Possibility of Polarized Proton Acceleration in KEK PS

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There are some estimations for the depolarization resonance of polarized proton beam during the acceleration in KEK 12 GeV PS.[1] However, these give only qualitative results. Thus we calculated the depolarization by the intrinsic spin resonance (due to betatron oscillation) and the resonance due to the closed orbit distortion (COD), quantitatively.

It is well known that the depolarization resonance occurs at $\gamma G \pm \nu_z + n = 0$ for the intrinsic resonance and $\gamma G + n = 0$ for the resonance due to COD, where γ is the relativistic factor, ν_z the wave number of vertical betatron oscillation, $G = g/2-1$ the anormalous gyromagnetic ratio, and n is an integer. In KEK PS there are 11 intrinsic resonances and 22 resonances due to COD. The polarization after passing through the n-th intrinsic resonance is given as[2]

$$P_f = P_i[2\exp(-a_n)-1], \tag{1}$$

where P_i is the initial polarization and a_n is given by

$$a_n = \frac{\pi|E_n|^2}{\omega_0(\dot{\gamma}G \pm \dot{\nu}_z)}, \tag{2}$$

where E_n is the resonance strength and ω_0 is the angular frequency of revolution. Eq.(1) represents that the spin flips for $a_n > 0.693$.

Fig. 1 shows the depolarizations $\Delta P/P_i = 2[1-\exp(-a_n)]$ at intrinsic resonances, in which the polarizations are averaged over the beam emittance. The total depolarization is 99.9 % during the acceleration from 500 MeV to 12 GeV in the usual operation of KEK PS ($\dot{\nu}_z \simeq 0$). To accelerate the polarized proton, we must choose the adequate value of a_n by choosing $\dot{\nu}_z$ (ν-jumping method). For the case that $\dot{\nu}_z \simeq \mp\dot{\gamma}G$ to increase a_n, we call "slow passage". On the other hand if $|\dot{\nu}_z| \gg \dot{\gamma}G$ to decrease a_n, we call "fast passage". These methods are schematically shown in Fig. 2. Applying the slow passage to the strong resonances and the fast passage to the weak resonances, we obtain the results of depolarizations as shown in Fig. 3, in which the total depolarization is less than 19.3 %. In order to apply the ν-jumping method successfully, 4 or 8 quadrupole magnets must be installed additively in PS. The operations of those fields are very critical and difficult but we think that is possible.

Fig. 4 shows the depolarizations arising from the resonances due to COD. In this calculation we use the statistical expectation values of the harmonic amplitudes of COD under the assumption of $\langle z_{COD}\rangle_{rms} = 0.5$ mm.[3] This result shows that the depolarization is less than several % for the resonances due to COD except for 4 resonances at T = 4.8, 6.9, 9.0 and 11.1 GeV. It is possible to avoid these depolarizations by increasing the harmonic amplitude of COD near the betatron wave number to about 3 mm, in this case the spin flips at these resonances. In order to control COD in such manner, it is necessary to improve the correction magnet system for COD which consists of 28 dipoles.

References

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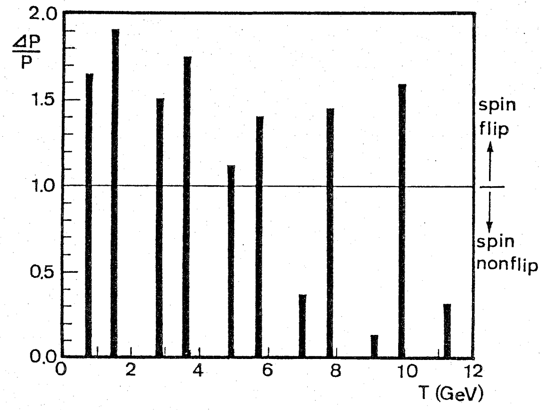

Fig. 1 Depolarizations by the intrinsic spin resonances. ΔP/P=0 means non-depolarization, ΔP/P=1 complete depolarization and ΔP/P=2 complete spin flip in which depolarization does not occur.

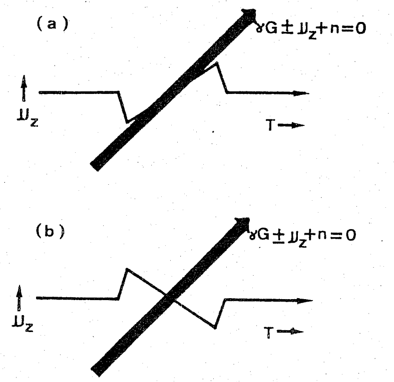

Fig. 2 Schematics of ν-jumping methods. (a) Slow passage. (b) Fast passage.

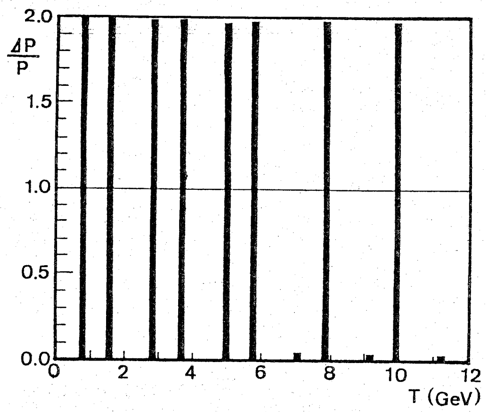

Fig. 3 Depolarizations in which ν-jumping method is applied.

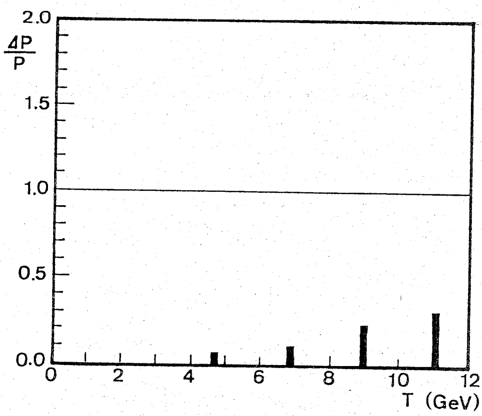

Fig. 4 Expected depolarizations by the spin resonances due to COD. $\langle z_{COD} \rangle_{rms}$=0.5 mm is assumed.