RHIC Spin Flipper Status

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RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

RHIC Spin Flipper Status

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Collider Accelerator Department

- RHIC Spin flipper
  - a dipole magnet with horizontally oriented oscillating magnetic field.
  - maximum magnetic field:
    100 Gauss-m, spin resonance strength:
  - oscillating frequency: 37.5 kHz
  - time for getting a full spin flip: 2seconds
  - capable of independantly achieve spin flipping in each ring.

- project status
  - Magnet:
    - DC magnetic field measurement:
      - transfer function:
        106.8 Gauss-m/kAmp
      - multipole components: < 1%
      - integral field angle: 6 mrad
    - AC magnetic field measurement:
      - 2nd & 3rd harmonic distortion: -60 dB
    - ready for installation.
    - Location : IP4

- project status
  - Electric system:
    - magnet inductance:
      - 104.96 μH @ 37.5 kHz
      - 26.362 μH @ 64.0 kHz
    - Q factor:
      - 320 @ 37.5 kHz
      - 309 @ 64.0 kHz
    - 6 kwatt power supply testing done
    - cap-bank assembly done
    - vertical testing

• project status

– Control system:

  • Front end computer installed
  • PA remote control PLC in progress.
  • Programing the Lecroy scope for digitizing magnet current readback done.
  • Application ready for integrated testing.

• schedule

– magnet installation:
  • estimated time for installation: 2 -3 shifts
  • between Oct. 1 and Oct. 15

– system review:
  • before Oct. 15

– system testing:
  • second week of Oct.

– Power supply and cap-bank installation:
  •estimated time for installation: 1-2 shifts
  • after Oct. 15

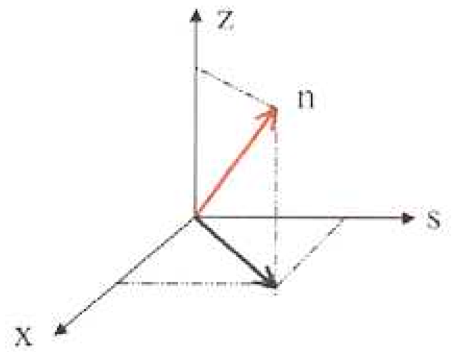
- commission the RHIC spin flipper
  - at injection
    - with both snakes
    - move the spin tune away from half integer by tunning the two snakes' axis slightly away from being perpendicular.
    - Slowly ramp the spin flipper frequency across the spin tune and measure the beam polarization after the frequency ramping.
  - At storage:
    - with both snakes
    - with one snake

- application of the RHIC spin flipper
  - flip the spin direction for reducing the systematic error.
  - measure the spin tune:
    - slowly move the spin flipper frequency towards the spin tune and then let the induced spin resonance be on top of the spin tune.
    - measure the beam polarization
    - the spin tune=

• in the frame which rotates at the same frequency as the spin flipper's frequency, the stable spin direction is

$$\hat{n} = \frac{\delta}{\lambda}\hat{e}_z + \frac{\varepsilon_1}{\lambda}\hat{e}_x + \frac{\varepsilon_2}{\lambda}\hat{e}_s$$

$$\lambda = \sqrt{\delta^2 + \varepsilon_1^2 + \varepsilon_2^2} \qquad \delta = \gamma_m - \gamma_r$$



RHIC Spin Collaboration Meeting
Oct 1, 2001

Spin Tracking for Spin Run2001

(Spin RHIC Collaboration Meeting VI, BNL Oct 1,2001) *

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October 3, 2001

1 General Strategy. RHIC with errors

During Run2001 we plan to inject polarized protons in both rings of RHIC, accelerate them to an energy of approximatively 100 GeV and make beams collide. We want to produce a polarization state either transverse or longitudinal in all interaction regions.

Since in each ring we have installed two Siberian Snakes but there will be no spin rotators yet, to produce longitudinal polarization at the IR's a possible strategy is to gradually turn off one snake in each ring, as shown by Waldo MacKay in a contribution to this meeting. With this, the spin orientation rotates adiabatically from the vertical to the longitudinal at all IR's if the proton spin tune $G\gamma$ is kept constant to a value multiple of 3. For this exercise we have chosen a value $G\gamma = 192$ that corresponds to a proton energy close to 100 GeV. A possible (optimized) path to produce this effect is shown in Fig.1, where the spin rotation angle μ and the axis of spin precession angle ϕ in both snakes are shown as a function of turn number. Along this path the currents in the two pairs of helices that constitute each snake are kept within allowed limits.

In the following we show results of spin tracking with the code *Spink*. The used RHIC configuration is the closest to the actual machine, that includes position errors in all elements. To create an input file for *Spink*, *MAD* reads the database containing the measured values of the displacements of all elements, using the *Doom* protocol. The machine is shown in Fig.2.

For non polarized beams a good orbit correction in a lattice affected by errors is normally obtained when the orbit is forced to pass as close as possible through the centers of the machine quadrupoles. For polarized particles, that behave as gyroscopes, it is instead more effective to correct the orbit on the absolute horizontal plane, as shown in the figure. The correction within 0.2 mm is being calculated by *MAD* using the *Micado* algorithm.

*Work performed under the auspices of the U.S.Department of Energy.

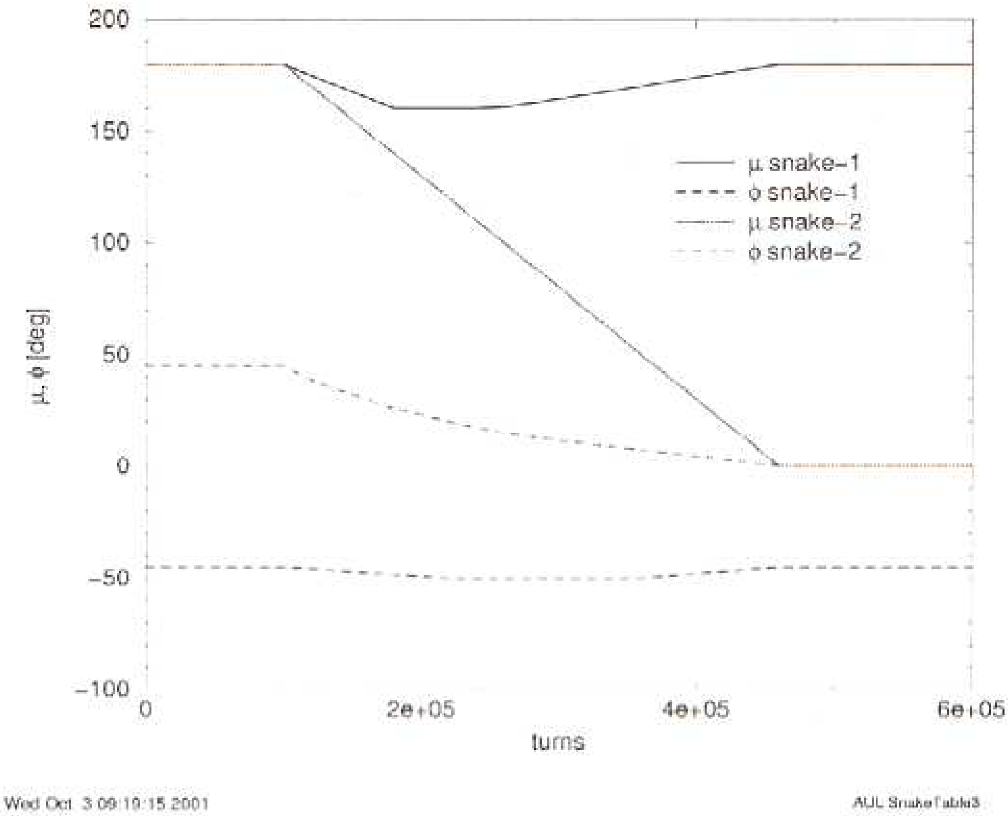

Figure 1: Snake Table 3. Spin precession angle μ and axis angle ϕ for Run2001

2 Scanning the tune space

An example of successful Spin tracking in shown in Fig.3. The figure shows the three components of the spin S_x (radial), S_y (vertical) and S_z (longitudinal) at the IR's CLOCK6 (STAR) and CLOCK8 (PHENIX). For this tracking one particle has been brought and then stored for 60,000 turns at an energy equivalent to $G\gamma = 192$. The initial particle spin was oriented along the stable spin direction (sensibly vertical). During storage Snake 2 is turned gradually off and Snake 1 is maintained close to its initial setting of $\mu = 180^0$ and $\phi = -45^0$.

As shown, the spin rotates from the initial vertical orientation to the final longitudinal orientation. The noise of the spin curves are due to the imperfections of the lattice.

The polarization will be continuously measured at POLAR, a location close to CLOCK12 (within 2% of the ring circumference). When the spin is oriented longitudinally at the IR (CLOCK) locations, its radial component S_x, measured at POLAR, reaches a value of ≈ 0.55. Fig.4 shows the result at POLAR for the "good" case of Fig.3.

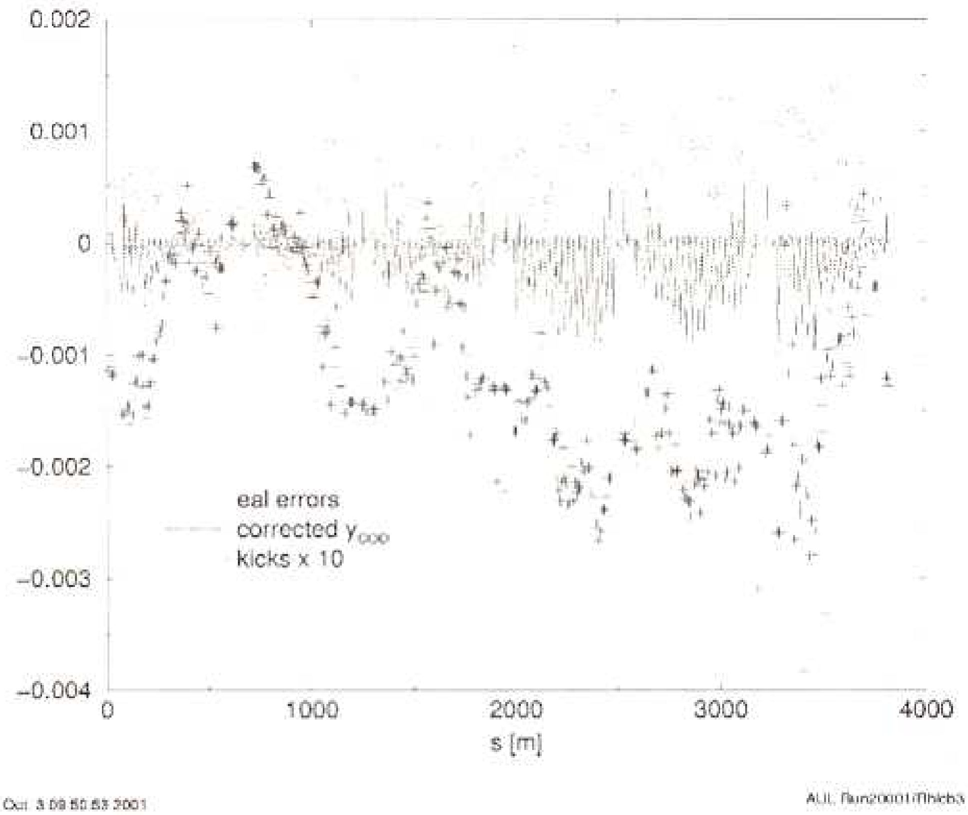

Figure 2: RHIC with errors. Measured vertical displacement errors are shown with crosses. The orbit has been corrected by *MAD* with *Micado* to the absolute horizontal. Corrected orbit and corrector strengths are also shown

In the same figure we show the spin tune of the particle under the action of the snakes. The value of the spin tune, calculated from the trace of the spin matrix for one complete spin turn (i.e when the particle returns to its starting position in the orbital phase space), is 0.5 with two snakes at the beginning of the tracking and returns to 0.5 with only one snake at the end of the tracking. In-between, the spin tune reaches lower values, ≈ 0.45 for the present energy equivalent to $G\gamma = 192$. When the spin tune is not constant at 0.5, i.e. when we temporarily operate with a full snake and a partial snake, combinations of the spin tune with the betatron tunes of the particle in its orbital motion may create spin instabilities. It is then imperative to explore the betatron tune space to find where conditions are adequate to preserve spin polarization.

Fig.5 shows a few results of spin tracking at POLAR for different values of the betatron tunes. In the figure, case #402, corresponding to the example of Fig.4 above is one of the good ones, while case #338 and #408 are bad. The former seem to show a spin depolarizing resonance when the sum of the betatron

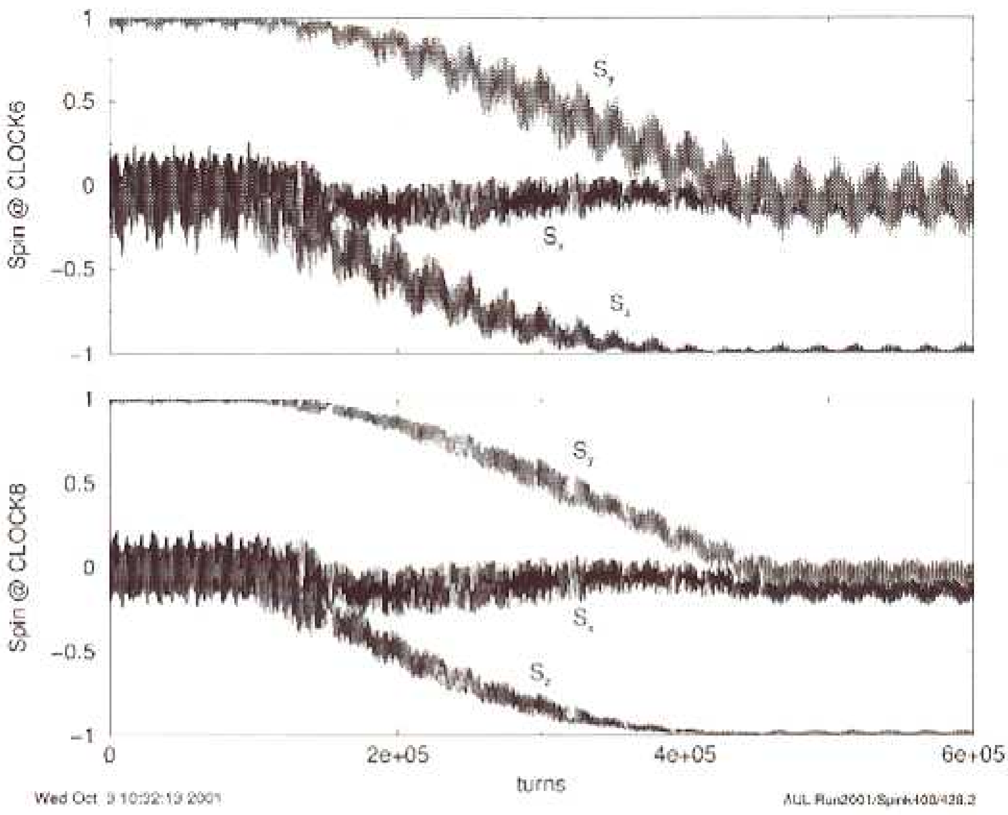

Figure 3: Components of the spin at two IR's. Track one particle on a phase contour of 10π mm-mrad for 60,000 turns at $G\gamma = 192$. Use Snake Table 3

tunes is equal to the lower average value of the spin tune and the latter when the sum of the two tunes crosses the spin tune curve twice.

Fig.6 shows a betatron tune landscape with good and bad cases. Full dots represent bad cases. Empty circles represent good cases. Three lines delimit regions. For points above the upper horizontal line the vertical tune alone interferes with the spin tune curve of Fig.4. The diagonal curve represent the sum of betatron tunes $\nu_x + \nu_y = const$, where the constant is the deepest point reached by the spin tune curve. Tune values in the region in the right upper corner of the chart above this line are unstable. The lower horizontal line represent $\nu_y = 1/6$ a notoriously unstable band for spin for a machine with periodicity 6.

Fig.7 shows a zoomed-in area of Fig.6, around tunes that best seem to suit RHIC. The "good" case described at the beginning in Figs.3 and following is labeled as case #402 on this plot.

All tracking examples so far assumed that the snake gymnastics at $G\gamma =$ 192 could be done in 60,000 turns. This is hardly realistic for the ramping

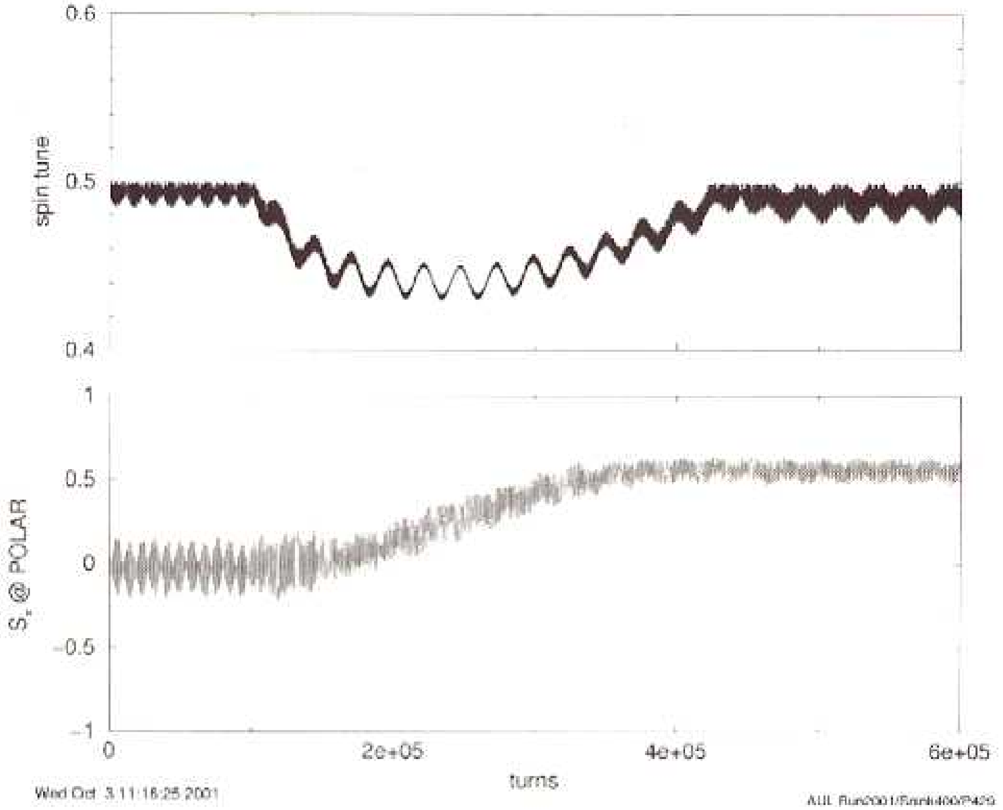

Figure 4: Spin Tune and radial component of the spin at POLAR for the conditions of Fig.3

capabilities of the present snakes and power supplies. If spin resonances are present, the growth rate of the resulting instabilities and the final value of the polarization depend on the speed of resonance crossing. It is then important to examine in deeper detail and with a slower tracking rate some of the good candidates. Fig.8 shows the same tracking of case #402(at POLAR) in 60,000 turns compared with tracking at 6.10^5 and 6.10^6 turns. *Spink* is symplectic enough to deal with a few million turns in RHIC without showing any non physical growth of emittance. The latter number, 6 million of turns is of the same order of what can be realistically achieved, and shows clearly the onset of some instability in the polarization (this tracking took about 32 hours on a 1.5 GHz Linux Box).

More systematic work is in progress.

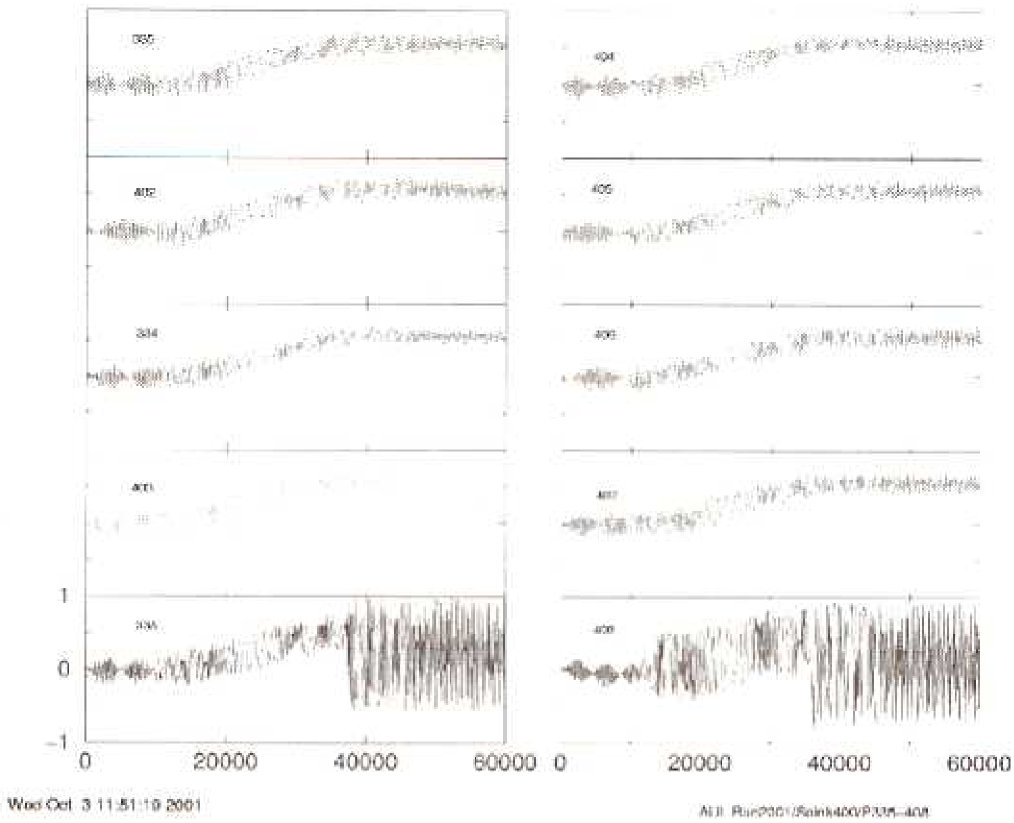

Figure 5: Radial component of the spin at POLAR for various betatron tunes

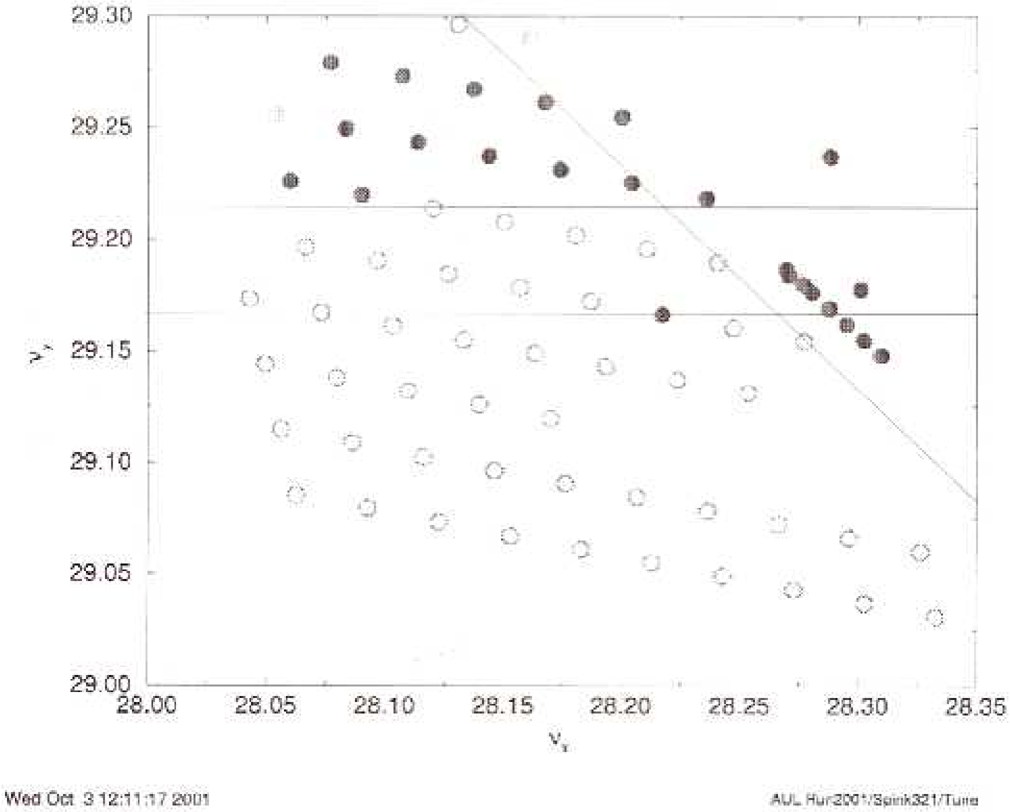

Figure 6: Chart of the betatron tune for spin stability in Run2001. Full dots are unstable cases, empty circles are good cases

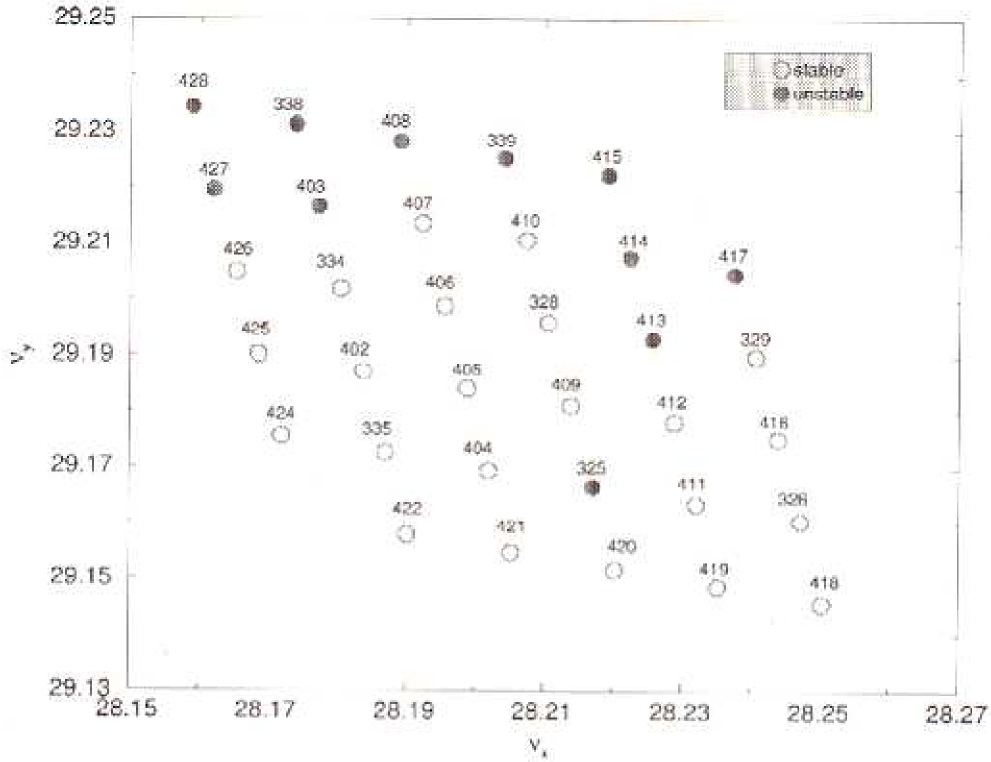

Figure 7: Zoomed-in Chart of the betatron tune for spin stability in Run2001

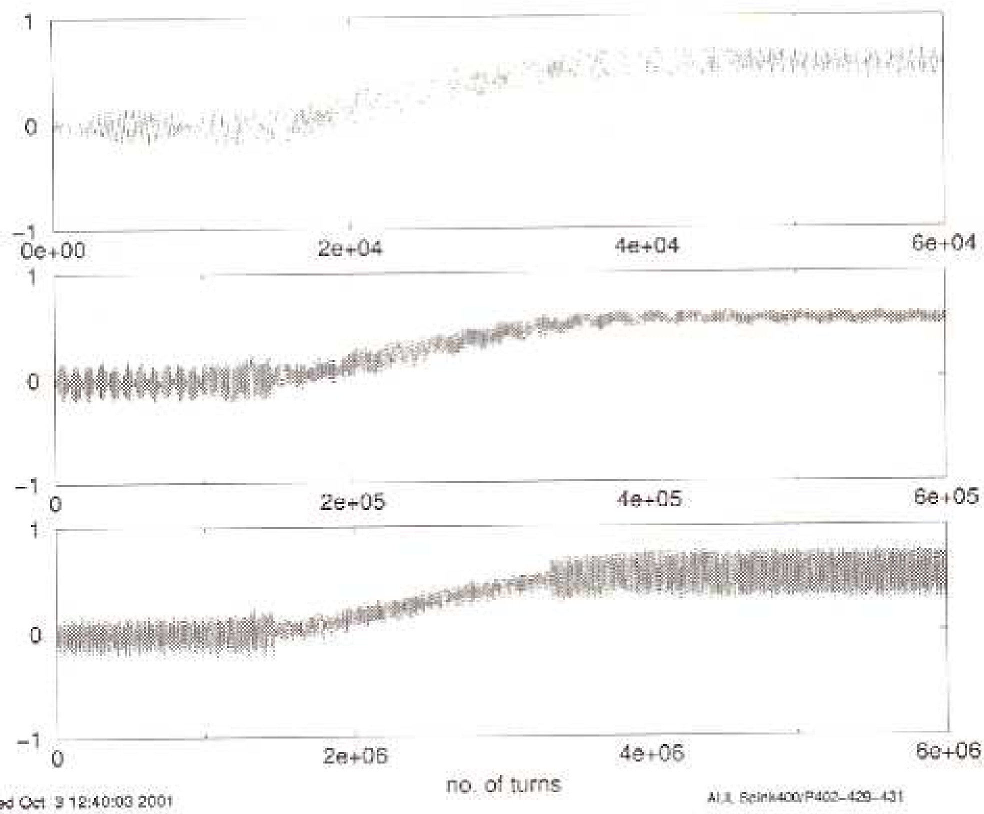

Figure 8: S_x at POLAR for Case #402 with snakes being ramped at different rates