Imperial College London

Science & Technology Facilities Council ISIS

Front End and Injection Options for FFAG

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Outline

- Introduction
- Full aperture injection for the FFAG decay ring
- Decay channel design
- Matching from the horn
- Matching into the ring
- Comments on stochastic injection
- Summary and future plans

Introduction

nuSTORM is a very interesting project:

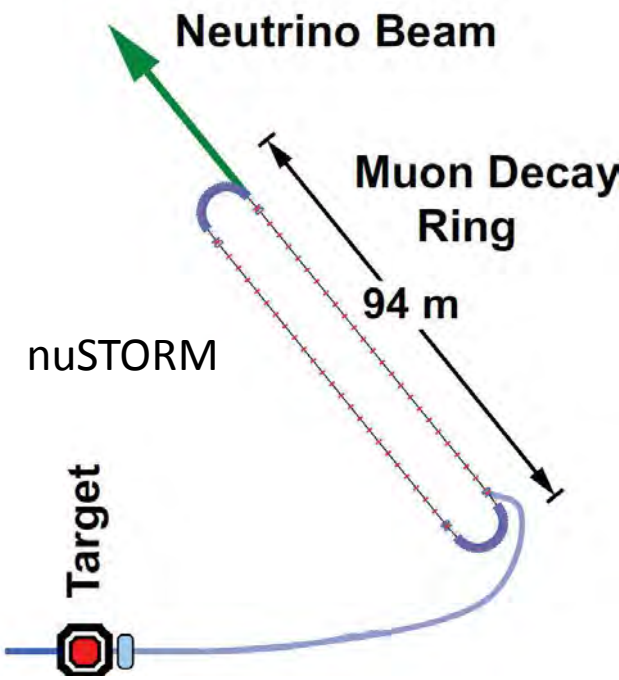
- It has a very strong physics case (sterile neutrino search, precise cross section measurements and more...)

- It may serve as a demonstration for the Neutrino Factory (muon storage ring based neutrino experiment), but also for a generic future muon accelerator.

- It may become an ideal test for accelerator and detector techniques needed in a future.

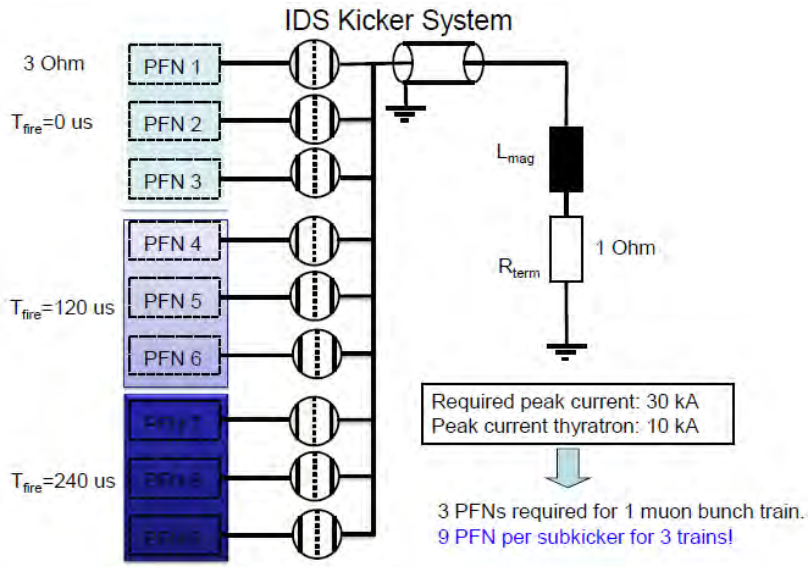
- NuStorm may become the first muon FFAG

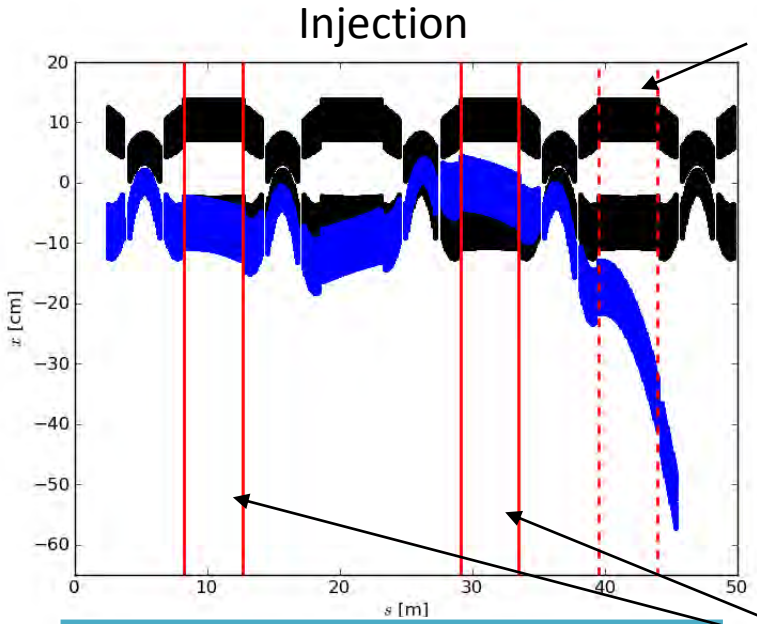
- ... or may have other potential uses (beam formation for an advanced muon cooling demonstration).



Introduction (2)
Muon FFAG for IDS-NF

•FFAGs are very attractive for muons as:
-They have a huge transverse and longitudinal acceptance
-Can perform very rapid acceleration
-Can be constructed with the present-day technology (most of designs).
-Can offer higher performance!





Injection	
Plane	Horizontal
No. Kickers	2
Kicker field (T)	0.089
Kicker Polarity	**+0+**
Septum field (T)	0.92

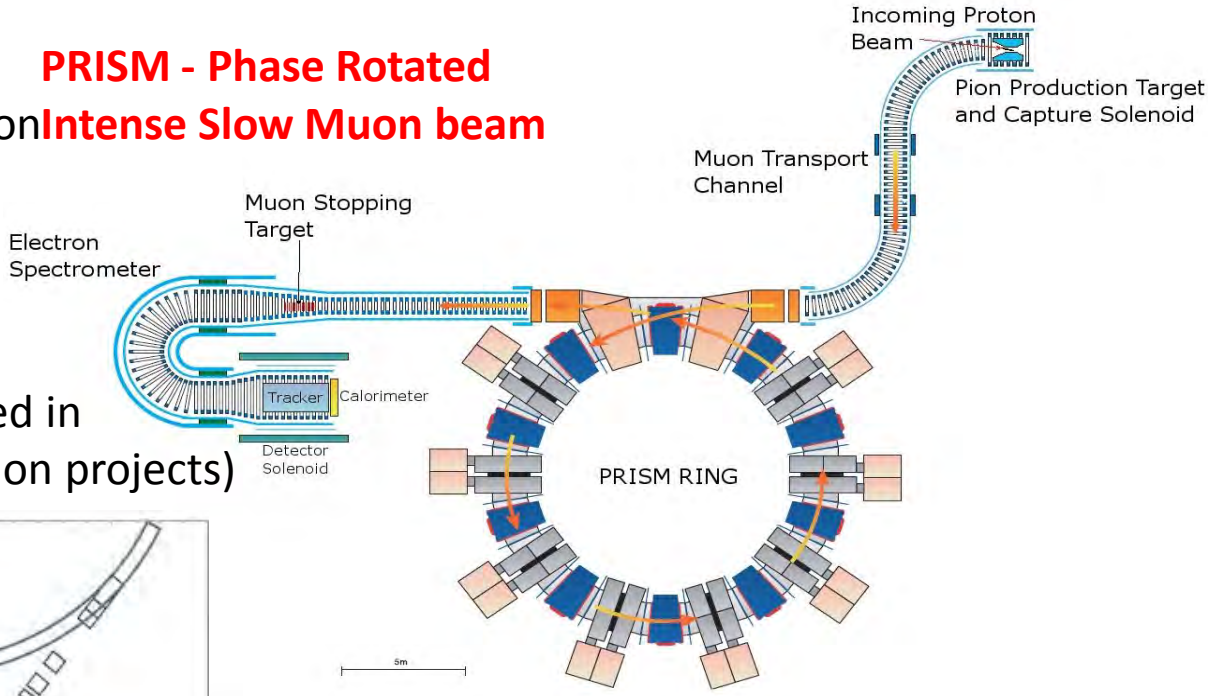
•We designed NS-FFAG for muon acceleration for IDS-NF including injection system.
• We believe it can be constructed and operated!

Introduction (3)

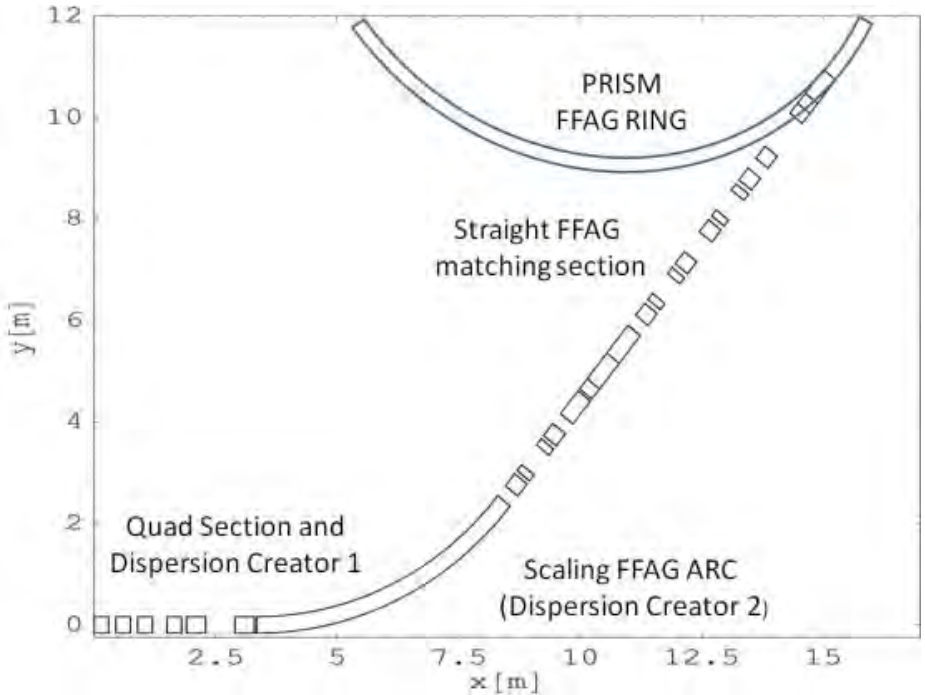
Muon FFAG Studies for PRISM

- PRISM Task Force designed the scenario for muon beam injection into PRISM FFAG with very large emittance and momentum spread.
- Preliminary results show 97% transmission.
- nuSTORM injection can be designed in a similar way (synergy between muon projects)

PRISM - Phase Rotated Intense Slow Muon beam

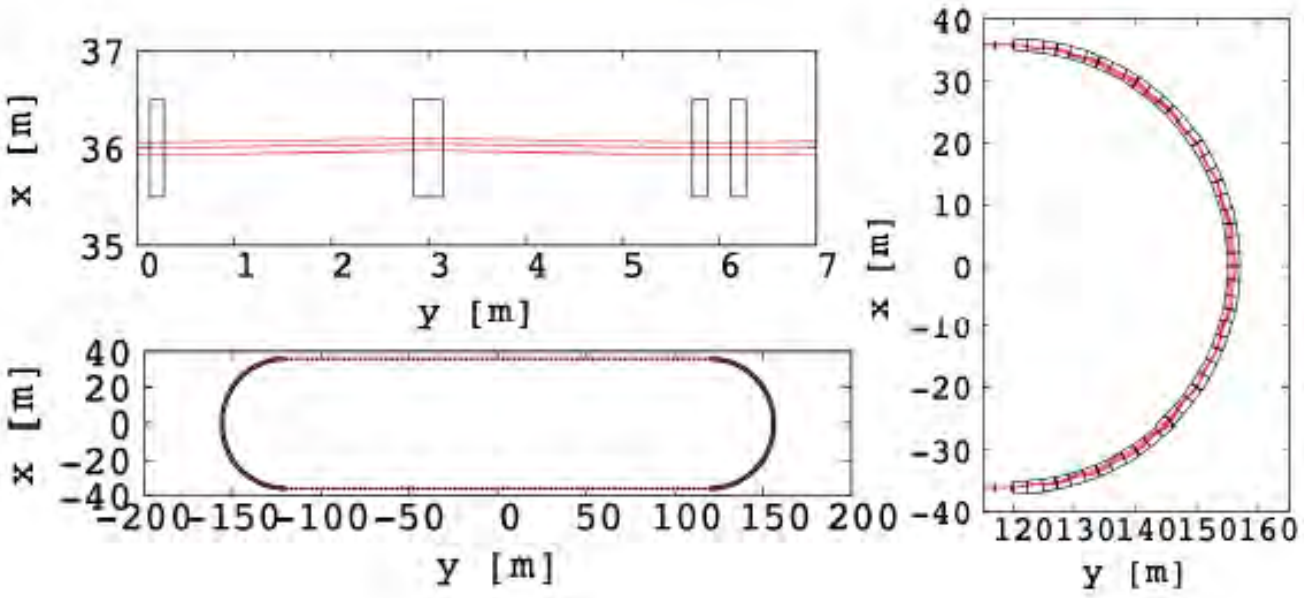


Layout of PRISM system

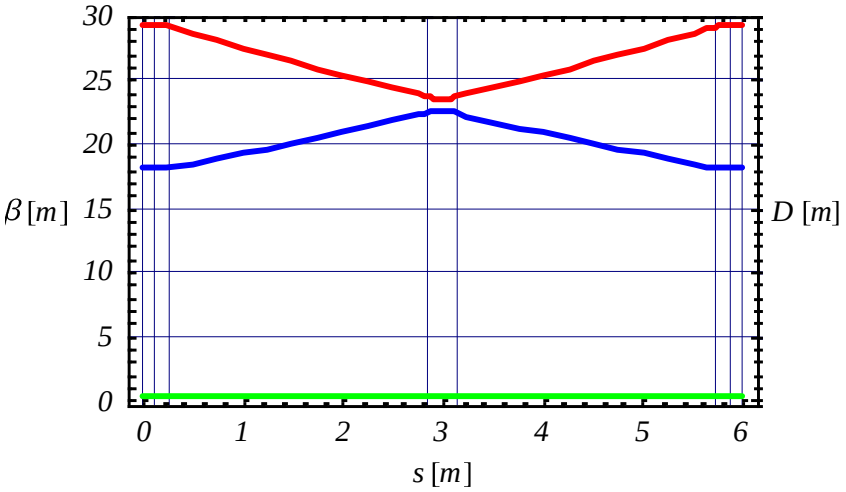


Layout of the PRISM front end and injection

FFAG Decay Ring for nuSTORM



Layout of Scaling FFAG option for nuSTORM (J-B. Lagrange, Y. Mori)



Modeling of straigh FFAG optics
in the production straight

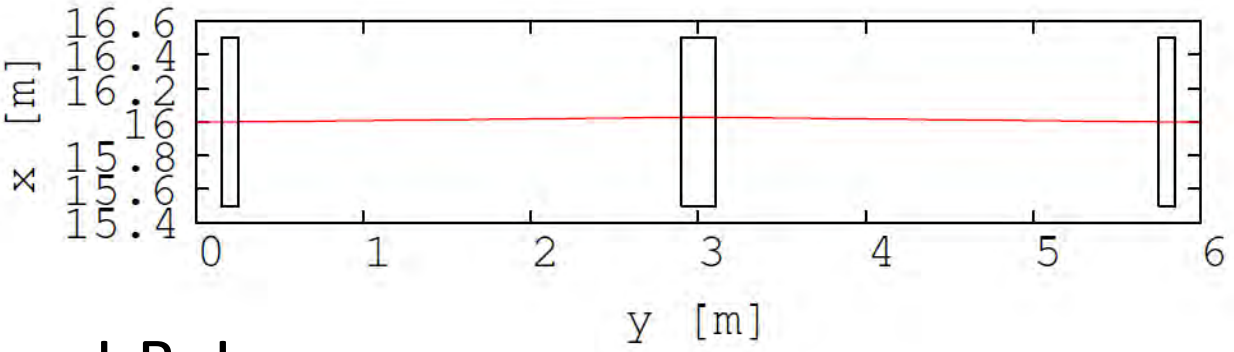
- Scaling FFAG offers superior performance (large acceptance and large momentum spread)
- Zero chromaticity allows for large transmission.
- Magnets can be constructed with current technology.

Assumptions and observations (2)

- The drift length in the straights are long (about 2.6 m) for the J-B. Lagrange/Y. Mori FFAG ring!
- They are ideal places to put kickers and septum.

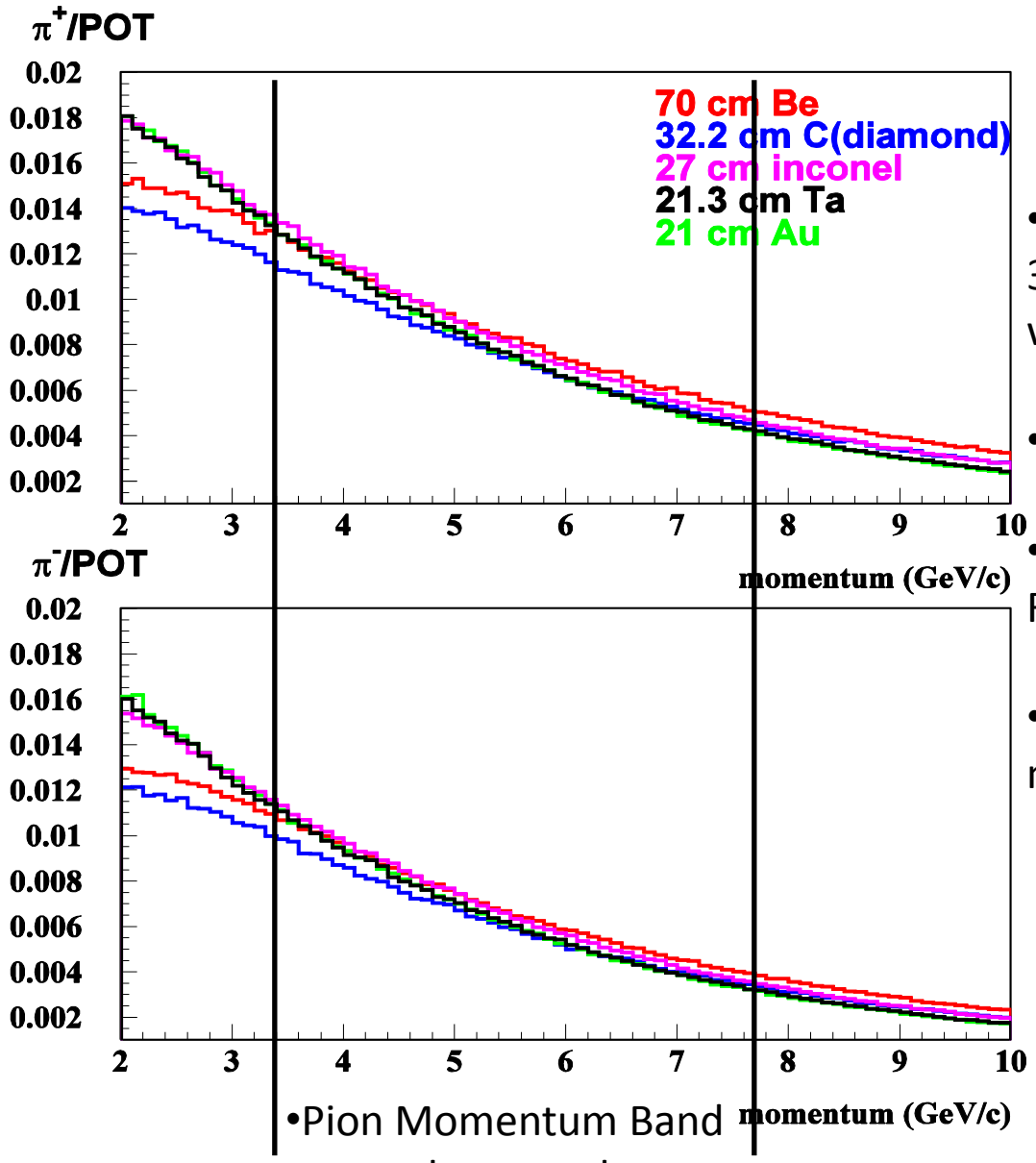
- I try to design injection system assuming that the muon beam is formed in the decay channel (no D. Neuffer's trick used).

- First we need a decay channel.



From J-B. Lagrange

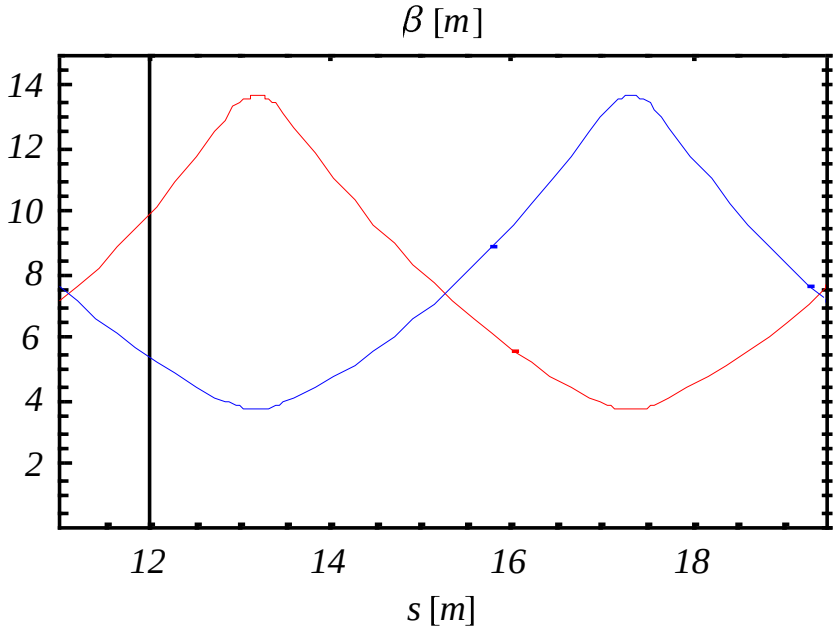
Considerations for decay channel



- Pion Momentum Band
- to produce good muons

- Pions in the momentum between 3.19 and 7.69 GeV/c can produce muons within 3.8 GeV/c ±16%.
- Mean momentum is ~5440 MeV/c.
- Spill needs to be 50% of the Decay Ring length
- To use those muons, the decay length needs to be about 210 m (~69%/39% of low/high energy pions decays).

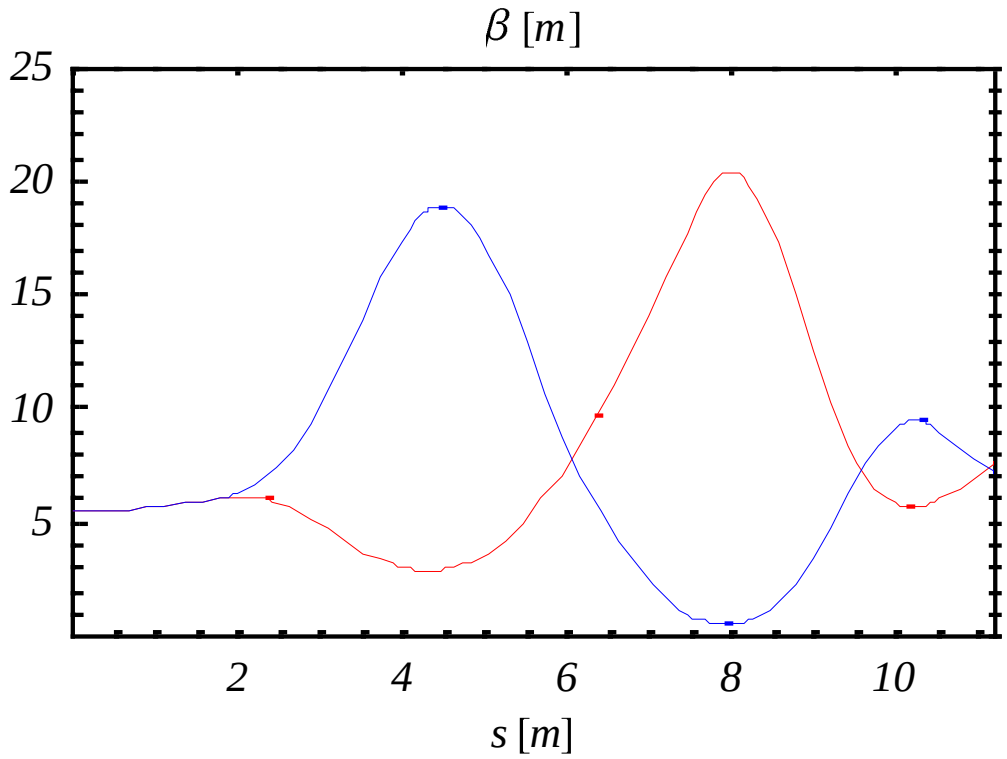
Decay Channel Considerations (2)



- Symmetric FODO type
- Cell length 8.3 m
- Quad length 0.65 m
- B field at the poles 1.4 T
- Half aperture 0.17 m -> Large quads!
- Central momenum 5440 MeV/c
- Momentum acceptance +-42%

  (for all pions contributing to the muons wanted-3.8 GeV/c+-16%, this means both forward and backward decays)
- Physical acceptance ~2 Pi.mm.rad
- Phase advance per cell 70 degrees
- Normal conducting quads

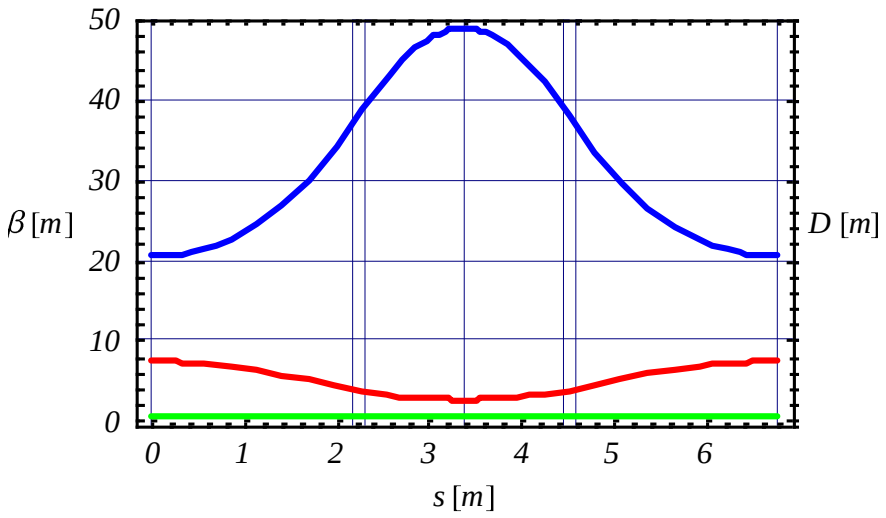
Matching with the horn

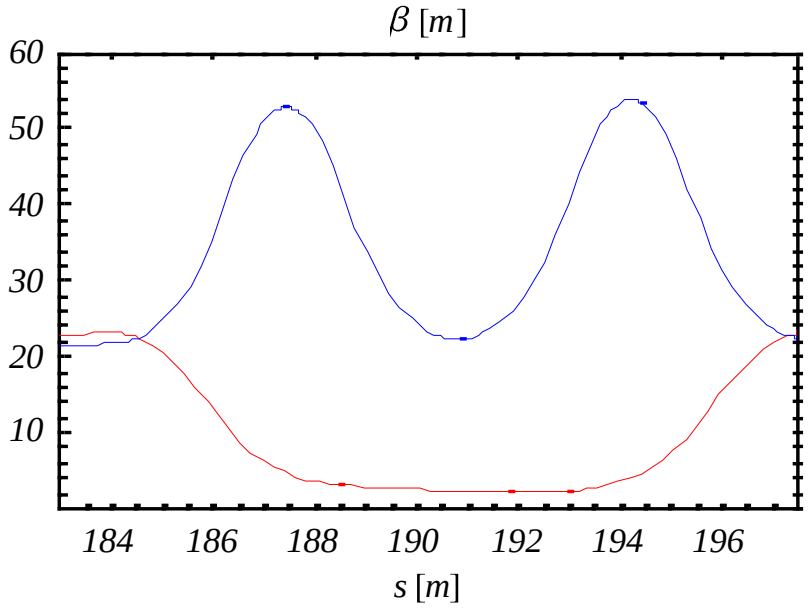


- Starting condition downstream the horn β=5.52 m, α=0.
- Consists of 4 normal conducting quads (max B about 2T).

Dispersion Creator to Match Ring Orbits

Symmetric optics

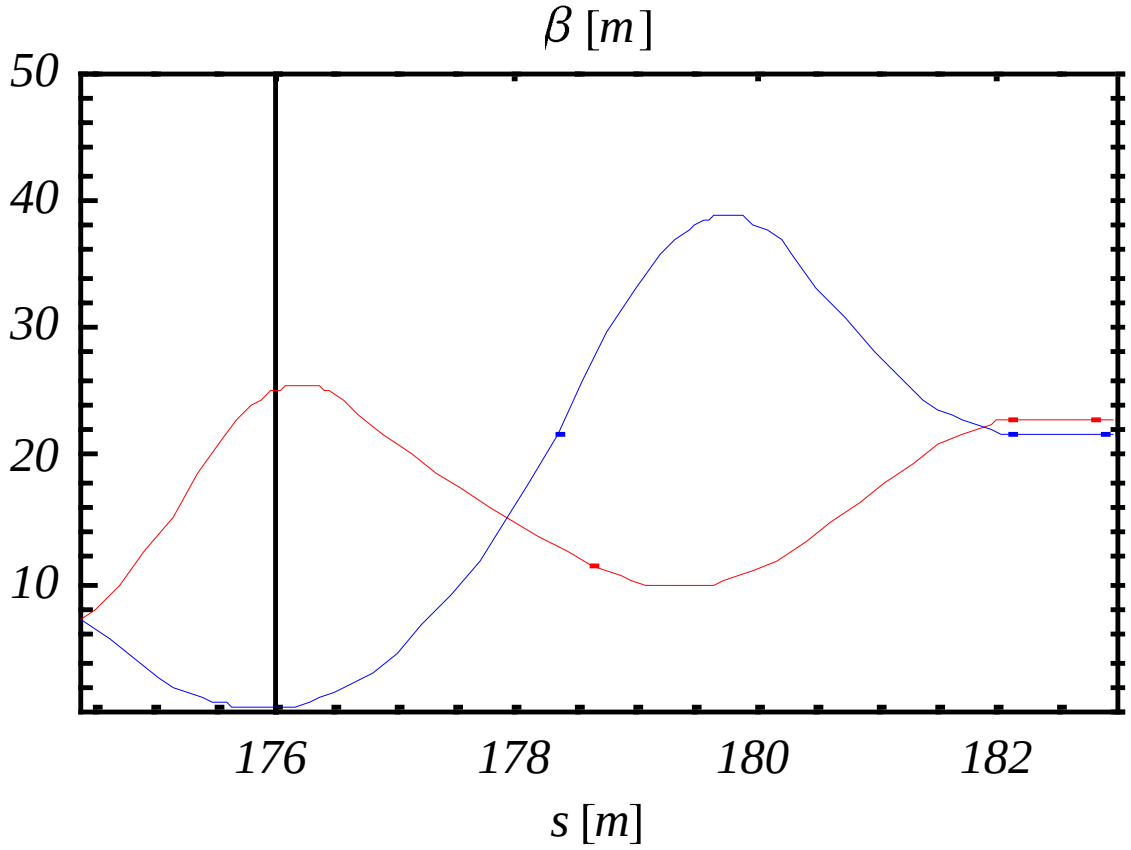




Optics included mismatch

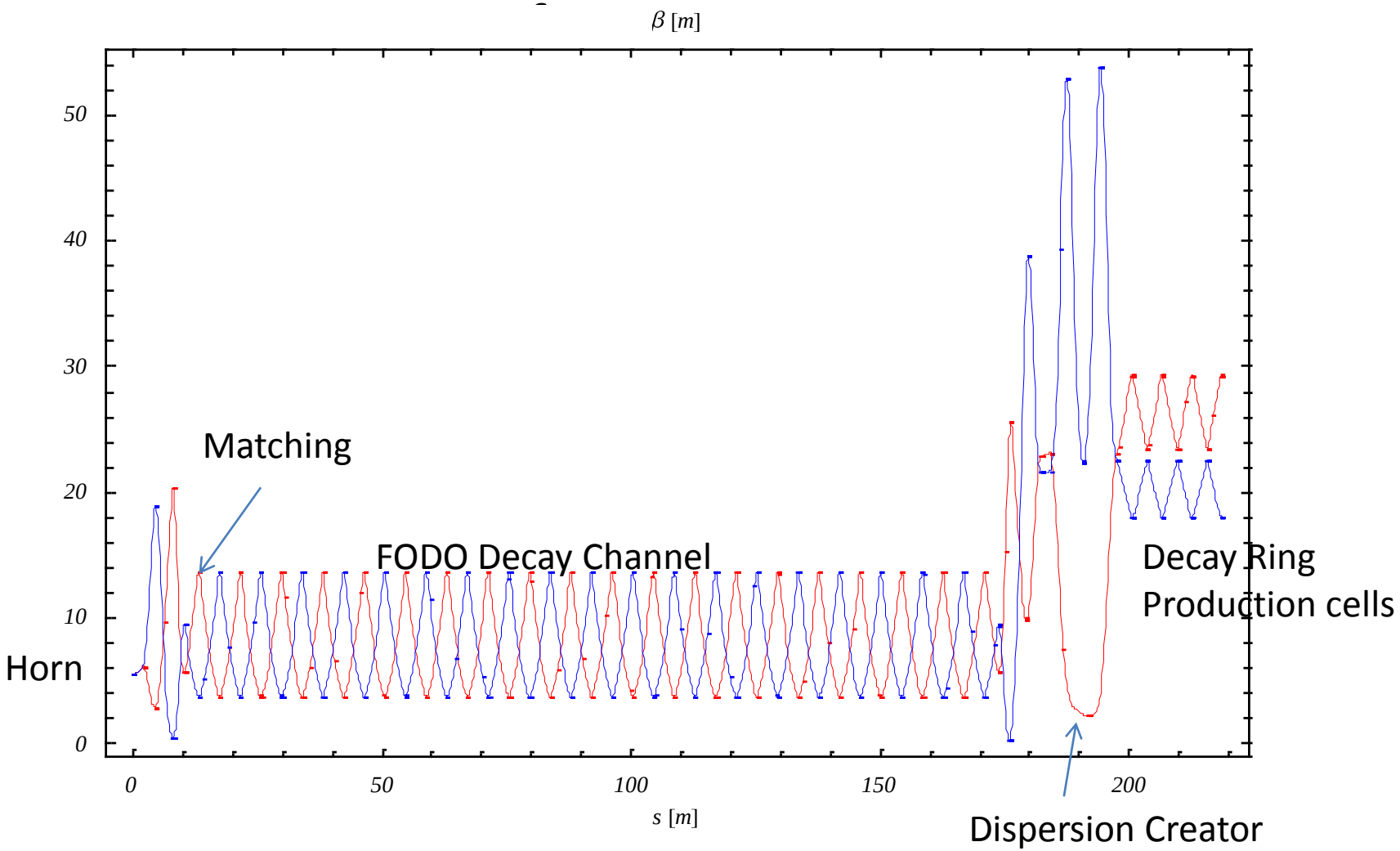
- 2 circular scaling FFAG cells
- 90% horizontal phase advance/cell
- R ~ 55 m
- Max B ~ 2 T (normal conducting)
- k 88
- Based on decay ring cell structure
- Effect of septum in beta matching is included.

Matching from FODO Channel into the Dispersion Creator



- Consists of 4 normal conducting quads (max B about 2T).

Optics in Pion/Muon Front End of FFAG decay

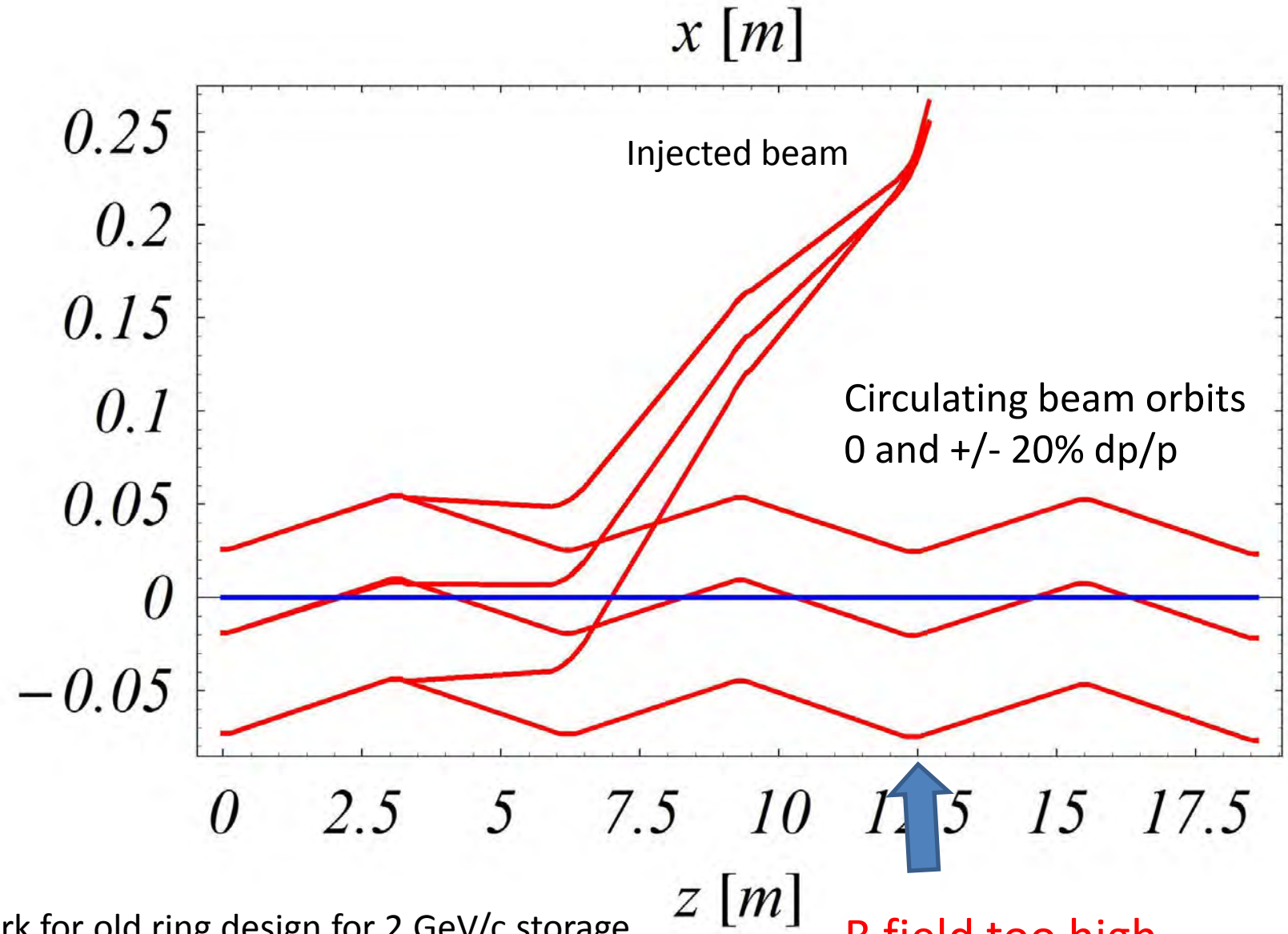


- Consists of only normal conducting magnets (max B about 2T).
- Matching at 5.44 GeV/c (in reality an adiabatic transition to 3.8 GeV/c at the end of FODO is needed.

Preliminary injection

- The long drifts are the natural place for septum and kickers.
- Kickers must be distributed (the more the weaker they are), but the matching conditions can be more difficult.
- Optics of the drift has been reproduced and zero chromaticity condition confirmed.
- Closed orbits have been calculated.
- The needed orbit separation was estimated based on the acceptance plots in the paper on the FFAG Decay Ring (by J-B and Mori-san) and is about 12cm*2+1cm~25 cm.
- The additional separation to clear the magnet was assumed to be about 20 cm.

Injection from the outside of the ring (version 1)



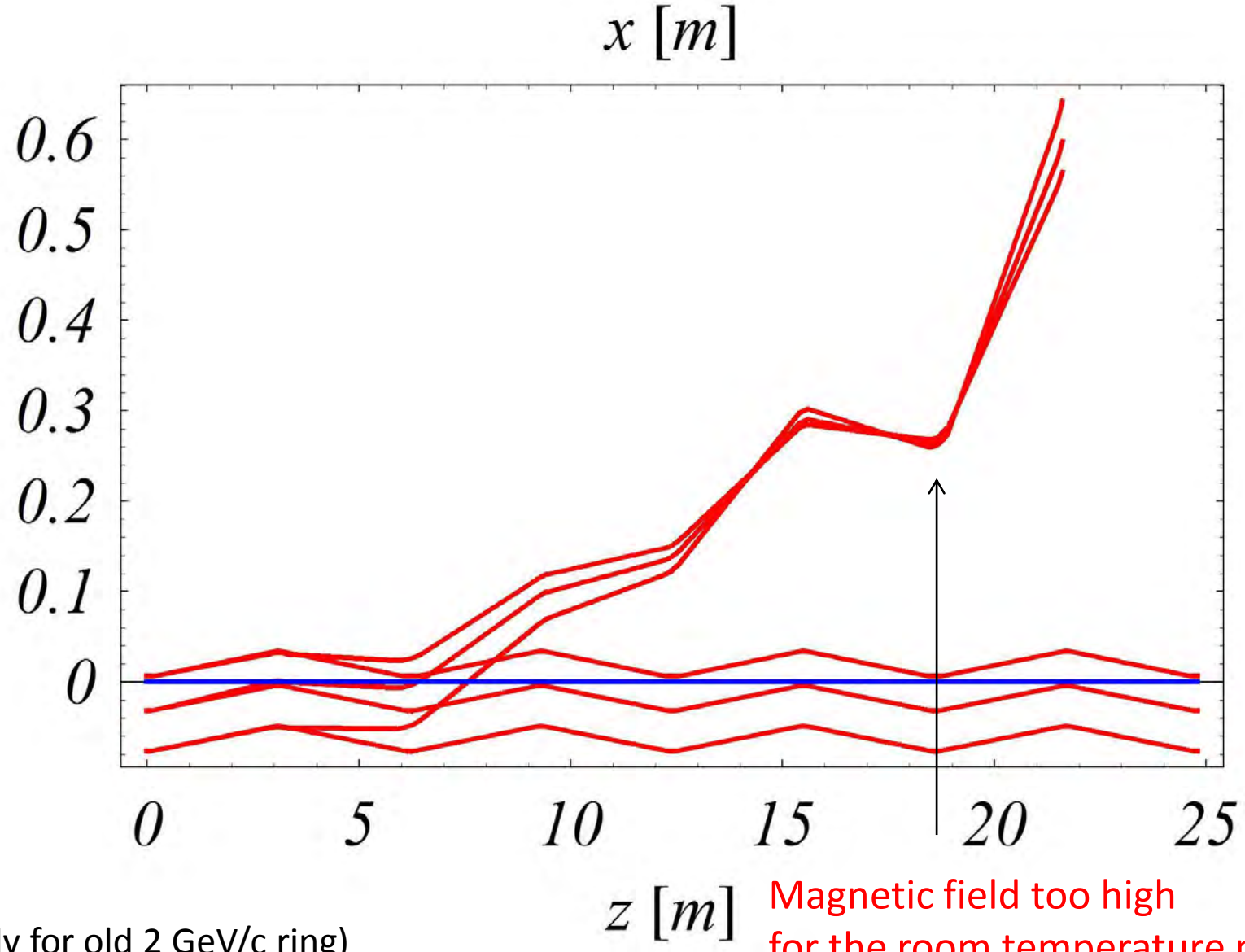
Work for old ring design for 2 GeV/c storage

B field too high
in the FFAG magnet!

Preliminary injection – parameters for injection from the outside of ring (version 1, old 2 GeV/c ring)

- Number of kickers 3
- Kicker B field 0.05 T
- Kicker length 2.6 m
- Kicker aperture 60x30 cm
- Septum B field 0.6 T
- Septum length 2.6 m in length and
- Septum aperture 30x30 cm

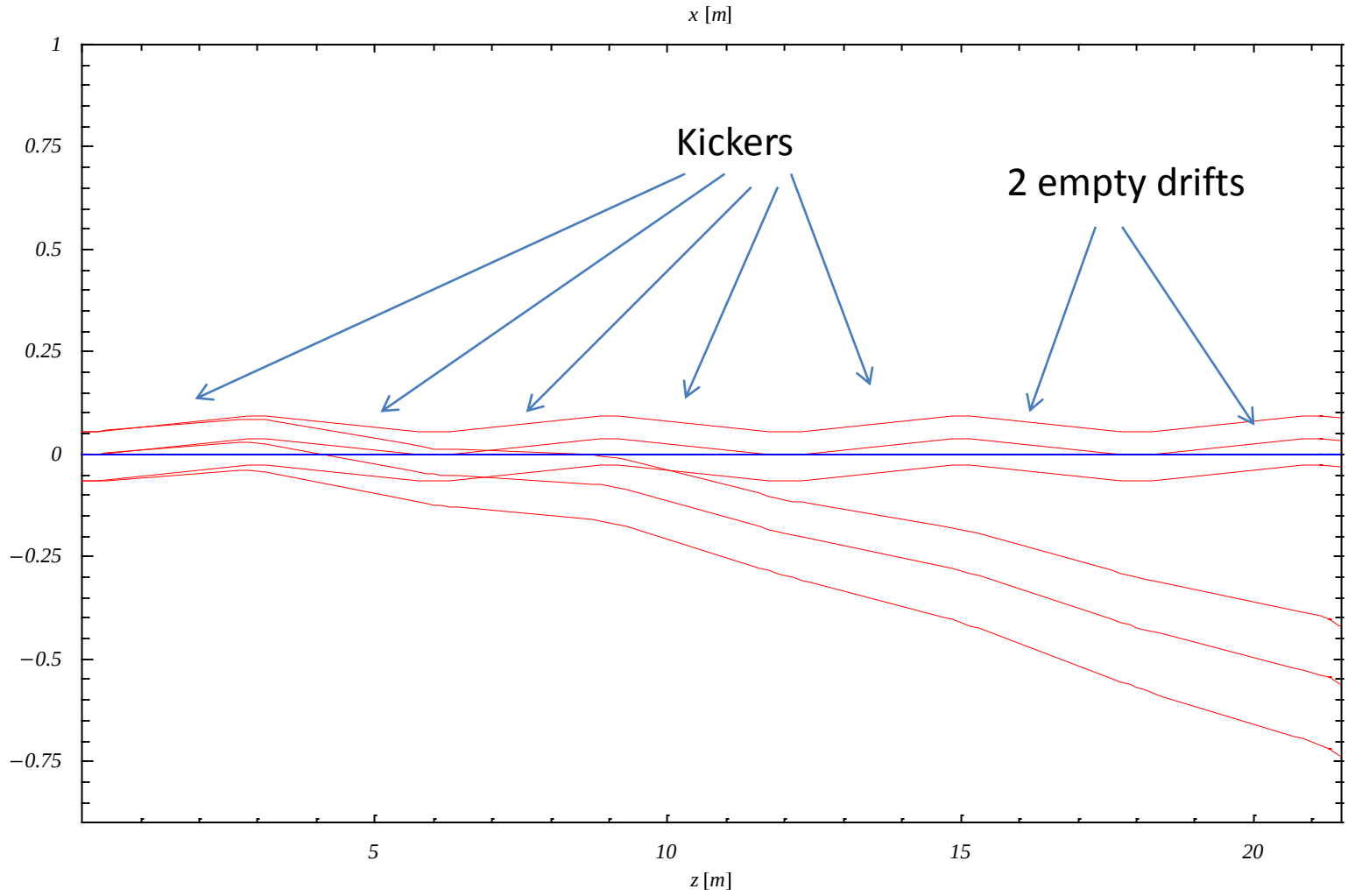
Injection from the outside of ring (version 2), (Orbits for +-16%, effect of 2 kickers and septum included)



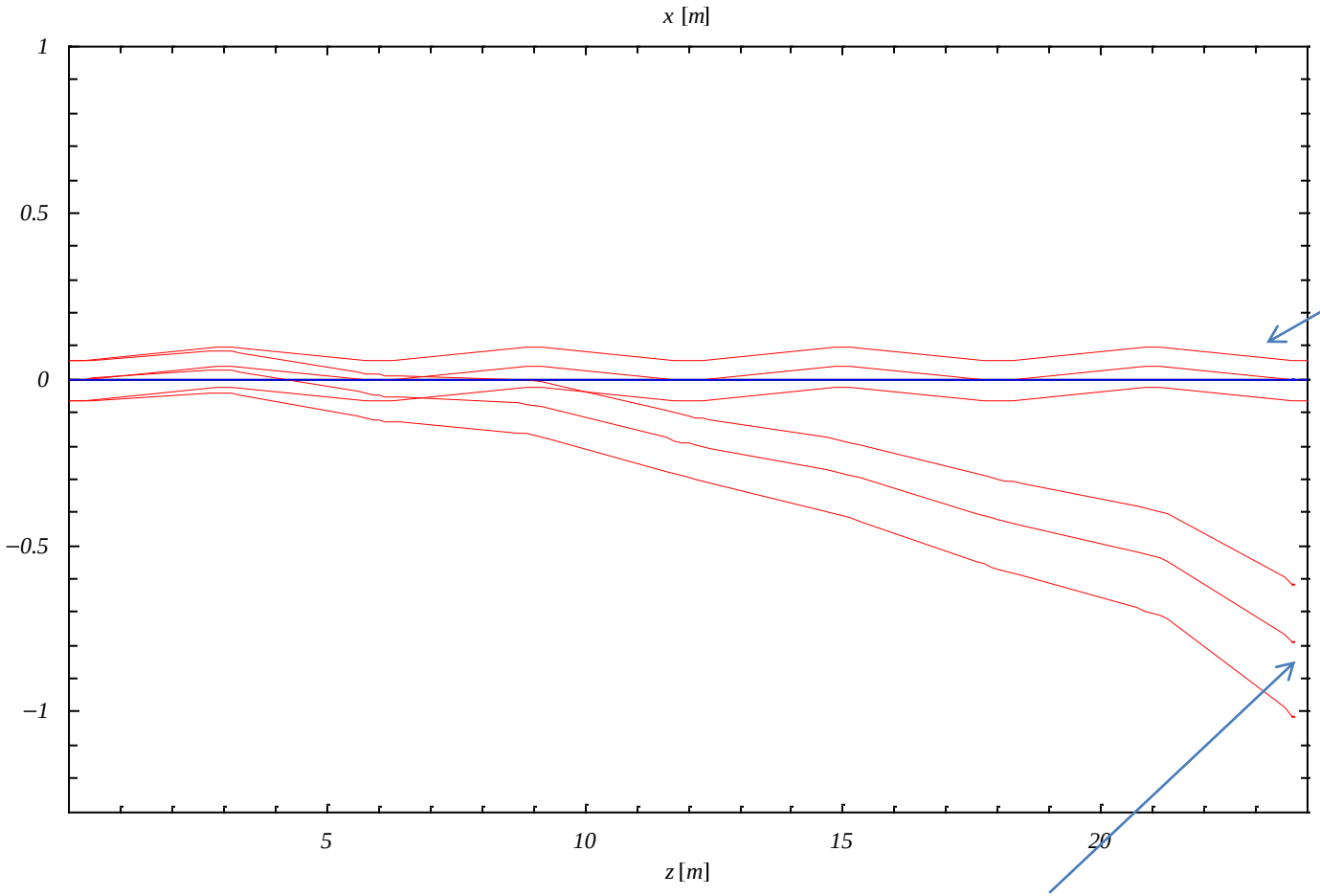
Study for old 2 GeV/c ring)

Magnetic field too high
for the room temperature magnets!

Injection from the inside of the new ring for 3.8 GeV/c (Orbits for +-16%, effect of 2 kickers without septum)



Injection from the inside of the new ring for 3.8 GeV/c (Orbits for +-16%, effect of 2 kickers with septum included)

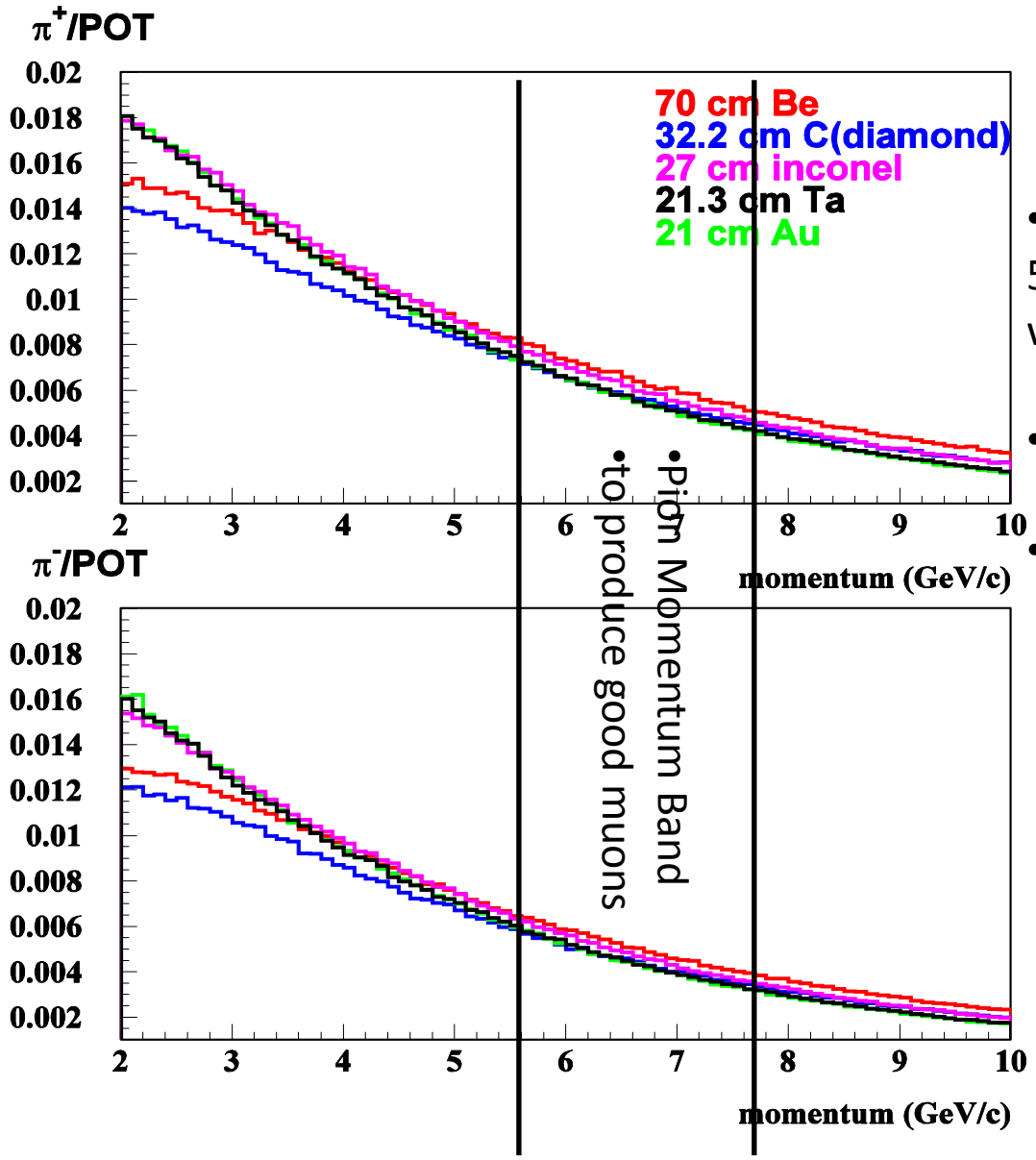


Larger dispersion could be reduced with FFAG-like septum
(in this study the septum is a pure dipole)

Parameters for injection from the inside of the ring (3.8 GeV/c)

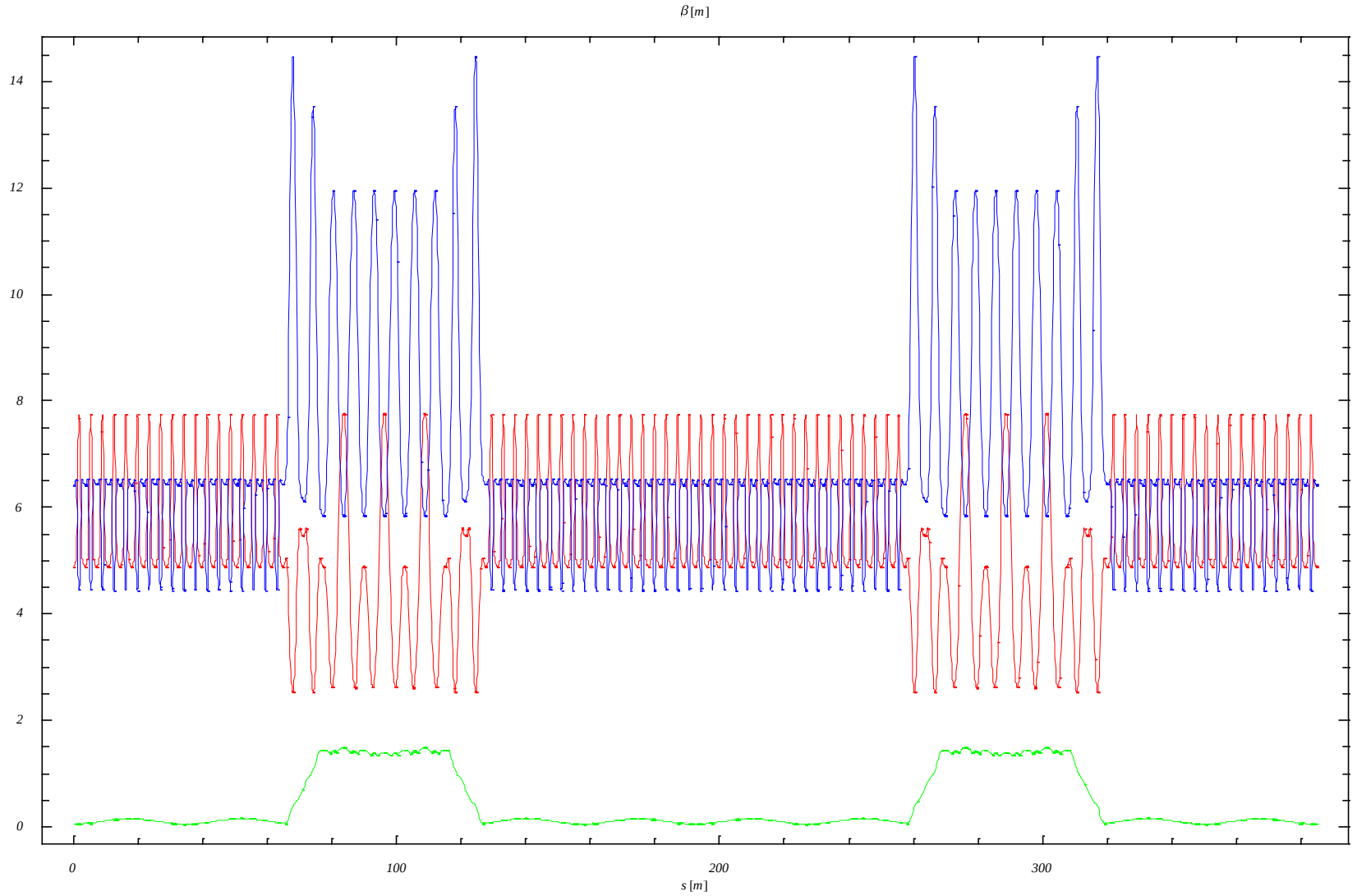
- Number of kickers 5
- Kicker B field 0.047 T
- Kicker length 2.275 m
- Max kicker aperture 75x30 cm
- Septum B field 0.6 T
- Septum length 2.275 m in length and
- Septum aperture 70x30 cm

Considerations for stochastic injection (D. Neuffer's scheme)



- Pions in the momentum between 5.57 and 7.69 GeV/c can produce muons within 3.8 GeV/c ±16%.
- Mean momentum is ~6631 MeV/c.
- Decay channel is not needed.

Towards the Scaling FFAG design for stochastic injection
Preliminary work performed for 2 GeV/c case



Essential is a small dispersion in the production straight (about 0.1 m for 2 GeV/c)

Summary and future plans

• Preliminary design for the single turn full aperture muon injection into FFAG Decay Ring has been worked out and seems feasible.

•Kickers are weaker than for IDS-NF FFAG (by a factor of 2).

• Geometry still needs to be updated (how to pass the arc?).

•The decay channel of ~ 200 m has been designed based on the FODO channel for both forward and backward decays using only normal conducting magnets.

• Betatron matching has been obtained.

• Performance versus cost needs to be evaluated.

•More work on the stochastic injection is needed.