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EXPERIMENTAL SET-UP ANOMALON FOR MEASUREMENT OF RELATIVISTIC NUCLEAR FRAGMENTATION CROSS SECTIONS

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Characteristics of experimental set-up ANOMALON installed at slow extraction beam VP-1 of the JINR Synchrophasotron are presented. The set-up has been designed to measure fragmentation cross sections for reaction $A(Z)+H \to A_f(Z_f)+X$ with high accuracy. It includes: magnetic spectrometer (proportional chambers and analysing magnet), liquid hydrogen target and Cherenkov hodoscope. The operation characteristics of proportional chambers in heavy ion beams are discussed. The values of 0.26*e* and 0.18*A* for the charge and mass resolutions have been achieved for products of ^{12}C fragmentation at 4.5 GeV/c per nucleon.

The investigation has been performed at the Laboratory of High Energies, JINR.

Экспериментальная установка АНОМАЛОН для измерения сечений фрагментации релятивистских ядер

Борзунов Ю.Т. и др.

Представлены характеристики экспериментальной установки АНОМАЛОН, расположенной на канале медленного вывода ВП-1 синхрофазотрона ОИЯИ. Установка была создана для измерения сечений фрагментации реакции $A(Z)+H \to A_f(Z_f)+X$ с высокой точностью. В установку входят: магнитный спектрометр (пропорциональные камеры и анализирующий магнит), жидководородная мишень и годоскоп черенковских счетчиков. Обсуждаются рабочие характеристики пропорциональных камер в пучках ядер. Для продуктов фрагментации ^{12}C при импульсе 4,5 ГэВ/с на нуклон для зарядового и массового разрешений были получены величины 0,26*e* и 0,18*A* соответственно.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Introduction

The knowledge of the cross sections of such nuclei as carbon and oxygen on hydrogen, is of particular interest for cosmic ray physics. This fragmentation process occurs in the interstellar medium (composed mainly of hydrogen) while the low energy cosmic ray nuclei propagate in it for about 10^7 years, producing measurable amounts of «secondary» nuclei such as Li, Be, B. Knowing the relevant cross sections, one can estimate the thickness of interstellar gas traversed by the parent nuclei from their sources to the Earth atmosphere. The propagation process is evidently an energy dependent phenomenon and the cross sections at different energies are needed to study it. The so far measured cross sections, published in the literature, are far from being complete [1,2,3]. This work is a part of a broader plan to measure ^{12}C and ^{16}O fragmentation cross sections into lighter isotopes in the momentum range of $2.65 \div 4.5$ GeV/c per nucleon.

2. Detectors

The set-up ANOMALON at slow extraction beam VP-1 (Fig.1) is a magnetic spectrometer based on the system of multiwire proportional chambers (MWPC) and analysing magnet SP-40. It also includes: liquid hydrogen target (*T*), Cherenkov hodoscope (*C*) and trigger system composed of scintillation counters (*S*) and Cherenkov counters (CI, CII). The Cherenkov hodoscope and the MWPC8-10 are aligned for the 80 mrad bending angle.

a) *Coordinate Detector.* The MWPC for the coordinate detector have been designed and constructed by the JINR LPP group [4]. To register primary beam track, three blocks of propotional chambers MWPC1-3 were used. Each block is composed of three separate MWPC having one anode wire plane oriented in vertical direction and two others — (+ 60°) and (− 60°) rotated. Blocks MWPC4-7 of the analogous construction, register the track of the fragment. The sensitive zone and anode wire spacing for MWPC1-4 are

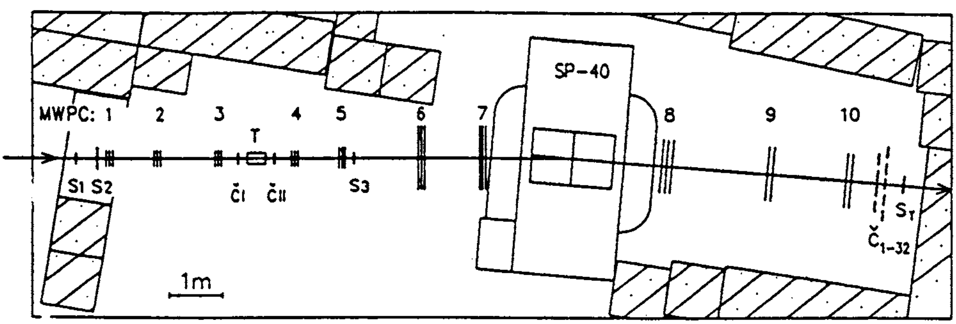

Fig.1. Layout of the set-up ANOMALON

∅ 64 mm and 1 mm, respectively. Other chambers have wire spacing 2 mm and sensitive zone ∅ 128 mm for MWPC5 and ∅ 384 mm for MWPC6,7. The blocks MWPC8-10 measuring the track after the analysing magnet SP-40, are composed of «X-Y» chambers with a sensitive area of 1280×896 mm^2 and wire spacing of 2 mm. MWPC8 has an additional «Y»-type chamber but it is rotated 60° clockwise. 32 channel LeCroy 7700 [5] readout electronics is used. The total number of readout channels is 4736. We have used gas mixture: argon + 28% isobutane + 2.8% propanol-2 + 0.2% freon13-B1.

b) *Target.* The fragmentation of relativistic nuclei occurs in the liquid hydrogen target with helium recondensation (*T*) designed and constructed by the JINR LHE group [6]. This cylindrical thin shell target (0.067 g/cm^2 mylar) is 136 mm long with diameter of 59 mm.

c) *Trigger.* The use of the Cherenkov counters CI, CII in addition to the scintillation counters S1-3 in the trigger logic gives us a possibility of separating the events where fragmentation in the target takes place. Adjusting the discrimination levels for the CI signals we reject the contamination of the primary beam. CII is used to suppress the events without fragmentation in the target. Due to the critical reflection condition our counters are sensitive only to the Cherenkov irradiating particles in the narrow angle of incidence..

d) *Cherenkov Hodoscope.* Cherenkov hodoscope (C1-32) — a detector of the relativistic fragment charge — is composed as one unit of 32 counters. The 35 cm radiators are made of plexiglass. All the radiators are aligned to cross perpendiculars to their surfaces in the centre of the analysing magnet. The hodoscope is made movable: for the beam calibration every counter could be placed in the central position.

3. Spectrometer Characteristics

The main problem of MWPC operation in the relativistic nuclear beams is knocked-on electrons background. The number of knocked-on electrons is proportional to the nuclear charge square (Z^2). The hard part of this spectrum widens the cluster size (the number of MWPC wires operated simultaneously) while the low energy electrons due to the multiple Coulomb scattering could be registered as separate clusters giving false track coordinates. The typical MWPC registration efficiency (ε) as a function of cathode-anode voltage (U) for nuclei with different Z is shown in Fig.2. One can see that when MWPC operates at a voltage corresponding to the «efficiency plateau» for nuclei with high Z, it strongly discriminates electrons. This is the case for the primary beam registration (MWPC1-3). Registering fragments in a charge region, for instance, $[3 \div (Z-1)]$, we have to fix the operation voltage at the level of «efficiency plateau» for Li thus the registration probability for electrons is not so low. Figure 3 presents the deviation of cluster centre coordinate x_C from track coordinate x_T for ^{19}F beam. When the voltage increases from 3.2 kV (^{19}F «plateau») to 4.6 kV ($Z = 1$ «plateau») the contamination of the false coordinates induced by knocked-on electrons grows up significantly. The mean cluster size for the last point is 2.5 and the mean cluster number reaches the value of 3.5. Nevertheless, the width of the distribution at the level of half maximum, stays constant.

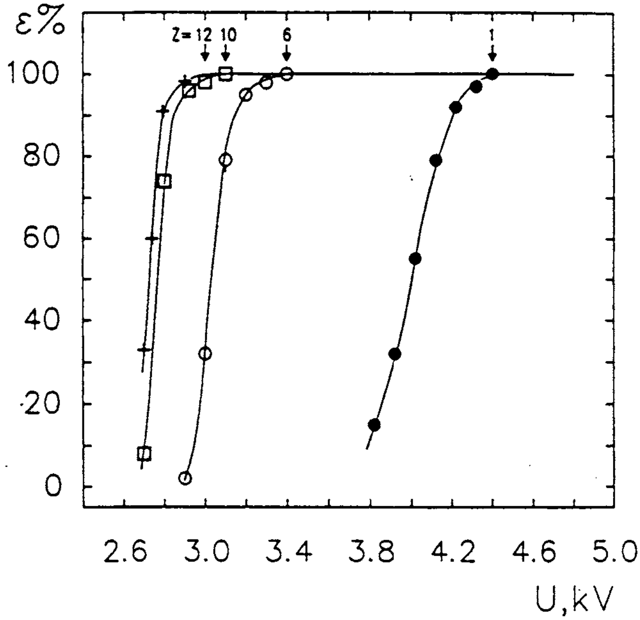

Fig.2. The registration efficiency of the MWPC for particles with different charge Z as a function of anode-cathode voltage U

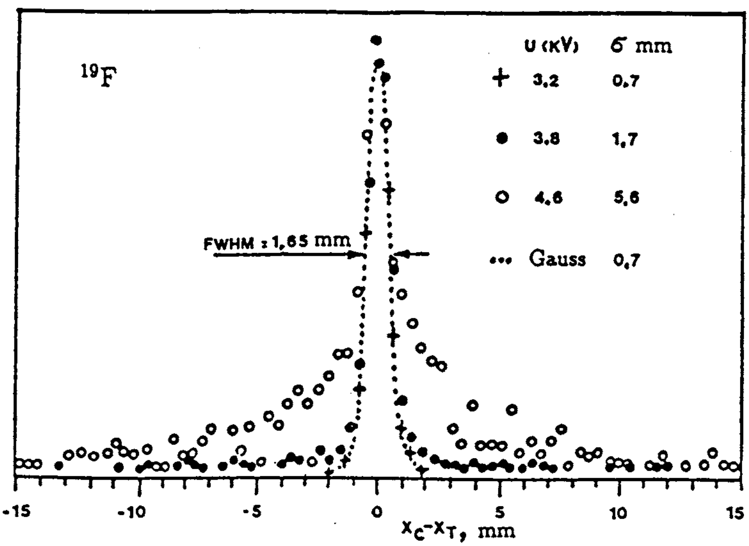

Fig.3 The deviation of the cluster centre coordinate x_C from the track coordinate x_T for ^{19}F beam at 3 values of anode-cathode voltage U

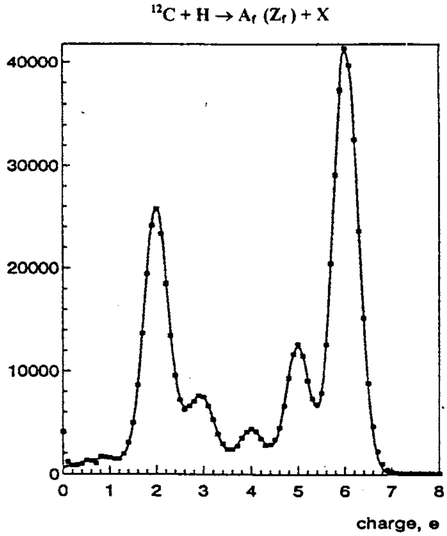

Fig.4. The Cherenkov hodoscope summary charge spectrum. The curve is the sum of Gauss fits

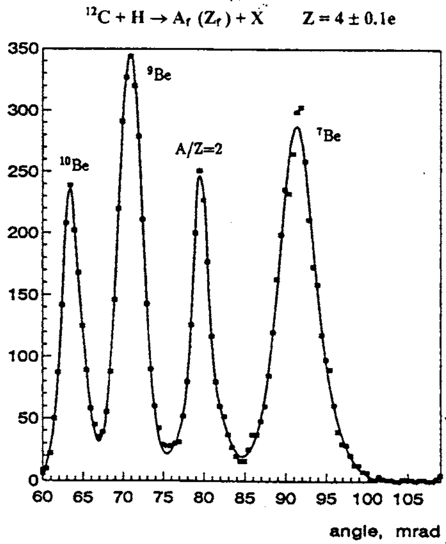

Fig.5. The isotope spectrum corresponding to the charge spectrum cut $Z=4\pm0.1e$ (see Fig.4). The curve is the sum of Gauss fits

We have reconstructed the tracks in three regions: 1) before the target (MWPC 1-3), 2) after the target (MWPC 4-7) and 3) after the analysing magnet (MWPC 8-10). To reject the false tracks we have checked the correlation of all the three tracks in «X» and «Y» projection. The track reconstruction efficiency has been obtained of about 60%.

Figure 4 shows the summary charge spectrum of the Cherenkov hodoscope for $^{12}C+H\rightarrow A_f(Z_f)+X$ fragmentation at 4.5 GeV/c per nucleon. This spectrum corresponds to the events with track reconstruction. The charge resolution for carbon peak ($Z=6$) is $0.26e$. Fitting the spectrum with appropriate functions one could estimate the amount of the events corresponding to the fragmentation into nuclei with different charge. We should mention that the «carbon events» are discriminated by the trigger and the events with $Z\leq2$ are discriminated in the level of track reconstruction because the operating voltage for the MWPC in the region 2) and 3), corresponds to the «efficiency plateau» for Li.

Figure 5 gives the isotope spectrum for the events with charge $Z=4\pm0.1e$ (Fig.4). The horizontal axis is a deviation angle of a particle in the field of the analysing magnet. The $A/Z=2$ peak characterizes the admixture of the particles with the charge different from $Z=4$ — mainly ^{6}Li and ^{10}B. One can see that for this spectrum we have a mass resolution of about $0.18A$.

4. Conclusion

Measurements of the relativistic nuclear fragmentation cross sections into light nuclei (B + Li) are of great importance for the cosmic ray physics. The detailed cross-section data for a wide range of fragmentation channels obtained at different projectile energies, could clarify the picture of the cosmic ray propagation.

The characteristics of the experimental set-up ANOMALON such as charge resolution of 0.26*e* and mass resolution of about 0.18A give a possibility of performing precise cross-section measurements with the relativistic nuclear beams of Dubna Synchrophasotron.

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