

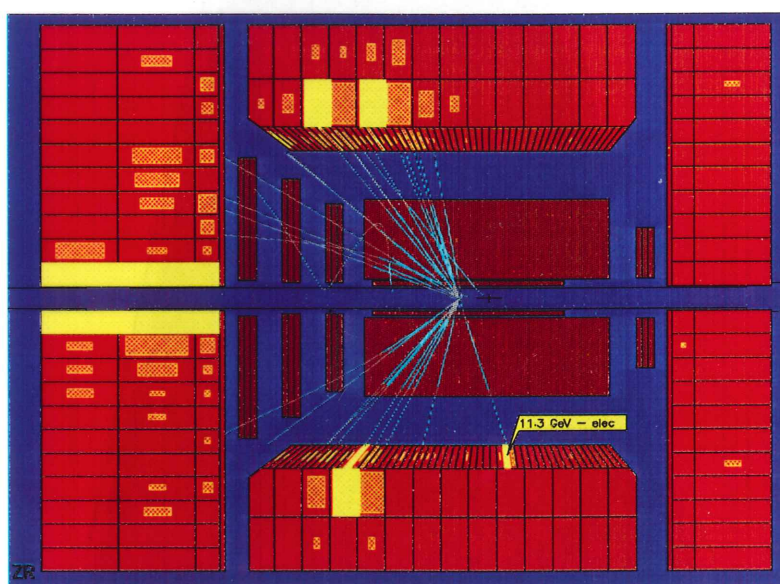
ICHEP2000

Osaka , July, 2000

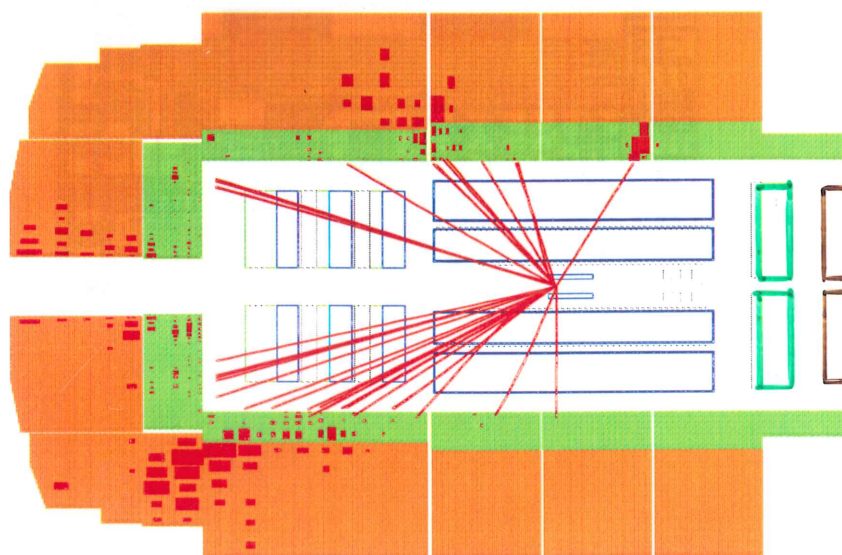
Jet Production in DIS at HERA

Jörg Gayler, DESY
for H1 and ZEUS

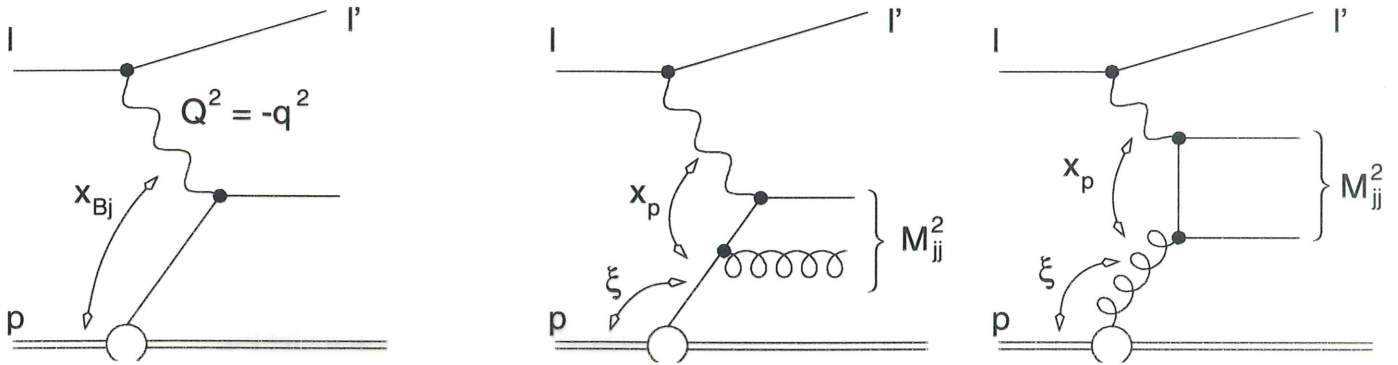
ZEUS

 e^+
→
27.5 GeV P
←
820 GeV

H1

 e^+
→ P
←Z
R

Kinematics and Jet algorithm



$$Q^2 = -q^2 = -(l - l')^2$$

$$x_{Bj} = Q^2 / 2p \cdot q$$

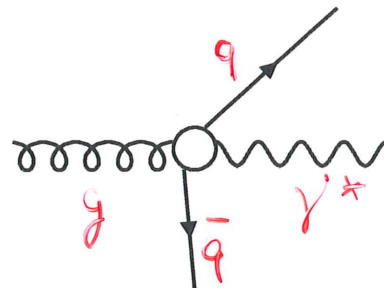
$$\xi = x_{Bj} (1 + M_{jj}^2 / Q^2) \quad , \quad x_p = x_{Bj} / \xi$$

$$\eta = -\ln(\tan\theta/2)$$



Breit frame :

$$2x_{Bj}\vec{p} + \vec{q} = 0$$



no p_T for QPM like events.

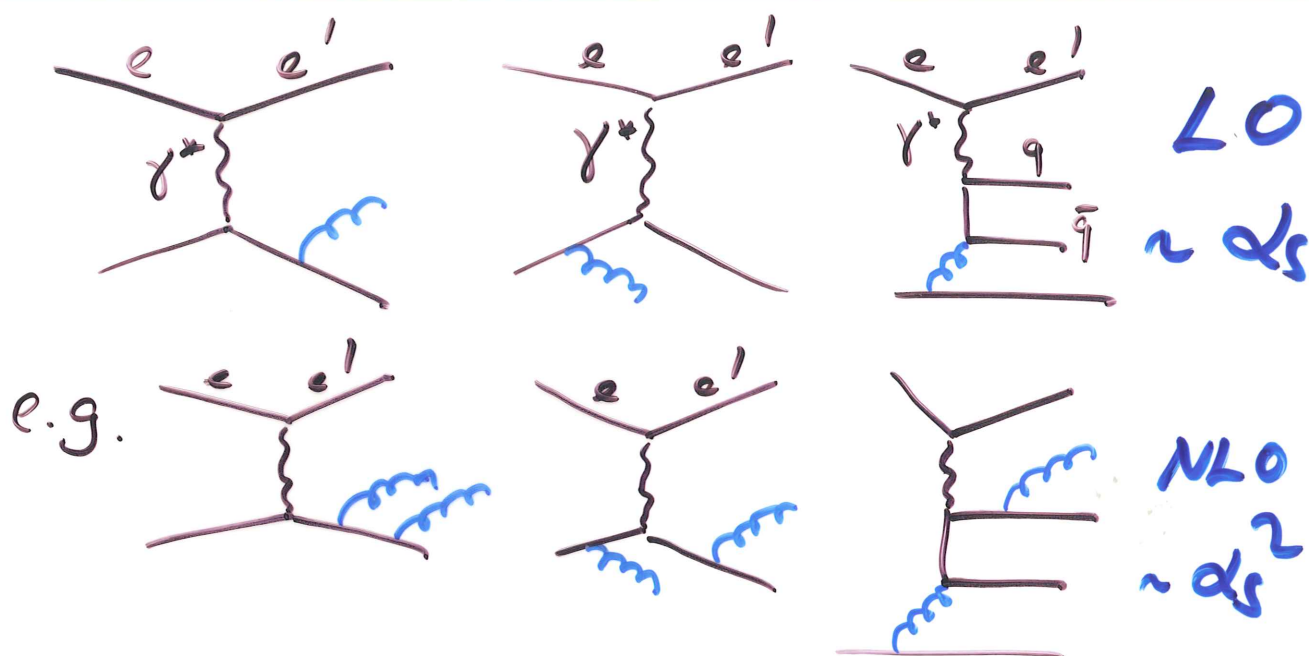
e.g. boson gluon fusion

Jet algorithm : mostly used **inclusive k_T** in Breit frame

distance measures: $d_i = E_{T,i}^2$ and $d_{ij} = \min(E_{T,i}, E_{T,j}) R_{ij}^2$

with $R_{ij}^2 = \Delta\eta_{ij}^2 + \Delta\phi_{ij}^2$

Multi-Jet Production in pQCD



Ansatz in pQCD:

$$\sigma = \sum_{a,n} \int_0^1 dx \alpha_s^n(\mu_r) c_{a,n} \left(\frac{x_{Bj}}{x}, \mu_r, \mu_f \right) f_{a/h}(x, \mu_f)$$

order n , flavour a renormalization scale fact. scale
predicted parton density

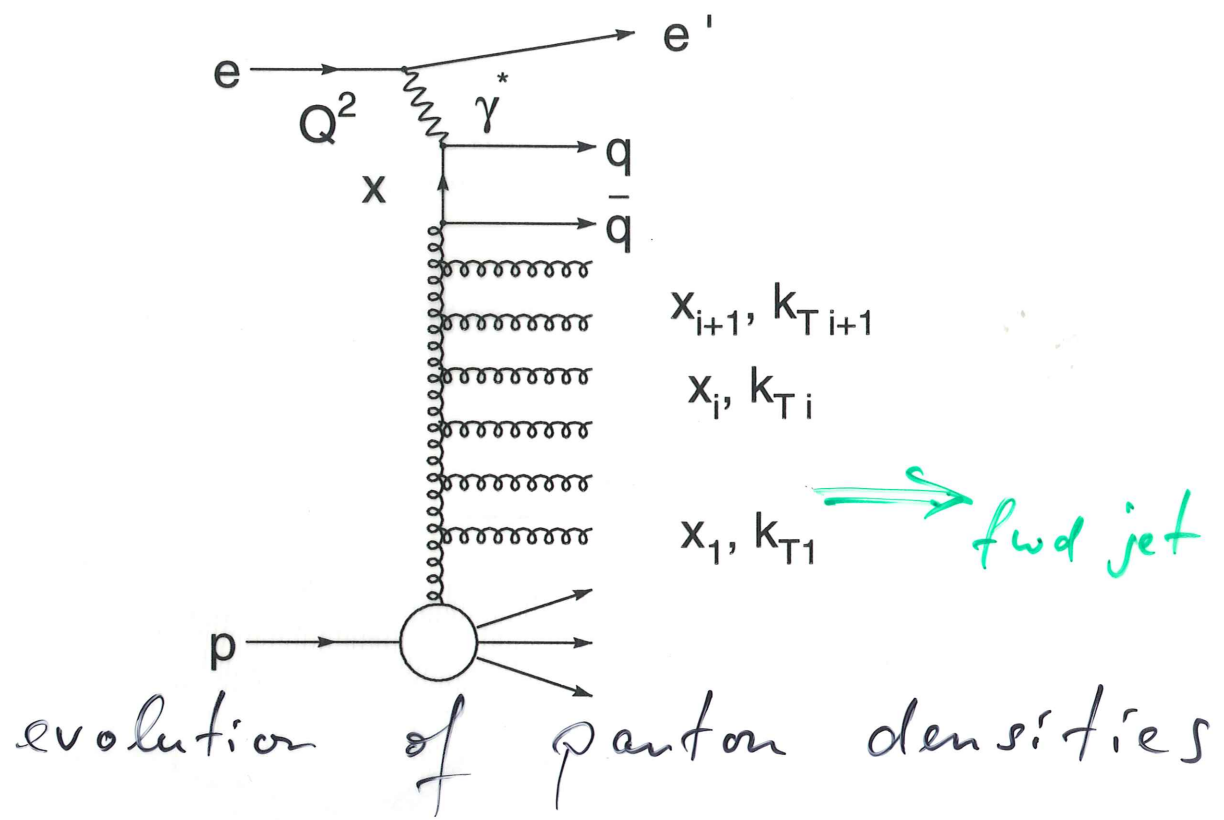
NLO programs **DISENT**, **PERJET**
 used for data comparisons

Important ambiguity: μ_R

choice of suitable scale $\frac{E_T^2}{Q^2}$?

Forward jets

(i.e. close to proton remnant)



standard
resumming

DGLAP

$$\alpha_s \ln Q^2$$

$$k_{T, i+1} \gg k_{T, i}$$

BFKL

$$\alpha_s \ln 1/x$$

no k_T order

How good are DGLAP based calculations in forward region?

QCD patterns in hadronic final state

Abstract 897

Mostly studied: jet structure (NC), see below

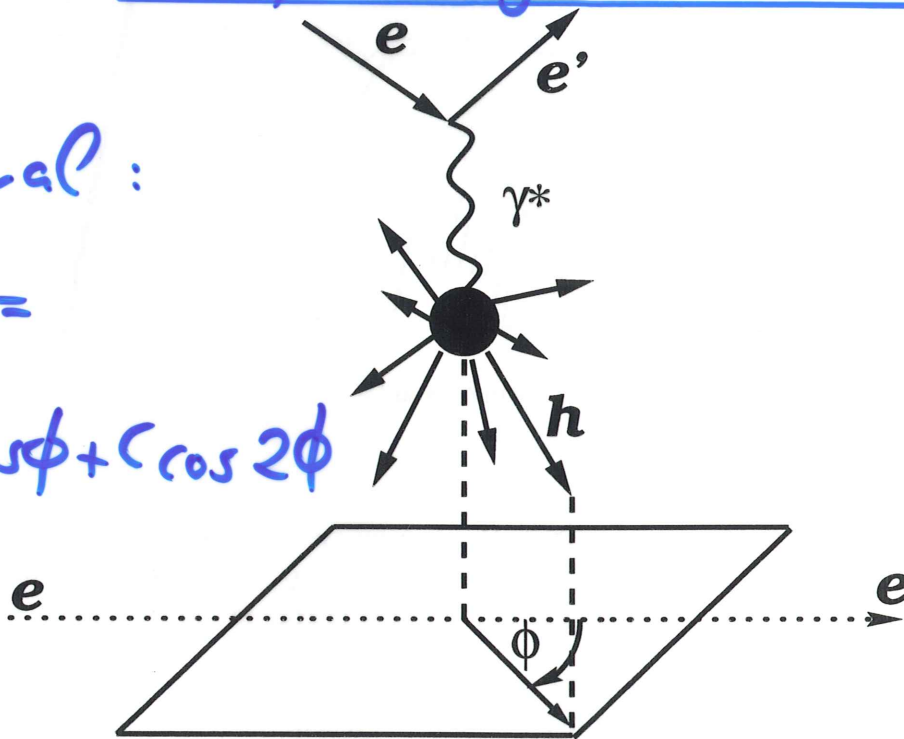
2 Consistency checks:

1) ϕ asymmetries

general:

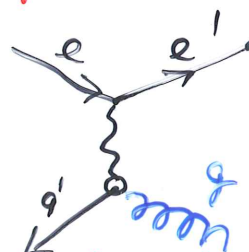
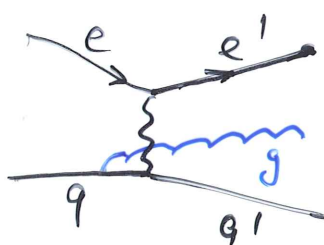
$$\frac{d\sigma}{d\phi} =$$

$$A + B \cos \phi + C \cos 2\phi$$



naive expectation ($O(\alpha_s)$)

- a) q - g plane preferentially close to lepton plane $C > 0$
- b) $\phi \rightarrow \pi$ for q -jet $B < 0$
(γ couples to quark)



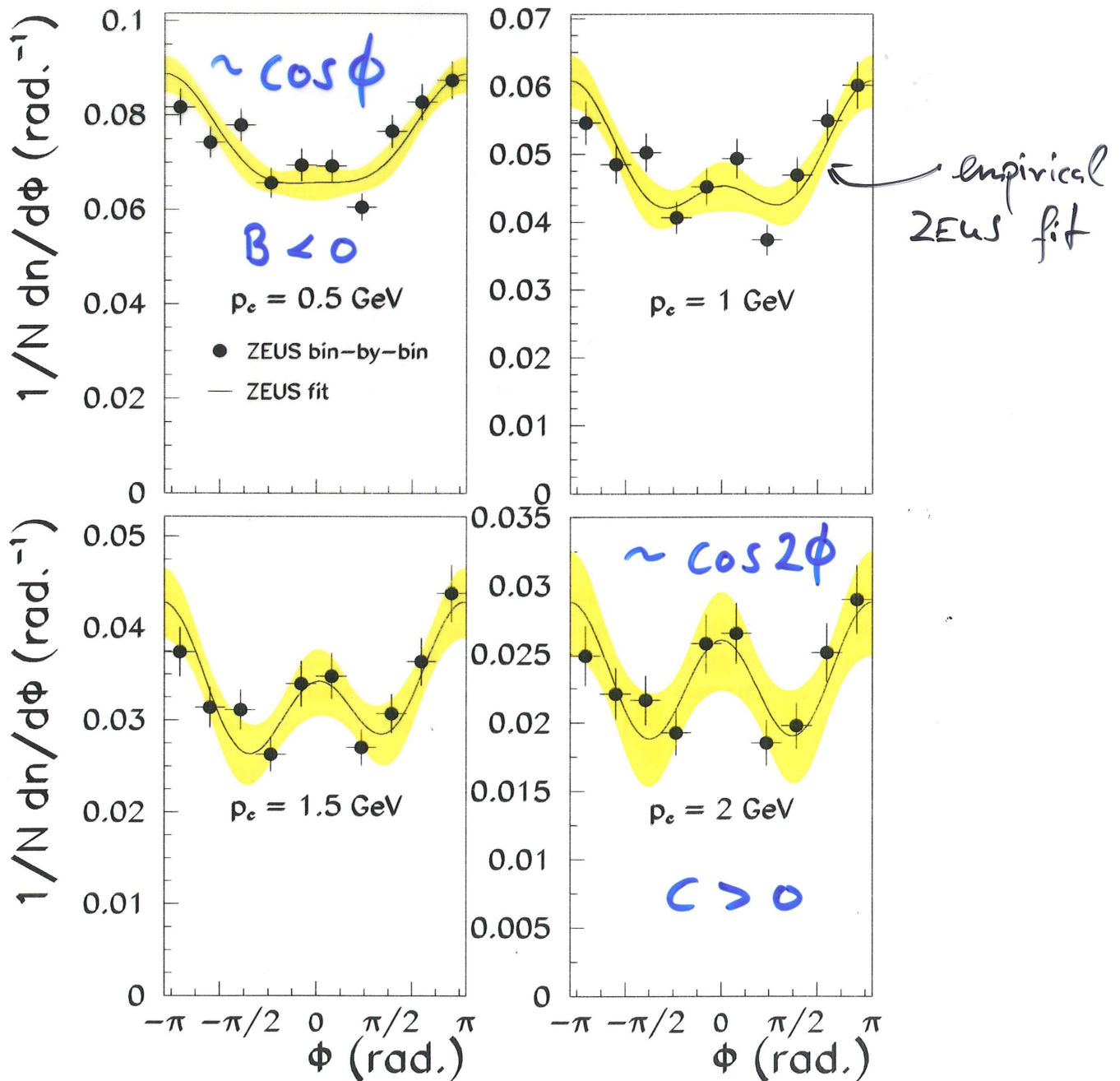
select leading track to tag q

ϕ distribution of hadron with substantial p_T in Breit frame

Abstract 897

hard track: $0.2 < z_h < 1$, $z_h = P \cdot p_h / P \cdot q$ $p_T^{Breit} > p_c$ $Q^2 > 180 \text{ GeV}^2$

ZEUS 1996–97



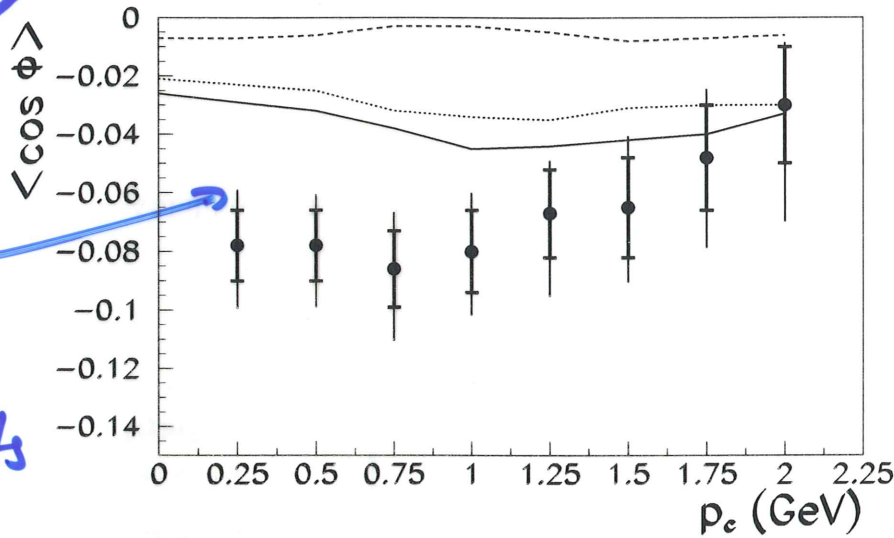
$\cos \phi$, $\cos 2\phi$ terms clearly visible

ϕ asymmetry vs. for $p_t > p_c$

Abstract 897

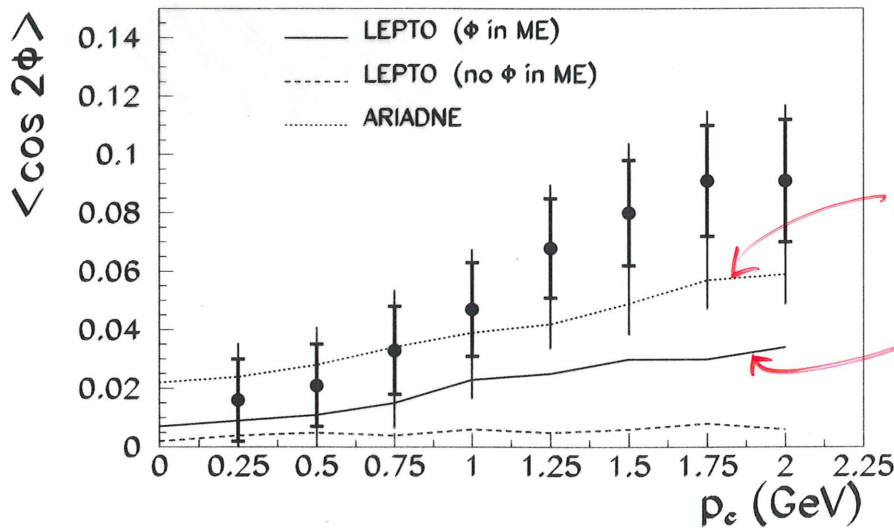
$\langle \cos \phi \rangle$

ZEUS 1996-97



p_c

$\langle \cos 2\phi \rangle$



p_c

At large p_{\perp}^{Brit} QCD models with $O(\alpha_s)$ matrix elements are roughly consistent with data

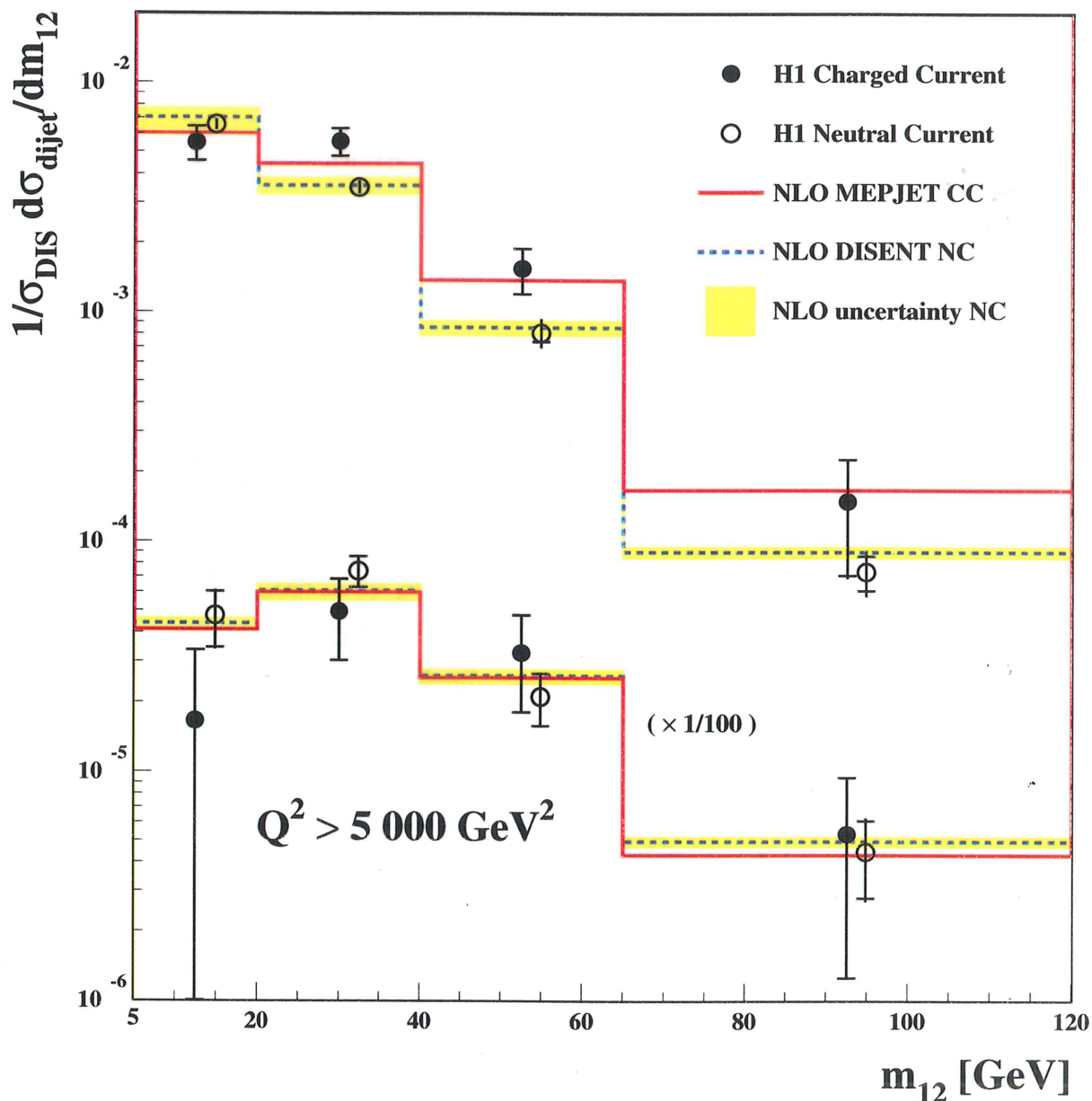
$\cos 2\phi$ effect seen also with jets
Abstract 890 (ZEUS)

2) what about CC ?

Abstract 993

 $P_T^{\text{lepton}} > 25 \text{ GeV} \quad (Q^2 > 640 \text{ GeV}^2)$

H1 preliminary

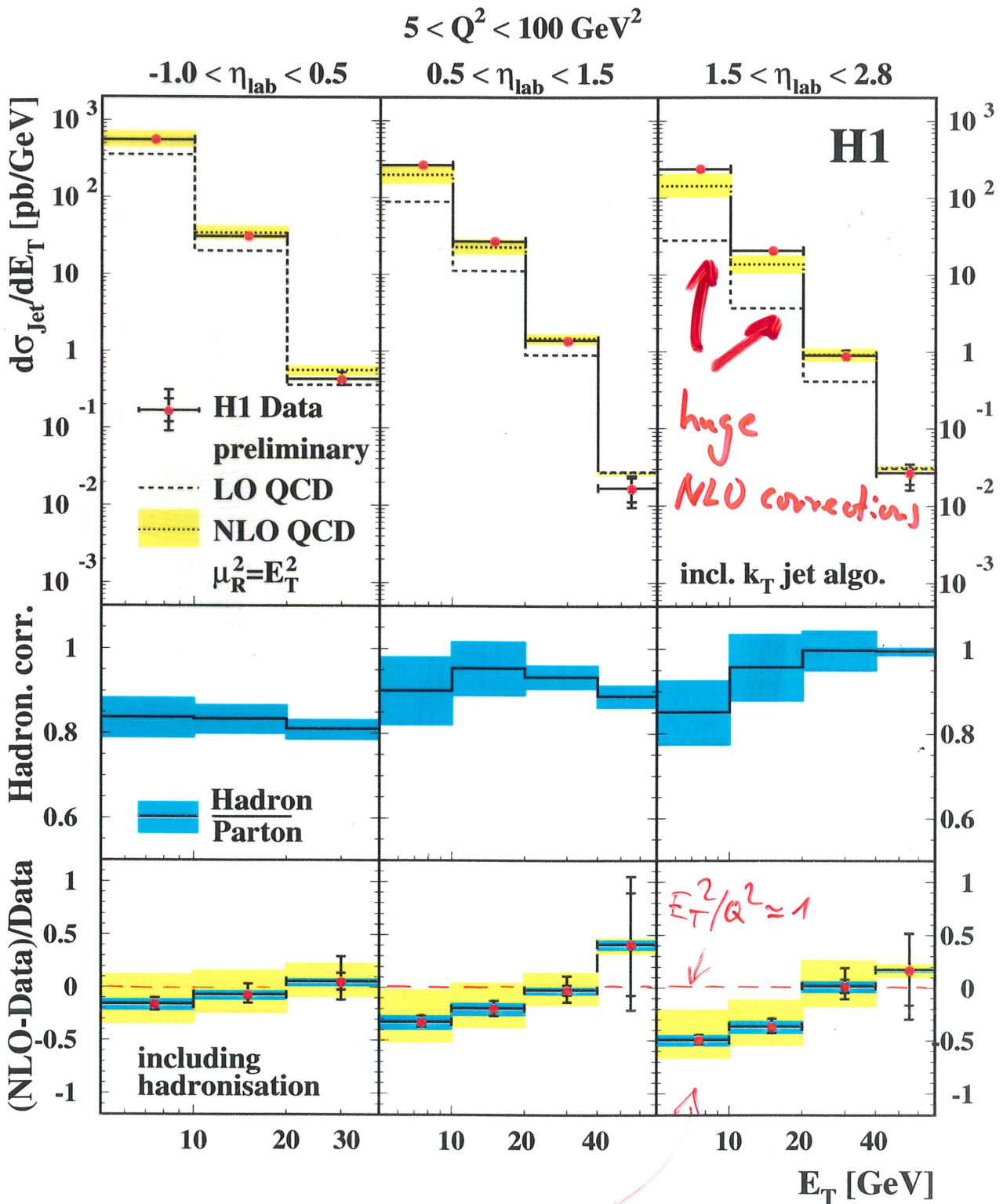


CC consistent with NLO QCD (as NC)
 differences NC ↔ CC due to
 $\sigma_{\text{tot}}(ep \rightarrow \nu X) \neq \sigma_{\text{tot}}(ep \rightarrow eX)$

Systematic Studies, low Q^2

Abstract 999

inclusive jets , $E_T^{Breit} > 5\text{ GeV}$:



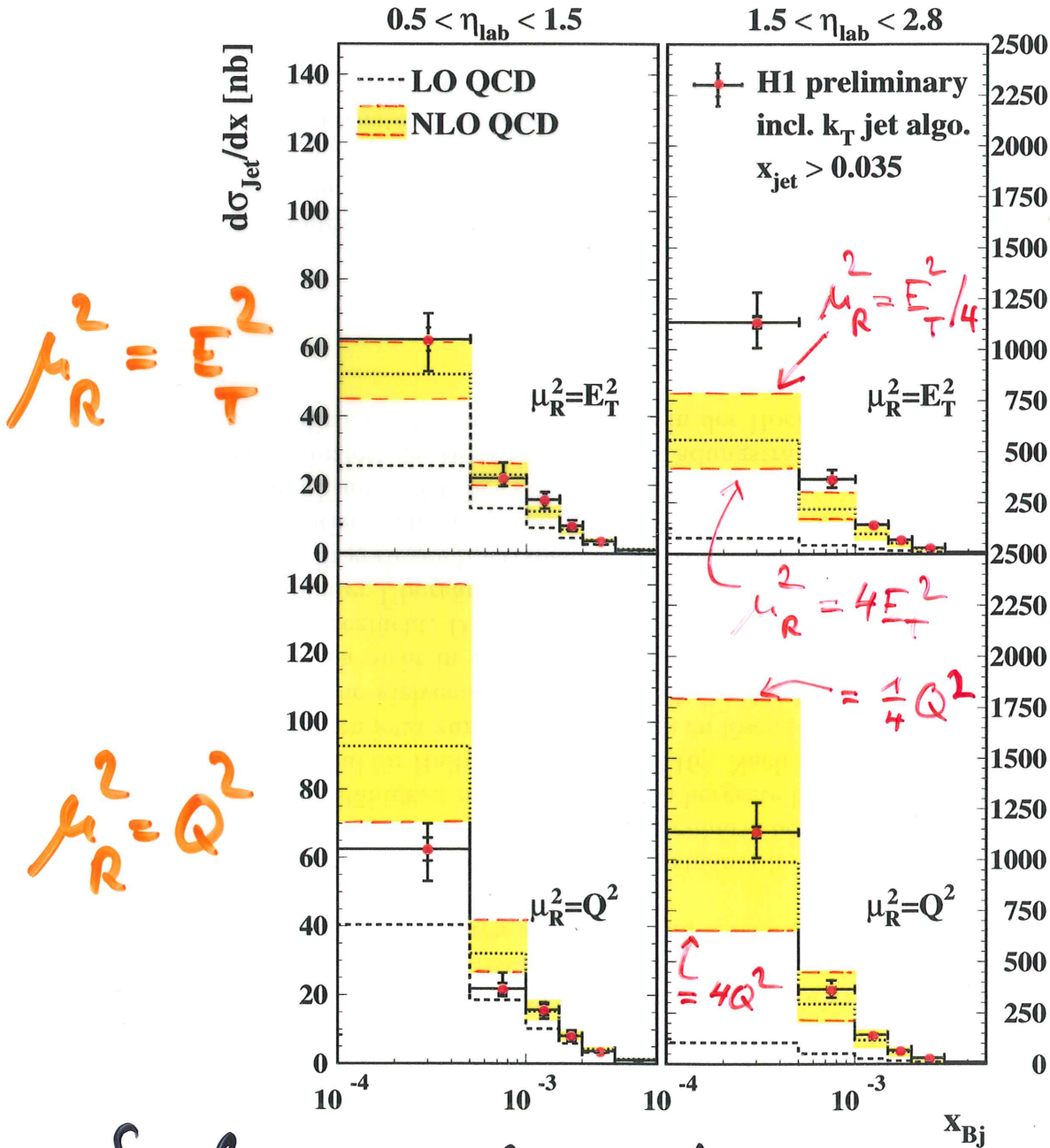
discrepancies are predominantly from small Q^2

x_{Bj} dependence and comparison with NLO, E_t^2 and Q^2 scales

Abstract 999

inclusive jets :

$Q^2 > 5 \text{ GeV}^2$



for x_j , Q^2 dependence see also Abstract 997 (#1)

$\mu_R^2 = E_T^2$

$\mu_R^2 = Q^2$

Small x_{Bj} , forward :

NLO below data, $\mu_R^2 = E_T^2$
 ~ agreement for $\mu_R^2 = Q^2$, but large sensitivity to scale variation

x_{Bj} dependence, comparison with models

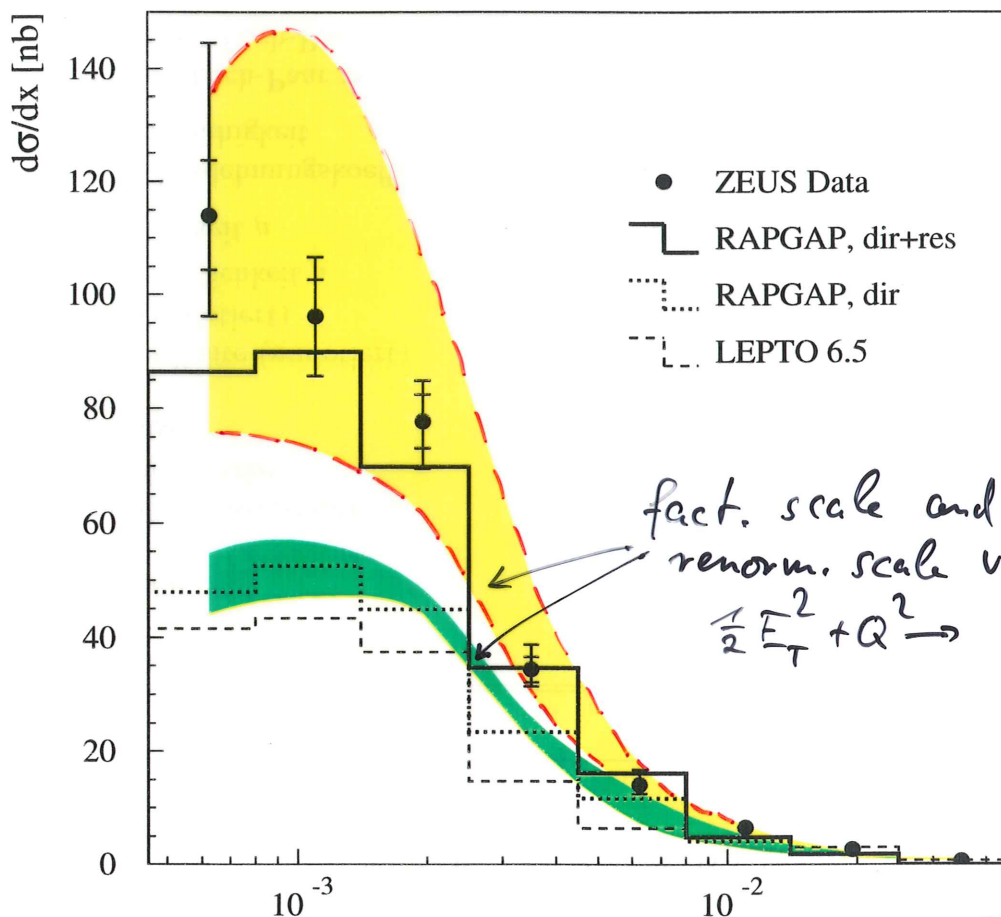
Abstract 896

Forward jets : $p_z^{Breit} > 0$ (proton direction)

$$x_{jet} = p_z^{had} / p_{-beam} > 0.036$$

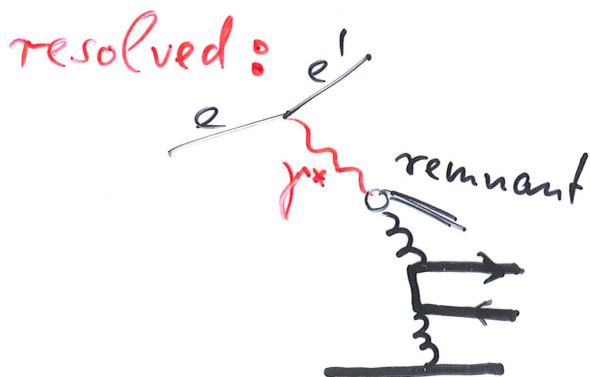
$$Q^2 > 10 \text{ GeV}^2, 0.5 < E_T^2/Q^2 < 2$$

ZEUS



DGLAP based MCs :

LEPTO : $O(\alpha_s)$ matrix elements + parton showers } fail
 RAPGAP : " " " " " } fail
 " " " " " } ~ o.k.
 + resolved γ^*



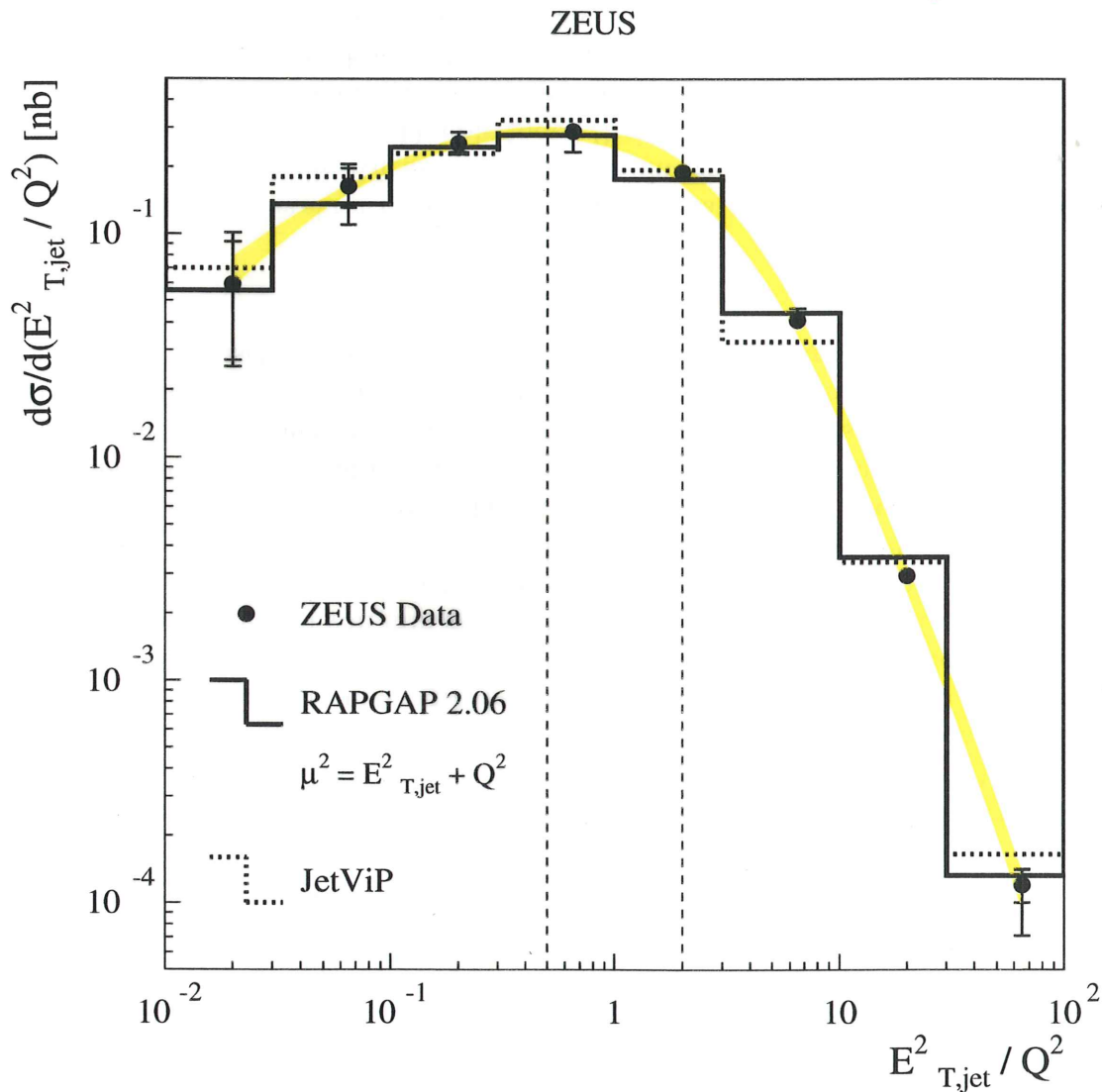
no strong k_{\perp} ordering

E_t^2/Q^2 dependence, NLO + resolved γ

Abstract 896

Forward jets : $p_z^{Breit} > 0$ (proton direction)

$Q^2 > 10 \text{ GeV}^2$

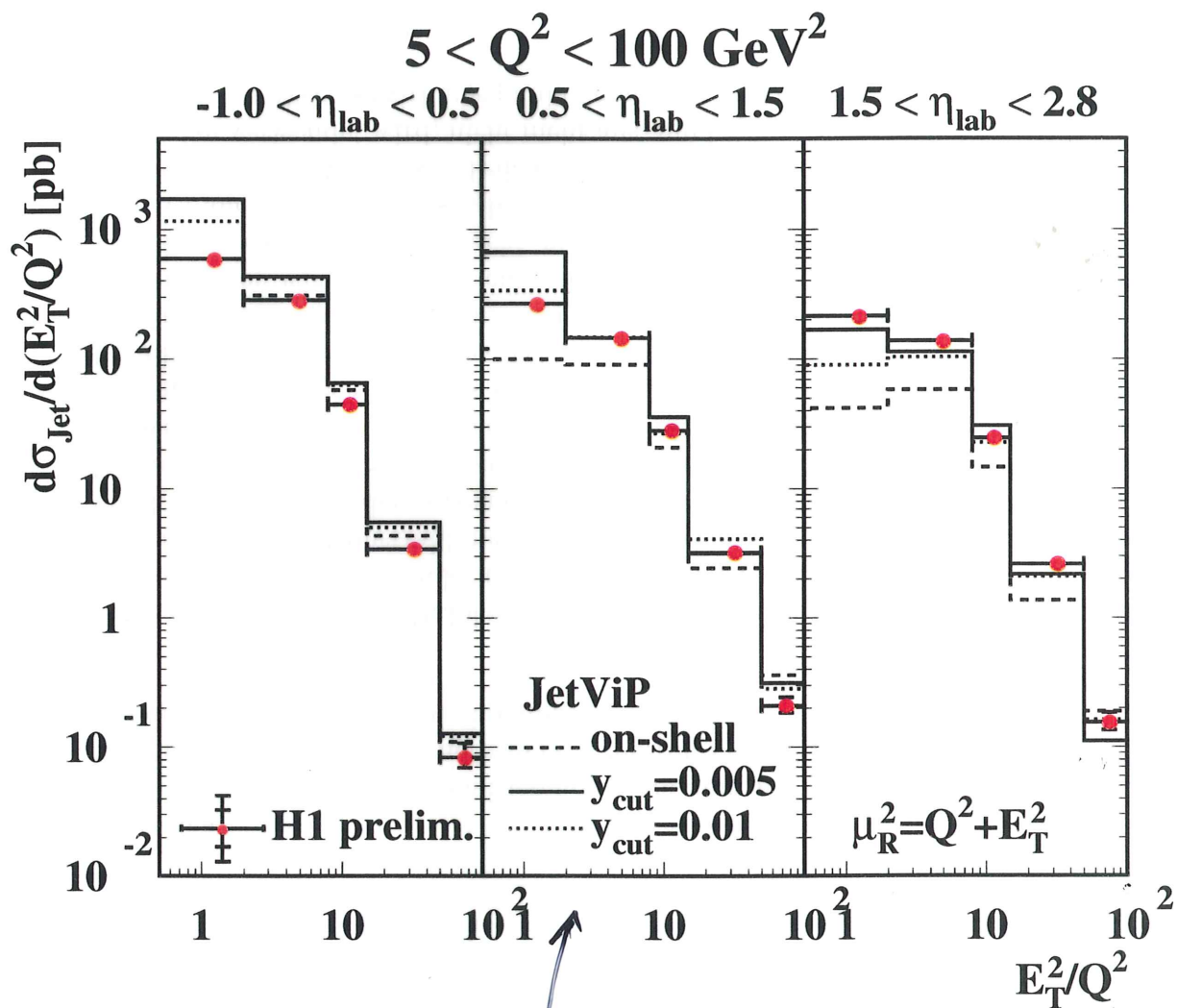


good description by RAPGAP + resolved γ^*
 and
 NLO p QCD + resolved γ^* (JetViP)

E_t^2/Q^2 dependence, NLO + resolved γ

Abstract 999

inclusive jets :



*different treatment of
parton masses (virtualities)*

*no solution yet for
extended phase space*

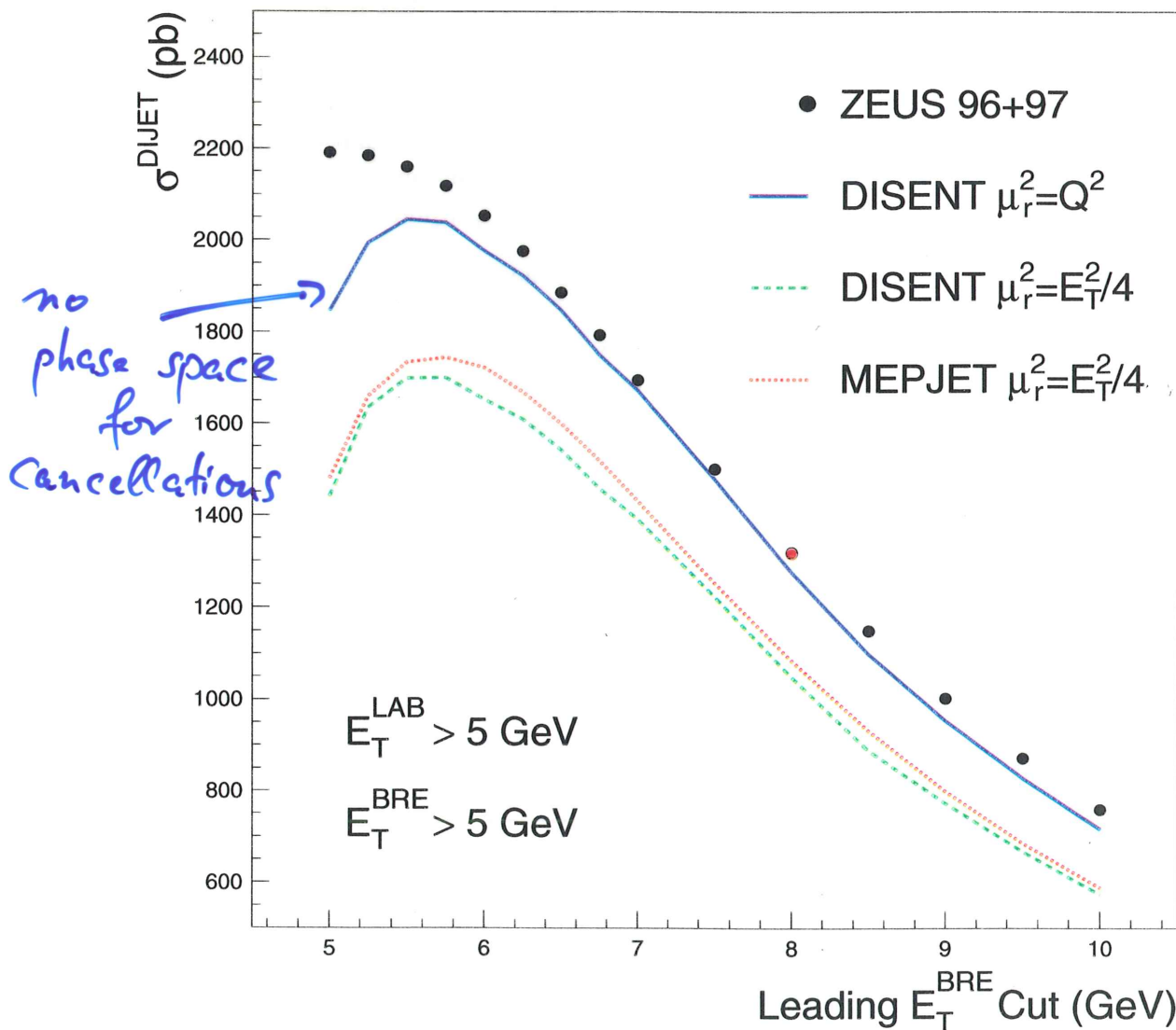
Di-Jets, need for asymmetric cuts

Abstract 888

symmetric cuts, e.g. $E_{T1}^{Breit} > 5 \text{ GeV}$, $E_{T2}^{Breit} > 5 \text{ GeV}$,
 problematic, if compared with NLO QCD with same cuts
 discussed in detail in Abstract 997 (H1)

$$Q^2 > 10 \text{ GeV}^2$$

ZEUS Preliminary



\rightarrow practice: $E_{T1} - E_{T2} \gtrsim 2 \text{ GeV}$
 $\propto E_{T1} + E_{T2} \gtrsim 15 \text{ GeV}$

Di-jets at high Q^2

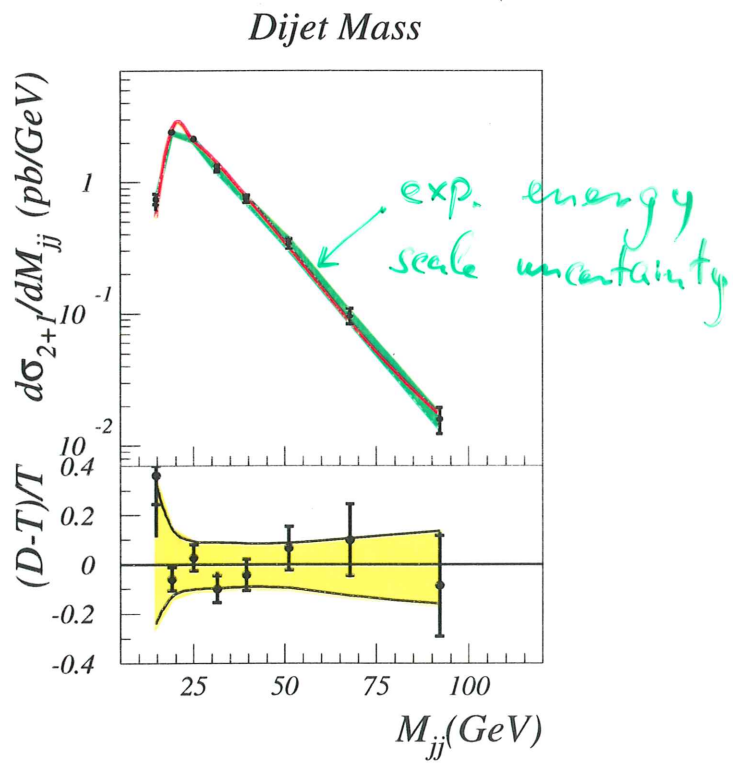
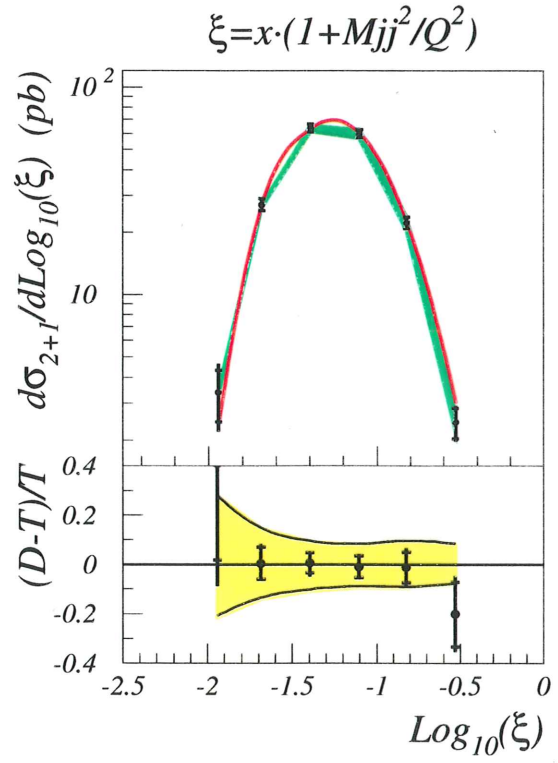
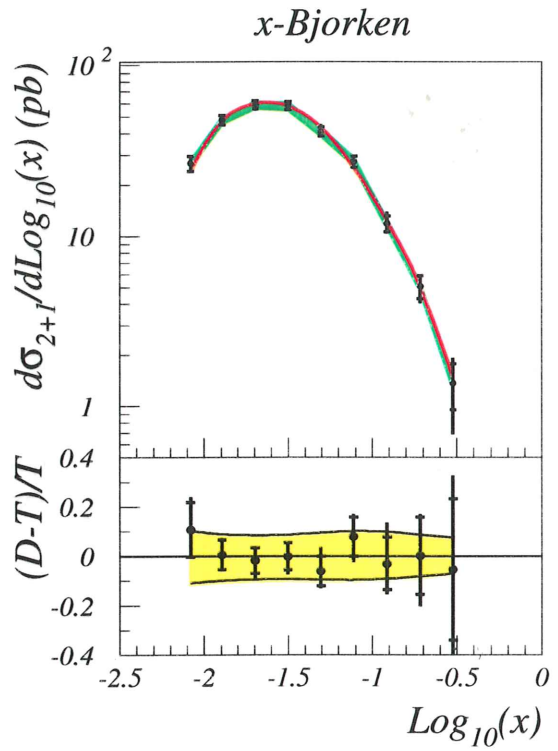
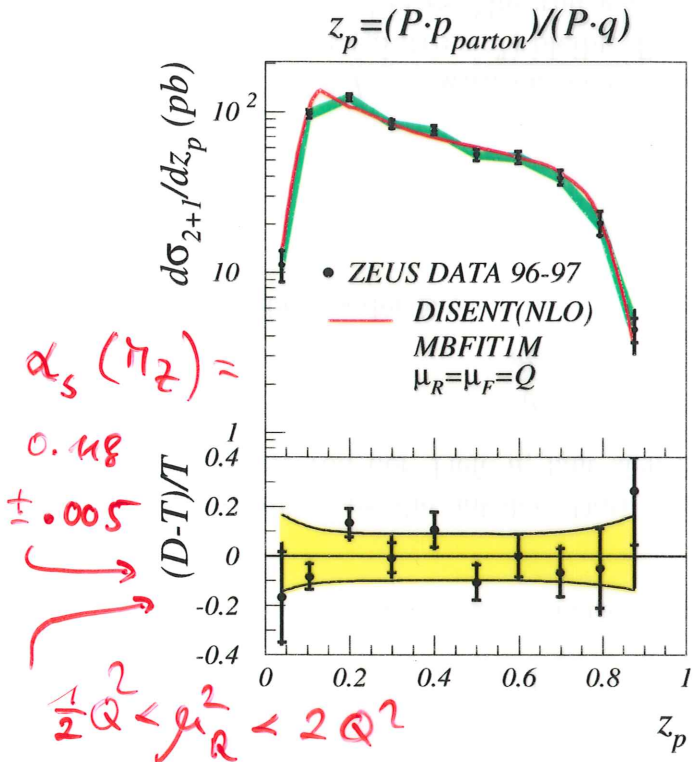
Abstract 891

$470 < Q^2 < 20000 \text{ GeV}^2$,

$-1 < \eta_{jet}^{lab} < 2$

$E_T^{jet1} > 8 \text{ GeV}$, $E_T^{jet2} > 5 \text{ GeV}$

ZEUS PRELIMINARY



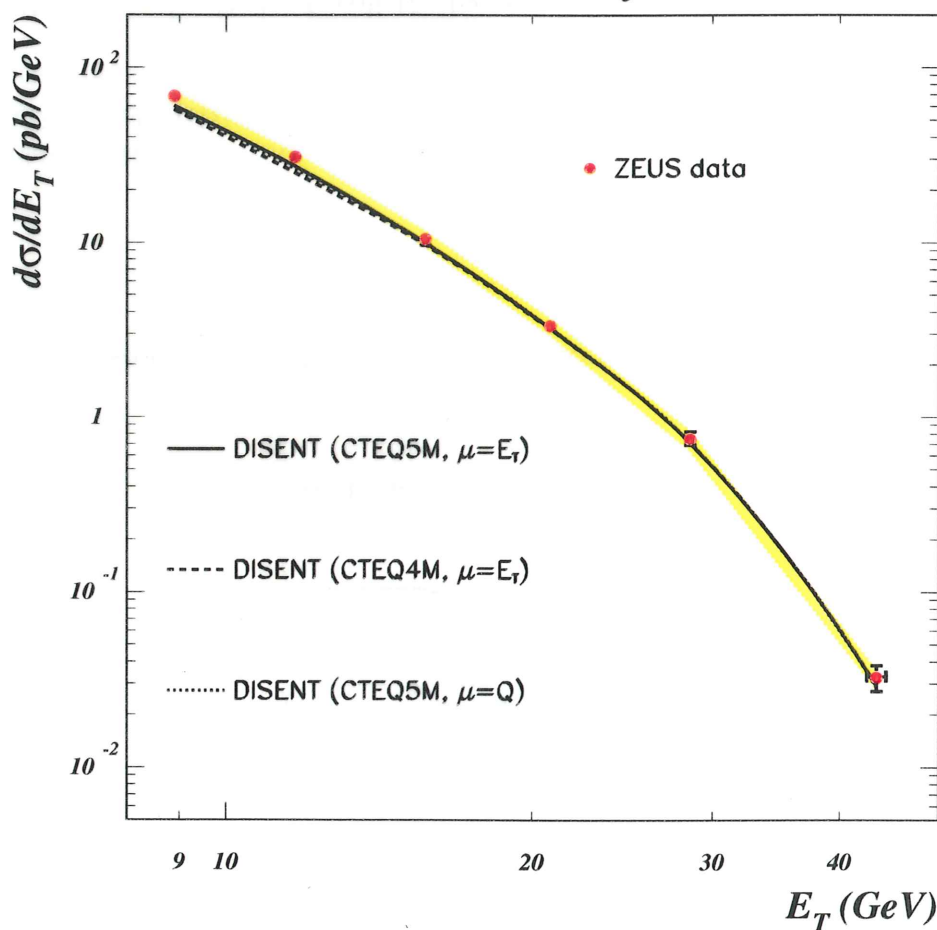
Inclusive Jets and NLO QCD at High Q^2

$Q^2 > 125 \text{ GeV}^2$, $-2 < \eta_{jet}^{Breit} < 1.8$

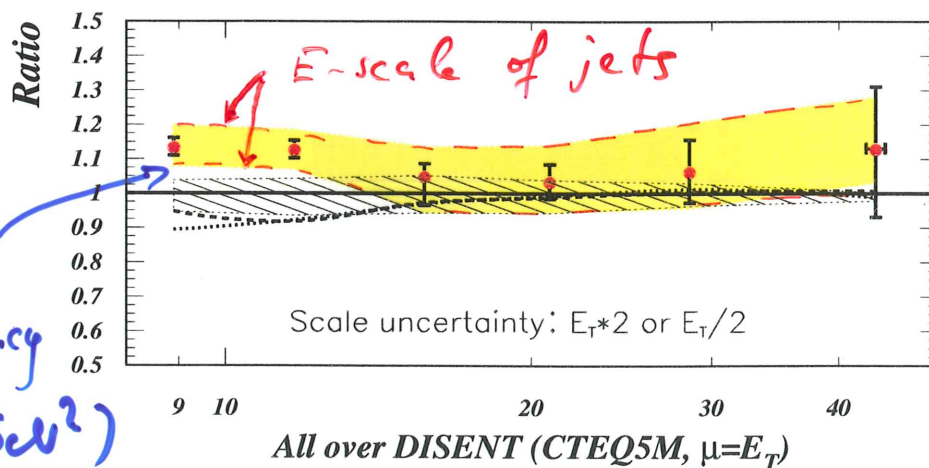
Abstract 890

$$d\sigma/dE_T^{Breit}$$

ZEUS Preliminary



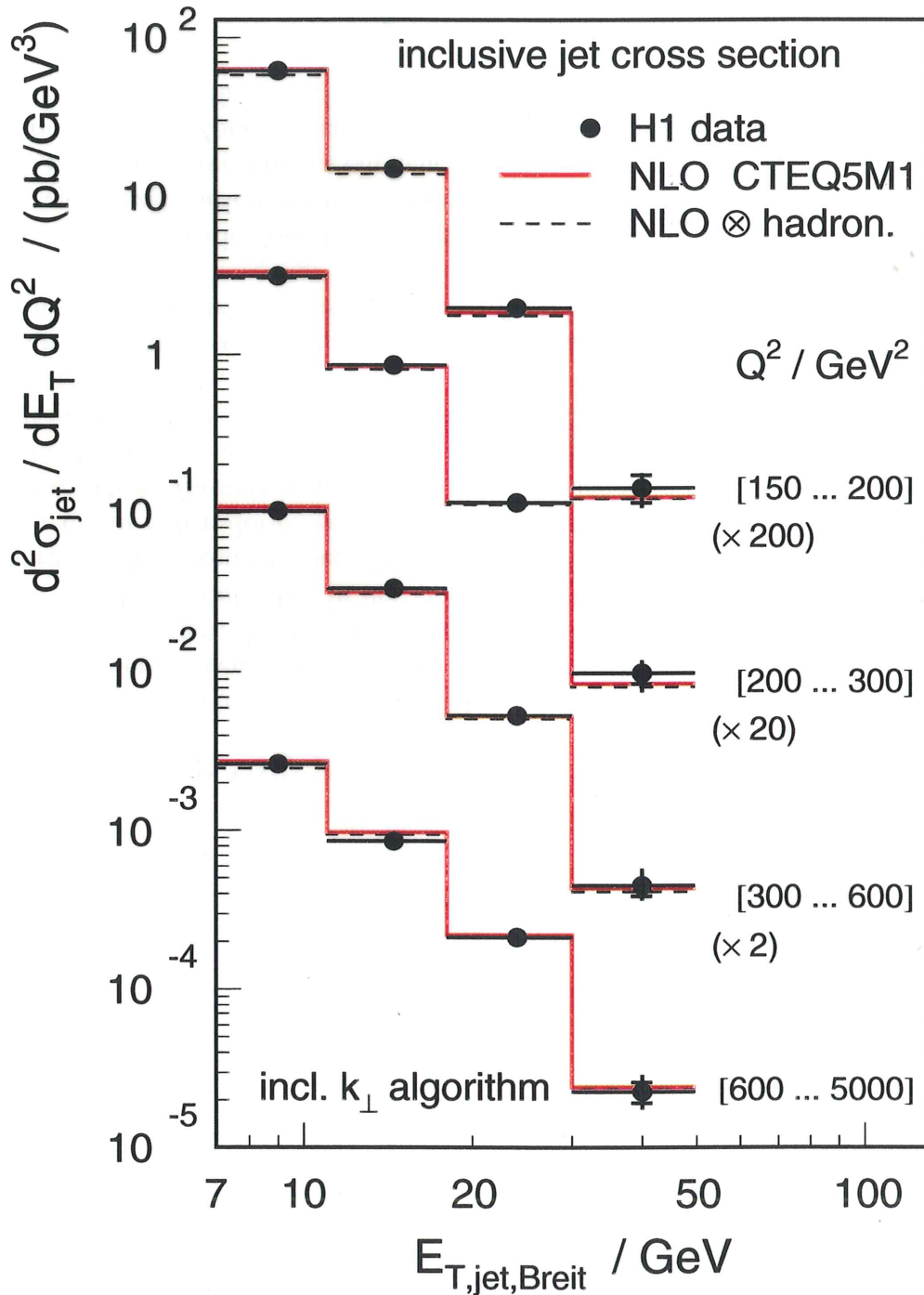
data corrected to parton level



≈ 15% discrepancy
($Q^2 < 250 \text{ GeV}^2$)

inclusive: $d\sigma_{jet}/dE_T$ for different Q^2

(Abstract 1000)

 $150 < Q^2 < 5000 \text{ GeV}^2, -1 < \eta_{jet}^{lab} < 2.5$


$\alpha_s(\mu_2)$
 $= 0.118$

Good description at high Q^2
 hadronization corrections small (< 10%)

Summary

Data low Q^2 , low x , forward region:

- Interplay of different scales
 E_T^2 : more definite discrepancies
 Q^2 : large effects of scale variations
- Photon structure can not be ignored
- NLO (α_s^2) remarkably good compared to LO, but clear discrepancies

Data at high Q^2 ($Q^2 \geq 150 \text{ GeV}^2$)

- Good description of data by NLO pQCD
- NLO corrections moderate, effect of scale variations, hadronisation corrections $\leq 10\%$
- Inviting for quantitative QCD analysis
 $\rightarrow \alpha_s, G(x)$ in proton \rightarrow Enrico Tassi