Plan for Run 13: Polarized Protons

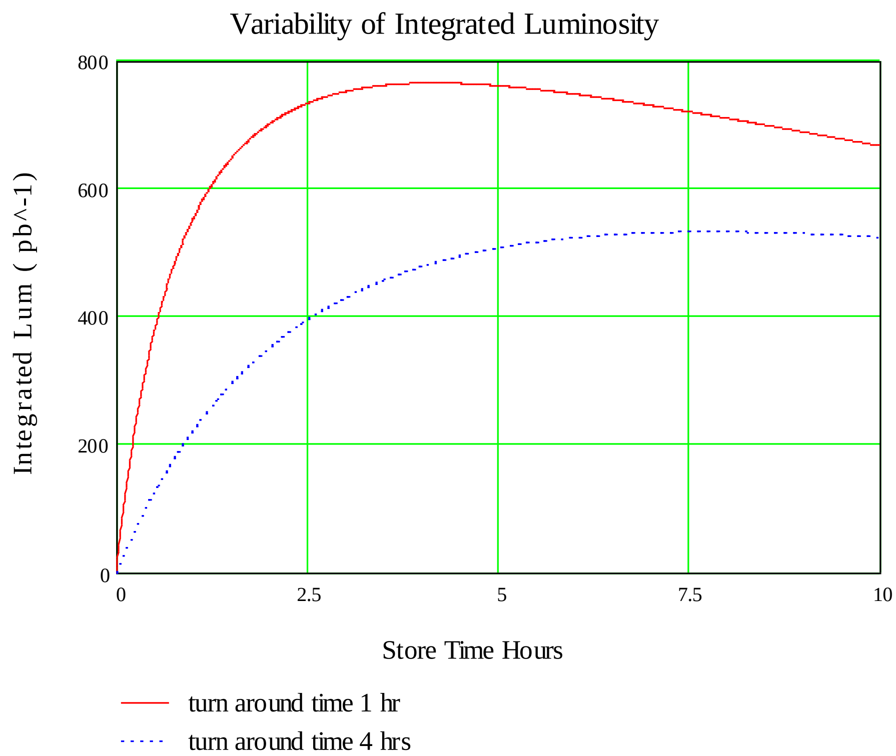
V. Ranjbar

Out line

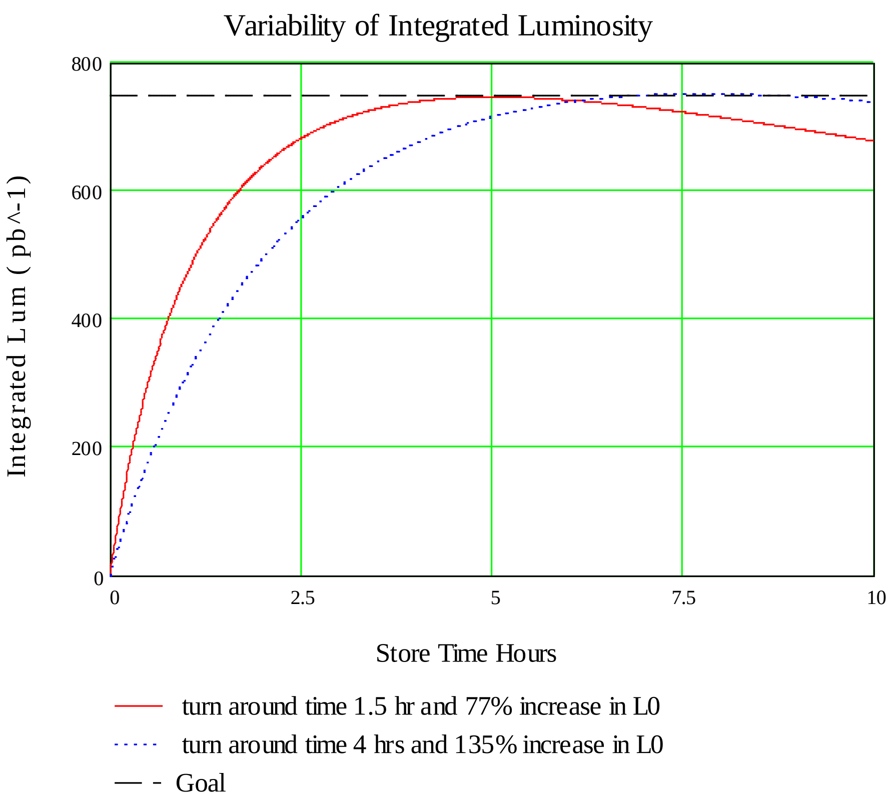
- What are our Goals for this Run?
  - Analysis of turn-around time.
- What are the major changes to the Machine?
- What can be done for RHIC?
  - Polarization On the Ramp
  - Lifetime
- What can be done for AGS?

We have an extremely Ambitious Goal for 250 GeV : 750 pb^{-1} for PHENIX

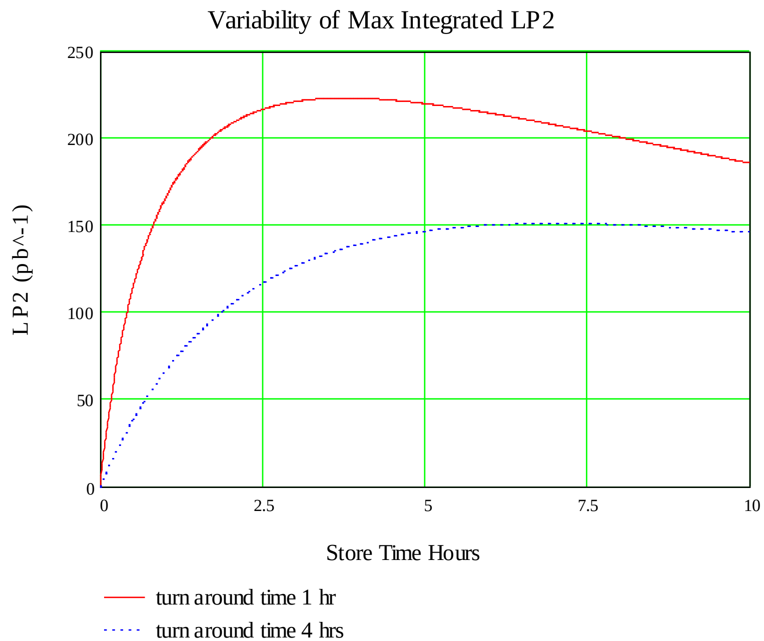
- One might say too Ambitious?
  - Our best estimates for 12 week run (W. Fischer) ~ 550 pb^{-1}
- So what could save us?
  - Turn around time? Right now we are at 4 hours. If we can drop that to 1 hour we might be able to get above 700 pb^{-1}. But we should also trim our store time down to ~ 5 hours.



Turn around time is **Very** Important!



With a turn around time of 1½ hour and a reachable (77%) increase in peak L, we can achieve integrated luminosity equivalent to 135% increase in peak luminosity. 77% could be achievable with 2.05e11 per bunch and 0.5 m bunch rms. (Wolfram's maximum is 2e11 per bunch).



Going to shorter stores becomes even more important if we consider LP^2 Luminosity value.

Analysis of Turn around Cycle (thanks to Vincent)

Injection tune Up 10 min	Fill Blue and Yellow 14 min	Pol. Meas. 5 min	Energy Ramp 5.5 min	Rebucketing & Pol. 10 min	Rotato Ramp 10 min	Store Prep. & Pol Meas. 10 min	Energy and Rot. Ramp down 18 min

The Current theoretical non-failure turnaround time = **82.5 min or 1.4 hours**

Areas which we anticipate saving:

1. Better long Matching system → 5 min
2. Double bunch injection → 7 min

Total new theoretical non-failure time = 1.37 min

Question Do we need so many Pol. Measurements? Cost us ~ 25 min can we make them faster? The actual measurement is only 30 secs..but takes several min to move data around.

Analysis of Typical Failure Modes

1. AGS RF drop outs → typically cost us 10 min but can escalate to 1 hour.
2. Timing lurches in RF → can lead to quenches which cost ~ 2 hrs.
3. Instability at injection due to bad Chrom/high intensity → loose Fill can cost us up to 1 hr. (fix by routinely measuring chroms before fill)
4. Losing Ramp due to large long. Emittance

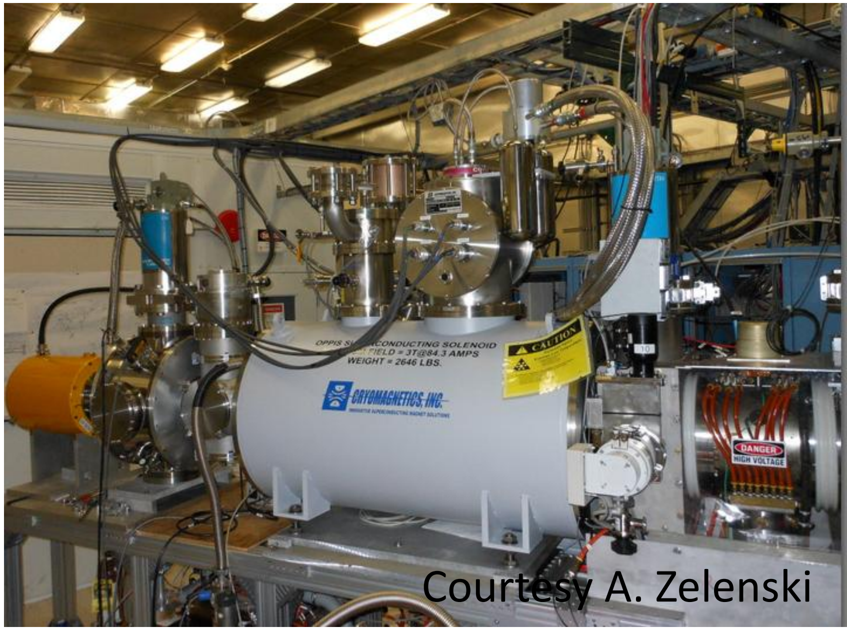
   → can cost us 1 hr. (perhaps we should routinely check emittance right before ramp set a threashold)

Lots of changes to the Machine

- If the this ambitious goal wasn't enough we are going to be commission several major items during this run:
  - Source Upgrade:
    - New RF bunch structure for Booster and AGS
    - Change in bunch spin pattern
  - E-lens :
    - New Lattice at new integer tune values
    - Change in abort gap location
  - Other RF Upgrades:
    - Vector Sum (real bunch-to-bucket phase measurement)
    - Next run we should calibrate the voltage readbacks with beam measurements (synchrotron frequency via Schottky)
    - I/Q feedback on bouncers for amplitude and phase accuracy
    - New landau cavities this year
      - harmonic this year (FY13) = 21 ½ x 9 MHz (not storage cavity)
      - Improve beam loading, enabling lower voltage at injection
    - New dipole mode longitudinal damper (already tested past run. Still needs work)

Courtesy M. Bennan

Source Upgrade



Courtesy A. Zelenski

OPPIS Improvements:

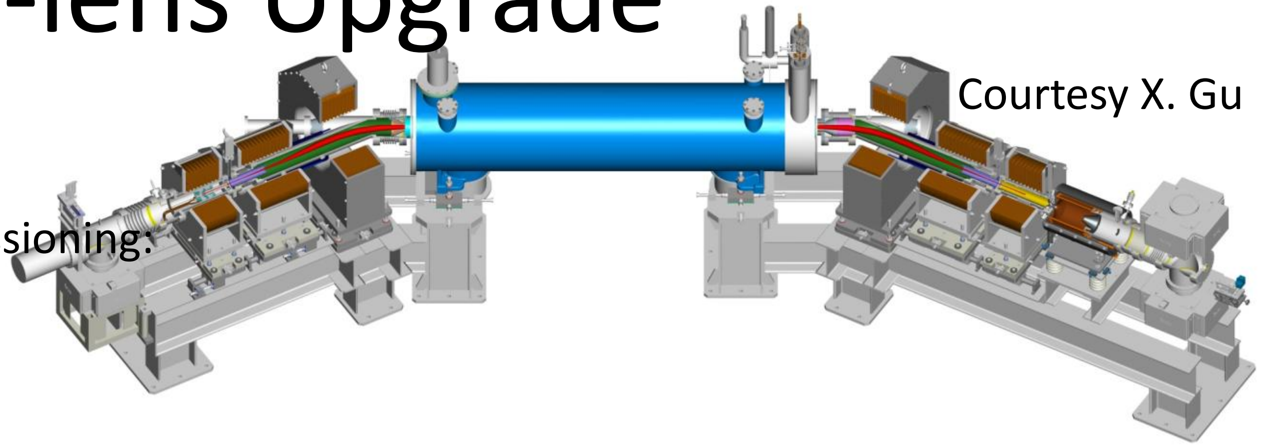
- Increase from 0.5 mA to 4 mA at the Linac from the source: More than a factor of **10 higher**
- The outstanding question is if high polarization can be maintained with this new source.

What to do with this higher Intensity?

- This motivates our RF changes in the AGS to exploit this.
  → This permits us to follow M. Brennan's plan:

1. Capture two bunches at Booster injection, h=2
2. Accelerate and transfer two bunches to ¼ of the AGS circumference (h = 8)
   Each one will have ½ the longitudinal emittance as in FY12 (scraped away)
3. Fill RHIC in ½ the time (hopefully experiments won't mind double polarization pattern).

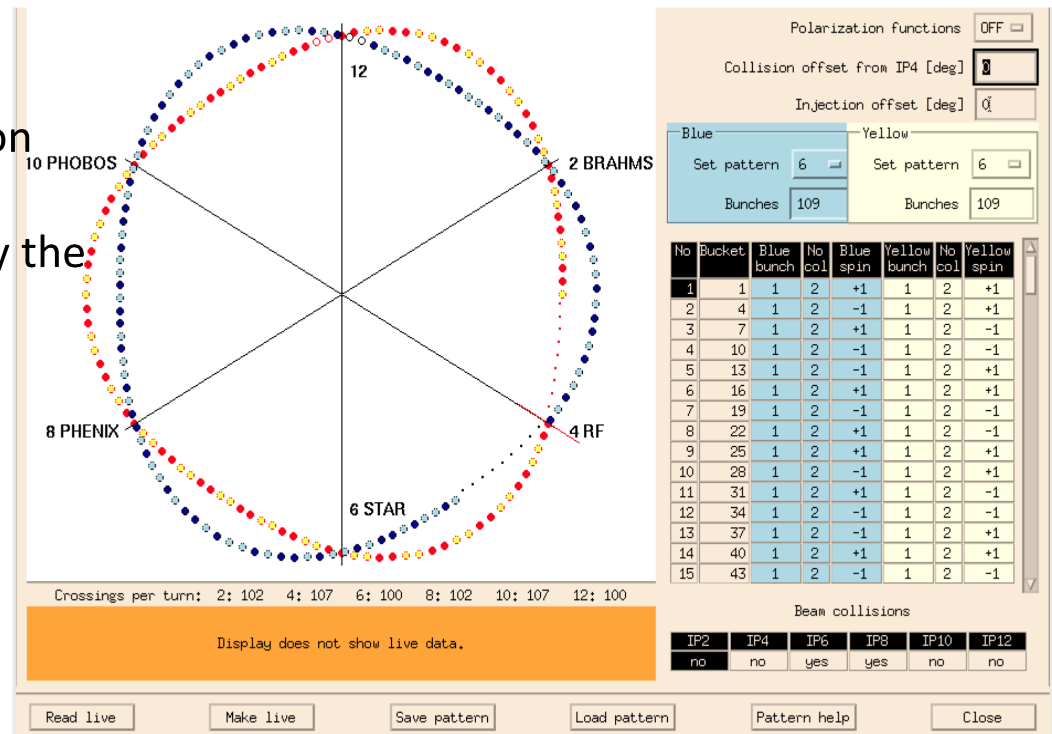
E-lens Upgrade



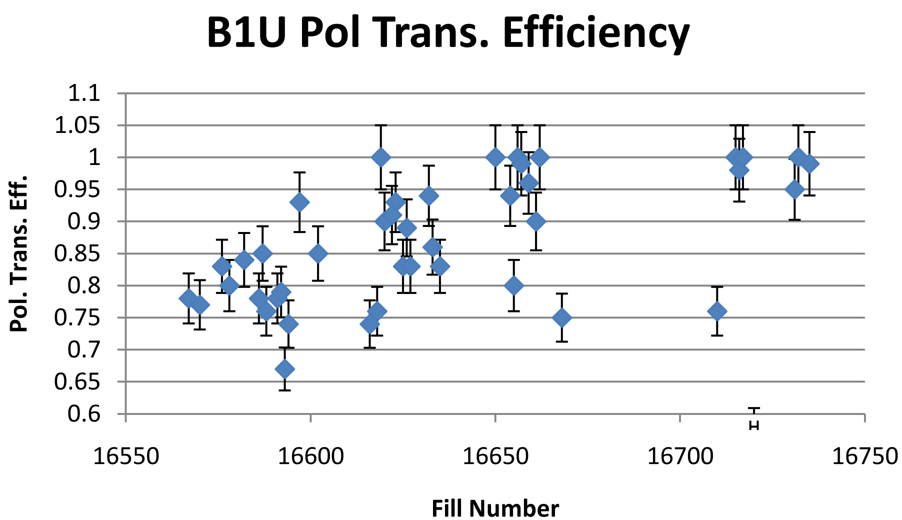
Courtesy X. Gu

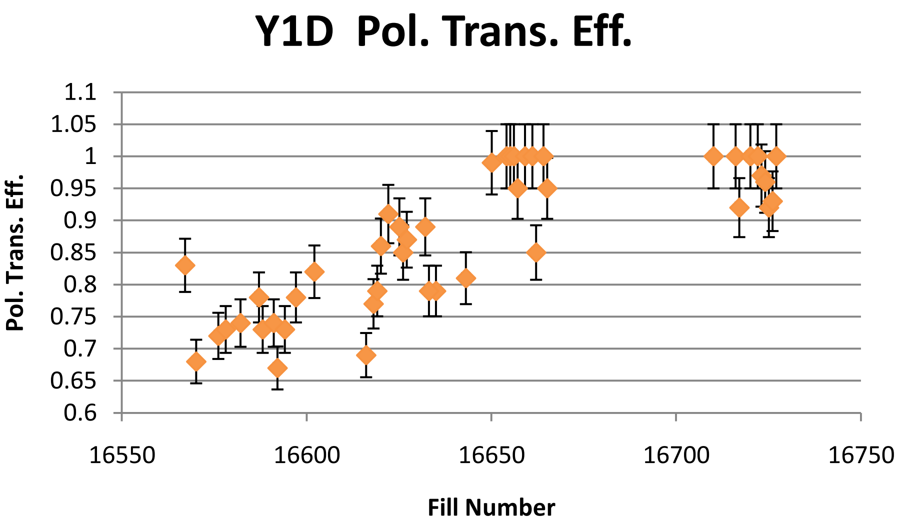
- Requires new Lattice Commissioning:
  - Yellow → 29.685 30.675
  - Blue → 27.685 29.675

- Change in abort gap timing:
  - Move from IP2/8 → IP4/10
  - I. This to permit the instrumentation for the E-lens to "see" the beam signal without being swamped by the proton beam.
  - II. This reduces number of collisions from 107 → 102



RHIC Polarization Ramp Efficiency

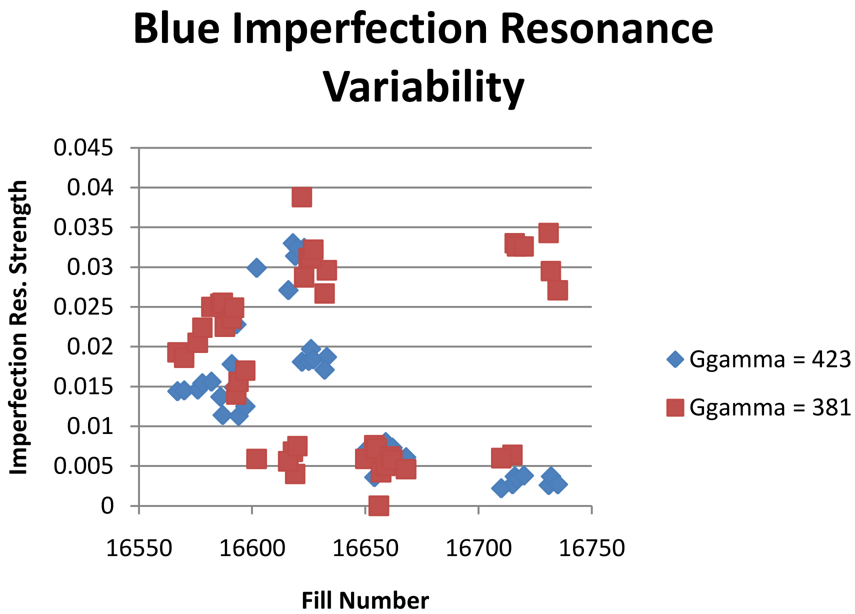


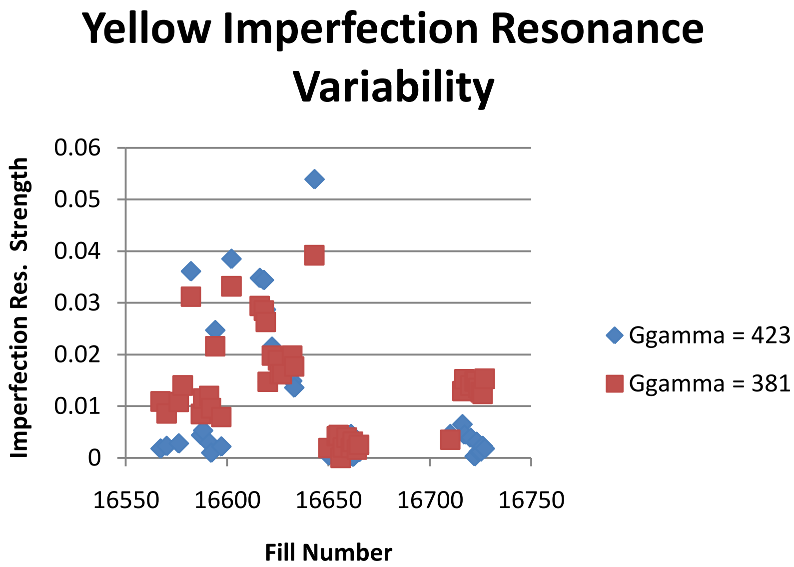


If we believe the CNI Polarimetry then we have several examples of basically 100 % transmission efficiency . So the question is why we don't get this all the time?

- 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

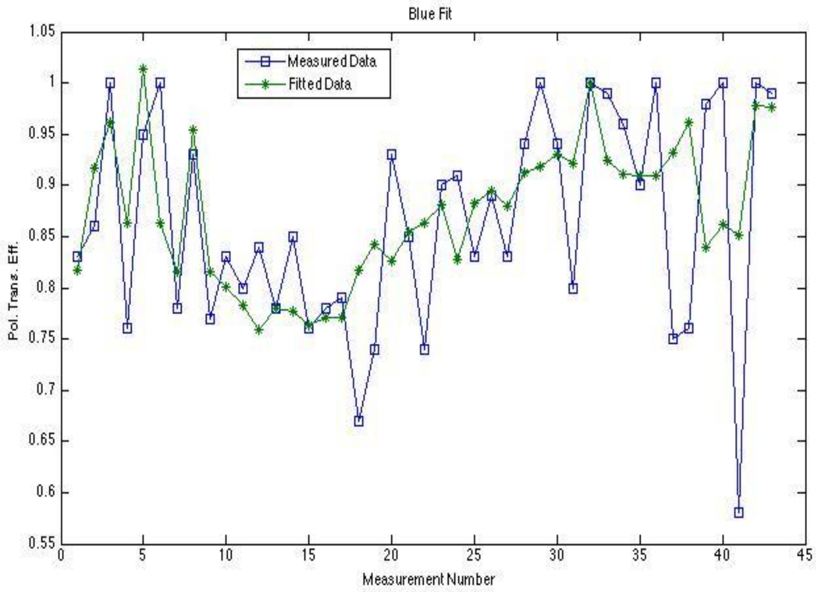
Tracking results indicate our threshold for losses across the last
Two strong intrinsic resonances are at 0.12. We see variability in the orbit at these
Resonances crossings which indicate a maximum of 0.05 imperfection resonance swing
this is consistent with an underlying Imperfection resonance strength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

So can we fit a simple model?

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

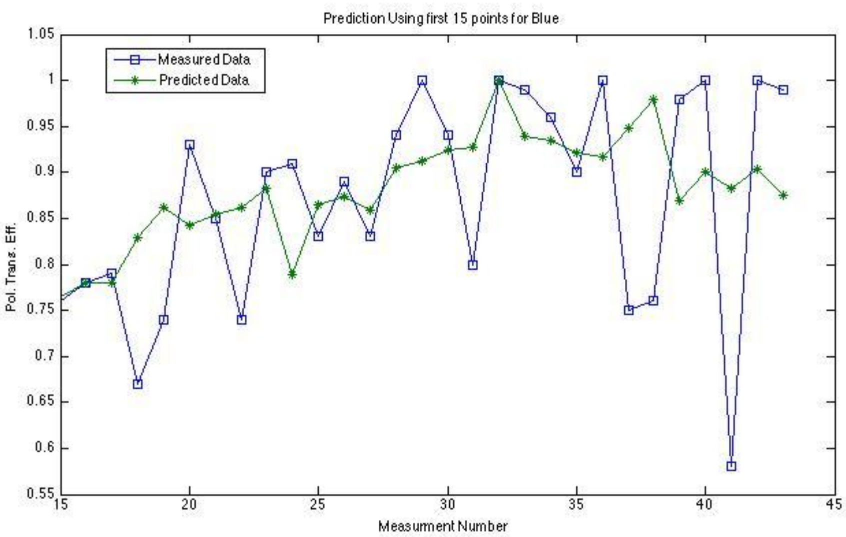
In this model we assume an underlying Imperfection resonance ϵ_{01} and ϵ_{02}
an Imperfection from the snakes ϵ_s and differential Imperfection resonance
caused by ramp to ramp orbit fluctuations. So we should capture both the
Orbit and some of the snake effects.

Blue Model Fit

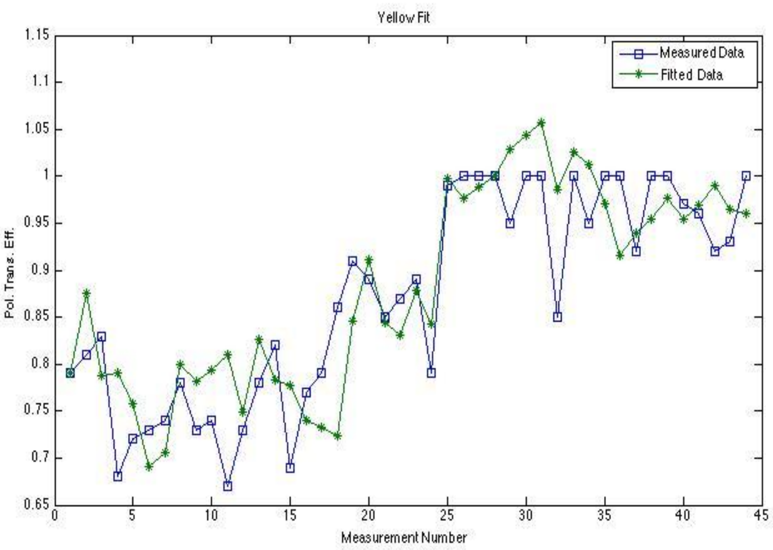


Fitted ϵ_{01} for 381 and 423 Imperfection Resonance = 0.08 and 0.07
Chi2 = 0.4

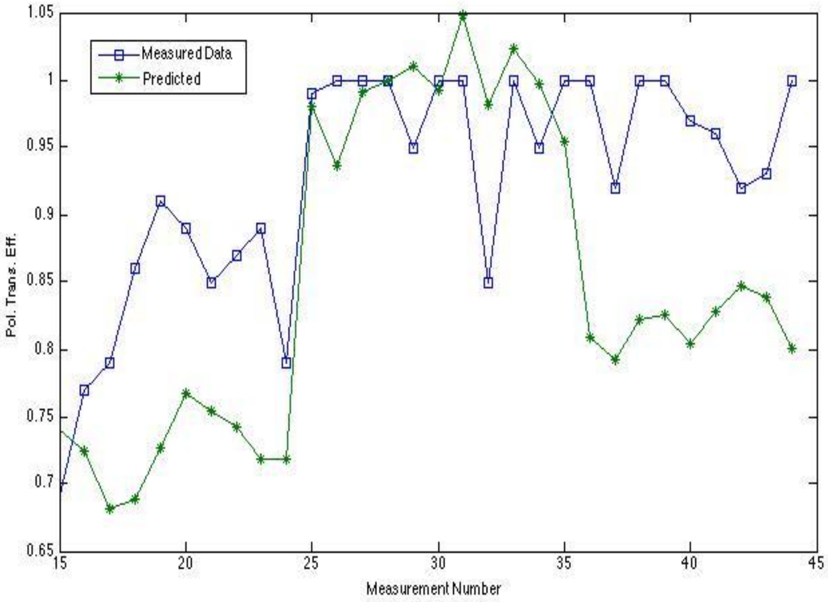
Prediction based on 15 points yields
Chi2 = 0.4



Yellow Model fit



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

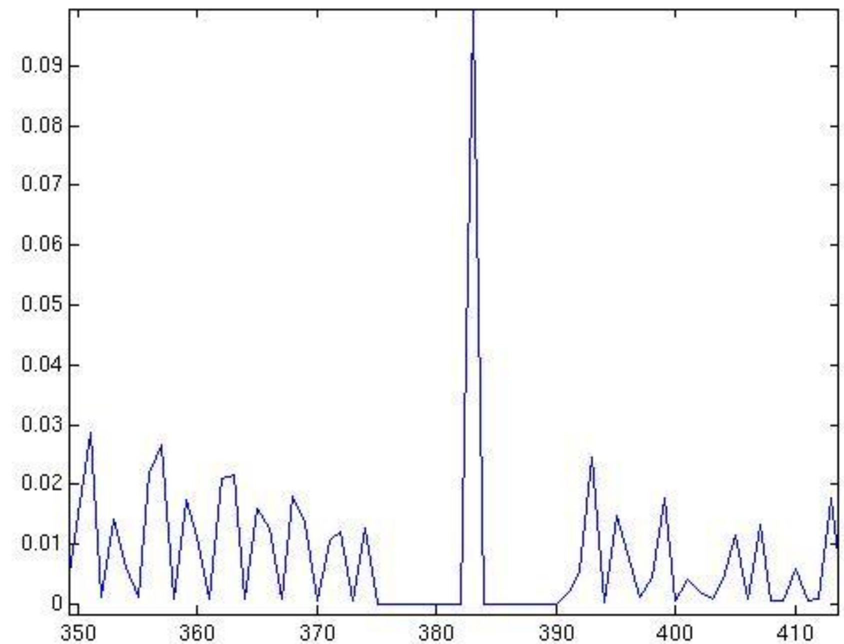


Chi2 fit for Predicted points is 0.5

Controlled RHIC Polarization Calibration

Model of course is not quite perfect but it tells us that our system responses to the strength of these imperfection resonances which is consistent with our theoretical understanding. A more deliberate calibration of the model using defined orbit distortions and snake de-tuning we believe will improve its predictive capacity so that we can better tune on polarization transmission efficiency.
too reduce Imperfection resonance fluctuation

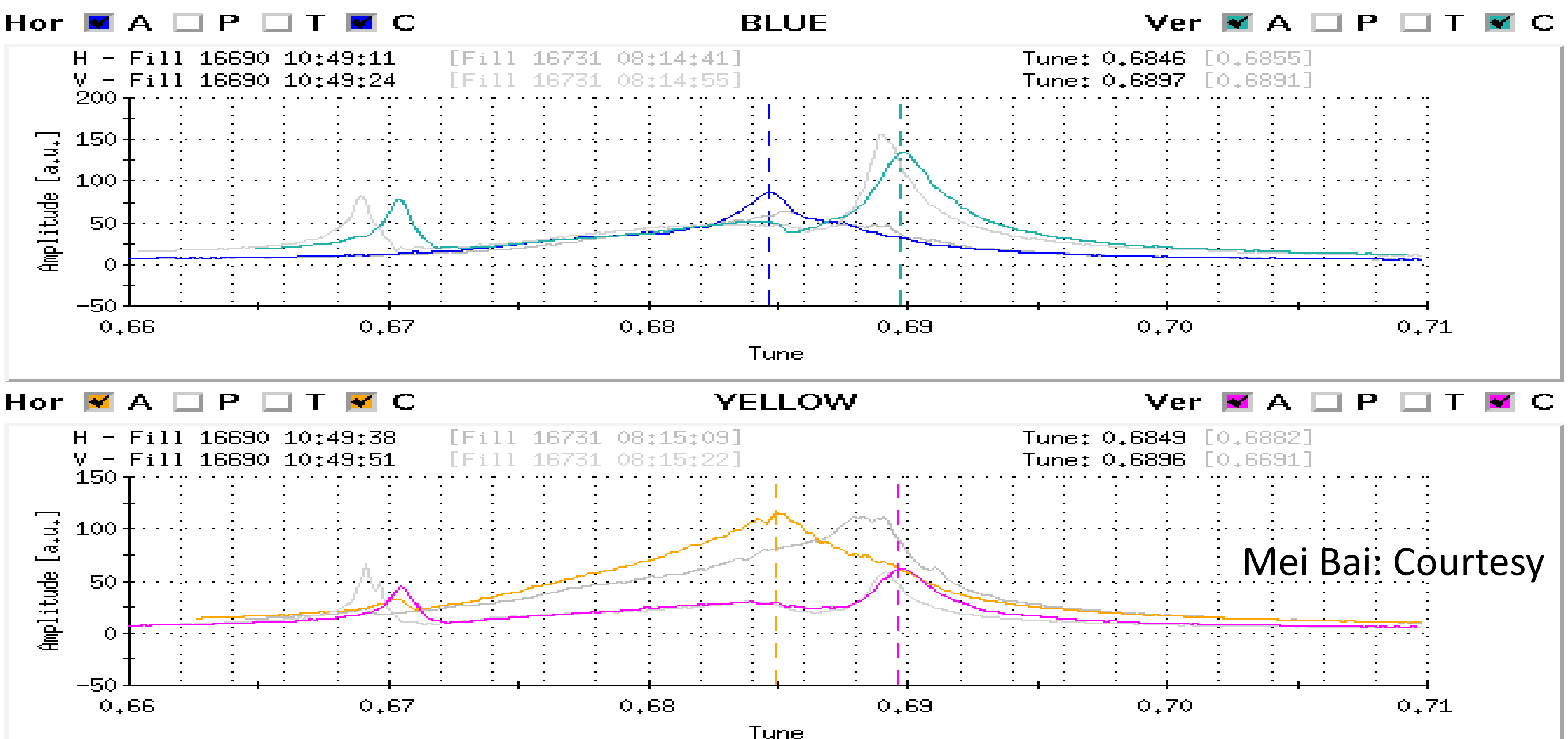
IMPERFECTION BUMPS



- Similar to ORM approach: apply controlled Imperfection resonance bumps during the first several stores these should effect Polarization < 20% level.
- Demonstrated during APEX 12
- We also should bump snake currents in a controlled manner.
- With knowledge of the underlying Imperfection resonance we could tune this out of our target orbit and then tolerate the 0.05 Swings in Imperfection.

RHIC Polarization Lifetime

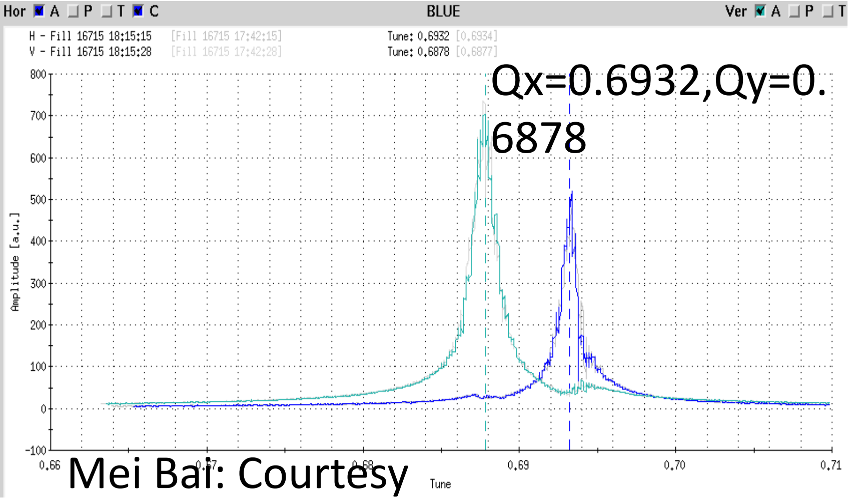
Based on analysis done by Mei and others the driver of our lifetime is due to collision induced betatron tune spread. Higher intensity will no-doubt make this worse. There appears to be fluctuation driven by emittance size and Snake detuning. We have yet to analyze the orbit data at store for any correlations but we do not expect to see anything significant.

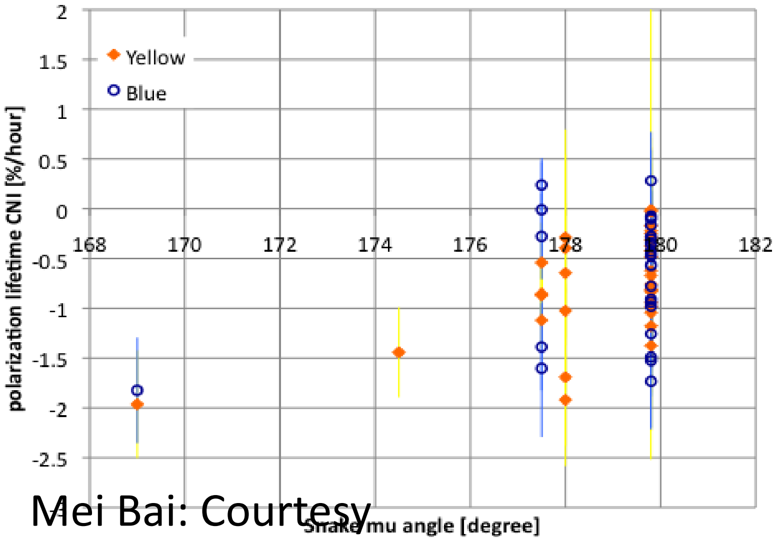


Mei Bai: Courtesy

Possible Lifetime knobs

- Coupling:
  - We are sitting awfully close to the 7/10 Snake resonance for the nominal horizontal tune.
- Snake Current (too hard):
  - There seems to be lifetime response in Yellow, blue undetermined
  - Probably too expensive unless Polarimetry statistics improve significantly.





AGS Planned Changes for Run 13

- Move to h=2 acceleration cycle. To fill yellow with two bunches (same sign) and blue, if experiments agree. (lower emittance per bunch, lower Polarization loss and faster RHIC fills)
- Add RHIC type IPM into AGS
- AGS jump quads shorter cycle: 4s. -> 3s. This is to reduce RHIC filling time .
- New C5 corrector for horizontal beta function measurement.

Courtesy H. Huang

AGS Development

The bulk of our polarization losses occur in the AGS ramp. So targeting this machine for particular attention will be a priority. I would like to make sure we are exploiting the “free” time with AGS cycles for optimization as much as possible. Ideally have a physicists working on testing some new idea or optimizing an existing system.

Projects to develop during AGS free time:

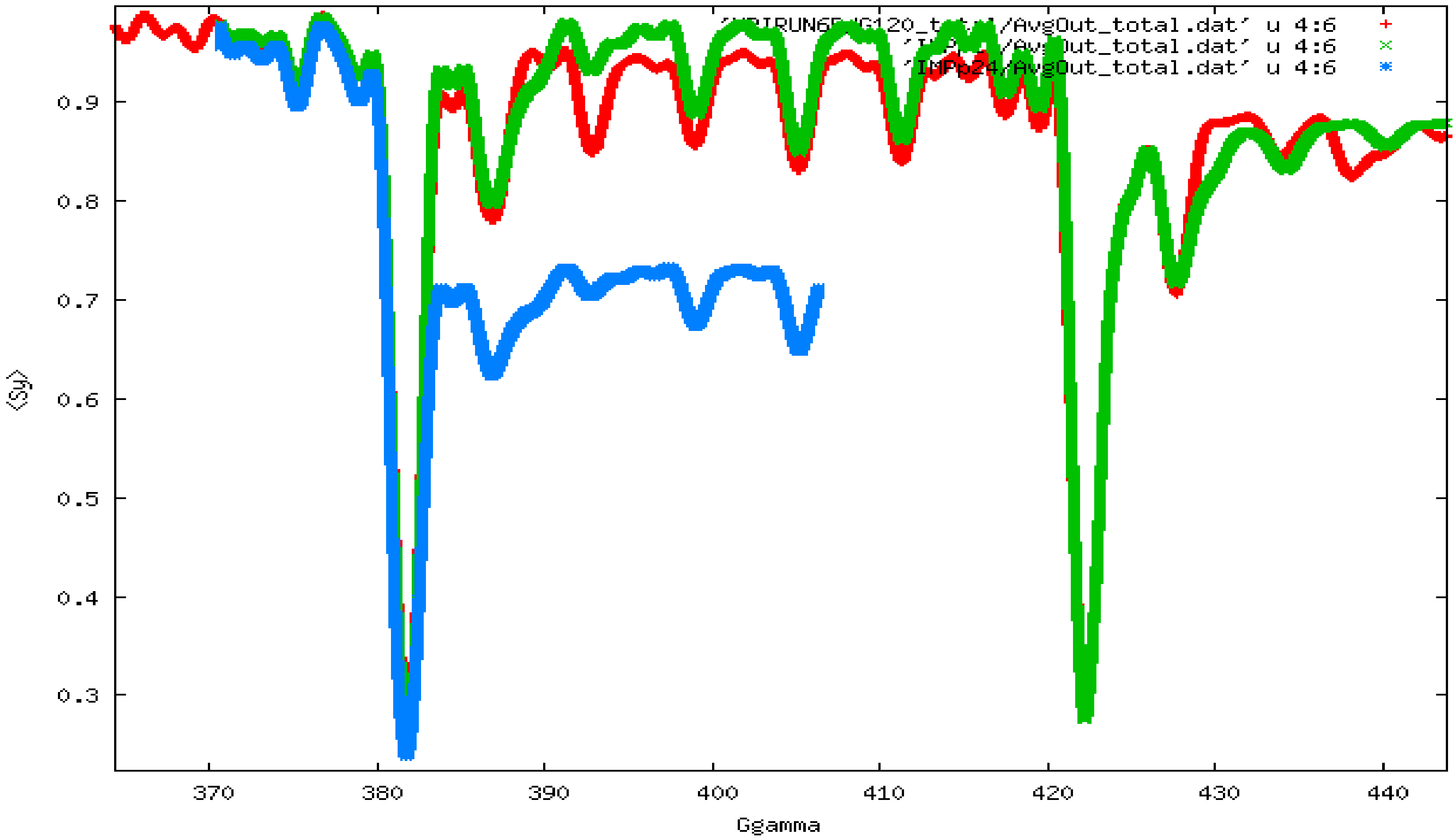
- Tune jump Quads optimization
- Test of extraction-on-the-fly. But first need expert to check the feasibility with 9MHz cavity.
- AGS ZGOUBI model as (semi-) online model, behind optical control, IPM.
- Automatic IPM beta function measurement.
- Automatic emittance correction (from space charge, dispersion-> requires longitudinal dimension measurement).
- Automatic chromaticity measurement.
- Snake and Harmonic correction configuration optimization
  - Best Snake strength vs. harmonic bump scheme to max. polarization
- bunching structure
  - Accelerating four bunches at half bunch length and merging two at AGS flattop?
    - lower space charge tune spread
    - lower transverse emittance induced losses

Courtesy H. Huang

Summary

- We have a very ambitious goal
- We have several significant things which are changing (e-lens, optics, RF)
- Too meet our goals we will need to really work on turnaround time.
  - (although it has been done before many times I am sure) I should sit down with Ops and parse each step of the steps leading to store to see where things can be optimized also for my education.
- RHIC polarization stability store to store
- AGS optimization

(Back UP) Sensitivity to Orbit (Imp res = 0.03,0.12,0.24)



APEX Experiment (achieved 0.18 Imp)

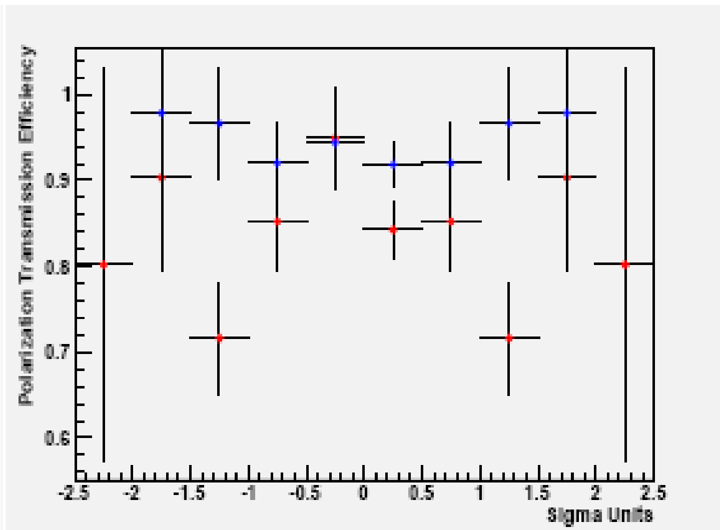


Figure 5: The polarization response of the Yellow ring due to excitement of a real 0.2 imperfection resonance at $G\gamma = 381$ (red). This plot comprises the average of five measurements taken at full energy divided by three taken at injection energy. The xaxis is in beam size sigma units. This is 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.

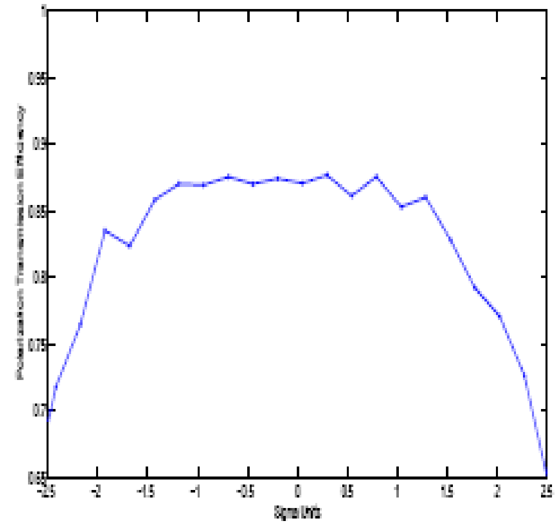


Figure 7: Simulated polarization response of the blue ring due to excitation of a real 0.24 imperfection resonance at $G\gamma = 381$. This results was generated from 32760 particles distributed using a Gaussian with a sigma consistent with 3.33 $\pi mm - mmrad$ cut off at 2 sigma for both transverse 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)

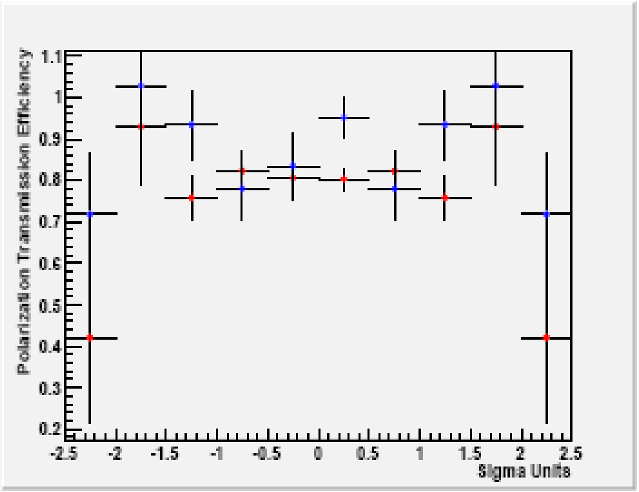


Figure 6: Polarization response of the blue ring due to excitement of a real 0.2 imperfection resonance at $G\gamma = 423$ (red). This plot comprises the average of five measurements taken at full energy divided by three taken at injection energy. The xaxis is in beam size sigma units. This is compared 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.