Final State Interactions in hadronic W pair decays at LEP: Status of combination

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- Introduction
- Colour Reconnection
- Bose-Einstein Correlations
- Conclusions

On behalf of the LEP W Working Group

All results are preliminary

LEP jamboree
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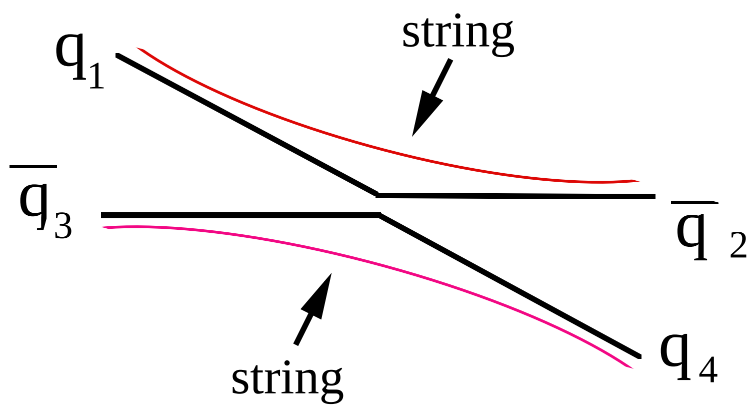
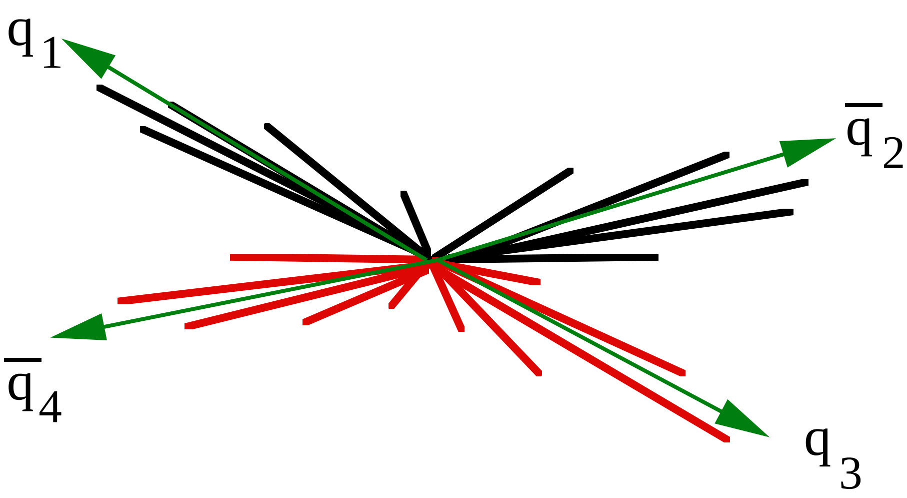
$e^+e^- \rightarrow W^+W^- \rightarrow q_1\bar{q}_2q_3\bar{q}_4$ events





W bosons decay at short distances ($1/\Gamma_W$=0.1fm)

$\rightarrow$ Coherent gluon emission from both $q\bar{q}$ systems for $E_g < \Gamma_W$)

$\rightarrow$ Large space-time overlap during hadronisation process (typical scale about 1fm)

$\Rightarrow$ "Colour Reconnection" in the non perturbative phase

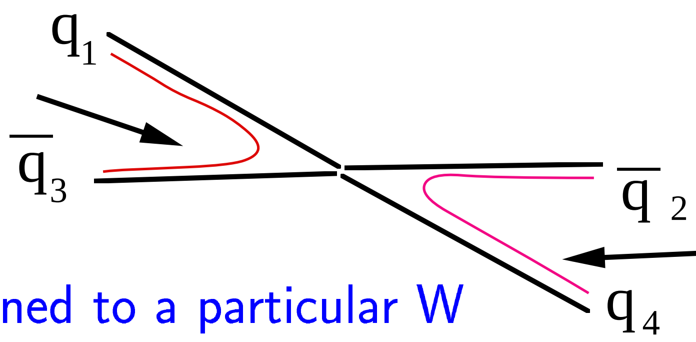
$\Rightarrow$ Bose-Einstein Correlations between particles from different W

Introduction: FSI and W mass

CR: ⇒ Colour flow pattern is modified

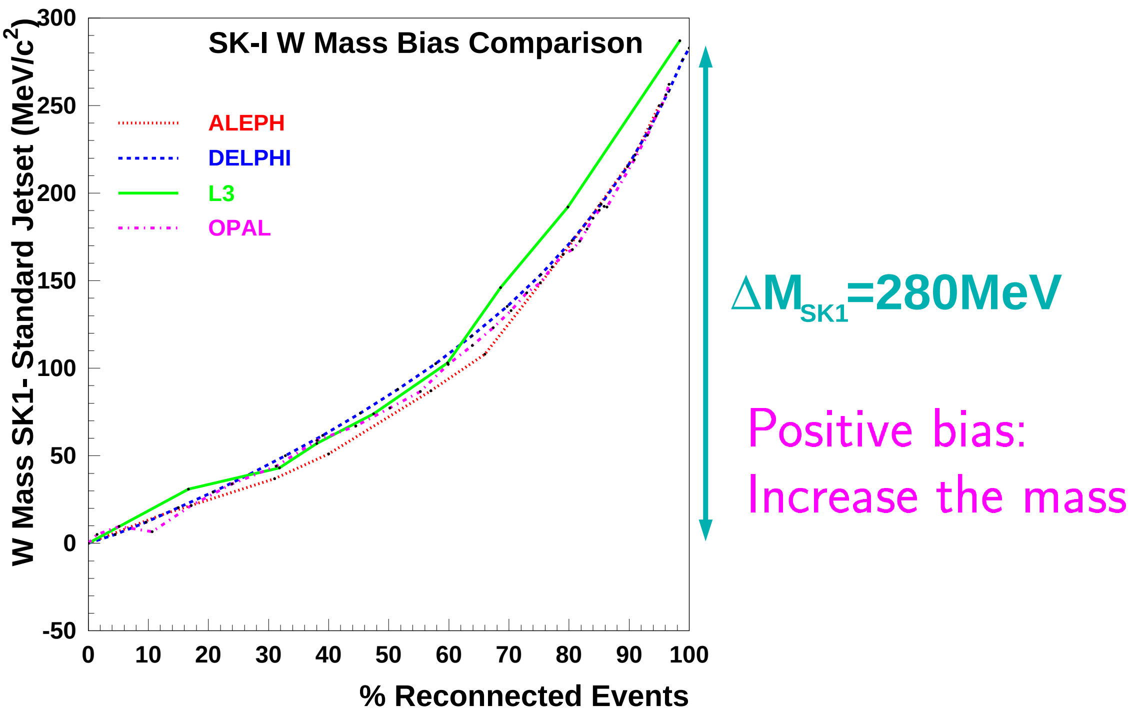
- Particle distributions are affected

⇒ depletion, enhancement etc...



- Particles cannot be uniquely assigned to a particular W

⇒ potential bias when determining M_W from jets.



⇒ essential to estimate or constrain P_{reco} from data.

BEC: ⇒ phase space for 2 identical particle emission is modified

- Particle densities between jets from different W are affected.

⇒ with inter W correlations $\Delta M_W \approx -35$ MeV .

Colour reconnection:

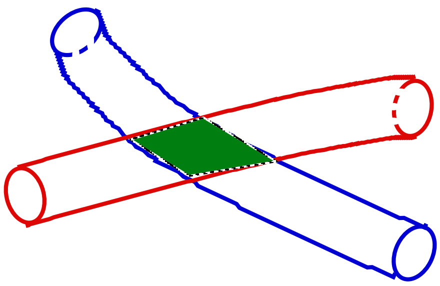
PYTHIA: Rearrangement of string topology

- SK: Sjöstrand-Khoze models (Z.Phys.C 62 (1994) 281.)

  Reconnections allowed if strings cross or overlap (SKI,II,II')
  (space-time evolution):

  $\Rightarrow$ SKI: extended flux tubes

  $\Rightarrow$ 1 reconnection: most overlapping



free strength parameter k_I
$\rightarrow$ control reconnection probability

$$P_{reco} = (1\text{-}e^{-f(\sqrt{s}).k_I})$$

ARIADNE: Gustafson-Häkkinen model (Z.Phys.C 64 (1994) 659.)

- Reconnections of colour dipoles if total string length reduced

  $\Rightarrow$ AR2: only after radiation of gluons with $E_g > \Gamma_W$

HERWIG: Local cluster reconnection (J.Phys.G24 (1998) 2.)

- In fragmentation phase, clusters are rearranged if reduction of the space-time extension of the clusters

Bose-Einstein Correlations:

PYTHIA: LUBOEI Jetset routines

- Reshuffle the final state particle momenta to simulate the BEC

The Particle Flow Method

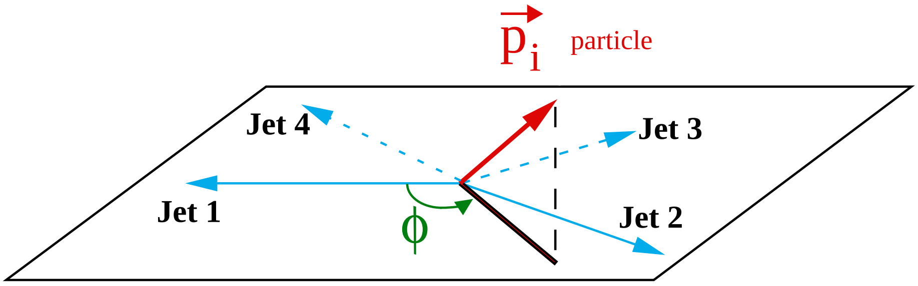
Idea initiated by L3: investigate the particle- flow between jets in qqqq events.

⇒ probe the colour topology of the events

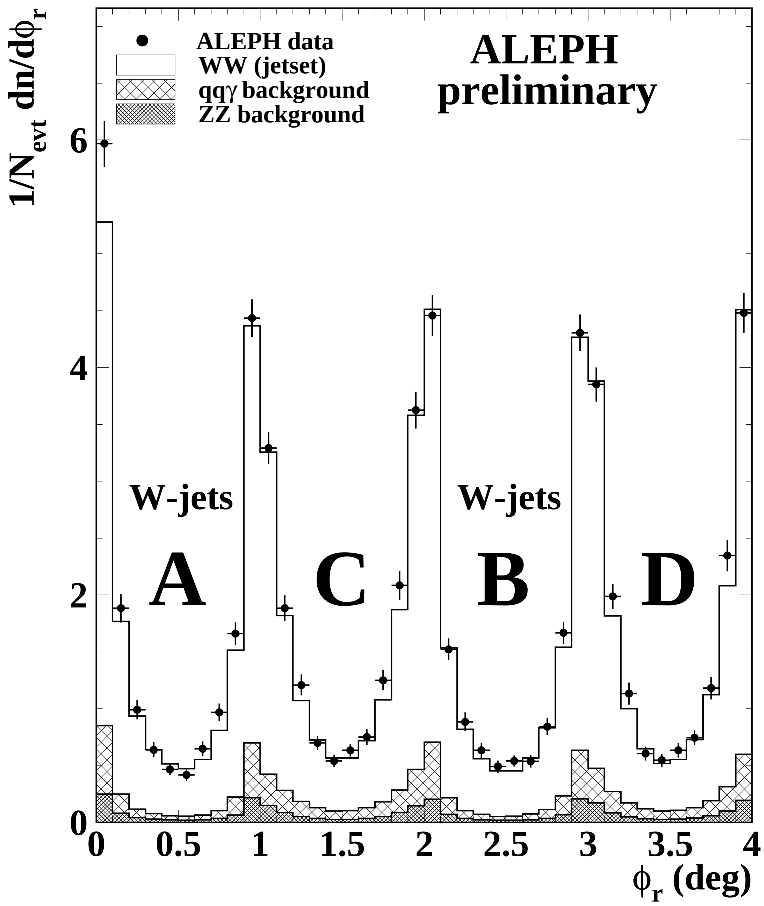
Principle:

In hadronic 4-jet events:

- Identify the jets from the two W boson decays.
- Build the particle flow distributions between pair of jets.



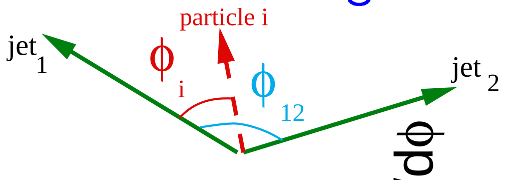
particle flow: $\frac{1}{N_{evt}} \frac{\Delta n}{\Delta \phi}$



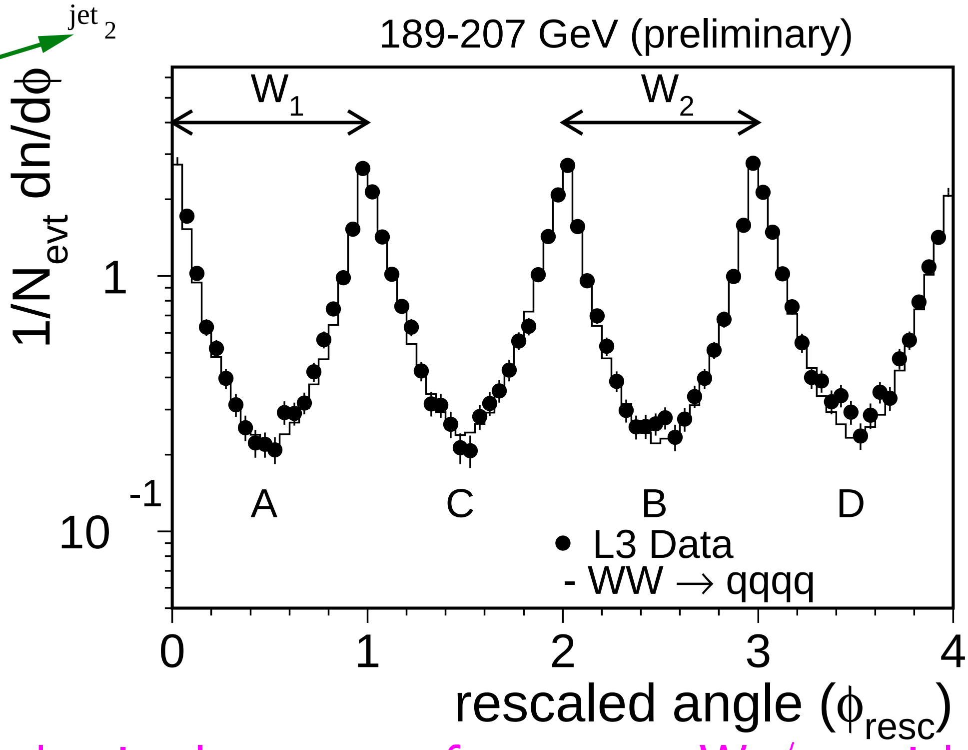
jets (1,2) and jets (3,4) are associated to the W's.

The Particle Flow Method

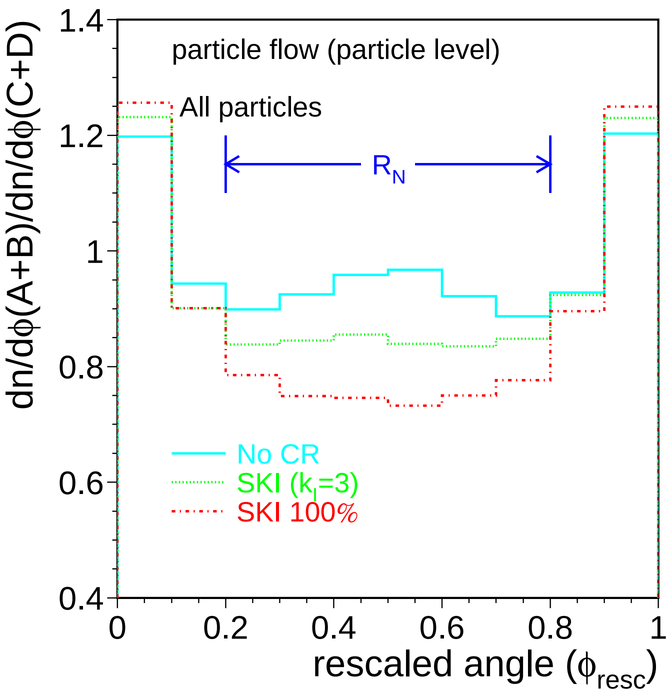
- Rescale angles and subtract background bin-by-bin



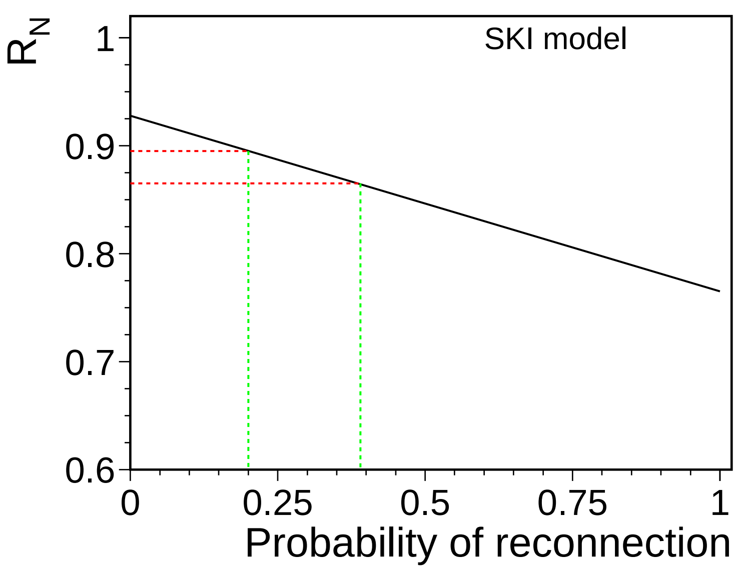
Interjet regions are sensitive to CR effects



Variable: particle density between q from same W / particle density between q from different W

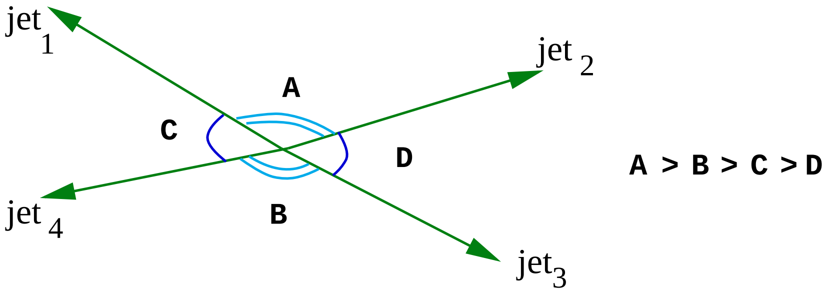


$$R_N = \frac{\int_{0.2}^{0.8} \frac{1}{N_{evt}} \cdot \frac{dn}{d\phi}(regions A+B)}{\int_{0.2}^{0.8} \frac{1}{N_{evt}} \cdot \frac{dn}{d\phi}(regions C+D)}$$



LEP particle flow: Event selection

- DELPHI and L3: Tight topological cuts based on interjet angles to assign jets to W.



clean event topology with symmetric interjet regions ⇒ trivial string configuration.
but low efficiency.

- ALEPH and OPAL: More inclusive selection based on their standard W analysis
  - association between pairs of jets and W using 4-jet Matrix Element (A) or a likelihood variable (O)

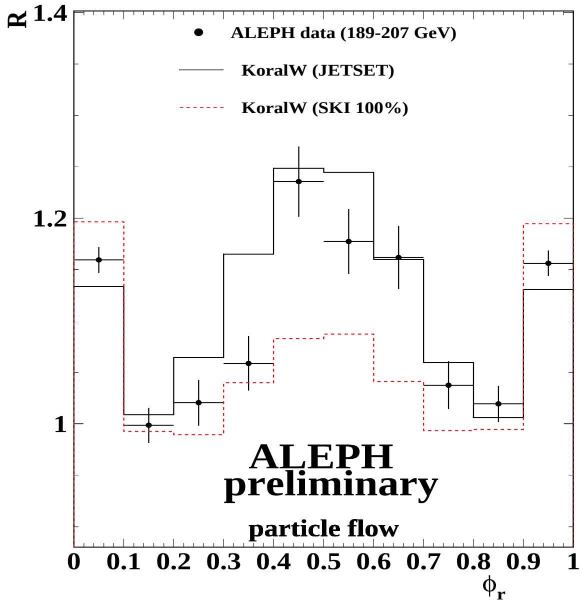
better efficiency, more statistics, .

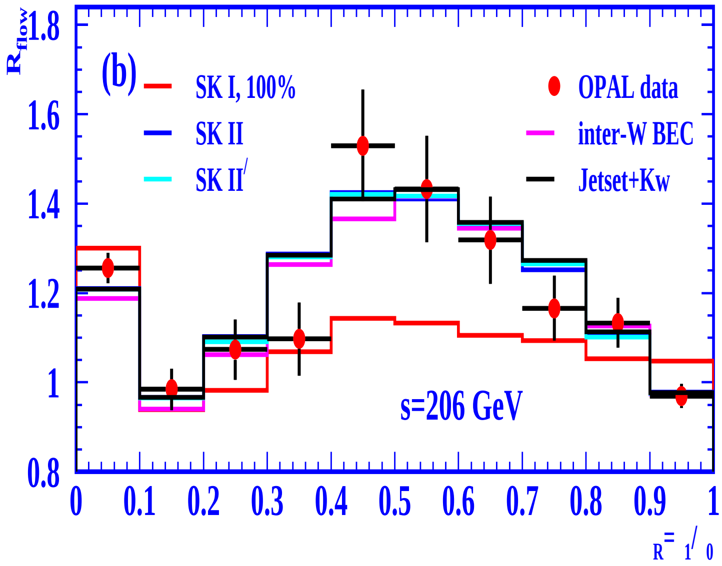
but less planar events ⇒ less trivial configuration.

	$\sqrt{s}$ (GeV)	$\int \mathcal{L}(\mathrm{pb}^{-1})$	# evts	ϵ	π	right pair.
DELPHI	183-208	601.4	782	12%	87%	76%
L3	189-208	626.6	666	12%	85%	91%
ALEPH	189-208	626	4748	85%	84%	74%
OPAL	189-208	625	2199	40%	86%	90%

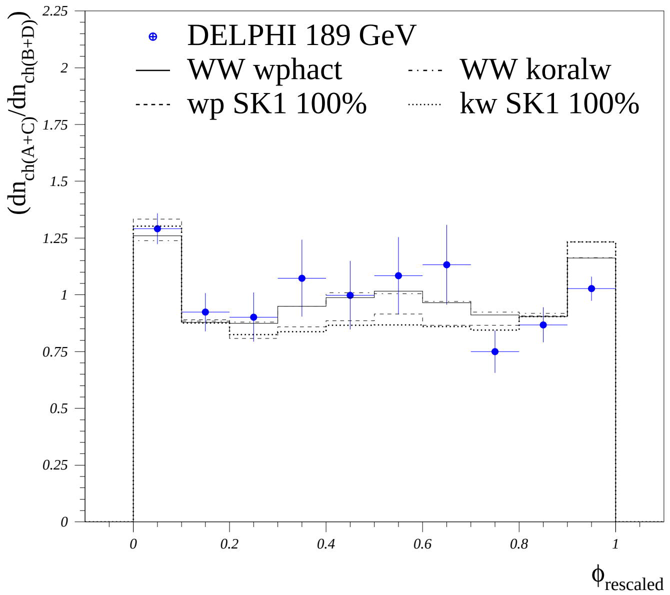
Latest Results submitted to ICHEP02

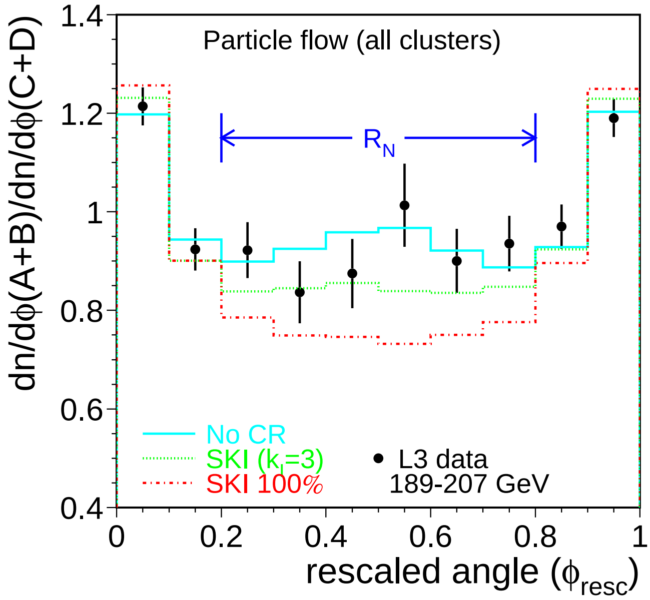
ALEPH and OPAL





DELPHI and L3





Combination Procedure

- Each experiment provides a value at 189 GeV

$$R_N = \frac{\int_{0.2}^{0.8} \frac{1}{N_{evt}} \cdot \frac{dn}{d\phi}(regions A+B)}{\int_{0.2}^{0.8} \frac{1}{N_{evt}} \cdot \frac{dn}{d\phi}(regions C+D)}$$

- since there is no unfolding the result $R_N^{\rm data}$ is normalised to the prediction of No CR model common to the 4 experiments

$$r = \frac{R_N^{\rm data}}{R_N^{\rm no-CR}}$$

- Combine results weighted by predicted sensitivity from common files.

the weight assigned for each CR model, i is:

$$w_i = \frac{(R_N^i - R_N^{\rm no-CR})^2}{\sigma^2_{R_N}({\rm stat.}) + \sigma^2_{R_N}({\rm syst.})}$$

- Common LEP MC samples: KORALW events

JETSET	SKI 100%
ARIADNE	AR2
HERWIG	Herwig CR

Systematic uncertainties

Correlated sources between experiments:

- •WW Fragmentation model: ±0.0081
  spread among JETSET, HERWIG and ARIADNE
- •qq background subtraction: ±0.0031
  qq Xsection variation
  ZZ Xsection variation
- •Bose Einstein effects: ±0.0012
  difference between BEC within same W and No BEC

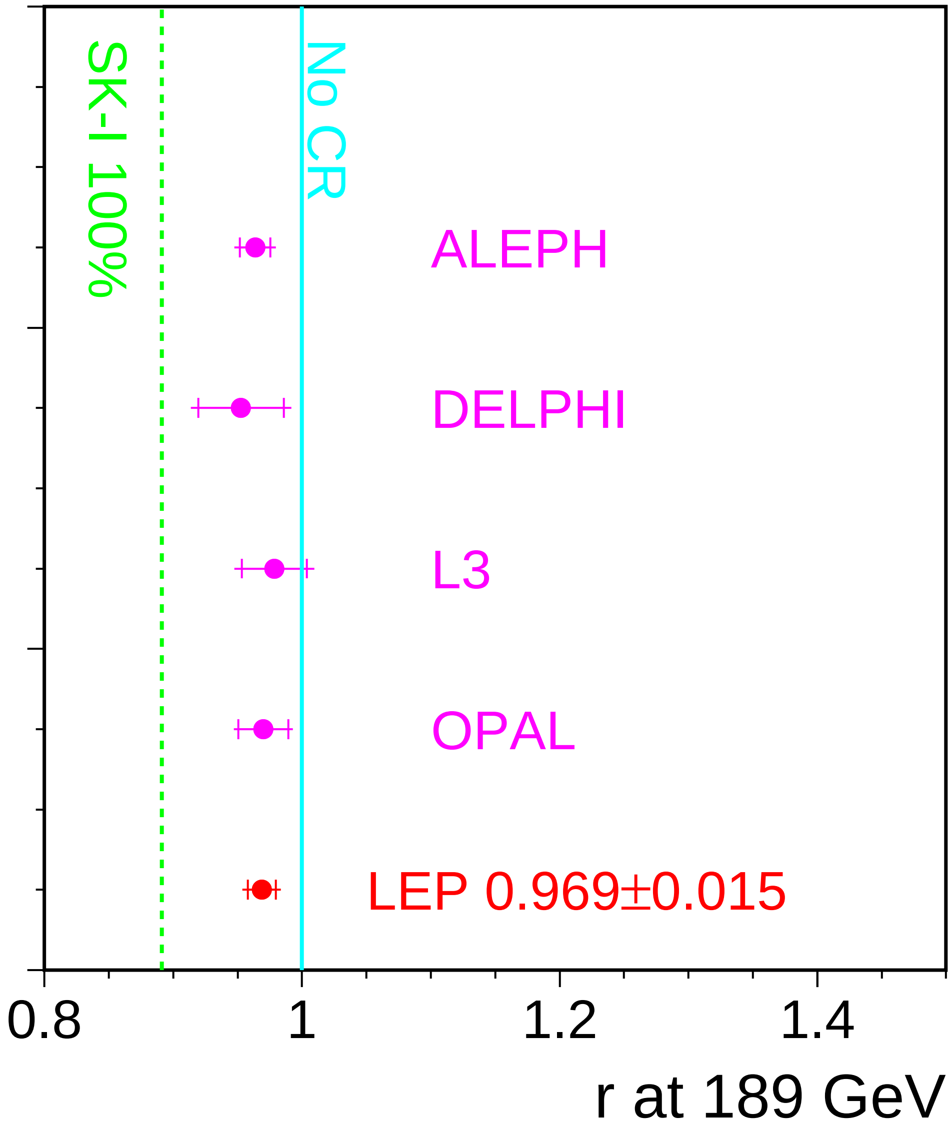
Assign the smallest uncertainty among the 4 exp. as correlated and the remainder (subtracted in quadrature) is treated as uncorrelated

Uncorrelated sources:

- •qq background shape: ±0.0010-0.0098
  qq model variation: Jetset versus Herwig or Ariadne
- • $\sqrt{s}$ extrapolation ±0.0023-0.0122
  compare results from various models
- • Detector related systematics ±0.0018-0.0055
  variation of energy flow objects

Example with SKI model 100%

$$r = \frac{R_N}{R_N^{No-CR}}$$



$r^{ADLO} =$

$0.969 \pm 0.011(stat.) \pm 0.009(corr.) \pm 0.006(uncorr)$

$r^{SK1(100\%)} = 0.8909 \Rightarrow$ significance: 5.2 σ