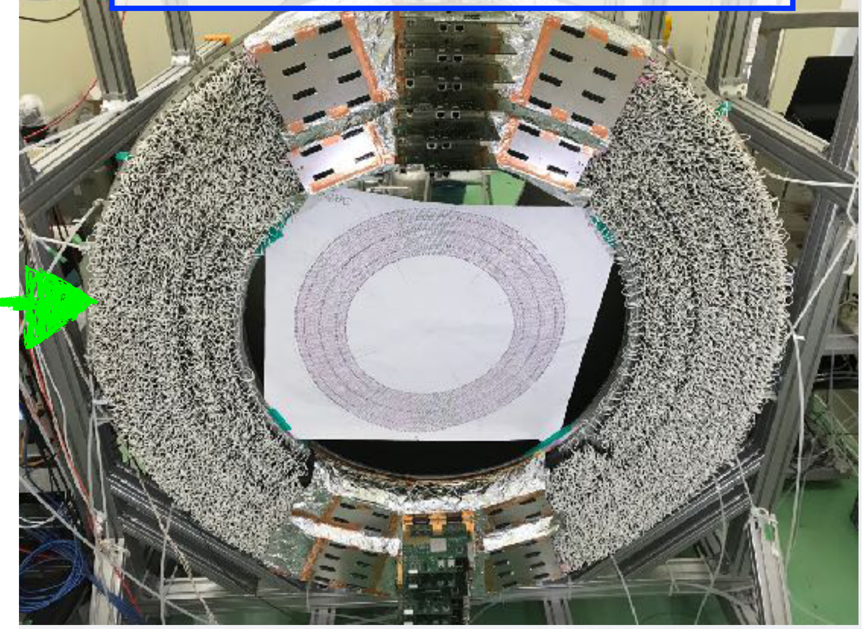
- A Bunched Slow Extraction (BSX) operation w/ 8GeV protons has been established for COMET @ J-PARC Main Ring
- Preparation for the muon beam-line is going well

CyDet

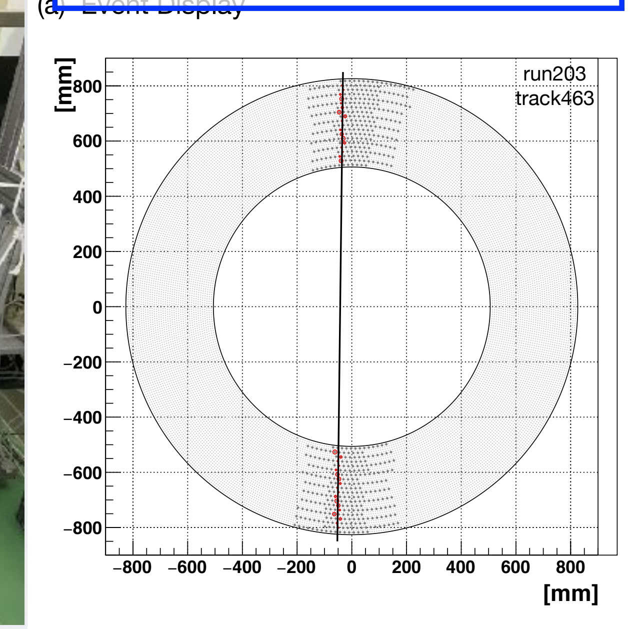
17 topping target discs, 0.2mT Al



CDC in operation of cosmic-ray test

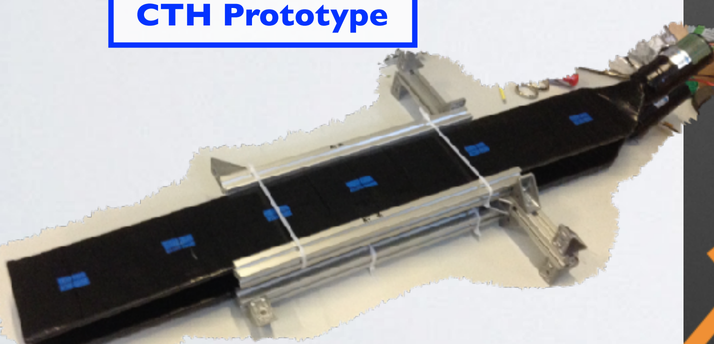


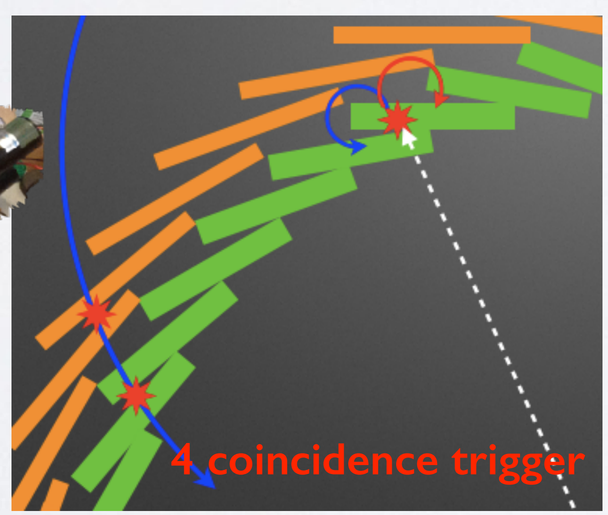
An example of cosmic-ray event



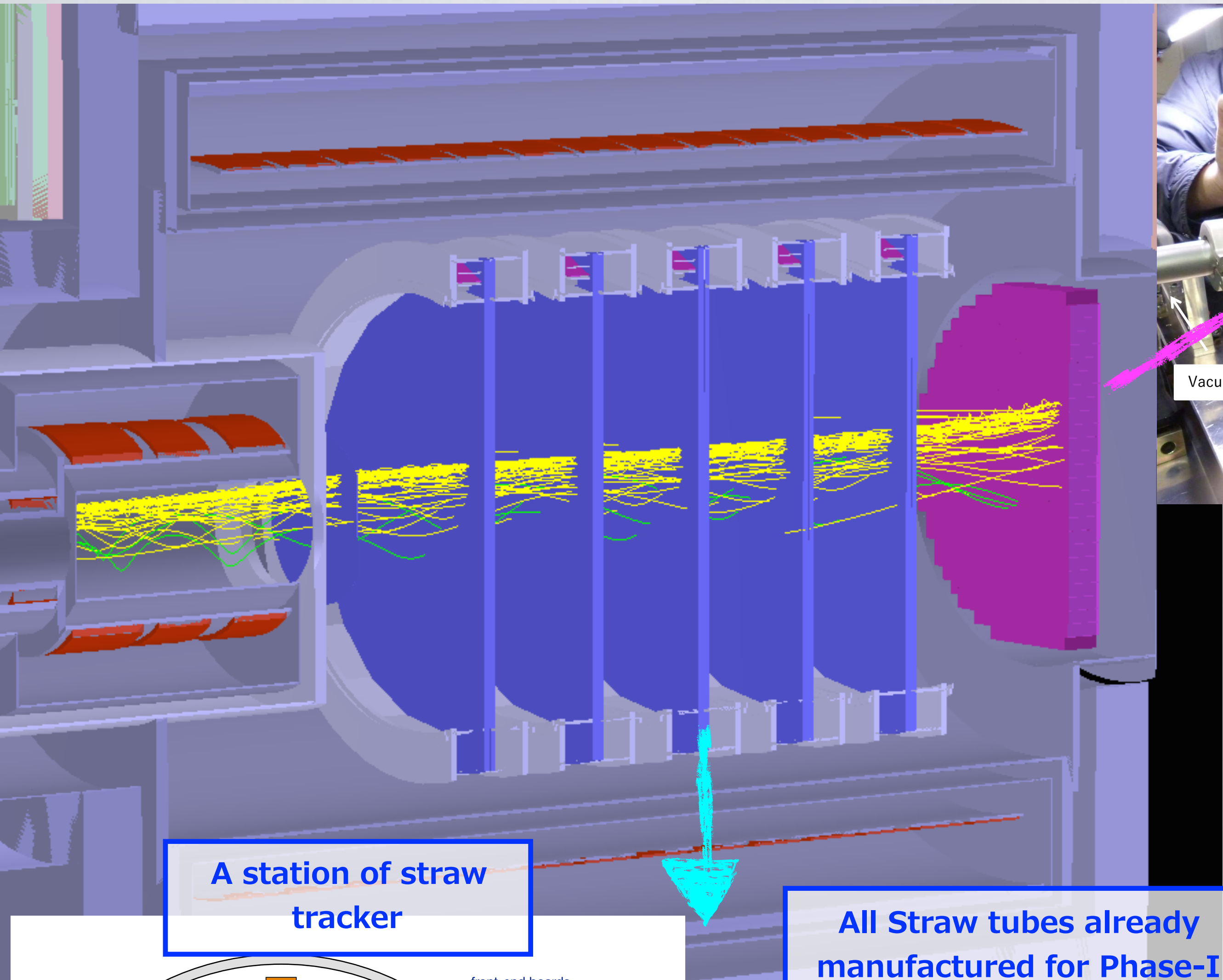
- **Cylindrical Drift Chamber (CDC)** consists of ~5k sense wires, all stereo, $He:iC_5H_{10}=90:10$
  - Already constructed and being tested using cosmic-rays → Details reported by M. Moritsu
  - All readout electronics were produced
  - **σ_x ~ 170μm**
- **CyDet Trigger Hodoscope (CTH)** is a set of 48(64) staggered pairs of a scintillator bar & a Cherenkov radiator
  - **σ_t <1ns**
  - Almost ready for the final production

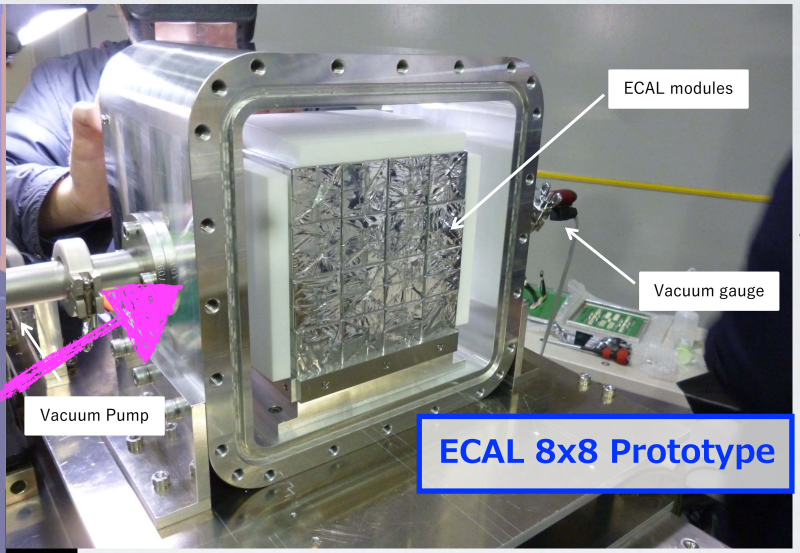
CTH Prototype



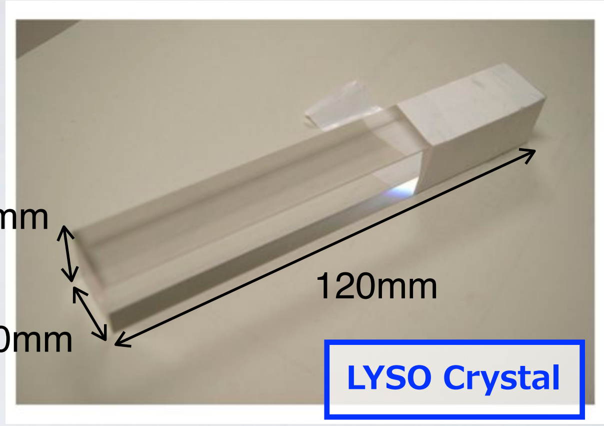


StrECAL





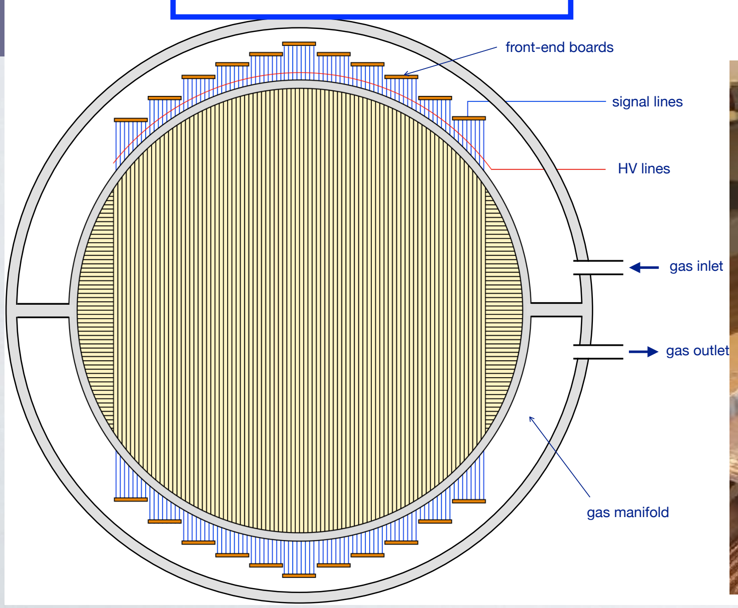
ECAL 8x8 Prototype



LYSO Crystal

- Phase-I beam measurement + Phase-II physics measurement
- **Straw-tube Tracker** consists of 2.4k straw tubes operational in vacuum
  - 20μm thick/10mmφ straws are ready for assembly (more details in Michail Kravchenko's poster)
  - **σ_x ~ 150μm**
- **ECAL** is a primary trigger detector
  - Measure the energy and timing of e- using ~2k LYSO crystals
  - **σ_E ~ 4.5%, σ_t <1ns** @105MeVe-

A station of straw tracker

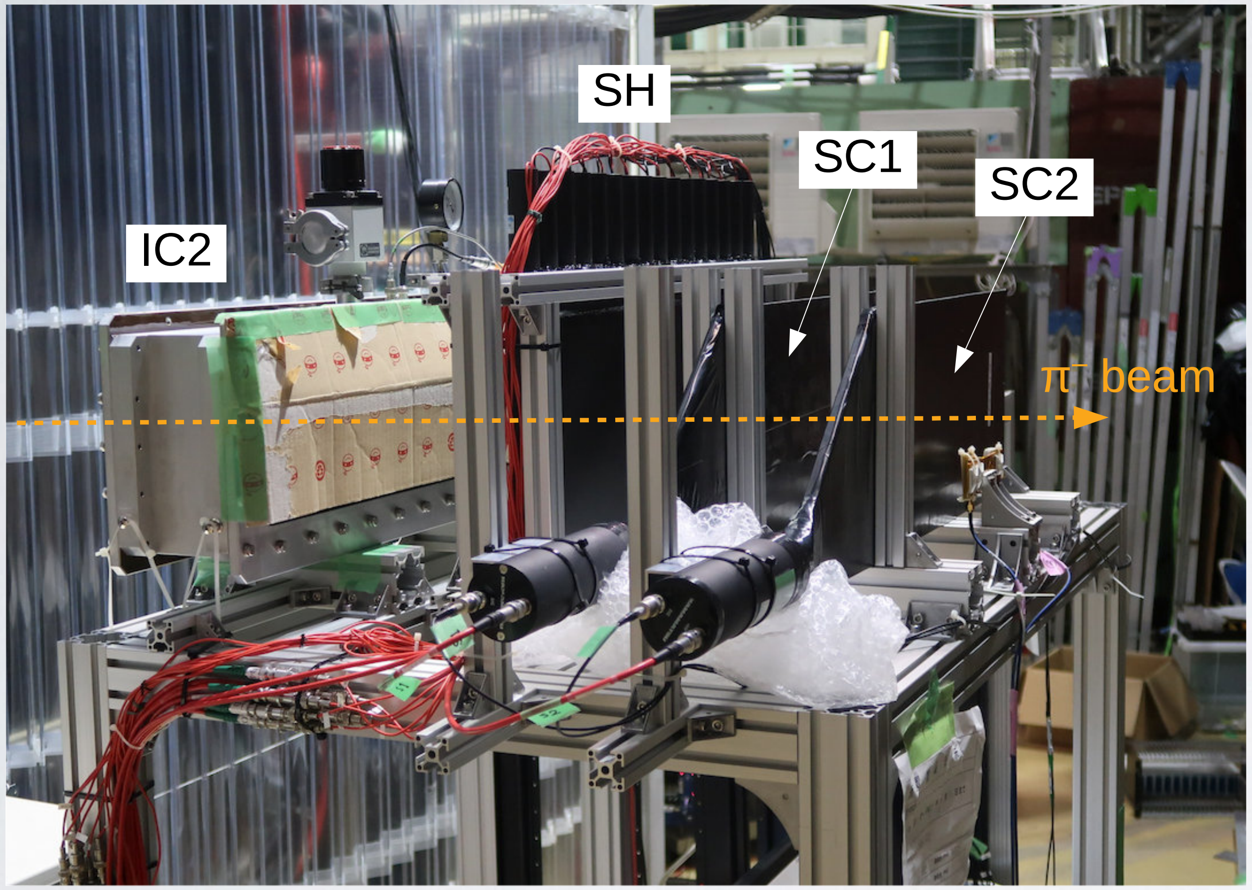


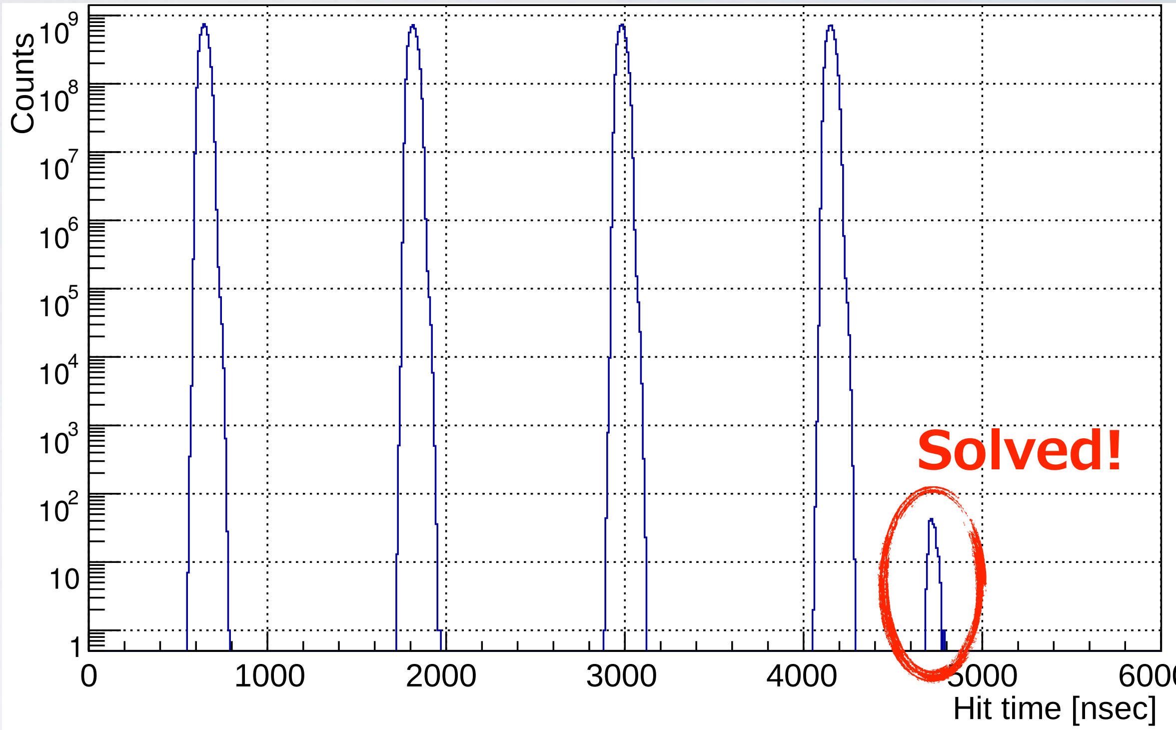
All Straw tubes already manufactured for Phase-I

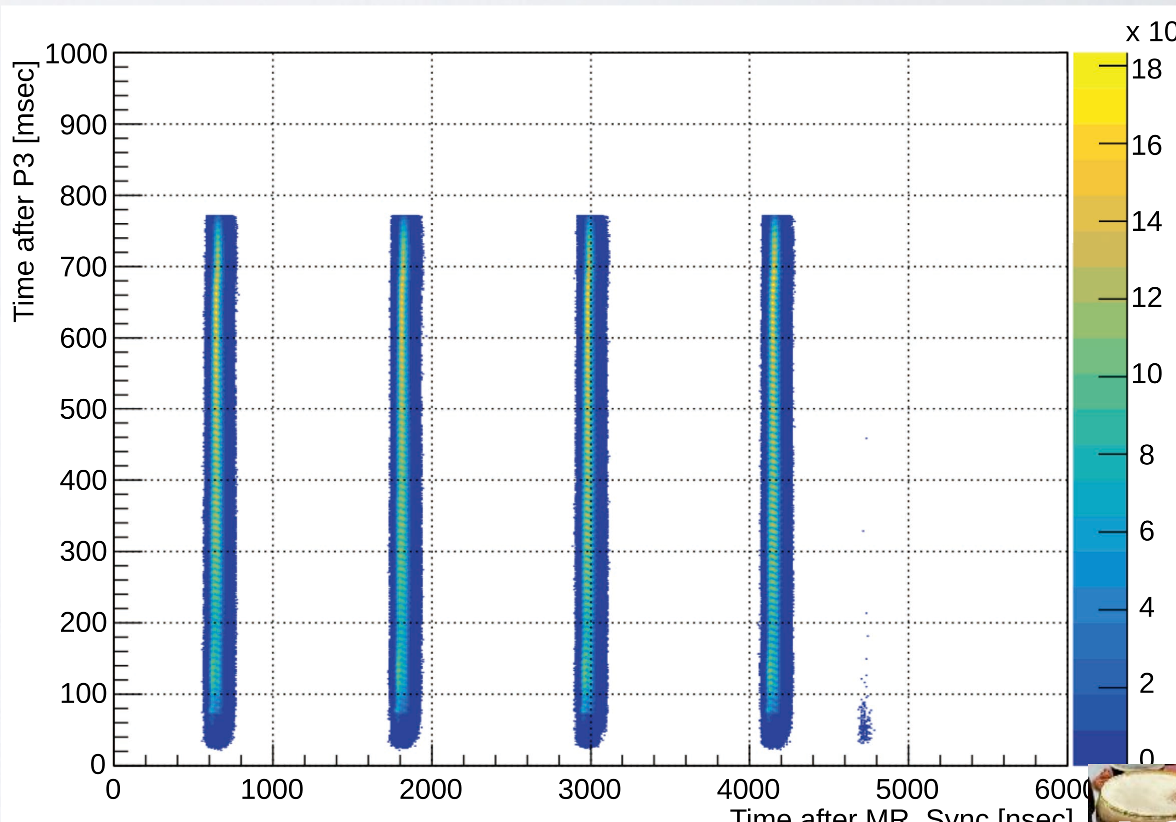
Phase-II Straw Tube

- Succeeded to manufacture **12µm** thick/ 5mmφ straw tubes
- Achieve the vacuum tightness against 4 bar pressure
- Further studies are ongoing @JINR

Extinction Measurement



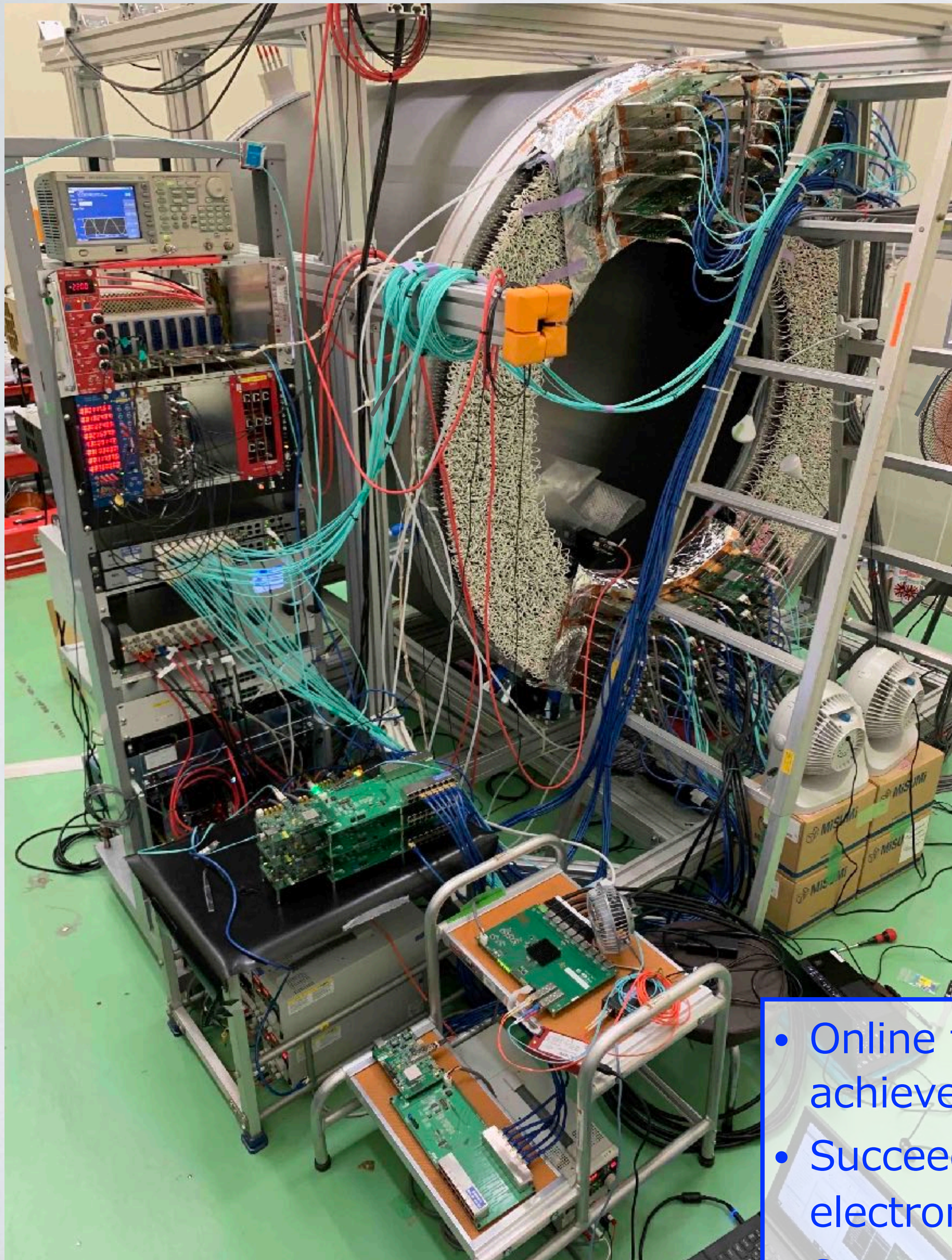


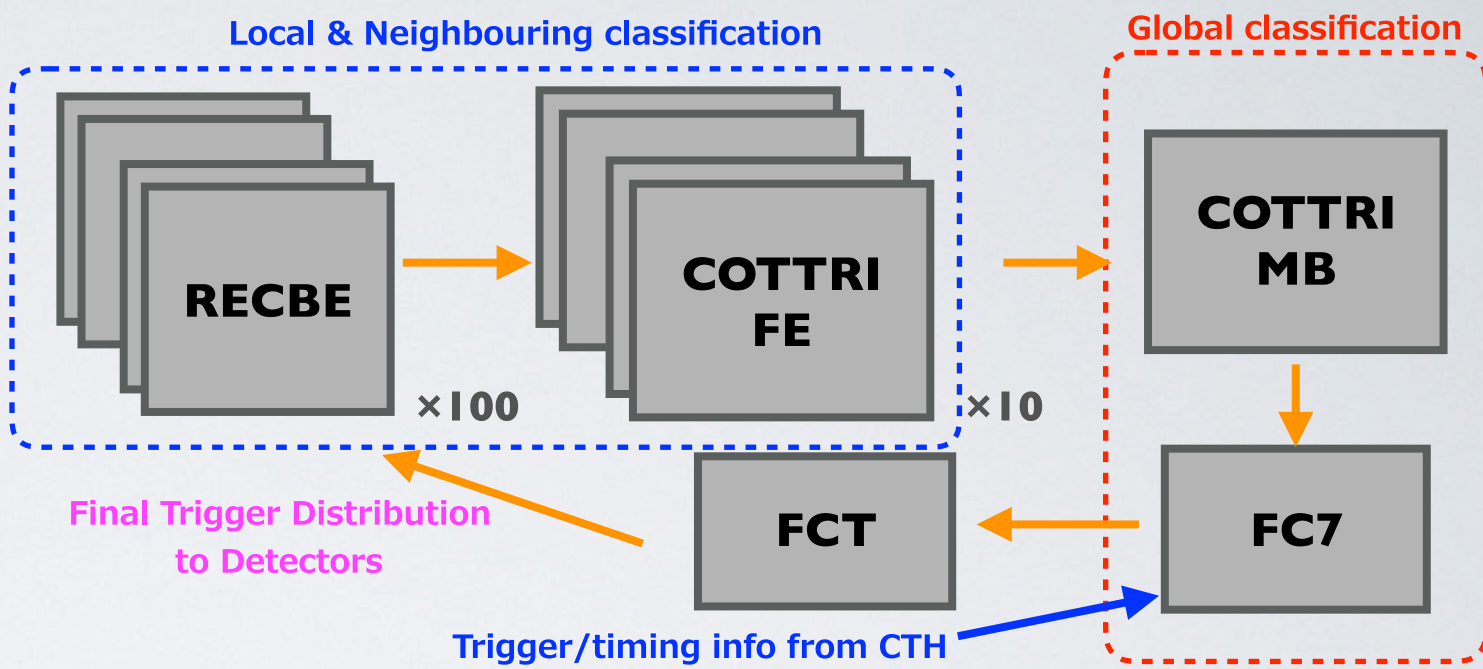


- Extinction factor is measured w/ 8GeV BSX mode @J-PARC in 2018
- Reason for the last bunched leakage protons was confirmed and fixed in 2019 (IPAC'19, H. Nishiguchi)
- Excellent extinction factor*, **$<6\times10^{-11}$** is achievable!

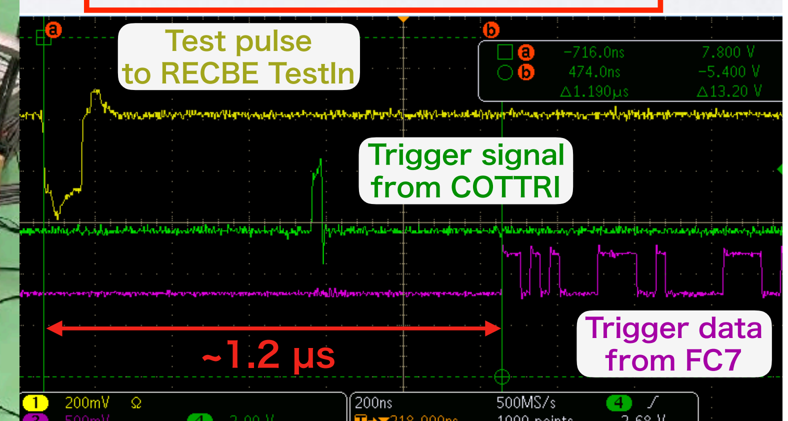
* (#of residual protons)/(#of protons in a pulse)

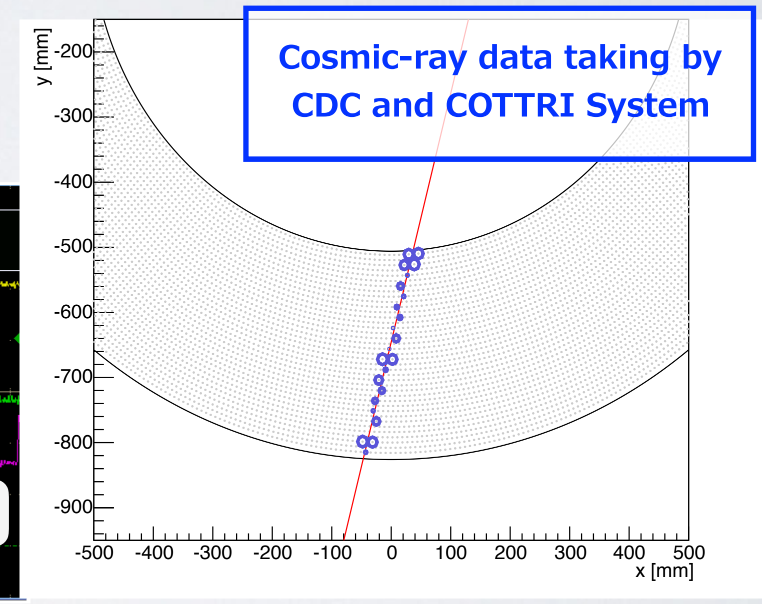
Online Tracking Trigger





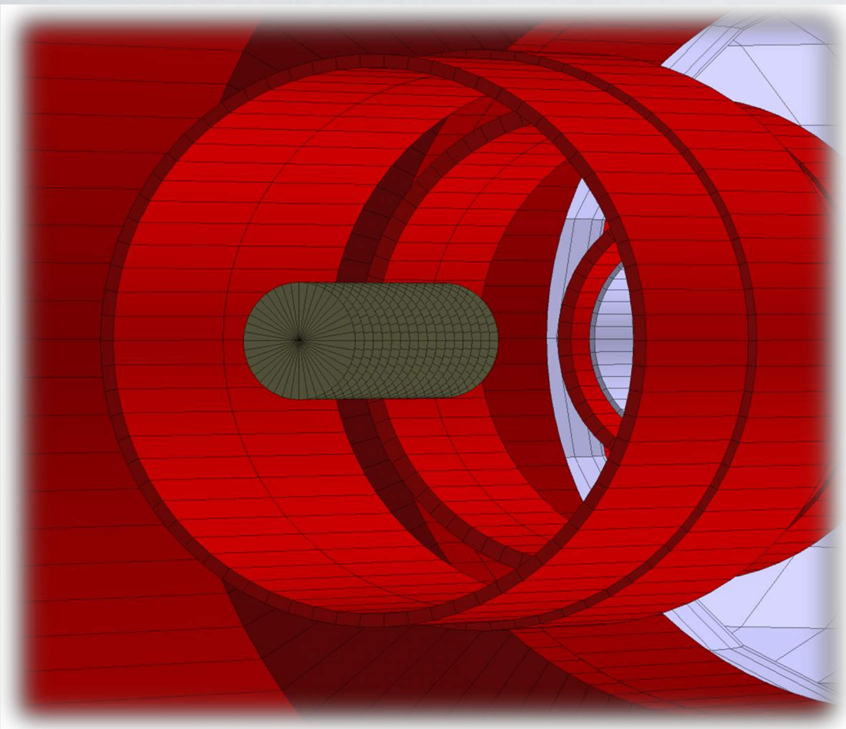
Measured trigger latency

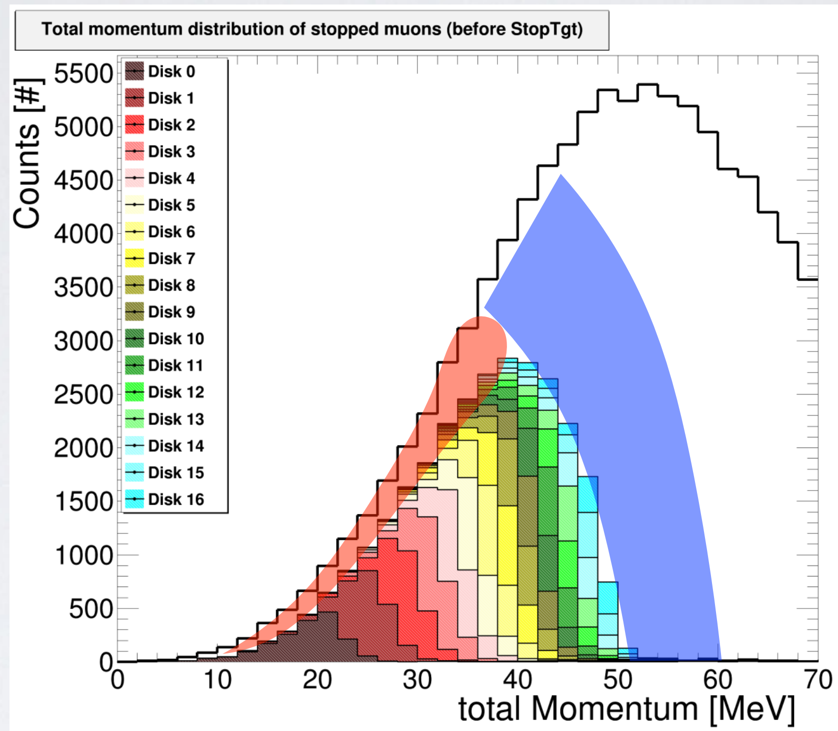




- Online trigger based on CDC information is being developed to achieve <10kHz trigger rate in COMET Phase-I
- Succeeded to take cosmic-rays w/ almost final ver. trigger/DAQ electronics
- See more details in Y. Nakazawa's talk

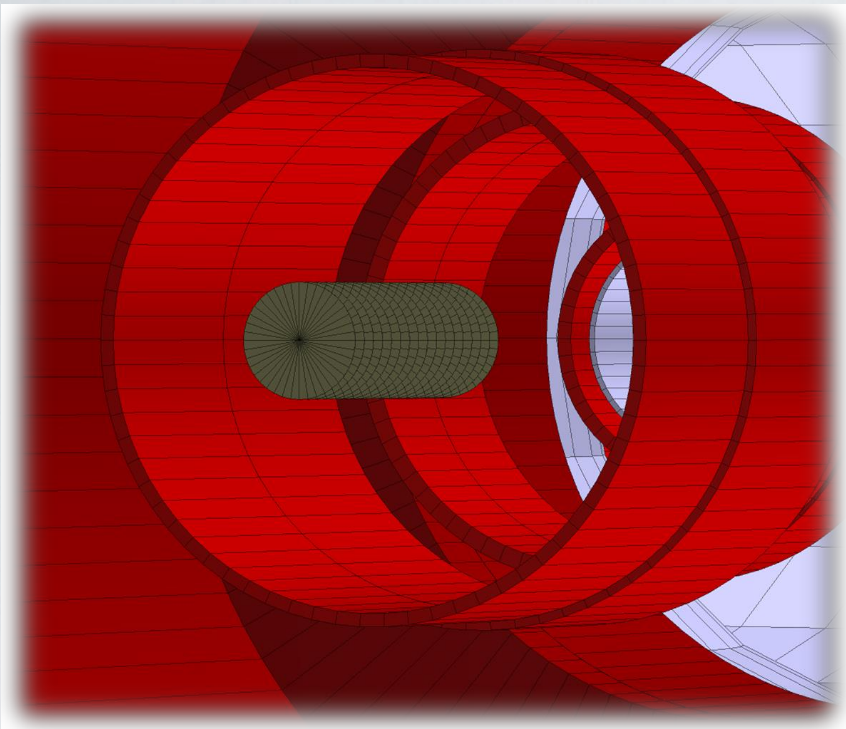
COMET Phase-II Study

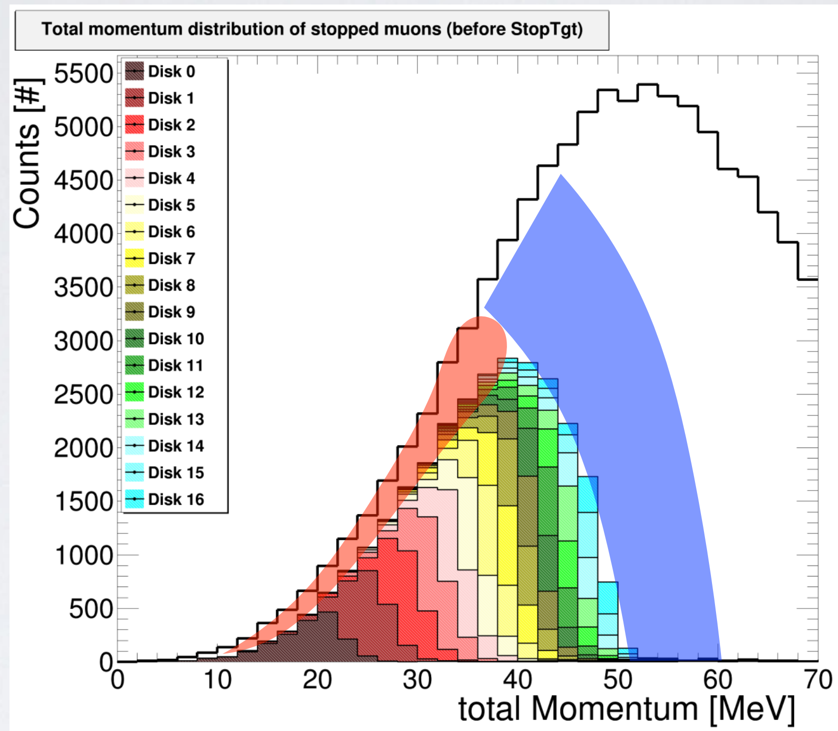




- Revisited Phase-II configuration to maximise the physics sensitivity
- Original sensitivity: $\sim 3\times10^{-17}$
- Being optimise;
    1. **Production target**
    2. **Magnetic fields**
    3. **Stopping target**
    4. Electron Spectrometer
    5. Detectors

COMET Phase-II Study





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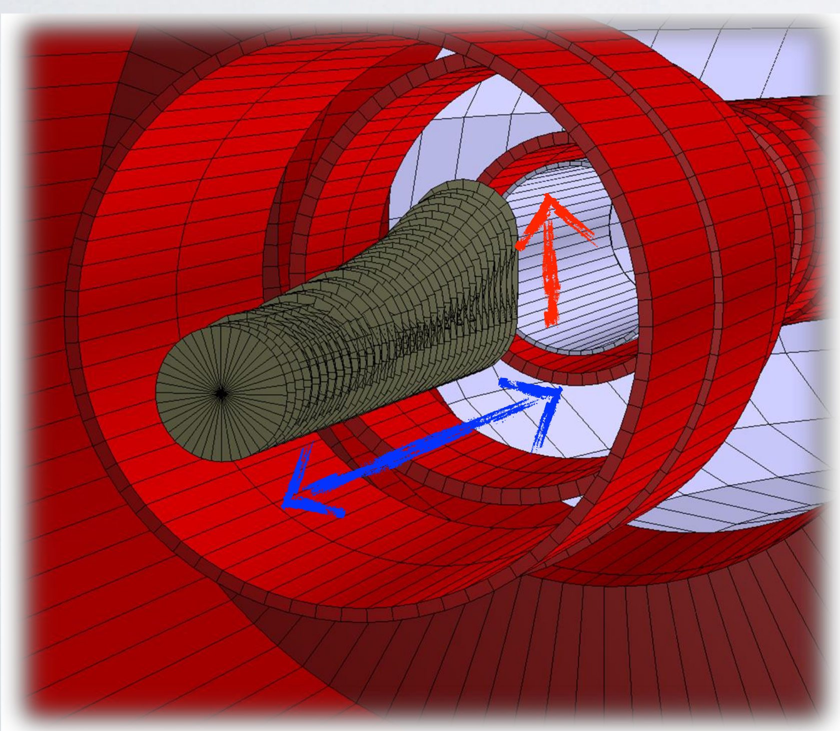
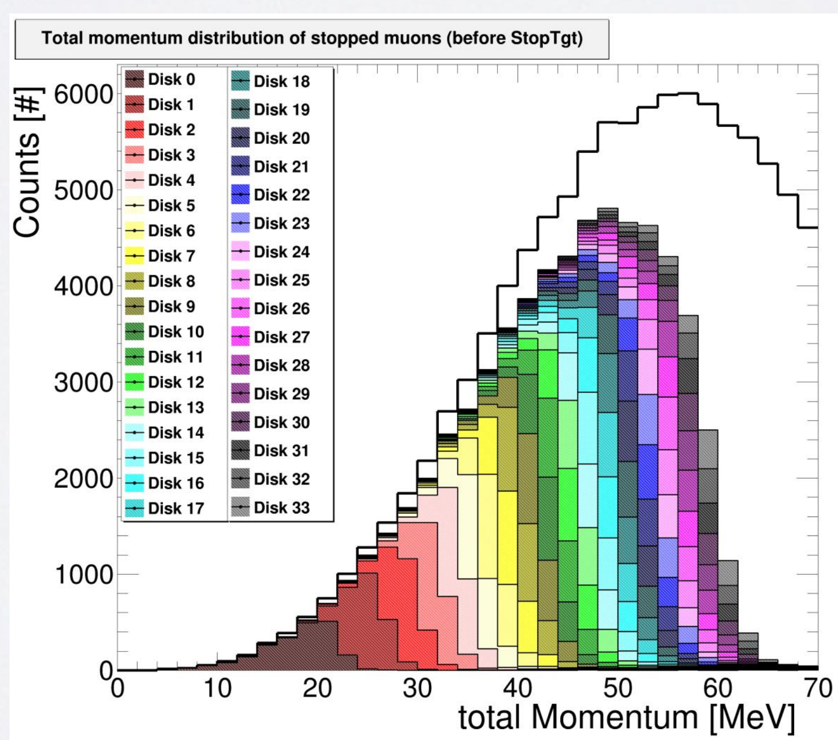
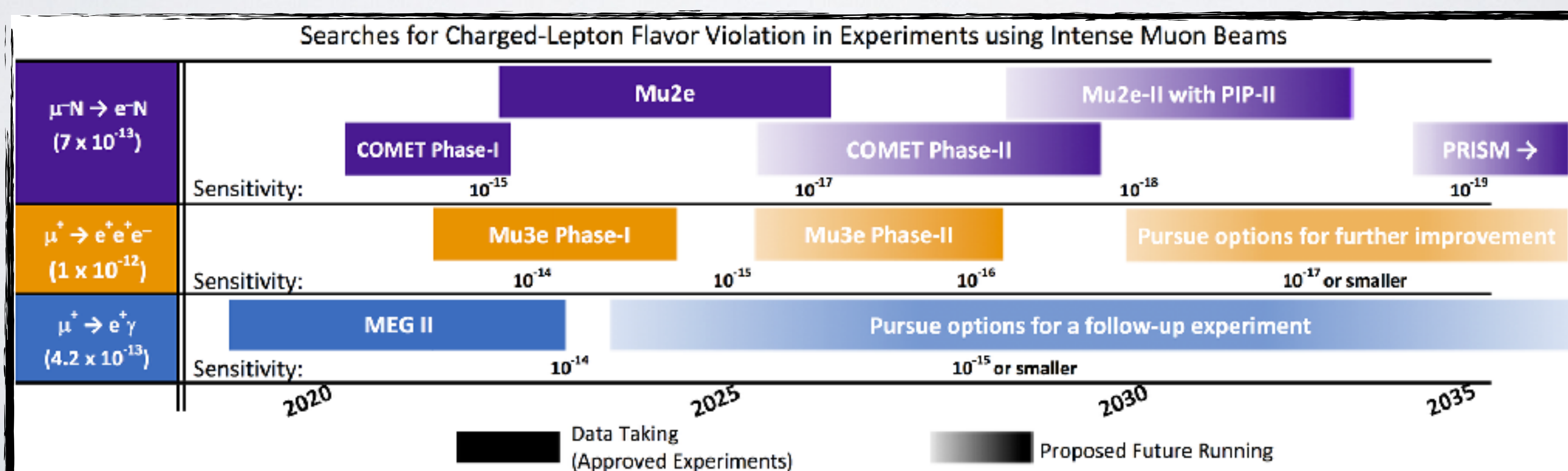




- Change geometry/location of production target, B-fields
  - $1.7\times10^{-3} \rightarrow 2.2\times10^{-3}$ μ-/POT
- Increase #of discs, Modify geometry of stopping target
  - $2.2\times10^{-3} \rightarrow$ **6.4×10^{-3}** μ-/POT
- **More room to improve**

Summary & Prospects

- **Summary**
  - COMET searches for the μ-e conversion to tackle the yet-unknown BSM physics
    - Phase-I preparation is ongoing to achieve **3×10^{-15}** of single event sensitivity
    - Phase-II will follow with a **×100** better sensitivity (& ×10 further improvement)
- **Prospects**
  - COMET Phase-I will start in the early 2020s
  - Phase-II will follow soon after
  - New generation CLFV searches will come in 2020s, ***Stay tuned!***



Backup