Estimating Underlying Imperfection Resonance strength

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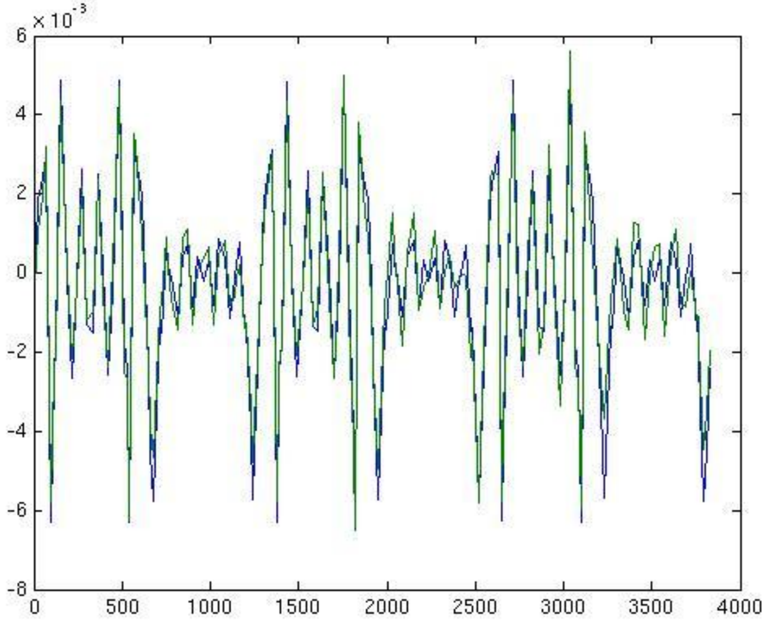
Over View

- Re-cap of 2012 APEX experiment
  - What did we learn?
- Analysis of Run12 Data
  - New data analysis technique.
- Towards a complete model of spin dependence on orbit and lattice with snakes

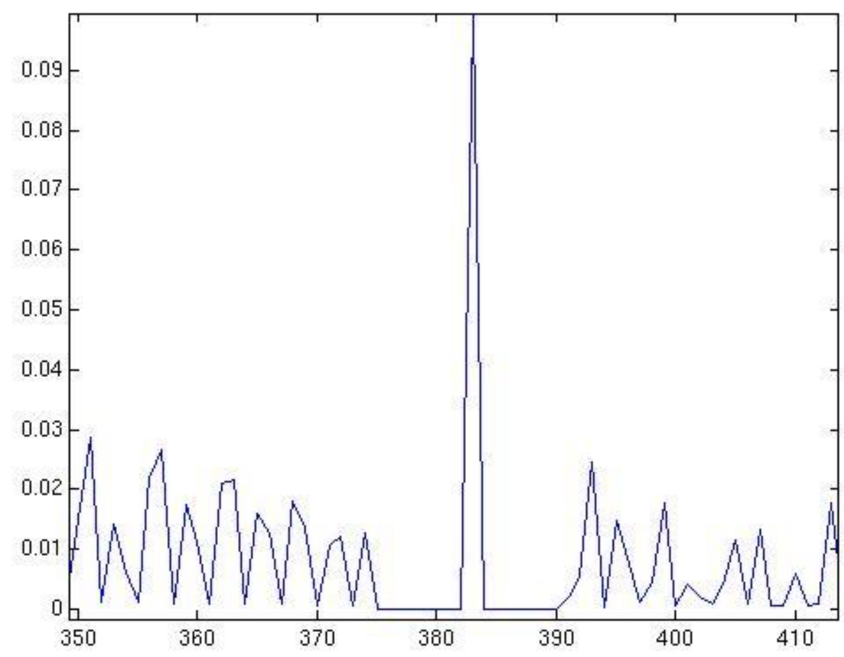
- Our Proposed experiments for APEX 13
  - Approach to generate better estimate of underlying resonance
  - How to suppress it

Re-Cap of APEX 12 Experiment

For the previous experiment we generated controlled Imperfection bumps at 381
423 Ggamma locations on the ramp. These bumps were created to be purely imaginary
Or real and of a defined value only at the resonance location and zero everywhere else. We
Performed two APEX experiments. First one to test our orbit response was what we expected
At injection. The second turned the orbit bumps on for the Blue and Yellow ring during
The acceleration ramp.



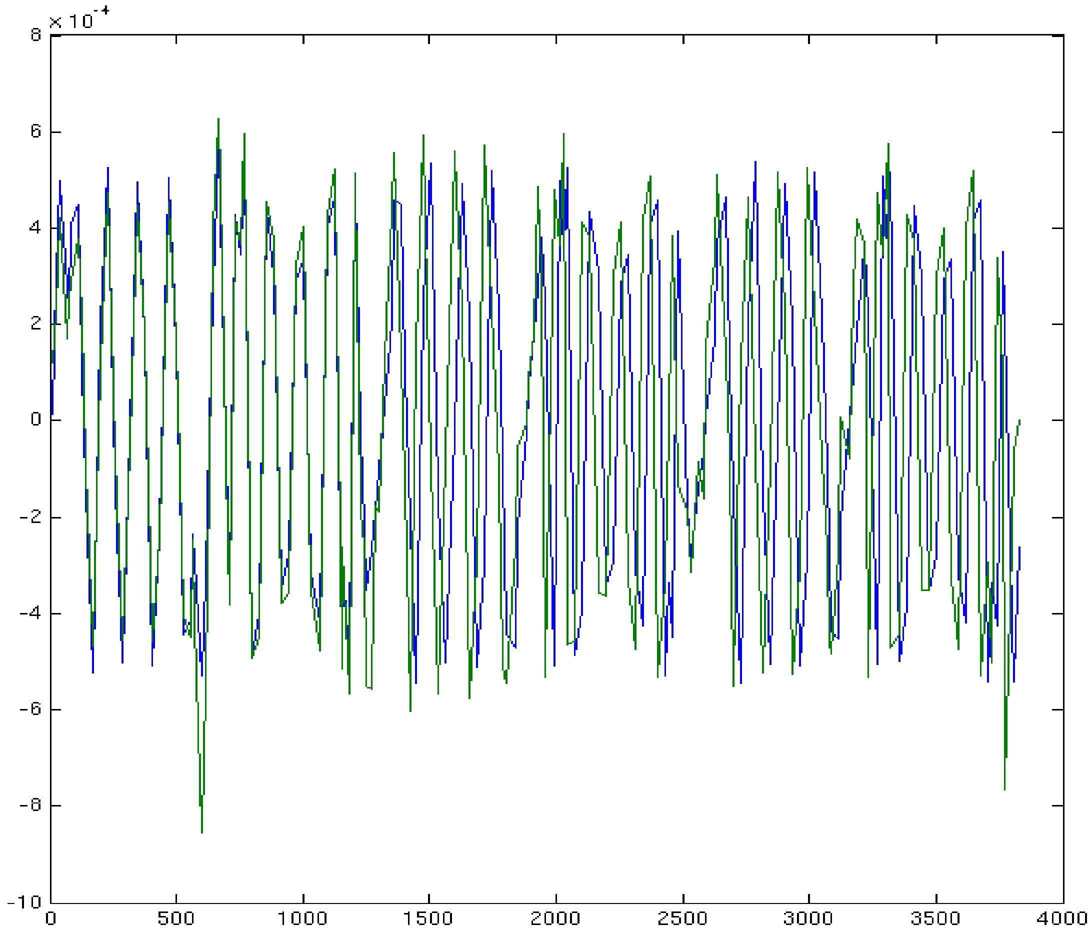
IMPERFECTION BUMPS



Blue Difference orbit at Ggamma=423

RMS predicted = 0.3622 mm
Measured = 0.385 mm

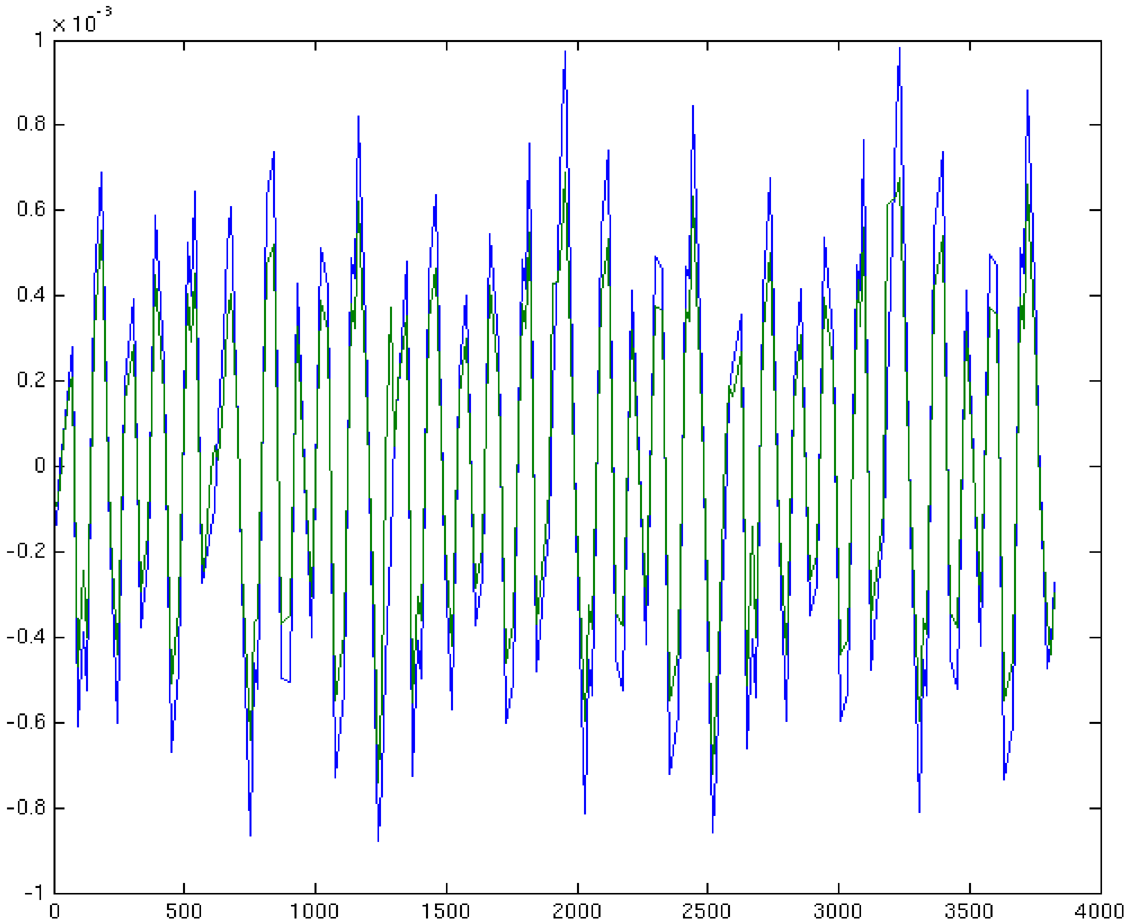
Vertical Tunes in model used
Were far off (29.65)



Yellow Difference Orbit at Ggamma=381

Rms predicted = 0.489 mm
Measured = 0.371 mm

Yellow Tunes of model Better (29.68)



APEX Yellow Experiment (achieved 0.18 Imp)

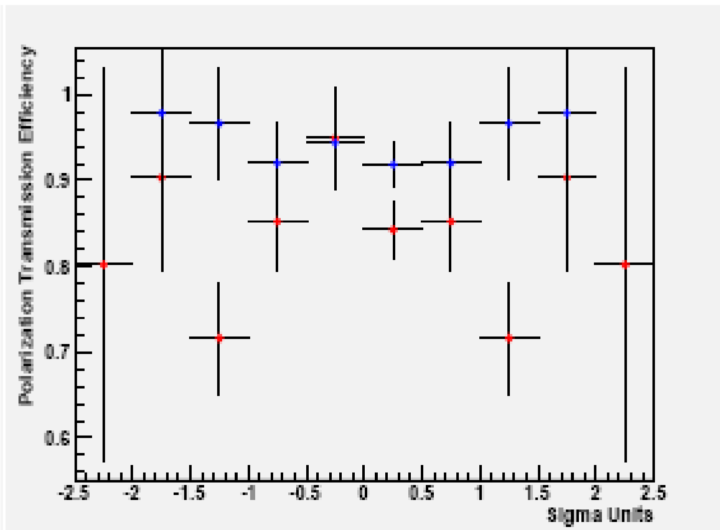


Figure 5: The polarization response of the Yellow ring due to excitement of a real 0.2 imperfection resonance at $G\gamma = 381$ (red). This plot comprises the average of five measurements taken at full energy divided by three taken at injection energy. The xaxis is in beam size sigma units. This is compared with the average efficiency from the previous four stores (blue). The data represents a ratio of the final polarization to the initial polarization at each sigma.

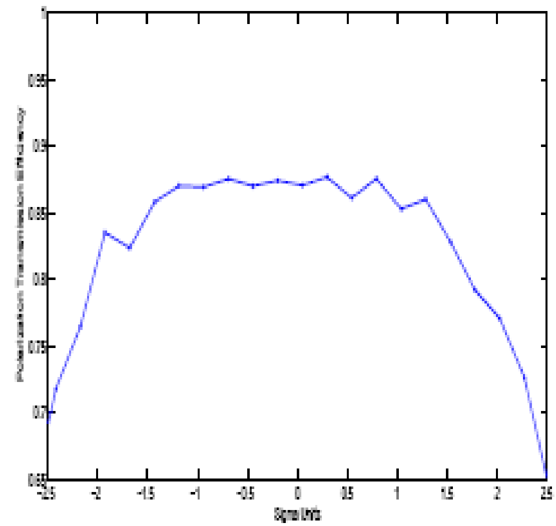


Figure 7: Simulated polarization response of the blue ring due to excitation of a real 0.24 imperfection resonance at $G\gamma = 381$. This results was generated from 32760 particles distributed using a Gaussian with a sigma consistent with 3.33 $\pi mm - mmrad$ cut off at 2 sigma for both transverse planes. The longitudinal assumed a 3 nsec rms bunch length match to the bucket. The acceleration rate was $d\gamma/dt = 8.55/sec$.

APEX Blue (achieved 0.13 Imp)

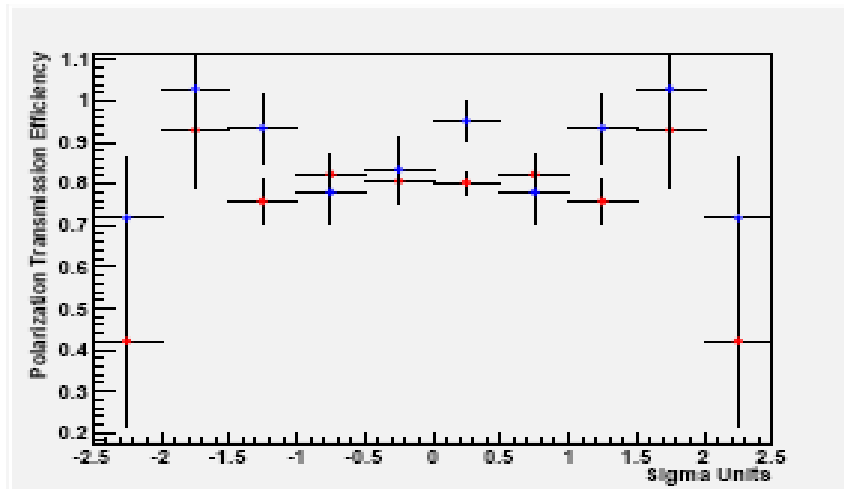


Figure 6: Polarization response of the blue ring due to excitement of a real 0.2 imperfection resonance at $G\gamma = 423$ (red). This plot comprises the average of five measurements taken at full energy divided by three taken at injection energy. The xaxis is in beam size sigma units. This is compared with the average efficiency from the previous four stores (blue). The data represents a ratio of the final polarization to the initial polarization at each sigma.

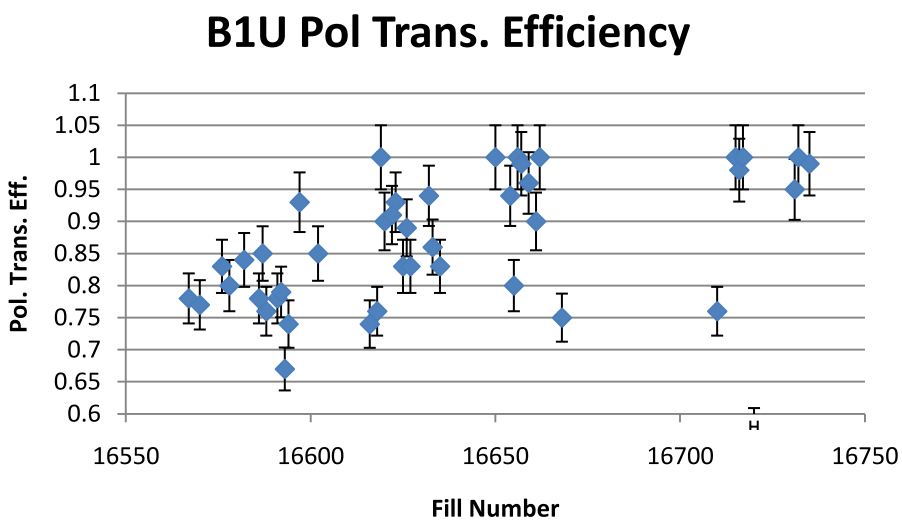
What did we learn?

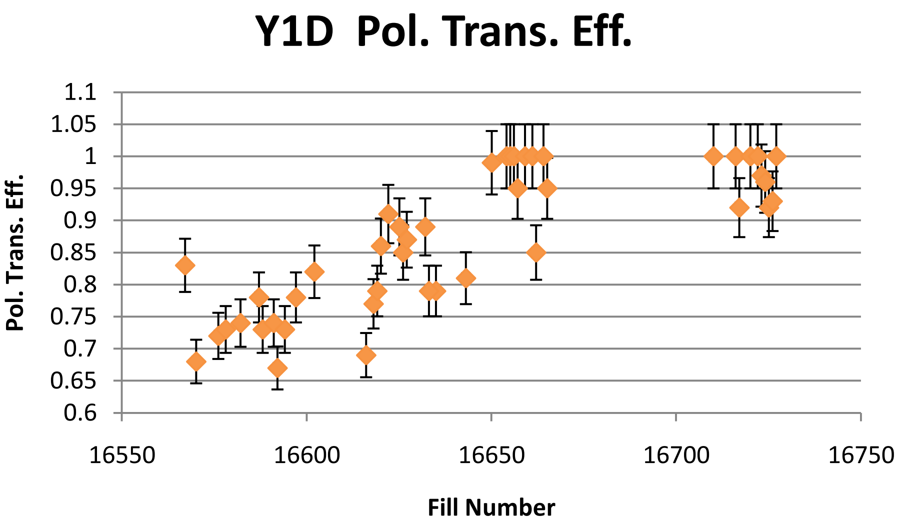
- We learned that we can generated sizeable and controlled Imperfection bumps on during the ramp
- These results seemed to confirm our simulation results

Analysis of 2012 Run Data

- We attempted to mine the Polarization transmission efficiency data and orbit data on the ramp to back out Information about the strength of the underlying Imperfection resonance.
- In the process developed some useful tools to analyze the orbit data in a new way.

RHIC Polarization Ramp Efficiency

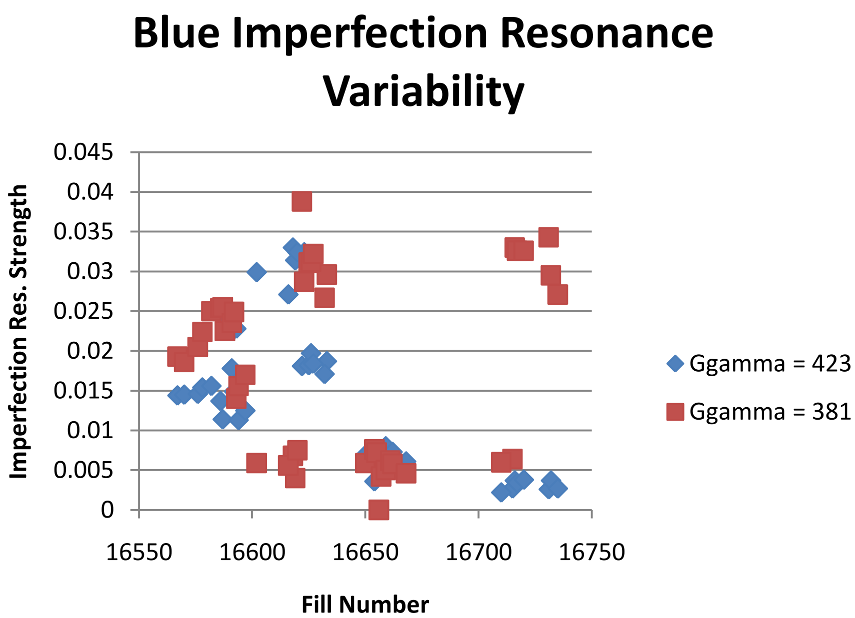


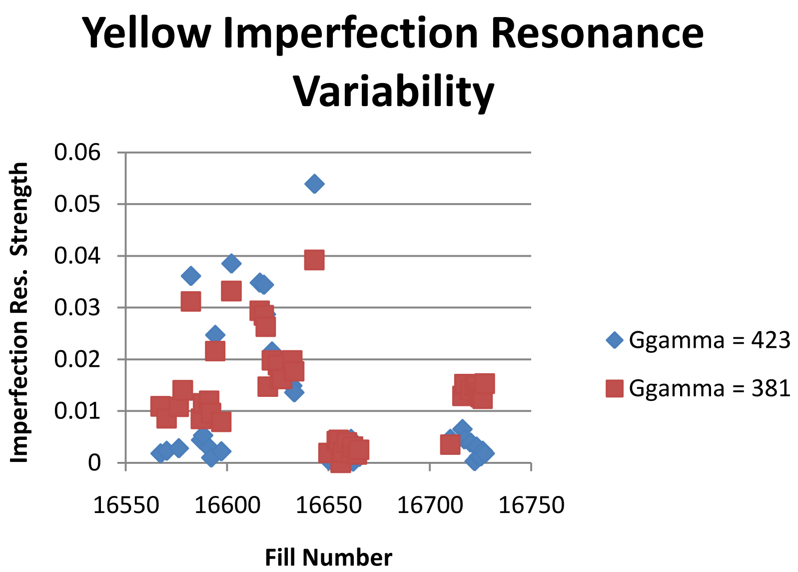


If we believe the CNI Polarimetry then we have several examples of basically 100 % transmission efficiency . So the question is why we don't get this all the time?

- Factors we think are causing loss on the Ramp
    - Snake incorrectly Tuned
    - Orbit driven Imperfection Resonances > 0.12
- Tunes are under Control and Chromaticity below 4 is not a factor
- Emittance only enhances underlying orbit or Snake issues

Backing Out Imperfection Strength





We picked a baseline orbit from one of the highest polarization transmission efficiency ramps and calculated differential orbits for each fill which we had polarization data. We then backed out the associated differential imperfection resonance strength by first calculating the corrector settings to recreate this orbit using SVD and then ran DEPOL on the final lattice.

Can we understand Polarization loss by considering a simple model

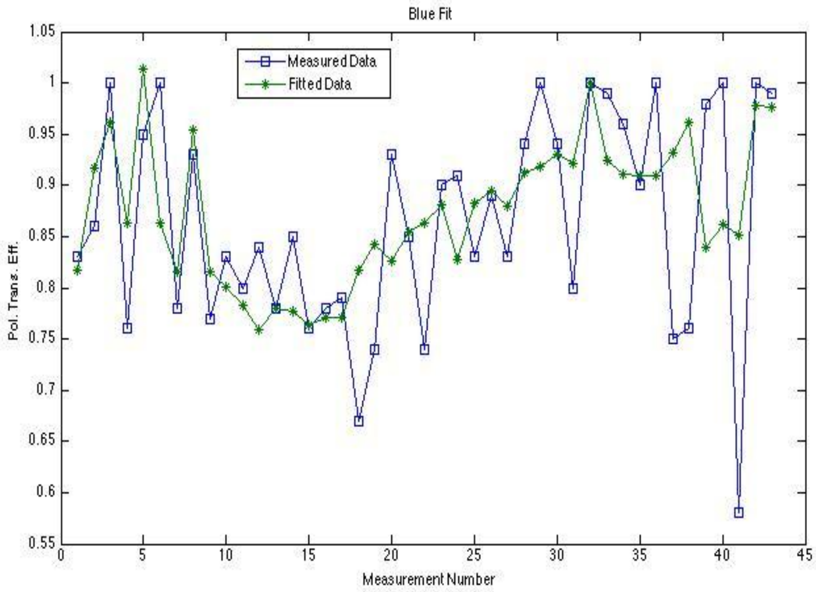
Tracking results indicate our threshold for losses across the last
Two strong intrinsic resonances are at 0.12. We see variability in the orbit at these
Resonances crossings which indicate a maximum of 0.05 imperfection resonance swing
this is consistent with an underlying Imperfection resonance strength of ~ 0.1

So can we fit a simple model?

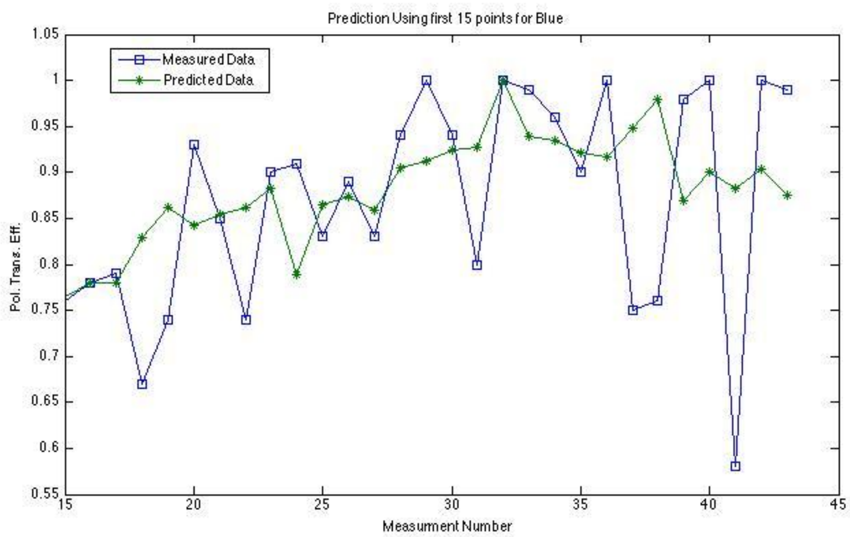
$$P - 1 := m_1 \cdot \left(\left| \varepsilon_{01} + \Delta\varepsilon_1 + \varepsilon_s \right| \right)^2 + m_2 \cdot \left(\left| \varepsilon_{02} + \Delta\varepsilon_2 + \varepsilon_s \right| \right)^2$$

In this model we assume an underlying Imperfection resonance ϵ_{01} and ϵ_{02}
an Imperfection from the snakes ϵ_s and differential Imperfection resonance
caused by ramp to ramp orbit fluctuations. So we should capture both the
Orbit and some of the snake effects.

Blue Model Fit

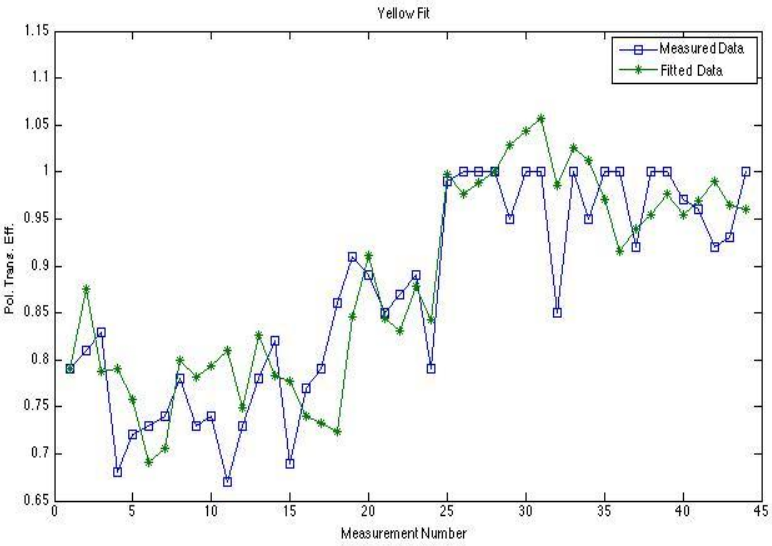


Fitted ϵ_{01} for 381 and 423 Imperfection Resonance = 0.08 and 0.07
Chi2 = 0.4



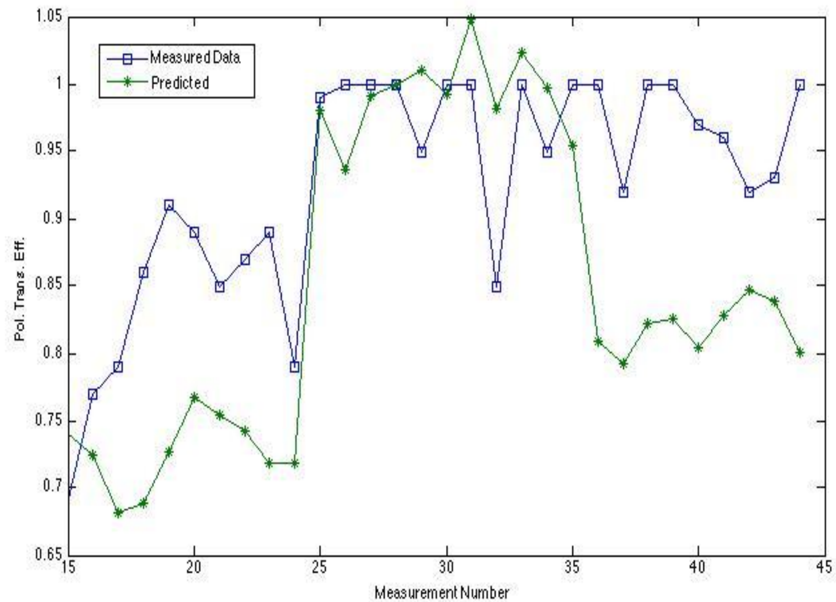
Prediction based on 15 points yields
Chi2 = 0.4

Yellow Model fit

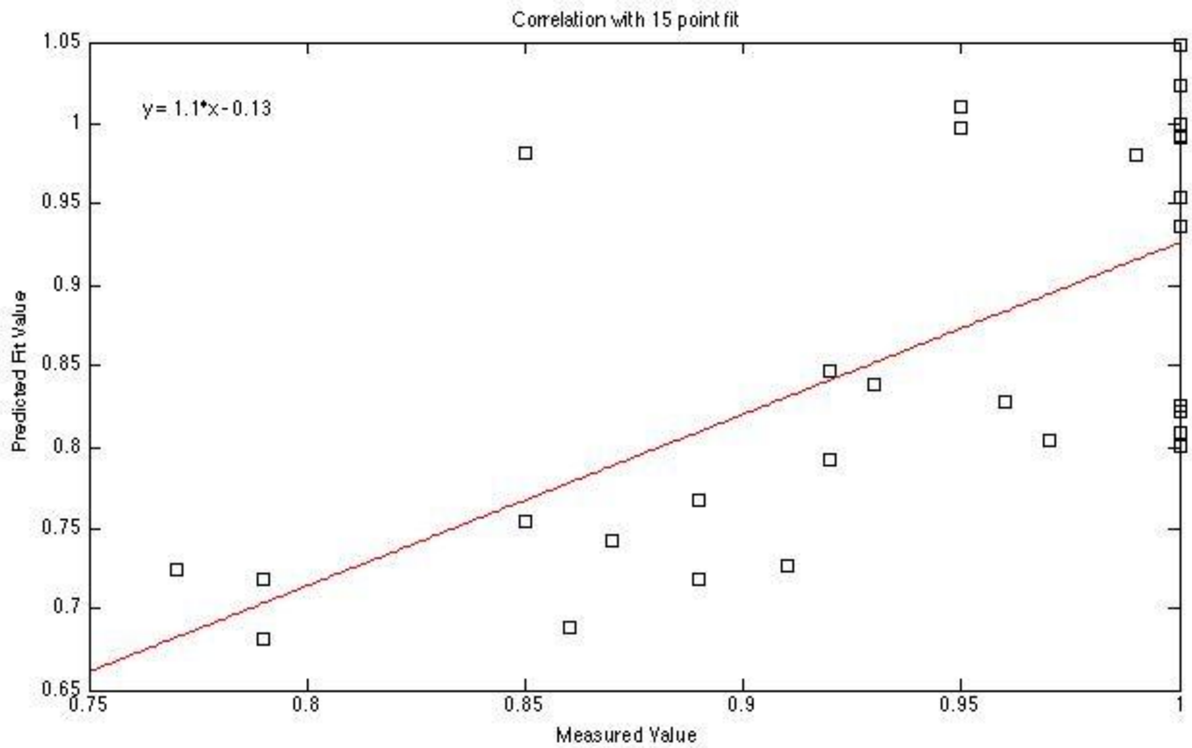


For underlying 381 and 423 Imperfection Resonance fit gives 0.1 and 0.08 respectively
Chi2 = 0.17

Chi2 fit for Predicted points is 0.5



Yellow correlation of measured with 15 point fit = 0.65, slope 1.06

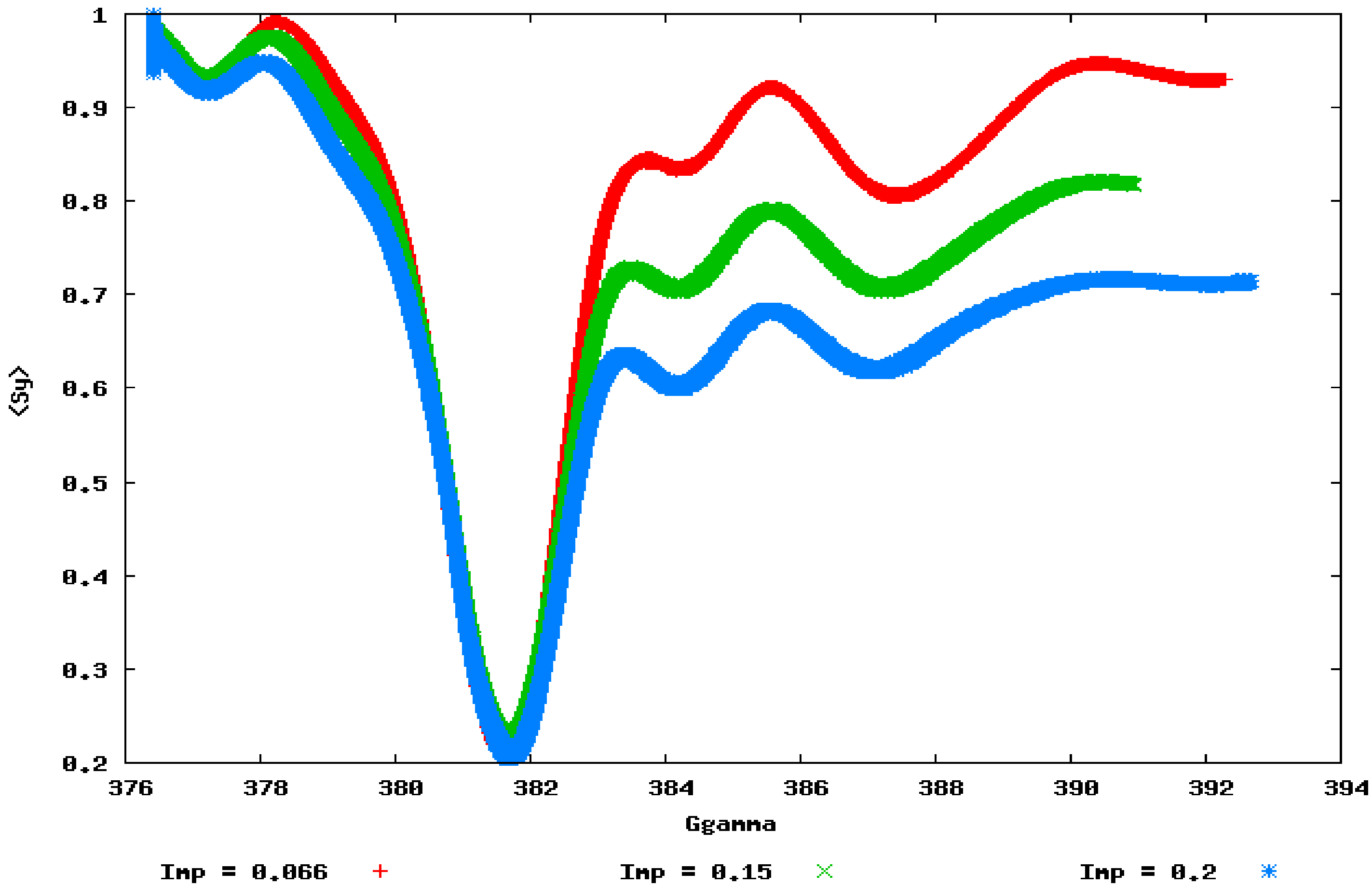


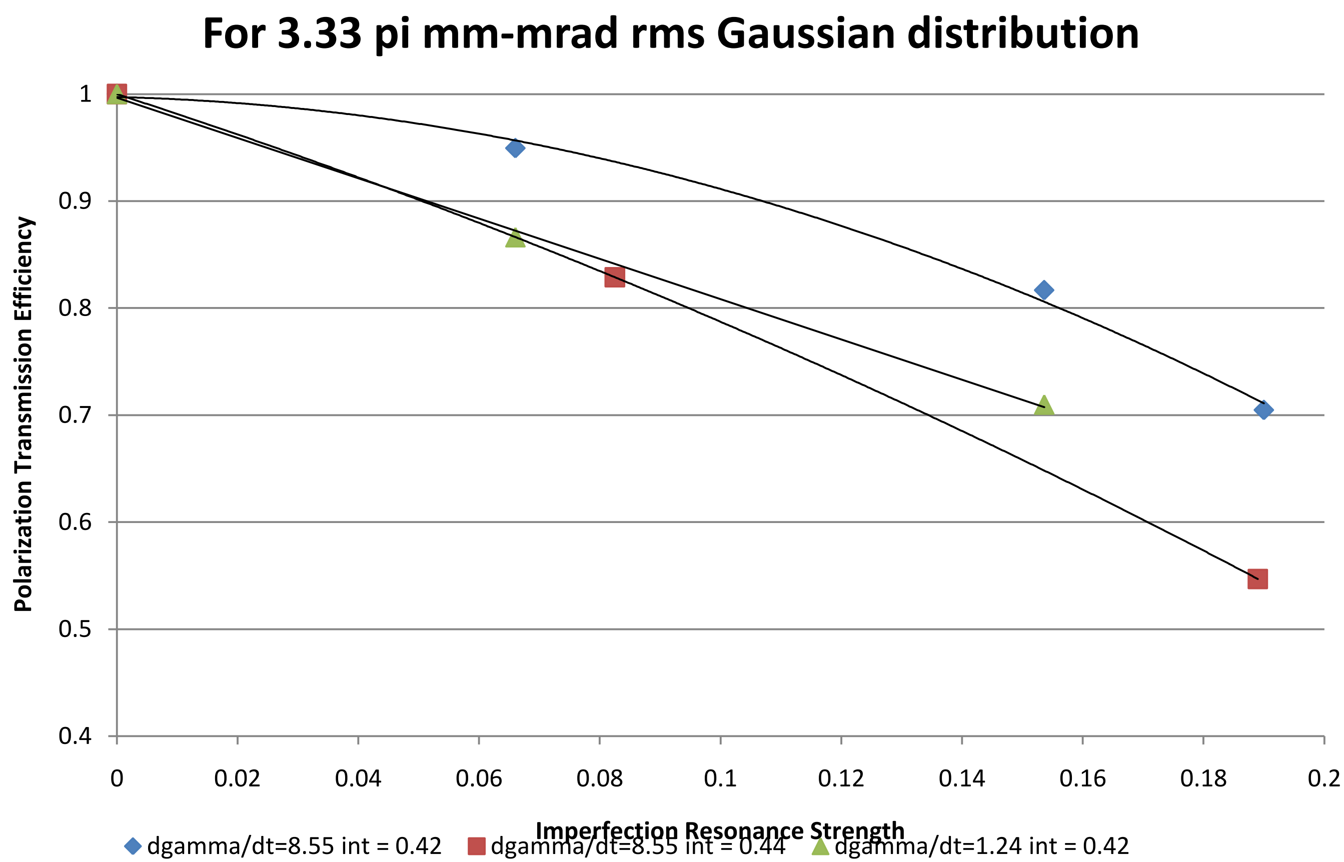
Blue correlation much worse only 0.3

Towards a complete model of spin dependence on orbit and lattice with snakes

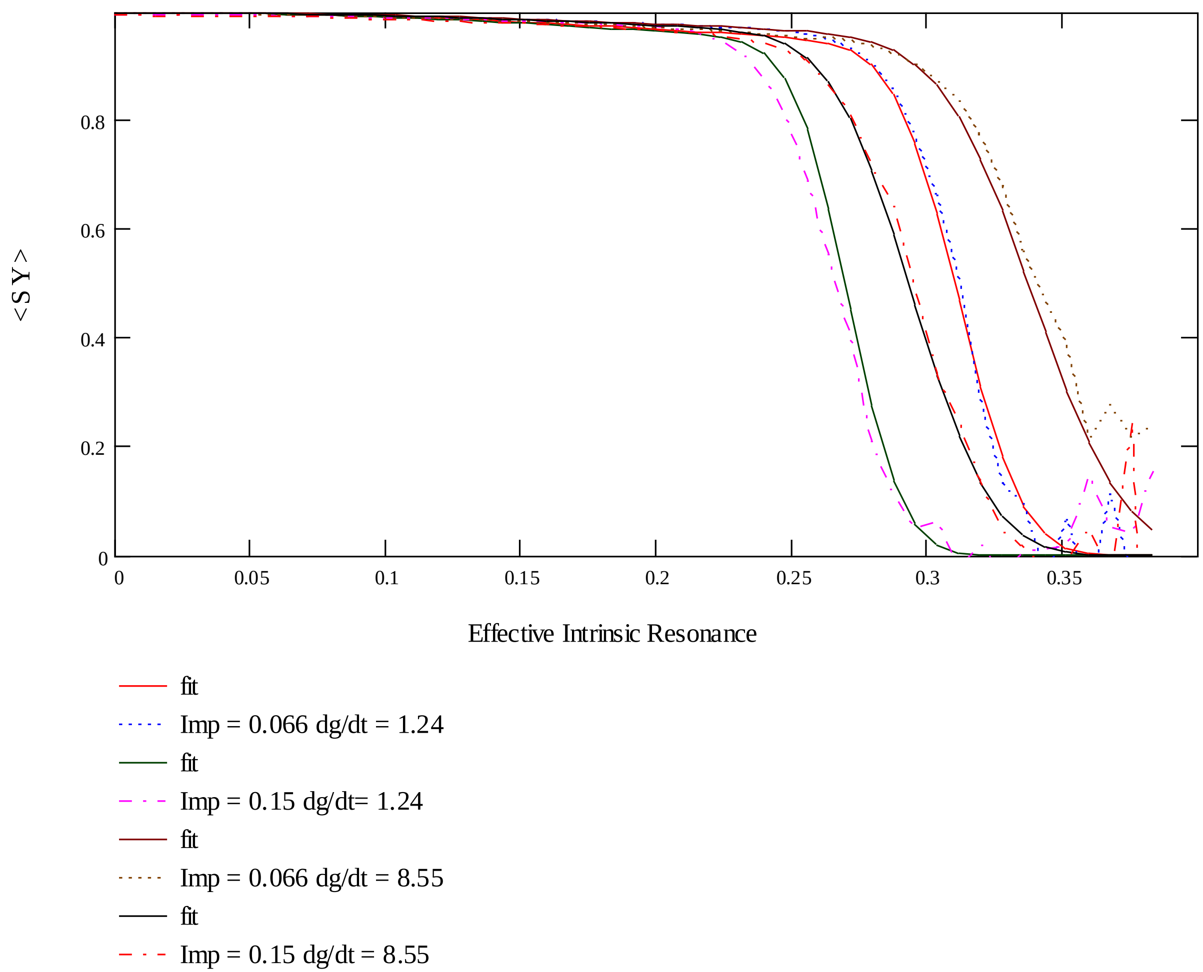
- During the past year performed extensive simulation work.
- We have 6D simulations 32,000 particle distributions crossing the two strong intrinsic resonances with different Imperfection resonance strength and acceleration rates.
- Developed empirical model for the spin response

Sensitivity to Orbit
(Imp res = 0.066,0.15,0.2)




For 3.33 pi mm-mrad rms Gaussian distribution
Polarization Transmission Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Imperfection Resonance Strength
dgamma/dt=8.55 int = 0.42
dgamma/dt=8.55 int = 0.44
dgamma/dt=1.24 int = 0.42

Empirical Fit to Simulations using two parameter model.



Fitting Equation

$$\left(2\cdot\exp\left(\frac{a}{100}\cdot q^{2}\right)-1\right)\cdot\left[\left(-\operatorname{erf}(a\cdot q-co)+1\right)\cdot 0.5\right]$$

APEX 13 Proposal

- More systematic Imperfection bumps applied to ramp
  - Four point bump approach: 1 Real positive and 1 Real negative bump, Imaginary positive and 1 imaginary negative bumps at Ggamma = 381 and 423 for blue and yellow.
  - Repeated several times for good statistics.
  - This should permit us to extrapolate our underlying imperfection Resonances at 381 and 423.
- One phase and strength are estimated then add correction to suppress them permanetly.

Conclusion

- I think there is good evidence that there is a correlation between Imperfection Resonance strength and Pol. Losses especially in Yellow.
- I think we have an approach to 'back' out the underlying imperfection resonance strength and then 'kill' it with controlled Imperfection bumps so that our orbit feedback will always keep our absolute imperfection resonance strength < 0.06 and thus maximize our Polarization on the ramp.