The differential cross section for dp-elastic scattering at 500-900 MeV/n and large transverse momenta

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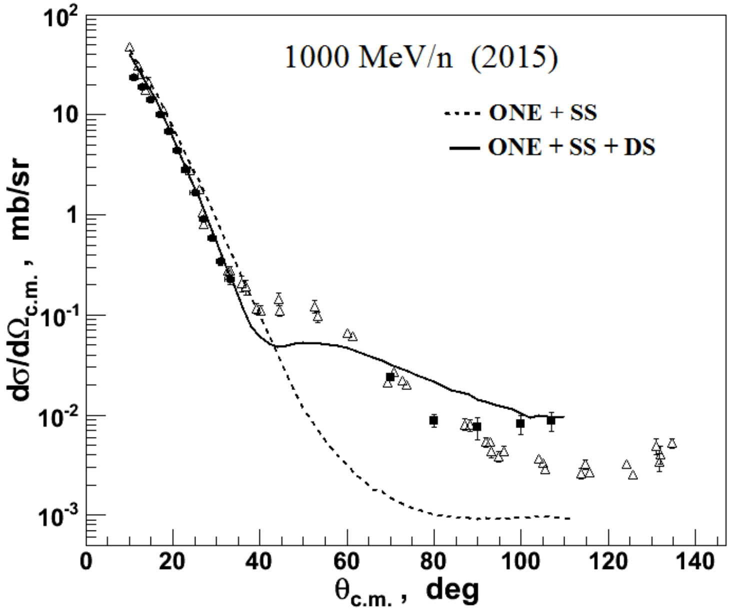
Introduction

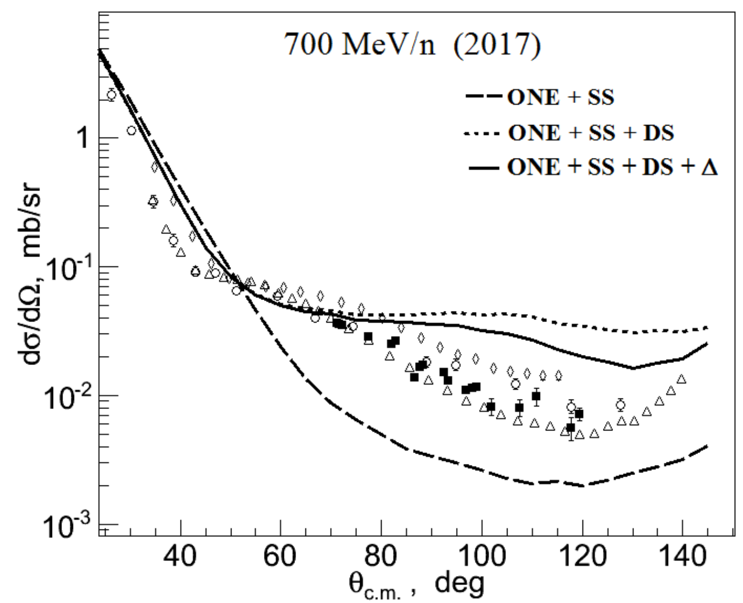
In recent years the experiments to dp-elastic scattering study were performed at Internal Target Station (ITS) at Nuclotron JINR. This setup allows us to obtain the different observables at angle range 60-140^{o} in the c.m.s. The measurements are performed in the frame of the DSS (Deuteron spin structure) project. The purpose of this project is the research of the three nucleon system in the energies domain up to 1000 MeV/n.

The data on the analyzing powers of the dp-elastic scattering were obtained at 440 MeV/n. Also the measurements of the differential cross section at the energies between 250 – 440, 700 and 1000 MeV/n were performed.

We shown in this presentation data of differential cross section for dp-elastic scattering at 500, 750 and 900 MeV/n, obtained at ITS at Nuclotron.

Differential cross section at 700 and 1000 MeV/n





Squares – data from [Terekhin A.A. et al. Phys.Part.Nucl.Lett. V12 (5) 2015 p. 695]

Circles – data obtained early for forward angles [Terekhin A.A. et al. EPJ A48, 2012. P.182.]

Triangles – data at 1000 MeV/n [Bennett G. W. et al. Phys. Rev. Lett. 1976. V.19 P. 387-390.]

The dashed and solid lines are the calculations without and with DS term, respectively. [Ladygina N.B. et al. EPJ A42, 2009. P.91.]

Squares – data from [Terekhin A.A. et al. Phys.Atom.Nucl. 80 no.6, 2017 p.1061-1072]

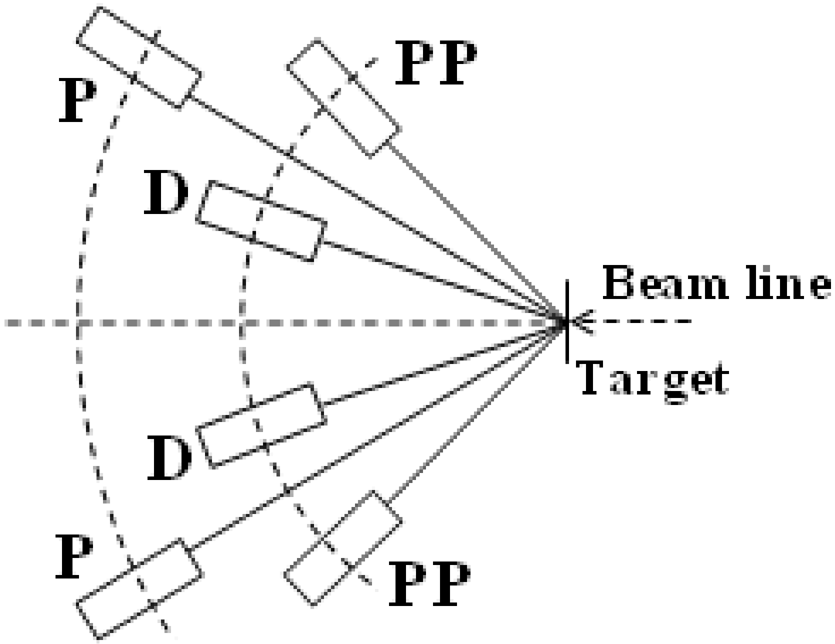
Diamonds - data at 641.3 MeV/n (Culmez E. Phys.Rev.C, V43, №5, 1991)

Triangles – data at 800 MeV/n (Winkelmann E. Phys.Rev.C, V21, №6, 1980)

Circles - data at 794 MeV/n (Culmez E. Phys.Rev.C, V43, №5, 1991)

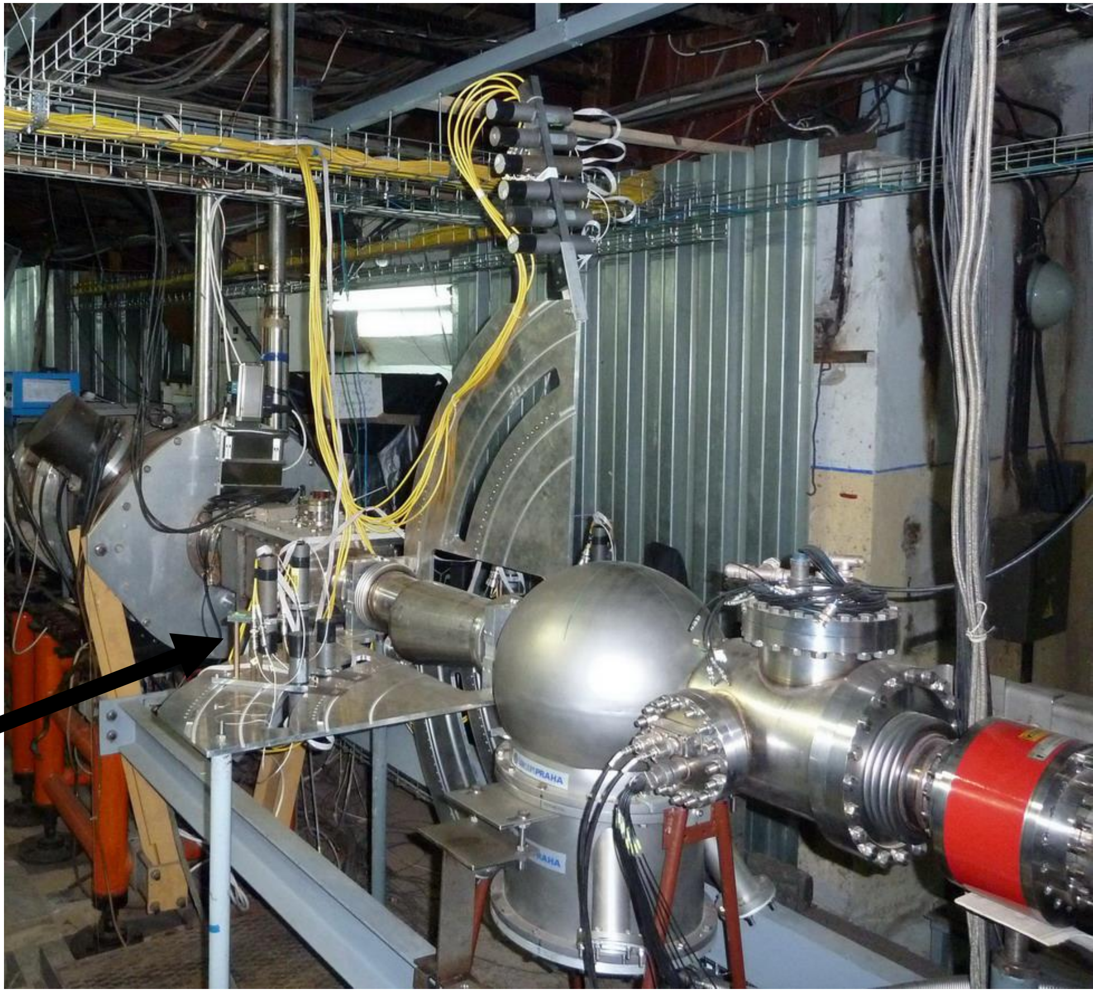
The lines are the calculations from Ladygina N.B. et al. Eur.Phys.J. A52, 2016 no.7, P.199

Layout of the counters with respect to the beam direction

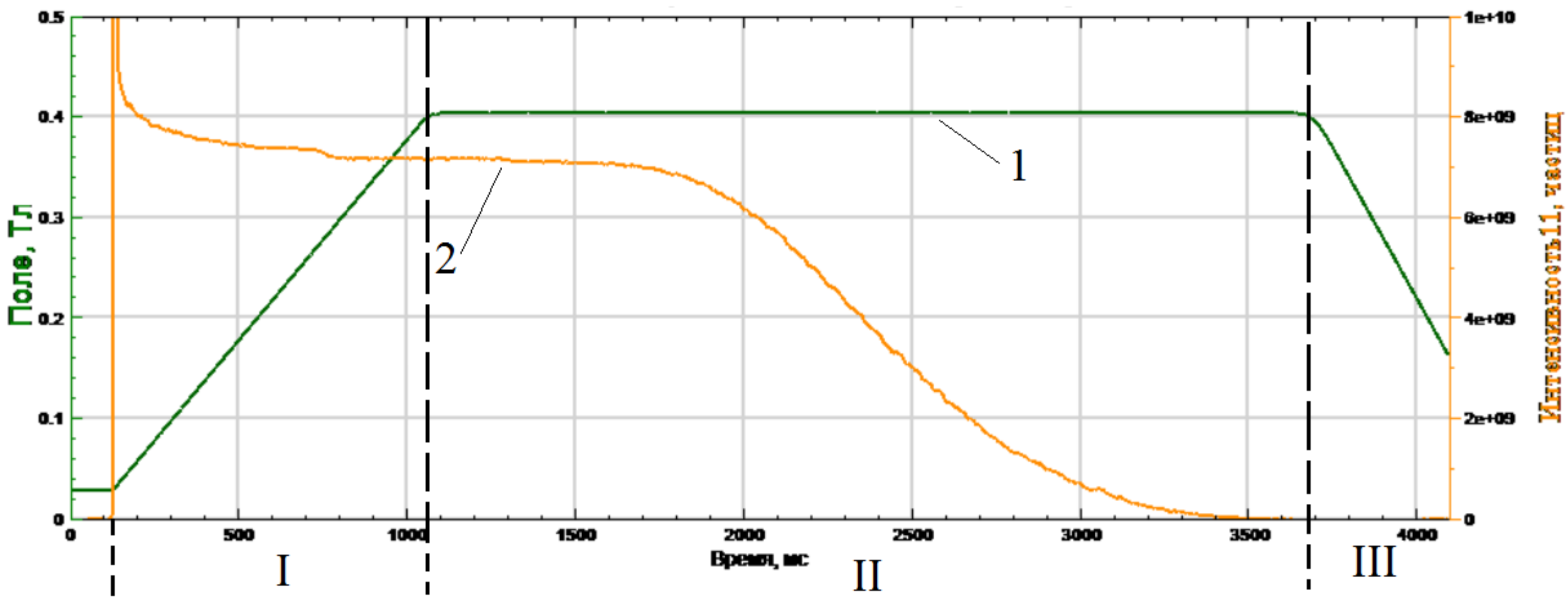


Detector	Size,mm^3	Distance from target,cm	Angular span,deg	
			lab.sys.	c.m.s.
P	20x60x20	58	2	4
D	10x40x24	56	1	2
PP	50x50x10	56	5	10

Measurements on the Internal target station



The subsystem of the diagnostic of beam intensity



I - increase of magnet field

II – the interaction of the targat with the beam

III - decrease of magnet field

1 - magnet field value

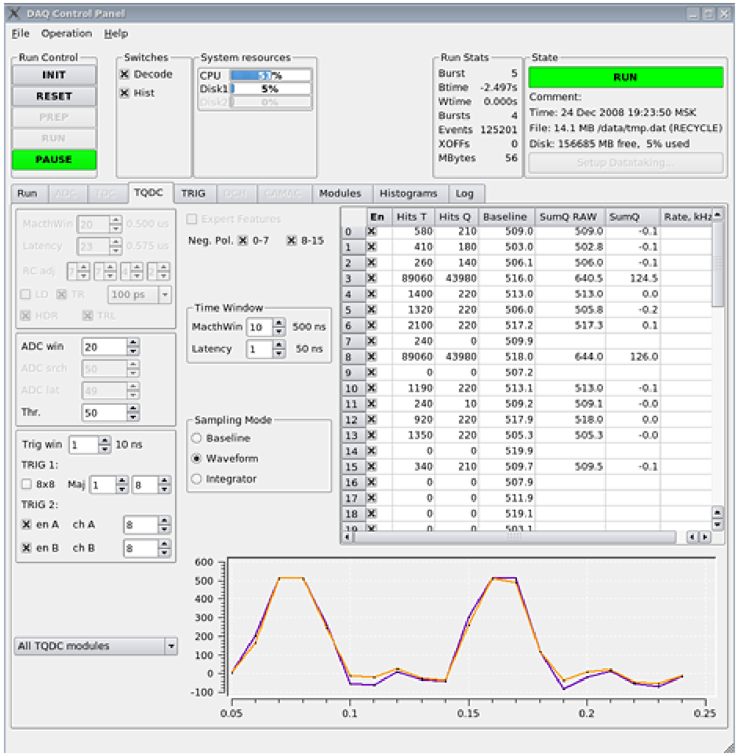
2 - the beam intensity

VME Data Acquisition System

The VME based data acquisition system was used for the data taking from scintillation detectors.

TTCM

TQDC-16

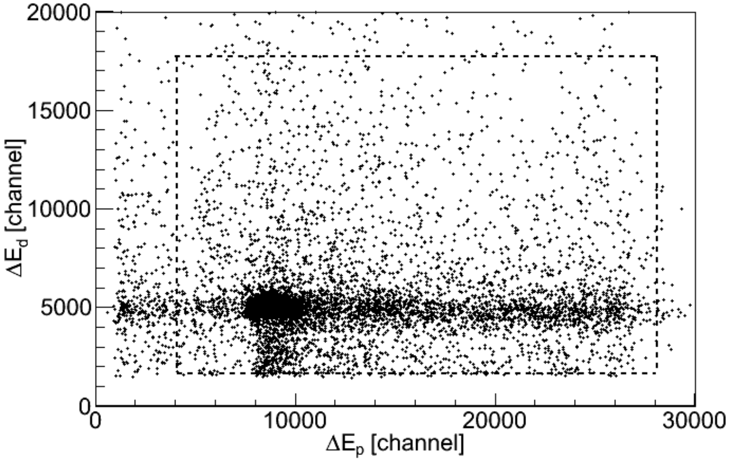


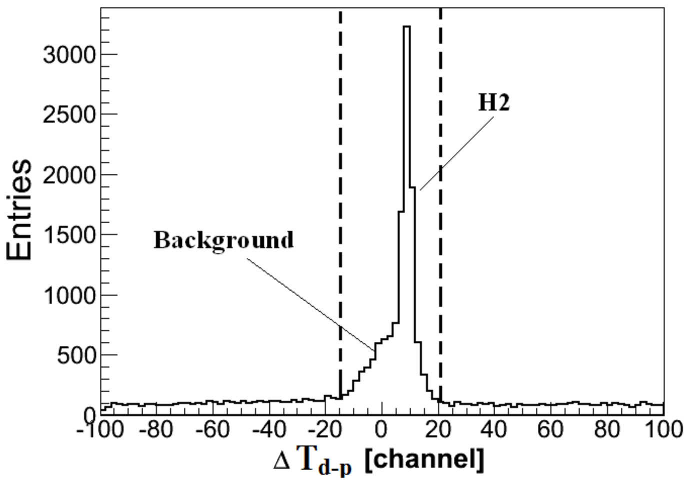
GUI Controls

TQDC-16 – 16 - channel time and charge digitizer

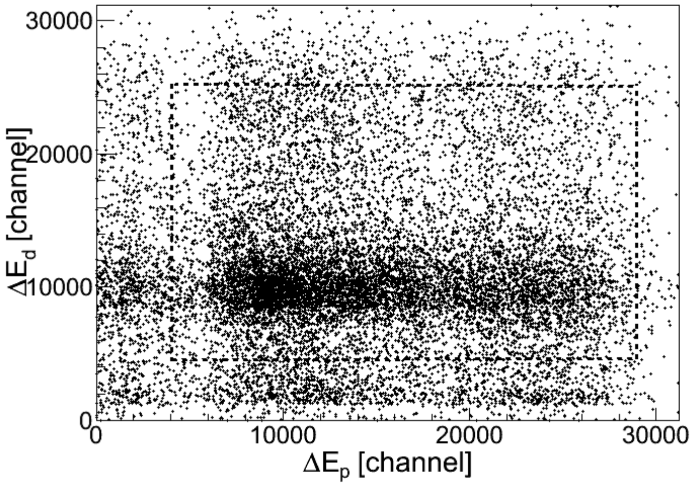
Time amplitude and time signals from D - and P - detectors

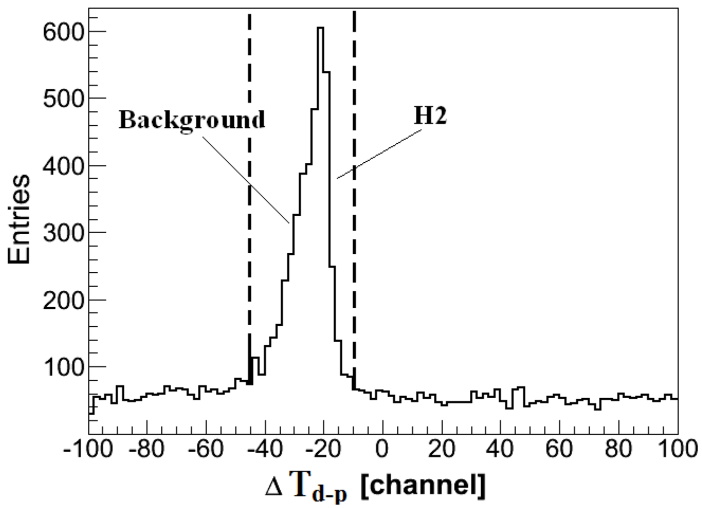
500 MeV/n





900 MeV/n





Differential cross section

$$\left(\frac{d\sigma}{d\Omega}\right)_{c.m.} = \frac{N_{dp}}{d\Omega^{D}_{lab}} \frac{k_{pp}}{N_{CH_2}} J_D C_{norm}$$

N_{dp} – the number of dp-elastic scattering events
$d\Omega^{D}{}_{lab}$ – the effective solid angle of the deuteron detector in the laboratory frame
N_{CH2} - the number of reconstructed events for PP-counters under the condition of their coincidence with each other in the case of scattering on the polyethylene target
k_{pp} - correction for the intensity of the carbon background in the N_{CH2}
J_D - transformation jacobian for the transition from the laboratory to the c.m. frame
C_{norm} - the normalization coeffcient

The effective solid angle and transformation jacobian were calculated by using of the Pluto event generator. N_{dp}, N_{CH2}, k_{pp} were calculated from the experiment.

CH_2-C subtraction

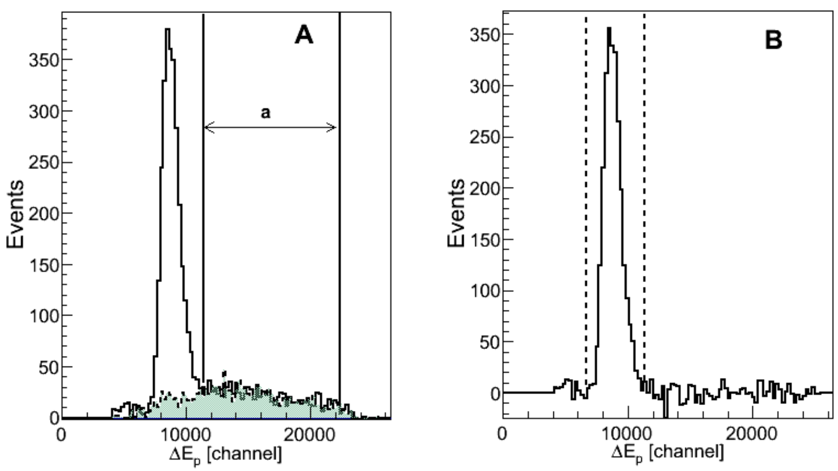
Carbon background subtraction deduced from the normalization in the interval $a_{min}<a<a_{max}$, were a - channels of CH_2- and C-amplitude distributions. I.e.

$$k = \frac{N_{CH_2}\big|_{a_{min}<a<a_{max}}}{N_C\big|_{a_{min}<a<a_{max}}}$$

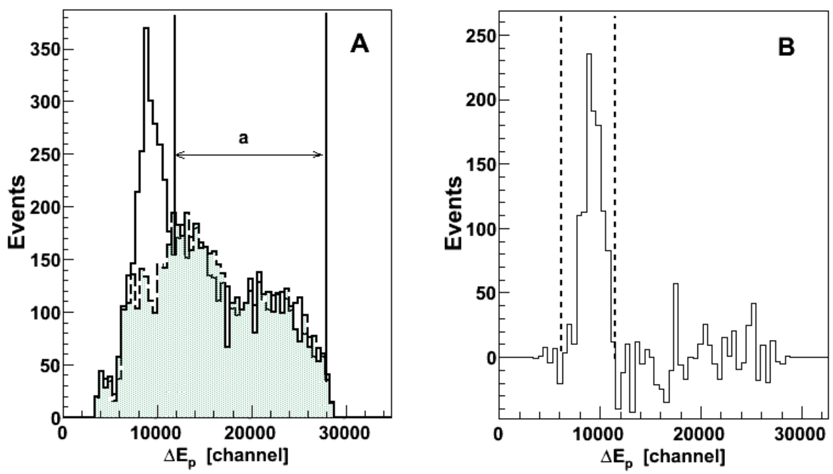
were k - normalization coefficient, N_{CH2} and N_C - CH_2- and C-amplitude distributions integrals in a-interval. The carbon background can be subtracted as:

$$N_{dp} = N_{CH_2} - kN_C$$

500 MeV/n



900 MeV/n



The CH_2-C subtraction is not performed for PP-detectors data at each $\theta_{c.m.}$ The estimation of the intensity of the carbon background in scattering on polyethylene was performed for the data sum for all values of the angle $\theta_{c.m.}$ The coefficient k_{pp} was calculated as the ratio of the total number of pp-quasielastic events obtained on the CH_2 target without carbon background subtraction to the number of events after subtraction.

The normalization factor C_{norm}

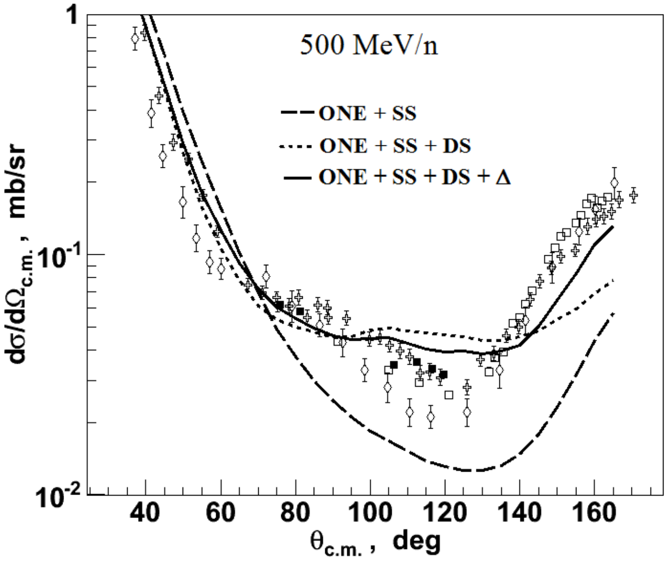
The normalization coeffcients C_{norm} at 500 and 900 MeV/n were calculated by using tha data at 700 MeV/n. The measurements at this energy were performed for scattering angle $\theta_{c.m.} = 75.8^o$. The obtained result for differential cross section was normalized to data at 700 MeV/n obtained early for the same angle $\theta_{c.m.}$ In order to calculate the normalization coefficient at the energy of 500(900) MeV/n, the correction R to the coeffcient $C_{norm}{}^{700}$ was introduced from the ratio of the differential cross sections for pp-elastic scattering at the energies 700 and 500(900) MeV/n in the region around the solid angle of the PP-detector.

$$R = \frac{\int \left(\frac{d\sigma}{d\Omega_{c.m.}}\right)^{700} dcos\theta_{c.m.}}{\int \left(\frac{d\sigma}{d\Omega_{c.m.}}\right)^{500(900)} dcos\theta_{c.m.}}$$

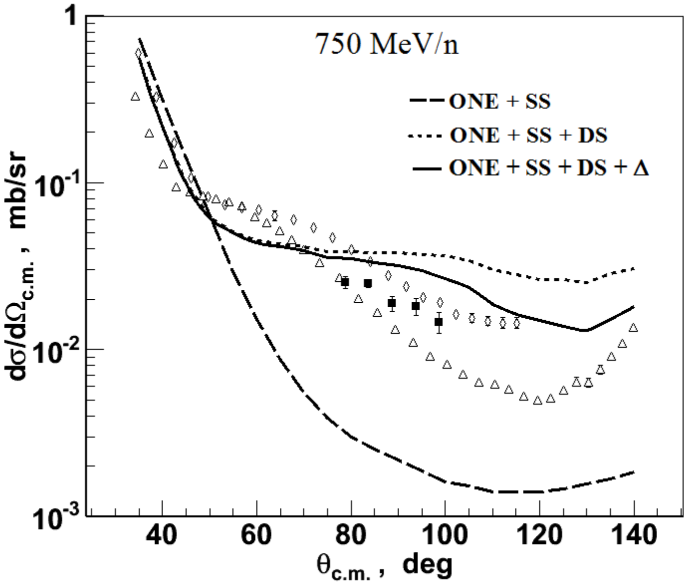
Here the integration is performed within the angular acceptance of PP-detector at 700 and 500(900) MeV/n, respectively. The normalization coefficient at the energy of 500(900) MeV/n was calculated as

$$C_{norm}{}^{500(900)} = C_{norm}{}^{700}/R.$$

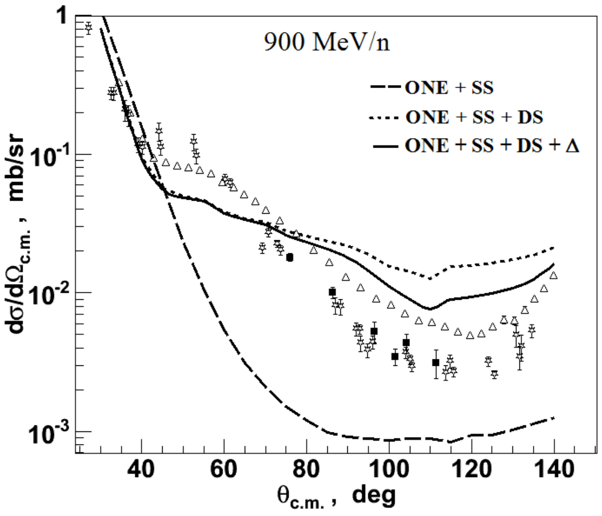
Differential cross section



Open squares – data at 470 MeV/n (Alder J.C. Phys. Rev. C 1972. V6. P.2010.)
Diamonds – data at 590 MeV/n (Vincent J.S. Phys. Rev. Lett. 1970. V24.5. P.236)
Crosses – data from 440 MeV/n (Booth N. E., Phys Rev D 1971 V4. P.1261)



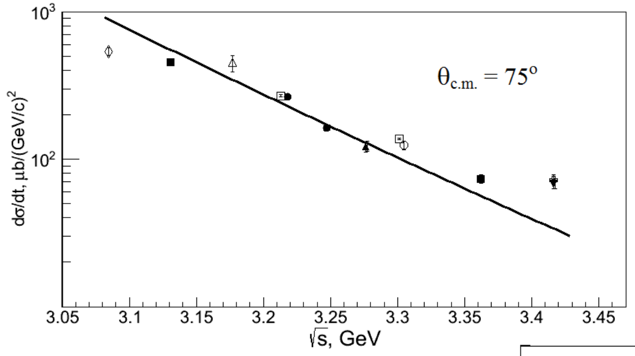
Diamonds– data at 641 MeV/n (Culmez E. Phys.Rev.C, V43, №5, 1991.)
Triangles – data at 800 MeV/n (Winkelmann E. Phys.Rev.C, V21, №6, 1980)

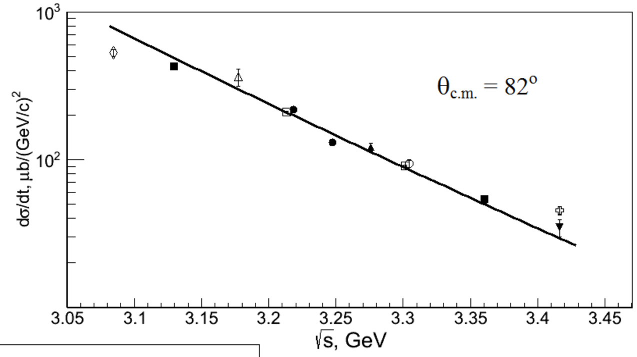


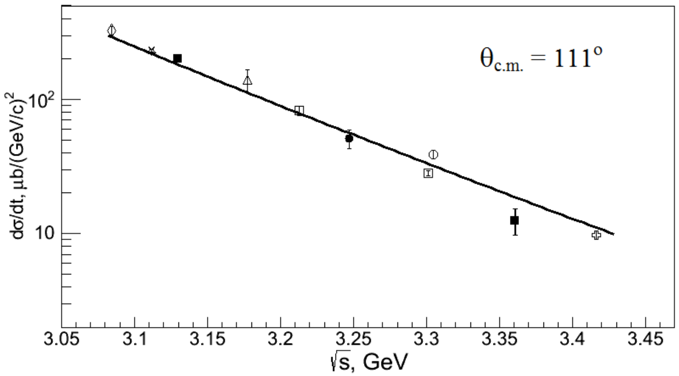
Open triangles – data at 800 MeV/n (Winkelmann E. Phys.Rev.C, V21, №6, 1980)
Stars – data at 1000 MeV/n (Bennett G. W. et al. Phys. Rev. Lett. 1976. V.19 P. 387-390)

The energy dependence

At high energies and large transverse momenta the constituent counting rules (CCR) predict a $1/s^{n-2}$dependence of the differential cross section for the binary reaction, where n is the total number of the fundamental constituents involved in the reaction. Differential cross section of dp-elastic scattering at three scattering angle of the c.m.s. covered a laboratory kinetic energies 0.44 - 1 GeV/n corresponding to total c.m. energies $\sqrt{s}$= 3.1 - 3.42 GeV. The world data are shown by the open symbols. The lines are the results of the world data fitting by the function ~ s^{-16}.







Conclusion

The differential cross section data for dp-elastic scattering at 500, 750 and 900 MeV/n are obtained. The data were obtained at Internal Target Station at Nuclotron by using the CH_2-C subtraction procedure. The results are in a reasonable agreement with the data at the similar energies.

The obtained data were compared with the calculations of the relativistic multiple scattering model. It was shown that the taking into account the Δ-isobars excitation in an intermediate state improves the description of the experimental results. The Δ–isobar contribution becomes sizable at angles $\theta_{c.m.} > 80^o$. The best agreement is at 500 MeV/n. The discrepancies between experimental data and theoretical predictions are increasing as the energy grows.

Differential cross section of dp-elastic scattering at fixed scattering angle were obtained. The data cover a total c.m. energies $\sqrt{s}$ = 3.1 - 3.42 GeV. The results are in a qualitative agreement with the behavior of the world data. All data are in a qualitative agreement with the prediction of CCR.

Thank you for attention!