PRISM/PRIME

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PRISM project

PRISM

Phase Rotated Intense Slow Muon source

secondary muon beam channel with

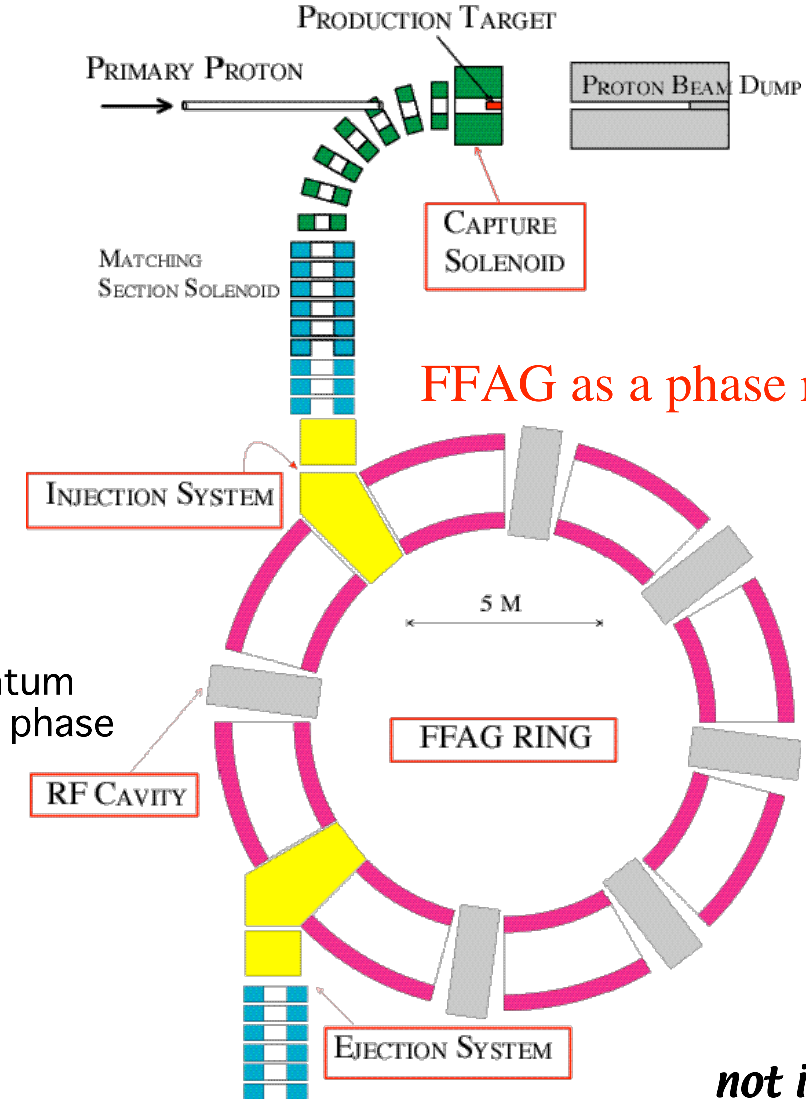
- high intensity
  - Superconducting Solenoid Magnet
- narrow energy spread
- High purity
  - Phase rotation

dedicated for the stopped muon experiments.

- intensity :
  10^{11}-10^{12}□$^{\pm}$/sec
- muon kinetic energy :
  20 MeV (=68 MeV/c)
  - □ range = about 3 g
- kinetic energy spread :
  ±0.5-1.0 MeV
  - □ ±a few 100 mg range width
- beam repetition :
  about 100Hz

PRISM layout

- Pion capture section
- Decay section
- Phase rotation section



FFAG advantages:

- synchrotron oscillation
  - need to do phase rotation
- large momentum acceptance
  - necessary to accept large momentum distribution at the beginning to do phase rotation
- large transverse acceptance
  - muon beam is broad in space

Ring advantages:

- reduction of # of rf cavities
- reduction of rf power consumption
- compact

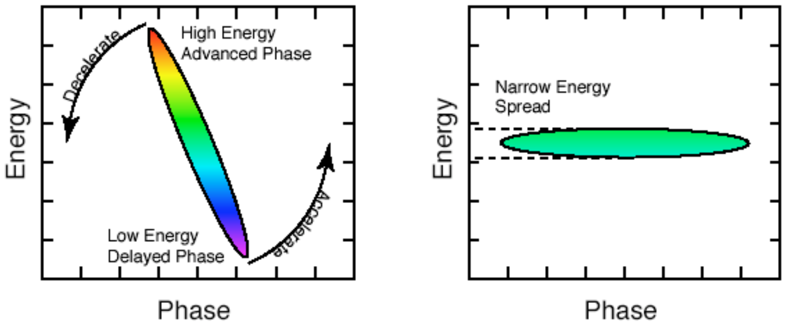
not in scale

PRISM Phase-Rotation Intense Slow Muon
High-Intensity Low-Energy μ Source

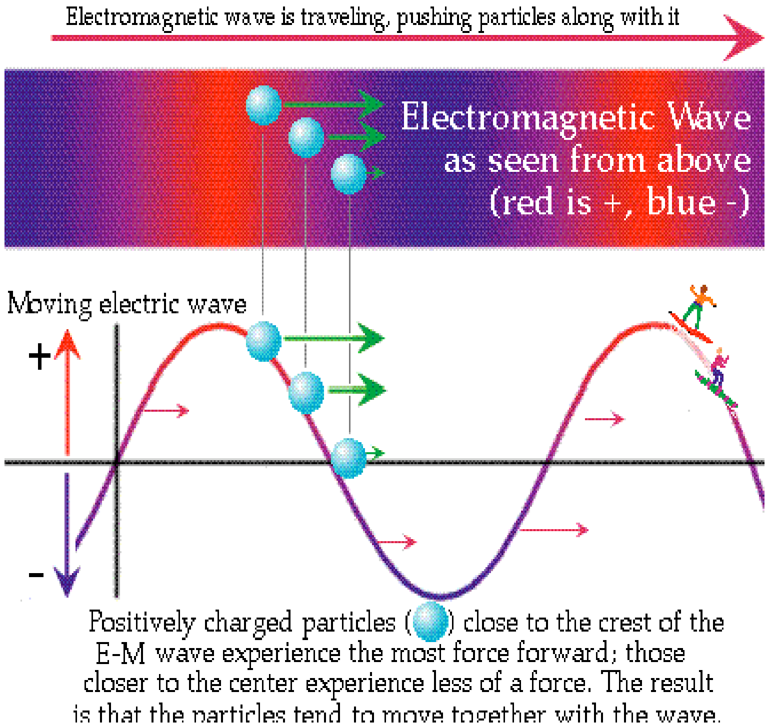
Phase Rotation

method to achieve a beam of narrow energy spread

- Phase Rotation = decelerate particles with high energy and accelerate particle with low energy by high-field RF

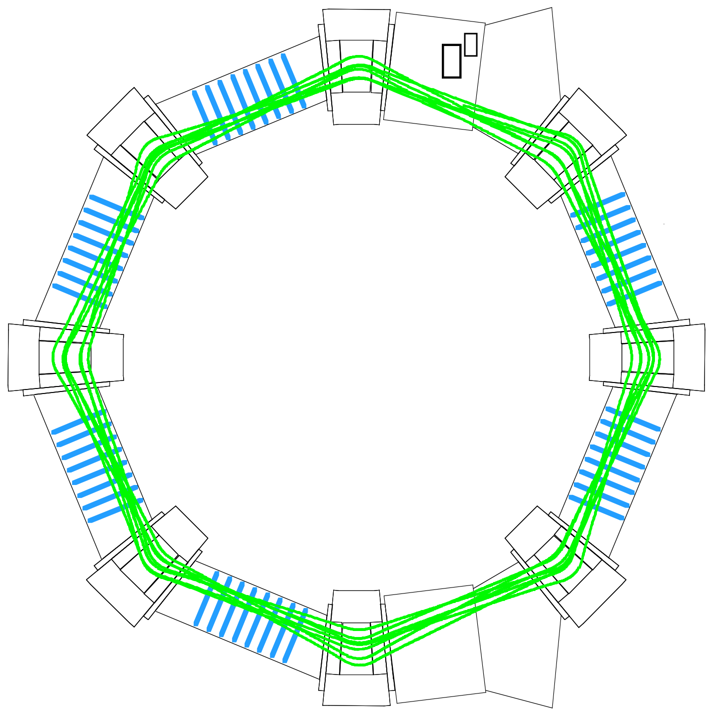


- A narrow pulse structure (<1 nsec) of proton beam is needed to ensure that high-energy particles come early and low-energy one come late.



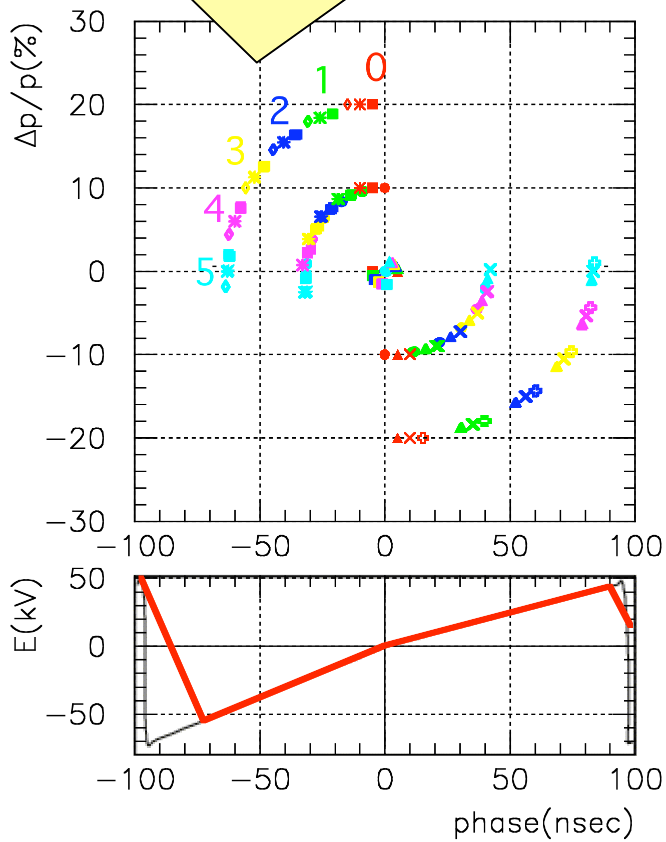
Simulation studies of phase rotator

- GEANT3.21 simulation
  - FFAG Acceptance, Phase rotation
  - Muon yield, background rate



RF : 5MHz, 250kV/m

ΔE/E = 20MeV+4%-5%

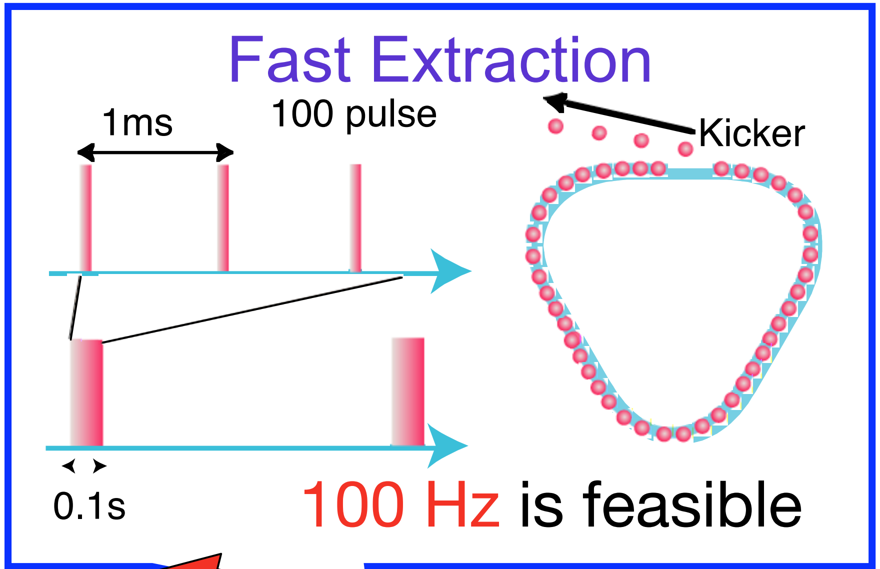


Pulsed Proton Beam Facility at J-PARC

50GeV-PS at J-PARC

- High intensity 0.75 MW
  - 10^{14}proton/sec
  - Upgradable to 4×10^{14}proton/sec
- A narrow bunched :

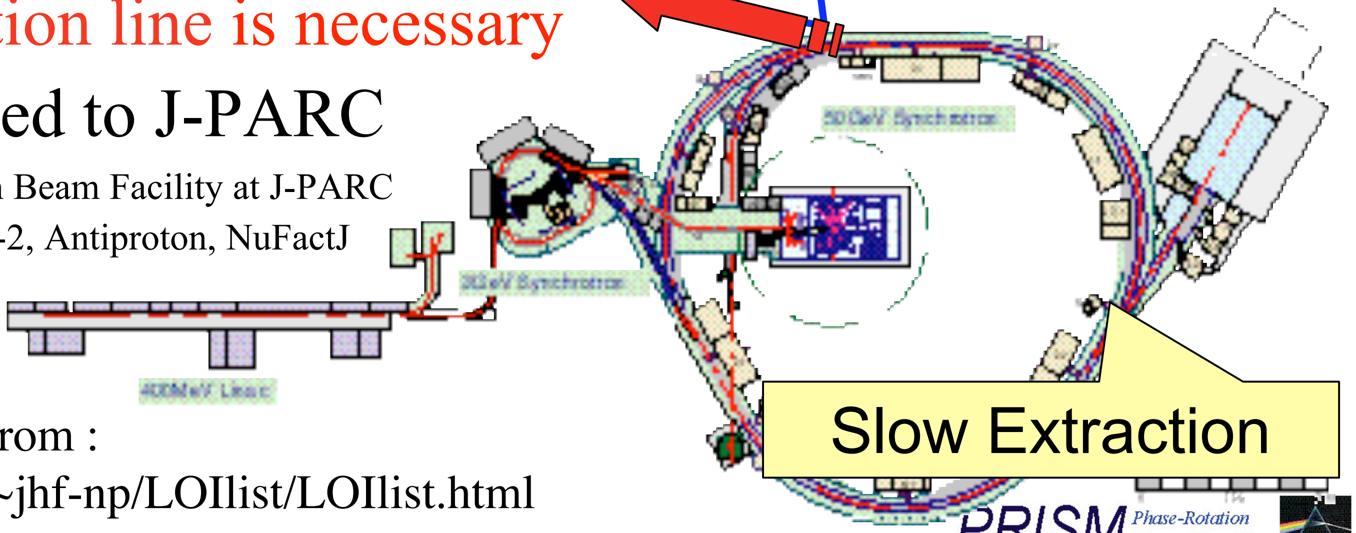
  for phase rotation



New Fast extraction line is necessary

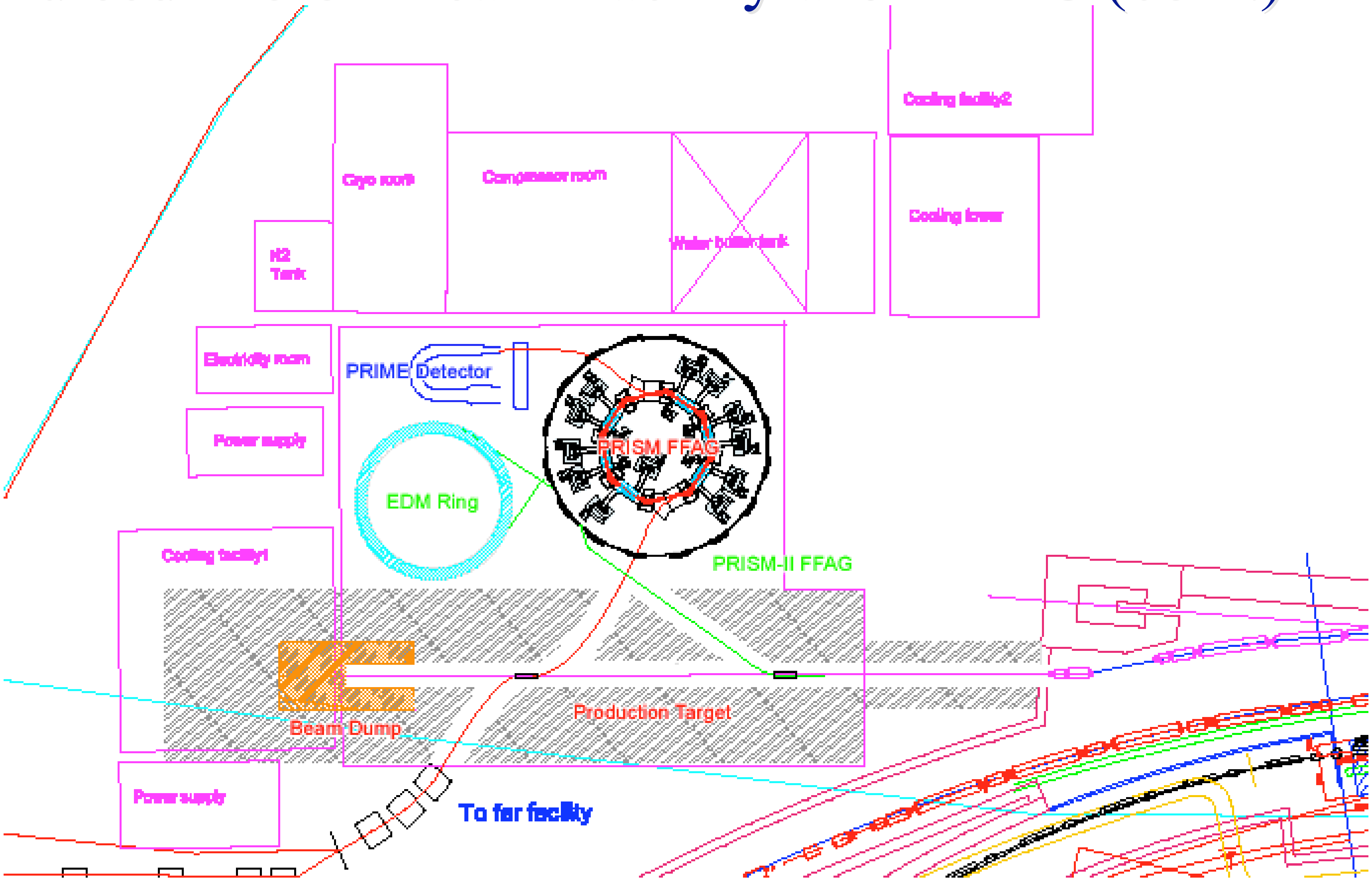
LOI was submitted to J-PARC

Request for A Pulsed Proton Beam Facility at J-PARC
PRISM/PRIME, EDM ,g-2, Antiproton, NuFactJ



LOIs are available from :
http://psux1.kek.jp/~jhf-np/LOIlist/LOIlist.html

Pulsed Proton Beam Facility at J-PARC (cont.)



PRISM R&D related talks

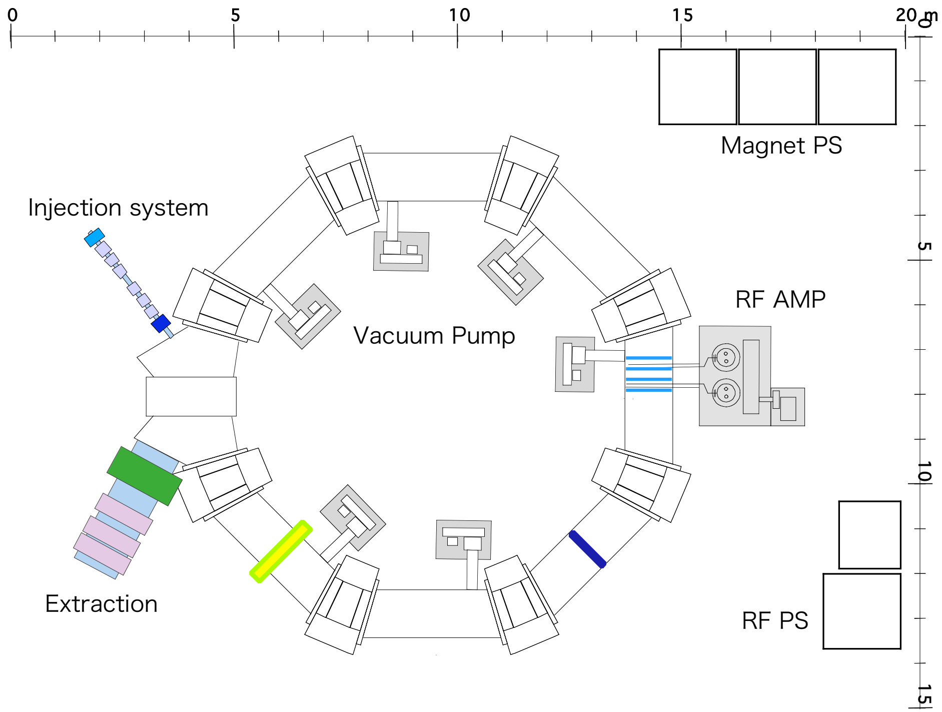
- 150MeV FFAG
  - 6 June 17:20 (WG3) J.Nakano
- PRISM target
  - 7 June 14:45 (WG2&3 joint) K.Yoshimura
- Pion production solenoid heat load mock-up test
  - 7 June 16:30 (WG2&3 joint) H.Ohnishi
- PRISM/PRISM-II
  - 7 June 11:30 (WG2&3 joint) M.Aoki
- FFAG construction for PRISM
  - 10 June 15:00 (WG3) A.Sato
- Normal and superconducting magnets for FFAG
  - 10 June 15:20 (WG3) M.Yoshimoto

Construction of the PRISM-FFAG

A budget for the PRISM-FFAG has been approved !
FY2003-FY2007
We will construct a full scale PRISM-FFAG

- To establish by proof
  - Phase rotation
  - Muon acceleration
  - Muon ionization cooling

- R&D components
  - RF with high
    - 5MHz, 250kV/m
  - Large acceptance Magnet
    - muiti coil

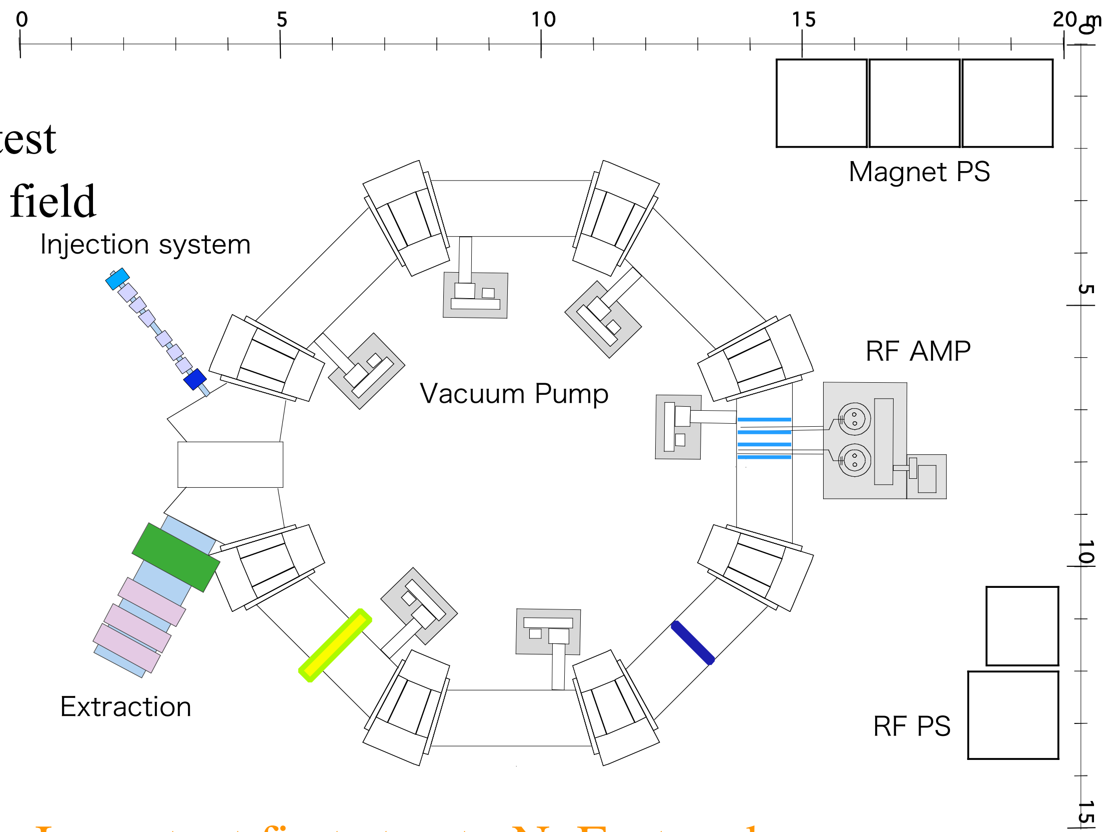


FFAG construction for PRISM :10th June (Tue.) 15:00 (WG3) A.Sato

PRISM Phase-Rotation Intense Slow Muon
High-Intensity Low-Energy μ Source

Schedule of the PRISM-FFAG construction

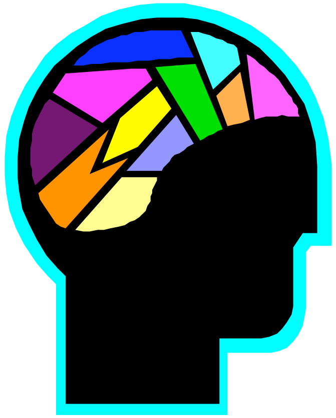
- FY2003
  - Lattice design, Magnet design
  - RF R&D
- FY2004
  - RFx1gap construction & test
  - Magnetx1 construction & field meas.
- FY2005
  - RFx4gap tuning
  - Magnetx7 construction
  - FFAG-ring construction
- FY2006
  - Commissioning
  - Phase rotation
- FY2007
  - Muon acceleration
  - Ionization cooling



Important first step to NuFact and muon collider

Application List with PRISM

- Particle, Nuclear Physics
  - Lepton flavor violation
    - **□e conversion**, **PRIME**
    - □+ □□ conversion
  - □ life time
  - □ edm
  - g-2
- Material Science
  - Muonic X-ray, □ sR
- Archeology
- Life science
  - Living cell
  - Brain scan



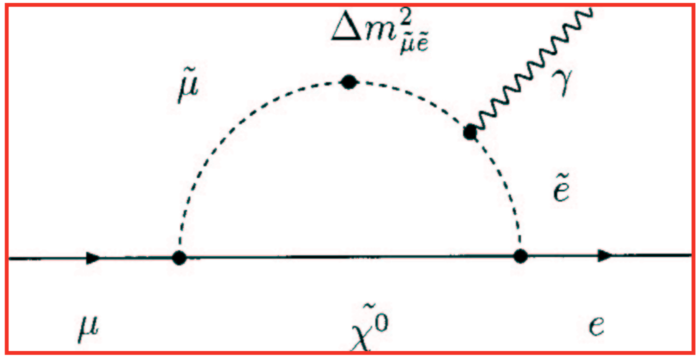
PRIME

PRISM Mu E conversion

Lepton Flavor Violation (LFV)

- LFV physics attracts a lot attention
  - Neutrino mass
  - g-2 new result
- LFV process in charged sector
  - Probes beyond standard model
  - flavor mixing (Slepton)

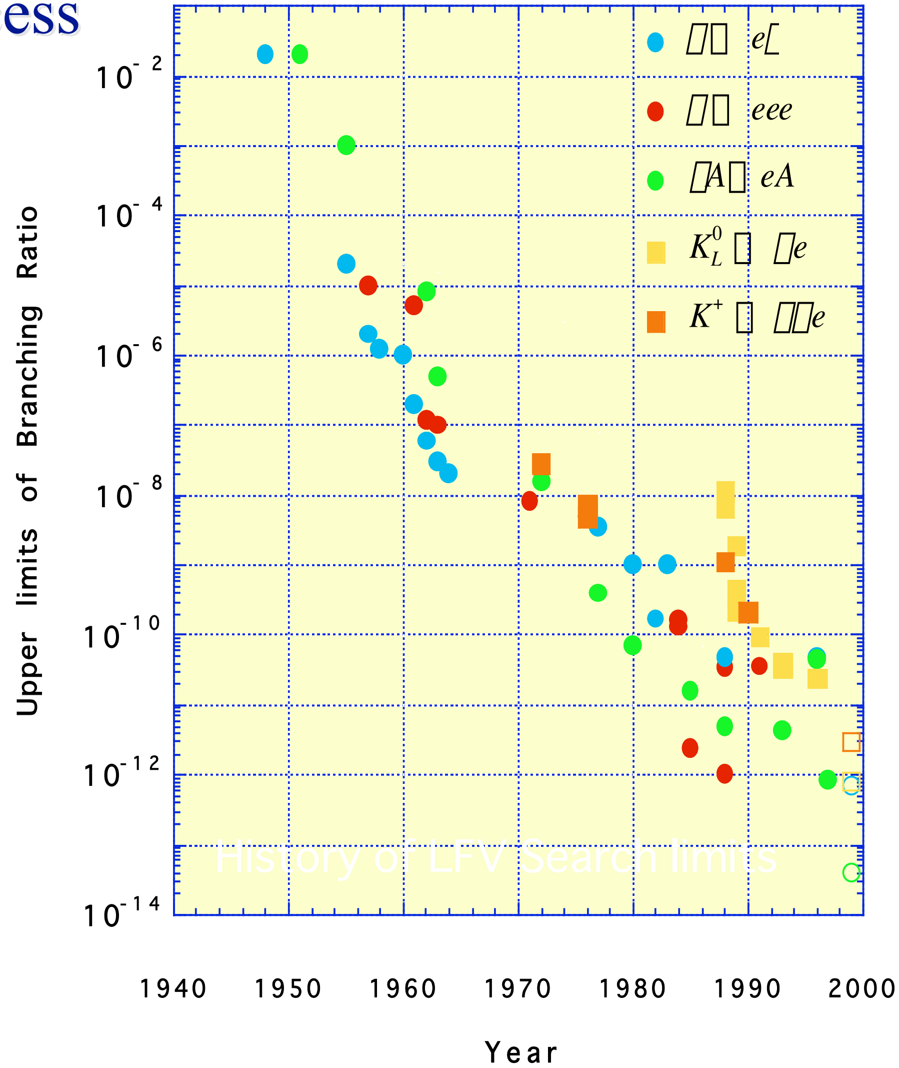
sensitive to slepton mixing



$$\begin{pmatrix} m^2_{\tilde e\tilde e} & \Delta m^2_{\tilde e\tilde\mu} & \Delta m^2_{\tilde e\tilde\tau} \\ \Delta m^2_{\tilde\mu\tilde e} & m^2_{\tilde\mu\tilde\mu} & \Delta m^2_{\tilde\mu\tilde\tau} \\ \Delta m^2_{\tilde\tau\tilde e} & \Delta m^2_{\tilde\tau\tilde\mu} & m^2_{\tilde\tau\tilde\tau} \end{pmatrix}$$

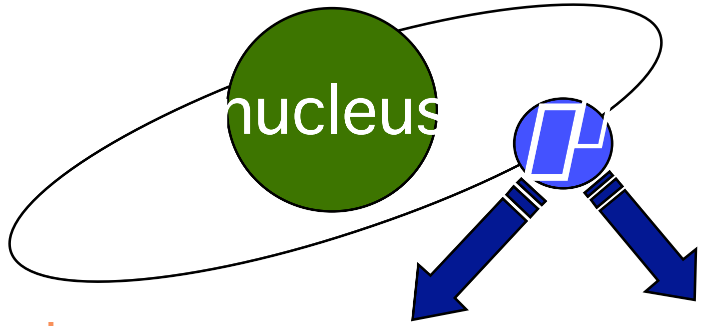
Search for
the Lepton Flavor Violating Process

- No evidence so far for charged lepton
- Limits have been improved steadily
  - two orders of magnitude per decade
- Sensitivities are superb in muon systems
- Getting harder
  - To obtain/handle more intense muon



□□ *e* conversion in a Muonic Atom

- muonic atom (1s state)



nuclear muon capture

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

muon decay in orbit

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

- neutrinoless muon nuclear capture (= □-*e* conversion)

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

coherent process

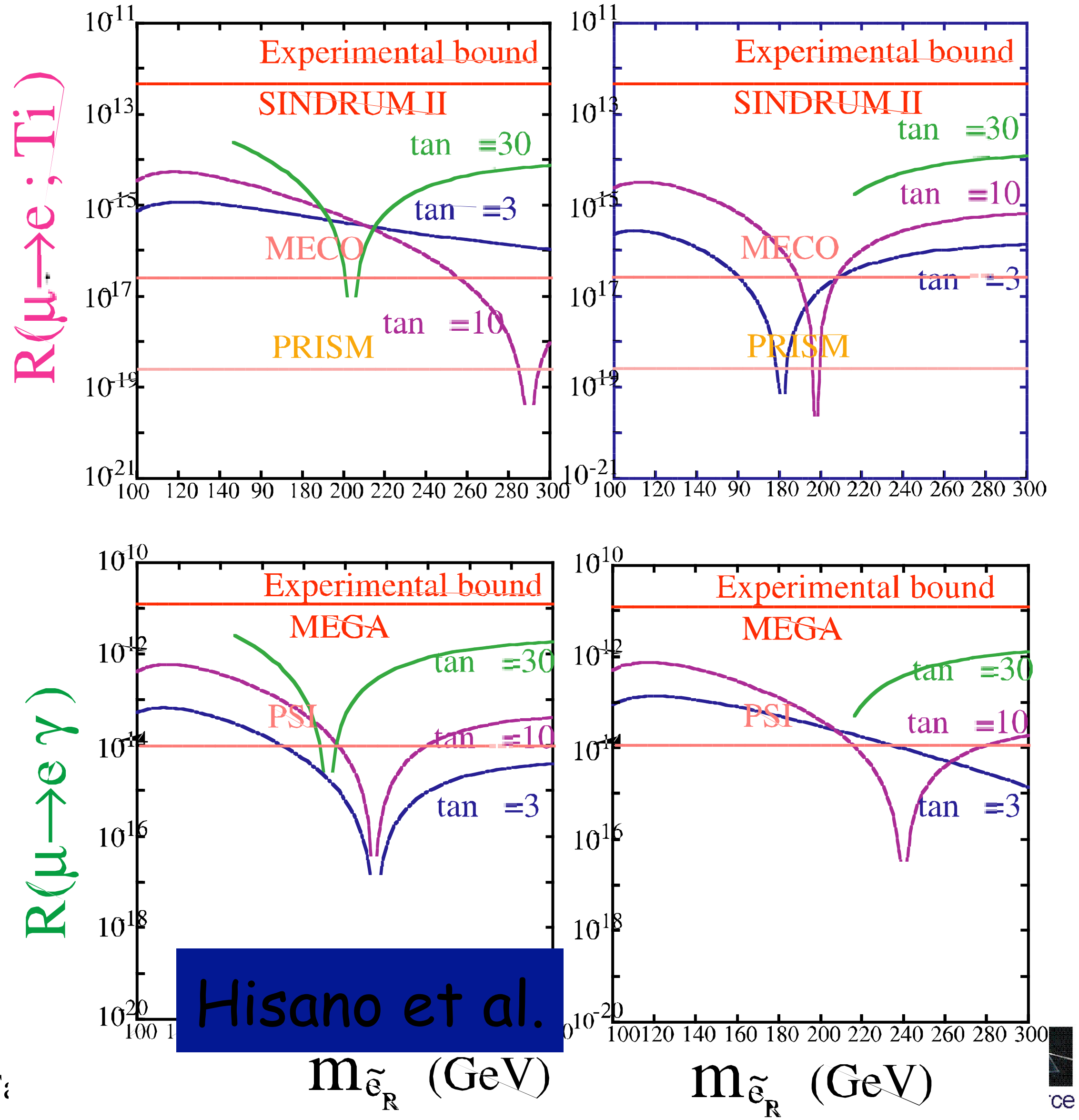
$$B(\mu^- N \to e^- N) = \frac{\Gamma(\mu^- N \to e^- N)}{\Gamma(\mu^- N \to \nu N')}$$

lepton flavors
changes by one unit.

LFV in SUSY GUT

- MECO@BNL,
- MEG@PSI
  - Equivalent sensitivity
- Future experiment

will cover most of parameter space with PRISM

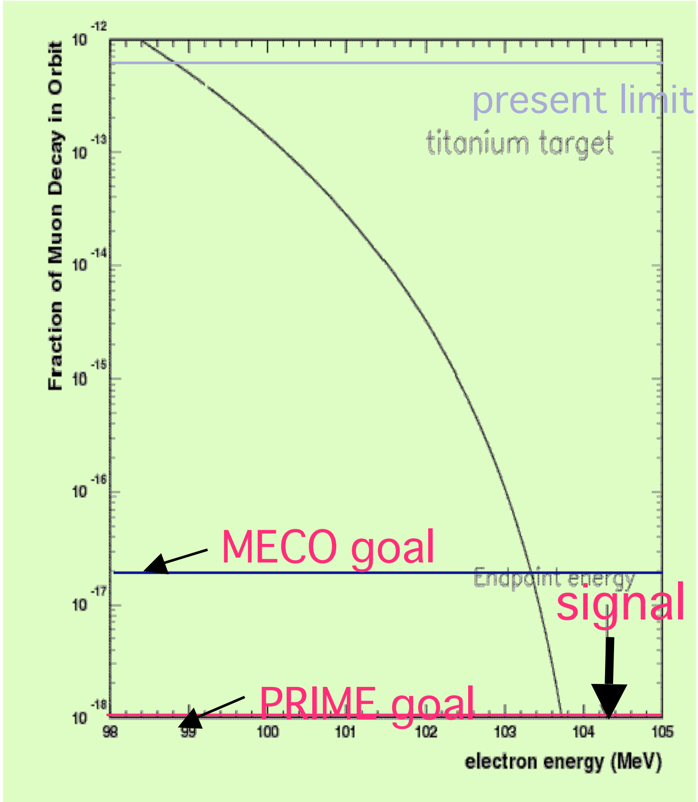


Expected background source - Muon Decay in Orbit -

Muon decay in orbit ($\mu\,(E_{\mu e}-E_e)^5$)

- $E_e > 103.9$ MeV
- $\Delta E_e = 350$ keV
- $N_{BG} \sim 0.05$ @ $R=10^{-18}$

Background	Rate	comment
Muon decay in orbit	0.05	energy reso 350keV(FWHM)
Radiative muon capture	0.01	end point energy for Ti=89.7MeV
Radiative pion capture	0.03	long flight length in FFAG, 2 kicker
Pion decay in flight	0.008	long flight length in FFAG, 2 kicker
Beam electron	negligible	kinematically not allowed
Muon decay in flight	negligible	kinematically not allowed
Antiproton	negligible	absorber at FFAG entrance
Cosmic-ray	< 10^-7 events	low duty factor
Total	0.10	



- reduce the detector hit rate

  Instantaneous rate : 10^{10}muon/pulse

- precise measurement of the electron energy

PRISM Phase-Rotation Intense Slow Muon
High-Intensity Low-Energy μ Source

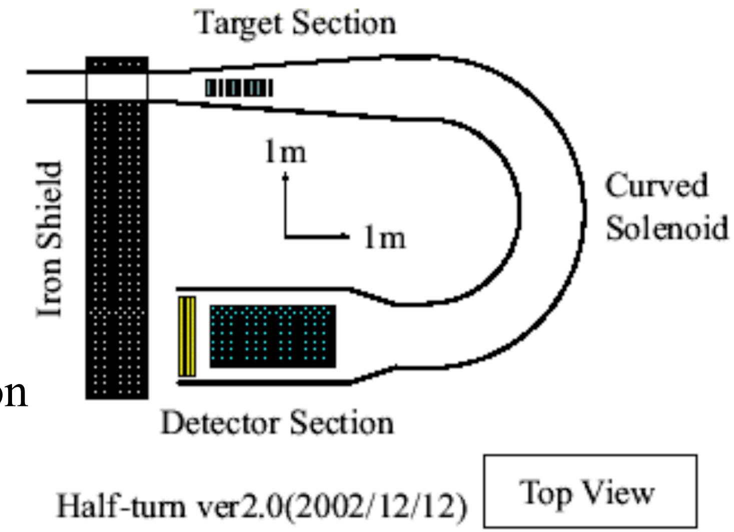
Curved Solenoid Spectrometer

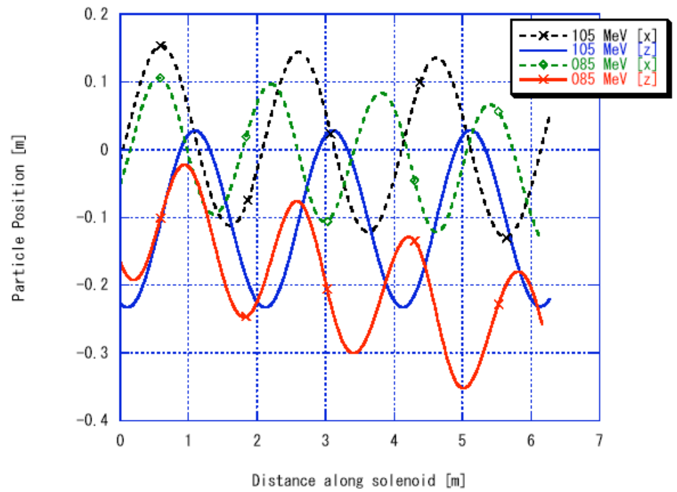
select a charged particle with a desired mom.

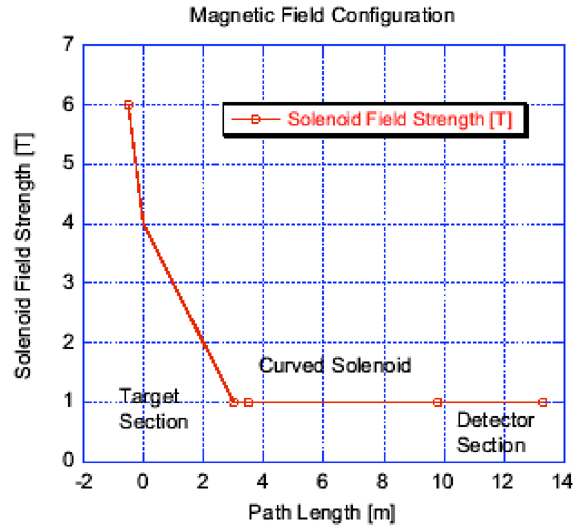
- Extract signal region only
  - Curvature drift

$$D = 1./(0.3B) \square s/R \square \frac{(p_s^2 + 0.5 p_t^2)}{p_s}$$

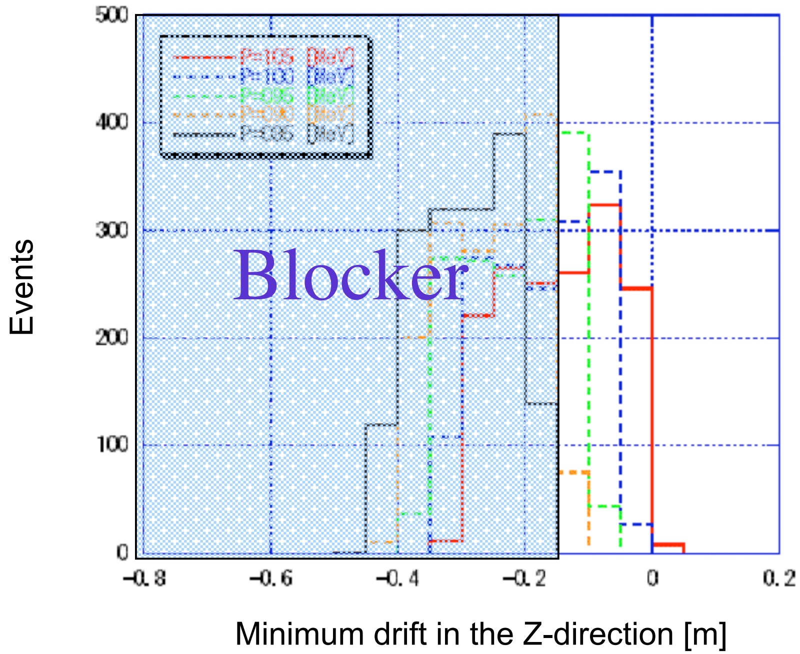
  - impose auxiliary field along the drift direction
  - Block unwanted particles
    - Positive
    - DIO (P<90 GeV/c)
- Reduce background and single rate

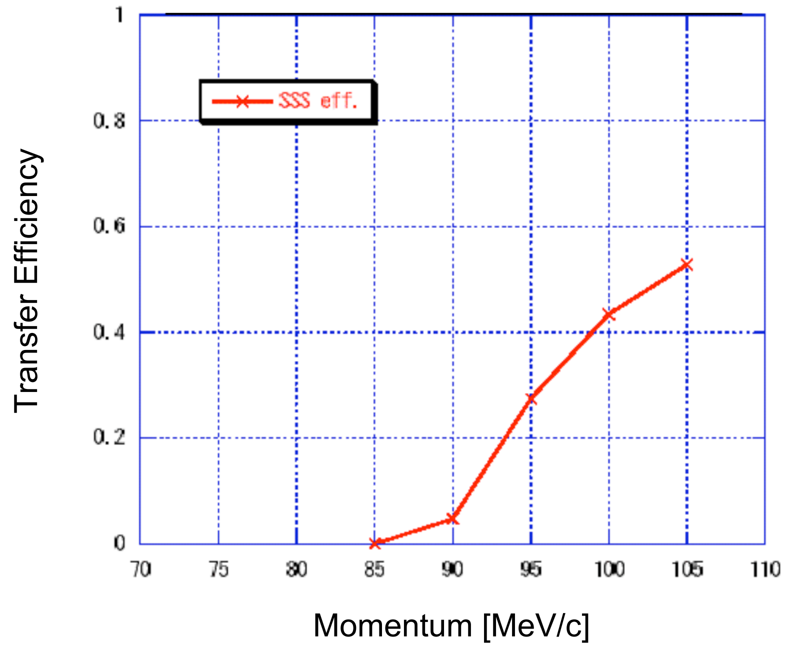






Curved Solenoid Spectrometer
- Transport Efficiency -





- 53% of signal events can be transported successfully
- Background rate low

quite efficient !

Muon yield

- Estimated by using MC simulation.
- depends on the technology choice. ; target, field magnitude ,,,
- Not fully optimized yet.

Target material	Capture field	Transport field	Muon yield per 10^{14} protons	Muon yield per 4×10^{14} protons
Graphite	16 T	4 T	4.8×10^{10}	19×10^{10}
	16 T	2 T	3.6×10^{10}	14×10^{10}
	12 T	4 T	3.6×10^{10}	14×10^{10}
	12 T	2 T	3.0×10^{10}	12×10^{10}
	8 T	4 T	3.0×10^{10}	12×10^{10}
	8 T	2 T	2.4×10^{10}	9.6×10^{10}
	6 T	4 T	1.8×10^{10}	7.2×10^{10}
	6 T	2 T	1.8×10^{10}	7.2×10^{10}
Tungsten	16 T	4 T	13×10^{10}	50×10^{10}
	16 T	2 T	11×10^{10}	46×10^{10}
	12 T	4 T	9.6×10^{10}	38×10^{10}
	12 T	2 T	9.0×10^{10}	36×10^{10}
	8 T	4 T	6.0×10^{10}	24×10^{10}
	8 T	2 T	7.2×10^{10}	29×10^{10}
	6 T	4 T	4.2×10^{10}	17×10^{10}
	6 T	2 T	4.8×10^{10}	19×10^{10}

Target length
3 interaction length
FFAG acceptance
H:20000□mm mrad
V:3000□ mm mrad
$□_{dispersion}$ = 100%
$□_{FFAG}$ = 100%

PRIME muon-LFV Sensitivity

	PRIME	MECO
Intensity (muons/sec)	1.3x10^11/sec	2X10^11/sec
Muon momentum	68 ± 2 MeV/c	15-90 MeV/c
mu stopping efficiency	80%	40%
Target material	Ti (life time=329 ns)	Al (life time=880 ns)
Physics Sensitivity	B(muN=>eN)/B(mu=>eg) =1/238	B(muN=>eN)/B(mu=>eg) =1/389
Target arrangement	20 layers of 50 um plate	(17-25) layers of200 um plate
Energy loss in target	<150 keV(FWHM)	636 keV(FWHM)
Spectrometer resolution	235 keV (FWHM)	900 keV (FWHM)
Spectrometer acceptance	35%	20%
Time window	Full time window (100%)	Delayed window (50%)
Beam Purity	mu only	mu, pi and e
Single event sensitivity	6x10^-19	2x10^-17
Remark	5 year (=10^7 sec/year) running time; Analysis eff of 0.8 assumed.	

Summary

- PRISM&PRIME
  - Super muon beam with new technology for stopped muon experiments.
  - Single event sensitivity : $B(\mu^- + A \to e^- + A) \sim 6 \times 10^{-19}$
- LOI for New Fast Extraction Beamline and Exp Hall at J-PARC
  - Multi purpose
    - PRISM, g-2, μ-EDM, antiproton, etc…
- A budget for the PRISM-FFAG has been approved. The PRISM-FFAG will be constructed by the end of 2007.
- Staging Scenario to NuFact and muon collider
  - PRISM can be a important step for the future muon physics and the NuFact.