YU ISSN 0015-3206
FZKAAA 13 (2) 147 (1981)

OBSERVATION OF PLANARITY EFFECT IN INELASTIC HADRONIC REACTION AT ACCELERATOR ENERGY

DIPAK GHOSH, JAYA ROY, SADHAN NAHA, KAUSHIK SENGUPTA and MADHUMITA BASU

High Energy Physics Division, Department of Physics, Jadavpur University, Calcutta — 700032, India

Received 16 January 1981

UDC 539.12

Original scientific paper

This paper presents a study of the planarity of hadronic reactions at high energy with the help of *Principal axis variable* method, using data from ϱ-nucleon interaction at 22.6 GeV/c. It has been observed that at this energy there is planarity in case of low multiplicities and also planarity effect decreases with increase of multiplicity.

1. Introduction

In recent years there have been intense experimental and theoretical efforts to explore the mechanism and systematics of multiparticle production in high energy reaction. One of the methods recently proposed for analysing the gross properties of multiparticle final states produced in high energy hadron-hadron or electron--positron collision is *Principal axis* variable method[1]. These variables depend on the momenta of all the particles produced and give an overall description of the final state as a whole. Further they can reveal features of the underlying dynamics which are not visible in single-particle distribution or in two-particle correlation functions. Now with help of *Principal axis* variable one can study the *planarity* in hadronic reactions, that is one can try to see if there is a preferred plane in which the momenta of the secondary particles lie. In a recent paper we have made the *Principal axis* variable analysis* of multiparticle production in ϱ-nucleon interaction in emulsion at accelerator energy[2]. In this paper, with the help of *Principal axis* variable we have studied the planarity of hadronic reactions using our data from ϱ-nucleon interaction in emulsion at 22.6 GeV/c.

2. *Formulation and method of analysis*

The idea of a studying planarity with the help of principal axis variable has been introduced by Counihan although the principal axis concept was first given by Baddt et al.[3], according to which the principal axis is defined as the line through the centre of mass system of the collision on which the sum of absolute values of the projections of the momenta of all particle is maximum.

An alternative new definition of *Principal axis*, as proposed by Counihan in a recent paper, is based on the matrix Q given by

$$Q^{\alpha\beta} = \sum_{i=1}^{N} p_i^{\alpha} p_i^{\beta} \tag{1}$$

where the summation is over all detected particle and refer to the three components of the particle momenta p_i. Then the principal axis $\hat{Z}_p$ is an eigenvector of Q. The three orthogonal eigenvectors of Q define a coordinate system known as the *Principal axis system.* This system is very much suitable for analysis the multiparticle production.

If $\hat{Z}_p^{(1)}$, $\hat{Z}_p^{(2)}$ and $\hat{Z}_p^{(3)}$ denote three eigenvectors, then the corresponding eigenvalues are the quantities

$$\lambda_k = \sum_i (p_i \cdot \hat{Z}_p^{(k)})^2. \tag{2}$$

The order of eigenvectors is taken in such a fashion, that

$$\lambda_1 \geq \lambda_2 \geq \lambda_3$$

then $\hat{Z}_p^{(1)} = \hat{Z}_p$ is the principal axis. The plane common to $\hat{Z}_p^{(1)}$ and $\hat{Z}_p^{(2)}$ will be referred to as the *Principal plane.* The parameter λ_k ($k = 1, 2, 3$) describe the over-all shape of the system of particle in momentum space. Thus the principal axis system is a physical coordinate system similar to the principal axis system of a rigid body. The three axis correspond to the principal axis of the ellipsoid of inertia.

With the help of the principal axis variable one can study the planarity in high energy hadron collision as suggested in Ref. 2. The study of planarity means to see whether the particle of the final state tend to lie in a preferred plane. Attempt to search for the planarity in the part gave contradictory results partly due to the choice of the variables for analysis. In terms of the principal axis variables the planarity effect would show up in the λ parameters. The shape of an interaction is determined by the three eigenvalues. The shape of an event will be ciger-like if $\lambda_1 \gg \lambda_2$ and $\lambda_1 \gg \lambda_3$ planer if $\lambda_1 \gg \lambda_3$ and $\lambda_2 \gg \lambda_3$ and spherical if $\lambda_1 \sim \lambda_2 \sim \lambda_3$. Thus the shape of any reaction is conveniently described by the ratios λ_1/λ_2 and λ_2/λ_3.

* The sphericity study and planarity study

In case of ciger-like event $\frac{\lambda_1}{\lambda_2}$ will be large. For planer reactions $\frac{\lambda_2}{\lambda_3}$ will be larger than ciger-like events. Further one can measure the shape of a reaction by a quantity called *sphericity* defined as[4]

$$S = \frac{3\,\lambda_3}{\lambda_1 + \lambda_2 + \lambda_3}. \tag{3}$$

Sphericity approaches zero for events with limited transverse momentum (jet-like event) and approaches 1 for events with large multiplicity and isotropic phase distribution.

3. *Experimental detail*

A stock consisting of photoemulsion plates of $10\,\text{cm} \times 10\,\text{cm} \times 400\,\mu\text{m}$ in size exposed to 22.6 GeV/c proton beam of the CERN proton synchroton has been used in the present investigation. The scanning of the plates was performed on a Leitz-Wetzlar microscope provided with a Brower travelling state. Places were scanned using an oil immersion 53.1 × objective in conjunction with a 16.8 × ocular.

The events were chosen utilizing the following criteria: i) the beam track must be $\leq 3^\circ$ to the mean beam direction in the pellicle, ii) interaction should not be within the top or bottom 20 m thickness of the pellicle, iii) events should have no blob at the point of production. Further, all primary beam tracks were followed back to be sure that the events chosen do not include interactions from the secondary tracks of other interactions. The primaries originated from other interactions were observed and the corresponding events were removed from the sample. With these criteria a sample of 280 events was selected for analysis. All the secondary tracks with grain density $g^* \leq 1.4\, g_{min}$ were taken as pions. To ensure the best approximation for a nucleon-nucleon collision the events with $N_h \leq 2$ and $n_s \leq 12$ were taken. The space angles and momenta of all the pions were measured in the laboratory system[2]. The system was then transformed to c. m. frame. From the knowledge of the momenta, values of λ were determined with the help of (1) and (2).

Results and discussion

To study the planarity effect we illustrate the distribution of ratios of λ_1, λ_2, λ_3 graphically for different multiplicities and discuss the possible significances.

Fig. 1 (a) and 1 (b) show the distribution of $R_1 (= \lambda_2/\lambda_1)$ and $R_2 (= \lambda_3/\lambda_2)$ respectively for $n_s = 4$ events. In view of what has been discussed above it can be inferred from the Fig. 1 (a, b) that the particles lie in the principal plane ($\hat{Z}_p^{(1)}$, $\hat{Z}_p^{(2)}$ plane) since Fig. 1 (a) clearly indicates the alignment of the particles along the principal axis and Fig. 1 (b) implies alignment along the $\hat{Z}_p^{(2)}$.

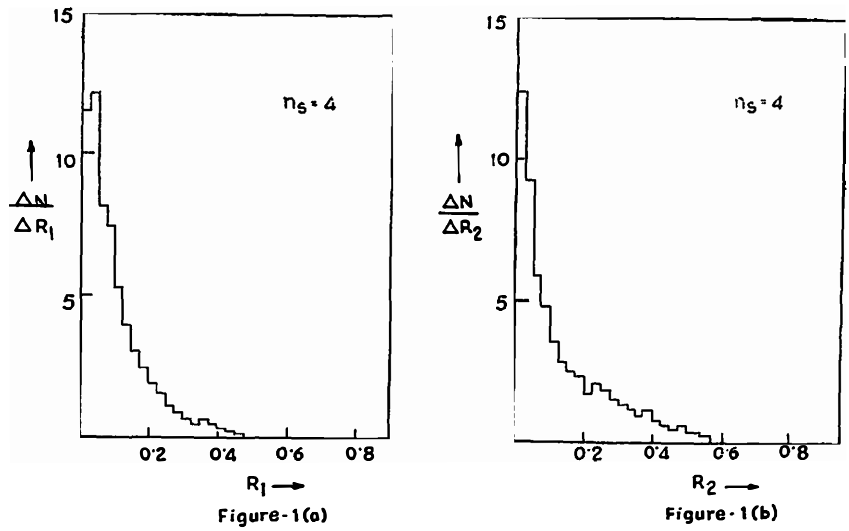


Fig. 1 (a, b). Distributions of R_1 $(= \lambda_2/\lambda_1)$ and R_2 $(= \lambda_3/\lambda_2)$ for $n_s = 4$ events.

Fig. 2 (a, b) and Fig. 3 (a, b) are the similar graphs for $n_s = 5$ and $n_s = 6$ events, respectively. The graphs clearly show that the planarity decreases with increase of multiplicity which is a reasonable expectation. Further we have plotted $\overline{R}_1 = (\lambda_2 >/<\lambda_1>)$ and $\overline{R}_2 = (<\lambda_3>/<\lambda_2>)$ against multiplicity (Fig. 4). It is again transparent from plot that with the increase of multiplicity the planarity effect decreases and the shape of the reaction tend to become more spherical. These results are in agreement with those of Ref. 2.

It wuold be interesting to investigate the planarity effect by means of more data at different higher energies and careful analysis thereof.

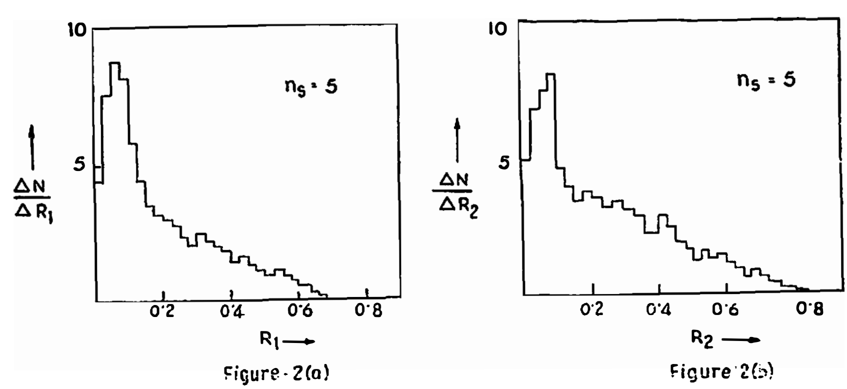
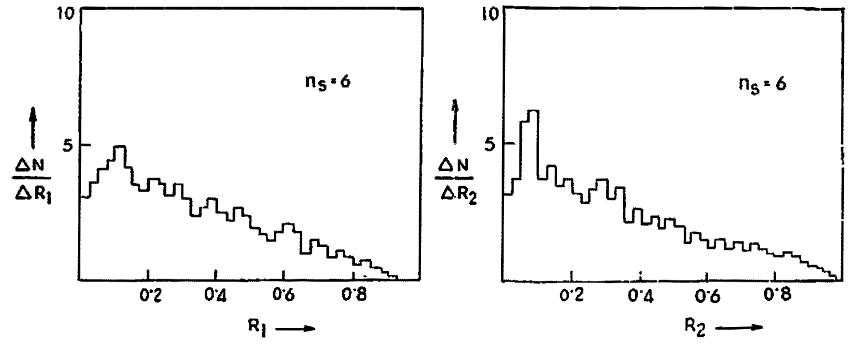
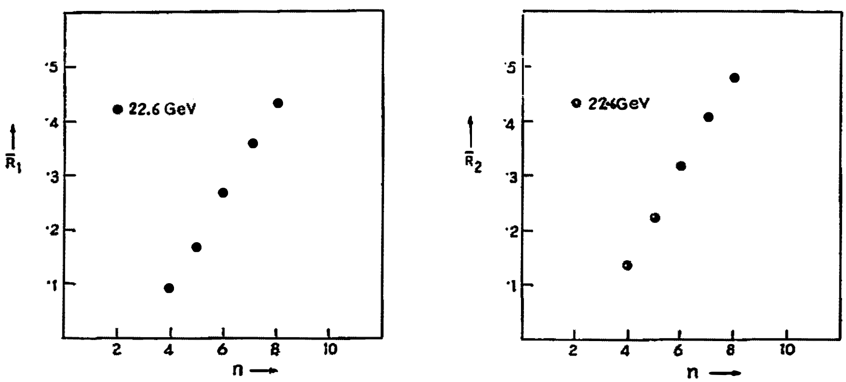


Fig. 2 (a, b). Distribution of R_1 $(= \lambda_2/\lambda_1)$ and R_2 $(= \lambda_3/\lambda_2)$ for $n_s = 5$ events.



Figure·3(a) Figure·3(b)

Fig. 3 (a, b). Distributions of R_1 ($= \lambda_2/\lambda_1$) and R_2 ($=\lambda_3/\lambda_2$) for n_s = 6 events.



Figure·4 (a) Figure·4 (b)

Fig. 4 (a, b). The plot of $R_1(\langle\lambda_2\rangle/\langle\lambda_1\rangle)$ and $R_2(\langle\lambda_3\rangle/\langle\lambda_2\rangle)$ with multiplicity.

Acknowledgment

The authors would like to express their appreciation to Prof. A. J. Herz of CERN for kindly supplying the exposed emulsion plates.

References

1) M. J. Counihan, Phys. Lett. **59B** (1975) 367;
2) D. C. Ghosh et al., Phys. Rev. **D19** (1979) 391;
D. C. Ghosh et al., Acta Phys. Austr. **51** (1979) 35;
D. C. Ghosh et al., Can. J. Phys. **86A** (1979) 57;
D. Ghosh, Can. J. Phys. 1980 (in press);
3) Brandt, Peyron, R. Sosnowski, A. Wrobleski, Phys. Lett. **12** (1964) 57;
4) G. Hanson et al., Phys. Rev. Lett. **35** (1975) 1609.

OPAŽANJE EFEKATA PLANARNOSTI U NEELASTIČNIM HADRONSKIM REAKCIJAMA NA AKCELERATORSKIM ENERGIJAMA

DIPAK GHOSH, JAYA ROY, SADHAN NAHA, KAUSHIK SENGUPTA i MADHUMITA BASU

High Energy Physics Division, Department of Physics, Jadavpur University, Calcutta-700032, India

UDK 539.12

Originalni znanstveni rad

Primjenom metode *variable glavne osi* studirana je planarnost hadronskih reakcija na visokim energijama, iz podataka o proton-nukleon međudjelovanjima na 226 GeV/c. Primijećeno je da na tim energijama postoji planarnost u slučaju malog multipliciteta i također da efekt planarnosti opada sa povećanjem multipliciteta.