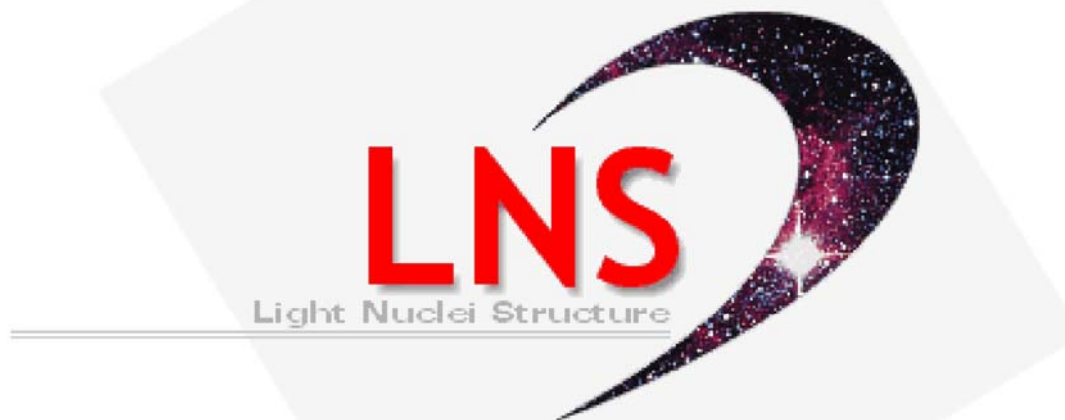


1

Investigation of deuteron-proton interaction at Internal Target at Nuclotron.



Piyadin S. M.

on behalf of LNS collaboration.

Prague, July 20 - July 26, 2008



Collaboration

- Joint Institute for Nuclear Research (LHE & LNP & LNR)
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- P.J.Safarik University, Kosice, Slovakia
- Advanced Research Institute for Electrical Engineering, Bucharest, Romania
- Institute of Physics Slovak Academy of Sciences, Bratislava, Slovakia
- Saitama University, Saitama, Japan
- Institute for Physical and Chemical Research (RIKEN), Saitama, Japan
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- M. Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland



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Three nucleon forces manifestation

- Nowadays a new generation of 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 **dp** elastic scattering and deuteron breakup are not described properly.
- Incorporation of the **3NF** makes it possible to reproduce the binding energy of the three-nucleon bound systems and also data on unpolarized **dp** interaction.
- Nevertheless, polarization data for the reactions with participation of three and more nucleons are not described even with inclusion of **3NF**.



dp elastic scattering at the intermediate energies.

- The cross section data for the **dp** 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**.

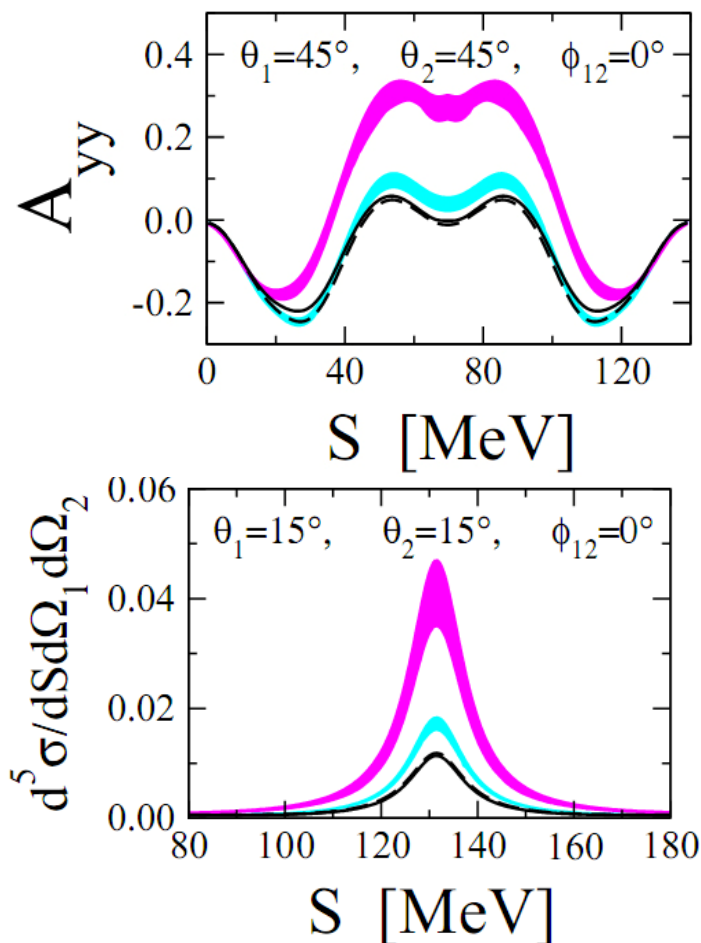
Therefore, obtaining the additional polarization data in the reaction of the **dp** interaction with the energies more than **135 MeV** is very desirable for the study of the spin structure of the **3NF** and the relativistic effects in **2NF**.

The purpose of this experimental program is to obtain the information about spin – dependent part of the **3NF** from two processes: dp-elastic scattering and dp-breakup with registration of two protons at energy **300 - 500 MeV**.



dp breakup reaction.

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.

Θ_1 – polar angle of the 1-st proton.

Θ_2 – polar angle of the 2-nd proton.

S – arc length along the kinematical curve.

Φ_{12} – azimuth angle with respect to the horizontal plane.

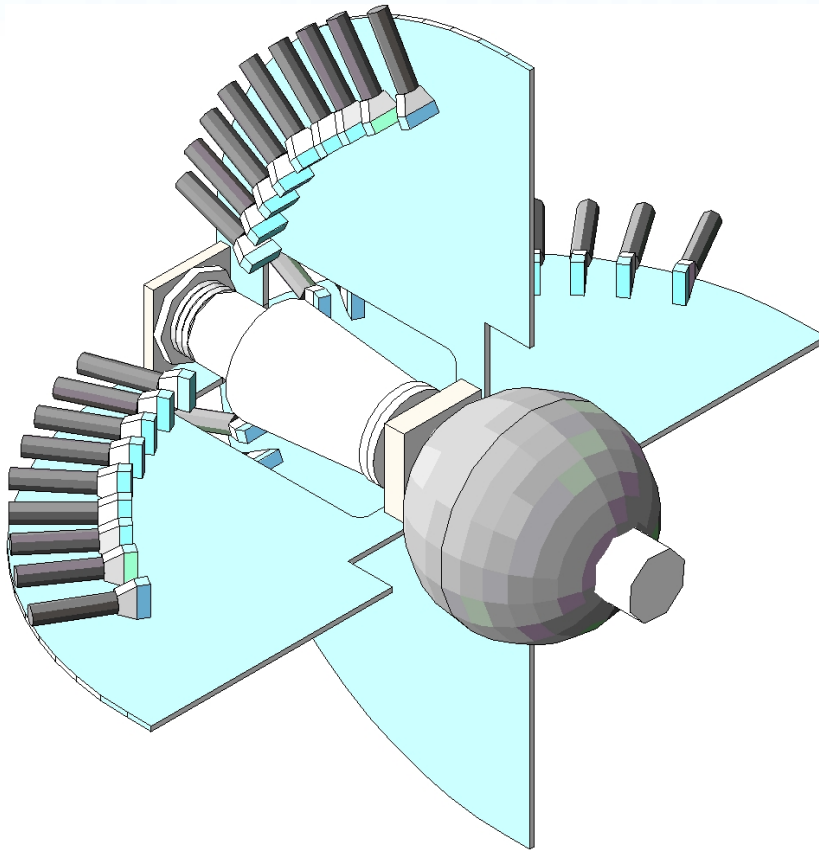


Polarimetry for NICA.

- One of the aims of our project is to obtain the data on analysing powers in dp elastic scattering at large angles, using polarized deuteron beam with the energies 270 – 2000 MeV at Nuclotron-M/NICA facility.
 - New facility RIBF at RIKEN will have polarized deuterons at 880 MeV.
 - The use of the same polarization standards will solve the problem of systematics for the experiments performed at different facilities.



Detection system

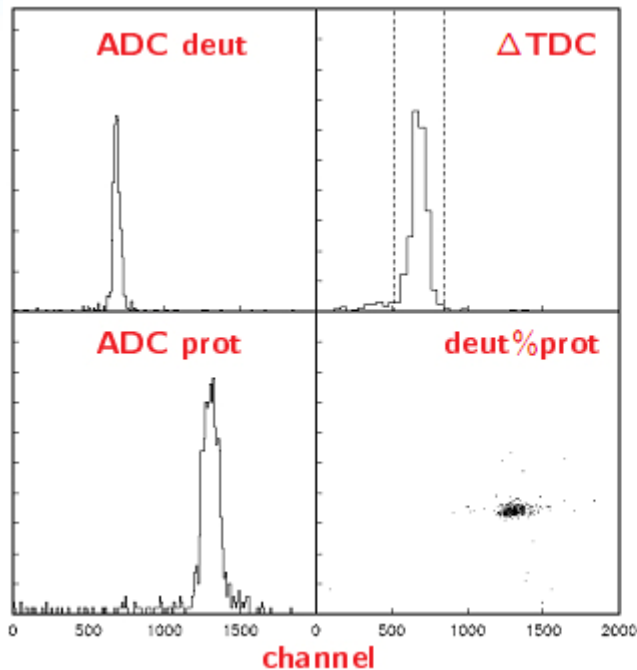


- Scintillation counters (48) based on Hamamatsu H7415 PMTs were placed on horizontal and vertical planes.
- Each pair of counters is arranged for the detection of the particles scattered to the left, right, up and down in coincidence.
- The detectors covered the angular range $60 - 140^\circ$ in the center of mass.
- VME+CAMAC (FERA, FERET) DAQ was used for data taking.



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

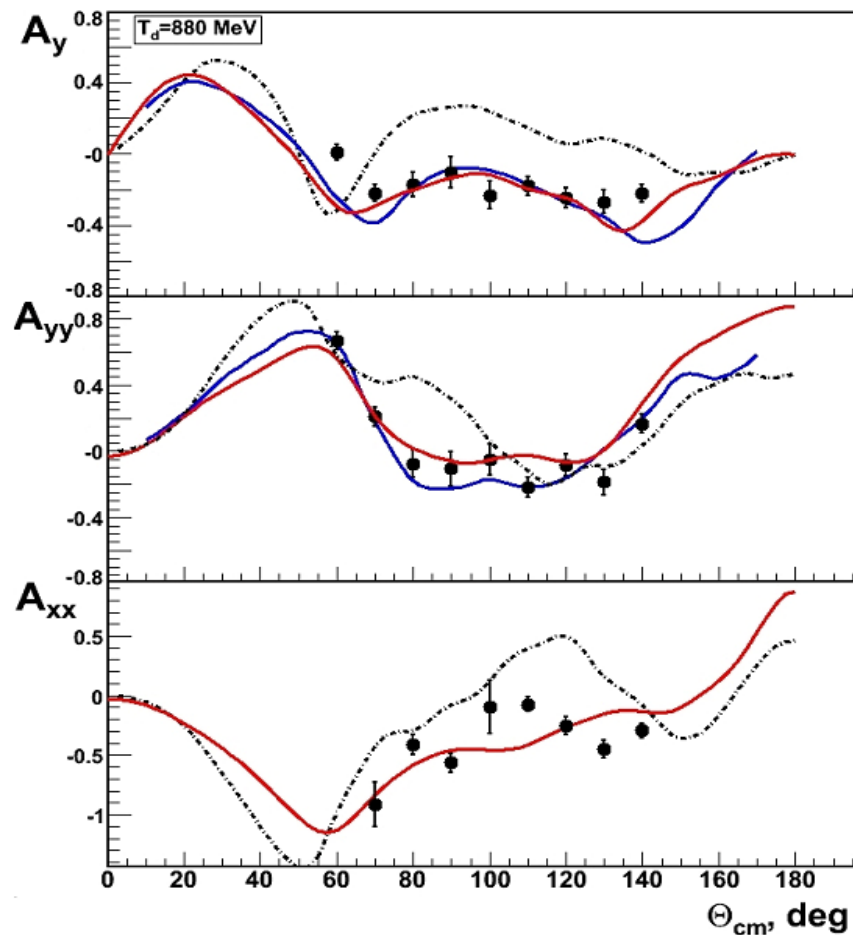
K.Sekiguchi, et al., Physical Review C70 (2004) 014001

K.Suda, et al., Nucl. Instr. Meth. in Phys. Res. A572

(2007) 745



Analyzing powers in dp elastic scattering at 880 MeV.



LHE JINR

— N.B. Ladygina
(arXiv:0705.3149)

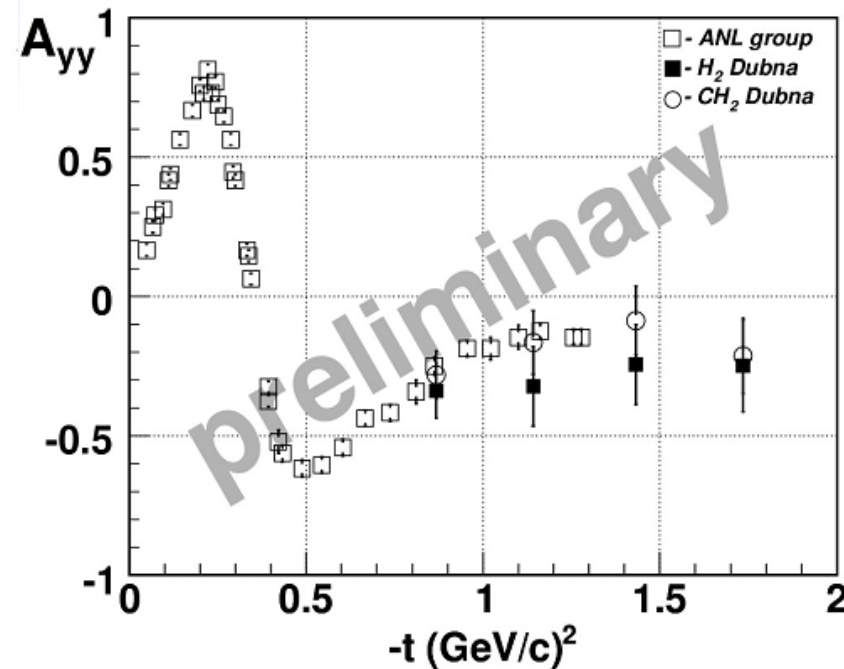
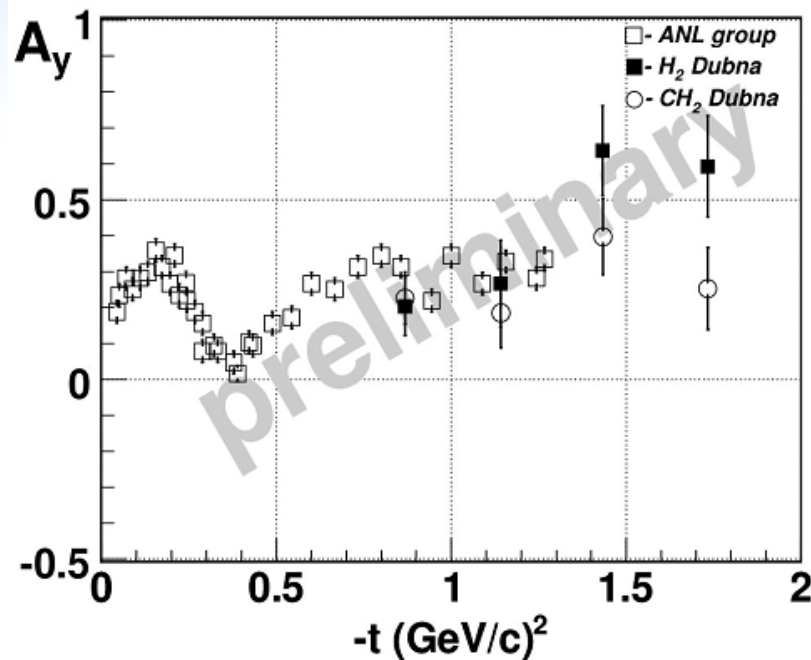
- - - M.A. Shikhalev
(arXiv:nucl-th/0612108)

Jagiellonian University

— H. Witala
(private communication)



Analyzing powers in dp elastic scattering at 2000 MeV.

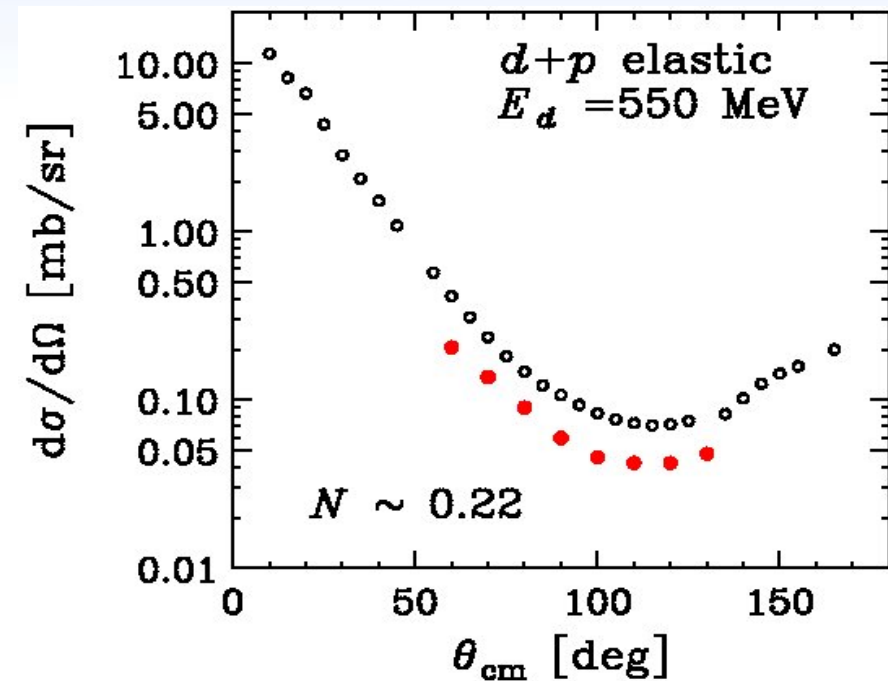
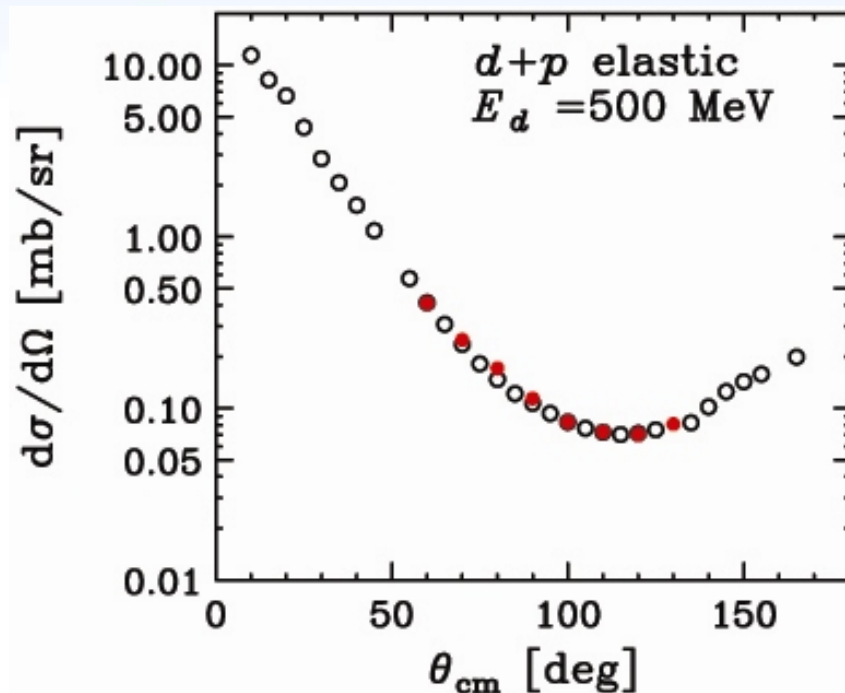


Vector A_y and tensor A_{yy} analyzing powers versus $-t$ for the dp elastic scattering at $T_d = 2.0$ GeV (\square) by ANL group and (\circ - CH_2 , \blacksquare - H_2) by Dubna group.



Cross section measurements

(T.Uesaka, K.Suda - CNS, Japan)



The shape of the cross section at 500 MeV obtained at Nuclotron (red) is in a good agreement with the data of *K.Hatanaka et al. (RCNP)*. Reasonable behavior at 450, 550 and 600 MeV.



Status of preparation (*dp elastic scattering*).

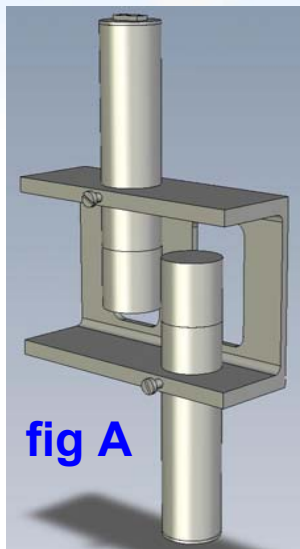


fig A

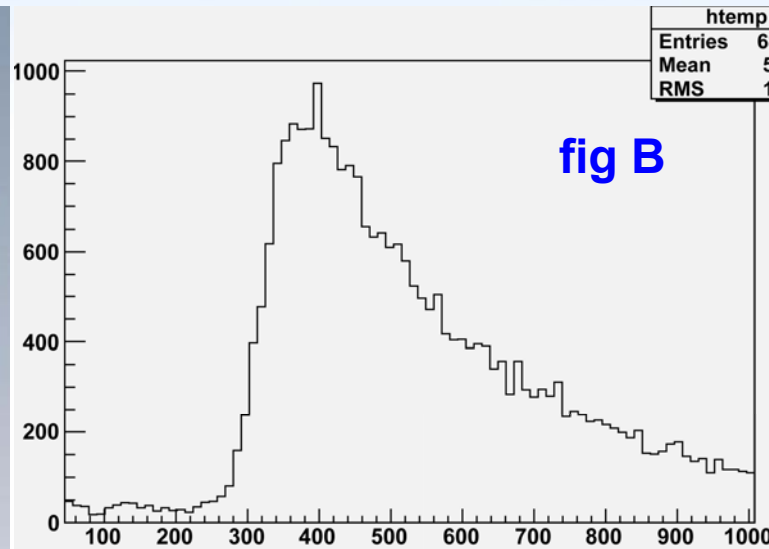


fig B

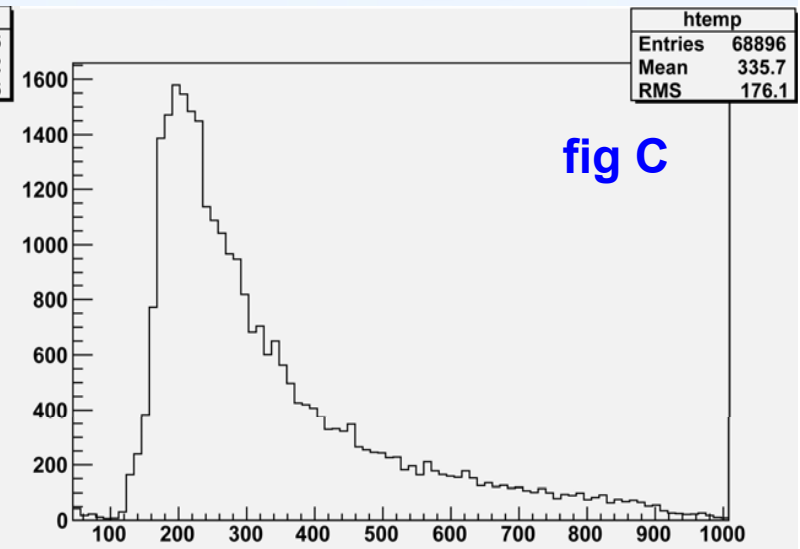
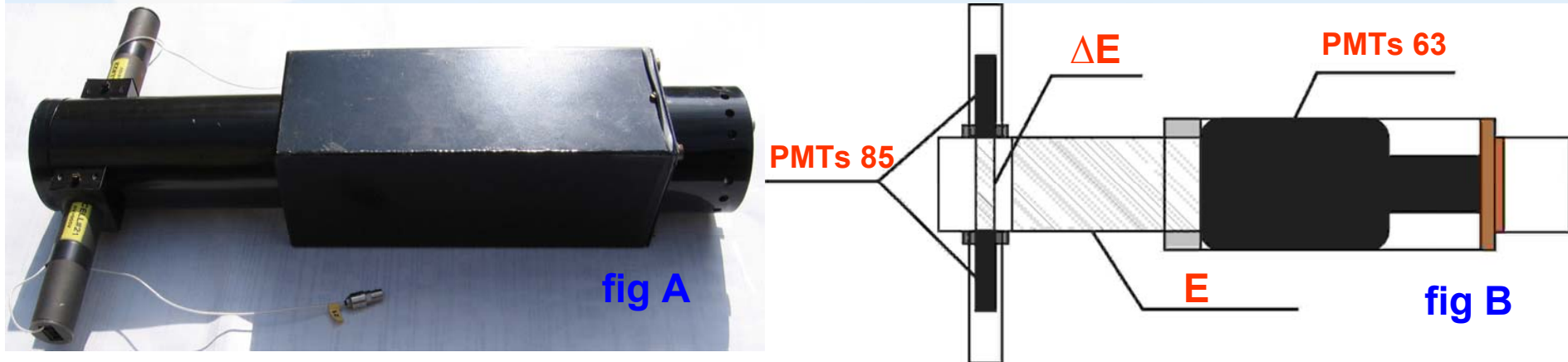


fig C

fig A is the schematic view of the counter for dp elastic scattering experiments. fig B is the signal amplitude from thin plastic and fig C is the amplitude from thick plastic. Data were collected with deuteron energy 1.5 GeV/n on ^{12}C target.



Status of preparation ($\Delta E - E$ detector).



Photography (fig A) and a schematic view (fig B) of the detection system.

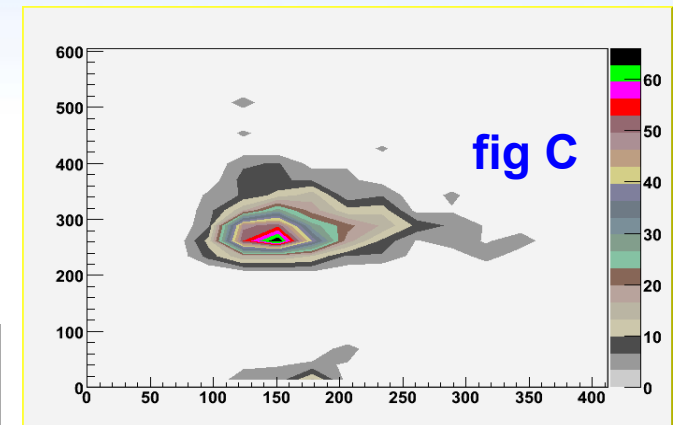
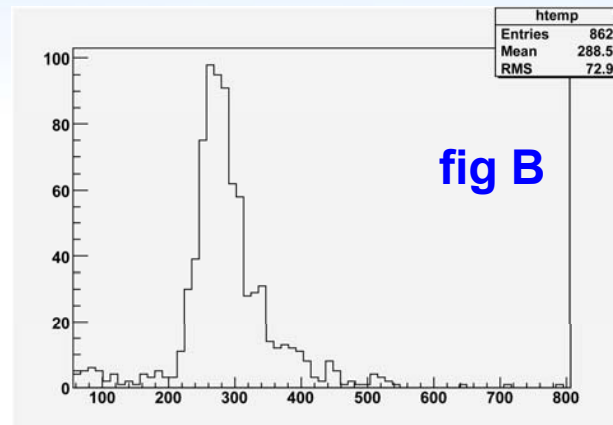
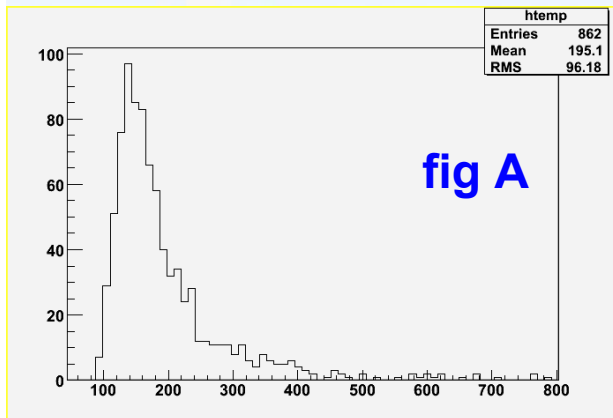
The dp breakup reaction will be investigated in another experiment using $\Delta E - E$ technique for the detection of protons.

Each detector consists of 2 scintillation counters: the first one with a thin scintillator (1 cm) and the second with 20 cm in length. The diameter of the E-counter scintillator is 10 cm. Useful events will be selected by the time of flight difference and $\Delta E - E$ information for the detected particles.



Status of preparation

(cosmic rays test for ΔE - E detectors).



Data shown were collected on cosmic muons in May 2008.

fig A is the amplitude from one PMTs 85.

fig B is the amplitude from PMTs 63.

fig C is the correlation of these amplitudes.



Status of preparation (*system of high voltage*)



Photography of voltage system based on module “Wenzel Elektronik N-1130”

Photomultiplier tube (PMT 85) is controlled by module connected with computer through the bus RS232. The module was designed at LHEP JINR.

The high voltage system for Photomultiplier tube (PMT 63) is based on “Wenzel Elektronik”, whose voltage is adjusted and checked online through DAC and ADC modules CAMAC.



Status of preparation (high voltage control system)

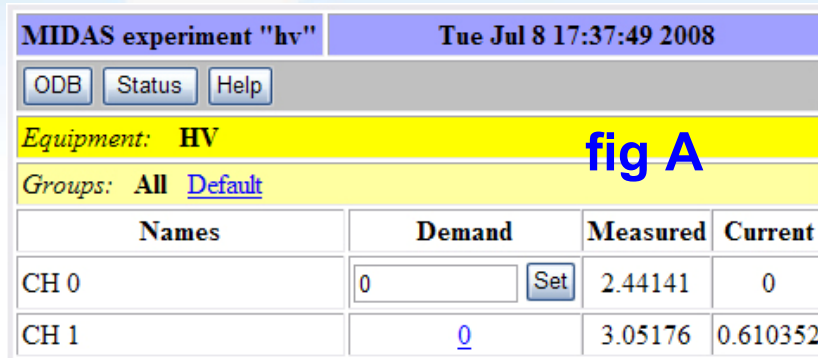
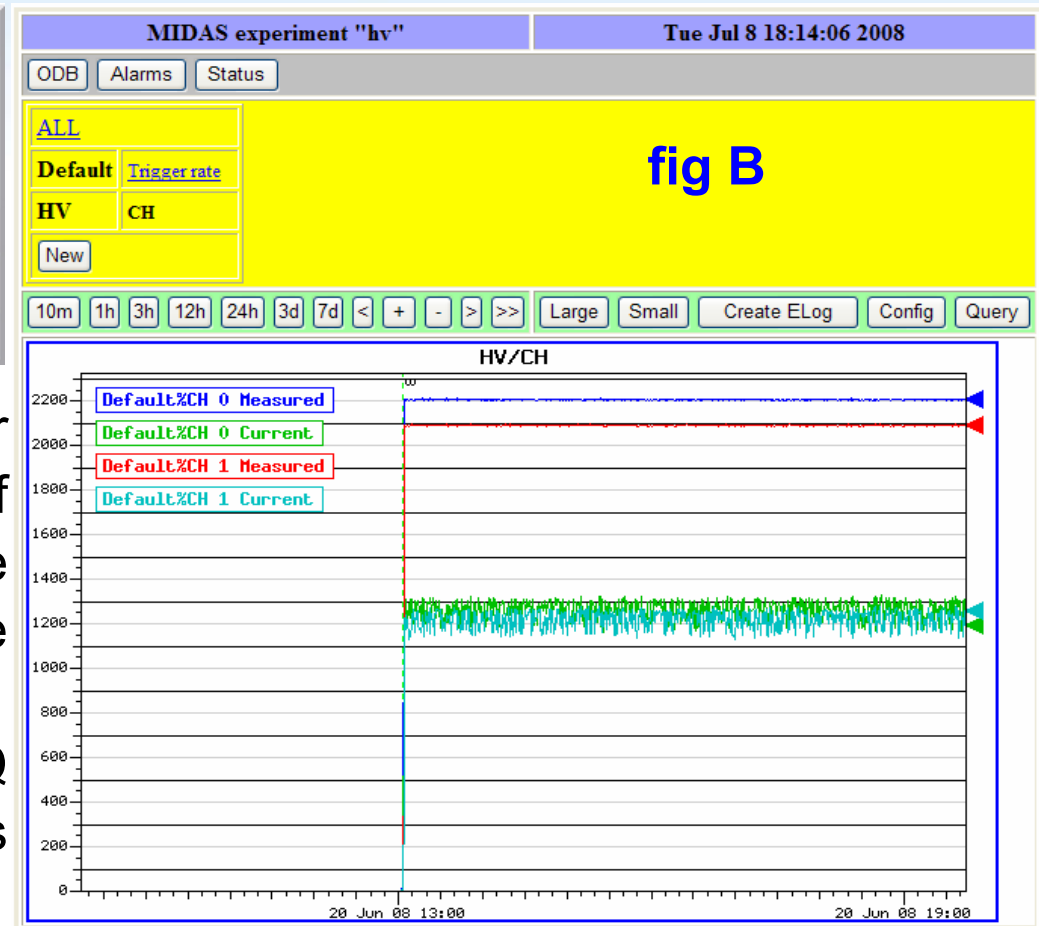


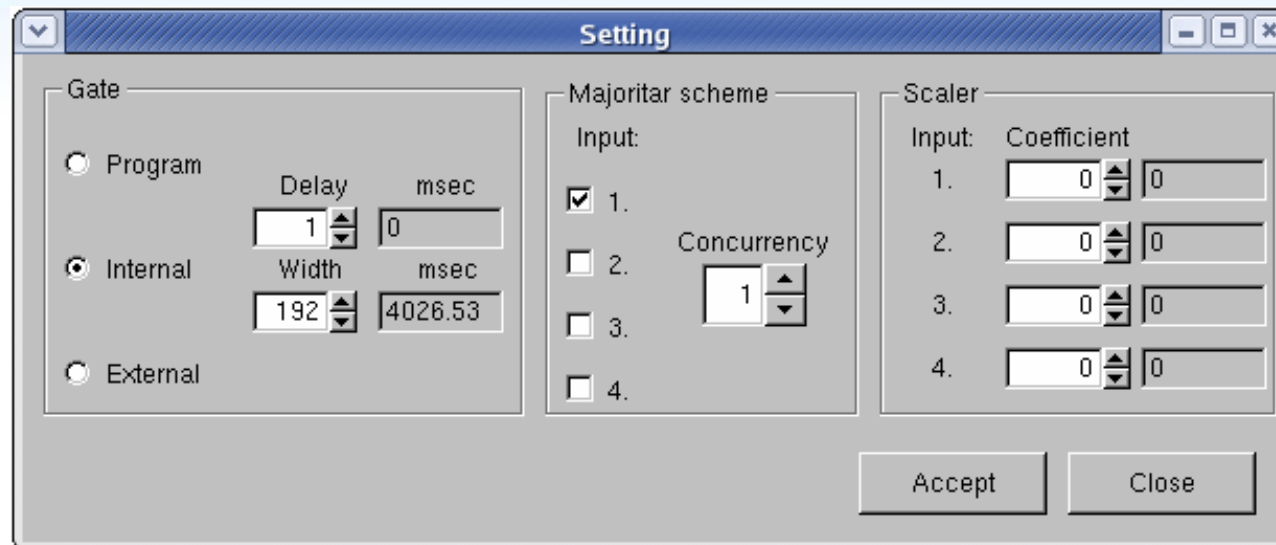
fig A is MIDAS window for online control and checking of high voltage module. fig B is the "history" window of package MIDAS.

MIDAS is a versatile DAQ system for middle range physics experiments.





Status of preparation (*trigger module LT320D*)



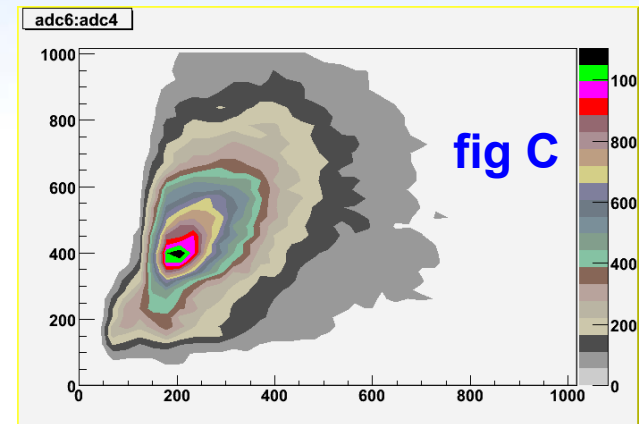
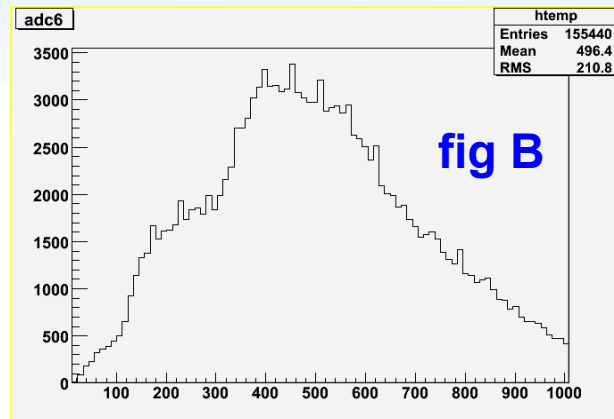
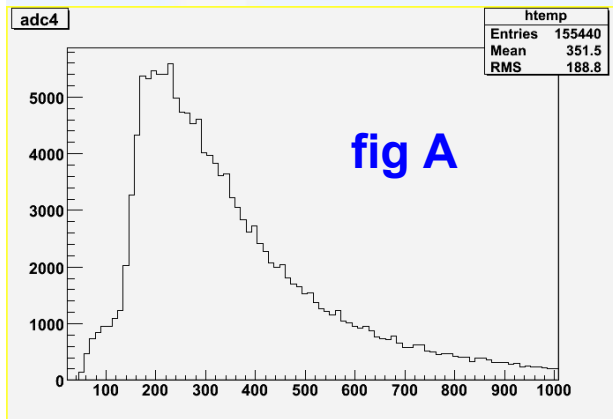
Screenshot of **LT320D** trigger module control program.

One of the important advantages of this module is the possibility to control online the status of majority coincidence circuit.



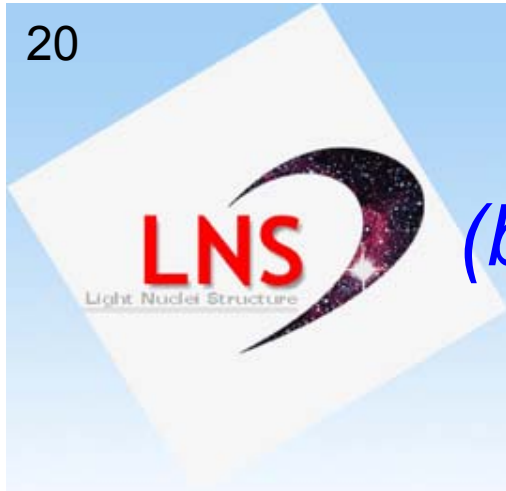
Status of preparation

(beam test for dp breakup experiment).



Data shown were acquired with deuteron energy 2.3 GeV on ^{12}C target in June 2008 using module LT320D. The trigger based on coincidence from two detectors located in the horizontal plane on the left and right from the beam.

fig A is the amplitude from one of the PMTs 85. fig B is the amplitude from PMTs 63 of the same detector. fig C is the correlation of these amplitudes.



Status of preparation

(beam test for dp breakup experiment).

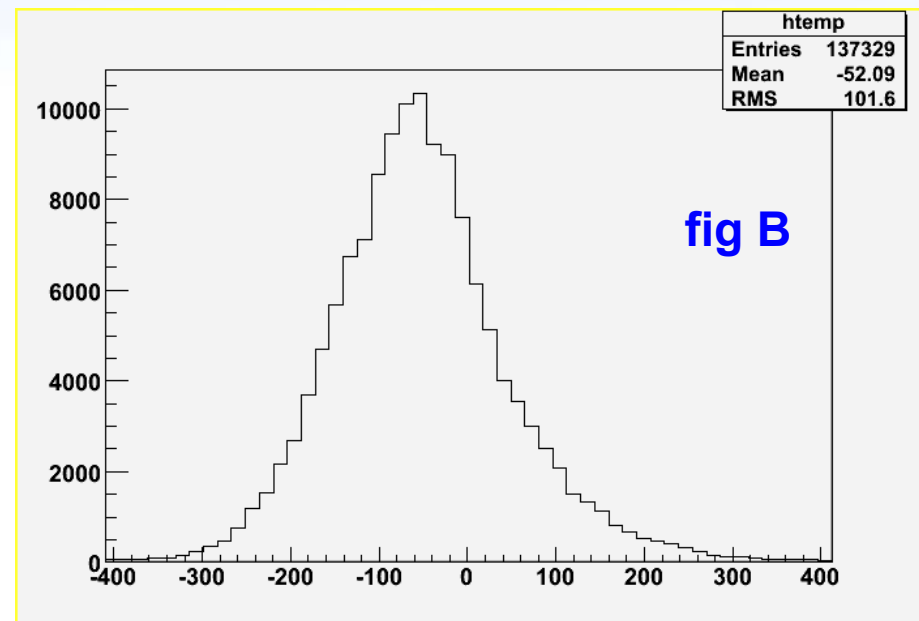
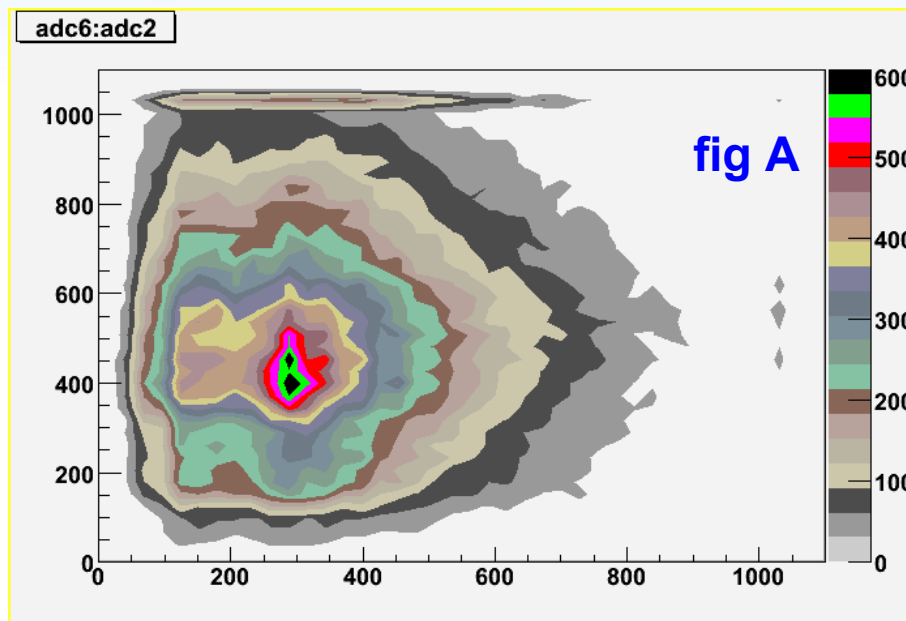


fig A is the correlation of amplitudes from two E-detectors. fig B is the time-of-flight difference for two E-detectors.



Nearest plans

2008 (unpolarized beam):

- Measurements of the dp elastic scattering cross section in the vicinity of Sagara discrepancy;
- Modification of the DAQ system to VME standard;
- Preparation of the experiment on $dp \rightarrow ppn$ reaction;
- Further data analysis.

2009:

- Cross section measurements for dp elastic scattering and $dp \rightarrow ppn$ with unpolarized beam;
- Measurements of the analyzing powers for dp elastic scattering in **300-2000 MeV** region and $dp \rightarrow ppn$ in **300-500 MeV**;
- Analysis of the obtained data from both experimental and theoretical sides.



Conclusion

- The data on the analyzing powers A_y , A_{yy} and A_{xx} in dp elastic scattering have been obtained at 270, 880 and 2000 MeV. It shows the sensitivity to 2N and 3N correlations.
- Presented results show the principal possibility to provide the polarimetry of high energies deuterons at **Nuclotron-M/NICA**.
- The upgrade of the setup at ITS (detectors, high voltage, DAQ etc.) is in progress.
- We are going to take the data on dp – elastic scattering and dp – breakup using both unpolarized and polarized deuteron beams at **Nuclotron** in 2008-2009.