

Proposal on the calibration of the deuteron beam polarimeter at 0.3- 2.0 GeV at Internal Target Station of Nuclotron



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Collaboration

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- RIKEN, Wako-shi, Japan
- Institute for Nuclear Research of RAS, Troitsk, Russia.
- University of Chemical Technology and Metallurgy, Sofia, Bulgaria
- Institute of Physics Slovak Academy of Sciences, Bratislava, Slovakia
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- Advanced Research Institute for Electrical Engineering, Bucharest, Romania

Goals of the project

- Calibration of deuteron beam polarimeter at 880–2000 MeV using Internal Target Station of Nuclotron.
- Systematic study of the energy behaviour of the spin dependent part of the three-nucleon forces via the measurements of the analyzing powers of the dp -elastic scattering at 300-2000 MeV.

These data are very important for several projects at Nuclotron and for new facility RIBF at RIKEN.

Motivation

- The experiments at Nuclotron like *PHe3 – CUPID3* project on the measurements of the polarization observables in the ${}^3\text{He}(d,p){}^4\text{He}$ reaction requires precise measurements of the both vector and tensor polarizations of the deuteron beam in a GeV range.
- New facility RIBF at RIKEN will have polarized deuterons at 880 MeV.
- Problem with the systematics for experiments at different facilities due to different polarization standards.
- Installation at LHE of the polarized ion source *CIPIOS* will require simultaneous measurements of the both tensor and vector polarizations of the deuteron beam.

Current polarimetry at LHE

- Low energy polarimeter (**LEP**) at the LINAC exit based on the ${}^3\text{He}(d, p(0^\circ)){}^4\text{He}$ and ${}^4\text{He}(d, d){}^4\text{He}$ reactions at $T_d = 10$ MeV for the tensor and vector polarization measurements, respectively.
- Tensor and vector polarimeter **ALPHA** based on the asymmetry measurement of the dp - elastic scattering at $T_d = 1600$ MeV and 7.5° of the deuteron scattering angle.
- Vector polarimeter at the focus **F3** based on pp - quasielastic scattering for the energies $T_N = 800\text{-}3660$ MeV.
- Tensor polarimeter at the **SPHERE**-setup based on the $dA \rightarrow p(0^\circ)X$ reaction at $P_p = 2/3 \cdot P_d$ at the energies $T_d = 1250\text{-}7320$ MeV.

Typical systematic error due to measurement of the beam polarization is not better than 5%.

RIKEN experience

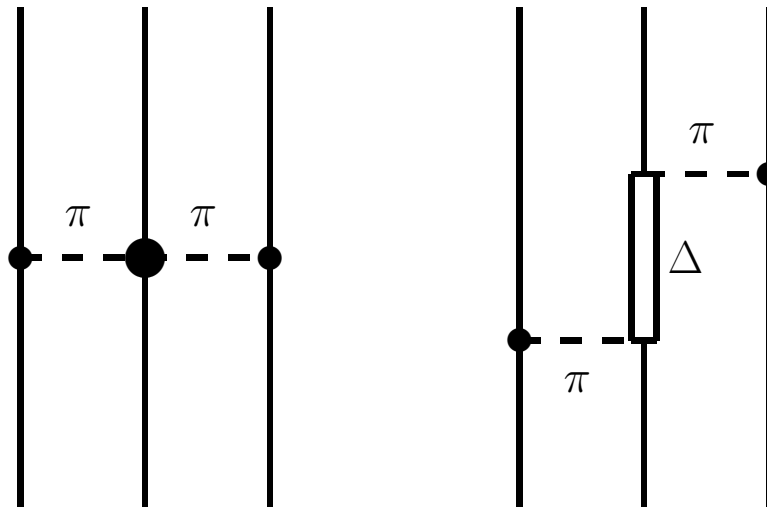
- The polarimeter based on dp elastic scattering is currently used at RIKEN at 140, 200 and 270 MeV.
- Selection of dp elastic scattering is done by the measurements of the energy losses of proton and deuteron in plastic scintillators and time-difference.
- Detection at large angles gives small background. Polarimeter can work in the counting regime.
- Polarimeter is absolutely calibrated at 140 and 270 MeV by the $^{12}\text{C}(d, \alpha)^{10}\text{B}^*[2^+]$ reaction.

Three nucleon forces manifestation

- During last several years a new generation of **NN** potentials are built (Nijmegen, CD-Bonn, AV-18 etc.). These potentials reproduced the **NN** scattering data up to 350 MeV with very good accuracy.
- But these potentials cannot reproduce triton binding energy (underbinding is 0.8 MeV for CD-Bonn), deuteron-proton scattering and breakup data.
- Incorporation of the 3 nucleon forces (**3NF**), when interaction depends on the quantum numbers of the all three nucleons, allows to reproduce triton binding energy and unpolarized deuteron-proton scattering and breakup data.
- However, the **3NF** cannot reproduce polarization data intensively accumulated during last decade.

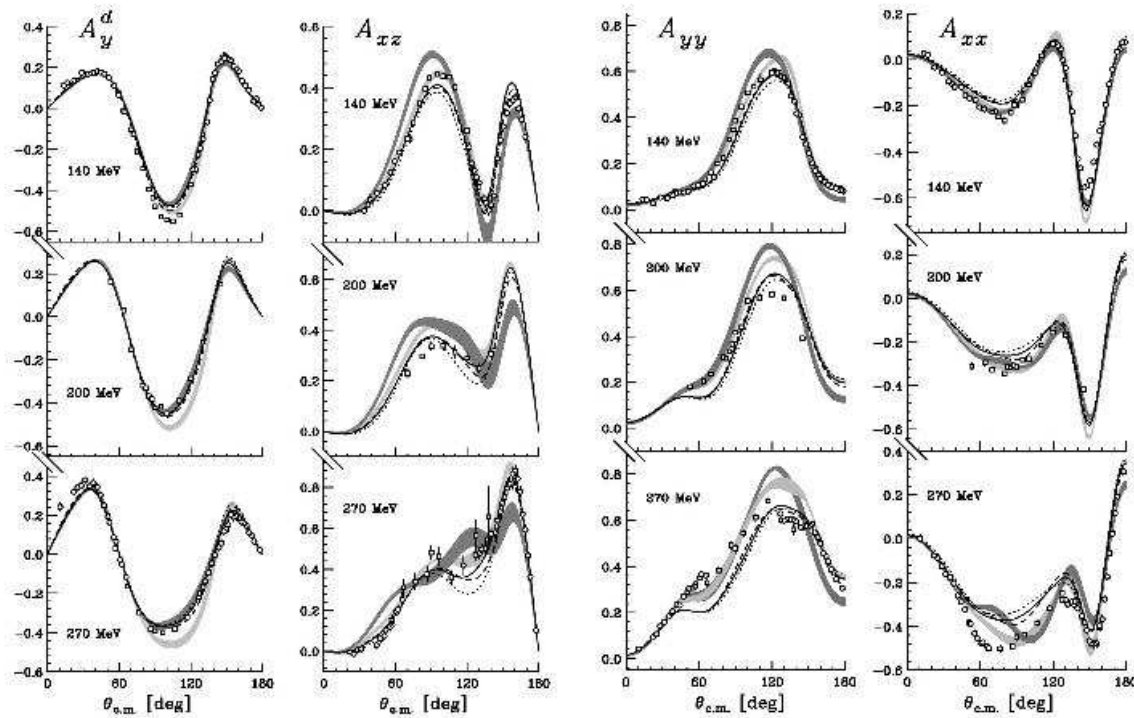
Spin structure of 3NF ?

Different models of 3NF



- Tucson-Melbourne
- Brazil
- Urbana-IX
- Fujita-Miyazawa ($N\Delta$)
- Chiral Effective Field Theory

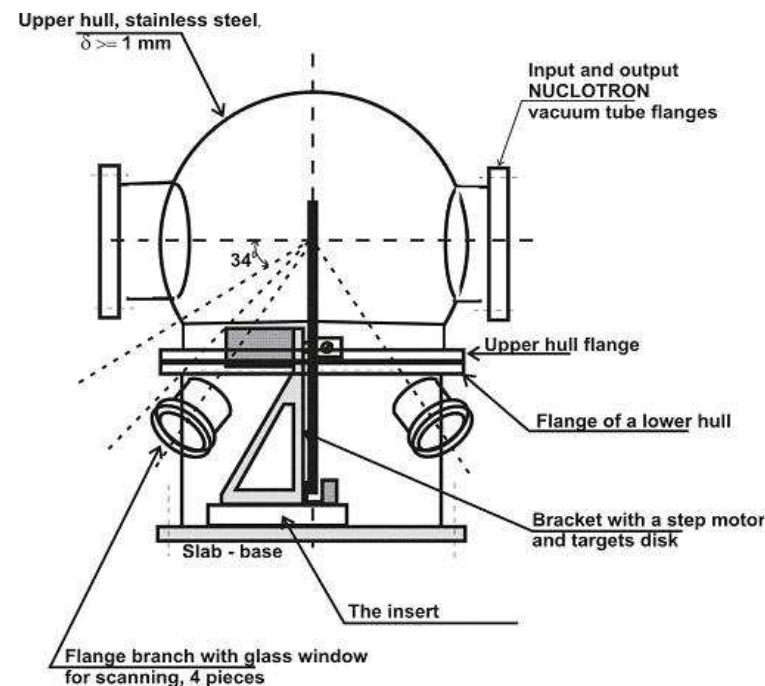
dp elastic scattering analyzing powers



The goal of the present project is to extend the measurement of the deuteron analyzing powers A_y , A_{yy} and A_{xx} to much higher energies than at RIKEN in order to follow the energy dependence of 3NF spin structure.

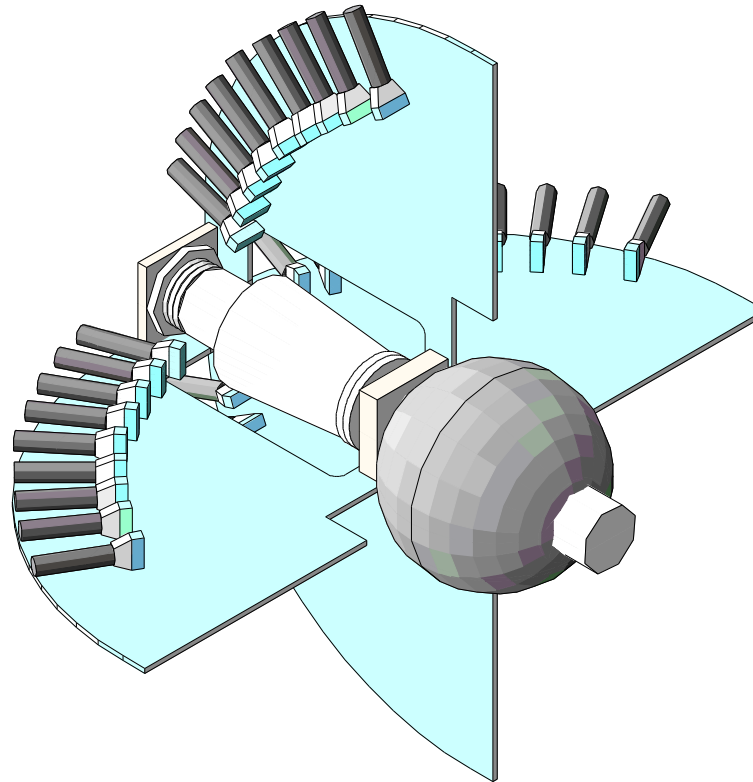
Internal Target Station

New Internal Target Station is very well suited for the experiment on the measurement of the *dp*- elastic scattering experiment at large angles in the center of mass.



Detection system

- Scintillation counters (48) based on Hamamatsu H7415 PMTs placed on the left, right, up and down were used at the same time.
- The detectors covered the angular range $60 - 130^\circ$ in the center of mass.
- VME+CAMAC (FERA, FERET) DAQ has been used for data taking.

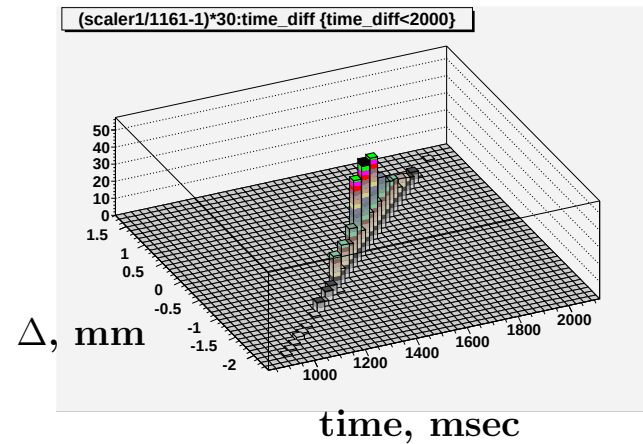
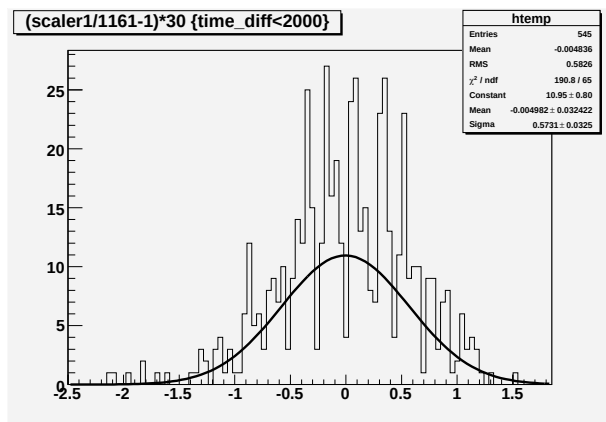


Condition of the June 2005 run at Nuclotron

- Polarized deuterons were provided by PIS **POLARIS**. Typical intensity in the Nuclotron ring was $2 \div 3 \cdot 10^7$ deuterons per spill.
- The $10 \mu\text{m}$ 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.

Target Position Monitor

During the experiment the information on the interaction point was stored in order to correct the data for the false asymmetry.



Typically, events were stored during 0.5-1.0 sec each spill

Analyzing powers at 270 MeV

- Complete set of the deuteron analyzing powers of dp elastic scattering exists at 270 MeV and 86.5° .
- This set has been obtained at RIKEN by the SMART group from the the absolute calibration of beam polarization at 270 MeV via the reaction $^{12}\text{C}(d, \alpha)^{10}\text{B}^*[2^+]$ reaction.

$$\begin{aligned}A_y &= -0.3779 \pm 0.0010(stat) \pm 0.0091(sys), \\A_{yy} &= +0.4311 \pm 0.0010(stat) \pm 0.0100(sys), \\A_{xx} &= -0.4555 \pm 0.0010(stat) \pm 0.0106(sys), \\A_{xz} &= +0.4337 \pm 0.0052(stat) \pm 0.0156(sys)\end{aligned}$$

The systematic errors are $\sim 2\%$ only for the both vector and tensor polarizations.

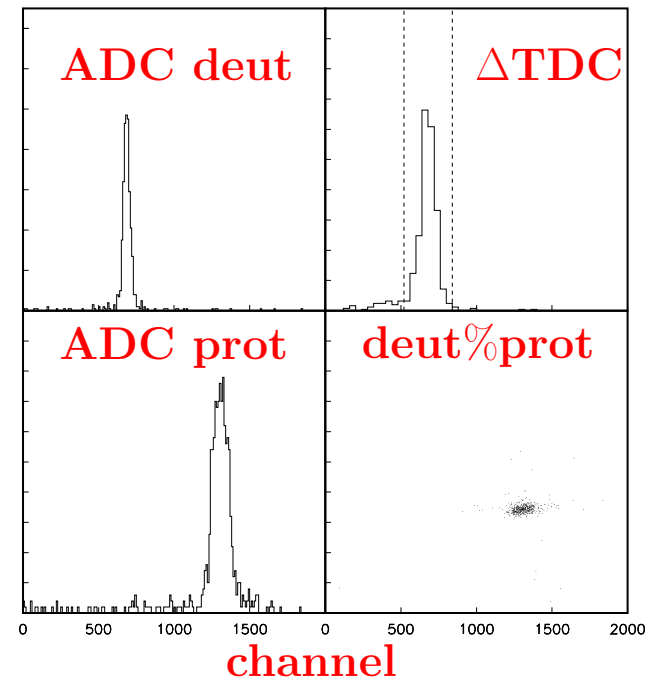
Polarization measurements at 270 MeV

$$P_{zz}^+ = 0.671 \pm 0.046$$

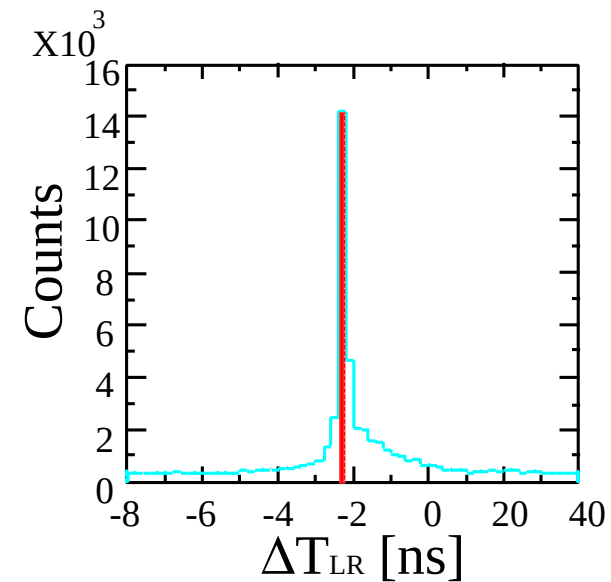
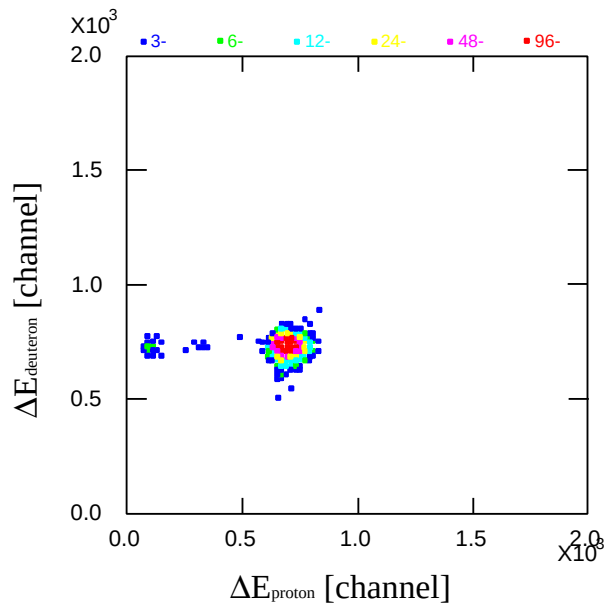
$$P_{zz}^- = -0.482 \pm 0.045$$

$$P_z^+ = 0.246 \pm 0.033$$

$$P_z^- = 0.251 \pm 0.026$$

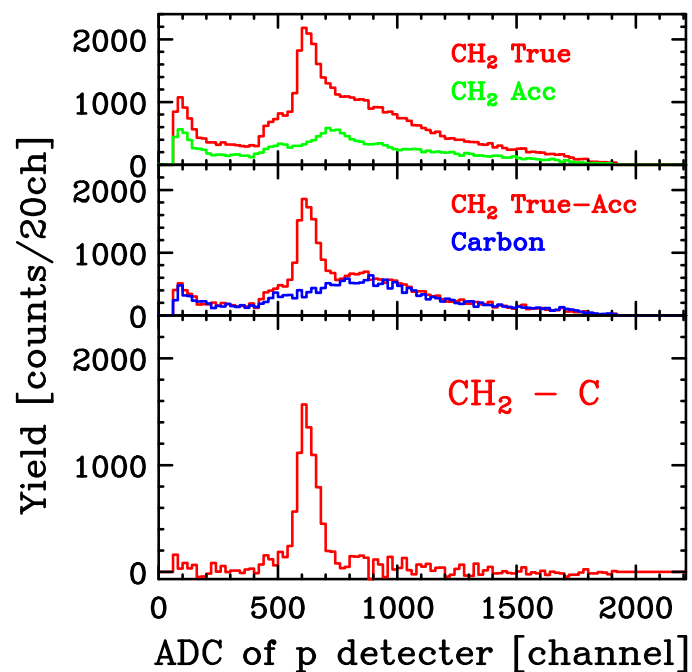
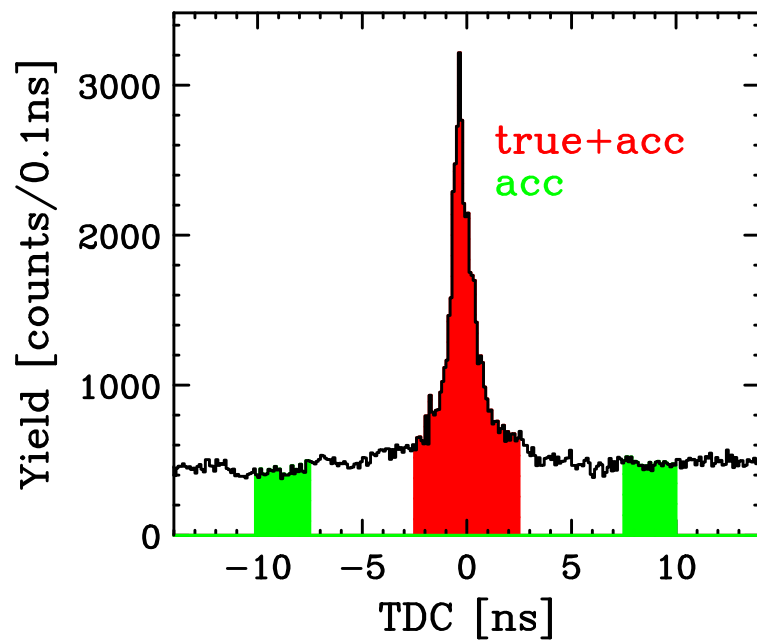


Selection of the *dp* elastic events at moderate energies

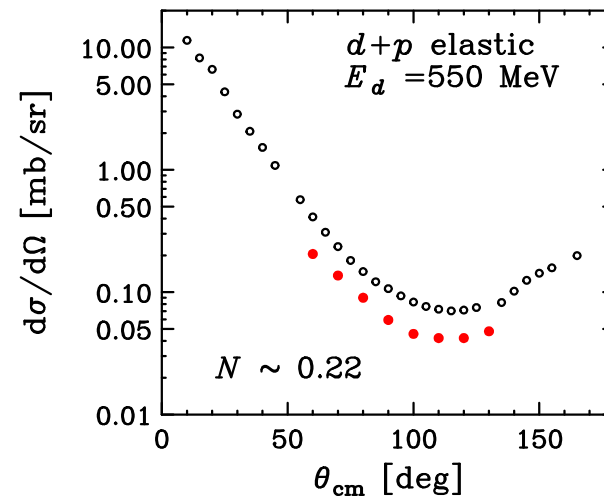
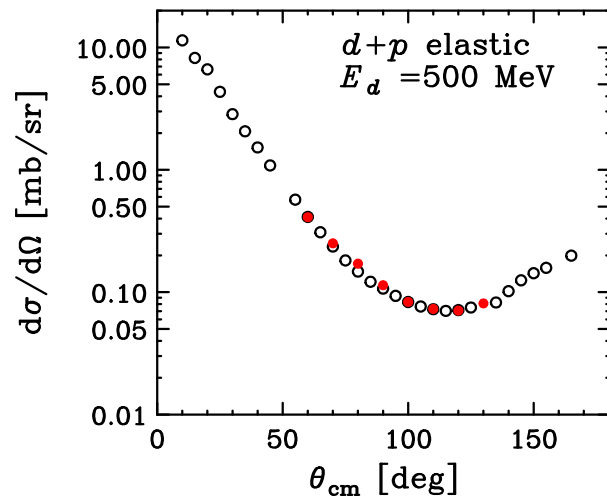


The contribution of the carbon at moderate energies is significantly lower than at high energies

Selection of the dp elastic events at high energies



Check: cross section measurements



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

Conclusion

- The feasibility of the measurements of dp elastic scattering at ITS of **Nuclotron** at the energies 270-2000 MeV is demonstrated. First physical data on the cross section in the vicinity of Sagara discrepancy are obtained.
- The polarization of the beam in June 2005 run has been measured by new tensor and vector polarimeter at 270 MeV at ITS. This allows to introduce the same polarization standard for 3 facility: **RARF**, **Nuclotron** and **RIBF**.
- The calibration of the high energy polarimeter has been performed at the energies 880 and 2000 GeV.
- New important data on the energy dependence of the spin dependent part of three-nucleon forces are obtained.
- Collaboration is planning to take the data with new polarized ion source **CIPIOS**.