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ACCELERATION OF POLARIZED ELECTRONS IN THE 2.5 GEV SYNCHROTRON AT BONN

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Abstract

Polarized electrons have been accelerated in a synchrotron for the first time. The experiments clearly state that acceleration of a polarized beam in a synchrotron is possible without loosing polarization at least up to 2 GeV. Strong depolarization is observed only in narrow energy bands due to imperfection and intrinsic resonances. Careful measurements of a certain imperfection resonance allows to do a very precise absolute energy calibration of the synchrotron.

Polarized Electron Source

A pulsed source of polarized electrons (1) with a repetition rate of 50 Hz has been developed for use at the Bonn 2.5 GeV synchrotron (2). The source is based on the Fano-effect of rubidium i.e. photoionisation of unpolarized alkali atoms with circularly polarized light. A Nd-YAG laser quadrupled in frequency served as the light source with pulse energies of 5-8 mJ at 266 nm. The linear polarized light of the laser is converted to circular by a quarter wave plate.

The RB-oven is built as a recycling system. It permits a running time of two weeks with only 60 g of Rb. The operation is interrupted only for 40 min every 8 hours for the recycling procedure.

The number of photoelectrons extracted from the interaction region was up to 2×10^9 electrons per pulse within 20 nsec. According to the Fano-effect they are longitudinally polarized. The polarization can be reversed from pulse to pulse by changing the circular polarization of the UV-light from left to right hand by rotating the quarter wave plate.

The extracted electrons are accelerated to 120 KeV. Their polarization vector is turned from longitudinal to transverse direction by a Wien-filter. The electron polarization degree is determined by Mott-scattering. The observed polarization was up to $(65 \pm 5)\%$ at 2×10^9 electrons/pulse. During a two weeks run no decrease in polarization was observed.

General Arrangement

The general arrangement of the polarized electron source, the accelerator and the polarimeter is shown in fig. 1.

From the source the polarized electron beam is bent to the linac by two 90° dipole magnets. To focus the beam on the 5 m long way to the linac and to align the polarization vector parallel to the synchrotron guide field four magnetic double lenses and a long solenoid are used. The beam transfer line for the low momentum electrons is screened against the influence of the magnetic earth-field by an iron-shield (μ-metal). Current, position and transversal size of the beam is measured by movable Zinc-sulfid screens and Faraday-cups.

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The beam is preaccelerated to an energy of 20 MeV by a one section linac and then transferred to the

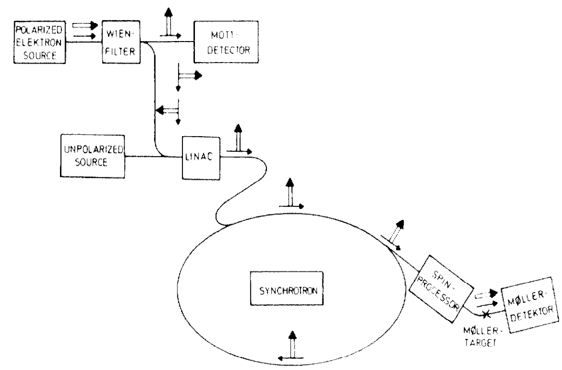

Fig. 1: Schematic diagram of the experimental set-up: production, acceleration and detection of the polarized electrons. The arrows indicate the direction of the momentum vector (→) and the polarization vector (⇒)

2.5 GeV synchrotron. It is 22 m in diameter and accelerates the beam to high energies within a 9 msec time corresponding to 38000 revolutions of the electrons inside the ring. The high energy beam is ejected from the synchrotron by a slow resonant extraction and transferred to the polarimeter to measure its vertical polarization degree. The polarimeter uses the spin dependence of the elastic electron-electron-scattering (Møller-scattering). Upstream of the Møller-target the transversal polarization is converted to longitudinal by deflecting the beam vertically. At present only 2% of the electrons emerging from the source and passing the accelerator and ejection system are reaching the Møller-target. A more detailed description of the experimental set-up is given in our paper (3).

Depolarization Resonances

During acceleration in the synchrotron two different resonance effects may change the polarization of the electron beam (4). Such resonances occur whenever the Thomas-frequency due to the electron's anomalous magnetic moment

$$\omega_T = (eBa)/(mc) \qquad (a=(g-2)/2,\ g=\text{electron g-factor})$$

is an integer multiple of either the cyclotron frequency

$$\omega_C = (eB)/(mc\gamma)$$

or the vertical batatron frequency

$$\omega_B = Q_Z \omega_C \qquad (Q_Z = \text{number of vertical betatron oscillations per turn})$$

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In the first case, the so called imperfection resonances occur at γ-values

$$\gamma = \frac{n}{a}, \; n = 1,2,3...$$

corresponding to electron energies E = n x 440 MeV. These energies are independent of the special magnet configuration of the accelerator. The energy of the second type of depolarization resonances (intrinsic resonances) depends on the periodicity N and the Q_z-value of the accelerator. For the Bonn 2.5 GeV Synchrotron N is 12 and Q_z is 3.4 and therefore only one intrinsic resonance at 1.5 GeV occurs in the feasible energy range.

Results

For the first test, the synchrotron has been run at an endpoint energy of 0.85 GeV, far above 0.44 GeV and just below 0.88 GeV. This allowed to pass fast through the 0.44 GeV resonance and thus limit depolarization.

To optimize the direction of the polarization vector of the electrons at injection the long solenoid in the injection line is used. The polarization of the beam has been measured as a function of the solenoid current. The result is shown in fig. 2. The data are in agreement with the expected sine dependence. In the maximum the primary polarization is maintained for about 80%. At the moment it is not clear whether or not the depolarization is due to the first imperfection resonance at 440 MeV. Perhaps it might be also due to non-resonant depolarization caused by the magnetic lenses of the low energy beam transfer line.

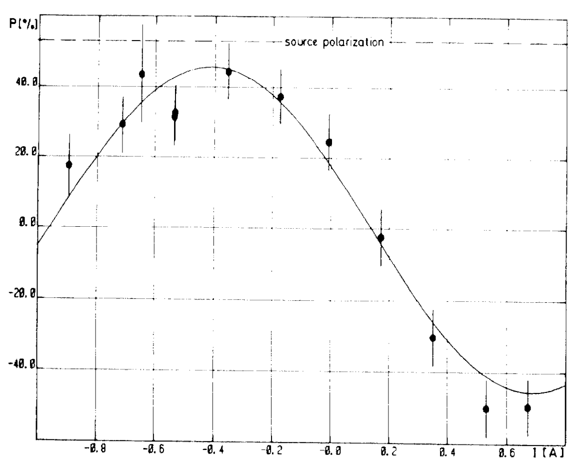

Fig. 2: Polarization of the ejected beam for different orientations of the polarization vector at the entrance of the synchrotron

With the optimum setting of the solenoid current the degree of polarization has been measured at energies between 0.85 and 2.0 GeV. The experimental results are presented in fig. 3 together with fitting curves based on an approximate description of the depolarization[5].

At the resonance energy the sign of the polarization changes sharply between two energy steps followed by a smooth rise to higher energies. This is due to a decreasing resonance crossing time with increasing endpoint energy.

To study the influence of the second and third imperfection resonance as well as that of the intrinsic resonance careful measurements of these resonances have been done. Especially the second imperfection resonance which appears to be the narrowest of all the observed resonances has been studied changing the endpoint energy of the synchrotron in steps down to 0.25 MeV, see fig. 4. The stability

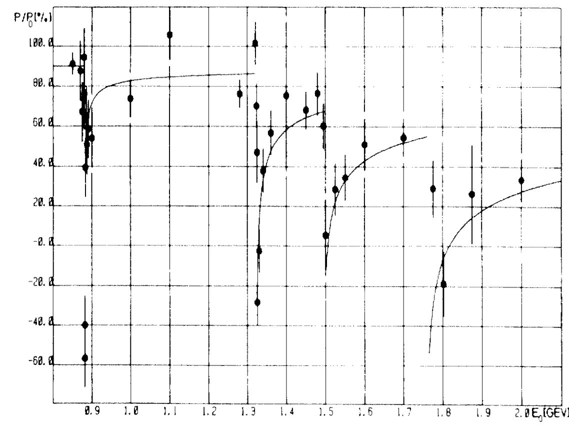

Fig. 3: Ratio of high energy beam polarization to initial polarization at endpoint energies of the synchrotron between 0.85 and 2.0 GeV

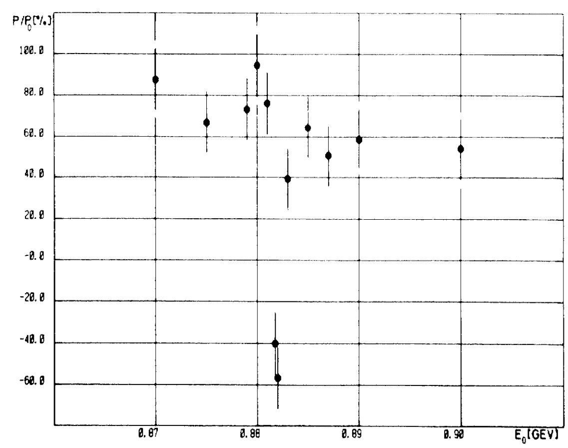

Fig. 4: Ratio of high energy beam polarization to initial polarization in a narrow region around the second imperfection resonance

of the power supplies just permits such a procedure. This measurement of the second imperfection resonance which is located at an energy defined by the value of a = (g-2)/2 only, makes possible a very precise absolute energy calibration of the synchrotron in the order of 10^{-4}.

By these experiments it is stated that a polarized electron beam might be accelerated in a strong focussing synchrotron as the Bonn 2.5 GeV Synchrotron without dramatic loss of polarization disregarding the near neighbourhood of imperfection and intrinsic resonances. The maintained polarization degree depends on the endpoint energy of the synchrotron, i.e. the beam energy.

To produce a high energy electron beam with high polarization degree and sufficient intensity to do elemetary particle physics experiments we intend to minimize depolarization by using pulsed dipoles and quadrupoles similar to the ZGS-scheme(6) and to build a new polarized electron source similar to the Peggy II source at SLAC(7).

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