The COMET experiment

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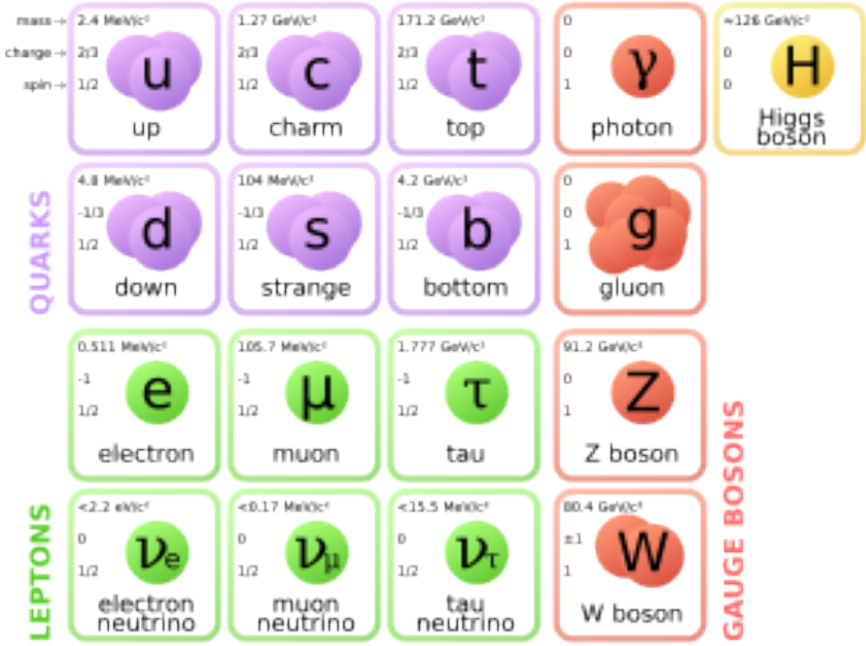
Outline

- Introduction
- Status and Plan of the COhrent 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



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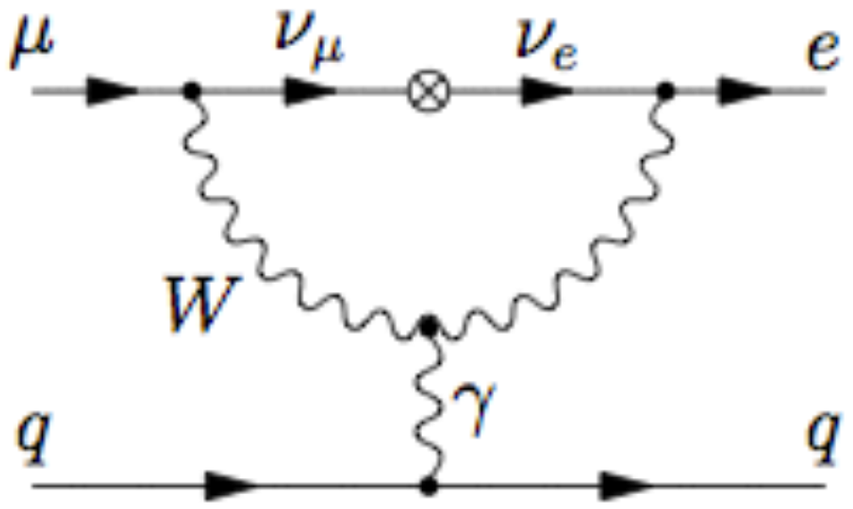

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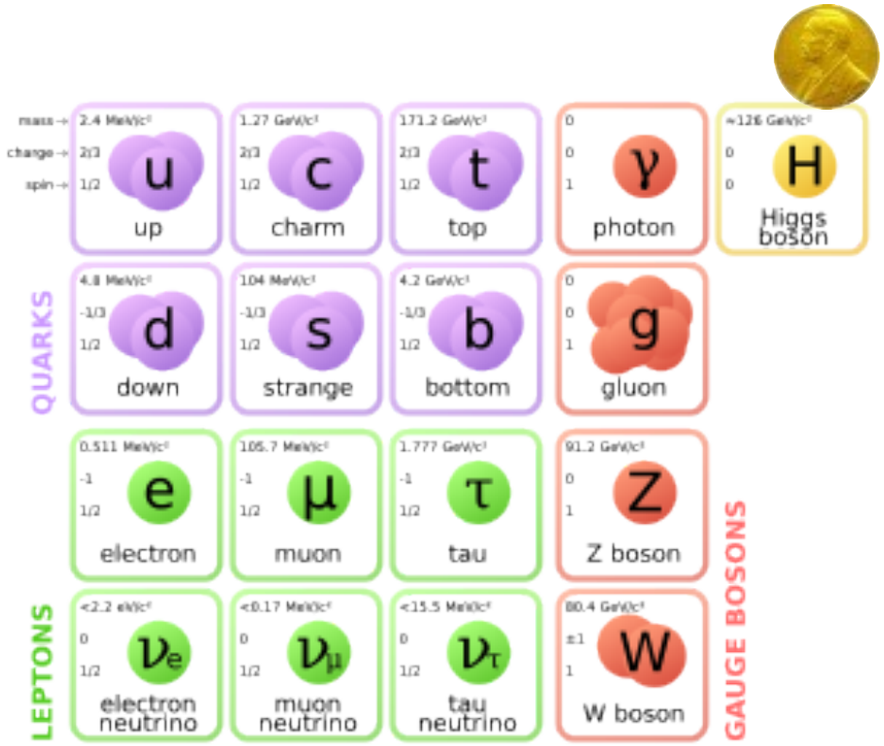
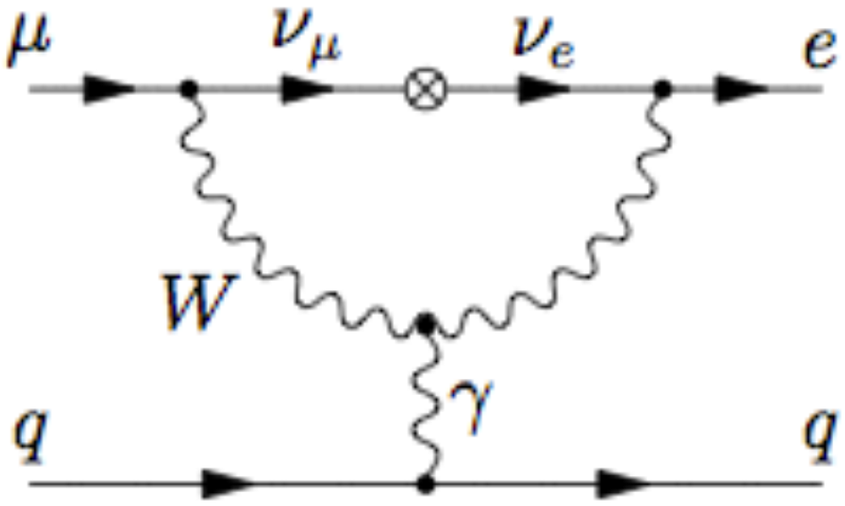
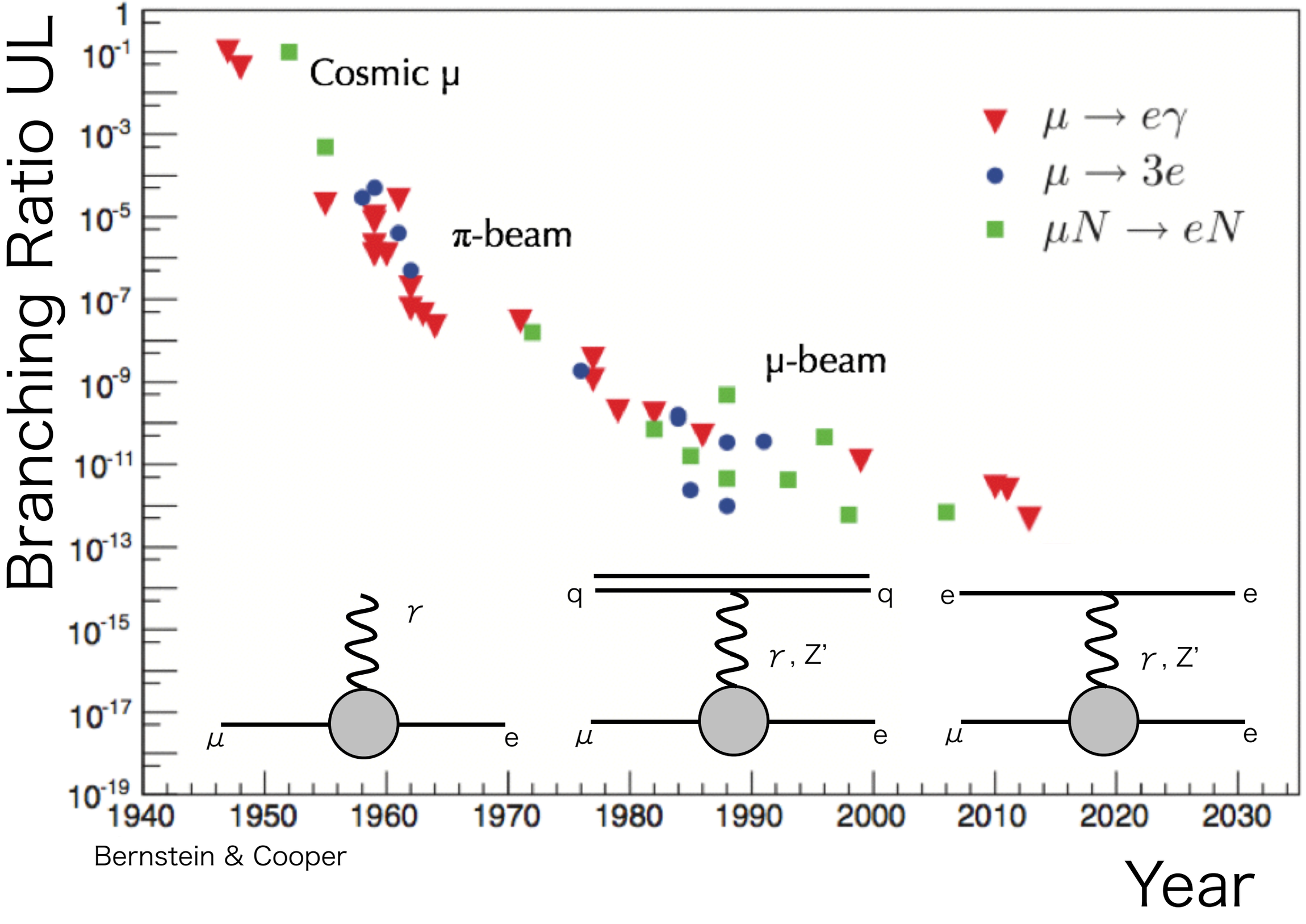
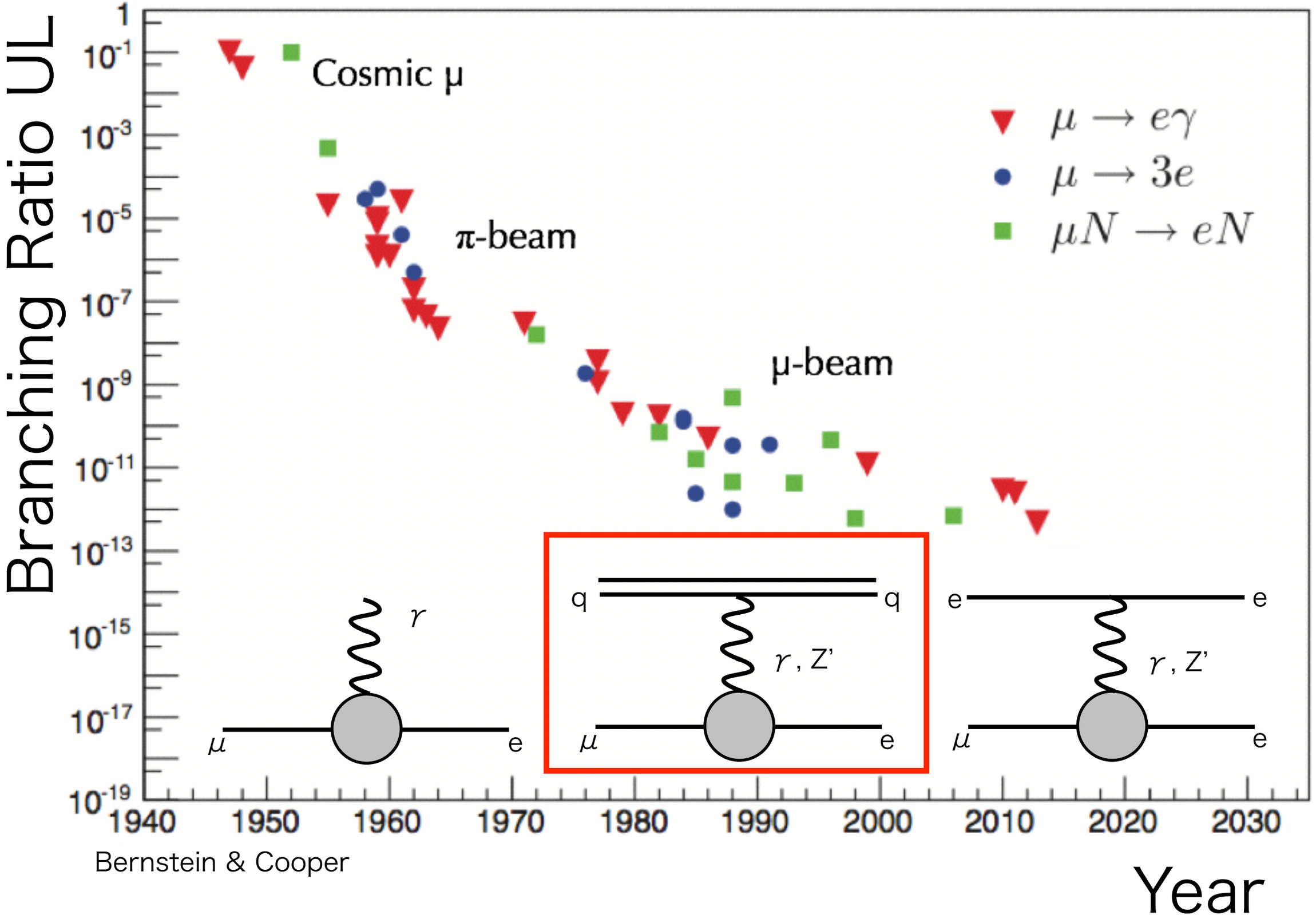




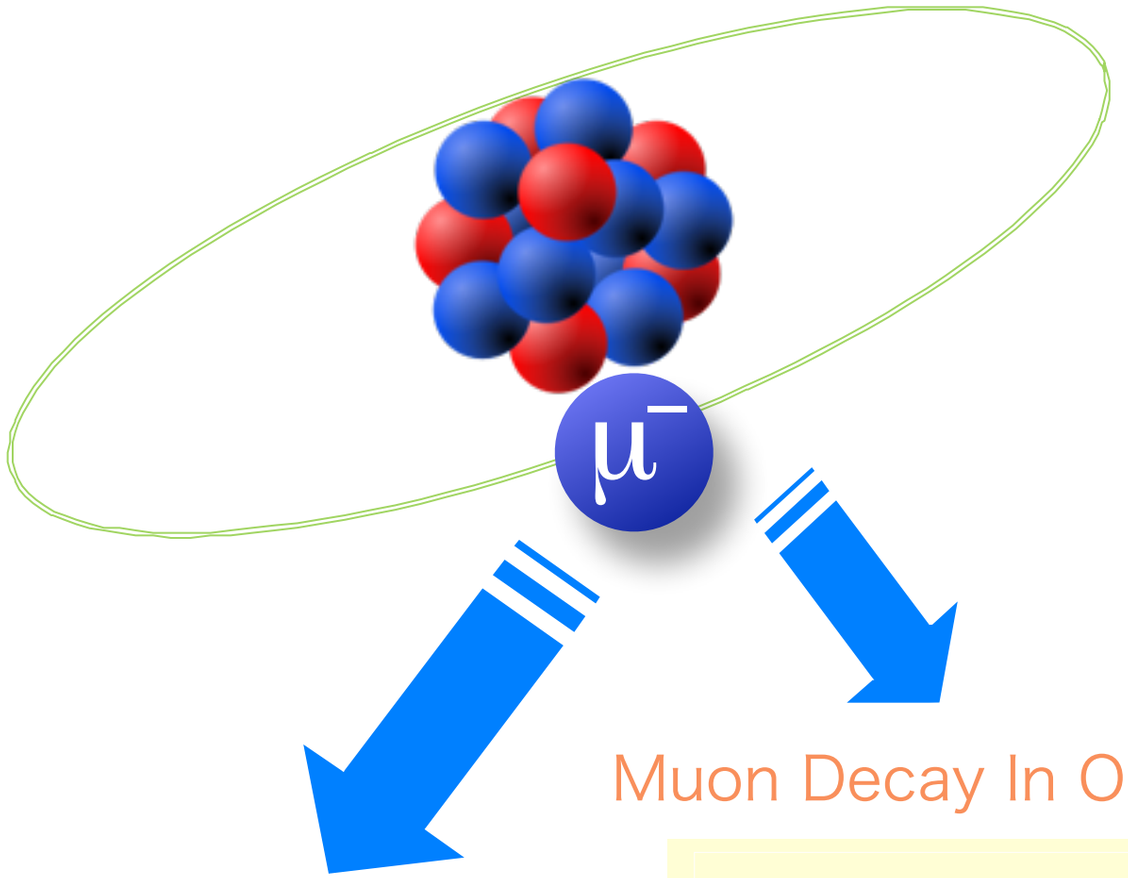


Bernstein & Cooper



Bernstein & Cooper

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



Muon Decay In Orbit

nuclear muon capture

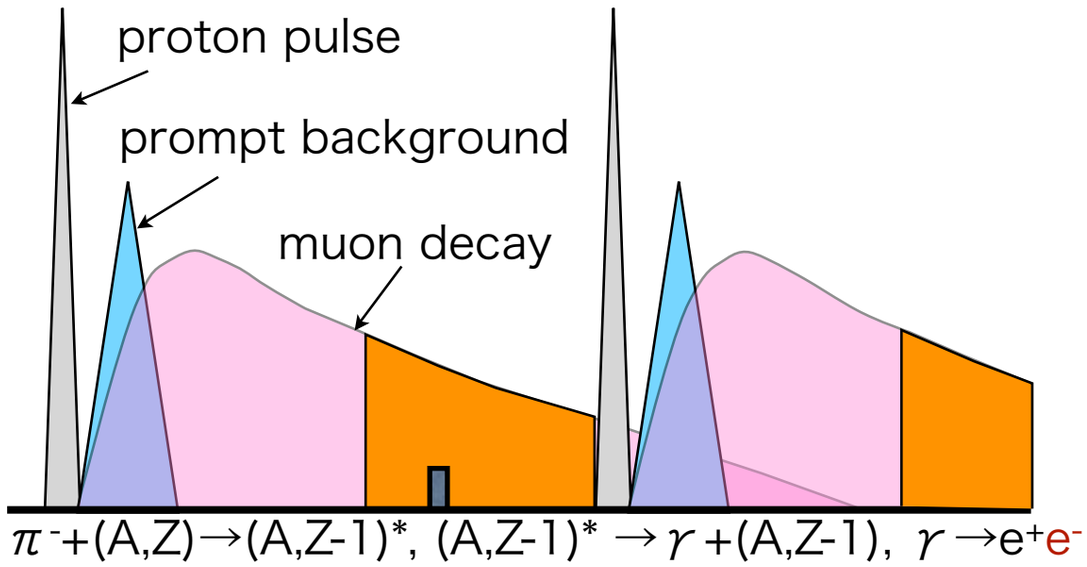
$$\mu^- \rightarrow e^- \nu \bar{\nu}$$

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

μ-e conversion

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

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



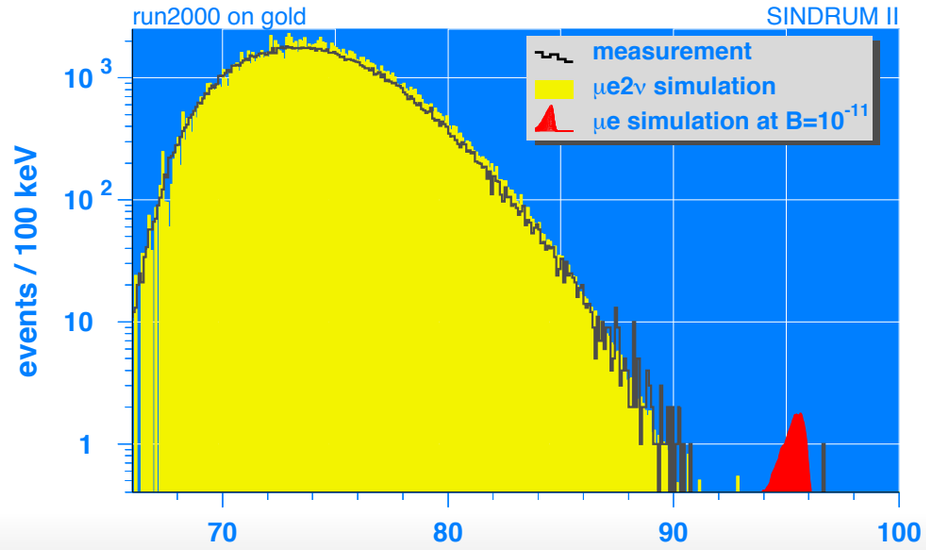
Prompt timing

Other sources

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

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

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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Rapid Cycle Synchrotron
Energy : 3 GeV
Repetition : 25 Hz
Design Power : 1 MW

Material and Life Science Facility

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Neutrino beam to Kamioka

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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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Material and Life Science Facility

Nuclear and Particle Physics Exp. Hall (Hadron Hall)

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Max Energy : 30 GeV
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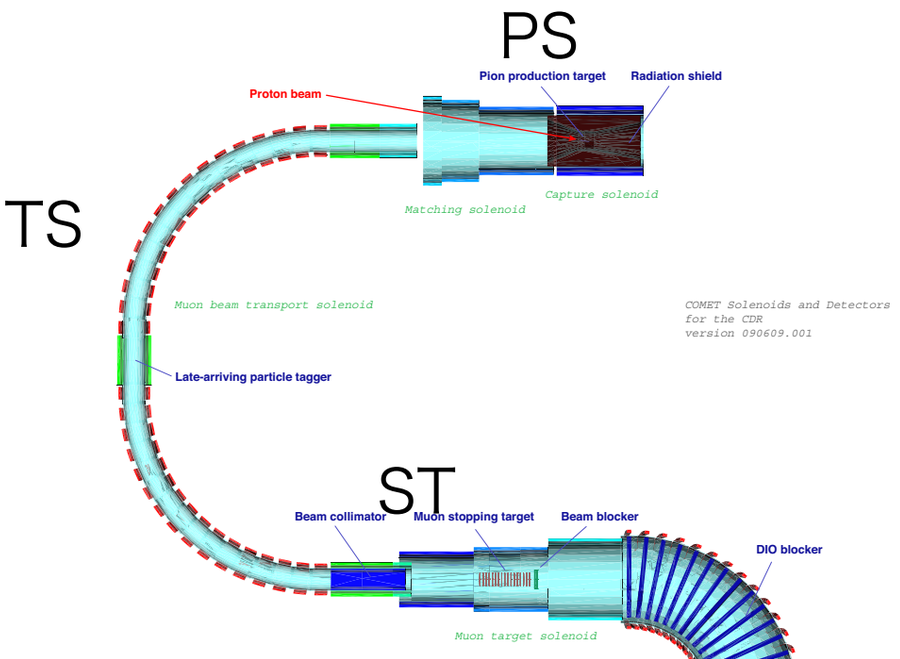
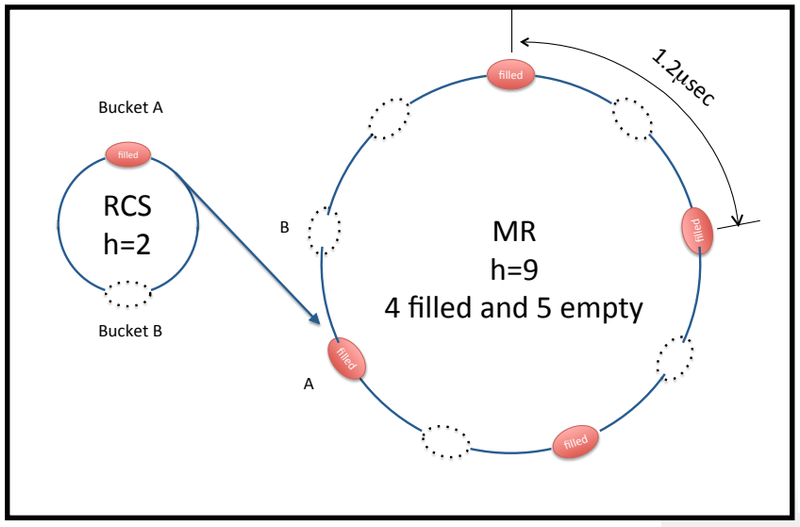
Expected Power for SX : > 0.1 MW

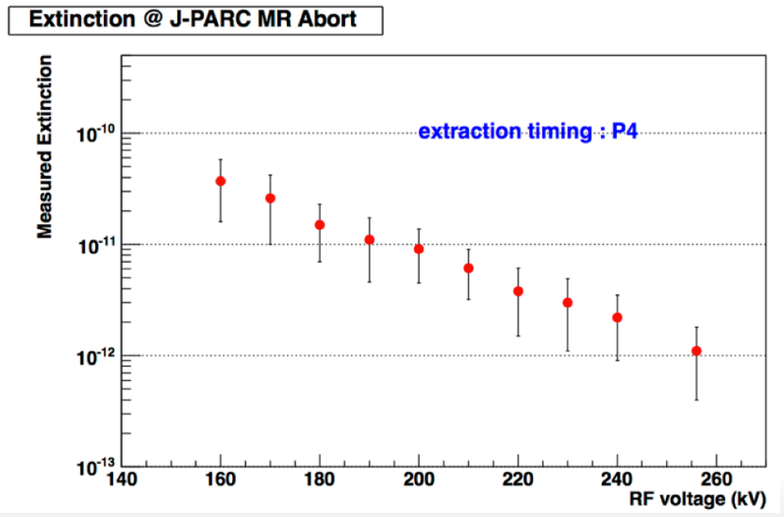
COMET at J-PARC

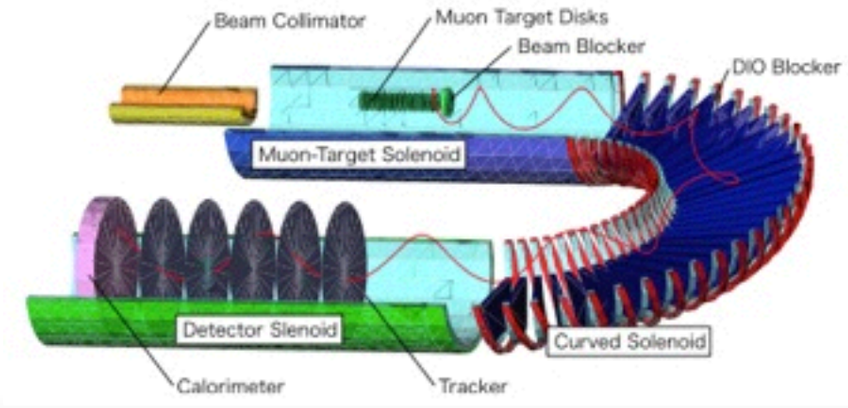
- J-PARC pulsed proton beam to produce pulsed muon beam
  - 8GeV, 3.2kW-56kW
  - Beam extinction factor study in May 2014
    - 8GeV w/o extraction < 10^{-11}

- 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)









COMET at J-PARC

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  - I
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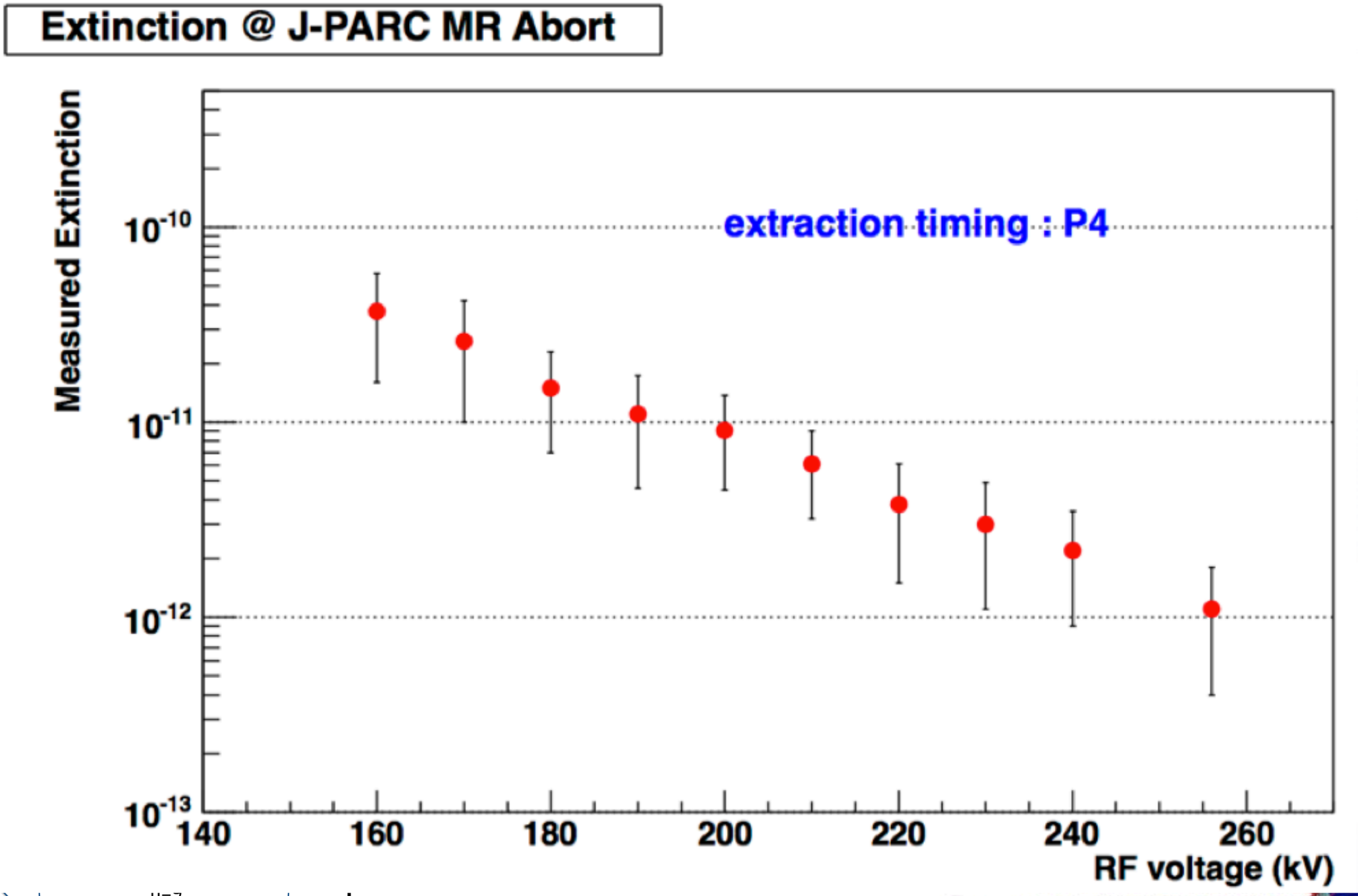
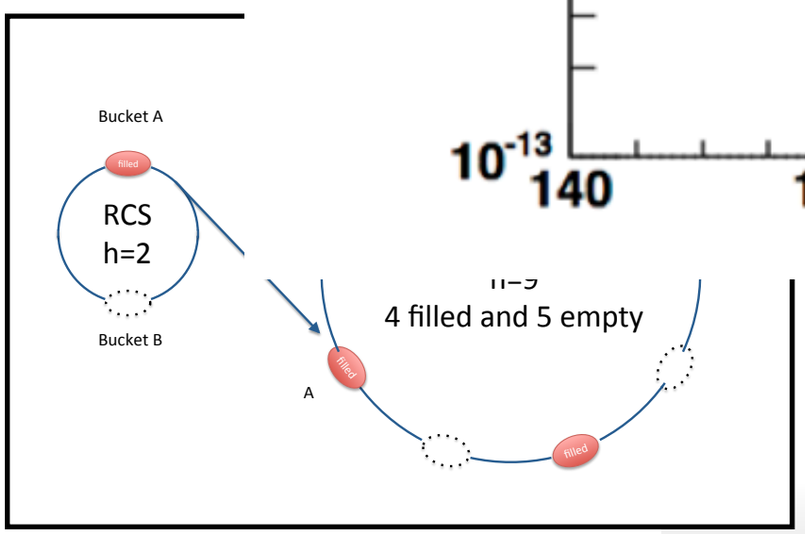
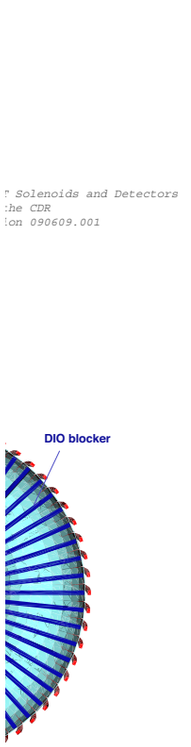
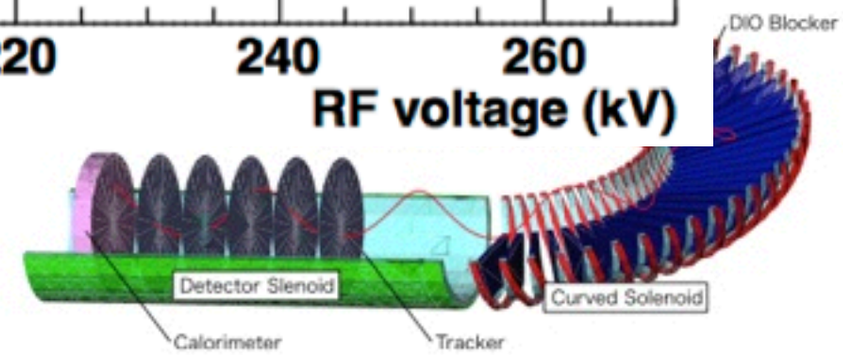


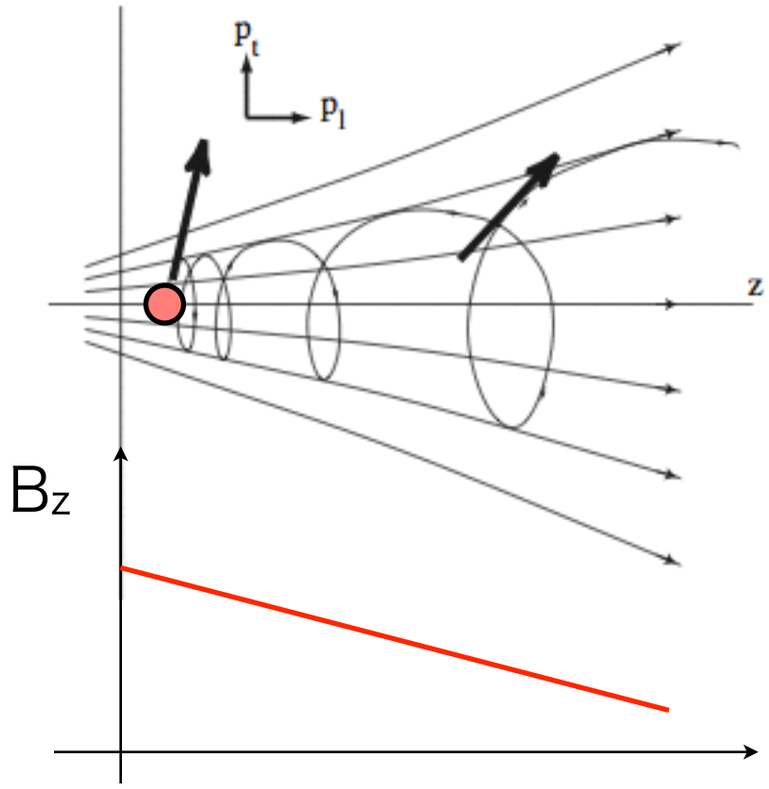






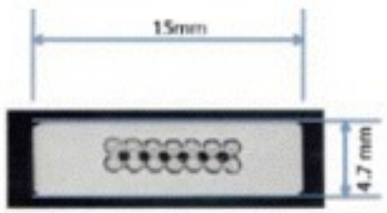
As many muons as possible!

Pion/muon collection using gradient magnetic field

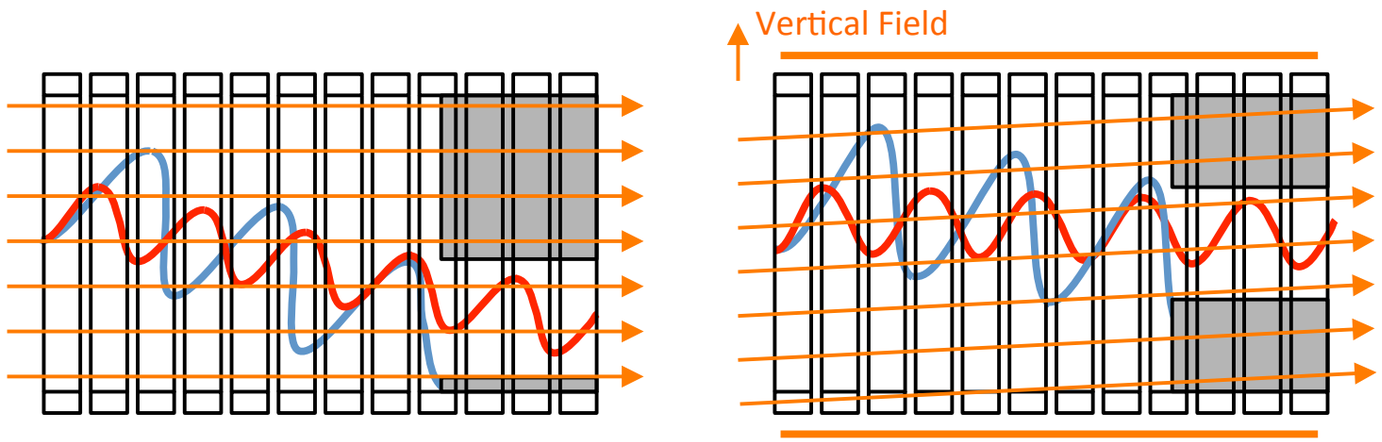


Strong Magnetic field in high radiation environment

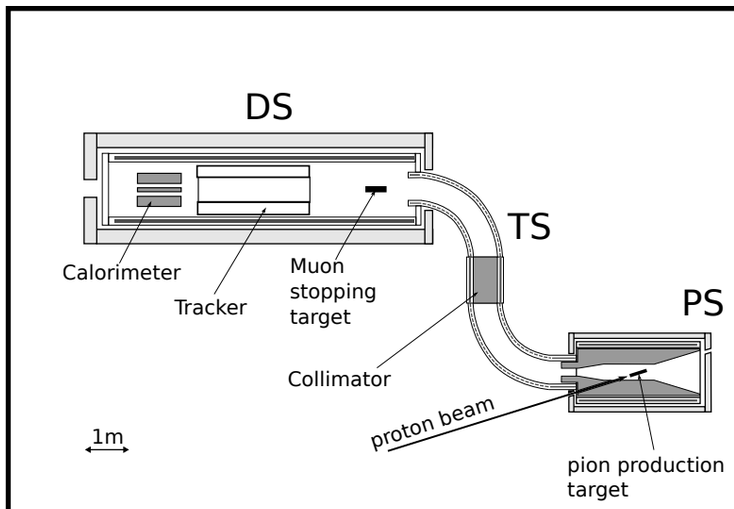
Aluminum stabilized SC
Collaborative R&D between COMET & Mu2e



Muon transport with large momentum acceptance and momentum selection



Mu2e



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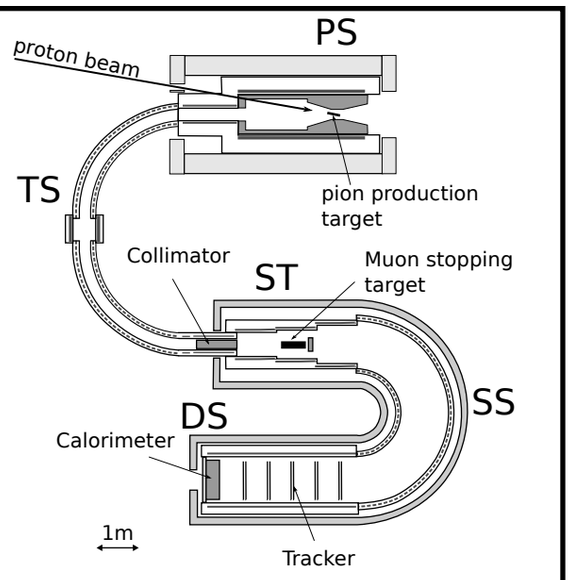
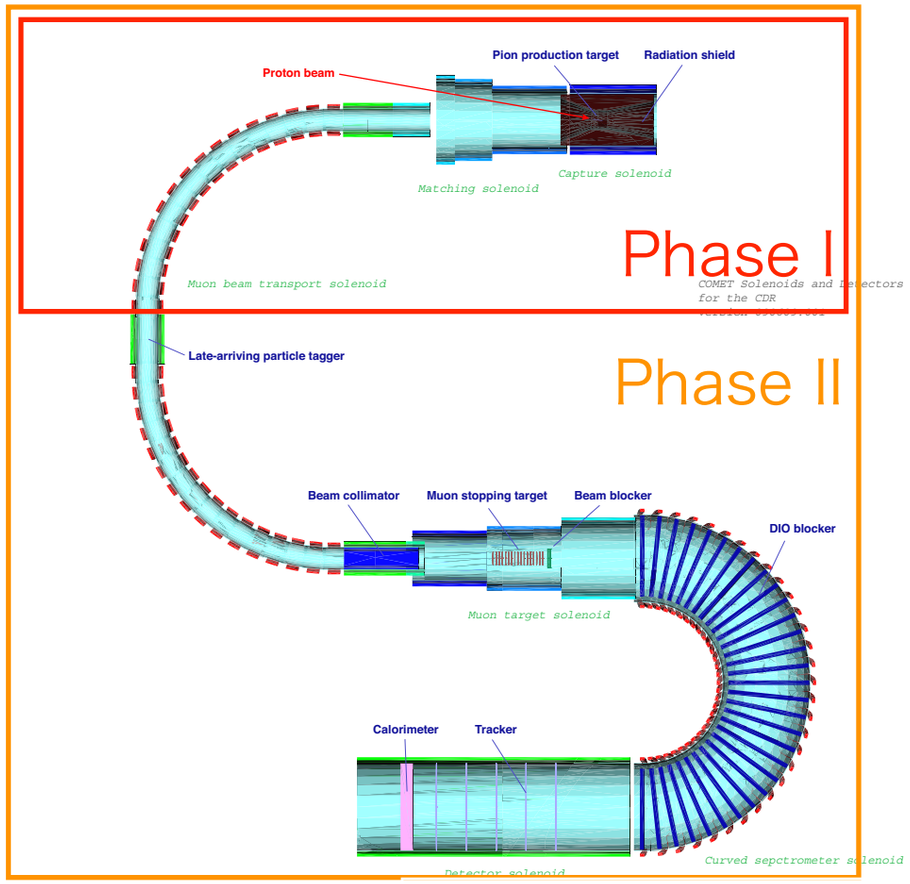
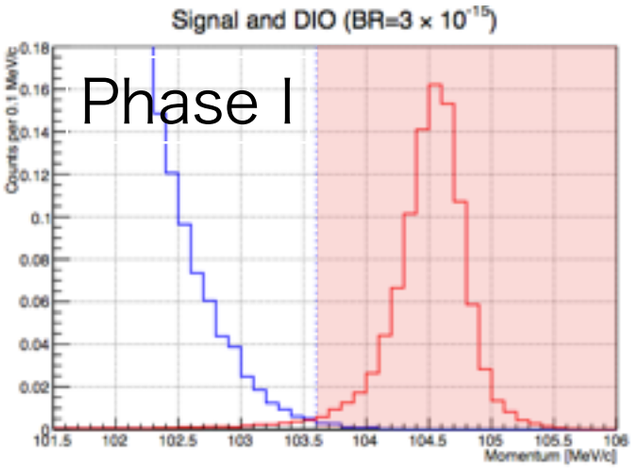


COMET Phase I & II

- 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)

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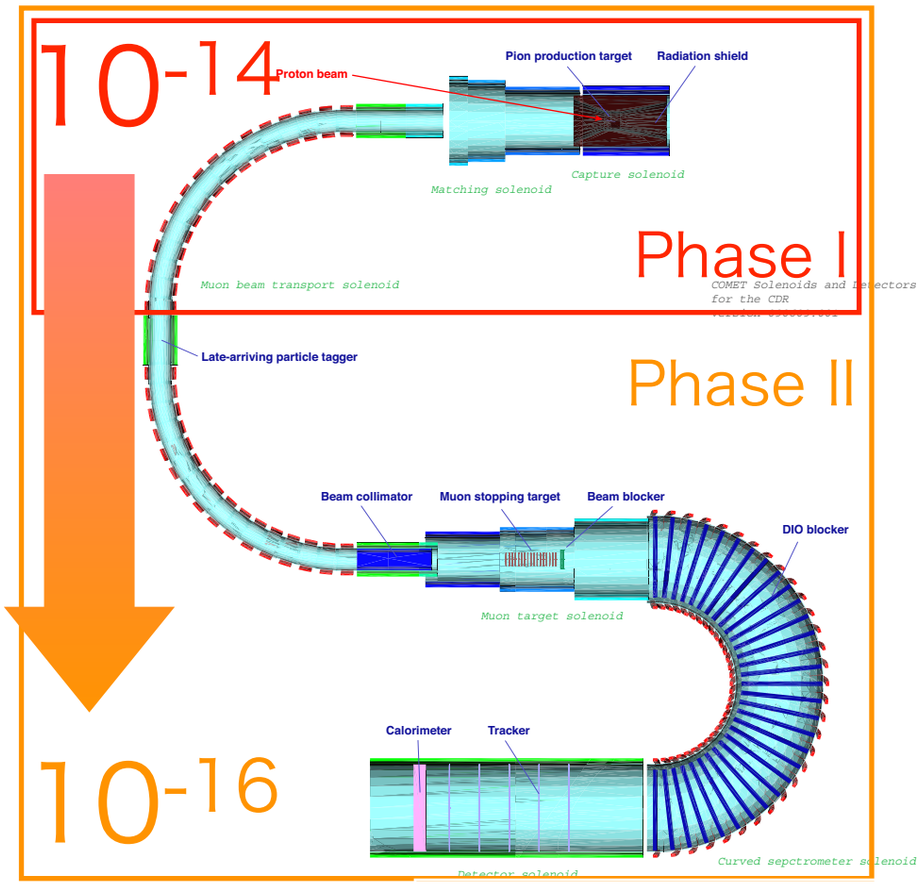

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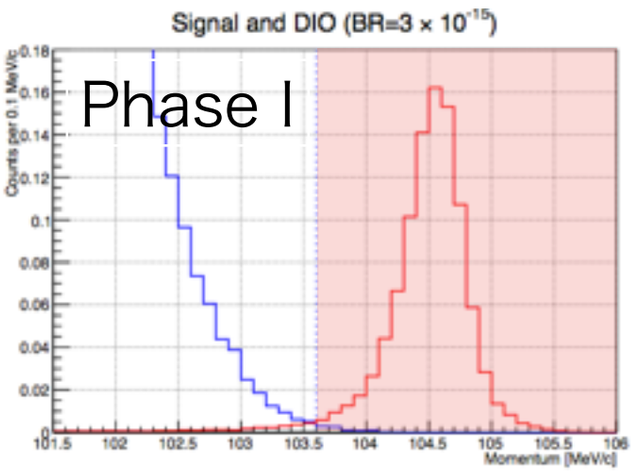

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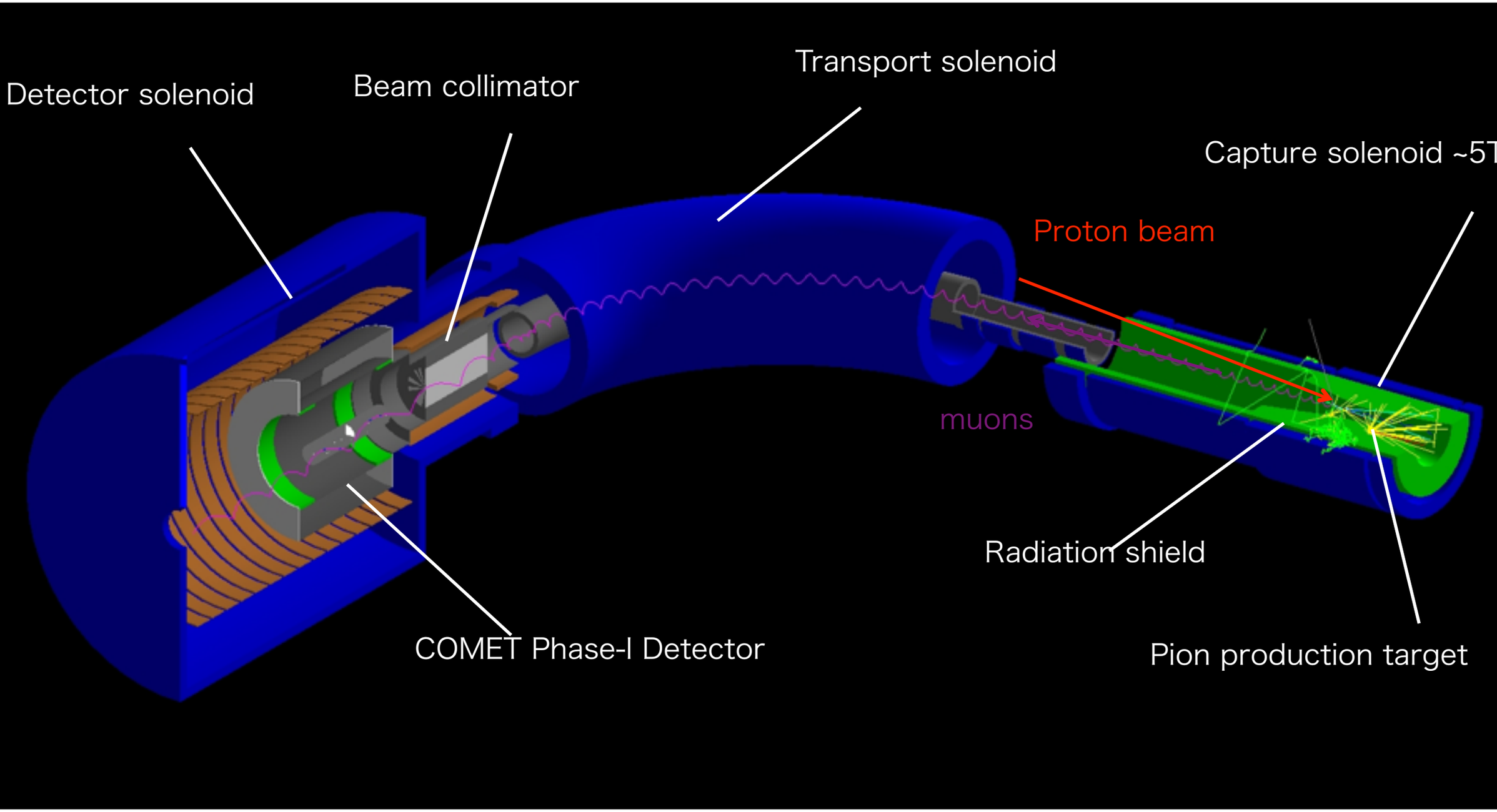
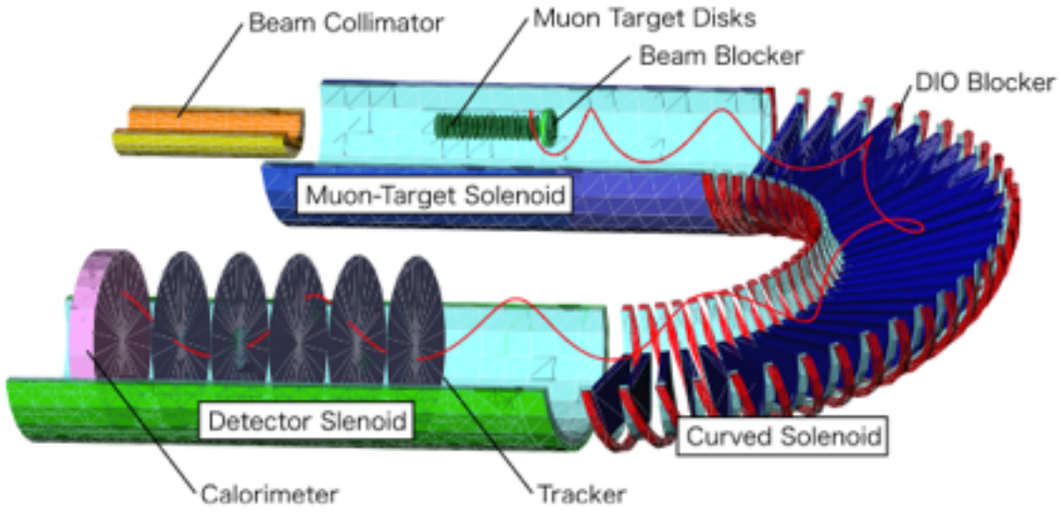
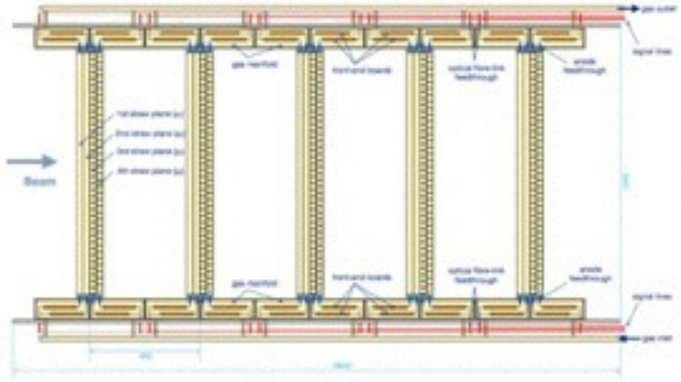
COMET Phase I Setup

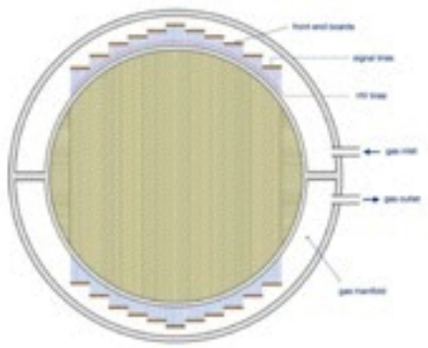


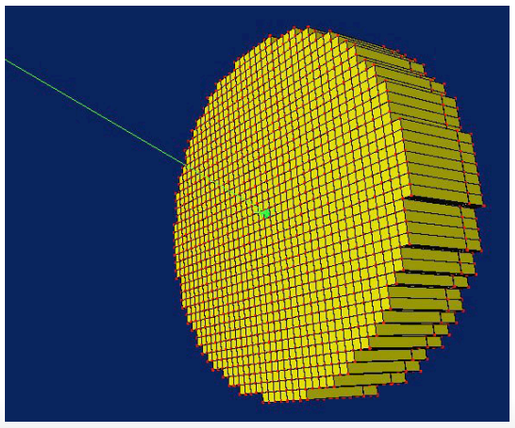
R&D toward Phase II

- 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_{cap}=0.61
  - N_{μ}=1.3x10^{16} muons (~90days@0.4μA)
  - S.E.S.=3.1x10^{-15}, 90% U.L. = 7.2x10^{-15}

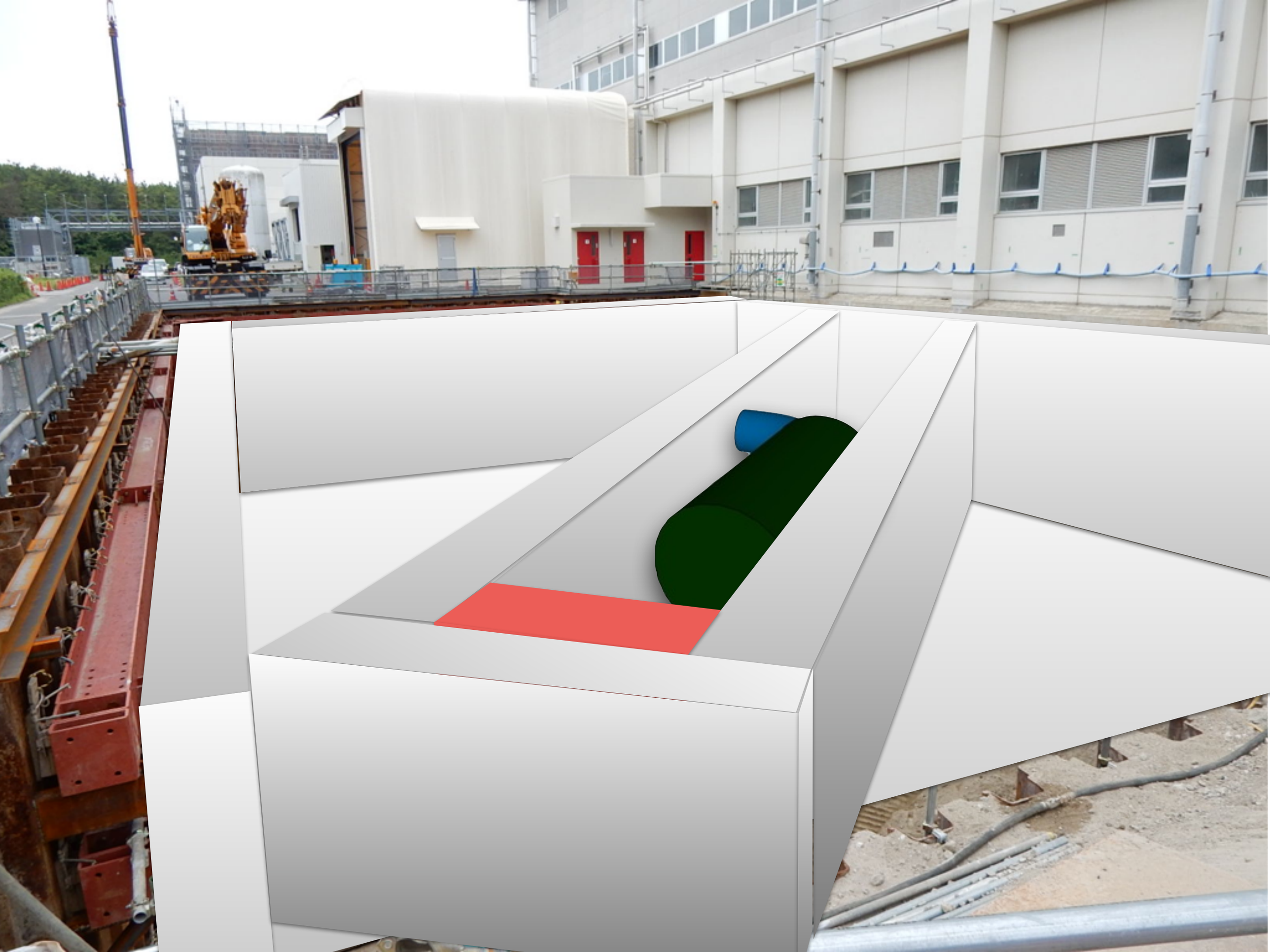
- Background

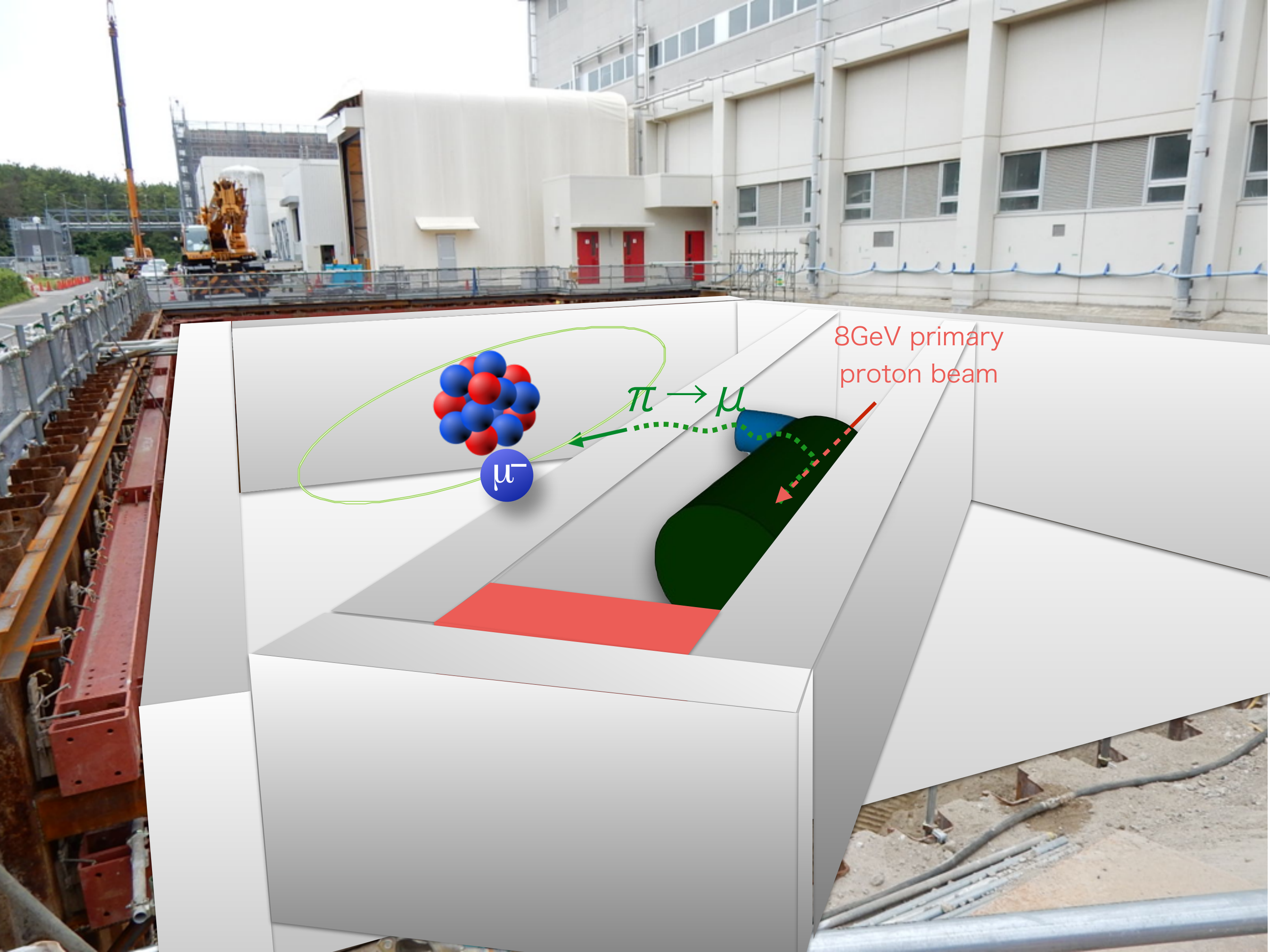
Type	Background	Estimated events
Physics	Muon decay in orbit	0.01
Physics	Radiative muon capture	5.6×10^{-4}
Physics	Neutron emission after muon capture	< 0.001
Physics	Charged particle emission after muon capture	< 0.001
Prompt Beam	Beam electrons (prompt)	7.1×10^{-4}
Prompt Beam	Muon decay in flight (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

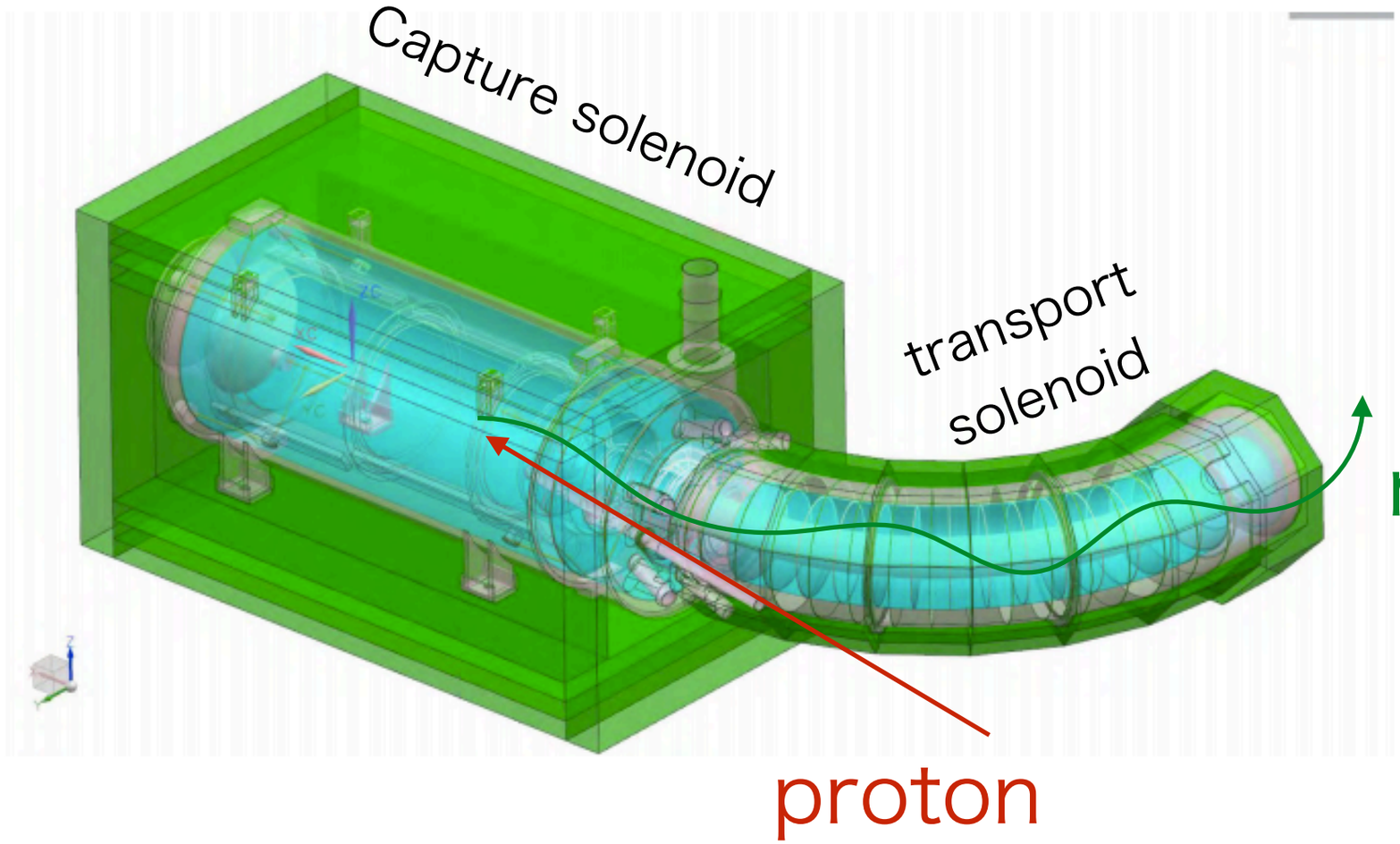
Status of COMET

- Facility construction
- Superconducting magnet construction
- Detector construction




8GeV primary
proton beam
$\pi \rightarrow \mu$
μ^-

SC Magnet Construction



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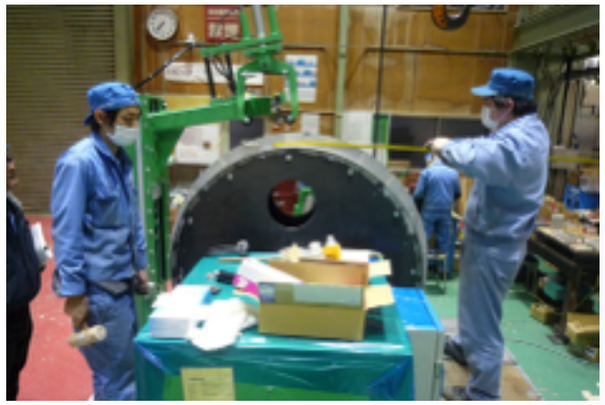

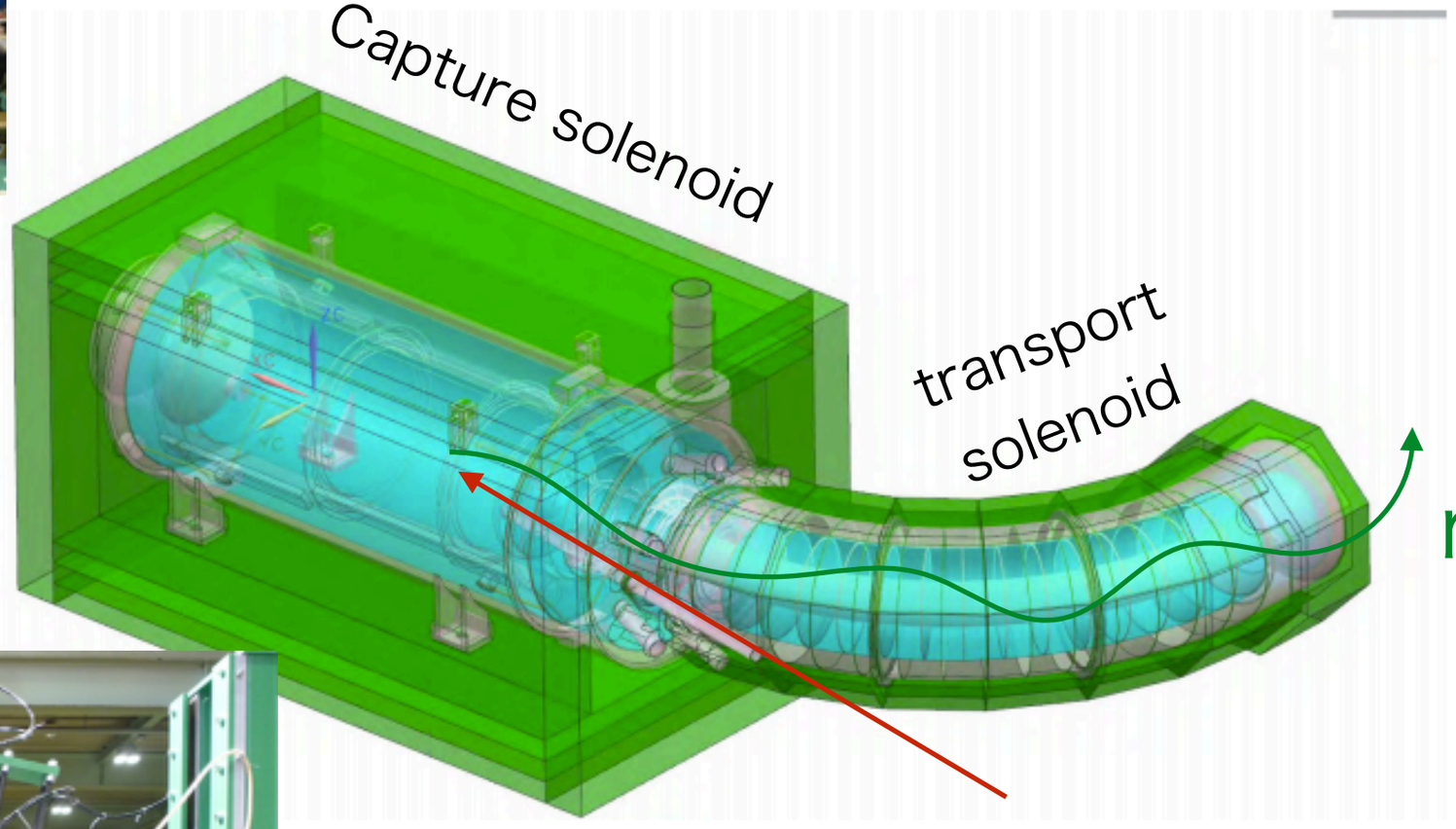

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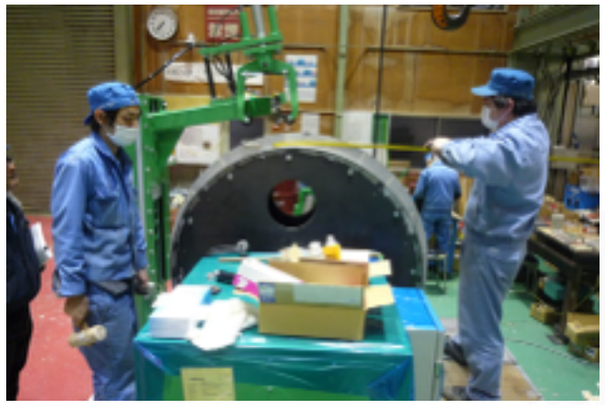

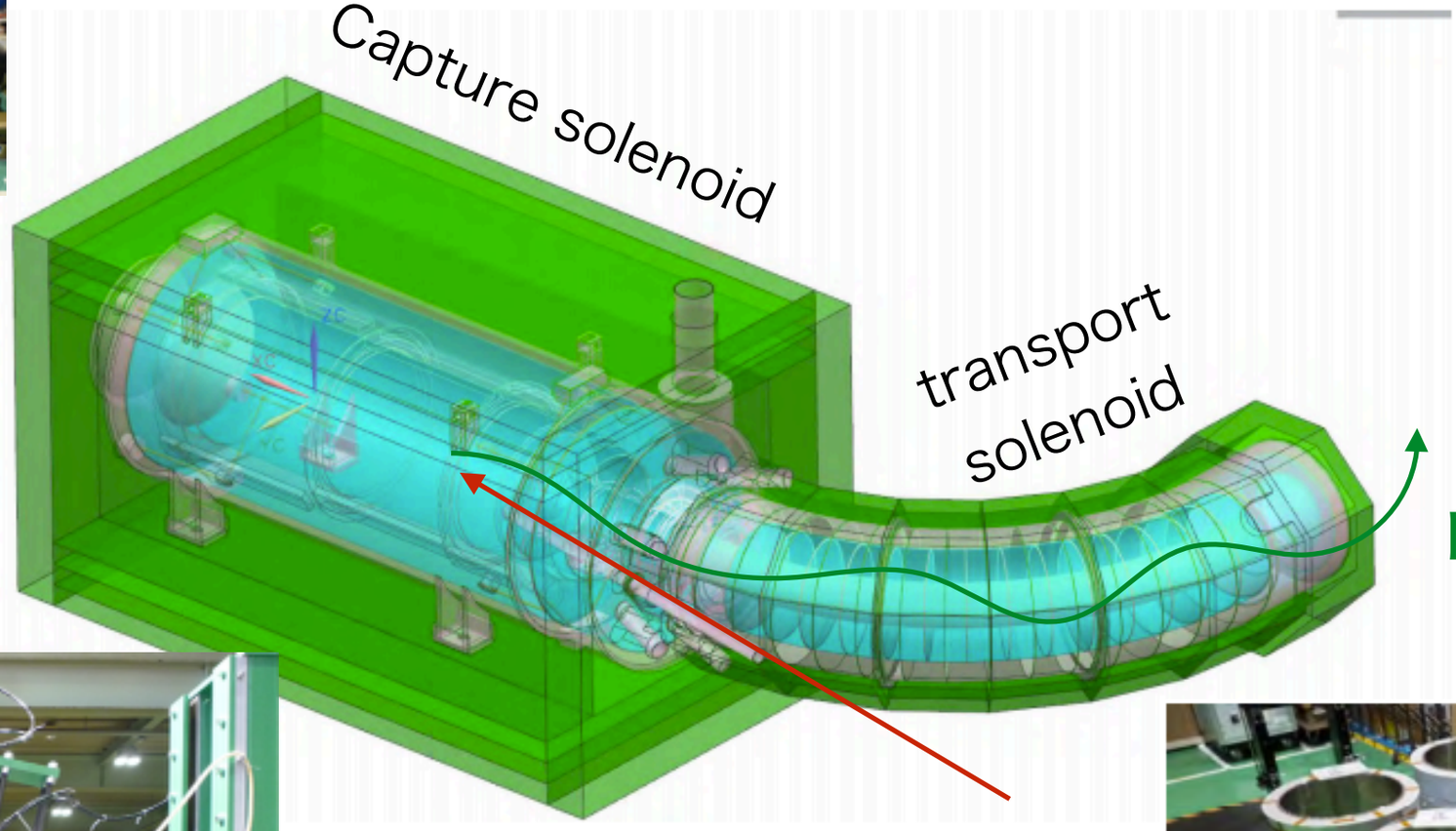

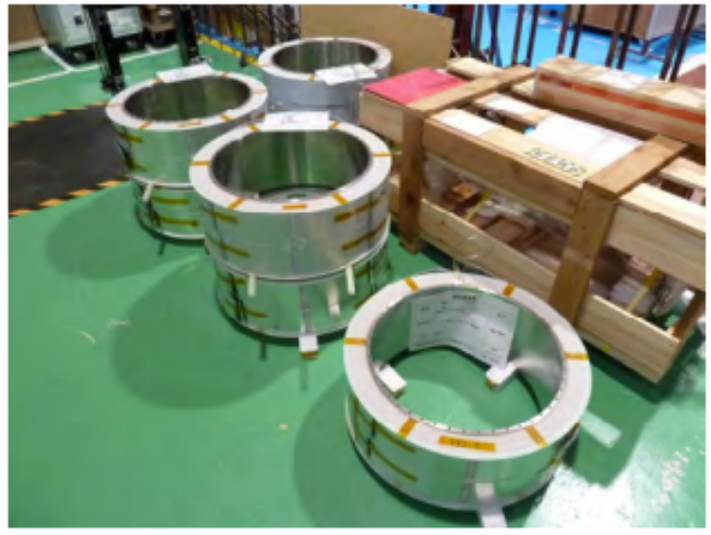

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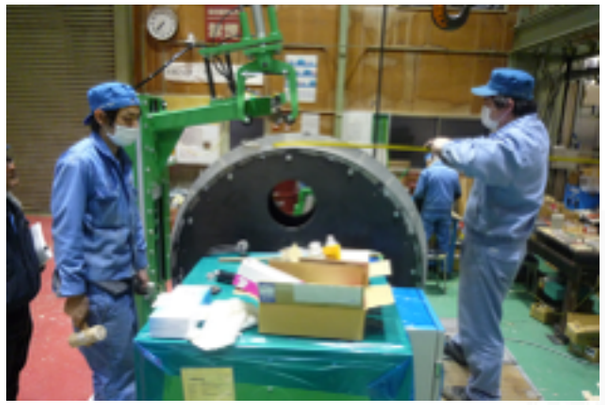

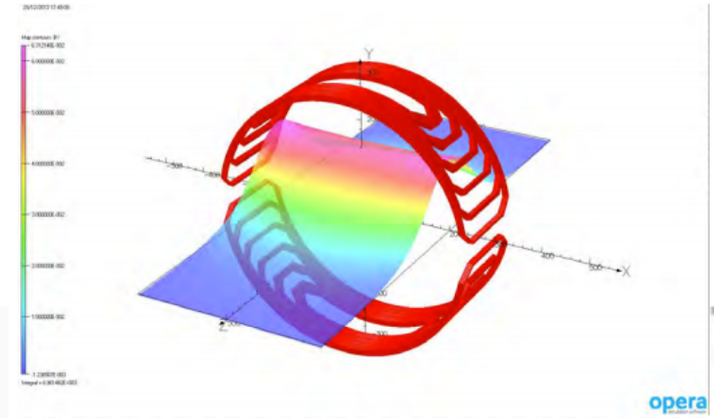

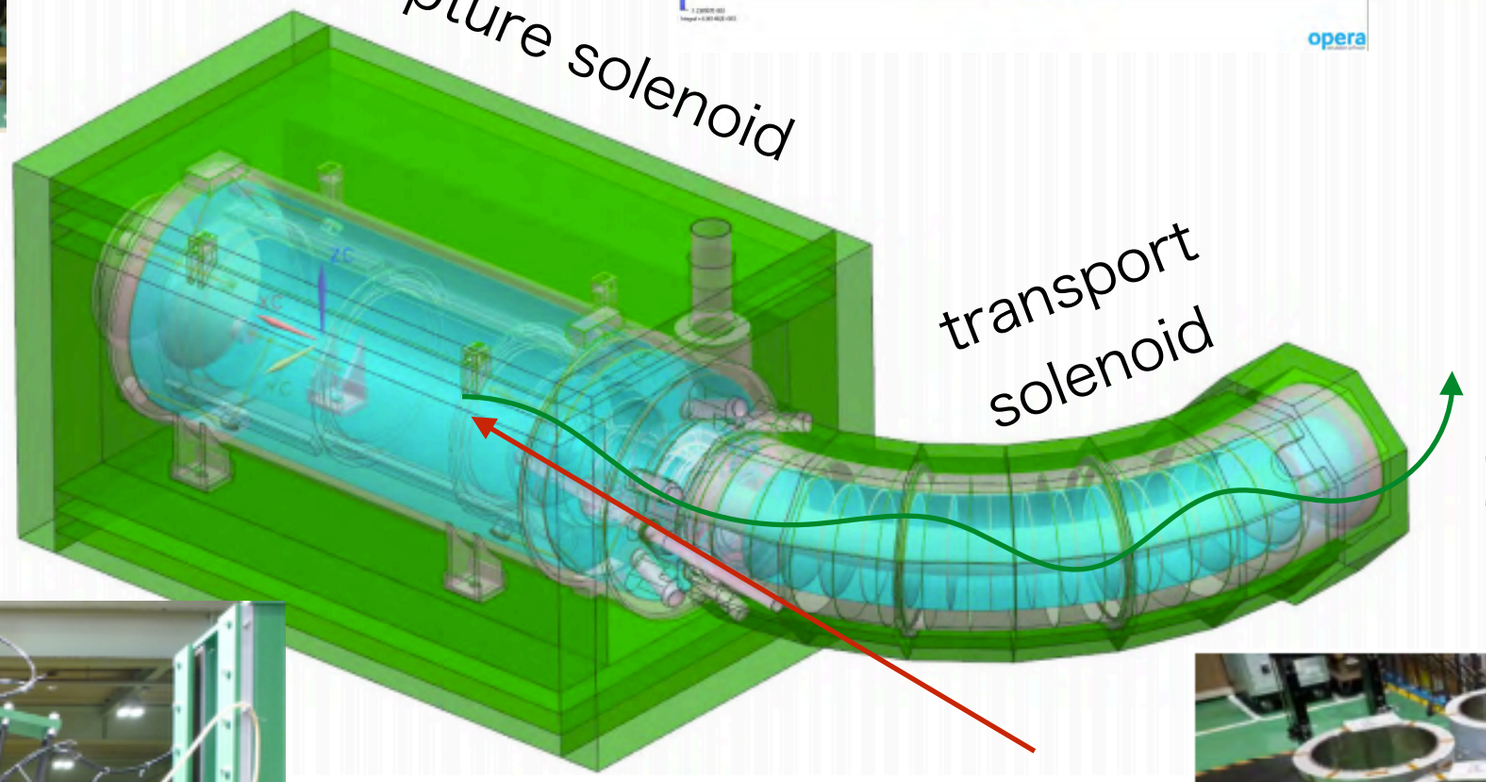

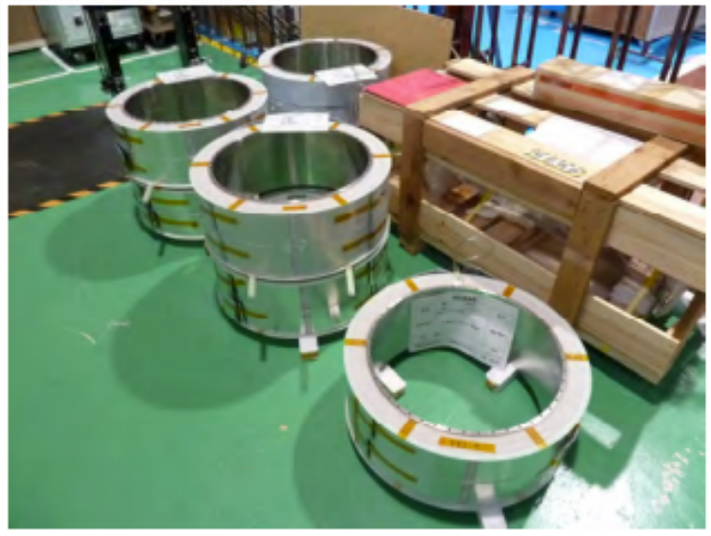

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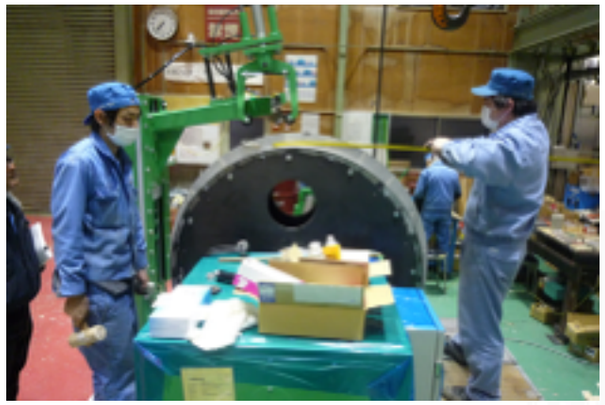
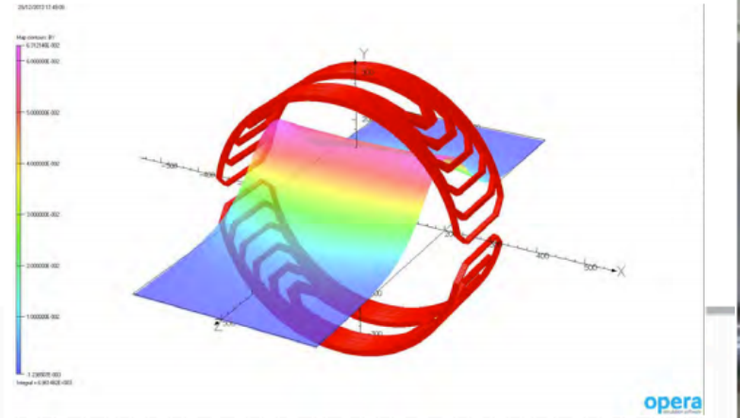
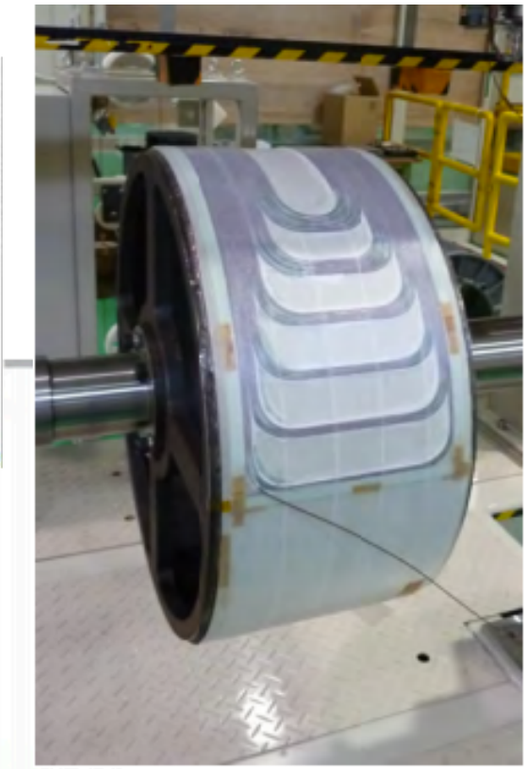
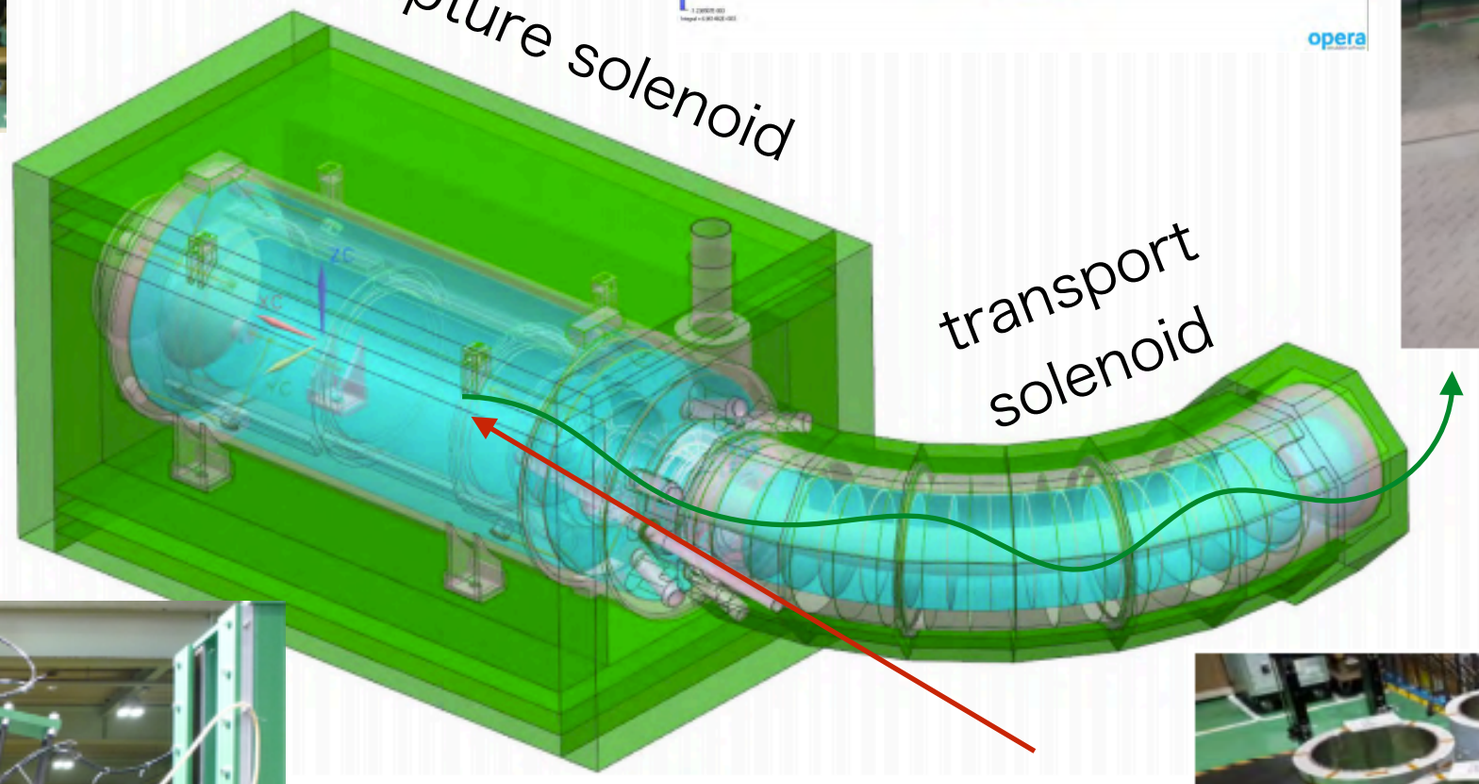
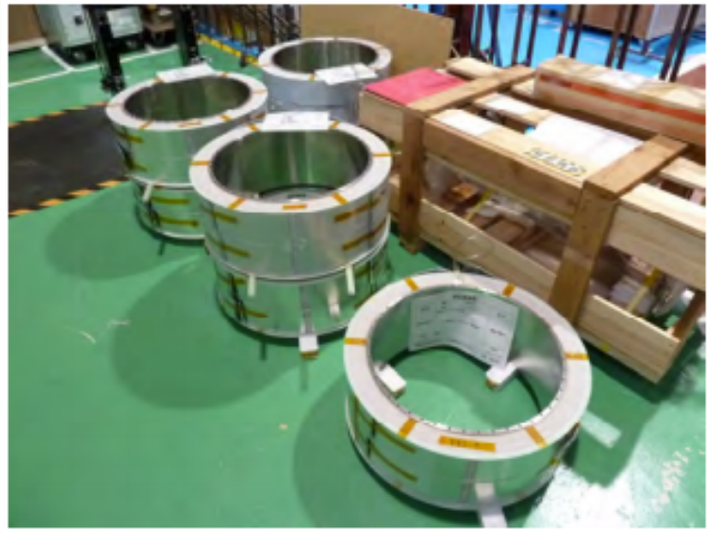


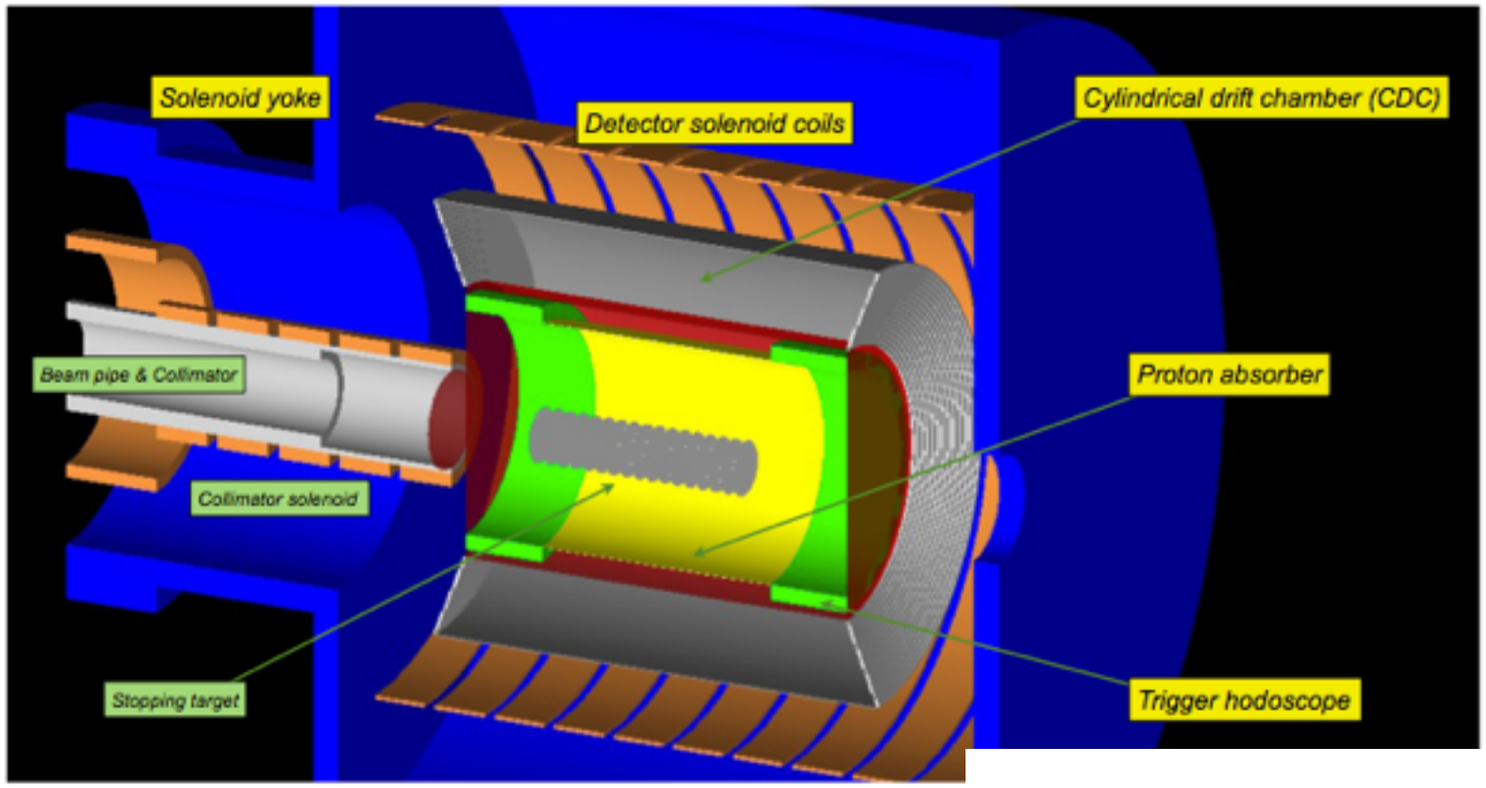


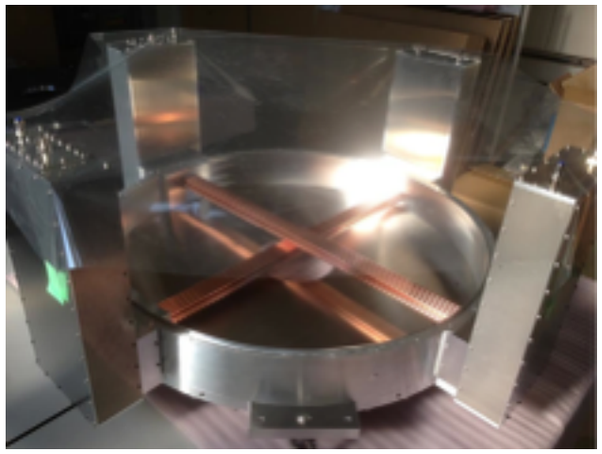


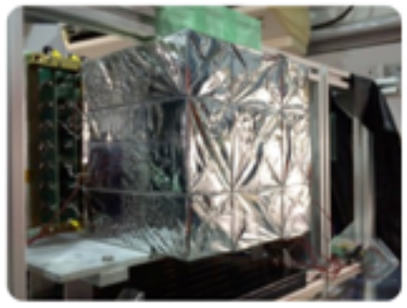


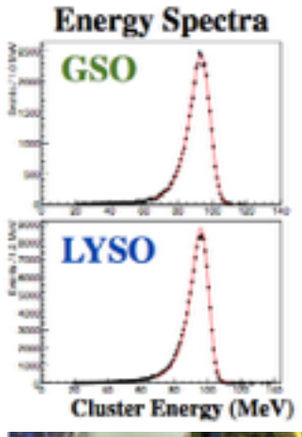


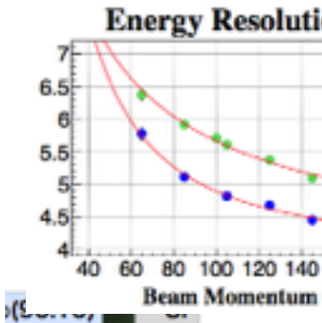
Detector Construction

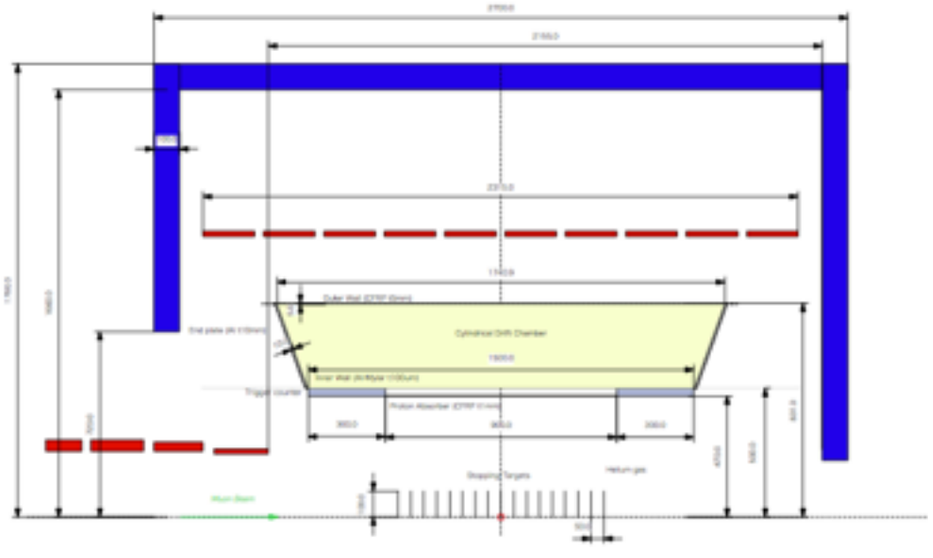


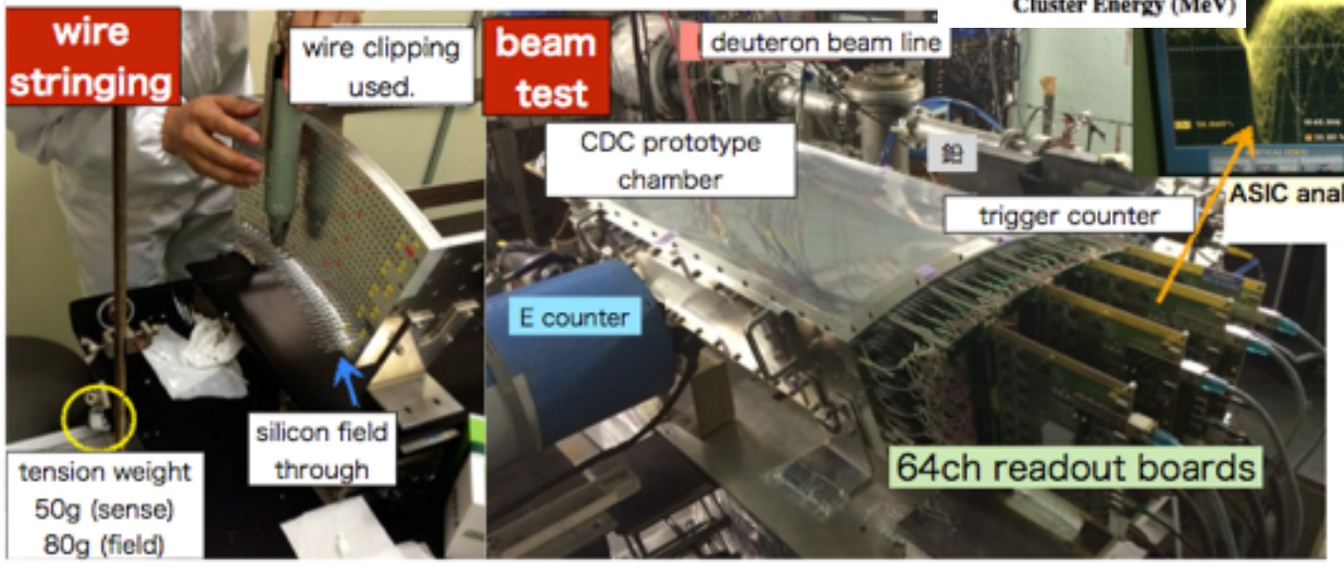












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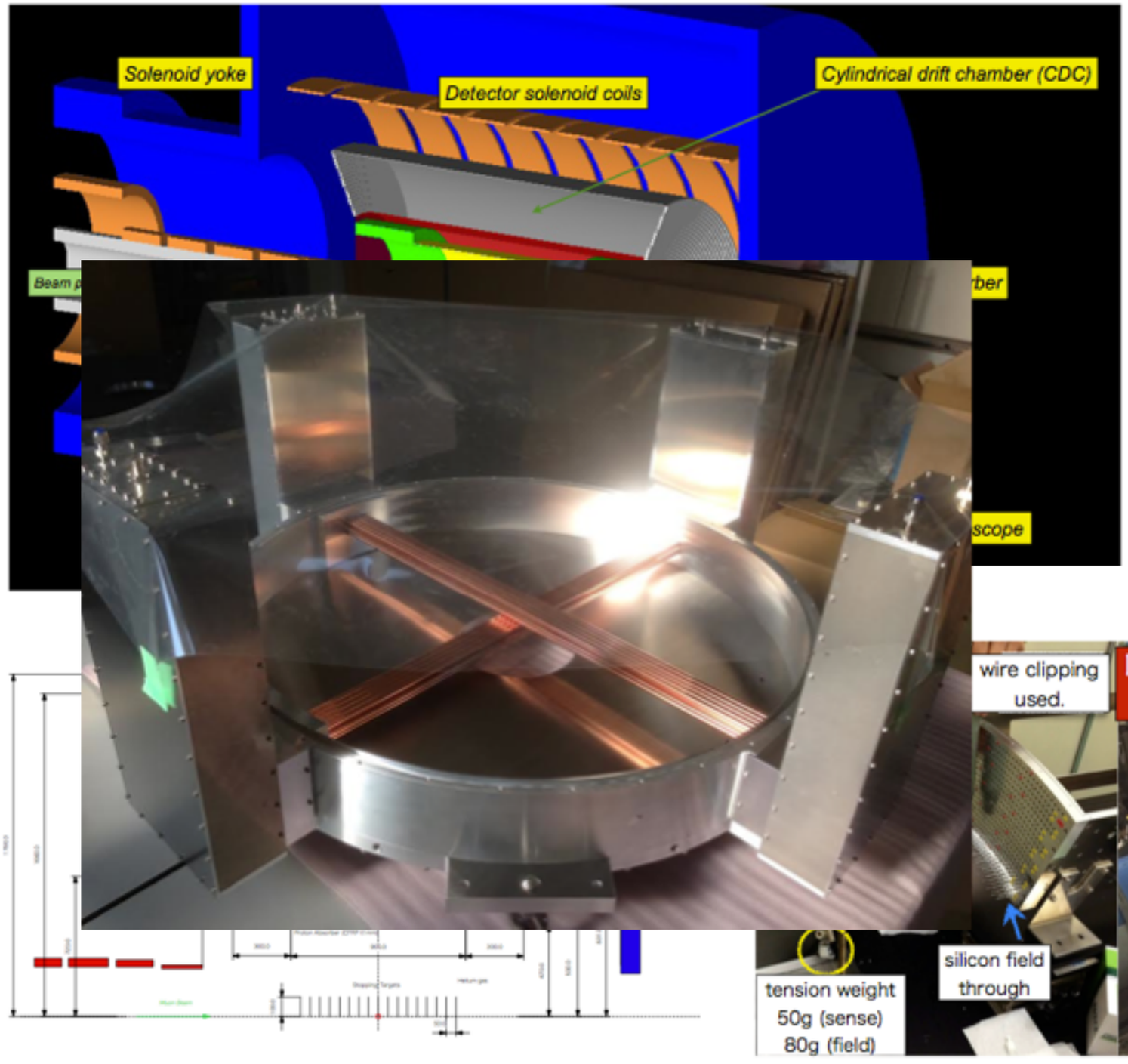

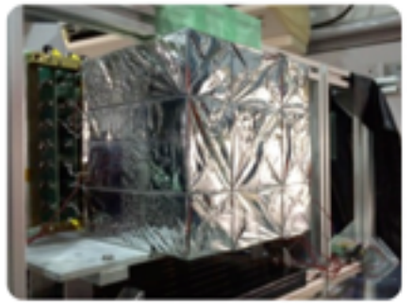

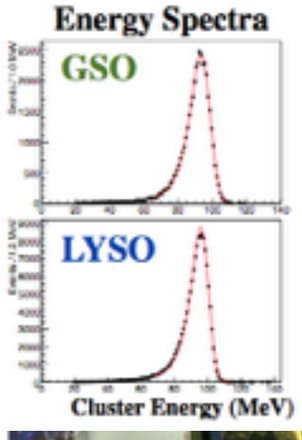

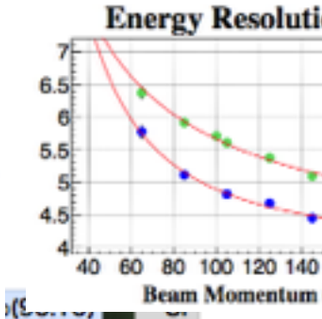

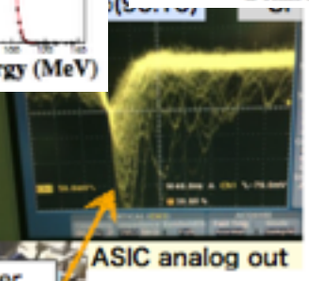

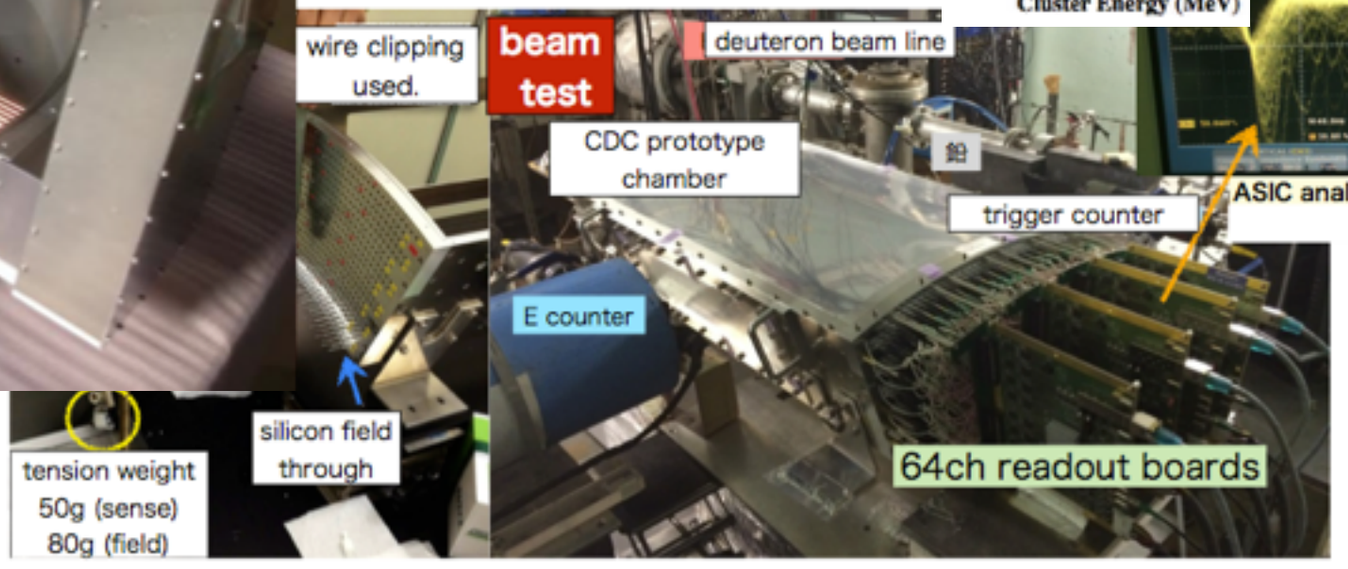

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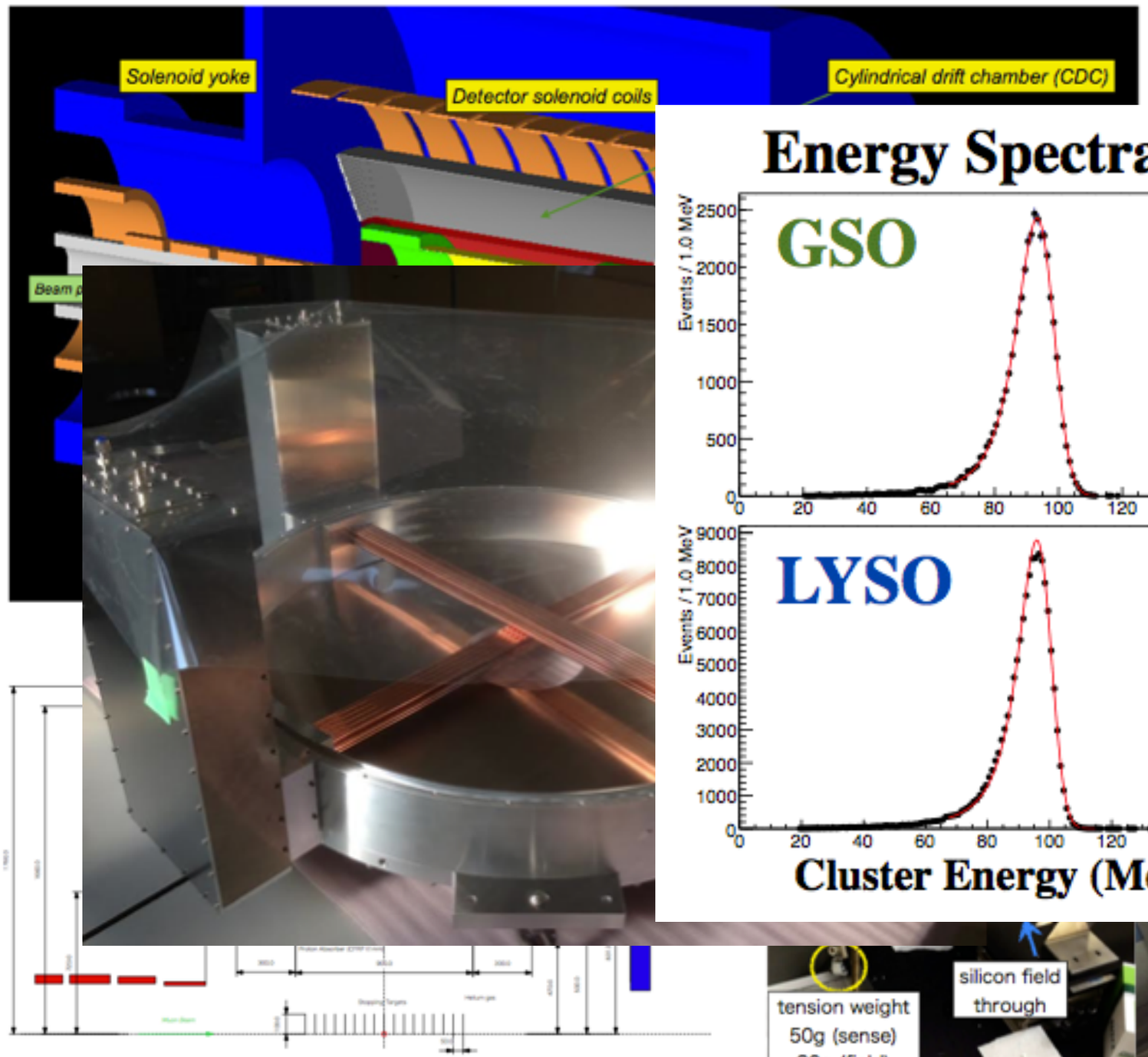
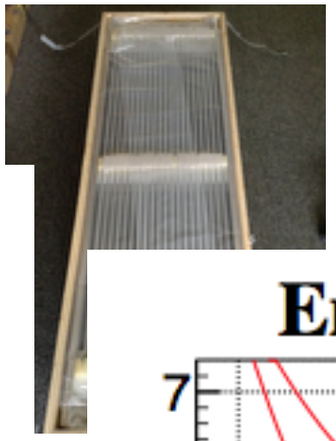
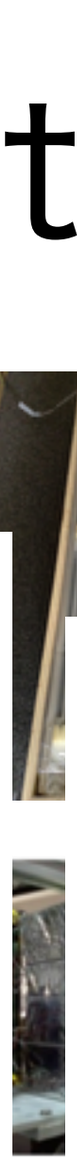
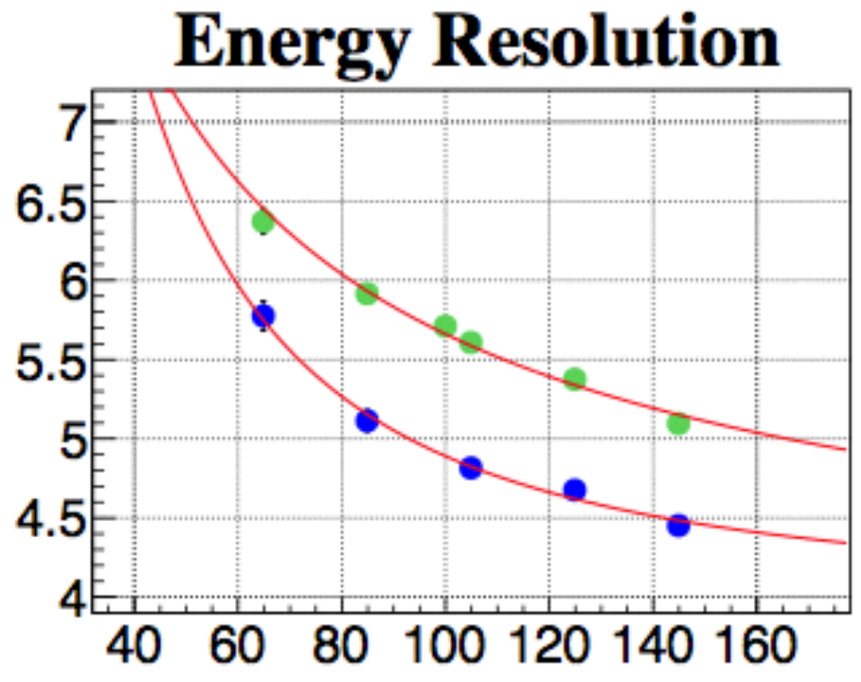
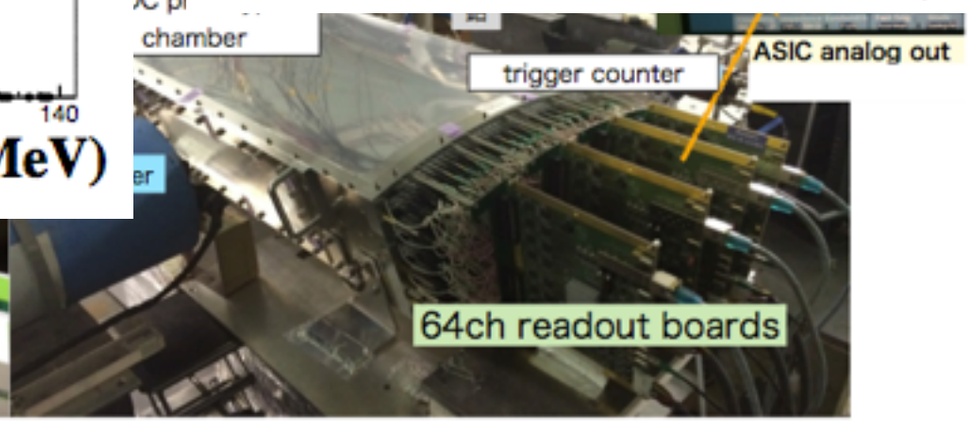




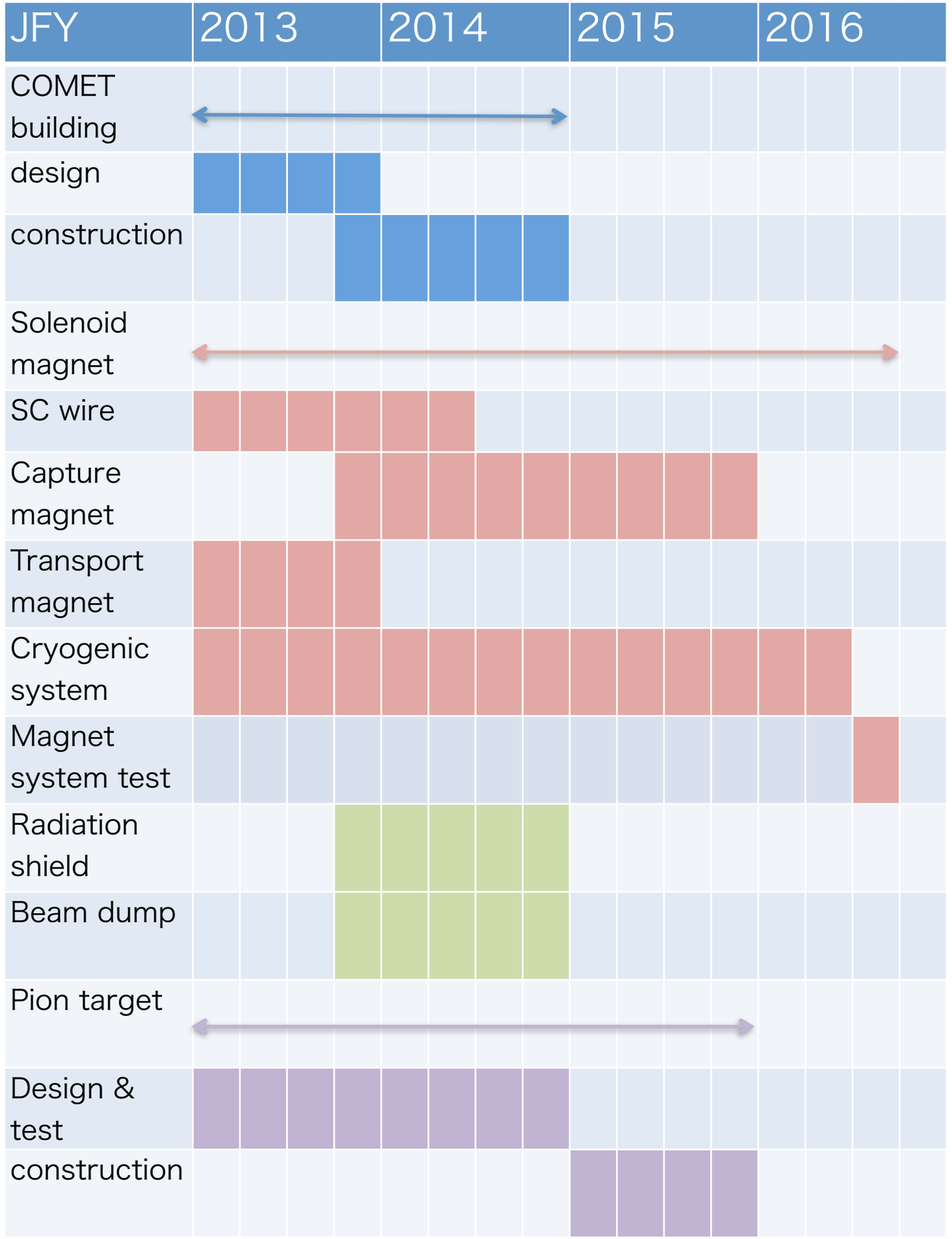






COMET Phase I Facility Schedule

- 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

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  - 10^{-14} sensitivity 2016-2017

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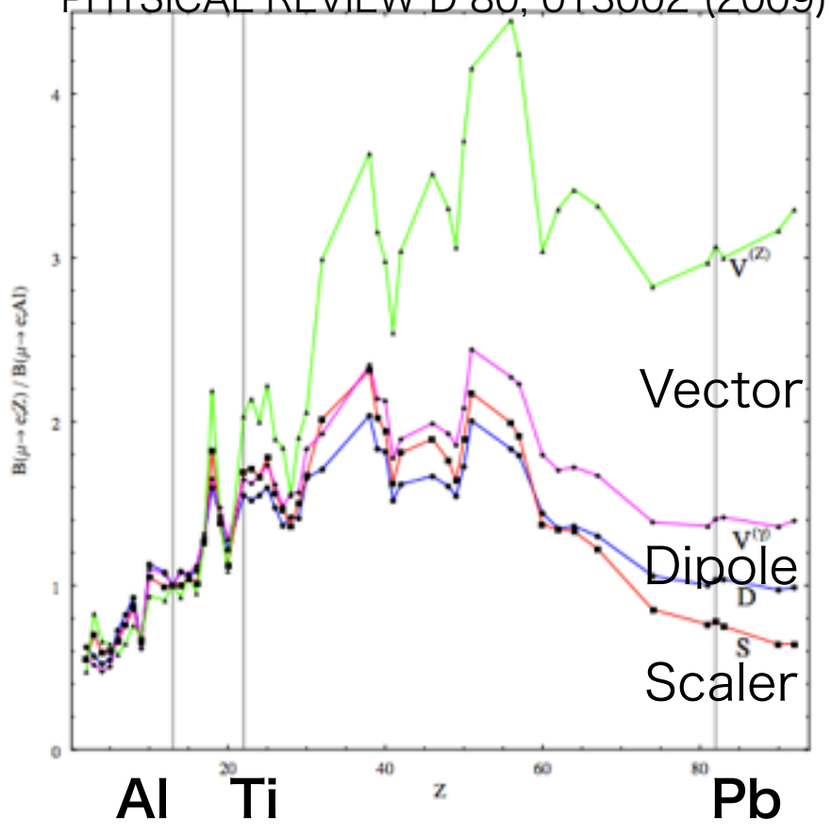
PHYSICAL REVIEW D 80, 013002 (2009)



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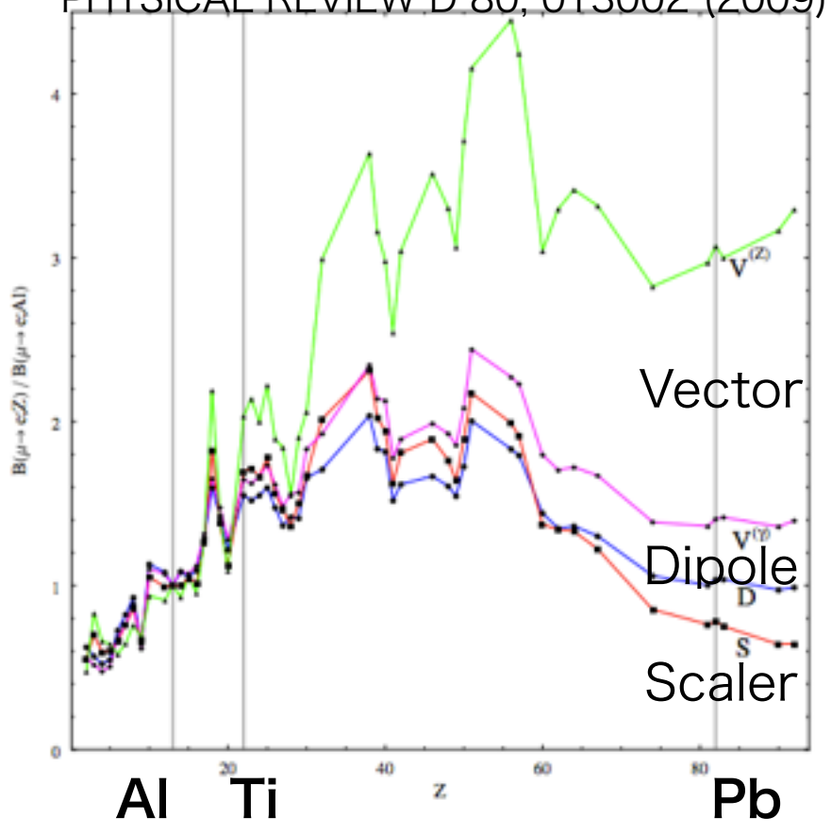

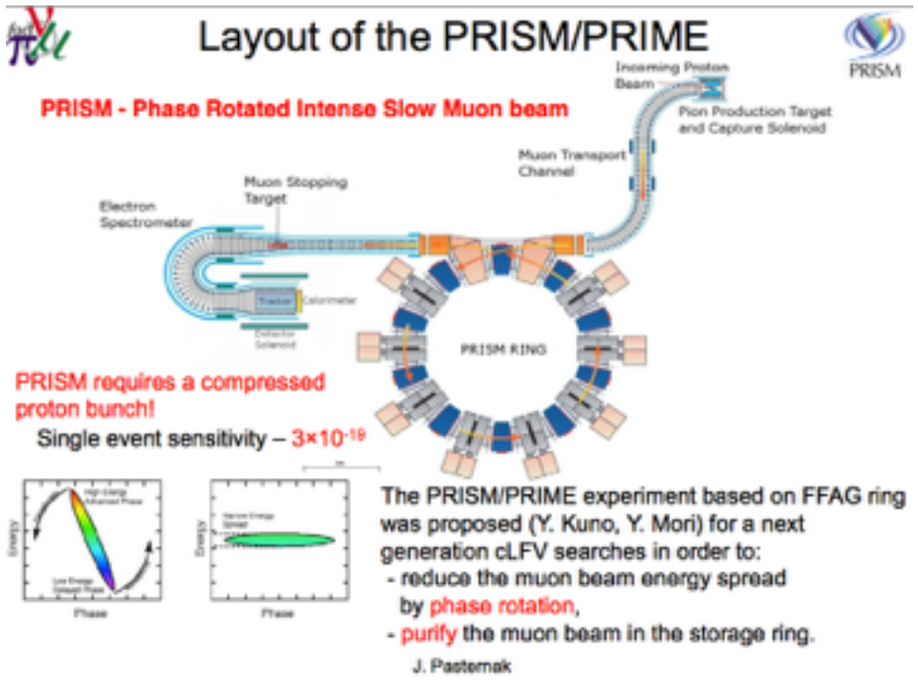

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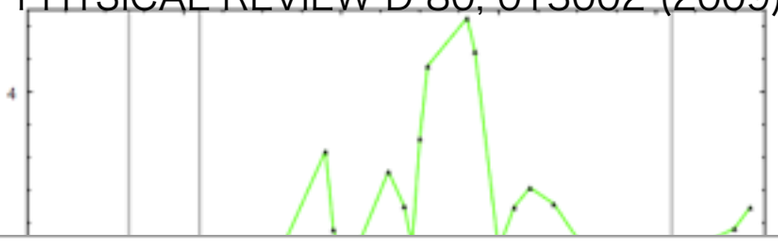

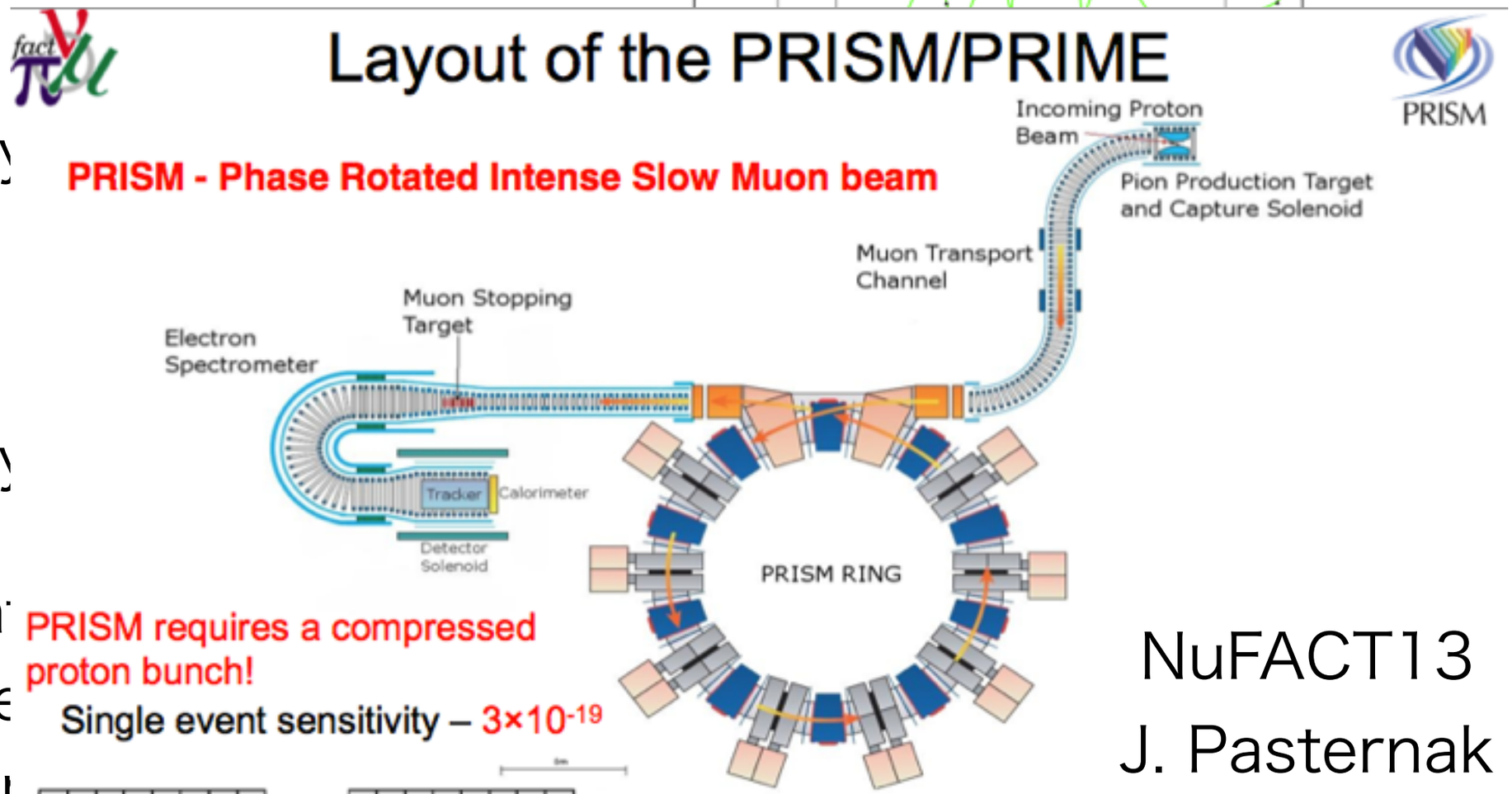

NuFACT13
J. Pasternak

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