Forward nucleon tagging at EIC

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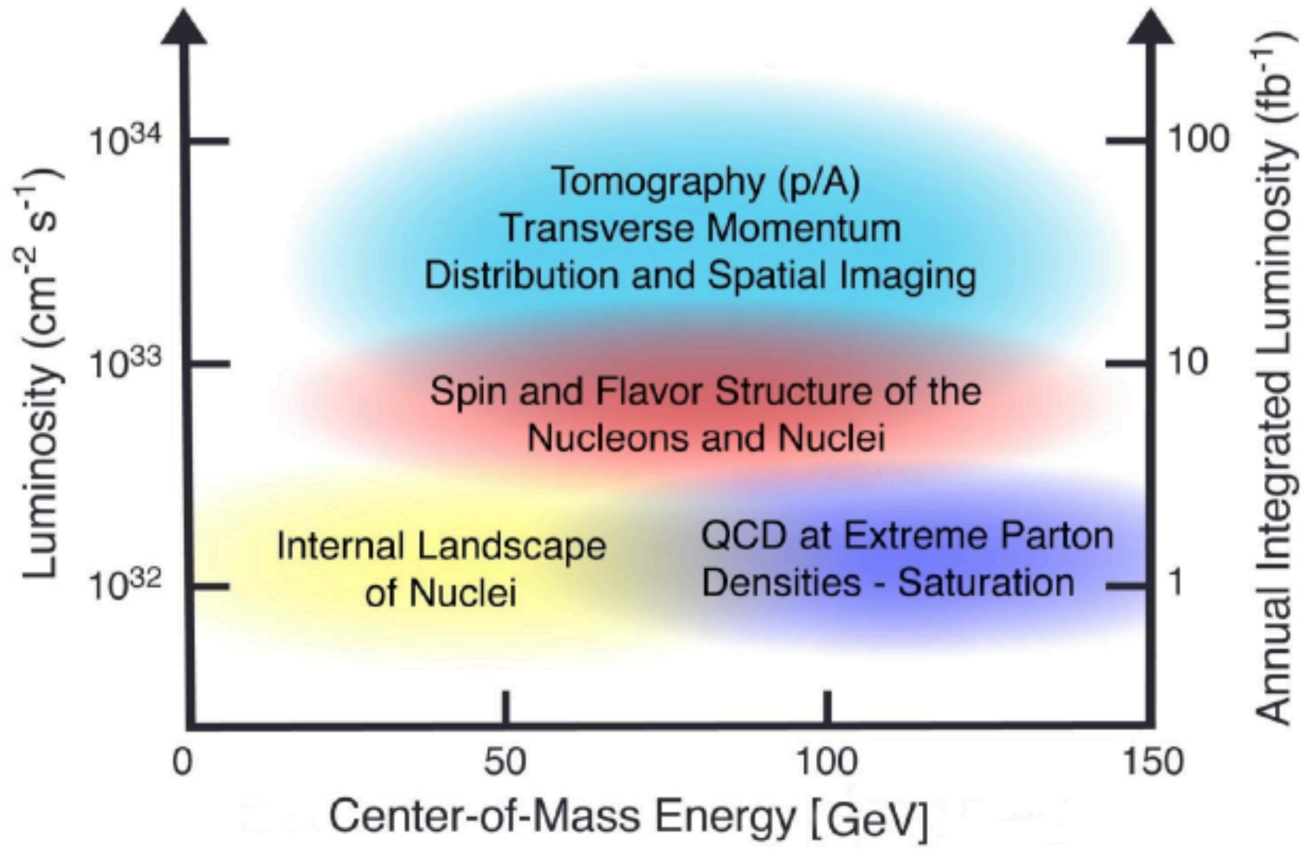
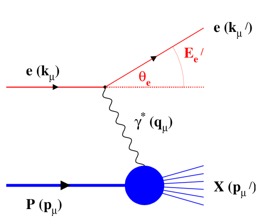
EIC User Group Meeting 2018

Outline

- EIC physics with (far-)forward nucleon tagging
  - focusing on protons with Roman Pots
- Interaction Region integration
- Requirement and considerations for measurements with Roman Pots

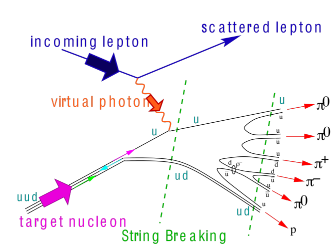
EIC physics and measurements





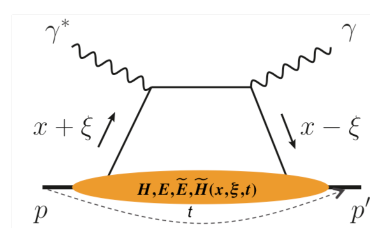
inclusive DIS

measure scattered electron with high precision



semi-inclusive DIS

detect the scattered lepton and final state (jets, hadrons, correlations in final state)

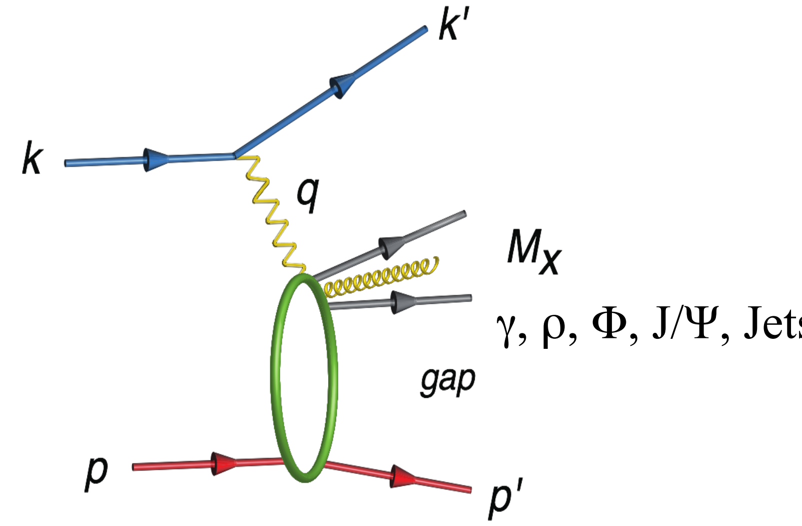


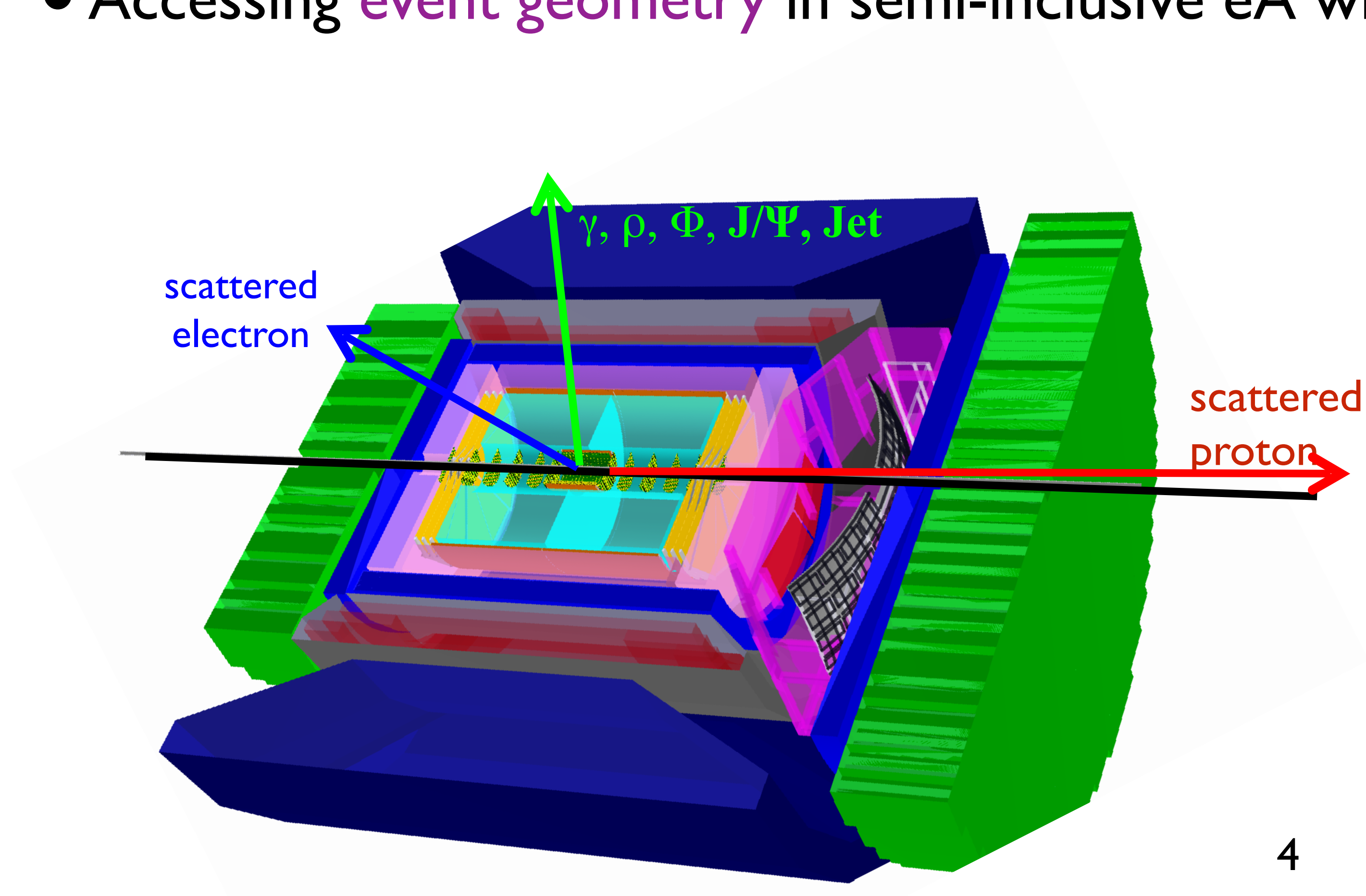
exclusive processes

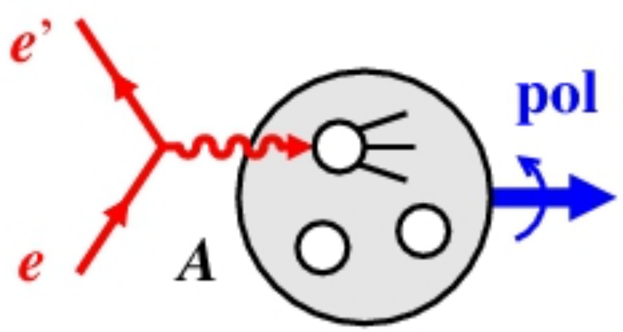
all particles in the event identified

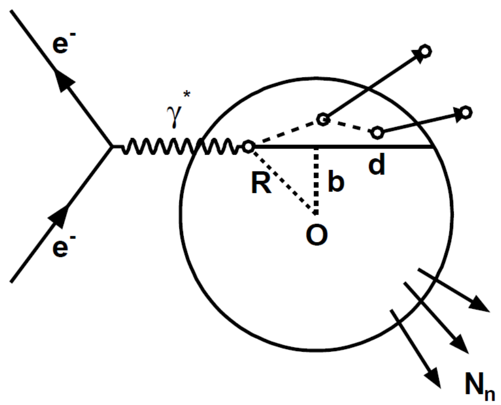
Physics with forward tagging

- Defining exclusive reactions in ep/eA:
  - ep: reconstruction of all particles in (diffractive) event including scattered proton with wide kinematics coverage
  - eA: identify with rapidity gap. need wide rapidity coverage [HCal for $1<\eta<4.5$]
- Identifying coherence of nucleus in diffractive eA:
  - ~100% acceptance for neutrons from nucleus break-up
- Sampling target in e+^{3}He,d with spectator nucleons
- Accessing event geometry in semi-inclusive eA with evaporated nucleons

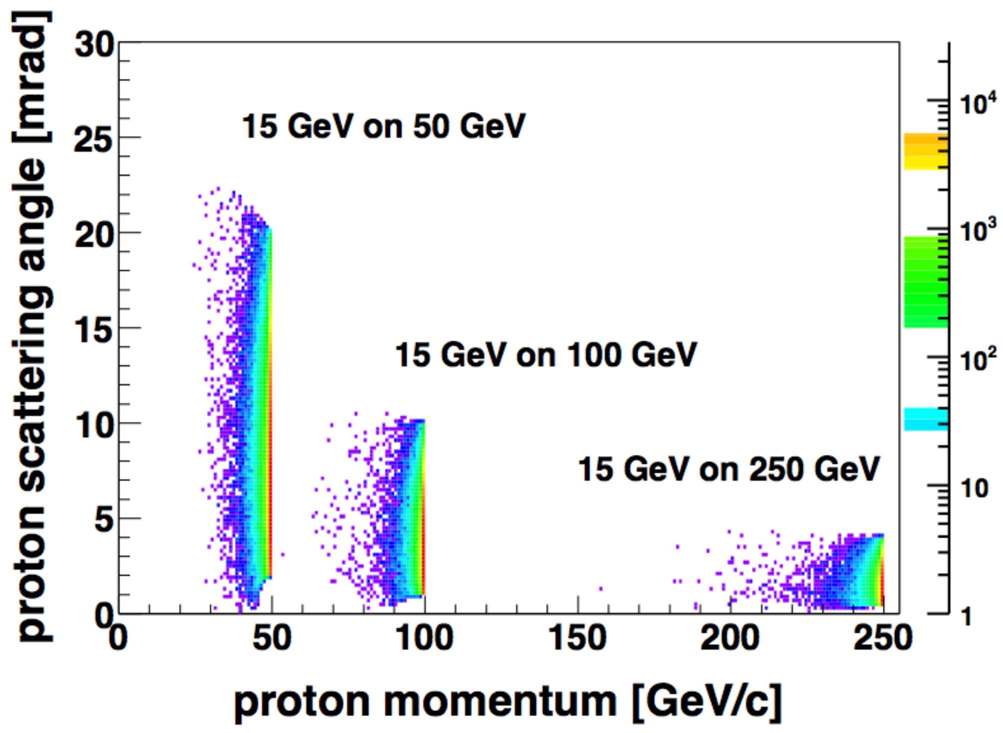


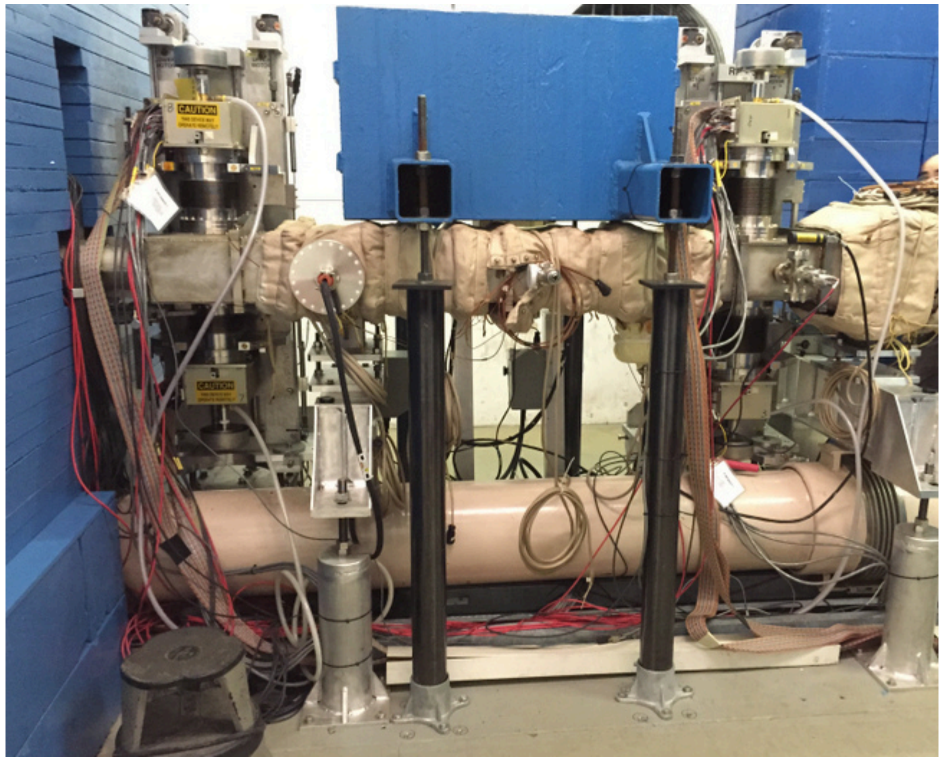






Forward protons in diffraction





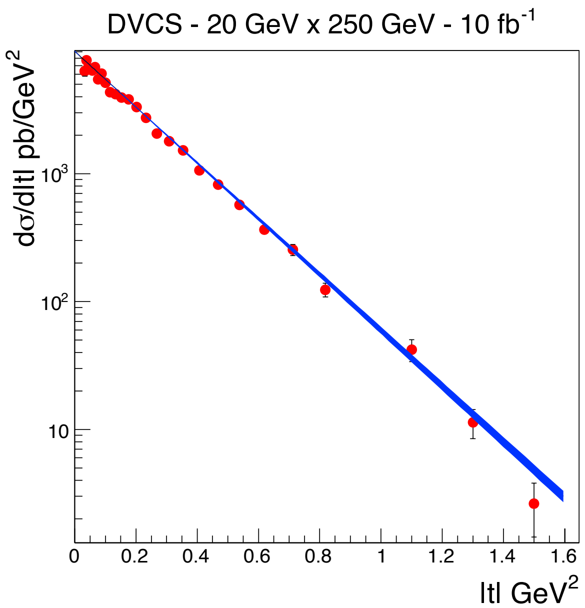
Roman Pots set up at STAR / RHIC

- Scattered with ~O(mrad): Need a detector close to the beam - Roman Pot to detect
- Large angle (high-t) acceptance mainly limited by beam aperture [$t \sim p_T^2 \sim p^2\theta^2$]
- Small angle (low-t) acceptance limited by beam envelop ($\sim< 10\sigma_{beam}$)
- Reconstruction resolution limited by
  - beam angular divergence (~O(100μrad)), emittance
  - uncertainties in beam offset, crossing, transport, detector alignment, vertex reconstruction resolution
  - at RHIC
    - $\delta p/p \sim 0.005$
    - $\delta t/t \sim 0.03/\sqrt{t}$
  - in addition, effect of crab crossing (expected to be << beam divergence) need to be simulated

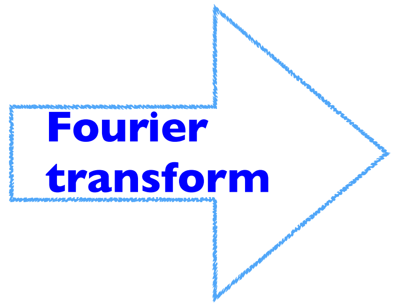
Impact of proton acceptance

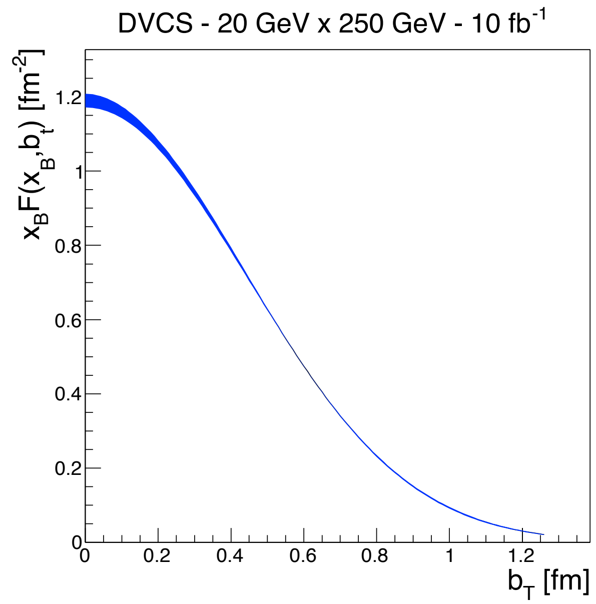
Measurement

Physics observable (cross-section vs impact parameter)

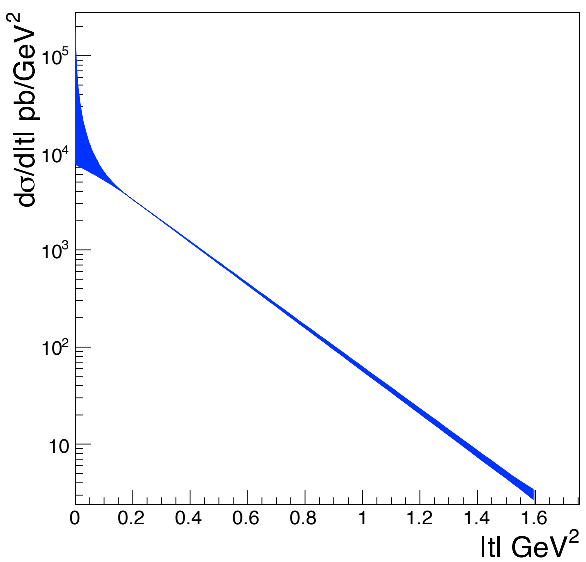


Plots from
EIC White Paper:

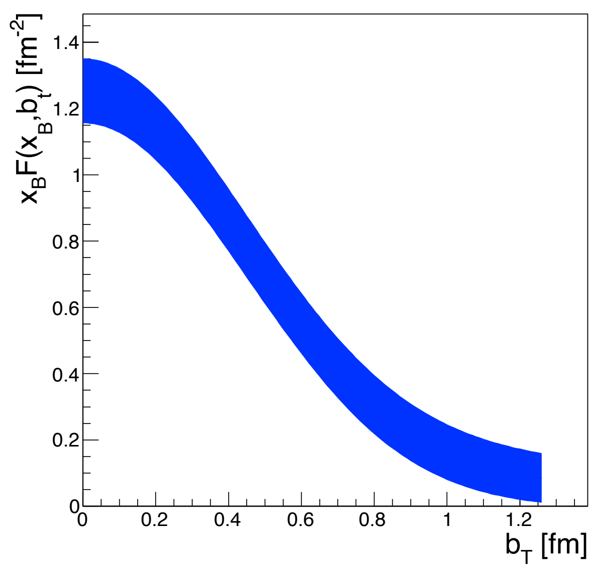




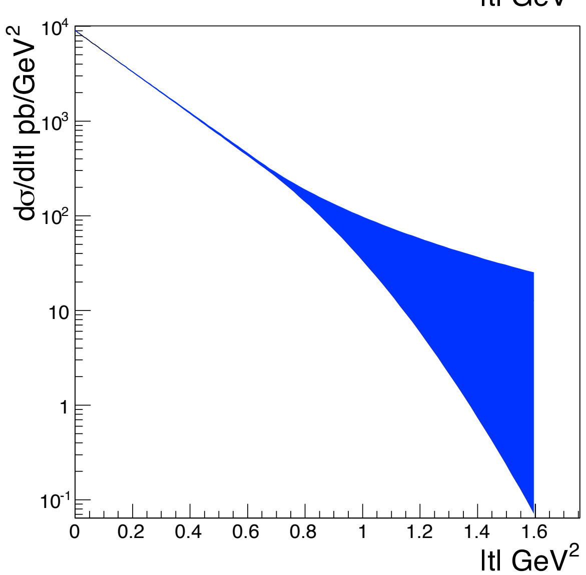
Requirement:
$\int L_{int} = 10 fb^{-1}$
$0.18 < p_t$ (GeV) < 1.3
$0.03 < |t|$ (GeV^2) < 1.6



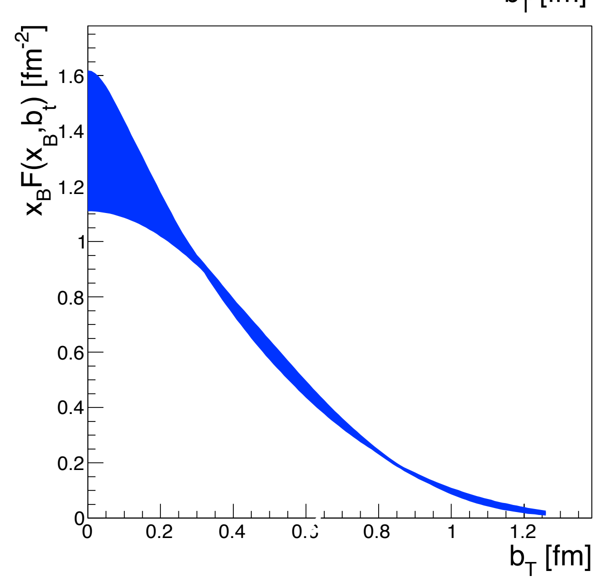
limited
lower
p_T-acceptance



$\int L_{int} = 10 fb^{-1}$
$0.44 < p_T$(GeV) < 1.3

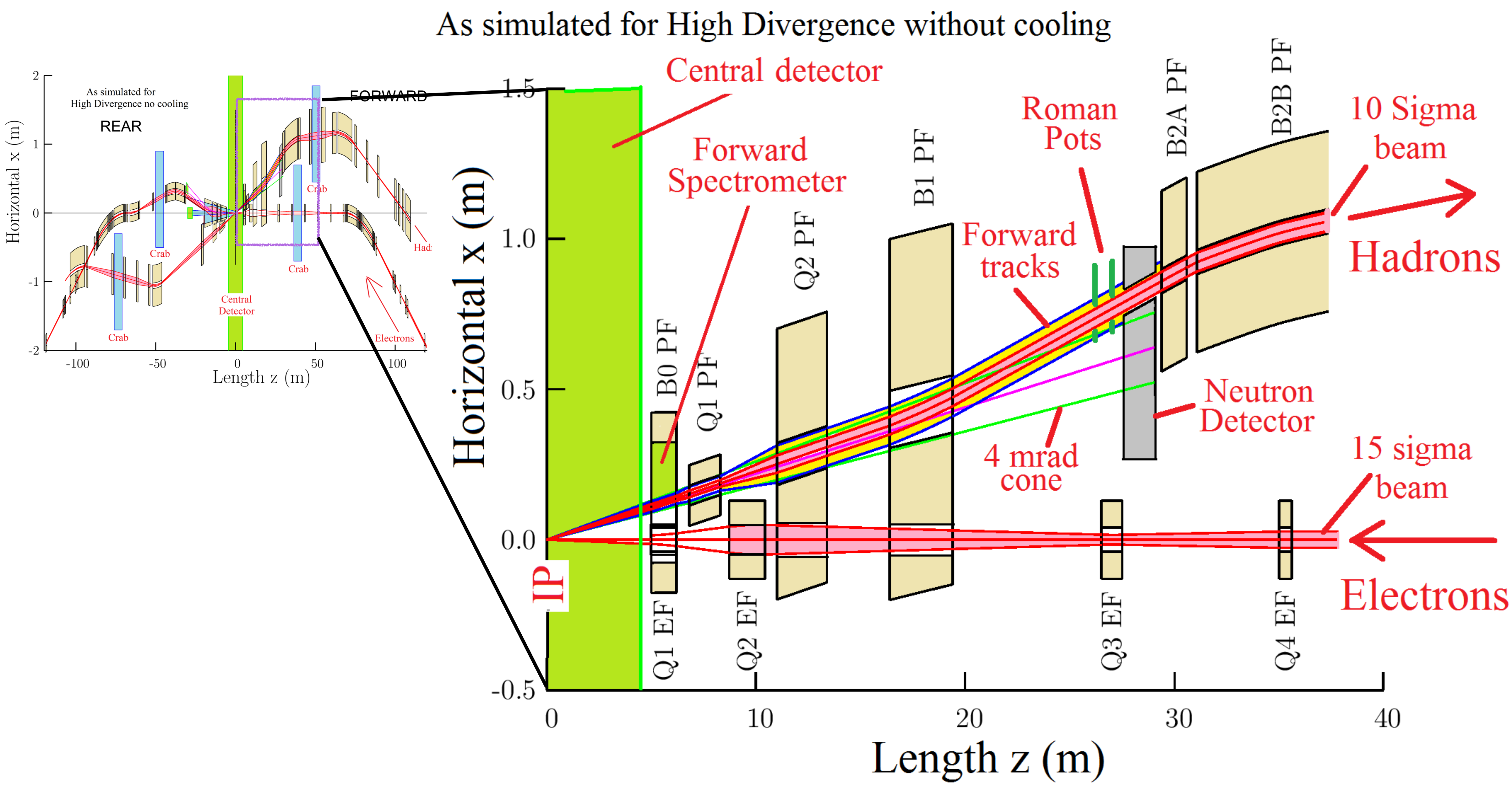


limited
higher
p_T-acceptance



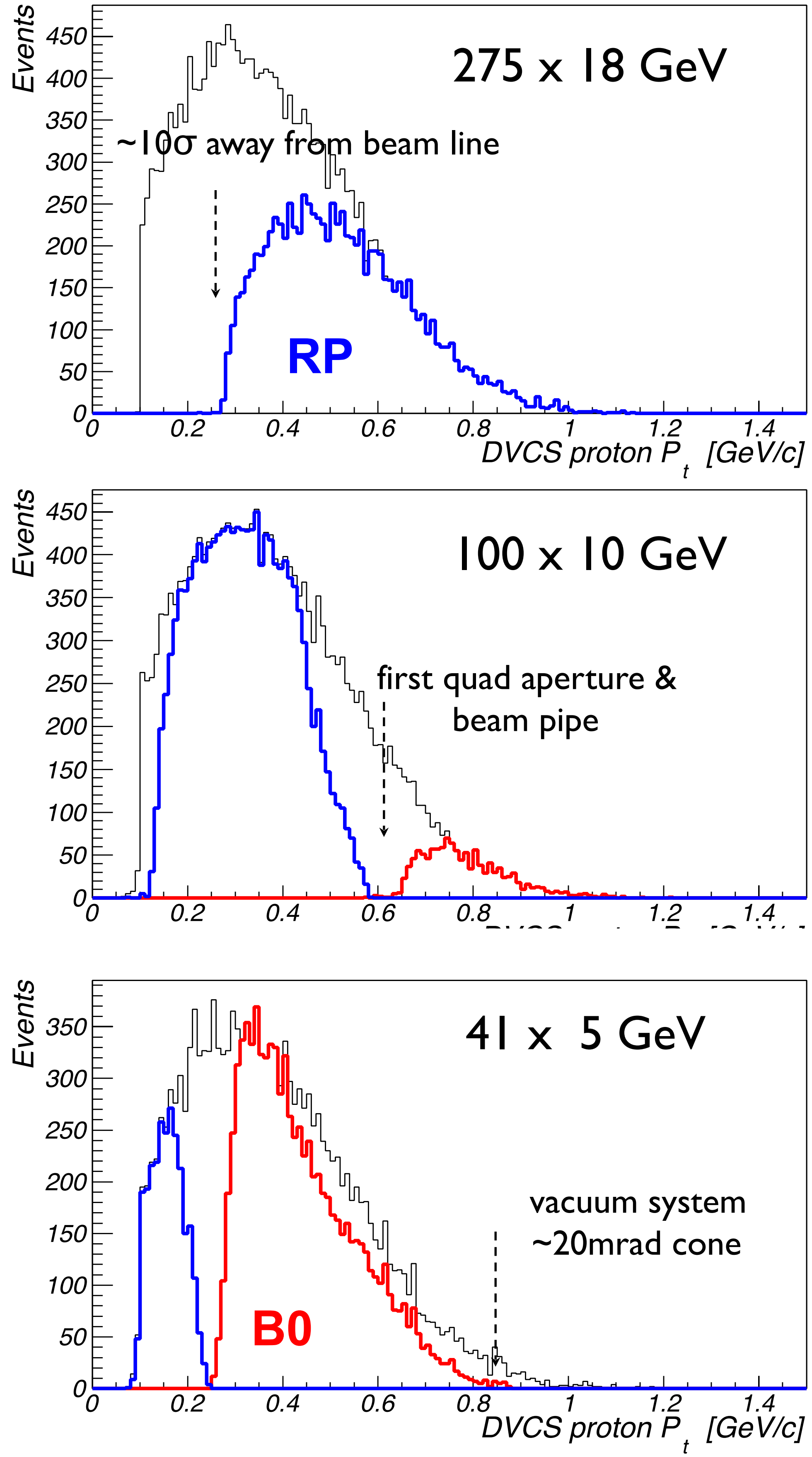
$\int L_{int} = 10 fb^{-1}$
$0.18 < p_T$ (GeV) < 0.8

IR design at eRHIC

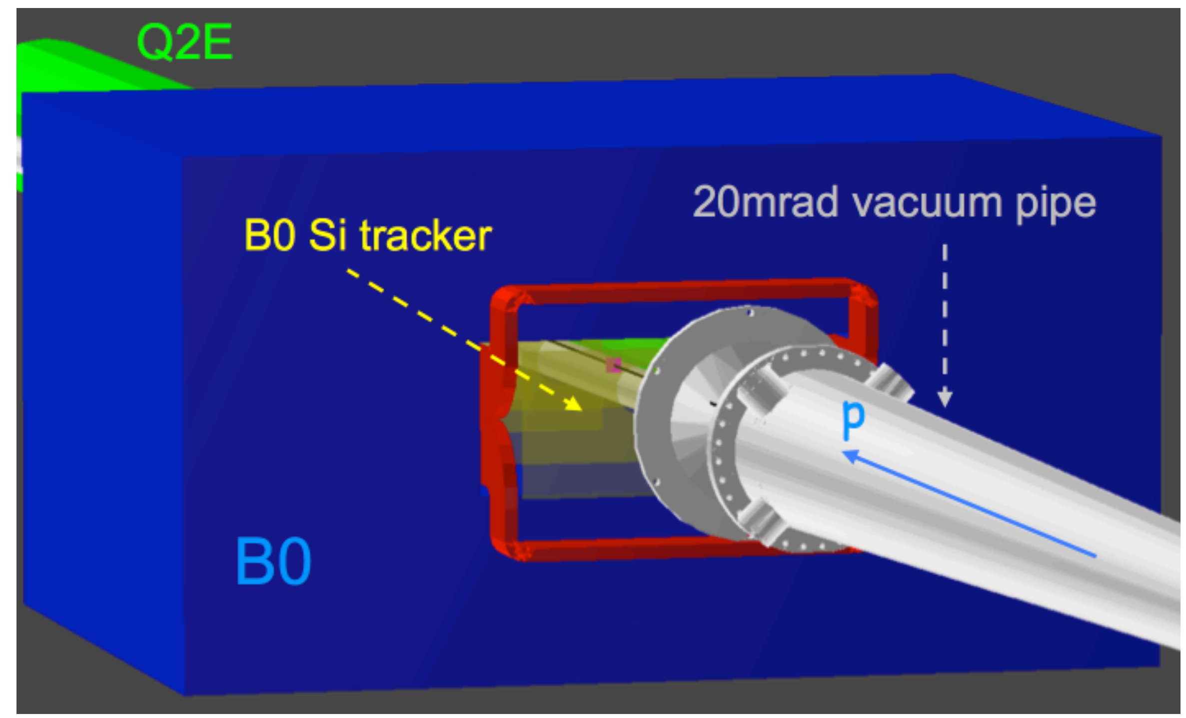


- Integrating requirements for hadron beam direction
  - Forward Detector (6 - 20 mrad)
  - Neutron detector ZDC (0 to 4 mrad)
  - Roman Pots (sensitive 1 to 5 mrad)
- electron and hadron polarimetry at separate IR @ IP-12

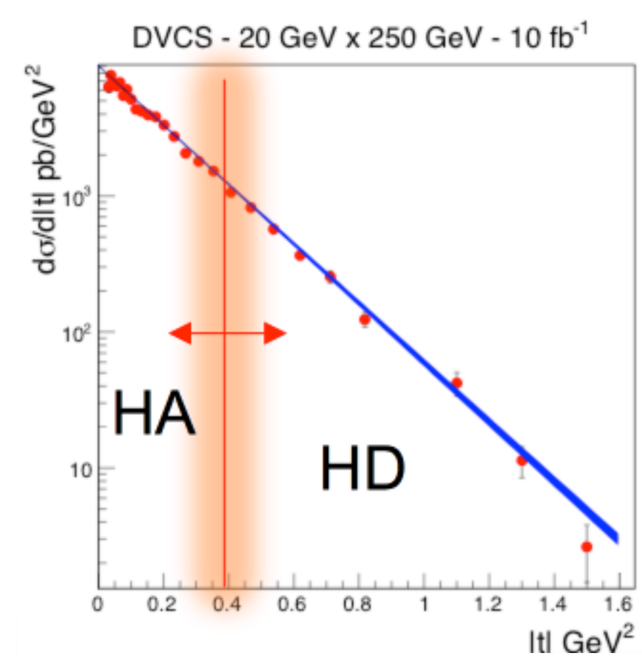
Proton acceptance with eRHIC



p_T acceptance for forward scattered protons from exclusive reactions

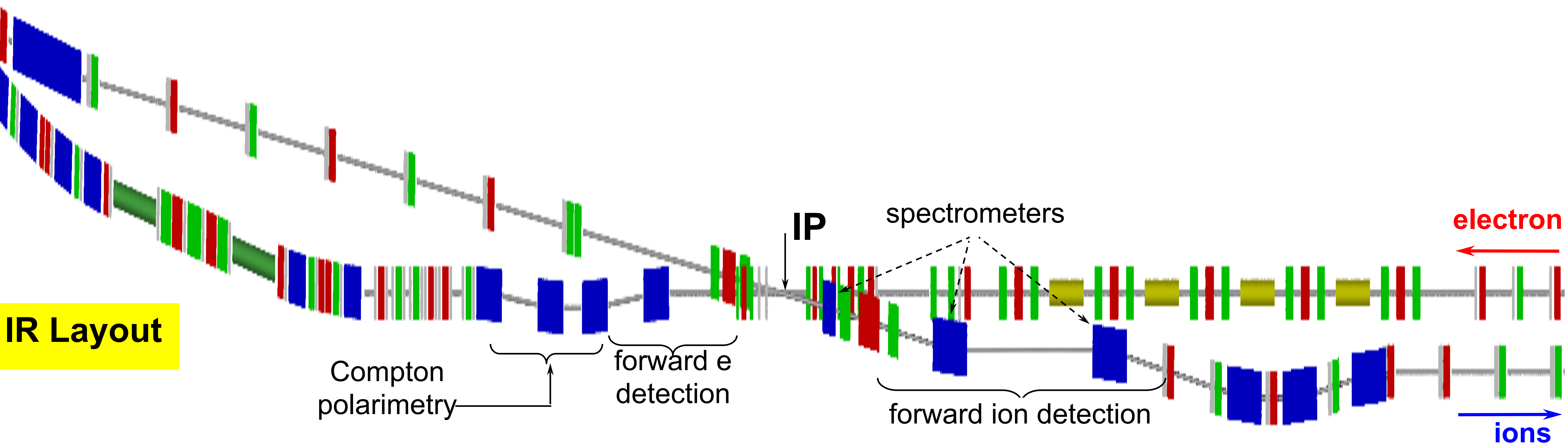


- Plots: HD (high divergence) mode
- Acceptance gap between RP and B0 will be further optimized



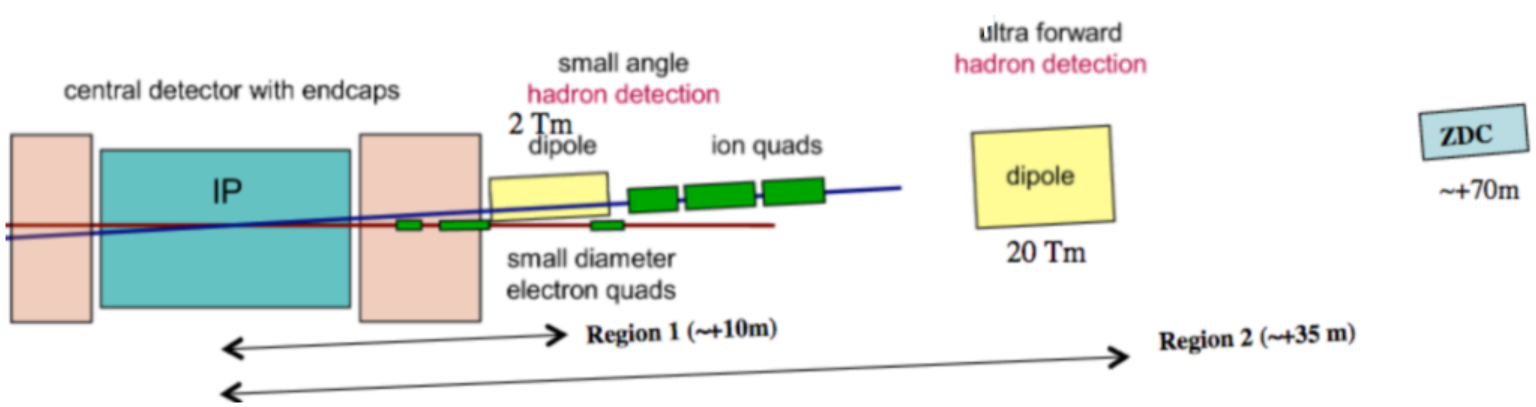
Accept 0.3 < p_T< 1.3 GeV and higher
→ Low p_T-part can be filled in with HA (high acceptance, smaller beam divergence) running mode

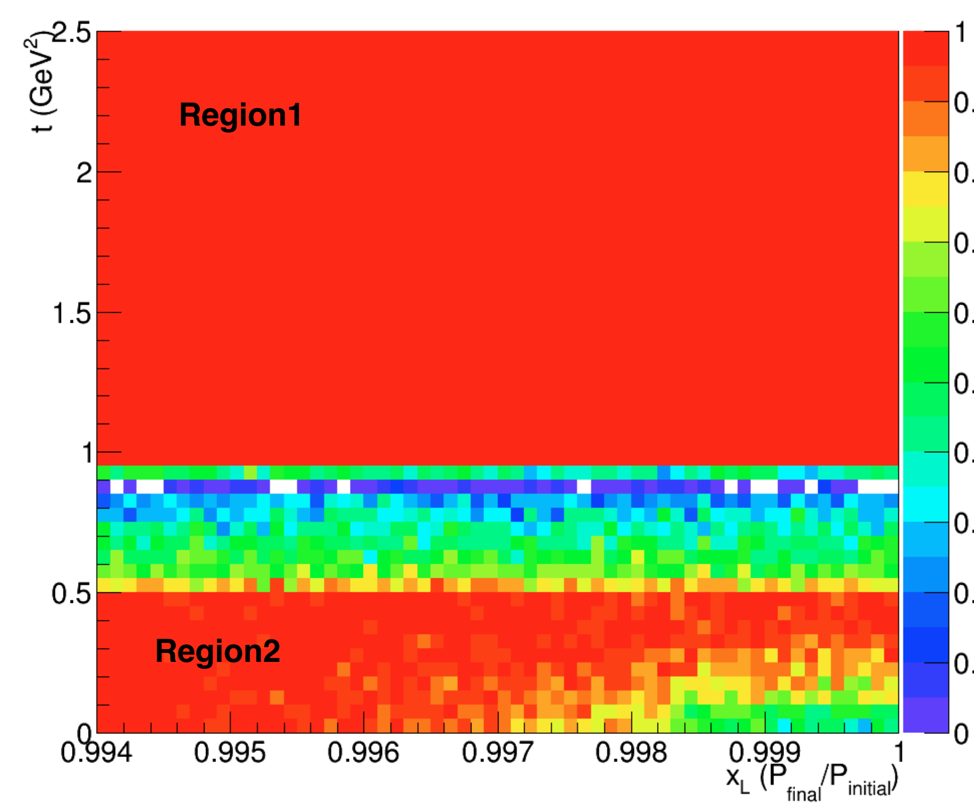
Proton acceptance with JLEIC



Two forward charged hadron detector regions:

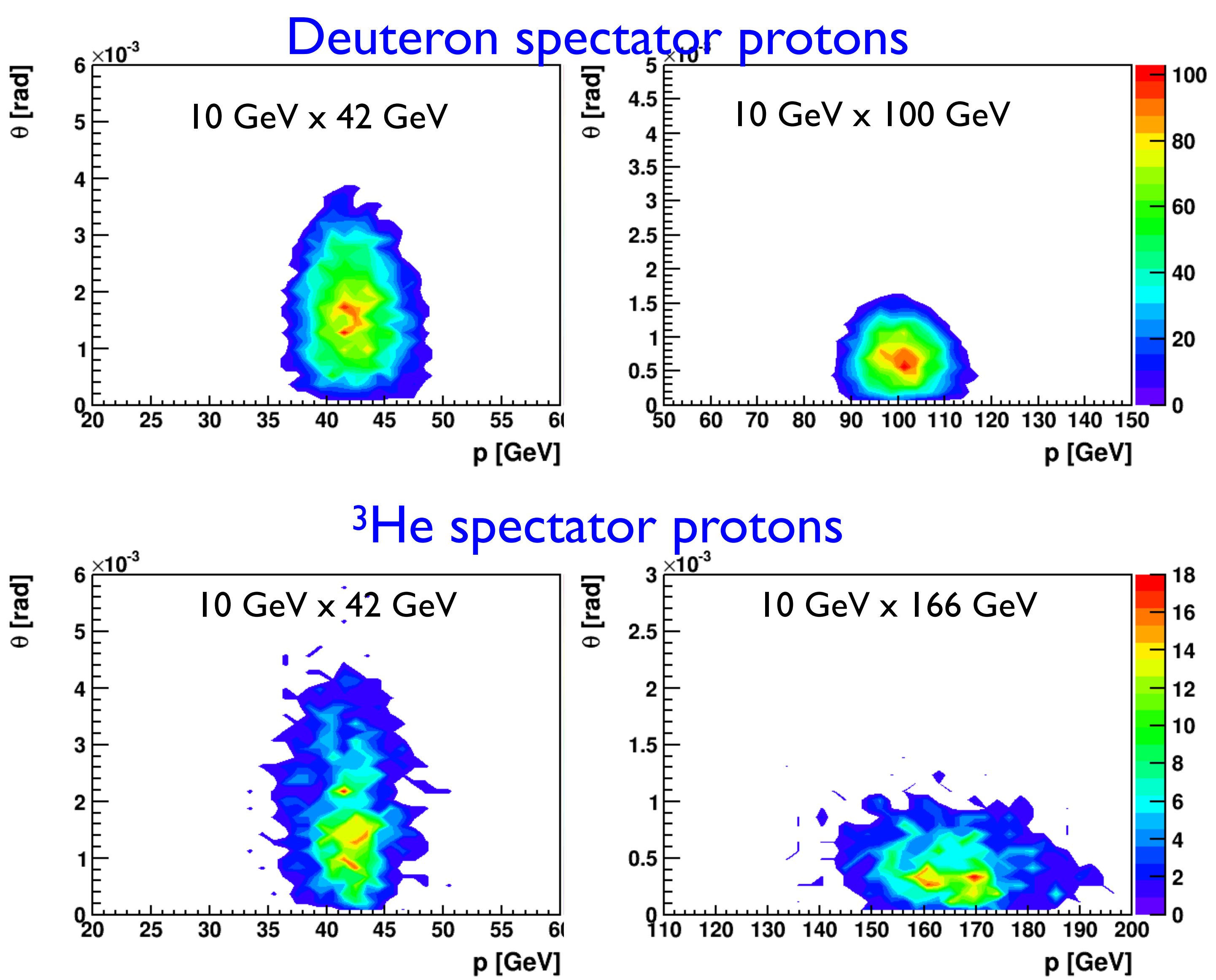
- Region 1: Small dipole covering scattering angles from 0.5 up to a few degrees (before quads)
- Region 2: Far forward, up to one degree, for particles passing through (large aperture) accelerator quads. Use second dipole for precision measurement. (Hi Res)





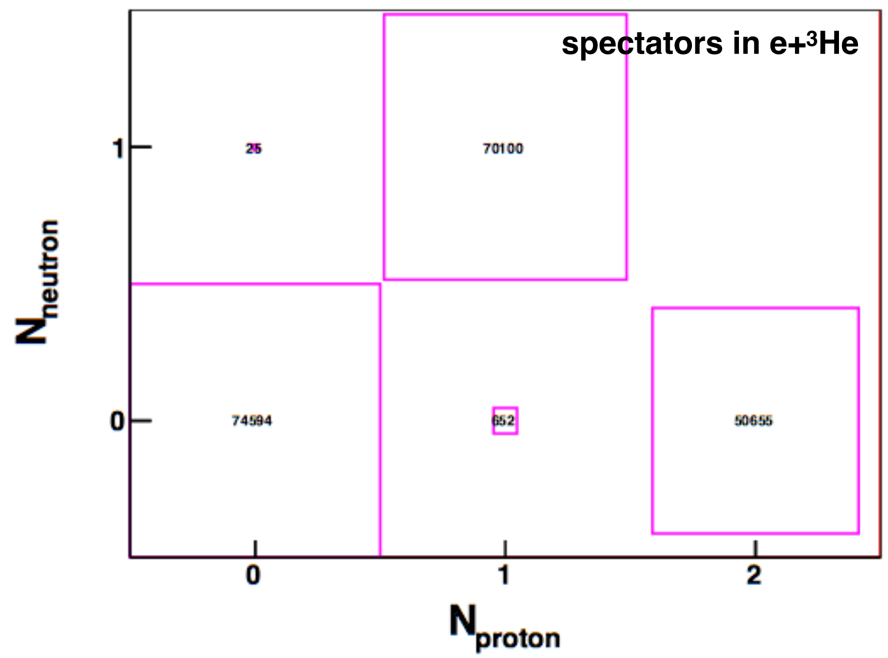
R.Yoshida Polarized Light Ions at EIC 2018

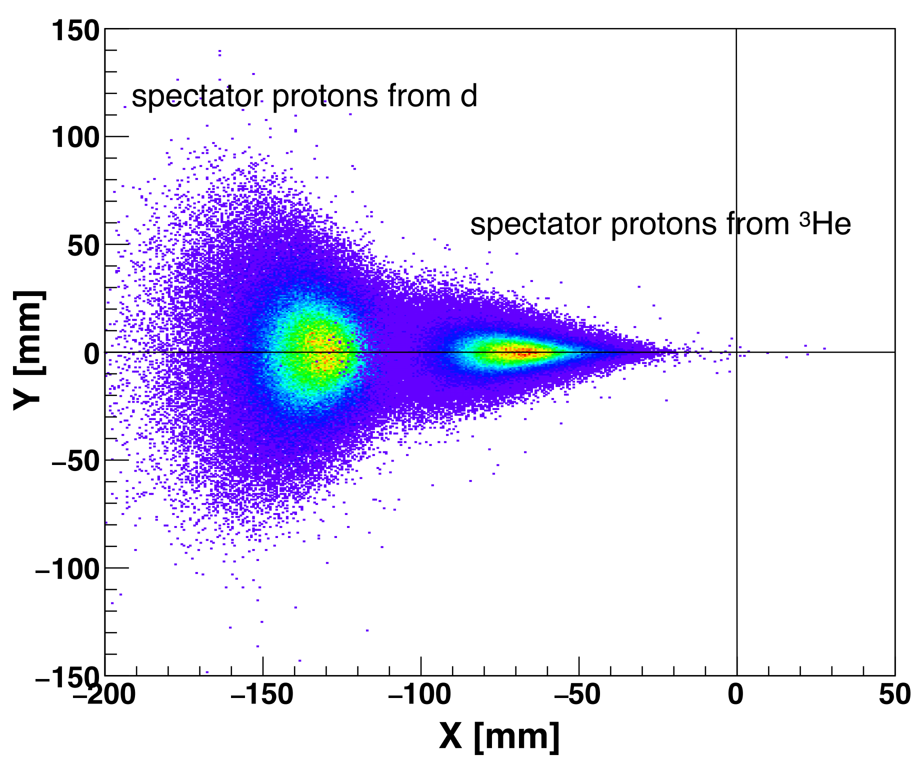
Spectator protons in ^{3}He, d



- Crucial for identifying processes with a neutron "target" [e(p)+n] in light ions - d, ^{3}He
  - Spectator neutron (<~4 mrad) can be identified by a calorimeter at beam rapidity (zero degree calorimeter)
  - Tagging spectator protons from d, ^{3}He
    - Relying on separation from magnetic rigidity (B_r) changes
      ^{3}He: p = 3/2:1 d:p = 2:1
    - Momentum spread mainly due to Fermi motion + Lorentz boost

Spectator protons with Roman Pots





- Unambiguously identified e+p event vs e+n event in e+^{3}He
  1p +1n vs 2p = 30% vs 22% (DPMJetIII)
- Common detector RP be utilized for tagging forward proton from diffraction and the spectator protons from ^{3}He?
- measurement can be done with RPs + forward detector + ZDC
- Shown example distribution at fixed RP locations at eRHIC IR
- Detectors can be configured to optimize the acceptance

Roman Pots at EIC: considerations

- Integral part of IR design
  - beam divergence, aperture limit, multiple running mode/beam parameters
  - optimized location for optimal performance and acceptance
- Coverage
  - need to measure diffractive protons in beam envelop - aperture limit with full φ acceptance
  - need wide coverage in momentum for tagging spectator protons for light ions
- Operation
  - operation no disturbance to the beam, routine operation
  - run simultaneously with normal operation for high luminosity sampling (ref: RHIC, LHC)
- Detector technology
  - tracking silicon/pixel + timing/triggering counter (ref: latest development at LHC)
  - space constraint for full φ coverage in horizontal: 2d-move
  - geometrical configuration/size for maximal coverage for various energies

Summary

- Forward nucleon tagging crucial part of EIC physics
- Requirement for forward detectors are integrated in the IR design
- The IR with the forward detector system (Roman Pot) can cover physics needs for wide ranges of nucleon energies in ep and eA (50 - 275 GeV/nucleon)
- More detailed simulation and detector design study with further optimization underway