Limiting fragmentation in e^+e^- annihilation, ep deep inelastic scattering and $p\bar{p}$ collisions

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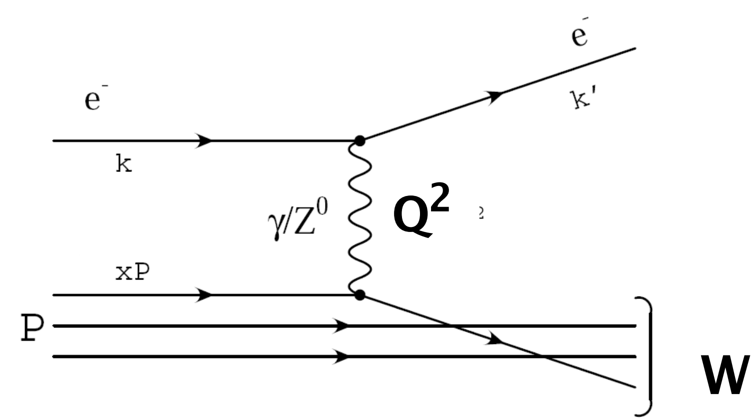
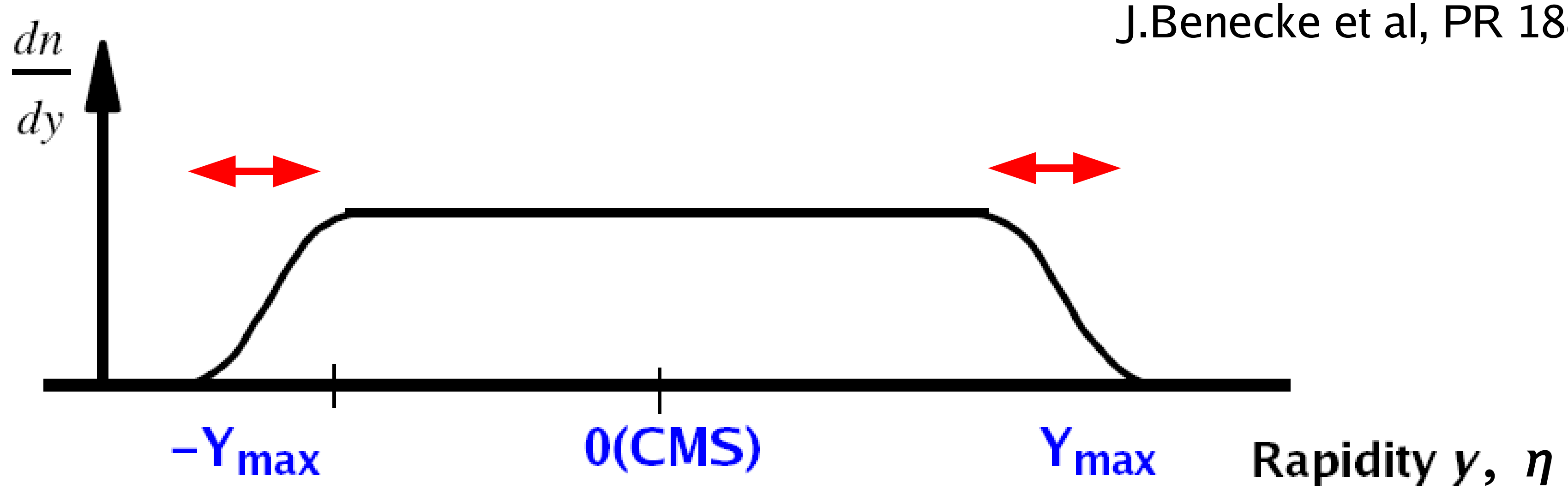
- Hypothesis of limiting fragmentation for pp, AA data
- Bialas-Jezabek model
- Motivation
- e+e- data from TASSO and ALEPH
- ep predictions
- Summary and conclusions



Limiting fragmentation in hh collision

J.Benecke et al, PR 188(1969)2159



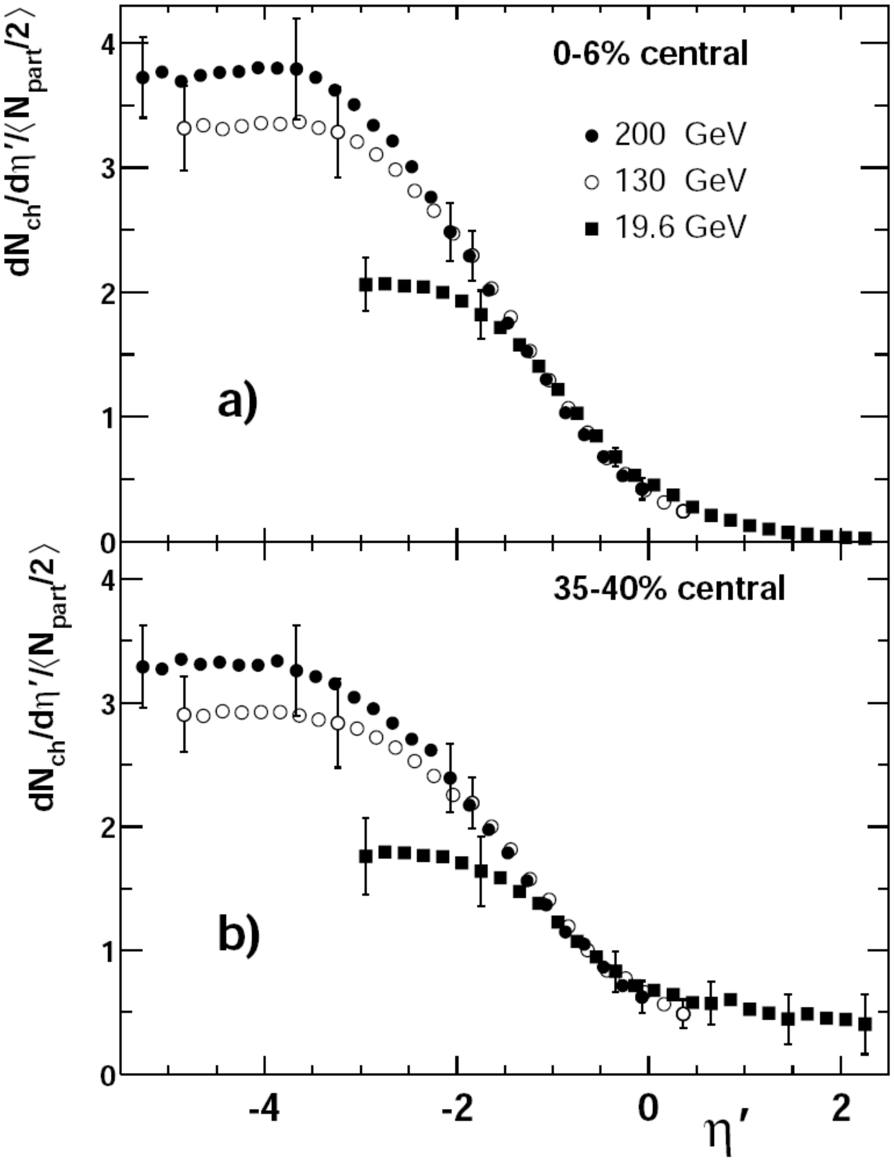
The ansatz of limiting fragmentation states that in hadronic collisions,
at high enough collision energy,
dn/dη reaches a fixed curve at $\eta \rightarrow Y_{beam} = Y_{max}$

and

becomes energy independent around $\eta \simeq Y_{beam}$

in contrast to the boost invariance scenario (Bjorken PR D27(1983)140)

AA collisions PHOBOS coll. PRL 91(2003)052303



typical syst. uncertainties are indicated.

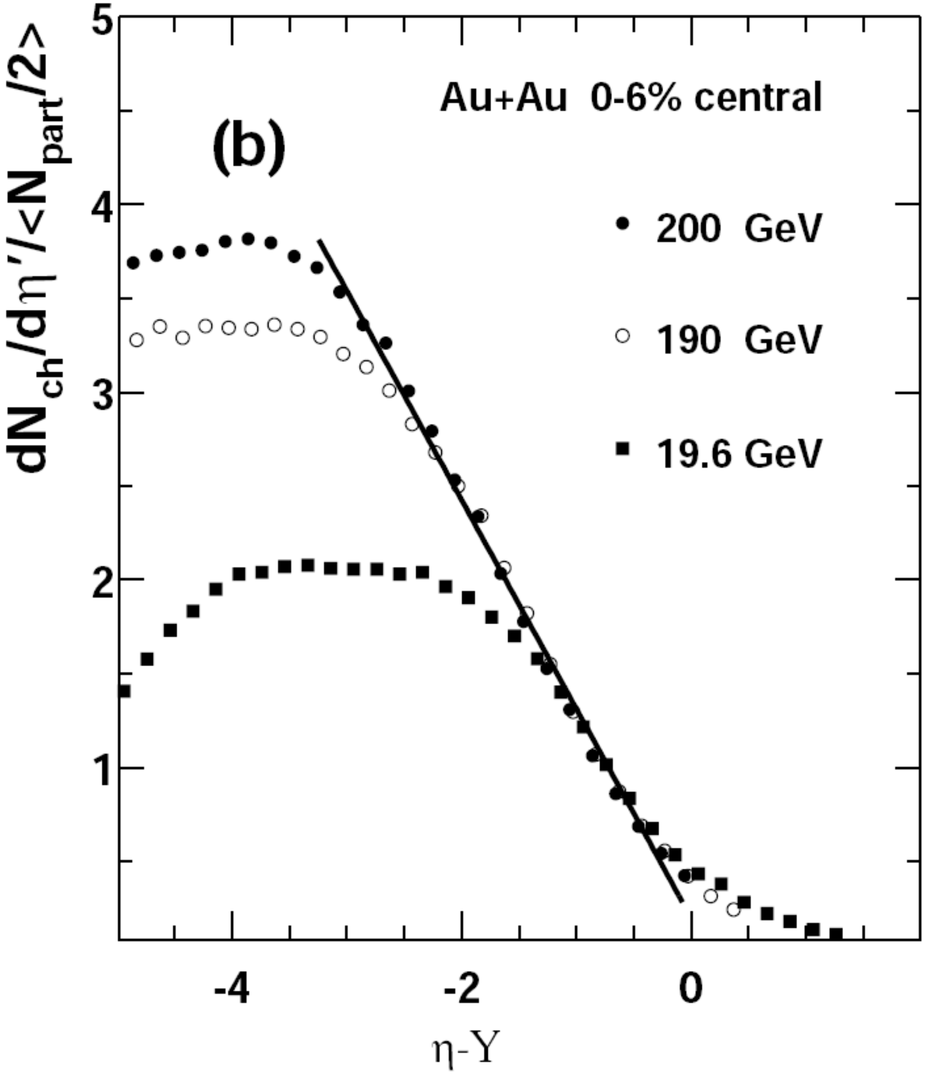
In limiting fragmentation region

- **the density of charged particles for various energies approaches some universal curve**
- **increase of region width with energy**

One of possible explanations: gluon saturation

$= Y_{beam} - y_h$

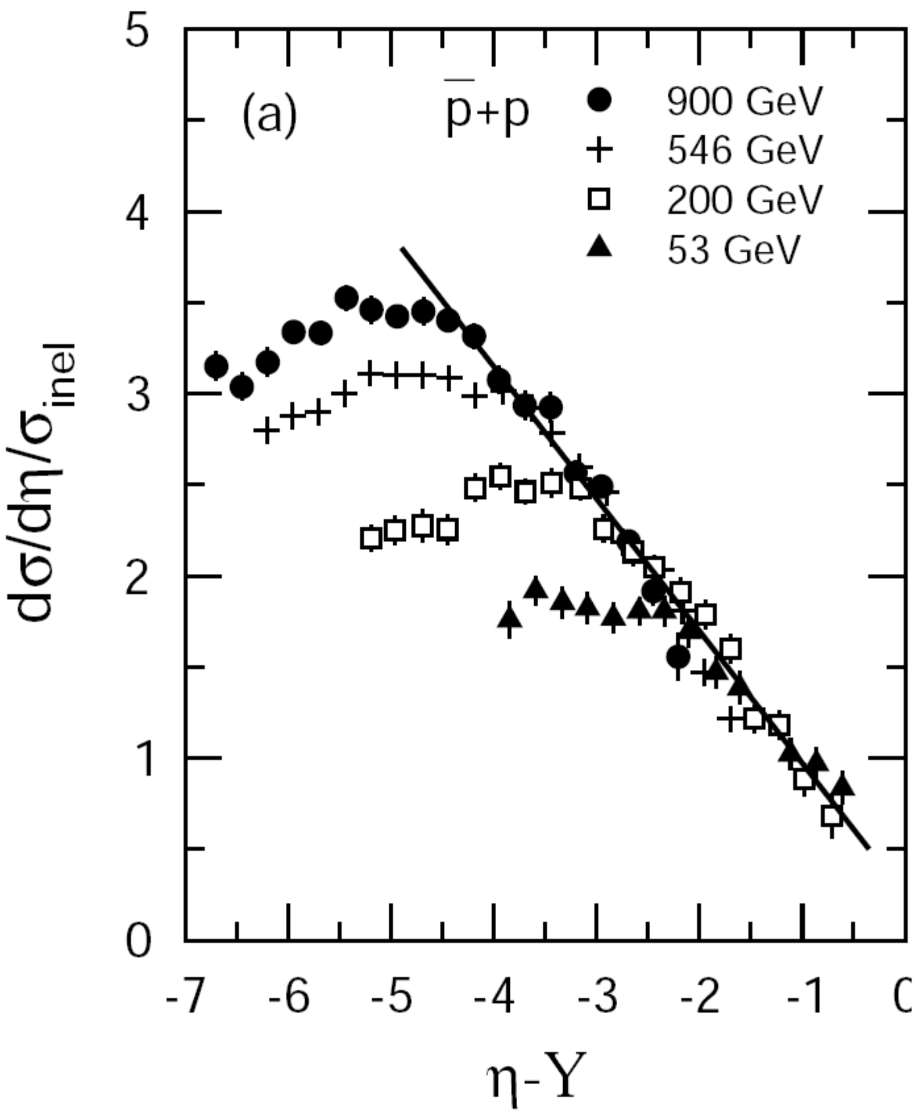
AA collisions PHOBOS coll. PRL 91(2003)052303



Linear dependence is observed

Y - beam rapidity

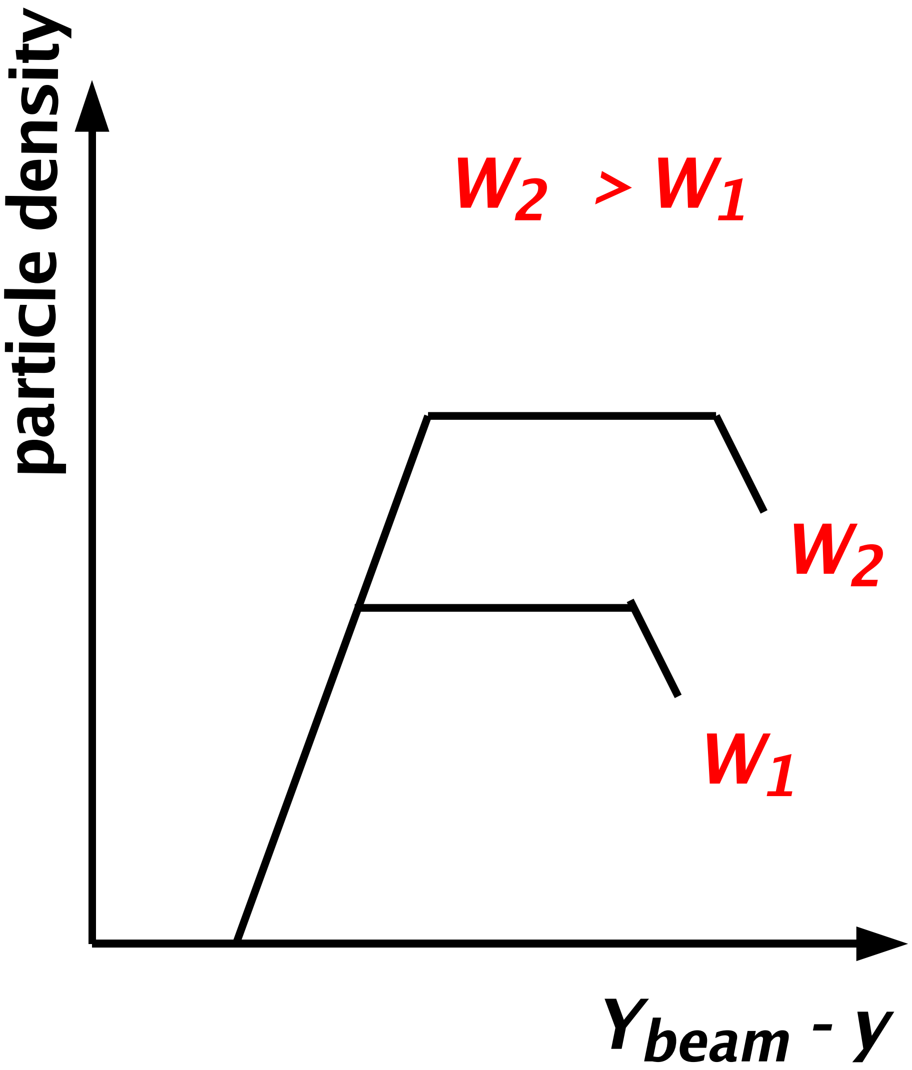
$p\bar{p}$ collisions UA5 coll. Z.Phys. C33(1986)1



The limiting fragmentation observed in pp, π-emulsion, p-emulsion.

i.e. the slope is constant

Białas-Jeżabek model



PL B590 (2004) 233

proposed for pp and AA collisions
symmetric collisions
to describe the soft particle production
in two steps:

- multiple gluon exchange between partons of the colliding objects creating the colour charges
- followed by the subsequent radiation of hadronic clusters
- described by bremsstrahlung relation

This leads to:

- Linear increase of rapidity spectra

$$d\sigma / dy = A\, y + B$$

- Increase of limiting fragmentation width and plateau height with energy

$$A = \lambda\, a\, b$$

Slope *A* in the Białas-Jeżabek model

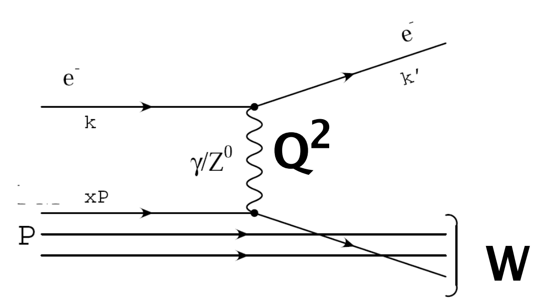
$A = \lambda \cdot a \cdot b$

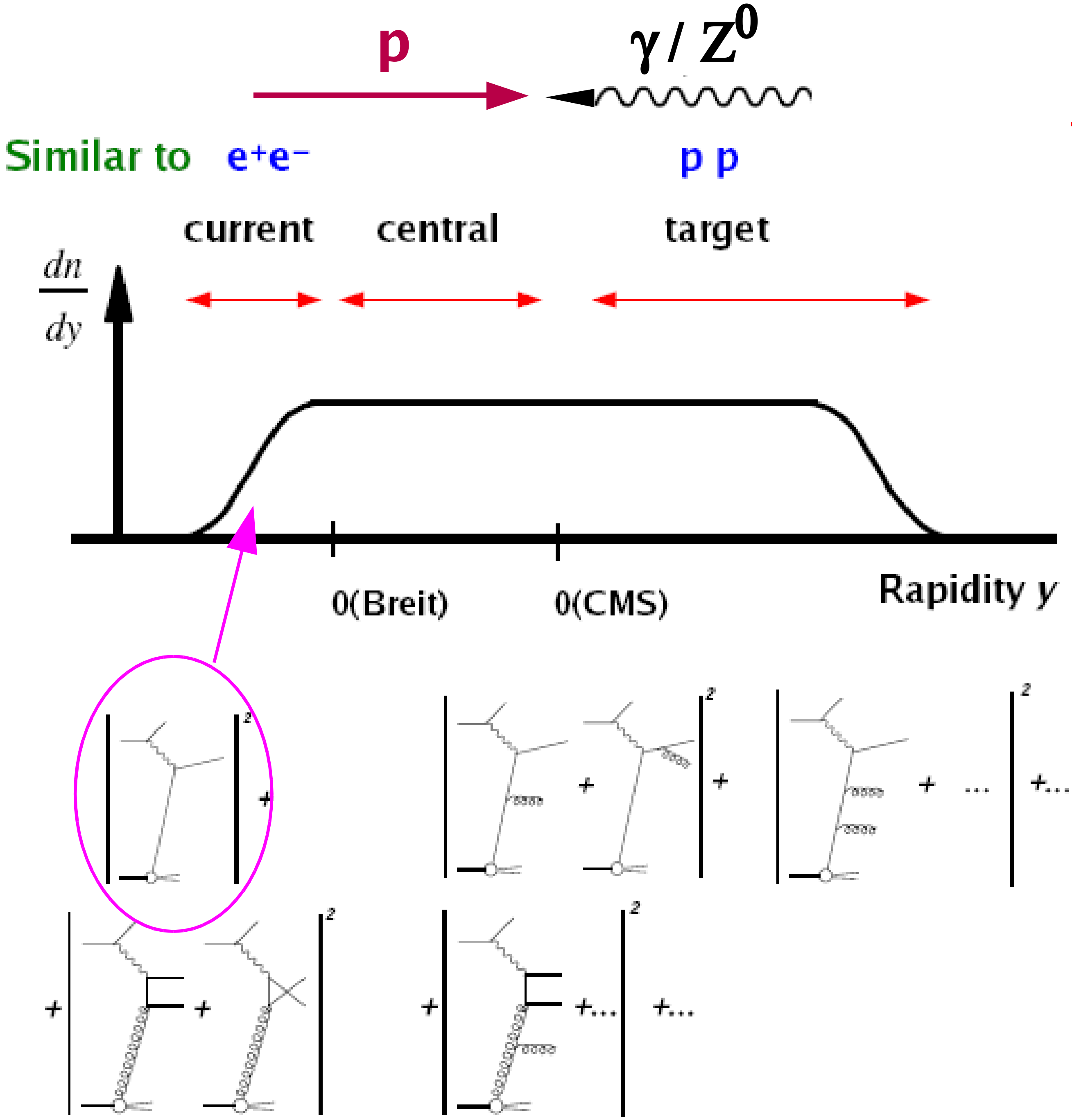
- λ fraction of "active" partons which participates in collision,
- a parton density per unit of rapidity,
- b density of emitted hadrons per unit of rapidity.

a, b – universal quantities, the same for $e^- e^+$, πp, pp, AA

Asymmetric collisions (pd, γp, ep)
<-- leakage between hemispheres can be important
Bialas, Czyz, Acta.Phys.P B36(2005)905

ep scattering defined by W and Q^2





Rapidity of particles defines their expected features,

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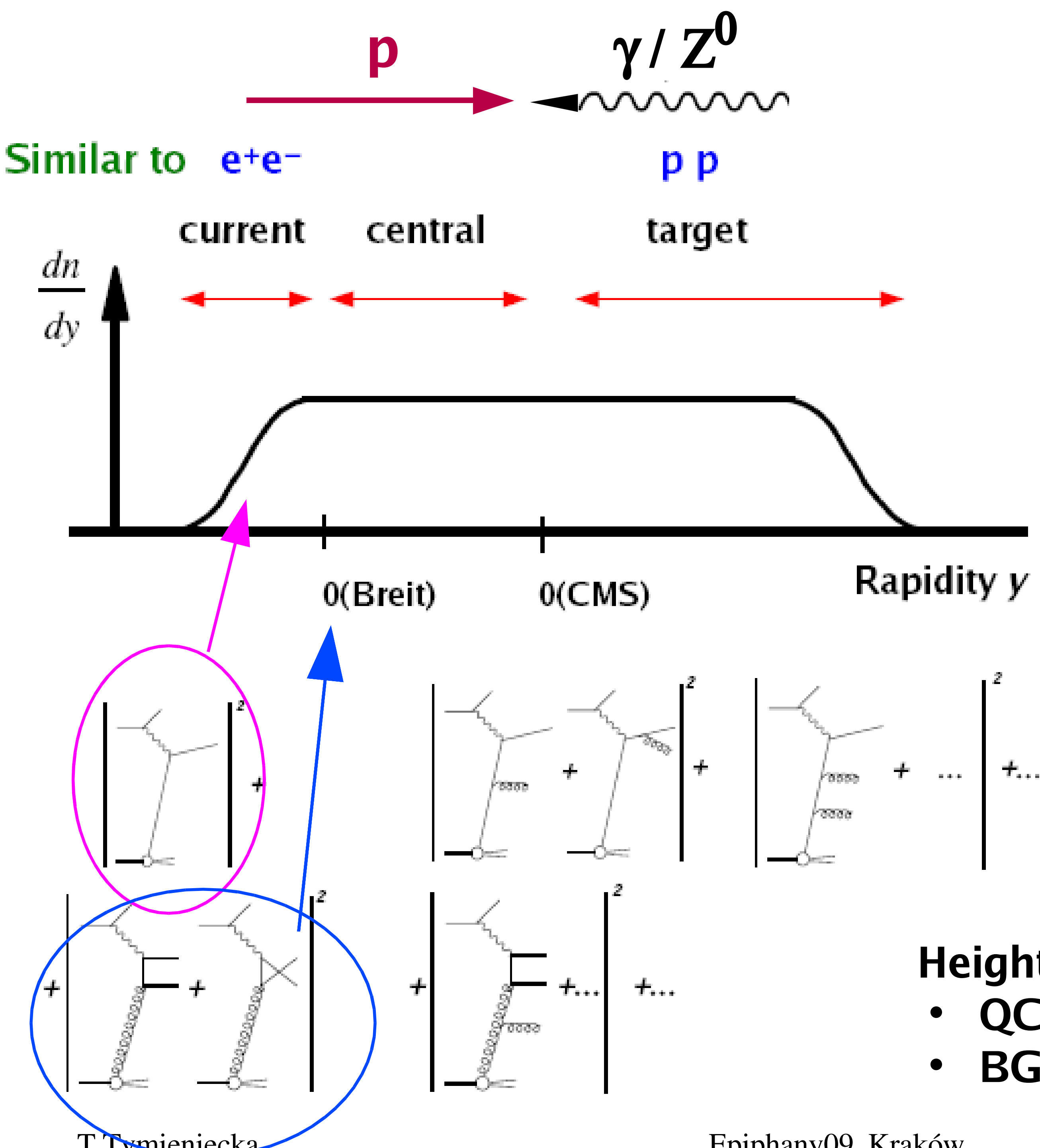


Height of plateau are sensitive to:

- **QCD Comptons**
- **BGF contribution** $(\gamma g \rightarrow q q)$

Method

Density of charged hadrons as a *f* (rapidity) is investigated

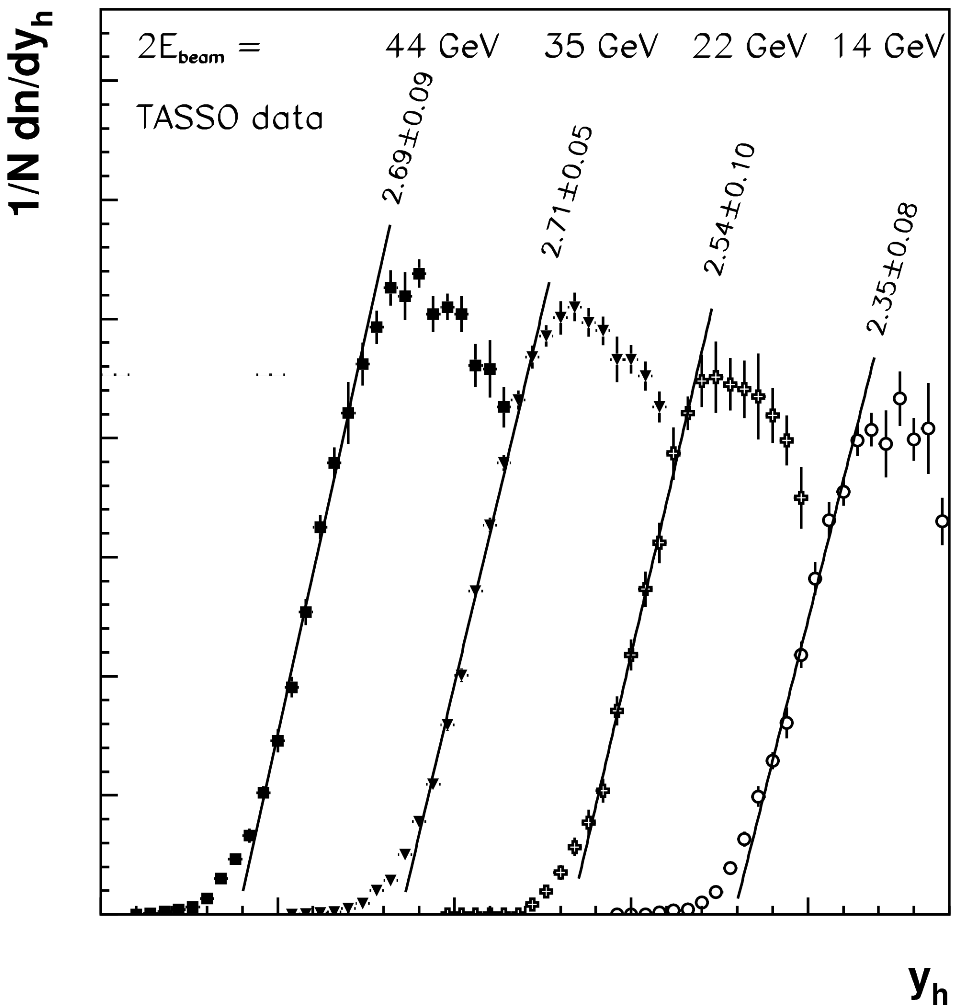
Study of the slope value in the limiting fragmentation region for e+e- and ep

- as $f(E_{beam})$ for e+e-
- as $f(W)$ for fixed Q^2 values } for ep
- as $f(Q^2)$ for fixed W values } for ep

- comparison with $p\bar{p}$

TASSO e^+e^- data at PETRA

K.Genser, Thesis, DESY F1-89-01(1989)

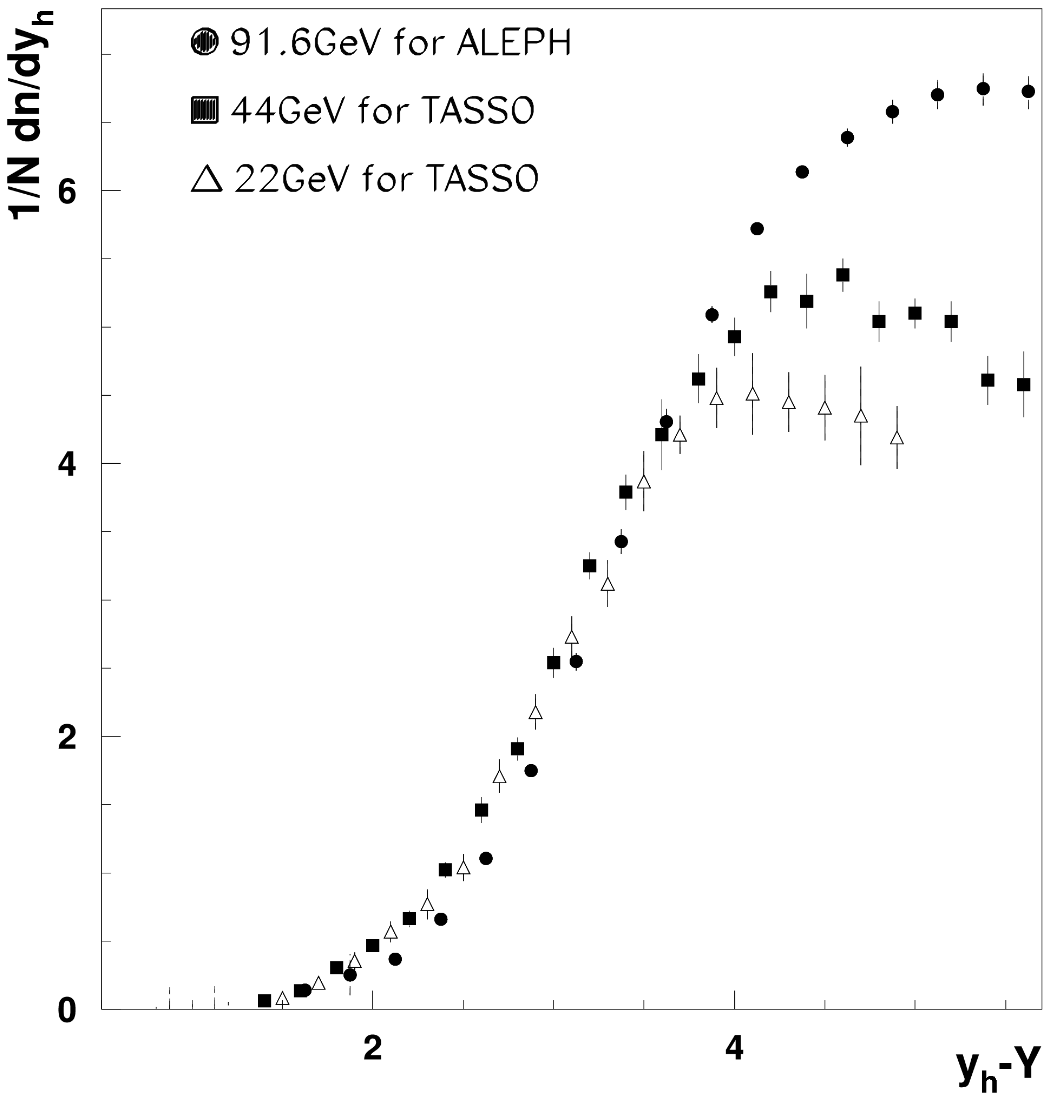


Trust axis is used

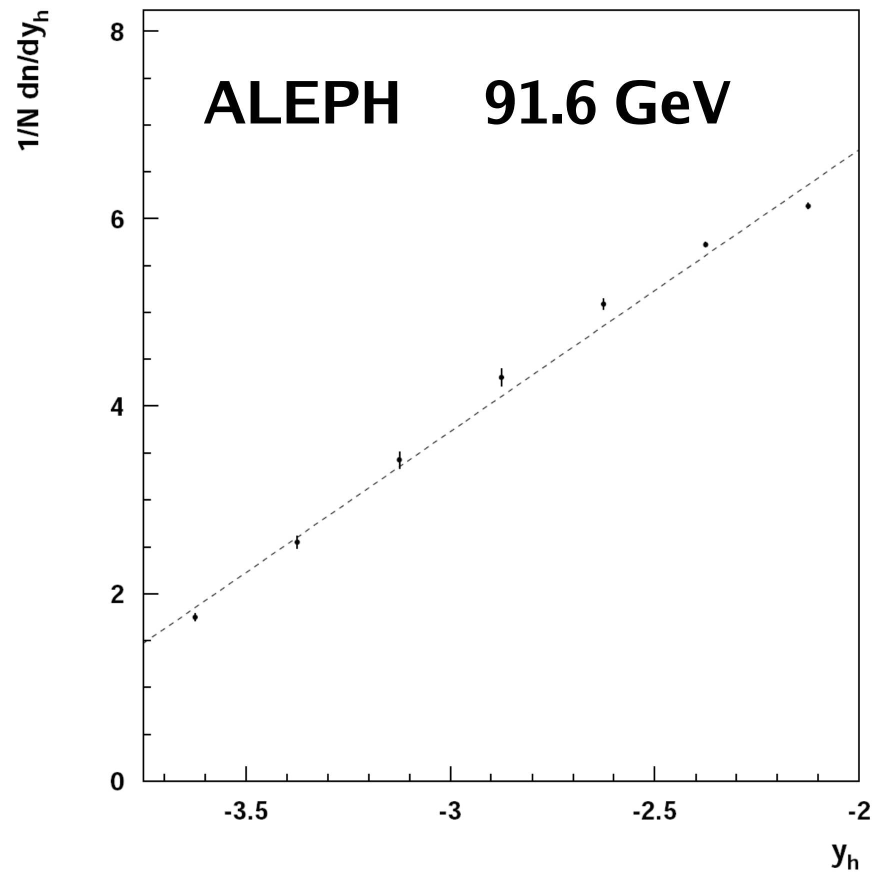
Data are folded around y_h=0
slope — divided by 2

The uncertainties should include different points taken into fit
↳ 0.07

e^+e^- TASSO and ALEPH data



K.Genser, Thesis, DESY F1-89-01(1989)
ALEPH coll., PhysReport 294 (1998) 1



$Y = \ln(W/m_{\pi})$ + 0.2 for ALEPH

+ 0 TASSO

Conclusion from e^+e^- data

One hemisphere

$2\,E_{beam}$	Slope *A*
14 GeV	1.18±0.07
22 GeV	1.27±0.07
35 GeV	1.35±0.05
44 GeV	1.34±0.07
91.6	1.55±0.01

- Slope is weakly dependent on energy
- Small deviation from linear dependence on rapidity (S-shape)
- Width and height of limiting fragmentation region is increasing with energy

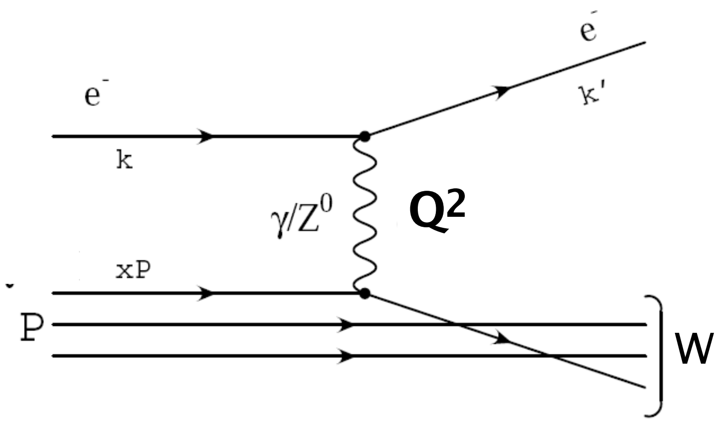
Slope for $p\bar{p}$ data

A= 0.72 ± 0.05

$$A(e+e-) : A(p\bar{p}) = \lambda(e+e-) : \lambda(p\bar{p}) = 1 : 0.5$$

fraction of the active partons

NC deep inelastic scattering



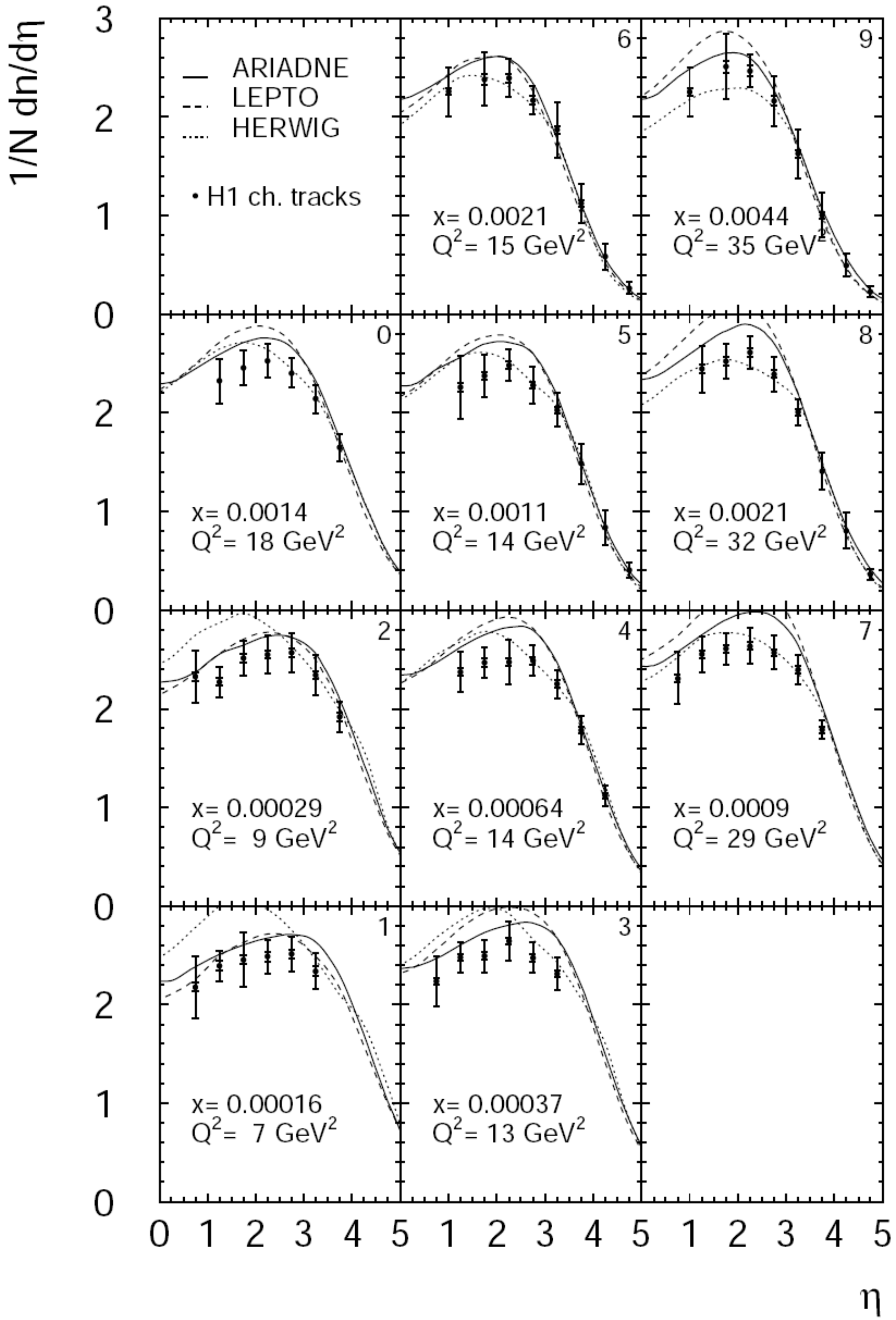
Described by Q^2 and W

Character of the exchanged boson changes with Q^2

	Contribution from
$Q^2 \leq 20\ GeV^2$	**resolved photons**
$20 < Q^2 < 1000\ GeV^2$	**point like photon**
$Q^2 \geq 1000\ GeV^2$	Z^0

Calculations done for $Q^2 = 4^2,\ 14^2,\ 90^2\ GeV^2$

To compare with $e^- e^+$ data $Q=2\ E_{beam}$



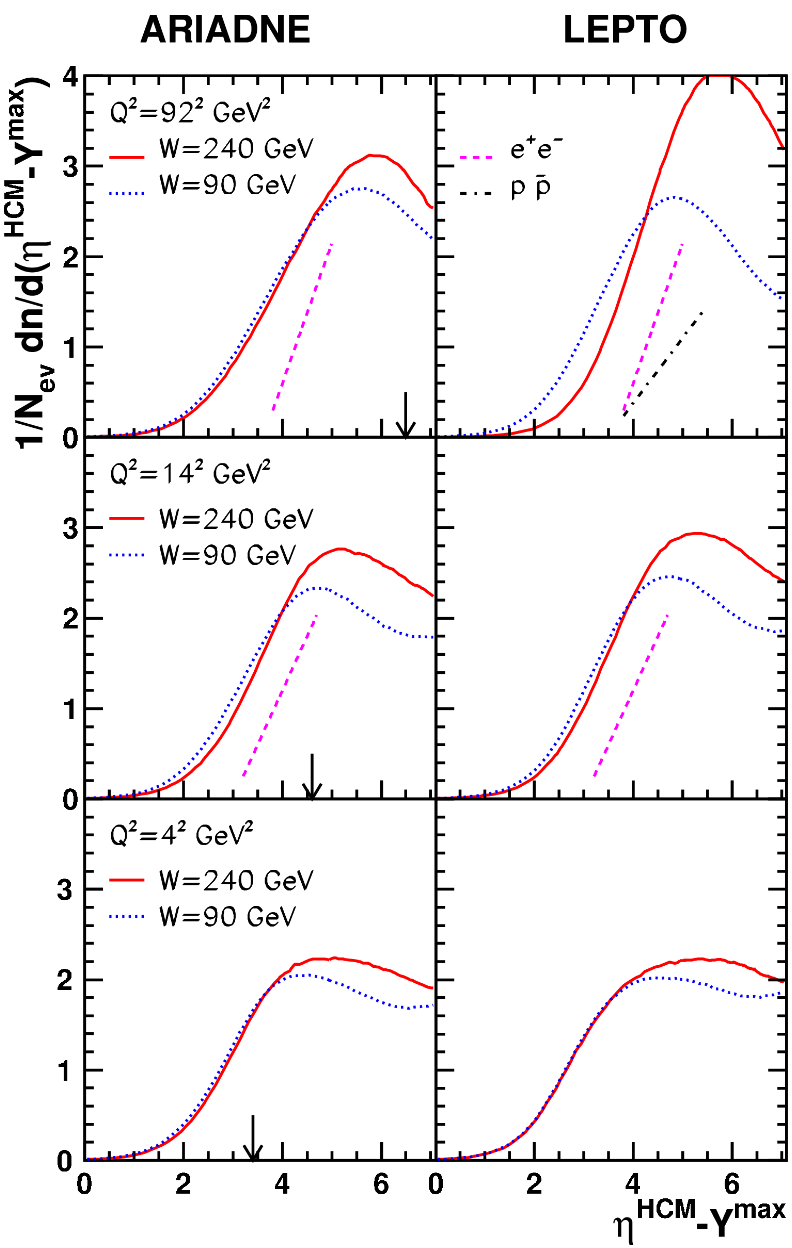
Existing data

H1 coll, NP B485 (1995)3

Prediction:

ARIADNE	**colour dipole model**
LEPTO-MEPS	**matrix element and parton shower**
Lund string	**hadronisation**

ep scattering (predictions)



fixed $Q^2 \approx$ 16, 200, 8000 GeV^2

different W = 240 or 90 GeV

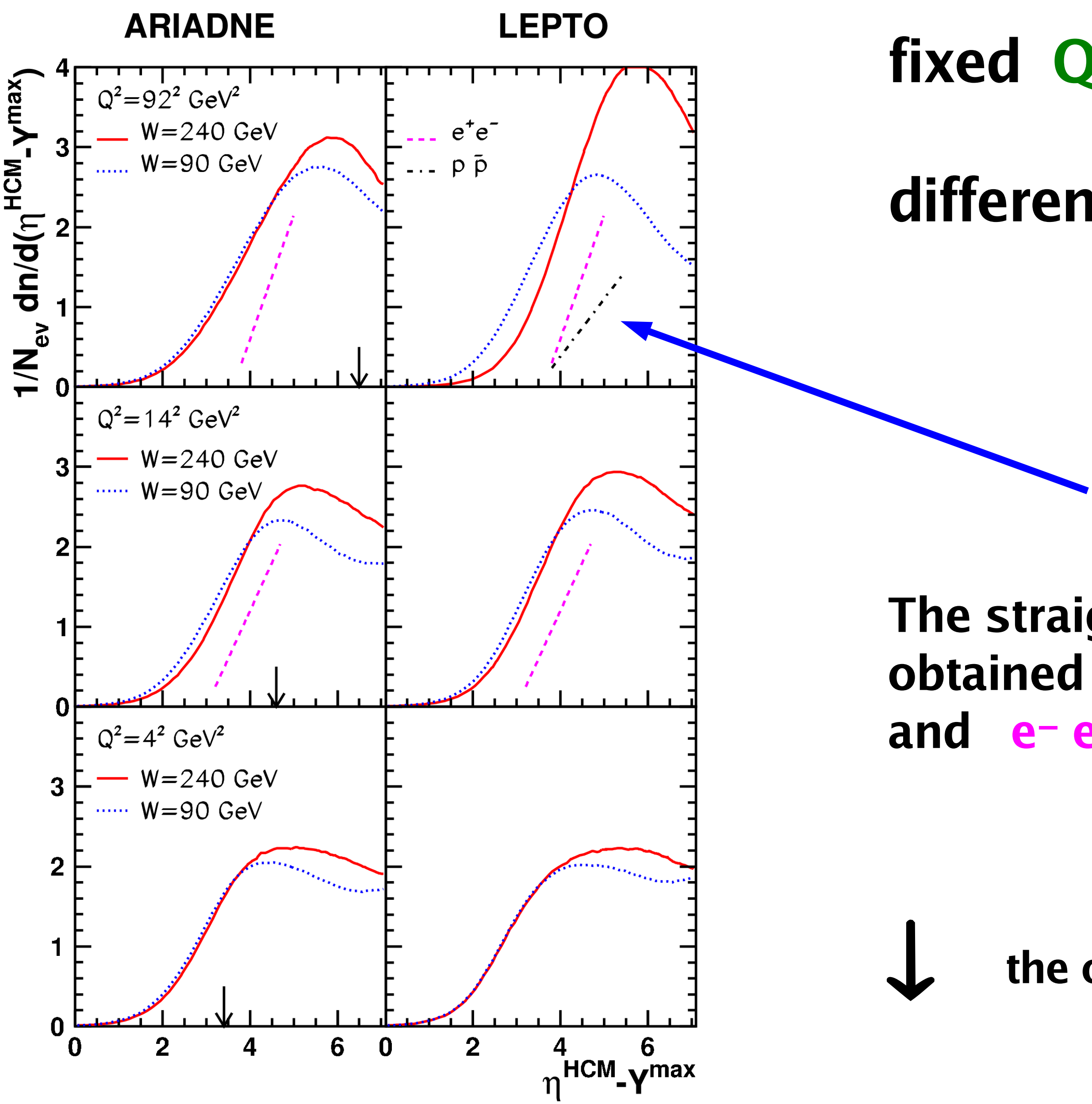
Z^0 dominates

point like γ

resolved γ

for $Q^2 \rightarrow M^2_Z$ differences in predictions

ep scattering (predictions)



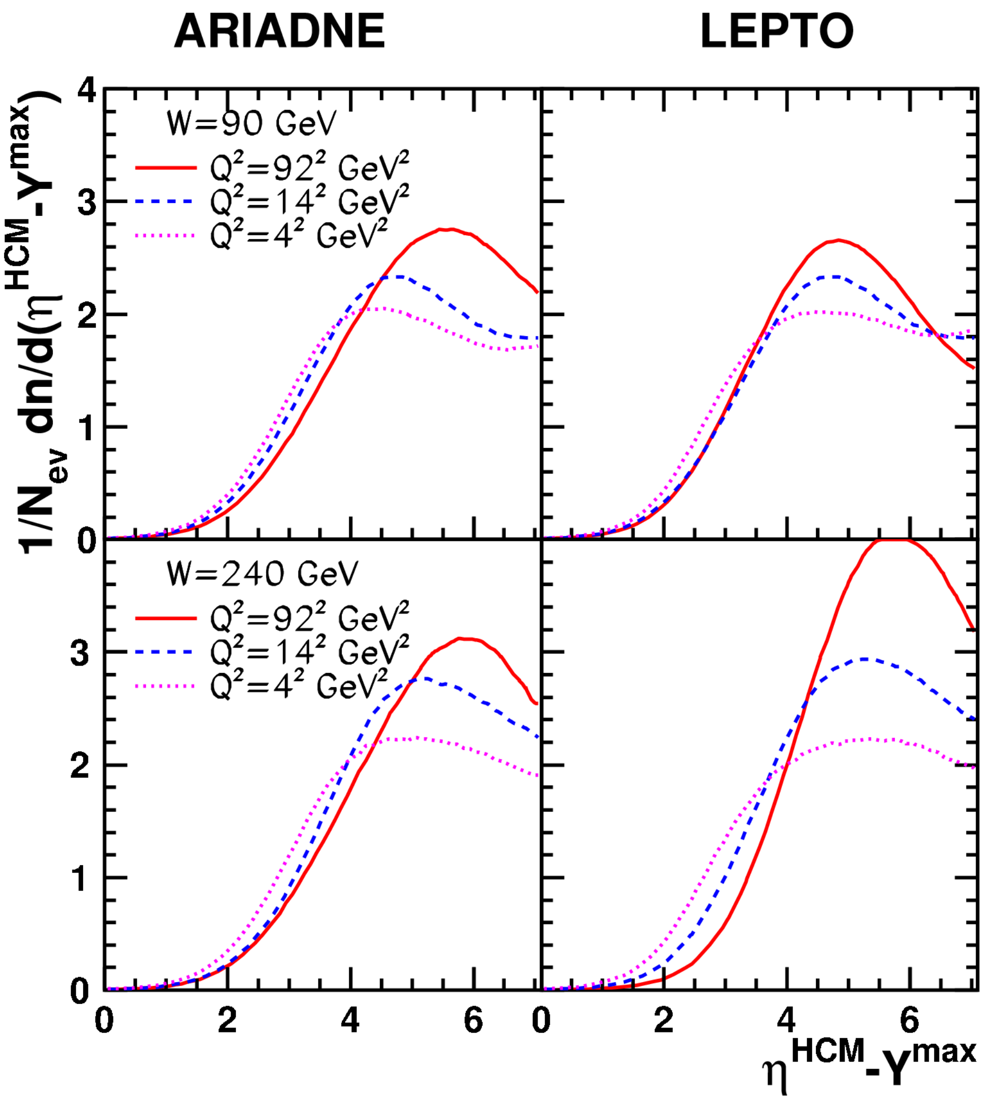
fixed $Q^2 \approx$ 16, 200, 8000 GeV^2

different W = 240 or 90 GeV

The straight lines represent slopes obtained from $p\bar{p}$ data (·-·-·-·-·) and $e^- e^+$ data (- - - - - -) at the given $Q=2E_{beam}$

↓ the origin of the Breit frame

ep scattering (predictions)



W fixed

different Q^2

From the Bialas-Jazabek model
fraction of active partons changes with Q^2

Summary and conclusions

Comparison of e+e-, ep and $p\bar{p}$ in the region of limiting fragmentation

The slope parameter from Bialas-Jezabek model is used

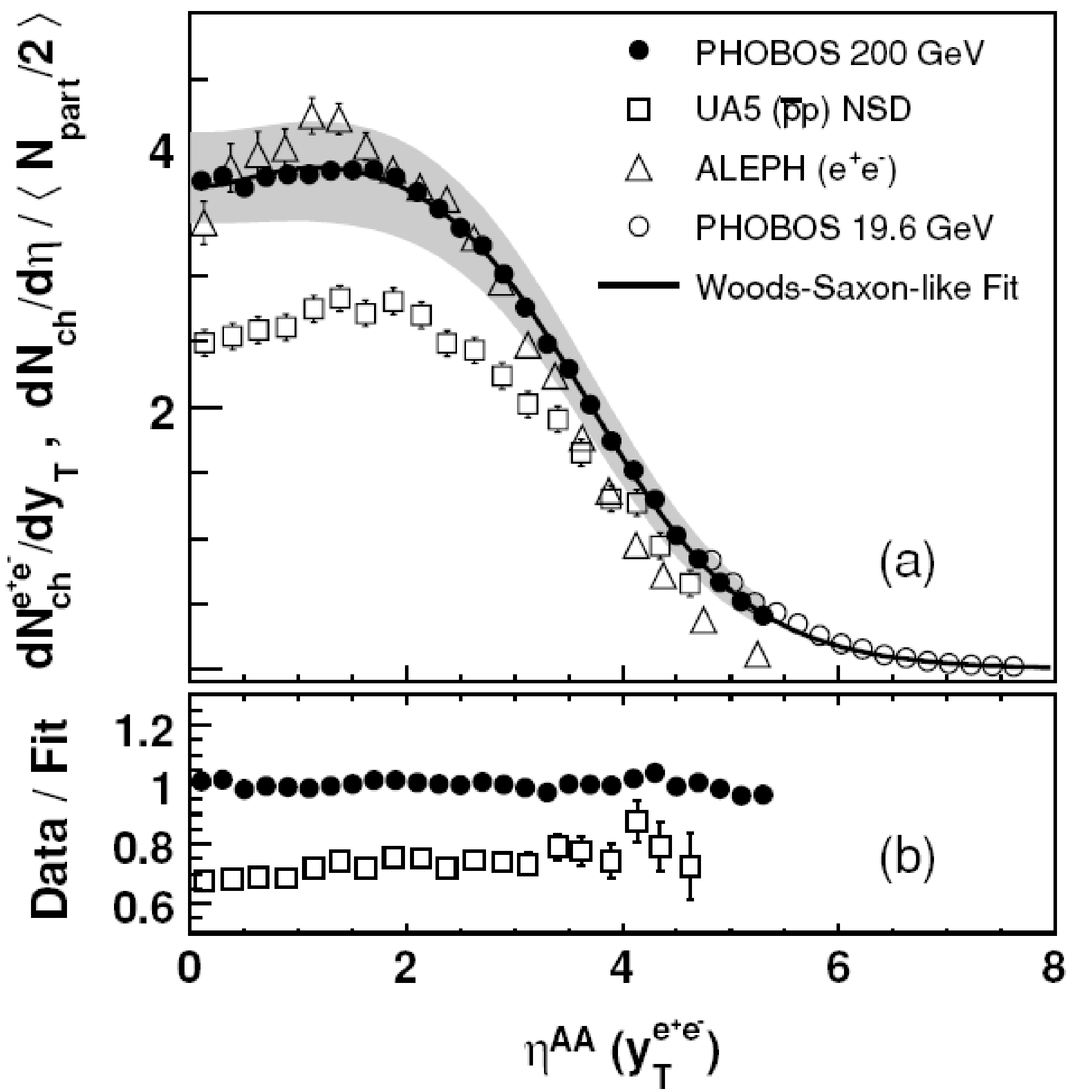
- **slope is steeper for e+e- than for $p\bar{p}$**
- **slope agrees for ep with the one for e+e- at $Q^2 << M_Z$**

  is different at $Q^2 \approx M_Z$

It is of interest to check on the large sample of data accumulated at HERA

AA collisions

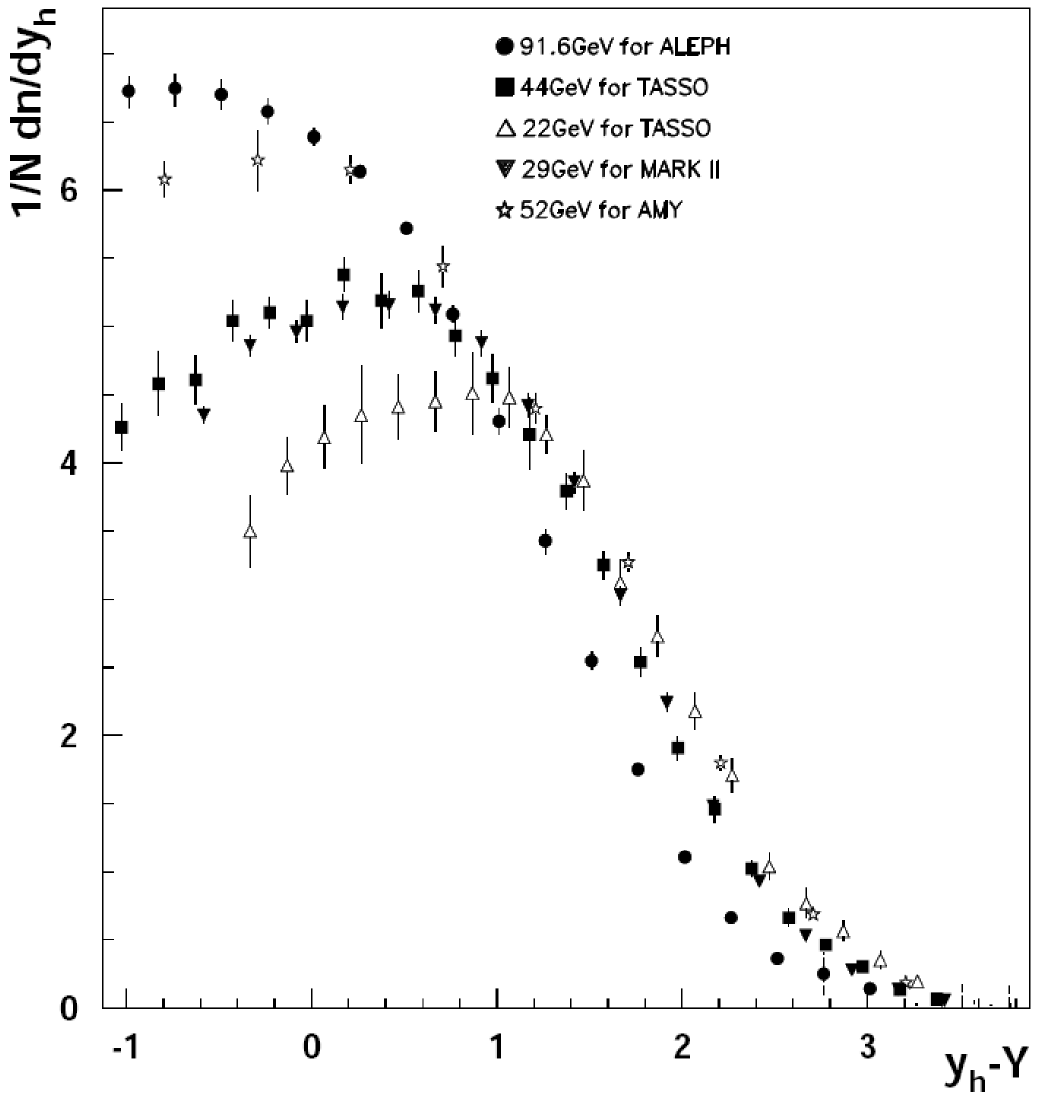
PHOBOS coll. PR C74(2006)021902



A similar study for one hemisphere of AA, ee and pp :

- **ee overlapped with AA**
- **the slope for ee steeper than for pp**

e^+e^- data



91.6GeV for ALEPH
44GeV for TASSO
22GeV for TASSO
29GeV for MARK II
52GeV for AMY
1/N dn/dy_h
y_h-Y