# Overcoming Depolarizing Resonances in the AGS with Two Helical Partial Snakes

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# Depolarizing Resonances in the AGS

**Imperfection Resonances**

arising from sampling of error fields, fields due to closed orbit errors, etc.

$G\gamma=n$ (integer)  $G\gamma=5,6,\ldots45$

**Vertical Intrinsic Resonances**

arise from sampling of focusing fields due to finite beam emittance.

$G\gamma=kP\pm\nu_y$  In the AGS, P=12: $G\gamma=0+\nu_y$, $24\pm\nu_y$,$48-\nu_y$, $12+\nu_y$, $36\pm\nu_y$

**Horizontal Intrinsic Resonances**

1. horizontal non-vertical stable spin direction due to strong partial snake interaction with horizontal motion.

2. betatron motion coupled to the vertical betatron motion by coupling elements: solenoid, helical magnet.

$G\gamma=k\pm\nu_x$

**Partial Snake Resonances**

strength proportional to nearby intrinsic resonance strength.

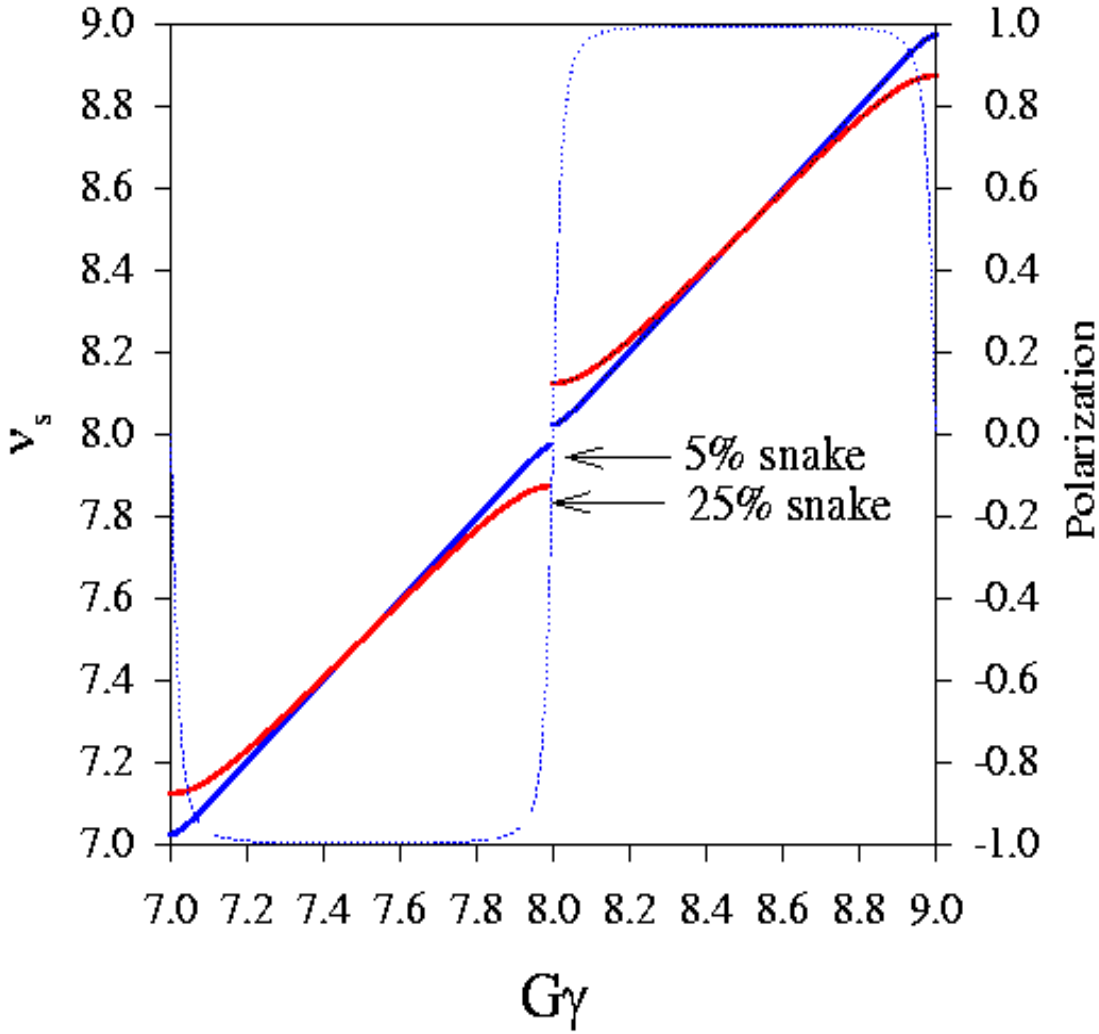
$G\gamma=kP\pm m\nu_y$ , $m>1$

# Spin Dynamics

- Partial snake generates spin tune gap.
- Spin tune gap is generated with a partial snake:

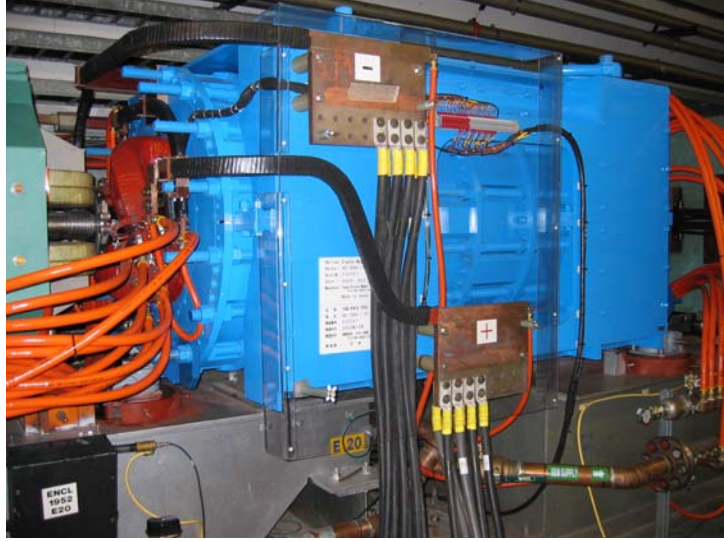
$\cos\pi\nu_s=\cos(\delta/2)\cos G\gamma\pi$

- $\nu_s$ can not be an integer, avoided all imperfection resonances
- Put betatron tunes into the spin tune gap, avoid all intrinsic resonances

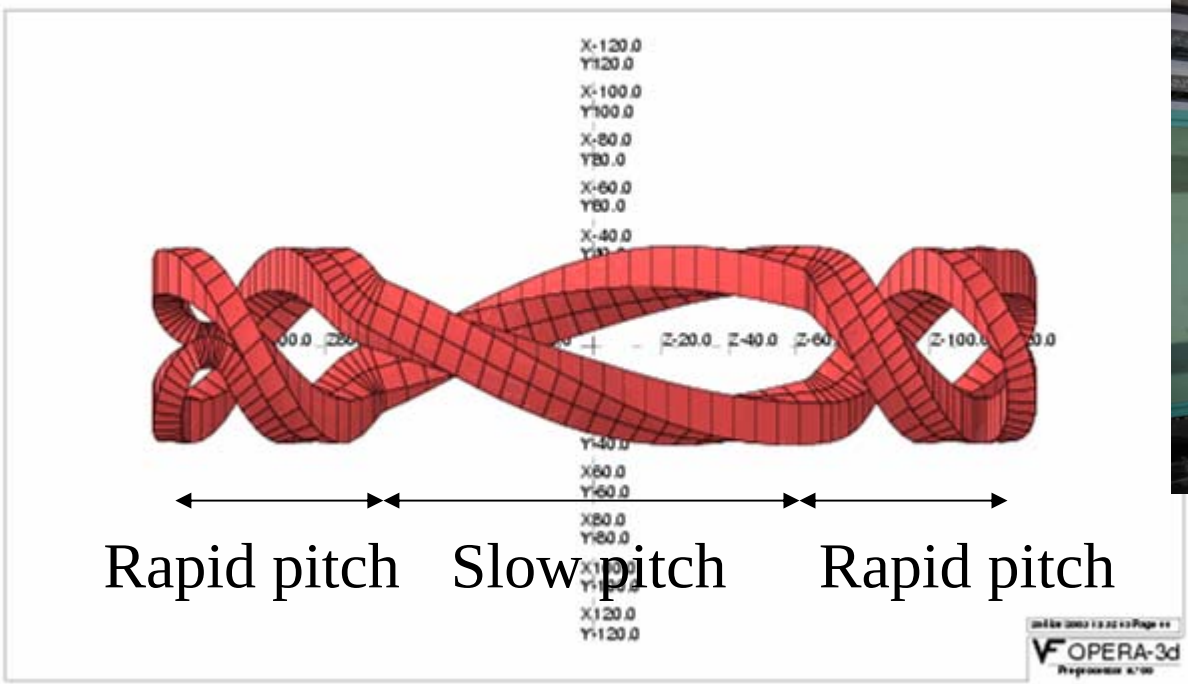


# Partial Snake Design

Normal Conducting partial snake (warm snake)

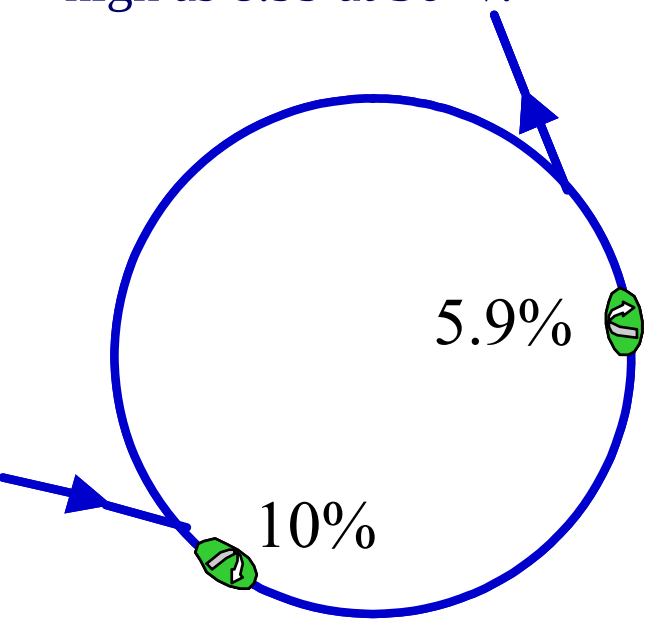


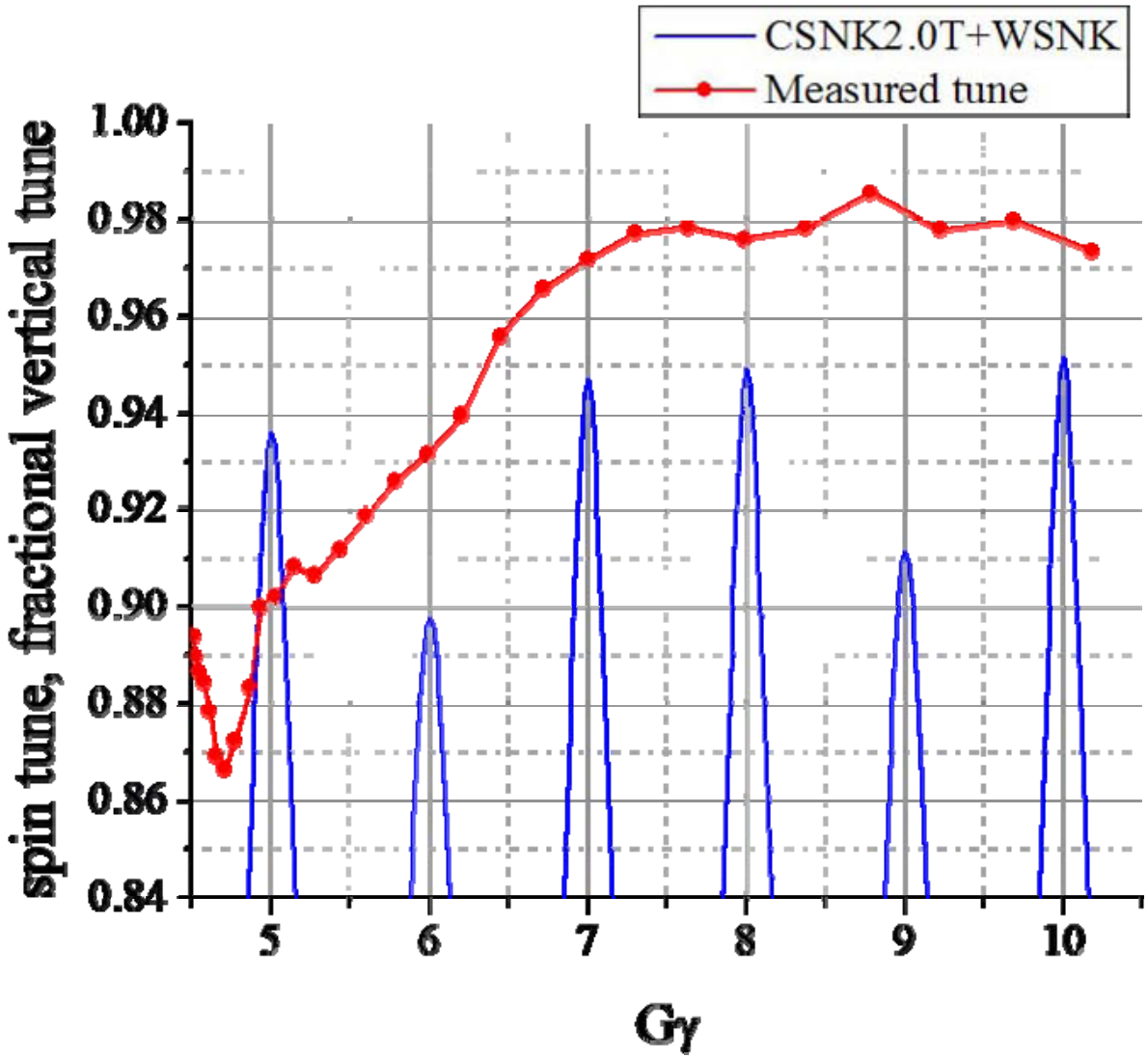
Super-Conducting partial snake (cold snake)



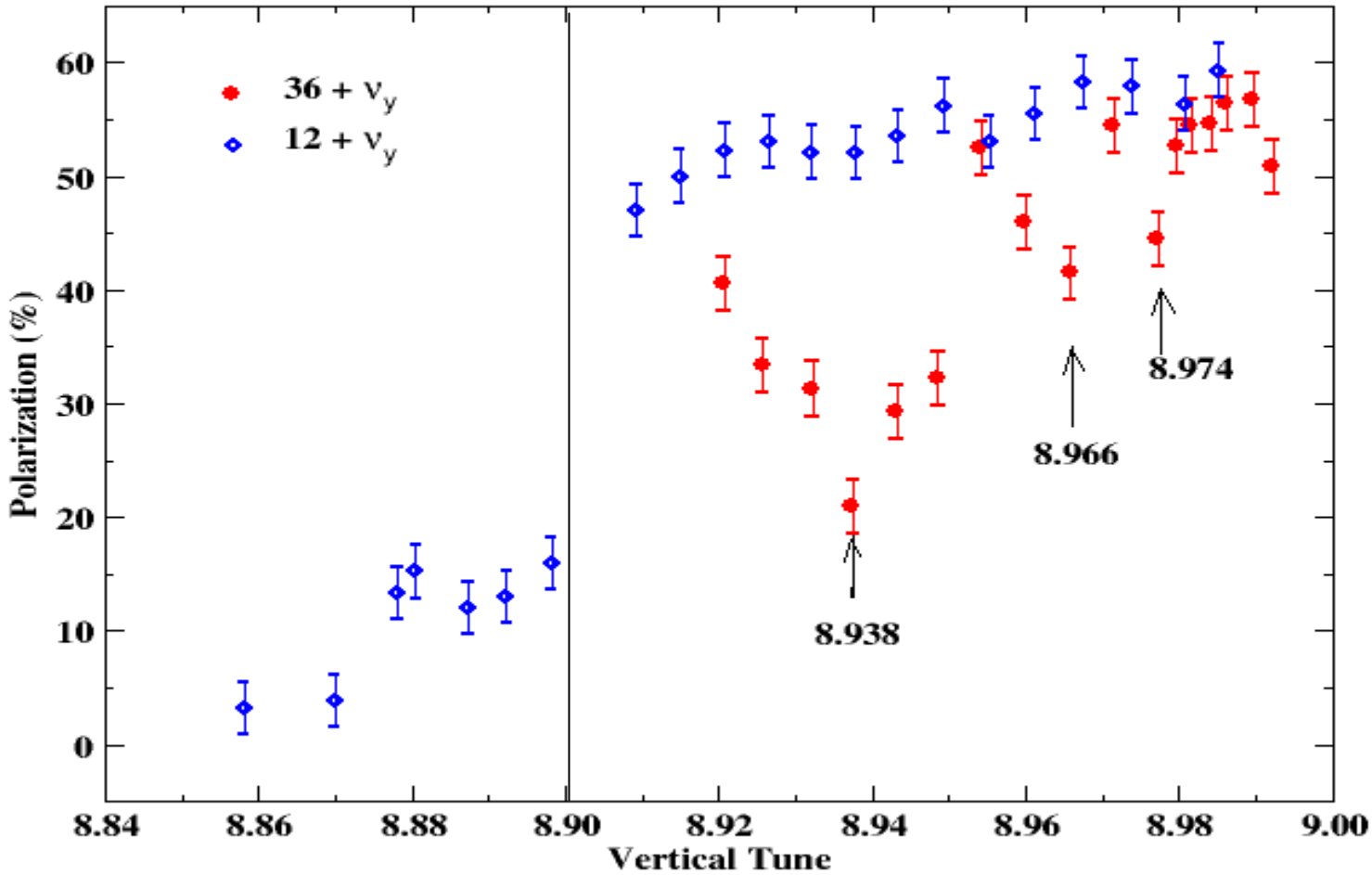
# Spin Tune and Fractional Vertical Tune

With two helical magnets installed, the lattice is largely distorted at low energies. It took quite a lot efforts to set the vertical tune close to integer. Vertical tune is higher than 8.98 at all major intrinsic resonances. It is even as high as 8.99 at 36+ν.



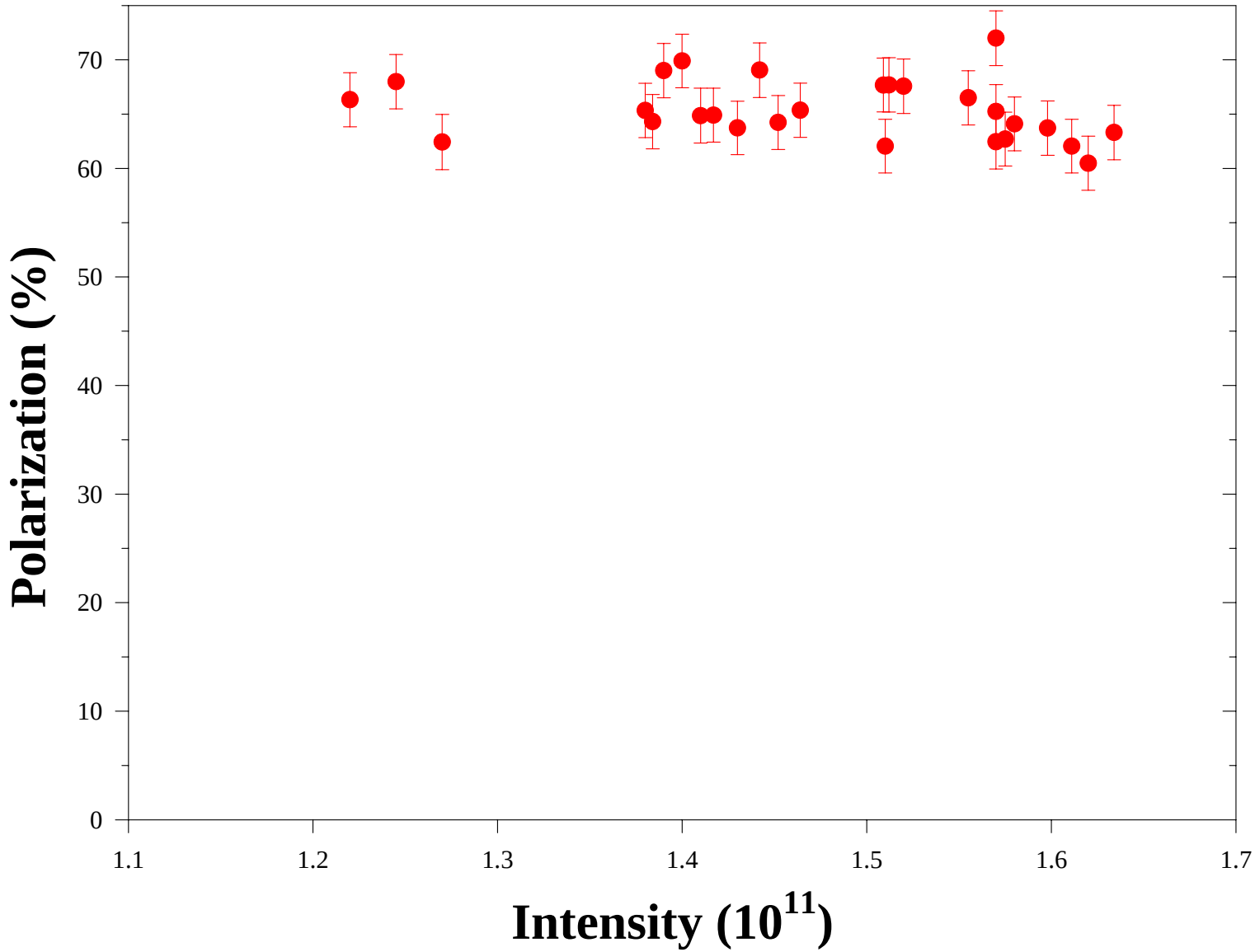



# Polarization as Function of Vertical Tunes




Snake resonance effect is clearly seen.

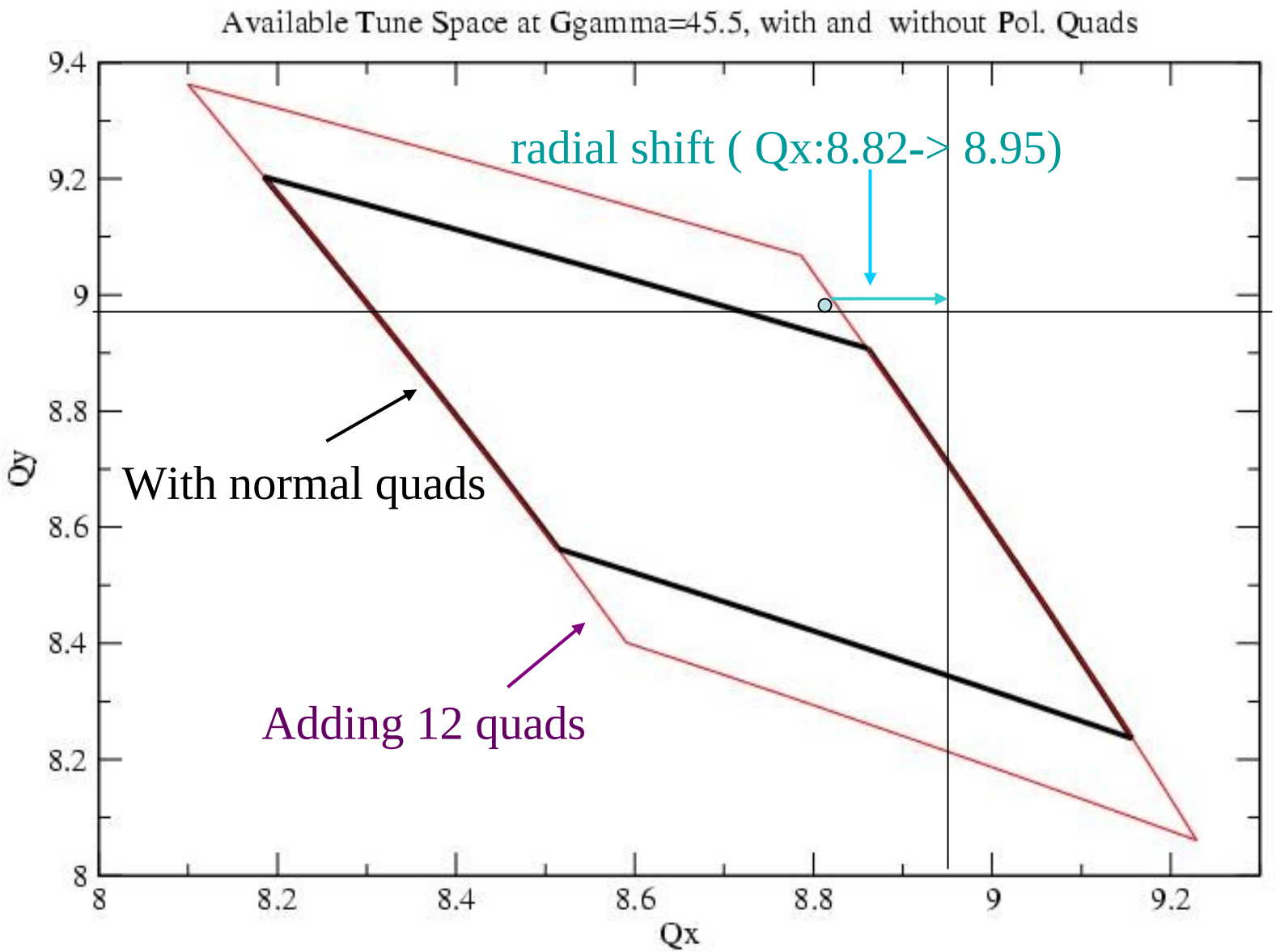
# Polarization Stays High with High Intensity



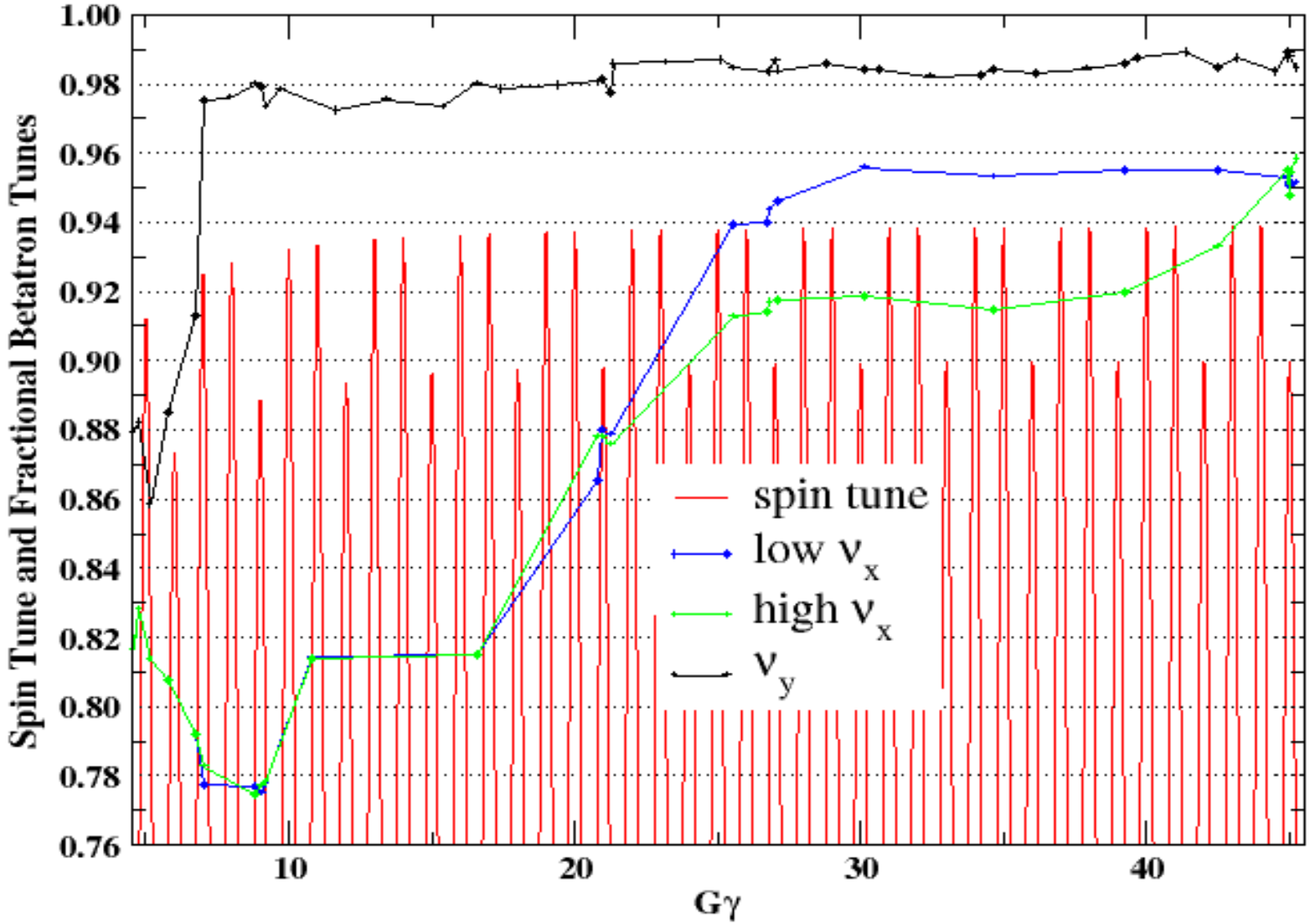
# Push Horizontal Tune Near Integer

- The idea is to put  horizontal tune near 9 (~8.95) while maintain vertical tune close to 9 (~8.98). Both tunes are within the  spin tune gap.
- With the fractional part of the two tunes are so close, the coupling has to be corrected very well. The skew quads are powered to minimize the coupling.
- Since the horizontal resonance strength are very weak, the horizontal tune does not need to be so as close to integer as vertical tune.
- A stronger cold snake is needed for both betatron tunes in the spin tune gap.
- Twelve quads were added to the vertical quad string.

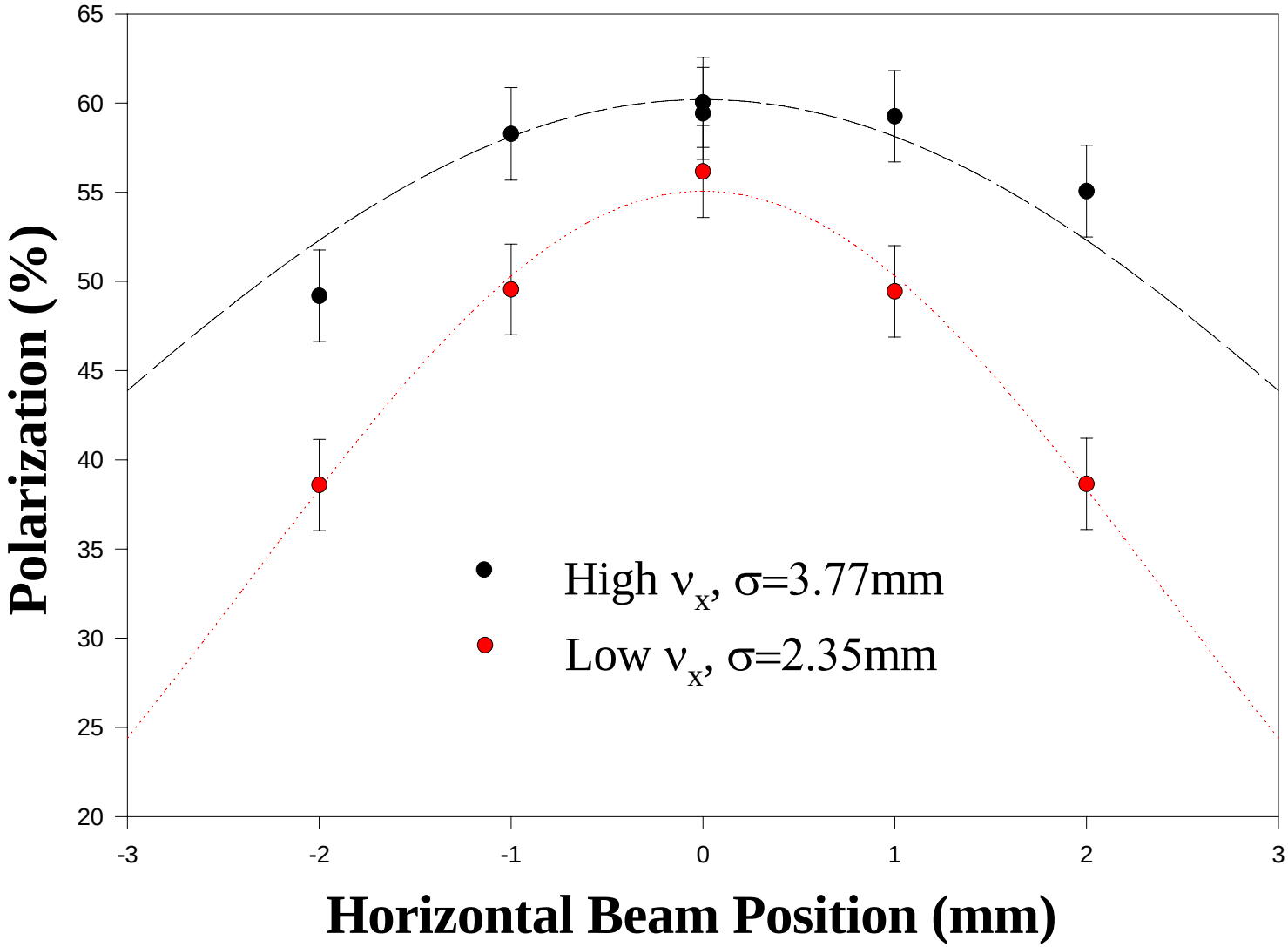
# Tune Plot at Extraction Energy



# Betatron Tune and Spin Tune



# Better Horizontal Polarization Profile for High $\nu_x$



# Summary

- 65% polarization with $1.5\times10^{11}$ intensity achieved with two partial snakes in the AGS.
- The following partial snake combination gave the best polarization:  10% cold snake and 5.9% warm snake.
- Four compensation quads for each snake are essential. The lattice is easier to handle.
- The intensity dependence is very benign with this setup.
- With a stronger cold partial snake, moving horizontal tune into the spin tune gap in the later part of the energy ramp gives better polarization.
- Work continues to push both polarization and intensity high.

Thursday Afternoon: THPAS011  F. Lin, et al., Investigation of Residual Vertical Intrinsic Resonances with Dual Partial Siberian Snakes in the AGS