Analyzing powers measurement for $d - p$ elastic scattering at the energies 880 and 2000 MeV.

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Collaboration

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Three nucleon forces manifestation

- Nowadays a new generation the NN potentials(Nijmegen, CD-Bonn, AV-18 etc.) was obtained. They reproduce data on the nucleon nucleon scattering up to 350 MeV with very good accuracy.
- However, these modern NN forces fail to provide experimental binding energies of few-nucleon systems.(for the ^3H underbinding is 0.8 MeV for CD-Bonn). Moreover the data on the $d-p$ elastic scattering and deuteron breakup are not described.
- Incorporation of the **3NF** makes it possible to reproduce the binding energy of the three-nucleon bound systems and also data on unpolarized of $d-p$ interaction.
- Nevertheless, polarization data for the reactions with participation of three and more nucleons are not described even with the **3NF** inclusion.

dp elastic scattering at the intermediate energies

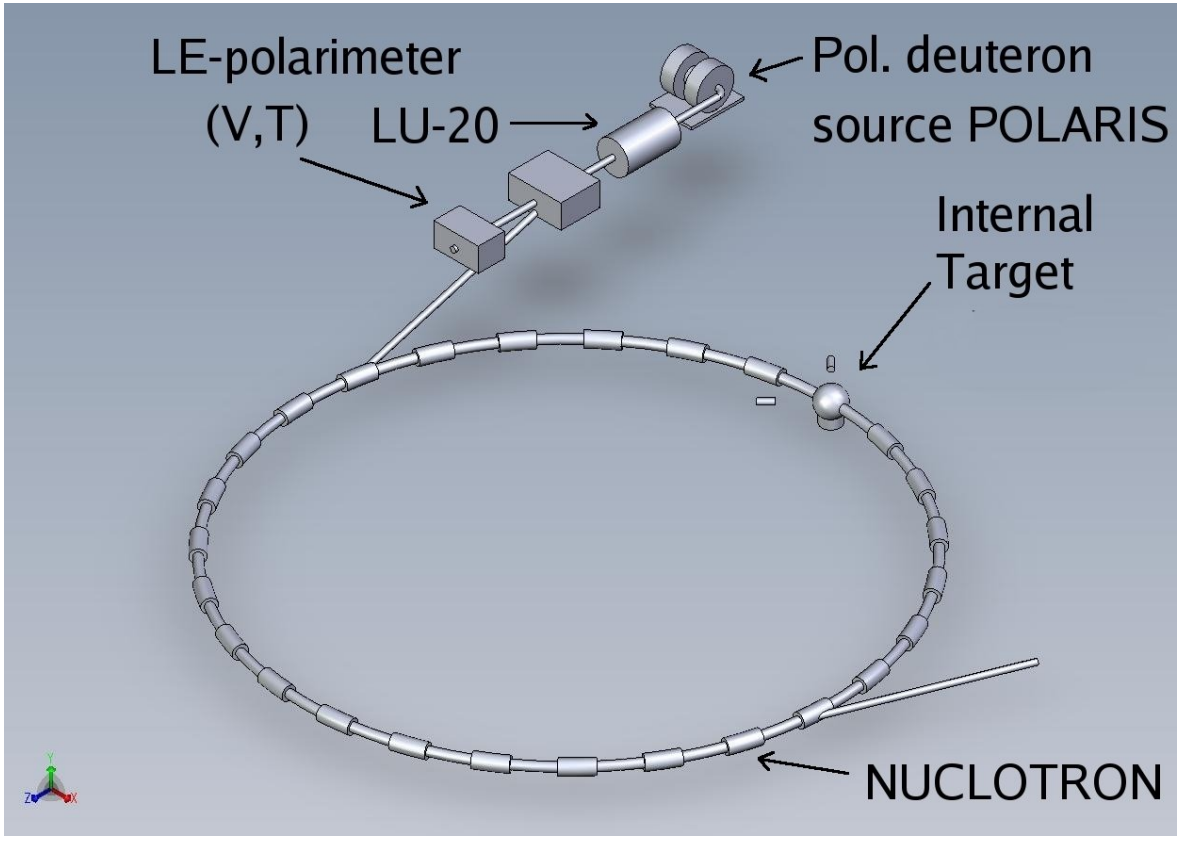
- The cross section data for the $d - p$ elastic scattering are reproduced well up to 150 MeV taking into account **3NF**. However, the cross section data are not described at the energy 250 MeV.
- The experimental data on polarization observables A_{yy}, A_{xx} and A_{xz} are not reproduced at the energy 135 MeV.

Therefore, obtaining the additional polarization data in the reaction of the $d - p$ interaction with the energies more than 135 MeV is very desirable for the study the spin structure of the 3NF and the relativistic effects.

Polarimetry

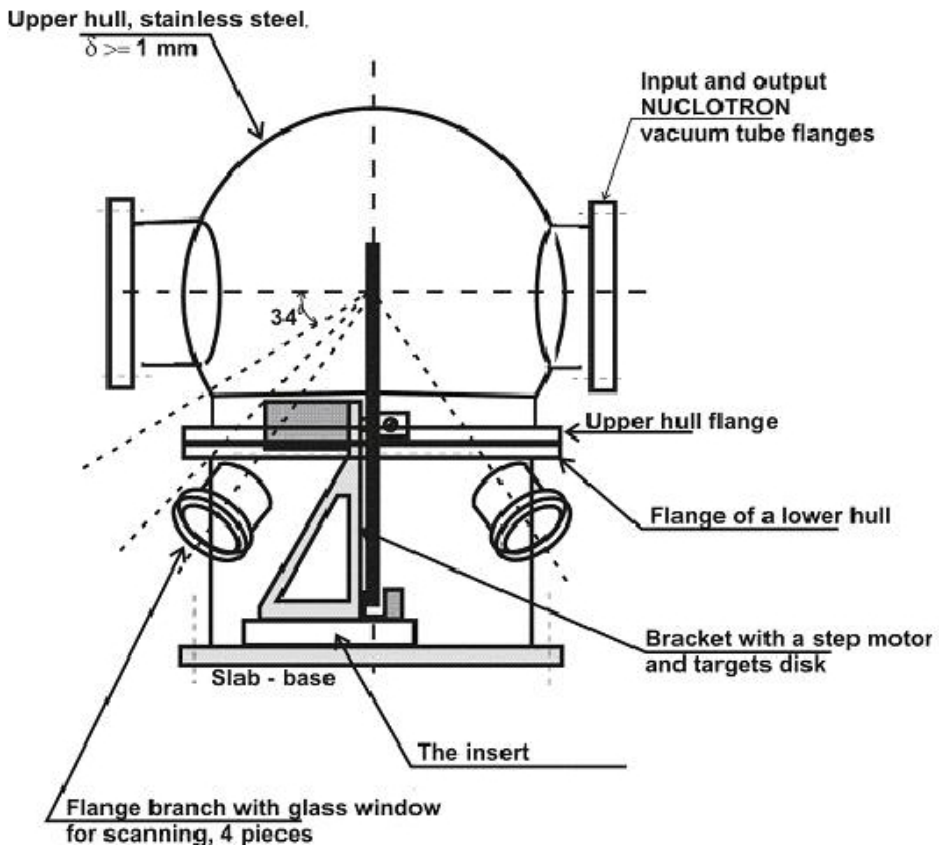
- The aim of the experiment is to obtain the polarization observables in $d - p$ elastic scattering at large angles at the energies $270 - 2000$ MeV. Also the possibility to the use this reaction for the polarimetry of high energy deuterons has been studied.
- The data at the energies in a GeV region are necessary for the *PHe3* project at the Nuclotron. In this experiment on the measurement of the polarization observables in the ${}^3He(d,p)^4He$ reaction it is necessary to measure of the both vector and tensor polarizations of the deuteron beam.
- New facility RIBF at RIKEN will have polarized deuterons at 880 MeV.
- The problem of systematics for the experiments on the different facilities is a result of different polarization standards.

NUCLOTRON Accelerator Complex



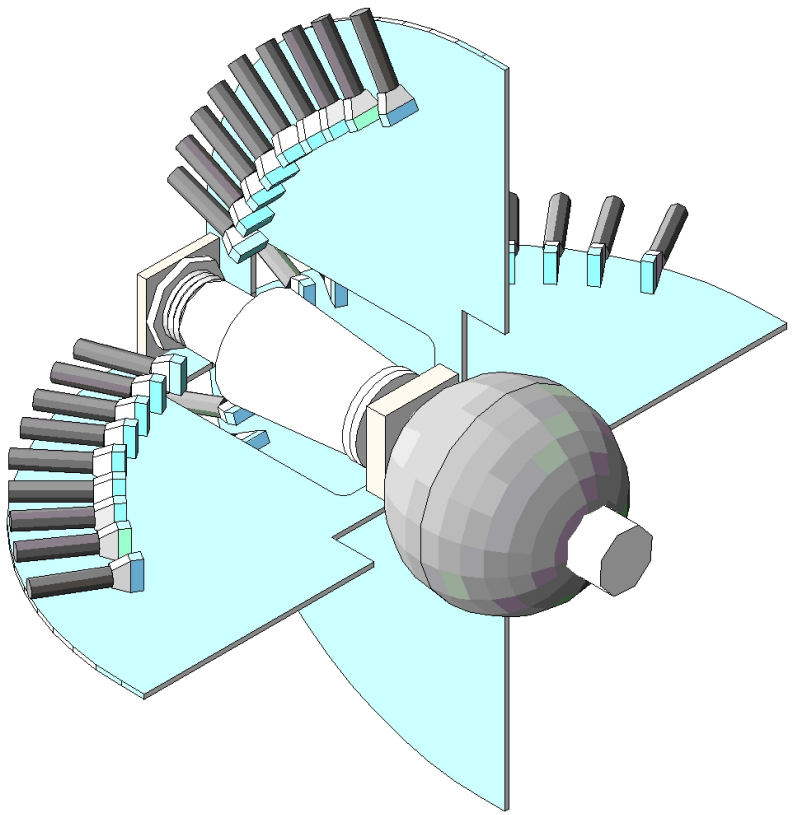
Internal Target Station

The Internal Target Station is well suited for the study reactions of the $d - p$ interaction at large angles in the center of mass system.



Detection system (CNS, Japan)

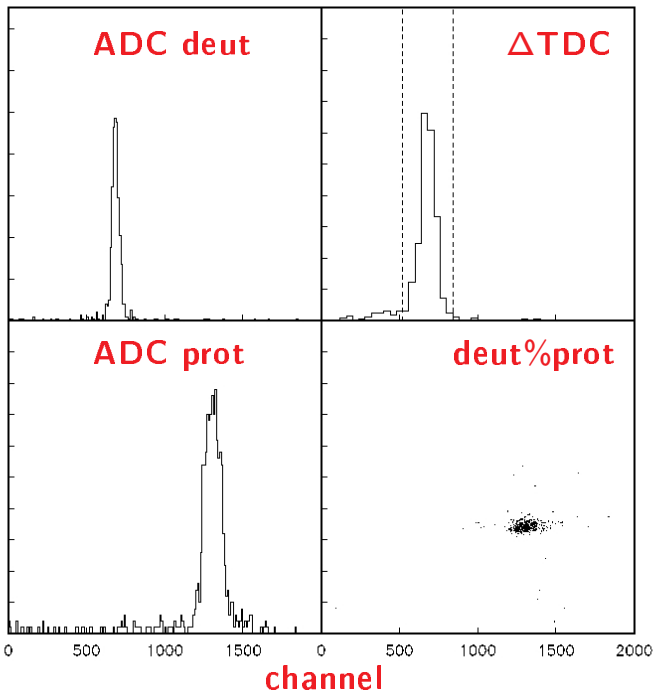
- Scintillation counters (48) based on Hamamatzu H7415 PMTs were placed on the left, right, up and down were used at the same time.
- The detectors covered the angular range $60 - 140^{\circ}$ in the center of mass.
- VME+CAMAC (FERA, FERET) DAQ was used for data taking.



Conditions of the measurements at Nuclotron

- Polarized deuterons were provided by PIS POLARIS. Typical intensity in the Nuclotron ring was $2 \div 3 \cdot 10^7$ deuterons per spill.
- Polarization mode $(p_z, p_{zz}) = (0, 0), (+1/3, +1), (+1/3, -1)$
- The 10 μm CH_2 foil has been used as the target. Also measurements with carbon target have been performed in order to estimate the background.
- The data have been accumulated at 270, 880 and 2000 MeV. The measurement of the beam polarization has been performed at 270 MeV.

Polarization measurement at 270 MeV
(LEP measurements by L.S.Zolin & Yu.K.Pilipenko)



	Pol.	Mode 2-6	Mode 3-5
ITS	T	0.605± 0.025	-0.575± 0.020
ITS	V	0.216± 0.015	0.208± 0.012
LEP	T	0.69±0.13	-0.67± 0.16

K.Sekiguchi, et al., Physical Review C65 (2002) 034003

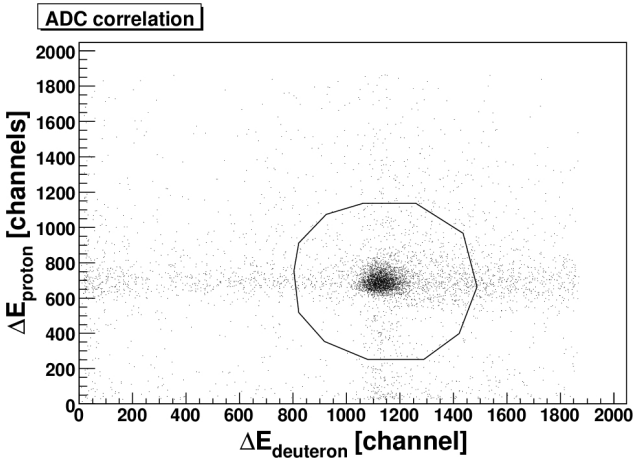
K.Sekiguchi, et al., Physical Review C70 (2004) 014001

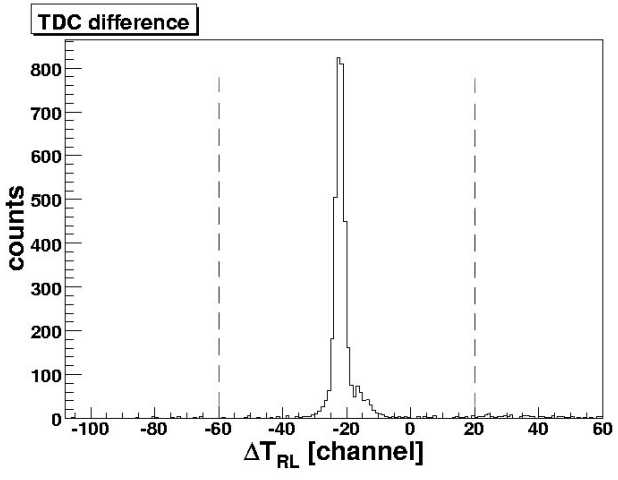
K.Suda, et al., Nucl. Instr. Meth. in Phys. Res. A572 (2007) 745

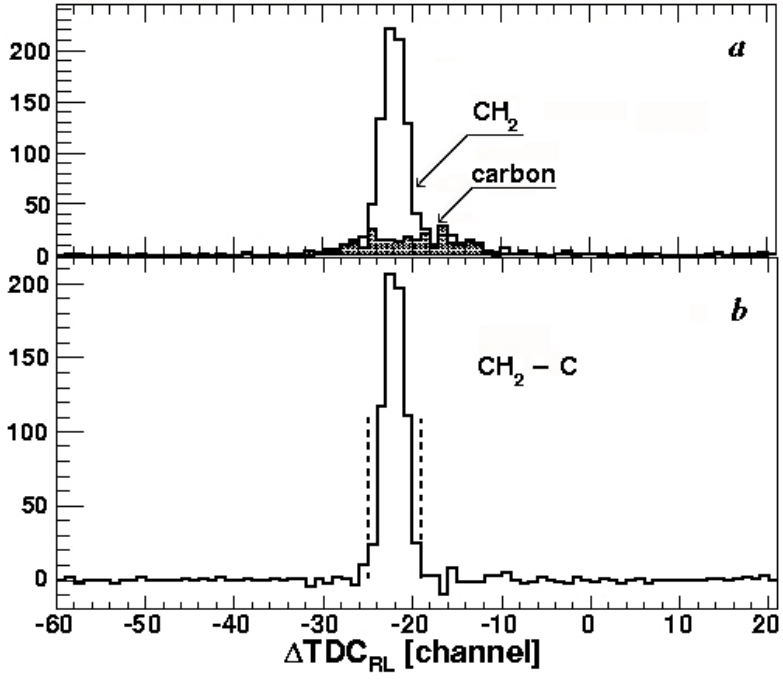
Measurements at 880 and 2000 MeV

- Detectors were located symmetrically in the directions of azimuthal angles.
- The analyzing powers A_y and A_{yy} were extracted from the counts of the left and right pairs detectors.
- The analyzing power A_{xx} were extracted from the counts of the up and down pairs detectors.
- A single pair of counters was used for pp quasi-elastic scattering measurement in the vertical plane.

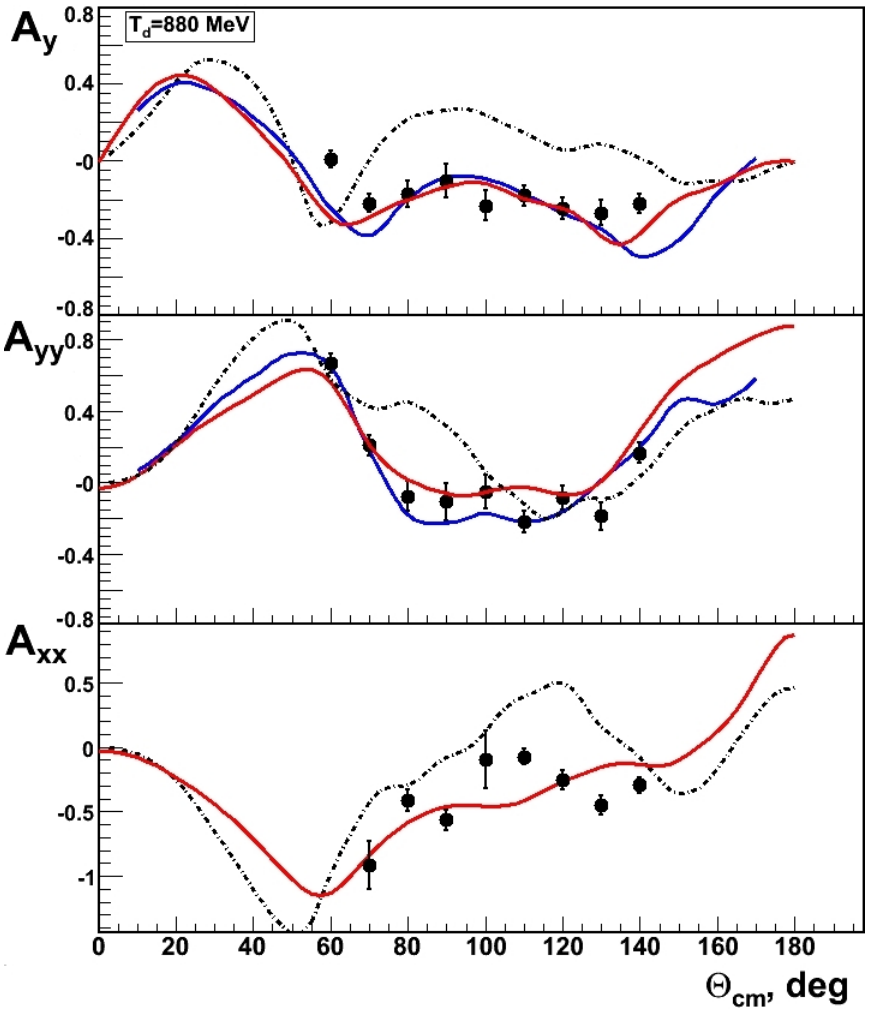
Selection of the $d - p$ elastic events at 880 MeV







Analyzing powers in $d - p$ elastic scattering at 880 MeV



LHE JINR

——— N.B. Ladygina

(arXiv:0705.3149)

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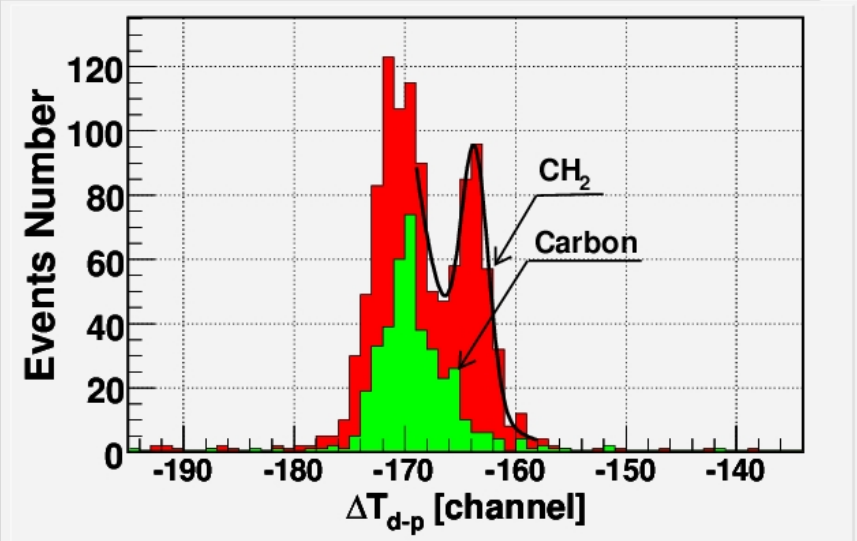
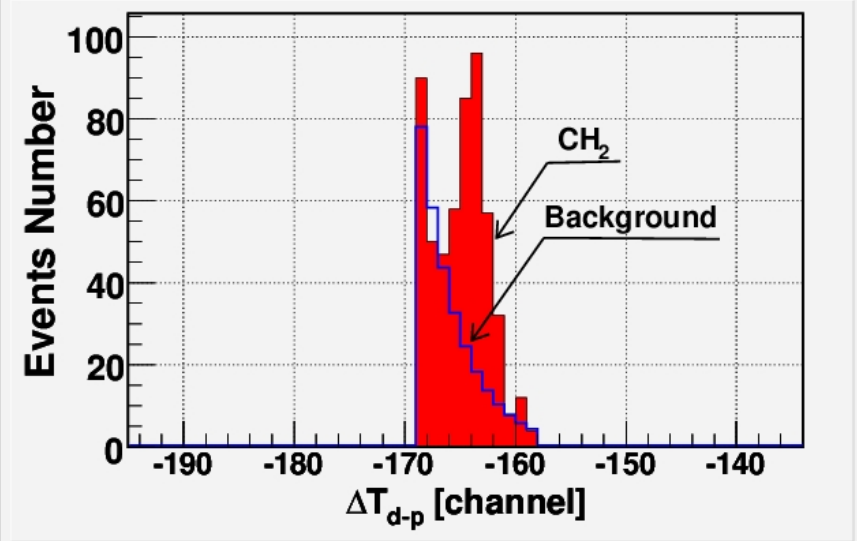
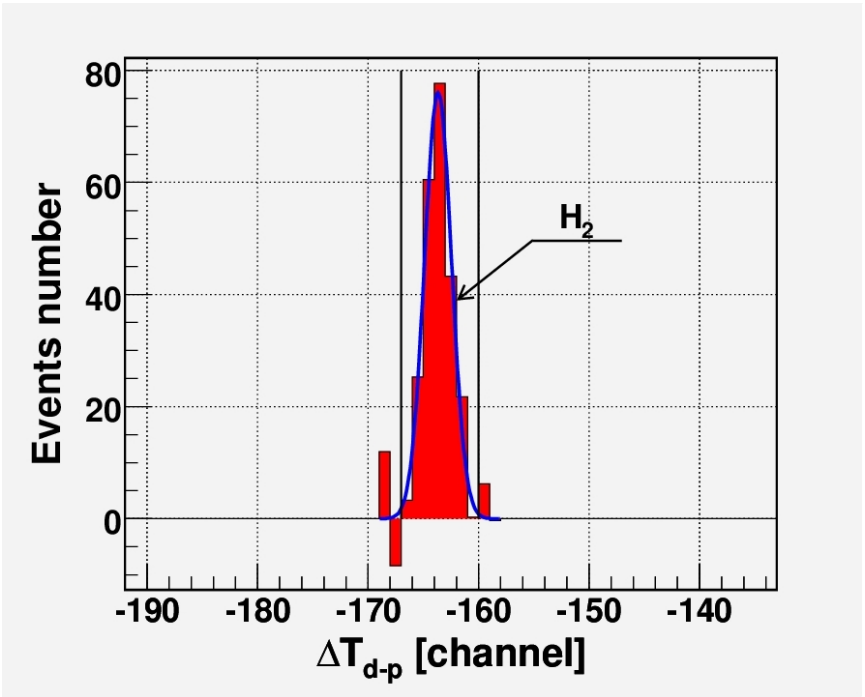
——— H. Witala

(private communicarion)

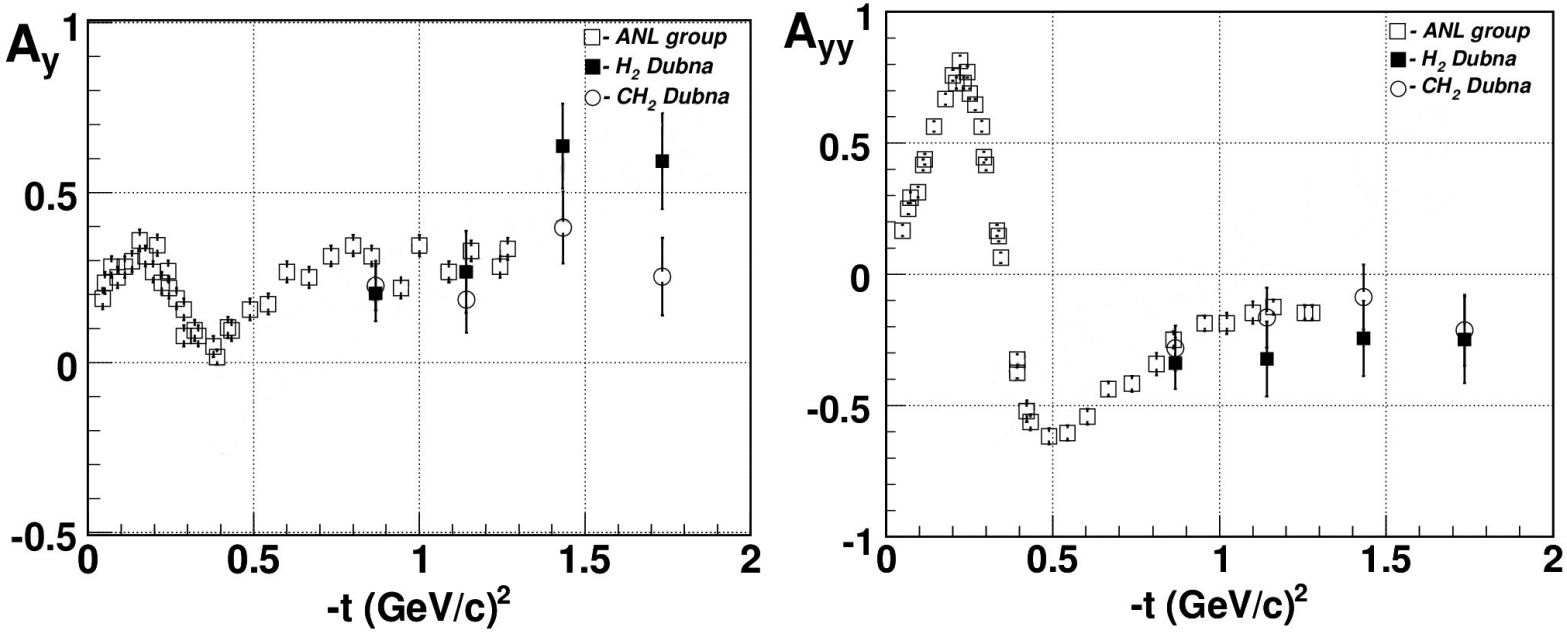
Selection of the $d - p$ elastic events at 2000 MeV







Analyzing powers in $d - p$ elastic scattering at 2000 MeV



Vector A_y and tensor A_{yy} analyzing powers versus $-t$ for the $d - p$ elastic scattering at $T_d = 2.0$ GeV ($\square$) by ANL group and ($\circ - CH_2$, $\blacksquare - H_2$) by Dubna group.

Conclusion

- The data on the measurement of the analyzing powers A_y, A_{yy} and A_{xx} at 880 MeV, covered angular region of $60 - 140^\circ$ in the c.m.s. are obtained.
- The data on the analyzing powers at 880 MeV are compared with several theoretical predictions without the 3NF inclusion. The calculations reproduces the obtained experimental data quite good.
- For the first time the preliminary results on the vector A_y and tensor A_{yy} analyzing powers at maximal $-t$ are obtained.
- The selection procedure of the $d - p$ elastic events by the correlation amplitude signals from deuteron and proton detectors and the time difference between the signals appearance for the conjugated deuteron and proton detectors allows to provide the efficient polarimetry of the deuteron beam at high energies.

Thank you for the attention!!!

Calculation of the analyzing powers

$$N(\theta;\beta,\phi) = 1 + \frac{3}{2}p_y(\beta,\phi)A_y(\theta) + \frac{2}{3}p_{xz}(\beta,\phi)A_{xz} + \frac{1}{2}p_{zz}(\beta,\phi)A_{zz} + \frac{1}{6}[p_{xx}(\beta,\phi) - p_{yy}(\beta,\phi)][A_{xx}(\theta) - A_{yy}(\theta)]$$

$$N_L(\theta;\beta,\phi) = N(\theta;\frac{\pi}{2},0), \quad N_R(\theta;\beta,\phi) = N(\theta;\frac{\pi}{2},\pi)$$

$$N_U(\theta;\beta,\phi) = N(\theta;\frac{\pi}{2},\frac{3\pi}{2}), \quad N_D(\theta;\beta,\phi) = N(\theta;\frac{\pi}{2},\frac{\pi}{2})$$

$$\begin{aligned} p_y(\beta,\ \phi) &= p_Z \sin\beta\cos\phi \\ p_{yy}(\beta,\ \phi) &= 1/2 p_{ZZ}(3\sin^2\beta\cos^2\phi - 1) \\ p_{xx}(\beta,\ \phi) &= 1/2 p_{ZZ}(3\sin^2\beta\sin^2\phi - 1) \\ p_{xz}(\beta,\ \phi) &= -3/2 p_{ZZ}\sin\beta\cos\beta\sin\phi \\ p_{zz}(\beta,\ \phi) &= -1/2 p_{ZZ}(3\cos^2\beta - 1) \end{aligned}$$

p_Z – the vector polarisation

p_{ZZ} – the tensor polarisation

β, ϕ – the direction of polarization vector

Calculation of the analyzing powers

$$N_R^{\pm} = N_R^0(1 - \frac{3}{2}p_z^{\pm}A_y + \frac{1}{2}p_{zz}^{\pm}A_{yy}) \tag{1}$$

$$N_L^{\pm} = N_L^0(1 + \frac{3}{2}p_z^{\pm}A_y + \frac{1}{2}p_{zz}^{\pm}A_{yy}) \tag{2}$$

$$N_{U,D}^{\pm} = N_{U,D}^0(1 + \frac{1}{2}p_{zz}^{\pm}A_{xx}) \tag{3}$$

$$A_y = \frac{2}{3}\frac{p_{zz}^-(N_L^+/N_L^0 - 1) - p_{zz}^+(N_L^-/N_L^0 - 1)}{p_z^+p_{zz}^- - p_z^-p_{zz}^+} \tag{4}$$

$$A_y = \frac{2}{3}\frac{p_{zz}^-(N_R^+/N_R^0 - 1) - p_{zz}^+(N_R^-/N_R^0 - 1)}{-p_z^+p_{zz}^- + p_z^-p_{zz}^+} \tag{5}$$

Calculation of the analyzing powers

$$A_{yy} = 2\frac{p_z^+(N_L^-/N_L^0 - 1) - p_z^-(N_L^+/N_L^0 - 1)}{p_z^+ p_{zz}^- - p_z^- p_{zz}^+} \tag{6}$$

$$A_{yy} = 2\frac{p_z^-(N_R^+/N_R^0 - 1) - p_z^+(N_R^-/N_R^0 - 1)}{-p_z^+ p_{zz}^- + p_z^- p_{zz}^+} \tag{7}$$

$$A_{xx} = \frac{2}{p_{zz}^{\pm}}(N_{U,D}^{\pm}/N_{U,D}^0 - 1) \tag{8}$$