Study of decay probability of heavy projectile fragments in ^{84}Kr interactions at ~1 GeV per nucleon

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Introduction

Nuclear emulsion detector is one of the oldest detector technologies and has been in use from the birth of the experimental nuclear and astroparticle physics. Fortunately, it is a unique and simple detector till today, due to very high position resolution (~1 μm) along with several unique features. The high position resolution allows easy detection of short-lived particles like the ι-lepton or charmed mesons. 4π visualization of tracks produced during interaction impelled us to pursue studies on physics beyond the Standard Model. Now-a-days, OPERA collaboration is using emulsion detector for tracking charged particles produced or emitted during neutrino interaction. Many experimental groups around the world are doing R&D with this detector for dark matter experiment. Multi-particle production and multi-fragment emission are crucial phenomena in high energy heavy ion interactions. Thus, it is quite interesting to study the projectile fragmentation process of heavy ions such as ^{84}kr projectile. The projectile charged fragments are affected by each other during emission, the "emission angle" measurement play important role to study the emission characteristics of projectile fragments (PFs).

Experimental Detail

In the present experiment, we have employed a stack of high sensitive NIKFI BR-2 nuclear emulsion pellicles of dimensions 9.8 x 9.8 x 0.06 cm^3, exposed horizontally to $^{84}Kr_{36}$ ion at a kinetic energy of around 1 A GeV. The exposure has been performed at GSI, Darmstadt, Germany. Detail experimental procedure is described in [1]. In the present analysis, 570 events out of 700 have fulfilled the required criteria for further investigation. All PF emission angles of minimum bias events have been determined from the vector directions of the incident projectile and emitted fragment tracks obtained by measuring of the x, y and z coordinates at three closest points from the interaction vertex separated by 50 μm each along the projectile and along each fragments using Olympus BH-2 optical binocular microscope having 2250X magnification and 0.5^o least count [1, 2]. The emission (space) angle is calculated as θ_s=Cos^{-1} (Cos θ_p* Cos θ_d), where θ_p and θ_d are projected and dip angles and are calculated as follows $\theta_p = \tan^{-1}(\Delta y/\Delta x)$ and $\theta_d = \tan^{-1} (\Delta z*S) / (\Delta x^2+\Delta y^2)^{1/2}$, where Δz is change in z. Coordinate in a distance x and y in the (x-y) plane and S is the shrinkage factor. The calculated value of shrinkage factor is 3.3 [1, 2].

Result and Discussion

The normalized space angle distribution of the identified single, double and multiple charge (z>2) PFs emitted in the interactions are shown in Fig. 1, and fitted with Gaussian function. From fig. 1 it's clear that the mean emission angle decreases with increase in the charge of the PFs [1]. We measured the space angle difference ($\Delta\theta_s$) between considered PFs with respect to the rest of the observed PFs in a interaction and plotted the normalized distribution of these difference with respect to charge of the PFs in fig. 2. Space angle difference measured considering the PF of particular charge with respect to the rest PFs of event referred to the charge of the considered PF. The positive and negative signs for angles are just representing upward and downward location of the considered PFs with respect to the beam direction.

It can be seen from fig. 2 that lighter charge (Z<9) PFs are showing two peaks, one in positive (upward) and other one is in negative (downward) side. The heavier charge more than 10 charge units just merge and do not show two peaks behavior exhibited by lighter charge projectiles.

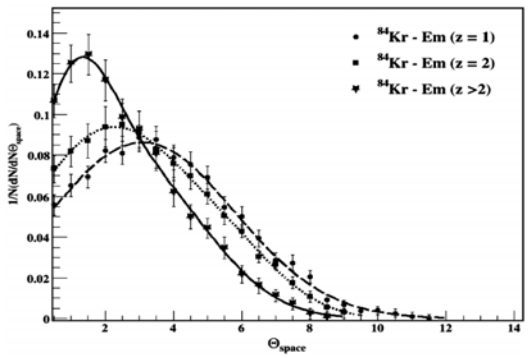

Fig. 1: The normalized distribution of θ_s for Z=1, 2 & >2 PFs. The solid, dotted and dashed lines are the best fitting function line [1].

The ratio of mean value of up and downward peaks distributions is shown in fig. 3. If both side peaks are located at same position i.e. symmetry then the ratio must be at 1. The best fit of the distribution for big peak mean ratio comes out to be 0.93 which is close to unity as shown in fig. 3(a). Fig. 3(a) is also depicts the variation of our measurements in close agreement with the expected results. Therefore, proves the symmetrical nature of PFs emission as shown in fig. 2.

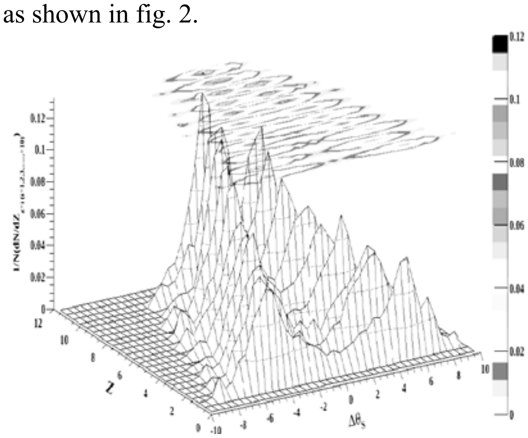

Fig. 2: Normalized distribution of the $\Delta\theta_s$ of different charge PFs with respect to the rest of the PFs of the interactions.

From fig. 2 it's evident that, there is small but significantly clear peaks on both-sides of the big peaks. The ratio of mean value of these peaks is plotted in fig. 3(b). The best fit value is 1.02. This shows both small peaks have similar mean value i.e. they are located at the same position but in opposite sides of the beam direction. It means some similar charge projectile fragments have different emission angle and therefore it is possible that they are coming from the decay products of the heavier PFs of the interactions. From fig. 2, we have evaluated 14.30, 6.67, 8.75, 6.52, 9.12, 10.44, 15.80, 11.05 and 11.14% of charge (Z) equal to 1, 2, 3, 4, 5, 6, 7, 8 and 9, respectively of PFs are not coming from direct interaction i.e. are possibly coming from the decay process of the heavy projectile fragments that are by products of the direct interaction or may be some other process [1].

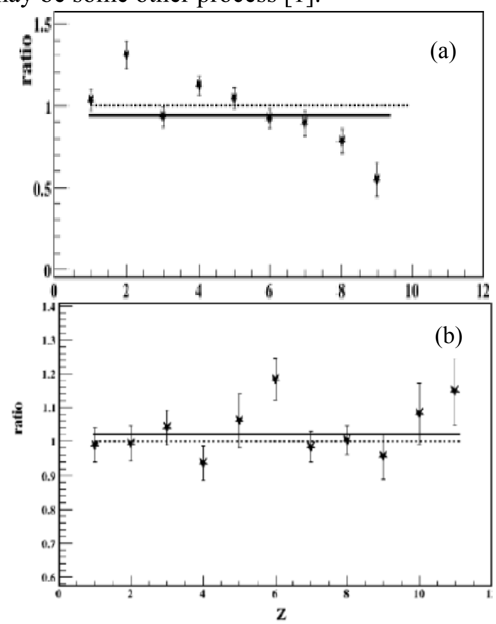

Fig. 3: The ratio of mean value of (a) big peaks and (b) small peaks located up and downward of the beam direction is distributed [1].

In our present study we found that the lighter PFs are strongly affected by other PFs emitted at same time with different emission angle as well as same/different charges and also having symmetrical nature during emission. The symmetrical nature decreases as we move from lighter to heavier charge PFs.

References

[1] M. K. Singh et al., Indi. J. Phys. **84,** 1257 (2010); M. K. Singh et al., arXiv: 1108.0280v1.

[2] M. K. Singh et al., Indi. J. Phys. **85,** 1523 (2011).