Injection/extraction studies for muon FFAG

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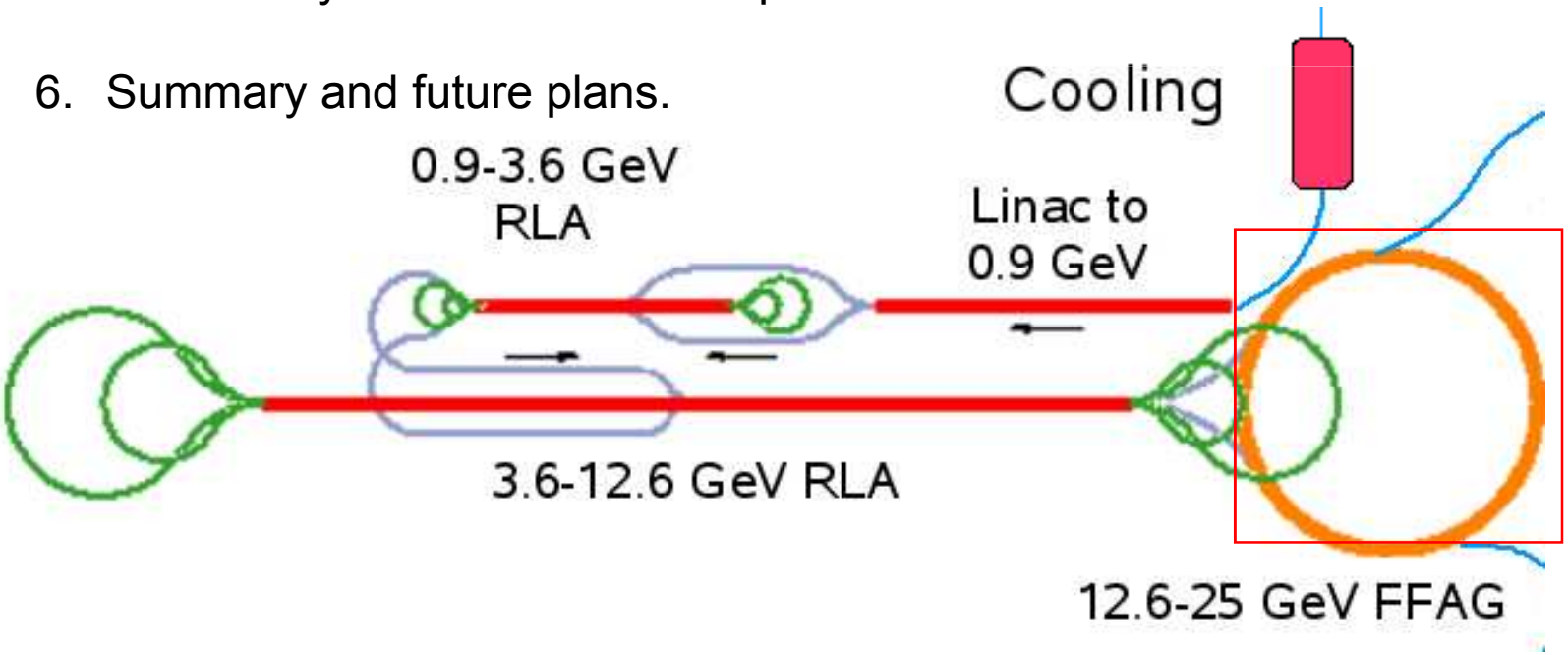
Outline

1. Introduction.
2. Injection and extraction for FODO.
3. Injection and extraction for Triplet.
4. Effect of special magnets
5. Preliminary muon FFAG kicker parameters.
6. Summary and future plans.



Introduction

Motivations for Non Scaling FFAGs as muon accelerators:
- quasi-isochronous –enables high frequency RF
- linear fields – gives huge DA and allows for simple magnets
- small orbit excursion – cost effective

Main problems:
- TOF with amplitude
- beam loading
- injection/extraction

Lattice choice FODO:
- cost-effective,
- allows for symmetric injection/extraction,
- but short drift

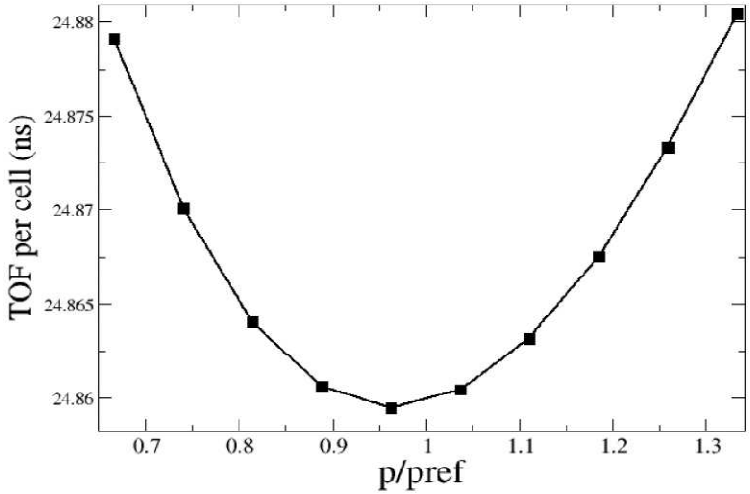
Triplet:
- more difficult,
- allows for symmetric injection/extraction,
- but longer drift

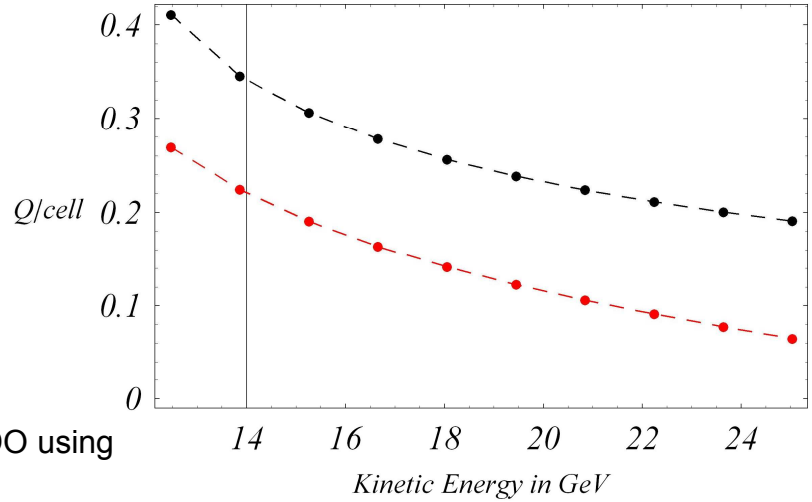
Parameters

	FCDC	FDCC	FDFCC	FDC	FDFC
Cells	62	62	55	77	70
D radius (cm)	9.5	10.2	12.5	7.7	9.2
D field (T)	7.6	8.3	7.3	8.1	7.7
F radius (cm)	20.7	20.3	16.7	14.0	12.2
F field (T)	3.4	3.1	3.9	4.0	4.2
Circ. (m)	462	467	445	426	422
RF Volt. (MV)	1526	1424	1246	903	814
Decay (%)	3.5	3.8	4.1	5.4	5.9

Introduction (2)

- Tunes, orbits, revolution times, DAs have been reproduced.
- Codes, which can be used – Zgoubi, PTC, MAD-X-PTC, BeamOptics
- Fringe fields have to be taken into account.
- For injection/extraction studies correct tracking of large amplitude is essential.



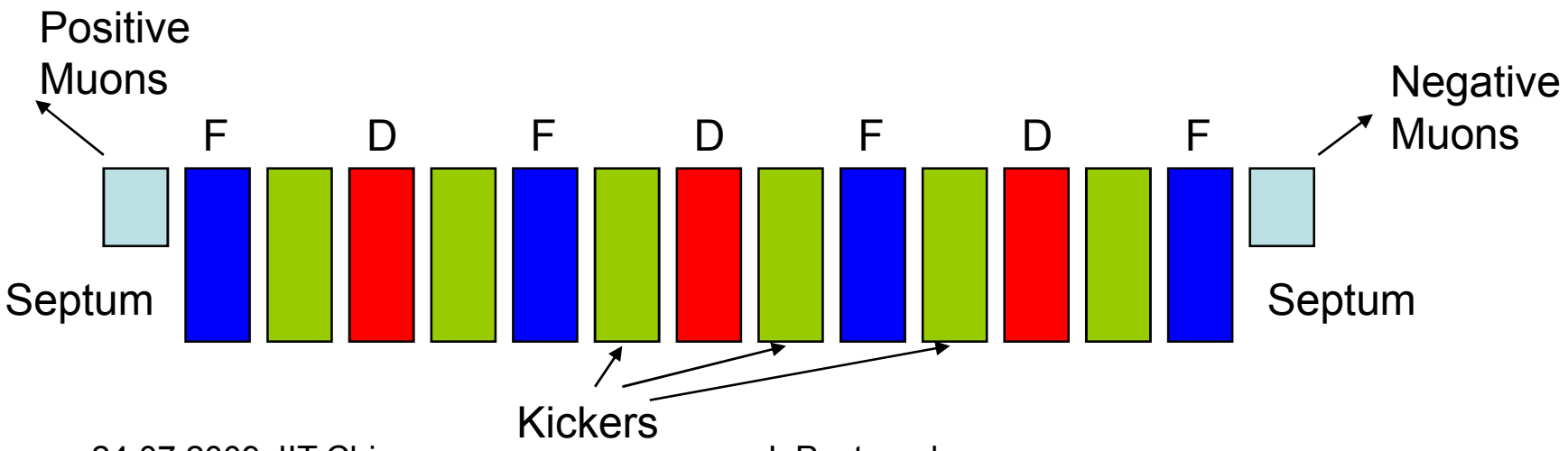


Comparison of tunes in FODO using Zgoubi and BeamOptics

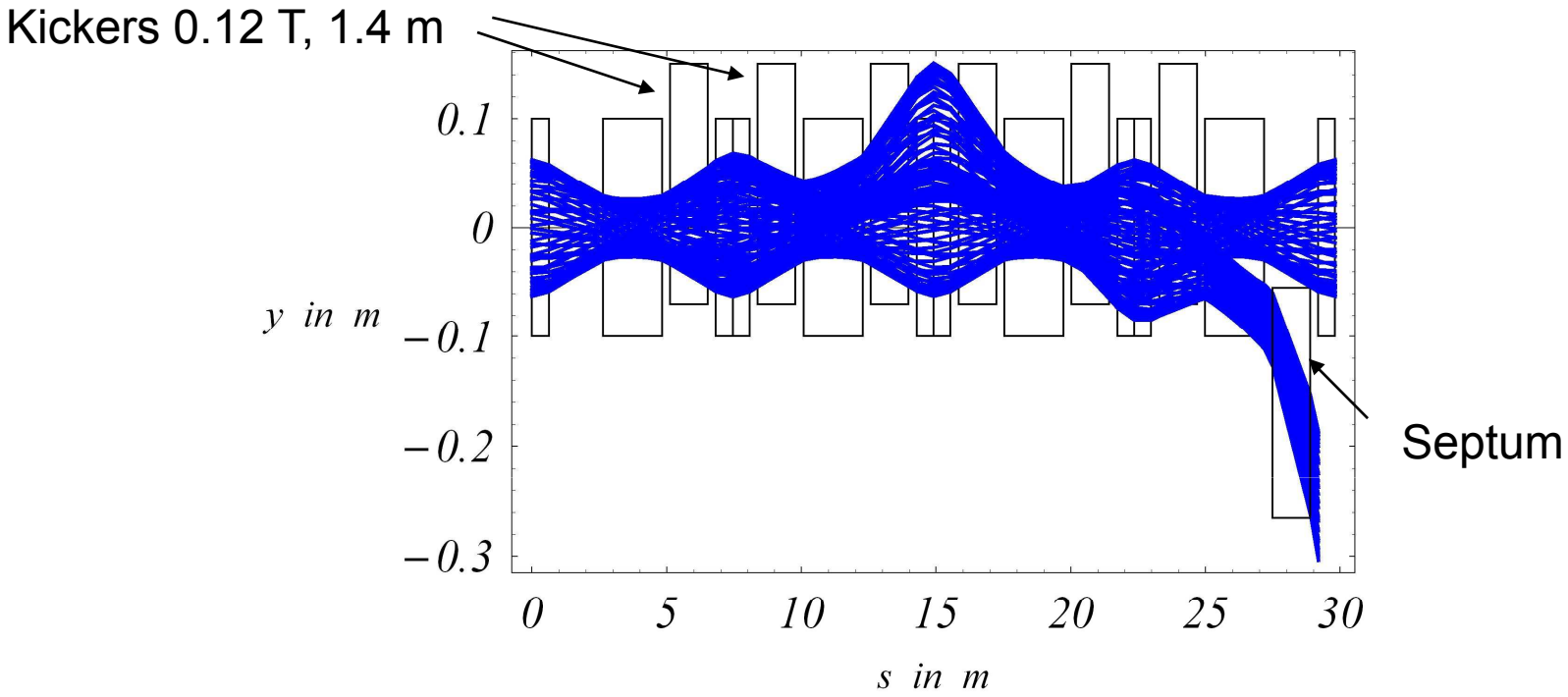
Introduction (3)

Working assumptions:

- Try to distribute kickers to reduce their strengths.
- Apply mirror symmetric solution to reuse kickers for both signs of muons.



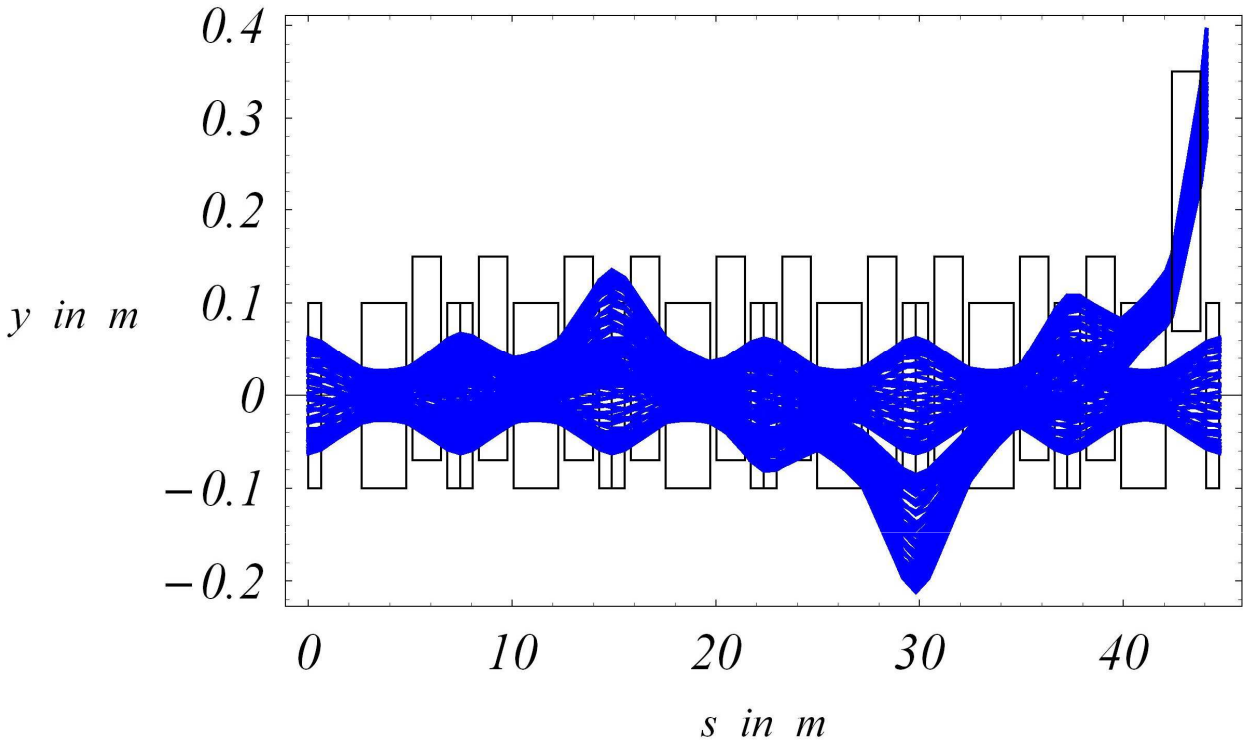
Vertical Injection into FODO



Parameters: 6 kickers (---+++) – 1.4 m, 0.12 T and septum – 1.4 m, 4 T.

- Does it require special magnets?
- More compact but requires stronger kickers
- Antisymmetric for both signs.
- No satisfactory solution for horizontal injection in FODO was found.

Injection -FODO (2)



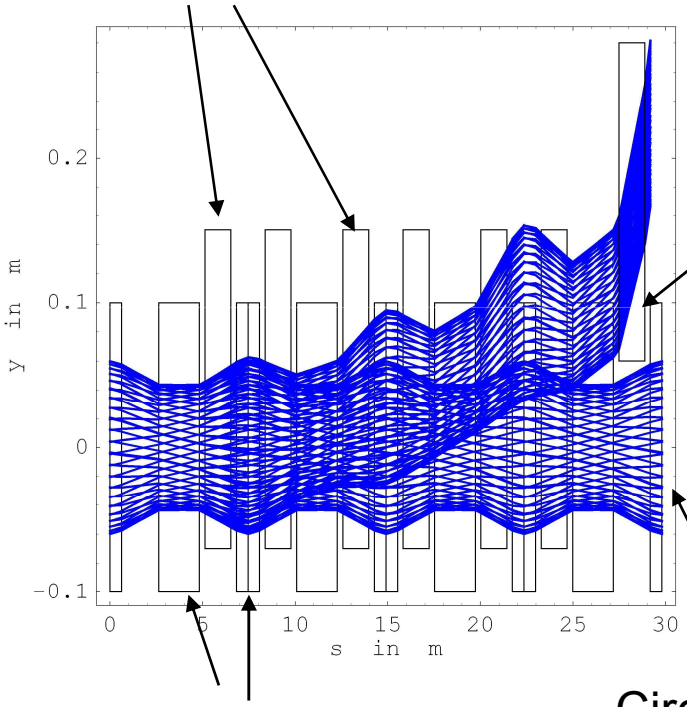
Parameters: 10 kickers – 1.4 m, 0.08 T and septum – 1.4 m, 2.5 T.

- Does require special magnets!
- Long but requires weaker kickers.
- Symmetric for both signs.

Extraction from FODO ring

- No satisfactory solution was found in horizontal plane
- The scheme using vertical plane requires special magnets
- Symmetric for both signs.

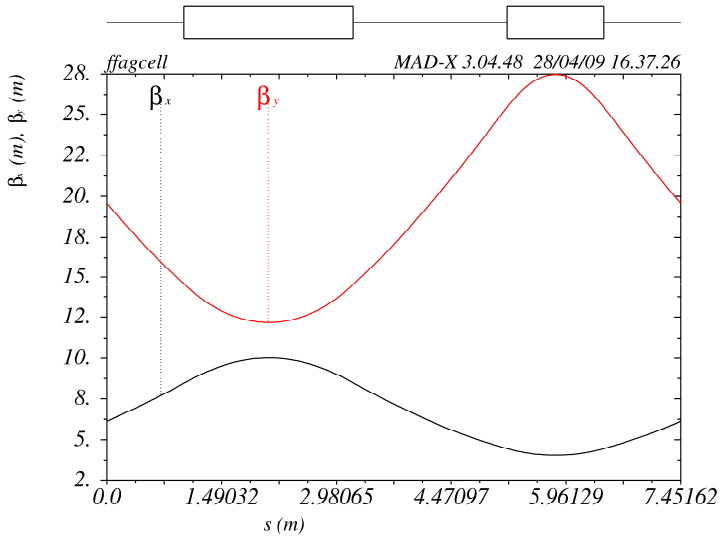
Kickers 0.1 T, 1.4 m



Septum, 4 T, 1.4 m

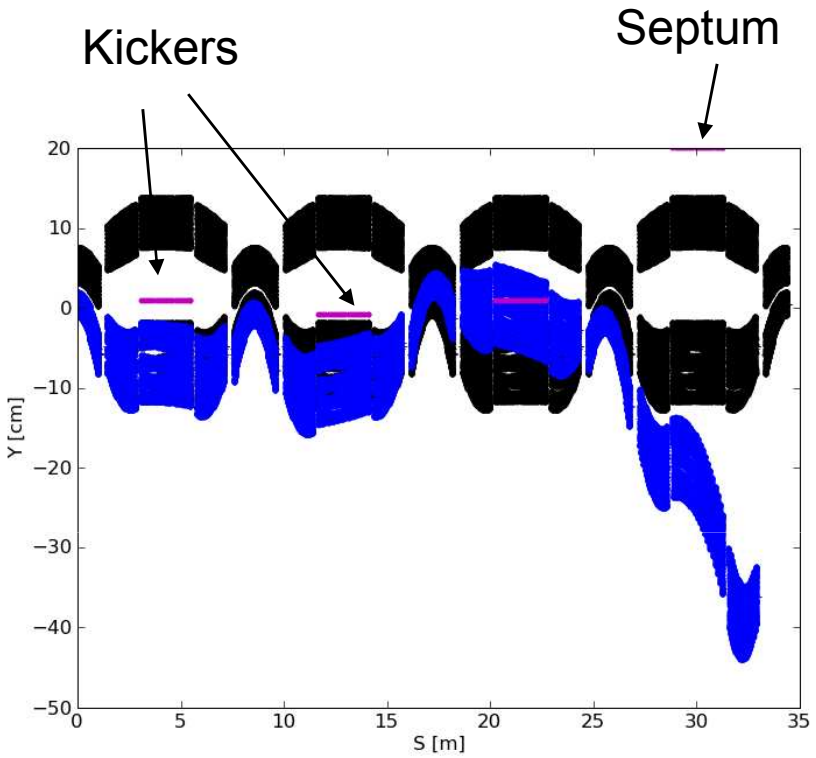
Main Magnets

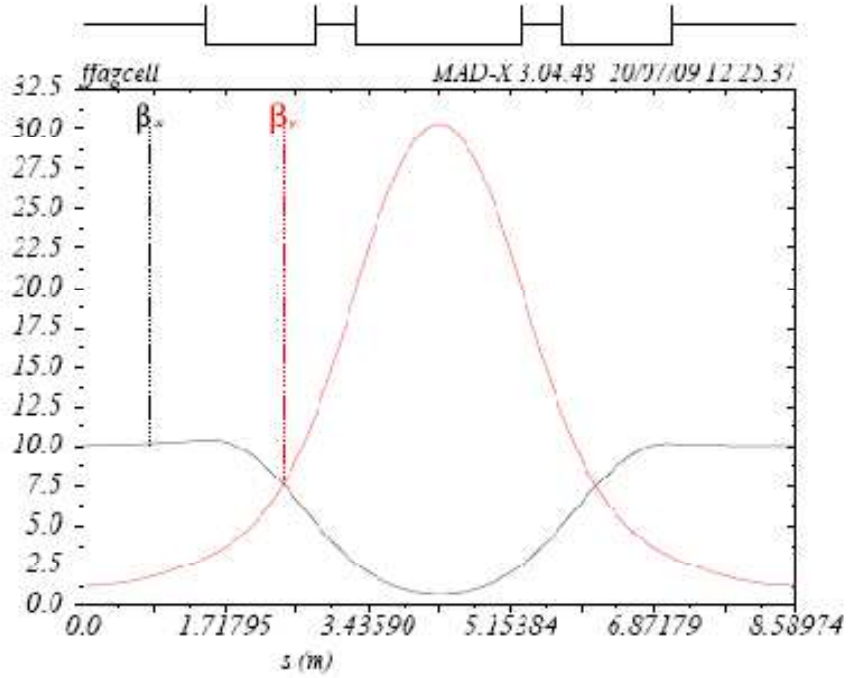
Circulating 25 GeV Beam, 3 cm emittance



Twiss functions in FODO at extraction

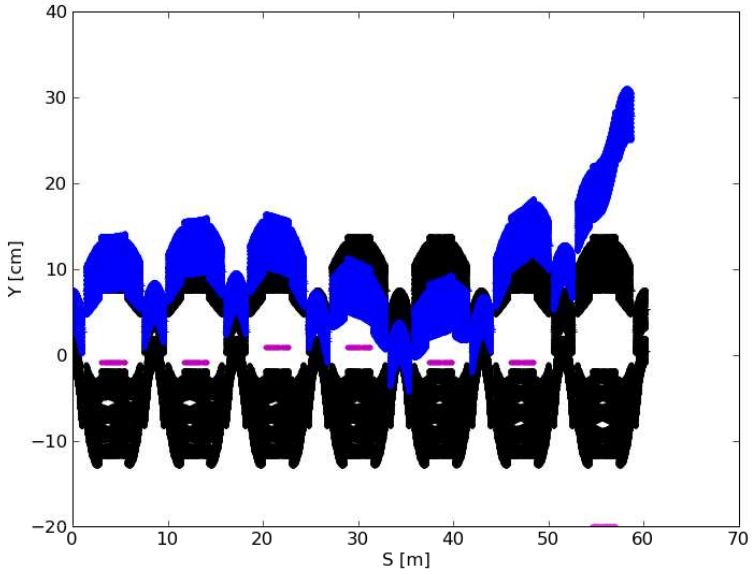
Injection - Triplet

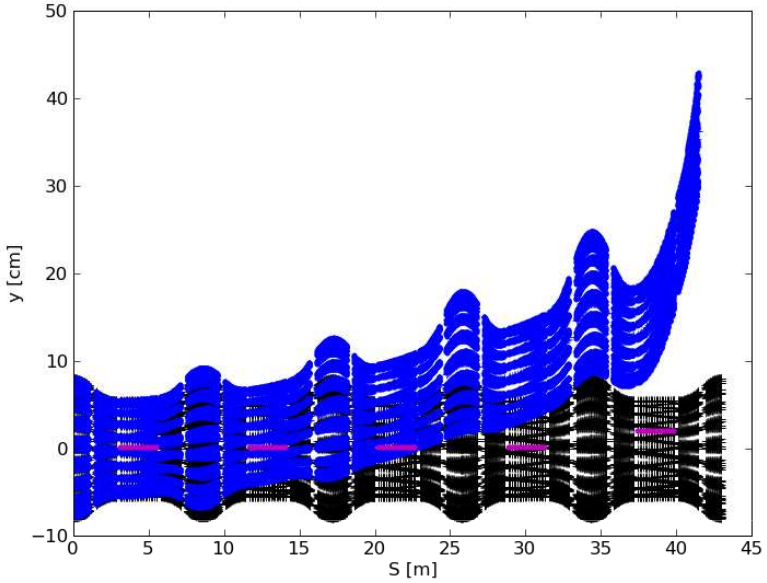




- Horizontal scheme is feasible in trilet.
- Scheme is less demanding with respect to special magnet needs.
- It uses 3 2.4 m long kickers at 0.0855 T and the 2.4 m long septum at 2 T.

Extraction - Triplet





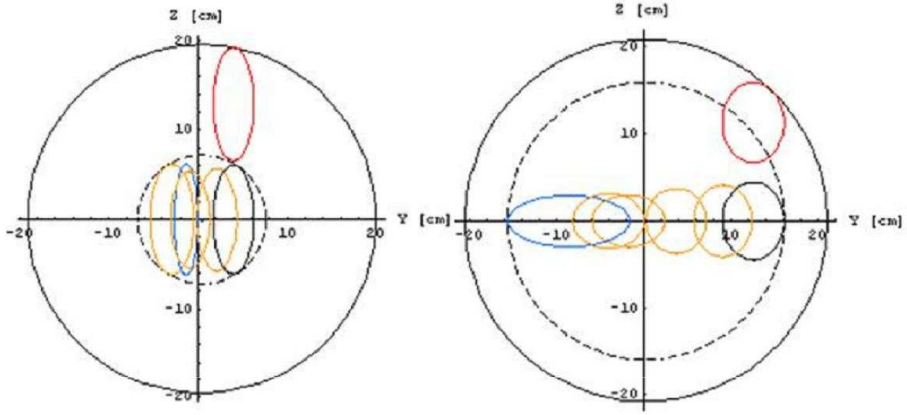
- Horizontal extraction is rather long.
- It needs 6 kickers 2.4 m long at 0.085 T.
- Special magnet needs is not so dramatic.

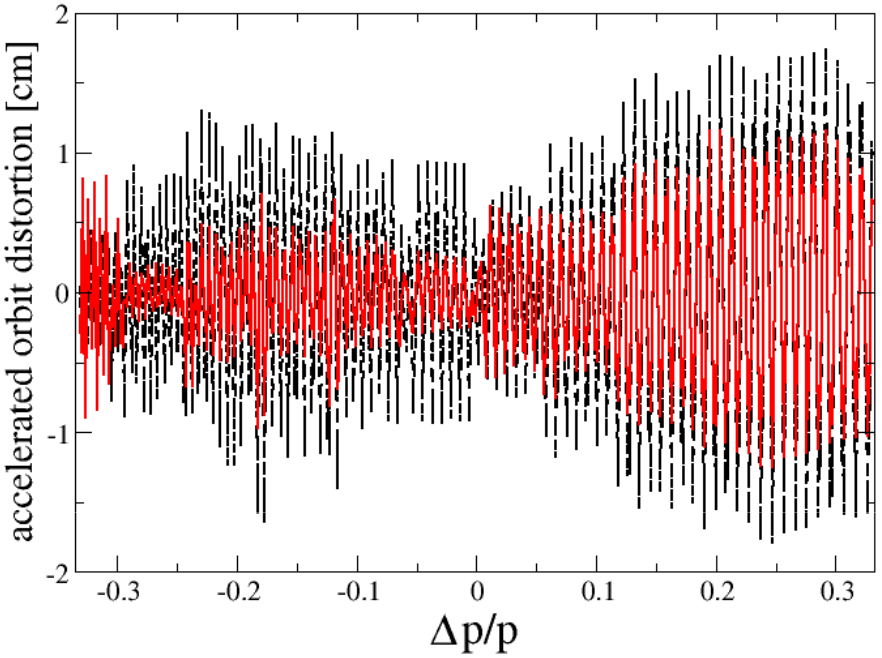
- Vertical extraction is more compact.
- It needs 4 kickers 2.4 m long at 0.08 T.
- Special magnets are needed!.

Summary of parameters for injection/extraction

Scheme	Injection I FODO	Injection II FODO	Extraction I(II) FODO	Injection Triplet	Extraction I Triplet	Extraction II Triplet
Plane	vertical	vertical	vertical	horizontal	horizontal	vertical
No. Kickers	6	10	6 (4)	3	6	4
Kicker top magnetic field	0.12 T	0.08 T	0.1 T	0.0855 T	0.085 T	0.08 T
Septum field	2.5 T	2.5 T	4T	2 T	2 T	2 T
Kicker/septum length	1.4 m	1.4 m	1.4 m	2.4 m	2.4 m	2.4 m
Mirror symmetry	(-)Yes	Yes	Yes	Yes	Yes	Yes
Cells needed	4	6	4 (3)	5	8	6

Effects of special magnets





- Beams close to septum push the magnet aperture.
- Special magnets with higher aperture is needed in injection/extraction regions.
- Those magnets introduce the ring lattice symmetry breaking, which can cause accelerated orbit distortion.
- Current studies show that the effect is not dramatic, but more simulations are needed.

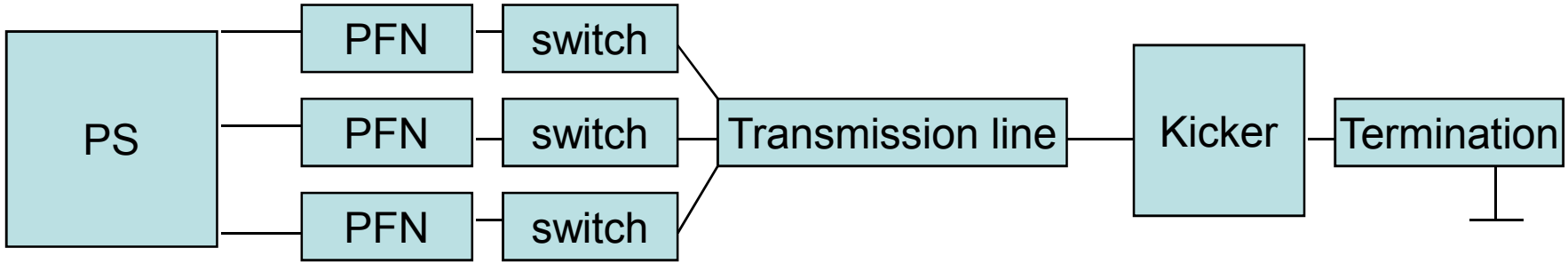
What are the kicker parameters?

FFAG IDS kicker (preliminary):
- size HxV (~ 0.3 x~ 0.3 m),
- field 0.1 T,
- I~ 27 kA,
- V~38 kV,
- rise time 1.5 us
- length 1.4 m

CERN LHC extraction kicker:
- size HxV (0.056 x 0.056 m),
- field 0.34 T,
- I~ 18.5 kA,
- V~30 kV,
- rise time 2.85 us

Preliminary ideas for kicker R&D?

- 3 independent Pulse Forming Networks (PFNs) and switches are needed for every muon train.
- Termination is very important to avoid reflections back to magnet (for injection).
- Current is most likely to high for thyratrons, but IGBTs should be OK as switches.
- We want to push conventional kickers, but may also look at new ideas.
- Kicker R&D are just starting for FFAG accelerators within IDS!



Some comments obtained:

- These kickers are still difficult due to large aperture!
- The superconducting setum will be difficult in operation.
- You may need to shield kickers from the magnetic field.

Summary and Future Plans

- Beam dynamics in Scott's FODO and Triplet has been studied with good results.
- We have a first geometry for both injection and extraction, but its feasibility still needs to be shown!

- More tracking is needed (fringe fields, accelerated orbit, etc.).
- Alternative scheme based on insertion schould be studied.
- R&D activity for kicker and septum is just starting.