INT 17-3

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Deep Virtual Exclusive Scattering with the Electron Ion Collider: Detector Design and Physics Goals

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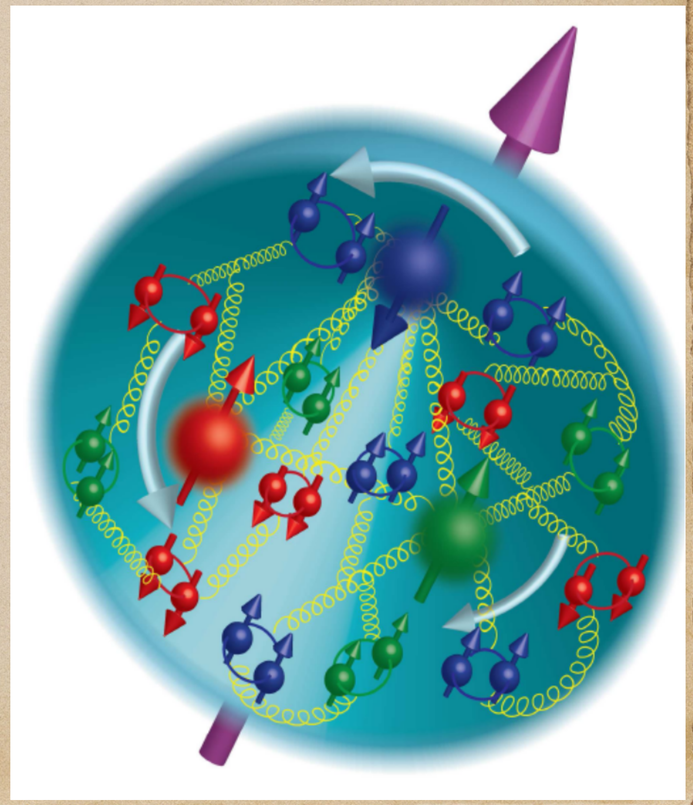
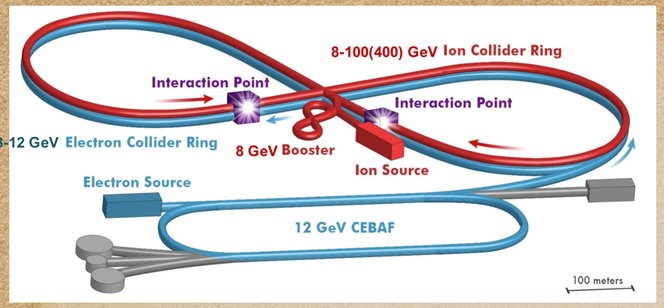


Imaging Quarks & Gluons in the Nucleon and in Nuclei

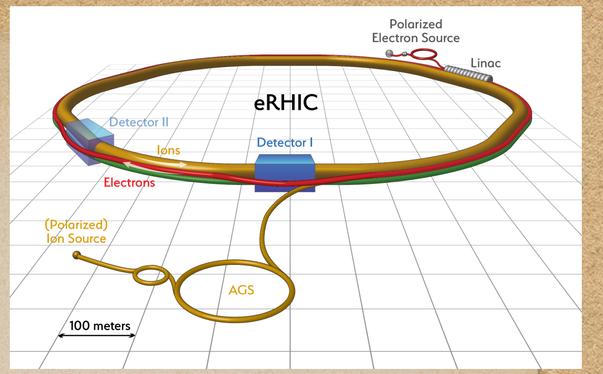
- DVCS: ep—> epγ: e_f^2, gluons
- Deep Virtual ϕ:
  - Gluons dominate with 10-20% s-quark interference at modest x
  - Strong Sudakov corrections for $Q^2 < 10$ GeV^2 (Goloskokov & Kroll)
- J/Psi: Gluons (intrinsic charm at high-x?)
- Pseudo Scaler mesons: Higher twist DA (instanton effects) and Nucleon GPD for $Q^2 < 10$ GeV2
- ρ, ω-meson, flavor sensitivity, mechanism unclear at modest Q^2
  - strong violation of SCHC in JLab, HERMES data.

JLab 12 GeV

- Extensive program on proton, x>0.2, Q2>2,
  - Unpolarized (Halls A,B,C) and Longitudinally polarized (Hall B)
- Deuteron
  - D(e,e'Vn)p, V = γ, vector-meson…
  - D(e,e'Vp_S)n: p(p_S) > 100 MeV/c
- Coherent D, ^{4}He (ALERT Detector)
- Transversely polarized targets still challenging
  (CLAS12 HDice , SOLiD TCS on transversely NH_3)



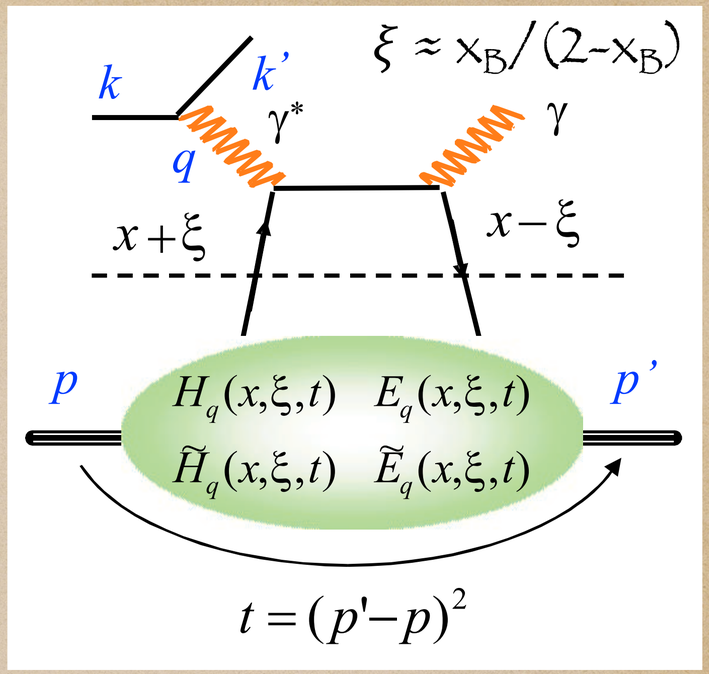
Electron Ion Collider



- $s_{EIC} \approx [s_{JLab}\, s_{HERA}]^{1/2}$
  - Luminosity $\approx 10^{34}$ /cm^2/s
    - High statistics possible on multiple beam-species & polarization states in ≤ 10 years
- L & T polarized light ion beams
  - Access to full spin structure of GPDs
- Ion beam has momentum $P_A = ZP_0$ and Rigidity $K = P_A/Z = P_0$
  - Spectator (p=0 in rest frame) has forward momentum ZP_0/A
    - Tag active neutron ≈"on-shell" by spectator proton tagging in polarized D, ^{3}He
      - Requires good acceptance and resolution for protons at ≈ 0.5 or 0.33 of beam rigidity
    - Daughter nucleus Rigidity relative to beam: $K/K_0 = (A'/Z')(Z/A)$
      - $|\Delta K|/K_0 \geq 1\%$ for A≤ 100 (positive for $\Delta Z = -1$, negative for $\Delta Z=0$, $\Delta A = -1$.
      - Veto nuclear break-up,
      - Tag spectators, evaporation n,p, d , residual nuclei

Detector Requirements:

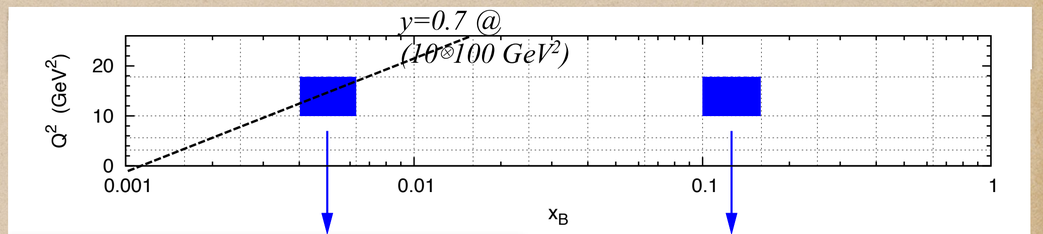
DVCS on the Proton (also π^0 and η)

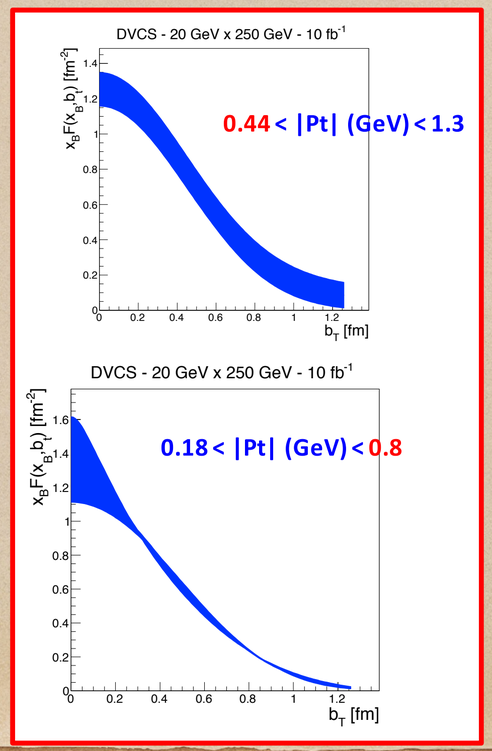


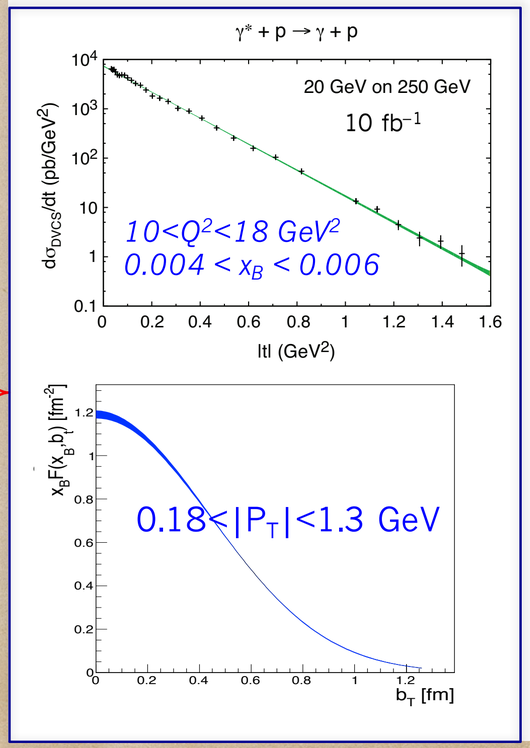
- Exclusivity:
  p(e,e'γp) triple coincidence (or N* → Nπ veto)
  veto neutron in ZDC or proton with $p/p_0 \leq M/M^*$
- Imaging:
  - $t \approx \Delta^2$ resolution requires dispersive focus at Roman Pots. Measure $\Delta=(p'-p)$ [better resolution than $\Delta=(k-k'-q')$].
- Full proton detection acceptance to "Beam-Stay-Clear (BSC)" limit of ~10× beam rms emittance

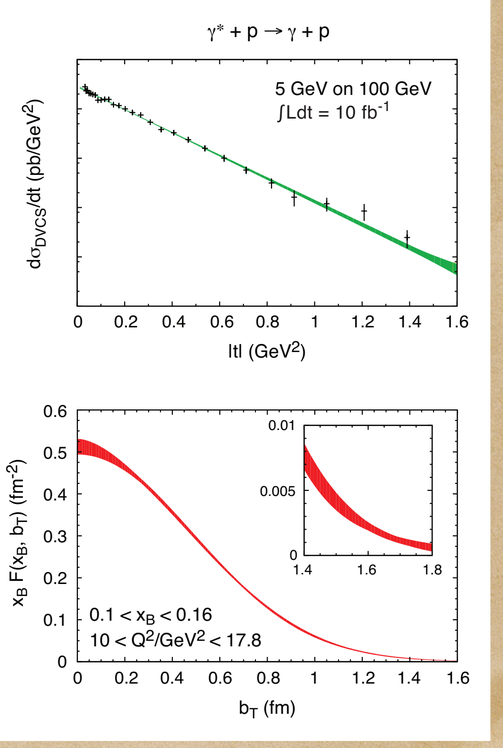
Deeply Virtual Compton Scattering on the Proton: Transverse Imaging vs x_B

- Tagging the recoil protons over the full momentum range is essential for precision imaging



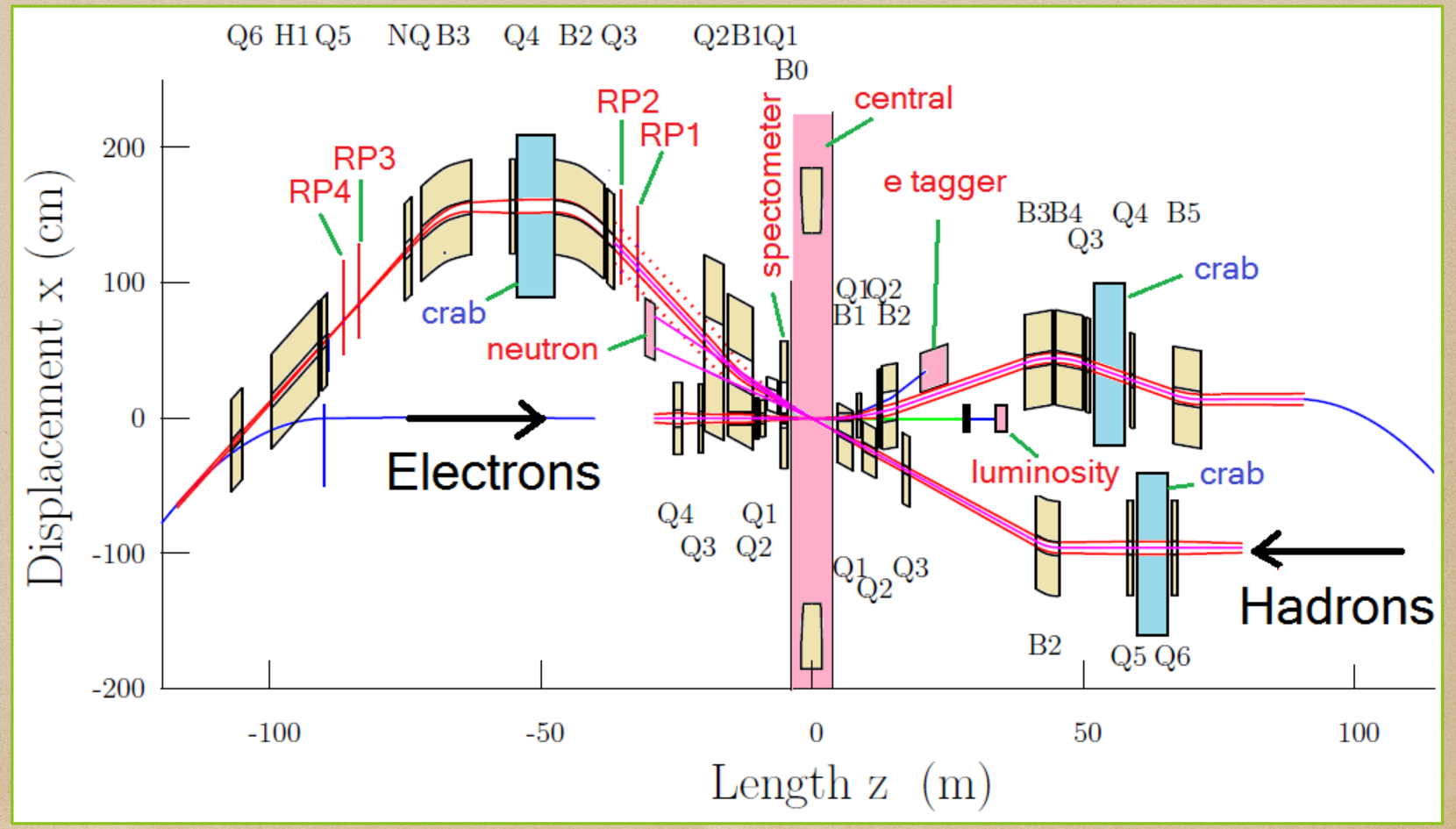




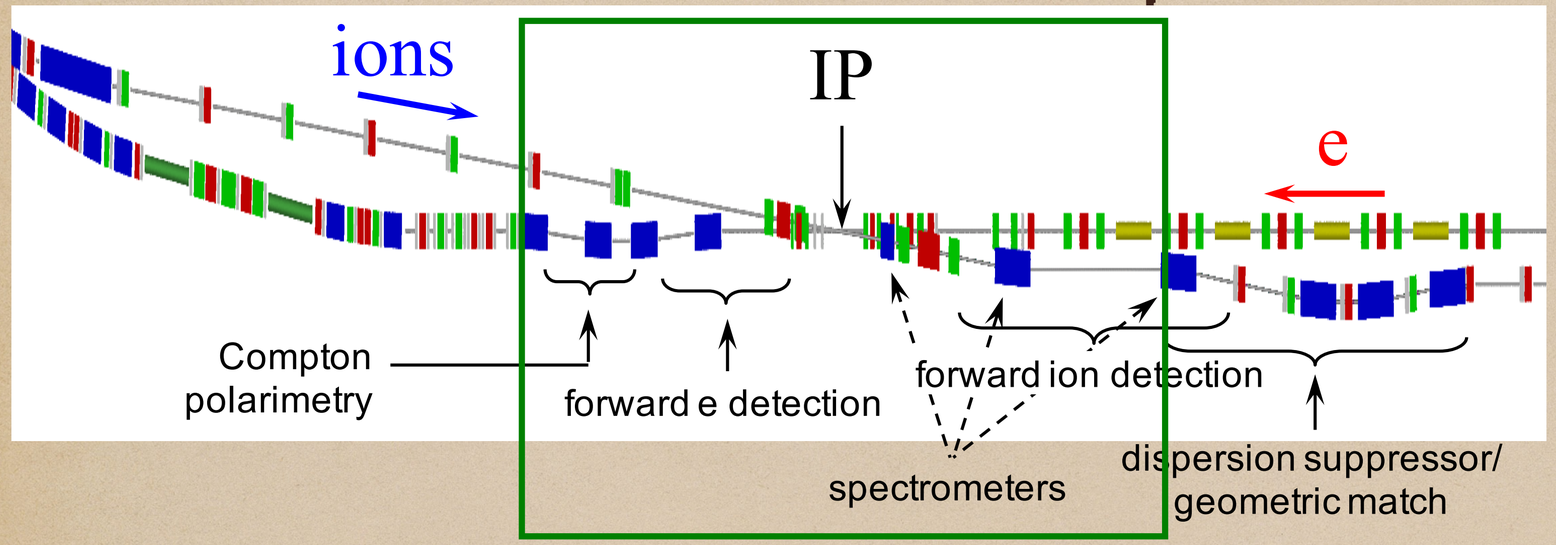


eRHIC Interaction Region Optics

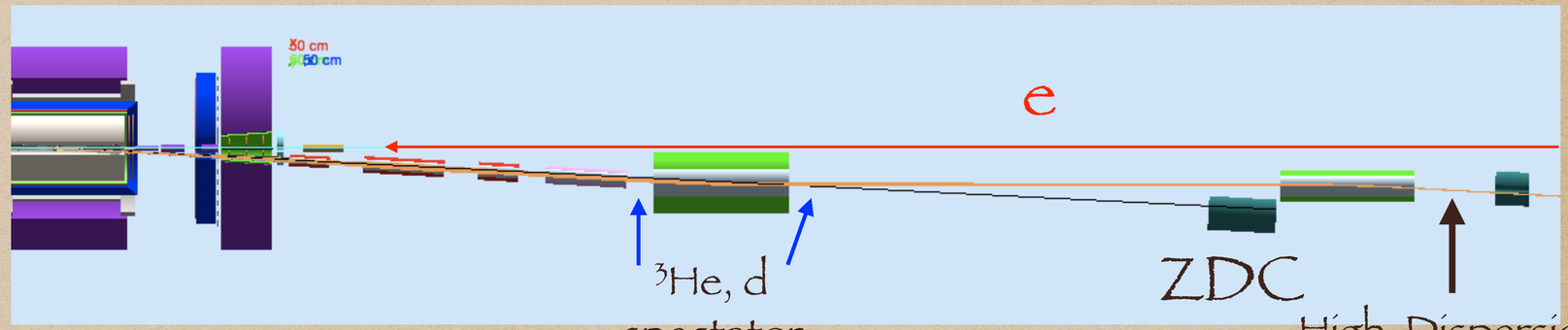
- Spectator protons in RP1,2
- DVCS Recoil protons in RP3,4



JLEIC Full Acceptance Detector

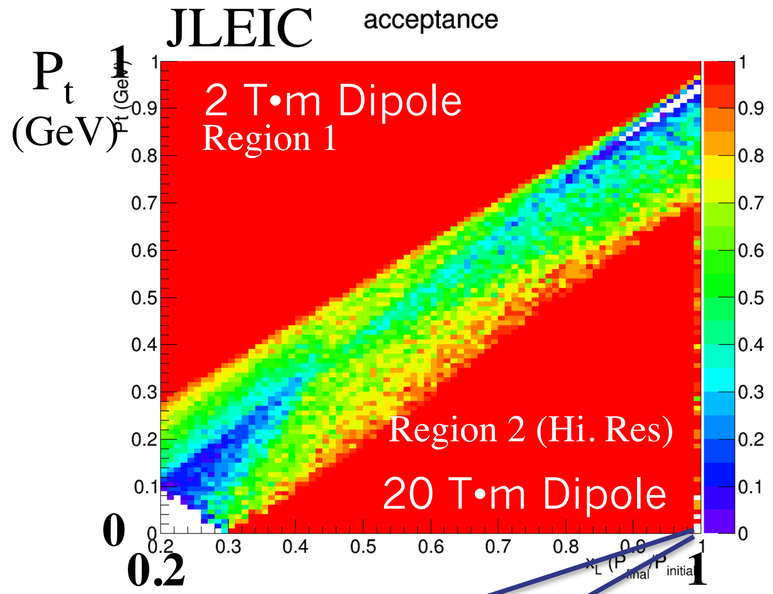


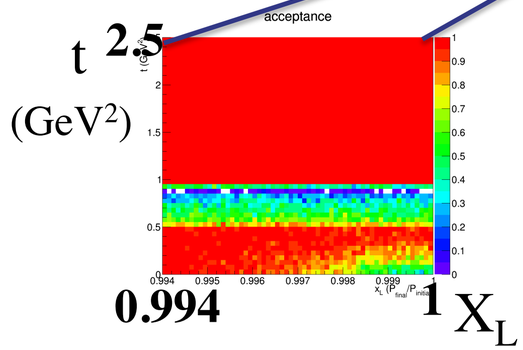
- e/π/K/p PID in central region
- Full acceptance in forward region, tracking detector design still required.



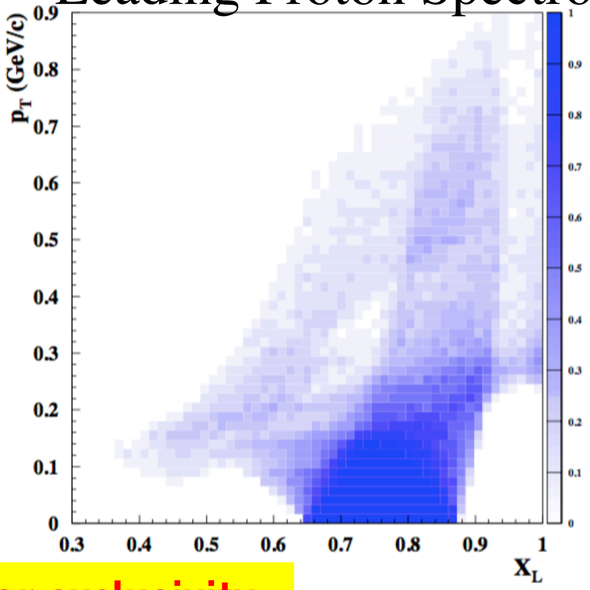
EIC vs HERA

Acceptance for p' in DDIS/DVES





ZEUS
Leading Proton Spectrometer



Tagging essential for exclusivity

Acceptance in diffractive peak (X_L>~.98)

ZEUS: ~2%

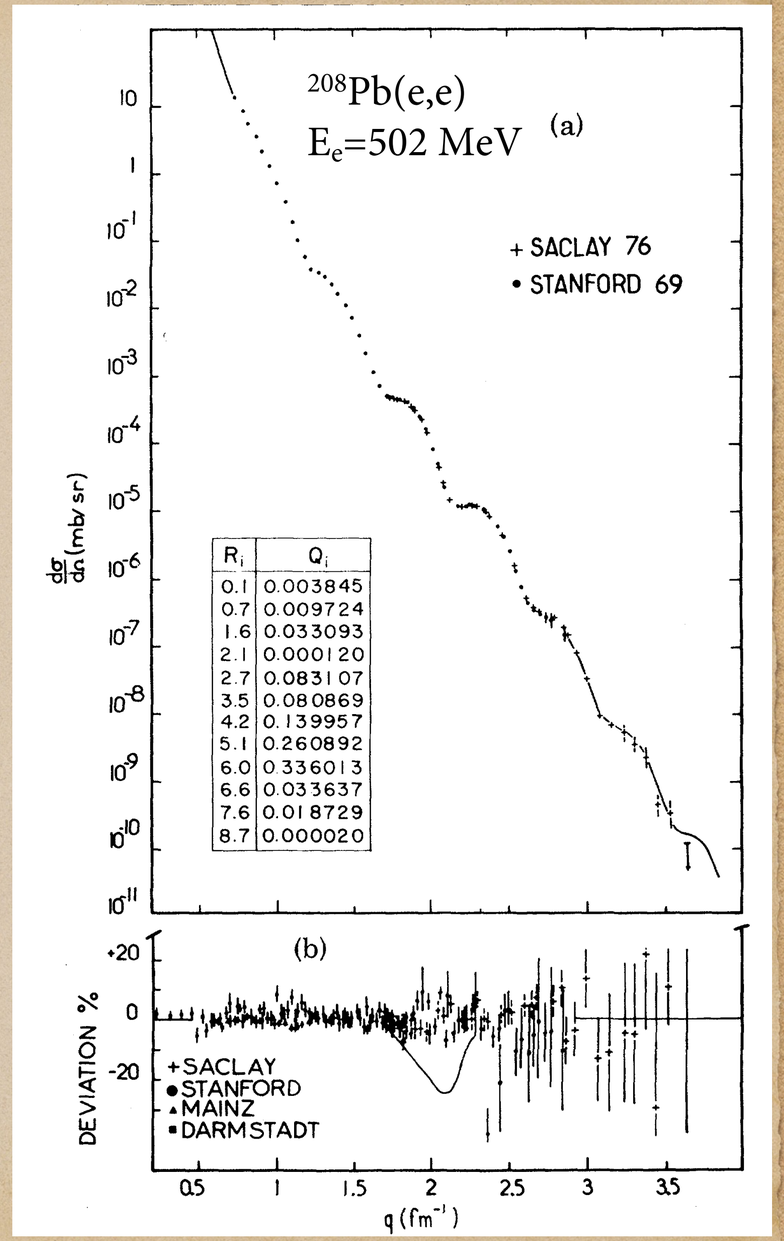
JLEIC: ~100%

Deep Virtual Vector Meson Production

- p(e,e'V)X:
  - Reconstruct $t=\Delta^2 \approx (k-k'-p^+-p^-)^2$ from charged particle final states: $\rho \rightarrow \pi^+\pi^-$, $\phi \rightarrow K^+K^-$
  - $\omega \rightarrow \pi^+\pi^-\pi^0$ constraint on ω mass refines ω momentum resolution.
- Tagging/Veto required for exclusivity

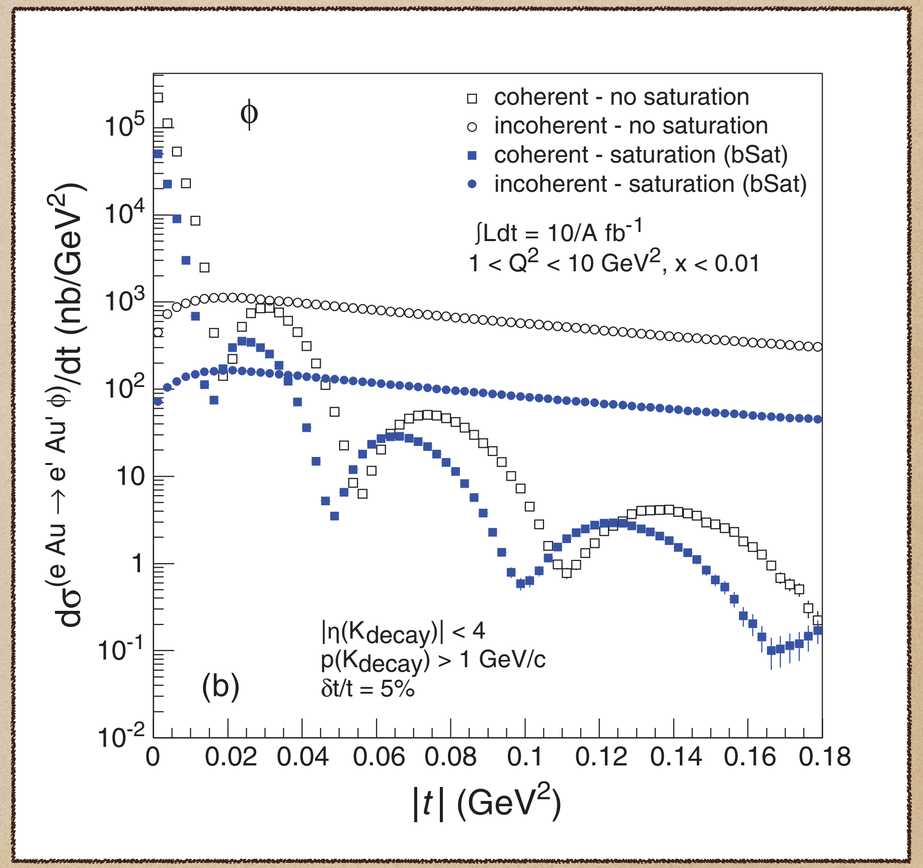
DVES on Nuclei

- Precision charge densities measured in 1970s ☛
- "Neutron Skin" of heavy nuclei has implications for nuclear equation of state & neutron star structure.
  - p/n ≅ u-quark / d-quark
  - ρ,ω: DVES amplitude has charge weight $e_u \mp e_d$.
- Gluon profiles of nuclei from J/Ψ and ϕ



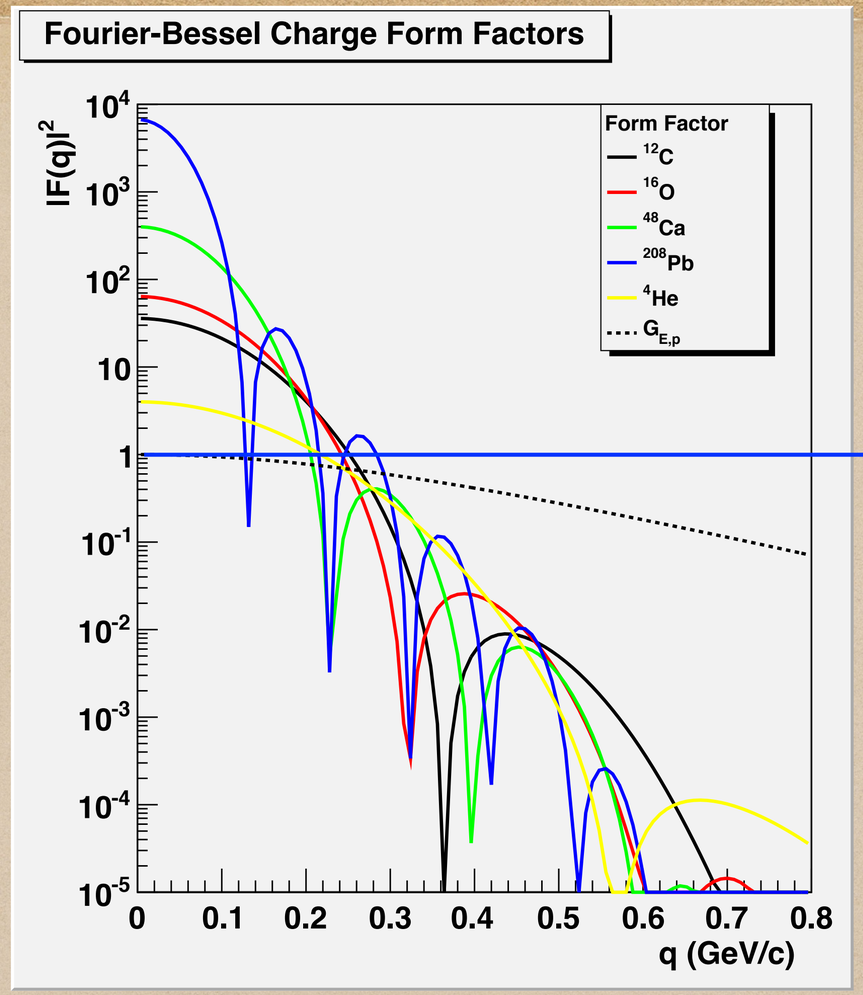
Deeply Virtual Vector Meson Production on Nuclei

- High resolution reconstruction of |t| from e.g. (e,e' K^+K^-) kinematics.
  - Coherent nuclear recoil is unresolvable: lost in 10σ-BSC.
- Excitation of bound-states will wash out minima of coherent scattering.
  - Doubly-magic nuclei, γ-decay energies are large



^{208}Pb(e,e') & DVES

- If bound-excited states are not resolved, they smooth out the diffraction pattern. 3^-(2.6MeV), 5^-(3.2 MeV), 2^+(4.1MeV), 4^+(4.3MeV)
- In DVES@EIC, γ-cascade boosted (×40 JLEIC, ×100 eRHIC)
- High Resolution ($PbWO_4$) forward EMCal can veto (~50% acceptance) E_γ > 100 MeV.
  - Backgrounds?



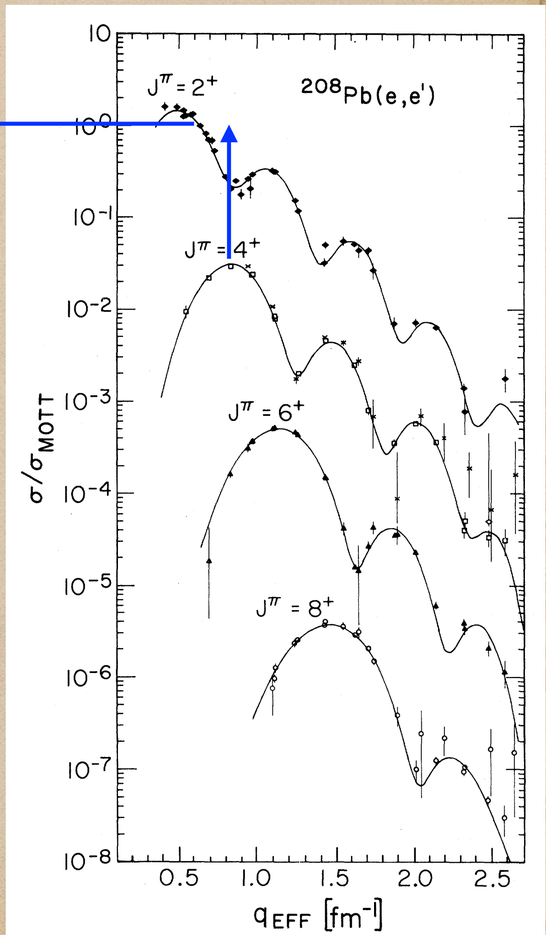


FIG. 3. Cross section for the even spin natural parity states in ^{208}Pb divided by (the cross section for a unit-point charge). Data and best fit for the 4^+ level are scaled down a factor of 0.03, for the 6^+ level a factor of 0.001, and for the 8^+ level a factor of 0.000 03.

Concluding Comment:

An arbitrary JLEIC Run-Plan (similar for eRHIC)

- **Neither time- nor priority-ordered.**
- **2 run periods per year**
- **15 years for ‘base program’**
- **Luminosity is important, even for “low luminosity physics”**

Species	e/A Energy/u	Ion Pol	Run Periods
ep	10 x 100	L & T	2
	5 x 100	L & T	4
	10 x 40		1
e d	10 x 50	L & T	4
e ^{3}He	10 x 75?	L & T	3
e ^{4}He	10 x 50		1
e ^{9}Be	10 x 40		1
e ^{12}C	10 x 50		1
e ^{40}Ca	10 x 50		1
e ^{48}Ca	10 x 40		1
e ^{120}Sn	10 x 40		1
e ^{208}Pb	10 x 40		1
e ^{238}U	10 x 40		1
Positrons			8
Total			**30**