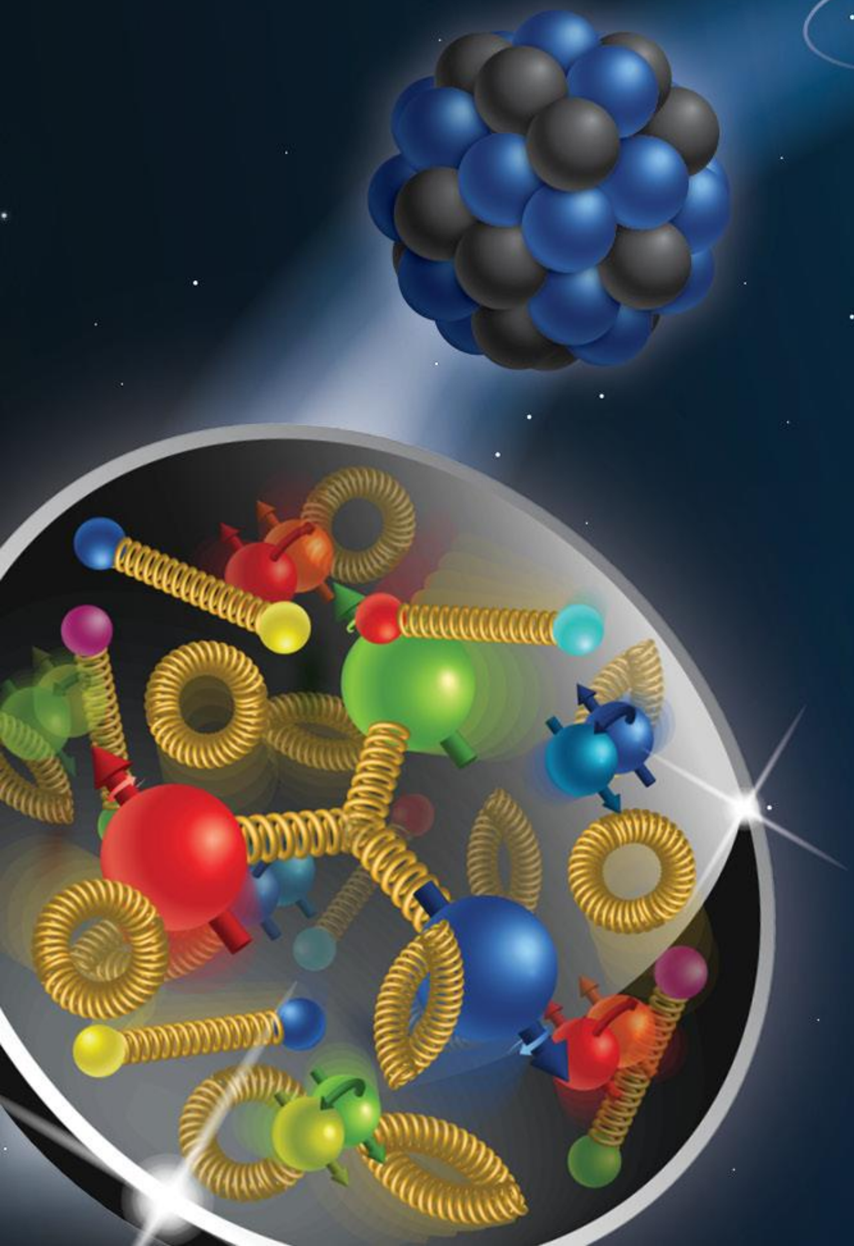


BNL EIC - IR

Holger Witte

January 27, 2020

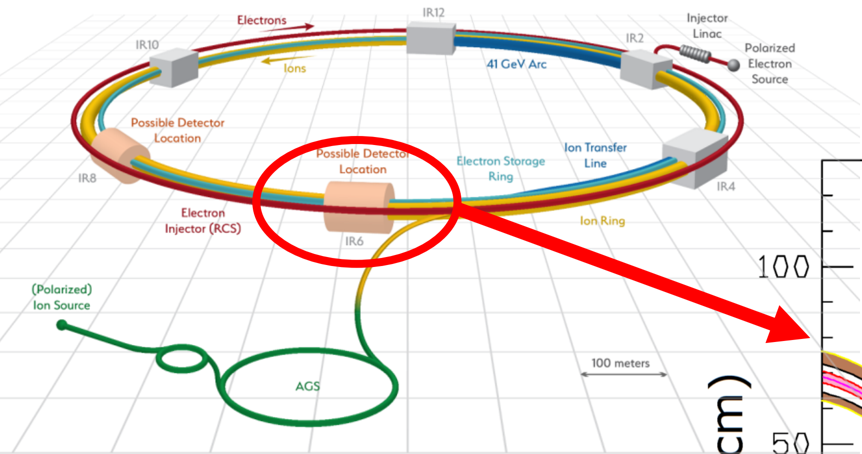
Electron Ion Collider – EIC at BNL

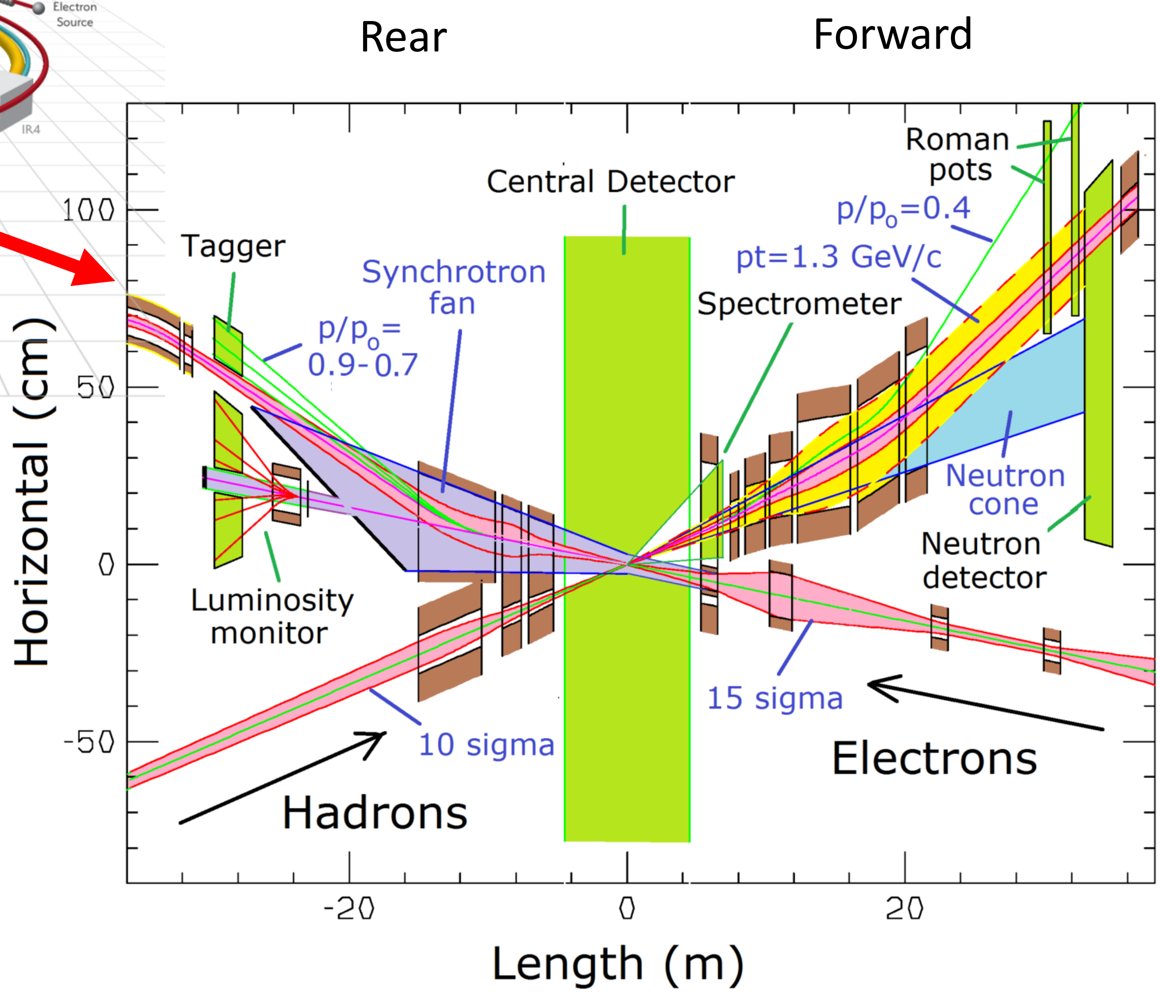
BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

- Overview IR
- Requirements / Considerations
  - Magnets
  - Geometric constraints
  - Optics
- Conclusion

EIC at BNL IR: Overview





RHIC yellow ring: EIC hadron ring

Add electron storage ring in existing tunnel

Possible IR location: IP6

IR Requirements

- BNL EIC IR designed to meet physics requirements
  - Machine element free region: +/- 4.5m main detector
  - ZDC: 60cm x 60cm x 2m @ ~30 m
  - Scattered proton/neutron detection
    - Protons 0.2 GeV < p_t < 1.3 GeV
    - Neutron cone +/- 4 mrad
- Machine requirements
  - Small β^*_y: quads close to IP, high gradients for hadron quads
  - Crossing angle: as small as possible to minimize crab voltage and beam dynamics issues
    - Choice: 25 mrad
  - Synchrotron radiation background
    - No bending upstream for leptons (up to ~50m from IP)
    - Rear lepton magnets: aperture dominated by sync fan

Considerations

- Geometry
  - RHIC tunnel (injection, RHIC magnets, RCS, eSR)
  - Experimental hall (IP6?)
  - Space for detector
- Physics considerations
  - See previous slide, other talks
- Accelerator/optics
  - Match into existing tunnel
  - Dispersion, chromaticity

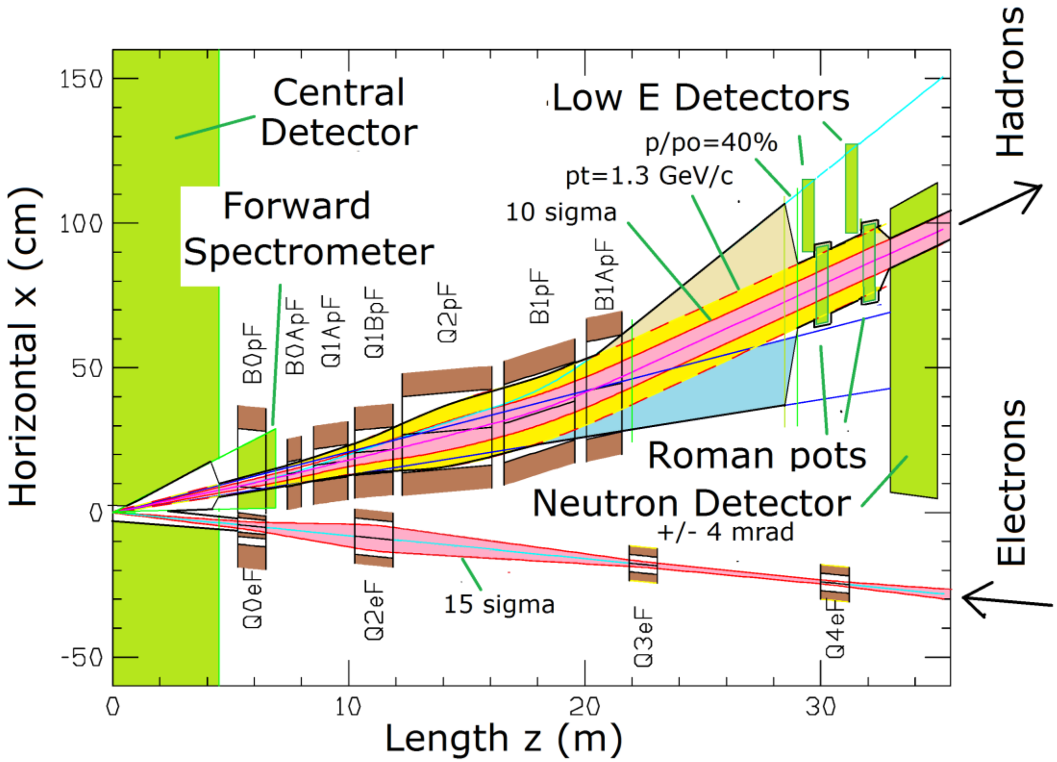
Considerations (cont.)

- Crab cavities
  - Location
  - Geometry
  - Phase advance
- Engineering
  - Magnets: feasibility
  - Cryostating
  - Utilities
- Project
  - Cost, risk
  - R&D required
  - Vendors

Considerations - Equipment

- Physics
  - Detector
  - ZDC
  - Roman pods
  - Lumi-monitor
  - E-tagger
- Bulky stuff
  - Crab cavities
  - Spin rotators
  - Snakes
  - eSR, RCS
- Has to fit in long./transv. Direction
- All of this is presently in IR section

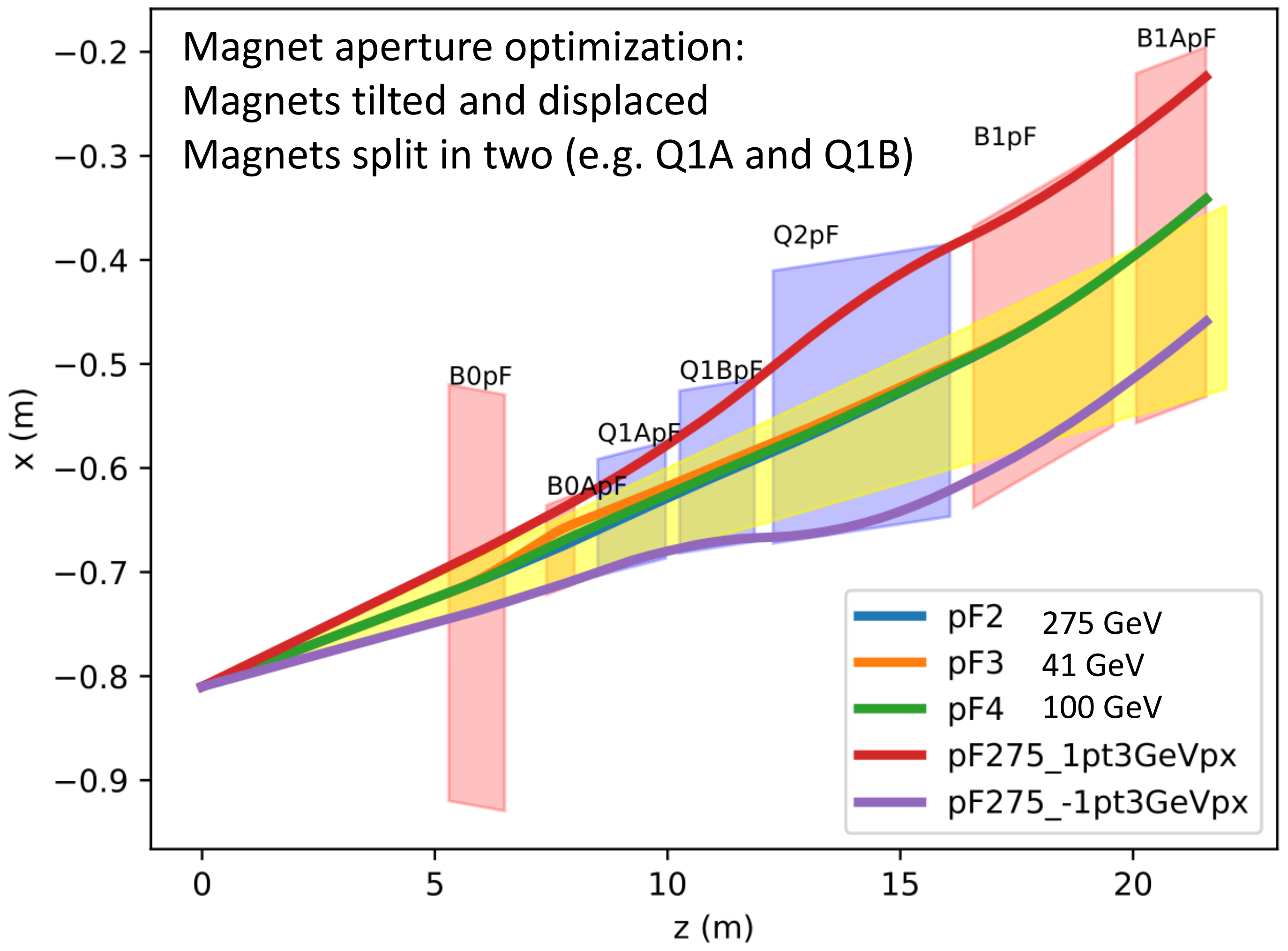
BNL EIC IR: Forward Direction



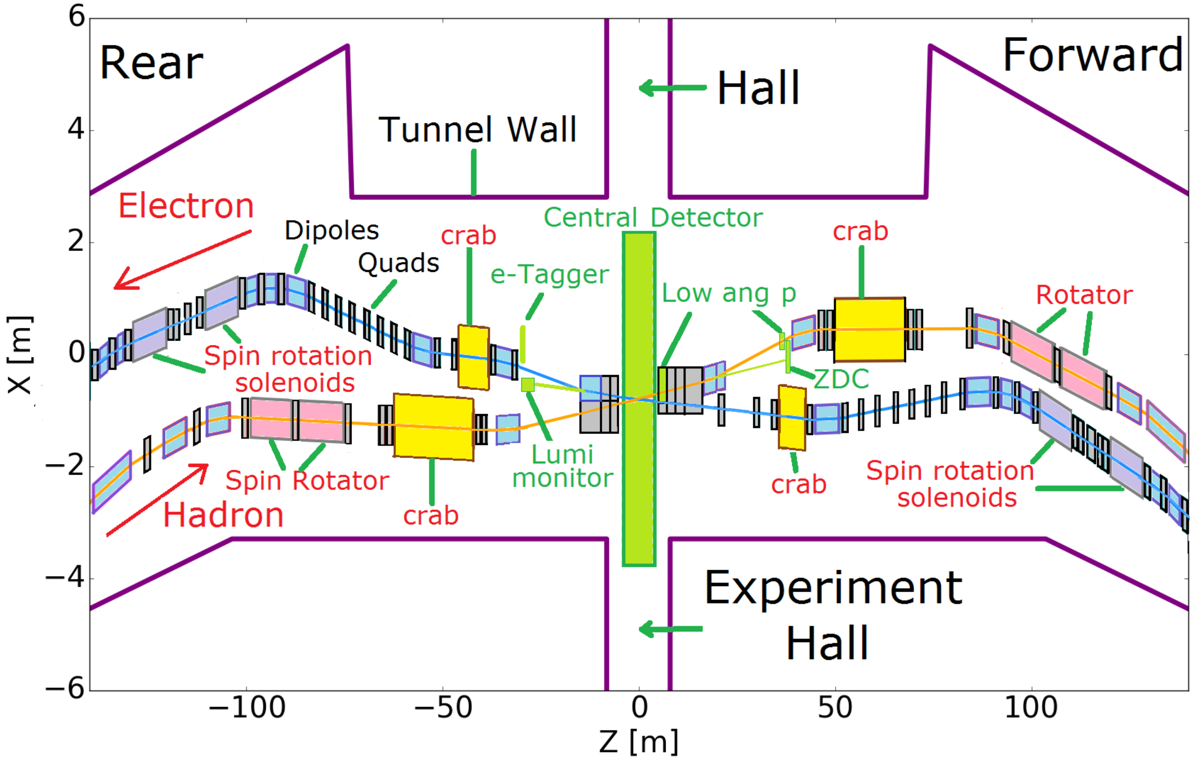
Name	R1	length	B	grad	B pole
	[m]	[m]	[T]	[T/m]	[T]
B0ApF	0.043	0.6	-3.3	0	-3.3
Q1ApF	0.056	1.46	0	-72.608	-4.066
Q1BpF	0.078	1.61	0	-66.18	-5.162
Q2pF	0.131	3.8	0	40.737	5.357
B1pF	0.135	3	-3.4	0	-3.4

- Requirements for hadron beam direction
  - B0pF: Forward Spectrometer (6 - 20 mrad)
  - Neutron Detector (+/-4 mrad)
  - Roman pots (sensitive 1 to 5 mrad)
- Mostly interleaved magnets
  - Exception: B0 and Q1BpF/Q2eF
- Large apertures of proton forward magnets
  - See next slide

Hadron Forward - Apertures



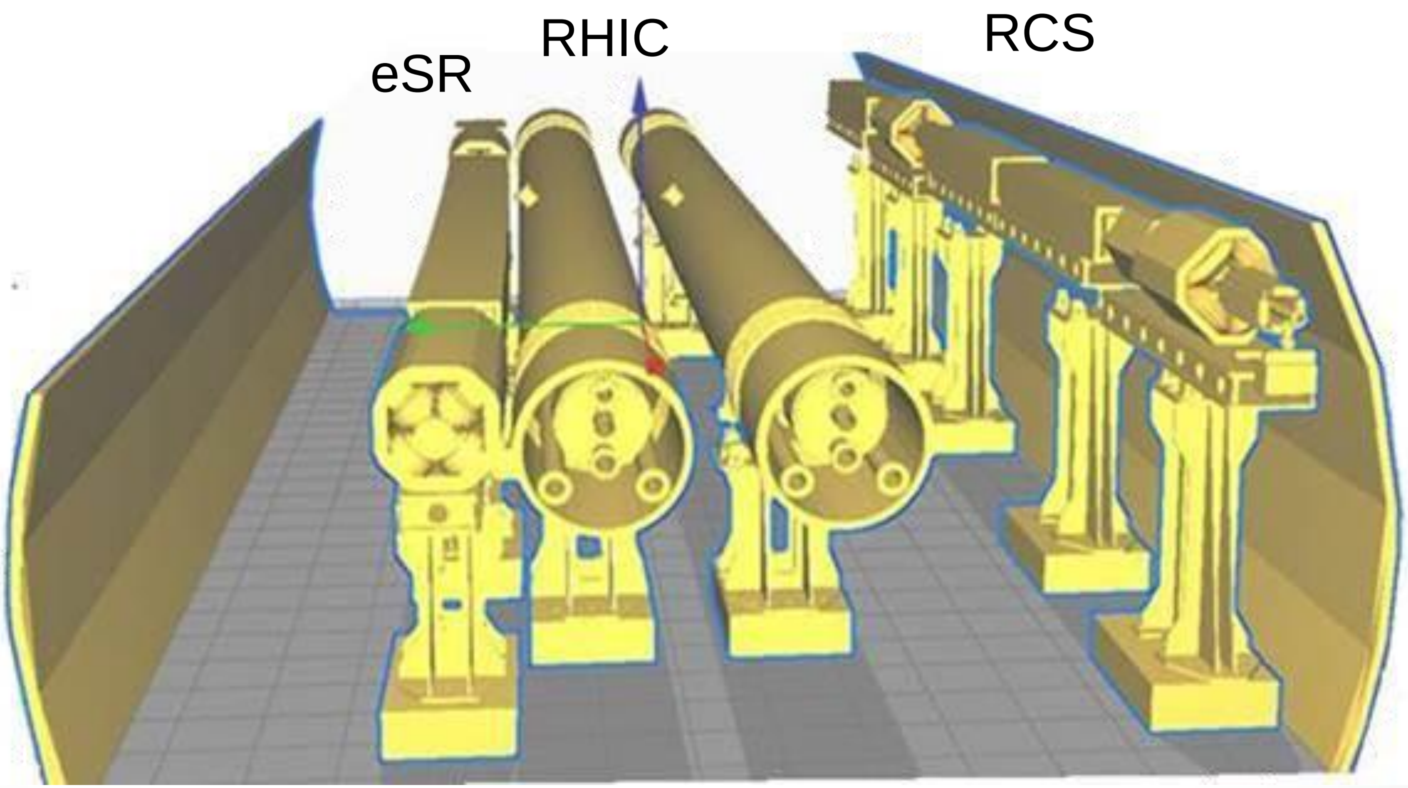
BNL EIC IR



- BNL EIC IR fits into RHIC tunnel
- Lattice: sufficient space for crab cavities and spin rotators

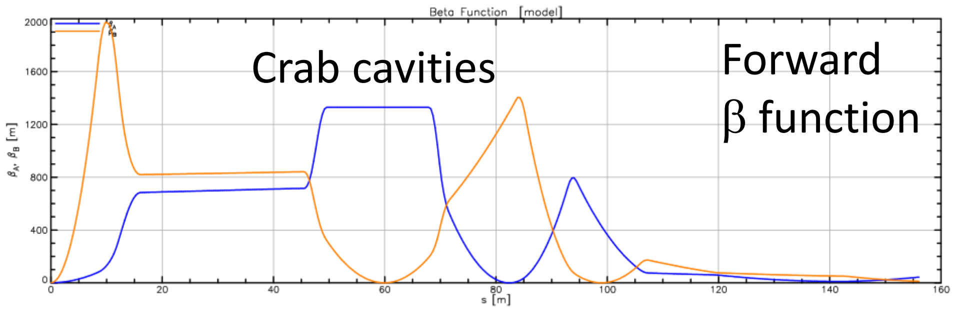
Tunnel Cross Section

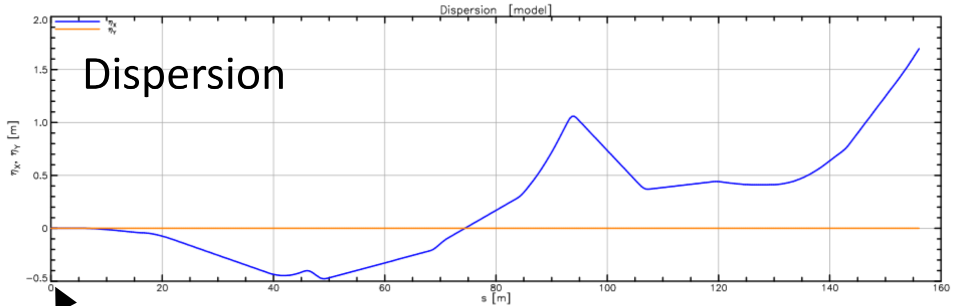
All accelerators fit into the existing tunnel

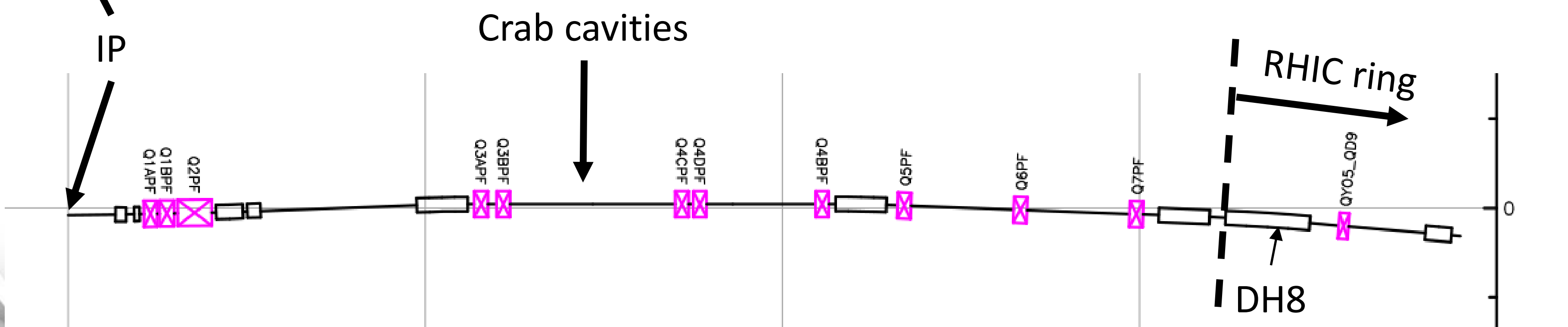


Existing
RHIC
tunnel

Match to RHIC Ring



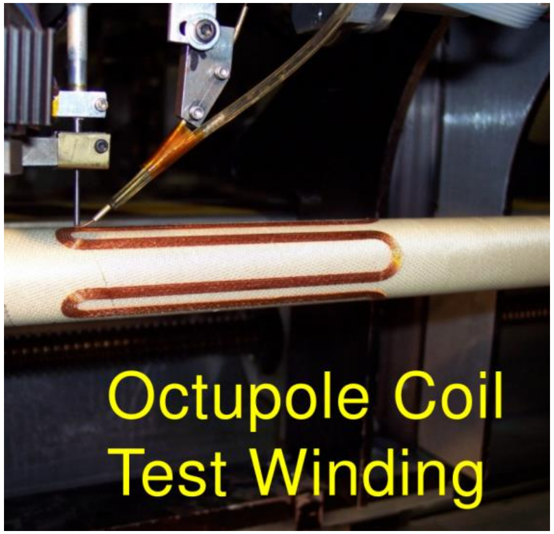




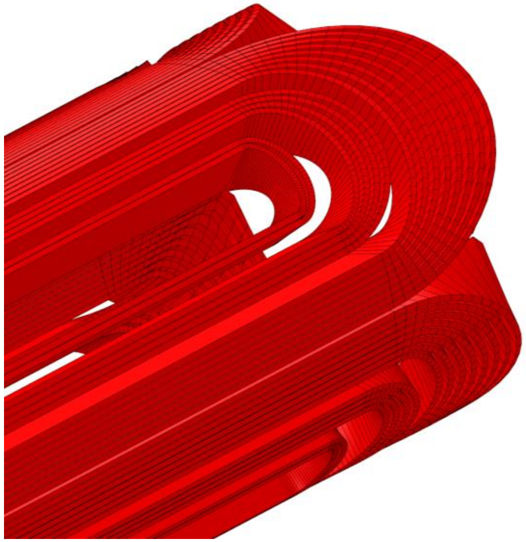
- Forward and rear hadron lattice matched into RHIC
- Requires
  - 6 dipoles
  - 17 quads
- Repurpose as many RHIC magnets as possible

IR Magnets - Overview

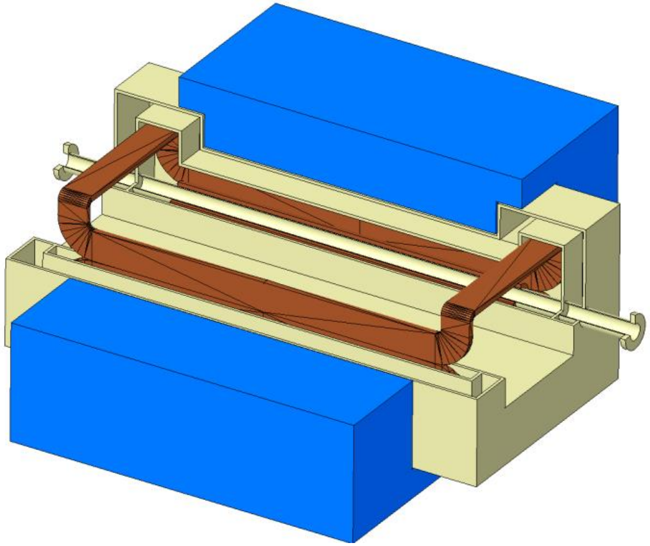
- Three groups of superconducting magnets
  - All NbTi
- (Also: normal conducting magnets, not addressed here)



9 Direct Wind Magnets (S-MD)



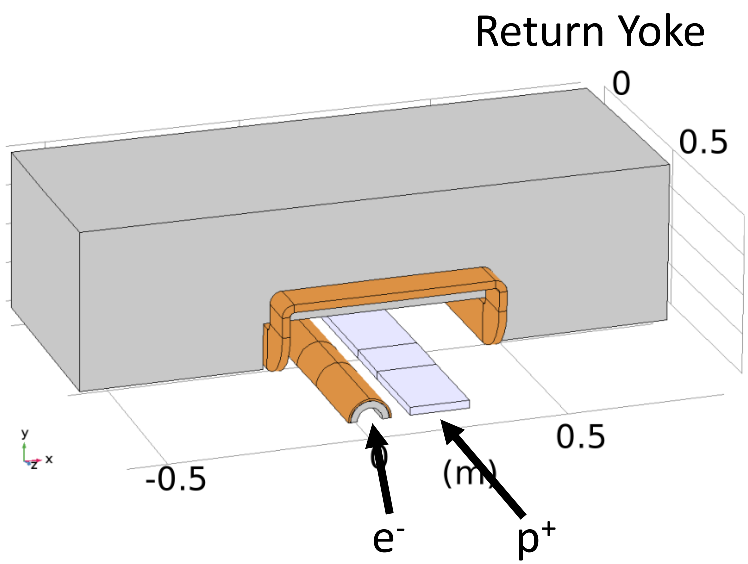
6 Collared Magnets

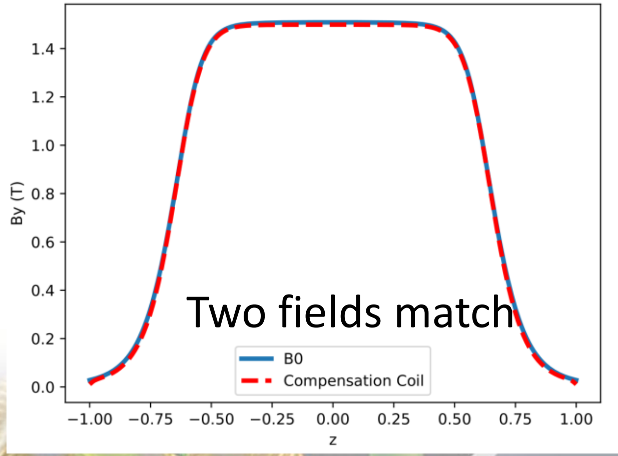


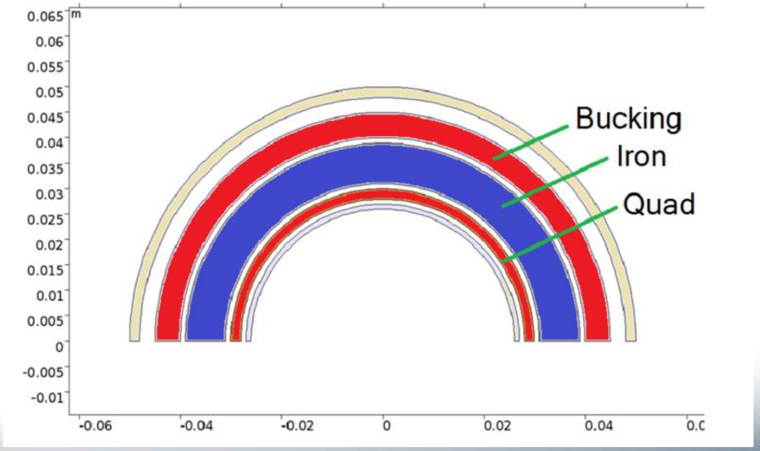
1 Special Magnet

B0pF Spectrometer Magnet

- Superferric 1.3T magnet
  - Fixed field
  - Option: normal conducting
- Aperture: $0.23 \times 0.5 m^2$
- Electrons: 15T/m gradient
  - In B0pF aperture
  - Requires cancellation dipole field
  - Bucking coil and iron collar

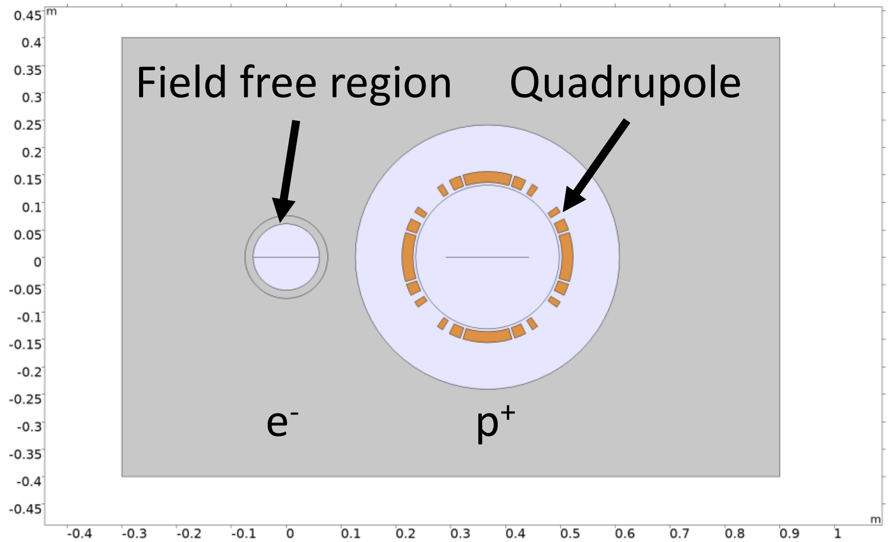


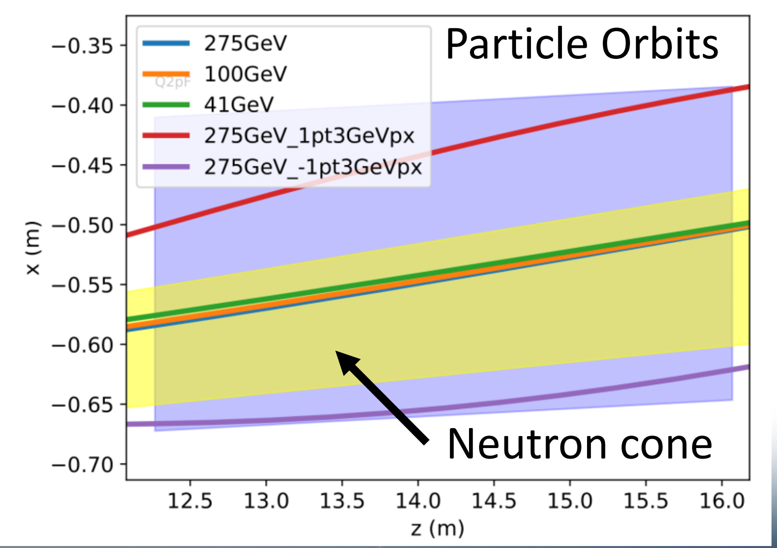




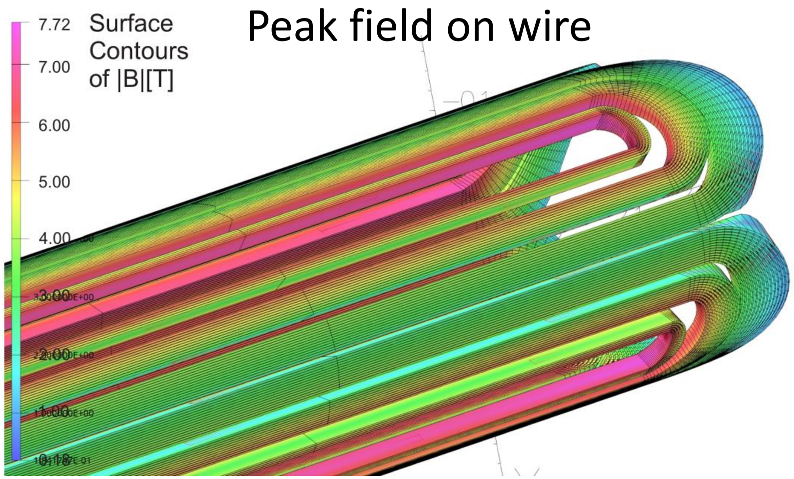
Q2pF – Collared Magnet

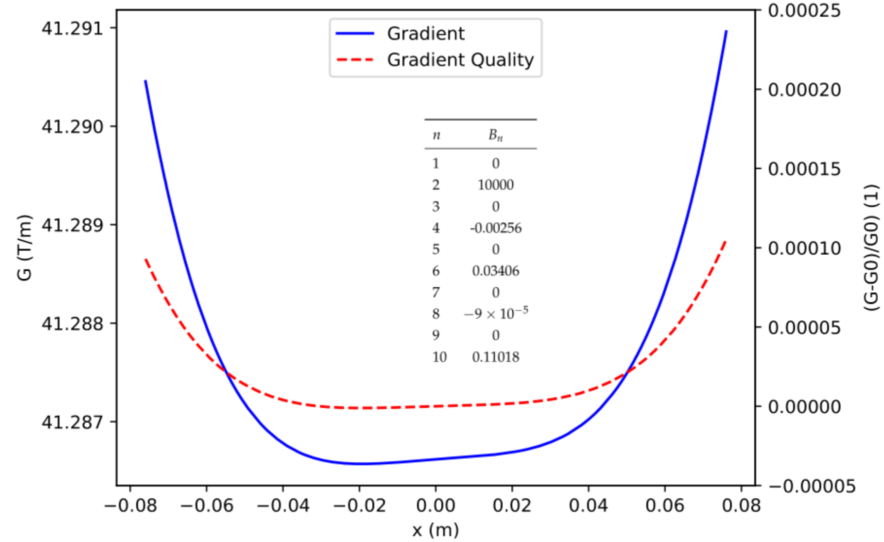
- Hadron quadrupole
  - Gradient: 41 T/m
  - 3.8m long
  - Aperture 262 mm
  - e-beam: 36-42cm distance
- Return yoke: 1.2x0.8 m^2
- Field-free region for electrons
- Magnet limitations
  - Gradient/field
  - Aperture
  - Stray field

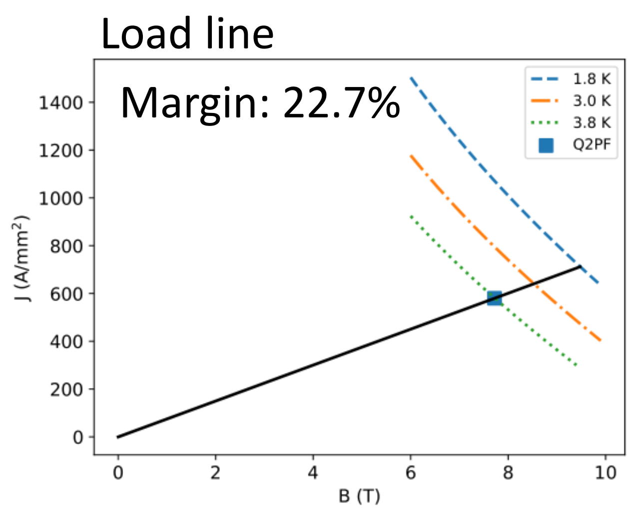


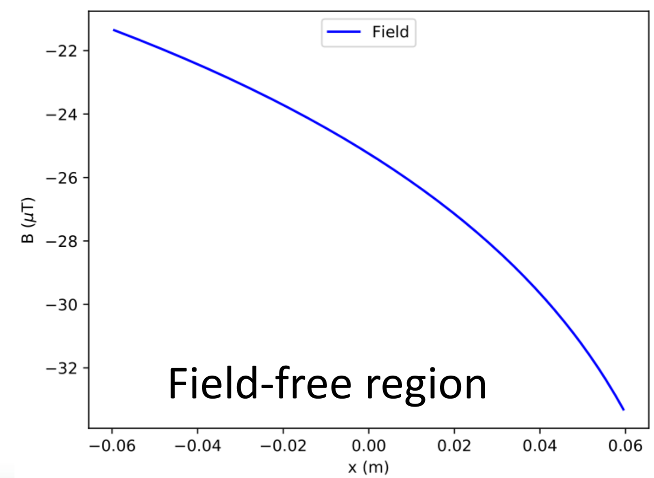


Q2pF Simulation Results



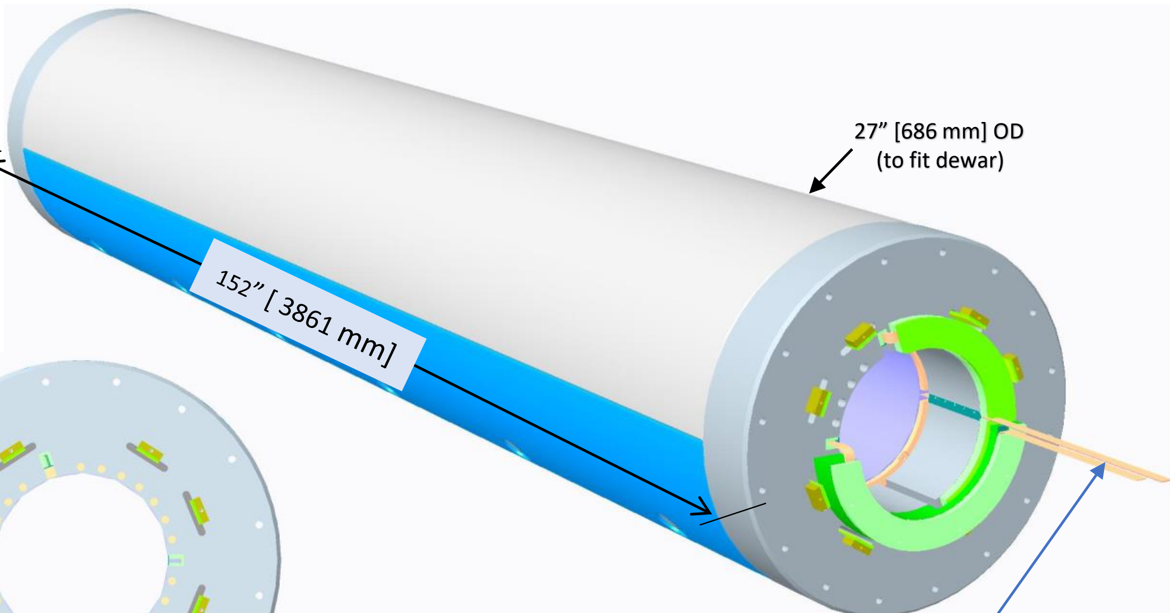


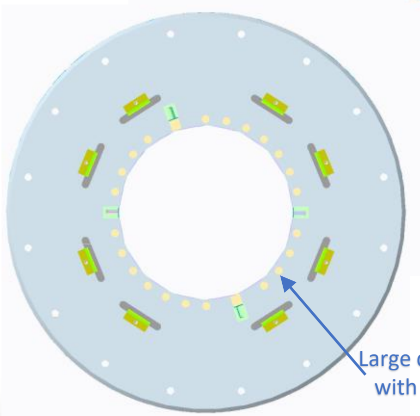


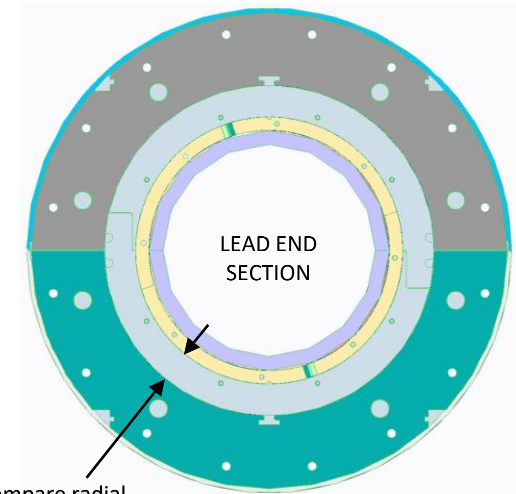


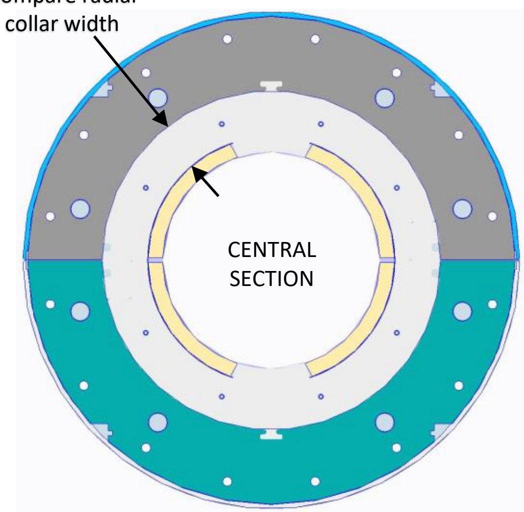
Cold Mass Concept

- Half shells welded to end plate
  - serves as helium containment vessel
  - Reacts longitudinal Lorentz forces
- Partial iron contained within shells (blocks? laminations?)
- Test vertically



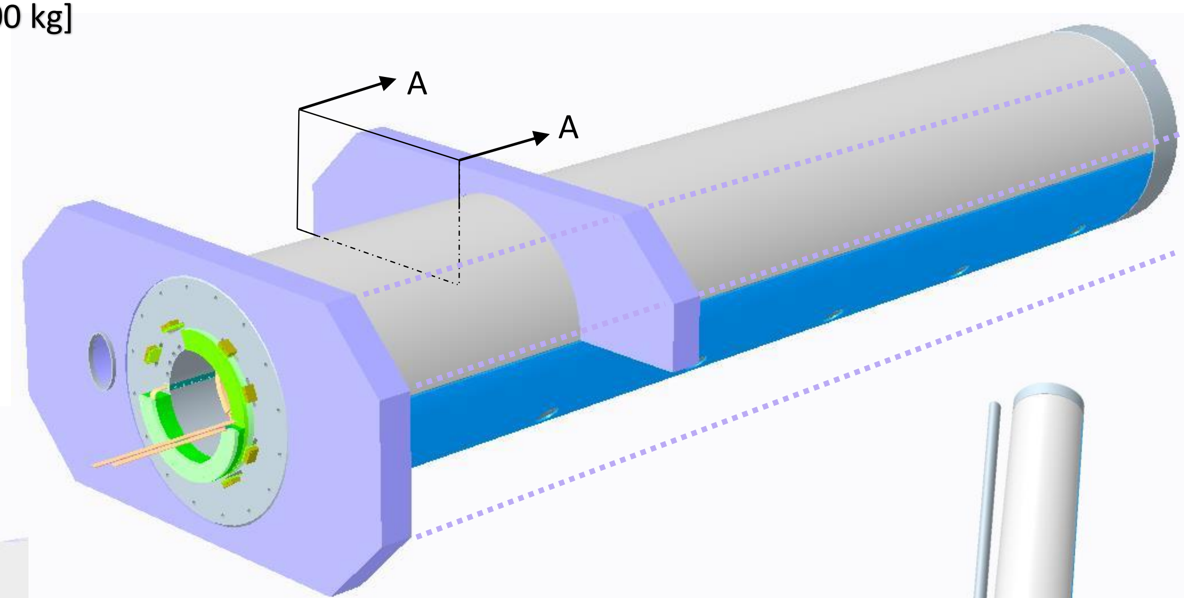


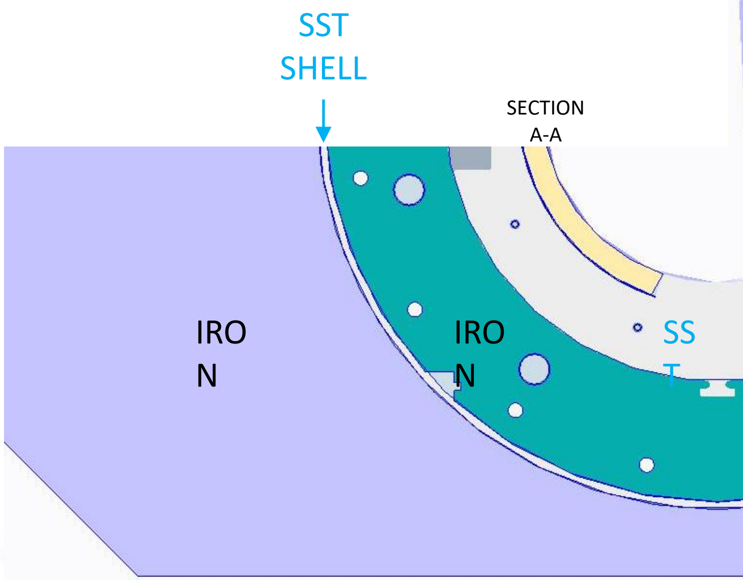


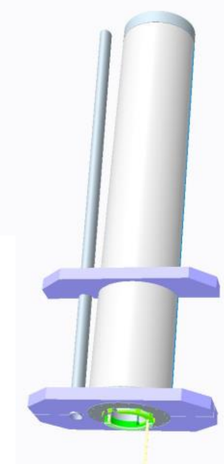


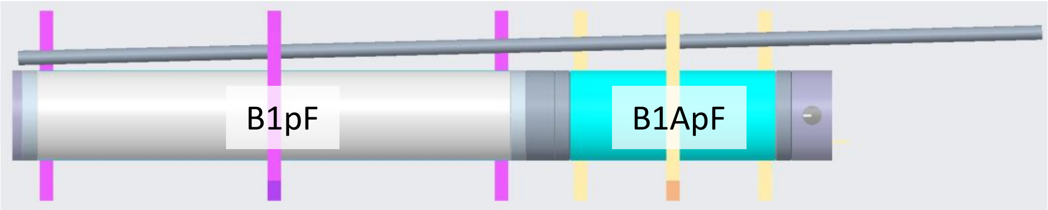
Cold Mass in Full Iron Yoke

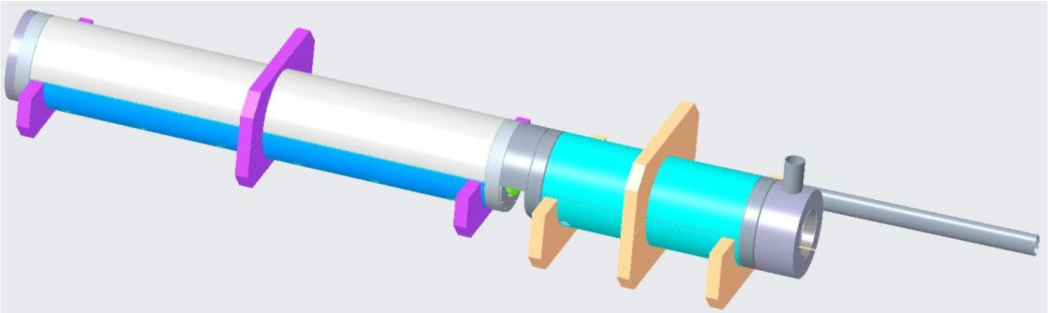
- Outer yoke - stacked blocks. Place cold mass in half yoke.
- Total magnet weight ~68,000 lbs [30,800 kg]
- Support of yoke?

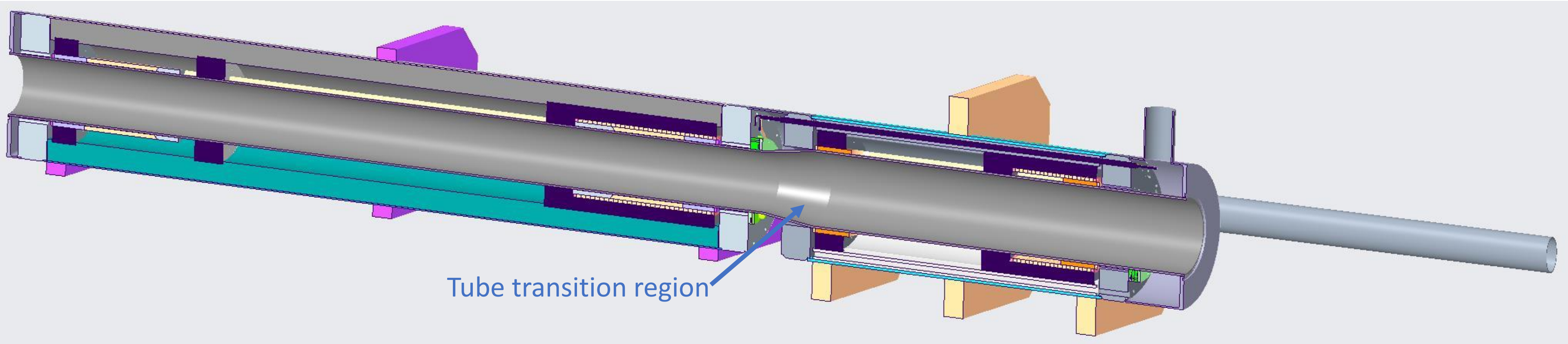







B1pF
B1ApF




Tube transition region

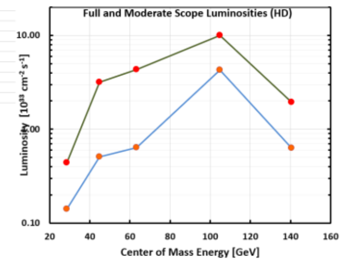
IR Development

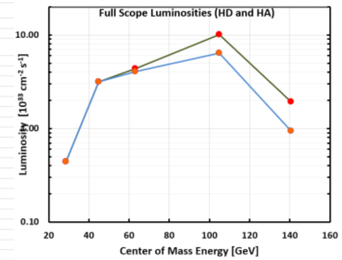
- Core group
  - Several experts matrixed (C-AD, NSLSII, SLAC)
- Meetings
  - Weekly IR meetings
  - Bi-weekly Synrad meetings
  - Future: Integration meetings
- How do we keep track?
  - Sharepoint: meetings, presentations, …
  - Lattice files with history
  - Concept specification documents
    - Being populated
- How do changes become the baseline?
  - Change control board (CCB)

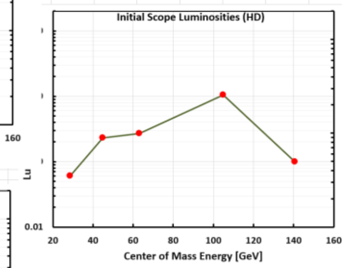
Baseline Parameters

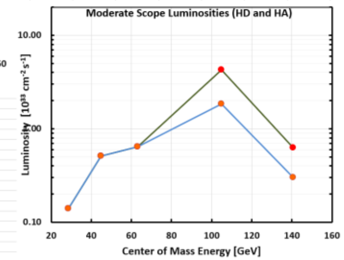
- Full set of parameters
- Initial vs full
- Hadron and electron beam

CME, GeV	Init-HA	Init-HD	Moder-HA	Moder-HD	Full-HA	Full-HD
28.6	0.06	0.06	0.14	0.14	0.44	0.44
44.8	0.23	0.23	0.51	0.51	3.16	3.16
63.2	0.27	0.27	0.64	0.64	4.07	4.35
104.9	0.59	1.05	1.85	4.28	6.40	10.05
140.7	0.06	0.10	0.30	0.63	0.94	1.93









PARAMETERS	Proton	Electron	Proton	Electron	Proton	Electron	Proton	Electron	Proton	Electron
energy, GeV	275	18	275	10	100	10	100	5	41	5
relativistic factor	293.1	35225.1	293.1	19569.5	106.6	19569.5	106.6	9784.8	43.7	9784.8
bunch_intensity,E10	20.444	7.294	6.881	17.203	6.881	17.203	4.658	17.203	2.639	13.294
number_of_bunches	290		1160		1160		1160		1160	
beam_current,A	0.74	0.265	1	2.5	1	2.5	0.68	2.5	0.38	1.932
rms_normaliz._emittance,h/v_um	4.6/0.74	845/71.2	2.8/0.45	391/23.9	4.0/0.22	391/25.4	2.7/0.27	196/20.0	1.9/0.45	196/34.2
rms_emittance,h/v_nm	15.8/2.5	24.0/2.0	9.6/1.5	20.0/1.2	37.1/2.1	20.0/1.3	25.1/2.6	20.0/2.0	43.6/10.3	20.0/3.5
emittance_y/emittance_x	0.159	0.084	0.158	0.061	0.056	0.065	0.102	0.102	0.236	0.175
beta,h/v_cm	90/4.0	59/5.0	90/4.0	43/5.0	90/4.0	167/6.4	90/4.0	113/5.0	90/7.1	196/21.0
IP_beam_size,h/v_um	119/10.1	119/10.1	93/7.8	93/7.8	183/9.1	183/9.1	150/10.1	150/10.1	198/27.1	198/27.1
K=sgm_y/sgm_x	0.084		0.084		0.05		0.067		0.137	
IP_rms_ang_spread,h/v_urad	133/251	201/201	103/195	215/156	203/227	109/143	167/253	133/202	220/380	101/129
beam-beam_parameter,h/v	0.004/0.002	0.100/0.100	0.014/0.007	0.073/0.100	0.010/0.009	0.075/0.057	0.015/0.010	0.100/0.066	0.015/0.009	0.053/0.042
long._bunch_area,evs	0.68		0.68		0.4		0.4		0.2	
rms_bunch_length,cm	6	0.9	6	2	7	2	7	2	7.5	2
rms_energy_spread,e-4	6.6	10.9	6.6	5.8	9	5.8	9	6.8	10.4	6.8
max_space_charge	0.006	neglig.	0.003	neglig.	0.028	neglig.	0.019	neglig.	0.05	neglig.
Piwinski_angle,rad	5.5	0.8	7.1	2.4	4.2	1.2	5.1	1.5	4.2	1.1
Longit._IBS_time,h	2.1		3.41		2		2.6		3.8	
Transv._IBS_time,h	2		2		2.32/2.36		2/4.8		3.4/2.1	
lumi_factor	0.86		0.86		0.85		0.83		0.93	
luminosity,E33	**1.93**		**10.05**		**4.35**		**3.16**		**0.44**	
main RF frequency, MHz	591	591	591	591	591	591	591	591	197	591
main RF Voltage, MV	18	68	18	20	8.5	20	8.5	13	9	13
harmonic RF frequency, MZ				1773		1773		1773		1773
harmonic RF voltage, MV				6.6		6.6		4.3		4.3
SR loss power, MW		10.00		9.00		9.00		3.20		2.47
synchronous voltage, MV		37.8		3.6		3.6		1.28		1.28
transverse radiation damping time, ms		9.2		59.4		59.4		70.1		70.1
ST (de-)polarization time, h		0.53		9.92		9.92		11.7		11.7

https://brookhavenlab.sharepoint.com/:x:/s/eRHIC/bnl&slac/ESBW8F9WAsdMqNAod1r127YB4wY1r1Xz-T0me06QpZMjPw?e=VHIW1V

Summary

- IR developed in collaboration with BNL Physics
  - Meets requirements of ‘white paper’
  - Is there anything we have been missing?
- Many considerations went into this IR
  - Geometric constraints
  - Engineering feasibility
  - Magnets, cryostating
- Changes are possible
  - Need to go through CCB
    - What problem needs fixing?
    - Requires all L2/L3s to sign off

Acknowledgements

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