JLEIC Forward Detector Design and Performance

Rik Yoshida

on behalf of the JLEIC detector study group

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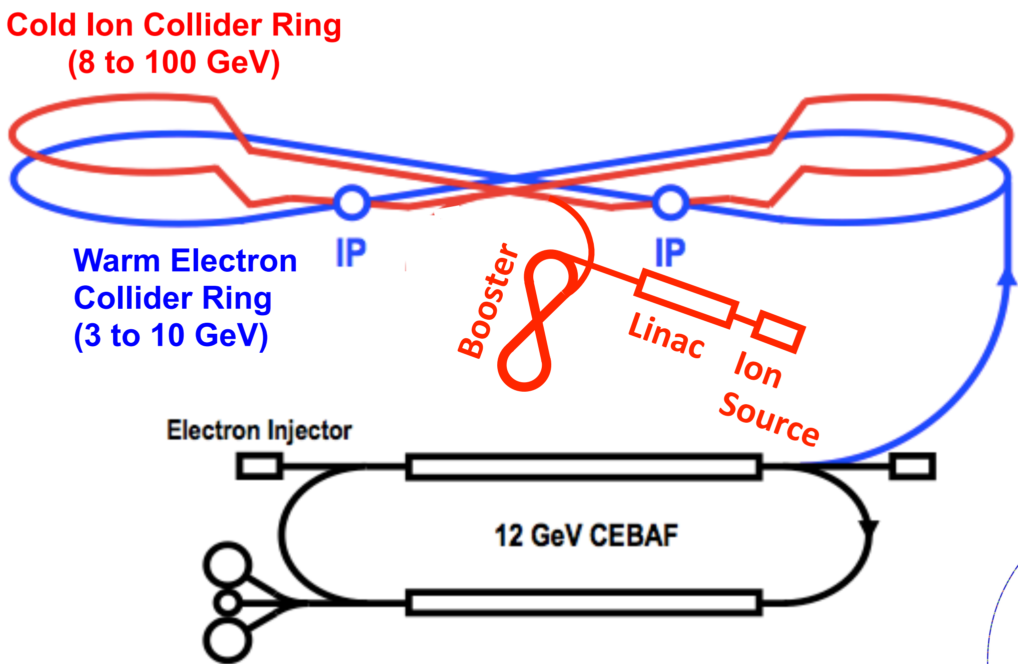
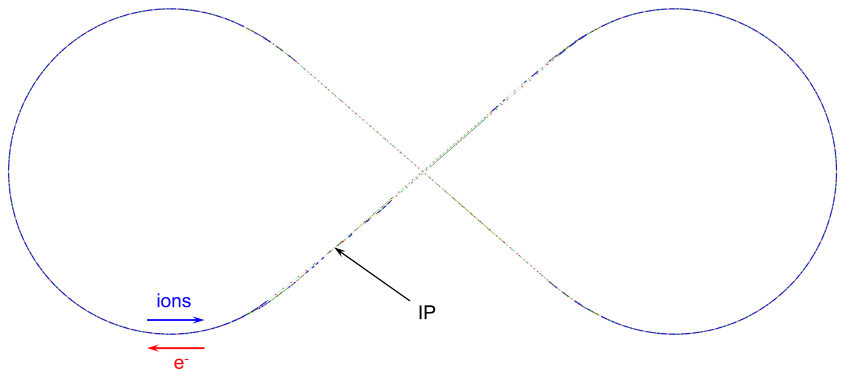
MEIC Layout & Detector Location



Two IP locations:

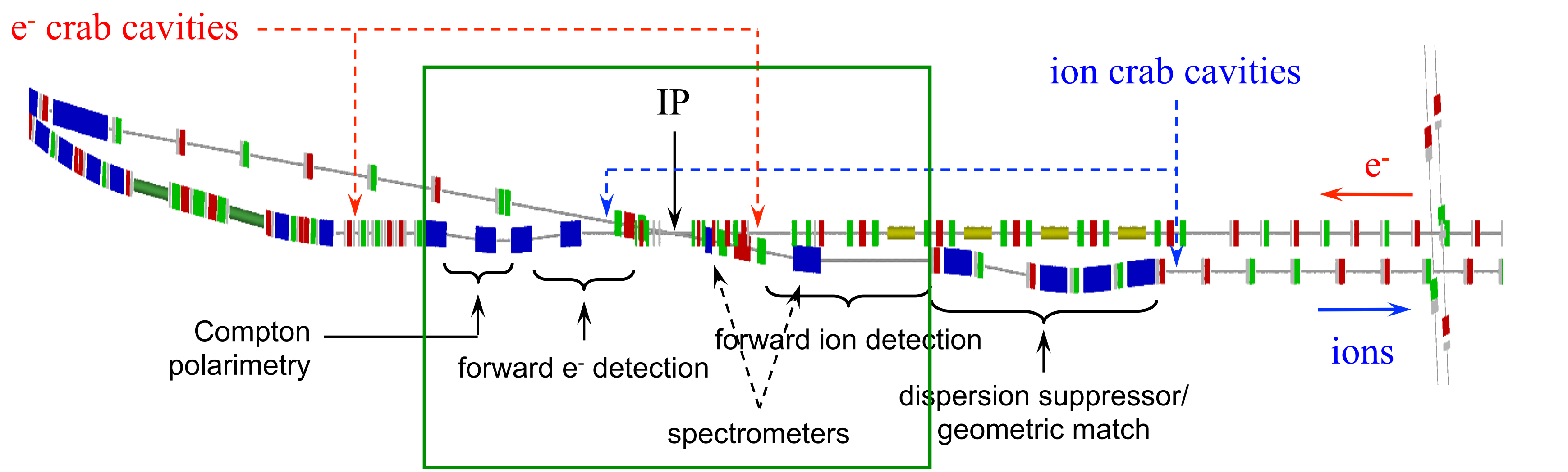
- One has a new detector, fully instrumented
- Second is a straight-through, minor additional magnets needed to turn into IP

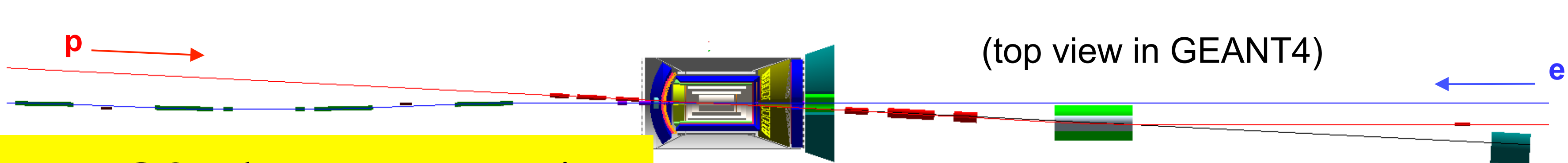


Considerations:

- Minimize synchrotron radiation
  – IP far from arc where electrons exit
  – Electron beam bending minimized in the straight before the IP
- Minimize hadronic background
  – IP close to arc where protons/ions exit

Detector Region Layout



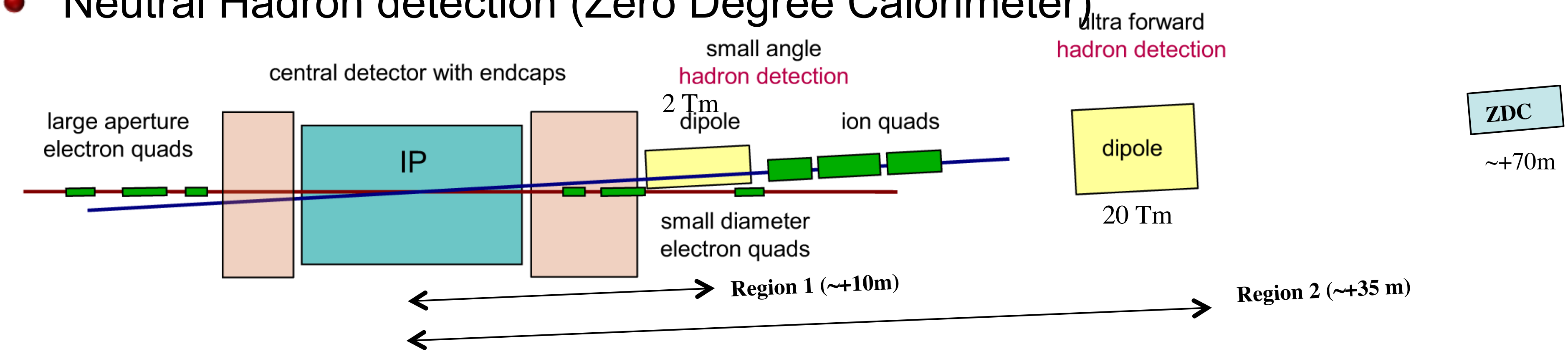


Low-Q2 Electron Detection Polarimeter

Forward Hadron Detection

Forward Hadron Detection

- 50 mrad crossing angle
  - No parasitic collisions, fast beam separation. Room for dipoles and detectors forward. (1m separation of beams at ~+30 m)
- 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)
- Neutral Hadron detection (Zero Degree Calorimeter)

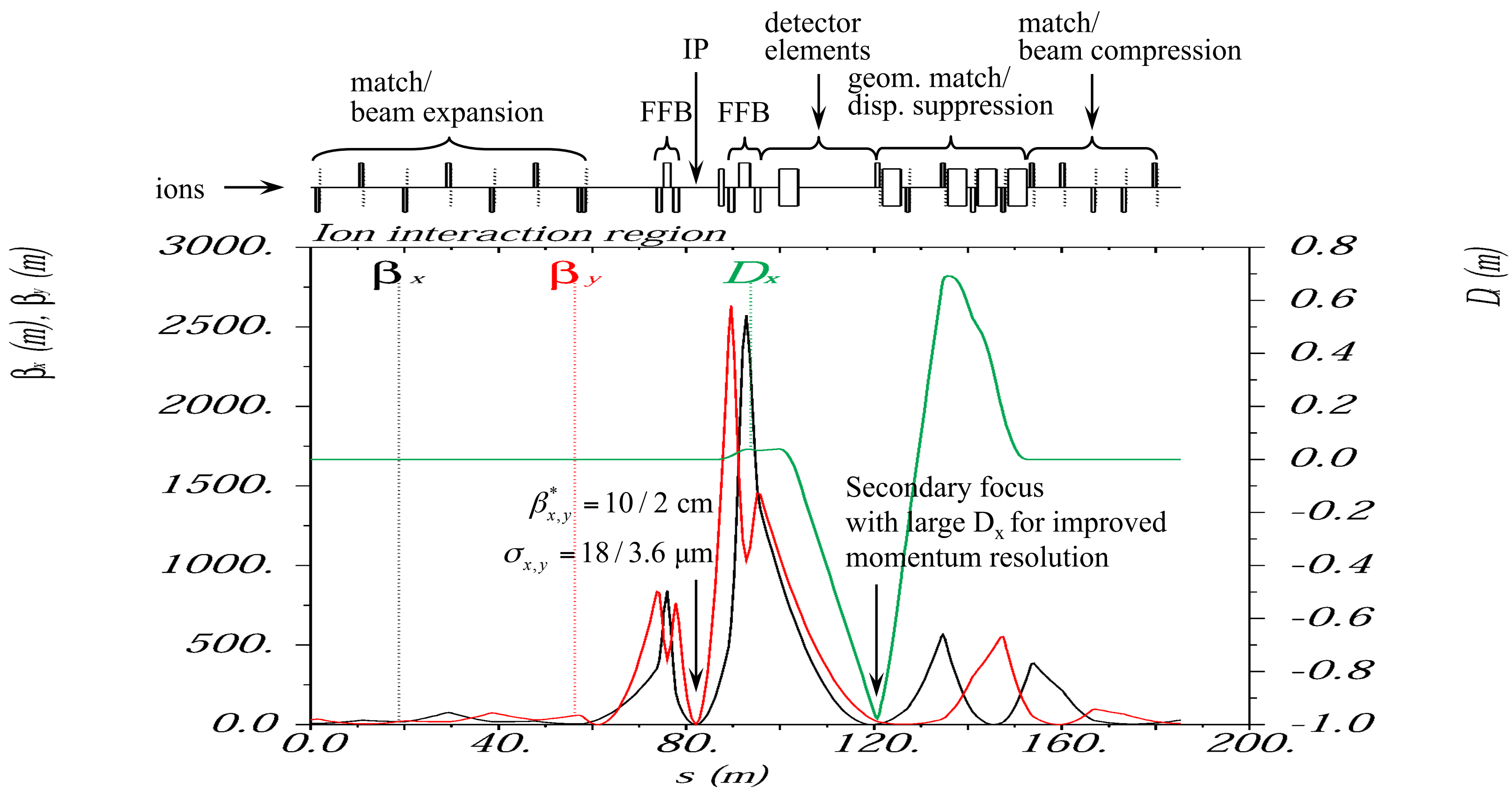


~100% acceptance for forward hadrons

P. Nadel-Turonski, R. Ent, C.E. Hyde

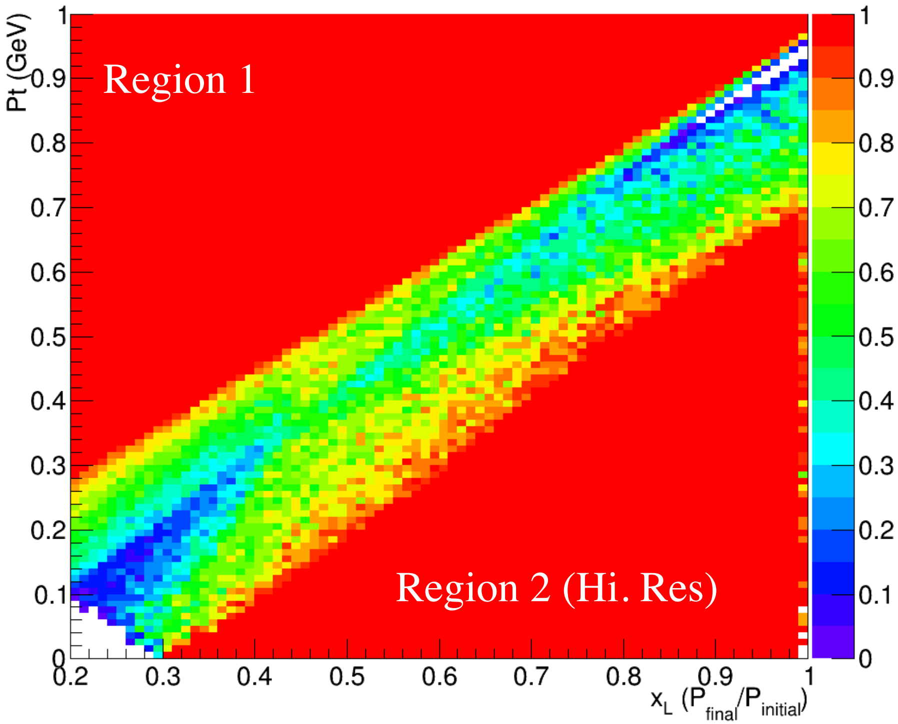
Baseline Ion Optics

- For forward detection region (region 2)
  - Secondary focus: enables detectors to get close
  - Large dispersion: maximize acceptance and resolution.



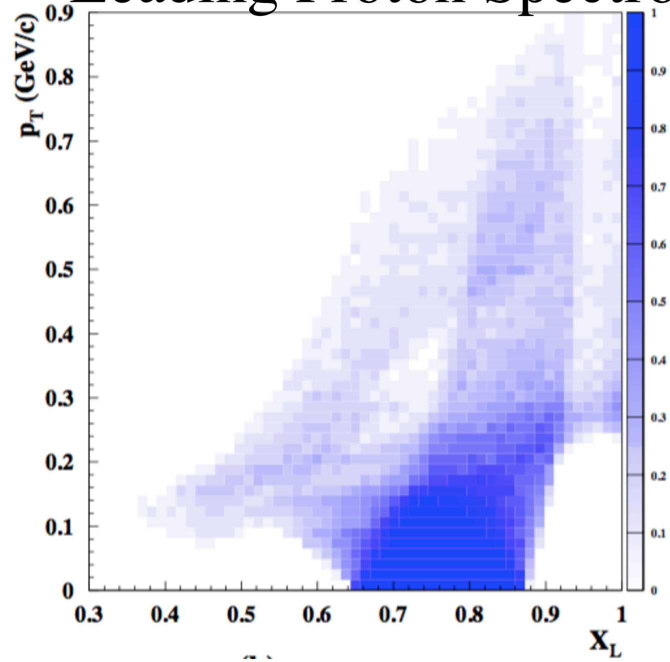
Acceptance for p’ in ep->e’Xp’

JLEIC acceptance



Zhiwen Zhao (Duke)

ZEUS
Leading Proton Spectrometer



Acceptance in diffractive peak (X_L>~.98)

ZEUS: ~2%

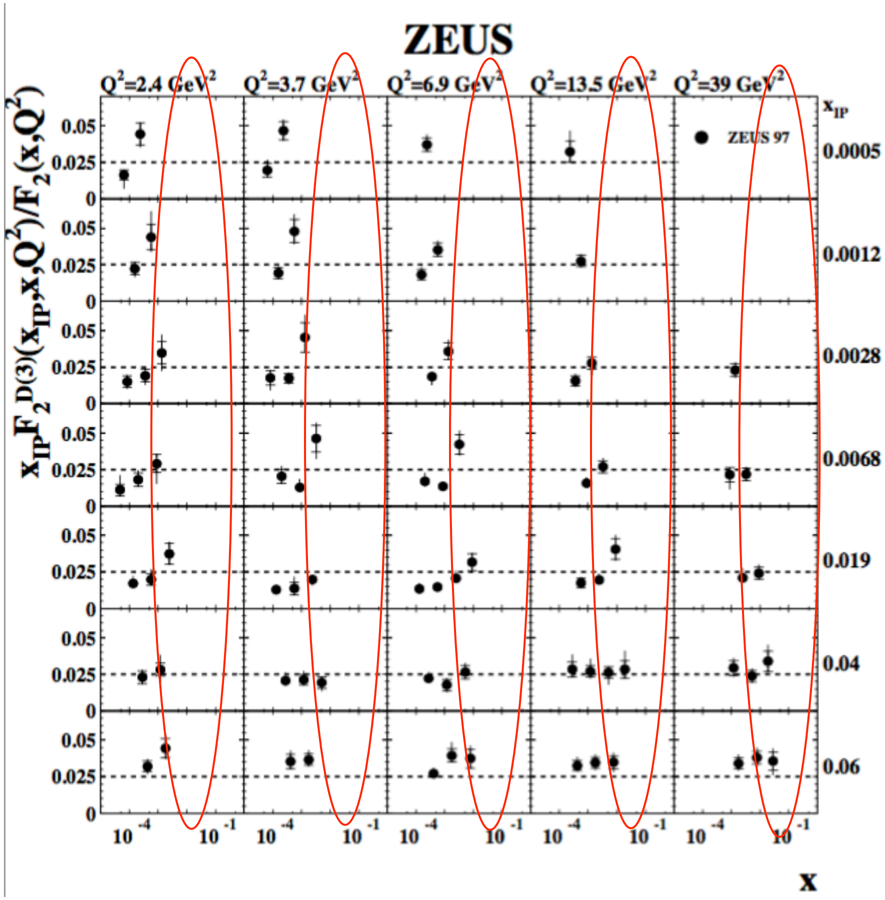
JLEIC: ~100% (also covers much higher X_L than ZEUS)

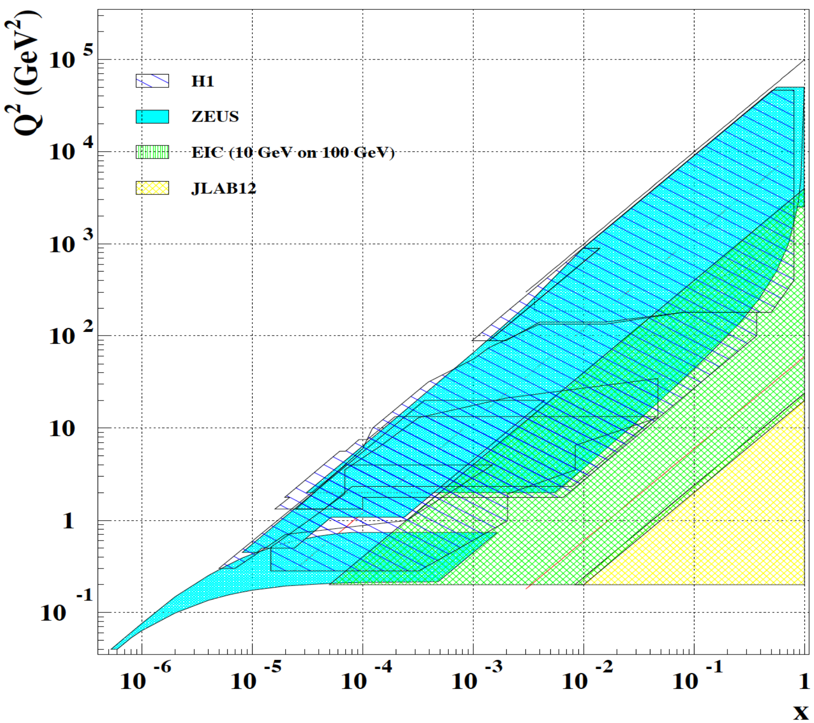
Implications of 100% Acceptance

- Compared to HERA: Increase in statistics for tagged forward protons:
  - Factor 50 from acceptance (compared to ZEUS LPS)
  - Factor 100-1000 from luminosity (10^{33-4} compared to 10^{31})
- Compared to HERA: Increase in phase space of diffractive measurements with tagged proton.
  - Higher X_L (Lower X_{IP}, as low as 10^{-4})
- Tagged proton is "always available":
  - No need to rely on the analysis of X in ep->e'Xp'.
  - No need for extrapolation of rapidity gap, or M_X
  - No estimate of inelastic part for subtraction needed.
- Lead to reduction in uncertainties
  - Statistical (factor 100)
  - Systematic (Acceptance uncertainties small in most kinematic regions.
- Proton tag always available for DVCS, and VM elastic productions.

Will revolutionize understanding of hadrons!

Precision DIS Diffraction



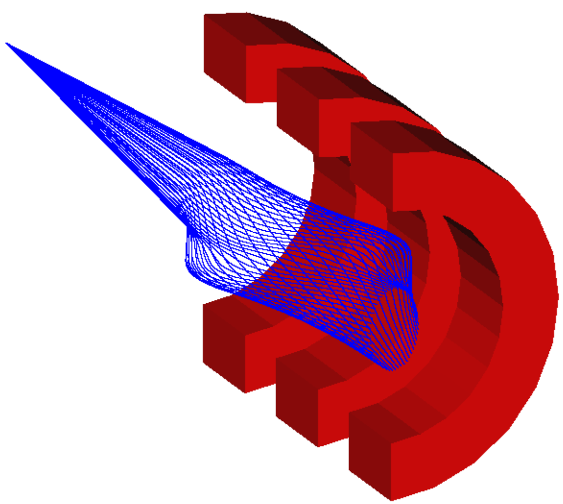


Will likely provide vastly improved precision compared to HERA (500 to 5000 more statistics)

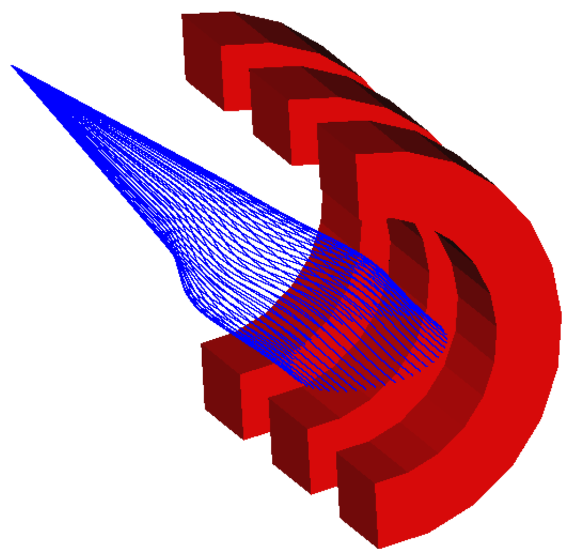
Far-Forward Acceptance for Ion Fragments

(protons rich fragments) (neutron rich fragments)

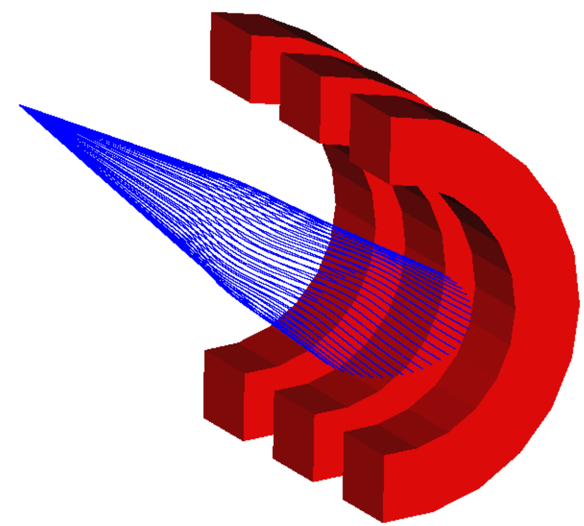
Δp/p = -0.5
(spectator protons from deuterium)



Δp/p = 0.0
(exclusive / diffractive recoil protons)

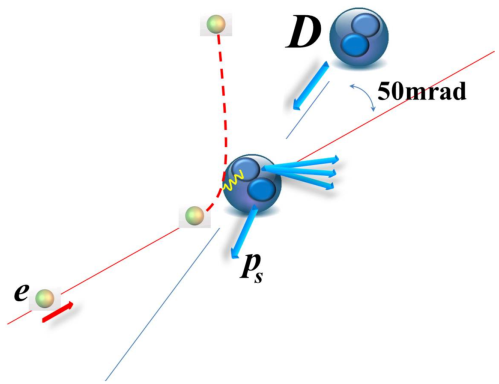


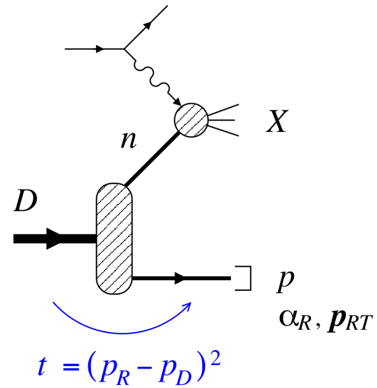
Δp/p = 0.5
(tritons from N=Z nuclei)

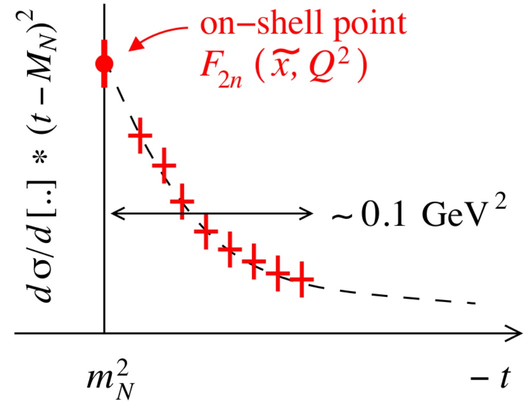


Forward geometry will provide ~100% acceptance for all cases

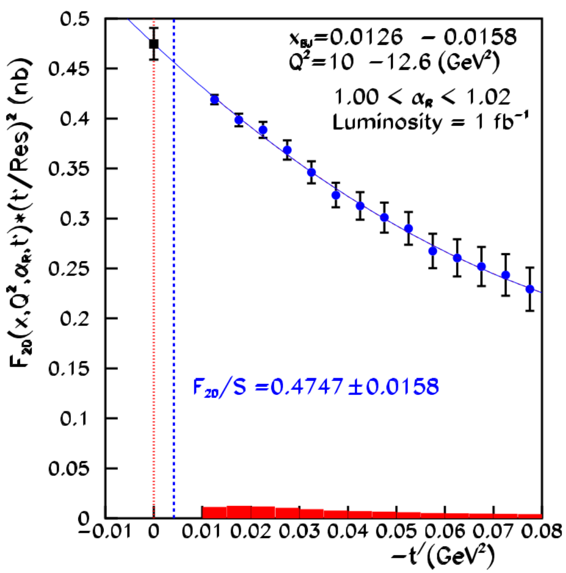
Neutron Structure Extrapolation in t







Kijun Park (ODU)

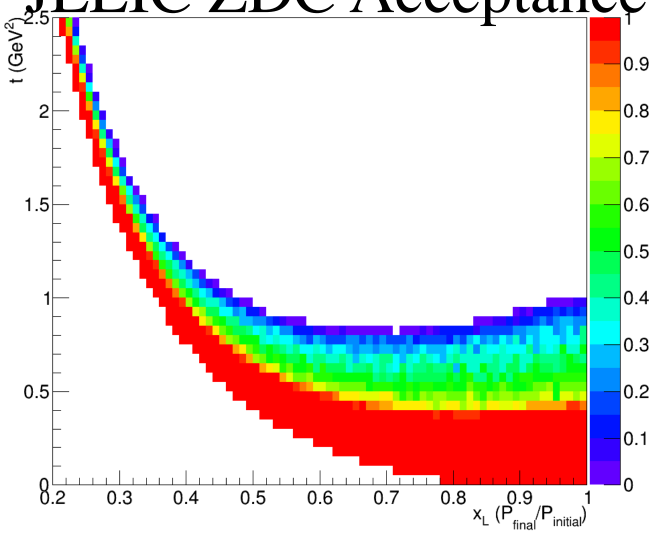


t resolution better than
Fermi momentum (20 MeV)
Set by ion beam momentum spread

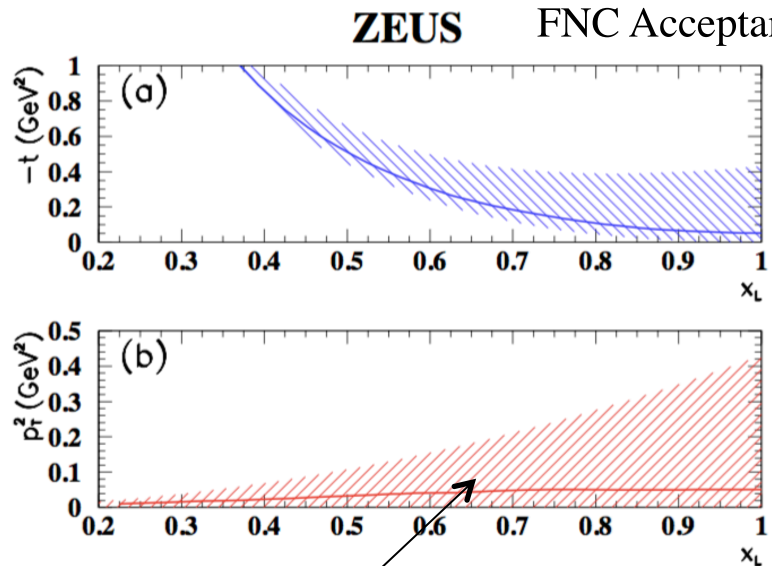
Precision Extraction of F2n

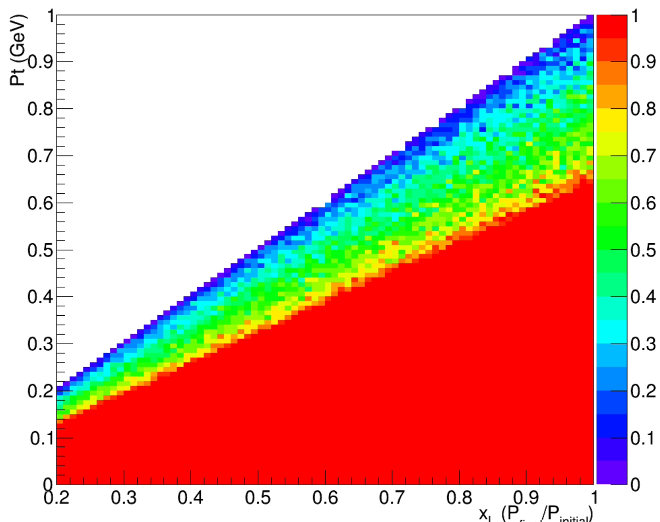
Neutron Acceptance for ep->e'Xn

JLEIC ZDC Acceptance



FNC Acceptance





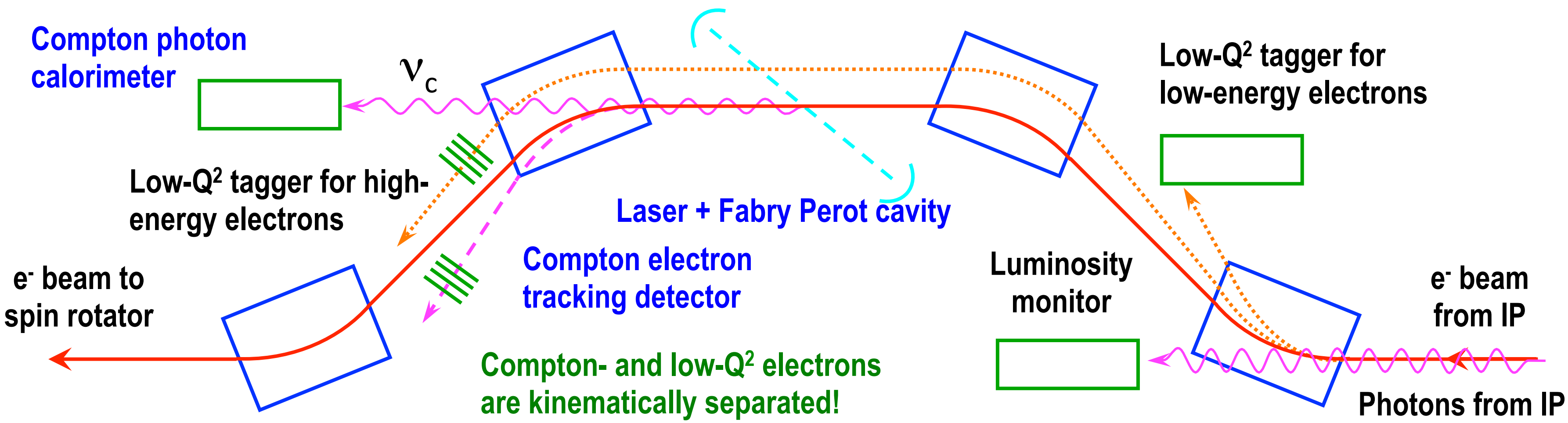
Zhiwen Zhao

~20% geometrical accep.

Doubles kinematic coverage
~5-10 times acceptance
compared to HERA

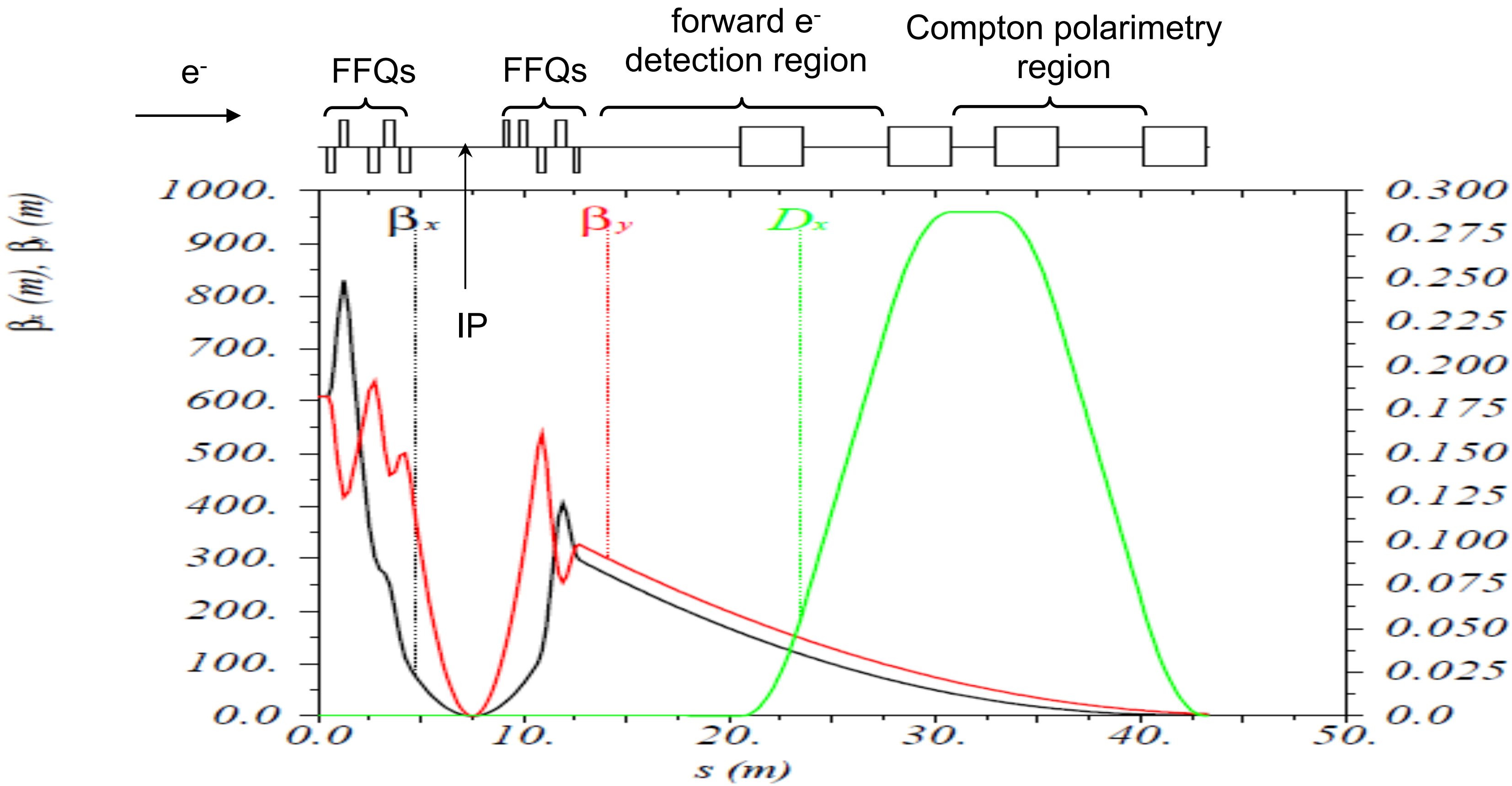
Forward e⁻ Detection & Pol. Measurement

- Dipole chicane for high-resolution detection of low-Q^2 electrons
- Compton polarimetry has been integrated to the interaction region design
  - same polarization at laser as at IP due to zero net bend
  - non-invasive monitoring of electron polarization



Baseline Electron IR Optics

- IR region
  - Final focusing quads with maximum field gradient ~63 T/m
  - Four 3m-long dipoles (chicane) with 0.44 T @ 10 GeV for low-Q2 tagging with small momentum resolution, suppression of dispersion and Compton polarimeter



Projected Rates and Measurements Times

Energy	Current	1 pass laser (10 W)		FP cavity (1 kW)	
(GeV)	(A)	Rate (MHz)	Time (1%)	Rate (MHz)	Time (1%)
3 GeV	3	26.8	161 ms	310	14 ms
5 GeV	3	16.4	106 ms	188	9 ms
10 GeV	0.72	1.8	312 ms	21	27 ms

1-Pass laser crossing angle: 0.3 deg.
FP cavity crossing angle: 2.6 deg.

Rates calculated analytically.

Time for 1% (statistics) measurement assumes 70% polarization
Rates integrated from asymmetry zero-crossing

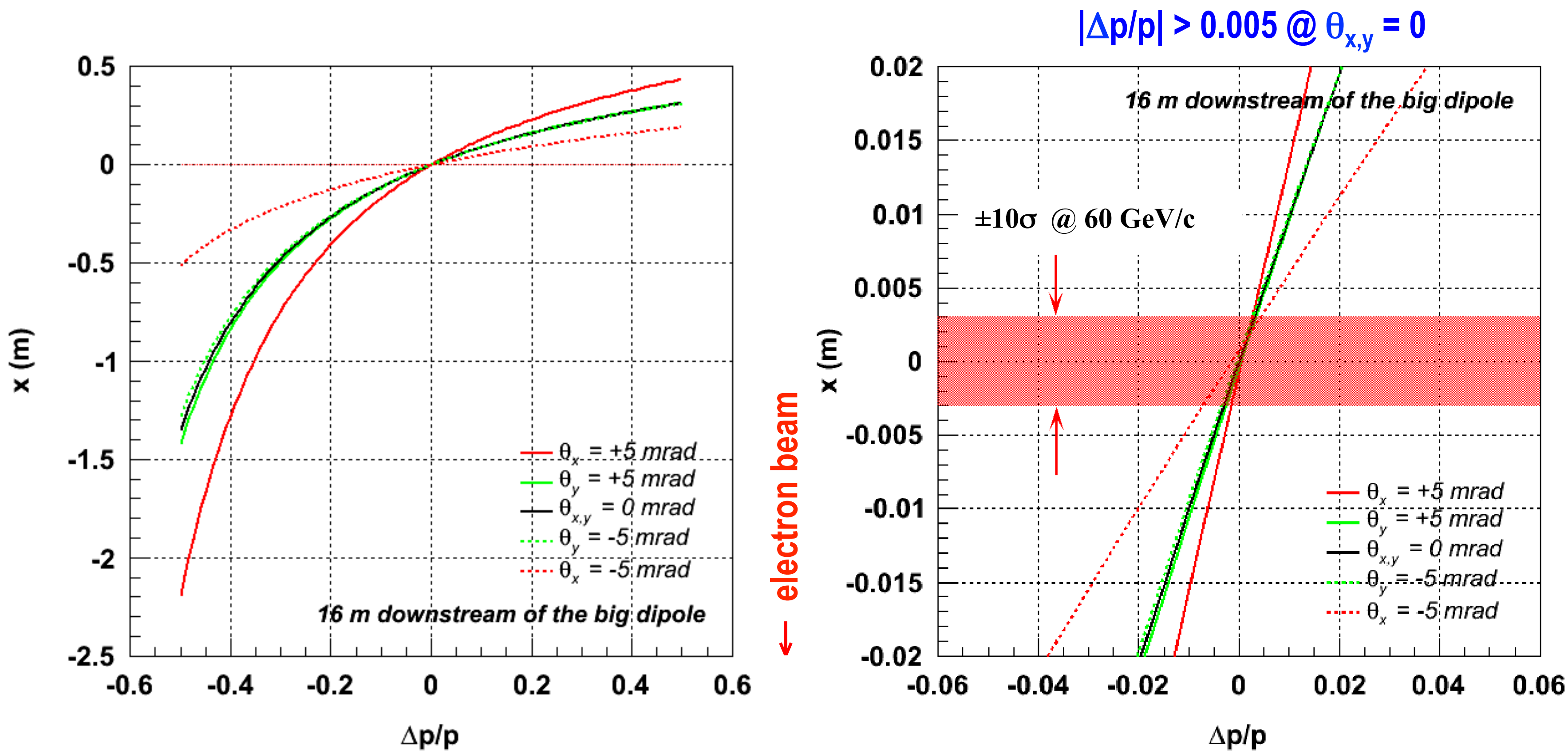
Extremely high rates when using FP cavity means that detectors (electron and photon) will have to operate in integrating mode in that case, but both options are viable.

Summary & Outlook

- *Some features of the Forward Detection area (both in the electron and ion directions) for JLEIC were described.*
- *Both areas extending 35 m (70m for ZDC), on either side, have been designed integrated with the accelerator.*
- *50mr beam crossing and careful design give the possibility for "100%" acceptance in both areas.*
- *In particular, I emphasized the acceptance in proton diffractive peak, in this talk.*
- *This unprecedented coverage, much superior to HERA collider detectors, is a key feature of JLEIC.*
- *The precision achievable in diffractive and elastic VM and DVCS, owing to this forward coverage, will likely qualitatively change the understanding of the nucleon, in the same way HERA changed the understanding of low-x region of the proton.*

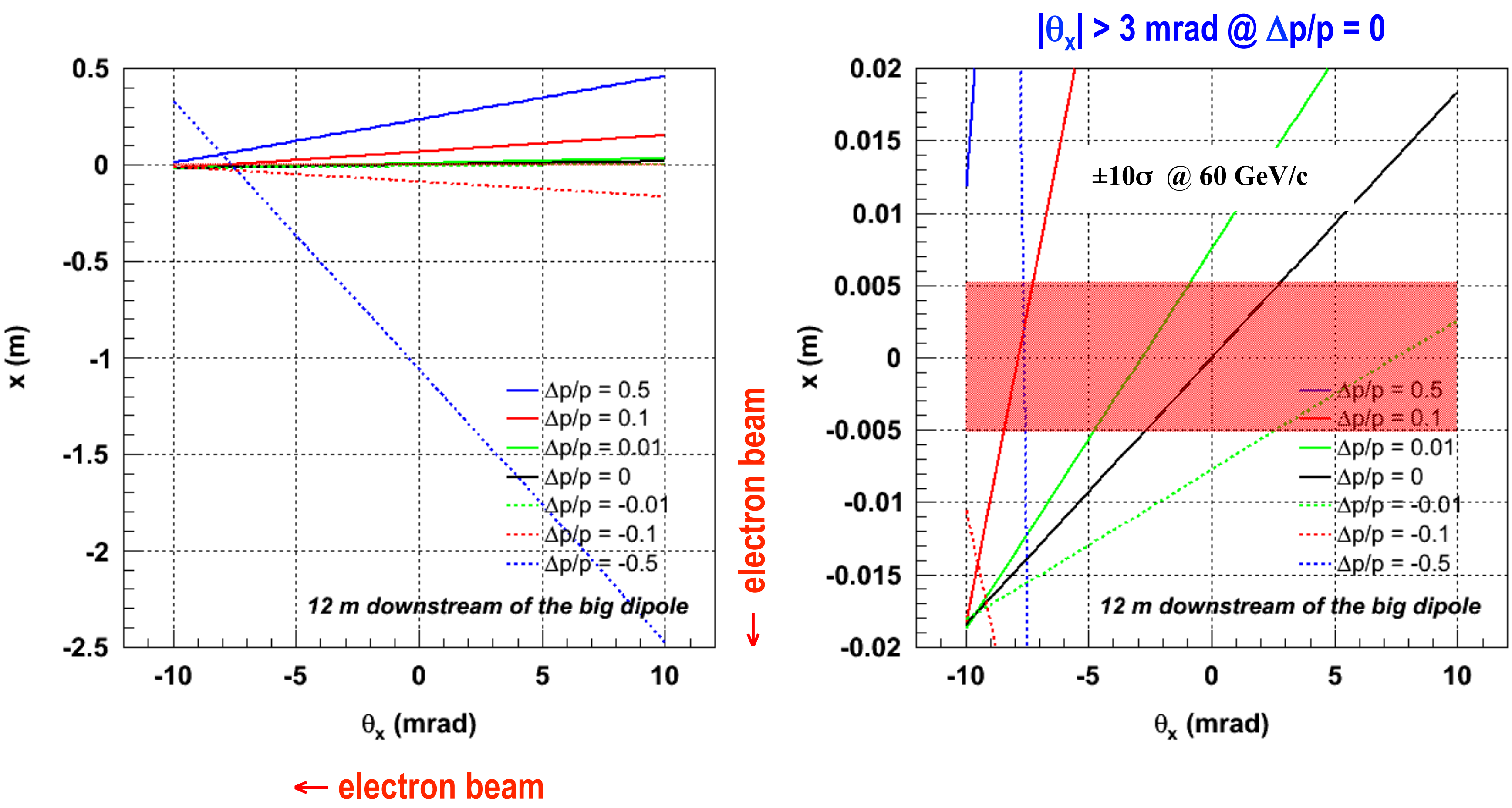
Ion Momentum & Angular Resolution

- Protons with Δp/p spread are launched at different angles to nominal trajectory
- Resulting deflection is observed at the second focal point
- Particles with large deflections can be detected closer to the dipole



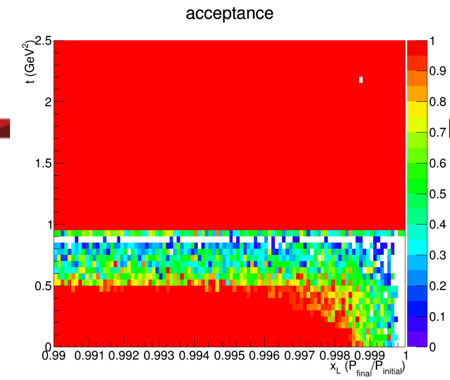
Ion Momentum & Angular Resolution

- Protons with different $\Delta p/p$ launched with θ_x spread around nominal trajectory
- Resulting deflection is observed 12 m downstream of the dipole
- Particles with large deflections can be detected closer to the dipole

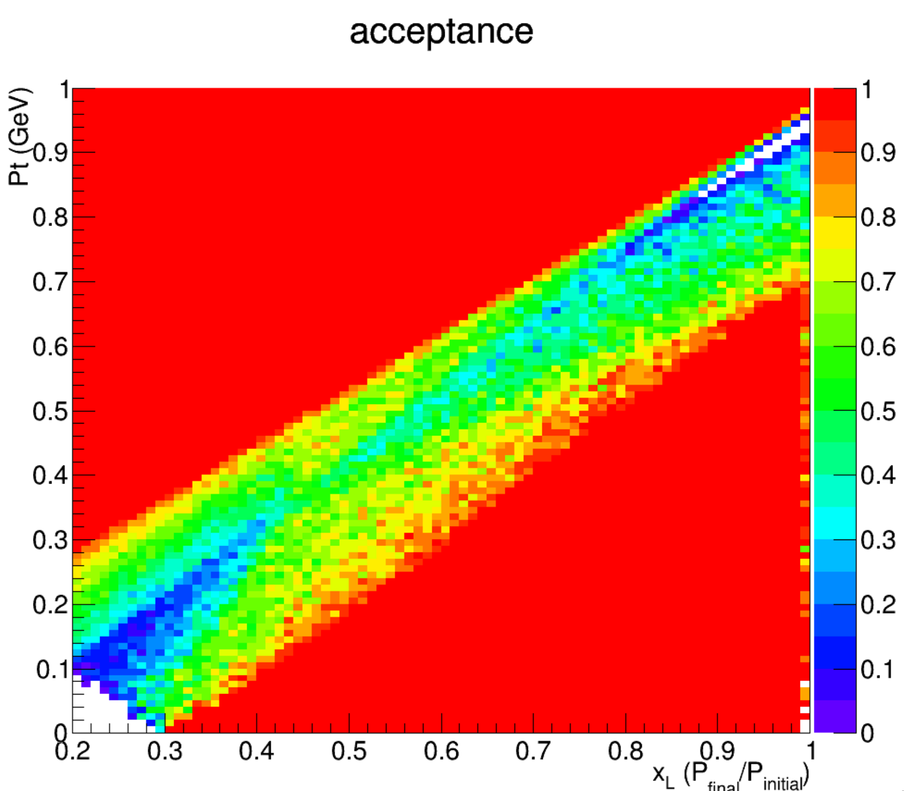


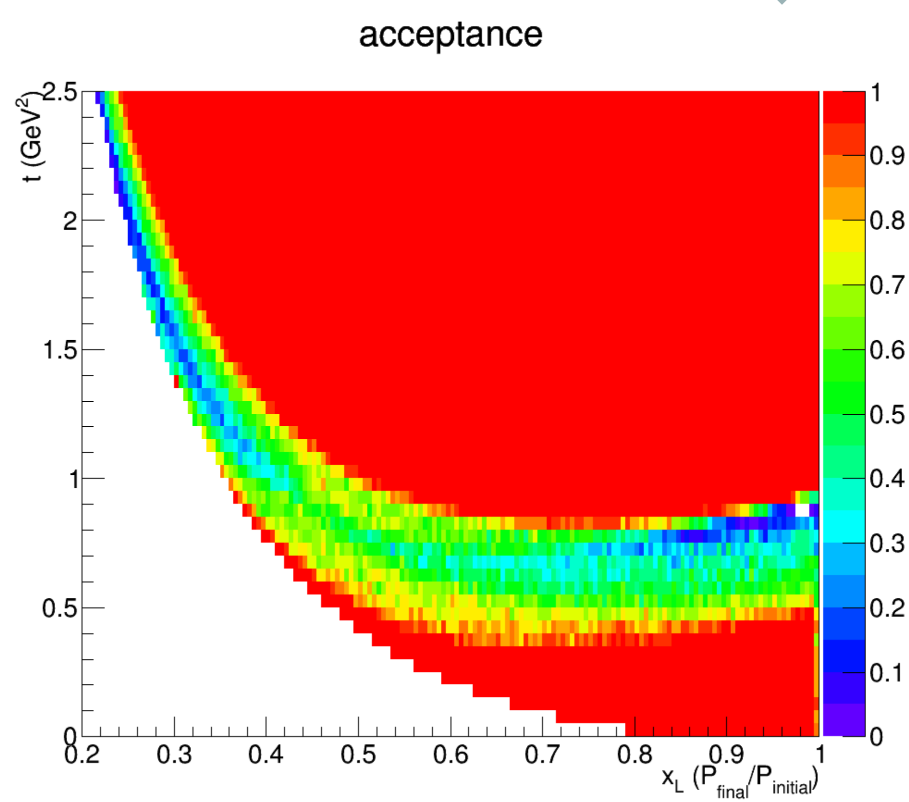
Proton acceptance

- Just phase space
- Cut away all lost in quad 1,2,3 with 6,6,6T tip field
- Cut away 10 sigma beam clearance at 2nd focus with eclipse shape x=1mm and y=0.5mm



Zoom in



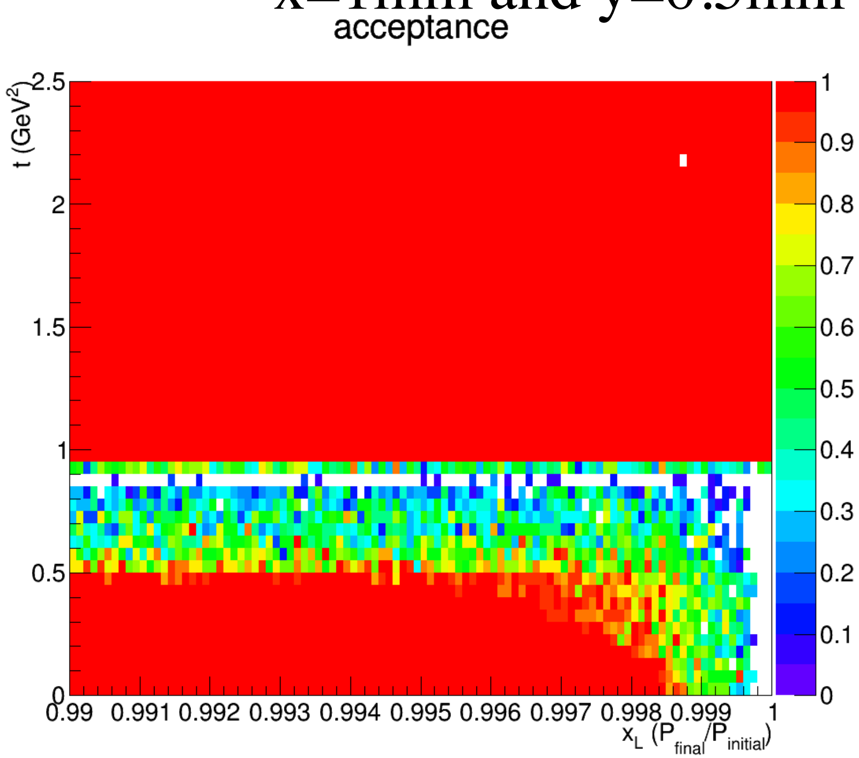


Proton acceptance

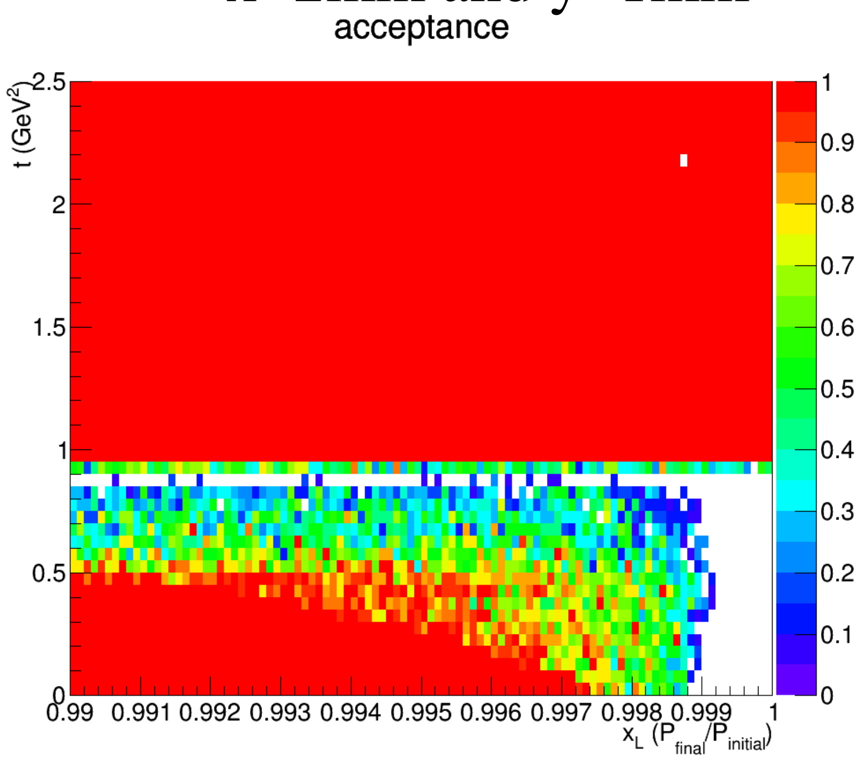
Quality ok, but still need to check details

Zoom in and try different beam clearance cut

With cooling
x=1mm and y=0.5mm



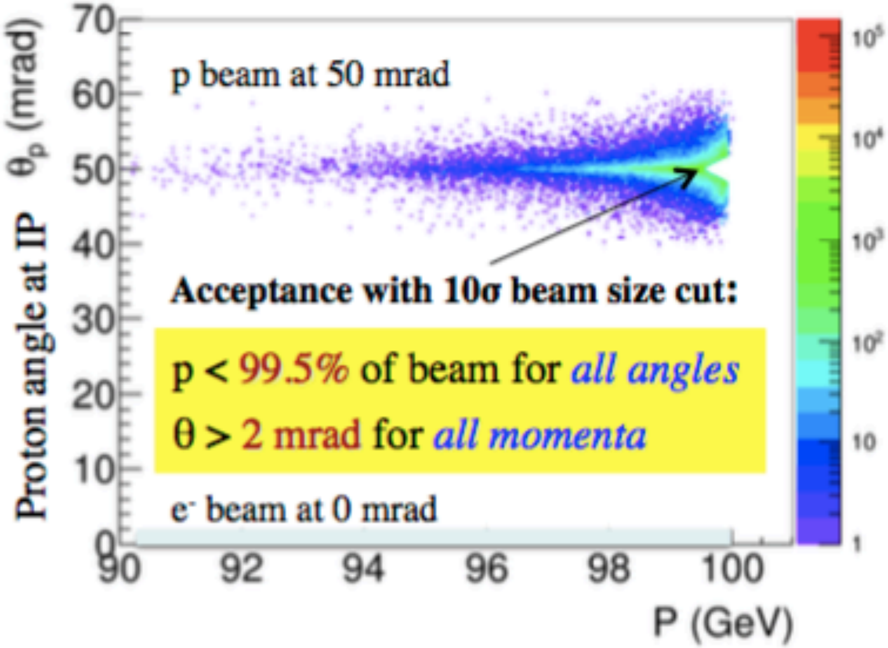
No cooling
x=2mm and y=1mm



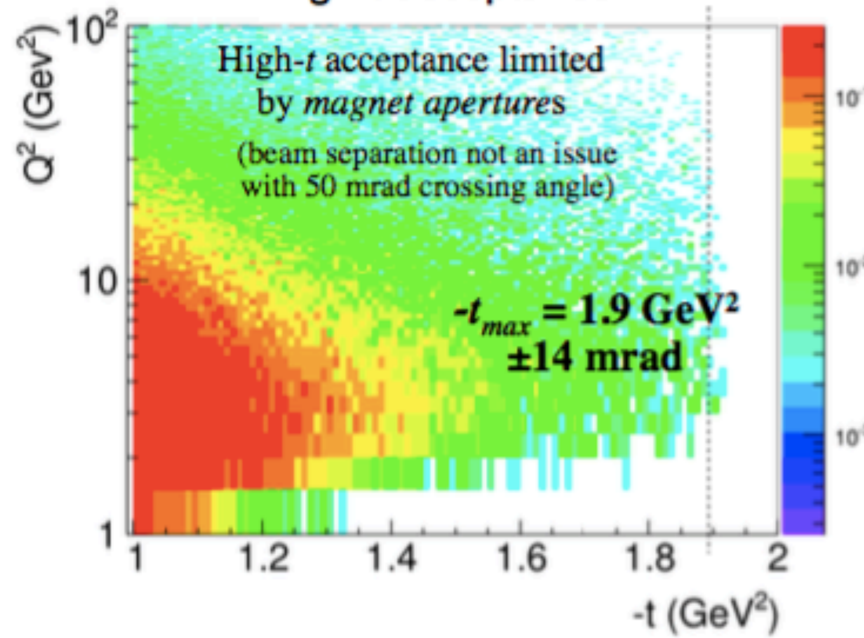
JLab: DVCS recoil proton acceptance

- **Kinematics:** 5 GeV e⁻ on 100 GeV p at a crossing angle of 50 mrad.
  - Cuts: $Q^2 > 1$ GeV^2, $x < 0.1$, $E'_e > 1$ GeV, recoil proton 10σ outside of beam
- **GEANT4 simulation:** tracking through magnets done using GEMC

low-*t* acceptance



high-*t* acceptance



- Recoil proton angle is independent of electron beam energy: $\theta_p \approx p_T/E_p \approx \sqrt{(-t)}/E_p$
- The ion beam size (focusing, emittance, *cooling*) introduces a low-p_T (-t) cutoff
- Larger cone at lower E_p pushes the *low*-t cutoff lower, and make precise tracking easier