Determination of Unintegrated Gluon Densities with $F_2^{c\bar{c}}$ at HERA

A. Cholewa, H. Jung, A. Kusina
H1 Collaboration, DESY

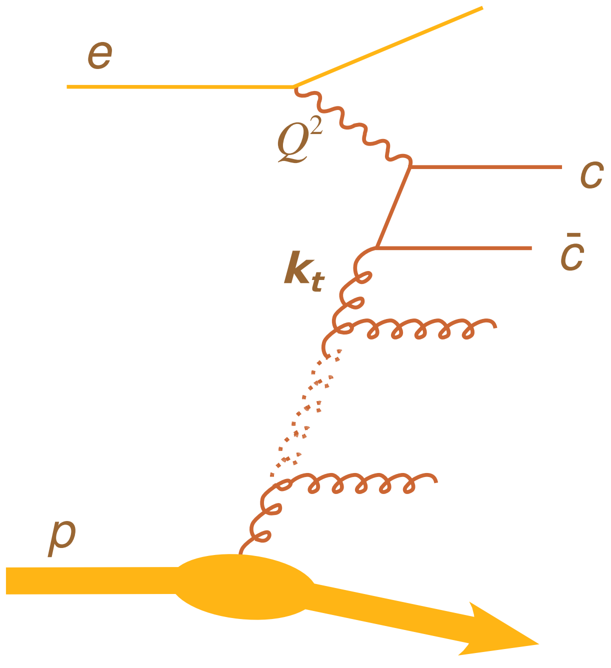
Overview

- **Reminder** - **Why unintegrated PDFs?**
- **Fits of uPDFs** - **General method and distinctive features**
- **Parameter scans** - **Sensitivity to α_s and gluons**
- **Resulting uPDFs** - **Different quarks, different gluons?**
- **Charm in DIS and γp** - **Fits to final state cross sections**
- **Summary and Outlook**

Reminder – Why unintegrated Gluon Densities?

Charm Production at HERA

- predominantly via Photon Gluon Fusion



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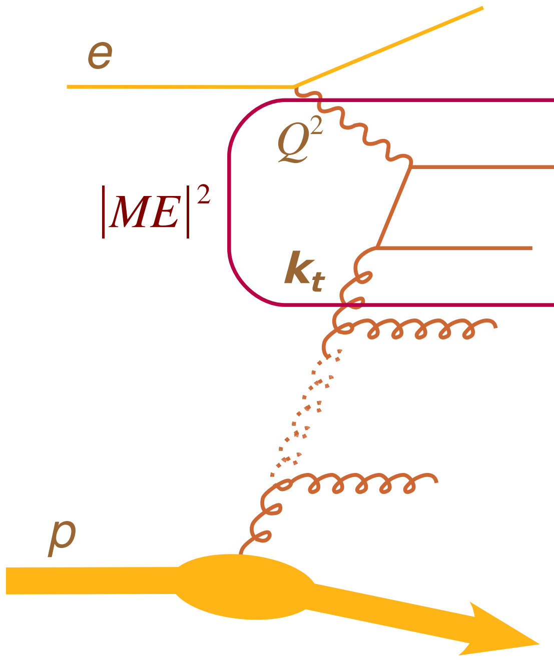
  - ✗ **collinear $|ME|^2$ gives vanishing p_t**



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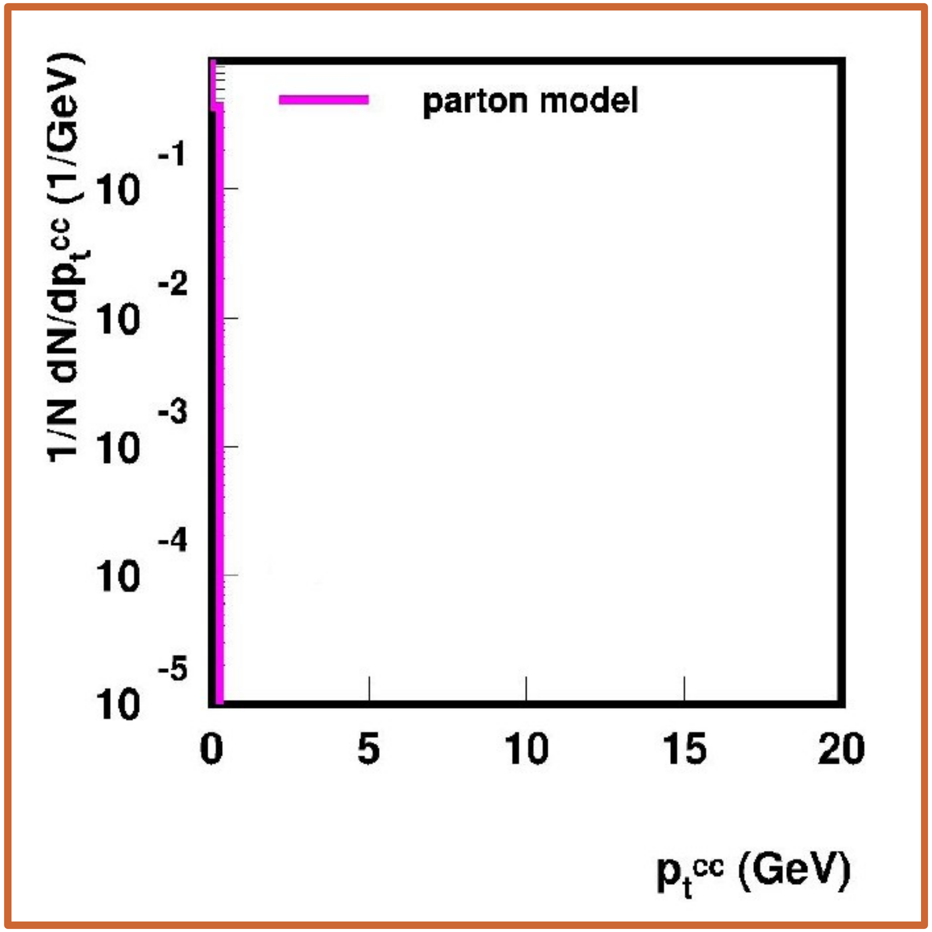

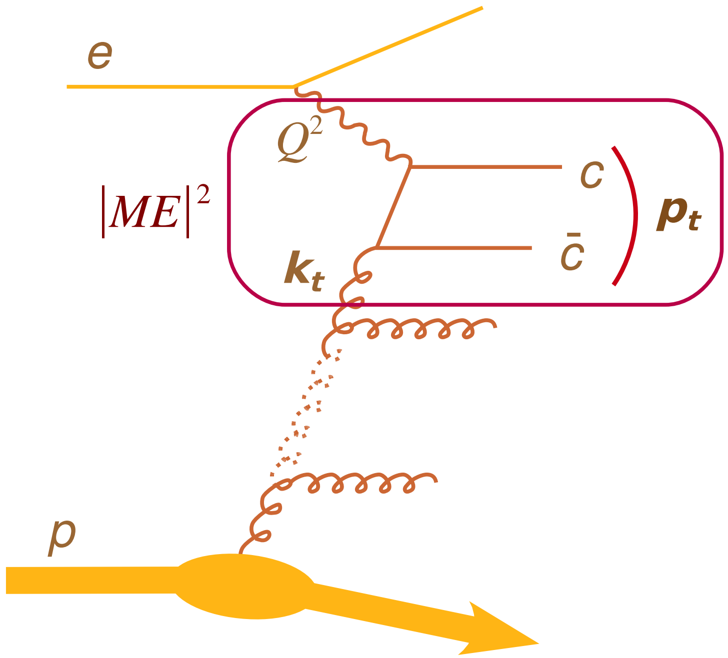

H. Jung, J. Collins: hep-ph/0508280

Reminder – Why unintegrated Gluon Densities?

Charm Production at HERA

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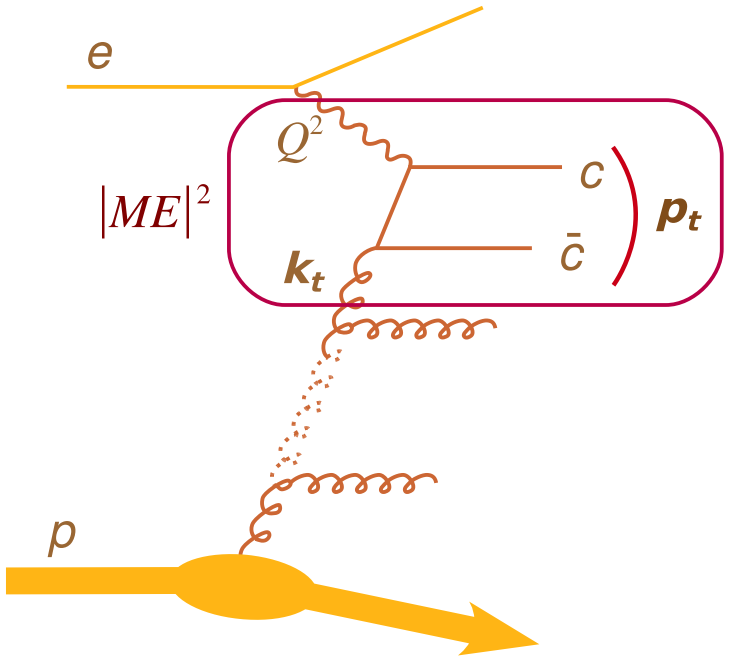
  - ✗ collinear $|ME|^2$ gives vanishing p_t
  - ✗ k_t factorisation using *CCFM*
    - ➔ off shell gluons in $|ME|^2$



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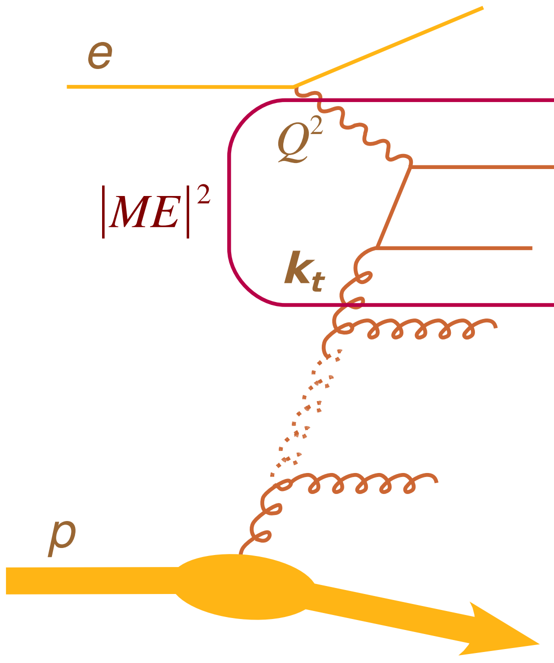
    - ➔ non-vanishing p_t



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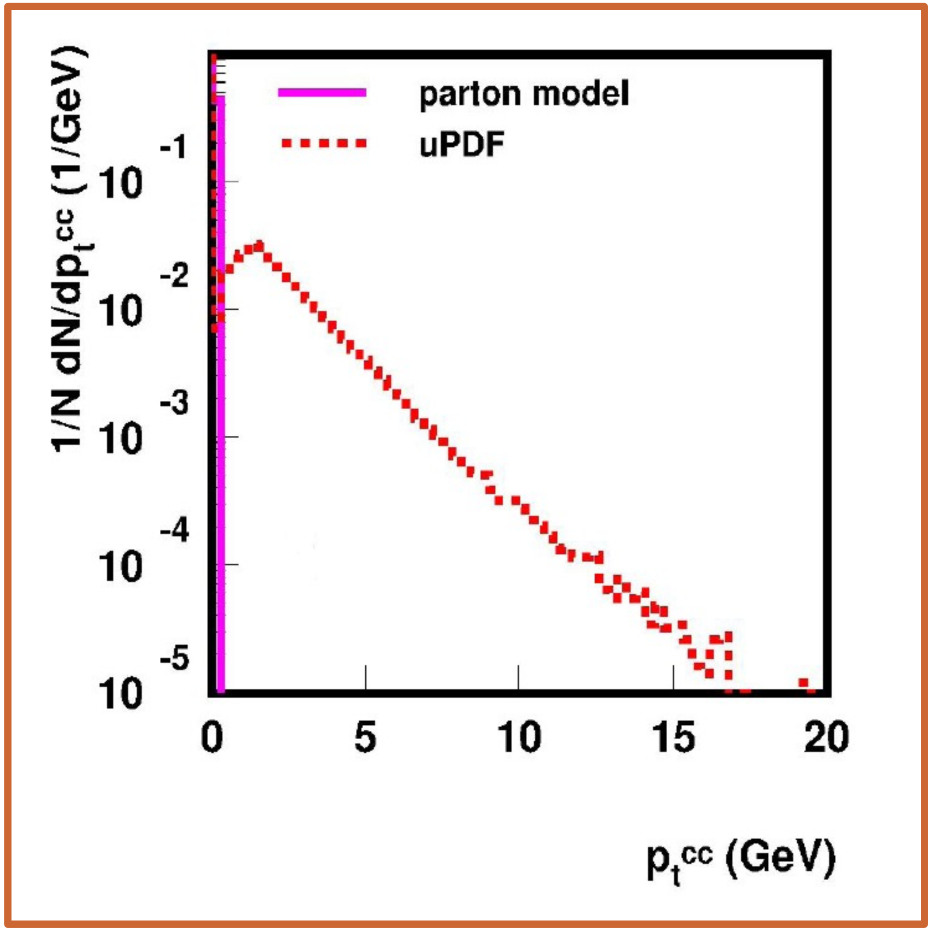

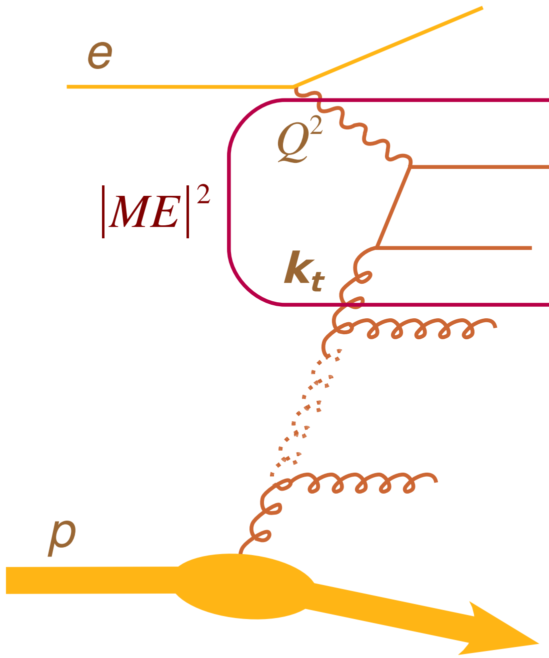

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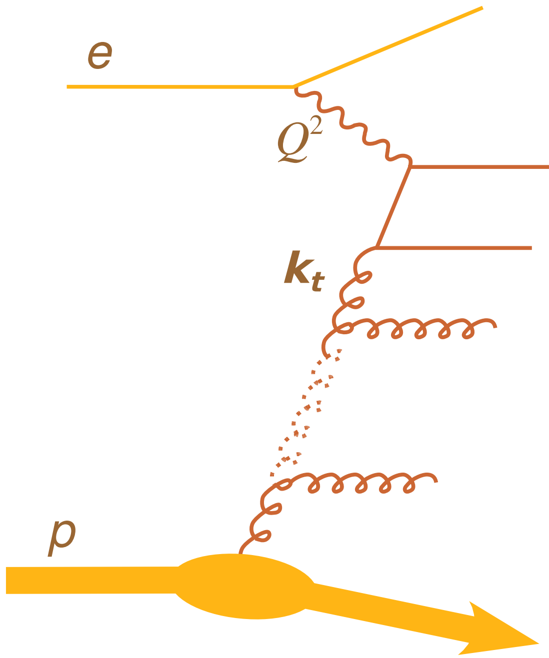
Fits of uPDFs - General method and distinctive features



Fits to inclusive measurements

- **Using program H1FITTER by E. Perez, T. Kluge, H. Jung et al.**
- **access to all inclusive H1 data**
  - **F_2, jets, F_2^{cc}**
- **generalised fitting method**
  - **applicable for CCFM *and* DGLAP**
- **allows choice of treatment of correlated errors**
  - **H1-like , theory shifted by systematics**
  - **CTEQ-like, data shifted by systematics**
  - **full covariance matrix**
    - ➔ **available options in program, not used here!**
- χ^2 **minimisation using MIGRAT (derivatives)**

Fits of uPDFs - General method and distinctive features

Fitting uPDFs to inclusive measurements

- **cross sections calculated by MC Generator CASCADE**
- **evolving gluons only → cut on *x***
- **initial gluon distribution**

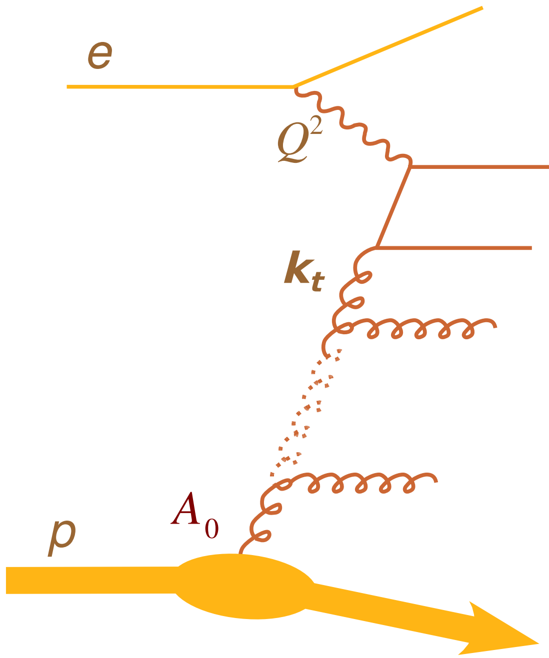
$$A_0(x) = Norm \left(\frac{1}{x}\right)^B (1-x)^C$$

- **fixed evolution from grid file**
- **define**

$$\chi^2 = \sum \frac{(D-T)^2}{\Delta_{stat}^2 + \Delta_{uncorr}^2}$$

  ✗ **correlated errors not used yet**

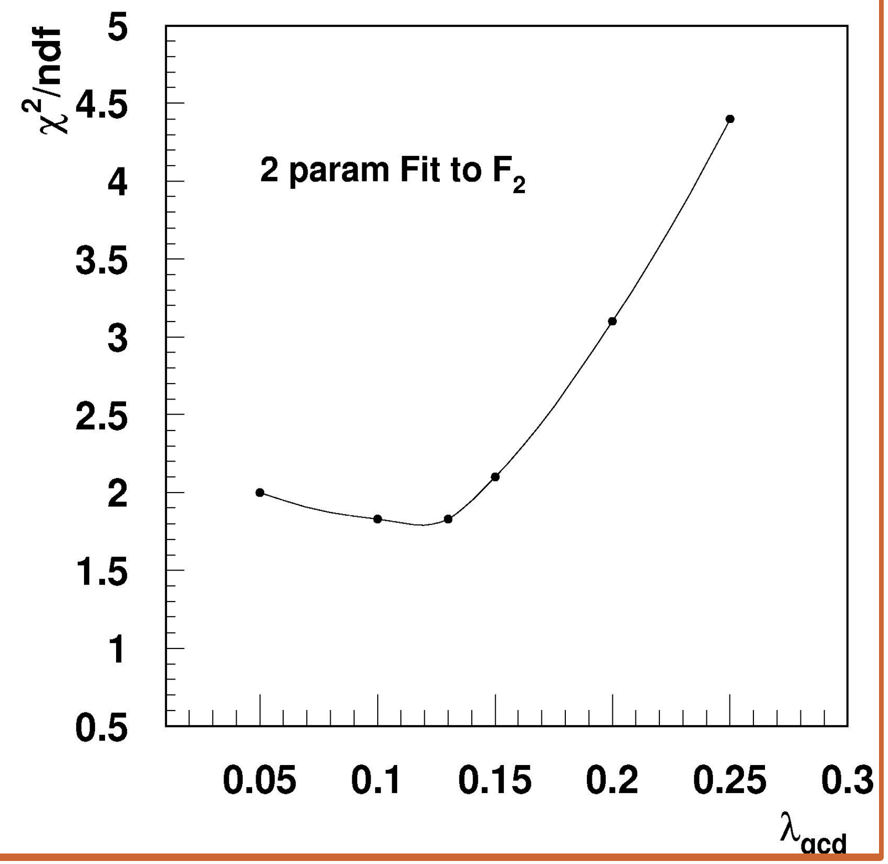
- **uncertainty bands on uPDFs defined by** $\Delta \chi^2 = 1$ **and varying parameters in orthogonal basis**



Parameter Scans - sensitivity to α_s and gluons

Consistency check

- performed fit to F_2
- $\alpha_s(M_Z)=0.118$ used in fit to F_2
- study sensitivity to $\alpha_s(\mu)$
- in one-loop $\alpha_s(\mu) \sim \frac{1}{1-\log\frac{\mu}{\Lambda_{QCD}}}$
- studied variation of Λ_{QCD}
  - ➔ $\Lambda_{QCD} \approx 0.13$ gives $\alpha_s(M_Z)=0.118$
  - ➔ lower than in former gluon densities



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- p
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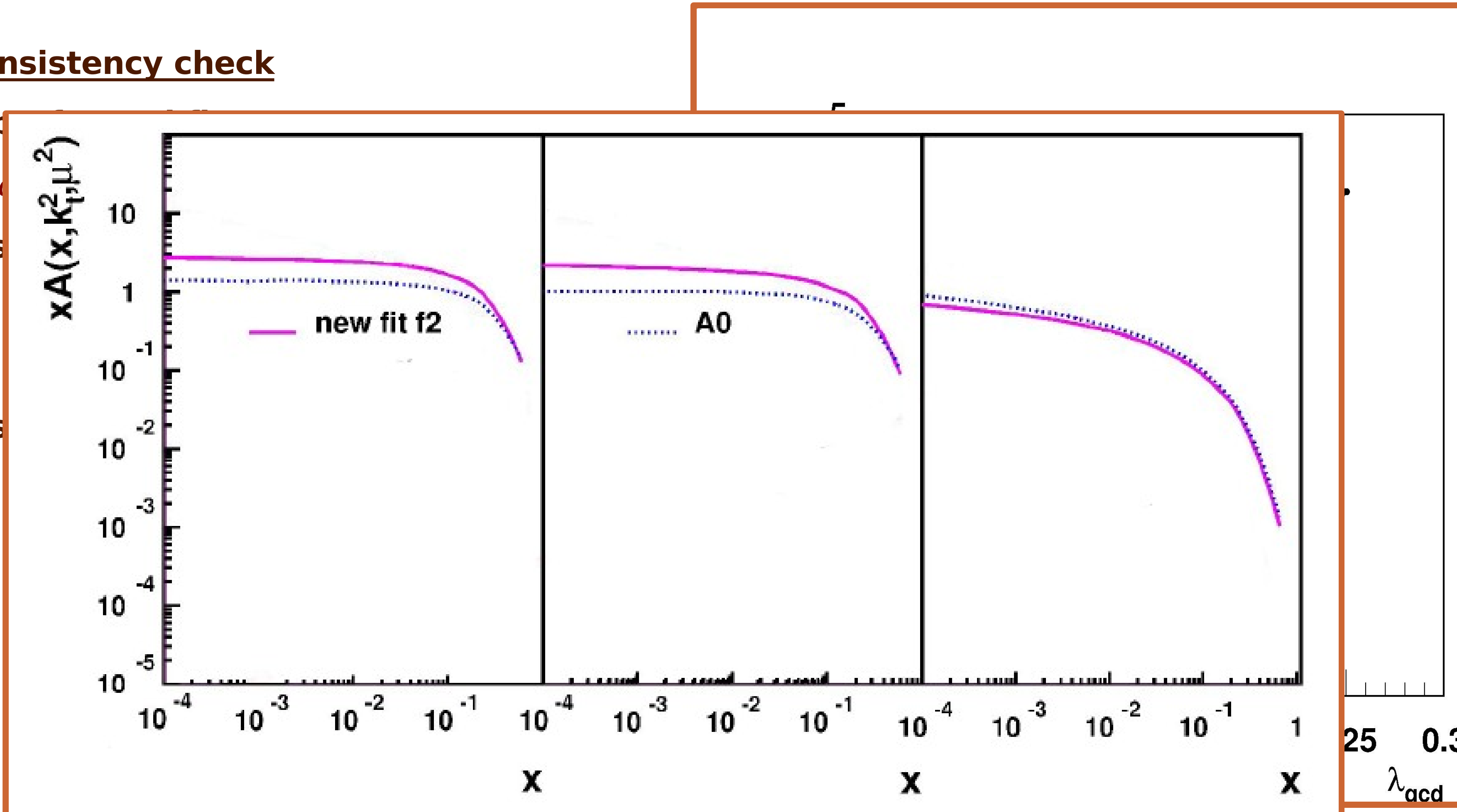
- s
- i
- s



Parameter Scans - sensitivity to α_s and gluons

The large-x term

- **Two parameter fit to F_2**

$$A_0(x) = Norm\left(\frac{1}{x}\right)^{0.02}(1-x)^C$$

➔ $C = 4$ **seems good choice**

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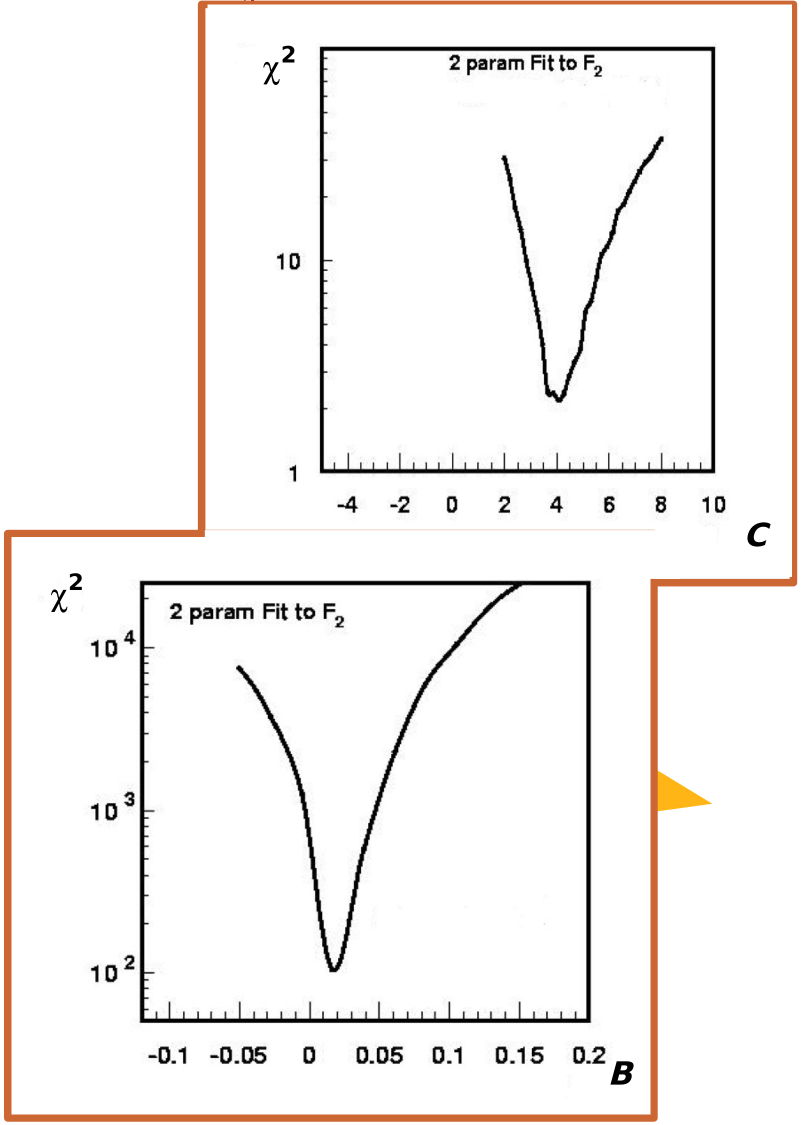
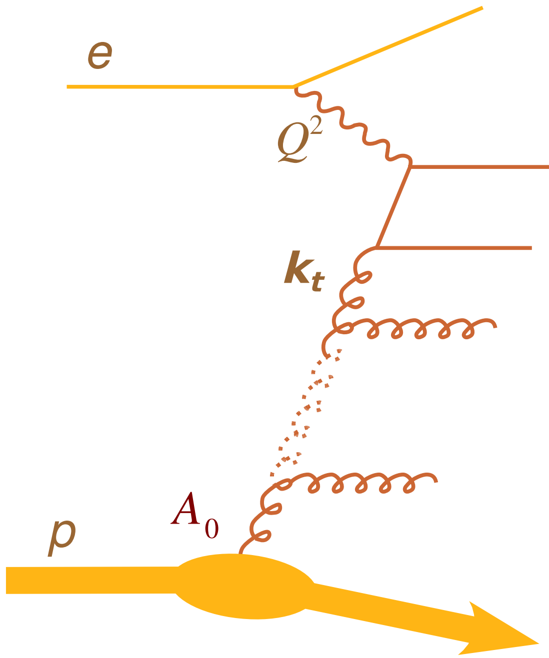


Results

χ^2 minimisation with F_2 data

- **Fitting data above starting scale $Q_0^2 = 5\,GeV^2$ and below $x_{cut} = 0.005$**
- **Fit yields good description of F_2 resulting in**

$$\frac{\chi^2}{ndf} \approx 2$$



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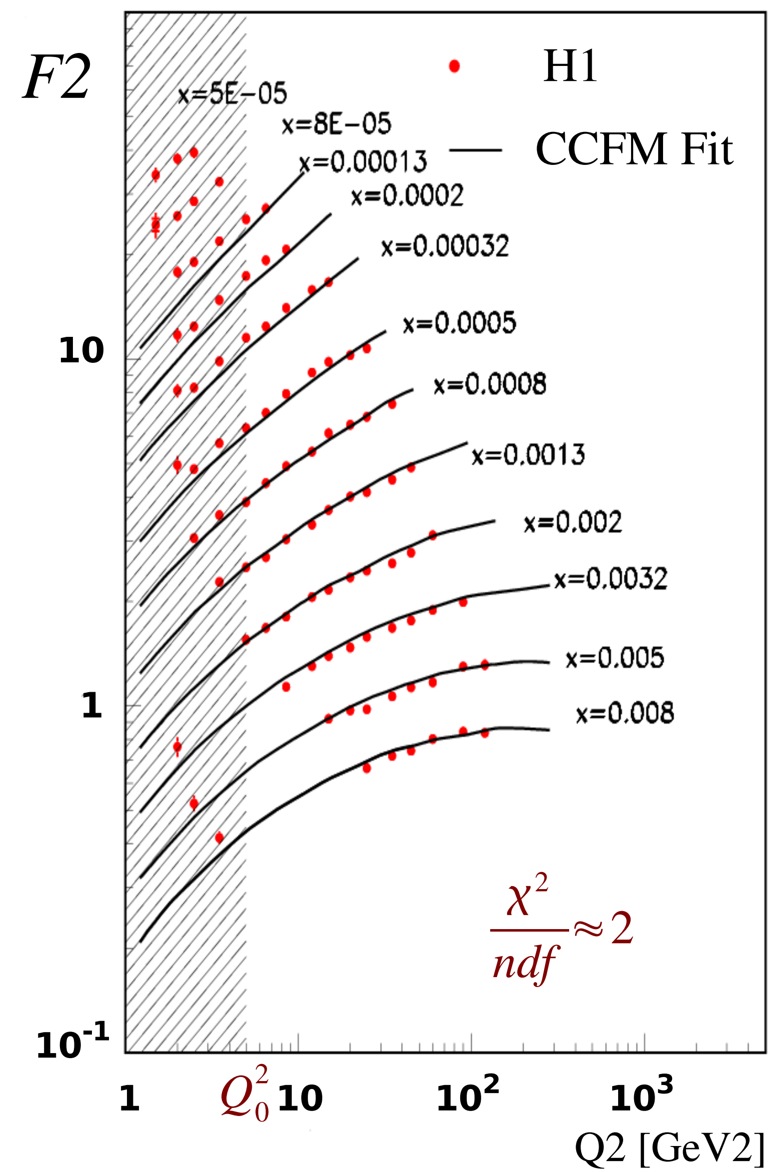

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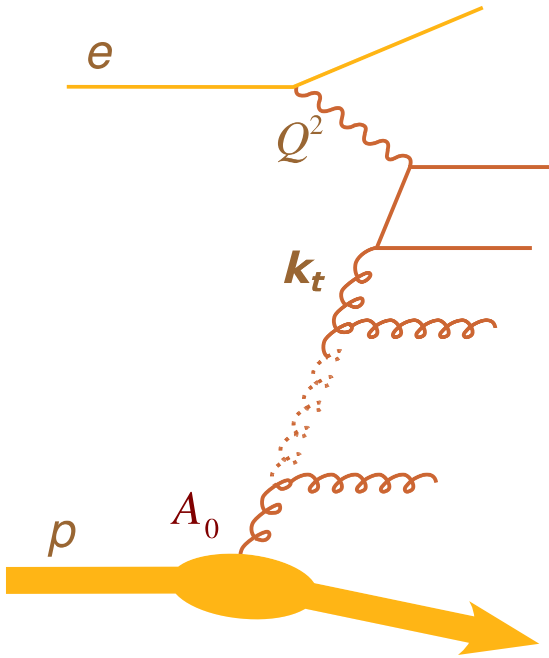

χ^2 minimisation with F_2^{cc} data

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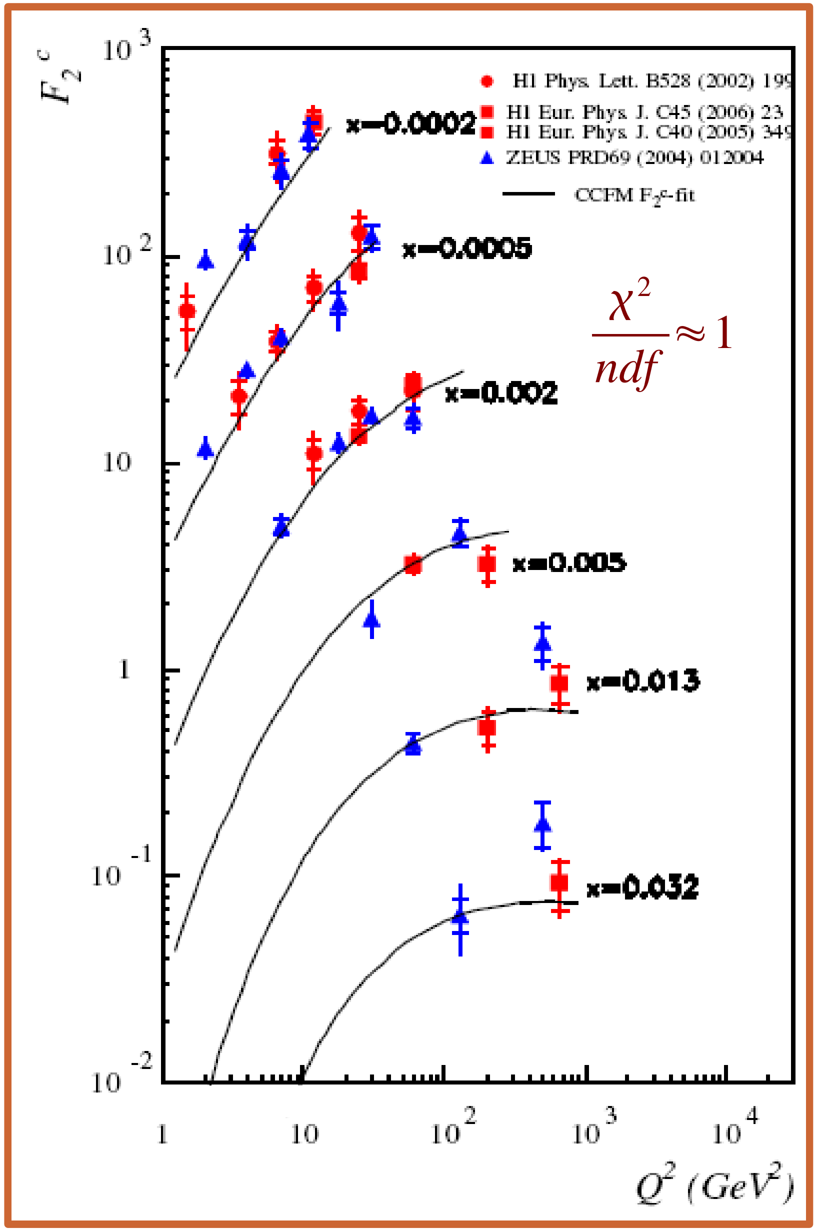

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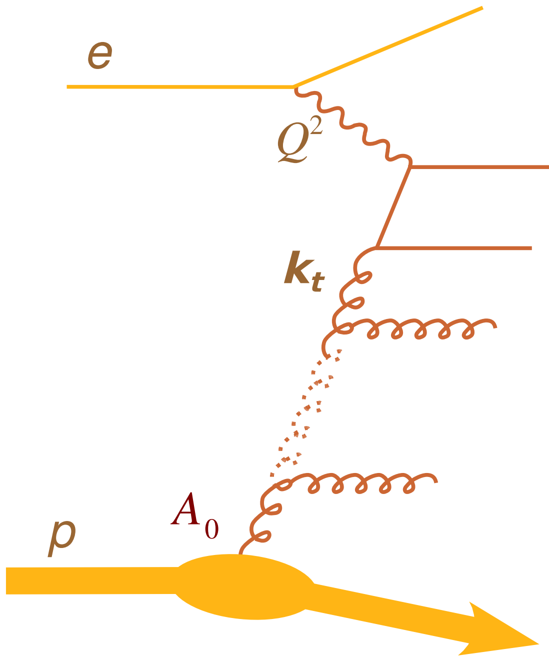
Results - different quarks

Uncertainty on gluon densities

- **gluon densities from fits:**
  - ✗ **variable transformation of fit parameters to orthogonal basis**
  - ✗ $A_0(x) = N \cdot x^{-B}(1-x)^C$
  - ✗ χ^2 **minimisation in orthogonal basis**
  - ✗ **variation of orthogonal parameters so that** $\Delta\chi^2 = 1$
    - ➔ **obtain parameters N, B and C**
    - ➔ **envelope defines uncertainty band**



Results - different quarks, different gluons?

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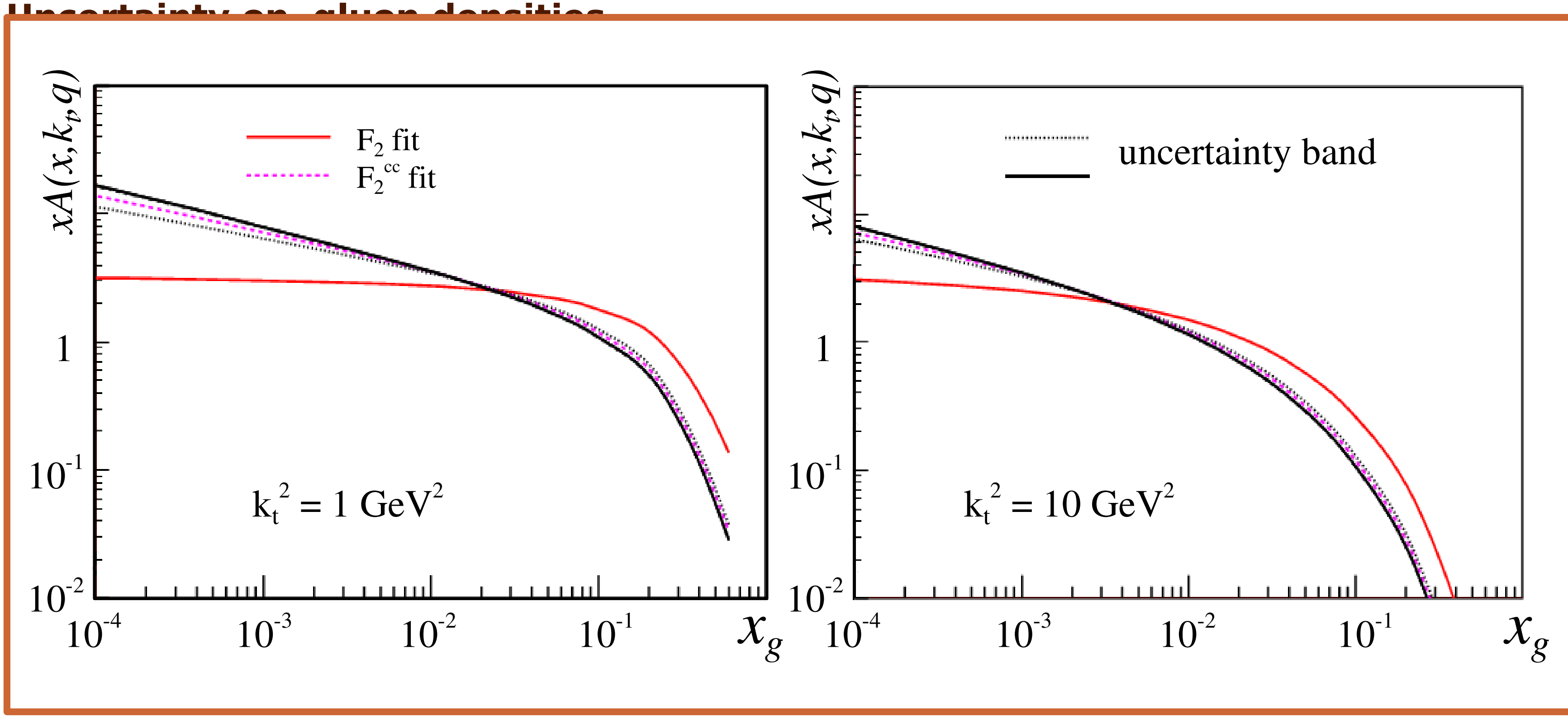
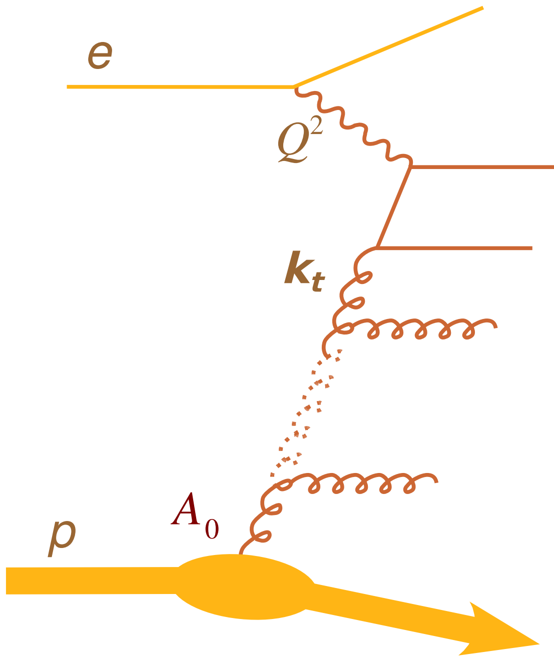


Results - different quarks, different gluons?

Obtained gluon densities

- Seperate Fits to inclusive data gives nice description, BUT ...
- Resulting gluon densities show large discrepancy!
  - ✗ F_2^{cc} contributing to F_2
    - ➔ difference in gluon densities hints at possible inconsistent treatment of gluons



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  - ✗ F_2^{cc} contributing to F_2
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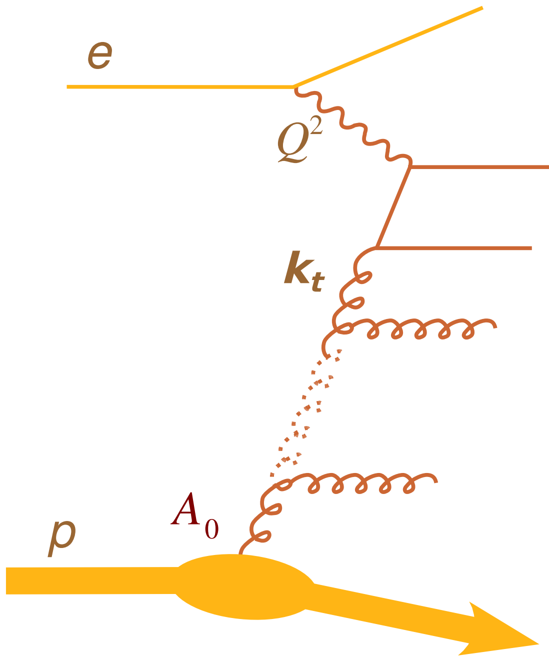
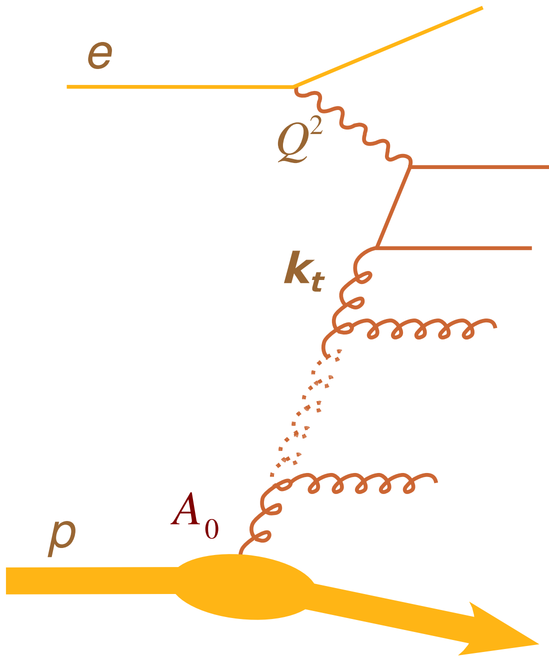
    - ➔ charm production adequate testing ground



Charm in DIS and γp - Fits to final state cross sections

Fits using HzTool

- Similar fitting method applied as above
  - ✗ SIMPLEX instead of MIGRAD (no derivatives)
- HzTool as interface between data and theory
- D* + jets in photoproduction
  hep-ex/0608042
  - ✗ former comparison of Cascade to data yielded $\chi^2_{paper}/ndf = 1.72$



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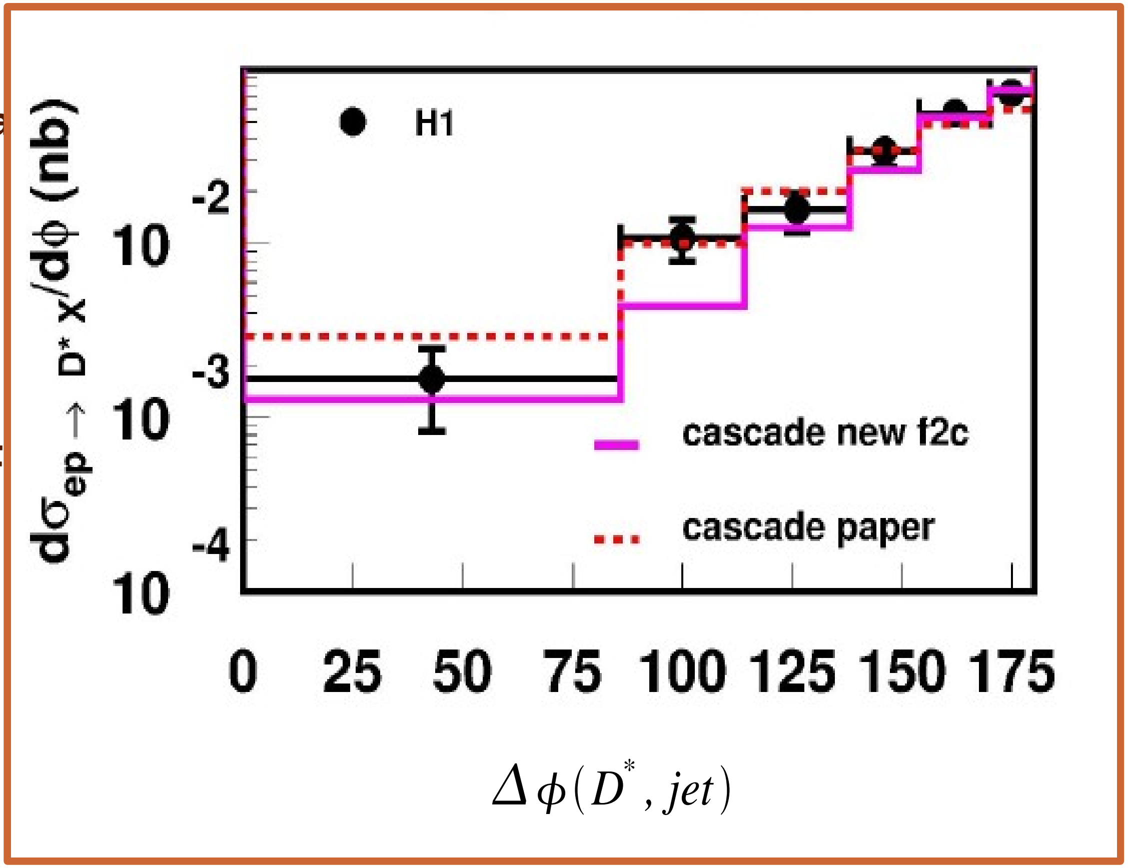

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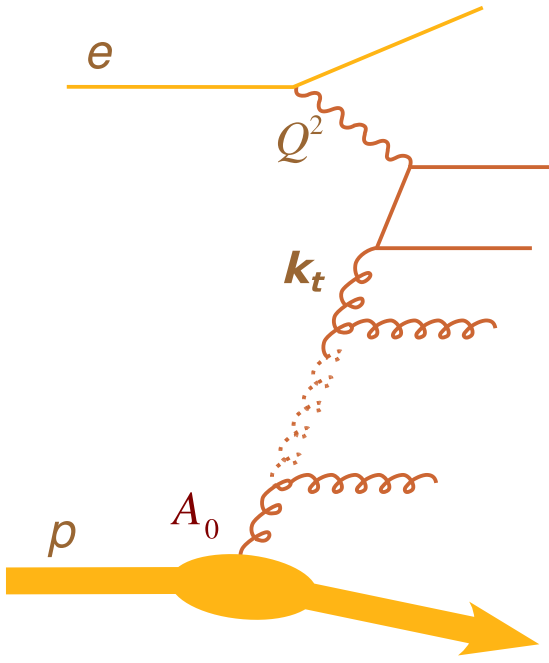

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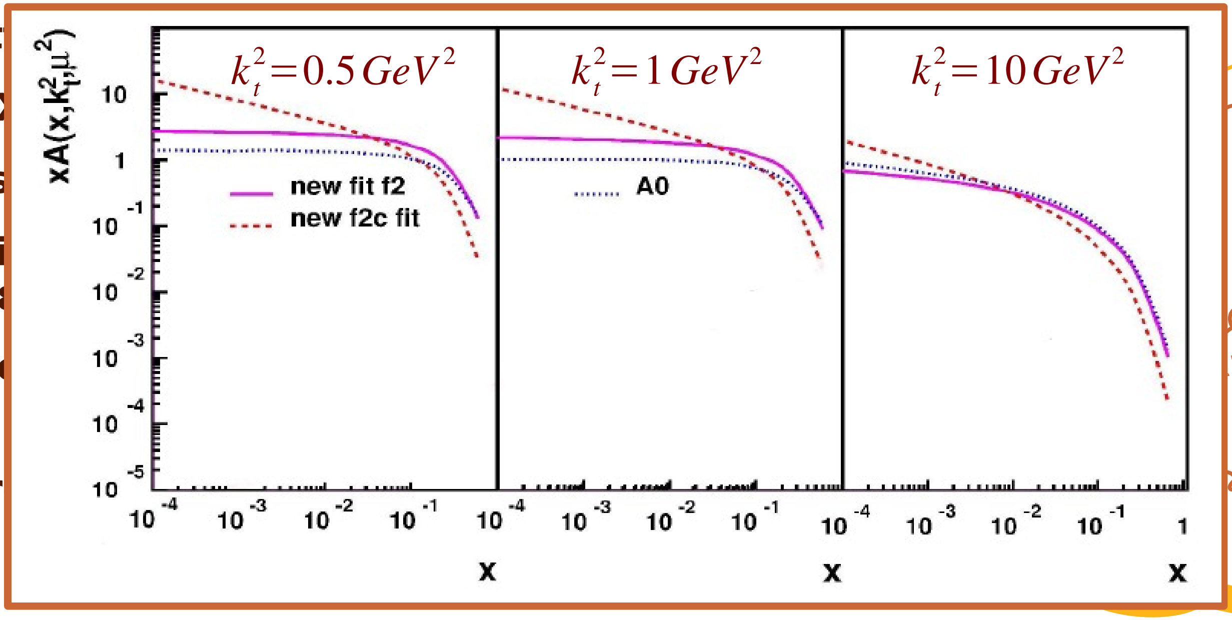

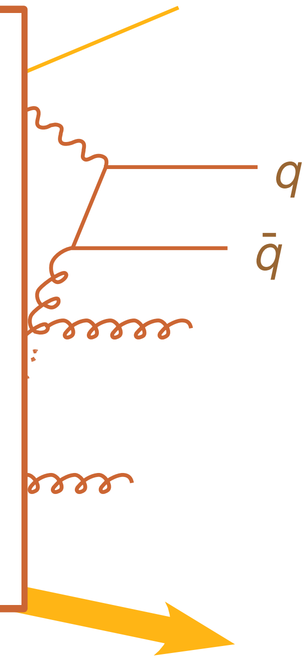

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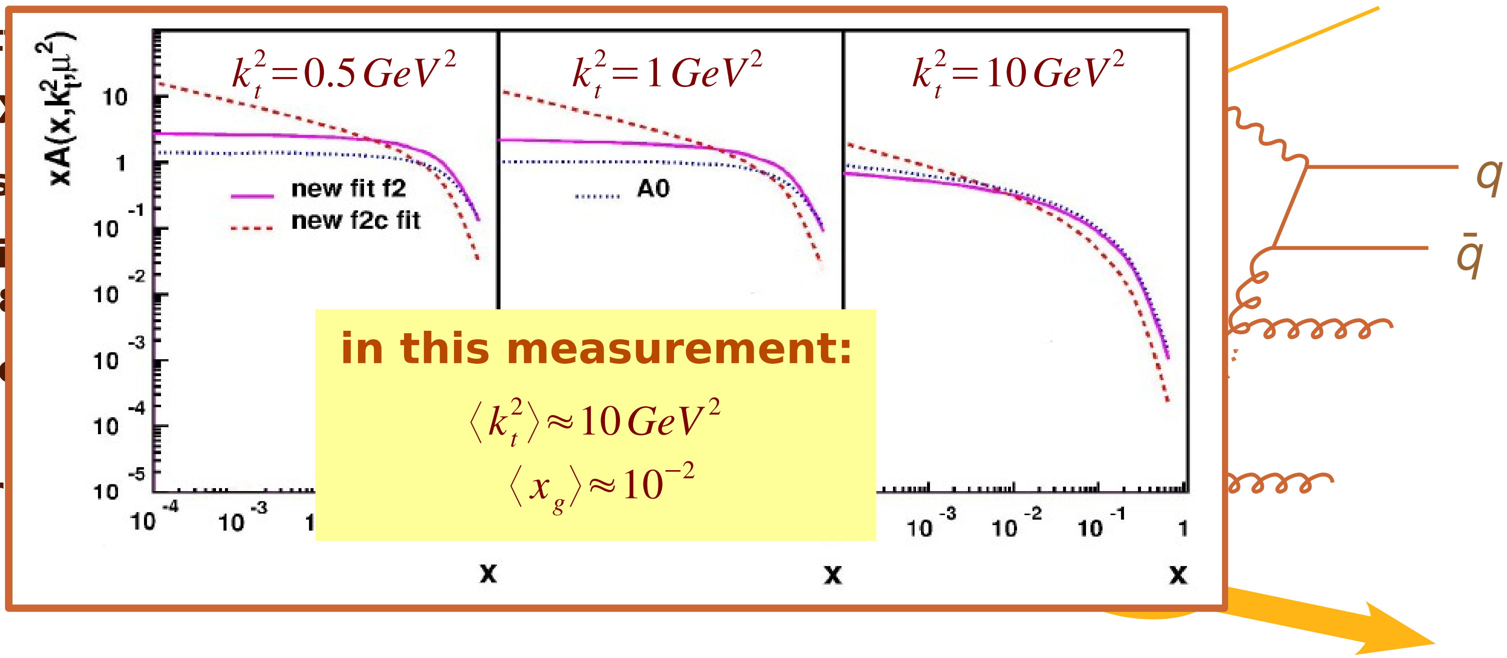

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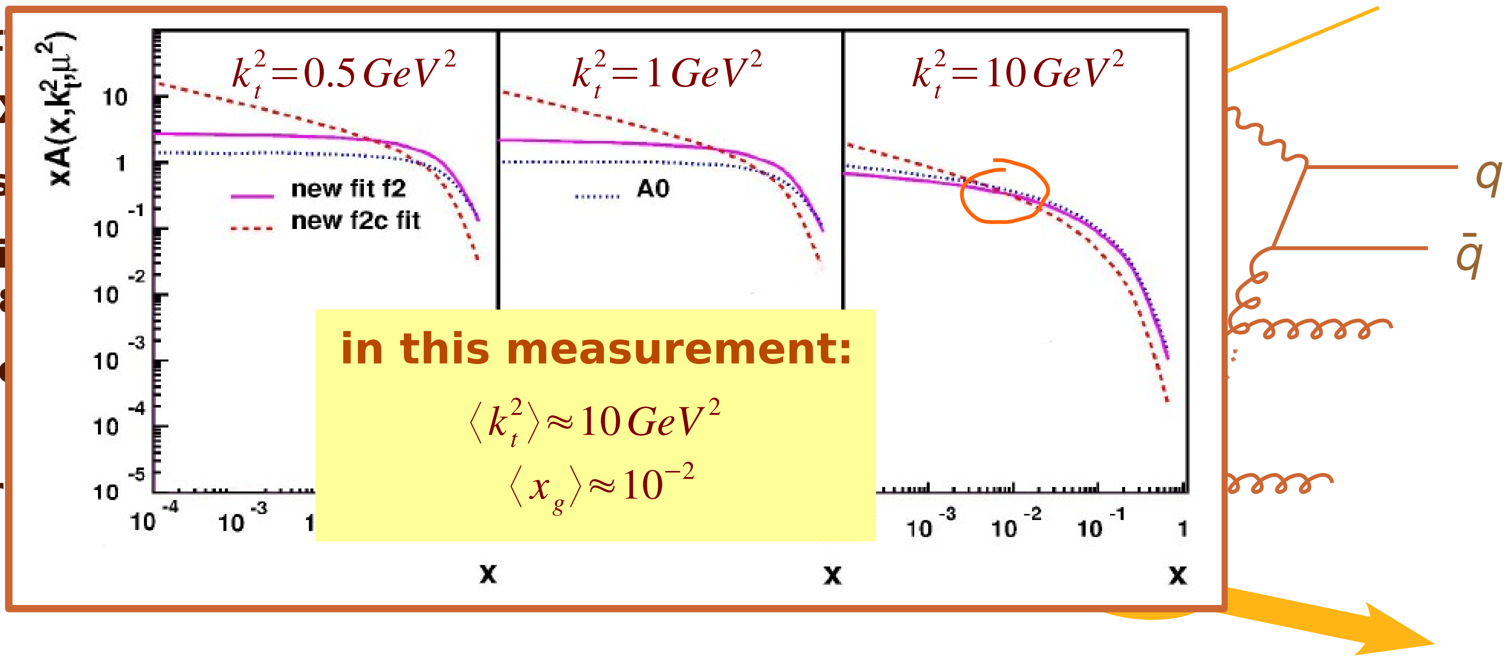

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  - ✗ former comparison of Cascade to data yielded $\chi^2_{before} = 9.09$
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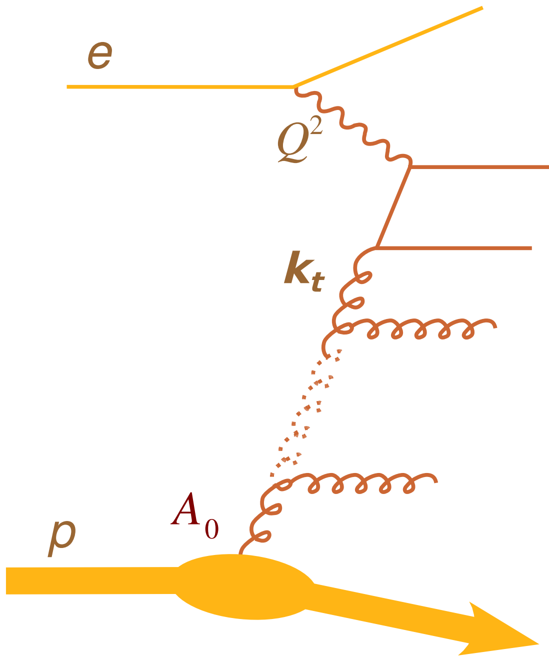
  - ✗ Fit done by Aleksander Kusina



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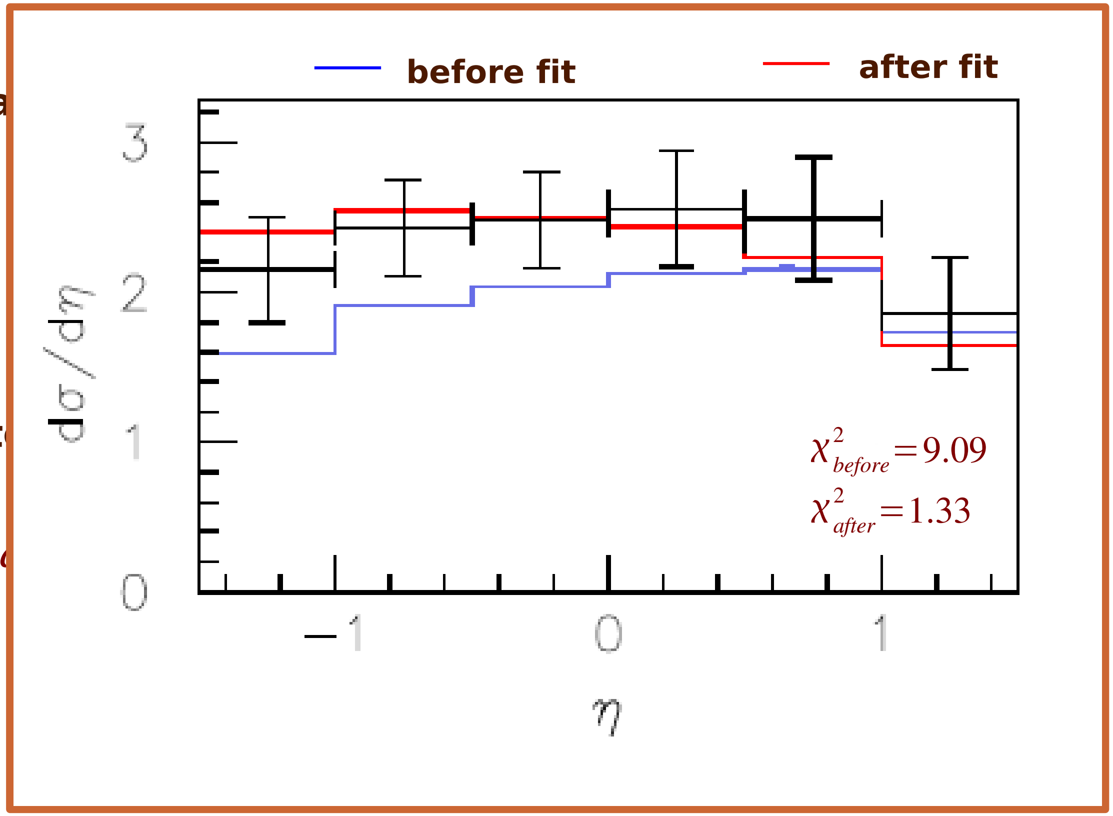

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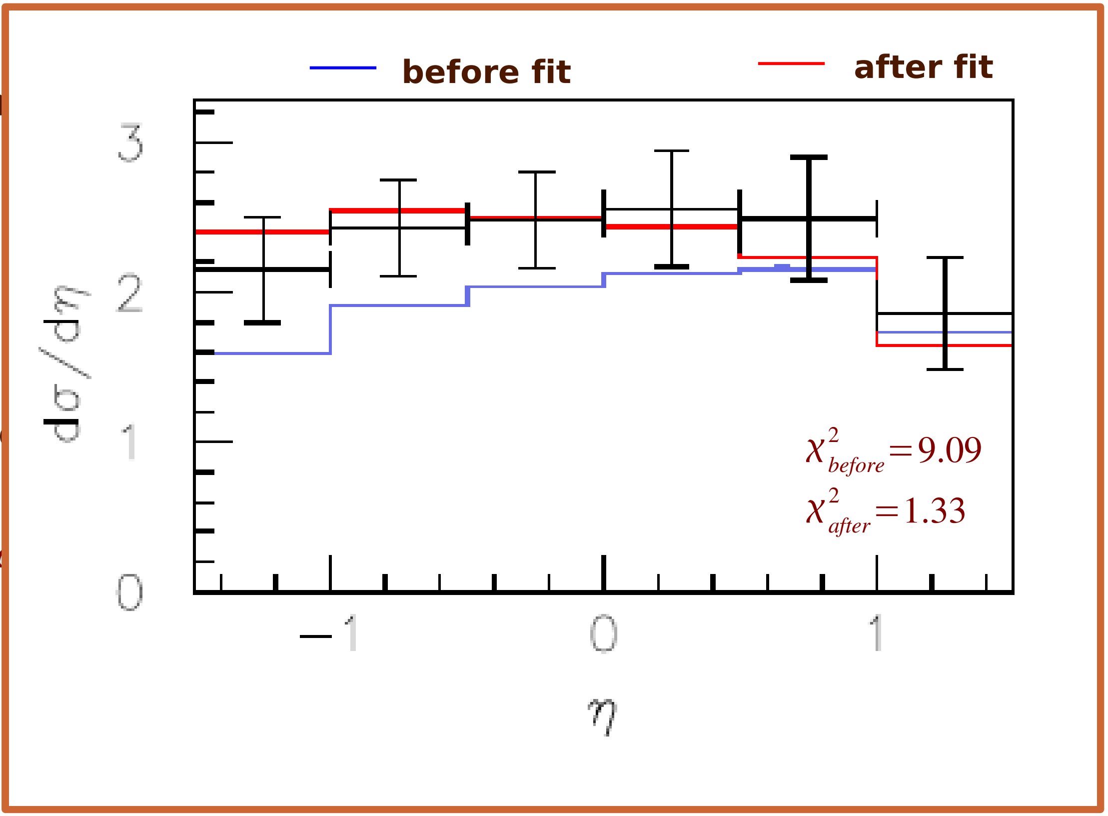

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  - **improved data description**

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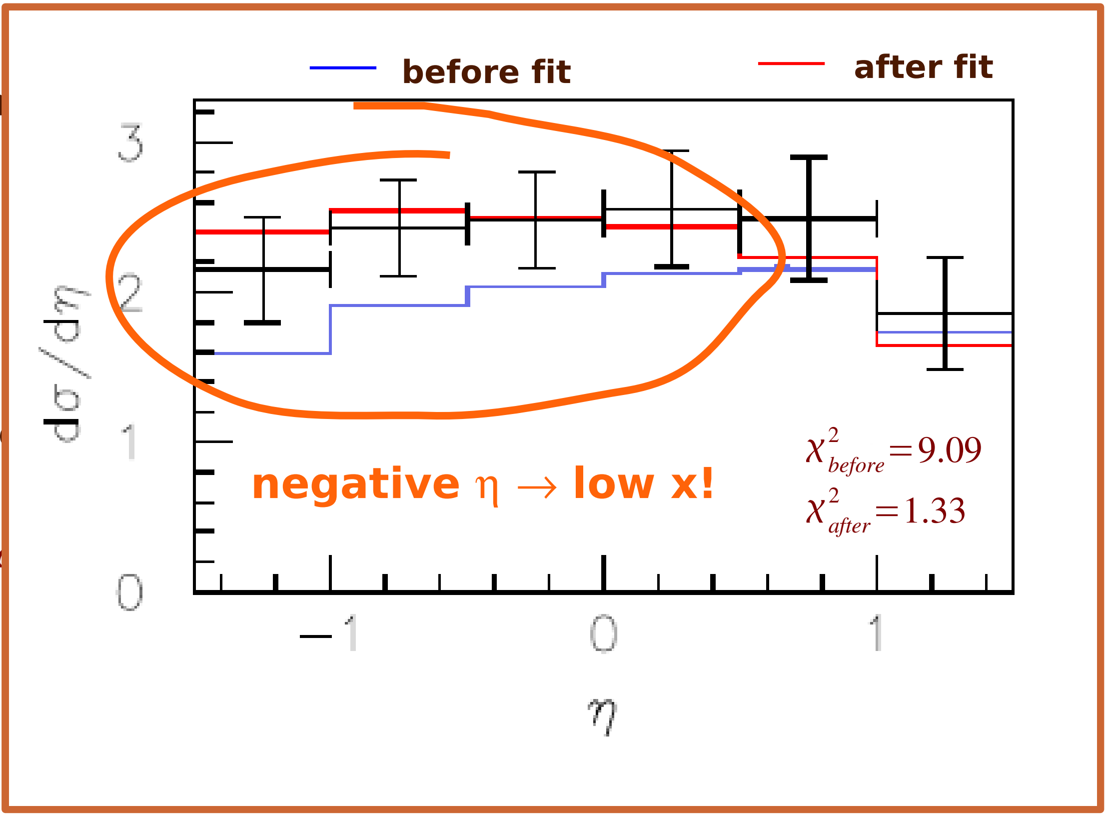
  - sensitive to gluon density



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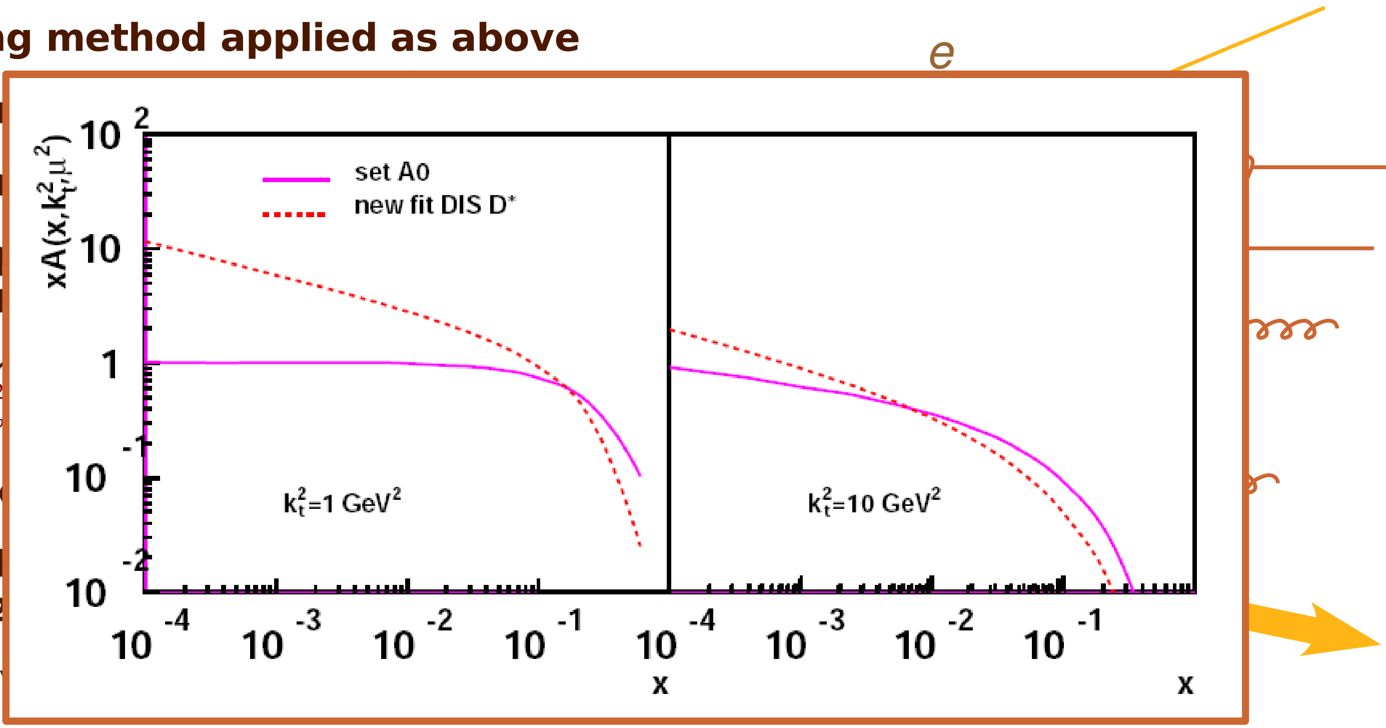

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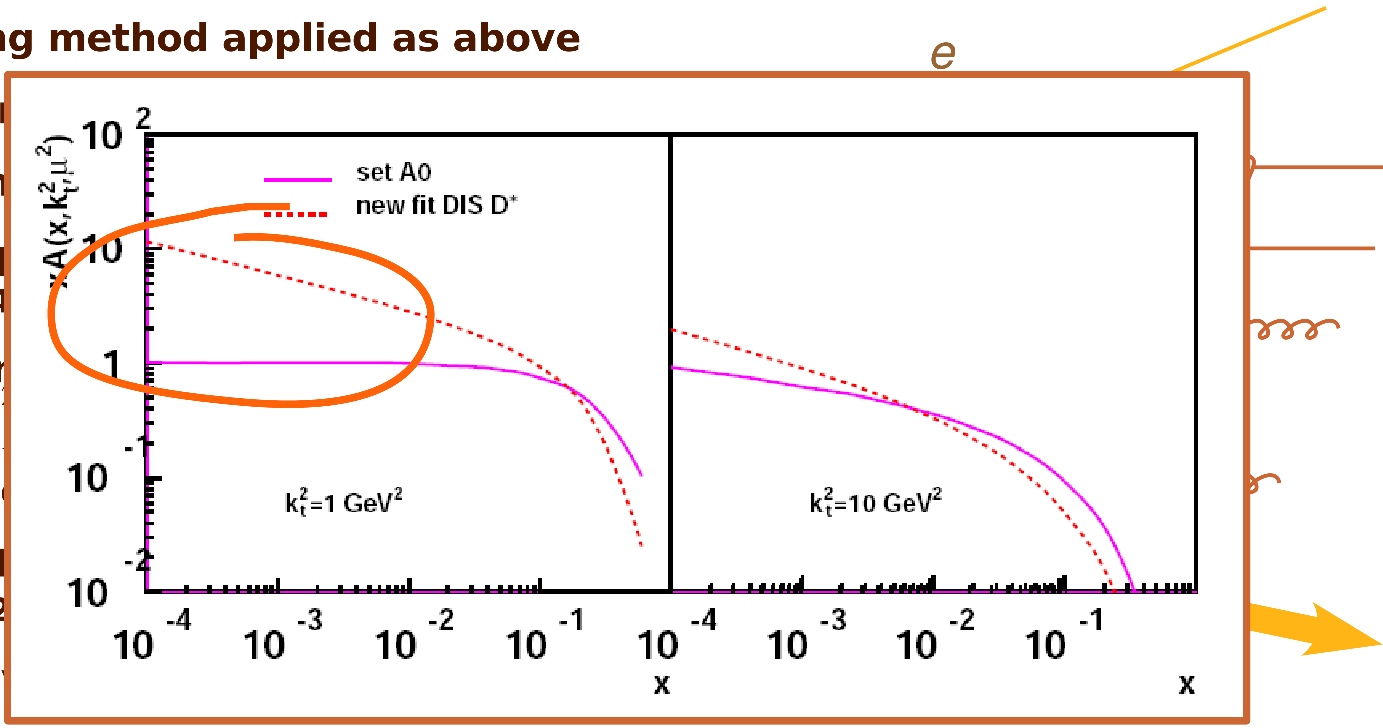
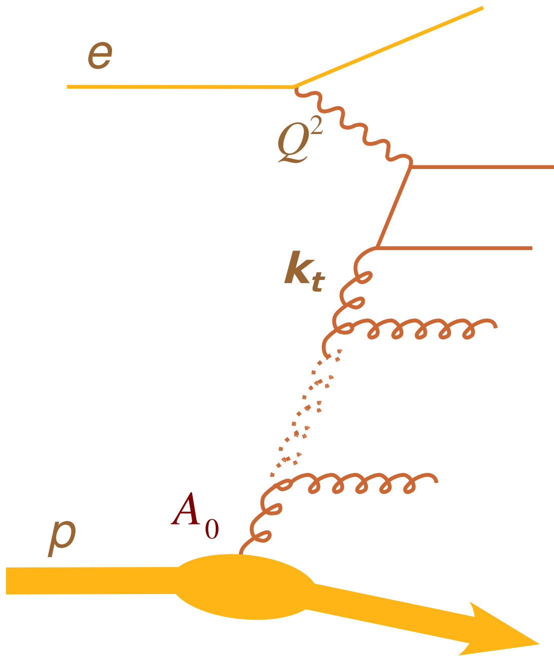
  - ✗ steep rise towards low x also observed



Summary and Outlook

- Fits of uPDFS to inclusive measurements including uncertainty bands
- F2 and F2cc yield different gluon densities
  - ➔ gluon from charm much steeper towards low x
- Fits to final state charm cross section (DIS,γp) with HzTool
  - ➔ steep rise at low x also present



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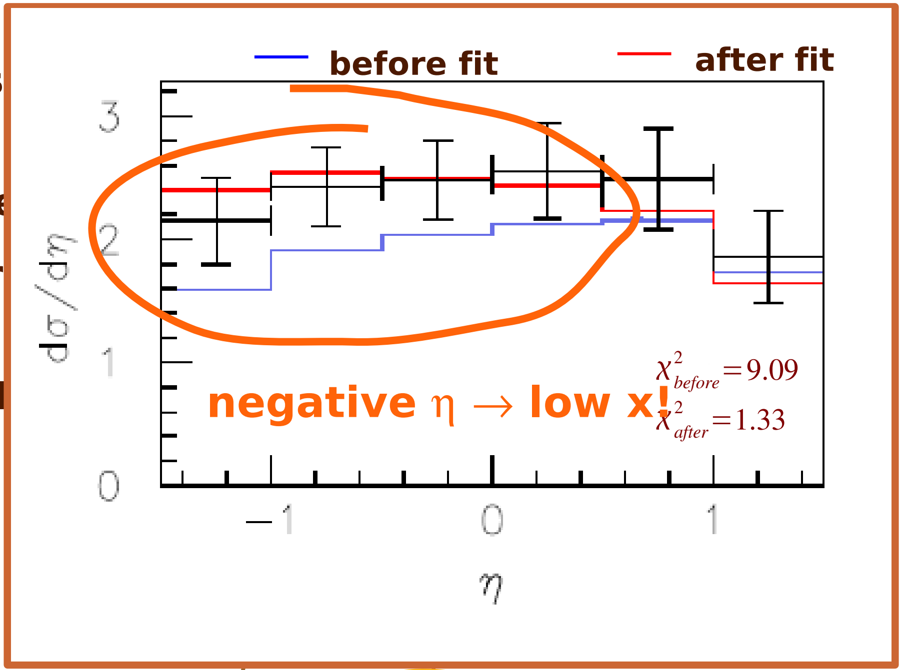

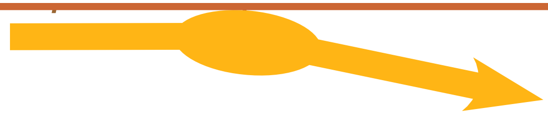

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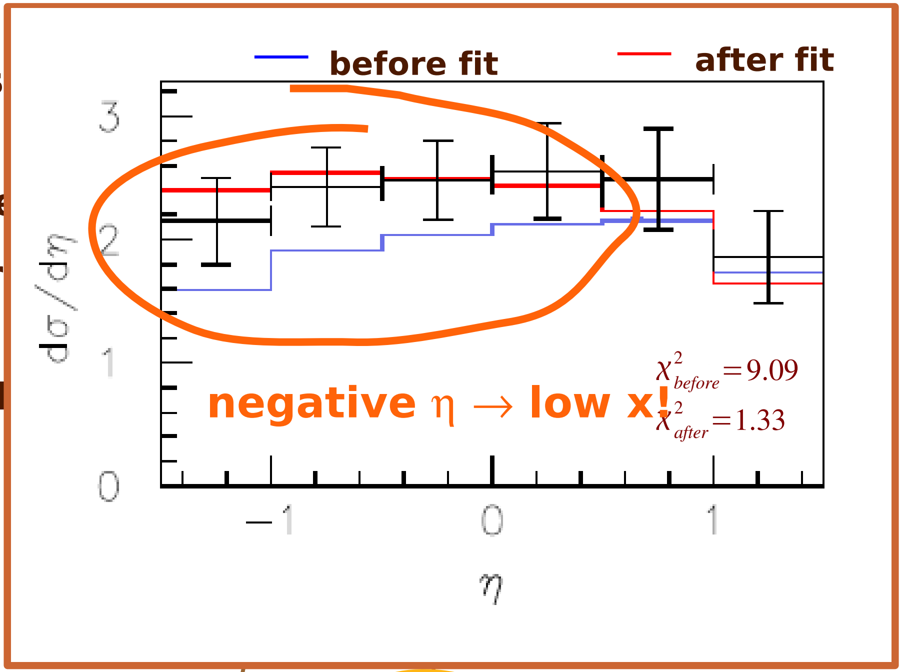

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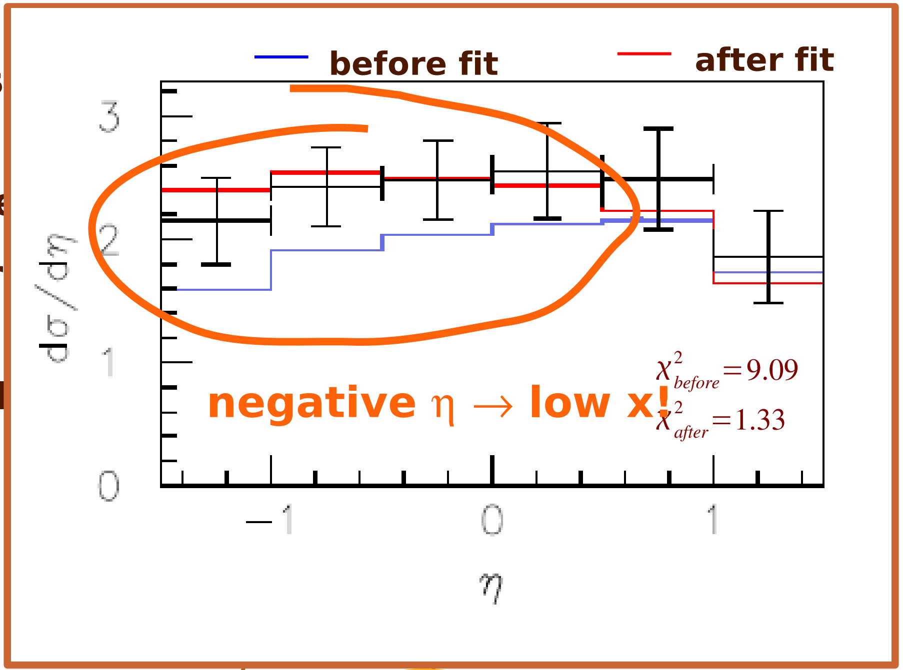
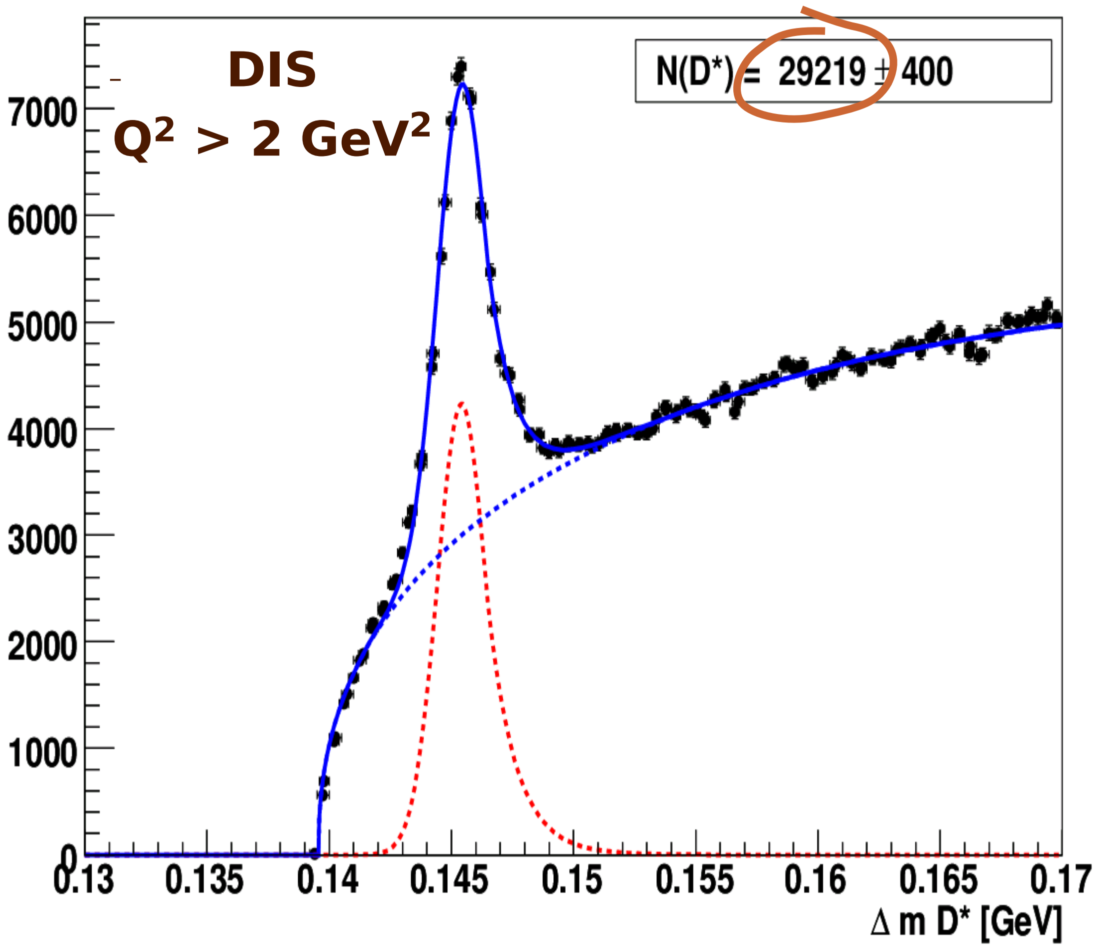
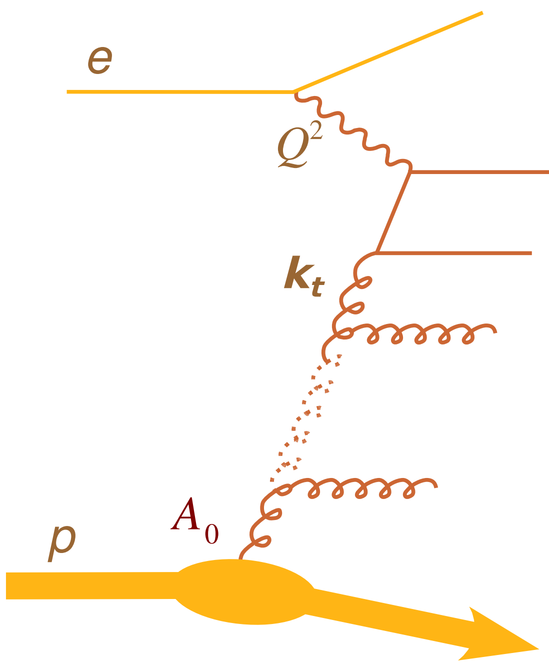
  - ➔ statistics still limit sensitivity
- Latest HERA years proved quite successful



$\Delta m = |m(K\pi\pi_s) - m(K\pi)|$





Summary and Outlook

- Fits of uPDFS to inclusive measurements including uncertainty bands
- F2 and F2cc yield different gluon densities
  - ➔ gluon from charm much steeper towards low x
- Fits to final state charm cross section (DIS,γp) with HzTool
  - ➔ steep rise at low x also present
  - ➔ sensitive to low x via η
  - ➔ statistics still limit sensitivity
- Latest HERA years proved quite successful
  - ➔ since 2001 factor 30 more D*s!
  - ➔ more precise charm measurements possible, both inclusive and final state cross sections
  - ➔ use data to constrain uPDFs