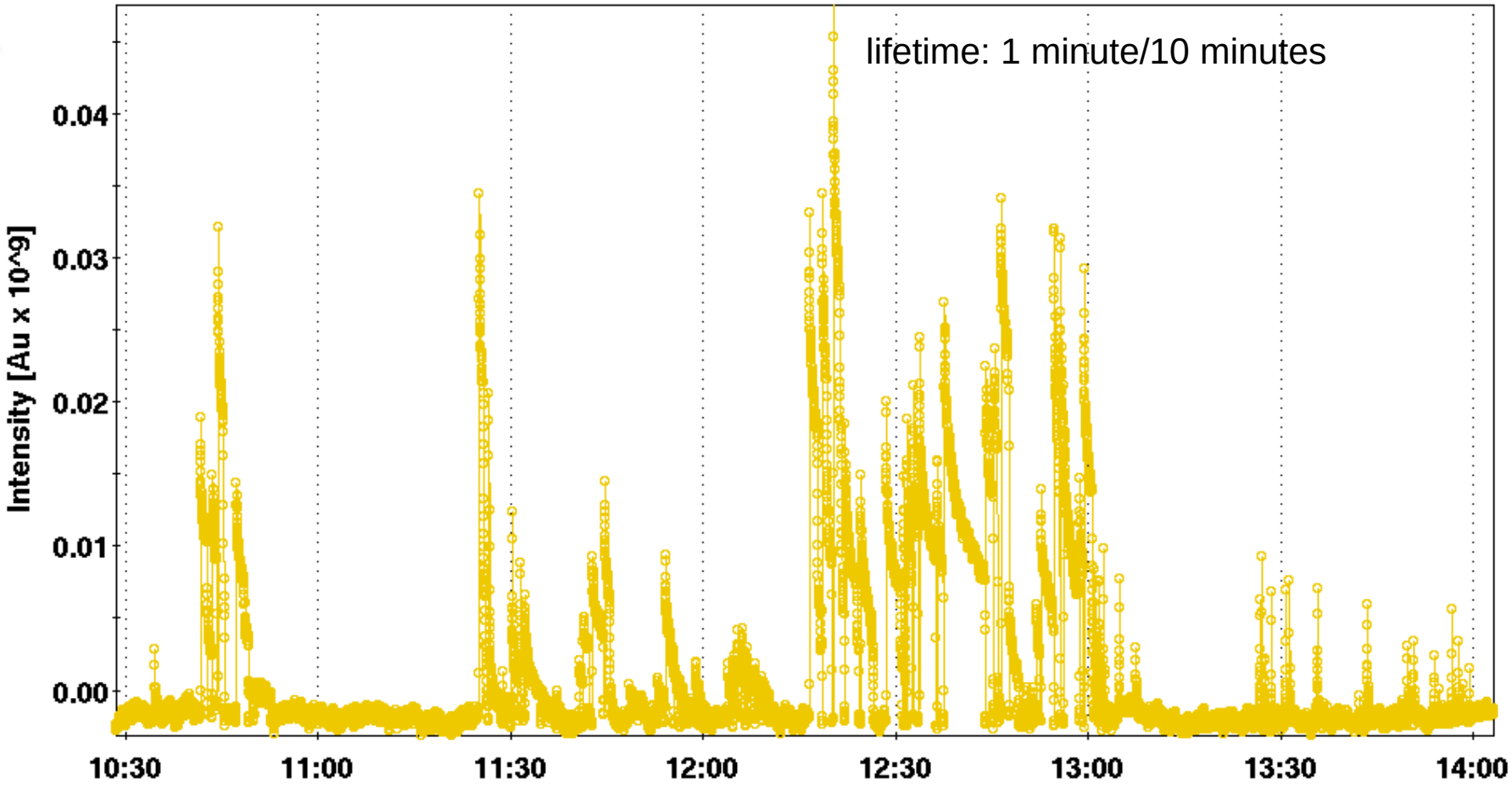
2008-9 Low Energy Tests: Experience and Parameters

	Gold 2007-8	Gold 2008	p 2009?
Ramp name	Au80	Au82	??
$\sqrt{s_{NN}}$ [GeV]	9.18	5.0	11.72
Beam energy [GeV/u]	4.59	2.5	5.86
Beam kinetic energy [GeV/u]	3.660	1.569	4.92
Relativistic γ	4.93	2.68	6.25
Relativistic β	0.979	0.928	0.987
Momentum [GeV/c]	4.496	2.320	5.79
Bρ [T-m]	37.40	19.30	19.30
Main dipole current [A]	217.7	112.3	112.3
Main quad current [A]	202.6	104.6	104.6?
Revolution frequency [Hz]	76571	72570	77187
RF harmonic number	366	387	363
RF frequency [MHz]	28.03	28.08	28.019
Max beam size $\hat{\sigma}$ [mm]	15.32	21.32	10.91
Beam/ring time available	27/30.5h	3.5/7h	??h

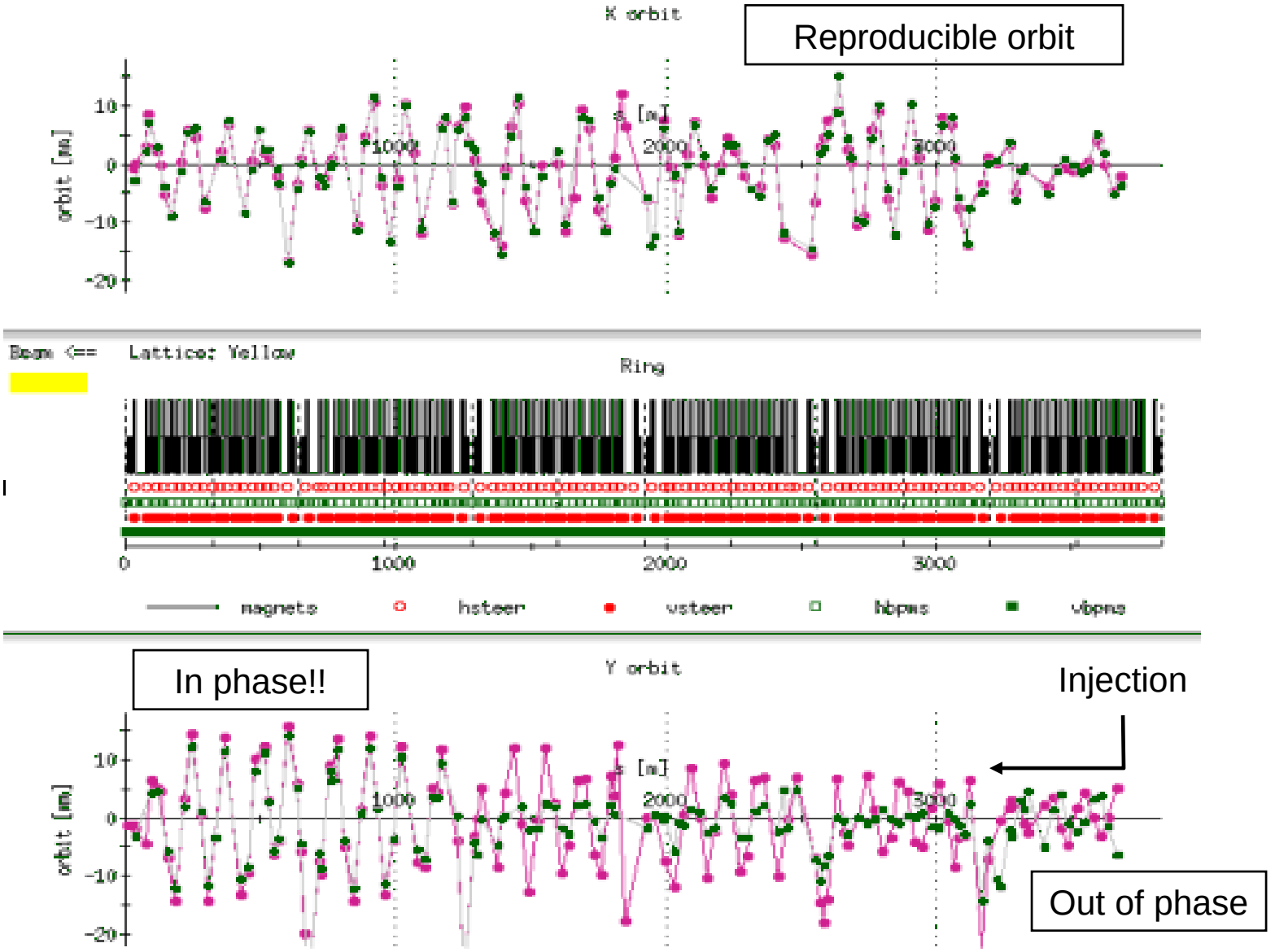
- Test runs: 2006, 2007, 2008
- 2008 Au test run (March 10-12)
  - 2007 9 GeV setup “in the can”
  - Test RF/timing/h≠360 fixes
  - Reproduce 2007 Au test; physics!
  - Explored lowest planned energy
  - Establish lowest energy baseline
- $\sqrt{s_{NN}}$ = 9.2 GeV Challenges
  - h=366 cogging
  - Finding experiment collisions
  - Setting up experiment triggers
- $\sqrt{s_{NN}}$ = 5.0 GeV Challenges
  - b4-dh0 PS failure; no blue ring
  - h=387 setup
  - Very nonlinear lattice

2008 Low Energy Test: 2.5 GeV Beam Activity

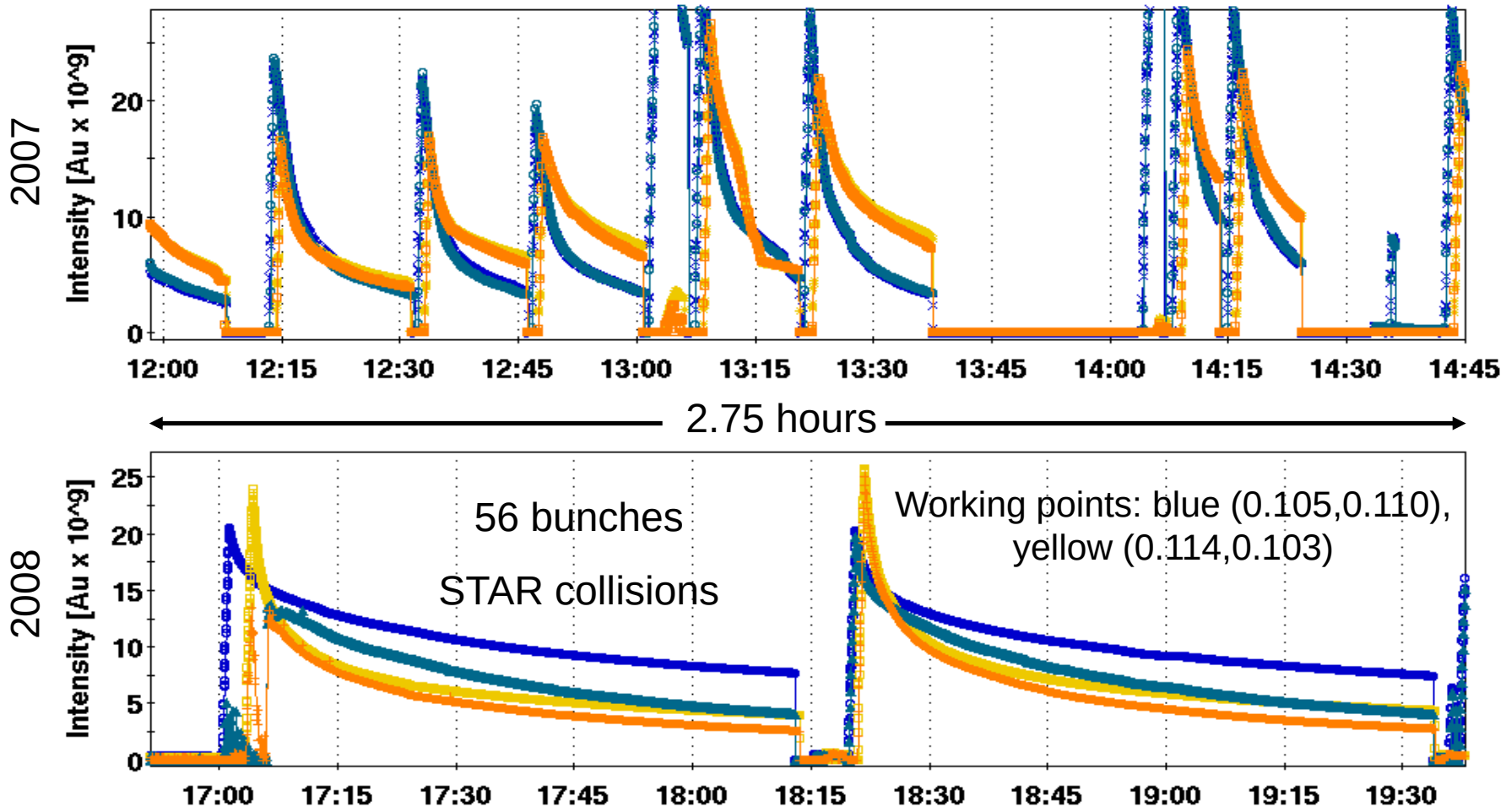


- Bunched beam signal in BPMs never exceeded 20 turns (usually 3-5)
- Injection (in)efficiencies of about 10%; orbit correction hardly worked at all
- Very nonlinear lattice; need to include in transfer functions and model

2008 Low Energy Test: 2.5 GeV Nonlinear Orbit



2007 vs 2008 Low Energy Test: Beam Lifetime

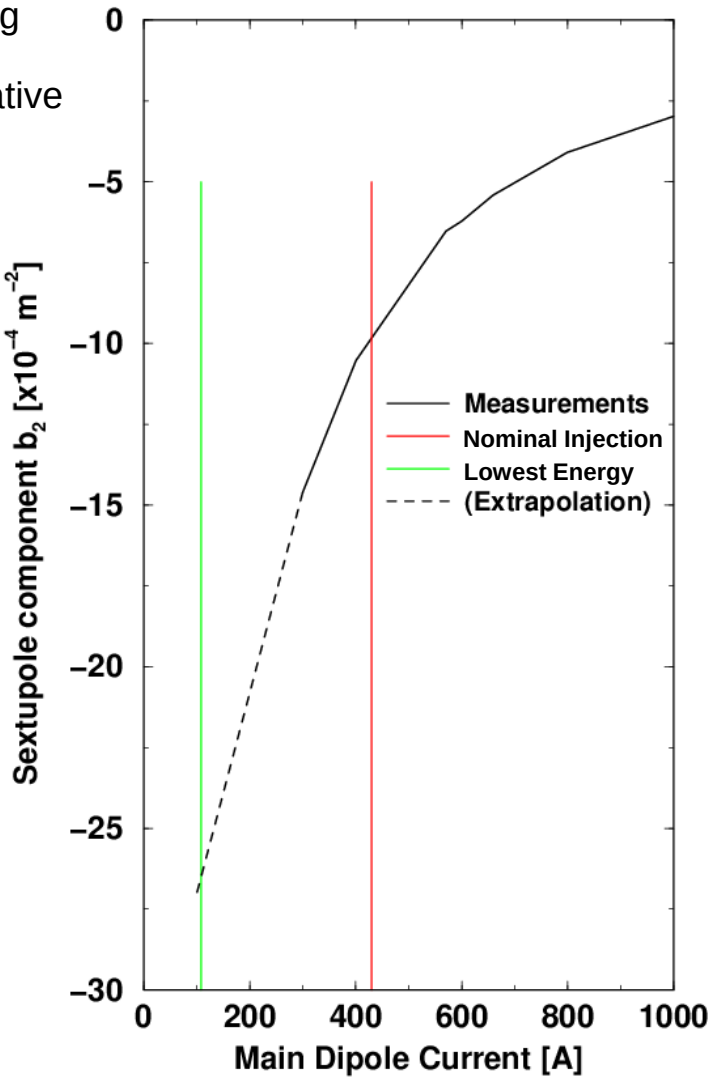


- 2008 blue beam lifetime: 3.5 minutes (fast), 50 minutes (slow)
- Sextupole reversal and elimination of octupoles clearly helped beam lifetime
- 2007 experience shows that we can circulate beam without sextupole reversal

Chromaticity and (In)Stability

Magnet	Design	Trim
bo6-sxf10	0.24228	-0.01235
bo6-sxd11	-0.01221	0.01922
bo6-sxf12	0.24228	-0.01235
bo6-sxd13	-0.01221	0.01922
bi8-sxd10	-0.01221	0.01922
bi8-sxf11	0.24228	-0.01235
bi8-sxd12	-0.01221	0.01922
bi8-sxf13	0.24228	-0.01235
bo10-sxf10	0.24228	-0.01235
bo10-sxd11	-0.01221	0.01922

2007 9.8 GeV without reversal: Defocusing sextupole strength should sum to negative



- Low-energy transverse beam stability requires negative chromaticity
  - But this is stability over 10s-100s of turns
  - Do we really need that sort of stability?
- Sextupole reversal, chrom settings worked
  - We understand main dipole b_2 at 215A
  - Expect minimum vertical chromaticity of ~+8
- Below $\sqrt{s_{NN}}$ = 9.3 GeV/u, require maintenance day to flip defocusing sextupole leads
- Strong octupoles were used to stabilize beam during the 2006/7 test runs

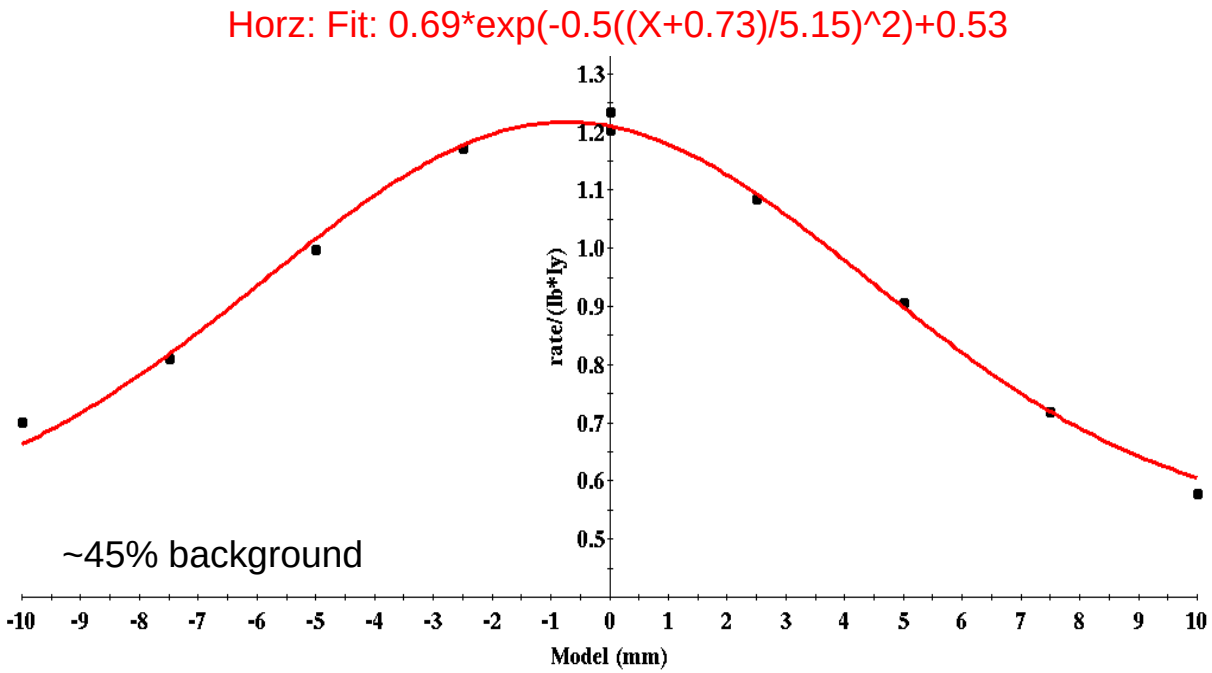
2009 Low Energy Test Plans

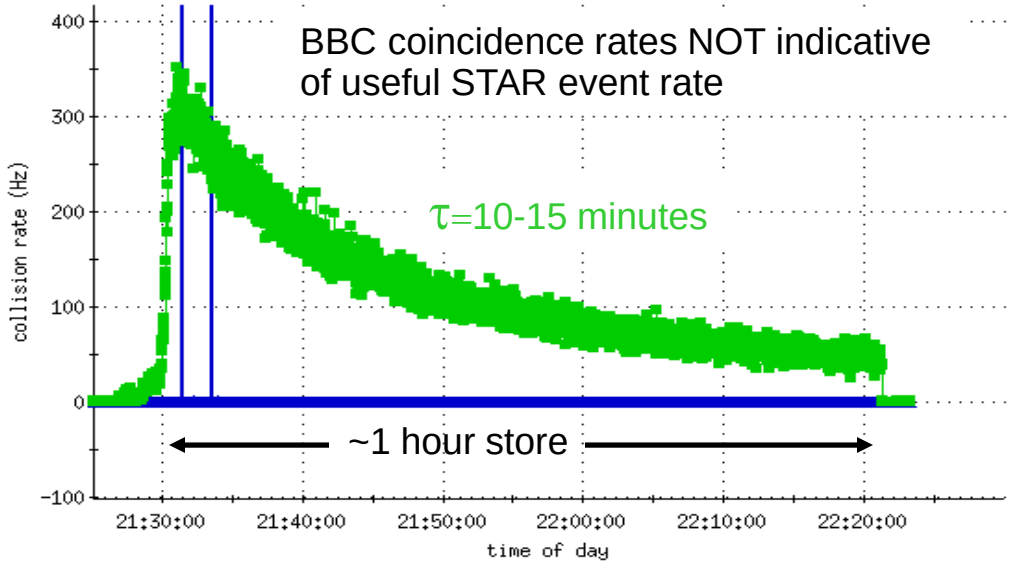
- $\sqrt{s_{NN}}$ = 9 GeV; Brho=37.4 T-m
  - Setup and physics with h=366; “in the can” for physics measurements
  - Demonstrated that main dipole b_2 is well-understood
    - No need to return to this setup in 2009 run

- $\sqrt{s_{NN}}$ = 5 GeV; Brho=19.3 T-m
  - Still major unresolved challenges remaining from 2008 test run
  - Only saw beam in one ring due to b4-dh0 failure
  - Very nonlinear machine due to large main dipole b_2; nonlinear orbit correction
    - Faster orbit correction possible with nonlinear model fit to measured orbit
      - PAC abstract co-authors: Todd, Joanne, Yun, Steve
    - Can explore nonlinear compensation with 90 degree phase advance lattice
    - Sextupole reversal, Au beam not required for continued progress
      - 1-2 day sextupole reversal would provide lifetime tuning opportunity

- Recommendations
  - Return to $\sqrt{s_{NN}}$ = 5 GeV; Brho=19.3 T-m with proton beam during APEX
  - No sextupole reversal; demonstrate nonlinear orbit correction, circulate p beam
  - Provides flexibility to reverse sextupoles, return to establish lifetime at end of run

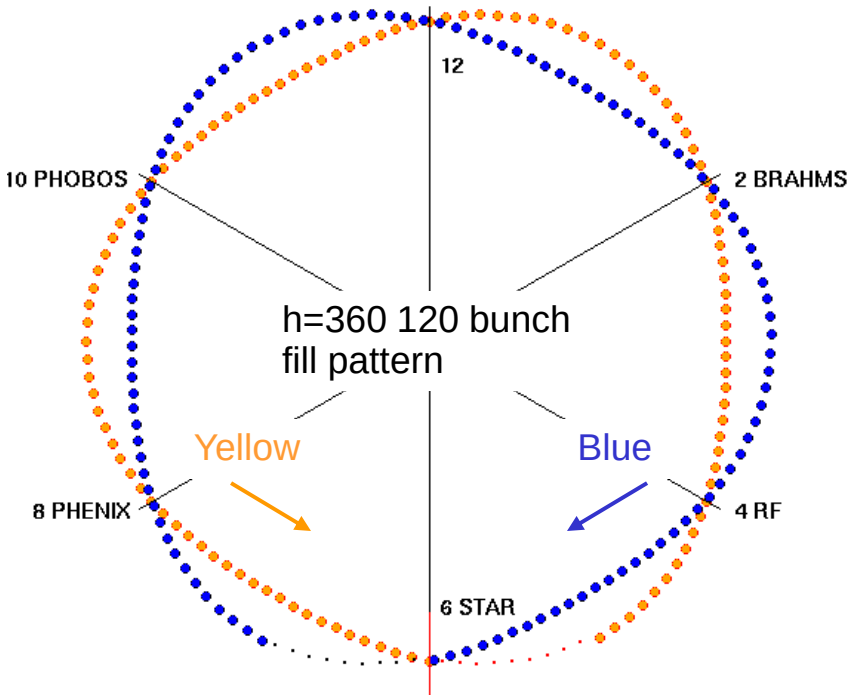
2008 Low Energy Test: Vernier Scan and Luminosity





- 56 bunch physics "stores"
- Good STAR vernier scans
  - +/- 8-10 mm scans
  - $\langle\sigma\rangle$ = 3.6 mm
  - $\langle\varepsilon(N,95\%)\rangle$=36 π μm
  - All scans consistent
  - IPM $\varepsilon(N,95\%)$=3-5 π μm?
- Measured luminosity
  - Ave: 1.2×10^{23} cm^{-2} s^{-1}
  - Max: 3.5×10^{23} cm^{-2} s^{-1}
- Experiment event rates
  - Useful rates: 0.7-1 Hz
  - STAR got 7000-10000 good events
- Better, more stable triggers and lumi signals needed

2008 Low Energy Test: RHIC RF Harmonic Number



h	Allowed $\sqrt{s_{NN}}$ [GeV]
360	16.7-107
363	11.4-15.0
366	9.0-10.5
369	7.7-8.6
372	6.9-7.4

h	Allowed $\sqrt{s_{NN}}$ [GeV]
375	6.3-6.7
378	5.8-6.1
381	5.45-5.7
384	5.15-5.38
387	4.91-5.1

- Nominal RHIC RF: h=360 bunches
- RHIC RF tuning range: 28-28.17 MHz

- With lower energy, RHIC RF frequency cannot fall low enough to maintain h=360
  - Must raise harmonic number
  - Retuning cavities is a prohibitive effort
  - Collisions at both experiments require h(mod3)=0; Experiment DAQ clocks also requires another h(mod3)=0
  - Cannot have simultaneous collisions in energy range $\sqrt{s_{NN}}$=8.6-16.7 GeV!
  - Harmonic number paper in progress

- Beam synchronous clock challenges
  - All RHIC single-bunch instrumentation
  - Abort system (needs to find gap)
  - Experiment DAQ clocks – okay!!
  - All C-AD timing fixes worked well
    - Challenges to cog beams reliably
    - Cogging ADO, 1 turn=360 “buckets”

2008 Low Energy Test: As Run Schedule

- 7-10 Mar: Tandem/Booster/AGS Au PPM setup (with NSRL)
- 10 Mar 08:00-15:00ish
  - Swap defocusing sextupole leads (at power supplies only)
  - Set up h=366 RF/clock; test experiment triggers, instrumentation
  - Test h=387/h=384 RF/clock; test experiment triggers, instrumentation
  - Optimize Tandem/NSRL dual-species operation; checkoff list
- 10-11 Mar 4.6 GeV
  - 1915: yellow circulating; 2311: blue circulating; 2345: rf setup done
    - Problems: tune settings, blue AGS/RHIC synchro, inj kicker timing
  - 0000-0330: multibunch injection, instrumentation timing, cogging tests
  - 0330: steer experiment DX BPMs to zero; 0400 STAR collisions!
  - 0600-1430: tuning, scanning for PHENIX collisions, STAR vernier scan
  - 1630-1900: Scanning, timing PHENIX collisions (1-6 Hz)
  - 1900-2300: Complete STAR data, document cogging issues, IBS
- 11 Mar 2.5 GeV (after blue D0 PS failure)
  - 1035: first circulating yellow beam (3e6); 1044: intensity up to 3e7
  - 1100-1400: Multi-turn tuning, machine apparently nonlinearity dominated