EXCLUSIVE MEASUREMENTS OF MEAN PION MULTIPLICITIES IN 4He-NUCLEUS REACTIONS FROM 200 TO 800 MeV/NUCLEON


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Mean multiplicities of π+ and π− in 4He collisions with C, Cu, and Pb at 200, 600, and 800 MeV/u, and with C and Pb at 400 MeV/u have been measured using the large solid angle detector Diogene. The dependence of pion multiplicity on projectile incident energy, target mass and proton multiplicity is studied in comparison with intra-nuclear cascade predictions. The discrepancy between experimental results and theory is pointed out and discussed.

1. Introduction. One of the major challenges of relativistic heavy ion physics is the determination of the nuclear equation of state for densities up to ~4 times normal density. During the last years, the use of the pion multiplicity (measured in central collisions) as a “nuclear matter thermometer” [1] in order to extract the equation of state from experimental data has raised considerable interest. However, the question whether this observable is mainly sensitive to the equation of state is still not settled [2–10]. It is clear that new experimental data are needed in order to constrain the models and clarify the situation. More generally, the study of the pion production in relativistic heavy ion collisions is a very interesting tool for probing the dynamics of the reaction [11].

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We report quasi-exclusive measurements of π+ and π− mean multiplicities for 4He+(C, Cu, Pb) at 200, 600 and 800 MeV/u, and 4He+(C, Pb) at 400 MeV/u [12]. They were performed at the Saturne synchrotron in Saclay, using the cylindrical drift chamber of the large solid angle detector “Diogene” [13]. These results contribute to remove the lack of data concerning charged pion production in this energy range and establish a link between proton [14,15] and heavy ion [11,15–17] induced reactions. The drift chamber surrounds the target, and is placed inside a magnet. A barrel of scintillators is placed around the chamber for use as a trigger. For each collision one measures simultaneously the angles and momenta of π+, π−, p, d, t and He emitted between 20° and 132°, above energy thresholds of ~23 MeV for pions and ~42 MeV for protons, with a momentum resolution dP/P that is typically 10–20% (FWHM). With the aim of selecting non peripheral events, the specific trigger for these 4He experiments required at least one charged particle in the scintillator barrel, emitted between 37° and 119°, with an
3. The cascade pion excess. An important result at this point is that the cascade strongly overpredicts our data. In summary, the ratio \( \frac{\langle n_{\pi^-} \rangle \text{ (cascade)}}{\langle n_{\pi^-} \rangle \text{ (experiment)}} \) increases when the target mass or the proton-like multiplicity increases, or when the incident energy decreases. Similar trends had been obtained for symmetric systems [1,17]. It has been proposed that the high densities reached during the collisions induce a high compressional energy which lowers the kinetic energy for pion production, and therefore the pion yield [1]. The cascade shows that in \( ^{4}\text{He} + A \) collisions at 800 MeV/nucleon, densities larger than \( 3 \rho_0 \) can be reached, in a small zone of about 2 fm diameter. Consequently, the compressional energy effects cannot be completely neglected. On the other hand, the fact that the cascade/experiment ratio of pion yields increases with increasing target mass or \( n_{\pi^-} \) multiplicity suggests that pion absorption in nuclear matter is underestimated in the cascade code. However, one has to keep in mind that in standard Cugnon's cascade used here, the binding energies of the two nuclei are not included. Therefore, we re-calculated the cascade pion yields, with the binding energy prescription introduced in ref. [2]. In this approach, the nucleons suddenly loose 40 MeV just before their first collision. We found that this prescription strongly reduces the discrepancy between the cascade and the experimental total pion multiplicities. The Pauli blocking effect has also been tested, using a prescription similar to what is used in the VUU [5] or BUU [3,20] codes. At 800 MeV/nucleon, its influence on the total pion multiplicities is smaller than the statistical uncertainties. If we include these two prescriptions in a "new" cascade, we find that at 800 MeV/nucleon, the ratio (cascade/exp.) of the total mean \( n_{\pi^-} \) multiplicities becomes 0.94, 1.1, and 1.4 for the targets C, Cu, and Pb respectively; while it was 1.5, 1.9, and 2.4 with the "old" version. But it has to be stressed that a large discrepancy remains for "high" \( n_{\pi^-} \) and heavy targets as it can be seen in Fig. 3 (dotted line).

In conclusion, first quasi-exclusive data measured with the Diogene detector are presented. Target mass, incident energy, and \( n_{\pi^-} \) dependences of the mean pion multiplicities measured in \( ^{4}\text{He} \)-nuclei collisions are studied. Comparisons to the cascade calculations clearly establish that, even for such a light projectile, the theory overestimates the experimental data. The discrepancy is reduced if the binding energy is taken into account in the model, but it remains large for heavy targets and high \( n_{\pi^-} \).

References