

Transverse momentum of charged particles at low Q^2 at HERA (H1)

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on behalf of the H1 collaboration

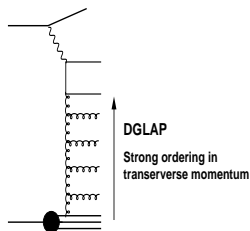
DIS 2010, Florence, Italy. April 2010

Outline

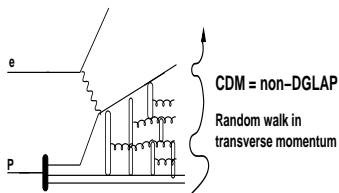
- Introduction and motivation
- Analysis details
- Results
- Summary

Evolution equations

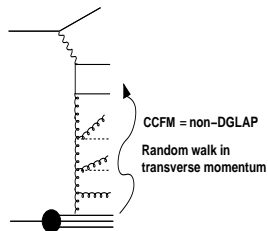
DGLAP



CDM (Color Dipole Model)



CCFM



DGLAP model (RAPGAP) $Q_0^2 \ll k_{T1}^2 \ll \dots \ll k_{Tn}^2 \ll Q^2$

DGLAP works when Q^2 is large, but x is not too small

beyond-DGLAP models (random walk in k_T)

- CDM (Color Dipole Model) (DJANGO-CDM)
(not evolution equation, but gives BFKL-like final state)
works for small x and Q^2 is not large
- CCFM (CASCADE) $\xi_0 < \xi_1 < \dots < \xi_n < \Xi$
Valid for both, small and large x

HFS as an access to the dynamics of the cascade

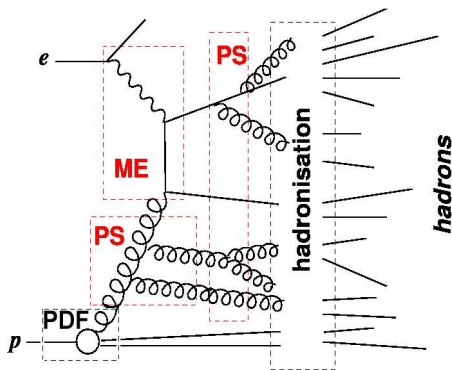
$F_2(x, Q^2)$ has too little sensitivity to discriminate between DGLAP and beyond-DGLAP. Semi-inclusive measurements $ep \rightarrow e' hX$ are believed to possess higher discriminating power.

The observables for physics beyond DGLAP at HERA:

- Transverse energy flow
- Forward jets with $p_{Tjet}^2 \sim Q^2$
- Transverse momentum spectra:

Hadrons at large p_T :
disfavoured by the strong p_T ordering \rightarrow difference between different parton dynamics

Low p_T region:
hadronisation effects are expected to play a role.
Small sensitivity to different parton dynamic models.



Experimental setup and reconstruction

- HERA beam energies: $E_e = 27.6$ GeV, $E_p = 920$ GeV
- Data 2006e⁺: $L = 88.64$ pb⁻¹

- *Scattered electron*

Information from scattered electron (E'_e, θ'_e) is used to reconstruct the kinematics:

$$Q_e^2 = 4E_e E'_e \cos^2 \frac{\theta'_e}{2}$$

$$y_e = 1 - \frac{E_e}{E'_e} \sin^2 \frac{\theta'_e}{2}$$

In this analysis:

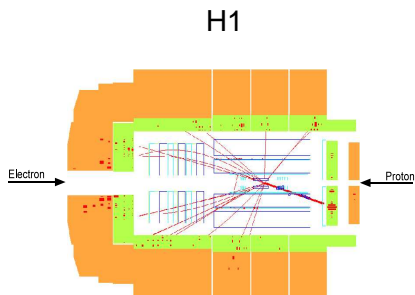
$$5 < Q^2 < 100 \text{ GeV}^2, 0.05 < y < 0.7$$

- *For charged particles*

Only central tracks are analysed.

Track selection:

$$p_T > 0.15 \text{ GeV}, 20^\circ < \Theta < 155^\circ$$



Reference frames

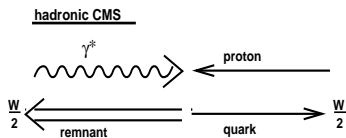
- Laboratory frame:

$$\eta = -\ln \tan\left(\frac{\theta}{2}\right)$$

θ - with respect to proton direction

$\eta > 0 \Leftrightarrow$ proton direction

- Hadronic centre-mass system (HCM):



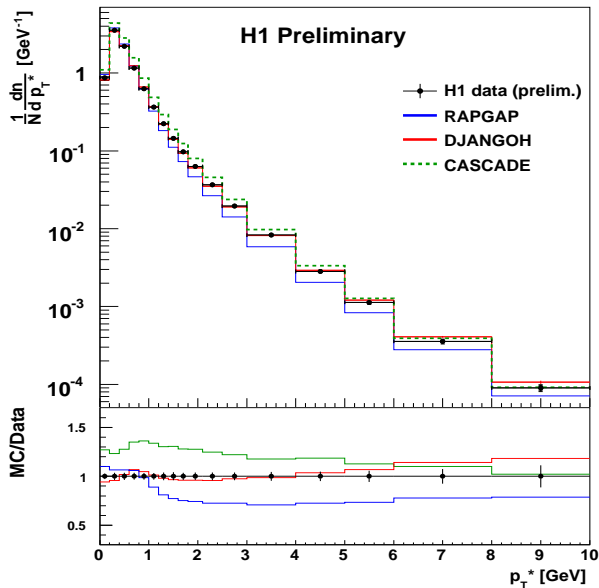
$$\eta^* = -\ln \tan\left(\frac{\theta^*}{2}\right)$$

θ^* - with respect to virtual photon direction

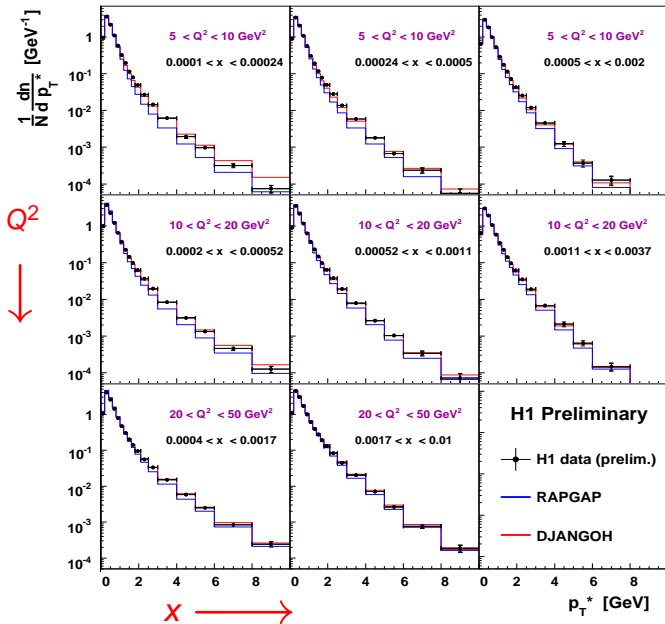
$\eta^* < 0 \Leftrightarrow$ proton direction

η^* region: $0 < \eta^* < 6$;

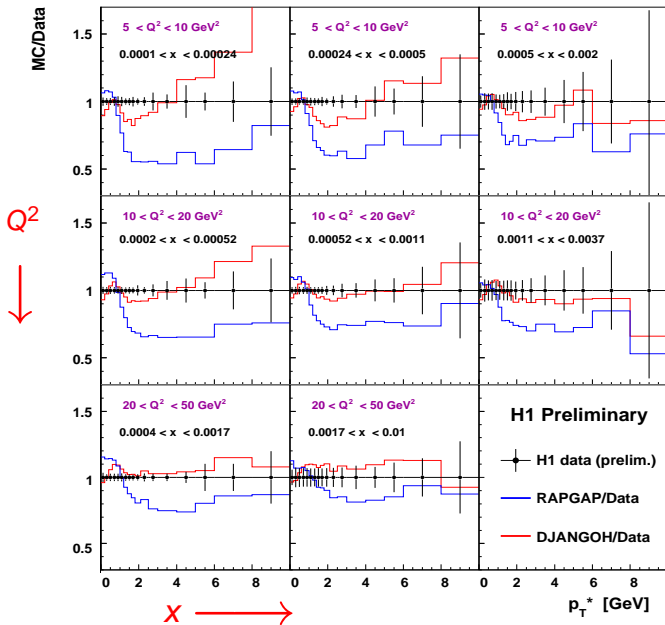
p_T^* distribution is studied in $1.5 < \eta^* < 2.5$ region

p_T^* spectra: DATA vs. DJANGO/RAPGAP/CASCADE

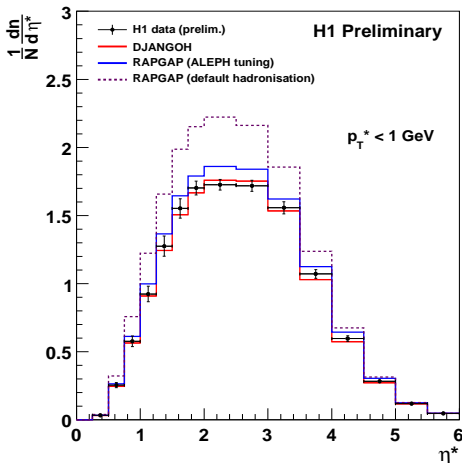
- DJANGO(CDM) describes new data for whole p_T^* spectra
- RAPGAP(DGLAP) is below the data for $p_T^* > 1 \text{ GeV}$
- In contrast, CASCADE(CCFM) is systematically above the data

p_T^* distribution in bins of (x, Q^2) 

RAPGAP(DGLAP) is below the data at lowest x and Q^2 region

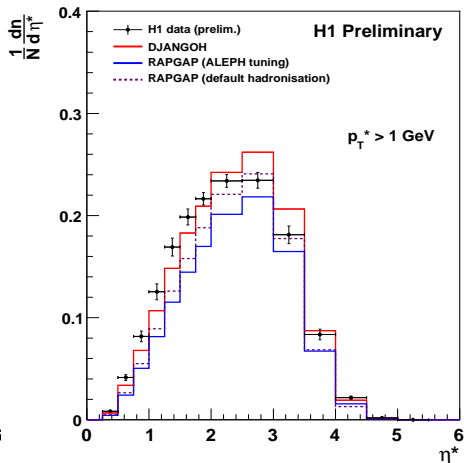
ratios of p_T^* distribution in bins of (x, Q^2) 

Strongest
disagreement
between both models
and the data at high
 p_T^* at low Q^2 and
low x

η^* - distributionsCharged particles with $p_T^* < 1$ GeV:

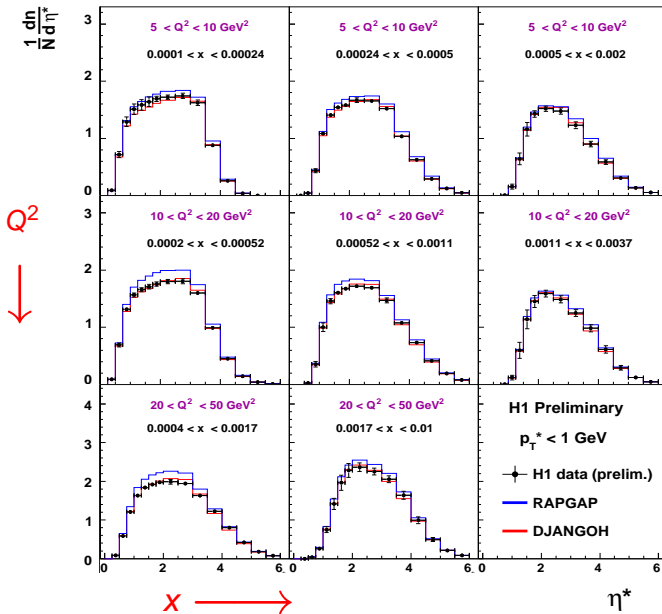
Strong sensitivity to hadronisation parameters.

Weak sensitivity to different parton dynamics.

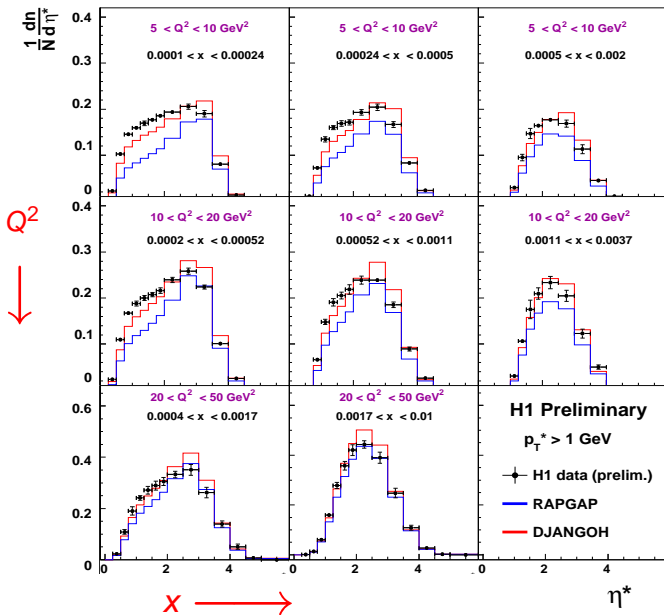
Charged particles with $p_T^* > 1$ GeV:

Strong sensitivity to different parton dynamics.

Weak sensitivity to hadronisation parameters.

η^* distribution in bins of (x, Q^2) for $p_T^* < 1$ GeV

Both RAPGAP(DGLAP) and DJANGO(CDM) provide reasonable description of the data for all (x, Q^2) -bins

η^* distribution in bins of (x, Q^2) for $p_T^* > 1$ GeV;

RAPGAP(DGLAP) is below the data for almost all (x, Q^2) -bins (except last 2 bins). The difference is more pronounced in forward direction ($\eta^* < 2$)

Summary

- Transverse momenta and rapidity spectra were measured with H1 detector at HERA (2006 e^+p data)
 - Obtained distributions, overall and for various (x, Q^2) -regions, are used to discriminate DGLAP and beyond DGLAP dynamics
 - Low p_T^* region ($p_T^* < 1$ GeV):
 - Both RAPGAP(DGLAP) and DJANGO(CDM) provide good description of the data for both p_T^* and η^* distributions
 - More studies needed for CASCADE
 - η^* distribution is sensitive to the fragmentation parameters
 - Hard p_T^* region ($p_T^* > 1$ GeV):
 - DJANGO(CDM) is better than RAPGAP(DGLAP) in describing both, p_T^* and η^* measured spectra, especially at low x
- data are in favor of beyond DGLAP models

Back up slides

Systematic errors

- Blue - uncertainties taken from publication DESY-09-162
- Red - resulting systematic errors

Source of the errors	$\frac{1}{N} \frac{dn}{dp_T^*}$	$\frac{1}{N} \frac{dn}{d\eta^*}, \text{soft}$	$\frac{1}{N} \frac{dn}{d\eta^*}, \text{hard}$
Model dependence (DJANGO, RAPGAP)	1.2 %	1.5	2.5
Hadronic energy scale ($\pm 2\%$)	0.05 %	0.2	0.3
SPACAL em energy scale ($\pm 1\%$)	3.6 %	3.2	4.5
Angle of scattered positron (± 1 mrad)	0.05 %	0.04	0.07
Tracking uncertainty ($\pm 2\%$)	2.0 %	1.8	1.9
Total error	4.3 %	3.9 %	5.4 %