

# Polarization Facilities at the JINR Accelerator Complex

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Polarization facilities are developed at the JINR accelerator complex in the framework of the polarization research program under the NICA project. Those are: the polarized deuteron and proton source SPI, SPI low energy polarimeter and a linac output polarimeter. The status of the above facilities and the results achieved are presented below.

**KEYWORDS:** polarized protons, polarized deuterons, source of polarized ions, polarimeter

## 1. Introduction

The high intensity pulsed source of polarized ions (SPI) has been developed at JINR to inject polarized deuterons and protons into the NUCLOTRON and future collider of heavy and light ions NICA [1]. The SPI is an atomic beam-type polarized ion source with a charge-exchange plasma ionizer and a storage cell in the ionization region [2-4]. To measure the SPI beam polarization, the following low energy polarimeters will be used: SPI low energy polarimeter (SPIRO) and a linac output low energy polarimeter (LEO).

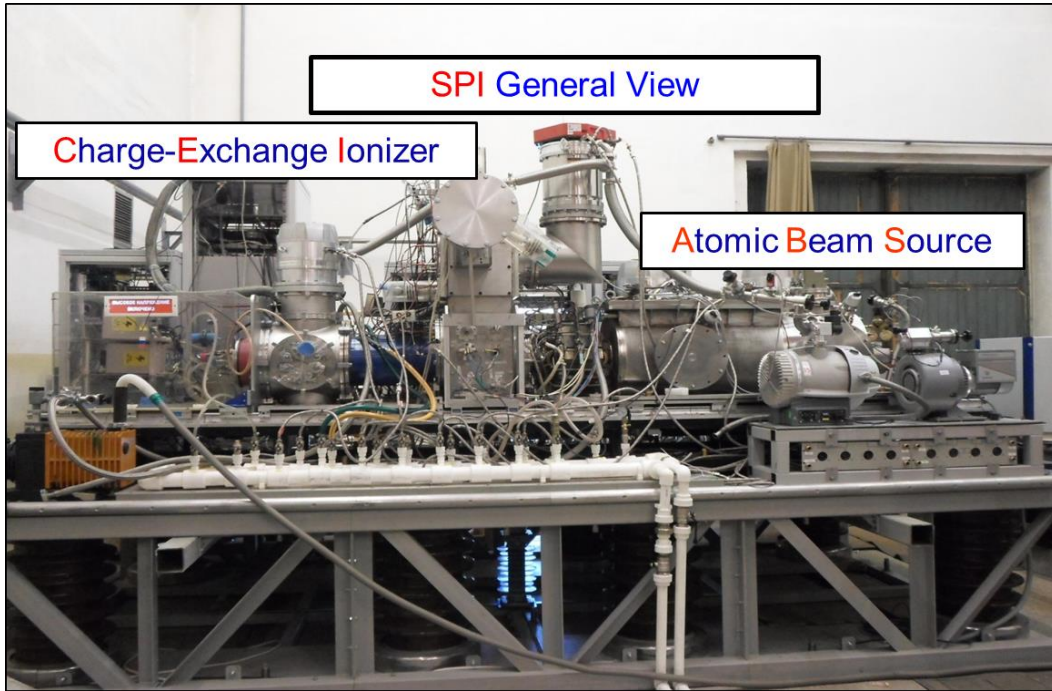
## 2. Source of polarized ions

The test bench installation of the SPI is shown in Fig. 1. The source consists of an atomic beam apparatus, a plasma charge-exchange ionizer and a system of transporting the polarized ion beam and turning the spin to the vertical direction.

When carrying out the runs with the polarized beams, the SPI is located on the high voltage platform and joint with the preaccelerator. The data obtained from the SPI remote control and management systems are readout from the high voltage platform of the Lu-20 linac by means of the fibre-glass system to the linac control room.

After successful runs with the polarized beams of deuterons and protons at the NUCLOTRON in 2016-2017 [5], the work has been continued to achieve the SPI design parameters. The goal of the project is to obtain polarized beams of deuterons and

protons at the output of the source up to 10 mA. At present we have managed to increase the current of the deuteron polarized beam of the SPI facility up to 6 mA.



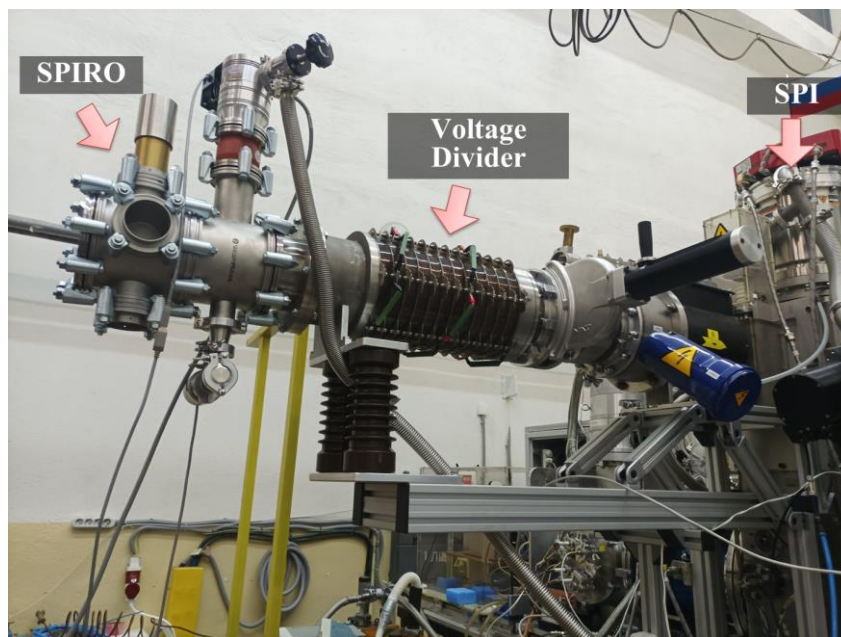
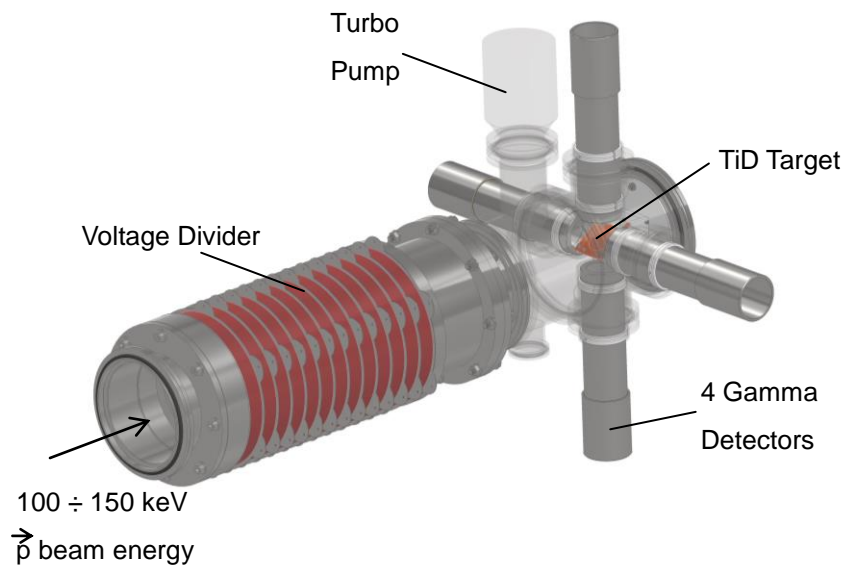
**Fig. 1.** SPI general view.

### 3. SPI low energy polarimeter (SPIRO)

Low energy polarimeter SPIRO has been developed for measuring the proton and deuteron beams polarization directly at the exit of the SPI source of polarized ions. The design and general view of the SPIRO are shown in Fig. 2 for the case of polarized protons, and in Fig. 3 – for the case of polarized deuterons. SPIRO has been designed to work with beam energies from 100 to 150 keV. This polarimeter will make it possible to control the beam polarization and tune the operation of the SPI nuclear polarization cells, as well as to determine the influence of the SPI perturbing devices on the beam polarization.

For polarized protons, it is proposed to use the  $D(p,\gamma)^3\text{He}$  fusion reaction [6] and detect gamma with energy near 5.5 MeV. The deuterated titanium will be used as a target. To make such a target, the titanium is sprayed on the copper plate. After that the deuterium is implanted in it under high pressure. Four GGG (Gadolinium Gallium Garnet) detectors will be used to register gammas. They will be located at the 90 degree scattering angle in up, down, left and right directions relatively to the interaction point. Such a detector scheme allows one to measure the vector polarization of protons and monitor the spin direction. The efficiency of detector's assembly is about 11%. The mean number of gammas produced per bunch (SPI generates one bunch every 5 seconds) at 100 keV and 1mA current, is assumed to be near 0.28.

For polarized deuterons, it is proposed to take the  $D(d,p)\text{T}$  reaction [7,8] having the



**Fig. 2.** SPIRO general view for the case of polarized protons.

same deuterated titanium target. Eight silicon detectors with  $20 \times 20 \text{ mm}^2$  size and  $300 \text{ }\mu\text{m}$  thick will be used to register protons at energies about 2.8 MeV. They will be located at 120 degree scattering angle including the up, down, left and right directions with respect to the interaction point. Such a detector scheme allows one to measure vector and tensor polarization of deuterons and monitor the spin direction. The efficiency of detector's assembly is near 0.52%. The mean number of protons produced per bunch at 100 keV and 1mA current is assumed to be approximately 11000.

It is assumed to test the setup in the near future.

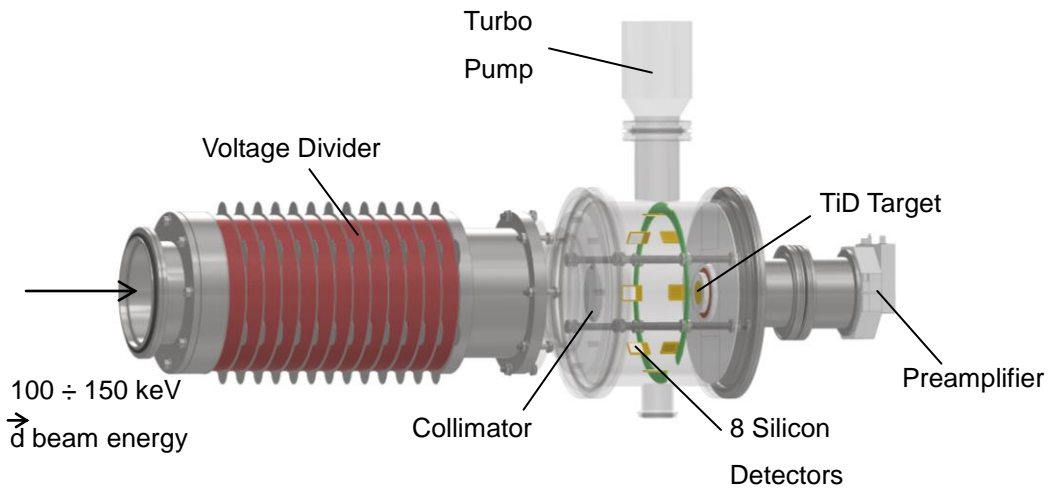


Fig. 3. SPIRO general view for the case of polarized deuterons.

#### 4. Low energy polarimeter (LEO)

Low energy polarimeter (LEO) is placed behind the linear accelerator Lu-20. Its operating energy is 5 MeV per nucleon. The main advantage of this polarimeter is that the setup may be used not only for polarization measuring but also for tuning SPI RF transition units (WFT, MFT, SFT). So, it is an important task to have an up-to-date working low energy polarimeter.

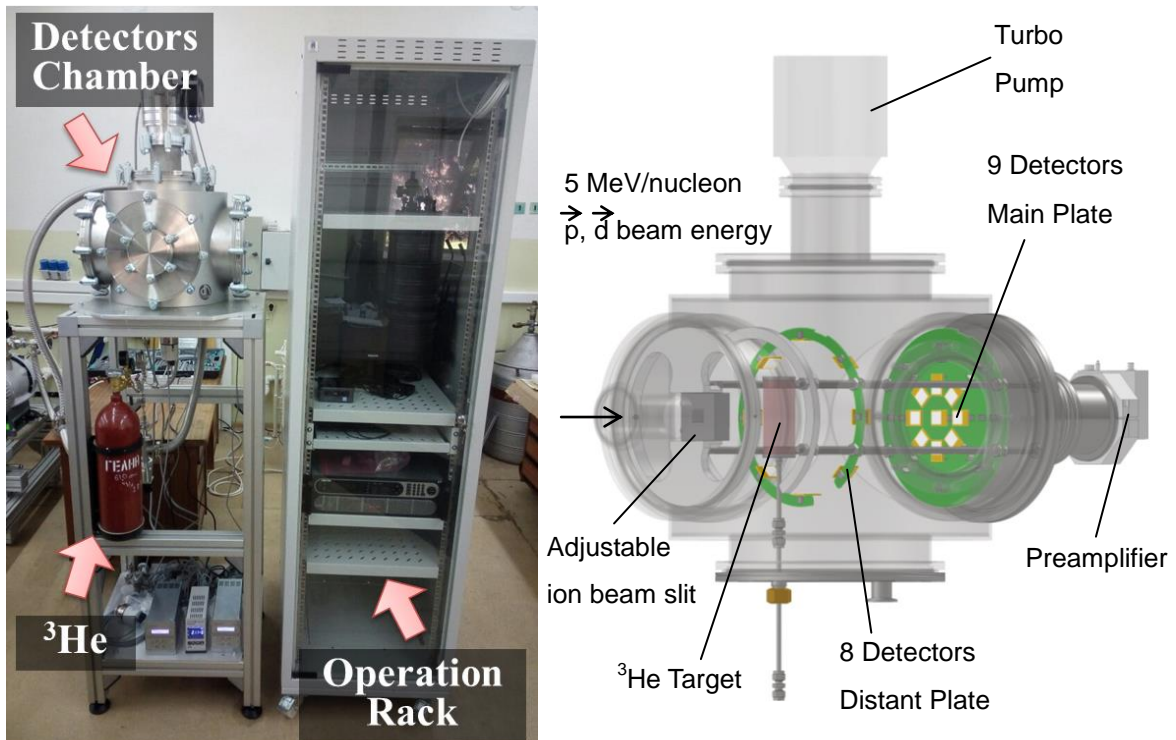


Fig. 4. LEO general view.

Figure 4 shows the general view of the low energy polarimeter LEO. The  $^3\text{He}$  target of this setup enables one to measure both the vector polarization of protons – with  $^3\text{He}(p,p)^3\text{He}$  elastic scattering reaction and the vector and tensor polarization of deuterons – with  $^3\text{He}(d,d)^3\text{He}$  elastic scattering reaction as well as  $^3\text{He}(d,p)^4\text{He}$  nuclear reaction. The main peculiarities of the LEO are:

- Usage of up-to-date fast detectors. It is assumed to measure each bunch polarization.
- The data flow will be protected against electromagnetic noises.
- It is assumed that the design of the polarimeter will make it possible to measure vector and tensor polarization of deuterons with one setup simultaneously. It is necessary because SPI can produce beams polarized in different tensor and vector modes at the same time.
- The dipole magnet will be used to remove the proton component from the deuteron beam. SPI produces mixture of polarized deuterons and  $\text{H}_2^+$  ions. After accelerating in the linear accelerator and passing through the stripping target the unpolarized protons are formed due to the  $\text{H}_2^+$  ion stripping. These protons will be removed by a dipole magnet.

The polarized deuteron or proton beam coming from the linear accelerator goes through the vacuum gate to the dipole magnet. Then going through the chamber with a movable Faraday cup it comes to the detector vacuum chamber. The Movable Faraday cup is applied to monitor beam parameters and it may be removed from the beam direction.

The  $^3\text{He}$  target represents a mylar cylindrical vessel filled with  $^3\text{He}$  gas. The gas absolute pressure is  $\sim 3$  bar. The mylar wall is  $170\ \mu\text{m}$  thick.

Figure 4 demonstrates the detector assembly for the LEO. The detectors will be placed in the vacuum chamber. It is assumed to use silicon detectors with the size of  $20\times 20\ \text{mm}^2$  and  $300\ \mu\text{m}$  thick. The detectors at the remote plate will be taken to measure polarization of the deuteron beam. The detectors at the main plate will be used to measure polarization of the proton beam. This detector scheme allows one to measure not only the 2-dimensional but 3-dimensional beam polarization.

Fabrication of the basic parts of the LEO polarimeter has been completed.

## 5. Conclusion

Taking into account all the above we can conclude that the development of SPI, SPIRO and LEO is rather important. The devices are unique apparatus in the proposed energy range. The fabrication of these setups is coming to its completing stage.

SPIRO and LEO polarimeters will be used to carry out polarization measurements of the deuteron and proton polarized beams in the low energy range. Also they will help to tune the operation of the SPI source. The polarimeters will promote successful runs with polarized beams at the JINR Accelerator complex in combination with high-energy polarimeters in the NUCLOTRON ring, collider NICA and on extracted beams.

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