

# Deuteron beam polarimetry at Nuclotron



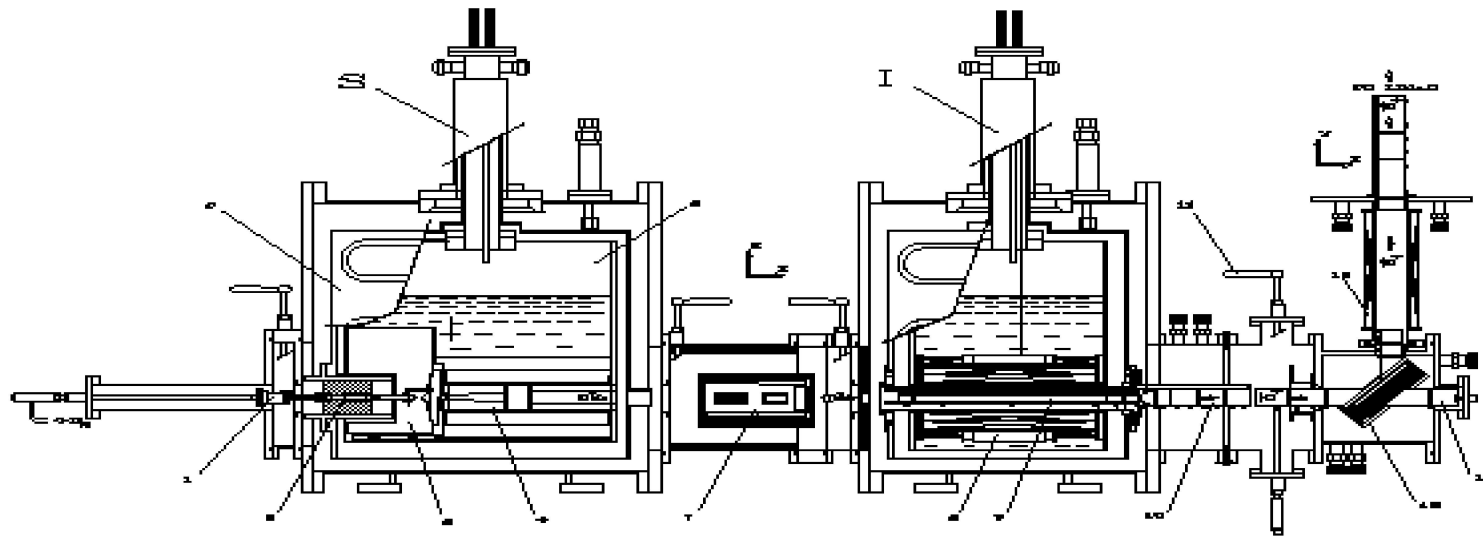
*V.P.Ladygin et al.*

*talk at PST05, 15 November 2005, Tokyo*

## Collaboration

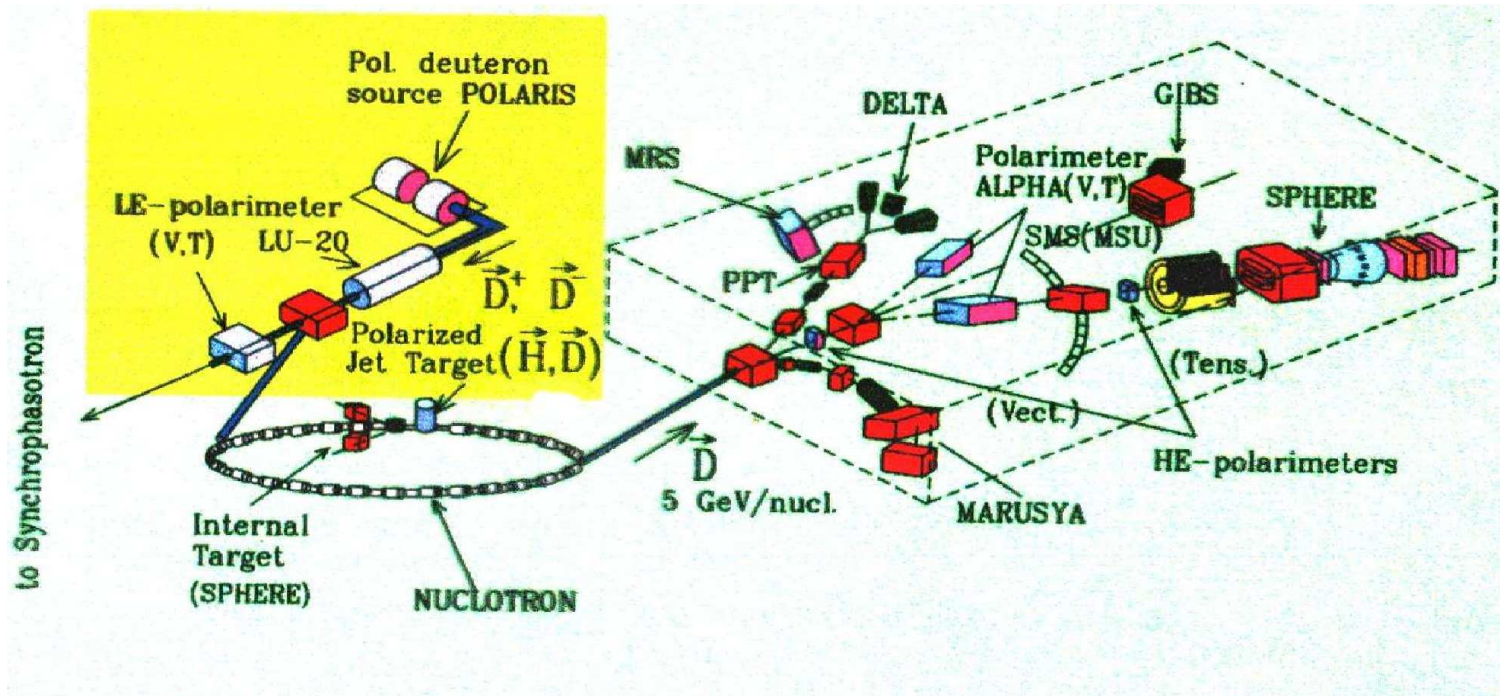
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## Polarized $D^+$ Source POLARIS



- Atomic stage: dissociator, nozzle atomic beam source, superconducting sextupole magnet for atom separation
- RF transition cells to produce vector and tensor nuclear polarization
- Penning ionizer: high field SC solenoid, electron and ion optics for ionization of polarized atomic beam
- Spin precessor magnet of vertical spin orientation of the beam
- Parameters: the current is 0.3–0.4 mA; the energy is  $\sim 3$  keV

# NUCLOTRON Accelerator Complex



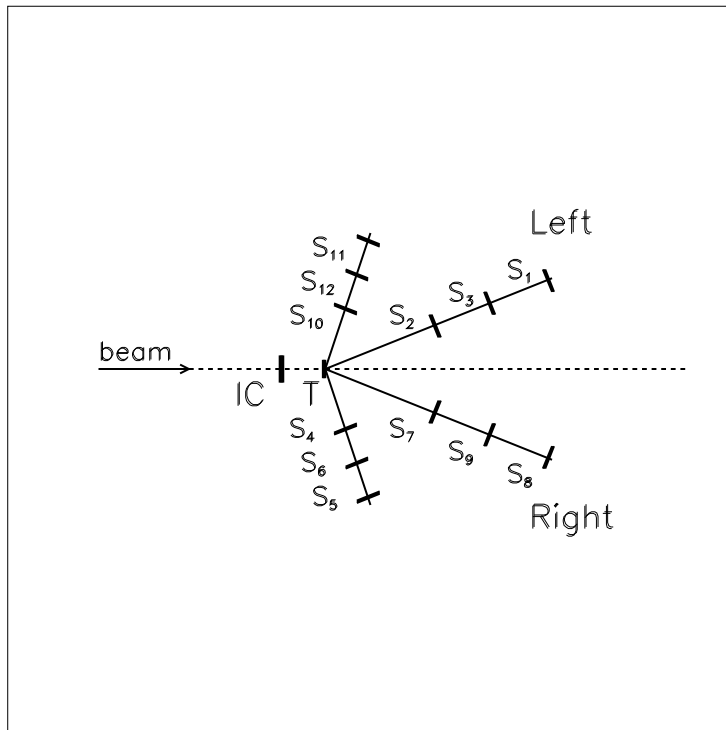
- PIS on 360 kV terminal
- 10 MeV/A LINAC
- Tensor and vector LEPs
- Nuclotron Ring: 6 GeV/A
- ITS polarimeter
- Extraction beam line
- HE polarimeters
- Experimental setups

## Existing polarimeters at NUCLOTRON

- Low energy polarimeters (**LEP**) at the LINAC exit are 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  $7.5^\circ$  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%.

## Vector HE deuteron polarimeter



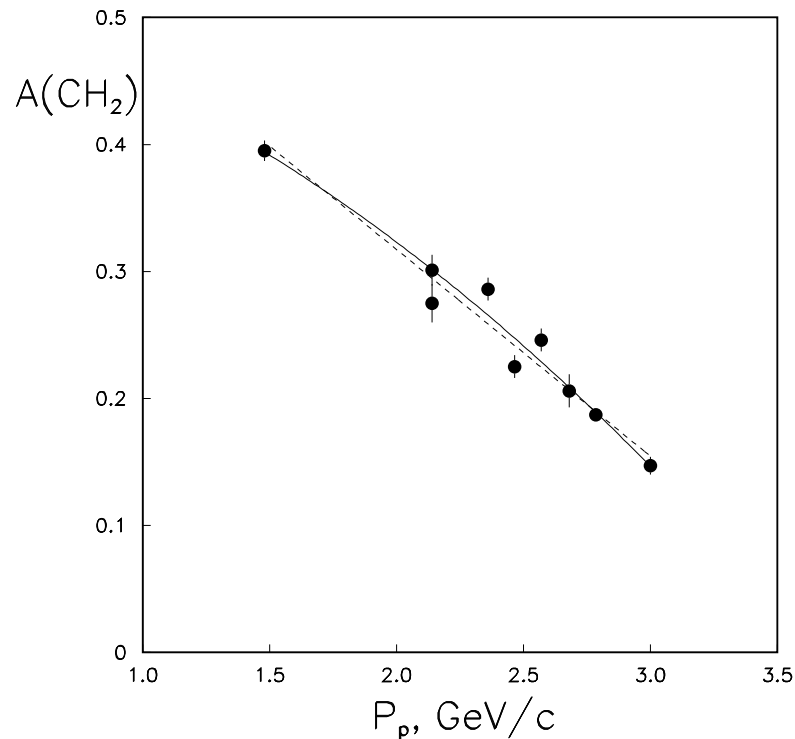
- Polarimeter is based on the asymmetry measurement in quasi-elastic **pp** scattering
- The six-fold coincidences of counter signals from each pair of conjugated arms define **L** or **R** scattering events
- Polarization of the beam can be extracted as

$$P^{\pm} = \frac{1}{A} \cdot \frac{n_L^{\pm}/n_R^{\pm} - n_L^0/n_R^0}{n_L^{\pm}/n_R^{\pm} + n_L^0/n_R^0},$$

where  $n_L^{\pm,0}$  and  $n_R^{\pm,0}$  are the respective numbers of events scattered leftwards and rightwards for different spin states of polarization source normalized to the beam intensity;  $A$  is an effective analyzing power of the polarimeter

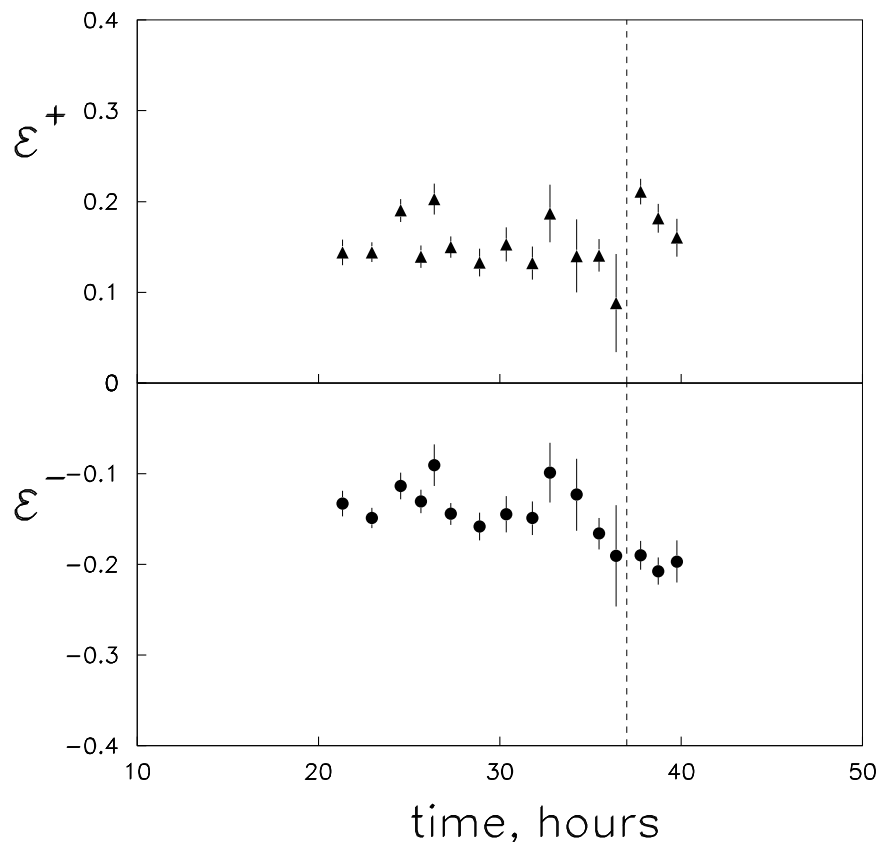
L.S. Azhgirey et al., Prib.Tech.Exp.1 (1997) 51;  
Nucl.Instr.Meth. A497 (2003) 340.

# Calibration of vector HE deuteron polarimeter at $14^\circ$



- Polarimeter has been calibrated using Synchrotron polarized deuteron beam at  $800 \text{ MeV/A}$  via  $CH_2 - C$  subtraction using the world data on the analyzing power of free  $pp$  scattering
- The effective analyzing power  $A(CH_2)$  at forward proton scattering angle of  $14^\circ$  has been obtained at different energies and parametrized as a function of  $T_p$
- The systematic error in the measurement of the beam polarization is estimated as  $5\%$

# NUCLOTRON vector polarized beam polarization measurements at 3.5 and 5.0 GeV/c: December 2002



$P_d$ GeV/c	$P^+ \pm \Delta P^+$ Mode <b>3-6</b>	$P^- \pm \Delta P^-$ Mode <b>1-4</b>	$P \pm \Delta P$
3.5	$0.531 \pm 0.026$	$-0.548 \pm 0.027$	$0.540 \pm 0.019$
5.0	$0.633 \pm 0.019$	$-0.578 \pm 0.020$	$0.606 \pm 0.014$
<b>LEP</b>	$0.62 \pm 0.07$	$-0.56 \pm 0.07$	$0.59 \pm 0.05$

Good agreement of the polarization values for **LEP** and **HE** polarimeter:

**NO DEPOLARIZATION EFFECTS at NUCLOTRON**

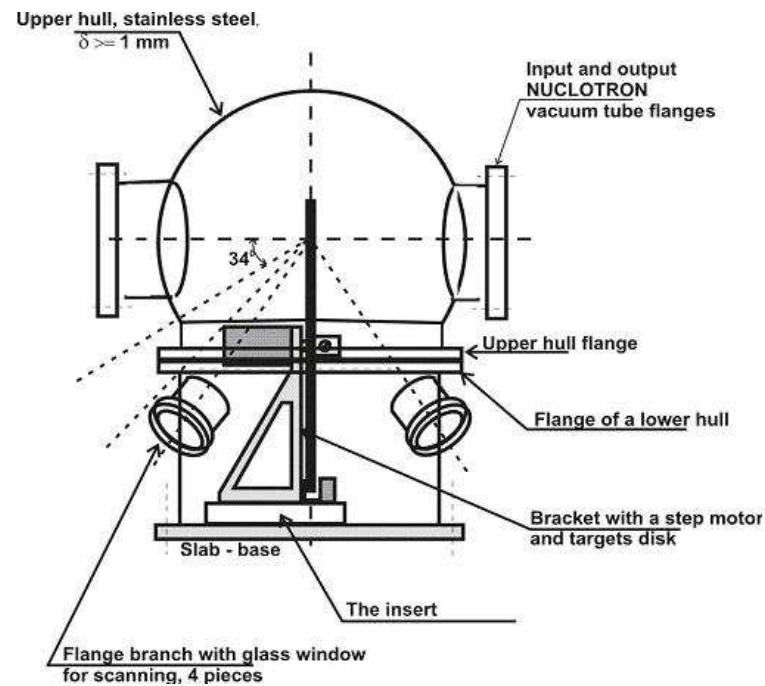


## Motivation for new deuteron beam polarimeter

- 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 require precise measurements of the both vector and tensor polarizations of the deuteron beam in a GeV range.
- 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.
- New facility RIBF at RIKEN will have polarized deuterons at 880 MeV.

# Proposal on the new polarimeter calibration at Internal Target Station of NUCLOTRON

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

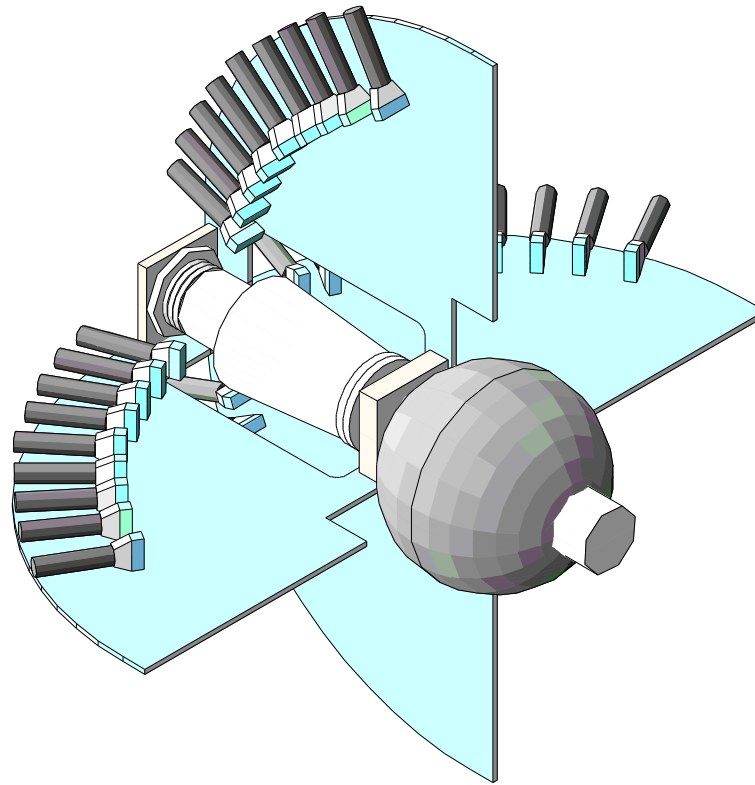


## RIKEN experience

- The polarimeter based on  $dp$  elastic scattering is currently used at RIKEN at 140, 200 and 270 MeV.
- Polarimeter is able to measure both tensor and vector polarizations of the beam. The systematic errors are  $\sim 2\%$  only for the both vector and tensor polarizations.
- 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.

## 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.

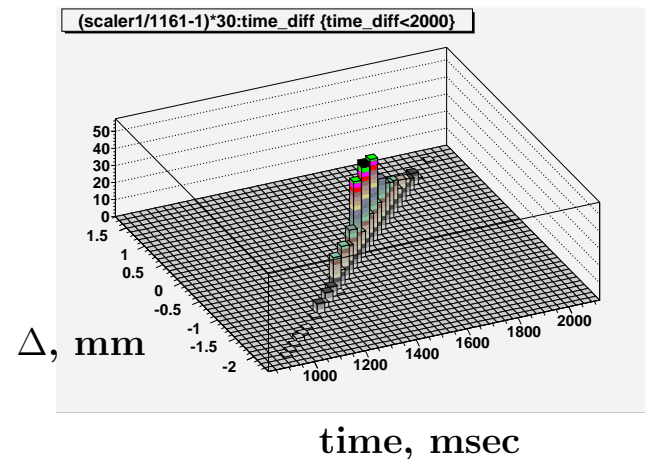
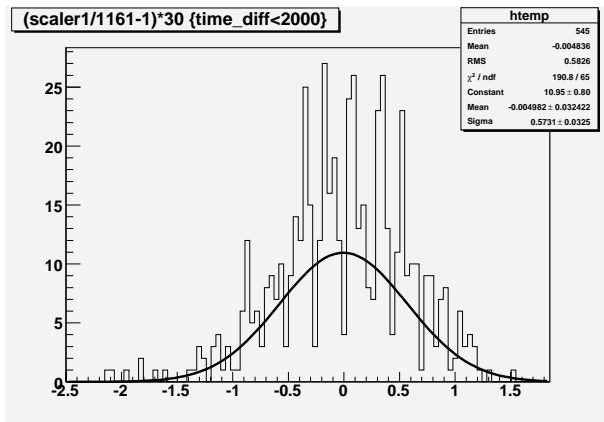


## Condition of the June 2005 run at Nuclotron

- Polarized deuterons were provided by PIS **POLARIS**. Typical intensity in the Nuclotron ring was  $2 \div 3 \cdot 10^7$  deuterons per spill.
- The  $10 \mu\text{m}$   $\text{CH}_2$  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

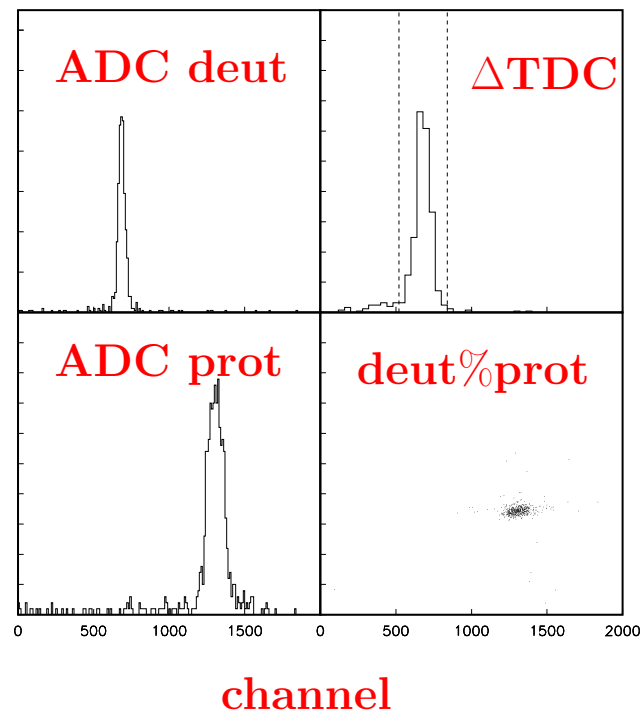
During the experiment the information on the interaction point was stored in order to correct the data for the false asymmetry.



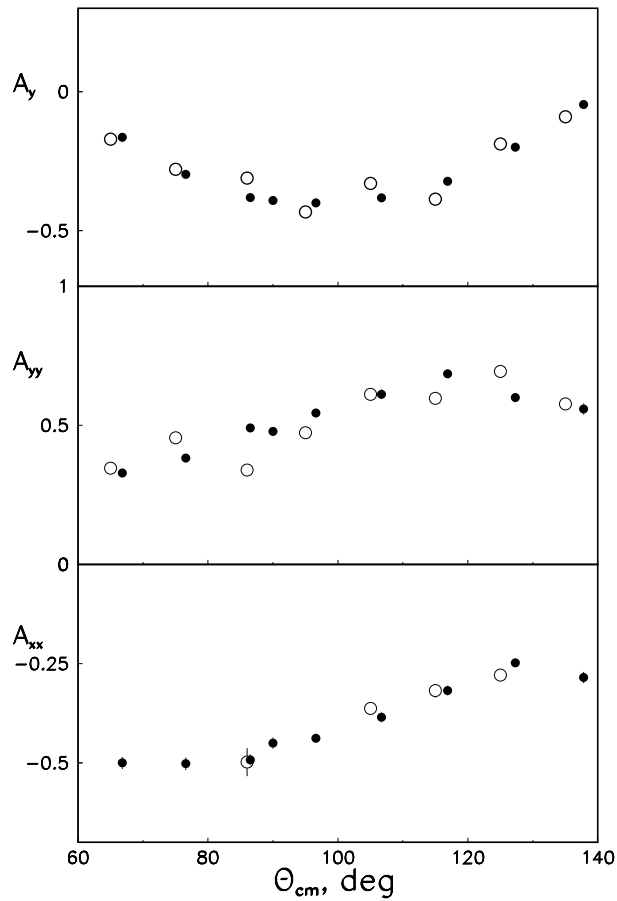
Typically, events were stored during 0.5-1.0 sec each spill

## Selection of $dp$ elastic events for beam polarization measurement at 270 MeV

- ADC information correlation
- Time-of-flight difference
- Cut on the target position monitor



## Polarization measurements at 270 MeV



	Pol.	Mode <b>2-6</b>	Mode <b>3-5</b>
<b>ITS</b>	<b>T</b>	$0.623 \pm 0.012$	$-0.600 \pm 0.009$
<b>ITS</b>	<b>V</b>	$-0.207 \pm 0.004$	$-0.206 \pm 0.003$
<b>LEP</b>	<b>T</b>	$0.69 \pm 0.13$	$-0.67 \pm 0.16$



## Conclusion

- The vector polarization of the extracted deuteron beam has been measured by **HE** polarimeter in December 2002. Good consistency of the polarization values before and after acceleration demonstrate the absence of depolarization effects at **NUCLOTRON**.
- 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 new data have been obtained at the energies 880 and 2000 MeV to develop the high energy polarimetry at **NUCLOTRON** and **RIBF**.
- Collaboration is planning to take the data with new polarized ion source **CIPIOS**.