PROTON – PROTON CORRELATIONS IN dp AND ^{16}Op INTERACTIONS

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SUMMARY

The correlation function of two protons has been measured in interactions dp and ^{16}Op at relativistic energies. Experimental data were obtained in full solid angle geometry with beams of light nuclei. Experimental correlation functions have been compared with theoretical calculations where the independent emission of protons from Gaussian shaped source was assumed. The root mean squared radii of the source, which can be compared with known radii of nuclei, have been obtained.

Keywords: *proton – light nuclei interactions, correlation function, radius of nucleus*

1. INTRODUCTION

The technique of intensity interferometry, which has its origin in astrophysics, has been also used in subatomic physics to investigate the space – time evolution of elementary particle and nuclear collisions. The construction of a two particles correlation function is involved. Particles are concerned to be radiated from a hot spatially localized source – reaction region. The extensive review about correlated emission in subatomic physics is in [1]. The proton – proton correlations at small momenta are due to the symmetry properties of the wave functions, strong N-N final state interaction and Coulomb interaction [2-4]. The large positive correlation is due to the attractive singlet S-wave nuclear interaction. The correlation function depends on the space – time dimension of the generation region.

In our previous paper [5] the correlation function for two protons and two deuterons in ^{4}Hep and ^{3}Hep interactions was studied. Strong positive correlation was observed for protons related mainly to the final state interaction in $^{1}S_0$ state. The root mean square radii of proton sources calculated from the correlation functions were in agreement with the radii of ^{4}He and ^{3}He nuclei.

Our experimental data were obtained in a full solid angle geometry with beams of light nuclei d, ^{3}He, ^{4}He and ^{16}O. The aim of present paper is, thus, to complete the obtained results on pp correlations from Hep interactions with the first results from dp and ^{16}Op interactions which are also available.

2. EXPERIMENT

The experimental data were taken by the 1 meter JINR hydrogen bubble chamber, which was irradiated in the beams of d and ^{16}O nuclei at momenta 1.67 A GeV/c and 3.25 A GeV/c, respectively. The use of a nuclear beam impinging on a proton target makes all fragments of the incoming nuclei fast in the laboratory frame what enables them to be detected, well measured and identified. The description of the experimental set–up can be found in [6].

In the case of dp interaction the geometrical reconstruction and kinematical analysis were carried out by using the CERN program package based on HYDRA library [7]. Reactions containing not more than one neutral particle can be studied in an exclusive approach. From the complete data summary tape containing 237 413 events of dp interaction a sample of 102 757 events fitting the dp $\rightarrow$ ppn reaction was collected. These events can be divided into two channels:

a) the charge retention channel – proton is the fastest secondary particle with respect to the deuteron rest frame (85 229 events)
b) the charge exchange channel – the fastest particle with respect to the deuteron rest frame is the neutron (17 518 events).

The two protons in the latter case have small relative momenta as the fastest particle is the neutron, that is why correlation between them can be expected. Proton momentum distribution in the deuteron rest frame for charge exchange channel of the reaction dp $\rightarrow$ ppn is shown in Fig 1.

In the case of ^{16}Op interaction the experimental procedure is described in [8]. The data summary tape contains 11423 events. Identified protons can be divided into two categories: protons unambiguously identified by ionization, with momenta less than 1 GeV/c in laboratory frame which are mainly recoiled target protons, and protons identified as fragments with charge Z=1.

They are expected to have momenta from the interval (1.75 – 4.75) GeV/c in the laboratory frame.

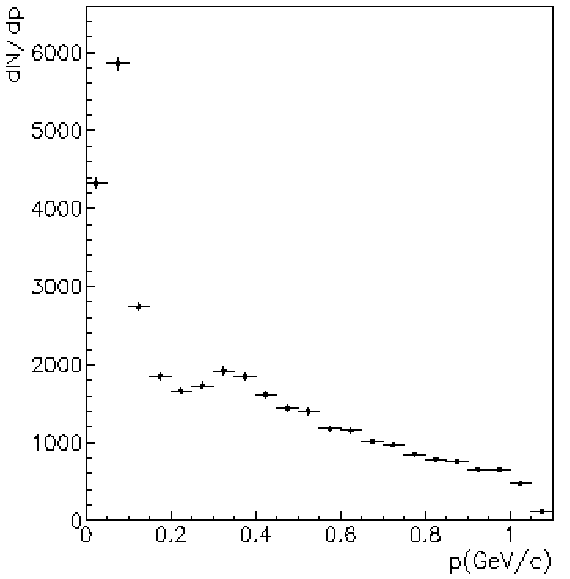

Fig. 1 Proton momenta distribution in dp interaction

Tab. 1 Numbers of protons

N_p	1	2	3	4	5	6	7-9
N_e	2885	2156	1295	704	325	145	59

Numbers of events (N_e) with various number of protons (N_p) are listed in Table 1. All events with two and more protons from the 2nd category have been included into correlation study. Momentum distribution of these protons is presented in Fig. 2. Measuring accuracy of proton momenta is (3.14 ± 0.01)%.

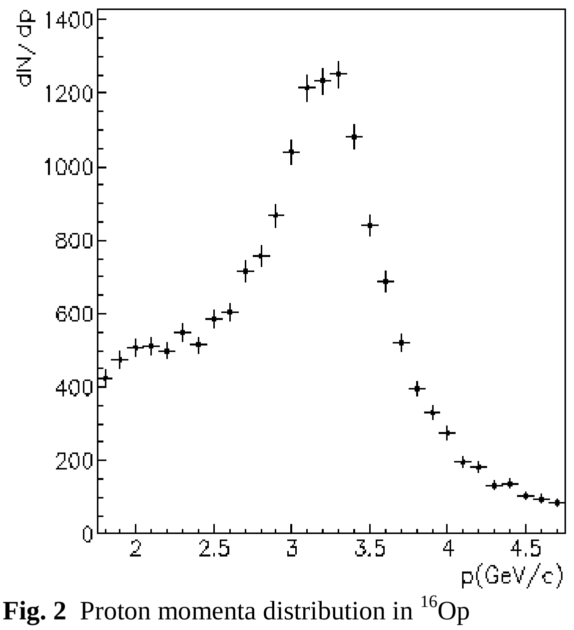

Fig. 2 Proton momenta distribution in ^{16}Op interaction

3. RESULTS AND DISCUSSION

The correlation function $R(p_1,p_2)$ of two protons is defined [5]:

$$R(p_1,p_2)=\frac{\sigma(p_1,p_2)}{\sigma(p_1)\sigma(p_2)}\,.$$

It is plotted as a function of the difference of four – momenta $k*$ of protons:

$$k*=\frac{\sqrt{(\bar{p}_1-\bar{p}_2)^2-(E_1-E_2)^2}}{2}$$

Theoretical curves for the correlation functions were calculated according to [3] where the independent emission of protons from Gaussian shaped source was assumed. The protons interact in the final state and S wave interaction dominates (for the relative momenta of two protons less than 100 MeV/c with accuracy better than 1%). The space – time distribution of proton generation points has been described as:

$$W(r,t)=(2\pi)^{-4}r_0^{-3}\tau_0^{-1}\exp\left(\frac{-r^2}{2r_0^2}-\frac{t^2}{2\tau_0^2}\right)$$

where r_0 and τ_0 characterize the dimension of the source in space and time. The root mean square radius of the source is equal $\sqrt{3}r_0$. It was shown in [5] that the results are not sensitive to the value of parameter τ_0 in the region of interest.

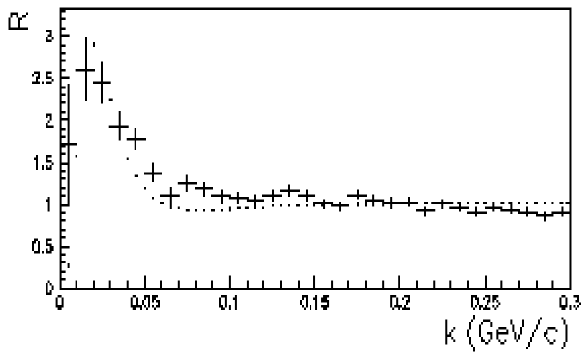

Fig. 3 Proton - proton correlation function for dp reaction. The curve represents the theoretical calculation.

In Fig. 3 the pp correlation function for two protons from charge – exchange dp → ppn reaction can be seen. The background distribution has been obtained by combining protons from different events of charge - exchange reaction. The best agreement between the data and the theoretical prediction has been achieved for r_0 = 1.6 fm (χ^2/ND = 4.3) what leads to value of 2.8 fm for root mean square radius of the emission source. Value of deuteron root mean square radius obtained in [9] is 1.96 fm. The value of deuteron radius calculated in the frame of liquid-drop model [10] is then 2.53 fm. Our result is closer to the latter one.

In Fig. 4 the correlation function for two protons – fragments from ^{16}Op interaction is depicted. Background distribution has been created by two protons randomly chosen from two events containing the same number of protons. The value of r_0 = 2.5 fm (χ^2/ND = 1.2) has resulted to the best agreement between the experimental data and the theoretical curve. It leads to the value of 4.33 fm for root mean square radius of the generation region. The simple estimation in the frame of the nuclear liquid-drop model for oxygen nucleus radius [10] gives 3.50 fm.

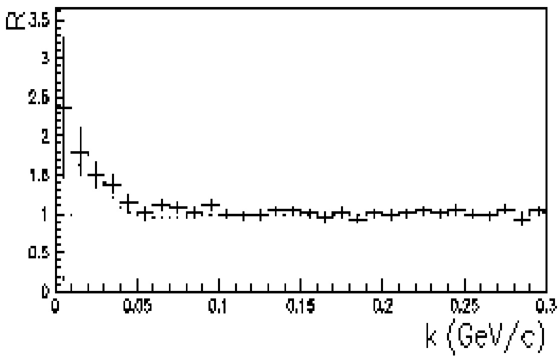

Fig. 4 Proton - proton correlation function for ^{16}Op reaction. The curve represents the theoretical calculation

4. CONCLUSION

First results on two protons correlation functions for dp and ^{16}Op reactions have been presented together with the theoretical predictions. Within errors there is a reasonable agreement between them. The root mean square radii, which can be compared with other results, have been calculated. From this comparison it can be seen that present results are slightly higher, closer to values of nuclear radii. We would like to emphasize that further study is needed, e.g. to investigate the influence of value of τ_0 on the agreement between the theoretical curve and data, to analyze the experimental correlation function dependence on the momenta of protons, to involve the correction for experimental resolution into the calculation of theoretical curves.

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