

On the Deuteron Relativistic Wave Function

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Abstract—Light front form of the relativization of the deuteron wave function is considered. Parameters of the wave function are extracted comparing theoretical results with experimental data. Experimental data are obtained on the two-metre propane bubble chamber of JINR (Dubna) bombarded by the deuteron beam with momentum of 4.2 GeV/c/nucleon.

Key words: nucleon, nucleus, stripping protons, relativization, light front.

From the very beginning of the development of relativistic nuclear physics the problem of relativization of nuclear wave functions has been posed. The problem is twofold: relativization of the intrinsic motion of nucleons in nuclei and the relativization of the movement of the nucleus as a whole [1].

In the present note relativization of the deuteron wave function is considered. From the experimental point of view the most convenient is the study of stripping proton distribution in the bubble chamber (the incoming nucleus is deuteron), since the deuteron relativistic wave function enters this distribution as a multiplier.

Consider the relativistic deuteron break up on the carbon target, when stripping protons are detected in the final state. In the impulse approximation the cross section of this process looks as follows [2]:

$$E^{st} \frac{d\sigma}{d\vec{p}} \sim \frac{\lambda^{1/2}(s_{NN}, m^2, m^2)}{\lambda^{1/2}(s, m^2, m_d^2)} \sigma_{tot}(s_{NN}) \left| \frac{\Phi(x, \vec{p}_\perp)}{1-x} \right|^2 \quad (1)$$

Here s is the usual Mandelstam variable,

$$s_{NN} = s(1 - x^{st}) + m^2 - \frac{\vec{p}_\perp^{st^2}}{x^{st}} + \frac{m^2}{x^{st}} \quad (2)$$

$\sigma_{tot}(s_{NN})$ is nucleon-nucleon total cross section, m is the nucleon mass, m_d is the deuteron mass.

$$\lambda(x, y, z) = (x - y - z)^2 - 4yz \quad (3)$$

The variable x^{st} in the laboratory frame is defined as follows:

$$x^{st} = \frac{E^{st} + p^{st}}{(E_d + p_d) + m} \quad (4)$$

$\Phi(x, \vec{p}_\perp)$ is the deuteron relativistic wave function. Its arguments are related to the observable quantities as follows:

$$x = 1 - \left(1 + \frac{m}{E_d + p_d}\right) x^{st} \quad (5)$$

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$$\vec{p}_\perp = -\vec{p}_\perp^{st} \quad (6)$$

We choose the deuteron relativistic wave function as a generalization of the well-known Hulthen wave function:

$$\Phi(x, \vec{p}_\perp) \sim \frac{1}{\left[\frac{\vec{p}_\perp^2 + m^2}{x(1-x)} - \alpha_R\right] \left[\frac{\vec{p}_\perp^2 + m^2}{x(1-x)} - \beta_R\right]} \quad (7)$$

α_R and β_R are adjustable relativistic parameters, which are extracted from the experimental data.

From (1) one-dimensional distributions $\frac{d\sigma}{dx^{st}}$ and $\frac{d\sigma}{dp_\perp^{st}}$ are obtained:

$$\frac{d\sigma}{dx^{st}} = \int_0^{p_\perp^{st, \max}} \frac{d^2\sigma}{dx^{st} dp_\perp^{st}} dp_\perp^{st} \quad (8)$$

$$\frac{d\sigma}{dp_\perp^{st}} = \int_{x_{\min}^{st}}^{x_{\max}^{st}} \frac{d^2\sigma}{dx^{st} dp_\perp^{st}} dx^{st} \quad (9)$$

Characteristic feature of the x^{st} distribution is the existence of maximum at the point:

$$x^{st} = \frac{1}{2\left(1 + \frac{m}{E_d + p_d}\right)} \quad (10)$$

Experimental data are obtained on the 2 metre propane bubble chamber *PBC-500* in the Laboratory of High Energies of the Joint Institute of Nuclear Research (Dubna). The chamber was bombarded by deuteron beam with momentum of 4.2 GeV/c per nucleon. Methodological problems of the experiment are given in Refs [3-8]. Proton is said to be stripping if its momentum is bigger than 3 GeV/c and emission angle less than 4° .

In Fig. 1 $\frac{d\sigma}{dx^{st}}$ distribution of stripping protons is compared with corresponding experimental data and parameters α_R and β_R are extracted.

In Fig. 2 the same procedure is performed for $\frac{d\sigma}{dp_\perp^{st}}$ distribution.

Numerical values of the parameters α_R and β_R are in a good agreement with the results obtained by other methods [2] ($\alpha_R = (3.522 \pm 0.006)(GeV/c)^2$ and $\beta_R = 3.383 \pm 0.033)(GeV/c)^2$).

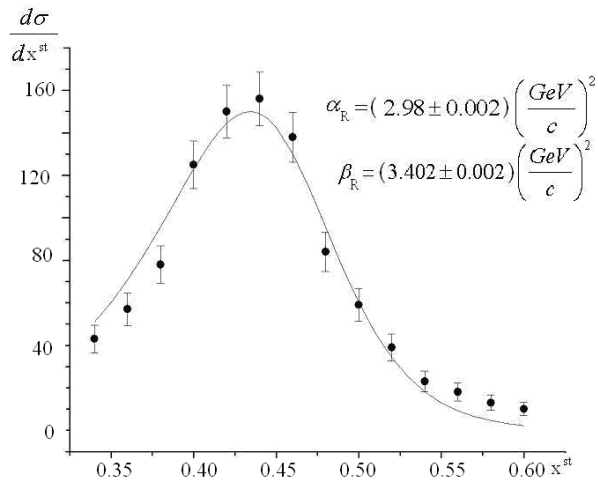


Fig. 1. $\frac{d\sigma}{dx^{st}}$ distribution of stripping protons
from the reaction $dC \rightarrow p^{st} + X$

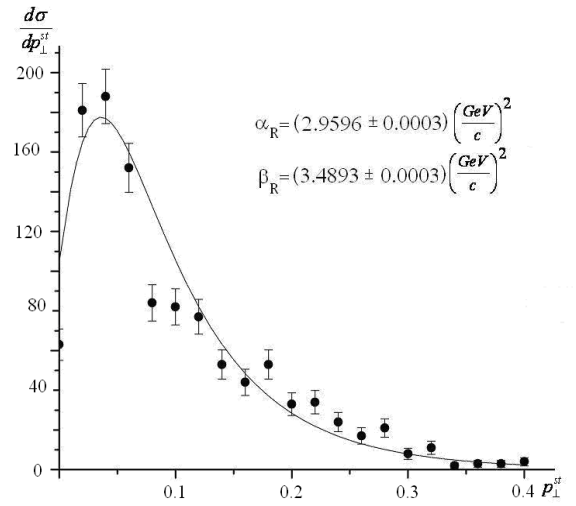


Fig. 2. $\frac{d\sigma}{dp_{\perp}^{st}}$ distribution of stripping protons
from the reaction $dC \rightarrow p^{st} + X$

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ფიზიკა

დეიტერიუმის რელატივისტური ტალღური ფუნქციის შესახებ

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(წარმოდგენილია აკადემიის წევრის ა. ხელაშვილის მიერ)

შესწავლილია დეიტერიუმის ტალღური ფუნქციის რელატივიზაცია სინათლის ფრონტის ფორმალიზმით. ტალღური ფუნქციის პარამეტრები დადგენილია თეორიული შედეგების შედარებით ექსპერიმენტულთან. ექსპერიმენტული მონაცემები მიღებულია ქ. დუბნის პროპანის 2 მეტრიანი ბუშტოვანი კამერიდან, რომელიც დასხივდა 4.2 გეევ/ც/ნუკლონი იმპულსის დეიტერიუმის ნაკადით.

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