Boundary conditions on the EIC detector design

Alexander Kiselev *(with a lot of recent input from Walt Akers)*

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Topics

- Space limitations
- Experimental hall(s)

- Material budget considerations
- IR vacuum chamber

- Central detector solenoid

- Detector maintenance

Space limitations

- Machine
  - L* should be small (luminosity)
  - Crossing angle is a must (luminosity)
  - Beam pipe diameter at the IP is substantial (synchrotron fan)

  - Beam pipe ~20 mrad opening angle in the hadron-going direction is required
- Experimental hall constraints (EIC is **not** a green field installation)

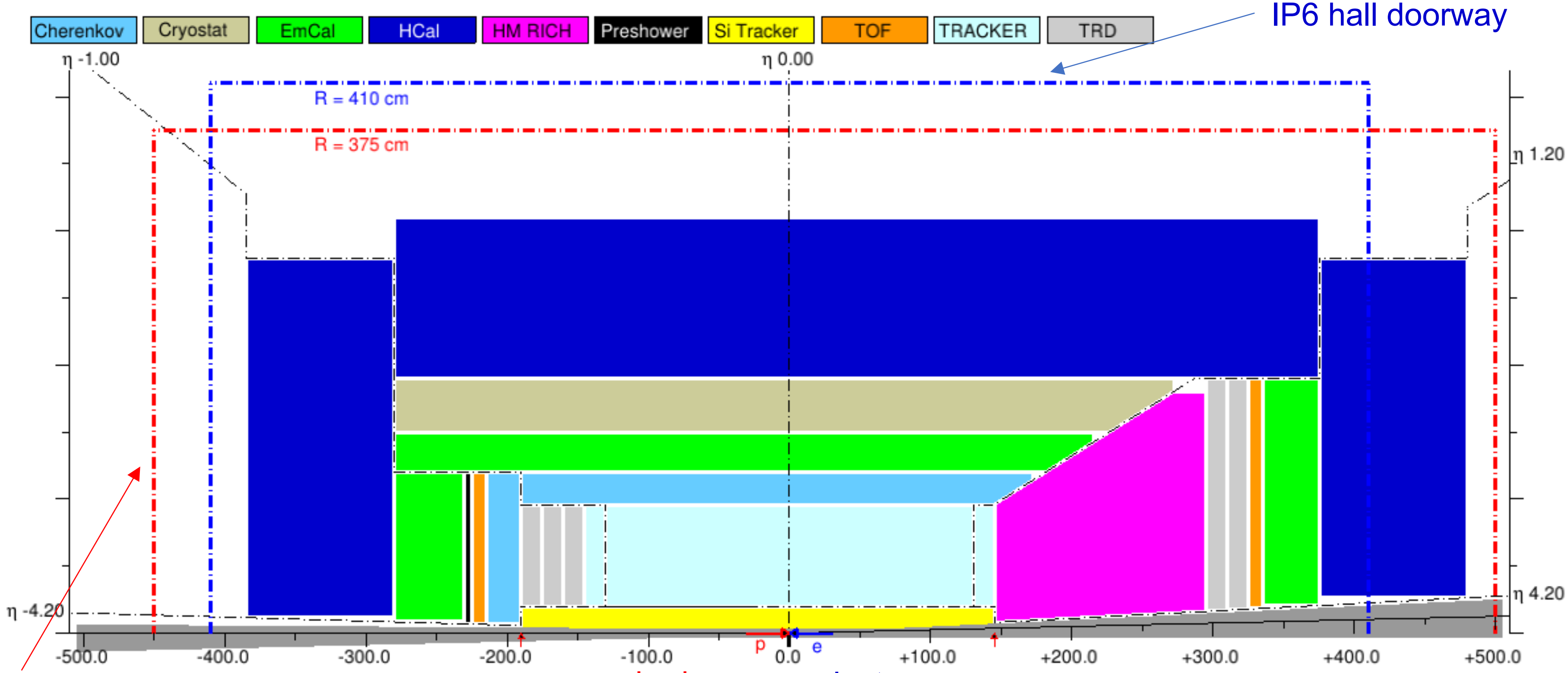
- Subsystem length vs performance
  - Hadronic calorimetry: how long is long enough?

η	~[-4 .. -1]	~[-1 .. 1]	~[1 .. 4]
ZEUS HCal (DU part)	~4 λ_I	~5 λ_I	~7 λ_I
EIC HCal	~5 λ_I	~5 λ_I	~6-7 λ_I

  - RICH: 100cm? 140cm (presently allocated)? 160cm (most of the studies to date)?
  - Forward / backward silicon tracker: well, the more the better

EIC reference detector in RHIC IP6

"Realistic" detector space allocations (but no support structures, etc.)



hadrons electrons

[-450 .. +500] cm along the beam line reserved for the main detector

IP6 hall center

Beam pipe footprint is to scale in this picture, but are we really getting down to +/- 4 in η ?

|η| = 3.00	|η| = 3.50	|η| = 4.00	|η| ~ 4.38	|η| = 4.50
~99.5 mrad	~60.4 mrad	~36.6 mrad	25.0 mrad	~22.2 mrad

$-4 < \eta < 4$ acceptance?

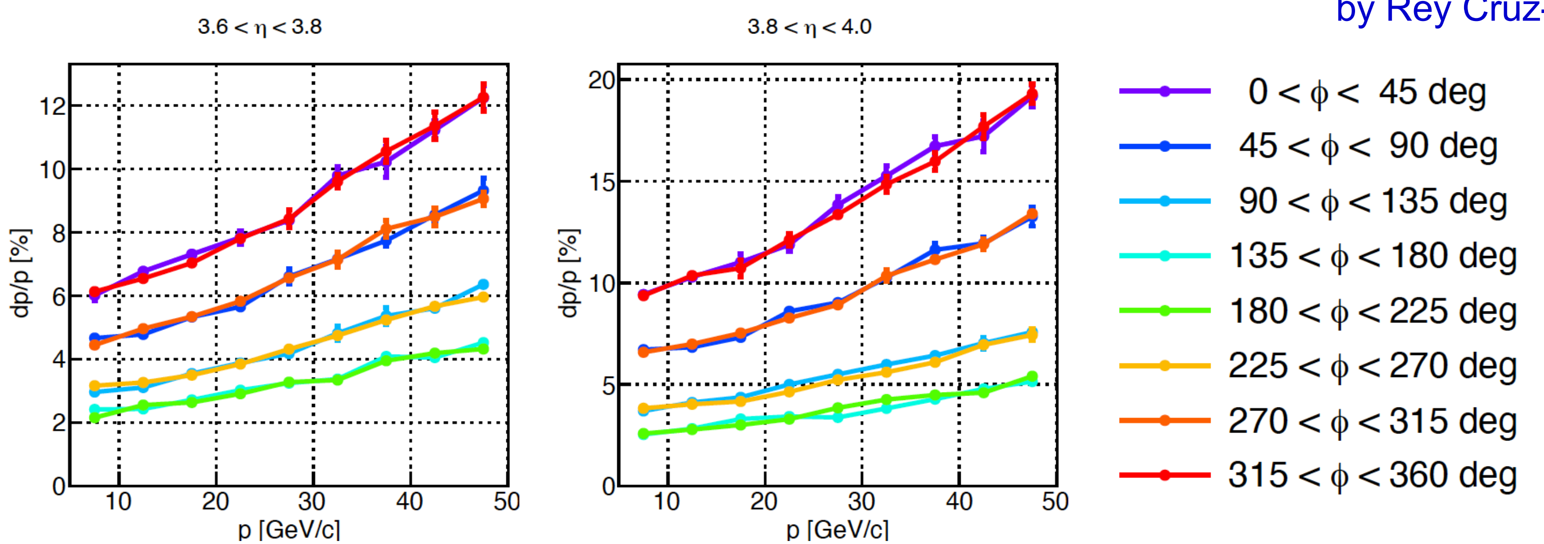
- Fiducial volume cuts
  - e/m calorimetry: typically one tower away from the edge for "nominal performance"
  - Hadronic calorimetry: one interaction length away from the edge (just *veto* otherwise?)
  - Trackers: outer frames (centimeters, small?; well, 1 cm at 2 meters is a loss of 5 mrad)
  - High-momentum RICH: gas vessel, photon detection inefficiency at high η

- Azimuthal asymmetry in acceptance and performance
  - Electron-going endcap: crossing angle and synchrotron fan in horizontal plane
  - Hadron-going endcap: strong asymmetry in B*dl integral

Forward silicon tracker momentum resolution study

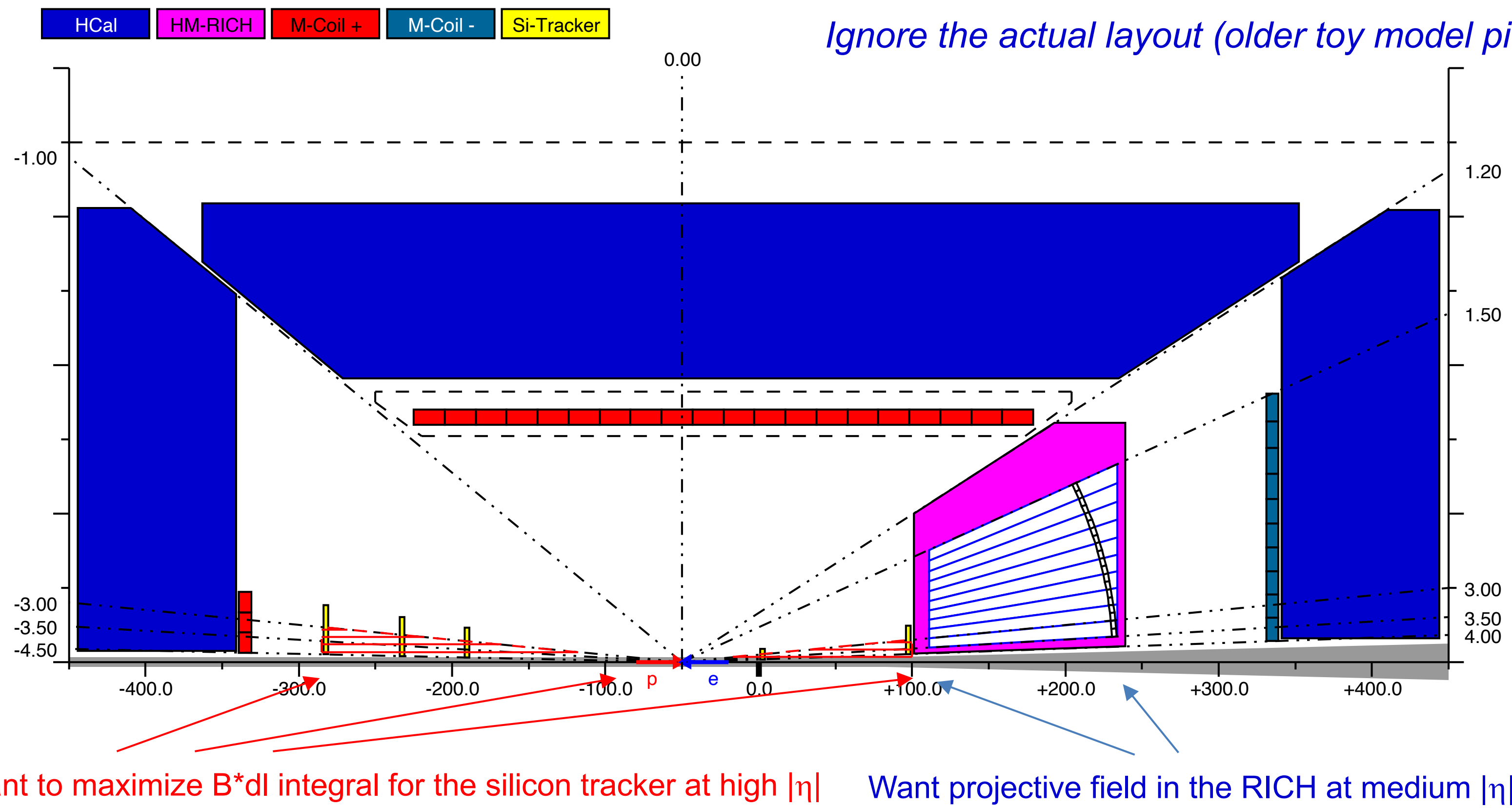
by Rey Cruz-Torres

Assume 5 ITS2-like stations, 3T field and 1m lever arm



Solenoid magnet considerations

Ignore the actual layout (older toy model picture)



- These two requirements are somewhat in a contradiction in the hadron-going endcap, especially if the additional high-resolution tracking stations behind the RICH are desirable

- Bore diameter can hardly exceed ~4m (otherwise the barrel detector won't fit through the IP6 exp. hall door); currently considered: up to 3.4 m green field design, ~2.8 m BaBar magnet
- Solenoid flux return scheme strongly depends on the HCal absorber choice (magnetic or not)

Solenoid magnet considerations

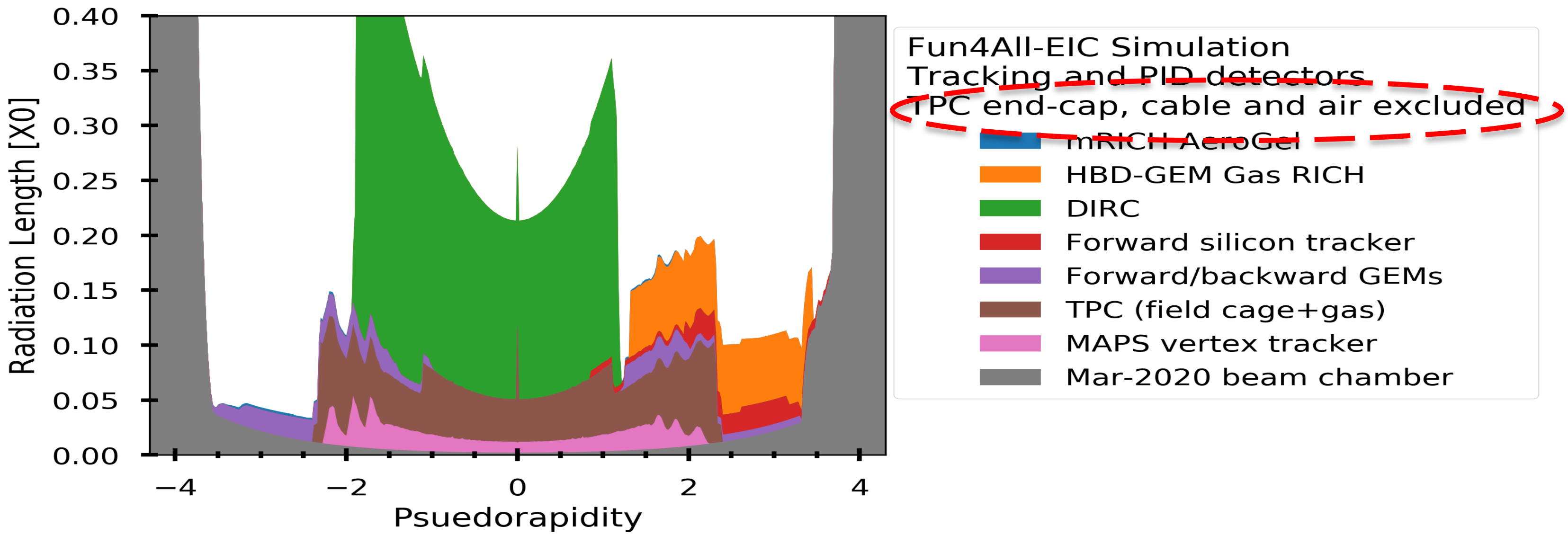
- 1.4T (BaBar), 2.0T, 3.0T?
  - High $|\eta|$ tracking
  - Low P_T (curling) tracks at central rapidities
  - Photo-sensors in high magnetic field; field orientation

- Comparison to HERA collider experiments:

	Central field	Bore diameter	Barrel EmCal	Barrel HCal
H1	1.15 T	~518 cm	inside	inside
ZEUS	1.43 T	~172 cm	outside	outside
EIC	up to 3.0 T	up to 340 cm	inside	outside

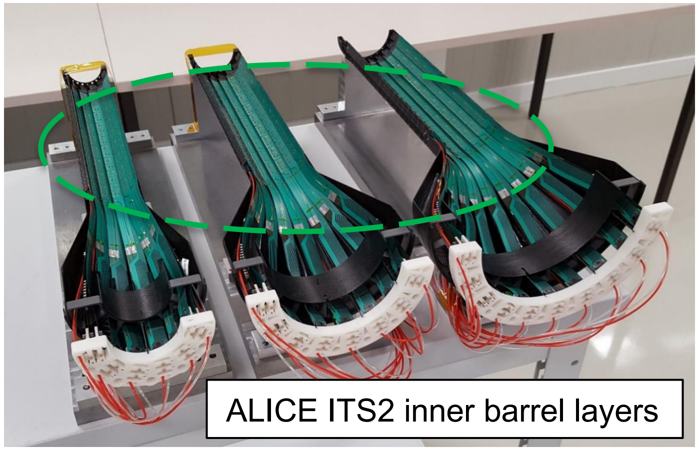
Material budget

- Low material budget is a must for EIC
  - Minimize bremsstrahlung and conversions for primary particles
  - Improve tracking performance at large |η| by minimizing multiple Coulomb scattering
  - Minimize the dead material in front of the high resolution e/m calorimeters

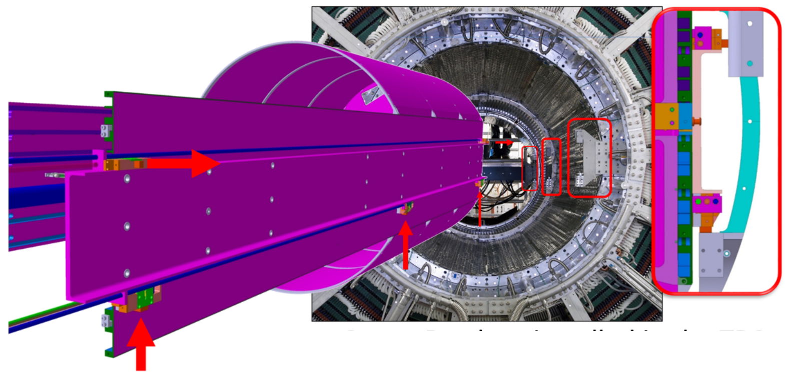


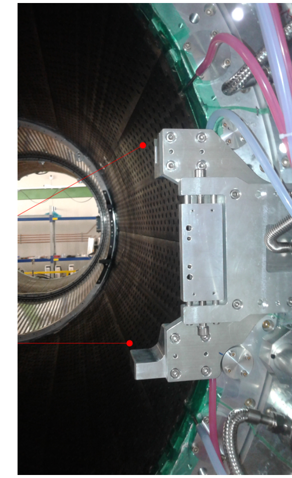
So: ~5% of tracker material in the whole angular range up to |η| ~ 3.5? NO

Material budget

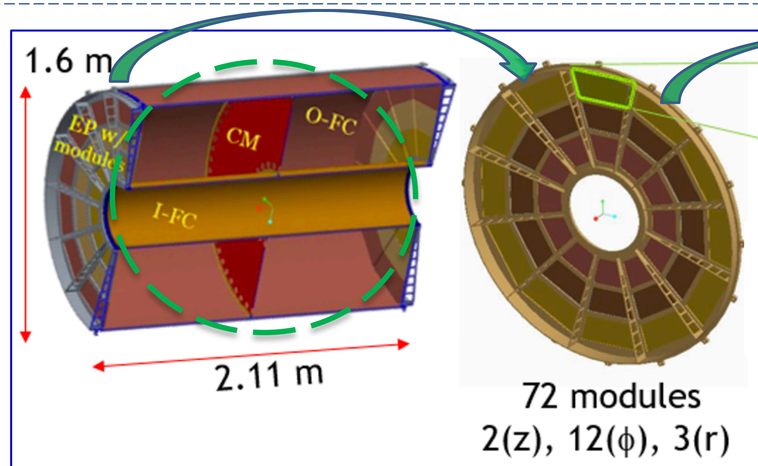


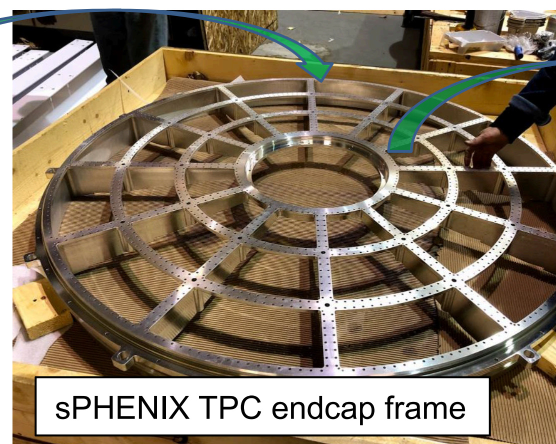
New Cage/TPC brackets fit check and positions survey →

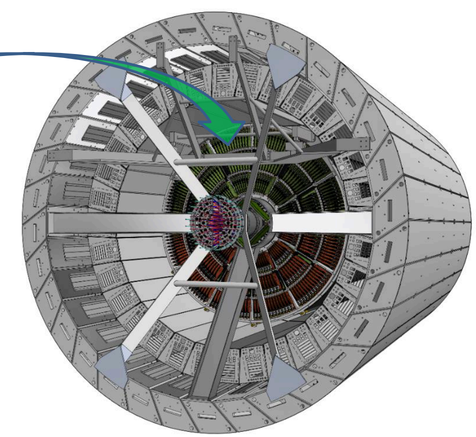




Clear acceptance is never the full story …

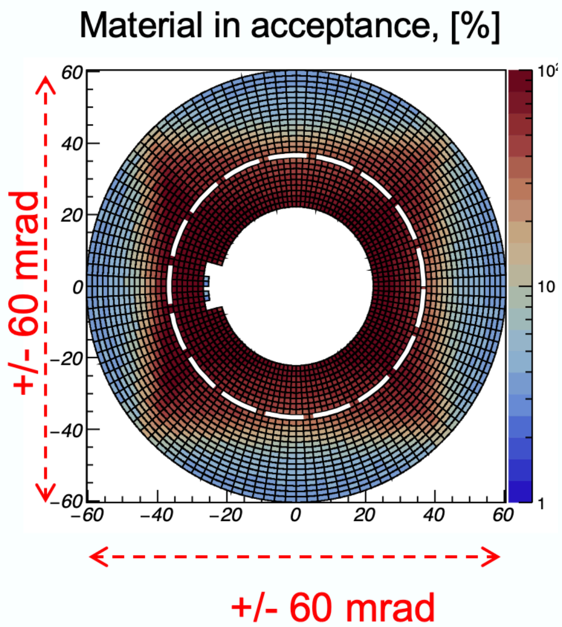




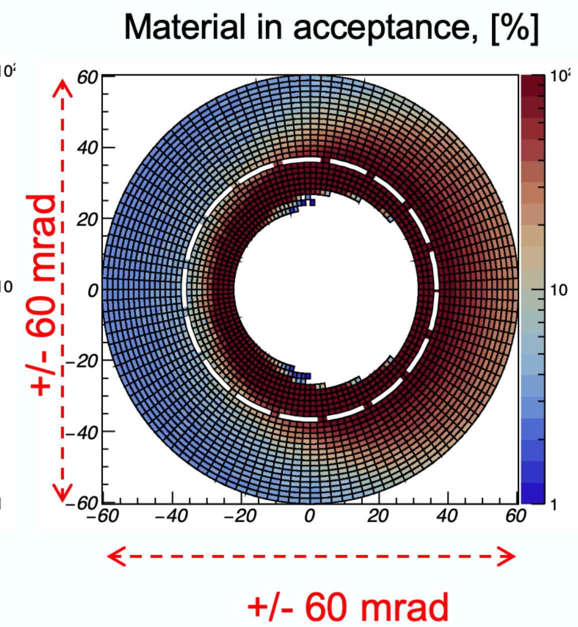


Beam pipe *(March 2020 design)* material scan

Electron endcap side



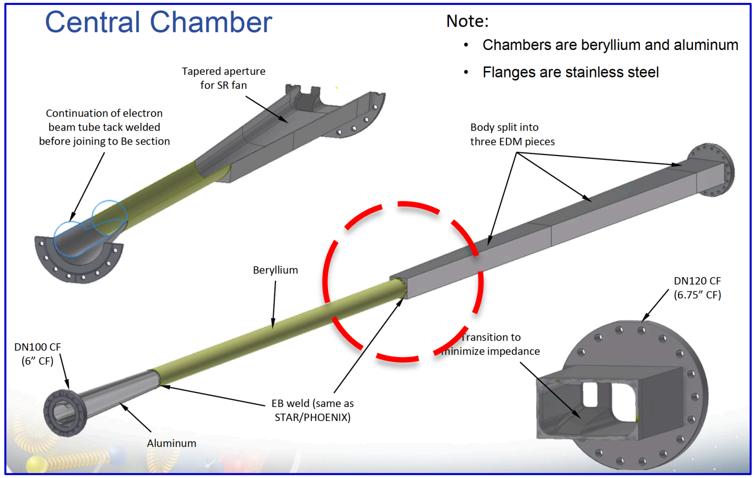
Hadron endcap side

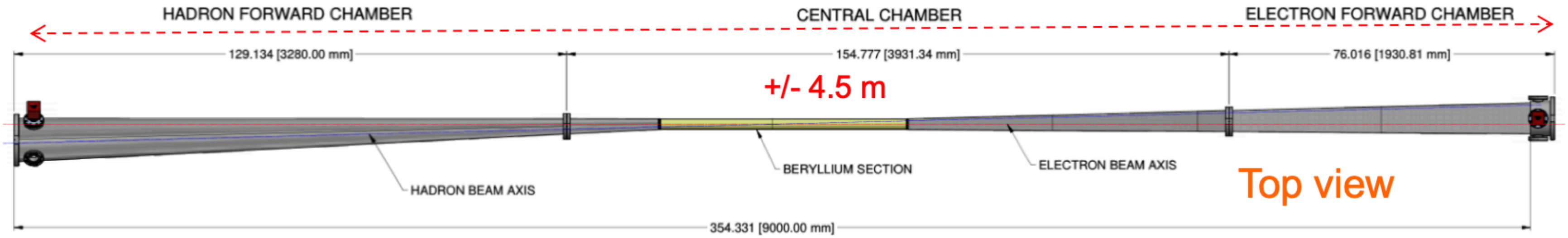


- ❑ Endcap pipe rectangular part: aluminum (layout needs improvement)
- ❑ Full range: $-4.5 < \eta < -3.5$
- ❑ White circle: $\eta = -4.0$

- ❑ Endcap pipe conical part: aluminum (layout needs improvement)
- ❑ Full range: $3.5 < \eta < 4.5$
- ❑ White circle: $\eta = 4.0$

- ❑ Central area (around IP): (ok) beryllium beampipe with the outer outer diameter 63.5 mm
- ❑ Few % radiation length material thickness in the most part of the required angular range

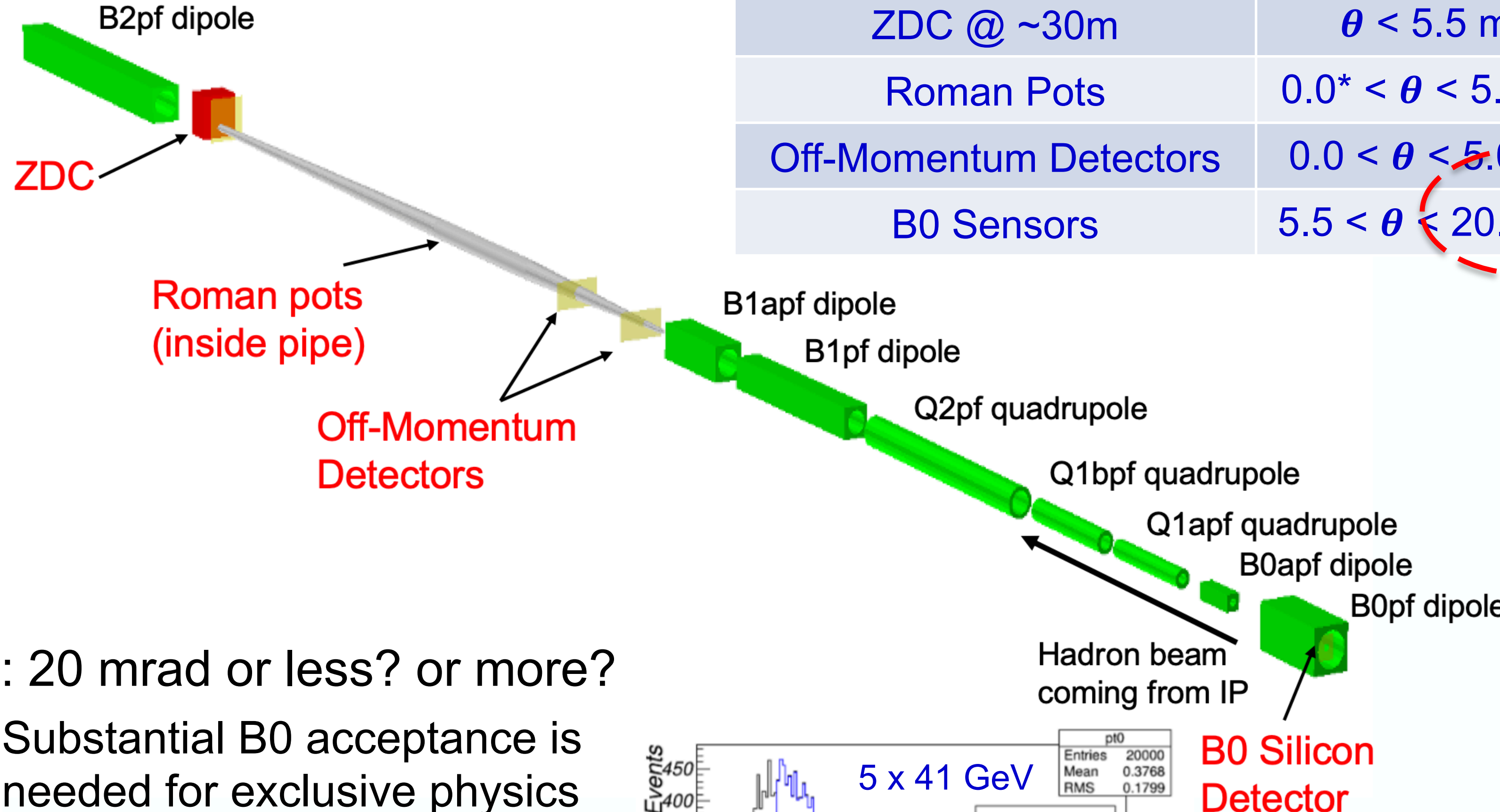




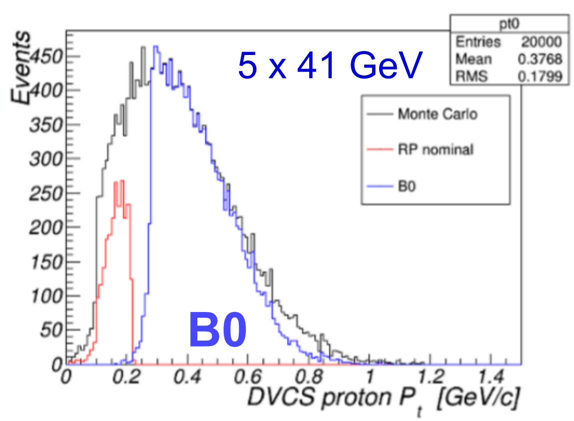
The new beam pipe design exists (longer Be section; optimized flange locations)

B0 spectrometer in the far forward region

Detector	Angular Acceptance
ZDC @ ~30m	θ < 5.5 mrad
Roman Pots	0.0* < θ < 5.0 mrad
Off-Momentum Detectors	0.0 < θ < 5.0 mrad
B0 Sensors	5.5 < θ < 20.0 mrad



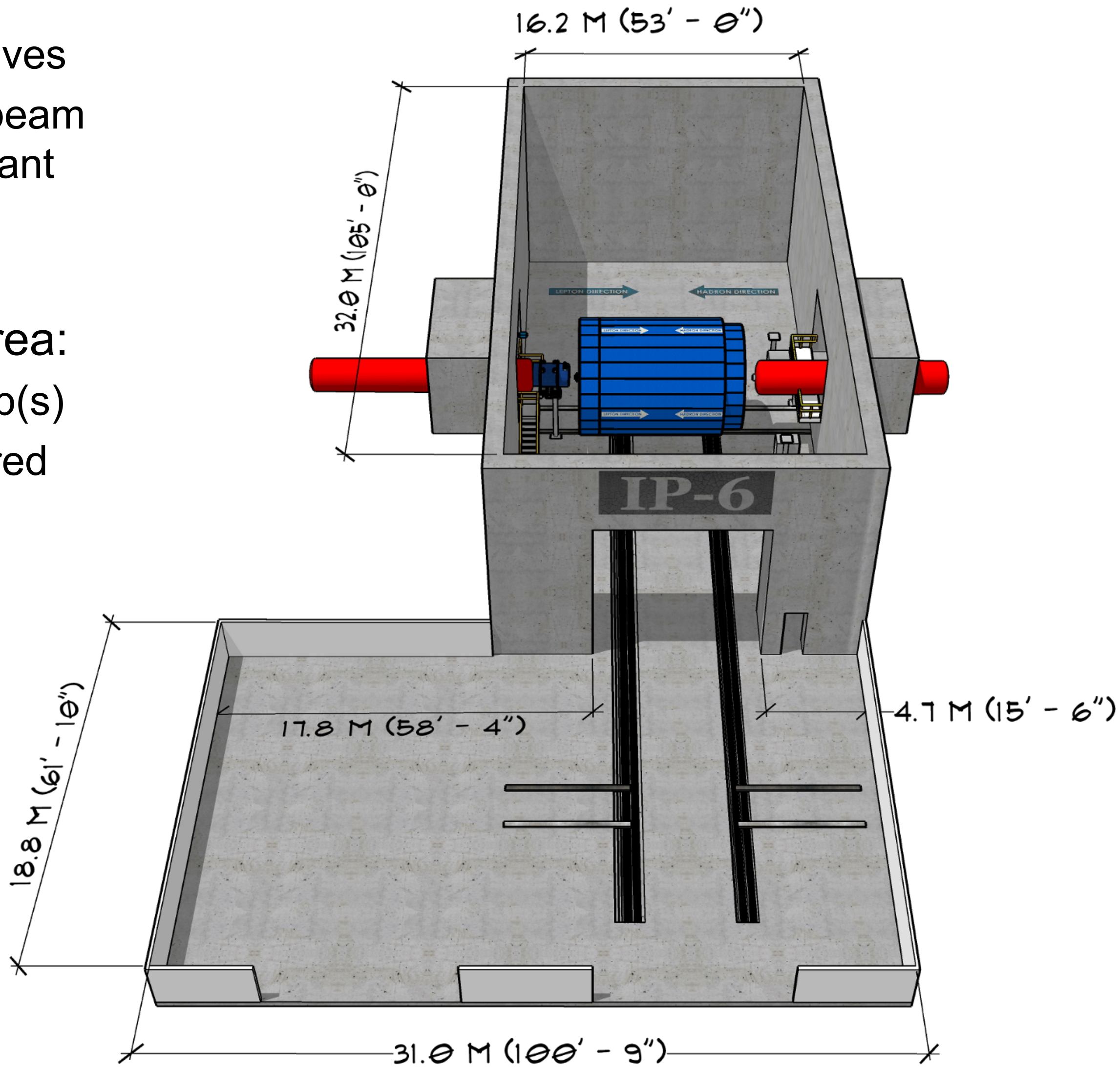
- B0: 20 mrad or less? or more?
  - Substantial B0 acceptance is needed for exclusive physics at small hadron beam energy
  - There will be neither PID nor calorimetry in this acceptance



EIC detector in RHIC IP6

- "Large" exp. hall:
  - Place for rolled-out endcap halves
  - But very little space along the beam line (which suggests no significant assembly work in this area)
- Small door to the installation area:
  - May need to split off the endcap(s)
  - Creative cryo connection required
- Low doorway
  - Electronics trailer can only be attached next to the detector
- Crane capacity:
  - 20 tons in the installation area
  - 40 tons in the assembly area

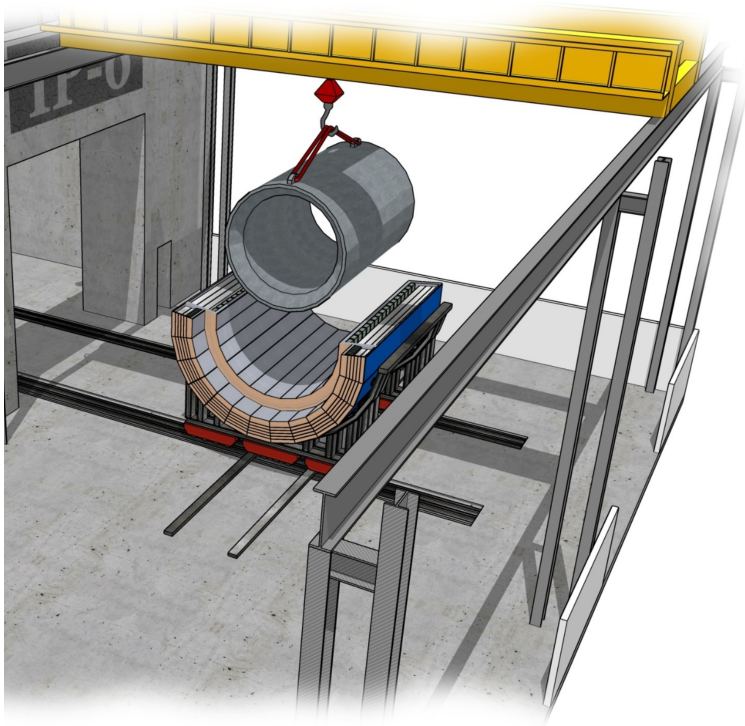
Door width	**823 cm**
Door height	823 cm

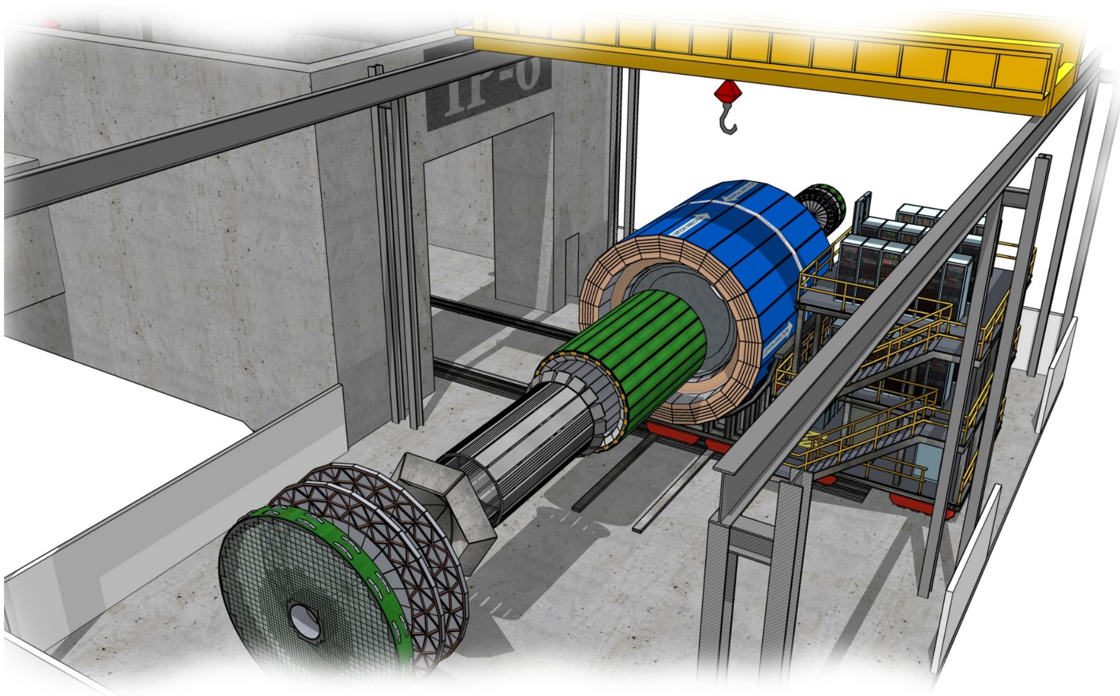


Maintenance modes & access options

- Short access (hours) – no major disassembly actions
  - Electronics trailer
  - HCal frontend electronics
  - Cryocan
- Longer access (days to weeks) – endcaps rolled out in halves
  - EmCal frontend electronics
  - B0 magnet detectors (silicon tracker and EmCal)
  - Outer part of the central detector (planar trackers, perhaps the gaseous RICH electronics, perhaps DIRC electronics)
- Regular maintenance (months) – barrel detector moved to the assembly hall
  - The only option to access the central tracker …
  - … and the forward / vertex / backward silicon trackers

Detector assembly in IP6

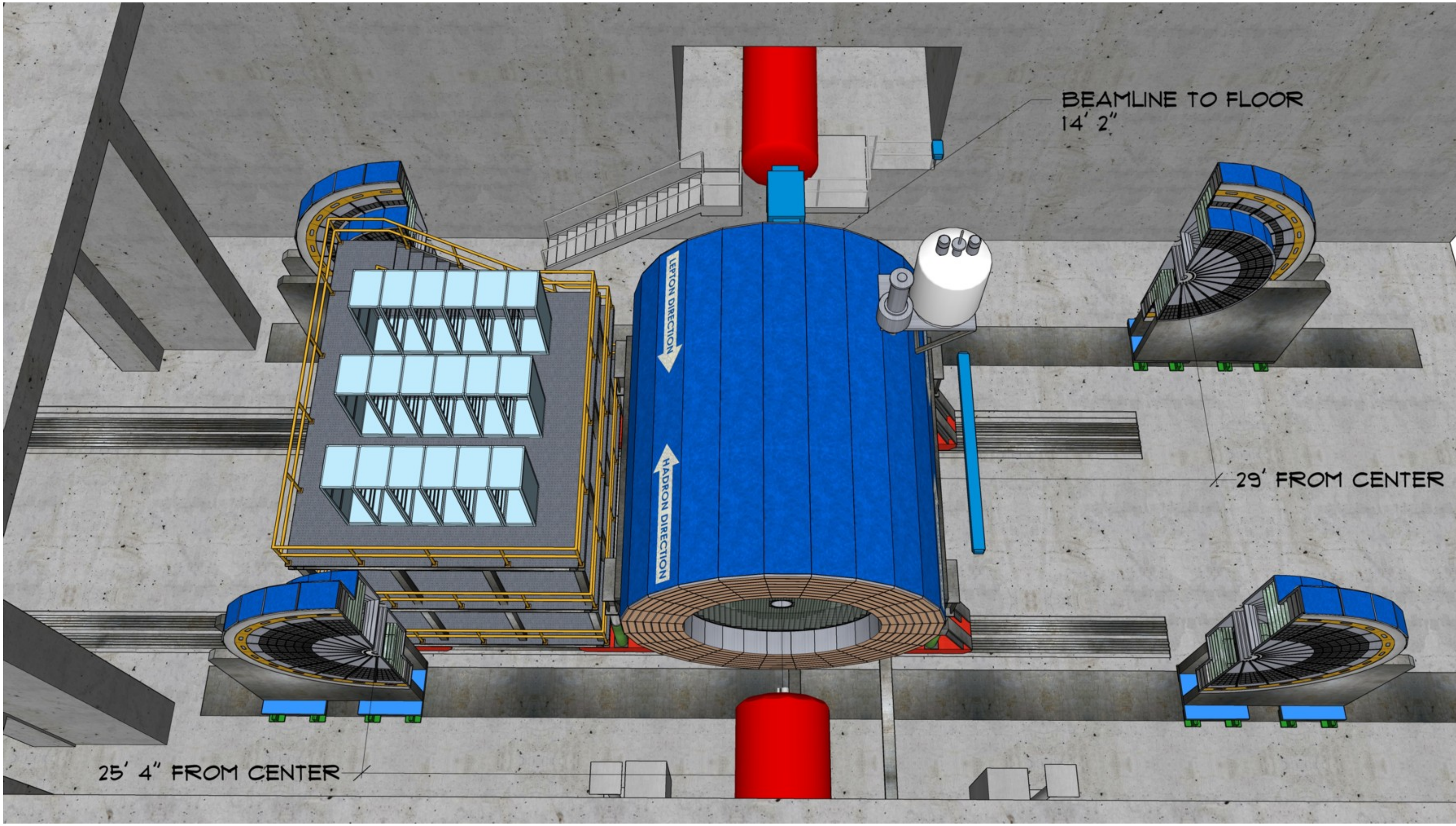




- Outer detectors (barrel hadronic calorimeter, cryostat) will be assembled in a “usual” way using crane (no clam shell configuration, as seen now)
- Inner detector insertion will require diverse tooling
- Beam pipe piece assembled together with the silicon vertex detector

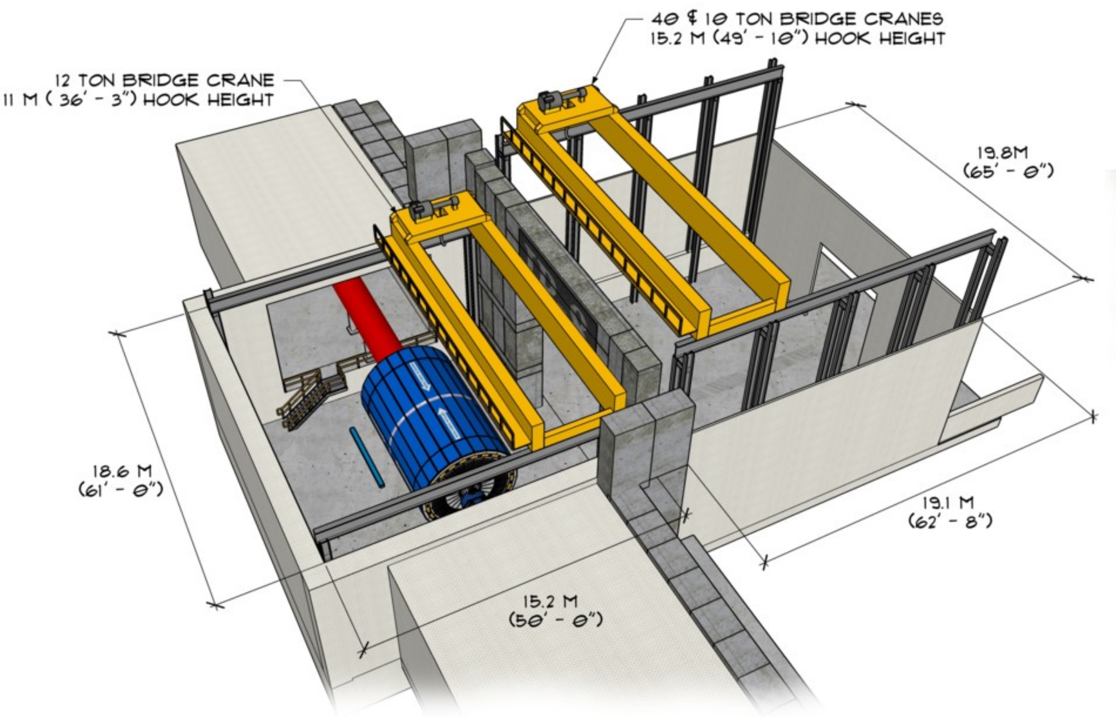
IP6: detector in the “longer access” maintenance

Somewhat outdated picture with the cryocan mounted on the detector



- Endcap(s) assembled in the experimental area once and stay there

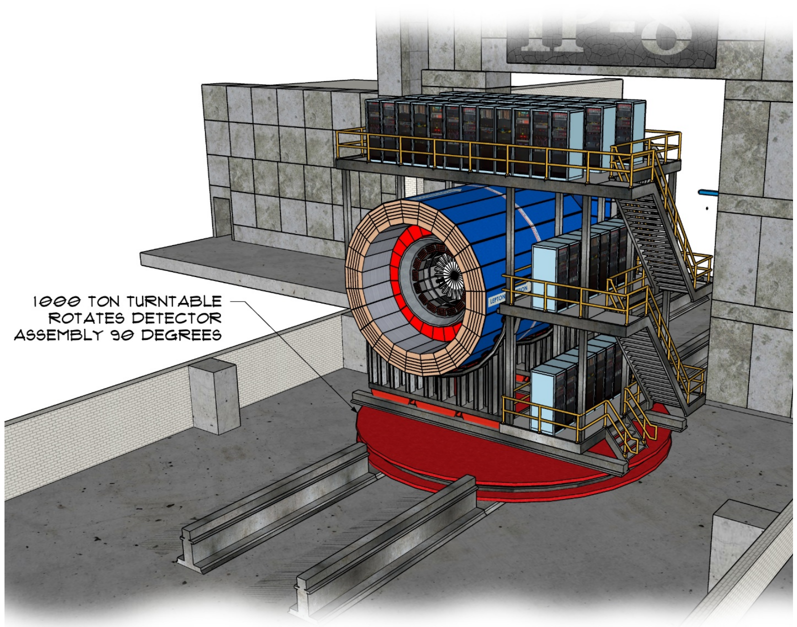
EIC detector in RHIC IP8



DIMENSIONS FOR IP-8 AND THE ASSEMBLY HALL

Door width	927 cm
Door height	1017 cm

- High enough doorway
  - Electronics trailer can be installed on top of the detector
- Rails will need to be moved



- Small exp. hall:
  - No space for either assembly work or detached endcap(s) …
  - … however the detector will likely fit through the door
- "Short" assembly hall
  - Either expand the area (or use a turntable?)

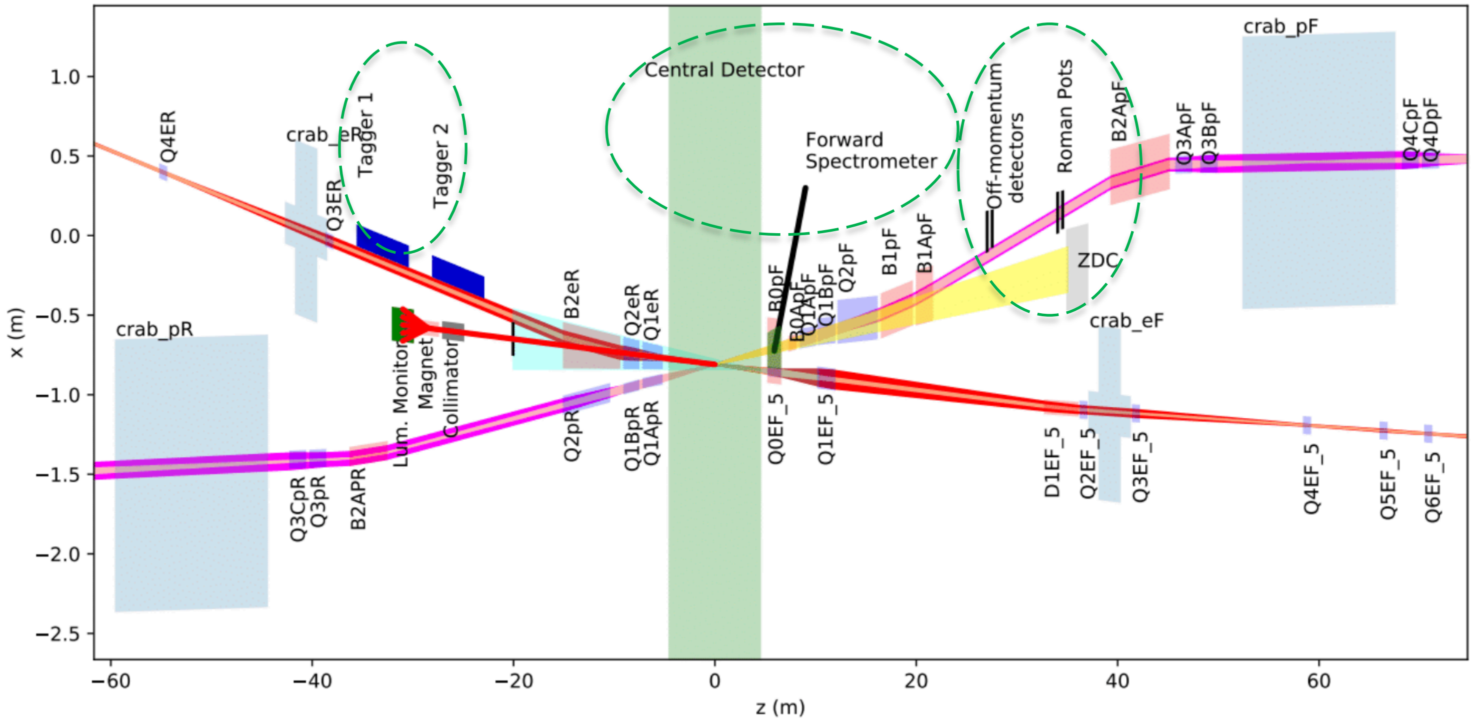
The takeaway message

- There are several “external” constraints on the central detector design
- They should better be observed when doing physics studies …
- … and be realistically accounted in the simulations, as well as in the overall detector design

- Integration work is ongoing

Backup

EIC Interaction Region layout



- ~9 m around the IP is reserved for the *central* detector
- But the *far forward* and *far backward* detector components are distributed along the beam line within ± 35 m
- Very important to keep full detector integration in sync with the accelerator design from the early stages on