LONGITUDINALY POLARIZED ELECTRONS AT AmPS

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Abstract

This report presents a current status of the polarized beam facility and measurements of the radiative effects in electron polarization at the AmPS storage ring.

1 Introduction

AmPS is an electron storage ring with a maximum energy of 900 MeV [1]. The machine is equipped with one internal target and dedicated to nuclear physics experiments. To enrich the physical program by experiments with polarized internal targets and longitudinaly polarized electrons joint efforts by NIKHEF and Budker INP were taken during last few years to develope, install and maintain the Polarized Electron Source (PES), Siberian Snake and Compton Backscattering Polarimeter.

2 Polarized electron source

The longitudinaly polarized electrons are extracted by a 100 KV pulse voltage from a strained GaAr(P) photocathod illuminated by 2.5 msec Ti:Sapphire laser light [?]. At present we obtain a beam current density of about $4A/cm^2$ with the polarization degree of 73%. The cathod life time is about 200 hours without a reactivation. To prepare a new cristal there is a special prechamber with two manipulators and other tools. About 20 minuts are required for the cathods replacement. PES includes also a so called Z-manipulator with two electrostatic bends and a number of solenoids to control the spin direction and the Mott polarimeter. Then after a bunching in a two cavities section, the electrons are accelerated in the main linac up to 700 MeV and injected into the ring with the snake on.

3 Siberian Snake

According to the Siberian Snake concept [2] the longitudinal beam polarization in the internal target area can be obtained by locating the snake at the opposite azimuth of the target. In this case a periodical solution of the BMT equation $\hat{\mathbf{n}}_\mathbf{0}$ lies in the horizontal plane (outside the snake) and has some energy dependent angle $\pm\phi$ to the closed orbit on the snake edges. The straight section suitable for the snake insertion is used also for the beam injection and there is only 4.7 m free space between two vertical kickers. Finally for the AmPS a mirror-symmetrical scheme was chosen with two superconducting solenoids (B = 6.5 T), four skew-quadrupoles and one cenrtal quadropole [3]. Total integral of the longitudinal magnetic field B is approximately equal to the half integral of the main guiding field H ($g \int Bdl = 2\pi HR$, where g is the electron's g-factor). A transport matrix of the snake-insertion is equivalent to the drift space which the snake occupies (4.7 m), with the exception that the matrix block of x-motion has a negative sign. To compensate for this additional horizontal tune shift of 0.5, strengths of the quads at three other straights have been changed with negligible optics disturbtions in all other places.

4 Spin matching and polarization life time

The simplest spin matching of the injected beam requires to deliver the beam polarization along the $\hat{\mathbf{n}}_\mathbf{0}$ from PES to the injection. It can be optimized by a tuning the Z-manipulator to a maximum of the beam polarization measured by the Compton polarimeter. A more complicated spin matching is needed to minimize the radiative depolarizing effects [6].

After the beam injection with an initial polarization degree P_0, it will decay $P(t) = (P_0 - P_{eq})\exp(-t/\tau) + P_{eq}$ with the spin relaxation time τ to an equilibrium level P_{eq} given by DK formula [4]:

$$P_{eq} = -\frac{8}{5\sqrt{3}}\frac{\alpha_-}{\alpha_+}; \quad \tau^{-1} = \frac{5\sqrt{3}}{8}\lambda_c r_0 c \alpha_+ \gamma^5$$

where

$$\alpha_- = \left\langle \frac{\hat{\mathbf{b}}}{|\rho|^3}\left(\hat{\mathbf{n}} - \hat{\mathbf{d}}\right)\right\rangle; \quad \alpha_+ = \left\langle \frac{1}{|\rho|^3}\left(1 - \frac{2}{9}(\hat{\mathbf{n}}\hat{\mathbf{v}})^2 + \frac{11}{18}|\hat{\mathbf{d}}|^2\right)\right\rangle$$

Here $\hat{\mathbf{n}}$ is a phase space dependent spin solution, vector $\hat{\mathbf{d}} = \gamma\dfrac{d\hat{\mathbf{n}}}{d\gamma}$ is the partial derivative of the $\hat{\mathbf{n}}$, ρ is the orbit bending radius, $\hat{\mathbf{v}}$ and $\hat{\mathbf{b}}$ are the unit vectors in the direction lies nearby the horizontal plane in the dipole magnets, therefore the Sokolov-Ternov polarizing mechanism (the first term in the expression for α_-) does not work. On the other hand, the vector $\hat{\mathbf{d}}$ has a vertical component in the dip provides a so-called "kinetic mechanism" of a self-polarization. Depolarization of the beam is caused by quantum emission of the synchrotron radiation, the term $|\hat{\mathbf{d}}|^2$ in the expression for α_+ gives the largest contribution. The values of the vector function $\hat{\mathbf{d}}$ were computed by the ASPIRRIN code [5]. Here we only remark that the spin relaxation time τ and the equilibrium polarization P_{eq} depend on the energy and the horizontal betatron tune. The best spin matching is when the snake has reversed polarities of all the quads. It gives much longer depolarization time than the reference version [6]. A disadvantage of this variant is only in a need to reverse polarity of the injection kicker.

activity at AmPS. Stacking of a 150 mA polarized beam current is a routine procedure now, and so are the beam polarization measurements with the Compton Backscattering Polarimeter [?]. At the energy of E=720 MeV the maximum initial polarization $P_0 = \pm 63\%$. A few runs were done to measure P_{eq} and the spin relaxation time τ at this energy with the regular betatron tune. ASPIRRIN's predictions for these conditions are: $P_{eq} = 6.5\%$ and $\tau = 6500$ sec. The measurements of the time dependence of the beam polarization for three different initial polarizations (+ 63%, 0 and - 63%) indicated a qualitive agreement with the DK-formula's predictions. That is the first evidance that the kinetic polarization mechanism works. To obtain more accurate comparison of the measurements with the DK-formula it's very desirable to optimize the experimantal conditions to a higher value of P_{eq} and to improve the systematics of the polarimeter.

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