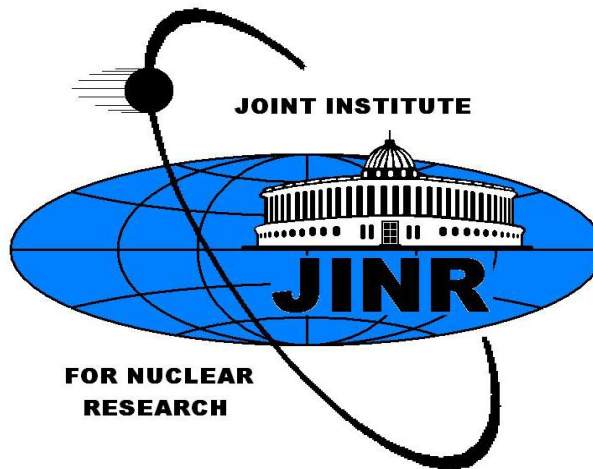


# Proton polarimeter for the experiments at the Nuclotron

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# Introduction

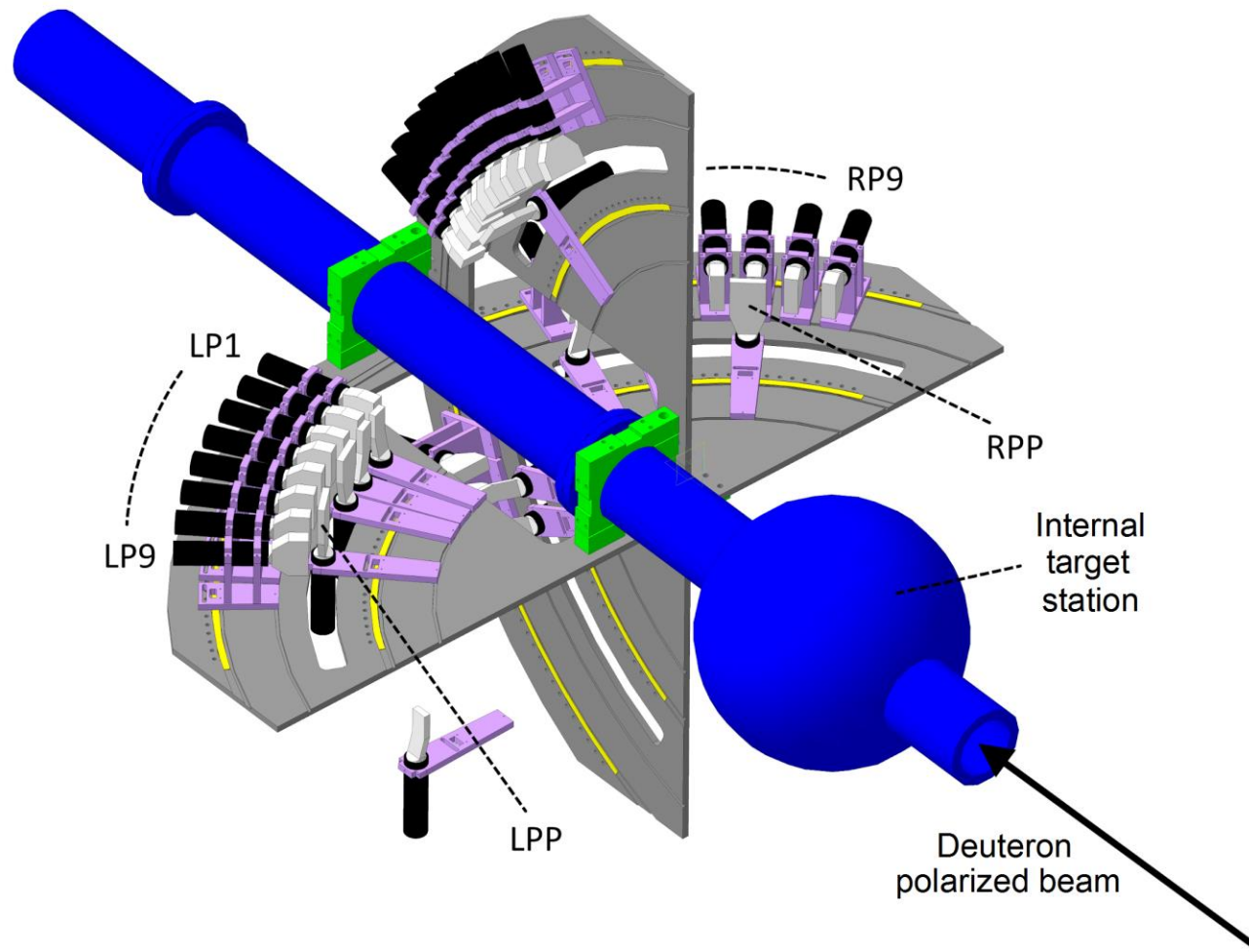
The study of the spin structure of two-nucleon and three-nucleon short-range correlations via the measurements of the polarization observables in the deuteron induced reactions is one of the major scientific goals at Nuclotron. The high precision polarimetry of the deuteron and proton beams is important for these investigations.

A deuteron beam polarimeter based on the spin-asymmetry measurements in the dp-elastic scattering at large angles in center-of-mass system has been constructed at the internal target station at the Nuclotron of JINR. This polarimeter is used for the measurements of the vector and tensor components of deuteron beam polarizations at the energies 270–2000 MeV simultaneously.

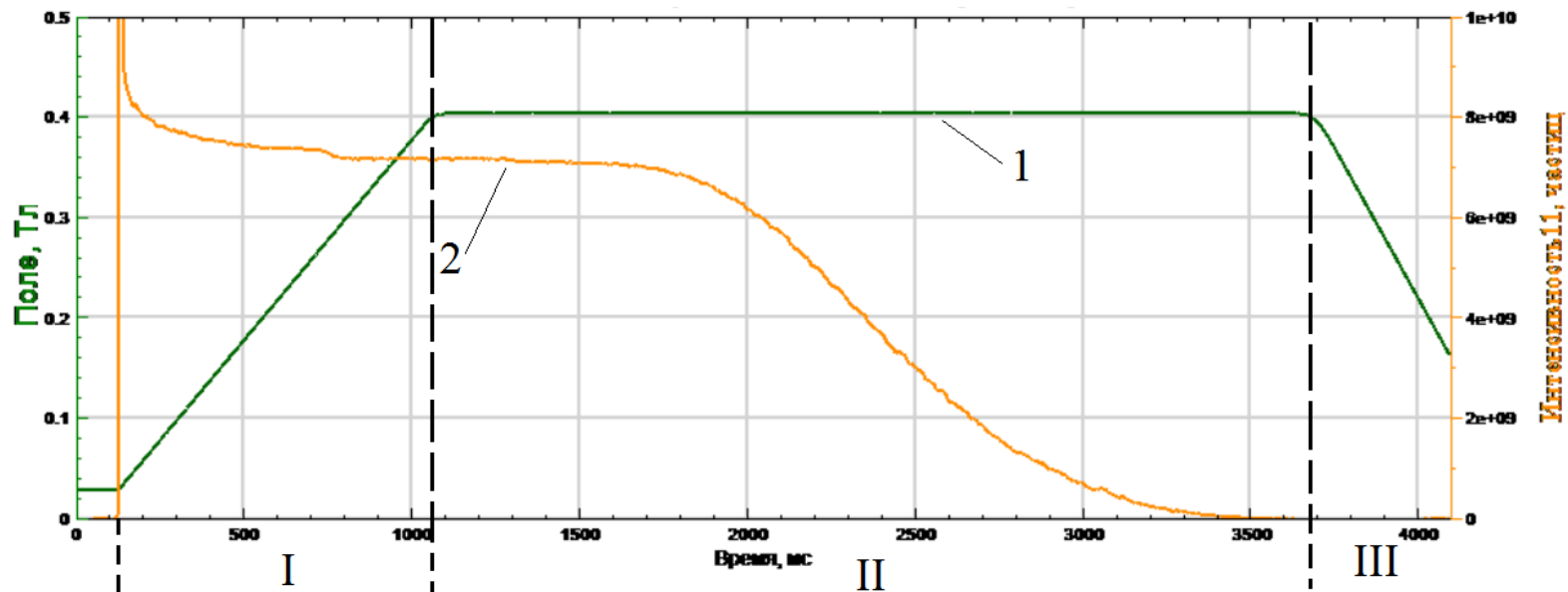
The results of the polarimeter upgrade at the Nuclotron internal target are presented. The upgrade is performed for measurements of the proton polarization. The study of the pp- and pd-elastic scattering at energies 100 – 1000 MeV are planned.

The measurements are performed in the frame of the DSS project.

# Measurements on the Internal target station



# The subsystem of the diagnostic of beam intensity



I - increase of magnet field

II – the interaction of the target with the beam

III - decrease of magnet field

1 - magnet field value

2 - the beam intensity

# VME Data Acquisition System

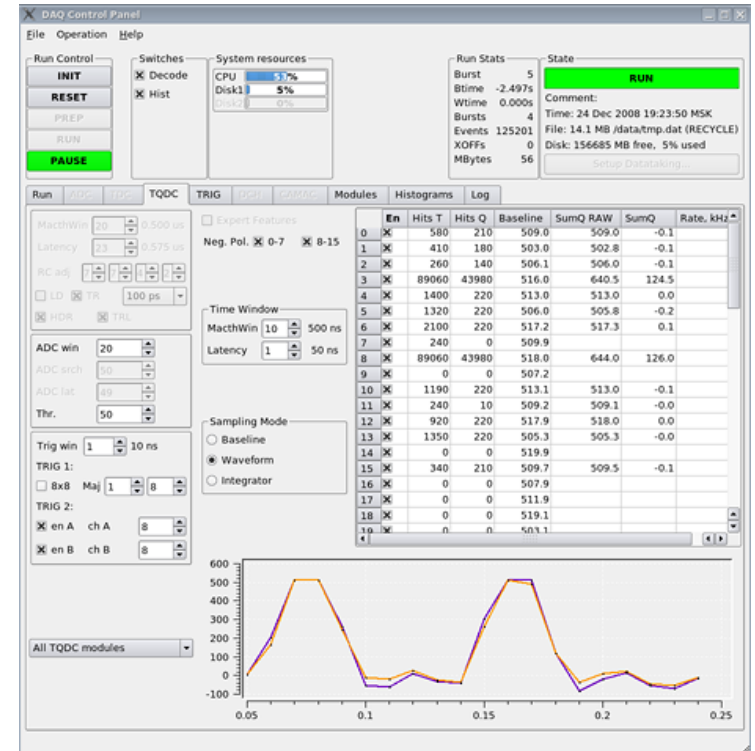
The VME based data acquisition system was used for the data taking from scintillation detectors.



TTCM



TQDC-16

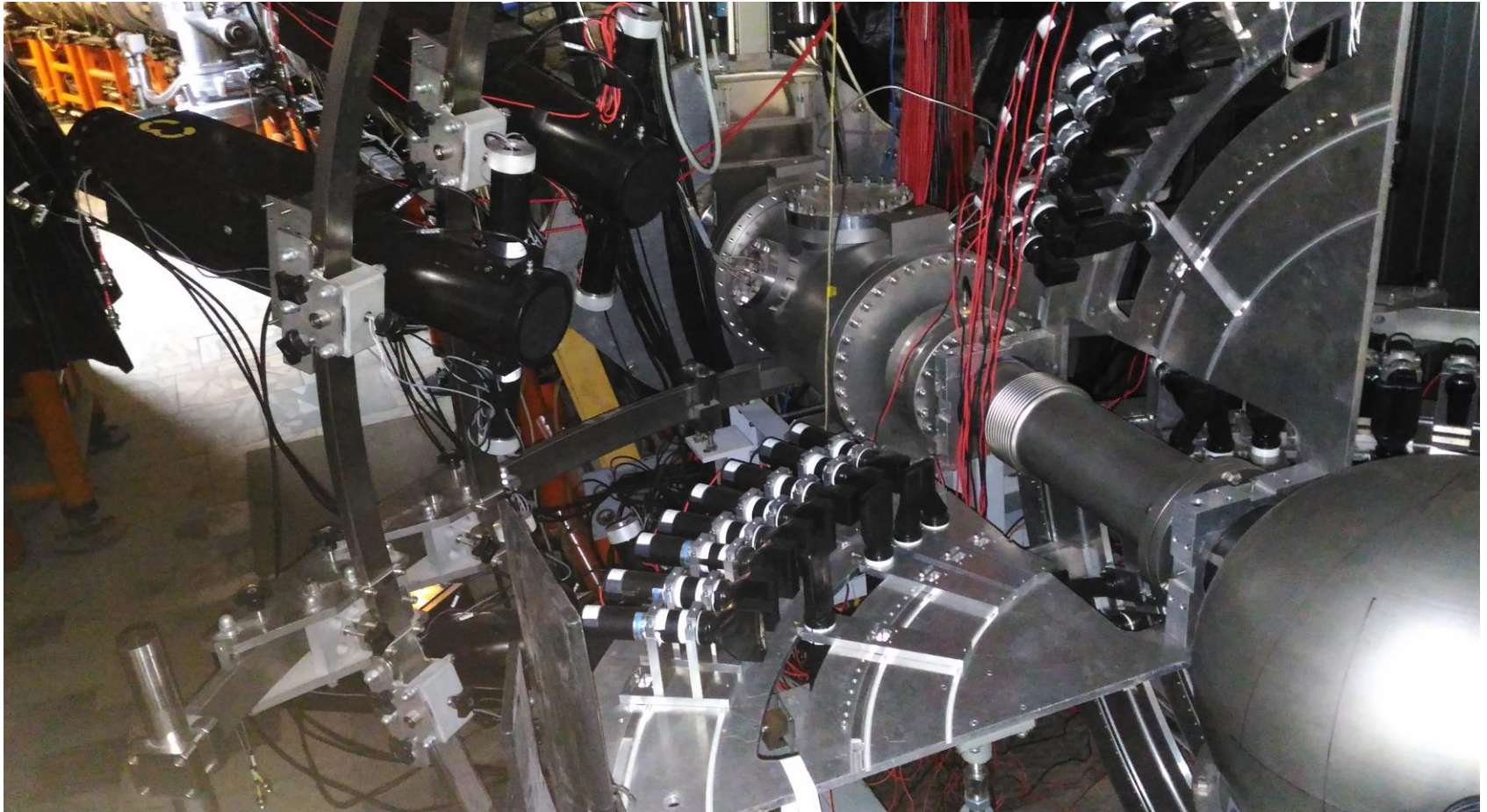


GUI Controls

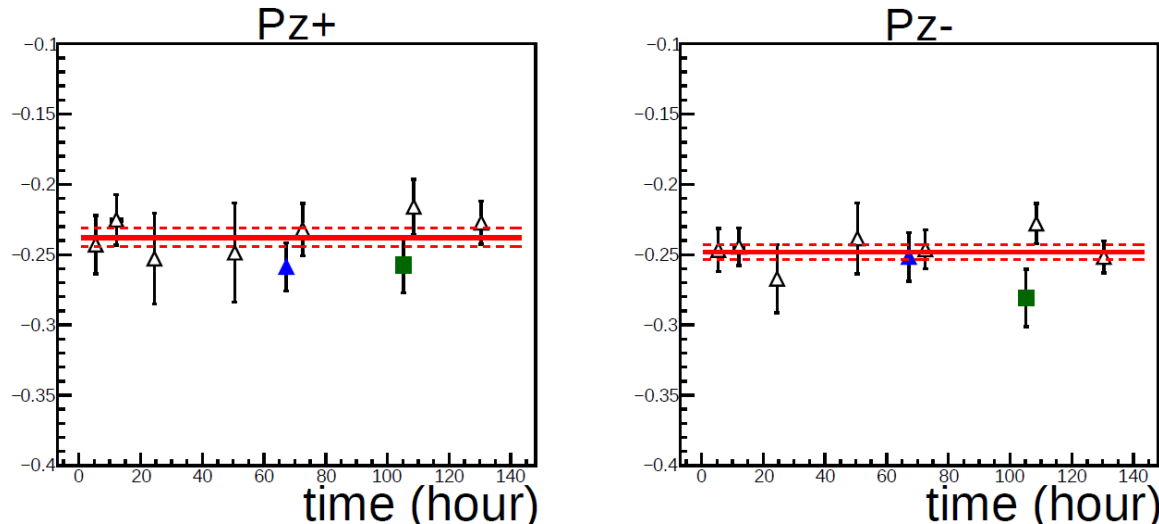
TQDC-16 – 16 - channel time and charge digitizer



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



## Deuteron polarization at 500 and 650 MeV



Open triangles – data calculated at 270 MeV/n [Skhomenko Ya.T.  
EPJ Web of Conferences 201, 04005, 2019]

Full triangle – data calculated at 500 MeV/n

Full square – data calculated at 650 MeV/n

## Proton polarization at 500 MeV

Having the asymmetries for 6 angles ( $55^\circ$ - $85^\circ$  in the cms)  
we obtained the averaged value of the proton beam  
polarization: **Unpolarized protons:  $P = 0.056 \pm 0.021$**

**Polarized protons:  $P = -0.367 \pm 0.015$**

# The polarimeter upgrade

- Detectors set modernisation:
- calculation of the detectors size
  - detectors number
  - distance to target

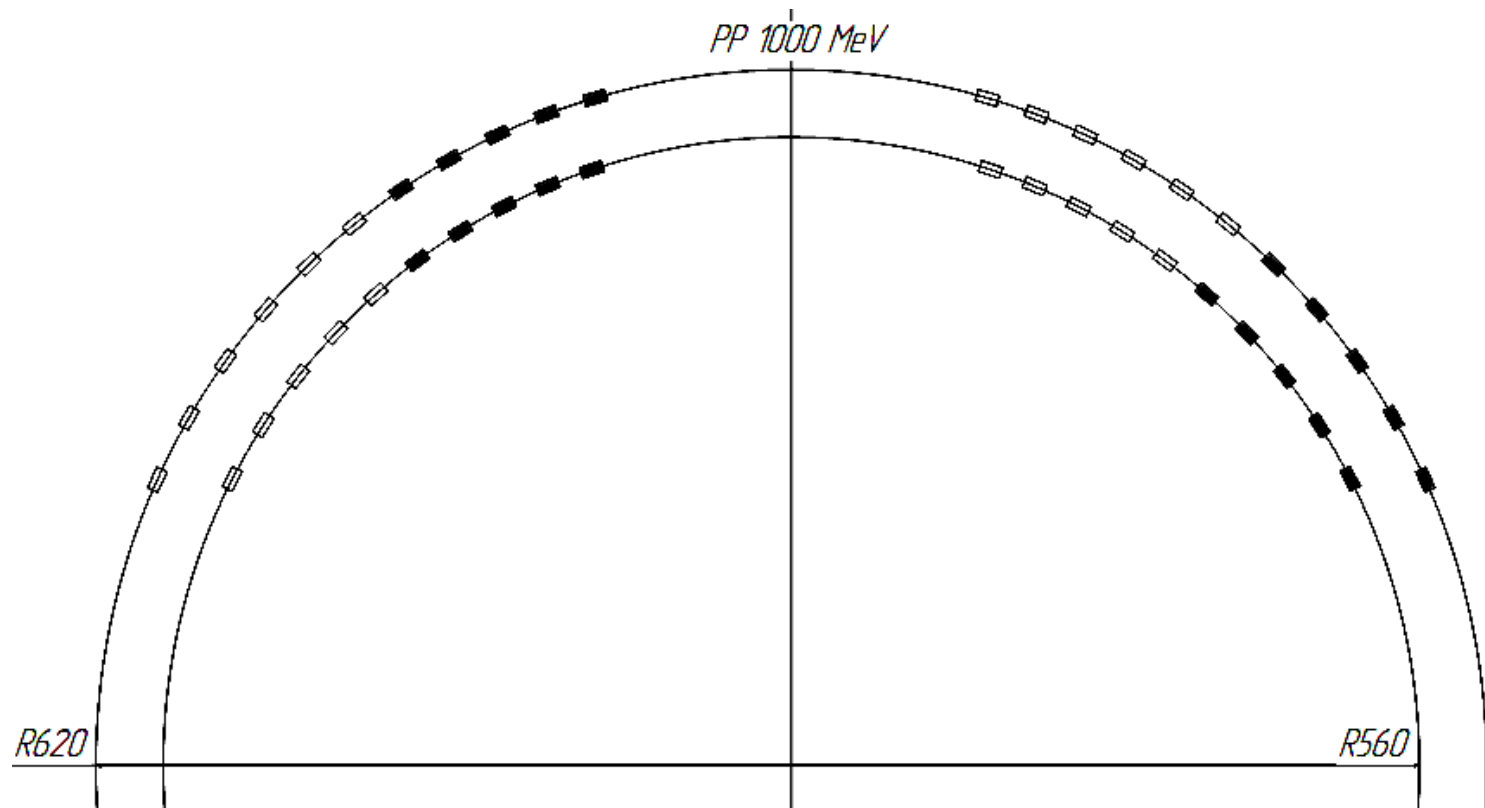
Important factors :

- The area of the detectors should be such that all falling events are recorded by the data acquisition system (no system overloads ).
- The area of the detectors should be such that the total number of events in all detectors will be not more  $5 \cdot 10^9$  events/cycle using the thin  $\text{CH}_2$  target.
- The effective area of the detectors should maximum equal to their geometrical sizes.
- If one detector is broken, it will be can easily to change to another detector.
- The sizes of the detectors and the distance to the target should allow to place a large number of counters. Herewith the overlap between detectors should be is minimum because it can make the select of the true events to more difficult.



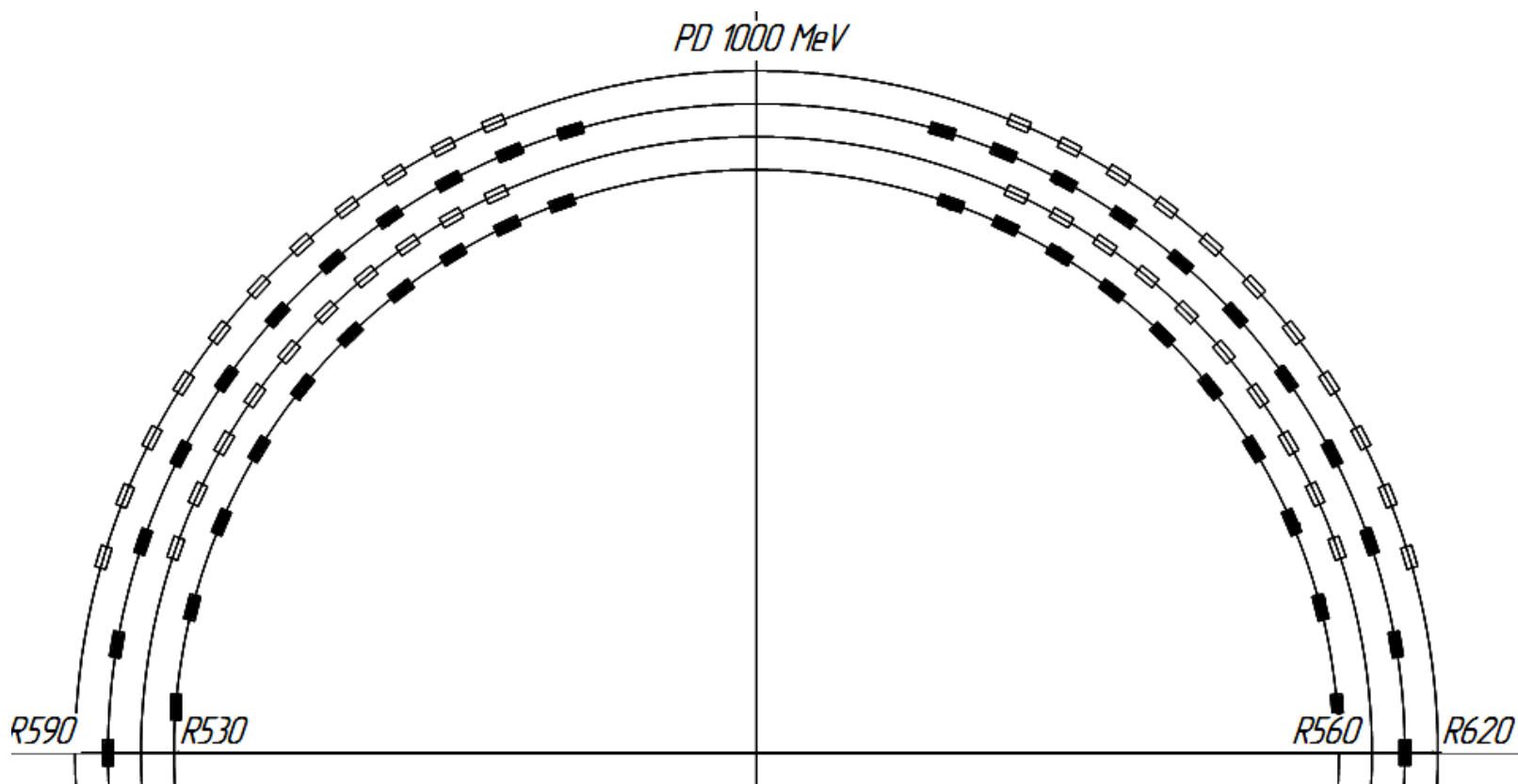
# The scheme of detectors for **pp**-elastic scattering

The scheme which include the 42 detectors for **pp**-elastic scattering. The counters will be placed every 5 degrees in the c.m.s. and will cover the range  $40^\circ < \theta_{\text{c.m.}} < 90^\circ$ . The calculation using the Pluto simulation give that ratio of the kinematical coincidence detectors should be equal 1/3. The detectors size were proposed as 2x2x2 cm and 2.3x6x2 cm.



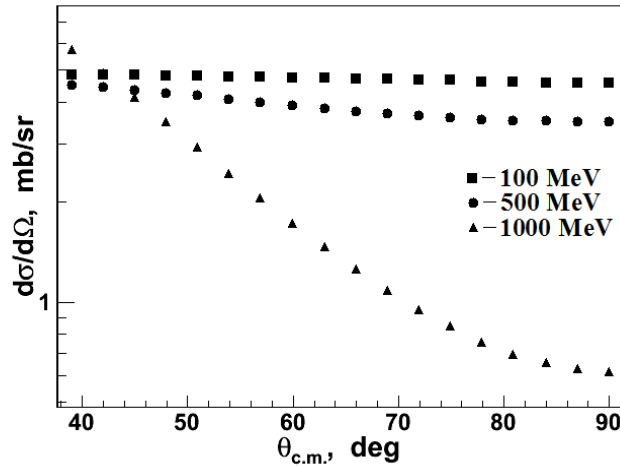
# The scheme of detectors for **pd**-elastic scattering

The scheme which include the 80 detectors for **pd**-elastic scattering. The counters will be placed every 5 degrees in the c.m.s. and will cover the range  $30^\circ < \theta_{\text{c.m.}} < 125^\circ$ . The detectors size were proposed as 2x2x2 cm and 2.3x6x2 cm.



# The simulation of the **pp**-elastic scattering by using the Pluto generator

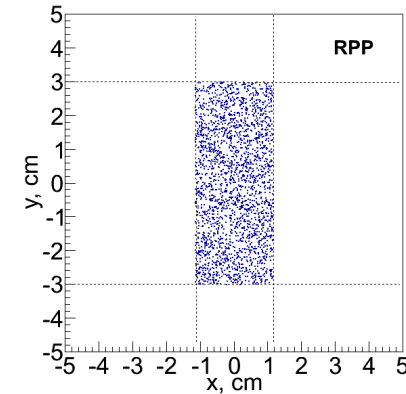
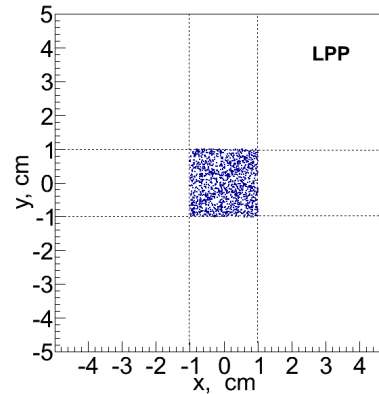
SAID data for the differential cross section



Distribution of the events in the detectors at 55° c.m. at 100 MeV

**A** - coincidence scheme is off (Detectors are working independently of each other)

**B** - coincidence scheme is on (Detectors are working in the regime of coincidence with each other)

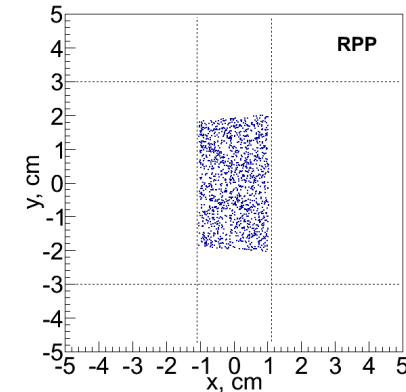
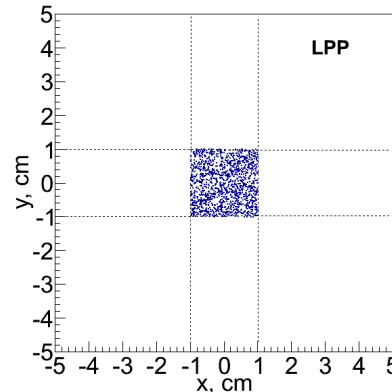
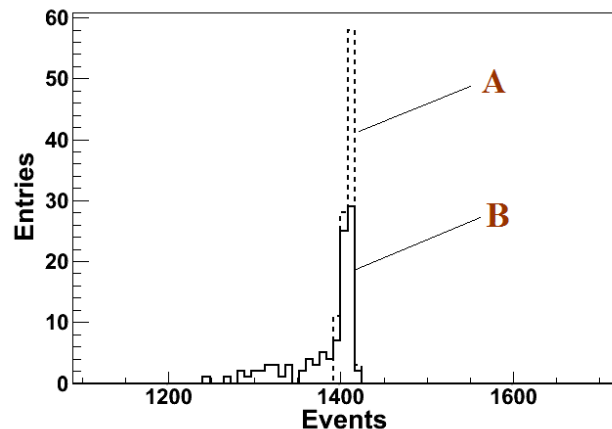


**A**

Events distribution at 55° c.m. at 100 MeV

**A** - coincidence scheme is off

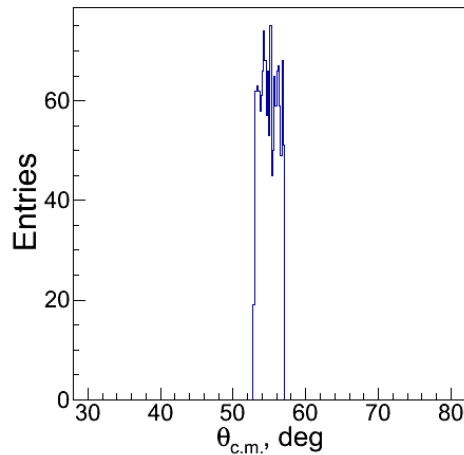
**B** - coincidence scheme is on



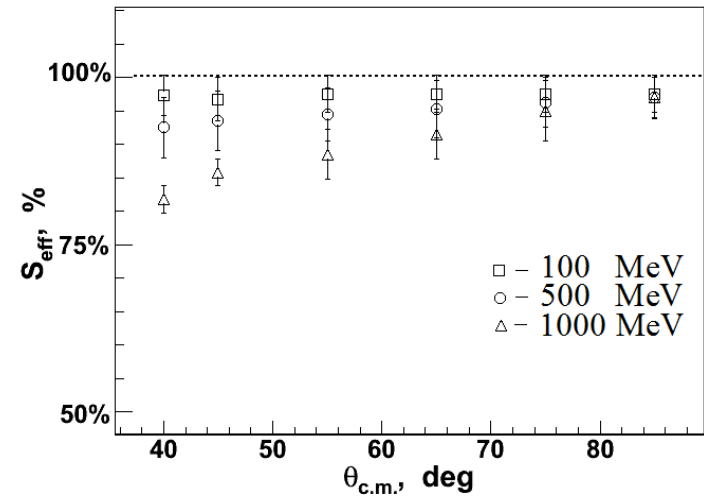
**B**

# The simulation of the $pp$ -elastic scattering by using the Pluto generator

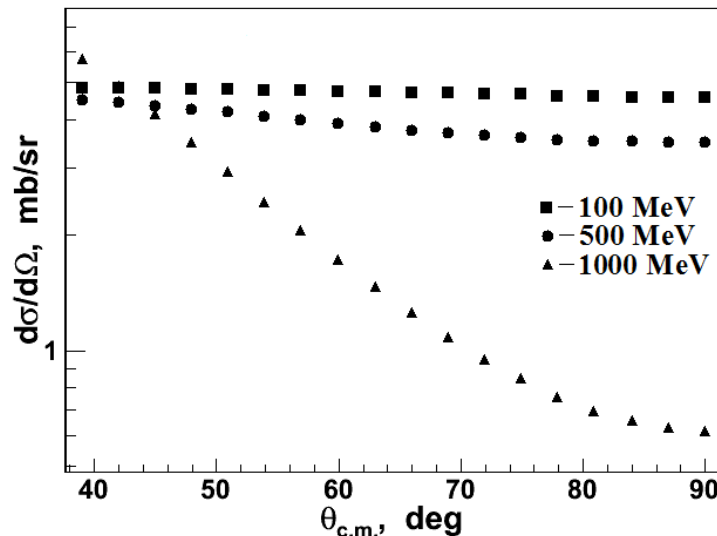
Distribution of the  $\theta_{c.m.}$



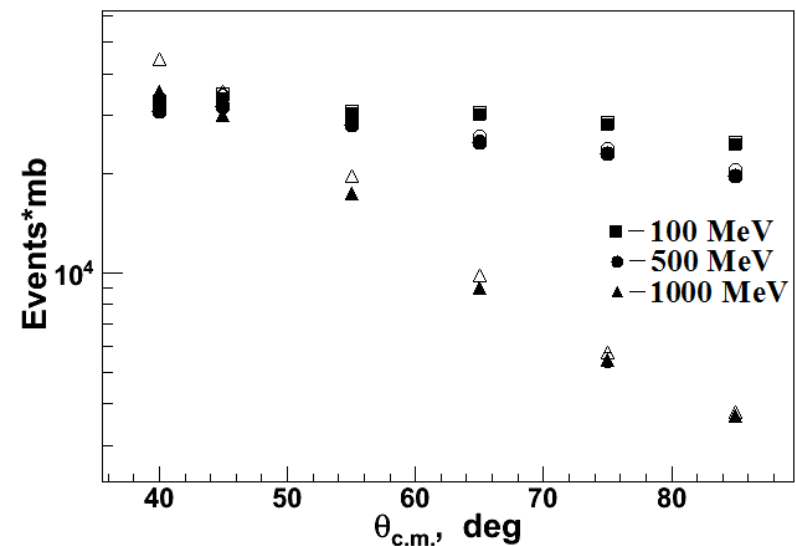
Angular dependence of the detectors effective area



SAID data for the differential cross section



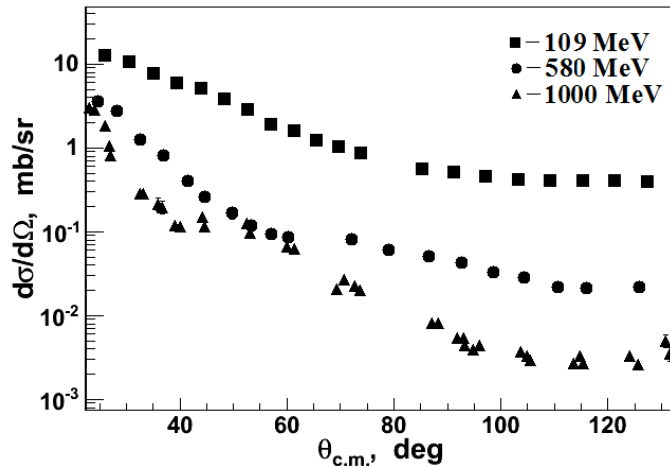
from generator



# The simulation of the **pd**-elastic scattering by using the Pluto generator

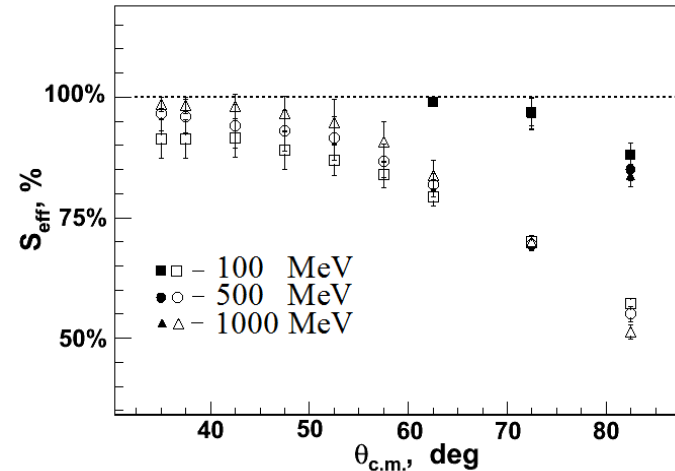
## Angular dependence of the detectors effective area

### Experimental data for the differential cross section



Open symbols – data for detectors: 2.3x6 cm

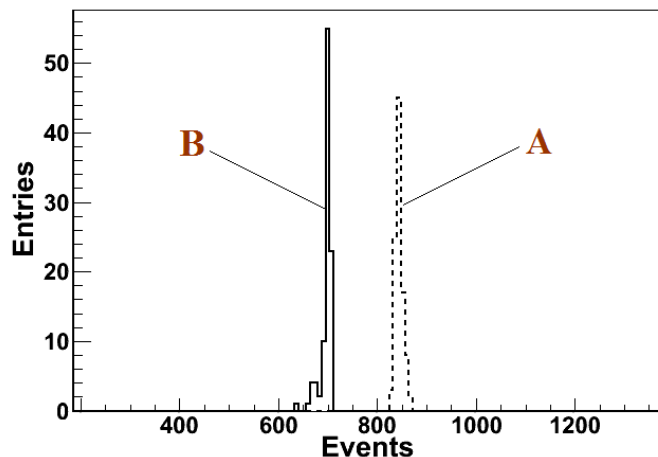
Full symbols – data for detectors: 3.5x6 cm



### Events distribution at 55° c.m. at 100 MeV

**A** - coincidence scheme is off

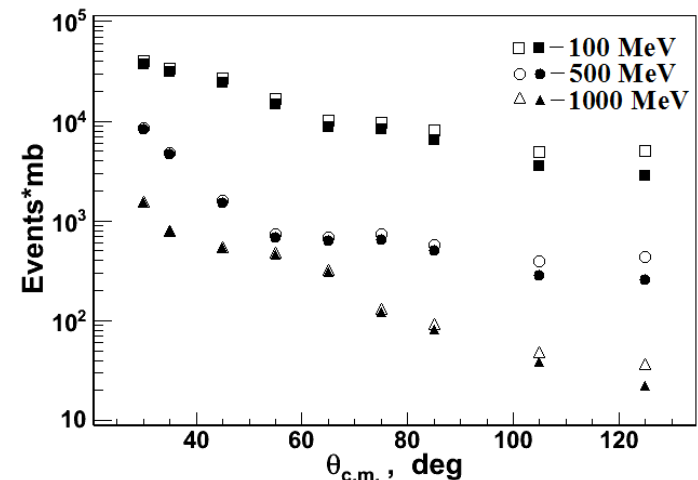
**B** - coincidence scheme is on



### Distribution of the normalized events from generator

Open symbols – coincidence scheme is off

Full symbols – coincidence scheme is on

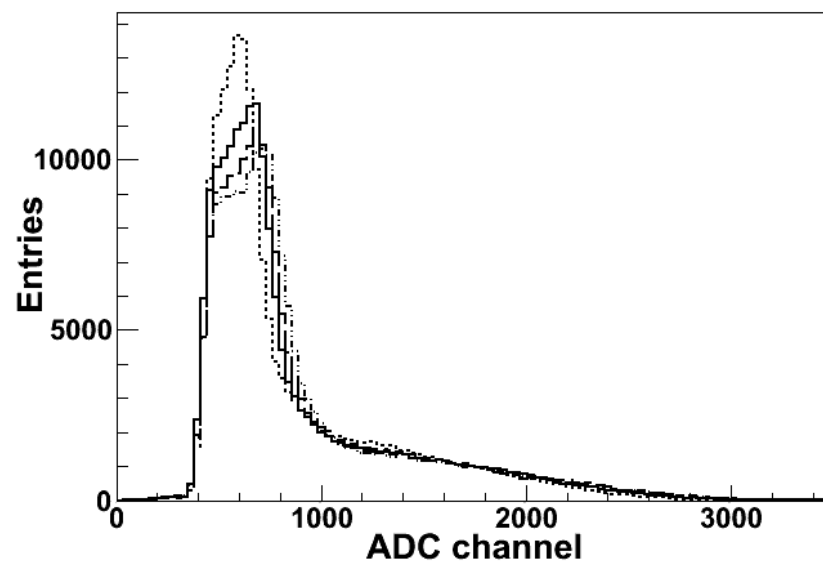


# First test of the detectors

## New scintillation detectors



## Amplitude signal from for some detectors

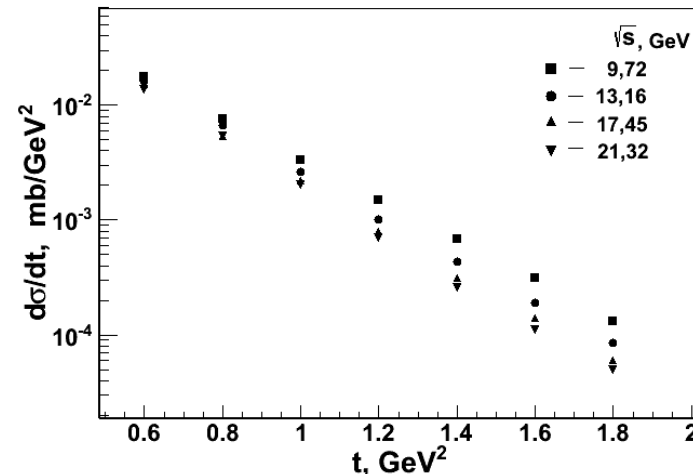
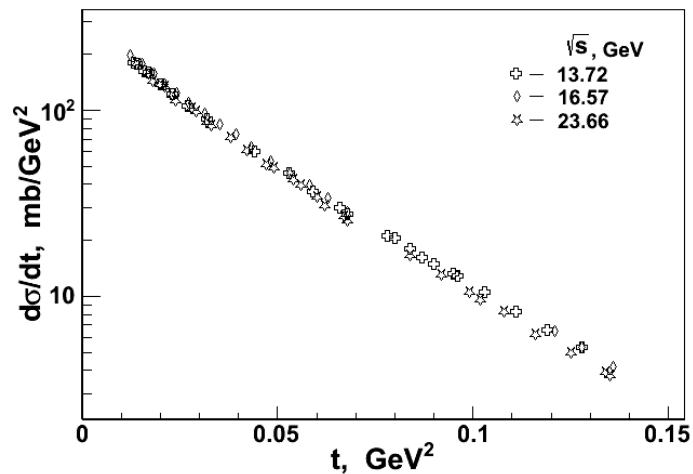
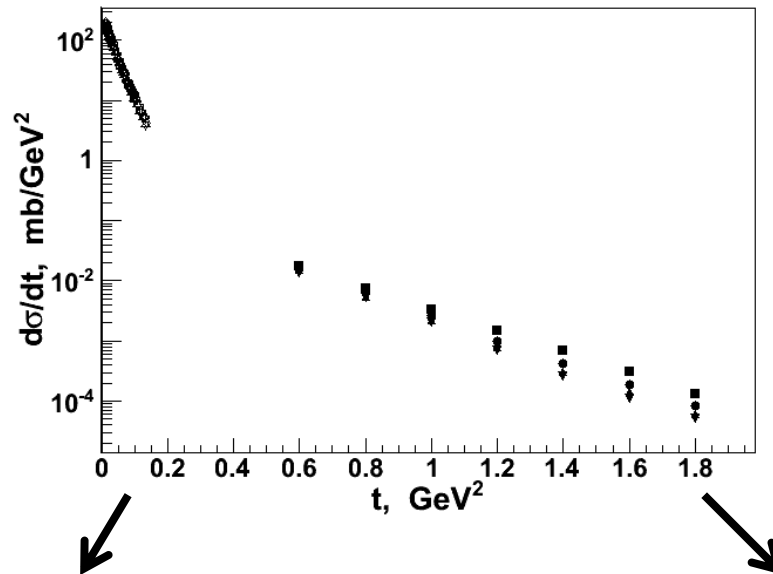




# PP- and PD- elastic scattering at energies $\sqrt{s} < 27$ GeV

## PD-elastic scattering

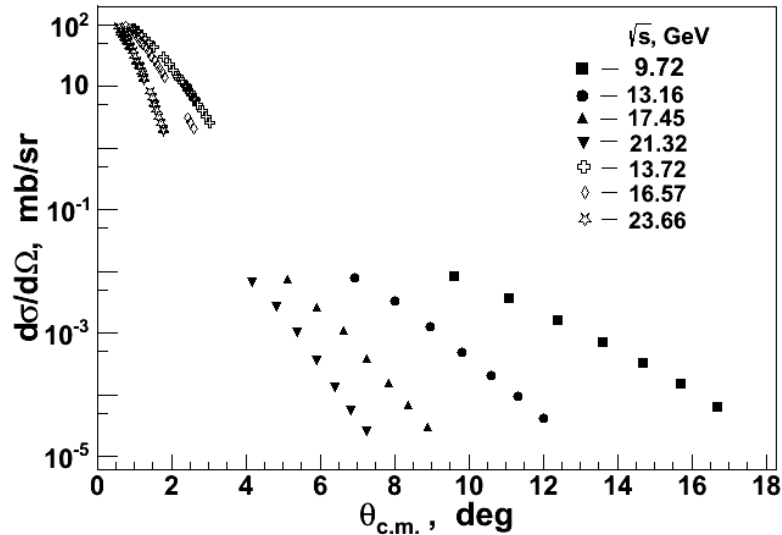
Experimental data from: Warren, G. , Gross, D. et al. // Nucl.Phys.B 207 (1982) 365-373, 1982.  
Akimov, Y. , Golovanov, L. // Phys.Rev.D 12 (1975) 3399, 1975.



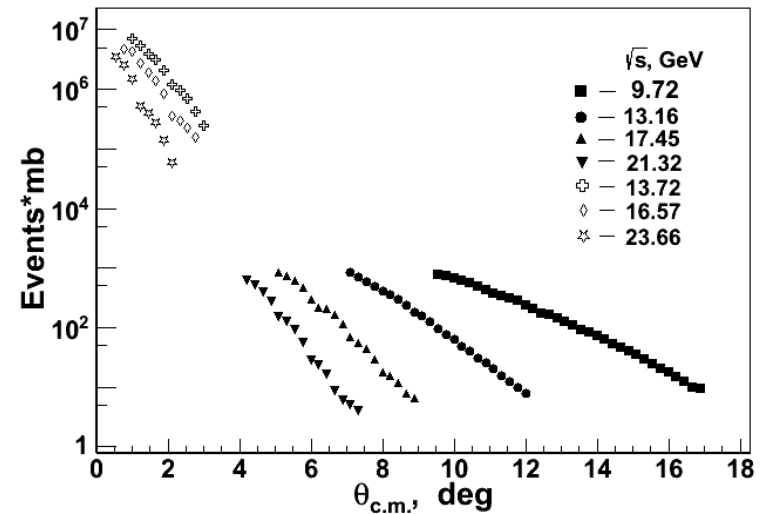
# PP- and PD- elastic scattering at energies $\sqrt{s} < 27$ GeV

## PD-elastic scattering

### Exist experimental data



### Pluto simulation



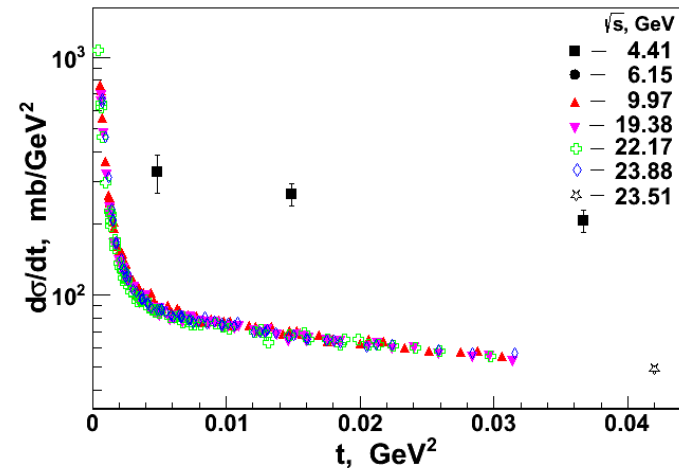
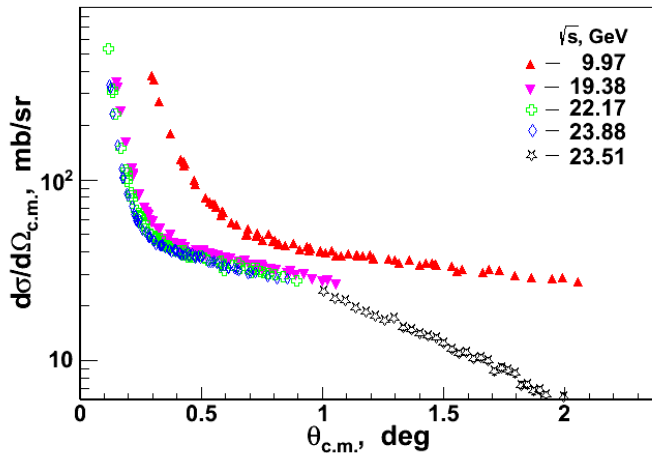
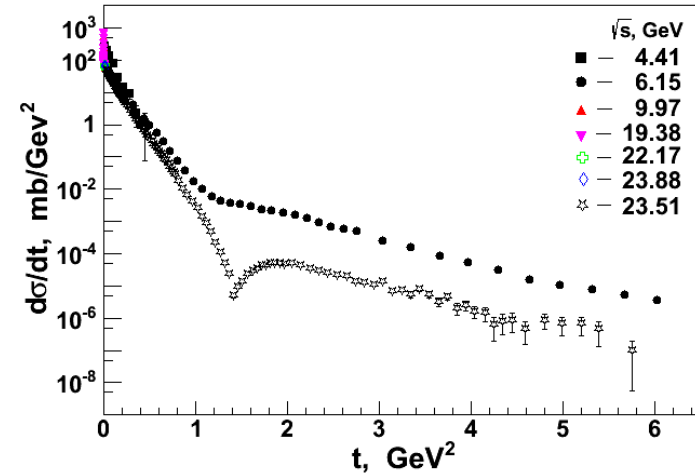
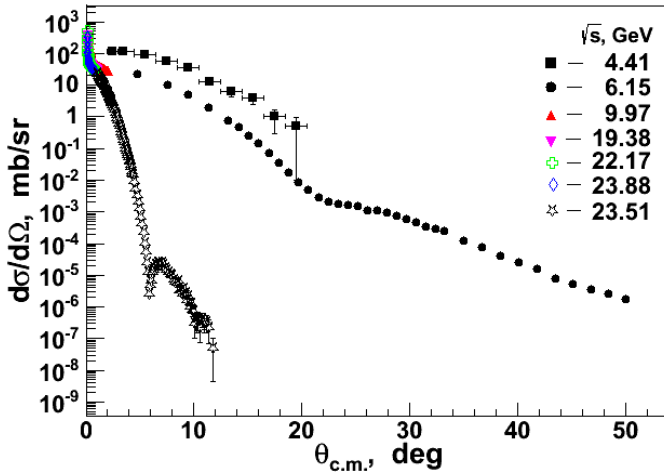
# PP- and PD- elastic scattering at energies $\sqrt{s} < 27$ GeV

## PP-elastic scattering

Experimental data from: Sov.Phys.JETP 14 (1962) 1243-1248, 1962.

Phys.Rev.Lett. 41 (1978) 217, 1978.

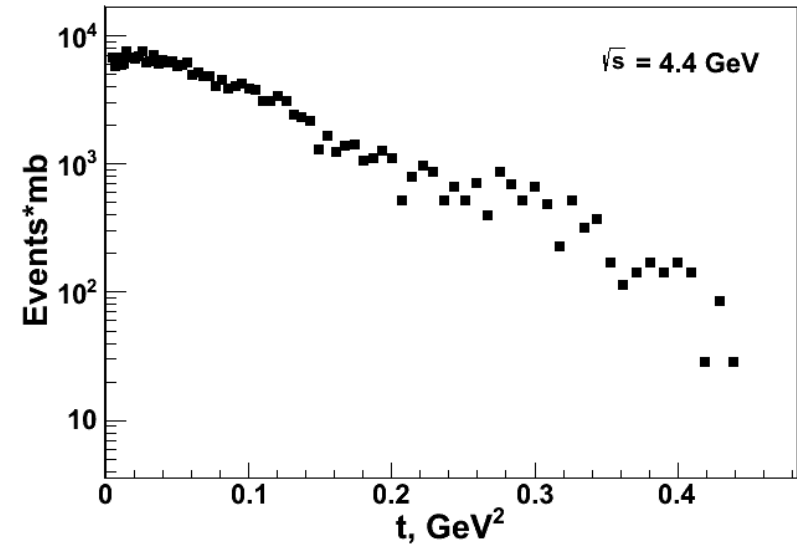
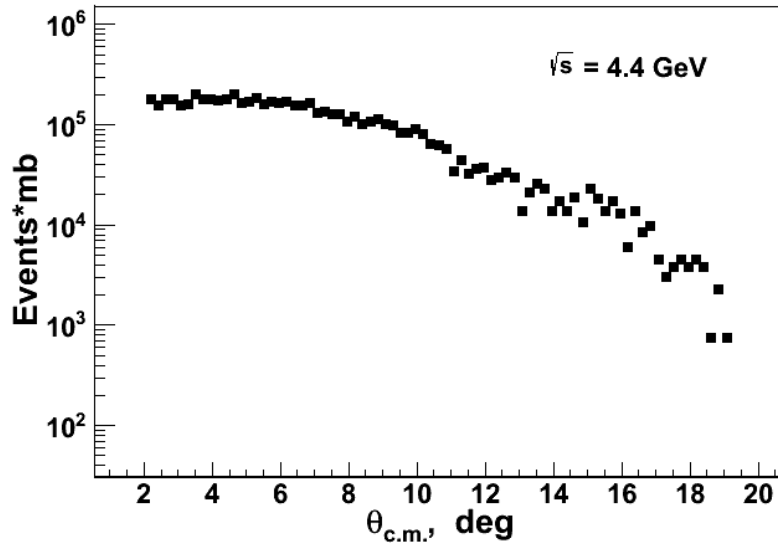
Nucl.Phys.B 166 (1980) 301-320, 1980 .



# PP- and PD- elastic scattering at energies $\sqrt{s} < 27$ GeV

## PP-elastic scattering

Pluto simulation



# Conclusion

- The experiments at Nuclotron with deuteron and proton beams are shown that the measurements of the proton polarization is possible at ITS.
- The modernization of the polarimeter at Nuclotron was proposed to study pp- and pd- elastic scattering at energies 100 – 1000 MeV.
- The pp-detectors are made. The first tests of the detectors on the radioactive source were performed.
- The first stage of the simulation of the PP- and PD- elastic scattering at energies  $\sqrt{s} < 27$  GeV has been performed.

Thank you for attention!