

AGS Cold Snake Status and Plan

Haixin Huang

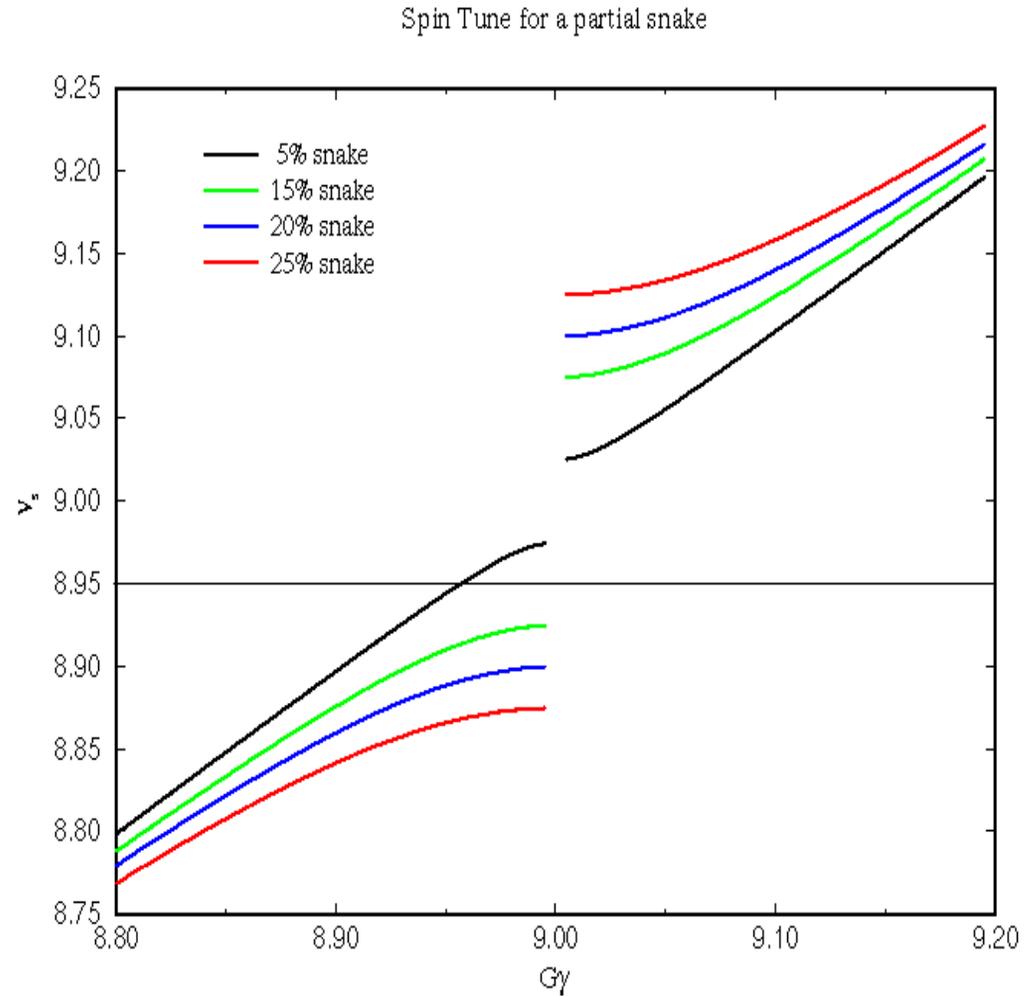
August 18, 2005
RSC meeting



Strong Partial Snake for AGS

- A strong partial Siberian snake generates large spin tune gap for $G\gamma=N$. With strong enough snake, the gap is large enough to cover both imperfection and intrinsic spin resonances.

- Note: With a strong snake, the stable spin detection will deviate from vertical direction (e.g., 18 degrees for 20% snake).



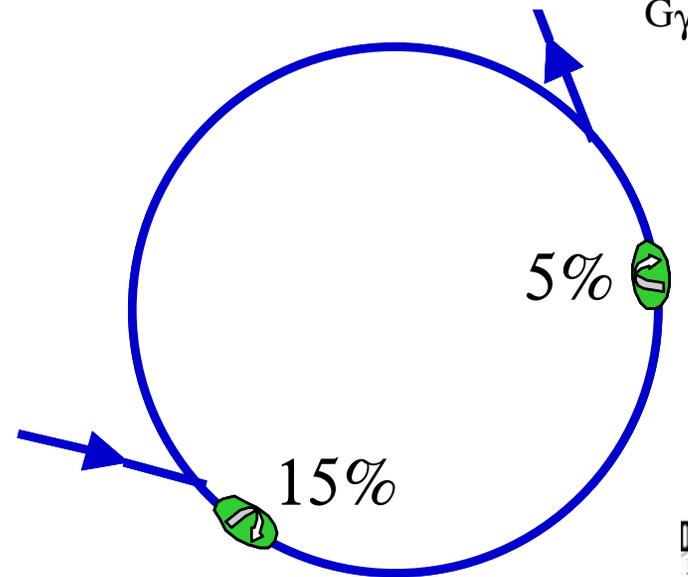
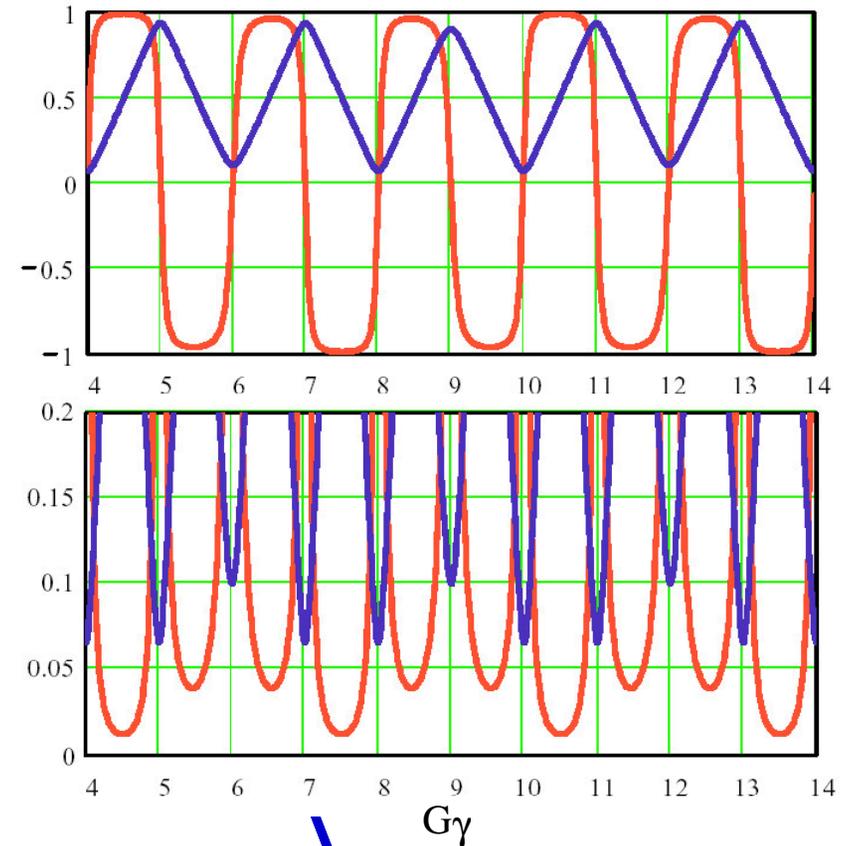
Two Snake Scheme

The two-snake solution provides better spin match at injection and extraction. With two partial snakes, a better spin match at injection and extraction can be achieved.

The two snakes separated by $1/3$ of ring. The snake strength is enhanced every three integer of $G\gamma$.



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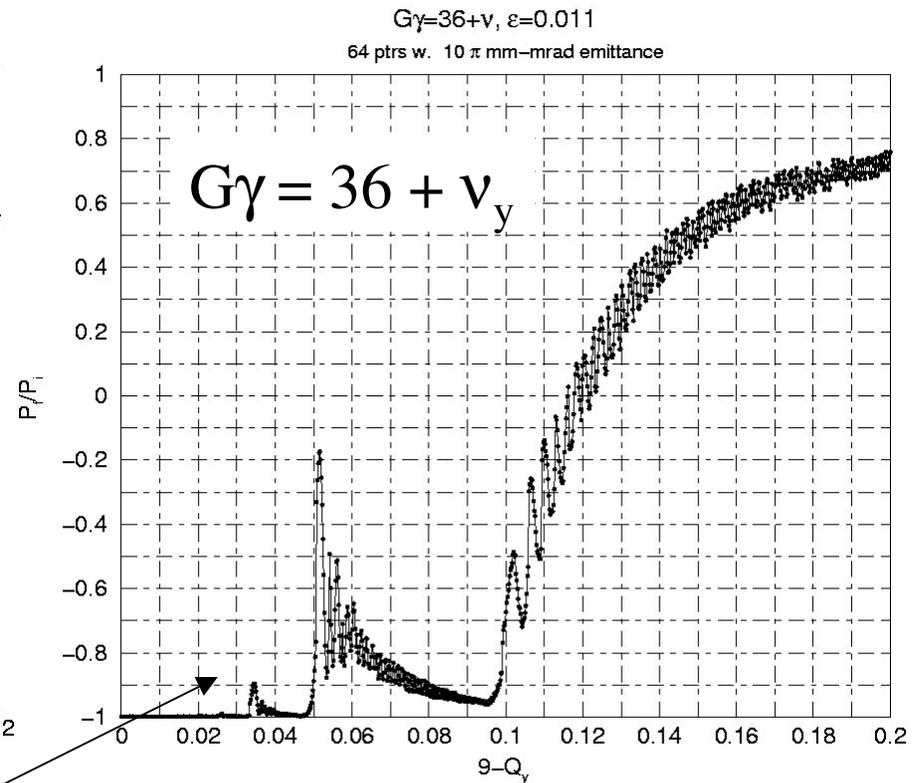
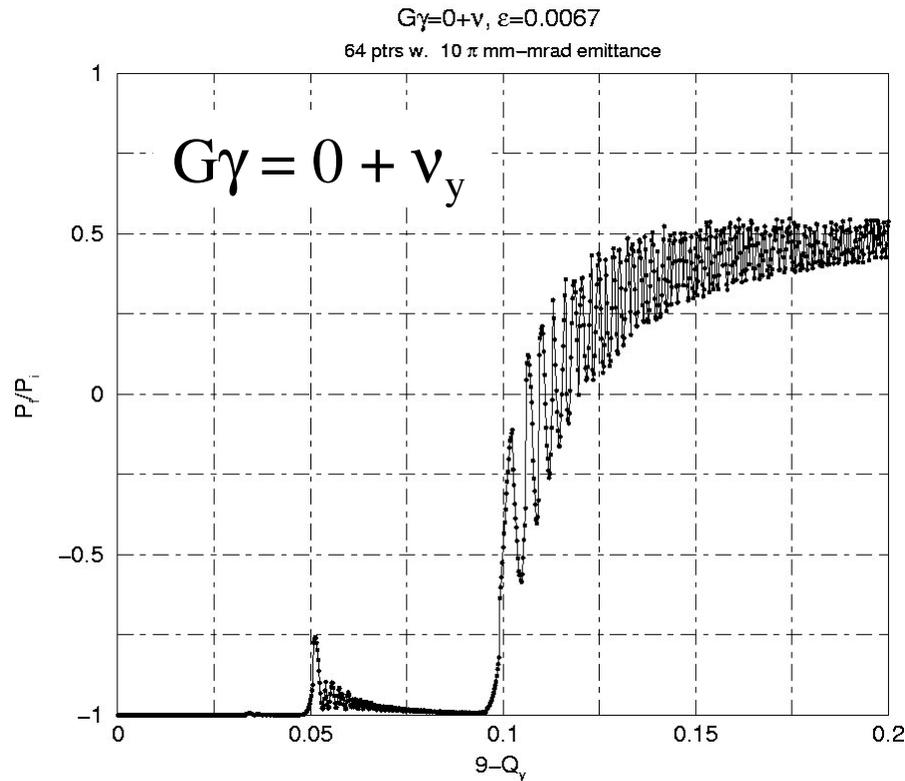
Cold Snake Timeline

- March 31: Cold snake installed in the AGS ring.
- May 3: First time to run 1.5T cold snake.
- May 5-20: Commissioning the 1.5T cold snake at injection.
- May 21: Commissioning the 2T cold snake at injection.
- May 22: Commissioning the 2.5T cold snake at injection.
- May 31: 2.5T cold snake +1.5T warm snake at $G\gamma=12.5$, >60% polarization measured.
- June 2-13: 2.5T cold snake +1.5T warm snake at $G\gamma=46.5$, >50% polarization measured.
- June 14-22: 2T cold snake +1.5T warm snake at $G\gamma=46.5$, >50% polarization measured.
- June 23-26: 2.5T cold snake only, >50% polarization measured.

Commissioning the Cold Snake

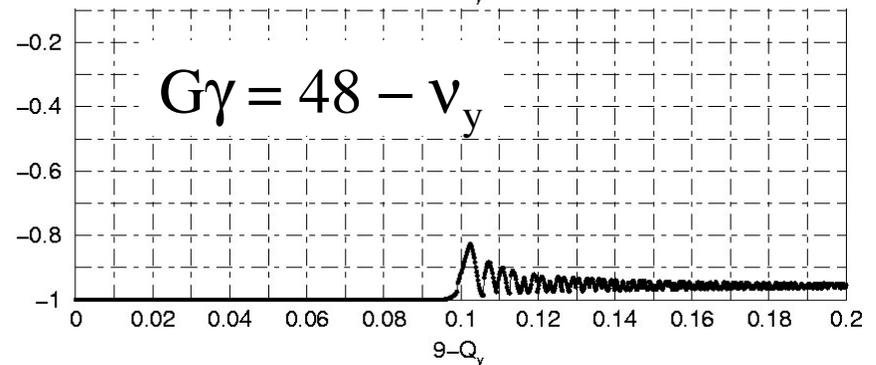
- Due to the partial snake resonances, the available tune space is reduced to about half. So the vertical tune has to be put above the half of the tune space. Consider some tune spread, we want to push it higher by another 0.01 unit. In the case of 15% snake, tune should be above 9.725.
- In addition, the snake strength varies with energy. It is crucial to put vertical tune higher at the weak snake strength case.
- With tune close to integer with the strong snake at injection is not possible (not a stable machine). We have to ramp up vertical tune during the energy ramp. The estimation is that vertical tune should be in the tune window by $G\gamma = 7$ (injected at $G\gamma = 4.5$).

Modeling of AGS Resonances with 20% Snake

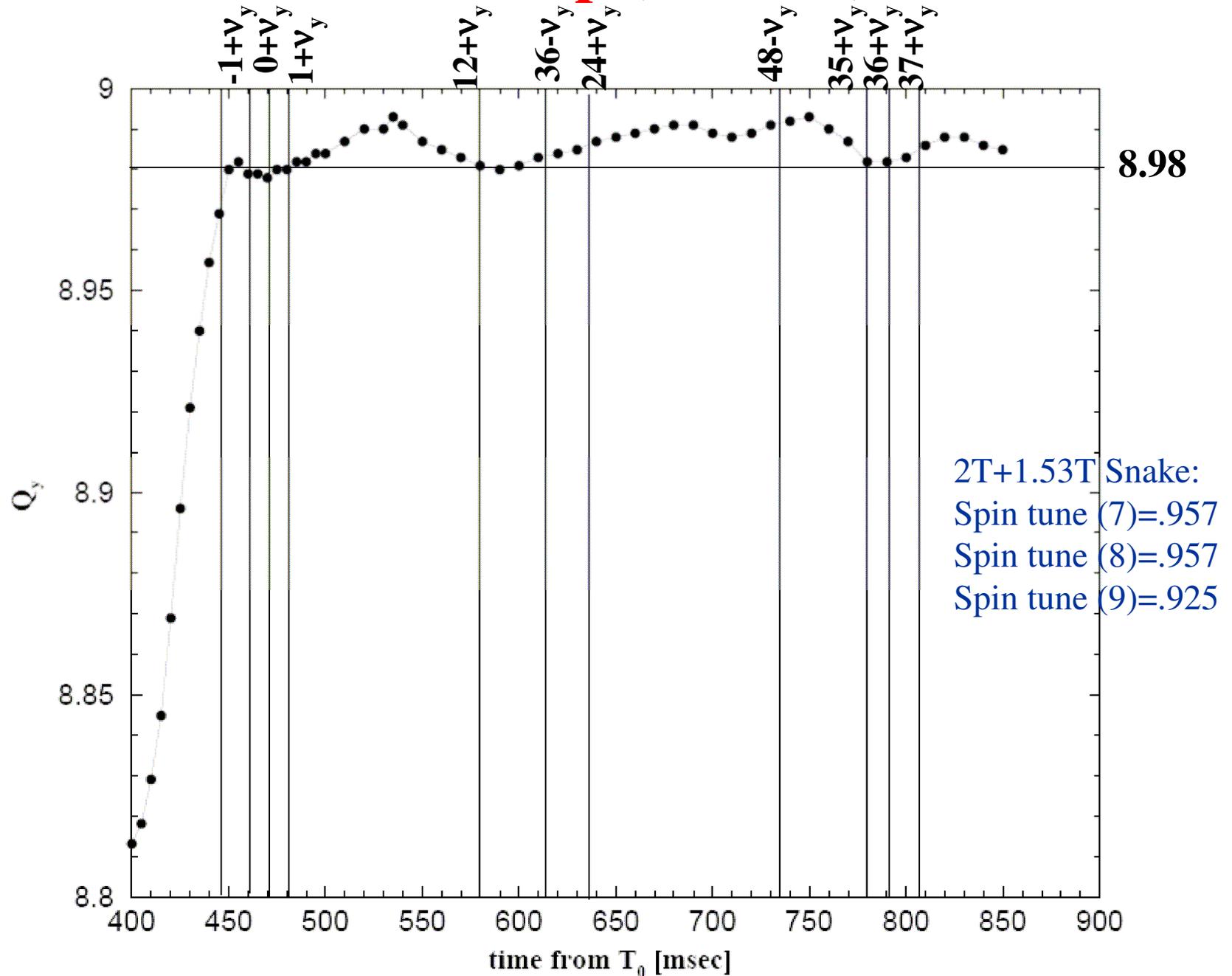


“Partial Snake Resonances”
 if $v_{sp} = n v_y$

(from Mei)



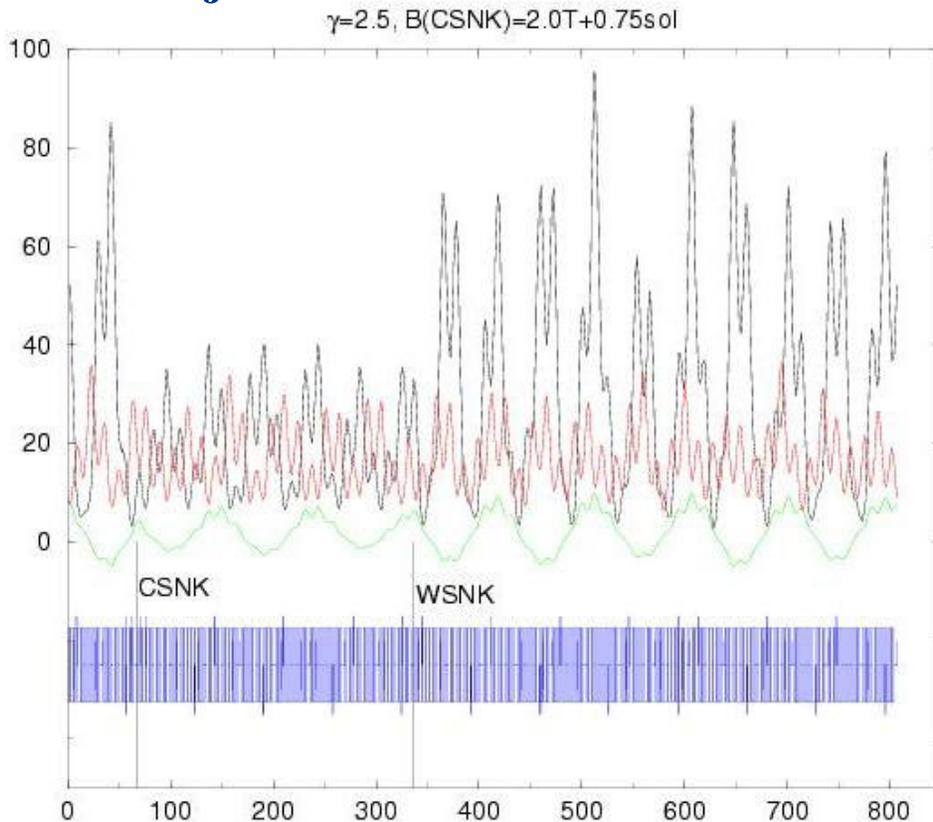
Tune Measurement on Ramp (June 15)



Lattice Function with Two Snakes

Lattices with two snakes and only two correction quads for the cold snake. With the lattice distorted so much, it is hard to push tune at injection close to 9. We have to ramp it up during energy ramp.

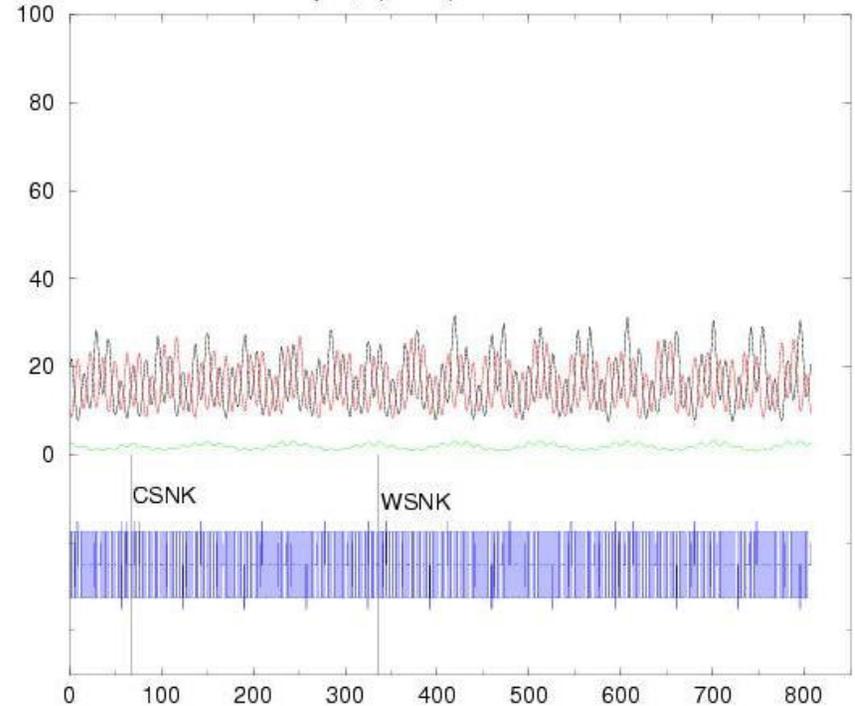
At Injection AGS - 2S 2QW



ALL 050613-01

AGS - 2S 2QW

$\gamma=5, B(\text{CSNK})=2.0T+0.75s_{ol}$



ALL 050613-02

At First Intrinsic Resonance

(Done by Alfredo)

Cold Snake Schemes

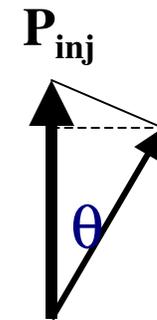
- 2.5T CSNK+1.5T WSNK: very hard to increase intensity, limited aperture.
- 2T CSNK+1.5T WSNK: easier to increase intensity, up to 0.75×10^{11} (By raising source Rb temperature). Can not move the solenoid field easily (has to retune orbit even for 20A change).
- 2.5T CNSK only: hard to push tune higher around 450ms. Indication of vertical limiting aperture. But solenoid field reduced by 60A, no need to adjust orbit— horizontal aperture is large with 4 quad solution, vertical is smaller.

Asymmetry at Injection

CSNK(2.5T)	WSNK	Asymmetry	Ratio	Expected Ratio
off	on	$65.0 \pm 0.8 \times 10^{-3}$		
on	on	$61.1 \pm 0.8 \times 10^{-3}$	0.94 ± 0.02	0.924
on	off	$58.8 \pm 1.1 \times 10^{-3}$	0.90 ± 0.02	0.895

The stable spin direction is tilted due to stronger snake in the AGS. The ratio of polarization measured at injection with E880 polarimeter agrees with the expectation.

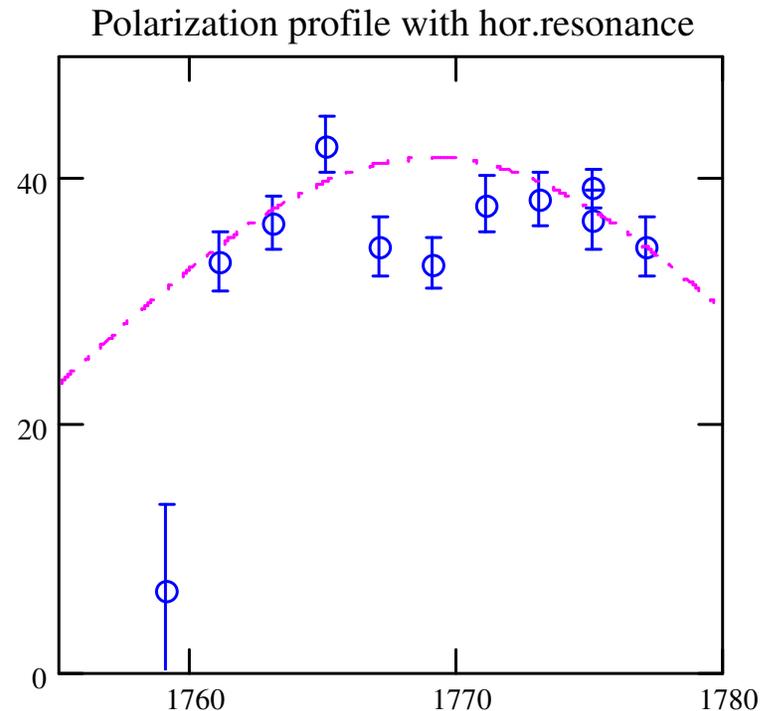
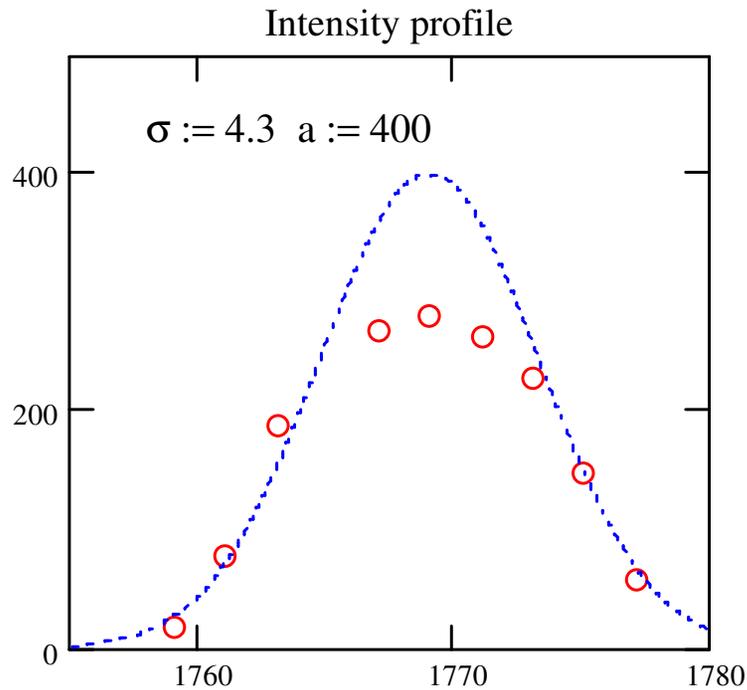
$$P_{\text{mea}} = P_{\text{inj}} * (\cos \theta)^2$$



The analyzing power is about 0.08, so the polarization with warm Snake only is about 80%.

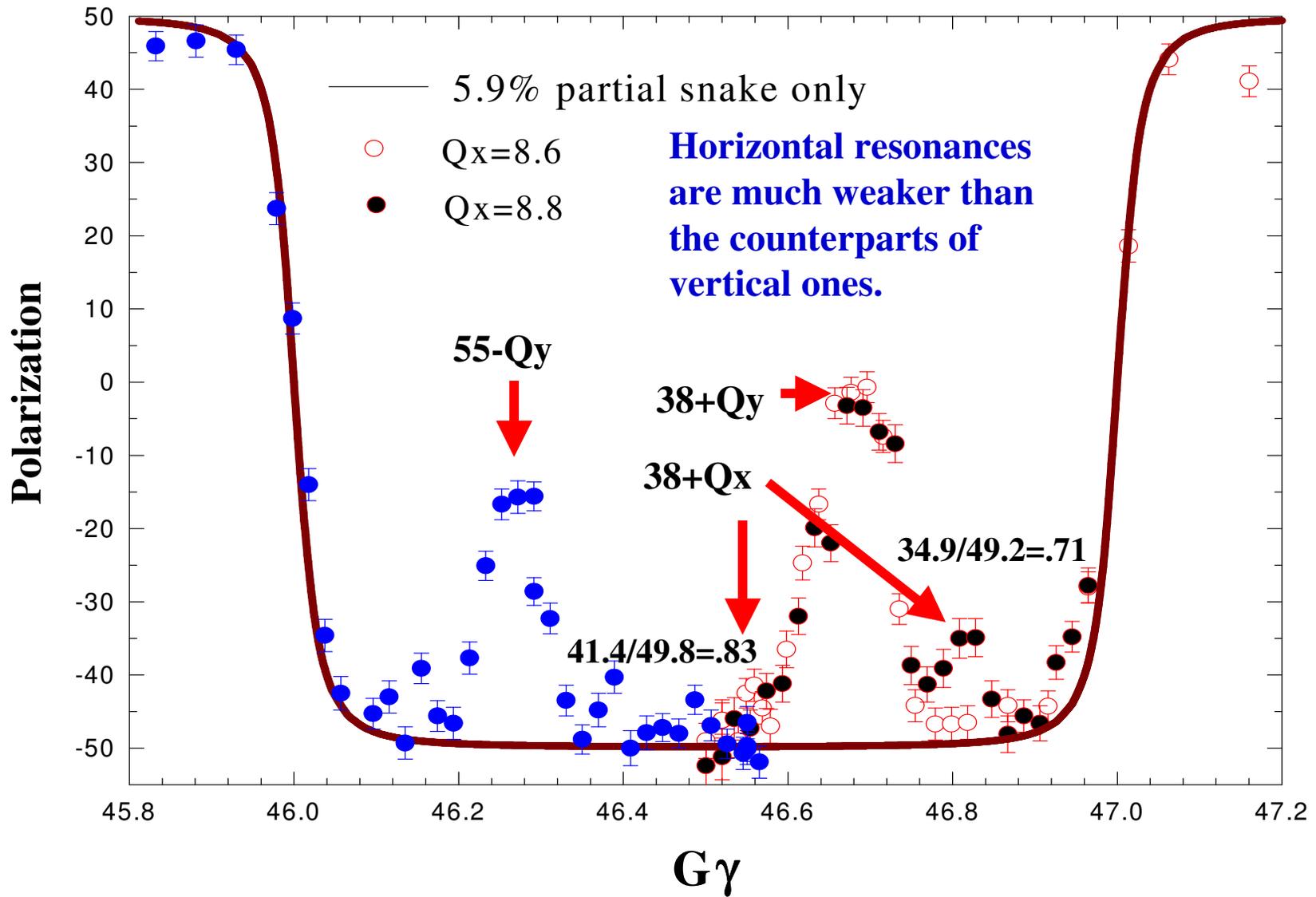
Horizontal Resonance Effects

(from T.Roser)

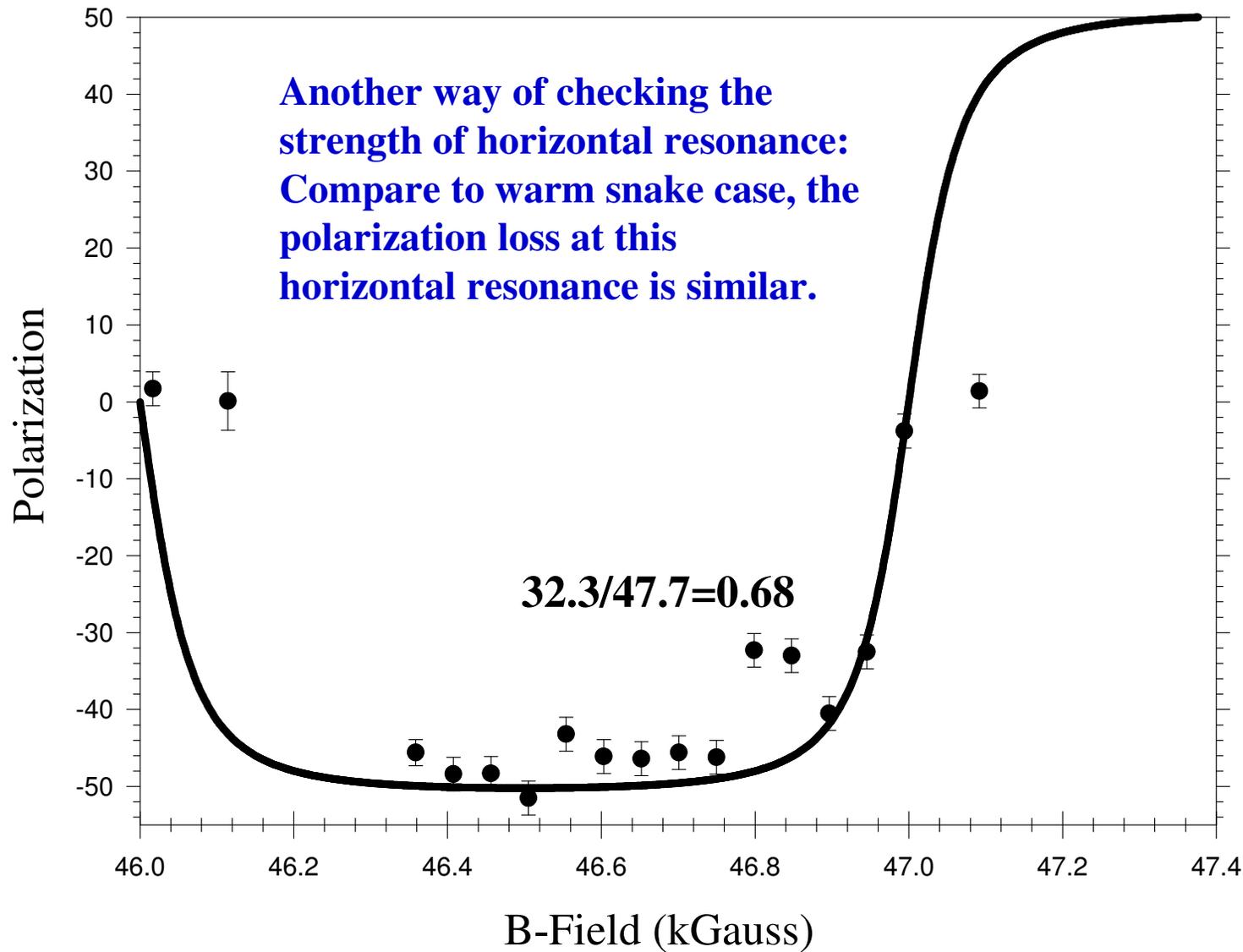


The polarization profile can be fitted as a flat line or a profile. Assuming the profile is real and is due to horizontal resonance effect, one can set the upper limit of the horizontal resonance effect from 84 horizontal resonances. It is about 5% in the relative scale.

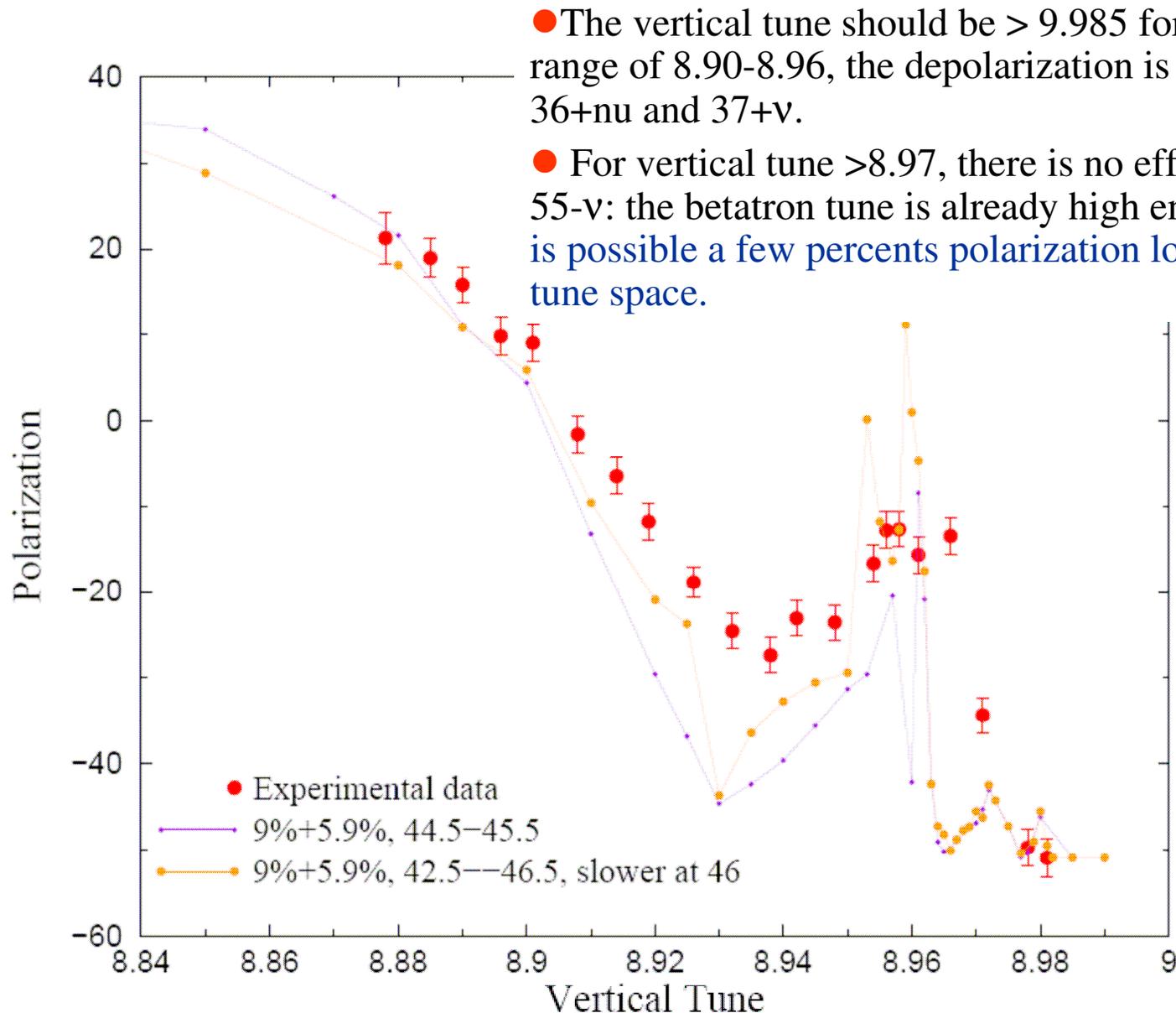
Field Scan (Warm Snake Only)



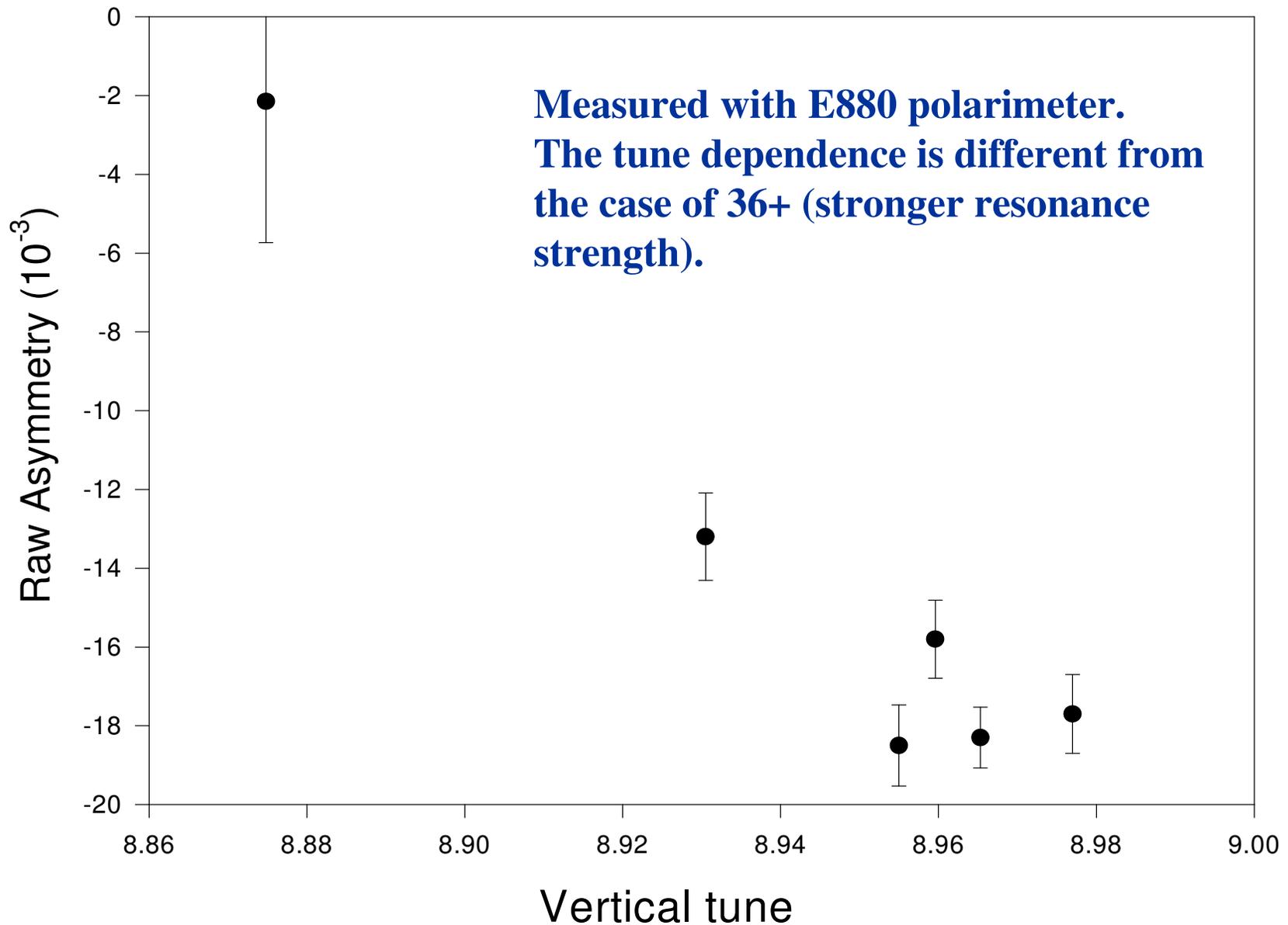
Field Scan (2T CSNK+1.5T WSNK)



Tune Scan around 36+ (2T+1.53T)

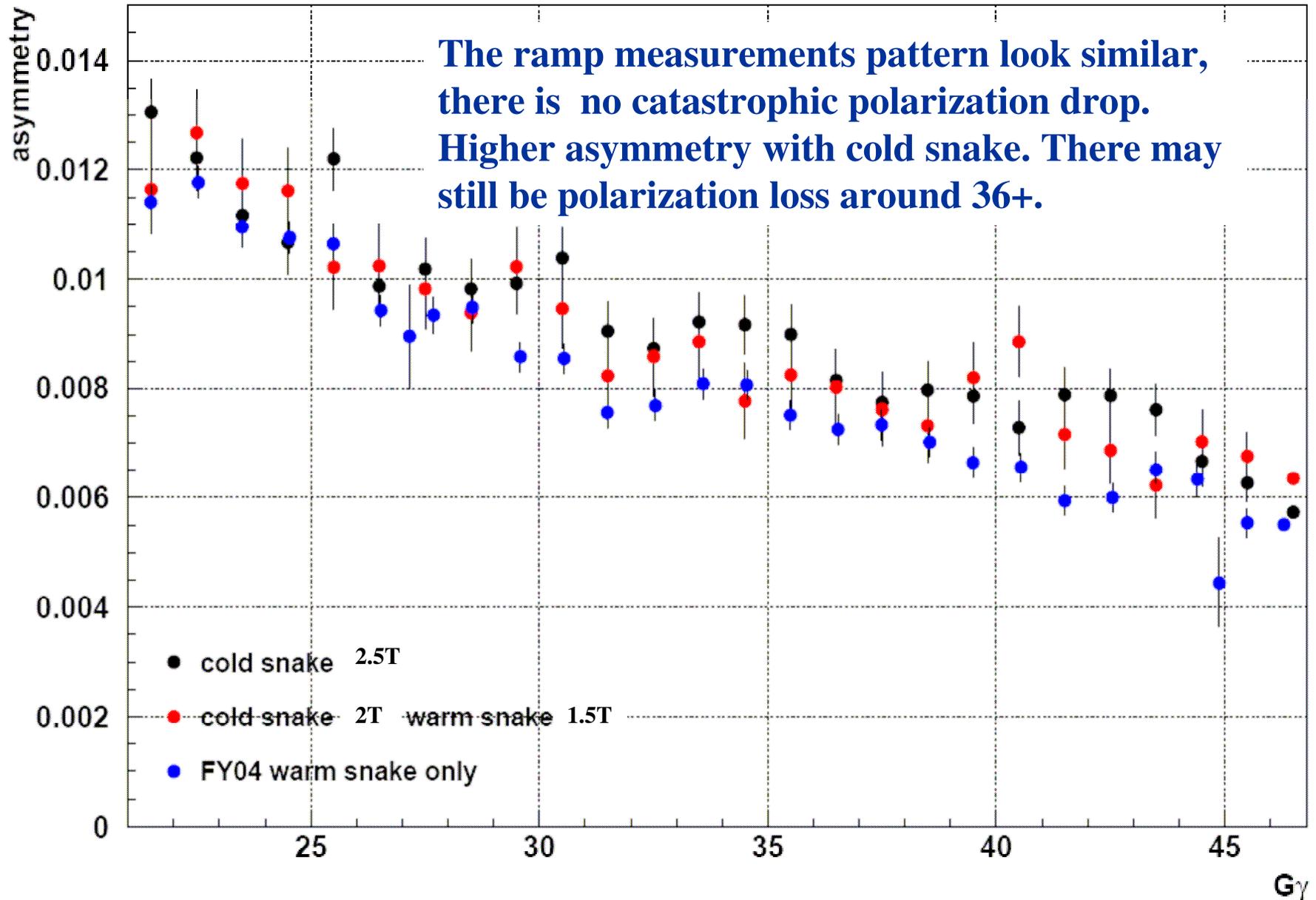


Asymmetry at $G\gamma=12.5$ (2.5TCSNK+1.5TWSNK)



Ramp Measurement

(from Jeff Wood)



Polarization Ratios

Week	Blue/Yellow	Blue/AGS	Yellow/AGS
0429	0.99710 +-0.01871	1.00417 +-0.02093	1.00722 +-0.02019
0506	0.98443 +-0.02079	1.13348 +-0.0179	1.01365 +-0.02097
0513	1.00331 +-0.01487	1.11397 +-0.01445	1.07544 +-0.01546
0520	0.98944 +-0.01727	1.11293 +-0.01790	1.11547 +-0.01780
0527	1.01341 +-0.01579	1.13749 +-0.01782	1.11870 +-0.01791
0603	0.90662 +-0.01716	1.12366 +-0.02232	1.19144 +-0.02205
0610	0.97128 +-0.01738	1.05653 +-0.01870	1.07134 +-0.01806
0617	0.92567 +-0.01854	0.99332 +-0.01975	1.07356 +-0.02088
0623	0.92475 +-0.02125	1.02355 +-0.02362	1.11715 +-0.02621

total 0.97210 +-0.00588 1.07171 +-0.00632 1.08524 +-0.00645

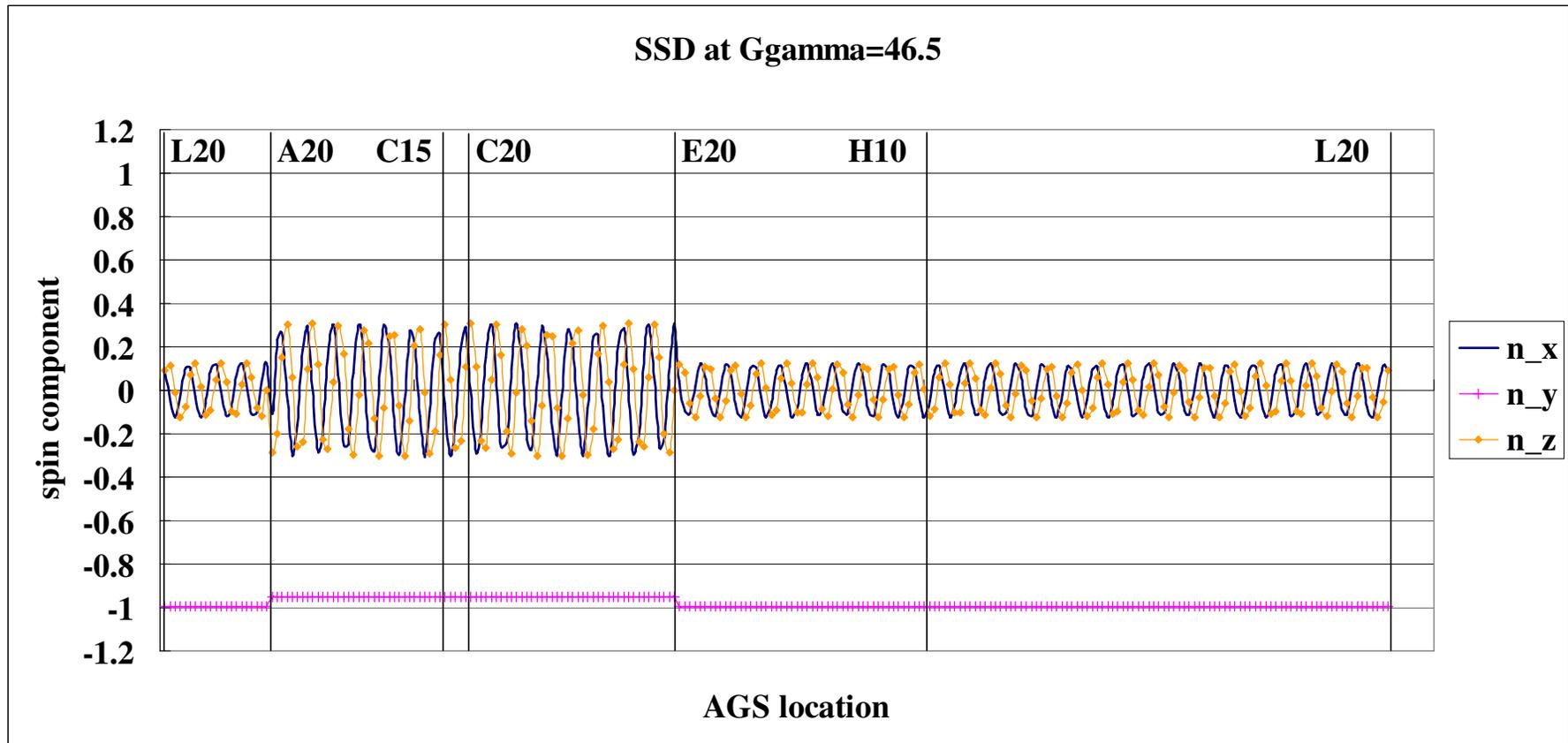
Expected 0.98 0.96 0.98

There seems no pol. Loss in RHIC ramp and polarization at store is crosschecked with jet. We can assume RHIC injection polarization measurement is real. Overall, the measured polarization in the AGS is a factor of 0.90 of the RHIC one.

We need a jet calibration run at RHIC injection!

Vertical Component at C15 Polarimeter

(from Junpei)



Vertical component at L20 = -0.992

CSNK=2.5T

Vertical component at C15 = -0.952

WSNK=1.53T

The ratio of vertical components at C15 and Ext: $.952/.992=0.960$

Comparison

	C2.5TW1.5T	C2TW1.5T	C2.5T	AC dipole
ϵ_x (π mm-mrad)	12	11	13	25
ϵ_y (π mm-mrad)	13	15	13	10
Vert. aperture limit	No	No	Yes	Limited at 0+
Hori. aperture limit	Yes	Yes	No	No
C15 vs. Extraction	0.960	0.974	1.0	1.0
A_N too high	0.90	0.90	0.90	0.90
Meas. Max. Polarization	52.5%	56.4%	55.1%	57.6%
Expected Ext. Polarization	60.8%	64.3%	61.2%	64.0%
Difficulty	intensity	intensity	Raise Q_y	0+ v aperture

The expected ext. polarization is obtained from dividing meas. Max. polarization by the factors of A_N too high and C15 vs. extraction. CSNK15% is with four quads, which gets horizontal beta function under control, but vertical beta function fluctuation getting worse.

Polarization Loss

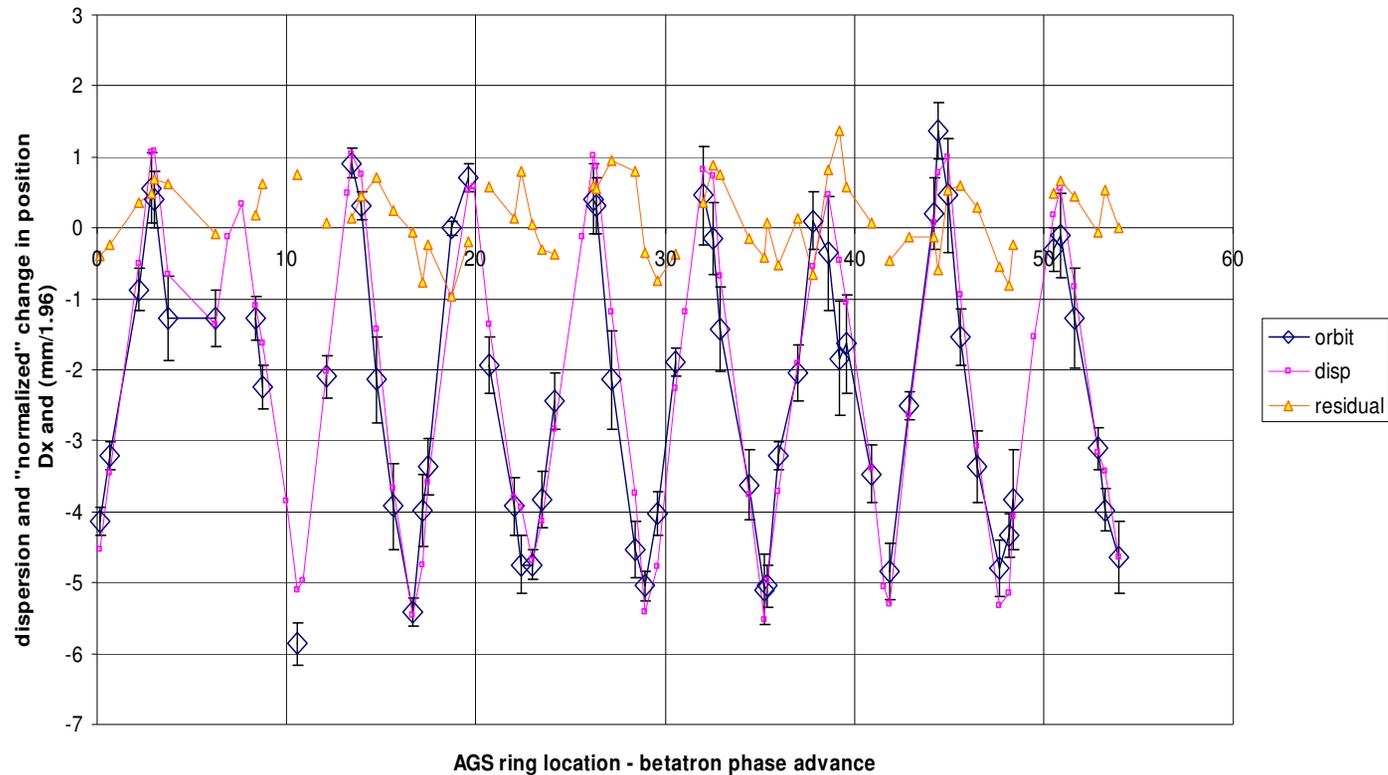
	C2.5T	C2.5T,W1.5T ⁴	C2T,W1.5T	AC dipole
Hori. res. ¹ :	0.94	0.89	0.94	0.99
Low v_y at 36+ ¹ :	0.95	0.95	0.95	1.00
Inj./Ext.:	0.915	0.967	0.994	0.987
Weak int.	1.00	1.00	1.00	0.85
Total ²	0.817	0.818	0.888	0.830
Measured ³	0.765	0.761	0.800	0.800
Expected at Ext.	0.86	0.86	0.93	0.83

1. The polarization loss due to horizontal res. and low v_y at 36+ is given as the upper limit, especially in the two snake cases (total snake strength varies).
2. There is also possible loss at early part of ramp when vertical tune is outside the tune window. It is estimated no more than a couple percents but spin tracking will follow.
3. 80% source polarization assumed. There is still a factor of 1.07 is missing.
4. C2.5T,W1.5T provides wider tune window, preferred for stable operation.

Dispersion Function with Horizontal Difference Orbit

Dispersion and "Normalized" beam position
2.5T CSNK, 4quads "as run" 25Jun05
full momentum range, rad cmd (1.8-1.3)(dp/p~.2%)

(from Leif)



Much larger momentum aperture for the CSNK only and 4-quad solution. The measured dispersion also agrees well with model prediction.

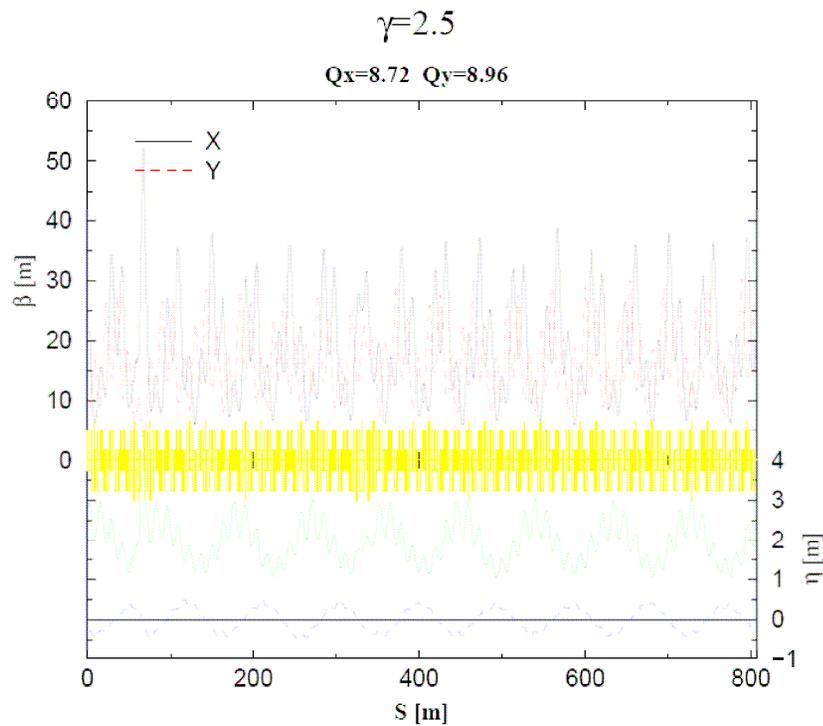
Improvement for Next Run

- The warm snake horizontal orbit correction is not a local one (easy to increase intensity with CSNK only machine; no effect from solenoid field change for CSNK only case). Add two thin quads at warm snake. Using four quads solution for the warm snake. Redesign the orbit bump. (Work has started and should be ready by November).
- Change the quads correction strength at the cold snake. Using four quad solution instead of two quads solution. Keep vertical tune as high as possible at injection. Redesign the orbit bump accordingly. (Already have solution for quads and orbit bump will follow).
- Difficult to raise vertical tune to 8.98 at high energy. Fix the tune quads power supply so that 700A current can be delivered to the magnets.
- Refurbish the horizontal sextupoles to get horizontal chromaticity zero.

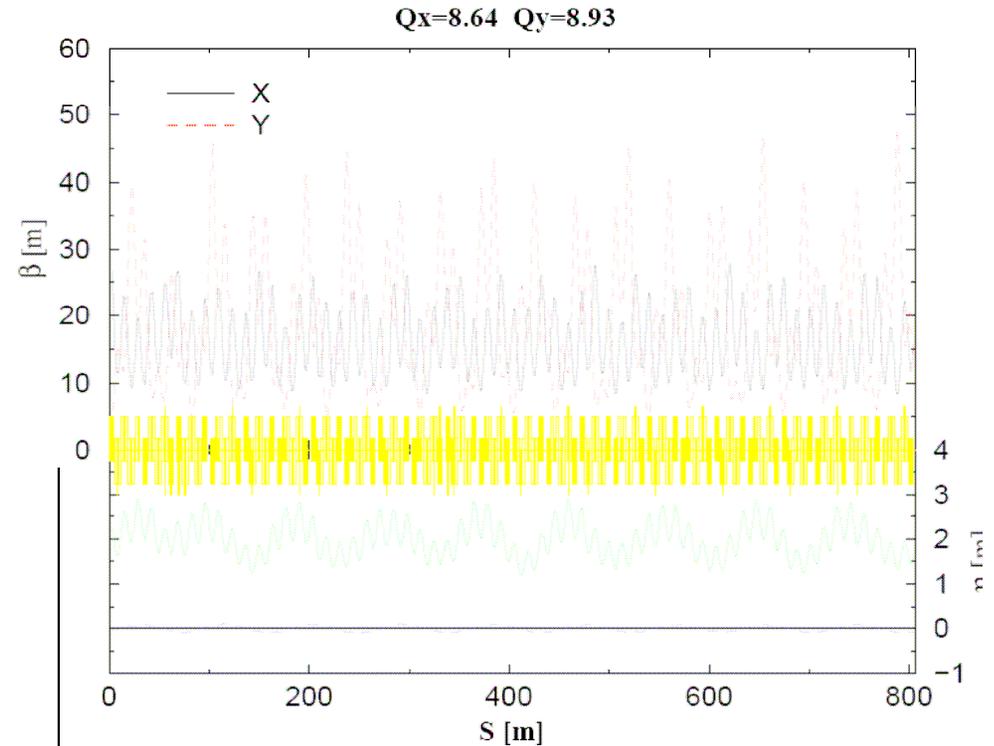
Lattice Functions with Four Quads

Much better lattice at injection.

At Injection



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At First Intrinsic Resonance

(done by Alfredo/Nick)

Haixin Huang

Improvement for Next Run (2)

- Build AGS on line model to deal with the complicated optical control of AGS after insertion of snakes.
- SPINK simulation of the early part of the energy ramp (with vertical tune ramping the same time).
- Simulation of horizontal resonance effect. There is already simple models to calculate the horizontal resonance effect. We are working on tracking study with real lattice.
- Study the intensity effect from both accelerator and polarimeter aspects.

AGS CNI Polarimeter

- Near the end of the run, it seems that polarimeter has intensity dependence: removing Booster scraping only modestly increased emittance, but polarization reduced significantly; changing pulse width from source changed polarization but not emittance. Smaller horizontal emittance may enhanced the effect.
- We should do polarization intensity scan at RHIC injection next run.
- We would like to install 45 degree Si detectors for next run, as stronger snake generates measurable radial components.
- The instantaneous rate for each AGS Si detector strip is actually higher than RHIC one. Should we also rotate the Si detectors in AGS by 90 degree?

Cold Snake Summary

- The experimental data already show that multiple strong snake idea works. The vertical tune actually can be set to very high value (>8.98). The polarization level has reached 60% equivalent at AGS extraction.
- The spin dynamics is understood: various polarization vs tune measurements (at different resonances and at different energies) behave quantitatively as expected. There may be a few percents loss due to tune not high enough. More simulation is going on.
- Possible horizontal resonance effect is also explored. Flattop B-field scan with warm snake only and cold snake only shows that the strength of horizontal resonance is smaller than the strength of general intrinsic resonance. The upper limit of the total effect of horizontal resonances is extracted from horizontal profile as a few percents.
- The emittance with lowered vertical tune ($-.02$) over the whole ramp was measured and compared with the nominal tune case. There is no difference. This is to ruled out emittance blow up due to tune so close to integer.

Plan

- AGS will start pp setup three weeks before RHIC pp run starts– right after Thanksgiving.
- Next year, CSNK+WSNK with the cold snake at 2.5T. The 4-quad correction scheme is a much better scheme as demonstrated at the end of run. We will apply it for both CSNK and WSNK and it is a very promising scheme.
- The goal is to reach 1.4×10^{11} /bunch with 65% polarization.
- The main focus is to increase bunch intensity while maintain the polarization.