MEASUREMENT OF BEAM-POLARIZATION IN THE STORAGE RING "PETRA"

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ABSTRACT

The degree of beam polarization in the electron-positron storage ring PETRA will be measured by backscattering circularly polarized photons from an Ar^+-laser. The existence of polarization manifests itself by an up-down asymmetry of the backscattered photons. These photons are emitted due to relativistics kinematics within an angle of ± 30μrad. Due to the small scattering angle of the photons, the detector must be 45 m away from the point where the laser beam and the particle beam interact. Detection is performed by the aid of a total absorbing shower counter. A movable converter in front of the shower counter converts the photon beam so that the counting rates in the upper and the lower plane can be measured in succession.

INTRODUCTION

In electron or positron storage rings the beam is polarized by the emission of synchrotron-radiation. At the moment of injection the beam is assumed to be totally unpolarized, meaning that the number of particles with spin parallel to the magnetic guiding field and the number of particles with spin antiparallel to the guiding field are nearly equal. The emission of the synchrotron-radiation in the bending magnets generally does not flip the spin. The spin direction is only flipped at an amount of 10^{-11} of the total synchrotron radiation power. Spin-transition from ↑ to ↓ and ↓ to ↑ occur. Both these transitions are not equally probable and in the course of time the beam becomes polarized. [1]

The time dependence of polarization is given by the formula

$$P = P_o(1-e^{-t/\tau})$$

wherein P = degree of polarization

$$P_o \approx 92\ \% \ ; \ \tau\ (sec) = 98\ \frac{R^3(m)}{E^3(GeV)}\ \frac{\langle R\rangle}{R}$$

<R> .. average radius of the storage ring,
R ... bending radius of the bending magnets,
E ... energy of the stored beam.

The polarization mechanism is depleted by depolarization effects. Hence, depolarization generally occurs when

$$(\frac{g-2}{2} \cdot \frac{E}{E_o} = n + mQ_z$$

g-2/2 .. anomalous part of the electron magnetic moment
E ..... energy of the electron
E_o ..... rest energy of the electron
Q_z ..... vertical Q-value of the storage ring
n,m ... integers

EXPECTED POLARIZATION AT PETRA

PETRA is a storage ring designed for about 7 to 15 GeV in the first stage. The bending radius is 197.15 m and the average radius is 367 m. According to the aforegoing formulas the polarization time is only less than one hour at energies greater than 10 to 11 GeV. Assuming the lifetime of the stored beam to be about one hour then reasonable amount of polarization is only to be expected at energies above 10 GeV.

The high Q-value of about 22, the high energy of the beam and the relatively high energy of the emitted quanta of synchrotron-radiation [2] will tend to depolarize the beam more than in storage rings working at lower energies than PETRA where polarization effects have already been detected. [3,4]

On the other hand, beam polarization is wanted and knowledge of the beam polarization is important for the study of the influence of the weak interaction in scattering processes between electrons and positrons.

THE PRINCIPLE IDEAS OF THE PETRA-POLARIMETER

The only effect which can be used for the measurement of beam polarization seems to be the spin-dependent backscattering of circularly polarized photons by the polarized particle beam [5]. The system is sketched in fig. 1 and fig. 2. The cavity dumper is triggered by the particle beam bunch. The laser pulse is circularly polarized by a KDP crystal and enters the vacuum chamber via two mirrors. The cross section for scattering in the restframe of the electrons is described by two terms

$$\sigma = \sigma_o + \sigma_{spin}$$

where the first term is spin-independent (see fig. 3)

$$\sigma_o \simeq (1+\cos^2\Theta) + \left(\frac{|\vec{K}_o|}{m_e} - \frac{|\vec{K}|}{m_e}\right)(1-\cos\Theta)$$

K_o .. energy of the incoming photon
K .. energy of the backscattered photo
m_e .. restmass of the electron
Θ .. scattering angle

and the second is spin-dependent

$$\sigma_{spin} \approx \frac{1}{m_e}(1-\cos\Theta)\,\vec{S}\cdot(\vec{K}_o\cos\Theta+\vec{K})$$

$\vec{S}$ .. unity vector in the direction of spin

The term $\vec{S}.\vec{K}$ leads to asymmetry of scattered particles meaning that more particles are scattered into the upper plane of fig. 3 than into the lower plane. The ratio σ_{spin}/σ_o is measured:

$$\sigma_{spin}/\sigma_o \approx \frac{(1/m_e)(1-\cos\Theta)\ \vec{S}\ )\vec{K}_o\cos\Theta+\vec{K})}{1+\cos^2\Theta}$$

The asymmetry ratio increases with K_o. K_o is defined both by the relativistic kinematics and the energy of the incoming photon. The interaction must be head-on.

On the other hand, maximum asymmetry is achieved when $1+\cos^2\Theta$ has a minimum, meaning that Θ is 90 degrees. Transforming this back into the laboratory system, this anlge must be multiplied by a factor $1/\gamma$. so that maximum asymmetry occurs in PETRA (15 GeV) within an angle of the backscattered photons of 30μrad. The interaction between photons and electrons must occur of a position where the natural divergence of the electron beam is smaller than these 30μrad. This condition is only fulfilled in the interaction quadrupoles where the divergence is about 10μrad. The detector must be at a distance of 45 m from the interaction point for two reasons: firstly, at this distance electrons and photons are so far apart that the detector can be installed on the side of the vacuum chamber: secondly, the distance must be so great that the particles being scattered in the upper or in the lower plane can be distinguished. The backscattered γ quantos have energies between 3 and 6 GeV.

The detector is sketched in fig. 4. The energy of the photons is detected by a total absorbing shower counter and a converter. The counting rated in the upper and lower plane are measured in succession. Charged particles are suppressed by a Veto-counter and unwanted uncharged particles beyond the converter by a trigger counter.

STATUS REPORT

PETRA began operating in the summer of 1978. Until present beams up to about 5 mA at energies between 5 and 7 GeV have been successfully stored and with these beams the first tests of the polarization monitors have been performed. Fig.5 demonstrates the horizontal beam profile of the electron beam measured by back-scatterering the laser photons. When PETRA reaches reasonable currents at energies near 10 GeV, hopefully within the next weeks, the first attempts to measure beam-polarization will be made.

REFERENCES

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3. J. Le Duff, P.C. Marin, J.L. Masnou, M. Sommer, Measurement of Beam Polarisation in the Orsay Colliding Beam Ring A.C.O. Rapport Technique, 5-72, Institute National de Physique Nucleaire

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4. Report of the SPEAR polarization group at this meeting.
5. F.W. Lipps and H.A. Tolhoek, Polarization Phenomena of Electrons and Photons, Physica XX (1954) 85-98.

FIGURE CAPTIONS

Fig. 1: Laser beam-electron beam interaction region. In this drawing the laser is seen to be in the paper plane and is in reality perpendicular to the paper plane.
Fig. 2: Path of the electron- and the gamma beam
Fig. 3: Definition of the scattering angle
Fig. 4: Detector arrangement
Fig. 5: Beam profile measured by backscattering the laser photons.