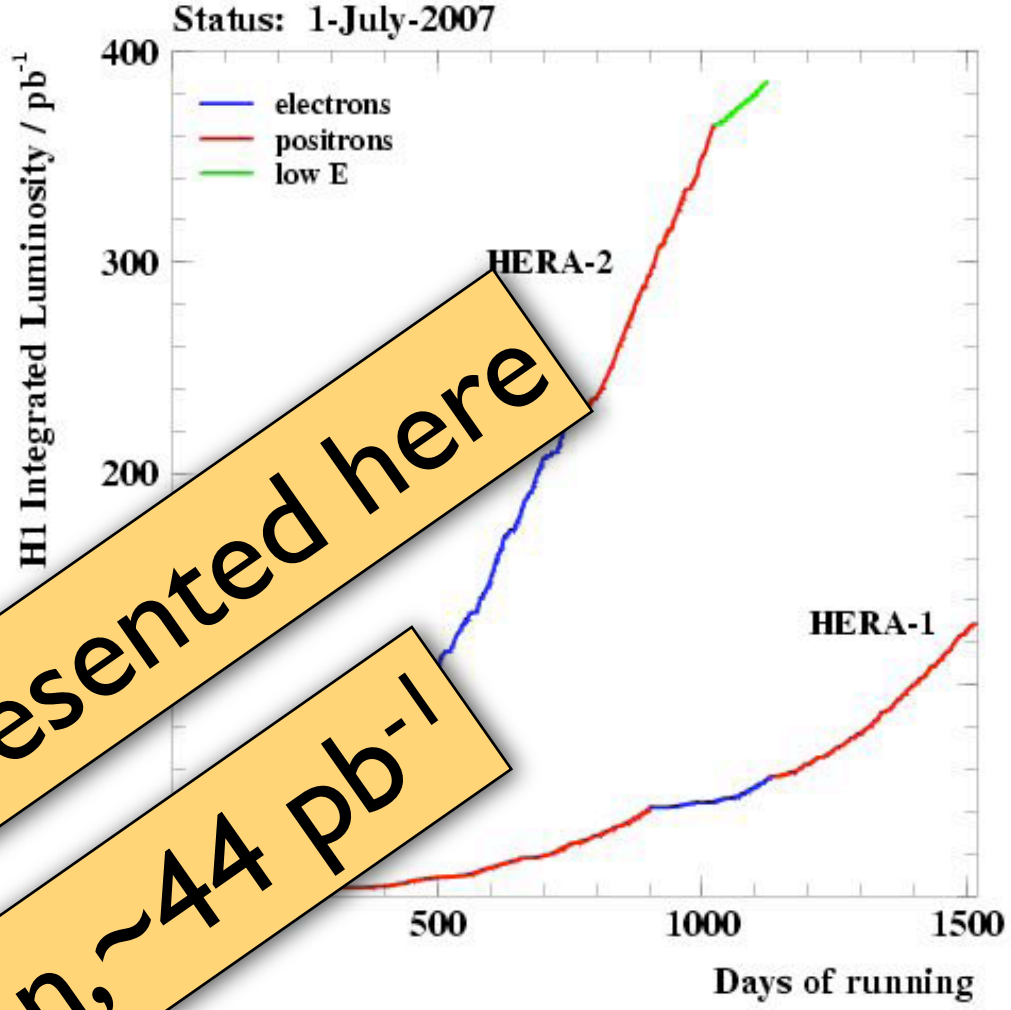
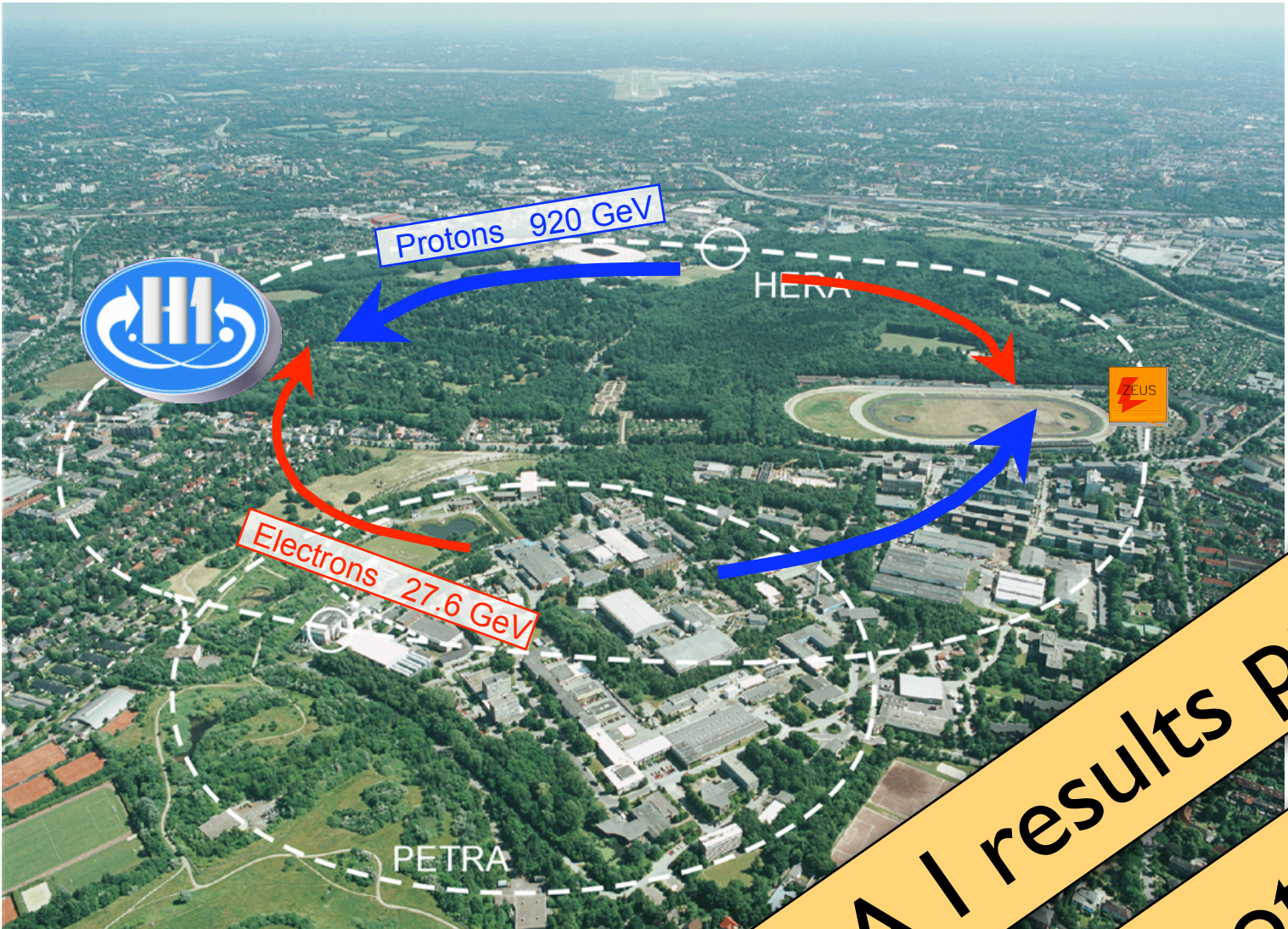


Hadronic Charge Asymmetry in DIS

Daniel Traynor, DIS09, 29/04/09

Overview

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

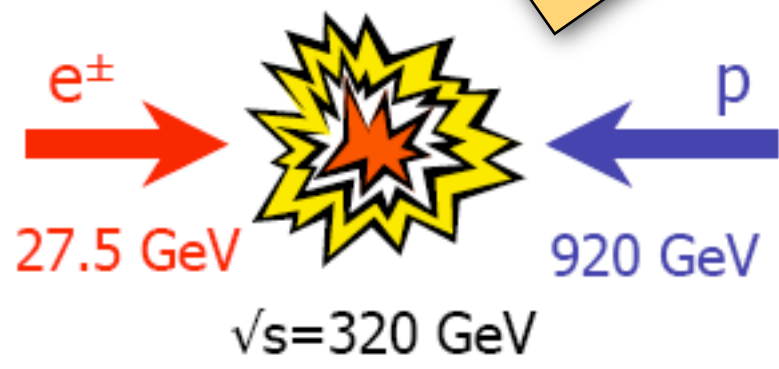


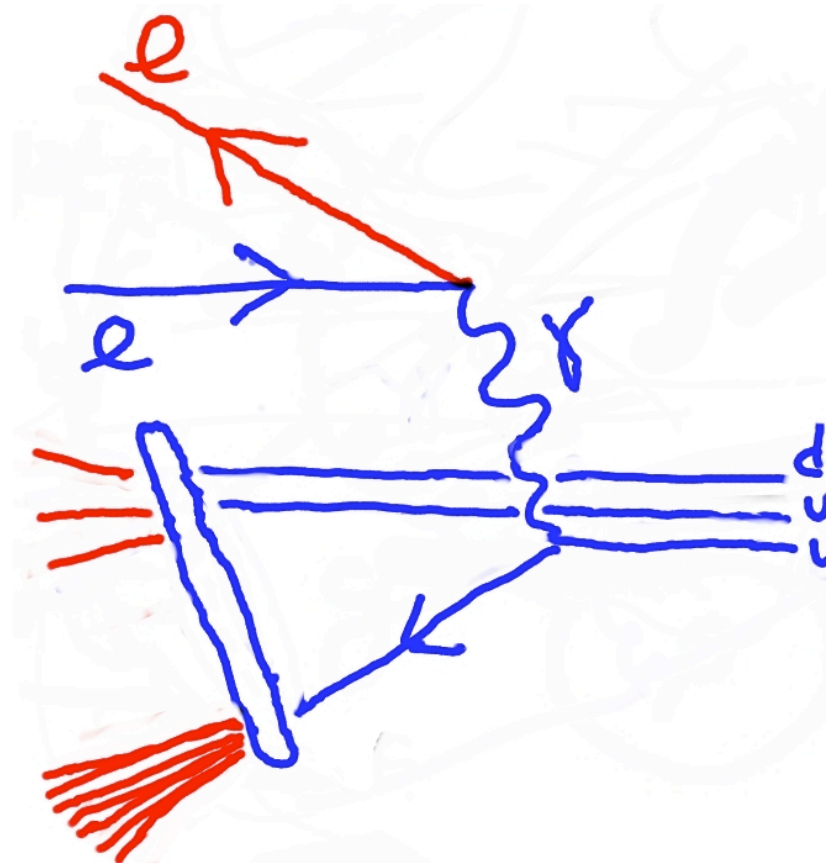
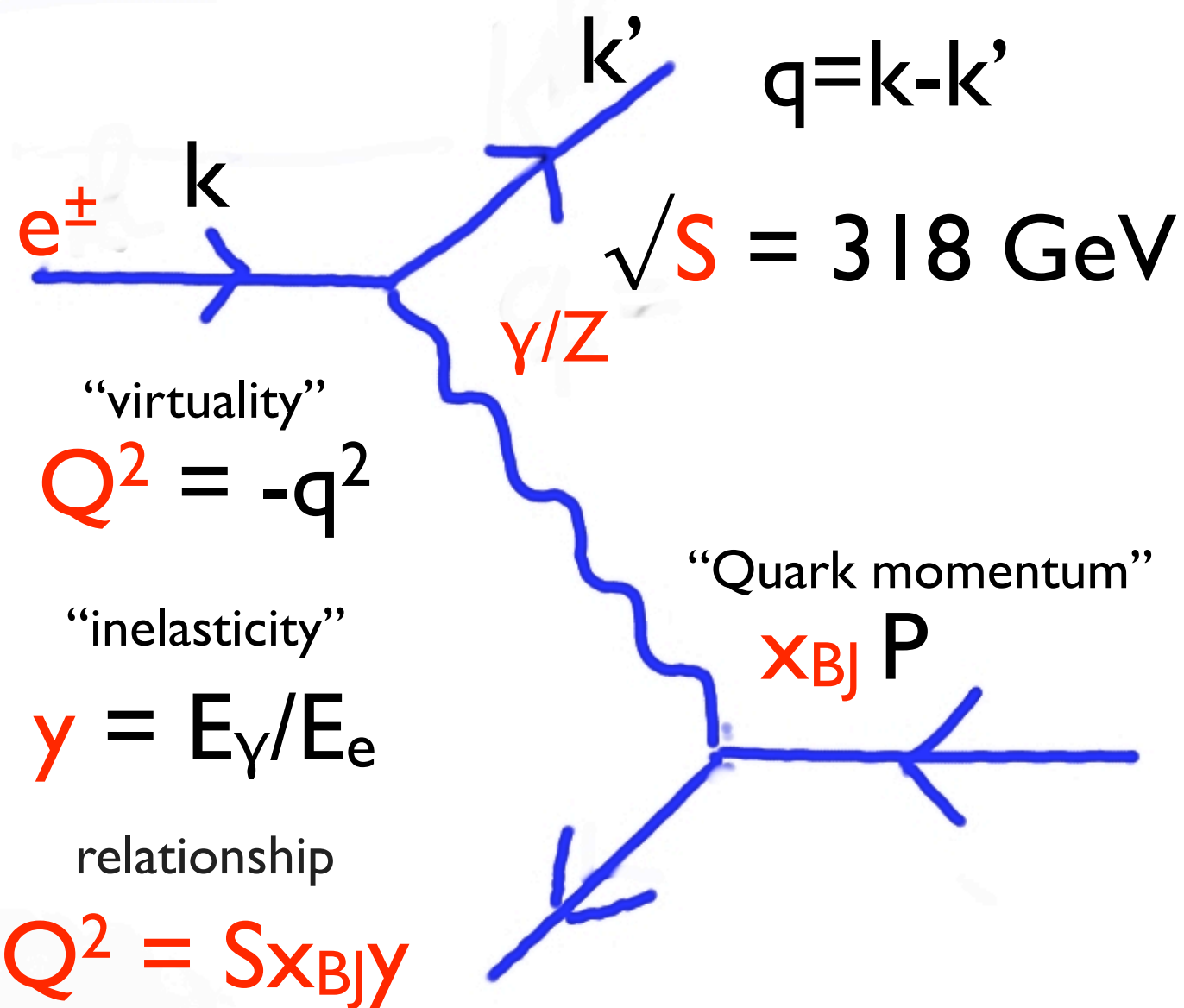
Only HERA I results presented here

positron - proton, ~44 pb⁻¹

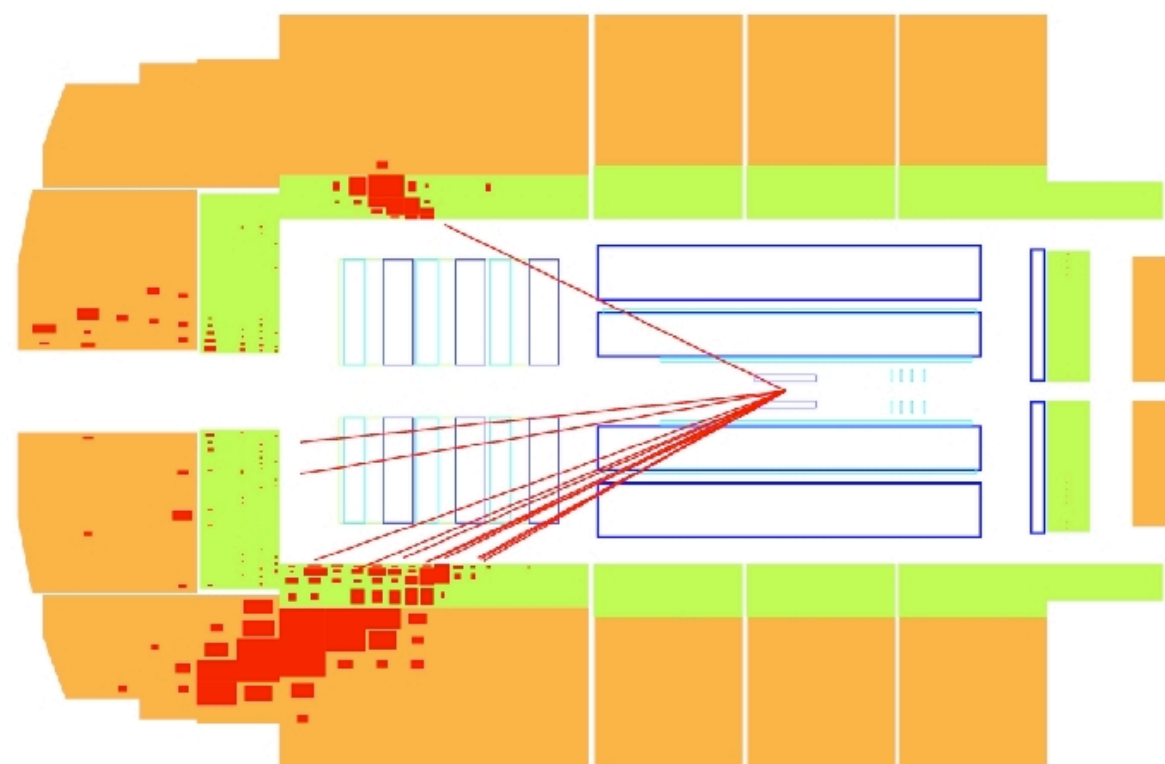
electrons or positrons
polarised lepton beams
4 different proton energies

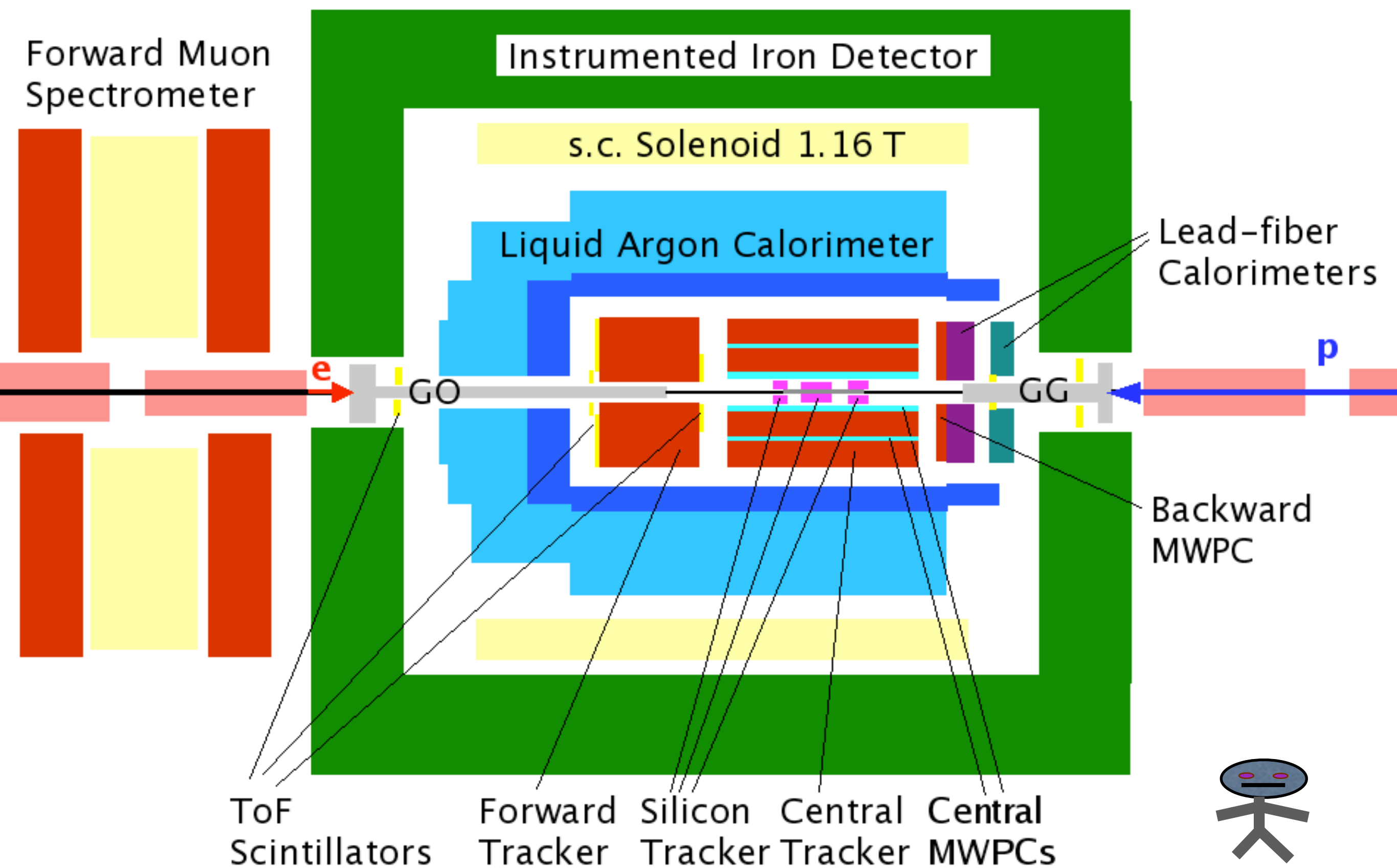
H1 Physics usable sample ~500 pb⁻¹



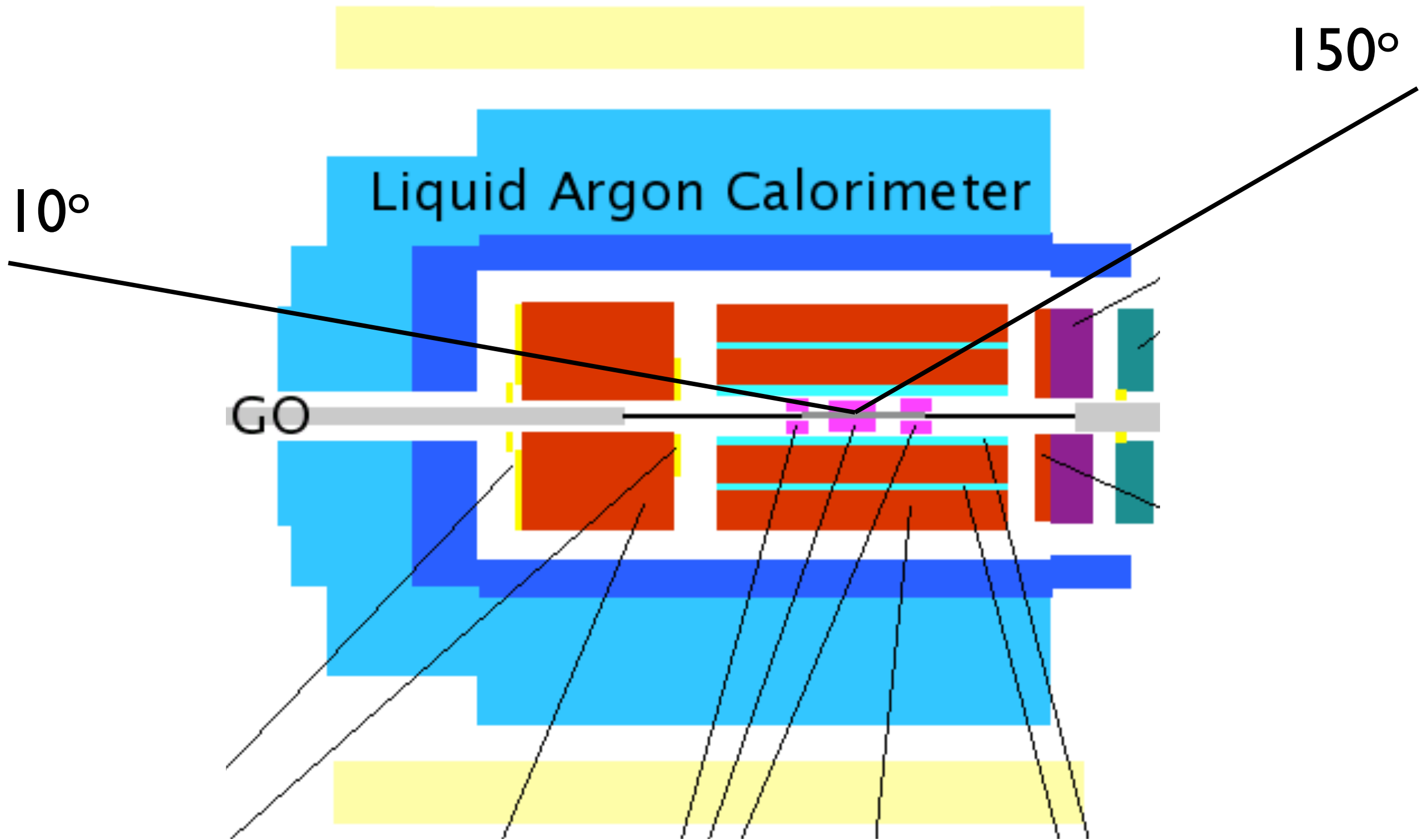


Neutral Current DIS



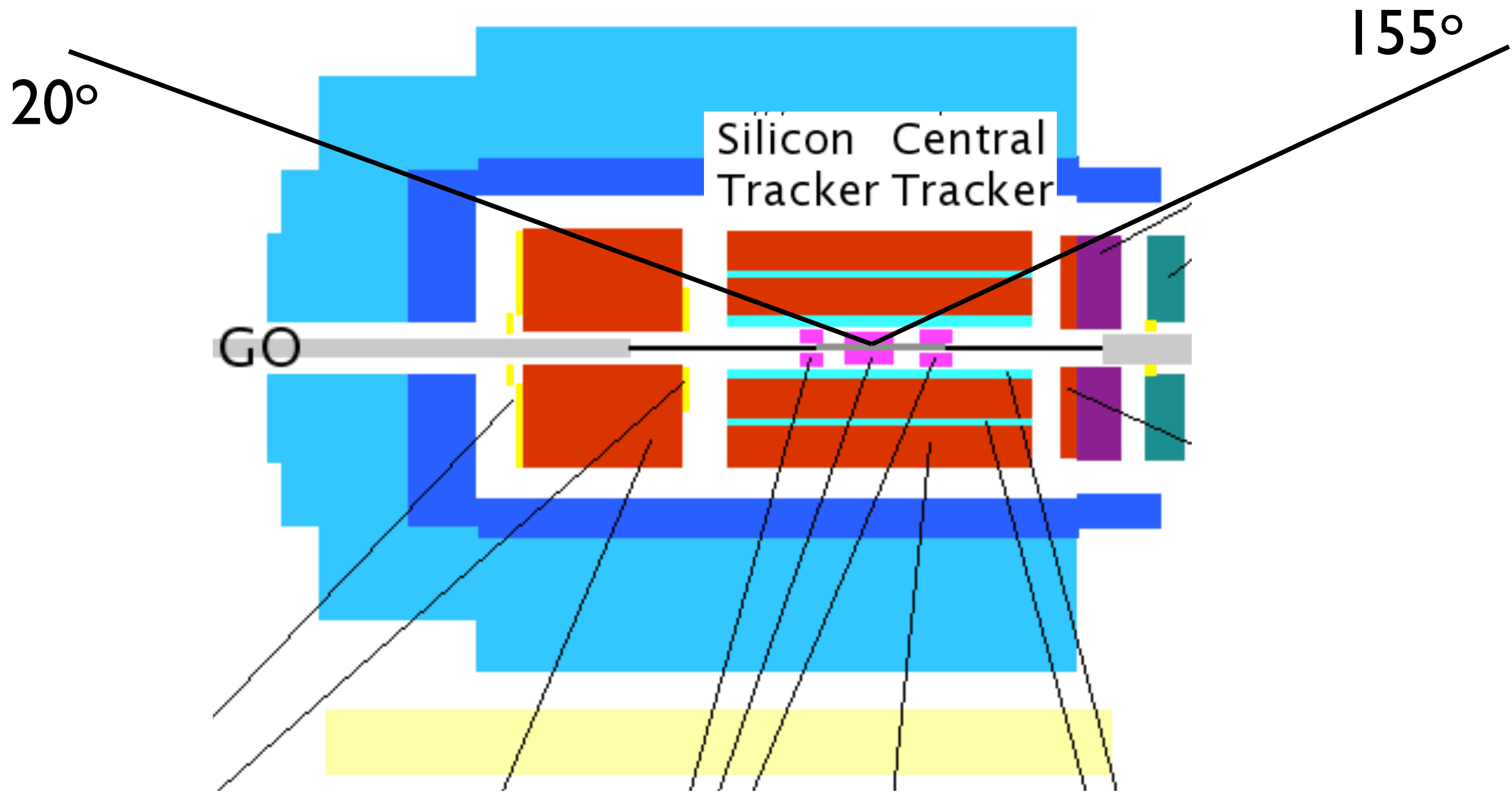


Scattered electron acceptance at high Q^2



Tracking acceptance of HFS

s.c. Solenoid 1.16 T



Kinematic phase space

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

$$0.05 < y < 0.6$$

$$\theta_{\text{electron}} > 150^\circ$$

$$30^\circ < \theta_{q,\text{lab}} < 150^\circ$$

quark scattering angle,
 $\theta_{q,\text{lab}}$, 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 $\sim 5\%$

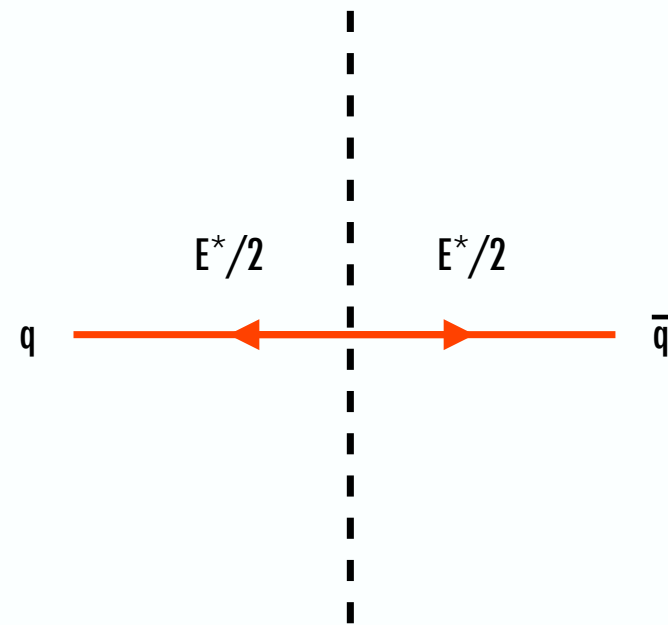
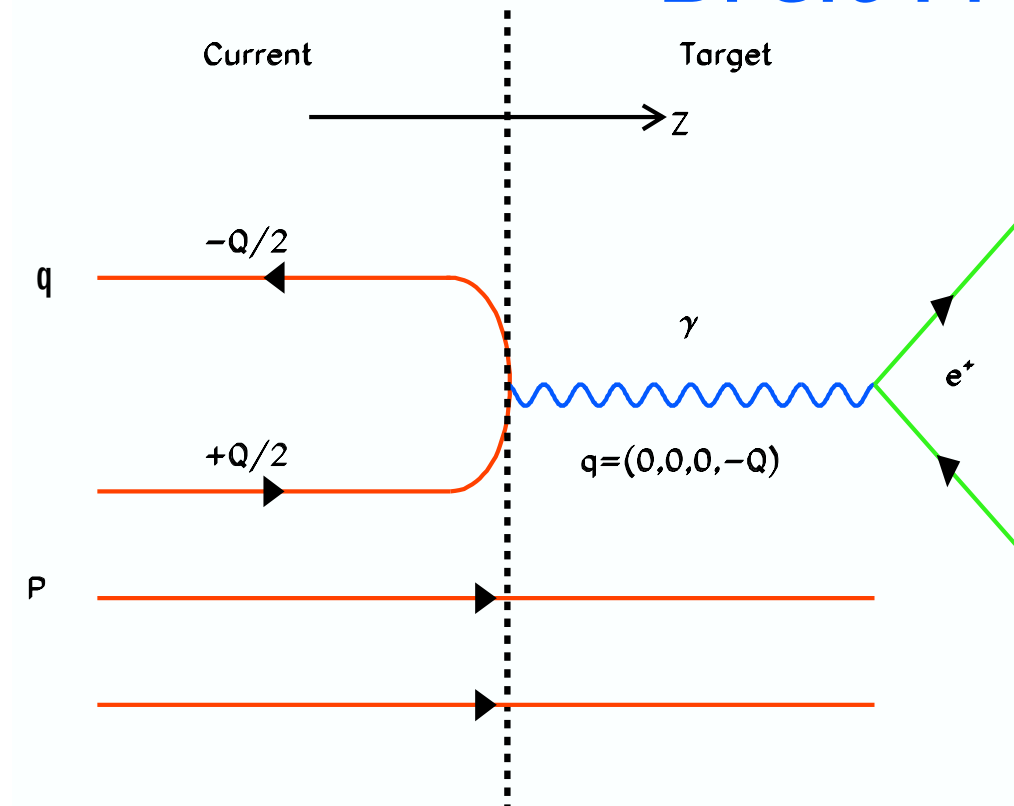
Asymmetry
correction factor ~ 1.0
systematics partial cancel



$$ep \rightarrow eX$$

Breit Frame

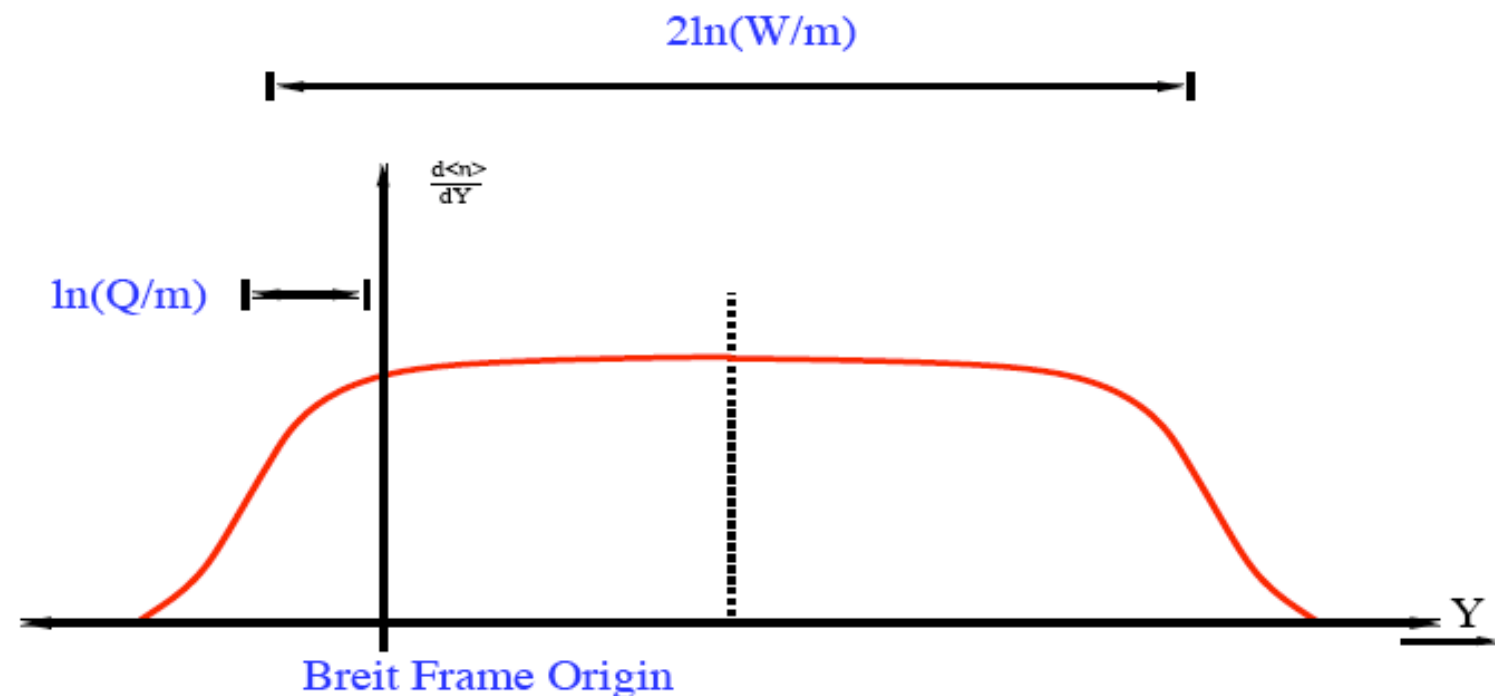
$$e^+e^- \rightarrow q\bar{q}$$



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 $p_{\text{breit}} = 0$!



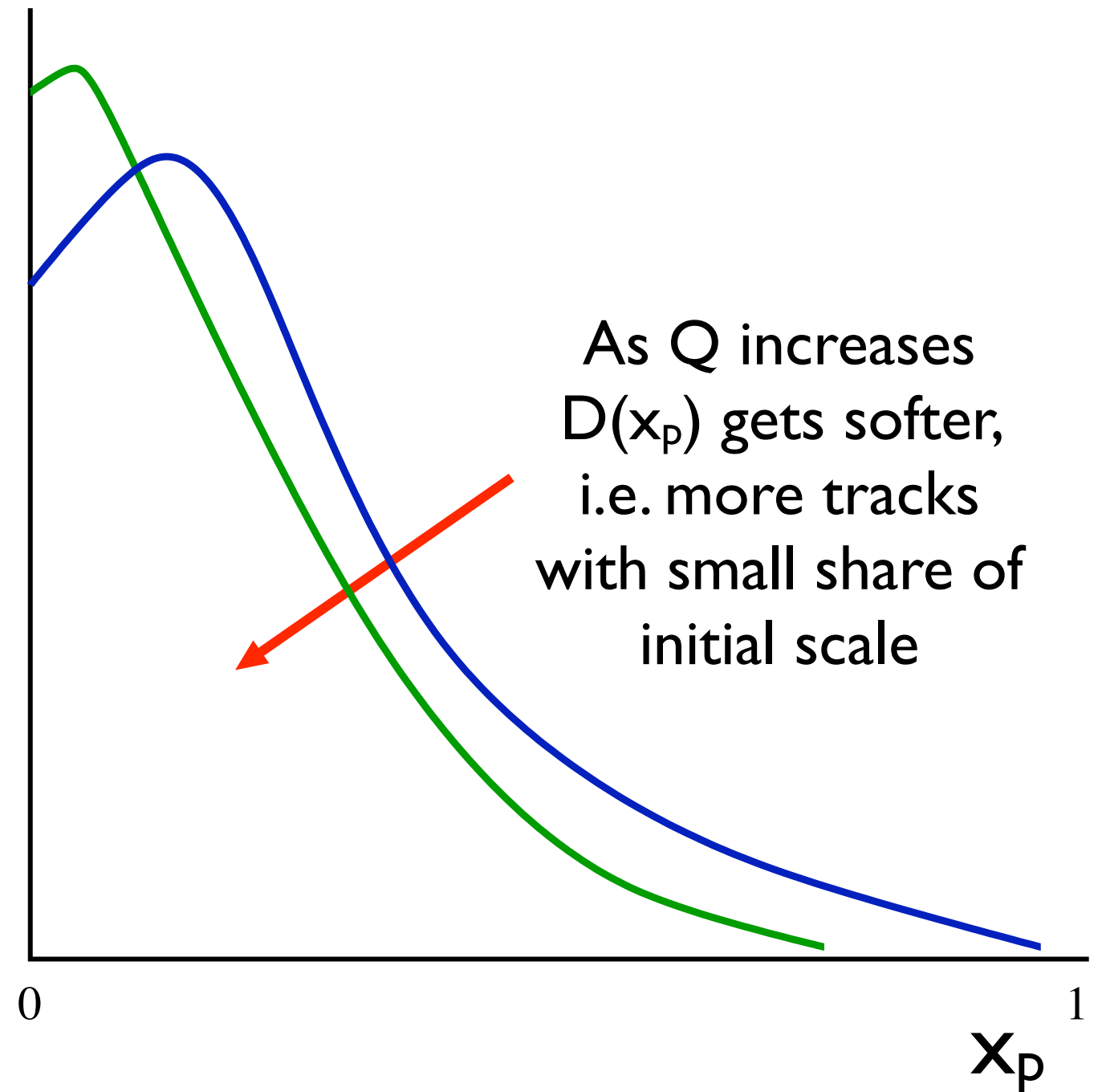
$$x_p = \frac{(2P_h)}{Q}$$

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

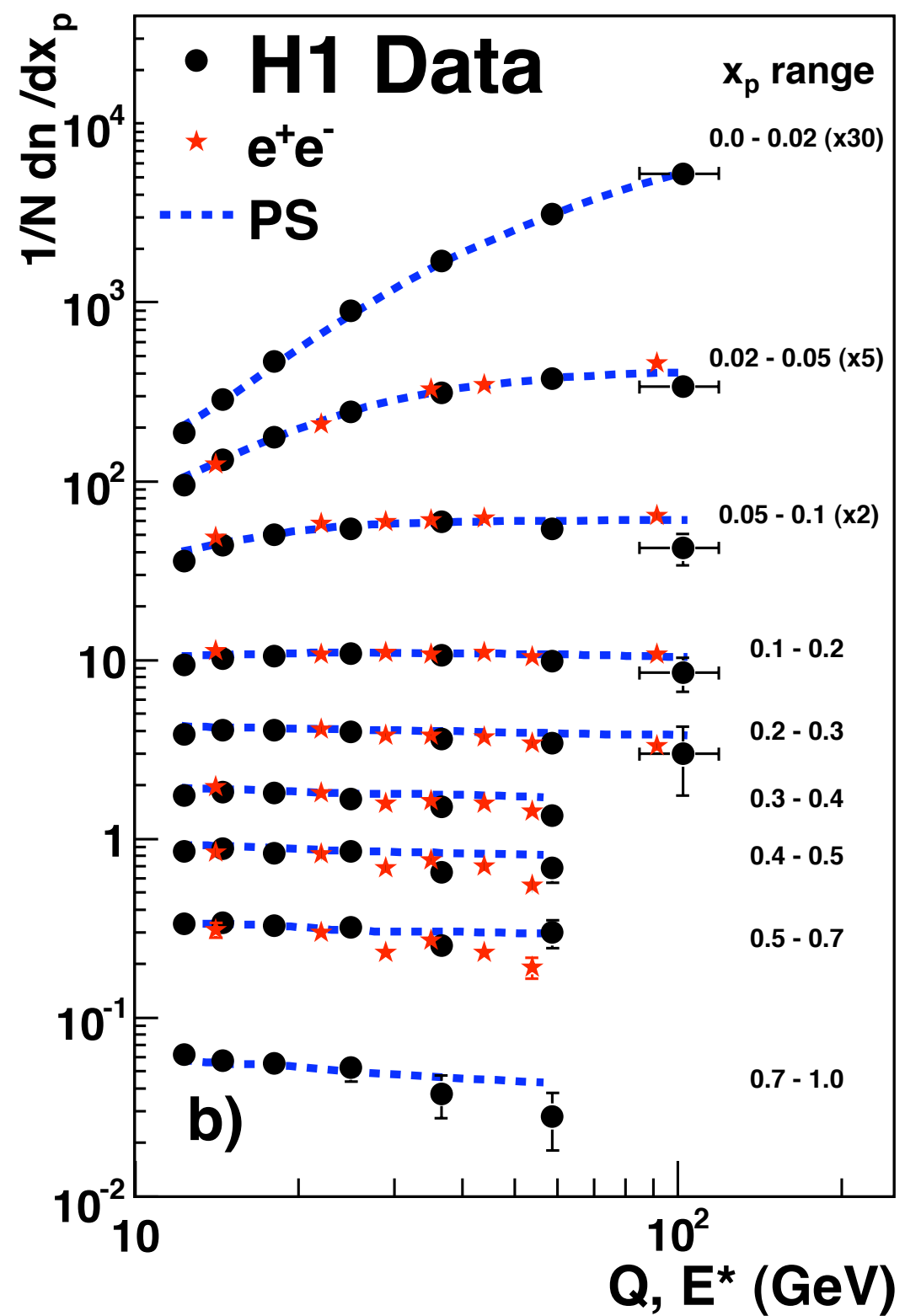
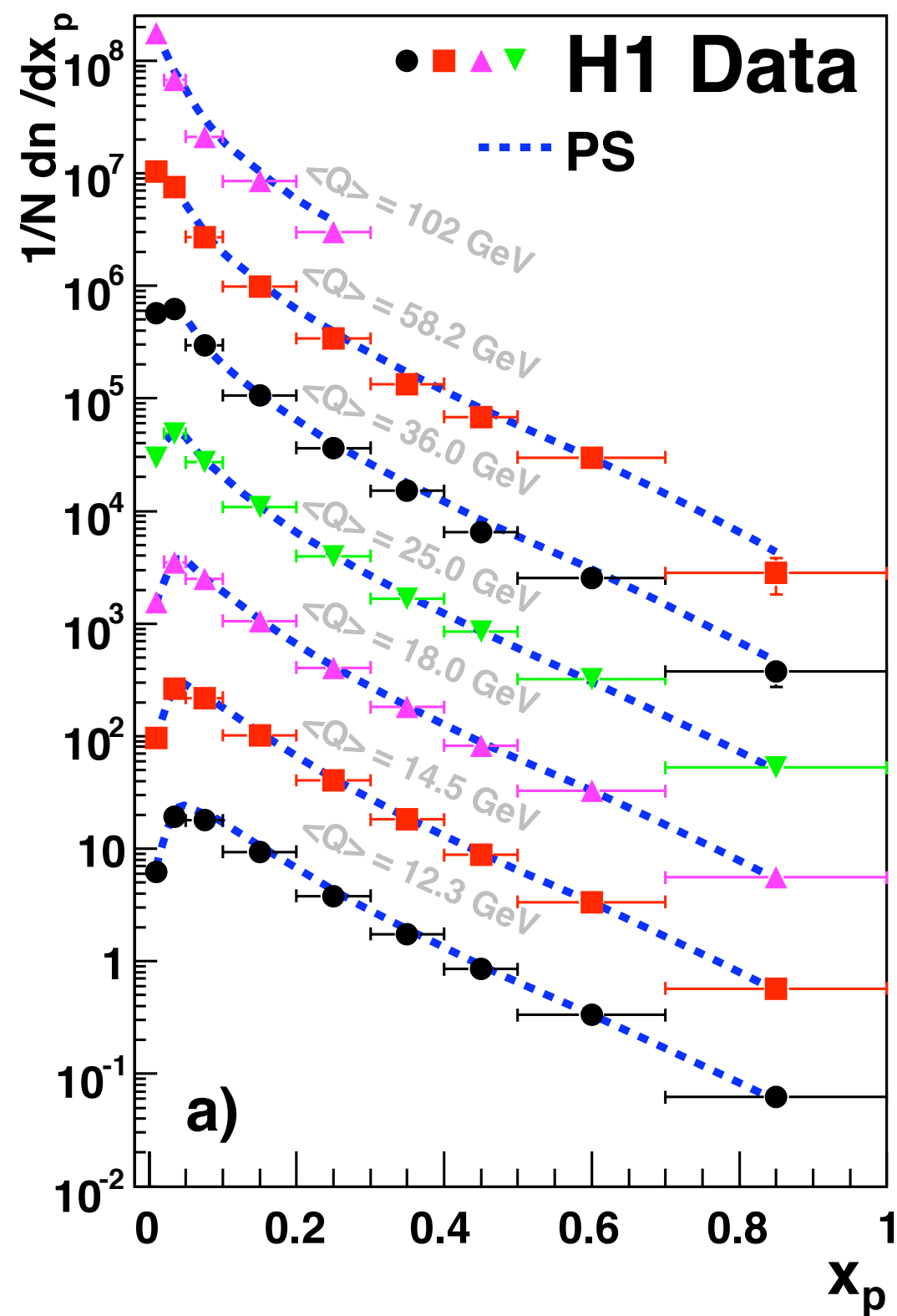
x_p = scaled momentum variable

$Q/2$ = 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

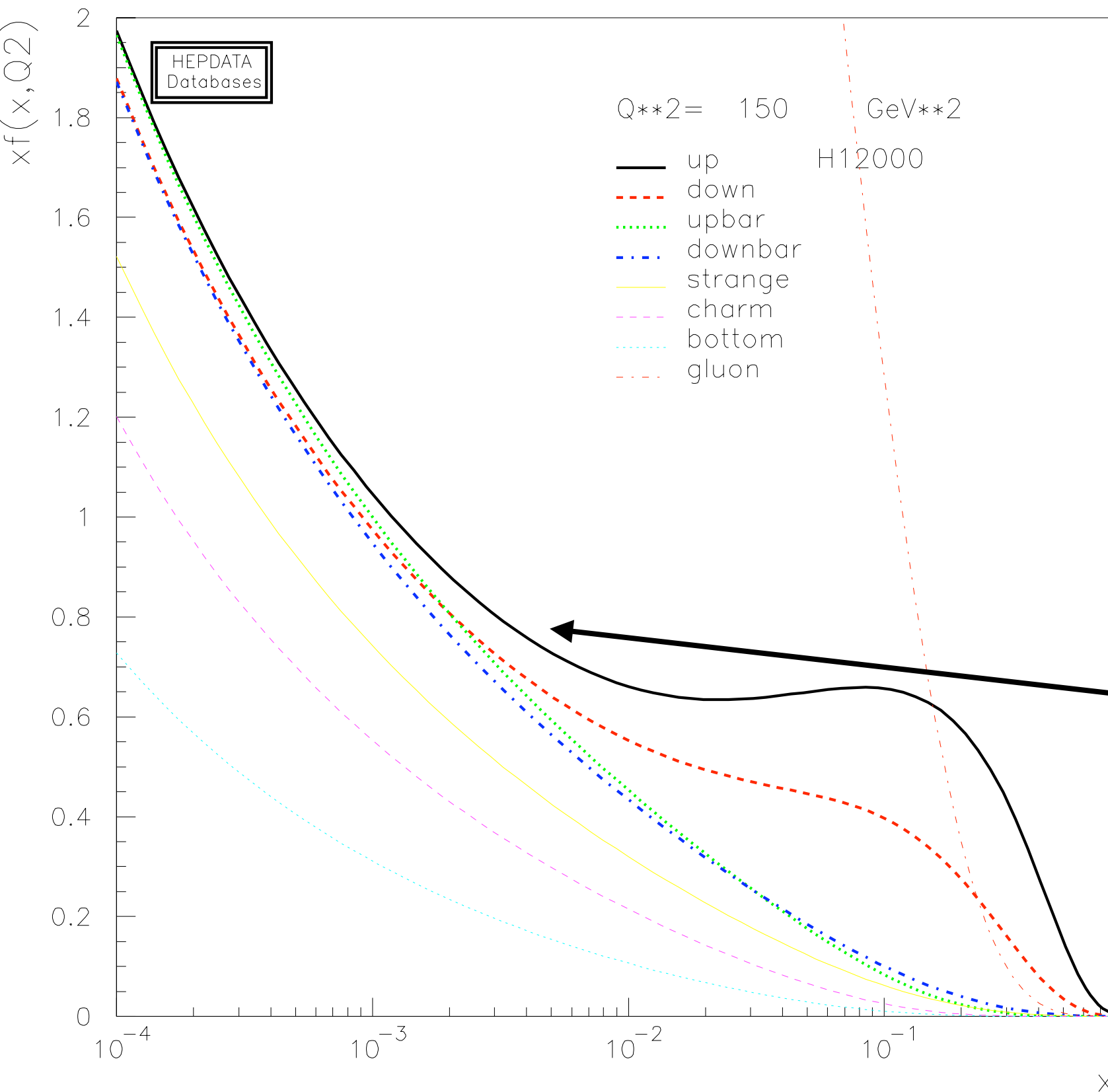


Reasonable agreement between ep and e^+e^- / Monte Carlo - broadly supports quark fragmentation universality.

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

Charge Asymmetry Motivation

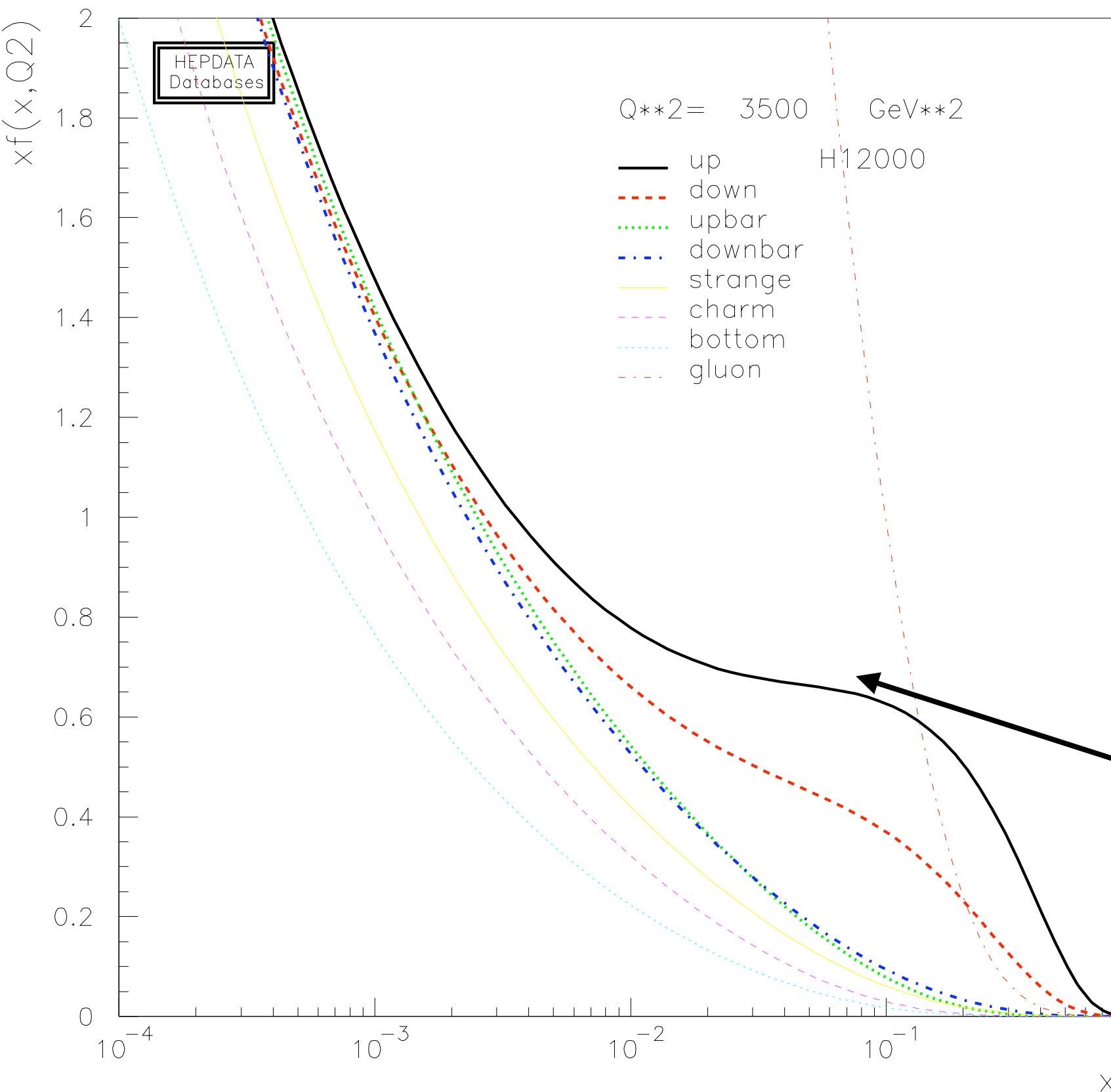
Quark contribution to PDF



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 $x \sim 0.005$.
sea quarks
dominate -
 $u \approx d \approx s \approx$
 $\bar{u} \approx \bar{d} \approx \bar{s}$

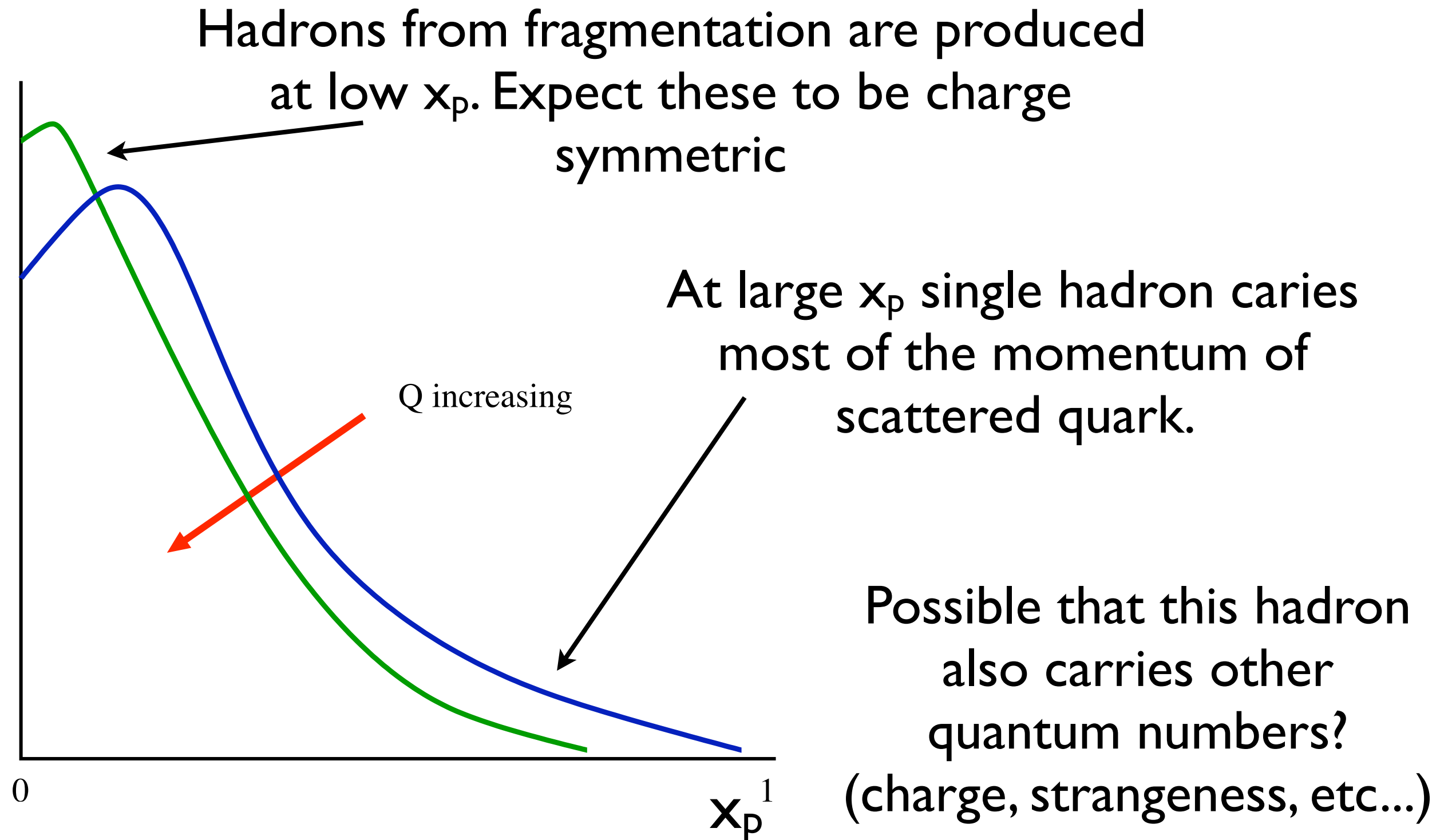
Quark contribution to PDF



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

Highest Q^2 bin has
average $x \sim 0.1$.
valence quarks
dominate $u > d \gg s$,
 \bar{u} , \bar{d} , \bar{s}

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



Charge Asymmetry

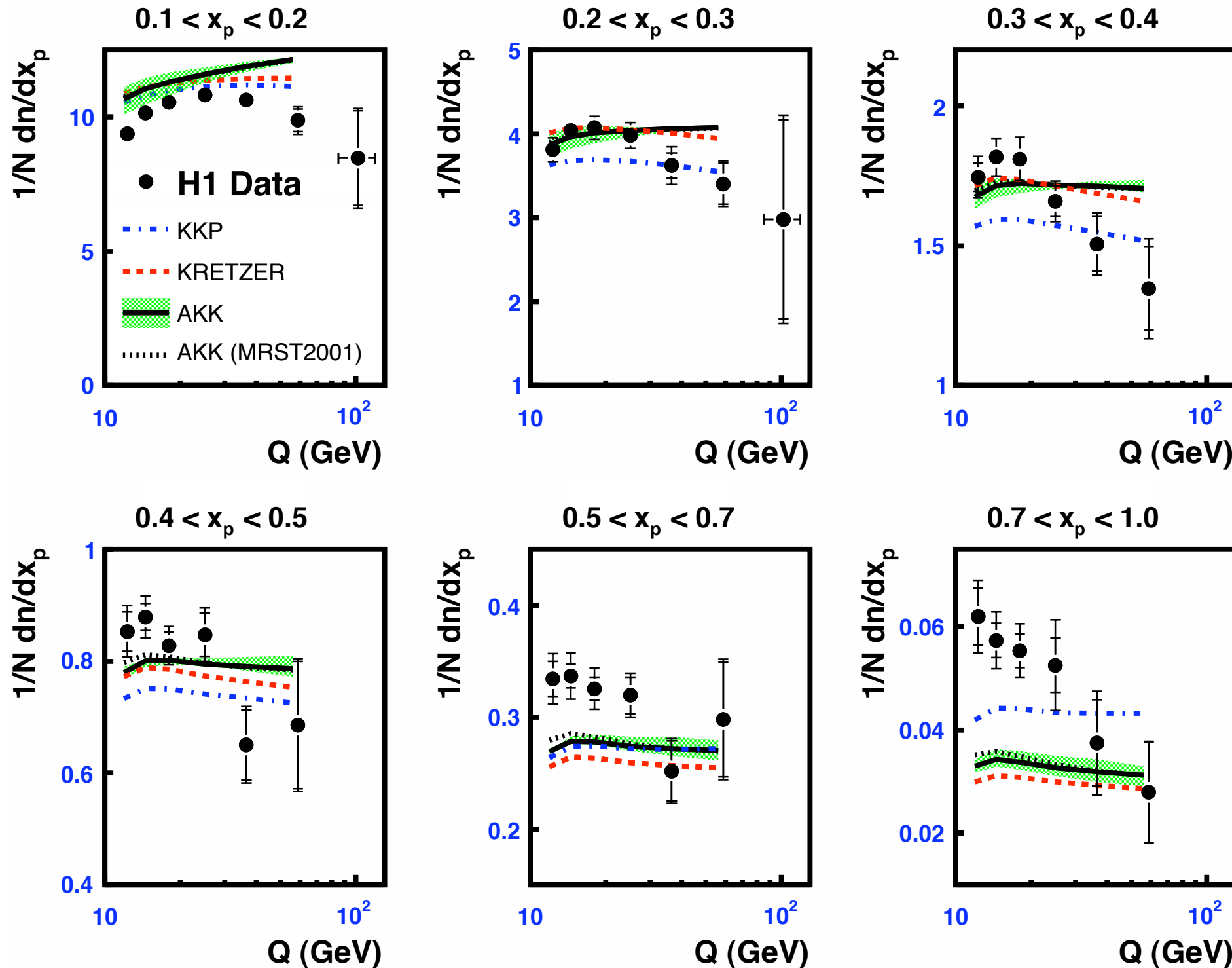
Charge sign asymmetry of RHIC data shown to be sensitive to valence quark distribution when analysing fragmentation data.

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

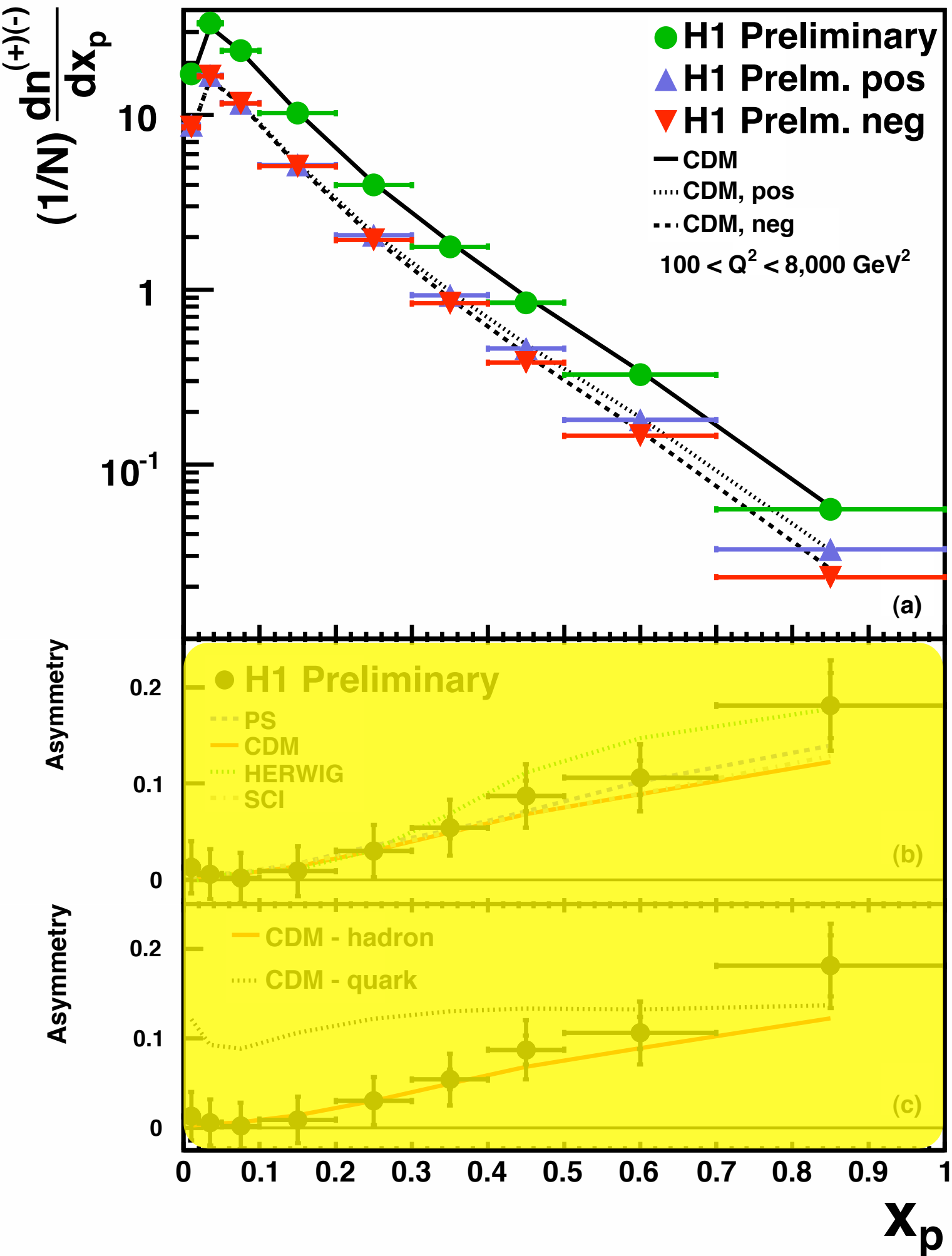
Scale and PDF errors small

Sensitivity to different FF

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

NLO theory does not describe the DATA!

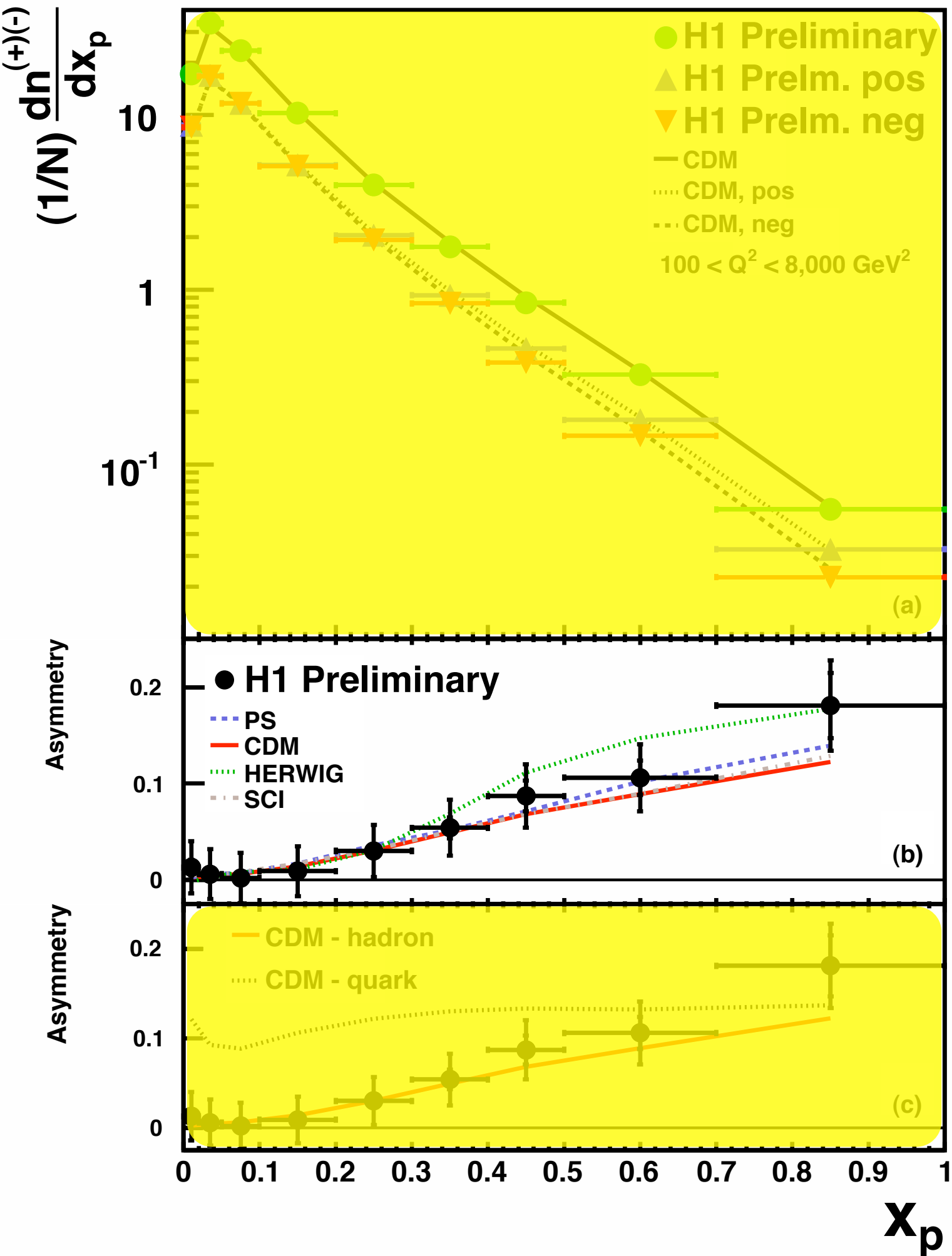
Charge Asymmetry Results



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

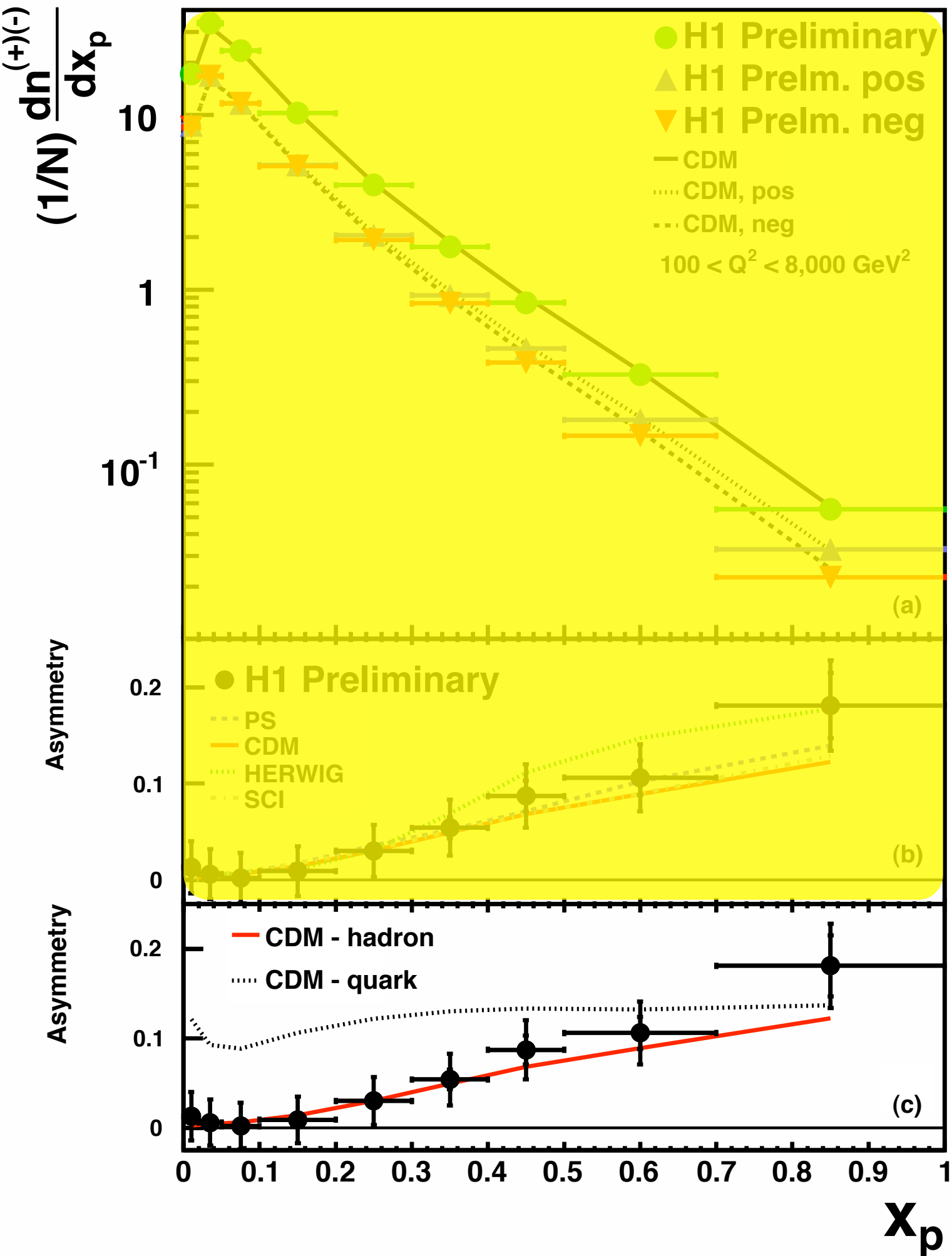


$$\text{Asymmetry} = \frac{pos - neg}{pos + neg}$$

Compatible with zero at low x_p , reaches $\sim 20\%$ at high x_p

Magnitude and evolution described by various Monte Carlo models

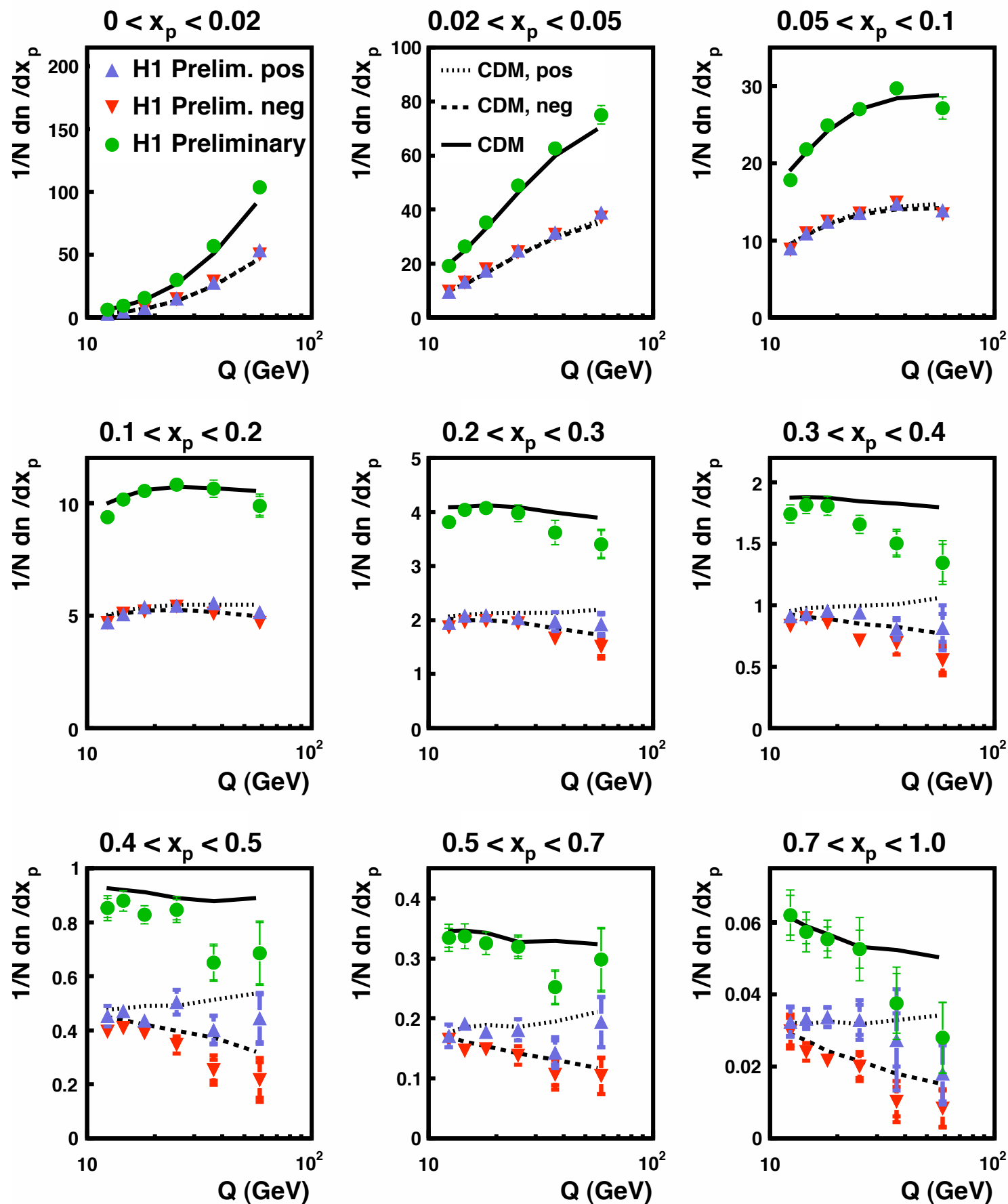
HERWIG has some differences at large x_p but still consistent with data



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

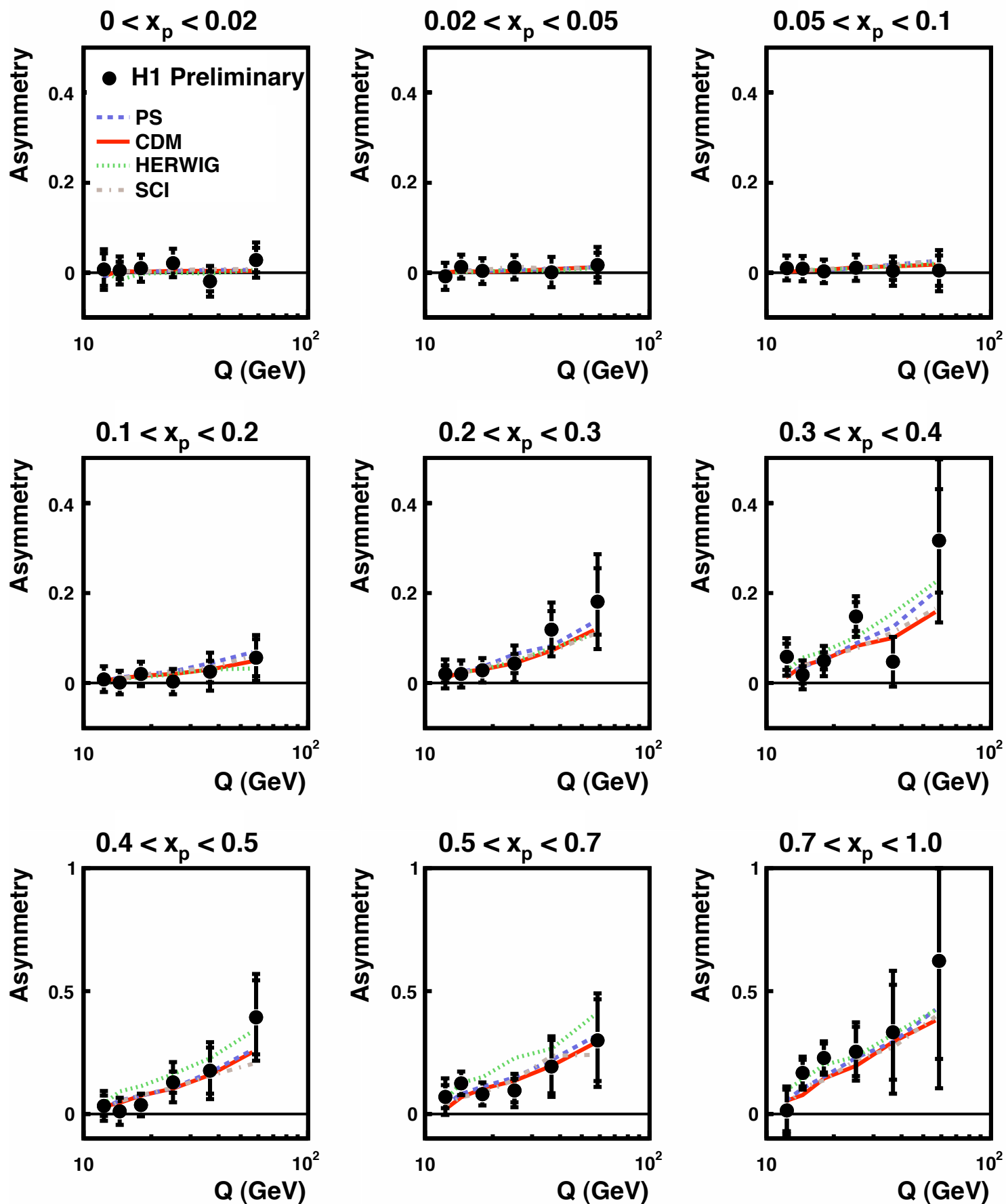
Similar asymmetry between
data and CDM at large x_p

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

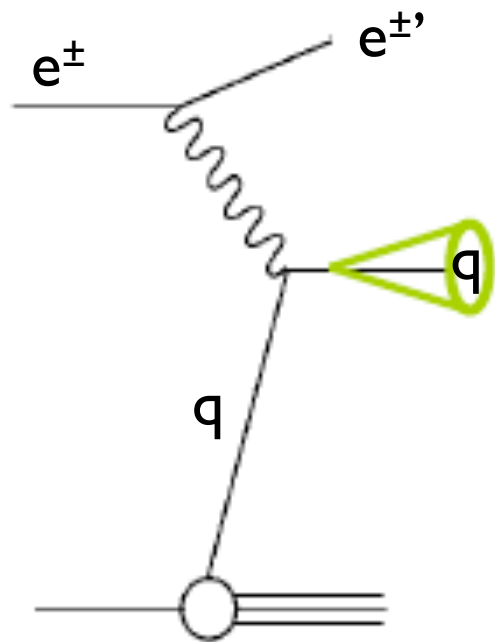
Monte Carlo models are
able to describe the
magnitude and evolution
of the asymmetry

Conclusions

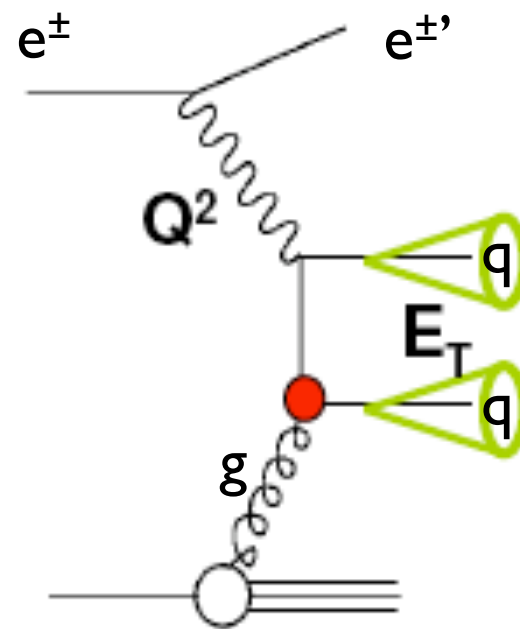
- First Observation of the charge asymmetry of the Hadronic final state in High Q^2 DIS.
- Method is general and can be applied to other environments (γP , $PPbar$).
- Asymmetry dependent on x_p and gets larger with larger Q^2 (x_{BJ}). Results consistent with expectation from charge asymmetry of valence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

backup

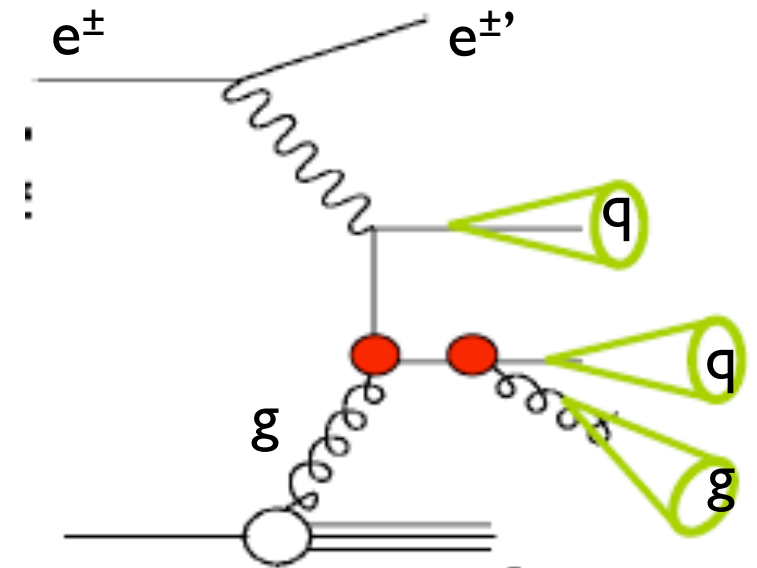
BORN



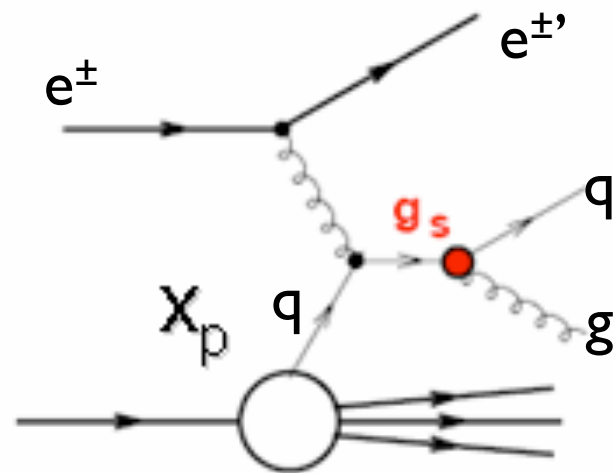
LO BGF

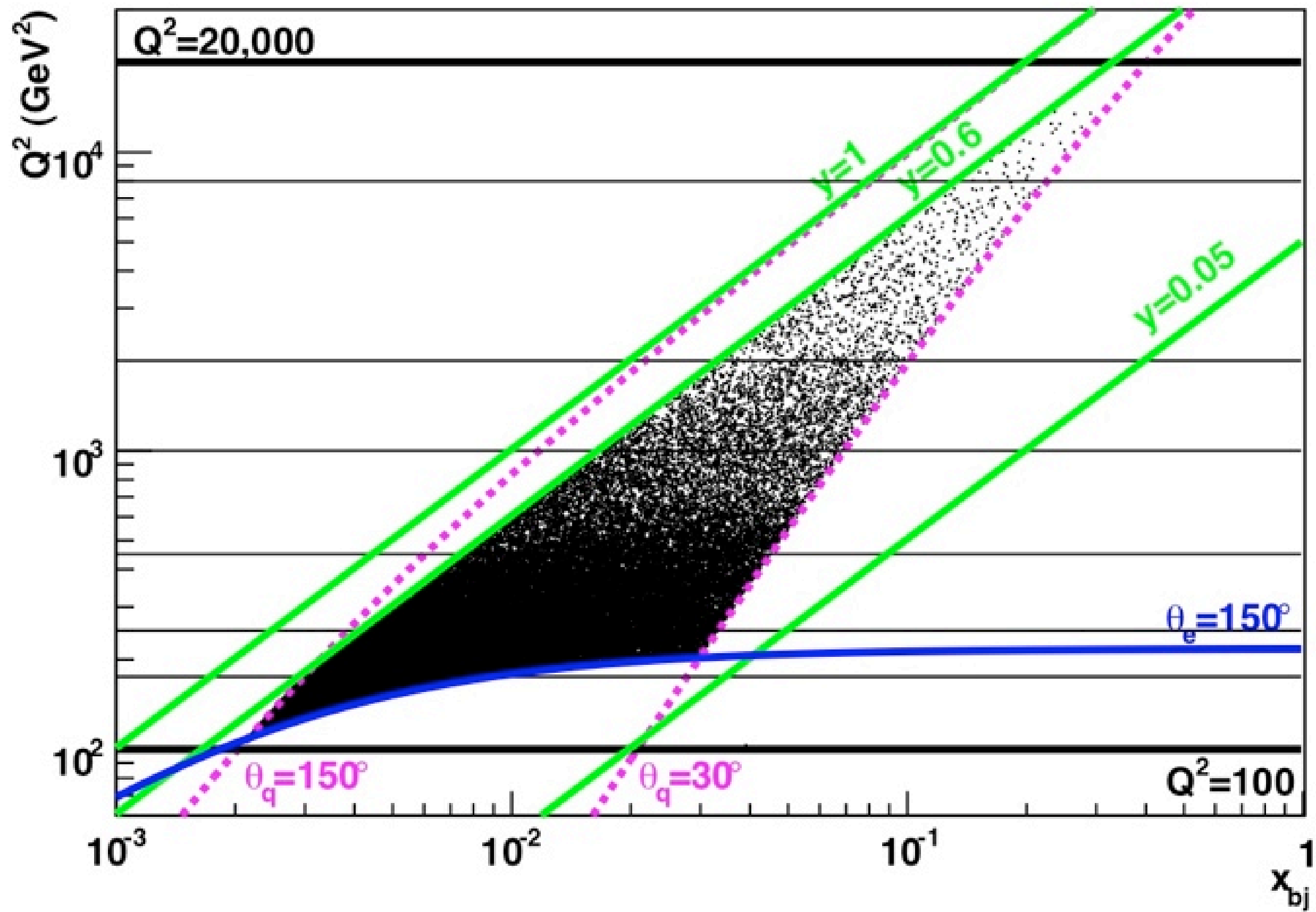


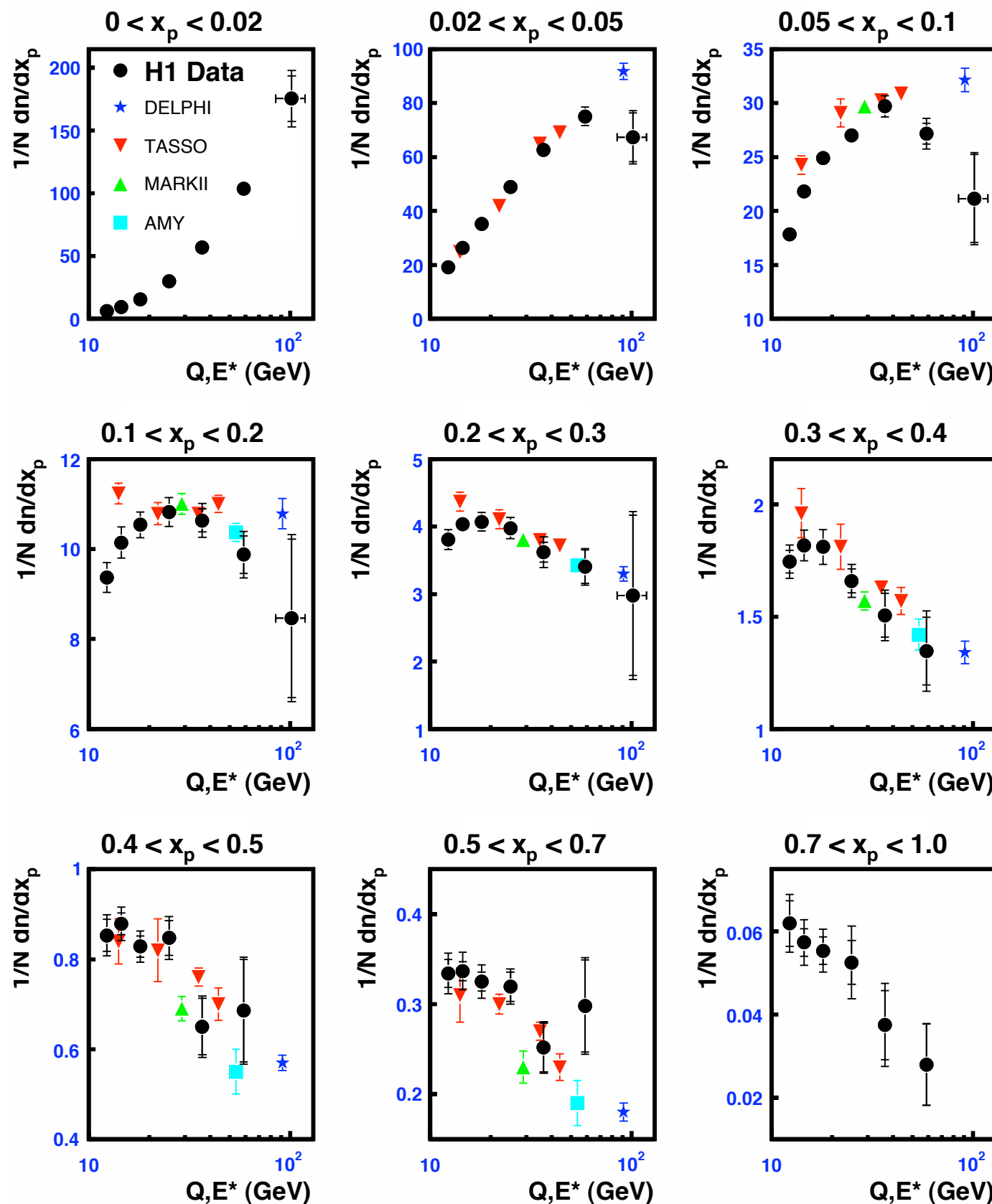
NLO



LO QCD Compton





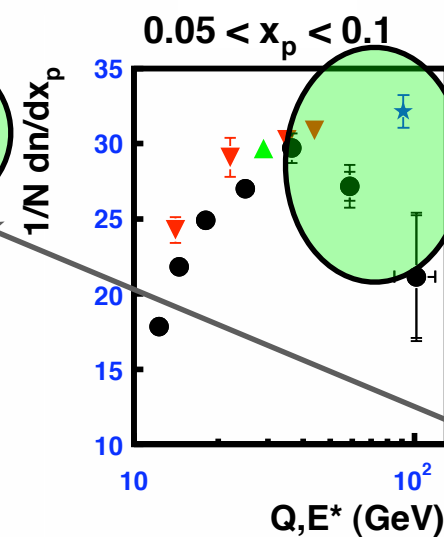
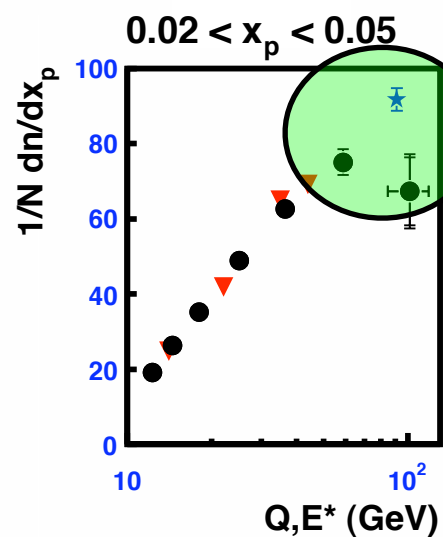
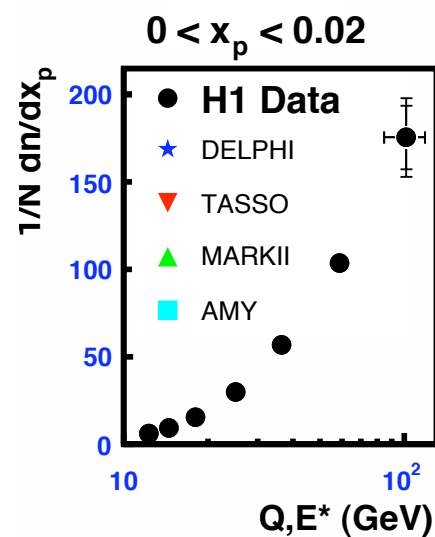


Pretty good agreement
between ep and e^+e^- !

high Q^2 and small x_p
reason unclear

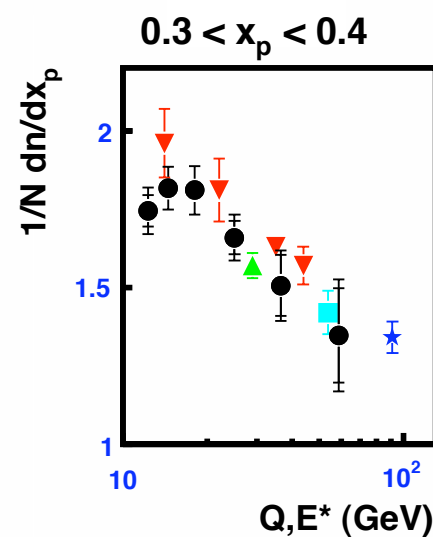
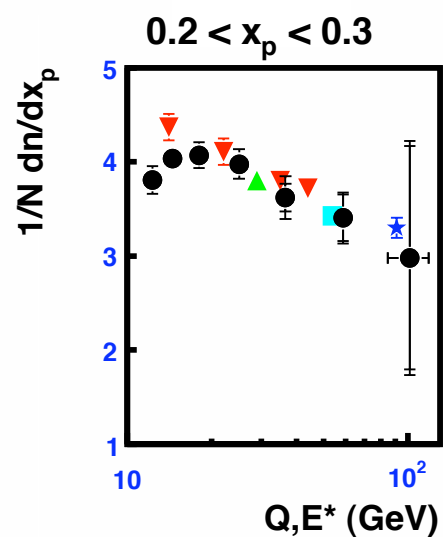
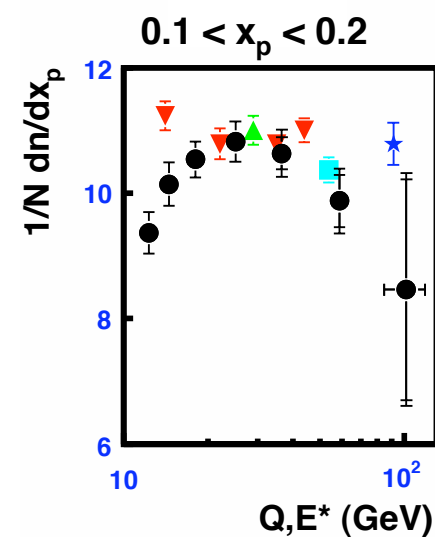
low Q^2 , mid x_p .
expected to be due to BGF
kinematics producing empty
current region

NB: suppressed zeros

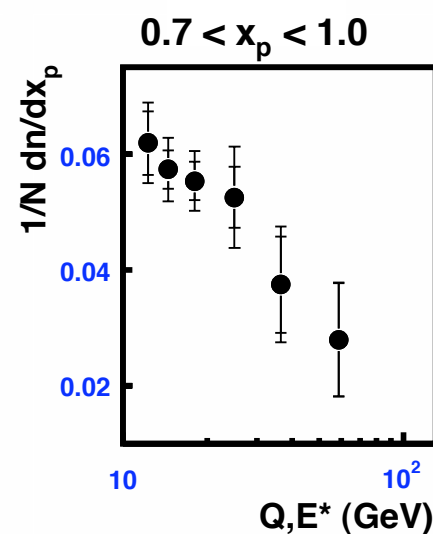
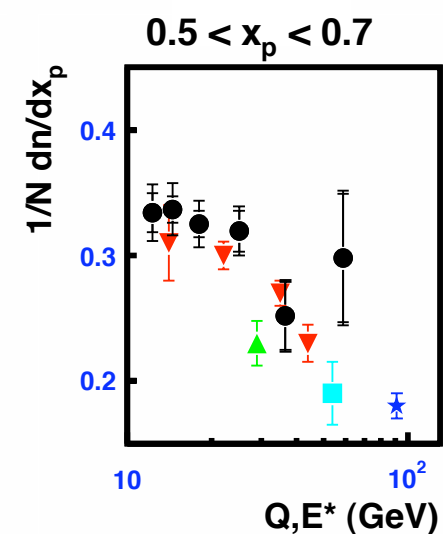
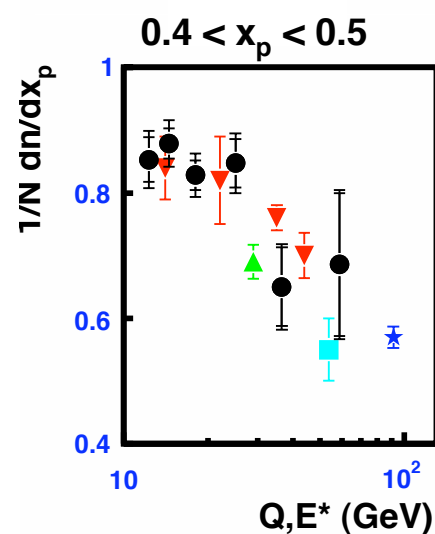


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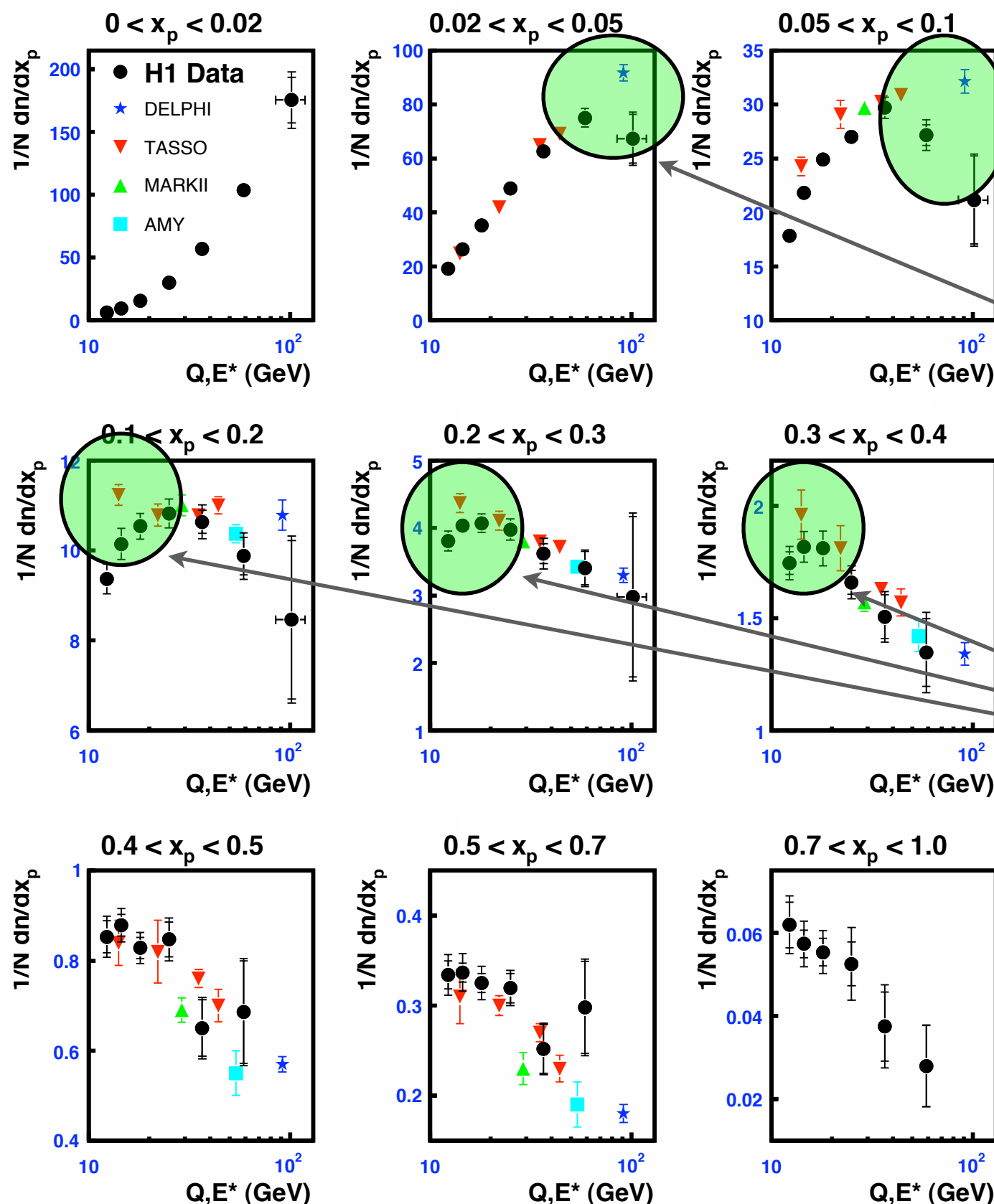
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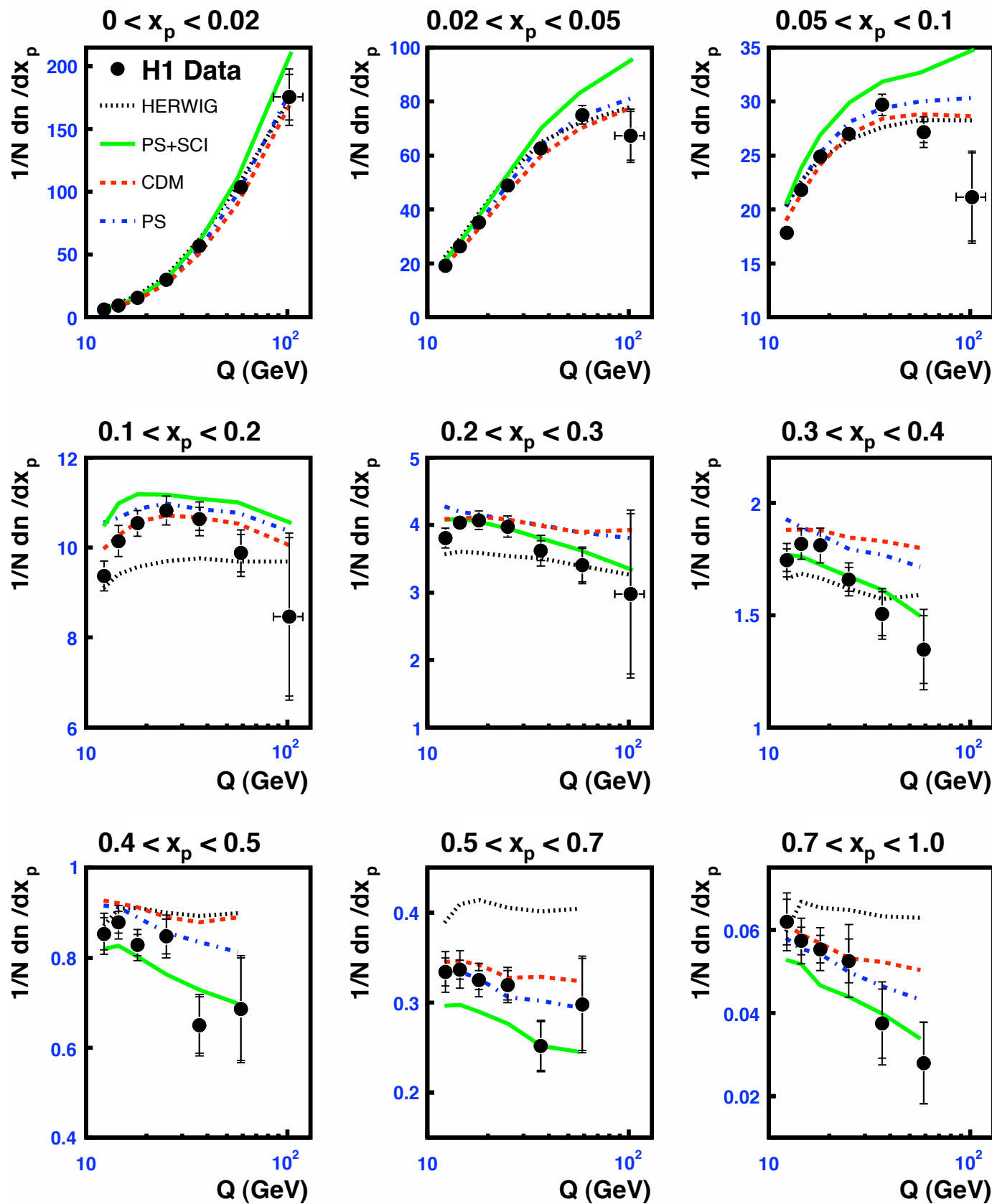


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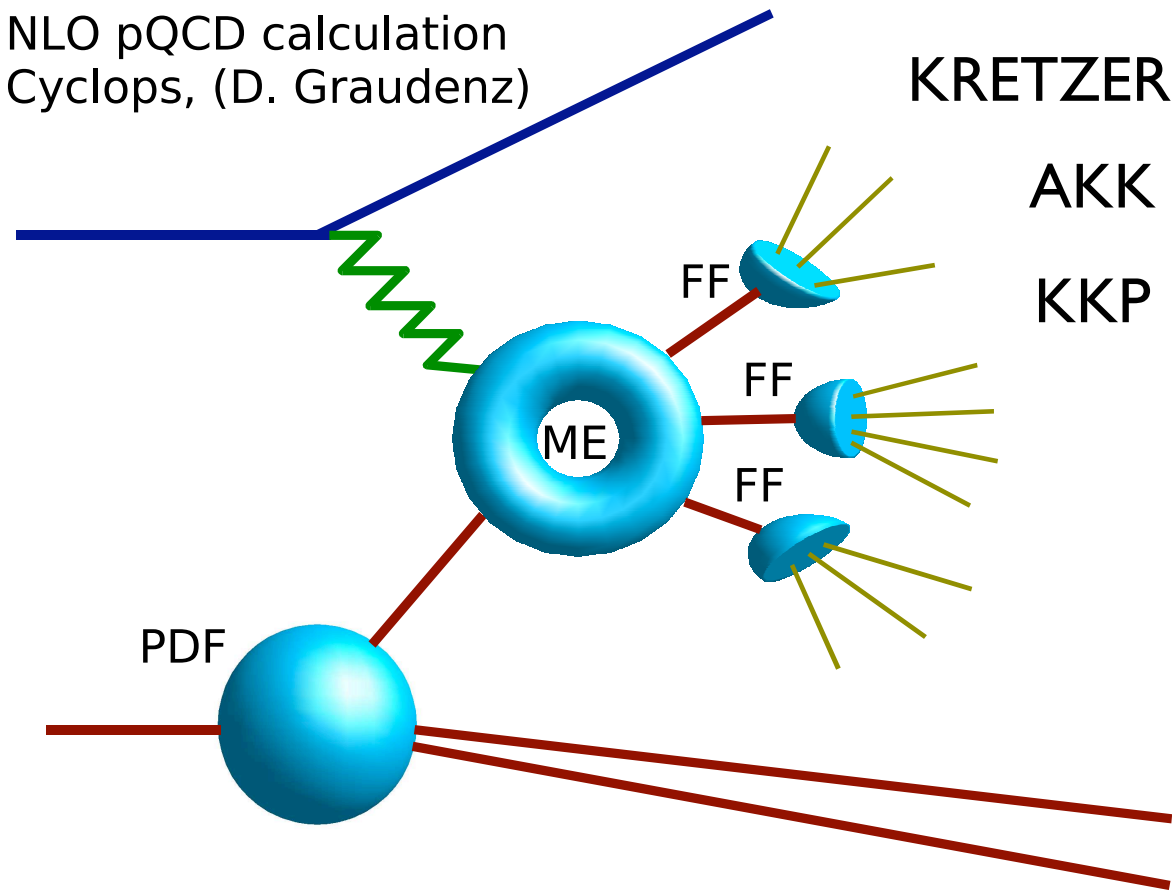


CDM and PS acceptable
description of data.
both tend to overestimate
the multiplicity at high Q^2

SCI model predicts too soft a
spectrum

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

NLO pQCD calculation
Cyclops, (D. Graudenz)



$$\sigma_h = \text{PDF} \otimes \text{M.E.} \otimes \text{FF}$$

NLO pQCD

CYCLOPS

Fragmentation Functions - e^+e^- fits

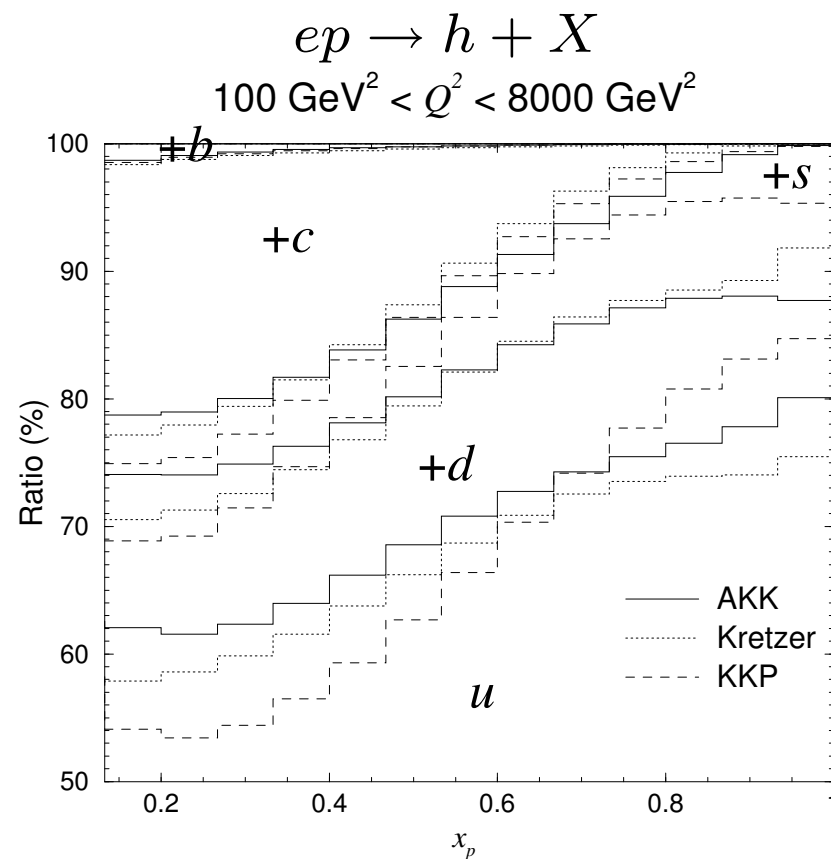
Infra red safe region ($Q^2 > 100$), $x_p > 0.1$

FF parameterised from $x_p > 0.1$

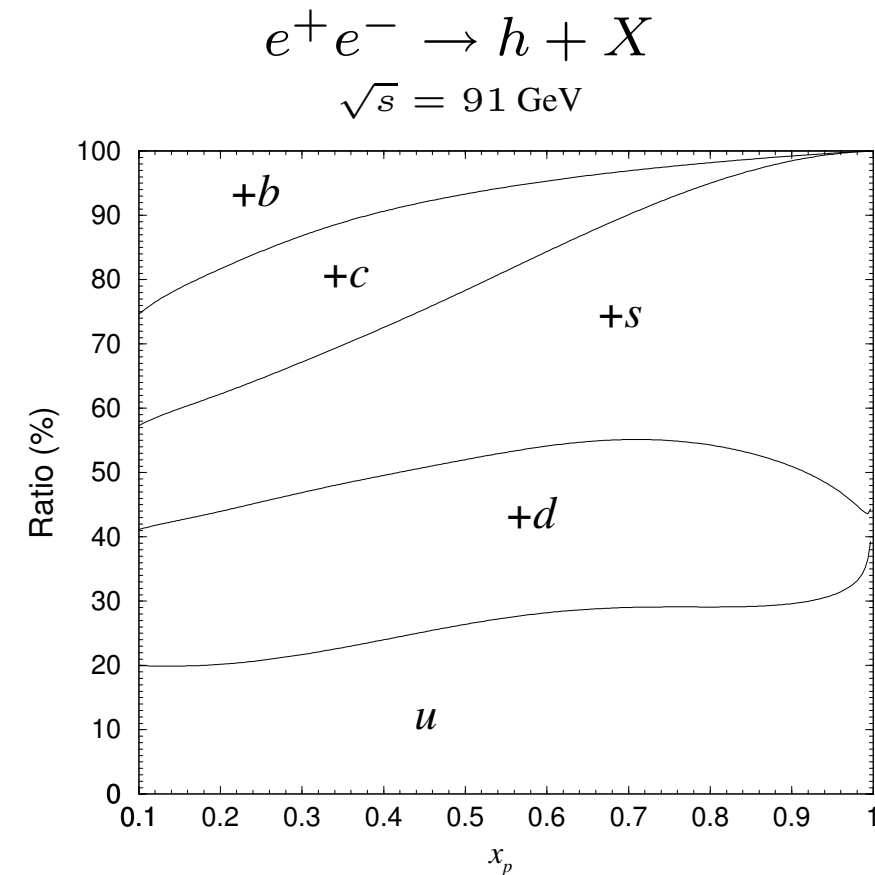
CTEQ6M, $\Lambda(5)\text{QCD} = 226 \text{ MeV}$ (also ME + FF)

Quark tagging (H1)

Identify quark flavour at e.w. vertex



Proton is good source of u



s relatively large

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