The study of dibaryons at the NICA SPD facility

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General information

Observables: 3-momenta of deuterons and pions in the final state for processes $d + d \rightarrow d + d + \pi^0 + \pi^0$, $d + d \rightarrow d + d + \pi^+ + \pi^-$, $d + d \rightarrow (p + p + \pi^- + \pi^0) + d$ **at 6.2 GeV**

Physics being addressed: phase transitions in nuclear matter, observations of the ABC effect and dibaryons d(2380), d(2470), d(2630) and new ones.

Theoretical motivation papers: [1], [2]

Competitiveness: Experiment allows to obtain new results for dibaryons currently under study and to discover new ones due to the possibility of pushing into the broader kinematic region, $\sqrt{s} > 4.4$ **GeV**

Complementarity: It is connected with investigations of phase transitions in nuclear matter.

Previous results: [3], [4]

Actuality: actual

Importance: investigation of fundamental properties of matter

Keywords: dibaryons, ABC effect

Experimental requirements:

Beam species: dd

Collision energy: 6.2 and 9.7 GeV for first and second experiments correspondingly

Luminosity: 2 10^{31} cm^{-2} s^{-1} (6.2 GeV)

Polarization: not necessary

Involved SPD subsystems: MCT, Straw tracker

Minimal duration of data taking: 3 days

Comment: The calculation was performed using very approximate estimates [5] of the cross section of the ABC dibaryon production on the basis of the data in [6]. All experiments performed earlier at lower energies give a zero cross section for the ABC dibaryon production in d-d collisions.

Expected performance:

Simulation information used: Estimations not completed yet

Total statistics:

Statistical accuracy:

Main sources of systematics:

References

1. V. A. Matveev, P. Sorba, Lett Nuovo Cim (1977) 435
2. J. J. de Swart et al., Few-Body Systems Suppl. 99, 1–10 (2018)
3. WASA-at-COSY Collaboration, PoS (Bormio 2013) 013
4. BGOOD experiment, arXiv:2202.08594v3 [nucl-ex] 29 Oct 2024
5. B. Kostenko, J. Pribis, PoS (Baldin ISHEPP XXII) 122
6. A. M. Baldin et al., JINR Communication 1-12397, 1979

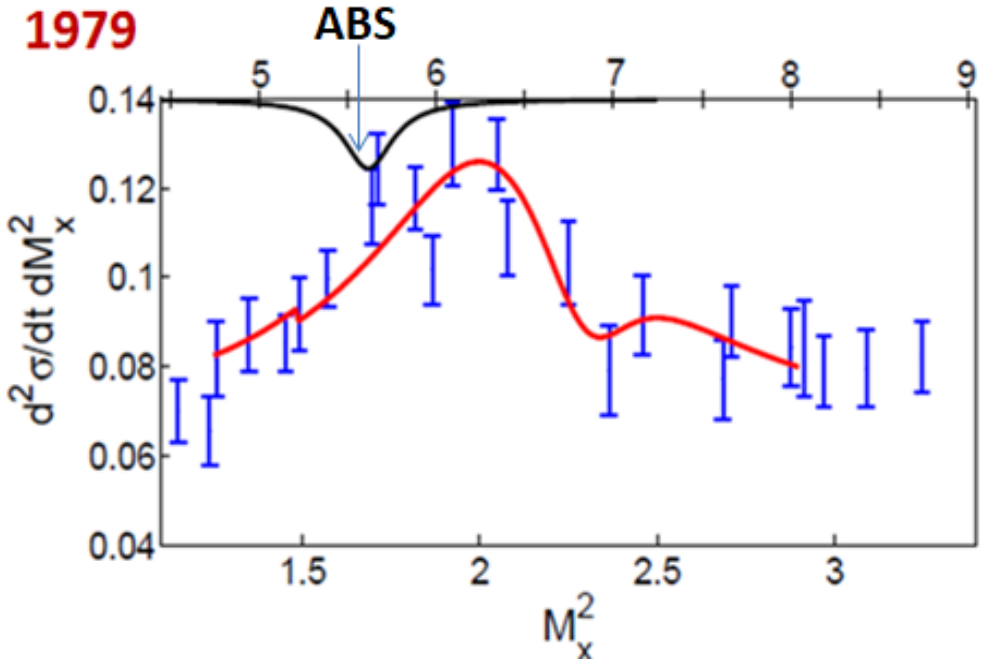
CELSIUS/WASA: $p + n \rightarrow d^*(2380) \rightarrow d + \pi^0 + \pi^0$ direct observation of d*(2380), $p + d \rightarrow {}^3He + \pi^0 + \pi^0$, $d + d \rightarrow {}^4He + \pi^0 + \pi^0$ indirect observation of d*(2380) in *p-d* and *d- d* collisions

WASA-at-COSY: $p\,d \rightarrow p\,d^*(2380) \rightarrow d\,\pi^0\,\pi^0\,p$ – direct observation of d*(2380) in ***p d*** collisions.

Unresolved experimental problem: direct observation of d*(2380) in d-d collisions has not yet been achieved. Possible reason - small phase volume at the energies used **($\sqrt{s}_{max}$ = 4.4 GeV)**.

Some indication of the possibility of the observation

Experimental data are taken from A.M. Baldin et al., JINR Comm., 1-12397, 1979



Using these data, it can be shown that in the experiment at our collider it is possible to obtain at least **250 events of d*(2380) production in d-d collisions in three days** (see Appendix)

Reactions to be studied

1. We can look for production of d*(2380), **I(J^P) =0(3+)** in *d-d* collisions using greater energies than in previous experiments: $d + d \rightarrow d^*(2380) + d \rightarrow 2d + 2\pi^0$.

We can also look for dibaryons, **I(J^P) =1(0+)**, corresponding to isovector decay modes:

2. $d + d \rightarrow d^* + d \rightarrow 2d + \pi^+ + \pi^-$,

3. And dibaryons, corresponding to compressed ***nn*** and ***pp*** systems

$d + d \rightarrow d^* + d \rightarrow (n + n + \pi^+ + \pi^0) + d$,

$d + d \rightarrow d^* + d \rightarrow (p + p + \pi^- + \pi^0) + d$

which may exist too.

A good example of intervention in a new area (new energies and new beams):

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The coherent reaction, $\gamma d \rightarrow \pi^0\pi^0 d$ was studied with the BGOOD experiment at ELSA from threshold to a centre-of-mass energy of 2850 MeV. A full kinematic reconstruction was made, with final state deuterons identified in the forward spectrometer and π^0 decays in the central BGO Rugby Ball. The strength of the differential cross section exceeds what can be described by models of coherent photoproduction and instead supports the three isoscalar dibaryon candidates reported by the ELPH collaboration at 2.38, 2.47 and 2.63 GeV/c^2. A low mass enhancement in the $\pi^0\pi^0$ invariant mass is also observed at the $d^*(2380)$ centre-of-mass energy which is consistent with the ABC effect.

Collider time required

The double differential cross sections $d\sigma/dt\, dM_x^2$ of processes d + d --> M_x + d at energy of $\sqrt{s}$= 6.16 GeV and t = - 0.495 $(GeV/c)^2$ had been measured in A.M. Baldin et al., JINR Comm., 1-12397, 1979. In the mass region M_x, where N* resonances should dominate, we also found some indications for the possibility of the production of the ABC dibaryon (at the level of ≈ 5% of sum of the cross sections of N* resonances production). In the d-d colliding beams experiment the dibaryon yield should be a factor of 2 larger. This is ≈ 0.34 10^{-30} $cm^2\, c^2/GeV^4$.

Even if we will observe dibaryons only in the interval, -t =[0.48, 0.51] GeV/c^2, where the double differential cross section data were obtained in the JINR Comm. 1-12397, the $d\sigma/dM_x^2$ cross section should be at least 10^{-32} cm^2/GeV^2. As an interval of allowable dibaryon masses we should take the ABC dibaryon width Γ = 70 MeV. As a result, we arrive at the following estimate of the cross section of the ABC dibaryon production in the above mentioned intervals of Δt and ΔM_x : $\Delta\sigma$ = 5 10^{-35} cm^2. The number of observed ABC dibaryons under the above-mentioned conditions will be for ΔT = 3 days: N = Δσ x Luminocity x ΔT = 5 10^{-35} cm^2 x 2 10^{31} cm^{-2} s^{-1} x 2.6 10^5 s = 260 events.

The number of observed ABC dibaryons may be much larger if we do not restrict ourselves to the very narrow range Δt of values of the Mandelstam variable t mentioned above.