Tools and approach to design of the EIC IR

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US FCC Workshop

April 25, 2023

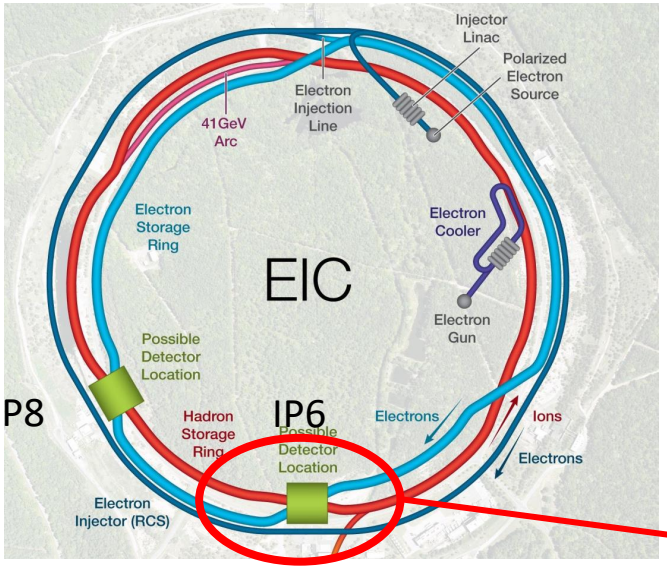
Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY

Jefferson Lab

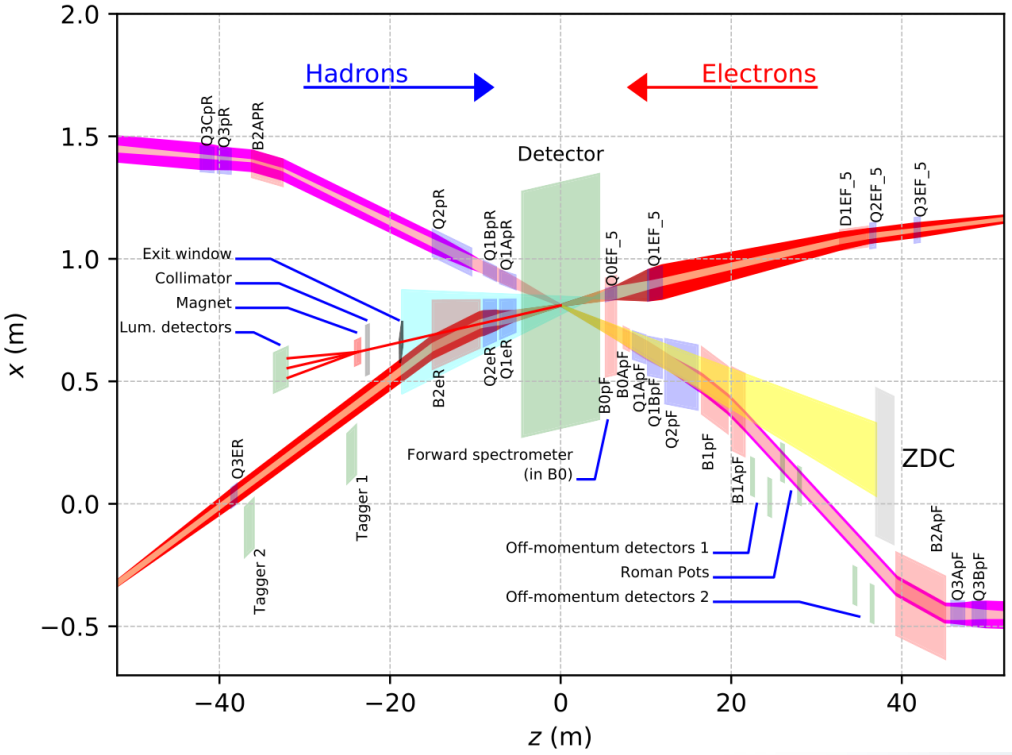
U.S. DEPARTMENT OF ENERGY | Office of Science

EIC IRs: Overview



Rear
RHIC Sector 6

Forward
RHIC Sector 5



- On-Project IR:
  - Detector at RHIC IP6
  - Included in project baseline
- Potential second IR:
  - Detector at RHIC IP8
  - Not included in project baseline
  - But provisions for a 2nd detector have to be maintained (presented by B. Gamage tomorrow)

Challenges and highlights of the EIC IR

- High Luminosity
  - High number of bunches (1160, ~10 ns separation)
  - High current (~ 2.5 A)
  - Small β^* values (h: 80/7.2 cm, e:45/5.6 cm)
- Polarized Hadrons and electrons
- Experimental detector
  - Machine element free region at IP
  - Forward detectors
  - Experimental solenoid & compensation.
- Existing tunnel/hall and existing hadron ring
- Installation of two additional rings inside tunnel and experimental halls
  - Interferences between the four beam lines

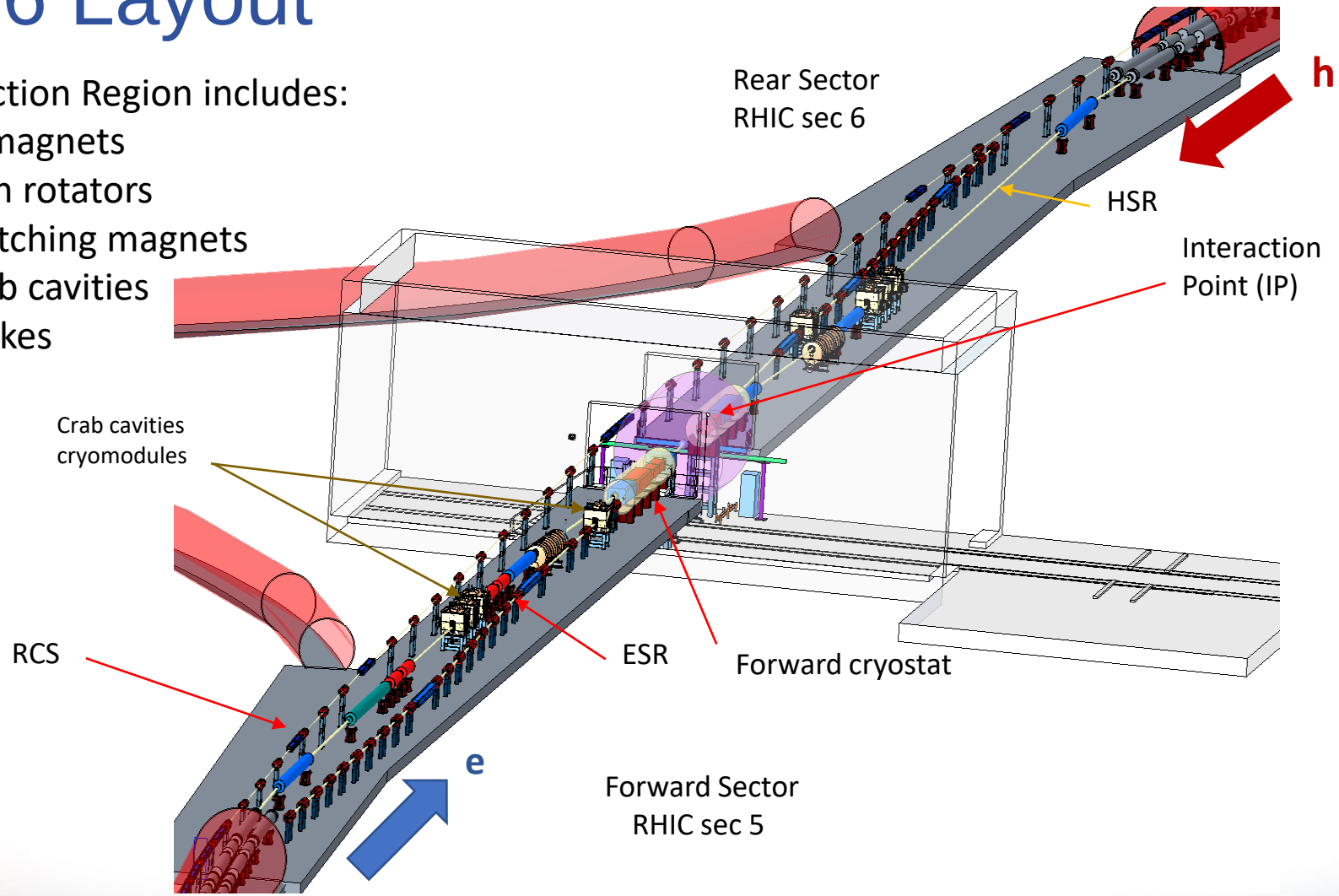
IR requirements & parameters

	On project IR @ IP6	
	proton	electron
Detector occupied region	-4.5 m +5.0 m Beam elements < 1.5° in main detector	
Polarimetry	Yes (tbd, local)	local
2nd focus	No	
β^* @ 275 GeV (h), 10 GeV (e)	β^*_x = 80 cm β^*_y = 7.2 cm	β^*_x = 45 cm β^*_y = 5.6 cm
ZDC	0.6m x 0.6m x 2m @ s ≅ 35 m n: ± 4 mrad, p± 6 mrad	
Roman Pots	1-5 mrad, @ s ≅ 30 m	
Scattered particle acceptance	p: 0.18 GeV/c < p_T < 1.3 GeV/c	
Q^2 tagger		Q^2< 0.1 GeV @ s ≅ -20 m to -40 m
Crossing angle	25 mrad	

IR6 Layout

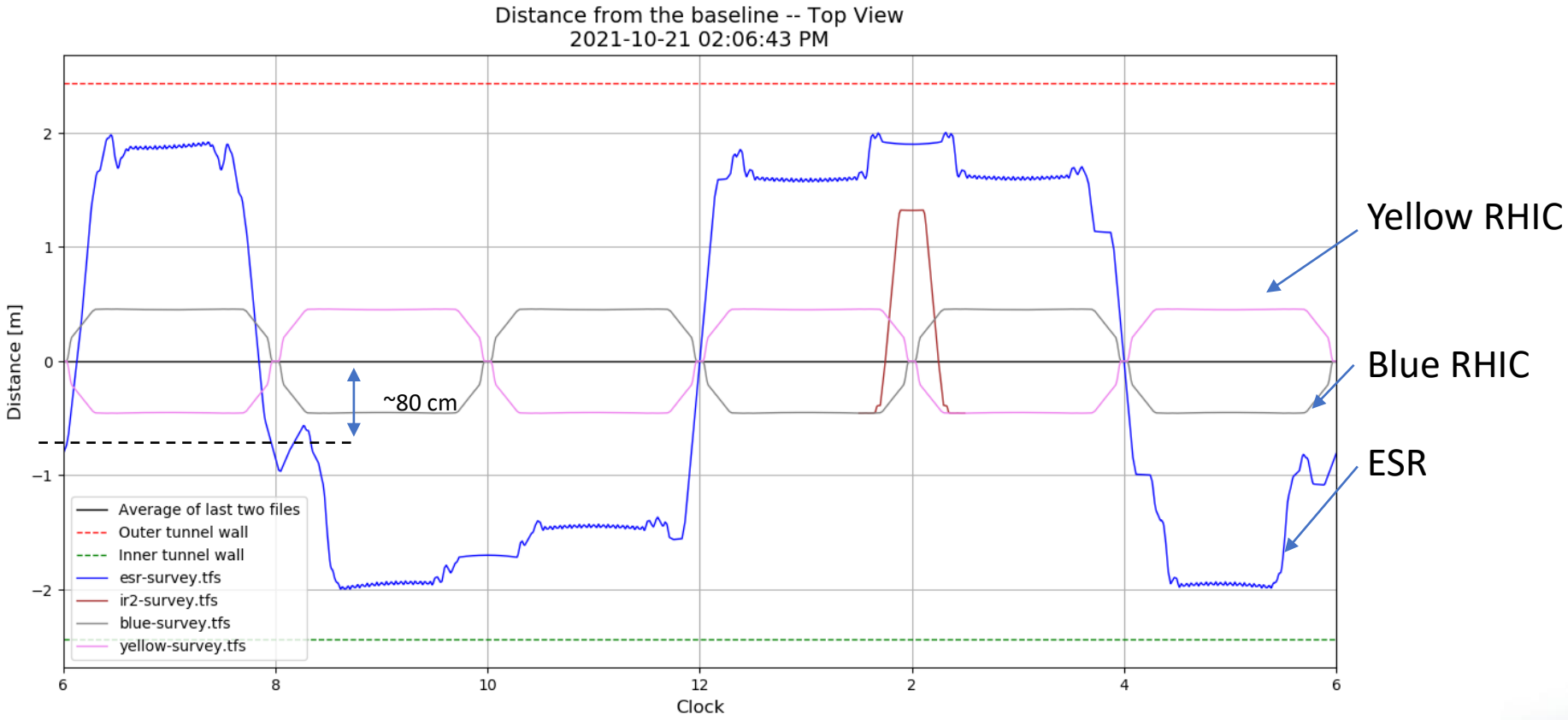
Interaction Region includes:

- IR magnets
- Spin rotators
- Matching magnets
- Crab cavities
- snakes



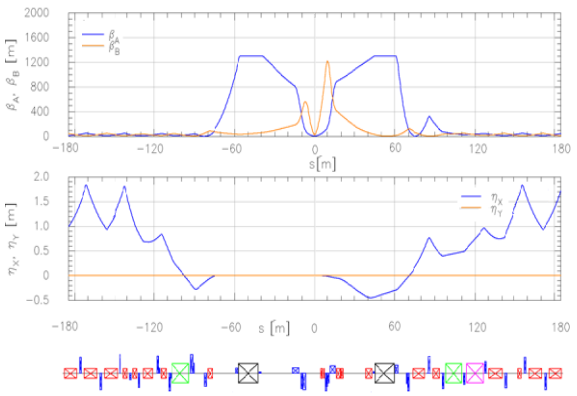
The Interaction Region has to extend to about +/- 130 m from the IP in both directions of the appending sectors to achieve the required conditions for an experimental detector.

ESR and HSR cross in several straight sections:

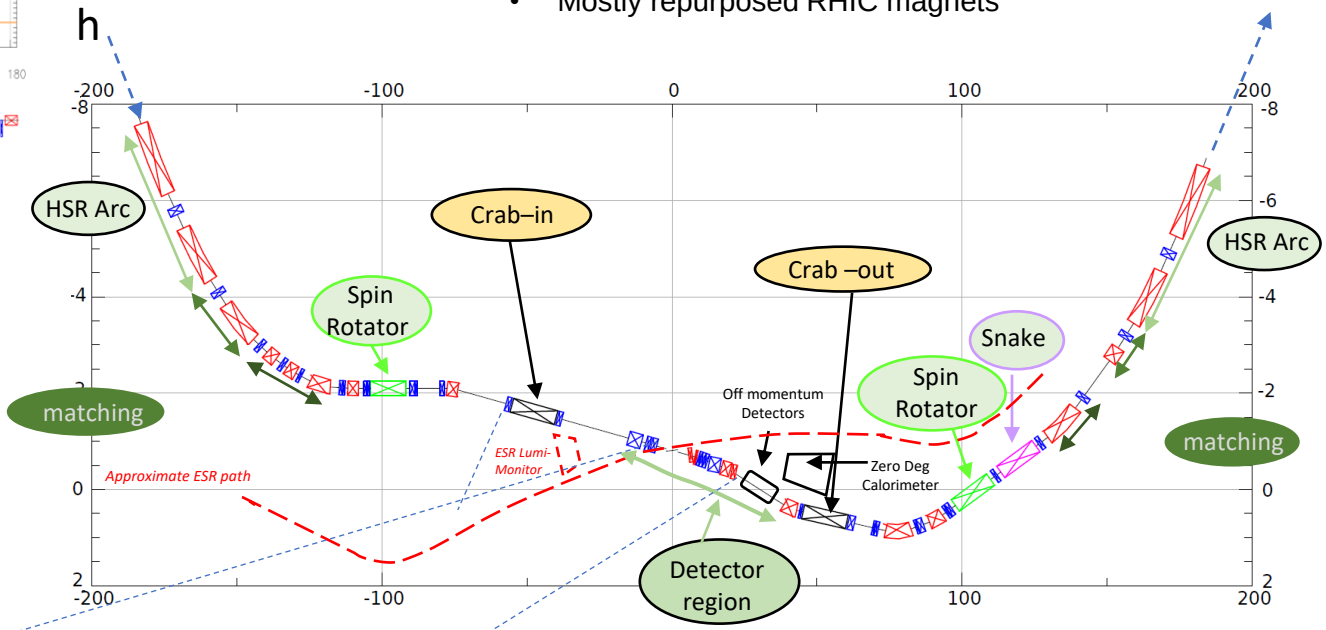


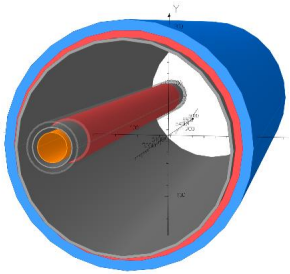
- Existing RHIC tunnel poses restrictions in several areas.
- IP6, IP8, IR4 and IR12 are crossing points
- Detectors move towards the inside @ IP6, IP8 to fit RCS

HSR layout in IR6



- Forward and rear hadron lattice matched into RHIC
  - Beta fct. 1300m at crab cavities
    - Hor. phase advance 90º
  - Matching Magnets
    - Mostly repurposed RHIC magnets

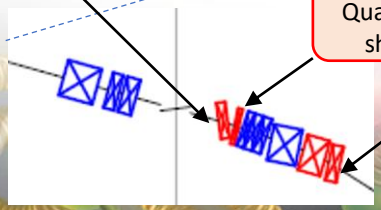




B0pF spectrometer

Nov 2021 layout

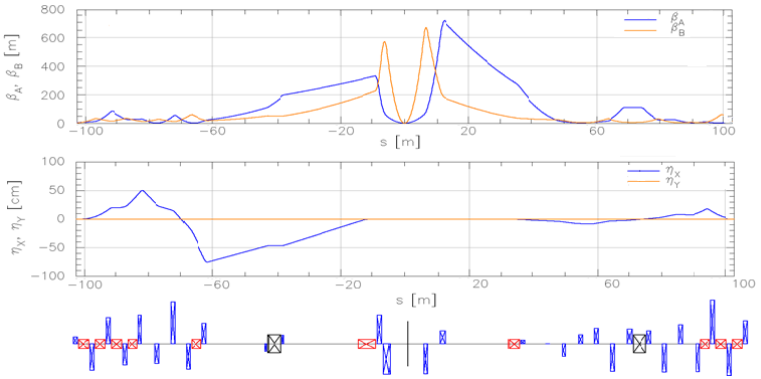
3 Dipoles and 3 Quadrupoles in one shared cryostat



ESR layout in IR6

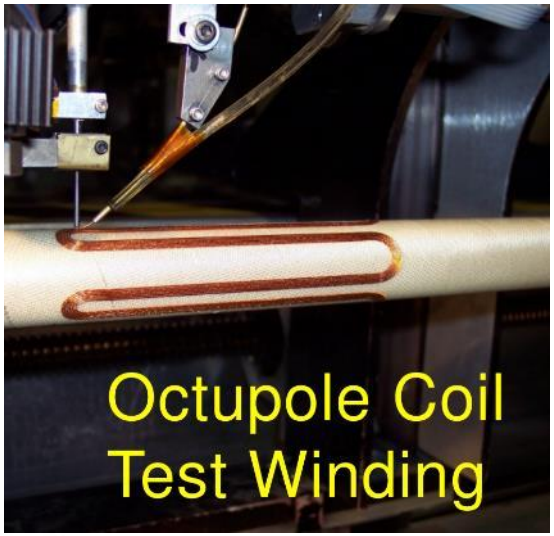
Design to:

- Provide room for detector components
- Mitigate synchrotron radiation issues
- Provide longitudinal spin (new spin rotators)

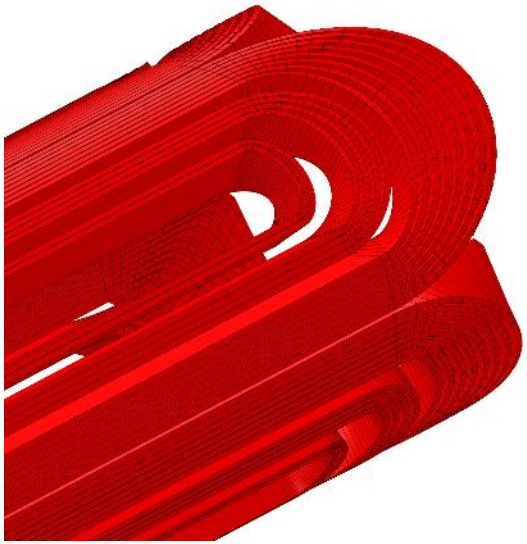


IR Magnets - Overview

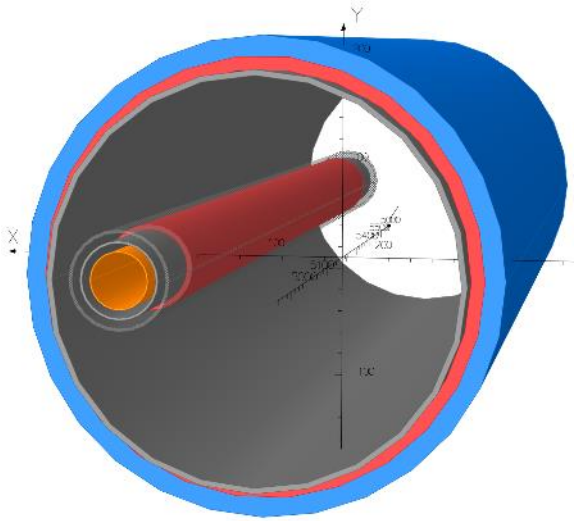
- Three groups of superconducting magnets
  - All NbTi
- (Also: normal conducting magnets, not addressed here)



Direct Wind Magnets (SMD)



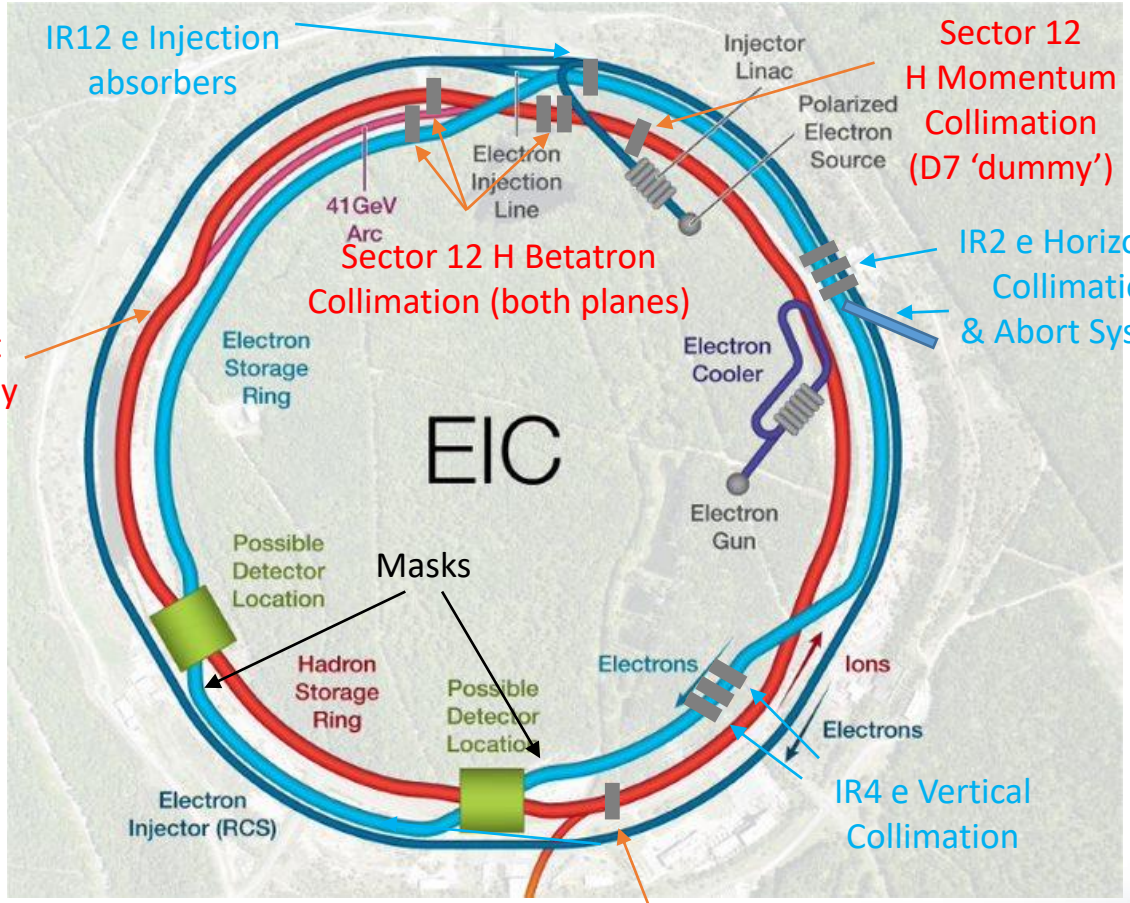
Collared Magnets



Special Magnet

Collimation, Machine & Detector Protection

More details on MPS and Collimation later



electron : 6 collimators

Hadrons : 8+1 collimators

+absorbers and masks

Summary Interaction Region

- Mature design
  - Requirements (general and functional) are defined and included into systems management
- ESR and HSR lattices in IR6 designed
- Stable solutions
- Some details are still in flux
  - Interferences
  - Beam dynamics
- Provides the conditions asked for in the requirements from detectors
- Magnet design for these solutions in progress
- Background contributions identified and effects studied

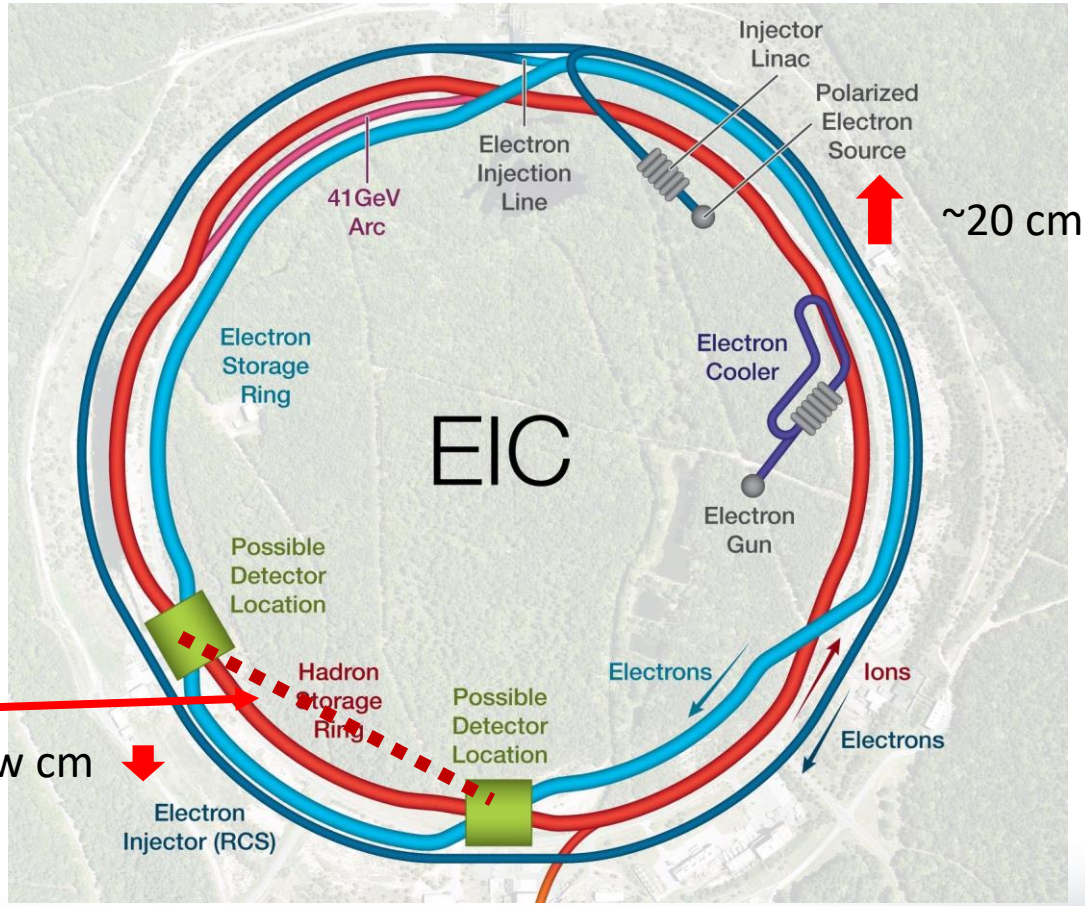
Additional Slides

Space issues: ESR Tilt

Elegant solution to some space issues in tunnel

Tilt ESR: 200urad
Rotation axis:
Line from IP6 to IP8
(Accepted as baseline)

Eliminates vertical bumps in ESR, which is challenging due to spin transparency



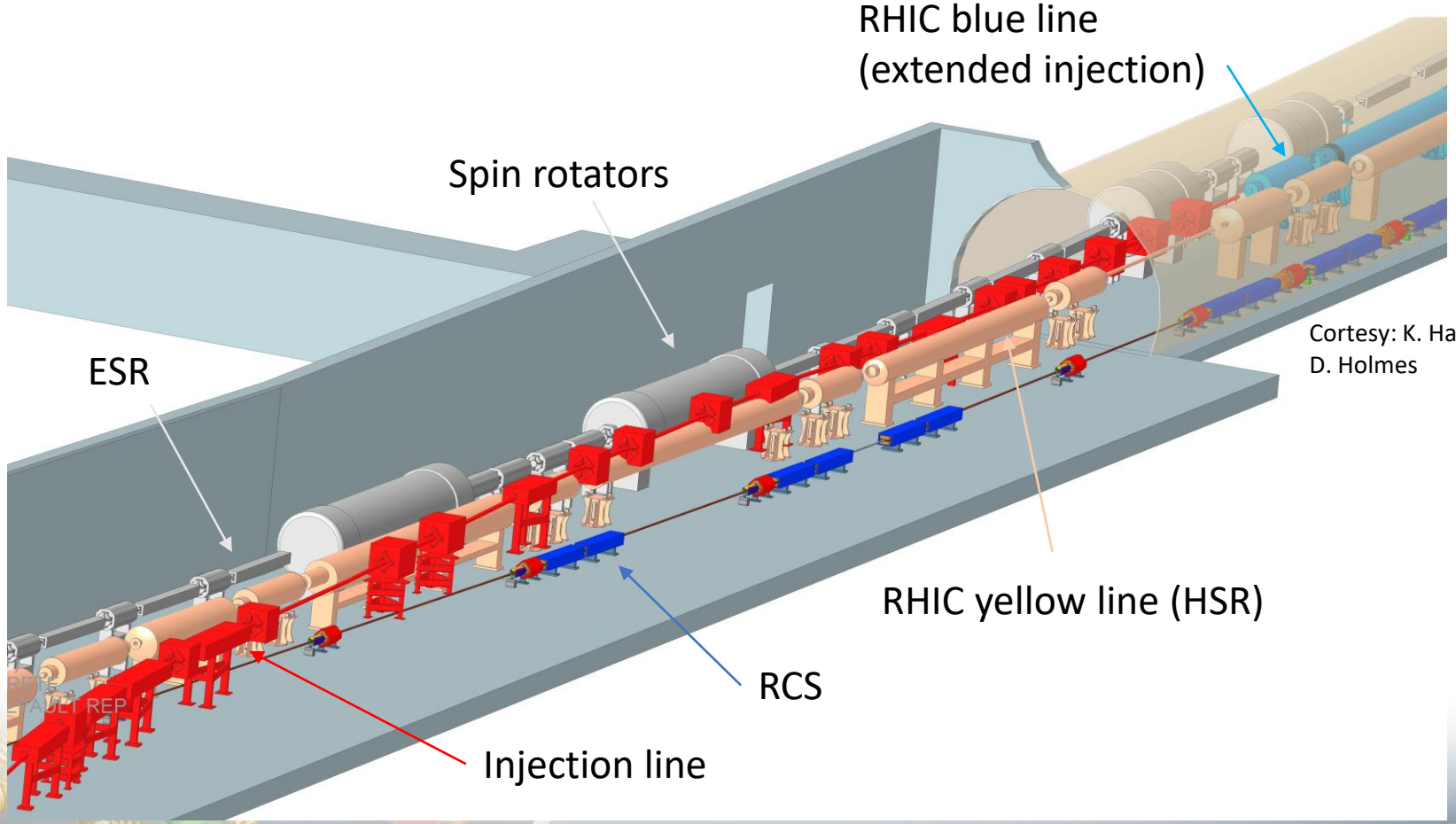
Rotation axis

few cm

Tilt effects need to be compensated in IR design

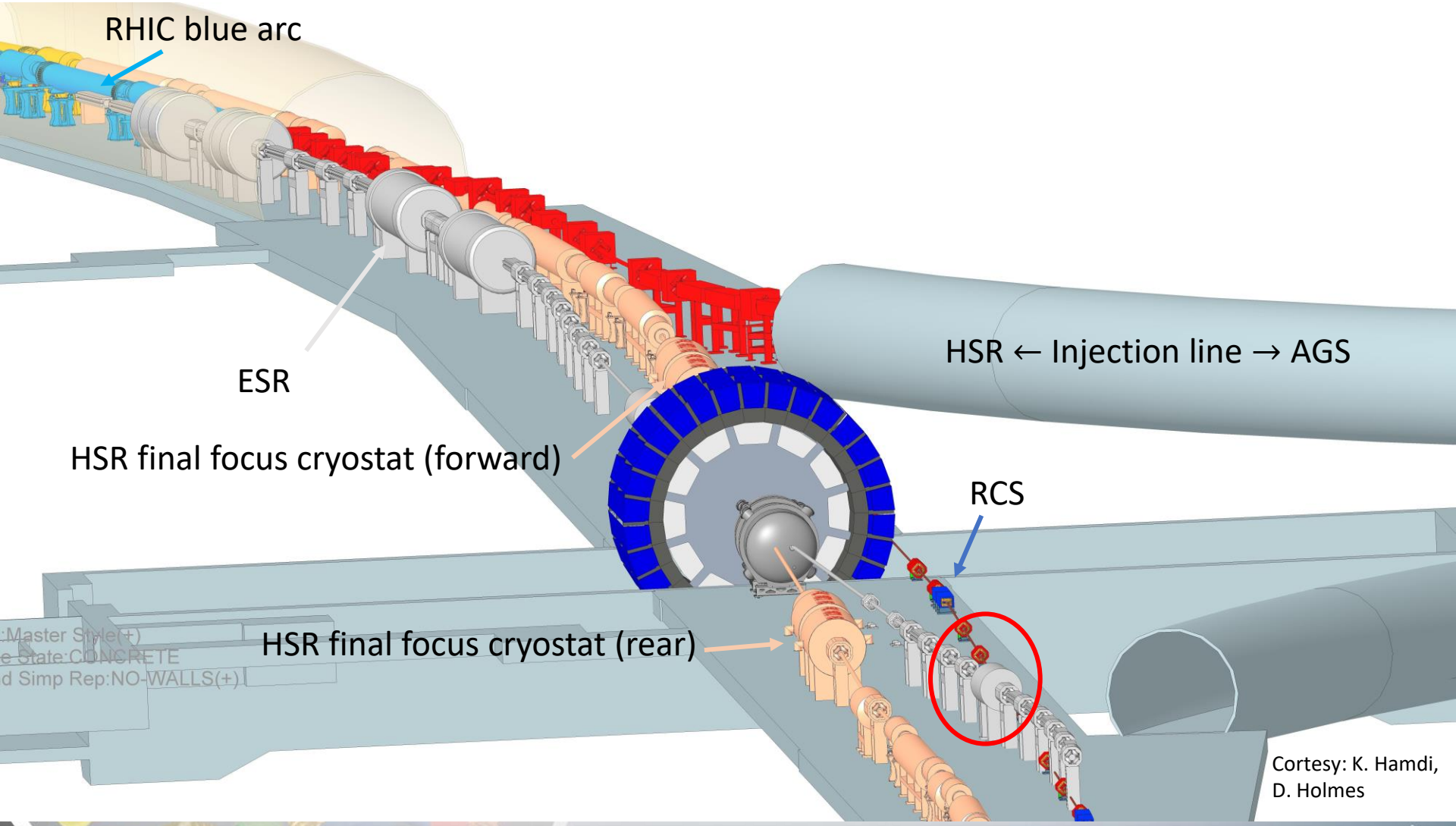
RCS is low and on the outside in all sectors

Sector 5: IR6 region including HSR injection line



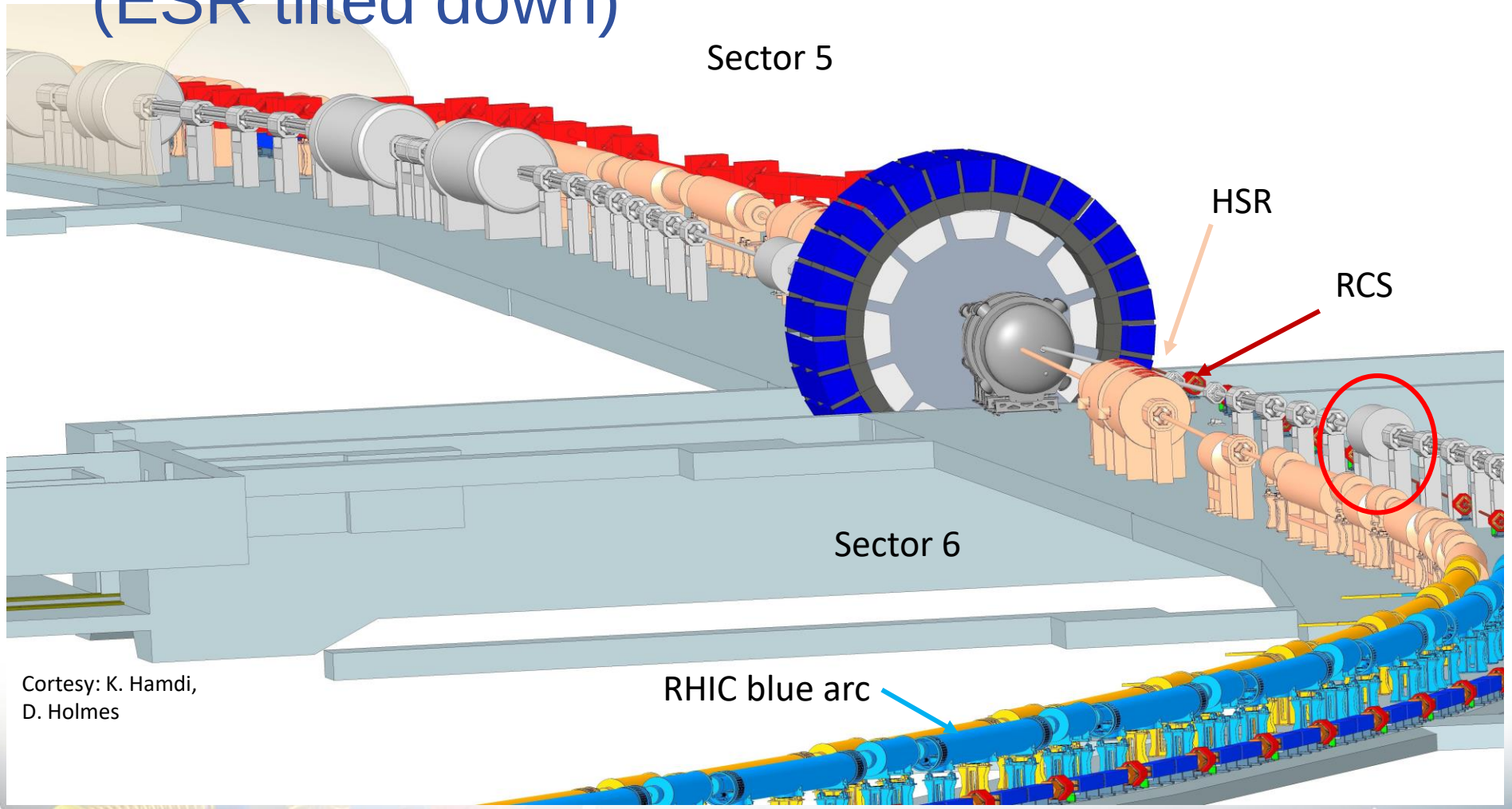
Cortesy: K. Hamdi, D. Holmes

… Around the IP ….



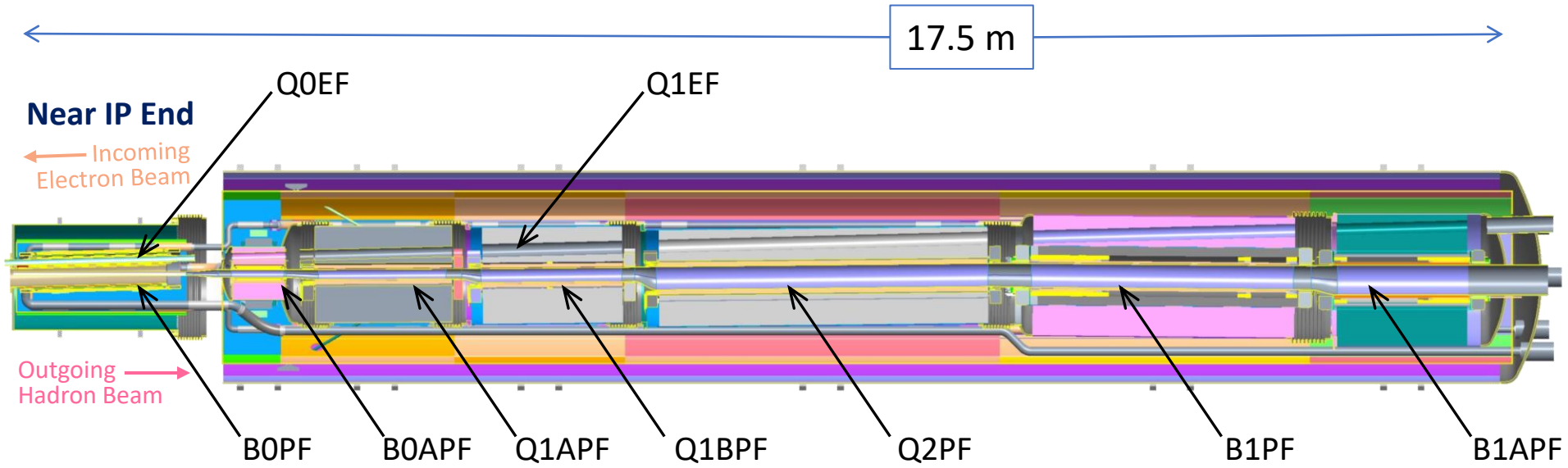
Cortesy: K. Hamdi, D. Holmes

Sector 6: arc from the IP6 towards IP8 (ESR tilted down)



Cortesy: K. Hamdi, D. Holmes

Forward Side, Two Cryostat Layout



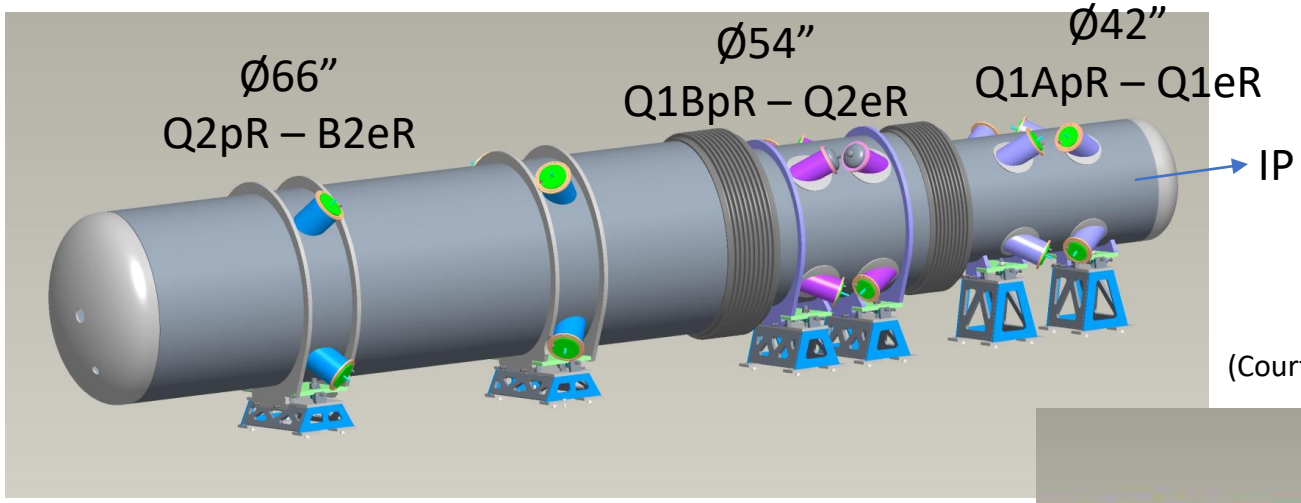
Highlights:

- Final assembly will be done inside the RHIC tunnel.
- Gaps between all magnets – space for coil leads (some nested in end plates), inner helium vessel welding.
- Bellows between all cold masses, at outer yoke/shells – no positional shifting due to welding.

Rear Side Design / Installation

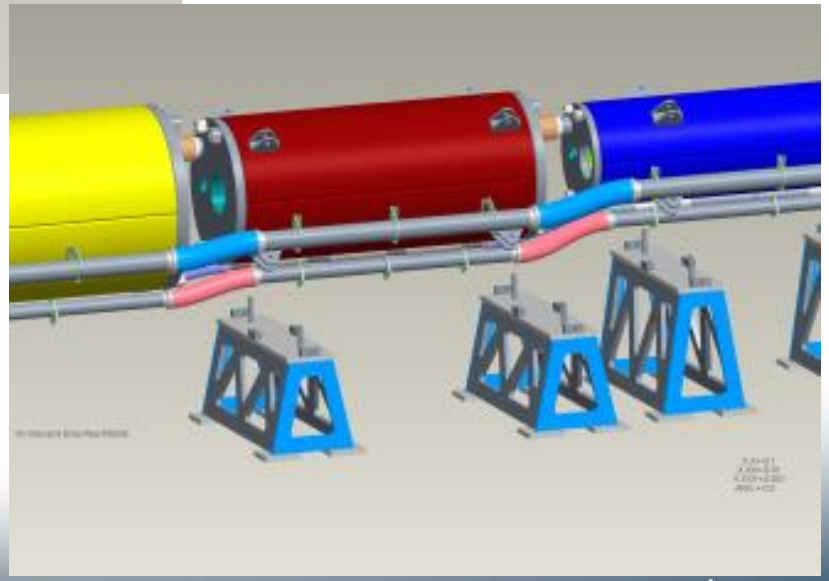
Separate cold masses - helium vessels

Separate circular cryostats with decreasing OD's toward IP

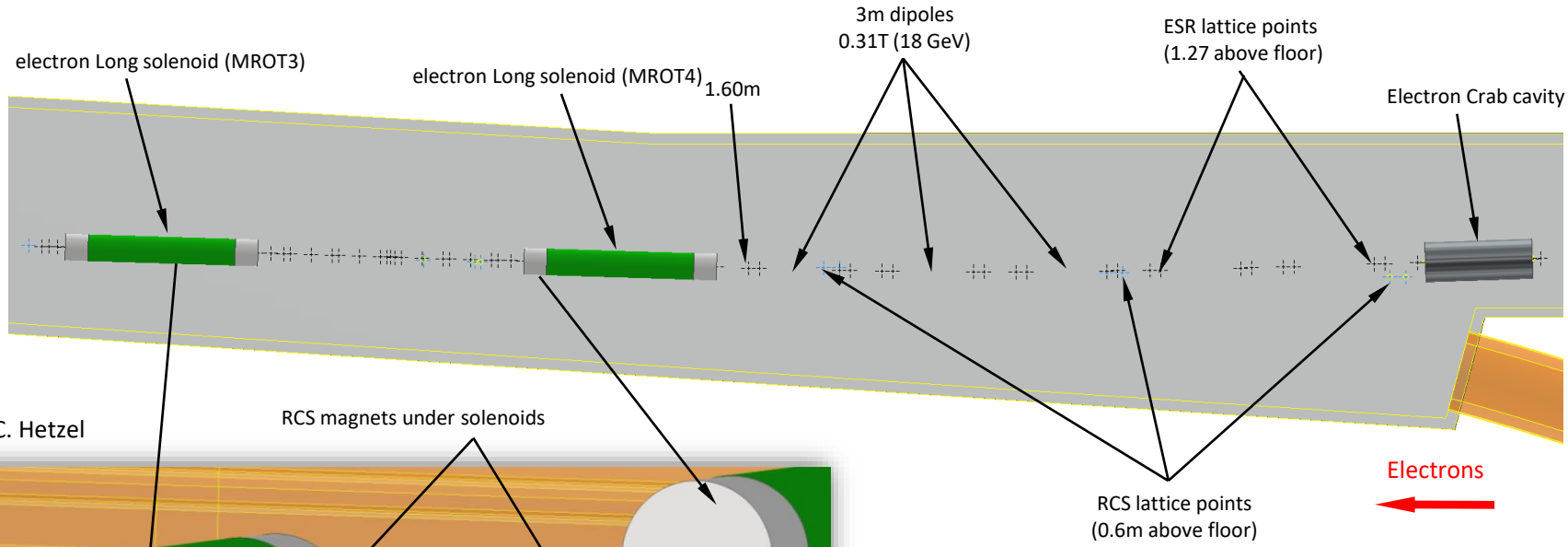


(Courtesy: M. Anarella, SMD)

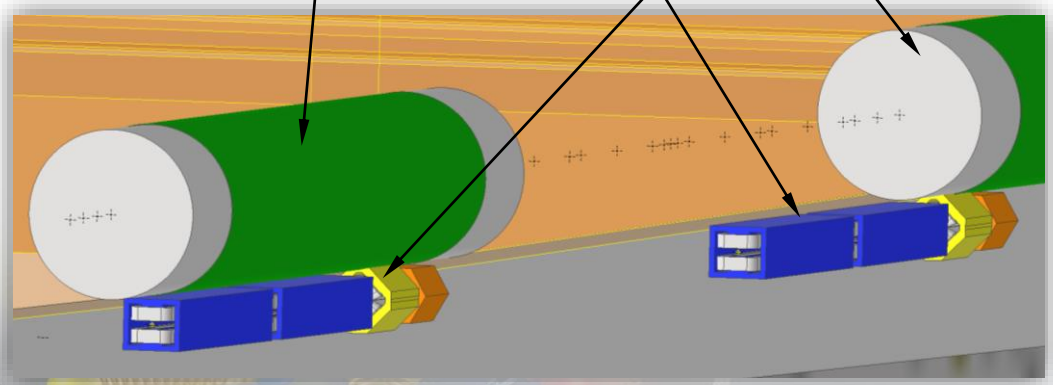
- Conceptual design of Helium piping and Cryostat stands completed
- Work still needed on cold mass supports, cryostat reinforcements – awaiting FEA (Q2pR – B2eR cold mass ~ 30 tons)



ESR-RCS interference
Electron Long Solenoid Modules – Rear Side (sector 6)



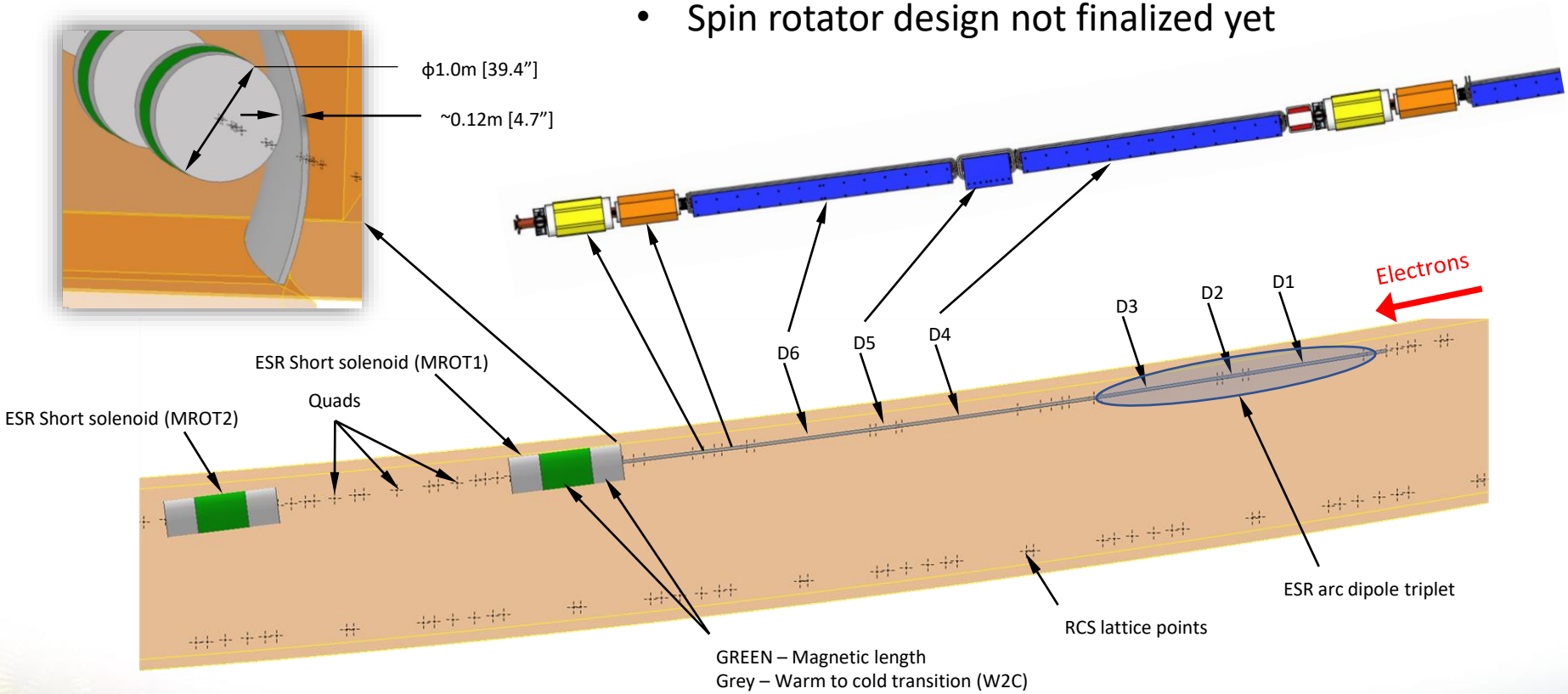
Courtesy: C. Hetzel



- Working on engineering solution:
  - Space
  - Field
  - Support girders

Potential ESR-tunnel enclosure interference Forward side (sector 5)

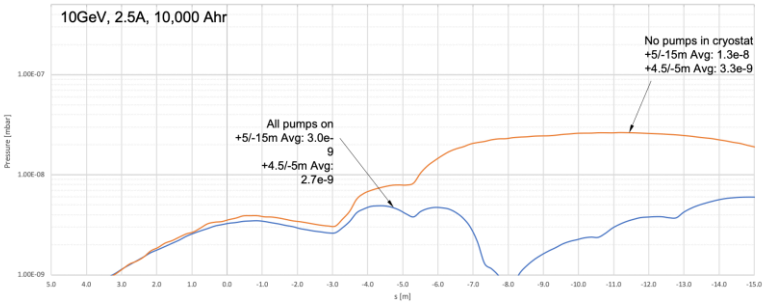
- Spin rotator design not finalized yet



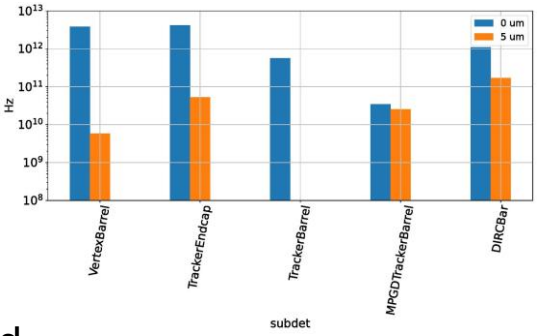
Courtesy: C. Hetzel

Machine-Detector Interface

Detailed assessment of beam vacuum, pump layout in the forward and rear cryostats and synchrotron radiation



Studies on beam induced detector backgrounds

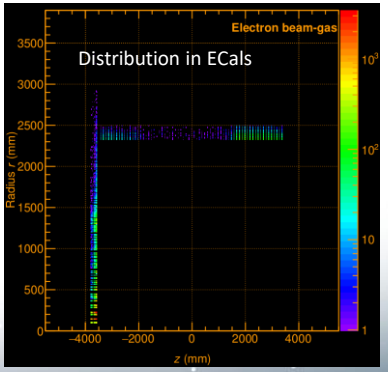


hadron beam:

- background during injection and ramp → collimators
- beam gas interactions p/A + $H^2_{restgas}$
  - detailed GEANT simulations including detector responses
  - current levels are tolerable

electron beam:

- background due to de-excitation of beam if bunches are replaced
  - collimated injected beam (6 σ) well inside aperture limits 13.5/23 σ
- beam gas interactions: e_{Beam} + $H^2_{restgas}$ → e' + γ + $H^2_{restgas}$
  - detailed GEANT simulations including detector responses
  - current levels are tolerable



- ❑ All background sources have been identified.
- ❑ Tools are developed to track the impact of design changes on the backgrounds in the detector.