solitons to azimuthal perturbations.

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Operation of a Polarized ^{3}He Source

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A source of polarized $^3He^{++}$ particles based on the Lamb shift in $^3He^+$ ions is now operating. After axial injection into a cyclotron and acceleration to 33 MeV the on-target beam intensity in a scattering chamber exceeds 0.1 nA. Nuclear scattering experiments together with a study of the source characteristics indicate a beam polarization value of $P = 0.40 \pm 0.05$.

The feasibility of producing a beam of $^3He^{++}$ ions with nuclear polarization was briefly reported in an earlier communication[1] and a proposed design for a polarized source has also been outlined.[2] This source, which is the first of its kind, has now been built and is currently used in nuclear reaction experiments. The present Letter describes its performance in operation with a cyclotron.

In the source, metastable $^3He^+(2S)$ ions are created by the collision of a primary $^3He^{++}$ beam with air molecules in a gas canal. The ions then pass through a strong axial magnetic field of 0.20 T in which Zeeman splitting of the $2S_{1/2}$ and $2P_{1/2}$ states takes place. The lower $2S_{1/2}$ states ($m_s = -\frac{1}{2}$, $m_I = \pm\frac{1}{2}$) are quenched to the short-lived $2P$ states by passage through a rf cavity in which a transverse electric field is excited at a frequency of 10 GHz. After entering a weak-field region in which hyperfine coupling is re-established the remaining metastable beam carries a nuclear polarization $P = 0.50$. The metastable component ($2S$) of the total beam is next ionized, with high selectivity with respect to the large $^3He^+(1S)$ ground-state component, in a second gas canal containing air. There is a fuller description of these processes in Ref. 2.

Among the factors determining the nuclear polarization of the final beam is the efficiency of the electron-transfer processes in the two gas canals. Measurements[1] have shown that the overall efficiency is approximately 0.1%, with a selectivity in excess of 5:1 for $^3He^{++}$ created from $^3He^+(2S)$ compared with $^3He^{++}$ created from the ground state ($1S$). This has been confirmed by detailed measurements[3,4] of the individual cross sections for the main processes in the two gas canals.

There are two main components of unpolarized background beam which must be eliminated from the source. The first is a large $^3He^{++}$ beam due to particles which do not undergo electron transfer in the canals. This is removed in a velocity filter after a preliminary energy reduction with respect to the $^3He^+$ beam between canals. The second is a $^3He^+$ beam due to particles which have only undergone one stage of electron transfer in the canals. This is removed in the cyclotron because the charge-to-mass ratio is not correct for acceleration.

The source has a spin-precessor coil placed in the weak-field region just before the second gas canal. When the transverse field induced by this coil is chosen correctly the electron spin direction can be rotated by 180°. This results in a reversal of the beam polarization sign.

The polarized $^3He^{++}$ ions are produced at an energy of 30 keV which is suitable for axial injection into a cyclotron where they are accelerated to 33 MeV and delivered to a scattering chamber by a conventional beam-transport system. The general arrangements are shown in Fig. 1.

The construction of the source follows closely the design outlined in Ref. 2 and the operational characteristics of the individual components were achieved without any major difficulties. For example, it is clear that the efficiency of the quenching process is high since the beam current is approximately halved when the quenching oscillator is switched on. The velocity filter is also highly effective since the beam current becomes negligibly small when the air supply to the two canals is turned off; the current remains negligible with only the second gas canal turned off. The satisfactory behavior of the magnetic fields in the source can be illustrated by the performance of the spin-precessor coil. The magnetic field due to the coil is only required to provide 180° precession but the field is sufficiently uniform so that when its value is raised to give up to $1\frac{1}{2}$ turns of precession the beam polarization is fully preserved.

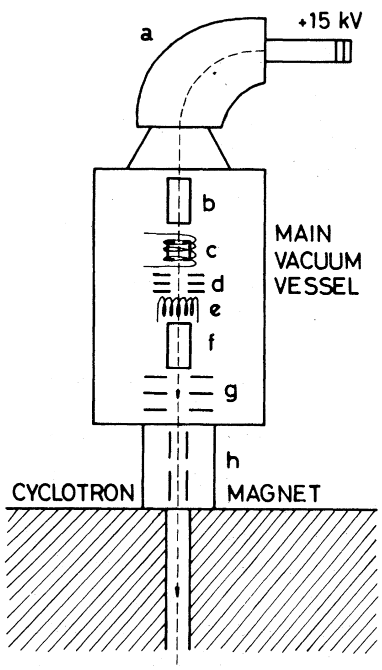

FIG. 1. Sketch of the polarized ^{3}He-ion source. *a*, ion-source magnet selecting the $^3He^{++}$ beam; *b*, first gas canal; *c*, rf cavity with the solenoid; *d*, 1-kV decelerator; *e*, spin-precessor coil; *f*, second gas canal; *g*, velocity filter; *h*, axial-injection lens box.

The transmission characteristics of the system have not yet been explored in detail but for a maximum current of 0.2 nA measured in the scattering chamber, a primary $^3He^{++}$ beam current of about 4 μA at 30 keV is measured just before the first gas canal. These figures are consistent with the previously measured 0.1% efficiency of the electron-transfer processes together with a 5% transmission efficiency for the combined source, axial injection system, cyclotron, and beam transport system.

In order to establish the beam polarization the accelerated beam was scattered by a polyethylene foil and the left-right asymmetry of the recoil protons at 27° (lab) measured. This reaction was also used to investigate the effect of variable source parameters, such as the klystron power, solenoid field, pressures in the gas canals, etc., on the source performance, and later as a continuous monitor of the beam polarization.

However, the ^3He+p scattering is rather unsuitable for determining the absolute value of the beam polarization, since its analyzing power, measured with a polarized ^{3}He target,[5] may be subject to a large systematic error. Thus, the elastic scattering of ^{3}He on ^{4}He was employed by using accurate polarization data[6] from a double-scattering experiment at 13 MeV. The beam polarization value obtained this way is $P = 0.40 \pm 0.05$. The error is mainly due to uncertainties arising from some scattering of the beam by the helium-gas–target window[7] as a result of the required degrading of the energy from 33 to 13 MeV.

The beam polarization measured in the nuclear reaction does not necessarily represent the polarization of the beam produced in the source since the latter may be subject to depolarization processes during acceleration and passage through various electric and magnetic fields in the cyclotron system. On the other hand, the ^{3}He polarization may be predicted by using the cross sections of the atomic processes involved. From the relevant data reported in Ref. 1 it follows that the expected value is between 0.35 and 0.40. Comparing the measured and predicted figures we conclude that no measurable depolarization takes place during acceleration, and in this respect, the polarized ^{3}He is similar in behavior to polarized protons and deuterons.

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Neutron Total Cross Sections on Nuclei from 30 to 270 GeV/c*

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We present results of measurements of the total cross section for neutrons on a variety of nuclei in the momentum range 30 to 270 GeV/c. The measurements were made with the standard transmission technique and have a typical accuracy $\sim 1\%$. The cross sections are compared with theoretical predictions. It is found that a correction for inelastic screening in the nucleus is required. The cross sections are found to vary as $A^{0.77}$ over the entire energy range.

A series of measurements of total cross sections for neutrons on various nuclei (^{2}H, Be, C, Al, Fe, Cu, Cd, W, Pb, and U) in the momentum range 30 to 270 GeV/c has been carried out in a neutron beam at the Fermi National Accelerator Laboratory. In this paper we present the results of the measurements, which are the first in this momentum region. The experimental arrangement is shown in Fig. 1. A previous paper[1] has described the experimental technique, method of data analysis, and our results for n-p total cross sections. Briefly, the standard transmission technique was used in conjunction with a total-absorption calorimeter to determine the neutron energy. Seven circular transmission counters, D_1–D_7, with radii ranging from 1 to 5 cm were placed in front of the calorimeter about 200 m from the target. A 1.25-cm-thick iron converter plate was placed immediately in front of the transmission counters. Charged particles produced by neutron interactions in the iron were then detected by the transmission counters. Partial cross sections were determined for each counter from the ratio of beam transmitted with and without the target. The measured cross sections are independent of the efficiency of the neutron detector, provided the efficiency is the same with target in and out. Great care was taken to ensure this was the case.

Targets could be placed in or out of the beam