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Polarized Proton Experiment in the AGS with a Partial Snake

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ABSTRACT

In three polarized proton runs at the AGS it was recently shown that the imperfection depolarizing resonances in the AGS can be overcome with a 5% partial snake and the intrinsic depolarizing resonances could be jumped with the pulsed tune-jump quadrupoles even in the presence of the partial snake. For the first time polarized proton beam was accelerated up to the required RHIC injection energy of 25GeV. No polarization was lost due to the imperfection resonances and the depolarization from most intrinsic resonances was avoided with the tune-jump quadrupoles. However, significant amount of polarization was lost at $0+\nu_y$, $12+\nu_y$ and $36+\nu_y$, which is believed to be partially due to coupling resonances. A novel energy-jump method and other new schemes to overcome the coupling and intrinsic resonances are discussed.

Traditionally, the imperfection depolarizing resonances are compensated with the tedious harmonic correction method and the intrinsic depolarizing resonances are overcome with tune-jump method. The polarized proton runs of experiment E-880 at the AGS aim to demonstrate the feasibility of polarized proton acceleration using a 5% partial Siberian snake[1]. In the first run in April 1994 it was shown that a 5% snake is sufficient to avoid depolarization due to the imperfection resonances[2]. The results are shown in Fig. 1 as open circles and dashed lines. The pulsed tune-jump quadrupoles were not powered in this run. Although some depolarization at intrinsic resonances are expected, the level of the depolarization does not agree with a simple model calculation. A spin tracking study was then performed and it showed that there is an extra resonance adjacent to the intrinsic resonance which causes further depolarization. Since the solenoidal 5% partial snake introduces considerable linear coupling between the two transverse betatron motions, the vertical betatron motion has a component with the horizontal betatron

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frequency. As a consequence, the beam will see an additional resonance, the so-called coupling resonance. Synchrotron motion also causes some additional depolarization.

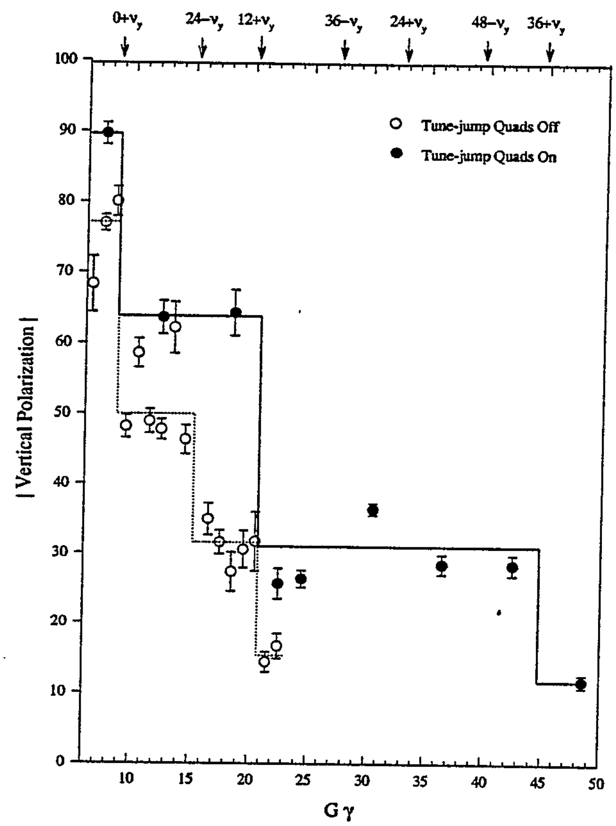

Figure 1: Results of AGS partial snake test.

The second run in December 1994 showed that it is possible to use the tune jump method in the presence of the partial snake. A new record high energy for accelerated polarized proton beam of 25GeV was reached with about 12% beam polarization left. Again no polarization was lost due to the imperfection resonances and depolarization from most intrinsic resonances was avoided with the tune jump quadrupoles. However, as can be seen from Fig. 1, significant amount of polarization was lost at $G\gamma = 0 + \nu_y, 12 + \nu_y$ and $G\gamma = 36 + \nu_y$. The first two of these three resonances were successfully crossed previously when the partial snake was not installed. It is believed that the losses are partially due to the coupling resonances. The tune jump method changes the vertical betatron tune within less than one revolution to effectively make the resonance crossing speed very fast. However, the coupling resonance is still crossed at the normal crossing speed and can cause polarization loss. The strength of the tune jump quadrupoles is not sufficient to jump the last resonance $G\gamma = 36 + \nu_y$. Instead, we attempted to induce spin flip at this resonance but were only partially successful. This is again due to the coupling resonance and the observed large momentum spread at this high energy.

The ratio of the coupling resonance strength to the intrinsic resonance strength with a 5% partial snake and 0.1 unit tune separation, used for the two 1994 runs, is about 0.07. This ratio makes it impossible to cross both resonances without depolarization from the coupling resonance and full spin flip at the intrinsic resonance. A novel energy-jump method was used to cross the coupling resonance and the results are summarized in Fig. 2. In the experiment, an acceleration rate which was only 5% of the regular one was used to induce full spin flip at the intrinsic resonance $G\gamma = 0 + \nu_y = 8.8$, while an energy-jump at about half of the regular acceleration rate was generated to cross the coupling resonance at $G\gamma = 0 + \nu_x = 8.6$. The energy-jump was accomplished by rapidly changing the beam circumference by 88 mm using the powerful AGS rf system. Because of the large momentum spread of the beam indicated as a hashed band in the lower part of Fig. 2, not all the beam particles are crossing the resonance during the jump unless the jump timing is carefully adjusted. From the beam momentum distribution, the ratio of the final to the initial polarization as a function of jump timing T_{jump} can be predicted and is shown as the solid line in the top half of Fig. 2. It shows good agreement with the data. It clearly demonstrates that the novel energy-jump method can successfully overcome coupling resonances and weak intrinsic resonances.

Another novel scheme of overcoming intrinsic resonances is to use a rf dipole[3]. Full spin flip can be achieved with a stronger artificial rf spin resonance excited by a rf dipole at a modulation tune ν_m. If we choose the rf spin resonance location $K_{rf} = n \pm \nu_m$ near the intrinsic spin resonance, the spin motion will be dominated by the rf resonance and the spin near the intrinsic resonance will adiabaticlly follow the spin closed orbit of the rf spin resonance. With the rf dipole, a new dominant resonance near the intrinsic resonance is introduced, instead of enhancing the intrinsic resonance and also the coupling resonance strength, as has been proposed earlier[4]. Spin tracking studies for the AGS ring have indicated that this scheme should work. A more sophisticated scheme is to use an rf dipole and a series of octupoles to induce full spin flip. The advantage of this latter scheme is a smaller rf dipole strength. It is planned to test these schemes in future AGS polarized proton runs.

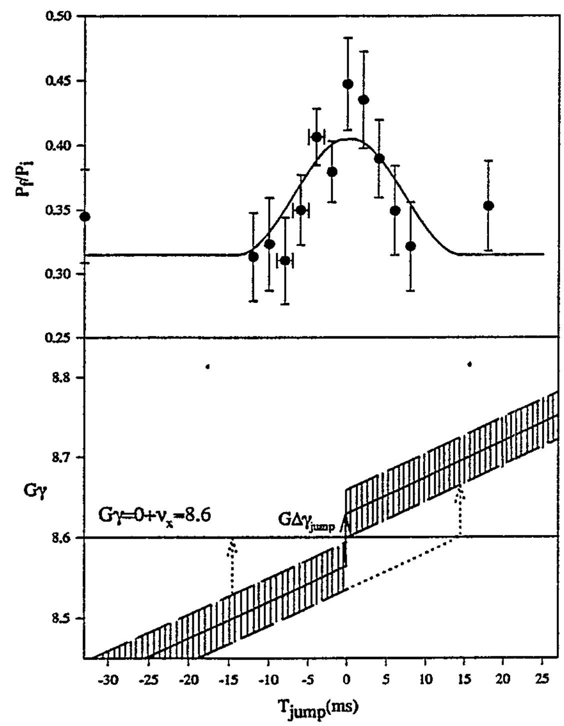

Figure 2. Energy jump data and schematics. In the top half, solid points are the experiment data, the solid line is the predicted curve. Bottom half shows the energy jump scheme.

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