Yield and transverse momentum of relativistic hydrogen isotopes in photonuclear spallation of ^{32}S ions at 200A GeV

A. Abdelsalam[1], S. Kamel[2], Kh. Abdel-Waged[3], N. Rashed[4]

[1] Physics Department, Faculty of Science, Cairo University, Egypt

[2] Physics Department, Faculty of education, Ain Shams University, Egypt

[3] Physics Department, Faculty of applied Science, Umm Al-Qura University, Saudi Arabia

[4] Physics Department, Faculty of Science, Cairo University, El-Fayom Branch, Egypt

Presenter: S. Kamel(sayedks@hotmail.com).

Production of multi-hydrogen (mH) isotopes in the spallation of 200A GeV sulphur projectile using nuclear emulsion is reported. Yield of mH isotopes is studied and compared with that of the lowest energy (3.7A GeV) data. The two-source emission picture is used to describe the transverse momentum (P_T) distribution of mH isotopes (with and without the e¤ect of ^{32}S(°; p)^{31}P channel). The Rayleigh type P_T-distribution seems to be in agreement with the corresponding experimental data. The contributions of low and high temperature emission sources show a dependence on the photonuclear processes.

1. Introduction

Many experiments have been devoted to investigate the transverse momentum distribution (P_T) of relativistic helium fragments using heavy ion beams when they became available at accelerators[1-5]. Recently, few similar experiments with relativistic proton PFs obtained either from nuclear [3] or electromagnetic [4,5] events have already been carried out to study the P_T distribution. In the present work and owing to the collection of our exclusive data given in ref. 6, the P_T distribution of all relativistic single charged fragments (308 hydrogen isotope fragments) emitted in the di¤erent visible decay modes (i.e. those involving charged fragments) of ^{32}S spallation at 200A GeV is studied. The given H-particles P_T-distribution analyzed with and without the e¤ect of single proton production through the ^{32}S(°; p)^{31}P channel [4], the dominant mode of decay (44 %), within a two-source emission formalism [5].

2. Discussion

In the present work, a stack of Fuji emulsion plates was exposed horizontally to the 200A GeV ^{32}S ions at the CERN-SPS (Exp. No. EMUO3). To obtain high scanning e¢ciency, the pellicles were scanned under 100 magni…cation using along the track scanning technique. Other details concerning the chemical composition of the emulsion used, irradiation and scanning are given in refs. 6.

Since in the emulsion experiment, only charged particles can be identi…ed such that the charge of each but not the mass could be determined, neutrons cannot be detected and isotopes are not separated. Consequently, in this work, the fragmentation modes having fragments accompanied with one or more neutrons are misidenti…ed.

The detected 210 EMD events due to the clean break up of 200A GeV ^{32}S projectile in emulsion were reported in ref.11. In Fig. (1), we show the charge yield curve for ^{32}S spallation in the emulsion at two widely di¤erent energies. The solid histogram in Fig. (1) represents our data at 200A GeV while the dashed one represents the data of 3.7A GeV [6]. The two distributions have a characteristic U-shaped form. The …gure shows clearly the e¤ect of incident energy at large values of Z, i.e. at Z ¸ 10. The number of single charged particles, N_H, could characterize the degree of hardness of interaction. These particles may be emitted from di¤erent sources. Therefore, for better probing the dynamics of heavy ion reactions, the present work which is an extension to our previous one [4], deals only with a sub sample of 175 EMD events having one or more H-particles in the …nal state (in addition to the heavy fragments). Following the analysis of the angular distribution of 308 H-particles presented in our sub sample, the average values of emission angles, < µ$_H$ >, are found [4] to be (0.889§0.081) mrad.

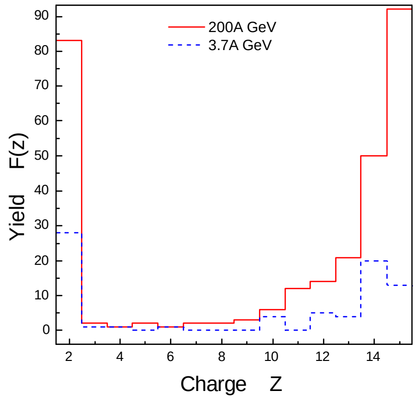

Fig.(1):The charge yield curve of the PFs emitted in the EMD events.

In fact, we deal with the interested EMD data sub sample as two major parts, namely single charged fragments [5] (mostly are protons) which are the most abundant particle in our data, ^{32}S(°; p)^{31}P, and the multiple hydrogen isotopes, mH. The measured cross section in ref.6 for the former decay mode, ¾$^{p}_{EMD}$ equals to (502 § 52) mb which represents (33 § 3) % of the measured total EMD cross section [6] where, ¾$^{tot:}_{EMD}$ = (1531 § 103) mb. While for the later ones, the cross section measured for mH emission channels, ¾$^{mH}_{EMD}$ represent about (55 § 4) % of the measured total EMD cross section. The cross sections measured for 1p and 1H; 2H; :::; mH emission channels induced by Ag target in emulsion [7,8], see after, sum to about (1340 § 90) mb, which represent roughly 88% of the ¾$^{tot:}_{EMD}$. This permits a comparison between P_T distributions of these two major parts. This study is considered complementary to energy measurements already reported in our recent work [7]. All of this information could help to obtain a consistent picture of the entire reaction process.

In this work, the transverse momentum of all (308) H particles emitted in the 200A GeV ^{32}S break-up is calculated. We divided such particles into two groups, as we already mentioned. The …rst group contains 92 protons emitted in the dominant decay mode ^{32}S(°; p)^{31}P and the second one contains 216 H particles emitted in the di¤erent other decay modes, see ref 6. Therefore, the transverse momentum distributions are investigated in Figs. 2 and 3 with and without the e¤ect of protons produced in the p +^{31} P channel, respectively.

The transverse momentum $P_T (= \sqrt{P_x^2 + P_y^2})$ obeys the Rayleigh distribution [9]:

$$f_{P_T}(P_T;\sigma_i) = \frac{P_T}{\sigma_i^2}\exp\left(\frac{-P_T^2}{2\sigma_i^2}\right) \quad (1)$$

For a two-source emission process, the P_T distribution is the sum of two Rayleigh distributions:

$$f_{P_T}(P_T) = A_L f(P_T;\sigma_L) + A_H f(P_T;\sigma_H) \quad (2)$$

where, A_L and A_H are the normalization factors for the low and high temperature emission of mH particles, respectively, while σ_L and σ_H are related to the temperature T of the emission sources [10] according to the relation $\sigma^2 = m_0\gamma T$ (γ is the mean lorentz factor).

In Fig. (2), the P_T distribution for all H particles is compared with the corresponding one of 92 protons. The solid histograms are the present experimental data. The curves are our calculated results. The contributions of low and high temperature emission sources are given by the dotted and dashed curves, respectively. The solid curves are the sum of the dotted and dashed curves. The values L and H are obtained by fitting the experimental data and equal 160 MeV/c and 470 MeV/c, respectively. The values of χ^2/degrees of freedom (DOF) for the low and high components of all mH isotopes are 0.507 and 1.319, respectively. While for the single protons, the corresponding values are 0.491 and 1.861, respectively.

In Fig. (3), we show the PT distribution for the 216 H particles i.e. without the effect of $p+^{31}P$ channel. The other conditions are the same as Fig. (2). The values of χ^2/DOF are now 0.518 and 1.857, respectively. From Figures. 2 and 3, one can see that the three experimental distributions have the same shape and the same trend. The best fit is observed for the low components of the P_T distributions, where the minimum value of χ^2/DOF is obtained. We also notice that the two-source emission picture gives a good description of the transverse momentum distribution for H particles in both investigated cases, i.e. with and without the effect of $p+^{31}P$ channel. This description shows the dependence of shape of P_T-distribution on the contributions of low and high temperature emission sources such that the great difference in these contributions cannot be described by a single temperature.

3. Conclusions

A study has been made of the production of multi-hydrogen (mH) isotopes during the break-up of 200A GeV ^{32}S projectile in nuclear emulsion. The decreasing yield and the extension of the production probability to higher multiplicity values may reflect the dependence of the degree of break-up on the response of the projectile nucleus to the absorption of one or more than one virtual photon. The P_T-distribution of mH isotopes was analyzed with and without the effect of single proton production through the $^{32}S(\gamma;p)^{31}P$ channel, the dominant mode of decay (44 %), within a two-source emission formalism. The calculated results show a good agreement with the experimental data.

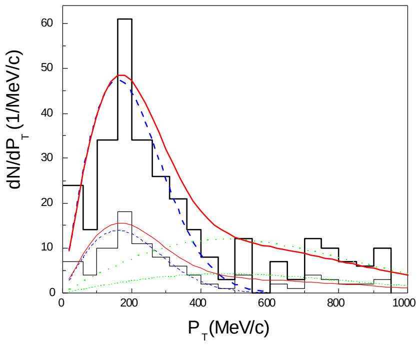

Fig.(2): The PT distribution for all (308) H- particles (thick lines) in comparison with that of 92 protons (thin lines).

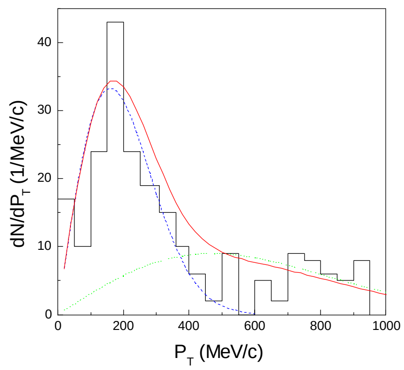

Fig.(3): The same as Fig. (2) but for only 216 H- particles.

This work was carried out at Mohamed El-Nadi High Energy Lab., Faculty of Science, Cairo University. The authors appreciate very much the help of the authorities of CERN SPS with the irradiation of the plates.

References.

[1] D. Ghosh, J. Roy and R. Sengupta, J. Phys. G 14, 711 (1988).

[2] S. Kamel, IL Nuovo Cimento. A 112, 733 (1999).

[3] D. Ghosh, S. K. Das and K. Ghosh, Nuovo Cimento Soc. Ital. Fiz. A 110, 565 (1997).

[4] M. El-Nadi et al., Radiat. Meas. 28, 231 (1997).

[5] S. Kamel, Nuovo Cimento Soc. Ital. Fiz. A 112, 327 (1999).

[6] M.EL-Nadi et al., J. Phys. G: Nucl. Part. Phys. 28, 241(2002).

[7] M. El-Nadi et al, Can. J. Phys. 82, 263 (2004).

[8] G. Singh and P. L. Jain, Z. Phys. A 344, 73 (1992).

[9] U. A. Abdurazatova, A. E. Bengus, A. I. Bondarenko, R. U. Kholmatova, G. M. Chemov, Sov. J. Nucl. Phys. 47, 827 (1988).

[10] Fu-Hu-Liu and Yuri A. Panebratsev, Phys. Rev. C 59, 941 (1999); Fu-Hu-Liu, Chin. J. Phys. 39, 401 (2001).