LETTERS TO THE EDITOR

FORWARD-BACKWARD LONGITUDINAL ASYMMETRY IN MESON-NUCLEON COLLISIONS AND FRAGMENTATION EFFECTS

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It is shown that the dominant source of the forward-backward asymmetry in the pion spectra in the central (low x) region in meson-nucleon collisions is the contribution from the decay of low mass meson resonances produced in the *fragmentation* region (say, $|x| \geqslant 0.3$, $x = p_L/p_L^{\max}$). Implications of this fact for models of multiparticle production are briefly discussed.

Since 1971 a considerable attention has been drawn by a forward-backward (F–B) asymmetry observed in the center of mass longitudinal momentum distributions of the pions produced in πp and Kp reactions [1]. For instance, in π^-p collisions the distribution of the forward emitted pions π^+ is broader than the distribution of the backward π^- (choosing forward π^+ and backward π^- one eliminates effects due to the leading pions). The main interest in this phenomenon arises from the fact that symmetry can be obtained in a new frame of reference, in which the ratio R of the incident proton to the incident meson momenta approximately equals 3/2 ($R = 1$ for CMS). The ratio 3/2 can be taken as some evidence for quark-quark collisions being responsible for multiparticle production, in the spirit of the additive quark model. If convincing, this interpretation would have an important impact on the picture of high energy collisions. It turns out that a more complete characteristics of the asymmetry phenomenon reads:

a) asymmetry is observed already for low (in the CMS) longitudinal momenta of pions ($p_L < 1$ GeV/c),

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b) asymmetry (consequently R) strongly depends on the multiplicity and *disappears with the increasing number of prongs*,

c) asymmetry is slightly stronger (R is higher) in case of incident pions than in the case of kaons.

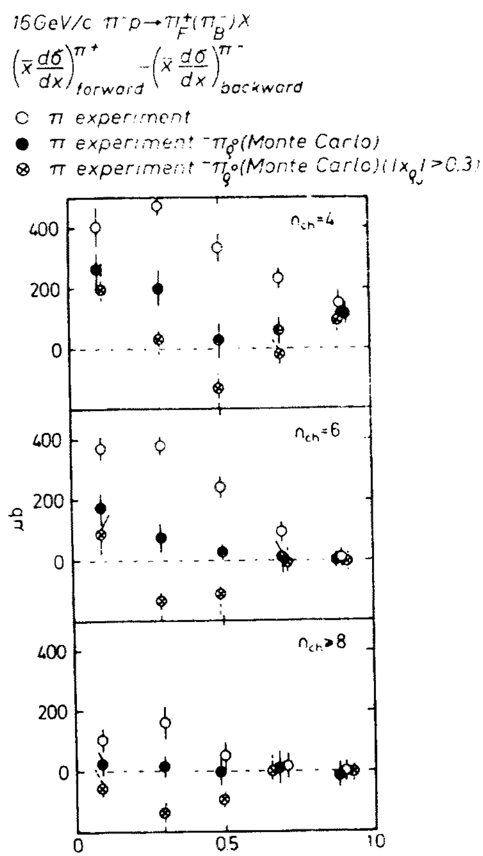

Fig. 1

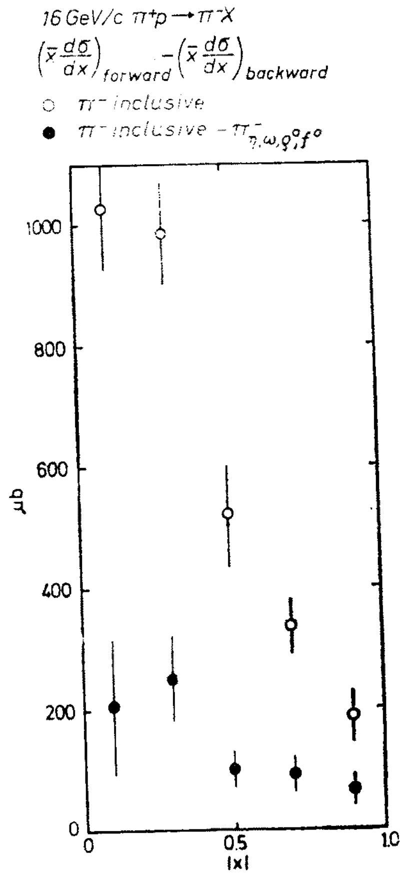

Fig. 2

Fig. 1. F–B asymmetry in the semiinclusive ($n_{ch} = 4, 6, \geqslant 8$) $\bar{x}\, d\sigma/dx$ distributions for the reaction $\pi^- p \to \pi_F^+(\pi_B^-)$ at $p_{LAB} = 16$ GeV/c — experimental one and one after subtracting pions from the decays of ρ^0 resonance (produced with $|x_\rho| \geqslant 0.3$; all)

Fig. 2. F–B asymmetry in the inclusive $\bar{x} d\sigma/dx$ distribution for the reaction $\pi^+ p \to \pi^- X$ at 16 GeV/c: experimental one and one after subtracting pions from all ρ^0, η, ω and f decays

These features (particularly point b) can be hardly reconciled with a simple picture of quark-quark collisions. In this letter we show that the dominant source of the forward-backward asymmetry in the pion spectra in the central (low x) region is the contribution from the decays of low mass meson resonances produced in the *fragmentation* regions (say, $|x| \geqslant 0.3$, $x = p_L/p_L^{max}$). Even fast fragmentation resonances contribute substantially to the final pion distributions at small p_L.

We consider the $\pi^{\pm}$ p and K$^-$p collisions at 16 GeV/c. At this energy we have at our disposal the following resonance data [2] (x distributions): ϱ^0, f, K^{*0}(890) in $\pi^{\pm}$p and K$^-$p; η and ω in π^+p. Also data exist for ϱ^0 semiinclusive production in π^-p collisions in 2,4, 6 $\geqslant$ 8 prong events.

In order to discuss the contribution to the F–B asymmetry from the fragmentation resonances we have generated with a Monte-Carlo programme the invariant x distributions of decay pions using experimental $\bar{x}d\sigma/dx$ distributions of resonances and assuming for

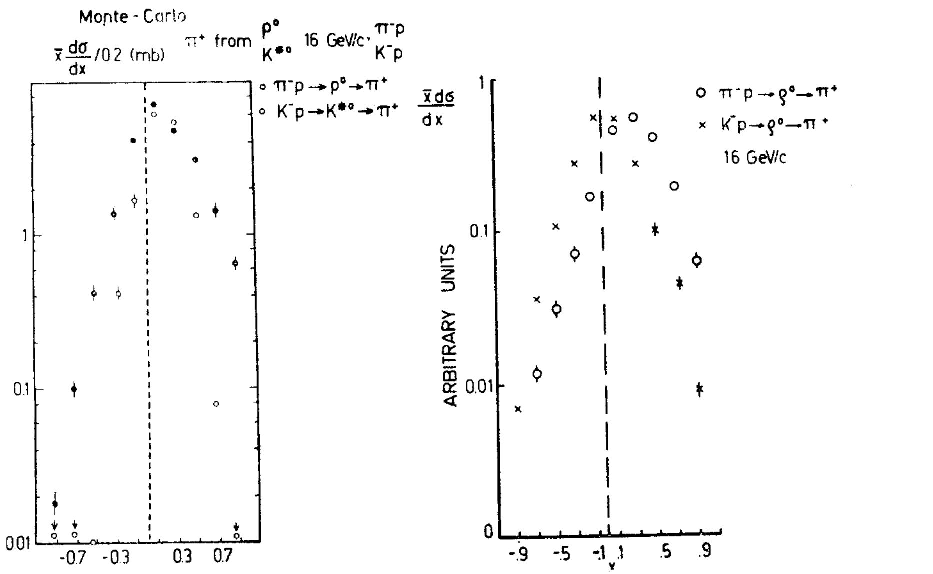

Fig. 3. Monte-Carlo inclusive x-distributions for the reactions: a) K$^-$p $\to$ K^{*0} $\to$ π^+ as compared to the reaction π^-p $\to$ ρ^0 $\to$ π^+ (in mb). b) K$^-$p $\to$ ρ^0 $\to$ π^+ as compared to the reaction π^-p $\to$ ρ^0 $\to$ π^+. These distributions are normalised to the same cross section in order to compare the shapes

them: (a) $d\sigma/dp_T^2 \sim \exp(-3.4p_T^2)$, (b) isotropic decay. In Fig. 1 we show experimental F–B asymmetry for different multiplicities in 16 GeV/c π^-p interactions (we compare forward emitted π^+ with backward emitted π^-) and the asymmetry left after subtracting the contribution from the decays of ϱ^0 resonance (a) produced with $|x_\rho| \geqslant 0.3$, (b) all. We observe that (i) there is little difference between cases (a) and (b), (ii) the decays of ϱ^0's produced with $|x_\rho| \geqslant 0.3$ account for a large part of the asymmetry in the pion distribution in the central region, (iii) pions from ϱ^0 decays give asymmetry with correct multiplicity dependence.

To support our Monte-Carlo calculations we also show in Fig. 2 the experimental F–B asymmetry for the reaction π^+p $\to$ π^-X at 16 GeV/c and the asymmetry left after subtracting the distribution of decay pions originating from all ϱ^0, η, ω and f resonances (decay pion distributions are published in Ref. [3]).

In the reaction K$^-$p $\to$ π^+X we can study the effect of K fragmentation into K^{*0} and ϱ^0 but on the level of the inclusive cross-sections only. Qualitatively we can expect that the asymmetry in $K^-p \to \pi^+X$ is weaker than in the $\pi^-p \to \pi^+X$ as is indeed observed because:

a) the spectrum $K^- \to K^{*0}$ is the same as the ϱ^0 fragmentation but pions from the K^{*0} decays are slower than those from ϱ^0 decays (due to $K-\pi$ mass difference),

b) the spectrum $K^- \to \varrho^0$ does not contain contributions from diffraction dissociation which are present in the $\pi^- \to \varrho^0$ (e. g. $\pi^- \to A_1 \to \varrho^0$ in the region of large x: $x \geqslant 0.5$). Using experimental spectra for the $K^- \to K^{*0}$ and $K^- \to \varrho^0$ we calculate the inclusive pion spectra shown in Fig. 3. For comparison we show also the pion spectra from the transition $\pi^- \to \varrho^0 \to \pi^+$. These results indeed explain why the asymmetry in the $K^-p \to \pi^+X$

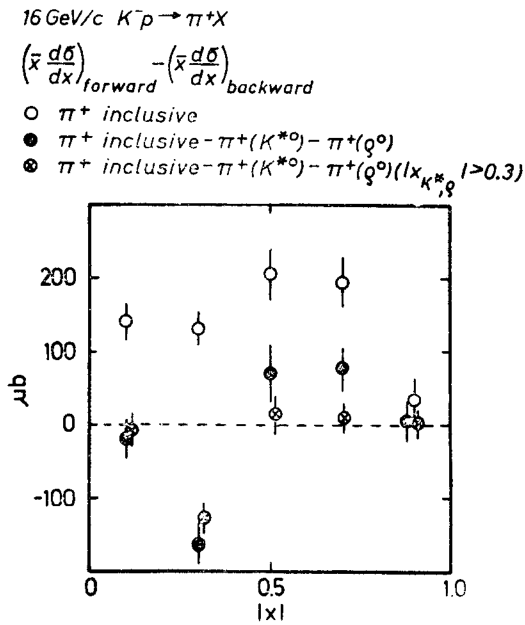

Fig. 4. F–B asymmetry in the inclusive $\bar{x}d\partial/dx$ distribution in the reaction $K^-p \to \pi^+X$ at $p_{LAB} = 16$ GeV/c: experimental one and one after subtracting pions from the decay of ρ^0 andn $K^{*0}(890)$ resonances (produced with $|x_{K\rho}| \geqslant 0.3$; all)

reaction is weaker than in $\pi^-p \to \pi^+X$ process. Finally, in Fig. 4, we show asymmetry in the $K^-p \to \pi^+X$ before and after the subtraction of the contribution from the K^{*0} and ϱ^0 decays. We see that, as in πp case, the main part of asymmetry is due to the K^{*0} and ϱ^0 produced with $|x_{K,\rho}| \geqslant 0.3$.

Finally we wish to point out that:

i) We have checked that production of Δ^{++} does not influence the F–B asymmetry, as π's from Δ^{++} decay are almost symmetric around $x = 0$; in general fragmentation $p \to N^*$ has little effect on F–B asymmetry.

ii) In the case of $K^-p \to \pi^+X$ reaction we have considered only $K^{*0}(890)$ and ϱ^0 production and have found that they account for a large part of the observed asymmetry. The rest is likely to be explained by K^{*-}, η, ω production especially if, as suggested by Bockmann et al. [2], the resonance fragmentation spectra are universal.

iii) Cross sections for ϱ^0 production at 16 GeV/*c* $\pi^{\pm}$p are probably underestimated, because reflections from $\omega \to (\pi^+\pi^-\pi^0)$ in $(\pi^+\pi^-)$ mass distribution were not taken into account.

iv) Proper inclusion of ϱ^0 polarization effects, present in low multiplicity events, should increase asymmetry caused by its decay.

We have demonstrated that the forward-backward asymmetry in the pion spectra in the *central* (low x) region is largely due to the contribution of the decays of low mass resonances produced in the *fragmentation* regions ($|\bar{x}| > 0.3$). This is so because in meson-nucleon collisions the x distribution of fragmentation resonances are strongly asymmetric with clear excess in the meson hemisphere [2]. If we accept the distinction between central production and beam (target) fragmentation (as suggested by many experimental and theoretical analyses) then our results imply that different meson and nucleon fragmentation into meson resonances is the main source of the asymmetry. Within the accuracy of presently available experimental data on resonance production and at this low energy we are unable to rule out the possibility that there is also some additional asymmetry in the central production but the data are compatible with its absence.

Difference between meson and nucleon *fragmentations* arises naturally in several theoretical models. One promising approach refers to the quark-gluon hadron structure and relates fragmentation of the incident particle to recombination of its valence quark with the additional centrally produced soft quarks [4]. Other approach is based on the quark counting rules [5]. Both approaches account for the experimentally observed differences in the x distribution of fragmentation resonances in case of fragmenting meson and nucleon respectively[1].

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[1] The difference is also partly due to the diffraction dissociation effects e.g. $\pi^- \to A_1 \to \rho^0$.