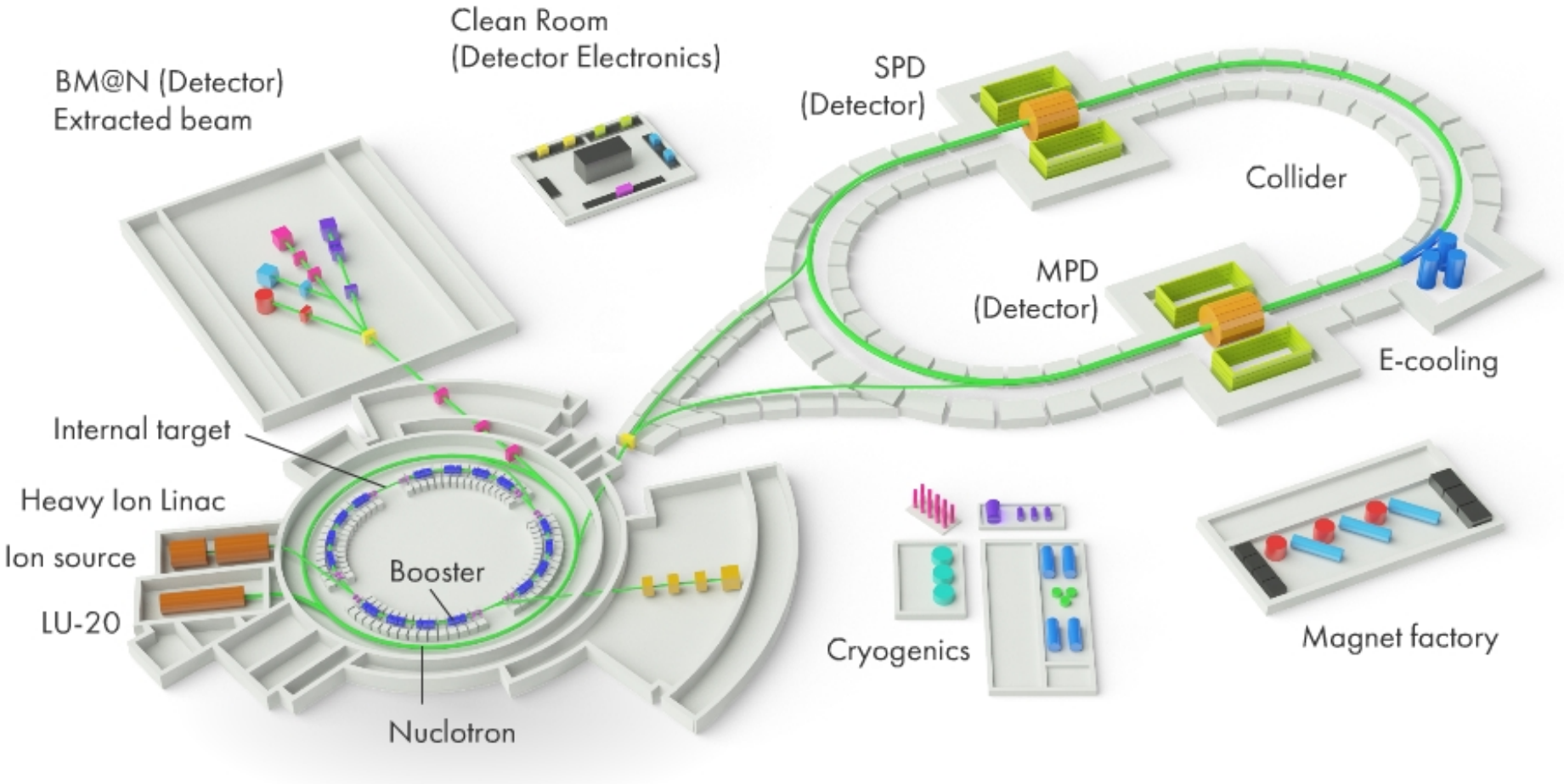
Deuteron and proton beams polarimetry at internal target at JINR Nuclotron

V.P. Ladygin on behalf of DSS collaboration

SPIN2018, Ferrara, 10-14 September 2018

NICA complex



Both collider (SPD, MPD) and fixed target (DSS, SP@N ...) spin experiments require polarized proton and deuteron beams

Studies at ITS at Nuclotron

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

dp(pd) -elastic scattering at the energies between 300 - 2000 MeV;

dp(pd) -breakup with registration of two protons at deuteron energies of 300 - 500 MeV.

The DSS studies require good knowledge of the deuteron (proton) beam polarization.

General View of SPI

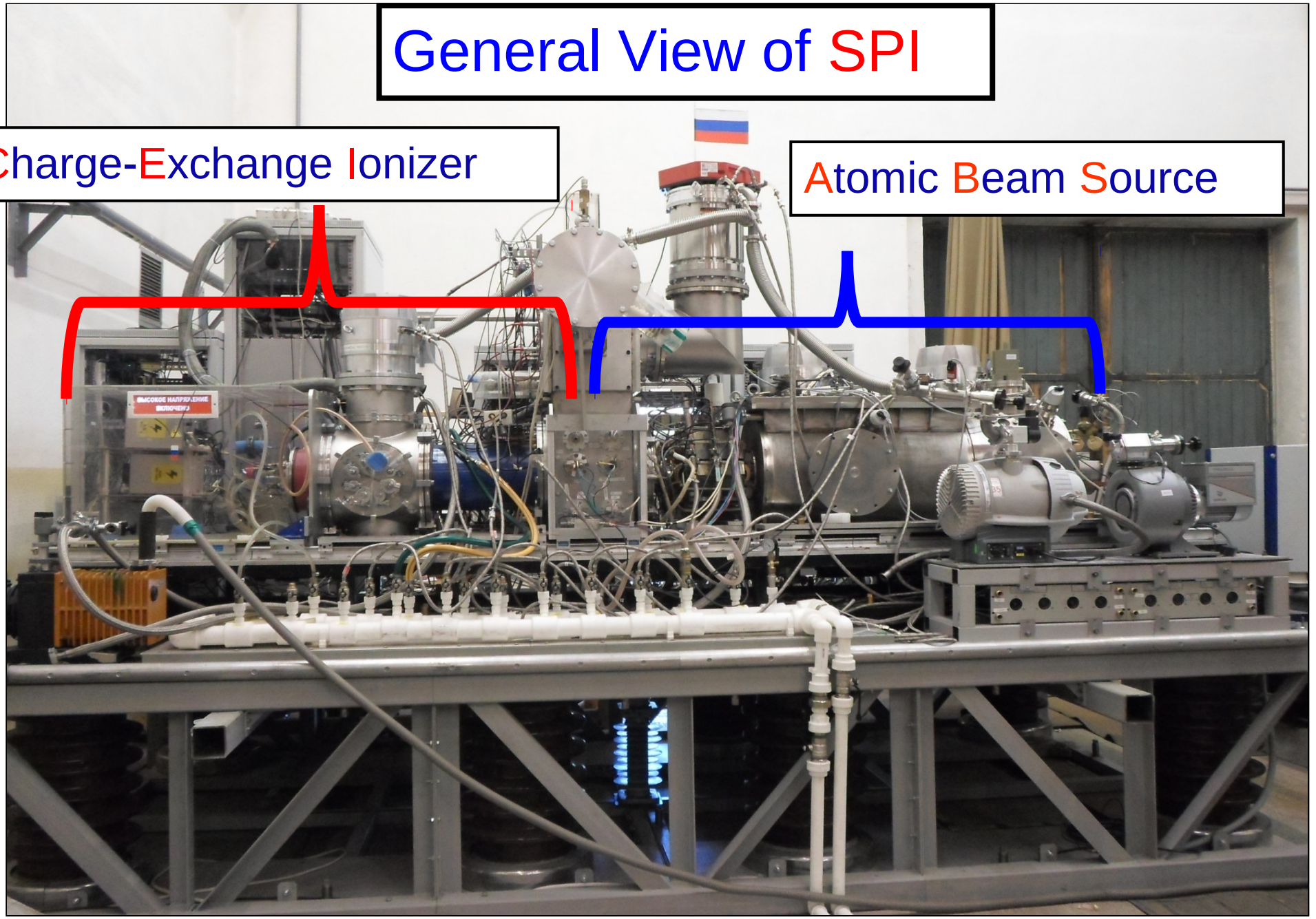
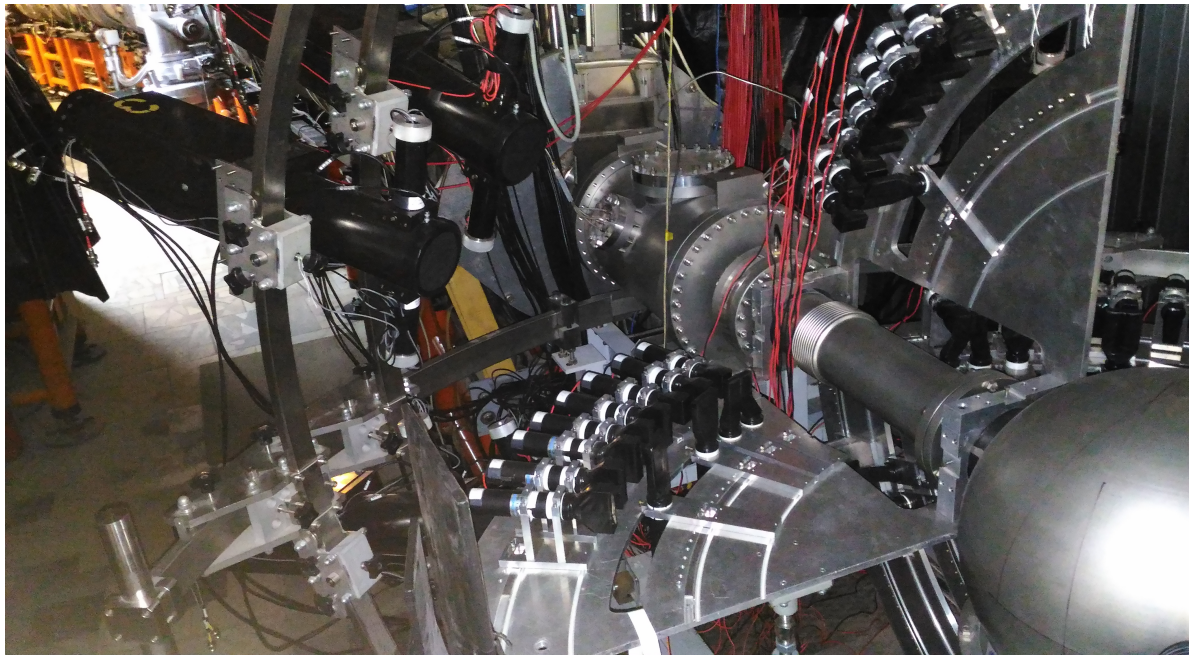


Figure of merit will be increased in future by a factor ~10^3

Setup to study dp- elastic scattering at ITS at Nuclotron in 2016-2017.



Deuterons and protons in coincidences using scintillation counters

Internal beam and thin CH_2 target (C for background estimation)

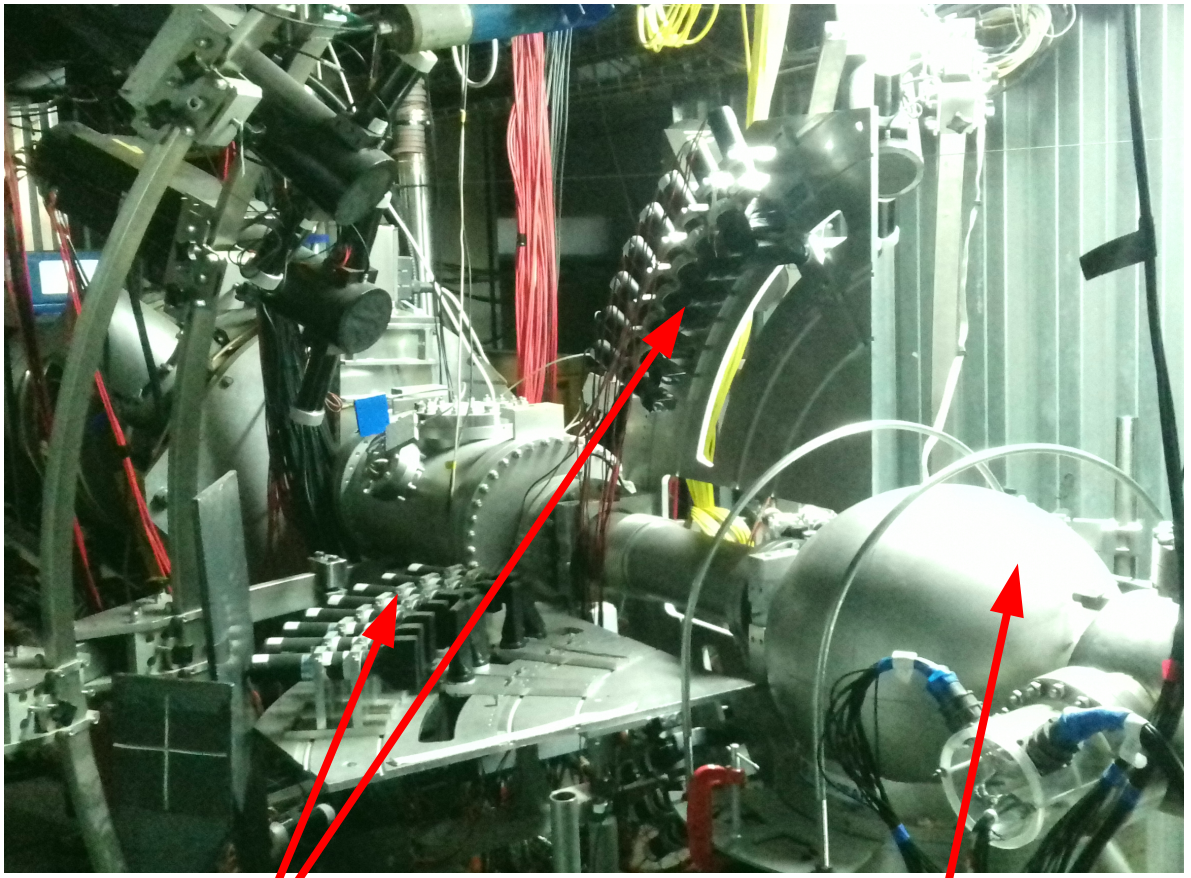
Permanent polarization measurement at 270 MeV (between each energy).

Analyzing powers measurement at 400-1800 MeV

The data were taken for three spin modes of SPI: unpolarized, "2-6" and "3-5" $(p_z,p_{zz}) = (0,0)$, (-1/3,1) and (-1/3,-1).

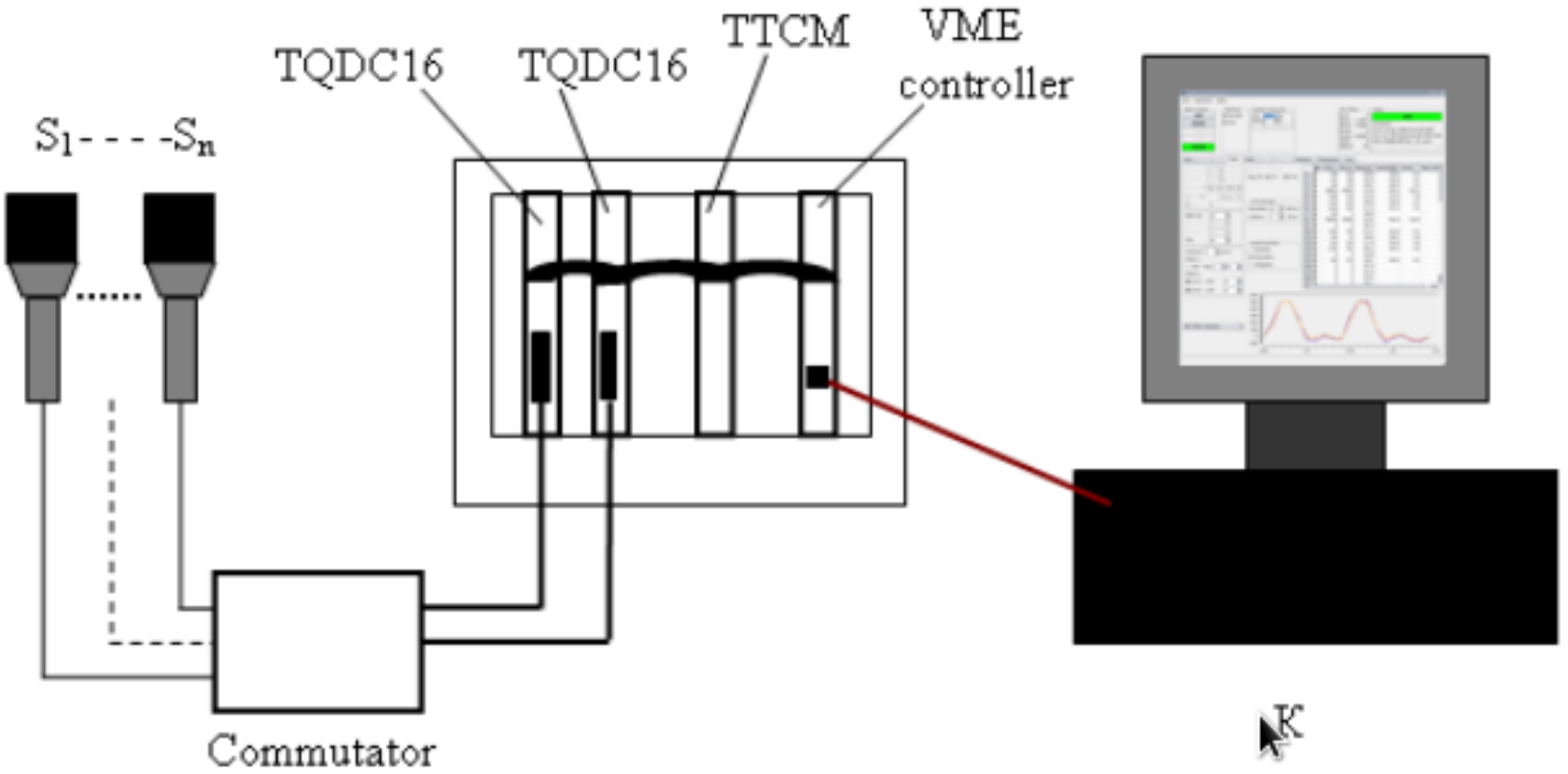
Typical values of the polarization was 70-75% from the ideal values.

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 set six different targets.**
- **The registration particles system is consisting of 39 plastic scintillation counters (and 7 monitor) located in the forward internal target station hemisphere.**

VME system



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

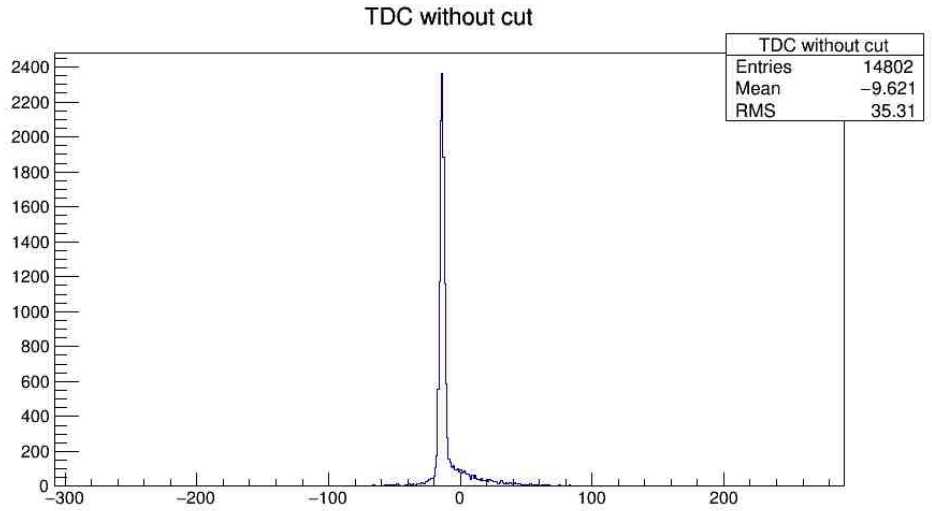
The number of data sets

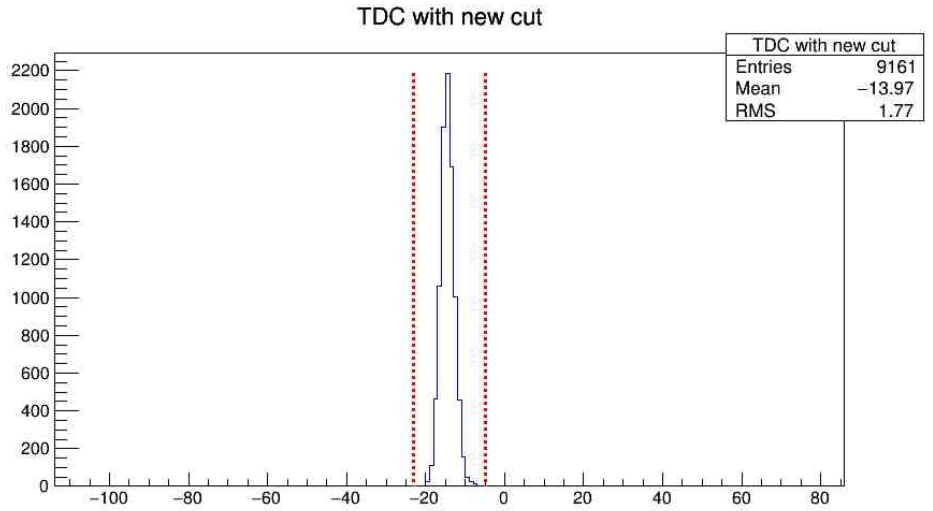
Our group performed the vector Ay and tensor Ayy and Axx analyzing powers measurement in dp — elastic scattering for the energy range 400 — 1800 MeV.

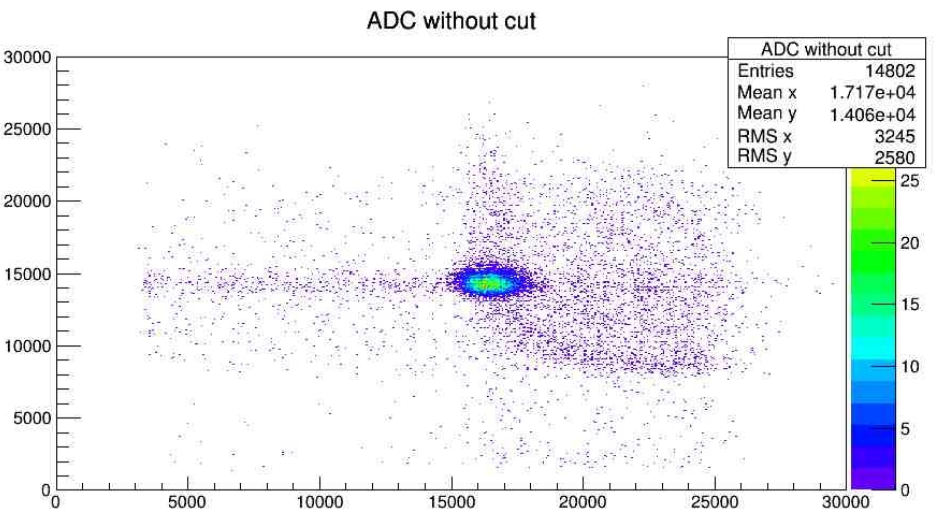
Polarized source of ions emitted particles with polarization values (Pz, Pzz) of (-1/3, +1), (-1/3,-1) and (0,0).

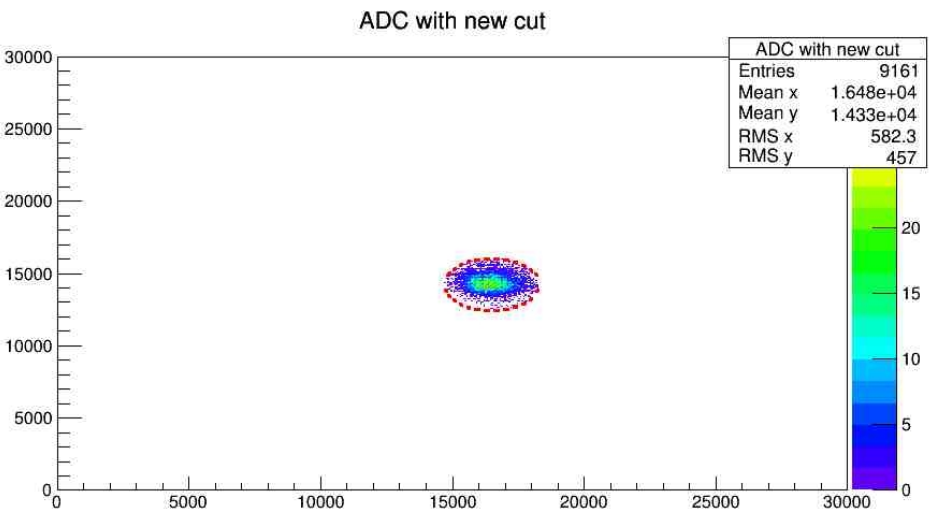
- November 2016 — 7 sets of data (81 hours);
- December 2016 — 6 sets of data (73 hours);
- February 2017 — 4 sets of data (56 hours);
- Total: (210 hours).

The dp-elastic scattering events selection



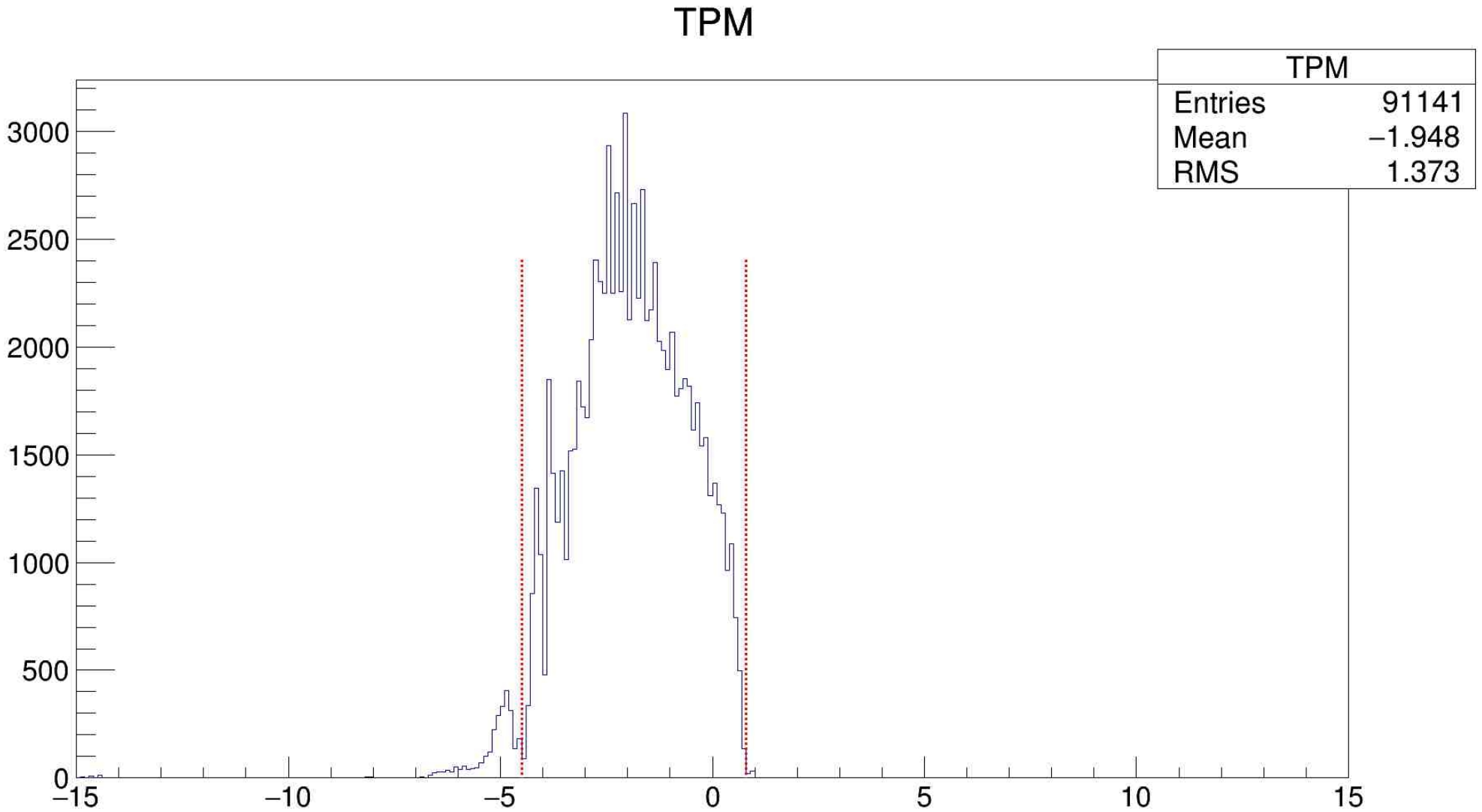






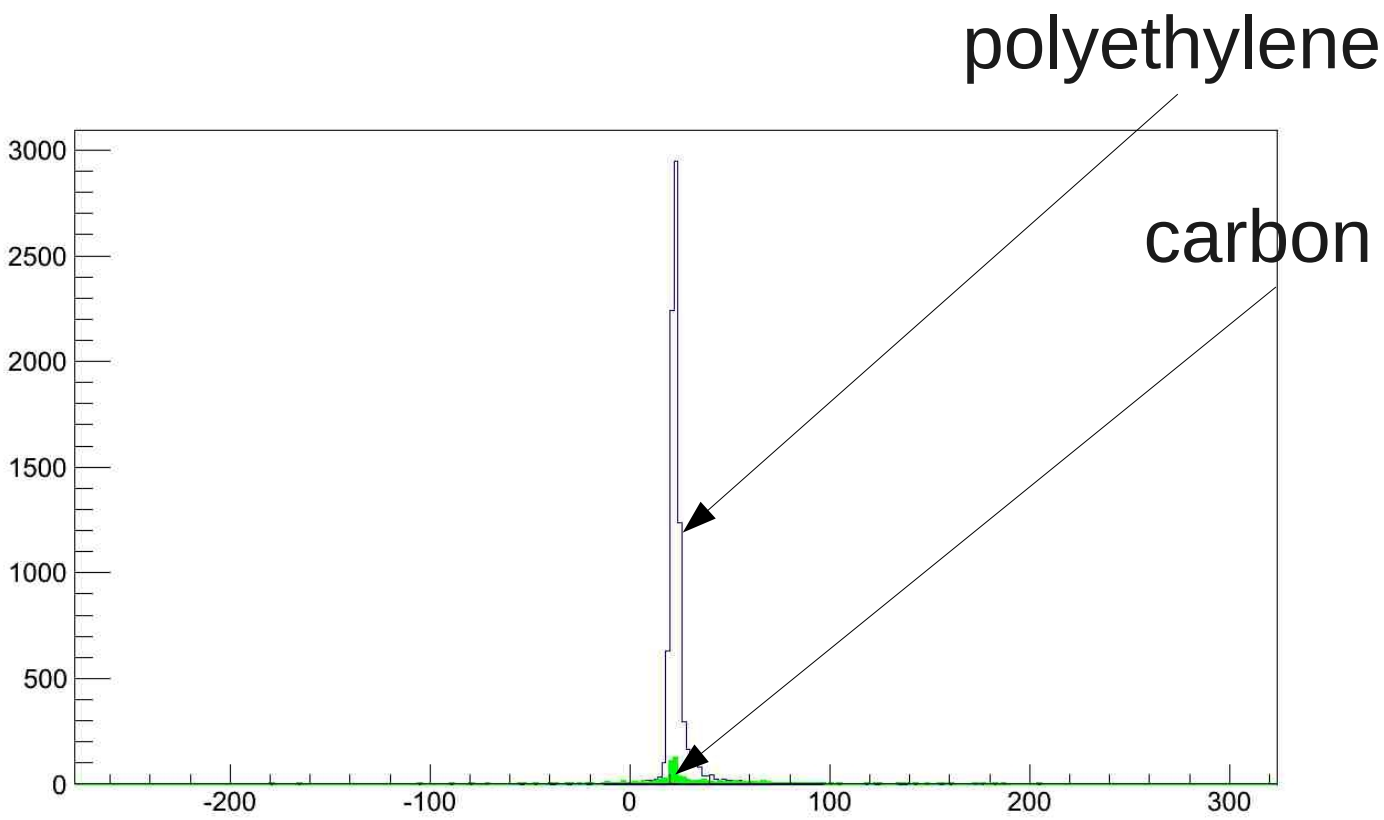
Examples of cuts for the detector pair placed at 105^0 in cms.

Target Position Monitor cut



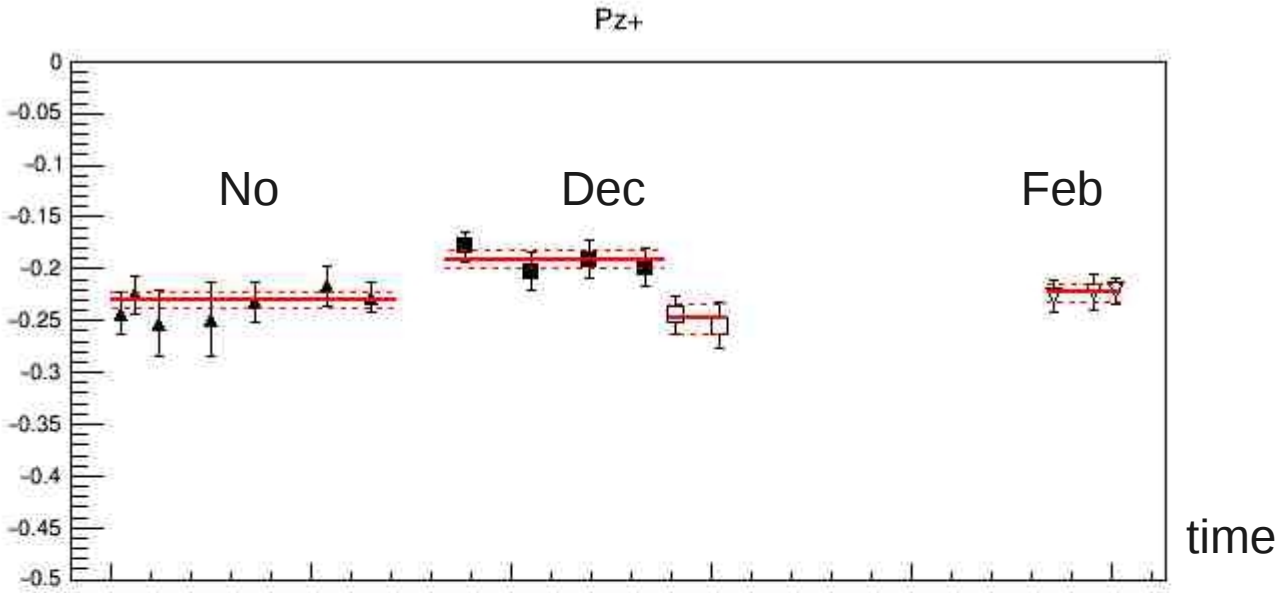
The background estimation

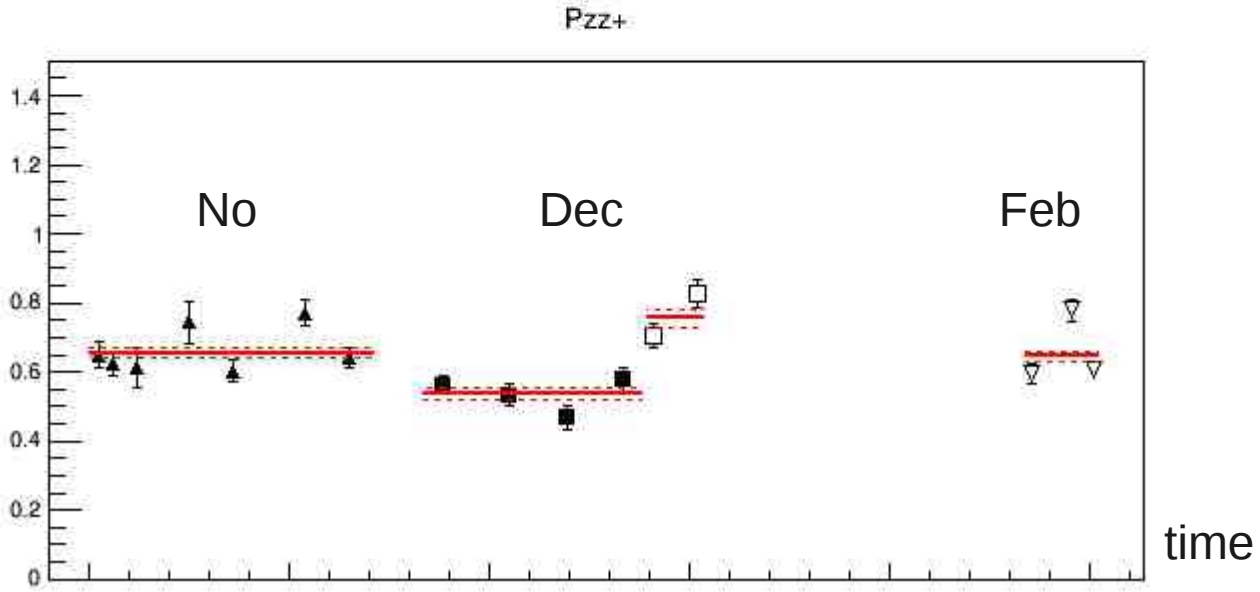
TDC spectra for polyethylene and carbon were normalized on the luminosity.



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 %

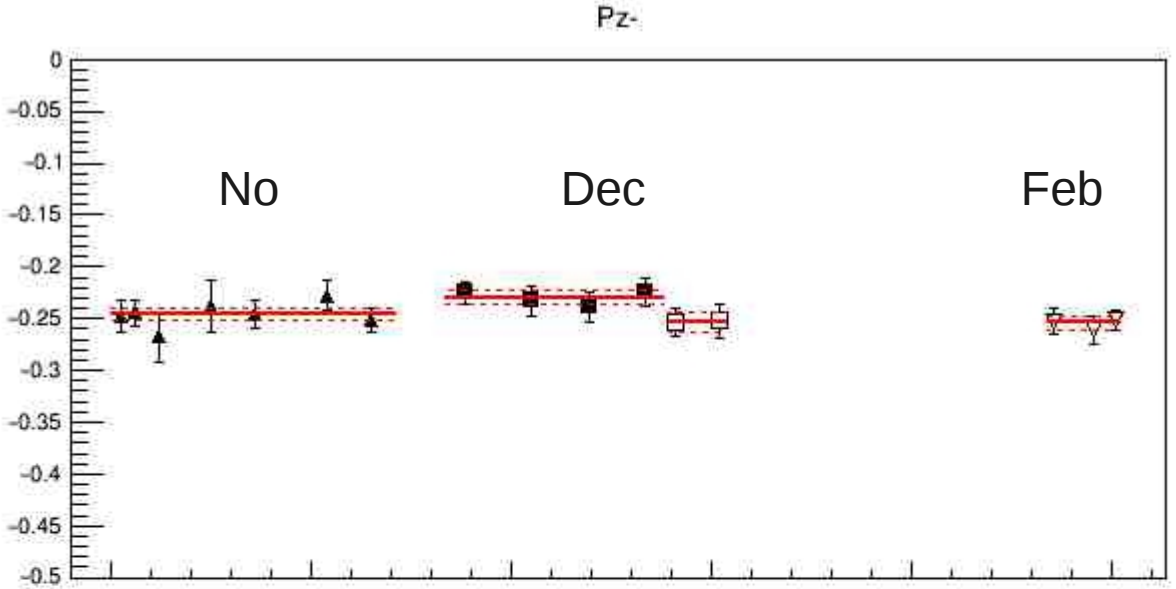
Polarizations values during the runs in 2016/2017 yy.



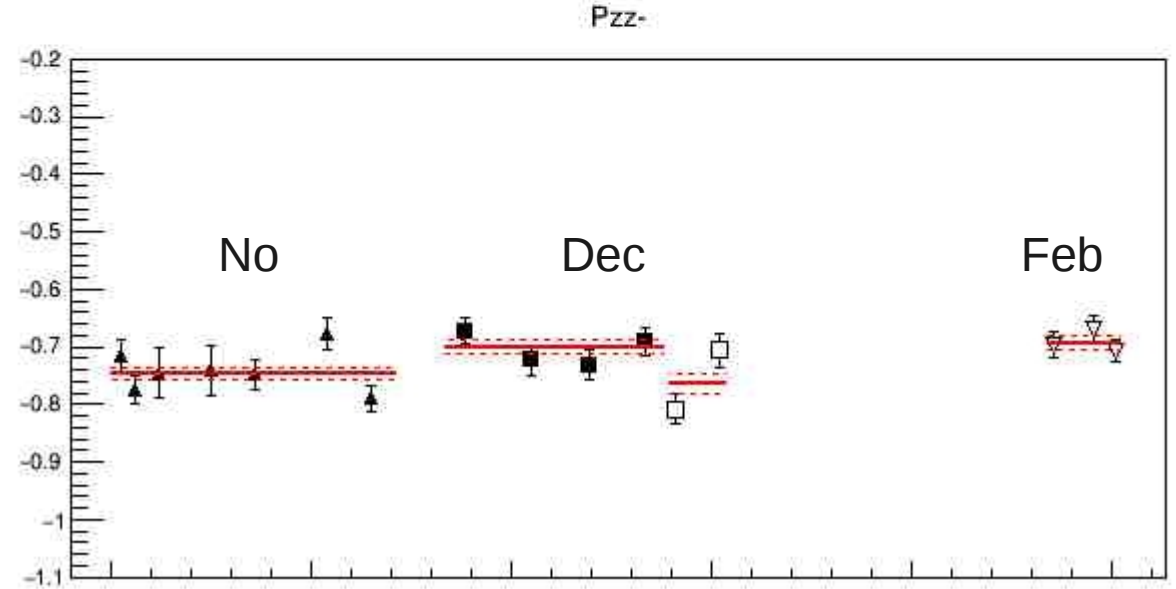


Pz+, Pzz+ - polarization for spin mode: (-1/3,+1)

Polarizations values during the runs in 2016/2017 yy.



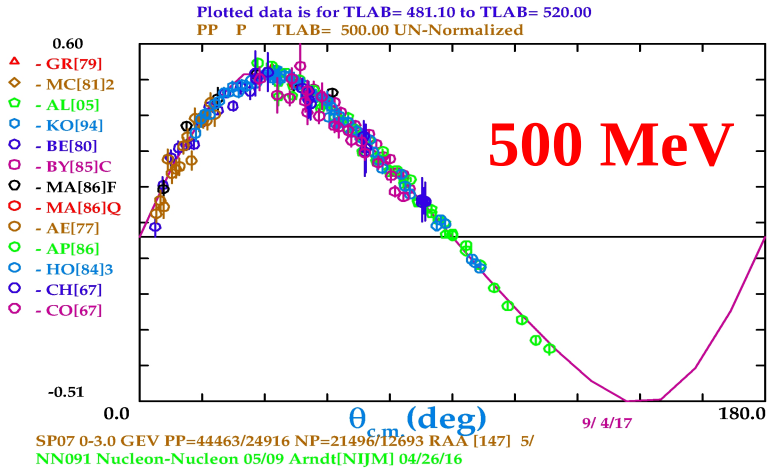
Pz-, Pzz- - polarization for spin mode: (-1/3,-1)

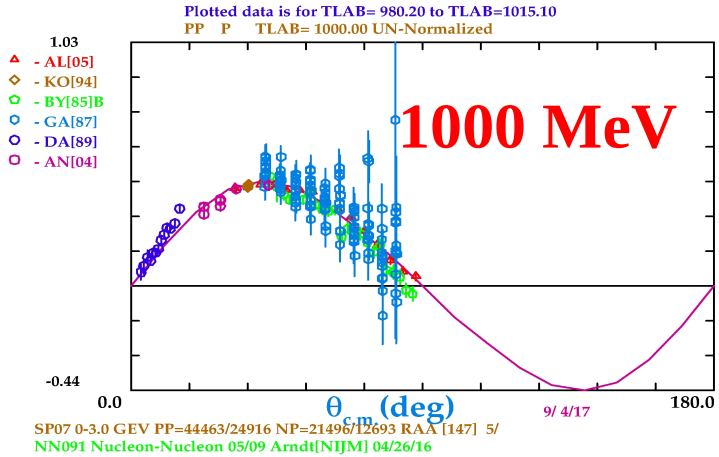


The vector and tensor polarization for different spin modes of SPI

Polarization values (p_z, p_{zz})	P_z	dP_z	P_{zz}	dP_{zz}
(-1/3,+1)	-0.272	0.019	0.733	0.035
(-1/3,-1)	-0.272	0.014	-0.792	0.026
(0,+1)	0.040	0.023	0.725	0.042
(0,-2)	0.042	0.013	-1.478	0.030
(-1,+1)	-0.648	0.016	0.628	0.027
(-2/3,0)	0.468	0.013	0.039	0.021

Use of pp- quasielastic scattering at ITS for the beam polarization measurements

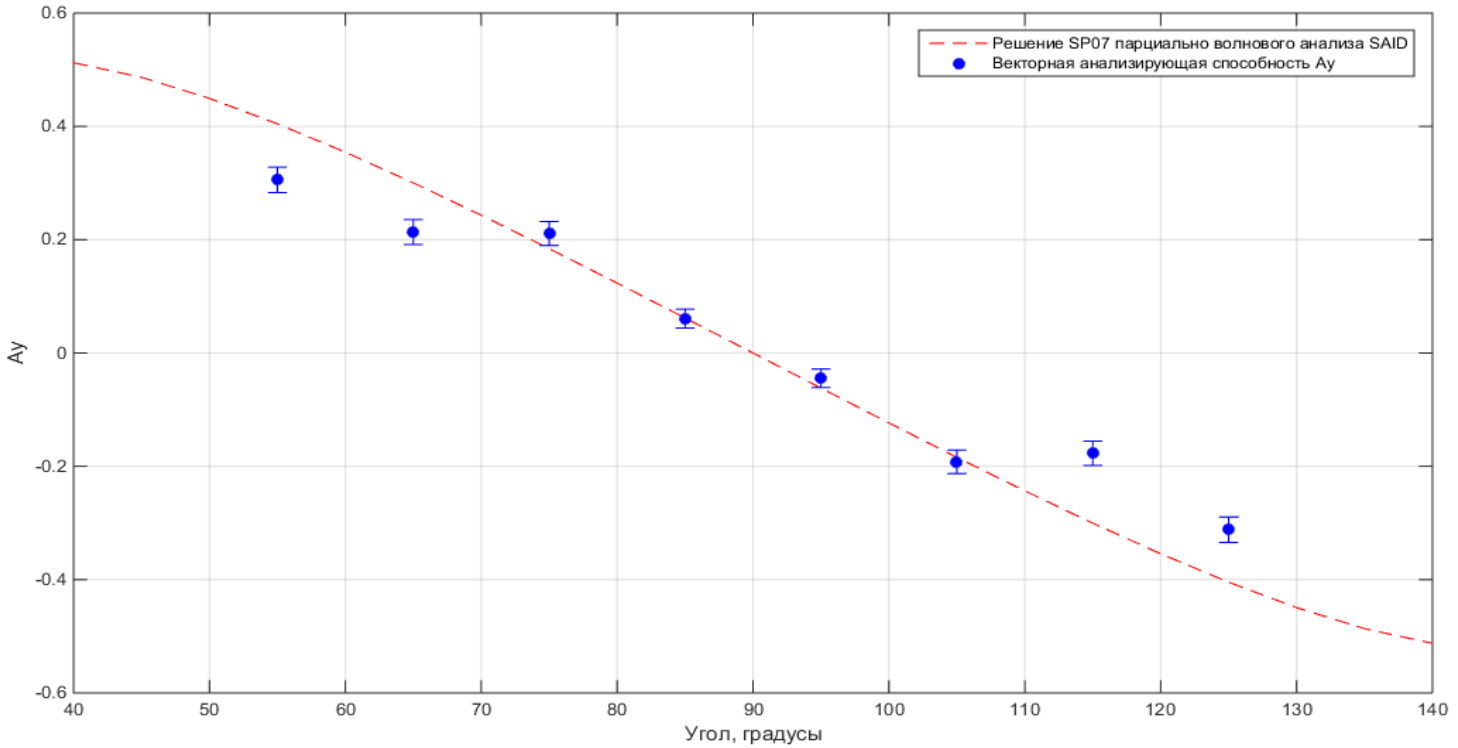




The use of only proton detectors to detect pp-(quasi)elastic scattering. Measurement at 8 different angles symmetric with respect to 90^0 in cms.

However, due to current detector support the positions of the scintillation counters is not optimal – no coverage at small (and large) scattering angles.

Comparison with SAID SP07 solution at 500 MeV.



The agreement of the data with PWA is very good.
(Tensor analyzing power is consistent with zero.)
Therefore, DSS proposed to use this method to measure the proton beam polarization at ITS in 2017.

Polarized protons at ITS.

Injection of 5 MeV protons into Nuclotron ring.
Acceleration up to 500 MeV- no serious depolarization resonances (Yu.Filatov).

Unpolarized protons: I∼1.5·10^8 ppp
Polarized protons: I∼2-3·10^7 ppp

IPol=1 P=-1 (WFT 1→3)
IPol=2 P=0 (unpolarized)
IPol=3 P=-1 (WFT 1→3)

beam 2/3 of time.

Having the asymmetries for 8 angles (55^0-125^0 in the cms) we obtained the averaged value of the proton beam polarization

Unpolarized protons: P= 0.017 ±0.021
Polarized protons: P=-0.354 ±0.022

Need to produce new detection system for protons.

Selection of pp- elastic scattering at 500 MeV.

55^0 125^0

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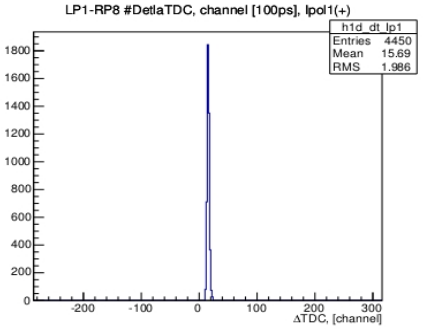

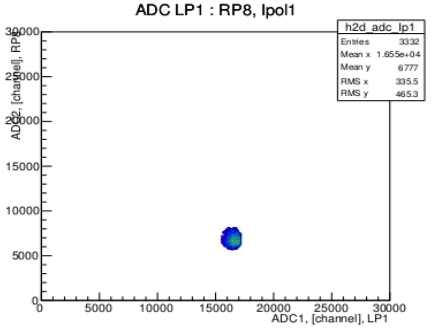

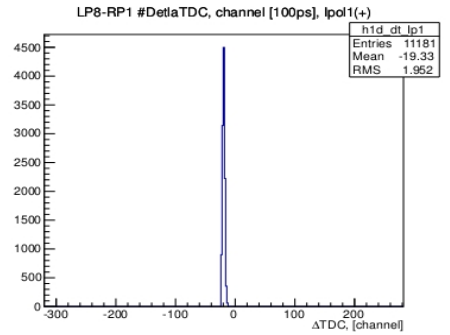

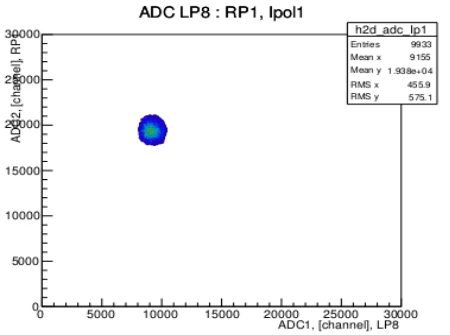

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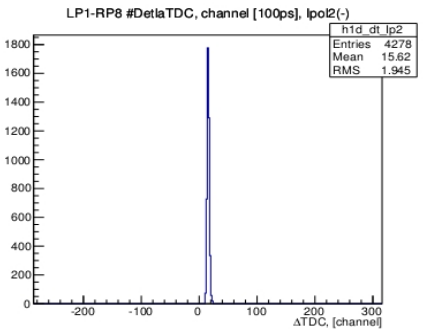

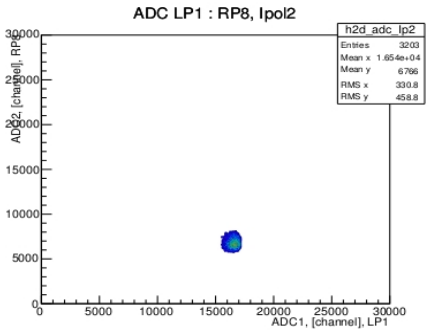

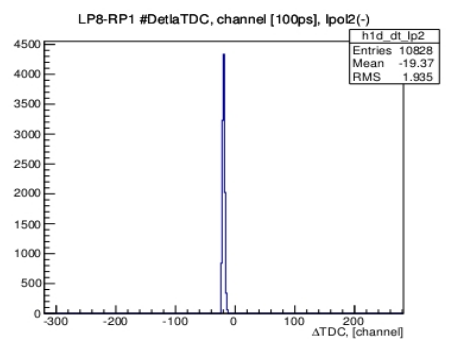

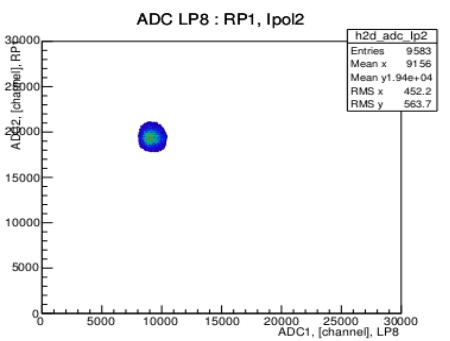

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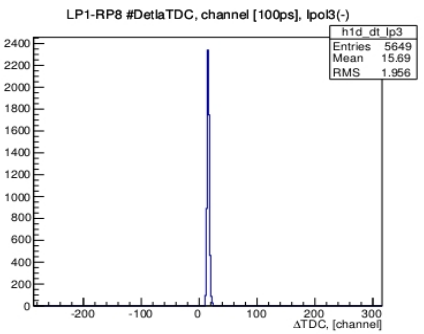
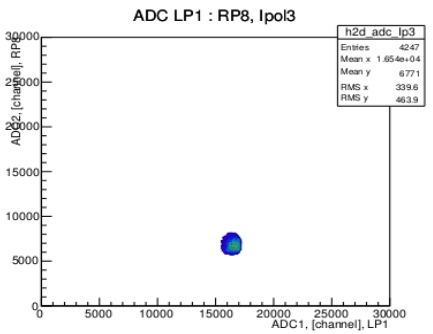
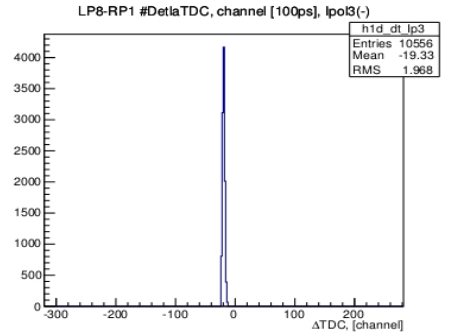
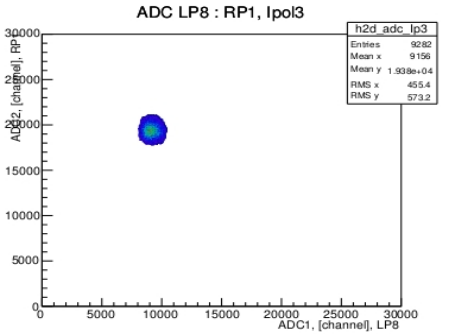








Conclusions

The upgraded version of the deuteron beam polarimeter has been used to obtain the vector and tensor polarizations using dp- elastic scattering at 270 MeV during 2016/2017 runs.

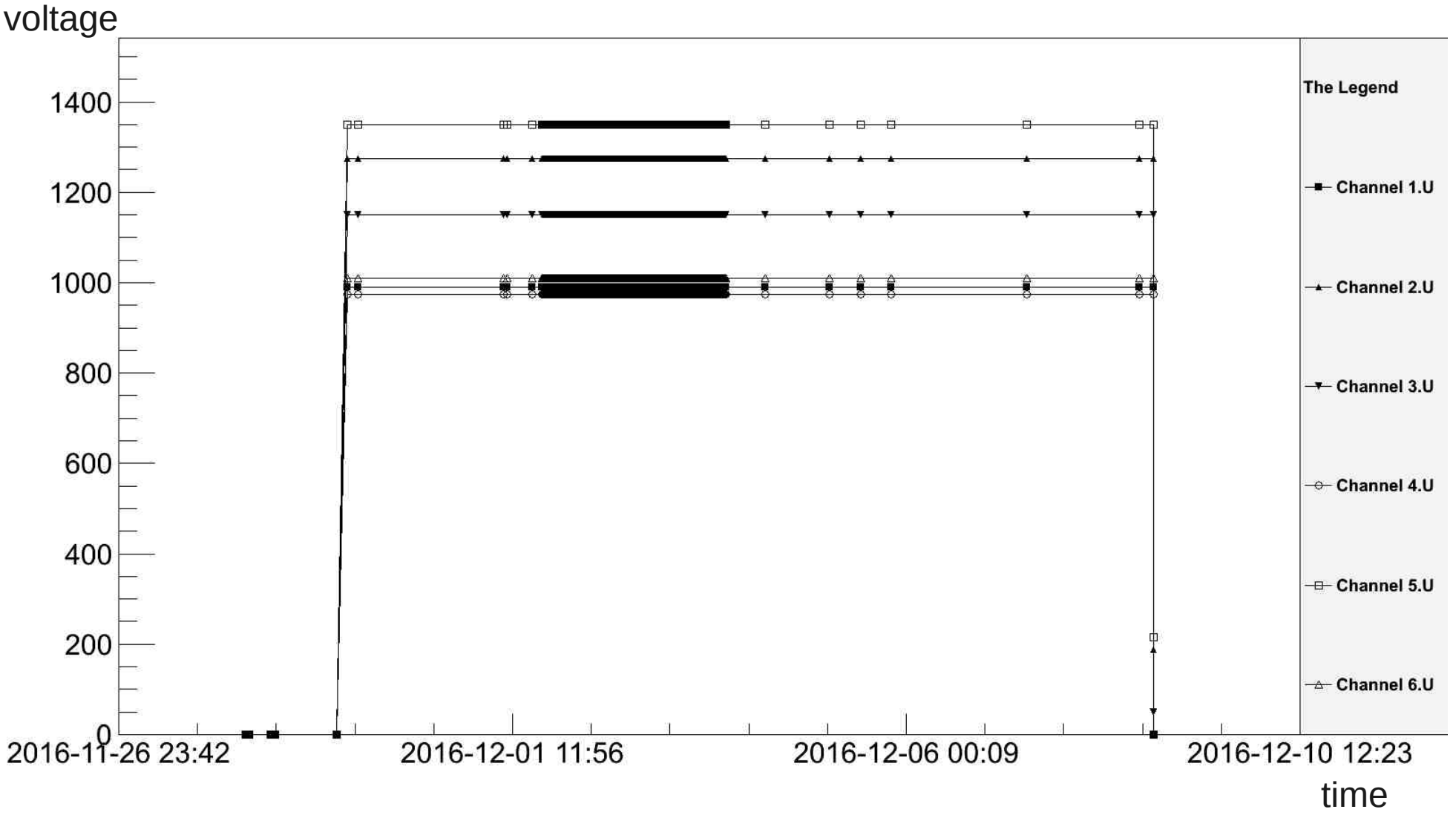
The time stability of the polarization values has been demonstrated for the spin modes (-1/3,+1) and (-1/3,-1).

The polarimeter has been used for tuning of the ion source parameters for 6 different spin modes. The polarization values were 70-75% from the ideal ones.

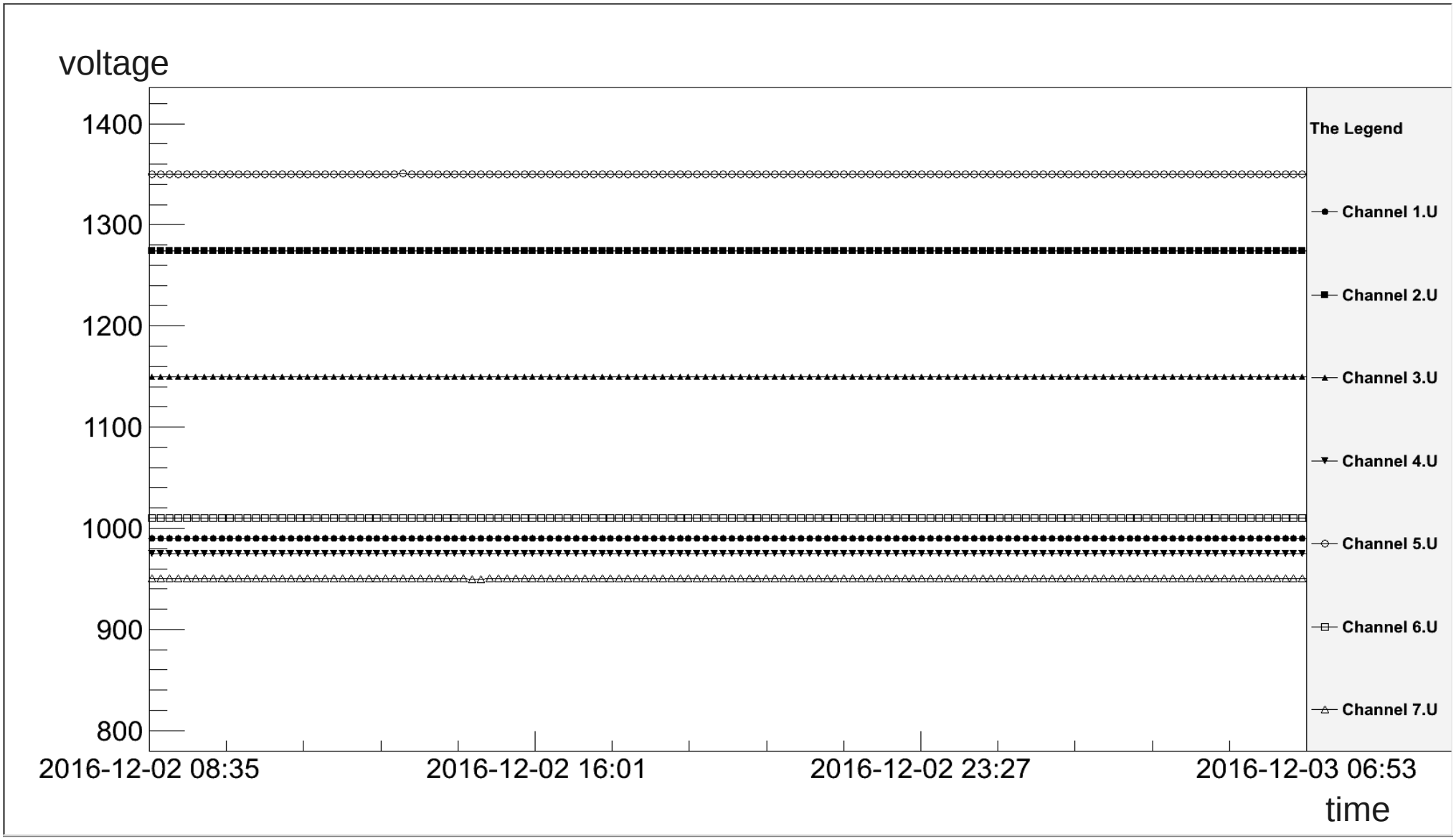
The current polarimeter has been also used to measure the proton beam polarization at 500 MeV using pp- (quasi)elastic scattering. The obtained value of the vertical proton polarization is -0.354 ±0.022.

Thank you for the 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

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

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

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

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

- 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.

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.