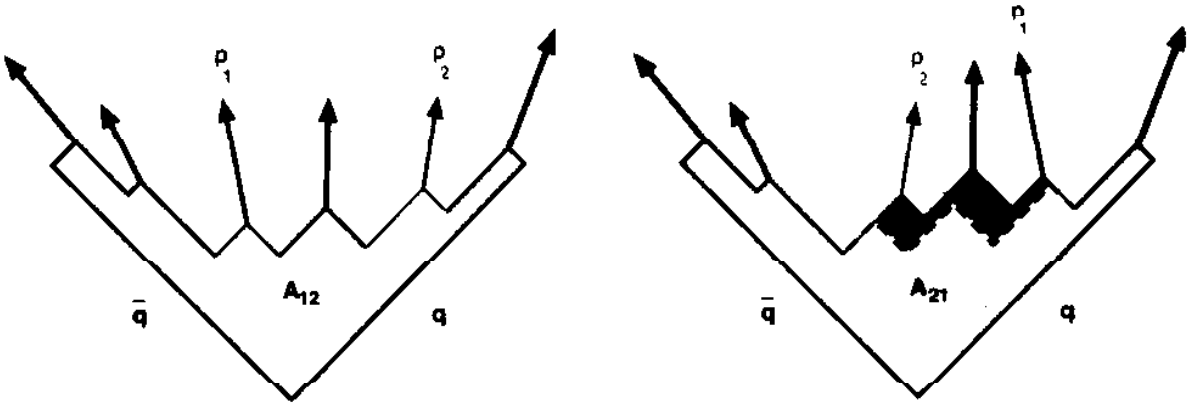
Bose-Einstein Correlations in Deep Inelastic e^+p Scattering at HERA

M. Charlet
for the
H1 collaboration

In color-string fragmentation interpretation
r is a measure of the string tension κ
(Andersson, Hofmann and Bowler)
(Particle World 2(1991)1, Phys. Lett. B169(1986)364)

e.g. two identical pions



yielding same final state
different area, different phase

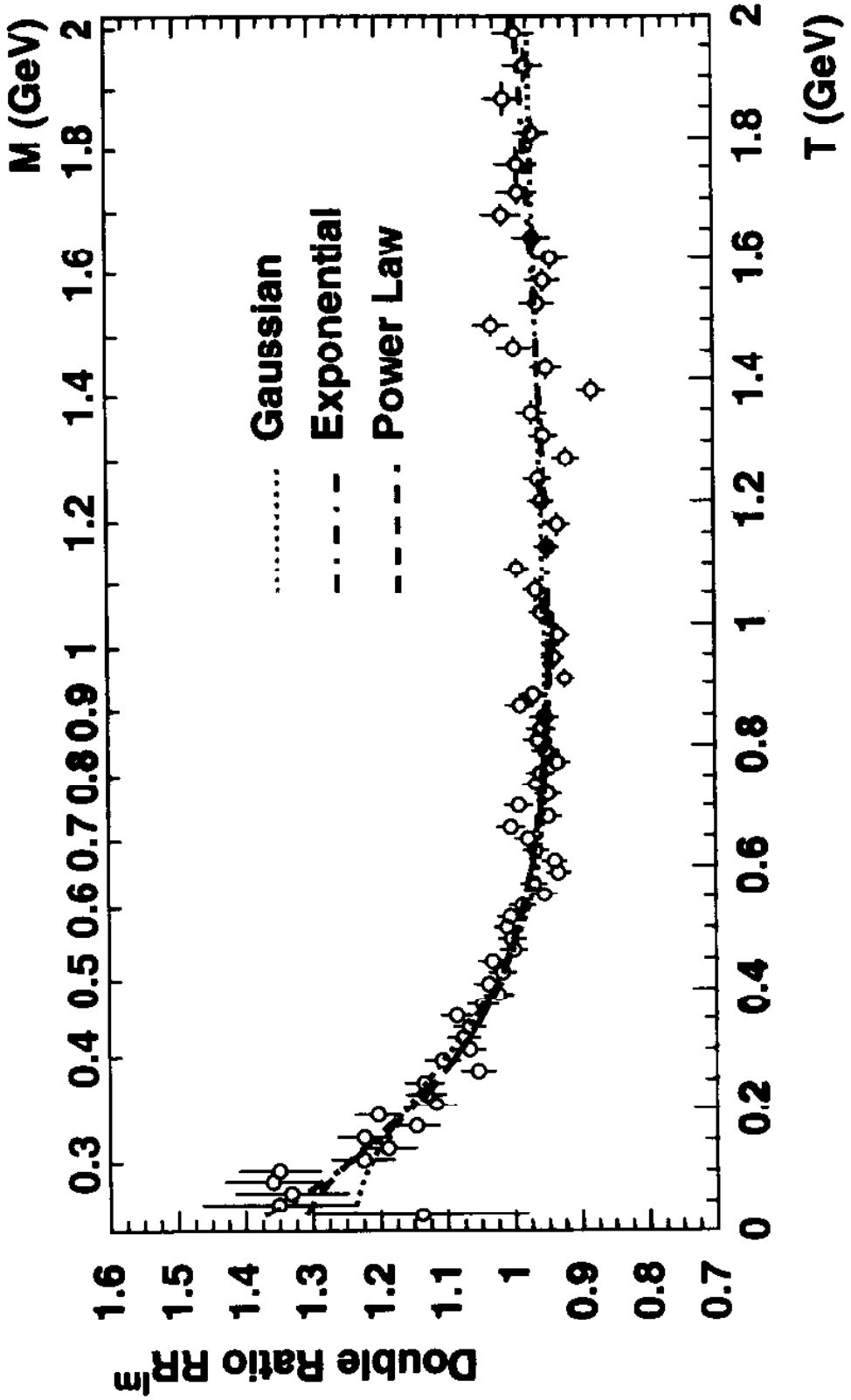
$$\psi \propto e^{i\kappa A_{12}} e^{-\frac{\mathcal{P}}{2}A_{12}} + e^{i\kappa A_{21}} e^{-\frac{\mathcal{P}}{2}A_{21}}$$

κ string tension
$\mathcal{P}$ splitting probability

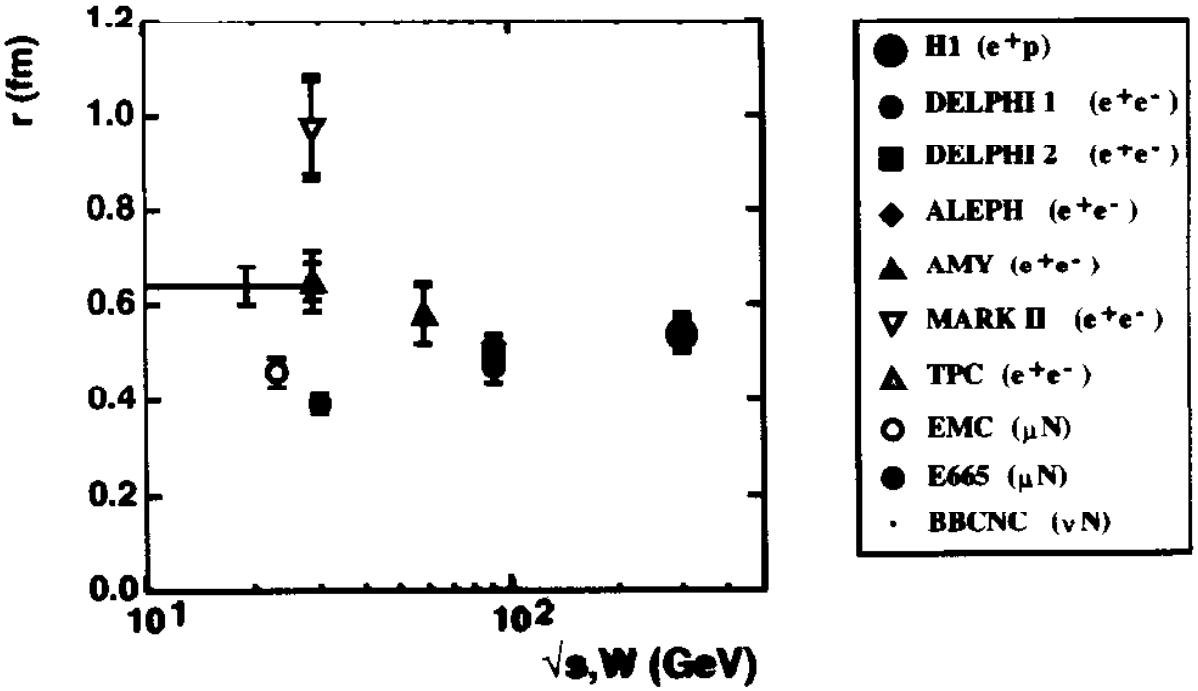
Full calculations
$\longrightarrow$ $R(T)$ roughly exponential

$$R(T) = R_0(1 + \lambda \exp(-rT))$$

$r(\kappa)$ is independent of the total interaction energy


M (GeV)
T (GeV)
Gaussian
Exponential
Power Law
Double Ratio RR^{lm}

3.4. Comparison with other experiments (Gaussian fits)



All values about the same
Except for MARK II

No evidence for energy dependence
No evidence for primary interaction dependence

supports more recent interpretations of r

The Linked Dipole Chain MC

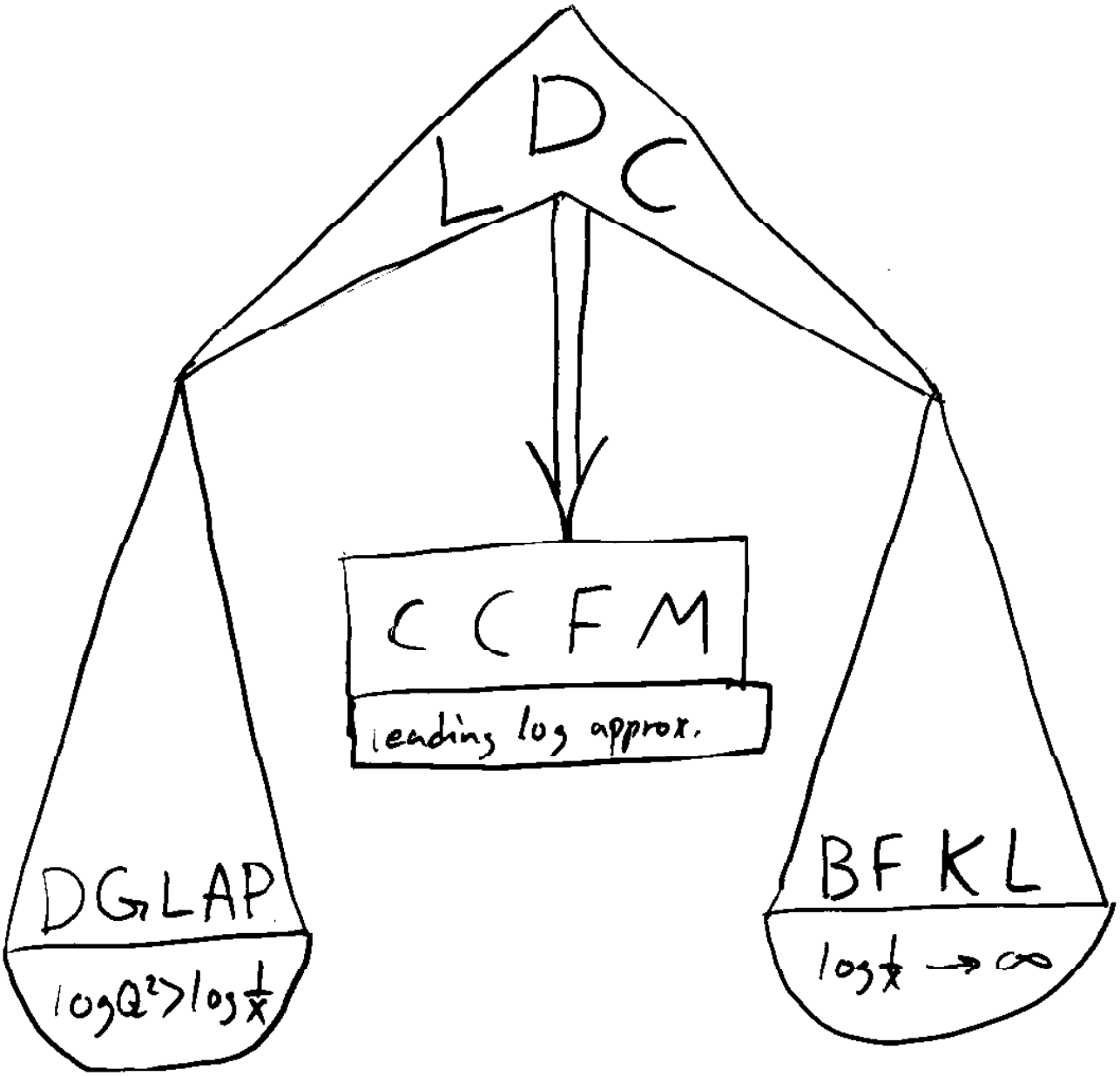
Hamid Kharraziha, Dept. of Theoretical Physics, Lund

- We are developing a full scale MC for e-p collisions!

This talk:

- The LDC-model
- the dipole model
- some leading log results
- The full MC

Collaborators: B. Andersson, P. Edén, G. Gustafson
L. Lönnblad, J. Samuelson

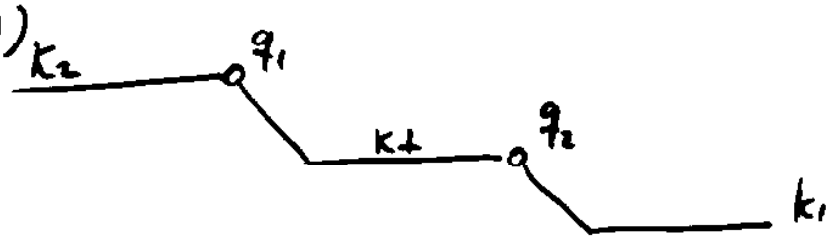

LDC
CCFM
leading log approx.
DGLAP
$\log Q^2 > \log \frac{1}{x}$
BFKL
$\log \frac{1}{x} \to \infty$

variable change & azimuth integration =>

$$dp_i = \bar{\alpha}\,\frac{dk_{\perp i}^2}{k_{\perp i}^2}\,\frac{dz_{+i}}{z_{+i}} \cdot \min\left(1, \frac{k_{\perp i}^2}{k_{\perp i-1}^2}\right)$$

along the chain:

i)



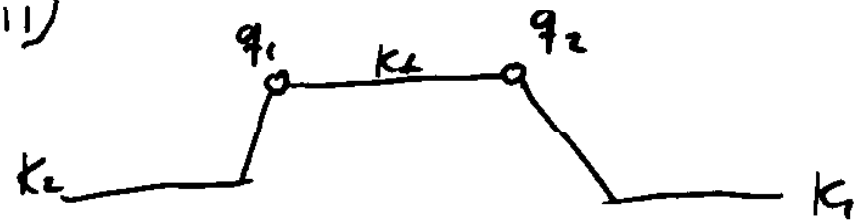
$$dp \propto \frac{1}{k_\perp^2}\,\frac{1}{k_{\perp 2}^2}$$

$k_\perp$

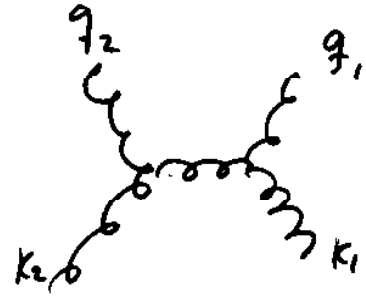
↑

ordinary DGLAP

ii)



$$dp \propto \frac{1}{k_\perp^4}$$

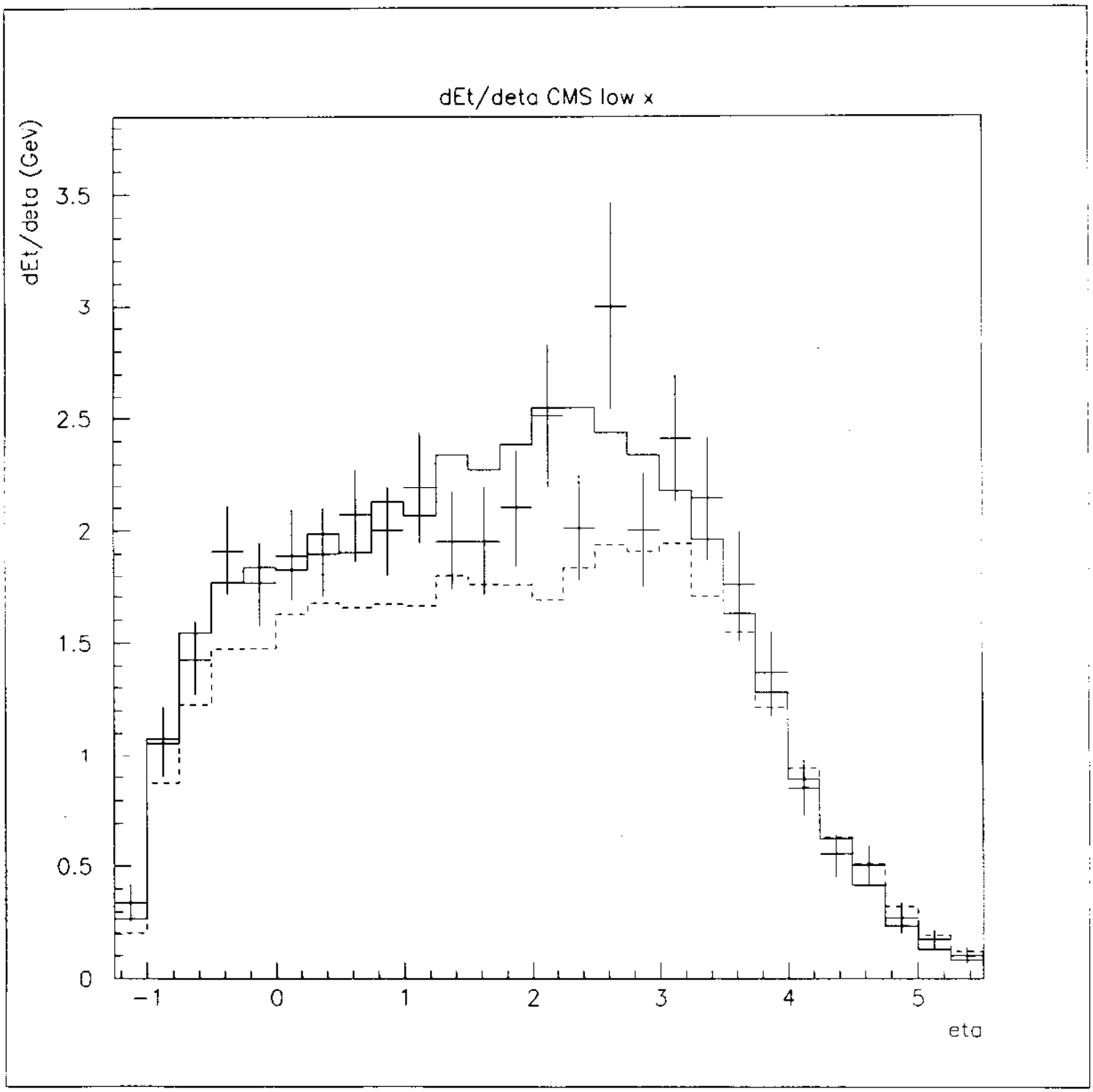


hard subcollision with

$\hat{t} \approx k_\perp^2$

iii)

$$dp \propto \frac{1}{k_{2\perp}^2}\,\frac{1}{k_{1\perp}^2}$$


dEt/deta CMS low x
dEt/deta (GeV)
3.5
3
2.5
2
1.5
1
0.5
0
−1
0
1
2
3
4
5
eta

Instanton Phenomenology at HERA

A. Ringwald

in collaboration with

F. Schrempp

and

M. Gibbs (Monte Carlo) S. Moch (PhD Thesis)

1. **Introduction**
2. **Monte Carlo Generator QCDINS**
   - Physics Input
   - Limitations
3. **Conclusions**

Copy available via WWW:

http://www.desy.de/~ringwald/dis97/talk.ps.gz

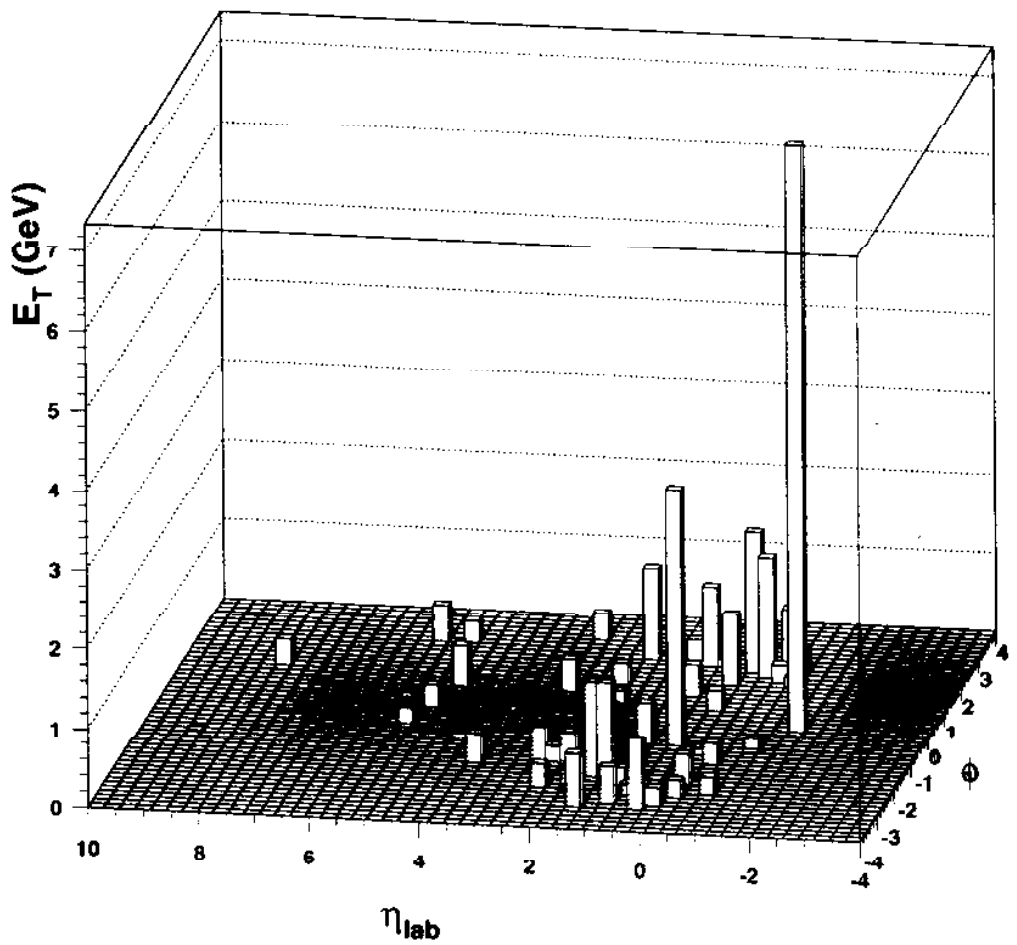
1. Introduction

- Hard scattering processes in strong interactions are successfully described in terms of the usual Feynman diagrams of perturbative QCD.
- Procedure behind Feynman diagrammatics:
  - Expansion of the Euclidean path integral expression for the corresponding Euclidean Green's functions

$$\frac{\int [dA][d\psi][d\bar{\psi}] A_\mu(x_1) \ldots \psi(x_i) \ldots \bar{\psi}(x_n) \exp\{-S[A,\psi,\bar{\psi}]\}}{\int [dA][d\psi][d\bar{\psi}] \exp\{-S[A,\psi,\bar{\psi}]\}}$$

    about the perturbative vacuum configuration, $A_\mu^{(0)} = 0$, with minimum Euclidean action $S^{(0)} = 0$.
  - Amplitudes: power-series in terms of α_s.
- The instanton $A_\mu^{(I)}(x)$ is a non-trivial solution of the Euclidean YM equations and thus a non-trivial local minimum of the Euclidean action with $S^{(I)} = 2\pi/\alpha_s$.
  - Expansion of the Euclidean path integral about the instanton can be summarized by modified Feynman rules.
  - Amplitudes: $\propto \exp\{-2\pi/\alpha_s\}$.
- In QCD with massless quarks usual perturbation theory and instanton perturbation theory describe two distinct classes of processes:
  - In usual perturbation theory, Green's functions corresponding to chirality (Q_5) violating processes vanish to all orders.
  - In instanton perturbation theory, only Green's functions corresponding to $\Delta Q_5 = 2n_f$ processes receive non-vanishing contributions.

Signature of instantons at HERA



Instanton decays isotropically in multi-parton state consisting of gluons and all quark flavours kinematically allowed:

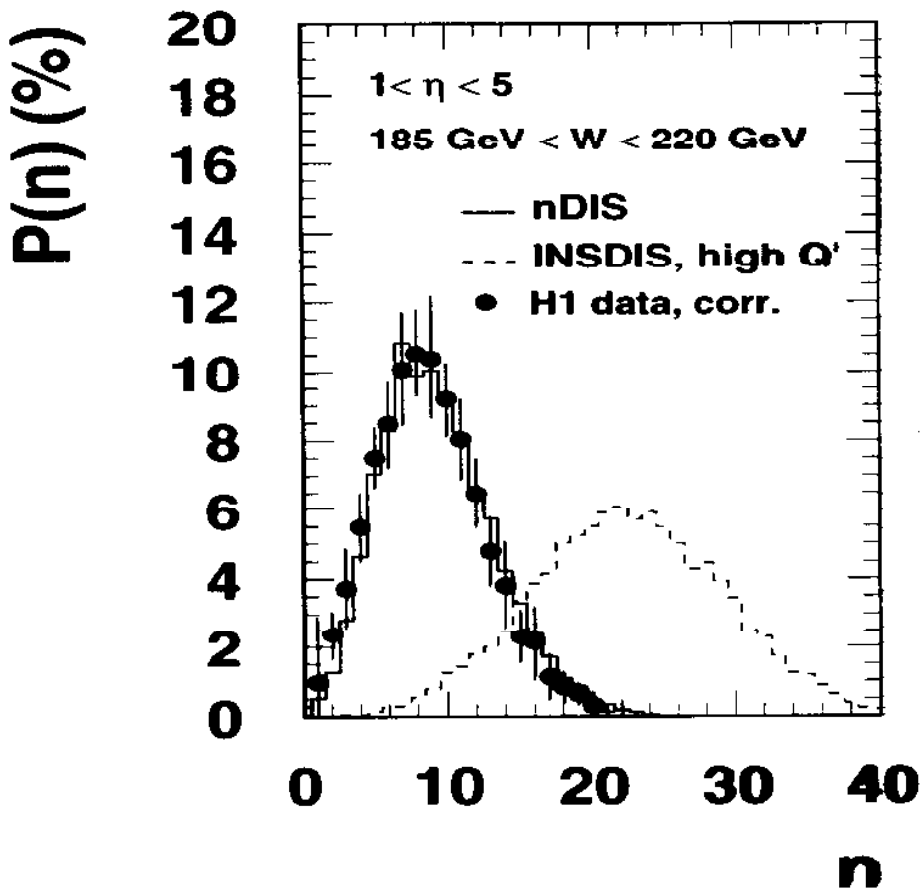
→ High multiplicity

→ densily populated narrow band in η, flat in ϕ

→ more strange/charm particle then in normal DIS

→ large transverse energy

Limits from Multiplicity Distribution



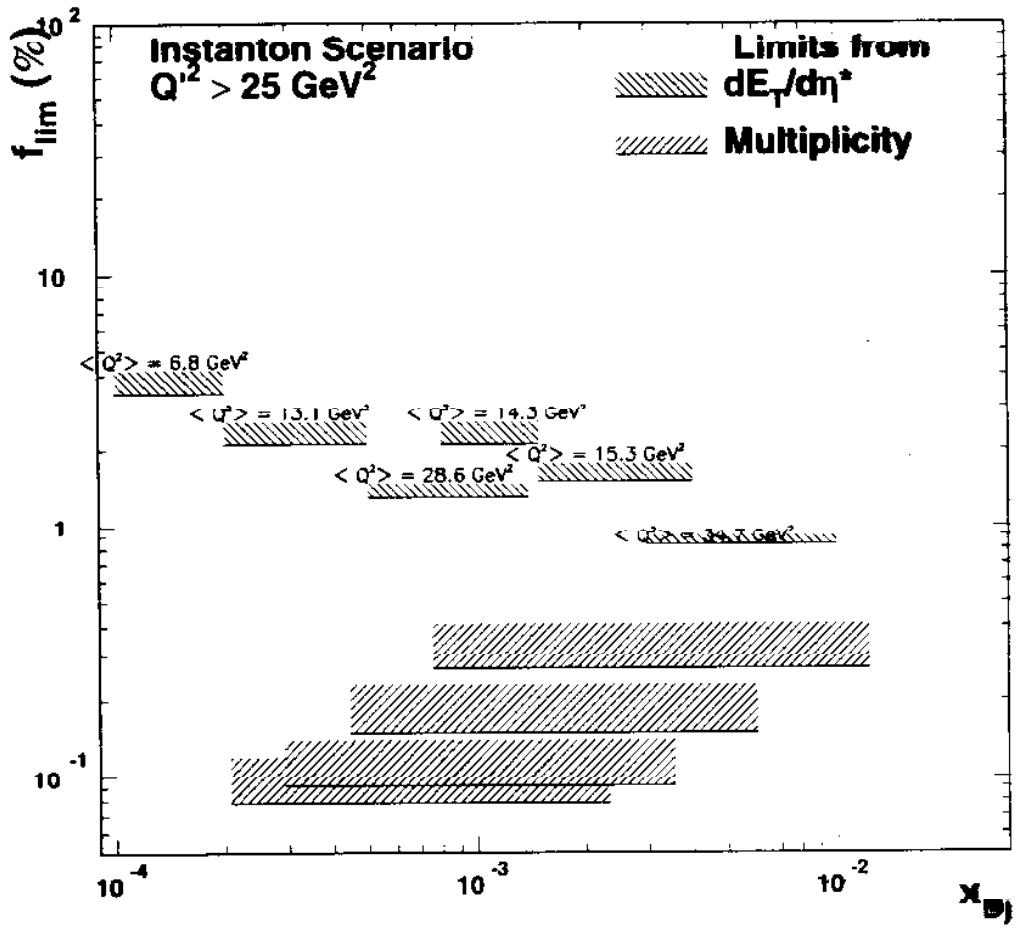
Determine n_{cut} beyond that no events have been measured:

Fractional limit (95% confidence limit):

$$f_I < f_{\text{lim}} = \frac{3/\varepsilon_I}{N_{\text{DIS}}}.$$

ε_I to detect instanton beyond n_{cut}

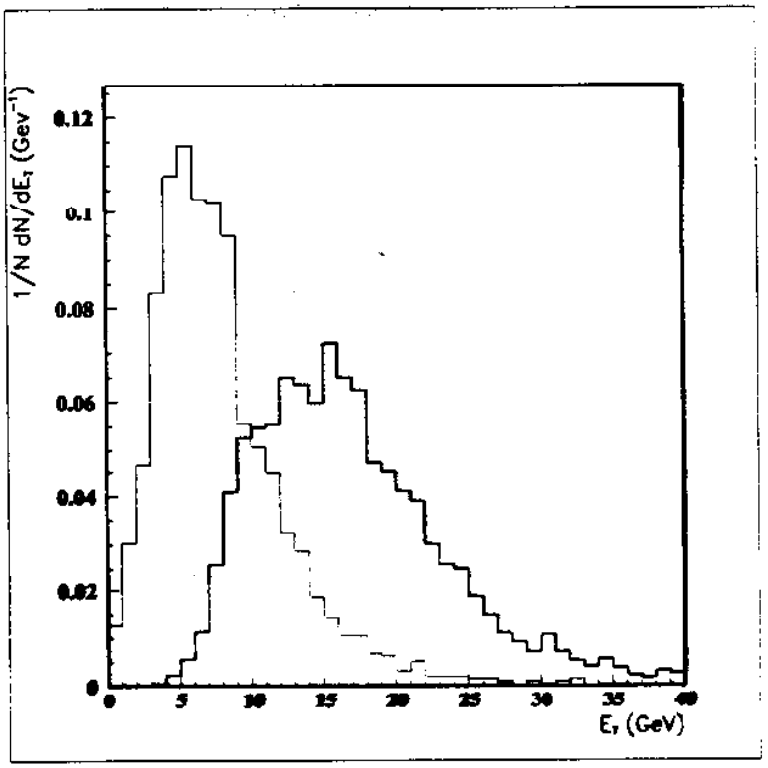
Maximally Allowed Instanton Fraction



[redacted]

- Limits from existing HERA data: c.f. T. Carli's talk later.
  - Searching for excess in multiplicities (all particles; Kaons), total transverse energy . . .
- Possible Search Strategies:

  [Gibbs, Greenshaw, Milstead, A.R., F. Schrempp, Proc. "Future Physics at HERA", 1996]
  - Combine event shape information with multiplicity cuts, transverse energy cuts and searches for K^0's and μ's.
  - Analysis in $\gamma - P$ rest-system:
    * In this system, (1+1) and (2+1) jet perturbative QCD processes deposit their energy predominantly in a plane passing through the $\gamma - P$ direction.
    * Energies from I-induced events are always distributed much more spherically (ISOTROPY!).
    * I-induced events have large $\langle E_T \rangle$! (Fig.)



Summary

- QCD instanton production was systematically confronted to HERA data
- Most sensitive observables:
  - Transverse energy flow
  - multiplicity flow of hard particles
  - multiplicity distribution
- Extracted limits extent kinematic domain: $1 \cdot 10^{-4} \lesssim x_{\mathrm{Bj}} \lesssim 1 \cdot 10^{-2}$ and $5 \lesssim Q^2 \lesssim 80$ GeV^2
- Best limit from multiplicity distribution:

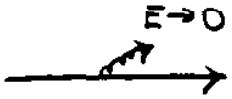
$$f_{\mathrm{lim}} \lesssim 1\% \qquad 10 \lesssim \sigma_{\mathrm{lim}} \lesssim 60 \text{ pb}$$

  Note: this limits directly scales with $\mathcal{L}$
- Only 1993/1994 data ($\sim 1-2$ pb) were used in this analysis much more data are on tape !

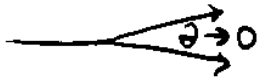
EVENT SHAPES

"THEORY DICTATES THE MEASUREMENT"

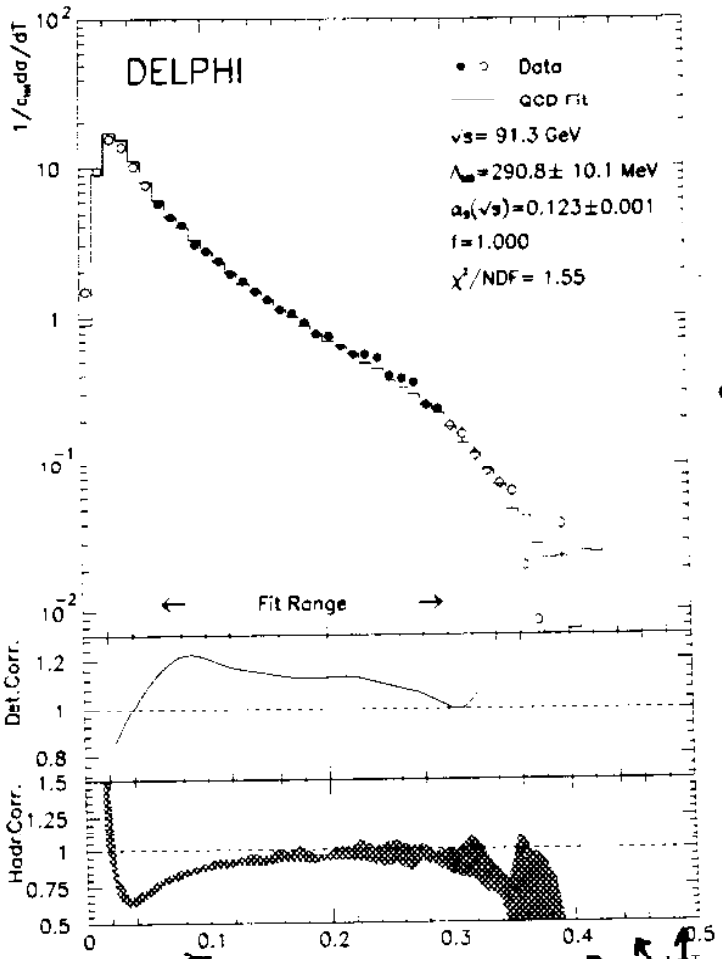
OBSERVABLE SHOULD BE INSENSITIVE TO



SOFT GLUON EMISSION



COLLINEAR PARTON BRANCHING

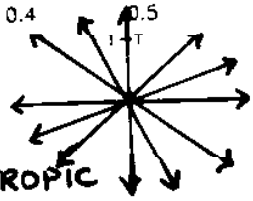


EXAMPLE:

THRUST

~ projection of hadron momenta onto jet axis.

1 - THRUST



PENCIL-LIKE TWO-JETS

ISOTROPIC

CROSS SECTION $\frac{1}{\sigma_0}\frac{d\sigma}{dT} \propto \alpha_s(\sqrt{s})$

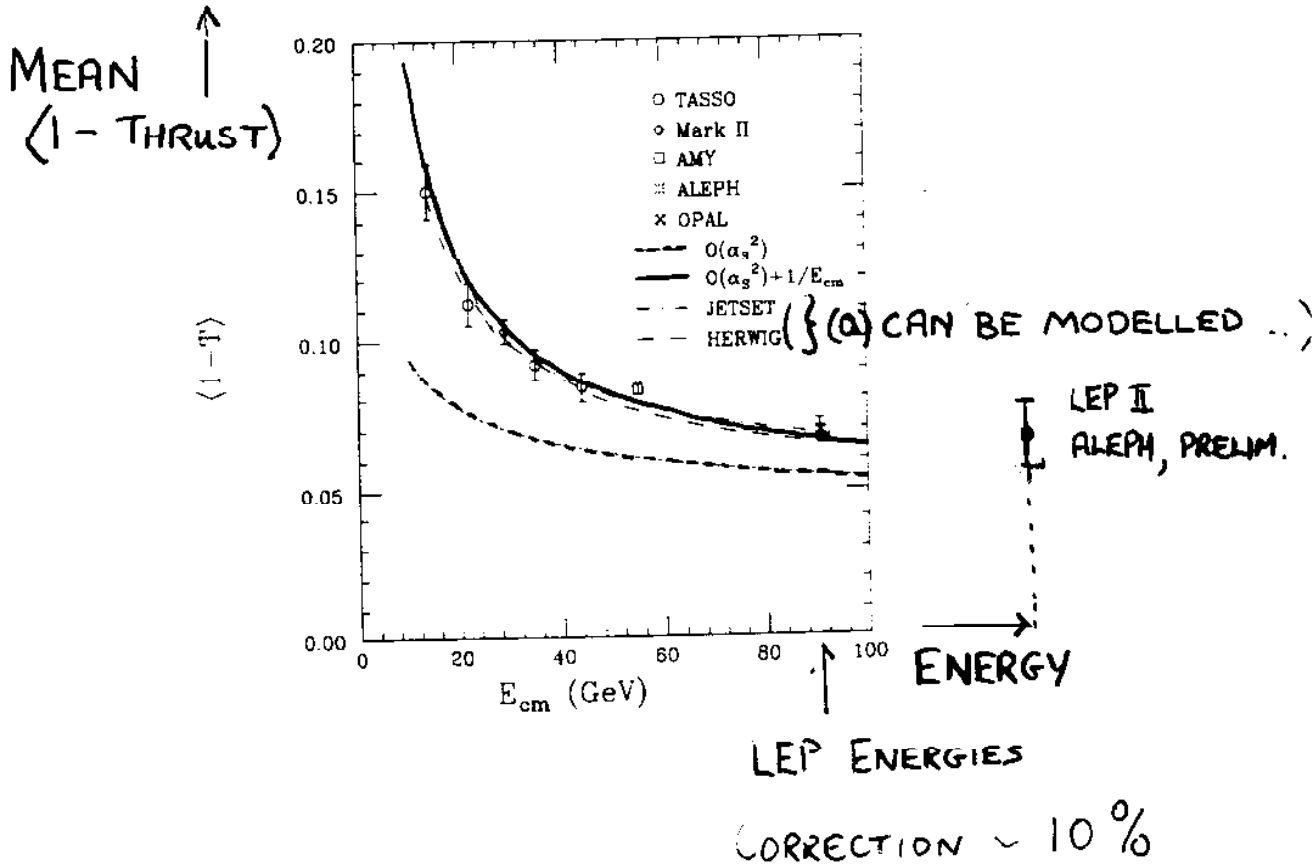
$\langle 1-T \rangle = 0.335\,\alpha_s + 1.02\,\alpha_s^2 + \mathcal{O}(\alpha_s^3)$ [LEP]

WHAT ARE THE UNCERTAINTIES?

OBSERVABLE SHOULD ALSO BE INSENSITIVE TO NON-PERTURBATIVE EFFECTS....

HADRONISATION CORRECTIONS

(DOMINATE AT LOW ENERGIES)



CORRECTION ~ 10 %

- DATA DESCRIBED BY $O(\alpha_s^2)$ CALCULATION + $1/E_{cm}$ CORRECTION —
- CORRECTION MAY BE CALCULATED (INFRARED RENORMALO
- AND/OR NEW QUANTITIES - INSENSITIVE TO HADRONISATION CORRECTIONS

→ IMPROVED DETN OF α_s (~ $O(\alpha_s^3)$ ACCURA

- **The Power Correction Part**

$$\langle F \rangle^{\rm pow} = a_F \frac{16}{3\pi} \frac{\mu_I}{Q} \ln^p \frac{Q}{\mu_I} \cdot$$

$$\left[\bar{\alpha}_0(\mu_I) - \alpha_s(Q) - \frac{\beta_0}{2\pi} \left(\ln \frac{Q}{\mu_I} + \frac{K}{\beta_0} + 1 \right) \alpha_s^2(Q) \right]$$

$$\propto a_F \frac{\mu_I}{Q} \ln^p \frac{Q}{\mu_I}$$

contains in addition to the new Scale μ_I and the non-perturbative parameter $\bar{\alpha}_0(\mu_I)$ two coefficients a_F and p, that are calculable and depend on F.

All Power Corrections investigated are $\propto 1/Q$, resp. $p = 0$, except for B_C, where $p = 1$. In our fits, however, the conjectured behaviour of $\langle B_C \rangle$ could not be verified and p was taken to be 0!

- **c_1, c_2 and a_F coefficients used in the QCD fits ($p = 0$ always):**

Observable	c_1	c_2	a_F
$\langle 1 - T_C \rangle$	0.384 ± 0.033	0.57 ± 0.21	1
$\langle 1 - T_Z \rangle / 2$	0.053 ± 0.033	3.45 ± 0.23	1
$\langle B_C \rangle$	0.990 ± 0.121	2.39 ± 0.86	2
$\langle \rho_C \rangle$	0.359 ± 0.048	-0.05 ± 0.30	1/2

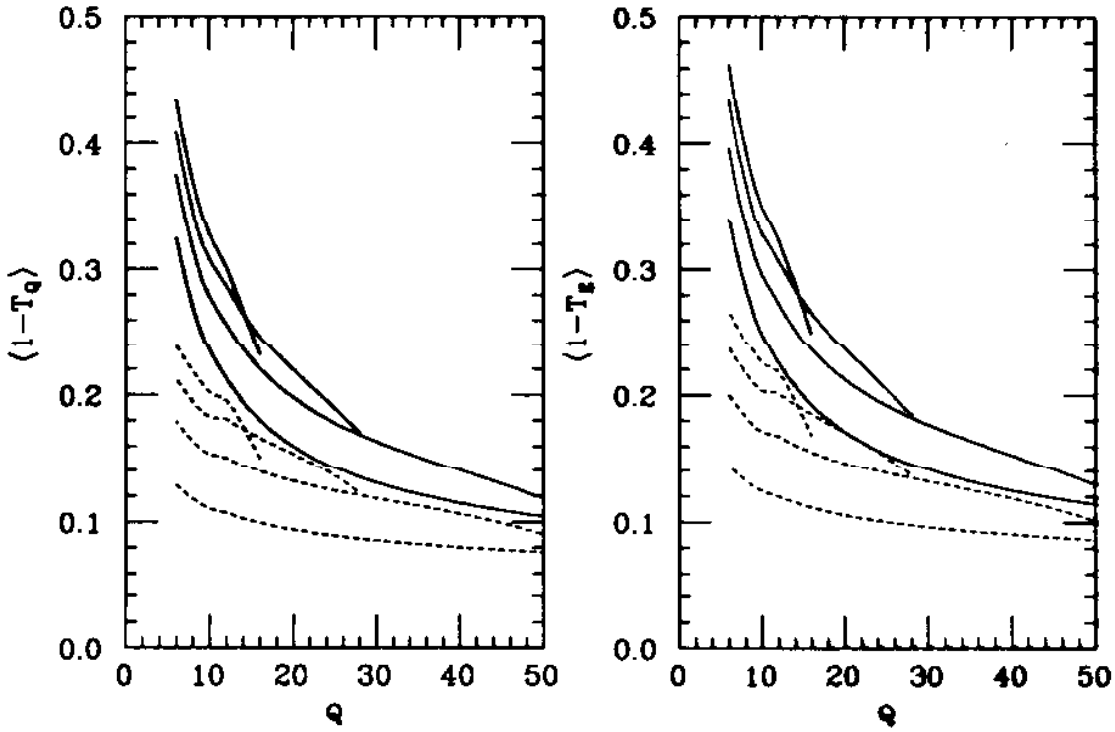
CURRENT JET THRUST

NEED ONLY INTEGRAL ALONG BOUNDARY.

$$F^T(x,\epsilon) \sim F_T(x,0) - 8\sqrt{\epsilon}\, q(x)$$

COMES FROM

$$\dot{F}(x,\epsilon) = \int_x^{\xi_p} \frac{d\xi}{\xi}\, \epsilon \frac{1+\xi^2}{(1-\xi)^2}\, q\left(\frac{x}{\xi}\right) + \int_{\xi_p}^{1} \frac{d\xi}{\xi} \frac{1+\xi^2}{\xi}\, q\left(\frac{x}{\xi}\right)$$



PLOT IS FOR BOTH NORMALIZATIONS

HERA ENERGIES $\sqrt{s} = 296$ GeV.

MRS A' PARTON DIST. USED

4 values of x $\cdot 003 \to \cdot 10$

dashed curve - pert. (α.0); solid curve = α.0 + power correction.

JET BROADENING

GET SLIGHTLY DIFFERENT BEHAVIOUR

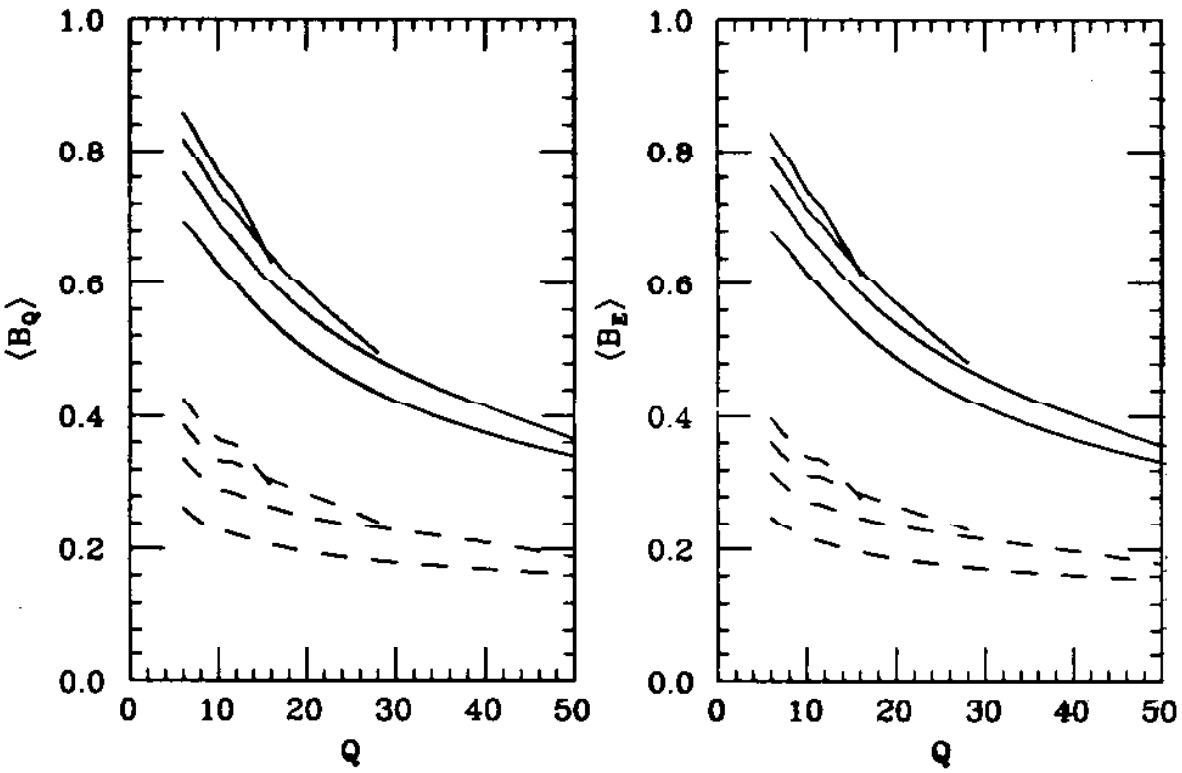
FULL (MASSIVE) CALCULATION GIVES

$$F^B(x,\epsilon) \sim F^B(x,0) + 8\sqrt{\epsilon}\,(\ln\epsilon + c)\, q(x)$$

$$\delta\langle B\rangle = \frac{8A_1}{Q} \ln\frac{Q}{Q_0}$$ Q_0 – unknown scale

Boundary approx. gives

$$\dot{F} = \sqrt{\epsilon}\int_x^{\xi_p} \frac{d\xi}{1-\xi}\,\frac{\xi^2+1}{\xi}\, q\left(\frac{x}{\xi}\right) + 2\sqrt{\epsilon}\int_{\xi_p}^{1/1+\epsilon} \frac{d\xi}{1-\xi}\,\frac{\xi^2+1}{\xi}\, q\left(\frac{x}{\xi}\right)$$



LARGE POWER CORRECTIONS + UNCERTAINTY ABOUT COEFFICIENT MEAN – NOT A GOOD VARIABLE FOR α_s EXTRACTION?

- **The perturbative Part $\langle F \rangle^{\text{pert}}$ may be obtained to $\mathcal{O}(\alpha_s^2)$ via**

$$\langle F \rangle^{\text{pert}} = \frac{\int_0^{F_{\max}} F \frac{d\sigma}{dF} dF}{\int_0^{F_{\max}} \frac{d\sigma}{dF} dF} = \frac{1}{\sigma_{\text{tot}}} \int_0^{F_{\max}} F \frac{d\sigma}{dF} dF ,$$

where the total cross section needs only be known to first order QCD.

Currently two NLO programs are available for this task:

1. MEPJET: **E. Mirkes, D. Zeppenfeld;**
   Phys. Lett. B 380 (1996) 205
2. DISENT: **S. Catani, M. Seymour;**
   Phys. Lett. B 378 (1996) 287

Due to the integration method applied in MEPJET, however, a lower cut in F, such that

$$0 < F_{\text{cut}} < F \leq F_{\max}$$

has to be used.

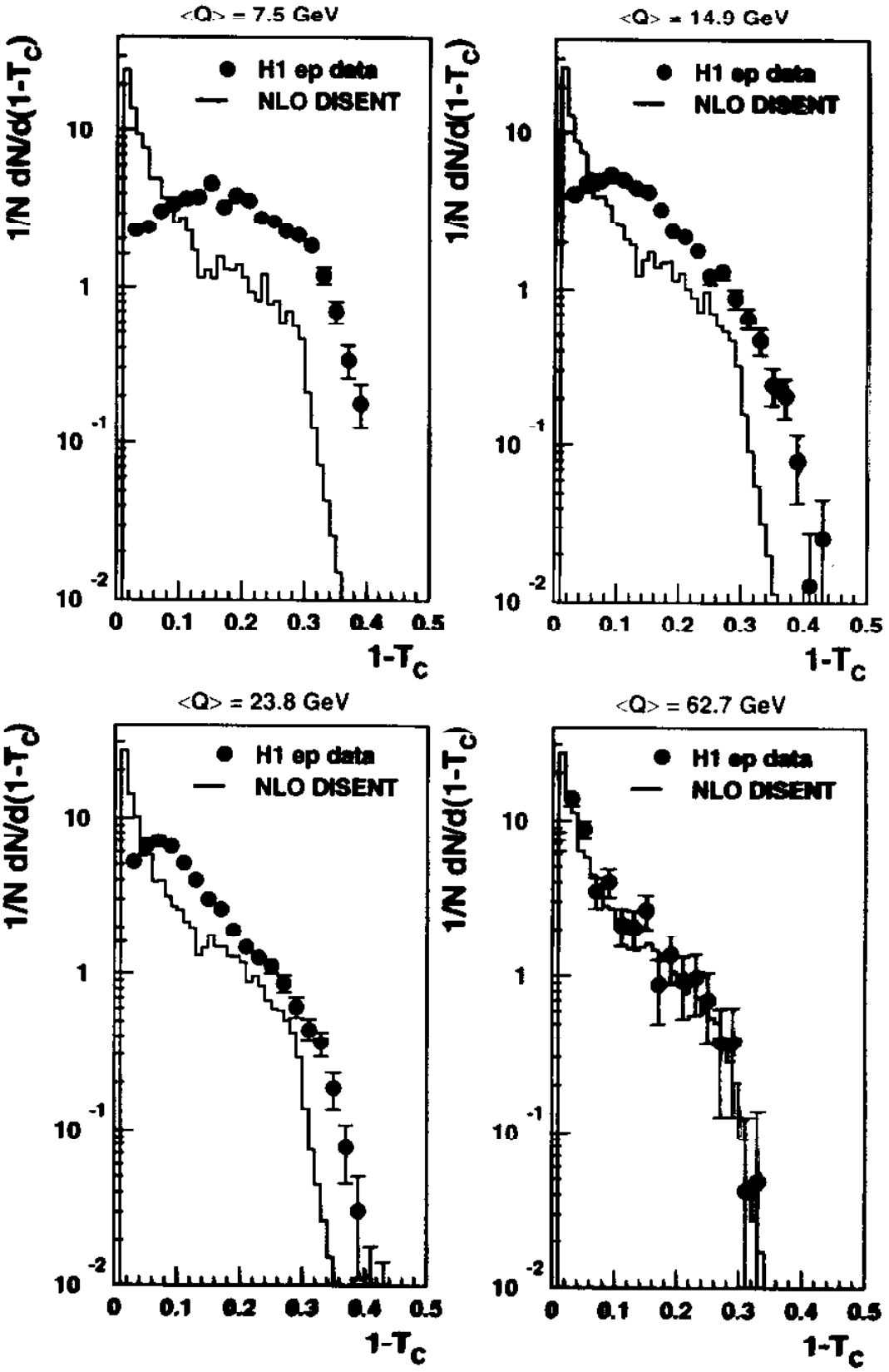
In DISENT special care has been taken concerning the numerical integration of $F\, d\sigma/dF$, which still contains integrable singularities for $F \to 0$.

$\Rightarrow$ It is allowed to use the complete phase space

$$0 \leq F \leq F_{\max}.$$

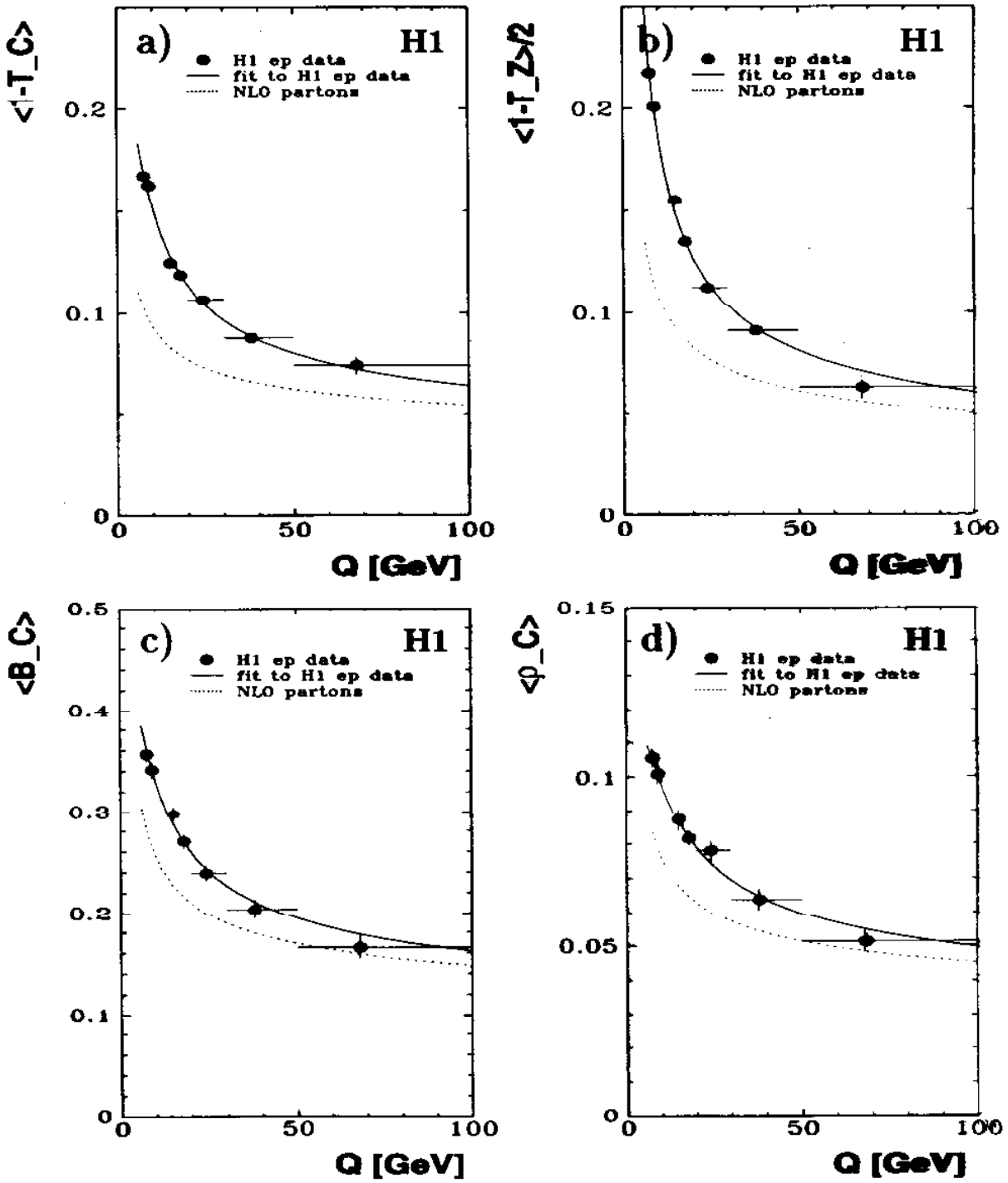
$\Rightarrow$ DISENT results are used in the analysis.

In the overlapping phase space MEPJET and DISENT agree to $< 1\,\%$ in $\mathcal{O}(\alpha_s)$ and $\sim 3\,\%$ $\mathcal{O}(\alpha_s^2)$.


<Q> = 7.5 GeV
<Q> = 14.9 GeV
<Q> = 23.8 GeV
<Q> = 62.7 GeV
H1 ep data
NLO DISENT
1/N dN/d(1-T_C)
1-T_C
10
1
10^-1
10^-2
0
0.1
0.2
0.3
0.4
0.5

5. Fit Results

Q dependence of H1 event shape means (full symbols), DISENT NLO calculations (dotted lines) and power correction fits (full lines):



- **Results on $\bar{\alpha}_0$ and $\alpha_s(M_Z)$ from fits to the Q dependence of the event shape variables (first error experimental, second error theoretical uncertainties):**

Observable	$\bar{\alpha}_0(\mu_I = 2\ \mathrm{GeV})$	$\alpha_s(M_Z)$	χ^2/ndf
H1 ep data			
$\langle 1 - T_C \rangle$	$0.497 \pm 0.005\ ^{+0.070}_{-0.036}$	$0.123 \pm 0.002\ ^{+0.007}_{-0.005}$	5.0/5
$\langle 1 - T_Z \rangle / 2$	$0.507 \pm 0.008\ ^{+0.109}_{-0.051}$	$0.115 \pm 0.002\ ^{+0.007}_{-0.005}$	8.5/5
$\langle B_C \rangle$	$0.408 \pm 0.006\ ^{+0.036}_{-0.022}$	$0.119 \pm 0.003\ ^{+0.007}_{-0.004}$	5.3/5
$\langle \rho_C \rangle$	$0.519 \pm 0.009\ ^{+0.025}_{-0.020}$	$0.130 \pm 0.003\ ^{+0.007}_{-0.005}$	3.1/5
Common fit without B_C, ignoring correlations!			
$T_C + T_Z + \rho_C$	$0.491 \pm 0.003\ ^{+0.079}_{-0.042}$	$0.118 \pm 0.001\ ^{+0.007}_{-0.006}$	39/19
e^+e^- data			
$\langle 1 - T_{ee} \rangle$	$0.519 \pm 0.009\ ^{+0.093}_{-0.039}$	$0.123 \pm 0.001\ ^{+0.007}_{-0.004}$	10.9/14
$\langle M_H^2/s \rangle$	$0.580 \pm 0.015\ ^{+0.130}_{-0.053}$	$0.119 \pm 0.001\ ^{+0.004}_{-0.003}$	10.9/14

$\Rightarrow$

- All investigated Event Shape Means exhibit consistently a $1/Q$ behaviour, no $1/Q^2$ terms are needed.
- The theoretical ansatz with $p = 1$ for $\langle B_C \rangle$ does not fit to the data.
- The concept of a 'universal' Power Correction parameter $\bar{\alpha}_0$ in DIS ep scattering and e^+e^- annihilation is supported.

Error Consideration:

- **Experimental Errors (statistical and systematical):**

$$\delta\bar{\alpha}_0 \simeq \pm 0.007 \qquad\qquad \delta\alpha_s \simeq \pm 0.003$$

- **Theoretical Uncertainties:**

1. NLO Calculations: $c_1 \pm \delta c_1,\ c_2 \mp \delta c_2$

$$\delta\bar{\alpha}_0 \simeq \pm 0.002 \qquad\qquad \delta\alpha_s \simeq \pm 0.001$$

2. Renormalization Scale: $0.8\,Q < \mu_R < 1.5\,Q$

$$\delta\bar{\alpha}_0 \simeq \pm 0.06 \qquad\qquad \delta\alpha_s \simeq^{+0.005}_{-0.004}$$

The interplay between non-perturbative (μ_I) and perturbative (μ_R) regions is problematic.

Recall: $\Lambda \ll \mu_I \ll \mu_R$
for a range in $\langle Q \rangle$ of $7.5 - 68$ GeV

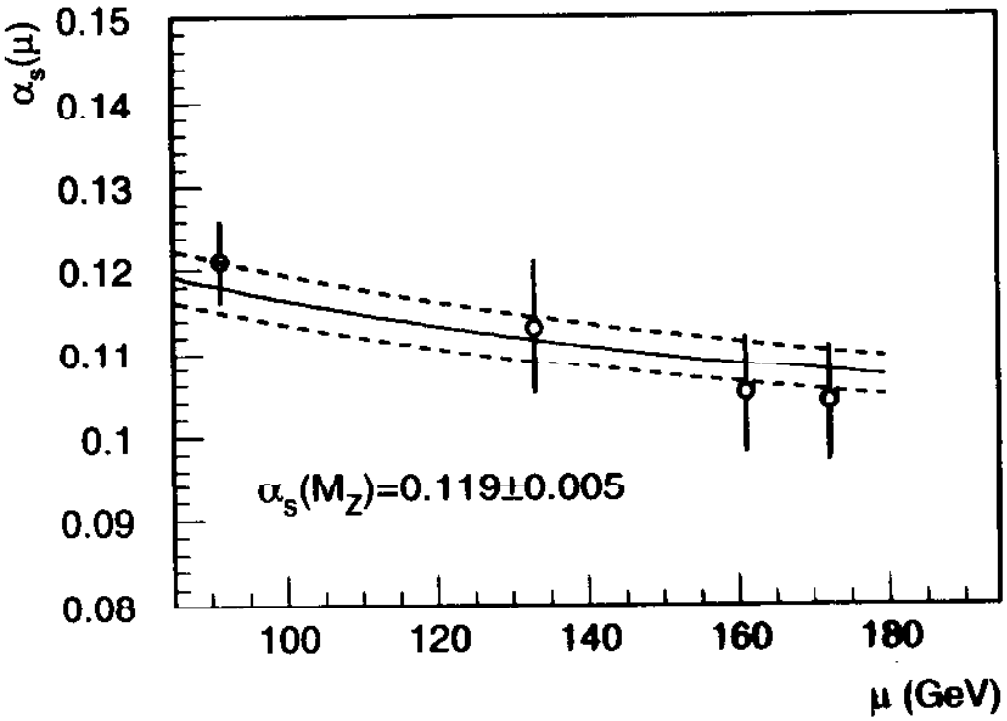
Lower value: require $3\,\mu_I < \mu_R$

3. 'Infrared Matching' Scale: $\mu_I = 2.0 \pm 0.5$ GeV

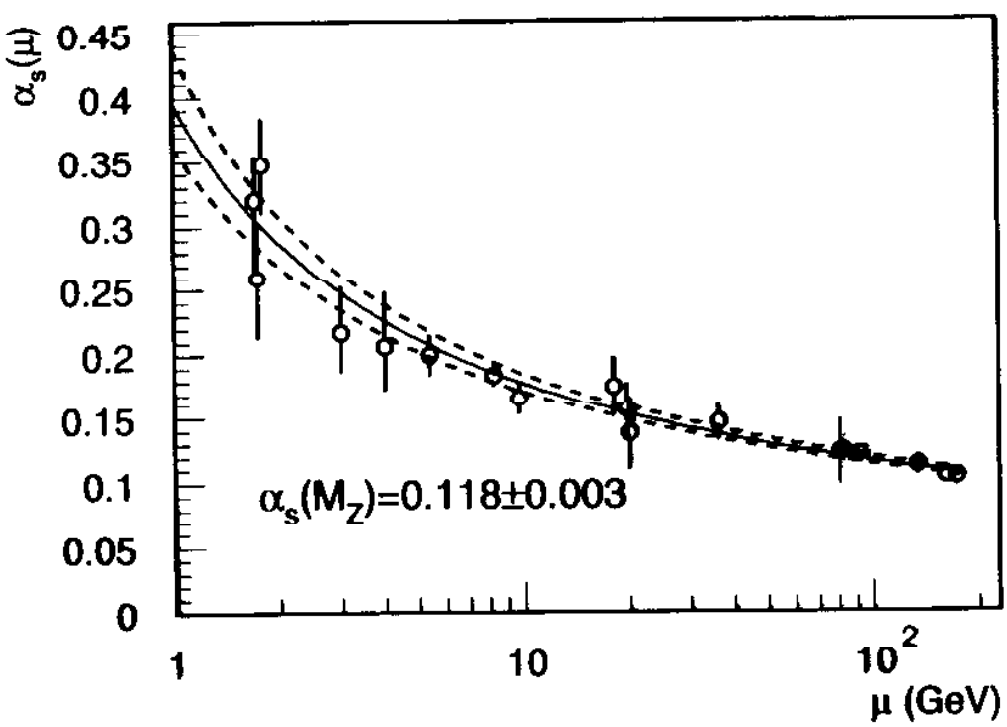
$$\delta\bar{\alpha}_0 \propto \mu_I \qquad\qquad \delta\alpha_s \simeq \pm 0.002$$

$\Rightarrow$ **Total error is dominated by theoretical uncertainties.**

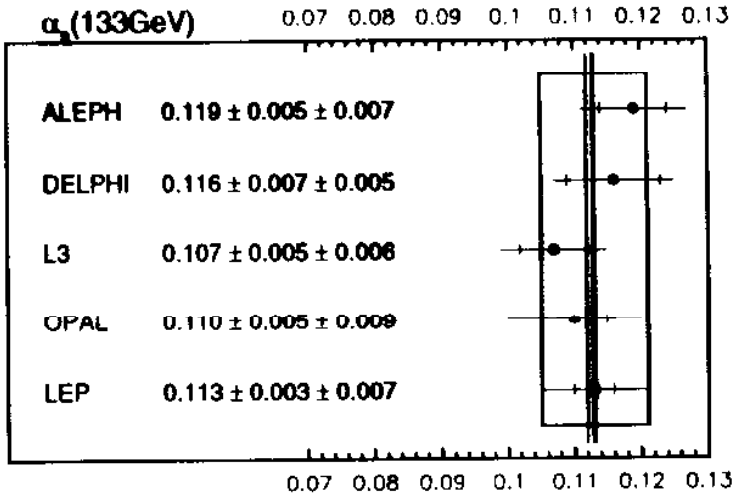
All LEP measurements:

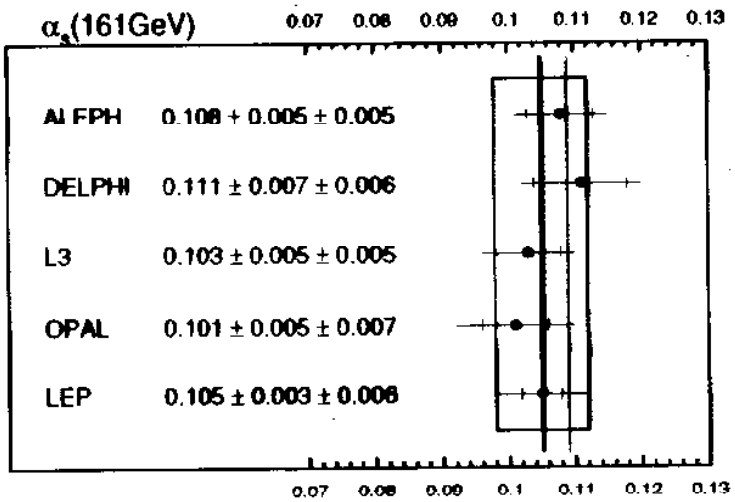


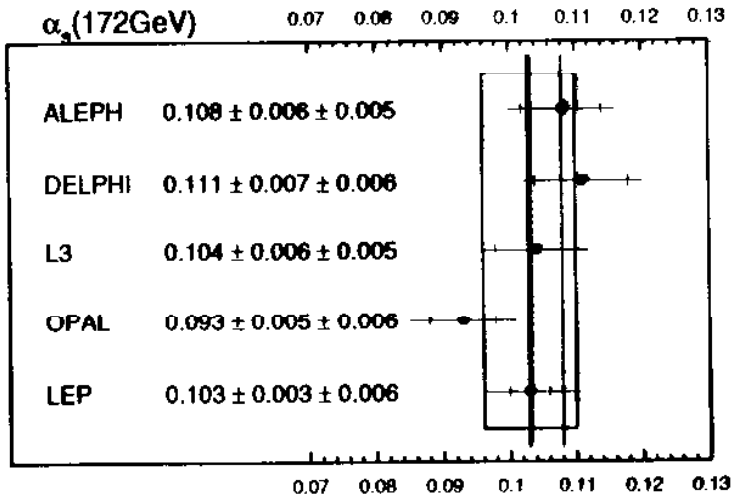
All α_s measurements:



Summary of α_s at LEP II

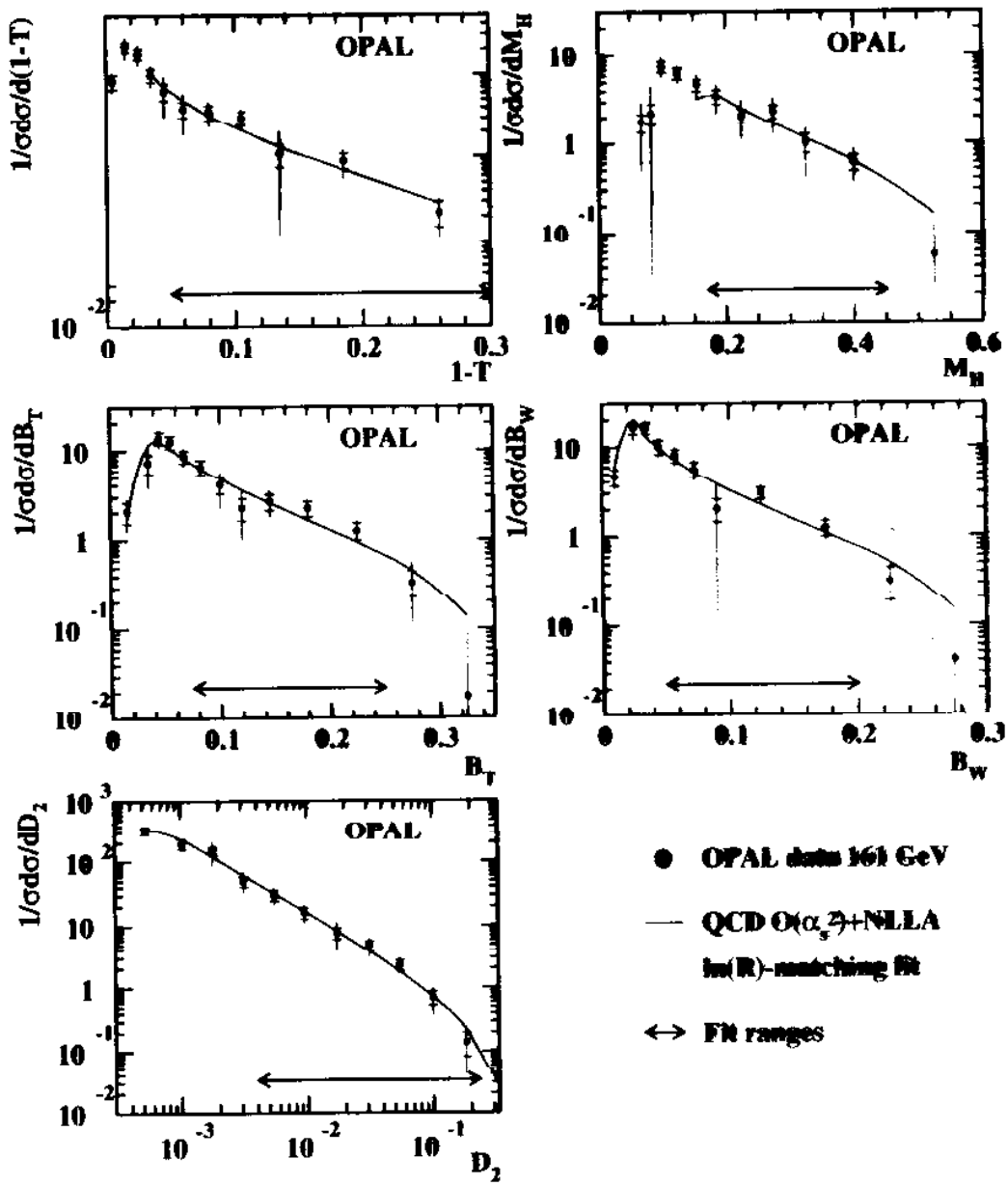






Event shapes at $\sqrt{s} = 161$ GeV

Preliminary



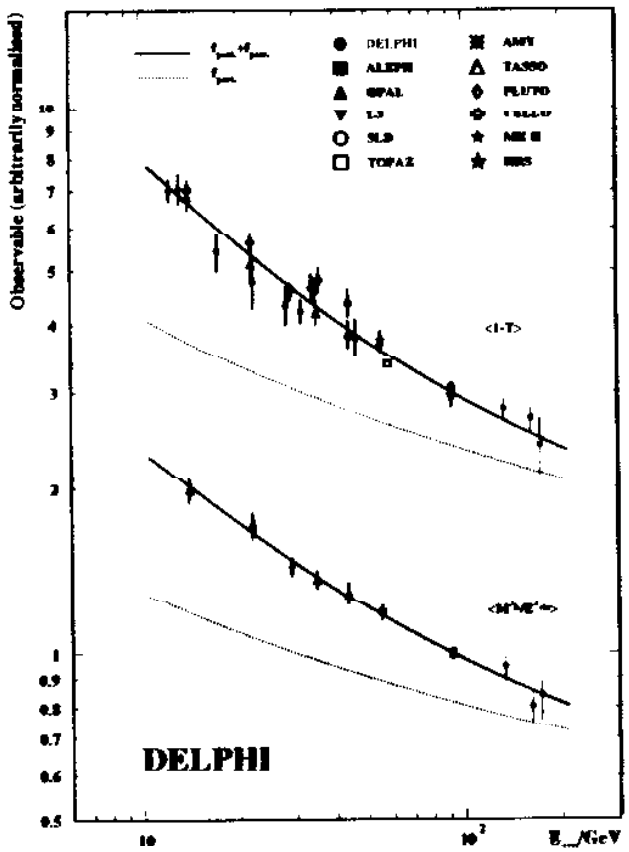
OPAL: $\mathcal{O}(\alpha_s^2)$ + **NLLA QCD**

$$\alpha_s(161\text{GeV}) = 0.102 \pm 0.005(\text{exp.}) \pm 0.007(\text{theo.})$$

Fragmentation Model Independent α_s Determination

$$\langle f \rangle = \frac{1}{\sigma_{tot}} \int f \frac{d\sigma}{df} df = \langle f_{pert} \rangle + \langle f_{pow} \rangle$$

$$\langle f_{pow} \rangle = a_f \cdot \frac{\mu_I}{E_{cm}} \left[\bar{\alpha}_0(\mu_I) - \alpha_s(\mu) - \left(b_0 \cdot \log \frac{\mu^2}{\mu_I^2} + \frac{K}{2\pi} + 2b_0 \right) \cdot \alpha_s^2(\mu) \right]$$



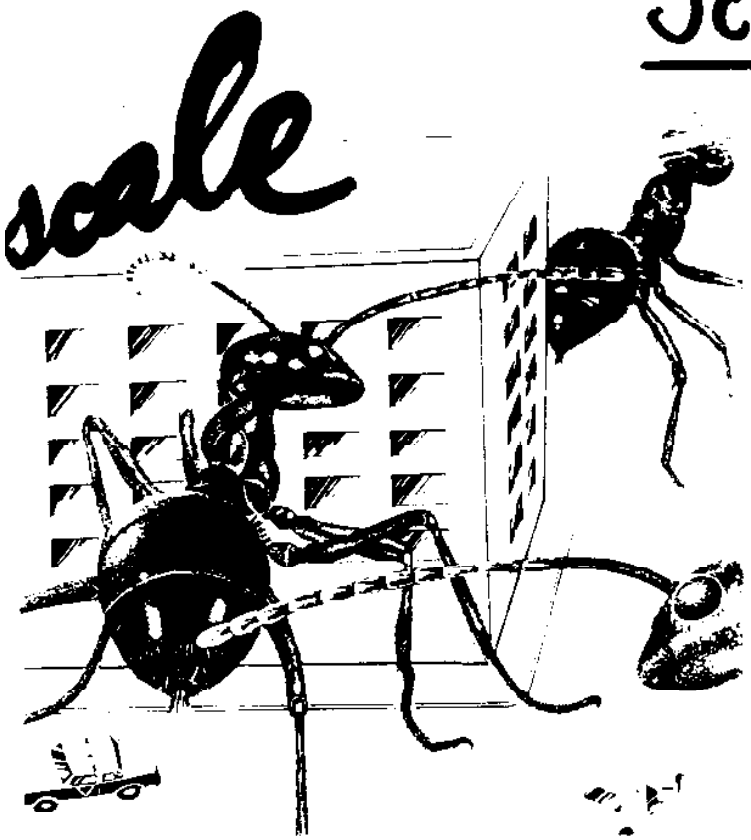
$$\alpha_s(133 \text{ GeV}) = 0.116 \pm 0.007_{exp}{}^{+0.005}_{-0.004}{}_{theo}$$

$$\alpha_s(161 \text{ GeV}) = 0.111 \pm 0.007_{exp}{}^{+0.005}_{-0.004}{}_{theo} \quad \text{(preliminary)}$$

$$\alpha_s(172 \text{ GeV}) = 0.111 \pm 0.007_{exp}{}^{+0.005}_{-0.004}{}_{theo} \quad \text{(preliminary)}$$

- The size of the non perturbative corrections decreases with $\sqrt{s}$

SCALE DEPENDENCE



DOMINANT SOURCE OF UNCERTAINTY ON MEASUREMENTS OF α_s

EQUIVALENT TO UNCERTAINTY DUE TO UNKNOWN HIGHER ORDERS $O(\alpha_s^3)$

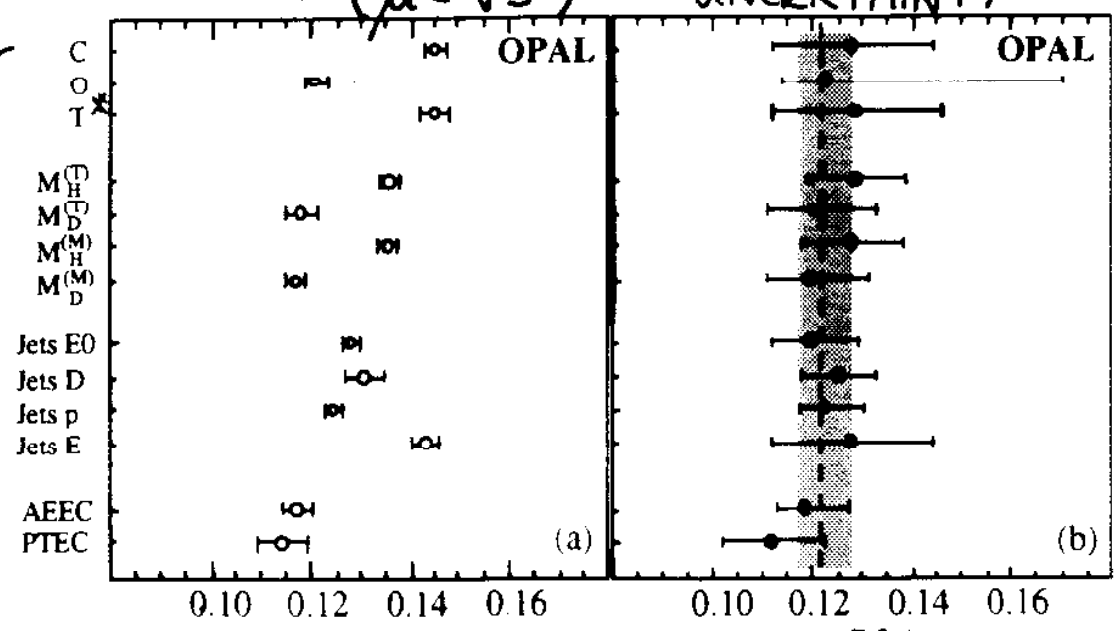
EXAMPLE : EVENT SHAPE VARIABLES

ie. EXPERIMENTAL UNCERTAINTIES ONLY

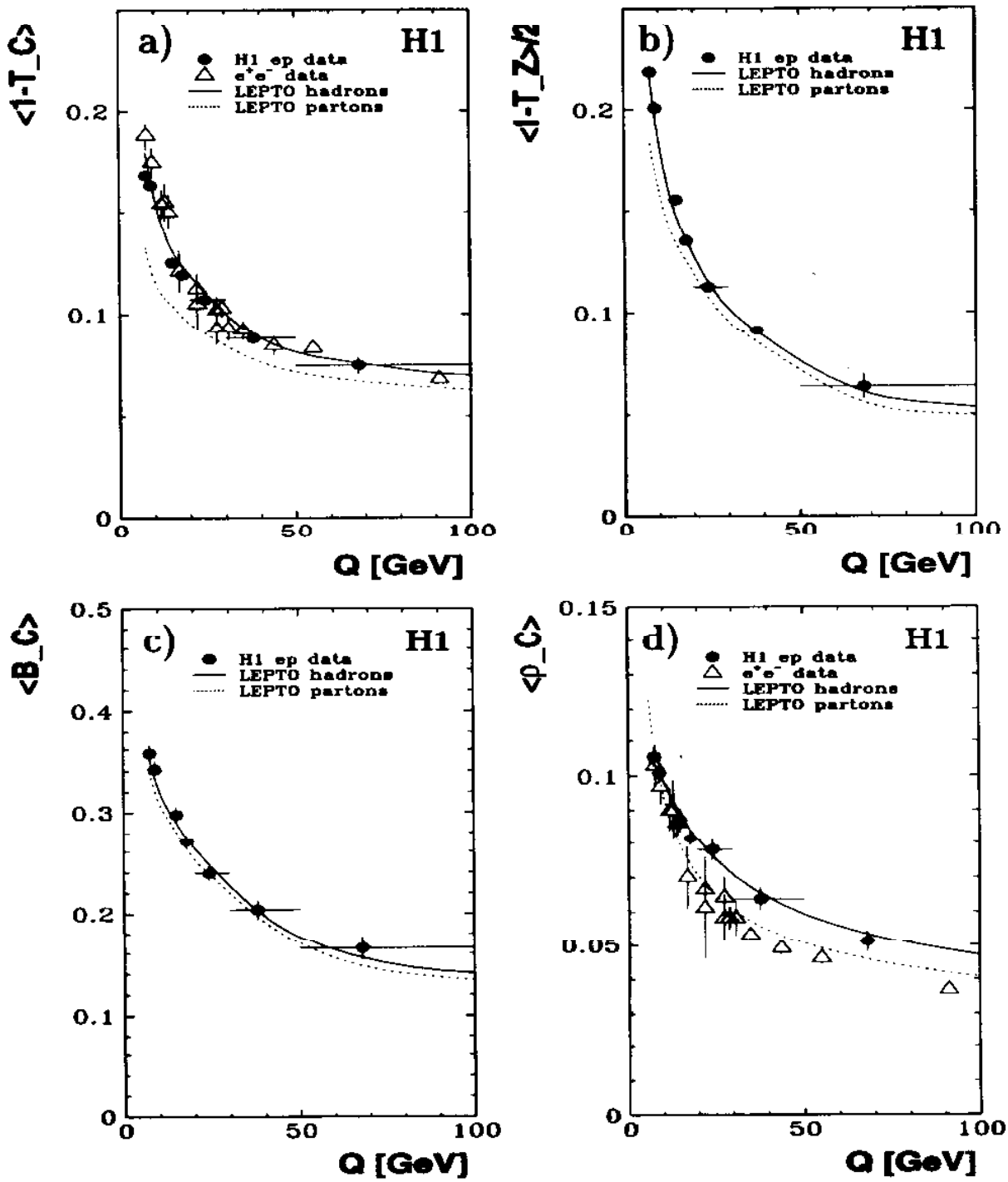
$\alpha_s(\sqrt{s})$ — FIXED SCALE ($\mu = \sqrt{s}$)

$\alpha_s(\mu)$ — INCLUDING SCALE UNCERTAINTY

VARIOUS EVENT SHAPE VARIABLES (JET RATES)

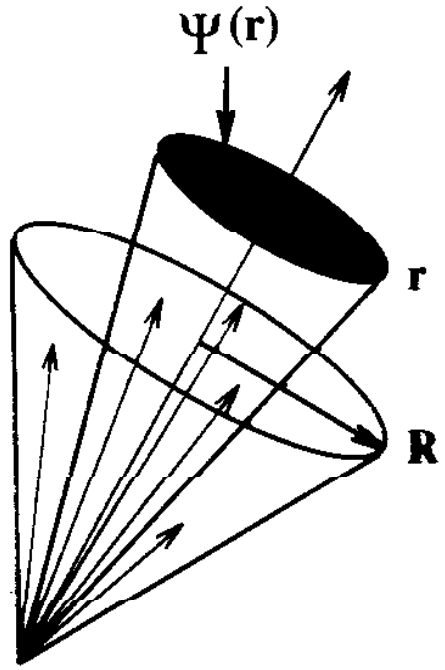


Q dependence of H1 event shape means (full symbols) in comparison with e^+e^- data (open triangles), LEPTO hadrons (full lines) and partons (dotted lines):



JET SHAPE DEFINITION

The jet shape is defined as the average fraction of the transverse energy of the jet which lies inside an inner cone of radius r concentric to the jet cone.



$$\Psi(r) = \frac{1}{N_{jets}} \sum_{jets} \frac{\Sigma_{k<r} E_T(k)}{\Sigma_{k<R} E_T(k)}. \qquad 0 < k < r$$

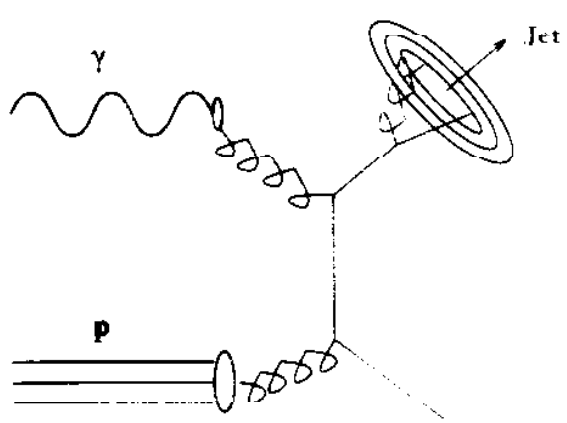
- The Jet Shapes are measured using the calorimeter.
- The Jet Shapes are corrected back to the hadron level.

NLO QCD Calculation in γp

- **Jets are reconstructed using a cone algorithm as in the data.**
- Up to three partons in the final state — no more than two partons within a jet.
- In NLO, $(1-\Psi(r))$ is computed in order to avoid collinear singularities.

$$1-\Psi(r) = \frac{\int_r^R dE_T E_T \, d\sigma \, \gamma p \to 3\text{partons} + X \quad dE_T}{E_T^{jet} + E_T^{jet}\ \text{LO}}$$

- $1-\Psi(r)$ **is** $O(\alpha_s)$ $\rightarrow$ **The jet shape is calculated only to lowest nontrivial order.**



NLO QCD Calculation in γp

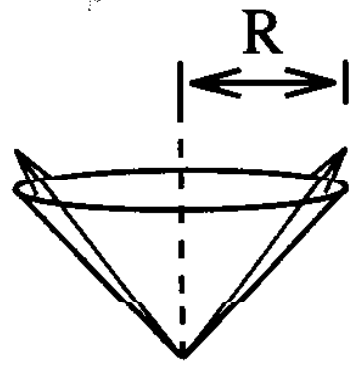
G. Kramer and S. Salesch (Phys. Lett B 317 (1993) 218)

M. Klasen and G. Kramer (DESY-Preprint 97-002)

- **Renormalization scale : $\mu = E_T^{jet}$**
- **1-loop α_s**
- Resolved and Direct processes
- Weizsäcker-Williams approximation

- **Parton distributions:**
  Proton (CTEQ4) Photon (GRV-HO)

- Merging: R_{sep} (Ellis,Kunszt,Soper)

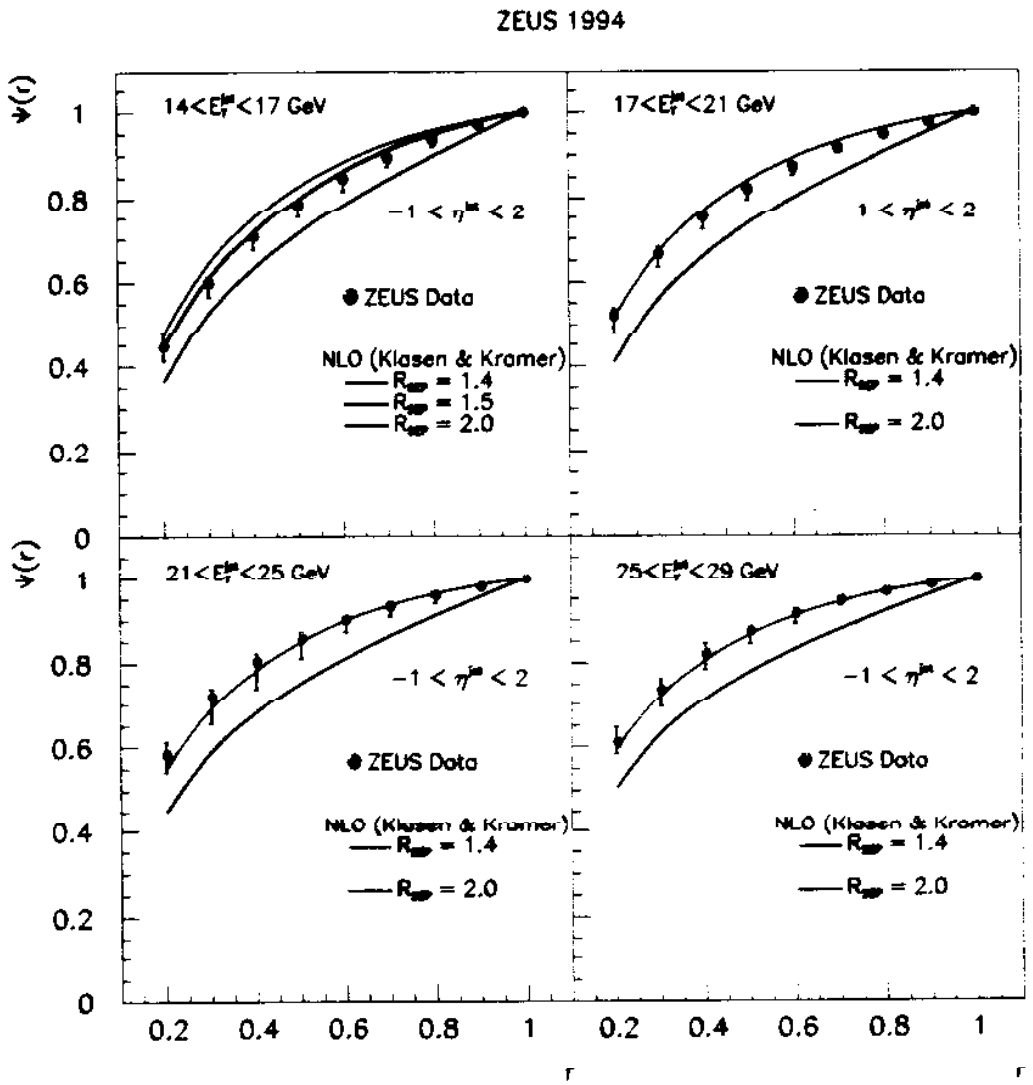


two partons are combined if

$$\Delta = \sqrt{\Delta_{12}^2 - \Delta_{12}^2} \quad \min \frac{E_T^{jet\,1} - E_T^{jet\,2}}{\max E_T^{jet\,1}, E_T^{jet\,2}} R \; R_{sep}$$

There is a strong dependence on μ and R_{sep}

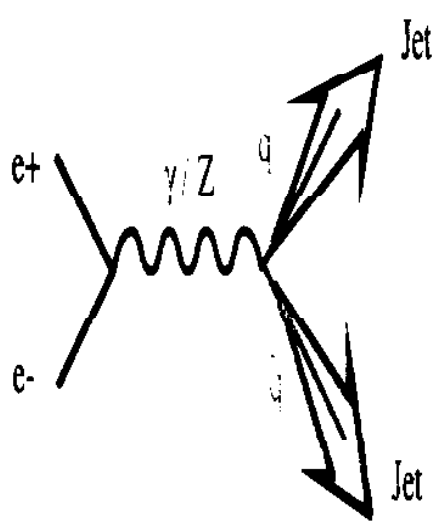
NLO QCD Calculation in γp

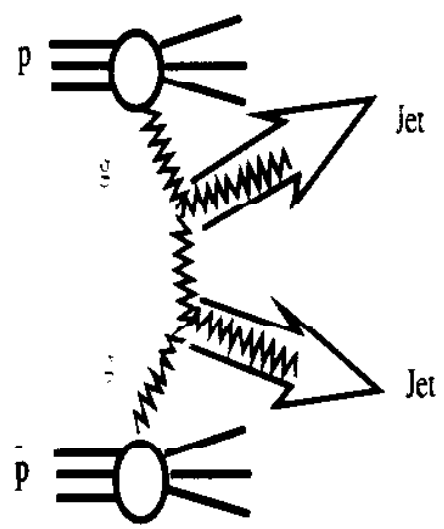


- NLO QCD calculations at the parton level are able to describe the measured jet shapes.
- For the E_T^{jet} dependence with $R_{sep} = 1.4$, except for the lowest E_T^{jet} region.

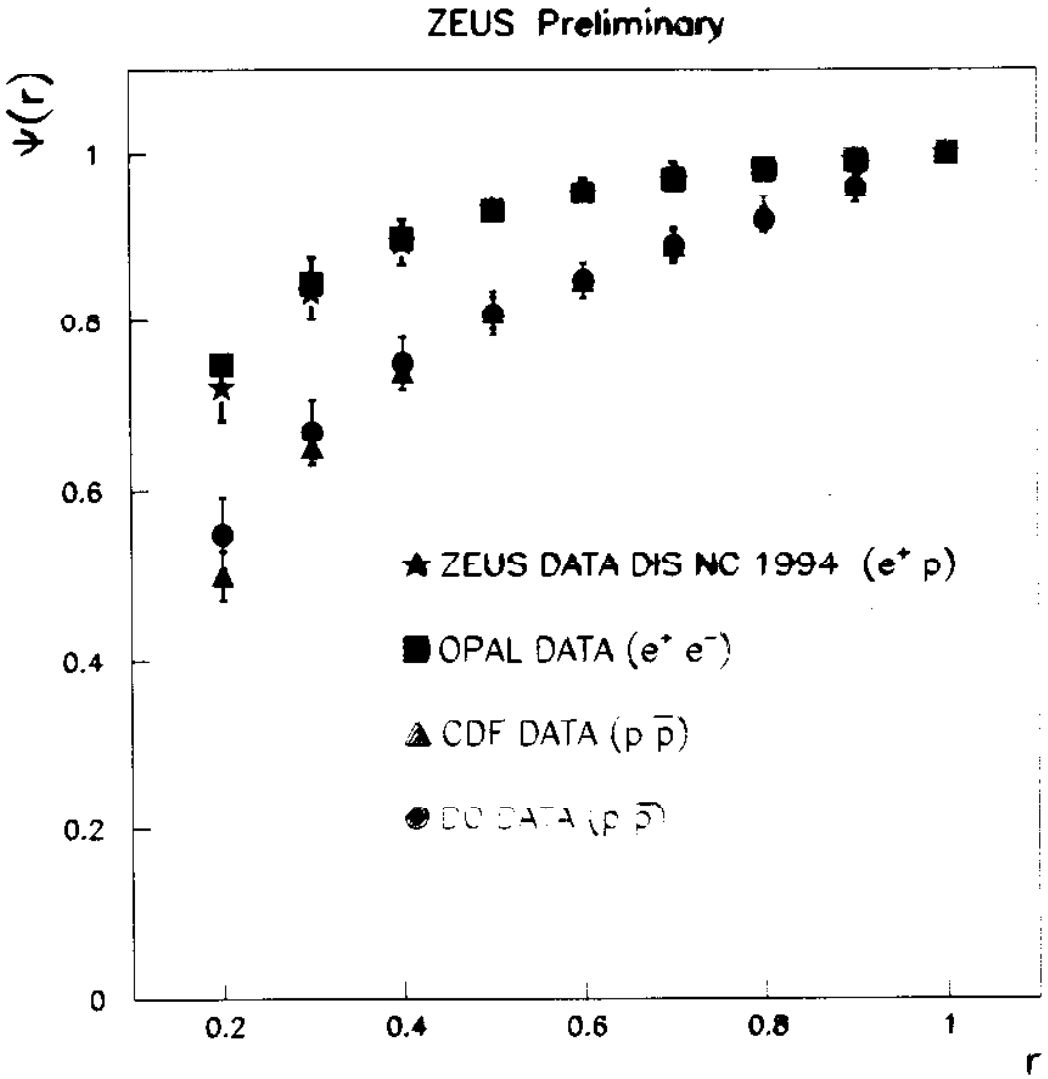
Comparison to e^+e^- and $p\overline{p}$

- **ZEUS (NC DIS):**
  Jets with $37 < E_T^{jet} < 45$ GeV
- **OPAL :**
  Jets with $E^{jet} > 35$ GeV
- **CDF :**
  Jets with $40 < E_T^{jet} < 60$ GeV
- D0 :
  Jets with $45 < E_T^{jet} < 70$ GeV





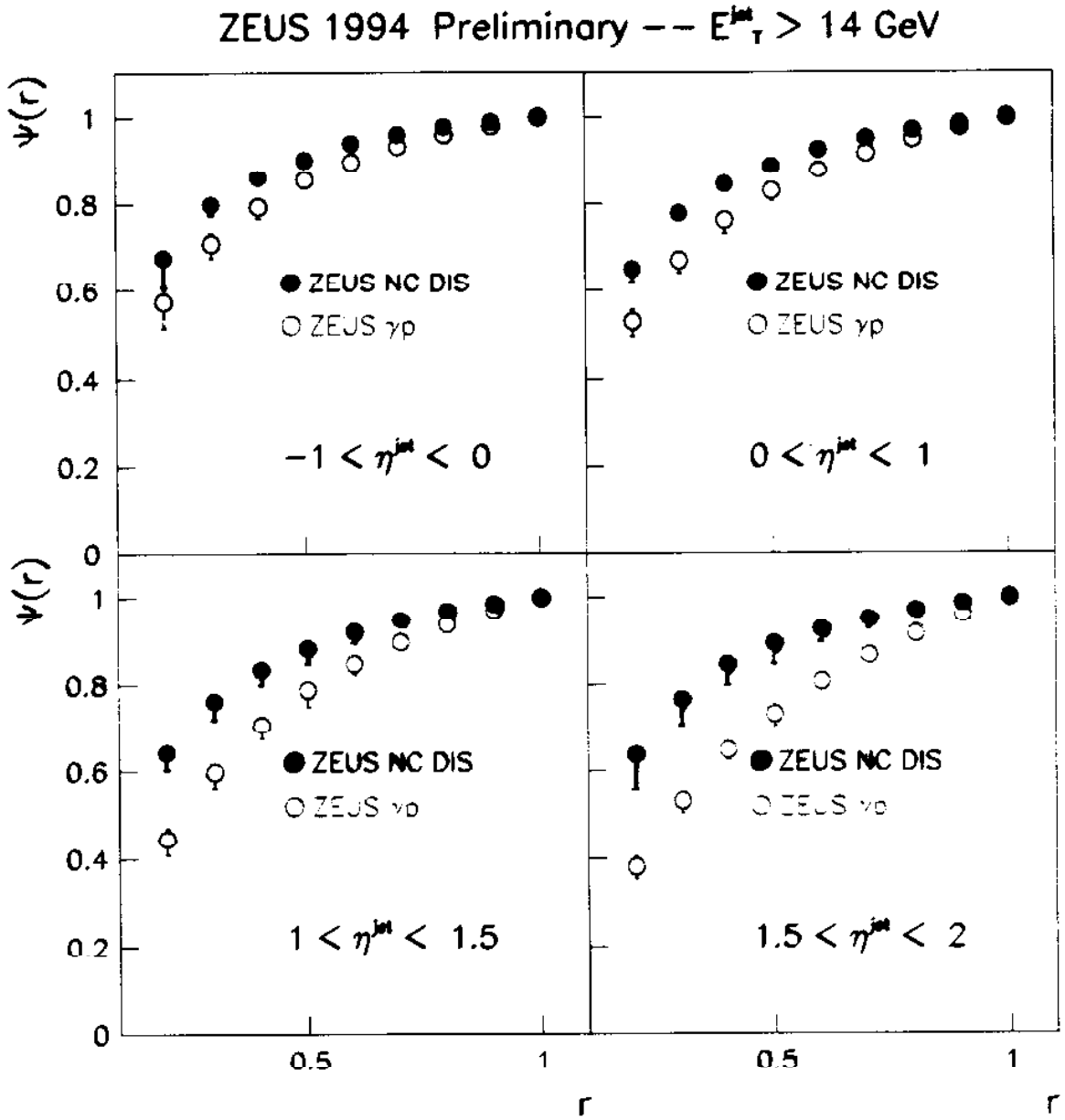
Comparison to e^+e^- and $p\bar{p}$



- ZEUS and OPAL → High E_T^{jet} jets predominantly coming from quarks. The results from ZEUS and OPAL are very similar.

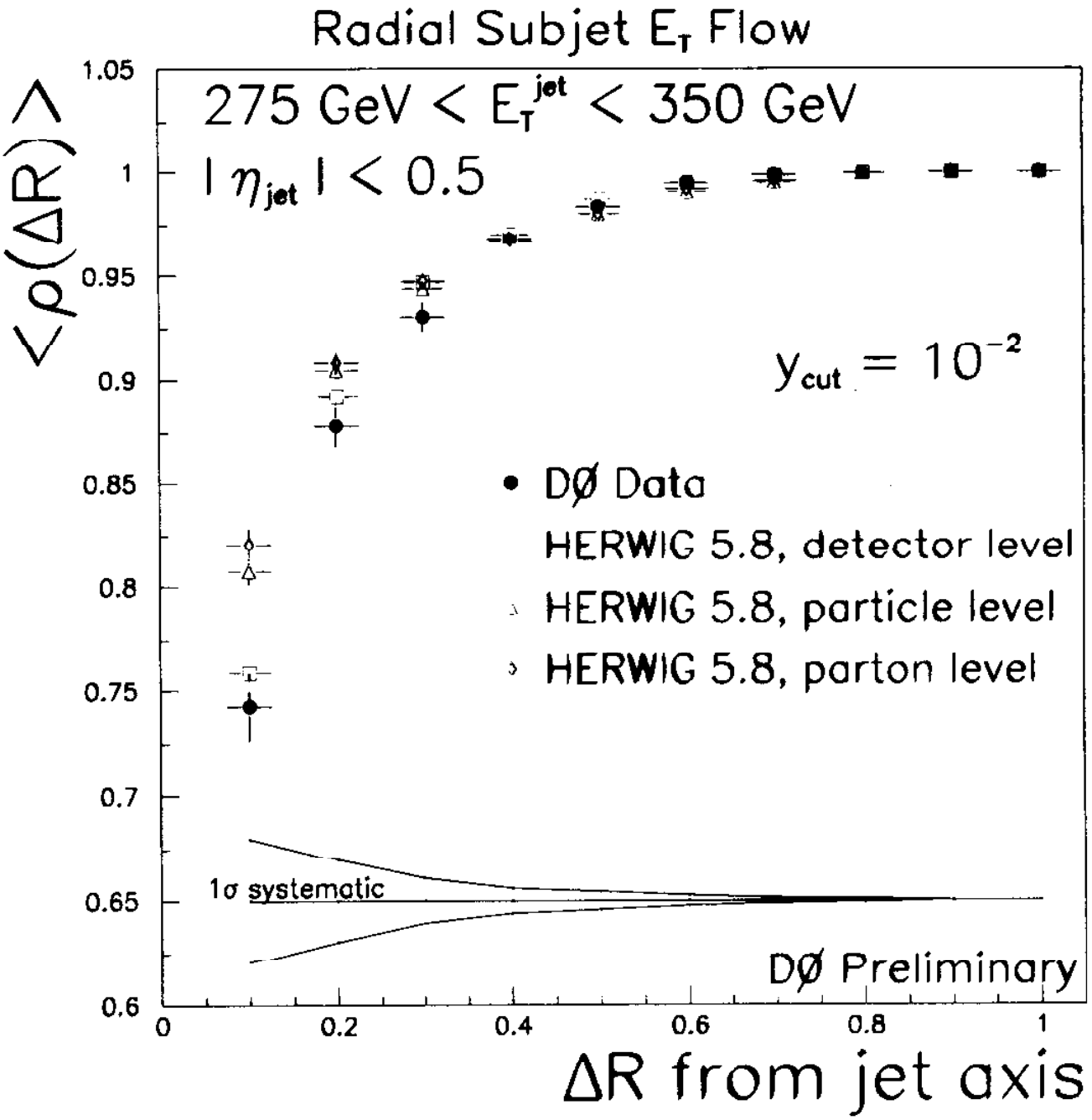
- CDF and DO — contributions from high E_T^{jet} jets predominantly coming from gluons.

NC DIS and γp Jet Shapes



- The observed differences increase as η^{jet} increases $\rightarrow$ the resolved γp processes dominate in the forward region.

$$\rho(\Delta R) = \frac{\sum p_\perp^{subjet} (\leq \Delta R)}{\sum p_\perp^{subjet} (\leq 1.0)}$$



DIJET RATES IN D.I.S.

- CONE [H1, MARKUS WOBISCH]
- JADE [H1, MARC WEBER ... α_s]
- K_T [H1, FABIAN ZOMER ... xgen]
  $\frac{1}{Q^2}$ POWER CORRECTIONS
- CONE [, KT] [ZEUS, DAINA MIKUNAS ... xgen]

PREVIOUSLY DATA WERE COMPARED TO SEMI-ANALYTIC CALC$^{\underline{N}}$ (PROJET, DISJET) - JADE SCHEMES ONLY.

NOW, COMPARE WITH MORE FLEXIBLE NLO MONTE CARLO'S:

MEPJET [MIRKES, ZEPPENFELD]

DISENT [CATANI, SEYMOUR]

Full NLO Monte Carlo program

MEPJET

- any jet definition scheme JADE
  cone
  k_T ...
- arbitrary experimental cuts
- package includes

  $ep \to ej(j)X$ (DIS) at LO & NL

  $ep \to ejj(j)X$ at VLO & LO

  $ep \to ejjjX$ at LO

  $ejjjjX$ at LO
- available upon request from

Erwin Mirkes:
mirkes @ ttpnxl.physik.uni-karlsruhe.de

D.Z.: dieter @ pheno.physics.wisc.edu

MEPJET – DISENT comparison

(M. Seymour & D.Z.)

- k_T scheme with $E_T^2 = Q^2$, $y_{cut} = 1$
- $Q^2 > 40\ \mathrm{GeV}^2$
- $\alpha = 1/137$, no Z-exchange
- MRS D_-'
- $\mu_R = \mu_F = R$, 2 loop α_s; $\Lambda_5 = 230$ MeV

	DISENT	MEPJET	
1j LO	21.958 ± 0.016	21.954 ± 0.015	n!
2j LO	395.6 ± 1.5	393.2 ± 0.9	p!
3j LO	33.0 ± 0.5	32.5 ± 0.2	p!
2j NLO	561 ± 7	559 ± 6	p!

with $p_{Tj} > 5$ GeV, $|\eta_j| < 3.5$

2j LO	339.0 ± 0.4	337.5 ± 0.4	p!
2j NLO	463 ± 8	480 ± 5	p!

Two-jet inclusive cross sections (in pb) for the four jet algorithms

	cone	k_T	W	JADE
LO	1107	1067	1020	1020
NLO (E)	1203	1038	2082	1507
NLO (E0)	1232	1014	1438	1387
NLO (p)	1208	944	1315	1265

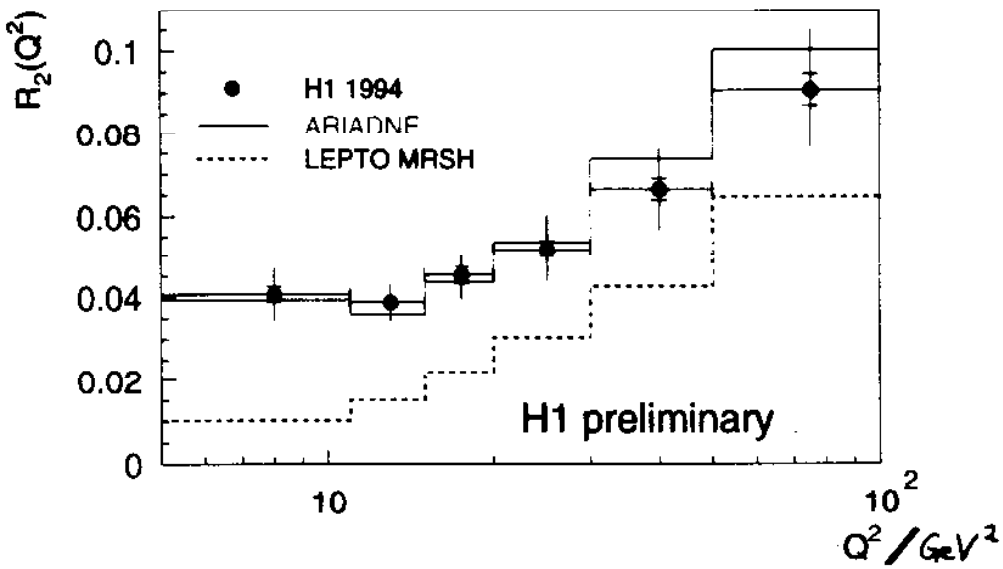
⇒ Large K-factor, strong recombinatio scheme dependence for W and JADE

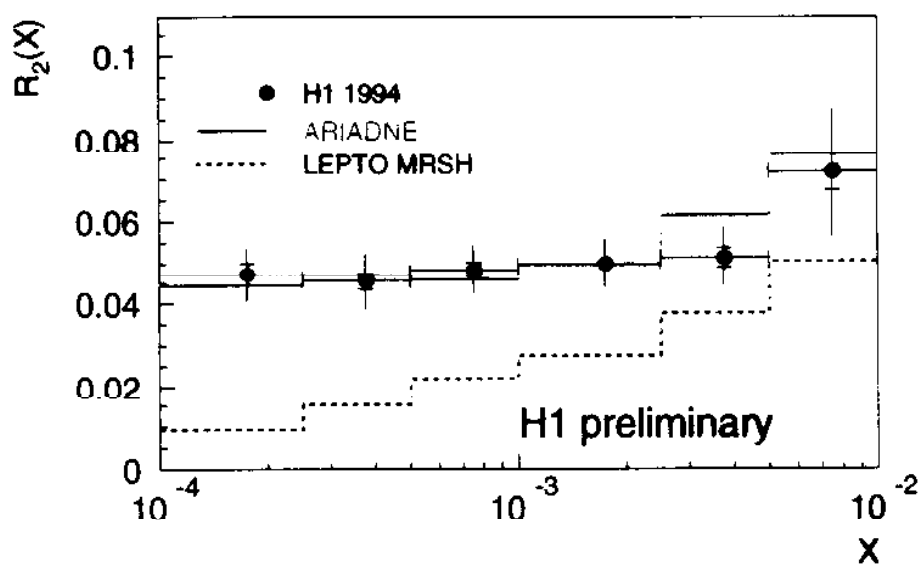
Recombination scheme effects are only modeled at LO

⇒ Variation with recombination scheme is subject to large $\mathcal{O}(\alpha_s^3)$ corrections

⇒ Large theory uncertainty for JADE & W

dijet rates (hadron-level)

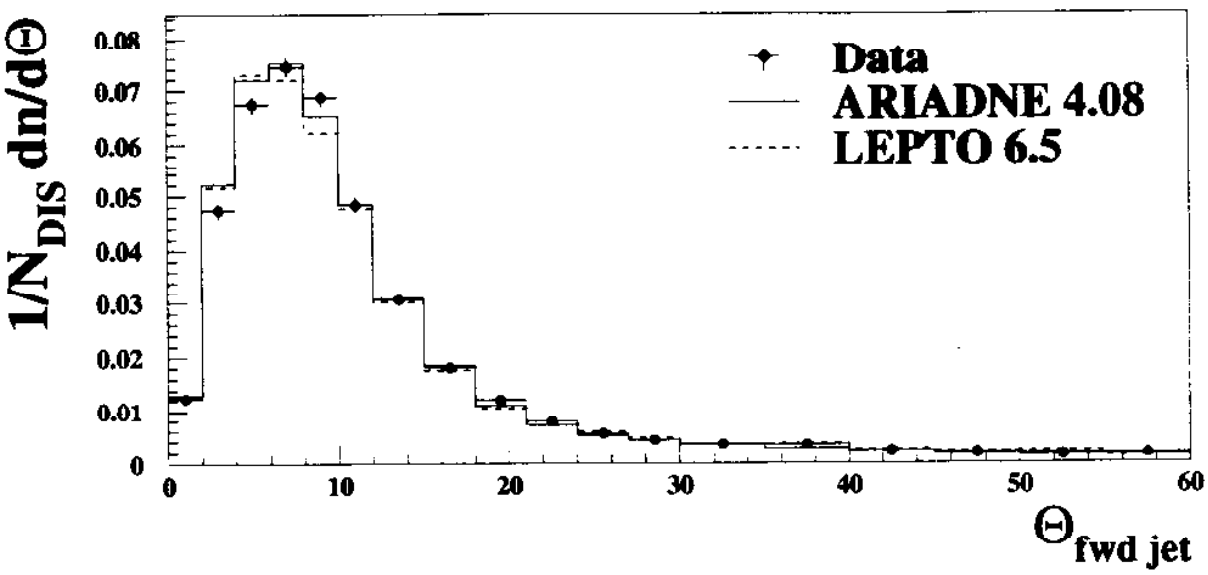




$E'_{el} > 11$ GeV $153^\circ < \vartheta_{el} < 173^\circ$ $y > 0.05$	cone algorithm in hcm $R_{cone} = 1.$ $p^*_{\perp jet} > 5.$ GeV 2 jets with: $\Delta\eta^* < 2.$

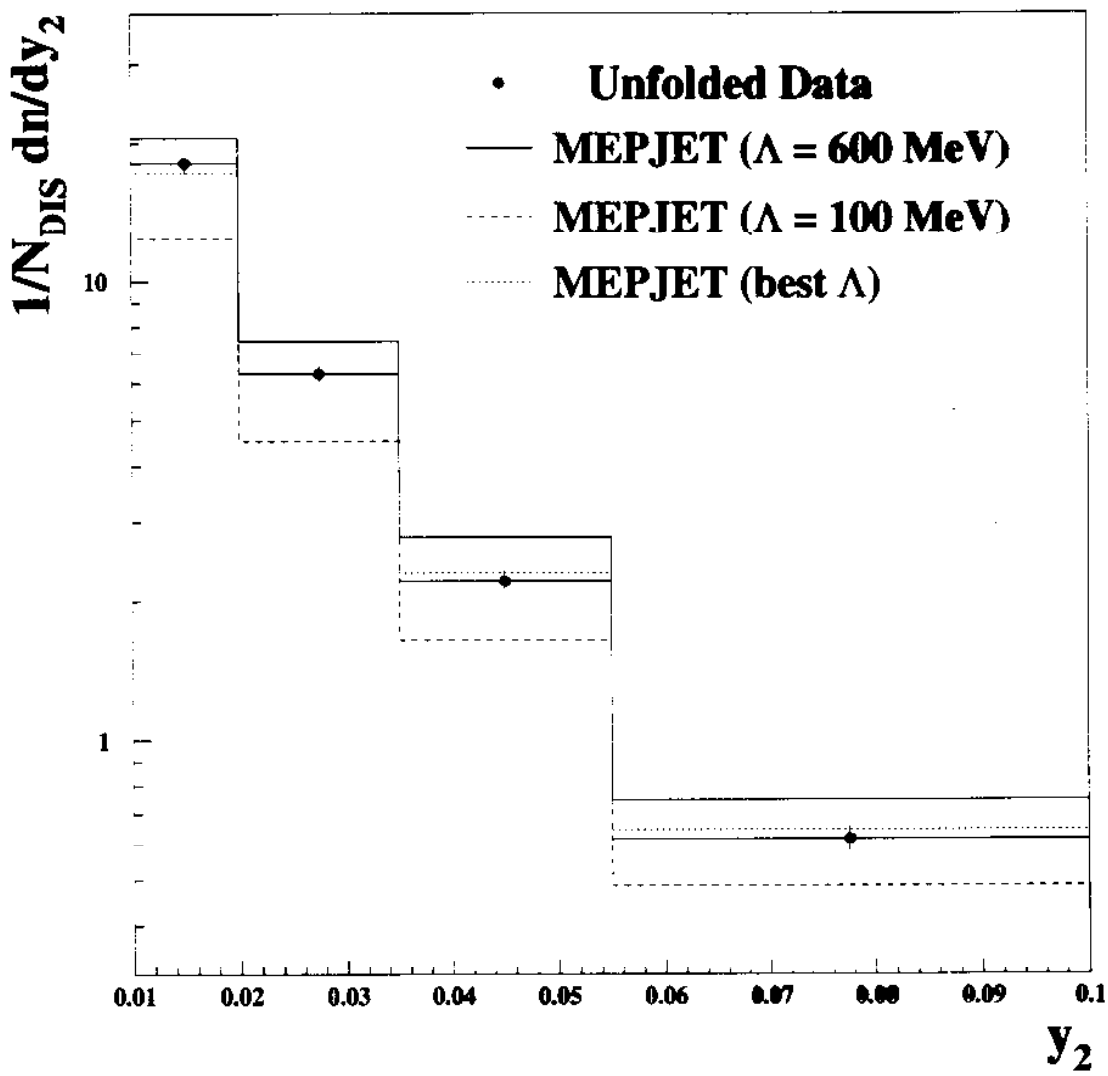
Comparison of Data vs Monte Carlo

$(Q^2 > 200\ \mathrm{GeV}^2,\ W^2 > 5000\ \mathrm{GeV}^2,\ y_2 > 0.01,\ \theta_{clus} > 7^\circ)$



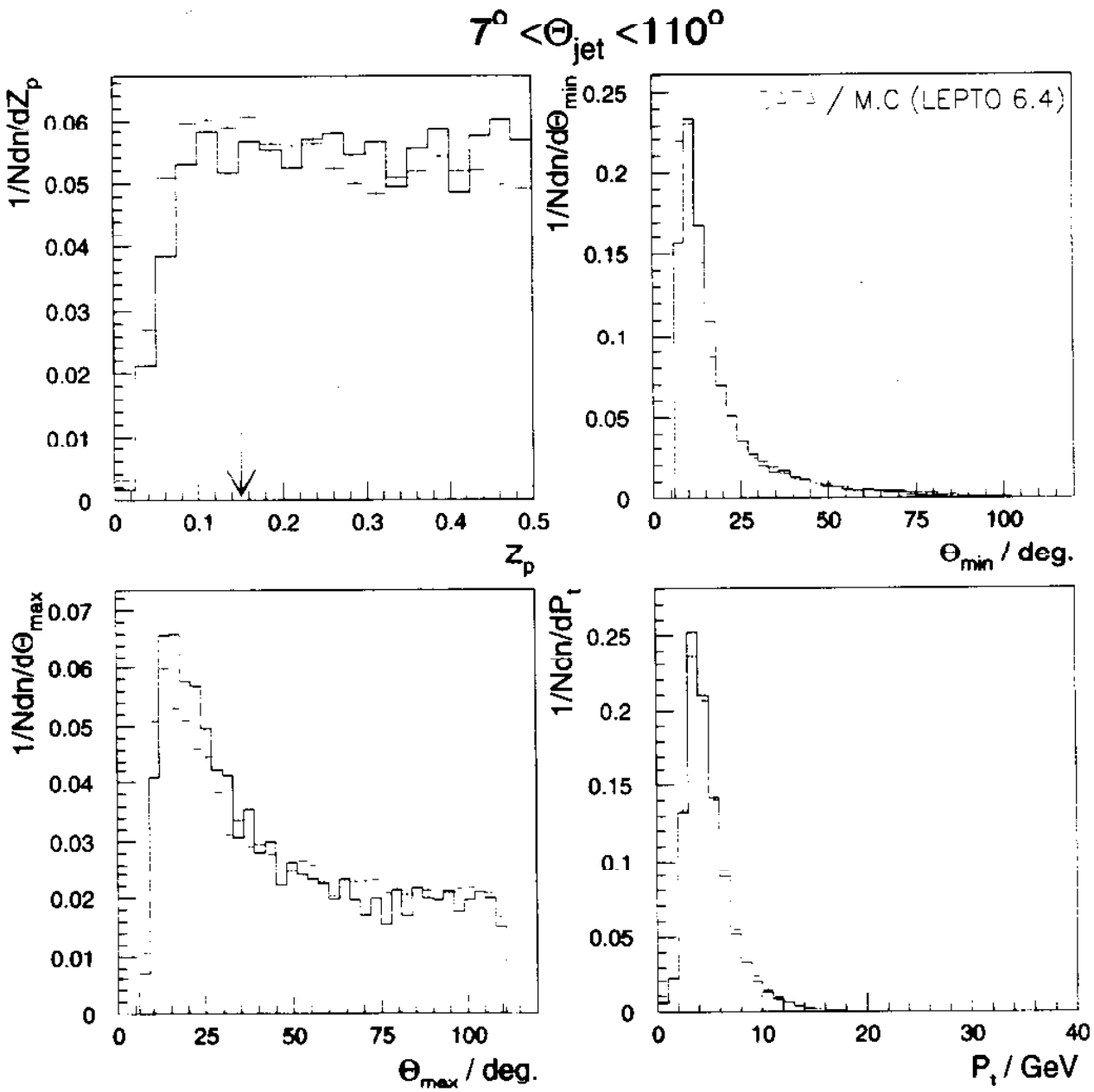
- a full set of complentary jet related observables was checked
- ARIADNE describes y_2 and z_p very well
- ARIADNE and LEPTO are poor in the description of the forward jet's polar angle distribution
- we unfold the data with ARIADNE in the following

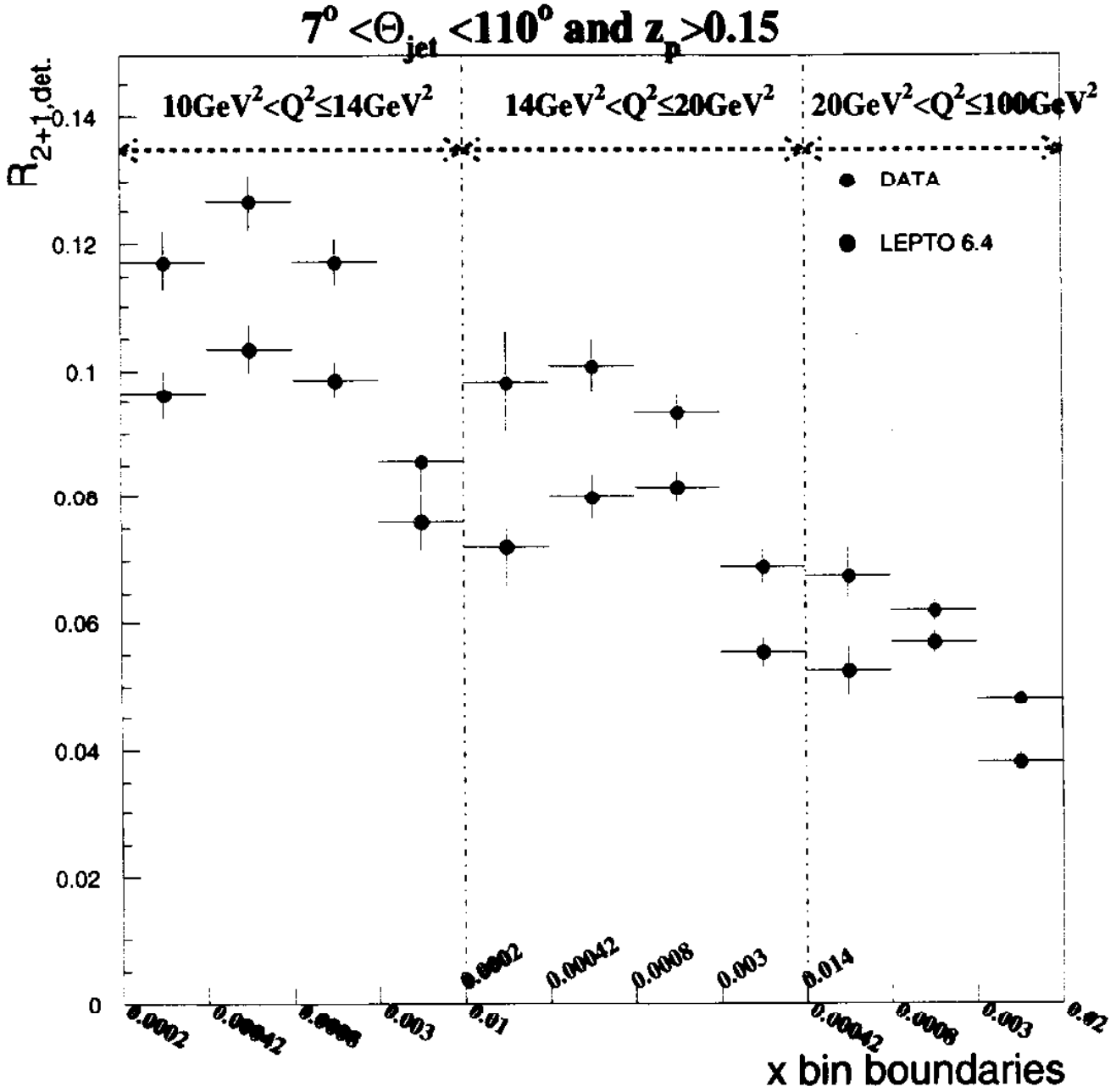
Sensitivity to α_s



- differential jet rate is clearly sensitive to value of α_s
- $A^{(4)}_{\overline{MS}}$ is fitted to unfolded data considering statistical correlation between bins
  (unfolding is based on ARIADNE)
- NLO and unfolded data agree excellently for α_s^{fit}

• shape comparison •
(<=> histos normelized to 1)




7° <Θjet <110° and zp>0.15
10GeV²<Q²≤14GeV²
14GeV²<Q²≤20GeV²
20GeV²<Q²≤100GeV²
R2+1,det.
DATA
LEPTO 6.4
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.0002
0.00042
0.0008
0.003
0.01
0.014
0.02
x bin boundaries

- Fit Resuts

- Starting Fit

  - No jet data: H1-F_2 ; NMC(F_2^p, F_2^D)

  - $\Lambda^4_{\overline{MS}} = 250$ MeV

  $\Rightarrow$ xg, Singlet, 2 non-singlet PdF are evolved From $Q_0^2 = 10$ GeV^2

- jet Rate introduced

  $\Rightarrow$ REFIT

  $\Downarrow$

  - no significant changes of the PdF

  - using $\frac{A}{Q^2} + B\frac{\ln Q^2}{Q^2}$ For Power correction & Fitting A, B

  $\Rightarrow \chi^2_{jet} > 200$ For 11 points

⇒ ask "theoretician"

- non pert. corr. are x-dependent.

⇒ Simple empirical x function is introduced:

$$\Delta\sigma^{2+1}_{(x,Q^2)} \overset{\text{no Pert.}}{=} \frac{h(x)}{Q^2}$$

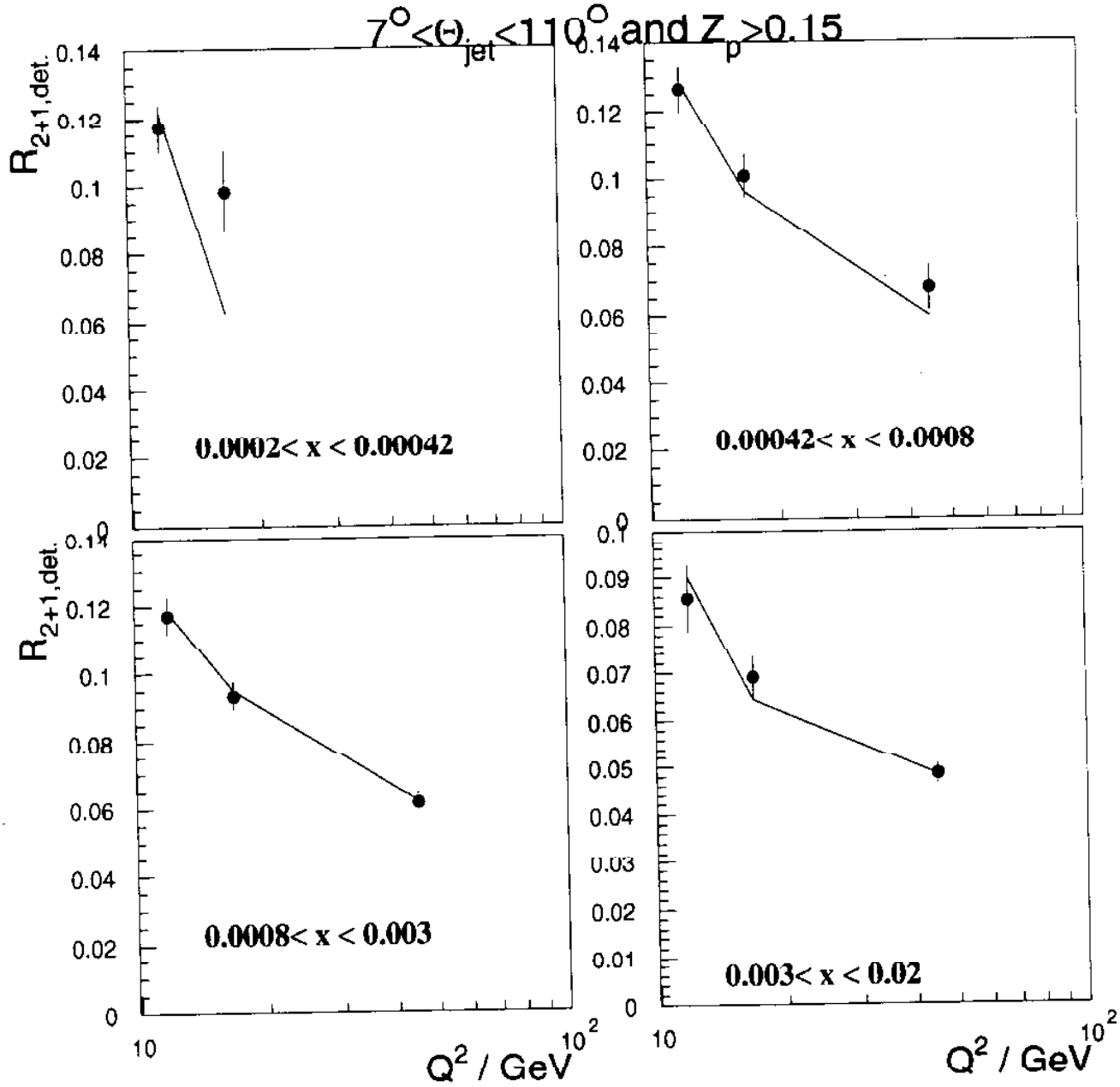
[we found: $\frac{\ln Q^2}{Q^2}$ not necessary]

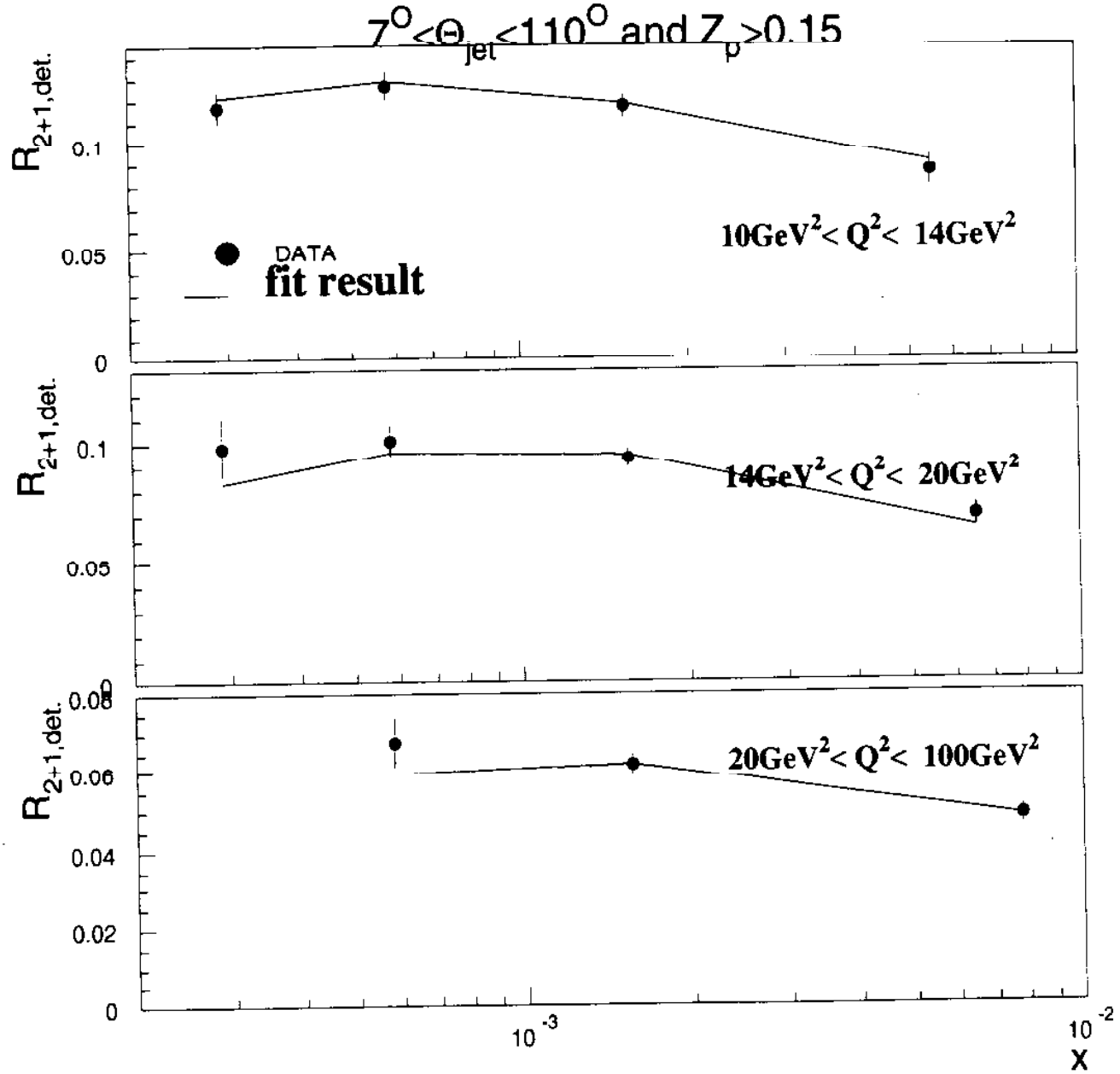
- with

$$h(x) = \alpha + \beta \ln\frac{x}{x_0} + \gamma \ln^2\frac{x}{x_0} + \delta \ln^3\frac{x}{x_0}$$

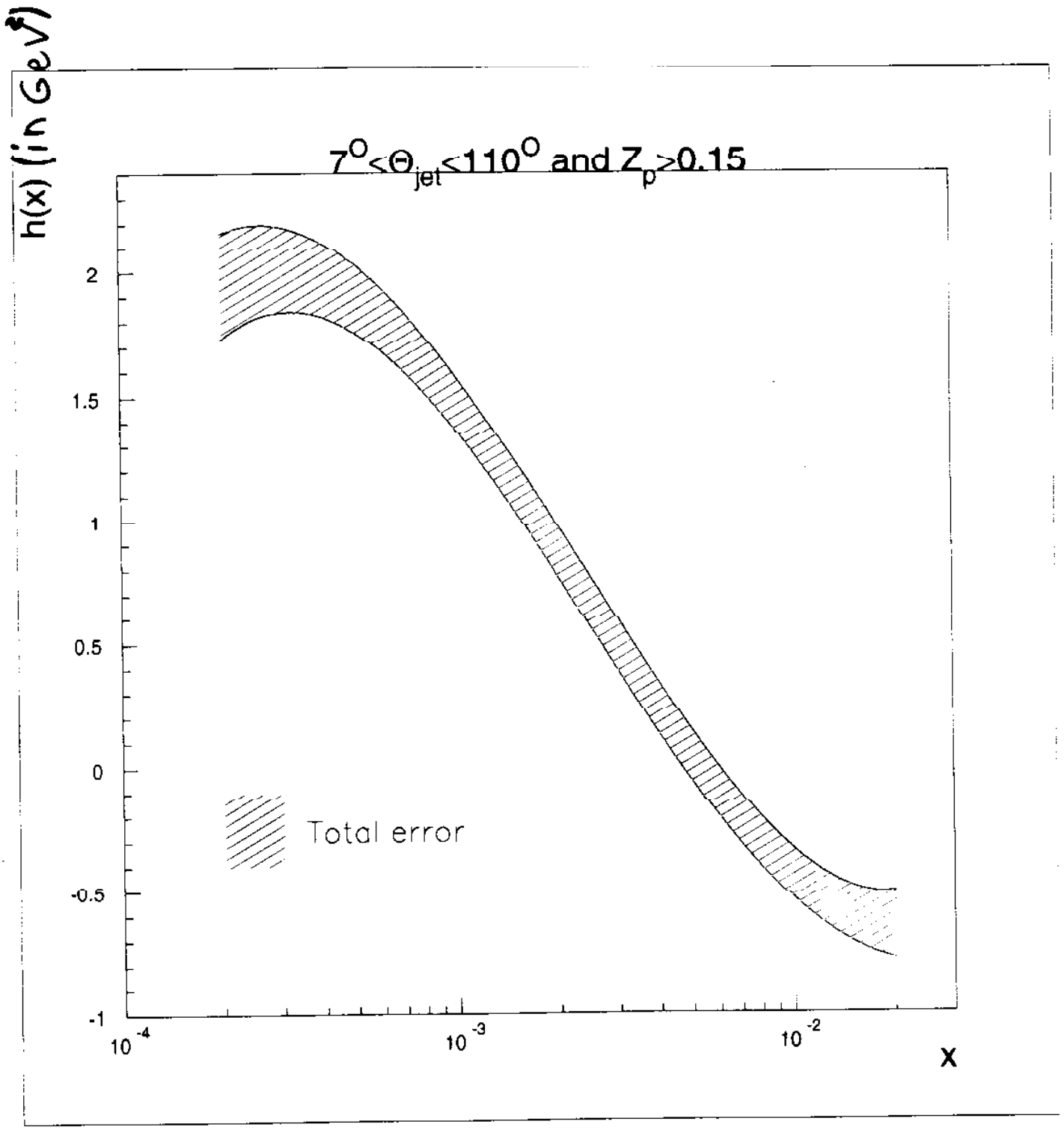
- $\alpha, \beta, \gamma, \delta$: free parameter

(- $x_0 = 10^{-4}$)


7°<Θjet<110° and Zp>0.15
R2+1,det.
0.0002< x < 0.00042
0.00042< x < 0.0008
0.0008< x < 0.003
0.003< x < 0.02
Q2 / GeV
10
10^2


7°<Θjet<110° and Zp>0.15
R2+1,det.
0.1
0.05
0
DATA
fit result
10GeV²< Q²< 14GeV²
14GeV²< Q²< 20GeV²
0.08
0.06
0.04
0.02
20GeV²< Q²< 100GeV²
10 -3
10 -2
X

- RESULT
  - Good χ^2 : $\chi^2_{jet} < 10$ (for 11 point:
  - Still : no significant modification of p.d.f
  - Very little improvement of the gluon error band.
  - But : extraction of non perturbativ function $h(x)$ with error band


h(x) (in GeV²)
7°≤Θjet≤110° and Zp>0.15
2
1.5
1
0.5
0
-0.5
-1
10 -4
10 -3
10 -2
X
Total error

• conclusion •

- Using k_t alg. with scale Q^2 does not "help" F_2 to determine xg

BUT

- Fitting simultaneously F_2 & jet-rate

  $\Rightarrow$ extraction of the non perturbative contribution to σ^{-2+1} : $\frac{h(x)}{Q^2}$

  $\Rightarrow$ experimental error band for $h(x)$

- A frame to study jet rate using QCD at NLO is provided

  $\Rightarrow$ what algorithm should we use? (to do a proper job)