Diffractive dijet photoproduction at EIC

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Outline:

- Lessons from diffractive dijet photoproduction at HERA
- Diffractive dijet photoproduction in NLO QCD at EIC
- Predictions for γp at EIC: distributions, diffractive PDFs, factorization breaking
- Predictions for γA at EIC

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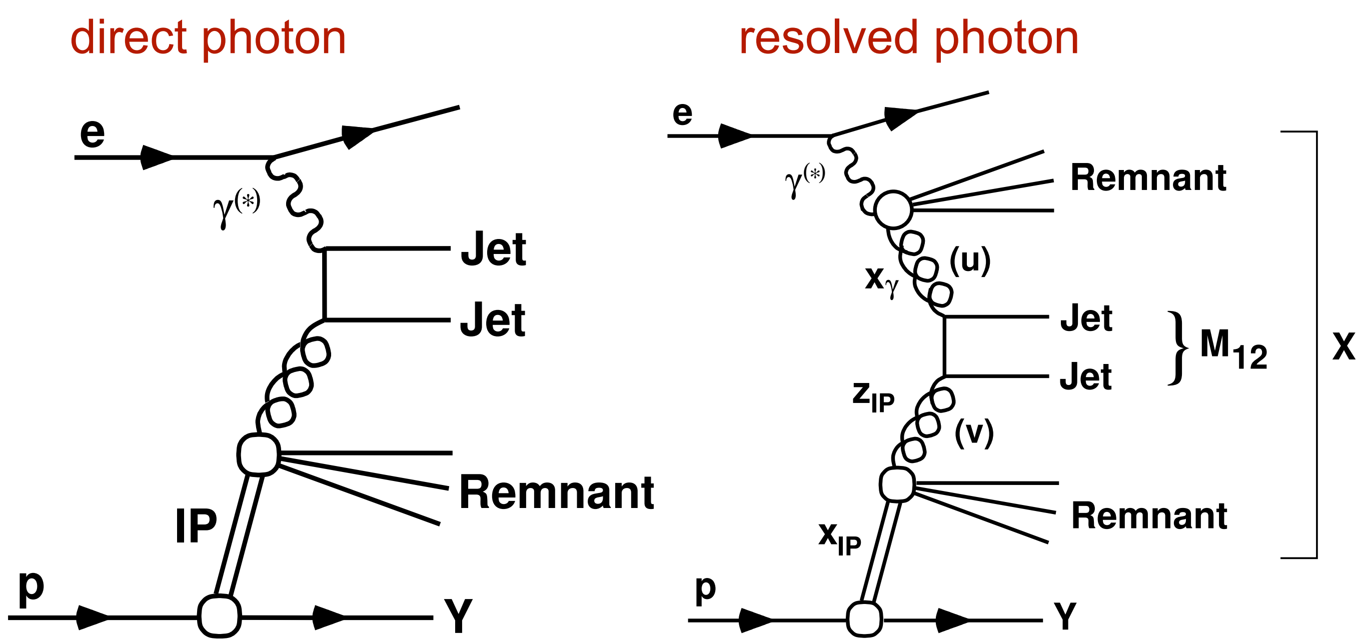
Diffractive dijet photoproduction at HERA

• At HERA with Ep=820-920 GeV and Ee=27.5 GeV ($\sqrt{s}$ ~ 300 GeV), diffraction makes up 10-15% of the total DIS cross section, Newman, Wing, Rev. Mod. Phys. 86, 1037 (2014)

• An example of diffractive final states is diffractive dijet photoproduction constituting a few % of the inclusive cross section, Aaron at al. [H1 Coll.], EPJ C70, 15 (2010)



• Characterized by large rapidity gap between the forward proton (its excitation Y) and the rest of hadronic activity X.

Diffractive PDFs and factorization at HERA

• QCD factorization theorem for diffraction, Collins, PRD 57, 3051 (1998); PRD 61, 019902 (2000) $\rightarrow$ universal diffractive parton distributions

$$d\sigma^{ep\rightarrow eXY}(x,Q^2,x_{I\!P},t)=\sum_i f_i^D(x,Q^2,x_{I\!P},t)\otimes d\hat{\sigma}^{ei}(x,Q^2)$$

• For convenience, one uses Regge factorization, Ingelman, Schlein, PLB 152 (1985) 256

$$f_i^D(x,Q^2,x_{I\!P},t)=f_{I\!P/p}(x_{I\!P},t)\cdot f_i(\beta,Q^2)\;+\;n_{I\!R}\cdot f_{I\!R/p}(x_{I\!P},t)\cdot f_i^{I\!R}(\beta,Q^2)$$

• QCD analyses of HERA data on inclusive diffraction in DIS $\rightarrow$ extraction of quark and gluon diffractive PDFs, Aktas at al. [H1 Coll.], EPJ C48, 715 (2006) and EPJC 48, 749 (2006); Chekanov at al. [ZEUS Coll.], NPB 831, 1 (2010)

• These diffractive PDFs successfully describe data on diffractive dijet and open charm production in DIS, Aktas at al. [H1 Coll.], JHEP 10, 042 (2007); EPJ C 71, 549 (2010); EPJ C 50, 1 (2007); Chekanov et al. [ZEUS Coll.], EPJ C 52, 813 (2007) $\rightarrow$ QCD factorization holds!

Factorization breaking in diffractive dijet photoproduction at HERA

• At the same time, perturbative QCD overpredicts cross sections of diffractive dijet photoproduction at HERA → factorization breaking, Aktas at al. [H1 Coll.], EPJ C 71, 549 (2007); Aaron et al. [H1 Coll.], EPJ C 70, 15 (2010); Andreev et al. [H1 Coll.], JHEP 05, 056 (2015); Chekanov at al. [ZEUS Coll.], EPJ C 55, 177 (2008).

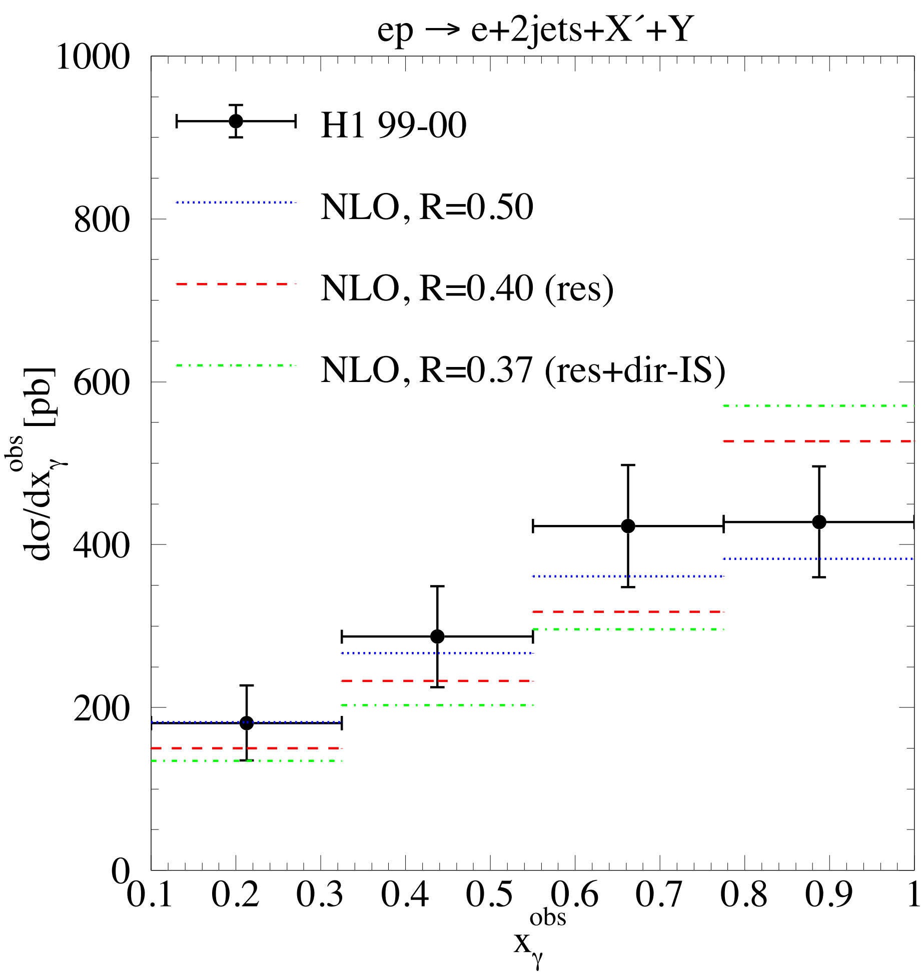
• The mechanism of factorization breaking remains unknown:

- global suppression factor R ≈ 0.5, or

- suppression of only the resolved photon contribution by R ≈ 0.34 as expected in hadron-hadron scattering, Kaidalov, Khoze, Martin, Ryskin, PLB 567, 61 (2003); Klasen, Kramer, EPJ C 70, 91 (2010), or

- a flavor-dependent combination of these mechanisms, Guzey, Klasen, EPJ C 76, 467 (2016)

• Solution of this puzzle could be conclusively addressed at EIC!



Diffractive dijet photoproduction in NLO QCD

- Using collinear QCD and Regge factorizations, cross section of diffractive dijet photoproduction e+p → e+2 jets+X+Y at NLO, Klasen, Kramer, Salesch, Z. Phys. C 68, 113 (1995); Klasen, Kramer, Z. Phys. C 72, 107 (1996), Z. Phys. C 76, 67 (1997); Klasen, Rev. Mod. Phys. 74, 1221 (2002):

$$d\sigma = \sum_{a,b} \int dy \int dx_\gamma \int dt \int dx_{I\!P} \int dz_{I\!P} f_{\gamma/e}(y) f_{a/\gamma}(x_\gamma, M_\gamma^2) f_{I\!P/p}(x_{I\!P}, t) f_{b/I\!P}(z_{I\!P}, M_{I\!P}^2) d\hat{\sigma}_{ab}^{(n)}$$

- Photon flux in improved Weizsäcker-Williams approximation, Frixione, Mangano, Nason, Ridolfi, PLB 319, 339 (1993)

$$f_{\gamma/e}(y) = \frac{\alpha}{2\pi} \left[\frac{1+(1-y)^2}{y} \ln \frac{Q_{\max}^2 (1-y)}{m_e^2 y^2} + 2 m_e^2 y \left(\frac{1-y}{m_e^2 y^2} - \frac{1}{Q_{\max}^2} \right) \right]$$

- Photon PDFs $f_{a/\gamma}(x_\gamma)$ in GRV NLO fit (transformed from DIS_γ to MSbar), Gluck, Reya, Vogt, PRD 46, 1973 (1992)

- Pomeron flux motivated by Regge theory: $f_{I\!P/p}(x_{I\!P}, t) = A_{I\!P} \cdot \frac{e^{B_{I\!P} t}}{x_{I\!P}^{2\alpha_{I\!P}(t)-1}}$

- “Pomeron” PDFs $f_{b/P}(z_P)$ from 2006 H1 fits A and B, Aktas at al. [H1 Coll.], EPJ C48, 715 (2006) and EPJC 48, 749 (2006) and ZEUS SJ fit, Chekanov at al. [ZEUS Coll.], NPB 831, 1 (2010)

Diffractive dijet photoproduction in NLO QCD at EIC

- The photon and Pomeron momentum fractions in terms of their observed hadronic estimators:

$$x_\gamma^{\text{obs}} = \frac{p_{T1}\, e^{-\eta_1} + p_{T2}\, e^{-\eta_2}}{2yE_e} \quad \text{and} \quad z_{I\!P}^{\text{obs}} = \frac{p_{T1}\, e^{\eta_1} + p_{T2}\, e^{\eta_2}}{2x_{I\!P}E_p}$$

- Jets with the anti-k_T formalism with distance parameter R=1.

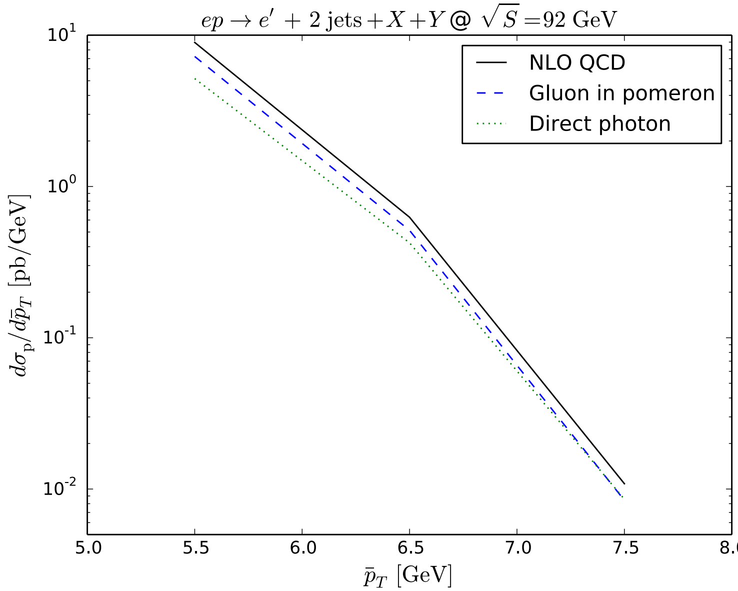
- Using HERA experience, assume $p_{T1} > 5$ GeV and $p_{T2} > 4.5$ GeV → will require good resolution of hadronic jet energy and subtraction of underlying event to avoid large hadronization corrections.

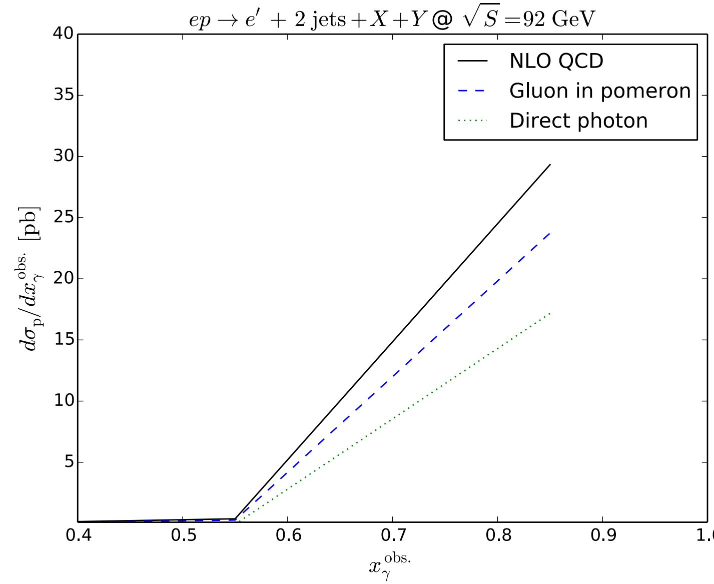
- Generic cuts: $0 < y < 1$, $Q^2 < 0.1$ GeV^2, $|t| < 1$ GeV^2, $M_Y < 1.6$ GeV and $-4 < \eta_{1,2} < 4$.

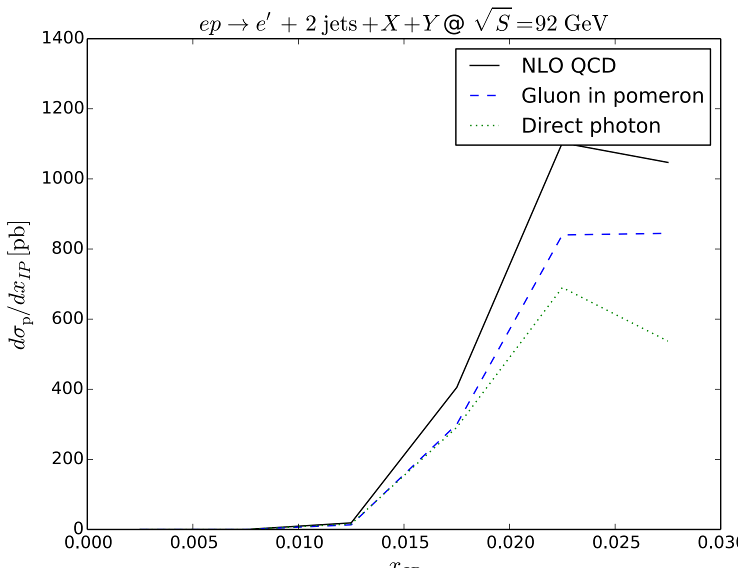
- Base $x_P < 0.03$ and higher $x_P < 0.1$ to extend the kinematic coverage.

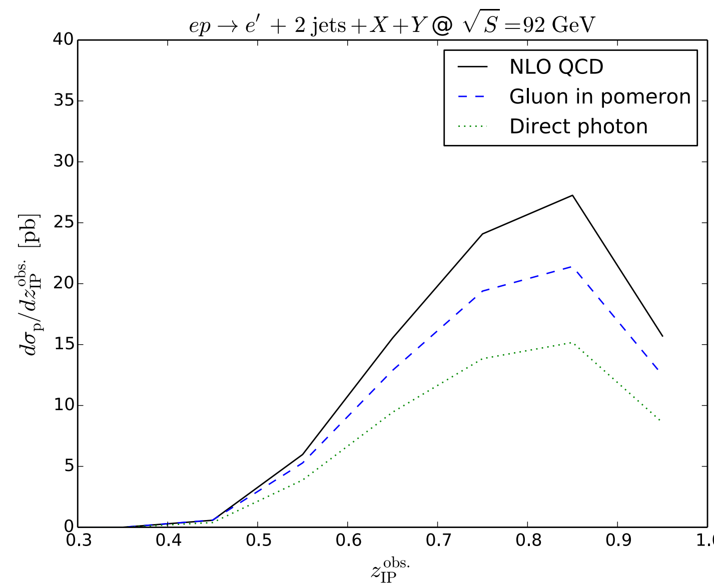
- The base configuration is **Ee=21 GeV** and **Ep=100 GeV** (√s ~ 92 GeV). To extends the kinematic coverage and study factorization breaking, also used Ee=18 GeV and Ep=275 GeV (√s ~ 141 GeV).

NLO QCD predictions for EIC: base config.





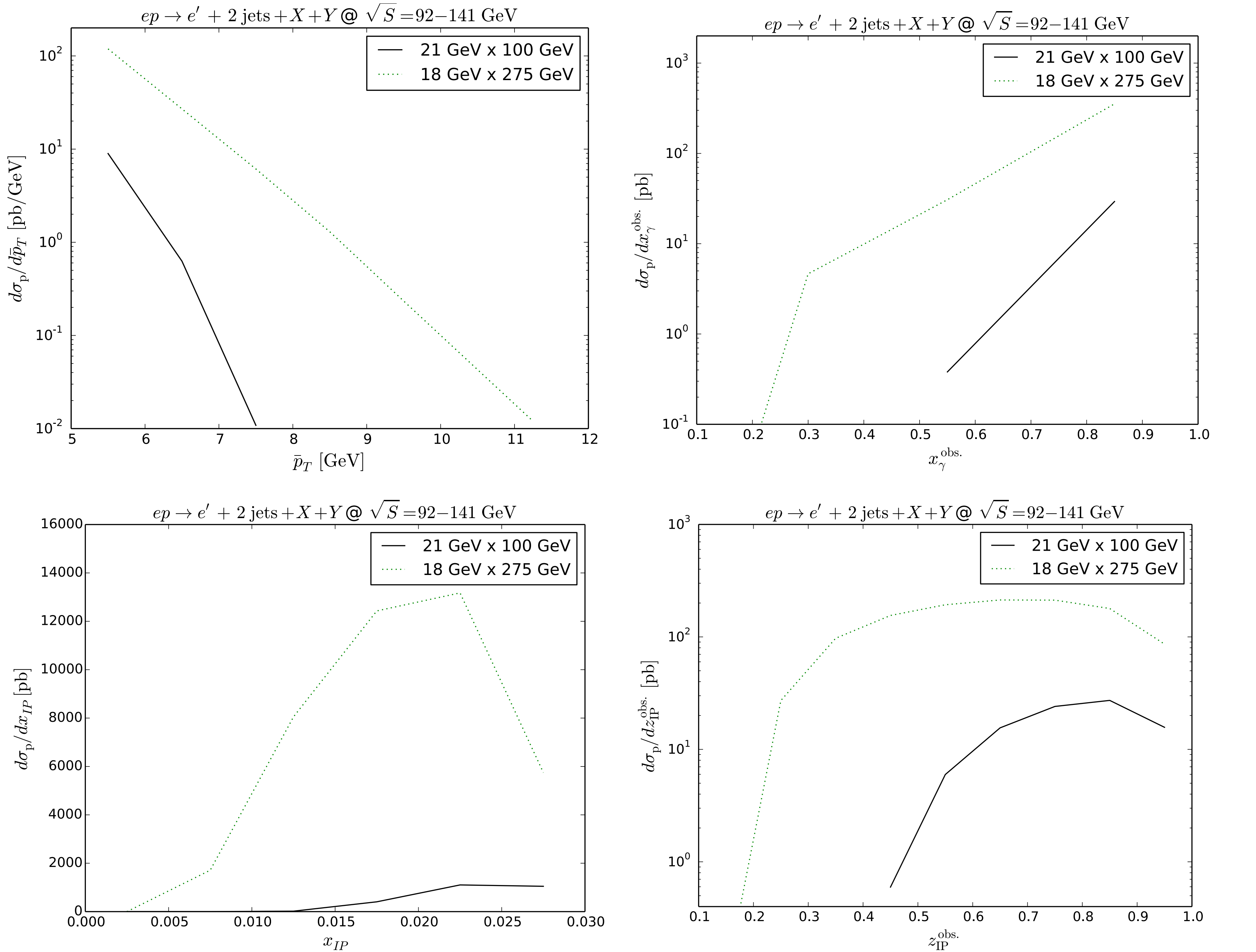




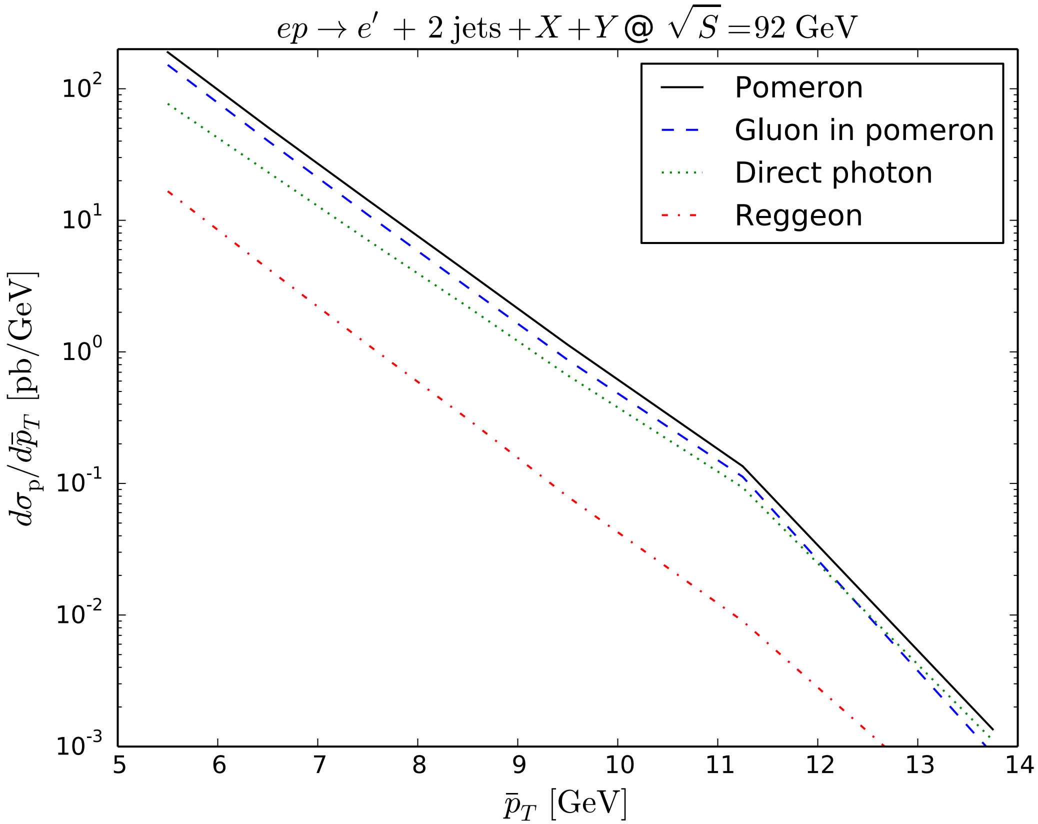
- Main features:

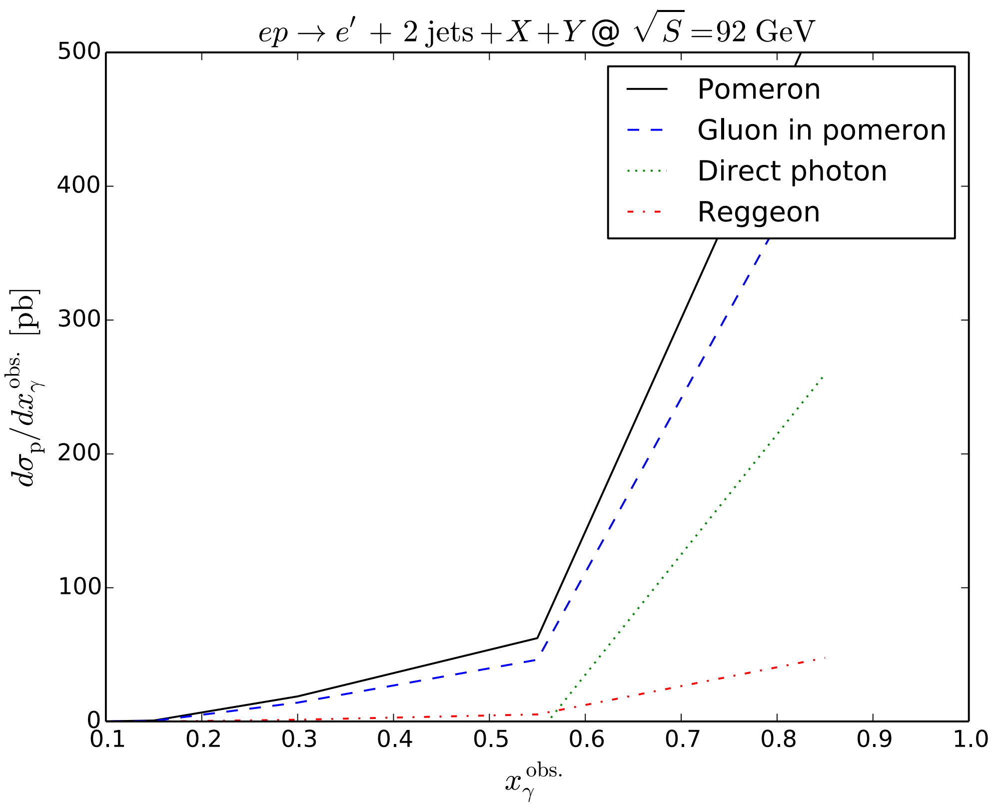
- $p_T = (p_{T1}+p_{T2})/2$ coverage up to 8 GeV
- dominated by direct photon contribution, i.e. large $x_\gamma > 0.5$ → challenging to address factorization breaking
- dominated by large x_P and z_P → probes mostly diffractive gluon density.

NLO QCD predictions for EIC: higher energy



NLO QCD predictions for EIC: $x_P < 0.1$

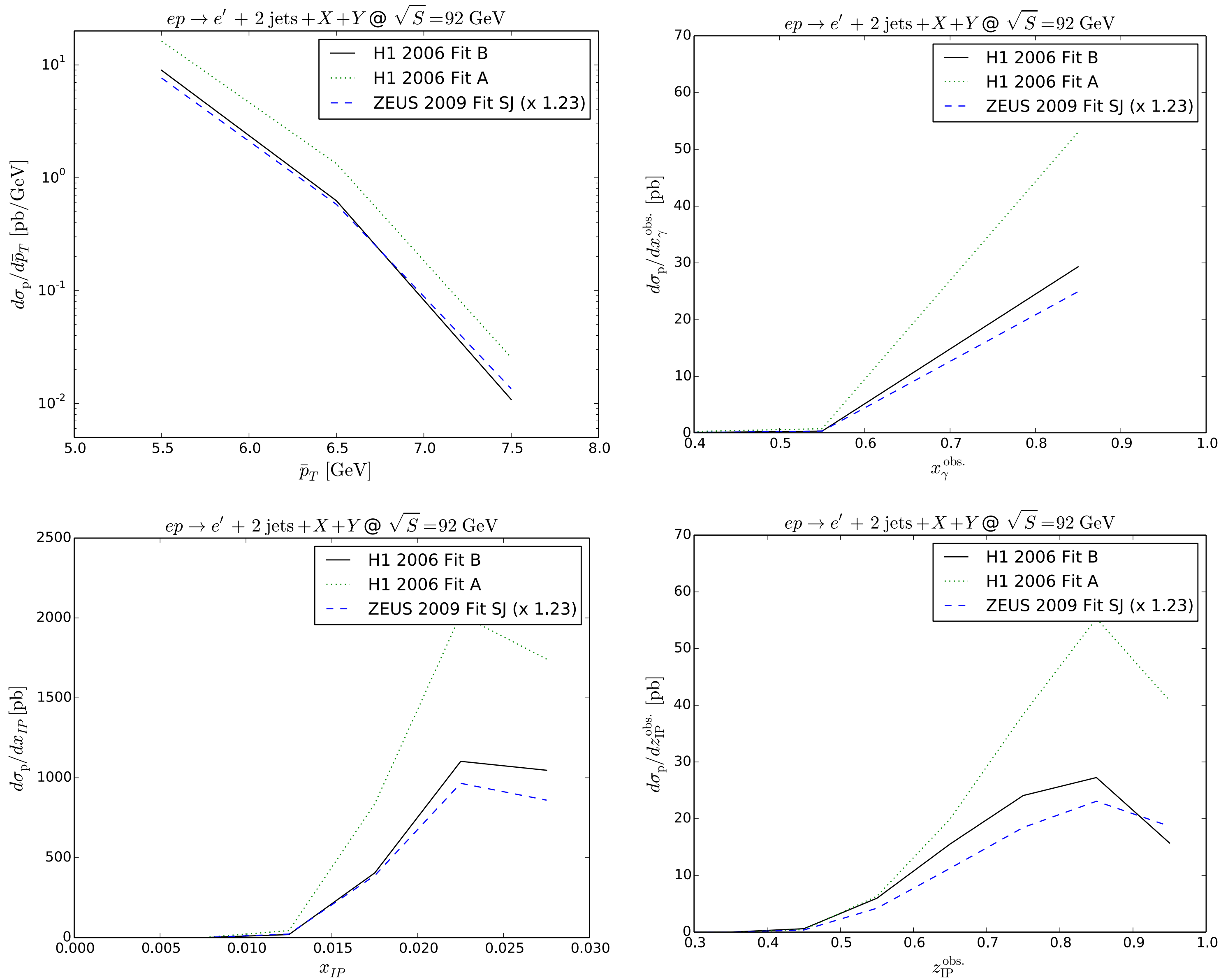




- Main features:

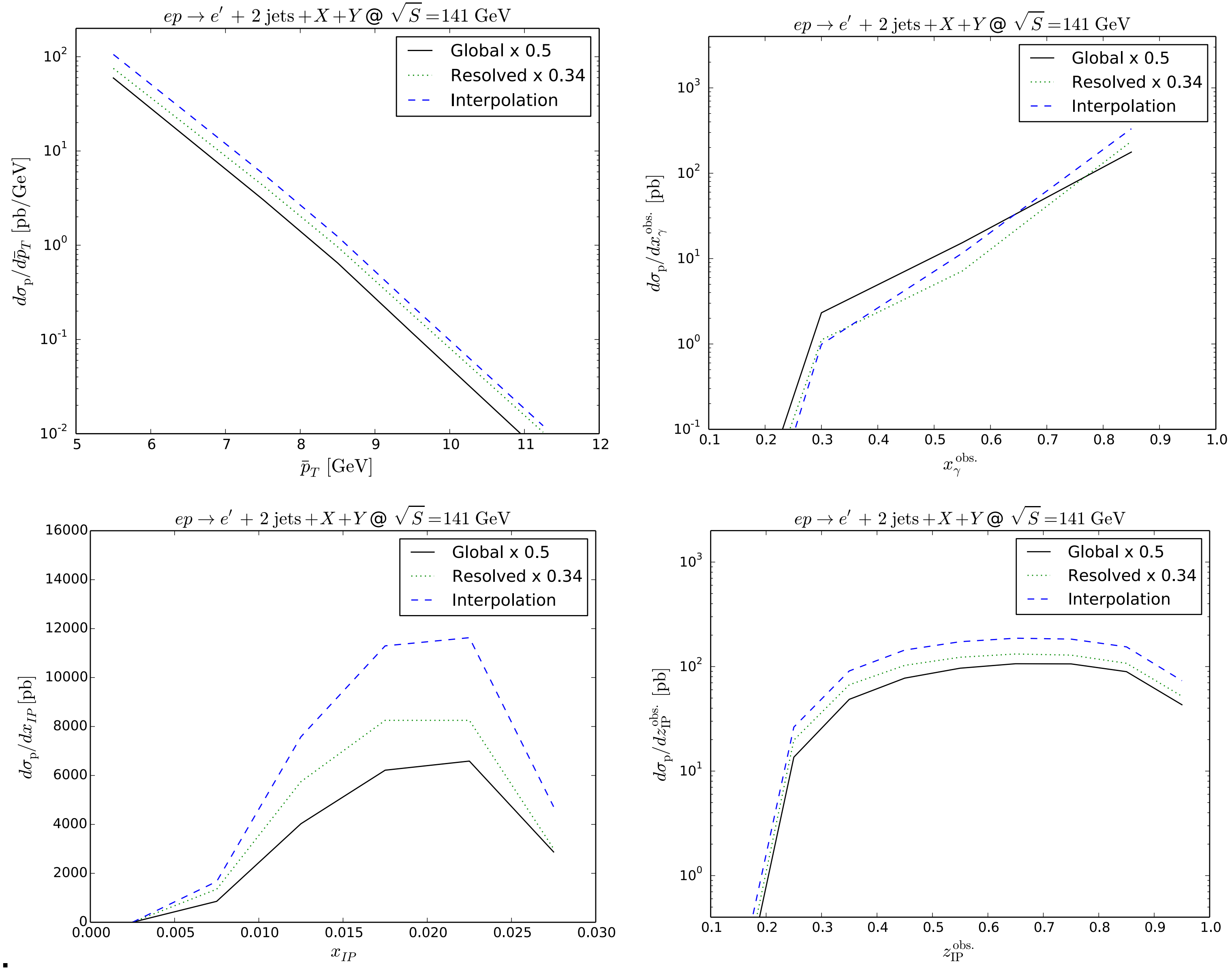
- p_T coverage is now up to 14 GeV
- photon momentum fraction down to $x_\gamma > 0.1$ → also resolved photon contributes
- 10-35% contribution of sub-leading Reggeon trajectory for $x_P > 0.06$.

QCD predictions for EIC: dependence on diffractive PDFs



- H1 Fit B and ZEUS SJ give similar predictions.
- Fit A predicts larger cross section due to larger diffractive gluon density at large z_P.

QCD predictions for EIC: factorization breaking



• Main features:

- Most promising observable is x_γ dependence → need wide coverage and high precision since the cross section drops.
- The rest of distributions differ mostly in normalization.

Diffractive dijet photoproduction on nuclei

• In collider mode, it is straightforward to measure coherent diffraction on nuclei by selecting events with a large rapidity gap and requiting that no neutrons are produced in zero-degree calorimeters (ZDCs).

• Diffractive dijet photoproduction on nuclei allows one to probe novel nuclear diffractive PDFs $f_{i/A}^{D}(z_P,Q^2,x_P)$.

• Nuclear diffractive PDFs differ from free nucleon ones. In particular, they are suppressed due to nuclear shadowing at small x, Frankfurt. Guzey, Strikman, Phys. Rept. 512, 255 (2012)

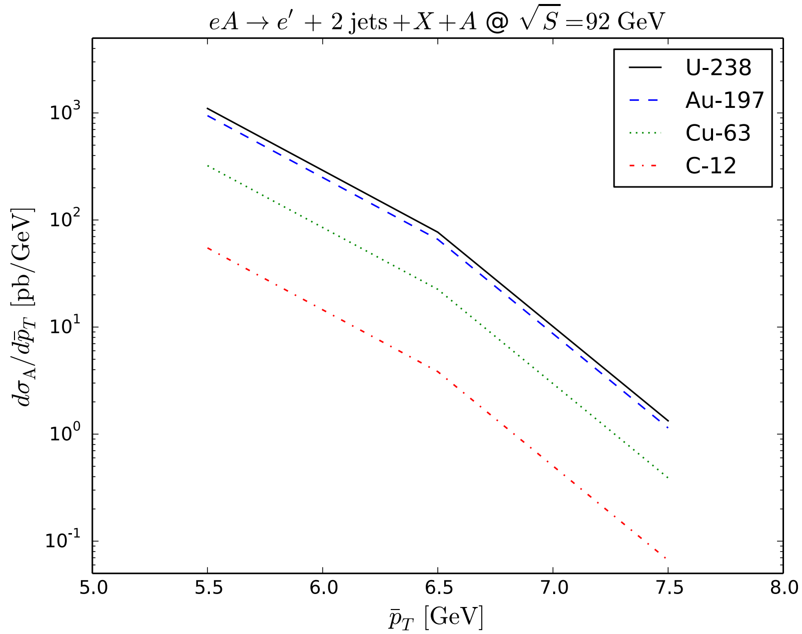
$$f_{i/A}^{D}(z_{I\!P},Q^2,x_{I\!P}) \approx 16\pi B_{\rm diff} f_{i/p}^{D}(z_{I\!P},Q^2,x_{I\!P}) \int d^2\vec{b} \left| \frac{1-e^{-\frac{A}{2}(1-i\eta)\sigma_{\rm soft}^{i}(x,Q^2)T_A(b)}}{(1-i\eta)\sigma_{\rm soft}^{i}(x,Q^2)} \right|^2 .$$

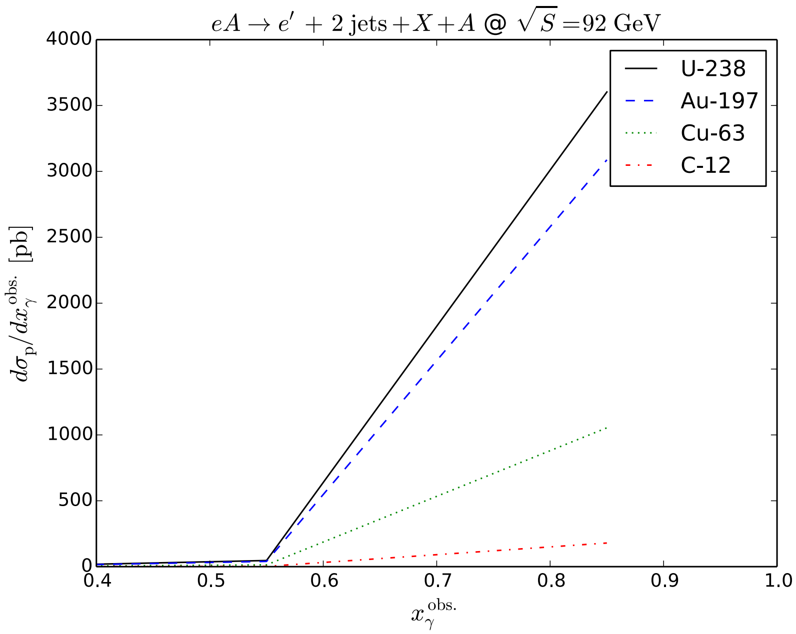
• Nuclear shadowing explicitly breaks Regge factorization of diffractive PDFs.

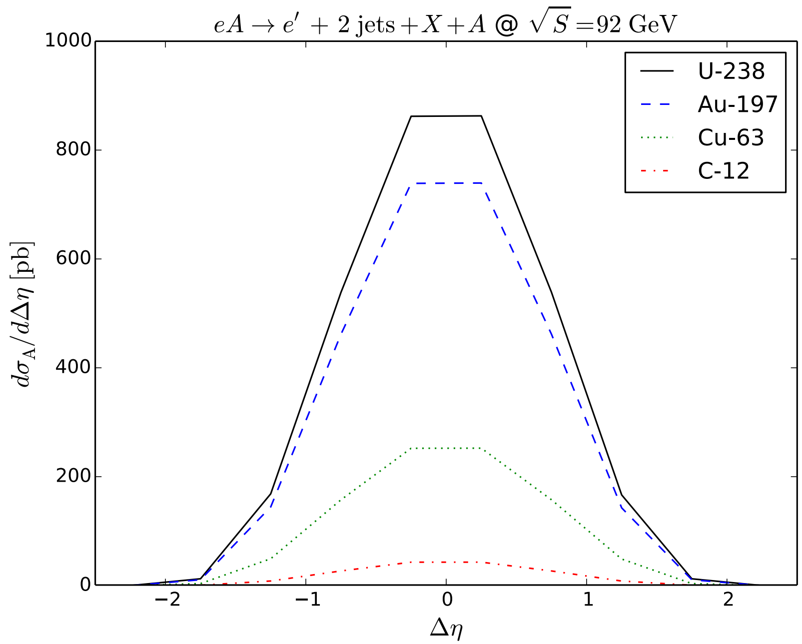
• Shadowing effects weakly depend on flavor and momentum fractions:

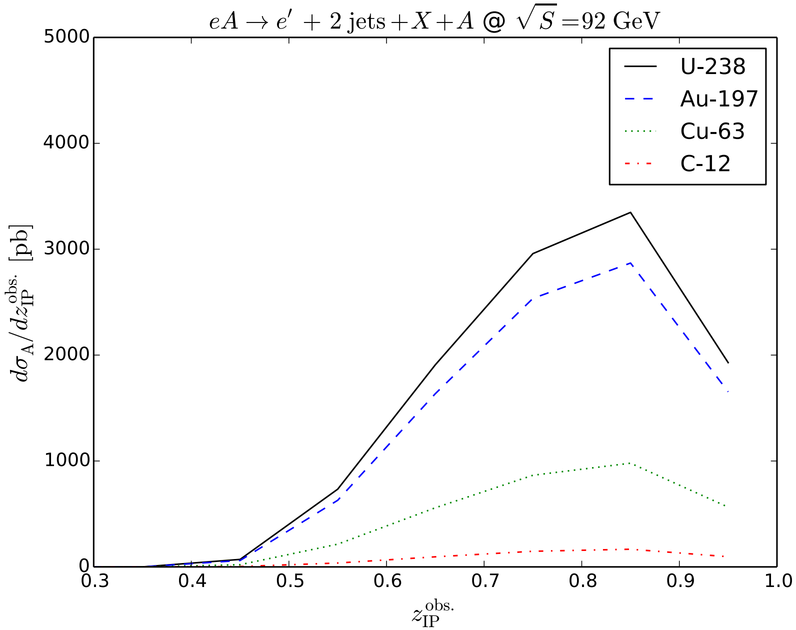
$$f_{i/A}^{D}(z_{I\!P},Q^2,x_{I\!P}) \approx A R(x,A) f_{i/p}^{D}(z_{I\!P},Q^2,x_{I\!P})$$ with R(x,A)=0.65.

NLO QCD predictions for diffractive dijet photoproduction on nuclei at EIC

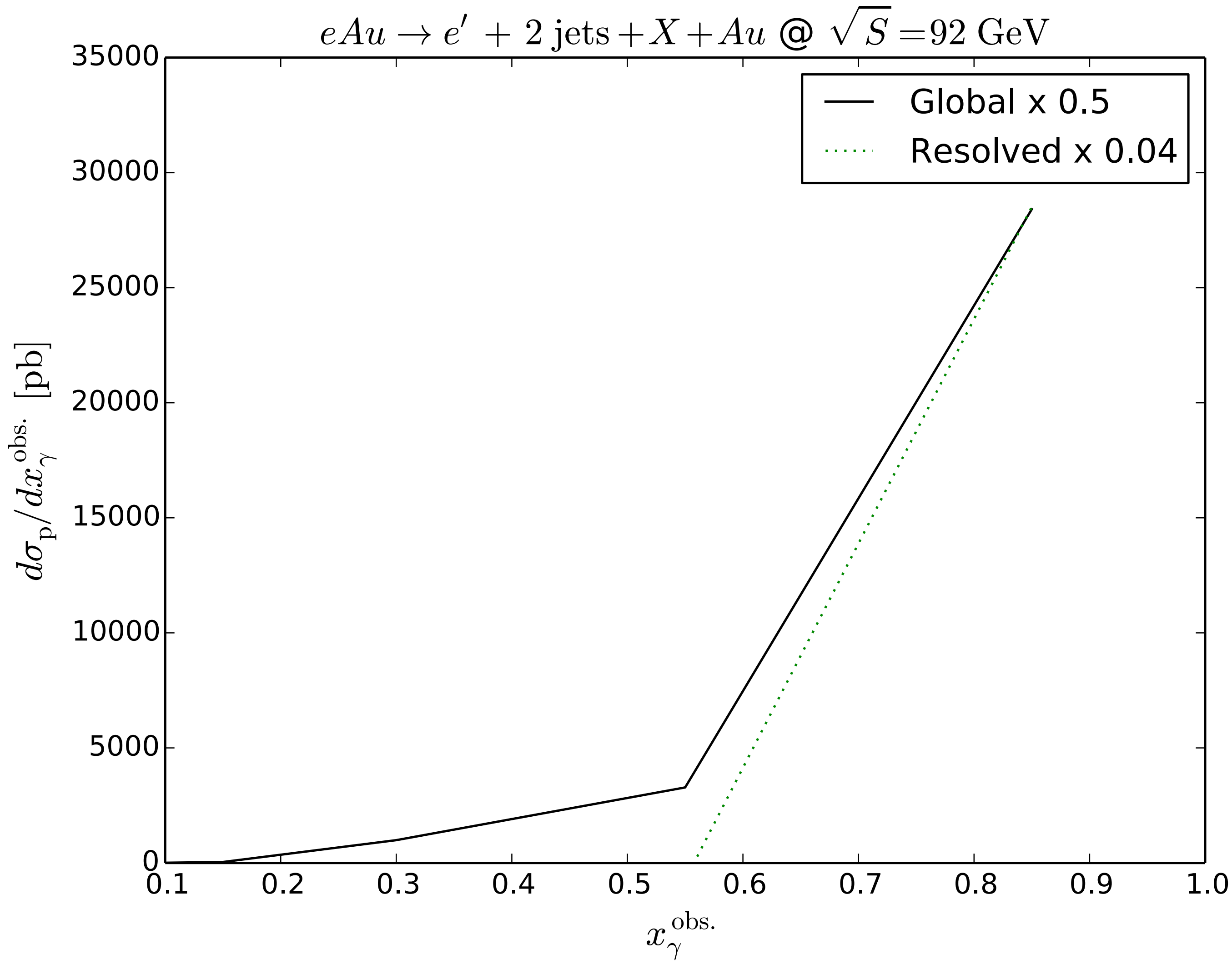








Diffractive dijet photoproduction on nuclei at EIC: factorization breaking



- x_γ dependence has the potential to distinguish between two used schemes of factorization breaking.

Summary

• Diffractive dijet photoproduction at EIC can help constrain proton diffractive PDFs and measure novel nuclear diffractive PDFs.

• In base EIC energy setting, our NLO pQCD approach predicts rates for $p_T < 8$ GeV, $x_\gamma > 0.5$, $|\Delta\eta| < 1.5$, $x_P > 0.01$, and $z_P > 0.4$.

• At EIC, the dijet photoproduction cross section is dominated by the direct photon contribution and gluon diffractive PDF.

• This process can solve the problem of the mechanism/pattern of factorization breaking in diffractive DIS: global suppression vs. resolved-only.

• For this, the most promising observable is x_γ dependence. To have wide coverage in x_γ, one needs the highest Ep and/or large range in x_P.