Scaled Charged Particle Momentum Distributions at High Q^2 at HERA (H1)

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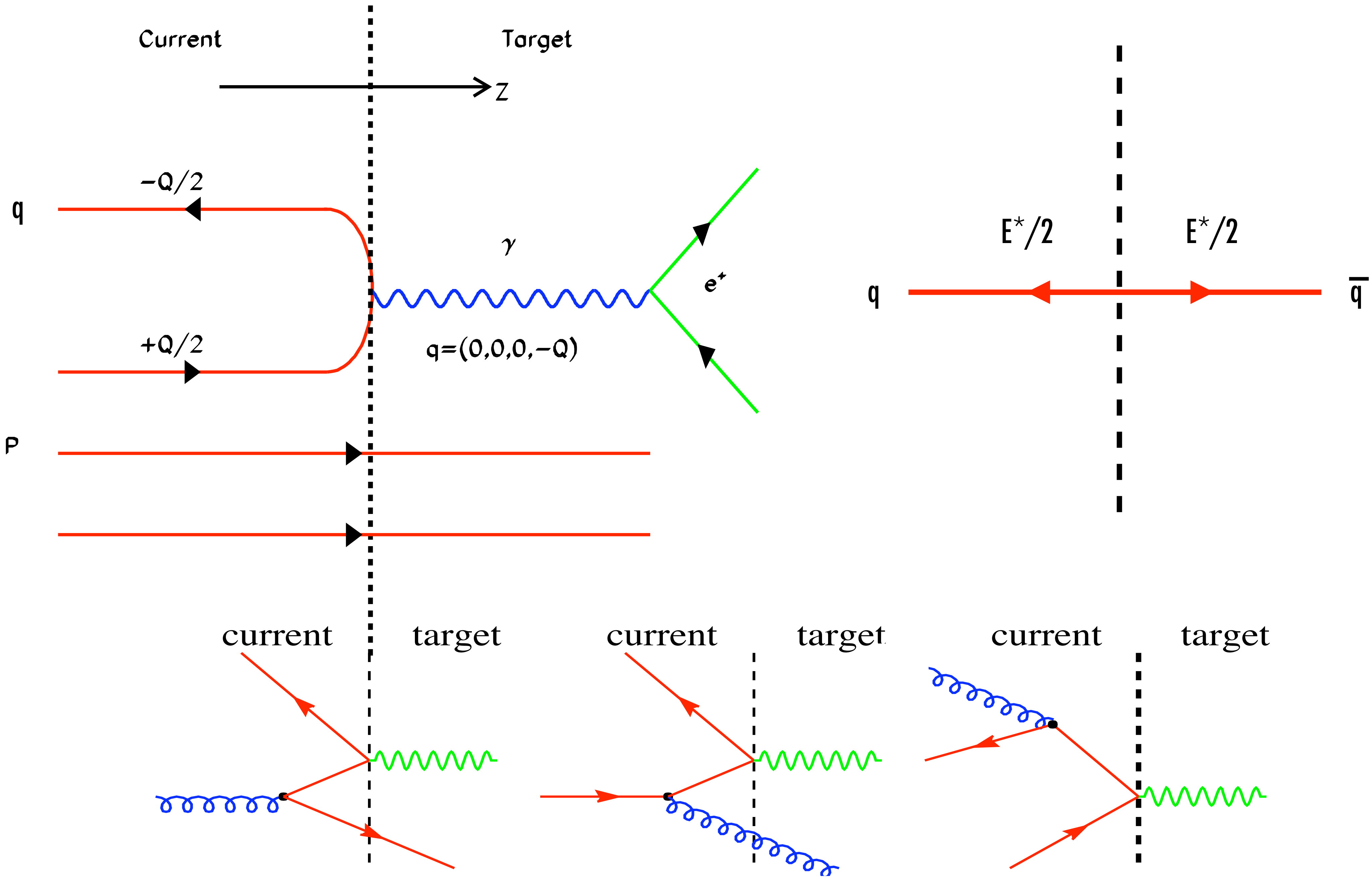
Motivation

- Parton splitting in pQCD causes scaling violations in structure functions. Also seen in fragmentation functions. Test pQCD
- Quark fragmentation universality and test of factorisation comparison with e+e- results. Test QCD
- Test of fragmentation (CDM/ PS) and hadronisation (String/Cluster) models and there tuning. Test npQCD

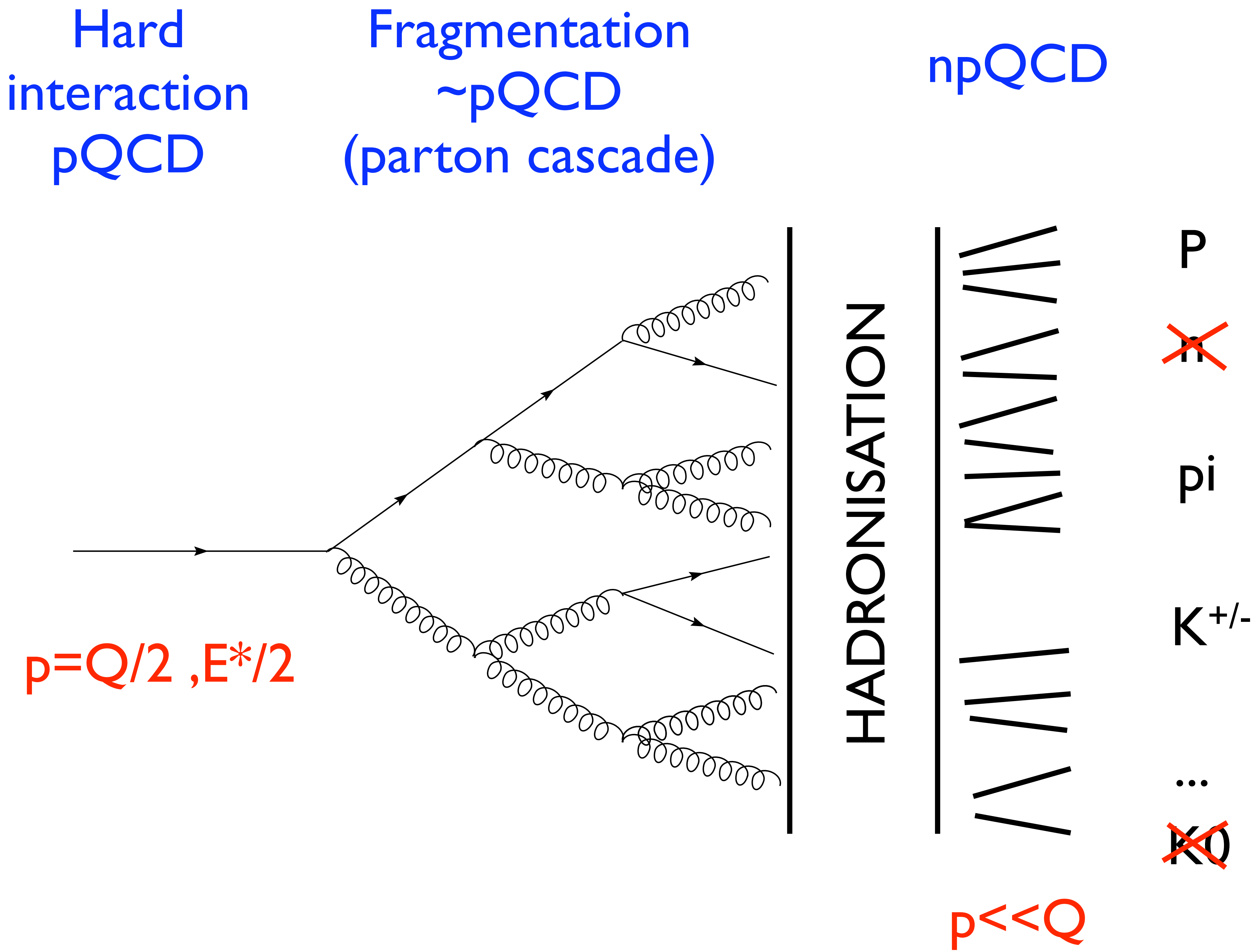
Breit Frame



Boson Gluon Fusion (BGF)

Initial state Compton QCD (ICQCD)

Final state Compton QCD (FCQCD)


Hard interaction pQCD
Fragmentation ~pQCD (parton cascade)
npQCD
HADRONISATION
P
n
pi
K+/-
...
K0
p=Q/2 ,E*/2
p<<Q

Observable $D(x_p)$

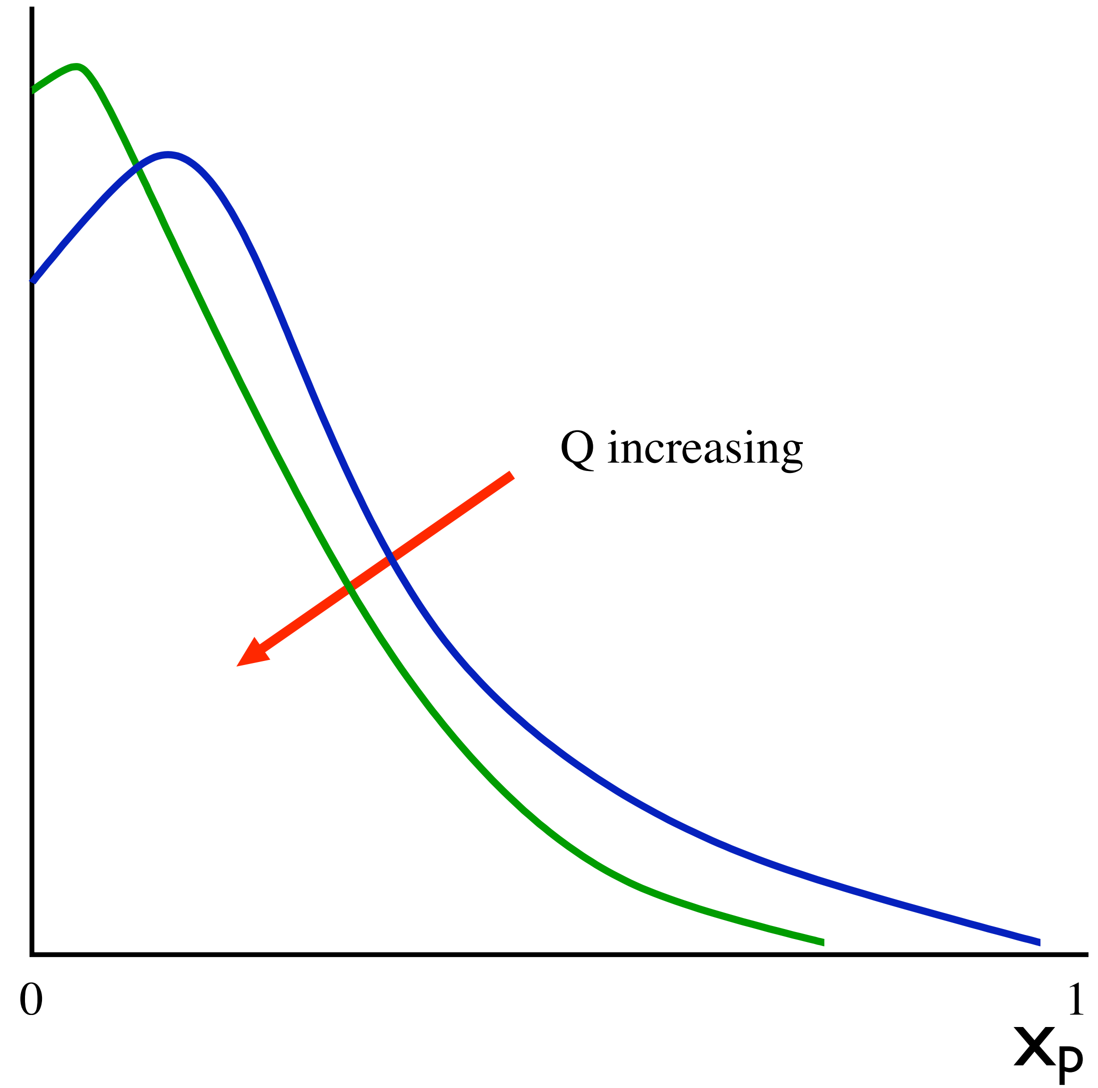
$$x_p = \frac{(2P_h)}{Q}$$

$$D(x_p) = \frac{1}{N_{event}} dn/dx_p$$

x_p = scaled momentum variable

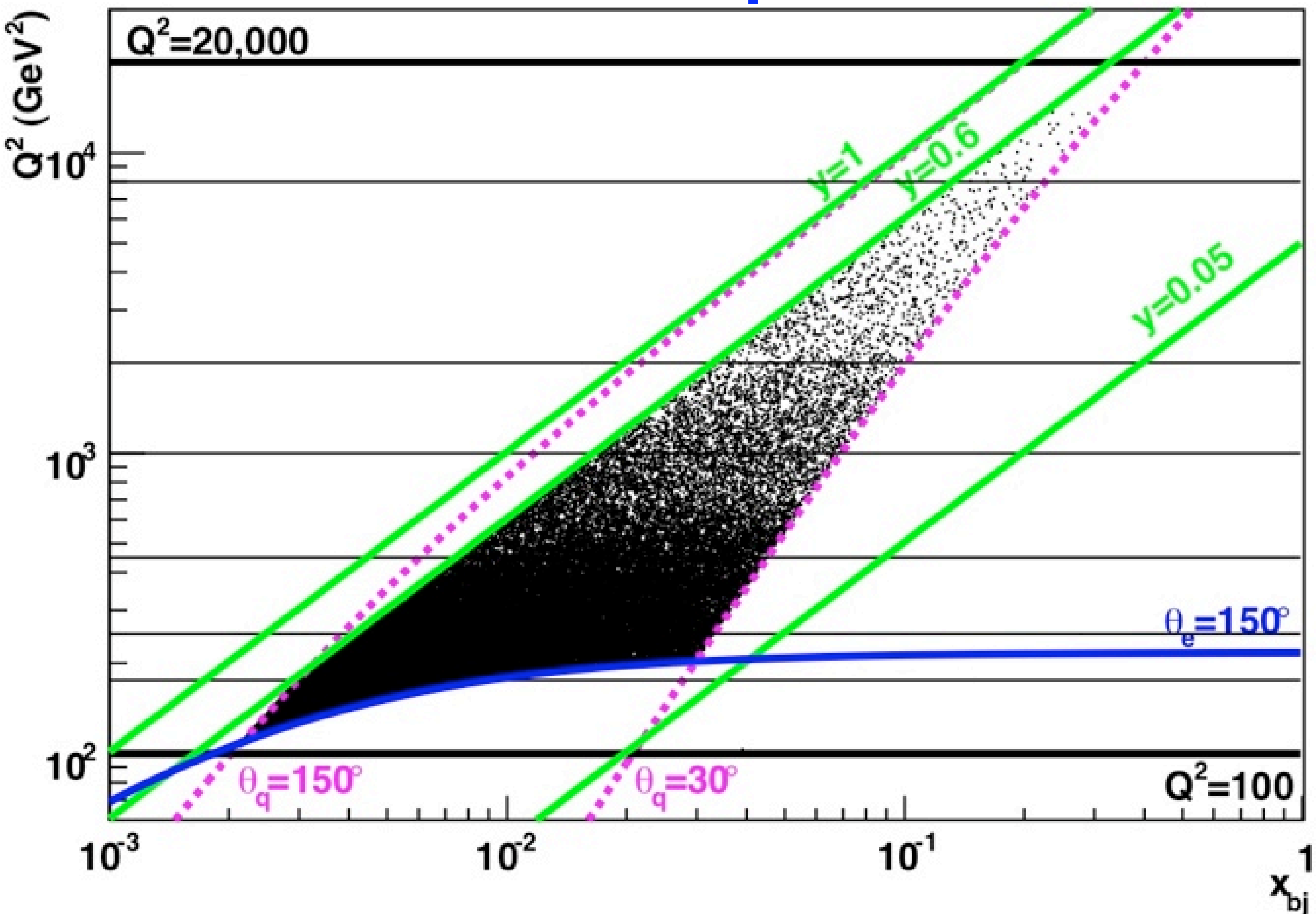
Q = Scale in current region of Breit Frame

p_h = momentum of charged track in current region of Breit Frame



D(xp) = event normalised, charged particle, scaled momentum spectrum

Phase Space



$100 < Q^2 < 20{,}000\ \mathrm{GeV}^2$ $y < 0.6$ $30^\circ < \theta_{quark} < 150^\circ$

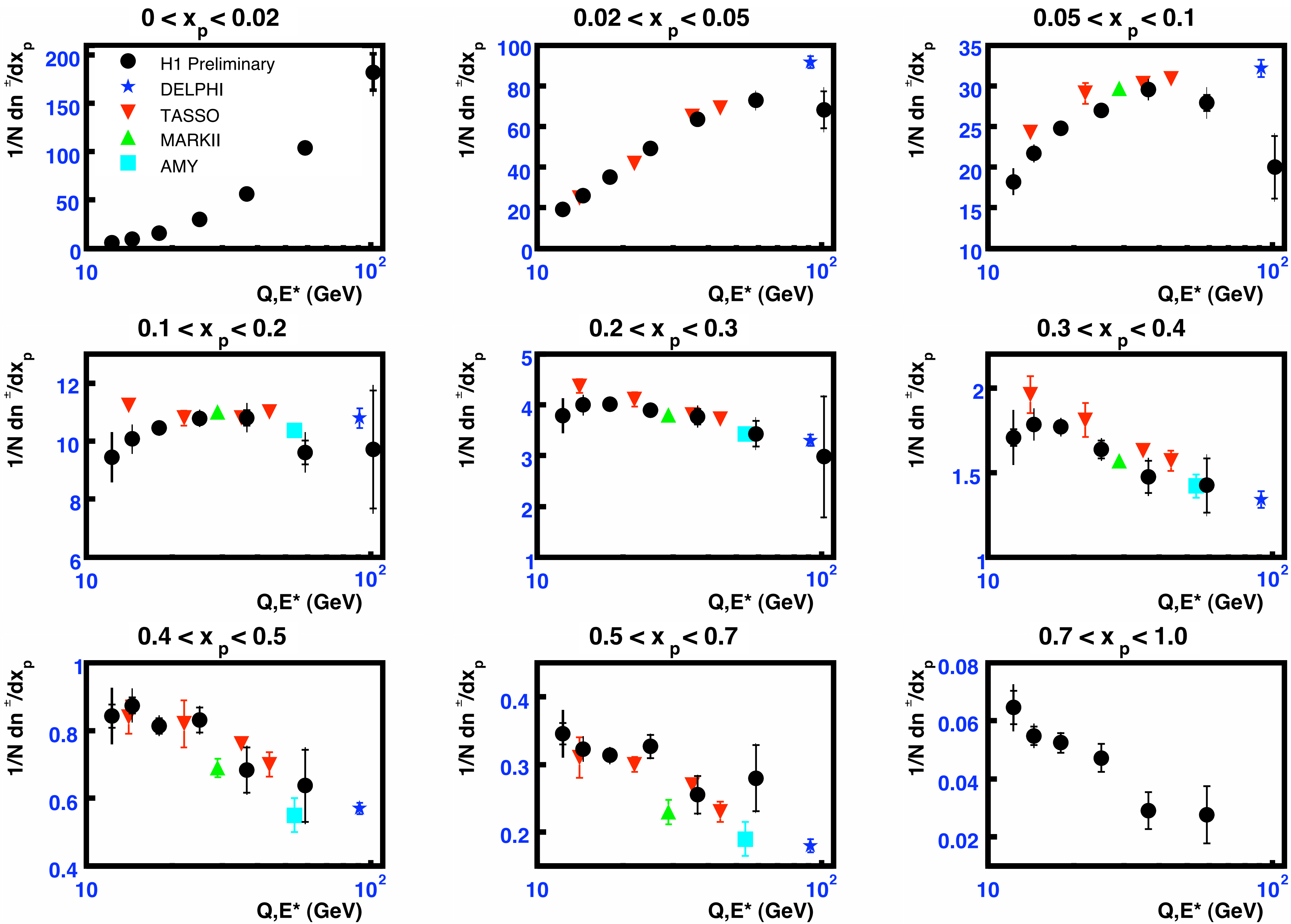
$\theta_{electron} < 150^\circ$ $p_{t,lab} > 120$ MeV $p_{t,Breit} > 0$ MeV

Compare to e^+e^-

How does 1 hemisphere of $e^+e^- \to q\bar{q}$
compare to current region of Brit frame?

e+e- experiments:
TASSO E*= 14, 22, 35, 44 GeV
MARKII E*= 29 GeV
AMY E*= 54GeV
DELPHI E*= 91 GeV

Physics differences :
quark source proton PDF not vacuum !
+ ICQCD and BGF !



0 < x_p < 0.02
0.02 < x_p < 0.05
0.05 < x_p < 0.1
0.1 < x_p < 0.2
0.2 < x_p < 0.3
0.3 < x_p < 0.4
0.4 < x_p < 0.5
0.5 < x_p < 0.7
0.7 < x_p < 1.0
H1 Preliminary
DELPHI
TASSO
MARKII
AMY
1/N dn ±/dx_p
Q,E* (GeV)

- Moving from low to high Q spectra becomes softer. More particles with a lower share of the total momentum. Scaling violations.
- e^+e^- data show same behaviour (slightly softer?).
- Good demonstration of quark fragmentation universality.
- Possible discrepancy between ep and e^+e^- at low Q (BGF / ICQCD?)

Hadronisation Models

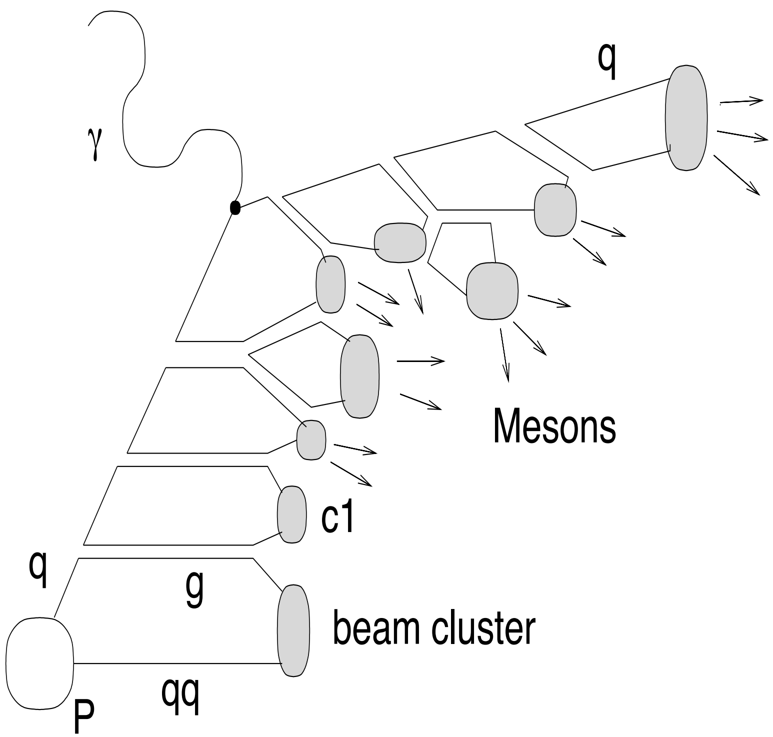
To take into account physics differences use Monte Carlo fragmentation model steering has been tuned to e+e-.

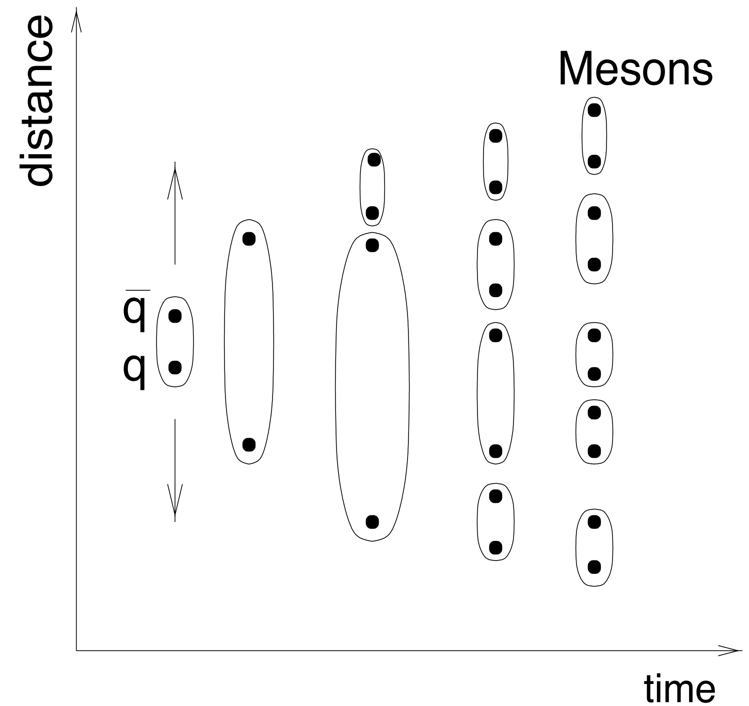
HERWIG (v6.5)
LO ME + parton shower + cluster hadronisation

RAPGAP (v3.1)
LO ME + parton shower + string hadronisation

CTEQ5L PDF used throughout

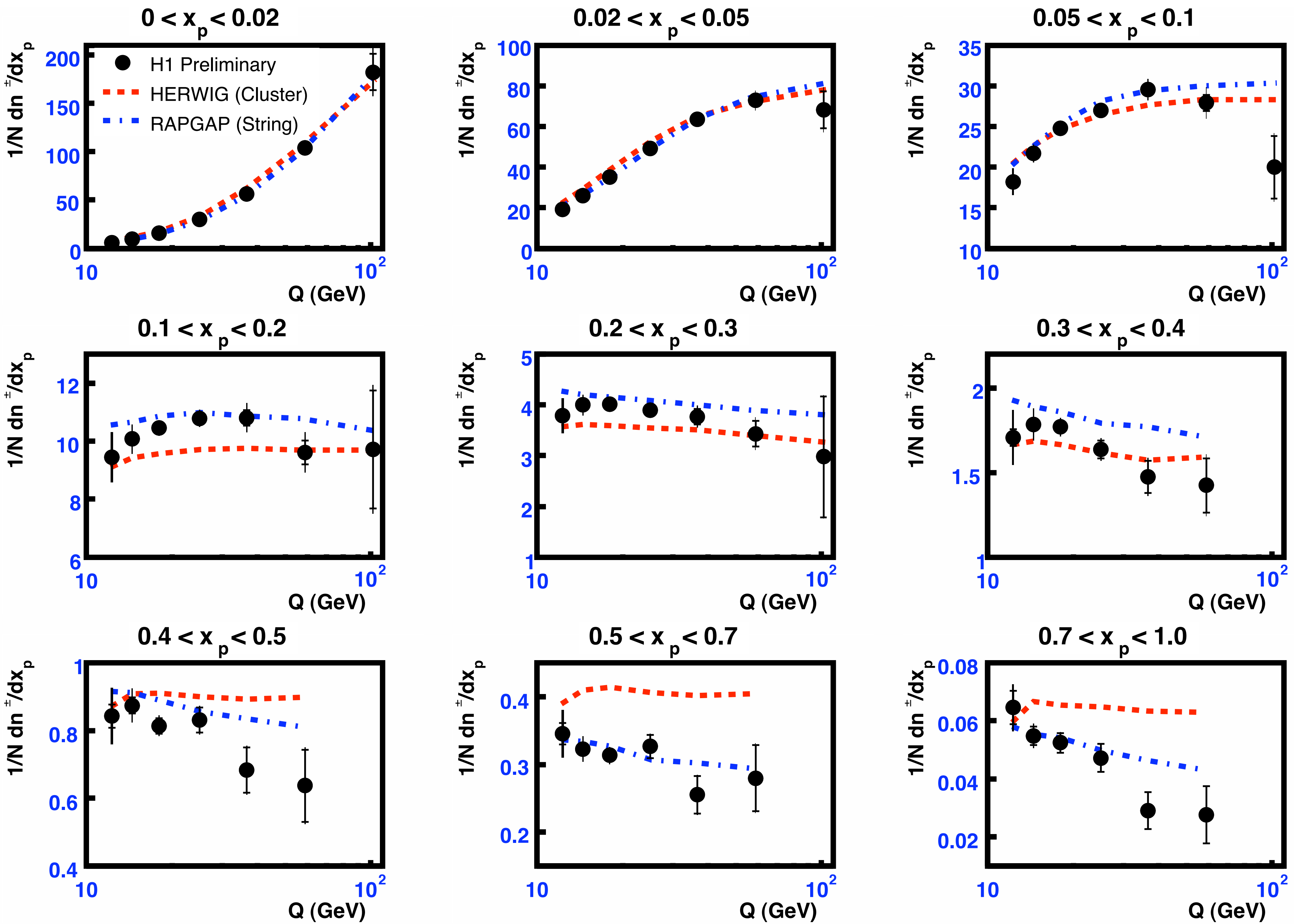
Hadronisation Models





Cluster Hadronisation

String Hadronisation



0 < x p < 0.02
0.02 < x p < 0.05
0.05 < x p < 0.1
0.1 < x p < 0.2
0.2 < x p < 0.3
0.3 < x p < 0.4
0.4 < x p < 0.5
0.5 < x p < 0.7
0.7 < x p < 1.0
1/N dn ±/dx p
Q (GeV)
H1 Preliminary
HERWIG (Cluster)
RAPGAP (String)

- ☑ Both models describe low x_p data (phase space limits hadron production).
- ☑ RAPGAP give a good description of the data.
- ☐ At high x_p HERWIG spectrum is too hard! HERWIG also looks very flat (where is the QCD?).

Parton Cascade Models

RAPGAP (v3.1)
LO ME + parton shower + string hadronisation

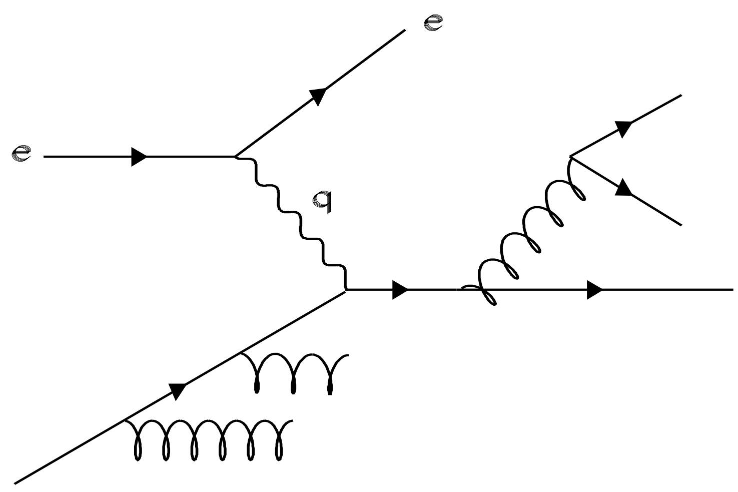
LEPTO (6.5)
LO ME + parton shower + soft colour interactions + string

DJANGO (H1.4)
LO ME + colour dipole model + string hadronisation

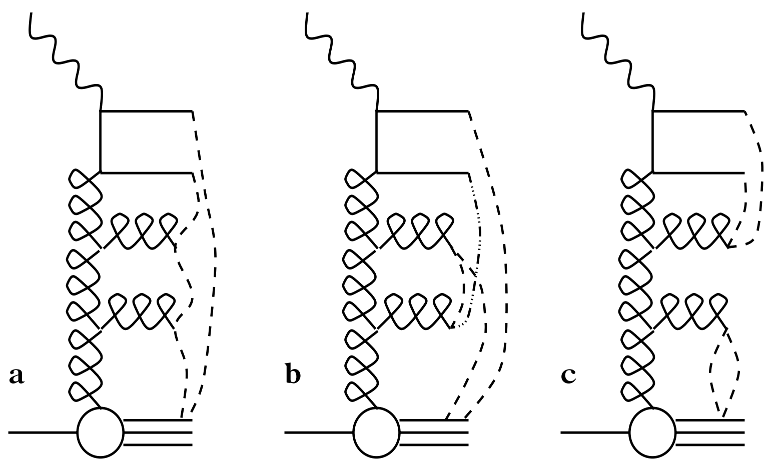
Monte Carlo models tuned to e+e- data

CTEQ5L PDF used throughout

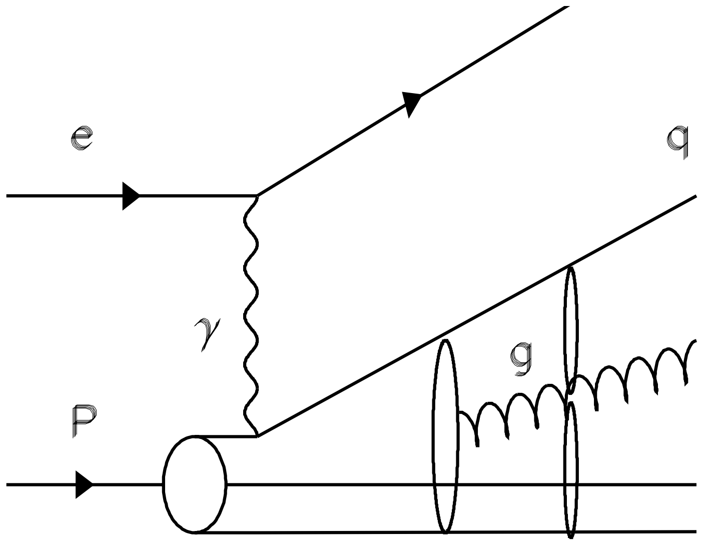
Parton Cascade Models



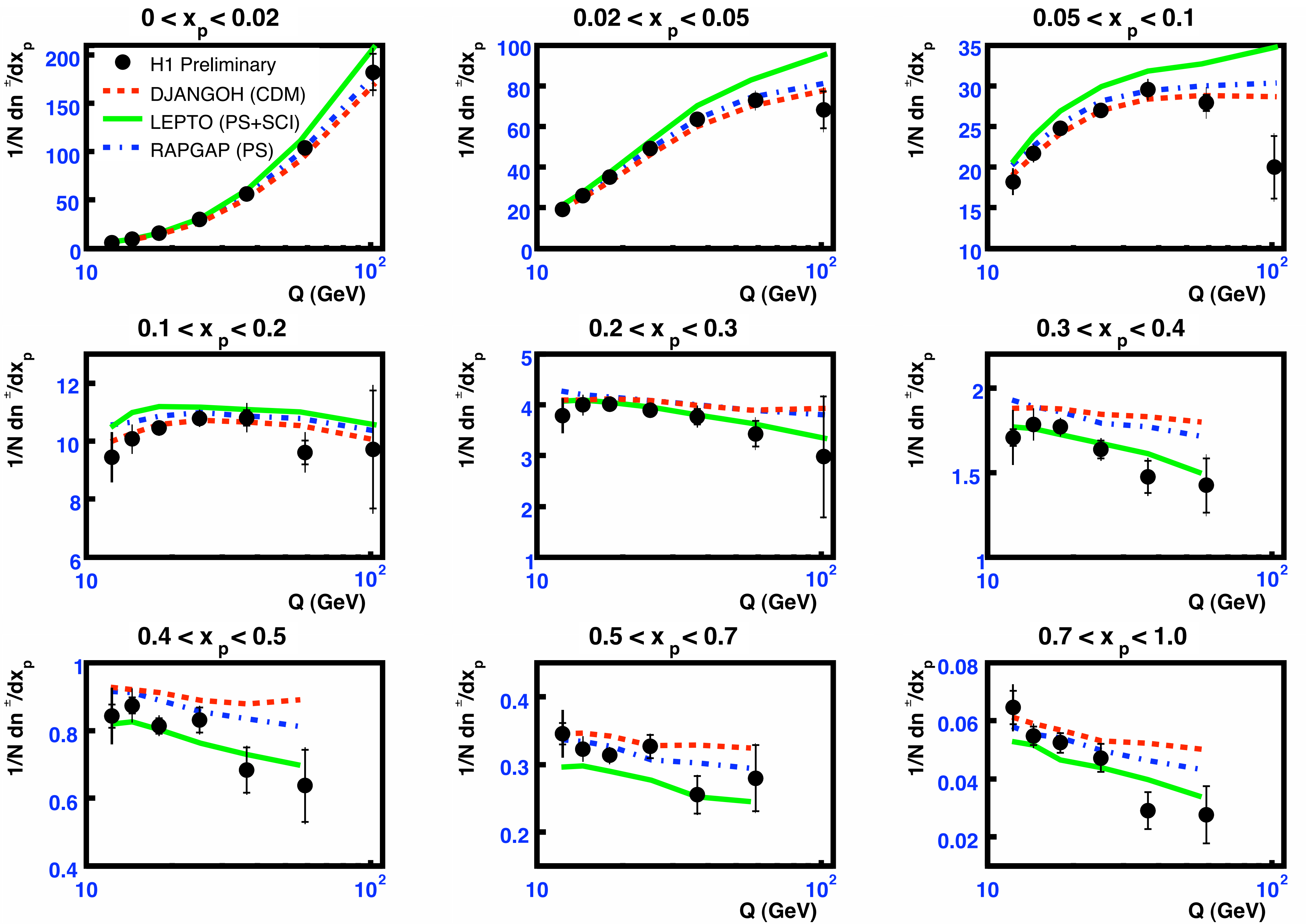
Parton Showers



Soft Colour Interactions



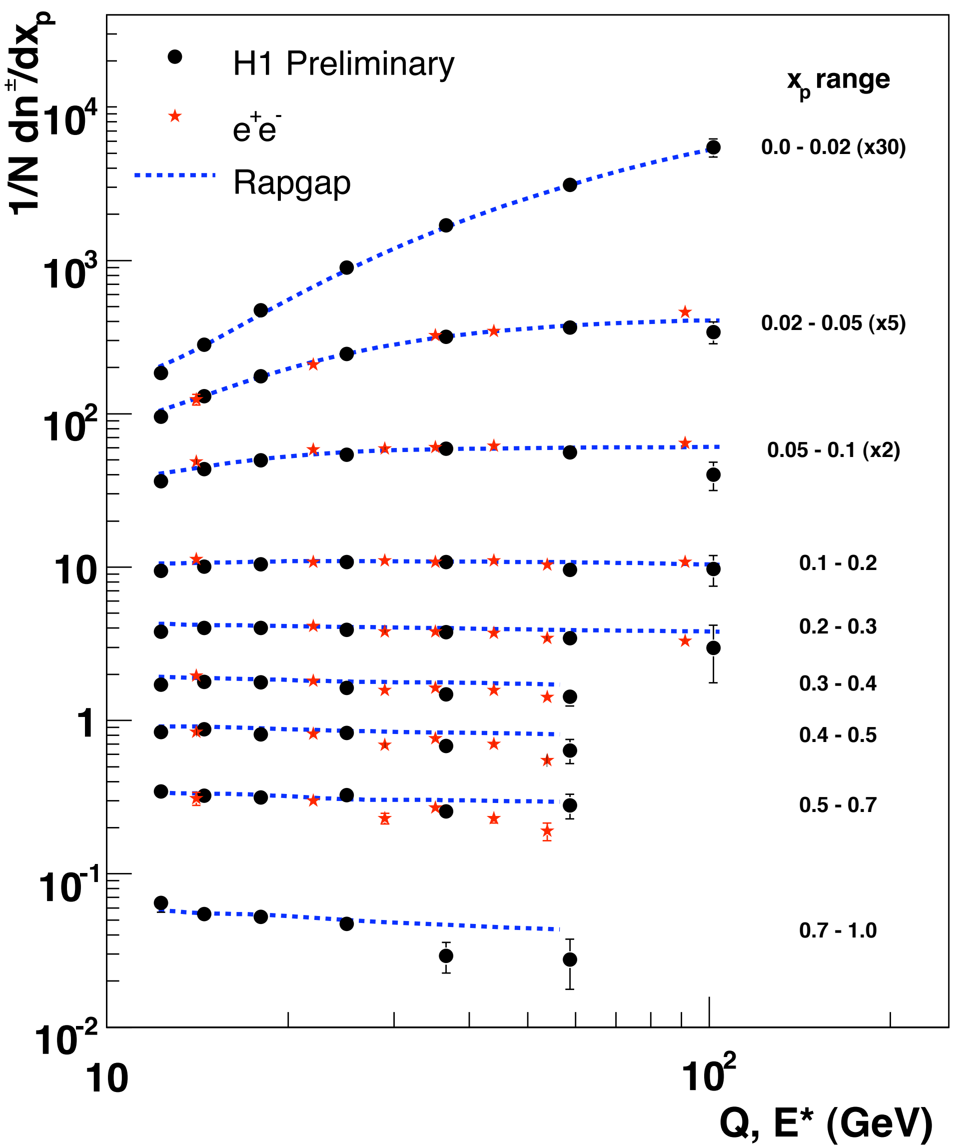
Colour Dipole Model

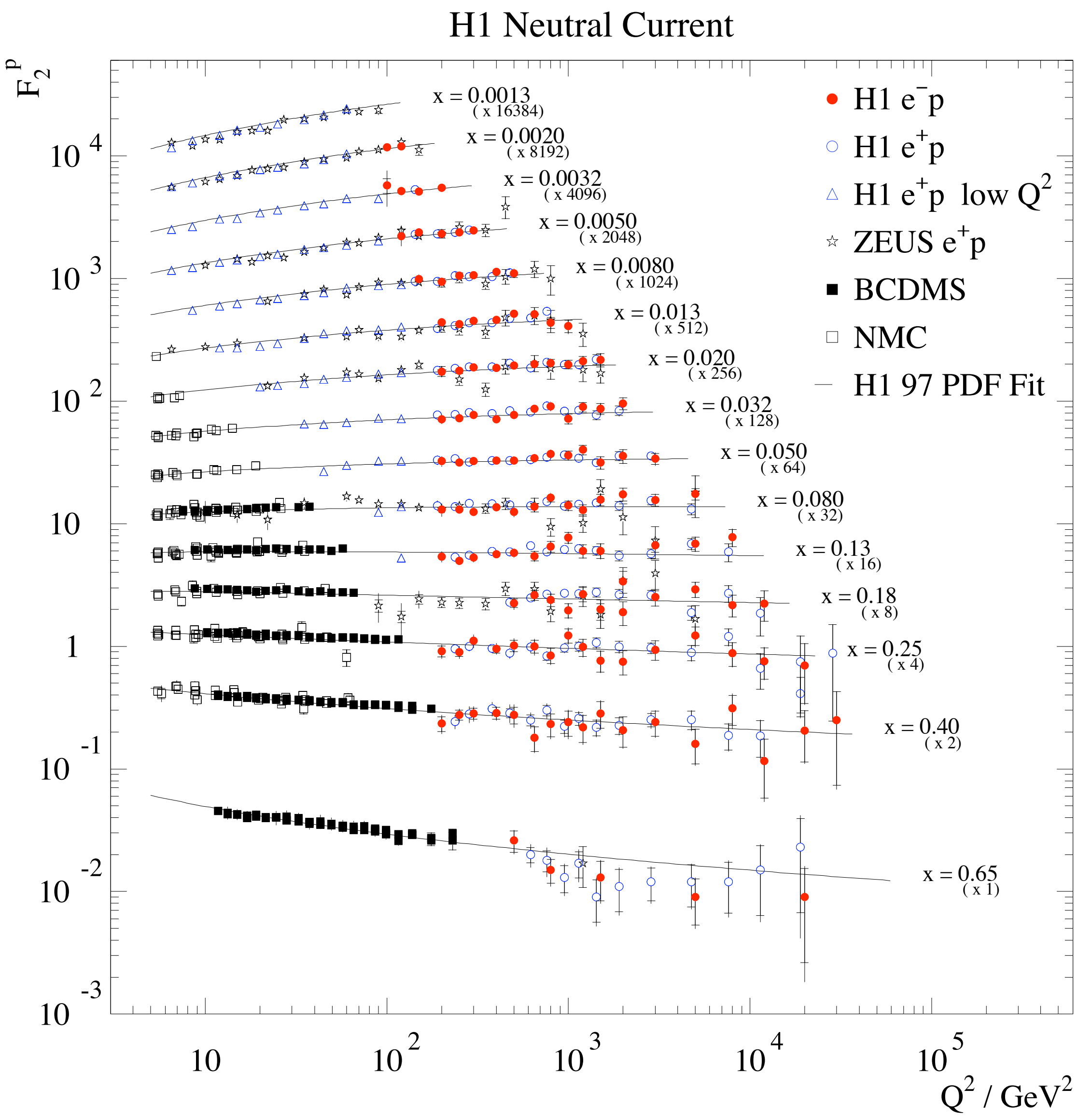


0 < x p < 0.02
0.02 < x p < 0.05
0.05 < x p < 0.1
0.1 < x p < 0.2
0.2 < x p < 0.3
0.3 < x p < 0.4
0.4 < x p < 0.5
0.5 < x p < 0.7
0.7 < x p < 1.0
1/N dn ±/dx p
Q (GeV)
H1 Preliminary
DJANGOH (CDM)
LEPTO (PS+SCI)
RAPGAP (PS)

- [x] Both RAPGAP (PS) and DJANGO (CDM) give similarly good description of the data.
- [ ] LEPTO (SCI) too soft.
- [x] Data tends to turn over faster than DJANGO / RAPGAP. More like LEPTO.

Scaling violations





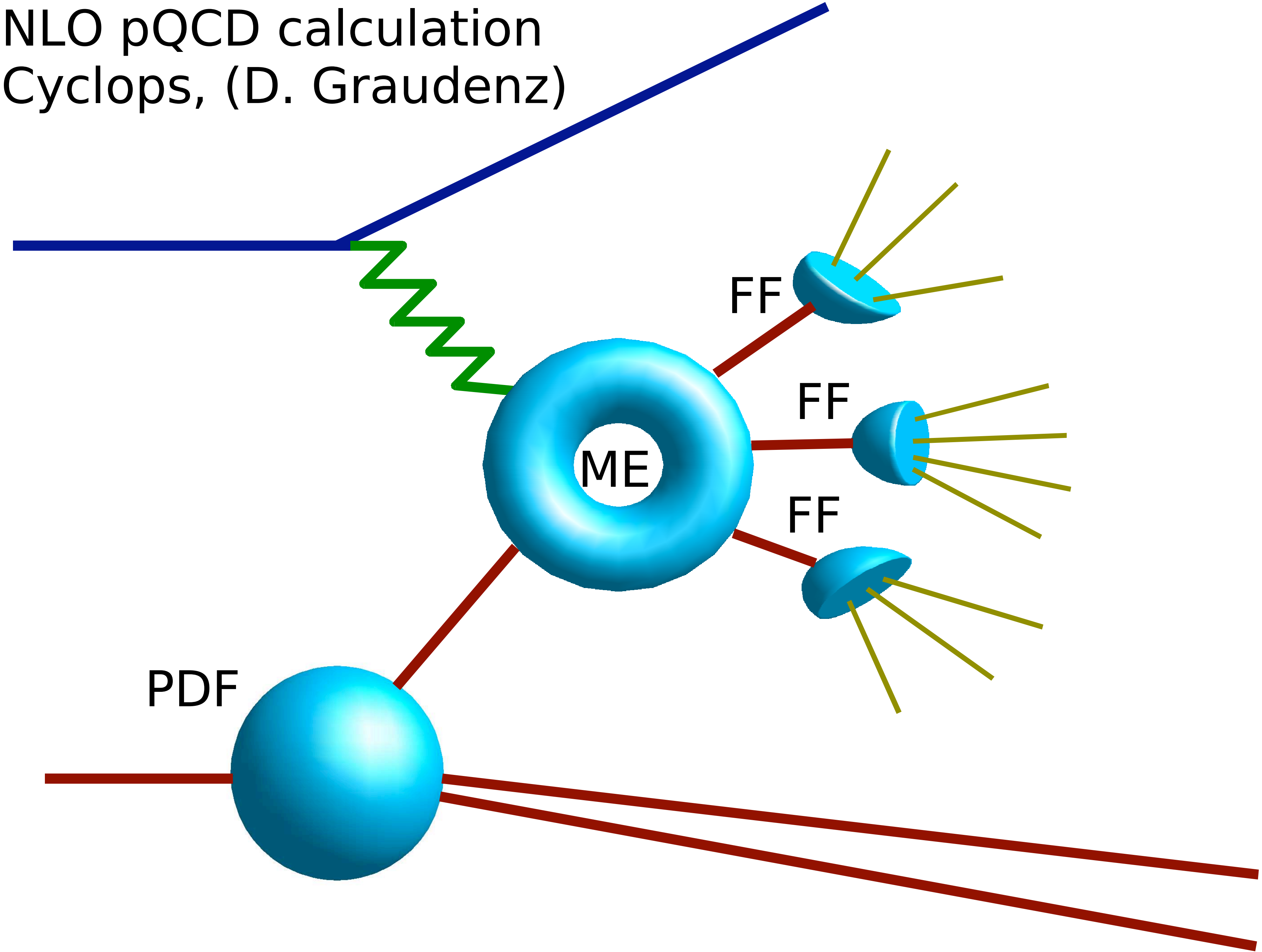
Summary

- ☑ Presented new results on the D(xp) distribution in current region of Breit frame in DIS ep interactions.
- ☑ DIS and e^+e^- results in agreement at high Q (this analysis).
- ☑ String hadronisation better than cluster
- ☑ Monte Carlo tuned from LEP data can successfully describes ep data over large region of Q.
- ☑ Comparison with full NLO predictions (CYCLOPS program).

Back up

Monte Carlo tunings

- CTEQ5L PDF throughout.
- LEPTO +SCI : John Rathsman retuning of LEP data (http://www3.tsl.uu.se/~rathsman/gal/)
- DJANGO + RAPGAP: ALEPH tuning for higher resonance, no BEC, Sophi below W = 5GeV
- HERWIG NC DIS, ME+PS, no soft underlying event


NLO pQCD calculation
Cyclops, (D. Graudenz)
FF
FF
ME
FF
PDF

	PDF	(light quark) Fragmentation Functions
Old version	MRSA	Binnewies, Kniehl, Kramer (1996)
Updated version	LHAPDF	Kniehl, Kramer, Pötter kkp(2000)
		Albino, Kniehl, Kramer akk(2004)
		Kretzer pkh(2000)

Standard paramaterisation — kkp(2000)

Uses MLLA for evolution — akk(2004)

Different authors — pkh(2000)

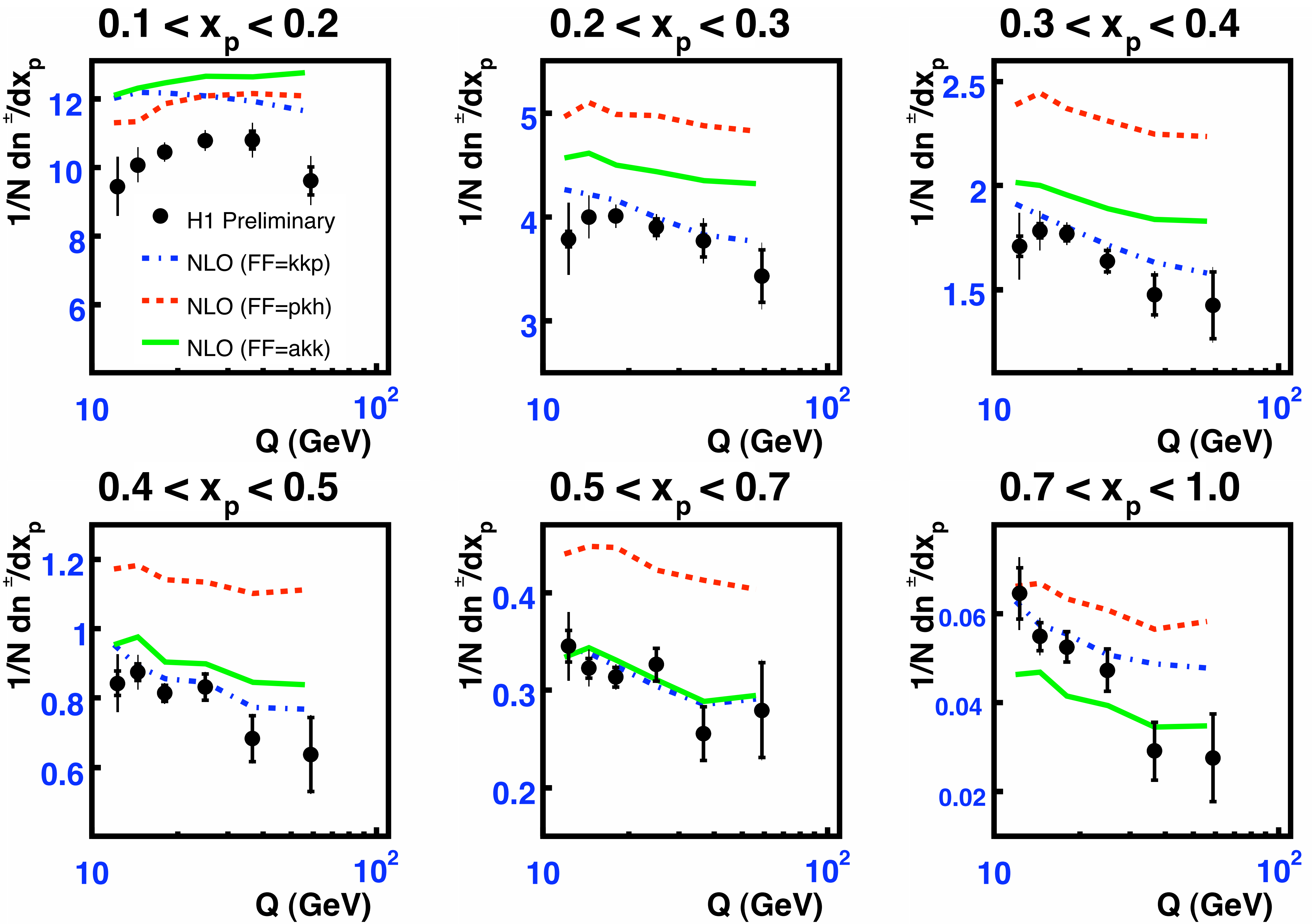
Infra red safe region (Q^2>100), x_p>0.1

FF parameterised from xp>0.1

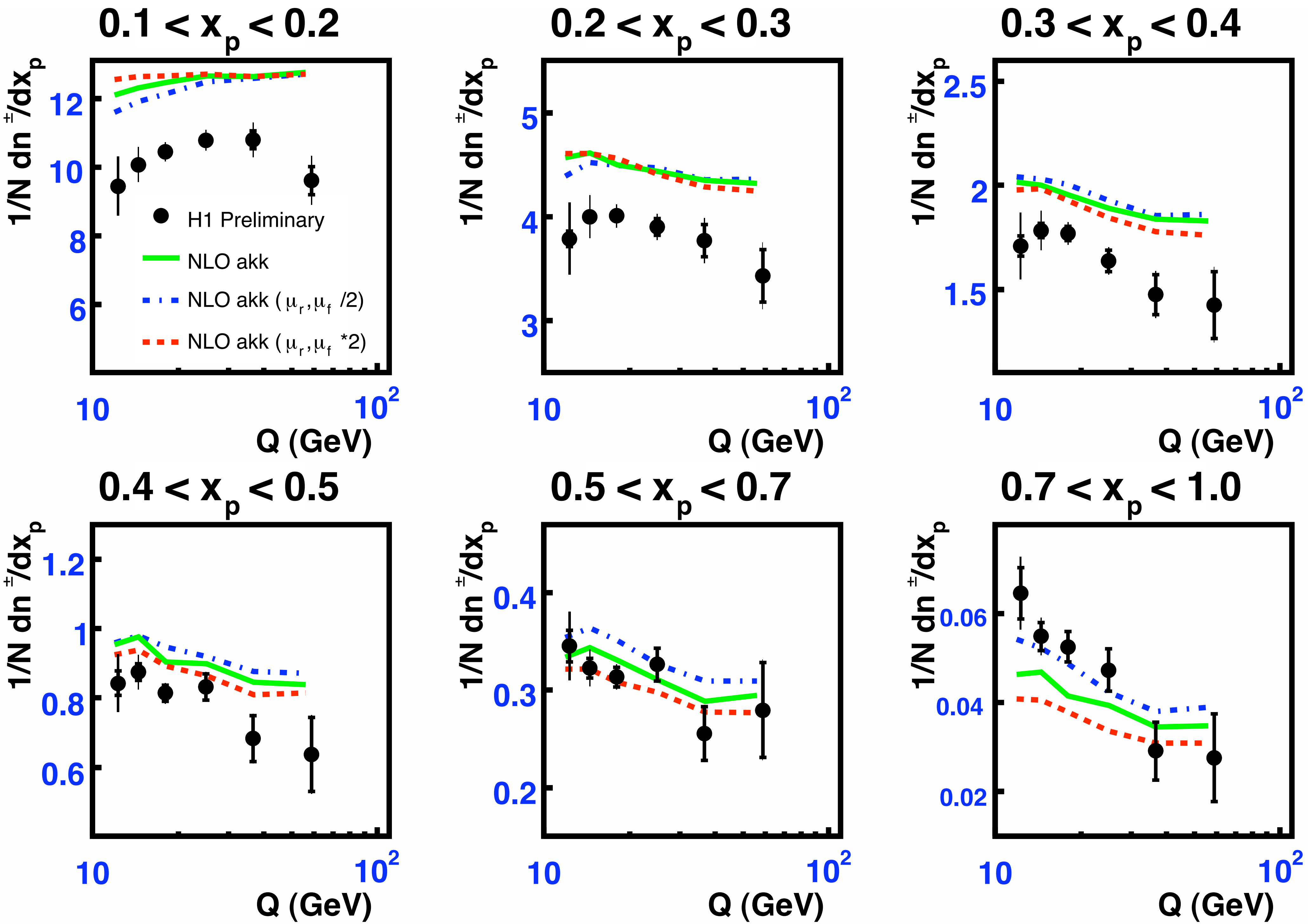
Highest Q2 bin (8,000 - 20,000) low in statistics and problematic phase space

CTEQ6M, $\Lambda(5)_{QCD}$ = 226 MeV
as used for ME + FF

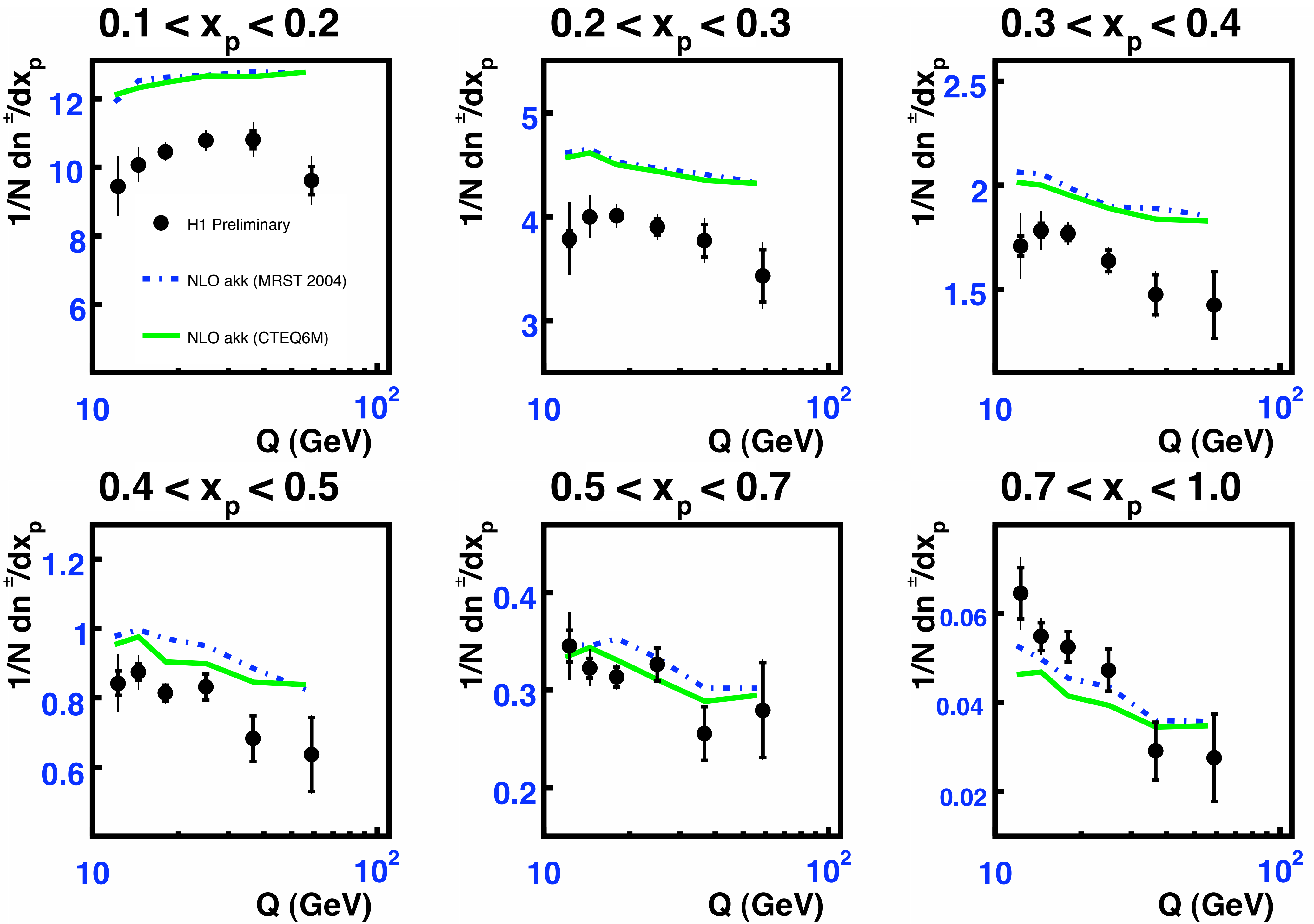
Scale/pdf errors not shown but expected to be small



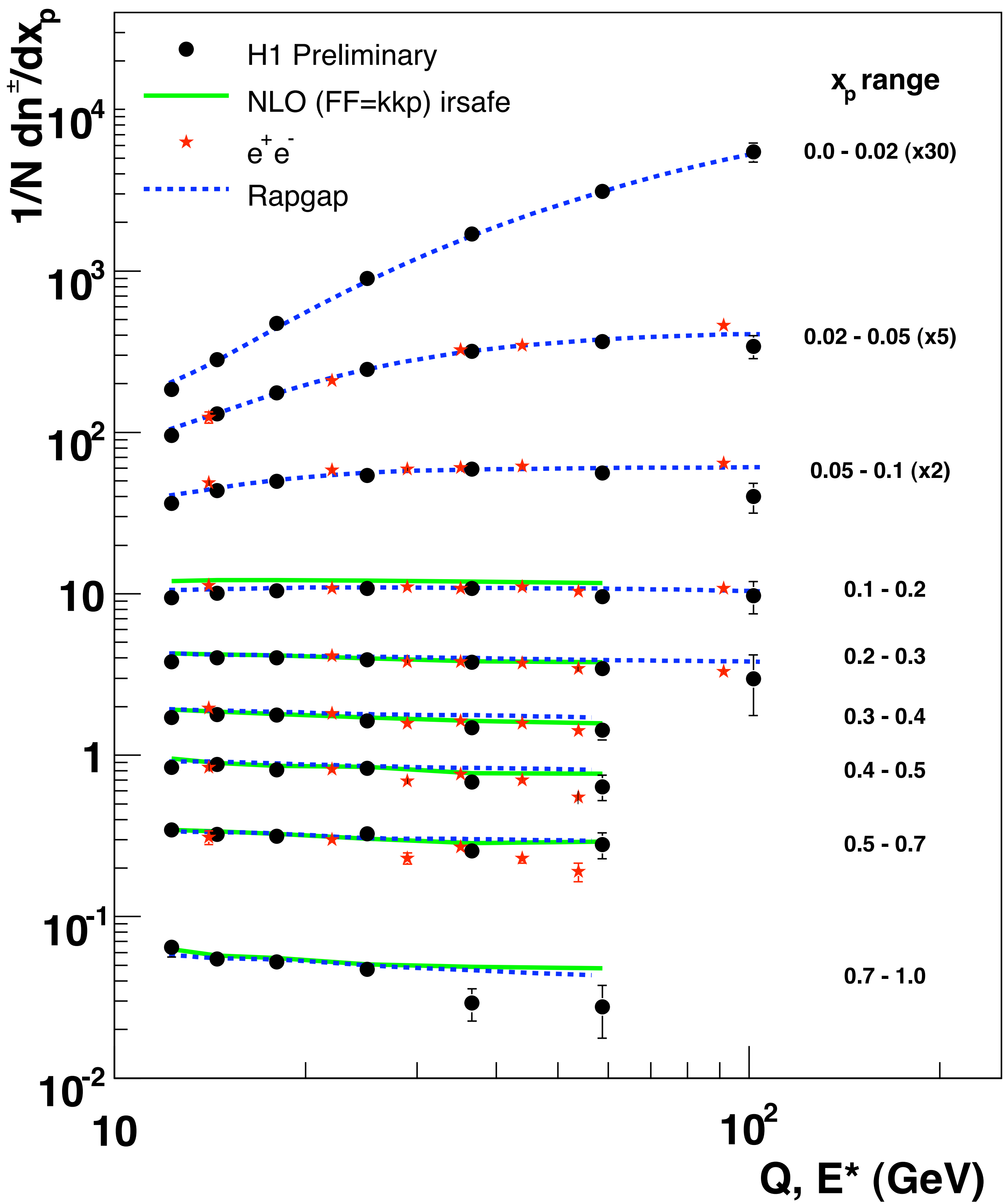
0.1 < x_p < 0.2
0.2 < x_p < 0.3
0.3 < x_p < 0.4
0.4 < x_p < 0.5
0.5 < x_p < 0.7
0.7 < x_p < 1.0
1/N dn^±/dx_p
Q (GeV)
H1 Preliminary
NLO (FF=kkp)
NLO (FF=pkh)
NLO (FF=akk)



0.1 < x_p < 0.2
0.2 < x_p < 0.3
0.3 < x_p < 0.4
0.4 < x_p < 0.5
0.5 < x_p < 0.7
0.7 < x_p < 1.0
1/N dn ±/dx_p
Q (GeV)
H1 Preliminary
NLO akk
NLO akk (μr,μf /2)
NLO akk (μr,μf *2)



0.1 < x_p < 0.2
0.2 < x_p < 0.3
0.3 < x_p < 0.4
0.4 < x_p < 0.5
0.5 < x_p < 0.7
0.7 < x_p < 1.0
1/N dn ±/dx_p
Q (GeV)
H1 Preliminary
NLO akk (MRST 2004)
NLO akk (CTEQ6M)



H1 Preliminary
NLO (FF=kkp) irsafe
e+e-
Rapgap
xp range
0.0 - 0.02 (x30)
0.02 - 0.05 (x5)
0.05 - 0.1 (x2)
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.7
0.7 - 1.0
1/N dn±/dxp
Q, E* (GeV)