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Brookhaven National Laboratory

First IR Design

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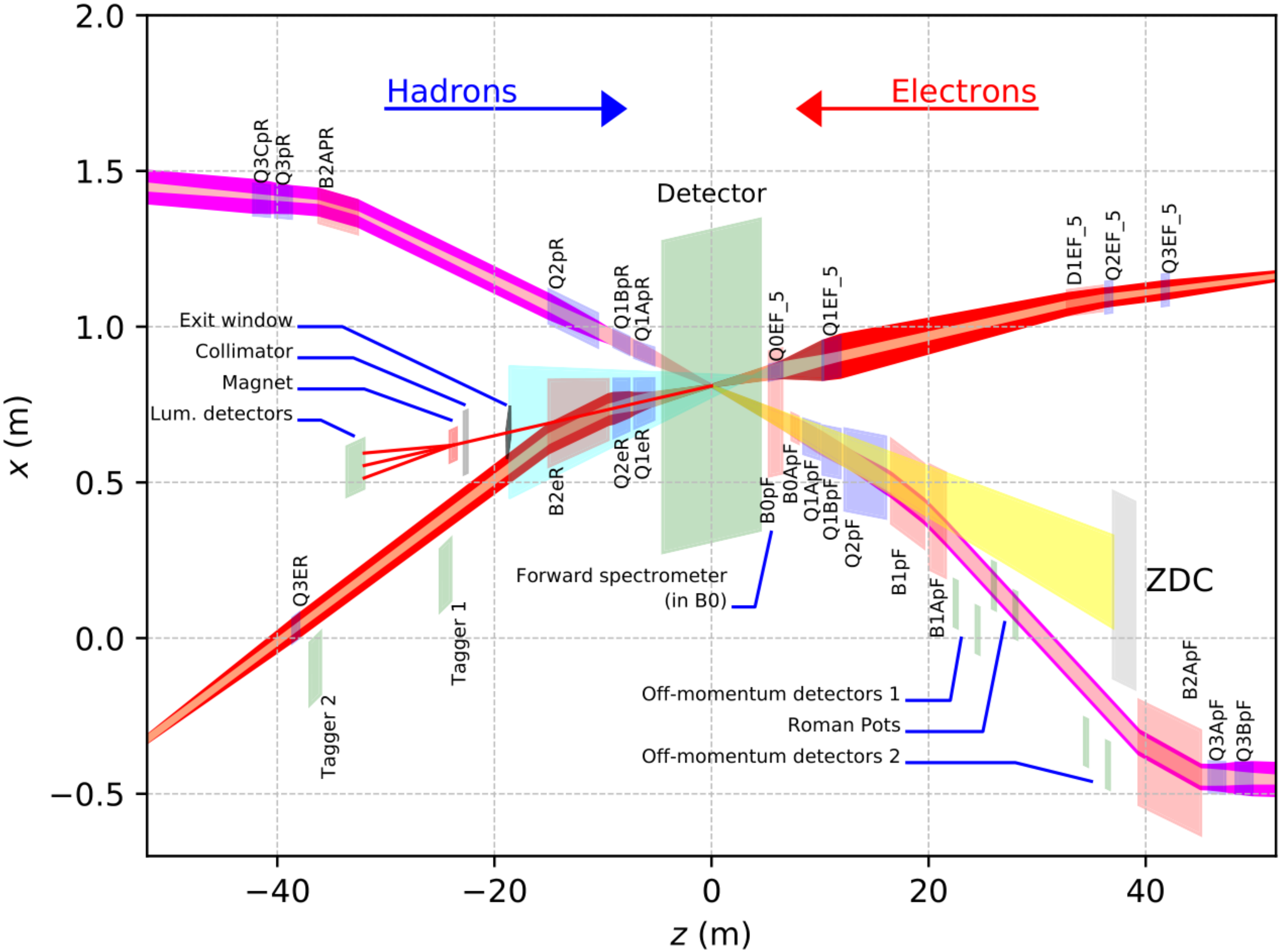
Colliding IR Overview

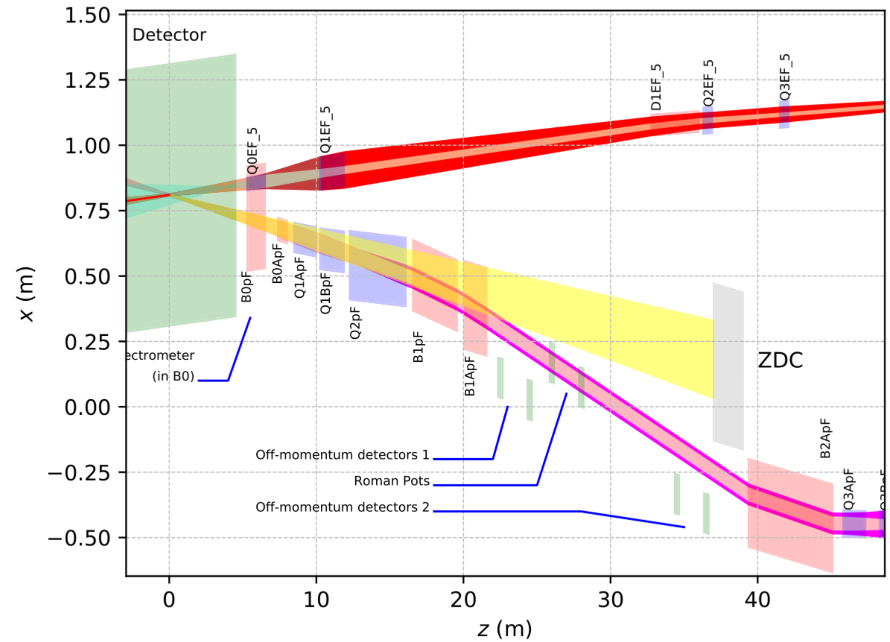
- Flat beams for maximizing luminosity
- *p*/*e* energies ranging from 41/5 to 275/18 GeV
- Crossing angle, rf cavities create “crab crossing”
  - Electron and hadron magnets share yoke
  - Avoid crosstalk
- Require −4.5/+5.0 m free region for detector

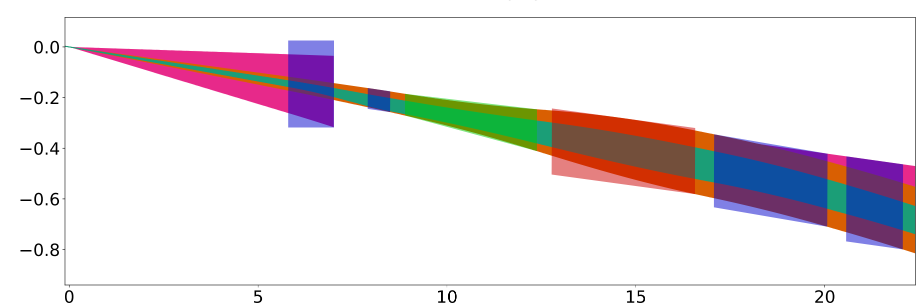
Colliding IR Overview



Forward Side

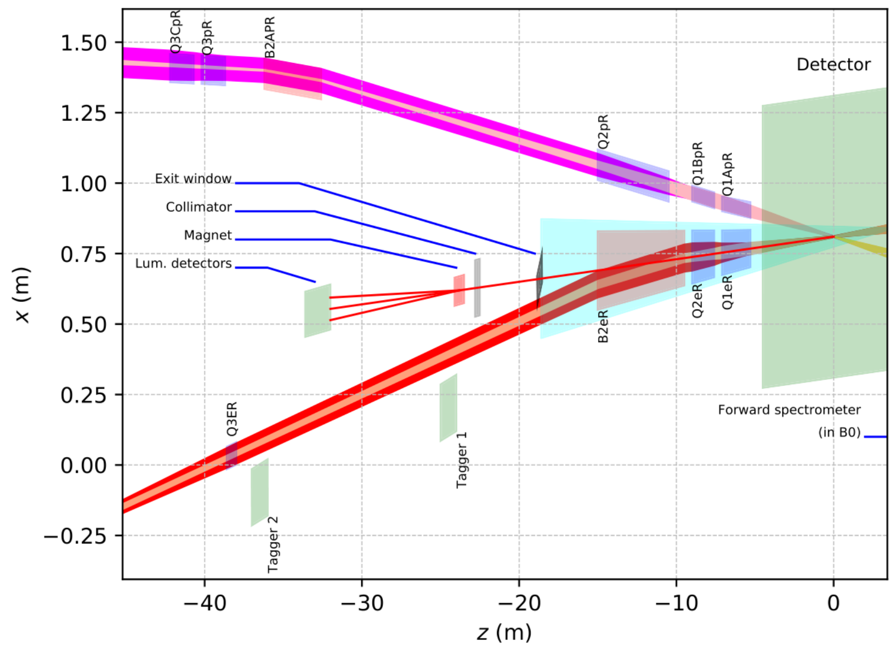
- Far-forward detectors require collision products to pass through hadron magnet apertures
- Neutral particles $\lesssim 4$ mrad
- 275 GeV protons, $p_T \lesssim 1.3$ GeV$/c$
- First hadron magnet: spectrometer dipole, embedded detector
- Don't bend electrons





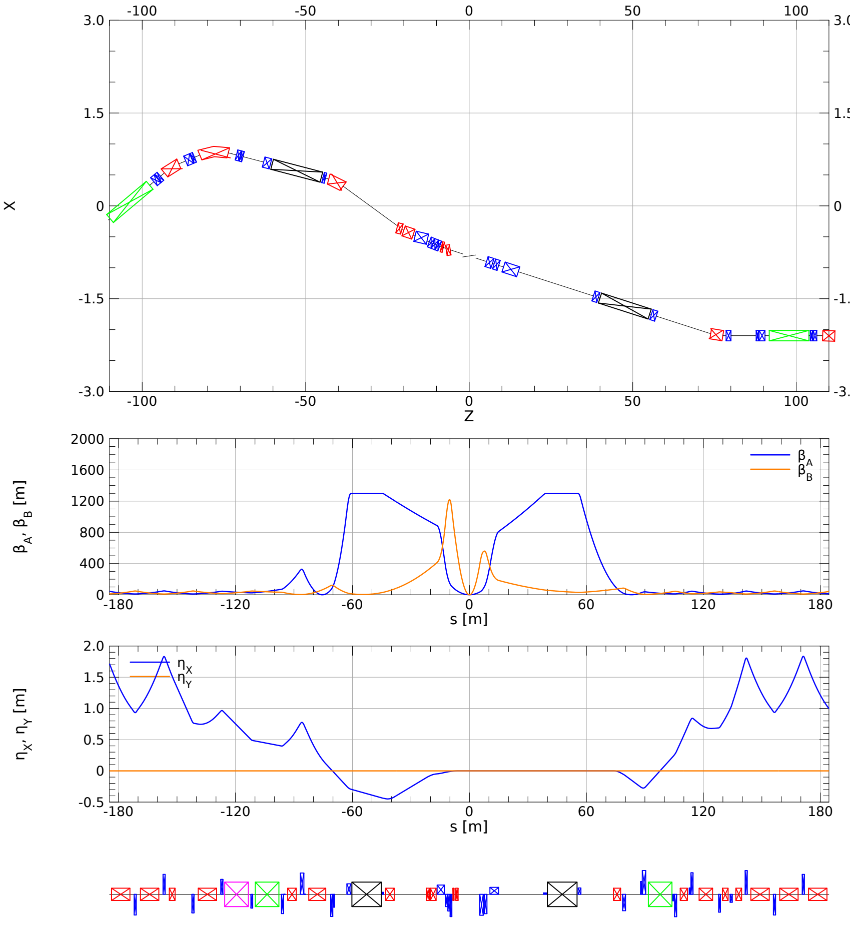
Rear Side

- Dipole for downstream electrons
  - Separate beam for luminosity monitor
  - Electron spectrometer
- Electron magnet apertures determined by synchrotron radiation

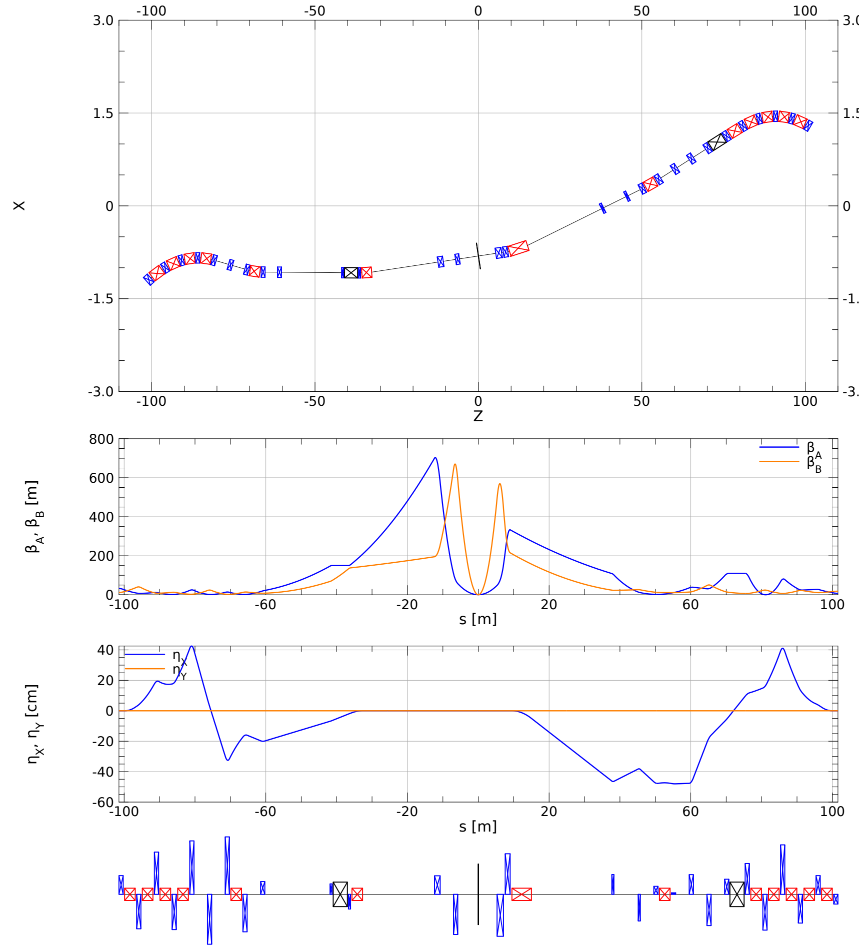


Lattices

HSR



ESR



Design Outline

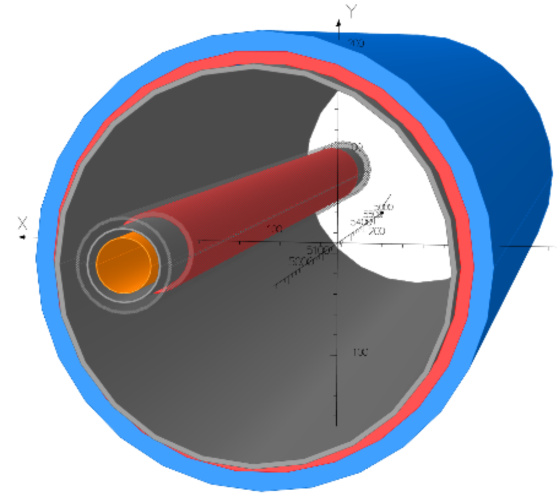
- Near IR focusing
  - Doublet, vertical focus first (small vertical beta)
  - Require large beta functions at crab cavities, so horizontal beta stays high
- 30-40 m reserved on each side for detector hardware
- Dipoles near detector for detector hardware create significant dispersion amplitude
  - Hadron forward dipoles separate beam from neutrals
  - Electron rear dipole separate electrons from photons for luminosity monitoring

Geometry

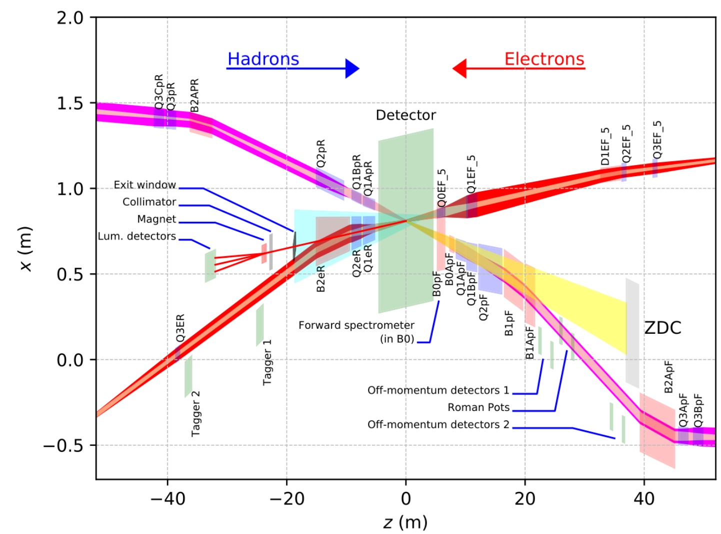
- IP is 81 cm inside of RHIC IP
- Beamlines tilted with respect to RHIC axis for crossing angle
- Need to get back to arcs
- Dipoles sign chosen so lines diverge
  - 25 mrad crossing
  - Crab cavity sizes
- HSR matching is very space constrained
  - Need spin rotators (both sides), snake (one side)
  - Snake must be at a specific angle
  - Use RHIC magnets almost exclusively
  - RHIC cryostats are long

Magnet Considerations

- First hadron dipole
  - Contains detector
  - Surrounds electron quadrupole
  - Quadrupole component to zero field at electron line. Maybe dipole winding on electron quadrupole.
  - Field independent of energy
    - Other dipoles correct orbit

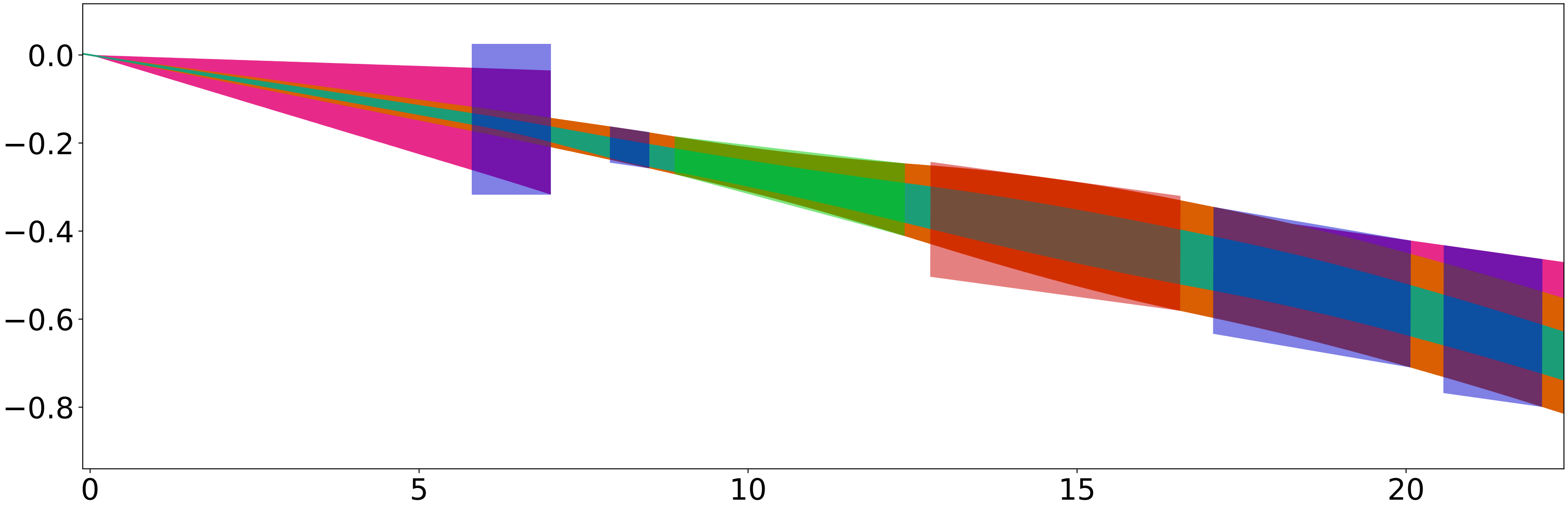


- Electron and hadron magnets placed to share yokes
- Magnet field/aperture/ crosstalk considerations limit what we can do; everything near its limit



Magnet Considerations

- Align hadron magnets
  - Pass neutrals and $p_T = 1.3\ \mathrm{GeV}/c$
  - Maximize distance to electron line
- Taper quadrupole to optimize gradient/aperture



Phase Advance to Crabs

- Multiple of π horiontal phase advance between crab cavities to keep crabbing in the IP region
  - Ideally odd multiple of $\pi/2$ from crab to IP
- Hadron crabs, $\beta_x = 1300$ m
- Electron crabs, β_x 100–150 m
- Hadrons fall 5° short of this: large beta functions
  - Not fixable without much stronger IR magnets
- Electrons, phase advance is too high for a crab near the IP
  - Place cavity further away on rear side, $\approx 3\pi/2$ phase advance
  - Phase advance perfectly 2π between crabs

Solenoid Compensation

- Add skew quadrupoles to compensate solenoid
- Between crab cavities, close the crab bump
  - Need skew windings for near-IR magnets
    - A feasibility study showed these could be incorporated
- Outside crab cavities, finish removing coupling with skew quadrupoles

Status

- Lattice is stable, but could use improvements
  - Put in better/updated models of IR magnets
  - Rotators should be more parallel (polarization), but geometry prevents doing much
  - Look at configurations other than high-divergence p (high-acceptance, ions, ramping…)
- Look into tapering other forward magnets (see H. Witte's earlier talk)
- Look at improving x_L coverage (stronger/longer IR quads, added and stronger quads near crab)

Acknowledgements

- Basic near-IR design was the work of Holger Witte and Bob Palmer
- Solenoid compensation: Vasiliy Morosov, Derong Xu, others
- Magnets: Holger Witte, Brett Parker, others in BNL Superconducting Magnet Divsion)
- Others I'm not listing…