New fits to uPDFs

H. Jung (DESY)

- Motivation: why full event information is needed for PDF fits
- Fit method
  - full event simulation and parton evolution
- Example application to uPDF
  - using CCFM to fit F_2, F_2^c and charm photoproduction

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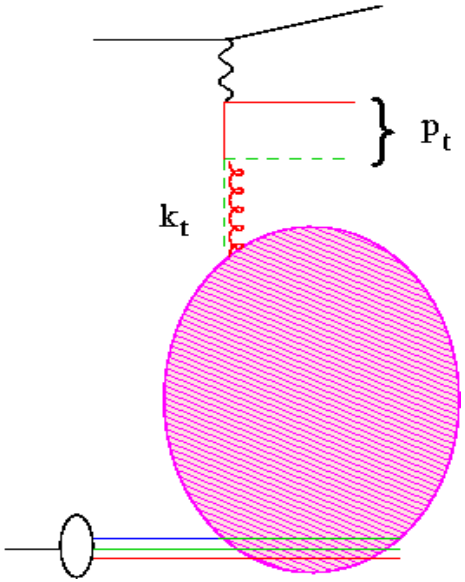
- Motivation: why full event information is needed for PDF fits
- Fit method
  - full event simulation and parton evolution
  - FULLFIT instead of FASTNLO
- Example application to uPDF
  - using CCFM to fit F_2, F_2^c and charm photoproduction
- Apologies...
  - talk more about intentions rather than results...
  - results will come for proceedings ...

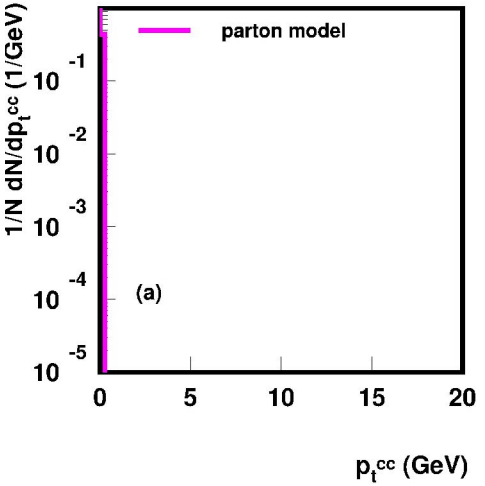
Need for uPDFs

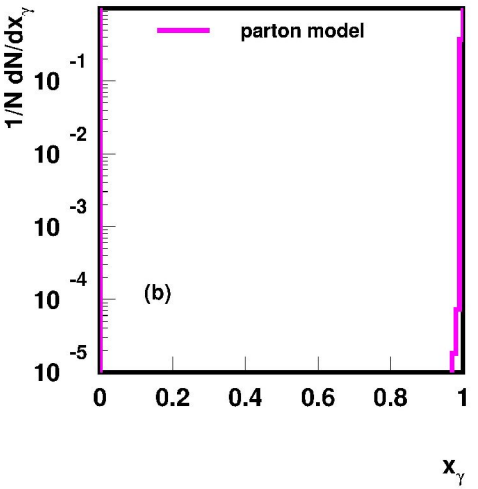
J. Collins, H. Jung

Define:

- $p_{T q\bar{q}}$
- $x_\gamma = \frac{\sum_{i=q,\bar{q}}(E_i - p_{z\,i})}{2yE_e} = \frac{p^-_{q\bar{q}}}{q^-}$







- parton kinematics

Need for uPDFs

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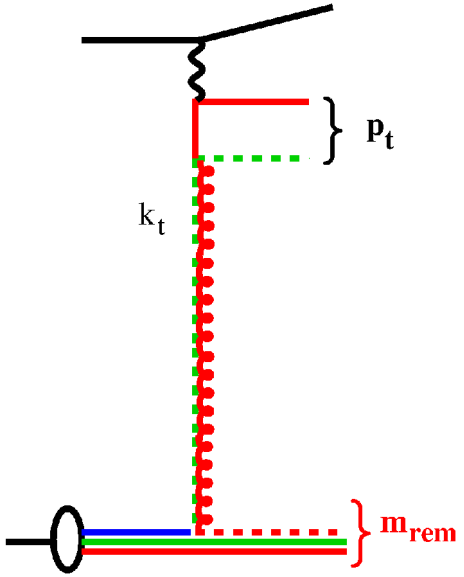
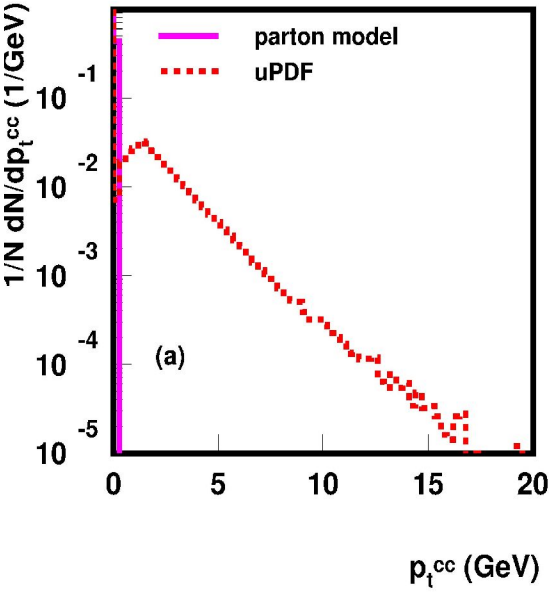
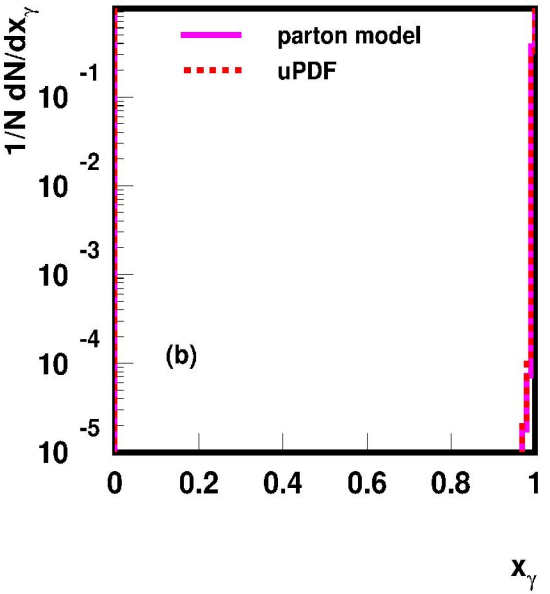


J. Collins, H. Jung



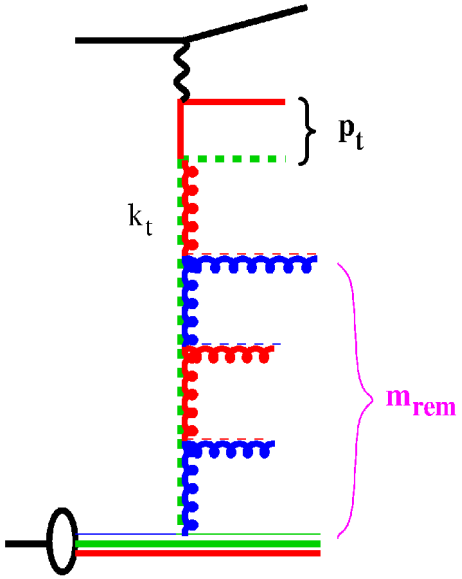


- parton kinematics
- uPDFs → for transverse component of still "inclusive" quantities

Need for uPDFs

Define:

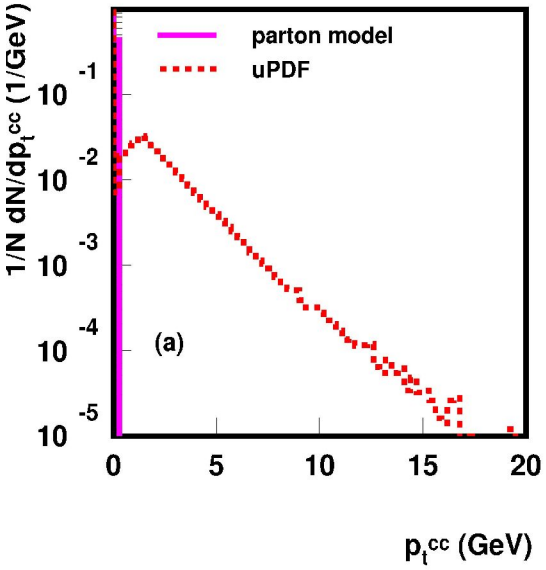
- $p_{Tq\bar{q}}$
- $x_\gamma = \frac{\sum_{i=q,\bar{q}}(E_i - p_{z\,i})}{2yE_e} = \frac{p^-_{q\bar{q}}}{q^-}$

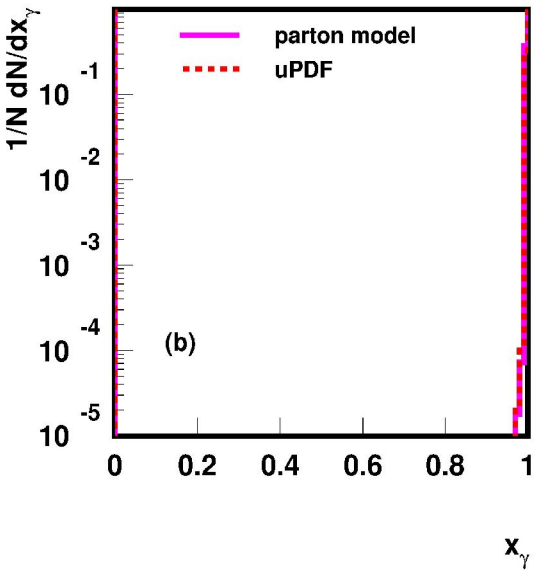


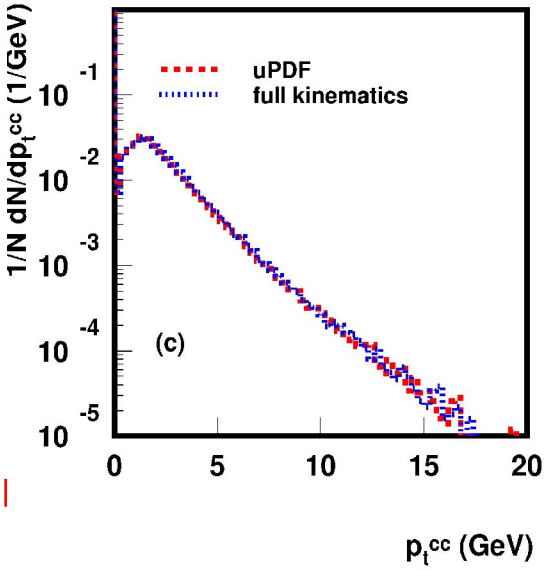
- parton kinematics
- uPDFs
- full kinematics

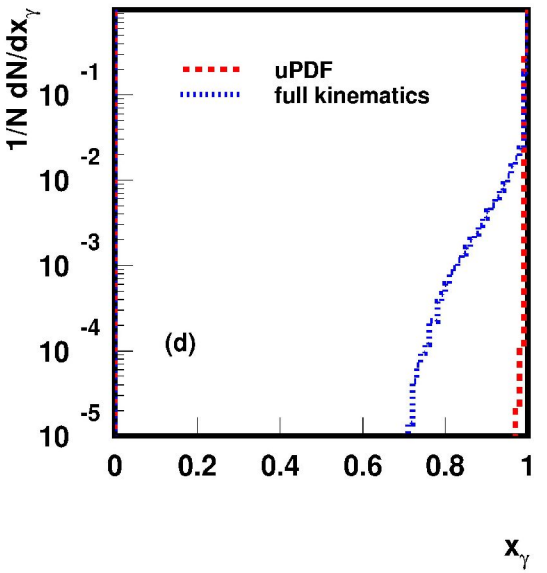
➔ history is needed for long. and tra components

J. Collins, H. Jung







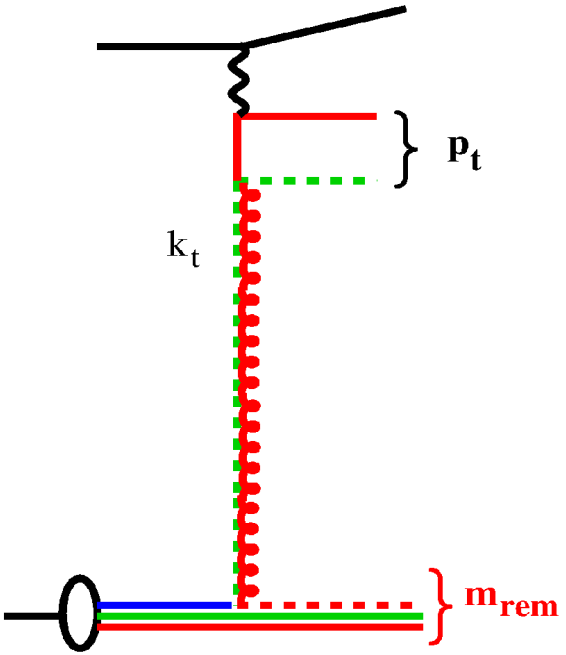


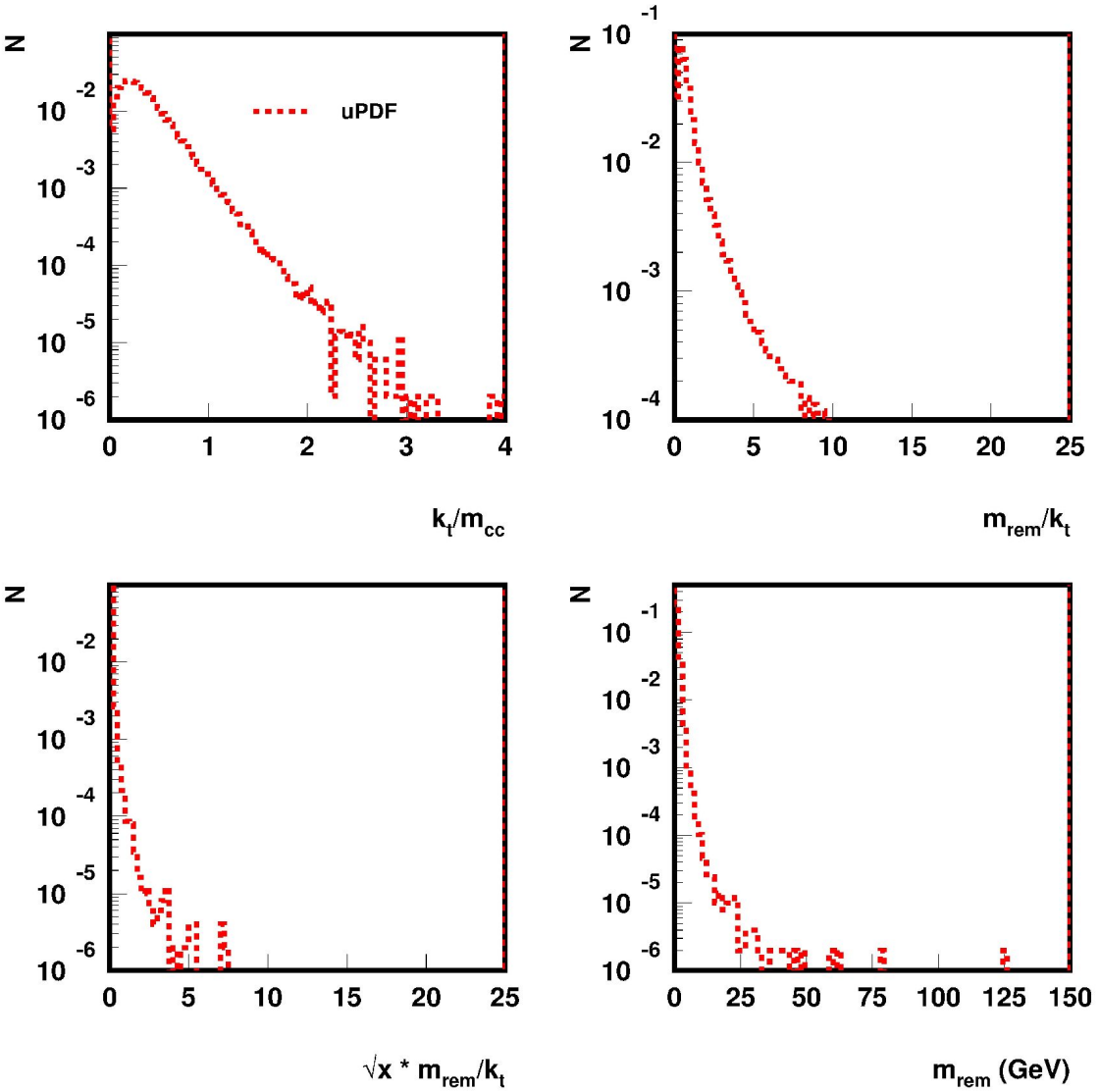
Full kinematics simulation

J. Collins, H. Jung

why full simulation is needed ?

$$k^2 = -(k_t^2)/(1-x)$$





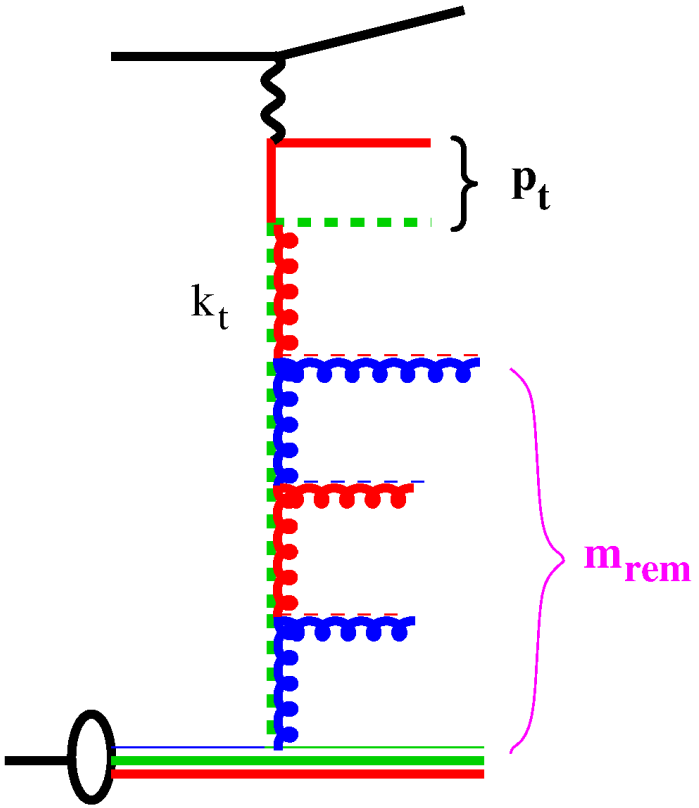
History of parton evolution

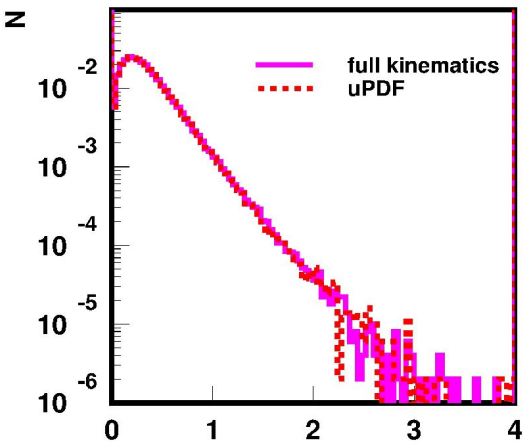
Full simulation: history of parton evolution

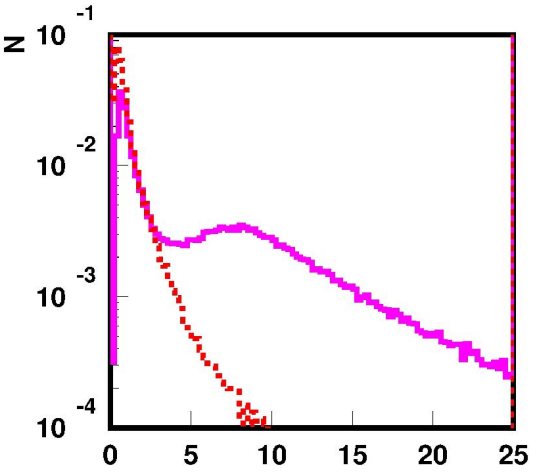
J. Collins, H. Jung

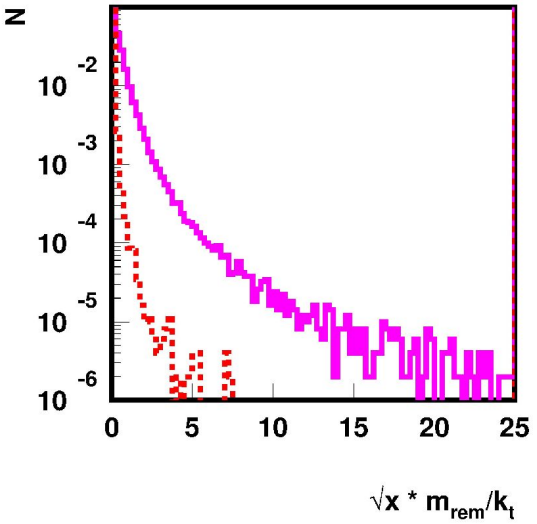
$$k^2 = -(k_t^2)/(1-x)$$

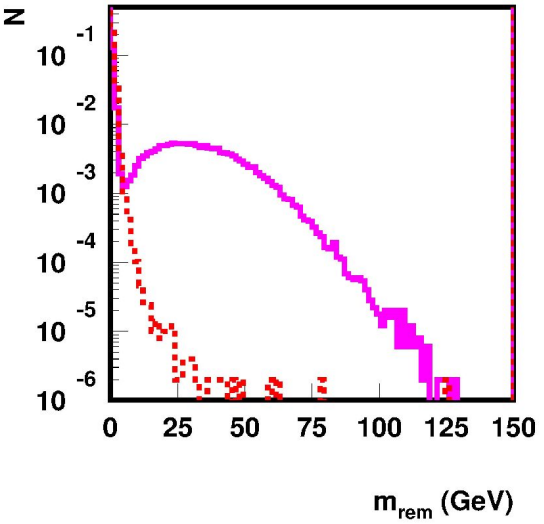
$$k^2 = -(k_t^2 + x m_{\rm rem}^2)/(1-x)$$











the remnant mass can be large ...

Need for fully uPDFs

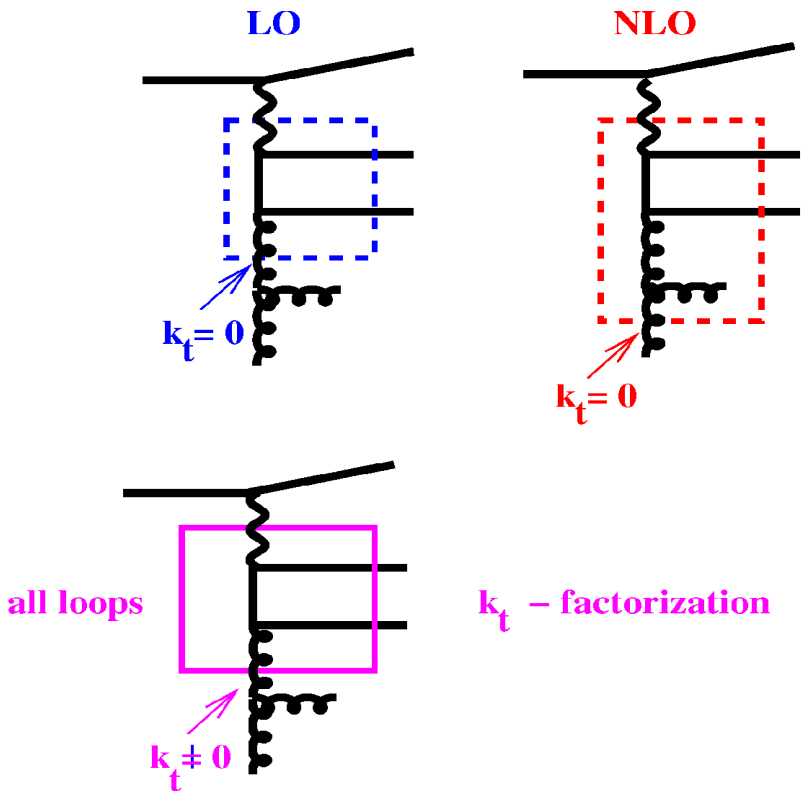
- full kinematics can only be described by fully (double) uPDFs
- dependence on k_t^2 and k^2
- reformulate pQCD methods in terms of fully uPDFs
- extension of $k_{t\ factorization}$
- Advantages:
  - kinematics correct already at LO
  - NLO corrections much smaller (BFKL example: 70 % from kinematics)
  - no need for separate methods (resummation or the CCS (Collins Soper Sterman))
  - unified treatment of ME calcs and MC generators

Different steps of approximations

- fully uPDFs
- uPDFs ($k_{t\ factorization}$)
- integrated PDFs + parton showers
- integrated PDFs + fixed order calculations in LO and NLO

Why all that works ?

- off-shell matrix elements (k_t – factorization) includes most of real NLO corrections:



- even soft k_t region is properly treated (not the case in part.level NLO calc)
- in addition contributions to all orders are included

Calculation of x-sections

- Collinear factorization
  - Inclusive F_2

$$\sigma(x,Q^2) = \int dz\ z f(z,Q^2)\hat{\sigma}(z,Q^2)$$

  - Jets

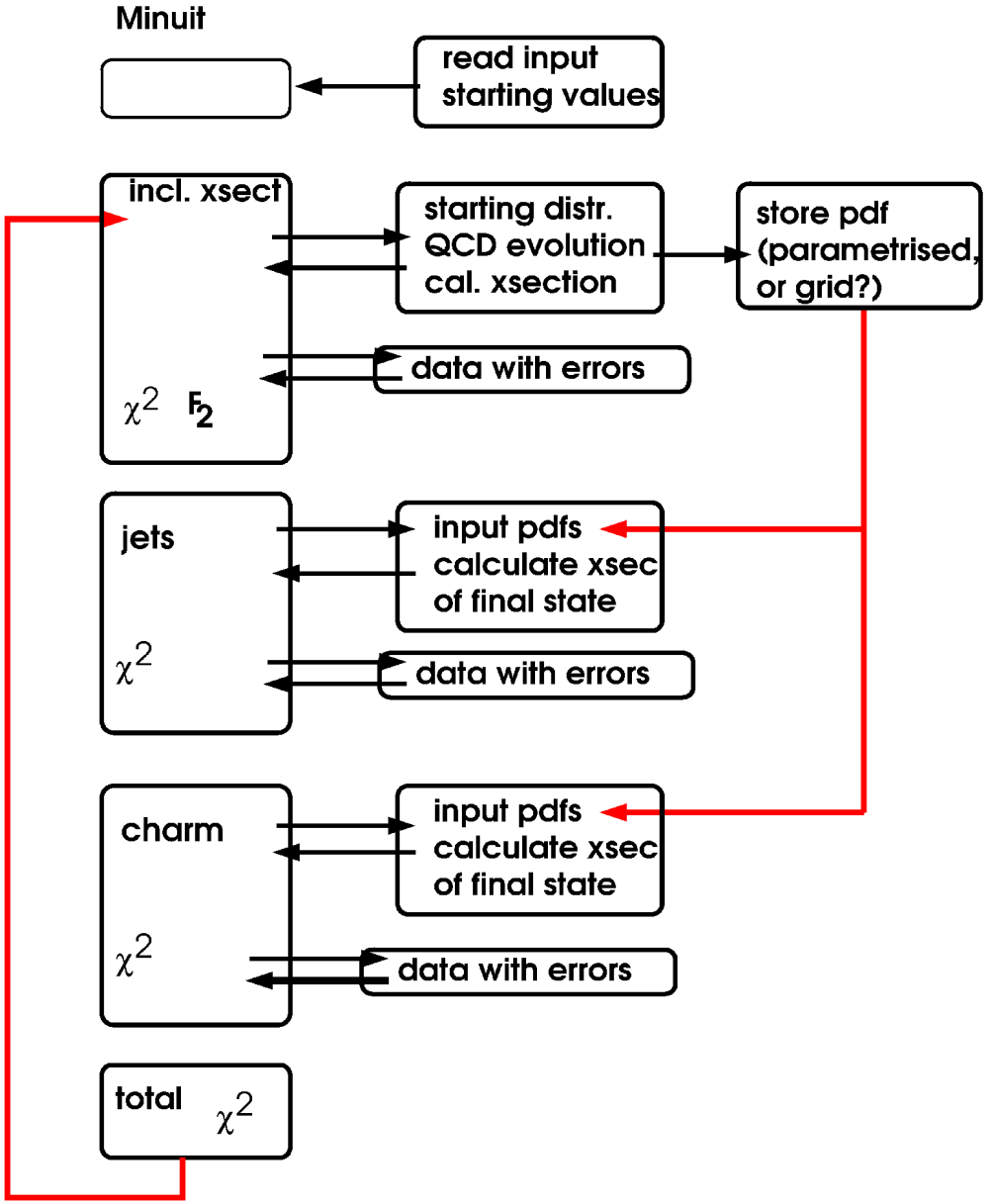
$$\frac{d\sigma^{jets}}{dE_T d\eta} = \sum \int\int\int dx\ dQ^2 d\ldots x f_i(x,Q^2)\hat{\sigma}_i^{jets}$$

- k_t- factorization

$$\frac{d\sigma^{jets}}{dE_T d\eta} = \sum \int\int\int dx_g\ dQ^2 d\ldots \left[dk_\perp^2\, x_g \mathcal{A}_i(x_g,k_\perp^2,\bar{q})\right]\hat{\sigma}_i(x_g,k_\perp^2)$$

- Time consuming calculation for final states...
- Only x-section can be compared.... NOT pdfs !!!!!!!!

PDF fit - program



Goals for PDF fits:

- fit inclusive and exclusive measurements
- using as many measurements as possible ... which can constrain the PDFs

➔ HZTool

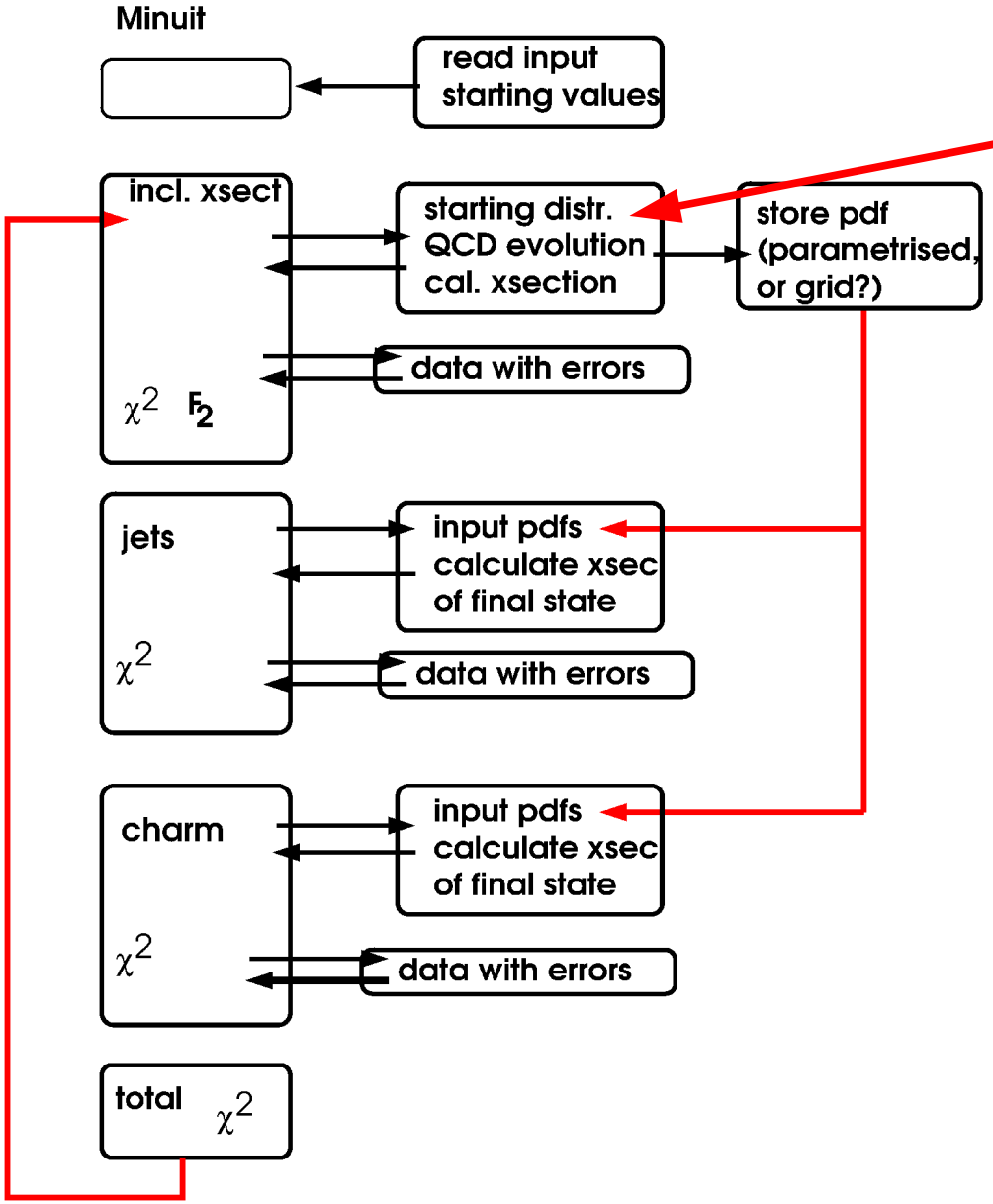
- using full information of final states

➔ MC@NLO or similar

➔ CASCADE

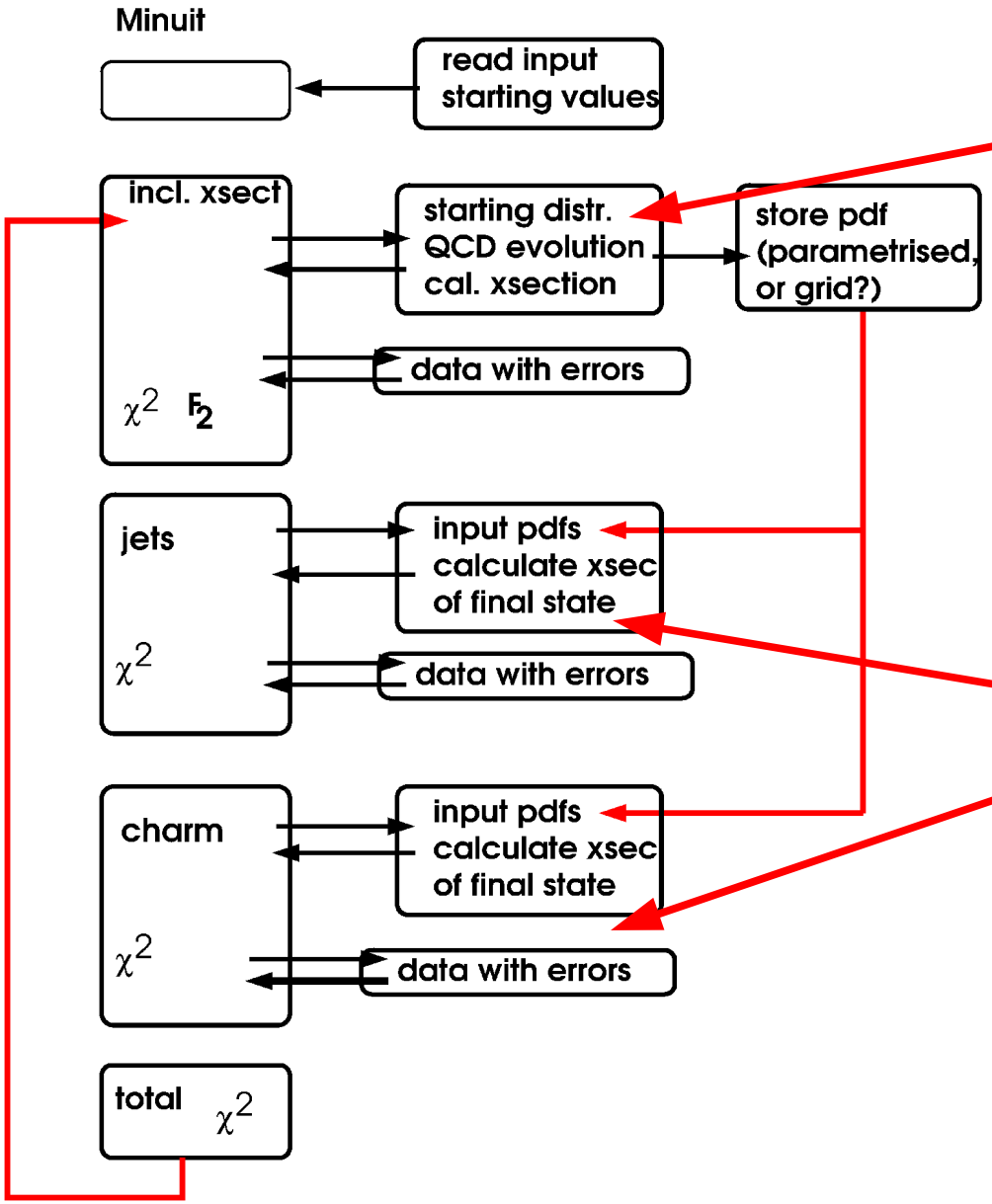
- consistent treatment of experimental and theoretical errors

PDF fits



- Coll factorization:
  - evolution code: QCDNUM,CTEQ, NNLO etc
  - Coefficient function in NLO,NNLO etc
- k_t factorization:
  - evolution code: CCFM, etc
  - off-shell ME
- Parametrization of PDFs

PDF fits



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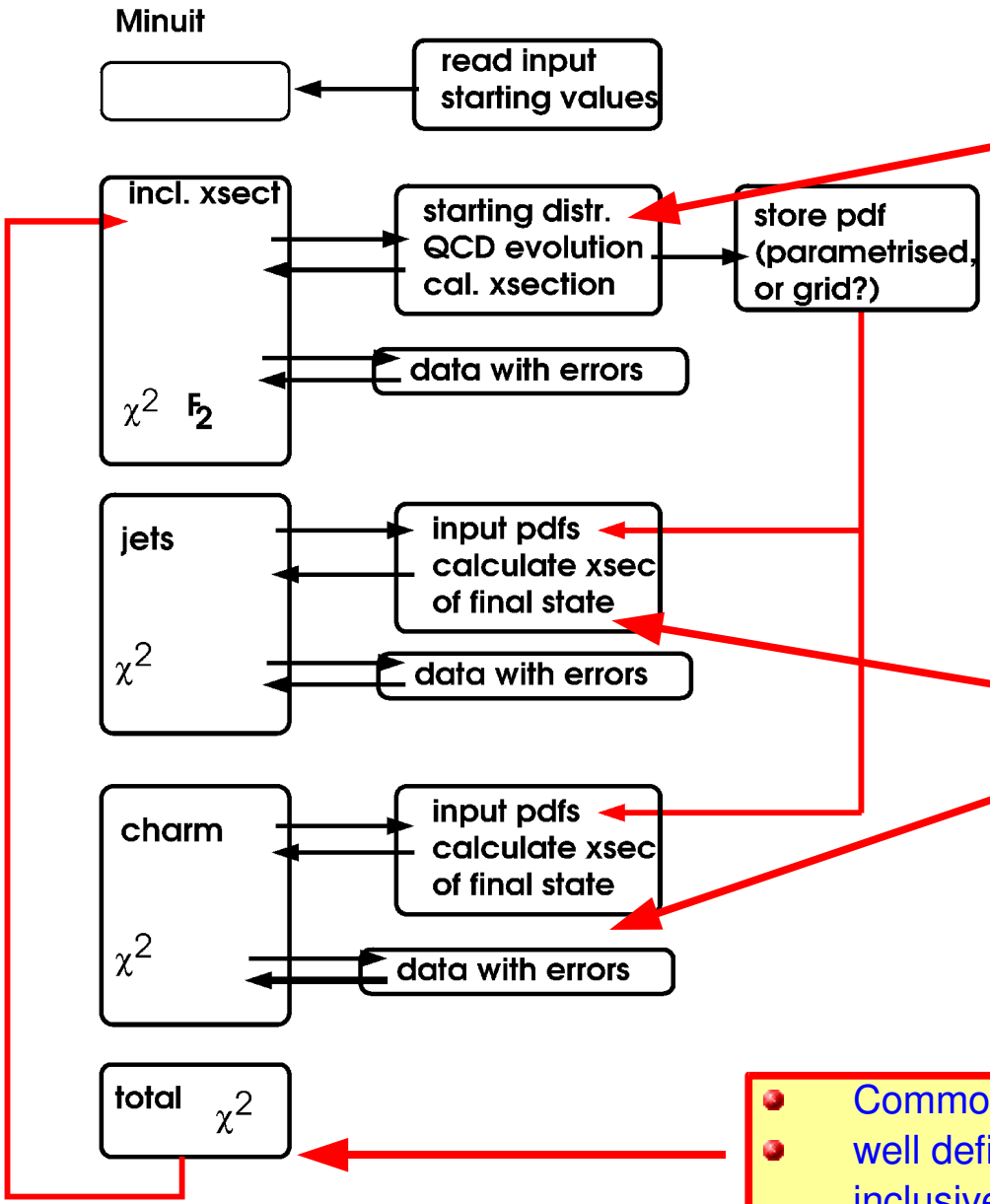
- Parametrization of PDFs

- Input from PDF
- Coll. factorization
  - FMNR, DISENT, NLOJET++,JETVIP ...
- k_t factorization
  - off shell ME's
- HZTool for xsection calc
  - jet algos, fragmentation, had. corrs

PDF fits



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- Coll. factorization
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- k_t factorization
  - off shell ME's
- HZTool for xsection calc
  - jet algos, fragmentation, had. corrs

- Common treatment of systematics
- well defined error treatment for inclusive and final state measurement

Method to fit incl. and final states

- Use full information of inclusive and final state measurements (using HZTOOL – histograms of predictions and measurements)
- Use full event simulation including parton showering and hadronization
- Method for uPDF a la CCFM:
  - generate grid file for $\tilde{\mathcal{A}}(x, k_\perp, \bar{q})$
  - use convolution with starting distribution $\mathcal{A}_0(x_0)$ to obtain full PDF:

$$x\mathcal{A}(x, k_\perp, \bar{q}) = \int dx_0 \mathcal{A}_0(x_0) \cdot \frac{x}{x_0} \tilde{\mathcal{A}}\left(\frac{x}{x_0}, k_\perp, \bar{q}\right)$$

  - simulate for many events
  - calculate chi**2 for different processes
- General purpose fitting procedure, can be applied also to DGLAP type fits and in collinear factorization
- Does not rely on any approximation or pre-calculation !!!

Fit details

- for minimization use SIMPLEX method with a fixed number of steps: NO numerical derivatives calculated...
  - MC event generation has fluctuations ... derivatives problematic
  - ➔ study fit as fct of random seed
  - ➔ observe fluctuations, even for large number of generated events (~ 10^6 events/iteration)
  - ➔ uncertainties of parameter determination

Fit details:

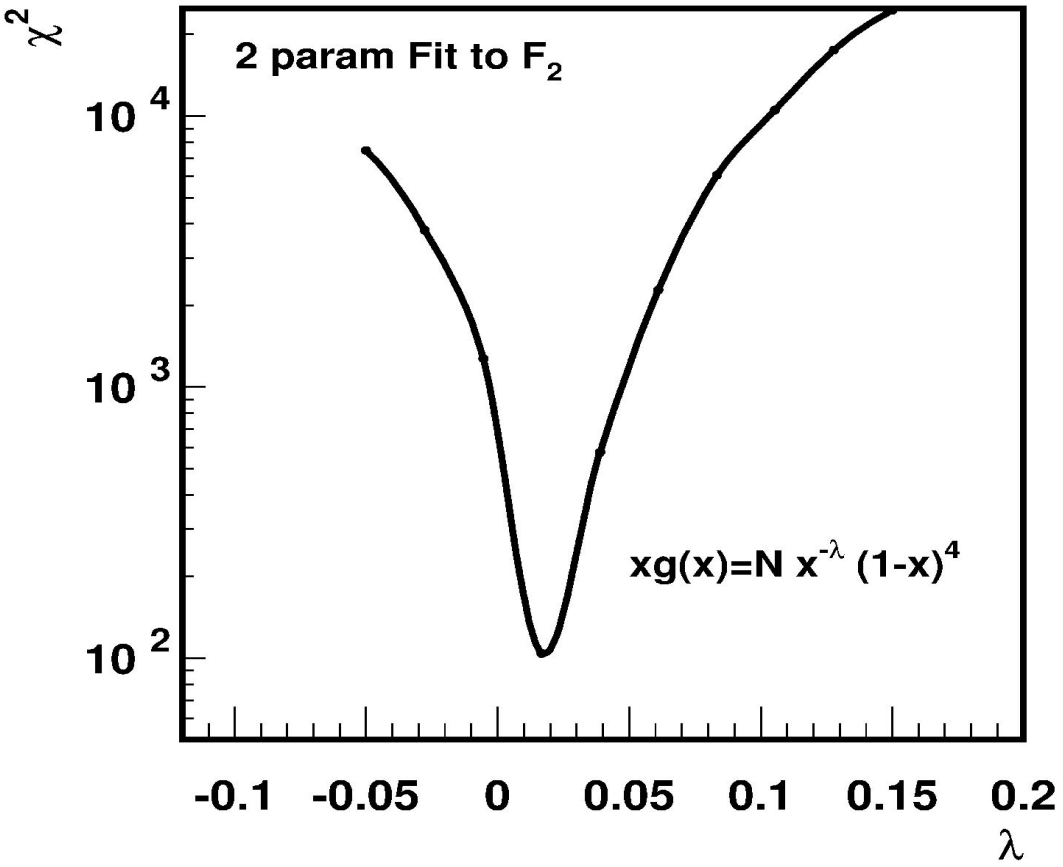
- using full splitting function in CCFM including non-singular terms
- using proper $\alpha_s(M_Z)$
  - but still one-loop

Fit to F_2 data

- Define $\chi^2 = \sum_i \left(\frac{\left(T - D - \sum_j \alpha_j \Delta_j^{sys}\right)^2}{\sigma_i^{2\,stat} + \sigma_i^{2\,uncor} + \sigma^{2\,T}} \right) + \sum_j \alpha_j^2$
- using offset method:
  - set $\alpha_j = 0$ for calculation of central value
  - later use $\alpha_j = \pm 1$ for calculation of uncertainty
- fit parameters of starting distribution

$$xg(x, \mu_0^2) = N x^{-\lambda} \cdot (1 - x)^4$$

- using F_2 data H1 (H1 Eur. Phys. J. C21 (2001) 33-61, DESY 00-181)
  - $x < 0.005$ $Q^2 > 5$ GeV^2
- Fit result: $\lambda = 0.018 \pm 0.003$



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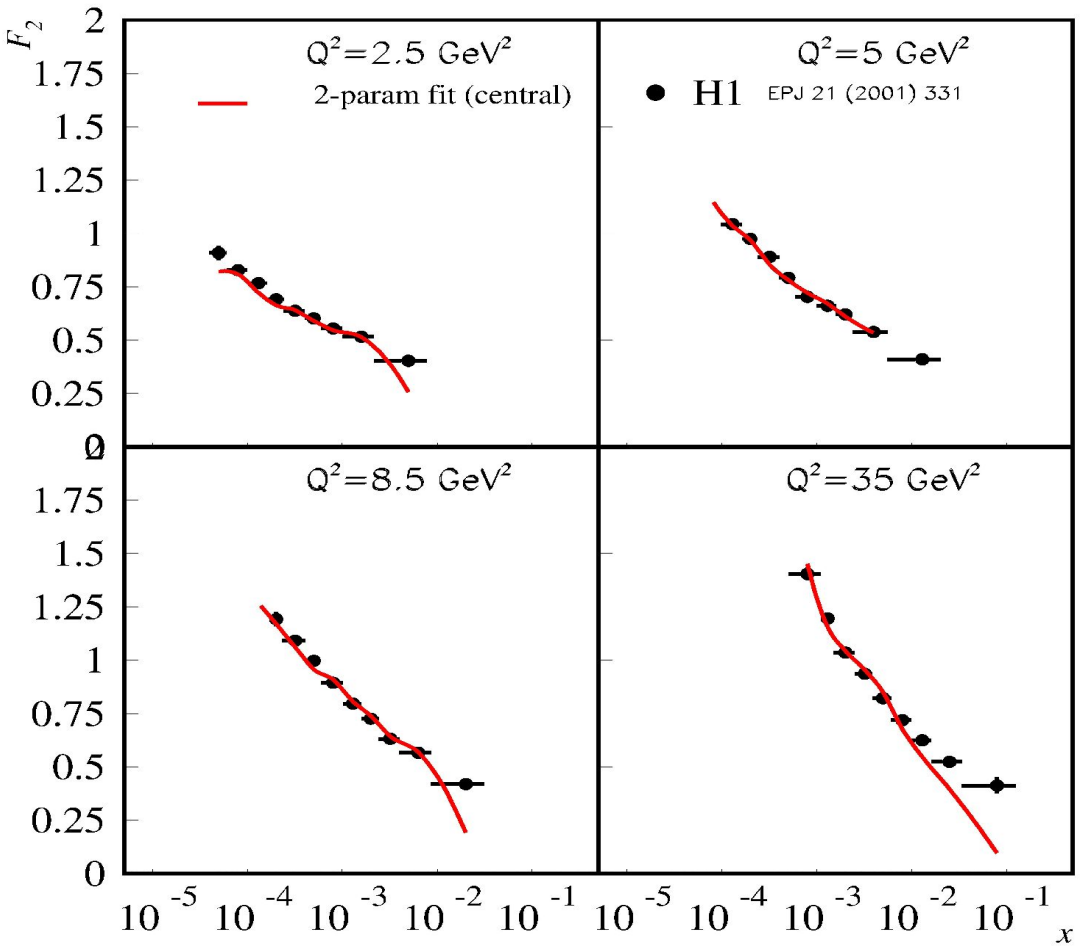

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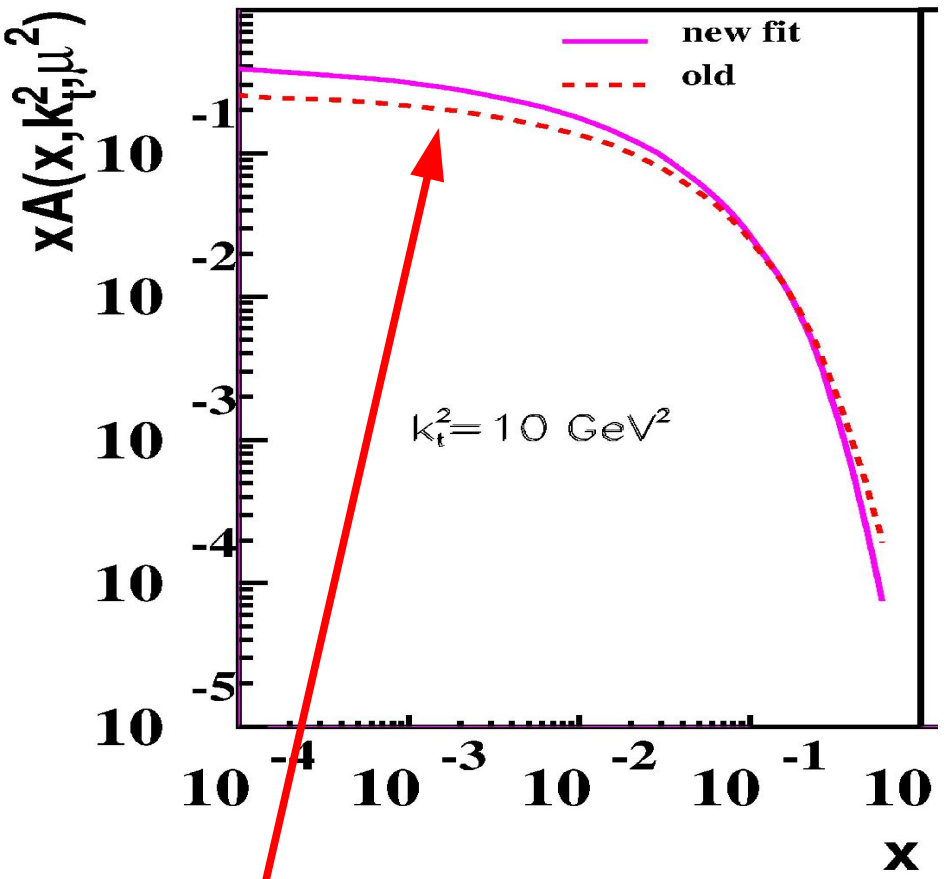


essentially from different α_s

Fit results

Fit details:

- using full splitting function in CCFM including non-singular terms
- using proper
  - still only one-loop $\alpha_s(M_Z)$

Results so far:

- no dependence on (1-x) parameters observed (fit only *x<0.005*) fix to *~(1-x)⁴*
- using stat and uncorr syst errors for fit
- $\chi^2/ndf \sim 1$ much better than before ....
- with different $\alpha_s(M_Z)$, k_t dependence of uPDF also different

NEW:

- fit of initial parameters $xg(x,\mu_0^2) = Nx^{-\lambda} \cdot (1-x)^4$

TO DO

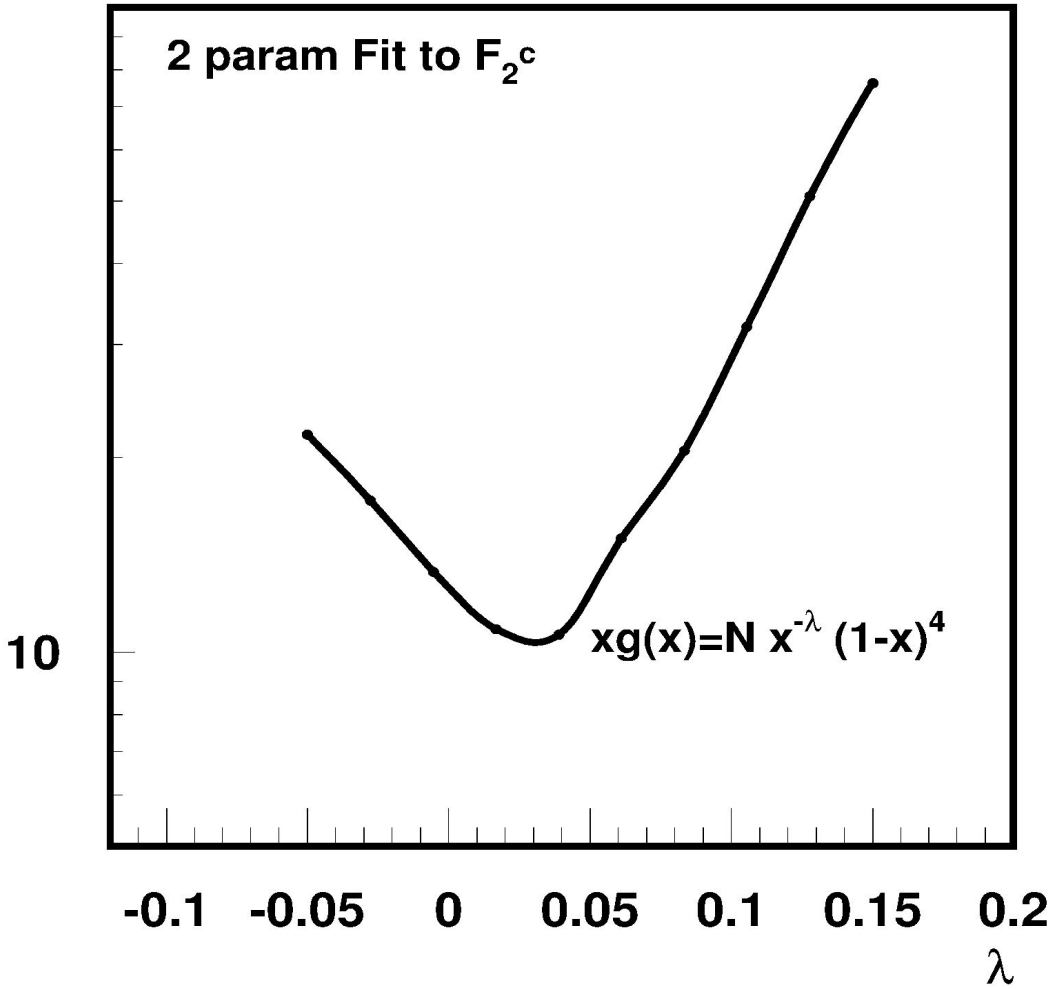
- study of experimental uncertainties
- systematic study of theory parameters

Fit to F_2^c data

- Define $$\chi^2 = \sum_i \left(\frac{(T-D)^2}{\sigma_i^{2\ stat} + \sigma_i^{2\ uncor} + \sigma^{2\ T}} \right)$$
- fit parameters of starting distribution

$$xg(x,\mu_0^2) = Nx^{-\lambda} \cdot (1-x)^4$$

- using F_2^c data H1 (H1 PLB528 (2002) 199, DESY 01-100)
  - $x < 0.005\ Q^2 > 1\ \mathrm{GeV}^2$
    - fit result: $\lambda = 0.03 \pm 0.005$
  - ➔ higher than for F_2 !?!?!?!
  - ➔ no big change of uPDF
  - ➔ BUT improved chi**2



Fit to F_2^c data

- Define $$\chi^2 = \sum_i \left(\frac{(T-D)^2}{\sigma_i^{2\ stat} + \sigma_i^{2\ syst} + \sigma^{2\ T}} \right)$$

- fit parameters of starting distribution

$$xg(x,\mu_0^2) = Nx^{-\lambda} \cdot (1-x)^4$$

- using F_2^c data H1 (H1 PLB528 (2002) 199, DESY 01-100)
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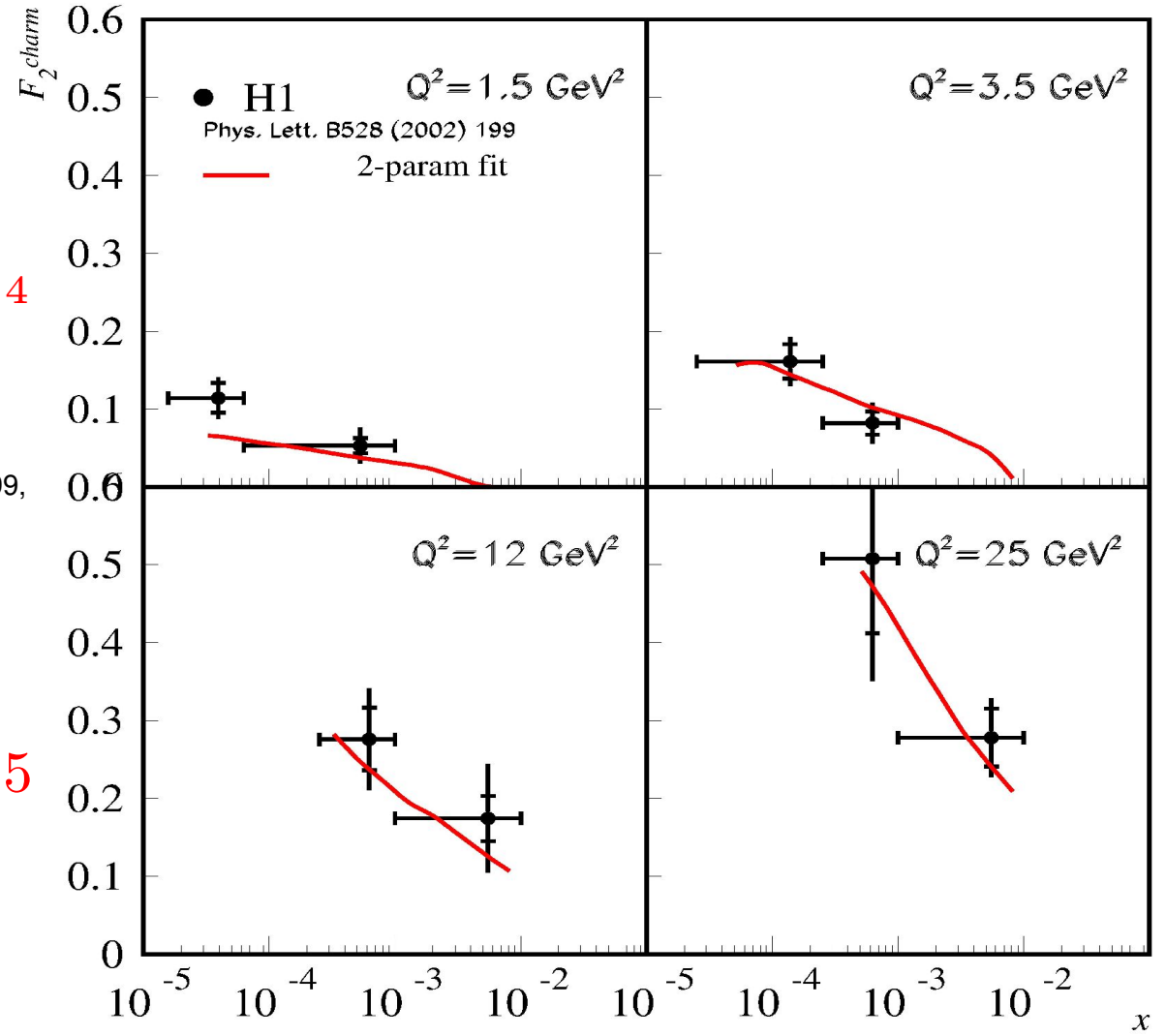
    - fit result: $\lambda = 0.03 \pm 0.005$
    - ➔ higher than for F_2 !?!?!?!
    - ➔ but essential no change of uPDF



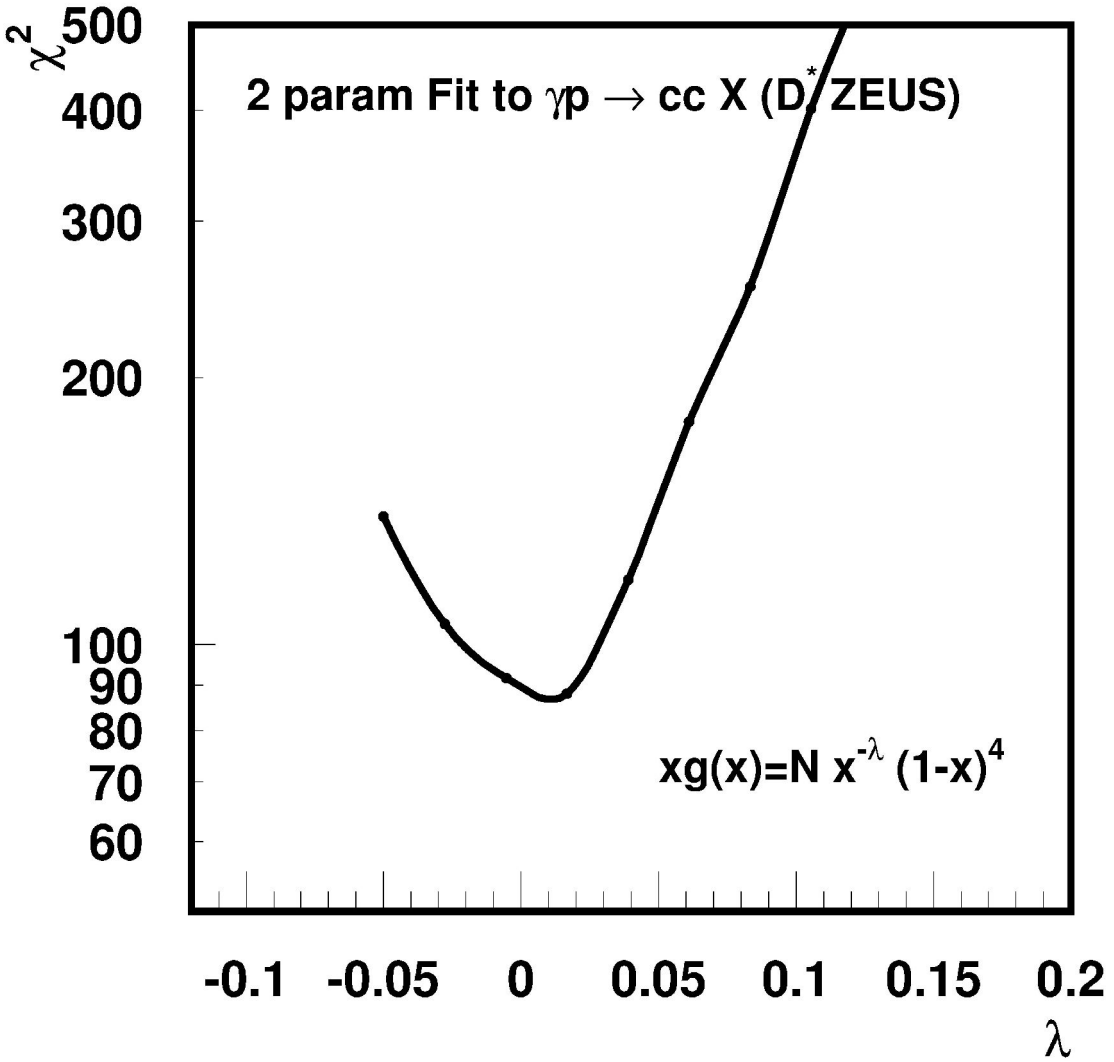
Fit to $\gamma p \to c\bar{c}X$ data

- fit parameters of starting distribution

$$xg(x,\mu_0^2) = Nx^{-\lambda} \cdot (1-x)^4$$

- using D* inclusive photoprod. data ZEUS

- fit result: $\lambda = 0.018$
- consistent result with fit to F_2
- improved chi**2 compared to old set
- next: investigate charm final states with jets ... xgamma



Next steps

- perform combined fits:
  - ➔ which measurements are sensitive to uPDF
  - ➔ combine different measurements
    - ➔ di-jets, charm, etc
- use full HERA data
- investigate experimental & theory uncertainties for uPDF

Conclusion

- Full treatment of kinematics in fits to PDFs necessary
  - at least if less inclusive quantities are investigated
- Fit method including full evolution and event generation works !
  - although slow and needs improvements
- Method applicable for all kinds of QCD evolution and measurements implemented in HZTOOL - package
- Example application - reasonable results for inclusive quantities:
  - F_2, F_2^c, photoproduction of charm

➔ **Making full use of all relevant experimental measurements !**

➔ **Consistent set of uPDFs from inclusive and final states (with proper kinematics) !**