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Fragmentation Functions and Two-Particle Correlations

LEP, SLD results from $e^+e^- \to Z^0 \to q\bar{q}$ decays

- Rapidity Correlations
- Bose-Einstein Correlations
- $f_J(2220) \to K_s^0 K_s^0$

- Total Transverse Momentum Correlations
- Flavour Dependent Fragmentation Functions

y correlation between π,K,p

PAPER 259 — SLD, SLAC-PUB-7824 (June 1998)

- charge, strangeness, baryon-number ... conserved

  $\Rightarrow$ correlation between particles with opposite quantum numbers

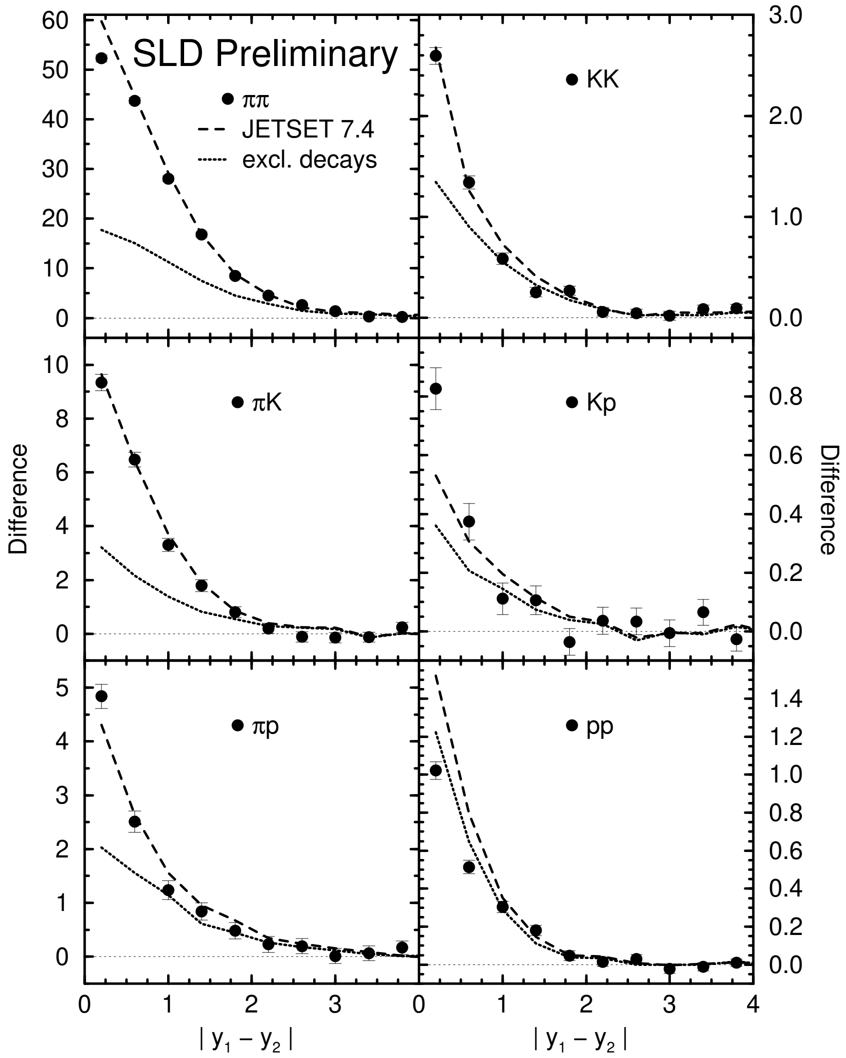
  - short range correlation (fragmentation process, decays)
  - long range correlation (leading particle production)

- identified charged π,K,p in $Z^0 \rightarrow$ light quarks

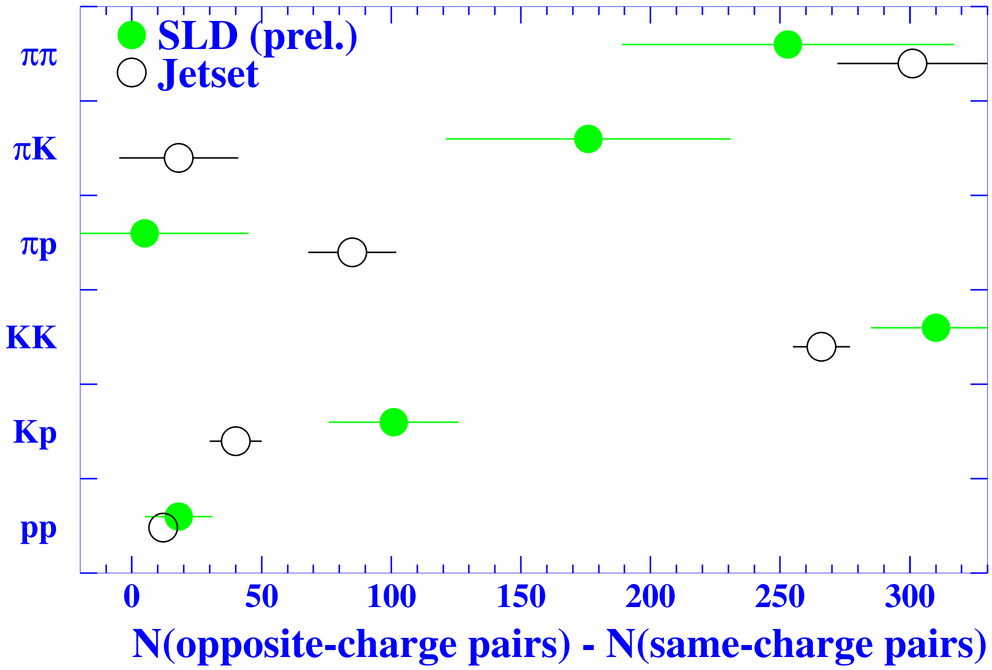
y: rapidity w.r.t. thrust axis

Δy: measure of "closeness"

Δy (opposite charge) $-\Delta y$ (same charge): $\Rightarrow$ correlation



- long range correlation: $|\Delta y| > 4$, $p > 9$ GeV



- signed rapidity

beam polarisation

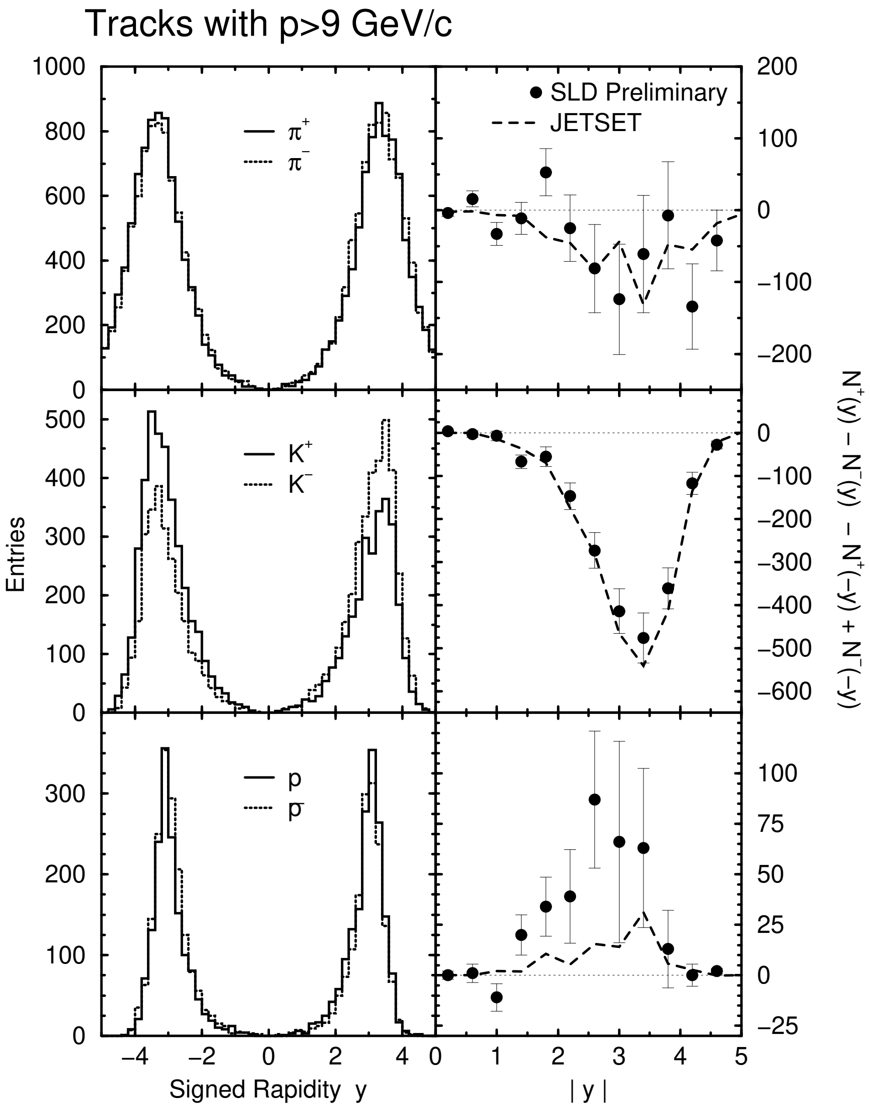
$+$

FB quark production asymmetry

$\Downarrow$

tag quark direction (73% correct)

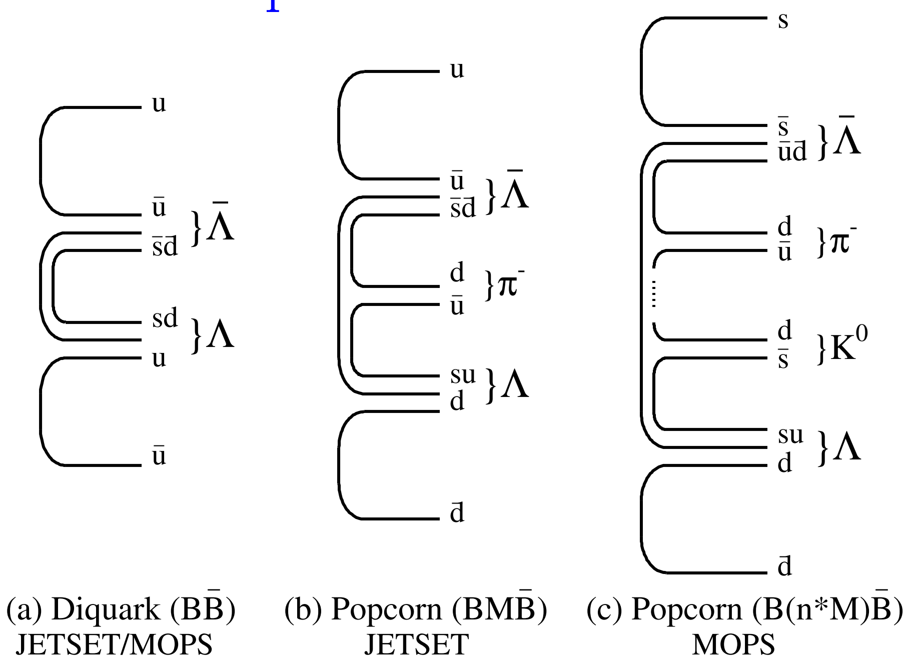
quark direction $\Rightarrow$ positive rapidity



y correlation between $\Lambda\bar{\Lambda}$

PAPER 298 — OPAL-PR-251 , submitted to Phys. Lett. B

- Λ production process:



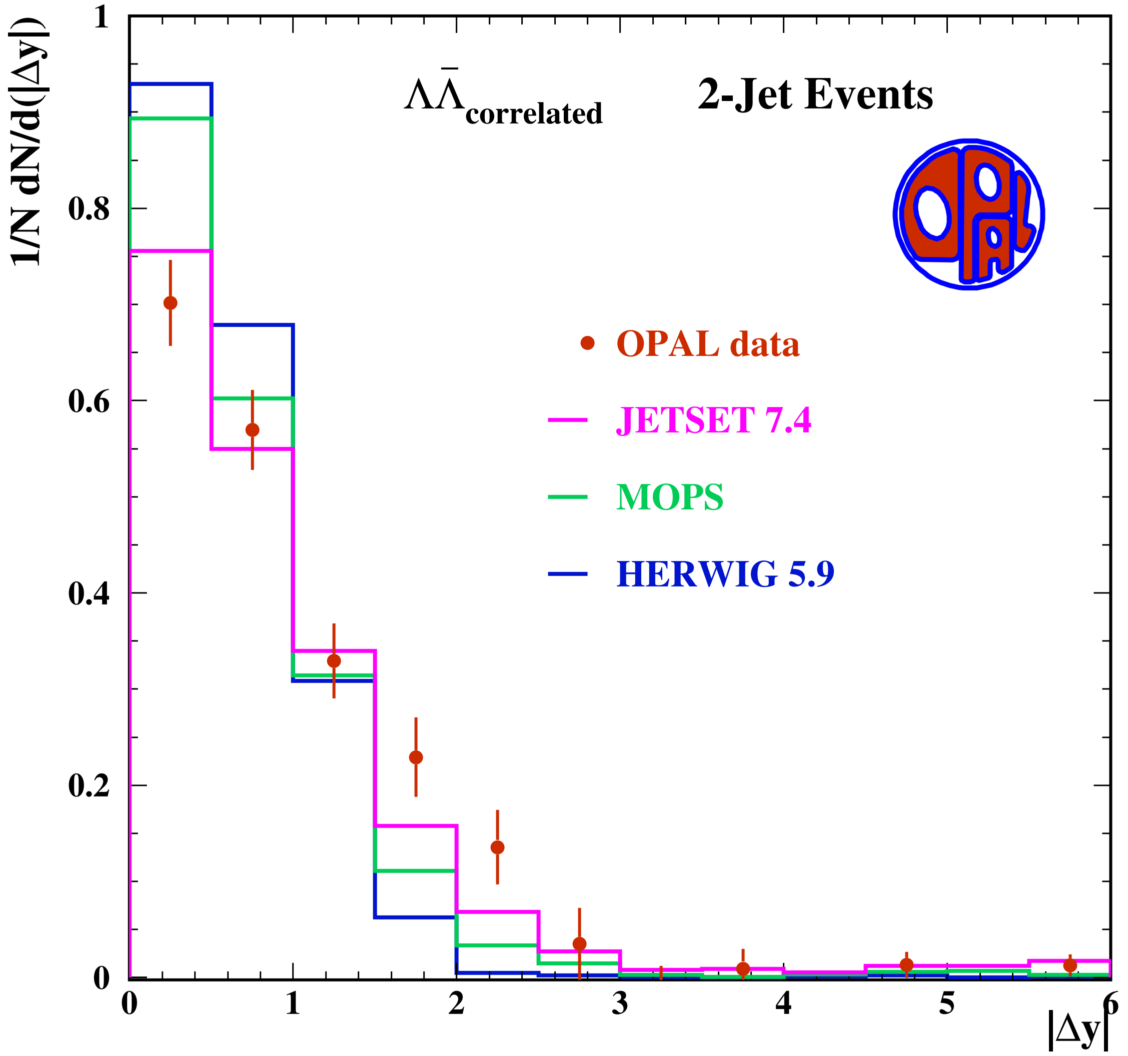
- production rate:

  - $\Lambda \to \pi$p, full LEP 1 statistic
  - background subtraction by two-dimensional sideband method
  - $N_{\Lambda\bar{\Lambda}}(\text{corr.}) = N_{\Lambda\bar{\Lambda}} - (N_{\Lambda\Lambda} + N_{\bar{\Lambda}\bar{\Lambda}})$

	$N_{\Lambda\bar{\Lambda}}(\text{corr.})$ /hadronic event $[\times 10^{-2}]$
This Analysis	6.1 ± 0.3
OPAL (previously)	6.2 ± 1.0
ALEPH	6.5 ± 1.0
DELPHI	7.2 ± 1.1

- rapidity difference:

  - studied in 2 jet events $\Rightarrow$ increased sensitivity



  - HERWIG and MOPS: correlation too strong
  - JETSET prediction improved when "popcorn parameter" changed from 0.5 to 0.7
  - attempts to tune MOPS failed

Bose-Einstein correlations of 3 charged π

PAPER 291 — OPAL CERN-EP/98-068, accepted by Euro Phys. Journal C

- BE correlation: extensively studied in 2-particle systems

$$R_2 = \frac{\rho(p_1, p_2)}{\rho(p_1)\rho(p_2)} = 1 + \lambda_2 e^{-Q_2^2 {r_2}^2}$$

  - $Q_2^2 = q_{1,2}^2 = -(p1 - p2)^2$
  - λ_2: strength of BE Correlation
  - r_2: size of 2-boson emitter

- 3-boson correlation

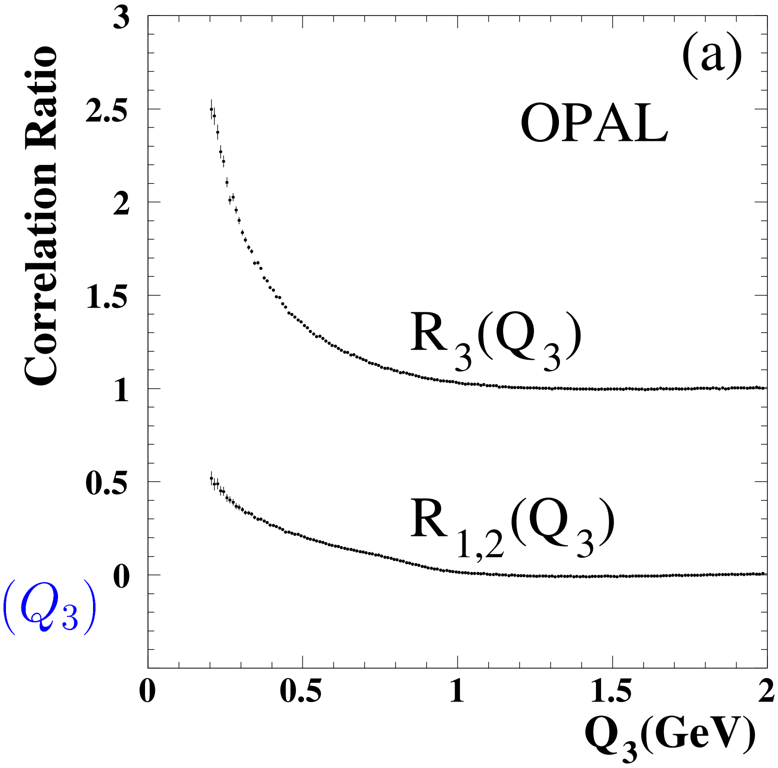
$$R_3 = \frac{\rho(p_1, p_2, p_3)}{\rho(p_1)\rho(p_2)\rho(p_3)} = 1 + 2\lambda_3 e^{-Q_3^2 r_3^2} + R_{1,2}$$

  - $Q_3^2 = q_{1,2}^2 + q_{1,3}^2 + q_{2,3}^2$
  - λ_3: strength of 3-boson BE Correlation
  - r_3 : size of 3-boson emitter
  - $R_{1,2}$: contribution from: $\Rightarrow$ 2 particles correlated
    $\Rightarrow$ 1 particle independent

- Measurement:

$$R_3(Q_3) = \frac{N^{\pm\pm\pm}(Q_3)}{M^{\pm\pm\pm}(Q_3)}$$

$R_{1,2}(Q_3)$: derived from $N^{\pm\pm\mp}(Q_3)$



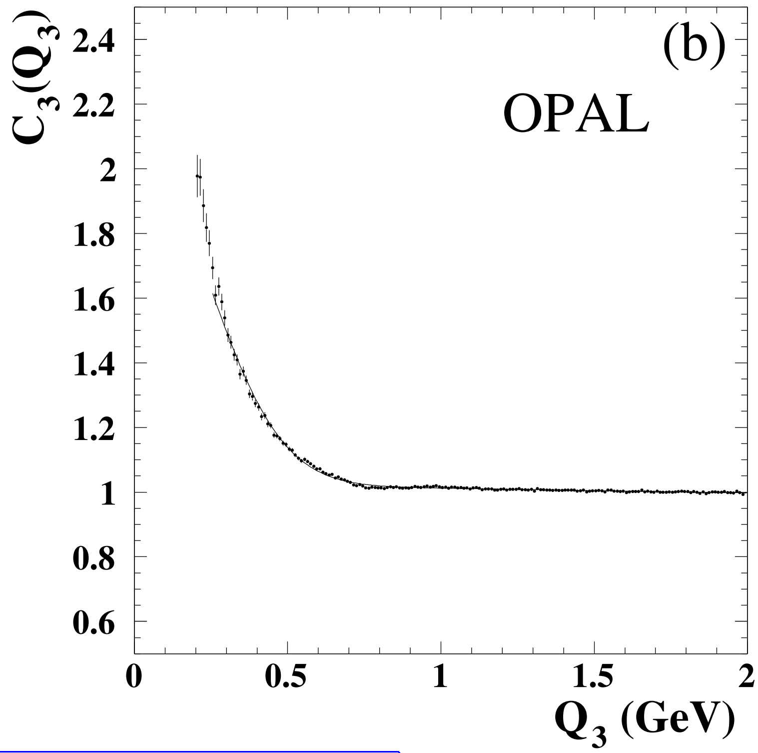
Coulomb corrections

positive for R_3

negative for $R_{1,2}$

(net effect on λ_3 : $+9\%$

on r_3 : -6%)



- Results: $\boxed{\begin{array}{l} r_3 = 0.580 \pm 0.004 \pm 0.029 \\ \lambda_3 = 0.504 \pm 0.010 \pm 0.041 \end{array}}$

  - EXPECTATION $r_3 = r_2/\sqrt{2}$ (I.Juricic et al.)

    $\Rightarrow \quad r_3^{\text{calc}} = 0.561 \pm 0.011$

  - DELPHI: $r_3 = 0.657 \pm 0.039 \pm 0.032$

    $\lambda_3 = 0.28 \pm 0.05 \pm 0.07$

2-Dimensional Study of BE Correlations

PAPER 546 — L3 note 2270 (June 1998)

- most simple ansatz:
  emitter source spherically symmetric

$$Q^2 = -(p1 - p2)^2$$

$$R_2 = \frac{\rho(p_1, p_2)}{\rho(p_1)\rho(p_2)} = 1 + \lambda e^{-Q^2 r^2}$$

- here: 2 dimensions

In the longitudinally co-moving system (LCMS):

$Q_\parallel$ 3-momentum difference parallel to thrust axis

$|\overrightarrow{Q_{\mathrm{T}}}|$ 3 momentum difference in plane $\perp$ thrust axis

$$R_2 = 1 + \lambda \exp\left(-Q_\parallel^2 {R_\parallel}^2 - \overrightarrow{Q_{\mathrm{T}}}^2 {R_{\mathrm{T}}}^2\right)$$

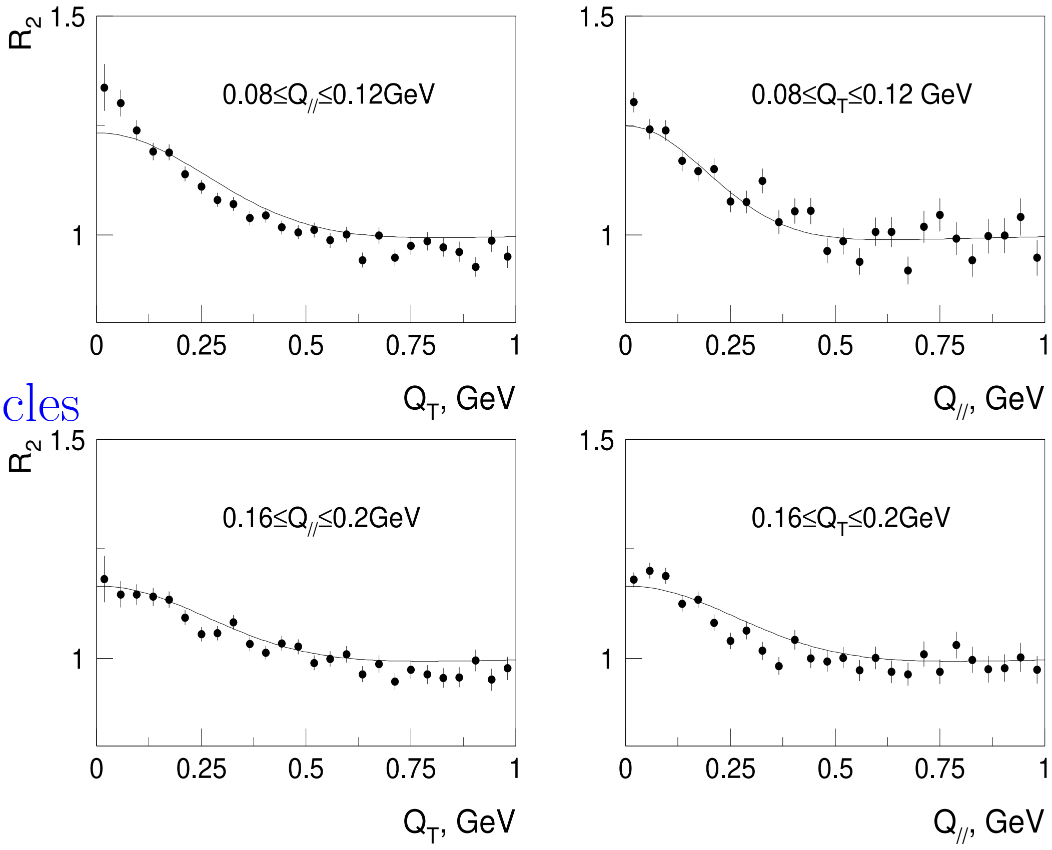
$R_\parallel$ long. geometric radius

R_{T} mixture of transverse radius and emission time

- Measurement:

R_2 measured

- in $Q_\parallel, |\overrightarrow{Q_\mathrm{T}}|$ bins
- for like sign particles



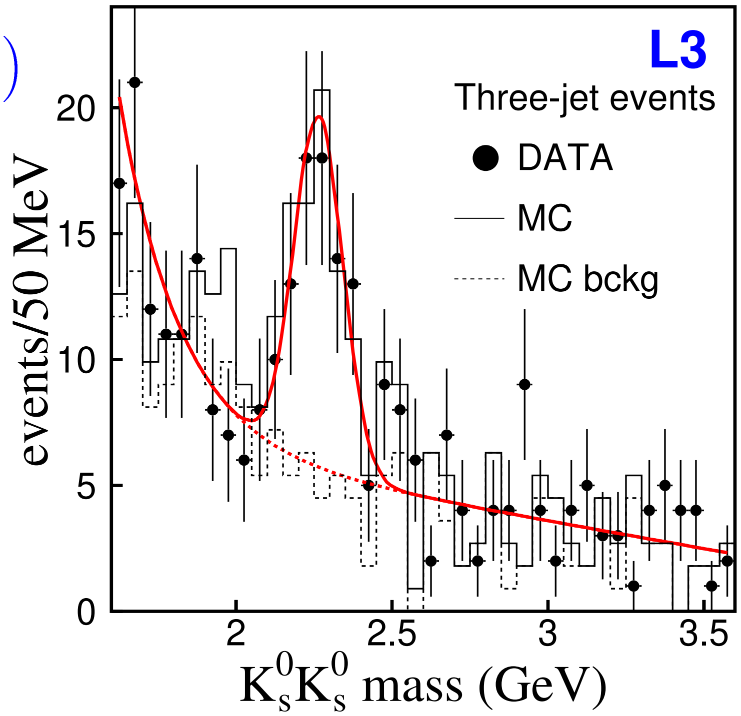
- Results: $\boxed{\begin{array}{c} \lambda = 0.30 \pm 0.01 \pm 0.07 \\ R_\parallel = 0.73 \pm 0.02 \pm 0.04 \\ R_\mathrm{T} = 0.54 \pm 0.02 \pm 0.05 \end{array}}$

  - $R_\parallel > R_\mathrm{T}$ as expected (Anderson,Ringnér)
  - no significant difference in 2-jet events
  - m_t dependence studied
    decrease of $R_\parallel, R_\mathrm{T}$ with m_t
    possible increase of λ with m_t NOT confirmed

$$\boxed{f_J(2220) \to K_s^0 K_s^0}$$

PAPER 299 — OPAL Physics Note 357 (July 1998)

- Tensor Glueball of mass $\approx$ 2.2 GeV predicted by Lattice Gauge theories
- $f_J(2220)$ ($\equiv \xi(2230)$) a candidate ?
  - 1986: MARK III observed narrow resonance in radiative J/Ψ decays
    Mass: 2.23 GeV width about 20 MeV
  - NOT confirmed by DM2
    (but some evidence for a broad structure)
  - but seen by BES in various decay channels
  - NOT seen in $\gamma\gamma$ collisions at CLEO
  - NOT seen at LEAR ...
- prel. L3 Signal (1997)
  (Jerusalem, Brookhaven)



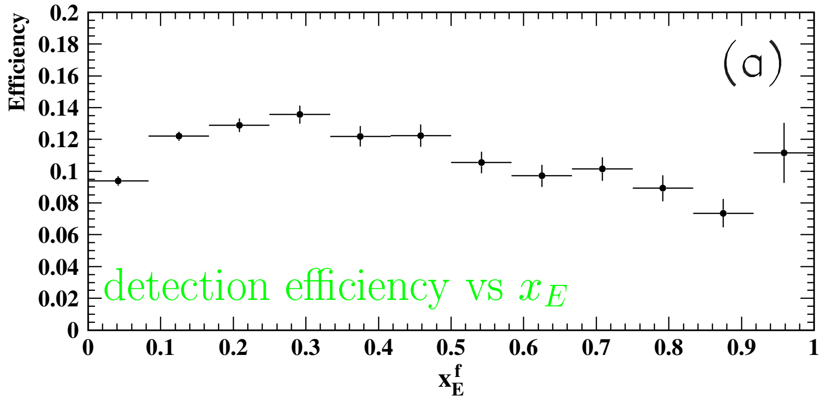
narrow signal

in 3 jet events only

most pronounced in least energetic jet

- OPAL: select $K_s^0 \to \pi^+\pi^-$ pairs ...

- generate $f_J(2220)$

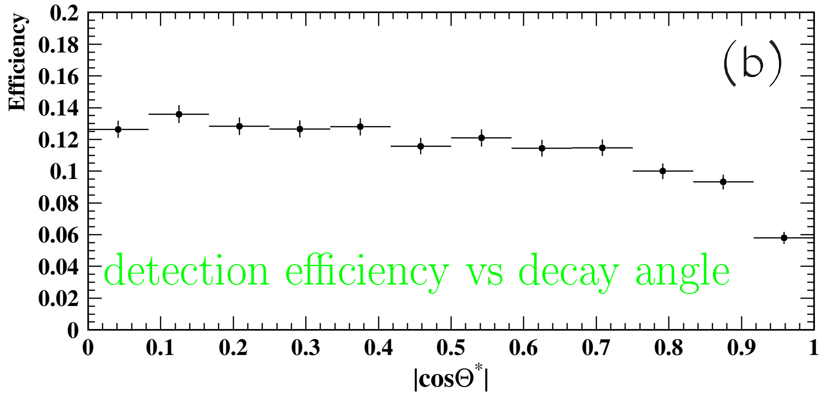


as conventional spin-2 tensor meson

like $f_2'(1525)$

mass and width from PDG

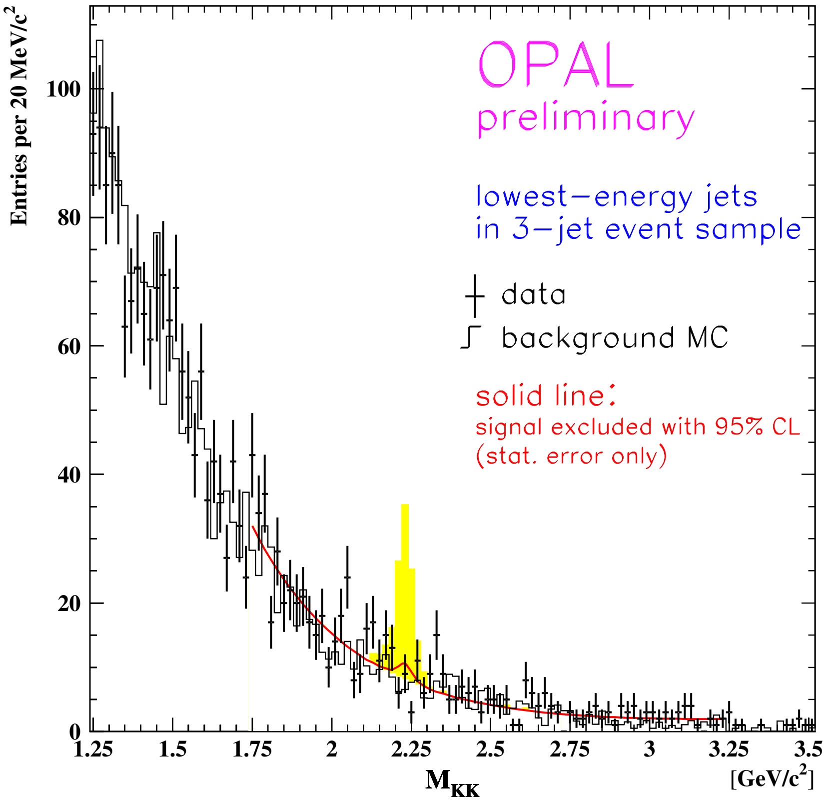
$m = 2231$ GeV; $\Gamma = 23$ MeV



mass resolution: 12 MeV

detection efficiency: 11.3%

- Results:



inclusive sample:

$N_{signal} = 0.4 \pm 60.1(\text{stat})$

3-jet sample:

$N_{signal} = 39.1 \pm 22.6(\text{stat})$

least energetic jet:

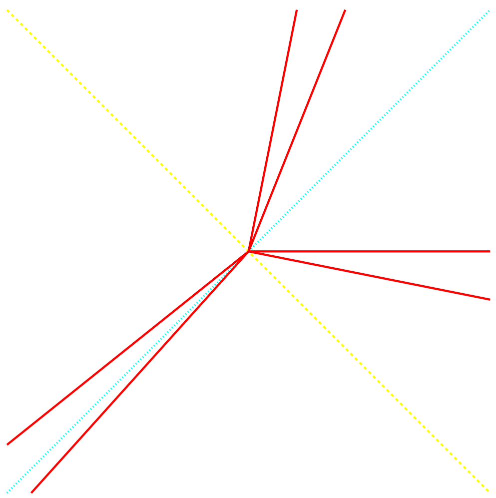
$N_{signal} = -8.7 \pm 6.5(\text{stat})$

$$\boxed{n_{f_j(2220)} \cdot BR_{f_J \to K\bar{K}} < 0.0028}$$

P_t correlations

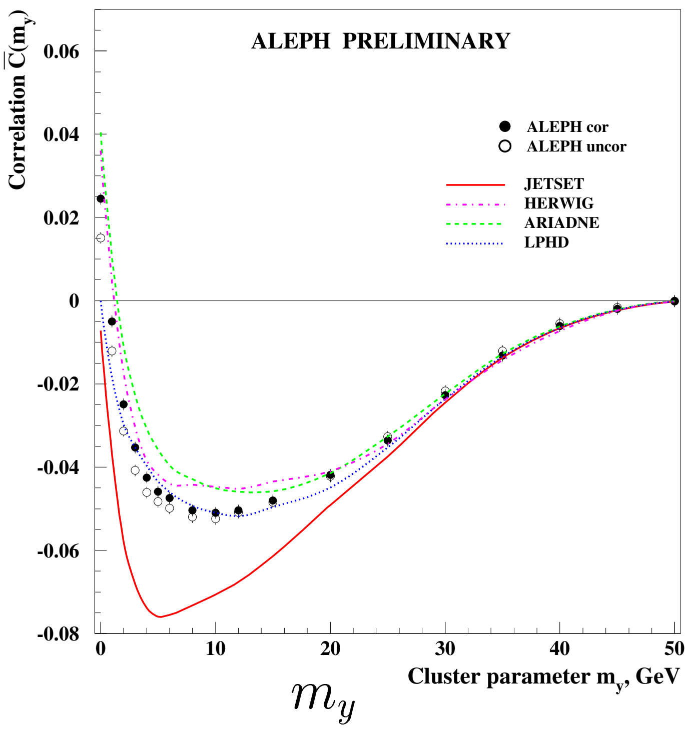
PAPER 932 — ALEPH 98-044 (June 1998)

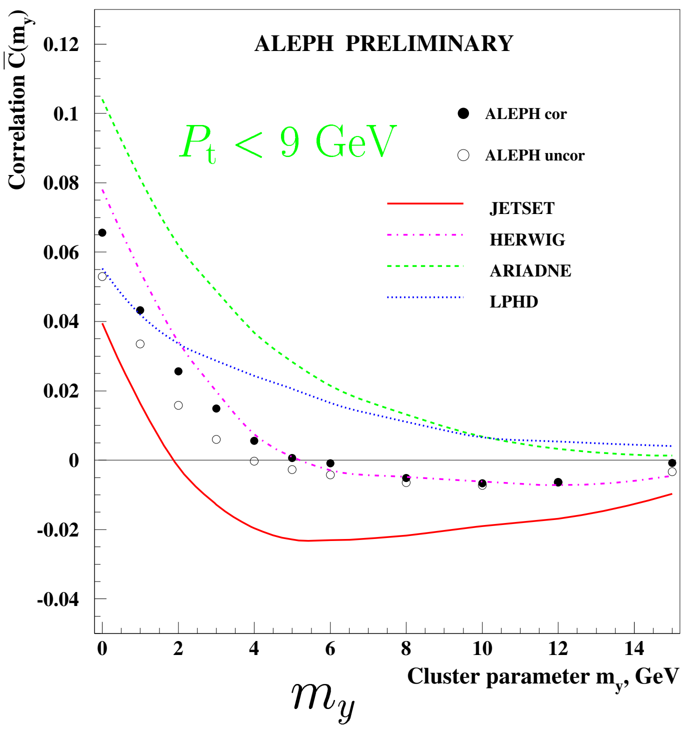
- Correlation between $P_t = \sum_{\text{hemisphere}} |P_{t,i}|$



- "i": jets (using Durham jet finder)
  $\Rightarrow P_t = P_t(m_y)$; $m_y = \sqrt{y_{cut} s}$
- large $m_y \Rightarrow$ perturbative effects
  small $m_y \Rightarrow$ non-perturbative effects

- $C(P_{t1}, P_{t2}) = \dfrac{\overline{P_{t1}, P_{t2}} - \bar{P}_{t1} \bar{P}_{t1}}{\sigma_{P_{t1}} \sigma_{P_{t1}}}$ (modified for analysis)





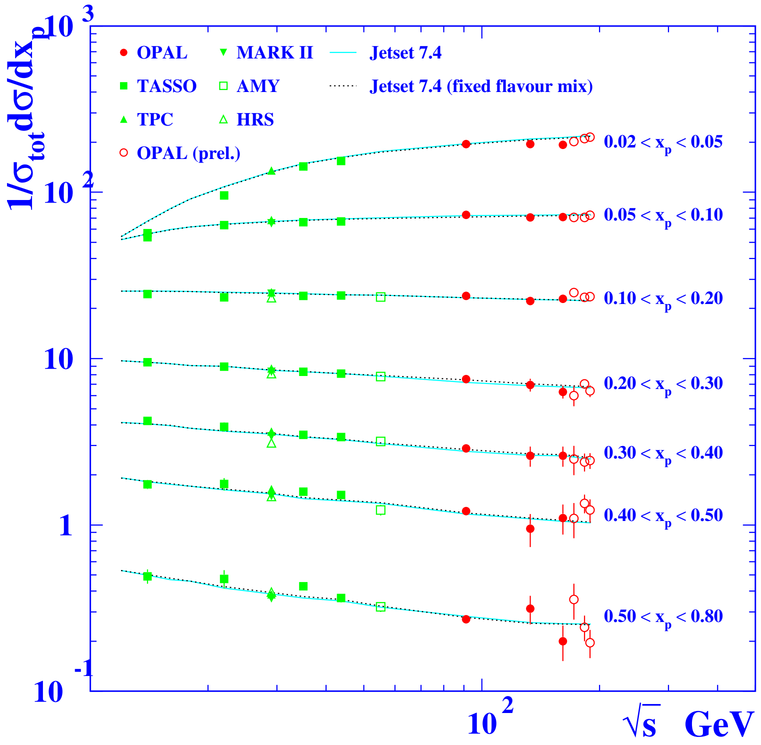
Flavour Dependent Fragmentation Function

PAPER 294 — OPAL, CERN-EP/98-089, submitted to Euro. Phys. Journal C

- $x_p = p/\sqrt{s}$ distributions at different cms energies

$\sqrt{s} = 22$ GeV : $R_b = 8\%$

$\sqrt{s} = 91$ GeV : $R_b = 22\%$



- $x_p = p/\sqrt{s}$ distributions at $\sqrt{s} = 91$ GeV

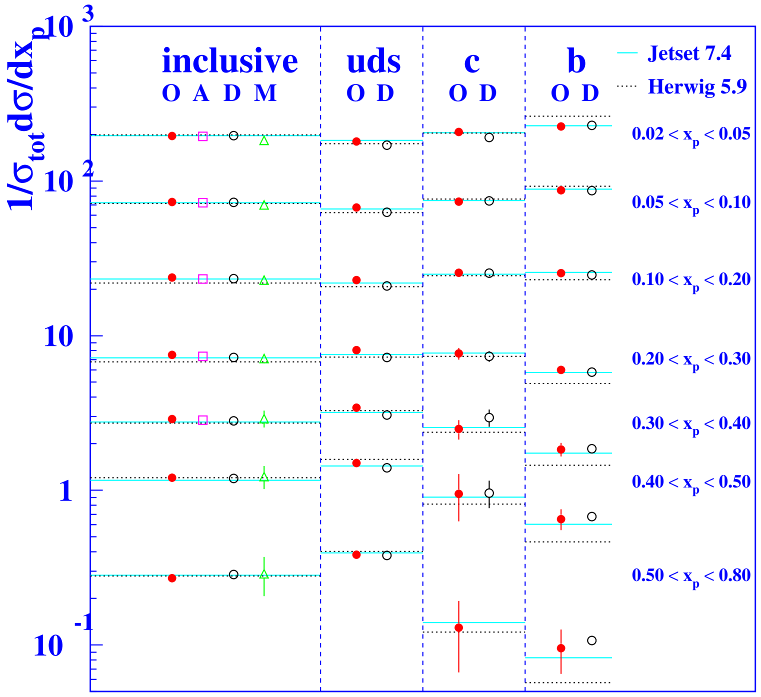
tagged uds, c, b events

$\Downarrow$

flavour dependent

- x_p
- $\xi = \log 1/x_p$

distributions.



O: OPAL A: ALEPH D: DELPHI M: MARK II

Summary

- Rapidity Correlations
  - π,K,p
    long range KK, $\pi\pi$, πK and pK correlations
    "signed rapidity"
  - Λ
    good description using Jetset
    popcorn parameter = 70%
- Bose-Einstein Correlation
  - 3 charged π
    significant genuine 3-pion correlation observed
  - 2-dimensional
    $R_{\|} > R_{\mathrm{T}}$
- $f_J(2220) \rightarrow K_s^0 K_s^0$
  signal can't be confirmed

- Total Transverse Momentum Correlation
  Jetset fails to describe data
- Flavour Dependent Fragmentation Functions
  soft x_b spectrum for b-quark events