Gluon distribution from jet analysis in EIC

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Outline

- Gluon distribution from jets
  - Difficulty in inclusive events $\Rightarrow$ looking at 2+1 jet events
  - What to expect: kinematic reach
  - What to expect: statistical errors
- Other jet-related processes
  - Diffractive jets
  - DGLAP vs. BFKL in forward jets (saturation?)

Gluon distribution from inclusive data

Standard way of extacting the gluon distribution:

- consider the inclusive F_2 (plus other inclusive quantities as Drell-Yan cross-sections)
- PDF parametrised at $Q^2 = Q_0^2$ and evolved with DGLAP
  At LO:

$$
\begin{aligned}
F_2(x, Q^2) &\propto xq(x, Q^2) \\
\partial_{\log(Q^2)} q(x, Q^2) &= \alpha_s [P_{qq} \otimes q(\xi, Q^2) + P_{qg} \otimes g(\xi, Q^2)] \\
\partial_{\log(Q^2)} g(x, Q^2) &= \alpha_s [P_{gq} \otimes q(\xi, Q^2) + P_{gg} \otimes g(\xi, Q^2)]
\end{aligned}
$$

The gluon distribution is accessed

- through a convolution (with the splitting function)
- through the slope of F_2

Gluon distribution from inclusive data

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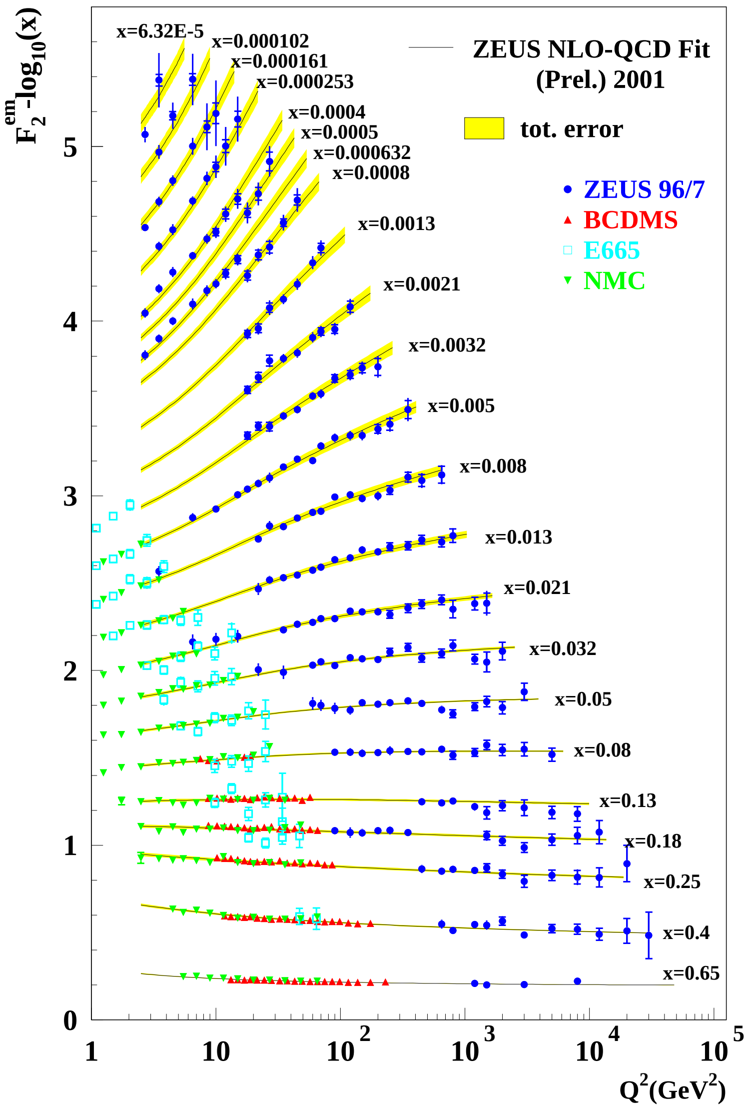
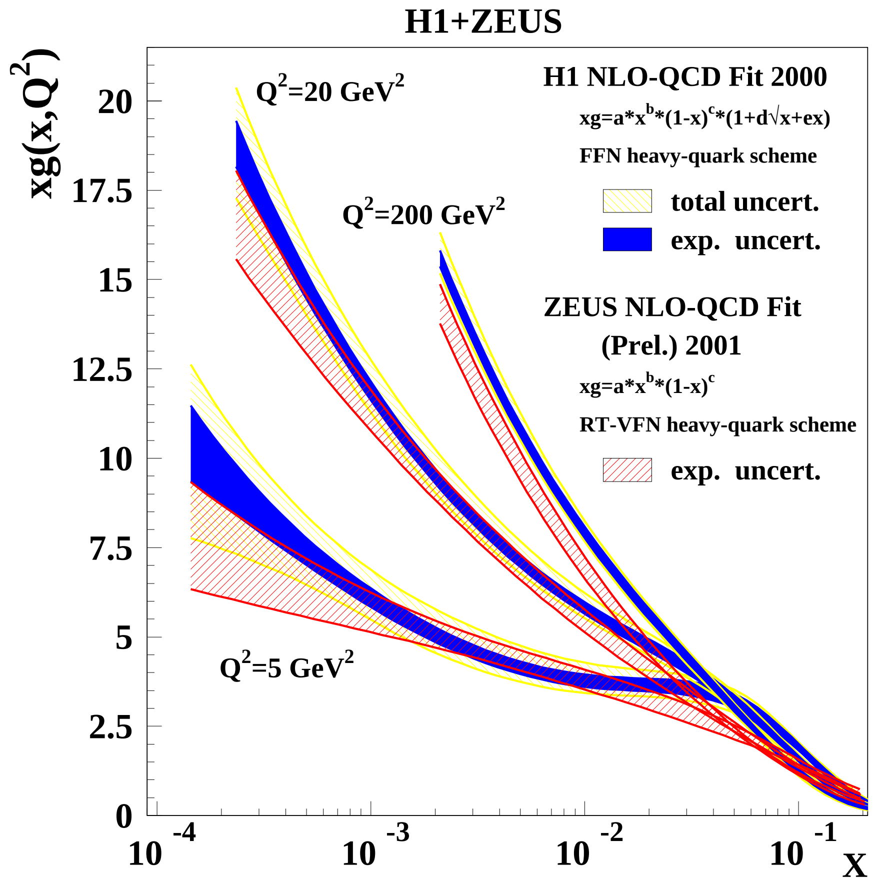
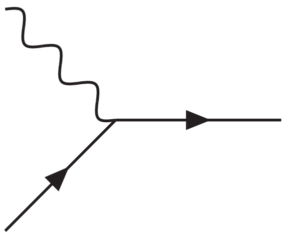


- more difficult to estimate
- particularly at small x where the Q^2 range is smaller

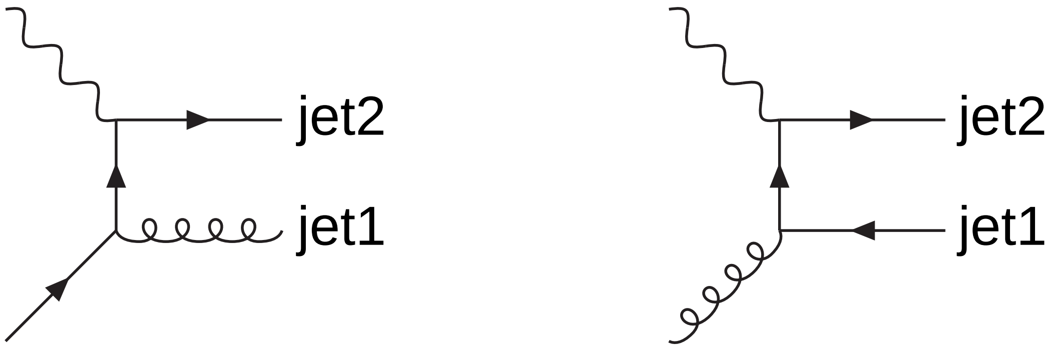


"1+1 jet" dominated by



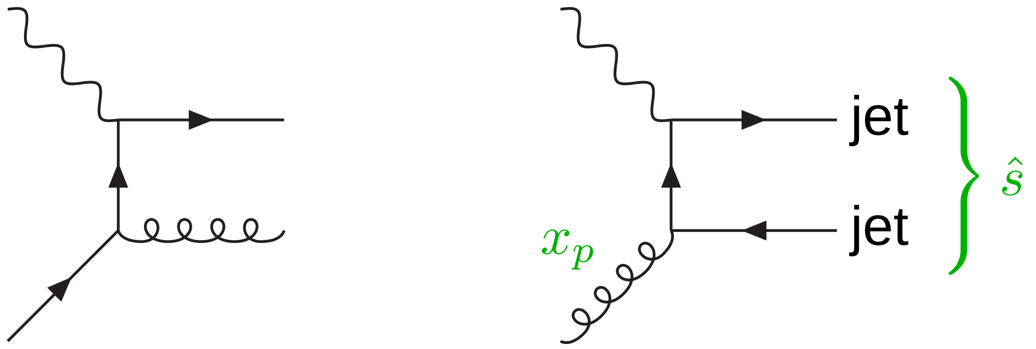
i.e. dominated by quarks (gluons start at NLO)

“2+1 jets” becomes more interesting



- involve quarks and gluons
- dominated by gluons at small x

"2+1 jets" becomes more interesting



Main formula:

$$\frac{d^2\sigma^{2+1}}{dx_p dQ^2} = \alpha_s \left[a\, g(x_p, Q^2 + \hat{s}) + b\, q(x_p, Q^2 + \hat{s})\right]$$

Technique:

1. a and bq: matrix elements & quark piece from Monte Carlo
2. $x_p = x\left(1 + \frac{\hat{s}}{Q^2}\right)$
3. Extract the gluon distrib: $g_{\text{extr.}} = \frac{1}{a_{\text{MC}}}\left(\sigma_{\text{meas.}} - b_{\text{MC}} q\right)$

Gluons from 2+1 jets

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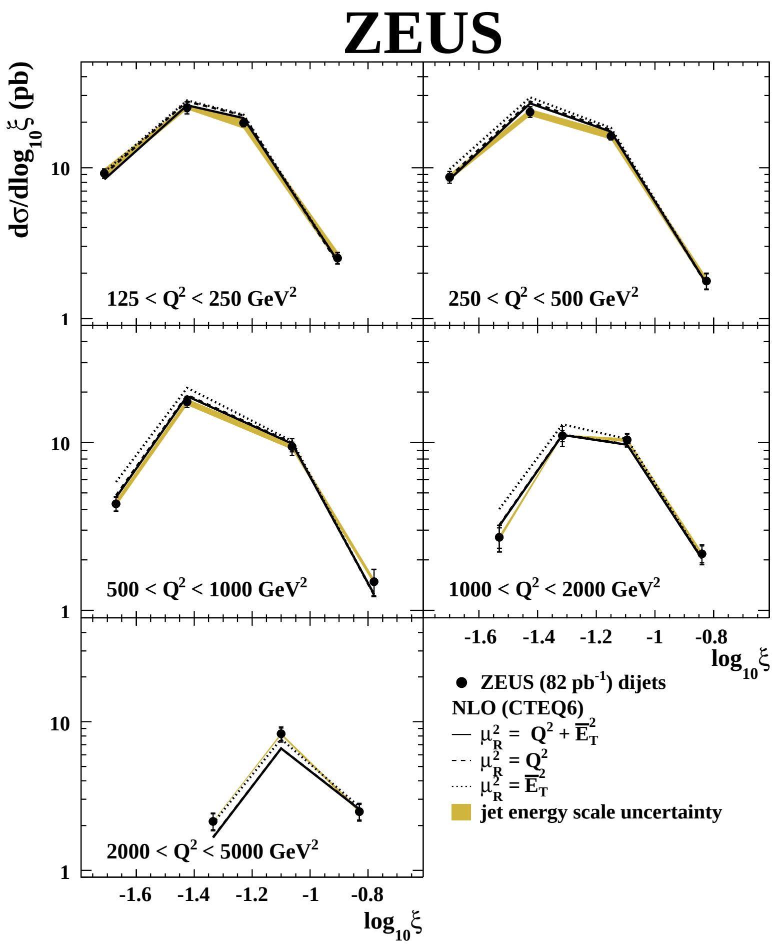
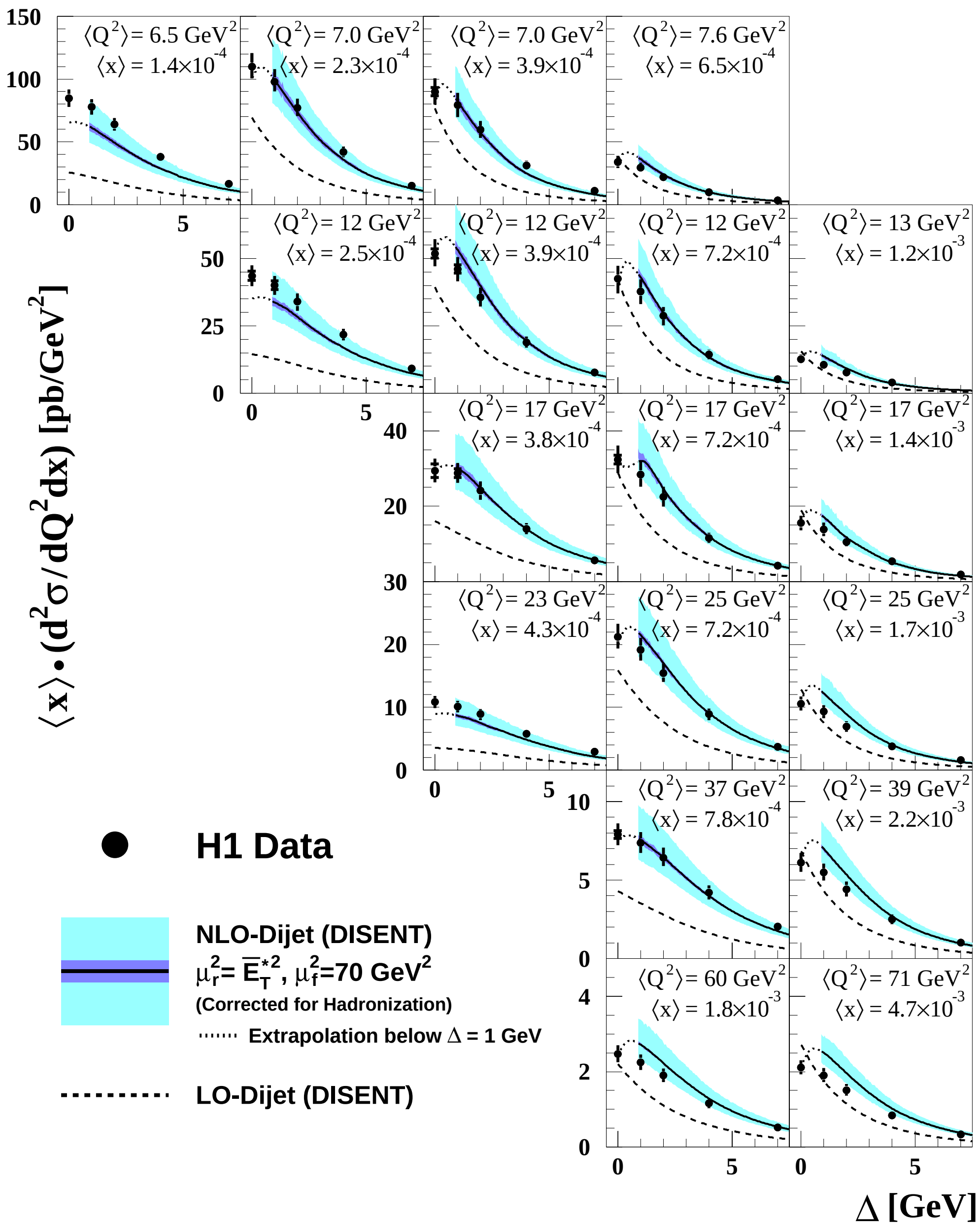
Measured at HERA





Matrix elements

Can, in principle, be computed from pQCD

Monte Carlo allows to

- put experimental cuts (*e.g.* outgoing electron energy)
- account for parton shower and hadronisation
- account for jet-clustering effects
- compute quark and gluon parts

EIC: Kinematic reach

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  - minimal $x = \frac{Q^2}{Q^2+4P(E-E'_{\text{min}})}$
  - minimal $\hat{s} = 2p_{t,\text{min}}^2 \left[1-\cos(R)\right]^2$

$$\Rightarrow \quad \boxed{x_g \le \frac{p_{t,\text{min}}^2 \left[1-\cos(R)\right]^2}{2P(E-E'_{\text{min}})}}$$

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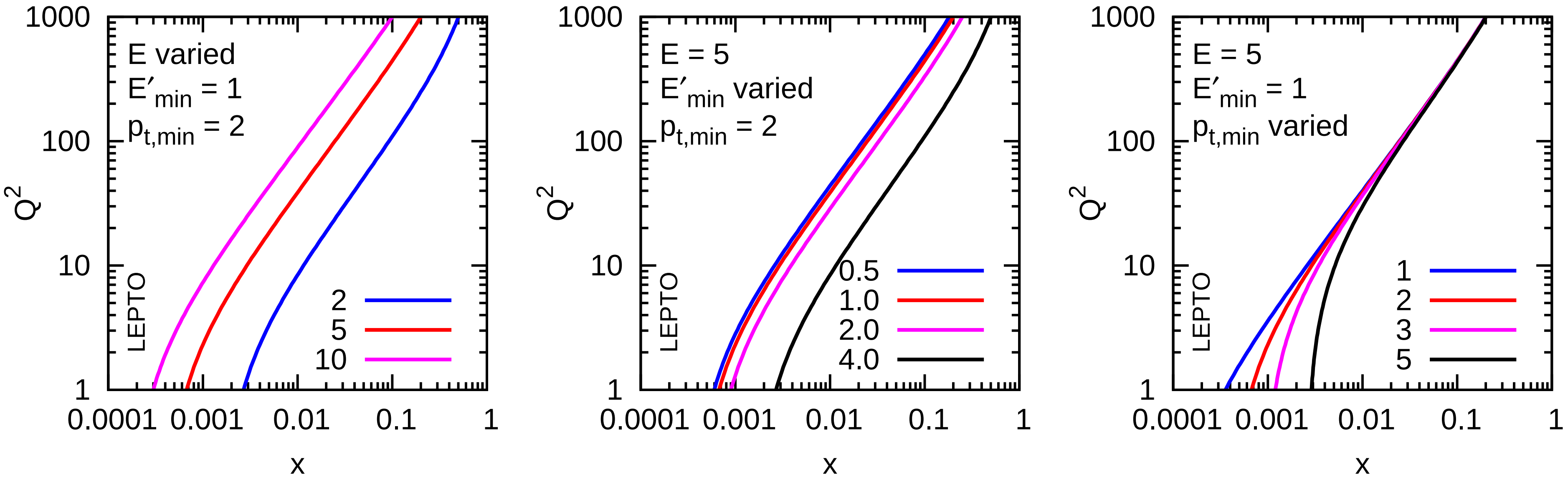
Reach small x:

- decrease $p_{t,\text{min}}$ or E'_{min}/ increase beam energies – experimental issue
- decrease R – more systematic errors

EIC: Kinematic reach

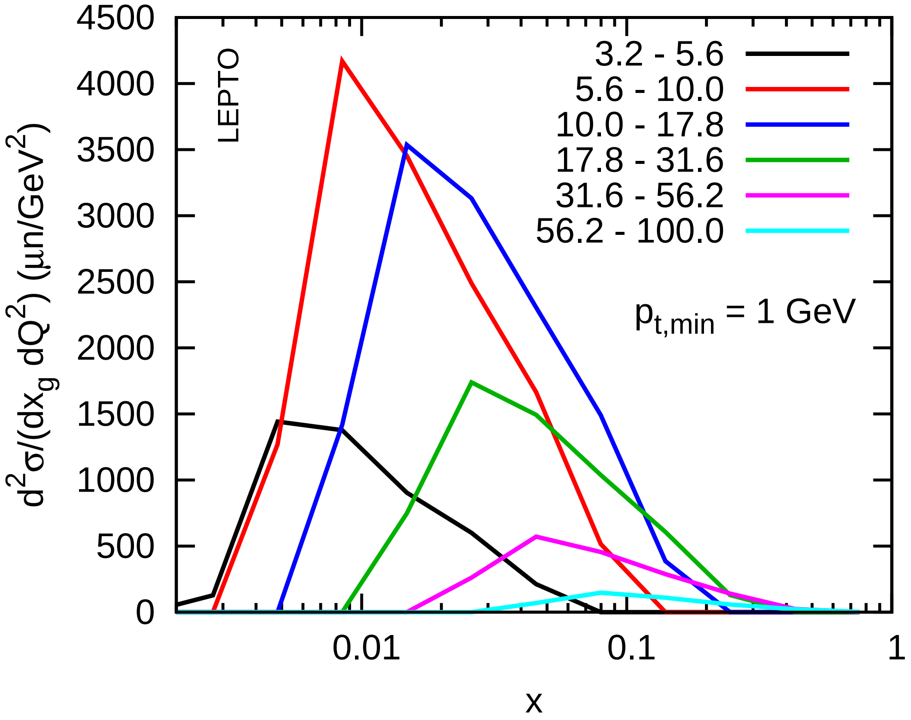
Hadron beam: $P = 250$ GeV

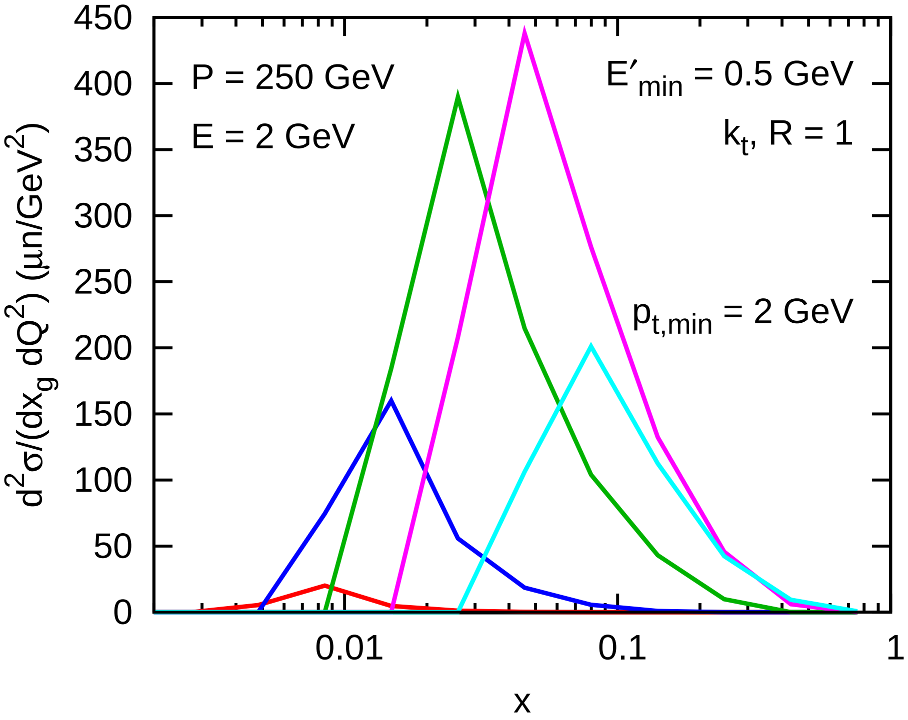
Clustering: k_t algorithm with $R = 1$



Hard to reach $x_g < 10^{-3}$

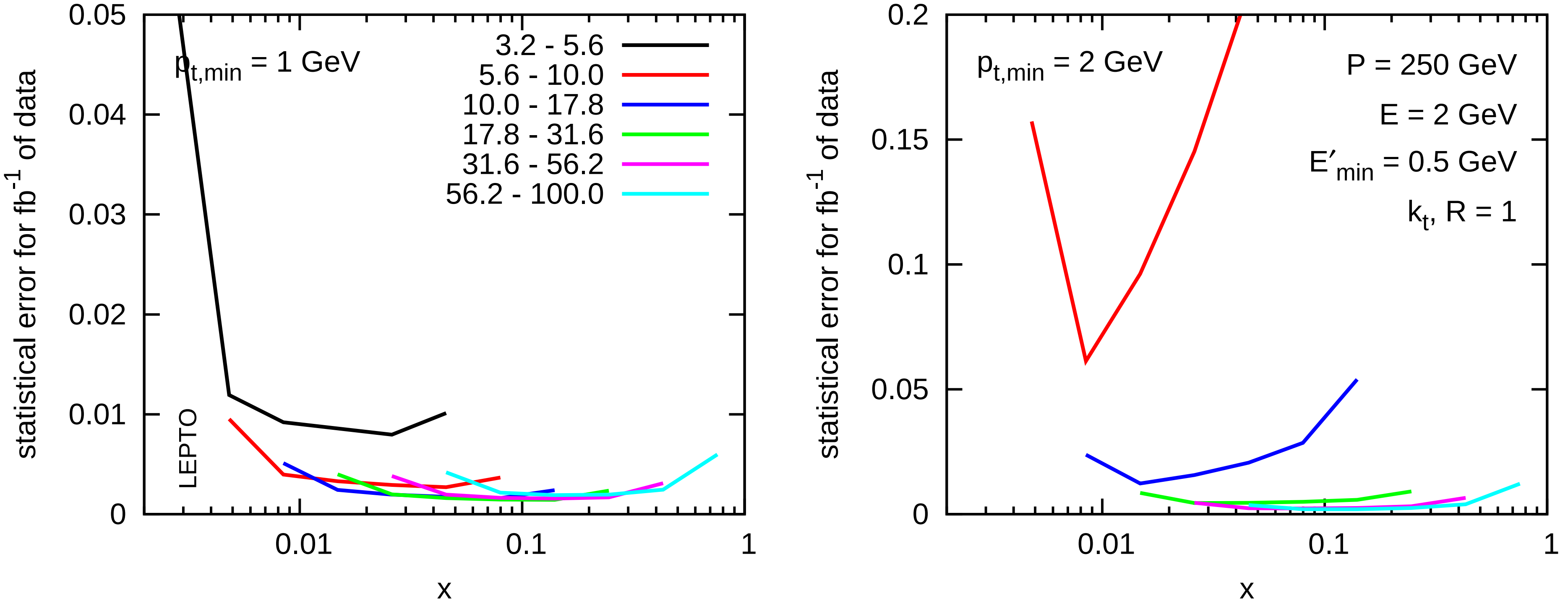
Cross-section





- Over optimistic cuts
- Less optimistic reduces x_{min}, Q^2_{min} and the cross-section

Statistical errors



- Fine with over optimistic cuts
- Less optimistic increases errors

Systematic errors

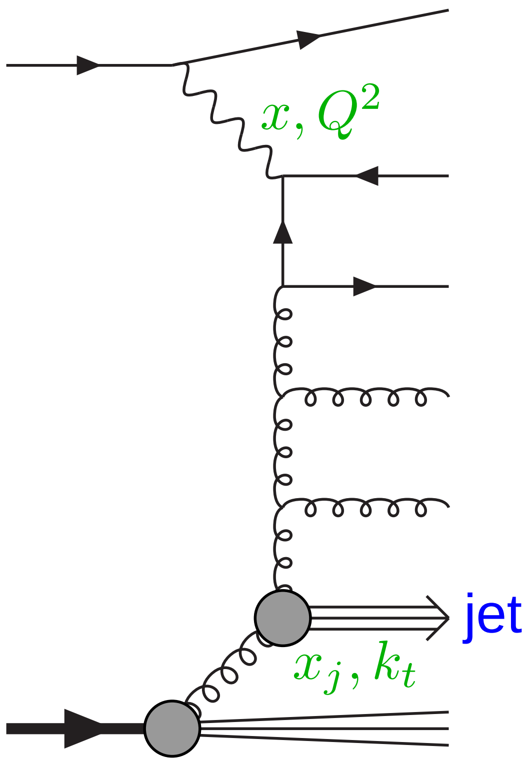
Some of the systematics come from theory:

- Scale in g: $Q^2 + \hat{s}$?, Q^2?
- Matrix element computation: effects of the cuts
- Errors on the quark contrib.: from incl. measurements
- Clustering effects: vary/optimise jet algorithm and parameter

Other useful jet measurement(s)

Forward jets

Tag a forward jet with $x \ll x_j$.

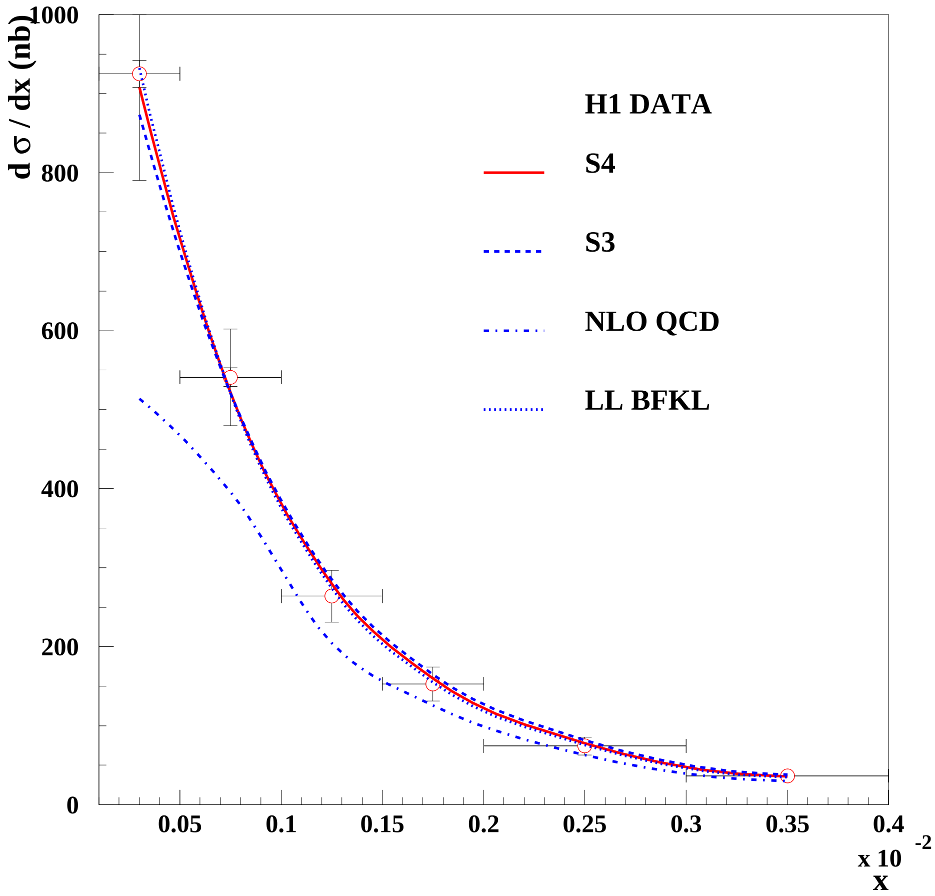


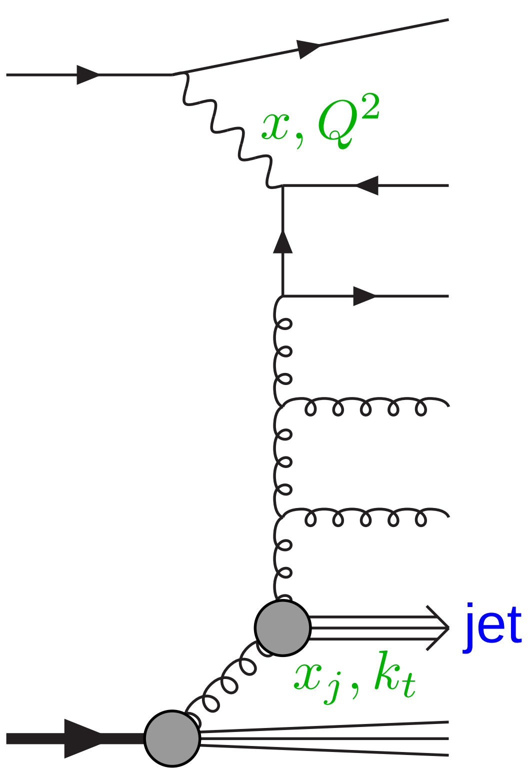
Forward jets

Tag a forward jet with $x \ll x_j$.

If $Q^2 \sim k_t^2$,

- DGLAP and fixed-order fail
- BFKL works





[Kepka, Marquet, Peschanski, Royon]

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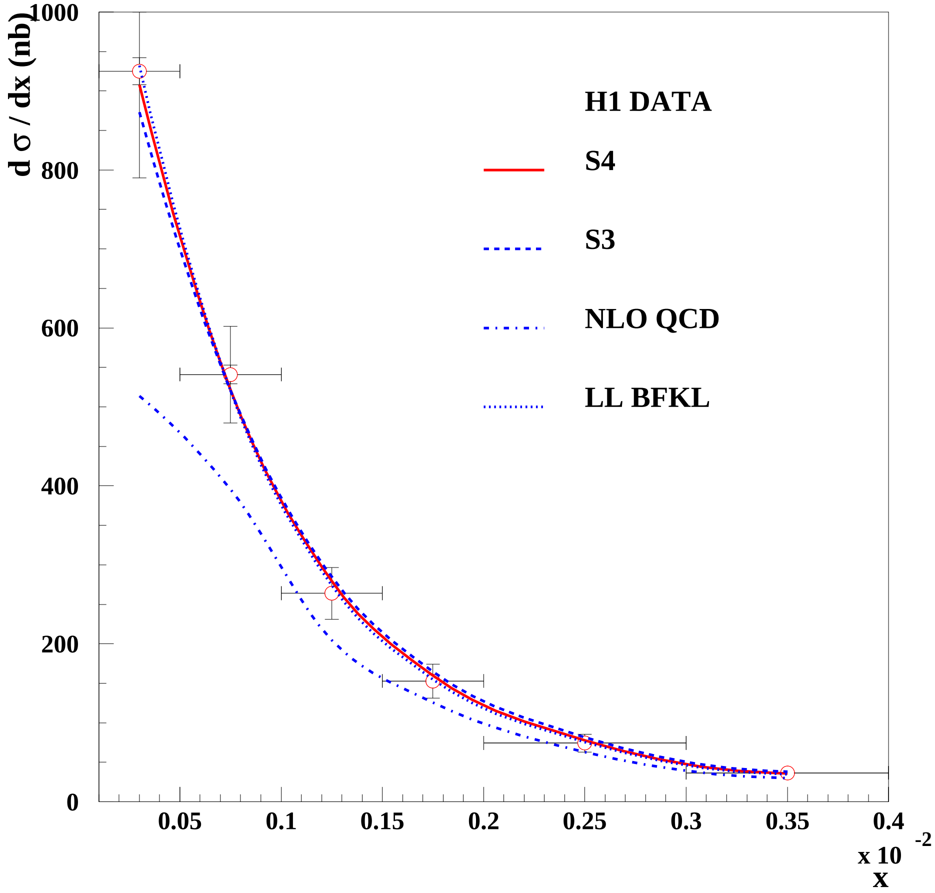

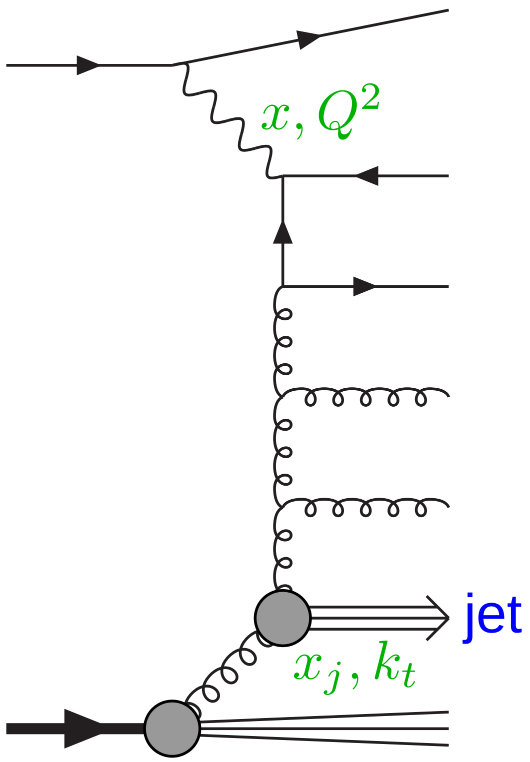

Question for EIC:

Hints for BFKL, saturation & multiple interactions effects in eA collisions?

Conclusions

What can we learn from jet physics at EIC

- gluon PDF
  - from 2+1 jets
  - Kinematics and statistical errors
    - Low-energy option: probably needs over-optimistic cuts
    - Larger-energy option promosing
  - ep vs. eA: multiple interactions effect (+shadowing)

- Other jet measurements
  - diffractive 2+1 jets $\longrightarrow$ diffractive PDF
  - BFKL (and saturation) tests from forward jets