Search for Lepton Flavor Violating Muon to Electron Conversion at J-PARC

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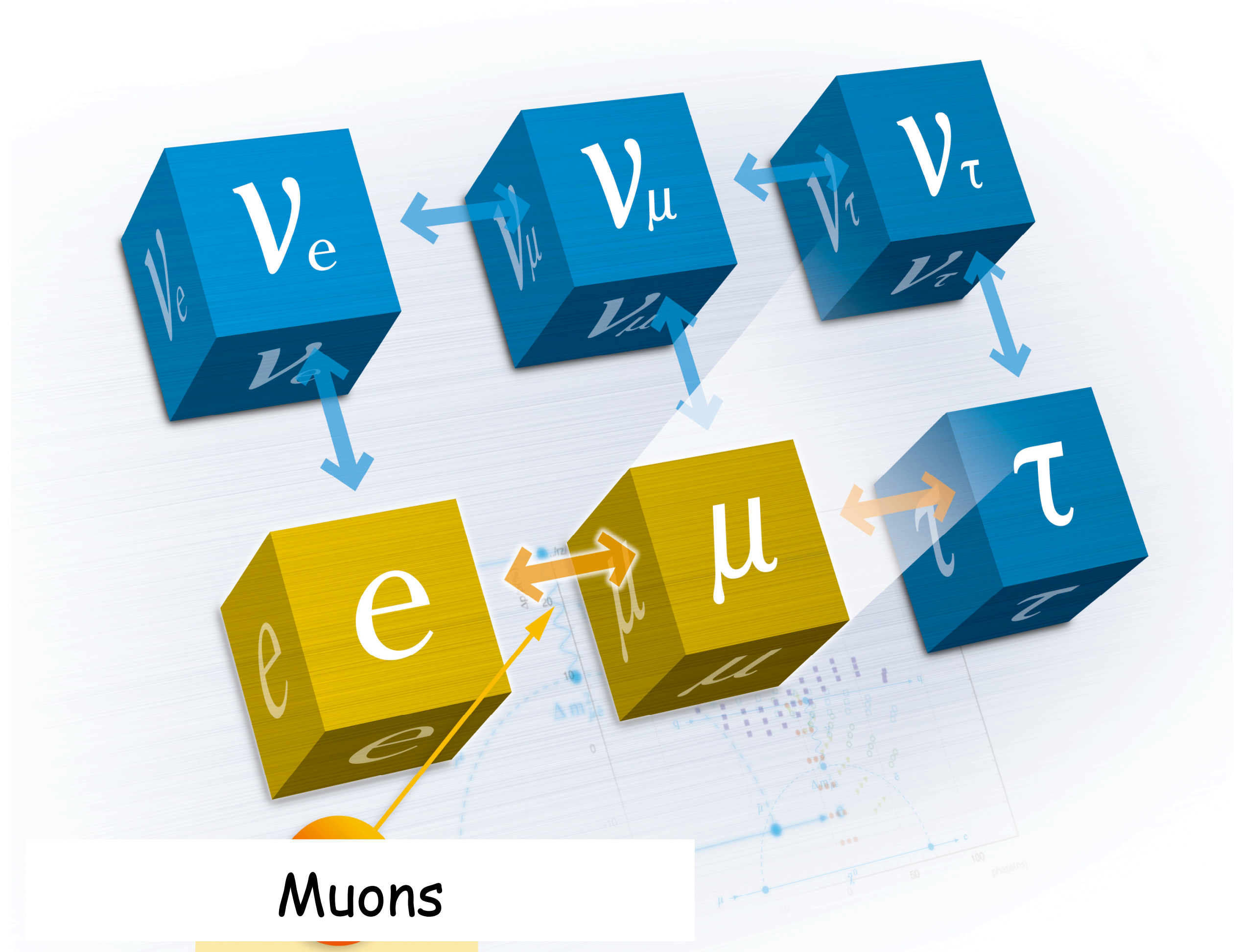

Outline

- Physics Motivation of Low Energy Muon Particle Physics
  - Why Precision Frontier ?
  - Why Lepton Flavor Violation (LFV) ?
  - Why Muons ?
- Phenomenology of LFV of Charged Leptons
  - LFV and Supersymmetry (SUSY)
  - Search for muon to electron conversion process
- New Experimental Proposals at J-PARC
  - COMET
  - PRISM
- R&D for PRISM Muon Storage Ring (FFAG Ring)
- Summary

Physics Motivation

Goal of Particle Physics

- The Standard Model of Particle Physics is known to be incomplete. It is considered to be a low-energy approximation of a more-complete theory.

- To understand a more-complete theory,

Search for New Physics at High Energy Scales

"Alignment"
S. Hayhurst 2002

We are here

time scale	energy scale
10^{13}sec	10^{-9}GeV
10^{2}sec	10^{-3}GeV
10^{-10}sec	10^{2}GeV
10^{-34}sec	10^{16}GeV
	10^{19}GeV

Electroweak Epoch

- Higgs particles
- Supersymmetry

Unification Epoch

- Grand unification of fundamental forces
- Origin of Neutrino mass (RH neutrino)
- Leptogenesis (baryogenesis)

Quantum Gravity Epoch

- Superstrings

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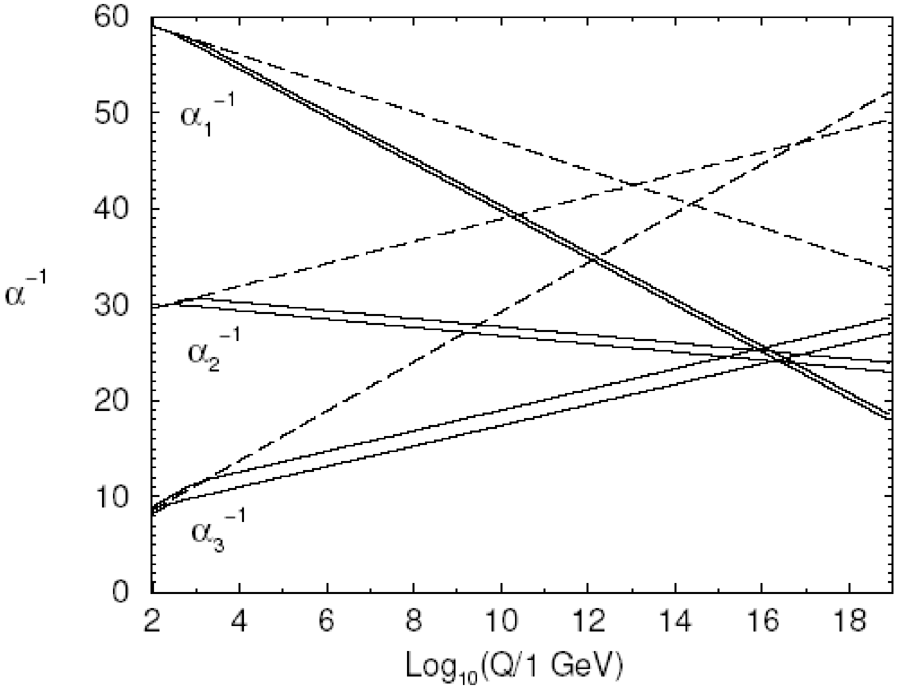
Quantum Gravity Epoch
- Superstrings

How to Study Phenomena at Higher Energy ?

- (1) High Energy Frontier Measurements
  - Direct searches for new physics
  - Energy scale to reach is O(TeV)
    - LHC (~14 TeV), ILC (0.5 TeV→), muon collider (multi TeV)
- (2) High Precision Frontier Measurements
  - Indirect searches for new physics at low energy
    - radiative corrections (renormalization equations)
  - Energy scale to reach could be much higher than accelerators.
  - Effects are small.
    - High precision measurements
    - High intensity beams

Quantum Corrections



Which Processes for New Physics in Low Energy ?

- Processes which are forbidden or highly suppressed in the Standard Model would be the best ones to search for new physics beyond the Standard Model.
- Flavor Changing Neutral Current Process (FCNC)
- FCNC in the quark sector
  - $b \to s\gamma$, $K \to \pi\nu\nu$, etc.
  - Allowed in the Standard Model.
  - Need to study deviations from the SM predictions.
    - Uncertainty of more than a few % (from QCD) exists.
- FCNC in the lepton sector
  - $\mu \to e\gamma$, $\mu + N \to e + N$, etc. (lepton flavor violation =LFV)
  - Not allowed in the Standard Model ($\sim 10^{-50}$ with neutrino mixing)
  - Need to study deviations from none
    - clear signature and high sensitivity

Why Muons, not Taus for LFV Search ?

- A number of taus available at B factories are about 1-10 taus/sec. At super-B factories, about 100 taus/sec are considered. Also some of the decay modes are already background-limited.
  - intensity improvement factor of about O(10).

- The number of muons available now, which is about 10^8 muons/sec at PSI, is the largest. Next generation experiments aim 10^{11}-10^{12} muons/sec. With the technology of the front end of muon colliders and/or neutrino factories, about 10^{13}-10^{14} muons/sec are considered.
  - intensity improvement factor of about O(1,000,000)

Synergy in Technology between Muon Physics and MCNF

Which Muon Processes for High Intensity Measurements ?

- List of typical muon LFV processes
  - $\mu^+ \to e^+\gamma$
  - $\mu^+ \to e^+e^+e^-$
  - $\mu^- + N(A,Z) \to e^- + N(A,Z)$
  - $\mu^- + N(A,Z) \to e^+ + N(A,Z-2)$
- When a high intensity beam is used, measurements that need coincidence requirements in detection of daughter particles would suffer from huge accidental backgrounds.
- Only experiments that have single particle detection would make the best use of high intensity of 10^{14} muons/sec.
  - muon-to-electron conversion (μ+N→e+N)
  - muon g-2, muon EDM (μ→eνν)

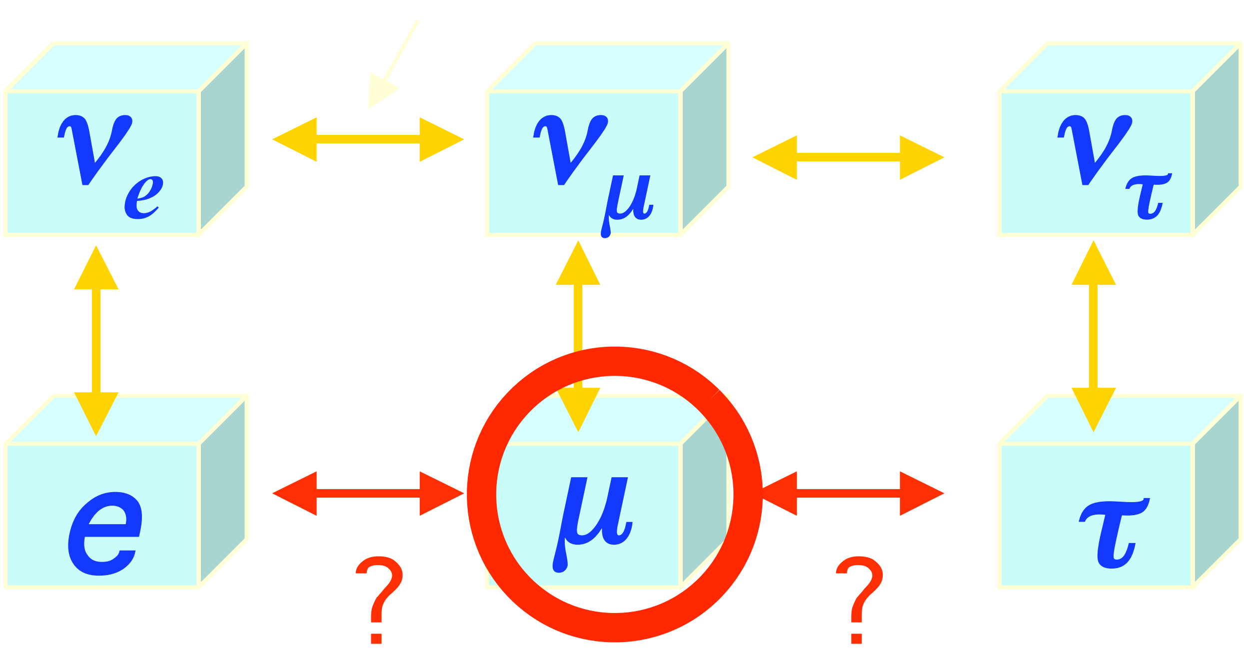
Present Limits and Expectations in Future

process	Present limit	Near Future	MC&NF
$\mu \to e\gamma$	1.2×10^{-11}	10^{-13} (MEG)	
$\mu \to eee$	1.0×10^{-12}	10^{-13} - 10^{-14}	
$\mu N \to eN$ (in Tl)	4.3×10^{-12}	10^{-18} (PRISM)	10^{-20}
$\mu N \to eN$ (in Al)	none	10^{-16} (mu2e,PI)	10^{-20}
$\tau \to e\gamma$	1.1×10^{-7}	10^{-8} - 10^{-9}	
$\tau \to eee$	2.7×10^{-7}	10^{-8} - 10^{-9}	
$\tau \to \mu\gamma$	6.8×10^{-8}	10^{-8} - 10^{-9}	
$\tau \to \mu\mu\mu$	2×10^{-7}	10^{-8} - 10^{-9}	

Lepton Flavor Violation of Charged Leptons

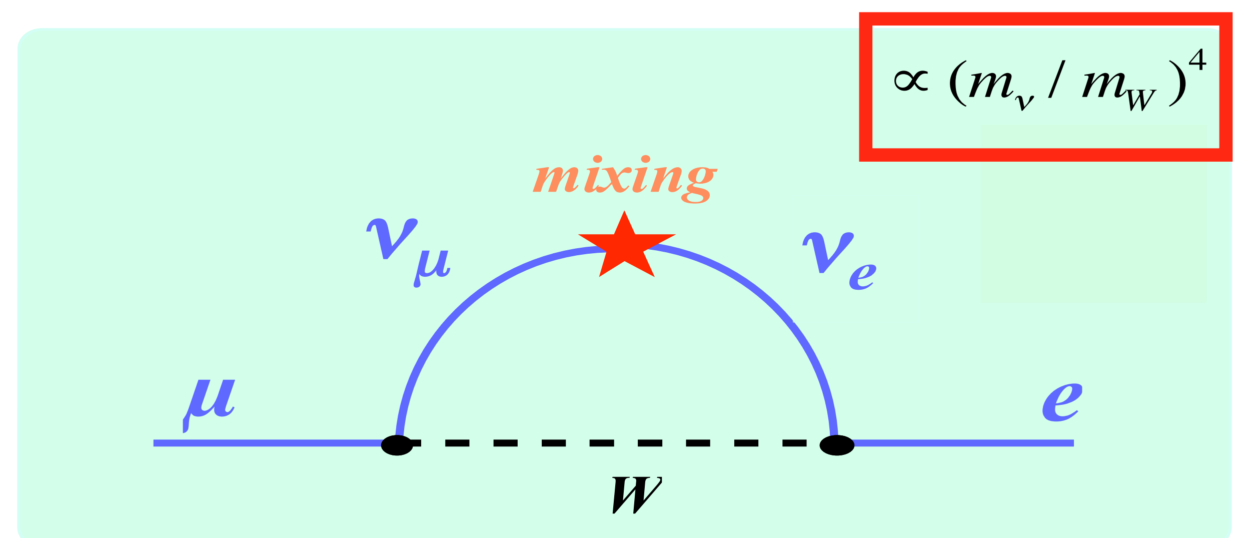
Lepton Flavor Violation of Charged Leptons (Charged Lepton Mixing)

Neutrino Mixing
(confirmed)



Charged Lepton Mixing
(not observed yet)

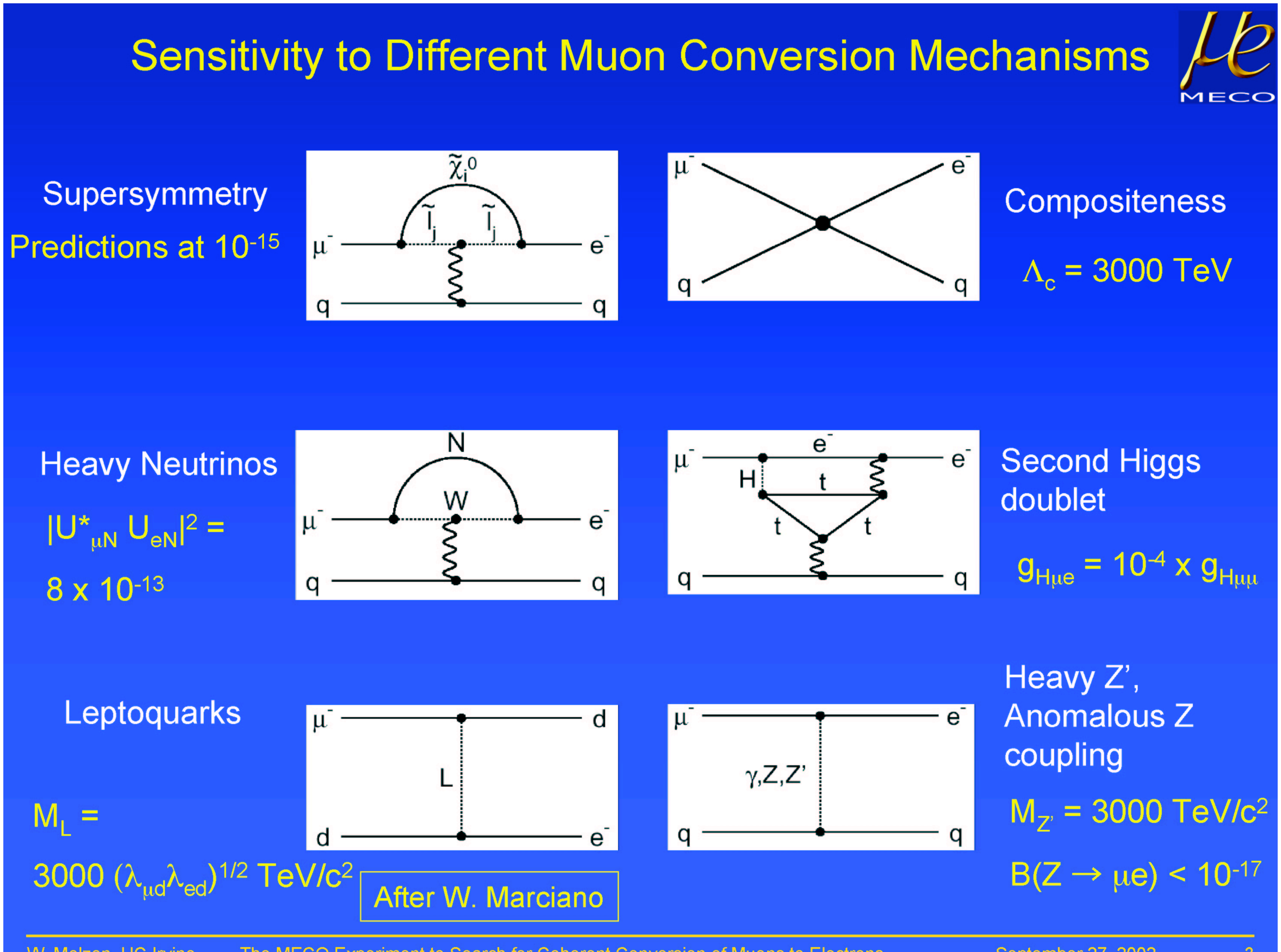
- What is The Contribution to Charged Lepton Mixing from Neutrino Mixing ?



Very Small (10^{-52})

Sensitive to new Physics beyond the Standard Model

Various Models Predict Charged Lepton Mixing.

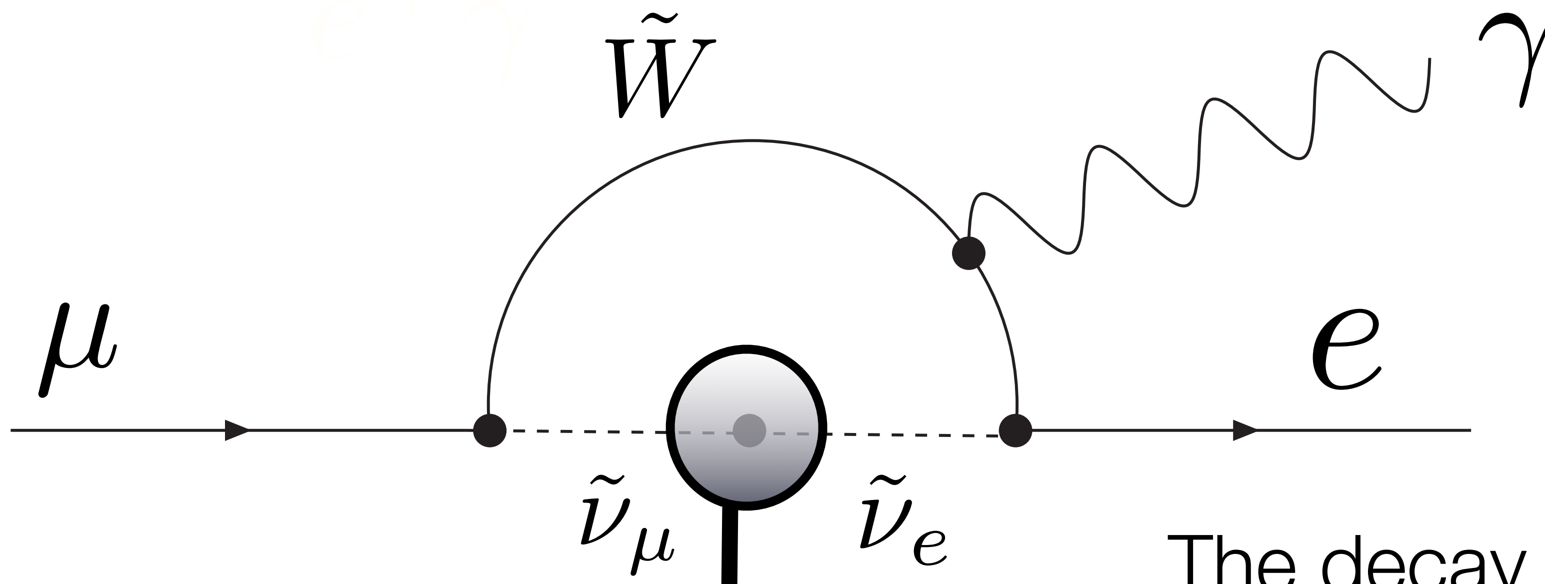


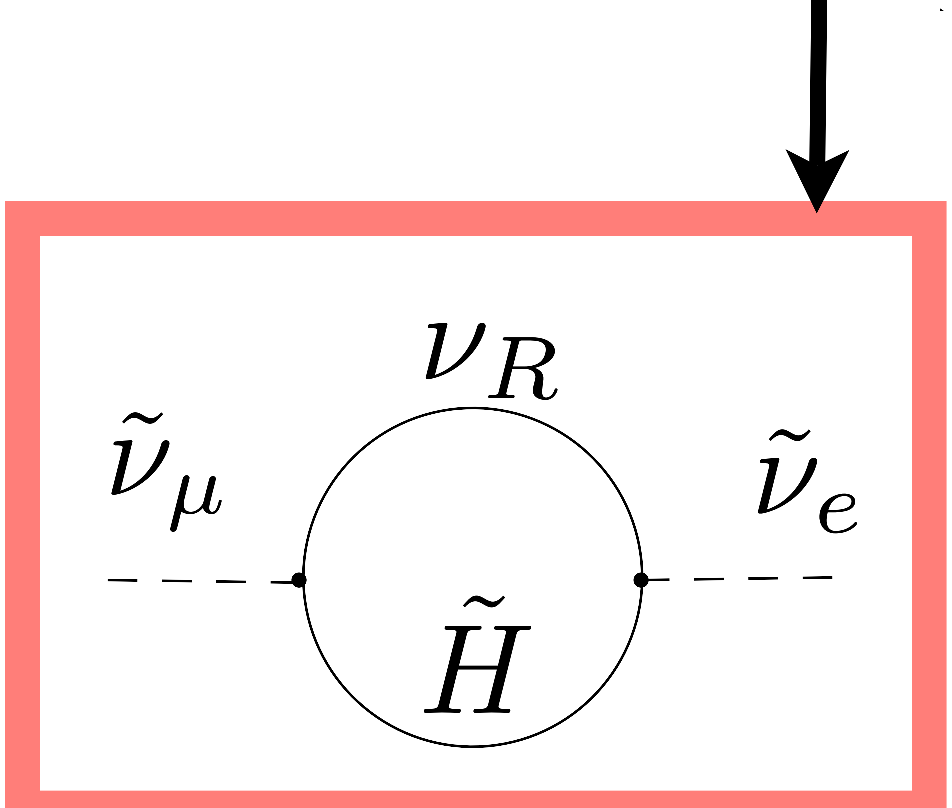
LFV in SUSY Models

$$\frac{B(\mu N \to eN)}{B(\mu \to e\gamma)} \sim \frac{1}{200}$$

(photon being attached to quarks in nucleons)

an example diagram



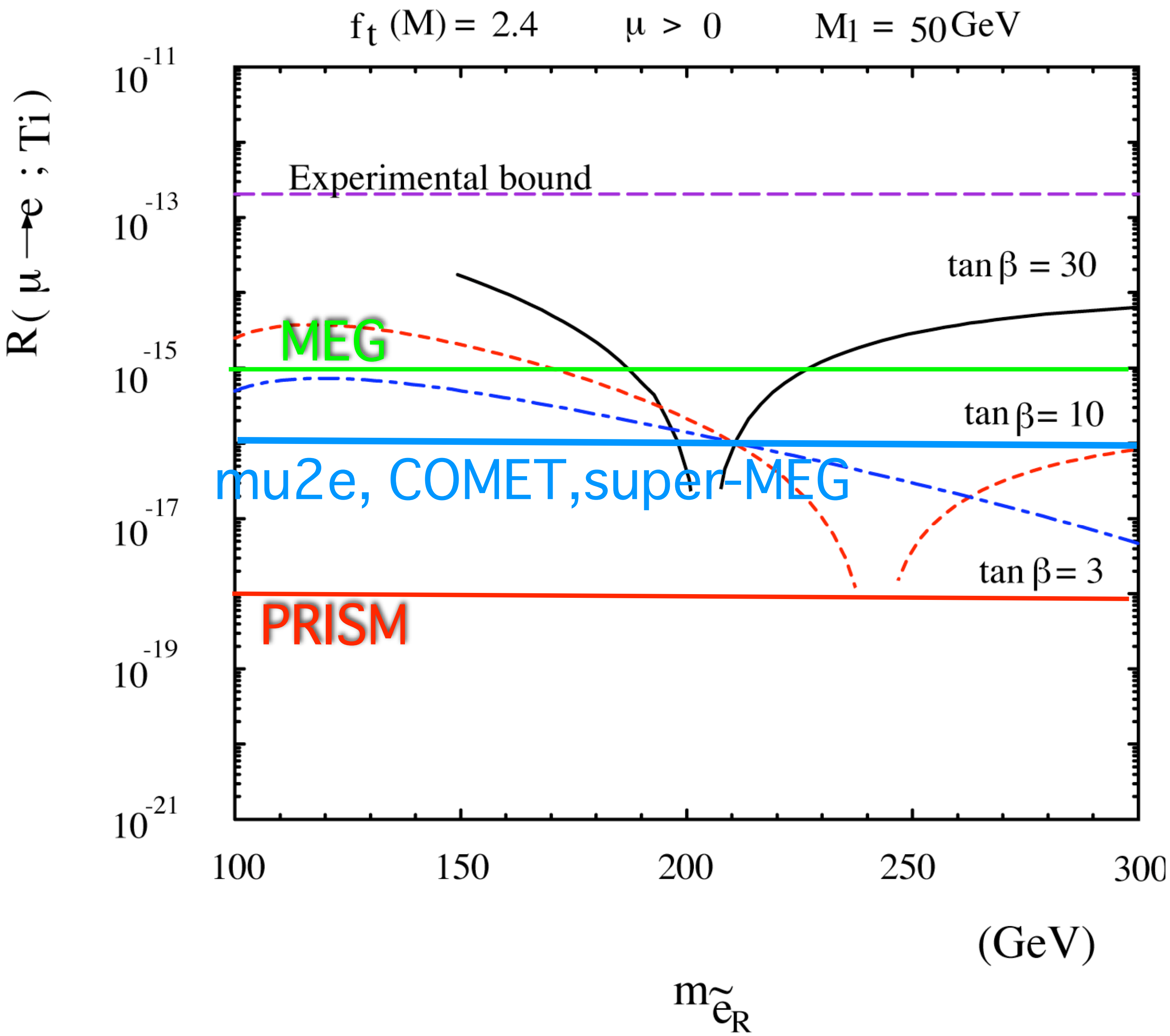


The decay rates is determined by SUSY-mass scale but the dot includes higher energy information.

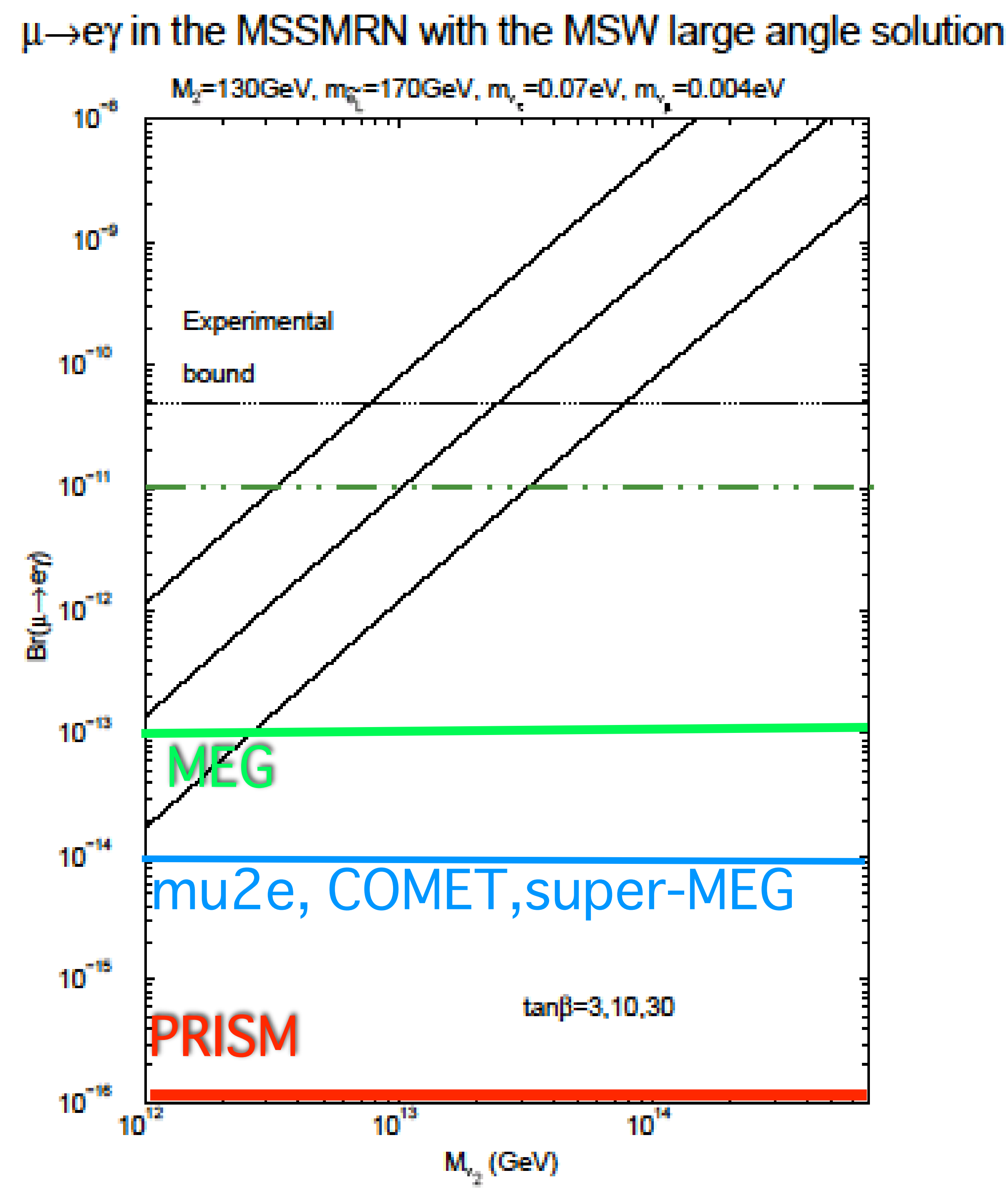
Through quantum corrections, LFV could access ultra-heavy particles such as ν_R (~10^{12}-10^{14} GeV/c^2) and GUT that cannot be produced directly by any accelerators.

SUSY GUT and SUSY Seesaw

SUSY Predictions for LFV with Muons



SU(5) SUSY GUT



SUSY Seesaw Model

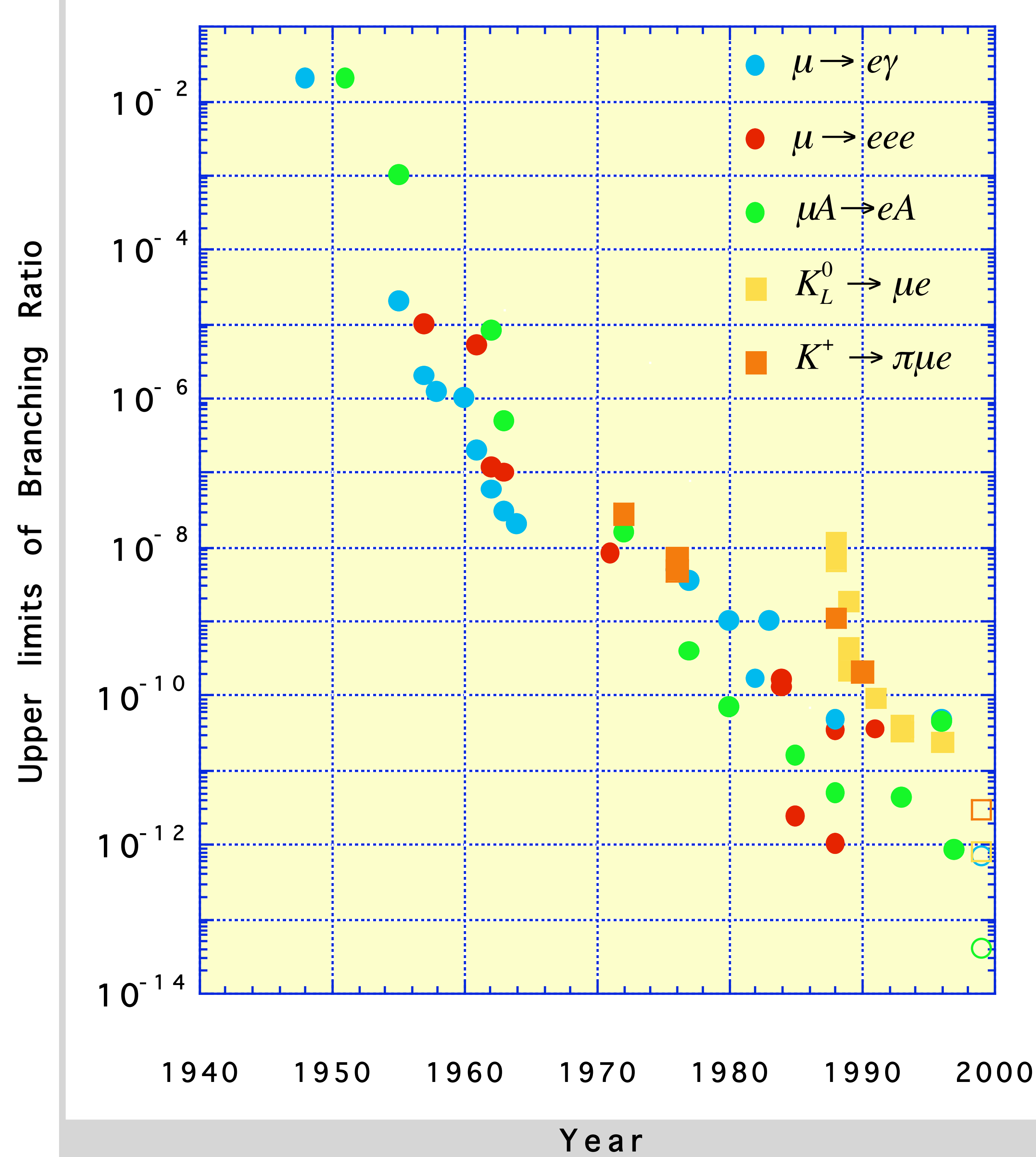
Energy Frontier, SUSY, and Charged Lepton Mixing

- In SUSY models, charged lepton mixing is sensitive to slepton mixing.
- LHC would have potentials to see SUSY particles. However, at LHC nor even ILC, slepton mixing would be hard to study in such a high precision as proposed here.

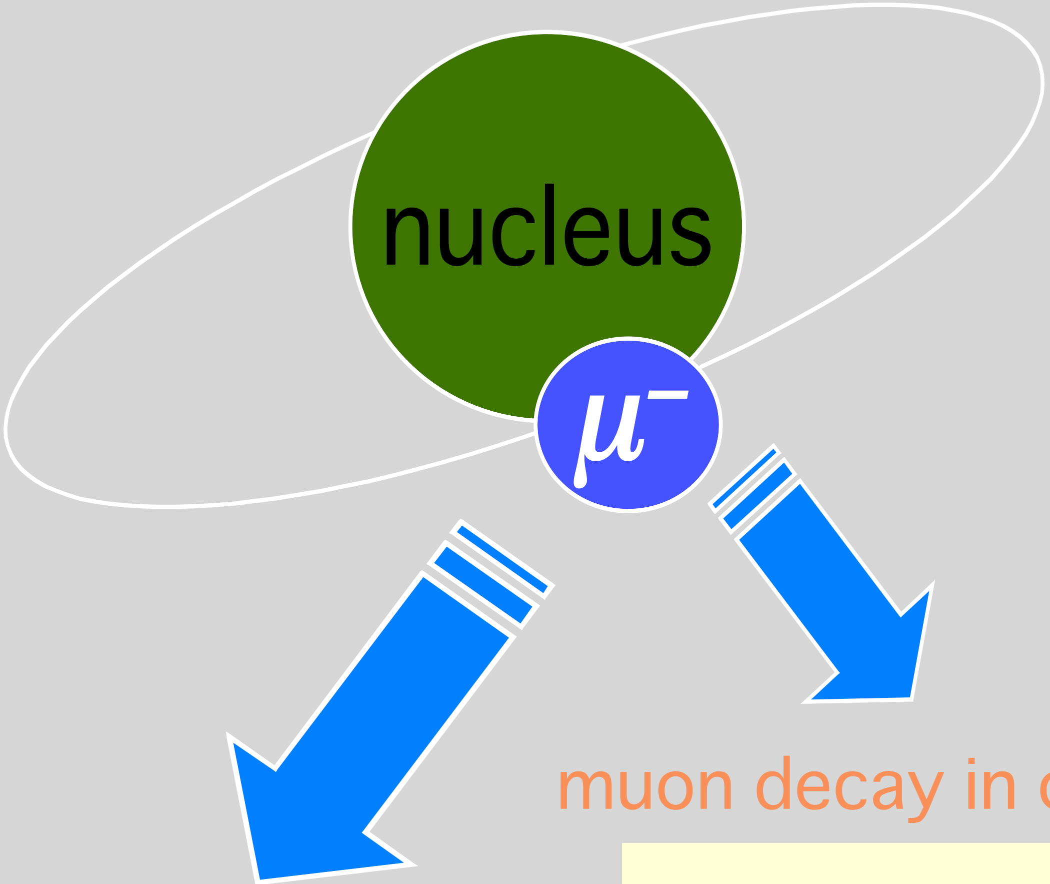
- Slepton mixing is sensitive to either (or both) Grand Unified Theories (SUSY-GUT models) or neutrino seesaw mechanism (SUSY-Seesaw models).
- If LFV sensitivity is extremely high, it might be sensitive to multi-TeV SUSY which LHC cannot reach, in particular SUSY models.

Searches in the Past

- No lepton flavor violation in the Standard Model.
- No lepton flavor violation in the charged lepton sector has been observed, although it in the neutrino sector has been observed.
- Upper limit improved by two orders of magnitude



1s state in a muonic atom



muon decay in orbit

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

nuclear muon capture

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

Neutrino-less muon nuclear capture (=μ-e conversion)

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

lepton flavors changes by one unit.

$$B(\mu^- N \rightarrow e^- N) = \frac{\Gamma(\mu^- N \rightarrow e^- N)}{\Gamma(\mu^- N \rightarrow \nu N')}$$

What is a μ-e Conversion ?

μ-e Conversion
Signal and Backgrounds

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

- Signal
  - single mono-energetic electron

    $$m_\mu - B_\mu \sim 105 MeV$$

  - coherent process (the same initial and final nucleus)

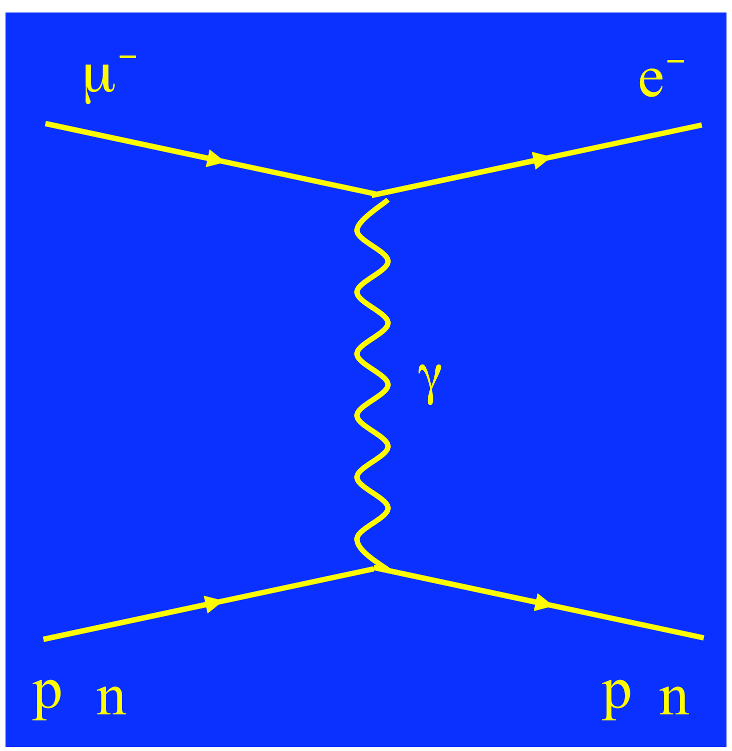
    $$\propto Z^5$$

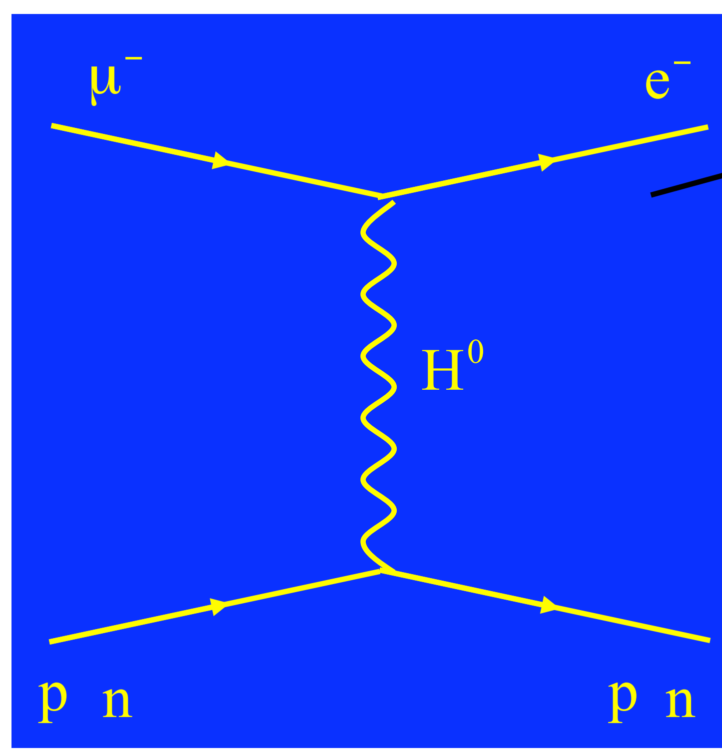
- Backgrounds
  - Muon decay in orbit
    - Endpoint comes to the signal region $\propto (\Delta E)^5$
  - Radiative muon capture
  - Radiative pion capture
    - pulsed beam required
    - wait until pions decay.
  - Electrons from muon decays in flight
  - Cosmic rays
  - and many others

Comparison between μ→eγ and μ-e Conversion (Physics sensitivity)

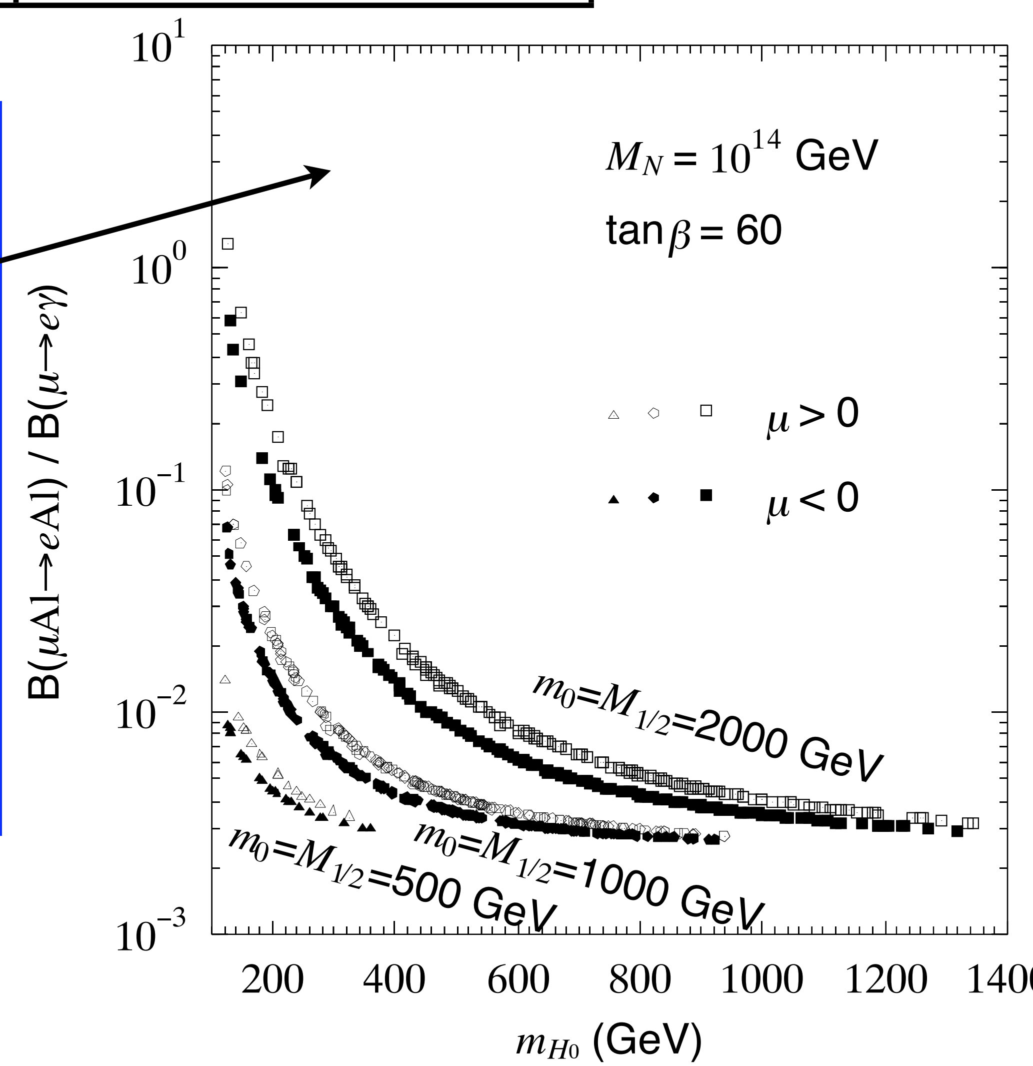
Photonic and non-photonic (SUSY) diagrams

	photonic	non-photonic
• μ→eγ	yes (on-shell)	no
• μ-e conversion	yes (off-shell)	yes

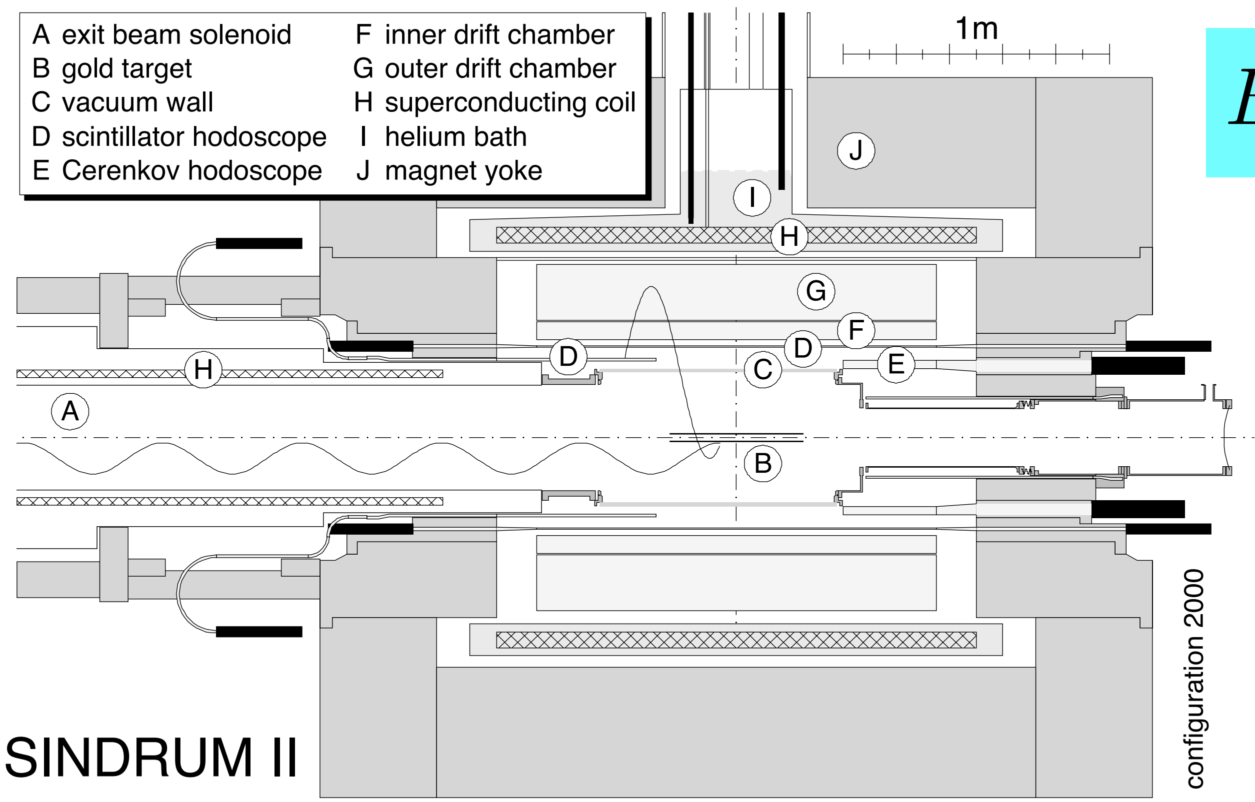




$$\frac{B(\mu N \rightarrow eN)}{B(\mu \rightarrow e\gamma)} \sim \frac{1}{100}$$

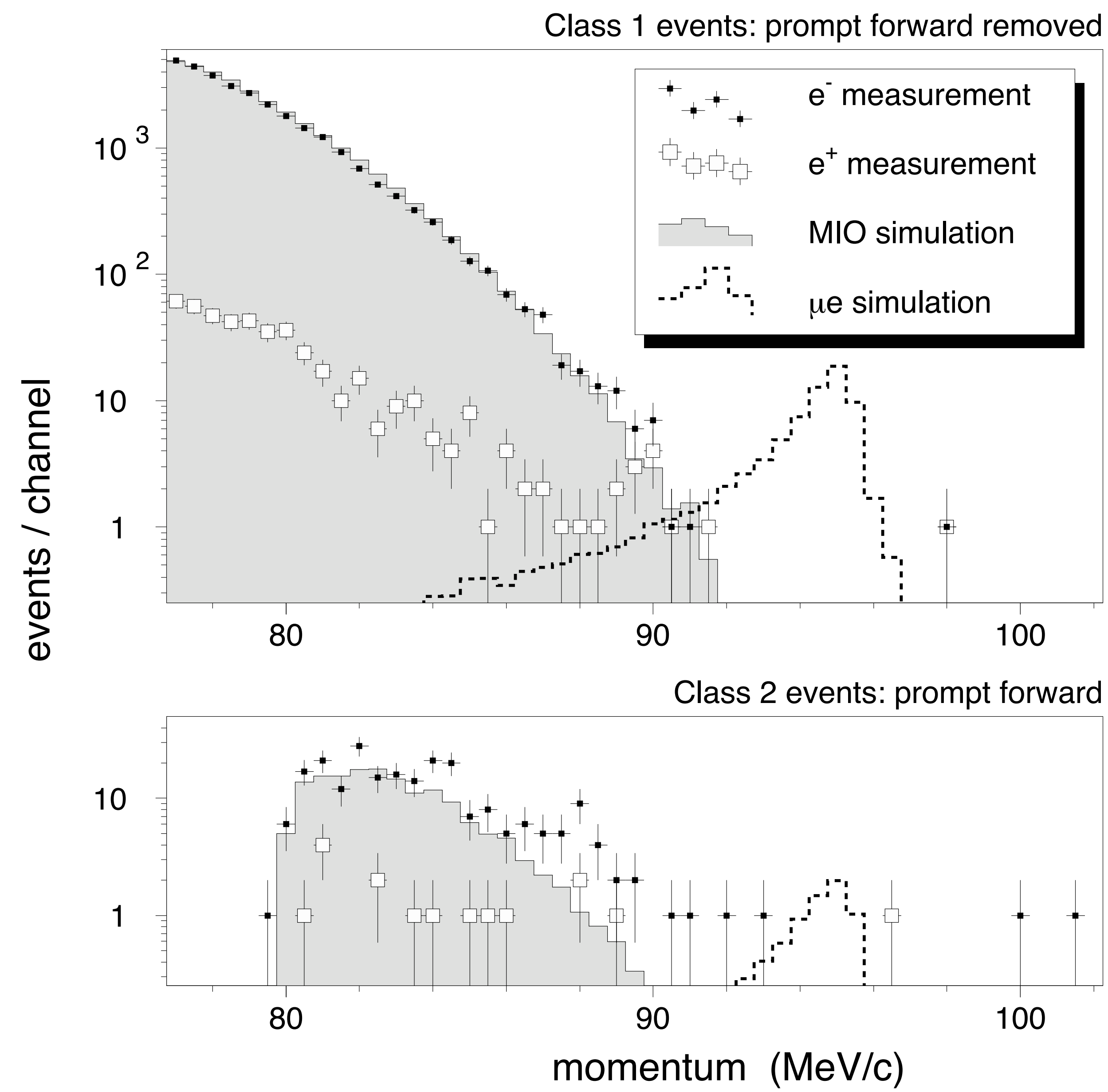


The SINDRUM-II Experiment (at PSI)



Published Results

$$B(\mu^- + Ti \to e^- + Ti) < 4.3 \times 10^{-12}$$



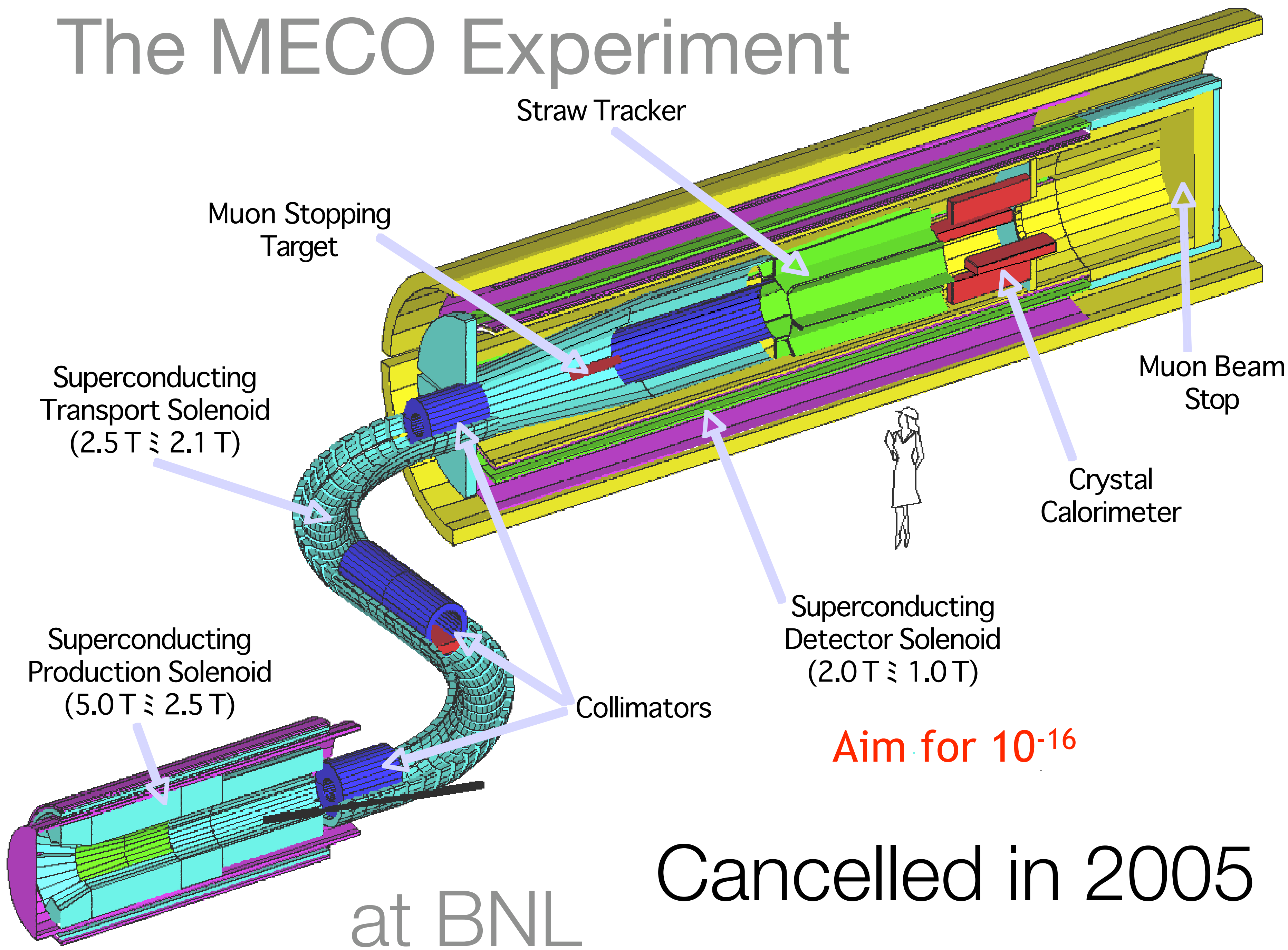
SINDRUM-II used a continuous muon beam from the PSI cyclotron. To eliminate beam related background from a beam, a beam veto counter was placed. But, it could not work at a high rate.

The MELC and MECO Proposals

MELC (Russia) and then MECO (the US)

- To eliminate beam related background, beam pulsing was adopted (with delayed measurement).
- To increase a number of muons available, pion capture with a high solenoidal field was adopted.
- For momentum selection, curved solenoid was adopted.

The MECO Experiment



Aim for 10^{-16}

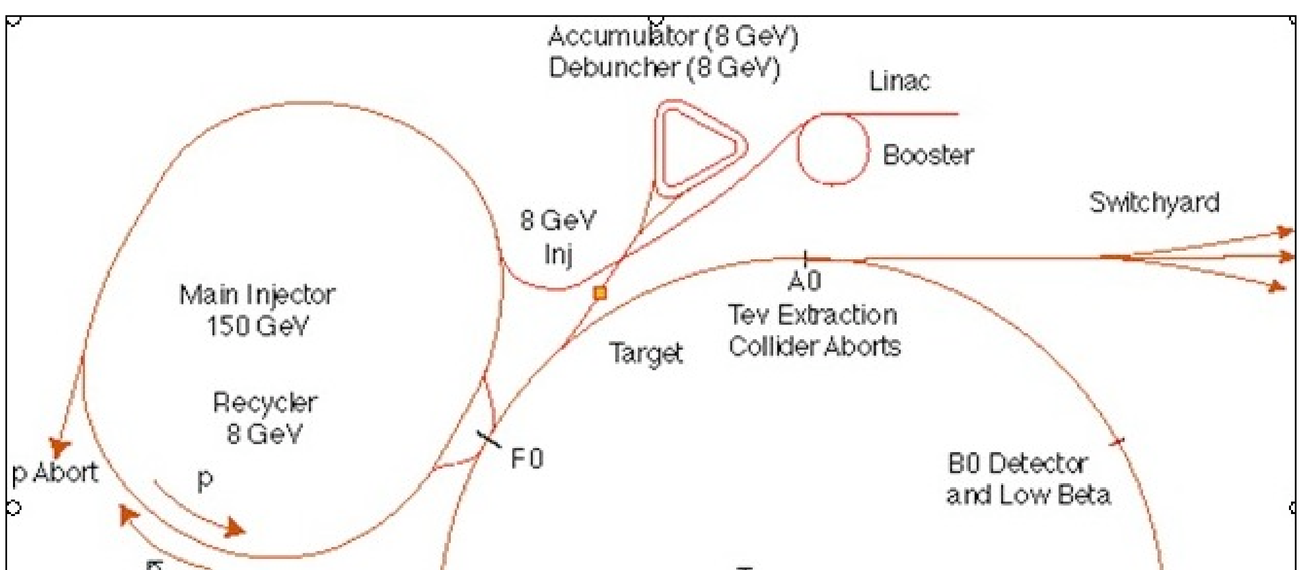
at BNL

Cancelled in 2005

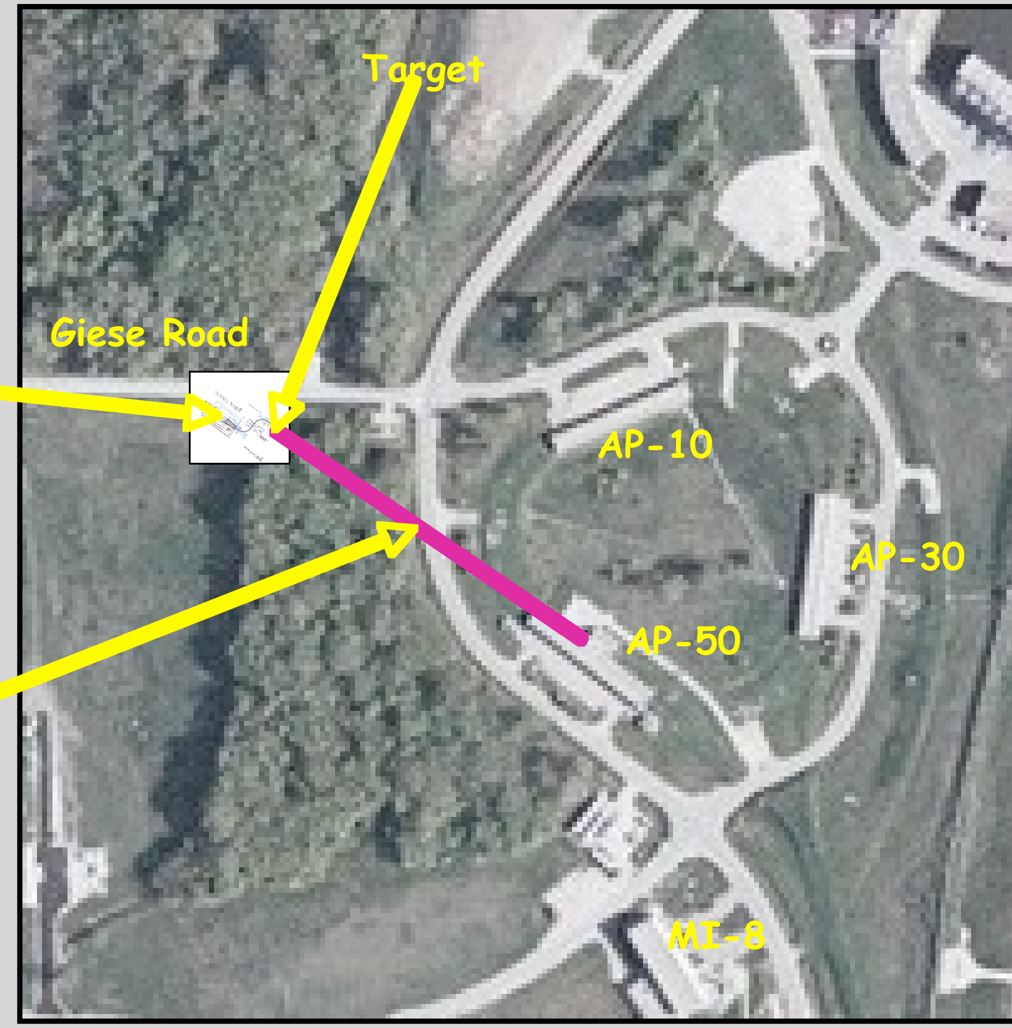
→mu2e @ Fermilab

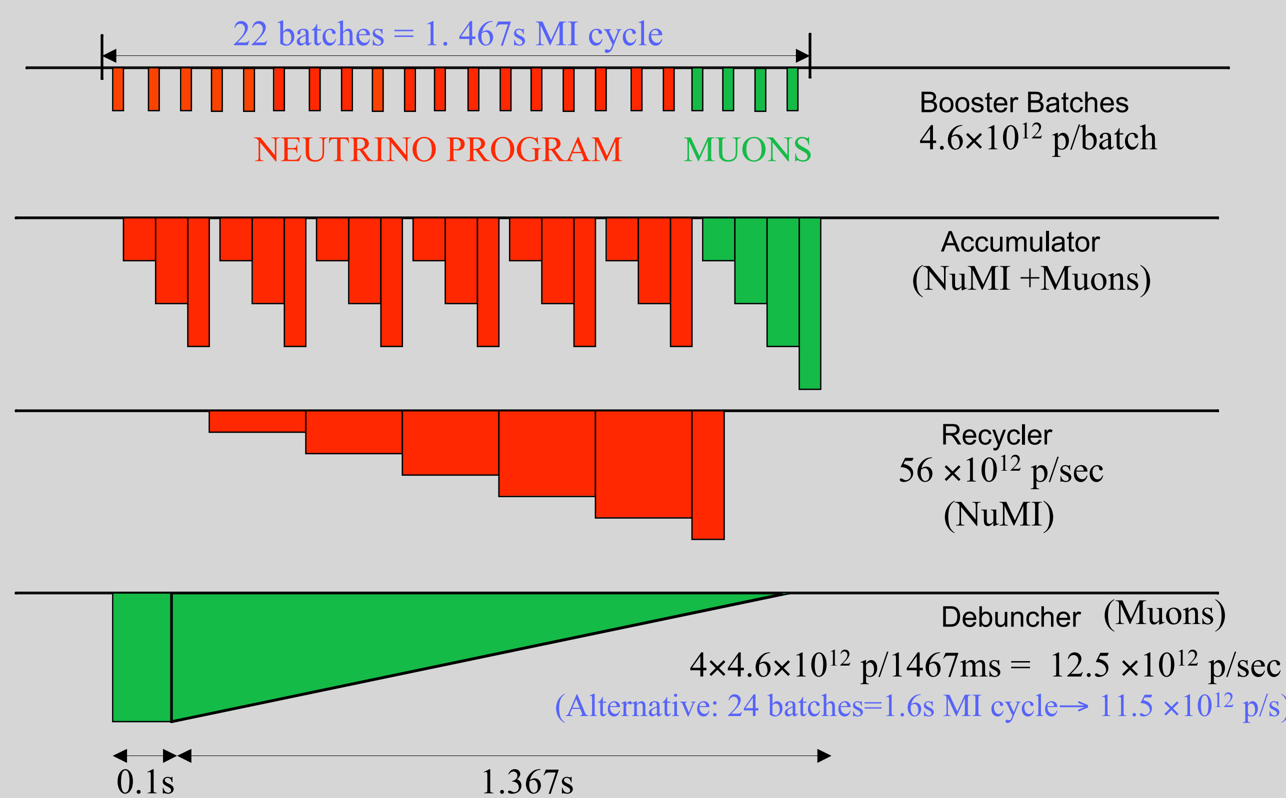
Mu2E @ Fermilab

- The mu2e Experiment at Fermilab.
  - EOI and LOI have been submitted. It is well accepted.
  - After the Tevatron shut-down.
  - use the antiproton accumulator ring and the debuncher ring to manipulate proton beam bunches.
  - sNUMI running with Nova.
  - with Project-X in future.



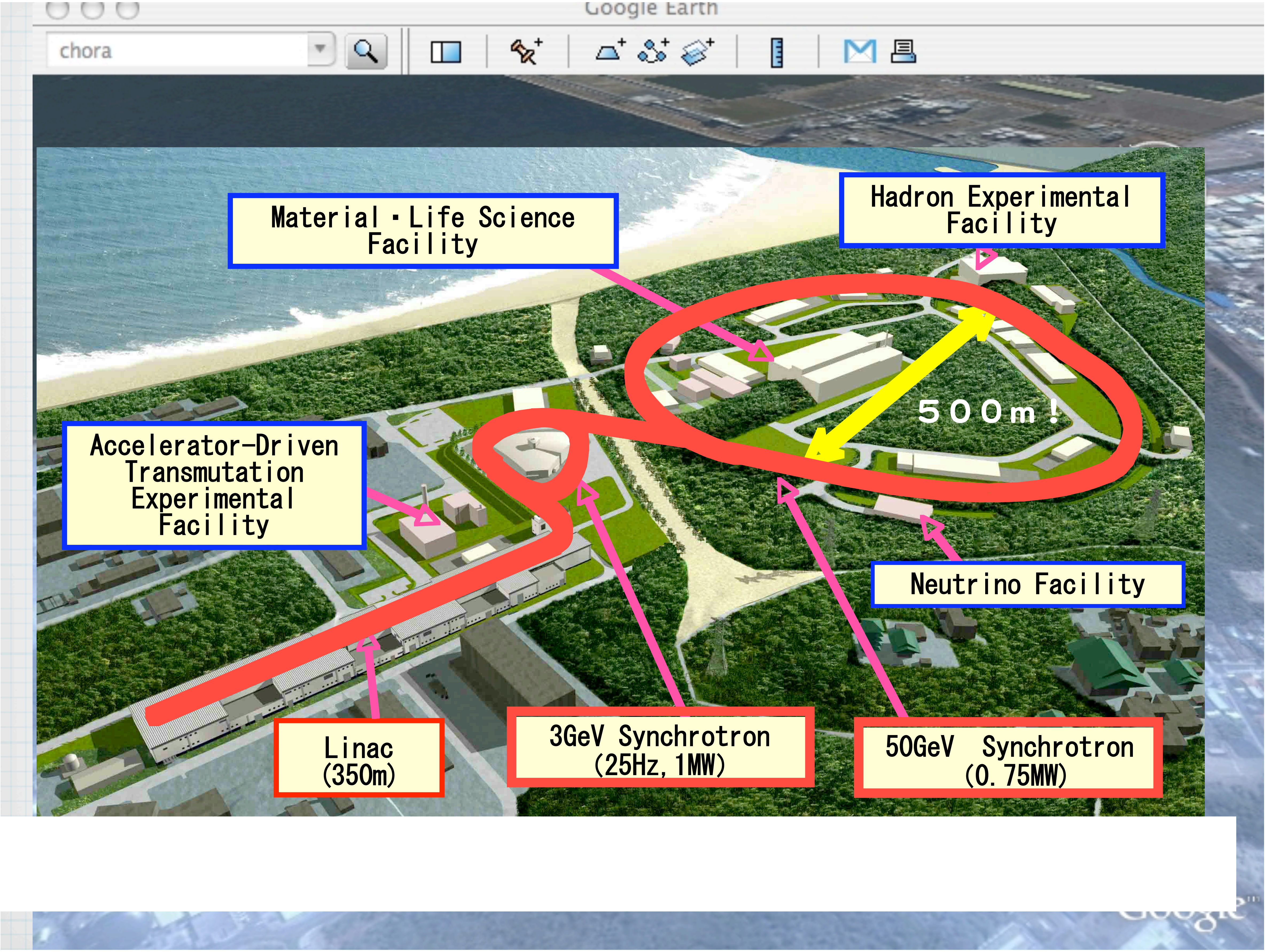
Fermilab Accelerators





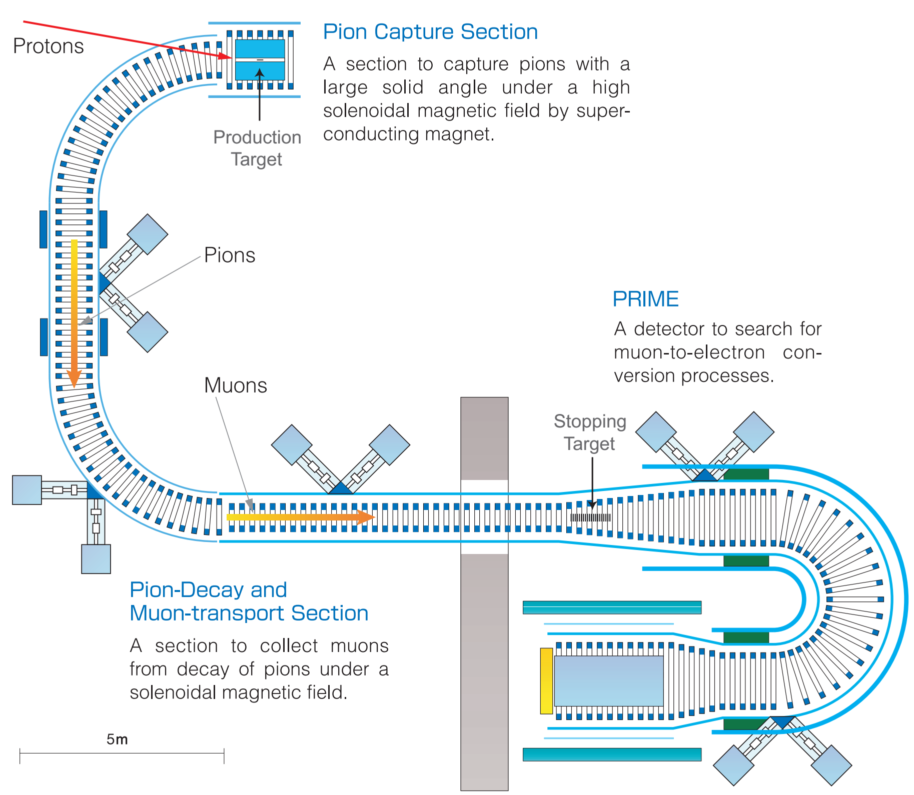
New Experimental Proposal at J-PARC

J-PARC at Tokai, Japan

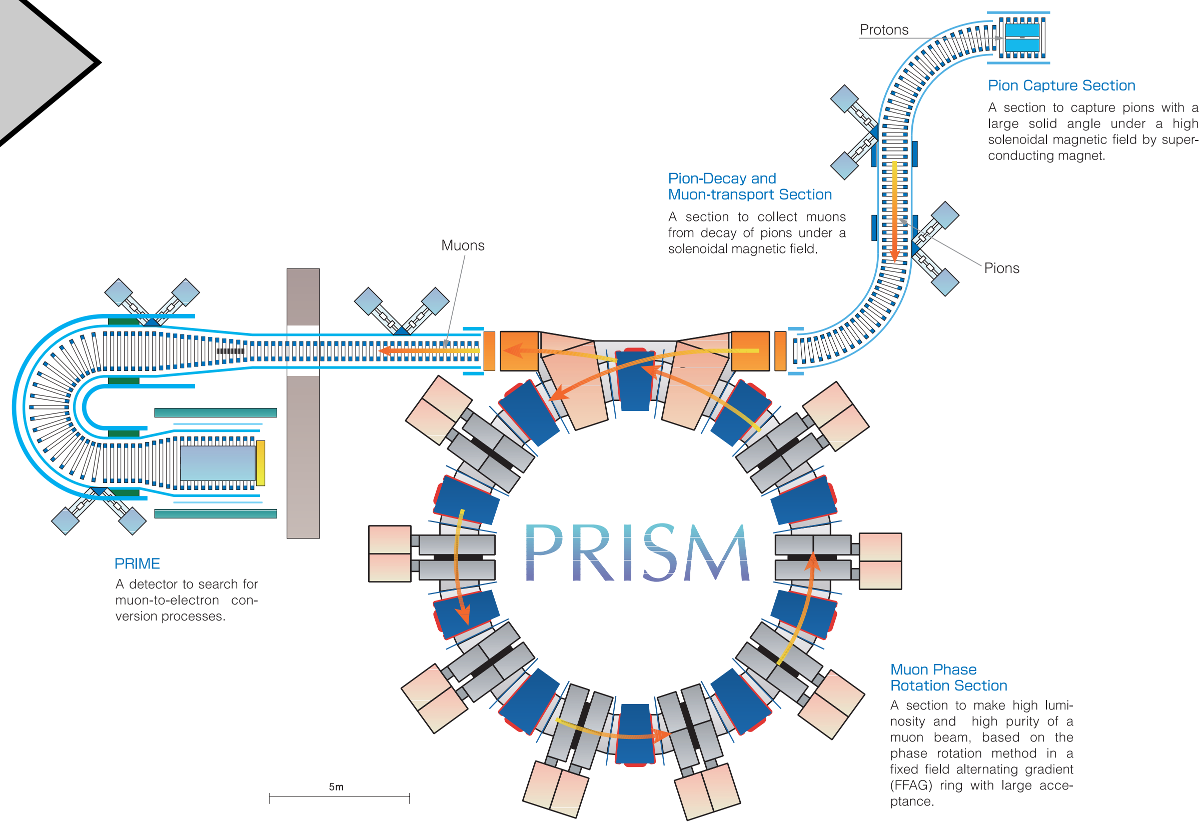


COMET/PRISM Projects in Japan

COMET



PRISM



$$B(\mu^- + Al \to e^- + Al) < 10^{-16}$$

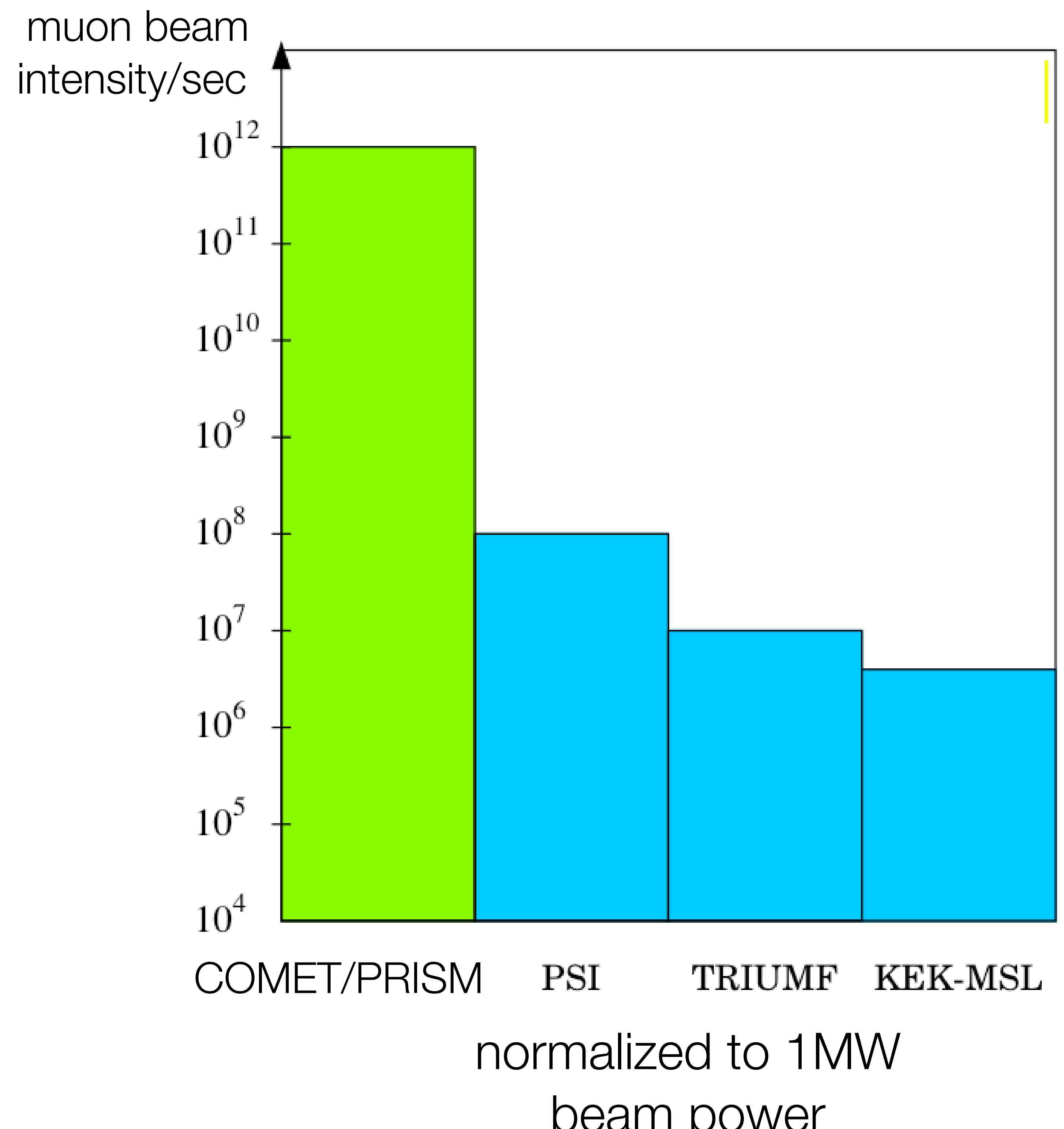
- without a muon storage ring.
- with a slowly-extracted pulsed proton beam.
- doable at the J-PARC NP Hall.
- regarded as the first phase / MECO type
- Early realization

$$B(\mu^- + Ti \to e^- + Ti) < 10^{-18}$$

- with a muon storage ring.
- with a fast-extracted pulsed proton beam.
- need a new beamline and experimental hall.
- regarded as the second phase.
- Ultimate search

Aiming the World Highest Muon Beam Intensity !

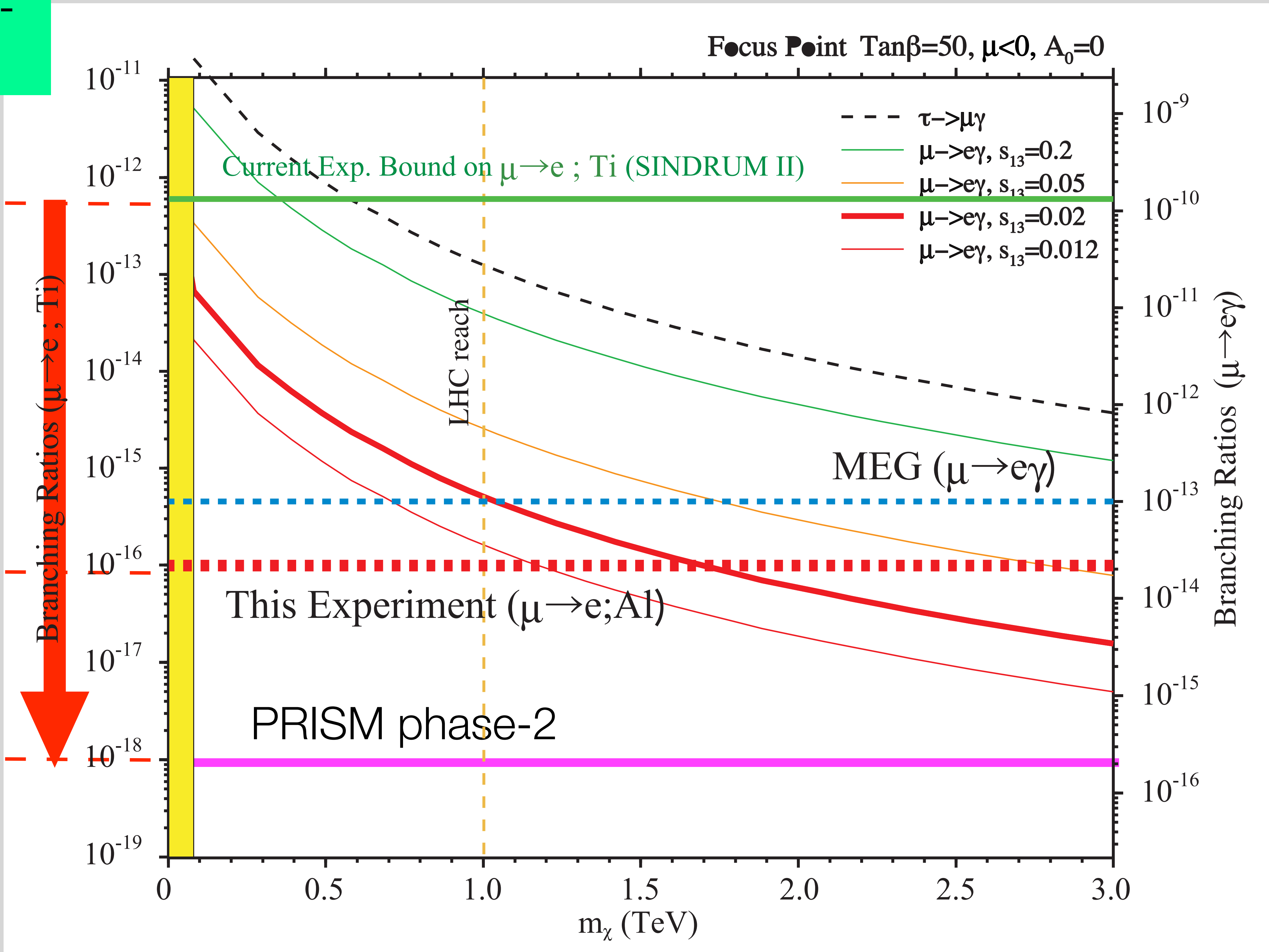
- Highest Muon Beam Intensit
  - 10^{11}-10^{12}/sec
  - 10^3-10^4 times the PSI muon beam intensity
  - pion capture with large solid angle by a solenoida magnetic field
  - a superconducting solenoid (SC) magnet surrounding a proton targe
  - good matching to muon transport beam line consisting of SC magnets
- Dedicated channel
  - one beam line / target.



mSUGRA with right-handed neutrinos

will be improved by a factor of 10,000.

will be improved by a factor of 1000,000.



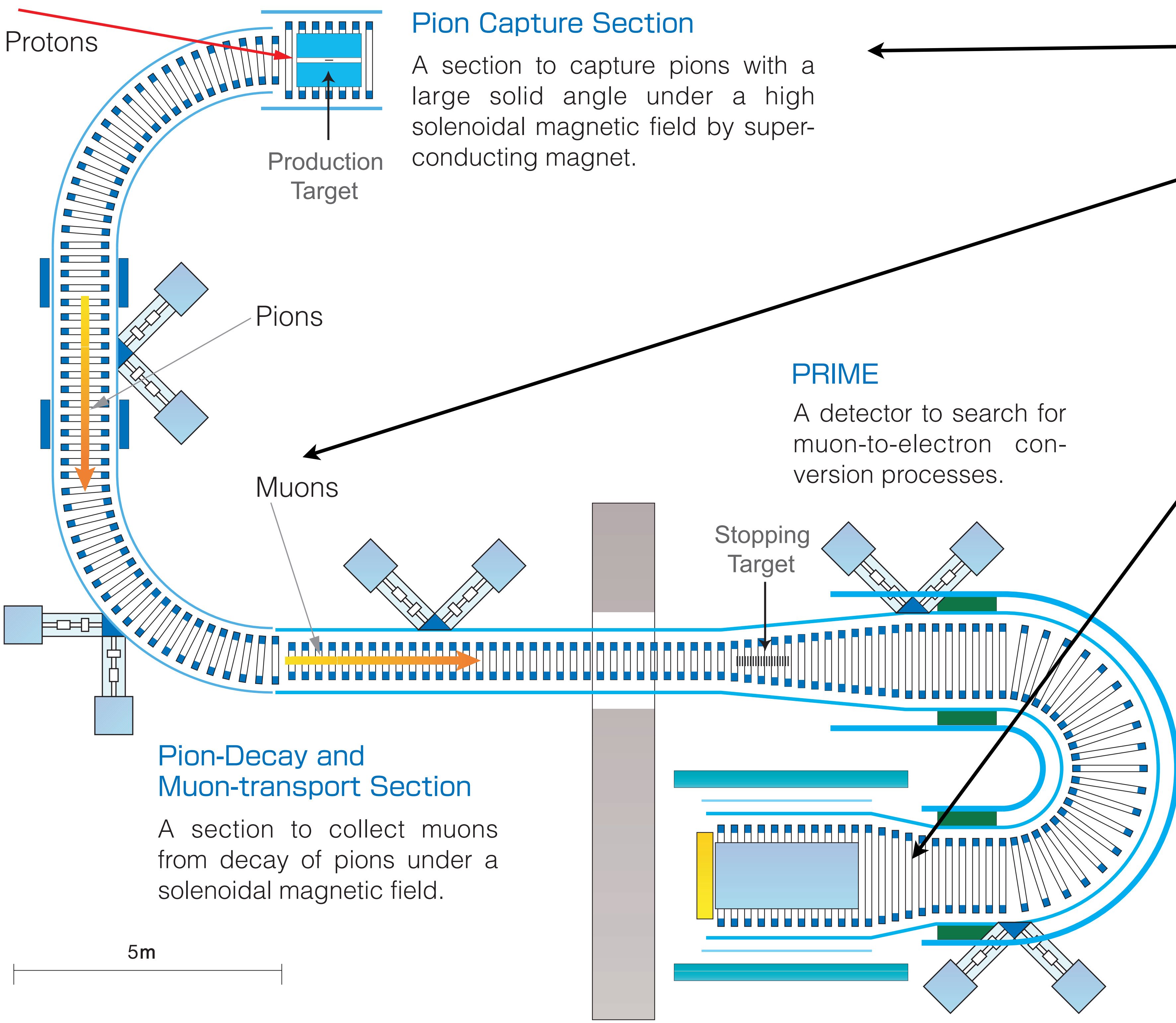
Sensitivity Goal

$$B(\mu^- + Al \rightarrow e^- + Al) < 10^{-16}$$

$$B(\mu^- + Ti \rightarrow e^- + Ti) < 10^{-18}$$

COMET

Overview of the COMET Experiment (COherent Muon to Electron Transition)



Proton Beam

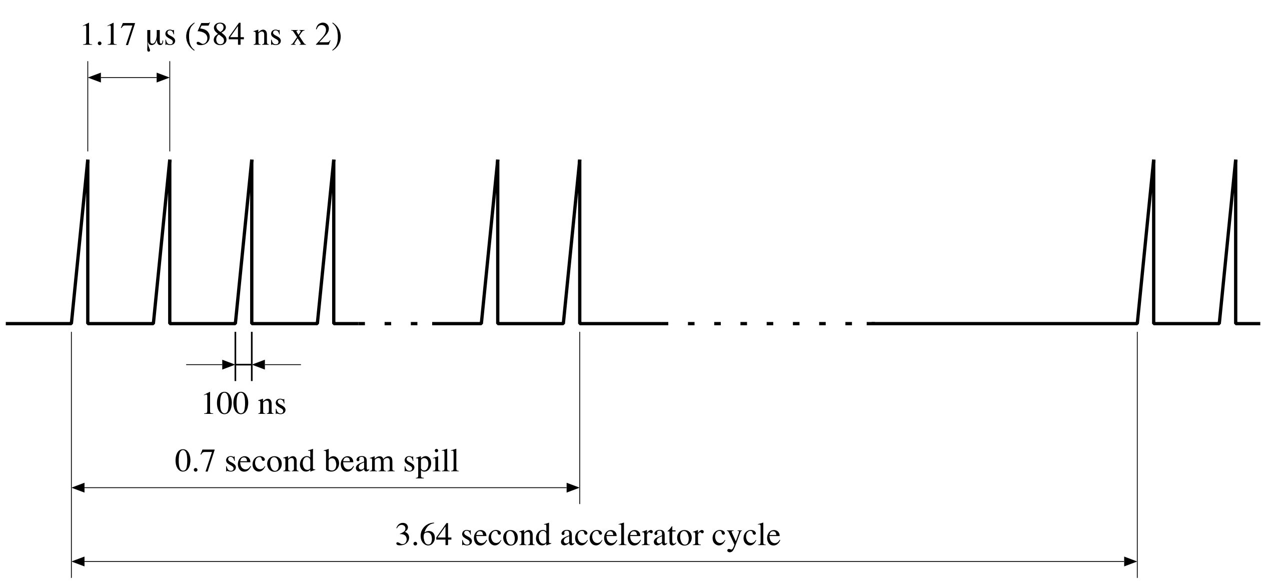
The Muon Source
- Proton Target
- Pion Capture
- Muon Transport

The Detector
- Muon Stopping Target
- Electron Transport
- Electron Detection

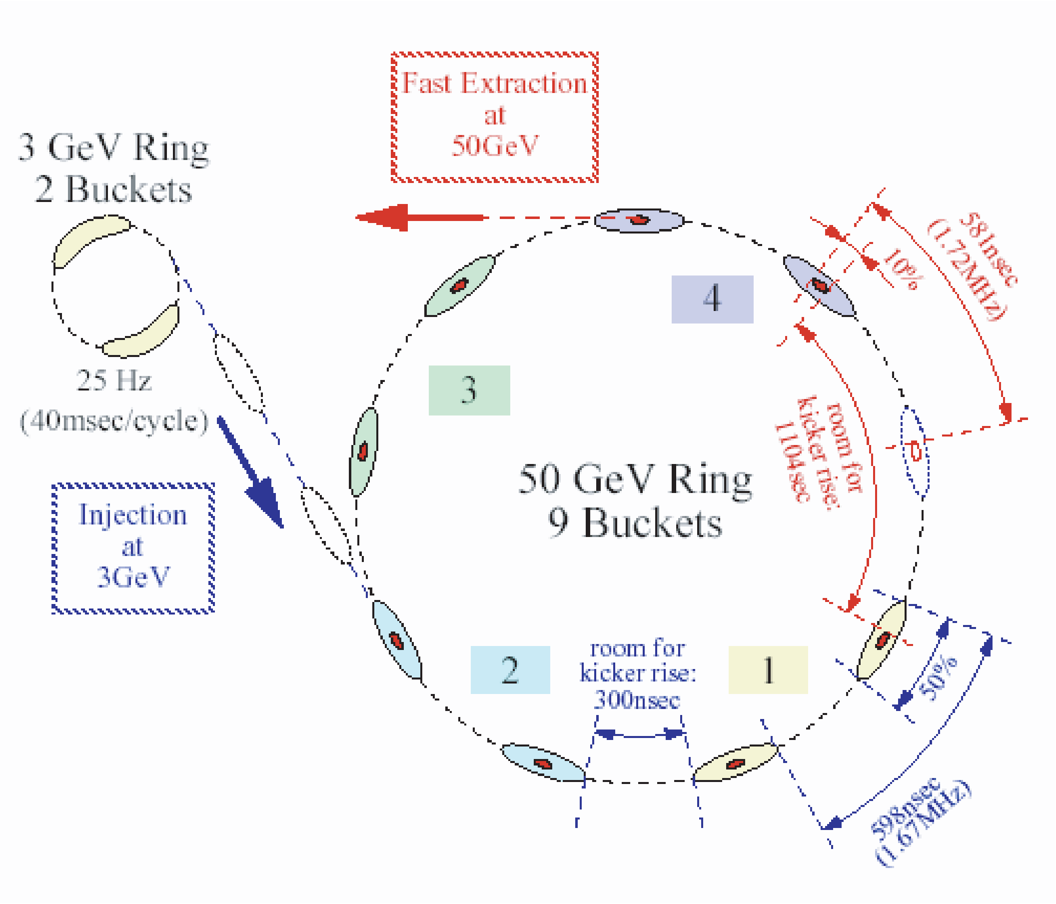
The beamline design is very important.

Proton Beam (1)

- A pulsed proton beam is needed to reject beam-related prompt background.
  - Detection will be made between pulses (delayed measurement).
- Time structure required for proton beams.
  - Pulse separation is ~ 1μsec or more (muon lifetime).
  - Narrow pulse width (<100 nsec)

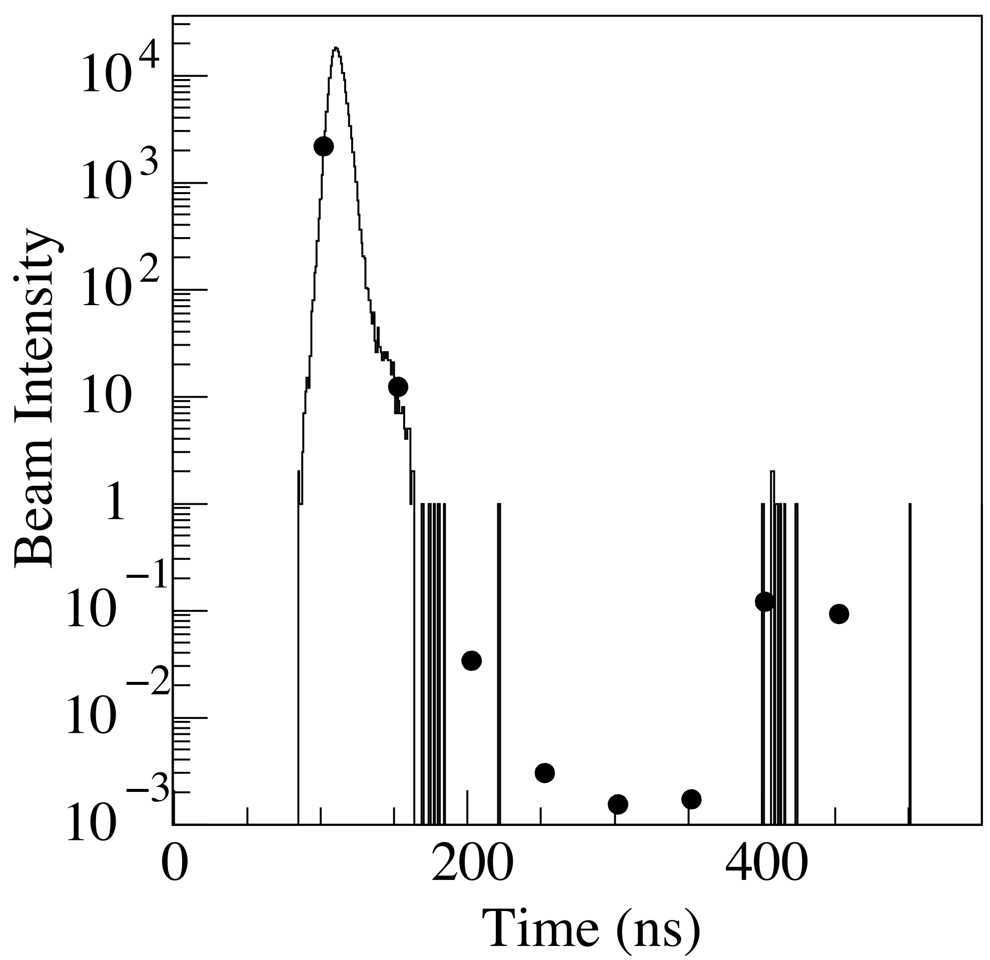


- Pulsed beam from slow extraction.
  - fill every other rf buckets with protons and make slow extraction with keeping bunches
  - spill length (flat top) ~ 0.7 sec
    - good to be shorter for cosmic-ray backgrounds.



Proton Beam (2)

- Proton Extinction :
  - (delayed)/(prompt)<10^{-9}
  - Test done at BNL-AGS gave 10^{-7} (shown below).
  - Extra extinction devices are needed.

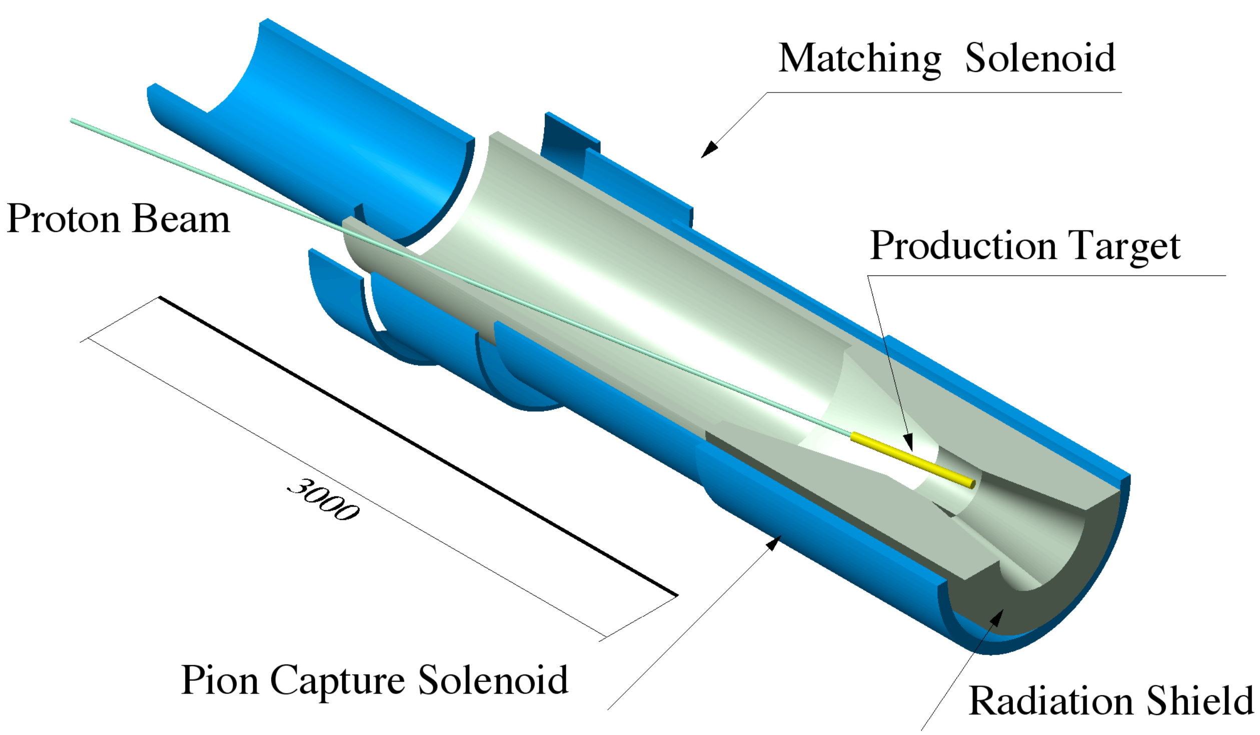


Test of Extinction at BNL-AGS

- Required Protons :
  - 8 x 10^{20} protons of 8 GeV in total for a single event sensitivity of about 0.3 x 10^{-16}.
  - For 2 x 10^7 sec running, 4 x 10^{13} protons /sec (= 7 μA).
  - A total beam power is 56 kW, which is about 1/8 of the J-PARC full beam power of 450 kW (30 GeV x 15μA).

Pion Capture

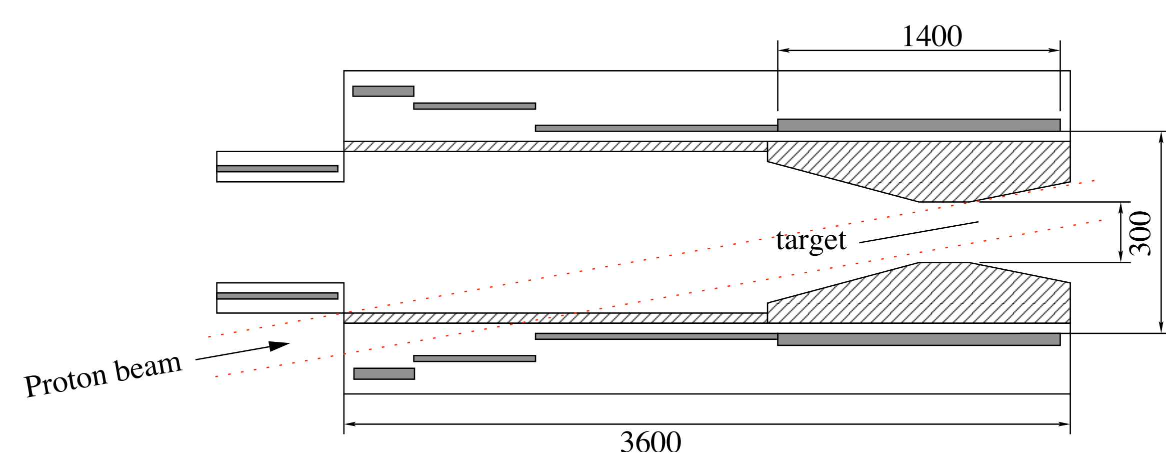
- A large muon yield can be achieved by large solid angle pion capture by a high solenoid field, which is produced by solenoid magnets surrounding the proton target.



$$P_T(GeV/c) = 0.3 \times B(T) \times (\frac{R(m)}{2})$$

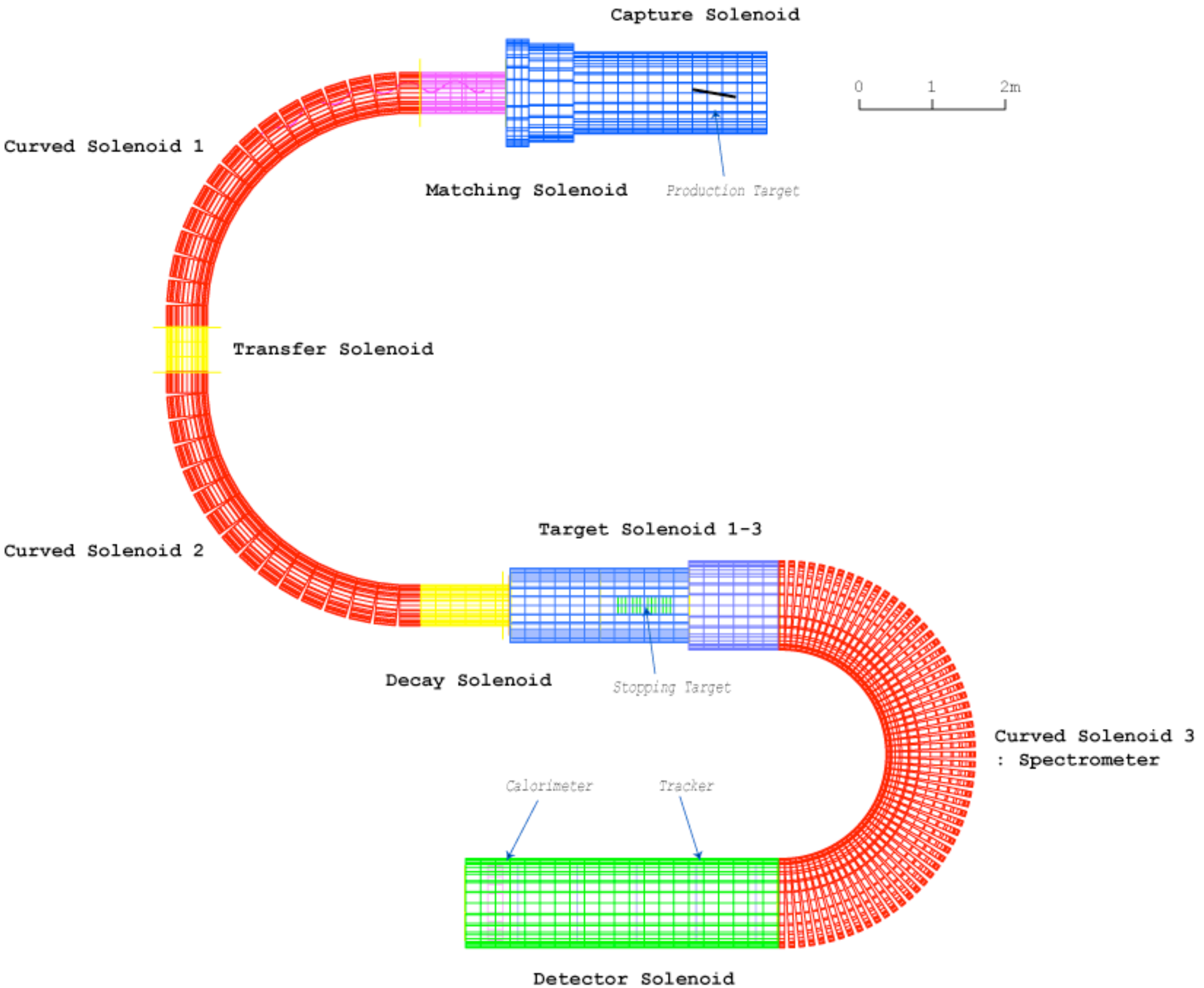
  - B=5T,R=0.2m, P_T=150MeV/c.

- Superconducting Solenoid Magnet for pion capture
  - 15 cm radius bore
  - a 5 tesla solenoidal field
  - 30 cm thick tungsten radiation shield
  - heat load from radiation
  - a large stored energy

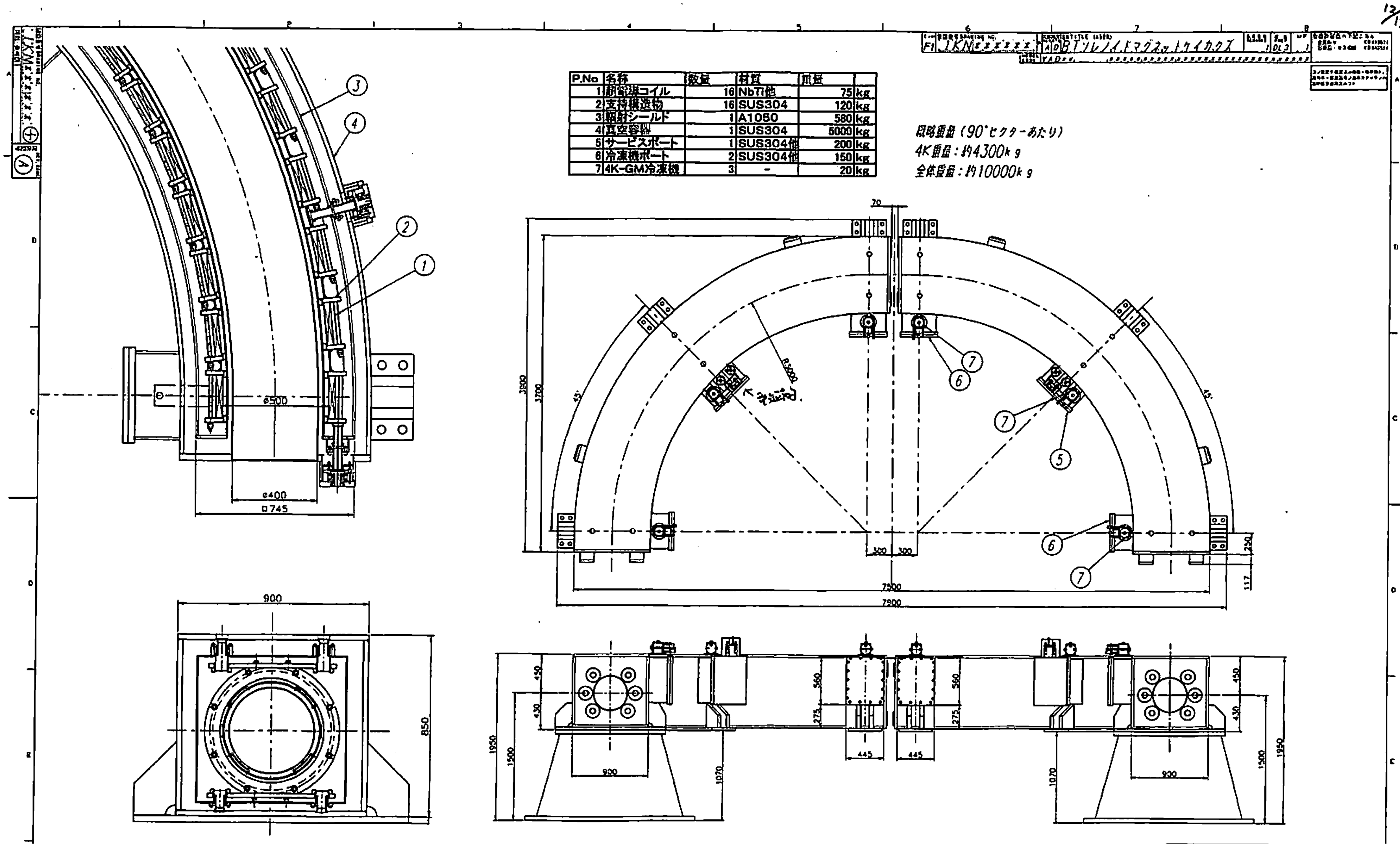


Muon Transport Beamline

- Muons are transported from the capture section to the detector by the muon transport beamline.
- Requirements :
    - long enough for pions to decay to muons (> 20 meters ≈ $2x10^{-3}$).
    - high transport efficiency (P_{μ}~40 MeV/c)
    - negative charge selection
    - low momentum selection (P_{μ}<75 MeV/c)
- Straight + curved solenoid transport system is adopted.



Transport Solenoid Design



P.No	名称	数量	材質	重量	
1	超電導コイル	16	NbTi他	75	kg
2	支持構造物	16	SUS304	120	kg
3	輻射シールド	1	A1050	580	kg
4	真空容器	1	SUS304	5000	kg
5	サービスポート	1	SUS304他	200	kg
6	冷凍機ポート	2	SUS304他	150	kg
7	4K-GM冷凍機	3	-	20	kg

Charged Particle Trajectory in Curved Solenoids

- A center of helical trajectory of charged particles in a curved solenoidal field is drifted by

$$D = \frac{p}{qB}\theta_{bend}\frac{1}{2}\left(\cos\theta + \frac{1}{\cos\theta}\right)$$

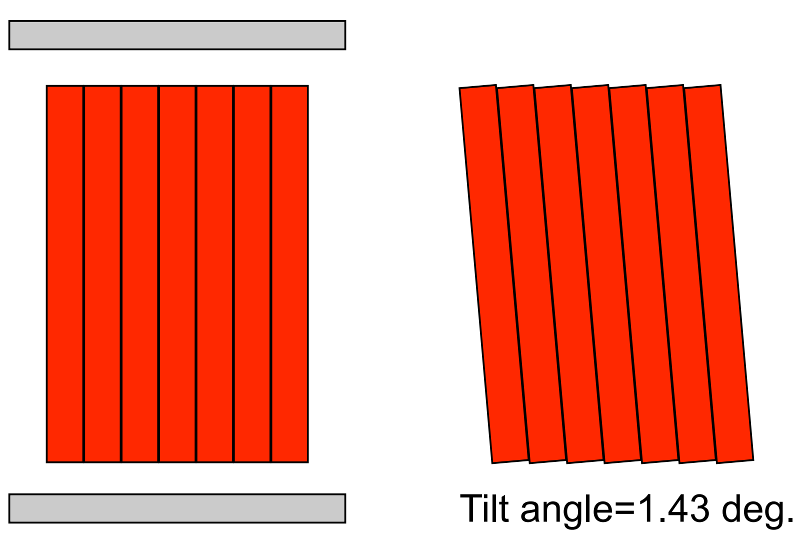
D : drift distance
B : Solenoid field
θ_{bend} *: Bending angle of the solenoid channel*
p : Momentum of the particle
q : Charge of the particle
θ *: atan*(P_T/P_L)

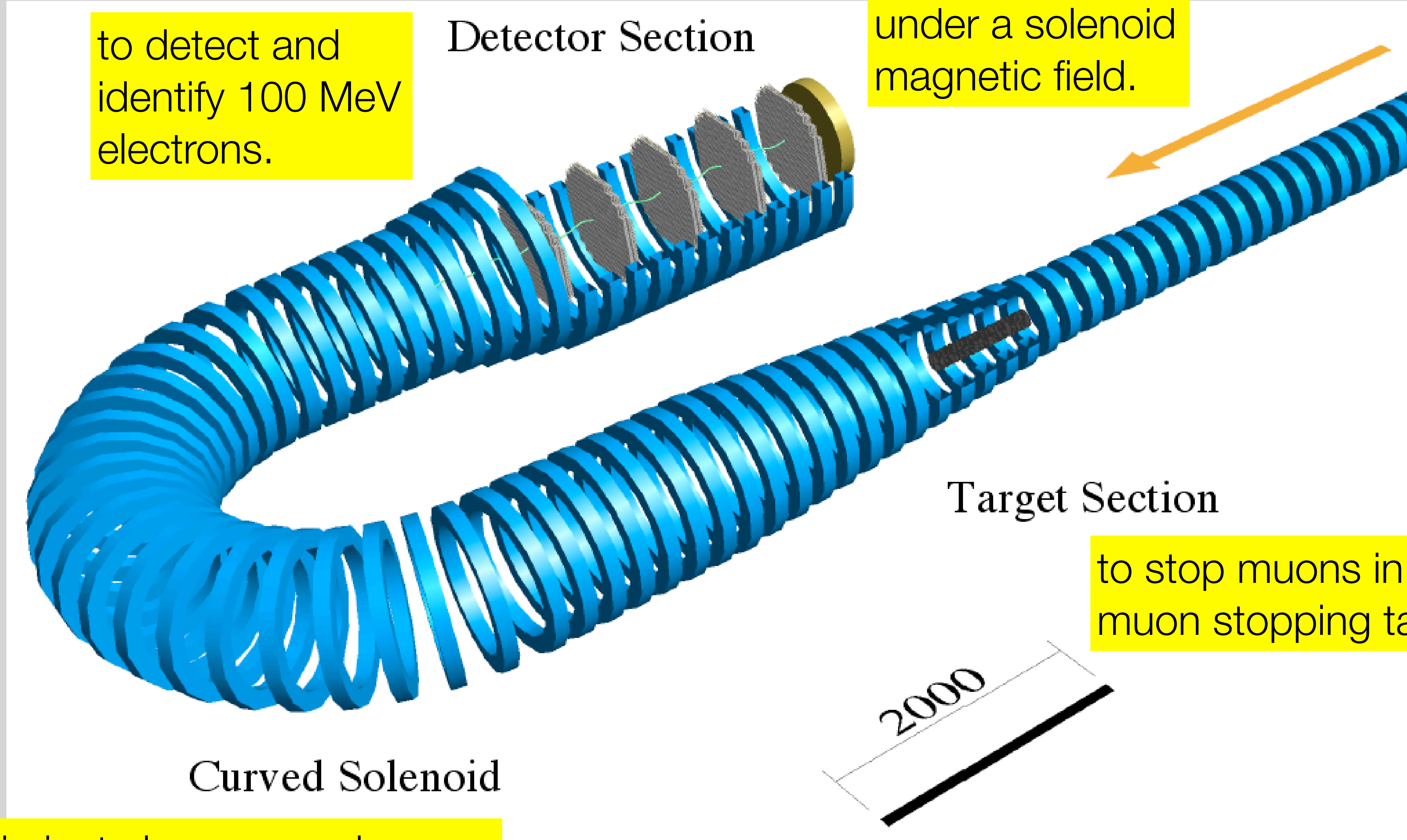
  - This effect can be used for charge and momentum selection.

- This drift can be compensated by an auxiliary field parallel to the drift direction given by

$$B_{comp} = \frac{p}{qr}\frac{1}{2}\left(\cos\theta + \frac{1}{\cos\theta}\right)$$

p : Momentum of the particle
q : Charge of the particle
r : Major radius of the solenoid
θ *: atan*(P_T/P_L)





to detect and identify 100 MeV electrons.

under a solenoid magnetic field.

to stop muons in the muon stopping target.

to eliminate low-energy beam particles and to transport only ~100 MeV electrons.

Detector Components

a muon stopping target, curved solenoid,tracking chambers, and a calorimeter/trigger and cosmic-ray shields.

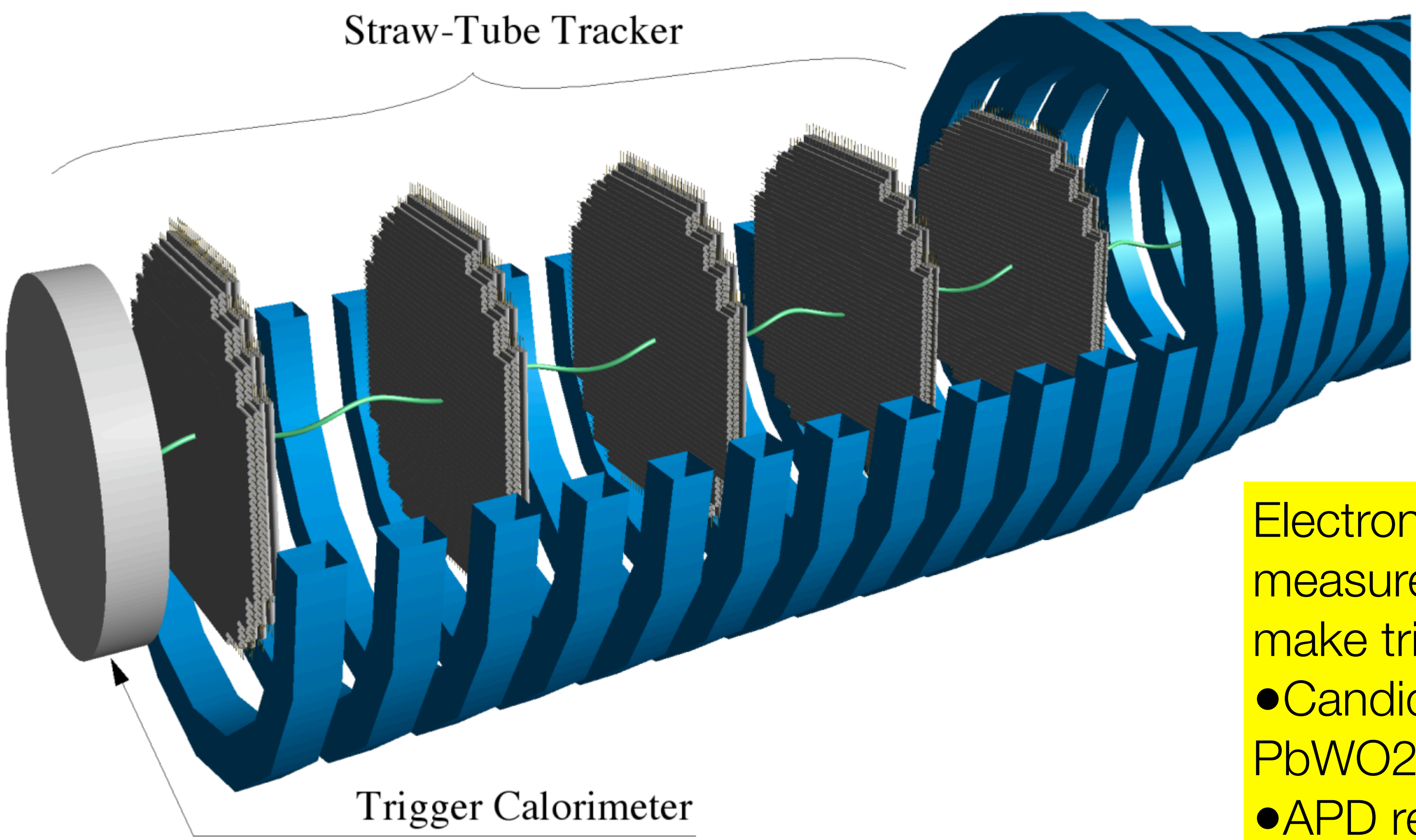
Electron Detection (preliminary)

Straw-tube Trackers to measure electron momentum.

- should work in vacuum and under a magnetic field.
- A straw tube has 25µm thick, 5 mm diameter.
- One plane has 2 views (x and y) with 2 layers per view.
- Five planes are placed with 48 cm distance.
- 250µm position resolution.

Under a solenoidal magnetic field of 1 Tesla.

In vacuum to reduce multiple scattering.



Electron calorimeter to measure electron energy and make triggers.

- Candidate are GSO or PbWO2.
- APD readout (no PMT).

Signal Sensitivity (preliminary) - 2 SSC years

- Single event sensitivity

$$B(\mu^- + Al \rightarrow e^- + Al) \sim \frac{1}{N_\mu \cdot f_{cap} \cdot A_e},$$

Tungsten target & beam line optimization → improvement of x2.7

- N_μ is a number of stopping muons in the muon stopping target. It is $1.5\text{x}10^{18}$ muons.
- f_{cap} is a fraction of muon capture, which is 0.6 for aluminum.
- A_e is the detector acceptance, which is 0.04.

total protons	$8\text{x}10^{20}$
muon transport efficiency	0.0071
muon stopping efficiency	0.26
# of stopped muons	$1.5\text{x}10^{18}$

$$B(\mu^- + Al \rightarrow e^- + Al) = \frac{1}{1.5 \times 10^{18} \times 0.6 \times 0.04} = 2.8 \times 10^{-17}$$

$$B(\mu^- + Al \rightarrow e^- + Al) < 5 \times 10^{-17} \quad (90\% \text{ C.L.})$$

BG with asterisk needs beam extinction.

Background Rejection Summary (preliminary)

	Backgrounds	Events	Comments
(1)	Muon decay in orbit	0.05	230 keV resolution
	Radiative muon capture	<0.001	
	Muon capture with neutron emission	<0.001	
	Muon capture with charged particle emission	<0.001	
(2)	Radiative pion capture*	0.12	prompt
	Radiative pion capture	0.002	late arriving pions
	Muon decay in flight*	<0.02	
	Pion decay in flight*	<0.001	
	Beam electrons*	0.08	
	Neutron induced*	0.024	for high energy neutrons
	Antiproton induced	0.007	for 8 GeV protons
(3)	Cosmic-ray induced	0.10	10^{-4} veto & 2×10^{7} sec run
	Pattern recognition errors	<0.001	
	Total	0.4	

Status of the COMET Proposal

- The COMET proposal was submitted to the J-PARC PAC in January, 2009. It is highly evaluated (saying "... would be one of the flagship experiments at J-PARC"), and some requests were made.
  - a more detailed CDR
  - coordination with KEK on a beam line and so on.
  - increase of the collaboration

New Collaborators are welcome to join us.

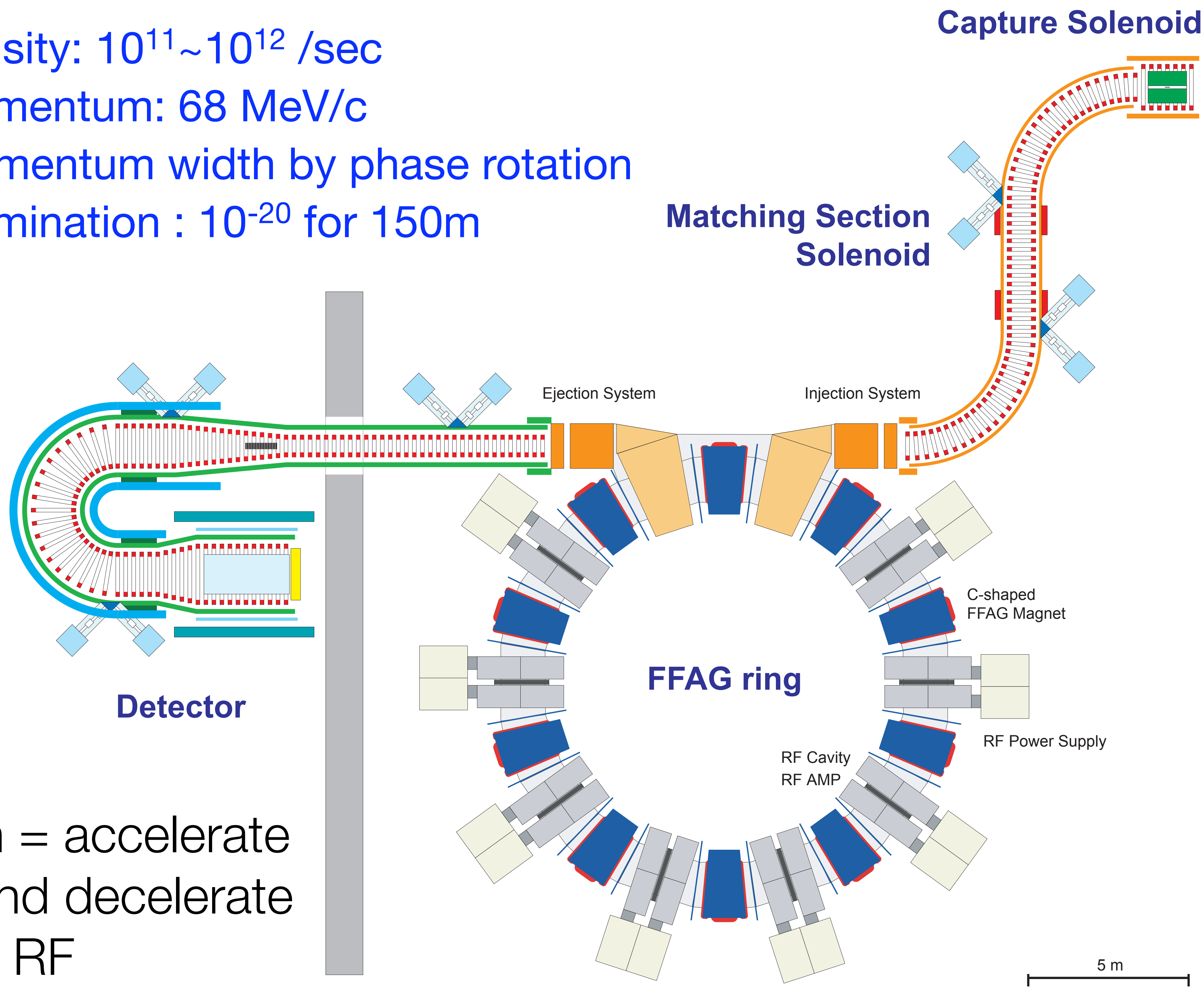
PRISM

PRISM

PRISM=Phase Rotated
Intense Slow Muon source

PRISM Muon Beam

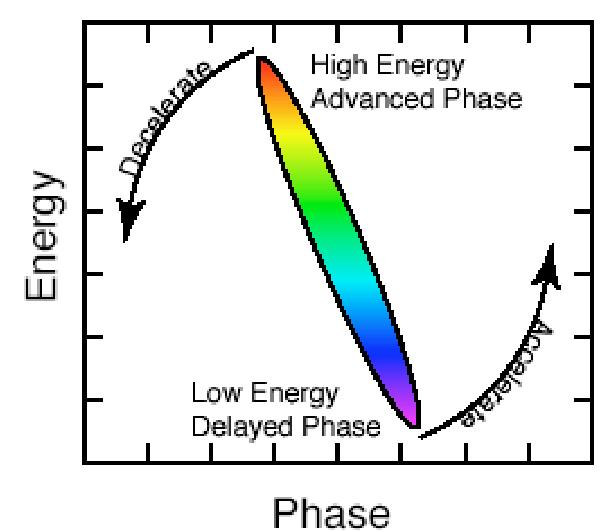
- muon intensity: 10^{11}~10^{12} /sec
- central momentum: 68 MeV/c
- narrow momentum width by phase rotation
- pion contamination : 10^{-20} for 150m

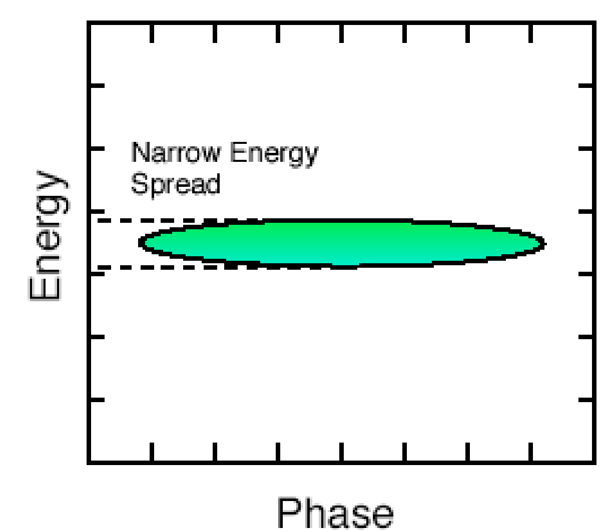


Phase rotation = accelerate slow muons and decelerate fast muons by RF

... To Make Narrow Beam Energy Spread

- A technique of phase rotation is adopted.
- The phase rotation is to decelerate fast beam particles and accelerate slow beam particles.
- To identify energy of beam particles, a time of flight (TOF) from the proton bunch is used.
  - Fast particle comes earlier and slow particle comes late.
- Proton beam pulse should be narrow (< 10 nsec).
- Phase rotation is a well-established technique, but how to apply a tertiary beam like muons (broad emittance) ?





Phase Rotation for a Muon Beam

Use a muon storage ring ?

(1) Use a muon Storage Ring :

A muon storage ring would be better and realistic than a linac option because of reduction of # of cavities and rf power.

(2) Rejection of pions in a beam :

At the same time, pions in a beam would decay out owing to long flight length.

Which type of a storage ring ?

(1) cannot be cyclotron, because of no synchrotron oscillation.
(2) cannot be synchrotron, because of small acceptance and slow acceleration.

Fixed field Alternating Gradient Ring (FFAG)

Types of FFAG

- Scaling type FFAG
  - betatron tune : constant (zero chromaticity)
  - non-linear field elements
- Non-scaling type FFAG
  - betatron tune : not constant
  - linear field elements

Scaling FFAG

$$B(r,\theta) = B_i\left(\frac{r}{r_i}\right)^k F\left(\theta - \eta \ln\frac{\mathrm{r}}{\mathrm{r_i}}\right)$$

Radial-sector

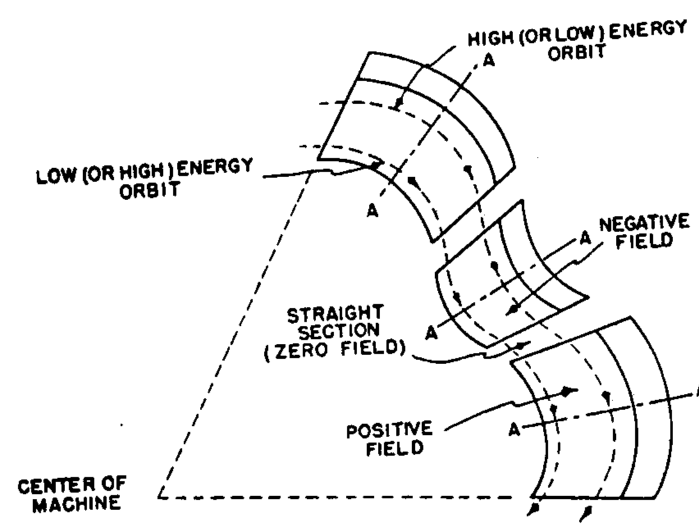


FIG. 2. Plan view of radial-sector magnets.

Spiral

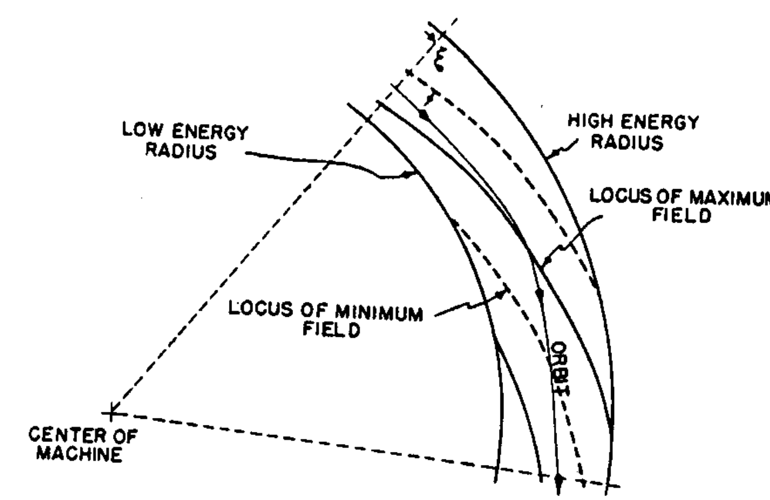
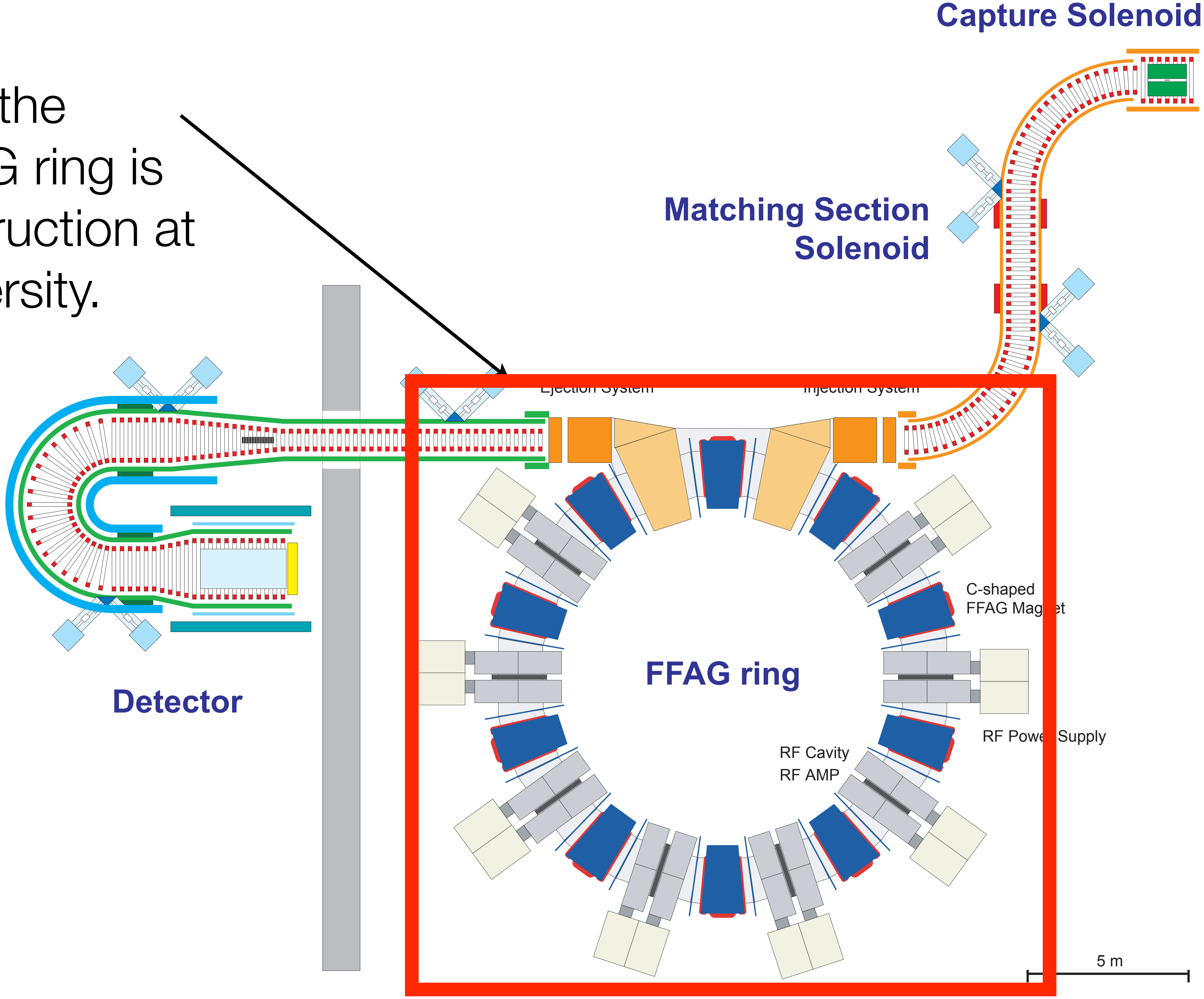


FIG. 3. Spiral-sector configuration.

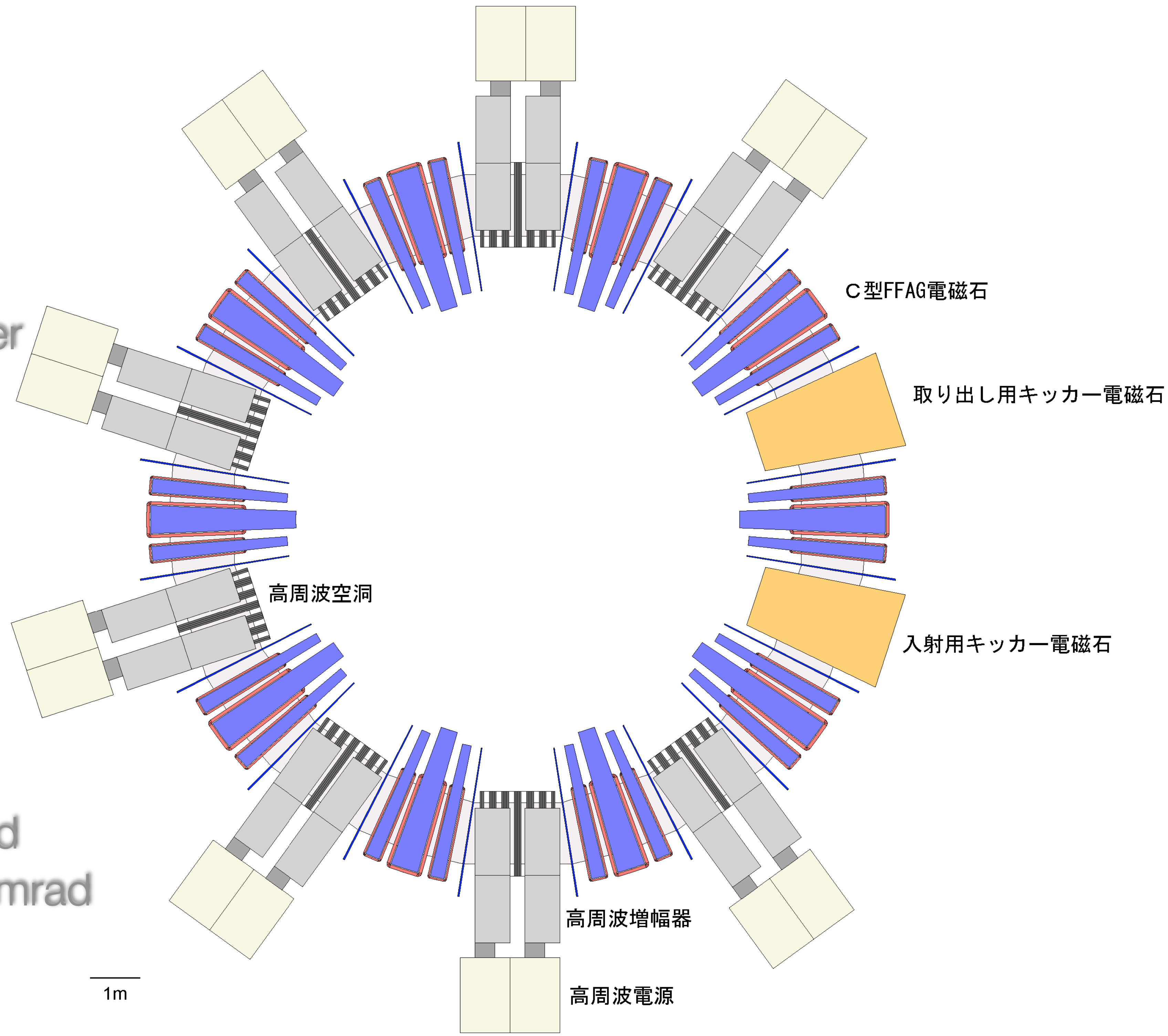
PRISM FFAG Ring R&D

A portion of the PRISM-FFAG ring is under construction at Osaka University.

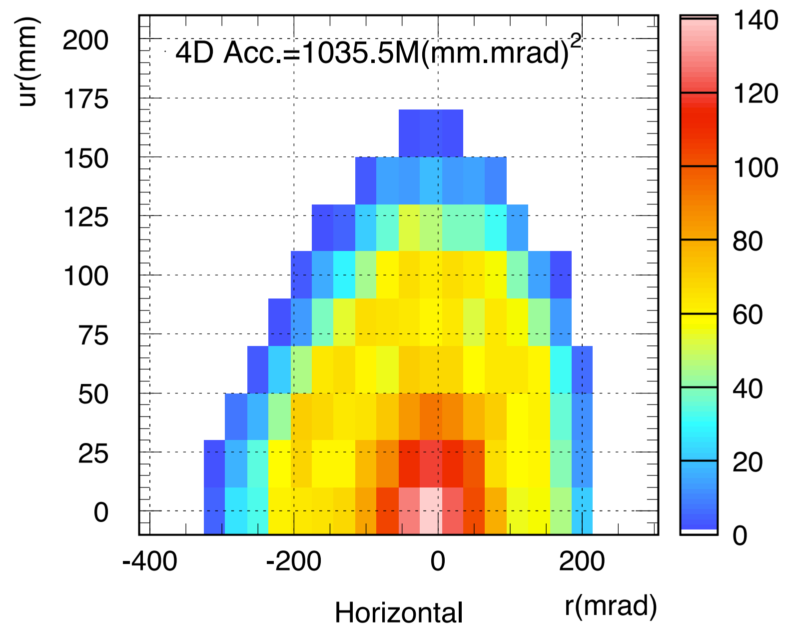


PRISM FFAG Lattice Design

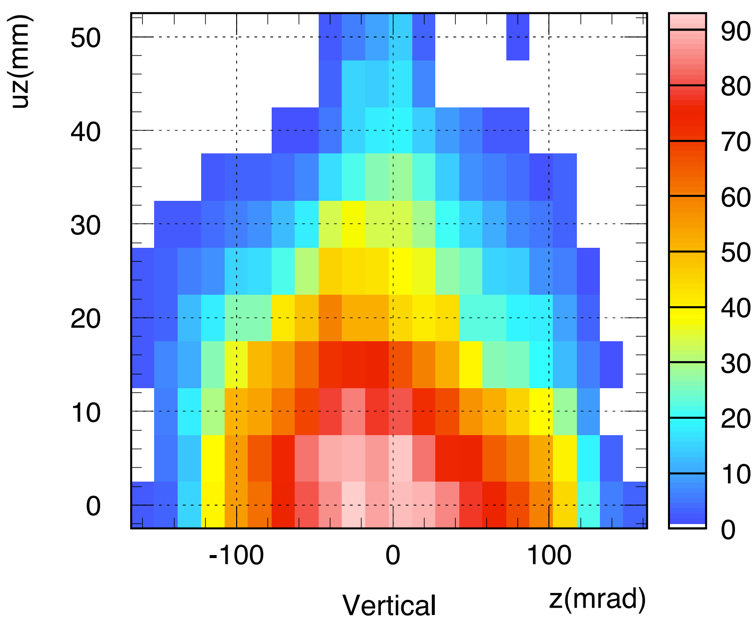
- 10 cells
- k=5(4.6-5.2)
- F/D(BL)=8
- r0=6.5m for 68MeV/c
- half gap = 15cm
- mag. size 110cm @ F center
- Triplet
  - θ_F=4.40deg
  - θ_D=1.86deg
- tune
  - h : 2.86
  - v : 1.44
- acceptance
  - h : 140000 π mm mrad
    - --> 40000 π mm mrad
  - v : 6500 π mm mrad



PRISM-FFAG Acceptance

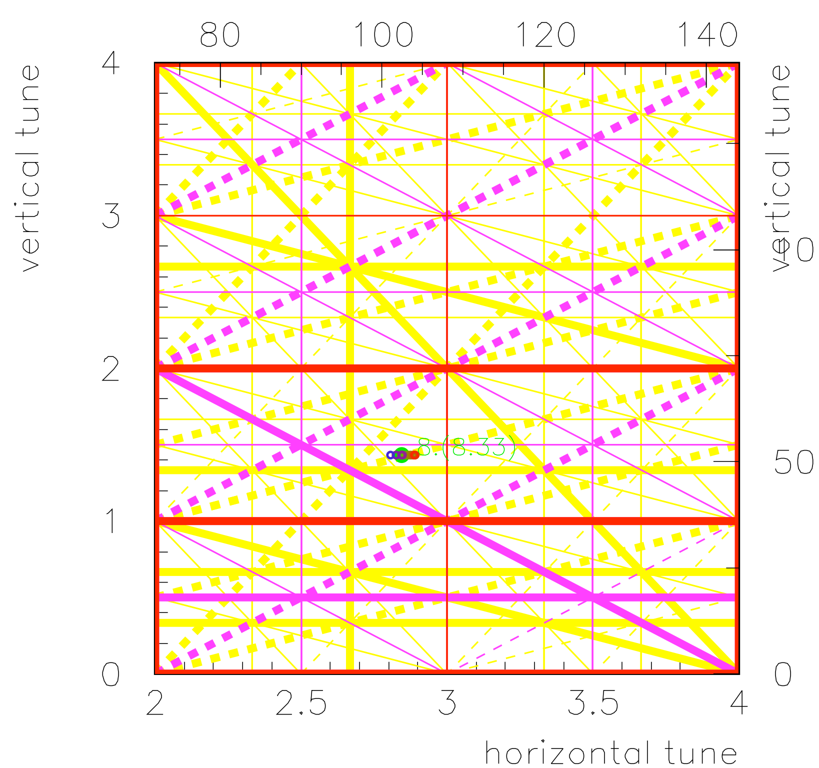


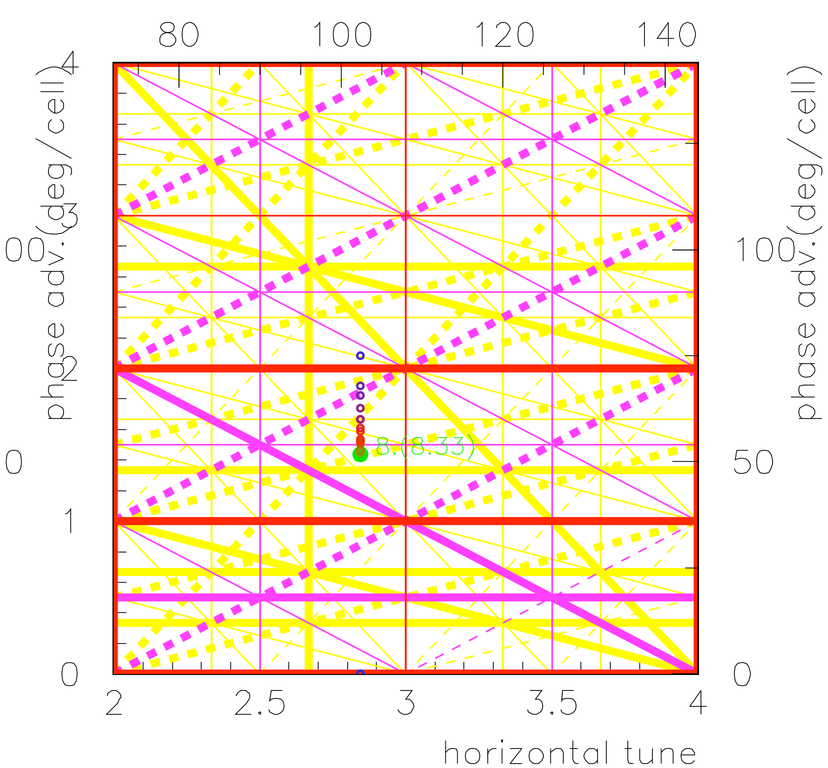
Horizontal Acceptance
40000π mm mrad



Vertical Acceptance
6500π mm mrad

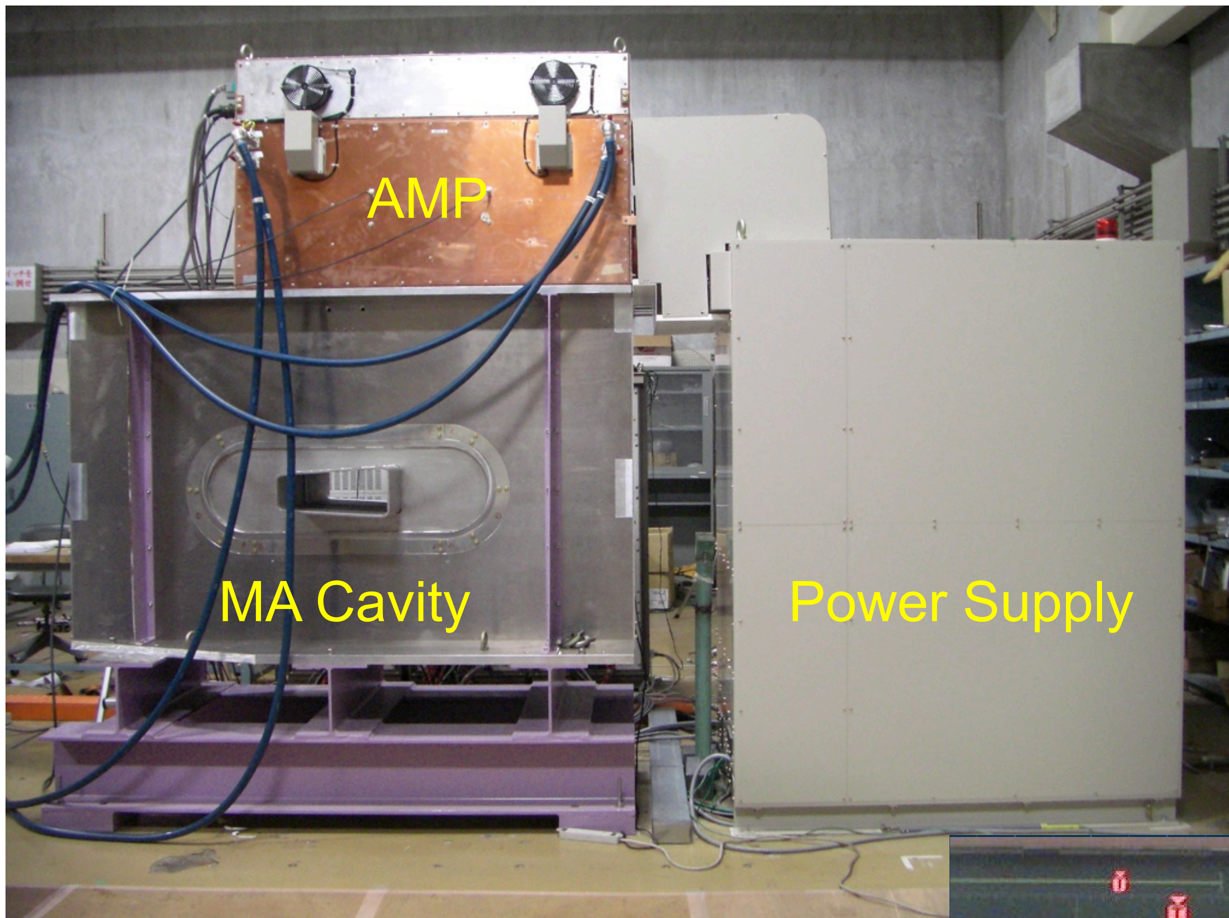
N=10
F/D=8
k=5
r0=6.5m
H:2.86
V:144

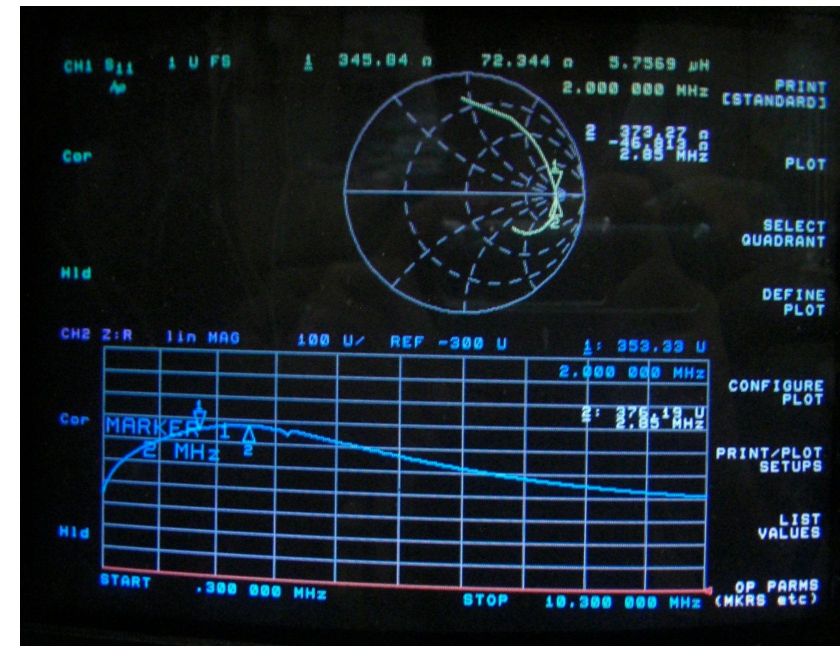


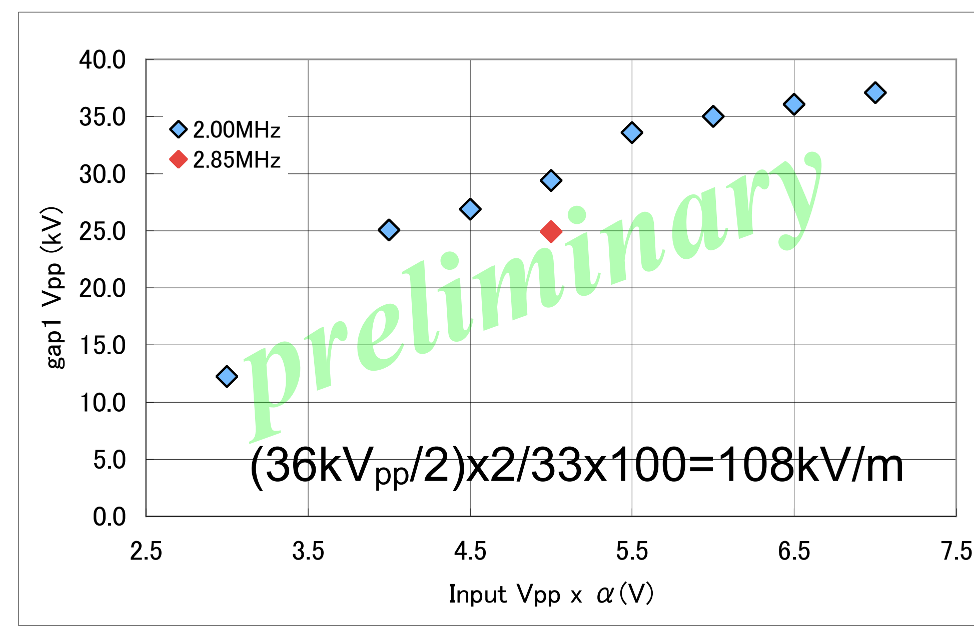


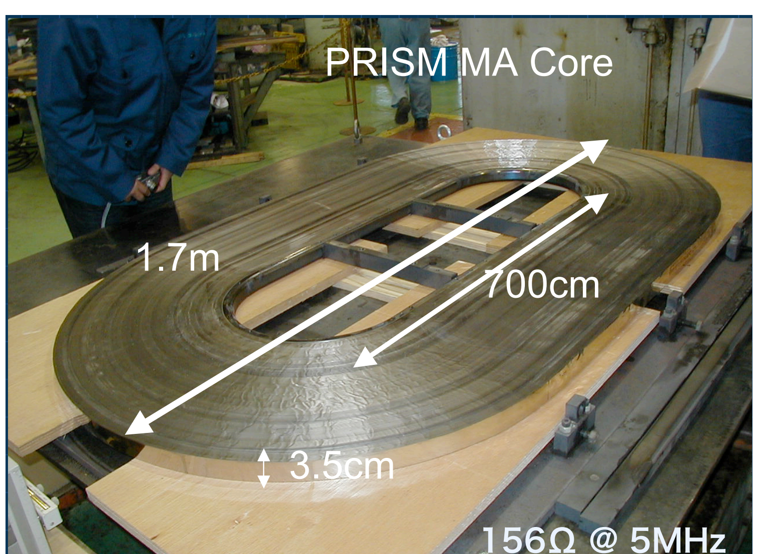
PRISM FFAG Ring R&D

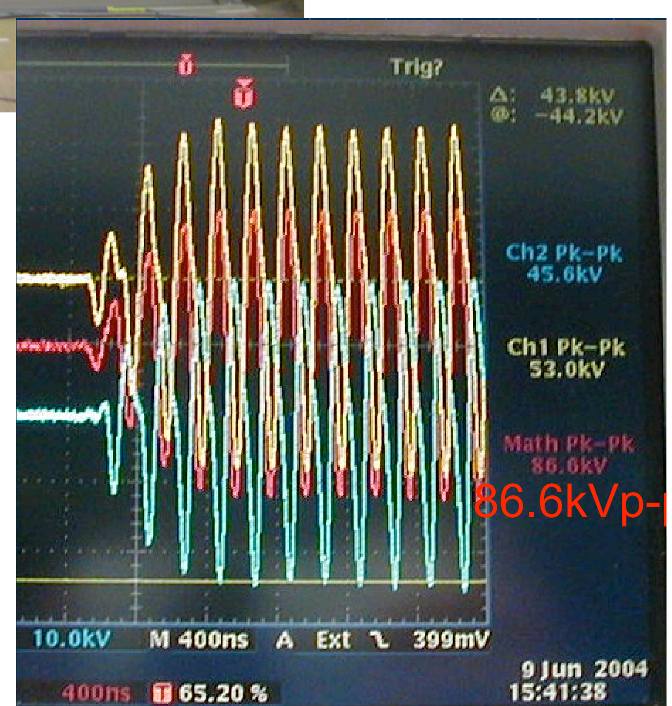
PRISM FFAG RF R&D









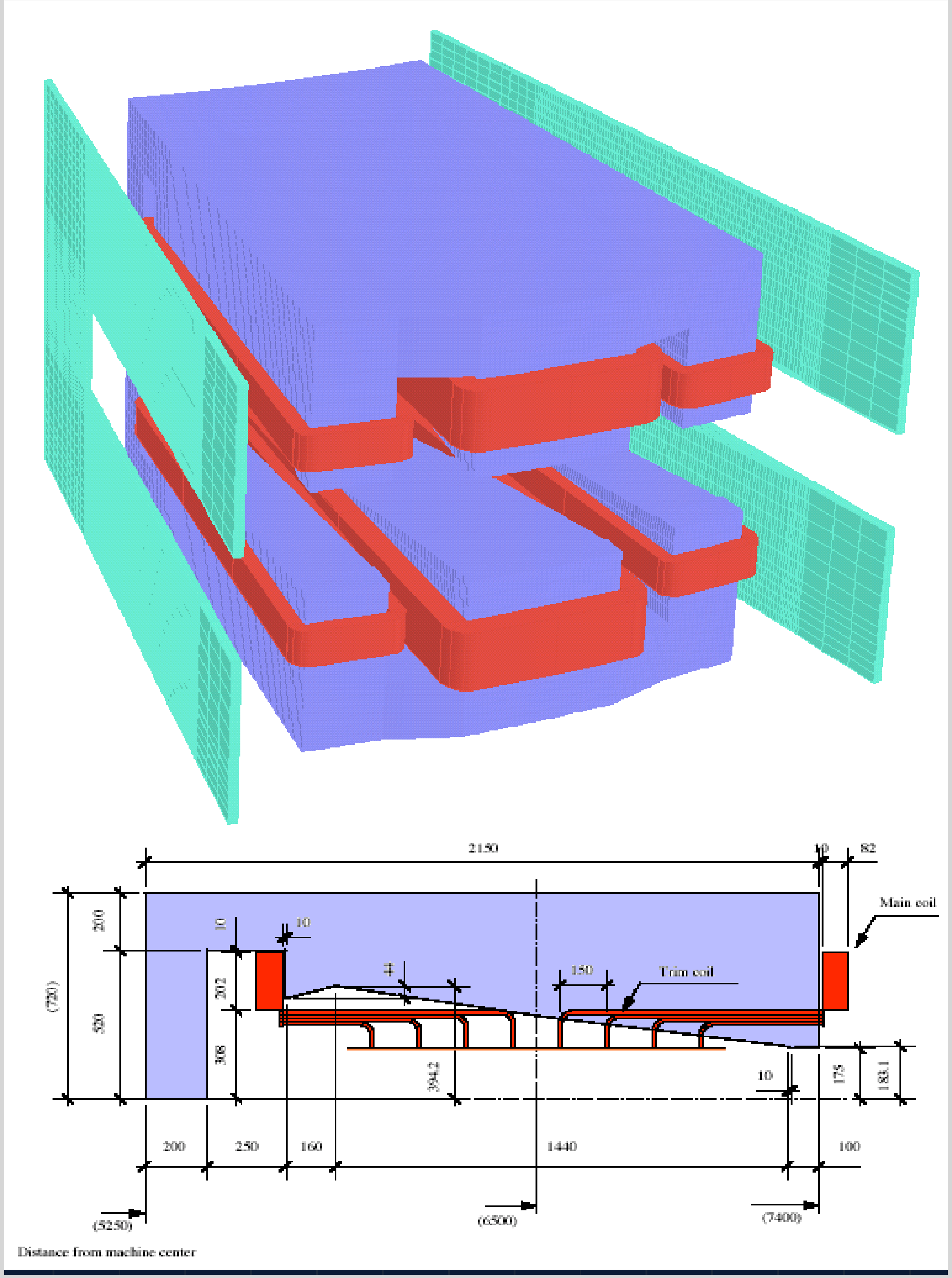


PRISM FFAG Magnets

- radial sector with C-type yoke
  - D-F-D triplet

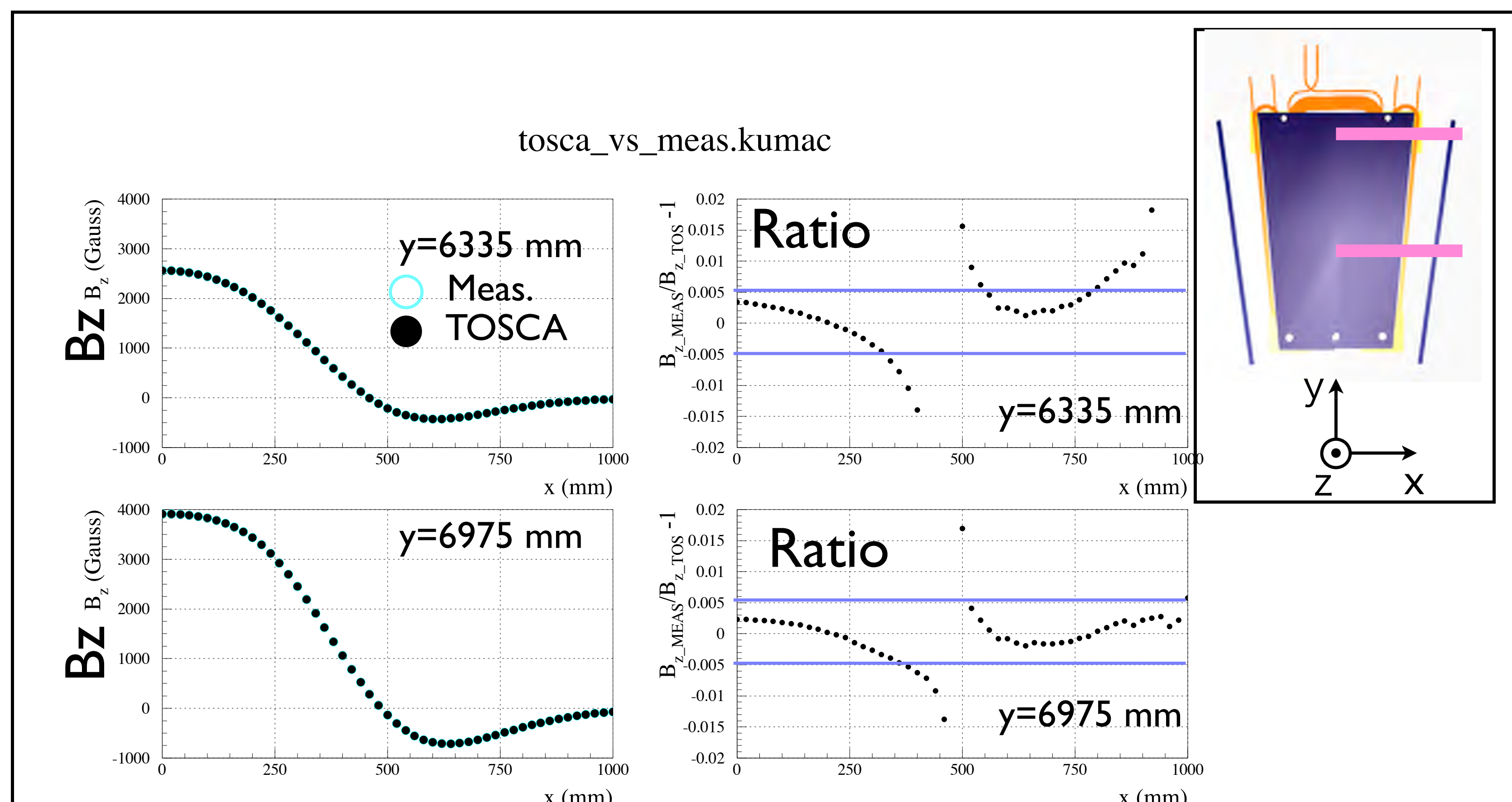
$$B(r) = B_0 \times (\frac{r}{r_0})^k$$

- machined pole shape to create field gradient (k)
- trim coils for variable k values (future)
- vertical tune : F/D
- horizontal tune : k value
- magnetic field design : TOSCA



FFAG Magnet Construction

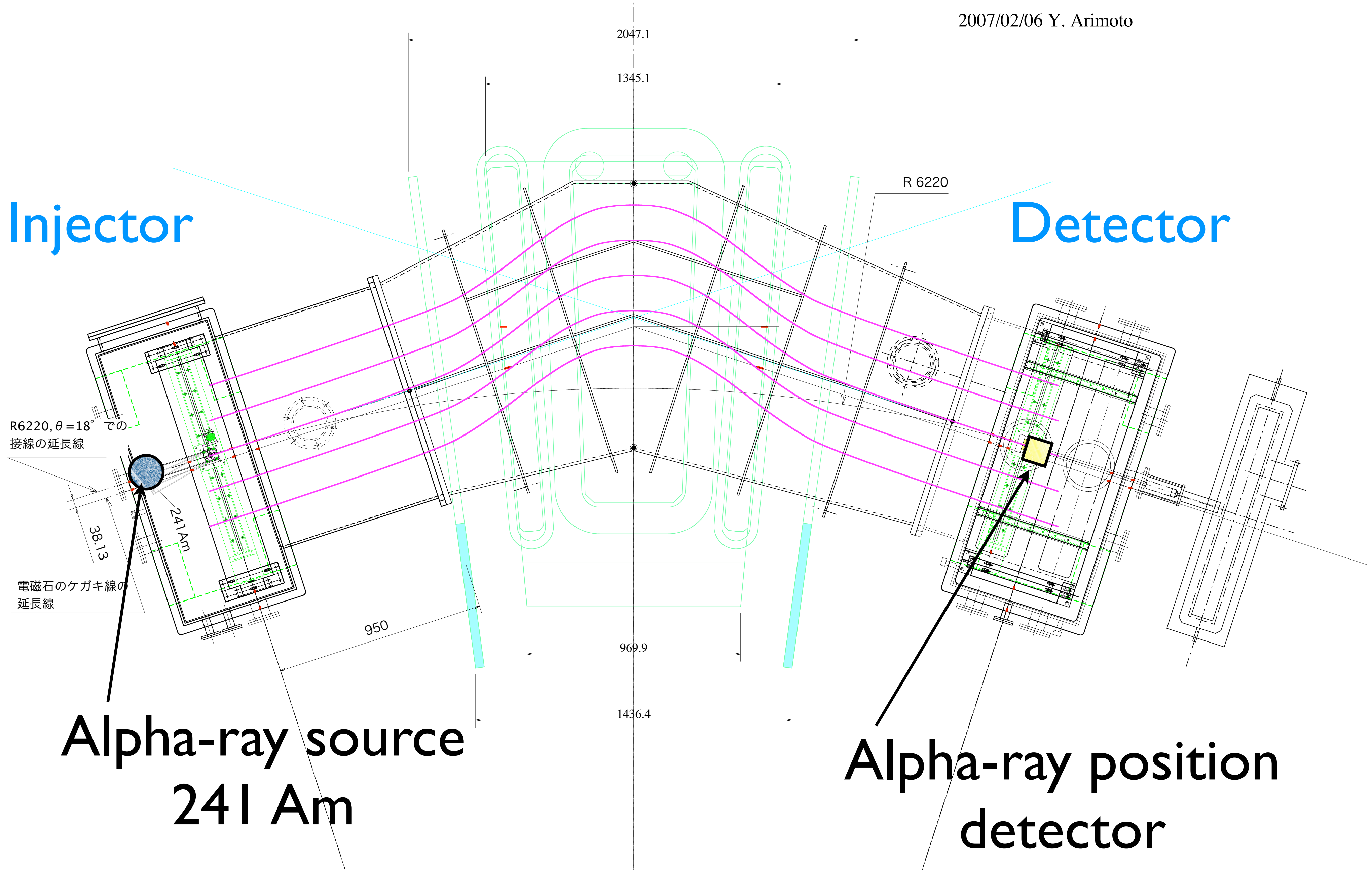
- Magnetic field measurements for PRISM FFAG magnet has been made in spring, 2006.
- The measured field distribution was compared with TOSCA calculation.
- Differences between them are less than 0,5%. It is within tolerance.



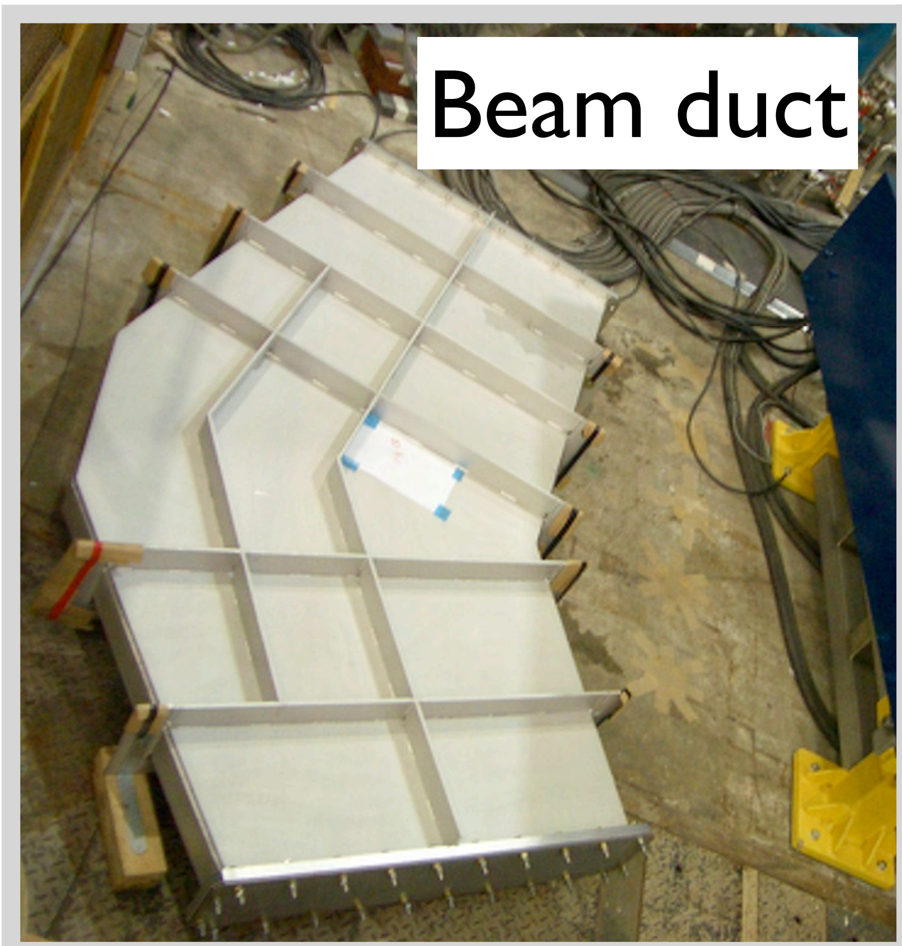
Alpha Particle Tracking with One Magnet Cell

Purpose: study beam dynamics at large amplitudes (non-linearity) by determining a transfer mapping between in and out.

muon 68 MeV/c = alpha particle 2.5 MeV.

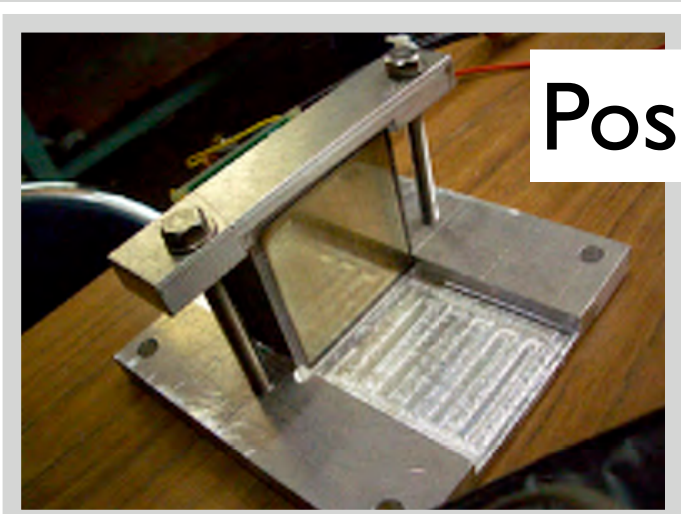


One-cell Test Stand under Preparation



Beam duct

Injector and detector chamber

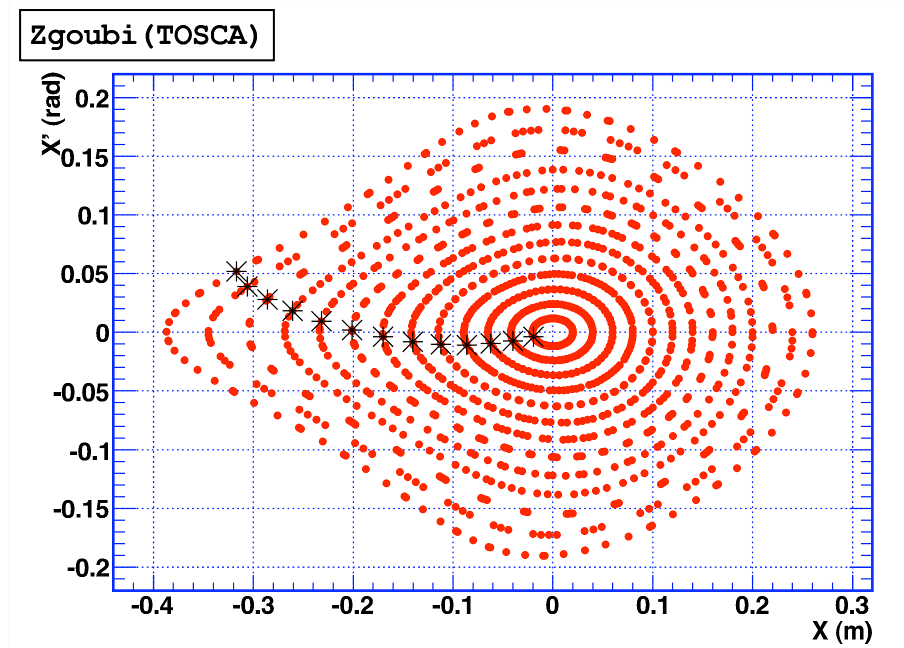


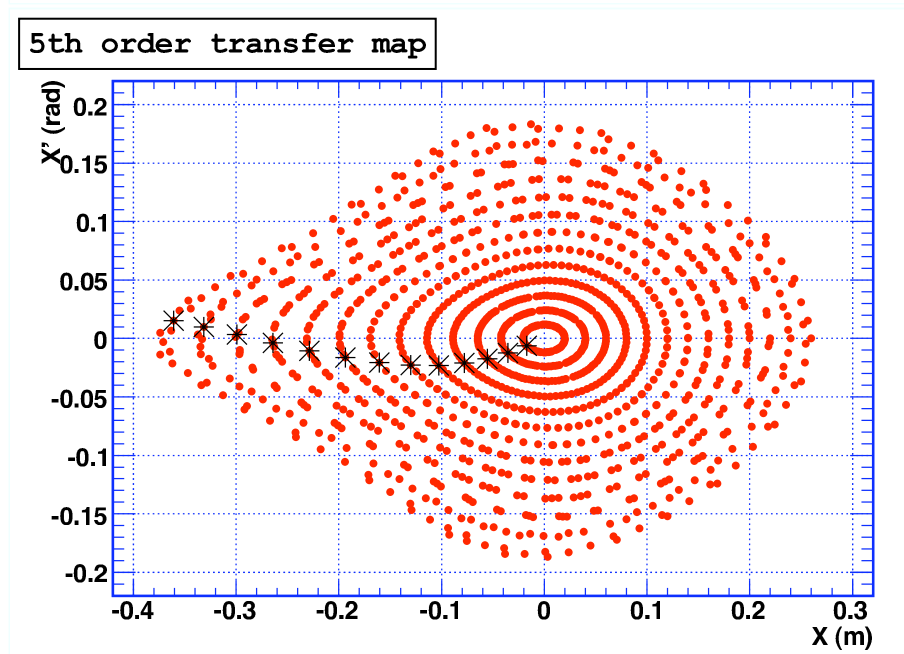
Position detector

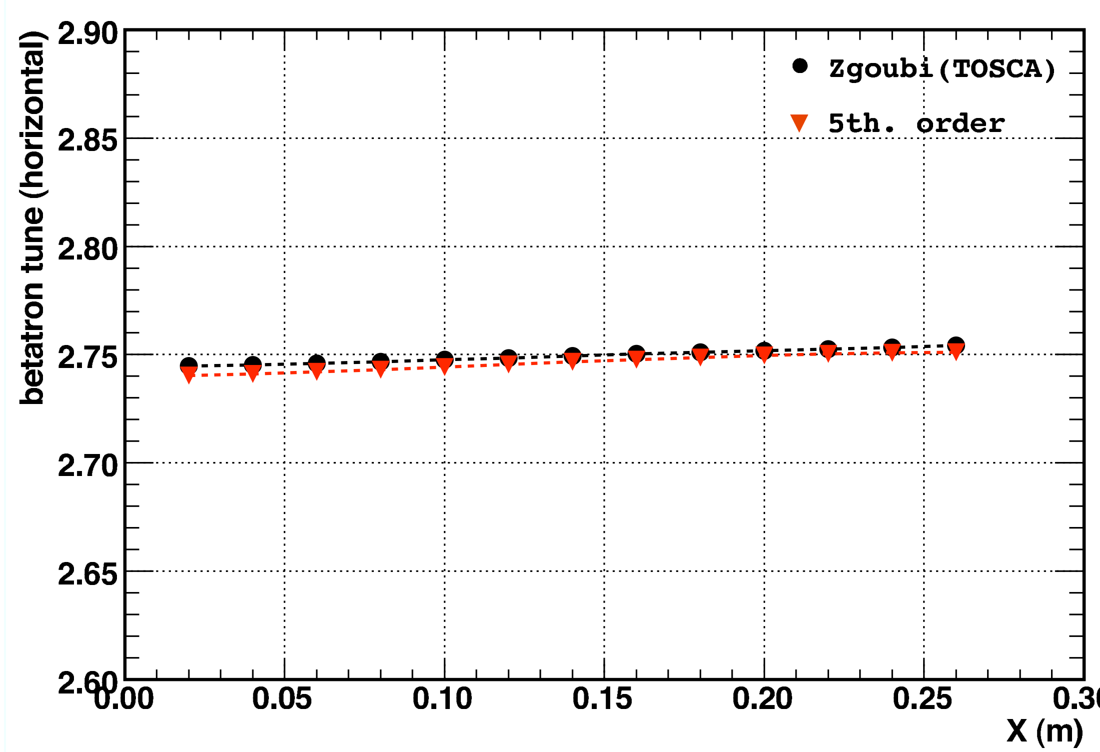
Injector collimator

Transfer Matrix Method with Truncated Taylor Expansion (by Y. Kuriyama)

- The transfer matrix (from one cell boundary to the other) has been experimentally determined by using alpha particles (for different positions, emission angles and energies).
- The transfer matrix is represented by a truncated Taylor expansion of the 5th order.
- By using the transfer matrix thus obtained, the closed orbits and betatron tunes were calculated. They are compared with tracking simulations.

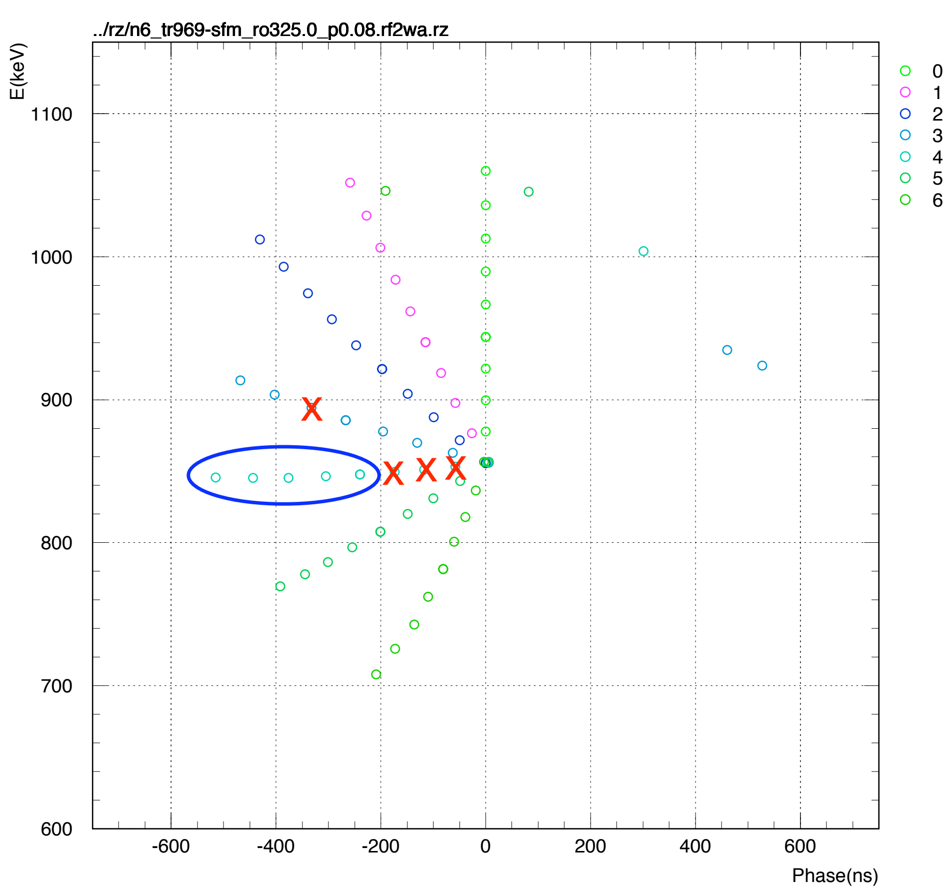


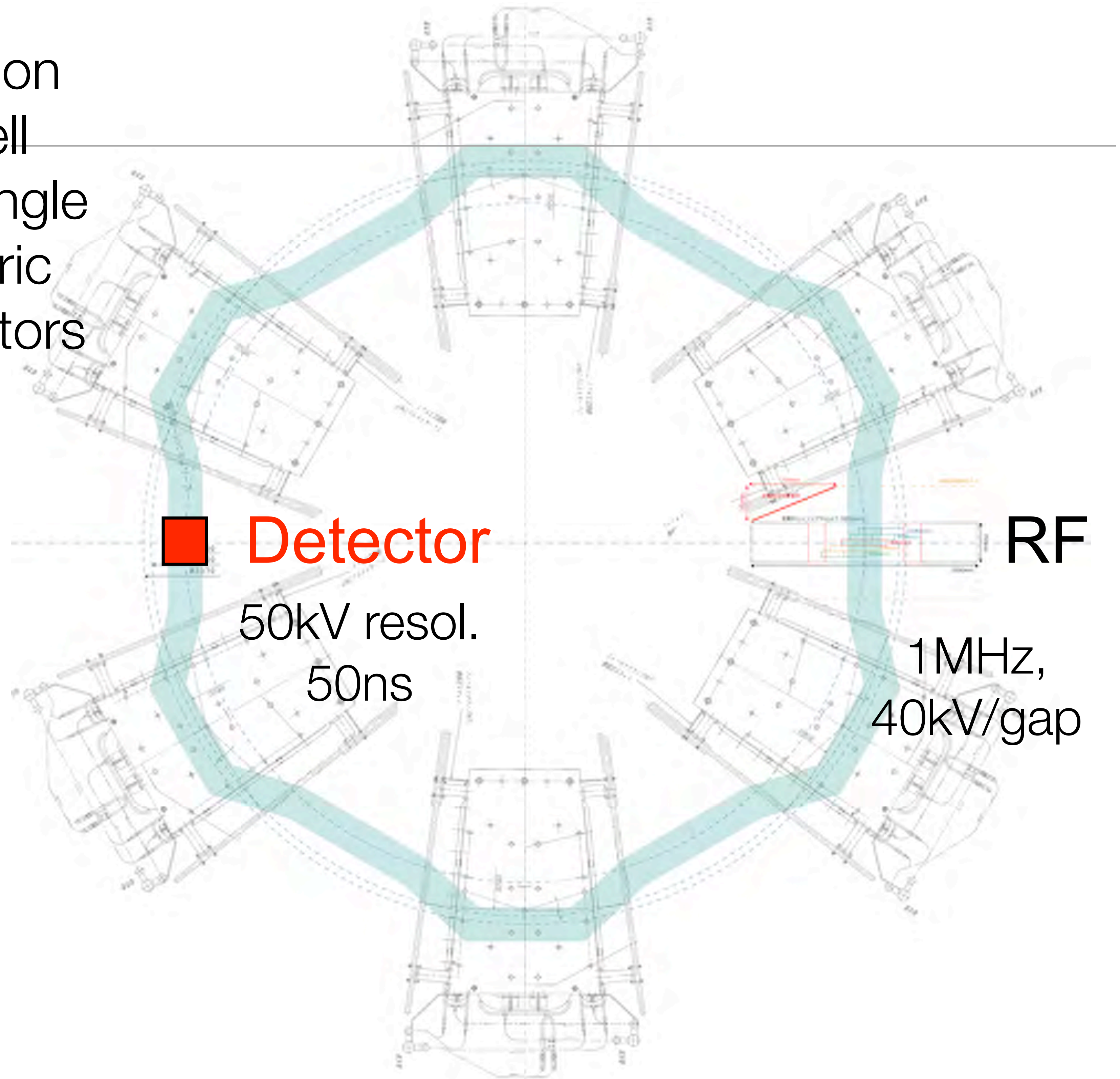




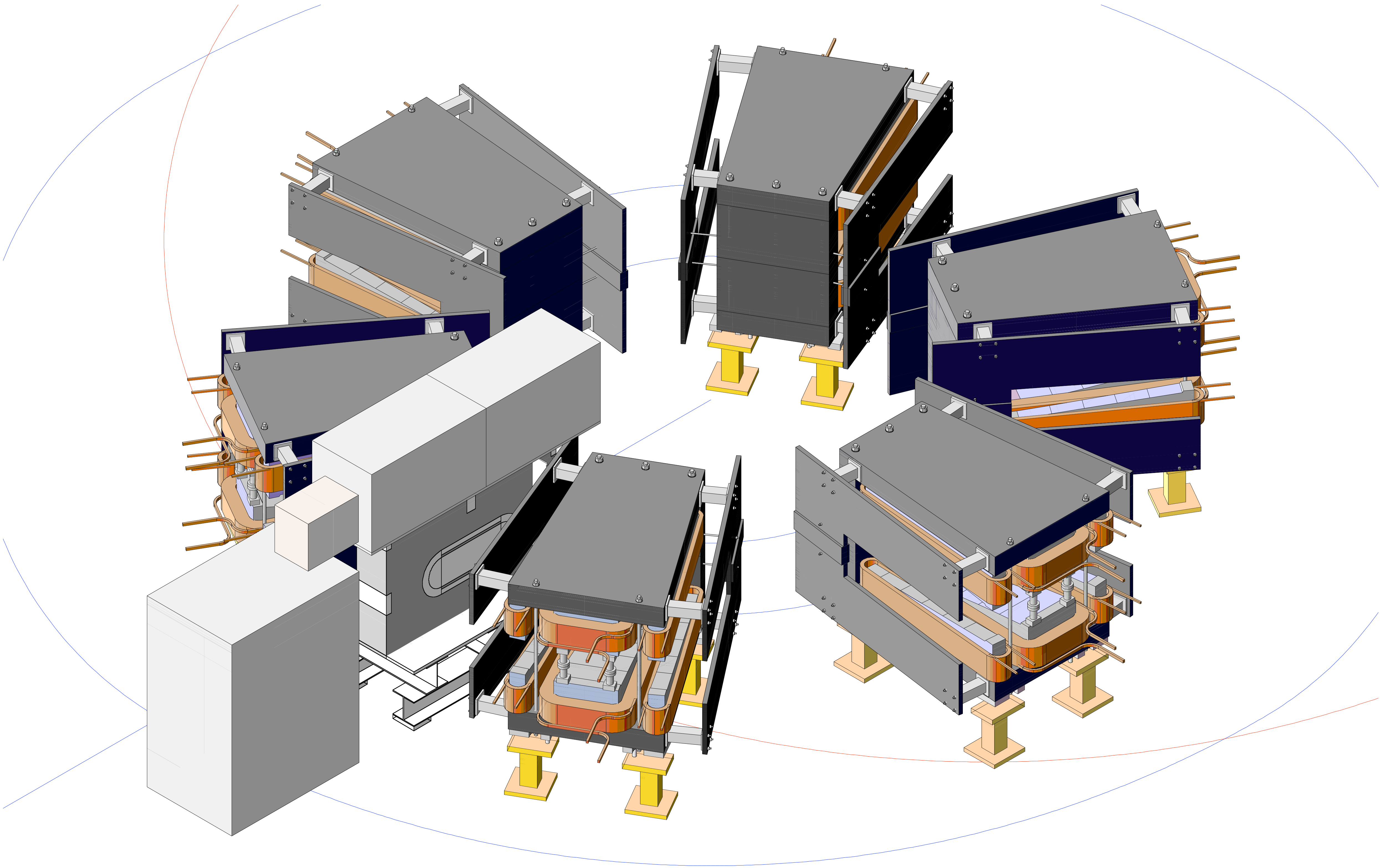
Alpha Particle Tracking with 6 Magnet Cells

Purpose: study demonstration of phase rotation with a 6-cell ring with one RF cavity by single alpha particle tracking. Electric static kicker plus SSD detectors are needed.





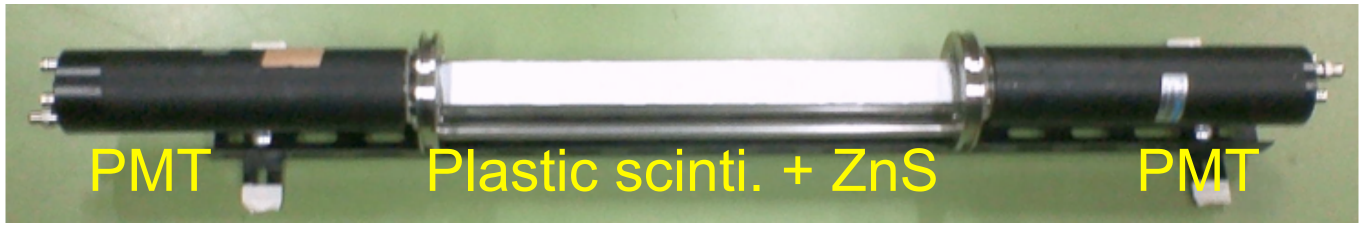
PRISM-FFAG 6 Cell Ring Layout

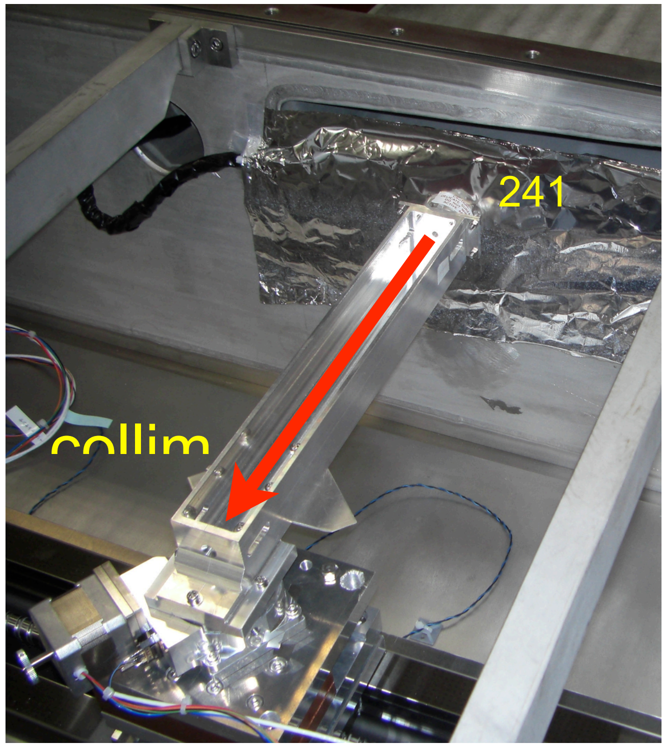


6-Cell PRISM FFAG Magnets at Osaka

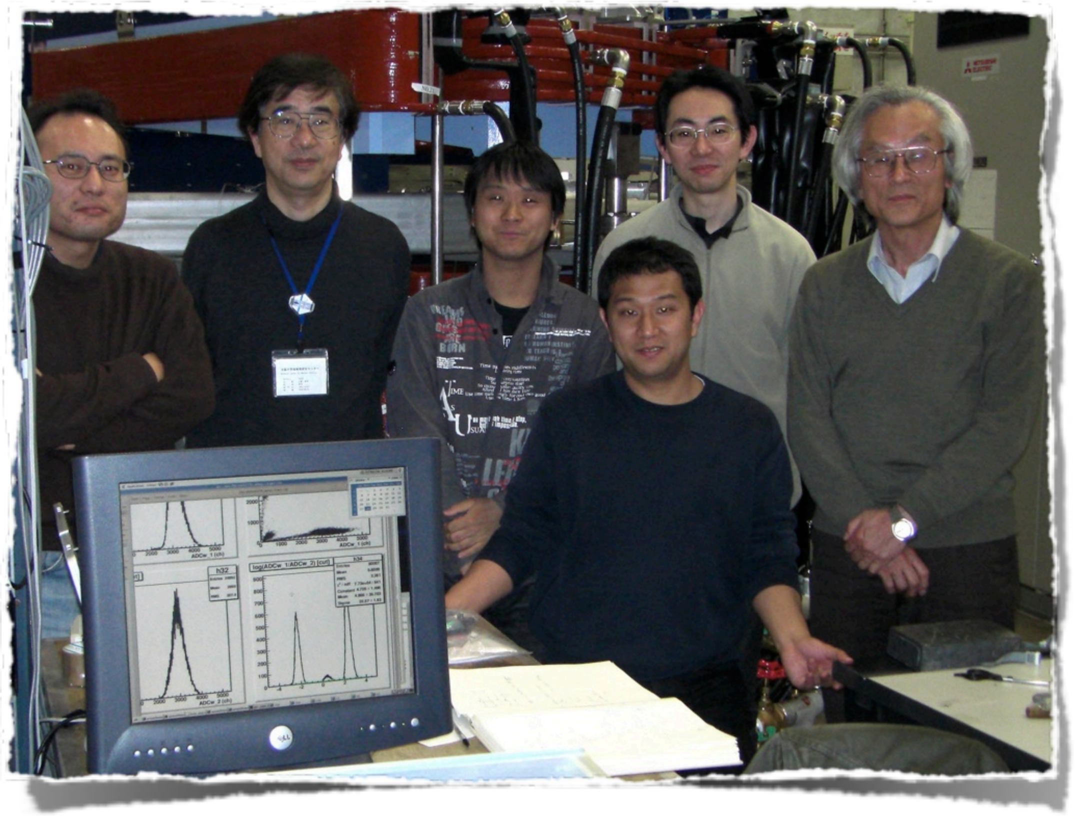
Studies of the 6-cell PRISM FFAG Ring

- Alpha particles from radioactive sources (Am) are used.
- Plastic scintillators and SSD are used for detection.



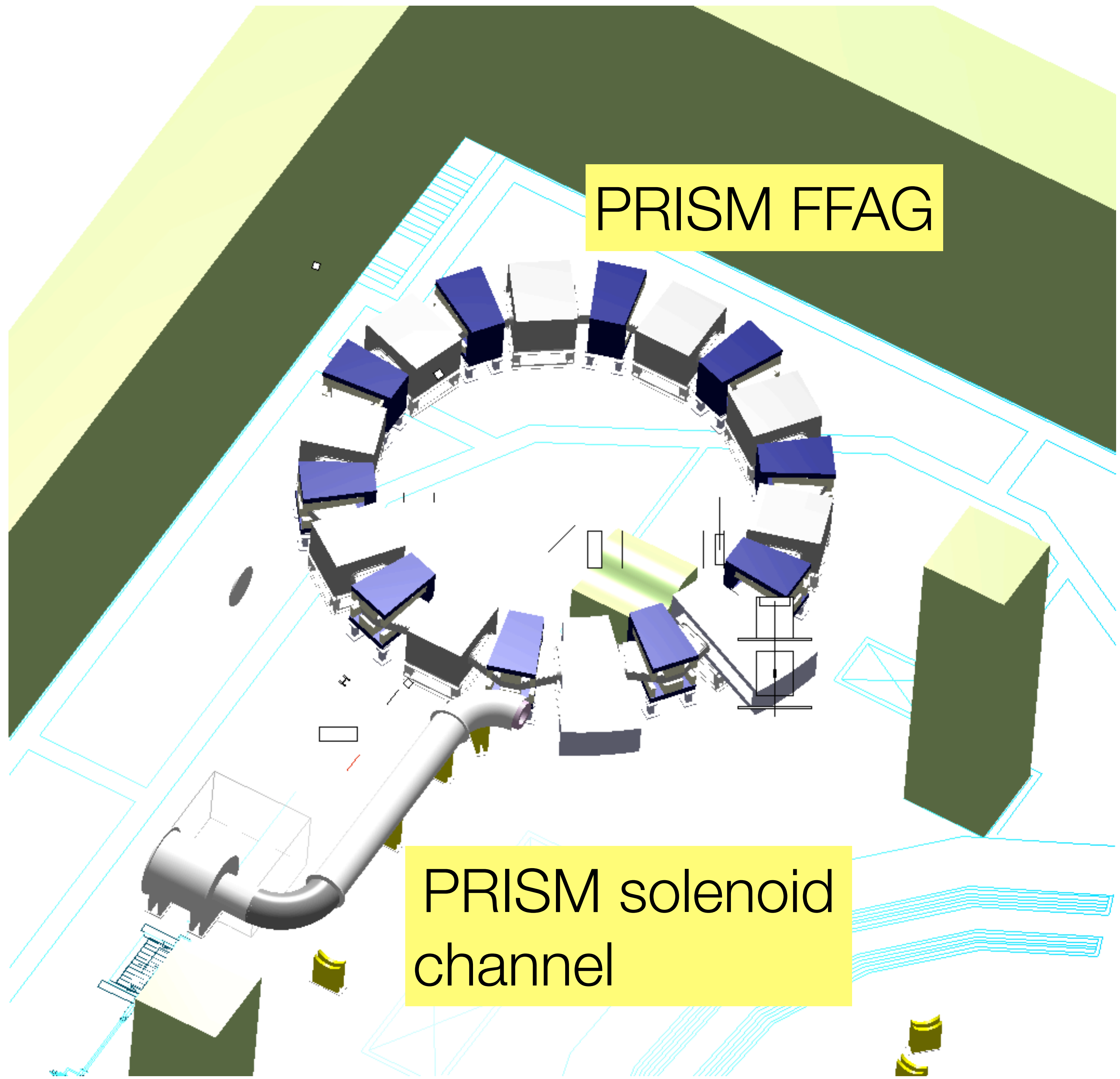


- Alpha particles that revolve in the ring were observed.
- The closed orbits were determined.
- Betatron tunes are being studied.
- Tests with RF is being prepared.

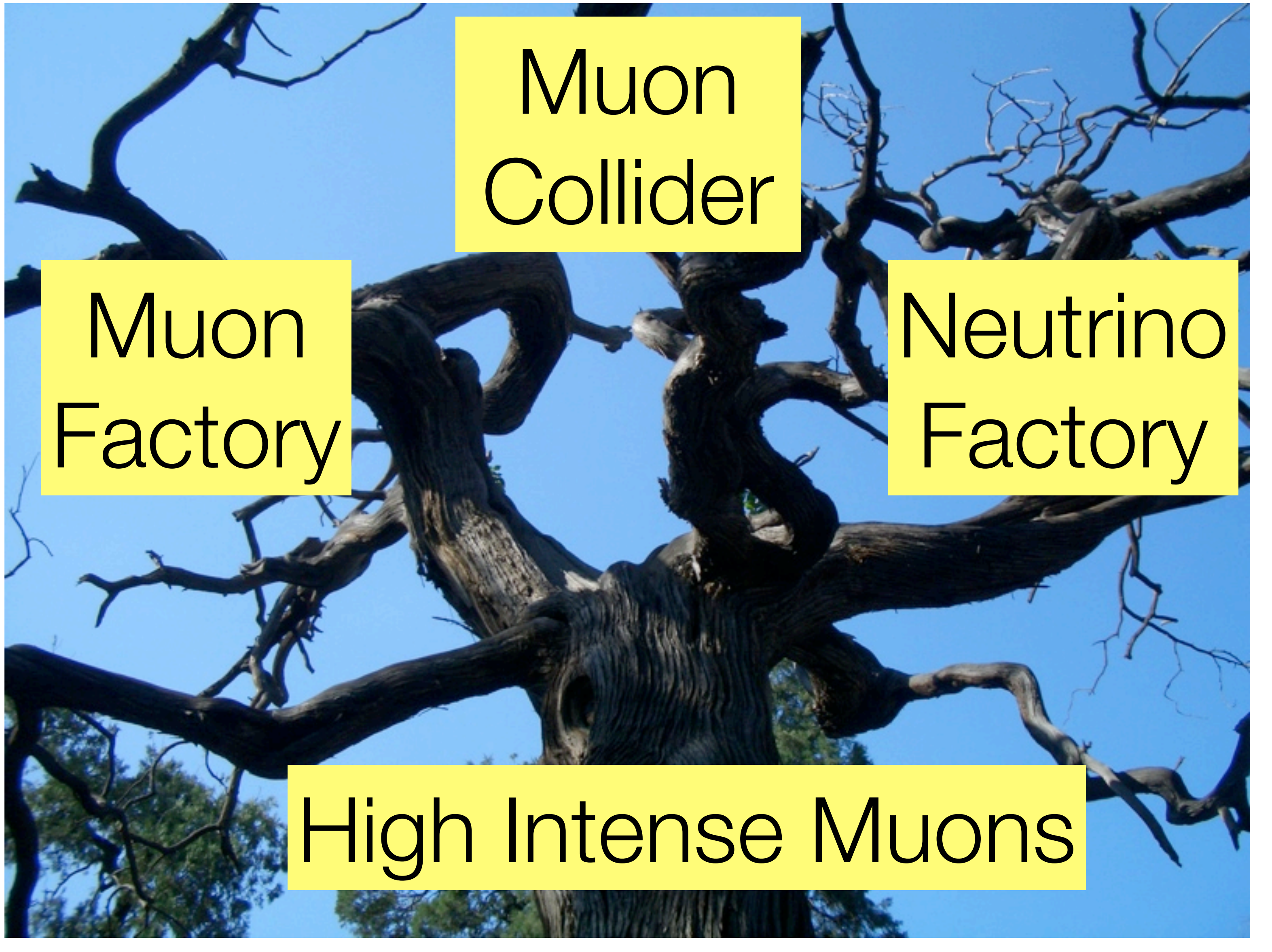


Muon Source at Osaka University, RCNP

- Research Center for Nuclear Physics (RCNP), Osaka University has a cyclotron of 420 MeV. The energy is above pion threshold.
- A plan is to install the PRISM at RCNP, and inject muons.
  - Test of PRISM FFAG with muons.
  - PRISM front provides high intensity muons.
- Wait for funding in future



Future


Muon
Collider
Muon
Factory
Neutrino
Factory
High Intense Muons

Synergy in Roadmap - Staging Approach

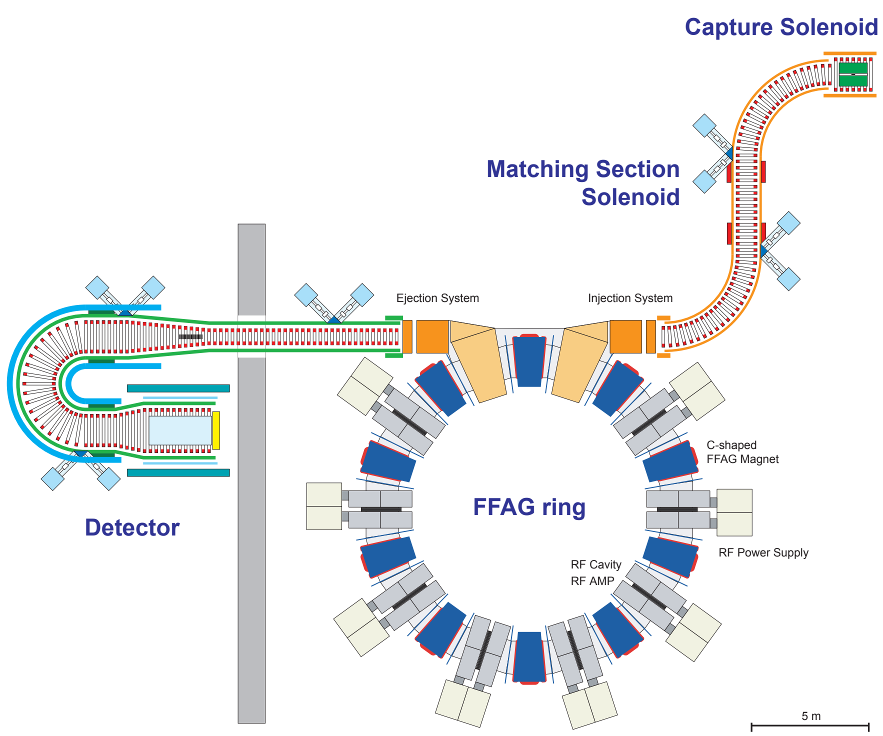
Based on common technologies

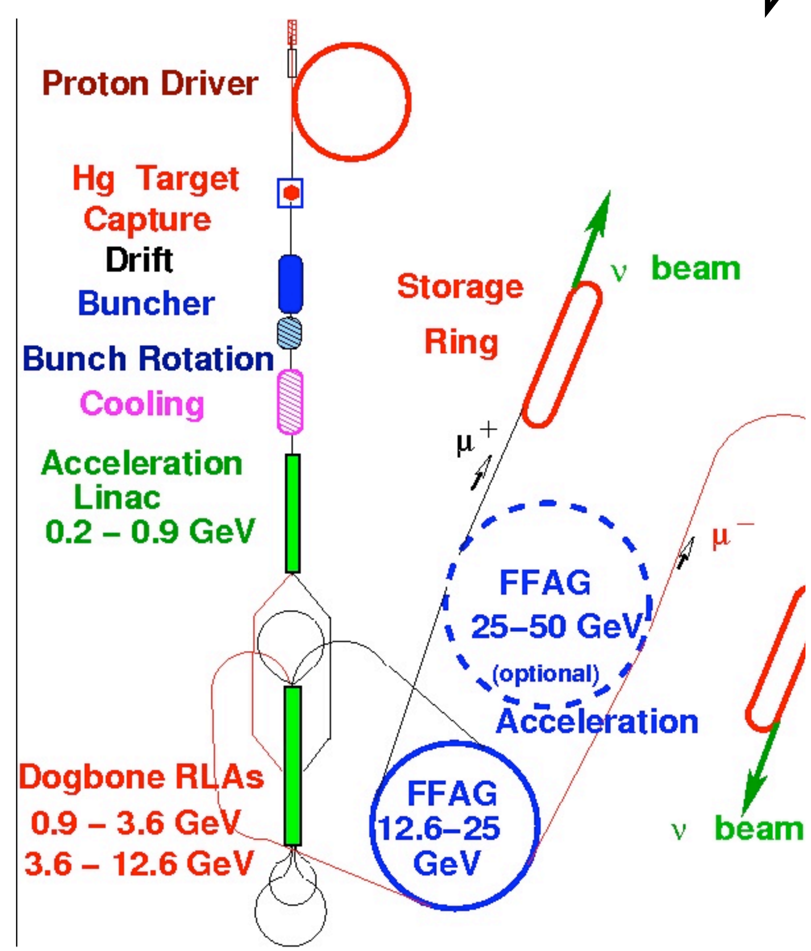
Muon Factory

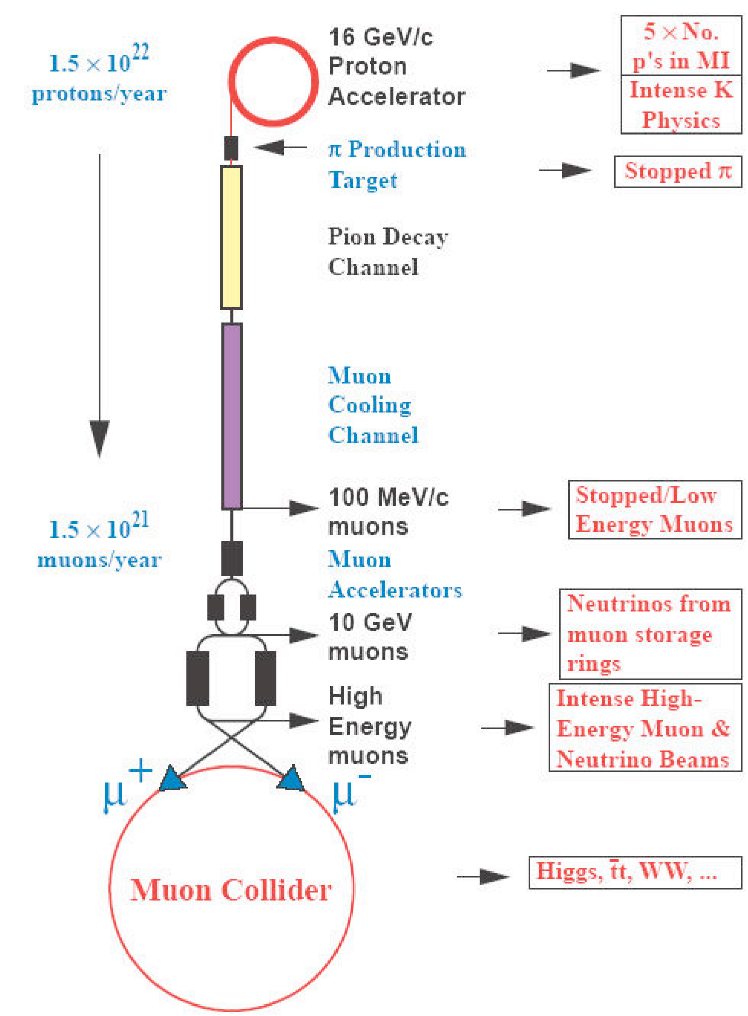
muon LFV,
muon g-2,
muon EDM
muon application

Neutrino Factory

Energy frontier
Muon Collider
- 1.5~4 TeV







Summary

- Muon particle physics is important to discover new physics phenomena, in particular lepton flavor violation in muons.
- To carry out muon particle physics, a highly intense muon source of 10^{11}-10^{12}/sec would be needed.
  - Thanks to neutrino-factory and muon collider R&D, a study of highly intense muon source can be developed.
- The Osaka University group is developing a new highly intense muon source, called PRISM.
- As the first step, a proposal on the COMET experiment, which does not have a muon storage ring, has been submitted to J-PARC MR.
- The muon storage ring R&D (based on FFAG ring) is being done at Osaka University, Research Center for Nuclear Physics (RCNP).
- A muon source at RCNP with PRISM front (~10^8) is also planned.

End of My Slides