Exclusive processes with EIC: Physics at small and large $t$

C. Weiss (JLab), EIC Collaboration Meeting, CUA, Washington DC, 31–Jul–10

- Transverse gluon imaging
  Nucleon center requires $|t| > 1 \text{GeV}^2$
  Importance for saturation
  Proton dissociation

- Regge dynamics in QCD
  Disappearance of diffusion at large $t$
  Physics in large–$t$ diffraction

- Chiral dynamics in peripheral collisions
  “Pion cloud” from $|t| \sim M^2_{\pi}$?
  Direct probe with large–$t$ knockout processes $\gamma^* N \rightarrow N + \pi + V$
Gluon imaging: Exclusive processes

- $Q^2, M^2 \gg$ hadronic scale: Meson produced in small–size configuration

\[ Q_{\text{eff}}^2 \gg |t| \]

Collins, Frankfurt, Strikman 96

GPDs: Gluonic form factor of nucleon, universal, process–independent

- Physical interest

Transverse spatial distribution of gluons and its change with $x \rightarrow$ Dynamics!

Longitudinal correlations $x_1 \neq x_2$
Gluon imaging: Importance for saturation

- Transverse spatial distribution of gluons essential input in saturation studies
  
  Gluons at $x > 10^2$ define initial conditions for non-linear QCD evolution
  
  \[ Q_s \sim \text{gluons/transverse area} \]

- Dipole model phenomenology
  
  Kowalski, Teaney 03; Rogers, Guzey, Strikman, Zu 03

  Optical picture of dipole–nucleon scattering

  Black–disk regime at high gluon density

- Considerable uncertainty in input for $b < 0.3 \text{ fm}$
  
  Munier, Stasto, Mueller 01; Rogers et al 03

Need transverse gluon density at proton center $b < 0.3 \text{ fm}$!
Gluon imaging: Required $t$–range

- Nucleon center $b < 0.3$ fm requires $|t| > 1$ GeV$^2$

  Expect power–like pQCD behavior at large $|t|$ . . . where does it start?

  $|t| > 1$ GeV$^2$ not covered at HERA
Gluon imaging: Challenges at large $|t|$

- High probability of nucleon dissociation

$$\frac{d\sigma/dt \text{ (diss)}}{d\sigma/dt \text{ (el)}} \approx 0.2 e^{3.5|t|} \quad \text{H1 2010}$$

HERA: Model-dependent correction for nucleon dissociation precludes observation of pQCD power behavior

→ Recoil detection!

- QCD factorization requires $Q_{\text{eff}}^2 \gg |t|$:

  $J/\psi$ photoproduction $Q_{\text{eff}}^2 \approx 3$ GeV$^2$

  Electroproduction with $Q^2 > 10$ GeV$^2$

  → Luminosity

- Physics in diffractive dissociation:

  Quantum fluctuations of gluon density

  Frankfurt, Strikman, Treleani, CW 08
Regge dynamics in QCD

- Fundamental question: How Regge dynamics emerges from QCD
  
  Energy dependence at $t = 0$
  
  $W^{4(\alpha P^2)} \leftrightarrow [G(x, Q^2)]^2$

  $Q^2$ evolution: DGLAP, BFKL? HERA

- More insight from $t$–dependence: $\alpha'$ from “diffusion” in partonic ladder

  $Q^2$ dependence explained by DGLAP
  
  FSW 04; Müller at al. 04

  Diffusion suppressed at $|t| \gg$ soft scale:
  Expect flattening of trajectory

  Blok, Frankfurt, Strikman, 10

- New physics in inelastic diffraction at $t \sim (Q^2 + M_V^2)$ BFS 10

  Great interest in $|t| \sim$ few GeV$^2$

Seen in HERA $\rho^0$ data? B. List, arXiv:0906.4945v1
Chiral dynamics: Effect on $t$–distribution

- Large–distance component at $b \sim 1/M_\pi$
  from chiral dynamics: “Pion cloud”

  Model–independent, cf. Yukawa tail

  Strikman, CW 03/09

  Sizable contribution to $\langle b^2 \rangle$ at $x < 0.1$,
different for quarks and gluons

- Can we detect it in $t$–distribution?

  Small effect – very challenging!

  Needs detailed modeling of non-chiral core
Chiral dynamics: Pion knockout processes

- Hard exclusive process on pion emitted by nucleon \textsuperscript{Strikman, CW 03}
  \[ k_{\pi}^2 \sim M_{\pi}^2 \text{ quasi-real} \]
  Requires \( x \ll M_{\pi}/M_N \sim 0.1 \)

- Kinematics with \( p_T(\pi) \gg p_T(N) \)
  suppresses production on nucleon
  \[ F_{\pi NN}(t) \text{ softer than } GPD_{\pi}(t) \]

- Probe gluon GPD in pion at \( |t_{\pi}| \sim 1 \text{GeV}^2 \)
  Fundamental interest
  Moments calculable in Lattice QCD

- Experimental requirements: Detection of forward nucleon and moderate \( p_T \) pion

Direct probe of chiral component of partonic structure!
Summary

- Imaging of nucleon center requires $|t|$ up to $\sim 2$ GeV$^2$
  Essential input to saturation studies

- Great interest in elastic and dissociative vector meson production at $|t| \sim$ few GeV$^2$

- Develop physics narrative for diffractive dissociation $\gamma^* N \to V + X$
  Quantum fluctuations of gluon density
  Diffusion dynamics in partonic many-body system
  Multiscale problem

- Chiral dynamics can be probed in knockout processes $\gamma^* N \to V + \pi + N$
Supplementary material
Gluon imaging: $J/\psi$ in $ep$ at HERA

- $t$–dependence of $J/\psi$ electroproduction ZEUS 04