DEPOLARIZATION OF A STORED PROTON BEAM IN PRESENCE OF AN INTERNAL GAS TARGET

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This experiment is a part of the A-region activities by the PINTEX collaboration. Its aim is the investigation of a possible depolarization of the stored polarized proton beam in presence of an internal gas target. The proposed depolarization mechanism is based on a coupling to a nearby depolarizing resonance. Depolarizing resonances occur at discrete beam energies when the precession frequency of the magnetic moment of a stored particle is an integer multiple of the frequency of some nonvertical perturbing field. The depolarization mechanism is coupling to an intrinsic resonance (caused by transverse field components of focussing quadrupoles). The precession frequency $G\gamma f_{orb}$ of the magnetic moment of a proton (G = 1.793) is for these resonances synchronous with the vertical betatron frequency $\nu_z f_{orb}$. For particles on the stable orbit, a nearby intrinsic resonance has no effect. Particles not on the stable orbit carry out betatron oscillations of amplitude $z = (\epsilon\beta_z)^{-1/2}$, where ϵ is the particle emittance and β_z the vertical betatron function. For such a particle the spin closed-orbit vector is tilted away from the vertical direction by an angle $\alpha = (\Gamma/\delta)\sqrt{\epsilon/\epsilon_{ref}}$, where Γ is the strength of the closest intrinsic resonance, evaluated at an emittance ϵ_{ref}, and $\delta = |G\gamma - \nu_z \pm m|$ with m an integer, chosen to make δ as small as possible.

If a proton on the stable orbit is scattered by a target atom but remains within the acceptance of the storage ring, its trajectory is suddenly bent away from that orbit and the particle undergoes betatron oscillations. As mentioned above, the spin closed orbit is now tilted away from the vertical direction by an angle α. The direction of the magnetic moment of that proton remains vertical. Only the projection on the tilted spin closed orbit is conserved, resulting in a partial loss of vertical polarization of $\Delta P/P = \alpha^2$, or, in terms of the scattering angle Θ_z,

$$\frac{\Delta P}{P} = -\frac{\Gamma^2}{\delta^2}\frac{\beta_{z,T}}{\epsilon_{ref}}\Theta_z^2. \tag{1}$$

The polarization loss due to many scatterings is *cumulative.* To calculate the depolarization per unit time, Θ_z^2 has to be replaced by $F(\Theta)$, with

$$F(\Theta) = d \cdot f_{orb} \cdot 2\pi \int (\theta\cos\Phi)^2 \frac{d\sigma}{d\Omega}\sin(\theta)d\theta, \tag{2}$$

where d is the target thickness, f_{orb} the orbit frequency, and Φ the azimuthal scattering angle with $\Theta_z = \Theta\cos(\Phi)$. Averaging over Φ gives $\langle\cos^2(\Phi)\rangle = 1/2$. We assume $\Theta \ll 1$, and set $d\sigma/d\Omega = \sigma_0/\Theta^4$ for Rutherford scattering. Then $F(\Theta)$ becomes

$$F(\Theta) = (\pi \cdot d \cdot f_{orb} \cdot \sigma_0) \cdot \ln\left(\frac{\Theta_{max}}{\Theta_{min}}\right). \tag{3}$$

The largest possible scattering angle without loss of the particle is determined by the ring acceptance A, namely $\Theta_{max} = (A/\beta_z)^{1/2}$. The so-called Coulomb logarithm $C = \ln(\Theta_{max}) - \ln(\Theta_{min})$ depends only weakly on the limiting angles.

Assuming a beam of small emittance, beam loss is given by the scattering rate with angles larger than Θ_{max}, and we can relate the beam lifetime τ to the target thickness by

$$(\pi \cdot d \cdot f_{orb} \cdot \sigma_0) = \frac{\Theta^2_{max}}{\tau}. \tag{4}$$

Combining the equations for beam lifetime τ (Eq. 4) and the beam depolarization (Eq. 1) yields

$$\frac{1}{P}\frac{dP}{dt} = -\frac{\Gamma^2}{\delta^2}\frac{A}{\epsilon_{ref}} \cdot C \cdot \tau^{-1}. \tag{5}$$

The experiment intends to measure this dependence of beam depolarization on the beam lifetime by measuring the depolarization parameter $\xi = (1/P) \cdot dP/dt$ for several different beam lifetimes. Different beam lifetimes are achieved by adjusting the target thickness.

The experiment makes use of the A-region target and detector setup described elsewhere. A first experimental period designed to determine a suitable method for the measurement was carried out in July, 1995. Two possible scenarios for the final measurement, planned for summer 1996, were investigated.

During the first part of this beam time, the beam polarization dependence on the beam lifetime was measured by using the A-region target cell with an unpolarized hydrogen target. The polarization was determined from the known analyzing power of pp scattering. This method was found to be limited by count rate capability in the A-region detector system. Because of this limitation, it was not possible to reduce the beam lifetime sufficiently to make a quantitative measurement of the depolarization parameter.

An alternate approach makes use of a thinner target in the A-region of the Cooler. To compensate for the associated lower count rate, one would like to use a target with higher analyzing power. By using a polarized hydrogen target in the A-region, one can use the large values of spin-correlation coefficients. In particular, the values of $A_{xx} - A_{yy}$ are large over the whole acceptance of the detector system ($A_{xx} - A_{yy} \approx 1.6$). It is well established from earlier measurements that the target polarization Q is very stable over a long time (days), which allows the determination of the time dependence of the beam polarization P (measurement of $P \cdot Q \cdot (A_{xx} - A_{yy})$). This scenario needs an additional target to reduce the beam lifetime, because the thickness of the A-region polarized target is limited by the output of the polarized atomic-beam source, and thus can not be adjusted. The T-region unpolarized gas jet target presents an instrument to adjust the beam lifetime. The model of depolarization is valid for interactions anywhere in the ring, such that by having two targets in the ring, the total target density contributing to the depolarization is a sum over the losses occurring in both targets. During a first test of this method, every cycle was divided into 3 phases. In Phase 1 only the polarized target in the A-region was used to measure the initial beam polarization. During phase 2 a thick H_2 target was put into the T-region to enhance the depolarization effect. And finally, phase 3 again used the polarized target in A to measure the remaining polarization.

A comparison of these scenarios favors the method using a thin polarized hydrogen target in the A-region as a polarimeter and an additional unpolarized gas target in the T-region to reduce the beam lifetime to the desired value. The final data run planned for summer 1996 will use this method with a N_2 target in the T-region. To improve the statistics, it is planned to measure in the A-region simulataneously with the insertion of the N_2 target in the T-region instead of using the three phase cycles described above. The aim is to measure the depolarization parameter for 3 to 4 different beam lifetimes.

POLARIZATION BUILD-UP OF A STORED PROTON BEAM BY INTERACTION WITH A PURELY ELECTRON-POLARIZED DEUTERIUM GAS TARGET

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It was shown in an experiment at the Test Storage Ring at Heidelberg in 1992 that an initially unpolarized stored beam of protons can be polarized by interaction with a polarized gas target. Since the spin-dependent attenuation is different for proton and target spins parallel ($\uparrow\uparrow$) and antiparallel ($\uparrow\downarrow$), one of the two initially equally populated spin-states of the beam is depleted more strongly than the other one. The effect was measured using a polarized hydrogen storage-cell gas target and a beam of 27-MeV protons stored in the TSR. At that energy the total polarizing cross section was determined[1,2] to be $\sigma_1 = 72.5 \pm 5.8$ mb. The total hadronic polarizing cross section for that process is 122 mb. A reason for the discrepancy between experiment and first order theoretical predictions was not identified at the time.

More recently, Meyer and Horowitz provided an explanation for the observed large discrepancy.[3,4] Three distinct spin-dependent mechanisms were identified that contribute to the result measured at Heidelberg. First, it is not correct to take into account only strong interactions for particle removal by scattering at angles larger than the acceptance angle of the storage ring, because there is a significant contribution from Coulomb-nuclear