Search for K Nuclear Cluster in Nuclear Collisions with FOPI ◇

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We propose to search for nuclear clusters (ppK^-, $ppnK^-$, $pppK^-$, $pppnK^-$ and $ppnnK^-$) as residues in nuclear collisions. These kaonic nuclei have recently been predicted by [1] to be narrow discrete bound states with large binding energies of about 100 MeV, so that their main decay channels to $\Sigma\pi$ are energetically forbidden. Due to the strong $K^- - p$ attraction, these nuclei are expected to be enormously condensed systems with an average nucleon density as much as 0.5 fm^{-3} and thus are called clusters. Very recently, experimental evidences [2] for $T = 0$ $ppnK^-$ and $T = 1$ $pnnK^-$ clusters have been obtained at KEK from $^4He(stopped - K^-, n)$ and $^4He(stopped - K^-, p)$ reactions, respectively. The observed binding energies are substantially larger than the predicted ones. We propose to produce and identify clusters in nuclear collisions by making use of the excellent capability of the FOPI [3] detector at GSI in identifying both K^0 mesons and Λ hyperon. Using $3.5 - 4.5$ GeV protons on a d target the $\Lambda^*(= \Lambda(1405) = pK^-)$ particle serves as a doorway to form ppK^- clusters as follows:

$$p + d \rightarrow [\Lambda^* p] + K^0 + p \rightarrow ppK^- + K^0 + p. \qquad (1)$$

In this reaction a missing-mass (MM) spectrum of ppK^- can be constructed using p and K^0 and according to the decay pattern:

$$ppK^- \rightarrow \Sigma^{+,-} + \pi^{+,-} + p \; or \; \Lambda + p, \qquad (2)$$

an invariant mass (IM) spectrum can also be built.

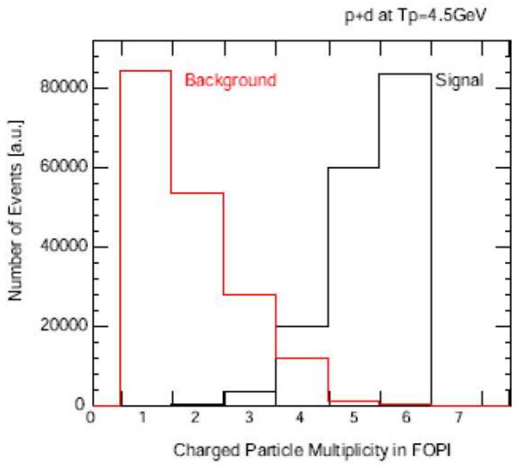

Fig. 1: Charged particle multiplicity distribution for the signal and the background in p+d collisions. The multiplicity shown refers to the particles emitted in the FOPI acceptance

Detailed simulation studies have been carried out for the reaction $p + d$ @4.5GeV to check the feasibility of the measurement of the ppK^- signal. The formation cross section for the Λ^* at this energy was estimated [4] to be of about 20 μb, the probability that it combines with a proton to form a ppK^- cluster depends on the relative momentum of the two and is about 1% ($Prel < 300MeV/c$).

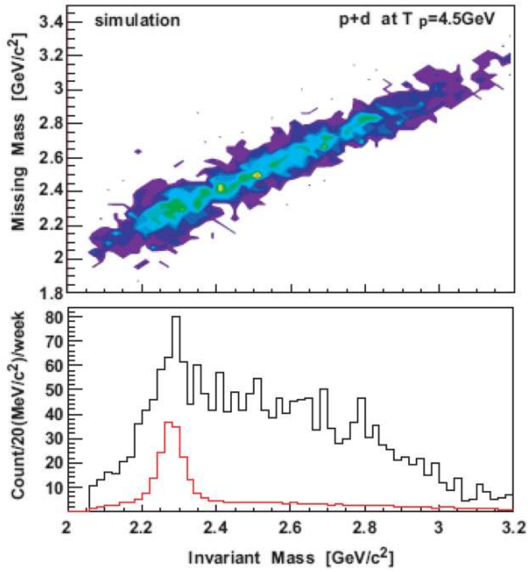

Fig. 2: (upper) Correlation plot of the IM versus MM and (lower) projection along the IM axis. The red line in the lower histogramm represents the signal, the black line the sum of the signal and background.

The formation probability for the cluster is hence about 0.2 μb and it has to be compared with the total reaction cross-section of 78 mb. All the p+d output channels have been simulated and an online multiplicity trigger has been investigated using the FOPI plastic wall and the Barrel. Fig1 shows tha charged particles distribution in the FOPI geometrical acceptance. Requiring at least 4 charged particles in the acceptance the background is reduced by a factor 8000 respect with the signal. Applying this trigger condition and assuming for the ppK^- a mass of 2279 MeV/c^2 and a width of 20 MeV/c^2, the combination of the MM and IM analysis, together with energy and momentum conservation condition, delivers the plot shown in Fig. 2. The projection on the IM axis shows that a signal to background ratio of 1/3 is achieved. This hypothesis will be verified by the scheduled beam-time at the end of 2005.

References

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