

ACCELERATOR PHYSICS

FIRST DEMONSTRATION OF A HIGHER ORDER DEPolarIZING RESONANCE

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The spin of a polarized proton in a storage ring will precess around the vertical ring fields with a frequency $f_s = f_c G \gamma$, where f_c is the circulation frequency, G is the anomalous magnetic moment of the proton, and $\gamma = E/m_p$. The spin tune $G\gamma$ is the number of spin rotations during each turn around the ring. Protons also experience non-vertical magnetic fields that can kick the spin away from the vertical direction. At certain energies, the protons see these non-vertical fields at a frequency that is synchronized with f_s ; these small kicks then can add coherently, causing a depolarizing resonance which destroys the polarization.

We have extensively studied the first-order-imperfection¹ and intrinsic² depolarizing resonances in the IUCF Cooler Ring. Higher order depolarizing resonances can also exist in a ring because of coupling between the x and y motion, nonlinear fields, and synchrotron motion. A depolarizing resonance can occur when

$$\nu_s = j + k\nu_y + m\nu_x + n\nu_{sync}, \quad (1)$$

where j , k , m , and n are integers, ν_y and ν_x are respectively the vertical and horizontal betatron tunes, and ν_{sync} is the synchrotron tune. With a Siberian Snake present, the spin tune ν_s is not equal to $G\gamma$; thus we have written the resonance condition in Eq. 1 in terms of the spin tune ν_s , which depends on the snake strength.

Recently we observed two new depolarizing resonances in the Cooler Ring. Coupling due to the solenoids in the Cooler Ring can mix the vertical and horizontal betatron

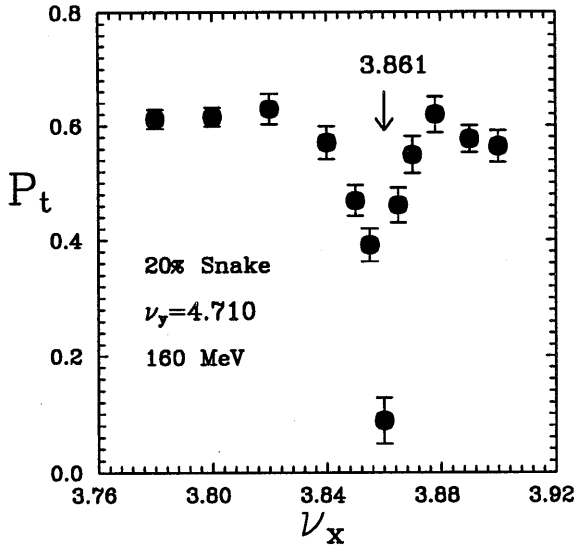


Figure 1. The transverse polarization P_t is plotted against the horizontal betatron tune ν_x . The expected $\nu_s = 6 - \nu_x$ resonance position of 3.861 with a 20% snake is shown.

motion. This will give a vertical betatron frequency component $f_c \nu_s$ that can cause a depolarizing resonance when $\nu_s = j \pm \nu_x$. We observed evidence for the $6 - \nu_x$ horizontal intrinsic depolarizing resonance in a November 1994 run at 160 MeV with a 20% snake; Fig. 1 shows the transverse polarization $P_t = \sqrt{P_v^2 + P_r^2}$ plotted against the horizontal betatron tune ν_x with a fixed vertical betatron tune of $\nu_y = 4.710$. With a 20% snake, the spin tune was then 2.139 at 160 MeV. The expected resonance position should be $\nu_x = 6 - \nu_s = 3.861$; this agrees quite well with the data in Fig. 1.

We also found an even narrower resonance at 160 MeV with a 20% snake while varying the vertical betatron tune ν_y with the horizontal tune ν_x fixed at 3.700. The data are shown in the two plots in Fig. 2. The lower plot shows a wide dip centered around $\nu_y = 4.87$, which is the $7 - \nu_y$ resonance. There is also a narrow dip at $\nu_y = 4.841$. We thought that this dip might be the second-order $\nu_s = 1 + \nu_y - \nu_x$ resonance; its calculated position seems to agree with the data. To test this hypothesis, we shifted ν_x to 3.640 and then repeated the ν_y scan. As indicated in the upper graph of Fig. 2, the narrow resonance moved by $\Delta\nu_y = 0.059 \pm 0.001$ to $\nu_y = 4.782$; this shift agrees almost exactly with its predicted movement, which is equal to $\Delta\nu_x = 3.700 - 3.640 = 0.060$. Therefore, this narrow dip must be the $\nu_s = 1 + \nu_y - \nu_x$ second-order intrinsic depolarizing resonance. This agreement in Fig. 2 appears to be the first experimental proof for the existence of a second-order depolarizing resonance.

These studies show clearly that higher-order depolarizing resonances can exist in the IUCF Cooler Ring with a 20% snake. These resonances should be considered for future polarized beam running.

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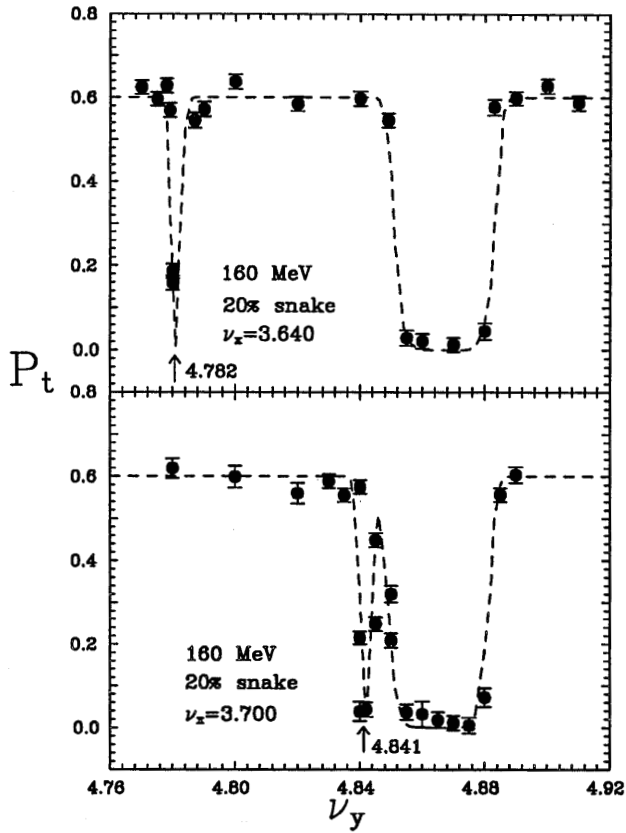


Figure 2. The transverse polarization P_t is plotted against the vertical betatron tune ν_y , for two values of the horizontal betatron tune ν_x . The expected $\nu_s = 1 + \nu_y = \nu_x$ resonance position based on the spin tune with a 20% snake is also shown in each plot.

1. Krisch, A.D. *et al.*, Phys. Rev. Lett. **63**, 1137 (1989).
2. Goodman, J.E. *et al.*, Phys. Rev. Lett. **64**, 2779 (1990).