eRHIC IR design

Dejan Trbojevic

eRHIC IR design

L~ 1.5 10^{34} cm^{-2} s^{-1}

- Interaction region design for electron-ion/proton collisions
  - Avoid bending electrons to avoid synchrotron radiation problems:

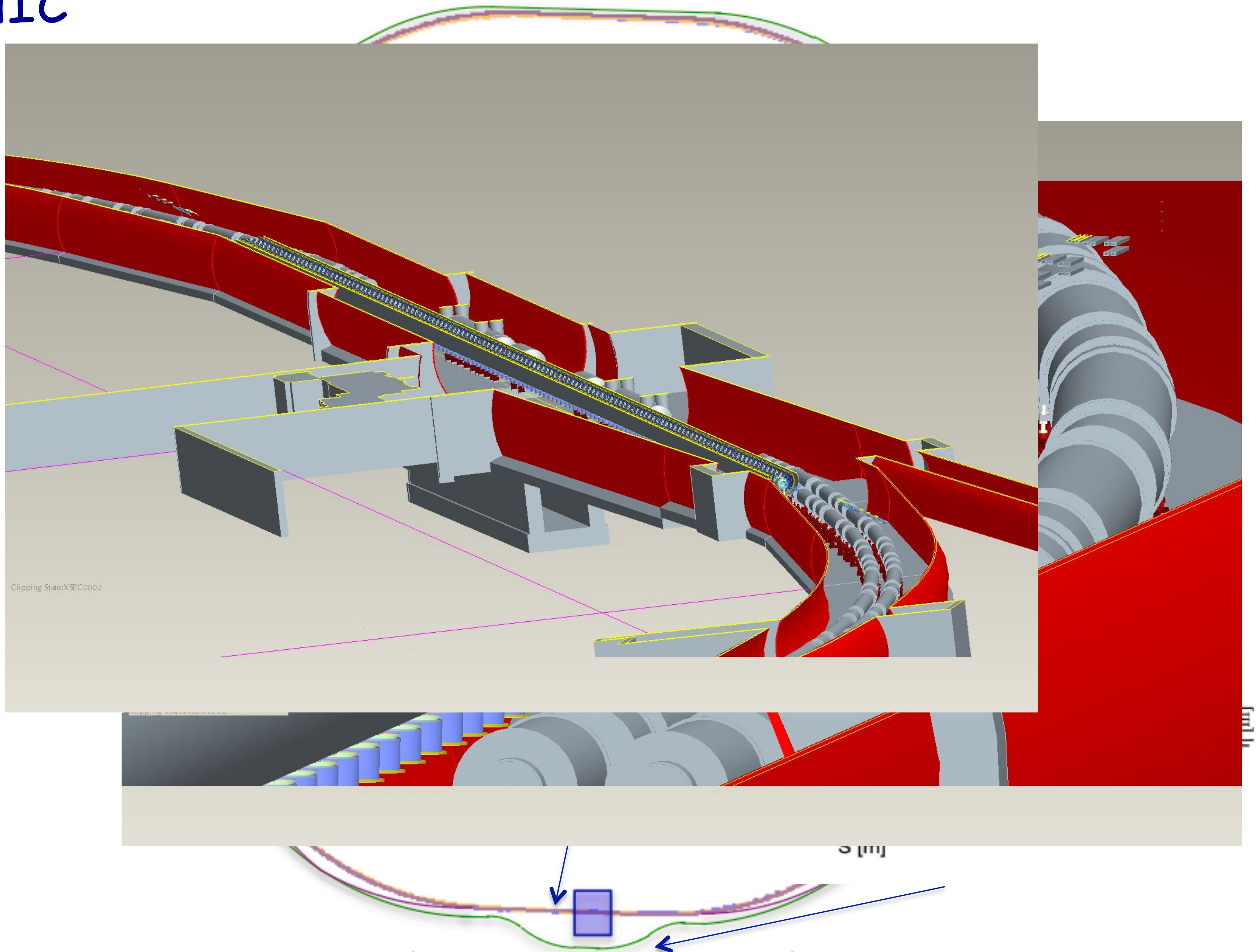
  IR design with 10 mrad crossing angle using the crab cavities
  - Design obtained by interaction with experiments demanding:
    - Detection of deep virtual scattering for protons-electron collisions
    - Neutron detection (ZDC) with a solid angle of 8 mrad
    - Detection of partons with lower energies (momentum $p_o/2.5$)
  - Assumptions:
    - Ion beam cooling will provide → small emittances
    - A design should be no different than the RHIC operating conditions
    - Based on Brett Parker combined function magnet design and present technology of the superconducting magnets D=90 or 120 mm

- IR lattice designs
  - β^* = 5 cm design keeps the maximum of β functions in triplets of the order of the existing in the RHIC lattice: β^* = 5 cm → β_{max}= 2960 m
  - Chromatic correction – arc + local sextupoles in the IP

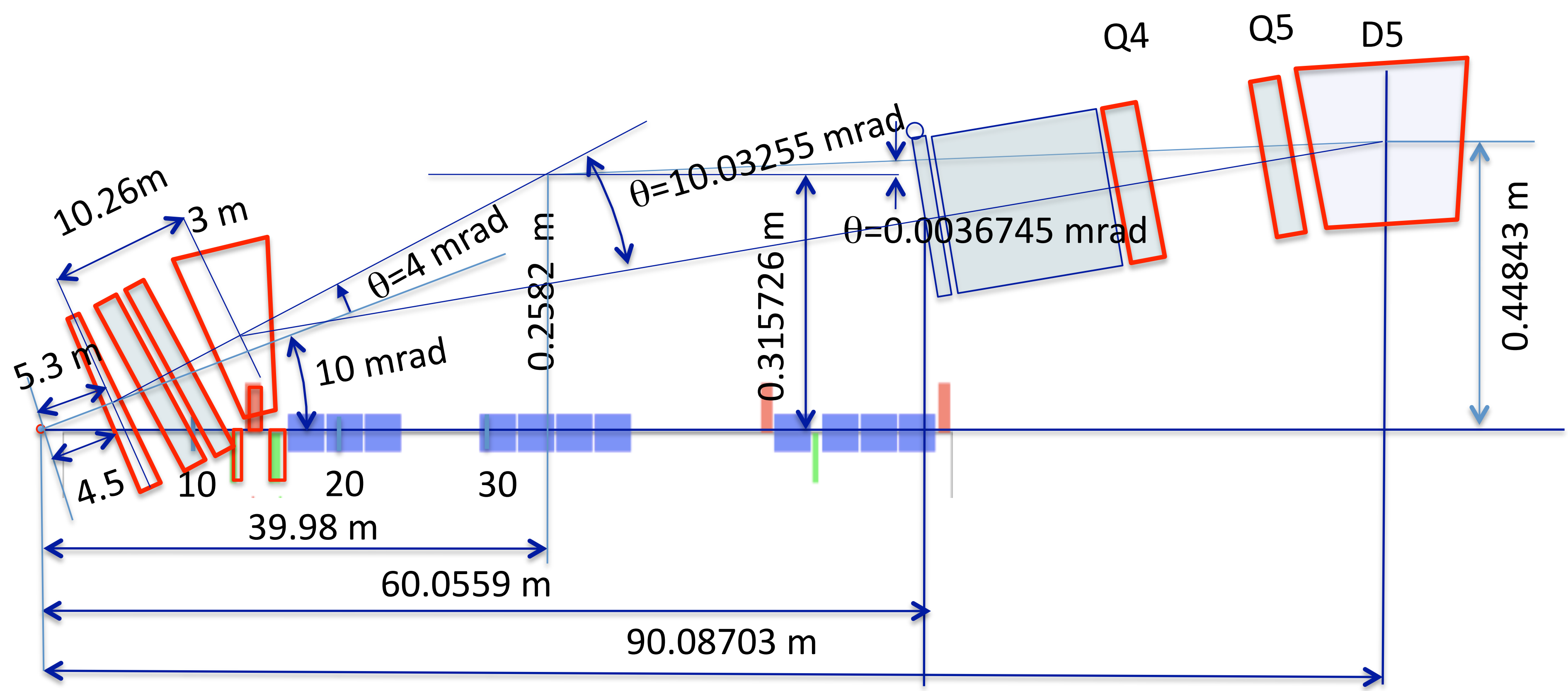
IR design bullets:

- Schematic of the eRHIC and IR magnet layout
- Particle tracking through the IR magnets
- Design based on the superconducting technology:
  - Magnets built and tested for the LHC upgrade
  - Brett Parker magnet design
- Chromaticity correction methods
- Lattice functions
- Electron IR and matching to the arcs
- Accomplishments and plans
- Few details of the eRHIC electron lattice
- Summary

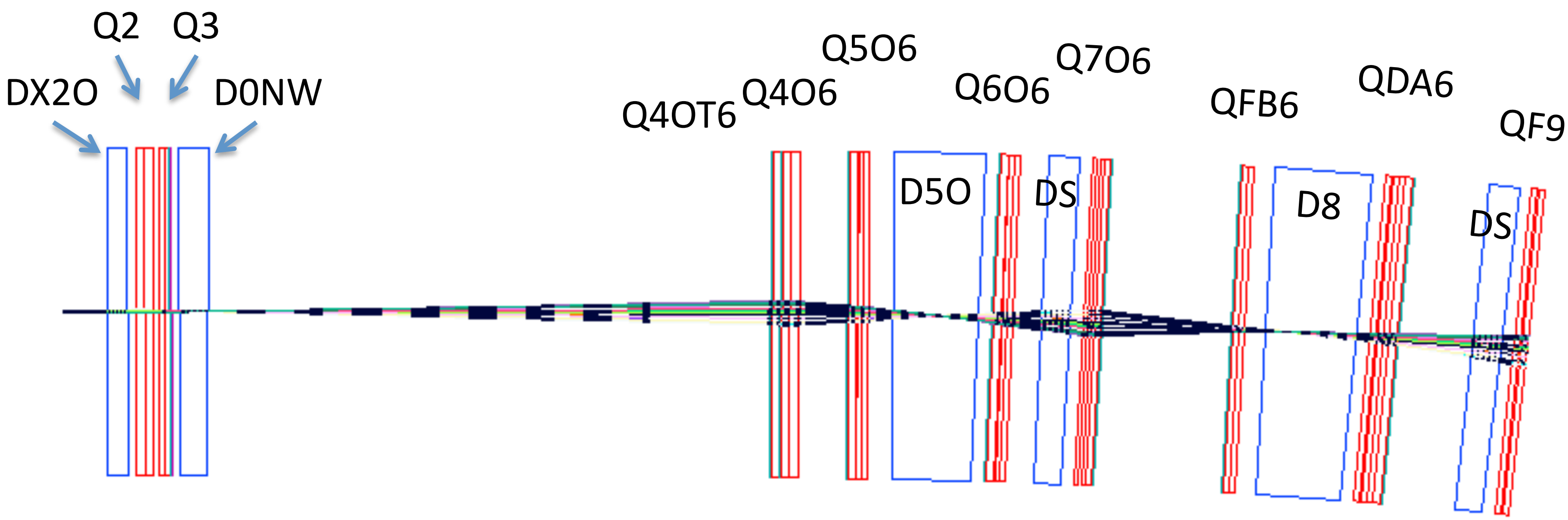
eRHIC



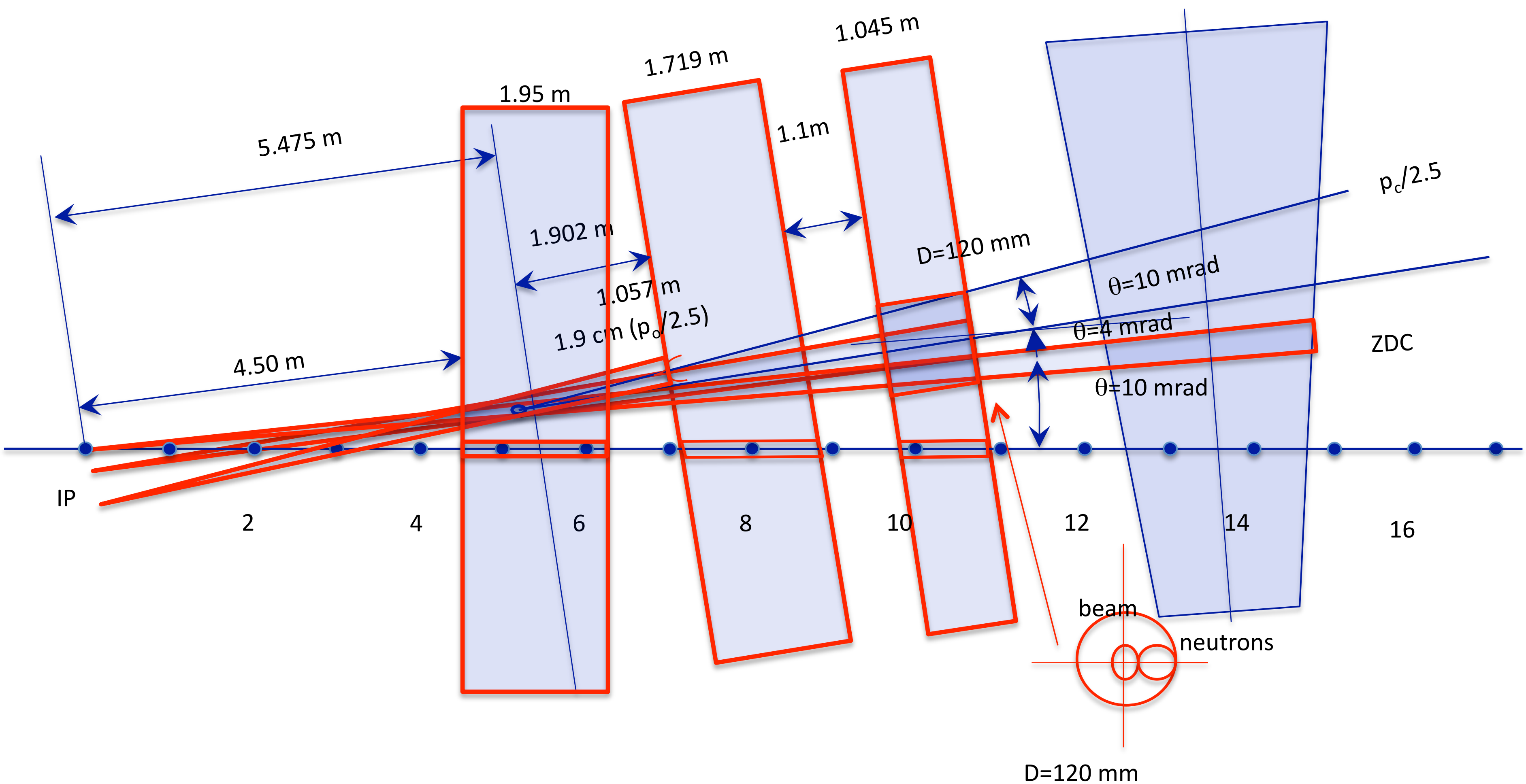
IP configuration for eRHIC



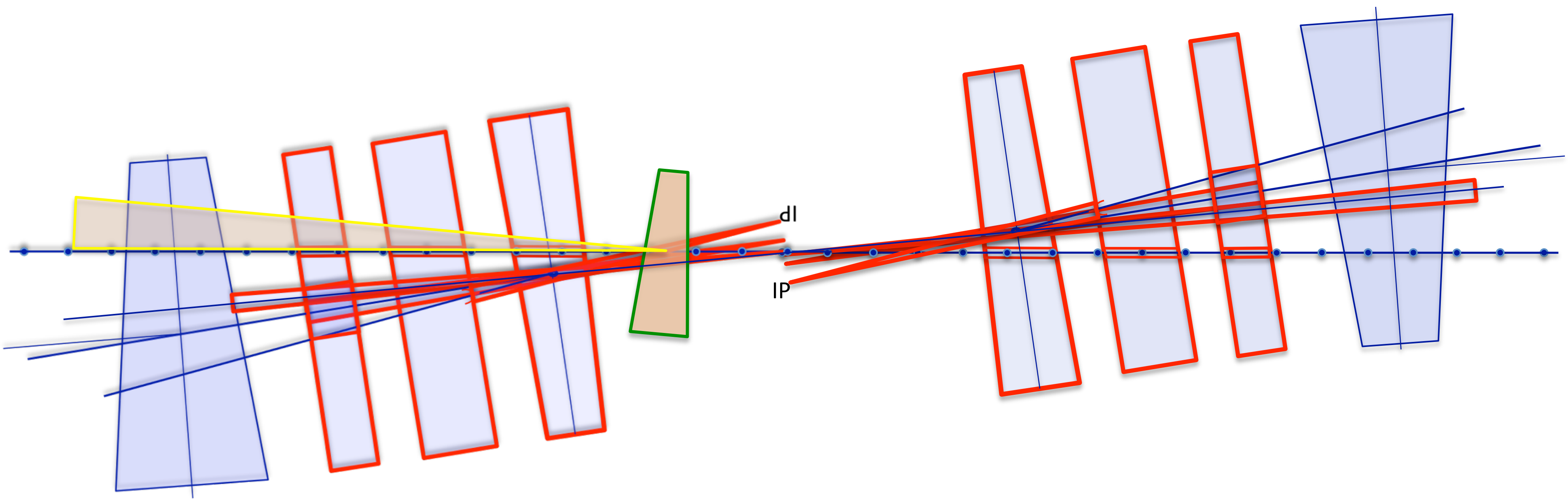
Tracking through the triplets:
The whole interaction region up to the arcs



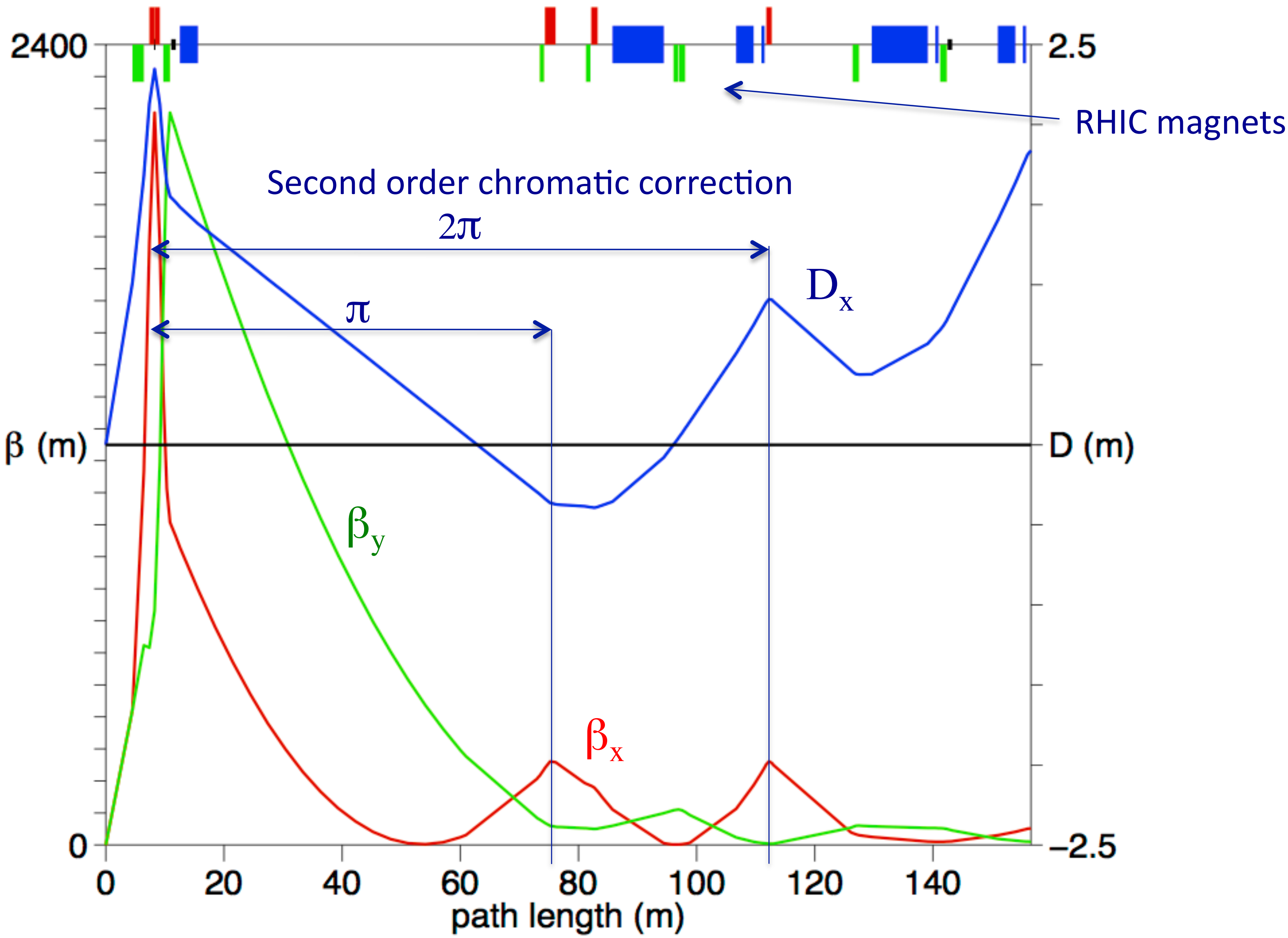
IP configuration for eRHIC



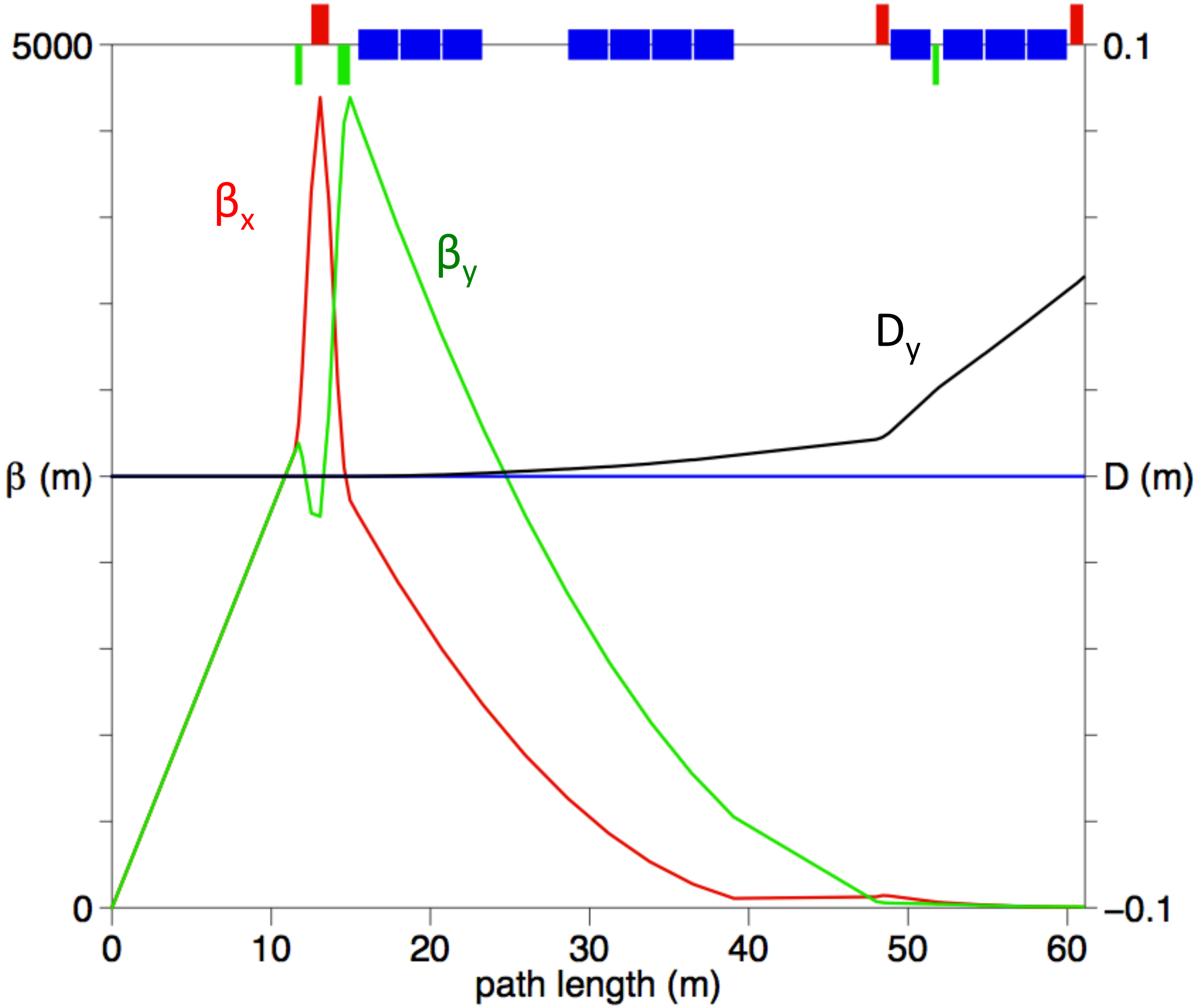
February 12, 2011, IP configuration for eRHIC



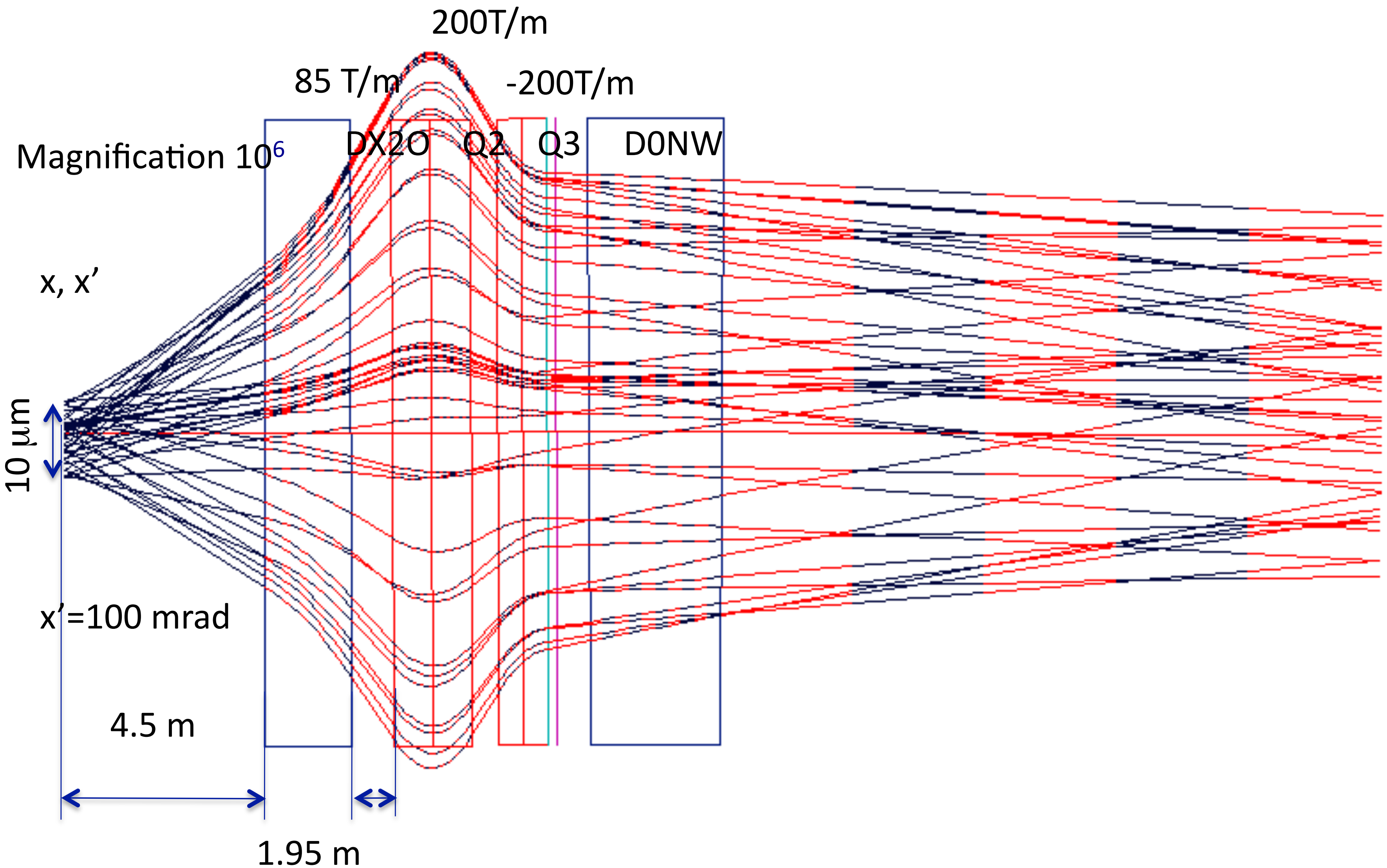
Interaction region with β^*= 5 cm for protons and heavy ions luminosity 1.5 10^{34} cm^{-2} s^{-1}



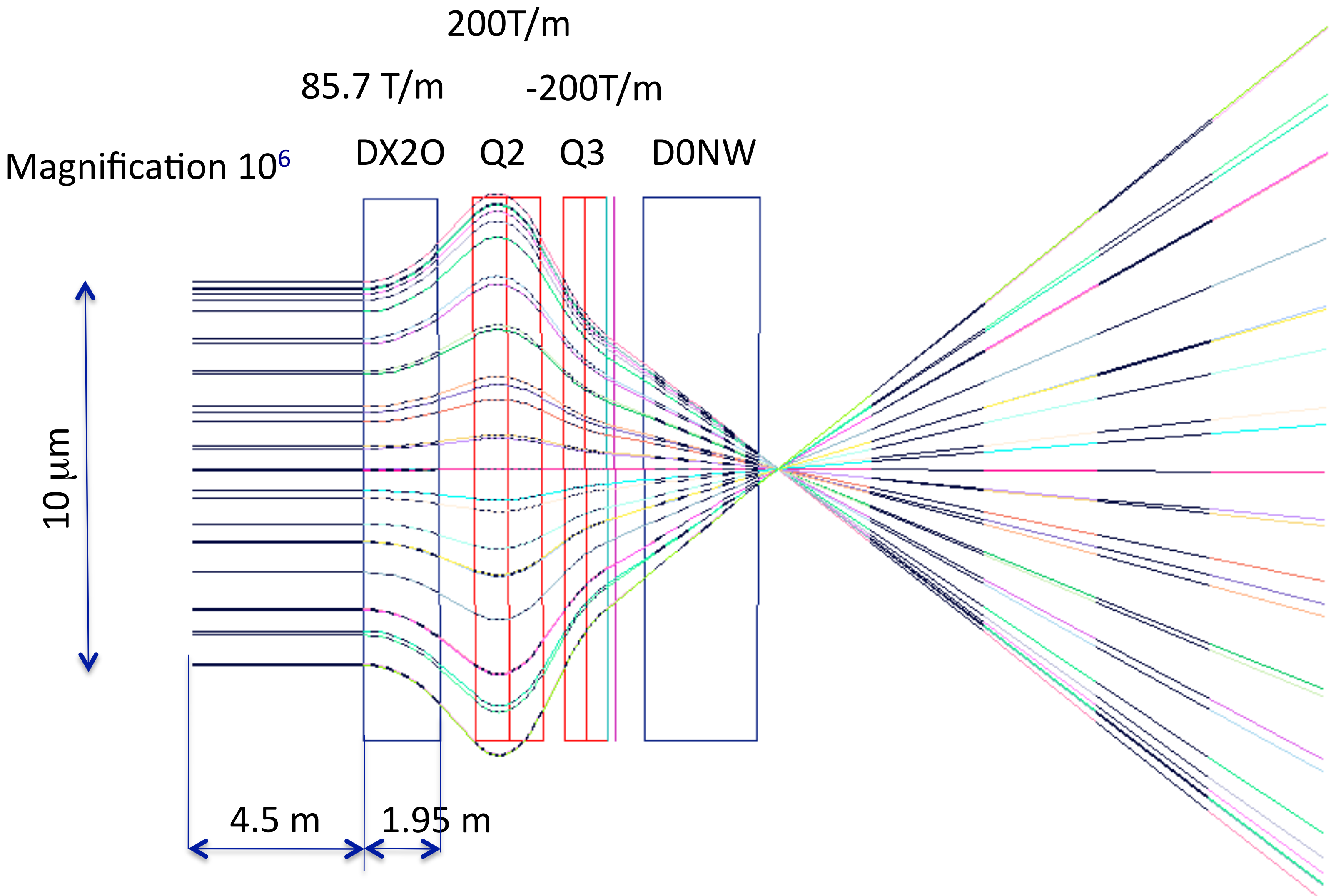
Interaction region with β^*= 5 cm for electrons



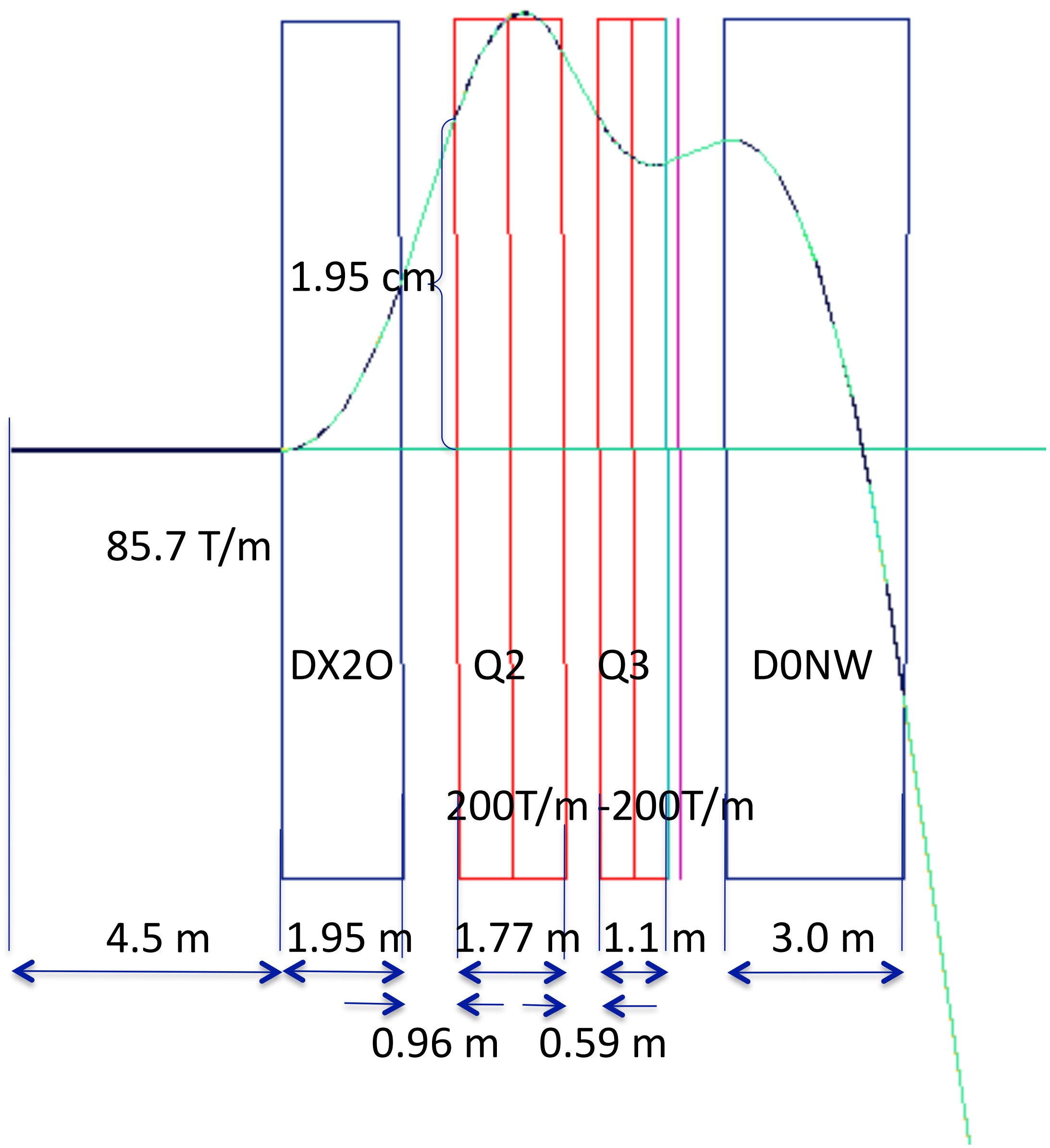
Tracking through the triplets: Just first four magnets



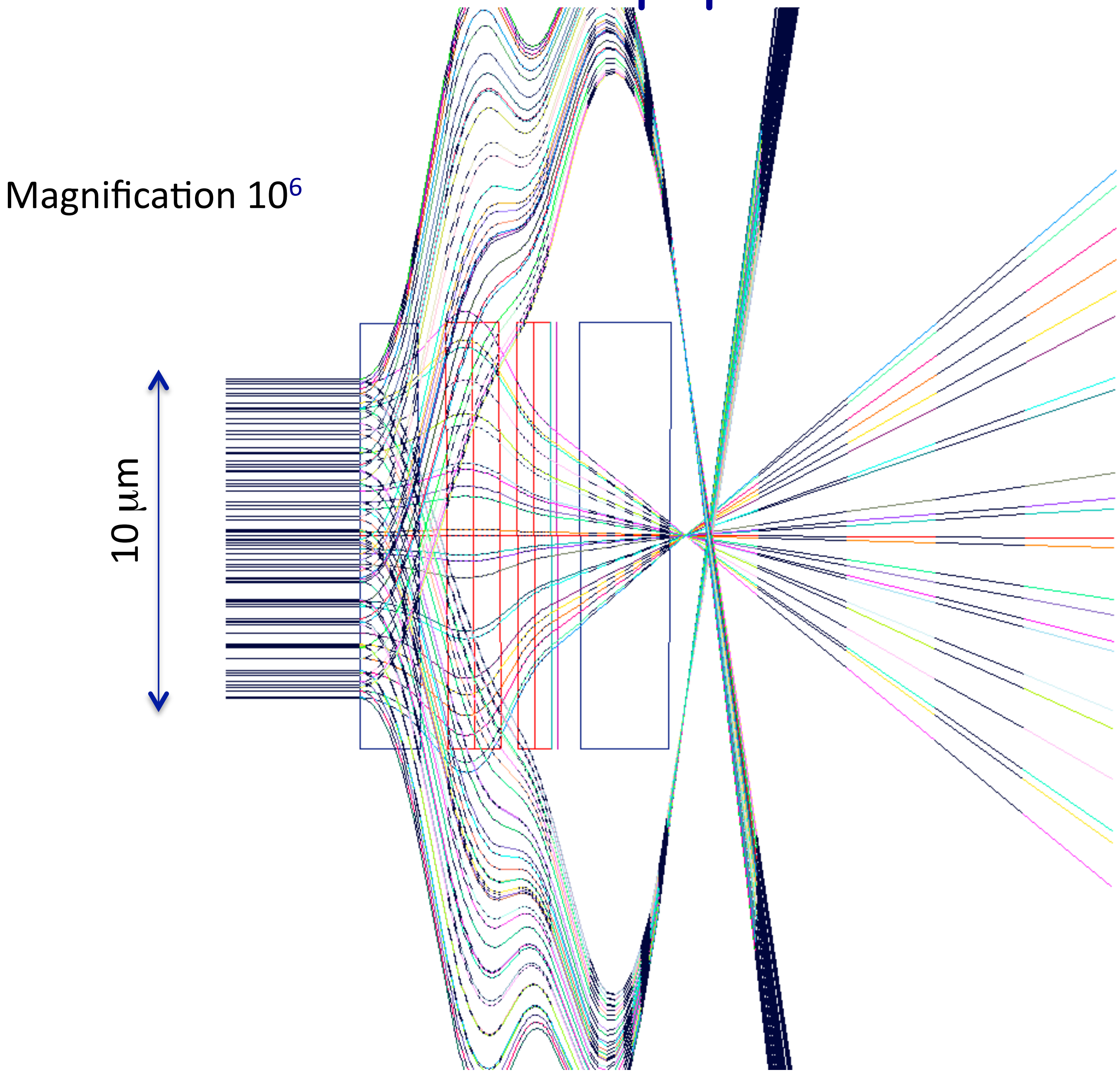
Tracking through the triplets:
The whole interaction region up to the arcs



Tracking through the triplets: momentum = $p_o/2.5$

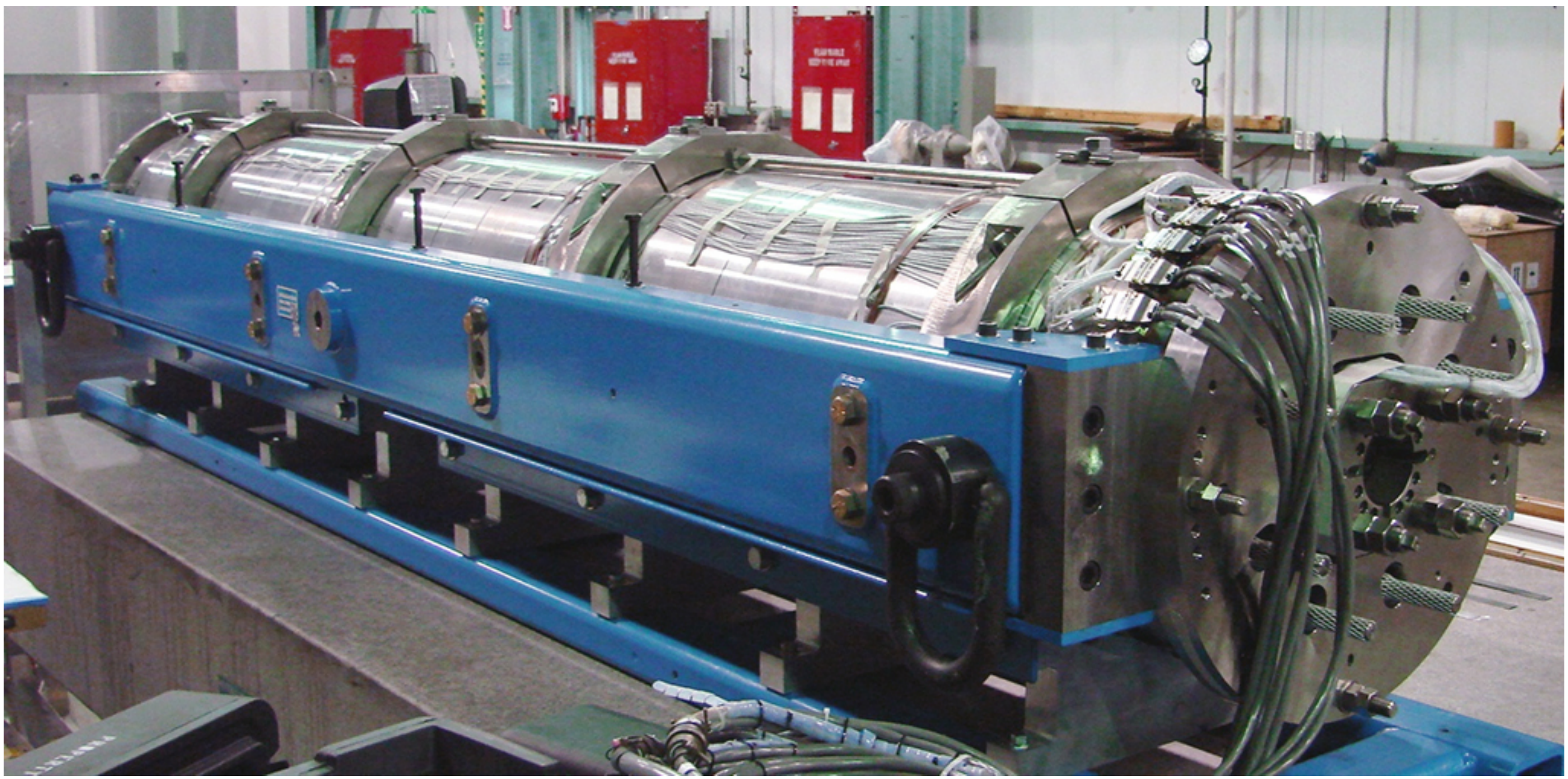


Particle tracking through the triplets
$\delta p/p = \pm 0.001$



Present technology of the superconducting magnets

- LARP triplet magnet designed, build and tested with A=90 mm and G=200T/m
- Special combined function magnets with no magnetic field region for electron (Brett Parker-BNL-March2011)



LARP large aperture Nb_3Sn quadrupoles for the LHC upgrade:

Collar-based LQ

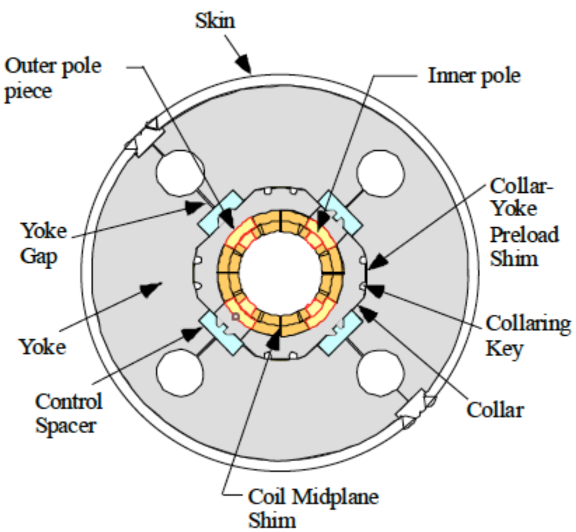


Figure 1: Collar-based LQ

Shell-based LQ

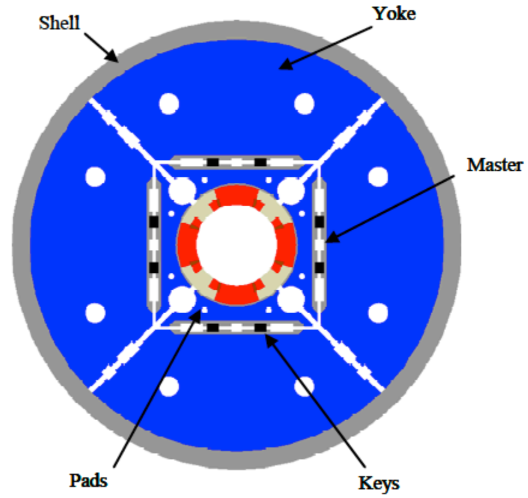
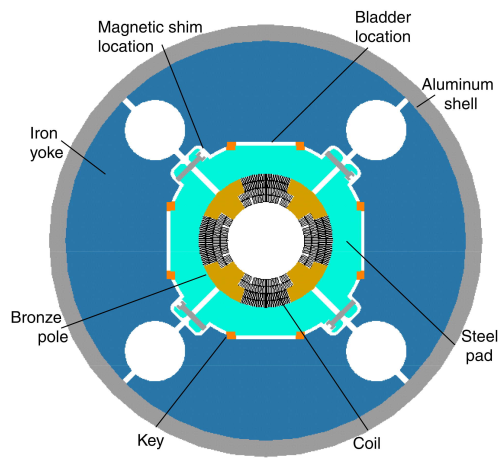


Figure 2: Shell-based LQ



4-layers:
G=280-310 T/m

2011-03-10 eRHIC, ePHENIX, eSTAR, EIC TF, eRHIC-CAD: Meeting

LARP quadrupoles:

Already achieved results:

4.2 K temperature					
Quench gradient	T/m	221	231	233	243
Quench current	kA	13.3	14	13.4	14
Peak field in the body at quench	T	11.5	13	11.9	12.4
Peak field in the end at quench	T	12	12.5	11.4	12.4
Inductance at quench	mH/m	4.6	4.6	4.9	4.9
Stored energy at quench	kJ/m	406	443	439	479
1.9 K temperature					
Quench gradient	T/m	238	249	251	262
Quench current	kA	14.4	15.1	14.5	15.2
Peak field in the body at quench	T	12.4	13	12.9	13.4
Peak field in the end at quench	T	12.9	13.5	12.4	13.4
Stored energy at quench	kJ/m	472	516	512	559

Combined function magnet with zero field for electron passage Brett Parker-March-2011-BNL

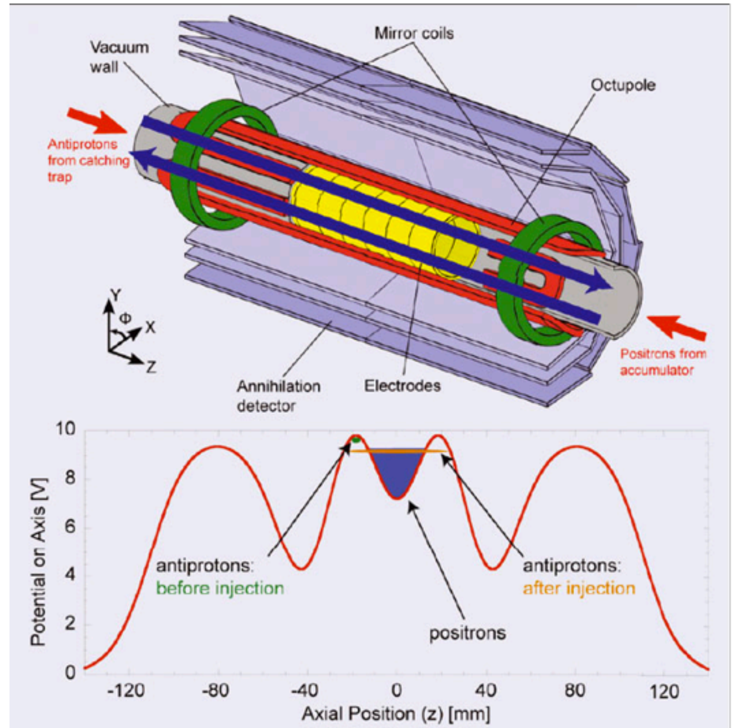
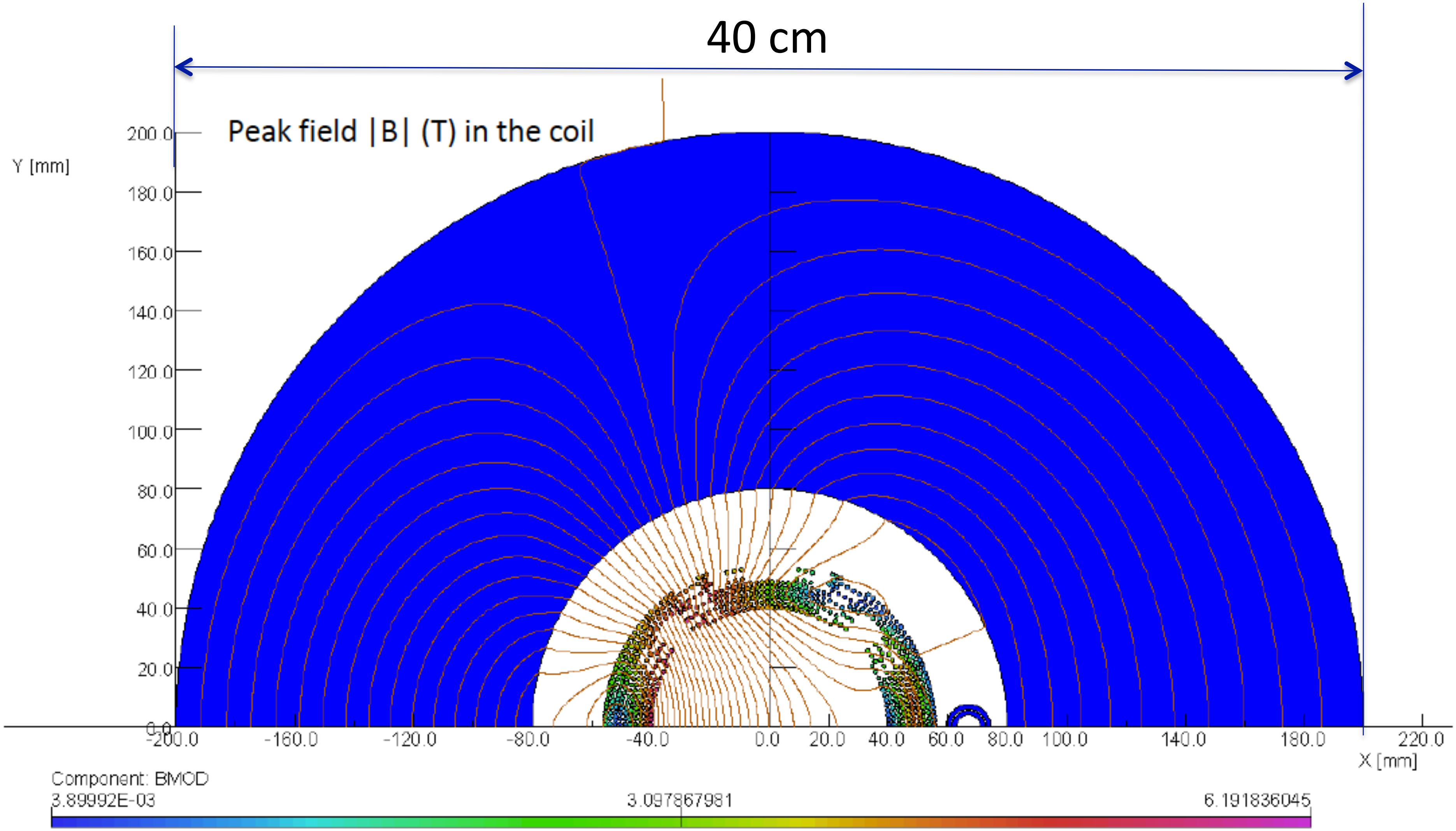


Fig. 1. Top: A cut-away, schematic diagram of the ALPHA central apparatus showing the Penning trap electrodes, magnets for the atom trap and the silicon vertex detector. The blue arrows indicate alternate electric "bias" fields applied to distinguish antiprotons from neutral antihydrogen (see text). Bottom: The potentials used for the mixing of antiprotons and positrons

close or Esc Key

Combined function magnet with zero field for electron passage Brett Parker-March-2011-BNL

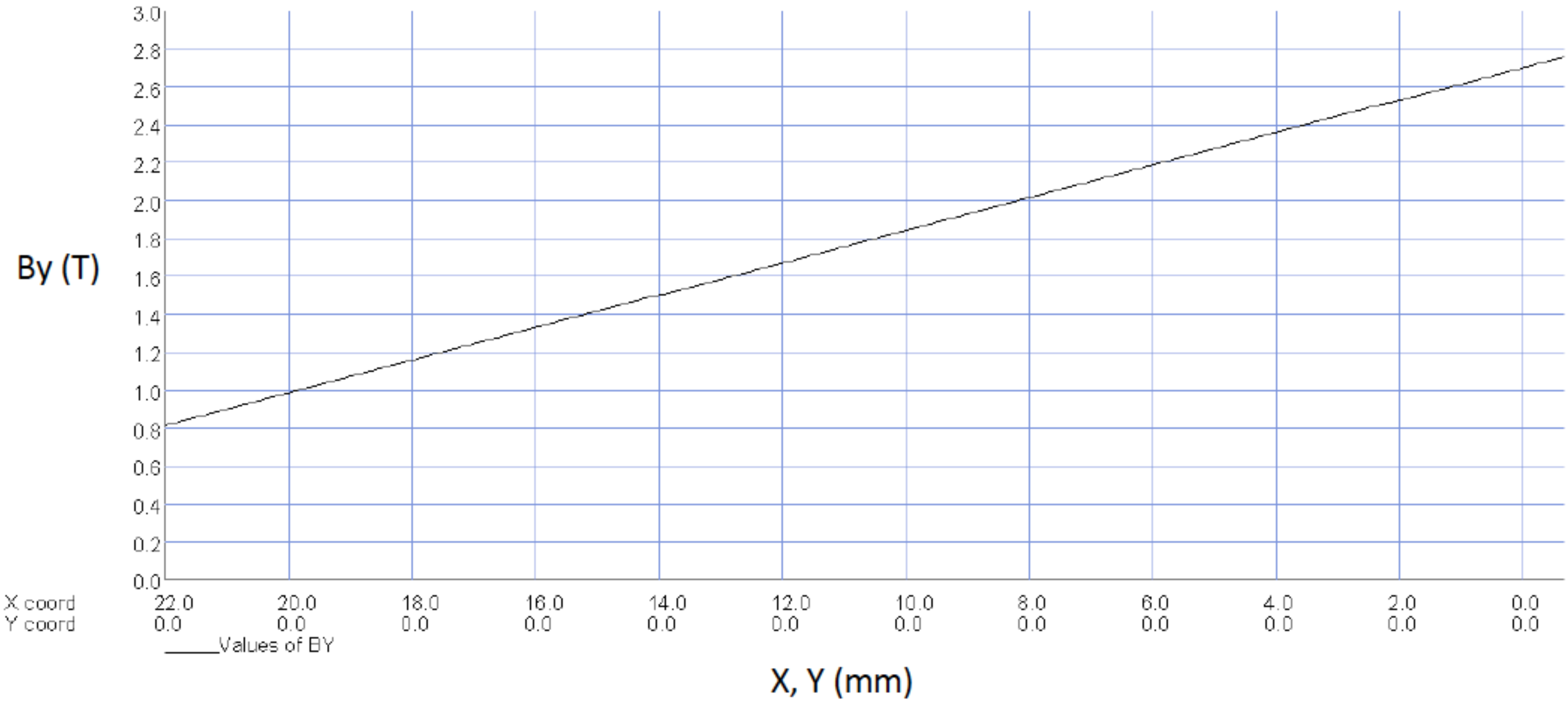
eRHIC IR Combined Function Magnet, 07-Mar-2011, B. Parker (1/3)



2011-03-10 eRHIC, ePHENIX, eSTAR, EIC TF, eRHIC-CAD: Meeting

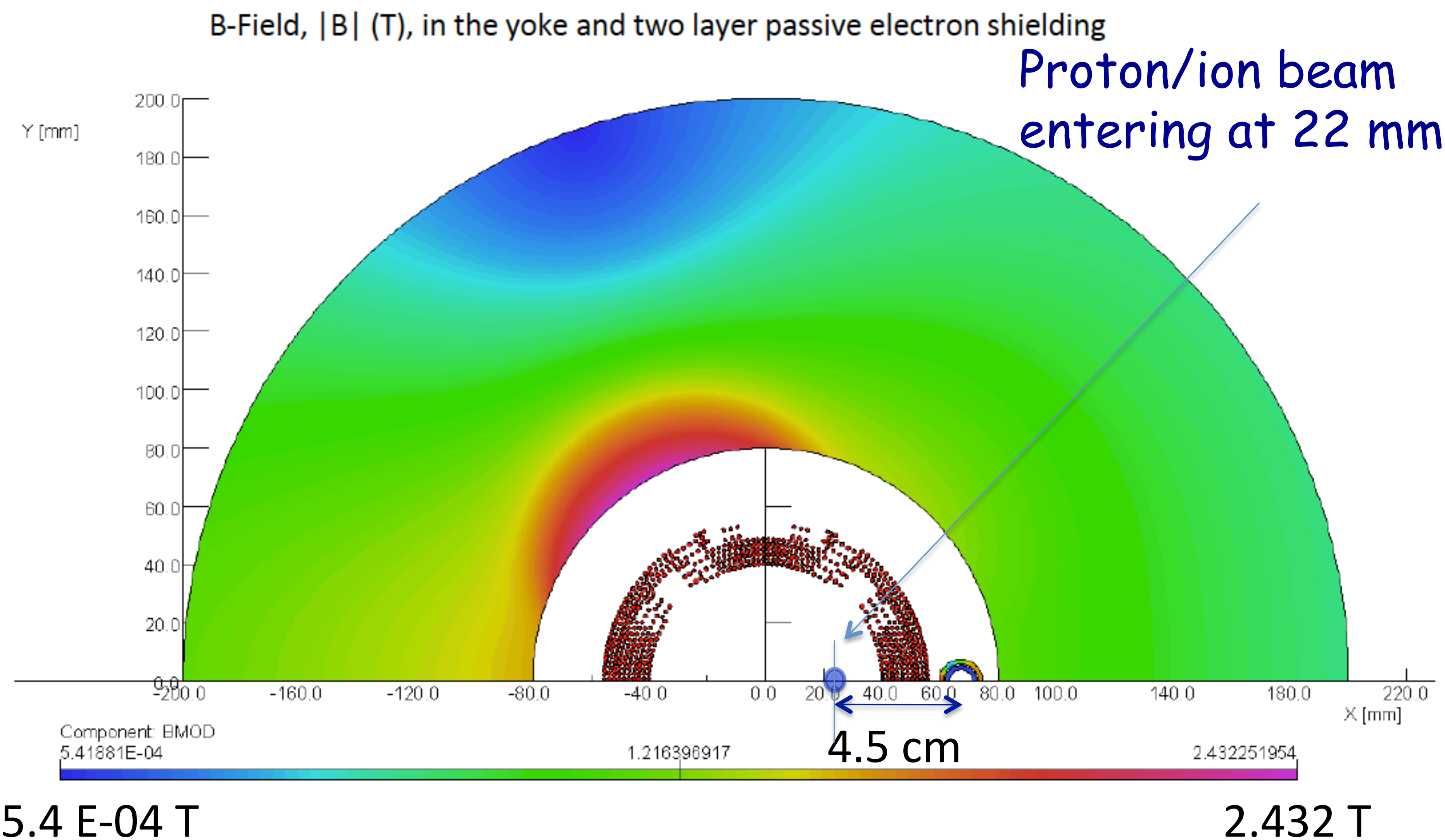
Combined function magnet with zero field for electron passage Brett Parker-March-2011-BNL

On Axis Field, By (T) , seen by the incoming hadron beam X = (22. to -0.67 mm) so that for an initial -10. mr angle (w.r.t. electron beam) the exit angle is -14.0 mr.
Here Bo = 2.701 T and Gradient = -85.74 T/m for Lmag = 1.95 m



Combined function magnet with zero field for

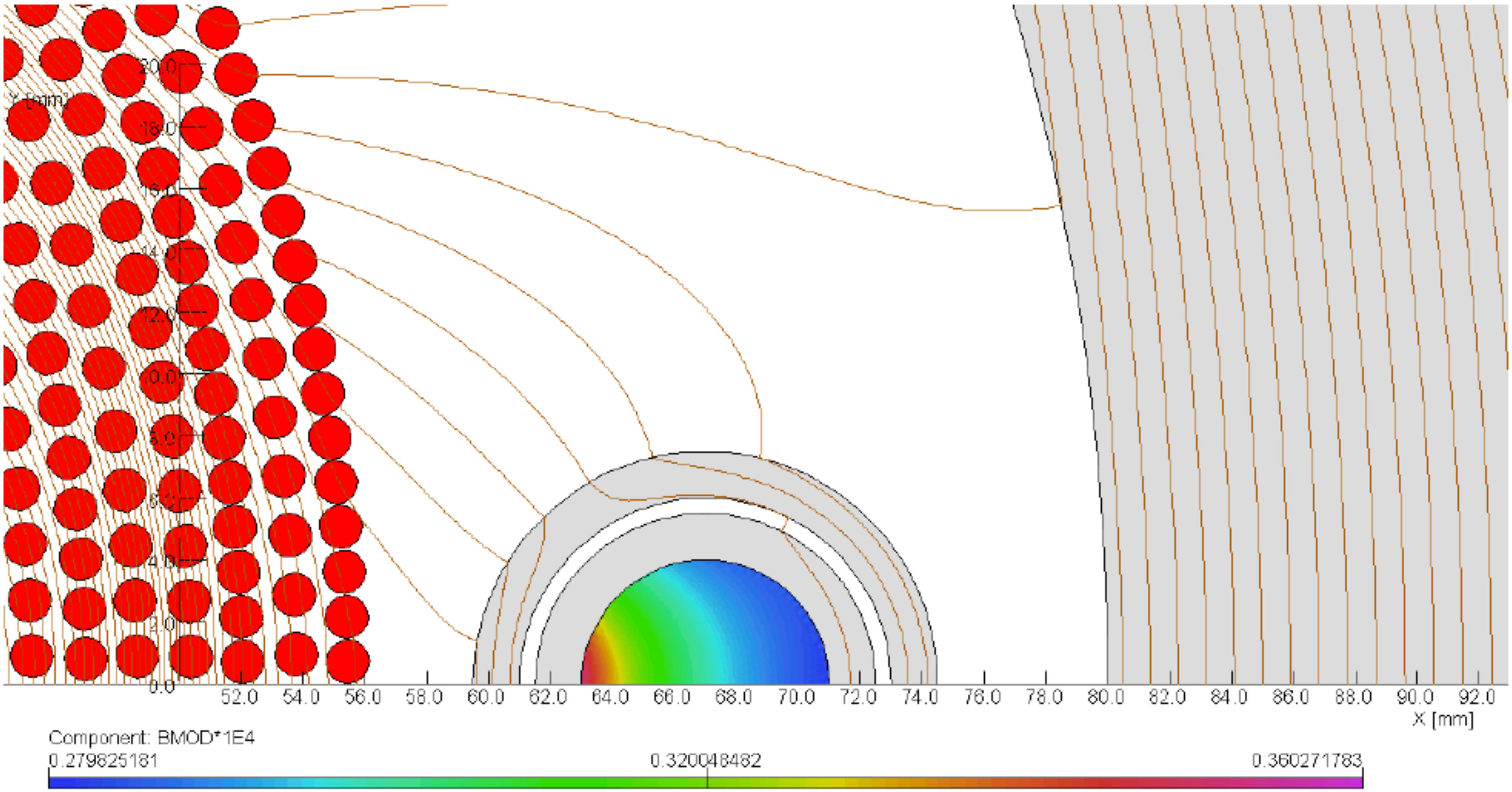
eRHIC IR Combined Function Magnet, 07-Mar-2011, B. Parker (2/3)



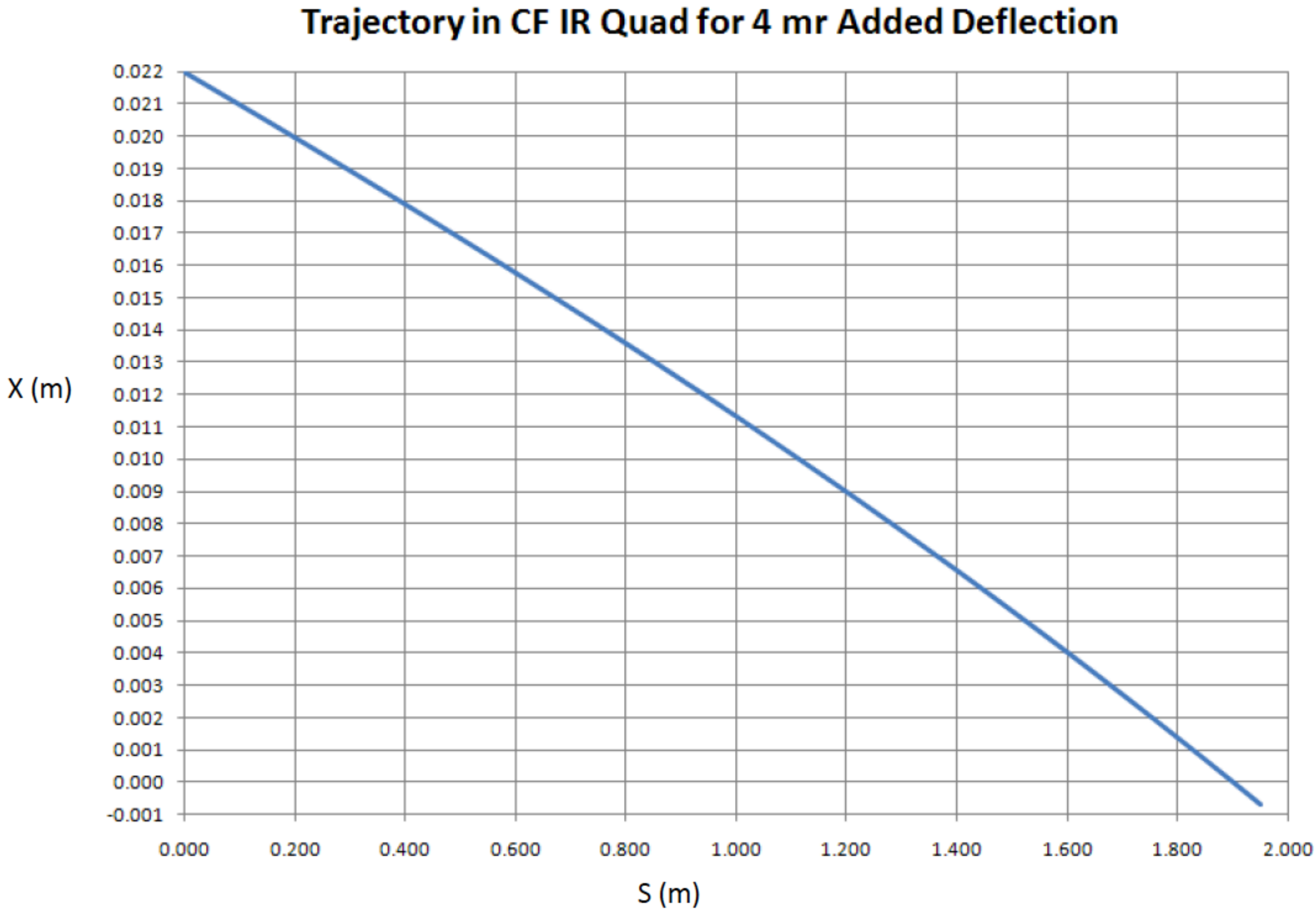
Combined function magnet with zero field for electron passage Brett Parker-March-2011-BNL

eRHIC IR Combined Function Magnet, 07-Mar-2011, B. Parker (3/3)

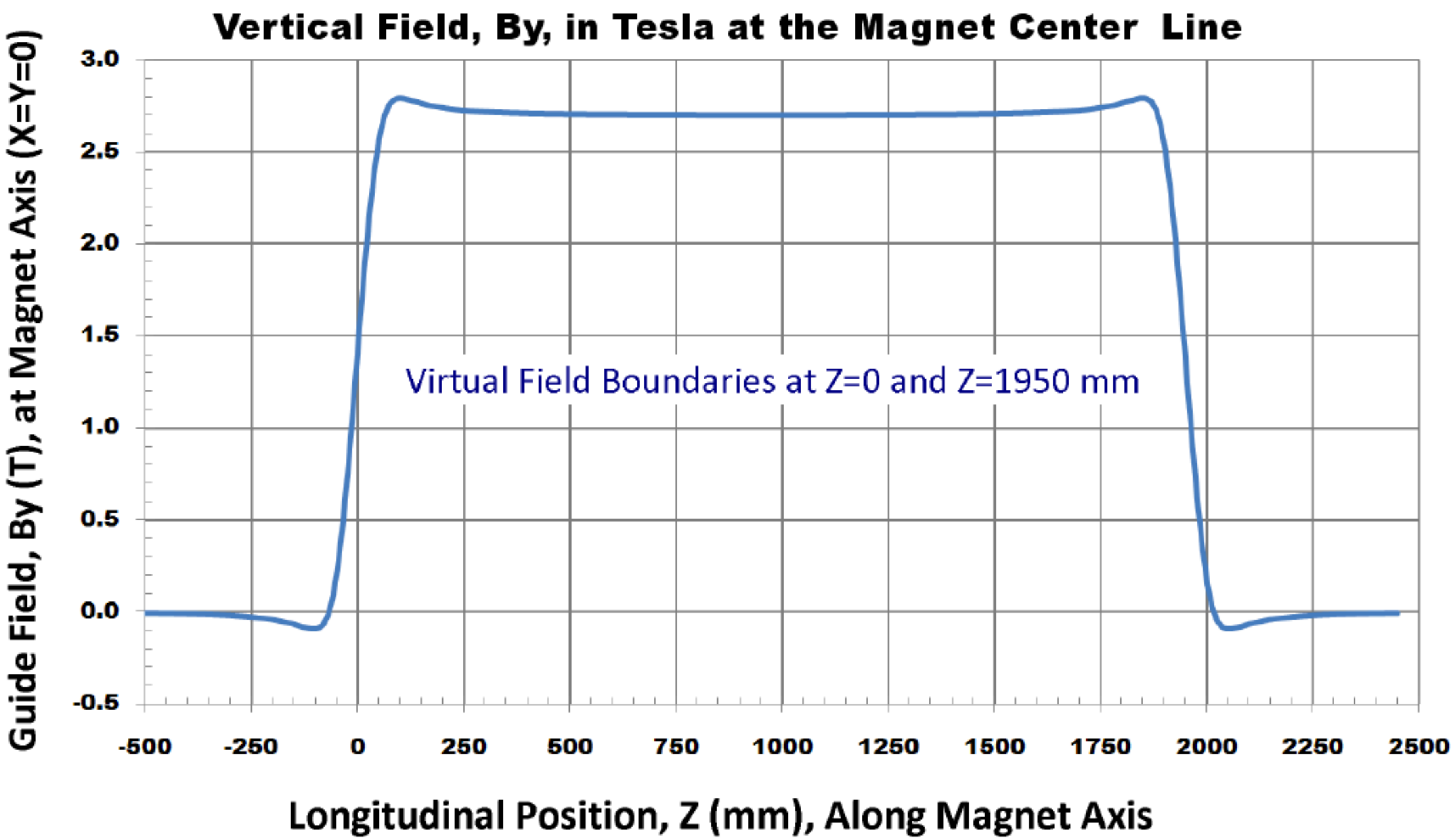
B-Field, |B| (Gauss), penetrating the passively shielded region



Combined function magnet with zero field for electron passage Brett Parker-March-2011-BNL

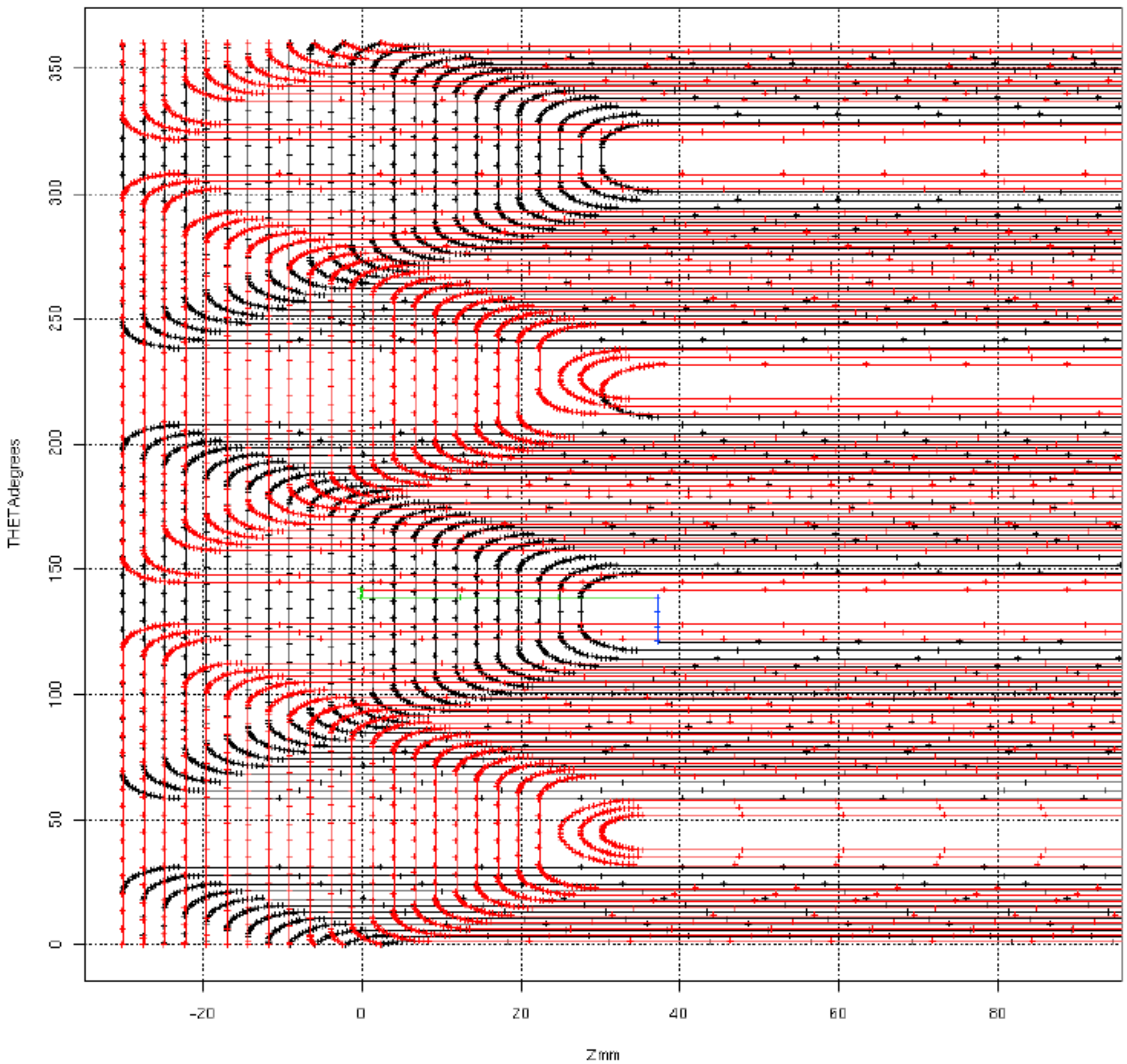


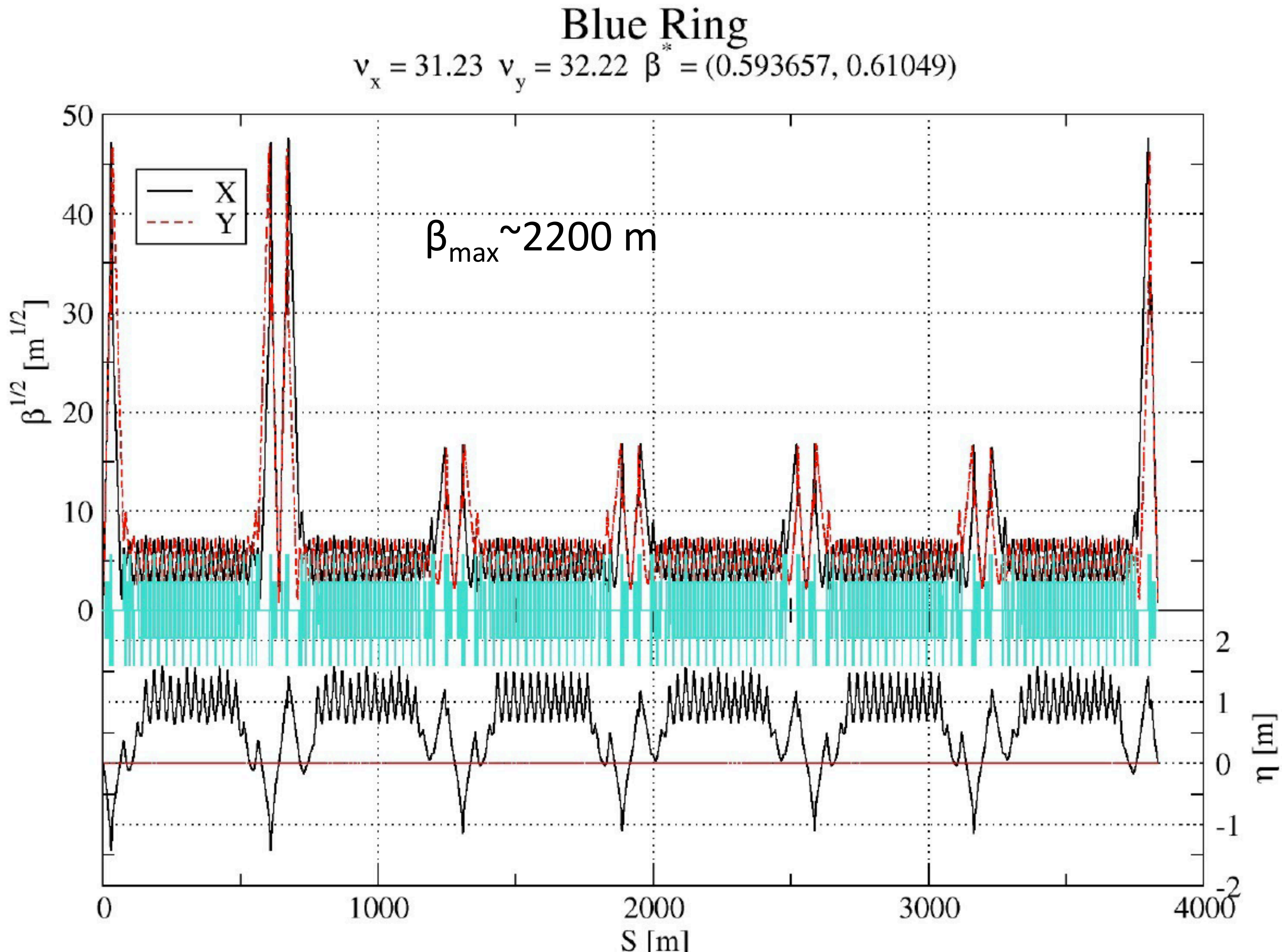
Combined function magnet with zero field for electron passage Brett Parker-March-2011-BNL



Combined function magnet with zero field for electron passage Brett Parker-March-2011-BNL

Combined Function IR Magnet: 1st Quad Coil Set at Lead End




Blue Ring
$\nu_x = 31.23 \ \nu_y = 32.22 \ \beta^* = (0.593657, 0.61049)$
β_{max}~2200 m
X
Y
$\beta^{1/2}$ [$m^{1/2}$]
η [m]
S [m]
0
1000
2000
3000
4000
50
40
30
20
10
0
2
1
0
-1
-2

Methods of correcting the IP chromaticities

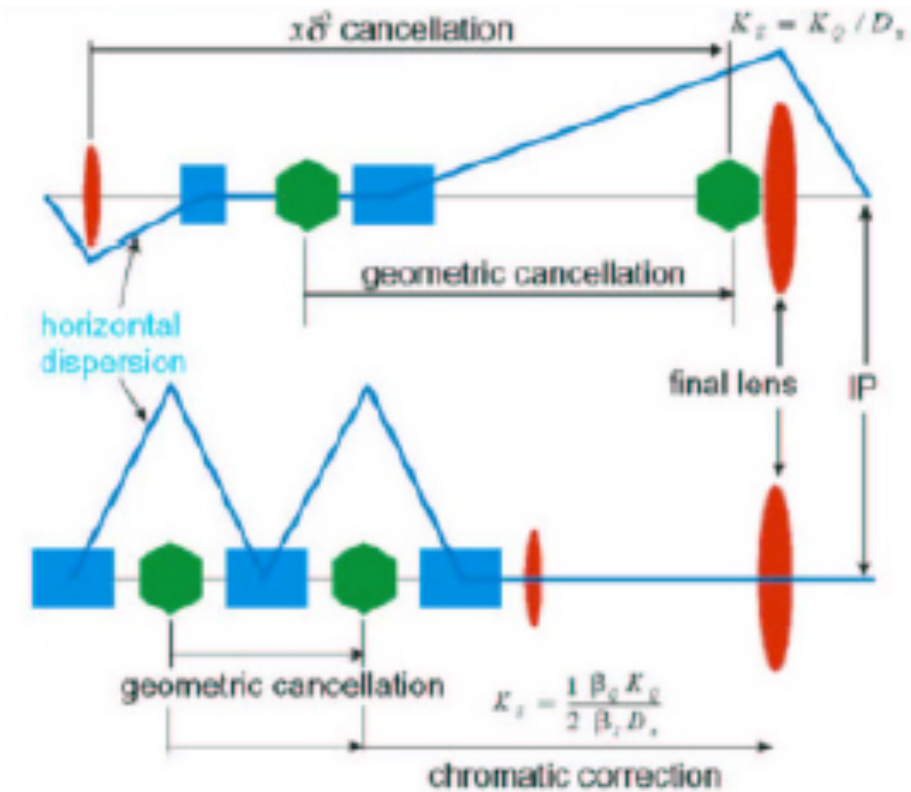
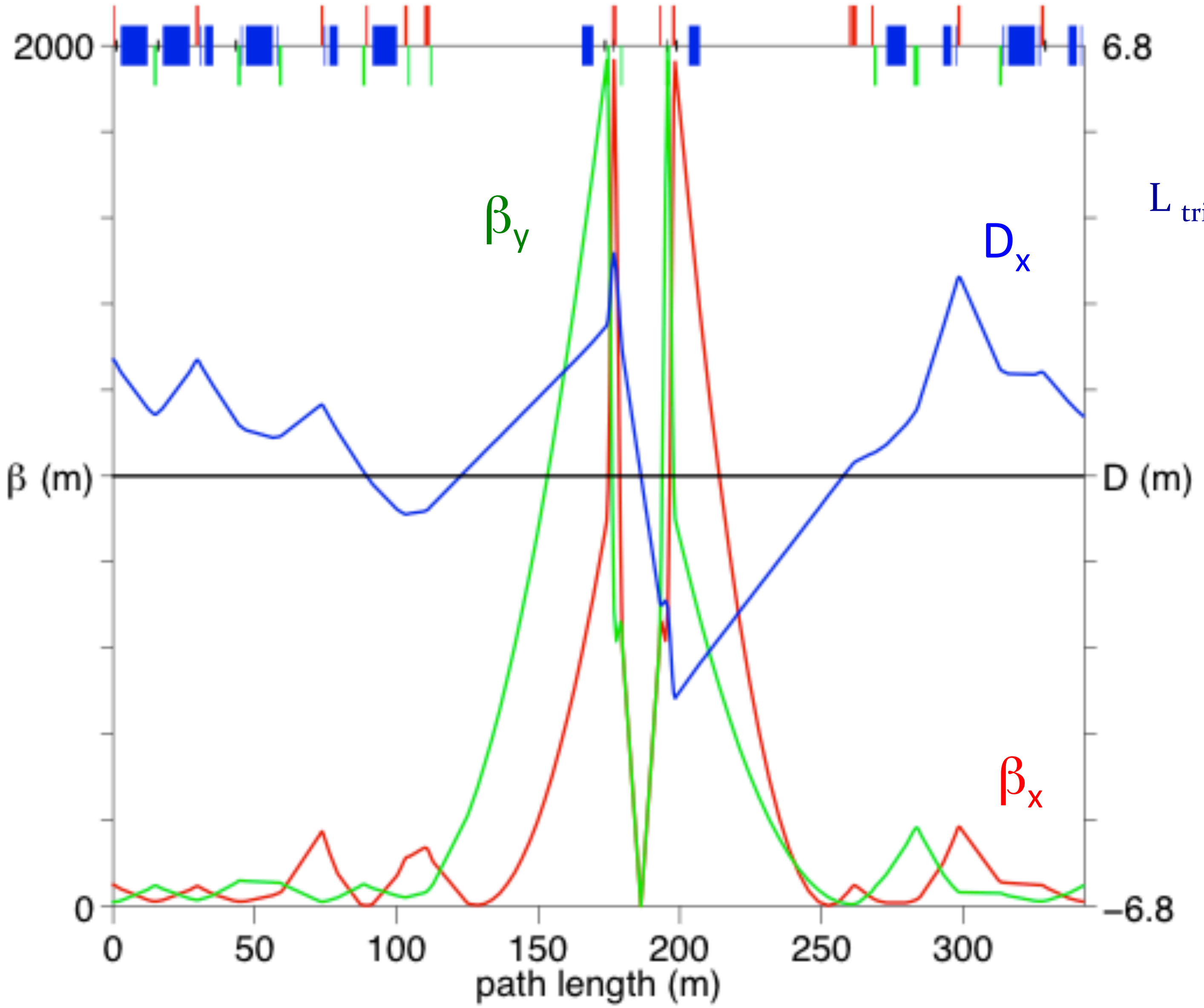


Figure 1: Schematic of the novel compact final focus with truly local chromaticity correction and nonzero slope of dispersion at the interaction point (IP), as developed by P. Raimondi and A. Seryi (top), and of the traditional final-focus design with a non-local chromatic correction, as pioneered by K. Brown around 1985 (bottom) [4] [N.J. Walker, 2002].

We are combining these two methods but not using high values of the triplet sextupoles to prevent the second order amplitude tune shift

RHIC interaction region with β*= 5 cm

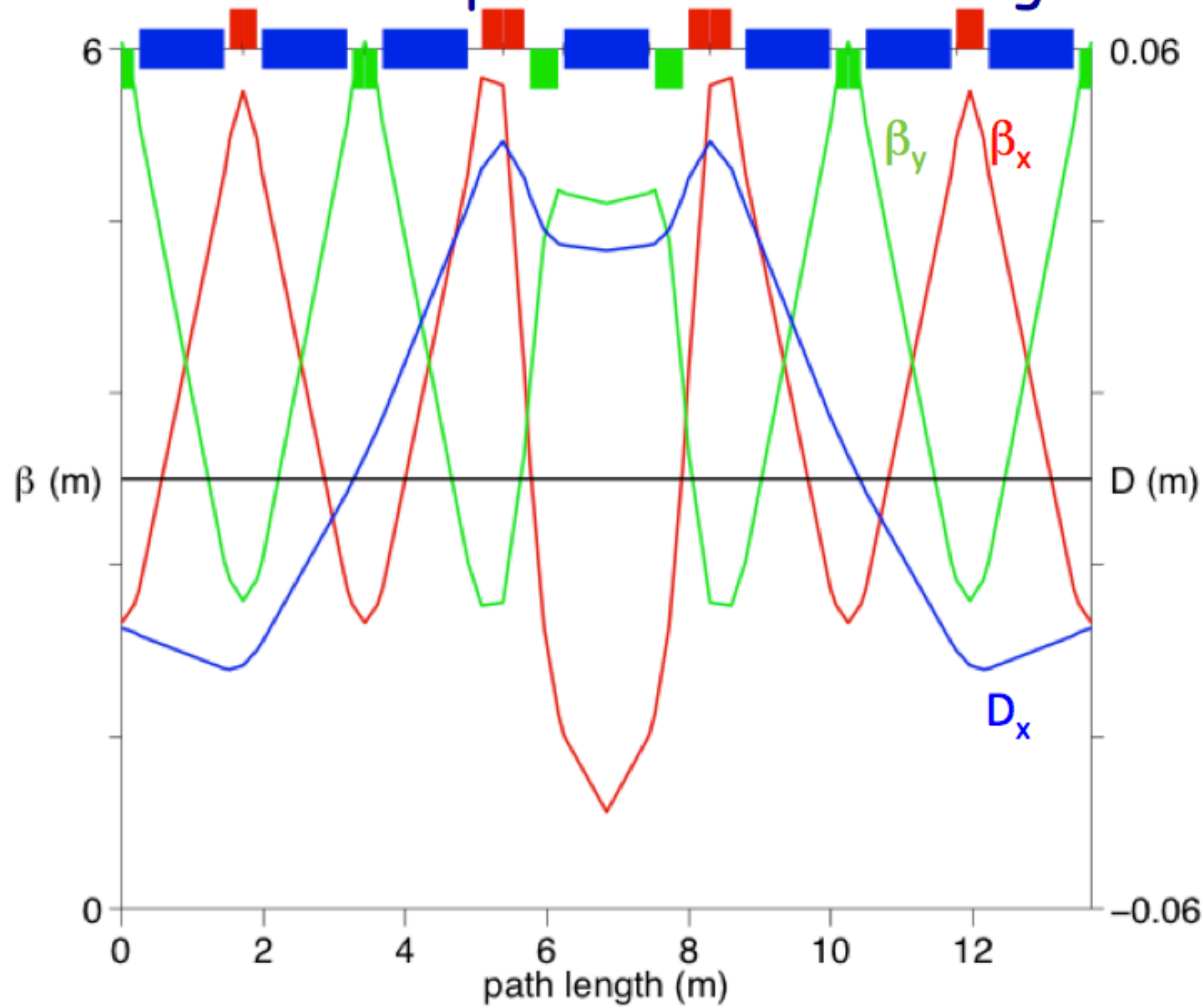


$L_{triplet}$=4.5 m

Achievements and plans in eRHIC lattice design

1. Lattices of the eRHIC electron passes are complete:
   - 1.1 eRHIC layout in the existing RHIC tunnel with a complete survey
   - 1.2 Beam optics with zero momentum compaction of required modules
   - 1.3 Interaction region lattice for 30 GeV electron beam:
     - 1.3.1 Without synchrotron radiation at interaction point
     - 1.3.2 Matched to the zero momentum compaction arcs
   - 1.4 Quadrupole free linac optics
   - 1.5 Linacs with splitters, combiners and arcs
   - 1.6 Straight sections passes through the interaction region of 30 GeV
   - 1.7 Bypasses of lower energy electron beams around detectors
2. RHIC proton and heavy ion lattice design
   - 2.1 Proton and heavy ion interaction region with β^*=5 cm
     - 2.1.1 Solid angle of 8 mrad for zero degree neutron calorimeter
     - 2.1.2 Detection of the partons with lower energies
     - 2.1.3 Deep virtual scattering for protons-electron collisions
3. Remaining work:
   - 3.1 Electron polarimeter and electron energy spectrum detection (in progress)
   - 3.2 Pipe size evaluations
   - 3.3 Engineering drawings of the layout with a cost estimate
   - 3.4 Dynamical aperture studies of both proton and electron designs
   - 3.5 Second and third order chromatic corrections studies
   - 3.6 Crab cavity placement and studies
   - 3.7 Complete the design of the interaction region quadrupoles

Arc cell with separated function magnets



Arc lattice with separated function magnets

E_{MAX}=30.0 GeV, BRHO = 100.069228545 Tm

Dipoles:

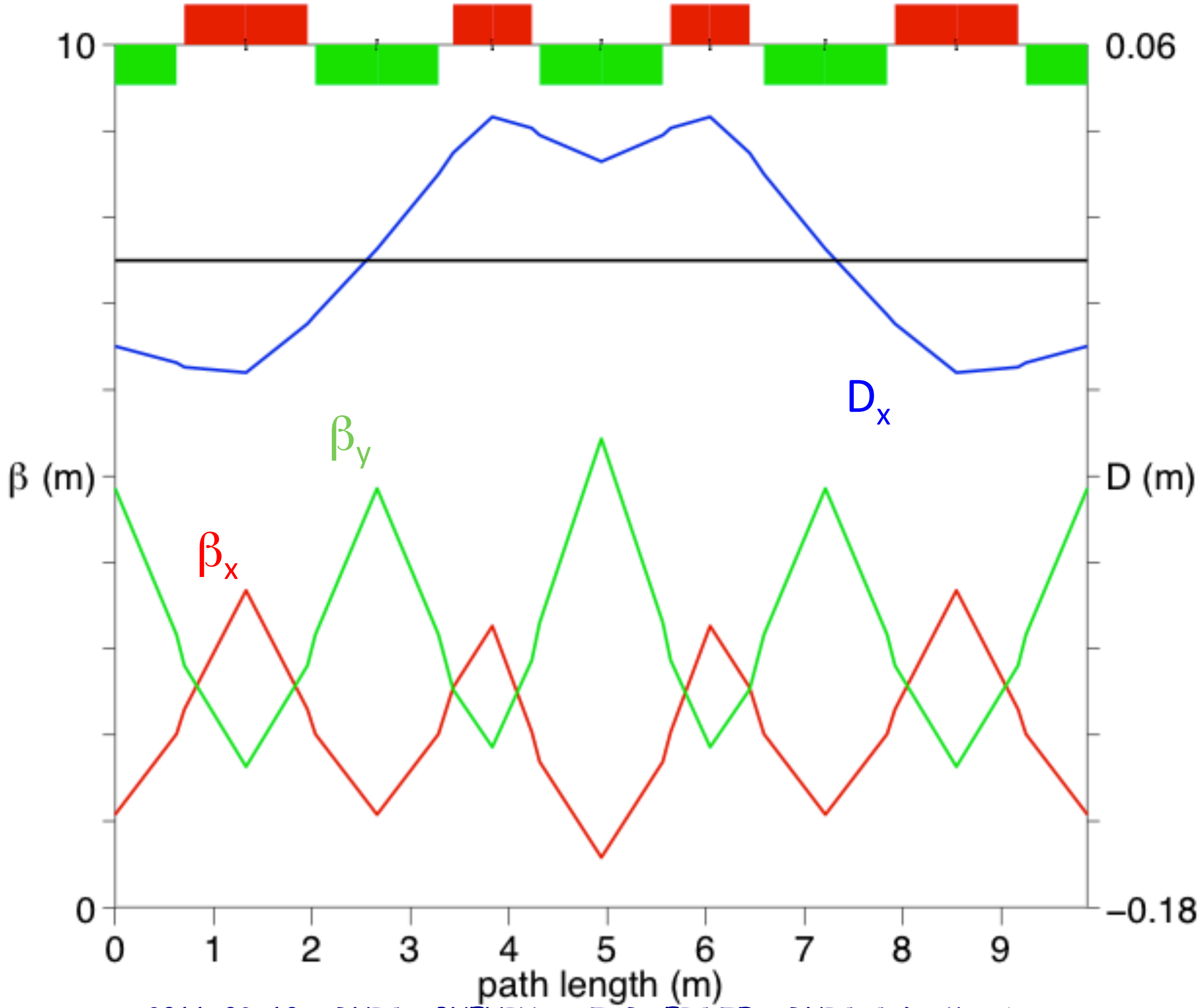
L=1.2 m, θ=0.005123124, B=0.427222589 T,
R=234 m (12 passes 7.5 GW) - 182 dipoles per sextant

Quadrupoles:

L_{fodo}= 0.40 m, G_f = 191.3245 T/m, G_d = -164.3118 T/m
L_{qf3} = 0.60 m, G_f = 212.739 T/m
L_{qd2} = 0.44 m, G_d =-202.53 T/m

Length of the arc cell= 13.6717 m
Seven dipoles per cell, 26 cells = 355.46433 m
Total dipole number per sextant 26•7=182.

Arc cell with combined function magnets



Arc lattice combined function magnets properties

E_{MAX}=30.0 GeV, BRHO = 100.0692 Tm
Combined Function Magnets:
L=1.2 m, θ=0.00356, B=0.28481 T,
R=351 m (For twelve passes deposited energy is 5.0 MW)

Gradients for focusing in the FODO cells:
G_f = 120 T/m and for defocusing G_d = -107 T/m.

Combined function magnets in the middle of the cell:
L_{qf3} = 0.80 m, G_f = 220 T/m L_{qd2} = 1.2 m, G_d =-121 T/m
Length of the arc cell= 9.8740 m
36 cells • 9.8740= 355.46433 m
Total dipole number per sextant 36•(6+2•QLF3/BL)=262.08