eRHIC INTERACTION REGION DESIGN*

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Abstract

Interaction region design of the future electron ion collider at Relativistic Heavy Ion Collider (eRHIC) is presented. Polarized protons/He^3 and heavy ions will collider with 5-30 GeV polarized electrons with a 10-mrad angle by using the crab cavity crossing. The interaction region is designed without bending electrons to avoid problems with synchrotron radiation. Use of the combined function magnet in the ion side allows detection of neutrons Design allows detection of deep virtual scattering as well as detection of partons with lower energies (po/2.5). The betatron function at collisions is 5 cm assuming use of three dimensional electron beam cooling. The local chromatic correction is applied in both sides of the ion straight section interaction region.

INTRODUCTION

A future "QCD factory" the eRHIC would provide collisions between electrons and: polarized protons in an energy range of 50-250 GeV, light ions (d, Si, Cu); heavy ions 50-200 (130) GeV/u; and, polarized He^3 215 GeV/u. The Electron Recovery Linac (ERL) design replaced previous ring-ring design as higher luminosities could be achieved due to improved conditions for to beam-beam tune shift. An additional advantage is ability to recover the large energy ~1 GW allowing the beam dumps at the injection energy. The IR design follows existing RHIC geometrical constraints. The last two bending magnets "D0" and "DX" as well as the RHIC triplets are assume to be removed during the electron-proton/ion collisions. The luminosity of $1x10^{34}$ cm^{-2} s^{-1} will be achieved with coherent electron cooling allowing short *rms* bunch length of 8.3 cm with the a small transverse size with β^*= 5 cm. Electrons and protons/ions will collide with an angle of 10 mrad. This will allow for electrons to get to collisions without synchrotron radiation on the detector walls. It also assumes of using the "crab" cavities without losing luminosity. The basic eRHIC parameters are shown in Table 1. The IR has been developed by continuous interaction with the future eRHIC experiments: a request for neutron detection was accomplished by introduction of the combined function magnet replacing the first quadrupole of the IR triplets. The combined function magnet provides a bending angle of 3.5-4 mrad to allow detection of neutrons (with the Zero Degrees Calorimeter – ZDC), as well as of the low energy partons (p_o/2.5). The quadrupole's aperture of a 120 mm diameter allows detection of deep virtual scattering in electron proton collisions. A distance of 4.5 m of the first triplet element makes possible a very small beam size at the interaction point (IP). The gradients in the second and third quadrupoles are 200 T/m following recent results from the "LARP" LHC IR upgrade [1].

Latest developments in the polarized electron sources are showing improvements in polarization, intensities, and life times of the electron beam. In eRHIC a "Gatling" polarized electron gun is being developed.

Table 1. eRHIC parameters

	e	p	$^{79}Au^{197}$
Energy, GeV	20	250	100
CM energy, GeV		141	89
#bunches/distance #bunch	74 ns	166	166
Bunch intensity x 10^{11}	0.24	2	0.79
Bunch charge, nC	3.8	32	5.2
Beam current, mA	50	420	67
Norm. emittance 95% μmrad		1.2	1.2
Polarization, %	80	70	none
rms bunch length, cm	0.2	8.3	8.3
β*[cm]	5	5	5
Luminosity/u x $10^{34}m^{-2}s^{-1}$		0.97	0.39

It will allow merging of 24 different polarized electron beams making the 50 mA required current. In eRHIC collisions between polarized protons or ions with polarized electrons will be provided. The optimal conditions for the "crab" cavities are the phase difference of 90° degrees between them and the IP and large horizontal betatron function.

GEOMETRICAL CONSTRAINTS

The RHIC is able to collide equal or unequal ion species, as there are two: "blue" and "yellow" superconducting rings. A common magnet "DX" 9.8 m away from the IP provides collisions between ions. It separates or brings the beams in or out of collisions, respectively.

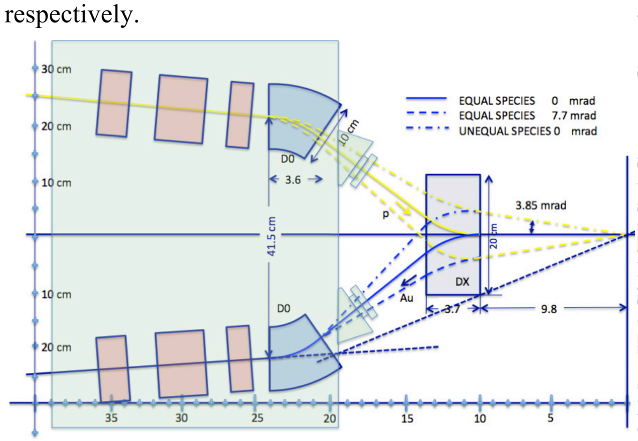

Fig. 1. Present layout in RHIC IR.

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The present RHIC interaction region layout is presented in Fig. 1. The eRHIC triplet magnets are placed closer to the IP (4.5 m) but proton or ion beam is directed to the spin rotator the last element in the existing IR line of the "blue" ring as shown in Fig. 2. Additional dipole is added to provide this connection.

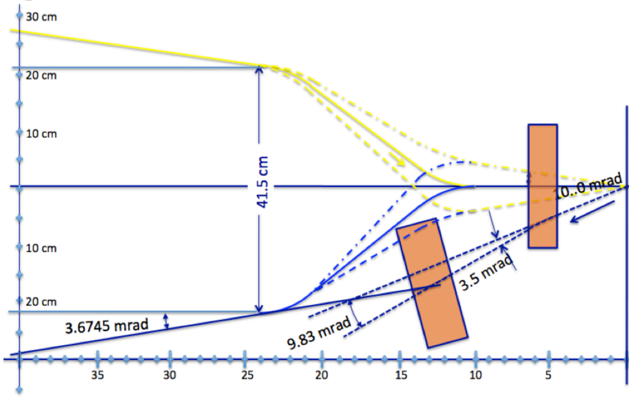

Fig. 2. eRHIC-bending magnets in the IR.

The eRHIC proton/ion IR elements are schematically presented in Fig. 3. The vertical axis is magnified to allow better view of the 10-mrad-collision angle between electrons and protons/ions. The first combined function magnet allows passage of electrons through a very small magnetic field less than 0.36 G. Neutrons are detected behind the triplet magnet with the ZDC detector. All three magnets have to provide zero magnetic fields for electrons to go through them.

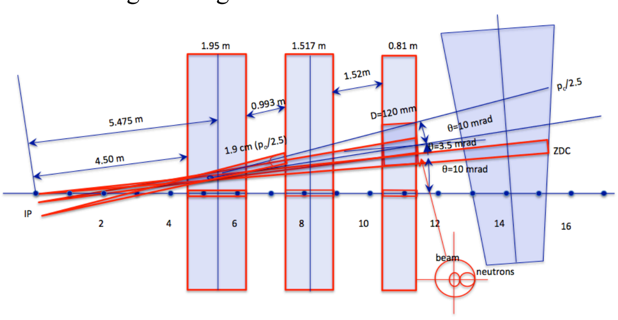

Fig. 3. Proton/ion eRHIC IR magnets.

The electron and proton/ion elements are schematically shown in Fig. 4.

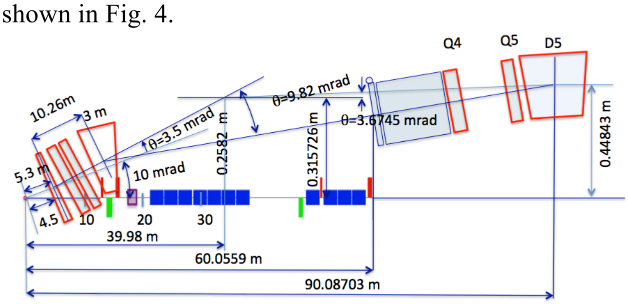

Fig. 4. eRHIC electron and proton/ion elements.

Magnet Design

A special 1.95 m long superconducting combined function magnet for eRHIC has been designed. The electron beam passes in the direction of its cylindrical axis as shown in Fig. 5. Electron passage is magnified and shown in Fig. 6. The combined function magnet is aligned along the electron direction. The protons/ions arrive to the magnets with an offset of 22 mm. The magnetic field on electrons is too weak to affect the e-beam (0.28 – 0.36 G).

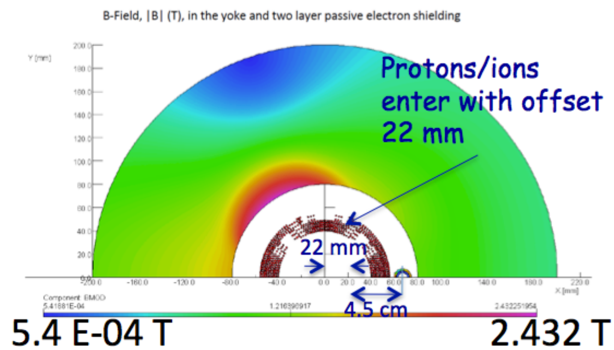

Fig. 5. A cross section of the combined function magnet. Protons/ions enter with 22 mm offset and are bent for 4 mrad.

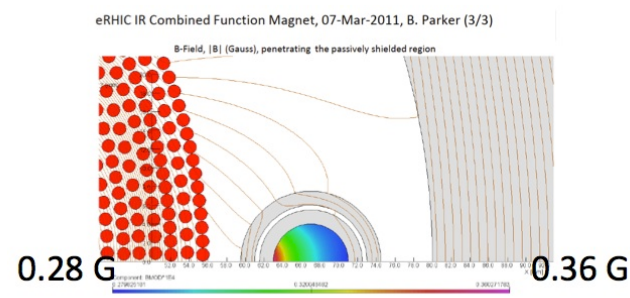

Fig. 6. Electron double shielded pipe in the combined function magnet. Electrons pass at 4.5 cm away from the axis.

IR LATTICE

The present RHIC lattice is shown in Fig. 7. This is the smallest beam size achieved until now during RHIC operations ß*=0.6 m. The maximum value of the ß functions in the triplets are ~2300 m.

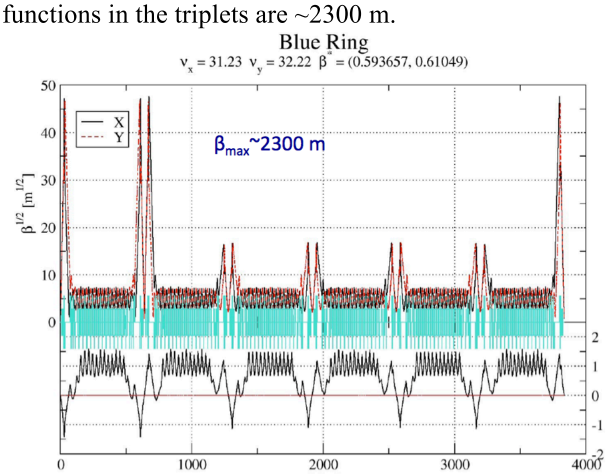

Fig. 7. RHIC present lattice $ß^*$=60 cm.

The eRHIC lattice design follows existing maximum values of the betatron functions not to have larger linear chromaticity then RHIC operating conditions, is shown in Fig. 8. The natural linear horizontal and vertical chromaticities are χ_h=-101.0 and χ_v=-106.3, respectively. The nonlinear second and third order chromaticites need to be corrected to allow good dynamical aperture. A design is still in progress with an intention to use two way correction: one by using sextupoles placed in the triplet quadrupoles where there is a large dispersion, but not to over power them as the second order amplitude tune shift would be enhanced. Four pairs of vertical and horizontal focusing sextupoles are placed in the interaction region away from the triplets at the phase difference of $n\pi$ with respect to the corresponding triplets.

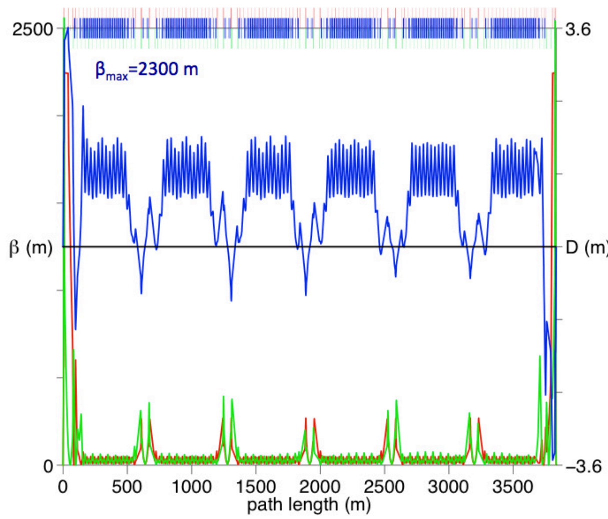

Fig. 8. The eRHIC lattice functions: the β_x is the horizontal; the β_y is the vertical betatron function, while D_x is the dispersion function.

The IR lattice for 30 GeV electrons is shown in Fig. 9

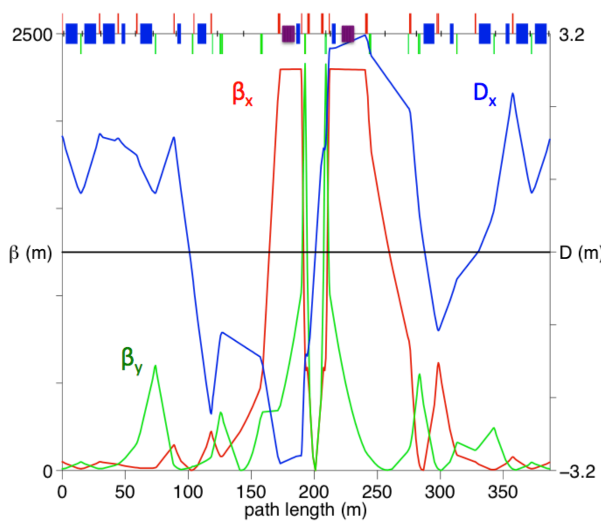

Fig. 9 Lattice functions in the eRHIC IR.

The IR chromatic correction sextupoles are shown in Fig. 10. This is half of the IR. The lattice functions for the electron IR are shown in Fig. 11.

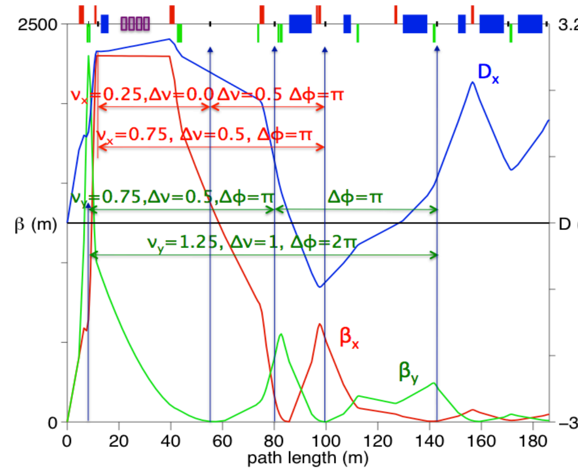

Fig. 11. Betatron functions in the half of the IR. The sextupole positions and their phase differences are marked with arrows.

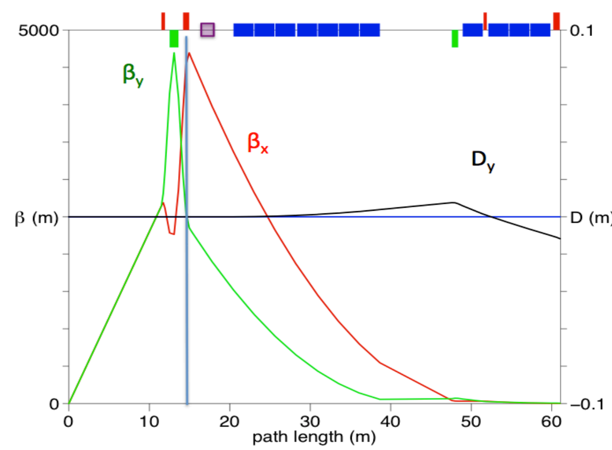

Fig. 9. Electron IR lattice functions.

SUMMARY

A new "QCD factory" the eRHIC project is a possible continuation of the existing, very successful and exciting nuclear-physics program at RHIC. Designs, of both electron and proton/ion lattices, with the β^*=5 cm at the collision point, are presented. Luminosity of $1 \cdot 10^{34}$ $s^{-1}cm^{-2}$ could be achieved. For electrons an ERL solution is selected to improve on luminosity. Polarized proton electron collisions as well as heavy ions on electrons are being prepared. In the present proton/ion lattice improvements in the second and third order IR chromatic corrections, together with the dynamical aperture studies are in progress.

REFERENCES

[1] P. Wanderer, IEEE Appl. Superconductivity, Vol. 19, no. 3, June 2009, pp. 1208-1211.