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Colour reconnection studies using particle flow between W bosons

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Abstract

The particle production between jets coming from the same and different W bosons has been investigated. The normalized particle flow distribution is found to be sensitive to effects coming from colour reconnection in the framework of the string model.

A scan over the free parameter k_i in the SKI colour reconnection model leads to a 1σ limit of $k_i < 1.4$. This corresponds to a shift in the W mass of less than 40 MeV.

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1 Introduction

In the energy range of LEP2 the average space time distance of the decay vertices of the W bosons is 0.1 fm, whereas the typical hadronic fragmentation scale is about 1 fm. Consequently the two W decay systems overlap strongly in space time and the fragmentation might not be independent in the fully hadronic channel.

Perturbative effects are highly suppressed by the structure of QCD [1], but interactions of the two systems during fragmentation might lead to effects like Bose Einstein correlations and colour reconnection between the W systems. These effects might also influence the W mass measurement.

In this contribution the particle flow between the jets is investigated following the approach of the L3 collaboration [2] and information about colour reconnection in the framework of the SKI model [1] is extracted. All results are preliminary.

2 Event sample, detector and event selection

The present analysis is based on data samples taken in the years 1998 and 1999. The taken luminosities at the considered energies were 176.9 pb^{-1} (189 GeV), 82.6 pb^{-1} (196 GeV) and 87.8 pb^{-1} (200 GeV). The ALEPH detector is described in detail elsewhere [3].

The used selection is following as close as possible the proposed method of the L3 collaboration [2]. The analysis is based on calorimetric objects as well as charged tracks measured in the tracking system. The total visible energy (E_{tot}) and the energy imbalance parallel ($E_{||}$) and perpendicular ($E_{\perp}$) to the beam axis is measured and is used for the following cuts:

- $E_{tot}/\sqrt{s} > 0.7$;
- $E_{\perp}/\sqrt{s} < 0.2$;
- $E_{||}/\sqrt{s} < 0.2$;
- $N_{efl} \geq 40$.

N_{efl} denotes the number of energy flow objects whose definition is described in [4]. To reduce the contamination from initial state radiation (ISR) and semileptonic WW decays, all events with a γ, $e^{\pm}$ or $\mu^{\pm}$ with an energy higher than 25 GeV are rejected.

After this selection the events are clustered with the DURHAM cluster algorithm with $y_{cut} = 0.01$. All 4-jet events are selected, the jet angles are measured and ordered. The smallest and second smallest jet angles should be lower than 100°, the next two jet angles must lie between 100° and 140°. The jets with the larger opening angles are defined to come from the same W boson (region A and C in figure 1). The pairing efficiency is found to be of the order of 88%. The result of the event selection is shown in table 1. As the selection is optimized for 189 GeV the efficiency is slightly decreasing with the center of mass energy. The purity is rather stable.

	189 GeV	196 GeV	200 GeV
N_{exp}	254	103	101
N_{data}	235	124	87
ϵ	13%	12%	9%
p	79%	81%	80%
$f_{q\bar{q}}$	15%	13%	13%
f_{ZZ}	6%	6%	6%
$\mathcal{L}$	176.9 pb^{-1}	82.6 pb^{-1}	87.8 pb^{-1}

Table 1: Result of the event selection. N_{exp} and N_{data} denote the expected and selected number of events respectively. The efficiency ϵ is decreasing with the energy, the purity p is rather stable, as well as the contamination of the $q\bar{q}$ and ZZ background ($f_{q\bar{q}}$ and f_{ZZ} respectively). The last row shows the luminosity ($\mathcal{L}$) at the given energies.

3 The particle flow

To define the particle flow we start with the highest energetic jet, followed by the jet coming from the same W boson (jets 1 and 2 in figure 1). The third jet is the one with the lower angle to jet 2. The remaining jet is jet 4. All the momenta of the particles are projected into the plane which is defined by the first two jets and the angles of the projected momenta are measured from the first (most energetic) jet. The particle flow is shown in figure 2. The structure of the four jets can clearly be observed, but the different interjet regions can not be compared. In order to be able to compare the particle production between the jets of the same and different W bosons the angle of the projected momentum of a particle is rescaled by the angle between the jets. If ϕ_i is the projected angle of particle i which is lying between the projected jets m and n where ϕ_{mn} defines the angle between them, the rescaled angle is defined as:

$$\phi_i^{resc} = \phi_i / \phi_{mn}.$$

This leads to the normalized particle flow distribution shown in figure 3. In this distribution the regions between the jets coming from the same and different W bosons are very similar and can be compared.

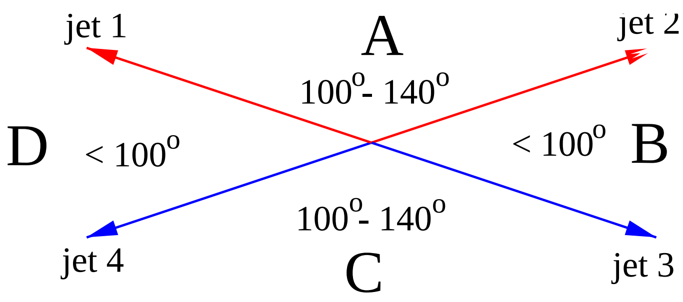

Figure 1: Schematic drawing of the angular selection. Region A and C define the regions between the jets from the same W-boson.

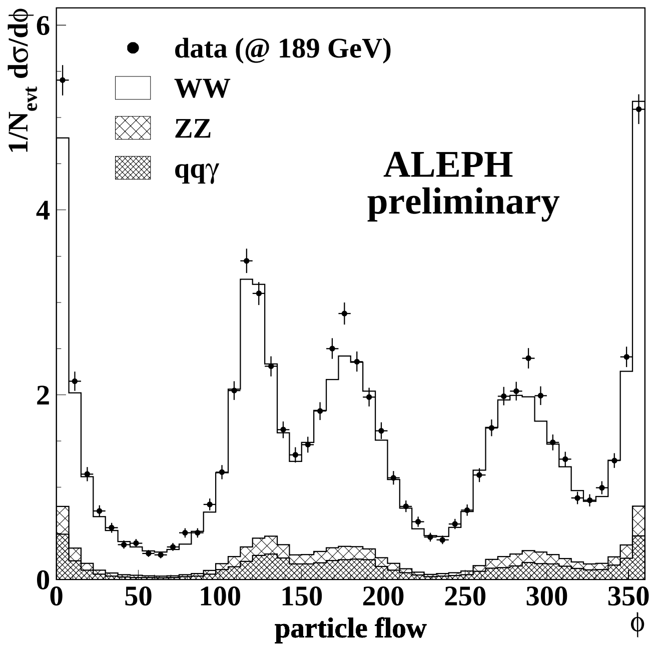

Figure 2: The particle flow distribution at 189 GeV.

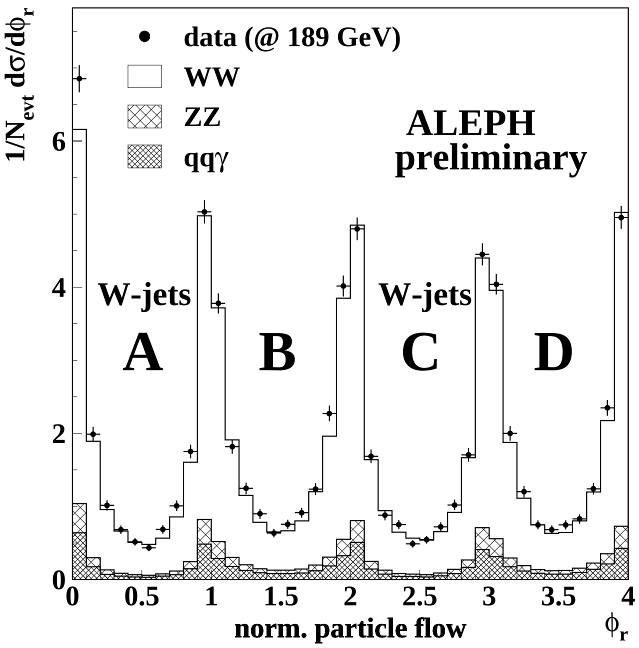

Figure 3: The normalized particle flow distribution at 189 GeV.

For the analysis the following observable is defined:

$$R = \frac{1/N_{evt} \cdot dn/d\phi(A+C)}{1/N_{evt} \cdot dn/d\phi(B+D)}.$$

This means the normalized particle flow of the regions A,C and B,D are summed up and compared by the ratio. This leads to the distribution which is shown in figure 4. This plot shows the combined data and MC distribution where the samples at the different energies are weighted with the number of events selected at the given energies.

It shows the data points compared to the KoralW MC sample with different values for the parameter k_i which defines the strength of colour reconnection in the SKI model. The used parton shower cut off parameter was $m0 = 1.52$. It can clearly be seen that colour reconnection leads to a decrease of the ratio distribution in the central region.

4 Scan over the free parameter k_i

Figure 5 shows the dependency of the fraction of reconnected events to the k_i parameter which is the free parameter of the SKI model. The circles show the dependency for the whole event sample, the triangles the one for the selected sample only. The selection leads to a suppression of the fraction of reconnected events, which is obvious from the described method of selection, because the two W systems are well separated.

The ratio distribution (figure 4) is integrated from 0.2 to 0.8 which was found to be the most

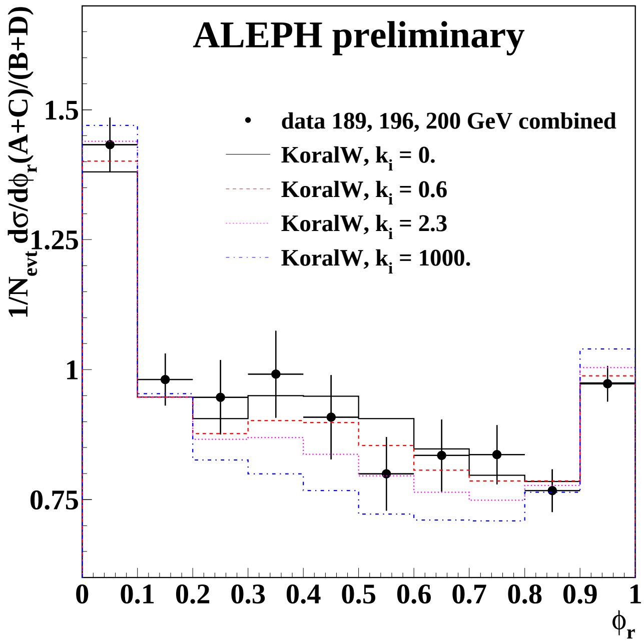

Figure 4: The ratio distribution as a comparison of data to different KoralW MC samples with different parameters k_i. The distributions are a combination of the event samples from the considered energies, weighted with the number of selected data events.

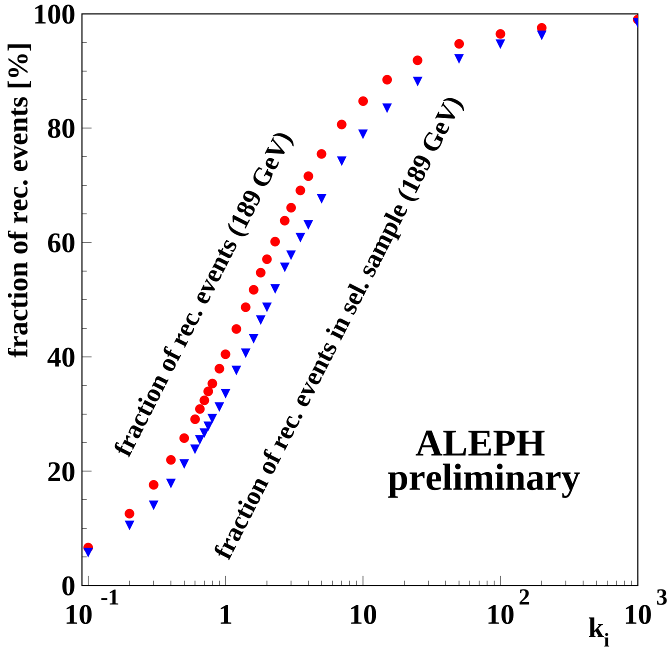

Figure 5: The dependency of the fraction of reconnected events in the whole and the selected MC sample to the free parameter k_i in the SKI model at 189 GeV.

sensitive region to colour reconnection:

$$R(0.2-0.8)=\int_{0.2}^{0.8}\frac{1/N_{evt}\cdot dn/d\phi(A+C)}{1/N_{evt}\cdot dn/d\phi(B+D)}dR'$$

The result for the data and the KoralW MC sample for different values of k_i is shown in figure 6. Bin-to-bin correlations are taken into account in the integration. The inner band defines the statistical error of the data point only, the outer includes the total error as the quadratic sum of statistical and systematical error. The systematic uncertainties are estimated by the following considerations:

- An event sample generated with KoralW and fragmented with jetset and herwig respectively is considered and the difference of the integrated ratio is taken as systematic error. As the 4-fermion final states are identical for the both samples, the uncertainties are considered to come from fragmentation only.
- The integrated ratio of a MC sample with Bose Einstein effect in one W only and between the W bosons is taken into account as systematic error. Again the 4-fermion final states are generated with KoralW and identical for the both samples.
- The background is varied by ±30%. The maximal deviation per bin is taken as a systematic uncertainty.

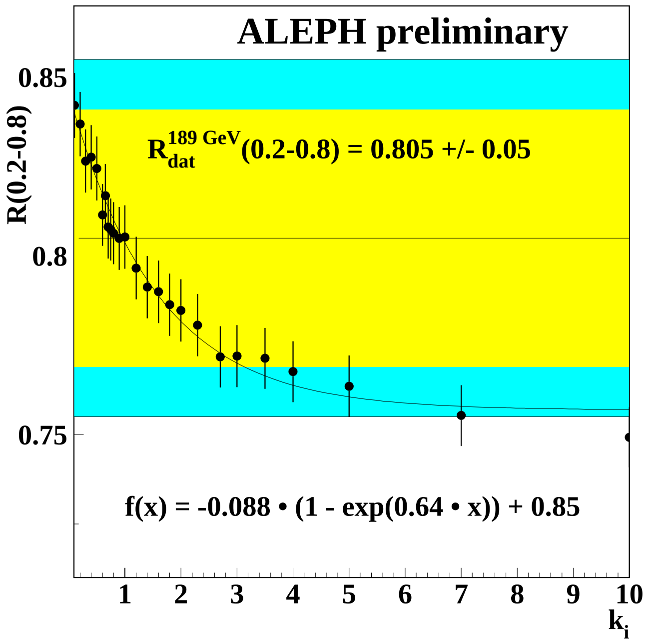

Figure 6: The value for the ratio R(0.2-0.8) in comparison of the data at 189 GeV with KoralW MC samples for different values for the free parameter k_i in the SKI model.

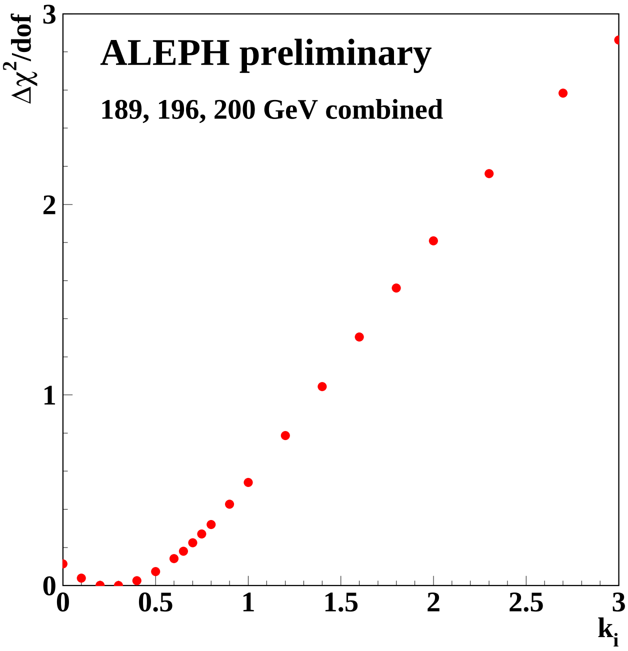

Figure 7: The combined χ^2 for the center of mass energies 189, 196 and 200 GeV.

Tracking systematics as well as uncertainties coming from neutral objects are investigated and found to be negligible. All the systematic uncertainties are estimated at 189 GeV and considered as 100% correlated between the energies and years. The systematic error is dominated by the uncertainty coming from fragmentation.

The KoralW MC points are parameterized with the function given in figure 6 (for 189 GeV) and the χ^2 between data - MC is calculated for each energy separately. Afterwards they are combined by simply adding the χ^2s for the samples at the considered energies. The $\Delta\chi^2$ of the combined χ^2s at 189, 196 and 200 GeV is shown in figure 7 and the 1σ limit leads to $k_i = 1.4$. Translated into the fraction of reconnected events at 189 GeV this leads to a value of 45%. This corresponds to a shift in the W mass in the hadronic channel of 40 MeV.

5 Conclusions

The particle production between jets coming from the same and different W bosons has been investigated. It is found that the normalized particle flow distribution is sensitive to effects coming from colour reconnection in the framework of the string model (SKI).

Integrating the ratio distribution and calculating the χ^2 of data compared to KoralW prediction with different values of the free k_i parameter in the SKI model leads to a 1σ limit on this parameter of $k_i = 1.4$ corresponding to a shift in the W mass in the hadronic channel of less than 40 MeV in the framework of the SKI model.

References

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