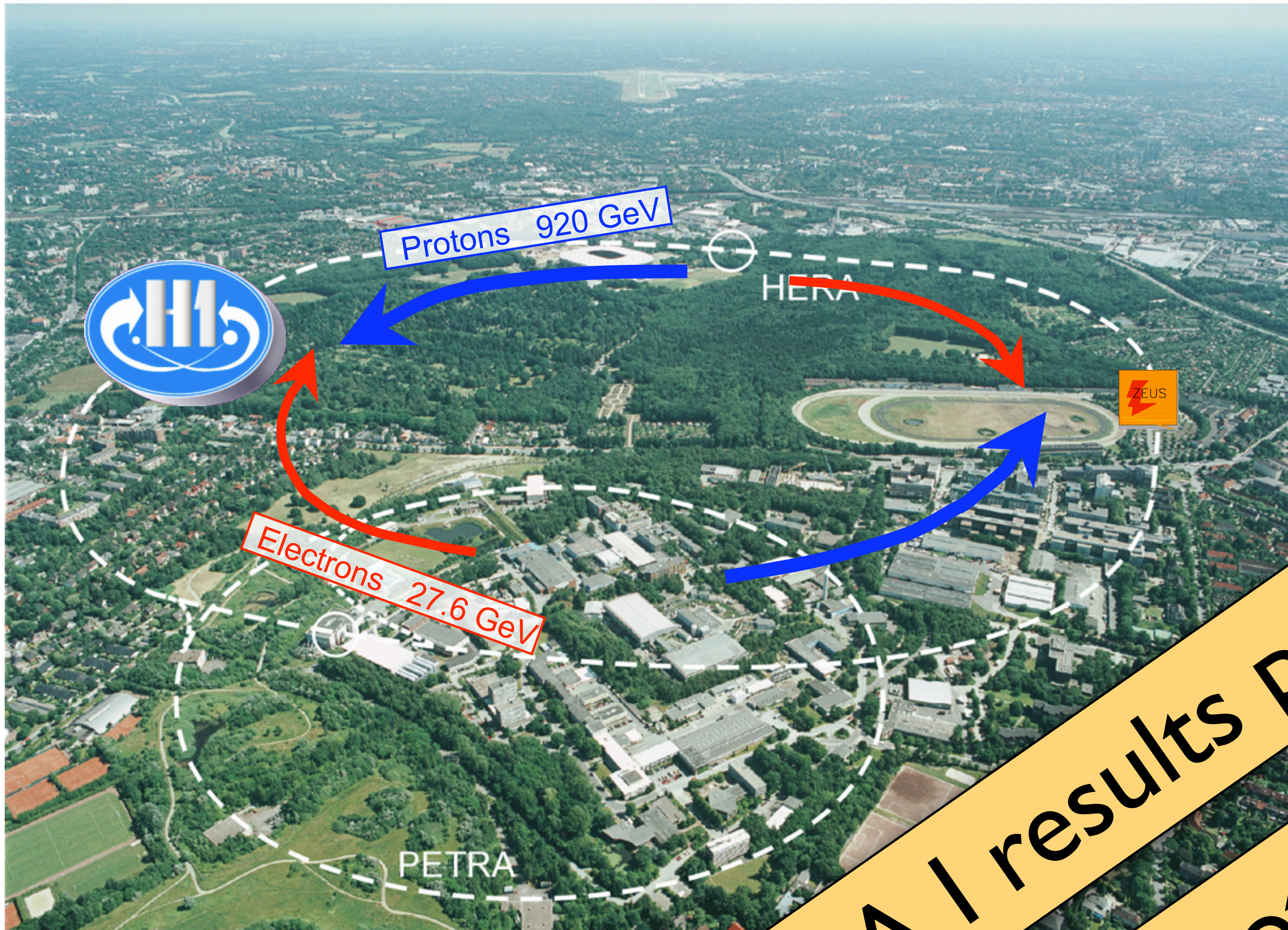
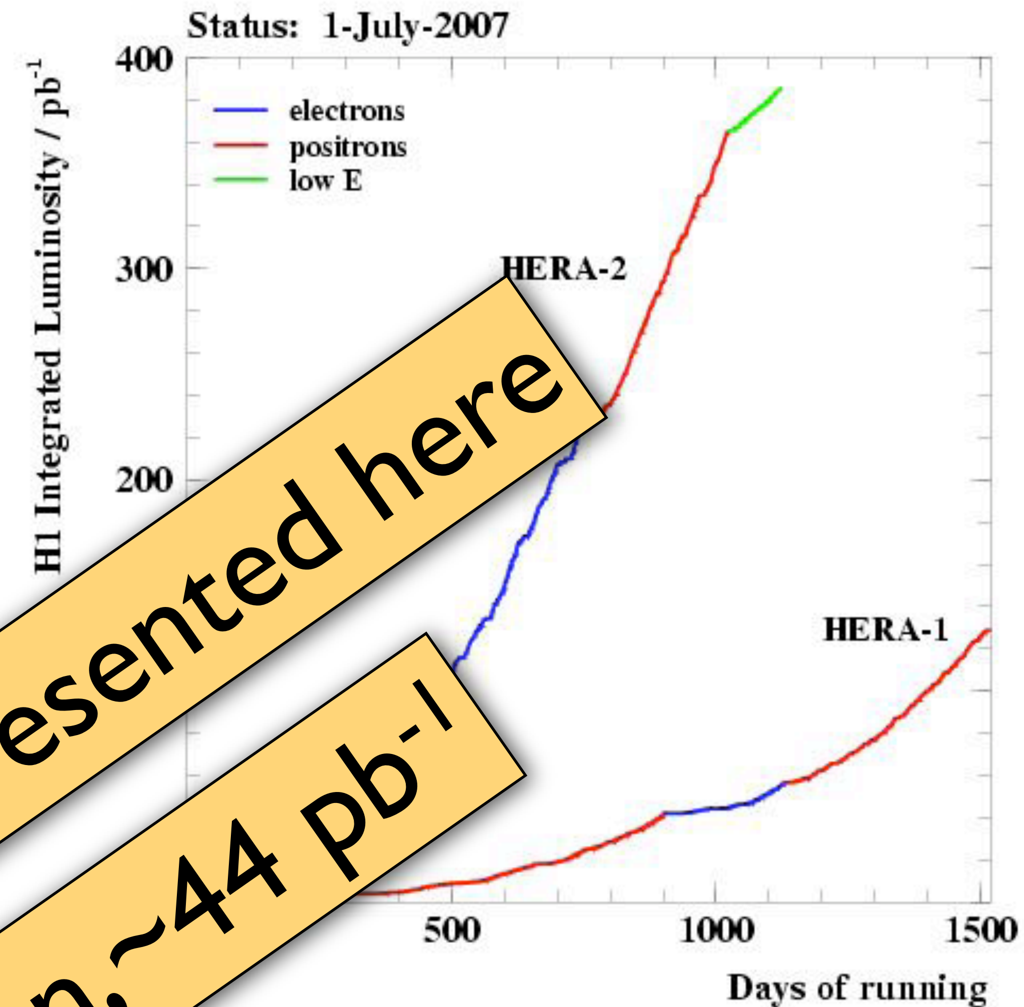
Hadronic Charge Asymmetry in DIS

Daniel Traynor, EPS09, 16/07/09

Overview

- HERA, H1 and DIS
- Recap - Fragmentation Function results.
- NEW - Charge asymmetry of the hadronic final state!





Only HERA I results presented here

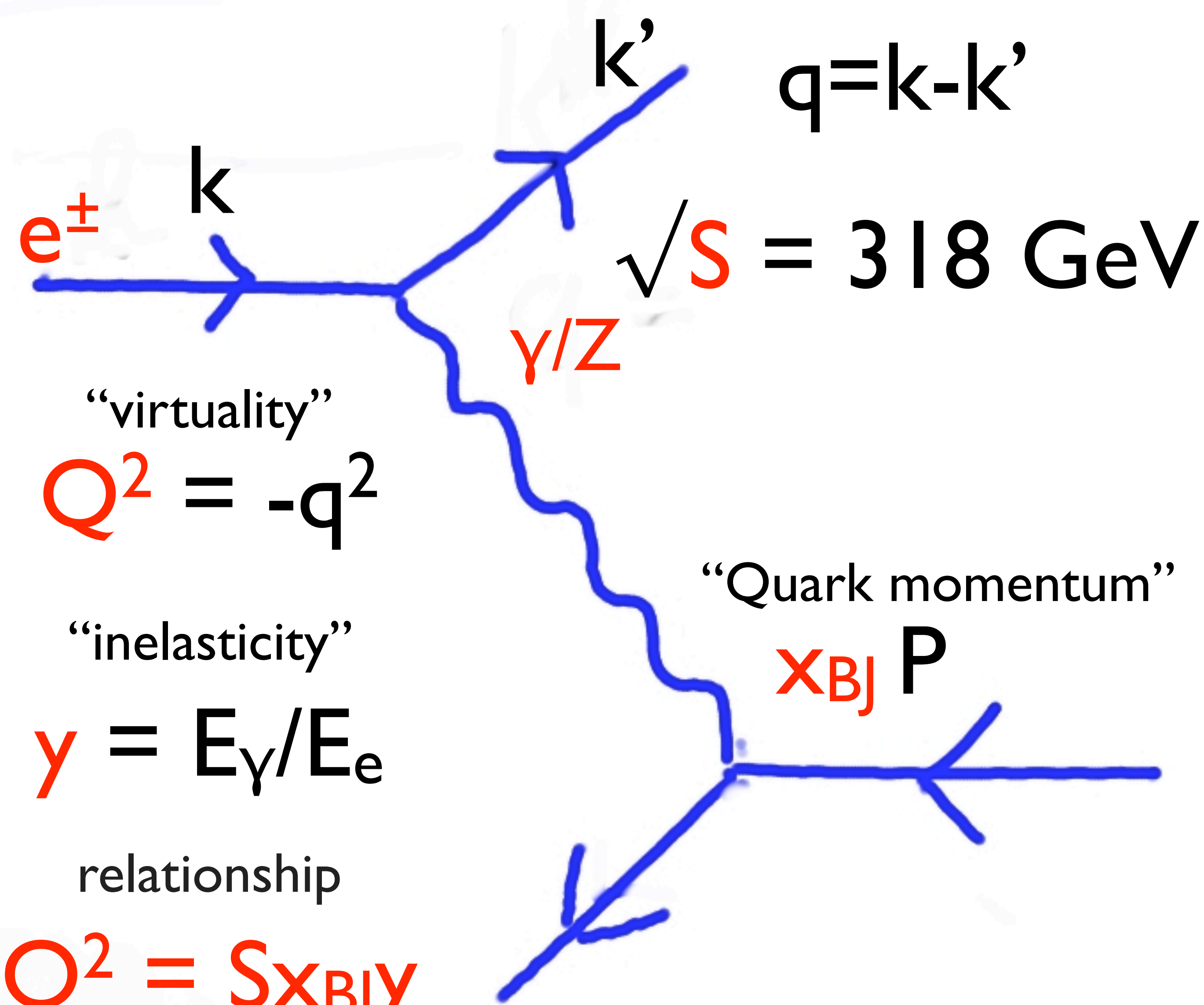
positron - proton, ~44 pb^{-1}

electrons or positrons

polarised lepton beams

4 different proton energies

H1 Physics usable sample ~500 pb^{-1}



"virtuality"

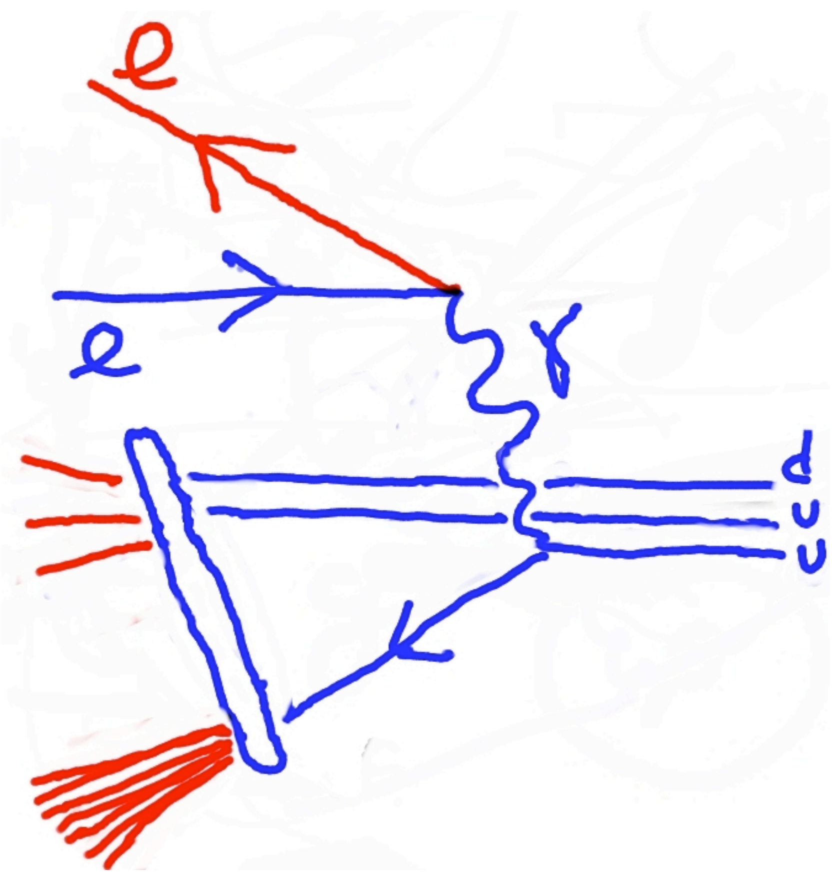
$Q^2 = -q^2$

"inelasticity"

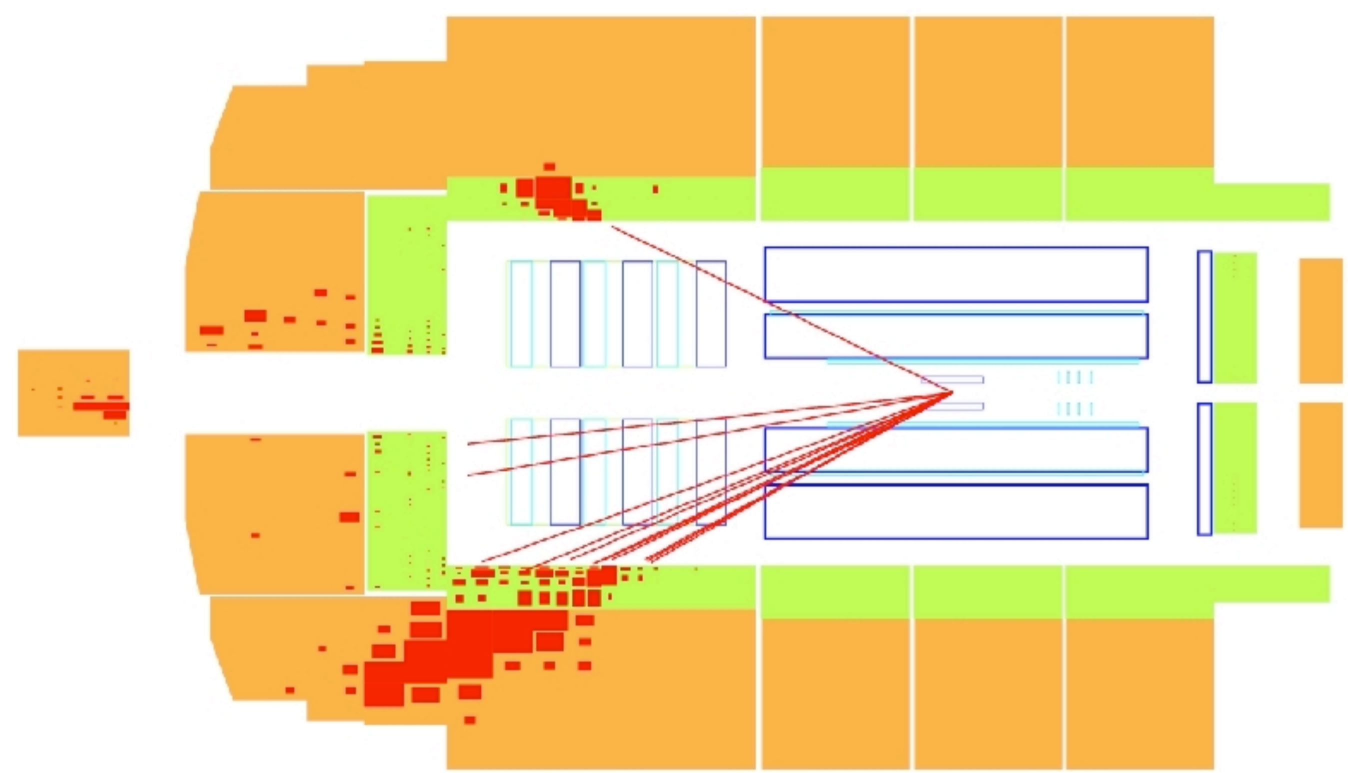
$y = E_{\gamma}/E_e$

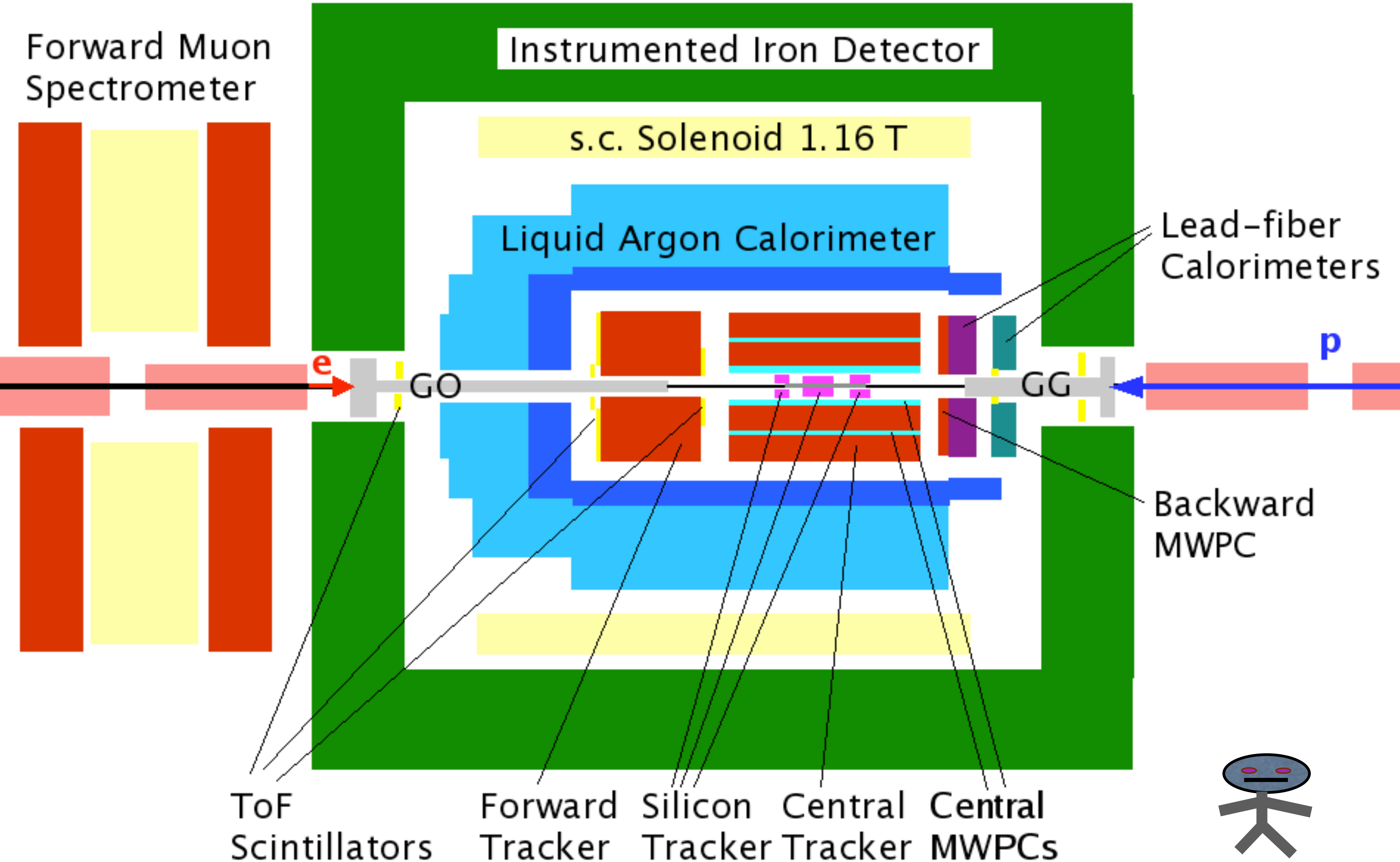
relationship

$Q^2 = S x_{BJ} y$

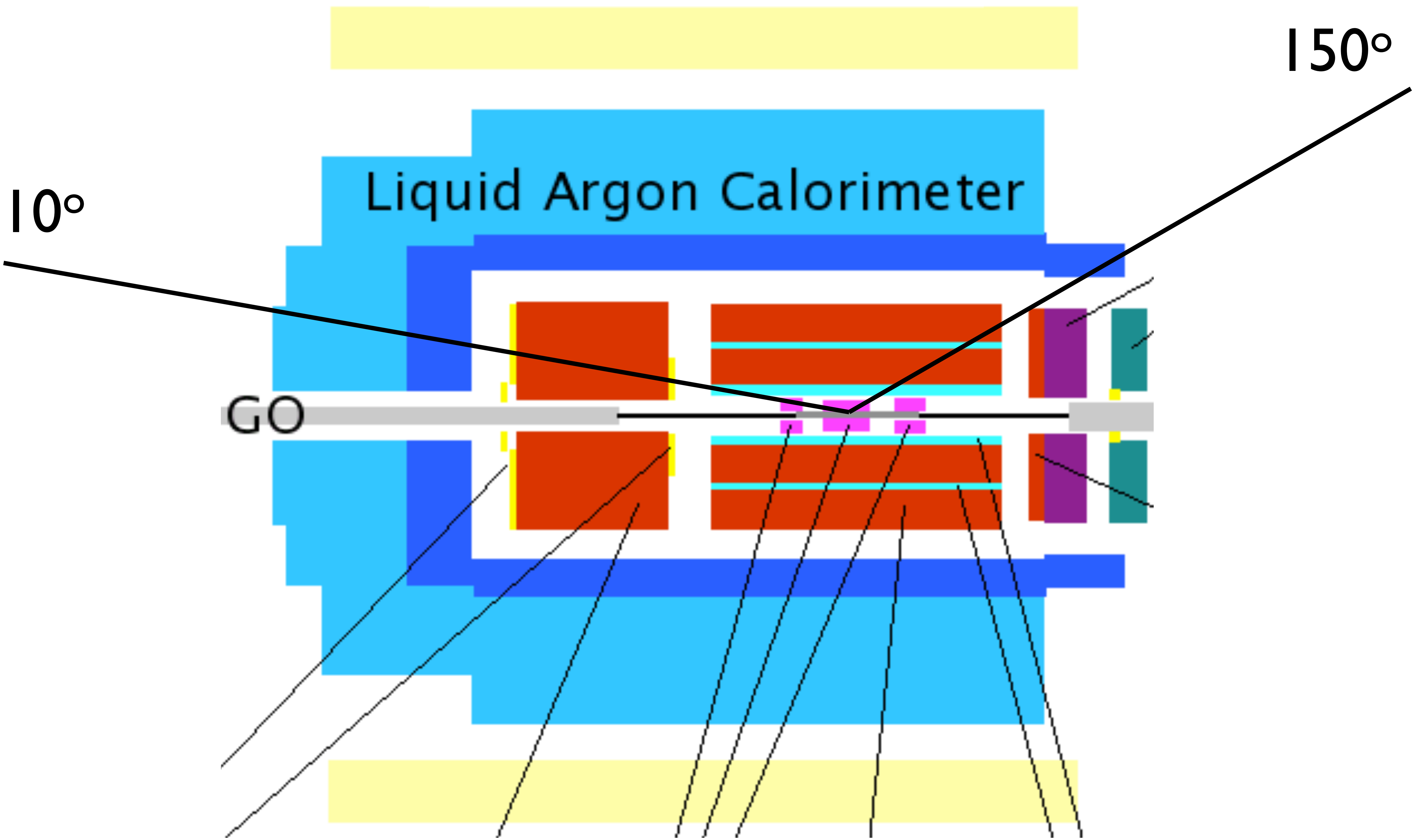


Neutral Current DIS

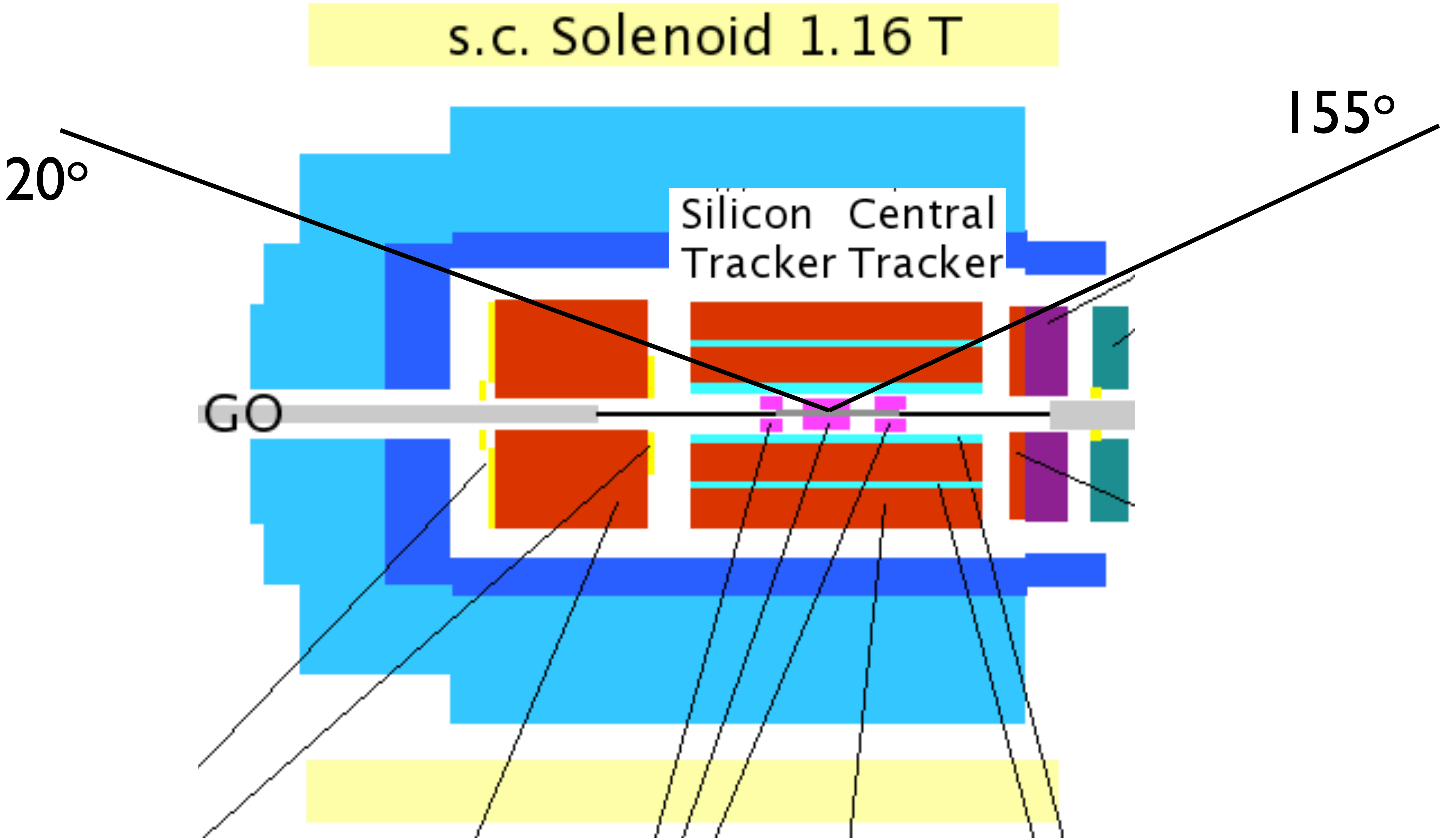



Forward Muon Spectrometer
Instrumented Iron Detector
s.c. Solenoid 1.16 T
Liquid Argon Calorimeter
Lead-fiber Calorimeters
e
GO
GG
p
Backward MWPC
ToF Scintillators
Forward Tracker
Silicon Tracker
Central Tracker
Central MWPCs

Scattered electron acceptance at high Q^2



Tracking acceptance of HFS



Kinematic phase space

$100 < Q^2 < 8{,}000$ GeV^2

$0.05 < y < 0.6$

$\theta_{electron} > 150°$

$30° < \theta_{q,lab} < 150°$

quark scattering angle,
$\theta_{q,lab}$, calculated from
kinematics.
ensures current region of
Breit frame remains within
tracking acceptance.
easy to calculate in theory!

K^0, Λ, etc.. considered as stable

correction factor < 1.2.
dominated by boost to breit
frame. correction for tracking
efficiencies few %

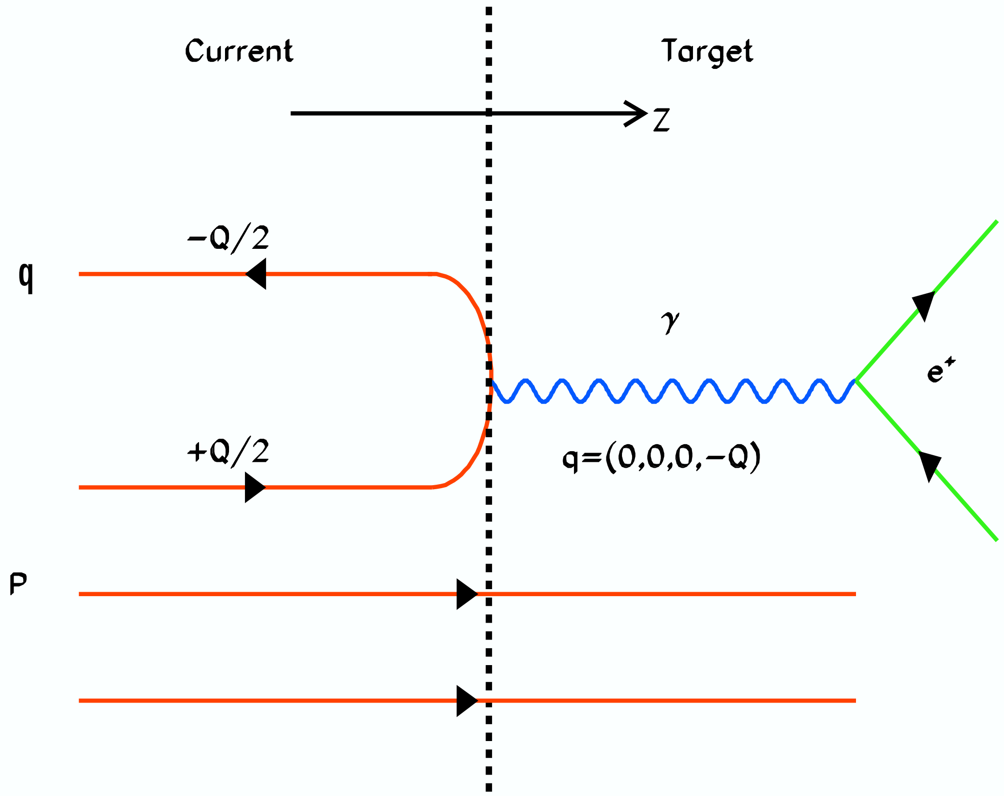
systematic error ~5%

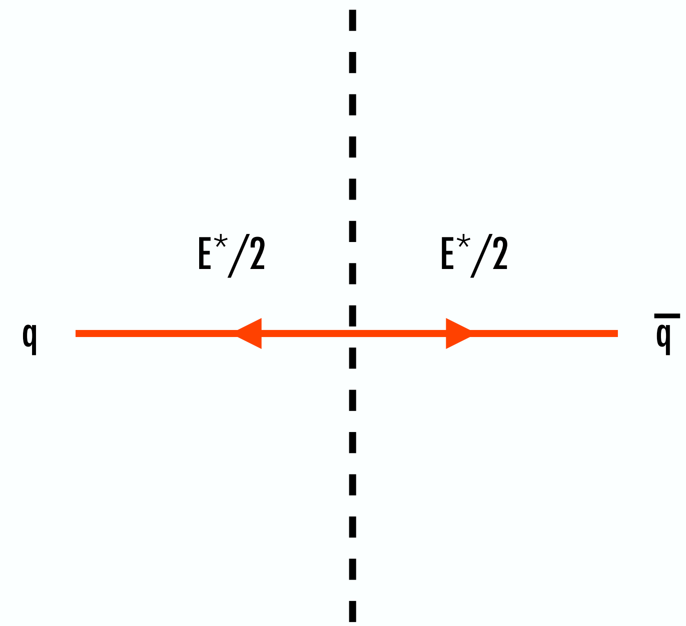
Asymmetry
correction factor ~1.0
systematics partial cancel

→

$ep \rightarrow eX$ $e^+e^- \rightarrow q\bar{q}$

Breit Frame

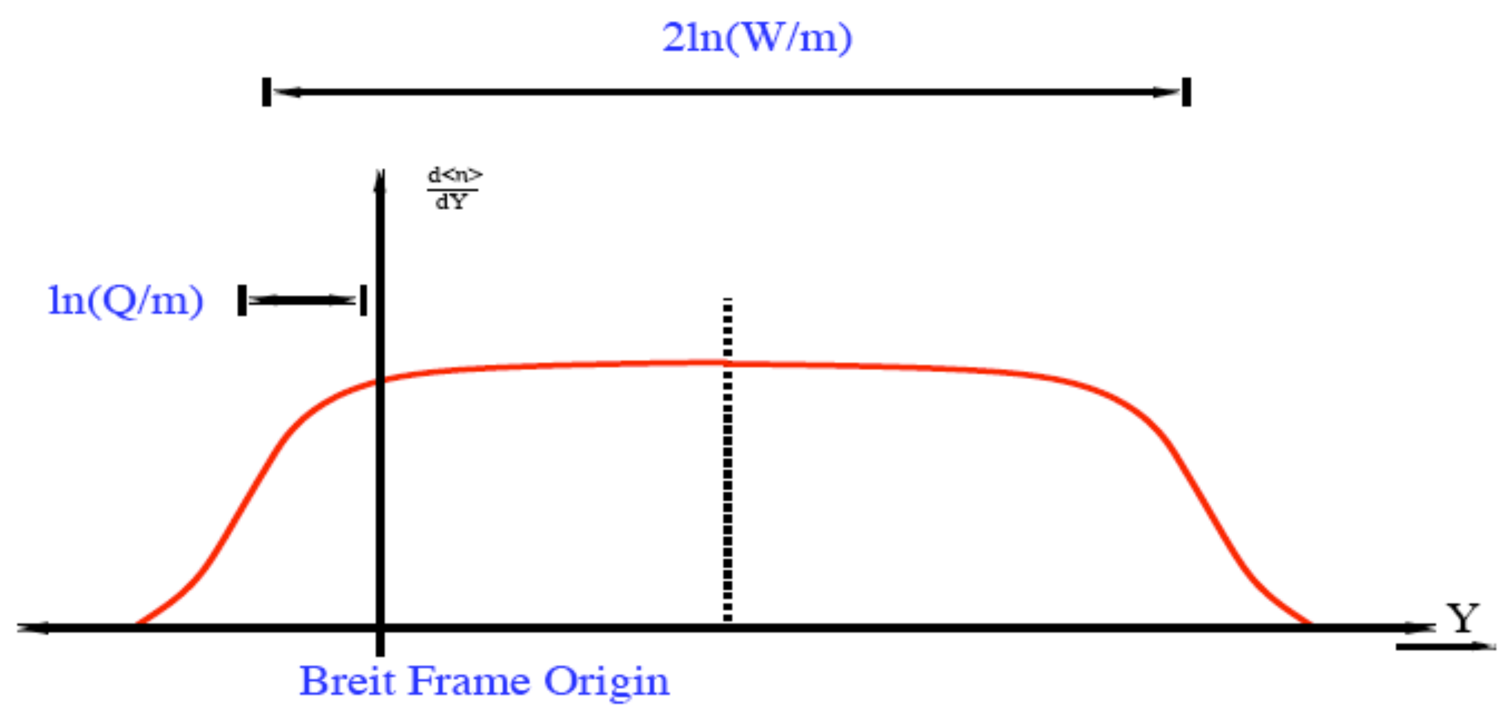




Provides clearest separation between particles from hard scattering and proton remnant. Allows for easy comparison with e^+e^- data

current region energy scale is Q/2

boost to breit frame means we measure down to p_{breit} =0!



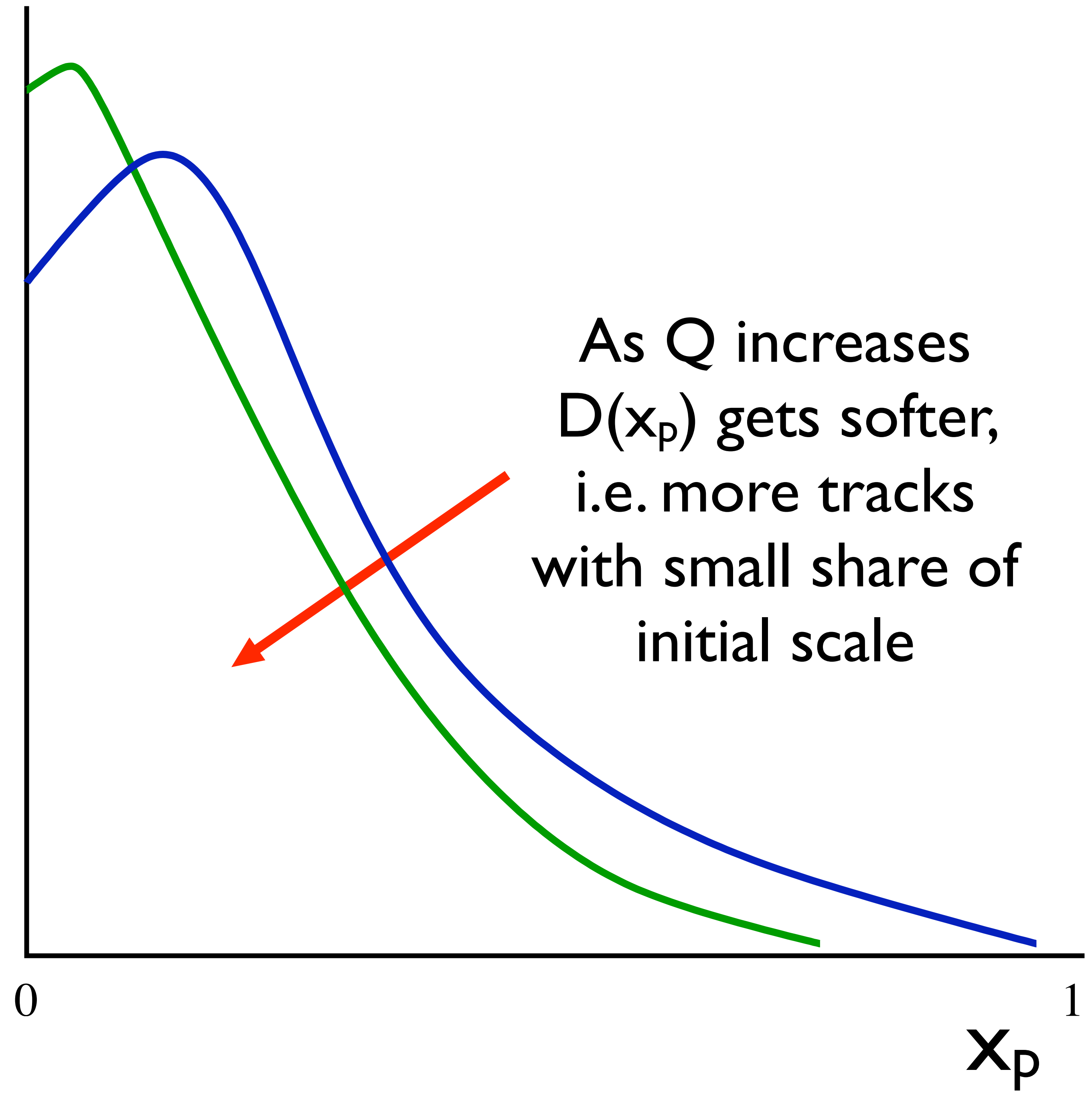
$$x_p = \frac{(2P_h)}{Q}$$

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

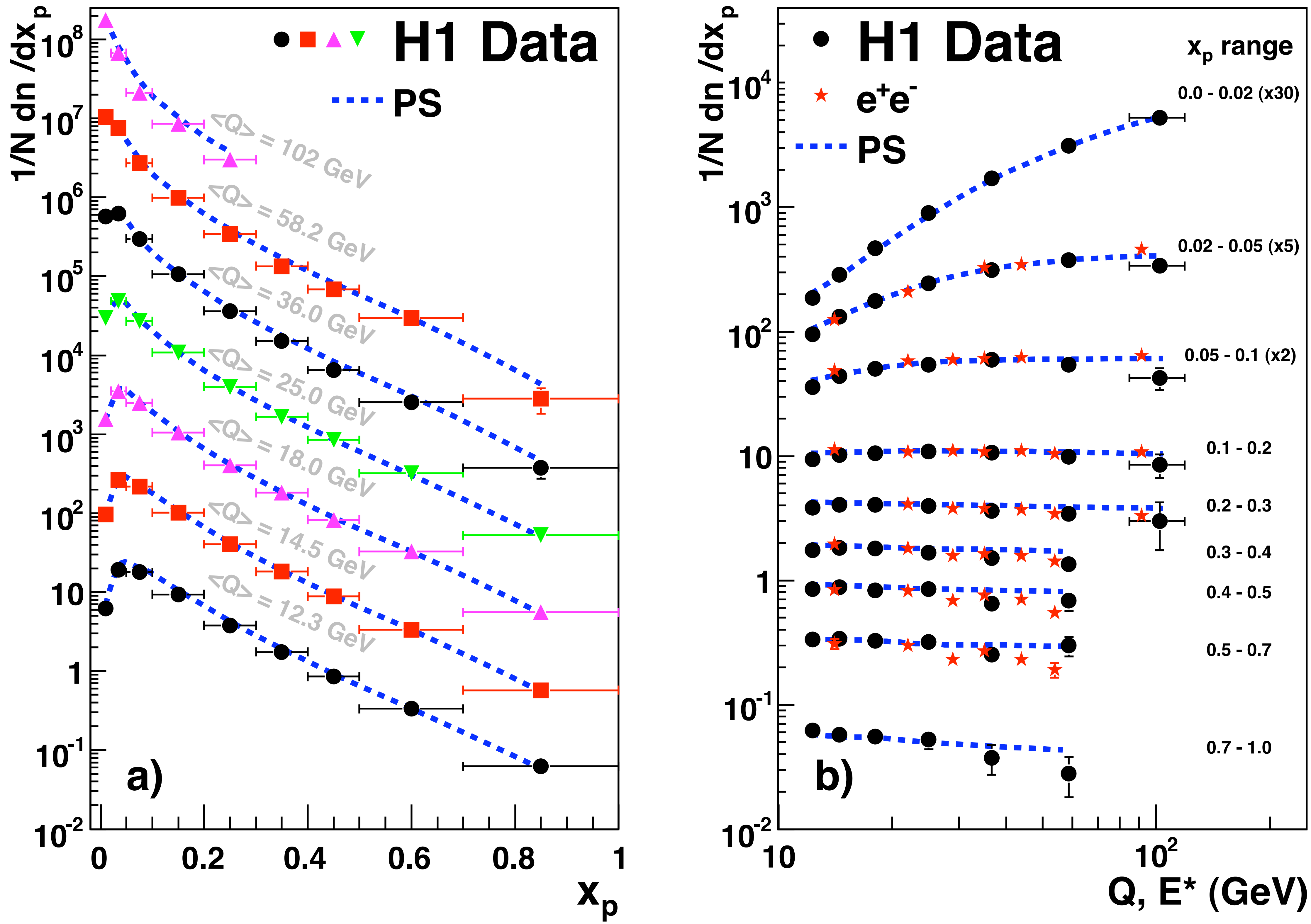
x_p = scaled momentum variable

$Q/2$ = Scale in current region of Breit Frame

p_h = momentum of charged particle in current region of Breit frame



$D(x_p)$ = event normalised, charged particle, scaled momentum distribution

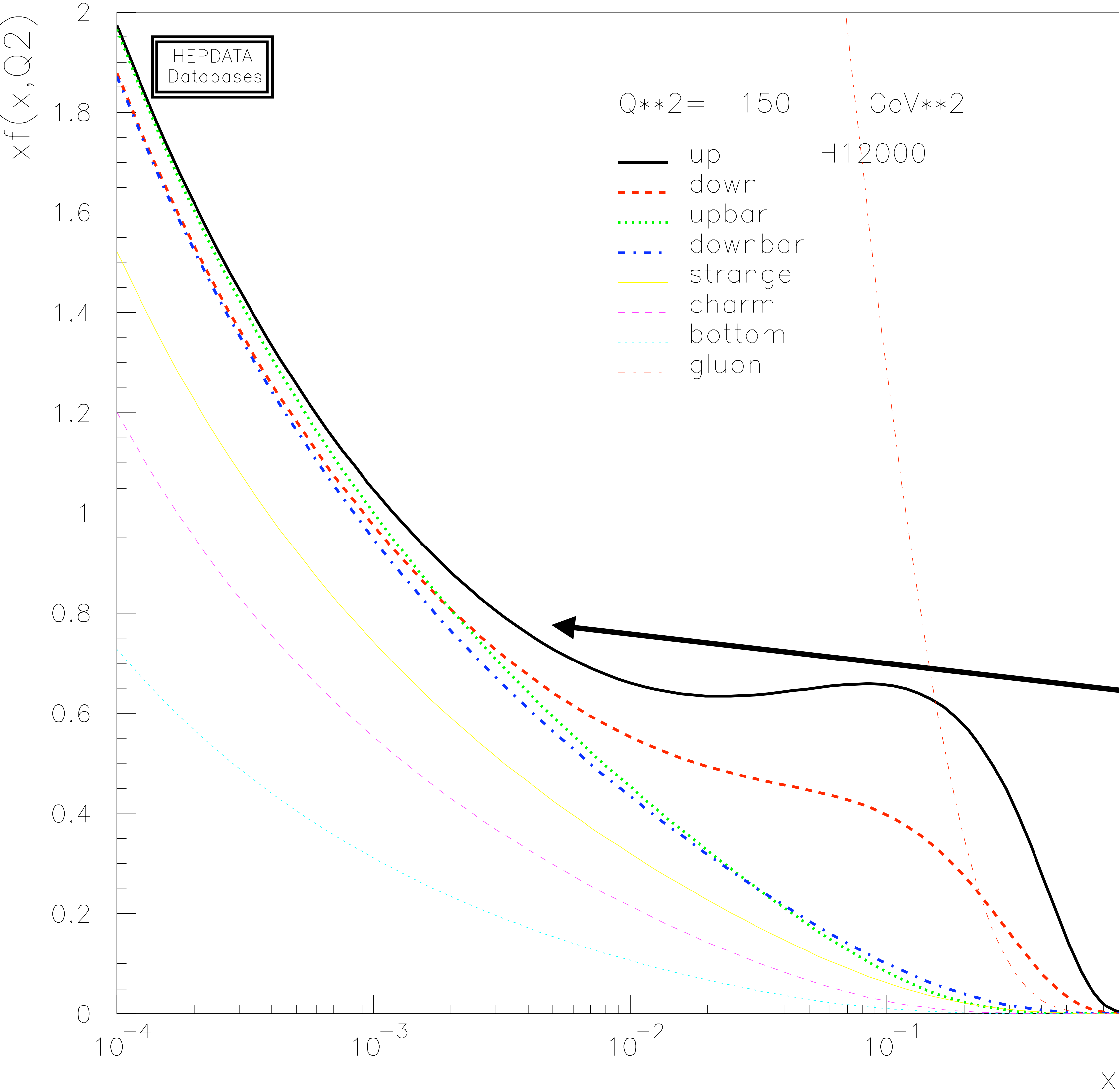


Reasonable agreement between ep and e^+e^- / Monte Carlo - broadly supports quark fragmentation universality.

H1 Collab., F.D. Aaron et al., Phys.Lett.B654:148-159,2007

Charge Asymmetry Motivation

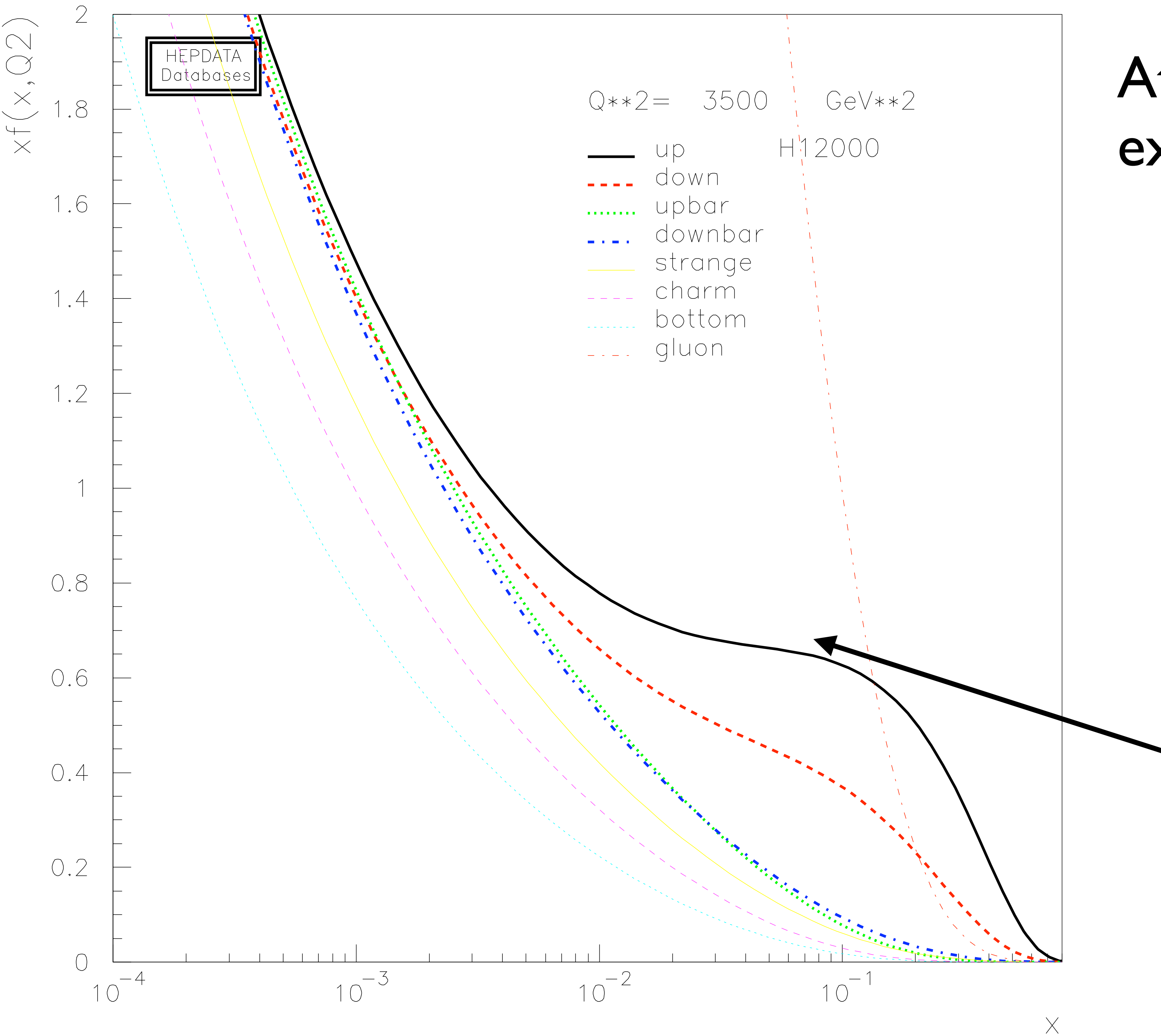
Quark contribution to PDF



At low Q^2 / low x_{BJ} expect that the proton PDF will be dominated by sea quarks and the gluon

Lowest Q^2 bin has average x~ 0.005. sea quarks dominate - u≈d≈s≈ ubar≈dbar≈sbar

Quark contribution to PDF

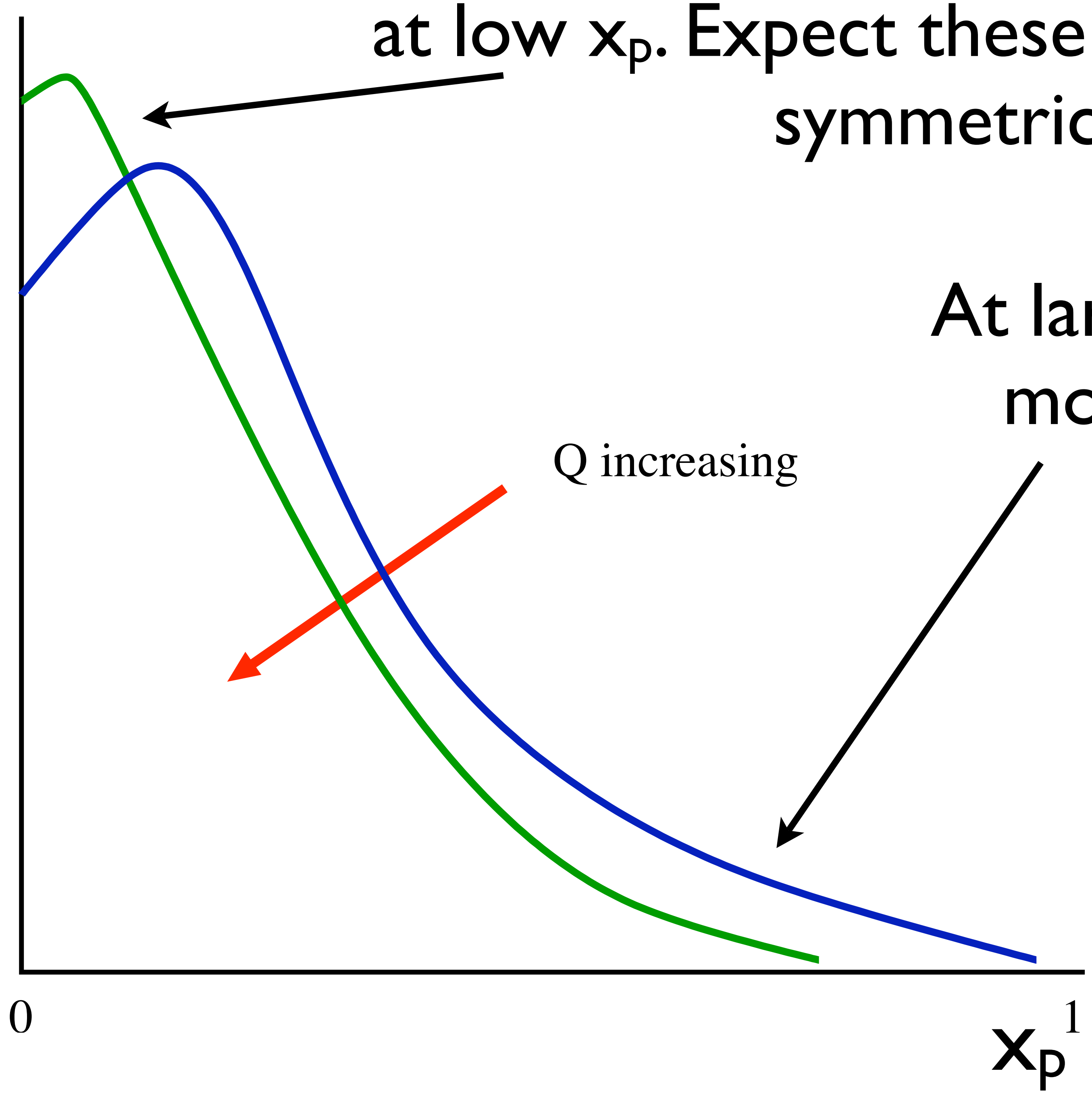


At higher Q^2 / large x_{bj} expect that the proton valence quarks will make significant contribution

Highest Q^2 bin has average x~ 0.1. valence quarks dominate u>d>>s, ubar, dbar, sbar

Expect that the $D(x_p)$ distribution good way of separating fragmentation effects (low x_p) from hard interaction (large x_p).

Hadrons from fragmentation are produced at low x_p. Expect these to be charge symmetric



At large x_p single hadron caries most of the momentum of scattered quark.

Possible that this hadron also carries other quantum numbers? (charge, strangeness, etc...)

Charge Asymmetry

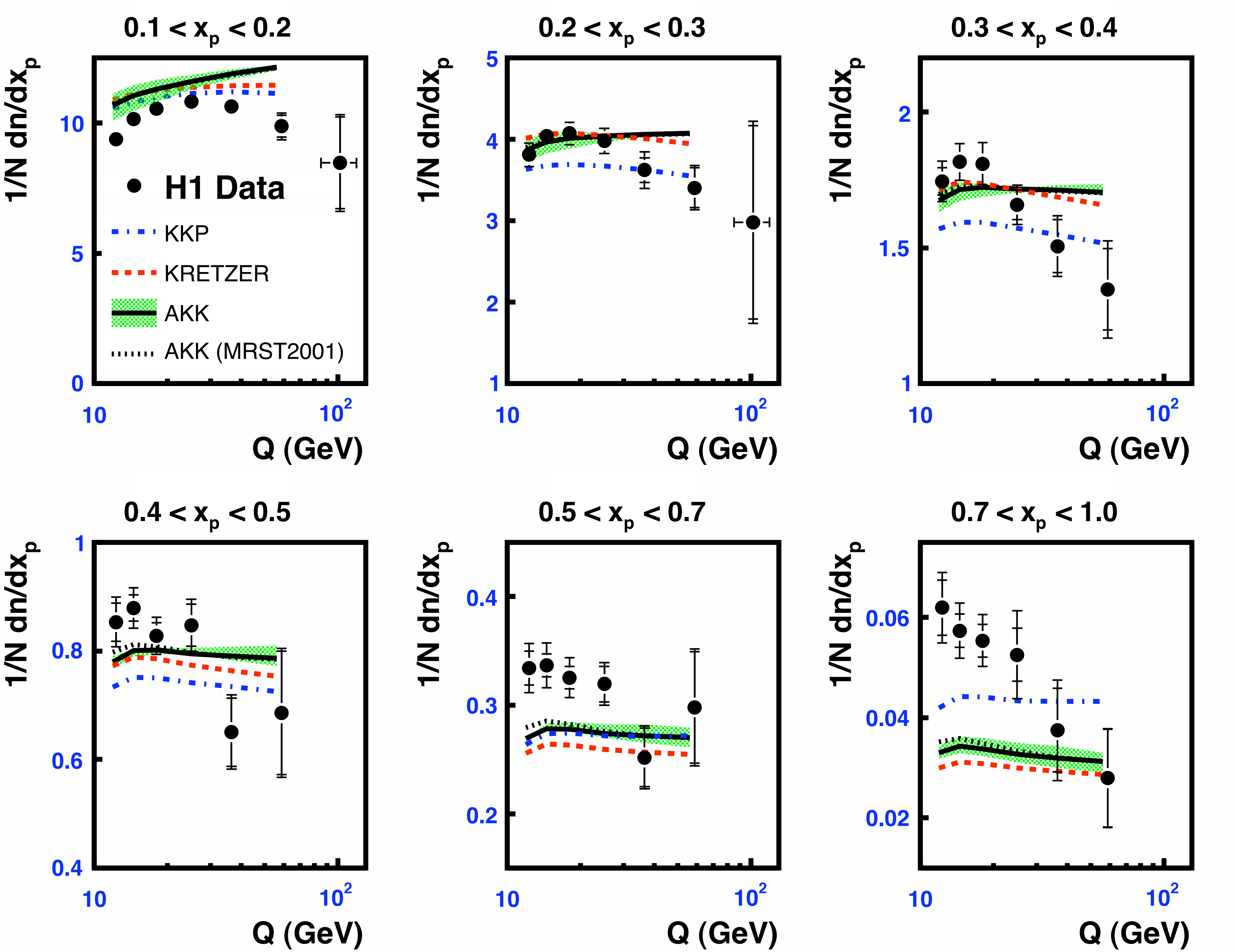
Charge sign asymmetry of RHIC data shown to be sensitive to valence quark distribution when analysing fragmentation data.

Albino, Kniehl & Kramer hep-ex/0803.2768

Suggested at last DIS conference to look at charge identified $D(x_p)$ to help investigate differences seen between data and NLO predictions.

Kniehl, comment DIS08

Possible to get NLO prediction for $D(x_p)$



Fragmentation functions (KKP, KRETZER, AKK)taken from fits to e^+e^- data

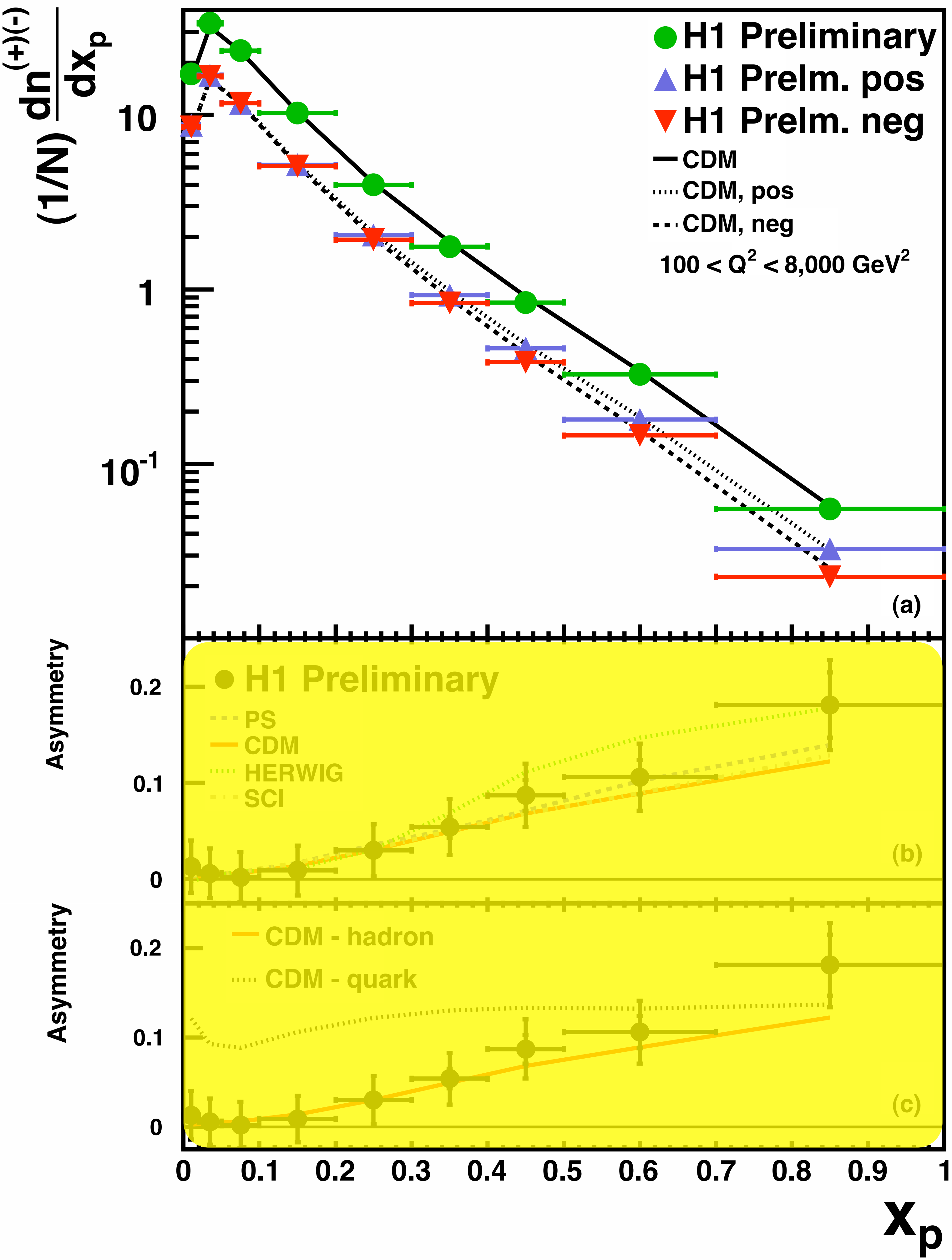
Scale and PDF errors small

Sensitivity to different FF

H1 Collab., F.D. Aaron et al., Phys.Lett.B654:148-159,2007

NLO theory does not describe the DATA!

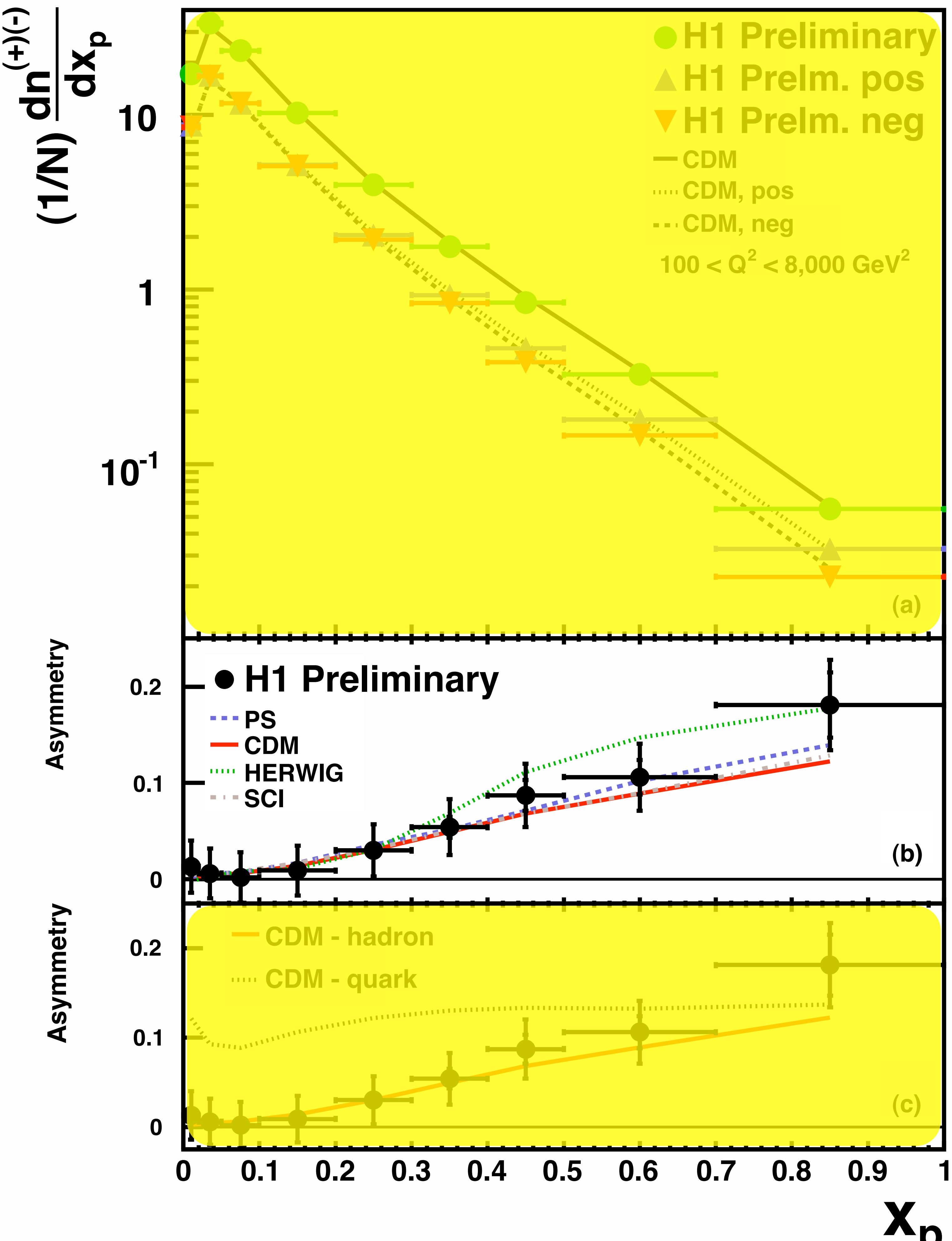
Charge Asymmetry Results



At low x_p similar distribution for positive and negative particles

At large x_p there is a clear difference between the pos and neg distributions

Difference described by Monte Carlo

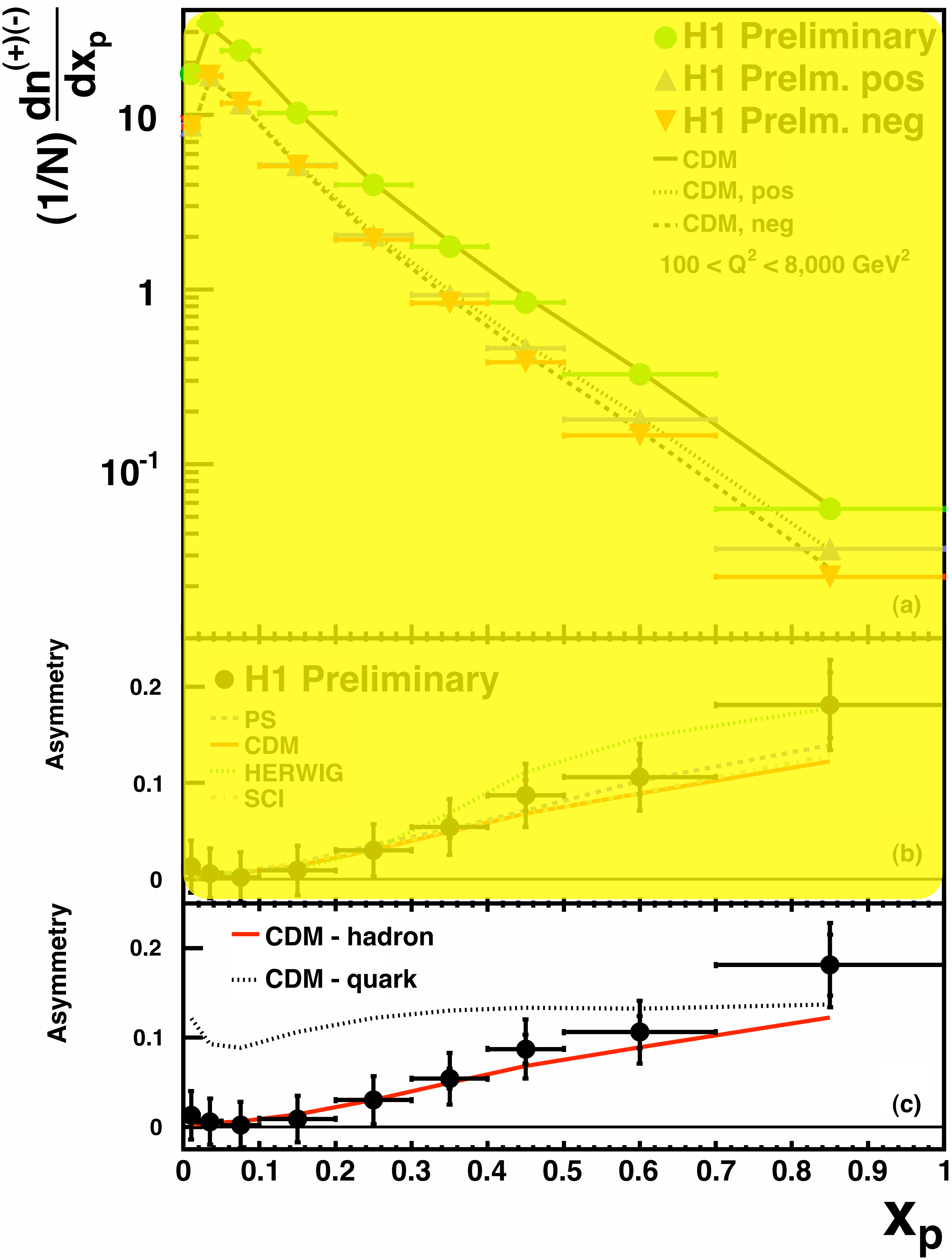


Asymmetry = $\frac{pos - neg}{pos + neg}$

Compatible with zero at low x_P, reaches ~20% at high x_P

Magnitude and evolution described by various Monte Carlo models

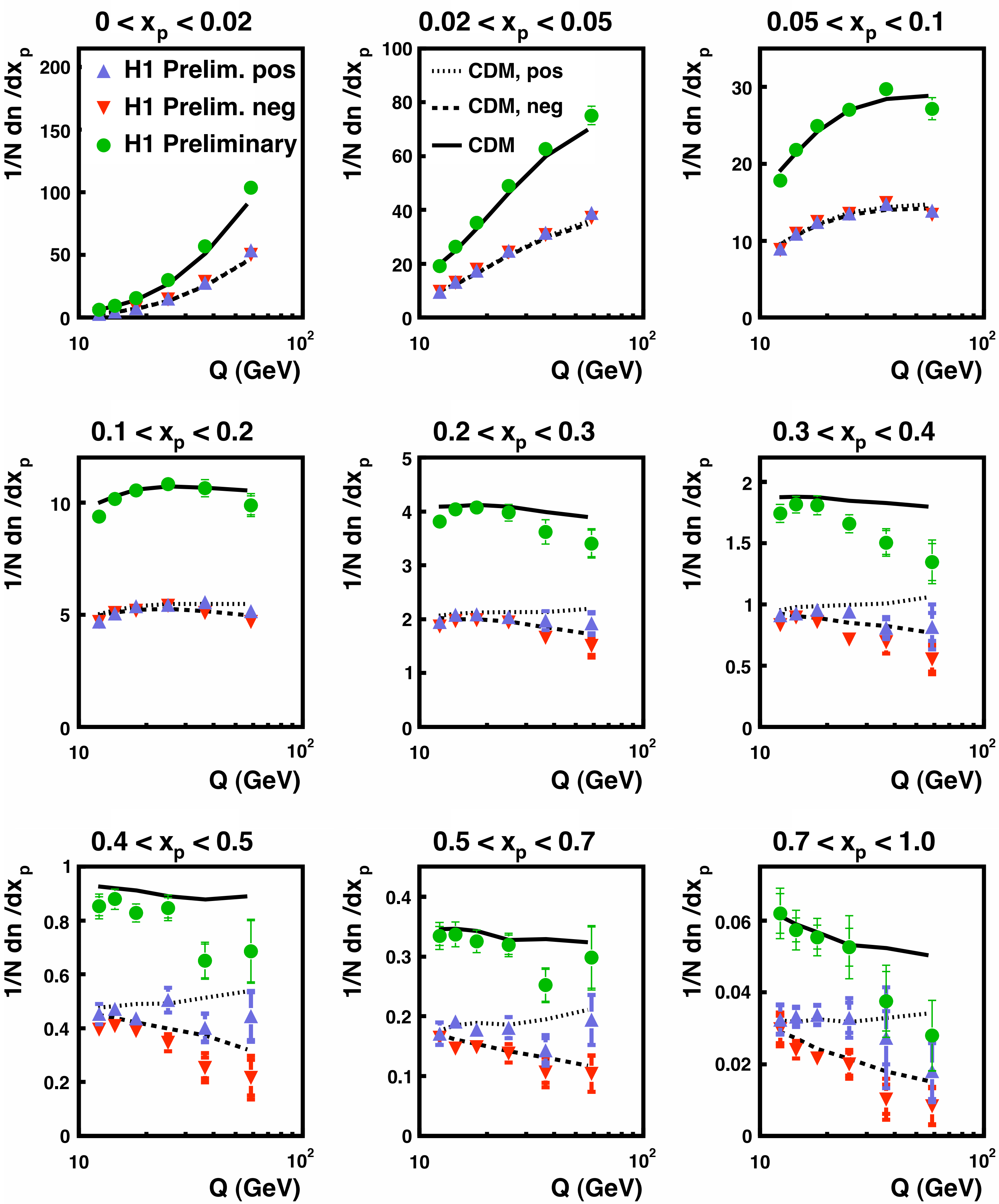
HERWIG has some differences at large x_P but still consistent with data



Quark level prediction obtained from CDM Monte Carlo with hadronisation turned off

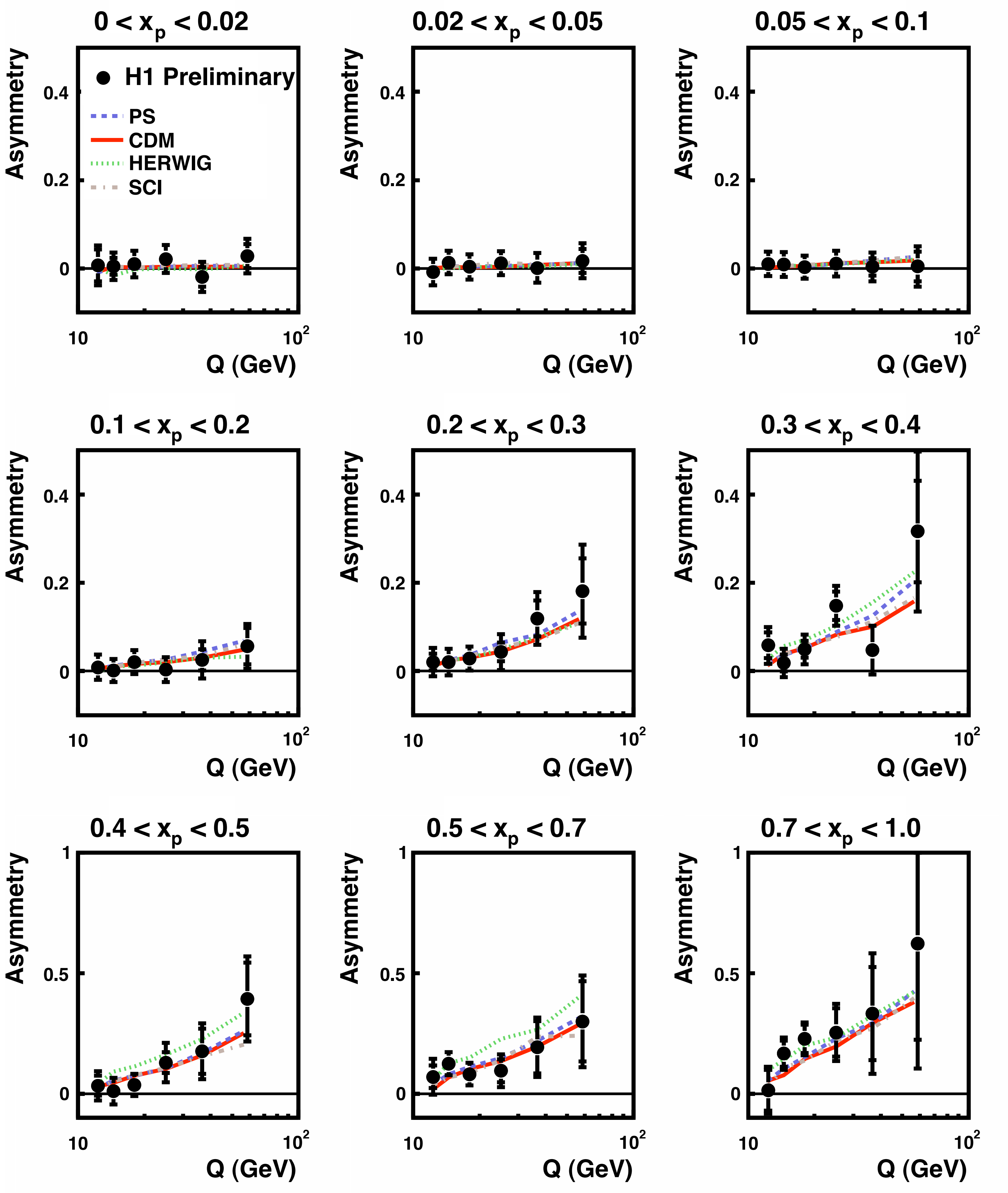
Similar asymmetry between data and CDM at large xp

Consistent with expectation that fragmentation dominates at low x_p, hard interaction at large x_p



At low Q^2 (low x_{BJ}) all x_p, pos and neg distribution similar

As Q^2 increases clear differences develop at high x_p, low x_p they remain consistent



At low Q^2 (low x_{BJ}) all x_p, asymmetry ~0

As Q^2 increases asymmetry develops at high x_p, low x_p it remains ~0

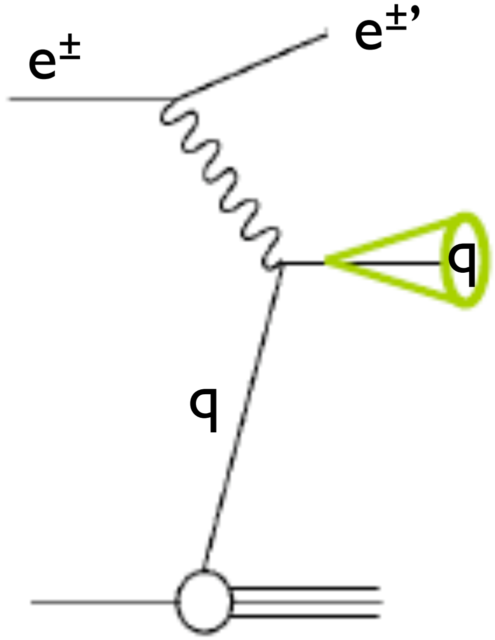
Monte Carlo models are able to describe the magnitude and evolution of the asymmetry

Conclusions

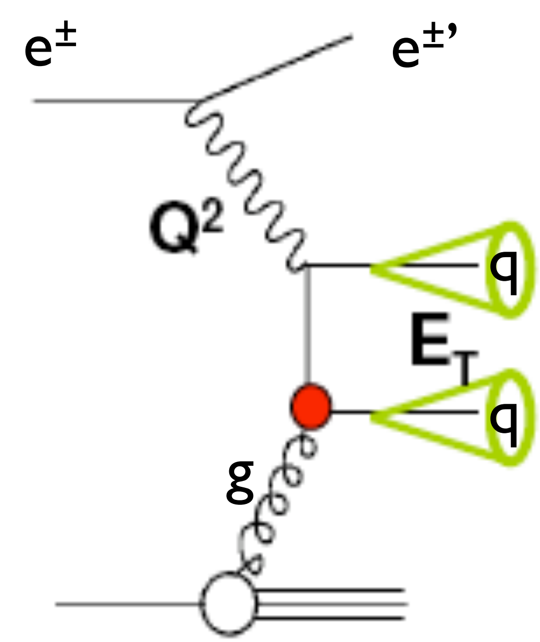
- First Observation of the charge asymmetry of the Hadronic final state in High Q^2 DIS.
- Method is general and can be applied to other environments (γP, PPbar,PP).
- Asymmetry dependent on x_P and gets larger with larger Q^2 (x_{BJ}). Results consistent with expectation from charge asymmetry of valence quarks.
- Provides useful data for extraction of fragmentation functions and valence quark distribution

backup

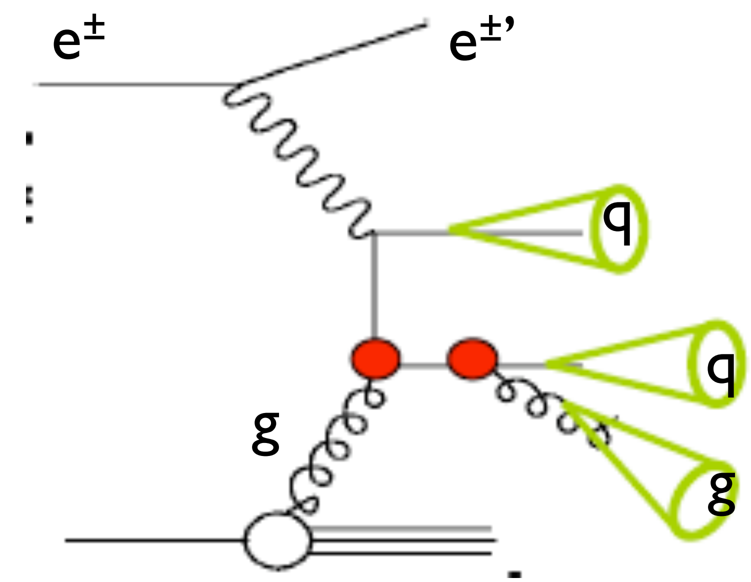
BORN



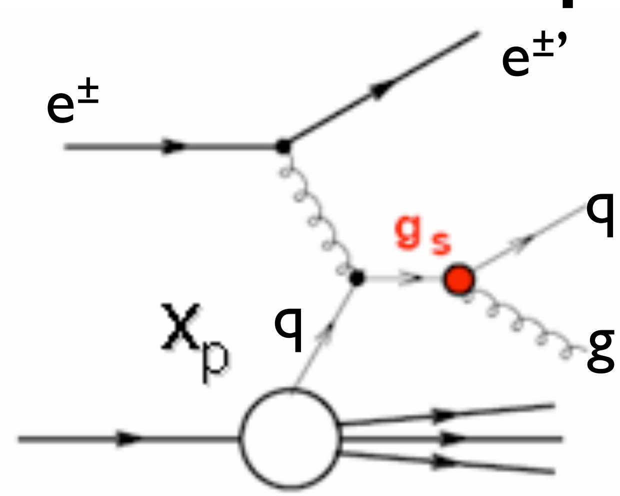
LO BGF

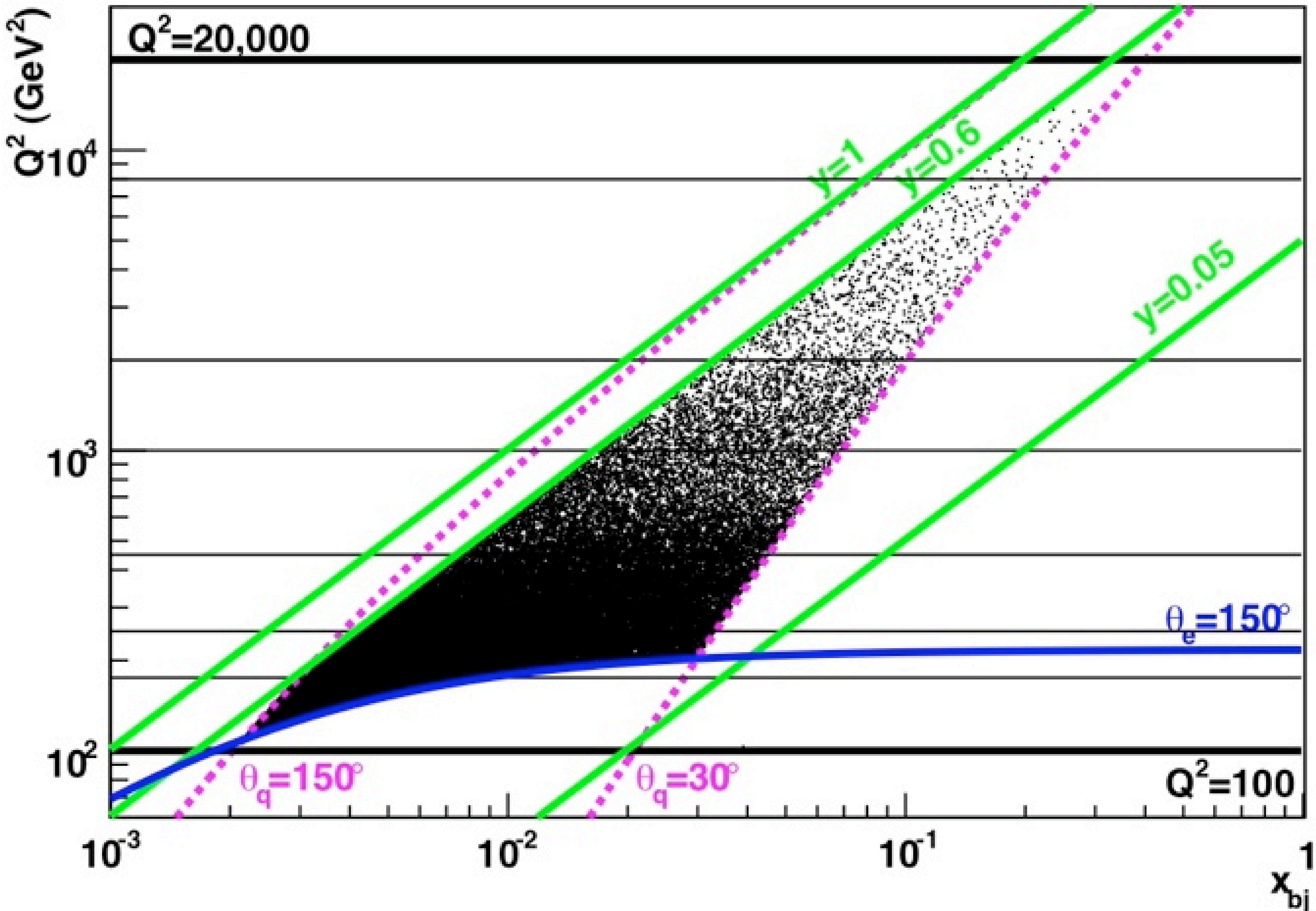


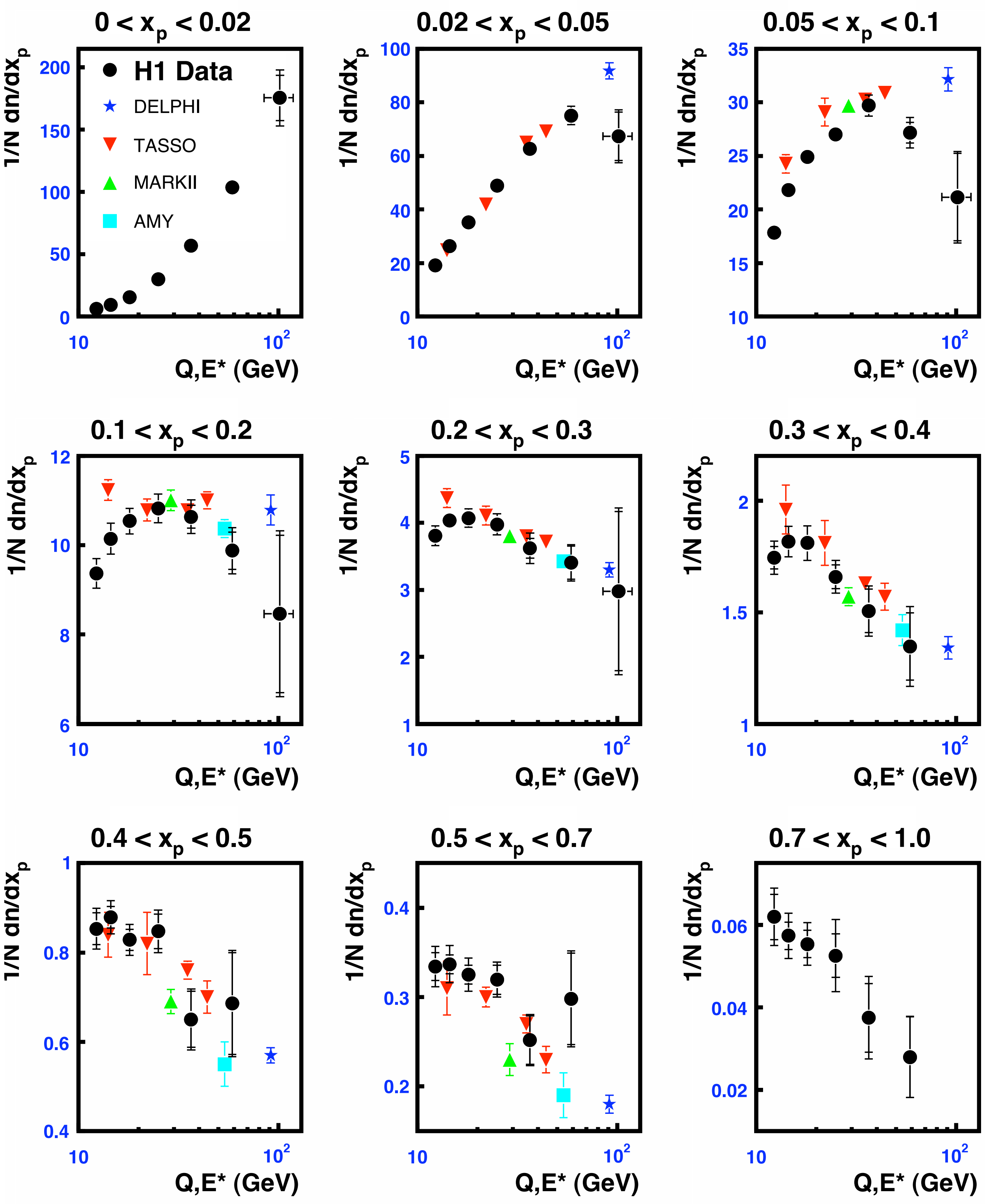
NLO



LO QCD Compton




Q²=20,000
Q² (GeV²)
10⁴
10³
10²
y=1
y=0.6
y=0.05
θe=150°
θq=150°
θq=30°
Q²=100
10⁻³
10⁻²
10⁻¹
1
xbj

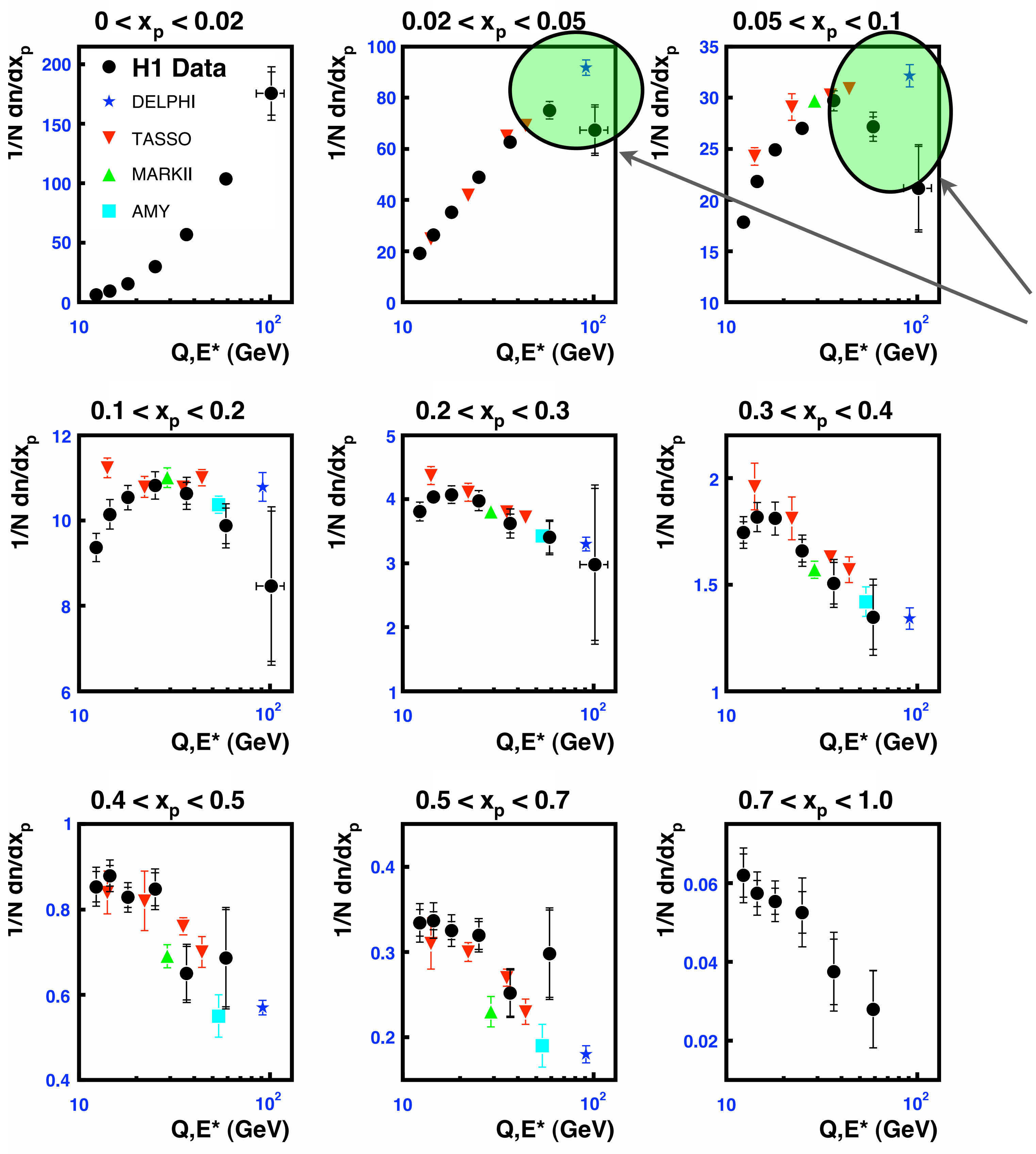


Pretty good agreement between ep and e^+e^- !

high Q^2 and small x_p reason unclear

low Q^2, mid x_p. expected to be due to BGF kinematics producing empty current region

NB: suppressed zeros



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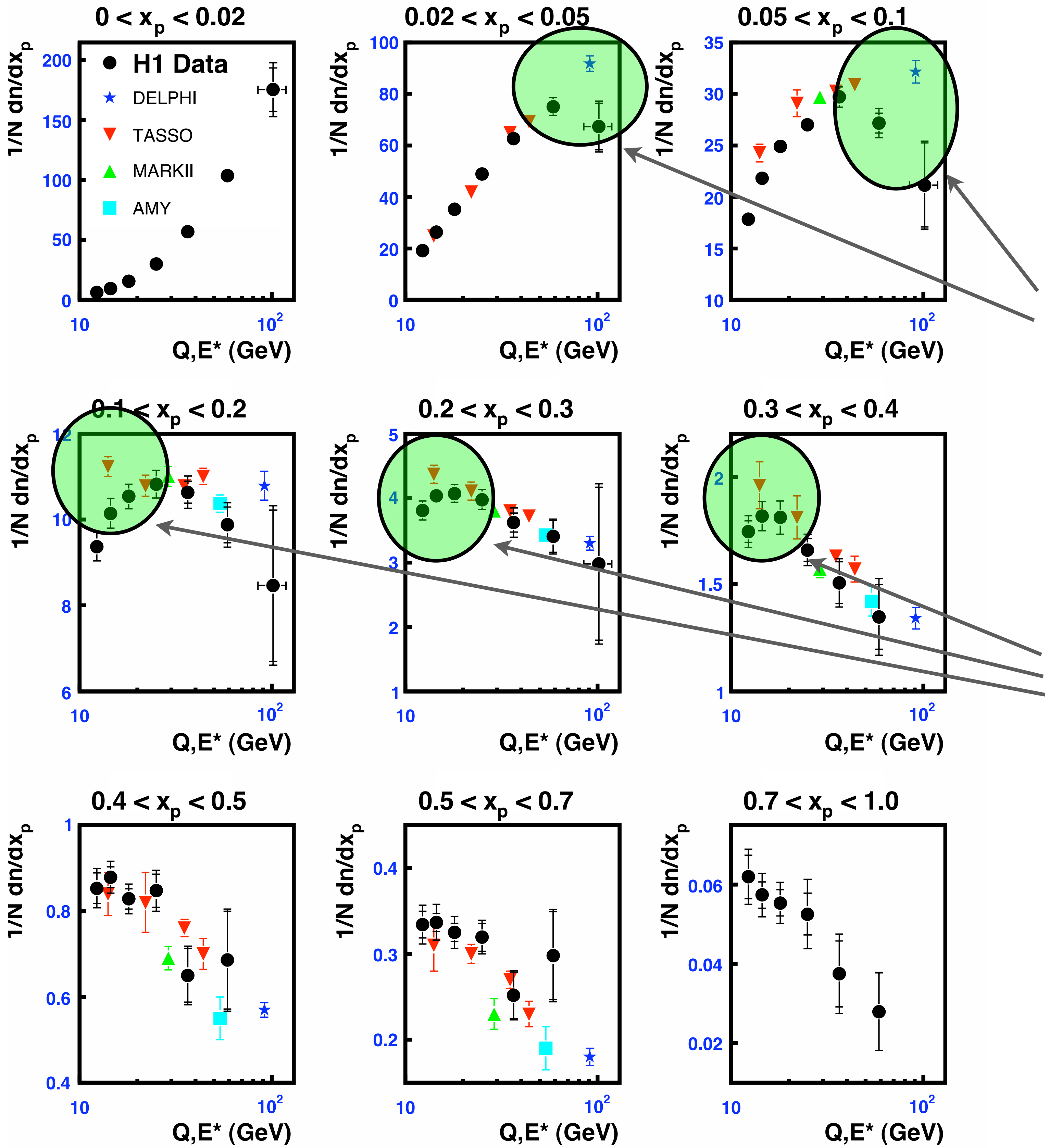

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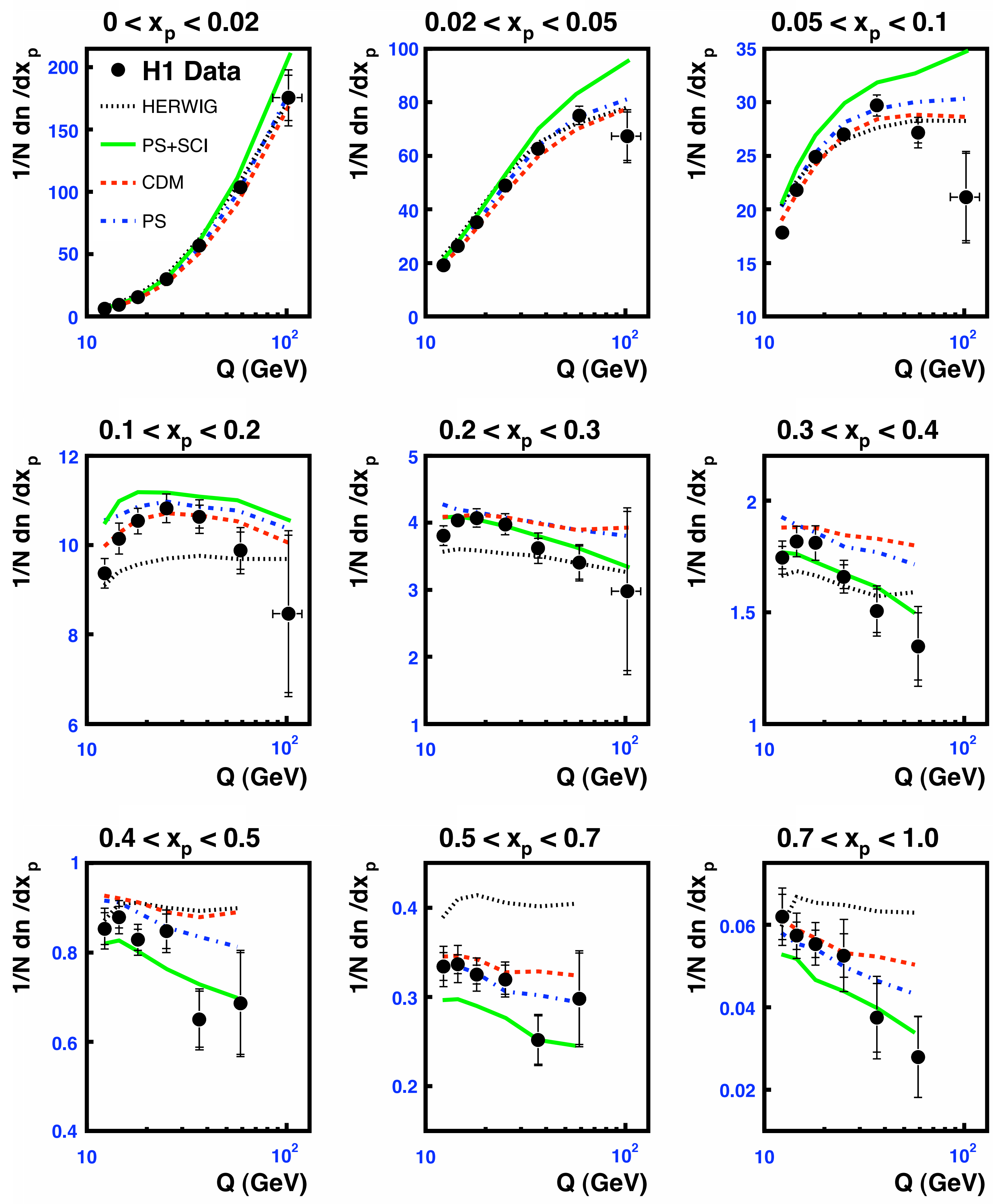
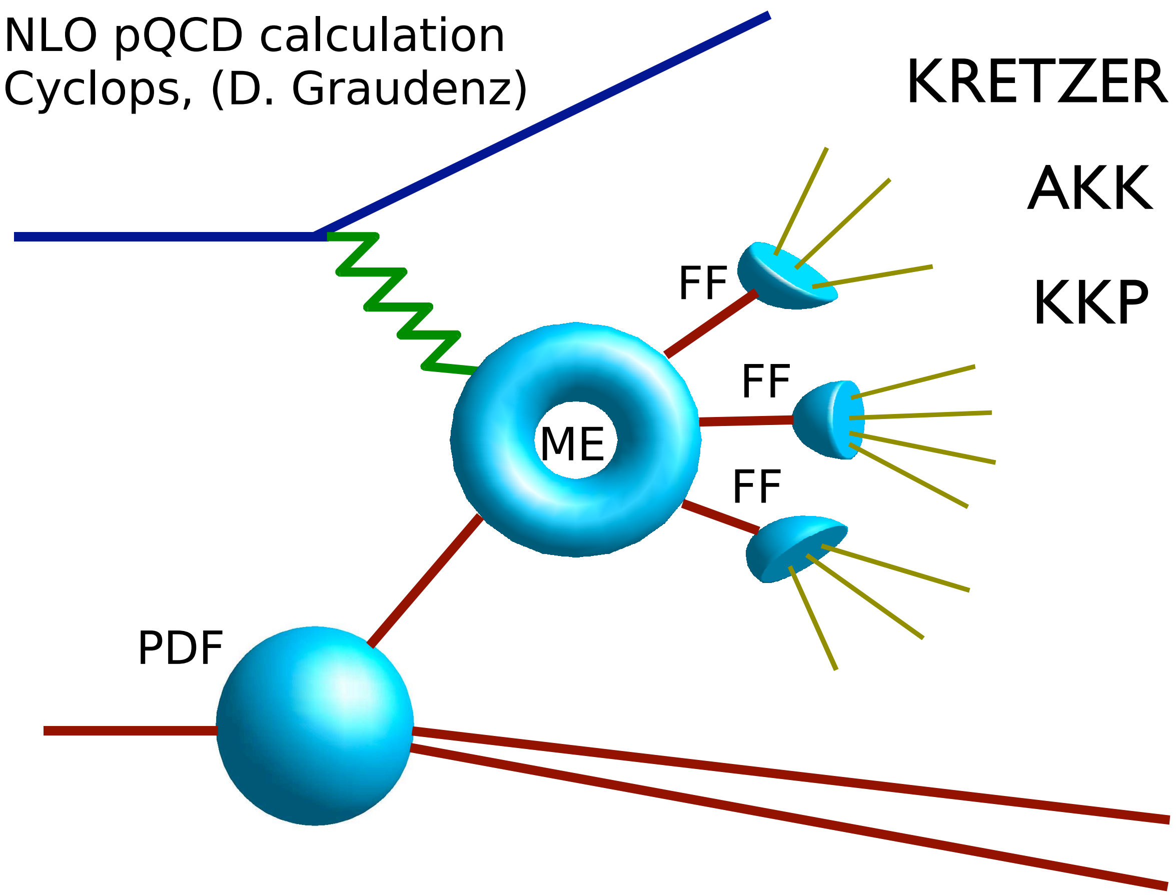


CDM and PS acceptable description of data.
both tend to overestimate the multiplicity at high Q^2

SCI model predicts too soft a spectrum

HERWIG is too hard and fails to reproduce scaling violations seen in the data



σ_h = PDF ⊗ M.E. ⊗ FF

NLO pQCD   CYCLOPS

Fragmentation Functions - e^+e^- fits

Infra red safe region (Q2>100), xp > 0.1

FF parameterised from xp>0.1

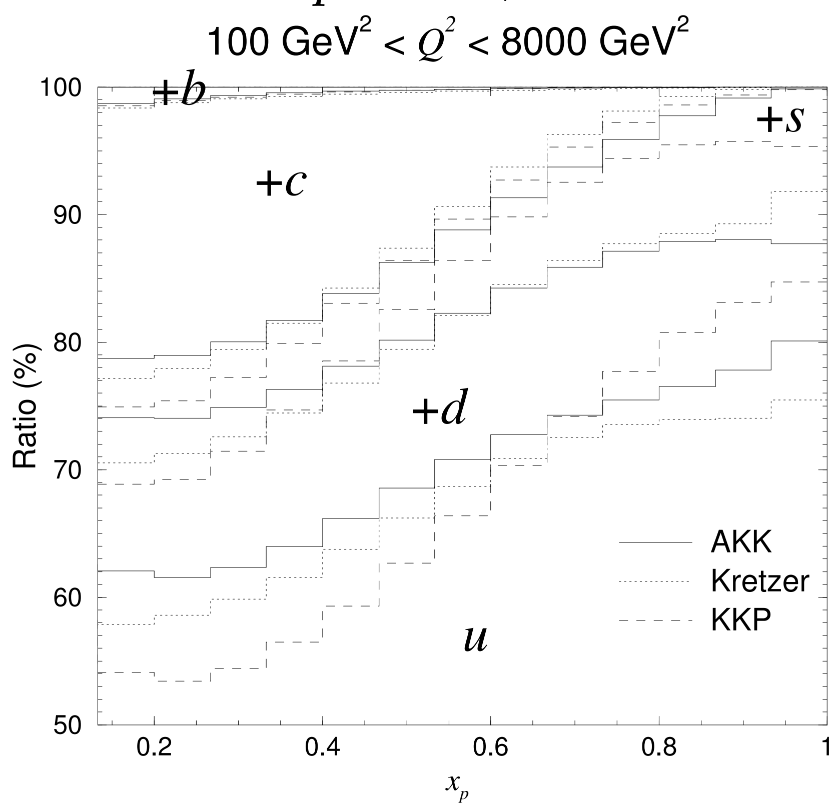
CTEQ6M, $\Lambda(5)$QCD = 226 MeV (also ME + FF)

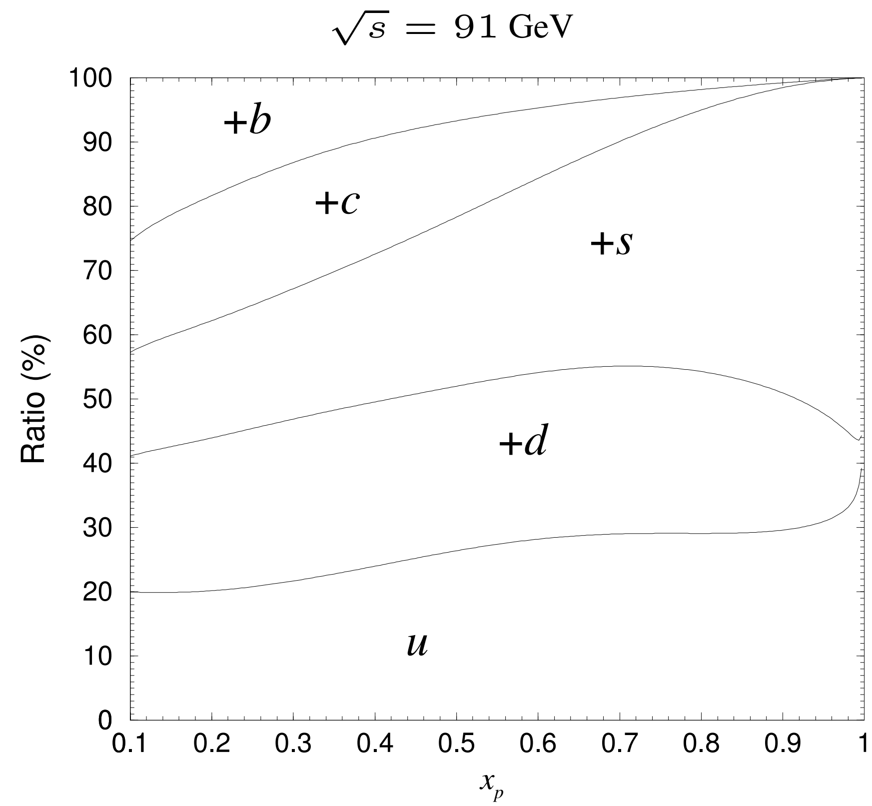
Quark tagging (H1)

Identify quark flavour at e.w. vertex

$ep \to h + X$

$e^+e^- \to h + X$





Proton is good source of u

s relatively large

In principle, ep and e^+e^- together can separate uds FFs