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## DEVELOPMENT OF A CRYOGENIC SOURCE OF POLARIZED DEUTERONS "POLARIS"

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## RESUME

Afin d'obtenir un faisceau de deutérons polarisés, une source cryogénique "Polaris" a été développée dans le cadre du programme de recherche du synchrotron de Dubna <sup>1/</sup>.

La source est raccordée à une borne haute-tension du préaccélérateur linac. Un faisceau de deutérons est accéléré dans le synchrotron <sup>2/</sup>. Cette source est actuellement à l'essai. Un polarimètre à cibles <sup>3</sup>He et <sup>4</sup>He a été conçu afin de mesurer la polarisation du faisceau après le linac. Les résultats de ces mesures sont publiés dans ce rapport.

## ABSTRACT

To obtain a beam of polarized deuterons, a cryogenic source "Polaris" has been developed according to the program of research at the Dubna synchrotron <sup>1/</sup>.

The source is installed on a high-voltage terminal of the linac pre-accelerator. A beam of deuterons from the source is accelerated in the synchrotron <sup>2/</sup>. At present the source is being improved. A polarimeter with <sup>3</sup>He and <sup>4</sup>He targets has been developed to measure the polarization of the beam of deuterons after the linac. Results of this work are presented in the report.

1. DESIGN OF THE SOURCE

A cryogenic pulsed source "Polaris" for a beam of polarized deuterons is described in the Proceedings of previous symposia <sup>1,2/</sup>. The design of the source has been changed and improved. A principal diagram of the source is shown in Fig.1.

Recently the problem of increasing the intensity of sources due to cooling an atomic beam to cryogenic temperatures has been of interest <sup>3,4/</sup>. This possibility can be easily realized in a cryogenic source.

Earlier a dissociator and a nozzle of the source "Polaris" were cooled to a temperature of ~120 K as they were attached to a shield cooled with liquid nitrogen. Presently, after the dissociator the atomic flow is supplied to a  $\phi$  3 mm teflon pipe 95 mm long, the end of which has a temperature of 12-38 K at the output depending on the state of contact with a liqued helium cryostat (Fig.1) <sup>5/</sup>. Due to decreasing the temperature of the atomic beam, the aperture and length of pole tips of a superconducting sextupole magnet is changed. The configuration of several versions of the system, their geometrical dimensions, values of ion current

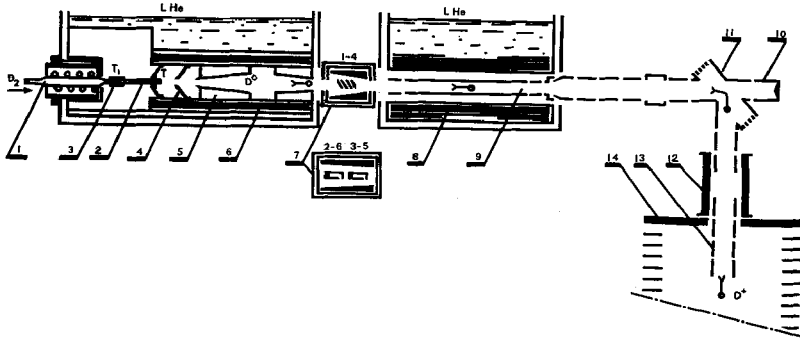


Fig.1. A principal diagram of the source "Polaris". 1 - dissociator, 2 - teflon pipe 3 mm in dia., l = 95 mm and accomodator, 3 - heater, 4 - separator 5 mm in dia, 5 - pole tips:  $\phi_{input} 10/\phi_{output} 18$ ,  $l_1=100$  mm;  $\phi_{input} 20/\phi_{output} 16$ ,  $l_2=70$  mm, 6 - superconducting sextupole, 7 - R.F. transitions, 8 - superconducting solenoid, 9 - ionizer electrodes, 10 - Faraday cup, 11 - electrostatic mirror, 12 - solenoid of the spin-precessor, 13-ion optics, 14-accelerating column,  $T_1=120$  K,  $T = 16$  K.

in relative units and other parameters are presented in Fig.2. As seen, if the atomic beam is additionally cooled, the ion current increases in the case of optimization of other parameters of the system. For chacking, the temperature of the teflon pipe was increased by putting a heater on what led to a decrease of the ion current by a factor of 1.5-2.5. The present design of the system is more simple and compact. It is not required to align the dissociator relative to the sextupole axis.

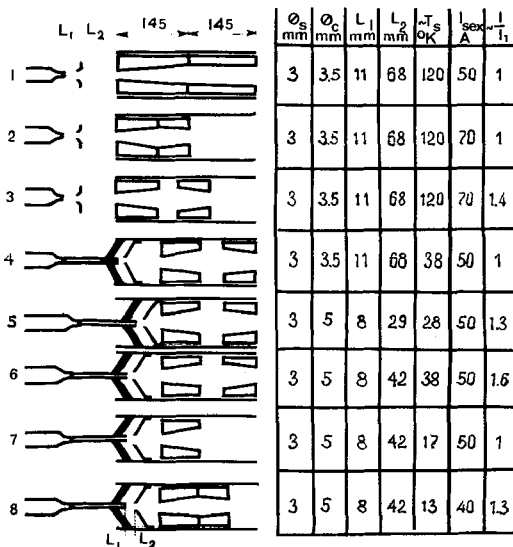


Fig.2. Ion current of the source depending on configurations of the system and temperature of the atomic beam. The apertures of the sextupole are 1)  $\phi_{input}=8$ mm,  $\phi_{output} = 12$  mm; 2-8)  $\phi_{input} 10/\phi_{output} 18$ ,  $\phi_{input} 20/\phi_{output} 16$ . The dissociator temperature,  $T_1$ , is 120 K.  $I/I_1$  is a relative ion current value.

To match the source and the linac, the spin-precessor consisting of a  $90^\circ$  electrostatic mirror and a solenoid (Fig.1) has been developed instead of the Wien filter type precessor used previously. An oscillogram of the ion current after the source is shown in Fig.3. In this case the intensity of the beam at the linac output (5 MeV/nucleon) is  $3 \cdot 10^{10}$  deuterons/pulse.

The atomic beam is ionized in the magnetic field of a Penning ionizer produced by a superconducting solenoid ( $B_{\text{max}} = 7\text{T}$ ). The operating magnetic field is lower ( $B = 2.6\text{T}$ ). Nevertheless, to diminish the influence of a stray magnetic field, it was required to place a double magnetic shield

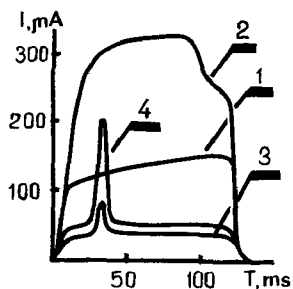


Fig. 3. Signal of the ion current. 1,2 - background and atomic signals measured by the Faraday cup; 3,4 - the same signals measured after the ion optics (13).

round R.F. transitions. The R.F. transitions were designed as boxes with a double shield as well.

Two types of R.F. transitions have been developed:

1) with a weak magnetic field for the transition  $1 \rightarrow 4$  ( $B = 7.5\text{ G}$ ,  $\Delta B = \pm 2.5\text{ G}$  and  $\nu = 7.0\text{ MHz}$ ),

2) with a strong magnetic field and two cavities for the transitions  $2 \rightarrow 6$  ( $B_0 = 40\text{ G}$ ,  $\Delta B = \pm 3\text{ G}$  and  $\nu = 380\text{ MHz}$ ) and  $3 \rightarrow 5$  ( $B_0 = 75\text{ G}$ ,  $\Delta B = \pm 8\text{ G}$  and  $\nu = 325\text{ MHz}$ ).

Static slope magnetic fields of the R.F. transitions are produced by electromagnets and can be controlled. The R.F. transitions have a positive gradient of the magnetic field relative to the beam.

The R.F. transitions, as well as the source dissociator, ionizer electrodes and spin-precessor solenoid, are on pulsewise by means of fiber glass electronics and controlled by a microcomputer<sup>/2/</sup>.

## 2. POLARIMETER

In order to measure vector and tensor polarizations of the beam after the linac, a polarimeter has been developed using reactions  $^4\text{He}(\vec{d},d)^4\text{He}$  and  $^3\text{He}(\vec{d},p)^4\text{He}$  recommended for 12-14 MeV polarimeters<sup>/6-9/</sup>. The polarimeter is schematically shown in Fig.4. The vector part of the polarimeter is placed in the chamber filled with  $^4\text{He}$  under a pressure of 1.0 atm. After the linac, the beam of polarized deuterons is collimated by means of a system of slits. The deuterons, elastically scattered backward ( $\theta_{\text{lab}} = 126^\circ$ ), have a large asymmetry. Not deuterons but recoil  $\alpha$ -particles, emitted at an angle of  $15^\circ$ , were detected in the polarimeter<sup>/7/</sup>. With this aim two silicon detectors  $60\ \mu\text{m}$  thick were used.

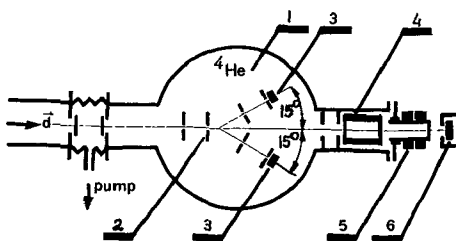


Fig.4. A diagram of the polarimeter. 1 -  $^4\text{He}$  chamber, 2 - system of slits, 3 - detectors for  $\alpha$ -particles, 4 -  $^3\text{He}$  target, 5 - Faraday cup, 6 - detector for fast protons.

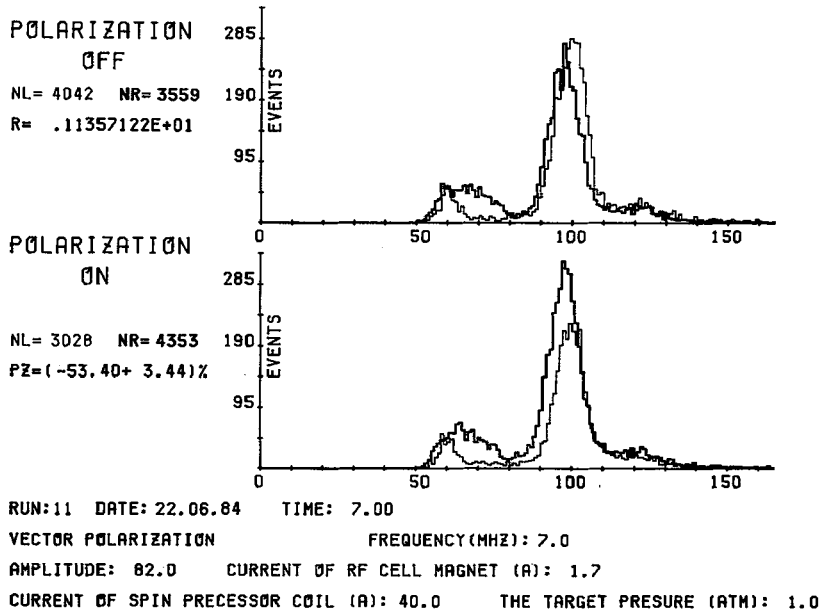


Fig.5. Spectra of recoil  $\alpha$ -particles.

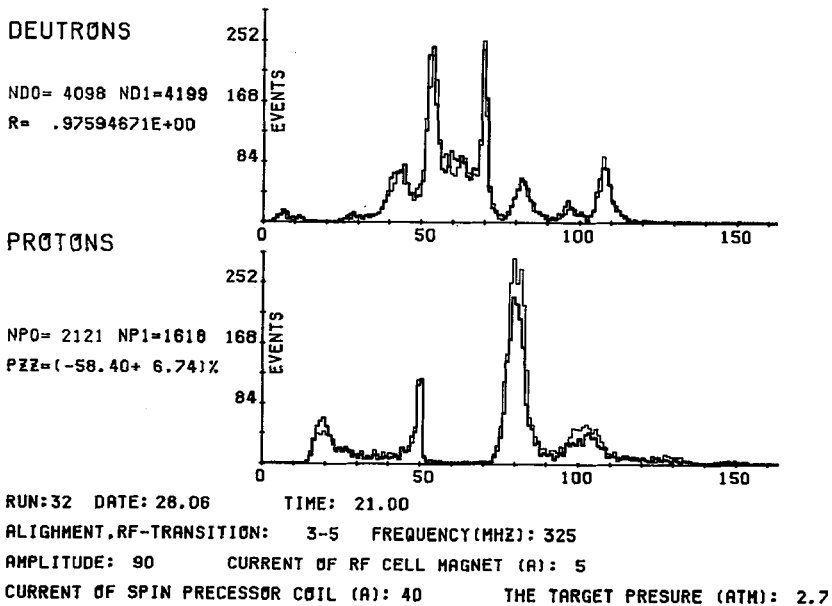


Fig.6. Spectra of fast protons.

The system of slits can be removed. As a result of this, the beam of deuterons interacts with the  $^3\text{He}$  target ( $\phi$  32 mm,  $l$  = 80 mm,  $P$  = 3 atm). The windows of the target are made of mylar 80  $\mu\text{m}$  in thickness. The beam of deuterons, having passed through the target, stops in a Faraday cup 280  $\mu\text{m}$  thick. At the same time the fast protons, emitted forward ( $\theta = 0^\circ$ ) from the  $^3\text{He}(d,p)^4\text{He}$  reaction, pass through the Faraday cup and are counted by means of a detector 2 mm thick or a photomultiplier<sup>9/</sup>. Typical spectra are presented in Figs.5 and 6. The analysing power,  $A_{ZZ}$ , of the reaction is precisely measured for our case<sup>10,11/</sup>.

The vector polarization of the beam of deuterons from the source,  $P_z$ , is  $-0.53 \pm 0.03$ . The spin direction was changed by means of the solenoid of the spin-precessor. The tensor polarization of the beam,  $P_{zz}$ , is equal to  $-0.58 \pm 0.06$ . The measurements were performed for the vertical orientation of the spin ( $\beta = 90^\circ$ ).

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