Fragmentation

of

Quarks and Gluons

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Contents:

Contributed Abstracts

- DELPHI-Collaboration :
  ABS231 Charged particle multiplicity in e^+e^- annihilations into $q\bar{q}$ at $\sqrt{s} = 206$ GeV
  ABS232 Hadronization properties of b quarks compared to light quarks in e^+e^- annihilations into $q\bar{q}$ at $\sqrt{s} = 206$ GeV
  ABS247 Topology dependence of the charged multiplicity in hadronic three jet events
  ABS233 Study of the charge of leading hadrons in gluon and quark fragmentation
- CDF-Collaboration :
  ABS359 Gluon and quark jet fragmentation at CDF
- OPAL-Collaboration :
  ABS577 Measurement of the scaling violations of the quark and gluon fragmentation functions
- SLD-Collaboration :
  ABS970 Production of charged $\pi^\pm$, $K^\pm$ and $p/\bar{p}$ in hadronic Z^0 decays
  ABS971 A study of correlations between identified charged hadrons in hadronic Z^0 decays
- H1-Collaboration :
  ABS1002 The photoproduction of Protons at HERA
  ABS1015 Inclusive D-meson production in DIS at HERA

I Multiplicities

The most obvious result of fragmentation:

A final state

with a large number
of hadronic particles

N_{ch} in e^+e^--annihilation at 206GeV (DELPHI)

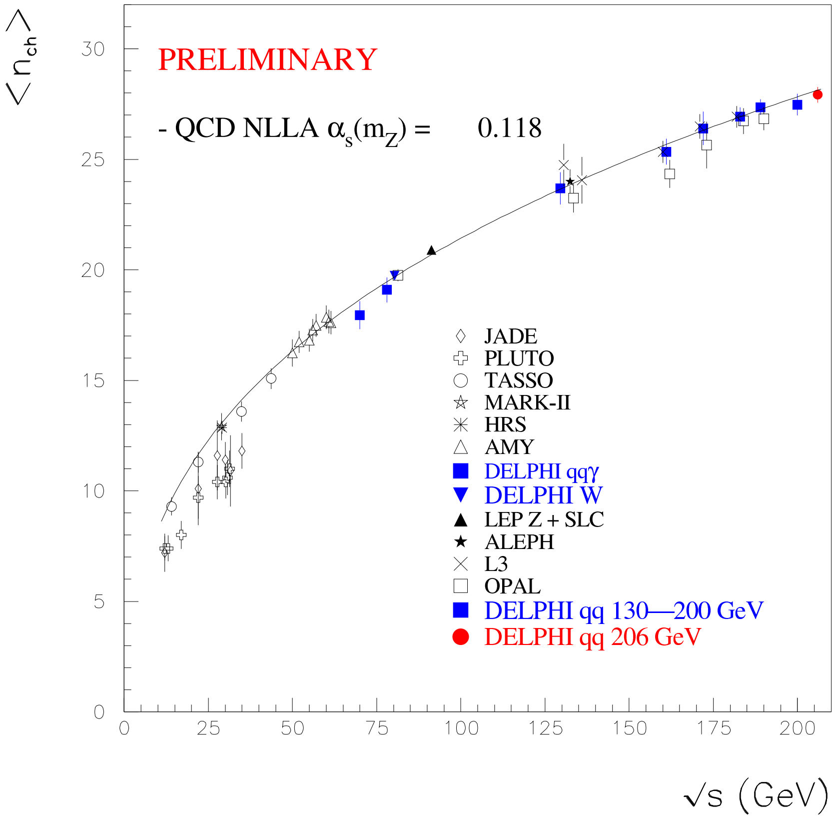
- In 2000 DELPHI collected $164\mathrm{pb}^{-1}$ with $\langle\sqrt{s}\rangle = 206\mathrm{GeV}$
- DELPHI: measurement of N_{ch} from integrated ξ_E-distribution $\xi_E = -\log\left(\frac{E}{\sqrt{s}/2}\right)$
- Main BG:
  - ISR $\longrightarrow$ $\sqrt{s'} > 0.9 \cdot \sqrt{s}$
  - ZZ, WW $\longrightarrow$ Narrow Jet Broadening < 0.065
  - $\longrightarrow$ 3047 events (BG: 682 expected, mainly WW)
- Results:

$$N_{ch}(206\mathrm{GeV}) = 28.03 \pm 0.22 \pm 0.27$$
$$D(206\mathrm{GeV}) = 8.97 \pm 0.16 \pm 0.13$$
$$\xi_p^*(206\mathrm{GeV}) = 4.21 \pm 0.04 \pm 0.02$$

- Main sources for systematic errors: Calibration factor , acceptance correction

N_{ch} in e^+e^--annihilation at 206GeV (DELPHI)

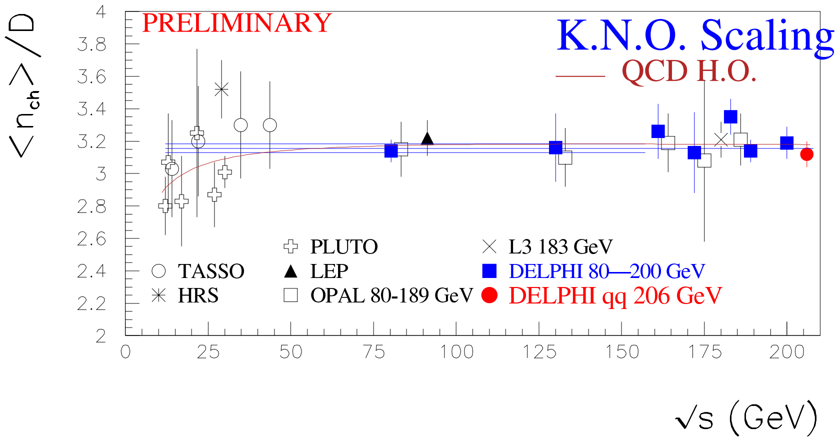
Energy development



NLLA:

$$N_{ch}(\sqrt{s}) = a[\alpha_s(\sqrt{s})]^b \cdot e^{c/\sqrt{\alpha_s(\sqrt{s})}}$$
$$(1 + \mathcal{O}(\sqrt{\alpha_s}))$$

KNO-scaling



Koba-Nielsen-Olesen scaling:

$$\frac{< N_{ch} >}{D} = \text{const.}$$

Expectations fulfilled up to 206 GeV

3 jet Events in e^+e^- annihilation (DELPHI)

- N_{ch} in dependence of event-topology at $\sqrt{s} = M_Z$
- Variation in energy scales of quark and gluon jets due to variation in topology
- Prediction for 3 jet multiplicity (P.Eden et al.)

$$N_{q\bar{q}g} = N_{q\bar{q}}(L,\kappa) + \frac{1}{2}N_{gg}(\kappa)$$

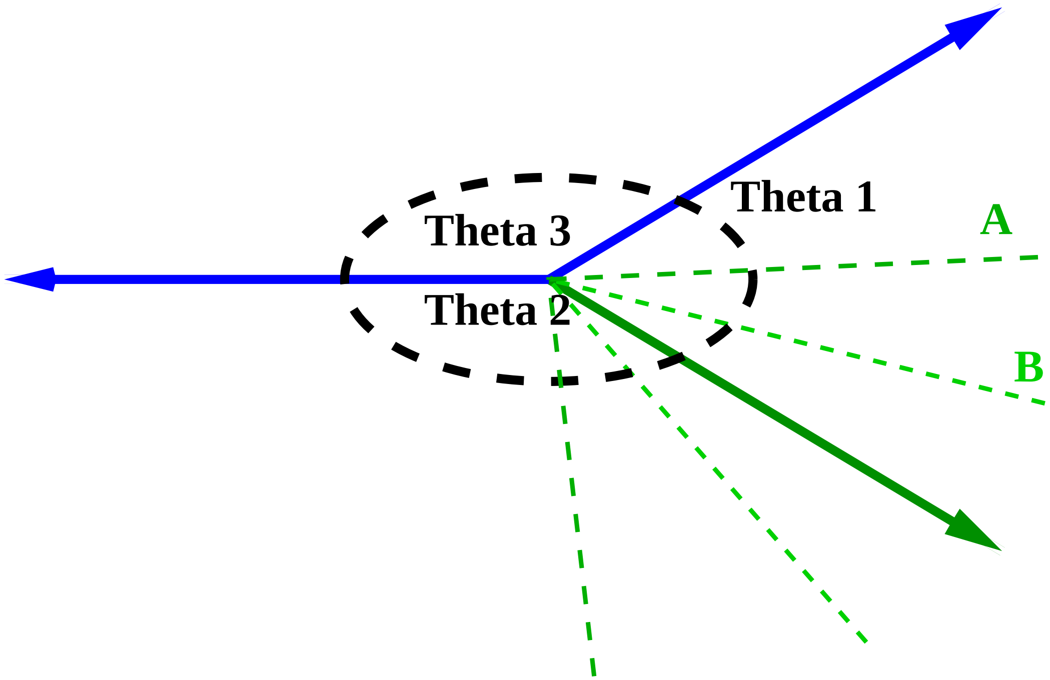
L: Quark scale, κ: Gluon (p_t-like) scale

- Coherence effects are taken into account by choice of scales
- Phase-space restriction in $q\bar{q}$-system due to gluon jet $\rightarrow$ $N_{q\bar{q}}$ depends on κ

$$\frac{dN_{gg}}{dL}(L + c_g - cq) = \frac{C_A}{C_F}\frac{dN_{q\bar{q}}}{dL}(L) \quad \left(1 + \frac{\alpha_0 c_r}{L}\right)$$

- $N_{q\bar{q}}$ measured before, constant of integration fixed by measurement of N_{gg}
- Prediction of $N_{q\bar{q}g}$ dependent on $\frac{C_A}{C_F}$

3 jet Events in e^+e^- annihilation (DELPHI)



- Scales function of θ_1, θ_3
- Two formulations of prediction
- Different definitions of gluon-contribution

$$\text{A}: \quad s_{q\bar{q}} \rightarrow L \qquad \frac{s_{qg}s_{\bar{q}g}}{s_{q\bar{q}}} \rightarrow \kappa$$

$$\text{B}: \quad s \rightarrow L \qquad \frac{s_{qg}s_{\bar{q}g}}{s} \rightarrow \kappa$$

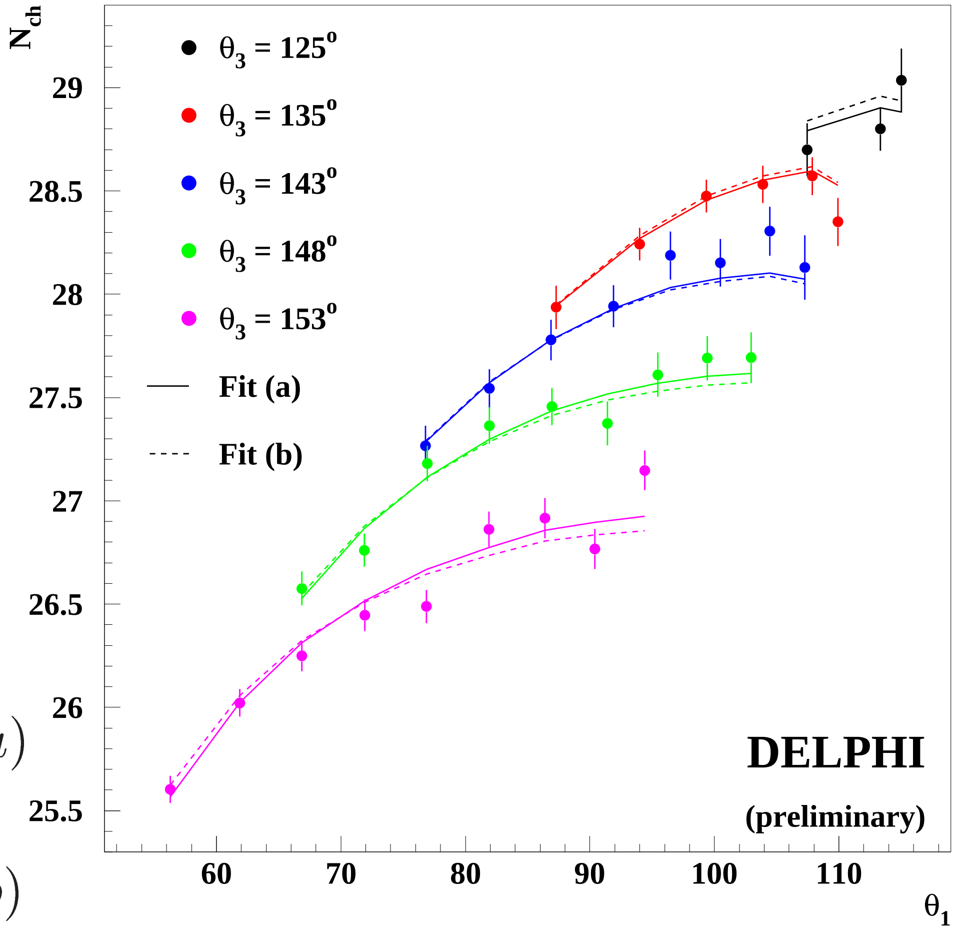
3 jet Events in e^+e^- annihilation (DELPHI)

- $N_{q\bar{q}g}$ as function of (θ_1, θ_3)
- Fit of C_A/C_F to data
- No b-tagging applied, δ_{lb} constant, additional offset N_0 fitted.
- Two formulations of prediction, different choice of scales
- (prel.) Result:

$$\frac{C_A}{C_F} = 2.277 \pm 0.02 \pm 0.05 \, (a)$$

$$\frac{C_A}{C_F} = 2.093 \pm 0.05 \pm 0.08 \, (b)$$

in agreement with $SU(3)_C$

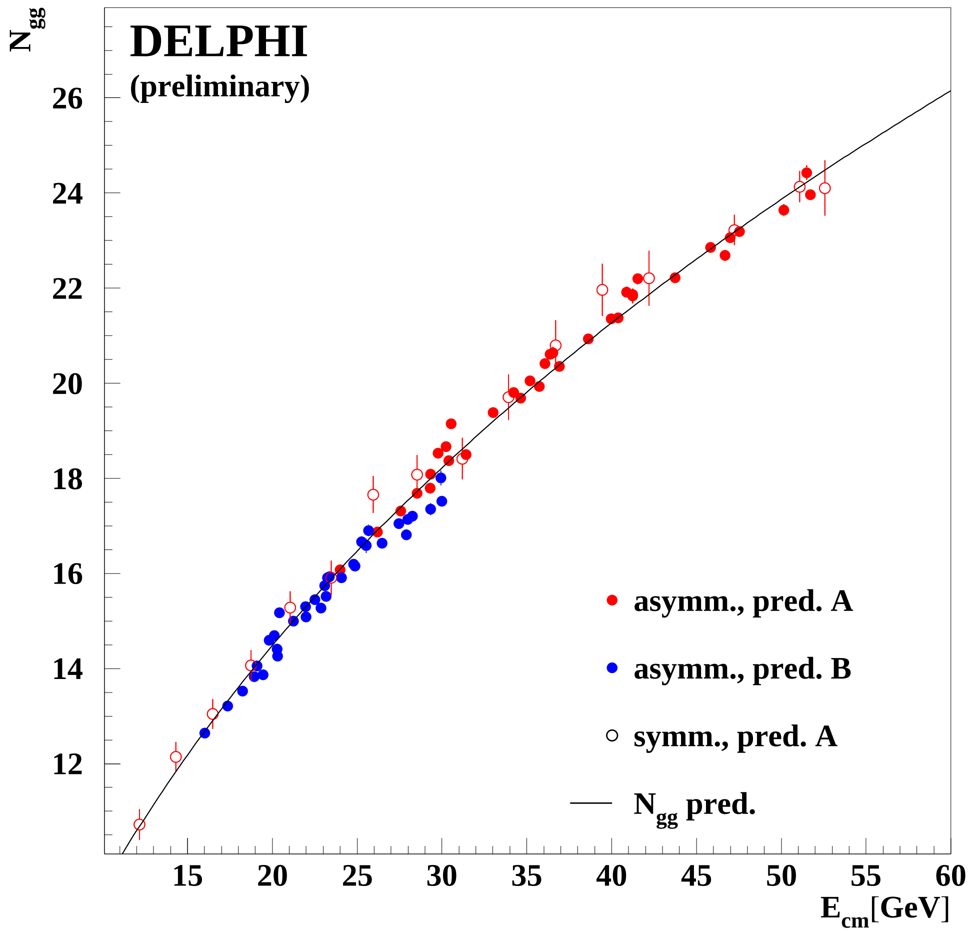


3 jet Events in e^+e^- annihilation (DELPHI)

- Measurement of N_{gg} possible:

$$N_{gg} = 2\left[N_{q\bar{q}g} - N_{q\bar{q}} - N_0\right]$$

- N_{gg} extracted for effective $E_{cm} = 16\ldots52\text{GeV}$
- Two used formulations of the prediction with different gluon scale
  $\rightarrow$ different energy ranges
- Good agreement with previous measurement and prediction (line)



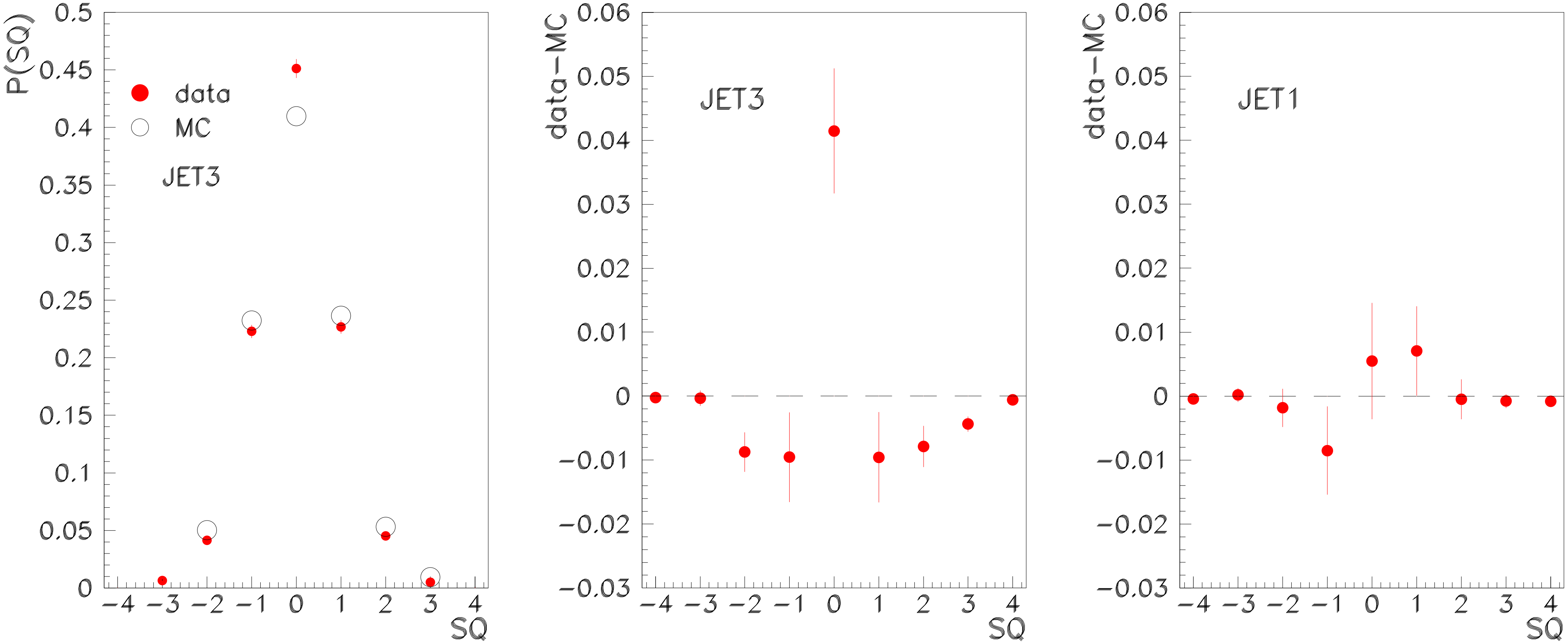
Leading Systems and Identified Particles

Colour Octet Neutralisation (DELPHI)

- Colour blanching in gluon jets possible via triplet and octet neutralisation
- Colour octet neutralisation necessary for bound gluonic states (glueballs)
- Signature: Surplus on neutral leading particles in gluon jets
- DELPHI: analysis of 3 jet events:
  Most energetic jet $\rightarrow$ quark jet ($\sim 90\%$)
  Least energetic jet $\rightarrow$ gluon jet ($\sim 70\%$)
- Leading system of a jet defined by
  particles with $y > 2$ and
  no particles with $0 < y < 2$
- Summed charges of leadings systems: Comparison with MC-Model without octett neutralisation

Colour Octet Neutralisation (DELPHI)

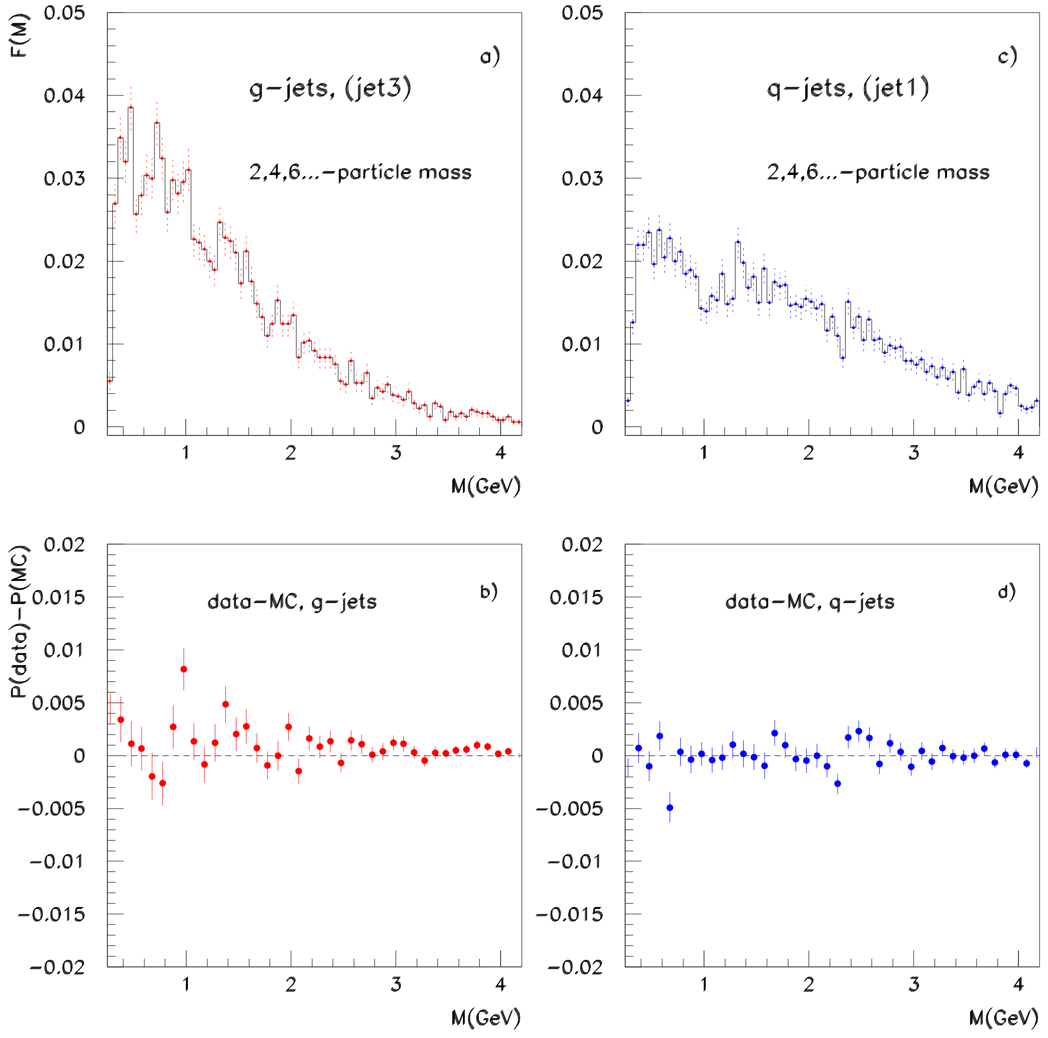
Leading systems: Sum of charges



Gluon enriched
Surplus of neutral leading systems

Quark enriched
Agreement with simulation

Mass Spectra of Leading Systems (DELPHI)



Quark sample:
no deviations from simulation

Gluon sample:
only deviations with little significance
But: Surplus concentrated at small masses

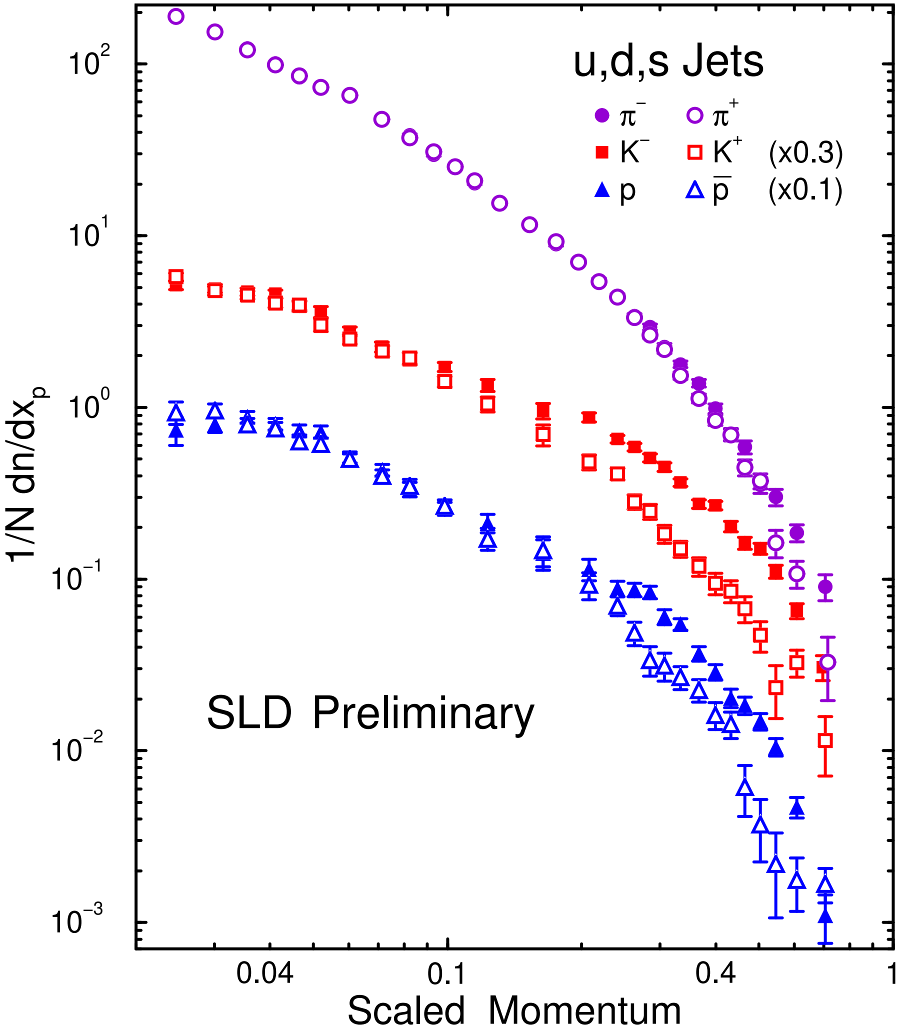
Identified π, K and p in e^+e^- Annihilation (SLD)

- Identified π, K and p in hadronic Z-decays
- Identification via SLD's RICH detector (CRID)
- Measured positions ξ^* of the maxima of the ξ-distributions:

$$\begin{aligned}
\xi^*_\pi &= 3.77 \pm 0.01 \pm 0.02 \\
\xi^*_K &= 2.63 \pm 0.01 \pm 0.03 \\
\xi^*_p &= 2.94 \pm 0.02 \pm 0.06
\end{aligned}$$

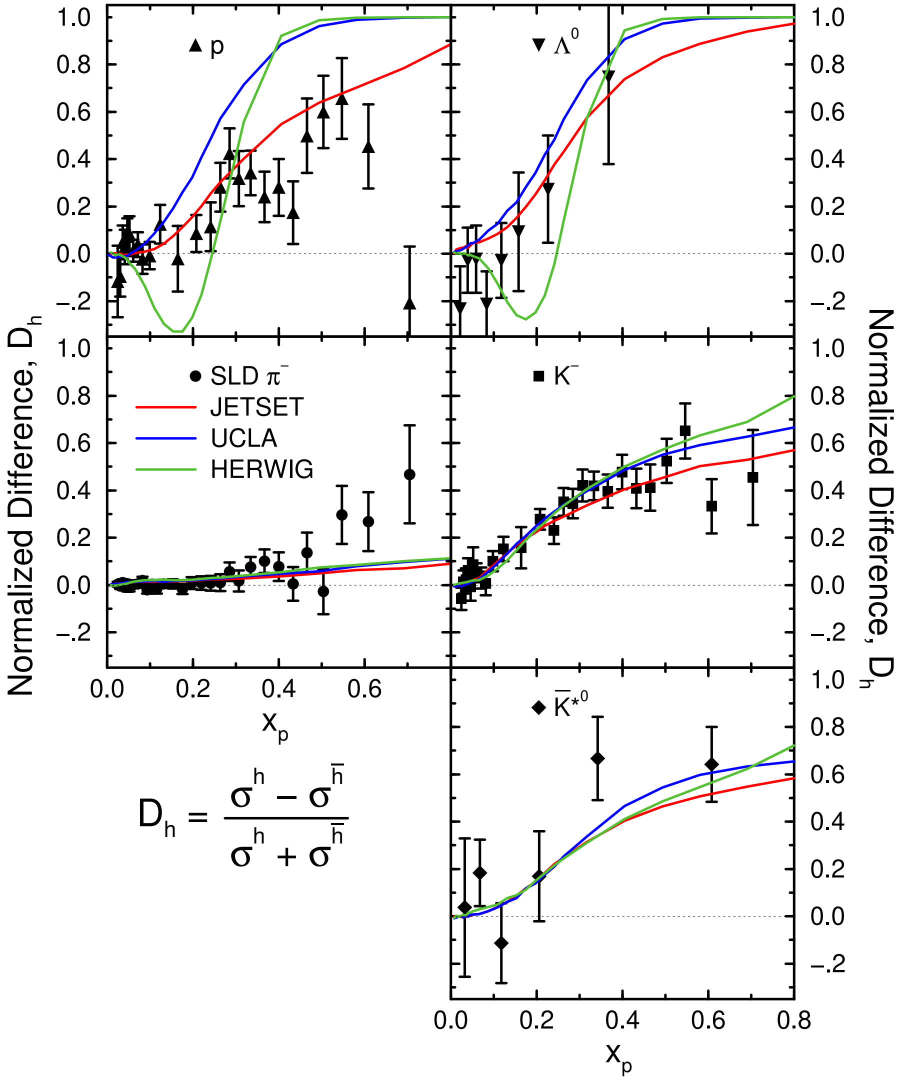
- Only $Z \to u\bar{u}/d\bar{d}/s\bar{s}$ due to veto against secondary vertices
- Polarized e^- beams and a large asymmetry of the Z:
  - Determination of the direction of the quark and the anti-quark possible
  - Hemisphere purity 73%

Identified π, K and p in e^+e^- Annihilation (SLD)



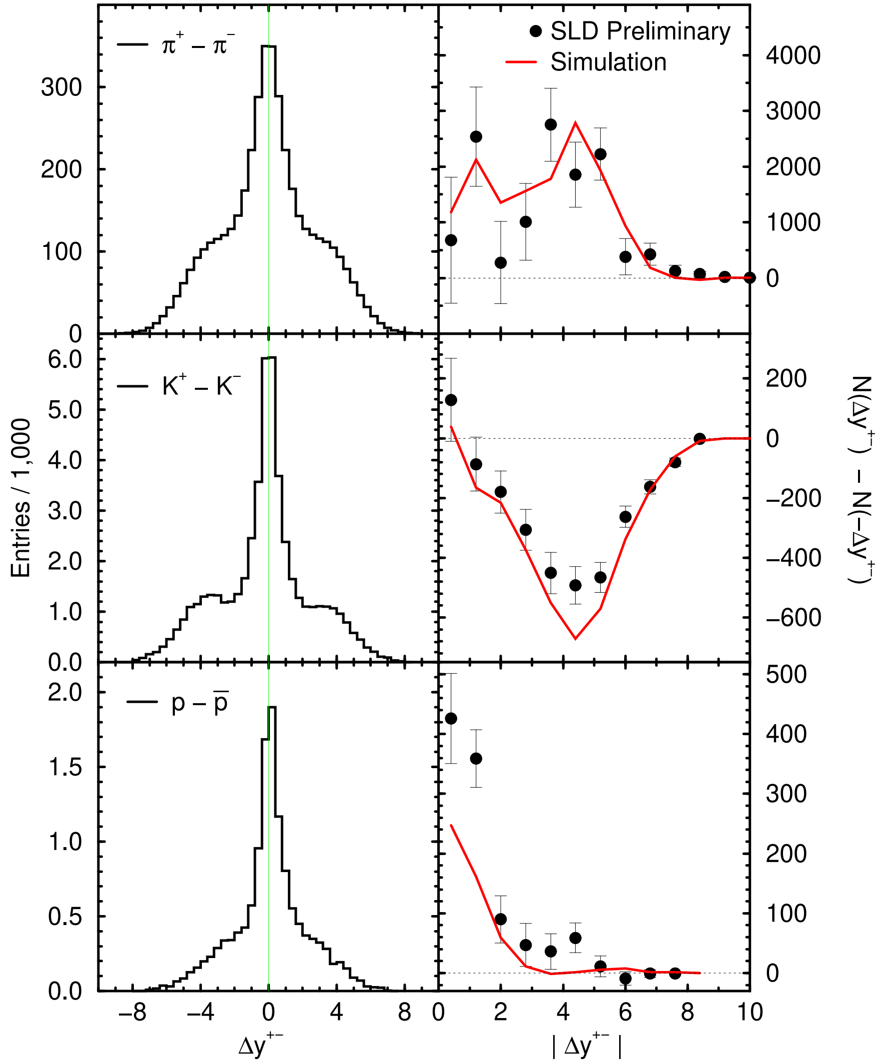
- Scaled momentum distribution in quark direction
- Charge conjugate in anti-quark direction included
- Leading particle effect in p and K distribution
- More protons and K^- at high x_p than c.c.
- Smaller surplus of π^- w.r.t. π^+

Identified π, K and p in e^+e^- Annihilation (SLD)



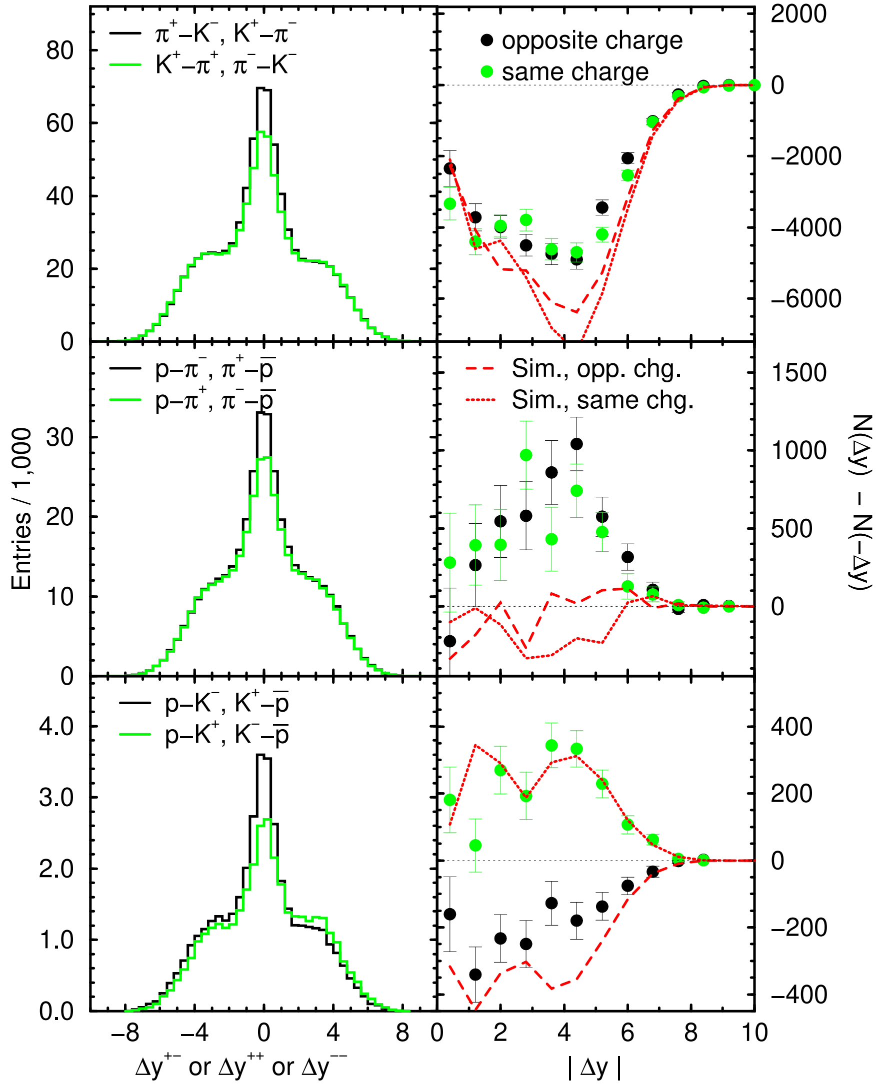
- Protons: $D_p > 0$ for high x, leading particle with only valence quarks
- π: $D_\pi \sim 0.27$ expected for uniform π-production
- instead: compatible with $0.27 \cdot D_p$
- $D_K > 0$ for high x
- Evidence for leading particle production

π, K and p: Correlations (SLD)



- Correlation studies
- Rapidity y signed due to quark direction
- $\Delta y^{+-} = y(h^+) - y(h^-)$
- Asymmetries in Δy^{+-}-distribution:
  $\rightarrow$ particle ordering along event-axis
- Proton: Positive asymmetry at low Δy^{+-}
  $\rightarrow$ leading baryon with local N_B-conservation (baryon number ordering)
- Kaon: Negative asymmetry at high Δy^{+-}
  $\rightarrow$ leading Kaon production in $s\bar{s}$-events

π, K and p: Correlations (SLD)



- Correlations between unlike particles
- Kaon-related asymmetries probably due to leading Kaons
- Discrepancy between data and simulation for $p - \pi$ pairs

Reconstructed D-Mesons in DIS (H1)

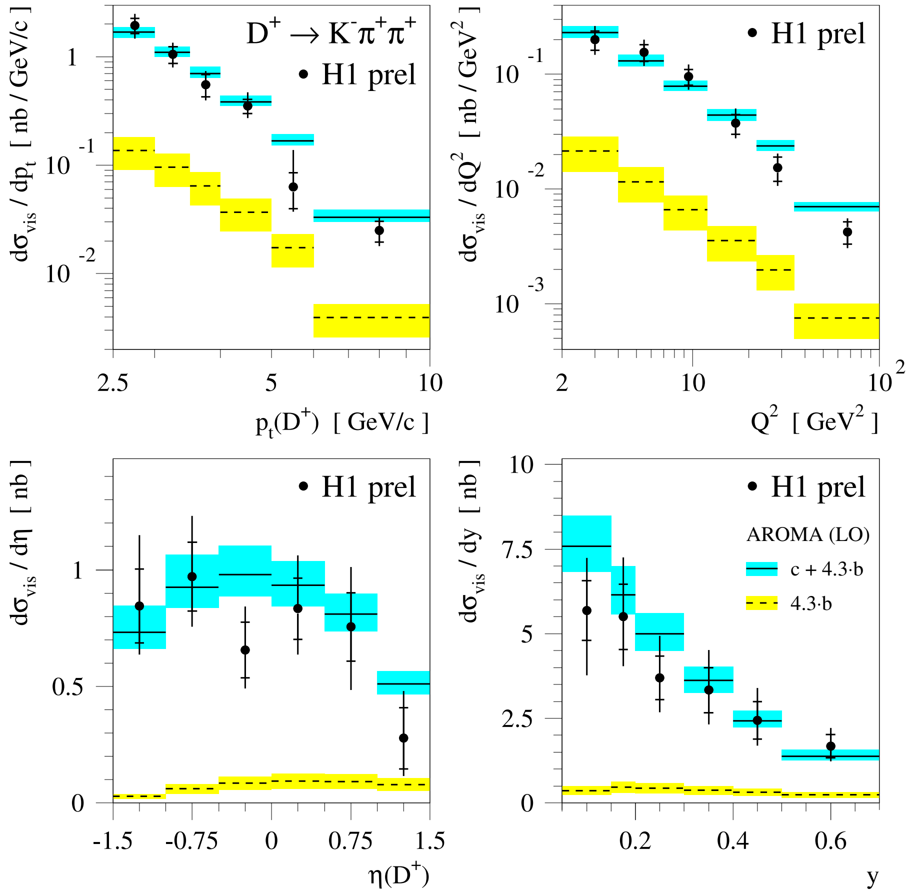
- Production of D-Mesons in DIS $\rightarrow$ Test of the universality of fragmentation
- H1: reconstruction of (charge conj. incl.)

$$\begin{array}{llll} D^+ & \rightarrow & K^-\pi^+\pi^+ & \\ D^0 & \rightarrow & K^-\pi^+ & \\ D_s^+ & \rightarrow & \phi\pi^+ & \rightarrow (K^+K^-)\pi^+ \\ D^{*+} & \rightarrow & D^0\pi^+ & \rightarrow (K^-\pi^+)\pi^+ \end{array}$$

- Kinematic range given by $2\mathrm{GeV}^2 \leq Q^2 \leq 100\mathrm{GeV}^2$, $0.05 \leq y \leq 0.7$, $p_t(D) \geq 2.5\mathrm{GeV}/c$ and $|\eta(D)| \leq 1.5$

	D^+	D^0	D_s^+	D^{*+}
$\sigma_{\mathrm{vis}}(ep \rightarrow eDX)(nb)$	2.16	6.53	1.67	2.90
stat. error	± 0.19	± 0.49	± 0.41	± 0.20
syst. error	$^{+0.46}_{-0.35}$	$^{+1.06}_{-1.30}$	$^{+0.54}_{-0.54}$	$^{+0.58}_{-0.44}$

Reconstructed D-Mesons in DIS (H1)

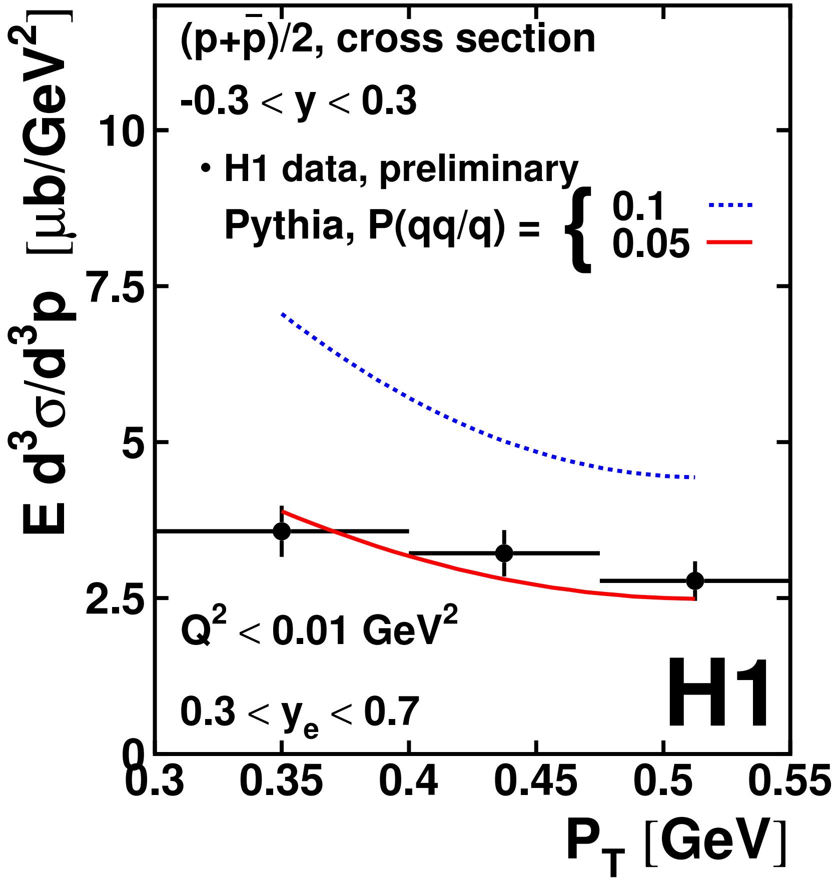


- Differential cross-sections for D^+
- Good agreement with LO simulation
- Fragmentation factors of c have been deduced
- The fraction of produced vector mesons (VM) has been deduced

$$P_V = \frac{VM}{PS + VM}$$

- $P_V = 0.693 \pm 0.045 \pm 0.004 \pm 0.009$
  $P_V = 0.613 \pm 0.061 \pm 0.033 \pm 0.008$
  (two approaches)
- In agreement with w.a. (e^+e^-)-value 0.601 ± 0.032

Photoproduction of protons in ep (H1)



- Photoproduction: quasi-real photon ($Q^2 < 0.01\text{GeV}^2$)
- $0.3 < y < 0.7$
- Proton ID by specific energy loss dE/dx
- Good agreement with simulation for $P(qq/q) = 0.05$
- $P(qq/q) = 0.1$ found in e^+e^- analyses

Summary

- The charged multiplicity in e^+e^- has been measured at 206GeV
- The quark and gluon contributions in 3 jet multiplicities have been studied, C_A/C_F and N_{gg} have been determined.
- Surplus of neutral leading systems of gluon jets indicate possible colour octet neutralisation
- Identified particles in Z-decays show leading particle effects and local baryon number conservation
- Cross section for D-production in DIS have been measured and the fragmentation factors and P_V have been derived
- The photoproduction of protons in DIS prefers a low diquark production fraction