

A new 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)*

DIS 2008, 7-11th April, London

Outline

- The unintegrated gluon density
- The fitting method
- Application: uPDF determination from HERA di-jet data

The unintegrated gluon density

The uPDF starting distribution:

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

N: Normalization (fitted)

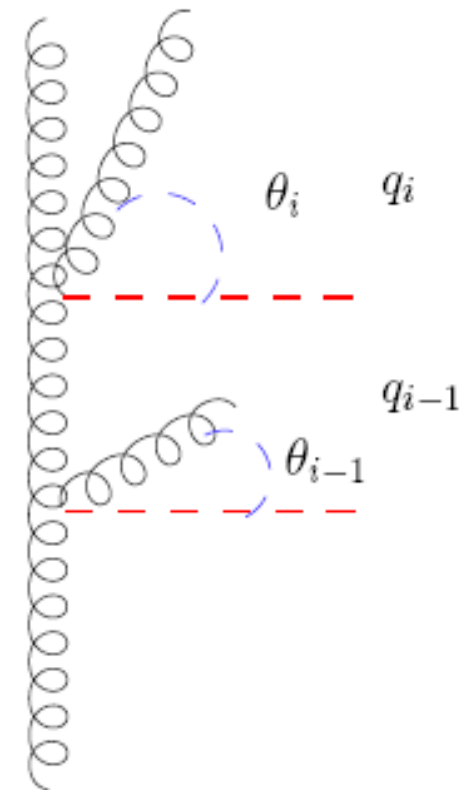
B: Small x behaviour (fitted)

C=4: Large x behaviour (kept fixed)

μ, σ Determines the shape of the intrinsic k_T of the gluon below $k_T = 1.2 \text{ GeV}$ (μ 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.



The parameters N, B, C, μ, σ , are not theoretically calculable.



We need to fit the uPDF to experimental data.

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.**

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*.

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 try to 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.

$$\sigma_{\text{poly}} = A + \sum_1^N B_i \cdot p_i + \sum_1^N C_i \cdot p_i^2 + \underbrace{\sum_{i=1}^N \sum_{j=i+1}^N D_{ij} \cdot p_i p_j}_{\text{Takes care of correlation between parameters}} + H.O.$$

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

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.

$$\sigma_{\text{poly}} = A + \sum_1^N B_i \cdot p_i + \sum_1^N C_i \cdot p_i^2 + \sum_{i=1}^N \sum_{j=i+1}^N D_{ij} \cdot p_i p_j + H.O.$$

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

This is done by **Singular Value Decomposition** and **takes a few seconds.**

Singular Value Decomposition

Number of Monte Carlo grid points > Coefficients \rightarrow **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.

$$P_{n,m} X_m = \sigma_{n,poly} \quad \text{where} \quad \begin{aligned} X_n &= (A, B_1, B_2, C_1, C_2, C_3, \dots) \\ P_n &= (1, p_1, p_2, p_1^2, p_1 p_2, p_2^2, \dots) \\ n &= \text{Grid point} \end{aligned}$$


Approach based on SVD algorithm:

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

SVD vs MINUIT

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

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



Minimization of polynomial coefficients stuck in local minimum

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 by SVD.

Step 1. and 2. are done for each data point in the measurement.

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 by SVD.

Step 1. and 2. are done for each data point in the measurement.

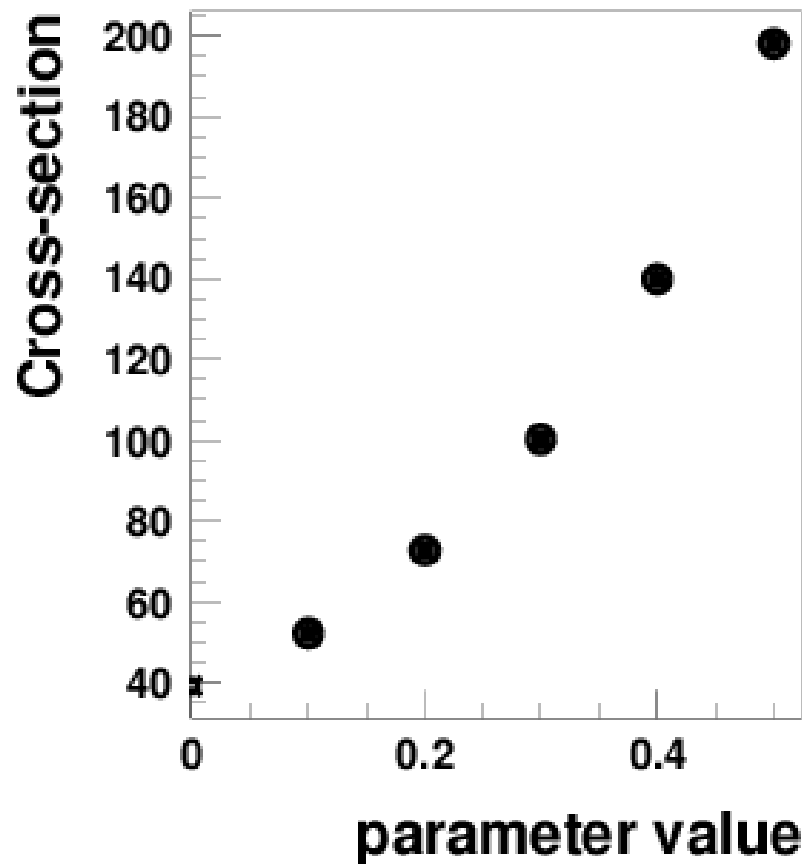
3. Determine PDF parameters, p_i , by fitting all the polynomials to data simultaneously
Also this takes only a few seconds.

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

1-dim Example

Simplest possible example
1 parameter, 1 data cross-section

1. Build up the grid

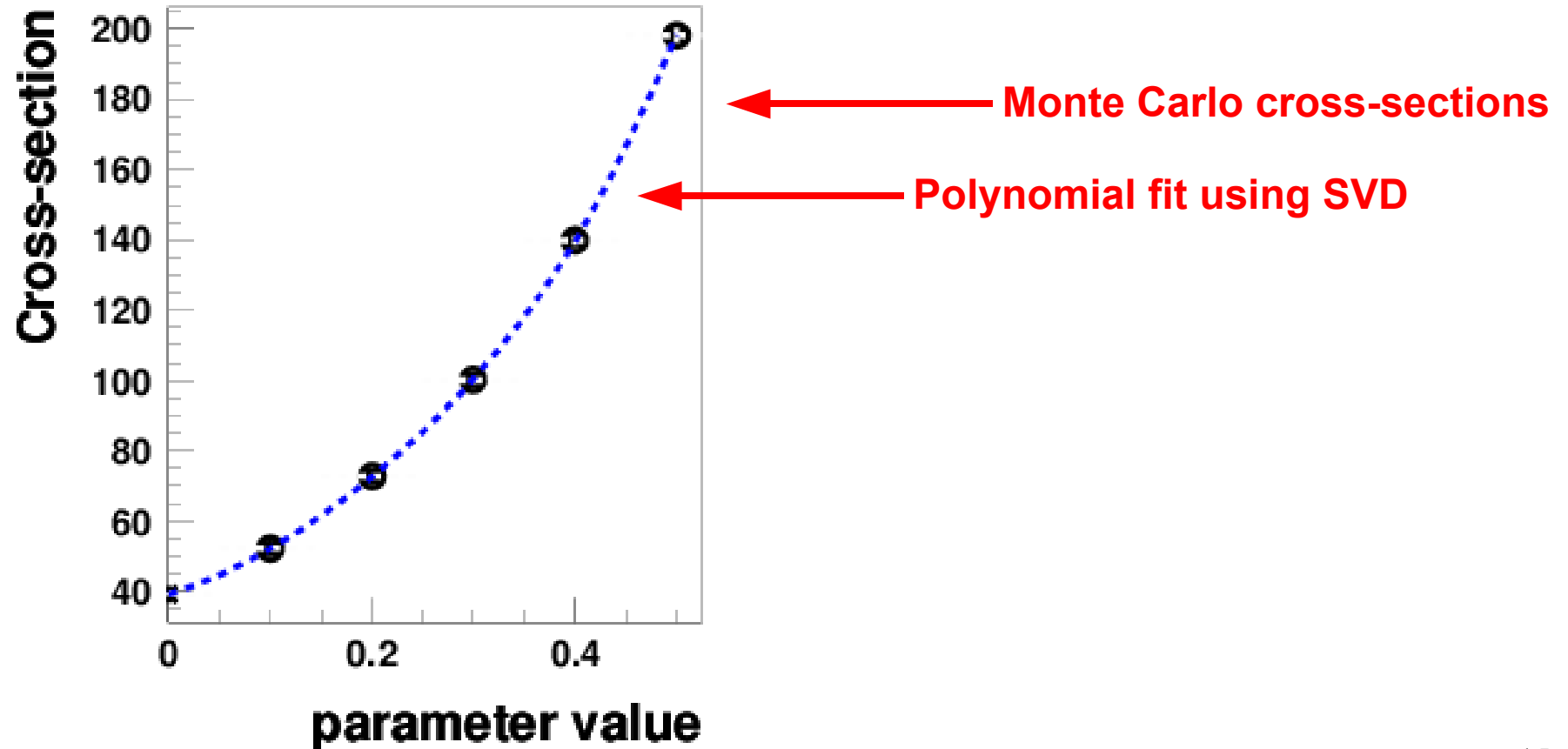


← Monte Carlos cross-sections

Simple Example

Simplest possible example
1 parameter, 1 data cross-section

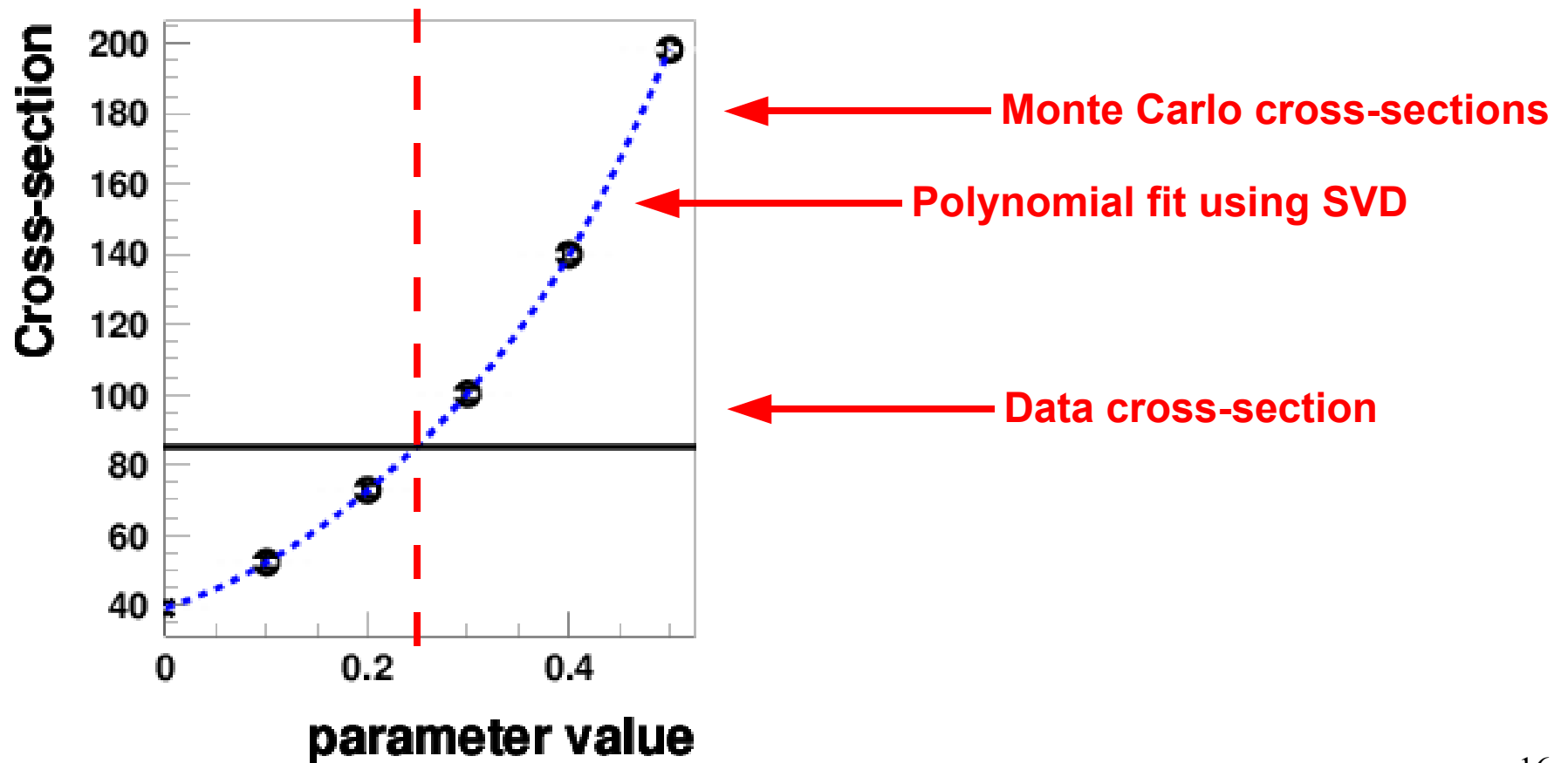
2. Determine polynomial using SVD



Simple Example

Simplest possible example
1 parameter, 1 data cross-section

3. Minimize χ^2 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)

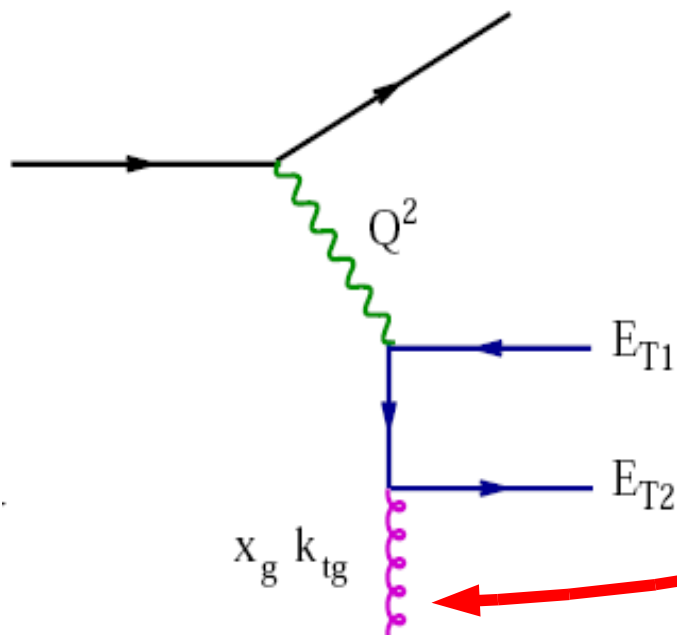
Example of application

Fit unintegrated gluon density to HERA di-jet data

H1 Collab., A. Aktas et al., *Eur. Phys. J. C*33 (2004) 477

Inclusive Dijet Production at Low x_{Bj} in DIS

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



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

and measure jet cross-section
as a function of Δ

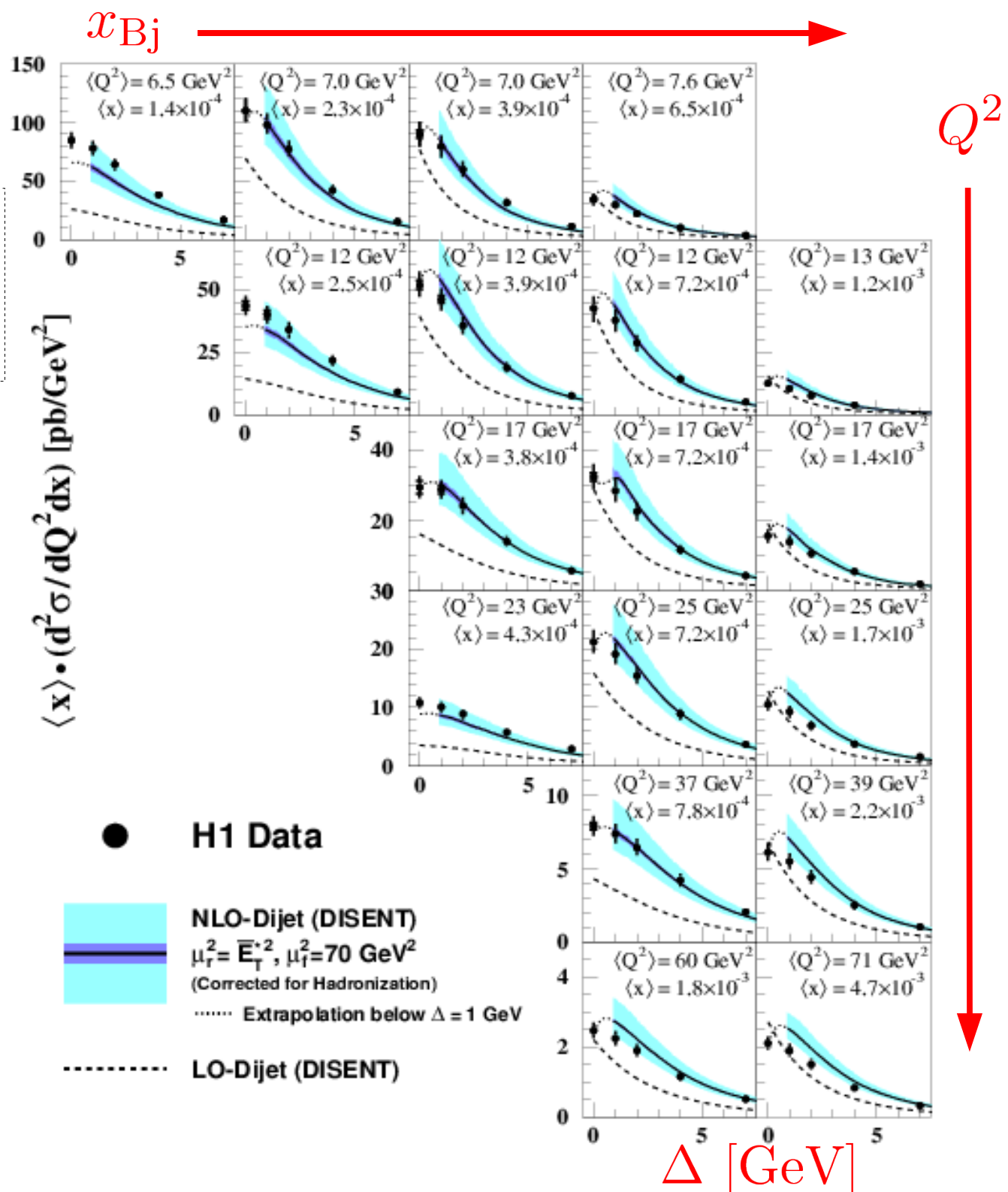
Sensitivity to gluon k_t

Di-jet data

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

Total dijet cross-section as a function of Δ

- NLO di-jet calculation fails in parts of phase space
- NLO di-jet calculation not possible for low Δ due to divergencies.



Di-jet data

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

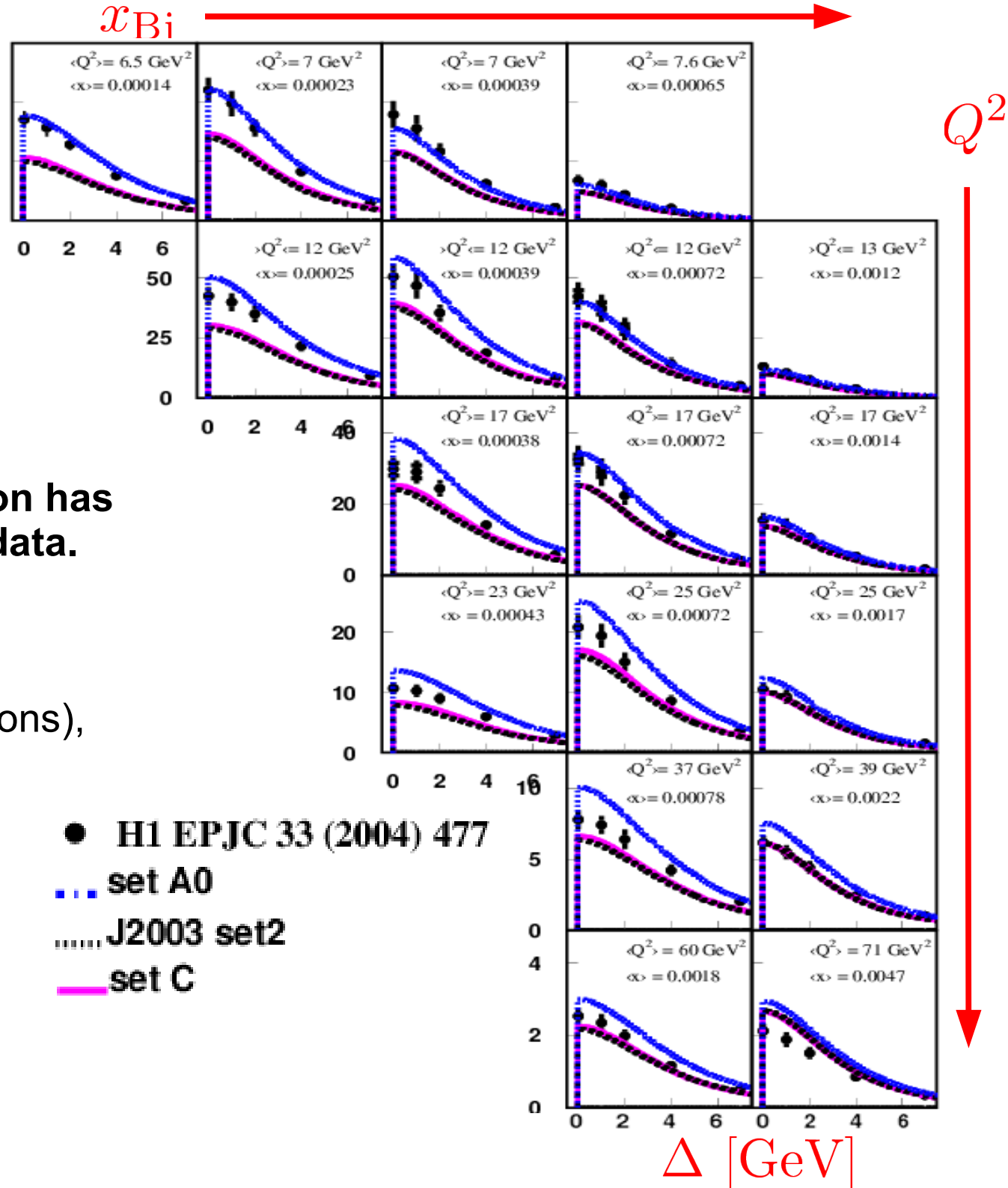
Total dijet cross-section
as a function of Δ

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
PROFIT...

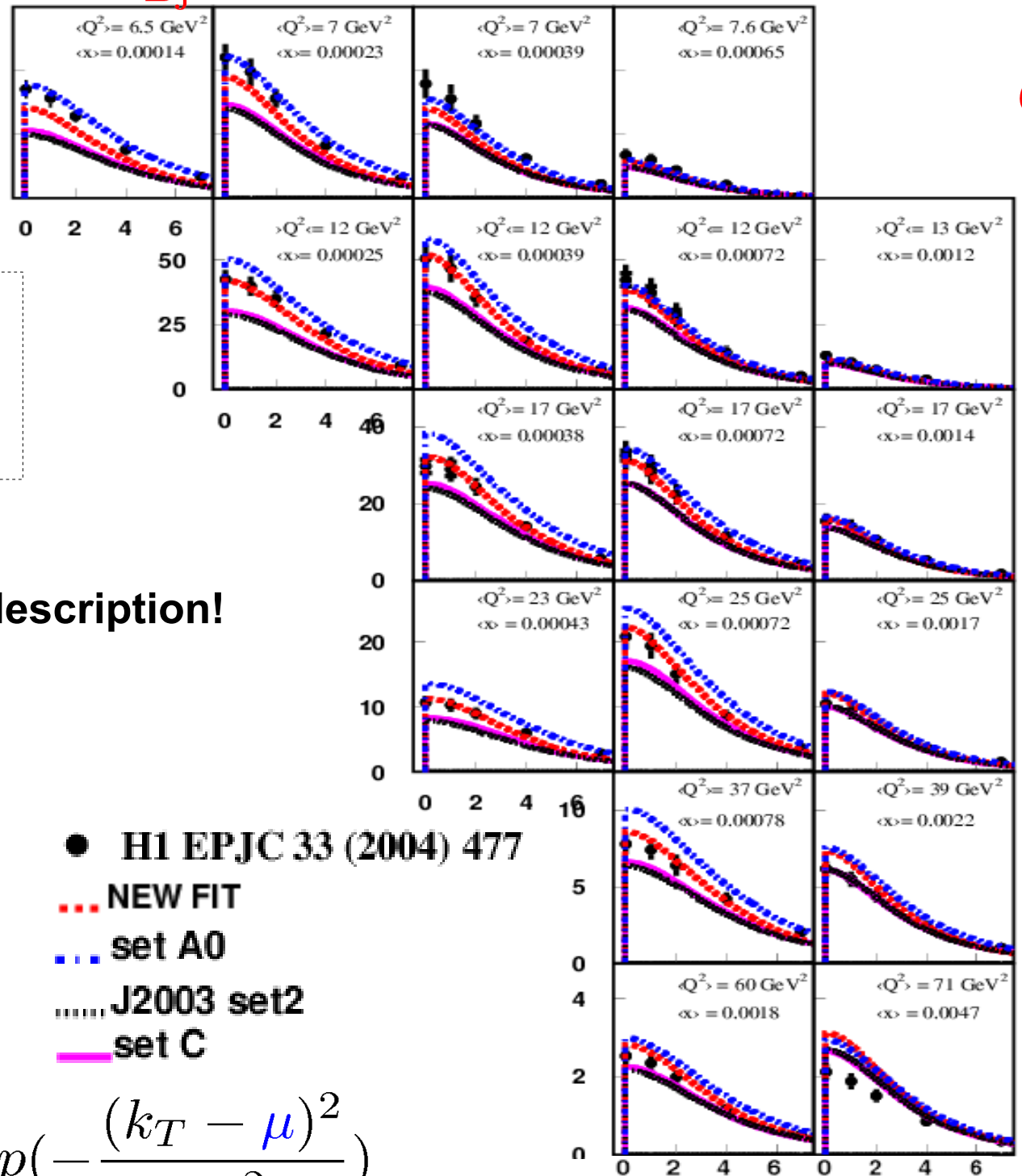
- H1 EPJC 33 (2004) 477
- set A0
- J2003 set2
- set C



Di-jet data result

x_{Bj}

Q^2



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

Total dijet cross-section as a function of Δ

Fitted uPDF improves data description!

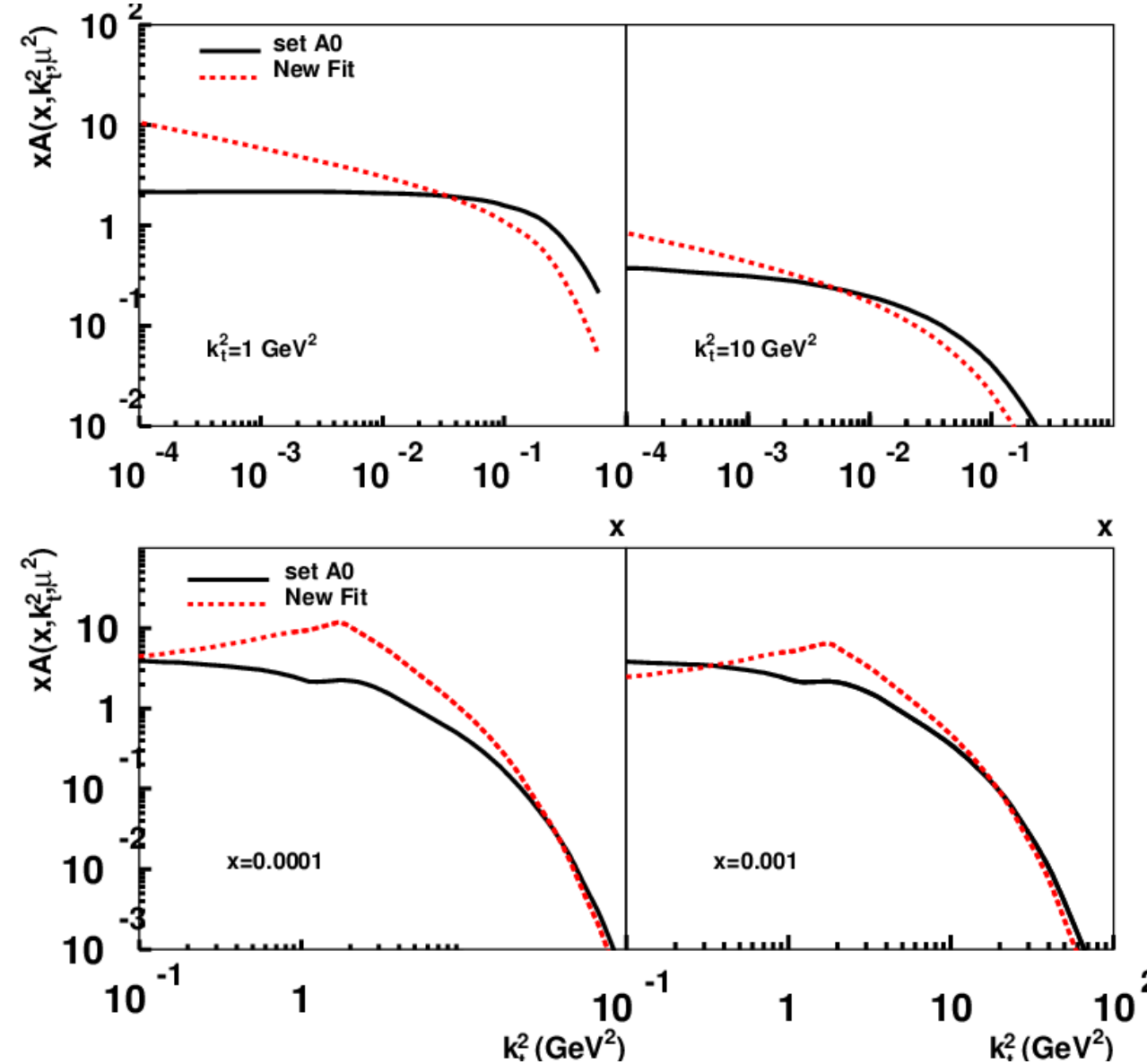
N	0.28 ± 0.02
B	0.25 ± 0.03
μ	3.0 ± 0.04
σ	2, fixed
$Chi2/ndf$	2.01

- H1 EPJC 33 (2004) 477
- ... NEW FIT
- ... set A0
- J2003 set2
- set C

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

Δ [GeV]

Comparison to existing uPDF



	Set A0
B	0
μ	0
$Chi2/ndf$	3.6

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
μ	3.0 +/- 0.04
$Chi2/ndf$	2

The new fit to the dijet data suggest *stronger rising x* and a *shifted gaussian for $k_{T,t}$* .

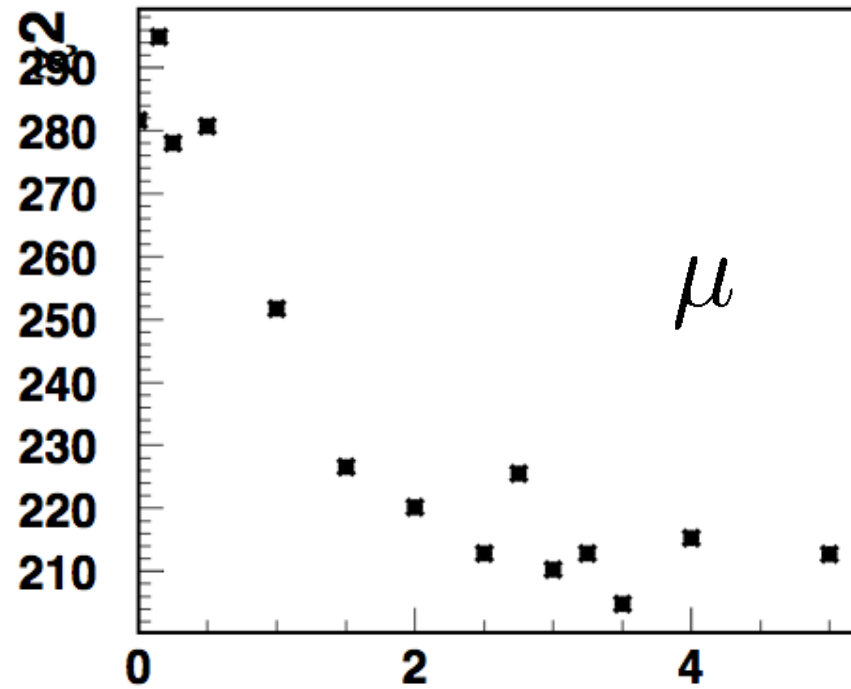
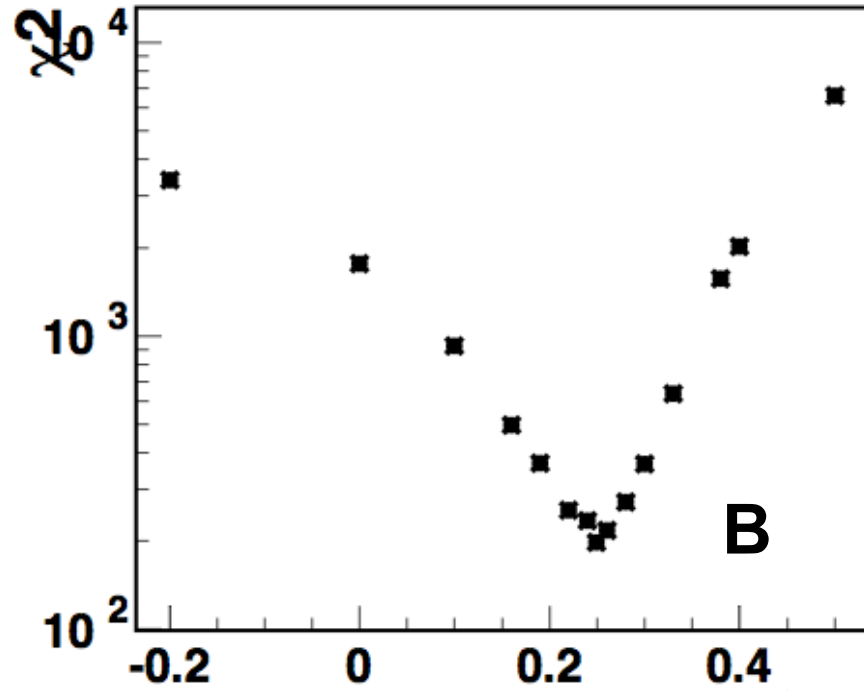
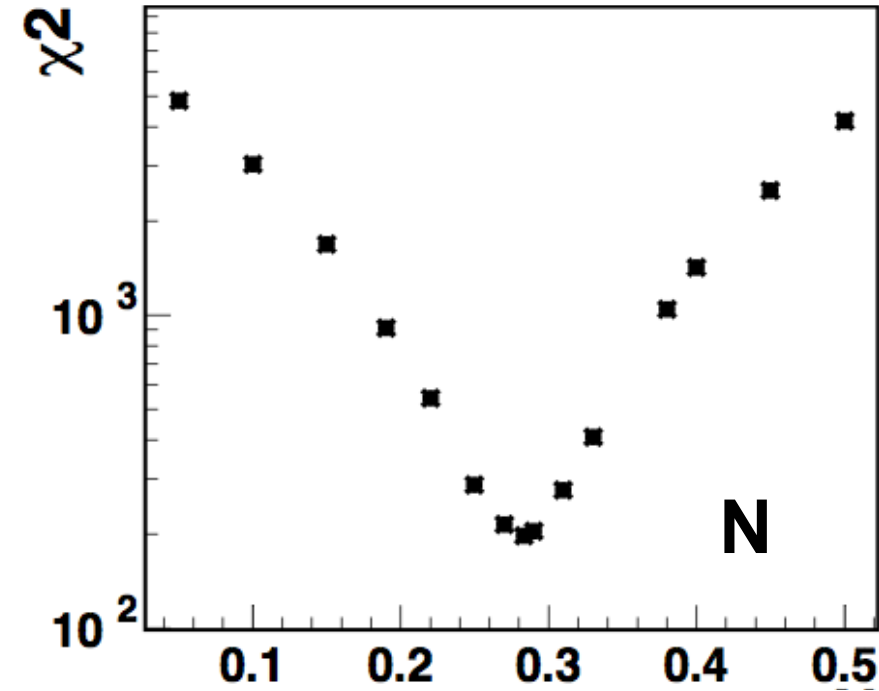
$$N \cdot x^{-B} \cdot (1-x)^C \cdot \exp\left(-\frac{(k_T - \mu)^2}{2\sigma^2}\right)$$

Summary

- A new approach for fitting (u)PDFs have successfully 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 k_t** of the gluon starting distribution.

Backup slides

Chi2 scans



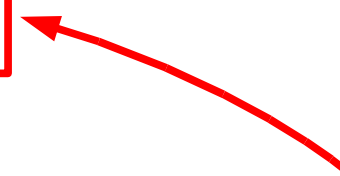
SVD vs MINUIT

Coefficients in 4th 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



For example here, large difference between Coefficients.

Resulting in that MINUIT gets stuck in local minimum

Chi2 [Polynomial-MC]/ndf: **1.8**

1.8

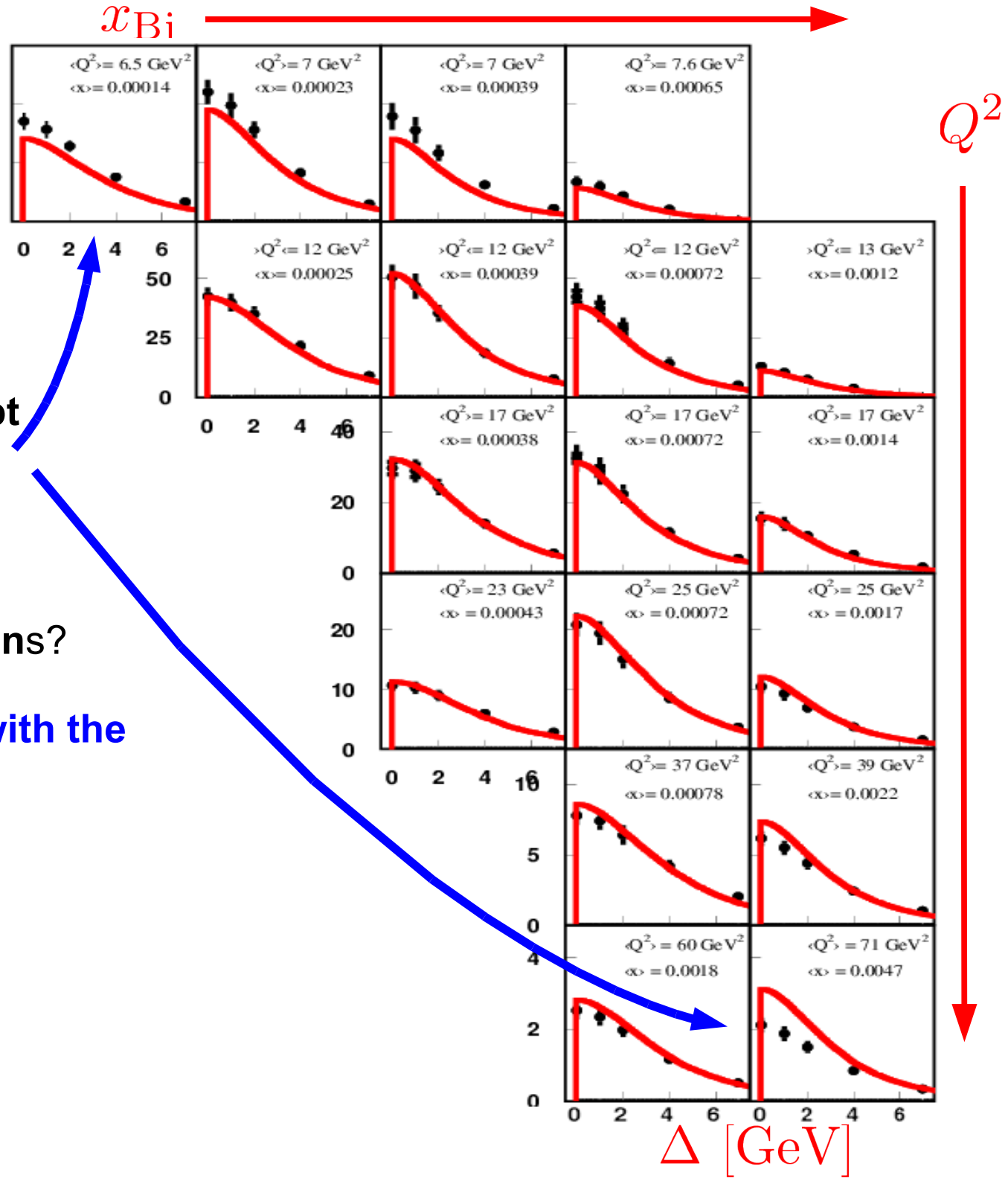
4.1

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 check with the new fitting method...



Di-jet data result

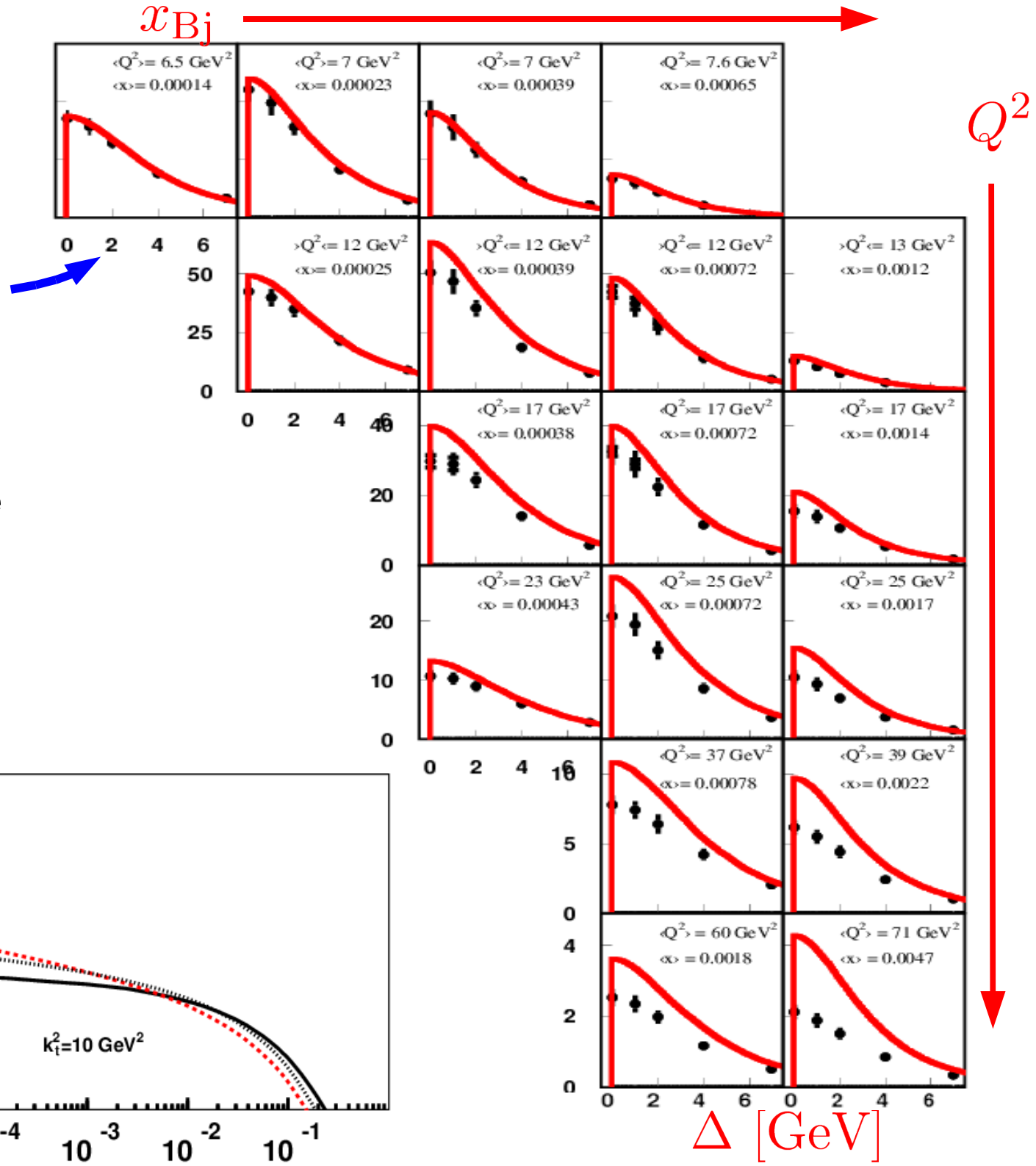
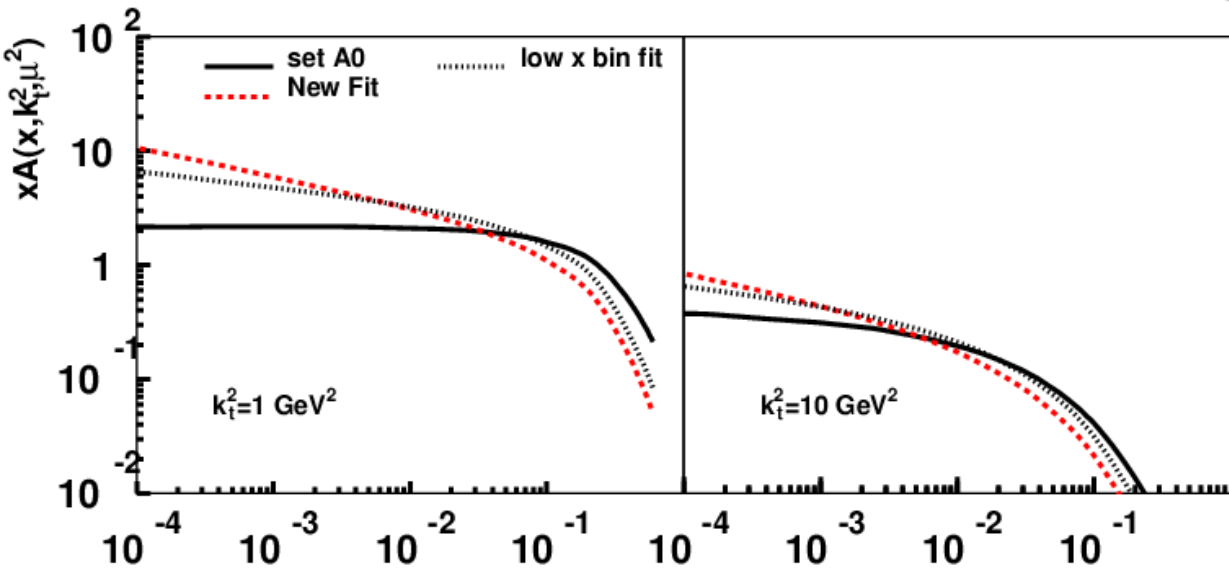
Fitting only the low x bin

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

$$\langle x \rangle = 0.00014$$

Suggests a lower B value

	All bins	Low x fit
B	0.25	0.13
μ	3	3



Di-jet data result

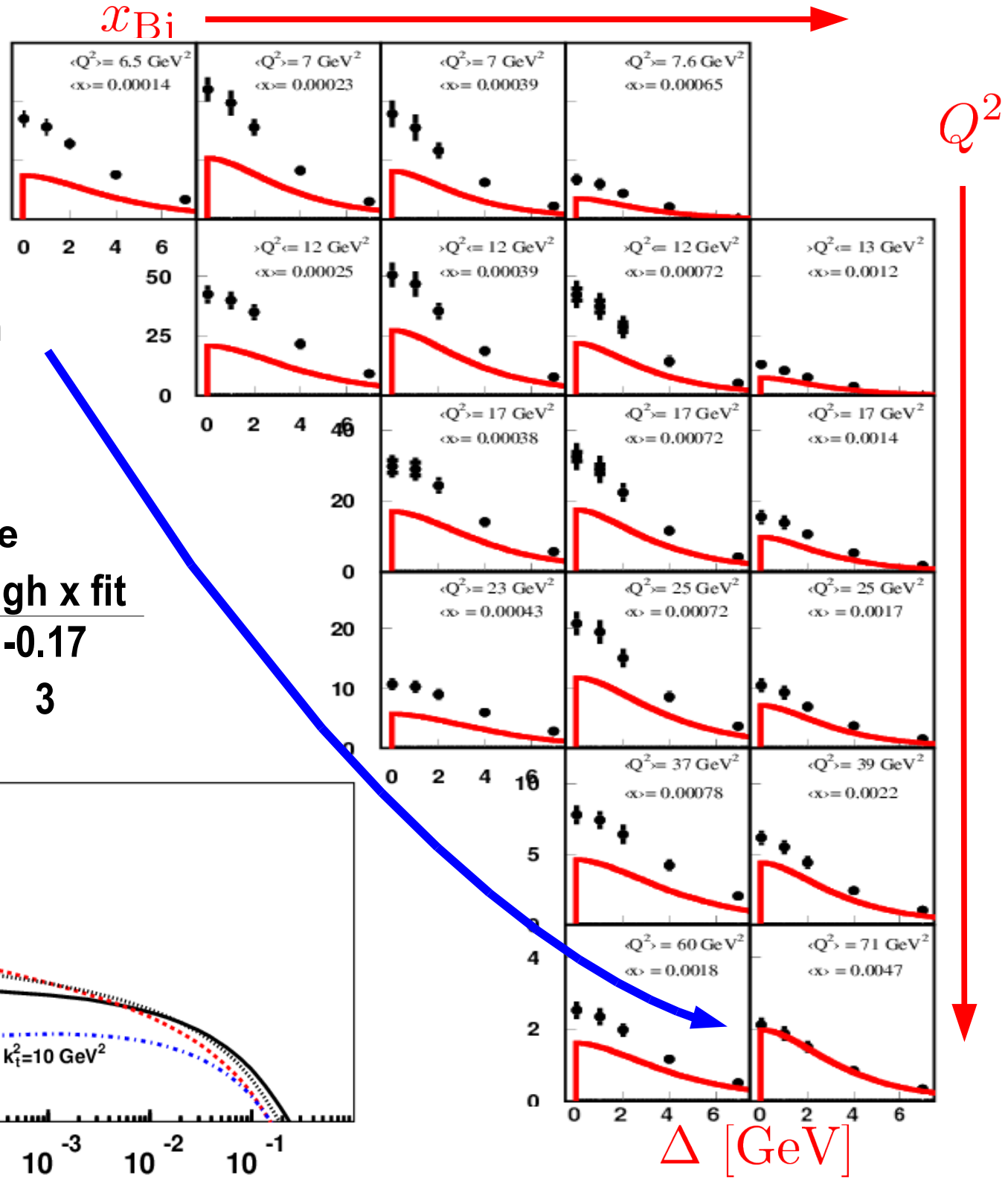
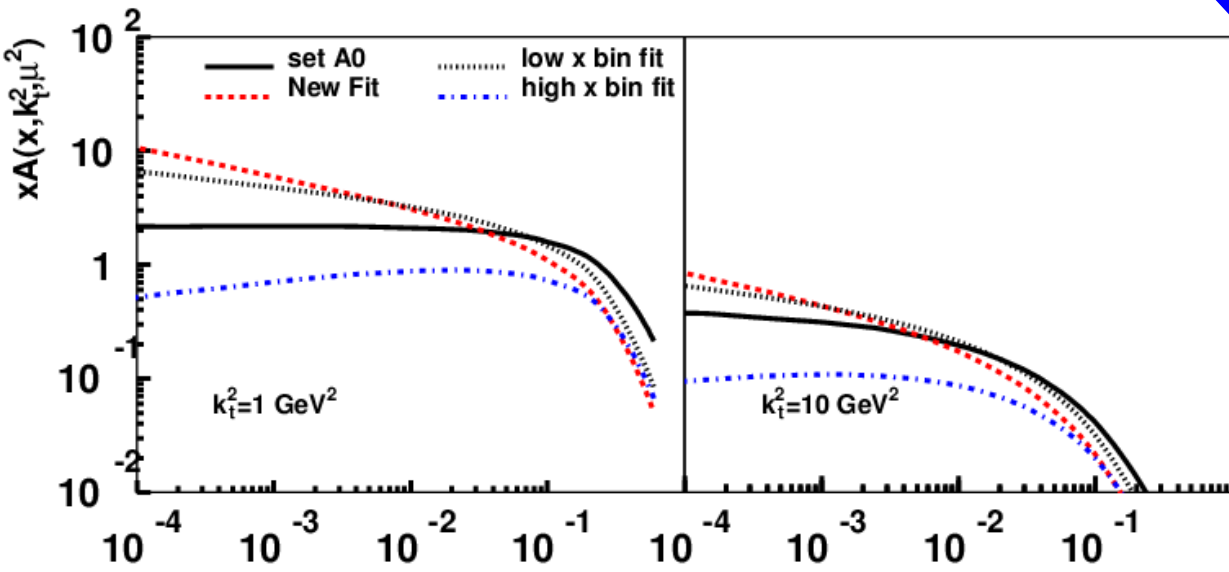
Fitting only the "high" x bin

$$\langle Q^2 \rangle = 71 \text{ GeV}^2$$

$$\langle x \rangle = 0.0047$$

Suggests a negative B value

	All bins	Low x fit	High x fit
B	0.25	0.13	-0.17
μ	3	3	3



Di-jet data result

Fitting only the “high” x bin

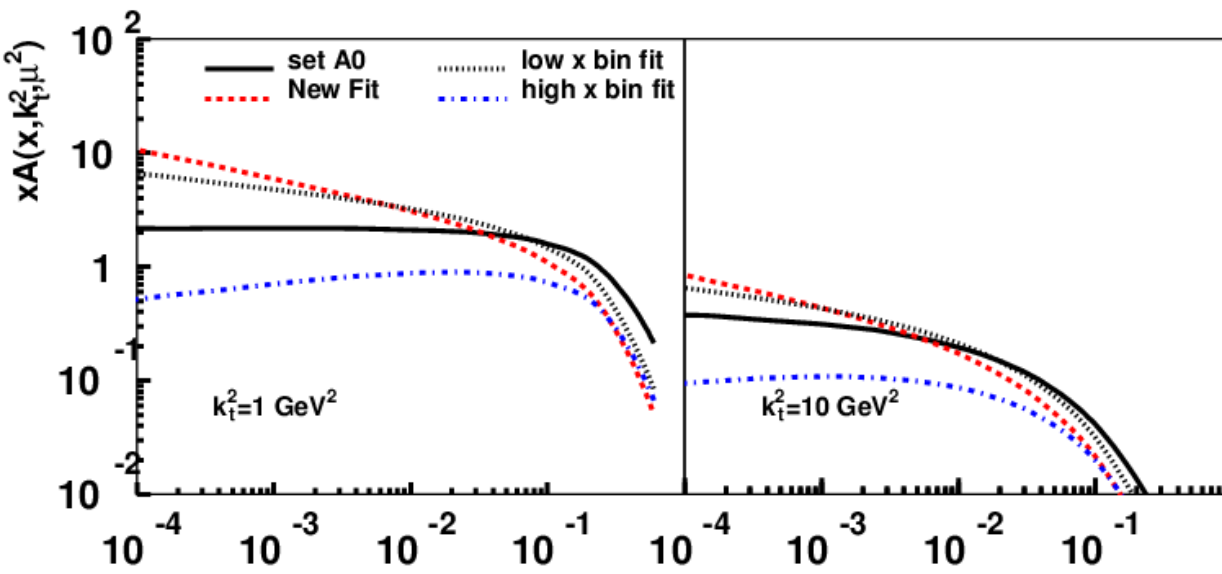
$$\langle Q^2 \rangle = 71 \text{ GeV}^2$$

$$\langle x \rangle = 0.0047$$

Suggests more flexibility in parameterisation...

Suggests a negative B value

	<i>All bins</i>	Low x fit	High x fit
<i>B</i>	0.25	0.13	-0.17
<i>μ</i>	3	3	3



Control of fit - Grid description

- Chi2/ndf for polynomial description of parameter space:

Degree of polynomial:	2nd	3rd	4th	5th
chi2/ndf for histo 1, bin 1 =	12.46	1.461	1.519	1.719
chi2/ndf for histo 1, bin 2 =	10.76	1.541	1.558	1.538
chi2/ndf for histo 1, bin 3 =	8.057	1.725	1.819	1.449
chi2/ndf for histo 1, bin 4 =	4.194	1.640	1.908	1.428
chi2/ndf for histo 1, bin 5 =	2.021	1.266	1.178	1.378
chi2/ndf for histo 2, bin 1 =	18.52	0.993	0.877	1.317
chi2/ndf for histo 2, bin 2 =	15.57	0.935	0.898	1.268
chi2/ndf for histo 2, bin 3 =	10.39	1.037	1.088	0.928
chi2/ndf for histo 2, bin 4 =	4.439	0.975	1.038	1.078
chi2/ndf for histo 2, bin 5 =	1.950	0.990	0.938	1.138
chi2/ndf for histo 3, bin 1 =	10.91	1.639	1.697	1.768
chi2/ndf for histo 3, bin 2 =	9.129	1.763	1.638	1.648
chi2/ndf for histo 3, bin 3 =	6.594	1.867	1.858	1.228
chi2/ndf for histo 3, bin 4 =	3.016	1.351	1.198	1.498
chi2/ndf for histo 3, bin 5 =	1.426	1.201	1.128	1.218
chi2/ndf for histo 4, bin 1 =	5.219	1.579	1.438	1.308
chi2/ndf for histo 4, bin 2 =	4.454	1.536	1.498	1.258
chi2/ndf for histo 4, bin 3 =	2.738	1.266	1.208	1.328
chi2/ndf for histo 4, bin 4 =	1.651	1.171	1.088	1.248
chi2/ndf for histo 4, bin 5 =	1.036	0.965	1.108	1.088
chi2/ndf for histo 5, bin 1 =	7.488	1.07	1.588	1.514
chi2/ndf for histo 5, bin 2 =	7.488	3.66	2.468	2.864
chi2/ndf for histo 5, bin 3 =	7.488	3.64	2.688	3.120
chi2/ndf for histo 5, bin 4 =	7.488	3.43	2.808	3.228
chi2/ndf for histo 5, bin 5 =	7.488	2.56	2.408	3.255
chi2/ndf for histo 18, bin 1 =	14.7	1.37	1.201	1.268
chi2/ndf for histo 18, bin 2 =	13.0			
chi2/ndf for histo 18, bin 3 =	9.68			
chi2/ndf for histo 18, bin 4 =	4.77			
chi2/ndf for histo 18, bin 5 =	1.44			

- Parameter values from fit to data:

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.

PROFIT

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 $\lambda$  (FUNCT=1)
***** or Number of coefficients 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
```


PROFIT

Steering card

```
*
***** Name of grid file
SPFIL steer_grid_dijets
*
***** Number of cross-sections for grid:
NXSEC 80
*
***** Grid fitting meth
GRFIT 1
*
***** Functional form (
FUNCT 1
*
***** Degree of polyA (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				
* p1	p2	p3	p4	
0.03	0.1	0.0	2	
0.03	0.1	1	2	
0.03	0.1	2	2	
0.03	0.1	3	2	
0.03	0.2	0.0	2	
0.03	0.2	1	2	
0.03	0.2	2	2	
0.03	0.2	3	2	
0.03	0.3	0.0	2	
0.03	0.3	1	2	
0.03	0.3	2	2	
0.03	0.3	3	2	
0.03	0.4	0.0	2	
0.03	0.4	1	2	
0.03	0.4	2	2	
0.03	0.4	3	2	
0.03	0.6	0.0	2	
0.03	0.6	1	2	
0.03	0.6	2	2	
0.03	0.6	3	2	
0.1	0.1	0.0	2	
0.1	0.1	1	2	
0.1	0.1	2	2	
0.1	0.1	3	2	
0.1	0.2	0.0	2	
0.1	0.2	1	2	
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
GRFIT 1
*
***** Functional form (
FUNCT 1
*
***** Degree of polynomial (F
***** or Number of coef
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
```

```
*****
* MC FILES *
*****
./dijets/dphi_0.03_0.1_2_0.hbook'
./dijets/dphi_0.03_0.1_2_1.hbook'
./dijets/dphi_0.03_0.1_2_2.hbook'
./dijets/dphi_0.03_0.1_2_3.hbook'
./dijets/dphi_0.03_0.2_2_0.hbook'
./dijets/dphi_0.03_0.2_2_1.hbook'
./dijets/dphi_0.03_0.2_2_2.hbook'
./dijets/dphi_0.03_0.2_2_3.hbook'
./dijets/dphi_0.03_0.3_2_0.hbook'
./dijets/dphi_0.03_0.3_2_1.hbook'
./dijets/dphi_0.03_0.3_2_2.hbook'
./dijets/dphi_0.03_0.3_2_3.hbook'
./dijets/dphi_0.03_0.4_2_0.hbook'
./dijets/dphi_0.03_0.4_2_1.hbook'
./dijets/dphi_0.03_0.4_2_2.hbook'
./dijets/dphi_0.03_0.4_2_3.hbook'
./dijets/dphi_0.03_0.6_2_0.hbook'
./dijets/dphi_0.03_0.6_2_1.hbook'
./dijets/dphi_0.03_0.6_2_2.hbook'
./dijets/dphi_0.03_0.6_2_3.hbook'
./dijets/dphi_0.1_0.1_2_0.hbook'
./dijets/dphi_0.1_0.1_2_1.hbook'
./dijets/dphi_0.1_0.1_2_2.hbook'
./dijets/dphi_0.1_0.1_2_3.hbook'
./dijets/dphi_0.1_0.2_2_0.hbook'
./dijets/dphi_0.1_0.2_2_1.hbook'
./dijets/dphi_0.1_0.2_2_2.hbook'
```

```
*****
* parameter values
* p1 p2 p3 p4
*****
0.03 0.1 0.0 2
0.03 0.1 1 2
0.03 0.1 2 2
0.03 0.1 3 2
0.03 0.2 0.0 2
0.03 0.2 1 2
0.03 0.2 2 2
0.03 0.2 3 2
0.03 0.3 0.0 2
0.03 0.3 1 2
0.03 0.3 2 2
0.03 0.3 3 2
0.03 0.4 0.0 2
0.03 0.4 1 2
0.03 0.4 2 2
0.03 0.4 3 2
0.03 0.6 0.0 2
0.03 0.6 1 2
0.03 0.6 2 2
0.03 0.6 3 2
0.1 0.1 0.0 2
0.1 0.1 1 2
0.1 0.1 2 2
0.1 0.1 3 2
0.1 0.2 0.0 2
0.1 0.2 1 2
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 $\lambda$  (FUNCT=1)
***** or Number of coefficients in function (FUNCT=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**

PROFIT

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 $\lambda$  (FUNCT=1)
***** or Number of coefficients 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 $\lambda$  (FUNCT=1)
***** or Number of coefficients 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

Example of application

Fit unintegrated gluon density to HERA data

H1 Collab., A. Aktas et al., *Eur. Phys. J. C*33 (2004) 477

Inclusive Dijet Production at Low x_{Bj} in DIS

Integrated PDF: DGLAP

LO: Gluon collinear with proton

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

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

Higher orders: $k_{t,\text{gluon}} \neq 0$
 $\Delta E_{T,\text{jets}} \neq 0$

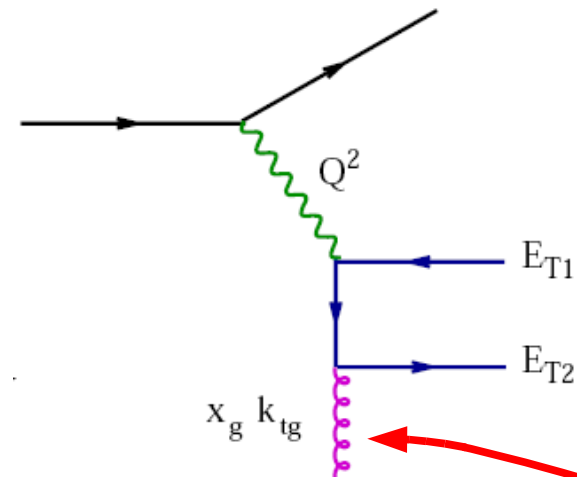
Unintegrated PDF: CCFM or BFKL

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

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

already at LO

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



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

and measure jet cross-section
as a function of Δ

Sensitivity to k_t of gluon