Measurement of Charged Particle Spectra in Deep-Inelastic *ep* scattering at HERA

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Charged particle spectra in DIS

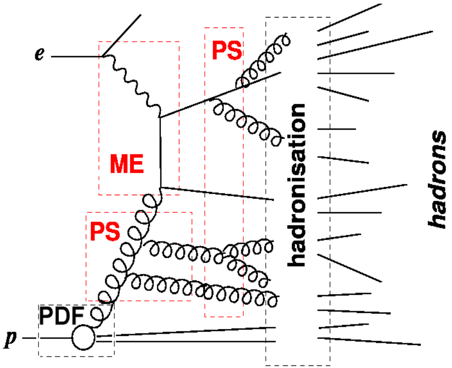
Measurement of hadron production in DIS constrain

Low p_T region:

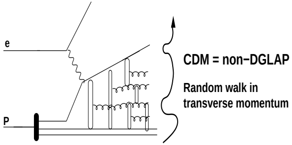
- hadronisation effects are expected to play a role
- small sensitivity to different parton dynamic models

Large p_T region:

- disfavoured by the strong p_T ordering → difference between different parton dynamics



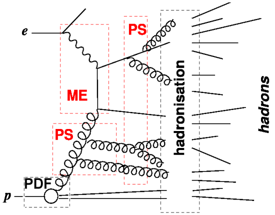
Models for *ep* scattering

MC programs	ME	Parton cascade	Hadronisation
RAPGAP	LO	DGLAP	Lund string
CASCADE	LO(off-shell)	CCFM	
DJANGOH	LO	Dipole (BFKL-like) 	
Herwig++	LO(Powheg)	DGLAP	cluster

Fragmentation parameters are tuned to e^+e^- data (ALEPH tune)

The observables for physics beyond DGLAP at HERA:

- Transverse energy flow
- Forward jets
- Charged particle spectra

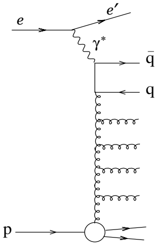


Analysis details

H1 Collaboration EPJC 73 (2013) 2406

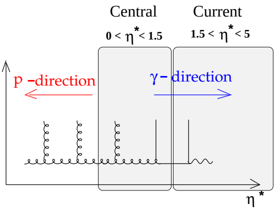
Kinematic range: $ep \to e'X$

- E_e = 26.7 GeV; E_p = 920 GeV, $\sqrt{s} = 319$ GeV
- $5 < Q^2 < 100$ GeV^2
  $10^{-4} < x_{bj} < 10^{-2}$
  $0.05 < y < 0.6$
- charged particles: $-2 < \eta < 2.5$ and $p_T > 0.15$ GeV in lab-frame

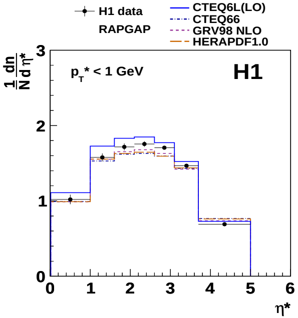


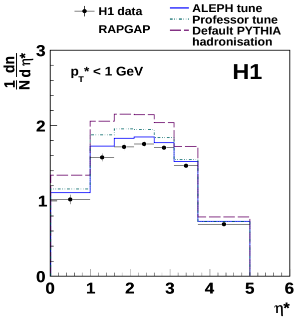
Measurement is performed in hadronic center-of-mass frame ($\gamma^* p$ rest frame)

- p_T^* and η^*
- $\eta^* < 0$: target (p-remnant) hemisphere
- $\eta^* > 0$: γ hemisphere
  - central: $0 < \eta^* < 1.5$
  - current: $1.5 < \eta^* < 5$



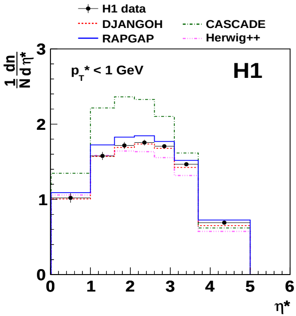
η^* distribution for $p_T^* < 1$ GeV; PDF and hardonisation uncertainties





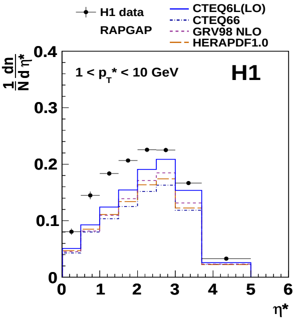
Soft p_T^*

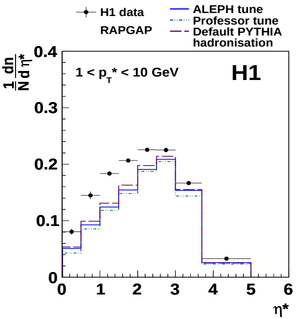
- $\sim$ flat plateau
- small dependence on parton densities
- large hadronisation uncertainty



All parton shower models, except CASCADE, describe data within the PDF and hadronisation uncertainty

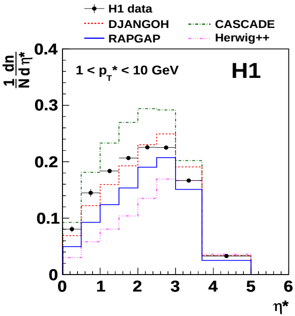
η^* distribution for $p_T^* > 1$ GeV; PDF and hardonisation uncertainties





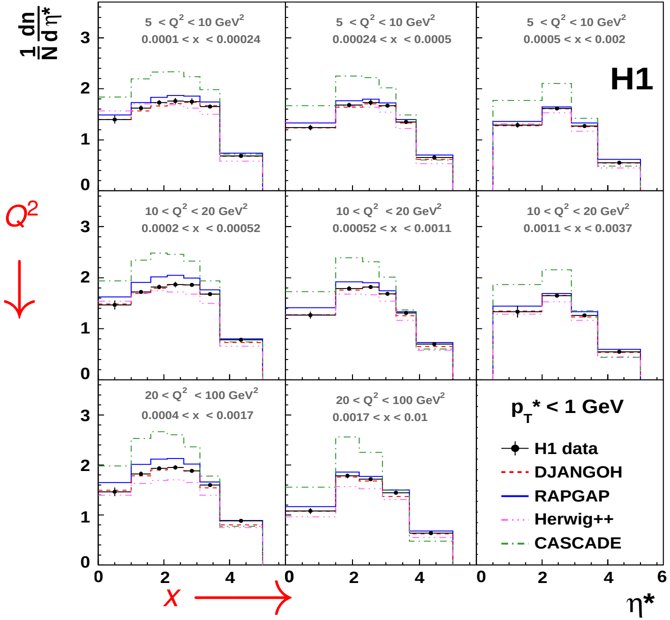
Large p_T^*

- slightly larger dependence on parton densities
- small hadronisation uncertainty



- Strong sensitivity to different parton dynamics
- Models with collinear parton shower fail to describe the measurement

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



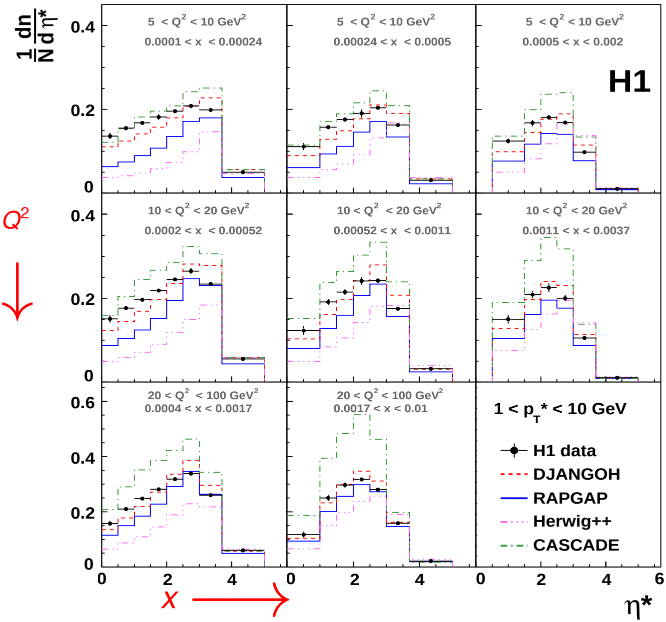
Soft p_T^*

- DJANGOH (CDM)
- RAPGAP (DGLAP)
- Herwig++ (DGLAP)
- CASCADE (CCFM)

Plateau size shrinks with increasing Q^2

All parton shower models, except CASCADE, describe data in all (x, Q^2) regions

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



Large p_T^*

DJANGOH (CDM)
RAPGAP (DGLAP)
Herwig++ (DGLAP)
CASCADE (CCFM)

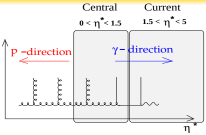
Models with collinear parton shower are below the data at small η^* and small Q^2, while become better at large Q^2

CASCADE(CCFM) is good at small η^* and small Q^2

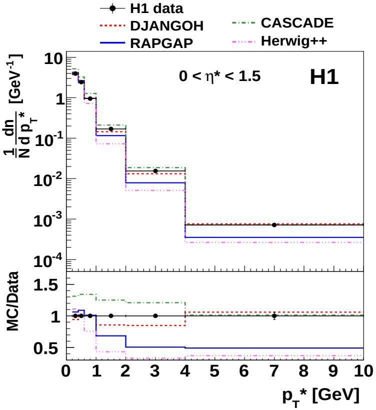
Color Dipole Model is reasonable over full range

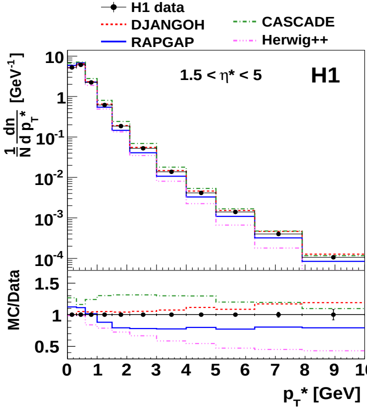
p_T^* distribution

Region sensitive to parton shower:



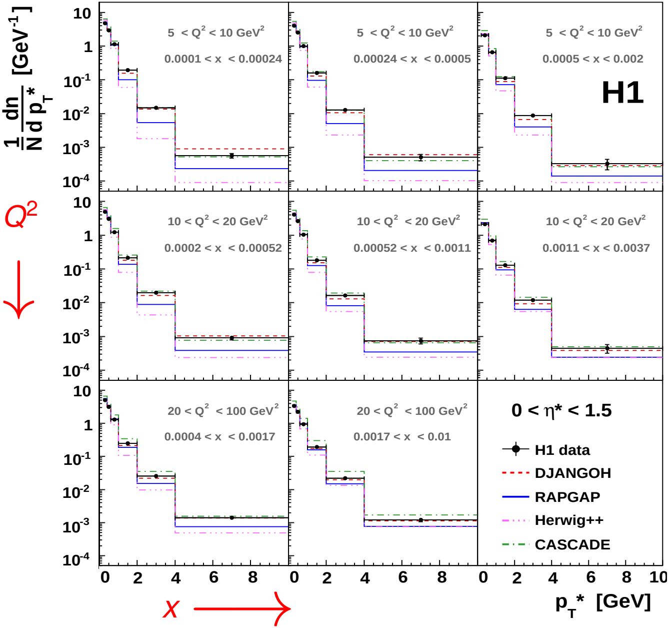
Region sensitive to hard scattering:

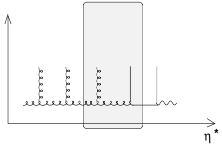




- Color Dipole Model describes the data for whole p_T^* spectra
- Models with collinear parton shower are below the data for $p_T^* > 1$ GeV (especially in the central region)

p_T^* distribution in bins of (x, Q^2); $0 < \eta^* < 1.5$

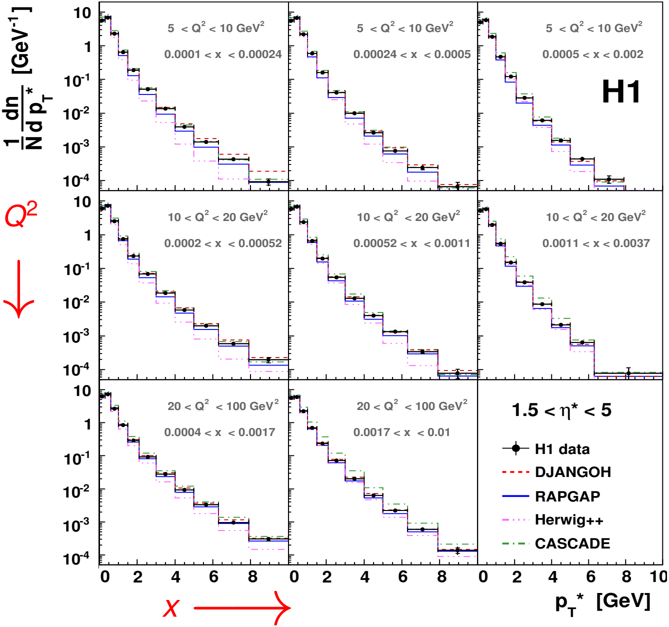


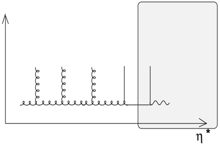


DJANGOH (CDM)
RAPGAP (DGLAP)
Herwig++ (DGLAP)
CASCADE (CCFM)

Models with collinear parton shower are substantially below the data at lowest x and Q^2 region for high p_T^*

p_T^* distribution in bins of (x, Q^2); $1.5 < \eta^* < 5$





DJANGOH (CDM)

RAPGAP (DGLAP)

Herwig++ (DGLAP)

CASCADE (CCFM)

Better description of the data by the models compared to the central region

Summary

- Transverse momenta and rapidity spectra were measured with H1 detector at HERA
- Low p_T^* region ($p_T^* < 1$ GeV):
  - Sensitivity to the fragmentation parameters
  - All parton shower models, except CCFM PS model, provide reasonable description of the data
- Hard p_T^* region ($1 < p_T^* < 10$ GeV):
  - Sensitivity to the different parton dynamic models
  - Collinear parton shower models fail to describe the data
  - Color Dipole Model is better than other models in describing both p_T^* and η^* measured spectra especially at low x