POLARIZATION AT THE NUCLOTRON

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A spin physics is an important branch of the LHE JINR scientific program.The 200 mcA cryogenic polarized deuteron source POLARIS is used to produce polarized deuteron beam at the JINR 10 Gev accelerator. Commission at the LHE of the new superconductiing accelerator NUCLOTRON gives a good chance to extend spin physics experiments. Simulations show that depolarization resonances are absent under an acceleration of the polarized deuterons almost at all energy range of this accelerator. There is a project to use a polarization technology at the NUCLOTRON, to produce a polarized deuteron beam and develop an internal jet polarized target. It is provided new good possibilities for spin physics experiments. A short review of developments for the NULOTRON ring, at the LHE JINR are presented.

1 Introduction

In 1981 the polarized deuteron beam from the cryogenic source POLARIS has been accelerated at JINR synchrophasotron to 4.5 GeV/nucl. energy. (Fig.1). A spin physics program was started at LHE and successfully continues and essential to day.

Commission of the new superconducting accelerator NUCLOTRON gives a good chance to extend spin physics experiments. Simulations show that depolarizating resonances are absent under an acceleration of the polarized deuterons almost at all energy range of this accelerator [7].

There is a project to use a polarization technology at the NUCLOTRON, to produce a polarized deuteron beam and develop an internal jet polarized target. It is provided new good possibilities for spin physics experiments.

In this project it is supposed to realize the following:
- to modify the cryogenic source POLARIS and to use it as the source of polarized deuterons,
- to develop a new effective charge exchange ionizer, to increase intensity of the polarized beam,
- to install ^3He, ^4He target polarimeters after the linac,
- to develop an internal jet polarized target for spin physics experiments.

Looking for new ways of the increasing luminosity of internal target experiments a study of the ultracold atomic beam production is continued.

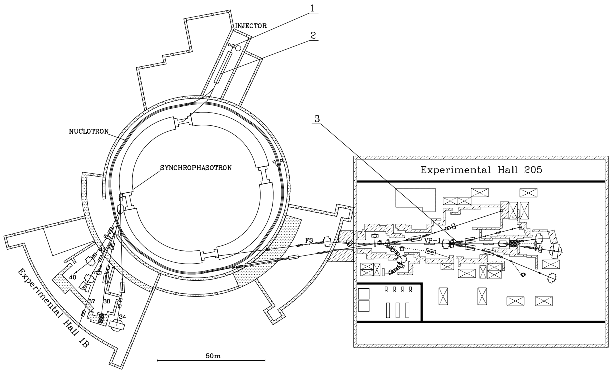

Figure 1: A layout of experimental spectrometers at the synchrophasotron and NUCLOTRON rings. 1 - POLARIS, 2 - 5 MeV/nucleon linac , 3 -two arm polarimeter ALPHA.

2 Cryogenic Source of Polarized Deuterons POLARIS.

Many years the source runs at the JINR 10 GeV synchrophasotron [1,2,3]. It is the atomic beam cryogenic source with superconducting magnets and internal cryopanels for a gas pumping. The atomic beam ionization takes place in into the cryogenic Penning ionizer.

The NUCLOTRON has short one torn injection, so to get a large intensity of the accelerator, a current from the source POLARIS should be increased as high as possible. To increase the current up to mA region a new short pulse charge exchange ionizer is developed [3,4], (Fig.2). Polarized deuterons are produced by change exchange between polarized deuterium atoms and ions of hydrogen plasma $D^0_\uparrow + H^+ = D^+_\uparrow + H^0$ and the ionization of $D^0_\uparrow$ takes place by plasma electrons too.

The fabrication of the new ionizer is over and test bench experiments are started. Using POLARIS atomic beam stage at output of deflecting magnet of the charge exchange ionizer 0.5 mA polarized D^+ beam have been measured. The efficiently of the ionizer is 3-5% instead of 1-2% for the our old Penning ionizer (0.2 mA D^+).

To get advantages of the cryosource the ionizer should be cryogenic too. So we developed a cryoversion of the charge exchange ionizer and did some preliminary tests.

It is a combination of the POLARIS LHe cryostat with 60 mm cold bore superconductive solenoid and H^+ plasma source of the warm charge exchange ionizer. The 1.2 A H^+ current is observed after extracting grids. A vacuum in the cryostat due to cryopumping of hydrogen is 2-4$*10^{-6} mbar$. To improve the vacuum cryosorbshen of hydrogen or pumping of LHe should be released. The study of the setup will be continued.

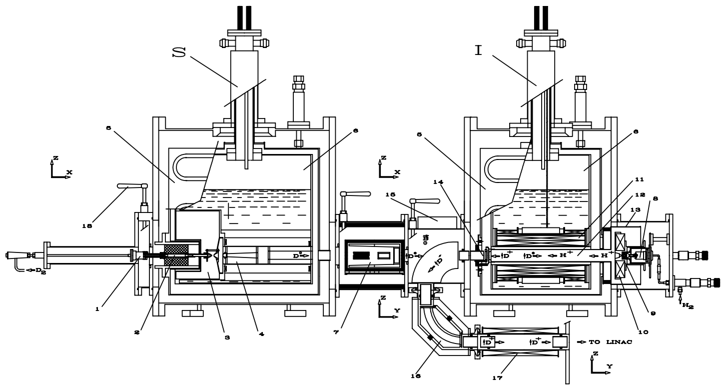

Figure 2: Polarized deuteron source POLARIS, charge exchange ionizer version. S - cryogenic polarized atomic source, I - cryogenic change exchange ionizer. 1 - D_2 gas valve, 2 - dissociator, 3 - nozzle chamber, 4 - SC sextupole magnet, 5 - LN_2 shield, 6 - helium cryostat, 7 - RF cell, 8 - H_2 gas valve, 9 - hydrogen plasma source, 10 - magnetic coil, 11 - SC solenoid, 12 - ionization volume, 13 - HV shield, 14 - extracting grids and forming electrodes, 15 - deflecting magnet, 16 - spherical mirror, 17 - solenoid of the spin-rotator 18 - vacuum gate.

3 Polarimetry

In order to measure vector and tensor polarizations of the beam after the 10 Mev linac, two polarimeters, using ^4He and ^3He targets have been developed [2].
The vector polarimeter will use reaction - $^4He(d\uparrow, d)^4He$. The deuterons, elastically scattered backward (126^0), have a large asymmetry.
The tensor polarimeter will use $^3He(d\uparrow, p)^4He$ reaction. Fast protons, emitted forward (0^0) are counted.
The are two polarimeters to measure the polarizations of high energy deuteron extracted beams too. At the synchrophasatron the polarizations have been the following: $\pm P_z$=0.53 - 0.55, $\pm P_{zz}$=0.7 - 0.76.

4 Pulsed Cryogenic Polarized Atomic Deuterium (Hydrogen) Jet Target.

For internal experiments the pulsed cryogenic polarized atomic beam jet target has been designed and fabricated [5,6]. The target is designed as a cryogenic apparatus with a vertical cryostat with three superconducting sextupole magnets inside (Fig.3). There are three functions of the source cryostat:
- cryopumping of the scattered gas,
- cooling of the superconducting sextupole magnets,
- cooling of the dissociator nozzle.

It allows to design the relatively compact and inexpensive apparatus operating pulsewise.
The cryogenic has many advantages, but there is a specific problem. A vapor pressure of solid hydrogen (compare to deuterium) at 4.2K cryosurface is relatively high ($2 * 10^{-6} mbar$). To get better vacuum the cryosurfaces and turbomolecular pumps should be used.

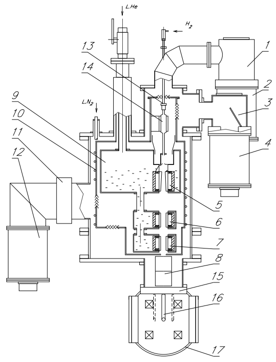

Figure 3: Schematic of the jet. 1,3,11,15 - valves, 2,4,12 - TMP (500 l/s), 5,6,7 - SC 6p magnets, 8 - RF cells, 9 - cryostat, 10 - LN_2 shield, 13 - gas valve, 14 - dissociator, 16 - storage cell, 17 - interaction box.

An atomic hydrogen beam is produced by a 80 MHz RF dissociator and a conical aluminum nozzle (l=10 mm, $\phi 5/2.8$ mm). The atomic beam is formed by a skimmer (ϕ 4.7 mm) and a collimator (ϕ 10 mm).

Spatial spin separation of the atomic beam takes place in the gradient field of three superconducting sextupole magnets. The coils and yoke of the each superconducting magnet are placed inside the cryostat volume and separated from vacuum. Pole tips of the magnet made of FeCoV alloy. The maximum magnetic field at the pole tips are 1.1 T.

To produce a nuclear polarization the target will be equipped with two RF cells. The RF cells will be placed behind the magnets. It allows to operate with the maximum intensity. A choice of the RF cells depends on a particular physical task. The transitions $1 \rightarrow 3$ and $2 \rightarrow 4$ produce two signs vector polarization for hydrogen without a magnetic field reversion in the interaction region. The transitions $1 \rightarrow 4$ and $3 \rightarrow 6$ produce vector polarization for deuterium. The transitions $3 \rightarrow 5$ and $2 \rightarrow 6$ produce two signs tensor polarization for deuterium. It is possible a medium field transition cell can be used.

Some preliminary tests of the target are performed. The measurements of atomic beam intensity are performed by thermal detectors. To match the focusing properties of the magnets and the velocity distribution of the atomic beam a nozzle temperature was scanned over a range of 16-80 K. The optimum nozzle temperature is about 27K. The pulse duration is varied from 0.02 to 1 s. The optimum feed rate at 0.15 s pulse is 0.045 $mbar * l/pulse$ or about 0.3 $mbar * l/s$. The intensities are estimated as: N_D=$5 - 8 * 10^{16} at/s$.

It is an intent to use a storage cell for polarized atoms inside the NUCLOTRON ring. The number of atoms along the beam will reach about $5 * 10^{13} at/cm^2$.

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