PRISM/PRIME

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on behalf of the PRISM Task Force

PRISM:

Phase Rotated Intense Slow Muon source

for stopped muon experiment

PRIME:

PRISM Muon Electron conversion

PRISM task force

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PRISM task force

Aims:

- Address the technological challenges in realising an FFAG-based muon-to-electron conversion experiment,
- Strengthen the R&D for muon accelerators in the context of the Neutrino Factory and future muon physics experiments.

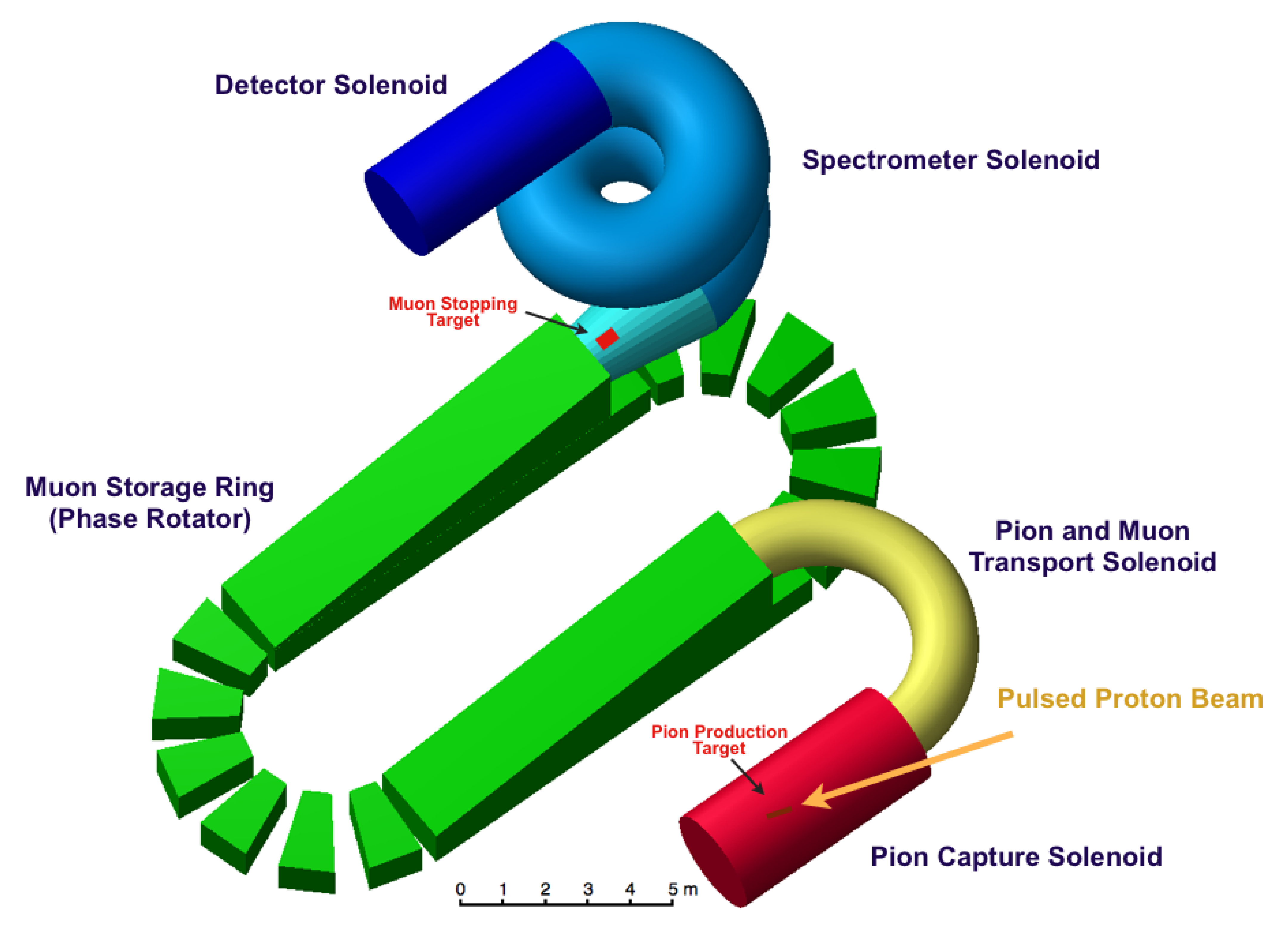
Areas of work:

- the physics of muon to electron conversion,
- proton driver,
- pion capture,
- muon beam transport,
- injection and extraction for PRISM-FFAG ring,
- FFAG ring design including the search for a new improved version,
- FFAG hardware systems R&D.

Outline

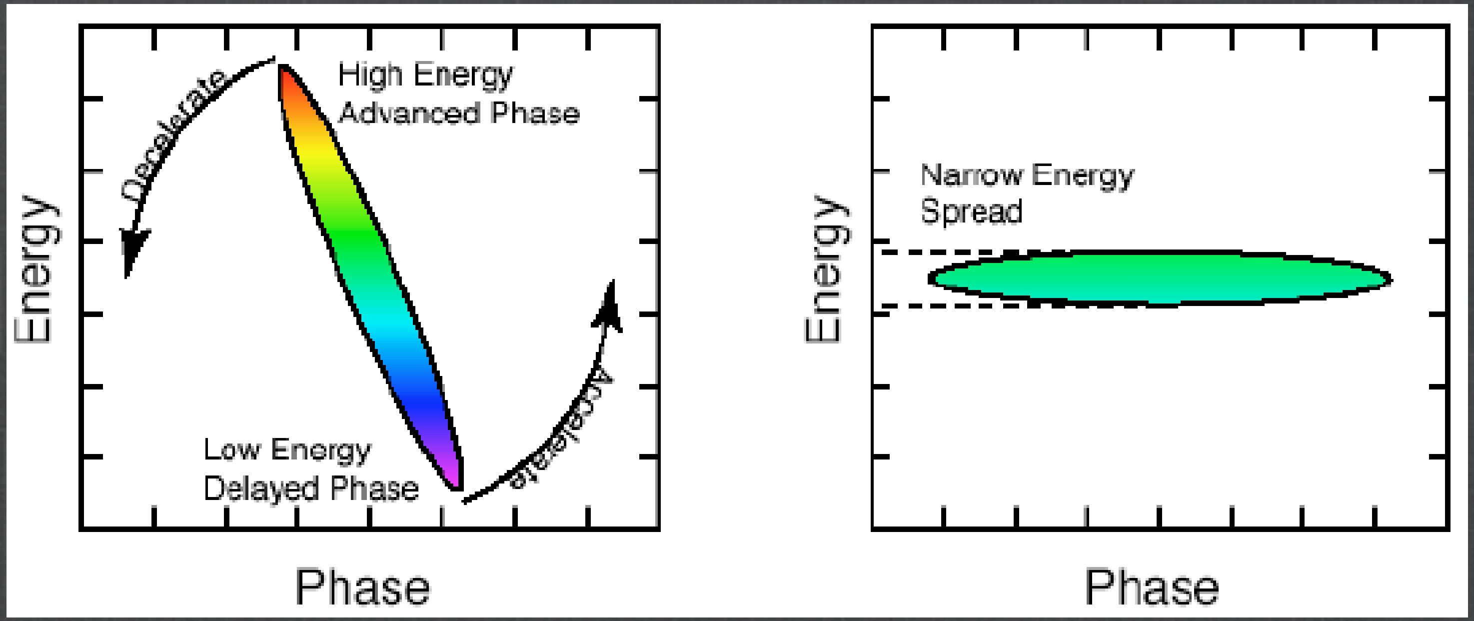
- Overview of PRISM
- Main challenges
- Achievements and status
- Summary and future plans

PRISM overview



PRISM features

- High muon intensity (10^{11}-10^{12} μ^-/s): large 6D acceptance (FFAG),
- Pulsed beam (for background rejection): >100 Hz,
- Low momentum muon (for less scattering backgrounds),
- Quasi-monoenergetic muon beam (for thinner muon-stopping target): phase rotation,



- No pion contamination ($<10^{-18}$), ~150 m in FFAG, beam extinction between pulses.

PRISM parameters

Proton Driver:	
Proton beam power	1–4 MW
Proton beam energy	several GeV
Proton bunch duration	10 ns
Target and pion capture:	
Target type	solid
Pion capture field	4–10 T
Phase rotator:	
Reference μ^- momentum	40–68 MeV/c
Momentum acceptance	$\pm$20%
Acceptance (H/V)	38/5 mm.rad
Harmonic number	1
RF frequency	3–6 MHz
RF voltage per turn	3–5.5 MV
Repetition rate	100–1000 Hz
Final momentum spread	$\pm$2%

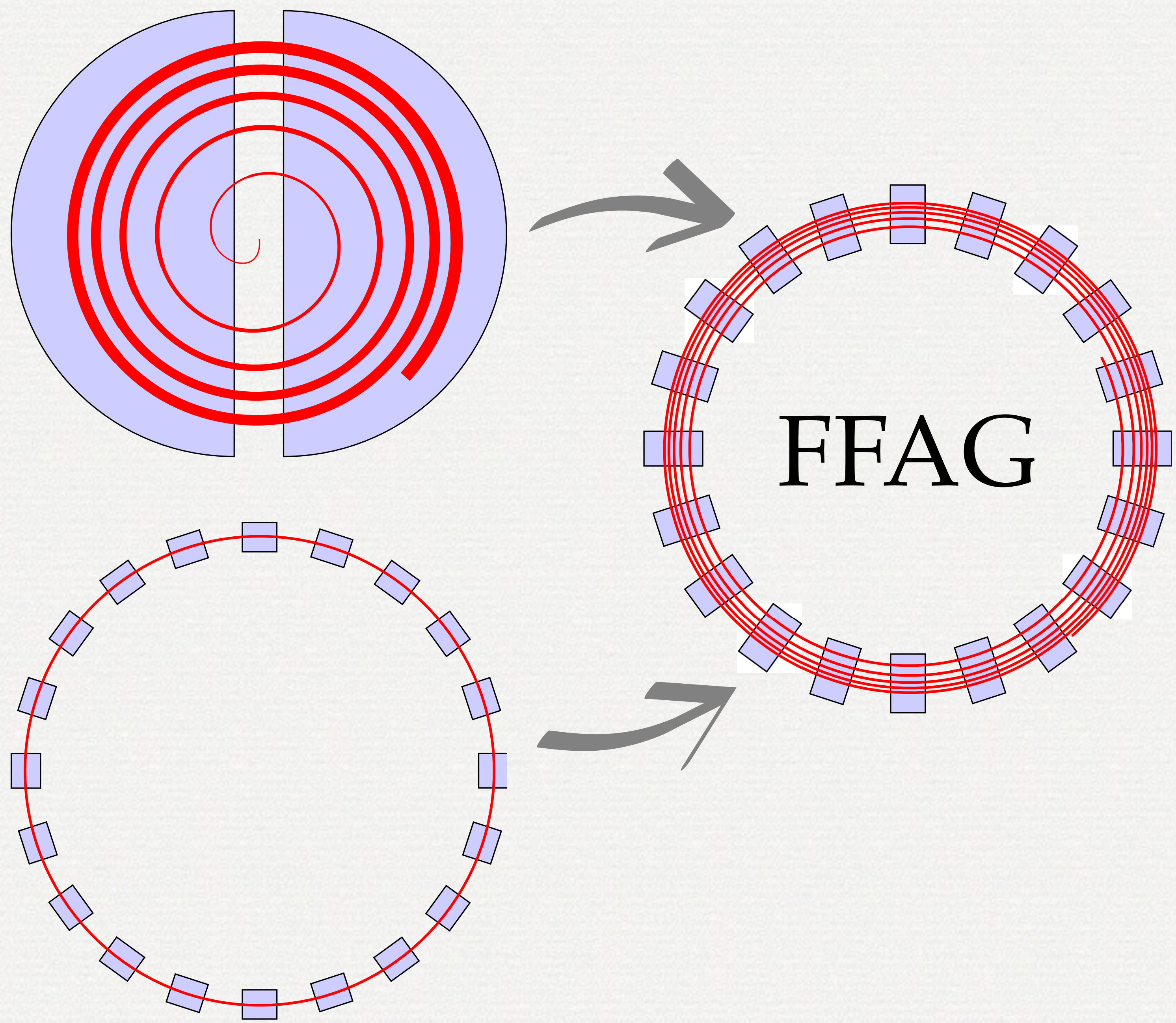
FFAG accelerator

FIXED FIELD ALTERNATING GRADIENT

- **a static guide field** like cyclotrons:

AND

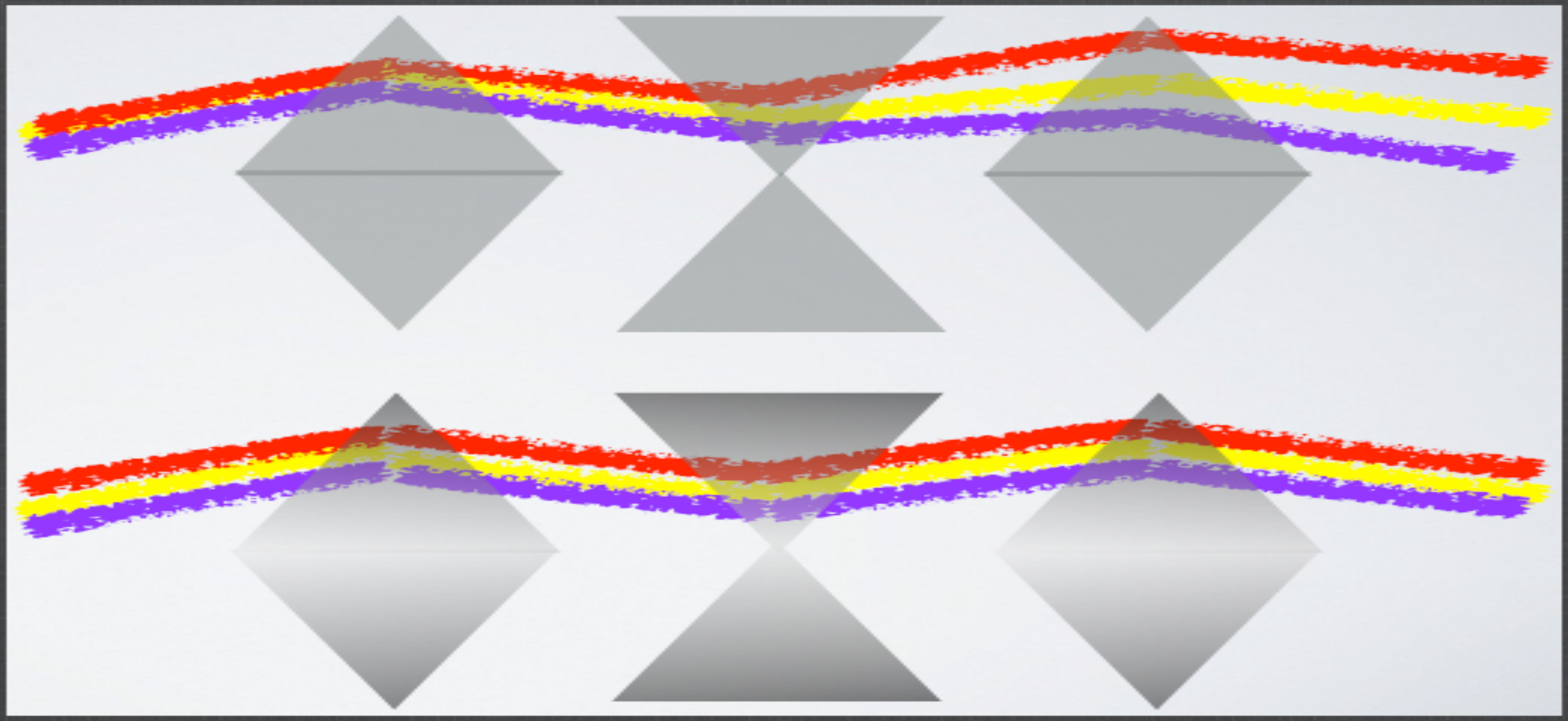
- **a strong focusing.** like synchrotrons:



Zero-chromatic FFAG

Advantages:

- stable optics for **<u>very large momentum spread</u>**.
- allows a good working point with a **<u>large acceptance</u>** far from harmful resonances.



→ Quasi-zero beam loss!

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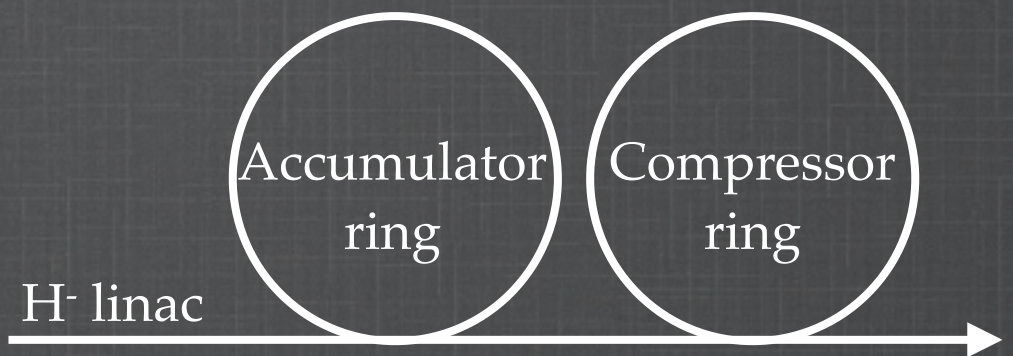
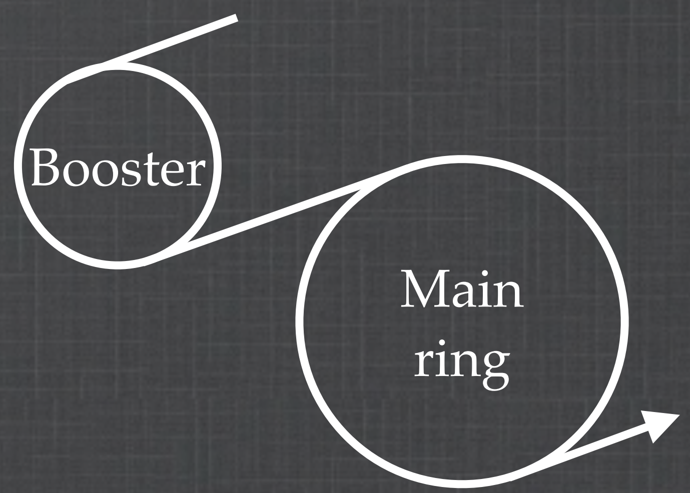
Challenges

Compressed bunch beam

- 2 methods established:
  - Based on LINAC,



  - based on high power synchrotrons.



- Where?
  - Fermilab,
  - J-PARC,
  - CERN,
  - RAL (MW upgrade),
  - ESS.

Challenges

Target and capture system:

- full synergy with the Neutrino Factory and a Muon Collider studies.
- requires a detailed study of the effect of the energy deposition induced by the beam

RF system

- large gradient at the relatively low frequency and multiple harmonics (the “sawtooth” in shape).

Challenges

Design of the muon beam matching from the solenoidal capture to the PRISM FFAG ring.

- very different beam dynamics conditions.
- very large beam emittances and the momentum spread.
- Muon beam injection/extraction into/from the FFAG ring.
- very large beam emittances and the momentum spread.
- affects the ring design in order to provide the space and the aperture.

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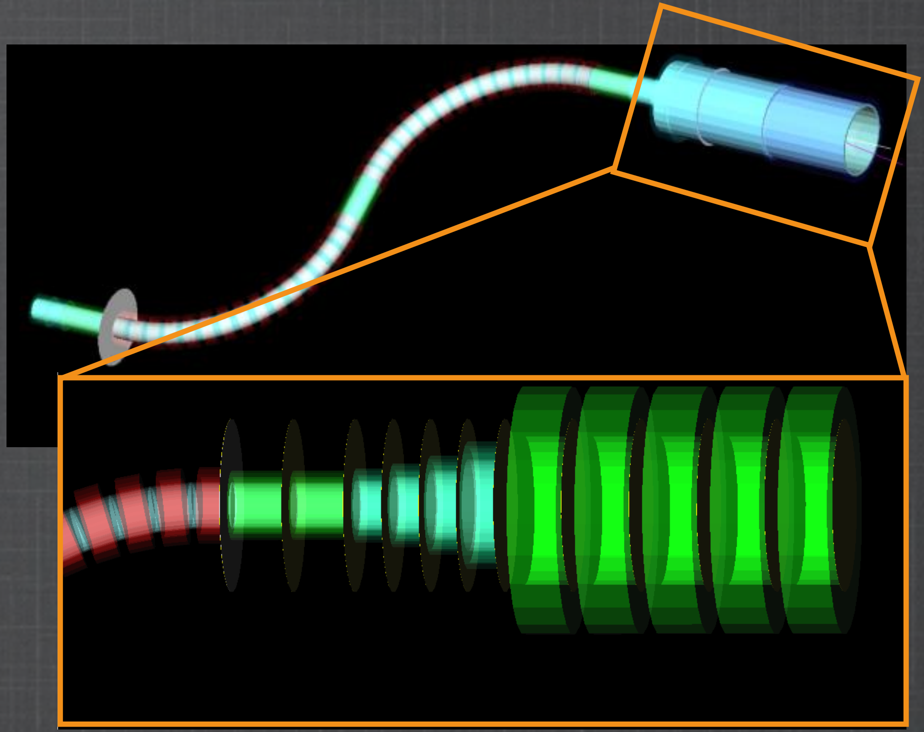
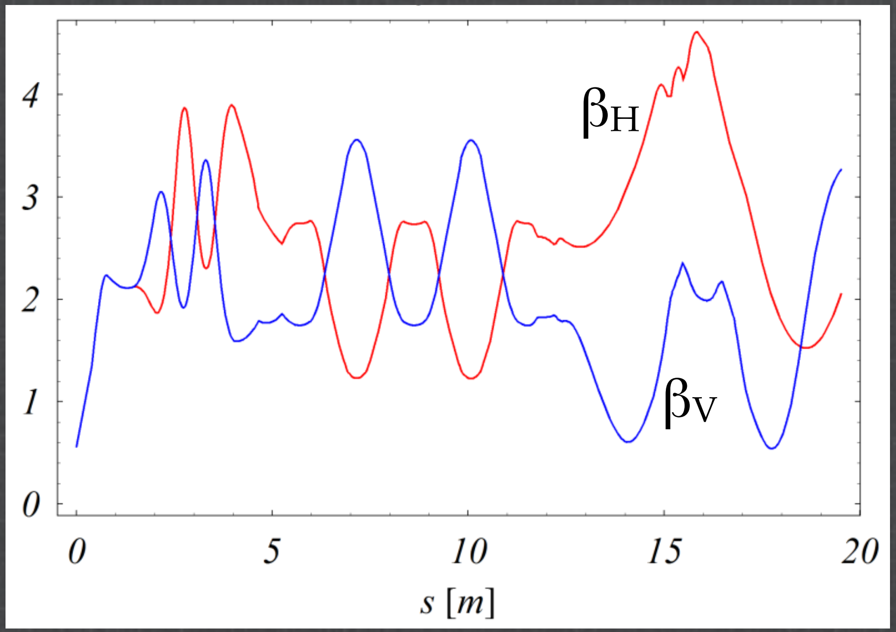
RF development

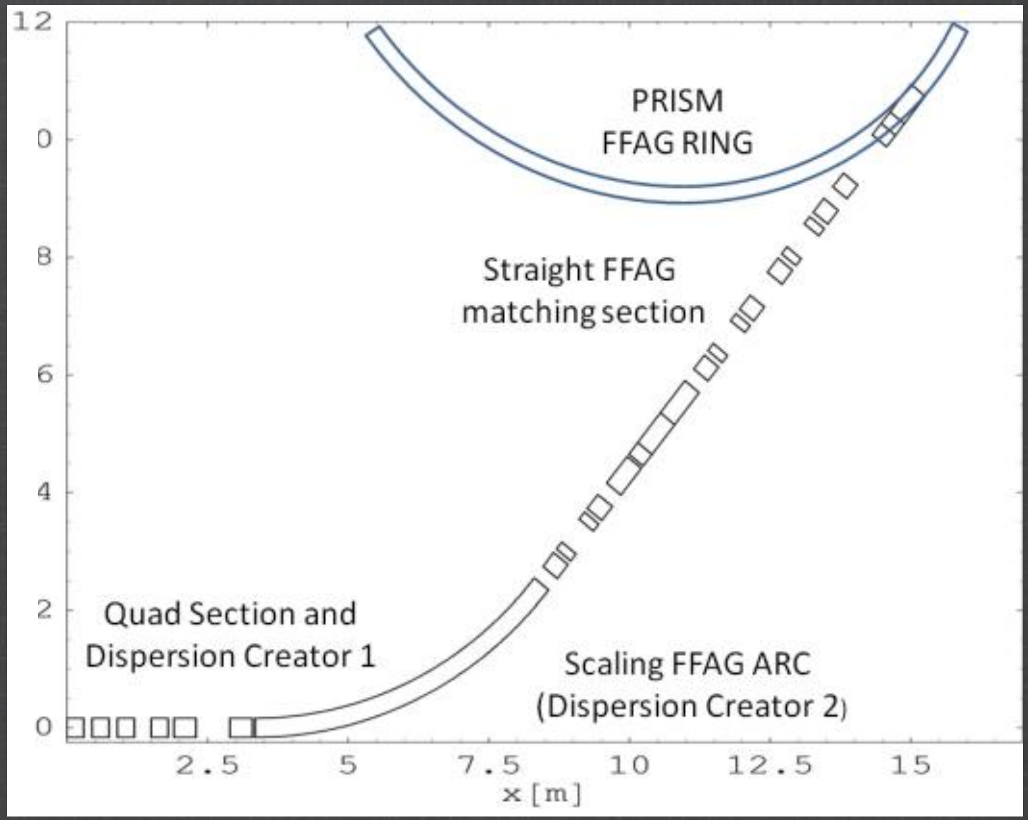
- Substantial progress has been achieved in the design of MA cavities using a new FT3L.
- Large-size MA cores have been successfully fabricated at J-PARC. Those cores have two times higher impedance than ordinary FT3M MA cores.
- For the PRISM RF system in order to either reduce the core volume cutting the cost by a factor of 3 or to increase the field gradient.

Solenoid-FFAG matching



- S-shaped scenario to transport muon beam from pion production to alternating-gradient channel.
- Matching solenoid, adiabatic switch from solenoid and 5 quad lenses.
- dispersions and beta-functions matched in dedicated transport channel.





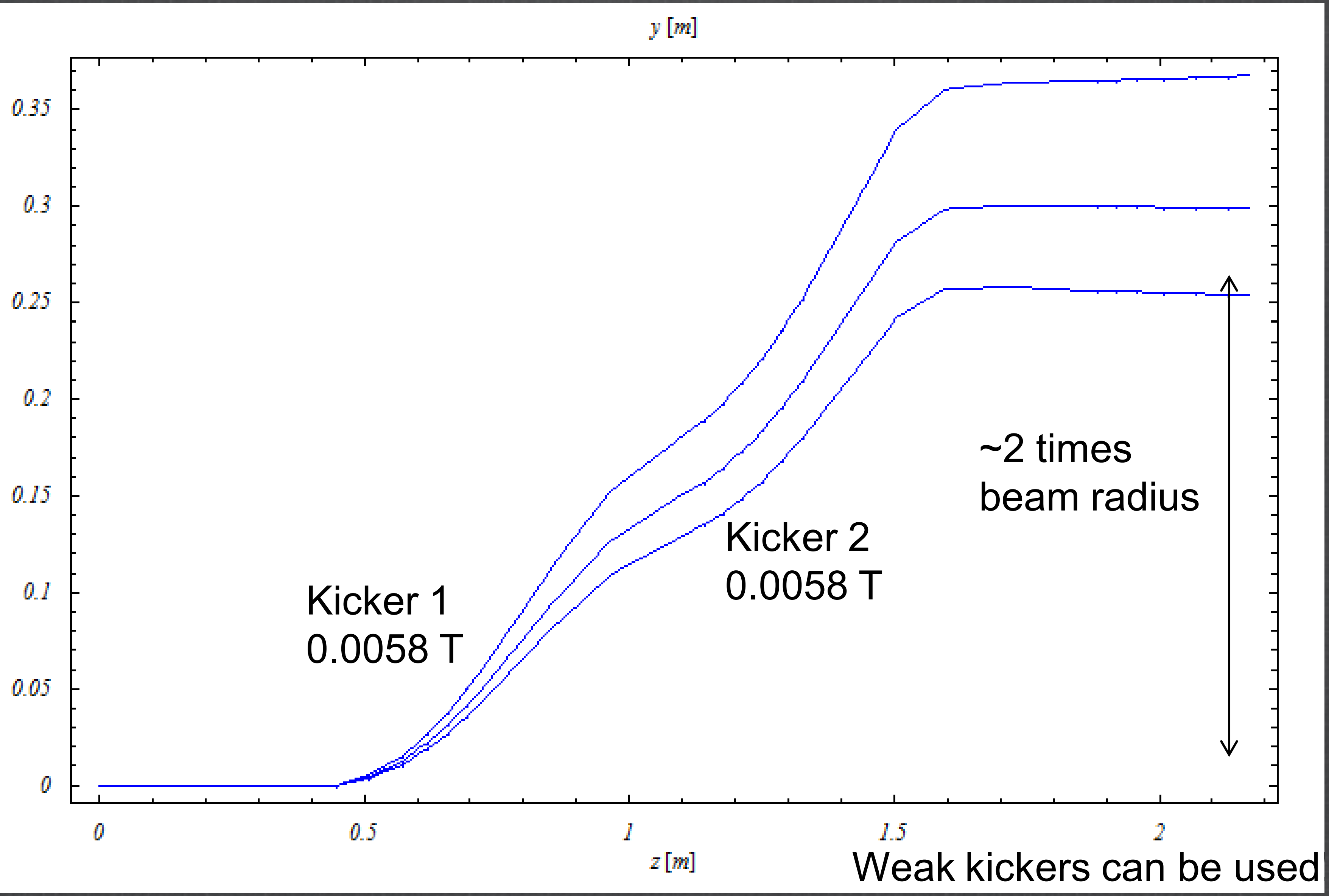
➡ can be done without big losses within the FFAG acceptances (transmission 97%).

JB Lagrange - nuFACT16

Injection in FFAG ring (1)

Vertical injection with 2 kickers and a septum.

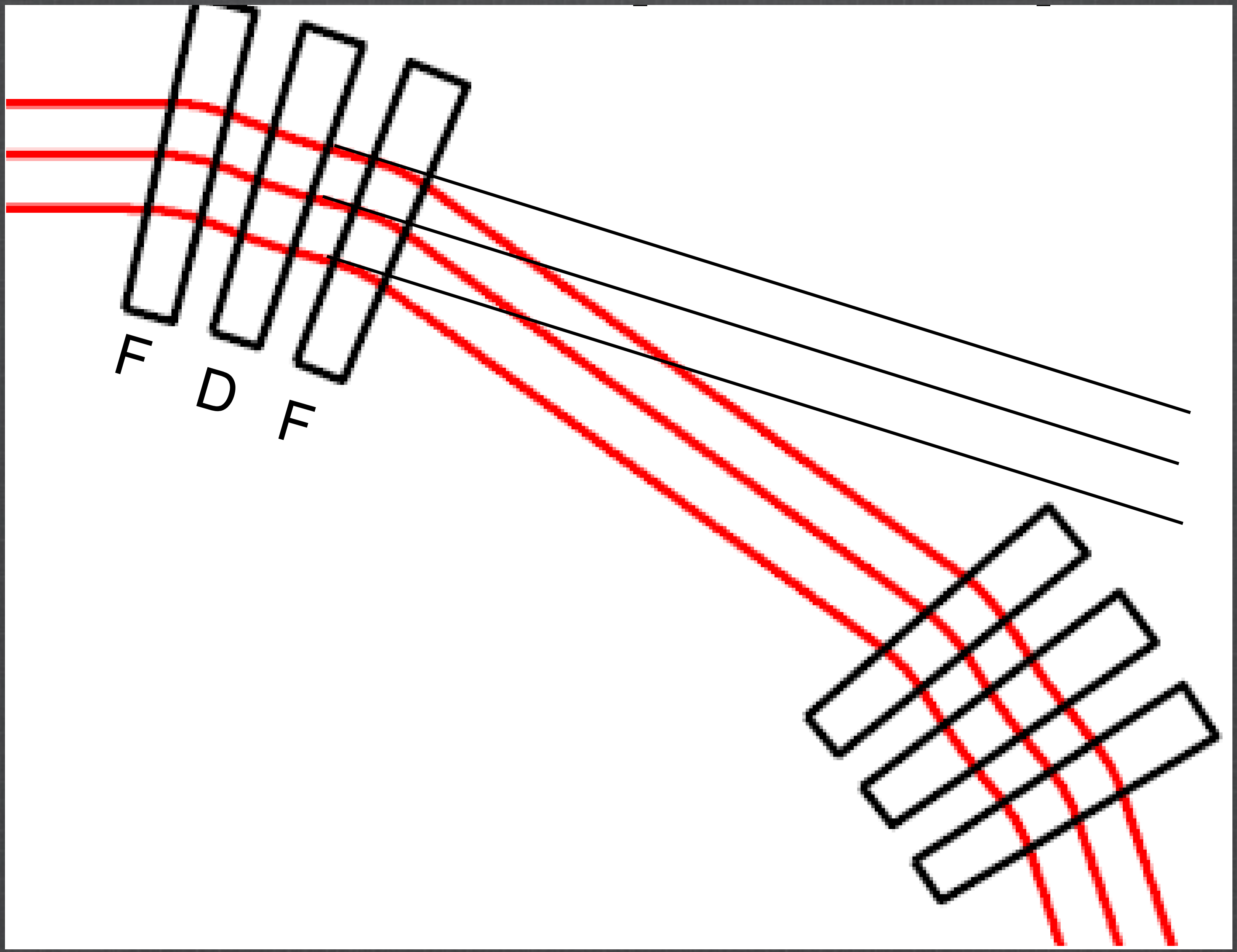
Remain challenging to cancel vertical dispersion for the whole momentum range.



Injection in FFAG ring (2)

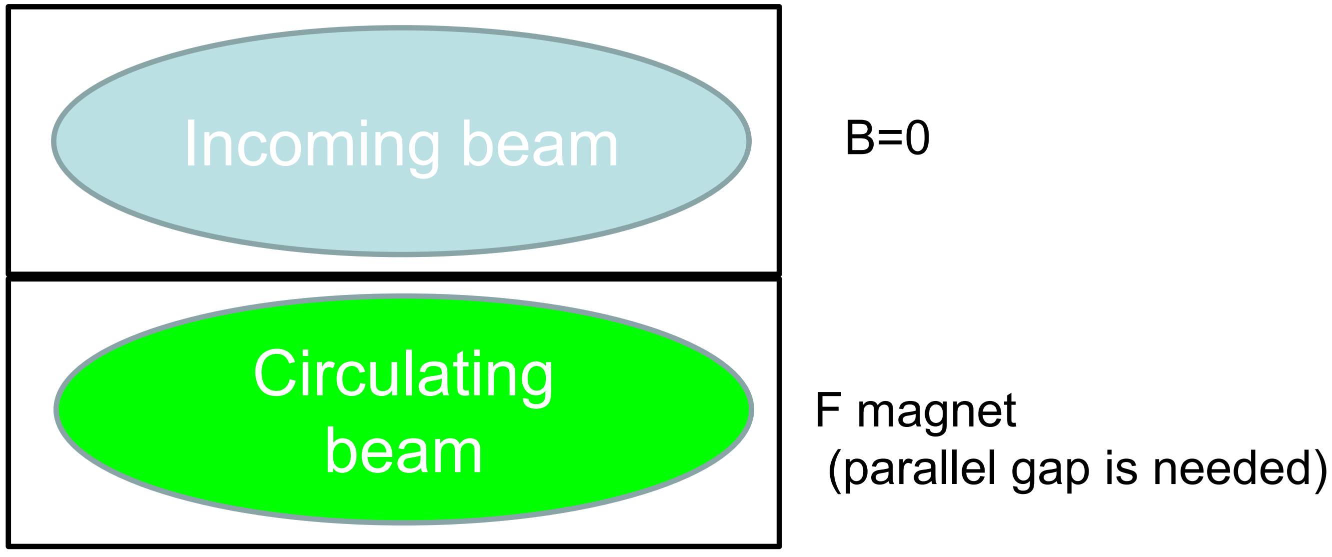
Alternative injection scheme

If we can switch off the F magnet…



Injection in FFAG ring (3)

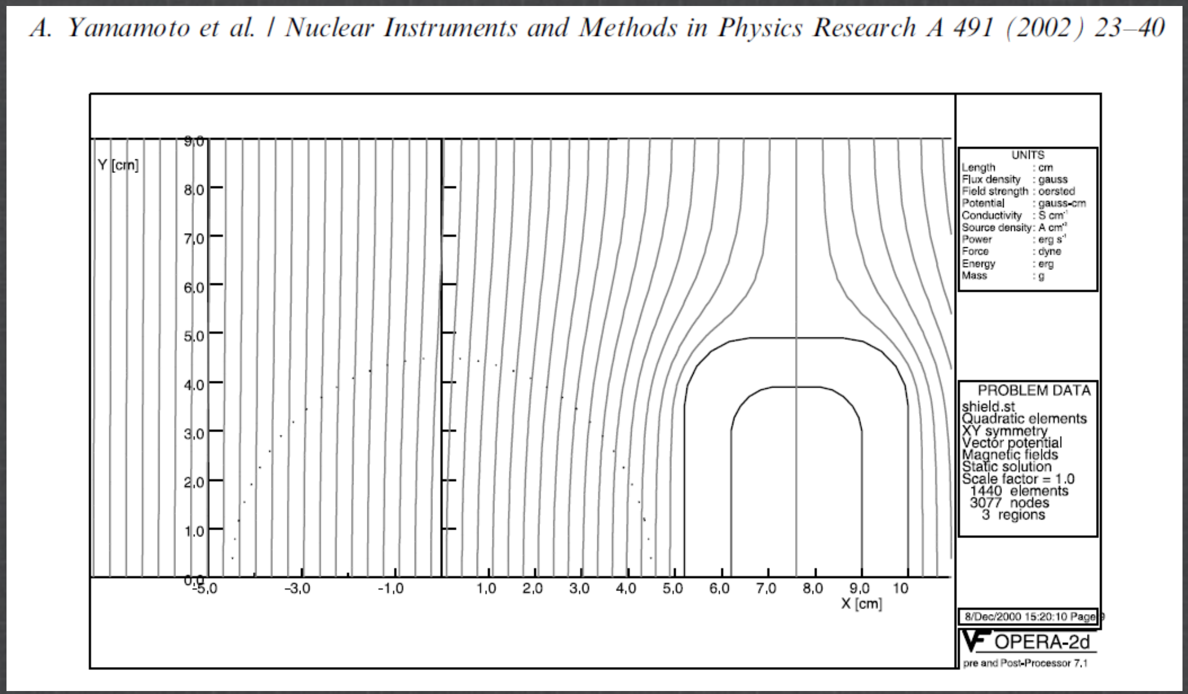
Alternative injection scheme



Beam can be put on orbit (injected) using kicker(s).

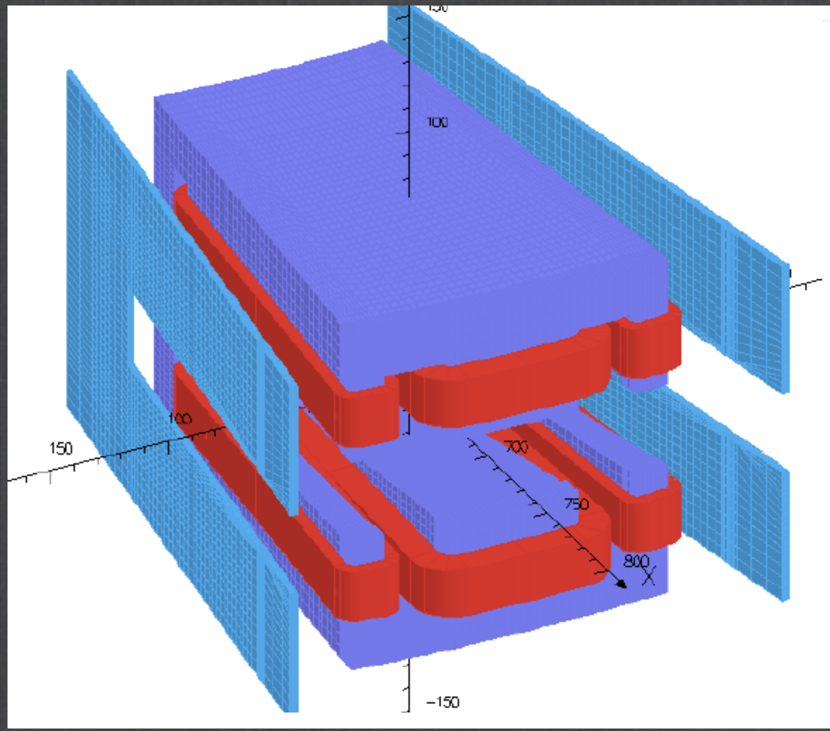
Inflector, flux shielding channel?

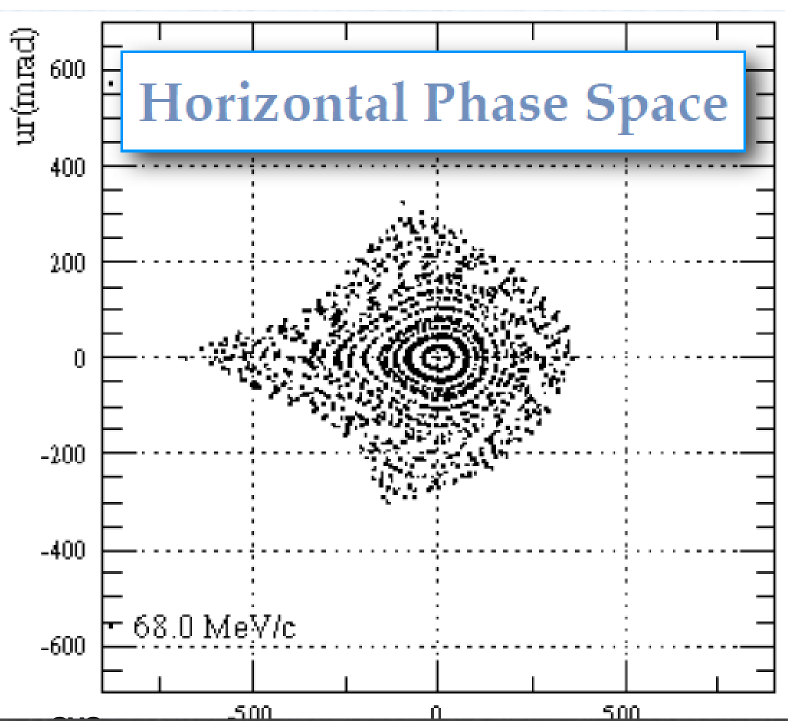
Inspiration from g-2 experiment:

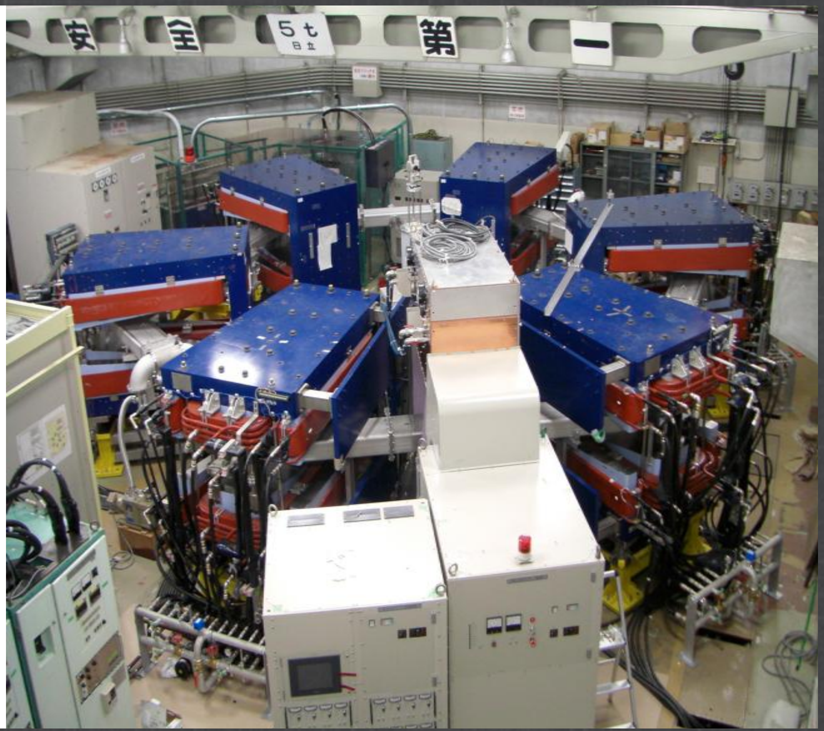


Phase rotator (1)

- 10-cell DFD FFAG ring designed at RCNP, Osaka University.
- FFAG magnet designed, manufactured and tested.
- Phase rotation principle demonstrated with α particles.
- Problems of injection/extraction.

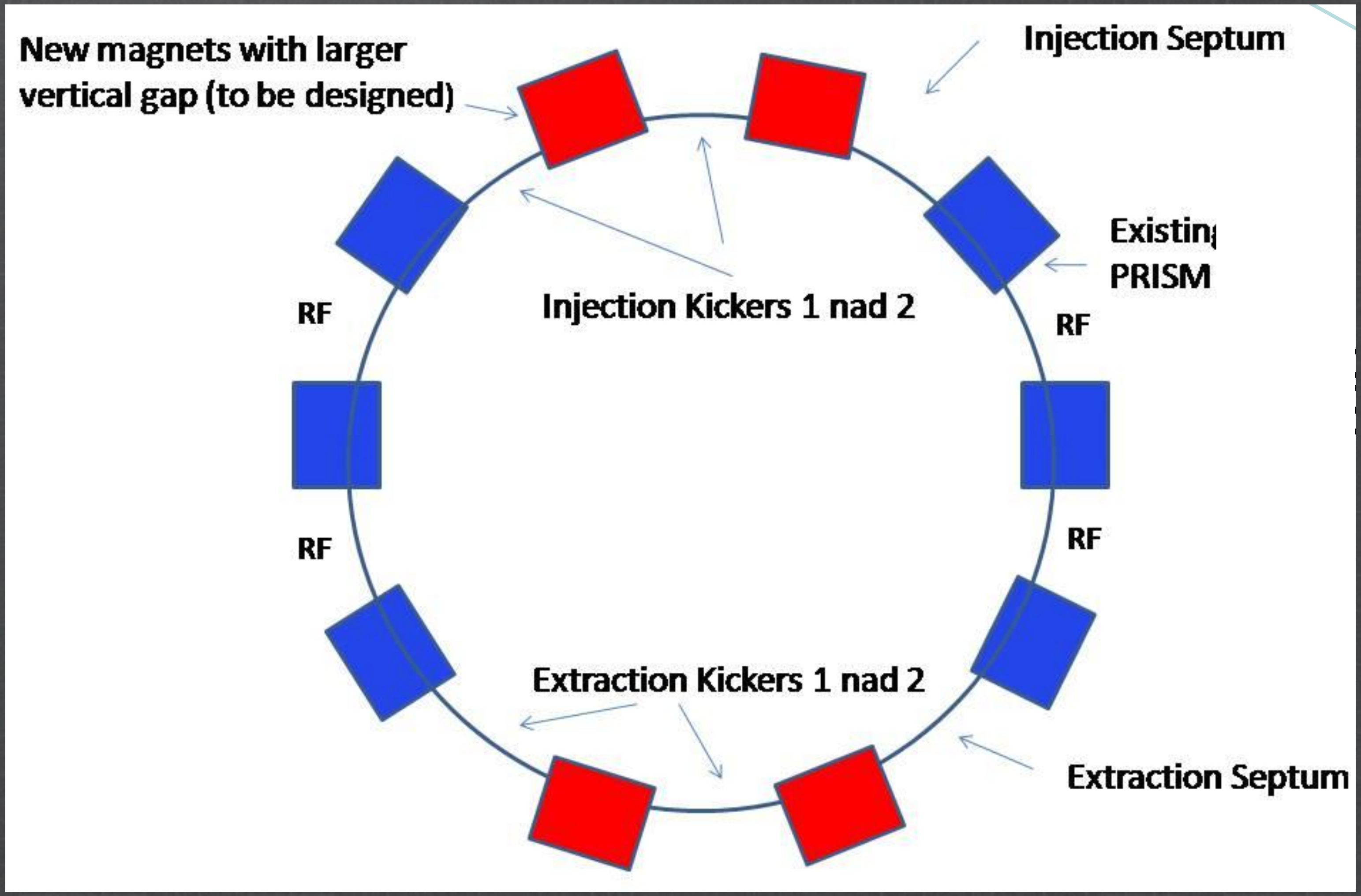






Phase rotator (2)

- Development of insertions with larger vertical gap magnets needed in this configuration.



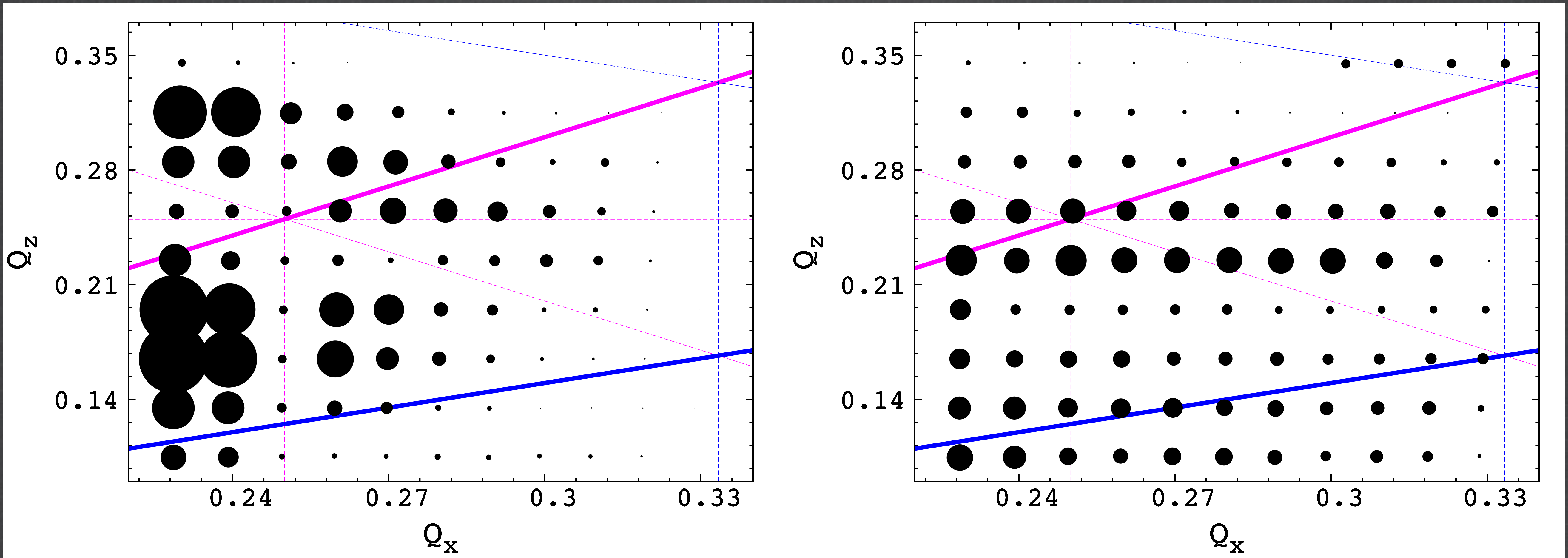
- Possibility to restore the dynamical acceptance.

Phase rotator (3)

Study of DA for new design

10-cell FDF FFAG

Horizontal | Vertical

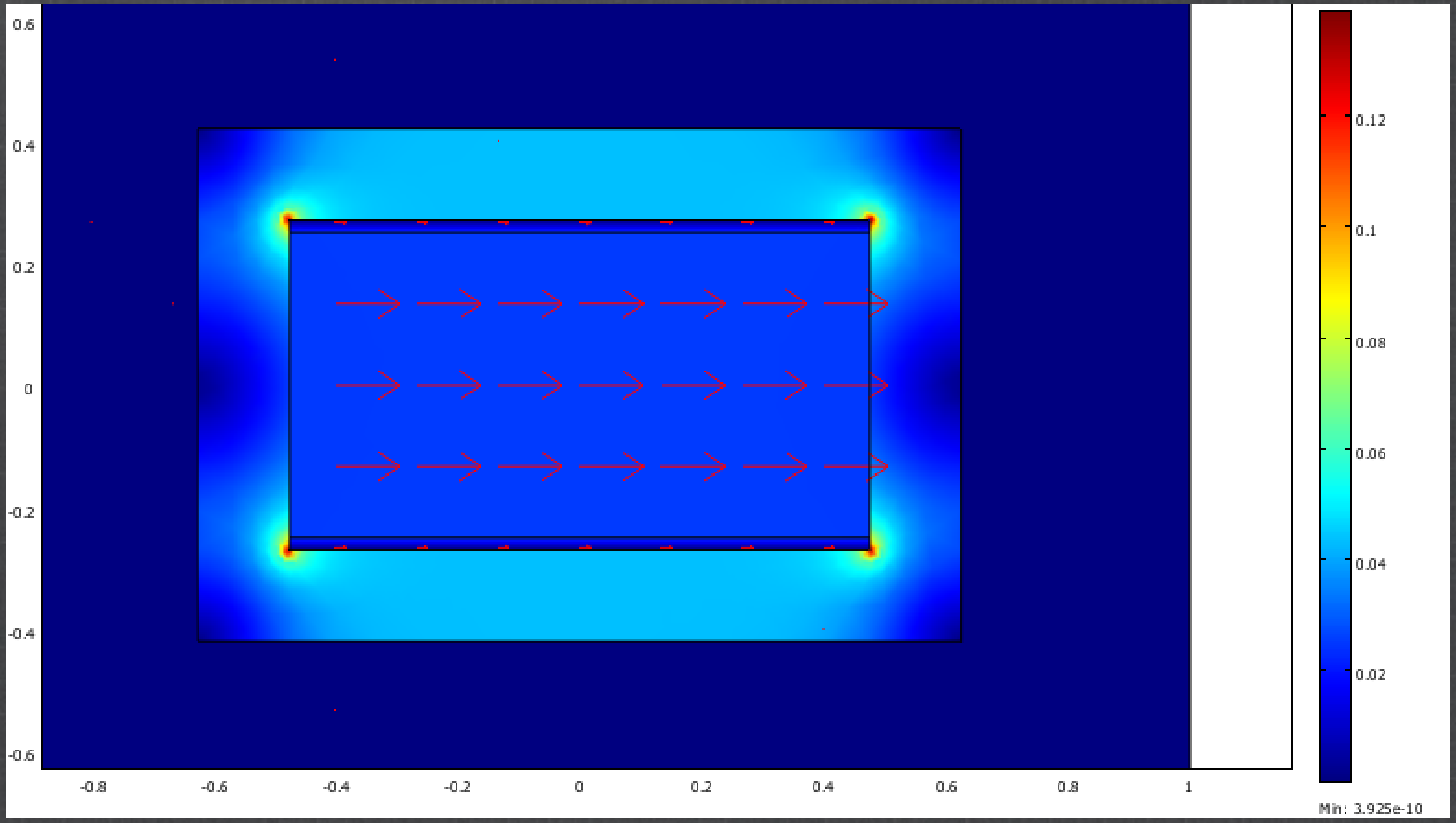


>50/>3 mm.mrad (H/V) achieved.

Kicker study

Preliminary

- Flat top 40/210 ns (injection/extraction)
- rise time 80 ns (for extraction)
- fall time ~200 ns (for injection)
- length=1.6m
- B=0.02T
- Aperture: 0.95 m x 0.5
- Wmag=186 J
- L = 3 μH (preliminary)
- Imax=16kA



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Conclusion (1)

- PRISM/PRIME aims to probe cLFV with unprecedented sensitivity (single event - 3×10^{-19}).
- The reference design was proven in many aspects (phase rotation, magnet design, RF system, etc.) in the accelerator R&D at RCNP, Osaka University.

Conclusion (2)

- Vertical injection is proven to be very challenging due to huge perturbation caused by the septum magnet(s). It seems we need a new idea for PRISM injection.
  - Concept of the inflector vertically separated effectively “switching off” one of the magnet followed by vertical kicker looks interesting.
  - The difficulty is pushed from optics into the magnet design.
  - This design needs a careful consideration before any conclusion can be formulated.

Thank you for your attention

The PRISM Task Force welcomes you!