Deuteron beam polarimetry at the Nuclotron

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Alushta, June 7, 2014

Content of the talk

- Introduction.

  Conception of the deuteron beam polarimetry at Nuclotron.
- Internal Target Station, Detection system.
- The 270 MeV deuteron beam polarimeter at ITS.
- Low energy deuteron beam polarimeter.
- Conclusion.

Conception for the deuteron beam polarimetry at the Nuclotron

Measurement of the beam polarization is an important element in different physical experiments.

- Absolute calibration of the beam polarization.
- Efficient calibrated polarimeters. Polarization standard.
- Permanent monitor of the beam polarization.
- Local polarimetry

$$\sigma = \sigma_0(1 + \frac{3}{2} p_y \cdot A_y + \frac{1}{2} p_{yy} \cdot A_{yy})$$

If the analyzing powers take known from the theory values one can obtain the value of the beam polarization avoiding the systematic errors due to uncertainty of the analyzing powers of polarimeter.

- Absolute calibration of the beam polarization

$A_y = \frac{1}{2}$ for $^{12}C(d,\alpha)^{10}B^*[2^+]$ reaction (K.Suda et al.,)

Nucl. Inst. and Meth. A572 (2007) 745

Polarimetry of the deuteron beams

Measuring of the tensor and vector beam polarization at ***LHEP*** at GeV energies

- *$^{1}H(d,p(0))X$* - tensor beam polarization
  L.S.Zolin et al., JINR Rapid Comm. 2[88]-98, 27 (1998)
- *pp* quasi-elastic scattering – vector beam polarization
  L.S.Azhgirey et al., Nucl. Instr. Meth. In Phys. Res. A497, 340 (2003)

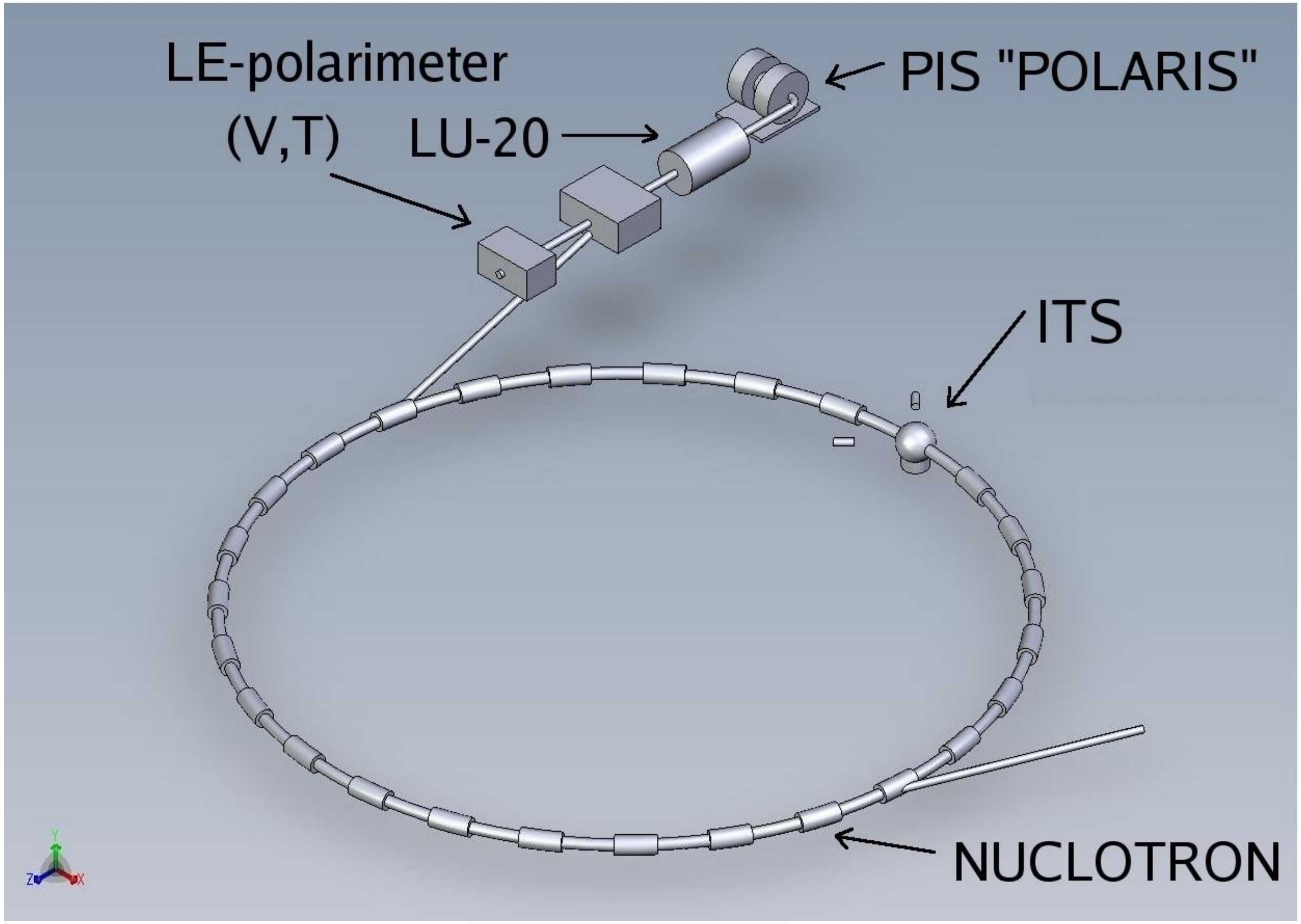
dp elastic scattering at forward scattering angles – vector and tensor polarymetry (ALPHA and ANKE(COSY) spectrometers)
dp elastic scattering at large angles ($\Theta_{c.m.}$ >60º) – deuteron beam polarimetry at RIKEN (E_d ~ 100 MeV)

Deuteron beam polarimetry in a GeV energy range.

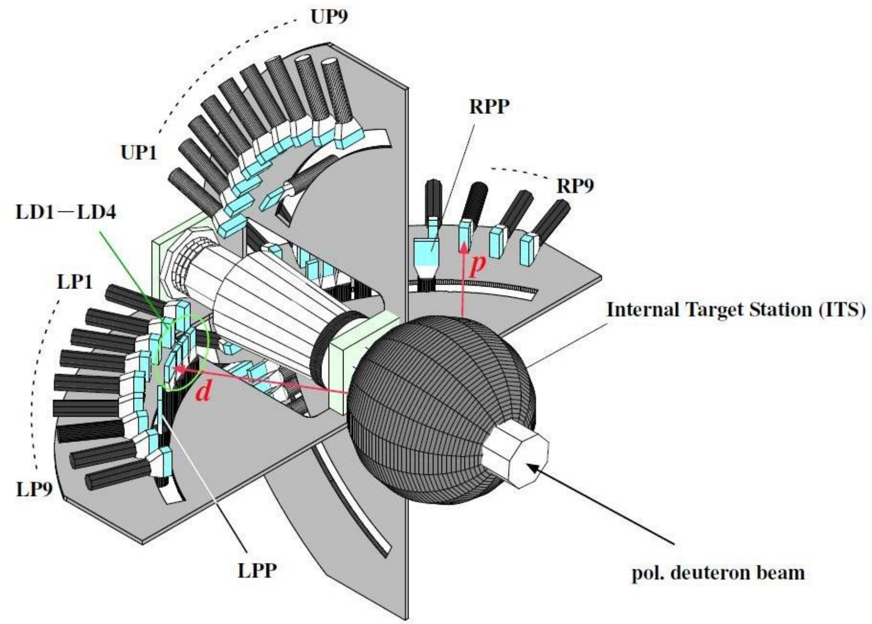
- The use of ***dp*** elastic scattering at large angles ($\Theta_{c.m.} > 60^o$) for the deuteron beam polarization measurements at the 270-2000 MeV energy range.
- Advantages
  - Analyzing powers this reaction have large values
  - The kinematical coincidence measurements of deuteron and protons with plastic scintillation counters suffice for the dp elastic events identification.

- Motivation
  - Measurement of the polarization observables in the 3He(d,p)4He reaction (DSS project at Nuclotron)
  - The energy of 880 MeV corresponds to the highest energy of a deuteron beam accelerated in RIBF (RIKEN)

Nuclotron-M accelerator complex

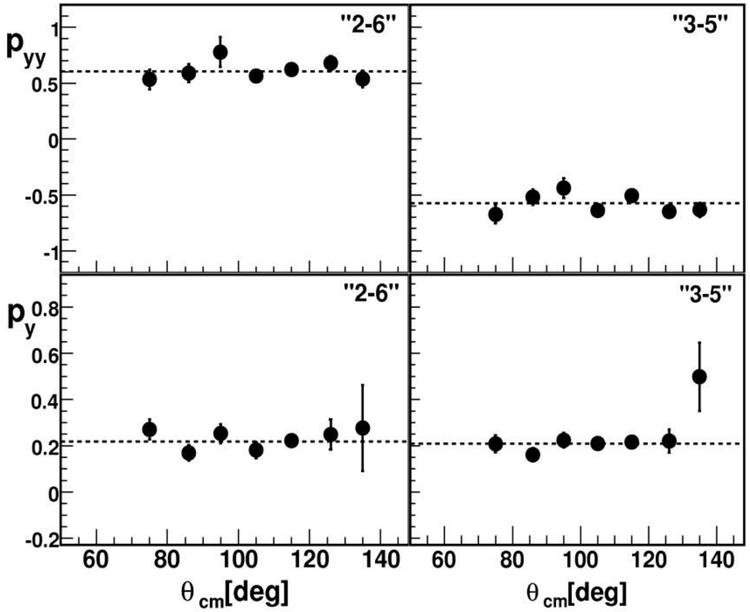


CNS-JINR setup to study dp- elastic scattering



- Deuterons and protons in coincidences using scintillation counters
- Internal beam and thin CH_2 target (C for background estimation)
- Polarization measurement at 270 MeV
- Analyzing powers measurement at 880 and 2000 MeV
- The data were taken for three spin modes of PIS: unpolarized, “2-6” and “3-5” $(p_z,p_{zz}) = (0,0)$, $(1/3,1)$ and $(1/3,-1)$

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



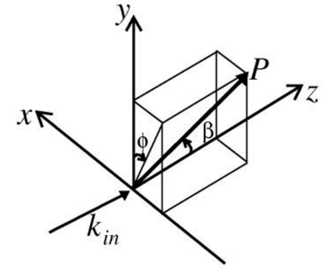
Tensor p_{yy} and vector p_y polarization of the beam for "2-6" and "3-5" spin modes of PIS POLARIS as a function of the deuteron scattering angle in the cms.

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

L,R,U,D $\theta_{c.m.} \geq 105^o$

L,R,U $\theta_{c.m.} < 105^o$

$\beta = -90.3^o \pm 1.2^o$



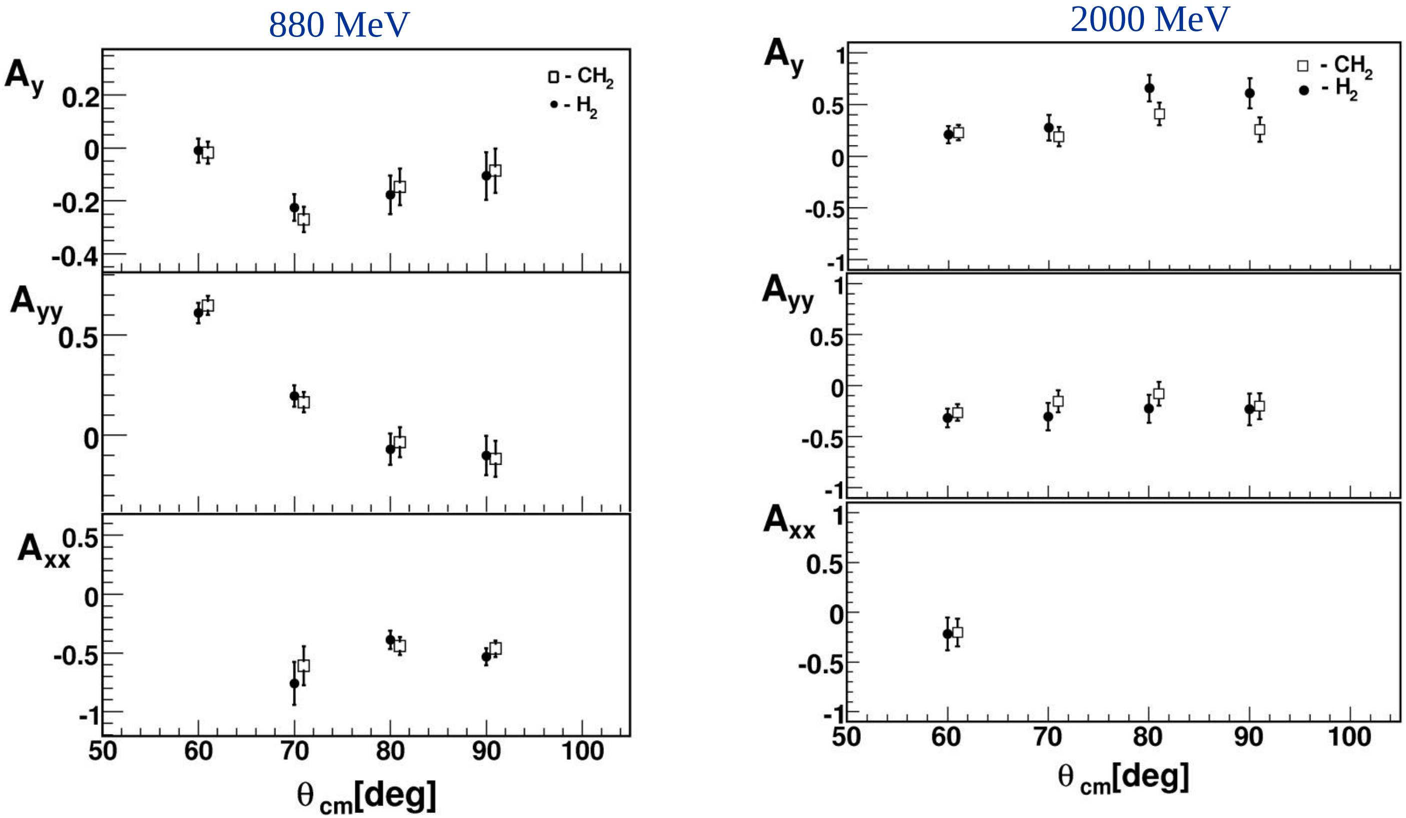
$$F_i^2 = \int \varepsilon A_i^2 d\Omega$$

$F_y \sim 1.0 * 10^{-4}$, $F_{yy} \sim 1.8 * 10^{-4}$, $F_{xx} \sim 0.8 * 10^{-4}$

- **Main deuteron beam polarimeter at Nuclotron-M.**

P.K.Kurilkin et al., Nucl. Instr. and Meth. A 642 (2011) 45

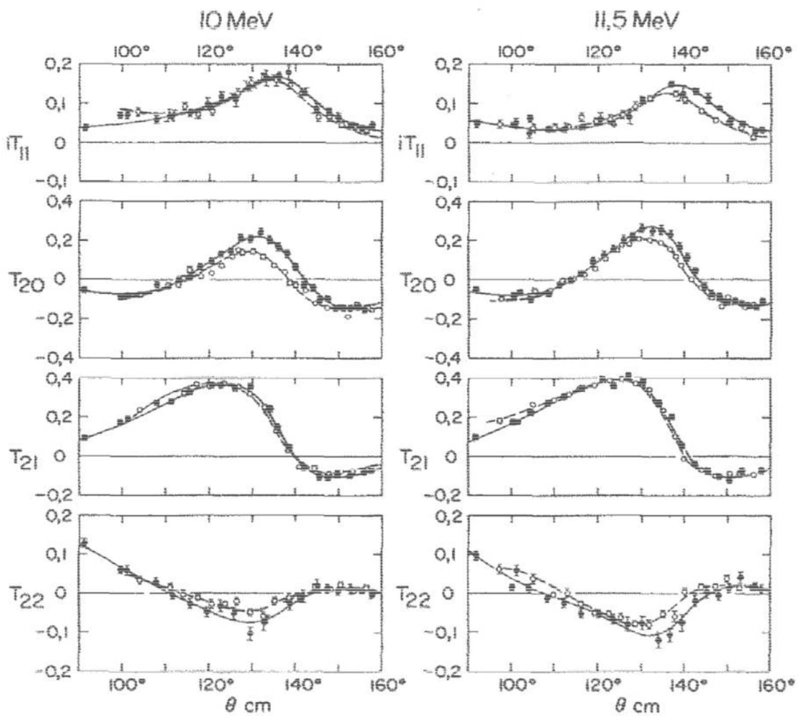
A_y, A_{yy} and A_{xx} in dp- elastic and quasielastic scattering at 880 and 2000 MeV

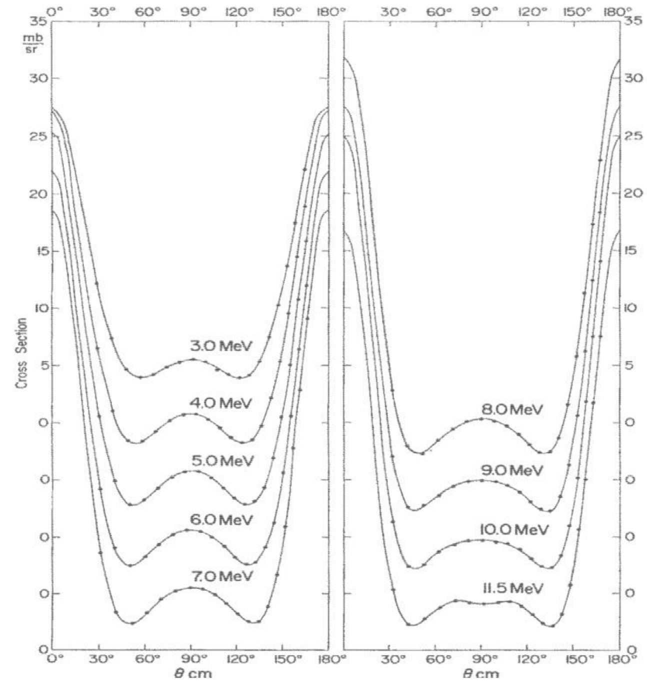


- The analyzing powers in dp-elastic scattering are large enough to provide both the vector and tensor polarimetry at high energies.
- The analyzing powers values for elastic and quasielastic deuteron scattering are comparable. Therefore, polarimeter can used in the counting mode (without event-by-event analysis).

Low energy deuteron beam polarimeter

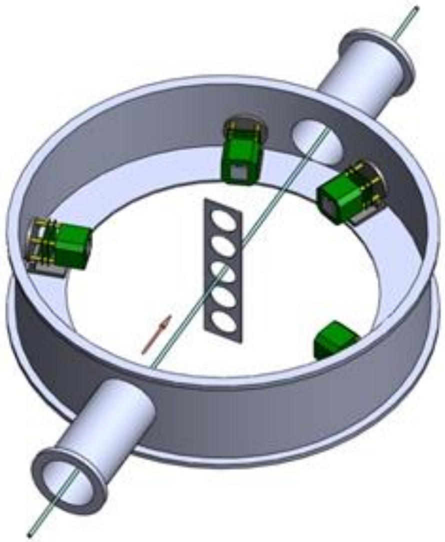
The use of the reaction d(d,p)t at 10 MeV with large values of the cross section and deuteron analyzing powers around 130º in cms



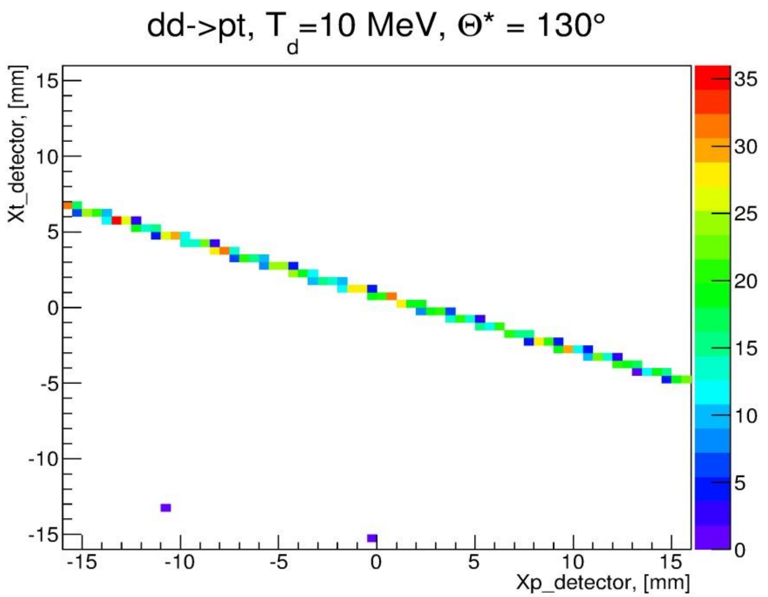


W.Grüebler et al., Nucl.Phys. A193 (1972) 179
V.König et al., Nucl.Phys.A331 (1975) 1

Low energy deuteron beam polarimeter



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



The d(d,p)t 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 and complanarity conditions will be also used in the analysis.

Conclusion

- The main polarimeters for deuterons must satisfy to the following requirements:

  a) to be able to measure both tensor and vector polarizations due to mixed spin modes of new PIS

  b) to measure the direction of the polarization vector

  c) analyzing powers must be obtained by the absolute method of the beam polarization measurements.

Such a polarimeter exists at ITS

- In the nearest run with polarized deuterons

  -measurements of the beam polarization at 270 MeV at **ITS**.

  -calibration of **ITS** polarimeter at the 270-2000 MeV.

  -simultaneous calibration of ITS, F3 and T20 polarimeters at 1600 MeV. Polarization standard for Nuclotron-M.

- This procedure will provide the error of 3% at the energies of 270-2000 MeV and better than 5% at higher energies.

Conclusion

- Permanent monitoring of the beam polarization:

  -the use of 2 flattops of the Nuclotron field: one of them for ITS polarimeter.

  -small scattering angle polarimeter at F3

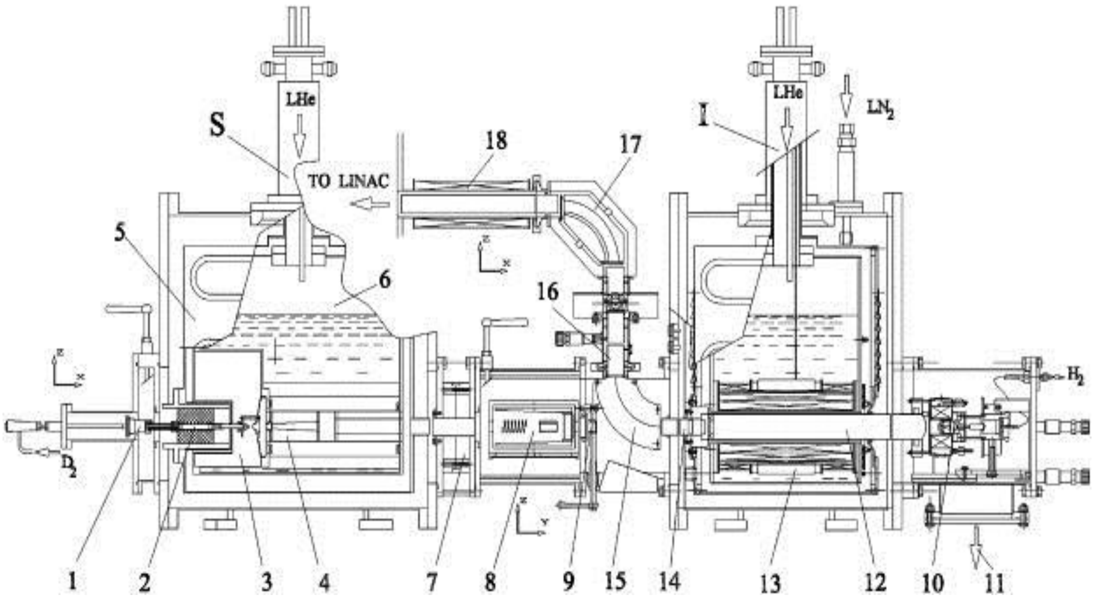
- Local polarimetry:

  -main polarimeters are based on the scintillation counters and can work in the counting mode.

- Low energy polarimeter for new source should be changed.
- Instead of $^{4}He(d,d)^{4}He$ and $^{3}He(d,p)^{4}He$ reactions at 10 MeV the reactions having both tensor and vector analyzing powers should be used: d(d,p)t or d(p,p)d. In any case silicon detectors must be changed for new ones.

Thank you for the attention!!!

Polarized ion source POLARIS



Схематичный вид ИПИ ПОЛЯРИС

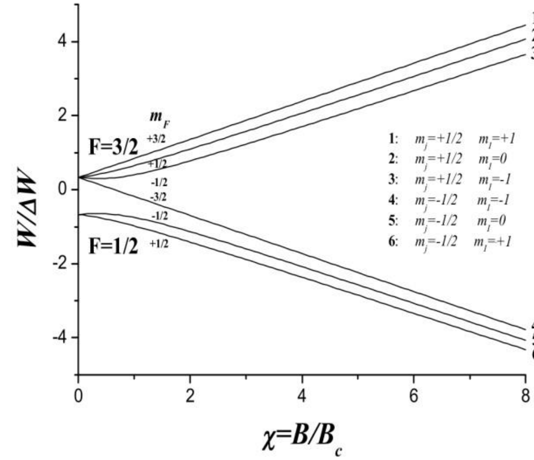


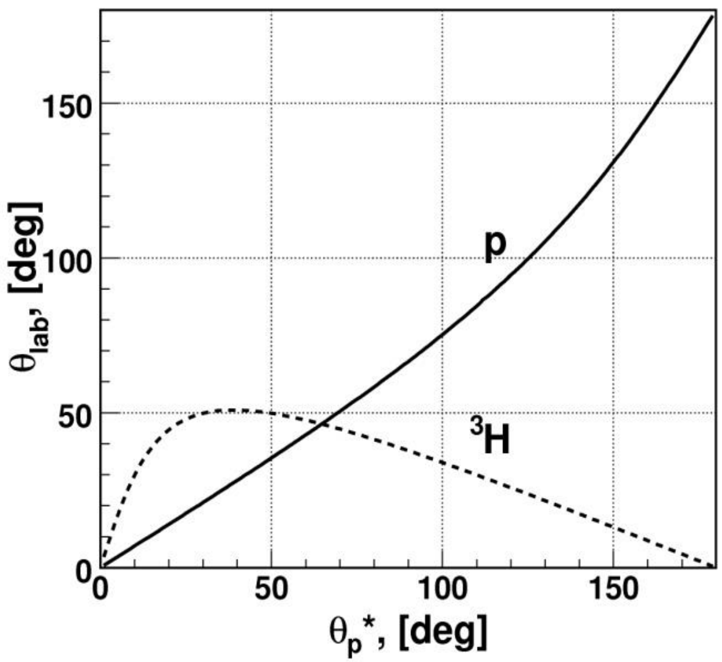
Диаграмма энергетических уровней атома дейтерия в магнитном поле B.

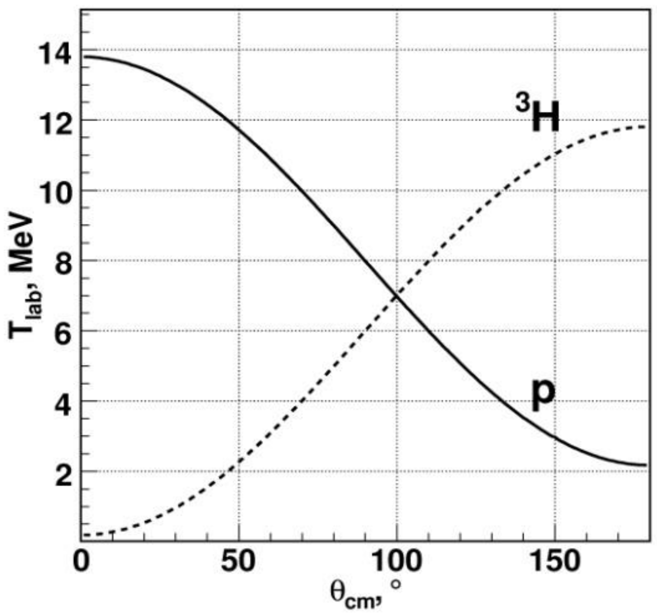
$$P_z(I=1)=\frac{N_{m_I=+1}-N_{m_I=-1}}{N_{m_I=+1}+N_{m_I=0}+N_{m_I=-1}}$$ - vector polarization

$$P_{zz}(I=1)=\frac{N_{m_I=+1}+N_{m_I=-1}-2N_{m_I=0}}{N_{m_I=+1}+N_{m_I=0}+N_{m_I=-1}}$$ - Tensor polarization

Mode “2-6”: $(P_z,P_{zz}) = (1/3,1)$
Mode “3-5”: $(P_z,P_{zz}) = (1/3,-1)$

Low energy deuteron beam polarimeter

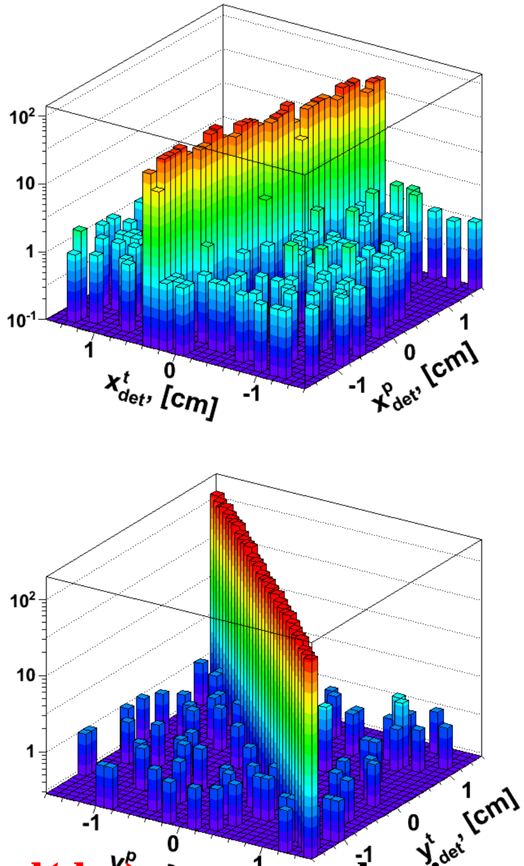


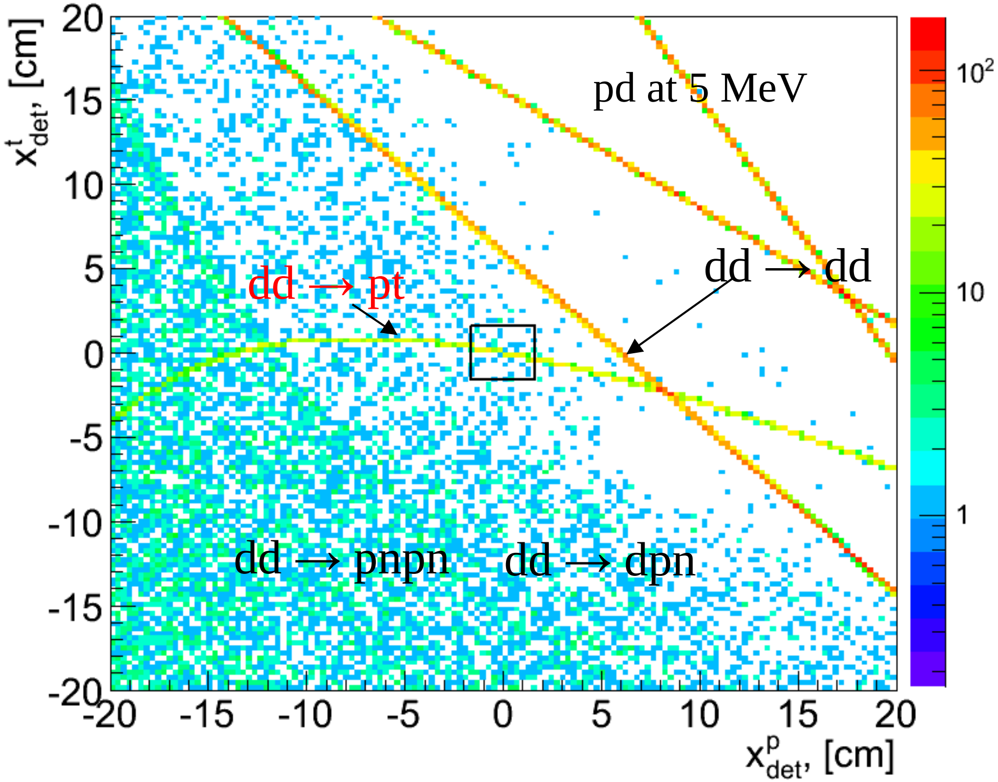


Kinematic relation for p and ^{3}H in d(d,p)t at 10MeV

Low energy deuteron beam polarimeter

(simulation)

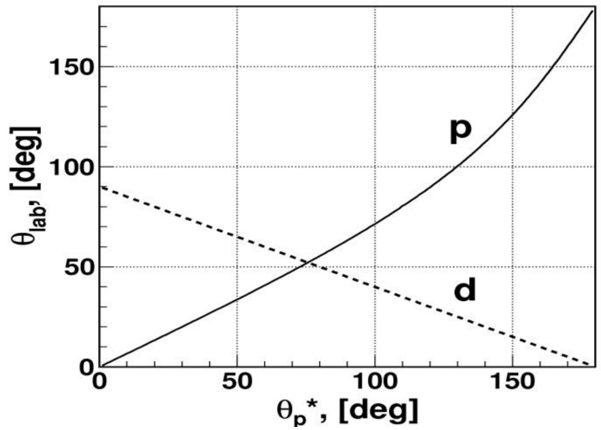


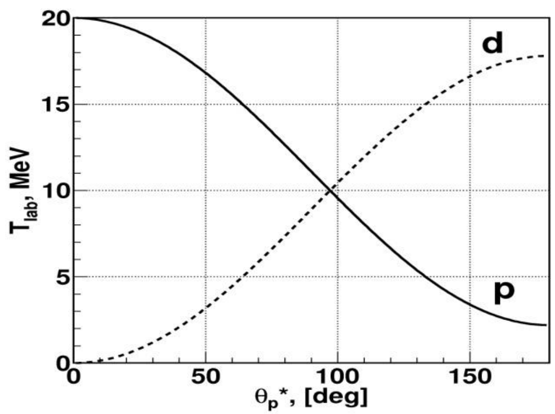


The d(d,p)t events selection using the relation between scattering angles of protons and tritons and complanarity condition 50° in c.m. at 10 MeV and distance of 60 cm from the target . The energy loss information will be also used.

Selection of the p(d,p)d reaction

Kinematic relation for p and d for pd –elastic scattering at 20 MeV





Scattering angle correlation and complanarity condition