Physics Drivers of Forward Tagging at the EIC

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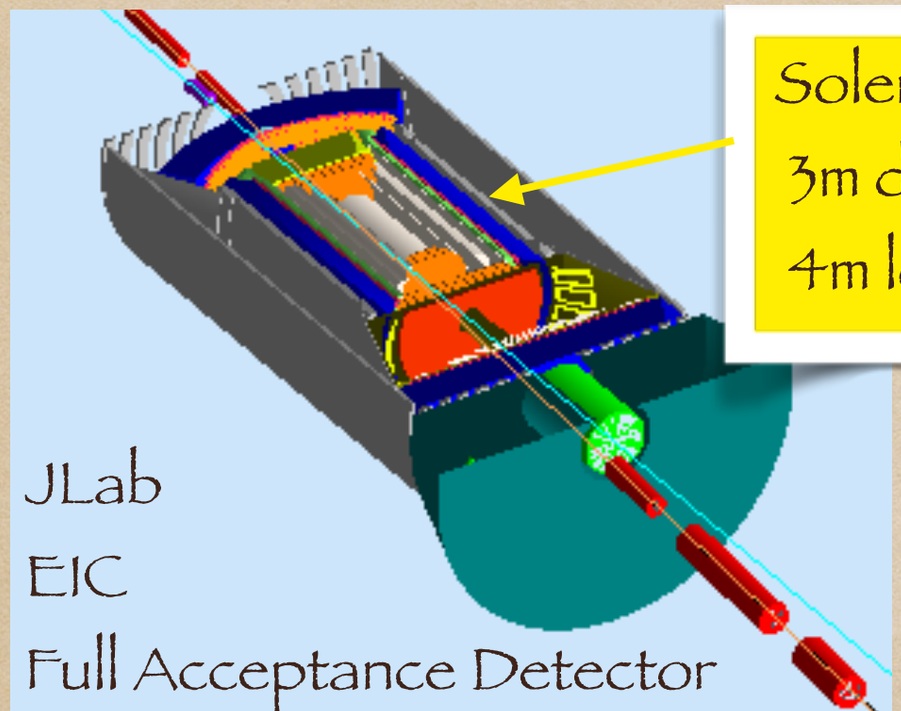
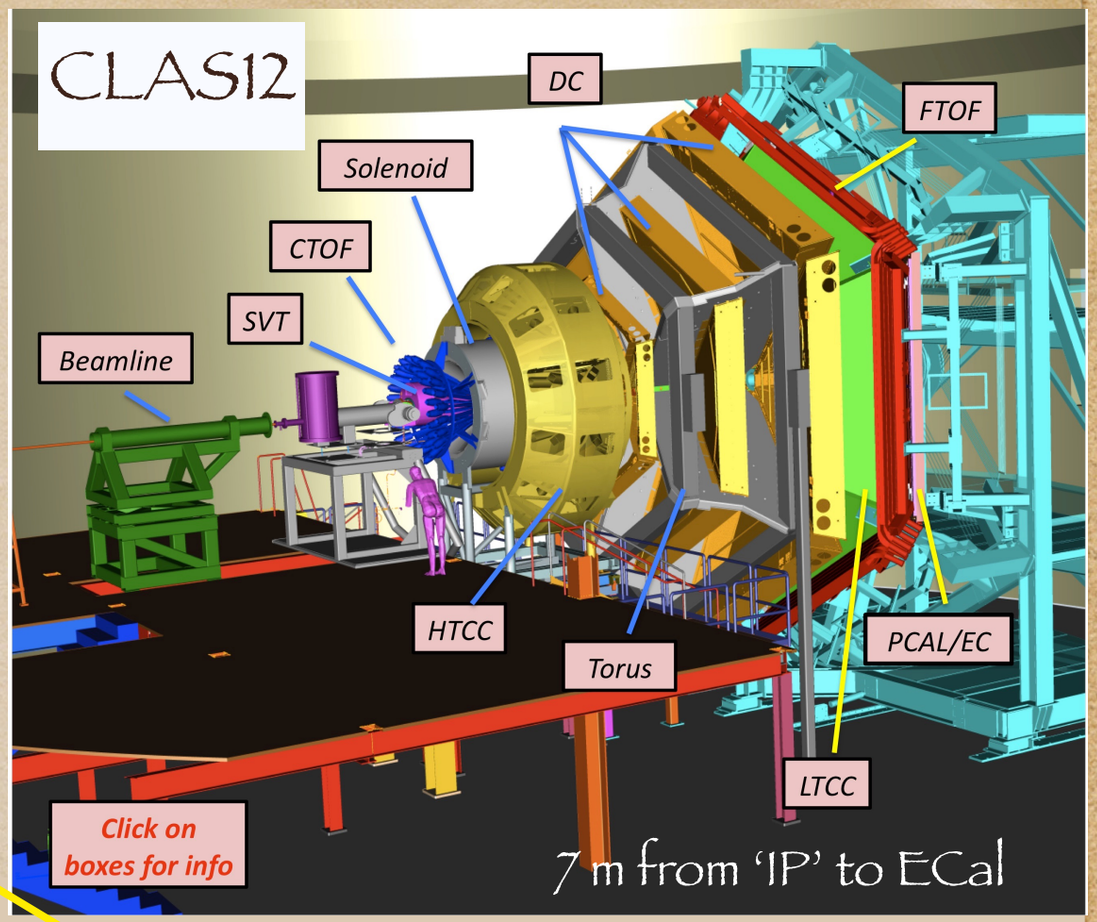
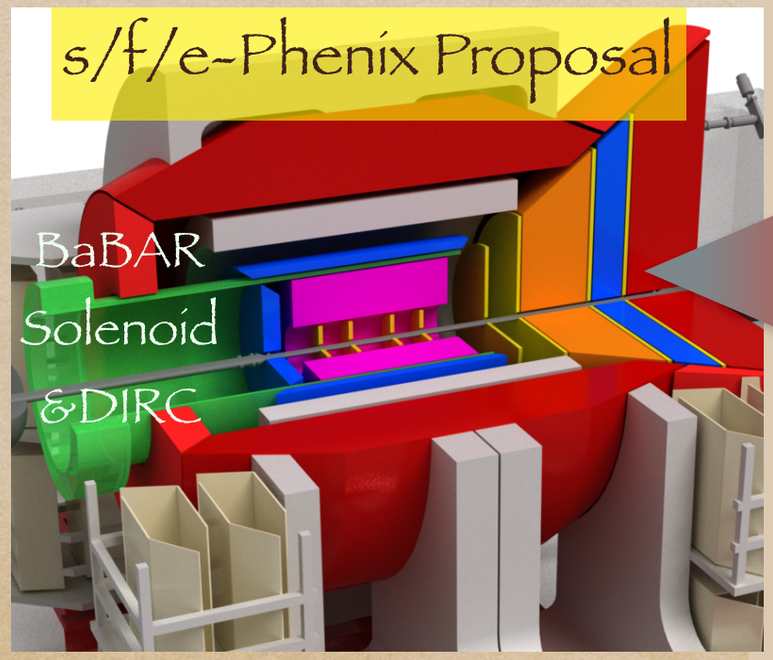
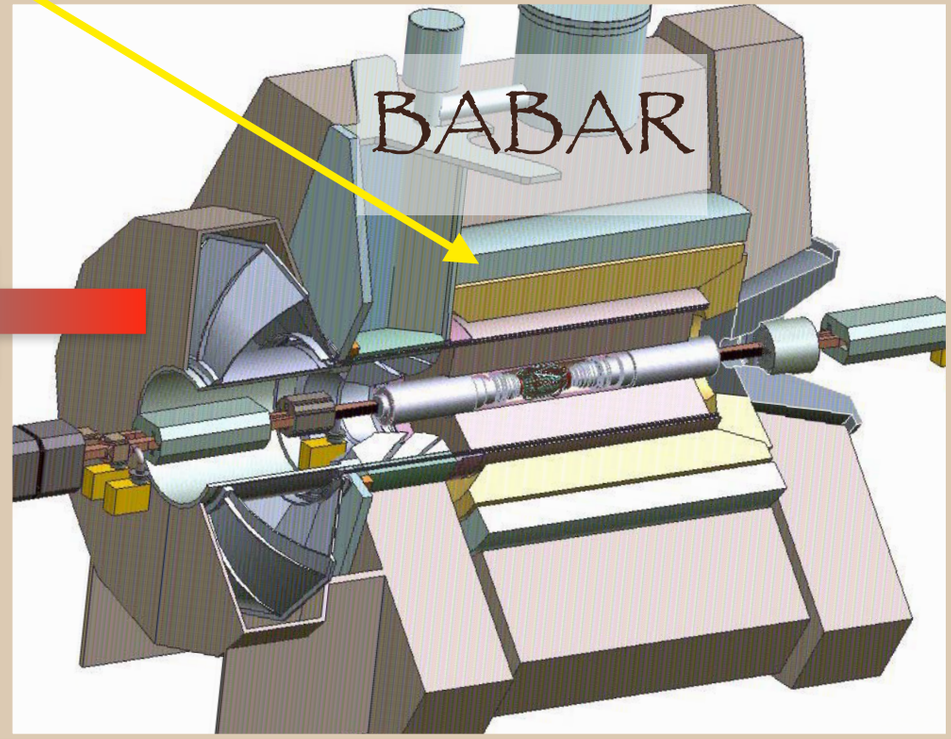
A Sampling of Nuclear/Particle Physics Detectors ~ to Scale





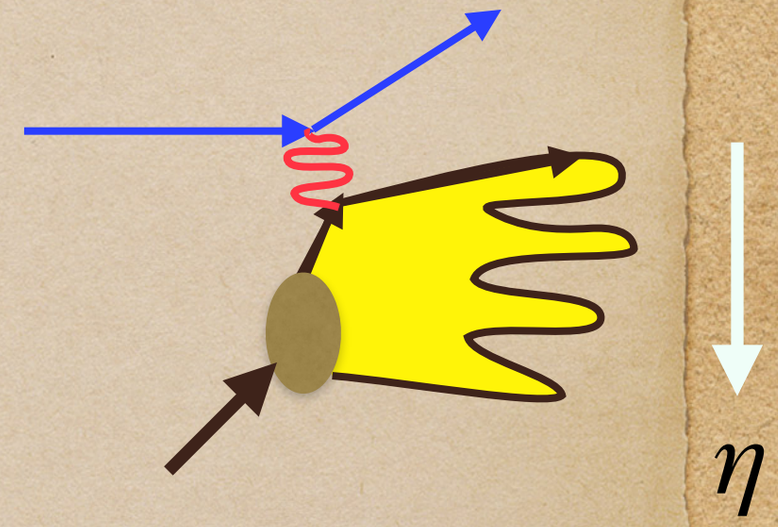




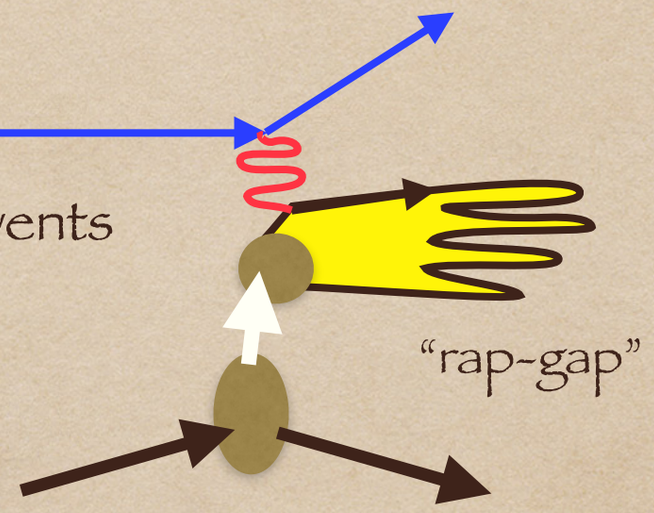
Common Topology of ep (DIS), pp, pA, AA: JLab-HERA-RHIC-LHC

- Parton fragmentation to hadrons is uniform in rapidity

$$\eta = -\frac{1}{2}\ln\left[\frac{E-p_z}{E+p_z}\right]$$



- HERA:
  Large (10-20%) probability of "Rapidity-Gap" (diffractive) events



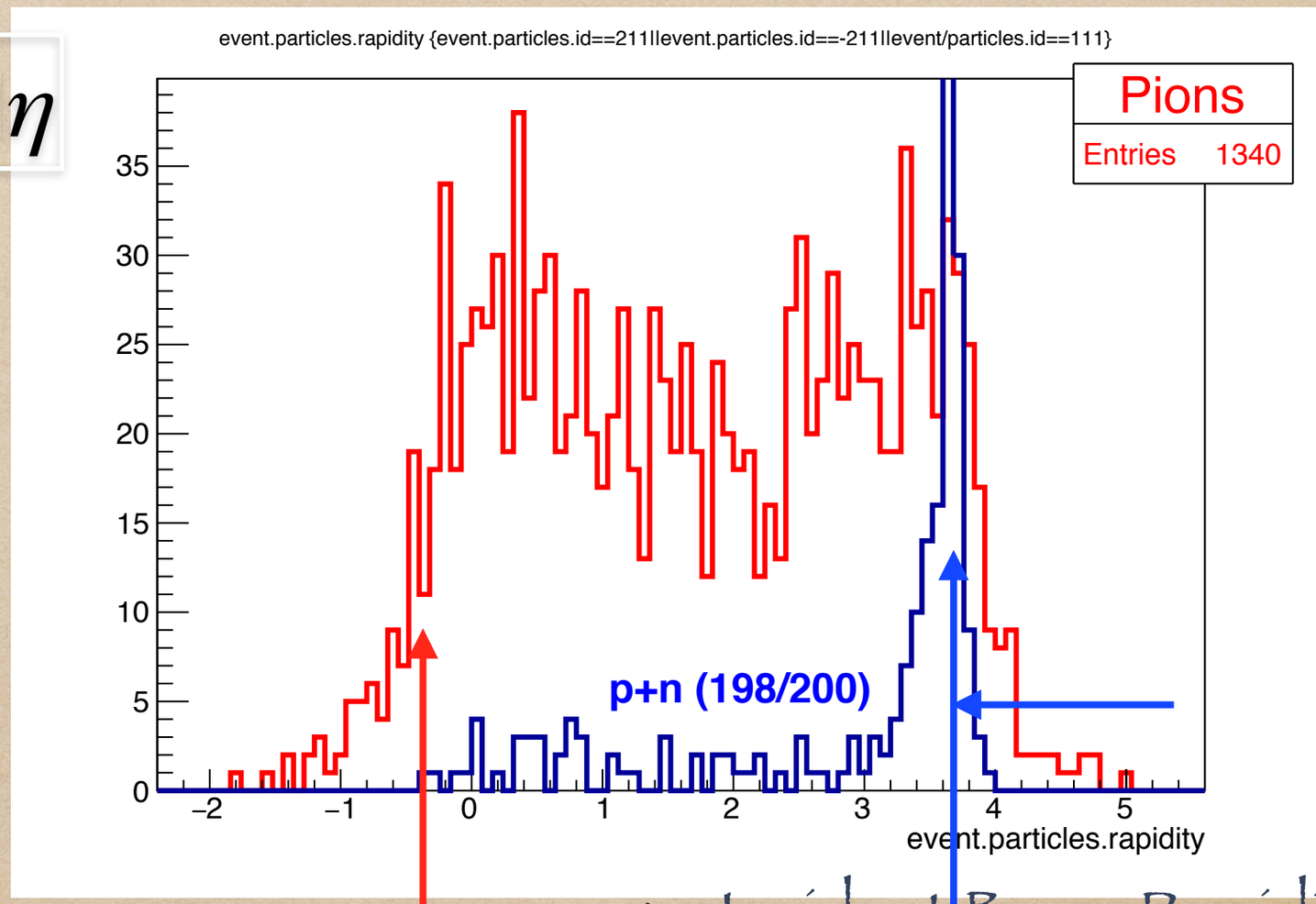
- Observing/vetoing forward particles essential
  - Exclusive processes for 3-D imaging
  - Baryon multiplicity, p_T for centrality tag in eA
  - Correlations between "Current Jet" and "Target Jet"

200 event PYTHIA Simulation

$ep=10\times100\ GeV^2$, $Q^2=6GeV^2$, $x_{Bj}=0.01$

$$200\frac{dN}{d\eta}\Delta\eta$$

J. Bjorken's vision: A detector should have full-acceptance and uniform granularity in rapidity

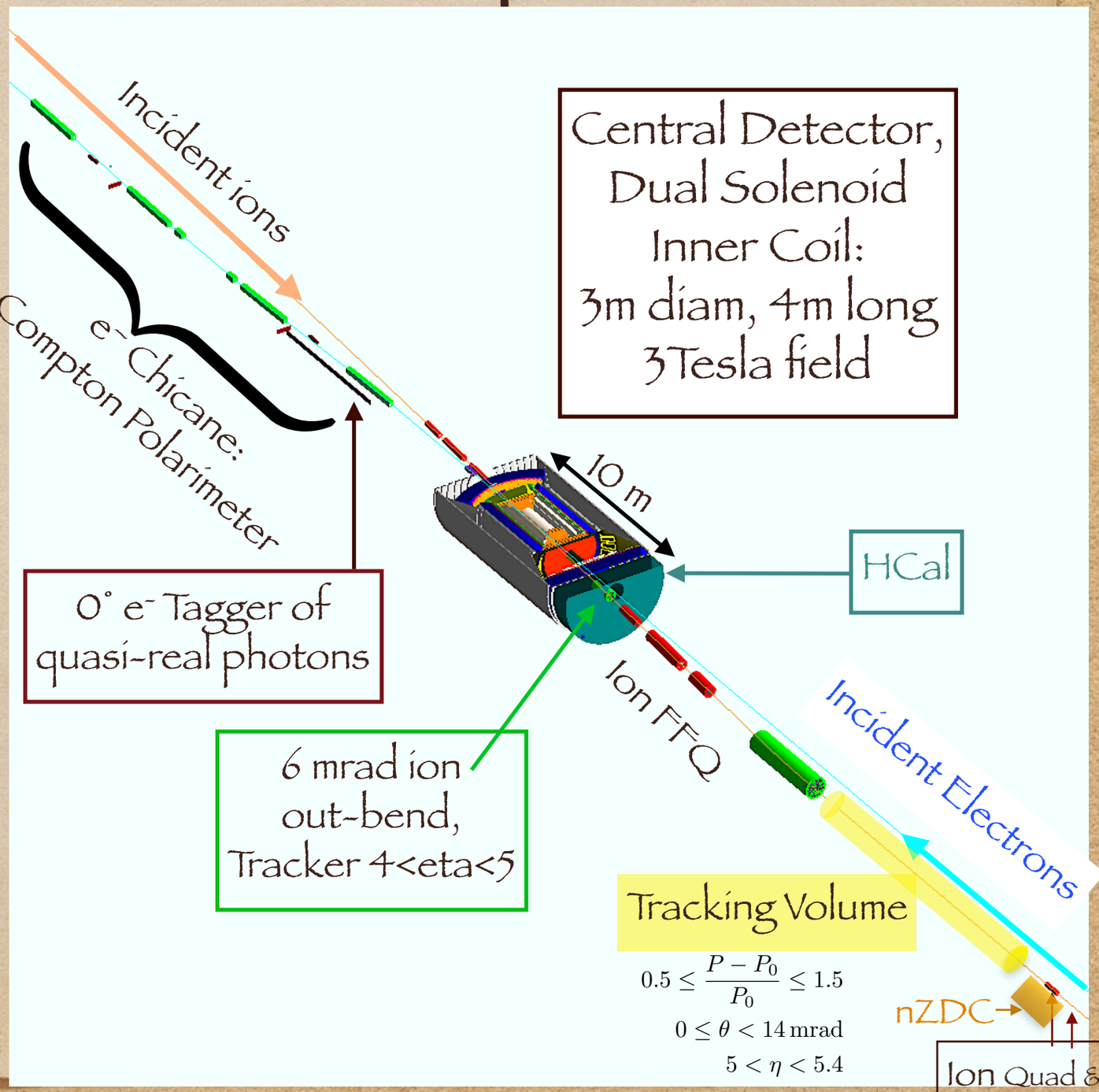


- Rapidity of $x_{Bj}P+q$
- Incident Beam Rapidity (shifted ~1.5 by 50mrad crossing angle)

The JLab EIC Full-Acceptance Detector Concept

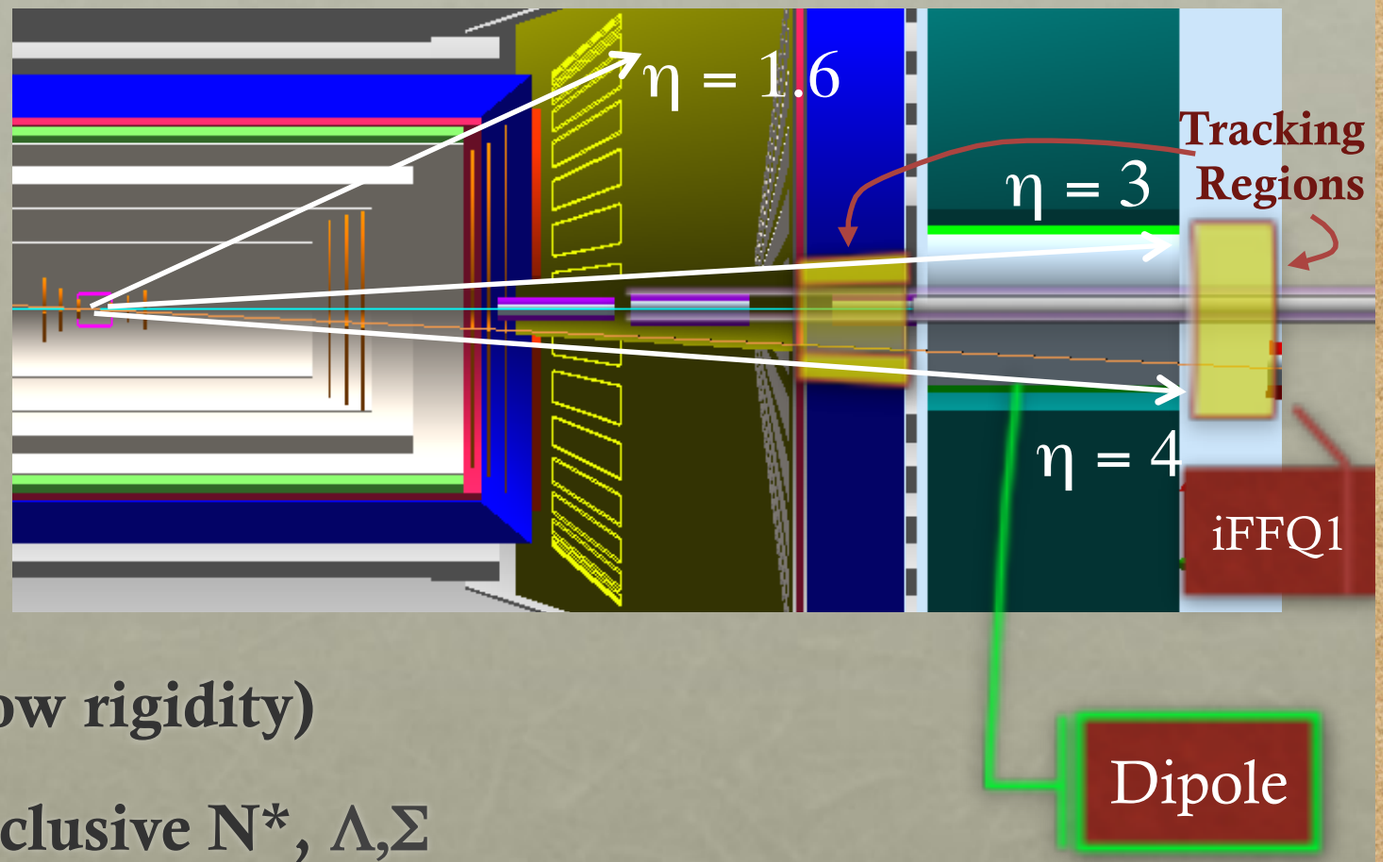
Detector is 80 m long

- Ion Direction: Forward Spectrometer:
  - >4mrad at full momentum, ≥0° for dP/P>0.005;
  - Secondary focus at z=36m
- Electron Direction:
  - =0° for 10%<k'/k<50%
  - >50 mrad for all electrons, hadrons



END-CAP & FORWARD REGIONS

- 2 Tesla-m Dipole (z=5.5m)
  - (*cf*. For θ < 80 mrad, Solenoid Bdl < 0.6 T-m)
  - Acceptance ± 90 mrad (relative to electron) (+40, –140 mrad to ion)
- Full Reconstruction of Projectile Fragmentation
  - High-P_T , and/or small $-x_F$ (low rigidity)
  - $3.5 < \eta < 5$
  - Mesons from decay of near exclusive N*, Λ,Σ
- NN correlations in heavy nuclei
  - $P_T/P_{||}$ < (1 GeV/c)/(40 GeV/c) = 25 mrad relative to ion-beam < 75 mrad relative to electron axis



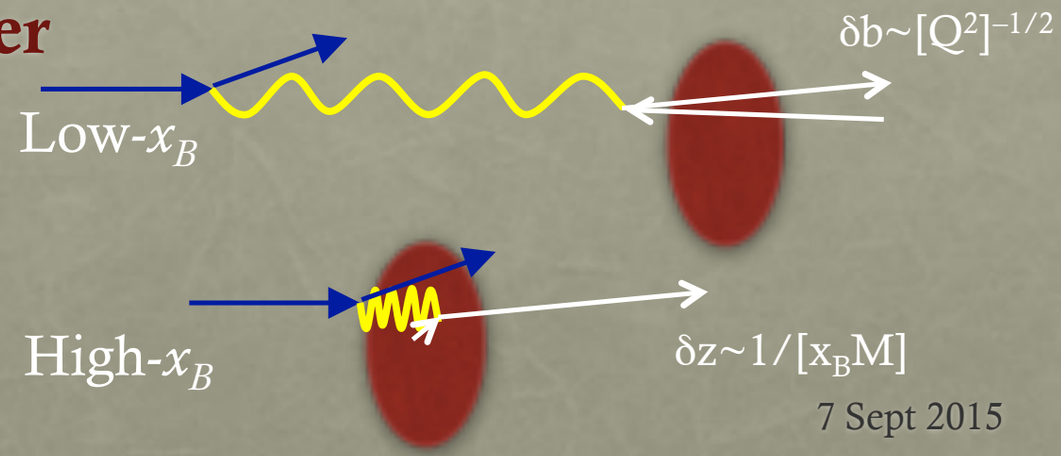
Far-Forward Spectrometer

- Deep Virtual Exclusive Processes:
  Spatial imaging of quarks and gluons in p,n, nuclei
  - Acceptance:
    x_{Bj}>0.005 at 0 ≤ P_T or $-t \sim (P_T)^2 > (400\ MeV/c)^2$ @ $x_{Bj} \leq 0.005$
    Angular acceptance ≤ 14 mrad
- Semi-Inclusive DIS:
  - 3-D Momentum Imaging
  - Flavor/spin/momentum correlations between target fragments and 'current' fragments
- Spectator Tagging
  - P_P ~0.5 P(proton in deuteron), 0.33 P(proton in ^{3}He), ^{3}H fragments in N=Z nuclei have rigidity 3/2 ×P/Z
  - tracking resolution ≈ beam emittance
  - ZDC can achieve 30%/$\sqrt{E_n}$ ≈ 4% for spectator neutrons
    ~ 20 MeV/c equivalent longitudinal resolution in Deuteron rest frame
    ~ 10 mm/40 m = 0.25 mrad transverse $\sigma(p_T)$=12.5 MeV/c

eA
PHYSICS & DETECTOR

- **Current-jet and Projectile-jet fragmentation**
  - **Hadronization Mechanism**
  - **Gluon Saturation signals**
- **Gluonic EMC effect**
  - **DIS Evolution: Luminosity, Precision**
  - **Open Charm: Vertex Detector**
- **'Spectator' Multiplicities**
  - **Proton, Neutron, Light fragments, Evaporation Residue**
    ZDC & Far-Forward Spectrometer
  - **Multiplicity tag on current-jet propagation distance:**
    - **DPMJetHybrid generator:**

      M. Baker EIC R&D, also Z.Citron 1405.4555
- **Deep Exclusive Processes**
  - **3-D imaging: quark and gluon mass densities *vs* Charge densities**
  - **Gluon Saturation signals**

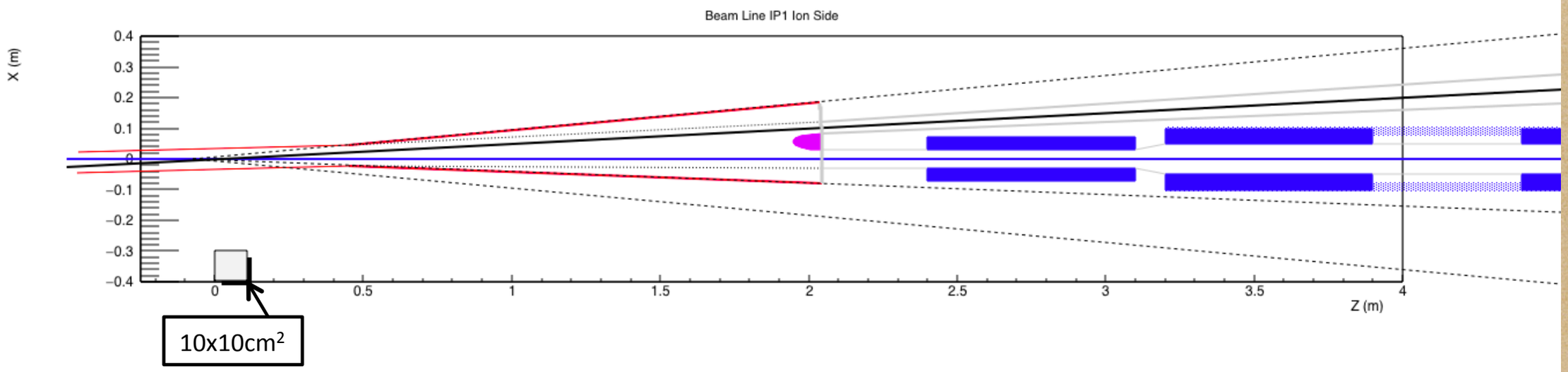


Vacuum Pipe Concepts

- Mechanical/Vacuum Stability
- RF shield for ~1 Amp beam currents
- Minimize multiple scattering for all detectable particles
  - Ion FFQ acceptance 10 mrad Horiz, 14 mrad vertical
    - Contain these in vacuum to large dipole, allow others to exit
- Contain 10-sigma beam from 20 to 100 GeV/c
  - Minimum 2-3 cm radius

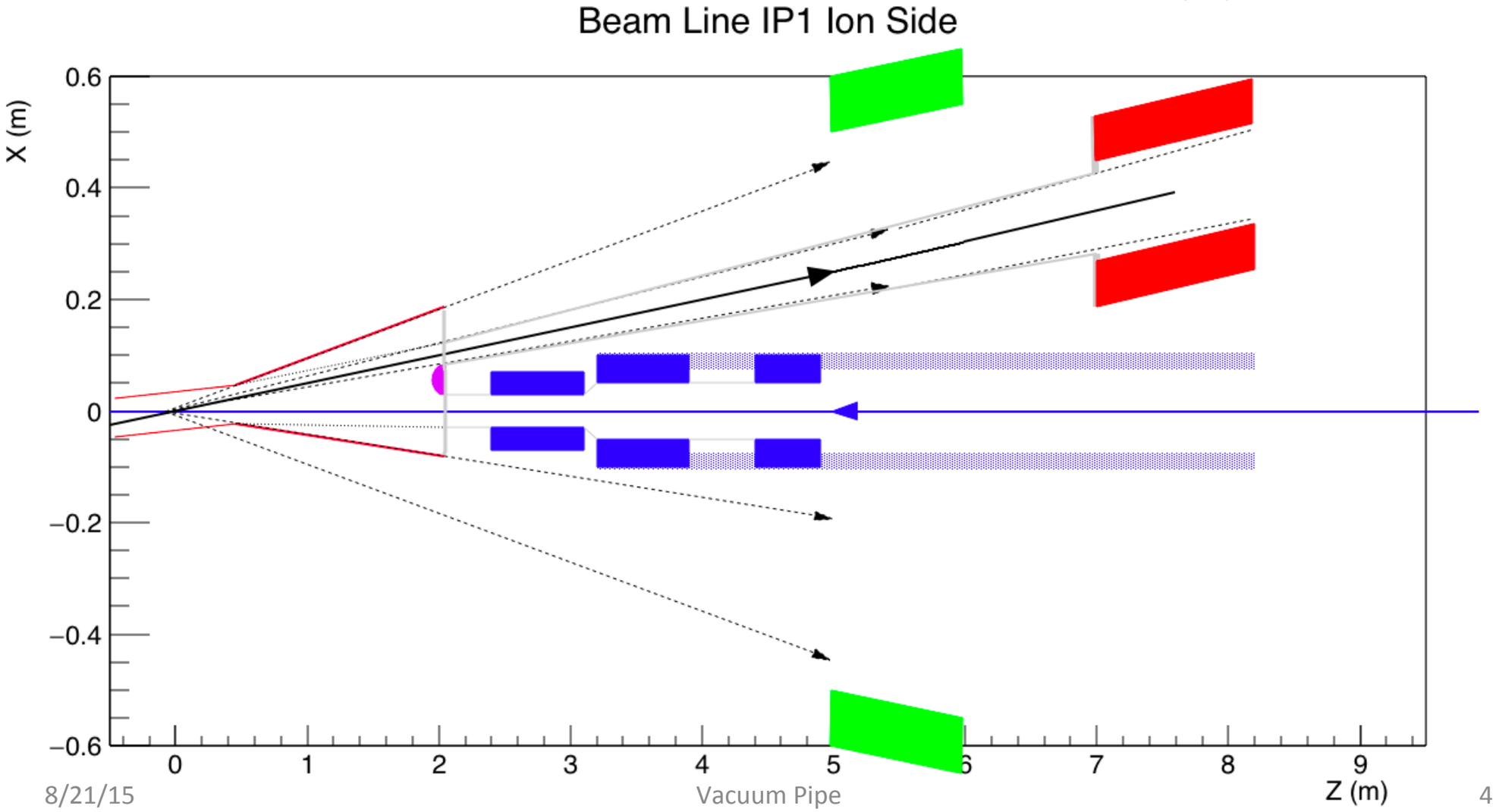
Example Concept: IP to iFFQ1

- 8 Tesla FFQ1,2: FFQ Acceptance ~10 mr
- Be Vertex chamber (VC):
  - 25 mrad offset; 3.5 cm radius; ±46 cm long
- ±64 mrad flare with 2cm BSC at junction to VC:
  - Approx acceptance of Small Dipole on Ion side.
  - Synchronization offset ±7.5 cm along Solenoid axis
- 100 µm RF mesh *(X/X0 = 0.0002/sinϑ)*



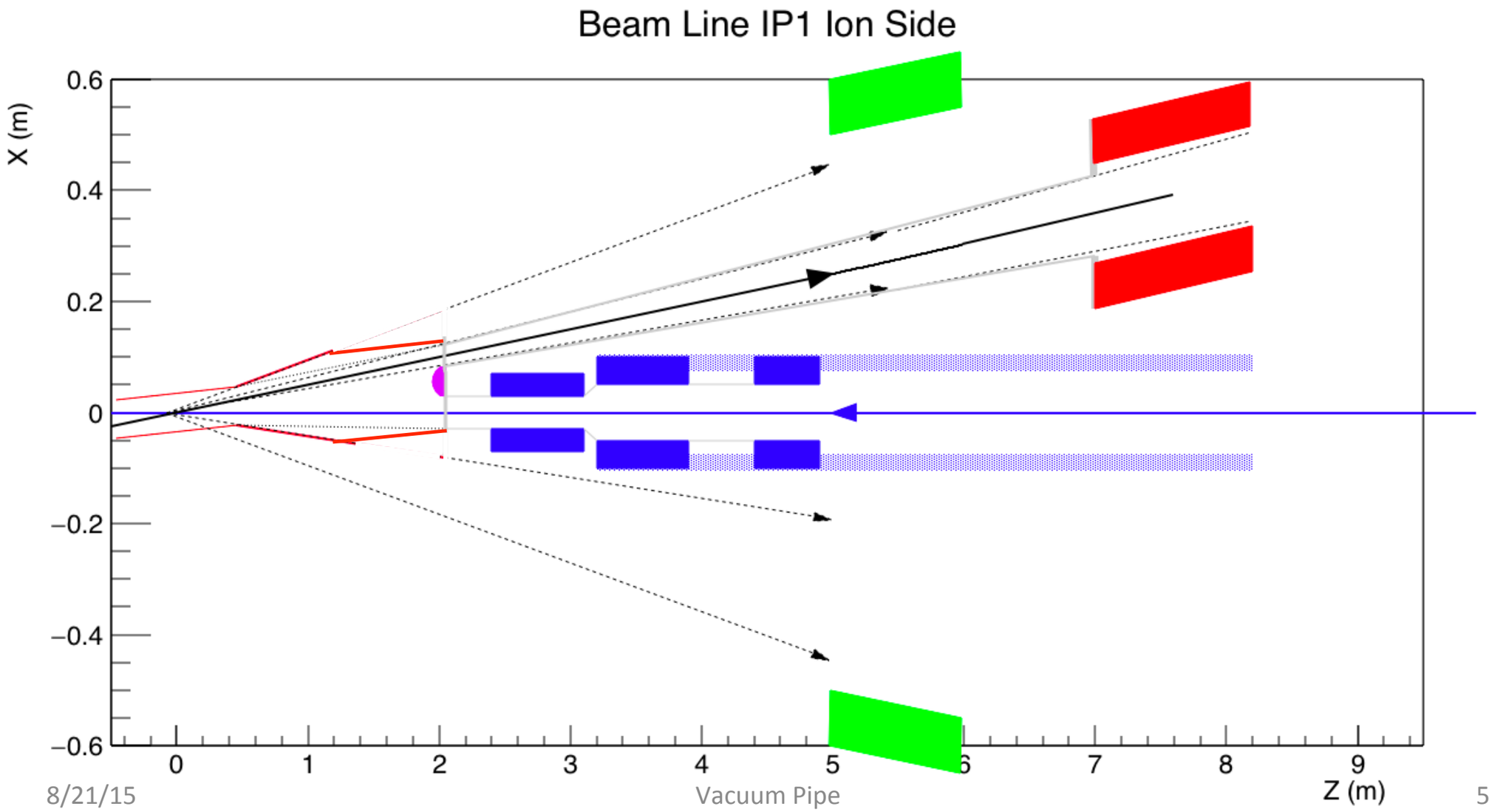
Expanded View: IP to iFFQ1

- Large Radius symmetric Dipole (6mrad out-bend)
- Flux exclusion Tube on Electron Beam Line
- RF absorber at vertex of electron and ion vacuum pipes



Eliminate Corners (and RF mesh):

- X/X_0 ~ 1 for forward ions at ~11 mrad (1 mm thick Al)
  - θ_{ms} ~ 1 mrad at p=14 GeV/c
- G4BeamLine Tracking study in progress: Momentum, angle, and vertex resolution.
  - Advice welcome.

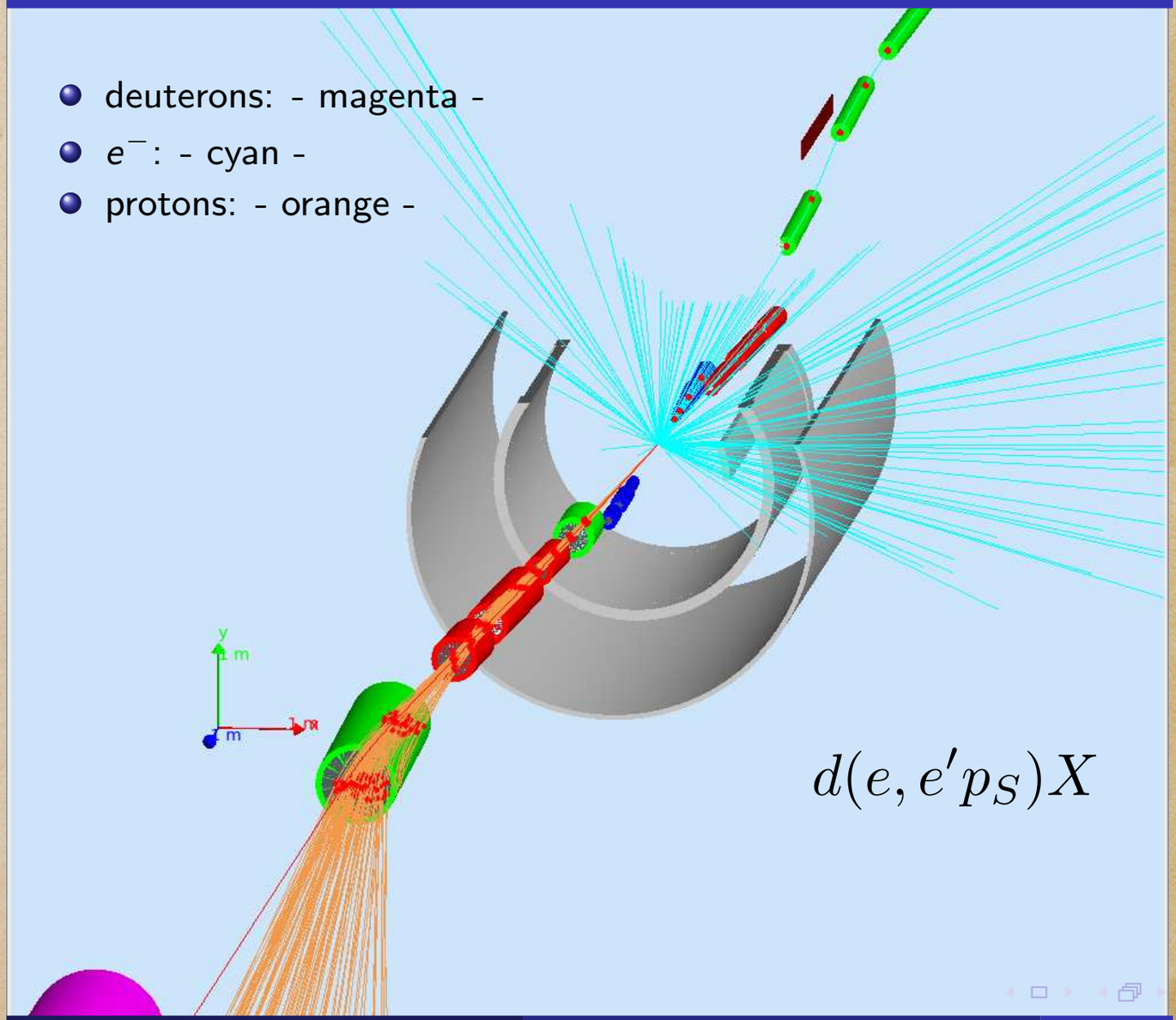


Conclusions

- Detector / Lattice integration is an essential part of the EIC design
  - This integration currently extends 40m downstream in both ion and electron directions
- We are designing a detector that is optimized for the exciting physics program.

MC Simulation / GEMC

- deuterons: - magenta -
- e^-: - cyan -
- protons: - orange -



$d(e, e' p_S) X$