Comparison of Pion Momentum
Distributions in 19-GeV/c
pp collisions with and without
Strange-Particle Production

Erwin Marquit*

The Niels Bohr Institute, University of Copenhagen.

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*On leave from the University of Minnesota

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Abstract

A comparison is made of the inclusive π^- momentum spectra for pp interactions at 19 GeV/c with V^0 and without V^0 (or any other strange-particle signal). It is found that the spectra for interactions with a V^0 and charged-particle multiplicity n correspond best to the spectra for interactions without a V^0 and multiplicity $n+2$.

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As a part of the studies in the Scandinavian collaboration of pp interactions at 19 GeV/c in the CERN two-meter hydrogen bubble chamber we have compared the inclusive π^- momentum spectra for interactions with the production of strange particles and without strange-particle signals to look for quantitative or qualitative differences in the respective spectra.

For this study we used the data of Bøggild et al. (1,2) supplemented by additional measurements made by the Copenhagen group. In particular, we compared the π^- momentum from interactions of the type

$$p + p \rightarrow \pi^- + \text{anything without } V \quad (1a)$$

with

$$p + p \rightarrow \pi^- + \text{anything with } V \quad (1b)$$

In reactions (1a) "without V" means that there were no observed decays of a neutral particle into charged particles associated with the interaction vertex. Furthermore, no interactions with possible charged, strange-particle signals (kinks) were included. In reactions (1b) "with V" represents observed decays which, upon measurement, were kinematically fitted to a Λ^0 or K_S^0 coming from the interaction vertex. It was further assumed that any negative tracks without kinks were pions.

Although the K^-/π^- ratio in all pp interactions at 19 GeV/c is only about 3 percent,⁽³⁾ we had to consider the possibility that in our sample of V events, where there is already at least one strange-particle present in the final state, this ratio could be high enough to distort significantly the results of this comparison. (The Σ^- hyperons are more likely to decay before leaving the bubble chamber.) We estimated the number of K^- mesons in the V events in the following ways: a) from the observed number of $K_S^0 K_S^0$ events* and under the assumptions that the K^0 's are equally divided between K_S^0 and K_L^0 and $\sigma(K^0 \bar{K}^0) = \sigma(K^0 K^-)$, we conclude that 82 negative tracks out of the 1215 used for this study are attributable to K^- mesons; b) if we take $\sigma(K_S^0 K^-) = \sigma(K_S^0 K^+)$ and determine the number of $K_S^0 K^+$ events by subtracting from the observed single K_S^0 events the number attributable to $K^0 \bar{K}^0$ (see (a) above), $K^0 \Lambda^0$ or $K^0 \Sigma^0$ (determined from the observed $K^0 \Lambda^0$ events), and $K^0 \Sigma^+$ (under the assumption that all kinks are due to Σ^+ decays), we find that our negative-track sample contains 106 K^- mesons; c) from the excess of negative tracks traveling forward in the cms over the number traveling backward (under the assumption that they are all pions) and comparison with the corresponding excess when K_S^0 mesons not accompanied by hyperon signals are transformed to the cms

*Our sample included 537 single K_S^0 events, 730 single Λ^0 events, 112 $K^0 \Lambda^0$ events, 27 $K_S^0 K_S^0$ events, and 109 charged decays associated with V's. We estimated the K_S^0 scanning and escape loss to be 8.5% and the Λ^0 scanning and escape loss to be 15.5%. We assumed arbitrarily that the charged-hyperon decays were detected with an efficiency of 90%.

after being assigned the pion restmass, we conclude that 141 negative tracks could be K^- mesons.

The three procedures gave estimates in the range 0.07 - 0.12 for the fraction of K^- mesons among the 1215 negative tracks. We therefore corrected each momentum distribution discussed below for K^- contamination in the following way. The corresponding K^0 distribution was calculated with the use of the pion restmass in place of the K^0 restmass. The resulting "pionized" K^0 distribution was subtracted from the negative pion distribution with a weight of 0.087 (corresponding to estimate (b) above). For this correction only events without a Λ^0 or charged-track decay were used. Variation of the weighting factor in the range 0 to 0.087 had no qualitative effect on the conclusions presented below.

For the comparison we used the cumulative cms longitudinal-momentum (p_l) and transverse-momentum (p_t) distributions normalized to unity.

Each multiplicity was plotted separately. No essential differences were observed between the K^0 and Λ^0 subgroups so these events were combined. The results for p_l are shown in Fig. 1. These distributions are properly histograms, but for the sake of clarity they are presented as line-segments and points.

In the case of interactions with four prongs, where we have the best statistical sample, namely 4817 π^- without

V's and 522 π^- with V's, the p_ℓ distributions for events with and without V's appear incompatible with one another (see Fig. 1). Application of the Kolmogorov-Smirnov test⁽⁴⁾ for goodness of fit gives a likelihood (significance level) of only 10^{-4} that two data-sets of size 4817 and 522, respectively, drawn from the same population will yield cumulative distributions with a maximum difference at least as great as that observed in Fig. 1. It turns out that the 4-prong distribution for π^- with V's is in good agreement with the 6-prong distribution without V's (significance level 0.78). Similarly, the 6-prong p_ℓ distributions are incompatible (significance level 10^{-4}); in this case the 6-prong distribution with V's appears to agree best with the 8-prong distribution without V's. In the case of 8-prongs with V's, the smaller number of π^- available reduce the sensitivity of the comparison, although here too the best agreement is obtained with a higher multiplicity for the events without V's (10-prongs).

The p_t distributions also show a tendency to greater effective multiplicity for the V events, but as was already shown by Bøggild et al.,⁽¹⁾ the dependence on the multiplicity is much weaker for p_t than for p_ℓ . Because of the smaller separation between the distributions of different multiplicity and the consequent confusion of detail, the plots for p_t are not shown. However, the results of the Kolmogorov-Smirnov test are given in the table for both the

p_ℓ and p_t distributions.

It is seen from the table that the highest value in every column for both p_ℓ and p_t occurs when the multiplicity of events without V's is two greater than the events with V's, although the differences in each case are not always significant.

It immediately comes to mind that the requirement that a V be associated with the interaction is equivalent to an *a priori* increase in the particle multiplicity by one. The requirement of strangeness conservation also acts to increase the effective multiplicity, but here an evaluation is more difficult owing to the various particle states available.

One may ask whether the observed changes (i.e., narrowing of the momentum distributions) are merely due to the phase space limitations resulting from the heavier masses of the kaons and hyperons relative to the pions and nucleons. If this were the case, then the relative displacements would decrease as the multiplicity increases and not correspond to a fairly constant increase in effective multiplicity.

We appear to be able to conclude that if interactions leading to strange-particle production tend to involve dynamical processes which are basically different from other interactions, this difference is not reflected in the momentum distributions of the accompanying pions.

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References

- (1) H. Bøggild, K. H. Hansen and M. Suk, Nucl. Phys. 27B (1971)
- (2) H. Bøggild et. al., Nucl. Phys. 27B (1971) 285.
- (3) J. V. Allaby et al., CERN report 70-12 (1970).
- (4) M. Fisz, Probability Theory and Mathematical Statistics
(John Wiley and Sons, New York, 1963).

TABLE

Significance levels for comparison of longitudinal (upper) and
transverse (lower) momentum distributions*

with V's without V's	4 prongs 522 π^-	6prongs 435 π^-	8 prongs 117 π^-
4 prongs 4817 π^-	10^{-4} 0.64	10^{-4} 0.29	10^{-4} 10^{-3}
6 prongs 1325 π^-	0.78 0.89	10^{-4} 0.42	10^{-3} 0.01
8 prongs 297 π^-	0.08 0.64	0.93 0.92	0.63 0.08
10 prongs 350 π^-	10^{-4} 0.03	0.58 0.48	0.81 0.35

*For interactions without V's the data for each multiplicity do not come from the same sample of bubble-chamber film. This is why, for example, there are more 10-prong pions than 8-prong pions.

Figure Caption

Fig. 1. The π^- cumulative distributions for cms longitudinal momentum. For events without V's the data points are connected by lines; for events with V's the data are shown as points. The distributions are normalized to unity.