FFAG Racetrack for various applications

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Outline

- Introduction
- Medical developments
- Machine for ISIS upgrade
- Test ring
- Summary and steps forward

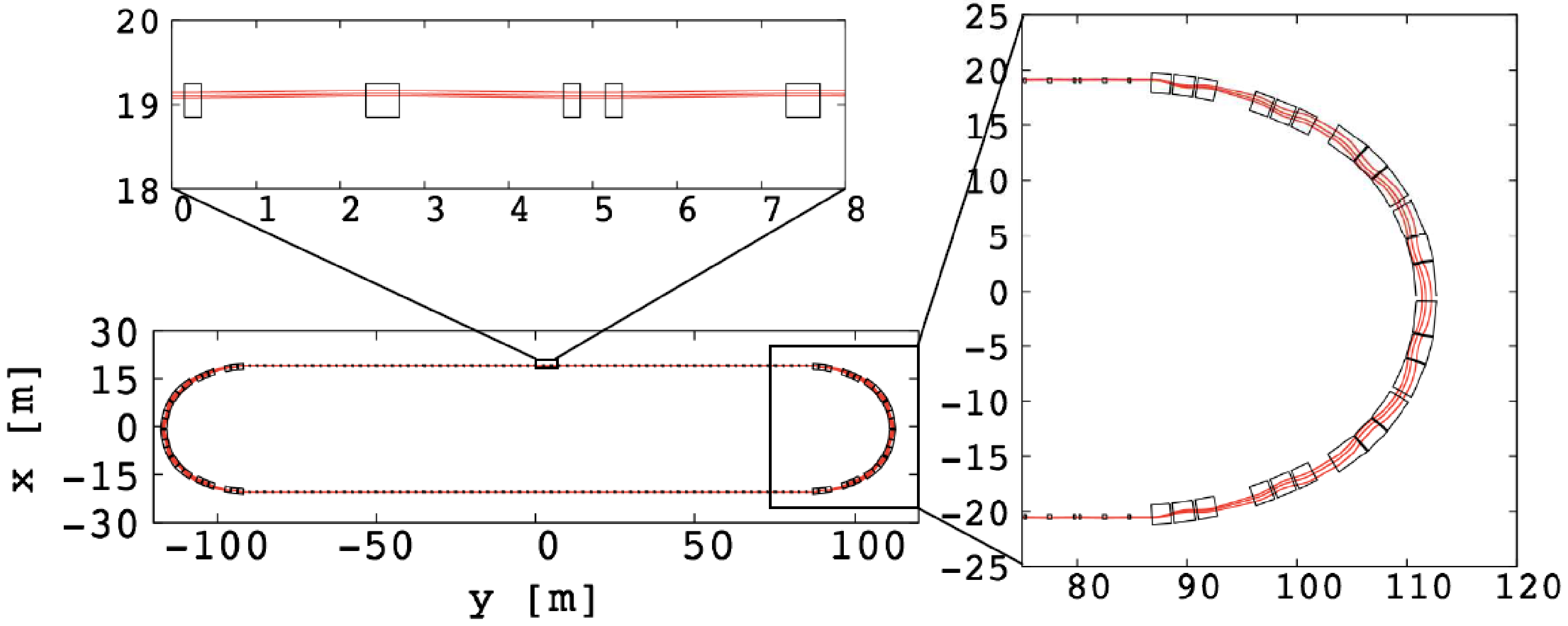
Introduction

Advantages of racetrack type ring shown using nuSTORM design as an example:

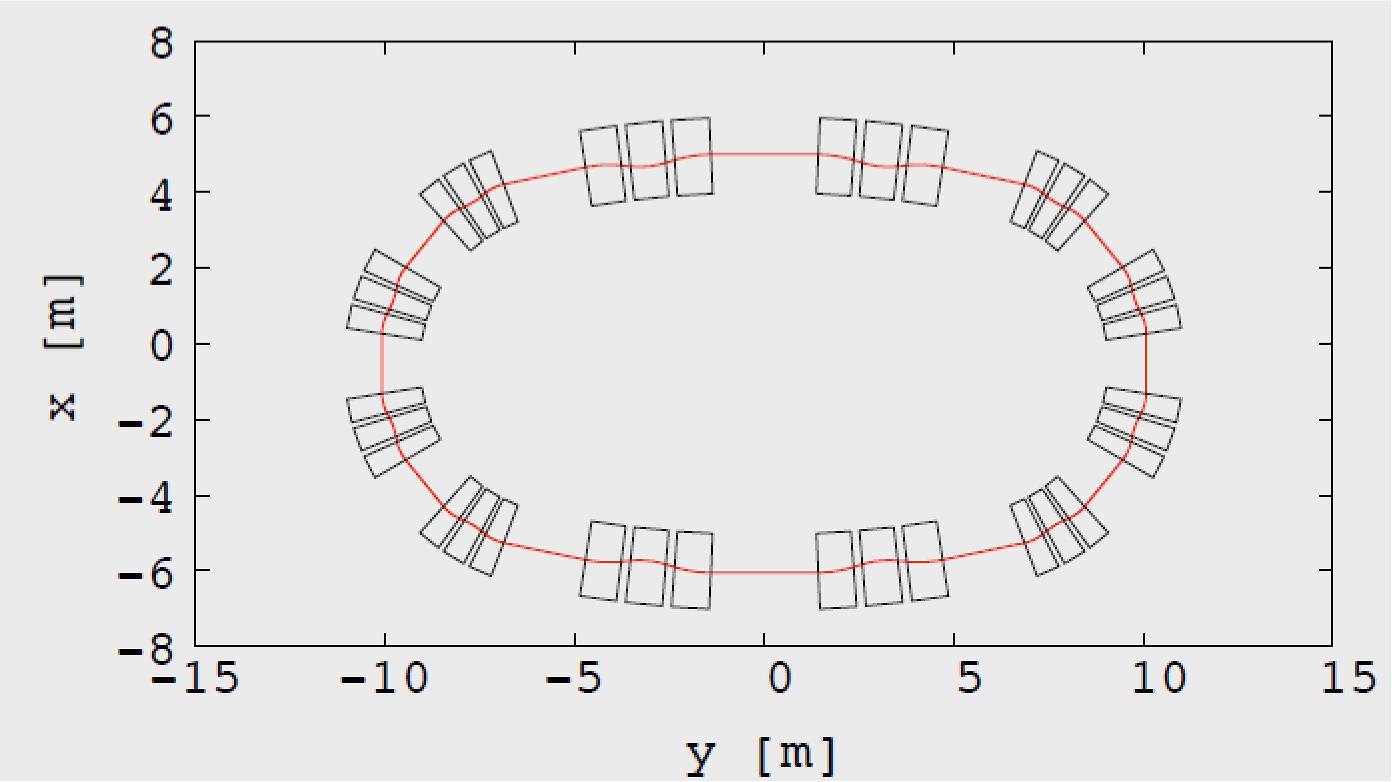
• Large space in the straight section for injection/extraction and other insertions, RF cavities etc.

• Straight magnets with weak magnetic field -> cheap

•Very compact arc with strong magnets to efficiently bend the beam

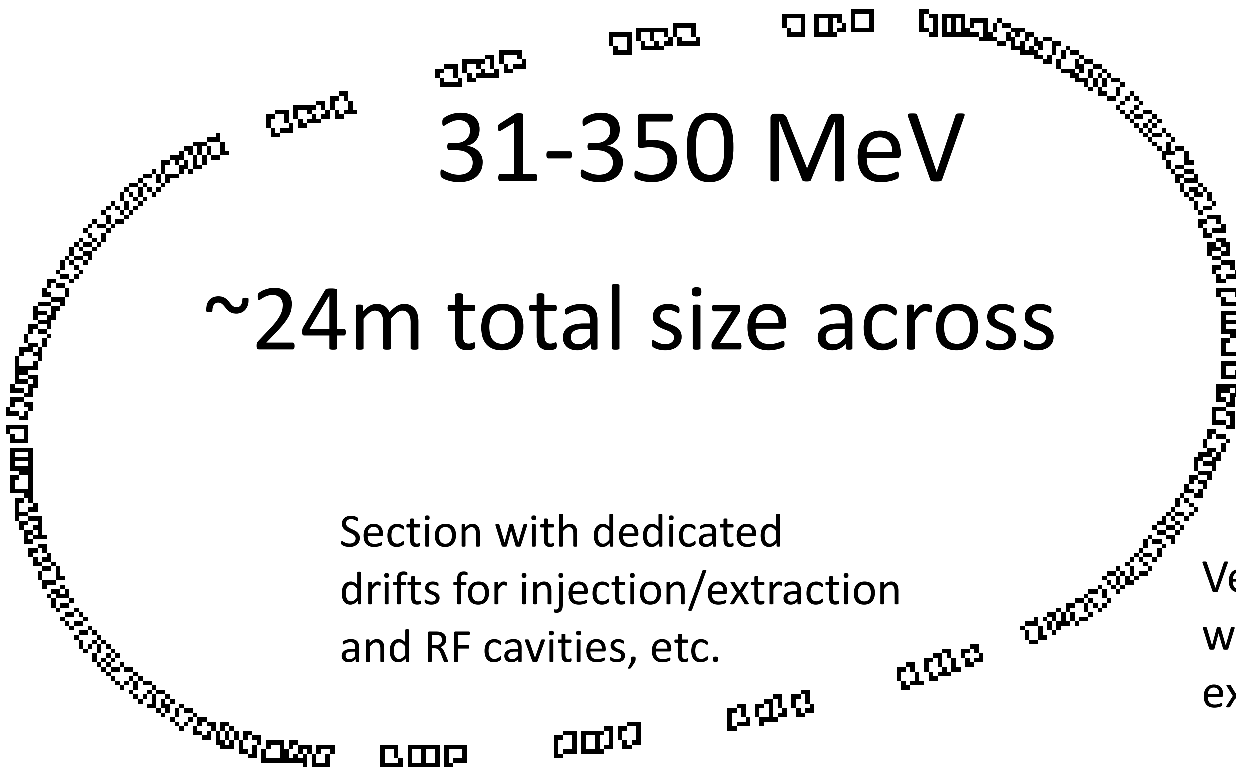


Similar concept – the “egg-shaped” ring



Scaling FFAG with 2 types of circular cells with different k and R matched such that orbit excursion is the same. Again bending is strong in one type contrary to the “straight” section part.

Egg shape ring for proton radiography, preliminary design to illustrate the principle



31-350 MeV

~24m total size across

Section with dedicated drifts for injection/extraction and RF cavities, etc.

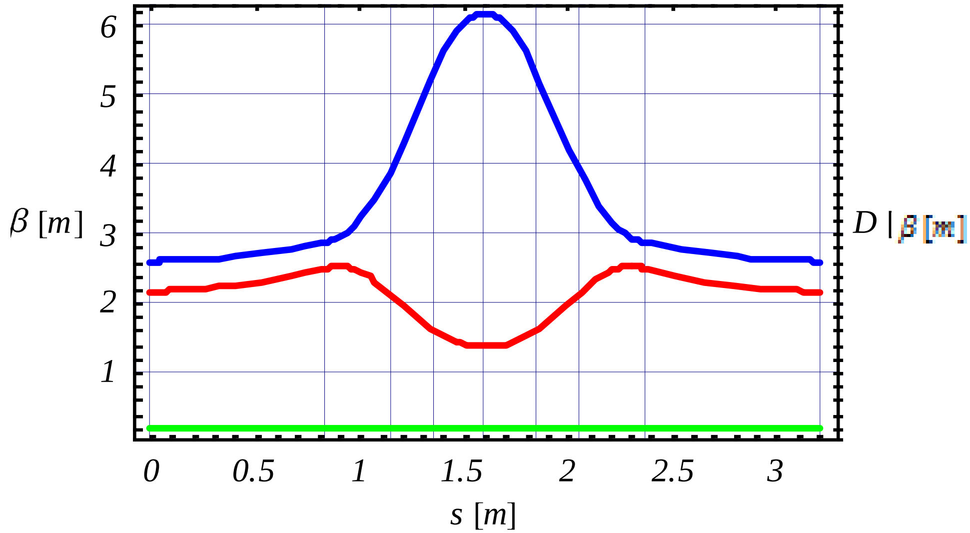
Very compact arc with small orbit excursion

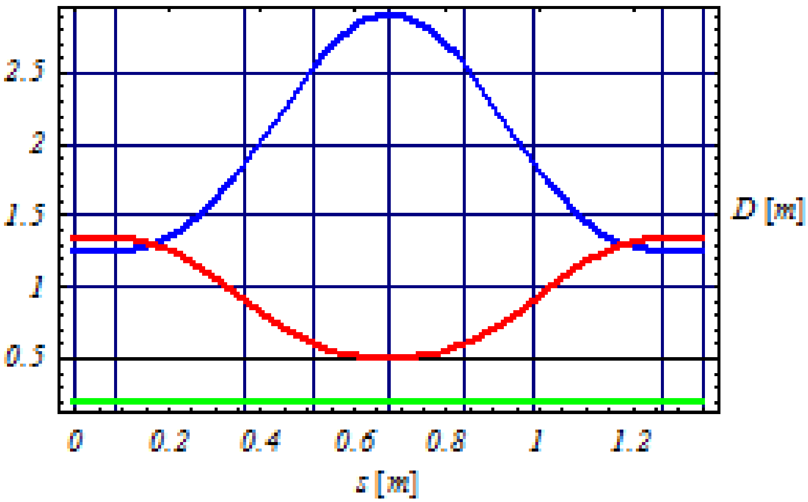
It can be made more compact.

Straight and arc sections

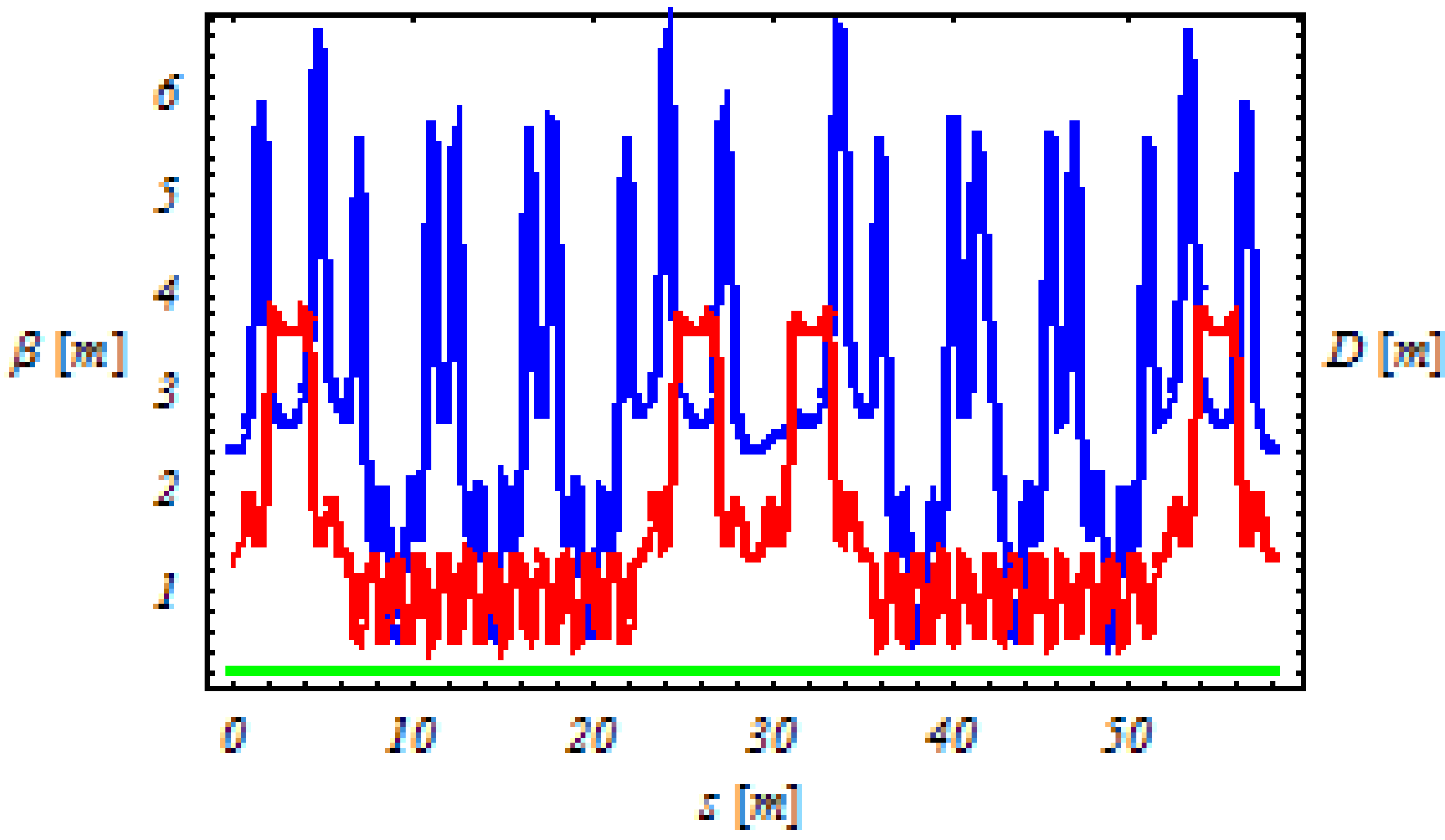
- k=188
- Fields ~1.5,1.4 T
- Orbit excursion 0.25 cm
- Tunes (0.249, 0.158)
- N=8

- k=28
- Fields ~3 T (superferric magnet)
- Orbit excursion 0.25 cm
- Tunes (0.257, 0.124)
- N= 24

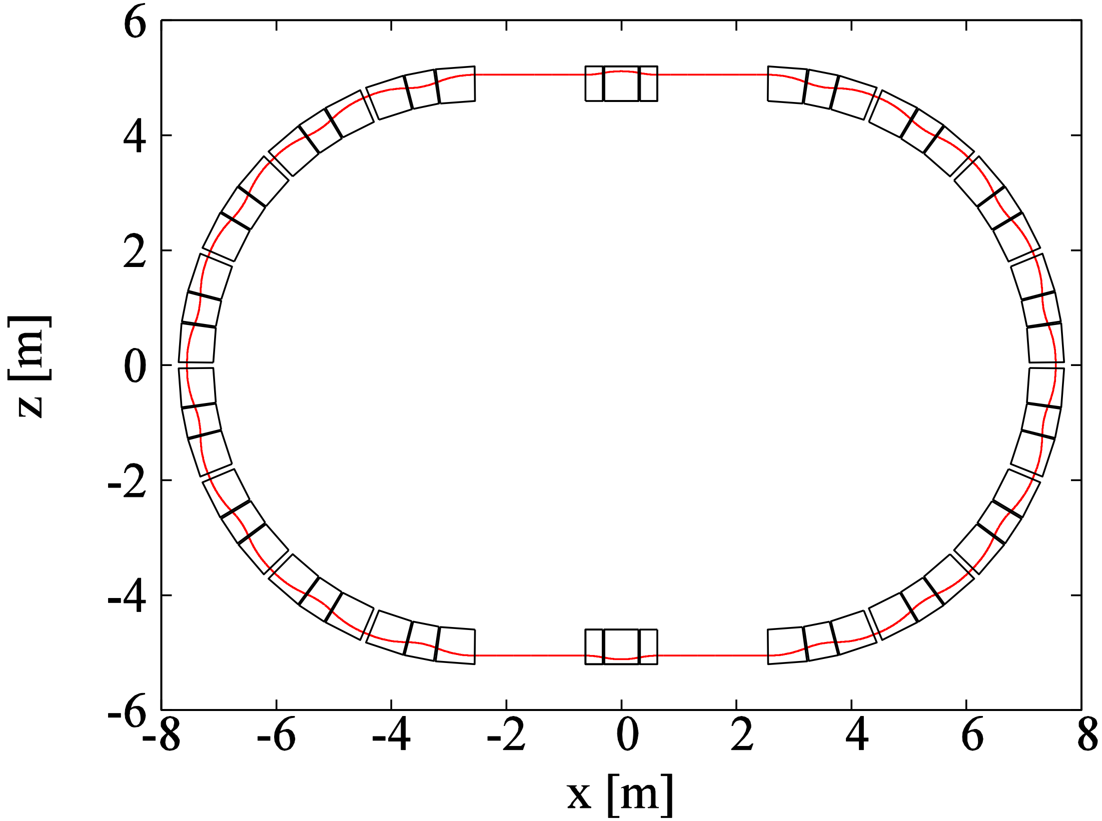




Beta Functions, total tune (8.18/4.24)



Medical Racetrack



tune/ring (H/V): 4.2/1.55.

straight FFAG cell:

- DFD (2 cells in the ring)
- m = 2.12 m^-1
- L(D) = 30 cm
- L(F) = 60 cm

horizontal phase advance: 35 deg.

circular FFAG cell:

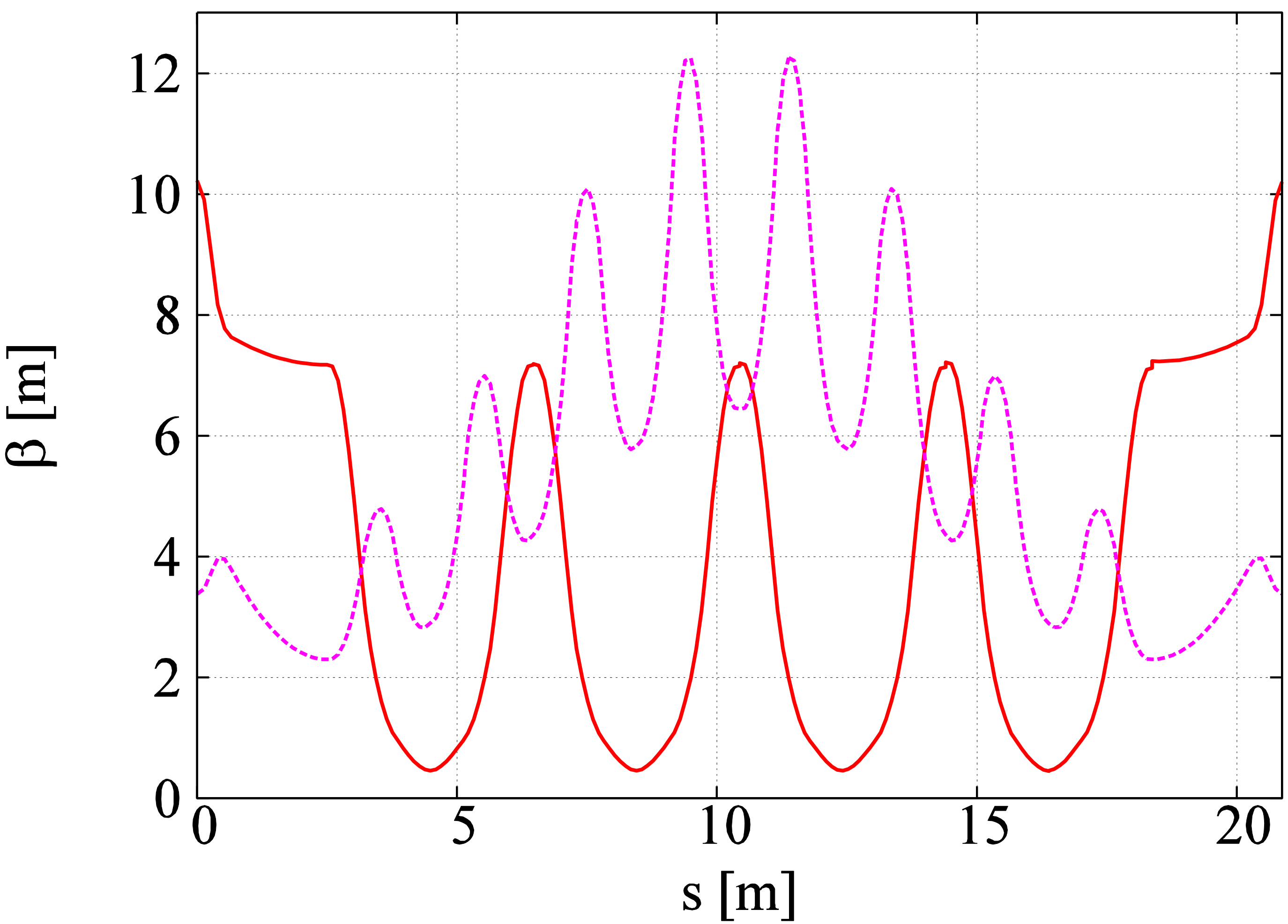
- FDF (16 cells in the ring)
- k = 11.03
- r(350MeV)=5 m
- L(F) = 7.5 deg.
- L(D) = 5.7 deg

horizontal phase advance: 90 deg.

Orbit excursion: ~50cm

Superferric magnet needed

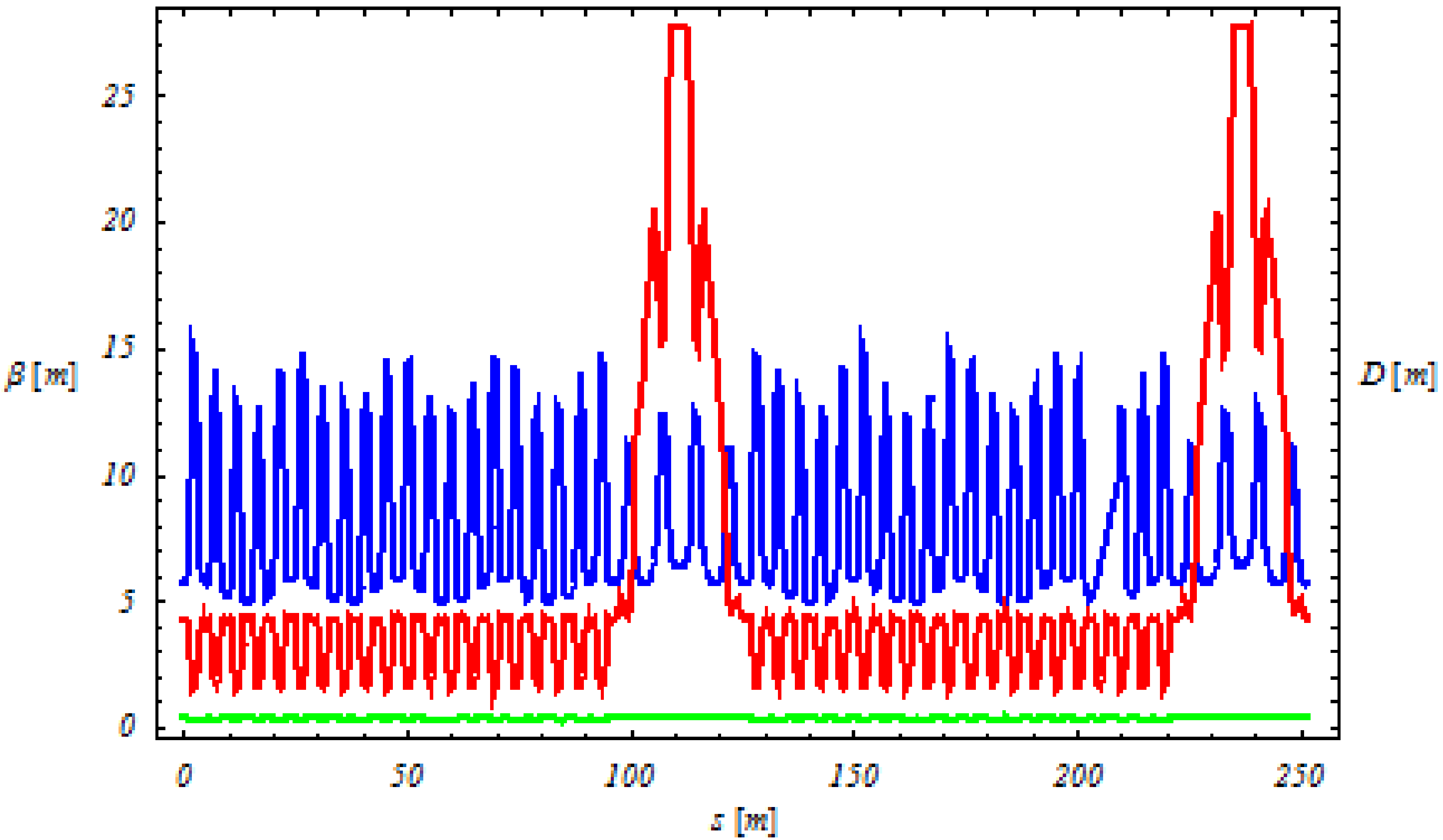
Medical Racetrack, Optics



High energy proton machine

- 400-3200 MeV
- 40 arc cells, 8 straight cells
- Orbit excursion ~40cm
- Tune (11.83, 5.58)
- Max B field on orbit 1.9 T
- Circumference 252m
- Long straight 3.5m

High energy proton machine, optics



Motivation to develop test racetrack ring

Machine can be considered as a prototype for:

1. future high intensity machine like ISIS upgrade or similar facility (high intensity driver for HEP needs)
2. for medical applications (including proton radiography)
3. Test optics for nuSTORM

Goals:

- To test space charge limit in FFAG type synchrotron
- To test H^- type injection in FFAG including phase space painting in 4D (6D).
- To demonstrate feasible and efficient injection/extraction in FFAGs.

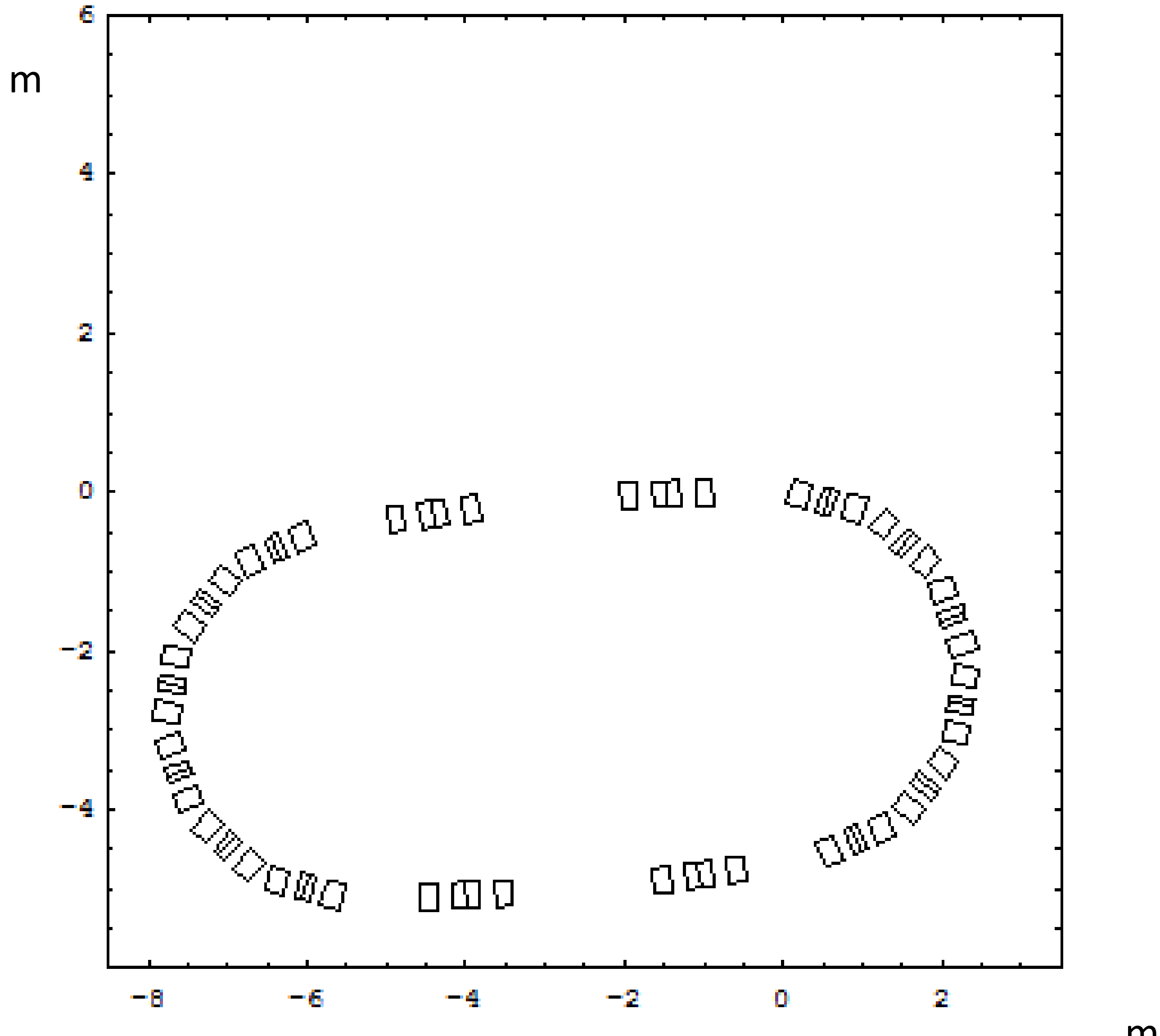
Goals for machine design

- Room temperature magnets (for easy commissioning and low cost)
- Reasonably small orbit excursion
- Zero chromaticity
- Long straight sections for injection/extraction and RF

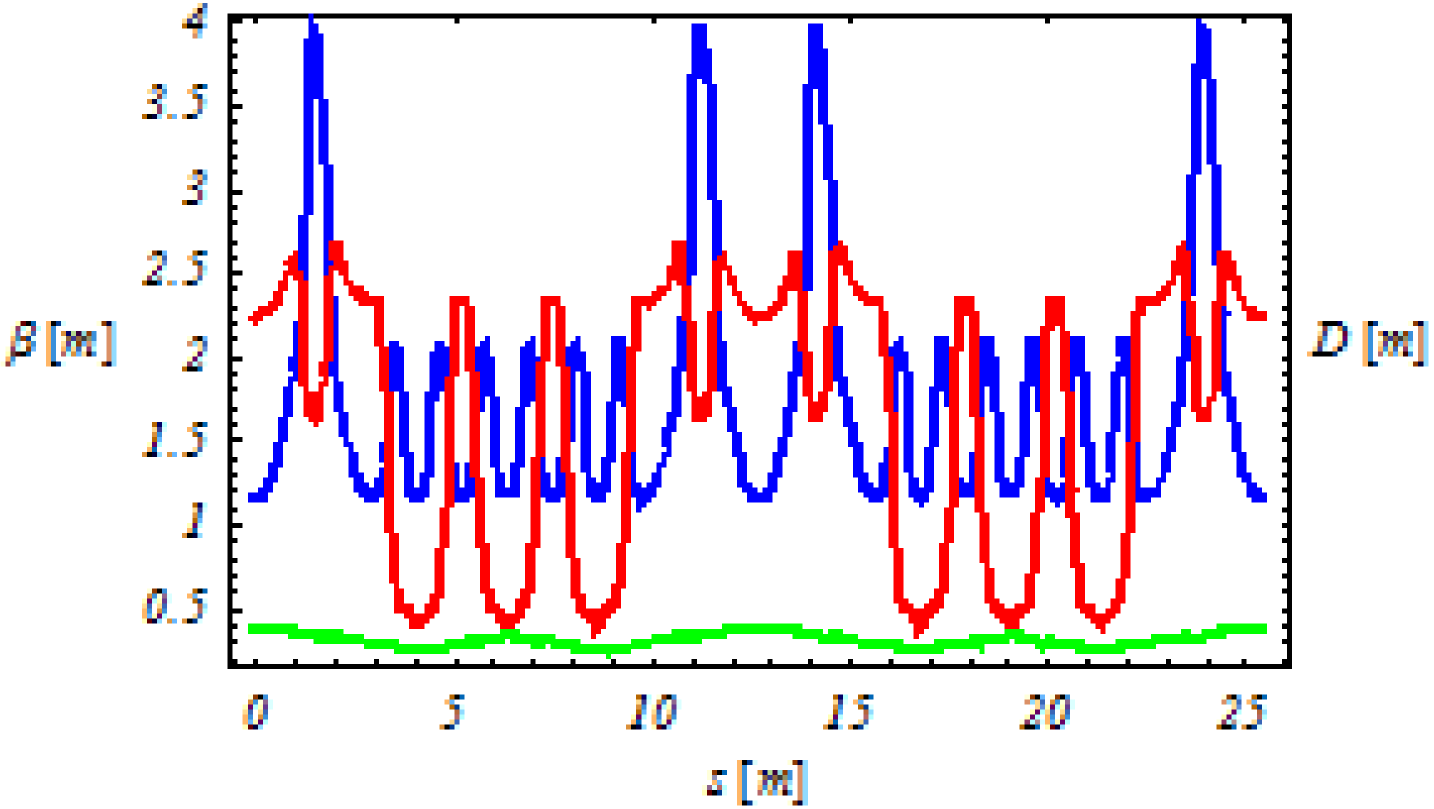
Some parameters

•Proton energy	3-40 MeV
•Injection type	H^- stripping
•Orbit excursion	0.365 m
•Circumference	25.44 m
•Tune (H, V)	(3.84, 2.59)
•Arc radius	2.3 m
• Radius in the "straight part"	34.1 m
•Long drift	1.8 m
•Bmax on orbit	1.5 T
• k in the arc	6.9
• k in the "straight part"	128.8
•RF frequency (h=1)	~0.9-3.4 MHz

Approximate layout for the racetrack machine (3-40 MeV)



Optics



Possible further studies

- Test and optimisation of DA in the ring
- Replacement of “straight” by real straight.
- Replacement of scaling arc by zero chromatic

without negative bend.

- Study of required/possible tuning freedom and how to achieve it.

Summary and next steps

- Racetrack FFAG machines are very attractive solutions with large potentials to be developed into multiple applications
- Further R&D is required
  - Optics and beam dynamics studies
  - Superferric magnet developments
  - Tracking with space charge and other intensity effects
- Small test ring would be very beneficial to demonstrate the concepts.