

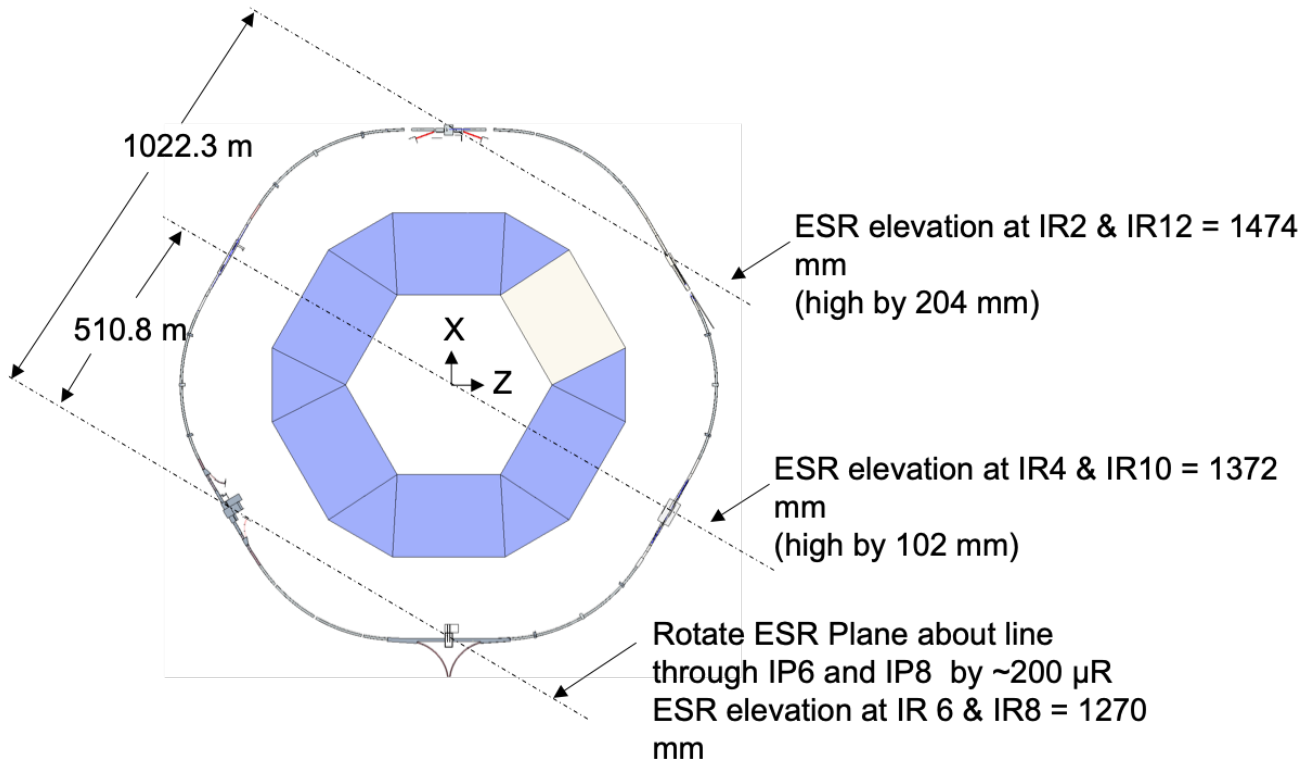
Coordinate systems used in EIC

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This document describes the different coordinate system used by different groups working on the design of EIC.

There are a couple of facts which should be mentioned right away

- The hadron beam has an angle of 17 mrad
- The electron beam has an angle of 8 mrad
→ this results in the total crossing angle of 25 mrad
- The IP is shifted compared to RHIC by 81 cm (shift = $\sqrt{dx^2 + dz^2}$ because the RHIC ring is rotated in space)
- ESR reference plane is rotate about a line through IP6 and IP8 by 200 μ R
 - Maintains ESR height at collision locations
 - ESR is then above the HSR by 204.46 mm at IP12 and IR2 for HSR crossing and SHC e-beam injection in horizontal plane
 - ESR is then above the HSR by 102.16 mm at IP4 for HSR crossing



In the following the coordinate systems are listed and an attempt is made to provide a way how to correlate them to each other

1 COORDINATE SYSTEM USED IN COMPUTER AIDED DESIGN (CAD) PROGRAM

The CREO Computer Aided Design (CAD) file coordinate system for top-level assembly files is located at the center of the RHIC machine, see Figure 1. The plane of the blue and yellow rings is coincident with the TOP view (Y=0) of the CREO files so that the:

- X-axis points to the ring outside to the east
- Y-axis points to the sky
- Z-axis points to the ring outside to the south

The origin (0,0,0) of this coordinate system is at in the ring center

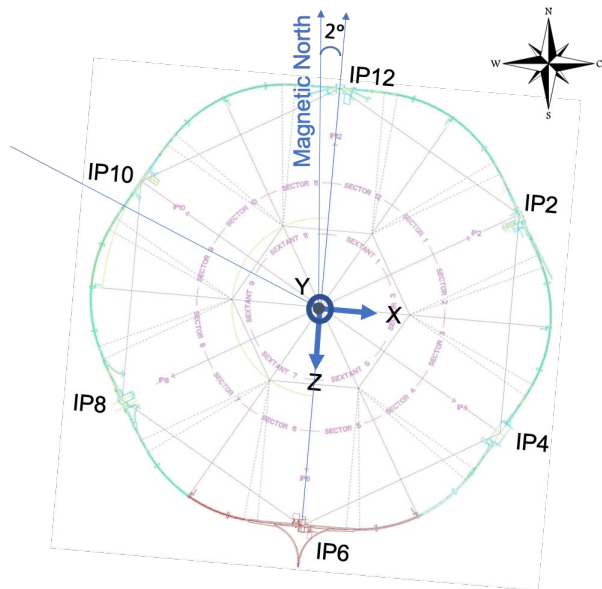


Figure 1: CAD coordinate system

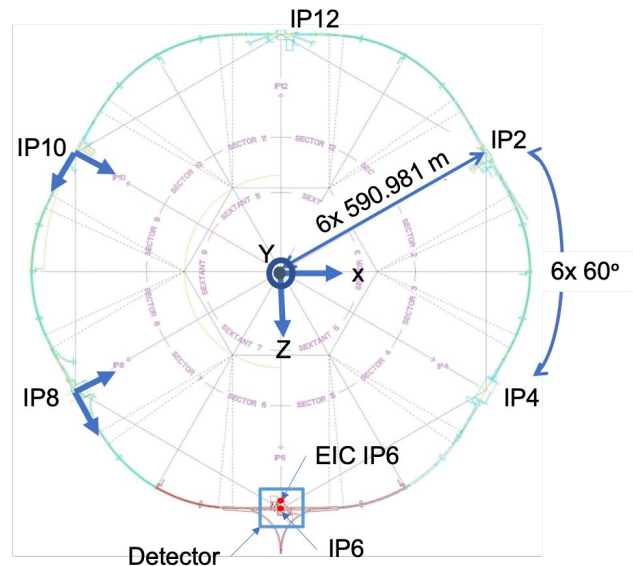


Figure 2: Ring Orientation in CREO files (Top View)

The EIC IP6 in the CAD coordinate system is X=0, Y=0, Z=589.77164 m

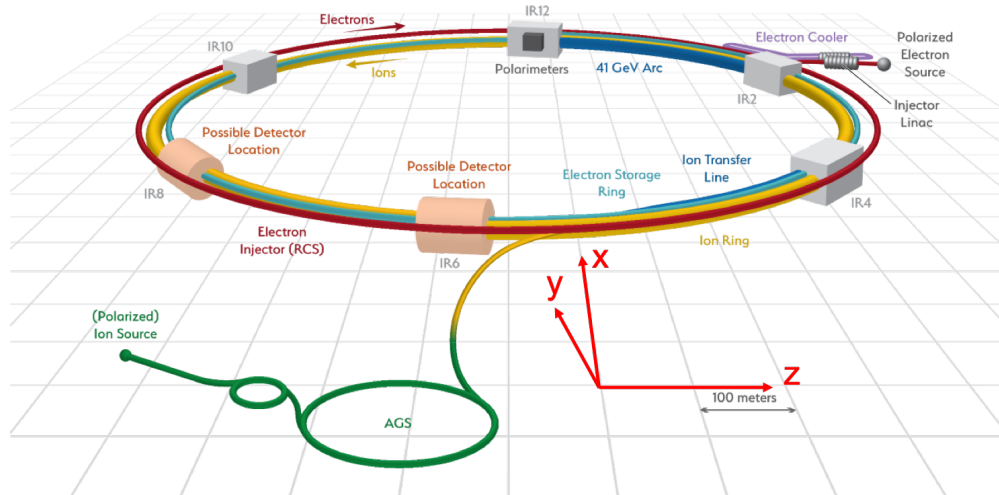
The RHIC IP6 in the CAD coordinate system is X=0, Y=0, Z=590.58164 m

RHIC IPs	X	Y	Z
IP12	0.00000	0	-590.58164
IP2	511.45870	0	-295.29082
IP4	511.45870	0	295.29082
IP6	0.00000	0	590.58164
IP8	-511.45870	0	295.29082
IP10	-511.45870	0	-295.29082

All RHIC IPs are radially 590.5816396 m from the RHIC center.

2 COORDINATE SYSTEM USED FOR DETECTOR

For EIC the hadron beam is going counter clockwise and the lepton beam clockwise as is shown below. The hadron beam defines the positive z axis and x points to the ring inside as would be correct for a right handed coordinate system.



y-axis pointing to the sky
 x-axis pointing to the ring inside
 z-axis pointing along the ring in the direction of the hadron beam
 The origin (0,0,0) of this coordinate system is at EIC IP-6.
 The IP is in the EIC detector coordinate system at $x=0, y=0,$ and $z=0$
 The RHIC IP is in the EIC detector coordinate system at $x= -80.9883\text{cm}, y=0, z= +13.77\text{mm}$

Current IR Layout:

Figure 3 represents a cartoon layout of the IR to visualize things. The detector is rotated by 8 mrad that its z-axis is aligned with the electron beam.

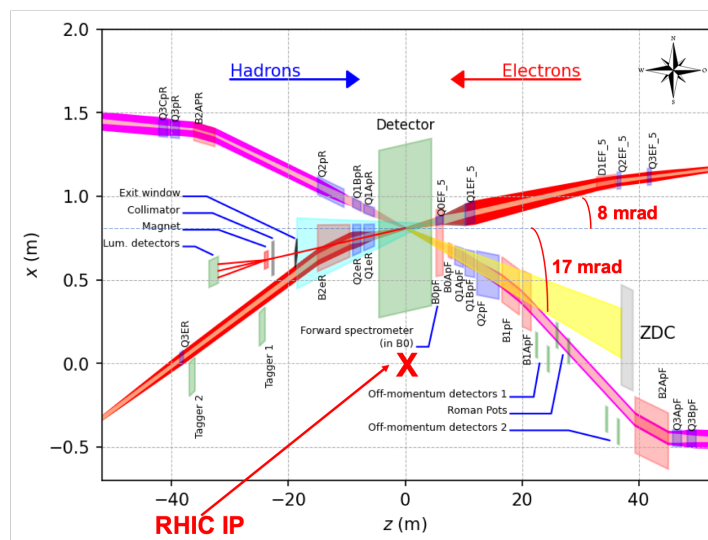


Figure 3: cartoon layout of the EIC IR at IP-6

The subsystems of the main detector should be oriented in the right handed coordinate system with the z-axis along the electron beam with positive z in the hadron beam direction. The luminosity detector and the low Q^2 -tagger should be oriented the same way, z axis along the electron beam with positive z in the hadron beam direction.

The ancillary detectors in the hadron beam, ZDC, Roman Pots and Off-momentum detectors should be oriented in the right handed coordinate system as described above, z-axis along the lepton beam and positive z in the hadron beam direction. $\rightarrow x = z \tan(25 \text{ mrad})$

3 COORDINATE SYSTEM USED FOR BMAD

The relevant files are provided from BMAD, which have the full layout of the hadron and electron machine integrated.

Both for the hadron and electron beam two files are provided one with has all the element positions which is labeled ***survey*** in the name and the 2nd file labeled ***optics*** which has the optics information about beta-functions and so on.

The coordinate system is the one used for RHIC, which is different to the one in the IR figures above.

- The files have the longitudinal, x and y position of the different elements, i.e. magnets. In general values are specified for the end of each element; the beginning is the end of the prior element.
- There is one file for the rear and forward side around IP6
- The first Quad is always vertically focusing
- The IP is shifted compared to RHIC by 81 cm ($\text{shift} = \sqrt{dx^2 + dz^2}$ because the RHIC ring is rotated in space)

The RHIC survey frame

Beams cross at six locations in RHIC, forming a regular hexagon that lies in the plane that contains both Blue and Yellow rings. In surveyors jargon[2], the center of this hexagon is called the Machine Center Point, or MCP. The location of the MCP in the Euclidian RHIC survey frame is given by coordinates (N,E,W), defined to be exactly

$$\begin{pmatrix} N \\ E \\ W \end{pmatrix}_{\text{MCP}} \equiv \begin{pmatrix} 32284.517011 \\ 30230.237553 \\ 0.000000 \end{pmatrix} \quad 1$$

All details about this RHIC coordinate system can be found in the following file RHIC_AP_12.pdf

Format for the ***survey*** file:

- Name: name of the element
- Key: type of the element
- S: longitudinal position around the ring for the reference orbit
- L: length of the element
- x-pitch: rotation in x-z plane of element
- x-offset: shift in x
- the following variables really give the absolute position of the elements in the RHIC coordinate system and should be used in the simulation. For further information on the RHIC coordinate system see technical note RHIC/AP/12 in same folder as this document.
- floor actual x (m): x-position of the element in the global “floor” coordinate system including offsets and rotations.

- floor actual y (m): y-position of the element in the global “floor” coordinate system including offsets and rotations.
- floor actual z (m): z-position of the element in the global “floor” coordinate system including offsets and rotations.
- floor actual theta (rad): Azimuth angle: Angle in the (X,Z) plane between the Z-axis and the projection of the z-axis onto the (X,Z) plane. A positive angle of $\theta = \pi/2$ corresponds to the projected z-axis pointing in the positive X direction.
- floor actual phi: Pitch (elevation) angle: Angle between the z-axis and the (X,Z) plane. A positive angle of $\phi = \pi/2$ corresponds to the z-axis pointing in the positive Y direction. Not used.
- floor actual psi: Roll angle: Angle of the x-axis with respect to the line formed by the intersection of the (X,Z) plane with the (x,y) plane. A positive ψ forms a right-handed screw with the z-axis. Not used.

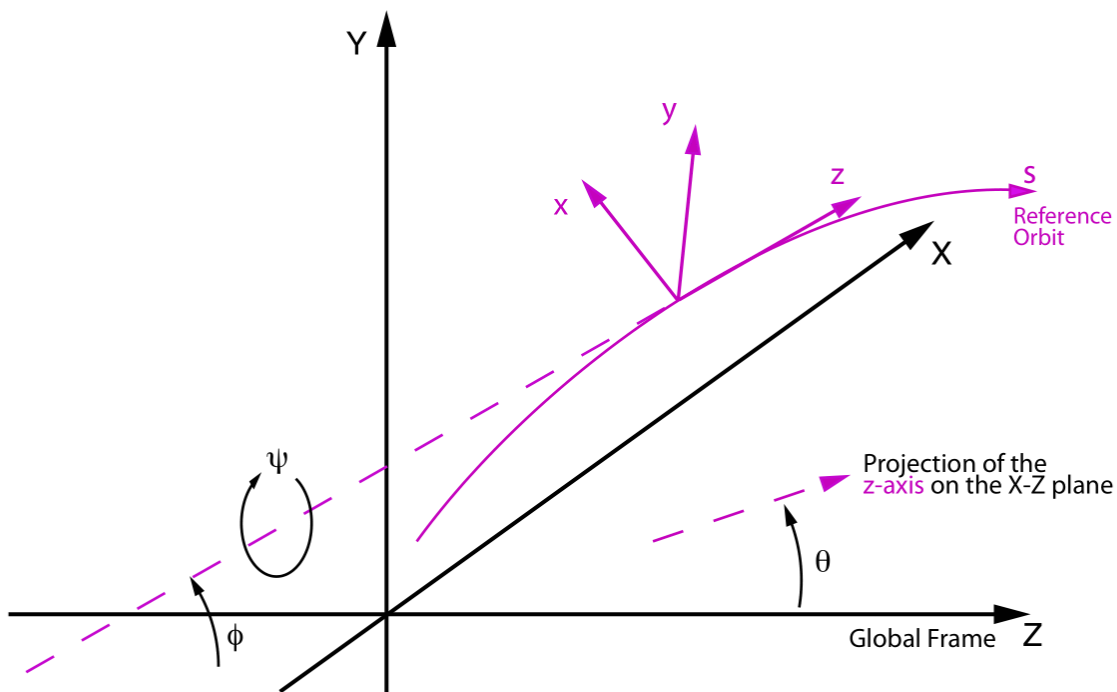
the starting coordinates for IP6 are (in m)

beginning[x_position] = 31694.295102

beginning[z_position] = 30209.627602

beginning[theta_position] = 3.106687849

The BMAD coordinate system definitions are illustrated in the following figure



Location of files on Sharepoint: