Lattice and Interaction Region Design of the RHIC Medium Ion Electron Collider

D. Trbojevic, N. Tsoupas, S. Tepikian, C. Montag, B. Parker, E. Pozdeyev,
Y. Hao, Yhao H.,D. Kayran, J. Beebe-Wang, V. Ptitsyn, and V. Litvinenko

Lattice for RHIC Medium Energy Electron Ion Collider

- **Requirements for the Energy Recovery Linac:**
  - Geometrical constraints
  - Lattice constraints
  - Methods and solutions
- **Lattice:**
  - Relativistic Heavy Ion Collider lattice modification – Steven Tepikian
  - New way of energy recovery linac lattice design – Eduard Pozdeyev
  - Asynchronous arcs – Dmitri Kayran, Dejan Trbojevic
  - Vertical splitters – Nicholaus Tsoupas
  - IP and detector protection C. Montag, B. Parker, J. Beebe-Wang, D. Kayran and D. Trbojevic.
  - Preliminary dipole and vertical corrector design – B. Parker.
  - 100 MeV injection energy recovery linac and matched beam lines
  - 4 GeV, 2.7 GeV, 1.4 GeV, and 0.1 GeV arcs, splitters, chicanes, and beam lines
  - 3.35 GeV, 2.05 GeV, and 0.75 GeV splitters, arcs, and chicanes
- **Summary:**

RHIC machine advisory committee's conclusions:

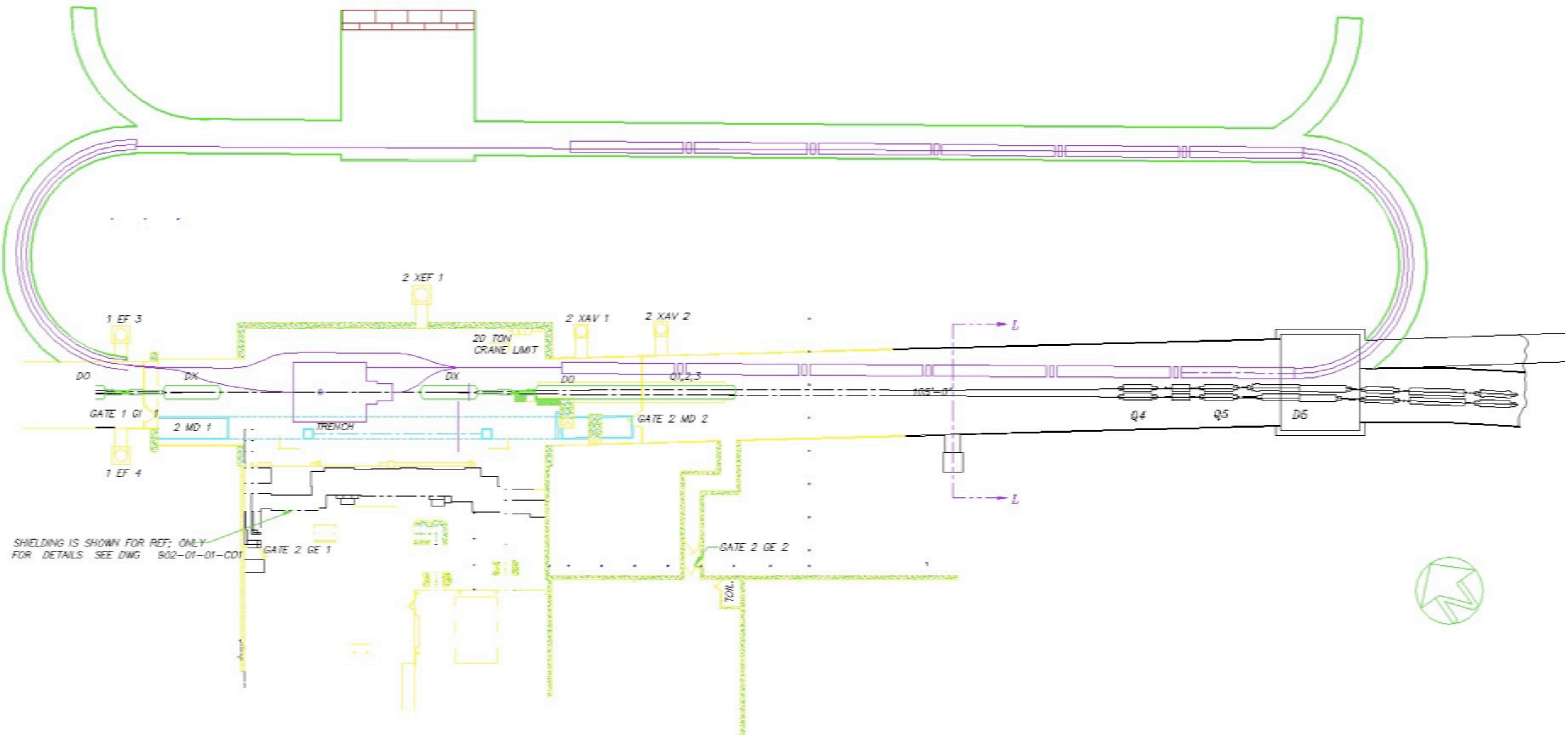
- Machine Advisory Committee: Georg Hoffstaetter, Chair, Cornell, Oliver Bruning, CERN, Jean-Pierre Delahaye, CERN, Geoff Krafft, Jefferson Lab, David McGinnis, FNAL, Kazuhito Ohmi, KEK, Markus Steck, GSI

- ***MEeIC RHIC R&D* -Layout and optics – Findings:**

- A design of isochronous arcs and an IR lattice based for the ERL was presented. The committee was impressed with the completeness, competence, and simplicity of the lattice choices made in the MEeIC arc designs. It is highly proper that the synchrotron radiation aspects of the IR design have been considered and incorporated early in the design process.

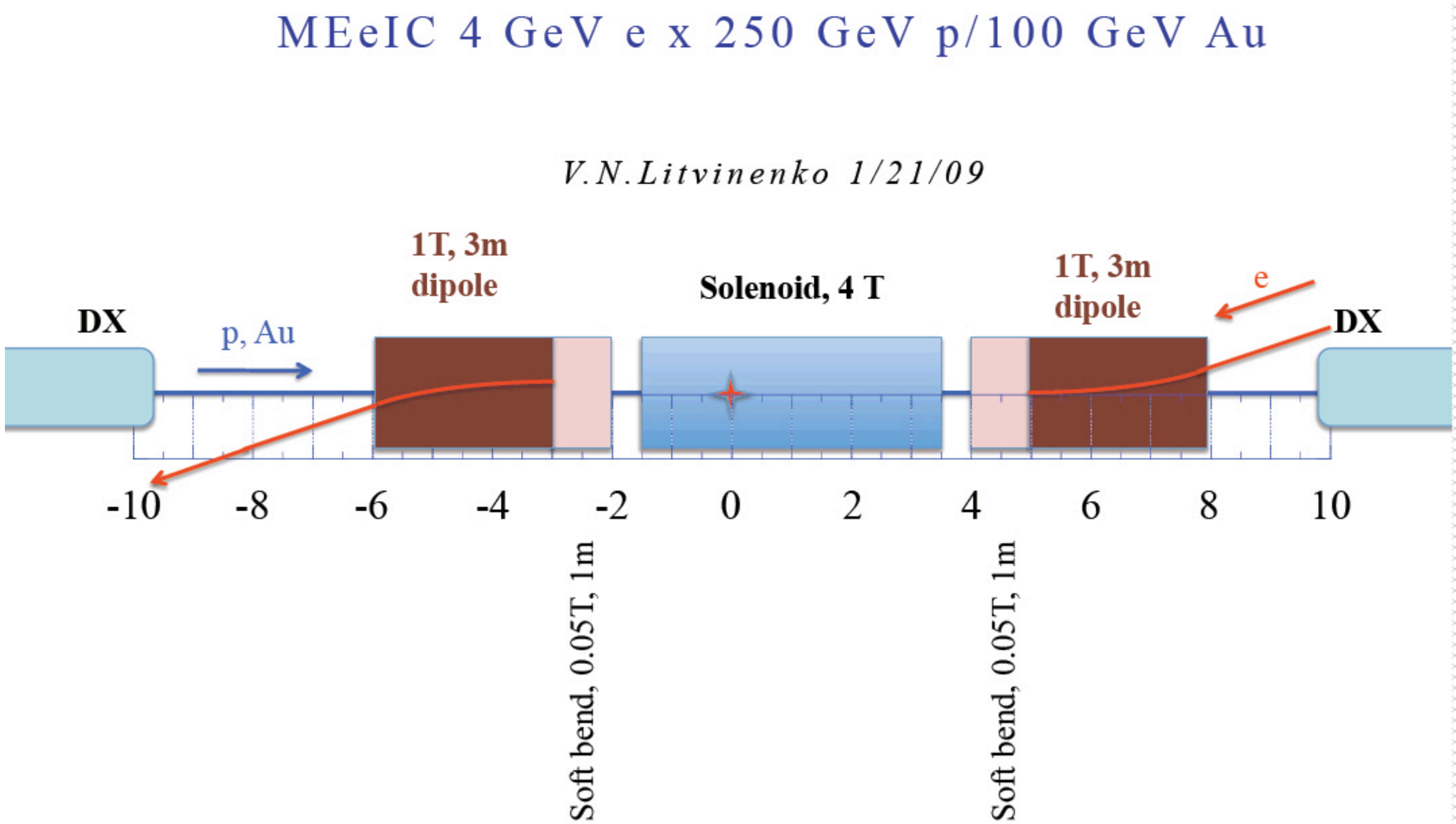
Requirements for the Energy Recovery Linac:

- Geometrical constraints: If it is possible use the existing interaction region at RHIC 2 o'clock and wider tunnel to place the superconducting linac inside it. Minimize civil construction cost:

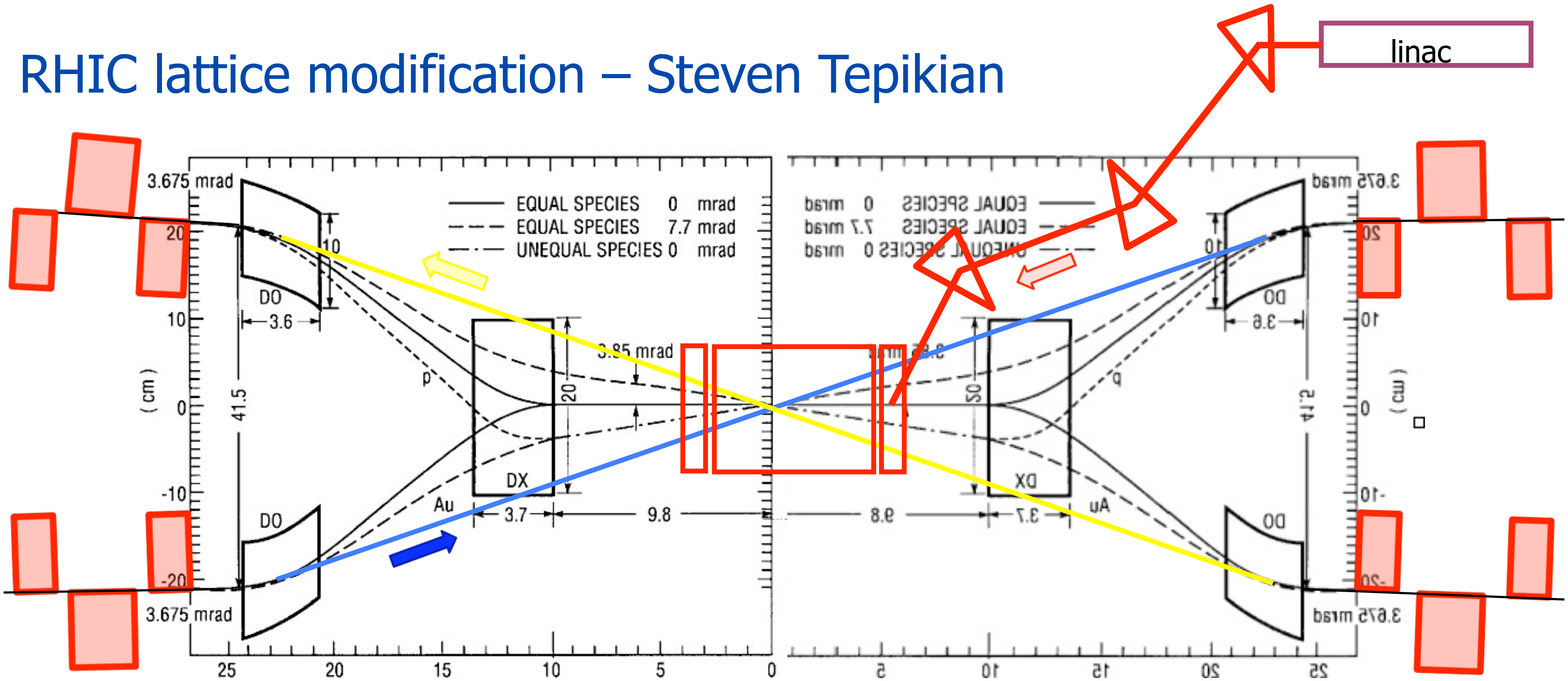


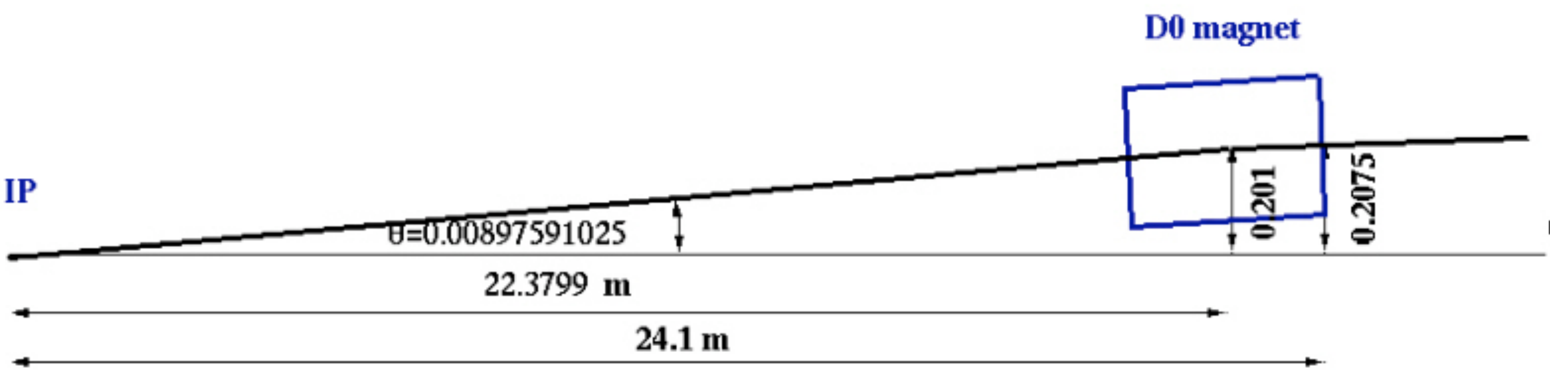
- Lattice constraints:

Passes during acceleration or energy recovery between the two linacs should be asynchronous (M_{56}=0), have small dispersion due to large $\delta p/p$ ($x_{\delta p}=D\ \delta p/p$), dipole and the quadrupole magnetic fields should be ~1.5-1.8 T, with zero dispersion through linacs and at the interaction point, reduce/remove the synchrotron radiation through detector, use vertical beam splitting, use the present detector layout.

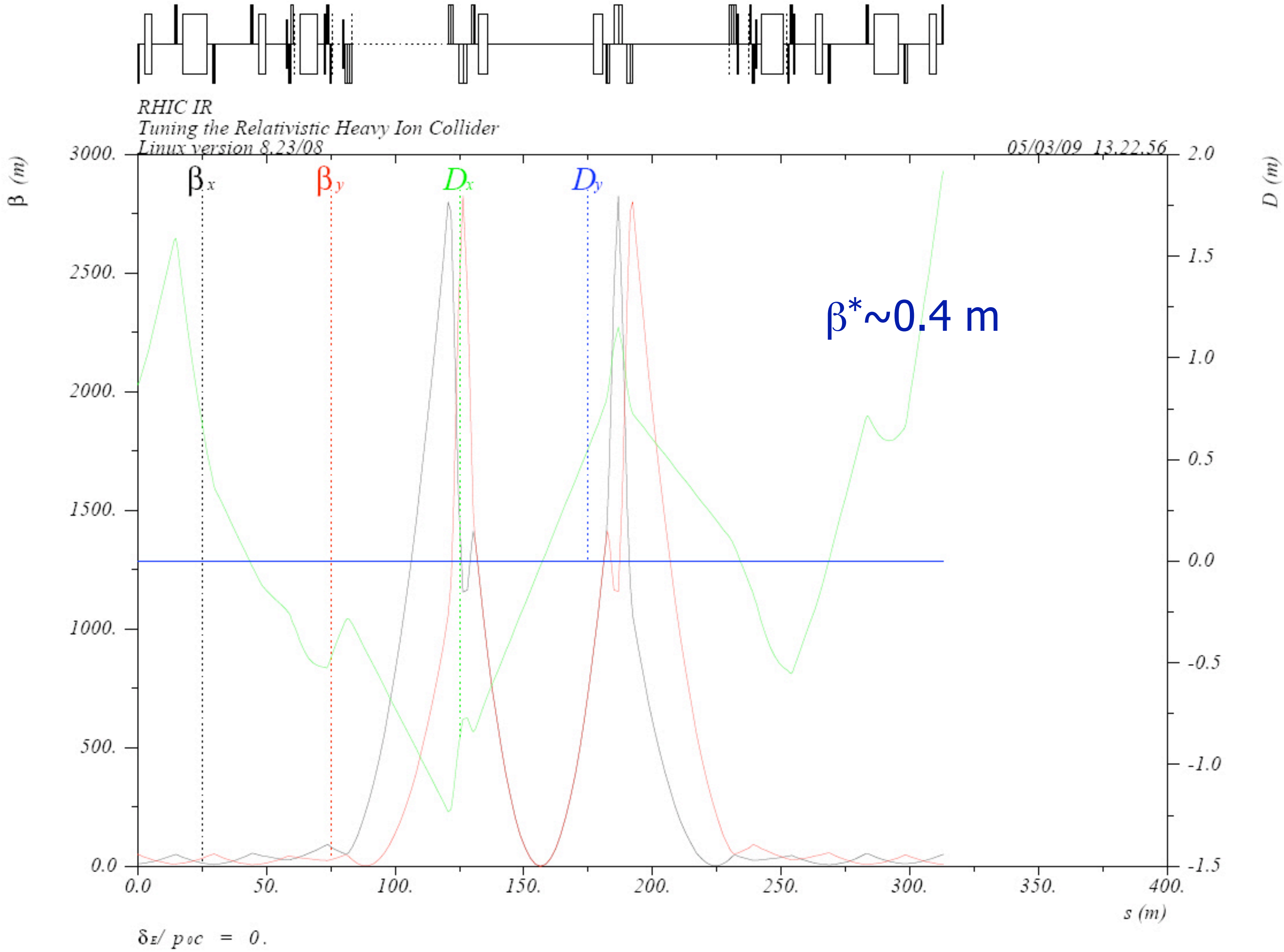


RHIC lattice modification – Steven Tepikian

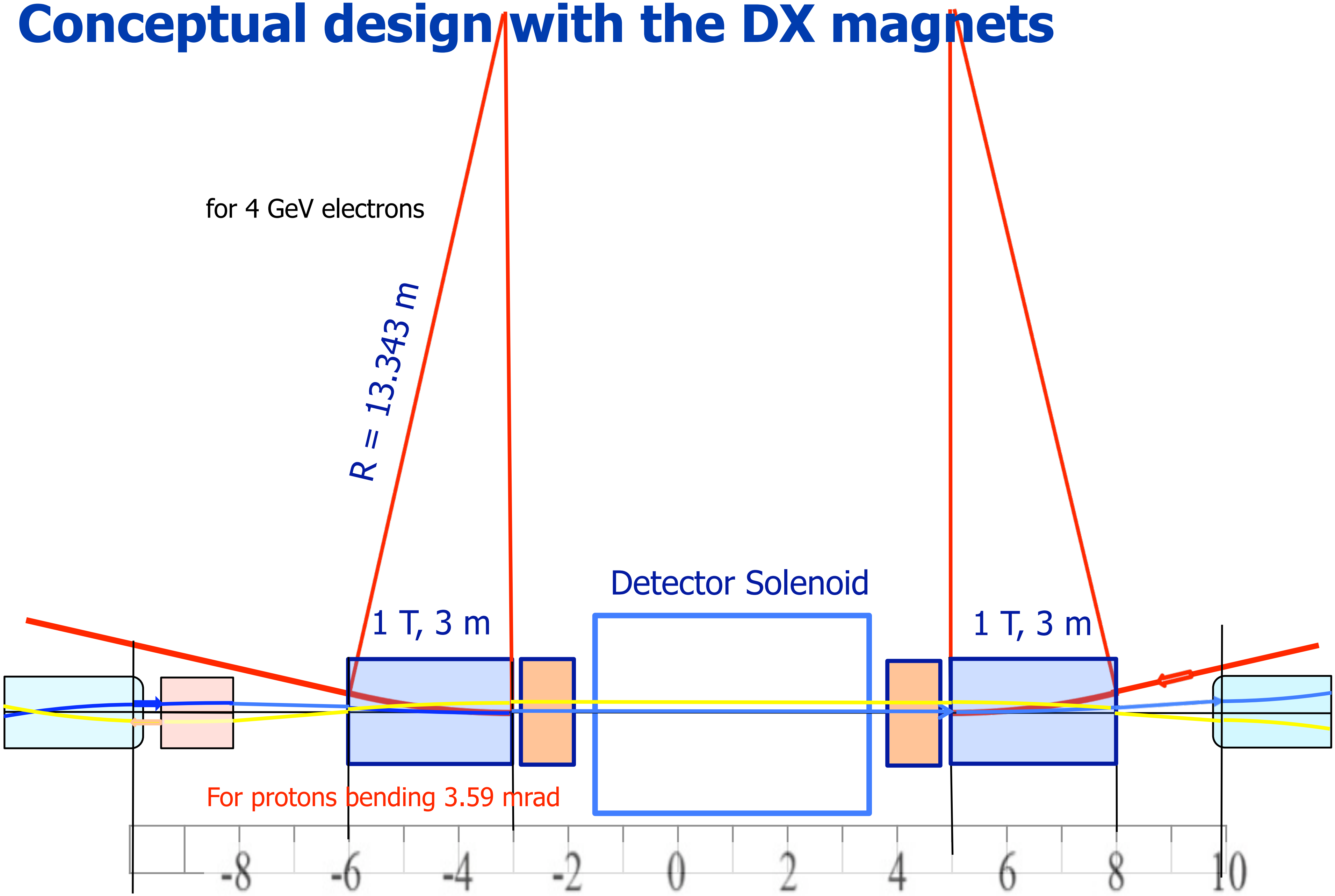




RHIC lattice modification – Steven Tepikian



Conceptual design with the DX magnets



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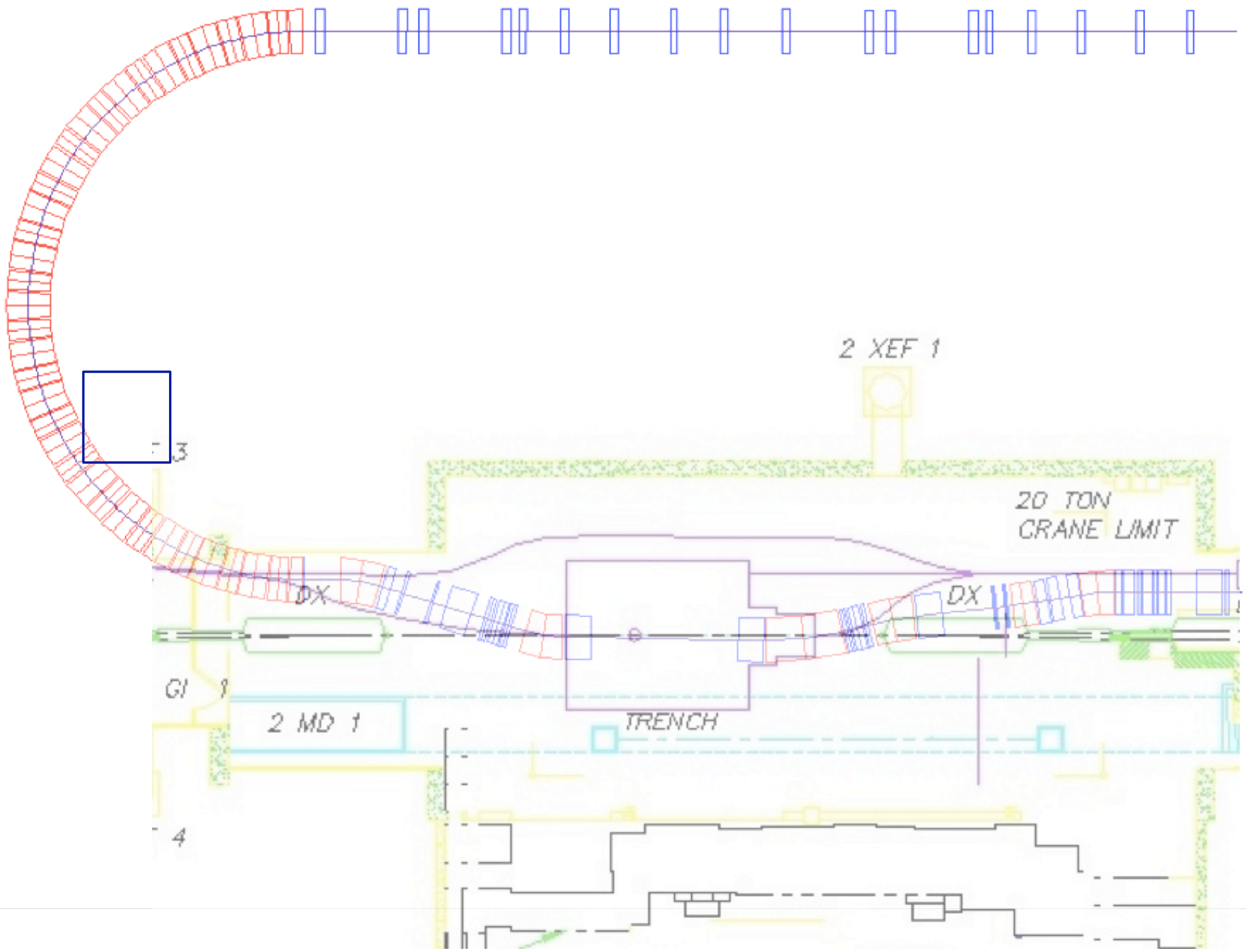

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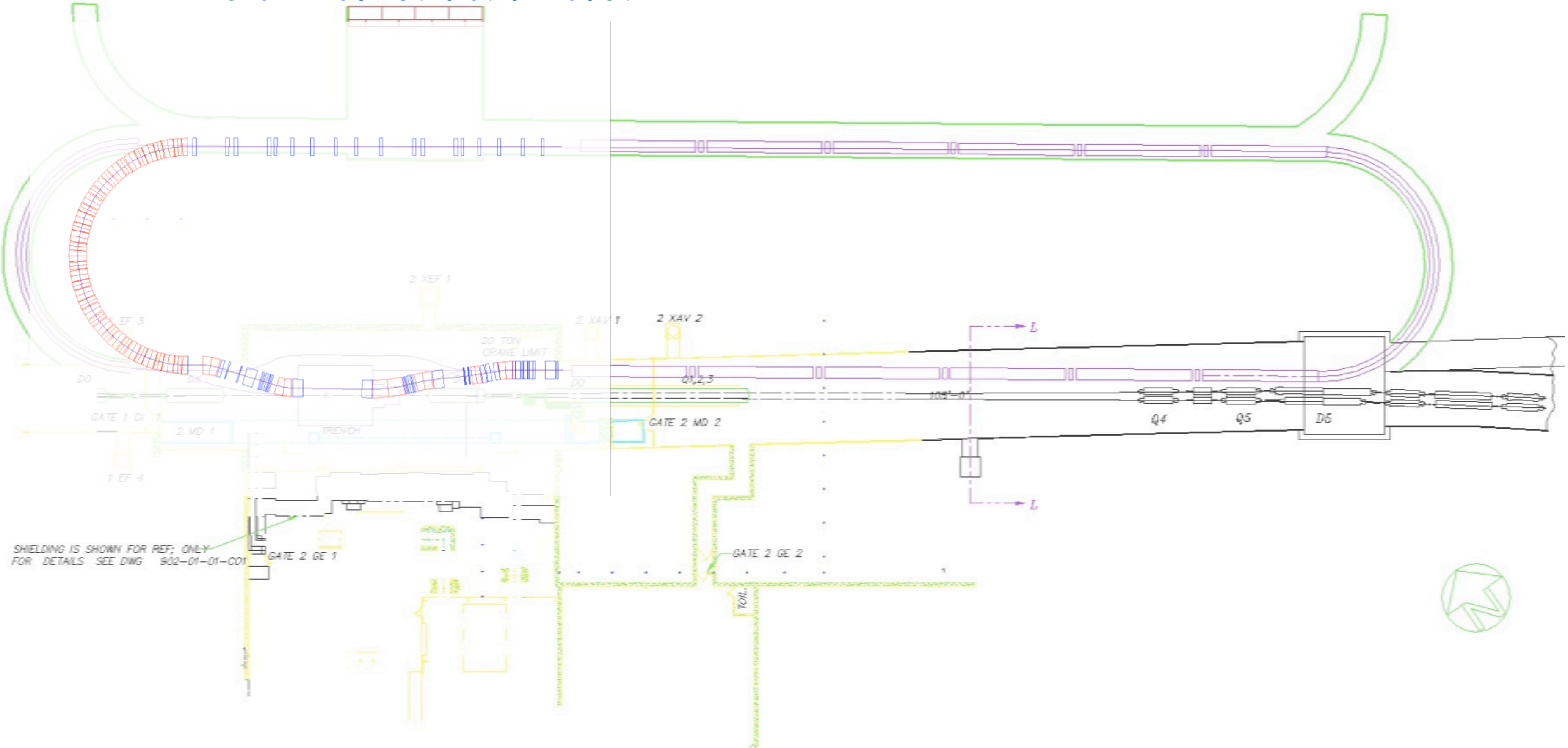
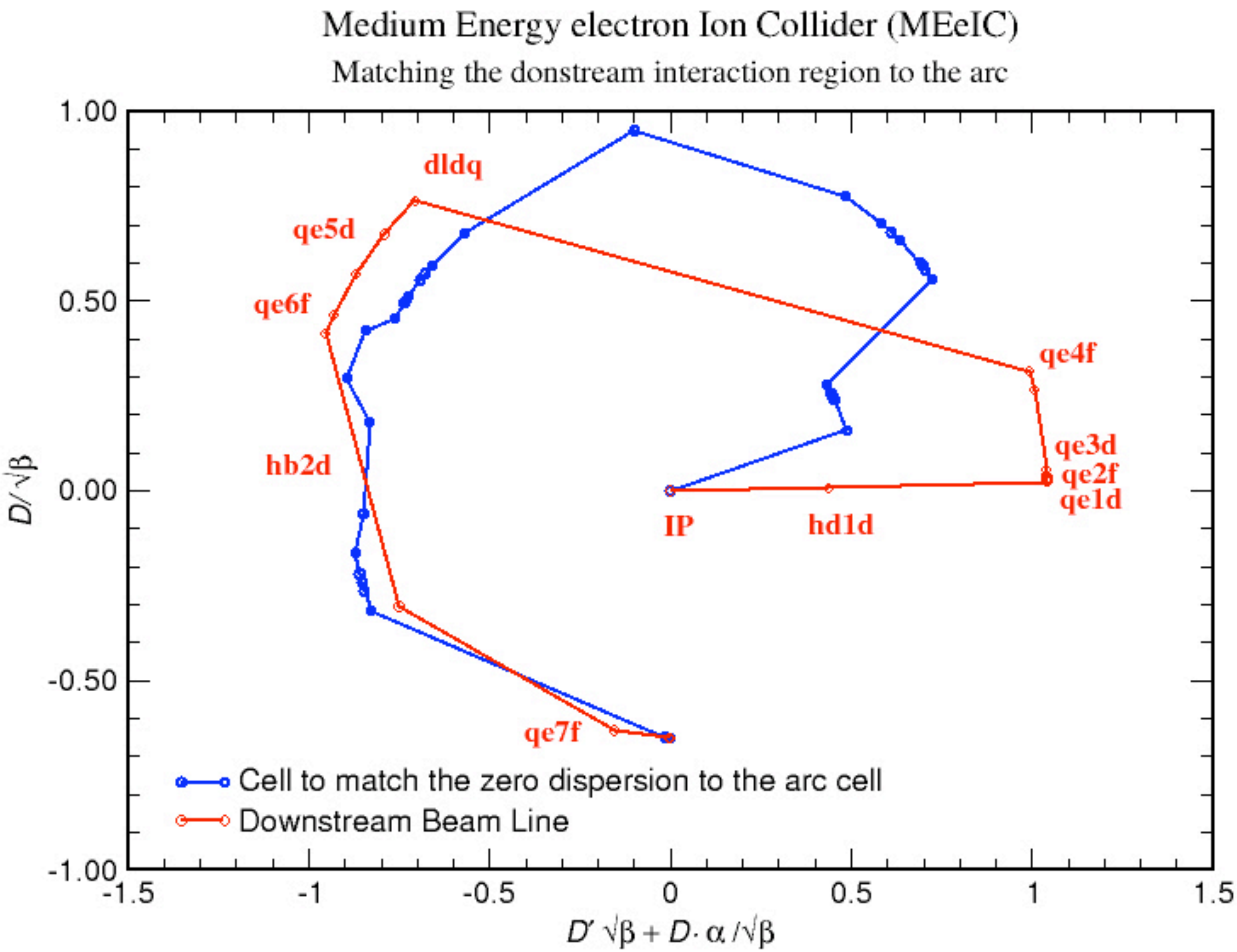
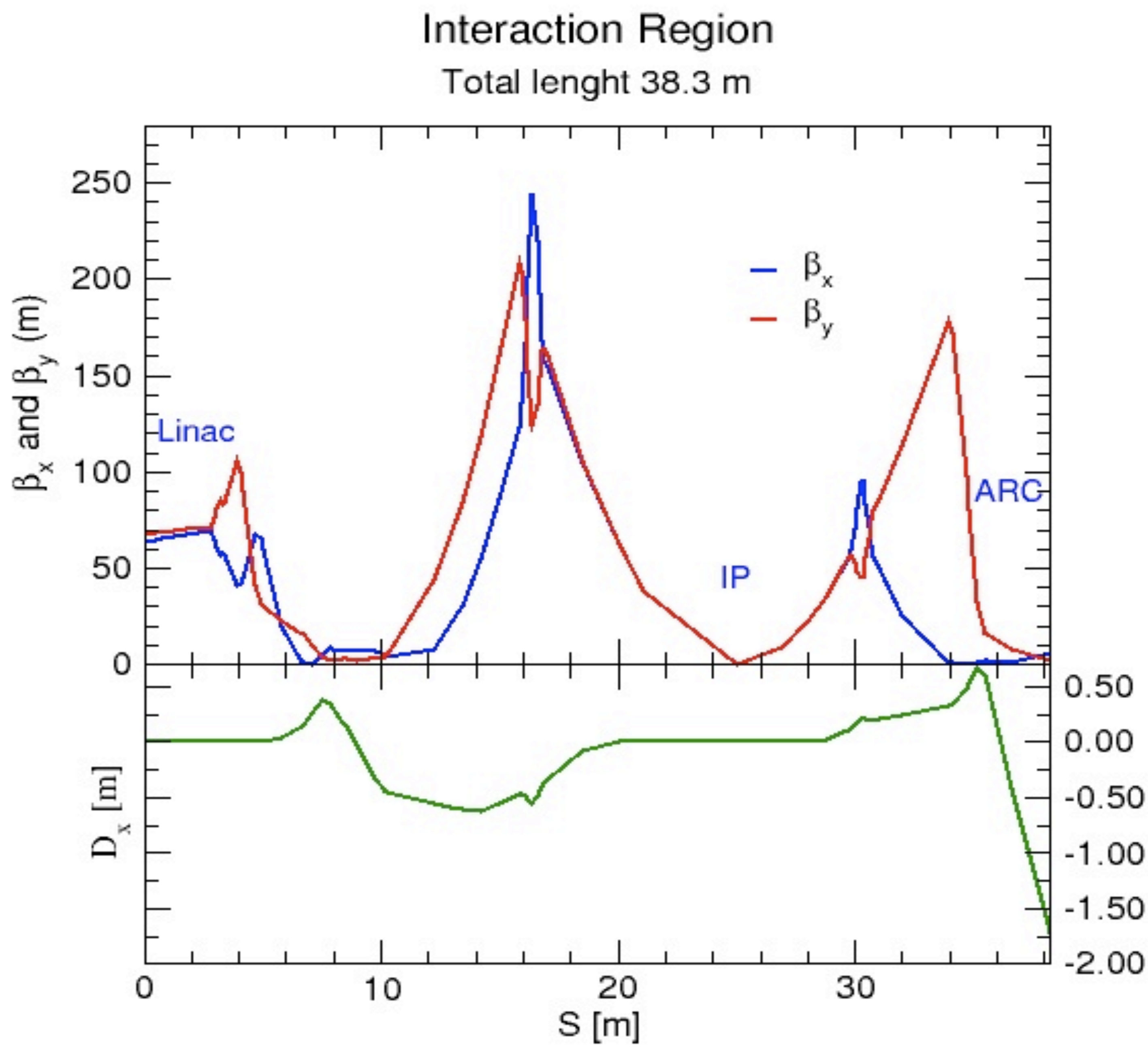
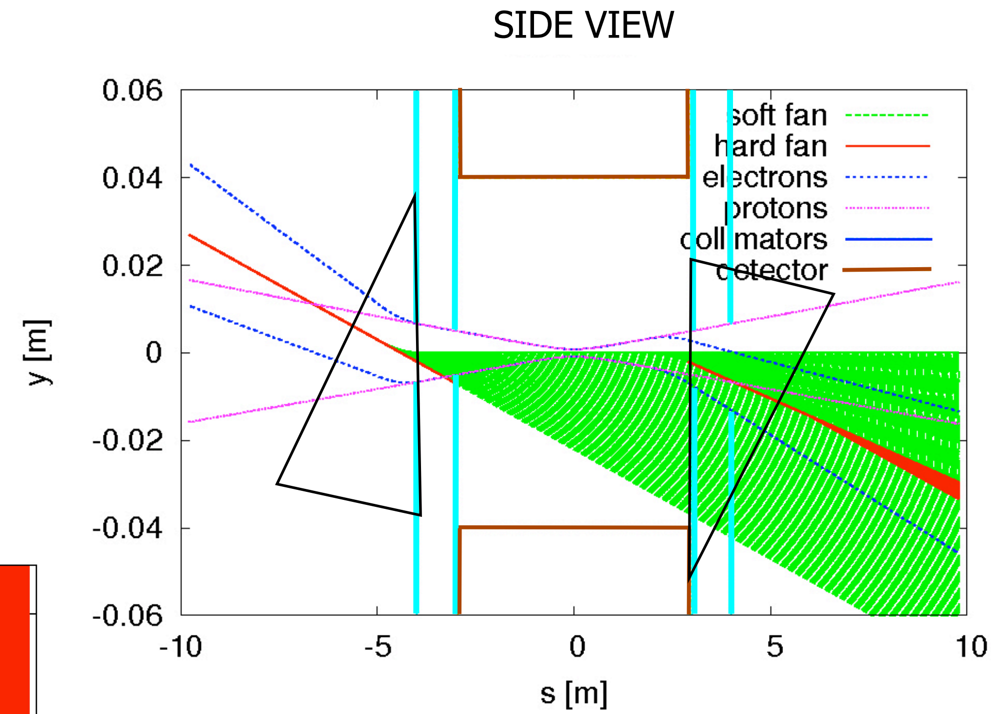


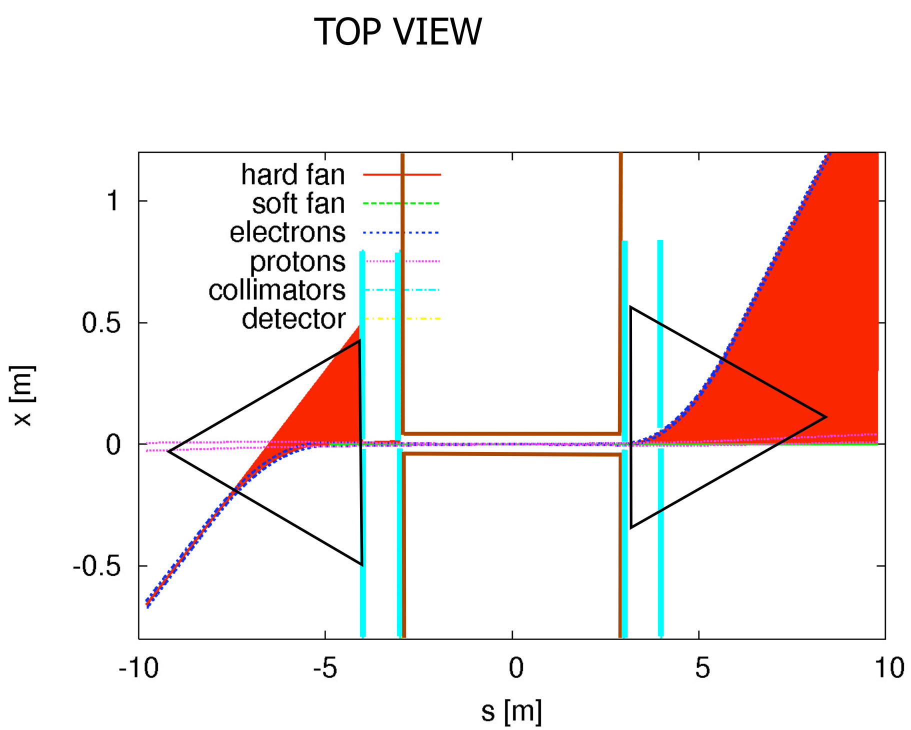


Medium Energy electron Ion Collider (MEeIC)
Matching the donstream interaction region to the arc
1.00
0.50
0.00
-0.50
-1.00
-1.5
-1
-0.5
0
0.5
1
1.5
D/√β
D′ √β + D· α /√β
dldq
qe5d
qe6f
hb2d
qe7f
qe4f
qe3d
qe2f
qe1d
IP
hd1d
Cell to match the zero dispersion to the arc cell
Downstream Beam Line

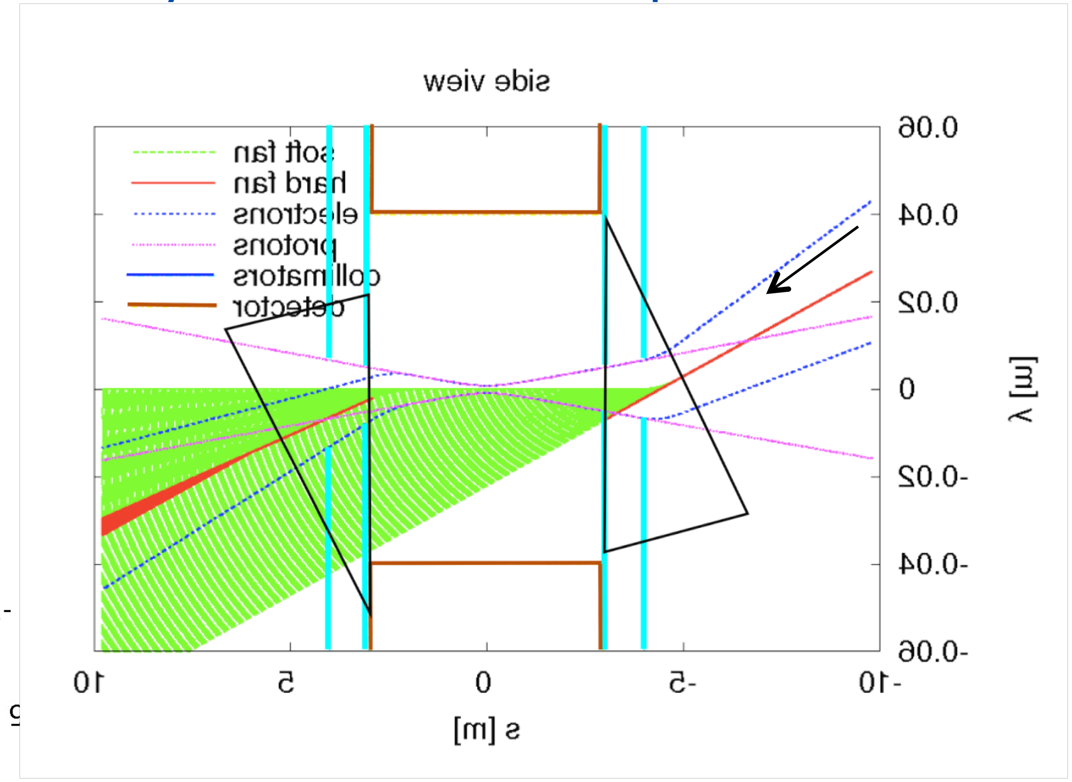

Interaction Region
Total lenght 38.3 m
βx and βy (m)
250
200
150
100
50
0
βx
βy
Linac
IP
ARC
Dx [m]
0.50
0.00
-0.50
-1.00
-1.50
-2.00
0
10
20
30
S [m]

Zero dispersion IP and detector protected Interaction Region
Christoph Montag, Brett Parker – synchrotron radiation protection

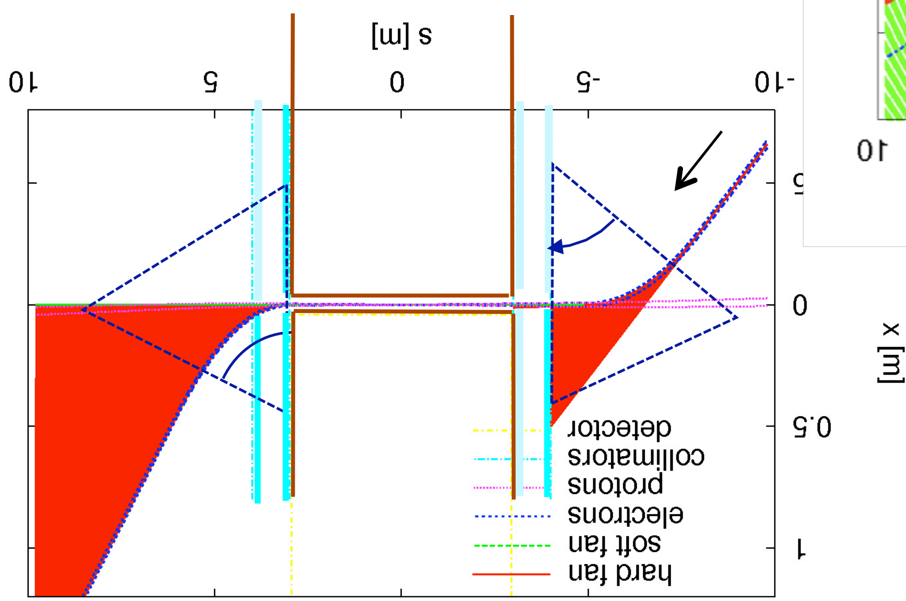




Zero dispersion IP and detector protected Interaction Region
Christoph Montag, Brett Parker – synchrotron radiation protection



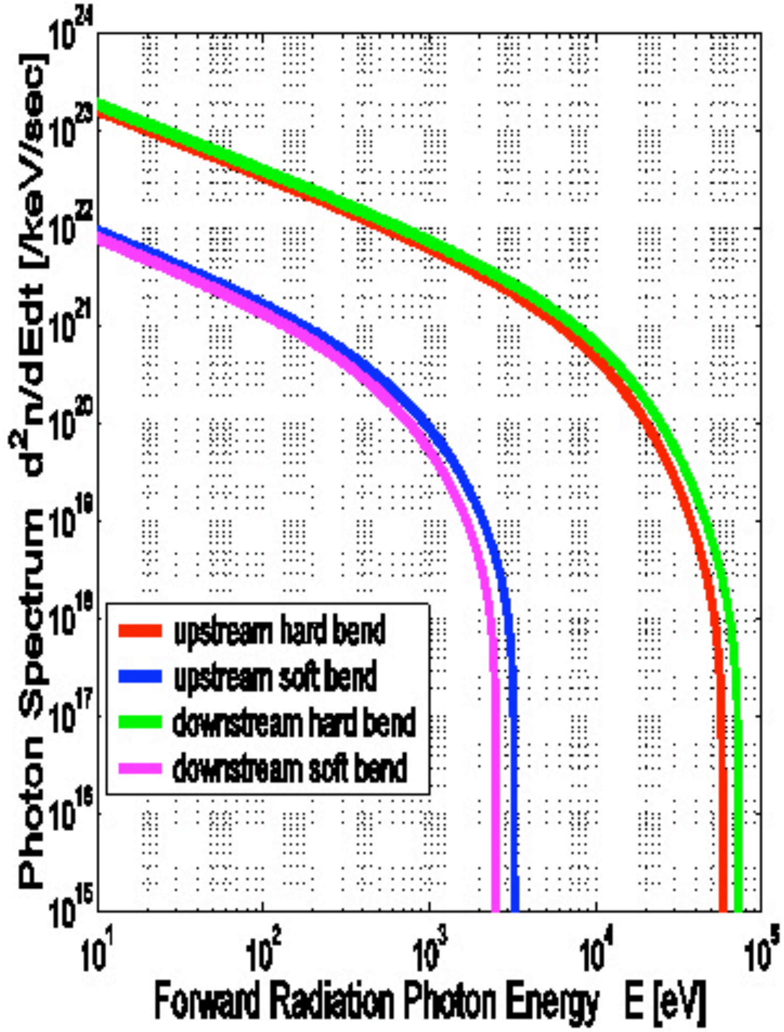
TOP VIEW



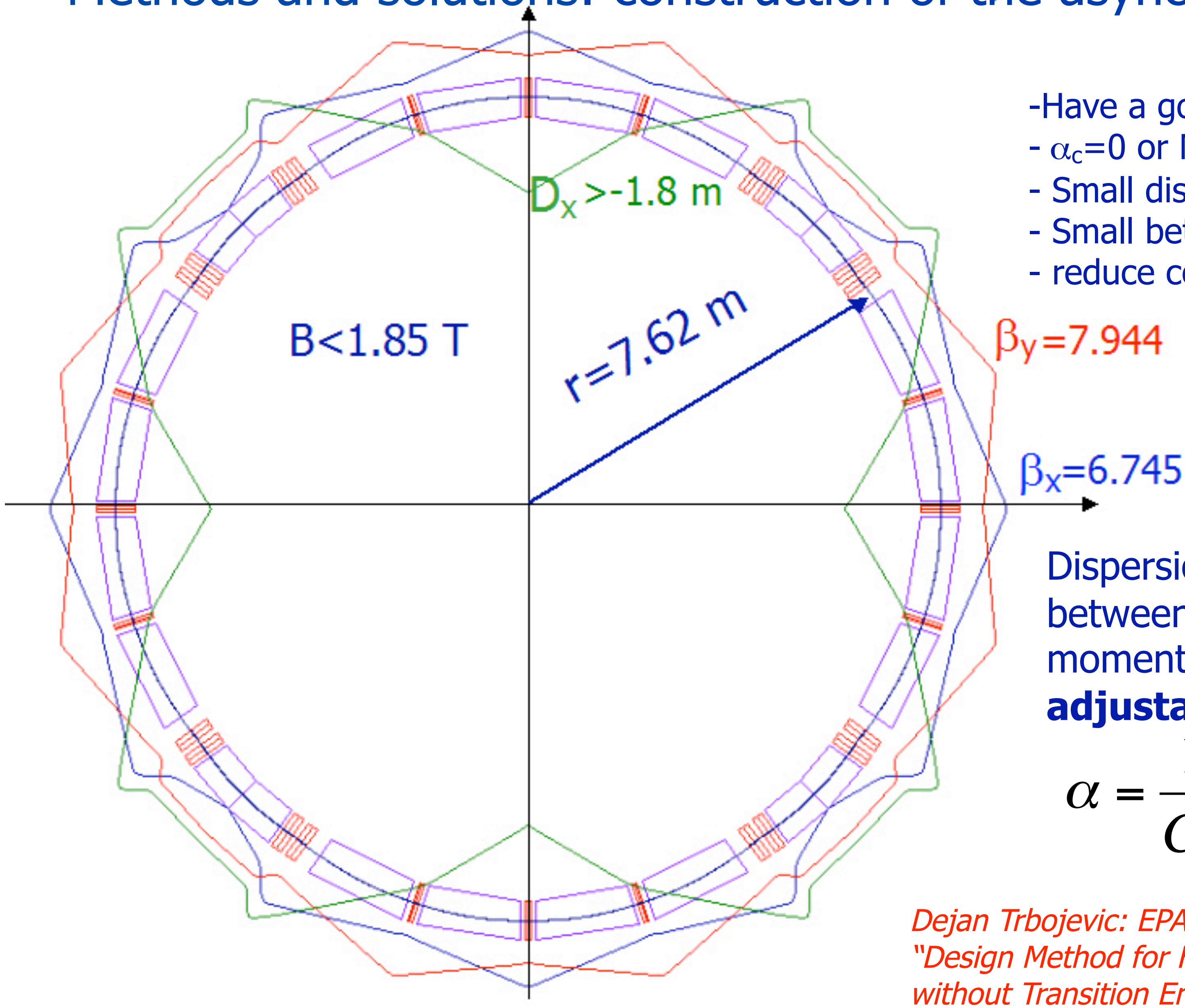
Detector Synchrotron Radiation Background

1. A horizontal hard bend and a vertical soft bend on both side of the detector;
2. The forward radiation from the up stream hard bend (red) is completely masked. No hard radiation passes through the detector;
3. The forward radiation from the up stream soft bend (blue) will passes through the detector without hitting detector wall.
4. The secondary backward radiation induced by the forward radiation generated in down stream bends will be largely masked from the detector;
5. The detector radiation background due to multiple scattering from the vacuum system, masks, collimators and absorbers will be investigated with computer simulations.

Forward Radiation Spectrum



Methods and solutions: construction of the asynchronous arcs:



Goals:

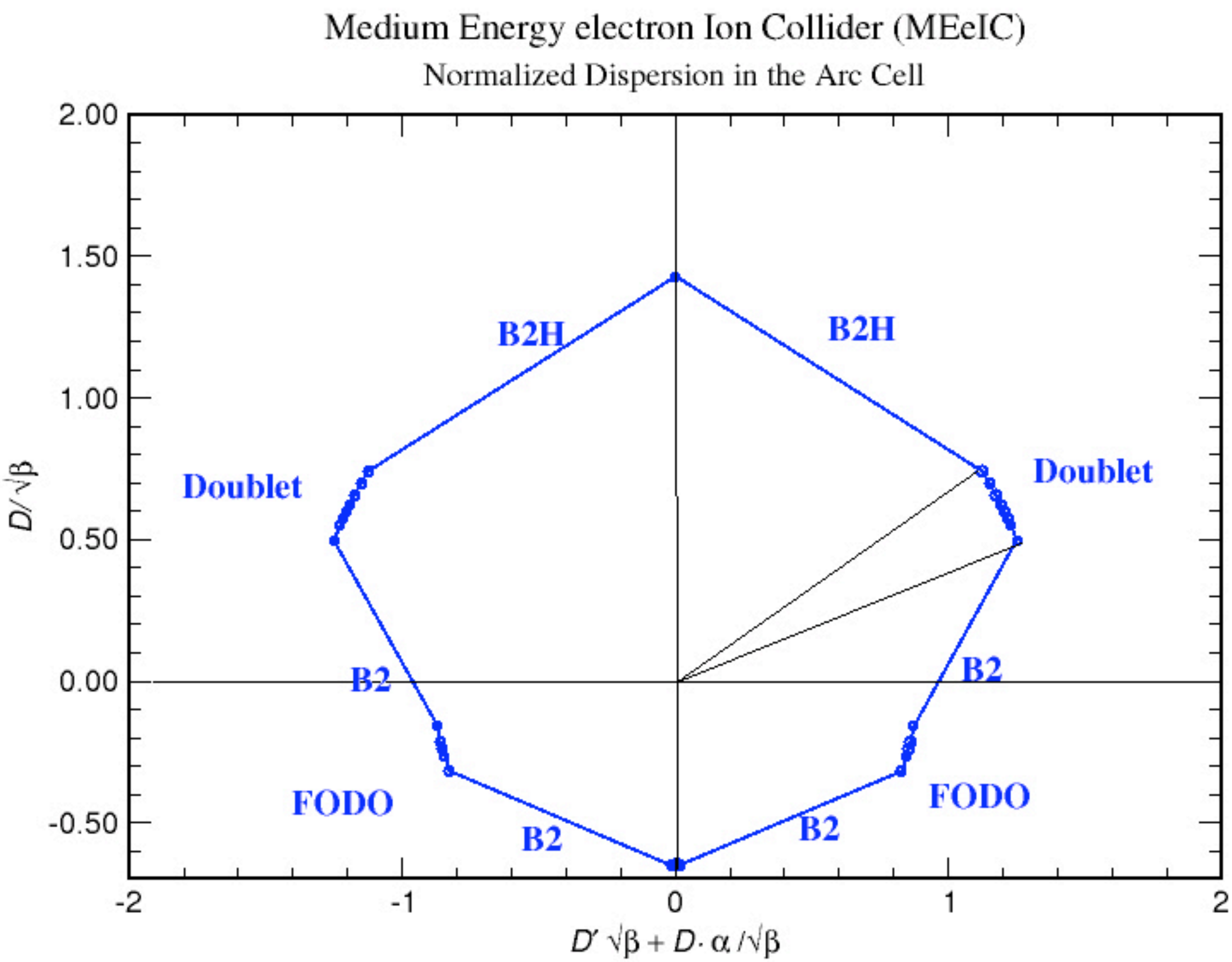
- Have a good packing
- α_c=0 or $M_{5,6}$=0
- Small dispersion
- Small betatron functions
- reduce cost of civil construction

Dispersion function oscillates between ±1.8 m and the momentum compaction is **adjustable**:

$$\alpha = \frac{1}{C_o} \int \frac{D}{\rho} ds \approx 0$$

Dejan Trbojevic: EPAC 1990, pp. 1536: "Design Method for High energy Accelerators without Transition Energy."

Methods and solutions: construction of the asynchronous arcs:



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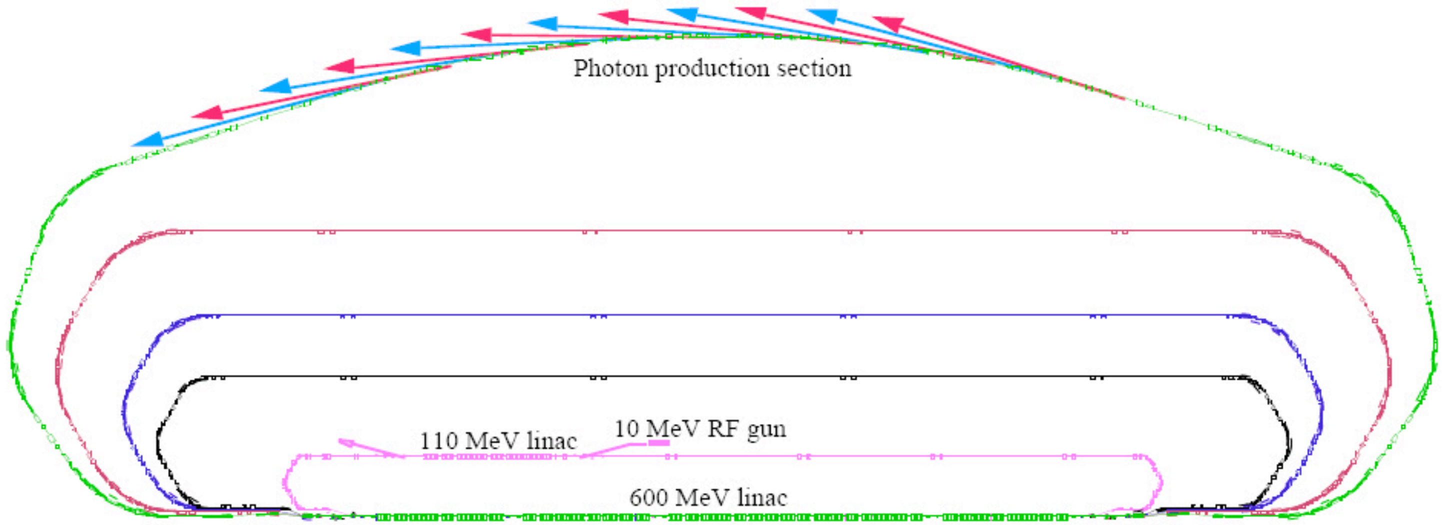


Figure 1. Recirculating linac for fs x-ray production

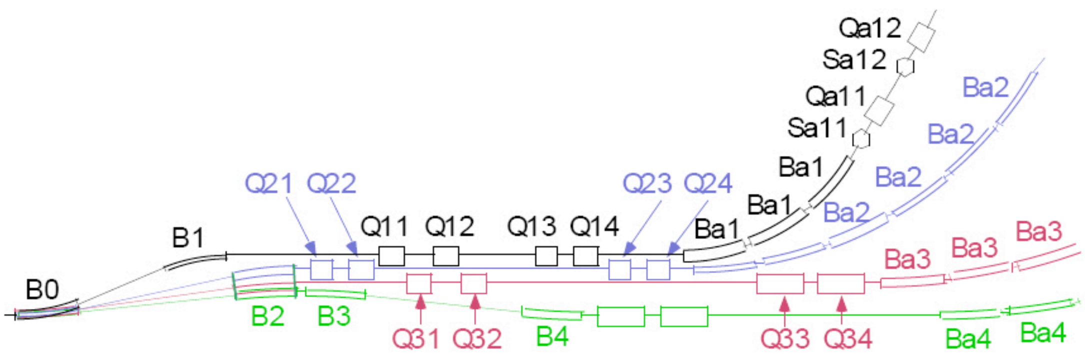


Figure 2. The beam spreader section that separates the beam at various energies into their respective transport paths.

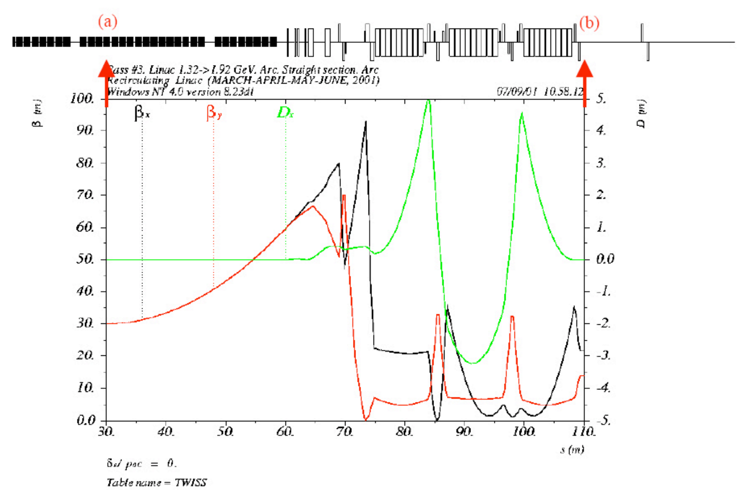
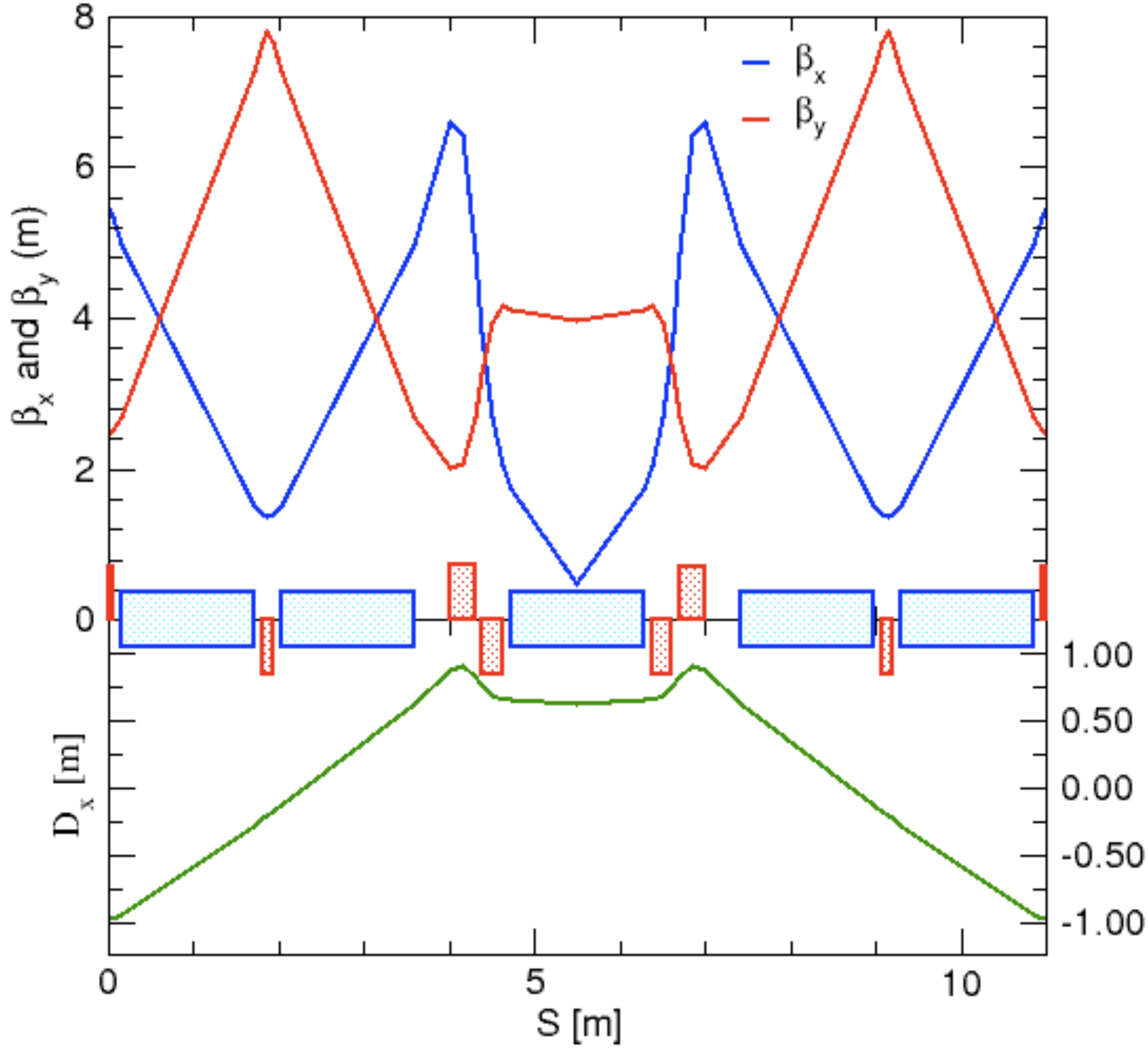


Figure 4. Lattice functions from the center of the main linac (a), through the end of arc 3 (b) (1.9 GeV).

4 GeV Arcs with the Flexible Momentum Compaction Lattice

Total lenght 11 m



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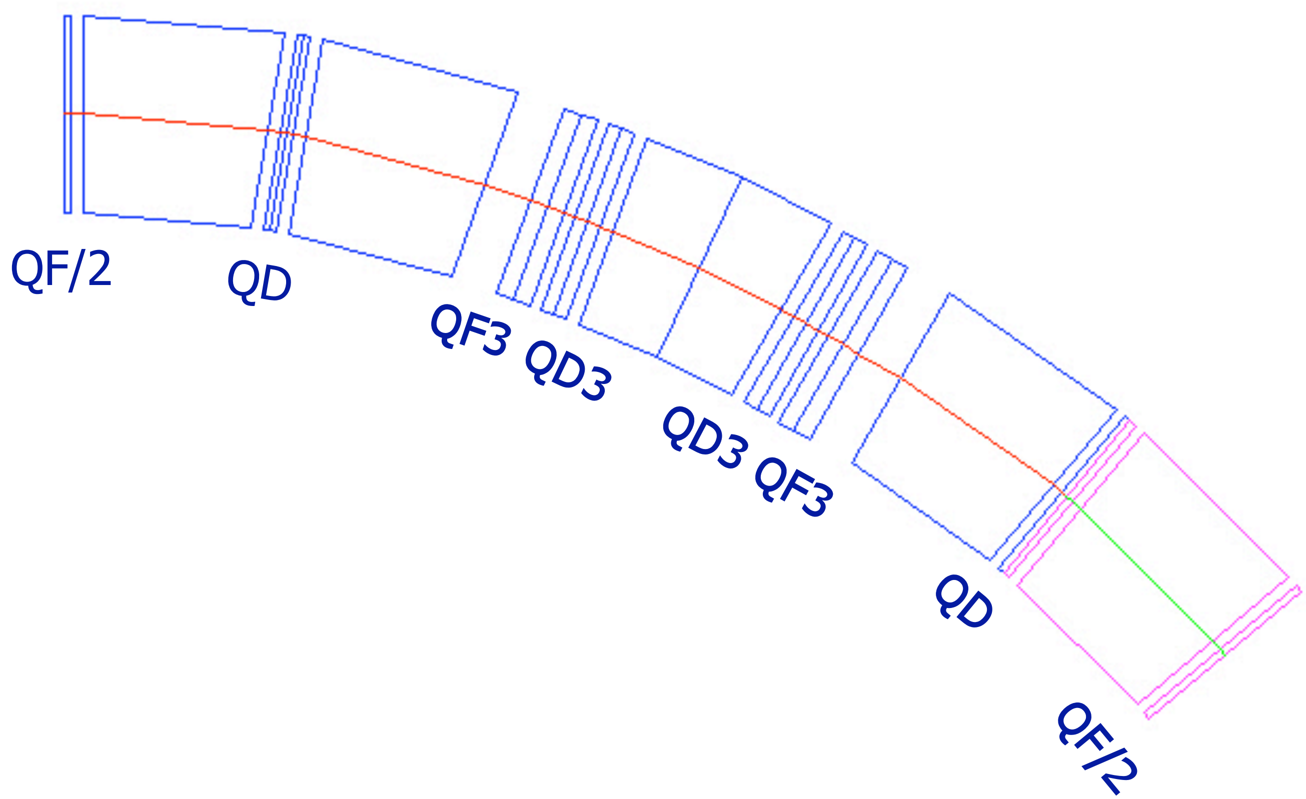
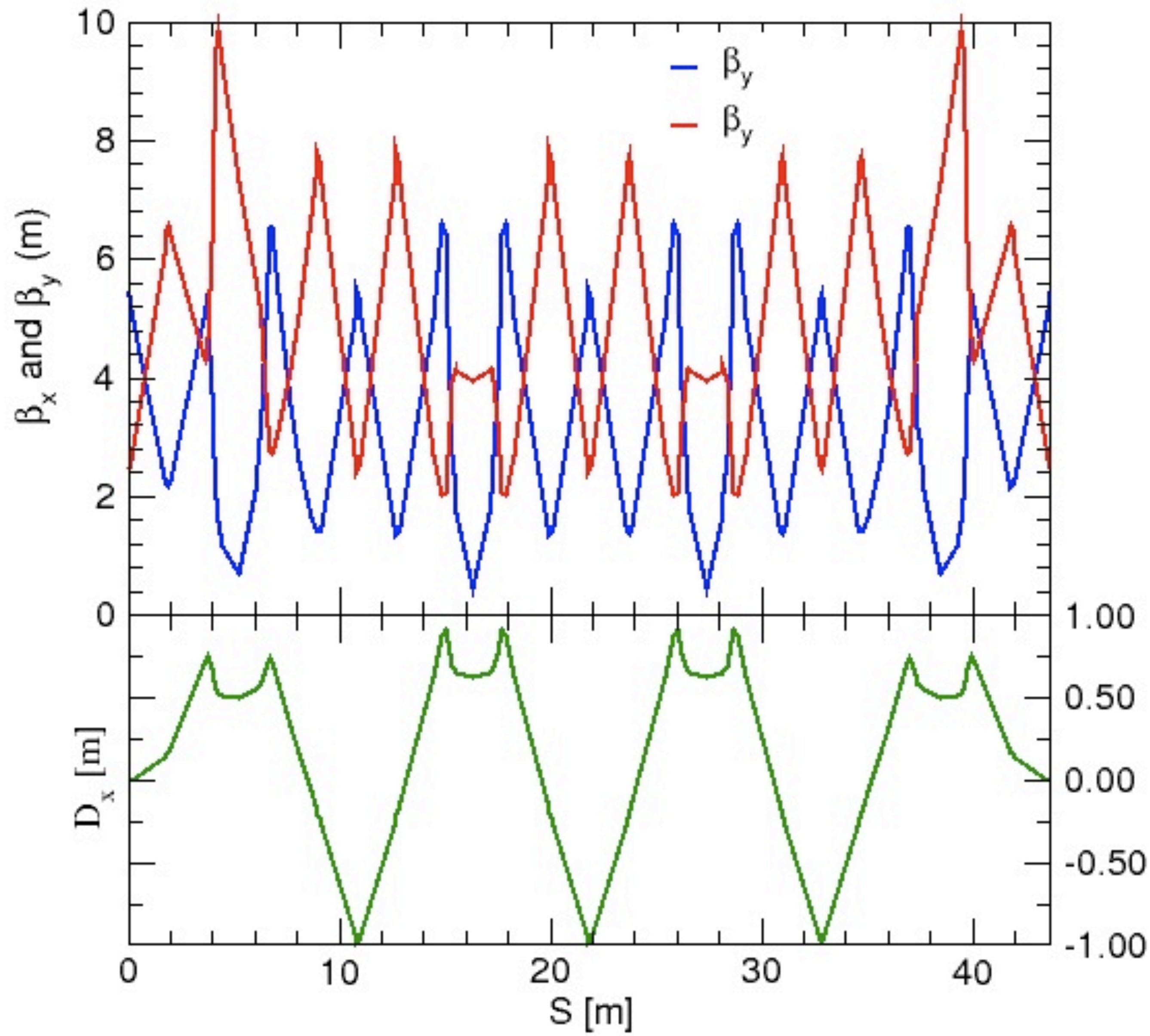
One Flexible Momentum Compaction Cell:

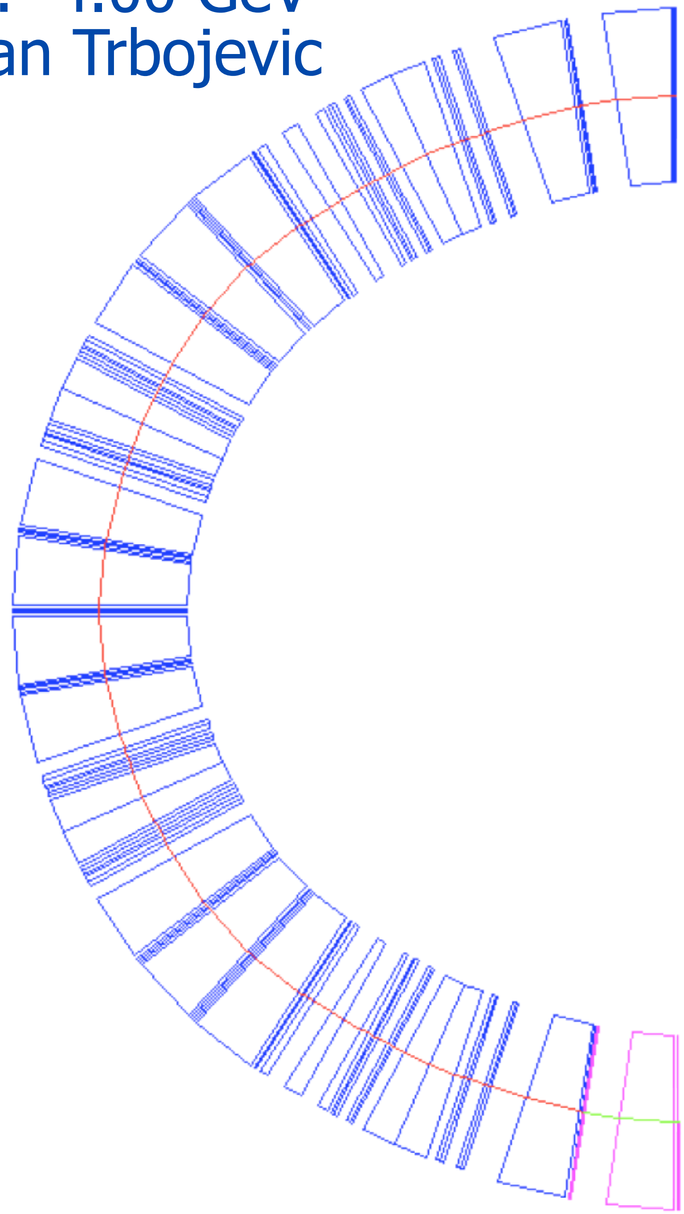


4 GeV Arcs with the Flexible Momentum Compaction Lattice

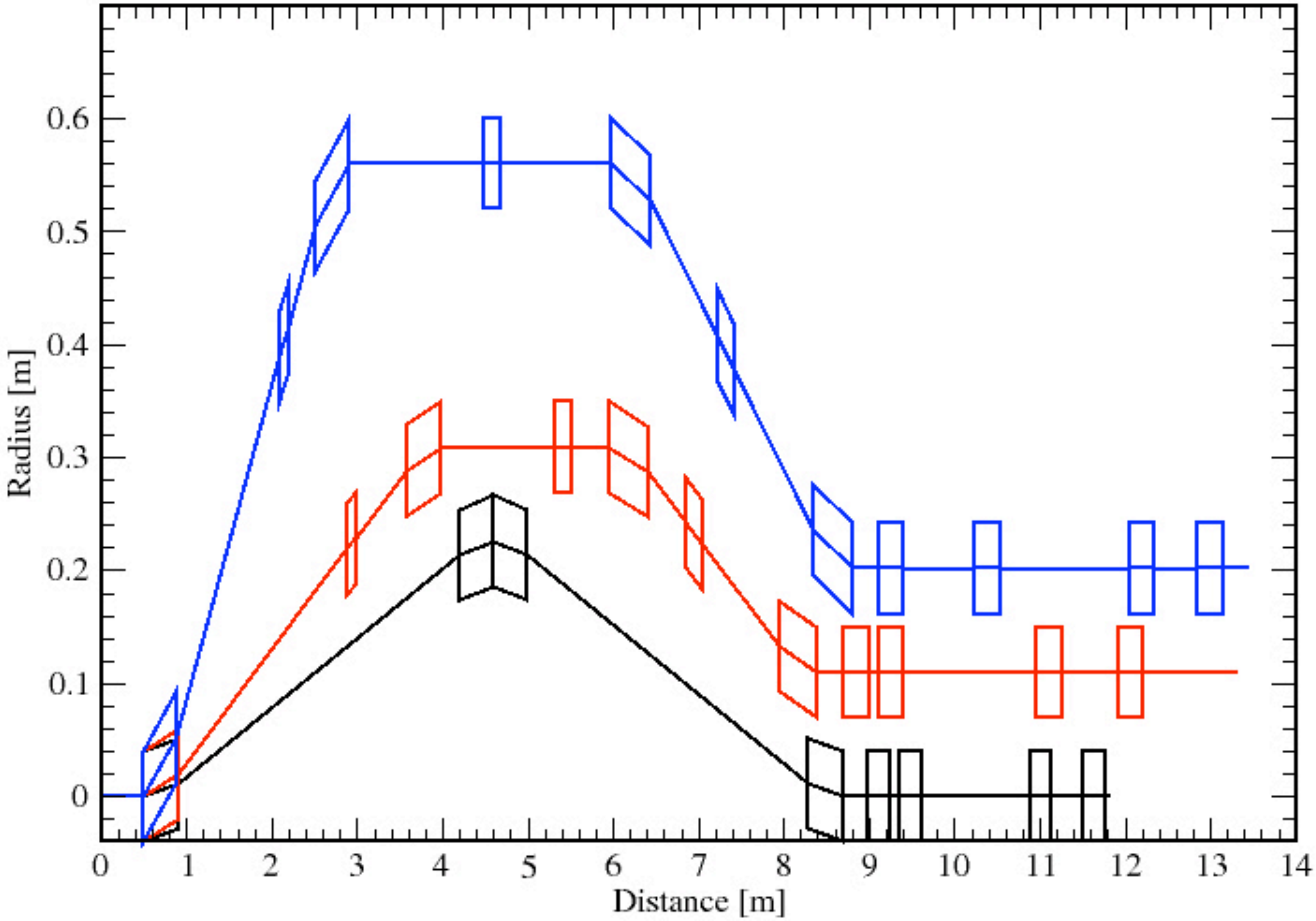
Total lenght 43 m

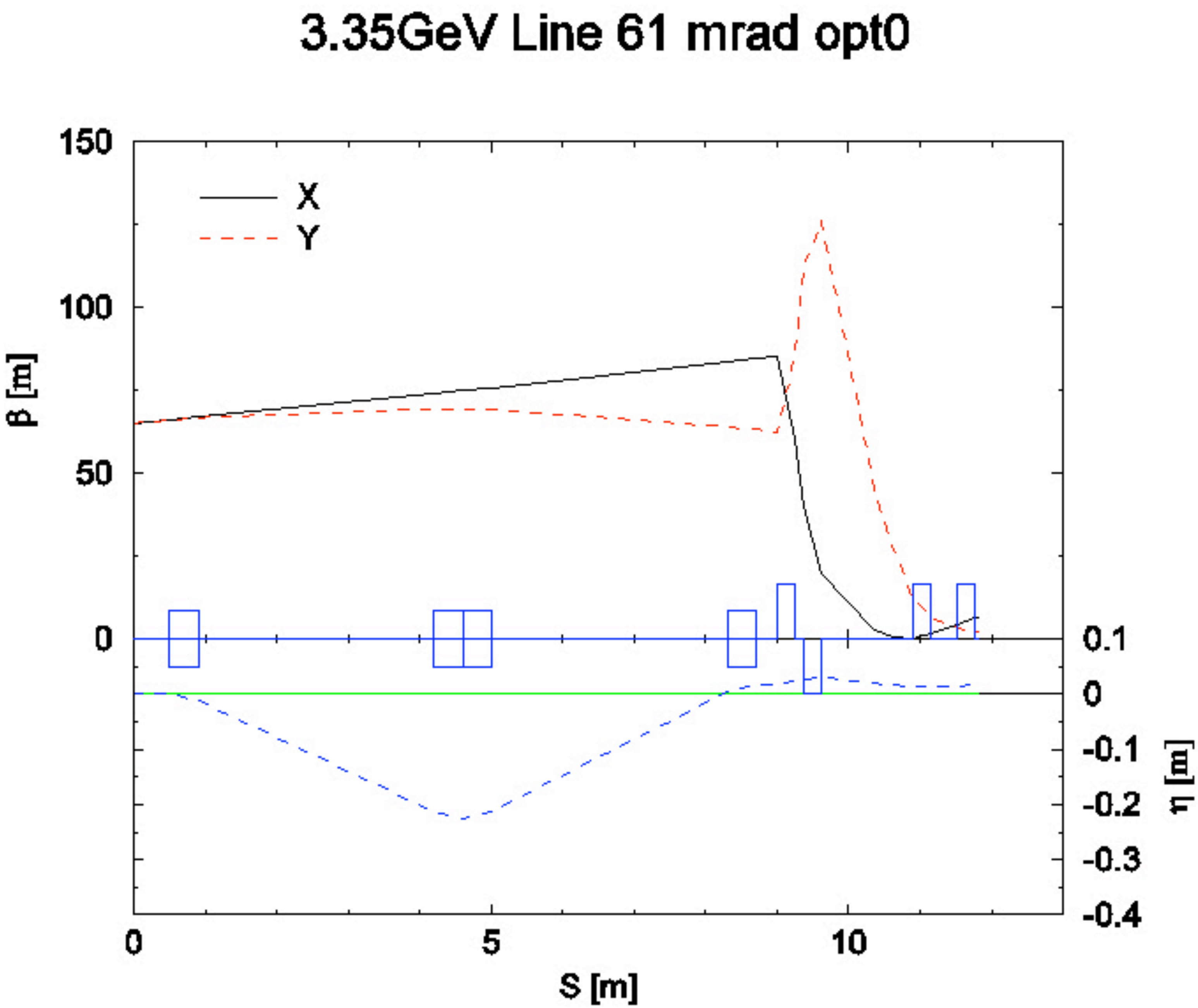


Asynchronous arcs: 4.00 GeV
Dmitri Kayran, Dejan Trbojevic



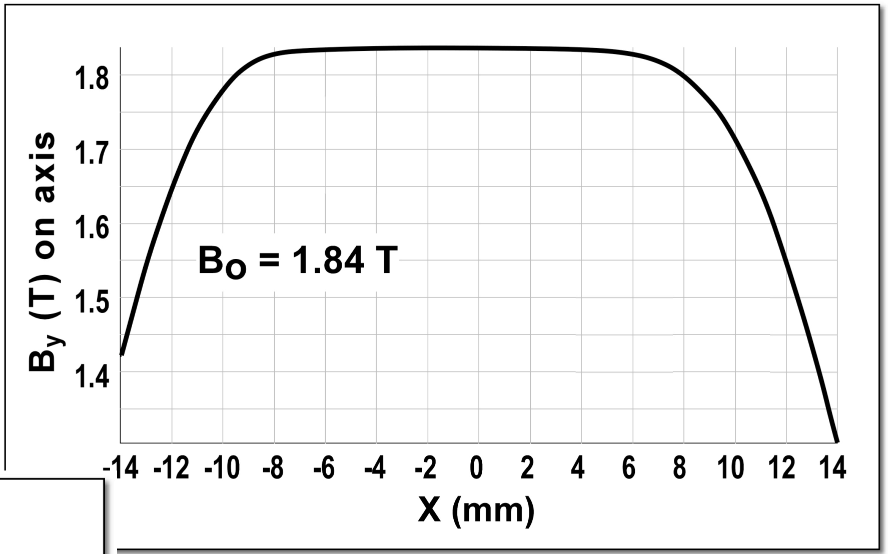
Vertical splitters – Nicholaus Tsoupas
3.35 GeV, 2.05 GeV, and 0.75 GeV

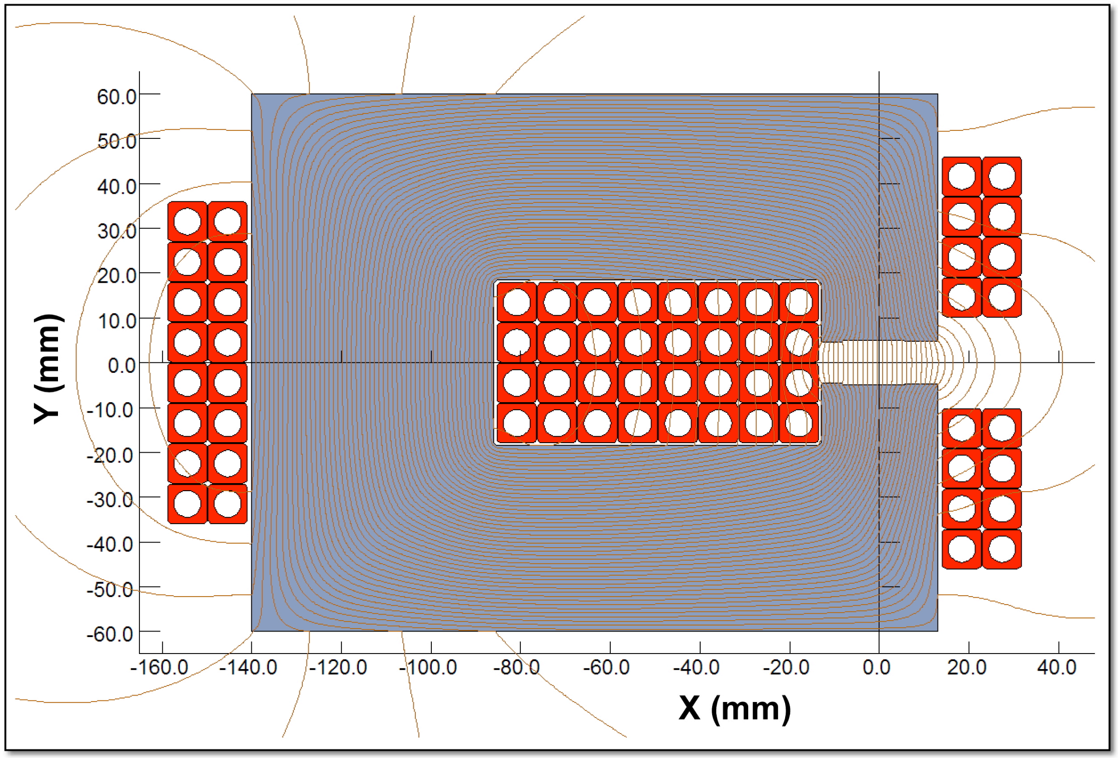



3.35GeV Line 61 mrad opt0
X
Y
150
100
50
0
β [m]
0.1
0
-0.1
-0.2
-0.3
-0.4
η [m]
0
5
10
S [m]

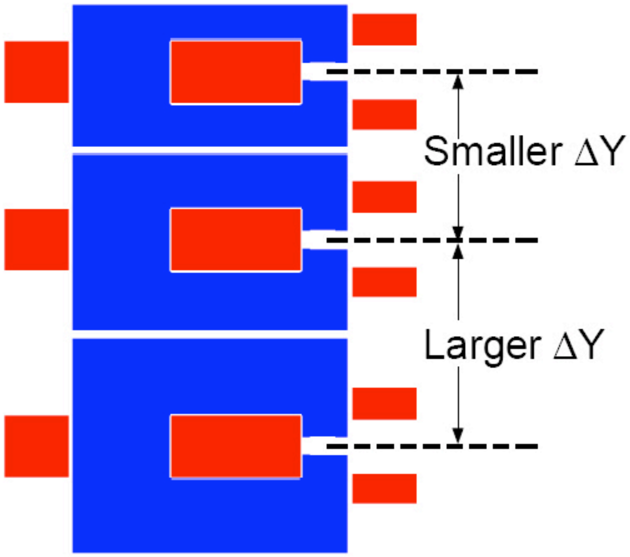
Brett Parker: Preliminary dipole design:

New dipole magnet:
L=1.55 m
B=1.5024 T
θ=0.174532925
There are 18 dipoles per arc
$18 * \theta = \pi$

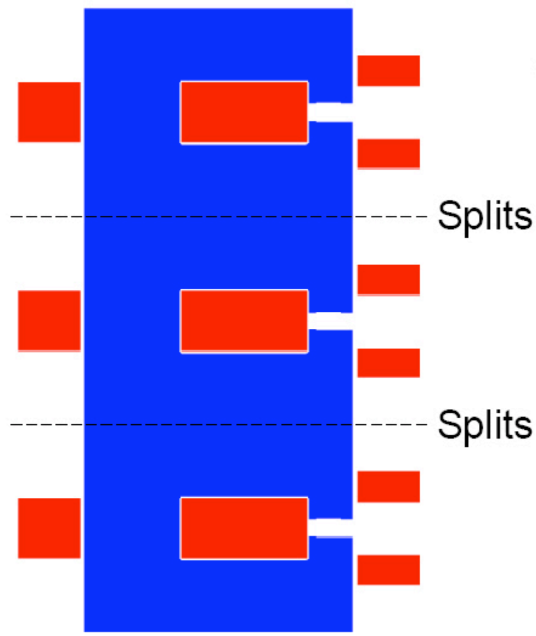




Brett Parker: Preliminary dipole and vertical correctors design:

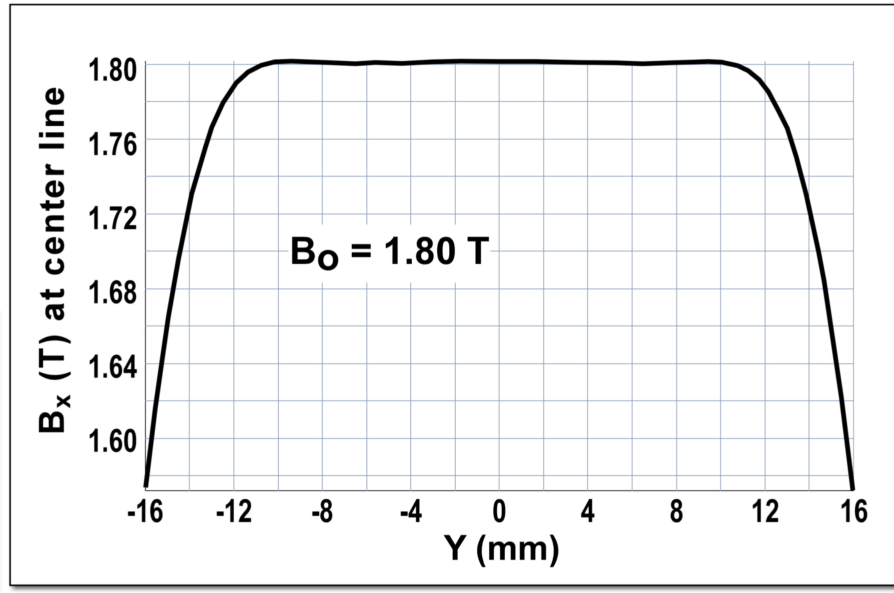


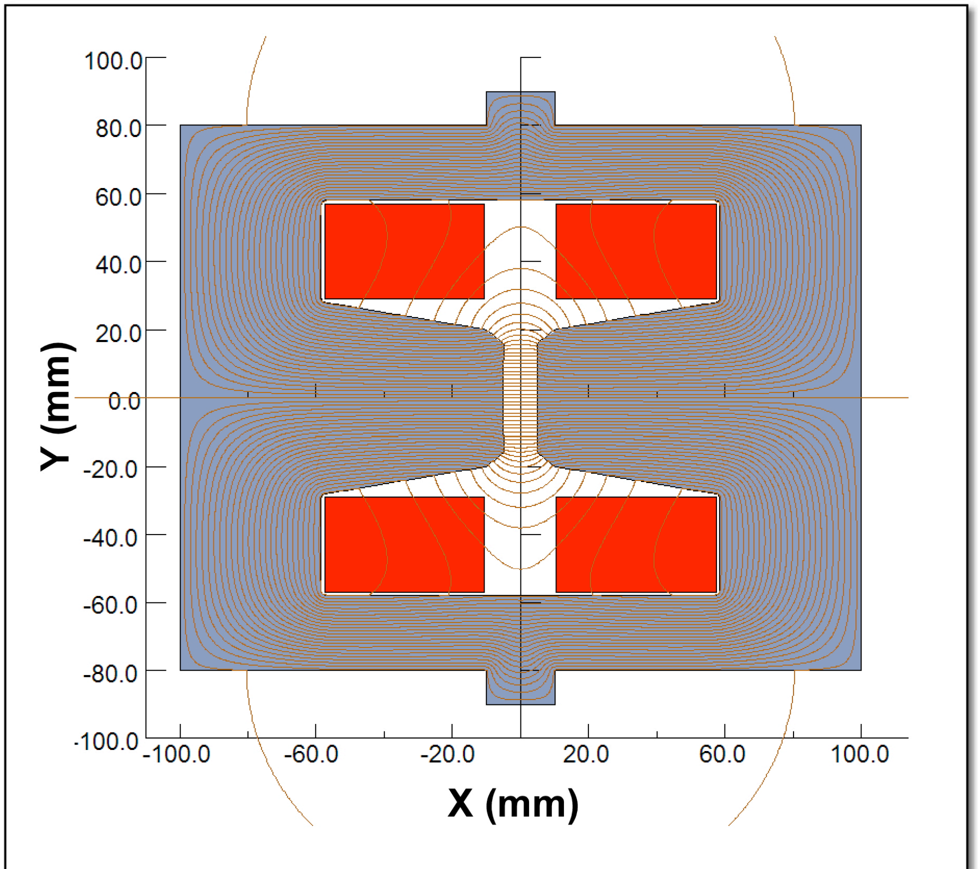
Object: To get more yoke space for higher field dipole magnets.



Need to be careful with optimization to minimize cross talk.

Brett Parker: vertical correctors design:





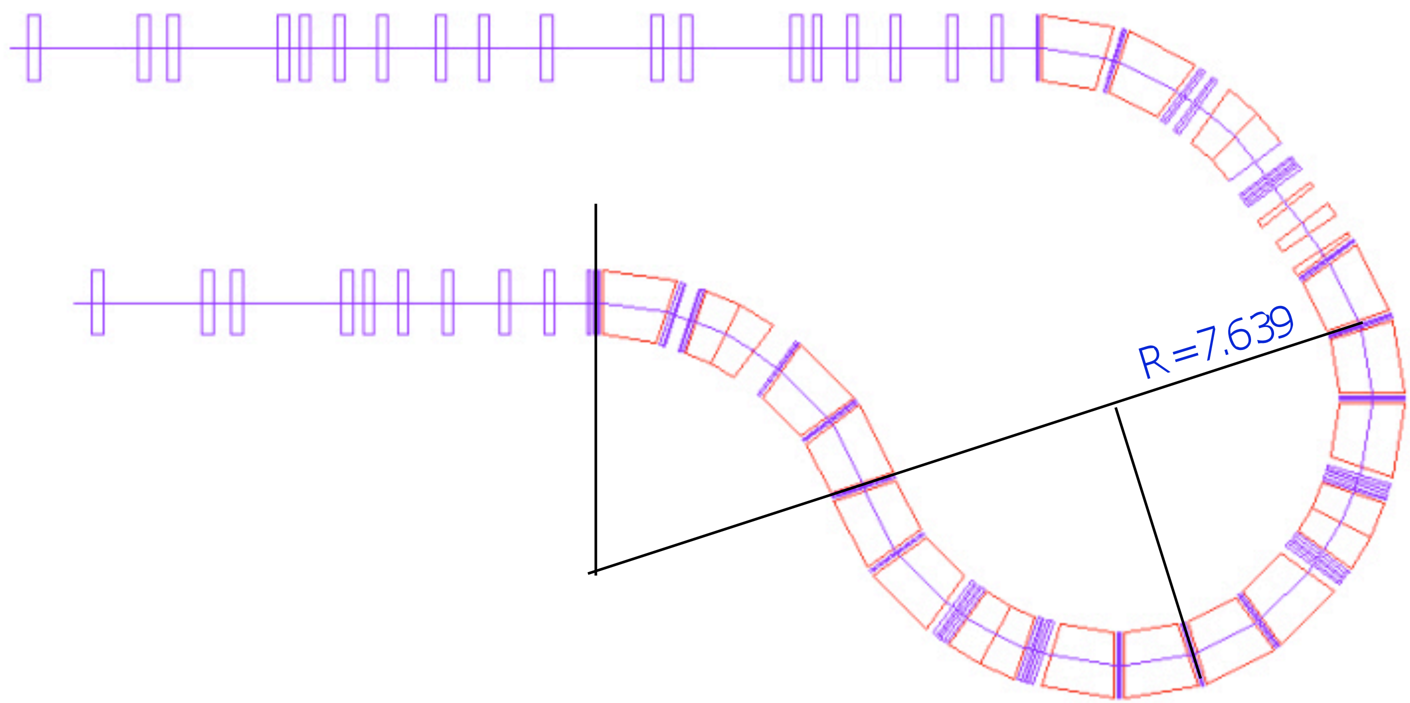
Summary:

- Lattice design of the electron recovery accelerator is almost completed.
- Advanced linac design provides many advantages.
- Present complete lattice design provides a very compact solution with a minimum civil construction.
- Asynchronous condition for any energy pass through the arcs is provided ($M_{56} = 0$).
- Preliminary magnet design of the dipoles and correctors shows requirements of the vertical aperture of the order of ~10 mm to reduce the power consumption.
- Preliminary cost estimate is now in progress.

Back up slides:

Zero dispersion IP and detector protected Interaction Region – C. Montag, B. Parker, J. Beebe-Wang, D. Kayran and D. Trbojevic

3.5 GeV Arc with opposite bend part



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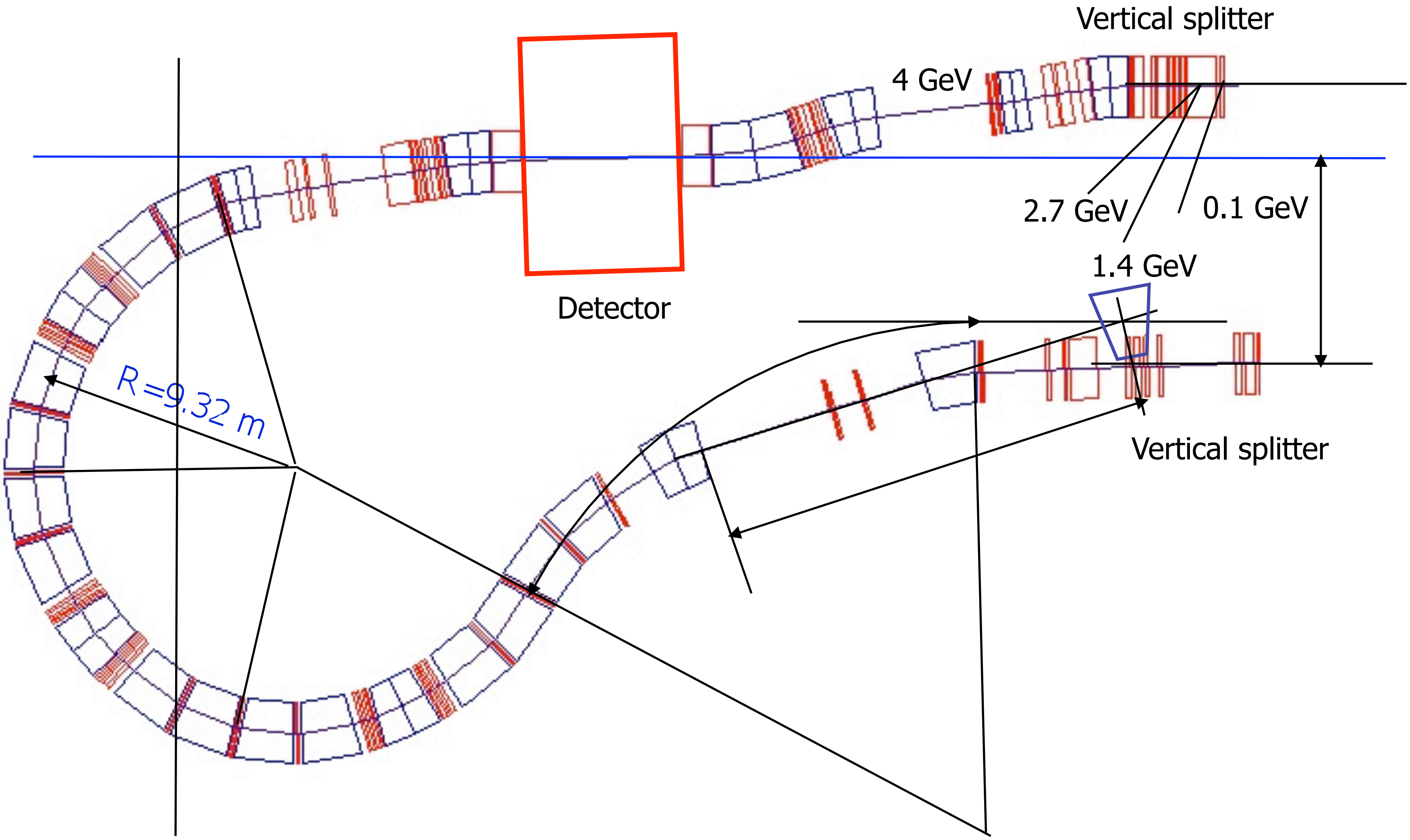
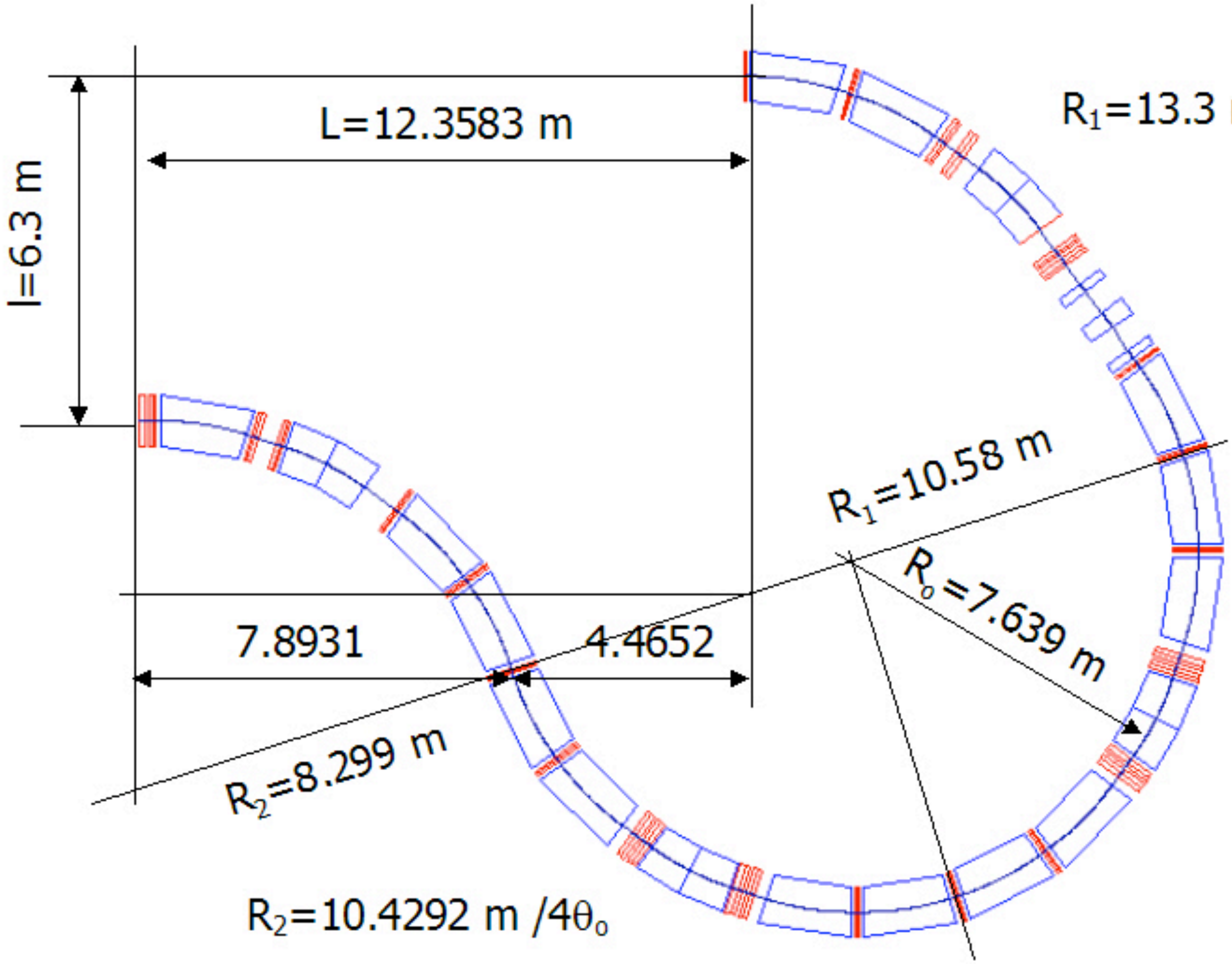


Asynchronous arcs: 3.35 GeV
Dmitri Kayran, Dejan Trbojevic



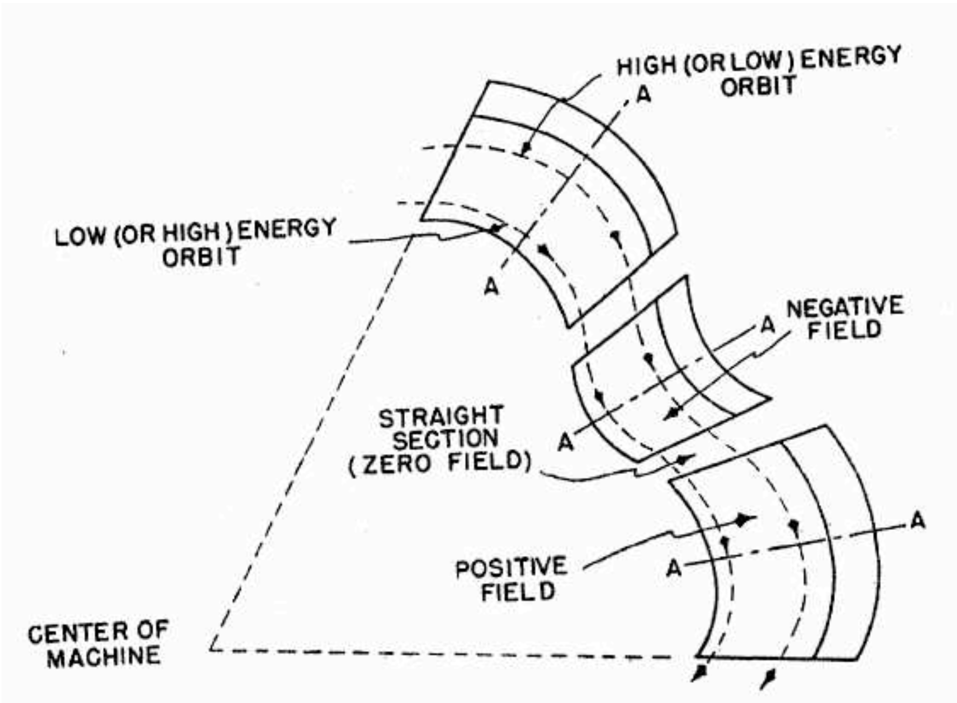
R_2=10.4292 m /4θ_o

θ_o=2π/20

Non-scaling FFAG

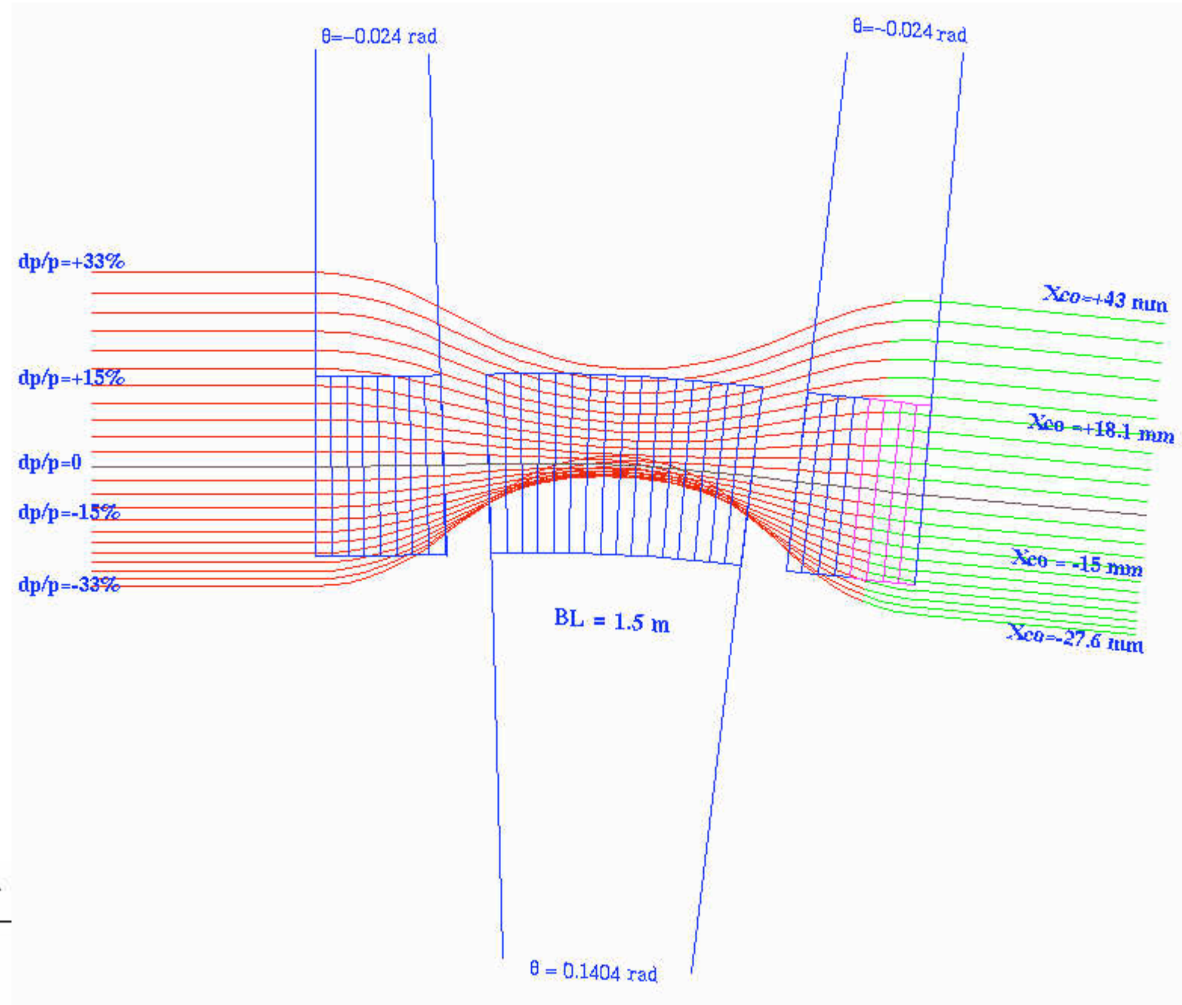
The scaling Fixed Field Alternating Gradient

$B = B_o (r/r_o)^k$ (k~1500)



Non-scaling FFAG

- **Extremely strong focusing with small dispersion function.**
- smaller energy acceptance.
- tunes vary.
- orbit offsets are small.
- magnets are small.



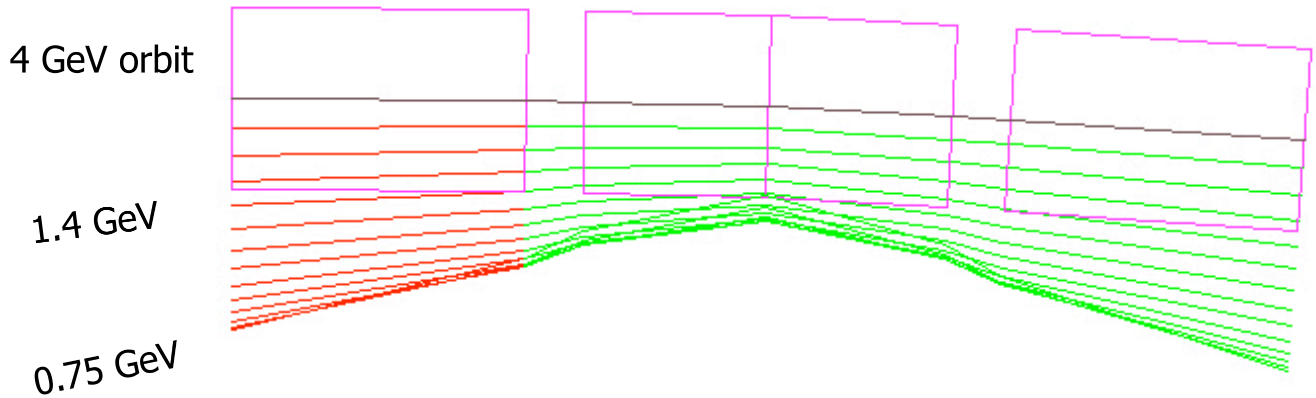
PHYSICAL REVIEW SPECIAL TOPICS -

Design of a nonscaling fixed field alternating gradient accelerator

D. Trbojevic,* E. D. Courant, and M. Blaskiewicz

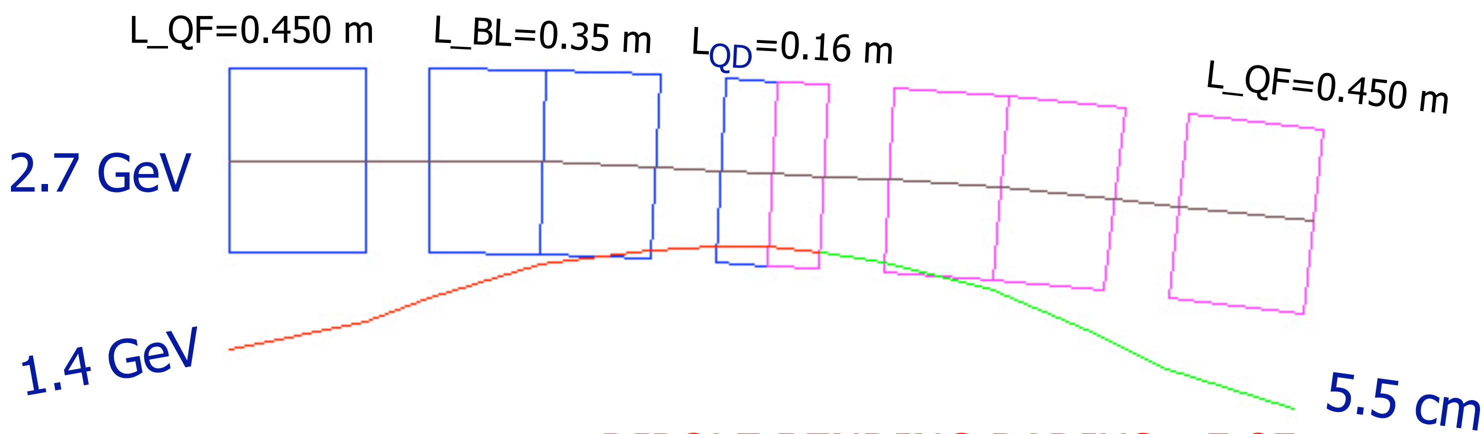
BNL, Upton, New York 11973, USA

Construction of the arcs by the FFAG combined function magnets – basic cell



-80% < δp/p < 0.0

Construction of the arcs by the FFAG separate function magnets – basic cell



ANG= 0.0561 rad DIPOLE BENDING RADIUS =5.85 m

BYD= 1.4435 T

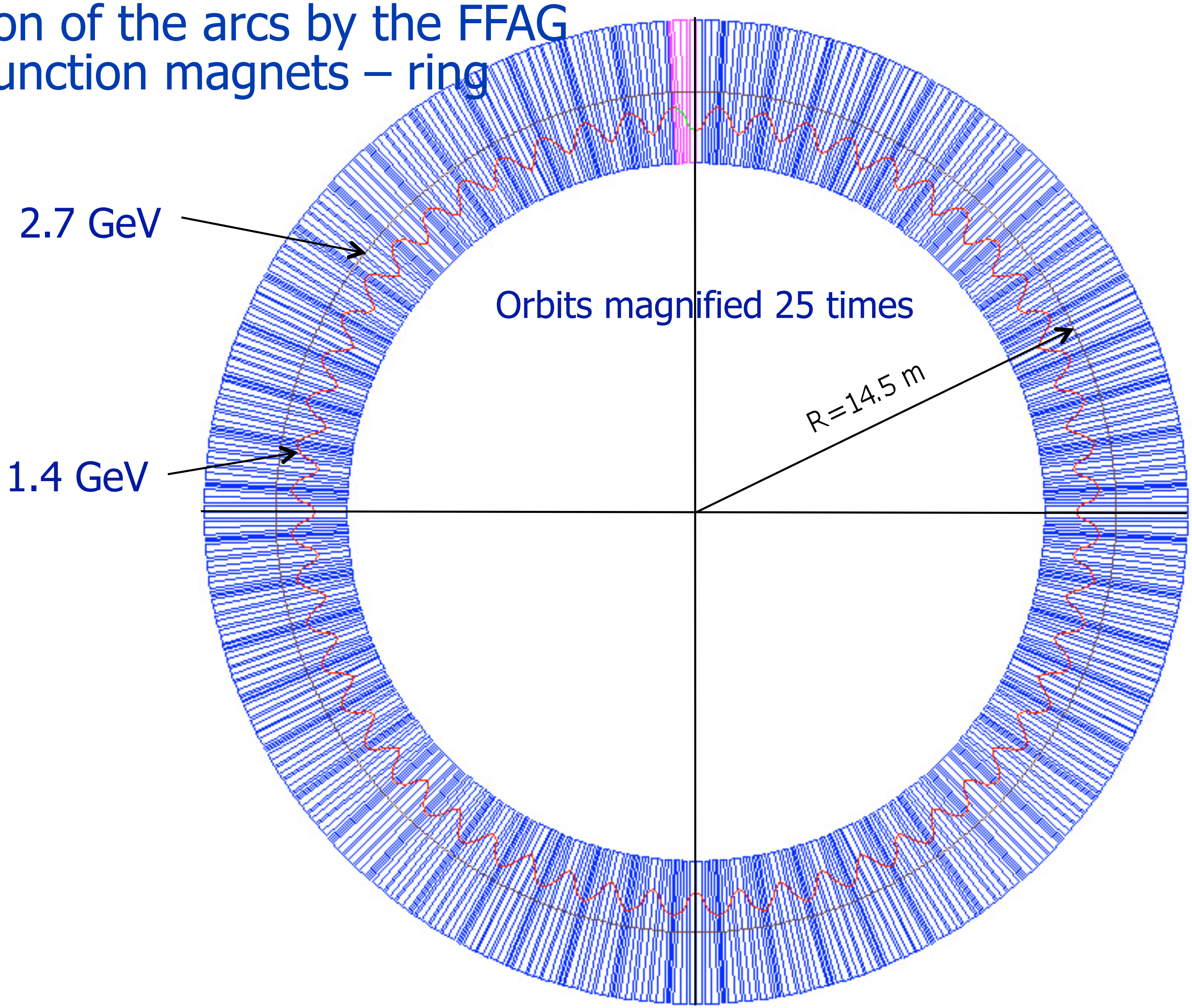
Gradients in quadrupoles:

KF = 30.0 T/m KD= -60.0 T/m

Lcell = 1.681177 m

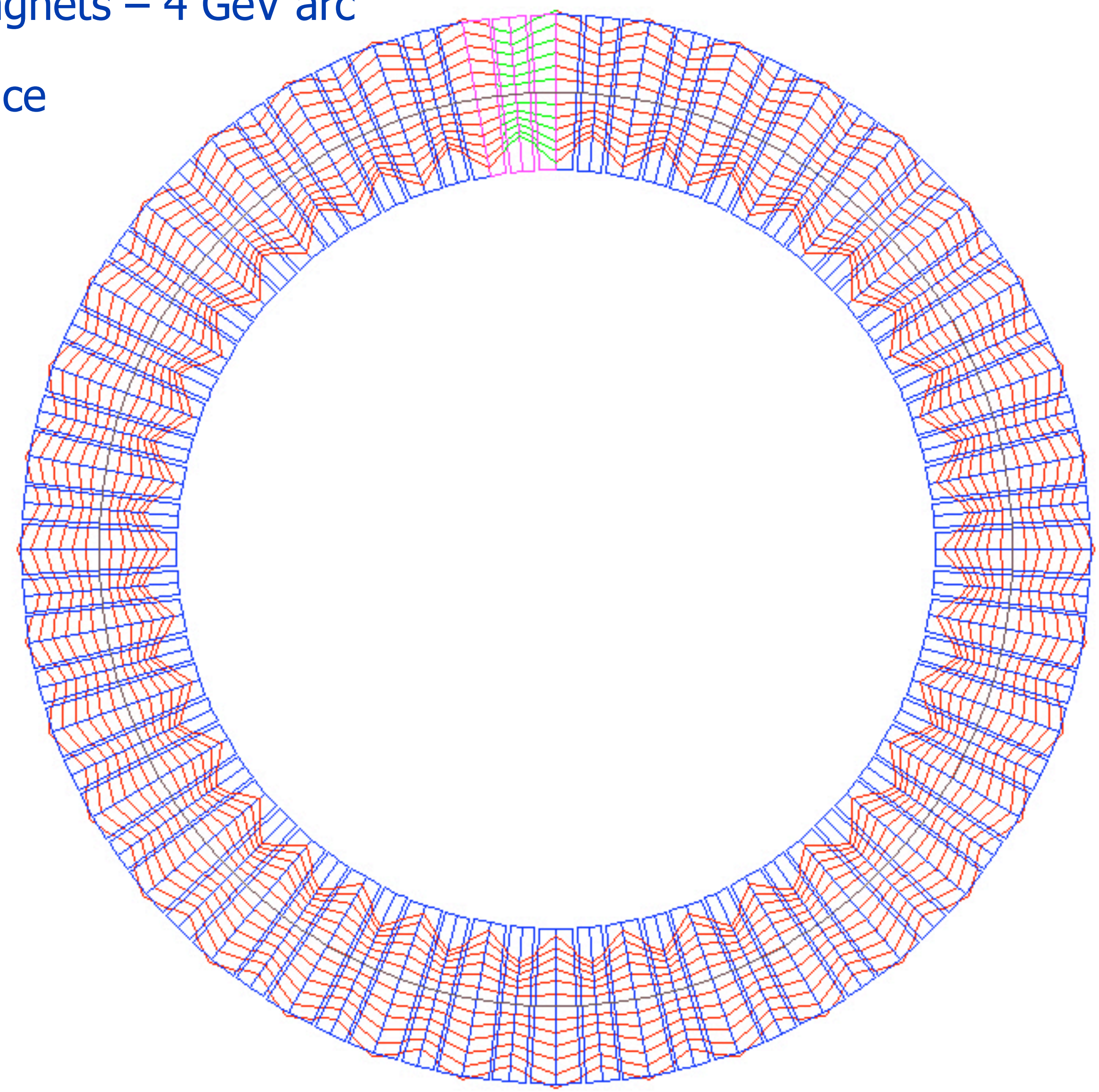
56 cells

Construction of the arcs by the FFAG separate function magnets – ring

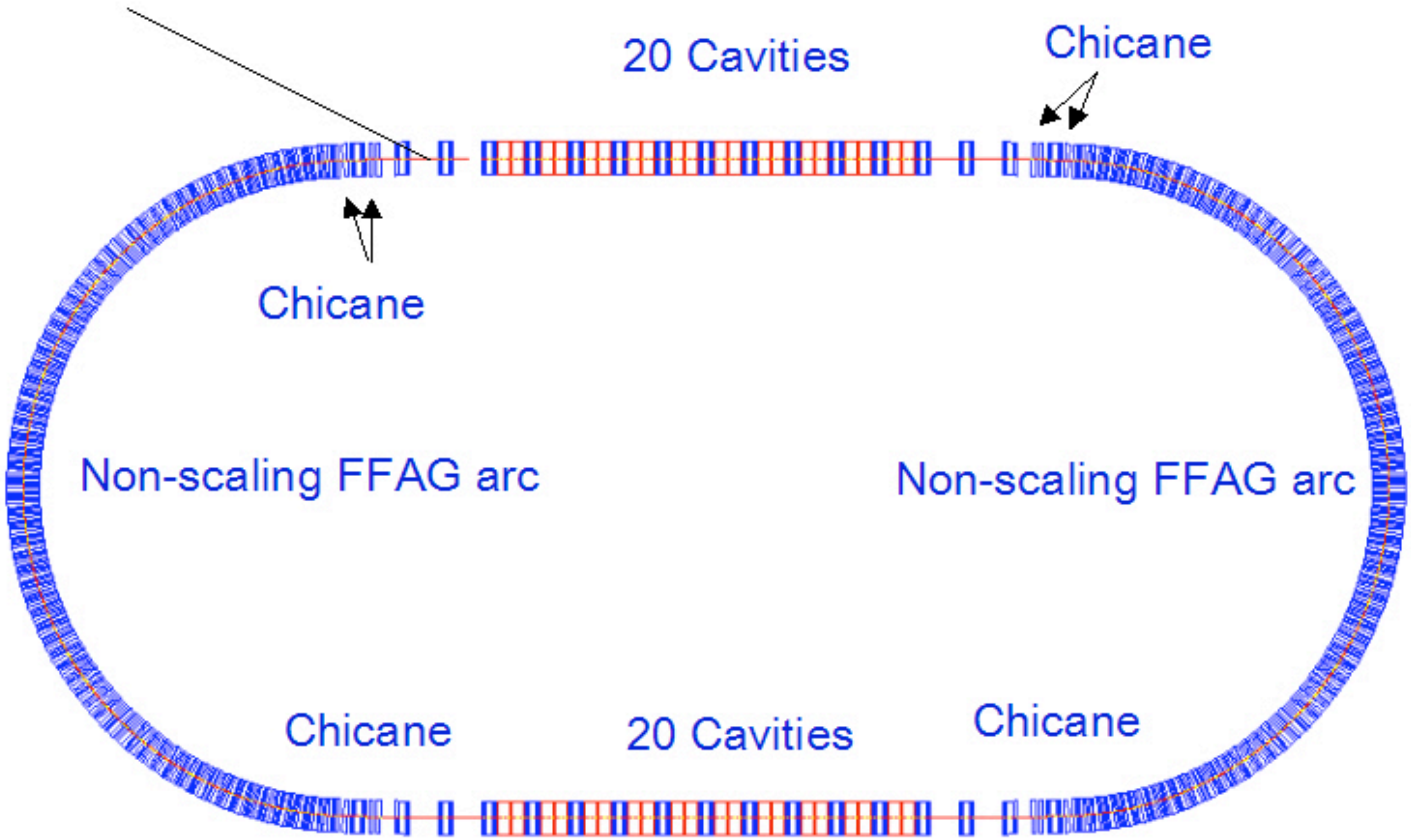


Construction of the arcs by the FFAG separate function magnets – 4 GeV arc

momentum acceptance
$\delta p/p$=+-50%



Multipass Linac - racetrack FFAG



Back up slides: