# An approach to fast fits of the unintegrated gluon density

(***PROFFIT*** – a PROgram For FITting)

*A. Bacchetta (Jef Lab), H. Jung, **A. Knutsson**, K. Kutak (DESY)*

**HERA-LHC workshop 2008, 26-30th May, CERN**

## Outline

- **The fitting method**
- **The unintegrated gluon density**
- **uPDF determination from HERA di-jet data**
- **Results**

*albert.knutsson@desy.de*

# Monte Carlo fitting

**Former fitting method:** Based on running the generator in an **interative procedure** in parameter space.

→ **Time consuming.**

**New Approach:** Describe **parameter dependence** **before parameter fitting**, by building up a ***grid in parameter space***.

*On the following slides I present the details.*

# Acknowledgement

**The new approach was developed for tuning Monte Carlo models**

Suggested already 12 years ago...

**"Tuning and test of fragmentation models based on identified particles and precision event shape data."**

*Z.Phys.C73:11-60,1996*

Also work on Tuning MC in Lund.

Parameter Optimisation in Monte Carlo Event Generators

Hendrik Hoeth

(University of **Lund**)

**1st Mcnet School, IPPP Durham, 18-20th April 2007**

**We carry out the same method for fitting uPDFs.**

# New fitting approach

1. **Build up a grid in parameter – cross section space using Monte Carlo.**

**If you have a CPU farm (or use the *GRID*) this ultimately takes the time of running the MC generator once.**

# New fitting approach

**1. Build up a grid in parameter – cross section space using Monte Carlo.**

**If you have a CPU farm (or use the *GRID*) this ultimately takes the time of running the MC generator once.**

**2. Fit polynomials to the Monte Carlo grid.**

$$\sigma_{\text{poly}} = A + \sum_{1}^{N} B_i \cdot p_i + \sum_{1}^{N} C_i \cdot p_i^2 + \sum_{i=1}^{N} \sum_{j=i+1}^{N} D_{ij} \cdot p_i p_j + H.O.$$

$A, B, C$ **and** $D$ **are determined by fitting the polynomial to the parameter grid. (Singular Value Decompostion)**

# Singular Value Decompostion

**Number of Monte Carlo grid points > Coefficients** $\longrightarrow$ **Overdetermined system**

$$\sigma_{\text{poly}}(p_1, p_2) = A + B_1 p_1 + B_2 p_2 + C_1 p_1^2 + C_2 p_2^2 + C_3 p_1 p_2 + H.O.$$

**i.e.**

$$P_{n,m} X_m = \sigma_{n,poly}$$

**where**

$$X_n = (A, B_1, B_2, C_1, C_2, C_3, \ldots)$$
$$P_n = (1, p_1, p_2, p_1^2, p_1 p_2, p_2^2, \ldots)$$
$n =$ ***Grid point***

## Approach based on SVD algorithm:

**To obtain solution we minimize** $|PX - \sigma|$

**by** $\chi^2$**-minimization**

# New fitting approach

**1. Build up a grid in parameter – cross section space using Monte Carlo.**

**If you have a CPU farm (or use the *GRID*) this ultimately takes the time of running the MC generator once.**

**2. Fit polynomials to the Monte Carlo grid.**

$$\sigma_{\text{poly}} = A + \sum_{1}^{N} B_i \cdot p_i + \sum_{1}^{N} C_i \cdot p_i^2 + \underbrace{\sum_{i=1}^{N} \sum_{j=i+1}^{N} D_{ij} \cdot p_i p_j}_{} + H.O.$$

$A, B, C$ **and** $D$ **are determined by fitting the polynomial to the parameter grid. (Singular Value Decompostion)**

**Takes care of correlation between parameters**

# New fitting approach

1. **Build up a grid in parameter – cross section space using Monte Carlo.**

   **If you have a CPU farm (or use the *GRID*) this ultimately takes the time of running the MC generator once.**

2. **Fit polynomials to the Monte Carlo grid.**

$$\sigma_{\mathrm{poly}} = A + \sum_{1}^{N} B_i \cdot p_i + \sum_{1}^{N} C_i \cdot p_i^2 + \sum_{i=1}^{N} \sum_{j=i+1}^{N} D_{ij} \cdot p_i p_j + H.O.$$

   $A, B, C$ **and** $D$ **are determined by fitting the polynomial to the parameter grid.**

***Step 1. and 2. are done for each data point in the measurement.***
***Takes only a few seconds.***

# New fitting approach

1. **Build up a grid in parameter – cross section space using Monte Carlo.**

   **If you have a CPU farm (or use the *GRID*) this ultimately**
   **takes the time of running the MC generator once.**

2. **Fit polynomials to the Monte Carlo grid.**

$$\sigma_{\text{poly}} = A + \sum_{1}^{N} B_i \cdot p_i + \sum_{1}^{N} C_i \cdot p_i^2 + \sum_{i=1}^{N} \sum_{j=i+1}^{N} D_{ij} \cdot p_i p_j + H.O.$$

   $A, B, C$ **and** $D$ **are determined by fitting the polynomial to the parameter grid.**

***Step 1. and 2. are done for each data point in the measurement.***
***Takes only a few seconds.***

3. **Determine PDF parameters,** $p_i$ **, by fitting all the polynomials to data simulatneously**

   **Also this takes only a few seconds.**

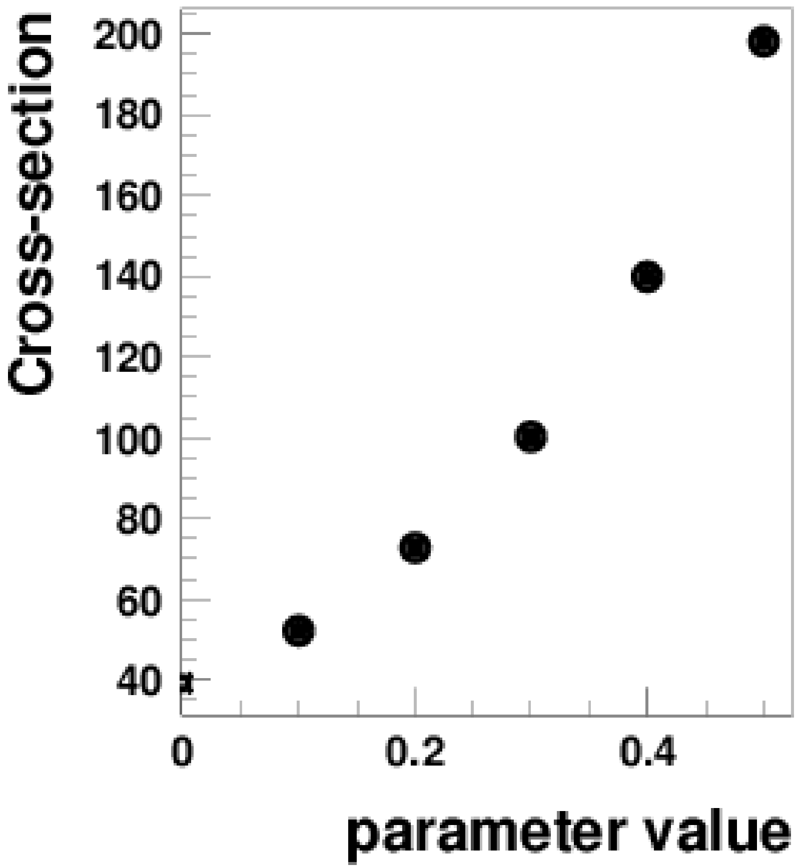
***Step 3. are done by Chi2-minimization using MINUIT.***

# 1 dimensional example

**Simplest possible example**

**1 parameter, 1 data cross-section**

## *1. Build up the grid*



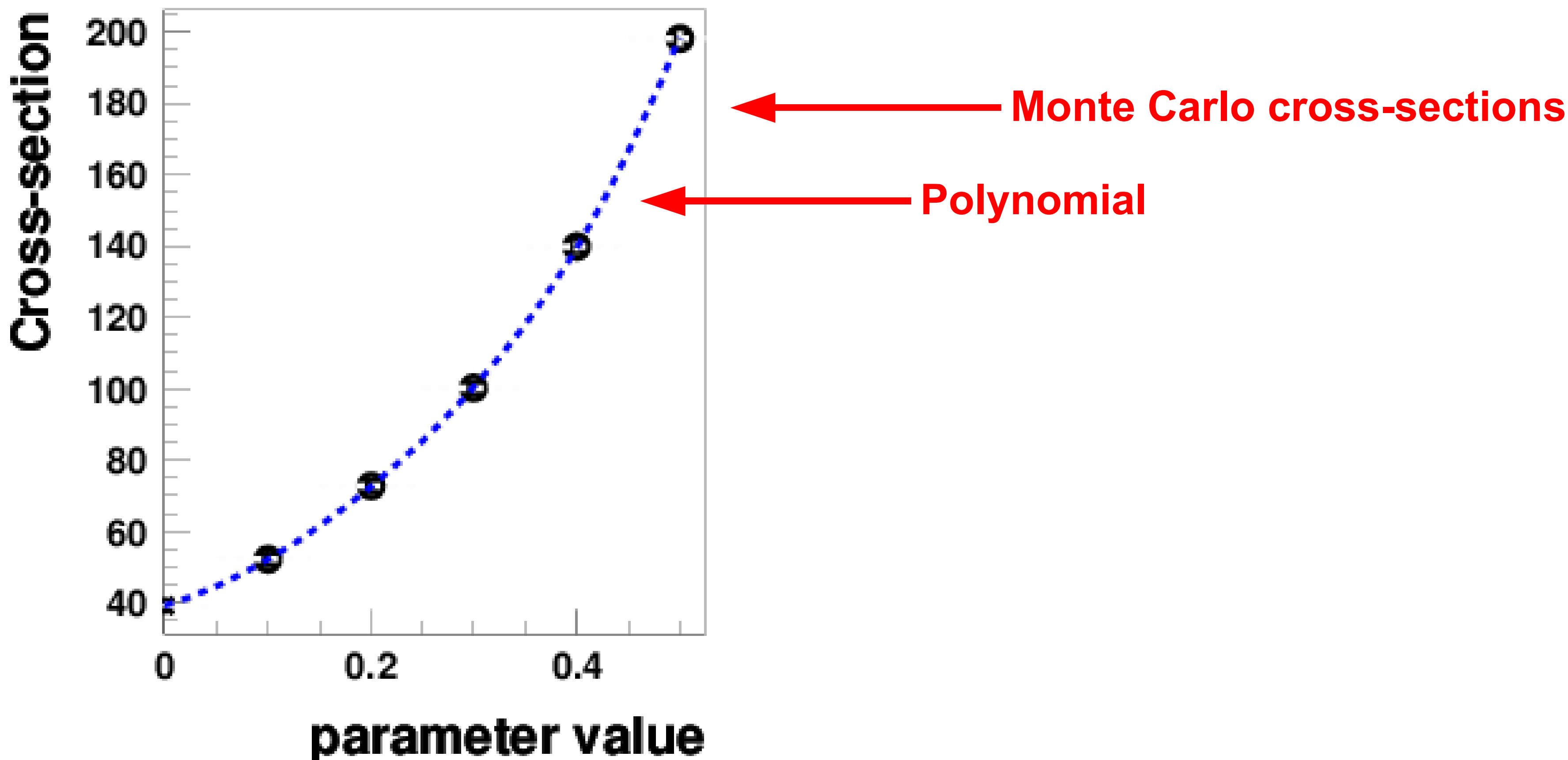

**Monte Carlos cross-sections**

# 1 dimensional example

**Simplest possible example**

**1 parameter, 1 data cross-section**

## ***2. Describe Monte Carlo by polynomial***

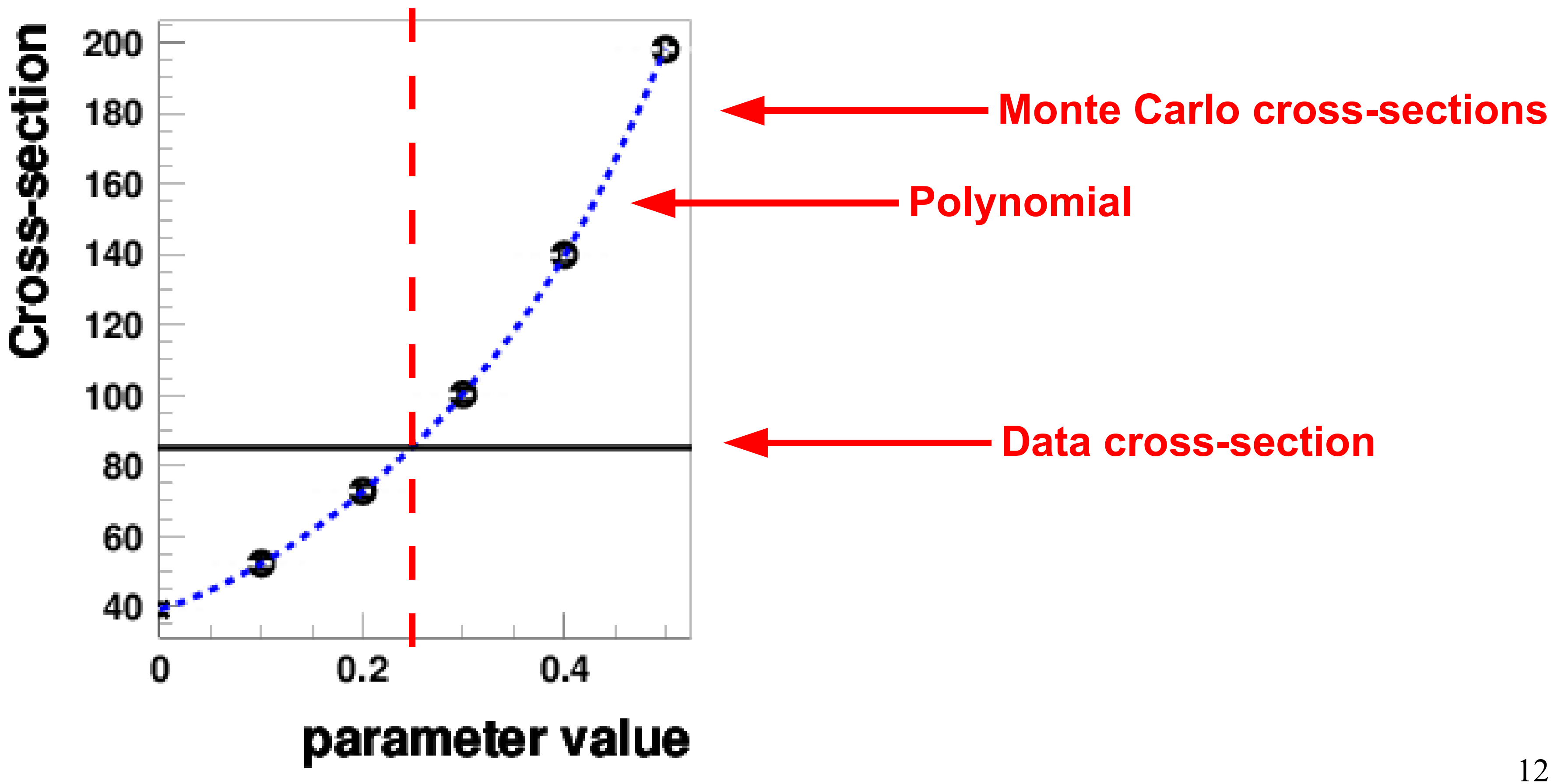


# 1 dimensional example

**Simplest possible example**

**1 parameter, 1 data cross-section**

## *3. Minimize Chi2 to data*



# PROFFIT – PROgram For FITting

- **The method is implemented into a program – PROFFIT check for updates on www.hepforge.org/PROFFIT.**

- **A lot of data available for tuning in hztool**

  (*“HZTool is a library of routines which will allow you to reproduce an experimental result using the four-vector final state from Monte Carlo generators.”*

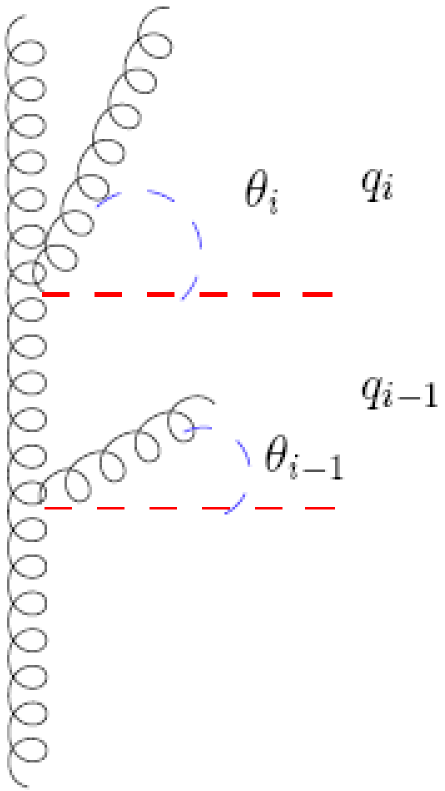
  *In the future replaced by RIVET*)

# The unintegrated gluon density

**The uPDF starting distribution:**

$$xA_0(x,k_T,\bar{q}_0) = N \cdot x^{-B} \cdot (1-x)^C \cdot exp(-\frac{(k_T-\mu)^2}{2\sigma^2})$$

***N***: Normalization (fitted)
***B***: Small x behaviour (fitted)
***C*=4**: Large x behaviour (kept fixed)
$\mu$, $\sigma$ **Determines the shape of the intrinsic $k_T$ of the gluon below $k_T$= 1.2 GeV ($\mu$ fitted)**




**Calculated at some starting scale ($\bar{q}_0$).**
**The uPDF is calculated for higher scales by emissions of gluons according to the *CCFM* evolution scheme.**
**(Monte carlo event generator *CASCADE(ep/pp)*)**

**The parameters N,B,C, $\mu$ ,$\sigma$, are not theoretically calculable.**

→ **We need to fit the uPDF to experimental data.**

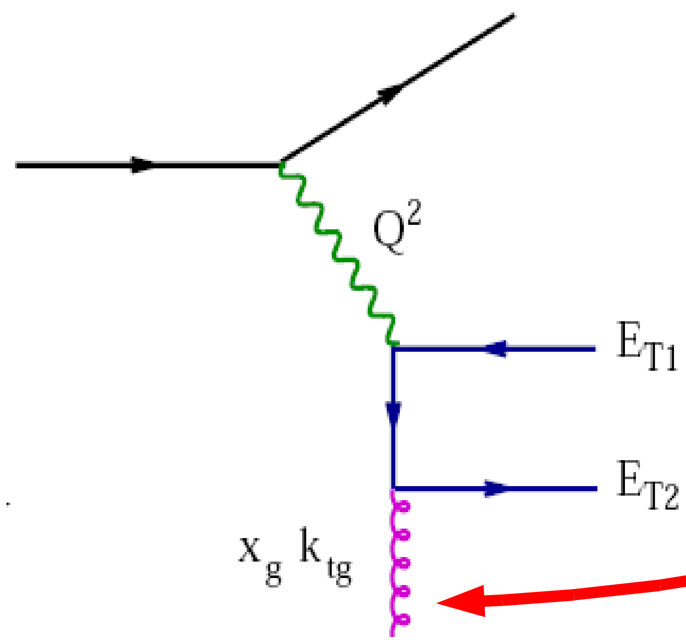
# Example of application

**Fit unintegrated gluon density to HERA di-jet data**

*H1 Collab., A. Aktas et al., Eur. Phys. J. C33 (2004) 477*

*Inclusive Dijet Production at Low x_Bj in DIS*

**Target hard di-jets.**
**Dominated by BGF, sensitivity to gluon.**




**Require** $E_{\mathrm{T,\ jet\ 1}} > (5 + \Delta)\ \mathrm{GeV}$
$E_{\mathrm{T,\ jet\ 2}} > 5\ \mathrm{GeV}$

**and measure jet cross-section as a function of** $\Delta$

**Sensitivity to gluon** $k_t$

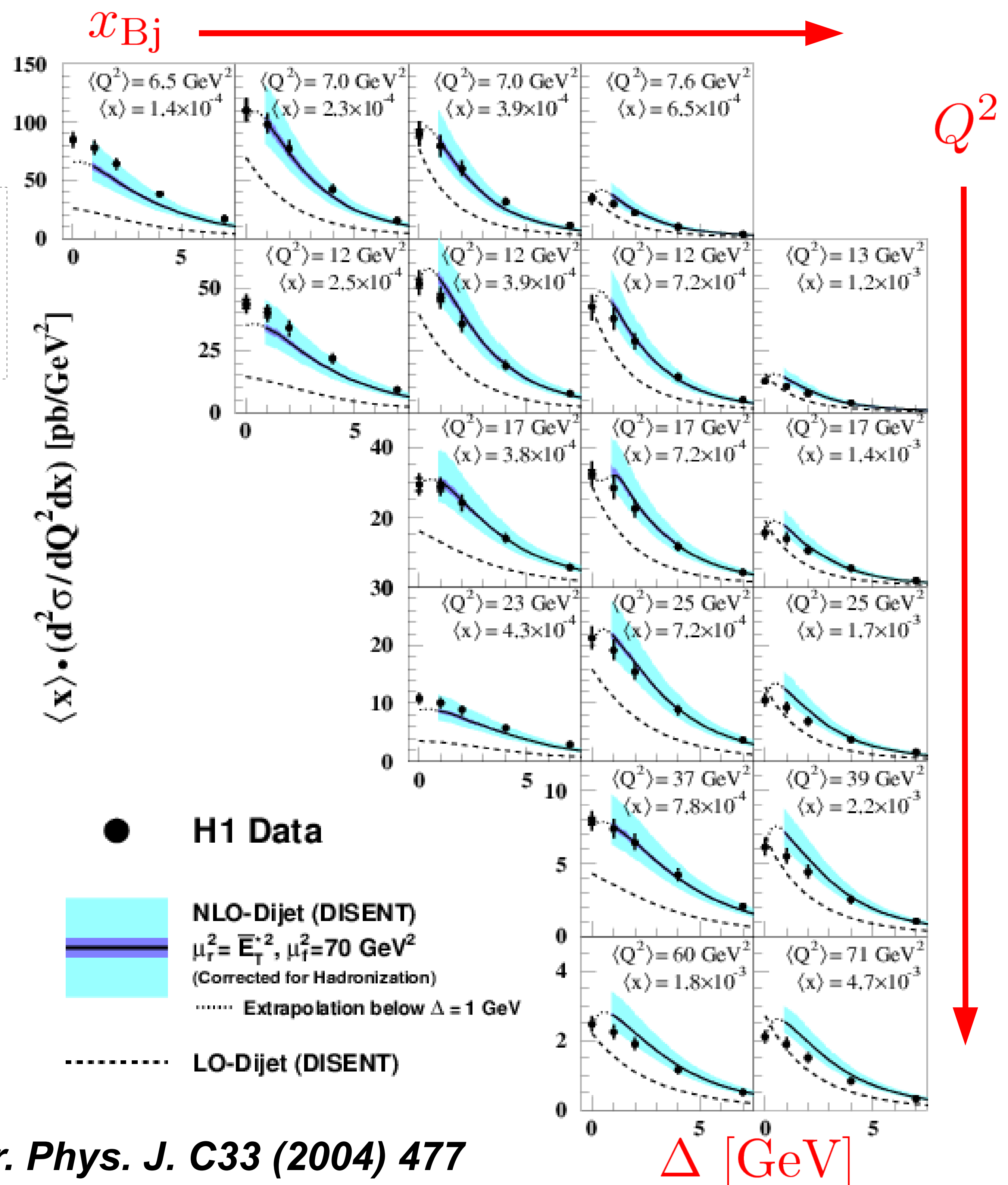
# Di-jet data

$E_{\mathrm{T,\ jet\ 1}} > (5+\Delta)\ \mathrm{GeV}$

**Total dijet cross-section as a function of $\Delta$**

- NLO di-jet calculation fails in parts of phase space

- NLO di-jet calculation not possible for low $\Delta$ due to divergencies.




*H1 Collab., A. Aktas et al., Eur. Phys. J. C33 (2004) 477*

# Di-jet data

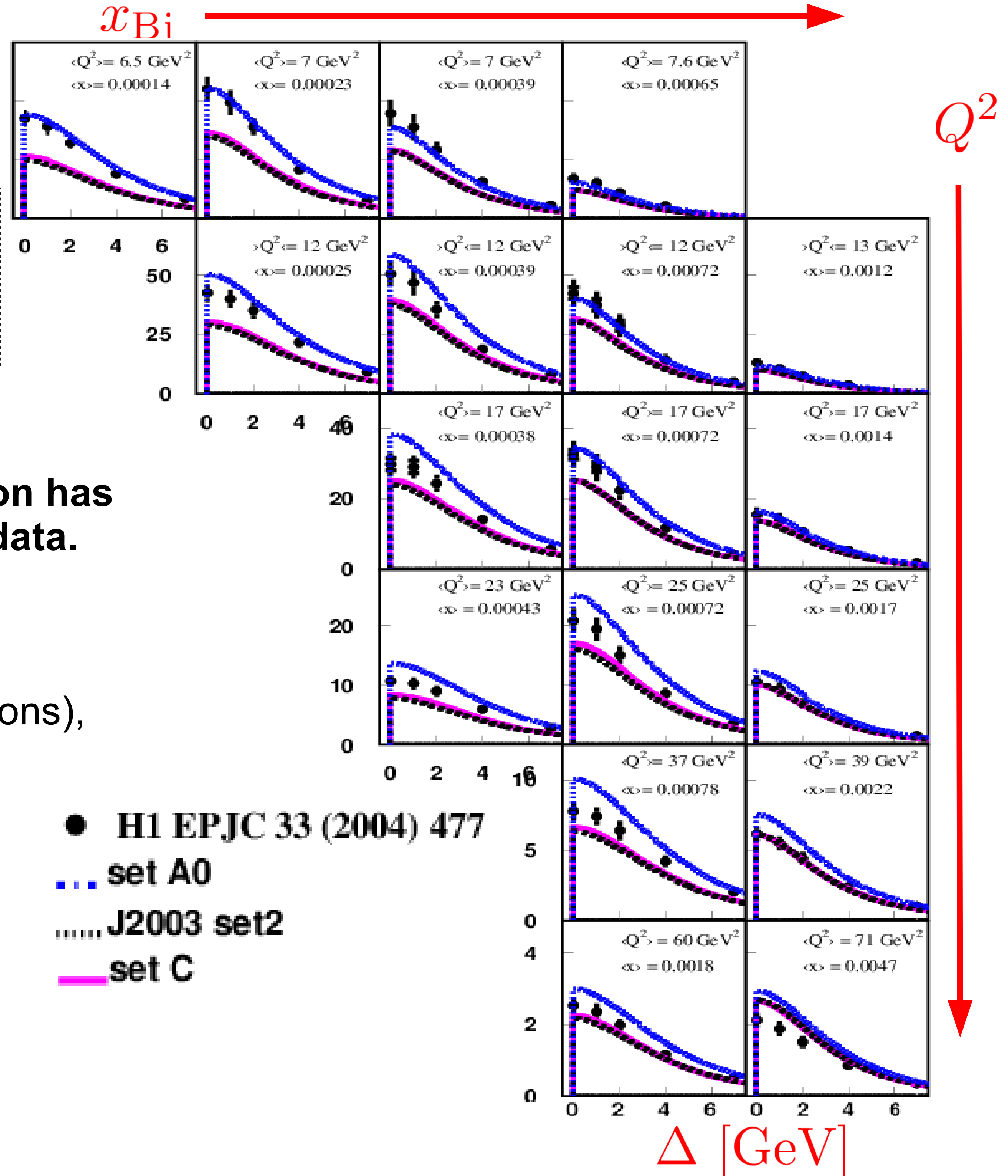
$E_{\mathrm{T,\ jet\ 1}} > (5 + \Delta)\ \mathrm{GeV}$

**Total dijet cross-section as a function of $\Delta$**

**Existing CASCADE prediction has some problems describing data.**

Best is "**set A0**" (determined by fit to proton structure functions), giving a **Chi2/ndf=3.5**

**Improve by fitting using PROFFIT...**



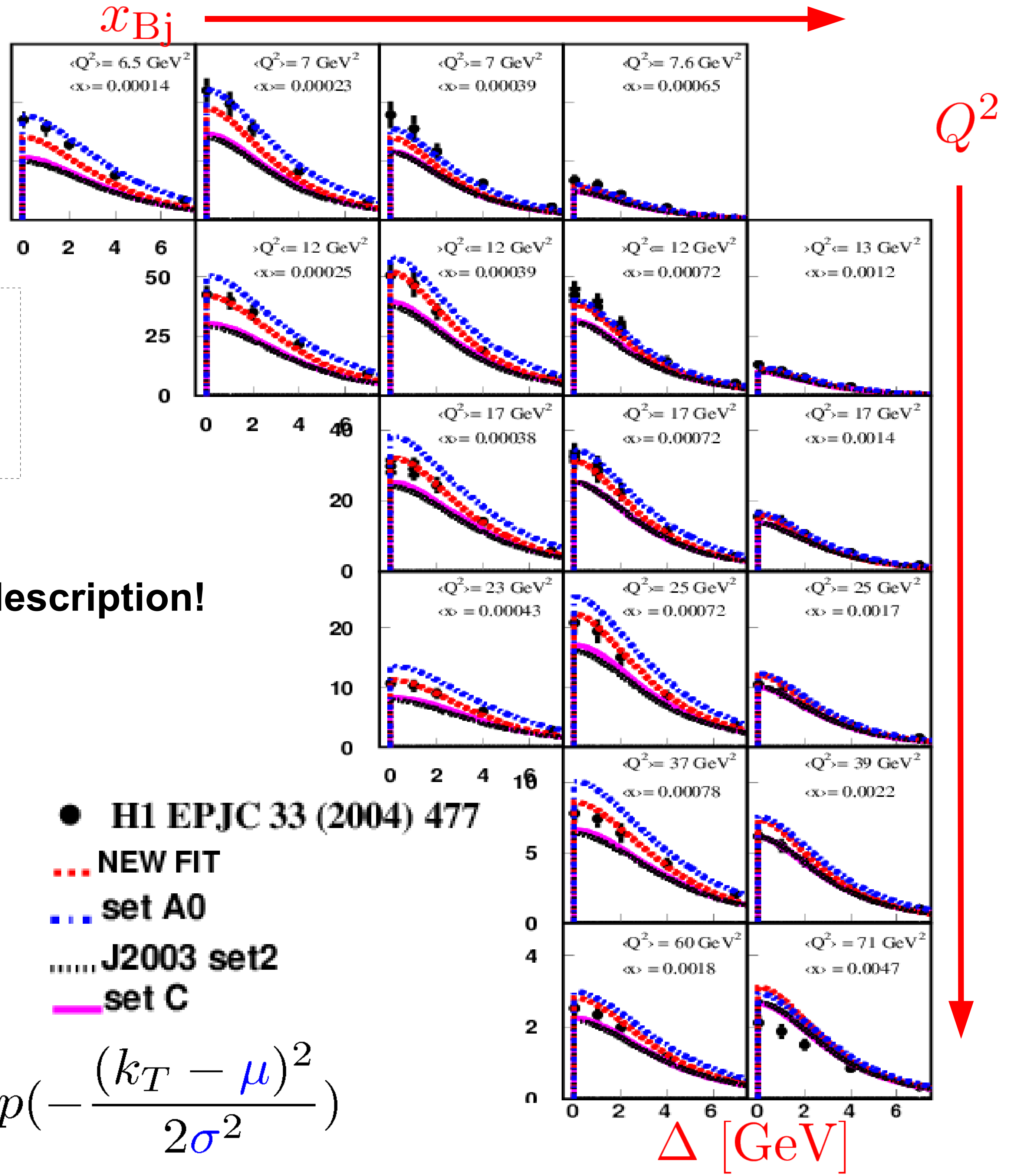
# Di-jet data - fit results

$E_{\mathrm{T,\ jet\ 1}} > (5+\Delta)\ \mathrm{GeV}$

**Total dijet cross-section as a function of $\Delta$**

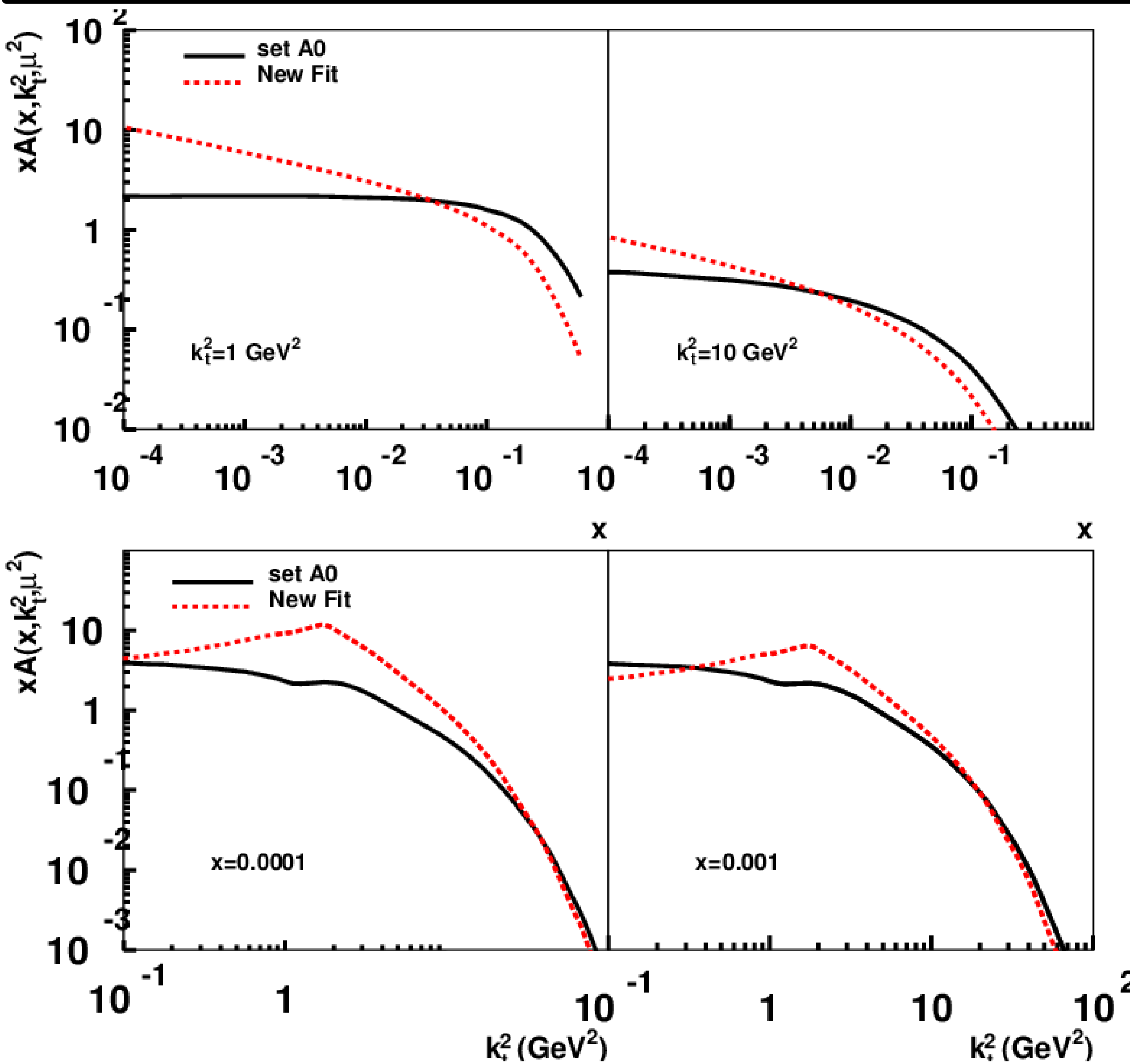
**Fitted uPDF improves data description!**

| | |
|---|---|
| ***Chi2/ndf*** | **2.01** |
| ***N*** | **0.28 +/- 0.02** |
| ***B*** | **0.25 +/- 0.03** |
| $\mu$ | **3.0 +/- 0.04** |
| $\sigma$ | **2, fixed** |




$$N \cdot x^{-B} \cdot (1-x)^C \cdot exp(-\frac{(k_T-\mu)^2}{2\sigma^2})$$

# Comparison to existing uPDF




$$N \cdot x^{-B} \cdot (1-x)^C \cdot exp(-\frac{(k_T-\mu)^2}{2\sigma^2})$$

**Set A0**

| | |
|---|---|
| ***B*** | **0** |
| $\mu$ | **0** |
| ***Chi2/ndf*** | **3.5** |

**Set A0 starting distribution determined from fit to F2-data (H.Jung, Comp.Phys.Com. 143:100-111,2002)**

**New Fit**

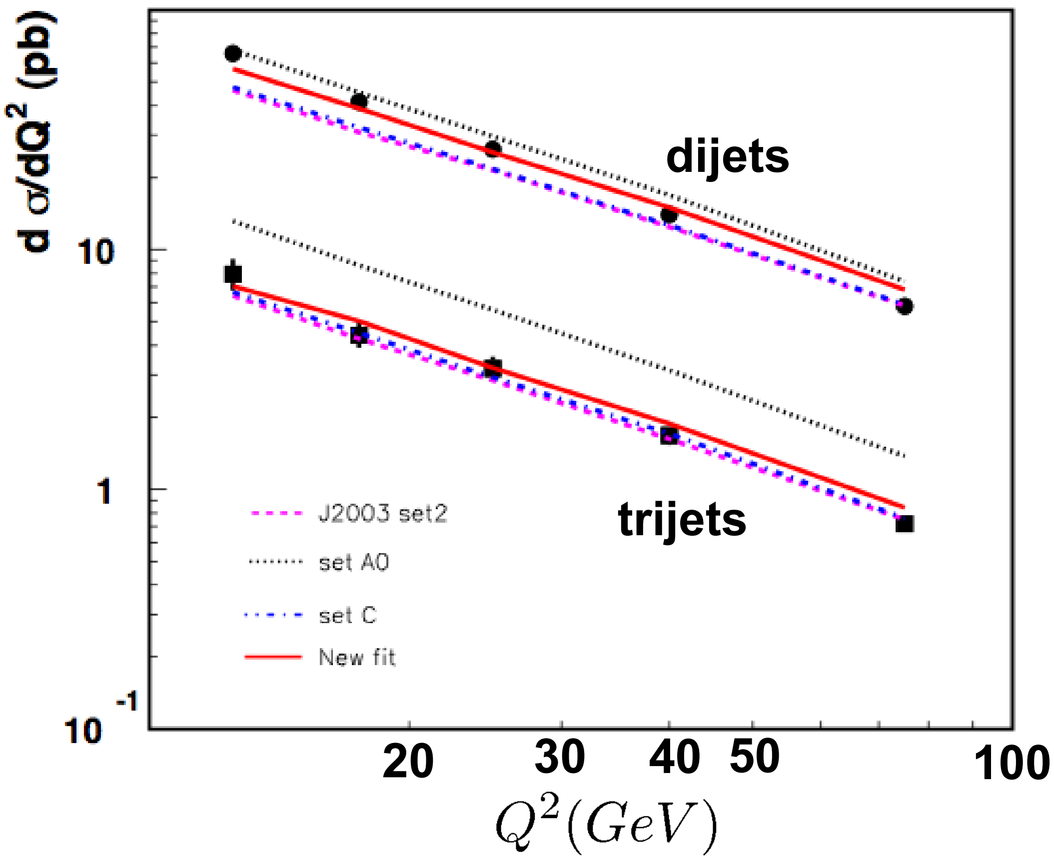
| | |
|---|---|
| ***B*** | **0.25 +/- 0.03** |
| $\mu$ | **3.0 +/- 0.04** |
| ***Chi2/ndf*** | **2** |

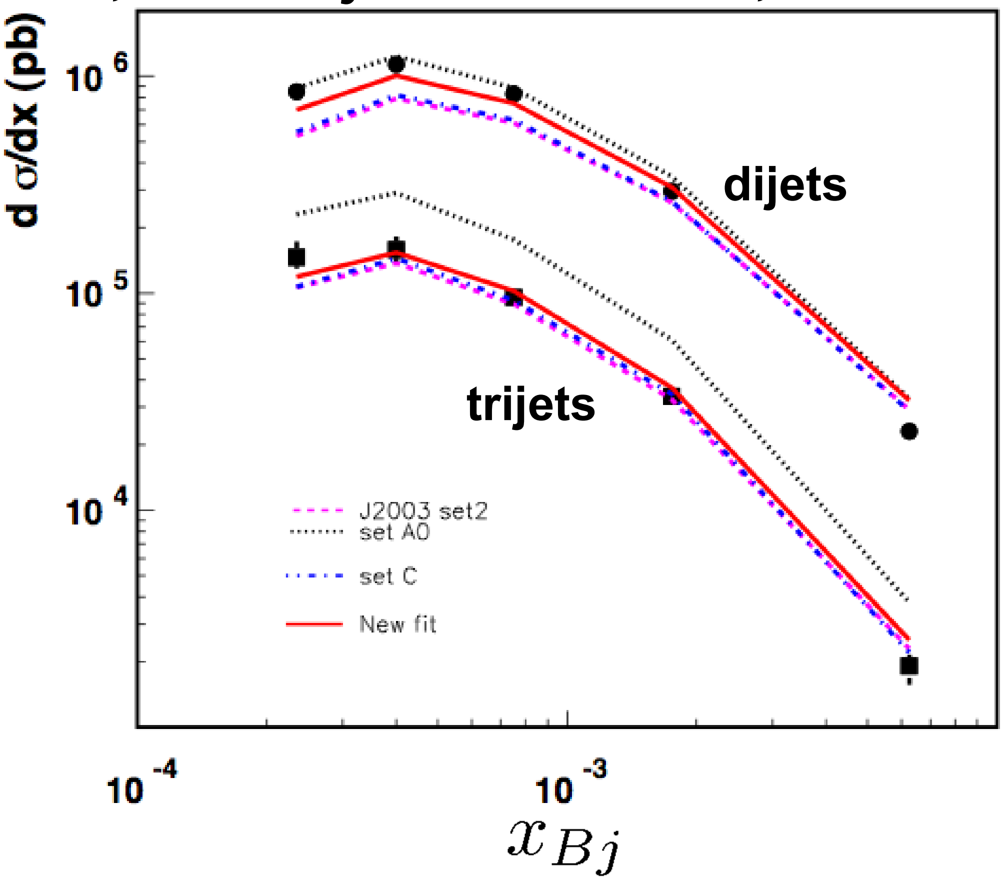
**The new fit to the dijet data suggest *stronger rising x* and a *shifted gaussian for k_t*.**

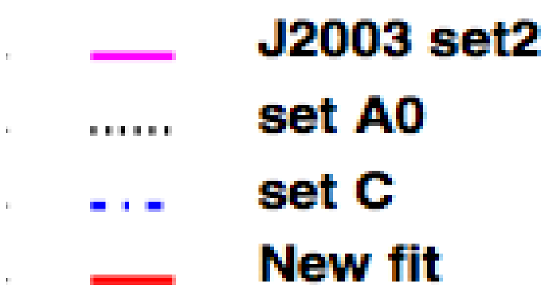
# Inclusive Multijet Cross-section in DIS

**Cross check with other data**

*ZEUS Collaboration, S. Chekanov et al, Nucl.Phys.B786:152-180,2007*



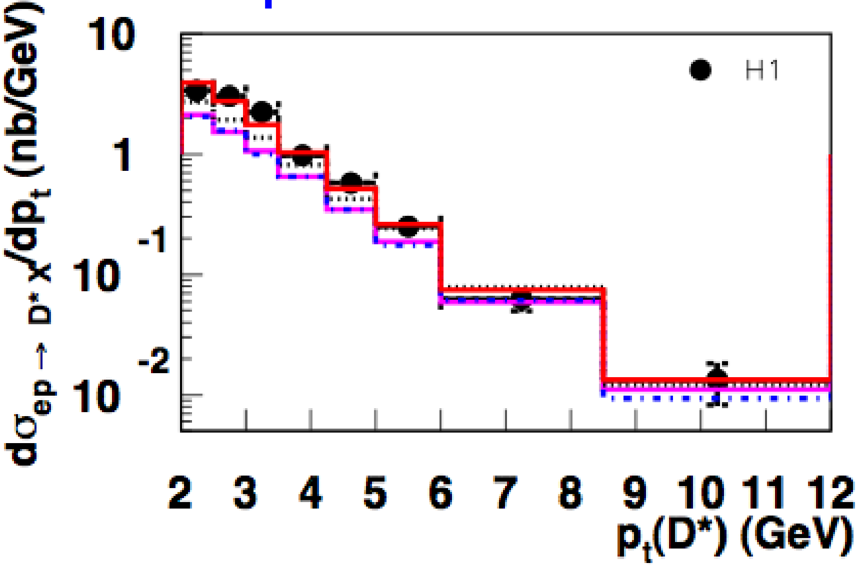



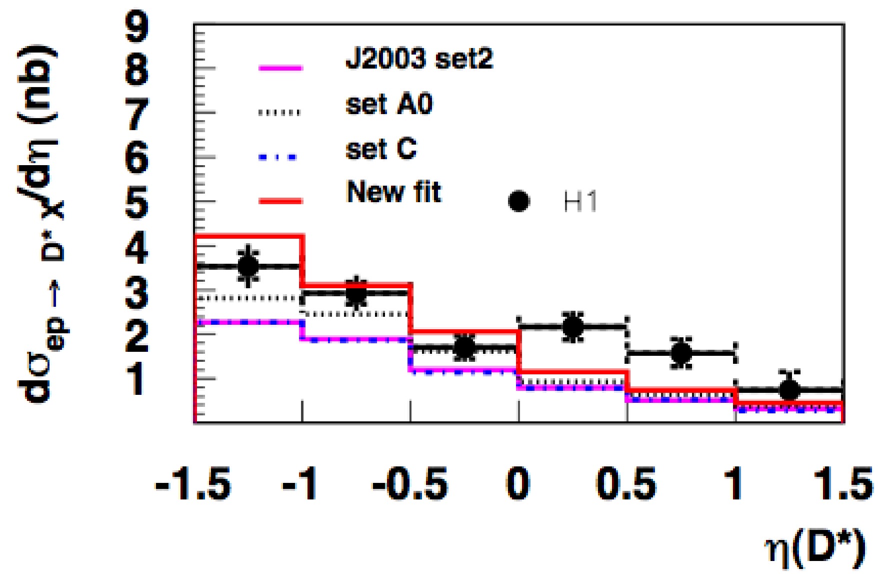

**Description of inclusive di-jet and**
**3-jet cross section improved by the new fit**

# D*-production in Photoproduction

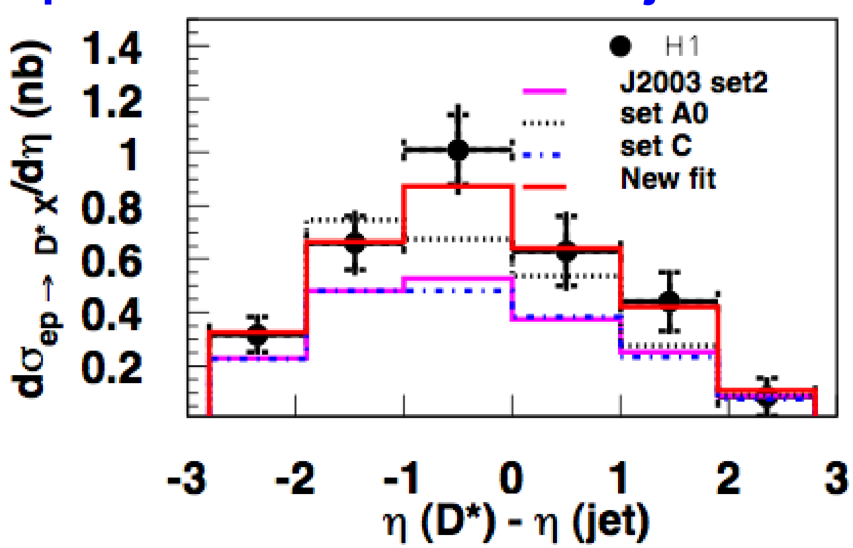
***H1 Collab., A. Aktas et al.,Eur.Phys.J.C50:251-267,2007***

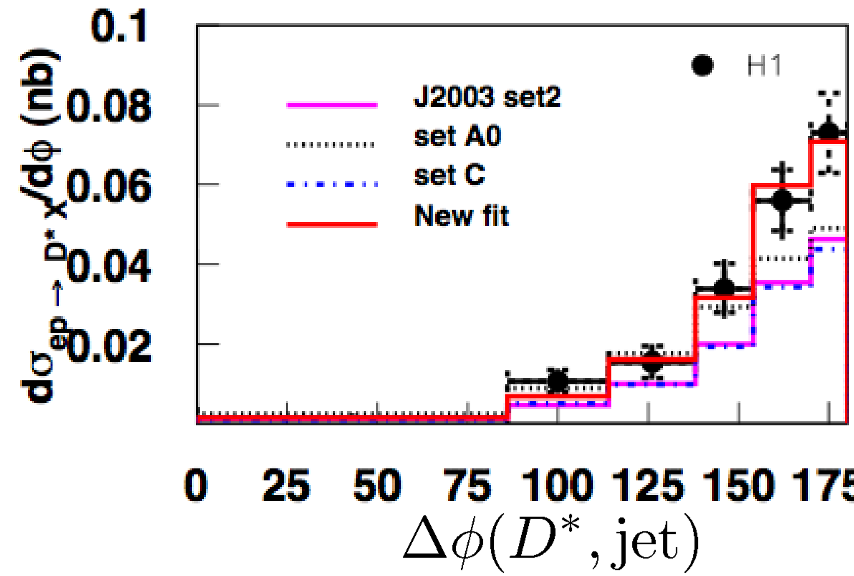
**Inclusive D* production in PHP:**




**D* production and additional jet:**



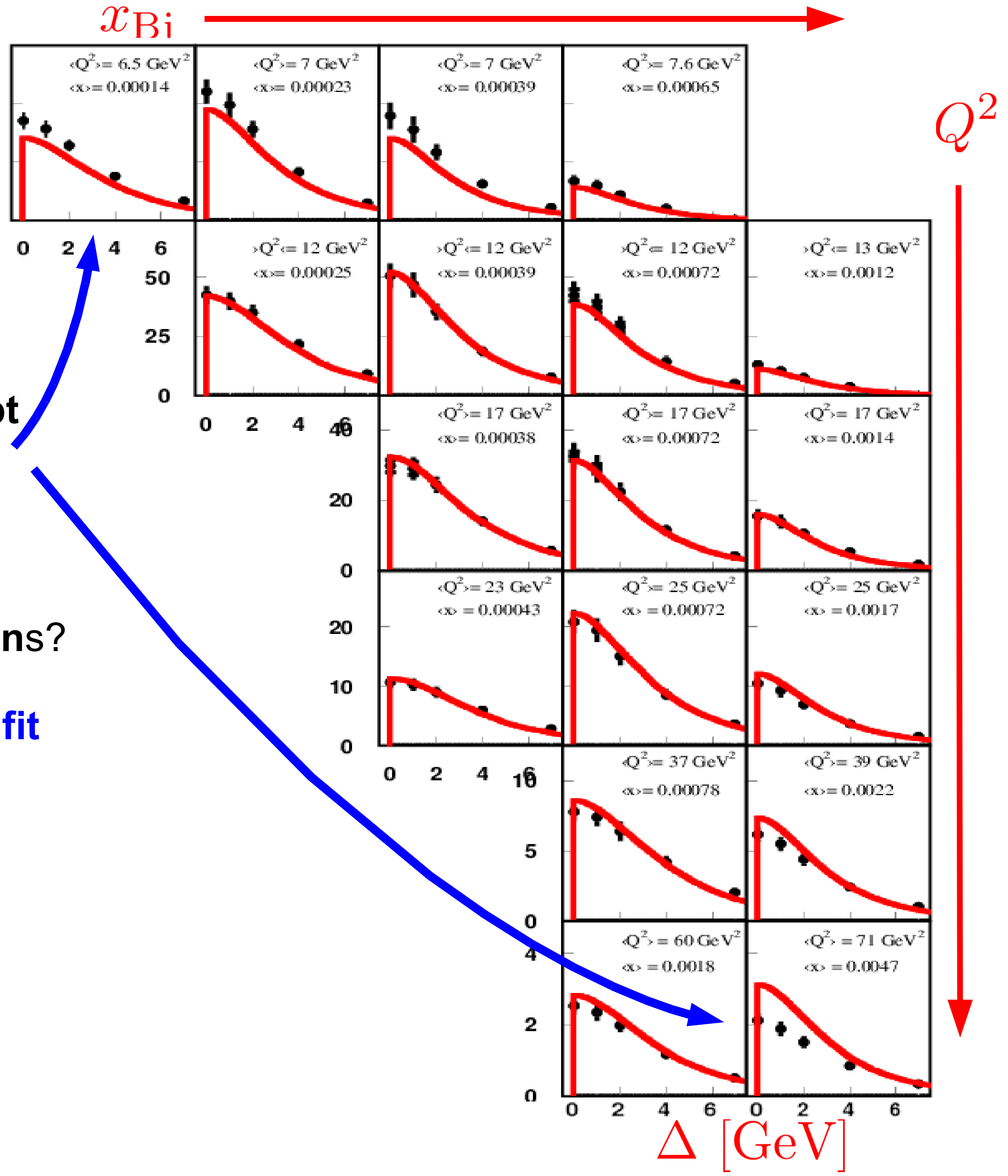






**PDF fit to di-jet in DIS → Better description of D* and D*-jet correlation in PHP**

# Di-jet data result

The **new PDF** gives a pretty good over all description **except at *very low x and "high" x*.**




**What is required in order to describe the data in these bins?**

**Very fast (~5 sec) to remake fit with PROFFIT...**

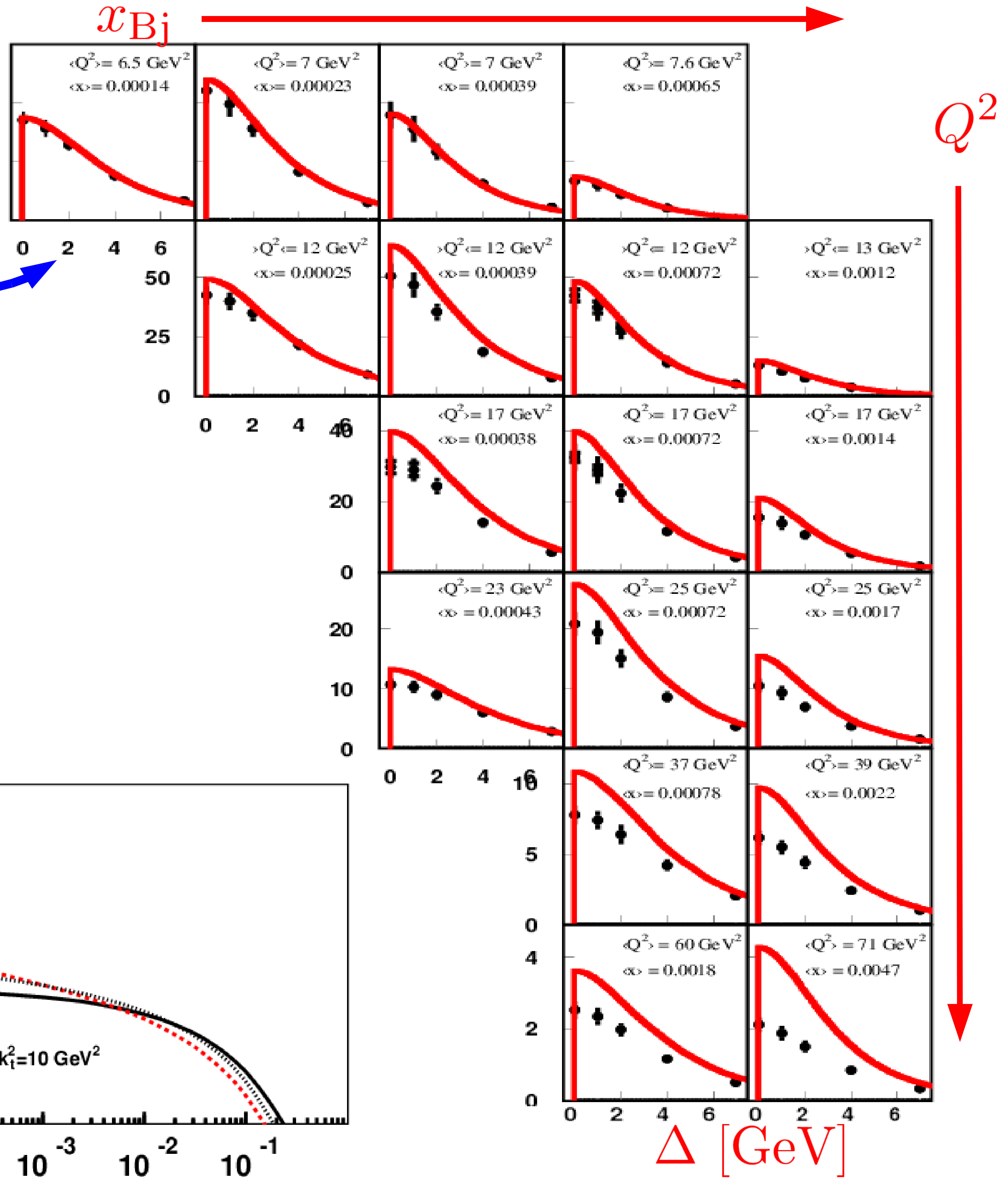
# Di-jet data result

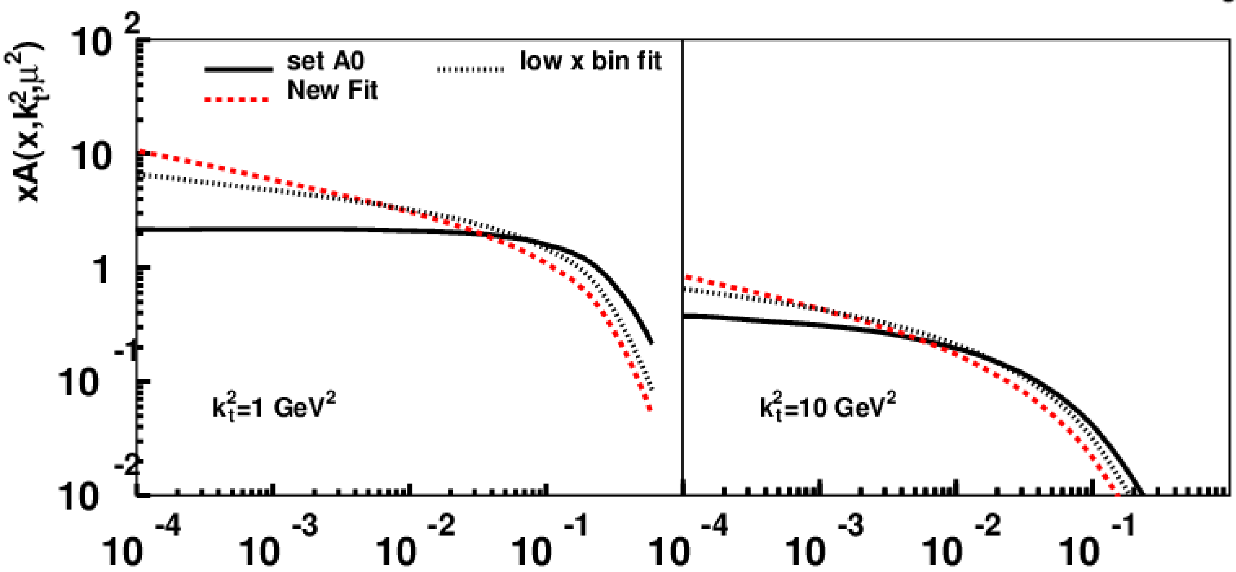
Fitting only the low x bin

$$\langle Q^2 \rangle = 6.5 \text{ GeV}^2$$
$$\langle x \rangle = 0.00014$$

Suggests a lower B value

| | *All bins* | Low x fit |
|---|---|---|
| *B* | *0.25* | 0.13 |
| $\mu$ | *3* | 3 |



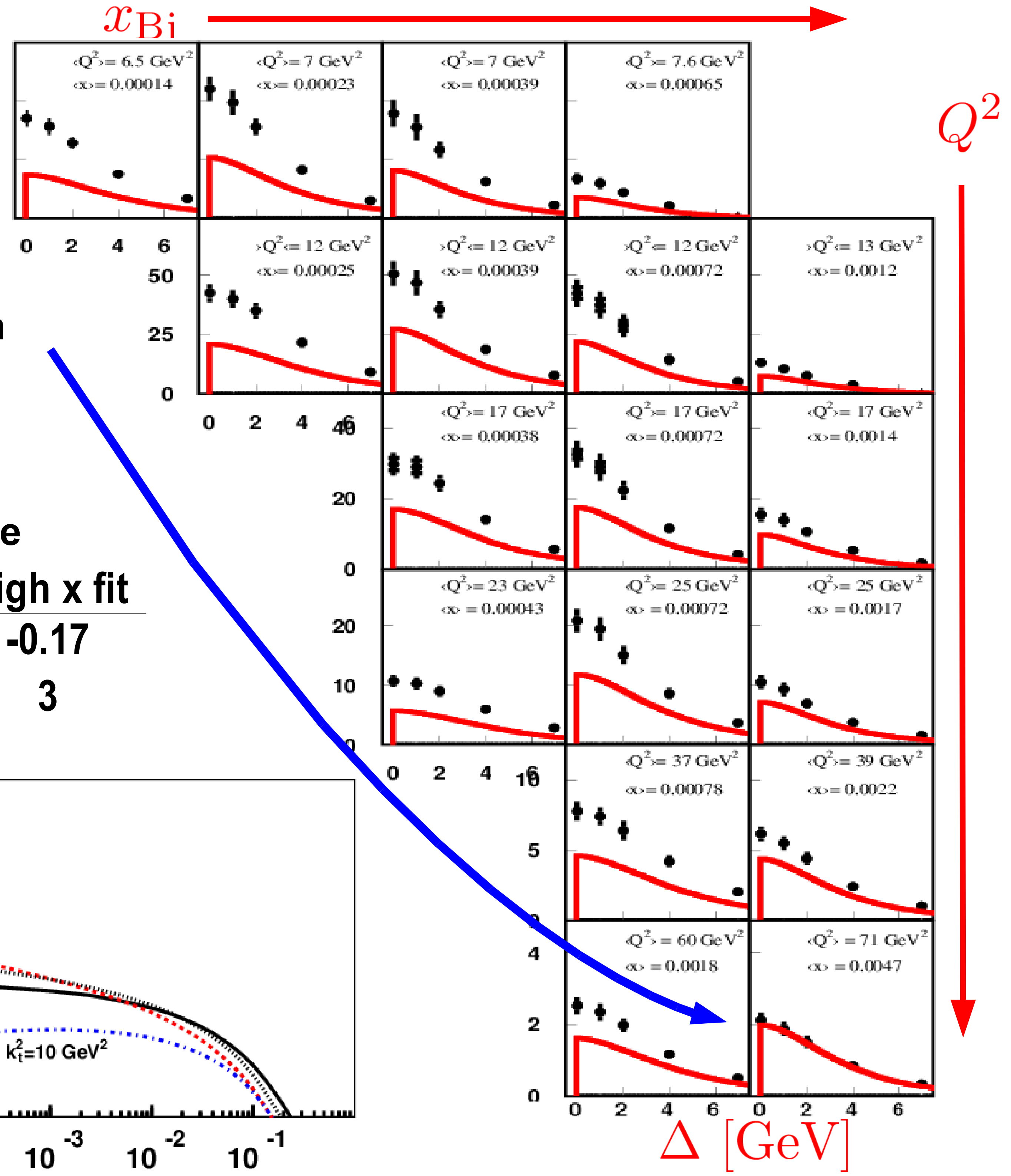
# Di-jet data result

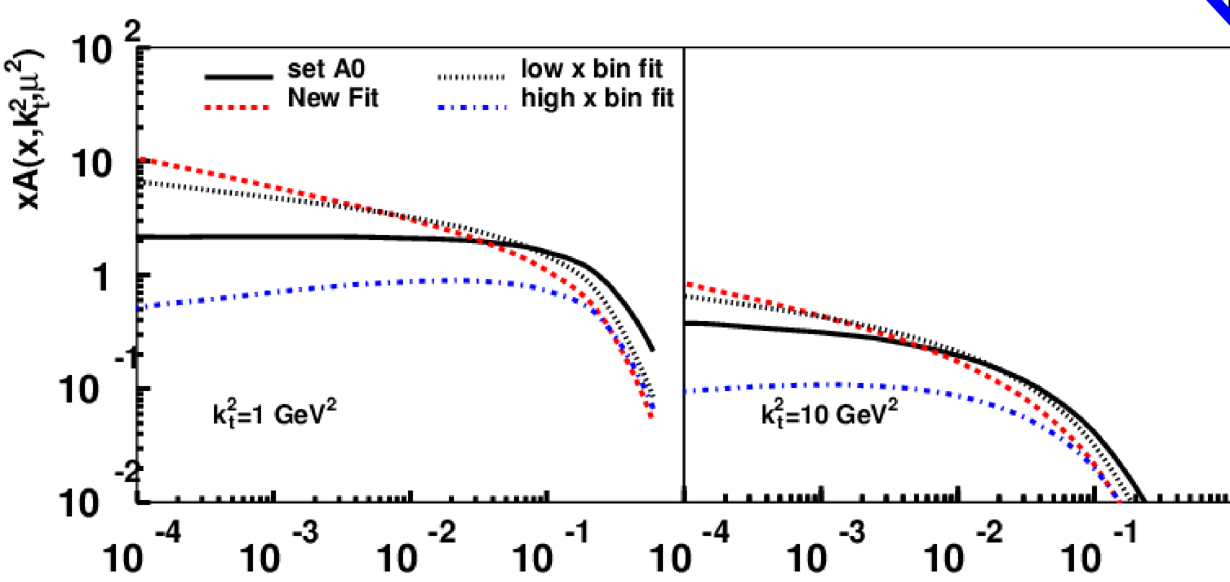
**Fitting only the "high" x bin**

$$\langle Q^2 \rangle = 71\ \mathrm{GeV}^2$$
$$\langle x \rangle = 0.0047$$

**Suggests a negative B value**

| | *All bins* | Low x fit | High x fit |
|---|---|---|---|
| $B$ | *0.25* | 0.13 | -0.17 |
| $\mu$ | *3* | 3 | 3 |



# Di-jet data result

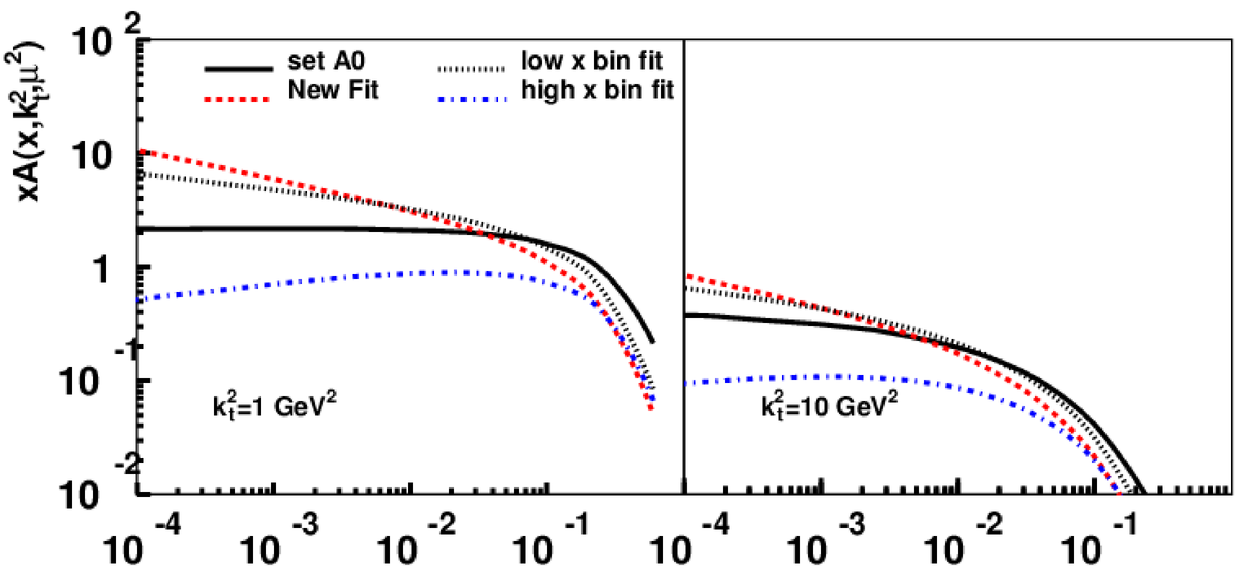
**Fitting only the "high" x bin**

$$\langle Q^2 \rangle = 71\ \mathrm{GeV}^2$$
$$\langle x \rangle = 0.0047$$

**Suggests a negative B value**

| | *All bins* | Low x fit | High x fit |
|---|---|---|---|
| ***B*** | ***0.25*** | **0.13** | **-0.17** |
| $\mu$ | ***3*** | **3** | **3** |

**Suggests more flexilbility in parameterisation of starting distribution**



# Summary

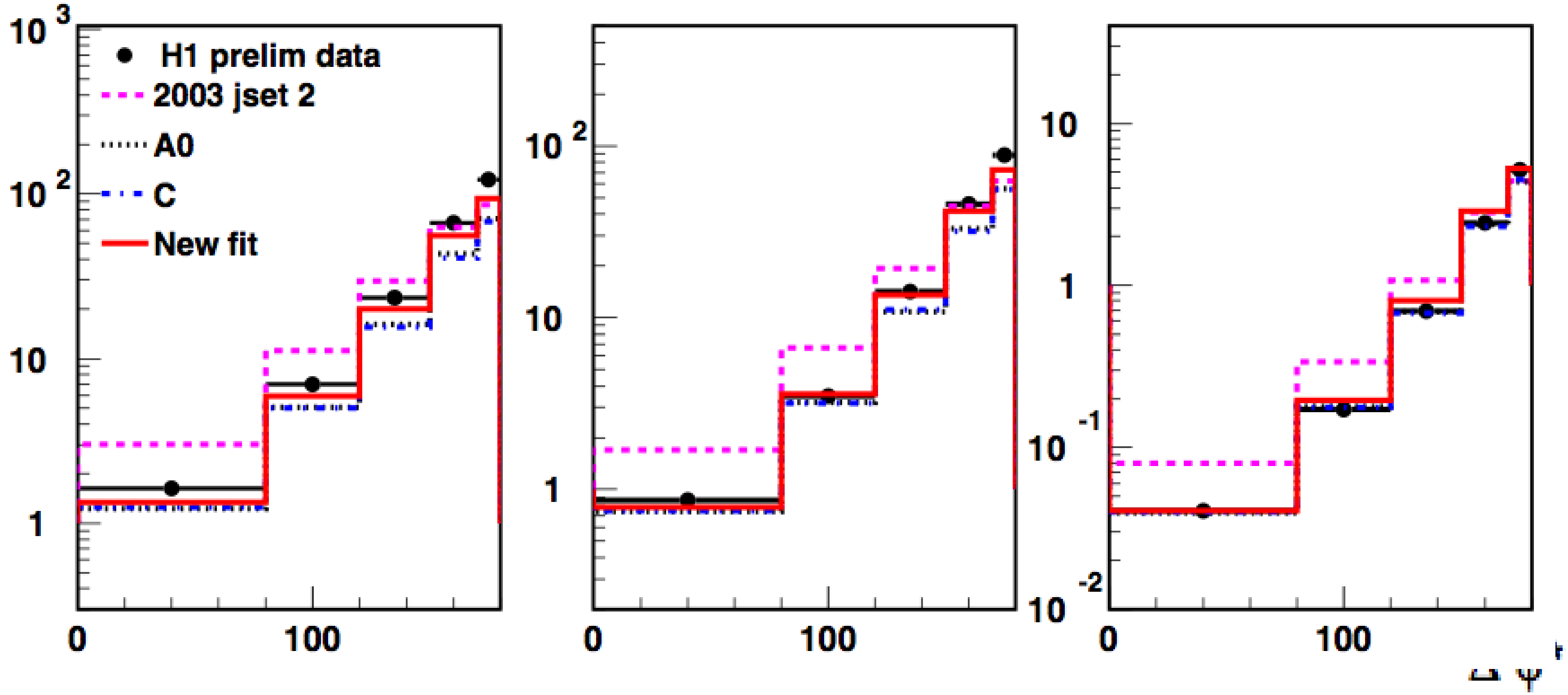
- A new approach for fitting (u)PDFs have succesfully been tested
- It is based on determination of parameter dependence, by grid interpolation, before the fitting is performed
- The method will be available in the program ***PROFFIT*** (www.hepforge.com/PROFFIT)
- Fitting uPDF to HERA dijet data suggests a strong dependence on x and a large shift of the intrinsic kt in the gluon starting distribution.



*albert.knutsson@desy.de*

# Backup slides

# Azimuthal jet decorrelations (H1)



# Former fitting approach

1. Calculate cross-section using Monte Carlo for a given set of parameter values
2. Compare to data, calculate Chi2 and feed it to MINUIT
3. MINUIT (e.g. the MIGRAD method) estimates new parameter values
4. Iterate 1. - 3. until Chi2 is minimized

**This means that if MINUIT needs 100 iterations to minimize Chi2, the generator is run 100 times, not simultaneously:**

**If one MC generator run takes 1 hour, the minimization takes 100hours.**

**One may need exclusive measurements**

$\rightarrow$

**A lot of MC statistics. Minimization >> 100h.**

# Former fitting approach

1. Calculate cross-section using Monte Carlo for a given set of parameter values
2. Compare to data, calculate Chi2 and feed it to MINUIT
3. MINUIT (e.g. the MIGRAD method) estimates new parameter values
4. Iterate 1. - 3. until Chi2 is minimized

**This means that if MINUIT needs 100 iterations to minimize Chi2, the generator is run 100 times, not simultaneously:**

**If one MC generator run takes 1 hour, the minimization takes 100hours.**

**One may need exclusive measurements**

→

**A lot of MC statistics. Minimization >> 100h.**

**Also delicate: Fitting several "event types" simultaneously,**
**e.g. Charm production and inclusive jet production**
***Above method makes separated event generation difficult.***

# Former fitting approach

1. Calculate cross-section using Monte Carlo for a given set of parameter values
2. Compare to data, calculate Chi2 and feed it to MINUIT
3. MINUIT (e.g. the MIGRAD method) estimates new parameter values
4. Iterate 1. - 3. until Chi2 is minimized

**This means that if MINUIT needs 100 iterations to minimize Chi2, the generator is run 100 times, not simultaneously:**

**If one MC generator run takes 1 hour, the minimization takes 100hours.**

**One may need exclusive measurements**

**→ A lot of MC statistics. Minimization >> 100h.**

**Also delicate: Fitting several "event types" simultaneously,**
**e.g. Charm production and inclusive jet production**
***Above method makes separated event generation difficult.***

**New Approach:** Describe **parameter dependence before parameter fitting**,
by using ***grid in parameter space***.

# Singular Value Decompostion

**Number of Monte Carlo grid points > Coefficients** → **Overdetermined system**

$$\sigma_{\rm poly}(p_1, p_2) = A + B_1 p_1 + B_2 p_2 + C_1 p_1^2 + C_2 p_2^2 + C_3 p_1 p_2 + H.O.$$

**i.e.**

$$P_{n,m} X_m = \sigma_{n,poly}$$

**where**

$$X_n = (A, B_1, B_2, C_1, C_2, C_3, ...)$$
$$P_n = (1, p_1, p_2, p_1^2, p_1 p_2, p_2^2, ...)$$
$n =$ ***Grid point***

## Approach based on SVD algorithm:

**To obtain solution we minimize** $|PX - \sigma|$
**by** $\chi^2$**-minimization**

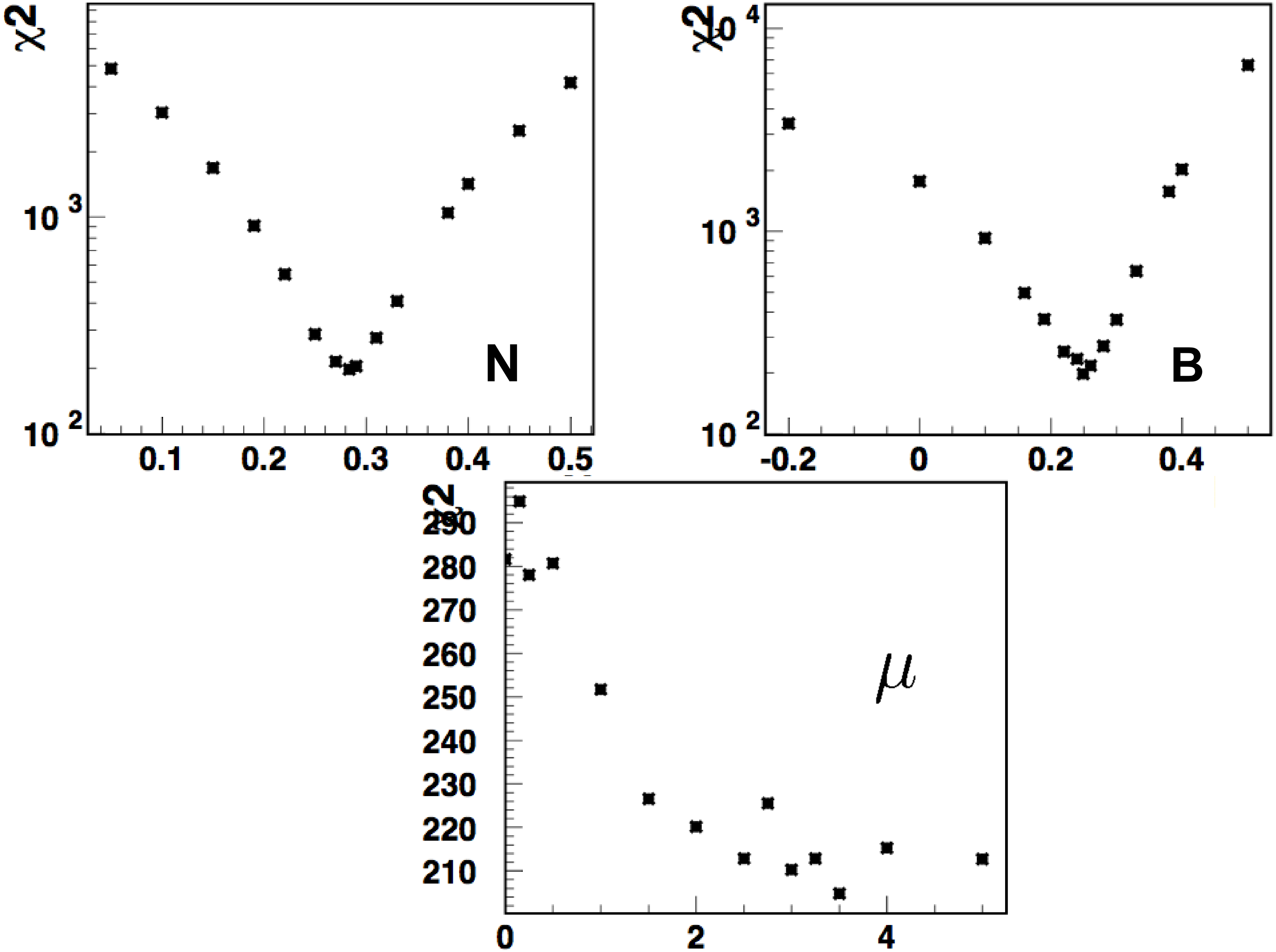
# SVD vs MINUIT

**Could also use MINUIT, but it is sensitive on starting values.**

| | SVD | MINUIT | MINUIT bad starting values |
|---|---|---|---|
| Chi2 [Polynomial-MC]/ndf: | 1.8 | 1.8 | 4.1 |

Minimization of polynomial
coefficients stuck in
local minimum

# Chi2 scans



χ2
10 3
10 2
0.1
0.2
0.3
0.4
0.5
N
χ2
10 4
10 3
10 2
-0.2
0
0.2
0.4
B
χ2
290
280
270
260
250
240
230
220
210
0
2
4
μ

# SVD vs MINUIT

**Coefficients in 4$^{th}$ order polynomial determined from:**

| SVD | MINUIT | MINUIT bad starting values |
|---|---|---|
| -25404.9082 | -25315.4624 | 358.56777 |
| 765676.064 | 762720.857 | 694969.672 |
| 357293.297 | 358067.861 | -52198.7414 |
| 3091.77111 | 2347.15353 | 3582.44715 |
| 114841.02 | 140499.037 | 52826.8157 |
| 166905.85 | 157433.813 | 1929633.41 |
| -31421.3098 | -32900.9618 | -61072.7505 |
| -927589.152 | -927572.803 | 98180.9293 |
| -60480.3599 | -61180.0691 | -12538.2387 |
| 2524.9688 | 4162.80871 | 1618.16049 |
| -1064150.37 | -1135039.64 | -465510.961 |
| 5799612.85 | 5804476.94 | 1334921.4 |
| 12981.5342 | 16228.0397 | 104971.842 |
| 2592311.1 | 2623536.1 | 1662889.02 |
| 313456.597 | 315635.922 | 284934.203 |
| -26463.8328 | -26091.529 | -22961.2676 |
| 429940.571 | 419854.565 | 553178.07 |
| 318899.245 | 320294.755 | -72213.1127 |
| -23885.6361 | -23727.0438 | 4989.53369 |
| 1446.24668 | 525.83837 | 308.886517 |
| 855372.625 | 918985.733 | -135820.813 |
| -3554618. | -3552083.15 | 354725.482 |
| 97974.8469 | 95580.1082 | 203313.617 |
| -5838295.7 | -5848044.35 | 536985.25 |
| -214807.392 | -216430.586 | -978685.349 |
| -9020.6301 | -9326.67473 | -22832.1865 |
| 10567702.9 | 10534823.1 | 2166665.32 |
| -437402.716 | -439016.175 | 427727.795 |
| **Chi2 [Polynomial-MC]/ndf: 1.8** | **1.8** | **4.1** |

For example here, large difference between Coefficients.

Resulting in that MINUIT gets stuck in local minimum

# Control of fit - Grid description

- Chi2/ndf for polynomial description of parameter space:

| Degreer of polynomial: | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|
| chi2/ndf for histo 1, bin 1 = | 12.46 | 1.461 | 1.51 | 1.71 |
| chi2/ndf for histo 1, bin 2 = | 10.76 | 1.541 | 1.55 | 1.53 |
| chi2/ndf for histo 1, bin 3 = | 8.057 | 1.725 | 1.81 | 1.44 |
| chi2/ndf for histo 1, bin 4 = | 4.194 | 1.640 | 1.90 | 1.42 |
| chi2/ndf for histo 1, bin 5 = | 2.021 | 1.266 | 1.17 | 1.37 |
| chi2/ndf for histo 2, bin 1 = | 18.52 | 0.993 | 0.87 | 1.31 |
| chi2/ndf for histo 2, bin 2 = | 15.57 | 0.935 | 0.89 | 1.26 |
| chi2/ndf for histo 2, bin 3 = | 10.39 | 1.037 | 1.08 | 0.92 |
| chi2/ndf for histo 2, bin 4 = | 4.439 | 0.975 | 1.03 | 1.07 |
| chi2/ndf for histo 2, bin 5 = | 1.950 | 0.990 | 0.93 | 1.13 |
| chi2/ndf for histo 3, bin 1 = | 10.91 | 1.639 | 1.69 | 1.76 |
| chi2/ndf for histo 3, bin 2 = | 9.129 | 1.763 | 1.63 | 1.64 |
| chi2/ndf for histo 3, bin 3 = | 6.594 | 1.867 | 1.85 | 1.22 |
| chi2/ndf for histo 3, bin 4 = | 3.016 | 1.351 | 1.19 | 1.49 |
| chi2/ndf for histo 3, bin 5 = | 1.426 | 1.201 | 1.12 | 1.21 |
| chi2/ndf for histo 4, bin 1 = | 5.219 | 1.579 | 1.43 | 1.30 |
| chi2/ndf for histo 4, bin 2 = | 4.454 | 1.536 | 1.49 | 1.25 |
| chi2/ndf for histo 4, bin 3 = | 2.738 | 1.266 | 1.20 | 1.32 |
| chi2/ndf for histo 4, bin 4 = | 1.651 | 1.171 | 1.08 | 1.24 |
| chi2/ndf for histo 4, bin 5 = | 1.036 | 0.965 | 1.10 | 1.08 |
| chi2/ndf for histo 18, bin 1 = | 14.7 | 3.66 | 2.464 | 2.864 |
| chi2/ndf for histo 18, bin 2 = | 13.0 | 3.64 | 2.682 | 3.120 |
| chi2/ndf for histo 18, bin 3 = | 9.68 | 3.43 | 2.804 | 3.228 |
| chi2/ndf for histo 18, bin 4 = | 4.77 | 2.56 | 2.405 | 3.255 |
| chi2/ndf for histo 18, bin 5 = | 1.44 | 1.37 | 1.201 | 1.268 |

- Parameter values from fit to data:

| | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|
| p1 = | 0.372 +/- 0.047 | 0.310 +/- 0.030 | 0.284 +/- 0.023 | 0.293 +/- 0.026 |
| p2 = | 0.144 +/- 0.041 | 0.215 +/- 0.035 | 0.247 +/- 0.030 | 0.235 +/- 0.032 |
| p3 = | 3. +/- 0.08 | 3. +/- 0.09 | 3. +/- 0.05 | 3. +/- 0.04 |

- 2nd degree polynomial bad grid description.
- For higher orders the final fit is consistent within errors of fit.

# Example of application

**Fit unintegrated gluon density to HERA data**

*H1 Collab., A. Aktas et al., Eur. Phys. J. C33 (2004) 477*

*Inclusive Dijet Production at Low x_Bj in DIS*

**Integrated PDF: DGLAP**

***LO:*** **Gluon collinear with proton**

$$k_{t,\text{gluon}} = 0$$

$$\Delta E_{T,jets} = 0 \text{ in HCM}$$

***Higher orders:***

$$k_{t,\text{gluon}} \neq 0$$

$$\Delta E_{T,\text{jets}} \neq 0$$

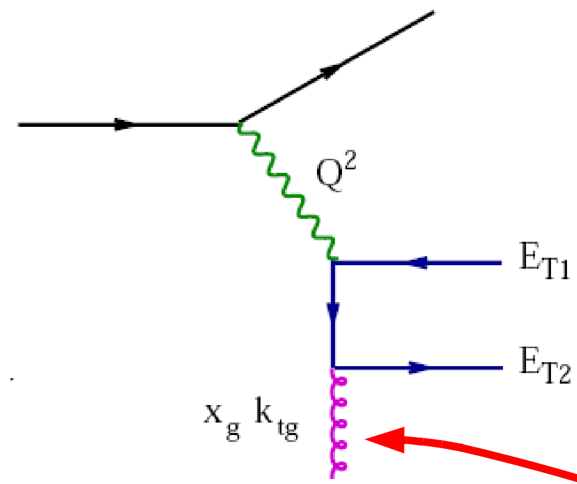
**Unintegrated PDF: CCFM or BFKL**

$$k_{t,\text{gluon}} \neq 0$$

$$\Delta E_{t,\text{jets}} \neq 0$$

**already at LO**

**Target hard di-jets.**
**Dominated by BGF, sensitivity to gluon.**




**Require**

$$E_{\text{T, jet 2}} > 5 \text{ GeV}$$

$$E_{\text{T, jet 1}} > (5 + \Delta) \text{ GeV}$$

**and measure jet cross-section as a function of** $\Delta$

**Sensitivity to kt of gluon**

# PROFFIT

## Steering card

```
*
*********** Name of grid file
GRFIL steer_grid_dijets
*
*********** Number of cross-sections for grid:
NXSEC 80
*
*********** Grid fitting method (1=SVD, 2=minuit):
GRFIT   1
*
*********** Functional form (1=poly, 2=user):
FUNCT   1
*
*********** Degree of poly, (FUNCT=1)
*********** or Number of koefficients in function (FUNC=2)
NPDGR   3
*
*********** Number of parameters:
NPARA   3
*
*********** Number of histos:
NHIST   18
*
*********** Reference to histos and number of bins:
* -dir-     -MC hist- -Data hist- -#bins-
HNAME
   03160      3011       -3111       5
   03160      3012       -3112       5
   03160      3013       -3113       5
   03160      3014       -3114       5
```

# PROFFIT

## Steering card

```
*
*********** Name of grid file
GRFIL steer_grid_dijets
*
*********** Number of cross-sections for grid:
NXSEC 80
*
*********** Grid fitting meth
GRFIT    1
*
*********** Functional form (
FUNCT    1
*
*********** Degree of poly. (F
*********** or Number of koef
NPDGR    3
*
*********** Number of paramet
NPARA    3
*
*********** Number of histos:
NHIST    18
*
*********** Reference to hist
* -dir-     -MC hist- -Data h
HNAME
   03160      3011      -3111
   03160      3012      -3112
   03160      3013      -3113
   03160      3014      -3114
```

```
                                                  *****************************
    ************                                  *        parameter values
    * MC FILES *                                  *    p1      p2      p3      p4
    ************                                  *****************************
'./dijets/dphi_0.03_0.1_2_0.hbook'      0.03    0.1     0.0     2
'./dijets/dphi_0.03_0.1_2_1.hbook'      0.03    0.1     1       2
'./dijets/dphi_0.03_0.1_2_2.hbook'      0.03    0.1     2       2
'./dijets/dphi_0.03_0.1_2_3.hbook'      0.03    0.1     3       2
'./dijets/dphi_0.03_0.2_2_0.hbook'      0.03    0.2     0.0     2
'./dijets/dphi_0.03_0.2_2_1.hbook'      0.03    0.2     1       2
'./dijets/dphi_0.03_0.2_2_2.hbook'      0.03    0.2     2       2
'./dijets/dphi_0.03_0.2_2_3.hbook'      0.03    0.2     3       2
'./dijets/dphi_0.03_0.3_2_0.hbook'      0.03    0.3     0.0     2
'./dijets/dphi_0.03_0.3_2_1.hbook'      0.03    0.3     1       2
'./dijets/dphi_0.03_0.3_2_2.hbook'      0.03    0.3     2       2
'./dijets/dphi_0.03_0.3_2_3.hbook'      0.03    0.3     3       2
'./dijets/dphi_0.03_0.4_2_0.hbook'      0.03    0.4     0.0     2
'./dijets/dphi_0.03_0.4_2_1.hbook'      0.03    0.4     1       2
'./dijets/dphi_0.03_0.4_2_2.hbook'      0.03    0.4     2       2
'./dijets/dphi_0.03_0.4_2_3.hbook'      0.03    0.4     3       2
'./dijets/dphi_0.03_0.6_2_0.hbook'      0.03    0.6     0.0     2
'./dijets/dphi_0.03_0.6_2_1.hbook'      0.03    0.6     1       2
'./dijets/dphi_0.03_0.6_2_2.hbook'      0.03    0.6     2       2
'./dijets/dphi_0.03_0.6_2_3.hbook'      0.03    0.6     3       2
'./dijets/dphi_0.1_0.1_2_0.hbook'       0.1     0.1     0.0     2
'./dijets/dphi_0.1_0.1_2_1.hbook'       0.1     0.1     1       2
'./dijets/dphi_0.1_0.1_2_2.hbook'       0.1     0.1     2       2
'./dijets/dphi_0.1_0.1_2_3.hbook'       0.1     0.1     3       2
'./dijets/dphi_0.1_0.2_2_0.hbook'       0.1     0.2     0.0     2
'./dijets/dphi_0.1_0.2_2_1.hbook'       0.1     0.2     1       2
'./dijets/dphi_0.1_0.2_2_2.hbook'       0.1     0.2     2       2
```

# PROFFIT

## Steering card

```
*
*********** Name of grid file
GRFIL steer_grid_dijets
*
*********** Number of cross-sections for grid:
NXSEC 80
*
*********** Grid fitting meth
GRFIT   1
*
*********** Functional form (
FUNCT   1
*
*********** Degree of poly. (F
*********** or Number of koef
NPDGR   3
*
*********** Number of paramet
NPARA   3
*
*********** Number of histos:
NHIST   18
*
*********** Reference to hist
* -dir-     -MC hist- -Data h
HNAME
   03160      3011      -3111
   03160      3012      -3112
   03160      3013      -3113
   03160      3014      -3114
```

```
                                                ******************************
     ************                               *          parameter values
     * MC FILES *                               *    p1        p2        p3        p4
     ************                               ******************************
'./dijets/dphi_0.03_0.1_2_0.hbook'         0.03      0.1       0.0       2
'./dijets/dphi_0.03_0.1_2_1.hbook'         0.03      0.1       1         2
'./dijets/dphi_0.03_0.1_2_2.hbook'         0.03      0.1       2         2
'./dijets/dphi_0.03_0.1_2_3.hbook'         0.03      0.1       3         2
'./dijets/dphi_0.03_0.2_2_0.hbook'         0.03      0.2       0.0       2
'./dijets/dphi_0.03_0.2_2_1.hbook'         0.03      0.2       1         2
'./dijets/dphi_0.03_0.2_2_2.hbook'         0.03      0.2       2         2
'./dijets/dphi_0.03_0.2_2_3.hbook'         0.03      0.2       3         2
'./dijets/dphi_0.03_0.3_2_0.hbook'         0.03      0.3       0.0       2
'./dijets/dphi_0.03_0.3_2_1.hbook'         0.03      0.3       1         2
'./dijets/dphi_0.03_0.3_2_2.hbook'         0.03      0.3       2         2
'./dijets/dphi_0.03_0.3_2_3.hbook'         0.03      0.3       3         2
'./dijets/dphi_0.03_0.4_2_0.hbook'         0.03      0.4       0.0       2
'./dijets/dphi_0.03_0.4_2_1.hbook'         0.03      0.4       1         2
'./dijets/dphi_0.03_0.4_2_2.hbook'         0.03      0.4       2         2
'./dijets/dphi_0.03_0.4_2_3.hbook'         0.03      0.4       3         2
'./dijets/dphi_0.03_0.6_2_0.hbook'         0.03      0.6       0.0       2
'./dijets/dphi_0.03_0.6_2_1.hbook'         0.03      0.6       1         2
'./dijets/dphi_0.03_0.6_2_2.hbook'         0.03      0.6       2         2
'./dijets/dphi_0.03_0.6_2_3.hbook'         0.03      0.6       3         2
'./dijets/dphi_0.1_0.1_2_0.hbook'          0.1       0.1       0.0       2
'./dijets/dphi_0.1_0.1_2_1.hbook'          0.1       0.1       1         2
'./dijets/dphi_0.1_0.1_2_2.hbook'          0.1       0.1       2         2
'./dijets/dphi_0.1_0.1_2_3.hbook'          0.1       0.1       3         2
'./dijets/dphi_0.1_0.2_2_0.hbook'          0.1       0.2       0.0       2
'./dijets/dphi_0.1_0.2_2_1.hbook'          0.1       0.2       1         2
'./dijets/dphi_0.1_0.2_2_2.hbook'          0.1       0.2       2         2
```

# PROFFIT

## Steering card

```
*
*********** Name of grid file
GRFIL steer_grid_dijets
*
*********** Number of cross-sections for grid:
NXSEC 80
*
*********** Grid fitting method (1=SVD, 2=minuit):
GRFIT   1
*
*********** Functional form (1=poly, 2=user):
FUNCT   1
*
*********** Degree of poly (FUNCT=1)
*********** or Number of koefficients in function (FUNC=2)
NPDGR   3
*
*********** Number of parameters:
NPARA   3
*
*********** Number of histos:
NHIST   18
*
*********** Reference to histos and number of bins:
* -dir-     -MC hist- -Data hist- -#bins-
HNAME
   03160      3011      -3111       5
   03160      3012      -3112       5
   03160      3013      -3113       5
   03160      3014      -3114       5
```

**Degree of polynomial for description of Monte Carlo grid**

# PROFFIT

## Steering card

```
*
*********** Name of grid file
GRFIL steer_grid_dijets
*
*********** Number of cross-sections for grid:
NXSEC 80
*
*********** Grid fitting method (1=SVD, 2=minuit):
GRFIT   1
*
*********** Functional form (1=poly, 2=user):
FUNCT   1
*
*********** Degree of poly (FUNCT=1)
*********** or Number of koefficients in function (FUNC=2)
NPDGR   3
*
*********** Number of parameters:
NPARA   3
*
*********** Number of histos:
NHIST   18
*
*********** Reference to histos and number of bins:
* -dir-     -MC hist- -Data hist- -#bins-
HNAME
   03160      3011       -3111       5
   03160      3012       -3112       5
   03160      3013       -3113       5
   03160      3014       -3114       5
```

Number of parameters to fit

# PROFFIT

## Steering card

```
*
*********** Name of grid file
GRFIL steer_grid_dijets
*
*********** Number of cross-sections for grid:
NXSEC 80
*
*********** Grid fitting method (1=SVD, 2=minuit):
GRFIT   1
*
*********** Functional form (1=poly, 2=user):
FUNCT   1
*
*********** Degree of poly (FUNCT=1)
*********** or Number of koefficients in function (FUNC=2)
NPDGR   3
*
*********** Number of parameters:
NPARA   3
*
*********** Number of histos:
NHIST   18
*
*********** Reference to histos and number of bins:
* -dir-     -MC hist- -Data hist- -#bins-
HNAME
   03160      3011      -3111       5
   03160      3012      -3112       5
   03160      3013      -3113       5
   03160      3014      -3114       5
```

Number of histograms

Histogram info