Deuteron beam polarization measurement at 270 MeV at Nuclotron internal target.

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Outline

- DSS project;
- Informations about experimental runs in 2016/2017 yy.;
- Experimental equipment;
- Procedure of polarization calculation;
- The polarization results.

DSS project

Elastic nucleon-deuteron scattering is the simplest composite interaction. This reaction is used to test few nucleon systems.

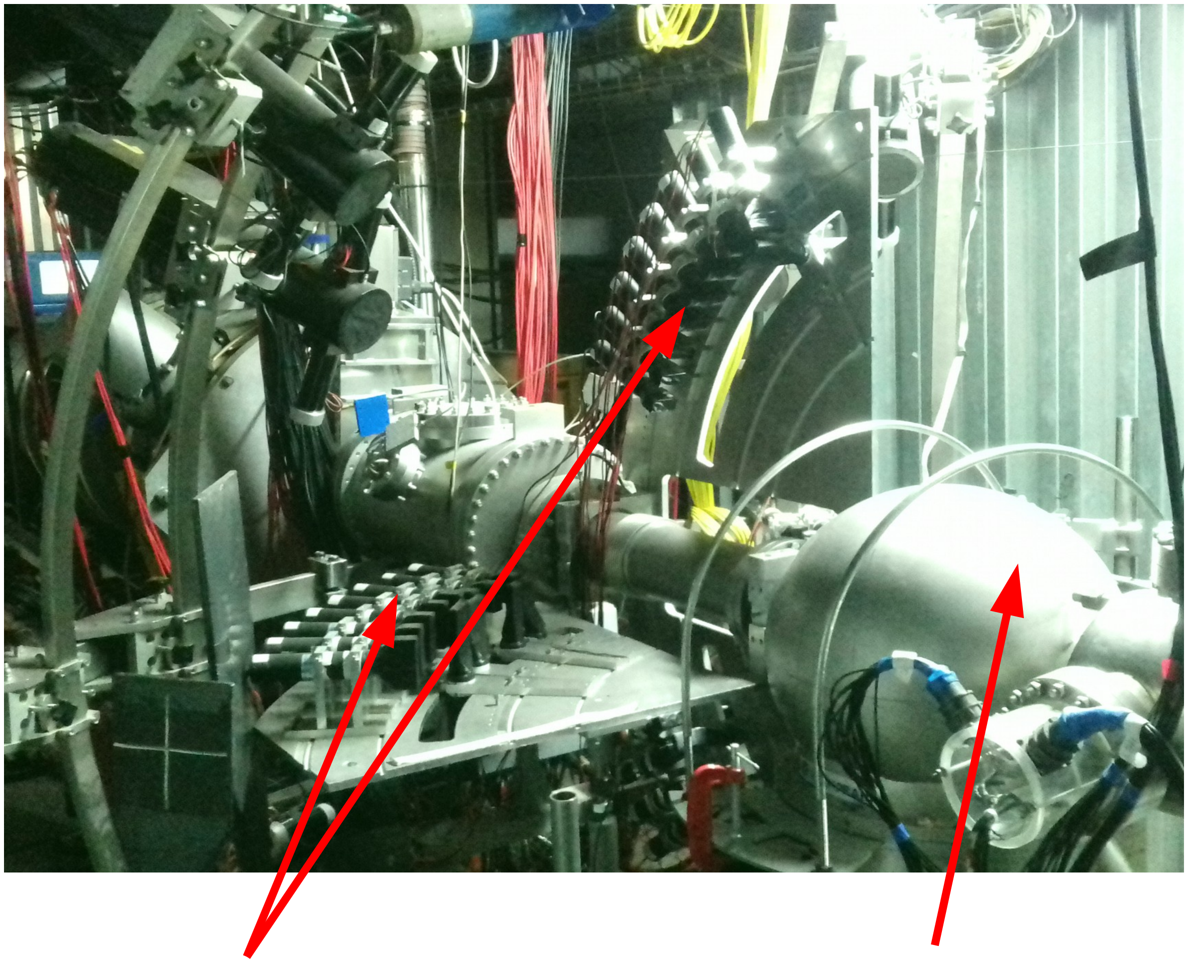
The main intention of the DSS (Deuteron Spin Structure) experiment is the study of the spin structure of two-nucleon and three-nucleon short-range correlations.

This study is being performed by the measurements of polarization observables in reactions with deuterons at the Nuclotron of JINR.

The experimental runs of 2016/2017 yy.

- The energy range: 400 — 1800 MeV;
- The angular range: 60° - 135° in c.m.s.;
- The polarization spin modes (p_z,p_{zz}): (-1/3,1), (-1/3,-1), (0,0);
- The studied proces was deutron-proton elastic scattering.

Polarimeter at Nuclotron internal target station

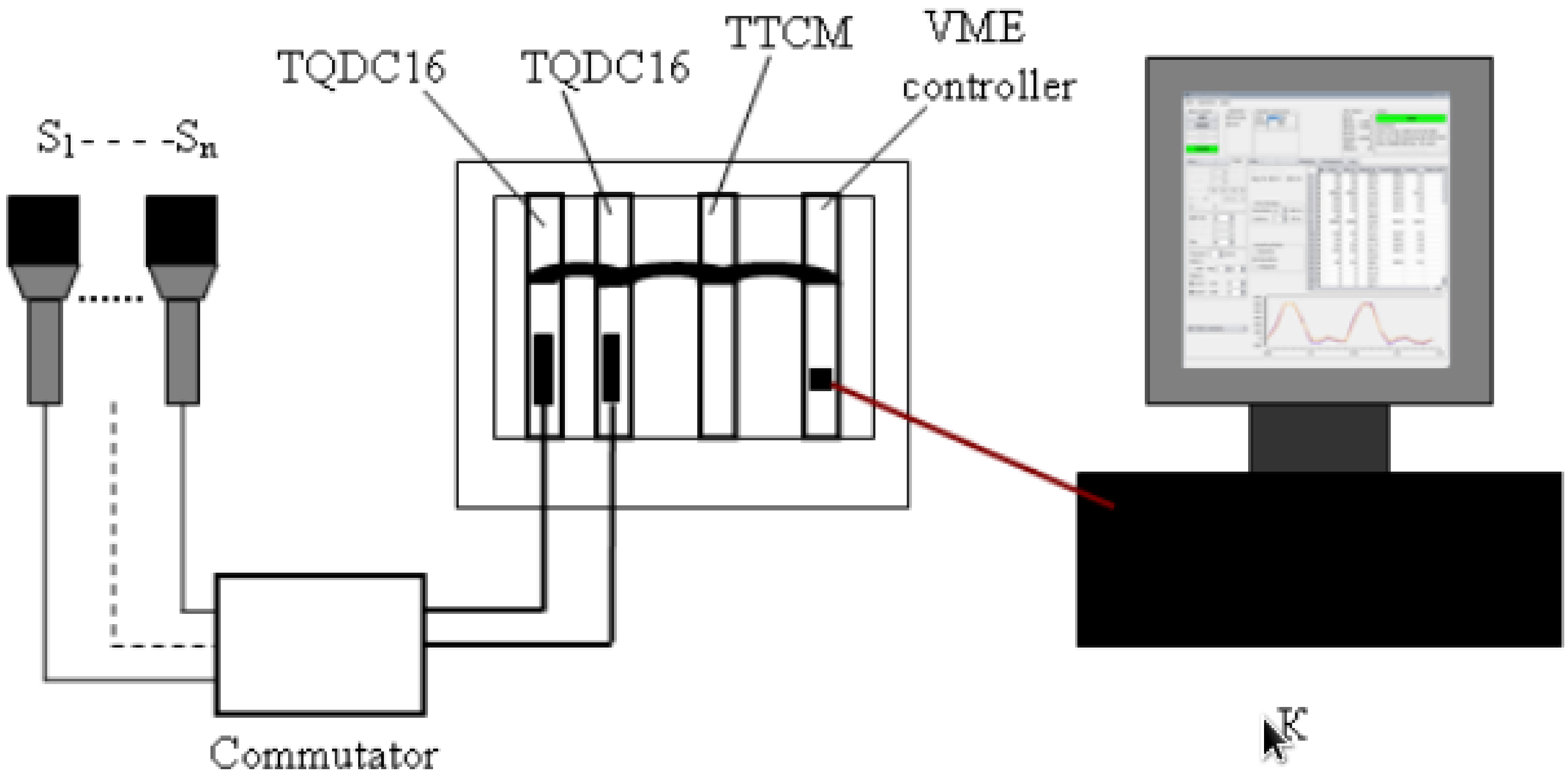


- Deuteron beam polarimeter is placed in the Nuclotron ring. It consists of a spherical scattering chamber and system change targets that can be set in six different targets.
- The registration particles system consisting 39 plastic scintillation counters (and 7 monitor) located in the forward internal target station hemisphere.

MPod power supply system

- We used multichannel high-voltage power supply system to provide power detection framework of the DSS experimental setup, which use scintillation detectors based on Hamamatsu photomultipliers.
- The total detectors number is more than 70. Wiener MPod system has up to 160 channels (maximal configuration) with the SHV connectors type.

VME system



1)S_1-S_n — detector number;
2)TQDC-16 — 16 channels modules;
3)TTCM – trigger module;
4)VME controller.

The number of data sets

Our group performed the vector Ay and tensor Ayy and Axx analyzing powers measurement in dp — elastic scattering for the energy range 400 — 1800 MeV.

Polarized source of ions emitted particles with polarization values (Pz, Pzz) of (-1/3, +1), (-1/3,-1) and (0,0).

- November 2016 — 7 sets of data (81 hours);
- December 2016 — 6 sets of data (73 hours);
- February 2017 — 4 sets of data (56 hours);
- Total: (210 hours).

The calculations stages

- Selection of the dp-elastic scattering events for each spin mode;
- Calculation of the vector and tensor polarization at eight angles;
- Weight averaged calculation.

We used software which was developed using the ROOT package in C++.

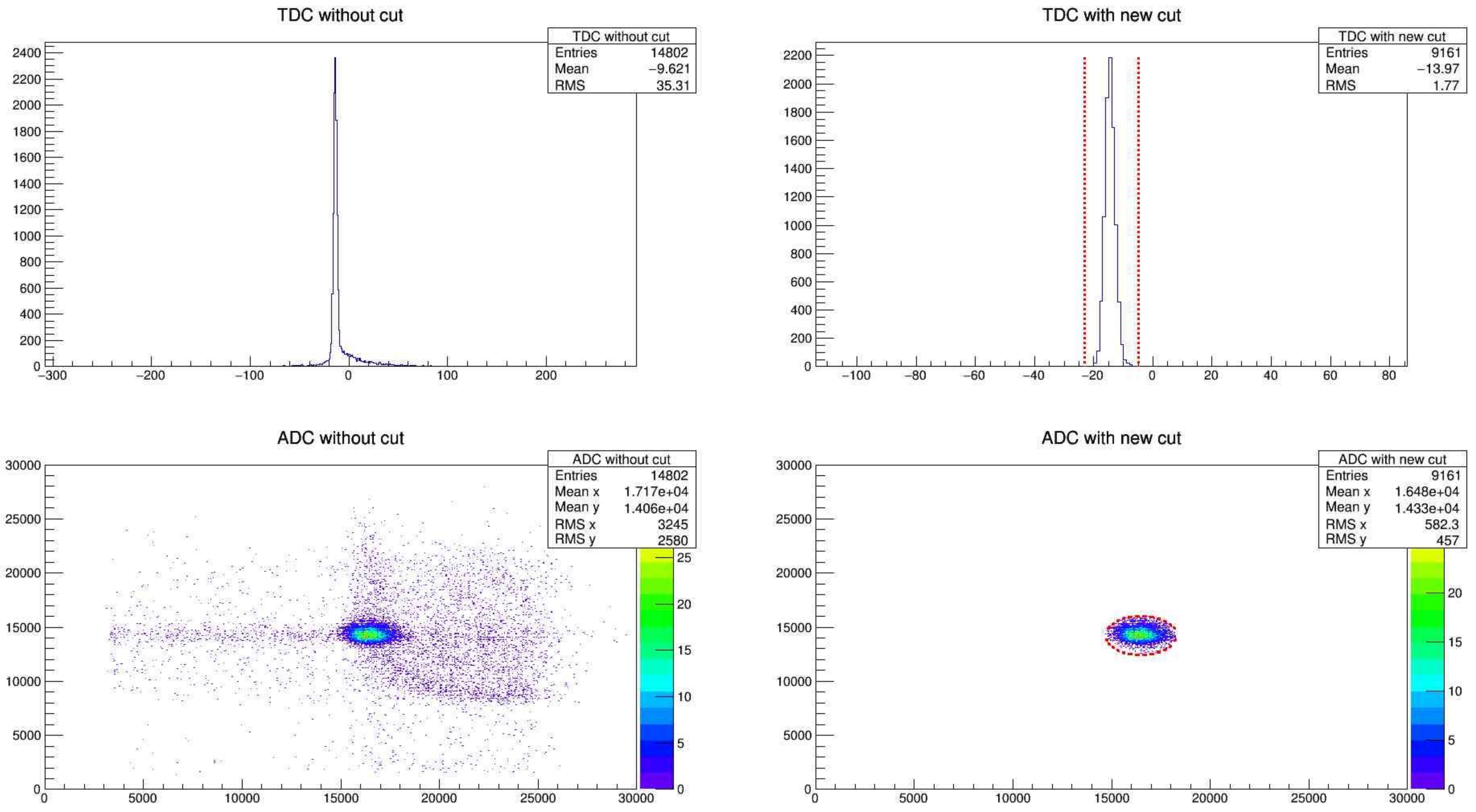
Well known analyzing powers values at the angles of 65, 75, 86.5, 95, 105, 115, 126.3, 135 degrees in the c.m.s. are used to determine the deuteron beam polarization.

Library classes

- Cut classes
  - 1D cut
  - 2D cut
    - Polygon
    - Ellipse
    - Rectangle
- Data classes
  - TDC
  - ADC
  - Correlation of ADC
  - TDC and correlation of ADC
  - TPM

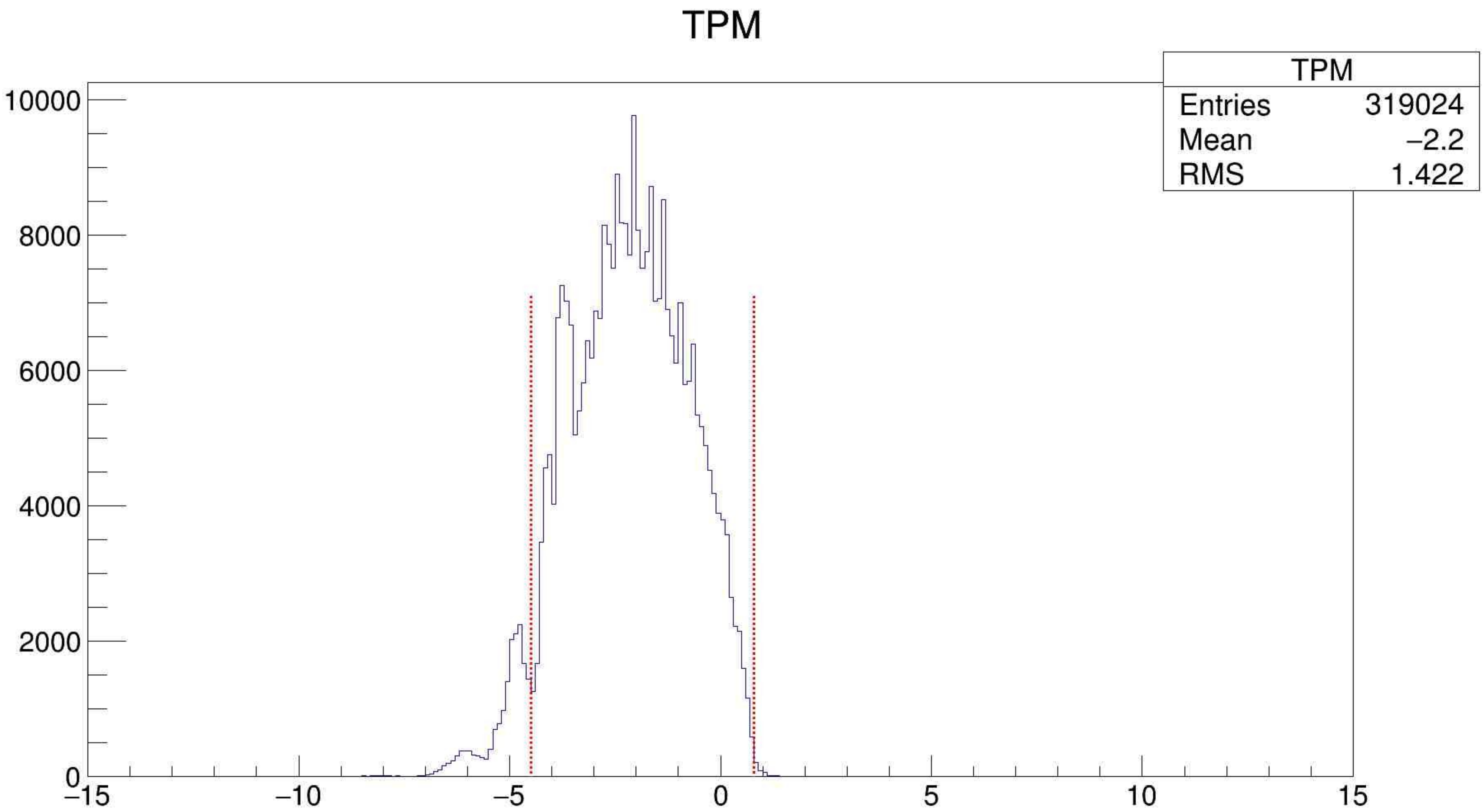
- Service classes
  - Array of the detector names
- General classes
  - TDC with tpm and 1D cut
  - ADC with tpm and 1D cut
  - Correlation of ADC with tpm and 2D cut
  - TDC and correlation of ADC with tpm and 1D cut

The dp-elastic scattering events selection



Examples of cuts for 105 degree cms detector pair

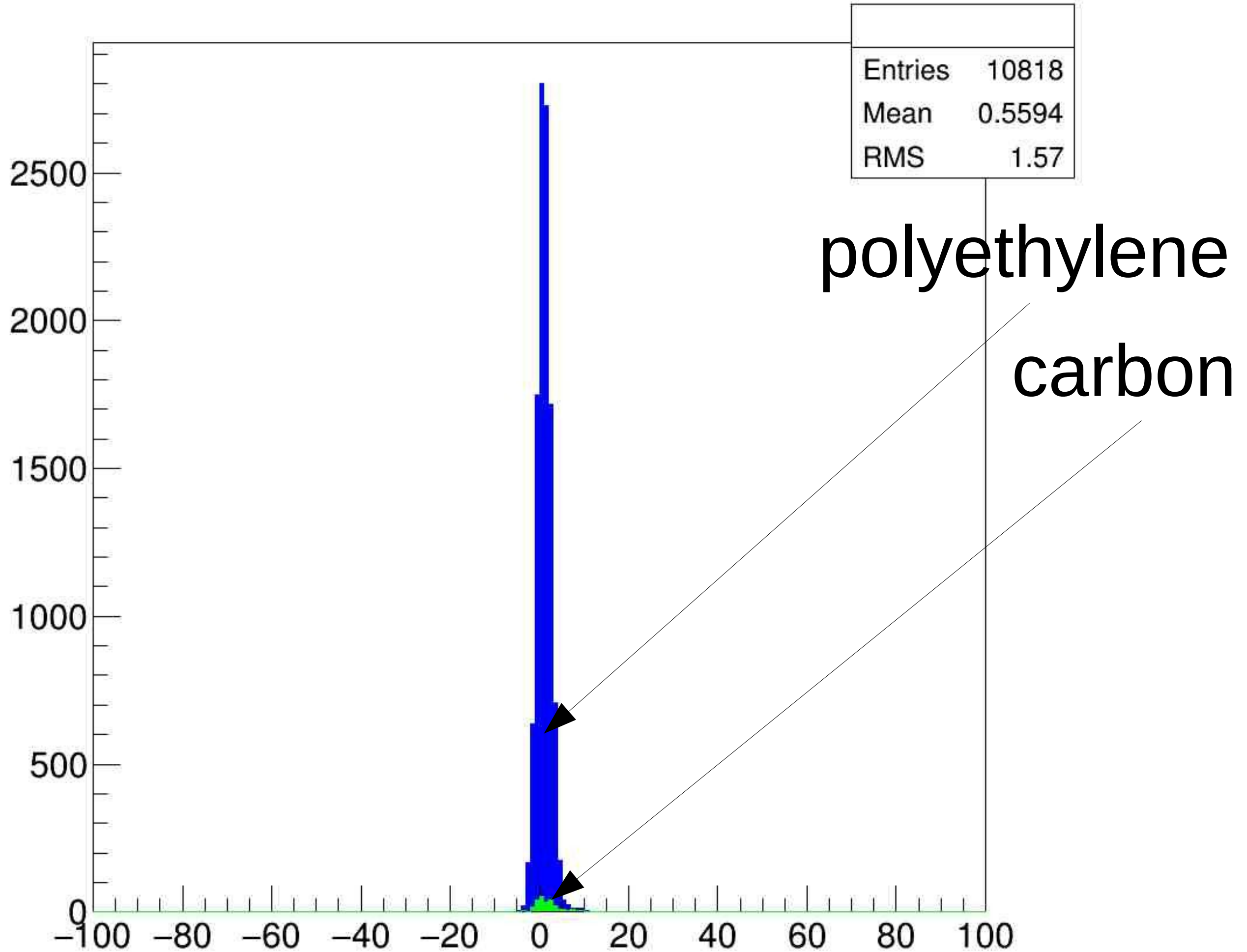
Interaction point of the beam



Example of interaction point cut.

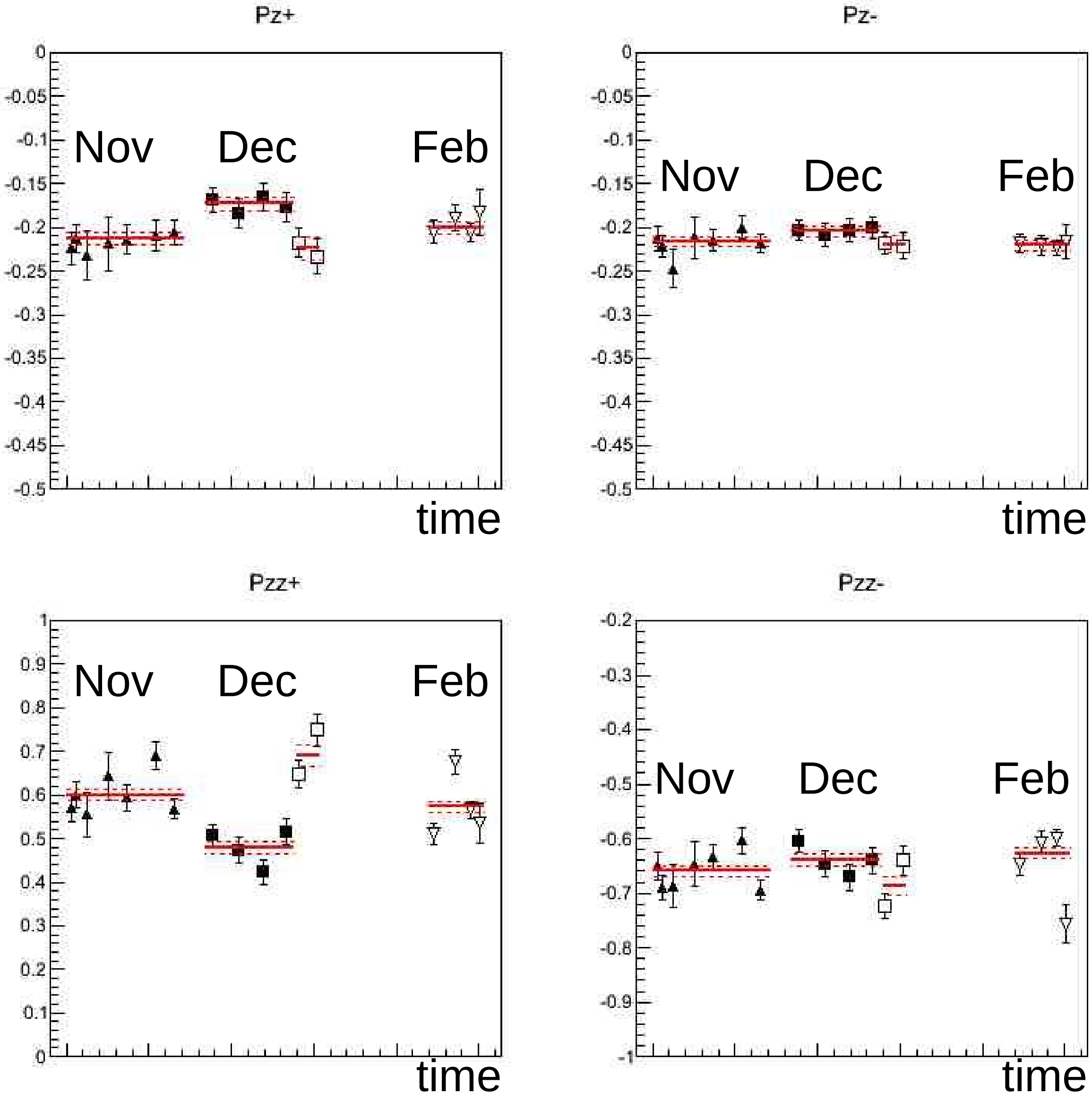
The background estimation

TDC spectra for polyethylene and carbon were normalized on the luminosity.



Time of flight difference between the signals for deuteron and proton detectors for polyethylene and carbon targets. The carbon integral refers to the polyethylene integral as 0.5 %

Polarizations values during the runs in 2016/2017 yy.



P_z+, P_z-, P_{zz}+ , P_{zz}- - polarization for spin mode: (-1/3,1);

The vector and tensor polarization for different spin modes of polarized source of ions

Polarization values (p_z, p_{zz})	P_z	dP_z	P_{zz}	dP_{zz}
(-2/3,1)	-0.489	0.026	0.631	0.045
(2/3,0)	0.427	0.021	0.061	0.037
(-1/3,1)	-0.254	0.022	0.637	0.039
(-1/3,-1)	-0.223	0.017	-0.621	0.030
(0,+1)	0.030	0.027	0.880	0.049
(0,-2)	0.046	0.015	-1.469	0.031

Conclusion

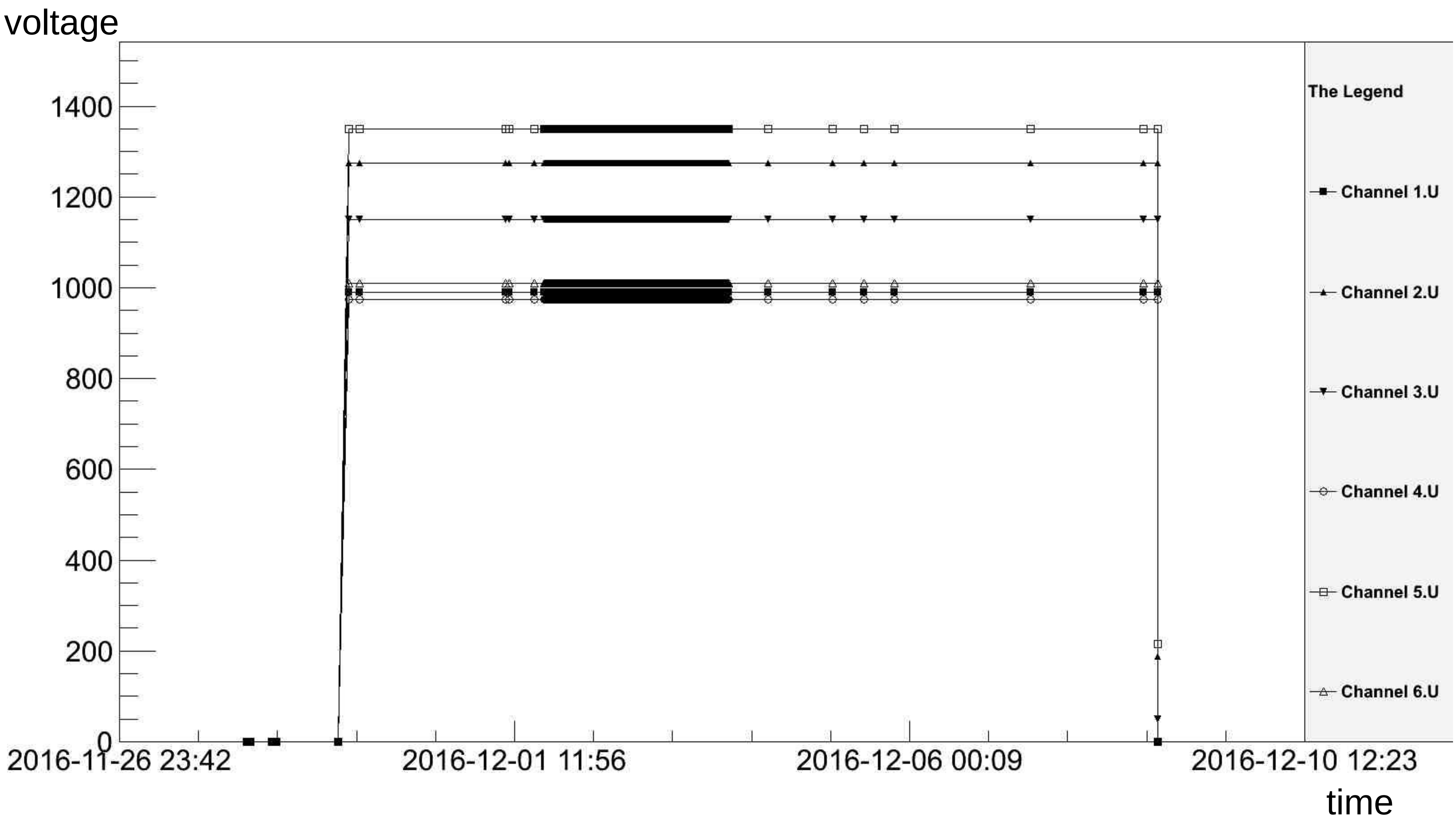
The upgraded version of the 270 MeV deuteron beam polarimeter has been used to obtain the vector and tensor polarization during 2016/2017 runs.

The stability of polarization has been demonstrated for the spin modes (-1/3,1) and (-1/3,-1).

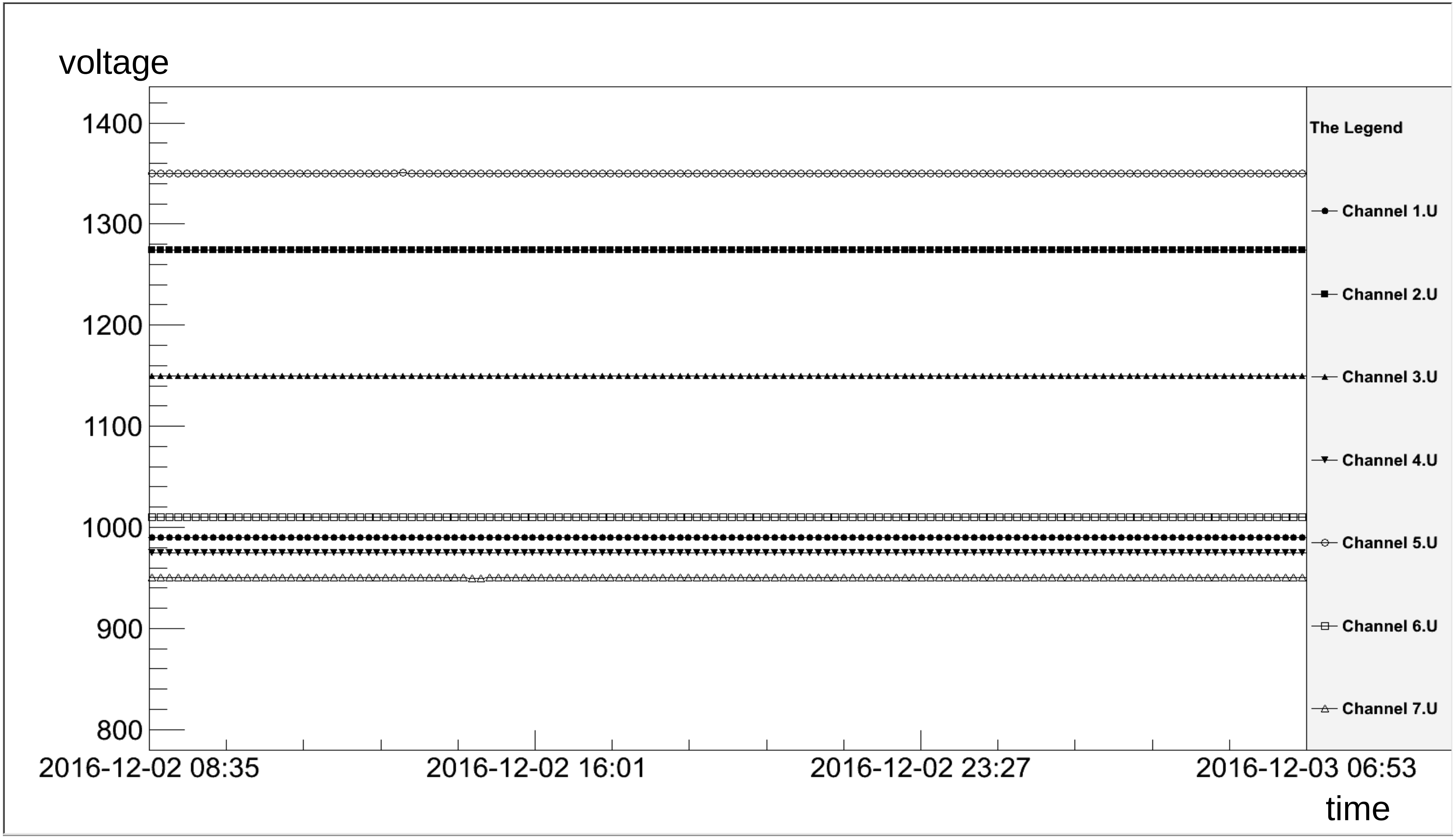
The polarimeter has been used for tuning of the ion source parameters for 6 different spin modes.

Thank you for attention!

MPod work stability



MPod work stability



The normalized yields of dp-elastic scattering

$$L = 1 + \frac{3}{2} p_y A_y + \frac{1}{3}\left(2 p_{xx} + p_{yy}\right) A_{xx} + \frac{1}{3}\left(2 p_{yy} + p_{xx}\right) A_{yy}$$

$$R = 1 - \frac{3}{2} p_y A_y + \frac{1}{3}\left(2 p_{xx} + p_{yy}\right) A_{xx} + \frac{1}{3}\left(2 p_{yy} + p_{xx}\right) A_{yy}$$

$$U = 1 + \frac{1}{3}\left(2 p_{yy} + p_{xx}\right) A_{xx} + \frac{1}{3}\left(2 p_{xx} + p_{yy}\right) A_{yy}$$

$$D = 1 + \frac{1}{3}\left(2 p_{yy} + p_{xx}\right) A_{xx} + \frac{1}{3}\left(2 p_{xx} + p_{yy}\right) A_{yy}$$

- L,R,U,D - The normalized yields of dp-elastic scattering events to the left (L), right (R), up (U), down (D);
- A_y, A_{yy}, A_{xx} — analyzing power;
- p_y, p_{yy}, p_{xx} — components of polarization.

The normalized dp-elastic scattering

$$p_x = -P_z sin\beta sin\varphi$$
$$p_y = P_z sin\beta cos\varphi$$
$$p_z = P_z cos\beta$$
$$p_{xx} = \frac{1}{2} P_{zz} \left(3\sin^2\beta \sin^2\varphi - 1 \right)$$
$$p_{xx} = \frac{1}{2} P_{zz} \left(3\sin^2\beta \cos^2\varphi - 1 \right)$$
$$p_{zz} = \frac{1}{2} P_{zz} \left(3\cos^2\beta - 1 \right)$$
$$p_{xy} = \frac{-3}{2} P_{zz} \sin^2\beta sin\varphi cos\varphi$$
$$p_{yz} = \frac{3}{2} P_{zz} sin\beta cos\beta cos\varphi$$
$$p_{xz} = \frac{-3}{2} P_{zz} sin\beta cos\beta sin\varphi$$

If Y is symmetry axis (β=90°, φ =0°), then polarization is calculate as

$$p_y = P_z$$
$$p_{yy} = P_{zz}$$
$$p_{xx} = p_{zz} = \frac{-1}{2} P_{zz}$$
$$p_x = p_z = p_{xy} = p_{yz} = p_{xz} = 0$$

Vector and tensor polarizations calculation

$$L = 1 + \frac{3}{2} P_z A_y + \frac{1}{2} P_{zz} A_{yy} \qquad P_z = \frac{L-R}{3 A_y}$$

$$\rightarrow$$

$$R = 1 - \frac{3}{2} P_z A_y + \frac{1}{2} P_{zz} A_{yy} \qquad P_{zz} = \frac{L+R-2}{A_{yy}}$$

$$U = 1 + \frac{1}{2} P_{zz} A_{xx} \qquad P_{zz} = \frac{2U-2}{A_{xx}}$$

$$\rightarrow$$

$$D = 1 + \frac{1}{2} P_{zz} A_{xx} \qquad P_{zz} = \frac{2D-2}{A_{xx}}$$

- L,R,U,D - The normalized dp-elastic scattering events to the left (L), right (R), up (U), down (D);
- Ay, Ayy, Axx — analyzing power;
- Pz, Pzz — components of polarization.

Weight average calculation

$$p_i = \frac{1}{s_i^2}$$

$$p = \sum_{i=1}^{n} p_i$$

$$x = \frac{\sum_{i=1}^{n} p_i x_i}{p}$$

$$\sigma = \frac{1}{\sqrt{p}}$$

$E(Pz_i) = p$ is the mathematical expectation vector polarization value;

$E(dPz_i^2) = si^2$ is the mathematical expectation of the squared error.