Some Comments on PRISM study towards the US-JP program

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Further Background Rejection to < 10^{-18}

PRISM

mono-energetic muon beam

- Muon DIO & Beam flush → narrow muon beam spread — 1/10 thickness muon stopping target

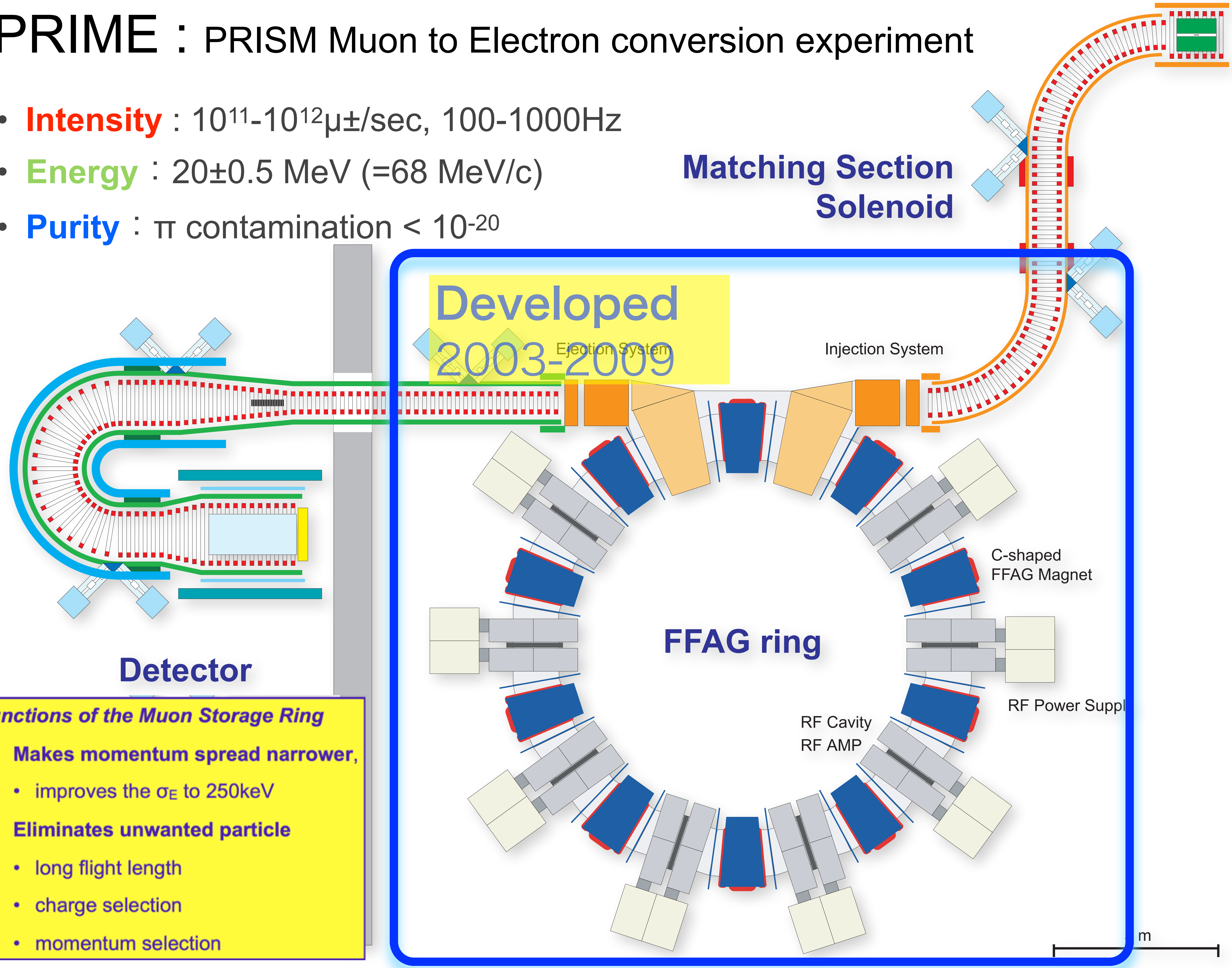
pure muon beam

- Pion background → long muon beam-line — muon storage ring
- Beam-related Background → Extinction at muon beam — fast kickers
  + phase rotator can select momentum and particle
- Cosmic-ray background → low-duty running — 100 Hz rather than 1 MHz

By adding an FFA-Phase Rotator

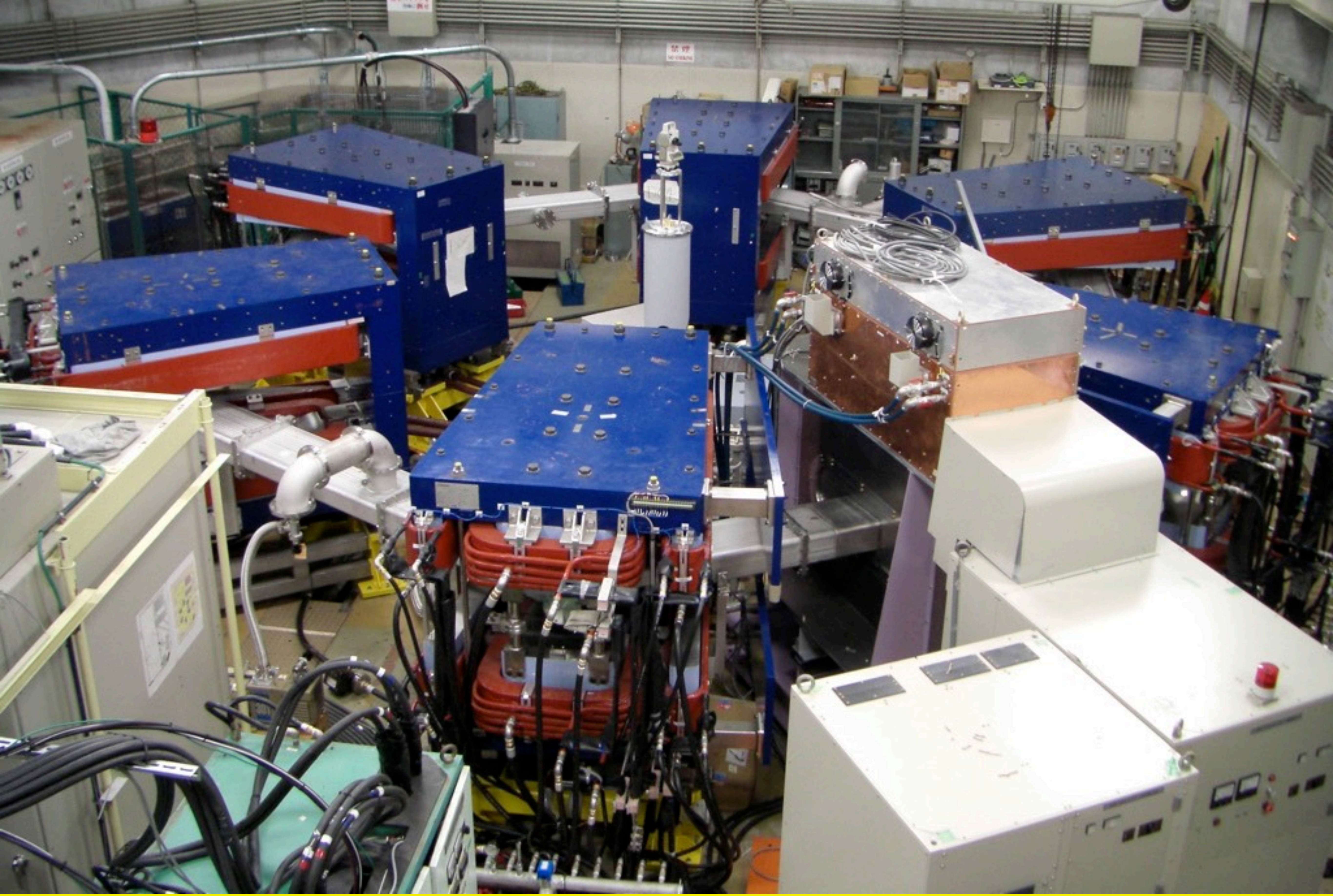
PRISM : Phase Rotated Intense Muon source
PRIME : PRISM Muon to Electron conversion experiment

- **Intensity** : 10^{11}-10^{12}μ±/sec, 100-1000Hz
- **Energy** : 20±0.5 MeV (=68 MeV/c)
- **Purity** : π contamination < 10^{-20}



Functions of the Muon Storage Ring

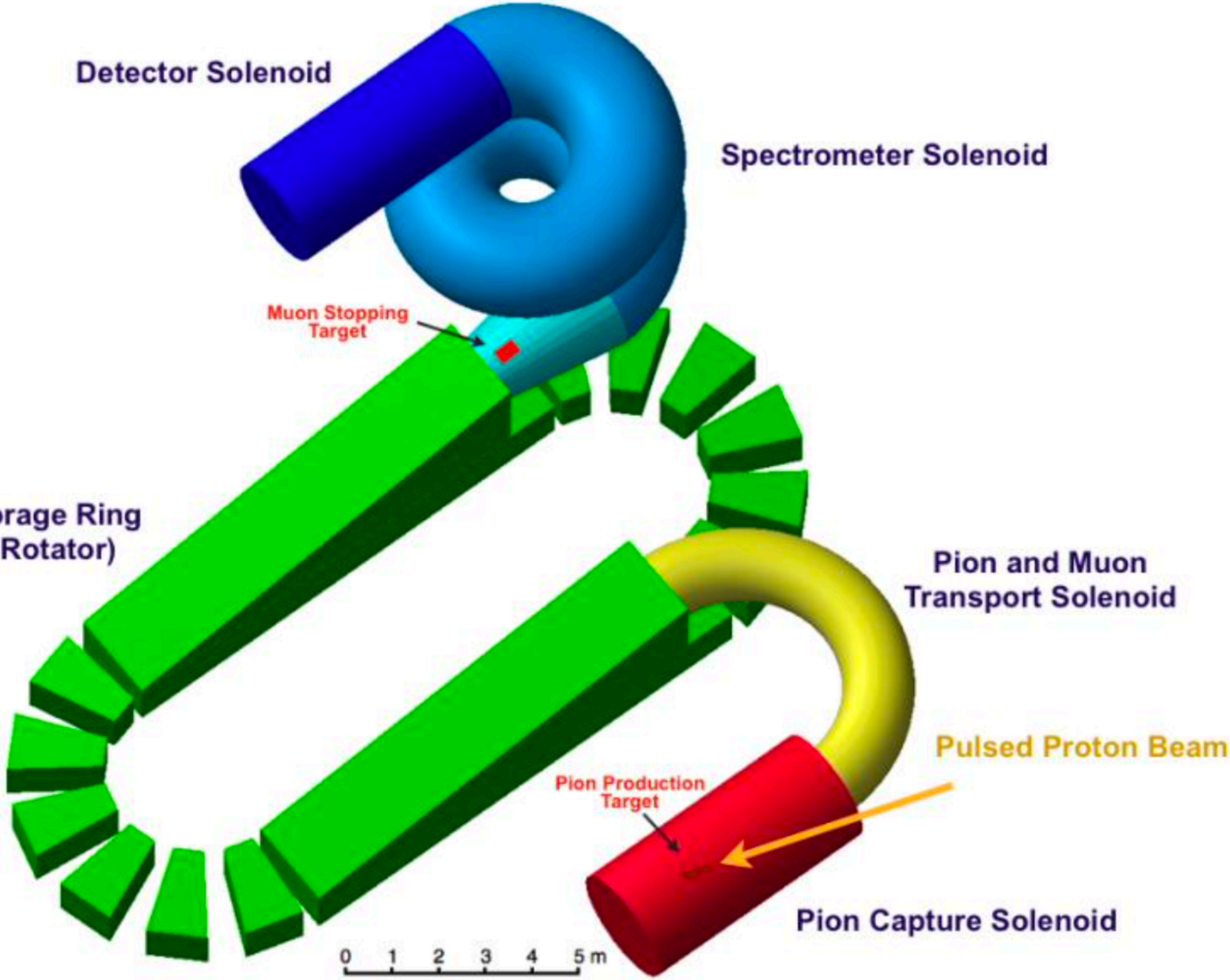
- **Makes momentum spread narrower,**
  - improves the σ_E to 250keV
- **Eliminates unwanted particle**
  - long flight length
  - charge selection
  - momentum selection



6-sector PRISM-FFAG at RCNP, Osaka Univ.

Comments

- There are some FFA designs for PRISM
  - 1st: 8 cell DFD by Prof. S.Machida
  - 2nd: **10 cell DFD by A.Sato → Baseline design**
    - Examined in detail: Beam dynamics, Phase Rotation
    - Build a full size FFA magnets and one RF cavity and amp.
    - Phase rotation was demonstrated by alpha-particle with the 6 sector FFA-ring.
    - But Injection/Extraction seems very difficult.
  - In PRISM task force
    - 10 cell FDF by J.Pasternak
    - Egg, racetrack by JB Lagrange
    - Super periodic solution by Prof. S.Machida
- Central momentum of the muon should be changed to 68MeV/c to <40MeV/c.
  - modify the FFA Lattice, kickers, and beam optics
- Phase rotation
  - The +- 2% momentum spread is also attractive for surface muons.
  - Examine whether it is possible to simultaneously phase rotate positively and negatively charged particles.
- Kicker
  - Make a realistic design.
- Simulation studies are needed throughout the entire system from muon generation to the electron detector.



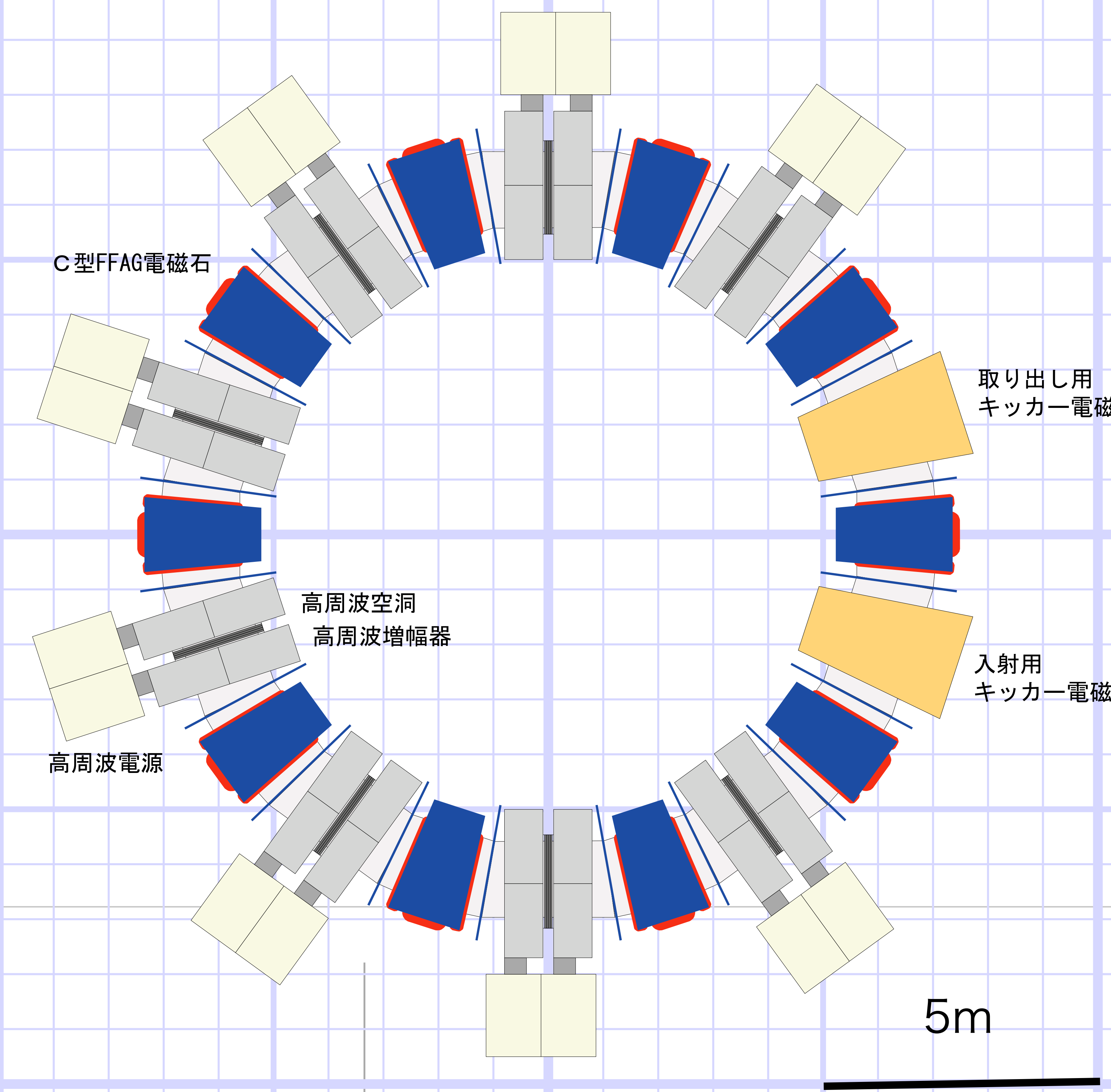
This is a very conceptual illustration I drew in 2009 based on what I thought were the best considerations at the time. The performance of this conceptual design needs to be confirmed by a full simulation.

Appendix 1:
Specification of the 10 cell DFD FFA

PRISM-FFAG

Phase Rotator

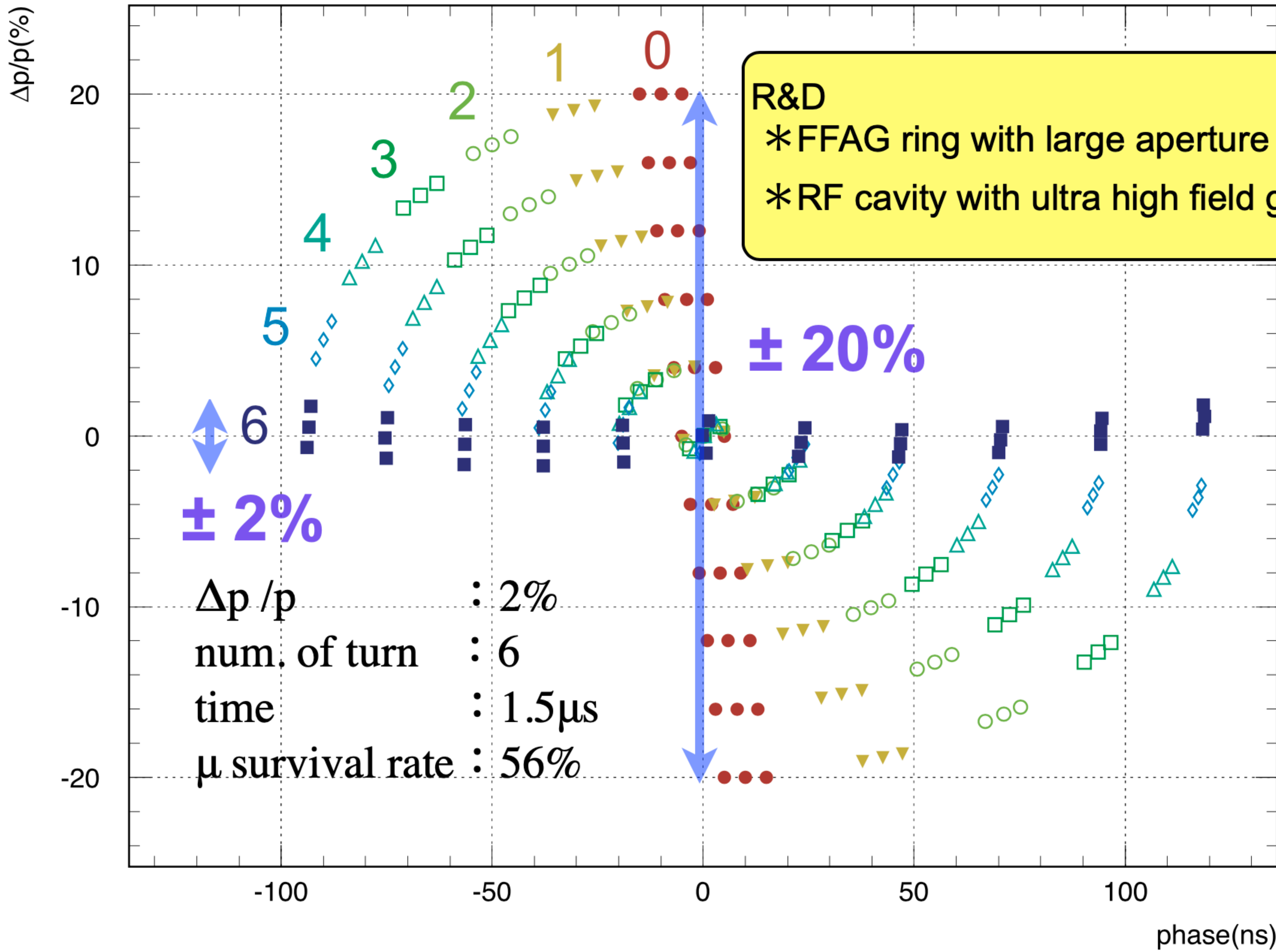
- N=10
- k=4.6
- F/D(BL)=6.2
- r0=6.5m for 68MeV/c
- half gap = 17cm
- mag. size 110cm @ F center
- Radial sector DFD Triplet
- $\theta_F/2$=2.2deg
- θ_D=1.1deg
- Max. field
- F : 0.4T
- D : 0.065T
- tune
- h : 2.73
- v : 1.58



PRISM-FFAG Features

- Radial sector type, Scaling FFAG
- Large transverse acceptance
  - Horizontal : 38,000 π mm mrad
  - Vertical : 5,700 π mm mrad
- High field gradient RF system
  - field gradient ~200kV/m (~2MV/turn)
    - quick phase rotation (~1.5μs)
    - large mom. acceptance (68MeV/c +- 20%)

Expected phase rotation with PRISM-FFAG

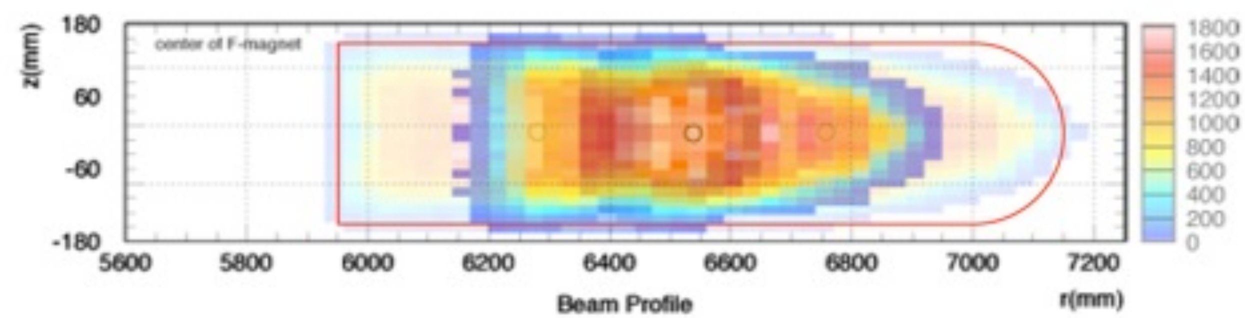


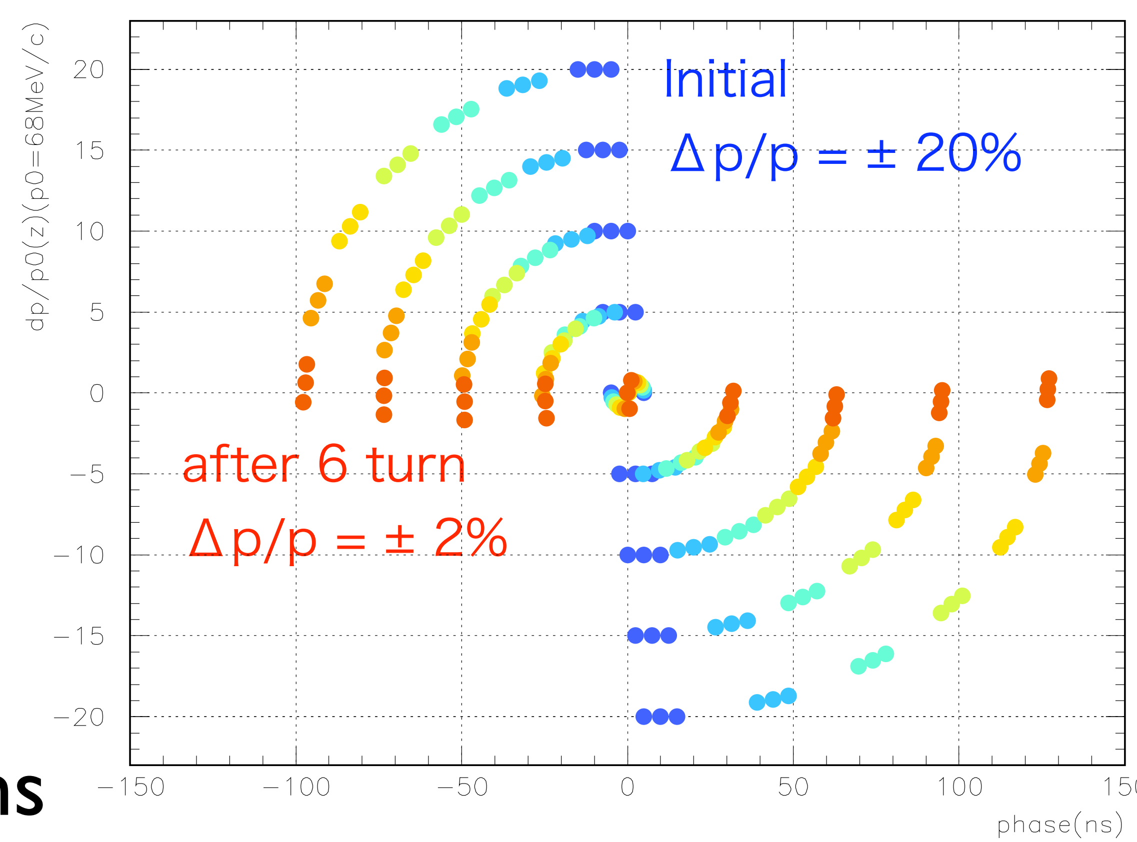
R&D
* FFAG ring with large aperture magnet
* RF cavity with ultra high field gradient

Δp /p	: 2%
num. of turn	: 6
time	: 1.5μs
μ survival rate	: 56%

Muon Beam

- at Injection
  - momentum : 68MeV/c+-20%
    - beam size
      - 100cmx30cm
  - time dist.: 40ns(/270ns)
    - kicker fall time < 230ns
- at Extraction
  - momentum : 68MeV/c+-2%
    - beam size
      - 70cmx30cm
  - time dist. : 200ns(/270ns)
    - kicker rise time < 70ns-100ns

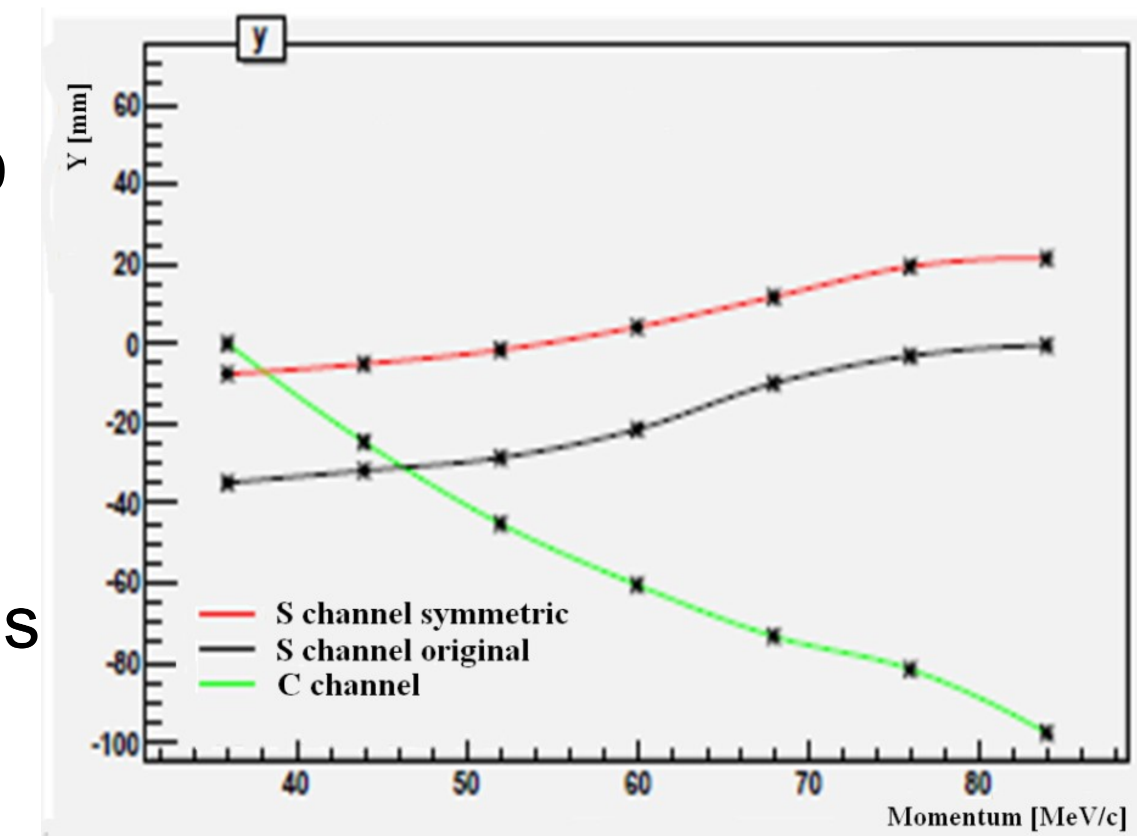


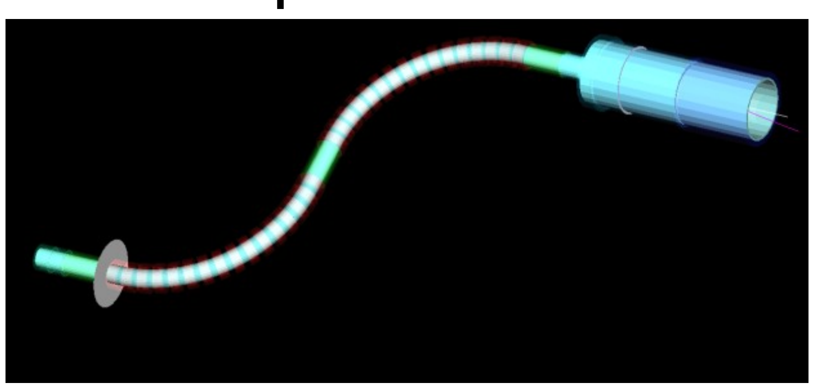


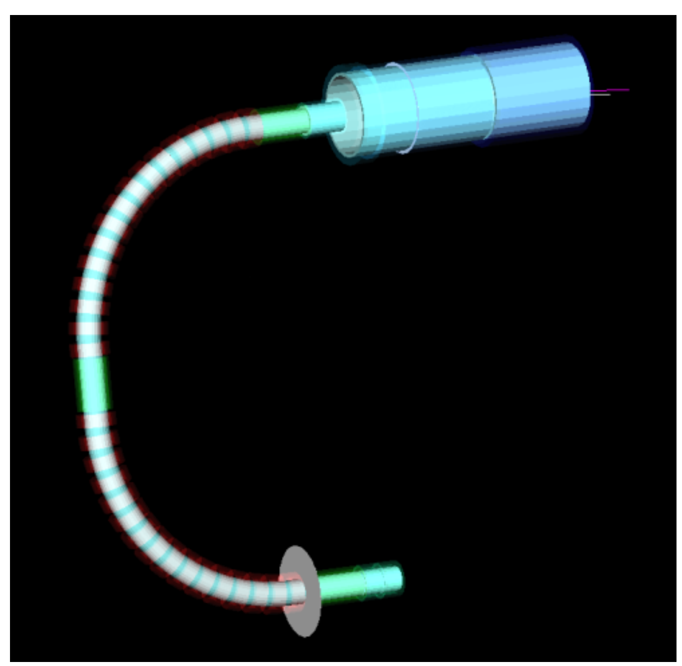
Appendix 2:
Injection/Extraction study by J. Pasternak

Matching to the FFAG I

- Muon beam must be transported from the pion production solenoid to the Alternating Gradient channel.
- Two scenarios considered, S-shaped and C-shaped.
  - S-shaped with correcting dipole field has the best transmission and the smallest dispersion.

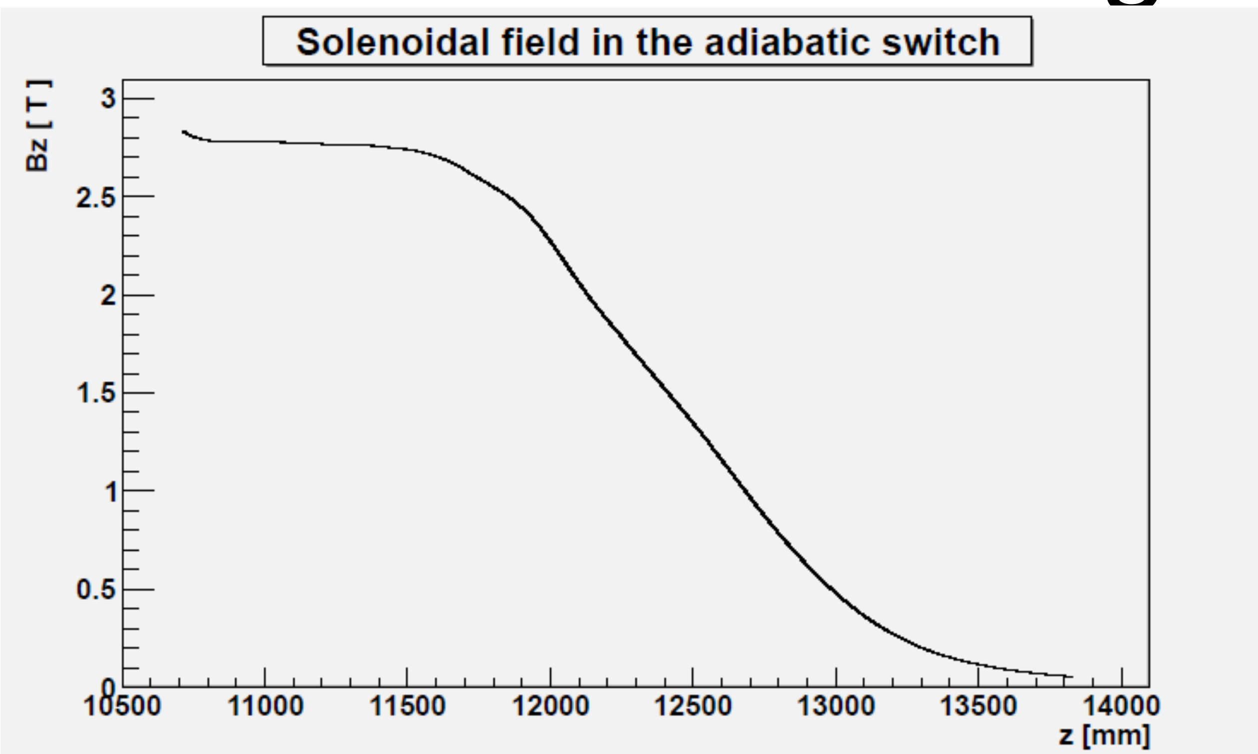




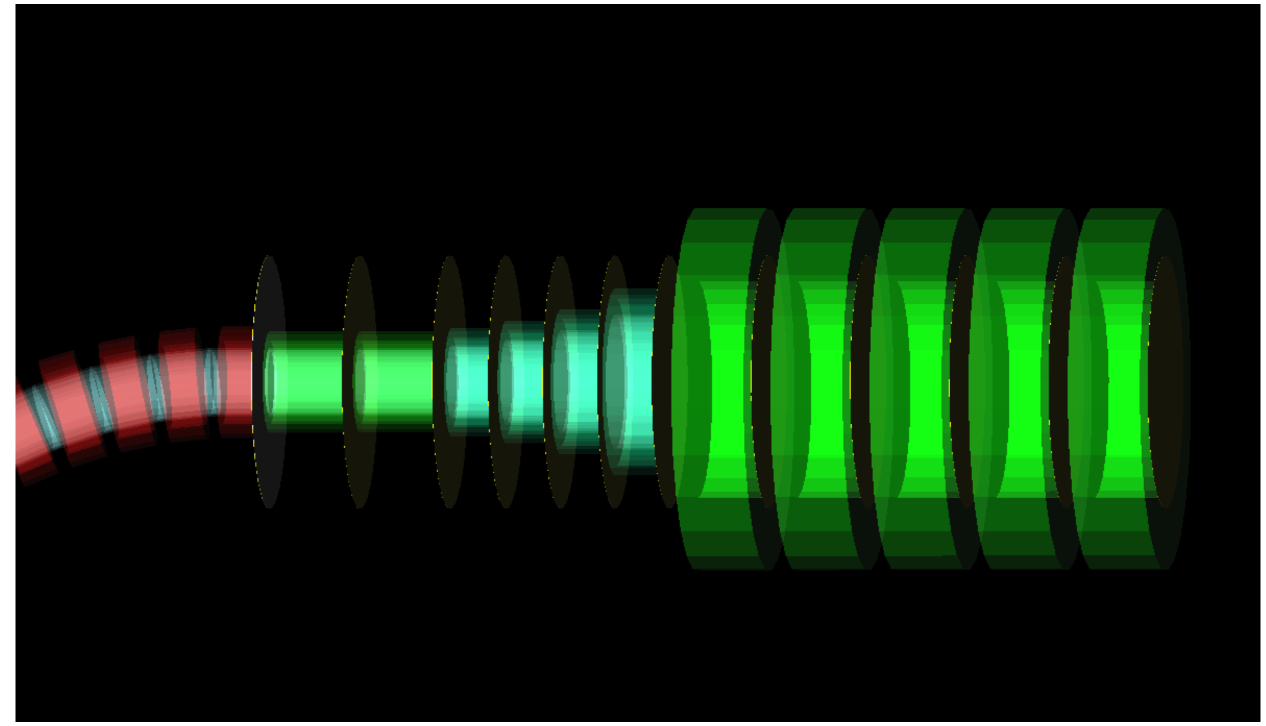


The mean vertical beam position versus momentum at the end of bend solenoid channel for various configurations.

Matching to the FFAG II



Initial version of the adiabatic switch



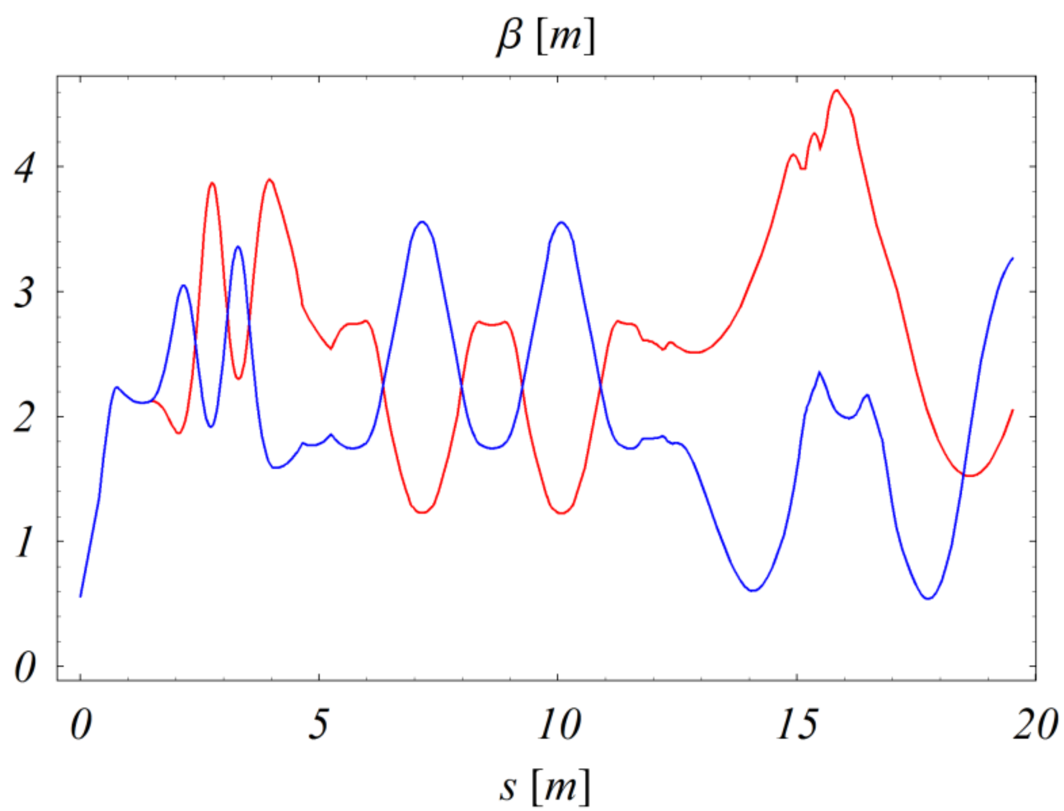
Preliminary geometry: the end of the S-channel together with matching solenoids, adiabatic switch and 5 quad lenses.

Current best version includes:

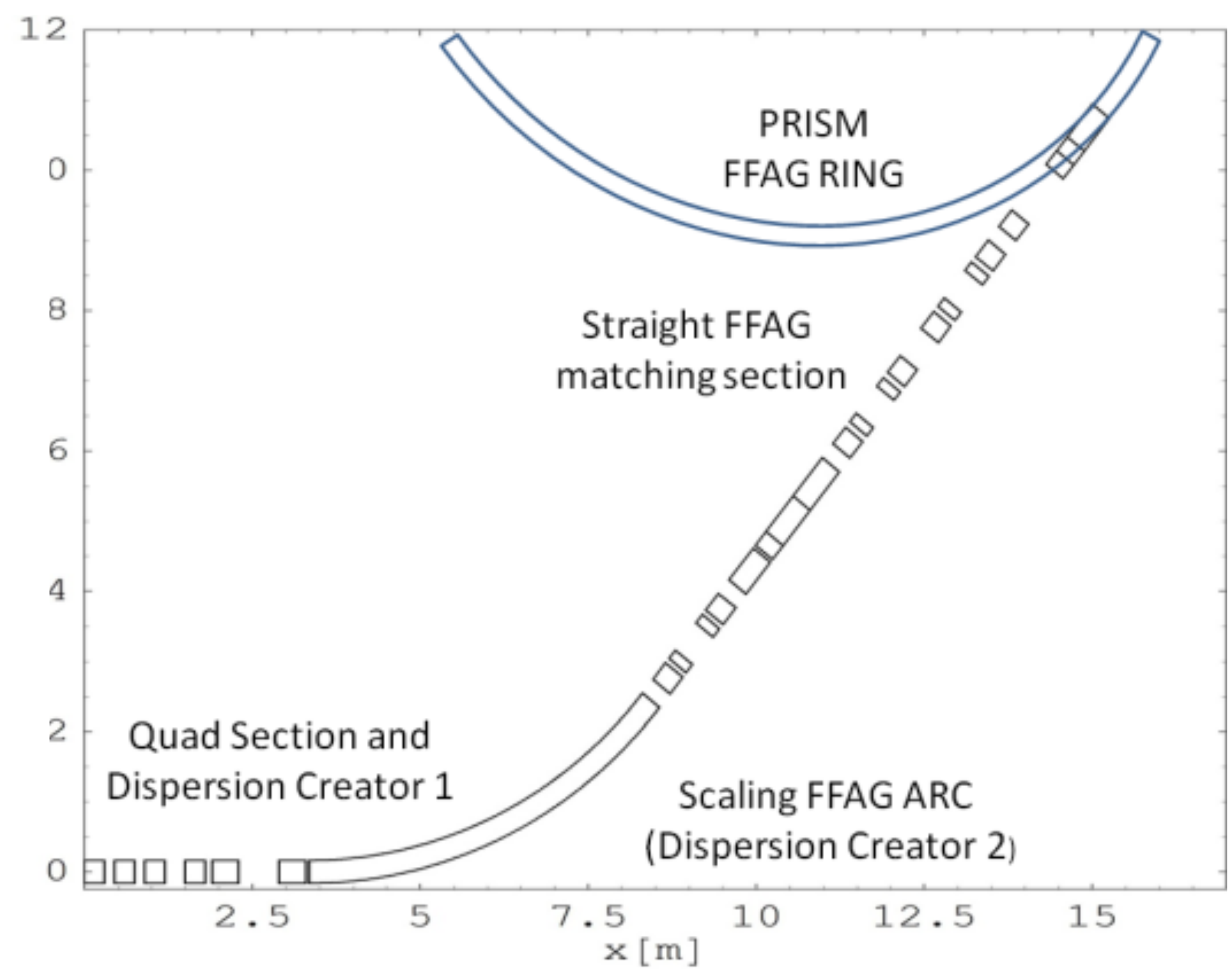
- adiabatic switch from 2.8 to 0.5 T (to increase the beam size),
- additional solenoidal lens to match α=0 (not shown in the pictures above),
- 5 quad lenses,

Matching to the FFAG III

- A dedicated transport channel has been designed to match dispersions and betatron functions.



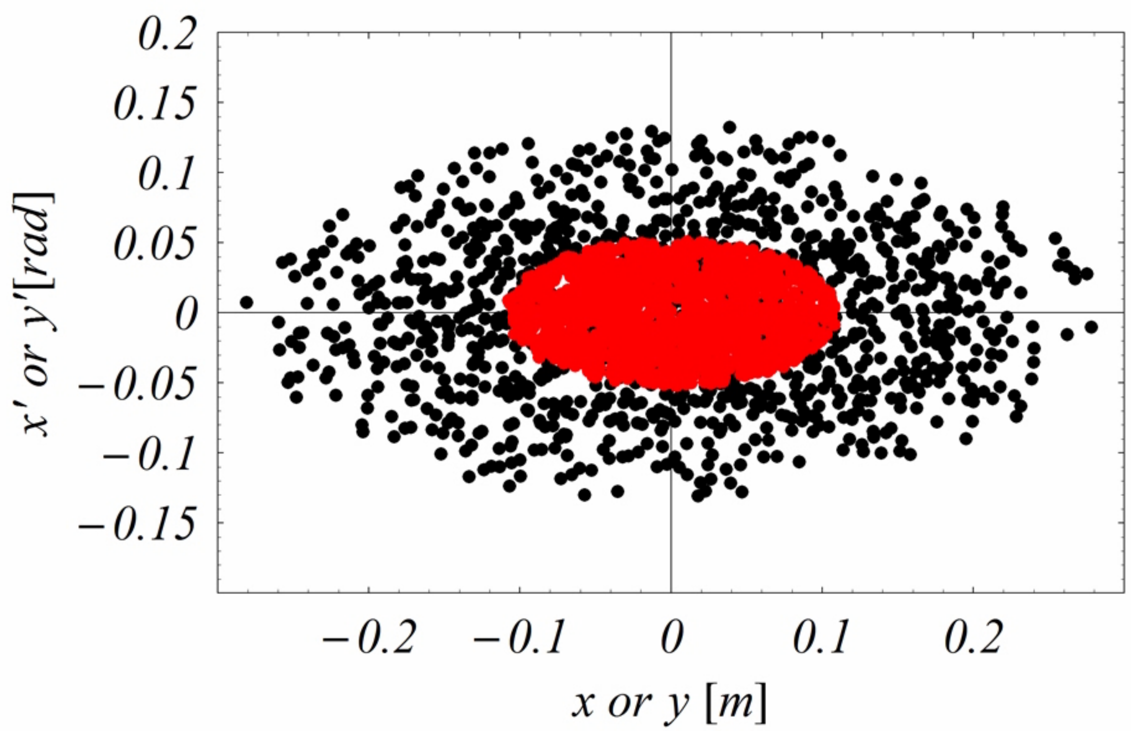
Horizontal (red) and vertical (blue) betatron functions in the PRISM front end.



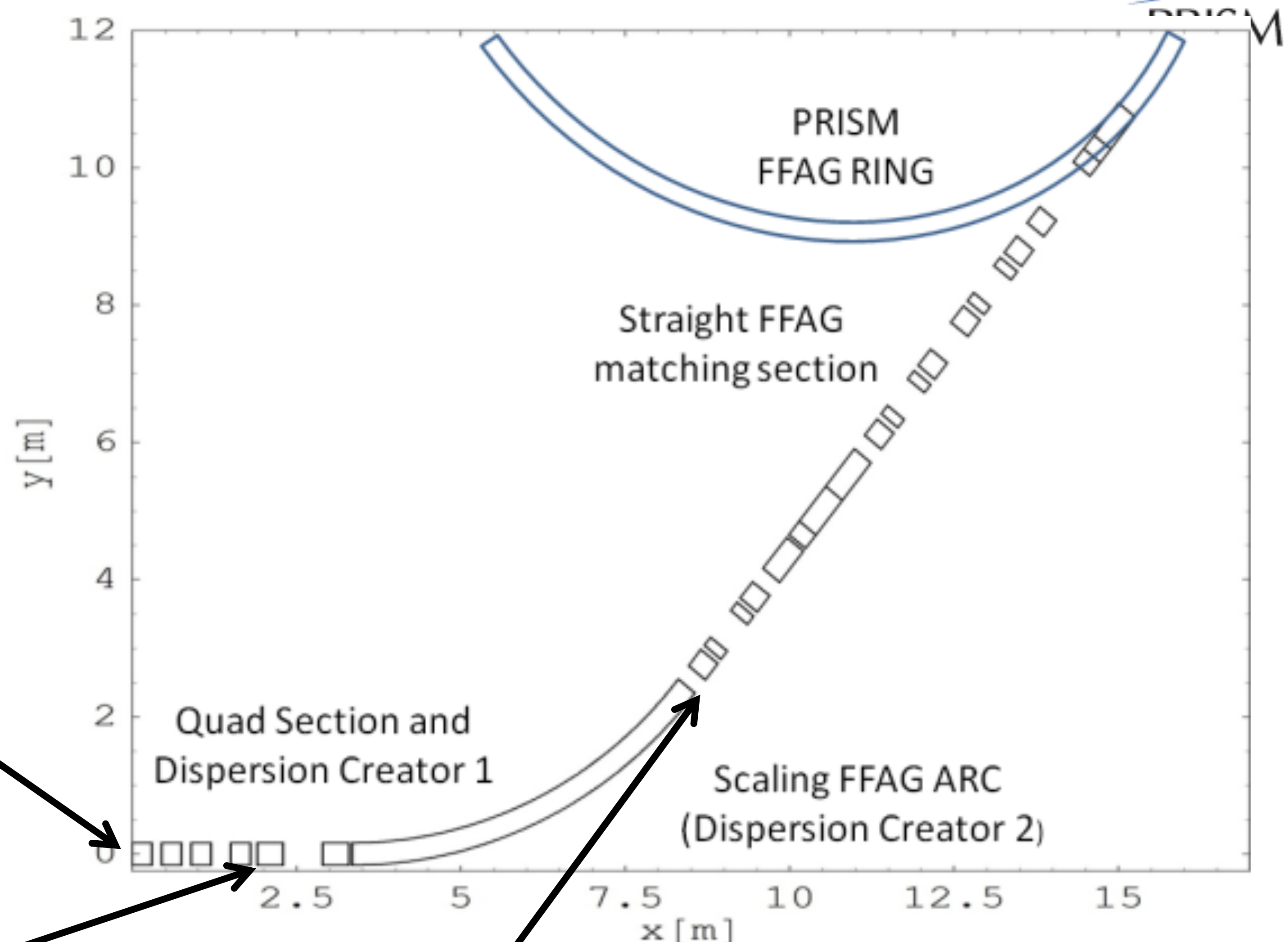
Layout of the matching section seen from the above.

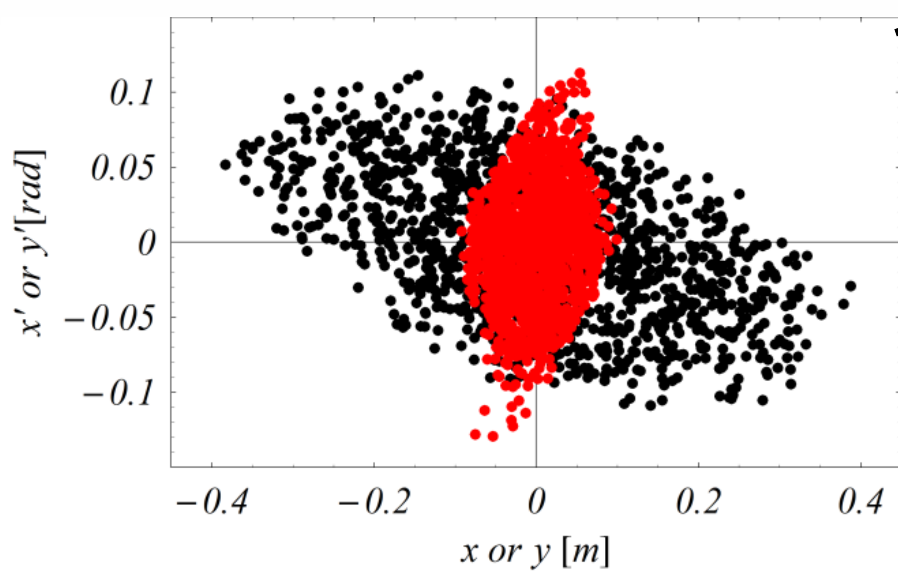
Matching to the FFAG IV

- Tracking status (work in progress)

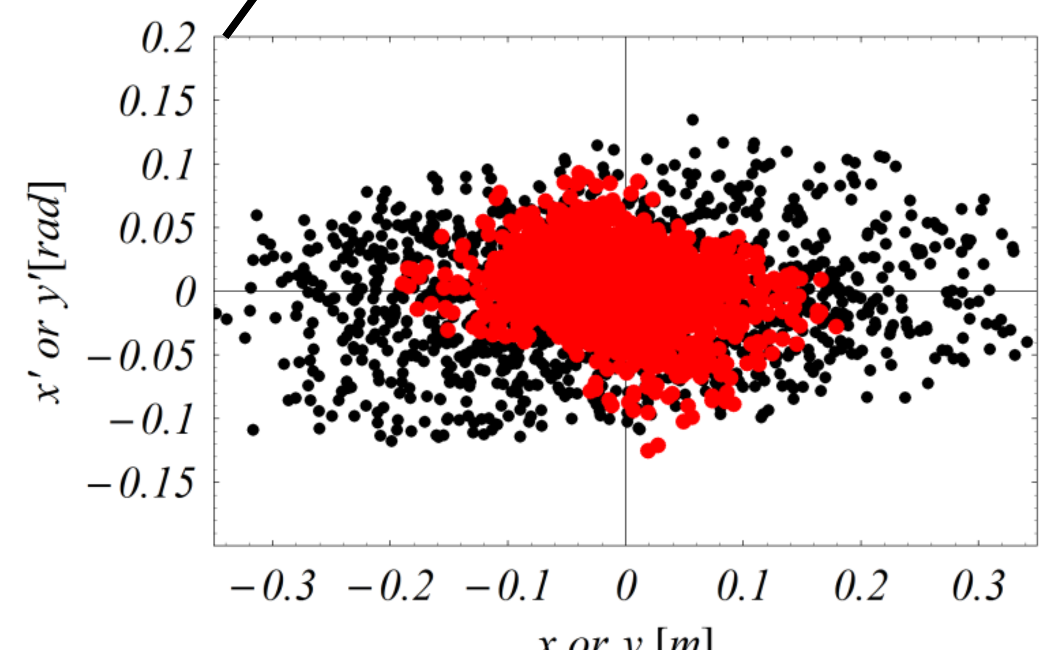


Horizontal (black) and vertical (red) phase spaces at the input to the AG part of the PRISM muon front end.





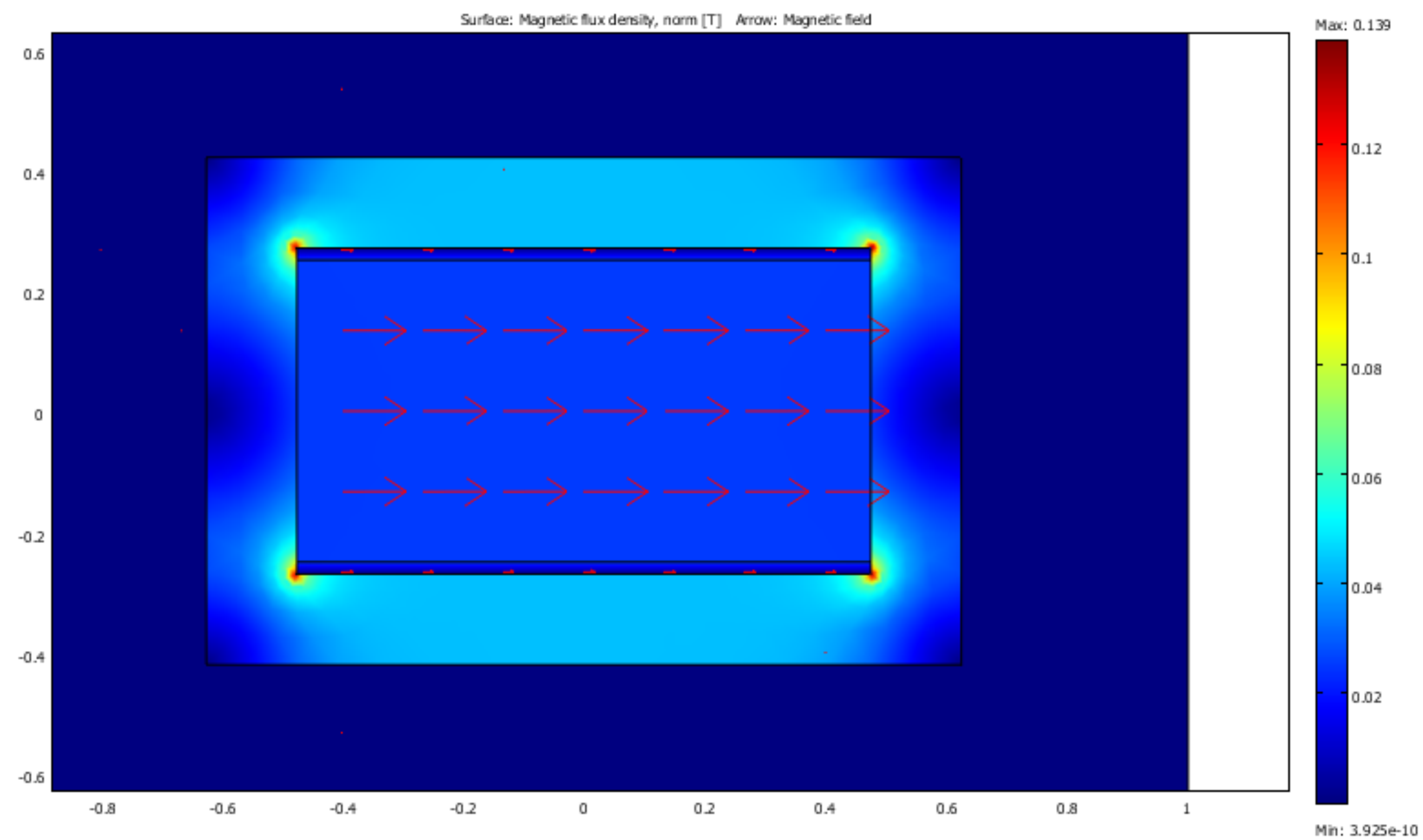
At the end of the quad Channel



At the end of the horizontal dispersion creator (t

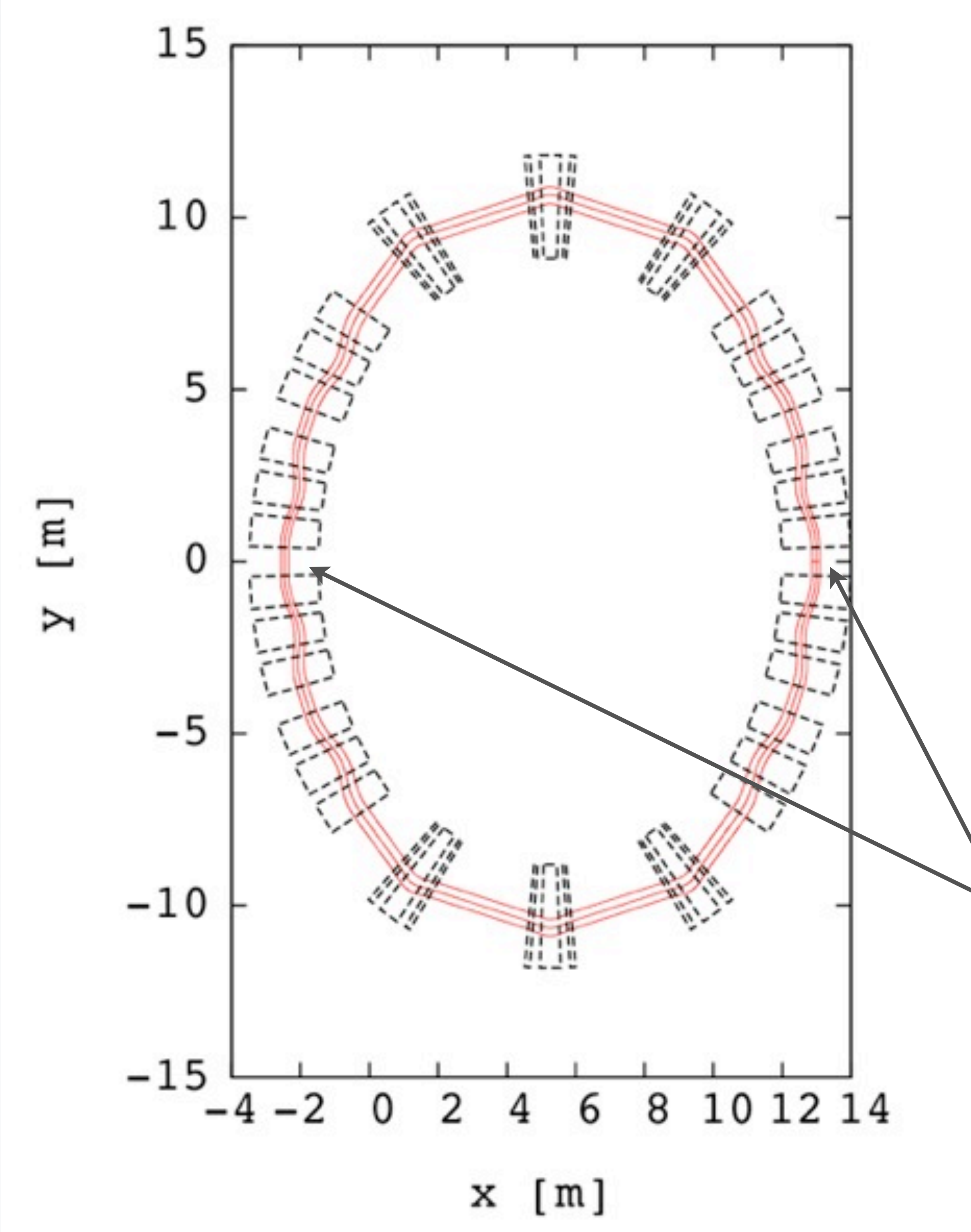
Preliminary PRISM kicker studies

- length 1.6 m
- B 0.02 T
- Aperture: 0.95 m x 0.5
- Flat top 40 /210 ns (injection / extraction)
- rise time 80 ns (for extraction)
- fall time ~200 ns (for injection)
- W_{mag}=186 J
- L = 3 uH (preliminary)
- I_{max}=16 kA



J. Pasternak

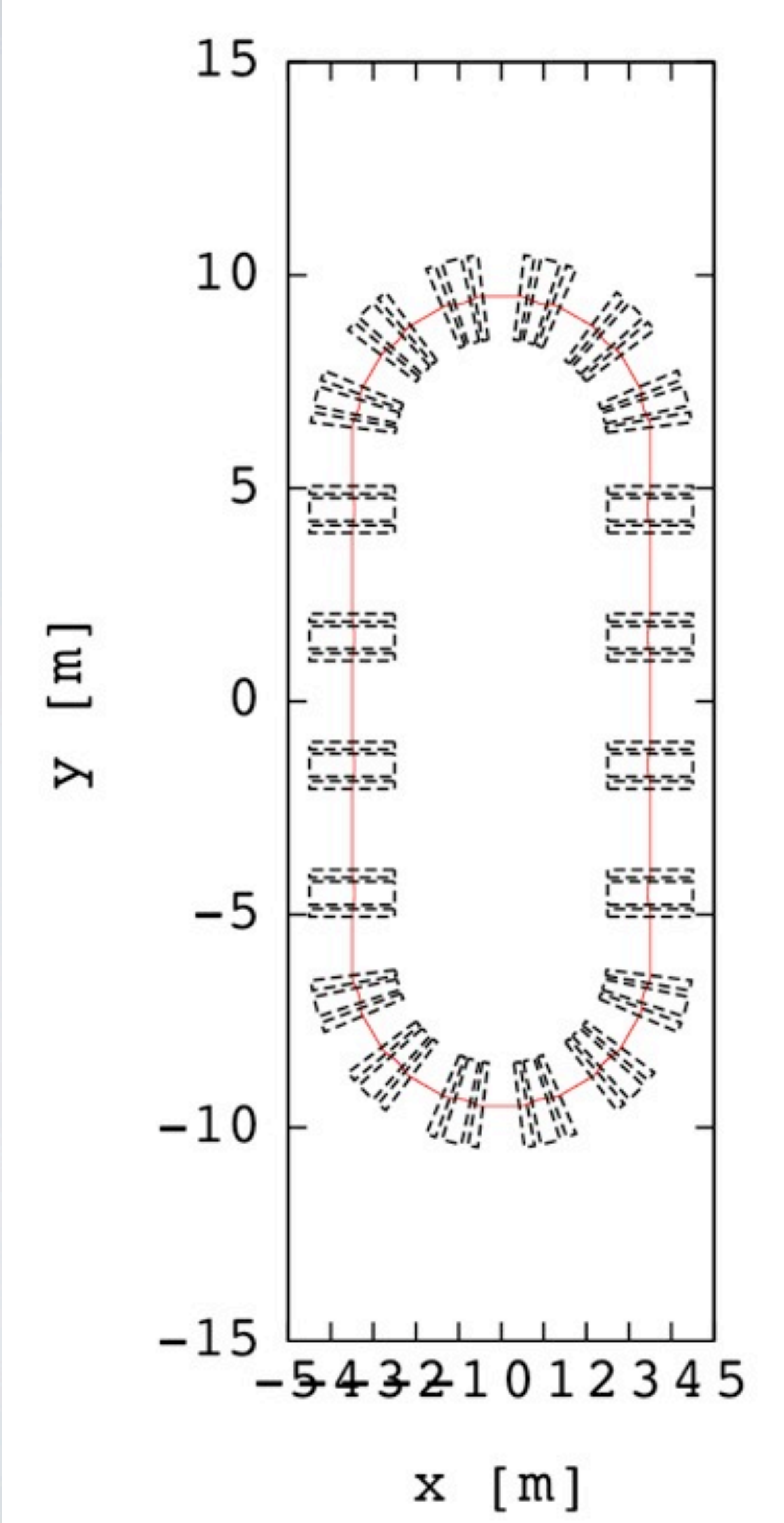
Appendix 3:
Egg and racetrack FFA by JB Lagrange



Dispersion suppressor cell FDF	
k	14.2
Average radius	13 m
Phase advances:	
horizontal μ_x	90 deg.
vertical μ_z	86 deg.
Dispersion	1.16 m to 0.58 m

Dispersion reduced areas

Figure 2: PRISM ring with 4 dispersion suppressors and 6 original PRISM magnets.



ANOTHER LATTICE

Bending cell	
k	6.5
Average radius	3.5 m
Phase advances:	
horizontal μ_x	90 deg.
vertical μ_z	87 deg.
Dispersion	0.47 m

Straight cell	
n/ρ	$2.14\, m^{-1}$
Length	$3\, m$
Phase advances:	
horizontal μ_x	24 deg.
vertical μ_z	87 deg.

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