Polarization Experiments at RHIC

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Outline

- No RHIC pp experiments in FY2007
- RHIC pp experiments for FY2007
  - Spin tune and de-coherence measurement
  - Polarization variation from bunch to bunch
  - Driven coherent spin precession
  - Spin echo and resonance interference

Spin tune and decoherence measurements

MacKay, Alekseev, Bravar, Bunce, Huang, Lin, Luccio, Nkagawa, Ptitsyn, Roser, Svirida, Takano

- Goal
  - To make a direct measurement of the spin tune and measure spin de-coherence time at injection in RHIC
  - to perform a better calibration of the snake settings.

Spin tune and decoherence measurements

- Experiment description
  - At RHIC injection
  - With two snakes:
    - $G\gamma=46$, at this energy, the beam is injected with polarization in the horizontal plane. Polarization vector gets processed around the vertical direction, the stable spin direction of RHIC
  - With one snake:
    - Regular RHIC injection energy at an half integer $G\gamma$. The one snake configuration makes the stable spin direction staying in the horizontal plane. Since the beam polarization at half integer of $G\gamma$ is vertical, the spin vector of the beam gets processed around the stable spin direction

Spin tune and decoherence measurements

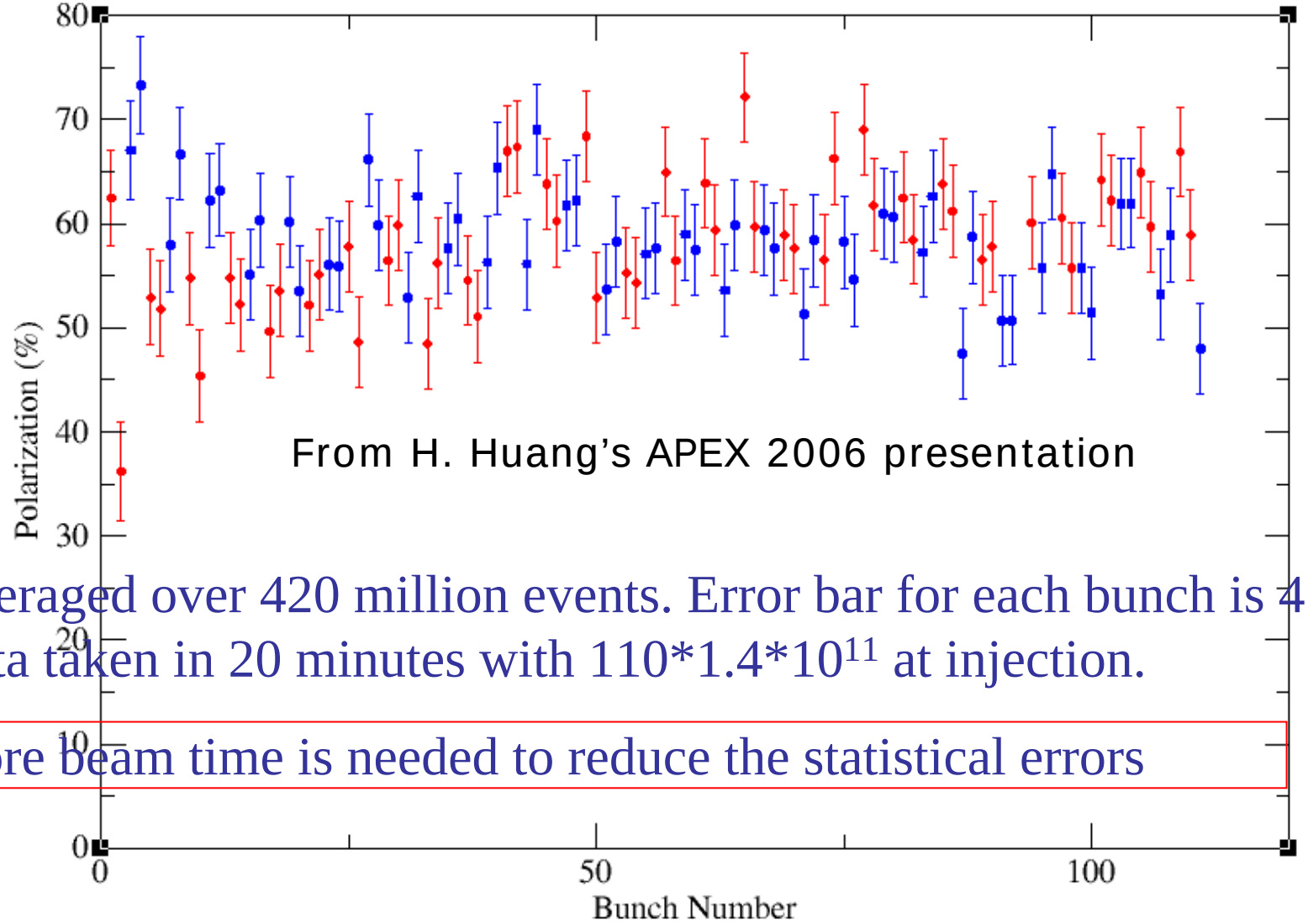
- Experiment status
  - Some attempts were made during RHIC 2006 pp run. But due to various technique problems, no conclusive data were taken

Polarization variation from bunch to bunch

H. Huang, A. Zelenski, W. MacKay, S. Bravar, J. Woods, S. Tepikian

- Goal
  - to understand the correlation between beam polarization with beam intensity
    - No intensity dependence in this intensity range. This is very different from last year's operation with ac dipole
  - to see if different polarization distribution would evolve differently through acceleration
    - Data taken during RHIC 2006 pp run

Polarization variation from bunch to bunch



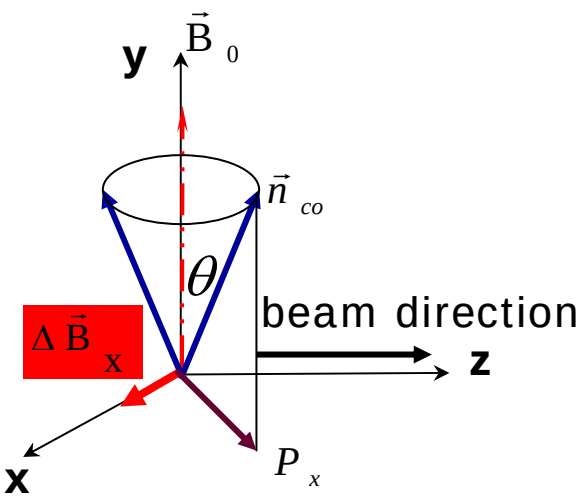
Averaged over 420 million events. Error bar for each bunch is 4.7%.
Data taken in 20 minutes with $110*1.4*10^{11}$ at injection.

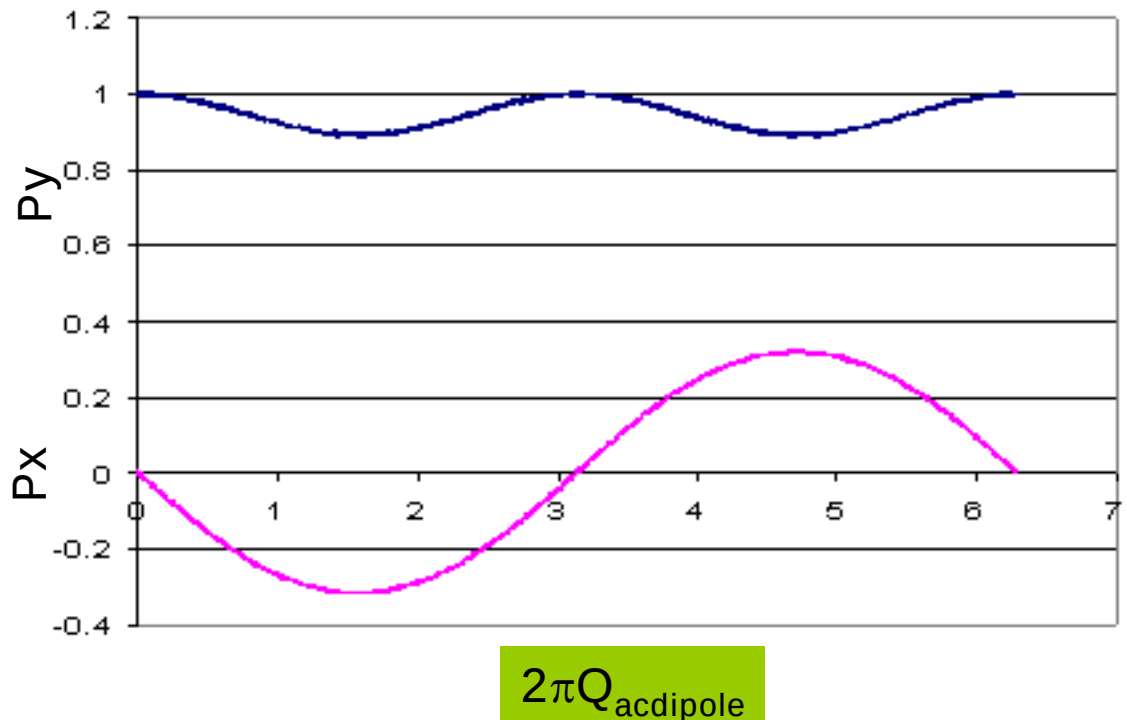
More beam time is needed to reduce the statistical errors

Driven Coherent Spin Precession

M. Bai, T. Roser, G. Bunce, A. Luccio, R. Gill, P. Oddo

- Use the single ac dipole to tilt the spin vector away from the vertical direction and induce a coherent spin precession in the horizontal plane. The turn by turn asymmetry measured by CNI polarimeter can be transformed into the rotating frame to give the coherent precession amplitude in the horizontal plane

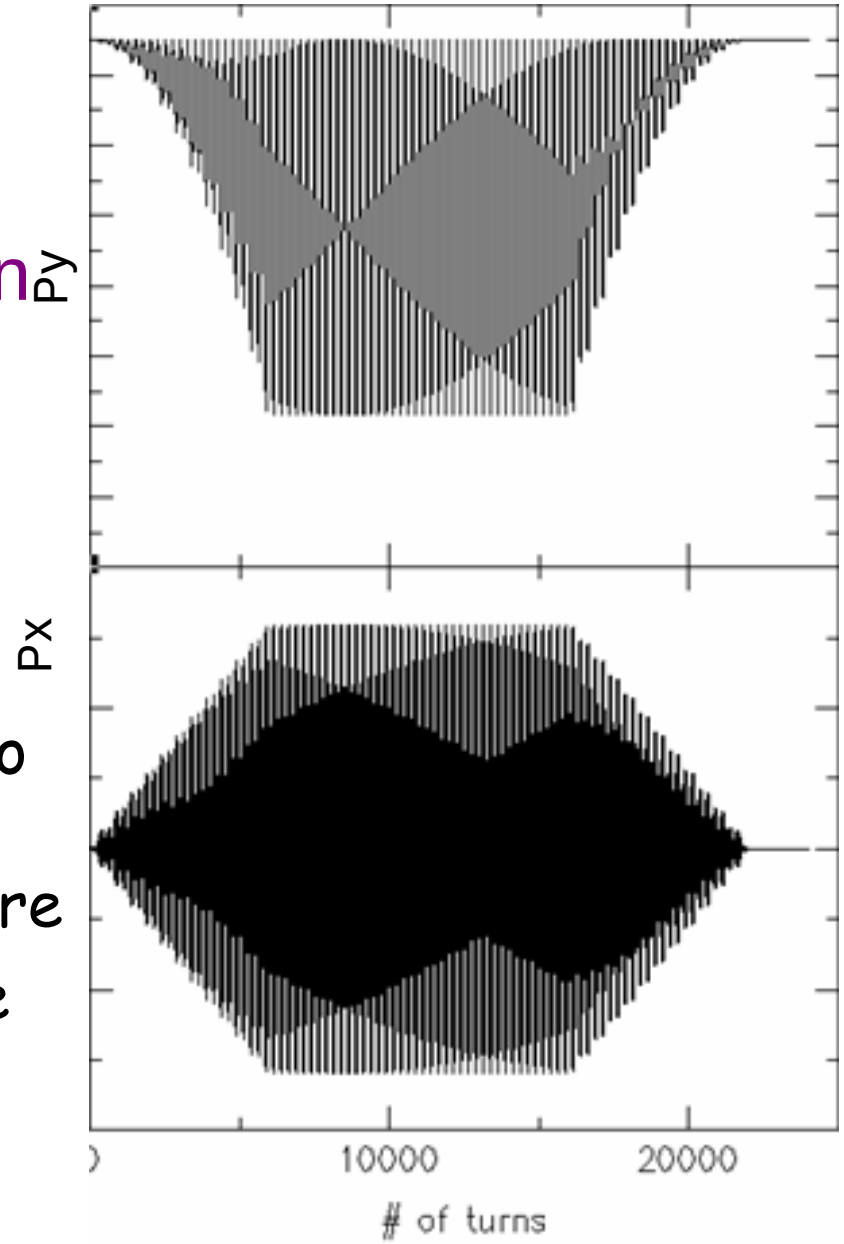




Measure driven coherent spin precession

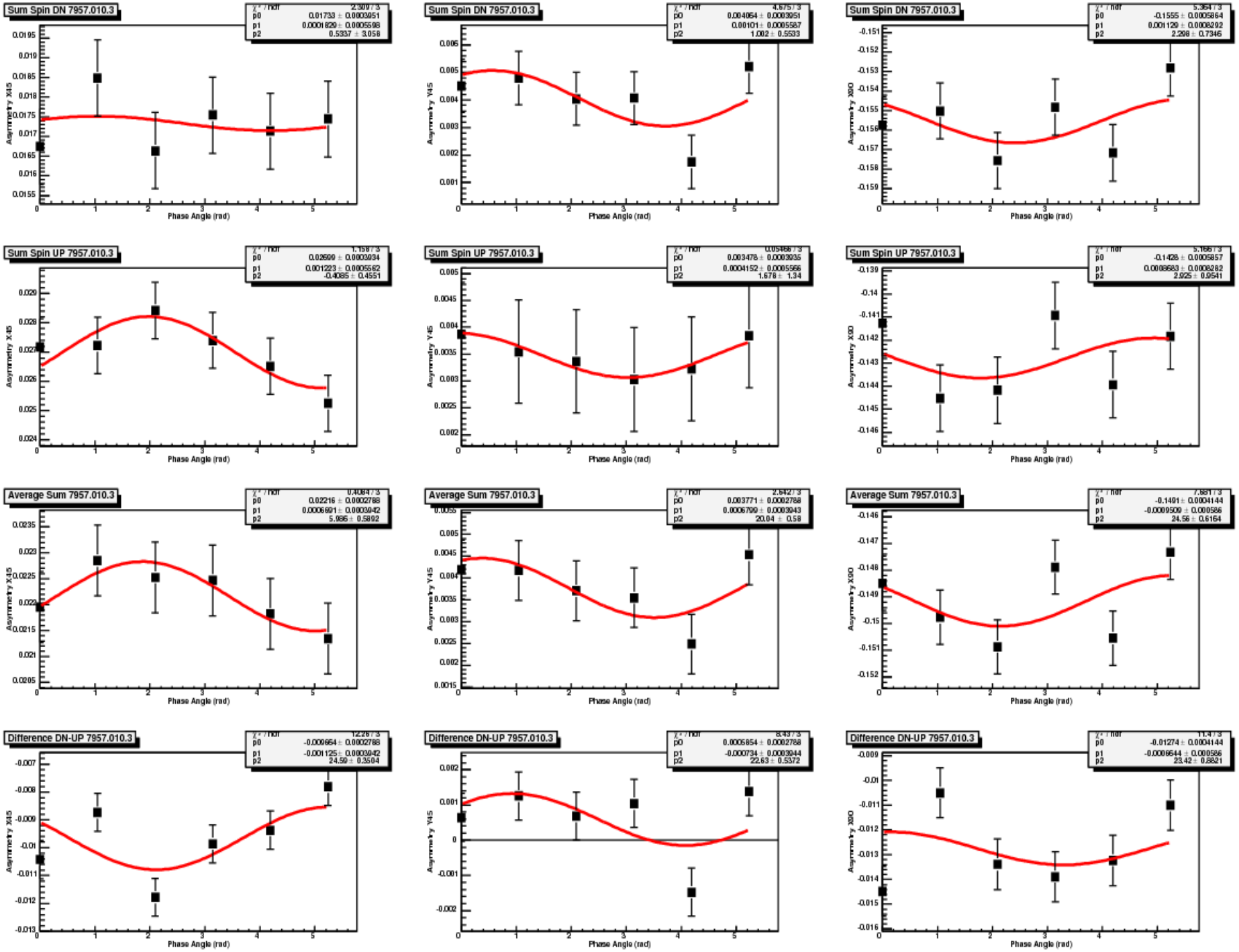
- Goal: to measure the coherent driven spin precession as a function of the ac dipole tune

- Benefit
  - The success of this will provide an effective way to measure the spin tune for injection as well as for store
  - This is also critical for the success of the future spin flipper for RHIC



Summary of the driven coherent precession experiment

- Results
  - Took data at injection and store(100 GeV)
  - Observed effect of ac dipole on beam polarization. Beam was fully depolarized injection when the ac dipole tune was set to 0.498
  - Encouraging data sets but not conclusive


Sum Spin DN 7957.010.3
χ² / ndf 2.309 / 3
p0 0.01733 ± 0.0003051
p1 0.0001820 ± 0.0005598
p2 0.5337 ± 3.058
Asymmetry X45
Phase Angle (rad)
Sum Spin DN 7957.010.3
χ² / ndf 4.675 / 3
p0 0.004064 ± 0.0003951
p1 0.00101 ± 0.0005587
p2 1.002 ± 0.5533
Asymmetry Y45
Phase Angle (rad)
Sum Spin DN 7957.010.3
χ² / ndf 5.364 / 3
p0 -0.1555 ± 0.0005864
p1 0.001129 ± 0.0008202
p2 2.298 ± 0.7346
Asymmetry X90
Phase Angle (rad)
Sum Spin UP 7957.010.3
χ² / ndf 1.158 / 3
p0 0.02699 ± 0.0003034
p1 0.001223 ± 0.0005562
p2 -0.4065 ± 0.4551
Asymmetry X45
Phase Angle (rad)
Sum Spin UP 7957.010.3
χ² / ndf 0.05468 / 3
p0 0.003478 ± 0.0003035
p1 0.0004152 ± 0.0005568
p2 1.678 ± 1.34
Asymmetry Y45
Phase Angle (rad)
Sum Spin UP 7957.010.3
χ² / ndf 5.166 / 3
p0 -0.1428 ± 0.0005857
p1 0.0009583 ± 0.0008282
p2 2.925 ± 0.9541
Asymmetry X90
Phase Angle (rad)
Average Sum 7957.010.3
χ² / ndf 0.4084 / 3
p0 0.02216 ± 0.0002788
p1 0.0006601 ± 0.0003042
p2 5.986 ± 0.5892
Asymmetry X45
Phase Angle (rad)
Average Sum 7957.010.3
χ² / ndf 2.642 / 3
p0 0.003771 ± 0.0002788
p1 0.0006709 ± 0.0003043
p2 20.04 ± 0.58
Asymmetry Y45
Phase Angle (rad)
Average Sum 7957.010.3
χ² / ndf 7.881 / 3
p0 -0.1491 ± 0.0004144
p1 -0.0009509 ± 0.000586
p2 24.56 ± 0.6164
Asymmetry X90
Phase Angle (rad)
Difference DN-UP 7957.010.3
χ² / ndf 12.26 / 3
p0 -0.009654 ± 0.0002788
p1 -0.001125 ± 0.0003042
p2 24.59 ± 0.3504
Asymmetry X45
Phase Angle (rad)
Difference DN-UP 7957.010.3
χ² / ndf 8.437 / 3
p0 0.0005854 ± 0.0002788
p1 -0.000734 ± 0.0003044
p2 22.63 ± 0.5372
Asymmetry Y45
Phase Angle (rad)
Difference DN-UP 7957.010.3
χ² / ndf 11.47 / 3
p0 -0.01274 ± 0.0004144
p1 -0.0006644 ± 0.000586
p2 23.42 ± 0.8821
Asymmetry X90
Phase Angle (rad)

Measure driven coherent spin precession

- Progress and status
  - low level waveform generator problem: fixed
  - Power amplifier tripping issue: fixed
  - an online ac dipole current/frequency readback data acquisition/logging implemented during RUN07

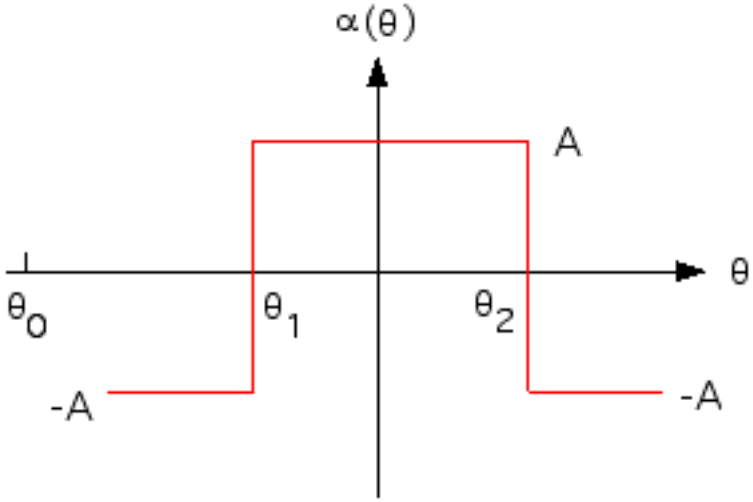
- Plan
  - Take the turn by turn asymmetry data with the six Si CNI detectors
  - Bin the data with the ac dipole frequency. The advantage of this is to improve the statistics greatly
  - Beam time: dedicated. Prefer to take the data at store where the driven orbital motion is negligible

Spin Echo & Resonance Interference

- Team:
  - L. Ahrens, M. Bai, A. Chao, V. Litvinenko, H. Huang, V. Ptitsyn, T. Roser, K. Yip
- Goal:
  - Observe spin echo
  - Study resonance interference

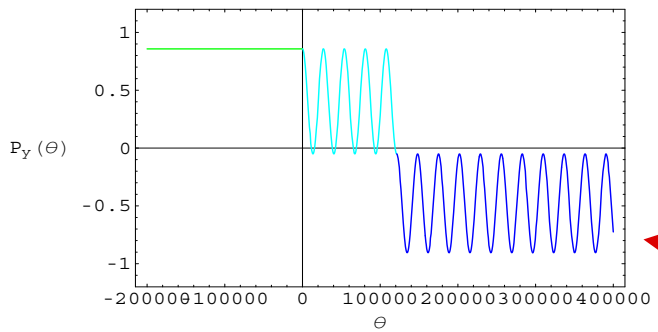
Spin Echo & Resonance Interference

- What is spin echo?
  - Proposed by A. Chao, "Spin Echo in Synchrotrons", SPIN2006, Kyoto, Japan, 2006
  - Recurrence of coherent spin precession when a polarized proton beam with non-zero energy spread jumps across a spin resonance twice
  - The echo occurs at a time τ after the 2nd jump. τ is also the time between the two jumps. The echo also happen once.
  - The width of the spin echo is determined by the spin tune spread while any diffusion of spin tune affects how strong the echo is



Spin Echo

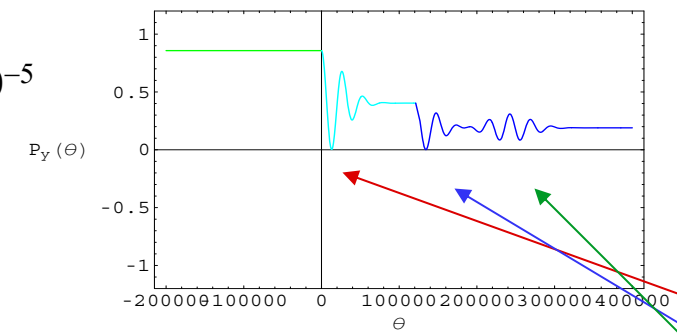
$\sigma_\delta=0$



When $\sigma_\delta=0$, all terms mix together. Result is what was obtained for single particle.

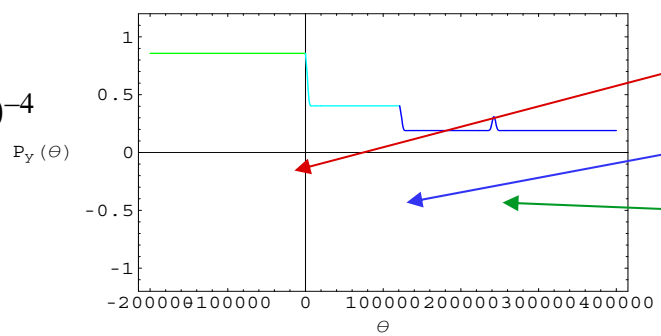
Interference between two jumps (constructive example shown)

$\sigma_\delta=10^{-5}$



When $\sigma_\delta\neq0$, different terms separate. Each term acquires its own physical meaning.

$\sigma_\delta=10^{-4}$



shock response to first jump

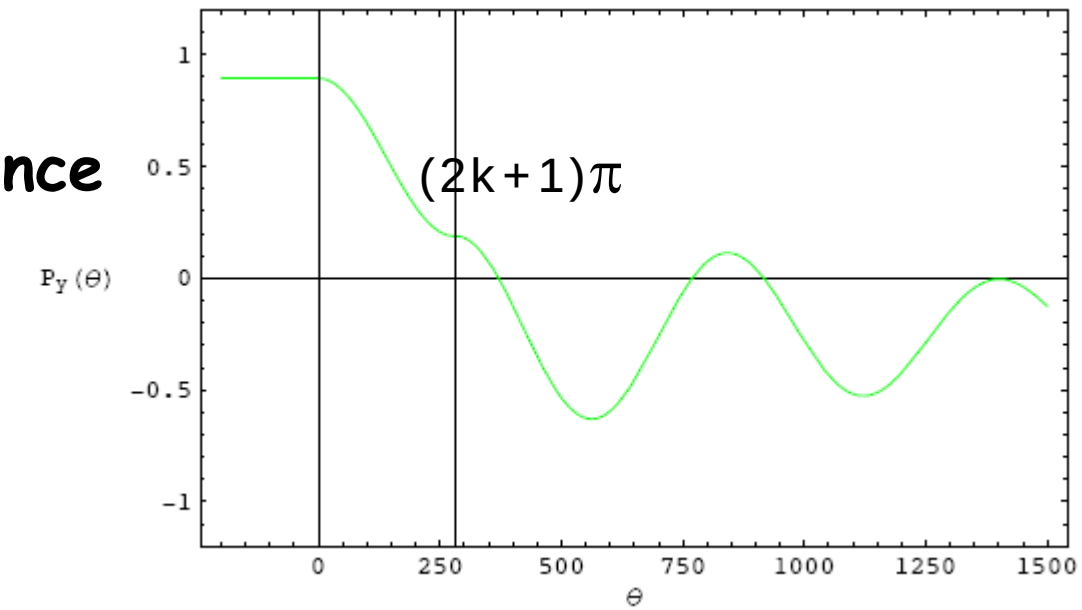
shock response to second jump

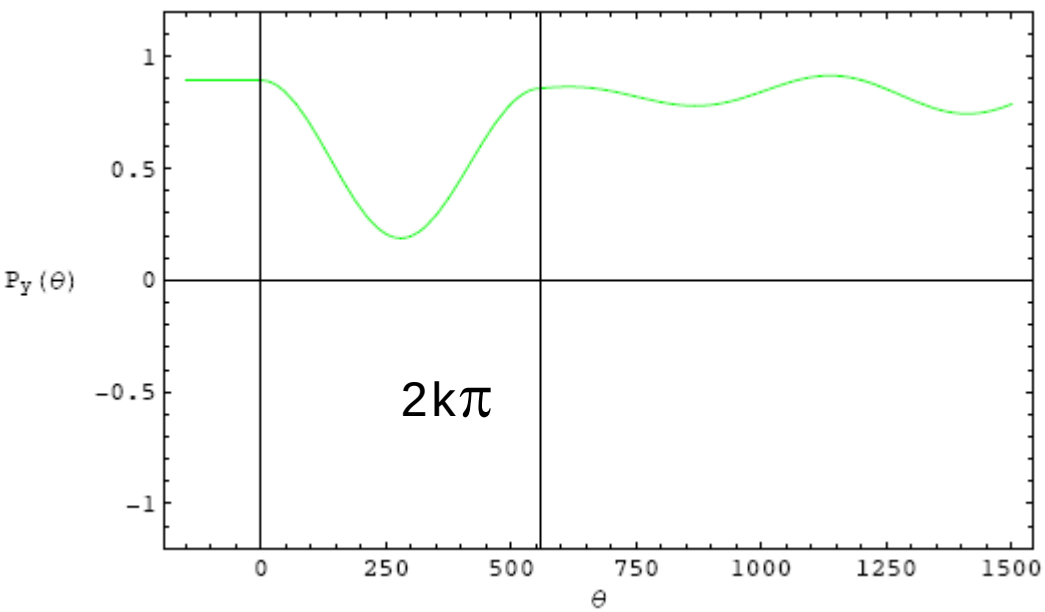
echo

Courtesy from A. Chao

Resonance Interference

Constructive interference





Destructive interference

Spin Echo and Resonance Interference

- Experiment description
  - Machine: AGS
  - Energy: $G\gamma = 4.6$
  - Part I: to measure the spin echo
    - Drive the ac dipole adiabatically at a tune near the spin precession tune 0.6. Cross the resonance by jumping the ac dipole tune through the spin tune. Wait a time of τ and jump the ac dipole tune back to its start value
    - Start the CNI polarimeter measurement right after the second jump for 2τ. In order to observe the echo, the data need to be binned in < 1ms window. Detailed studies/simulation is in working progress
  - Part II: to study the resonance interference