



The COMET experiment

Satoshi MIHARA

KEK-IPNS/J-PARC Center/Sokendai

Outline

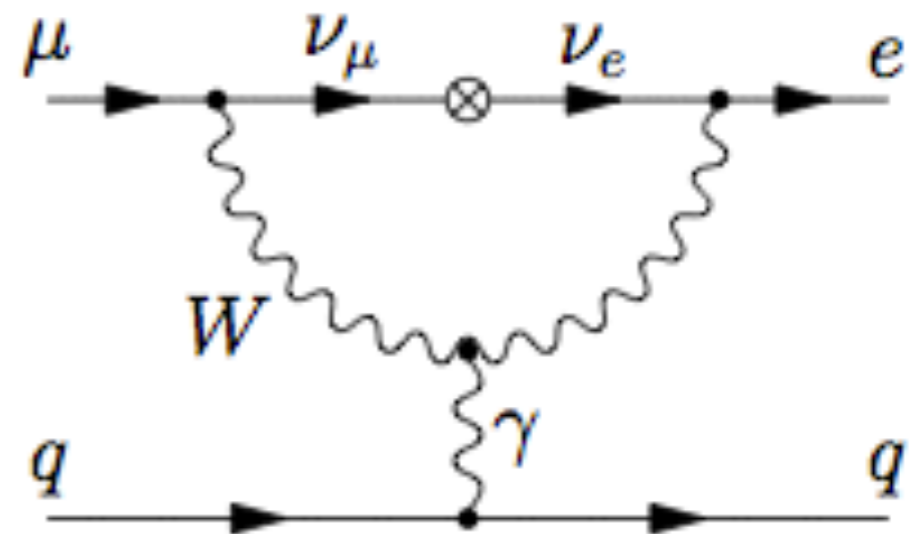
- Introduction
- Status and Plan of the COherent Muon-to-Electron Transition (COMET) experiment at J-PARC
- Future prospect of COMET
- Summary

Charged Lepton Flavor in SM

- Precise measurement of charged lepton behavior contributed to establish the SM
- No observation of “exotic decay mode”
 - Concept of Generation (Flavor)
- Lepton flavor transition is strictly forbidden in the charged lepton sector
- Neutrino Oscillation has been observed
 - ν oscillation + SM

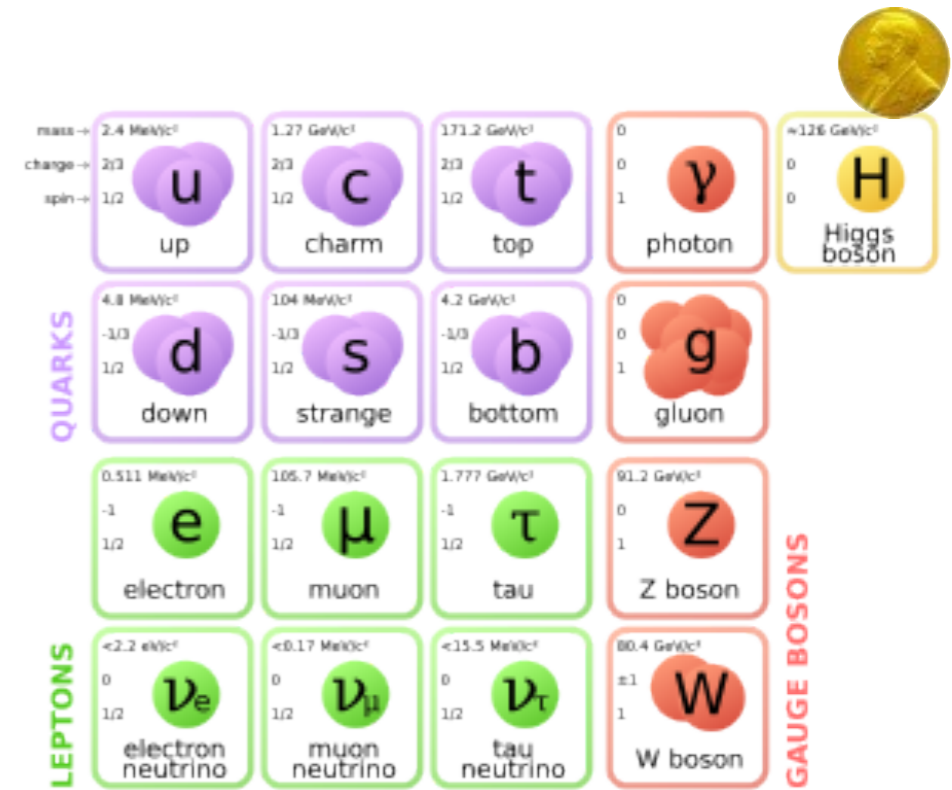
| | | | | | |
|----------------|---|---------------------------------------|--------------------------------------|-------------------------|-------------------------|
| mass → | 2.4 MeV/c ² | 1.27 GeV/c ² | 171.2 GeV/c ² | 0 | ≈126 GeV/c ² |
| charge → | 2/3 | 2/3 | 2/3 | 0 | 0 |
| spin → | 1/2 | 1/2 | 1/2 | 1 | 0 |
| | u up | c charm | t top | γ photon | H Higgs boson |
| QUARKS | | | | | |
| | 4.8 MeV/c ² | 104 MeV/c ² | 4.2 GeV/c ² | 0 | |
| | -1/3 | -1/3 | -1/3 | 0 | |
| | 1/2 | 1/2 | 1/2 | 1 | |
| | d down | s strange | b bottom | g gluon | |
| | | | | | |
| | 0.511 MeV/c ² | 105.7 MeV/c ² | 1.777 GeV/c ² | 91.2 GeV/c ² | |
| | -1 | -1 | -1 | 0 | |
| | 1/2 | 1/2 | 1/2 | 1 | |
| | e electron | μ muon | τ tau | Z Z boson | |
| LEPTONS | | | | | |
| | <2.2 eV/c ² | <0.17 MeV/c ² | <15.5 MeV/c ² | 80.4 GeV/c ² | |
| | 0 | 0 | 0 | ±1 | |
| | 1/2 | 1/2 | 1/2 | 1 | |
| | ν_e electron neutrino | ν_μ muon neutrino | ν_τ tau neutrino | W W boson | |
| | | | | | GAUGE BOSONS |

wiki

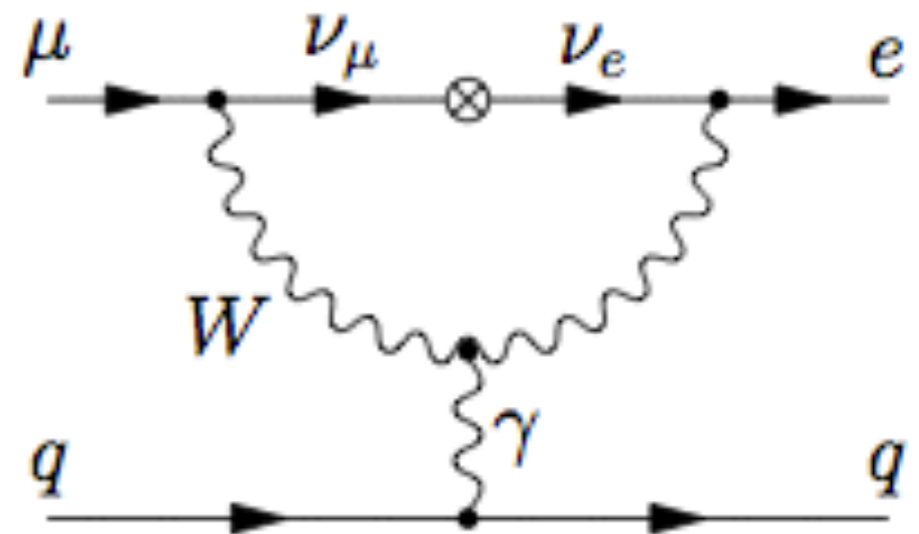


Charged Lepton Flavor in SM

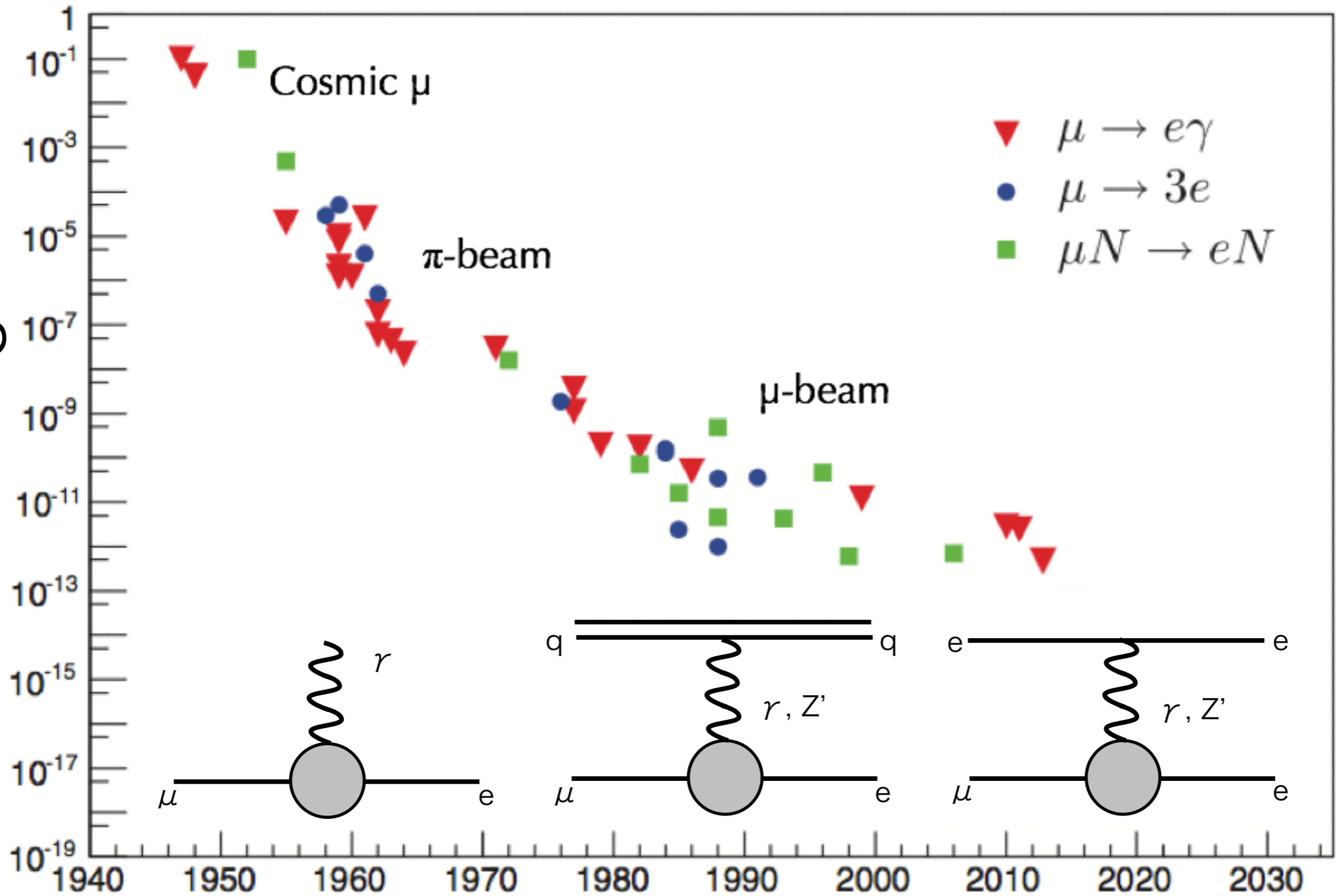
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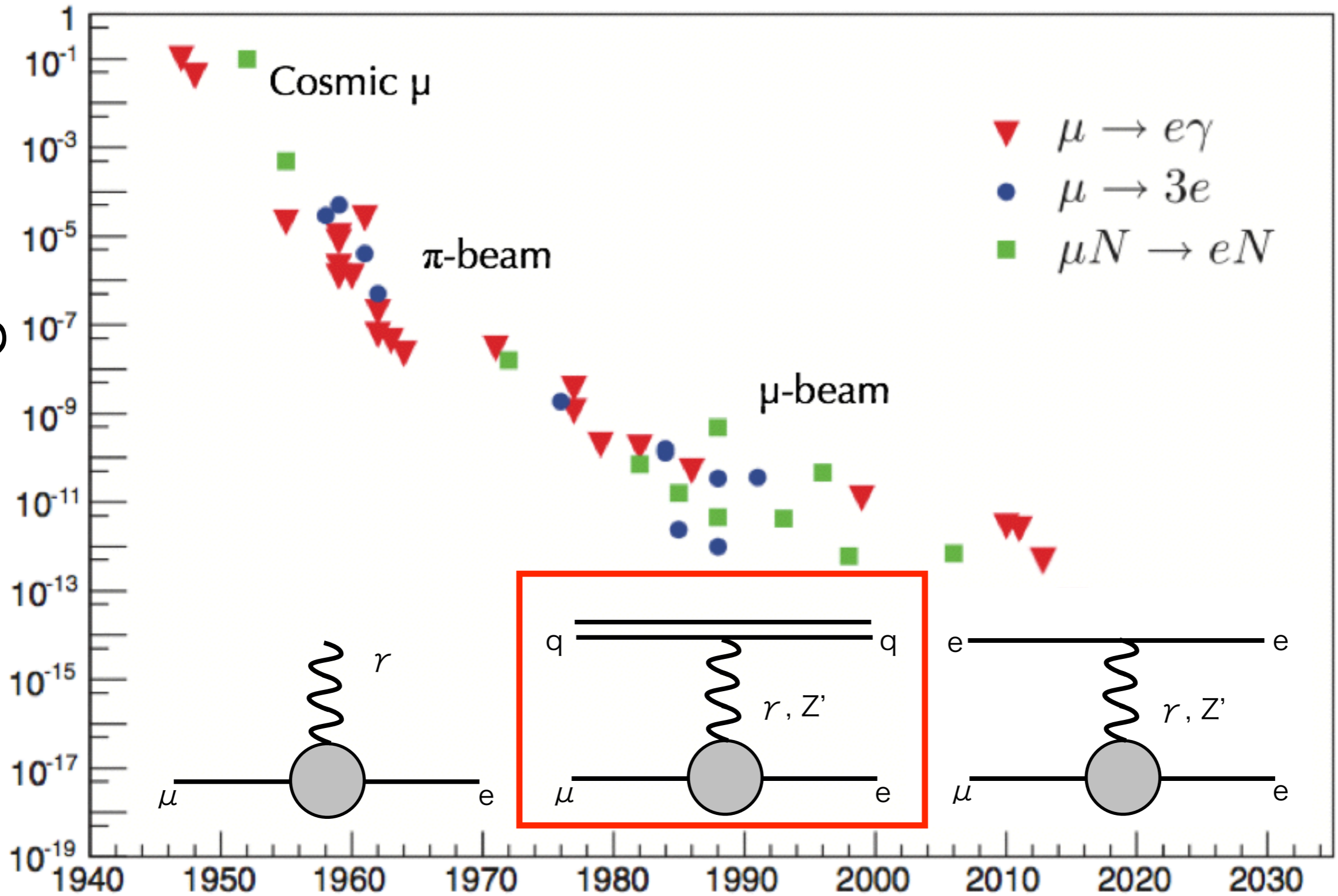
Branching Ratio UL



Bernstein & Cooper

Year

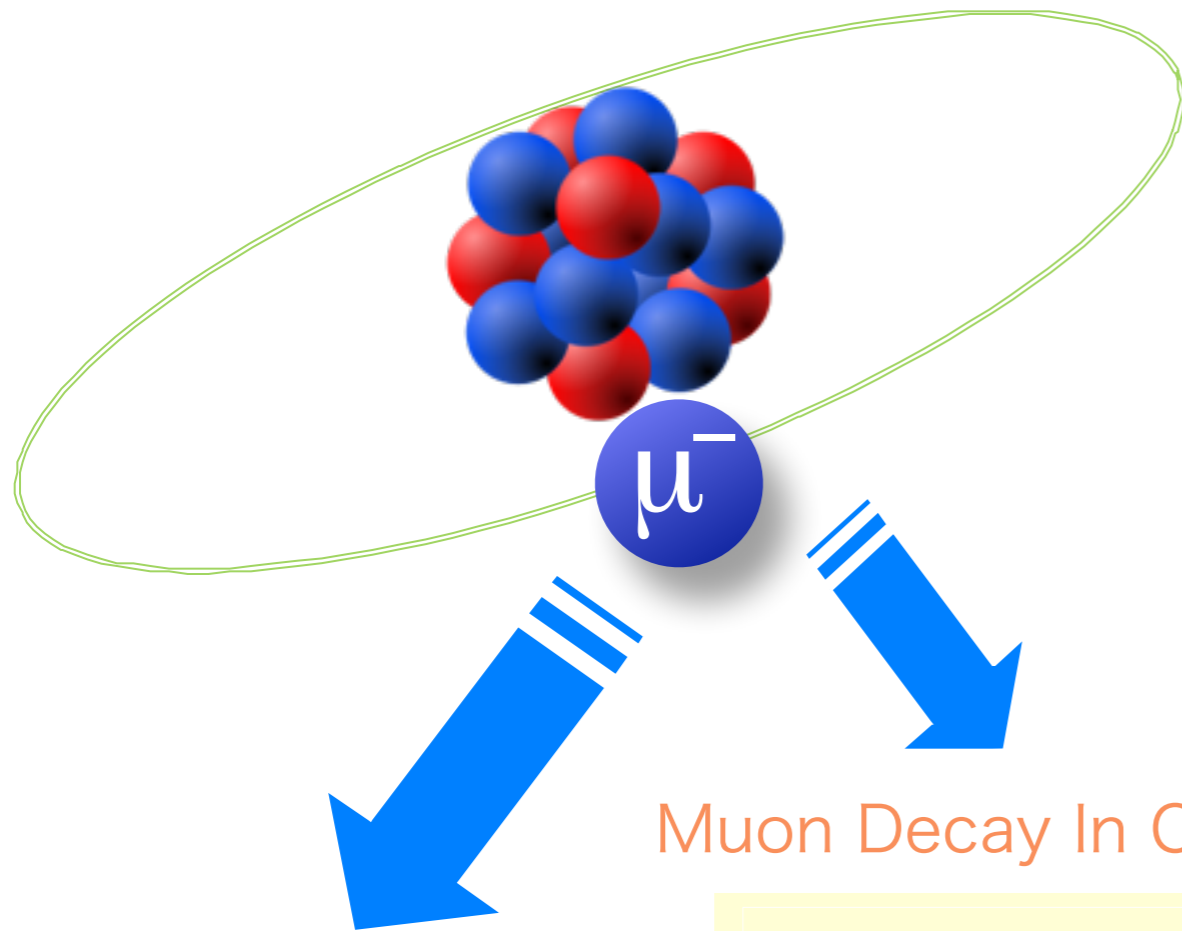
Branching Ratio UL



Bernstein & Cooper

Year

$\mu \rightarrow e$ search using pulsed muon beam



Muon Decay In Orbit

$$\mu^- \rightarrow e^- \nu \bar{\nu}$$

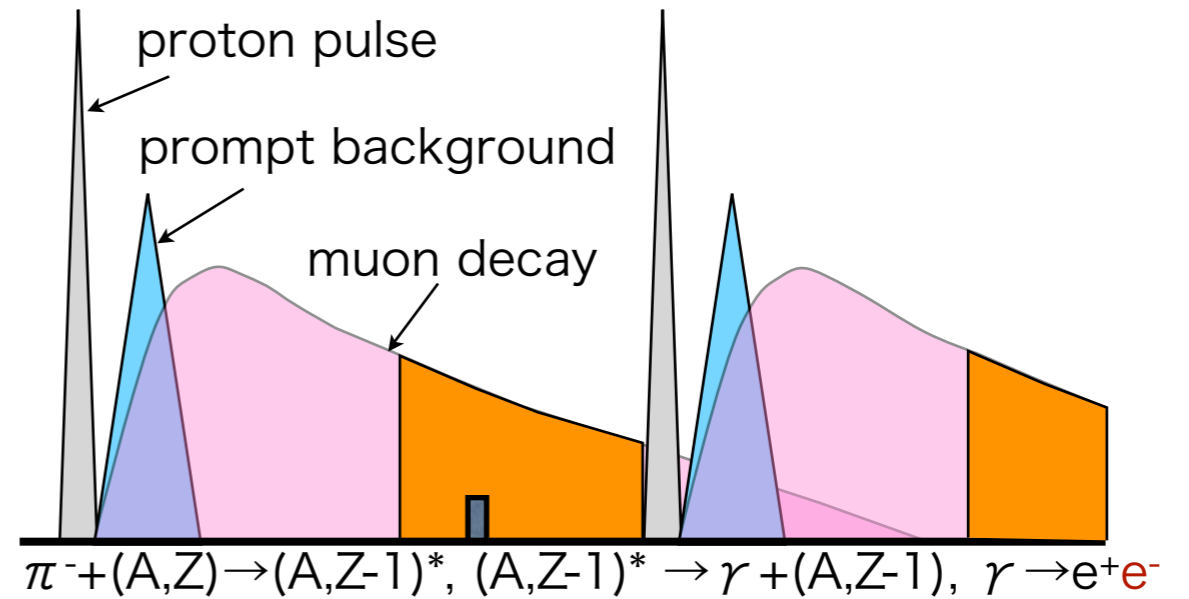
nuclear muon capture

$$\mu^- + (A, Z) \rightarrow \nu_\mu + (A, Z - 1)$$

μ -e conversion

$$\mu^- + (A, Z) \rightarrow e^- + (A, Z)$$

- $E_{\mu e}(Al) \sim m_\mu - B_\mu = 105 \text{ MeV}$
 - B_μ : binding energy of the 1s muonic atom



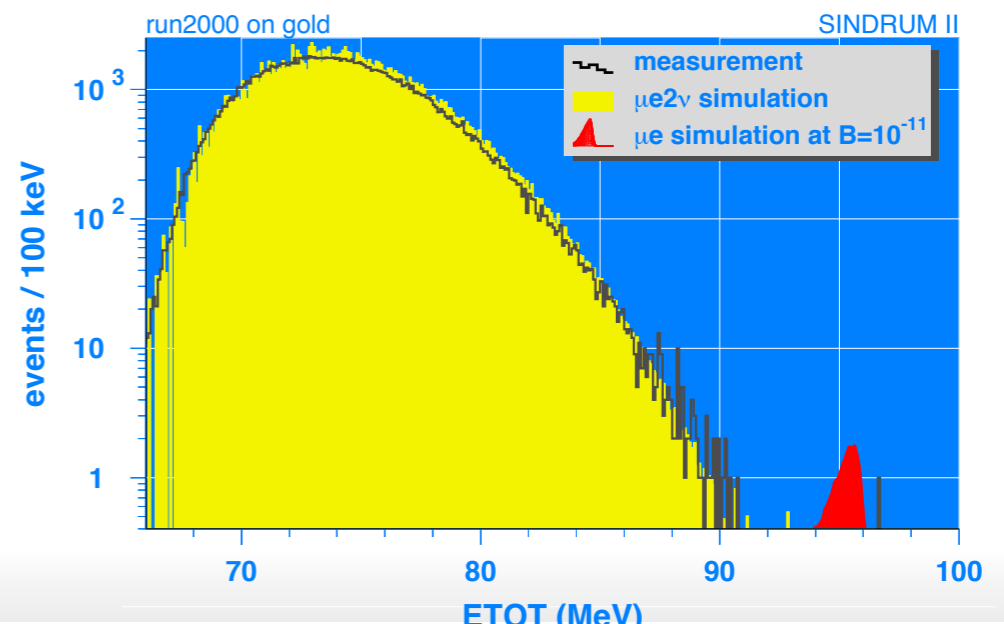
Prompt timing

Other sources

μ^- decay-in-flight, e^- scattering, neutron streaming

$$R_{\text{ext}} = \frac{\text{number of proton between pulses}}{\text{number of proton in a pulse}}$$

SINDRUM II $BR[\mu^- + Au \rightarrow e^- + Au] < 7 \times 10^{-13}$



J-PARC Facility (KEK/JAEA)



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LINAC

181 MeV → 400 MeV



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181 MeV → 400 MeV

Material and Life Science Facility

Rapid Cycle Synchrotron

Energy : 3 GeV

Repetition : 25 Hz

Design Power : 1 MW



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LINAC
181 MeV → 400 MeV

Neutrino beam to Kamioka

Material and Life Science Facility

Rapid Cycle Synchrotron
Energy : 3 GeV
Repetition : 25 Hz
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Main Ring
Max Energy : 30 GeV
Design Power for FX : 0.75 MW
Expected Power for SX : > 0.1 MW



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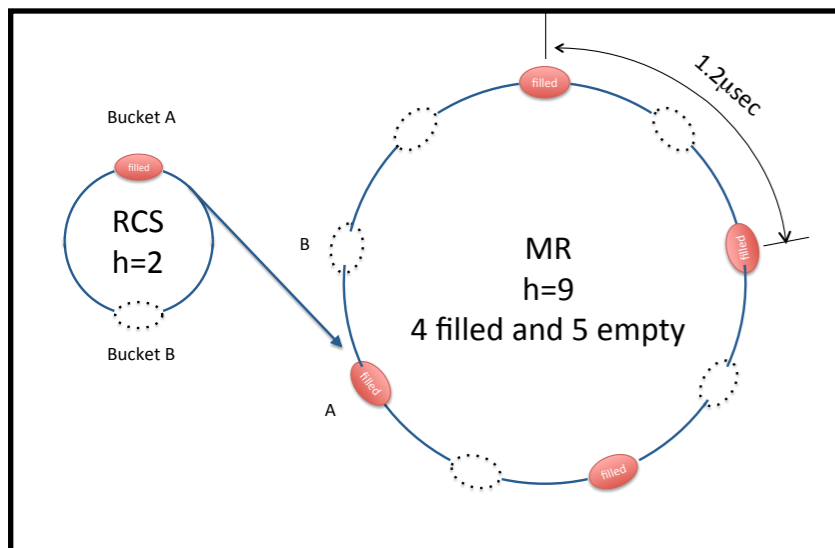
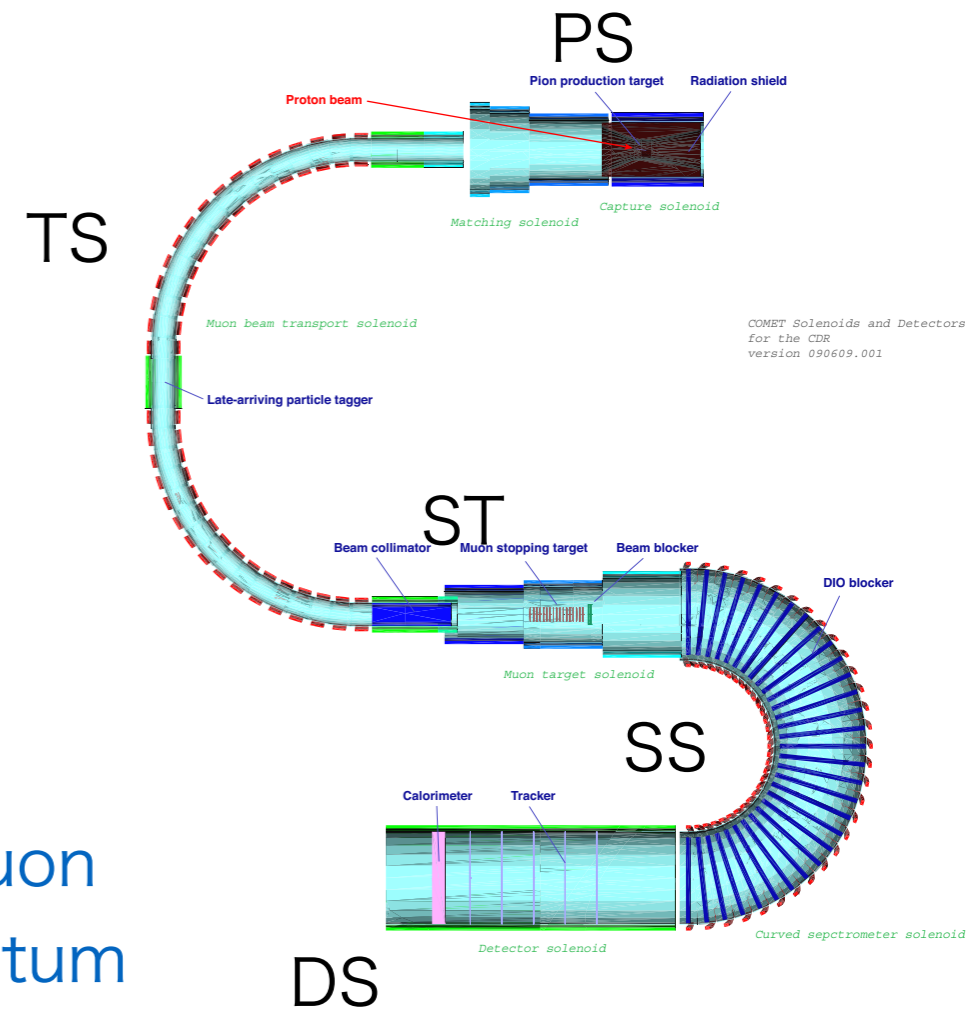
Nuclear and Particle
Physics Exp. Hall
(Hadron Hall)

Main Ring
Max Energy : 30 GeV
Design Power for FX : 0.75 MW
Expected Power for SX : > 0.1 MW

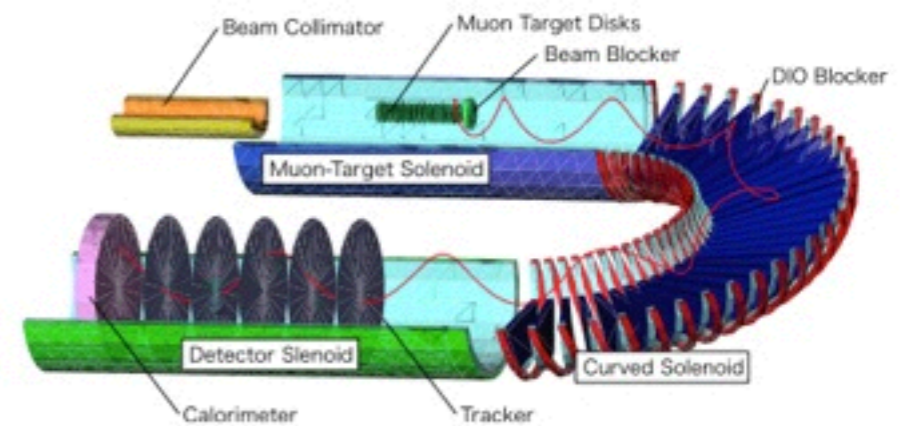
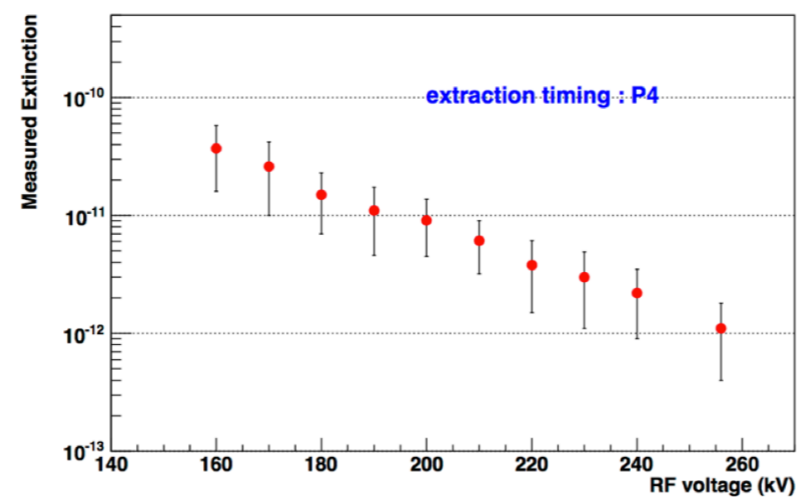


COMET at J-PARC

- J-PARC pulsed proton beam to produce pulsed muon beam
 - 8GeV, 3.2kW-56kW
 - Beam extinction factor study in May 2014
 - 8GeV w/o extraction $< 10^{-11}$
- 32m long chain of SC solenoid magnets
 - pion collection (PS), muon transport (TS), muon focusing on the target (ST), electron momentum selection (SS), and electron spectrometer (DS)



Extinction @ J-PARC MR Abort



COMET at J-PARC

Extinction @ J-PARC MR Abort

- J-PARC

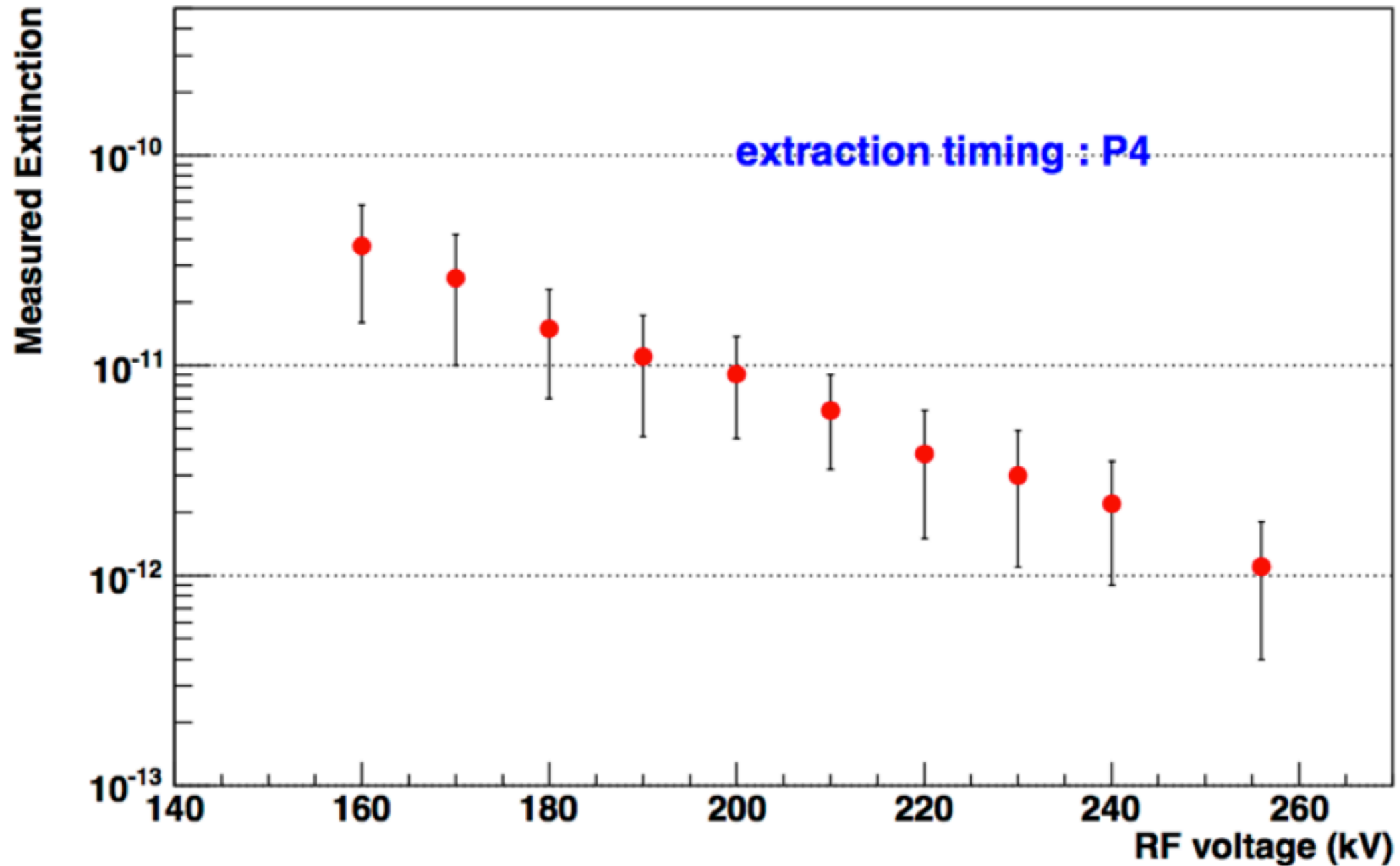
- muon

- 8

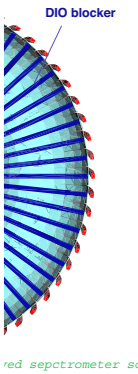
- 1

- 32r

- 1

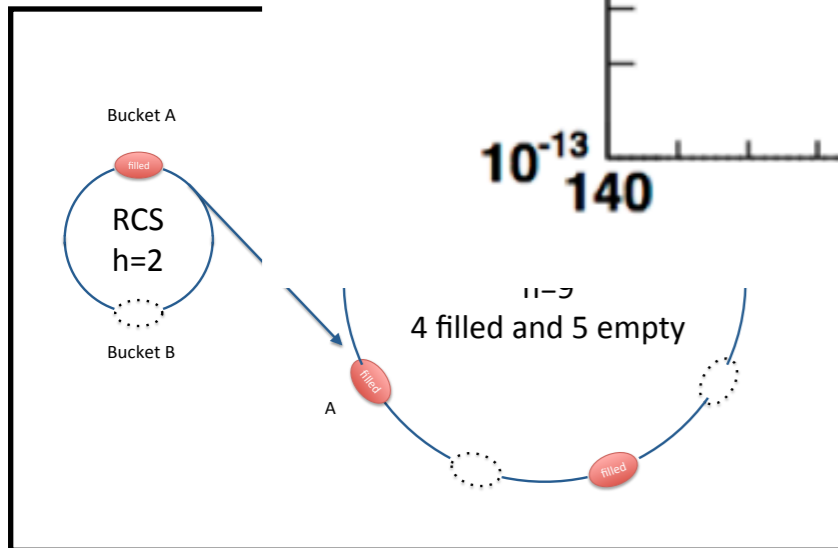
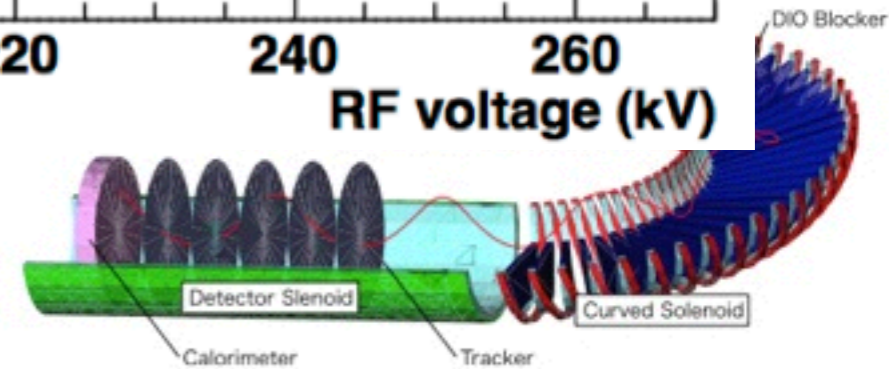


Solenoids and Detectors
the CDR
ion 090609.001



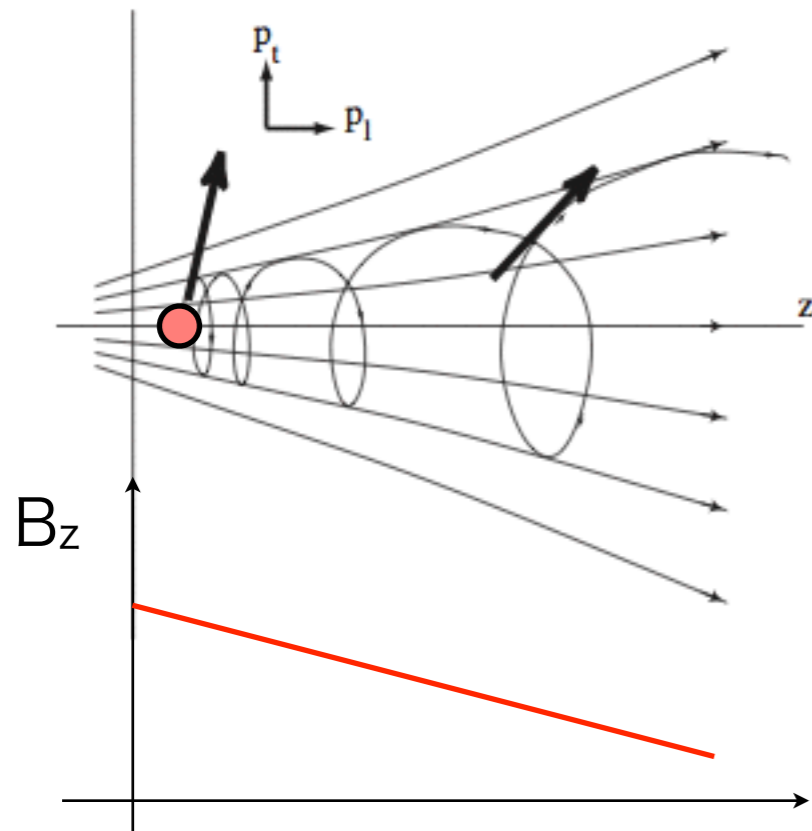
red septrometer solenoid

DIO Blocker



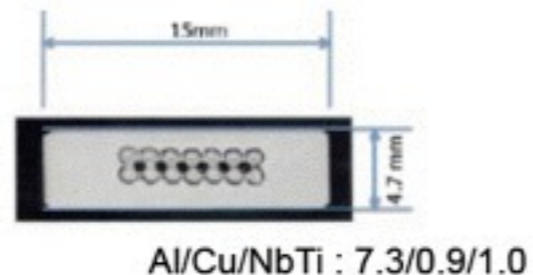
As many muons as possible!

Pion/muon collection using gradient magnetic field

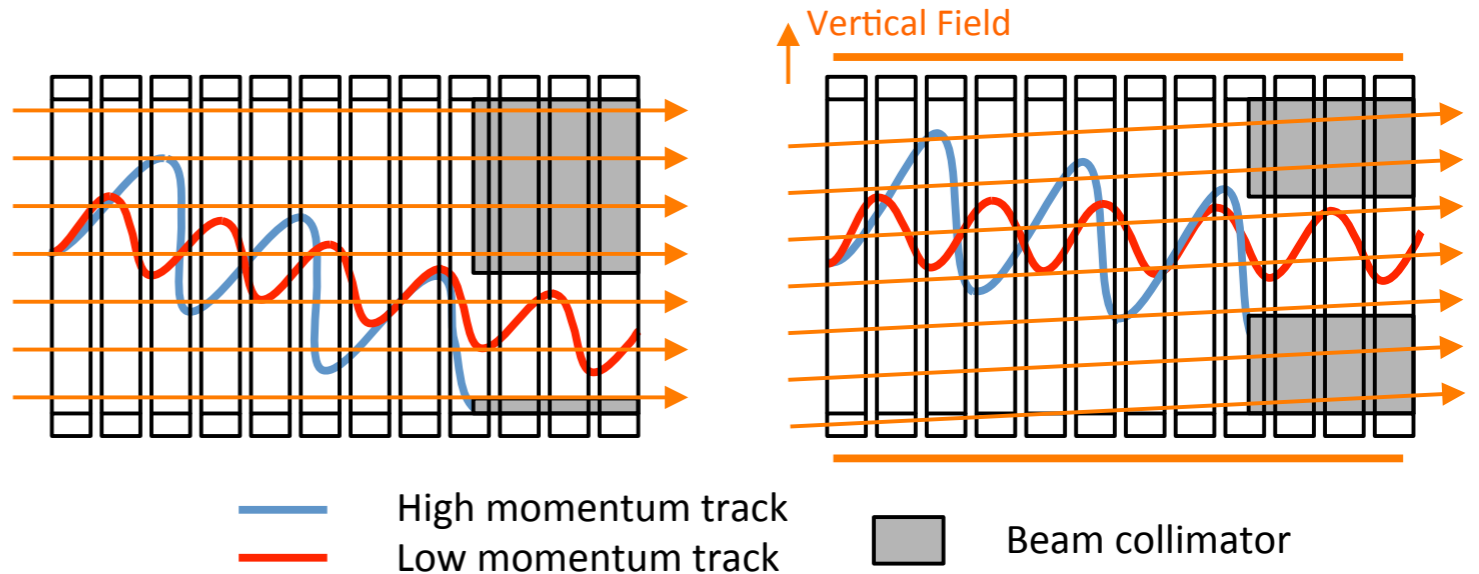


Strong Magnetic field in high radiation environment

Aluminum stabilized SC
Collaborative R&D between
COMET & Mu2e

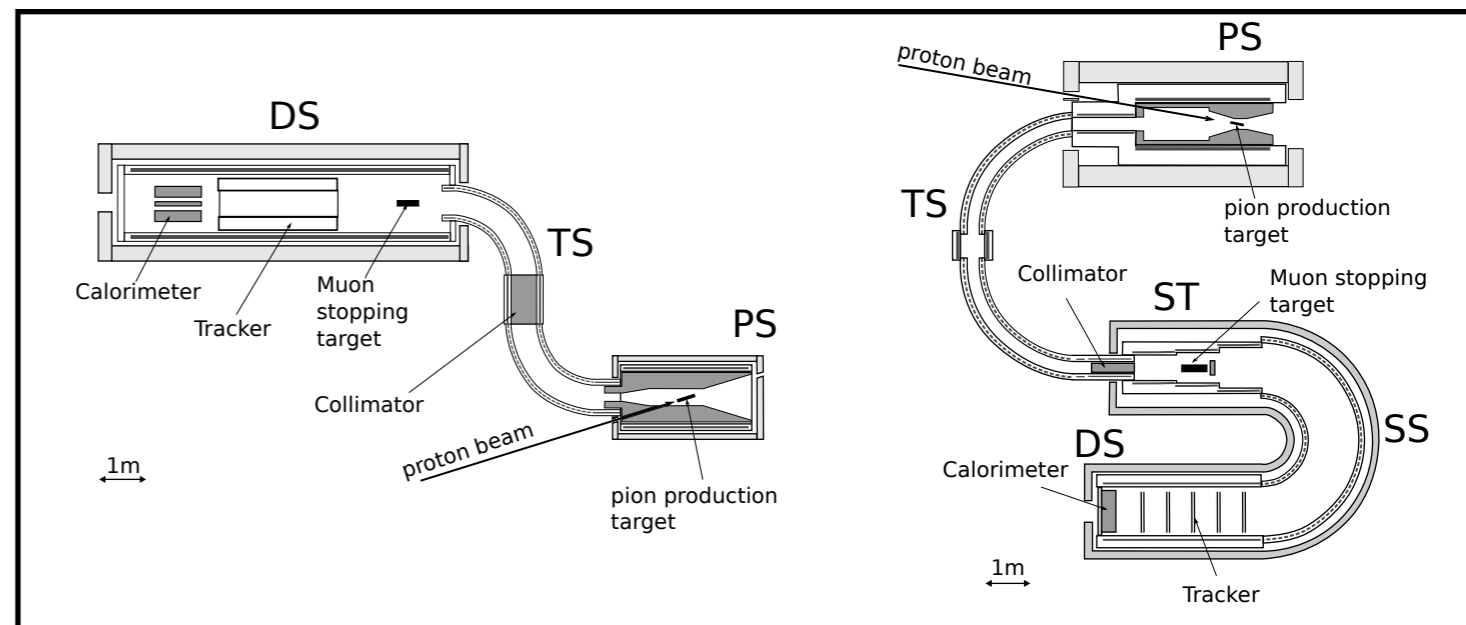


Muon transport with large momentum acceptance and momentum selection



Mu2e

COMET



COMET Phase I & II

Phase I

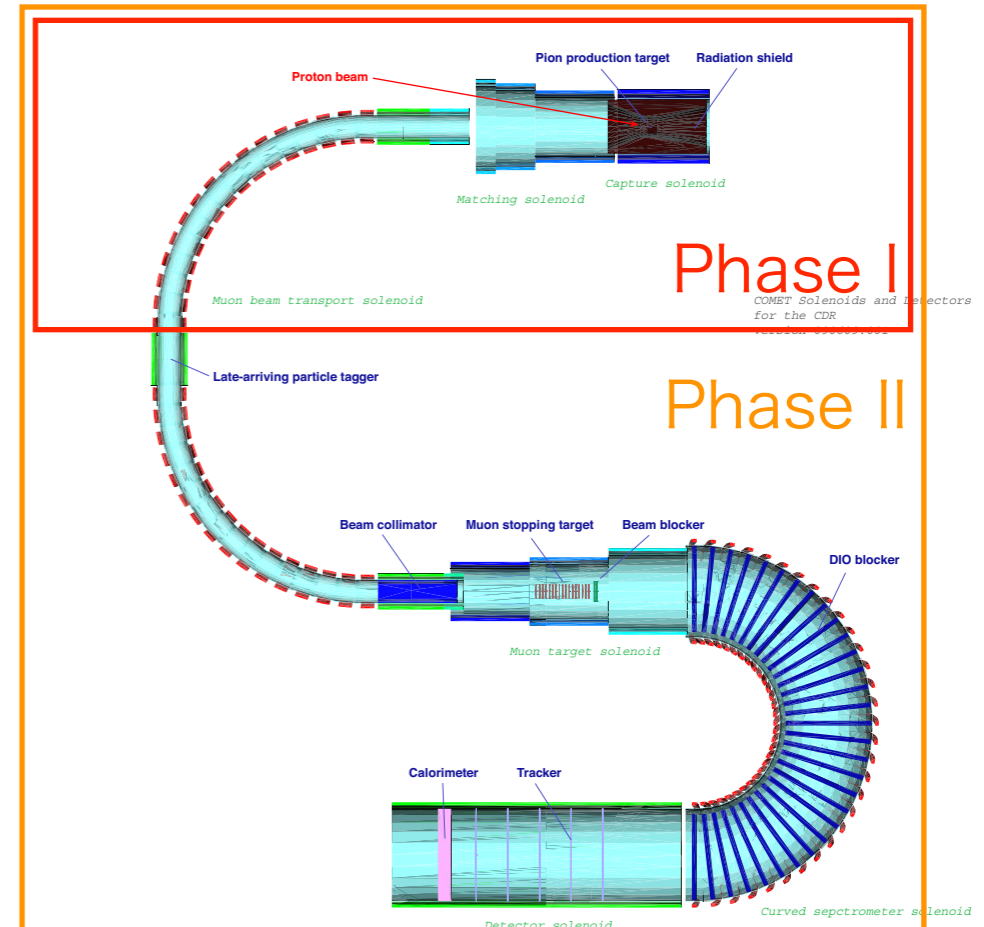
Beam background study and achieving an intermediate sensitivity of $<10^{-14}$

- Graphite as a pion production target
- 8GeV, ~3.2kW, ~90 days of DAQ

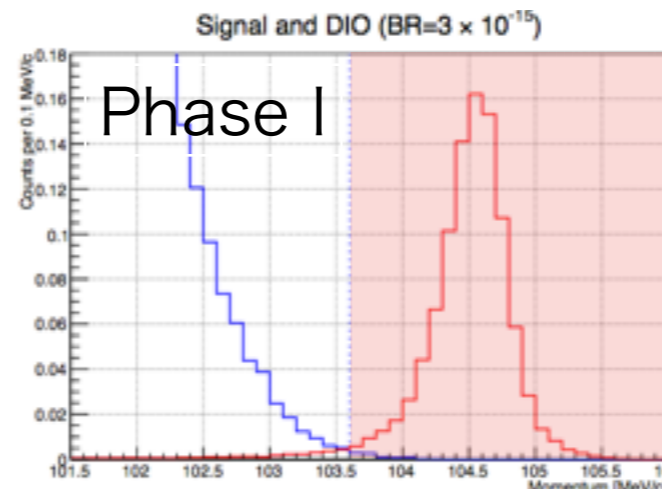
Phase II

Achieve the COMET final goal of $<10^{-16}$ sensitivity

- Tungsten as a pion production target
- 8GeV, ~56 kW, 1 year DAQ



0.01 BG expected in 8.0×10^6 sec running time



Phase I

2013-2015

Facility construction

2013-2016

Magnet construction & installation

2016-2017

Eng. run & Physics run

Phase II

Eng. run in 2019 (funding not secured yet)

COMET Phase I & II

Phase I

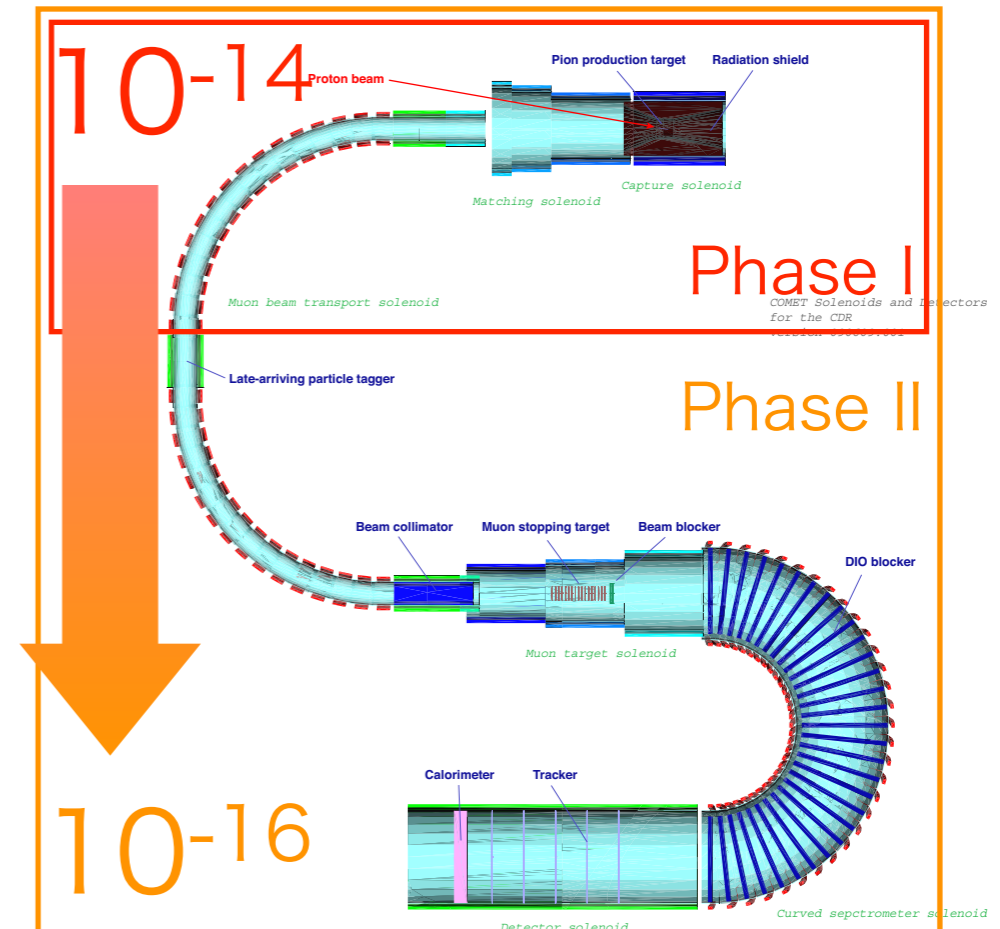
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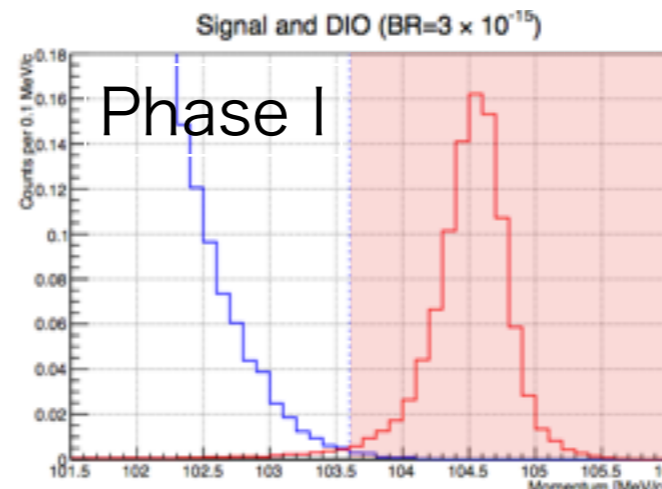
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2013-2016

Magnet construction & installation

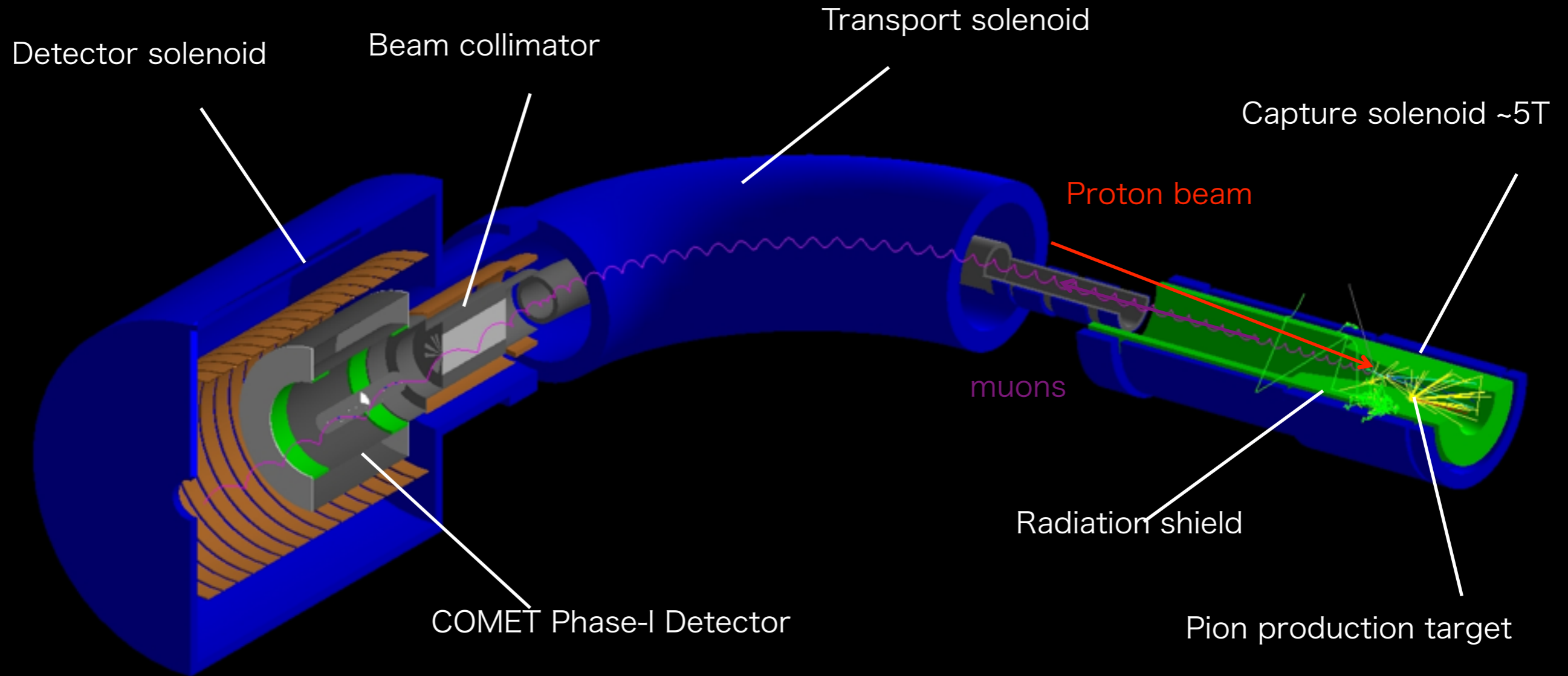
2016-2017

Eng. run & Physics run

Phase II

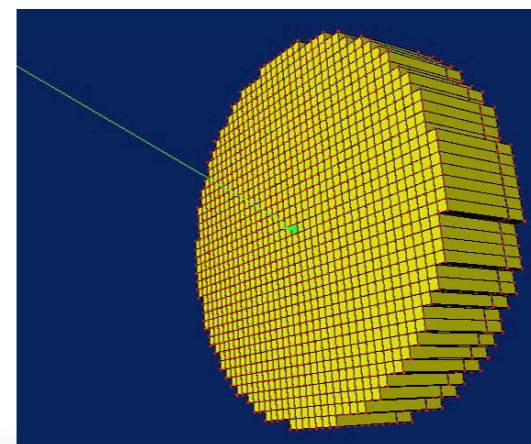
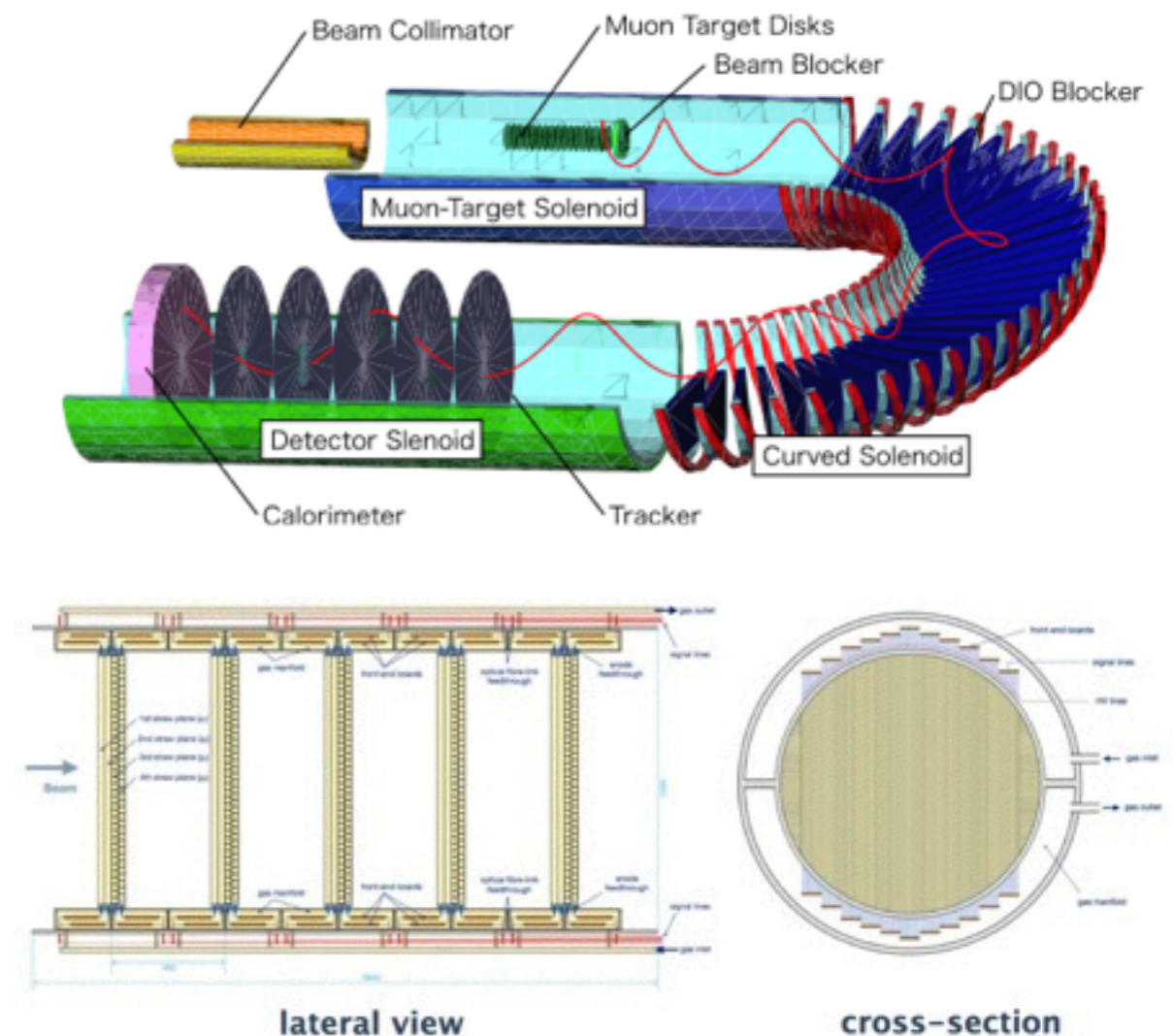
Eng. run in 2019 (funding not secured yet)

COMET Phase I Setup



R&D toward Phase II

- In Phase II another curved solenoid will be implemented for electron momentum selection
 - electron momentum/energy measurements after selection
- Straw tube tracker & crystal calorimeter
 - operation in vacuum to suppress multiple-scattering effect
- **Part of these detectors are constructed and tested in phase I**
 - Muon beam & background study
 - Performance evaluation of the spectrometer



Sensitivity & background in Phase I

- Sensitivity

- Acceptance=0.046

- 0.29 (geometrical) x 0.97(mom. sel.) x 0.30 (timing sel.) x 0.80 (trigger) x 0.80 (DAQ) x 0.8 (reconst.)

- Atomic capture rate

$$f_{\text{cap}}=0.61$$

- $N_{\mu}=1.3 \times 10^{16}$ muons
(~90days@0.4 μ A)

- S.E.S.= 3.1×10^{-15} , 90% U.L. =
 7.2×10^{-15}

- Background

| Type | Background | Estimated events |
|--------------|--|---------------------------|
| Physics | Muon decay in orbit | 0.01 |
| Physics | Radiative muon capture | 5.6×10^{-4} |
| Physics | Neutron emission after muon capture | < 0.001 |
| Physics | Charged particle emission after muon capture | < 0.001 |
| Prompt Beam | Beam electrons (prompt) | 7.1×10^{-4} |
| Prompt Beam | Muon decay in flight (prompt) | $\leq 1.7 \times 10^{-4}$ |
| Prompt Beam | Pion decay in flight (prompt) | $\leq 2.0 \times 10^{-3}$ |
| Prompt Beam | Other beam particles | $\leq 2.4 \times 10^{-6}$ |
| Prompt Beam | Radiative pion capture(prompt) | 4.24×10^{-4} |
| Delayed Beam | Beam electrons (delayed) | ~ 0 |
| Delayed Beam | Muon decay in flight (delayed) | ~ 0 |
| Delayed Beam | Pion decay in flight (delayed) | ~ 0 |
| Delayed Beam | Radiative pion capture (delayed) | ~ 0 |
| Delayed Beam | Anti-proton induced backgrounds | 0.007 |
| Others | Electrons from cosmic ray muons | < 0.0001 |
| Total | | 0.019 |

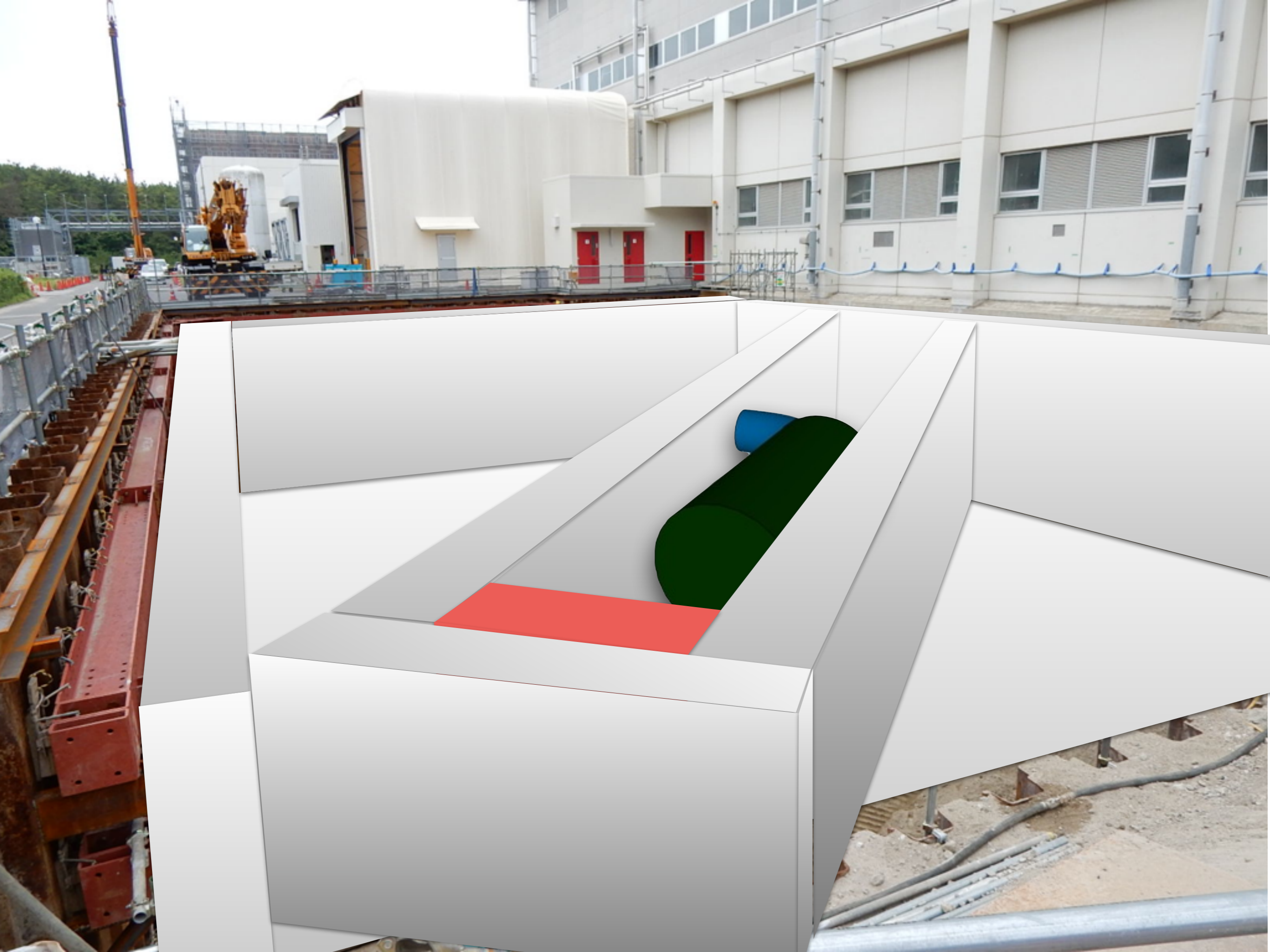
- Intrinsic & beam related

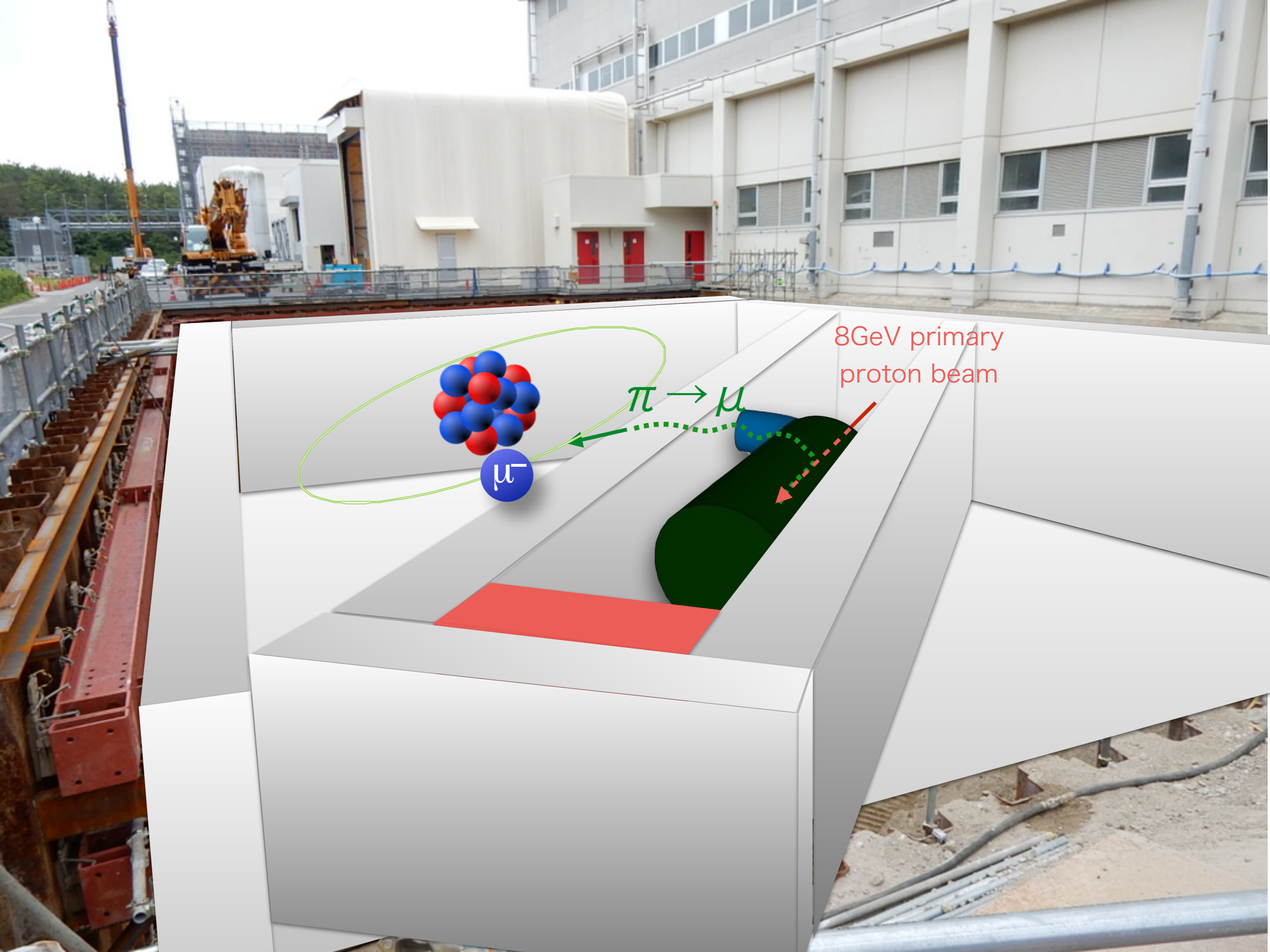
- Measurement in Phase I
- Straw & Ecal for Beam related BG study

Status of COMET

- Facility construction
- Superconducting magnet construction
- Detector construction



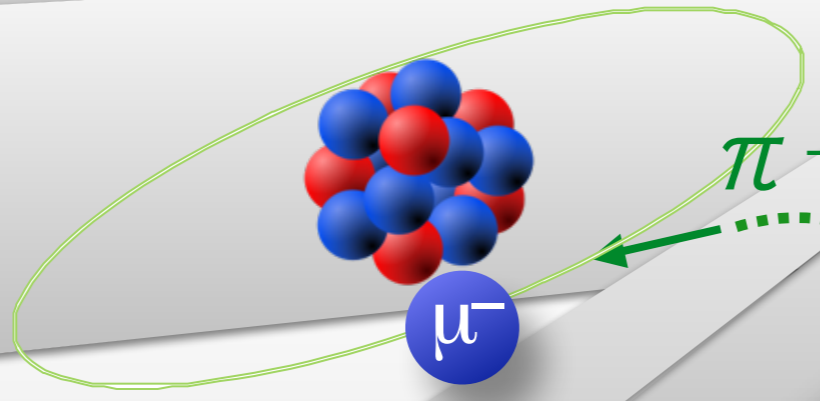
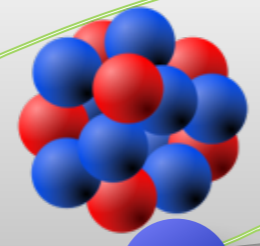




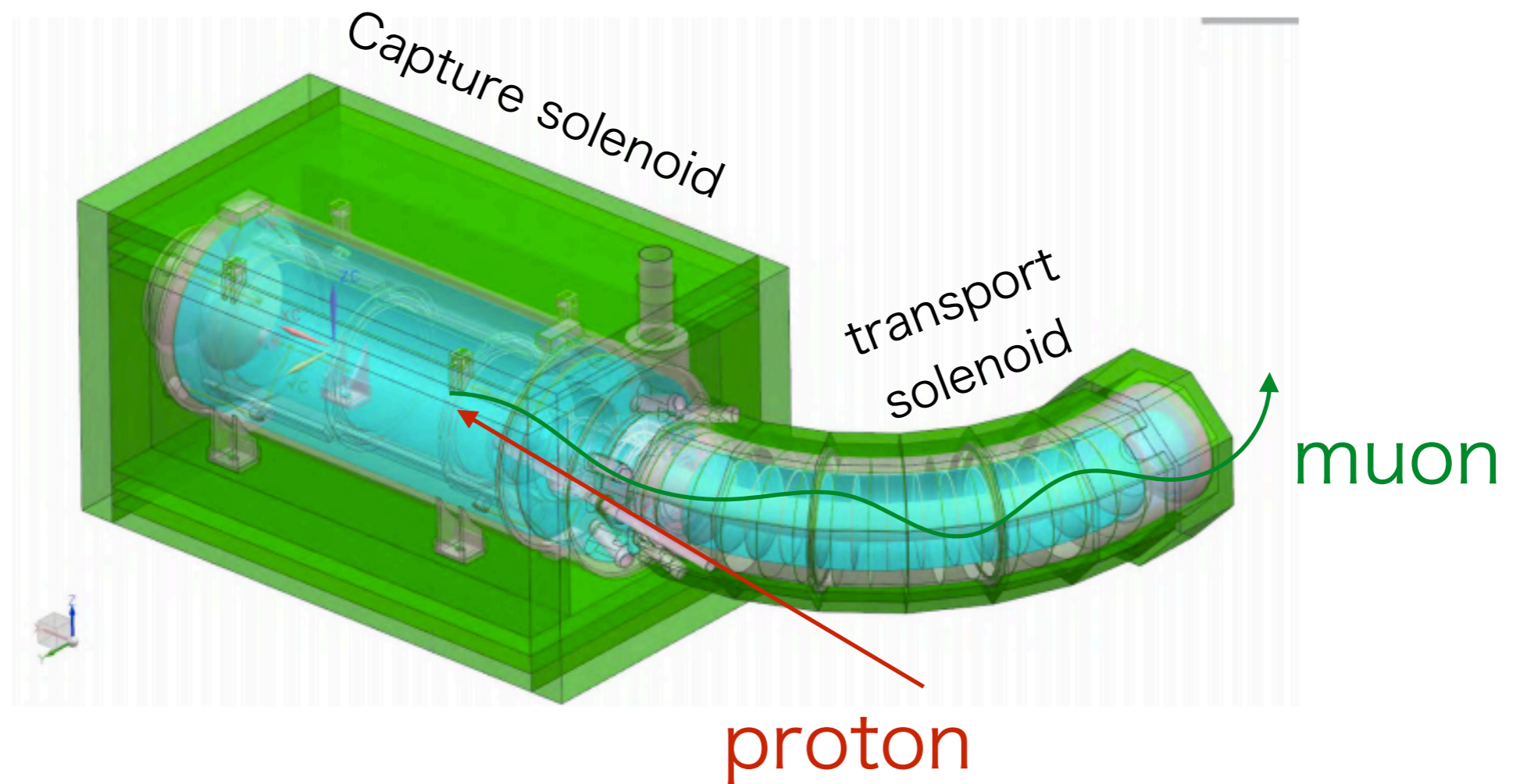
8 GeV primary proton beam

$\pi \rightarrow \mu$

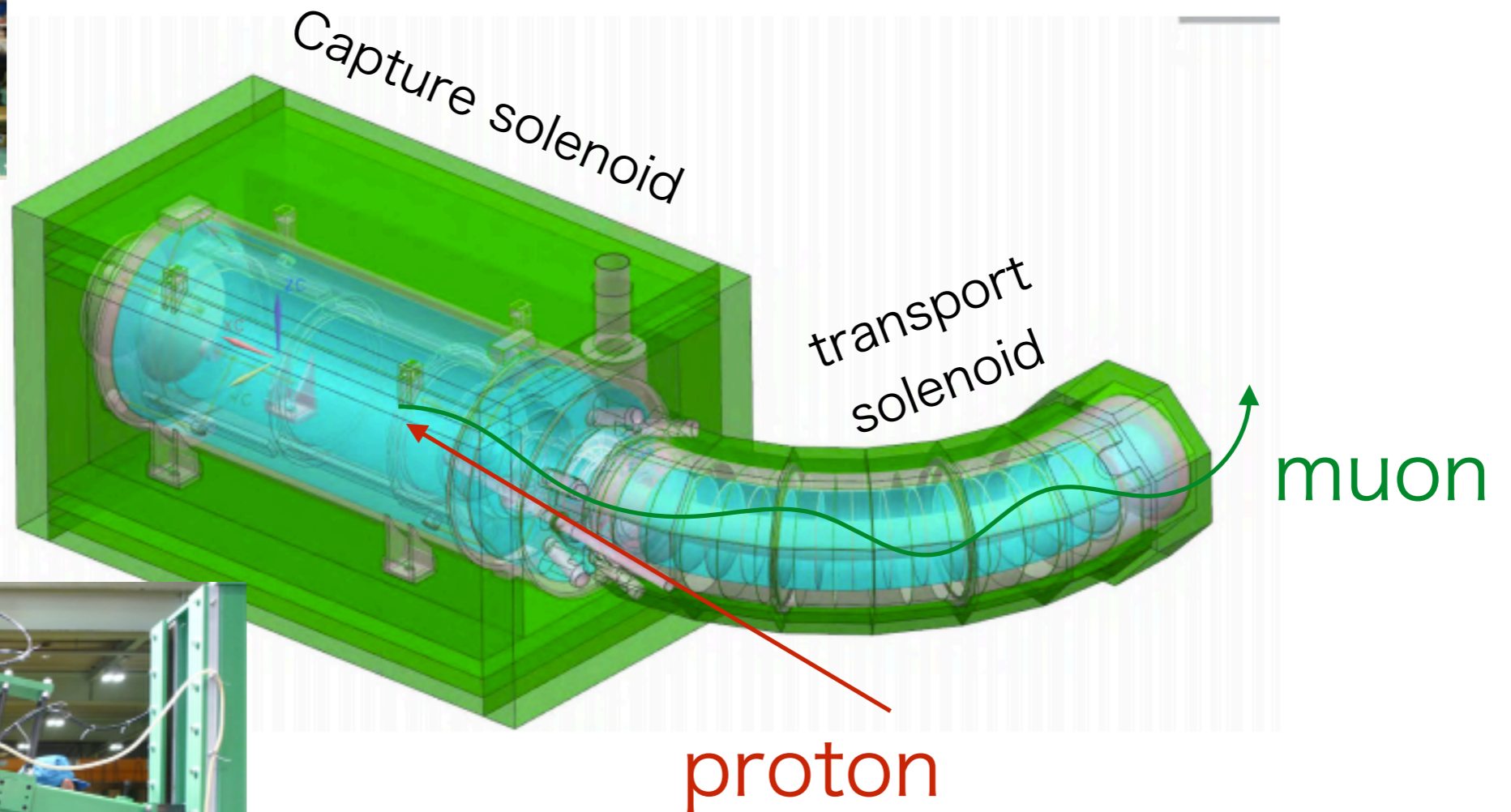
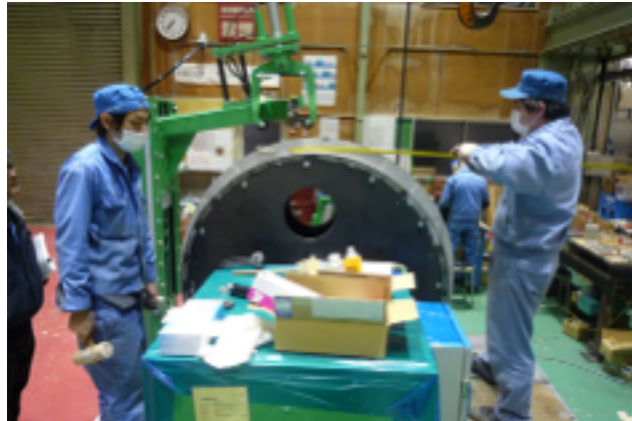
μ^-



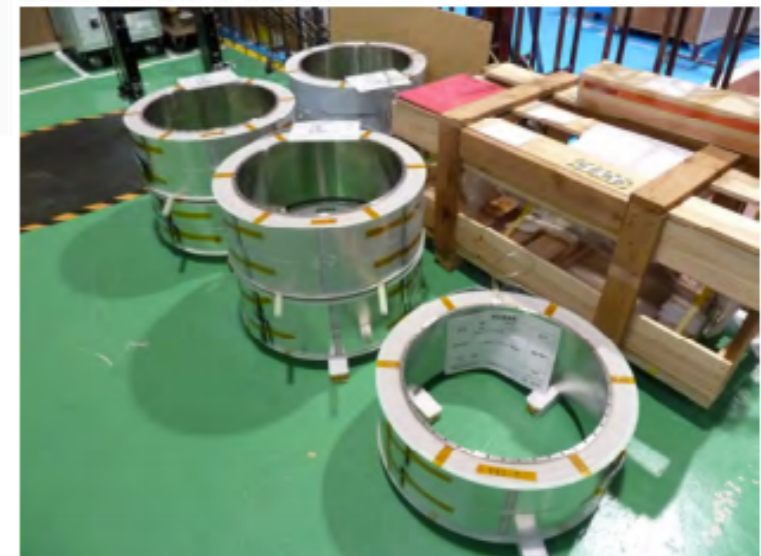
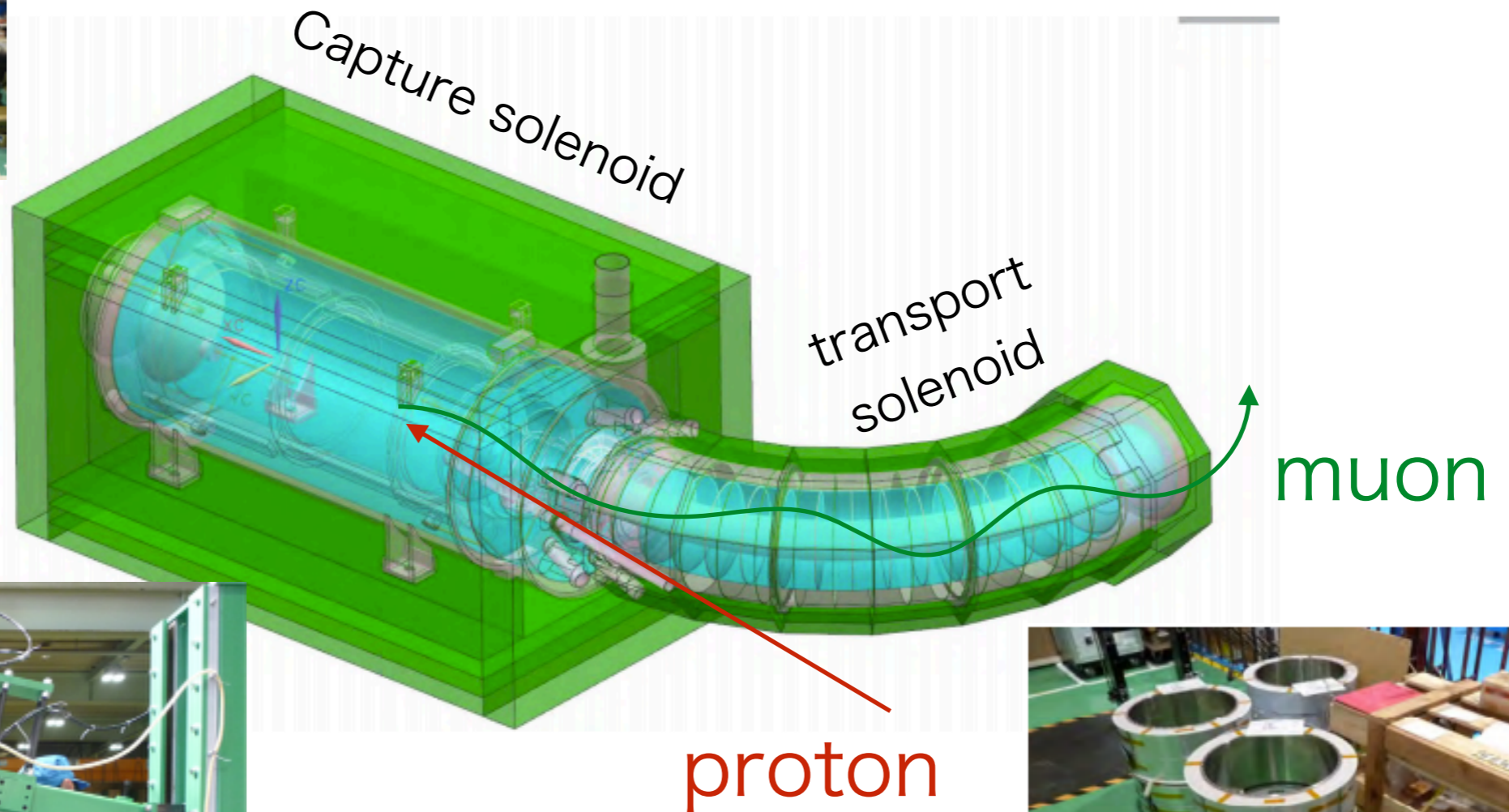
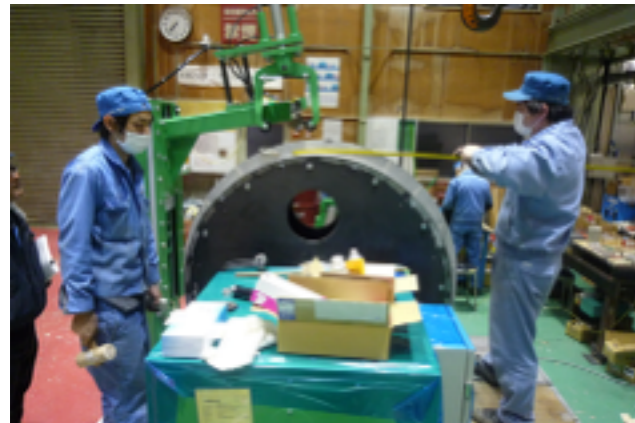
SC Magnet Construction



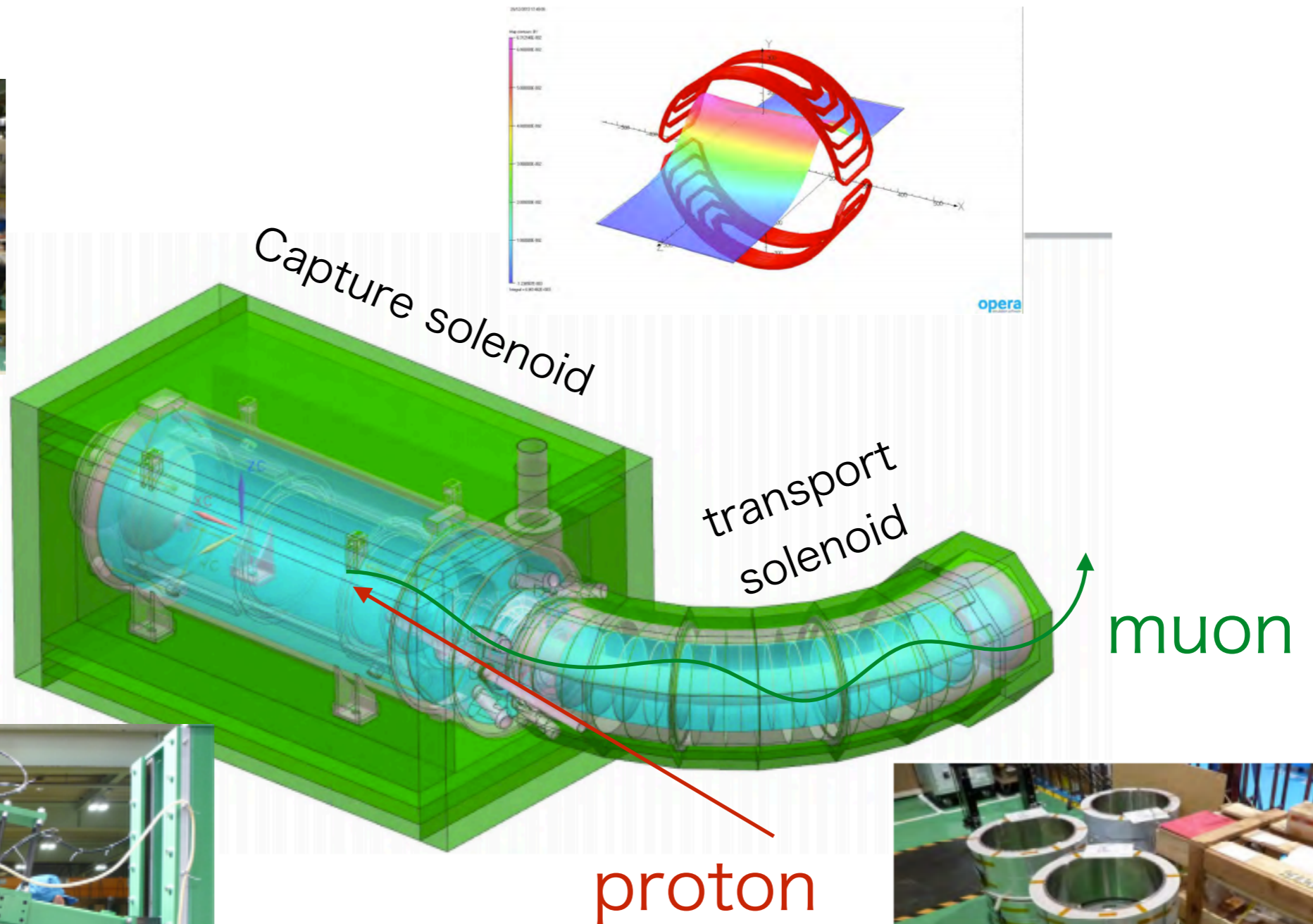
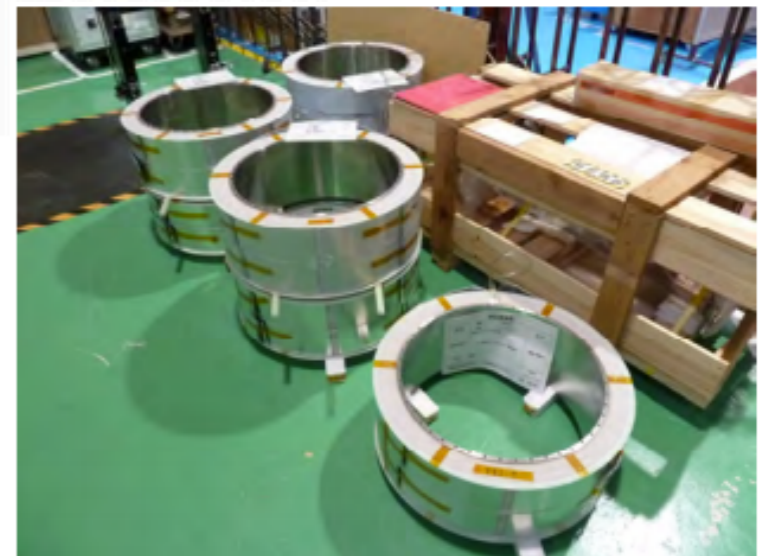
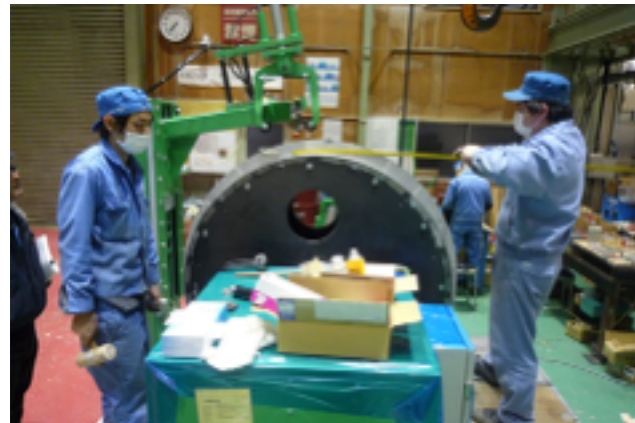
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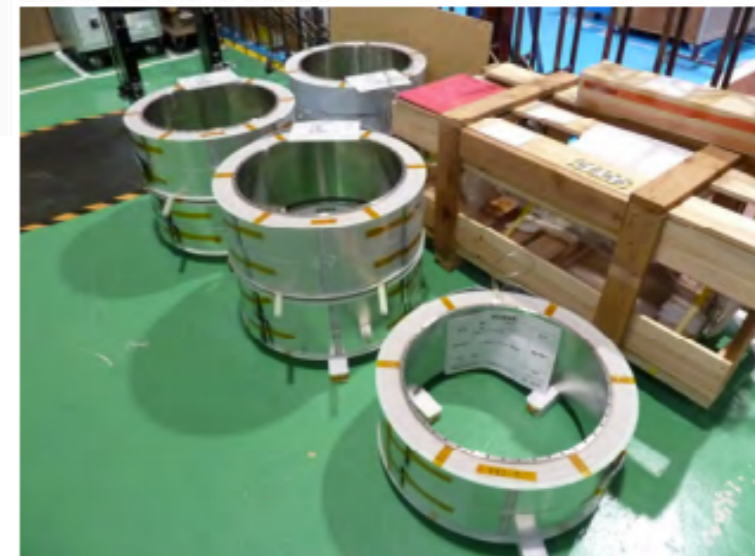
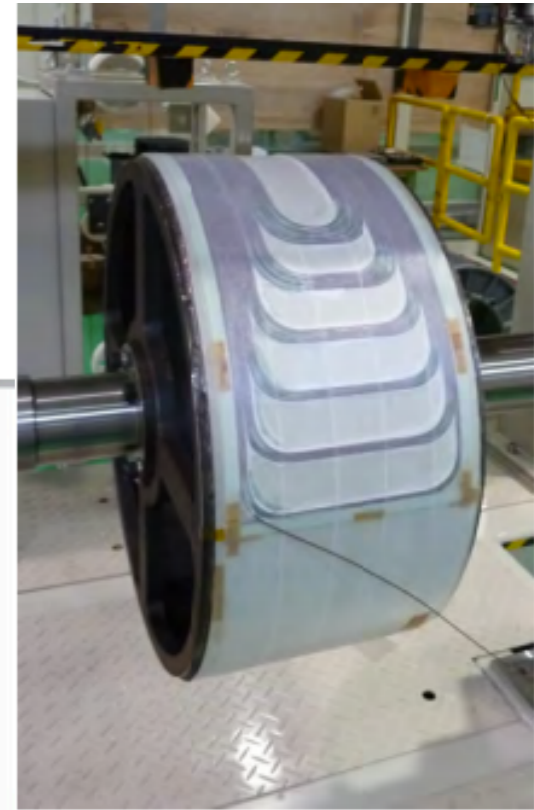
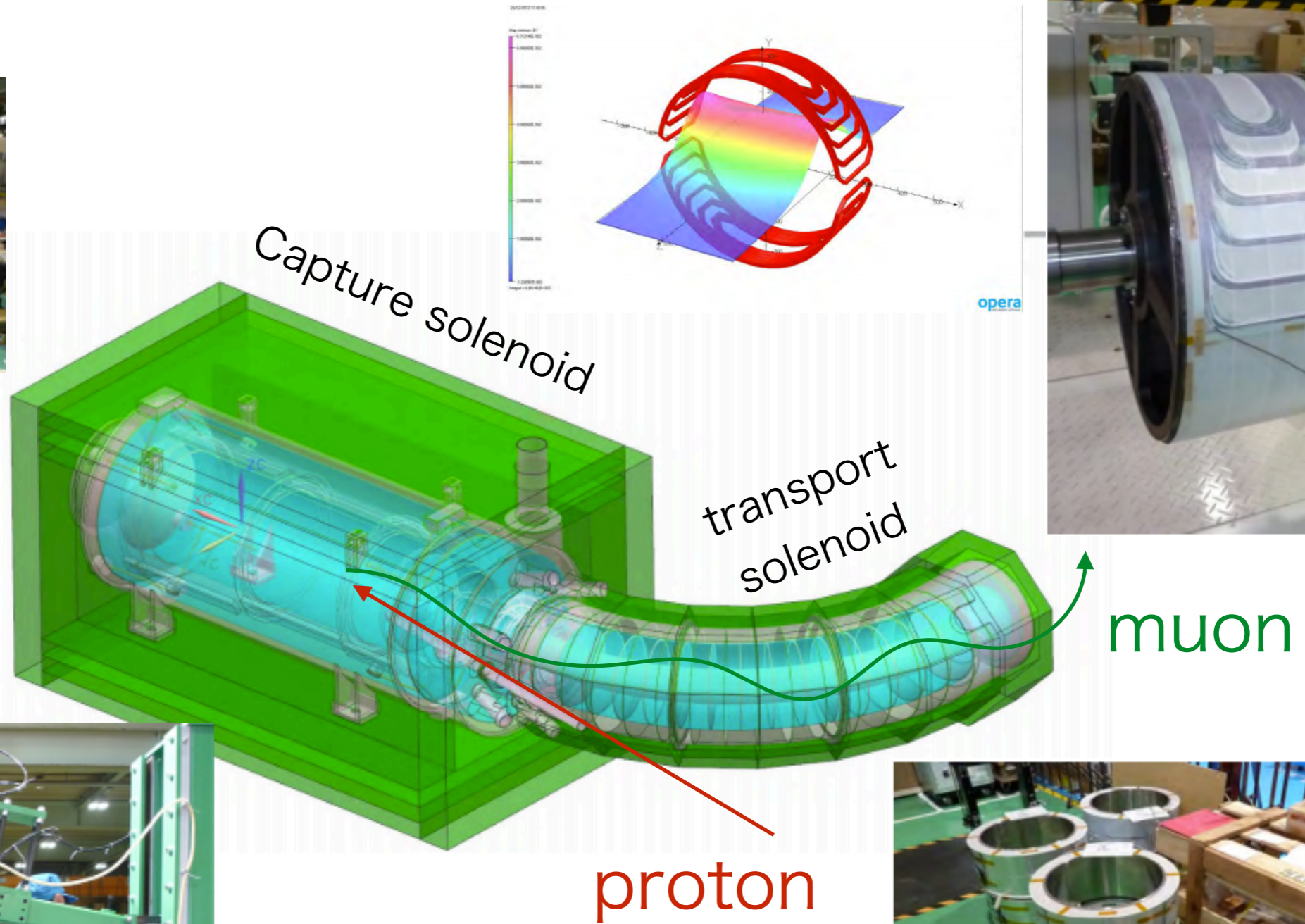
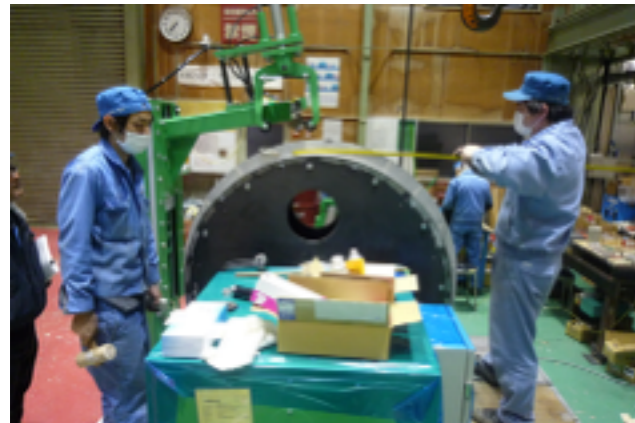
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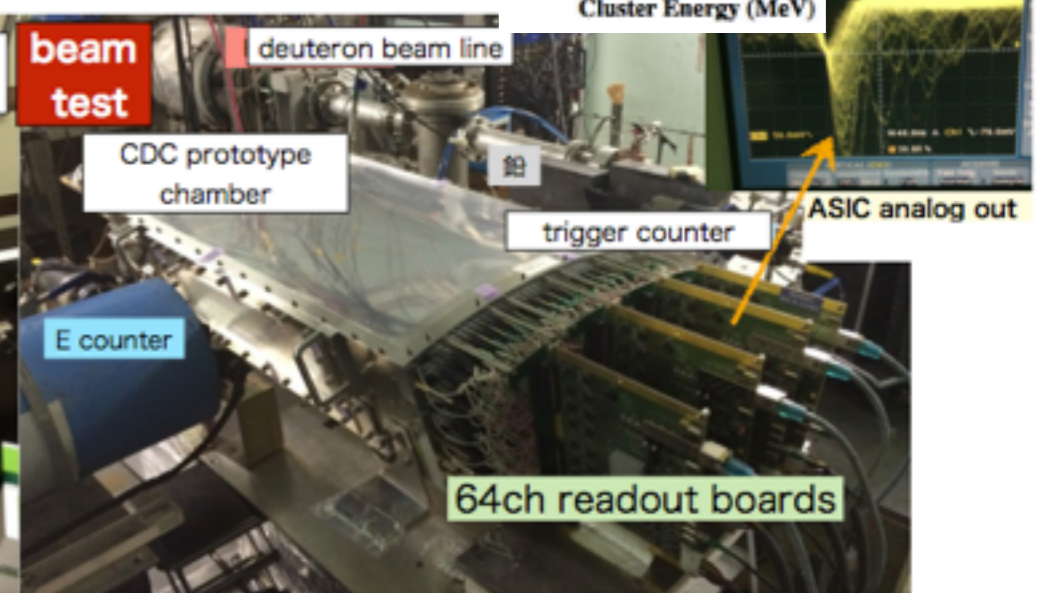
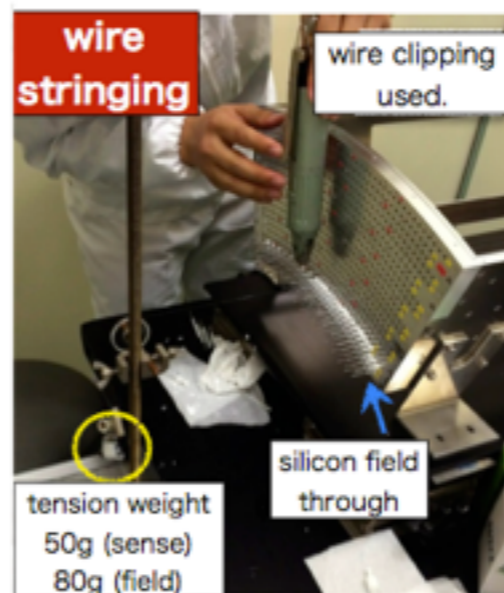
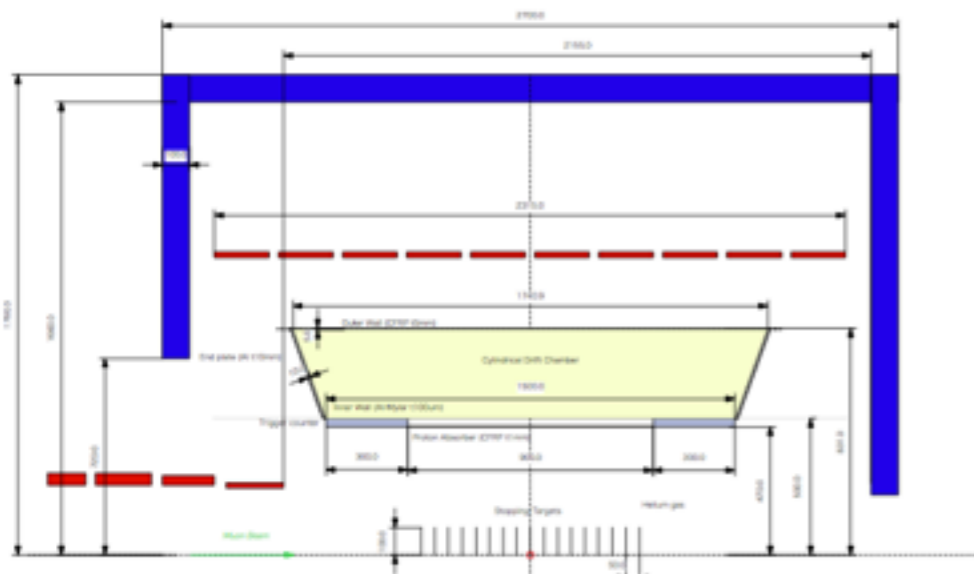
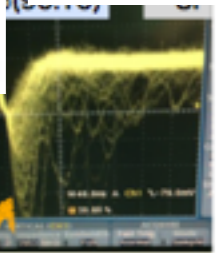
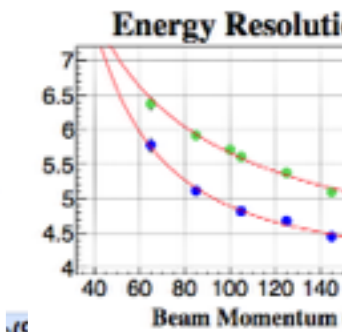
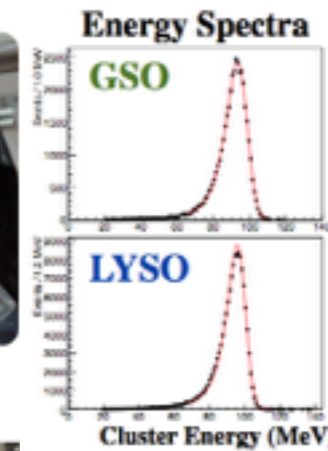
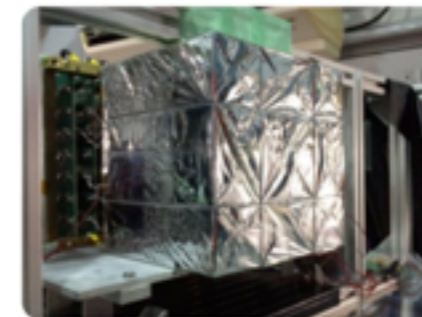
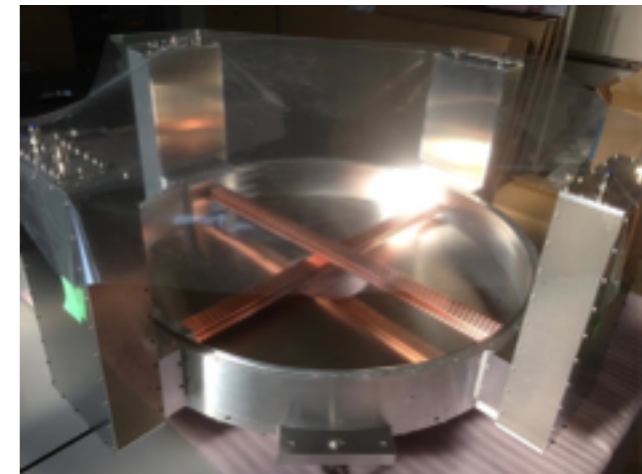
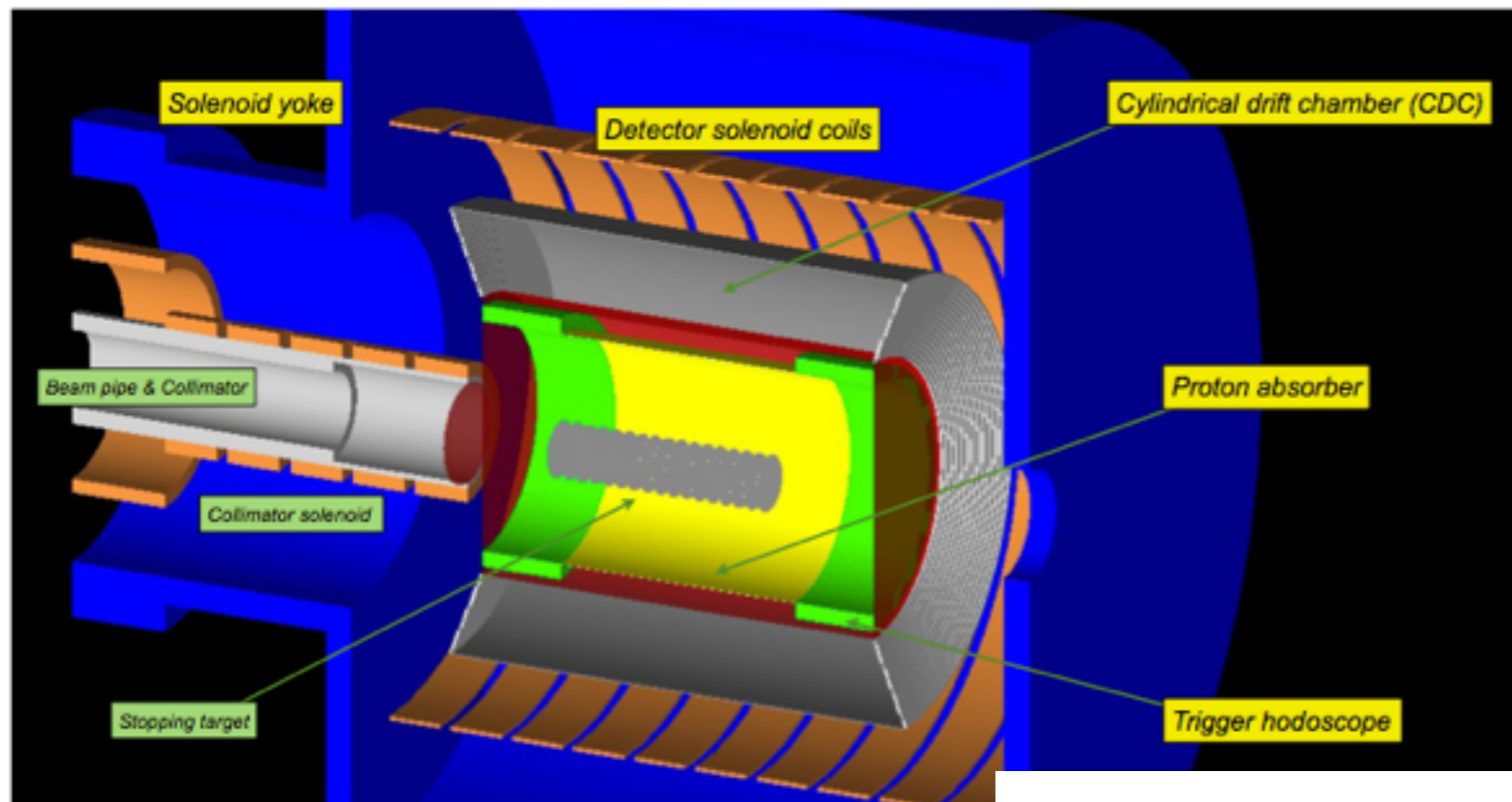
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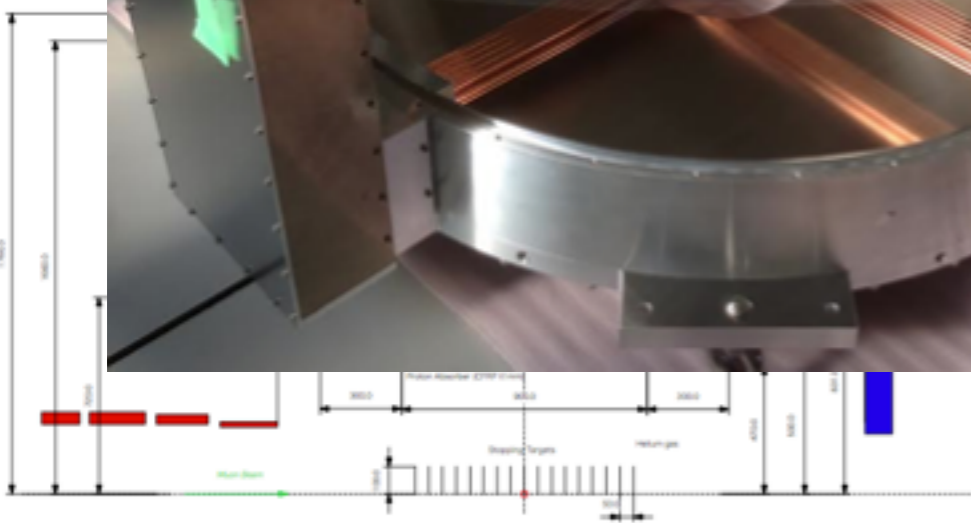
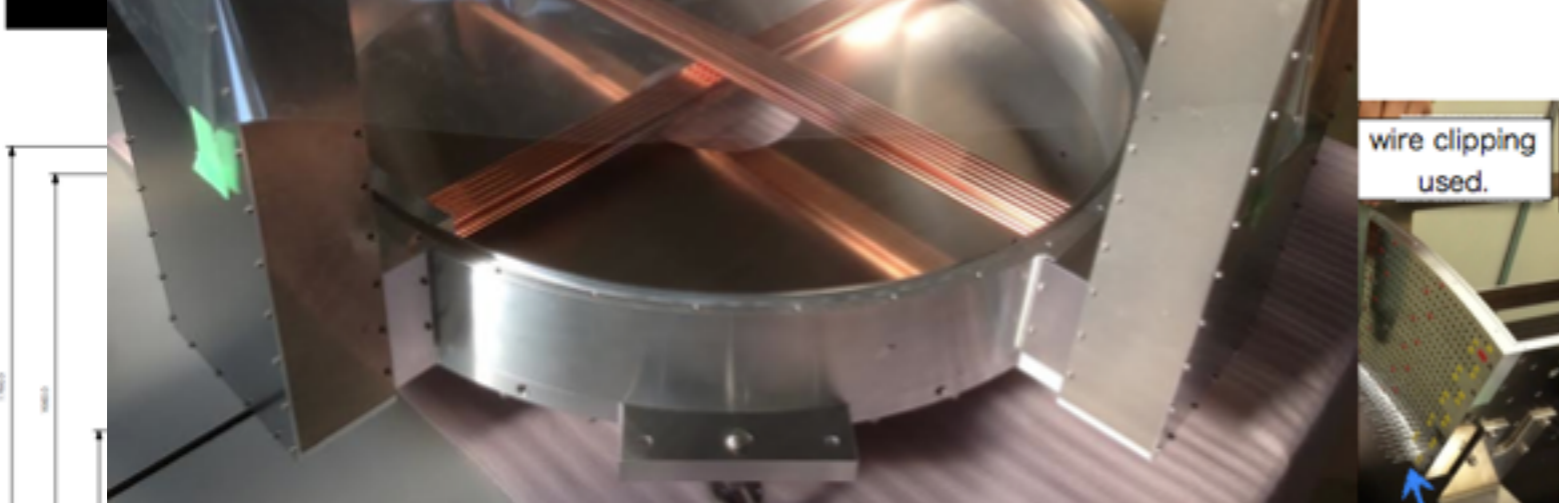
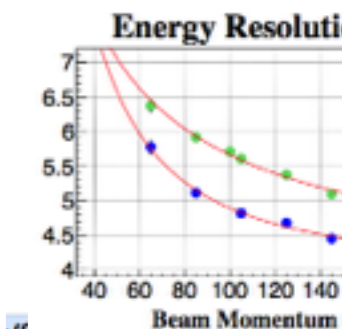
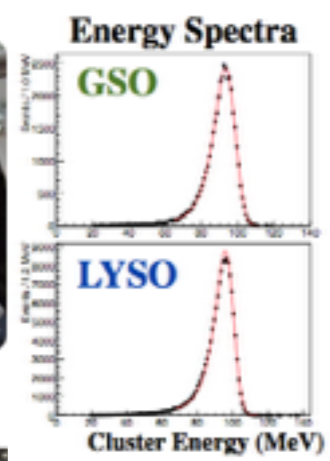
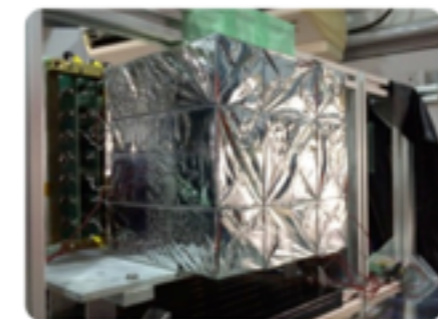
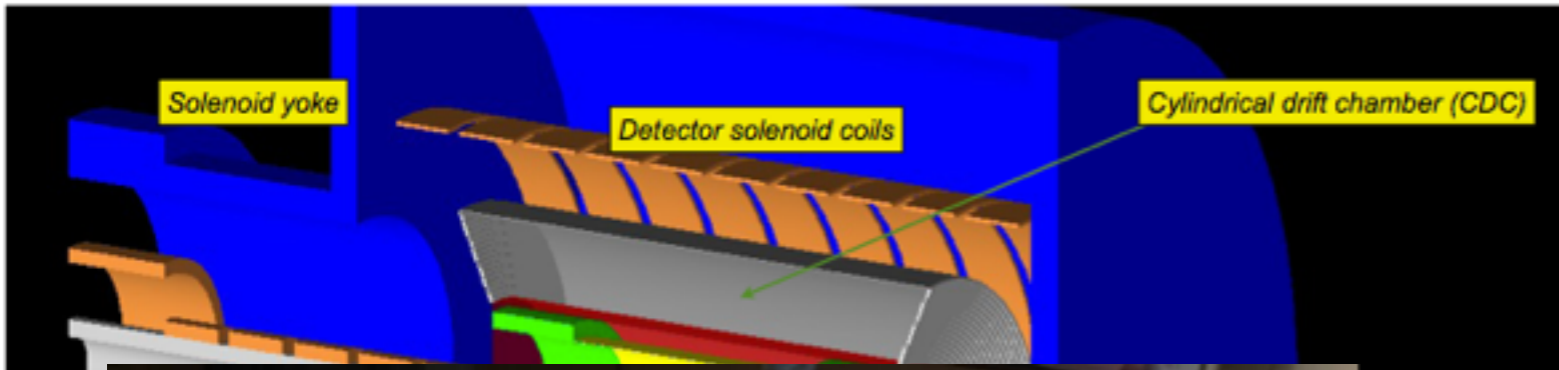
SC Magnet Construction



Detector Construction



Detector Construction



wire clipping used.

beam test

deuteron beam line

CDC prototype chamber

trigger counter

ASIC analog out

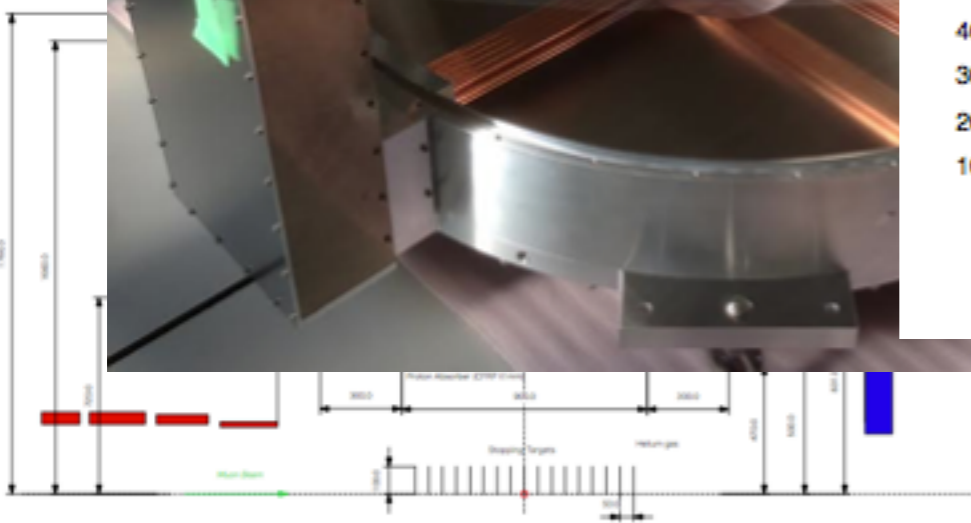
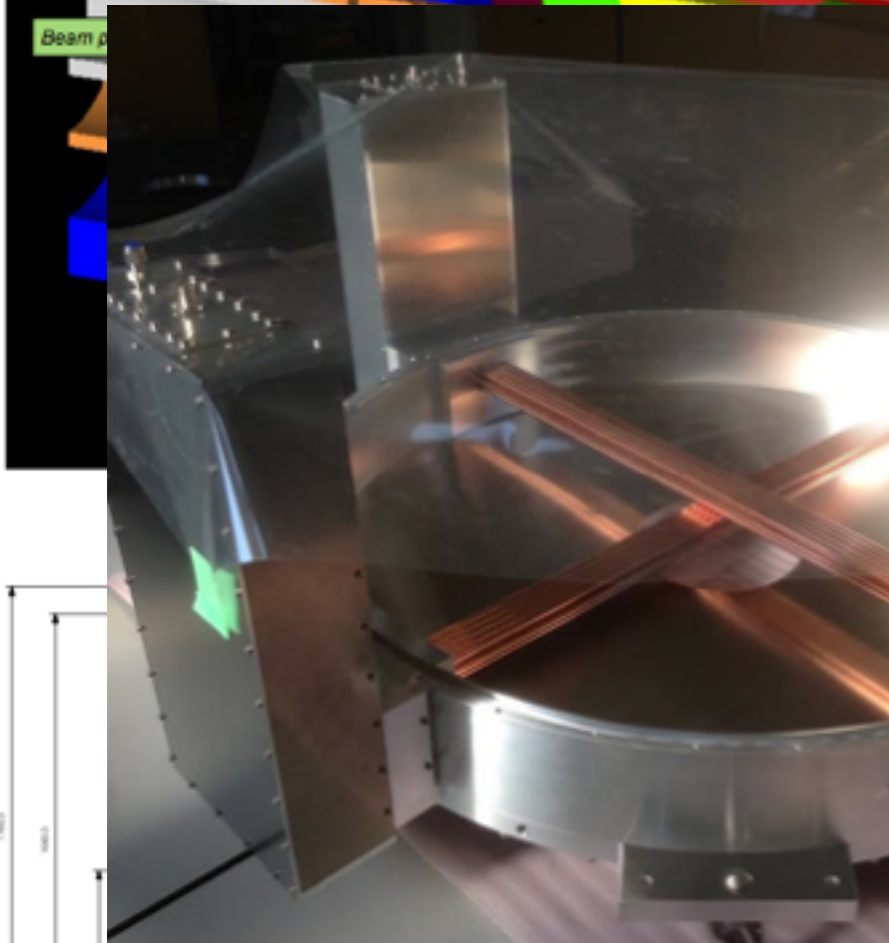
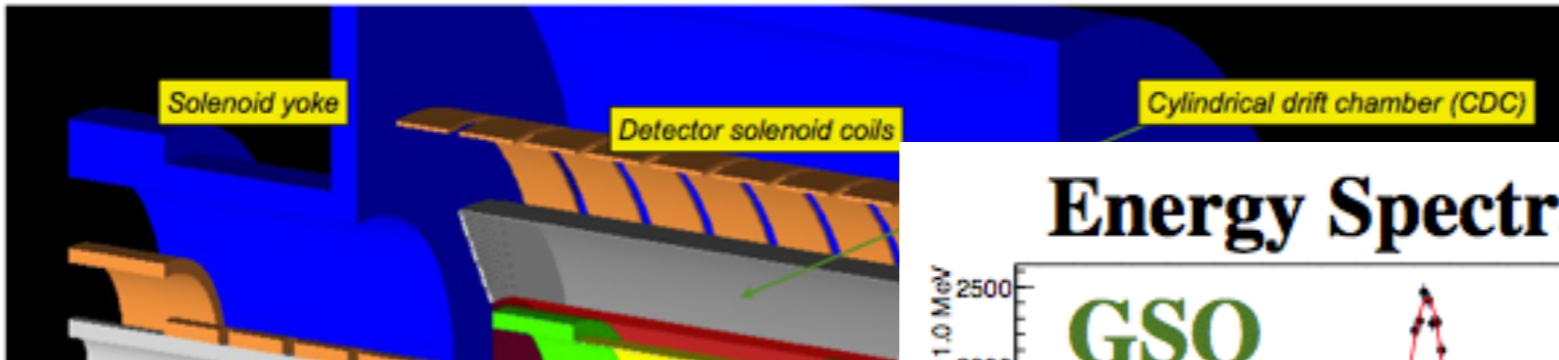
E counter

64ch readout boards

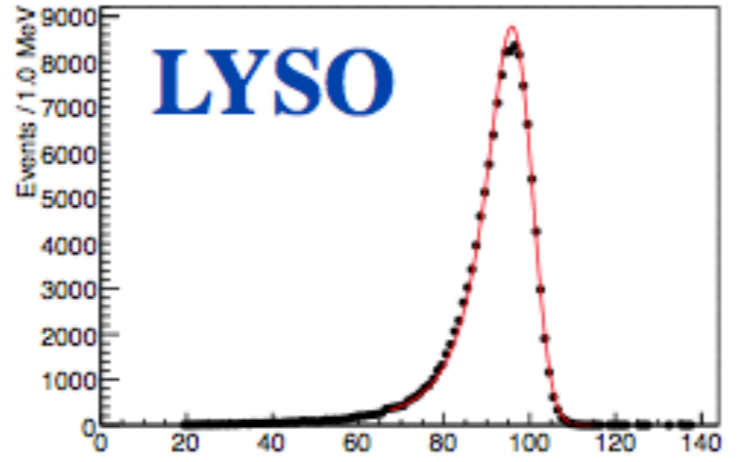
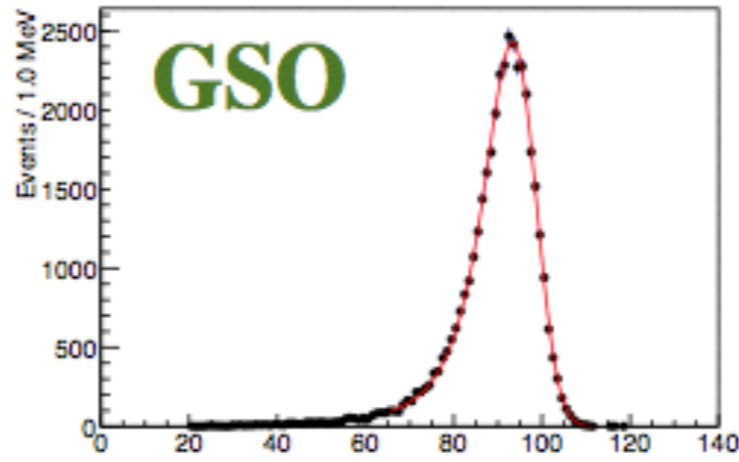
tension weight
50g (sense)
80g (field)

silicon field through

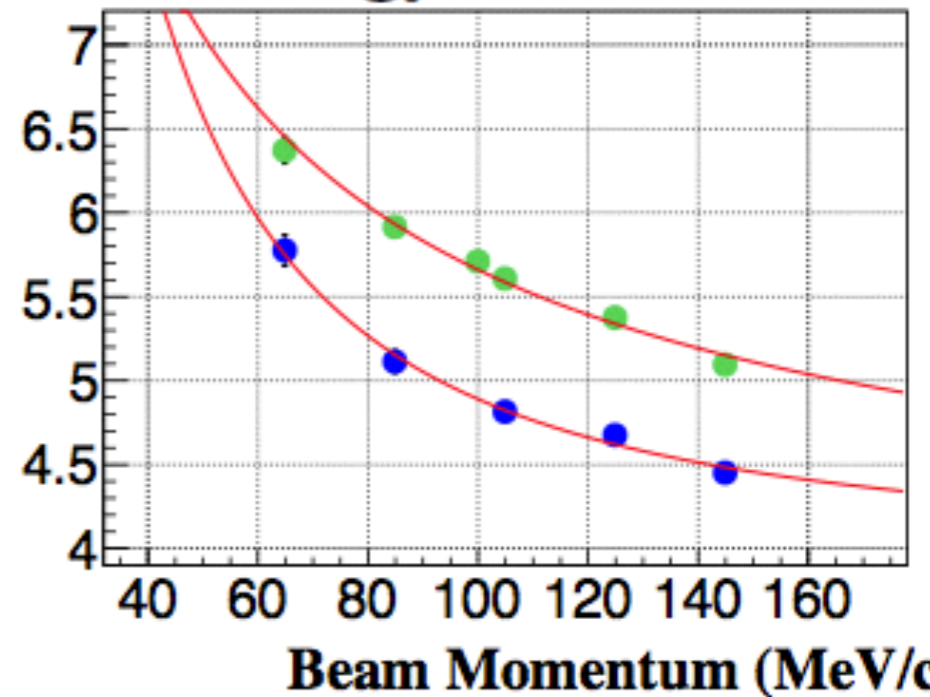
Detector Construction



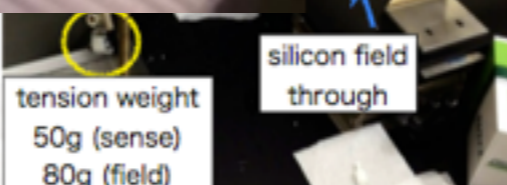
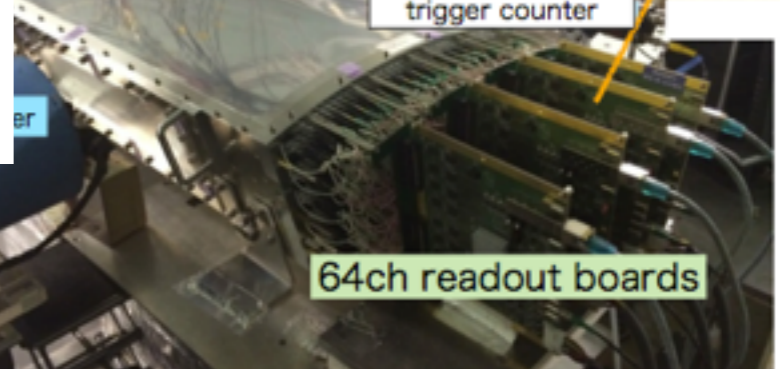
Energy Spectra



Energy Resolution

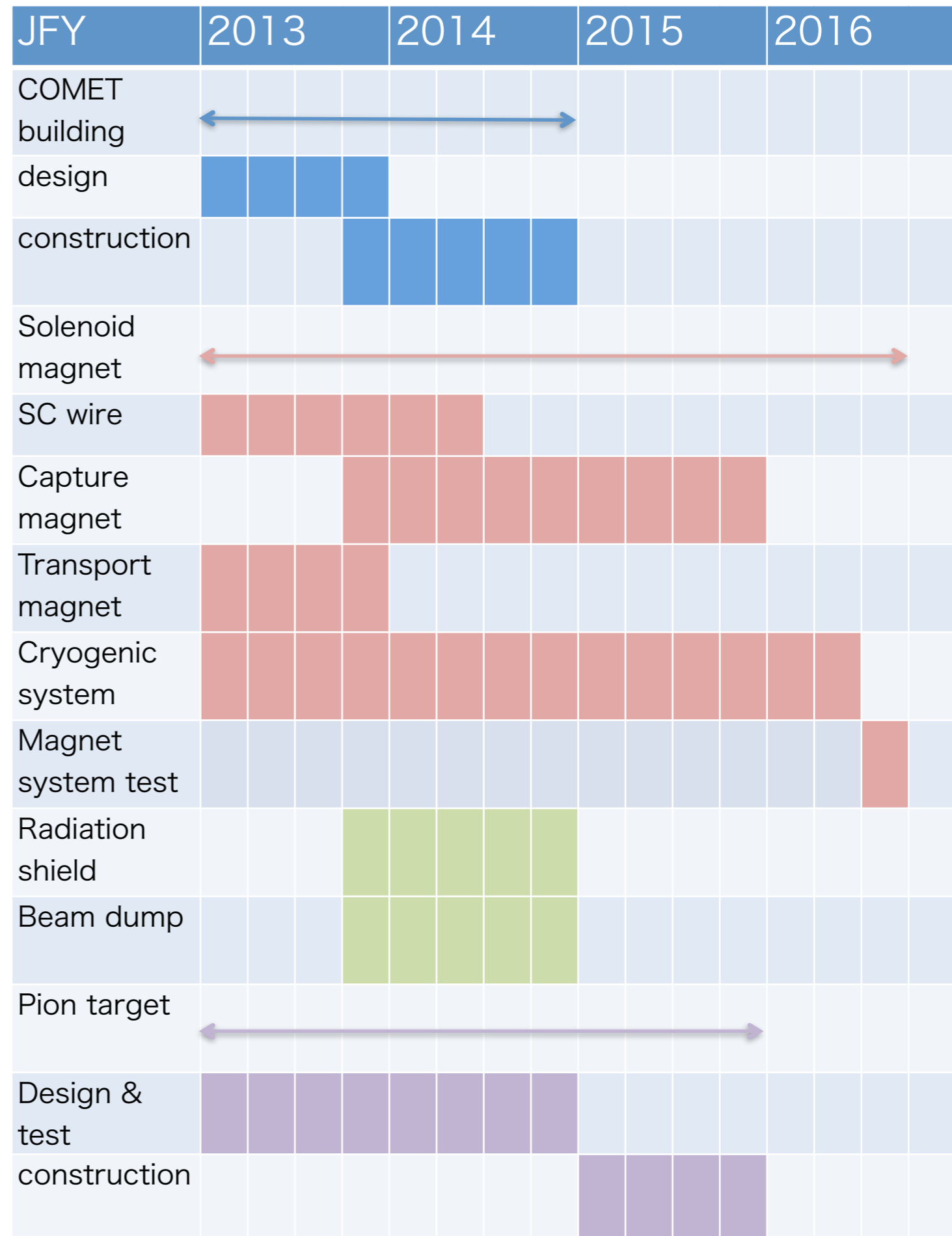


trigger counter
ASIC analog out



COMET Phase I Facility Schedule

- 2013
 - Design of the building & beam line
 - Bid tendering and start construction
 - Design of superconducting solenoid magnets and start of construction
 - Production of SC wires as well
 - Design of the pion production target
- 2014
 - Completion of the building
 - Construction of superconducting solenoid magnets
 - Start magnet and radiation shielding (and beam dump) installation
 - Transport solenoid
 - Start preparation of cryogenic system
 - Tests of the target production target
- 2015
 - Construction of superconducting solenoid magnets
 - Preparation of cryogenic system
 - Construction of the pion production target
- 2016
 - Installation of the capture solenoid
 - Completion of the cryogenic system
 - Tests of the magnet system
 - Installation of the target
 - Ready to accept the 8GeV beam



Future Prospect

Future Prospect

- Phase I
 - 10^{-14} sensitivity 2016-2017

Future Prospect

- Phase I
 - 10^{-14} sensitivity 2016-2017
- Phase II
 - 10^{-16} sensitivity 2019-2020

Future Prospect

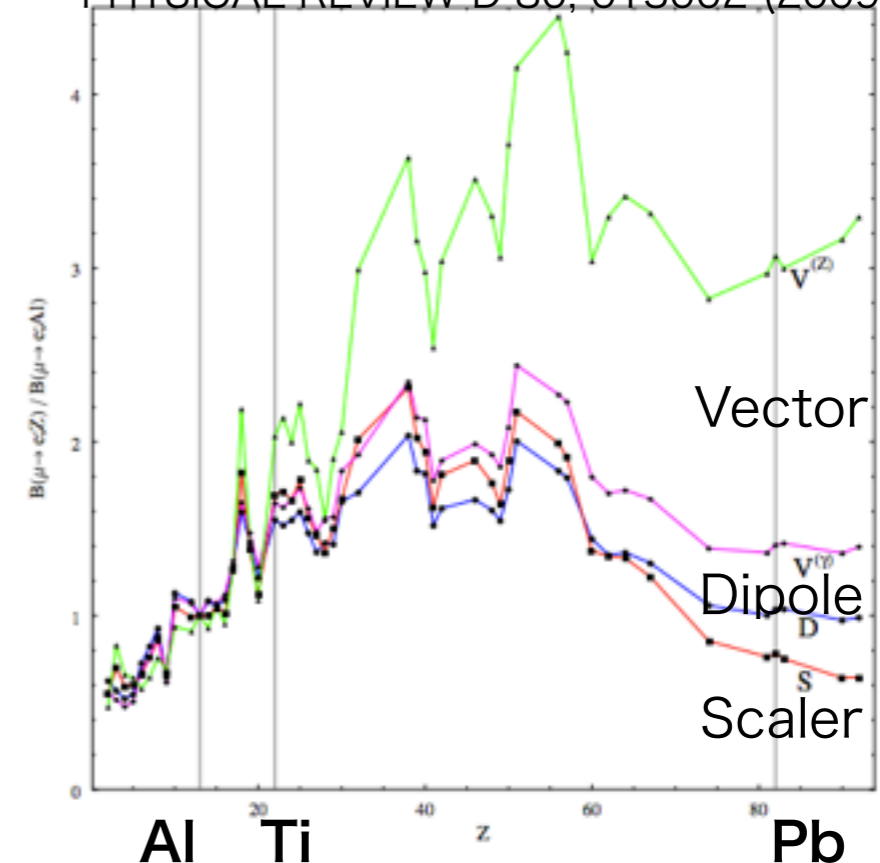
- Phase I
 - 10^{-14} sensitivity 2016-2017
- Phase II
 - 10^{-16} sensitivity 2019-2020
- R&D for more intense & suitable muon beam for mu-e conversion experiments
 - Once the signal is found...

Future Prospect

CIRIGLIANO, KITANO, OKADA, AND TUZON

PHYSICAL REVIEW D 80, 013002 (2009)

- Phase I
 - 10^{-14} sensitivity 2016-2017
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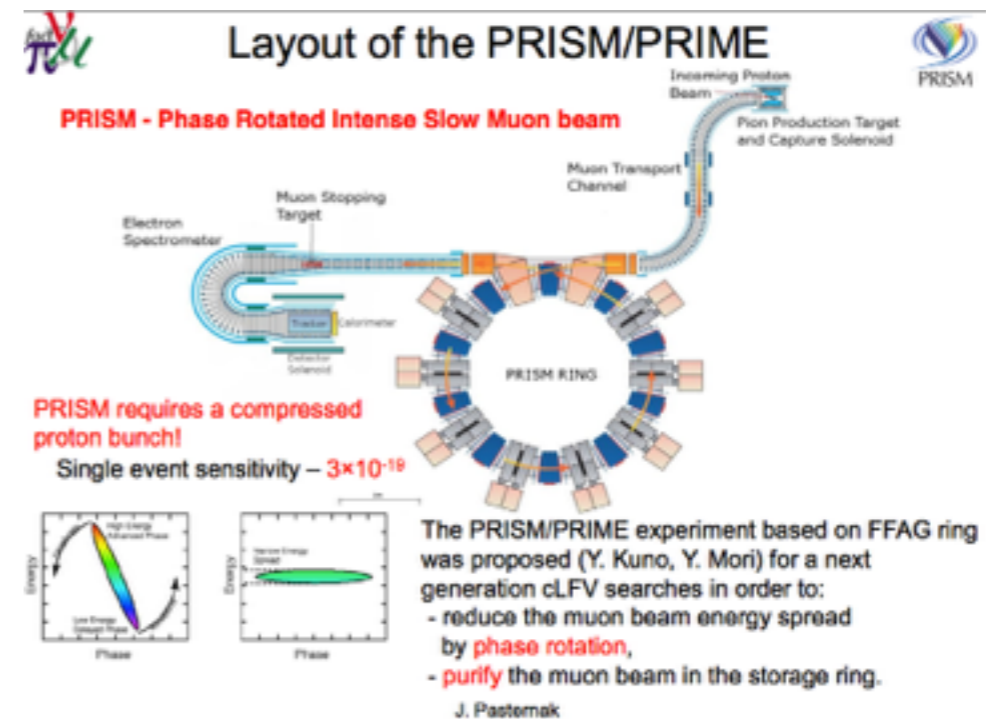
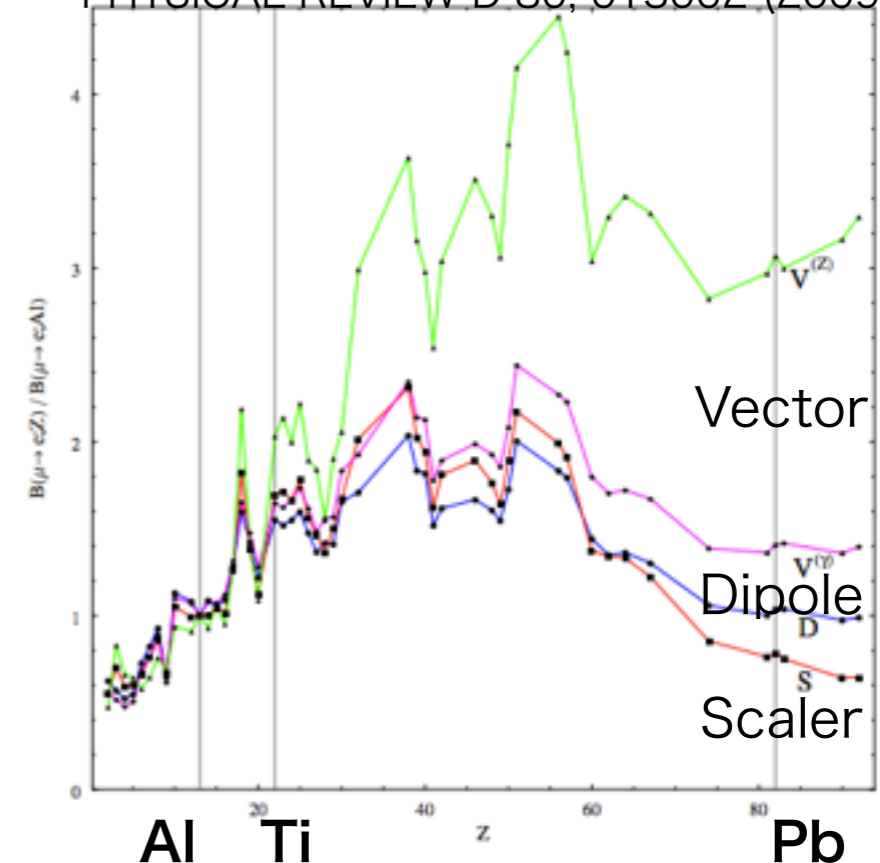


Future Prospect

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PHYSICAL REVIEW D 80, 013002 (2009)

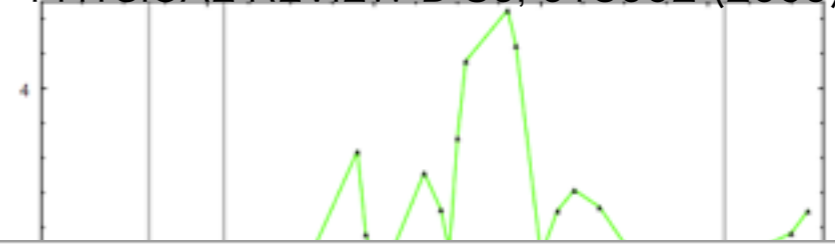
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Future Prospect

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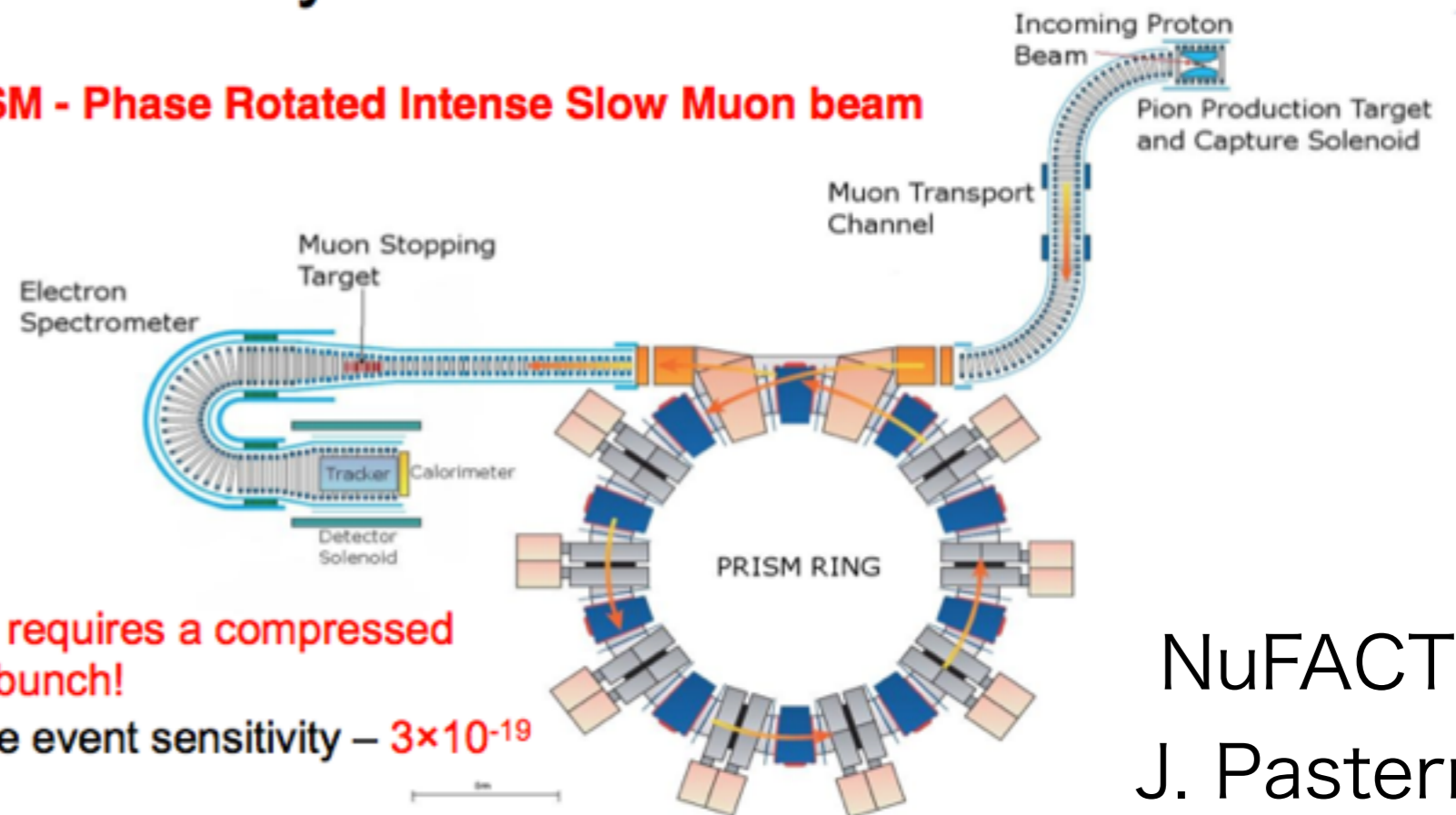
- Phase I
- 10^{-14} sensitivity
- Phase II
- 10^{-16} sensitivity
- R&D for more insuitable muon beam conversion experiment
- Once the signal is observed



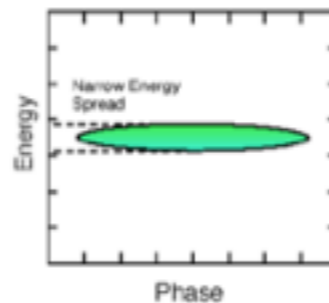
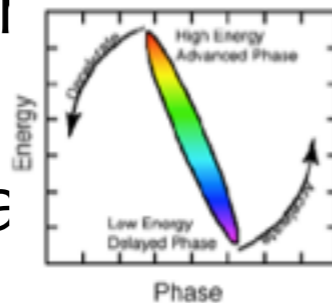
Layout of the PRISM/PRIME



PRISM - Phase Rotated Intense Slow Muon beam



NuFACT13
J. Pasternak



The PRISM/PRIME experiment based on FFAG ring was proposed (Y. Kuno, Y. Mori) for a next generation cLFV searches in order to:

- reduce the muon beam energy spread by **phase rotation**,
- **purify** the muon beam in the storage ring.

Summary

- cLFV as a clue to the new physics
- MEG & MEG II at PSI (R. Sawada's talk)
- New experiment at J-PARC in Japan
 - COMET collaboration searching for μ -e conversion
 - 10^{-14} sensitivity in Phase I and 10^{-16} in Phase II
 - Phase I facility construction is in progress to start the physics DAQ in 2016-2017
 - The facility is sufficient to accept Phase II beam power with additional radiation shielding

Search for Lepton Flavor Violation

✓ Lepton Flavor Violation in charged lepton sector, forbidden in SM

✓ New physics models beyond SM predict existence of conversion process

✓ COMET searches for μ -e conversion with a target sensitivity of 10^{-16} using high intensity muon beam provided at J-PARC

✓ Innovative J-PARC facility