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Bose-Einstein Correlations, Colour Reconnections, etc. at the Z^0

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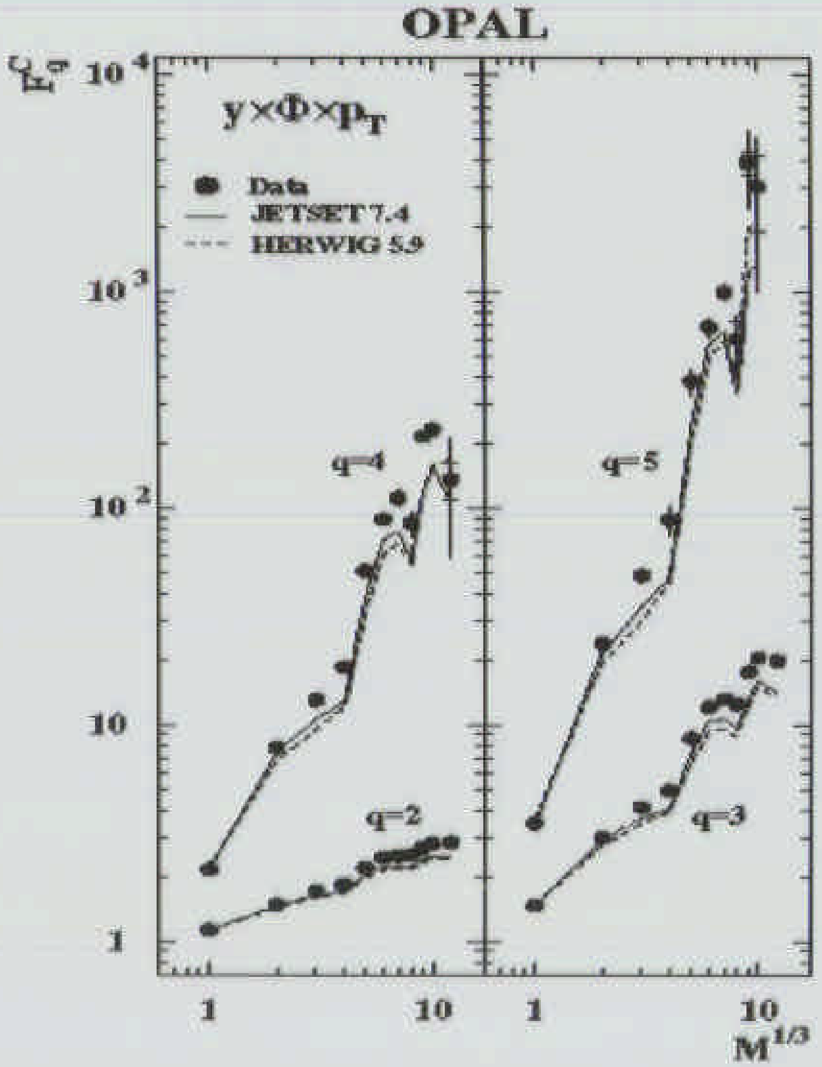
Mini-review of papers :

1) #117 OPAL Intermittency & Correlations
2) #643 L3 Moments of ch. multiplicity distribution
3) #101 OPAL BE in K^+K^+ in Z->2jets
4) #637 DELPHI BE in W^+W^- and Z^0 (Z^0 aspects)
5) #104 OPAL Transverse & Longitudinal BE in $\pi^+\pi^+$

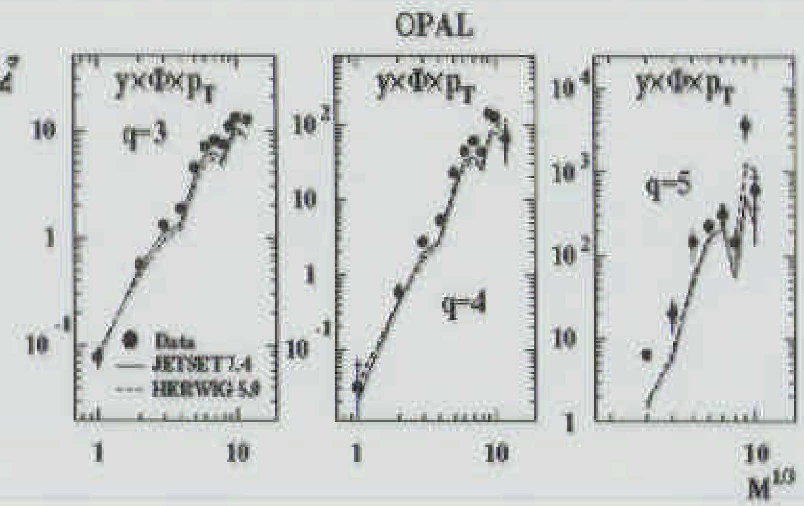
1)Intermittency and correlations (OPAL, Paper #117)

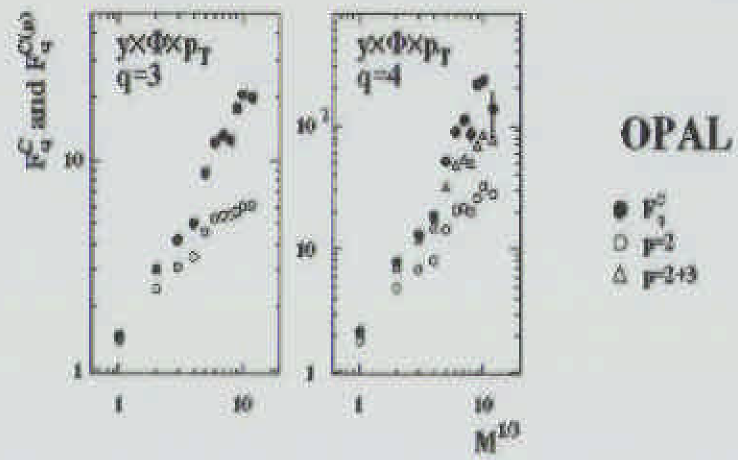
- **Results:**
- no intermittency in p_t (contrary to hadron-hadron)
- intermittency larger in y than in Φ
- saturation in y and Φ for $M \geq 10$ (QCD ?)
- intermittency behaviour of F_q enhanced 1dim->3dim
- no saturation in 2 & 3 dim (jet formation ?)



1)Intermittency and correlations (OPAL, Paper #117)

- Cummulants large & positive → genuine multiparticle correl. exist (larger than in hh)
- Genuine multiparticle correl. are larger in higher dimension
- Considerable contributions up to four-particle observed
- Contributions of many particle correlations increase with decreasing bin size
- Herwig5.9 and Jetset7.4 reproduce the data qualitatively, but underestimate for M>10



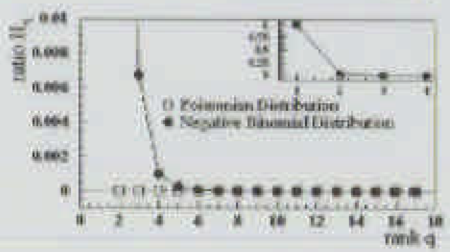


2) Moments of multiplicity distr. (L3, #643, Preliminary)

- **Method:**

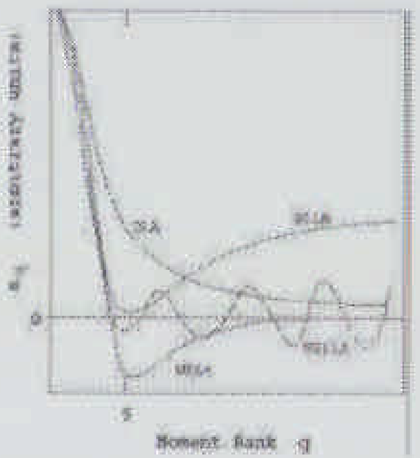
$$H_q = \frac{K_q}{F_q}$$

(same order of magnitude over wide q range; F_q, K_q grow rapidly with moments order q)



H_q measures the genuine q-particle correlation integral relative to the density integral

Can be calculated in pQCD for soft gluon multiplicity distristribution using different approximations:

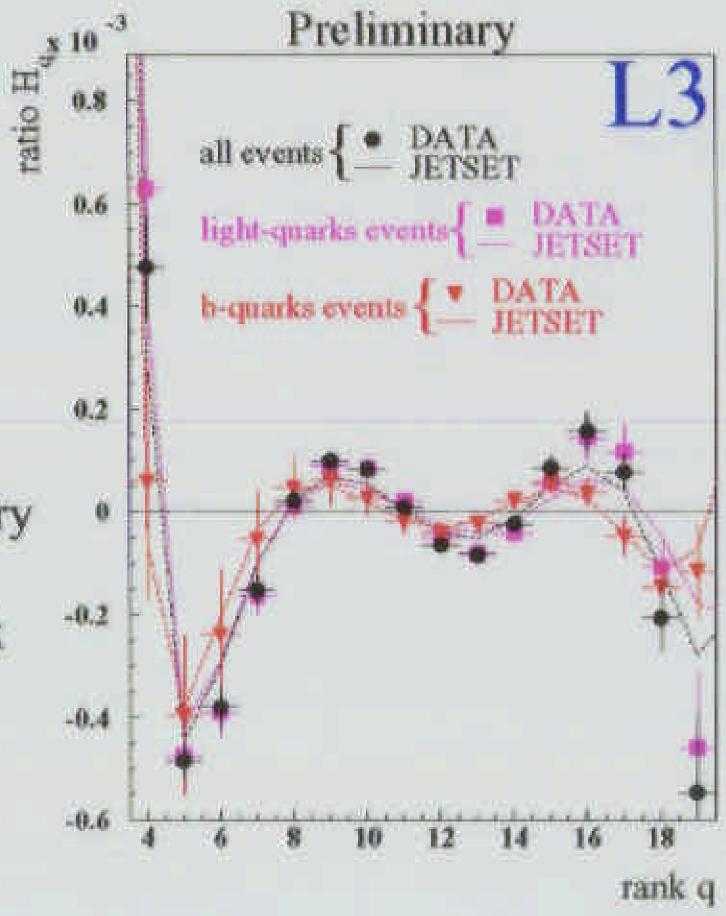


The same behaviour can be expected for particle distributions, assuming LPHD hypothesis

SLD : oscillations observed → NNLLA confirmed

2) Moments of multiplicity distr. (L3, #643, Preliminary)

Data: 1.5M Z^0 (1M selected)
- Distributions corrected with iterative unfolding method (less MC dependence)
- quark tagging : Purity 93% for uds (ε=90%), 97% for b (ε=37%)



Results:
- Negative minimum at q=5-6 and oscillatory behaviour at high q observed
- no significant difference for uds / b (quark mass effects play no role?)
- JETSET agrees well with the data (although it is not NNLLA calculation)
-HERWIG agrees qualitatively, but oscillations too strong

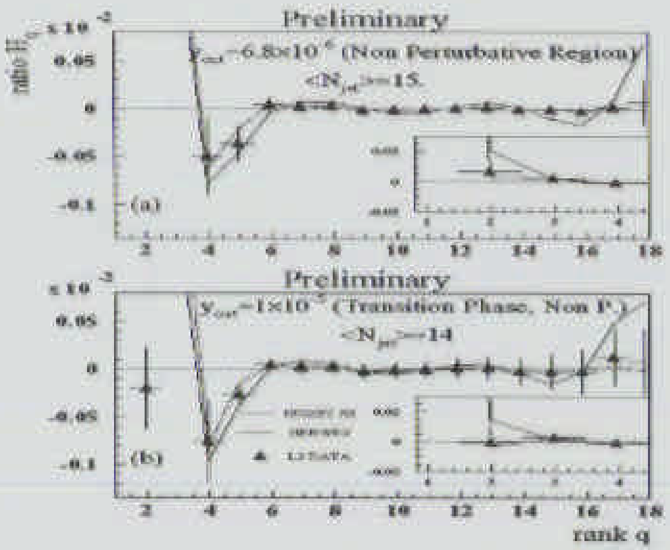
2) Moments of multiplicity distr. (L3, #643, Preliminary)

Jet multiplicity analysis:

- Assume the jet mult. is related to parton mult. at the energy scale = the jet resolution

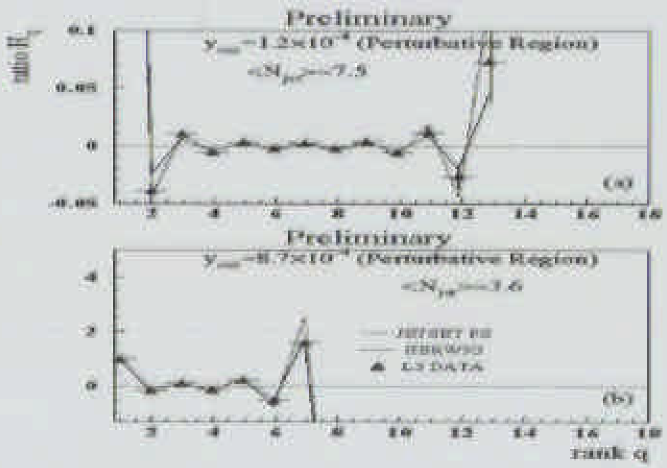
-Cambridge jet algorithm

-with increasing y_{cut} (E scale 0.23 →2.7 GeV) the minimum and oscillations disappear



MC study:

- all parton gneration and string fragmentation variants of JETSET and HERWIG show the oscillatory behaviour of the H_q



Conclusion:

the oscillations are unlikely to be related to the NNLLA

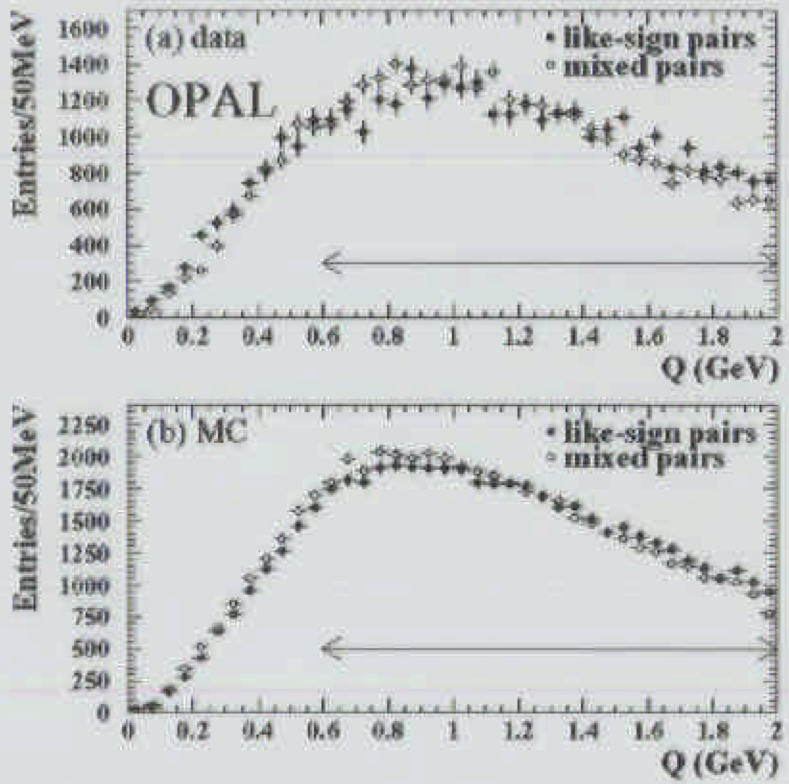
Conclusions on intermittency and correlations

- Intermittency clearly observed by the LEP experiments
- MC programs correctly describe the trend in the data (why?), but quantitative agreement is less impressive
- The genuine multiparticle correlations exist and are larger than those observed in hadron-hadron (effect of smaller number of elementary processes?)

3) BE Correlations in $K^{\pm}K^{\pm}$ (OPAL, #101)

- Information on correlations in identical strange boson pairs is scarce:
  $K^{\pm}K^{\pm}$ - one measurement (DELPHI)
  K^0K^0 - three measurements (A,O,D), but possible complications from $f_0(980)$
  - R_{KK} measurement important to clarify the possible dependence of the source dimension on the boson mass

- **Data:** 3.9 M $Z^0 \rightarrow$ hadrons
  $\rightarrow$ 76k 2jet events (thrust >0.95)
  Purity(KK)=48%



- **Method:** $C_{mix}(Q) = \dfrac{N_{++}^{data}(Q)}{N_{mix}^{data}(Q)} \Big/ \dfrac{N_{++}^{MC}(Q)}{N_{mix}^{MC}(Q)}$

$$C(Q) = N(1+\lambda e^{-(RQ)^2})(1+\delta Q+\varepsilon Q^2)$$

$$Q^2 = -(p_1 - p_2)^2$$

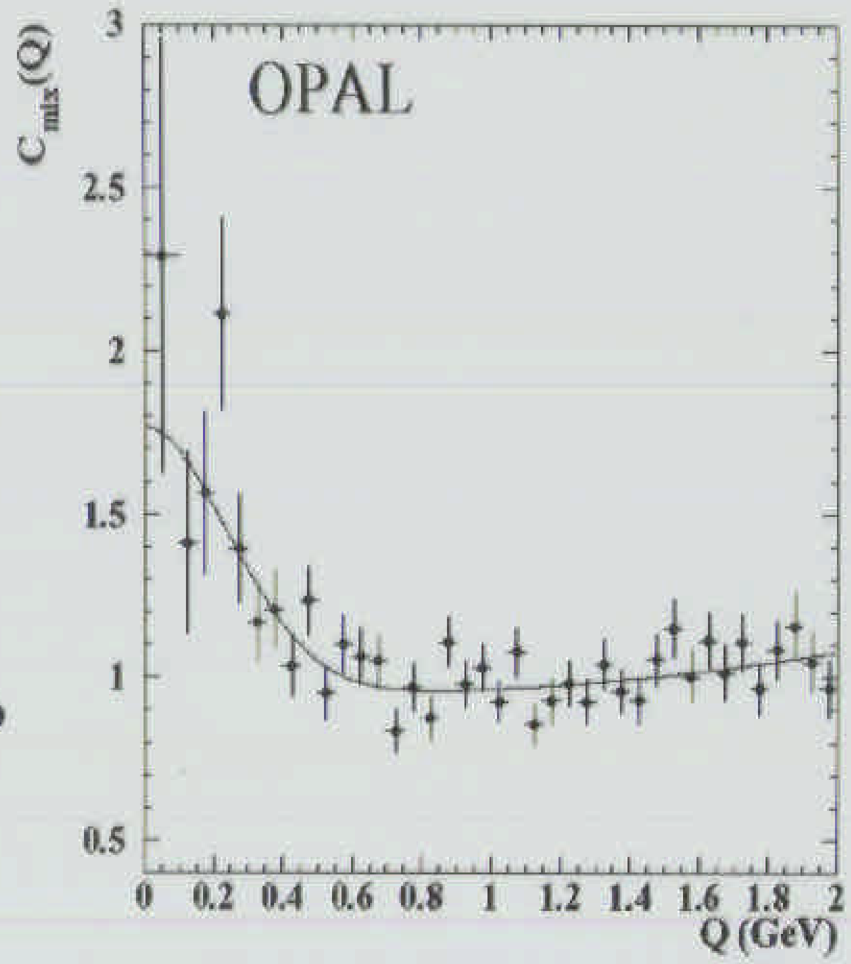
3) BE Correlations in $K^{\pm}K^{\pm}$ (OPAL, #101)

Results:

$$\lambda = 0.82 \pm 0.22^{+0.17}_{-0.12}$$

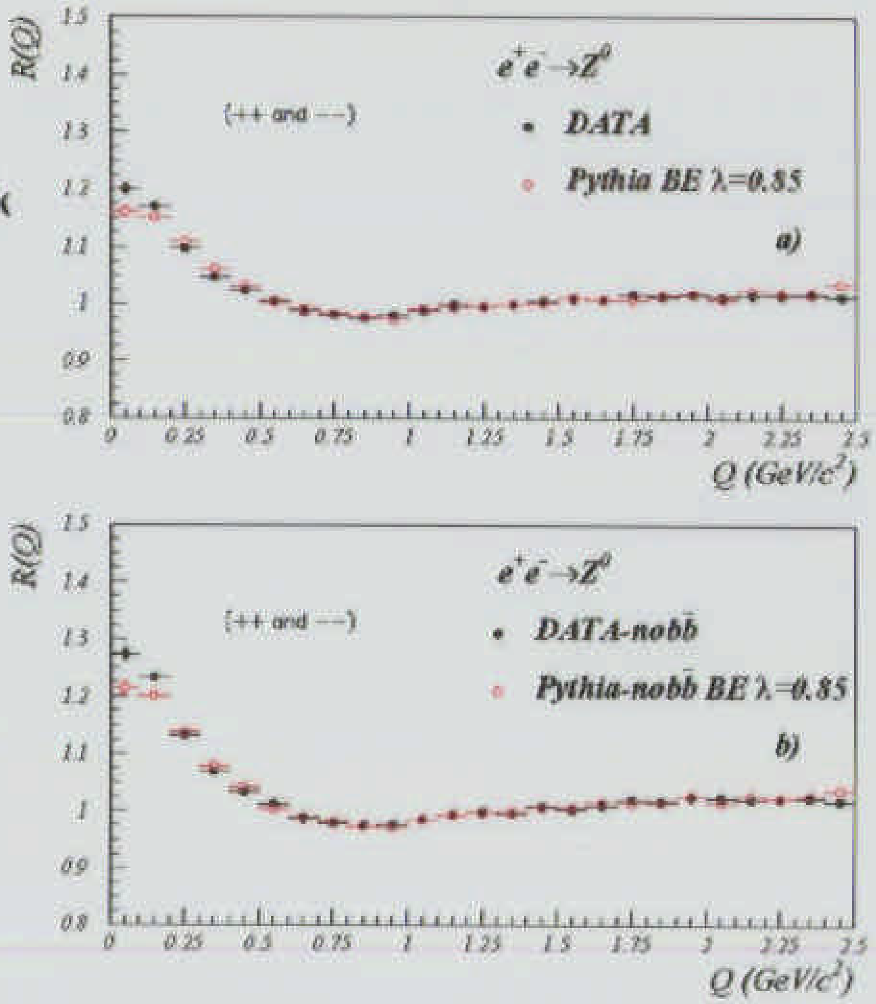
$$R_0 = (0.56 \pm 0.08^{+0.08}_{-0.06})\,fm$$

- no correction for final-state interaction (small effect)
- effect of short lived sources small
- the result is compatible with measurements of the $\pi\pi$ source radius **obtained with the same technique** (two jets,mixed ref. sample,double ratio)



4) BE Correlations in $\pi^{\pm}\pi^{\pm}$ from Z^0 (DELPHI, #637)

DELPHI(preliminary)



- As a part of the study of two-particle correlation function in hadronic Z decays, fully hadronic and mixed hadronic-leptonic WW decays

- Reference sample : MC like sign pairs

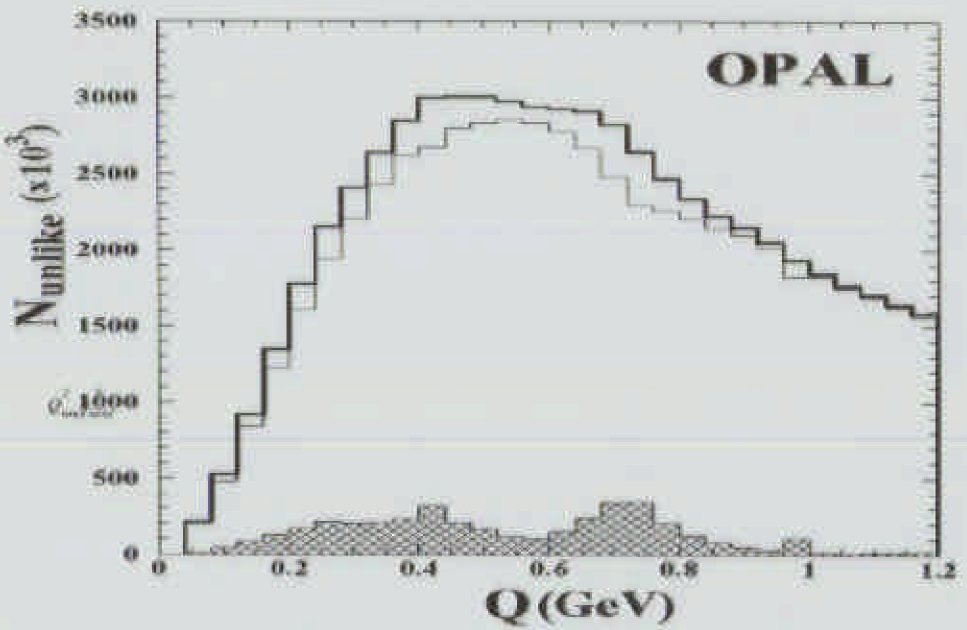
- Two measurements:

$$\lambda_{all} = 0.233 \pm 0.007(stat)$$
$$R_{all} = 0.573 \pm 0.016(stat)\, fm$$

$$\lambda_{no-bb} = 0.306 \pm 0.009(stat)$$
$$R_{no-bb} = 0.585 \pm 0.016(stat)\, fm$$

5) Transverse&Longitudinal BE in $\pi^{\pm}\pi^{\pm}$ (OPAL, #104)

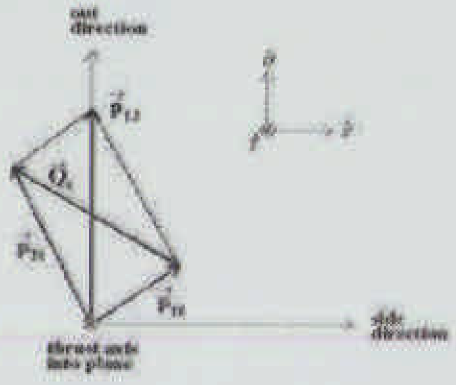
Data: 4.3M $Z^0 \rightarrow$hadrons
inclusive sample & 2jet (Durham)



Method:

Refererence sample : $\pi^+\pi^-$ from the data (K^O_S, resonances subtracted, Coulomb interactions corrected)

3 dim analysis in Longitudinaly CoMoving System (LCMS): space dim. of the source in Q_l ,Q_{tside} space-time in Q_{tout}



Correlation function parametrized with 3 dim Goldhaber formula (+ term describing long-range correlations)

5) Transverse&Longitudinal BE in $\pi^{\pm}\pi^{\pm}$ (OPAL, #104)

Results:

$\lambda = 0.443 \pm 0.005$

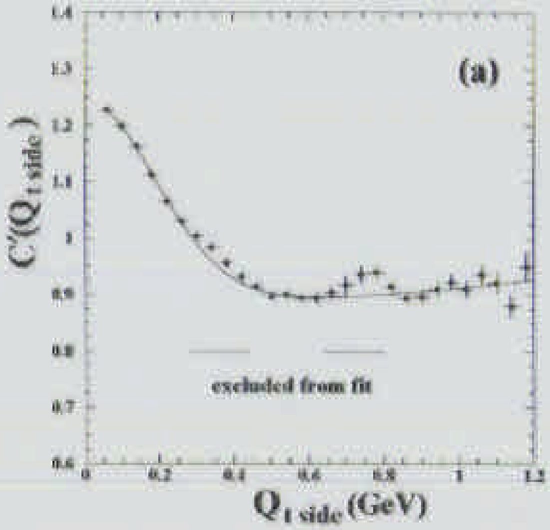
$r_{tside} = 0.809 \pm 0.009^{+0.019}_{-0.032}\ fm$

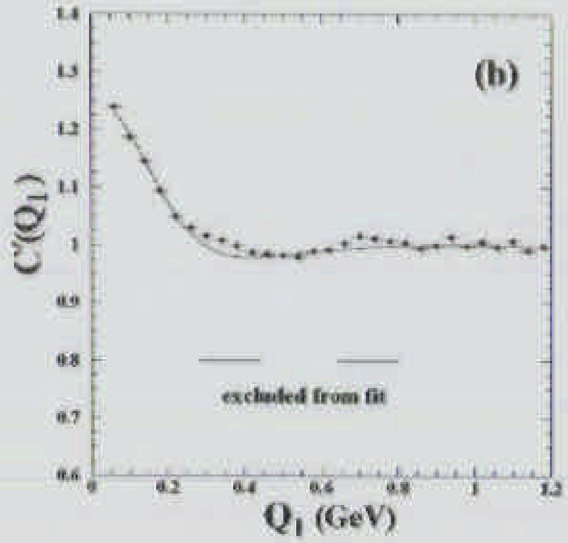
$r_l = 0.989 \pm 0.011^{+0.030}_{-0.015}\ fm$

$r_{tout} = 0.647 \pm 0.011^{+0.024}_{-0.124}\ fm$

$r_l / r_{tside} = 1.222 \pm 0.027^{+0.075}_{-0.012}$

(y_{cut}=0.04)





- Compatible with results of L3($1.23 \pm 0.03^{+0.29}_{-0.05}$) and Delphi ($1.60 \pm 0.07 \pm 0.15$ (mixed reference sample in both, Delphi: 2dim analysis)
- r_l does not depend on y_{cut}, while r_{tside} and r_{tout} show small dependence (opposite)
- 1 dim analysis gives : $r = 1.002 \pm 0.016^{+0.023}_{-0.096}\ fm$

Conclusions on BE Correlations

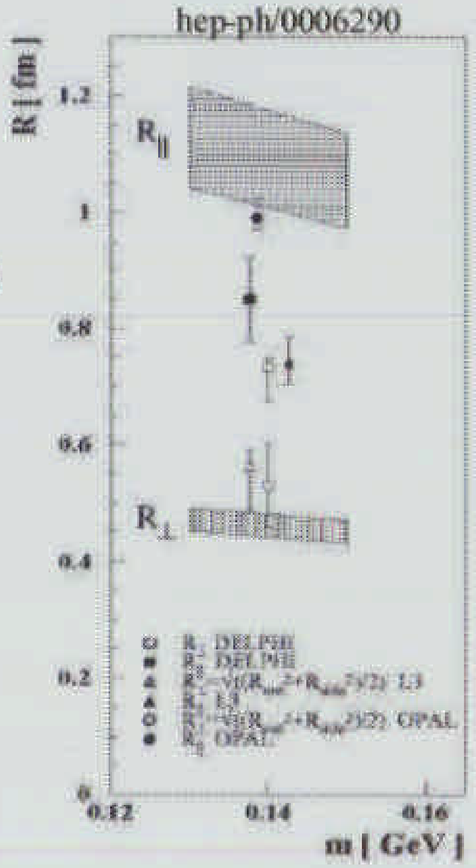
1) Longitudinal elongation of the source of pions (by ~20%) seen by OPAL, L3 ,DELPHI

•Expected in the string phenomenology of e+e- → hadrons (B.Andersson,M.Ringner Phys.Lett. B421(1998) 283)

•Obtained also in a classical picture of particle production from expanding tube (A.Bialas et al. hep-ph / 0006290) based on the Gottfried-Bjorken hypothesis of in-out cascade

2) Question if $r_{\pi\pi} > r_{KK}$ still needs to be clarified, however $r_{\Lambda\Lambda}$ measurements (no need for the reference sample) suggest rather strong mass dependence of the correlation radius

•r=f(m) may be understood from the uncertainty principle (G.Alexander et al. Phys.Lett. B452 (1999) 159), if the observed correlation radii correspond to the actual size of the emission region



Conclusions on BE Correlations

•The model of Bialas et al. predicts the mass dependence, the change in the correlation radius comes only from the correlation between the 4-momentum of the particle and the space-time coordinate at which it is produced

3) Measurements of BE correlations are **relative** measurements (thus difficult - see the plot), this calls for some standarization of the reference sample and phase space region in which measurements are done