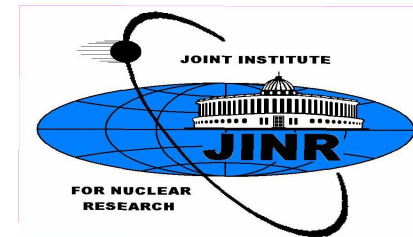


# Investigation of the light nuclei spin structure from hadronic channels at Nuclotron



*P.K. Kurilkin on behalf of DSS collaboration*

Baldin ISHEPP-XXII, September 15-20, 2014 , Dubna, Russia

# Outline

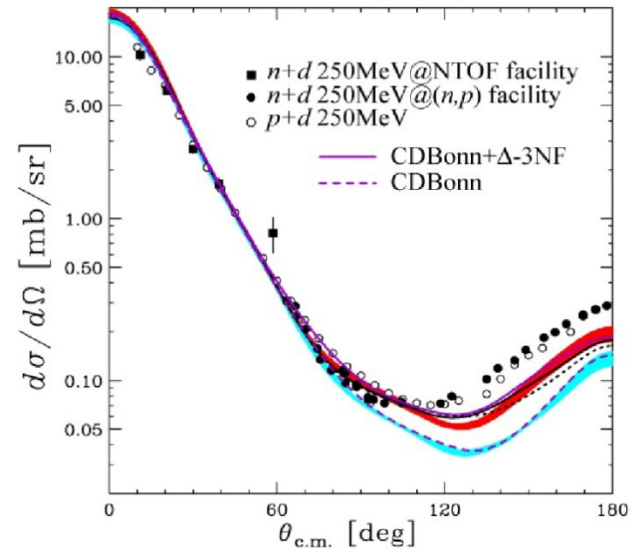
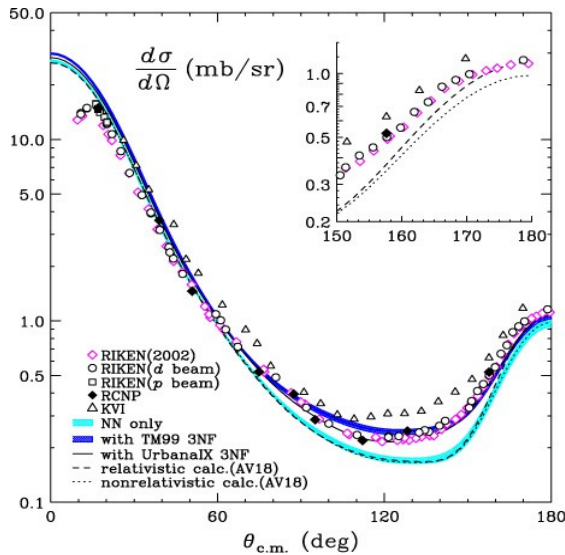
- **Introduction**
- **Recent results on the analyzing powers measurement of **dp**-elastic scattering at intermediate and high energies**
- **Plans for Nuclotron**
- **Deuteron beam polarimetry**
- **Conclusion**

Collaboration: [Bulgaria-JINR-Japan-Romania-Russia-Slovakia](#)

# Motivation

- Modern NN potentials (CD-Bonn, AV-18, Nijmegen etc.) accurately reproduce the NN data set up to about 350 MeV. However they fail in the description of the binding energy and data on unpolarized **dp**-elastic scattering and breakup reactions.
- Incorporation of three nucleon forces (3NF), when interaction depends on the quantum numbers of the all three nucleon, allows to reproduce the binding energy of the three-nucleon bound systems and the data on unpolarized **dp**- interaction.
- Polarization data for the reaction with participation of three and more nucleons aren't described even with the 3NF inclusion.
- The cross section data for **dp**- elastic scattering are reproduced well up to 150 MeV taking into account 3NF. Manifestation of three-nucleon forces effect in the cross-section of **dp**-elastic scattering at this energy: up to **30%** in the vicinity of Sagara discrepancy.

# Cross section in **dp**- elastic scattering at intermediate energies



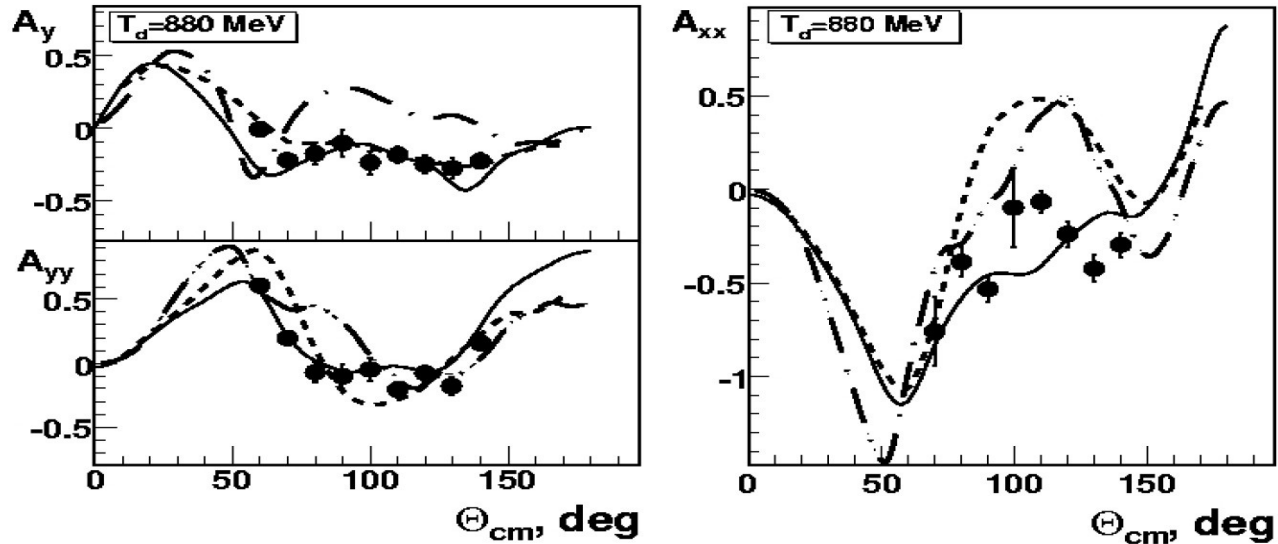
The differential cross section in elastic Nd scattering at the energy of 135 (left figure) and 250 (right figure) MeV/u.

K. Sekiguchi et al., Phys. Rev. Lett. 95, 162301 (2005)

K. Hatanaka et al., Phys. Rev. C 66, 044002 (2002)

The study of hadronic reactions induced by deuterons at **Nuclotron** will allow to study the structure of **2N** and **3N forces**.

# Analyzing powers in **dp**- elastic scattering at 880 MeV



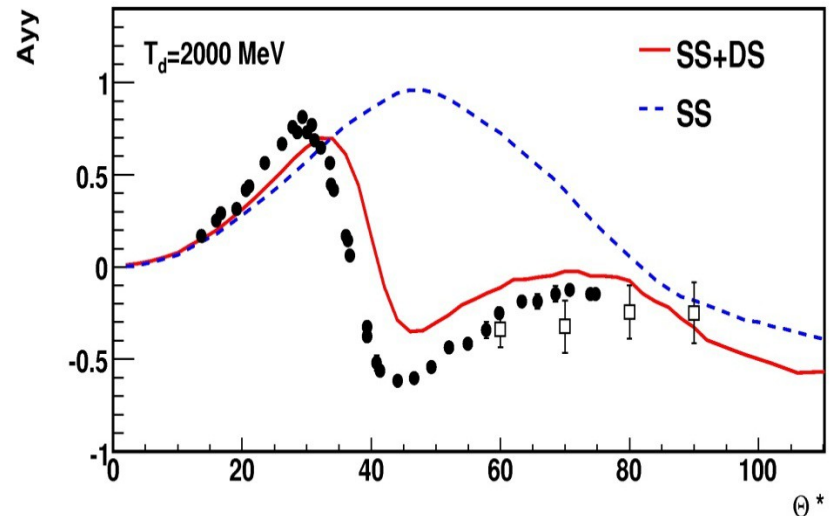
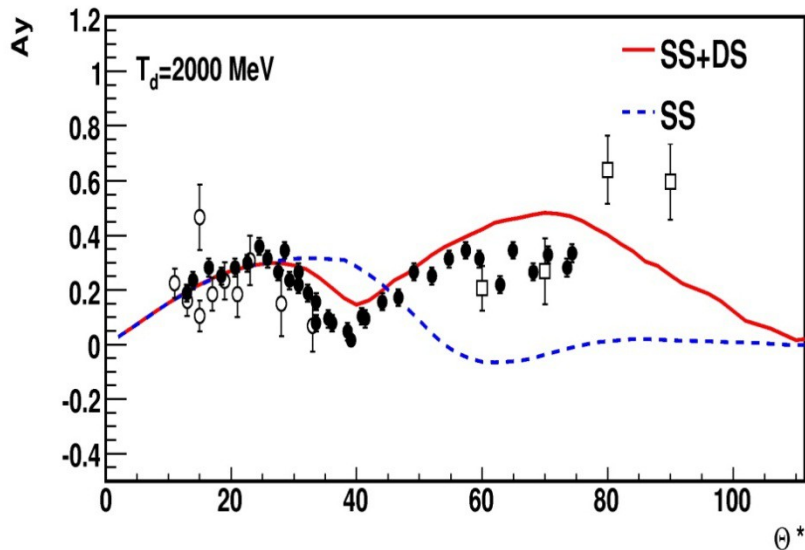
Dashed lines are the multiple scattering model calculations using  
CD-Bonn DWF (N.B.Ladygina, Phys.Atom.Nucl.71 (2008), 2039)

Solid lines are the Faddeev calculations using CD-Bonn potential  
(H.Witala, private communication)

Dott-dashed lines are the optical-potential calculations using Dibaryon  
DWF (M.Sikhalev, Phys.Atom.Nucl.72 (2009), 588 )

Published in P.K.Kurilkin et al., Phys.Lett.B715 (2012) 61-65

# $A_y$ and $A_{yy}$ in **dp**- elastic scattering at 2000 MeV



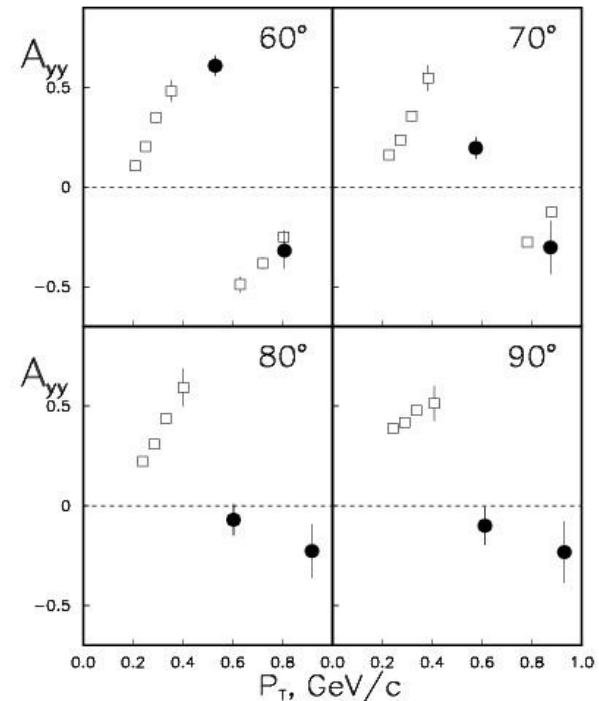
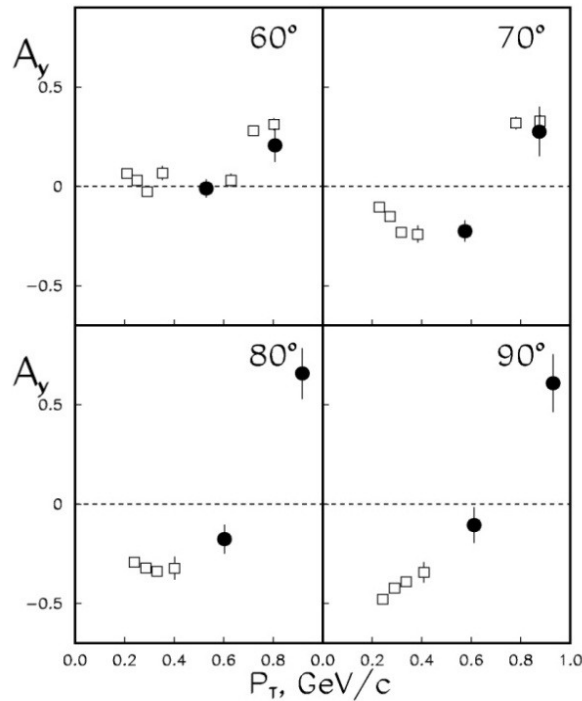
Open squares are the data obtained at Nuclotron **JINR**.

Open circles are the Synchrotron data ([V.V.Glagolev, Eur. Phys. J. A48 \(2012\) 182](#))

Solid symbols are the data obtained by ANL group ([Haji-Saied et al., Phys.Rev.C.36 \(1987\) 2010](#)).

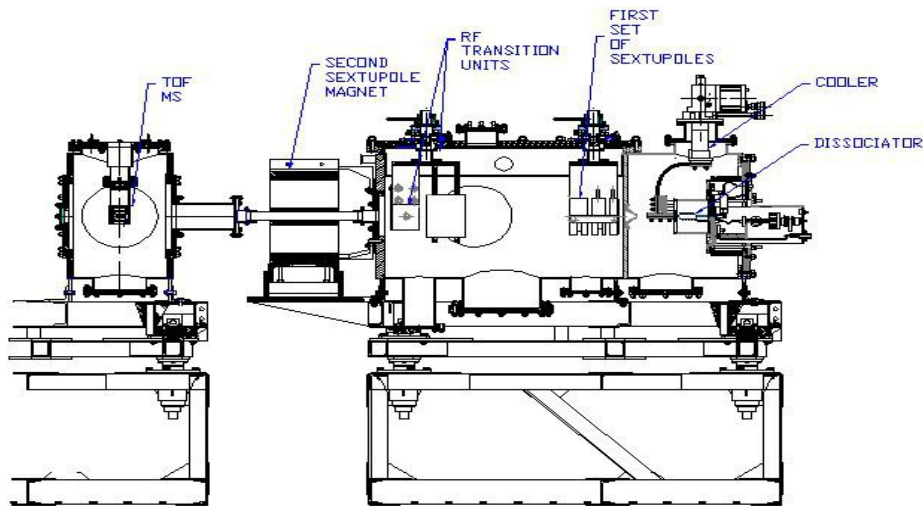
Dashed and solid lines are the relativistic multiple scattering model calculations using **CD-Bonn** DWF taking into account single scattering and single+double scattering, respectively.

# Energy dependence of the **dp**-elastic scattering analyzing powers at fixed scattering angles in the c.m.s.



- Full symbols are the data obtained at **JINR**
- Open symbols are the data obtained at RIKEN, Saclay and ANL.

# New Polarized Deuteron Source for LHEP



- New source will provide up to  $2 \cdot 10^{10}$  ppp and higher values of polarization than **POLARIS**.

Large variety of the spin modes. **DSS** project will use the spin modes with the following ideal values of  $(p_z, p_{zz})$ :  $(0,0)$ ,  $(0,-2)$ ,  $(2/3,0)$  and  $(-1/3,+1)$

Figure of merit increasing by a factor  $\sim 10^3$



## Experimental program of **DSS** project

The purpose of the **DSS** experimental program is to obtain the information about **2NF** and **3NF** (including their spin – dependent parts) from several processes:

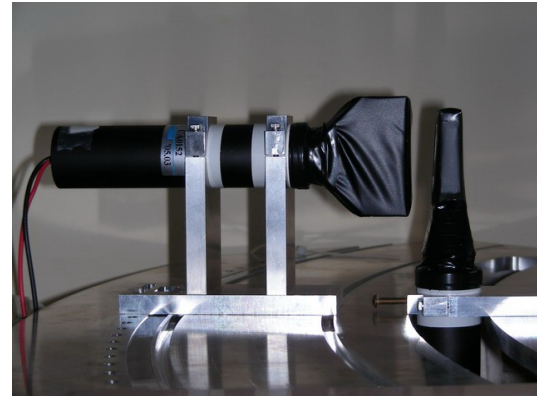
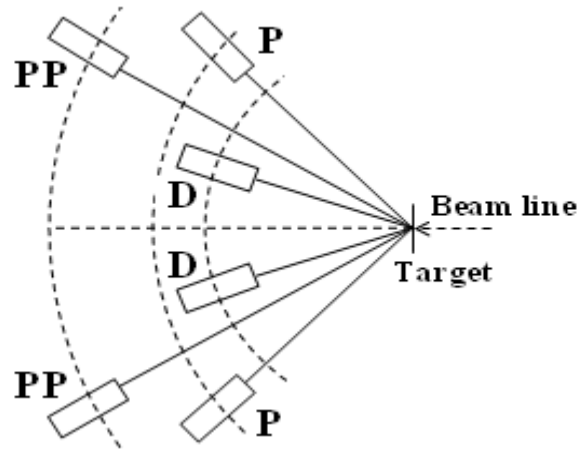
1. dp- elastic scattering at the energies between **300 - 2000 MeV**.
2. dp-breakup with registration of two protons at deuteron energies of **300 - 500 MeV**.
3. Measurement of the tensor analyzing powers **T20** and spin correlation **C<sub>y,y</sub>** in  $d+{}^3\text{He}\rightarrow p+{}^4\text{He}$  reaction in the deuteron kinetic energy range between **1.0** and **1.75 GeV**.

# Experiments at Internal Target Station at Nuclotron (DSS-proect)



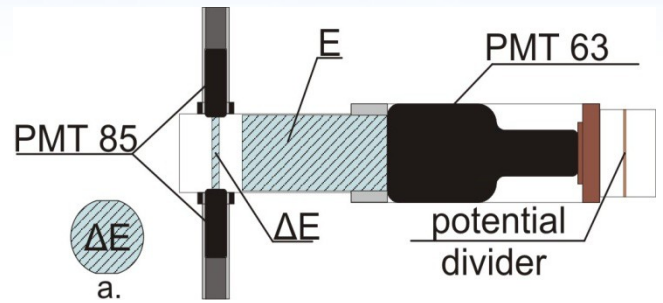
Internal Target Station is very well suited for the measurements of the **deuteron**- induced reactions observables at large scattering angles.

# Scheme of the HE-dp experiment

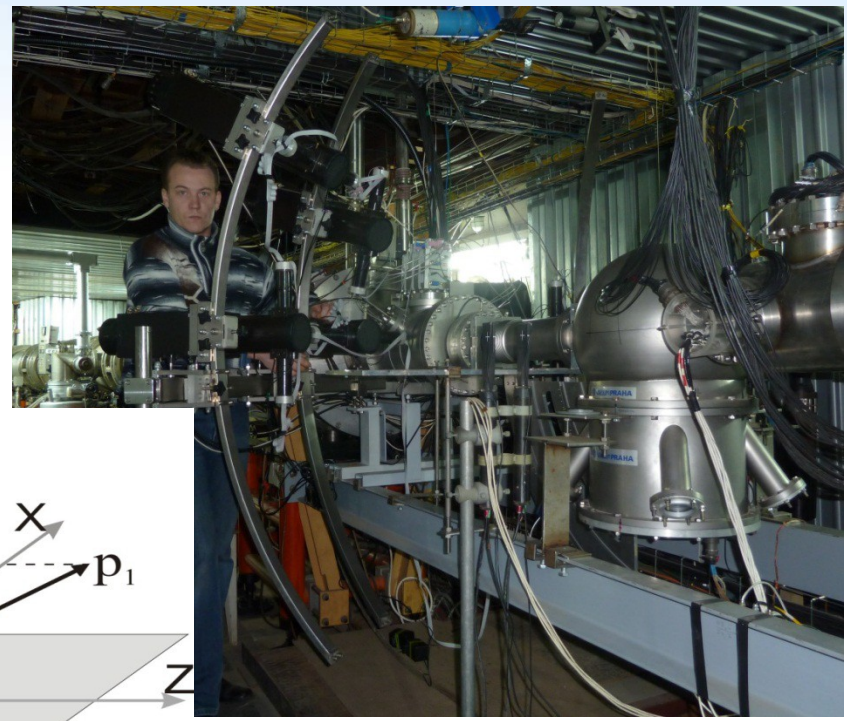
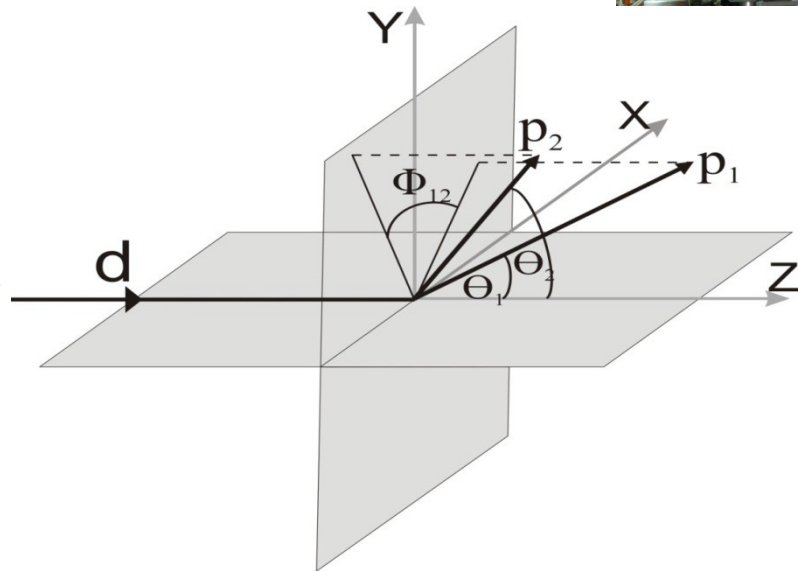


dp- elastic scattering cross section data have been accumulated at 400-2000 MeV.  
The data analysis is in progress (see talk [A.Terekhin](#)).

# Experimental system for dp-breakup.

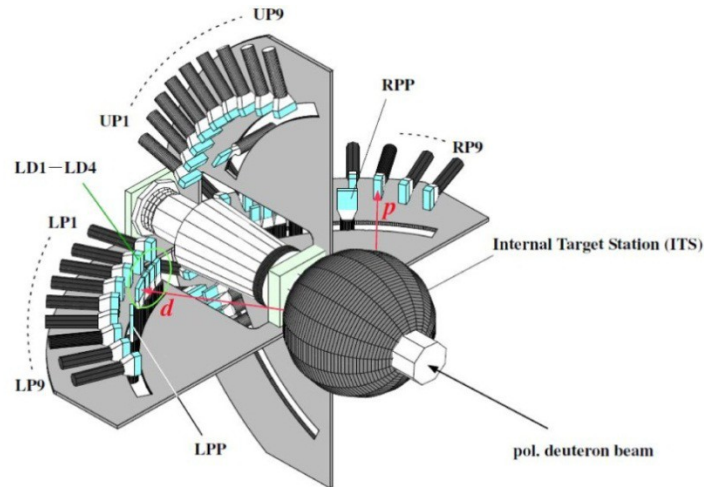


$\Theta$  ( $12^\circ, 45^\circ$ )  
 $\Phi$  ( $0^\circ, 360^\circ$ )  
 Space angle of the detector  $4.6^\circ$ .

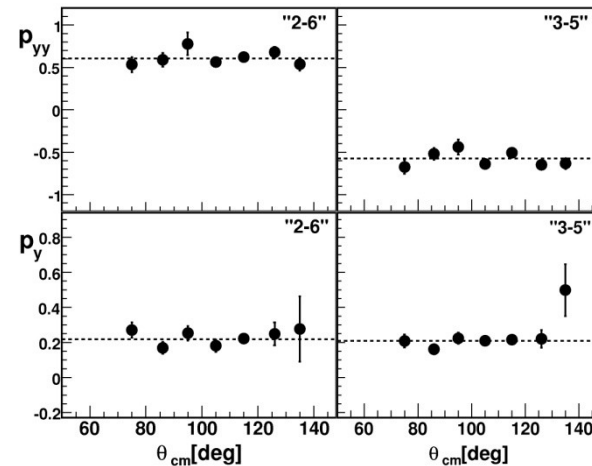


S.Piyadin

# Measurement of the deuteron beam polarization at ITS using CNS detection system at 270 MeV



A schematic view of the polarimeter setup installed downstream the ITS spherical chamber.

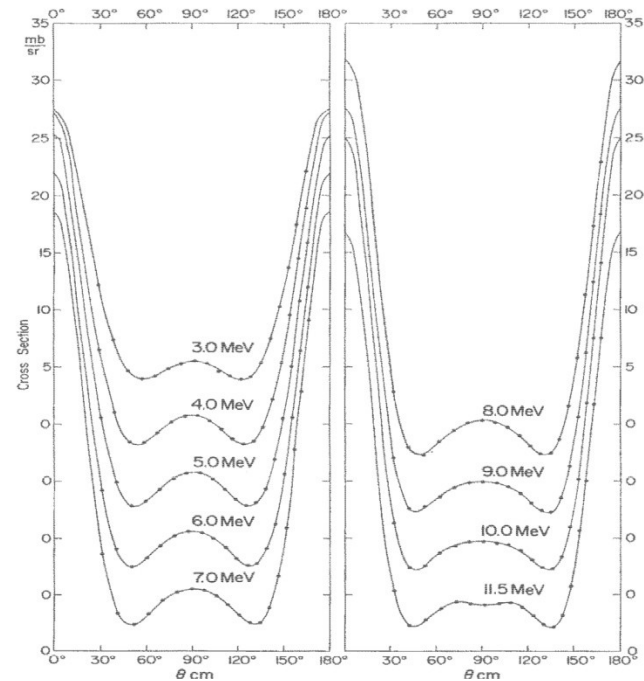
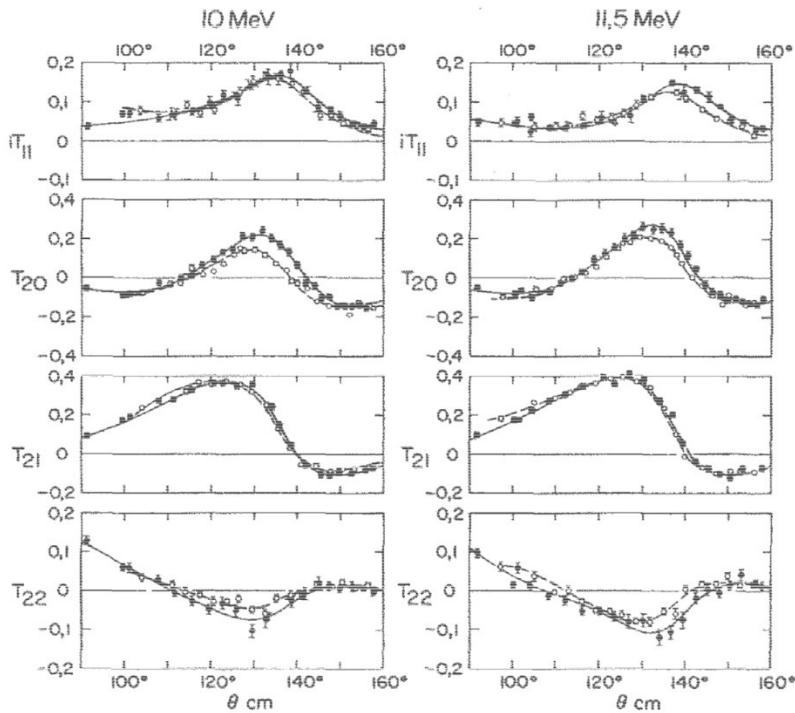


Tensor  $p_{yy}$  and vector  $p_y$  polarization of the beam for "2-6" and "3-5" spin modes of PIS POLARIS as a function of the deuteron scattering angle in the c.m.s.

- Main deuteron beam polarimeter at Nuclotron-M.
- **dp**- elastic scattering at large scattering angles in the center of mass system.
- The detectors cover the angular range  $60-140^\circ$  in the c.m.s.  
(P.K. Kurilkin et al., Nucl. Instr. and Meth. A 642 (2011) 45 )

# Low energy deuteron beam polarimeter

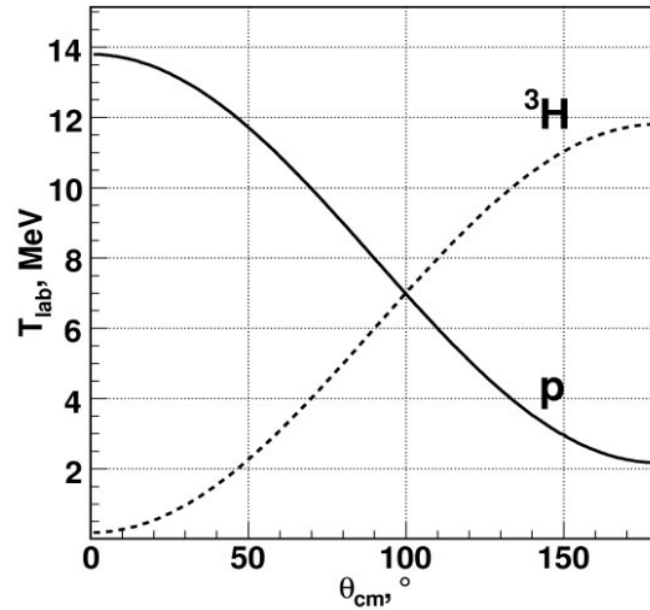
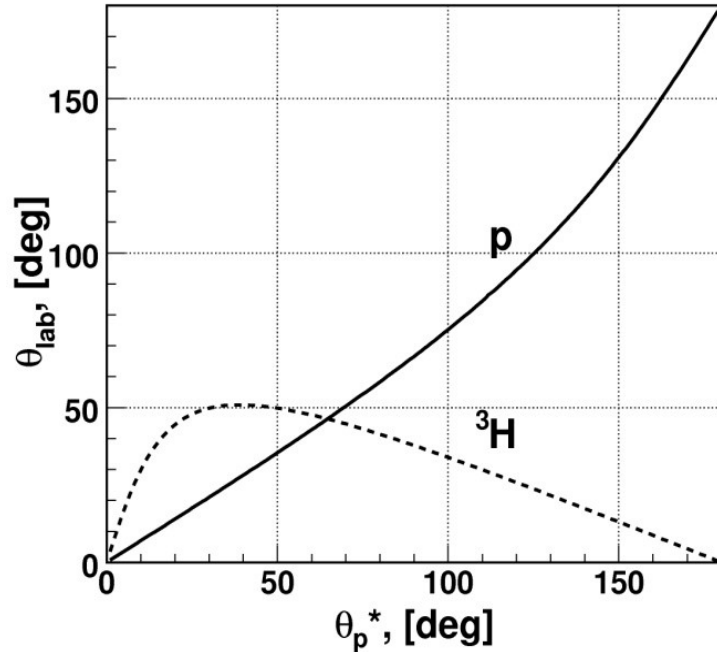
The use of the reaction  $d(d,p)^3\text{H}$  at 10 MeV with large values of the cross section and deuteron analyzing powers around  $130^\circ$  in cms



W.Grüebler et al., Nucl.Phys. A193 (1972) 179

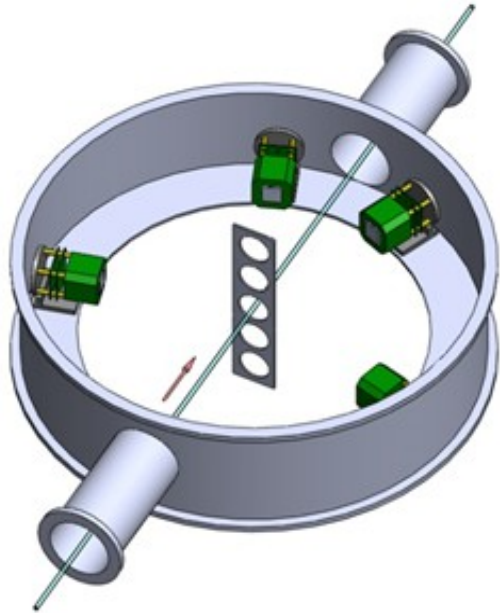
V.König et al., Nuc

# Low energy deuteron beam polarimeter

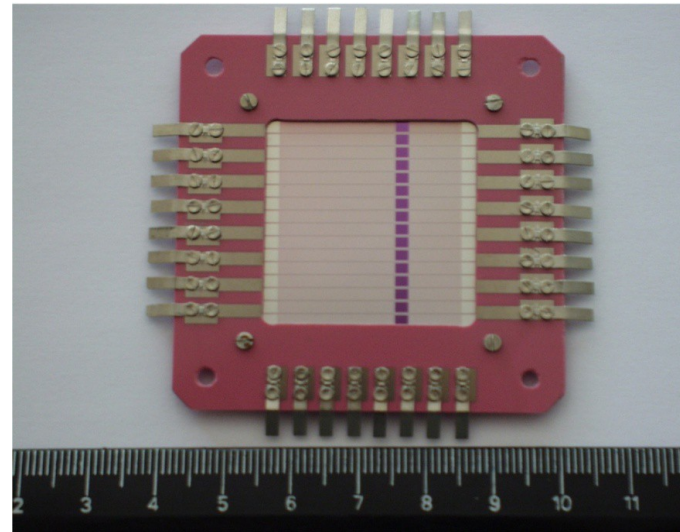


Kinematic relation for **p** and  $^3\text{H}$  in  $d(d,p)^3\text{H}$  at 10 MeV

# Low energy deuteron beam polarimeter



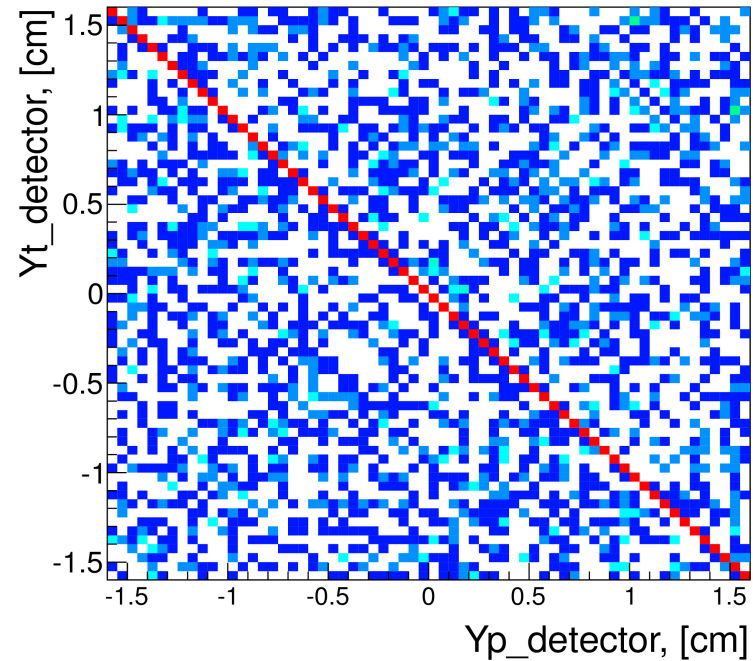
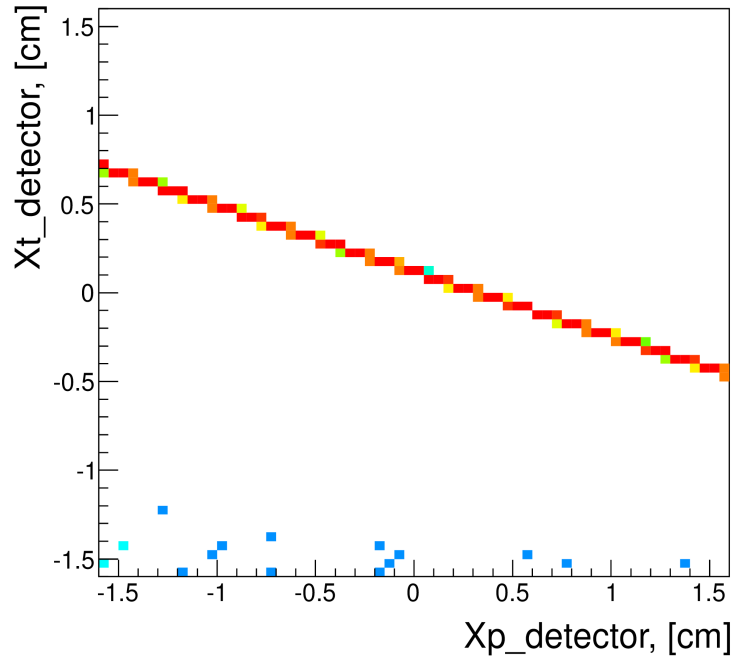
Schematic view of the setup for the deuteron beam polarization measurement at 10 MeV



The microstrip double sided silicon detector for proton and triton in coincidences



# Low energy deuteron beam polarimeter



The  $d(d,p)^3\text{H}$  events selection using the relation between scattering angles of protons and tritons and at 130 in c.m. at 10 MeV and distance of 20cm from the target. The energy loss information will be also used in the analysis.

# Conclusion

- The data on the analyzing powers  $A_y$ ,  $A_{yy}$  and  $A_{xx}$  in **dp**- elastic scattering have been measured at ITS at the Nuclotron at the energies of **880** and **2000 MeV**.
- The data on the energy dependence of the **dp**- elastic scattering cross section have been accumulated at **400-2000 MeV**. The data analysis is in progress.
- The data on **dp**- nonmesonic breakup have been obtained at **300, 400** and **500 MeV** for different kinematic configurations.
- Future studies of the deuteron-induced reactions like  $dp \rightarrow pd$ , **dp**-breakup,  $dd \rightarrow {}^3\text{H}p({}^3\text{He}n)$  and  $d{}^3\text{He} \rightarrow p{}^4\text{He}$  at Nuclotron are related with new PIS developed at LHEP-JINR.
- The **270 MeV** deuteron beam polarimeter exists at ITS. It is able to measure both tensor and vector polarization of the beam and direction of the vector polarization.
- Low energy polarimeter for new source should be changed. Instead of  **${}^4\text{He}(d,d){}^4\text{He}$**  and  **${}^3\text{He}(d,p){}^4\text{He}$**  reactions at 10 MeV the reactions having both tensor and vector analyzing powers should be used:  **$d(d,p){}^3\text{H}$**  or  **$d(p,p)d$** .

Thank you for the attention!!!