Forward Jets

+ fitting of the unintegrated gluon density

HRJRG Kick-off meeting

Moscow 8/2-2008

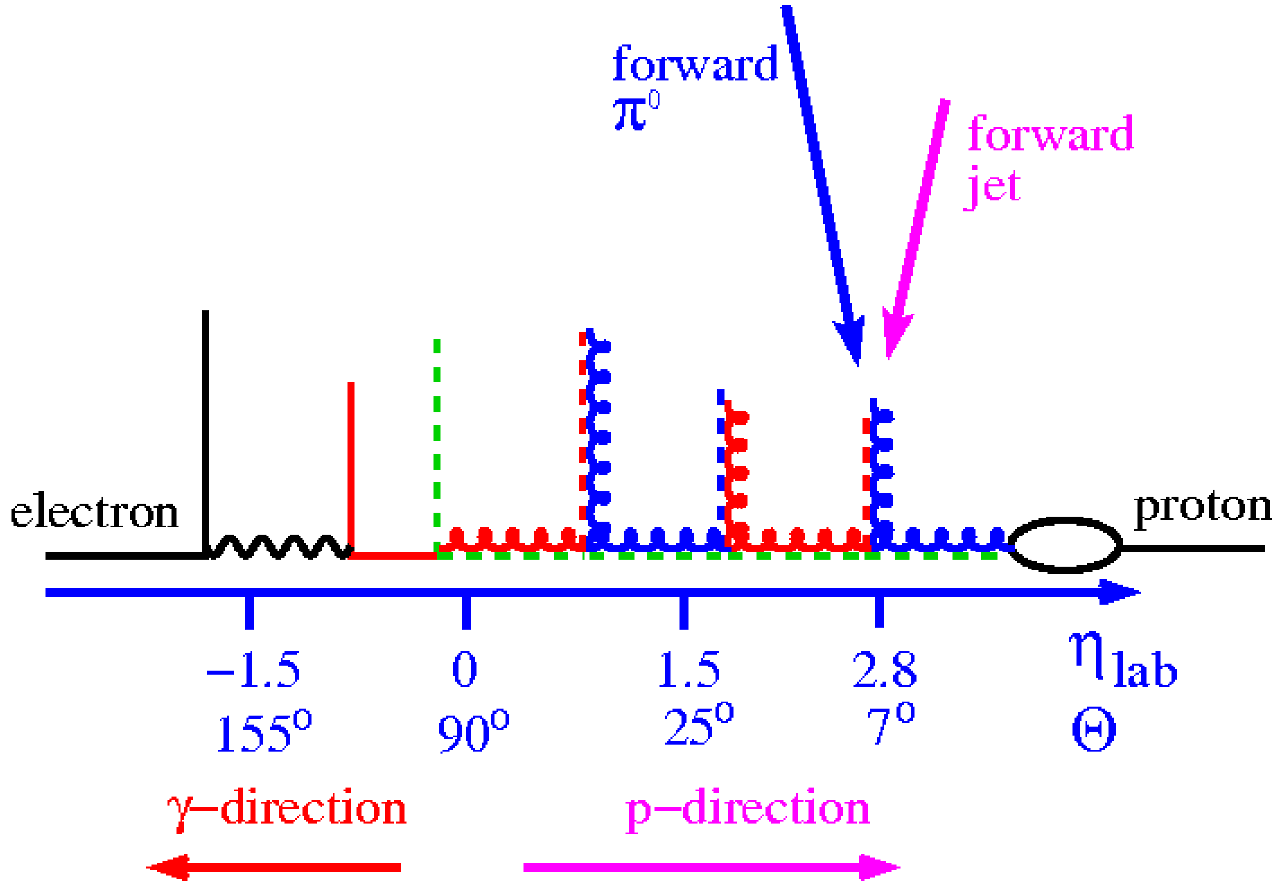
Albert Knutsson

Outline

- Physics Motivation
- Forward jets at HERA and LHC
- *SimpFit* – a new fitting program
- Fitting the unintegrated gluon
- Summary

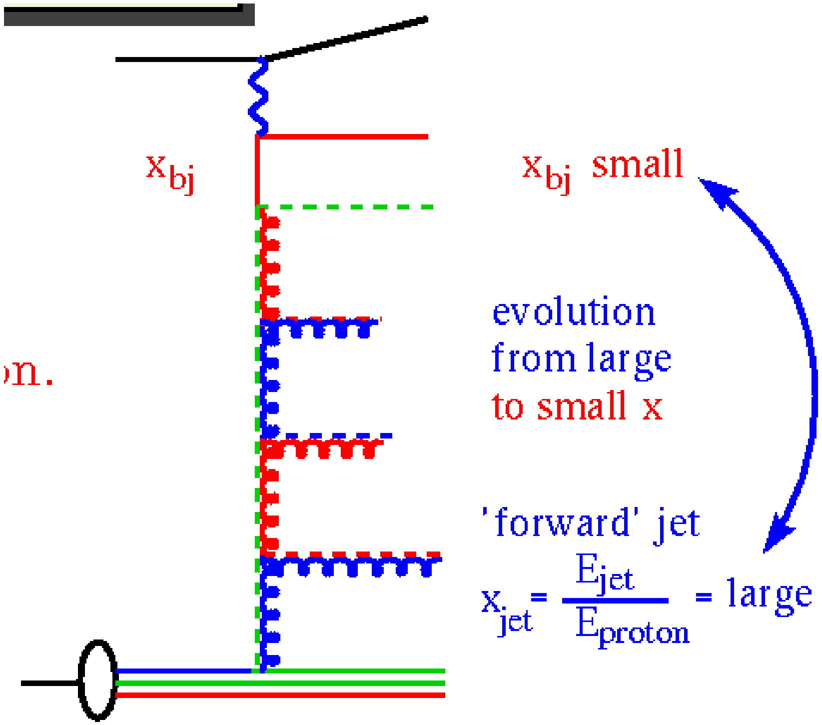
Forward Physics - motivation

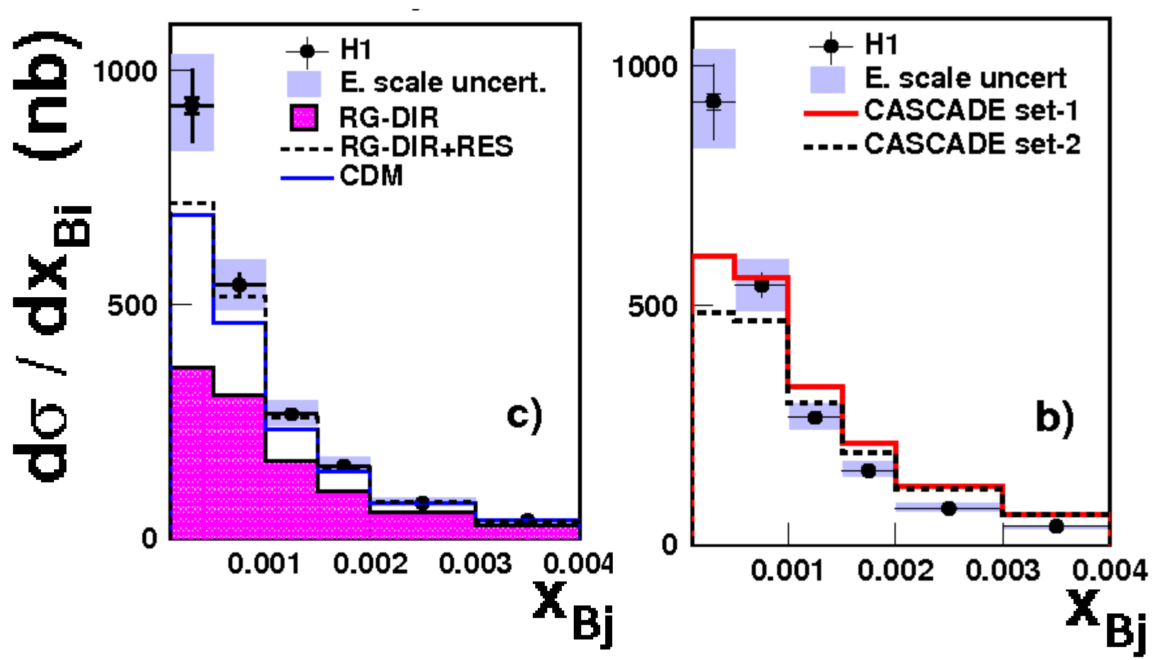
Deep in elastic scattering



F_2 - very inclusive - very well described by DGLAP.	Dijet cross-section, Jet Rates - measure hard subsystem.	Energetic jet/particle in forward region - information on full evolution ladder.

Forward jets in DIS





Main conclusion: Ordering of virtuality/kt of emissions (DGLAP) are not sufficient. Need to break the ordering. Here, for example with a resolved photon or using the Color Dipole Model (BFKL like scenario).

CASCADE (CCFM) does not describe the data satisfactory. Possibility to improve description by better determination of the uPDF (by fitting).

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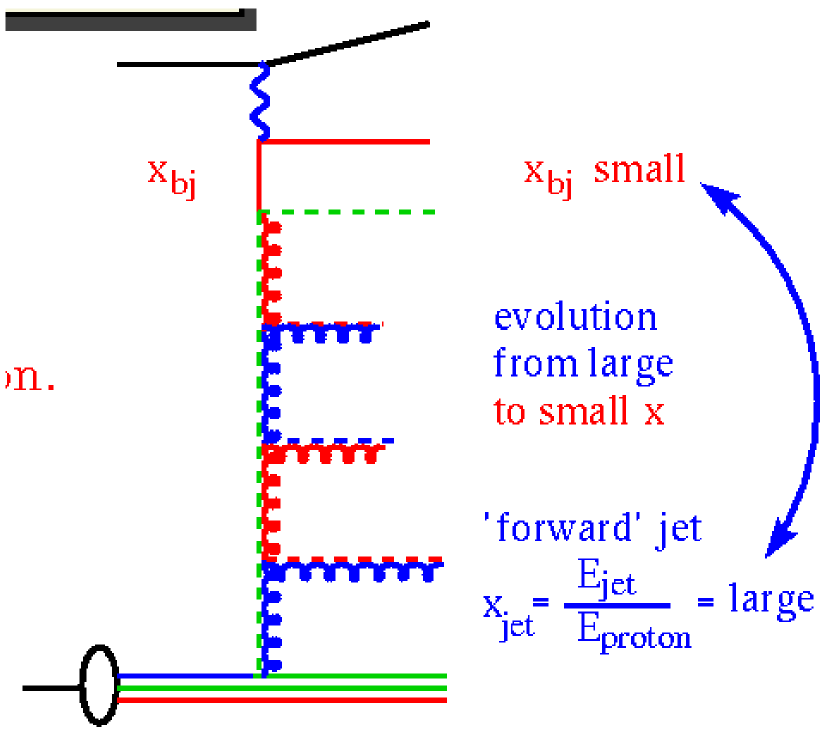

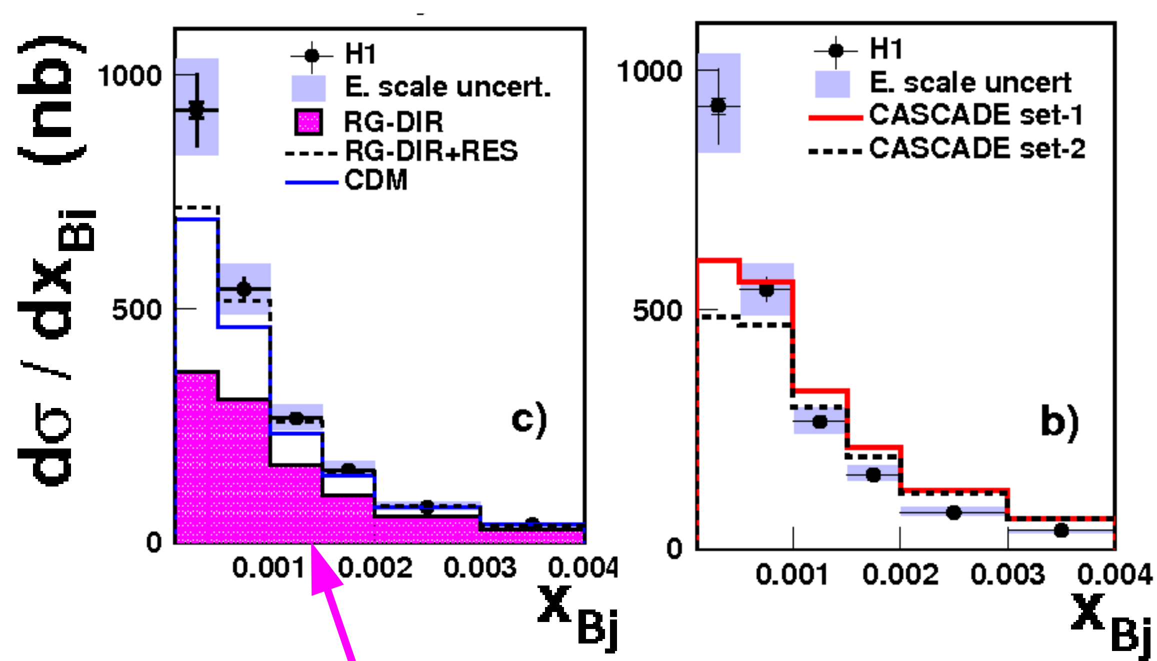

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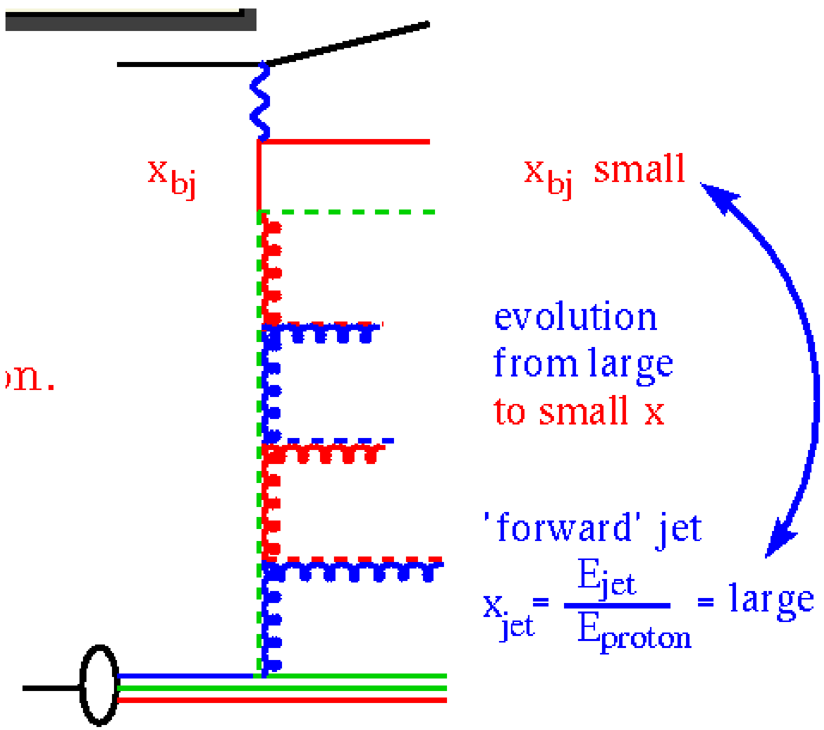

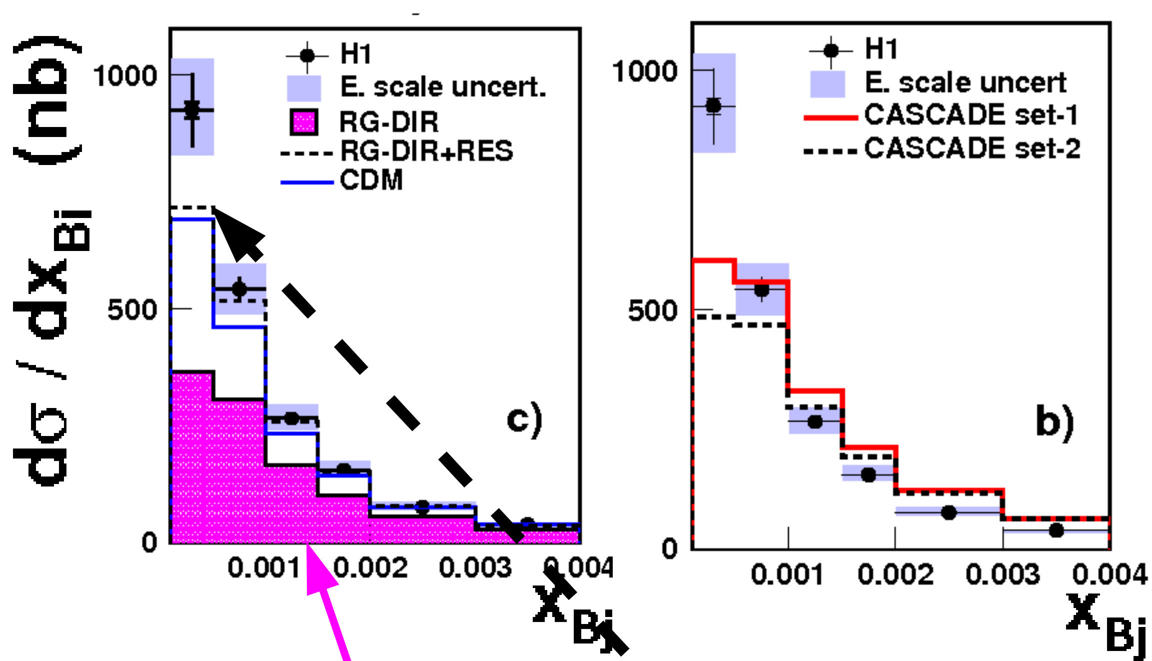

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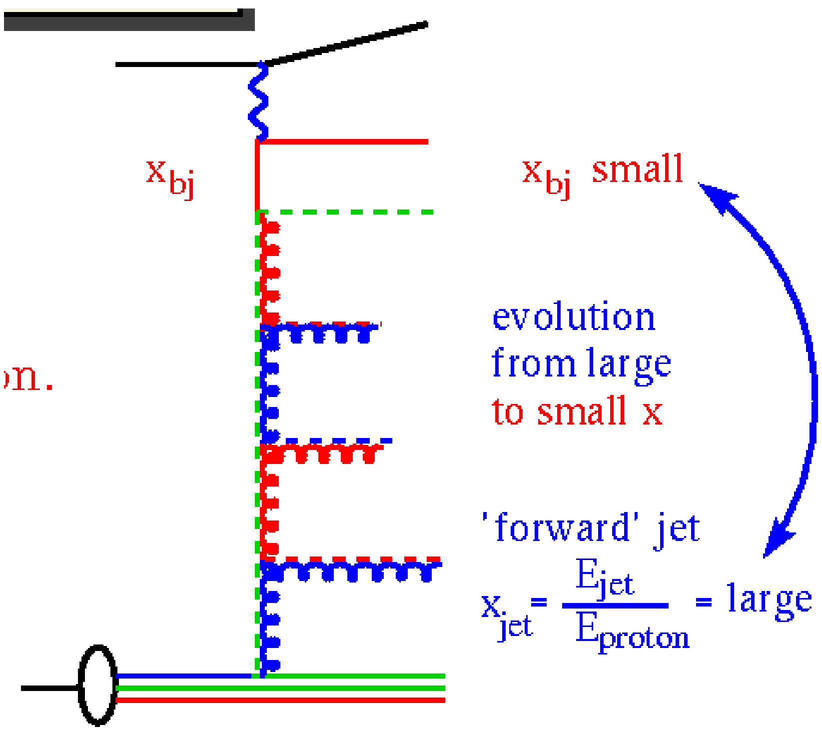

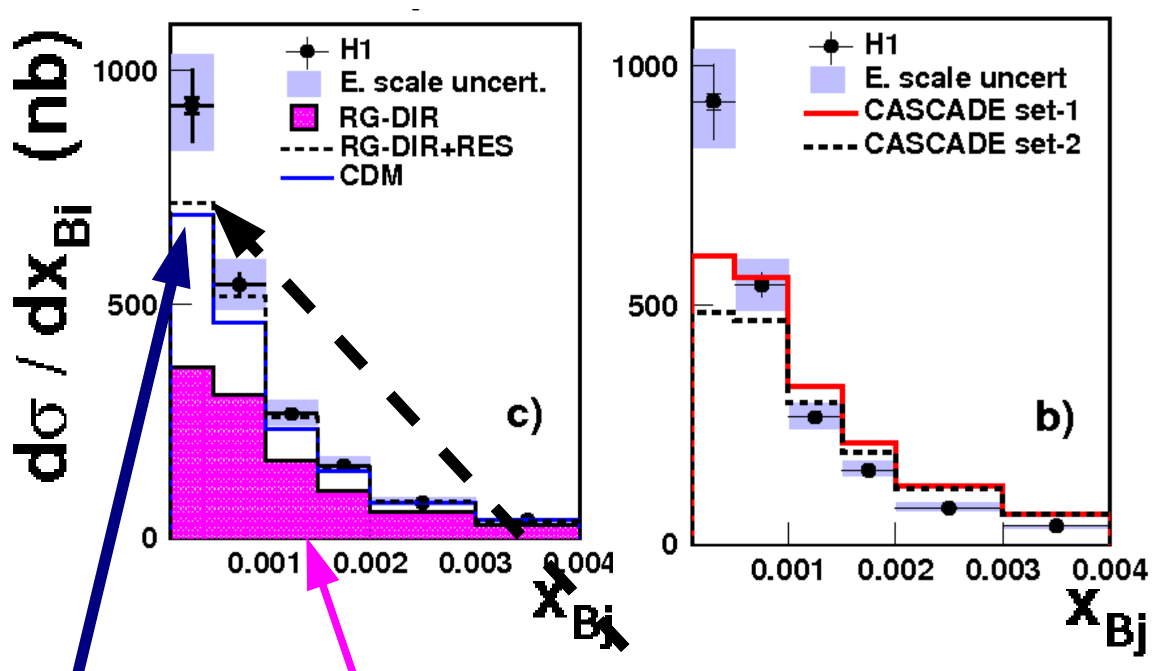

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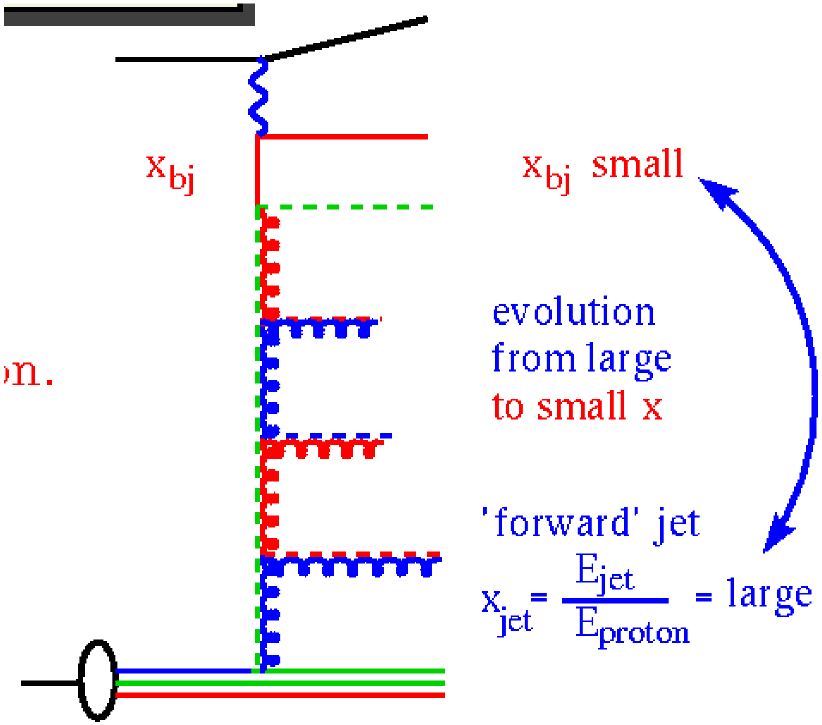

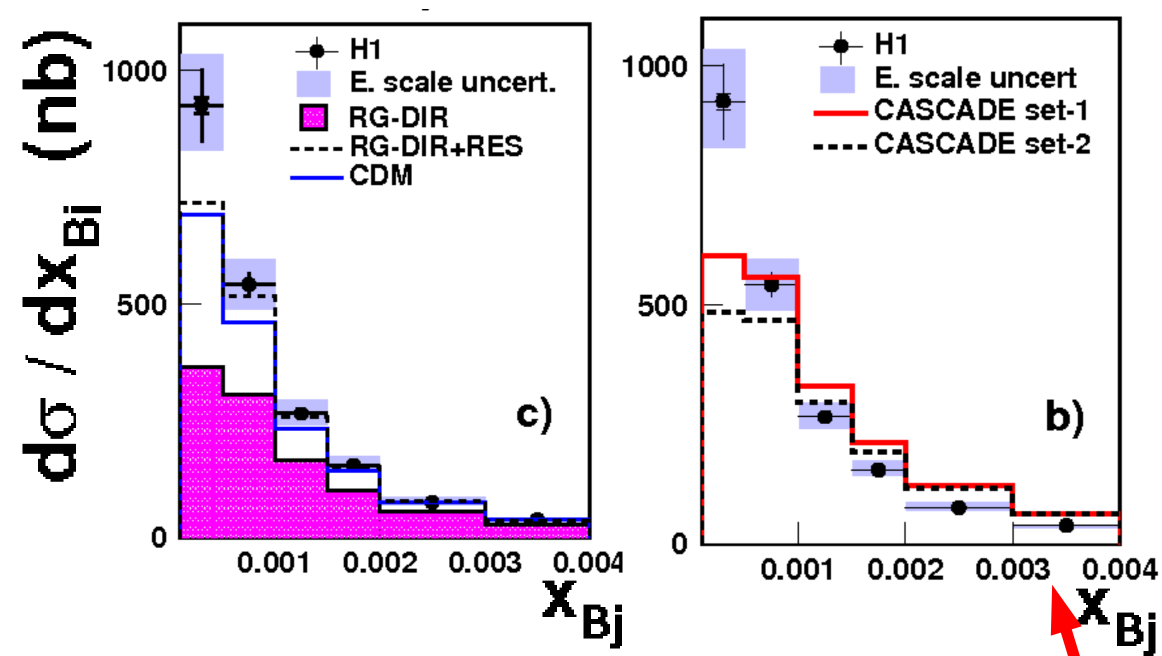

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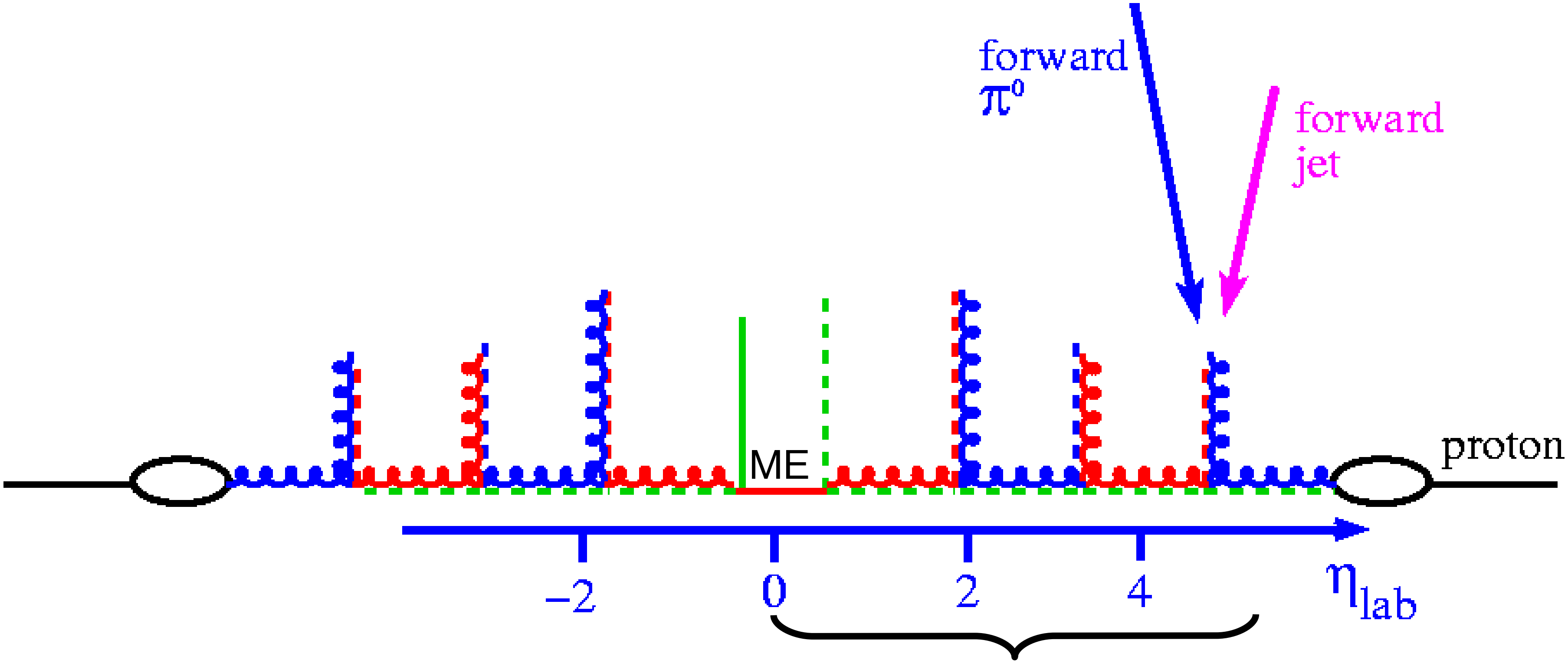
Forward Physics - LHC

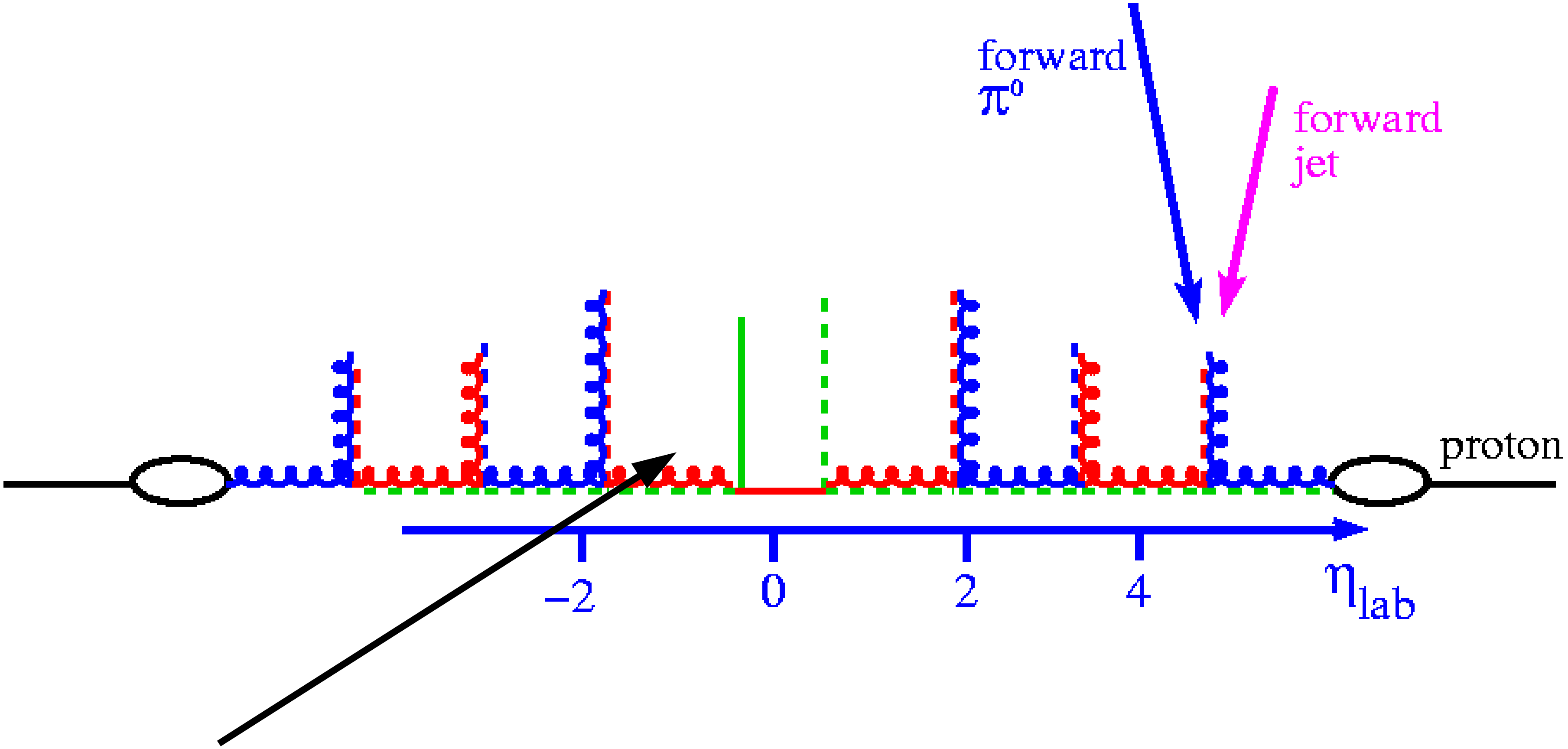


Hard jet or particle in forward region,
large rapidity range between ME and jet/particle

- **Opens up phase space for emissions, higher order reactions**
- **Small x physics**
- **Possible to apply constraints on parton ladder (e.g. further suppress DGLAP)**
- **Gain information of the full evolution**

Tool to study higher order QCD reactions

Forward Physics - LHC



2 hard central jets in addition to forward jet.

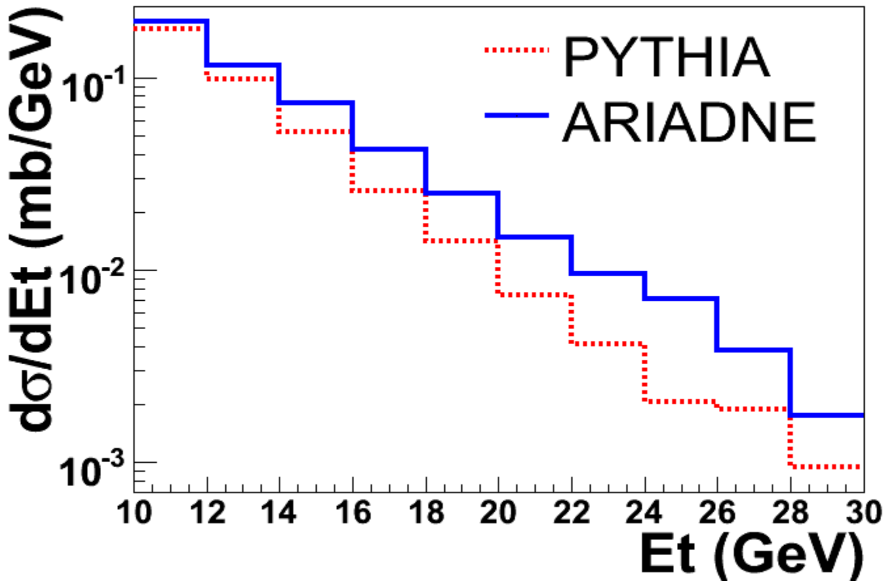
In addition possibility to
supress DGLAP like dynamics
(ordering in virtuality ~ E_t)

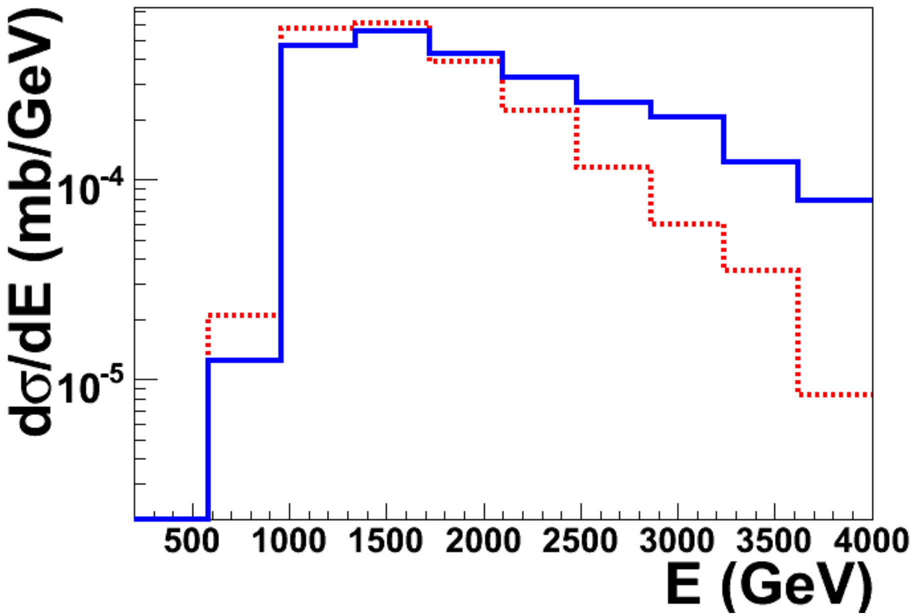
$$\frac{E_{t,\mathrm{forward\ jet}}}{< E_{t,\mathrm{di\text{-}jet\ jets}} >} \sim 1$$

MC studies for LHC and CASTOR

Selection: 2 central jets, 1 jet in CASTOR region $(5.2 < \eta < 6.6)$
with $E_t > 10$ GeV

Hadron level



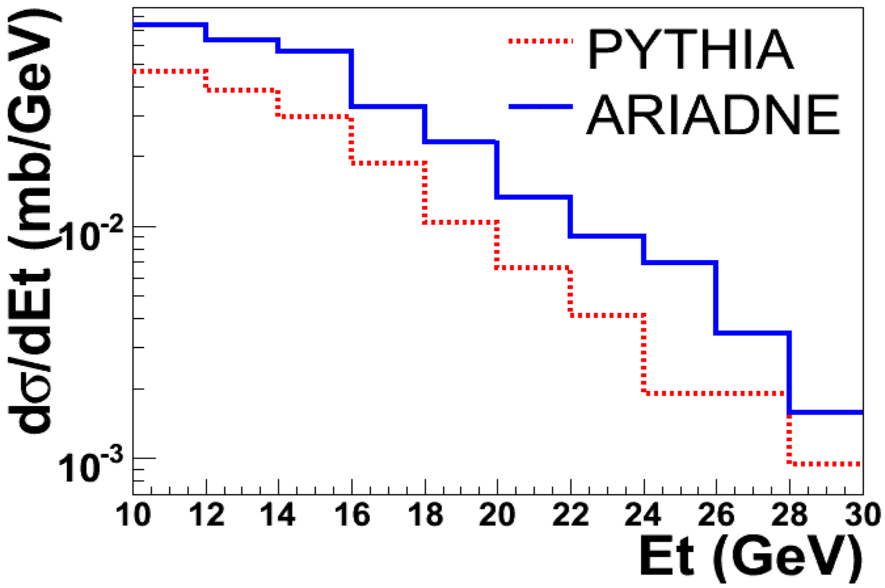


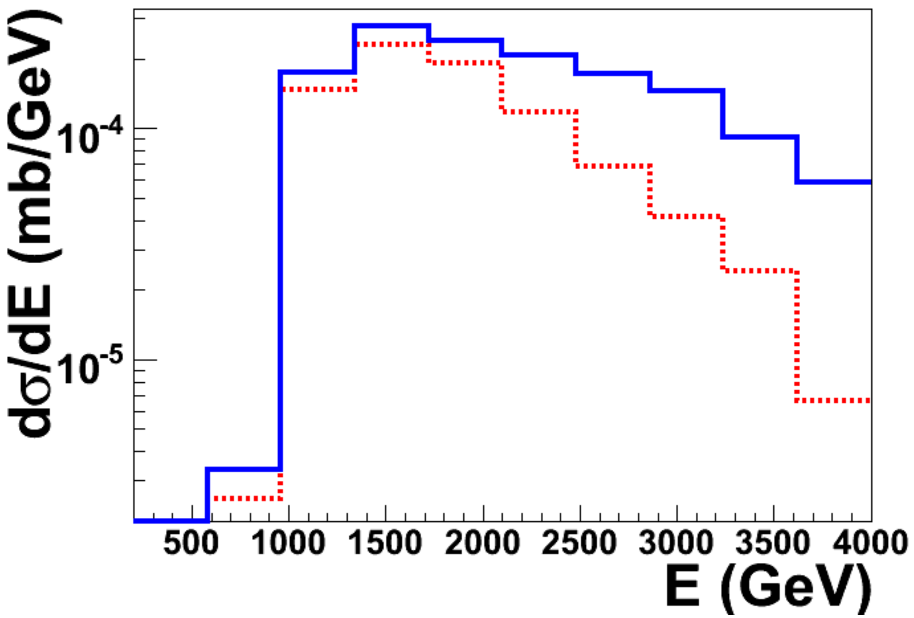
ARIADNE with the Color Dipole Model – giving a more BFKL like final state –
with partons unordered in kt – predicts more hard jets in the CASTOR region.

MC studies for LHC and CASTOR

Selection: 2 central jets, 1 jet in CASTOR region $(5.2 < \eta < 6.6)$
with $E_t > 10\ \mathrm{GeV}$

In addition require $$0.5 < \frac{E_{t,\text{forward jet}}}{< E_{t,\text{di-jet jets}} >} < 2.0$$





Supressing DGLAP like dynamics further. → Difference between DGLAP and CDM. already at low Et.

However...

A lot of free parameters in MC generators...

In order to make good MC predictions and understand the physics we need to tune/fit the implemented models.

Together with ***Krzysztof Kutak*** and ***Alessandro Bachetta*** we have developed a program (***SimpFit***) for fast fits of the gluon and tuning of MC models.

Working ground: Fitting the unintegrated gluon density used in CASCADE (CCFM) to H1 di-jet cross-sections

The unintegrated PDF

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)**
μ, σ: Determines the shape of the intrinsic k_T of the gluon below k_T= 1.2 GeV (fitted)

In CASCADE the uPDF is calculated for higher scales by emissions of gluons according to the CCFM evolution scheme.

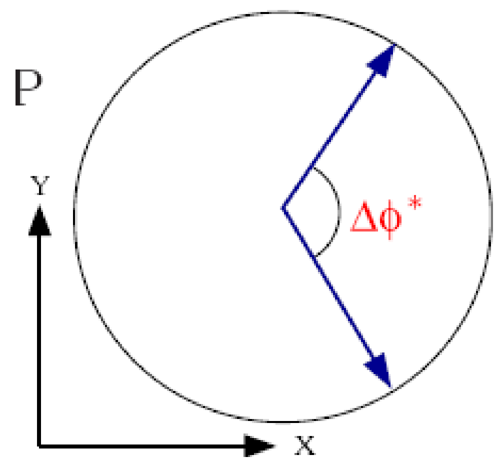
The parameters N,B,C, μ ,σ, are not theoretically calculable.

→ We need to fit the uPDF to experimental data.

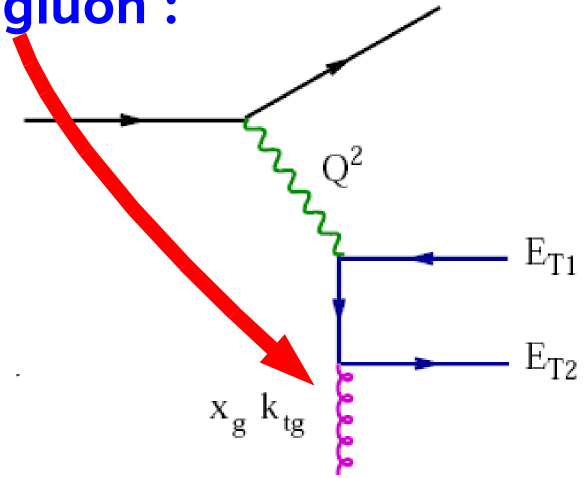
The Data – Dijets and azimuthal decorrelations

For development of fitting
procedure we are fitting
do preliminary H1 di-jet data.

Measure $\Delta\phi^*$ between the dijets:



Sensitivity to the gluon :



<u>Integrated PDF: DGLAP</u>

LO: **Gluon collinear with proton**

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

$$\Delta\Phi = 180^o \text{ in HCM}$$

Higher orders:

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

$$\Delta\Phi < 180^o$$

<u>Unintegrated PDF: CCFM or BFKL</u>

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

$$\Delta\Phi < 180^o$$

already at LO

Fitting (unintegrated) PDFs

The conventional fitting method:

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

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

If one CASCADE run takes 1 hour, the minimization takes 100hours.

To fit uPDF one needs exclusive measurements (like the azimuthal di-jet measurement)

$\longrightarrow$

A lot of statistics. Minimization >> 100h.

Fitting unintegrated PDFs

Alternative, faster method

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.

Based on a method suggested by Hendrik Hoeth
(1st Mcnet School, IPPP Durham, 18-20th April 2007)

Fitting unintegrated PDFs

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.**

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

A, B, C **and** D **are determined by fitting the polynomial to the parameter-xsection grid.**
This takes a *few seconds*.

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

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   A, B, C **and** D **are determined by fitting the polynomial to the parameter-xsection grid.**
   This takes a *few seconds*.

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

3. **Once the parameter space is described by a polynomial the parameters can be fitted to the data.**

   Also this takes only a few seconds.

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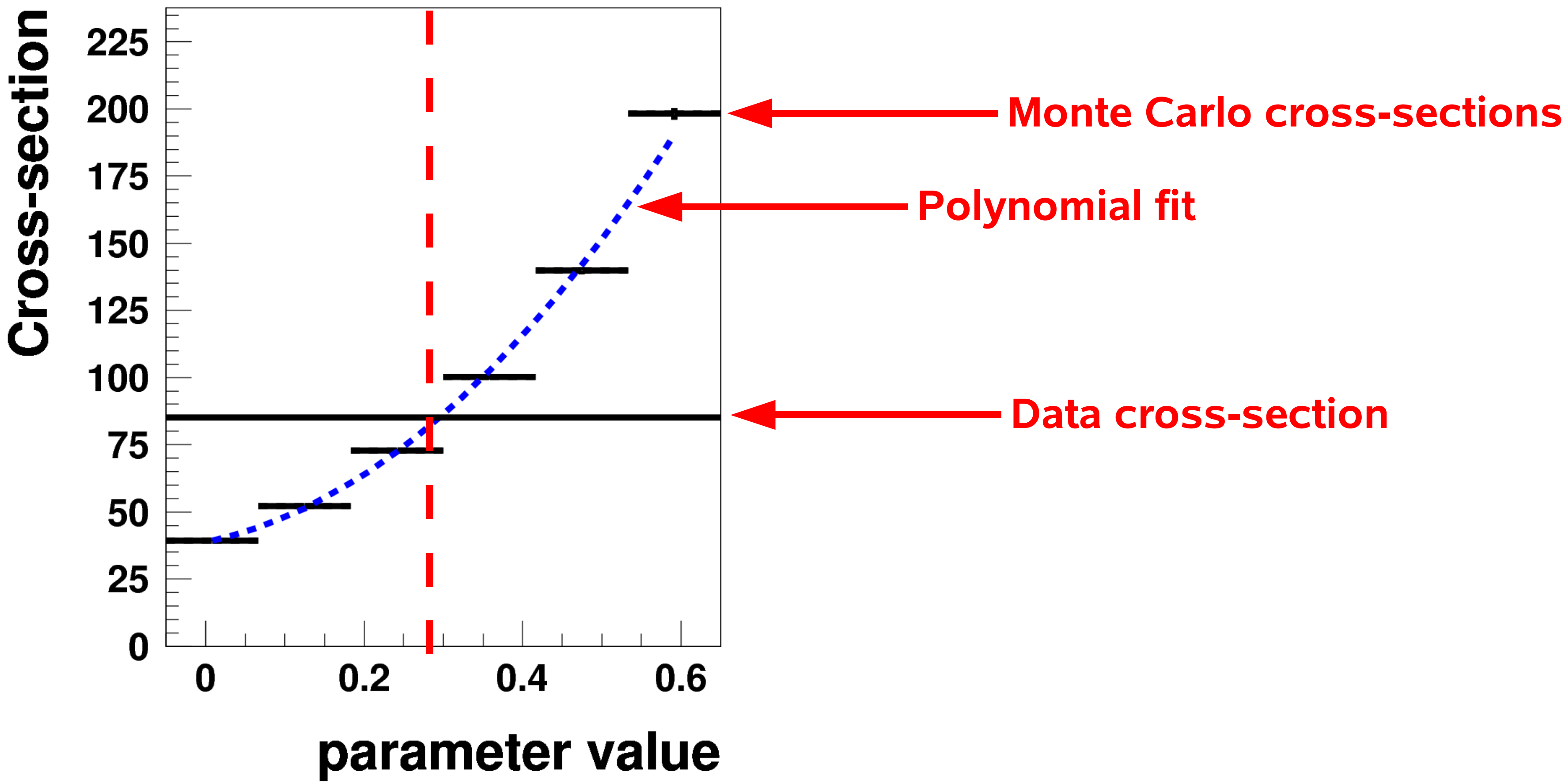
Simple Example

Simplest possible example

1 parameter, 1 data cross-section

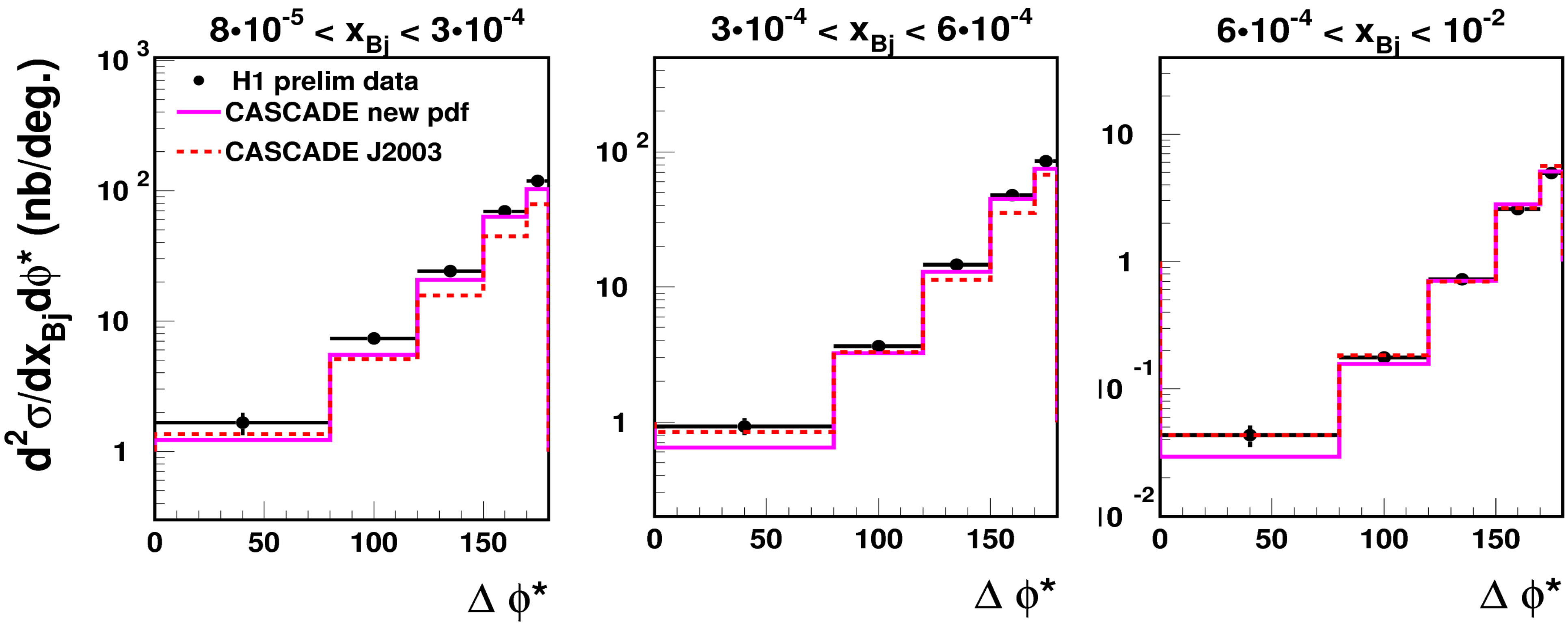


We do the same thing in 4 dimension

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

Fitting unintegrated PDFs

The results of the fit compared to data and the old uPDF

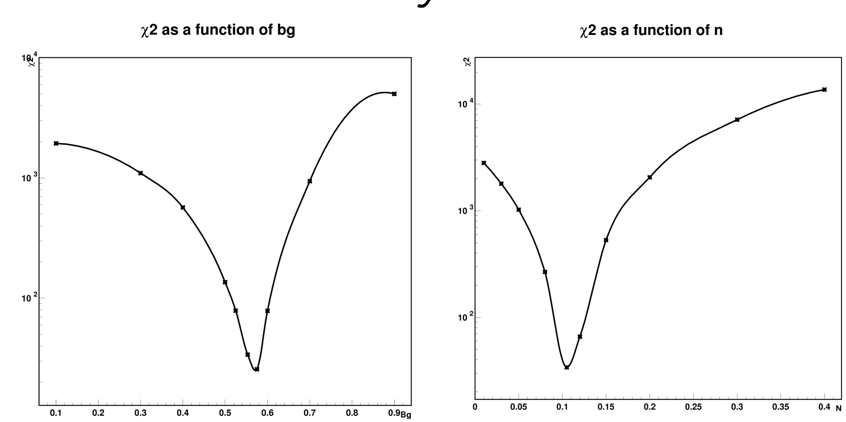


$$\chi^2 = 2.25$$

$$N = 0.11 \quad B_g = 0.55$$

$$\sigma = 1.5 \qquad \mu = 3.0$$

Confirmed by scans:



In the pipe-line: F2-charm fits, etc..

Summary

- Already at HERA signals for non-DGLAP like parton dynamics have been seen.
- Measuring forward jets in the CASTOR region may be a good tool search for parton dynamics beyond DGLAP.
- A new program for fast fits is developed, and will soon be available for everyone. It can be used to fit PDFs and tune Monte Carlo models.
- Already an improved determination of the unintegrated gluon has been carried out.

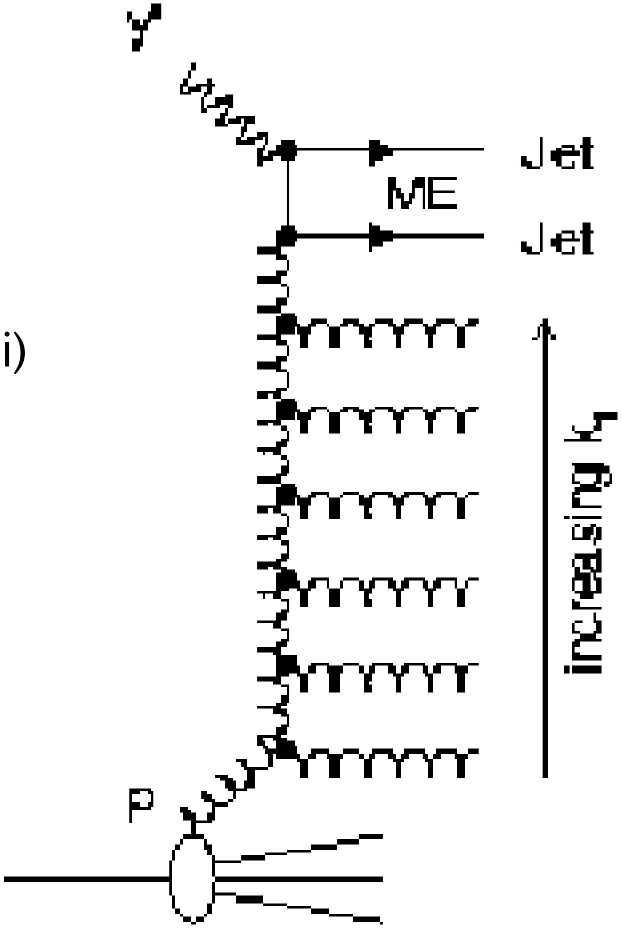
Unfinished backup slides

Summary Parton Dynamics

DGLAP (Dokschitzer-Gribov-Lipatov-Altarelli-Parisi)

Evolution equation resumming log(Q^2) terms, resulting in strong ordering of parton virtualities, and kt.

Implemented in for example:
RAPGAP (ep), PYHTIA(ep/pp)

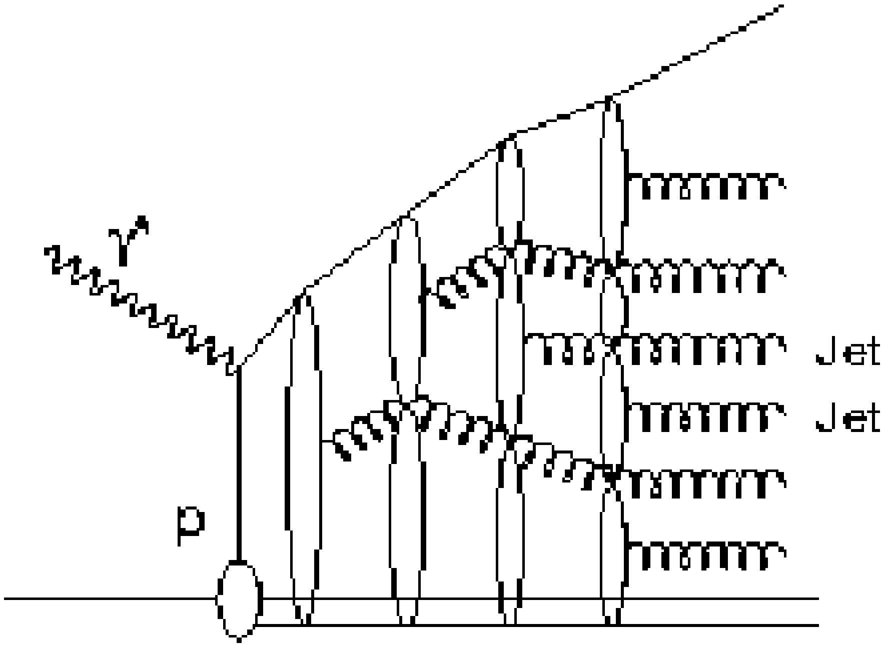


Summary Parton Dynamics

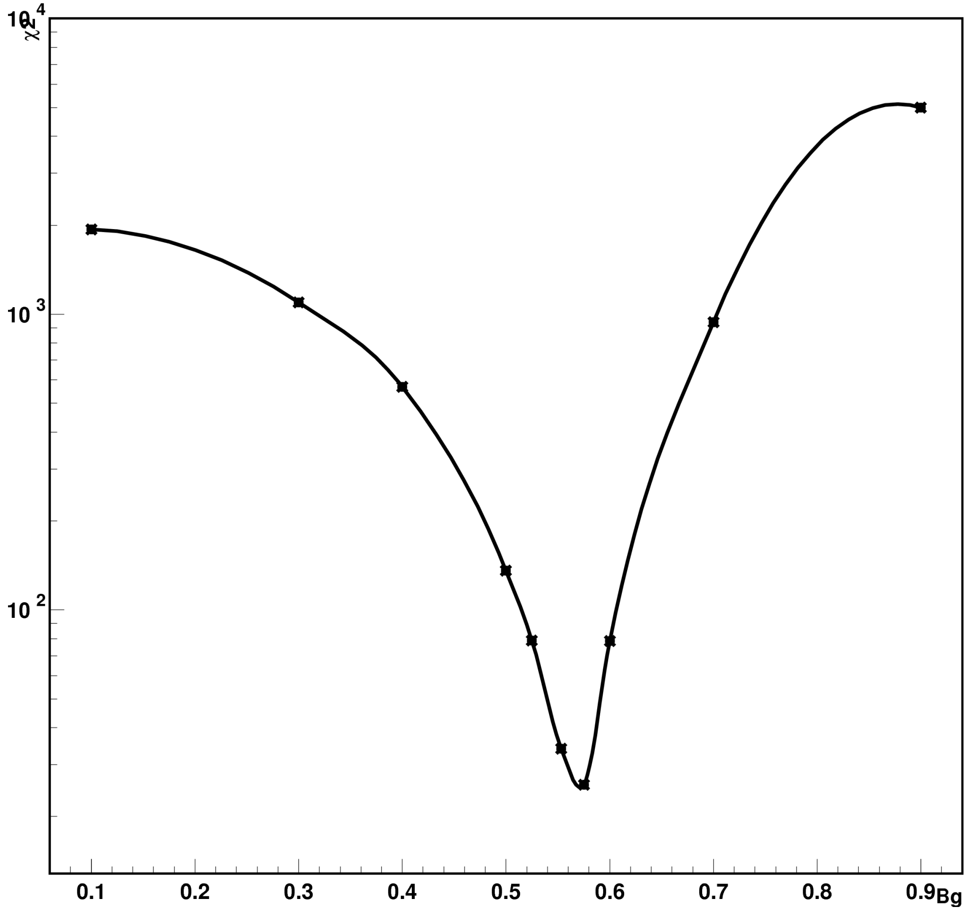
CDM (Color Dipole Model)

Radiation from decaying color dipoles,
resulting spanning of new color dipoles,
and a random walk in kt (BFKL like)

Implemented in ARIADNE



χ2 as a function of bg



χ2 as a function of n