AGS RF dipole Experiment

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Normally, particles in a beam with different oscillation amplitudes have different spin resonance strengths. The smaller the oscillation amplitude, the weaker the spin resonance strength. Therefore after crossing a spin resonance, the spin vectors for different particles spread out and the beam polarization, which is the ensemble average of all the particles spin vectors, is decreased. To avoid this happen, one can excite a coherent betatron oscillation to force all the particles have large oscillation amplitudes to enhance the beam spin resonance strength and obtain a full spin flip. An adiabatic coherent betatron oscillation can be excited and maintained without causing beam emittance growth by using an RF dipole. This technique was successfully tested in the recent polarized proton experiments at the Brookhaven AGS to overcome three strong intrinsic spin resonances at $0+\nu_z$, $12+\nu_z$ and $36-\nu_z$. The experimental data show that measured beam polarization became saturated at large oscillation amplitude which indicates a full spin flip was achieved.

A new type of spin resonance at $G\gamma = 60-\nu_z-9$ was found in the most recent polarized proton run at the AGS. This resonance was found to be associated with horizontal closed orbit distortion and can be understood as a 2nd order effect of the spin precession tune modulation due to the horizontal focusing fields when large horizontal closed orbit distortion occurs. In the experiment, the horizontal harmonic correctors were employed to eliminate the horizontal closed orbit distortion and correct this semi-intrinsic resonance.

Fitting Model, $\delta_f = \delta_0 \dfrac{1 - b\,[(x-c)^2 + (y-s)^2]}{1 + b\,[(x-c)^2 + (y-s)^2]}$

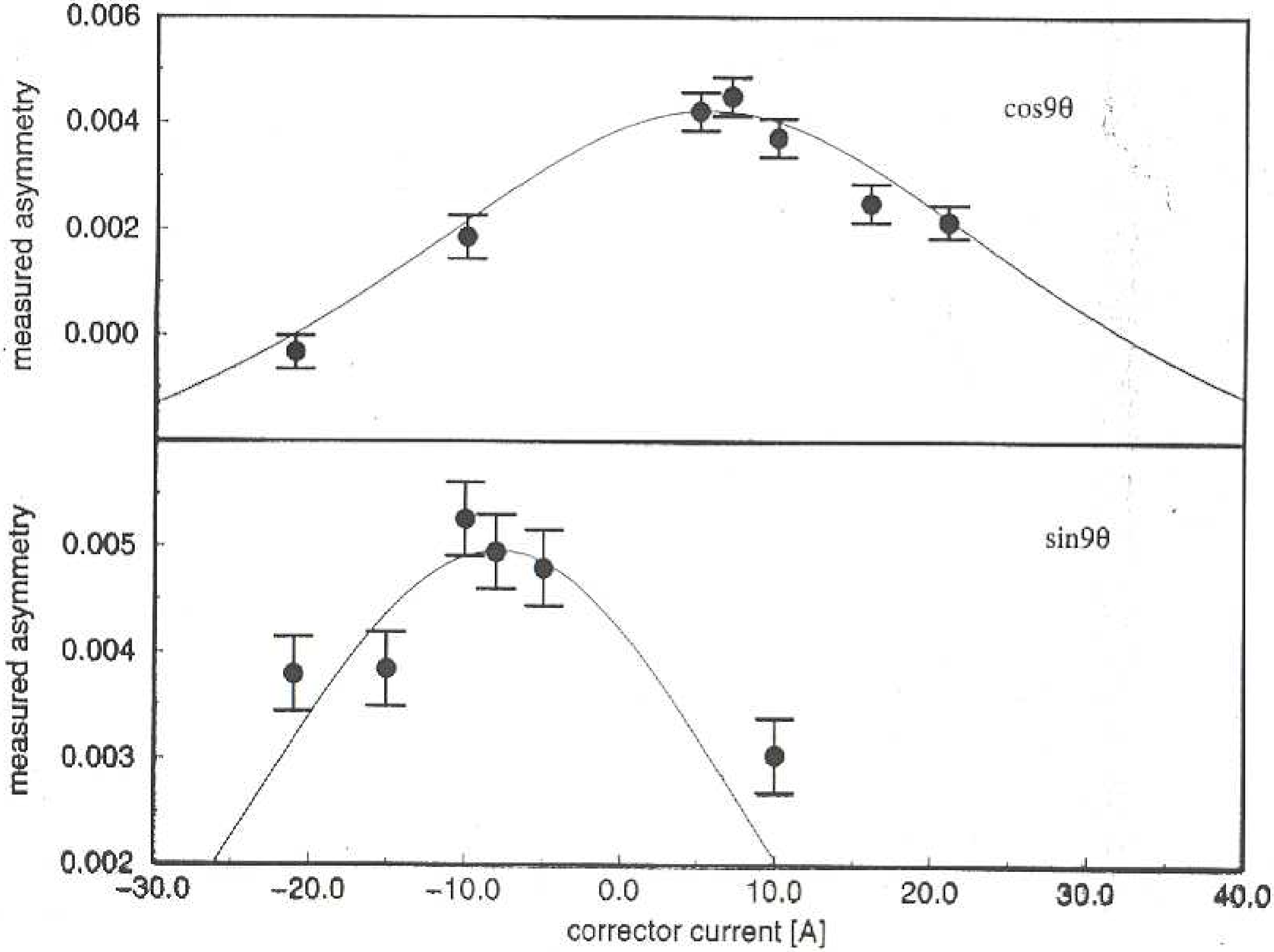
Best fit:

$\delta_0 = (4.99 \pm 0.26) \times 10^{-3}$

$b = (1.287 \pm 0.18) \times 10^{-3}$

$c = 5.59 \pm 1.5$

$s = -7.95 \pm 1.2$



$G\gamma = 60 - \nu_z - 9$

cause: modulation of spin precession tune due to the horizontal focusing field. This resonance can be treated as the 2nd order effect parasitic to the intrinsic spin resonance $G\gamma = 60 - \nu_z$.

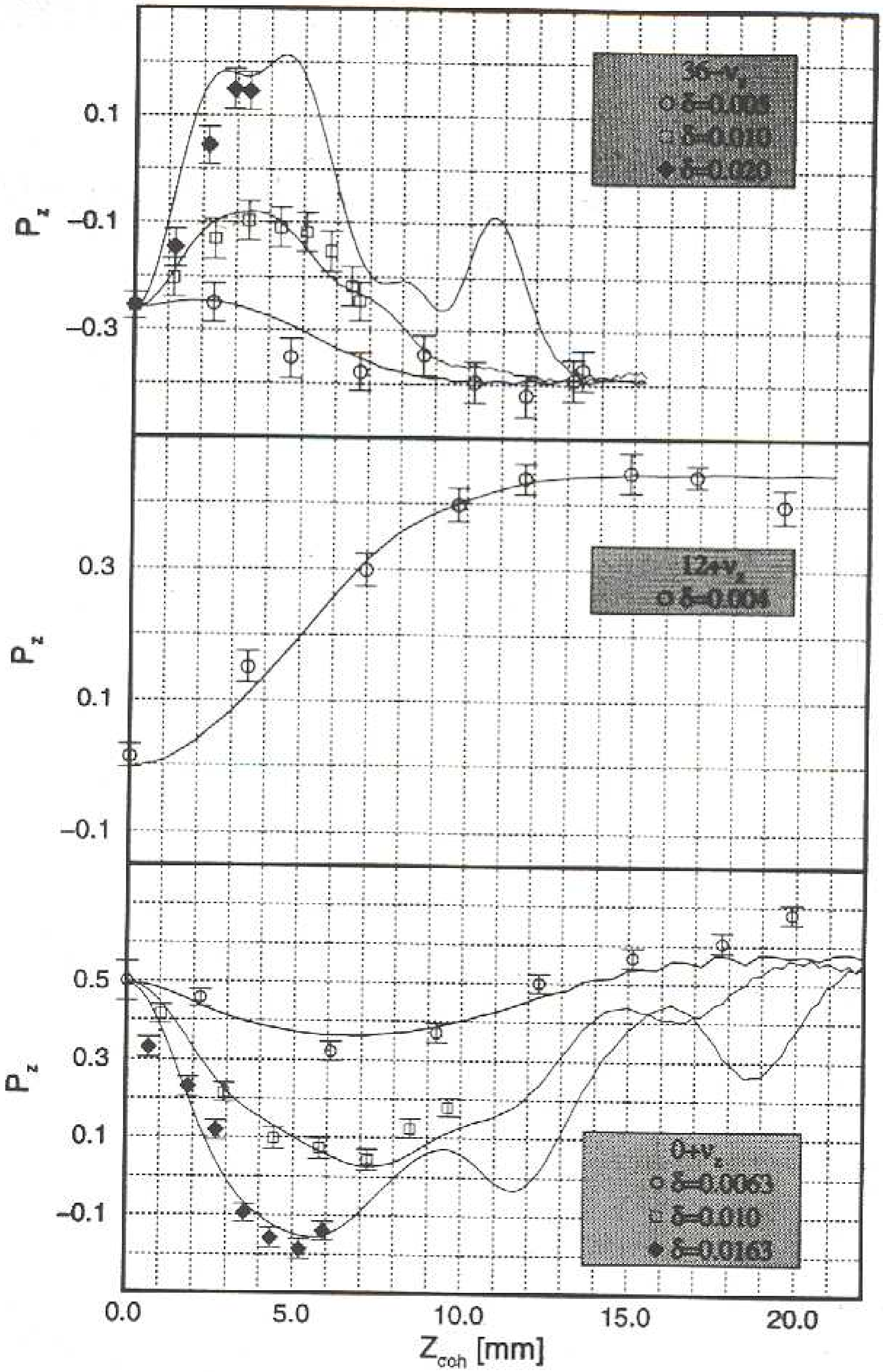
Generally,

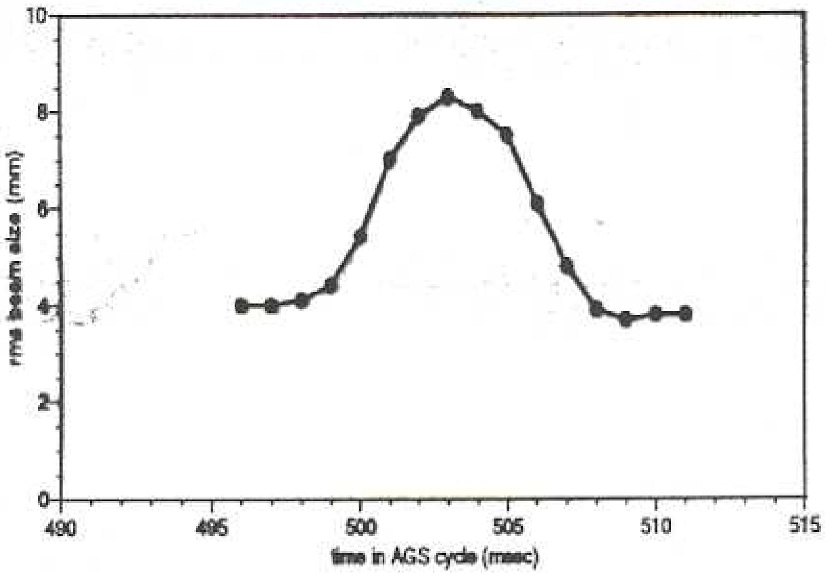
$G\gamma = K - m \cdot n$ is parasitic to the spin resonance $G\gamma = K$

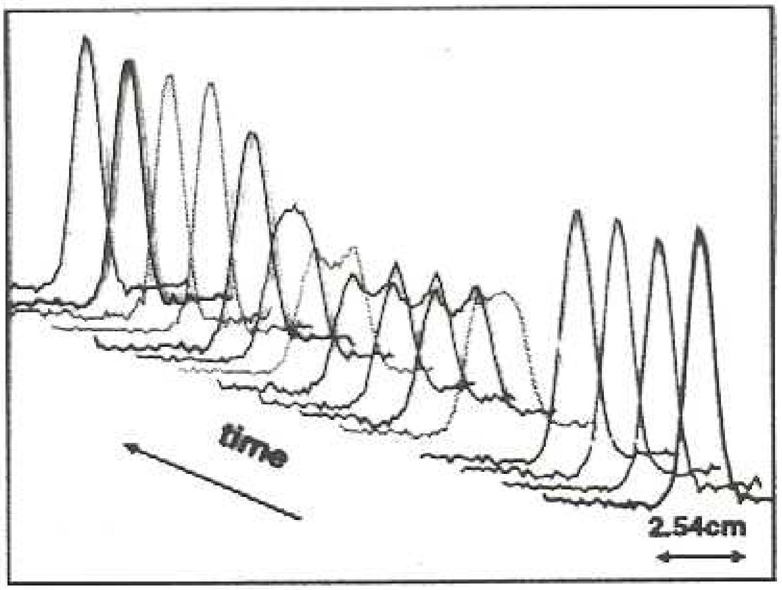
- m: integer
- n: harmonic of horizontal closed orbit

$$\varepsilon_{K - m\cdot n} = \varepsilon_K J_m(g)$$

- $\varepsilon_{K - m\cdot n}$: Resonance strength of $G\gamma = K - m\cdot n$
- ε_K: Resonance strength of $G\gamma = K$
- J_m: Bessel Function
- $g = 9 \cdot X_{co} \cdot (1 + G\gamma)/R$


36-ν
○ δ=0.008
□ δ=0.010
◆ δ=0.020
12+ν
○ δ=0.004
0+ν
○ δ=0.0063
□ δ=0.010
◆ δ=0.0163
P
0.1
-0.1
-0.3
0.3
0.5
0.0
5.0
10.0
15.0
20.0
Z [mm]

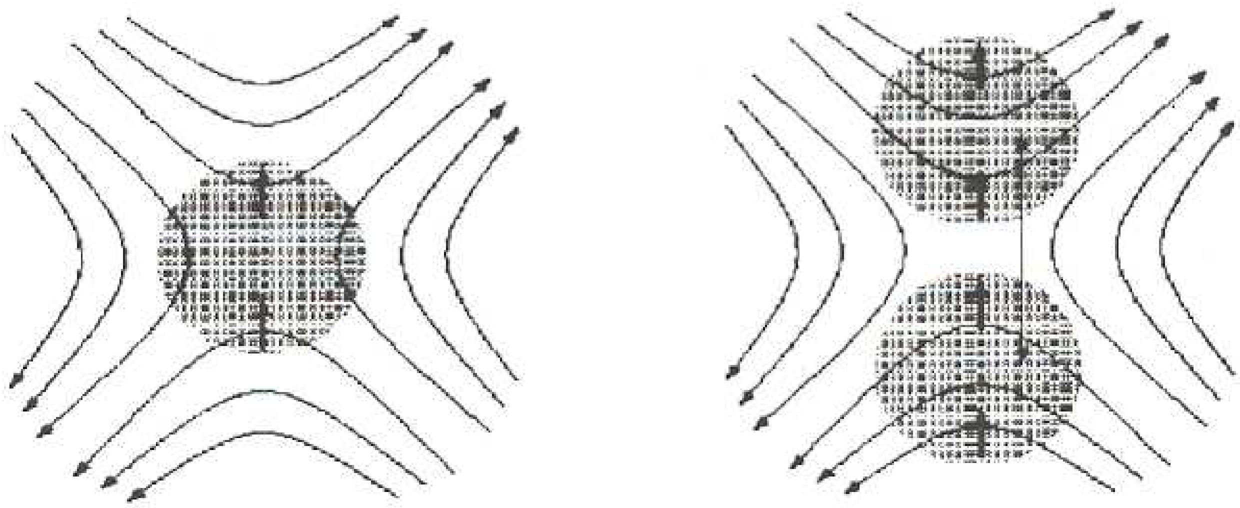

rms beam size (mm)
time in AGS cycle (msec)
0
2
4
6
8
10
490
495
500
505
510
515


time
2.54cm

Exciting coherent betatron oscillation when crossing the intrinsic spin resonance

The idea of exciting a vertical coherent betatron oscillation is to let all the particles have strong resonance strength so that a full spin flip can be obtained under the nominal acceleration rate

Intrinsic Resonance Crossing



Vertical focuing fields causes depolarization

Driven beam oscillation
- **whole beam sees the the same field**
- **spin flip**

Introduction:

An **RF dipole** magnetic field is given by: $B = B_m \cos(2\pi \nu_m n)$

where B_m : RF dipole magnetic field amplitude

n : number of revolutions around the accelerator

ν_m : RF dipole modulation tune defined as the ratio of its oscillation frequency to the accelerator revolution frequency

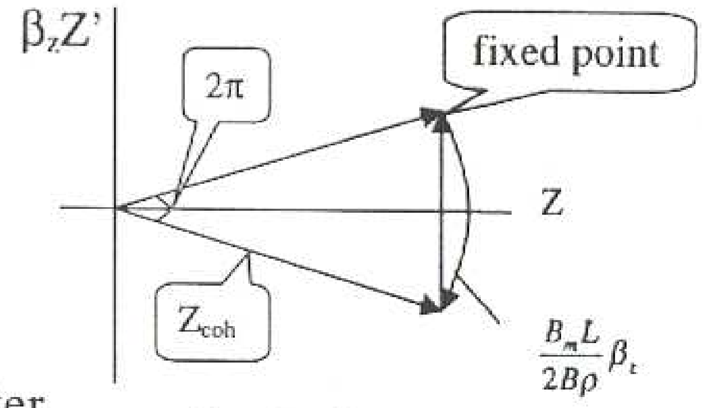
Advantage over using a pulsed kicker:

❶ beam emittance can be preserved. ❷operation is easier to control

The coherent oscillation amplitude Z_{coh} is:

$$Z_{coh} = \frac{B_m L}{4\pi B\rho\delta}\beta_z$$

$\delta = |\nu_m - \nu_z|$ is the resonance proximity parameter



Rotating frame