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?)
  - Cold medium quenching

Gluon distribution from inclusive data

Standard way of extracting the gluon distribution:

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

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

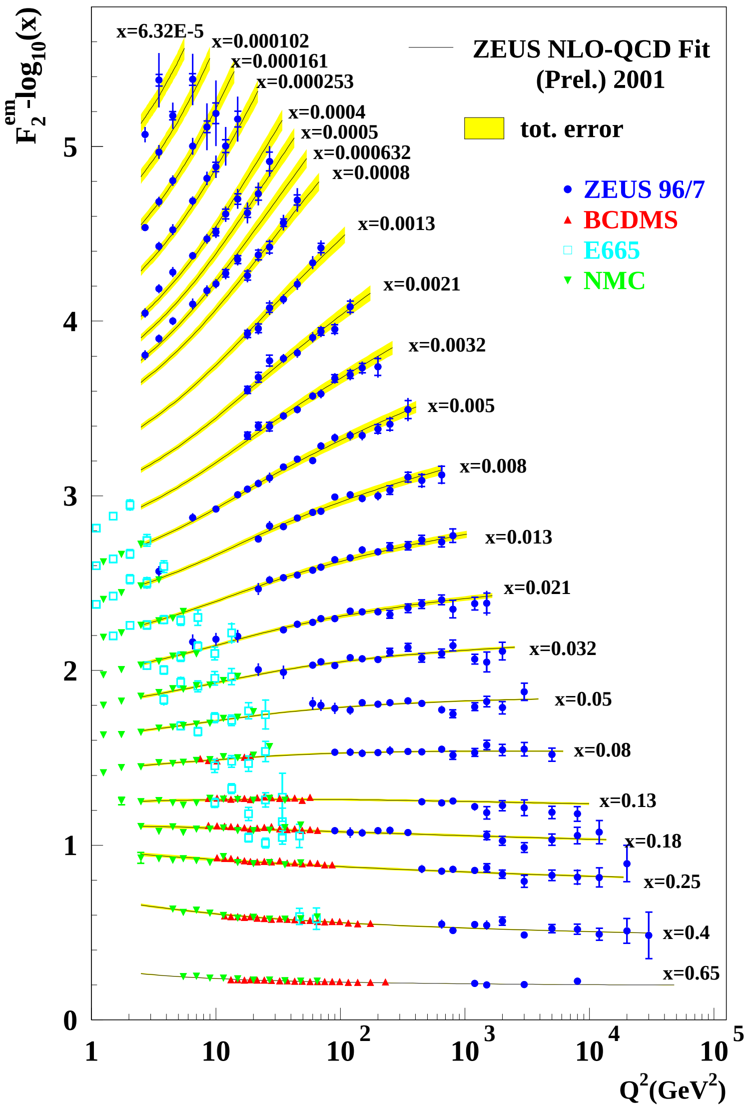
The gluon distribution is accessed

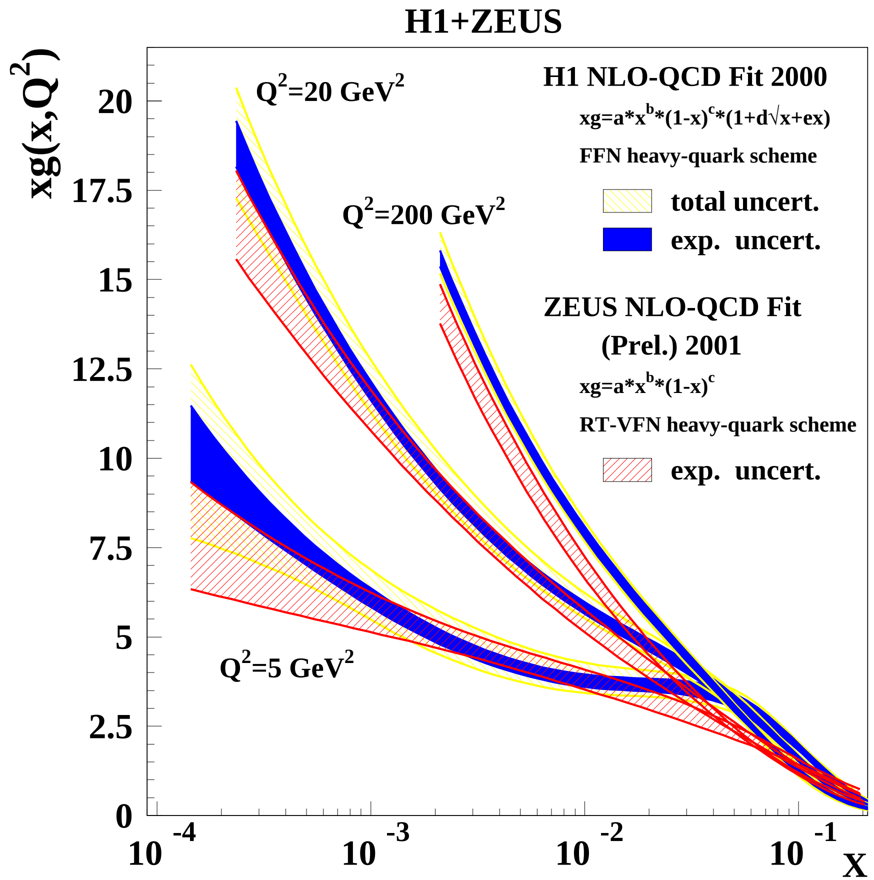
- through a convolution (with the splitting function)
- through the slope of F_2

Gluon distribution from inclusive data

The gluon distribution is accessed through the slope of F_2

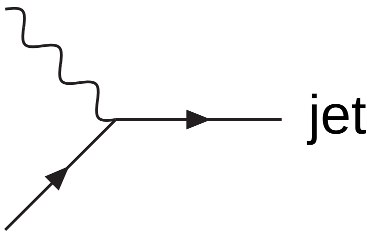
- more difficult to estimate
- particularly at small x where the Q^2 range is smaller





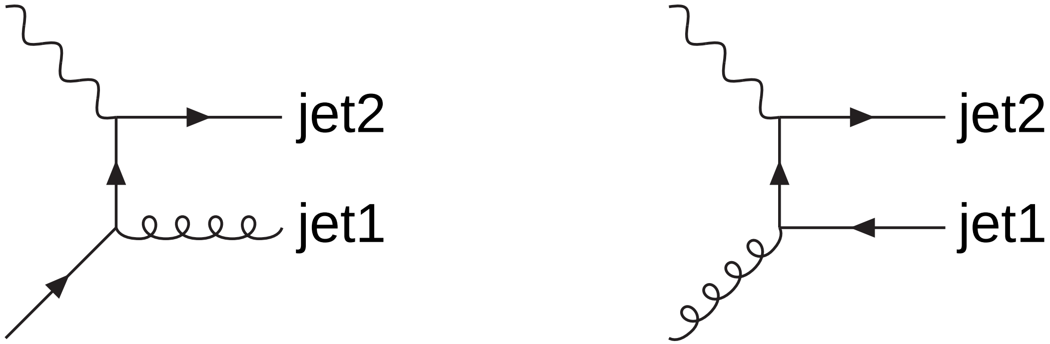
Jets in DIS

"1+1 jet" dominated by



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

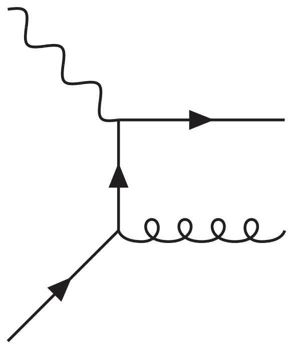
"2+1 jets" becomes more interesting

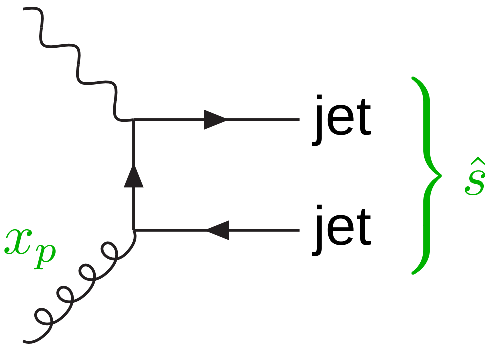


- involve quarks and gluons
- dominated by gluons at small x

Jets in DIS

“2+1 jets” becomes more interesting





Main formula:

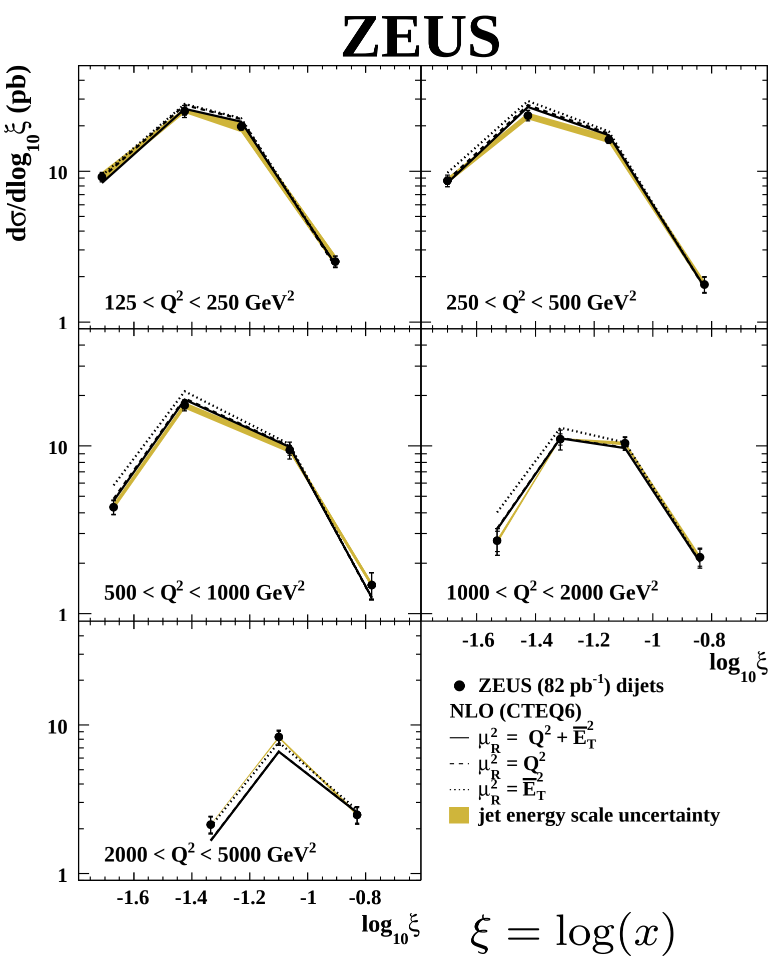
$$\frac{d^2\sigma^{2+1}}{dx_p dQ^2} = \alpha_s \left[a\, g(x_p, Q^2) + b\, q(x_p, Q^2)\right]$$

Technique:

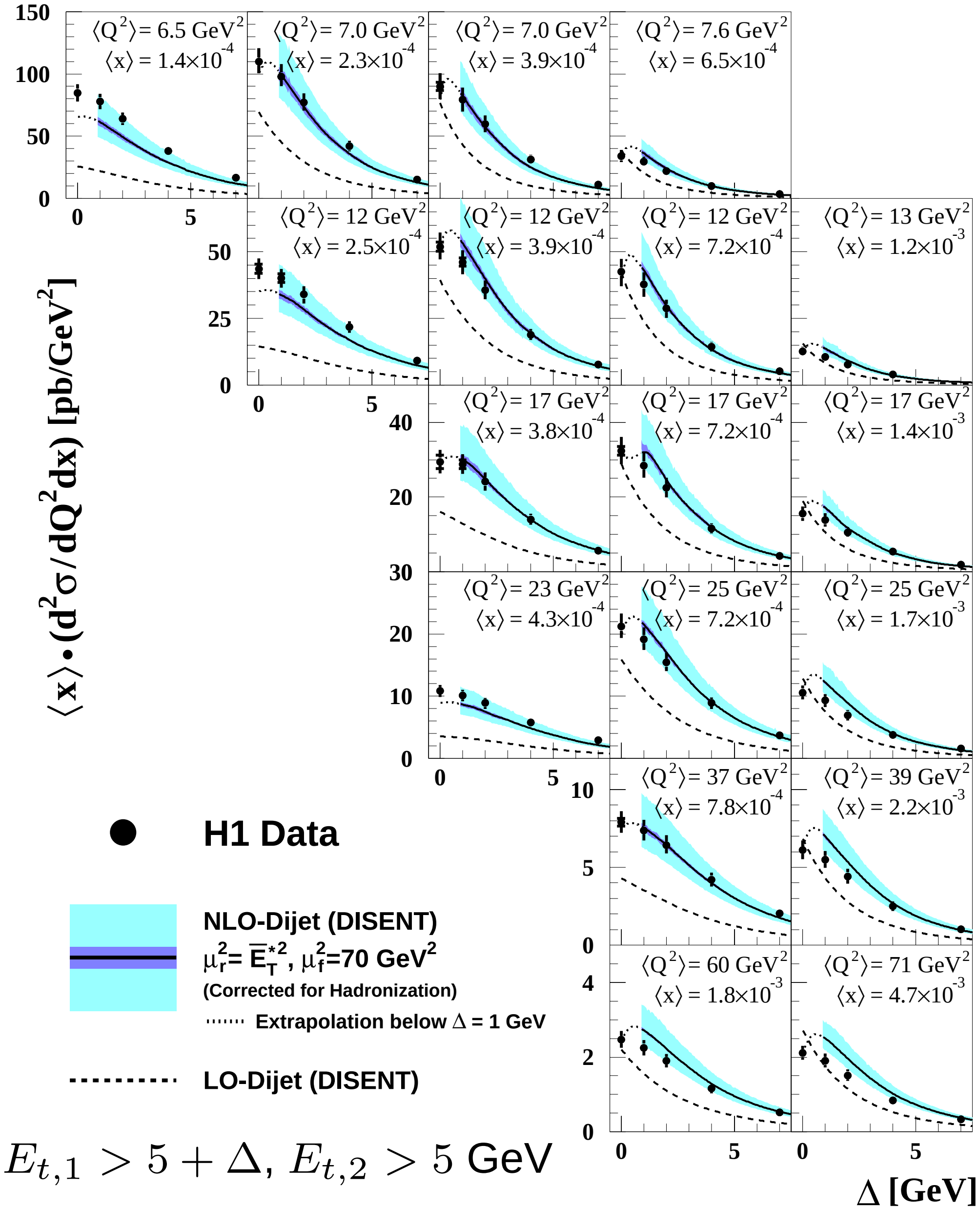
1. a and bq: matrix elements & quark piece from Monte Carlo
2. $x_p = x\left(1 + \frac{\hat{s}}{Q^2}\right)$
3. Extract the gluon distrib: $g_{\text{extr.}} = \frac{1}{a_{\text{MC}}}\left(\sigma_{\text{meas.}} - b_{\text{MC}} q\right)$

Gluons from 2+1 jets

Measured at HERA



$\xi = \log(x)$



$E_{t,1} > 5 + \Delta,\ E_{t,2} > 5$ GeV

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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  - Outgoing electron energy: E'_{min}
  - Minimal jet p_t: $p_{t,\text{min}}$ (in the Breit frame)
  - Azimuthal separation between the 2 jets: $\Delta\phi > \pi - \varepsilon$ (in the Breit frame — ensures that the 2 jets come from the hard scattering)

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- Consequences:
  - minimal $x = \frac{Q^2 E_0}{P[Q^2+4E_0(E-E_0)]}$ (with $E_0 = \max(E'_{\text{min}}, Q^2/(4E))$)
  - minimal $\hat{s} = 4p^2_{t,\text{min}}$

$$\Rightarrow \quad \boxed{x_g \geq \frac{p^2_{t,\text{min}}}{P(E - E'_{\text{min}})}}$$

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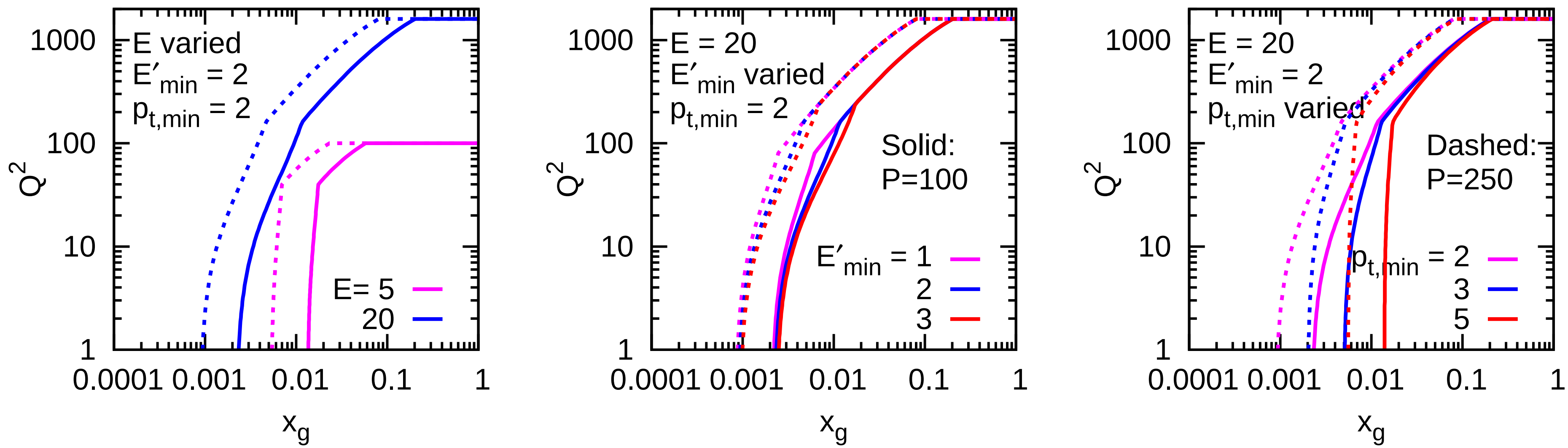
Reach small x:

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

EIC: Kinematic reach

Hadron beam: $P = 100$ (solid) or 250 GeV (dashed)

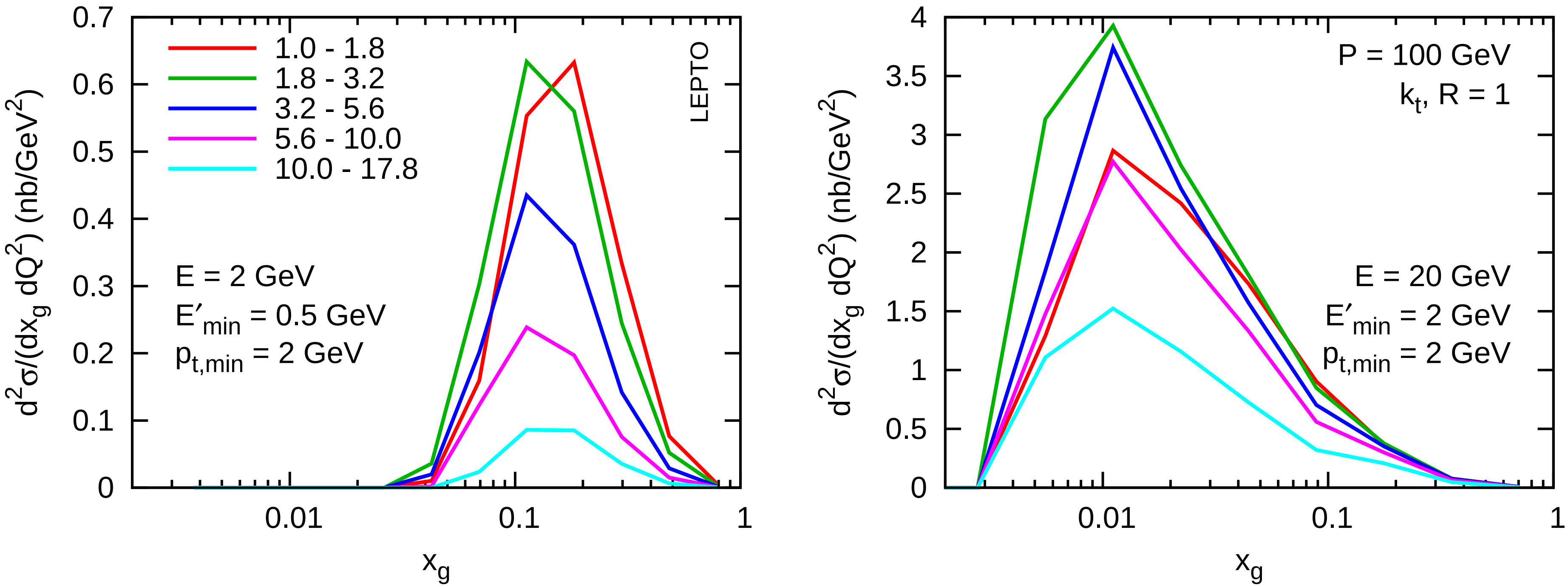
Clustering: k_t algorithm with $R = 1$



Hard to reach $x_g < 10^{-2}$

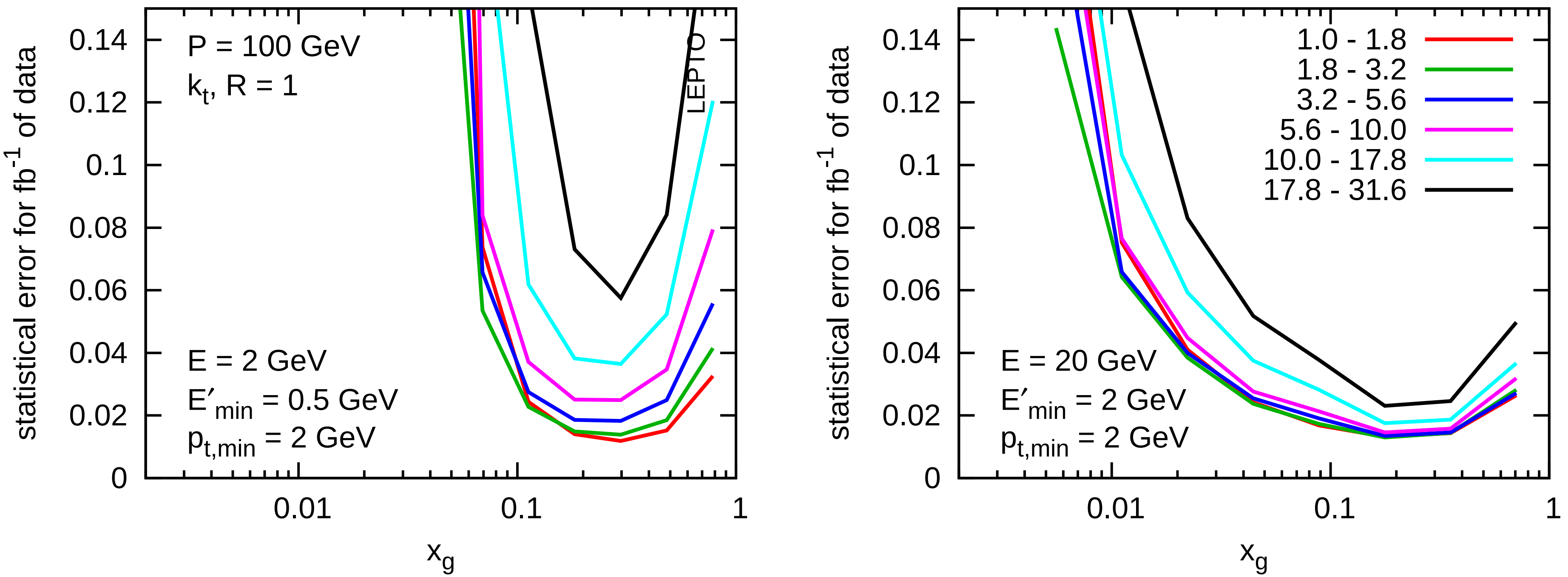
Cross-section

Cross-section for gluon-initiated dijet events (obtained with LEPTO)



Statistical errors

Stat. errors assuming 1 fb^{-1} of data:



- small at mid & large x
- larger at small x (effect of the cuts)

Systematic errors

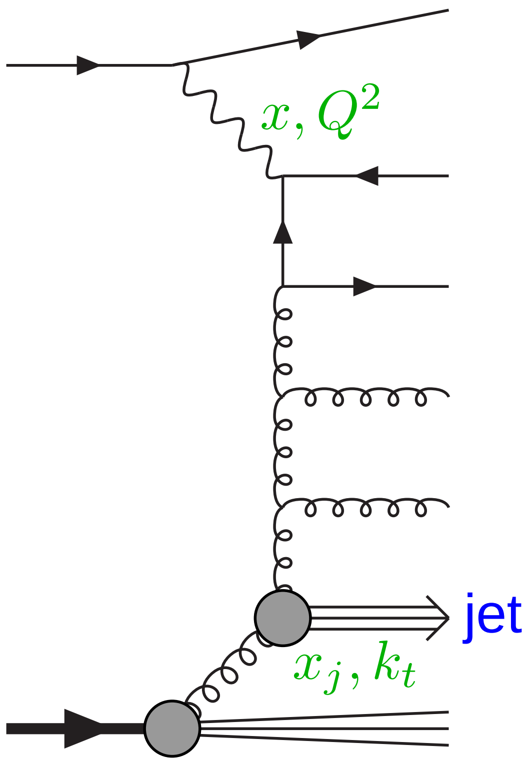
Some of the systematics come from theory:

- Scale in g: Q^2 or $Q^2 + \hat{s}$?
- Matrix element computation: effects of the cuts
- Errors on the quark contrib.: from incl. measurements

Other useful jet measurement(s)

Forward jets

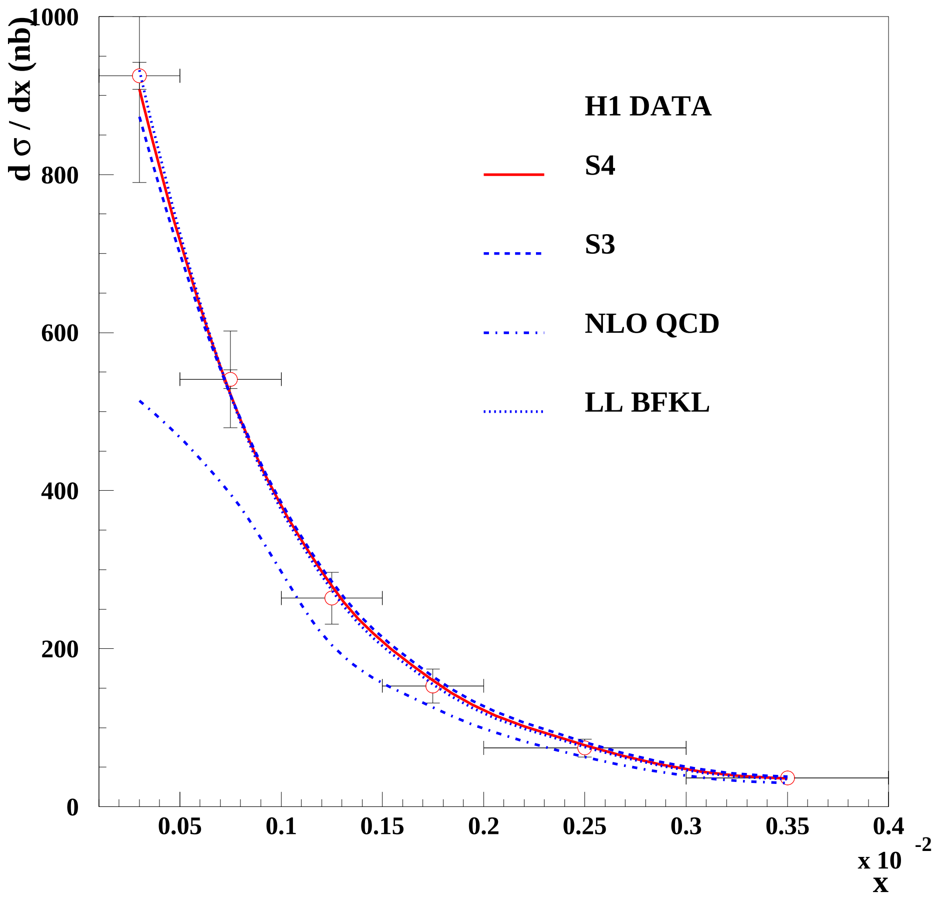
Tag a forward jet with $x \ll x_j$.

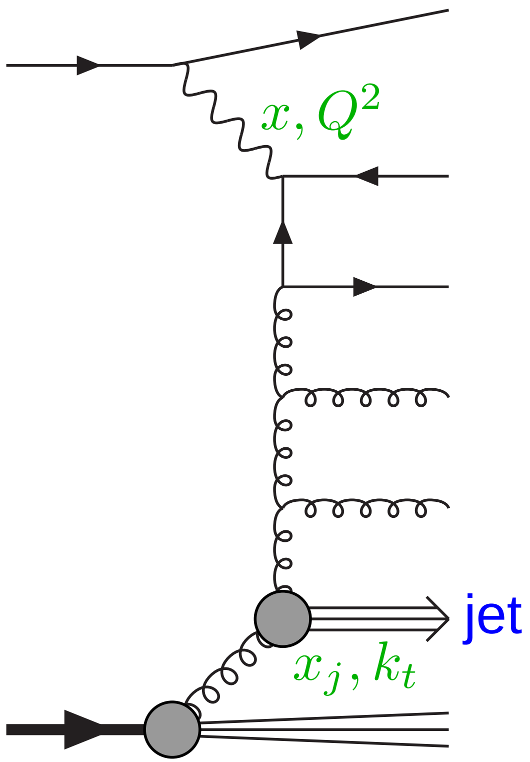


Forward jets

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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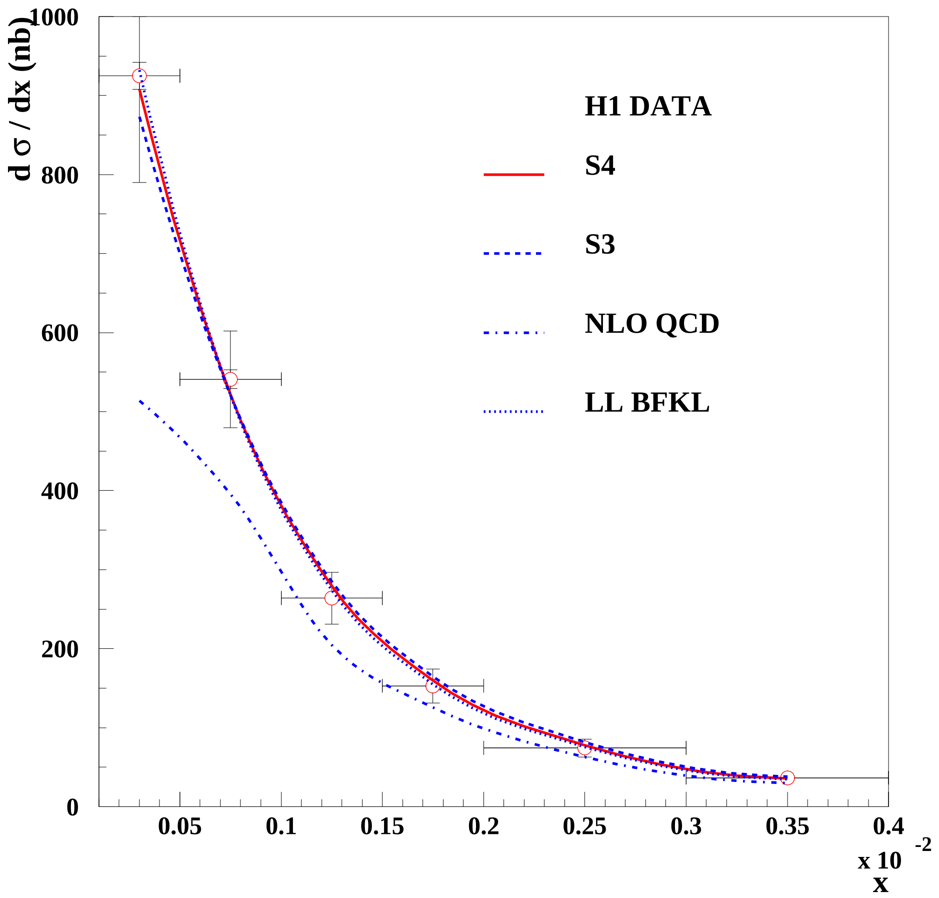

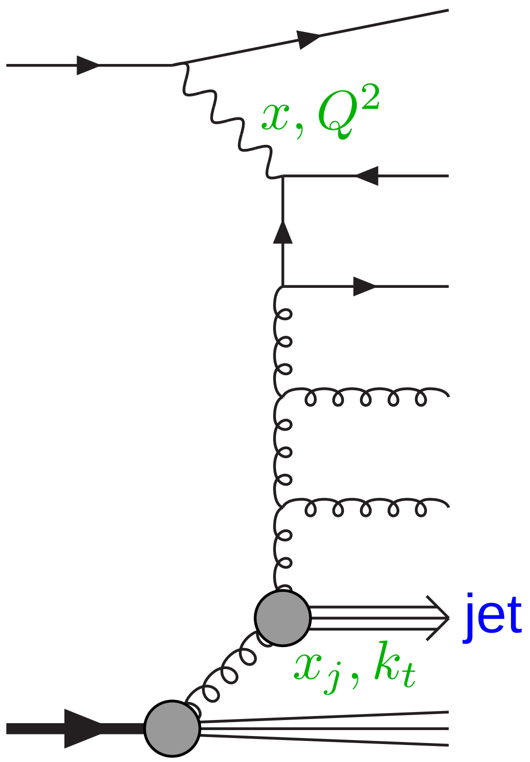

Question for EIC:

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 optimistic cuts
    - Larger-energy option more promising
  - ep vs. eA: multiple interactions effect (+shadowing)

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