PROFFIT

A. Bacchetta (Università di Pavia), H. Jung (DESY),
A. Knutsson (DESY), K. Kutak (Antwerp),
F. S-Himmelstjerna (DESY)

MC4LHC readiness workshop

CERN, 29-31 March 2010

Outline

- Introduction to PROFFIT
- Fragmentation tune to HERA data
- Summary/Outlook

About PROFFIT

- A couple a years ago Hendrik Hoeth (PROFESSOR) gave a talk about MC tuning at the MCNet school in Durham

- We wanted to try the method for fits of the unintegrated PDFs for which a standard iterative fitting method is too time consuming, in particular when determining the kt-dependence in the uPDF. (Need ~100 iterations to find minimum.
  Need decent statistics: 1 MC run ~12h.)

- In addition we needed a proper error treatment for the PDFs.

- The data we wanted to use existed already in analyses routines in the fortran based HZTOOL framework.

- However, PROFFIT is standalone and the user can code the data and MC reading himself depending on the format.

An alterntive approach for fitting

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

→ **Time consuming for exclusive final states. A high statistics MC run can take more than 24h, and ~100 iterations are needed.**

Also a challenge: Fitting several "event types" simultaneously, e.g. Charm production and inclusive di-jet production

Above method makes separated event generation difficult.

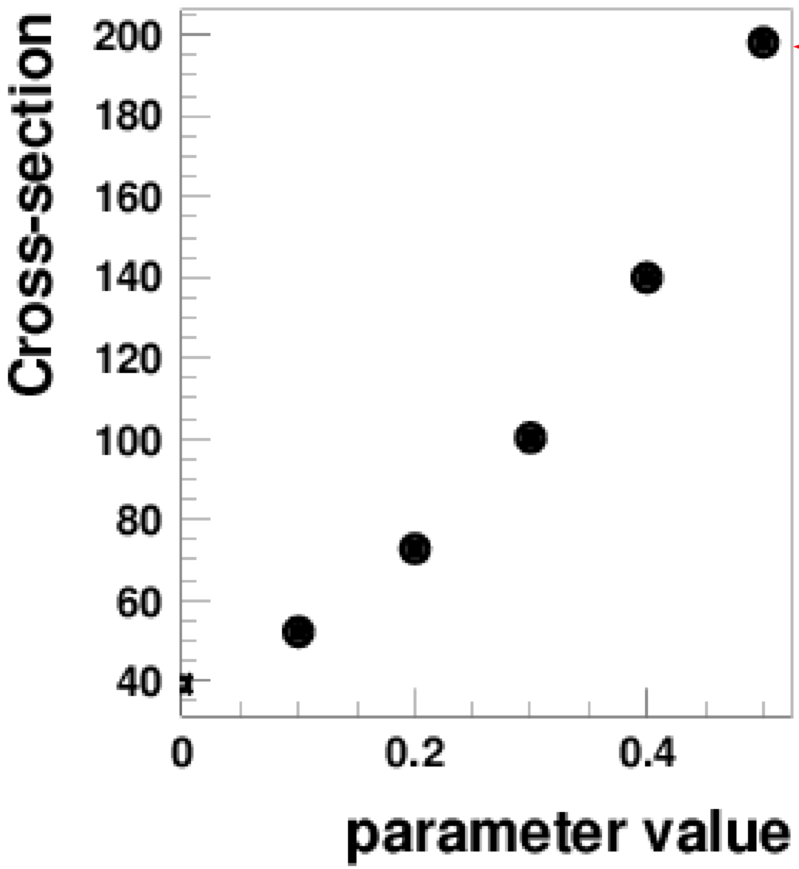
New Approach: Describe **parameter dependence before parameter fitting**, by building up a ***grid in parameter space***.
The MC grid points can be calculated simultaneously.
The fitting itself then takes a few seconds.

1-dim Example

Simplest possible example

1 parameter, 1 data cross-section

1. Build the MC grid



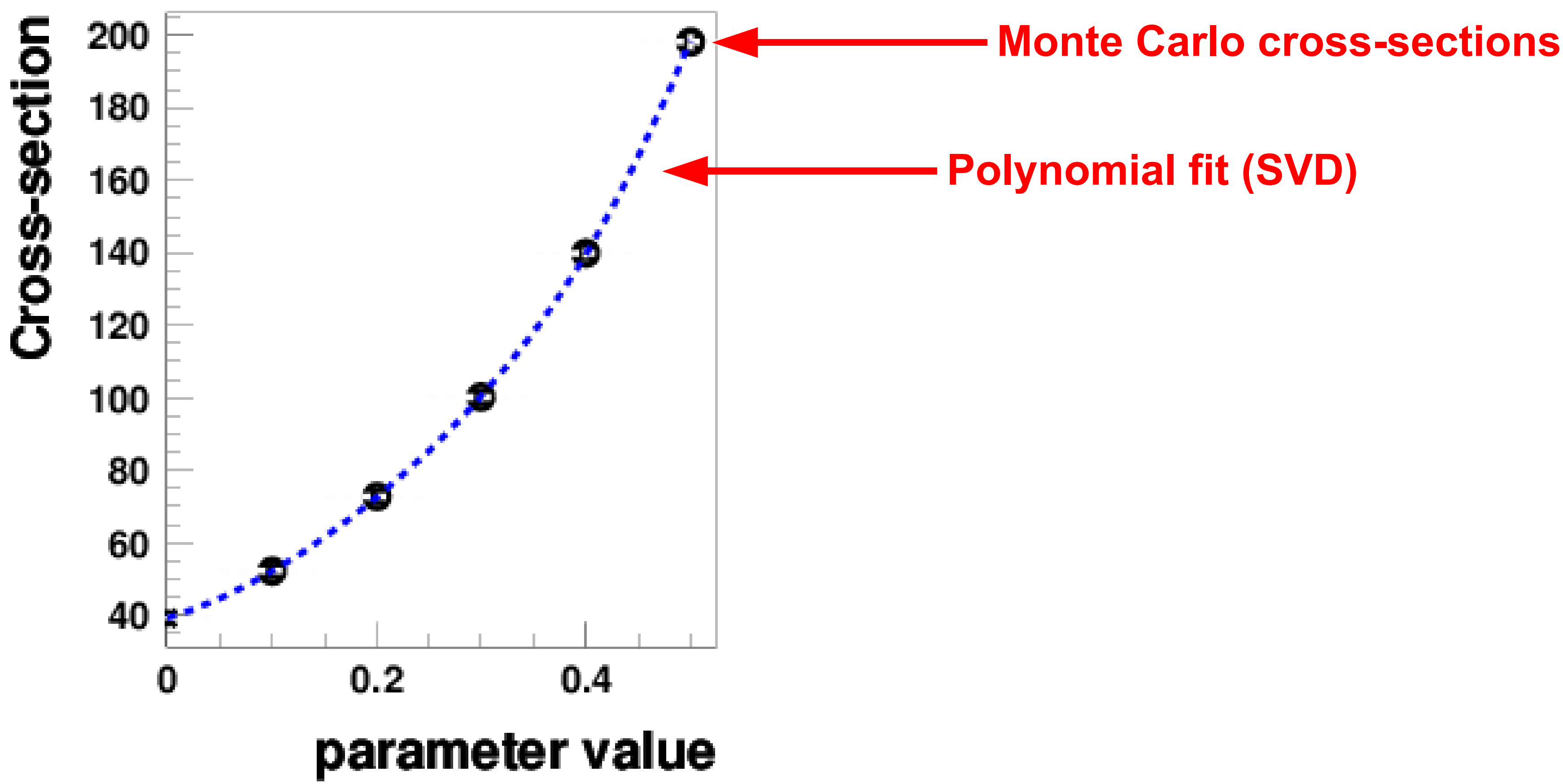
Monte Carlo cross-sections

Simple Example

Simplest possible example

1 parameter, 1 data cross-section

2. Approximate MC with polynomial

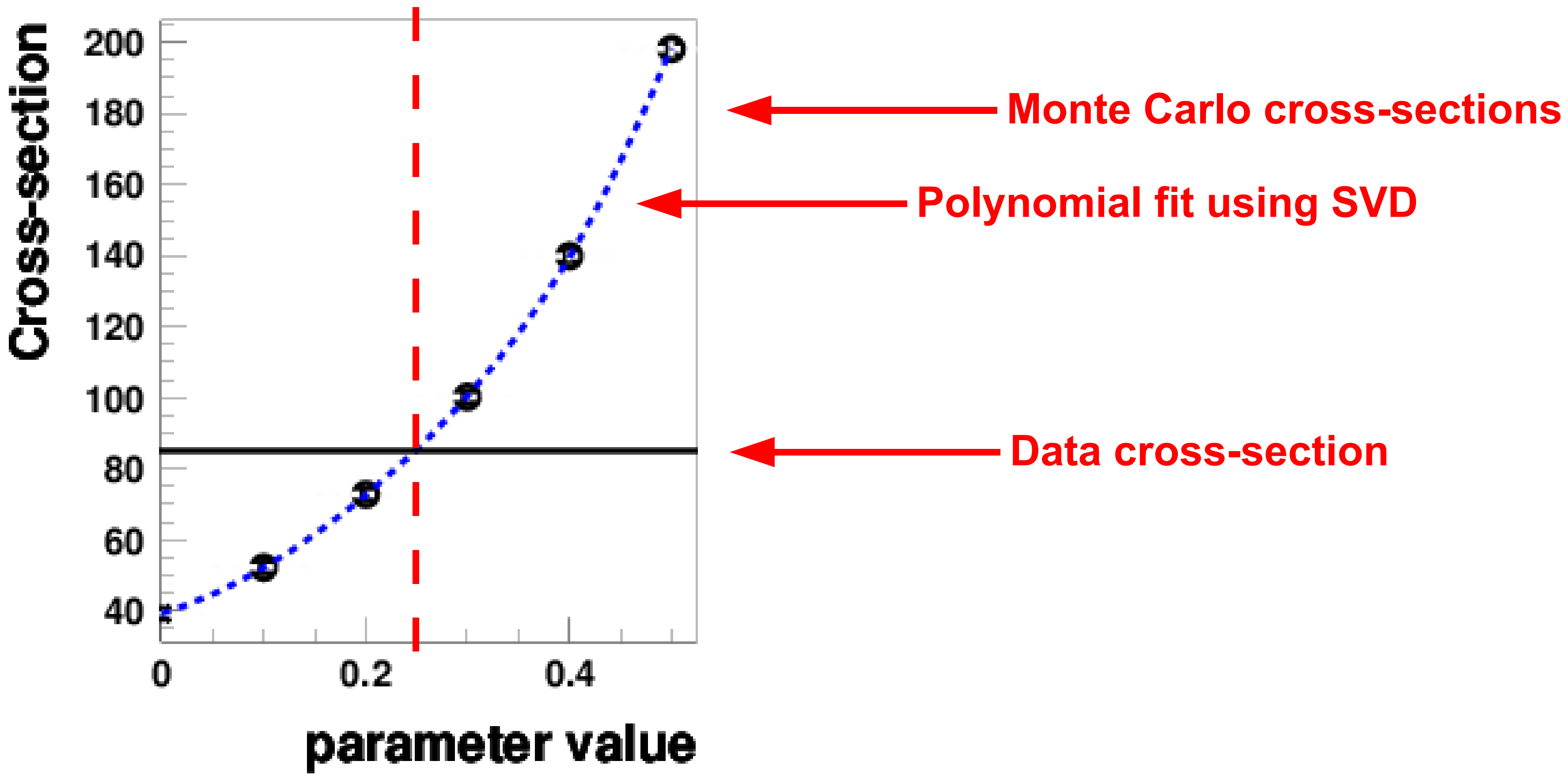


Simple Example

Simplest possible example

1 parameter, 1 data cross-section

3. Minimize Chi2 with a fit to data



About PROFFIT

- **Singular Value Decomposition** used to determine the polynomial describing the MC grid. 2^{nd}, 3^{rd} or 4^{th} order polynomial can be used to described the MC grid.

- The fit of the MC parameters (in the polynomial) to the data is done by Minuit (**MIGRAD**)

- Equidistant MC grids has been used for the uPDF fits, but this is not possible for tunes with many parameter since the number of points needed for parameterization is at least 4^N for N parameters. ⟶ Randomize the MC grid.

Error treatment

- **The statistical errors of the MC is propagated to the coefficients of the polynomial. A co-variance matrix for the coefficients are calculated.**

- **The CTEQ error calculation is used to take the correlated errors in the data into consideration. Basically the χ^2 is differently calculated.**

In the fit of the MC parameters to the data the uncorrelated errors and the different correlated errors can be treated separately according to:

$$\chi^2 = \Sigma \frac{(X_{Data} - X_{Polynomial})^2}{\alpha^2} - \Sigma_j \Sigma_{j'} B_j (A^{-1})_{jj'} B_{j'}$$

$\alpha^2 =$ **Sum of uncorrelated errors (data and polynomial)**

$\Sigma_j \Sigma_{j'} B_j (A^{-1})_{jj'} B_{j'} =$ **Term related to the correlated systematic errors (vector *B*), and their correlations (matrix *A*)**

(From the CTEQ group, hep/ph/0101051,
code from Federico von Samson-Himmelstjerna, diploma thesis at DESY)

Tuning of Hadronization parameters to HERA data

Motivation:

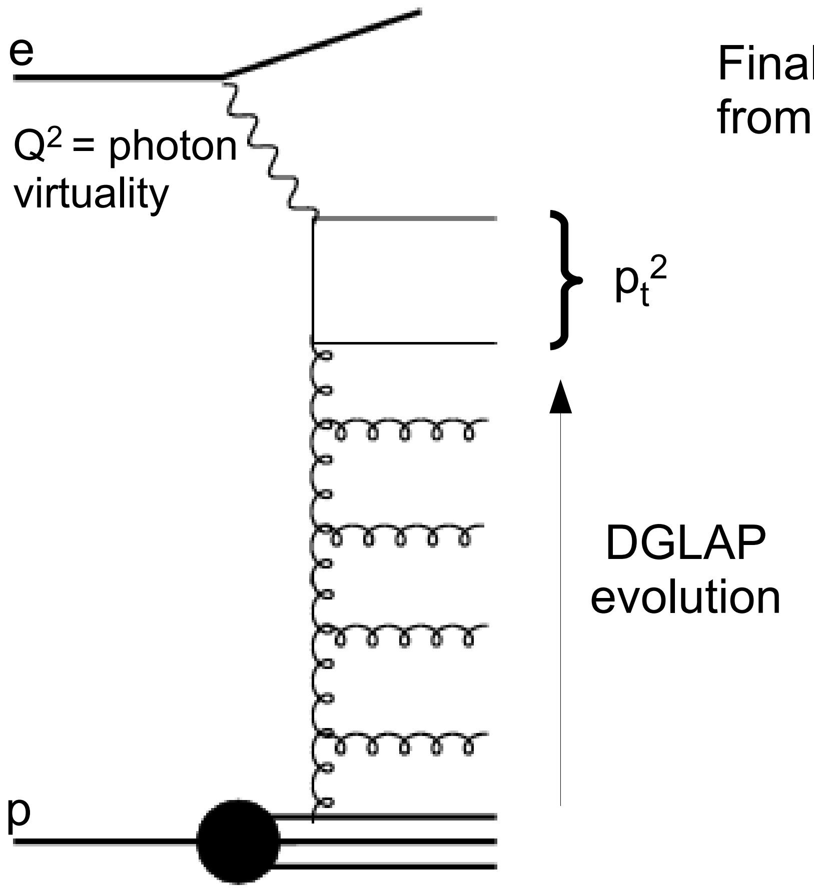
- **Test of factorization ansatz of hadronisation**

- **Does a tune to HERA data give the same result as the PROFESSOR tunes to LEP data?**

RAPGAP

Monte Carlo event generator for *ep*-scattering with LO ME and DGLAP intial and final state parton showers.
(H. Jung, Comput.Phys.Commun.86:147-161,1995)

Final state parton showers and hadronization from PYTHIA.



Settings for the hadronization tune:

PDF: CTEQ6.1L
Scales: $\mu_F = \mu_R = Q^2 + p_t^2$

Default parameters, but
flavour parameters:
The PROFESSOR tune to LEP data

The data

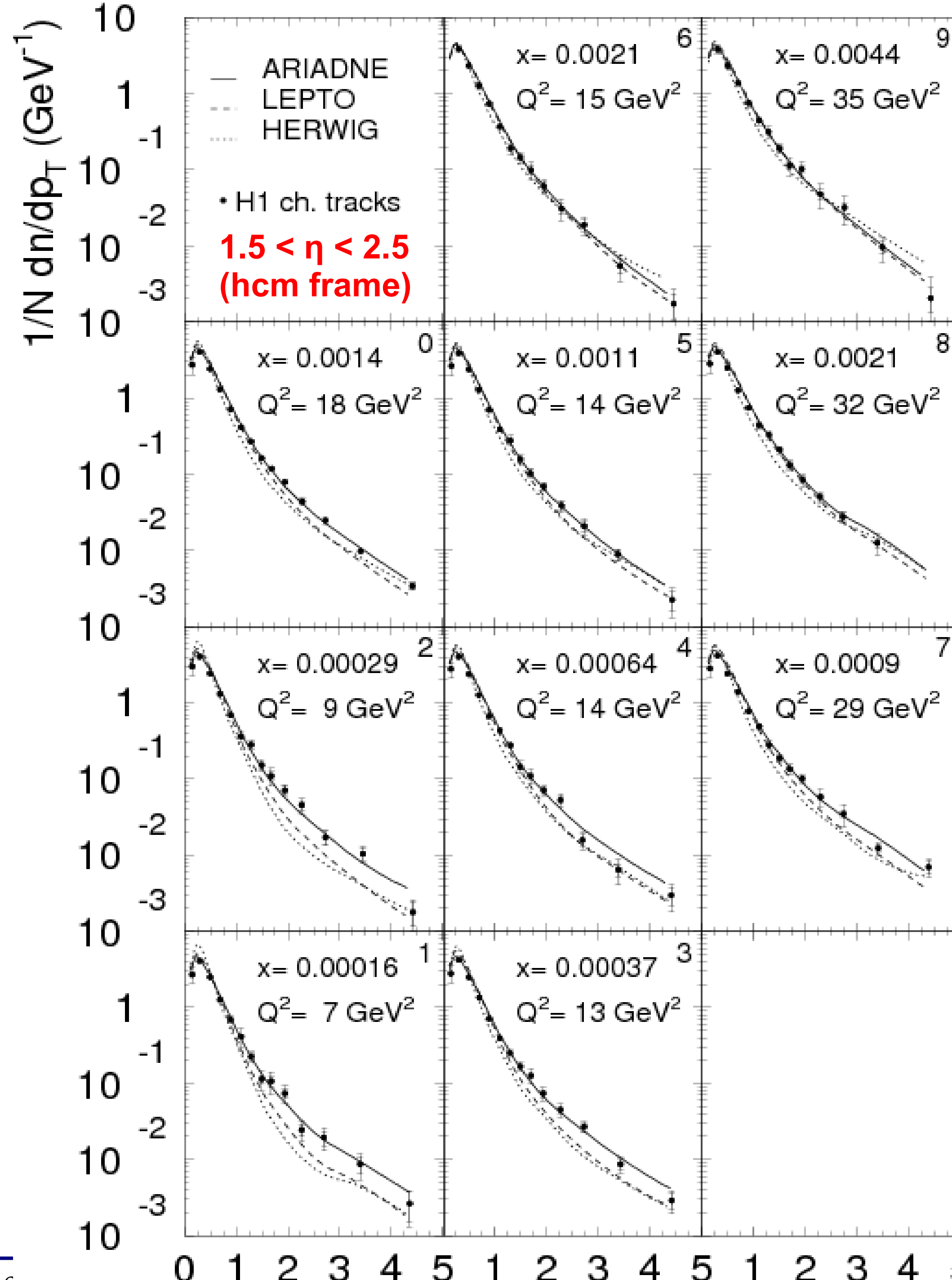
Transverse momentum spectra of charged particles in deep in-elastic scattering *ep*-collisions at HERA.

- Figure from publication: Average charge particle multiplicity as a function of the the transverse momenta of the particles.

- Non-DGLAP based model is expected to produce more hard particles.

- ARIADNE with the Color Dipole Model (CDM), descibes the data better at high p_T

→ p_T > 1.25 GeV region not included in the tuning.



H1 Collaboration, Nucl.Phys.B485:3-24,1997, hep-ex/9610006

The data

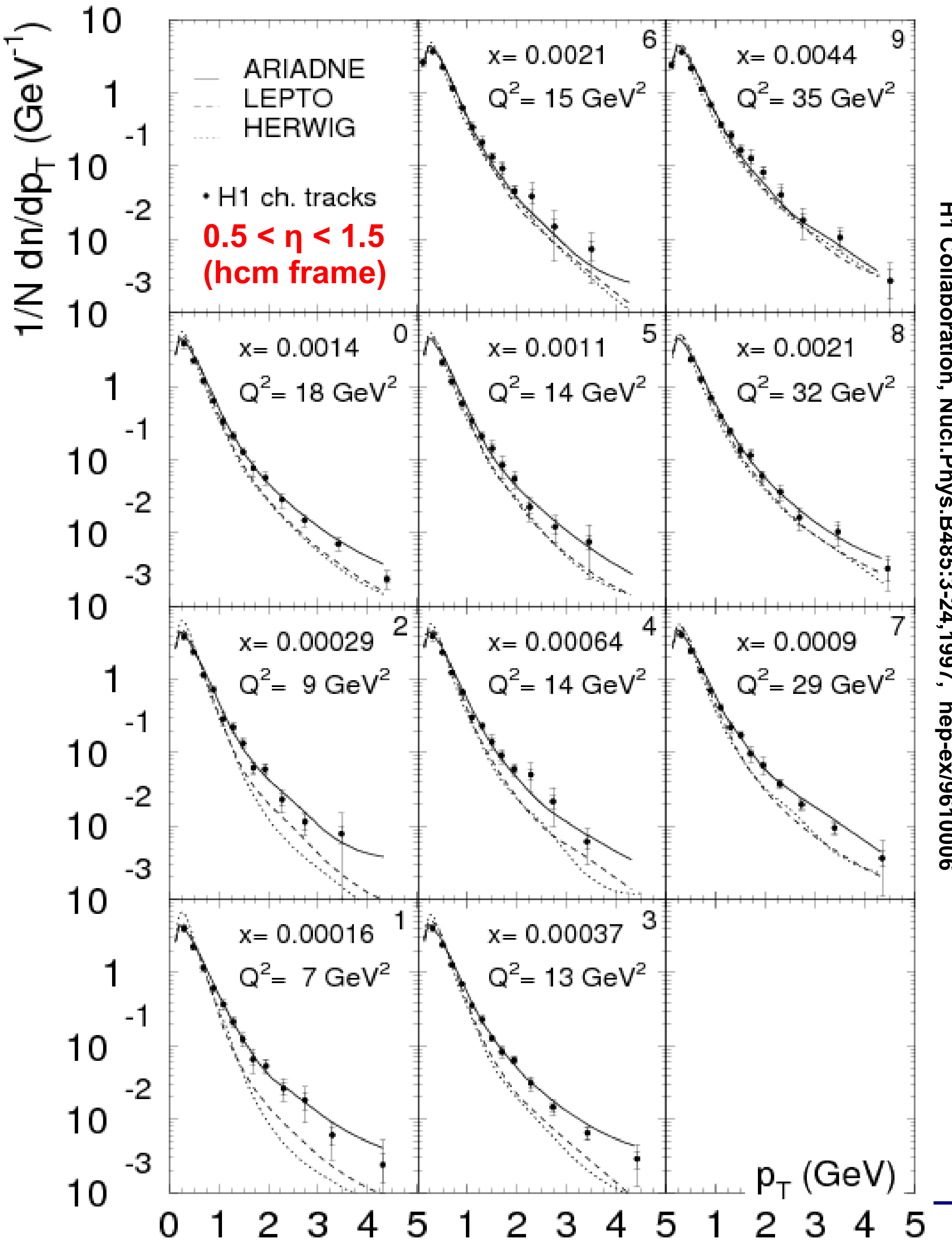
Transverse momentum spectra of charged particles in deep in-elastic scattering *ep*-collisions at HERA.

- Figure from publication: Average charge particle multiplicity as a function of the the transverse momenta of the particles.

- Non-DGLAP based model is expected to produce more hard particles.

- ARIADNE with the Color Dipole Model (CDM), descibes the data better at high p_T

→ **p_T > 1.25 GeV region not included in the tune. Also forward (lab) region excluded.**



The Tune

Tune the following hadronisation parameters to the HERA data:
Same parameters as tuned in the PROFESSOR tune to LEP data

PARJ(21)	σ_q – width of Gaussian for px and py of primary hadrons
PARJ(41)	a } parameters in the Lund fragmentation function
PARJ(42)	b } parameters in the Lund fragmentation function
PARJ(47)	r_b – interpolation between Bowler and Lund fragmentation. (1=pure Bowler shape)
PARJ(81)	Λ_{QCD} for α_s in parton showers
PARJ(82)	Invariant mass cut-off for PS. Partons below this value do not radiate.

Only statistic and total systematic errors provided in the publication. Systematic error is used uncorrelated. Statistical error in MC considered.

The Tune

PARJ(21) σ_q – width of Gaussian for px and py of primary hadrons

PARJ(41) a
PARJ(42) b } parameters in the Lund fragmentation function

PARJ(47) r_b – interpolation between Bowler and Lund fragmentation. (1=pure Bowler shape)

PARJ(81) Λ_{QCD} for α_s in parton showers

PARJ(82) Invariant mass cut-off for PS. Partons below this value do not radiate.

Parameter	Default	Professor Tune	HERA Tune
PARJ(21)	0.36	0.325	0.43 ± 0.01
PARJ(41)	0.3	0.5	1.07 ± 0.18
PARJ(42)	0.58	0.6	0.77 ± 0.17
PARJ(47)	1.0	0.67	0.45 (no sensitivity)
PARJ(81)	0.29	0.29	0.2 ± 0.02
PARJ(82)	1.0	1.65	2.97 ± 0.96
χ^2/ndf *	245/94=**2.59**	417/94 = **4.4**	69.7/94=**0.74**

* χ^2 values are calculated for the HERA data by running the generator with the different parameter sets (errors of parameters are not considered)

The Tune

Parameter	Default	Professor Tune	HERA Tune
PARJ(21)	0.36	0.325	0.43 ± 0.01
PARJ(41)	0.3	0.5	1.07 ± 0.18
PARJ(42)	0.58	0.6	0.77 ± 0.17
PARJ(47)	1.0	0.67	0.45 (no sensitivity)
PARJ(81)	0.29	0.29	0.2 ± 0.02
PARJ(82)	1.0	1.65	2.97 ± 0.96
χ^2/ndf (p_t<1.25 GeV)	245/94=2.59	417/94 = 4.4	69.7/94=0.74
χ^2/ndf (p_t<0.8 GeV)	65.6/67=0.98	102/67= 1.5	36.3/67=0.54

Note: **At lower pt all parameters sets work!**

Warning!!! Is there non-DGLAP physics at pt>0.8 which is “lost” in the hadronization tune?

How to disentangle hadronization effects and small x effects?
How can we identify the different contributions?

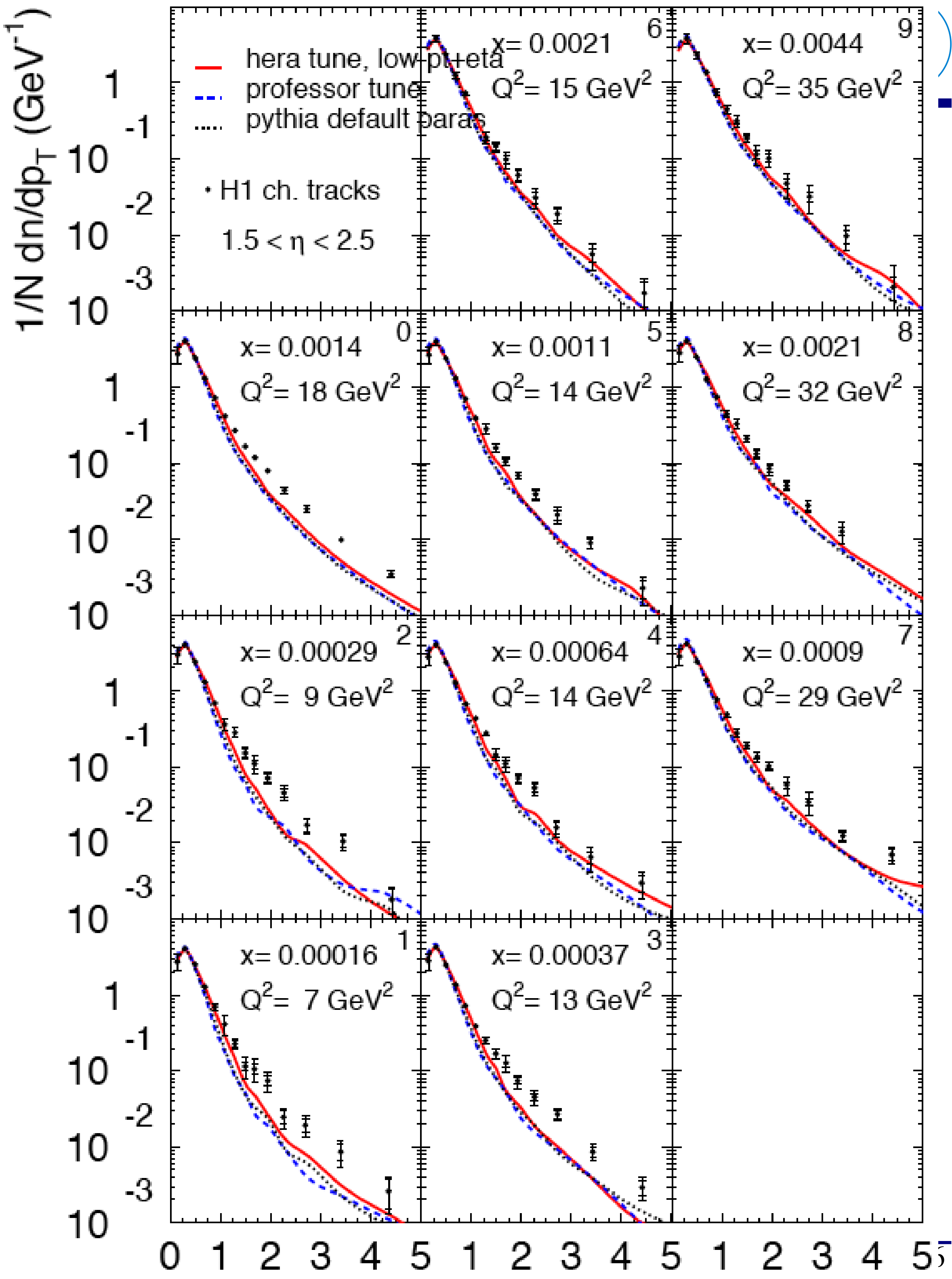
The question is also very relevant for LHC tunes: For example how do we distinguish different contributions to the UE, e.g. MI and parton showers

The Results

Pt -spectra.

Visually no big difference between the tunes.

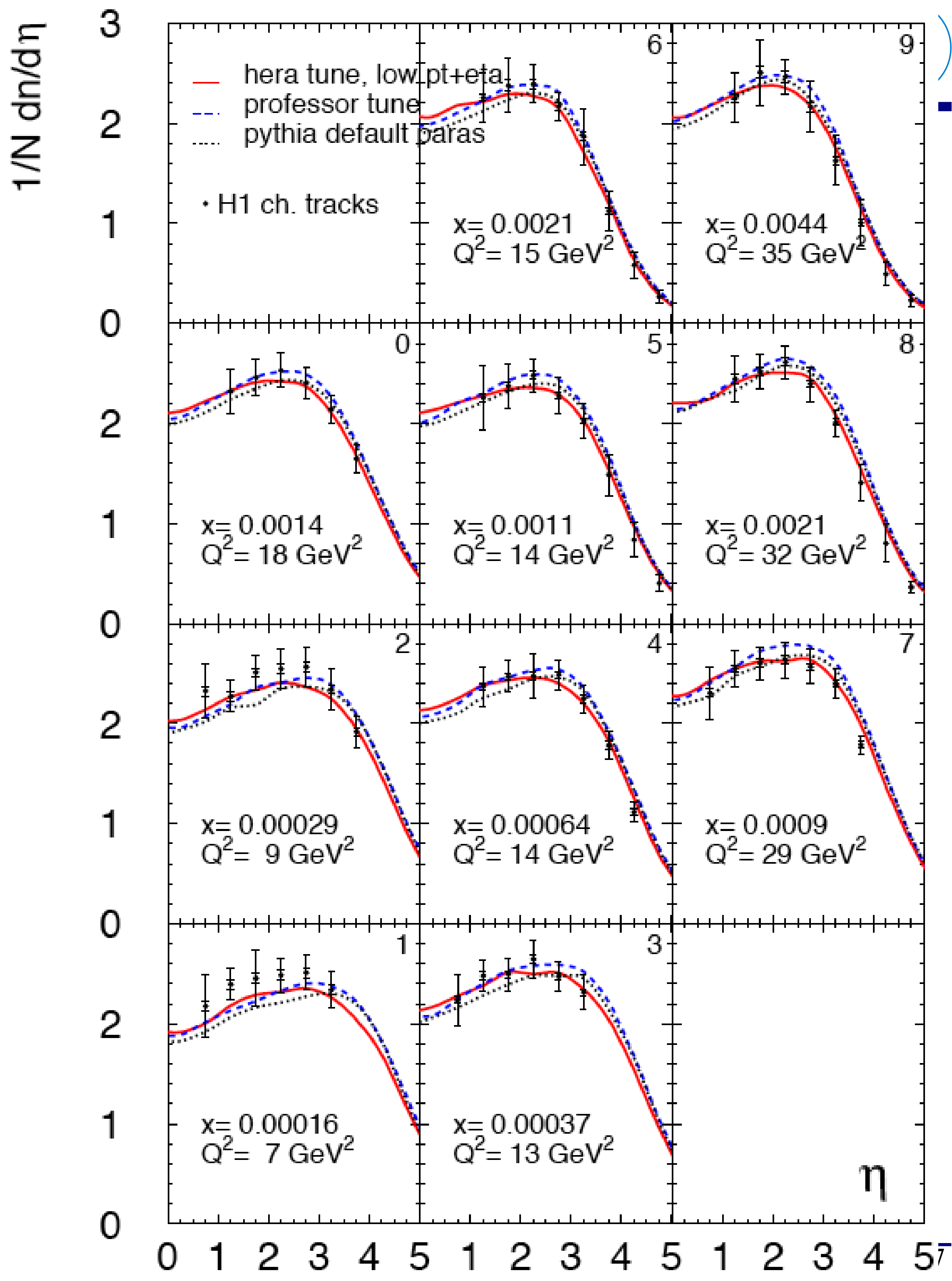
Red line – HERA tune
Blue dashed – PROFESSOR tune
Black dotted – Default parameters



The Results

Rapdity spectra. Central region included in the tuning.

Red line – HERA tune
Blue dashed – PROFESSOR tune
Black dotted – Default parameters



Summary and outlook

Summary

- **PROFFIT** – Fully functionally for multidimensional tunes.
- Has been used for a **first hadronization tune to HERA data**.
- Tune influenced by small x effects? The sensitivity to perturbative physics is a matter of investigation. Similar issues important for pp: UE/MI etc
- PROFFIT has the possibility to correctly treat correlated systematic errors. Used in the fits of uPDFs to high precision HERA data.

Outlook

- Code available on HEP Forge within 1 week.
- Future tuning activities in the Analysis Center MC group at DESY is planned.
- Improve the HERA tune of hadronization parameters. Include more data. More systematic study of minimum, etc...
- Join the tuning effort at LHC, including HERA data

albert.knutsson@cern.ch