Experimental data on the \( dp \rightarrow ppn \) reaction at 300-500 MeV energy of deuteron obtained at ITS at Nuclotron

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The purpose of this experimental program is to obtain the information about spin-dependent part of the 3NF from two processes:

1. dp-elastic scattering;
2. dp-breakup with registration of two protons at energy 300 - 500 MeV.
This slide presents tensor analyzing power $A_{yy}$ (top) and differential cross section in selected breakup configurations at 200 MeV (bottom).

- The light shaded band (blue) contains the theoretical predictions based on CD-Bonn, AV18, Nijm I, II and Nijm 93.
- The darker band (magenta) represents predictions when these NN forces are combined with the TM 3NF.
- The solid line is for AV18+Urbana IX and the dashed line for CD Bonn+TM

One can see that the inclusion of 3NF have great impact on the values of analyzing power and cross section.

$\Theta_1$ – polar angle of the 1-st proton.

$\Theta_2$ – polar angle of the 2-nd proton.

$S$ – arc length along the kinematical curve.

$\Phi_{12}$ – azimuth angle with respect to the horizontal plane.
Detection system for dp-breakup.

$\Theta (12^\circ, 45^\circ)$
$\Phi (0^\circ, 360^\circ)$
Space angle of the detector $4.6^\circ$. 
Setup of the experiment at Internal Target Station.

Detection angles for registration of two protons

The position of the detectors at Internal Target Station at Nuclotron.
Configuration of detectors at Internal Target Station.

28 possible configurations.
2 pairs detection dp-elastic scattering.
3 pairs detection pp-quasi.
10 pairs detection dp->ppn reaction.

This configuration detectors was selected for simultaneous set of physical data and calibration detectors on pp-quasi reaction.
The calibration of E scintillation detectors

Results calibration E-scintillator:
1. Cosmic muons;
2. pp-quasi elastic:
   for 1 pairs $90^0$ cms,
   for 2 pairs $110^0$ cms;
3. dp-elastic scattering for $87^0$ cms.

Simulation histogram were obtained as balance of energy losses of protons after energy losses in Delta E scintillation counters.

Also the calibration for $\Delta E$ scintillation detectors were obtained.

$E_{det} = E + (\Delta E_1 + \Delta E_2)/2$
Simulation of the dp-ppn reaction

Energy losses of protons when passing through scintillator
Experiment to study of dp breakup.

The missing mass spectrum.

Deuteron energy: 400 MeV.
Configuration: $\Theta_1=25^0, \Theta_2=43.6^0, \varphi_{12}=178.5^0$

dp-elastic scattering: 87° cms

Energy deuteron: 229.7 MeV
Energy proton: 170.32 MeV

Cut on missing mass:
1. dp-elastic&dp-breakup:
   $<950$ MeV
2. dp-breakup:
   $940$ MeV $\pm$ 10 MeV

One can see that in this spectrum allocation dp-breakup and dp-elastic scattering.
Experiment data for dp breakup.

Correlation of the two energies with the cut on missing mass.
Deuteron energy: 400 MeV.
Configuration: $\Theta_1=25^0, \Theta_2=43.6^0, \varphi_{12}=178.5^0$
dp-elastic scattering: 87$^0$ cms
Energy deuteron: 229.7MeV
Energy proton: 170.32MeV
Black curve – kinematic locus for dp-breakup reaction.
**CH$_2$-C$^{12}$ for TDC spectrum**

Deuteron energy: 300 MeV.

**CH$_2$ – red color spectra**

Green color corresponds to the events obtained from a carbon target for the evaluation of background.

Results **CH$_2$-C$^{12}$**

$Q_1 = 25^\circ$, $Q_2 = 44^\circ$, $\Phi_{12}=180^\circ$

dp-elastic scattering: $87^0$ cms

Red line shows the limit which marks the region for the normalization of background.

$Q_1 = 44^\circ$, $Q_2 = 44^\circ$, $\Phi_{12}=180^\circ$

pp-quasi $90^0$ cms
**CH$_2$-C$^{12}$**

for ADC spectrum

Deuteron energy: 300 MeV.

CH$_2$ – red color spectra
C$^{12}$ – green color

Results CH$_2$-C$^{12}$

Q1 = 25°, Q2 = 44°, $\Phi_{12}$=180°
dp-elastic scattering: 87° cms

Q1 = 25°, Q2 = 34°, $\Phi_{12}$=135°
**CH$_2$-$^{12}$C**

for missing mass spectrum

\[ Q_1 = 25^\circ, \ Q_2 = 44^\circ, \ \Phi_{12}=180^\circ \]

\[ Q_1 = 25^\circ, \ Q_2 = 53^\circ, \ \Phi_{12}=135^\circ \]

\[ Q_1 = 34^\circ, \ Q_2 = 44^\circ, \ \Phi_{12}=135^\circ \]

One can see from the picture that the missing mass regions taken for used the normalization of background for each configuration are different. But the coefficient of normalization of background events remains unchanged for TDC, ADC and missing mass mass distributions.
The energies $E_1$ and $E_2$ of each event were transformed into a new variable:

$S$ - the value of the arclength along the kinematics with the starting point ($S=0$) chosen arbitrarily at the point where $E_2$ reaches its minimum.
$Q_1 = 34^\circ, Q_2 = 44^\circ, \Phi_{12}=135^\circ$

$Q_1 = 25^\circ, Q_2 = 34^\circ, \Phi_{12}=135^\circ$
Conclusion.

• The preliminary results for dp→ppn reaction at 300-500 MeV for different geometries at Internal Target Station at Nuclotron are obtained.
• The procedure of the dp – breakup reaction events selection is established.
• The setup on the study of deuteron non-mesonic breakup reaction of Nuclotron and used for data taking in 2012-2015 was put into operation.
• Upgrade of the ΔE-E detectors for the dp-breakup reaction is started.
THANK YOU
FOR THE
ATTENTION!
Modernization of the $\Delta$E-E detector for dp-breakup

PMT 85 → Hamamatsu h7415

PMT 63 → Hamamatsu h6559
The deuteron energy 300 MeV.

\[ \Theta_1 = 25.2^0, \Theta_4 = 33.9^0, \varphi_{14} = 135.3^0 \]

\[ \Theta_2 = 25.2^0, \Theta_3 = 33.9^0, \varphi_{23} = 133.5^0 \]

\[ \Theta_3 = 33.9^0, \Theta_4 = 33.9^0, \varphi_{34} = 180^0 \]

Correlations of the proton energies with the cut on missing mass (940 MeV ± 10 MeV) of deuteron energy 300 MeV.
The deuteron energy 400 MeV.

Correlations of the proton energies with the cut on missing mass (940 MeV ± 10 MeV) of deuteron energy 400 MeV.

- $\Theta_1 = 25^0$, $\Theta_3 = 33.7^0$, $\varphi_{13} = 44.6^0$
- $\Theta_1 = 25.2^0$, $\Theta_8 = 53.6^0$, $\varphi_{18} = 135.5^0$
- $\Theta_2 = 25^0$, $\Theta_4 = 33.7^0$, $\varphi_{24} = 46.5^0$
The deuteron energy 500 MeV.

\[ \Theta_1 = 24.7^0, \Theta_3 = 33.3^0, \]
\[ \varphi_{13} = 44.6^0 \]

\[ \Theta_1 = 24.7^0, \Theta_8 = 53.3^0, \]
\[ \varphi_{18} = 135.4^0 \]

\[ \Theta_2 = 24.7^0, \Theta_4 = 33.3^0, \]
\[ \varphi_{24} = 46.5^0 \]

Correlations of the proton energies with the cut on missing mass\((940\text{MeV} \pm 10\text{MeV})\) of deuteron energy 500 MeV.