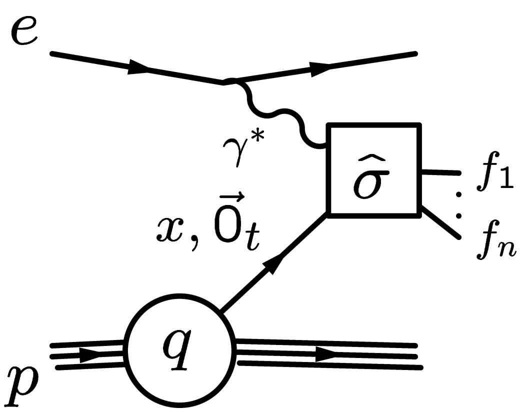
Unintegrated parton distributions

Graeme Watt (IPPP, University of Durham)



Collinear factorisation using (integrated) parton distribution functions $q(x,\mu^2)$:

$$\sigma_{\gamma^* p}(\mu^2) = \sum_q \int \mathrm{d}x\, \widehat{\sigma}_{\gamma^* q}(x,\mu^2)\, q(x,\mu^2)$$

- Incorporate transverse momentum $\vec{k}_t$ into PDF:

$$q(x,\mu^2) \sim \int^{\mu^2} \frac{\mathrm{d}k_t^2}{k_t^2} f_q(x, k_t^2, \mu^2),$$

  where $f_q(x, k_t^2, \mu^2)$ is the *unintegrated* PDF.

- How does a parton acquire $\vec{k}_t$?

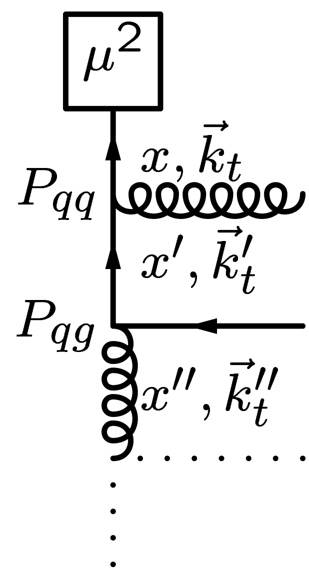
DGLAP evolution

- In physical gauge, *ladder* diagrams resum the leading $\alpha_S \ln \mu^2$ contributions:

$$\int^{\mu^2} \frac{\mathrm{d}k_t^2}{k_t^2} \int^{k_t^2} \frac{\mathrm{d}k_t'^2}{k_t'^2} \int^{k_t'^2} \frac{\mathrm{d}k_t''^2}{k_t''^2} \ldots$$

- Leading Log. Approximation (LLA) $\Leftrightarrow$ strong ordering in transverse mom.:

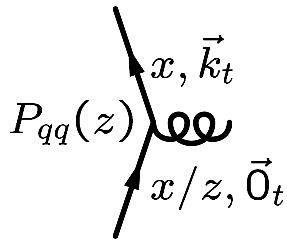
$$\mu^2 \gg k_t^2 \gg k_t'^2 \gg k_t''^2 \gg \ldots$$

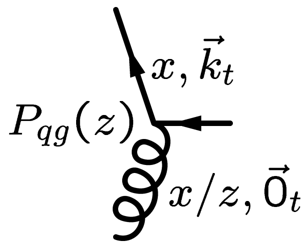


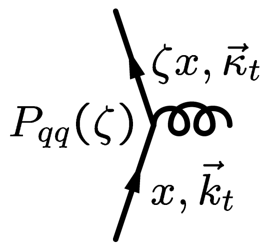
Calculate $f_q(x, k_t^2, \mu^2)$ by unfolding last step of evolution
(Kimber, Martin, Ryskin, hep-ph/0101348)

- Start from modified DGLAP equation:

$$\frac{\partial q(x,k_t^2)}{\partial \ln k_t^2} = \frac{\alpha_S(k_t^2)}{2\pi} \times \Bigg[\underbrace{\int_x^{z_{\max}} \frac{\mathrm{d}z}{z} P_{qq}(z) q(\frac{x}{z}, k_t^2)}_{\text{real}} + \underbrace{\int_x^1 \frac{\mathrm{d}z}{z} P_{qg}(z) g(\frac{x}{z}, k_t^2)}_{\text{real}} \underbrace{- q(x,k_t^2) \int_0^{\zeta_{\max}} \mathrm{d}\zeta \, P_{qq}(\zeta)}_{\text{virtual}} \Bigg]$$







- Resum virtual term in Sudakov form factor:

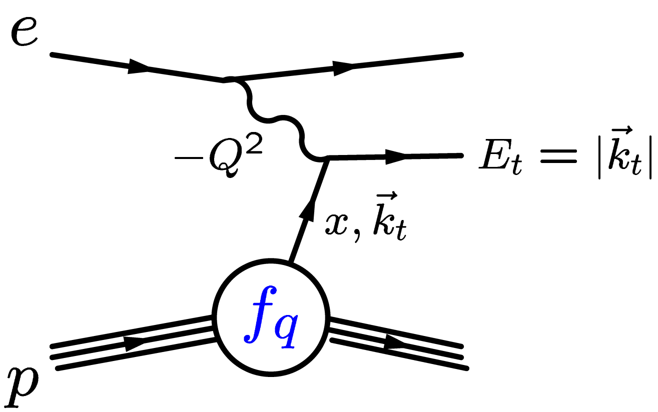
$$T_q(k_t^2, \mu^2) = \exp\left(- \int_{k_t^2}^{\mu^2} \frac{\mathrm{d}\kappa_t^2}{\kappa_t^2} \frac{\alpha_S(\kappa_t^2)}{2\pi} \int_0^{\zeta_{\max}} \mathrm{d}\zeta \, P_{qq}(\zeta) \right)$$

- Colour coherence $\Rightarrow$ angular-ordered gluon emission $\Rightarrow z_{\max} = \frac{\mu}{\mu + k_t}$ and $\zeta_{\max} = \frac{\mu}{\mu + \kappa_t}$.

- Then the unintegrated quark distribution is:

$$\boxed{f_q(x, k_t^2, \mu^2) = T_q(k_t, \mu) \left(\frac{\partial q(x, k_t^2)}{\partial \ln k_t^2} \right)_{\text{real}}}$$

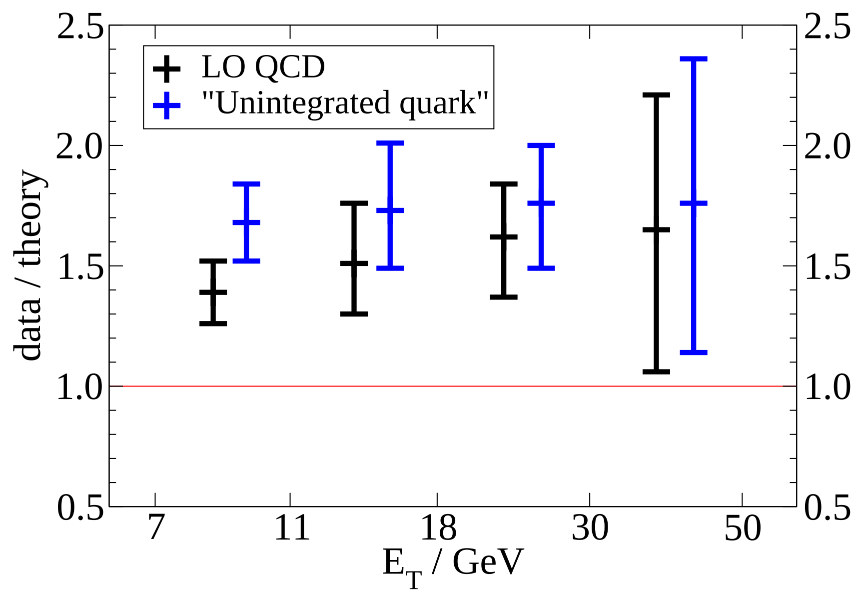
Simplest application: inclusive jet production in DIS



- $f_q = f_q(x, z, k_t^2, \mu^2)$
- Work in *Breit* frame.
- Account for real emission hidden in f_q. This diagram $\rightarrow$ *two* jets with E_t.
- Compare prediction to H1 data.

- *Check*: reproduce structure function $F_2(x, Q^2)$ ✓

- Initial results for dσ/dE_t with $150 < Q^2 < 200$ GeV^2, $-1 < \eta^{\text{LAB}} < 2.5$ and $\mu^2 = E_t^2 + Q^2$:



"Unintegrated quark" prediction close to LO QCD, but not to data. Need to extend calculation to NLO and/or obtain better data.

- *Future work*: W, Z, prompt photon production, . . .