Beam Experiments At RHIC

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Montmtauk, May 23 2003

Outline

Beam experiments program at RHIC – intro

HALO-related beam experiments

- dynamic aperture
- measure of diffusion coefficients
- stochastic cooling test

Other results from run 2003

- IR nonlinear correction
- nonlinear chromaticity
- resonance measurements
- pressure rise/e-cloud
- beam-beam, AC dipole, instabilities discussed at the workshop by Fischer, Bai, Blaskiewicz

A glance towards run 2004 and beyond

Beam Ex: motivation, goals

GOALS

- Improve machine **performance** (longer time scale than 'now' machine performance)
- **Luminosity**, **upgrade** (RHIC-II) upgrades are not straightforward
- Development of beam **diagnostics** techniques
- Inter-lab **collaborations** (common goals, exploit synergies, exchange personnel, remote operations etc.)

Beam experiments → operations

Examples runs 2001, 2003:

- **IR correction**: skew quadrupole, sextupole
- **Chromaticity** measurements via radial wiggle
- **Octupoles** around transition
- **PLL** high resolution tuning
- **Tune scans** in collision→ working points

Beam Ex Program run 2003

AC dipole (twiss, coupling)	M. Bai
Beam-beam	W. Fischer
Chromaticity	S. Tepikian
Collimation, diffusion	A. Drees, R.Fliller
Nonlinear	V. Ptitsyn
Instabilities	M. Blaskiewicz
Pressure rise, e-cloud	S.Y.Zhang
Stochastic cooling	M. Blaskiewicz
Transition (alpha-1)	C. Montag

www.cadops.bnl.gov/AP/RHIC2003/BeamEx2003/

Beam Ex Organization

- Proposals – WEB based form
- Prioritization (Accelerator Experiments Approval Committee)
- 12 h of beam time/week during physics running (not during set-up and luminosity optimization time)
- WEB tools: Beam Experiments webpage, Beam Experiments electronic logbook

(Dynamic) aperture measurements

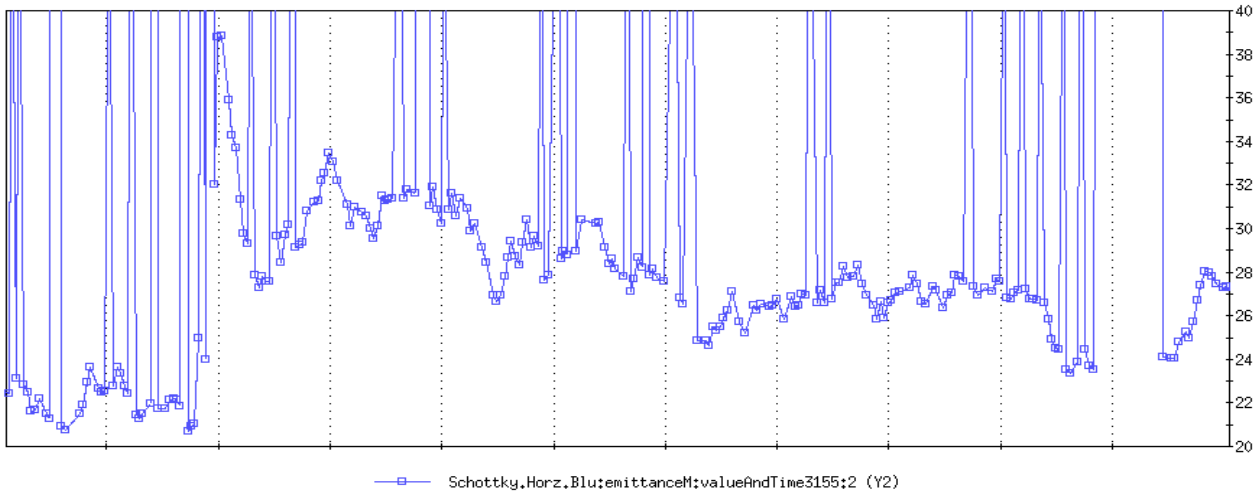
Initial aperture measurements in 2003 – *work in progress*

Goal: collect data to compare with predictions during the shutdown – starting end of may

Method used:

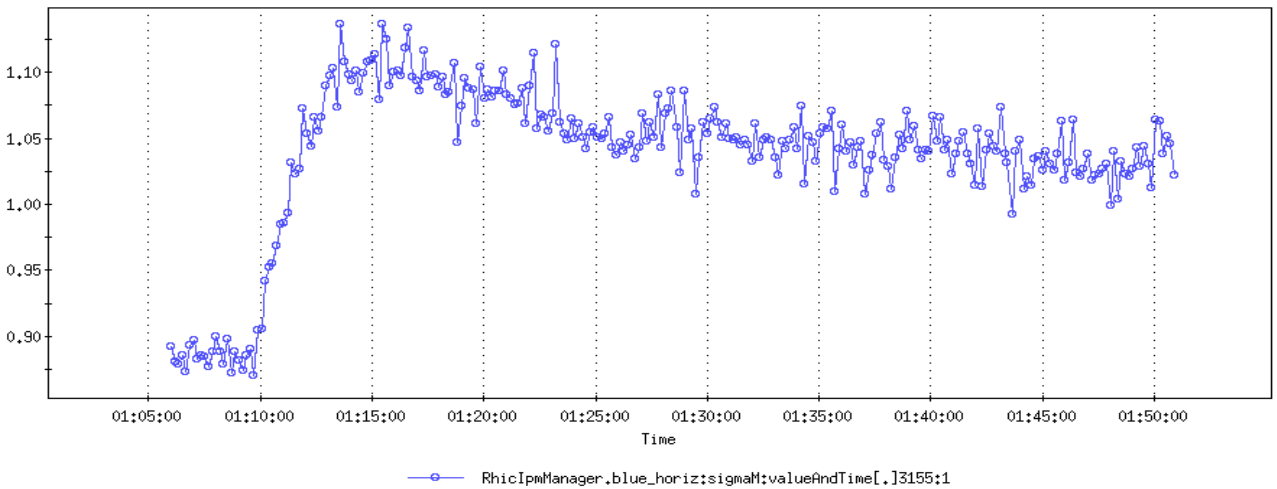
- ramp 6 bunches (avoid possible emittance blow-up), nominal tunes
- use scrapers to confirm halo beam size (PIN diodes) and core beam size (DCCT and WCM, beam intensity)
- increase H emittance of bunches selectively via tune meter kicks (1 Hz)
- measure continuously emittance with IPM and Schottky
- emittance 'saturation' defines aperture
- use scrapers to confirm beam size
- check loss pattern and use orbit to discriminate physical from dynamic aperture
- repeat procedure for vertical emittance
- repeat procedure for horizontal tune close to the 0.25 resonance

Dynamic aperture, blue, flattop



Calibration horizontal emittance

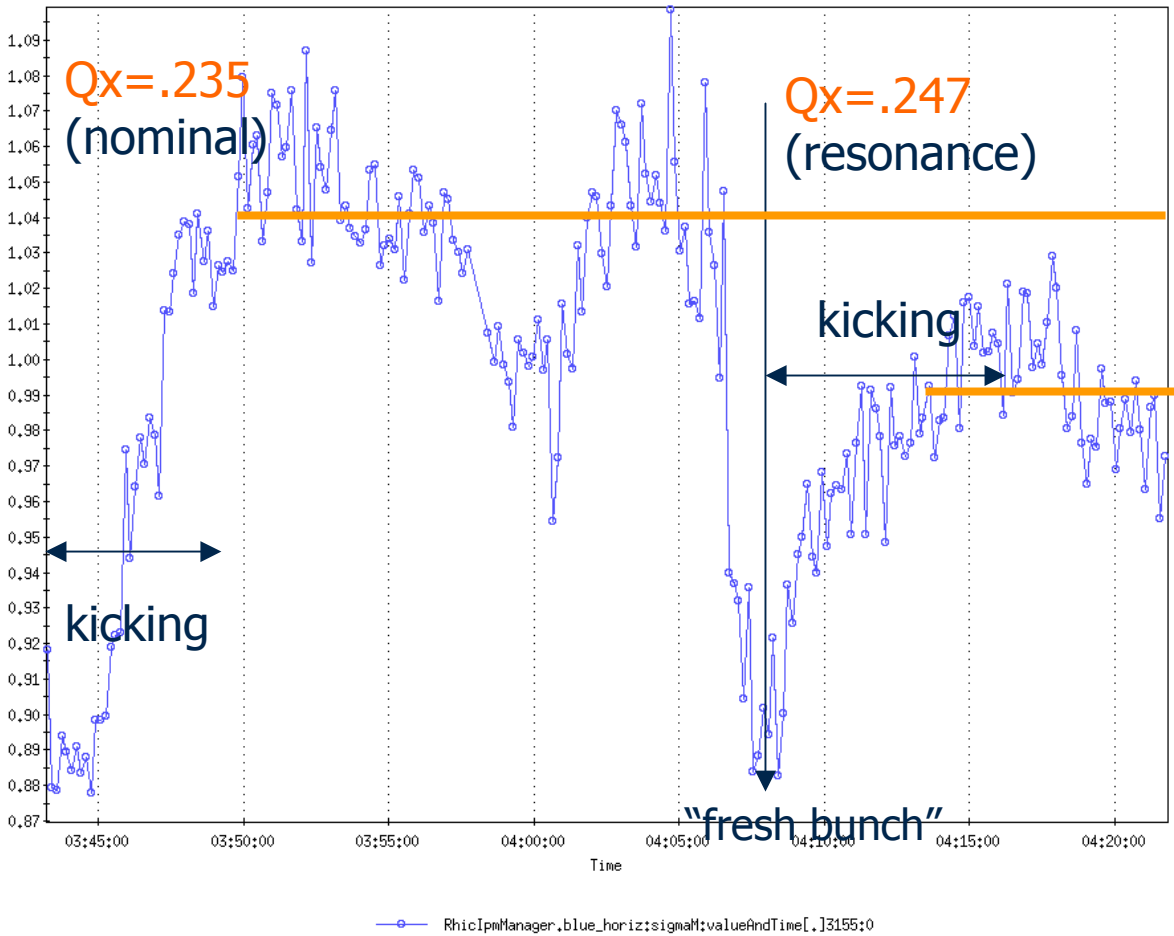
Schottky (emittance)



IPM (sigma)

Dynamic aperture, blue, flattop

Blue ring - β^*=2m in IP6 and IP8

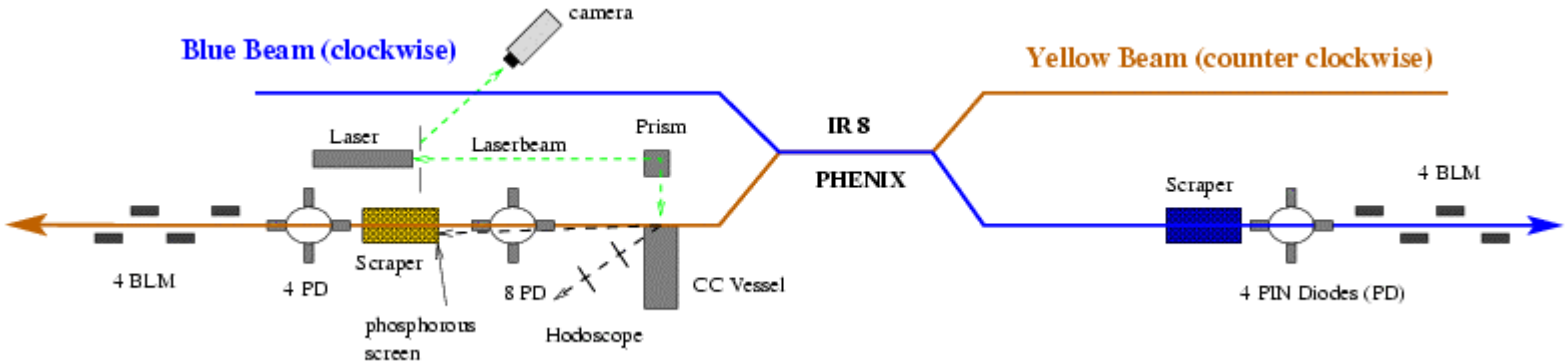


Dynamic aperture (nominal tune) ~**4.5 sigma**
By rescaling the emittance
To the initial one

Dynamic aperture (resonant tune) ~**3.6 sigma**

data to compare with simulation

Measure of diffusion coefficients



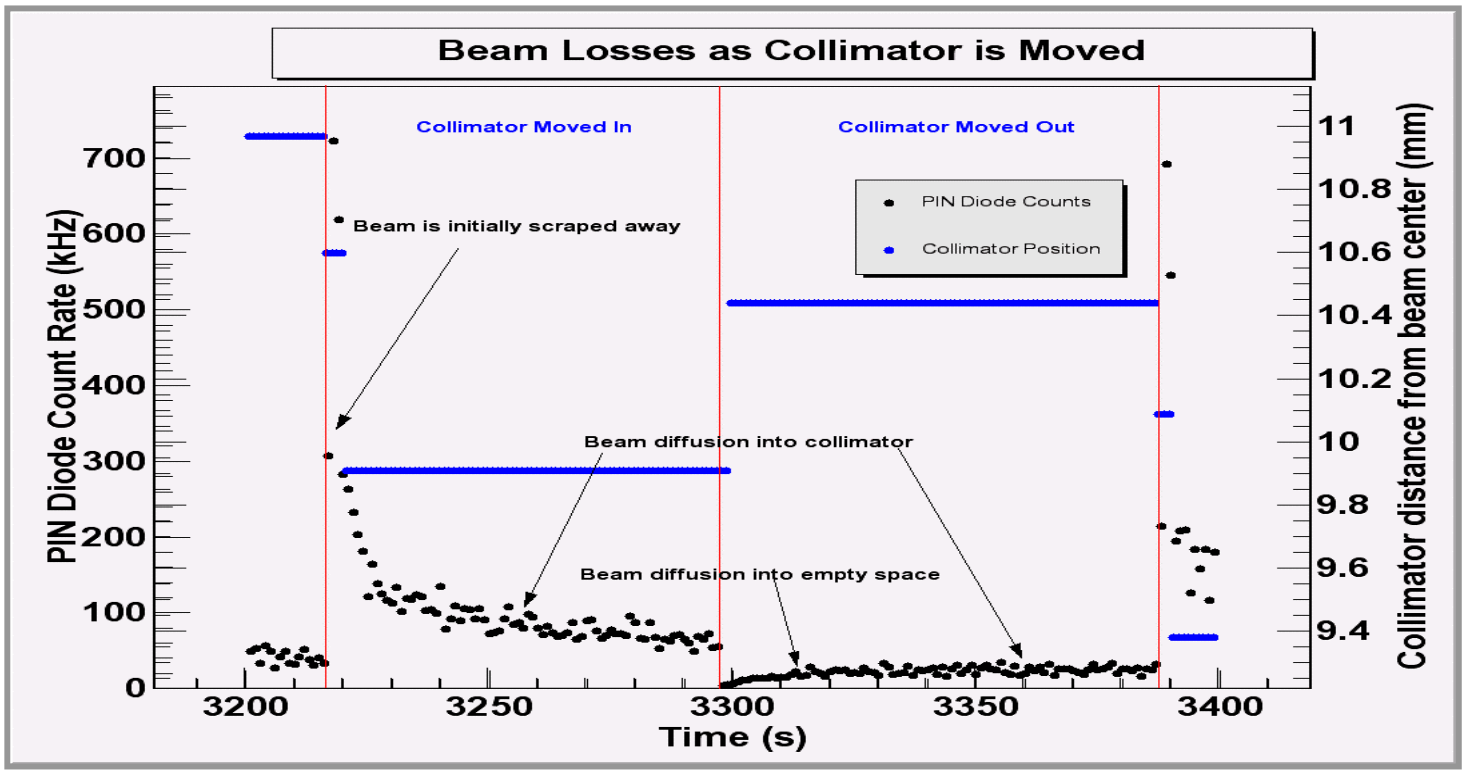
Halo growth by measuring the **diffusion rate** of the beam with collimator.
loss rate at a collimator→**diffusion coefficients** as a function of action (method by M.Seidel – thesis)
Near the collimator $B(J)=b_o(J/J_c)^n$

By using the **diffusion equation** and approximations valid for **actions near the collimator** it is possible to write explicit expressions for the **diffusion rate** for collimator moved **into the beam** and **away from the beam**.
→fit →diffusion coefficients

R.Fliller et. al. PAC2003

Diffusion at injection

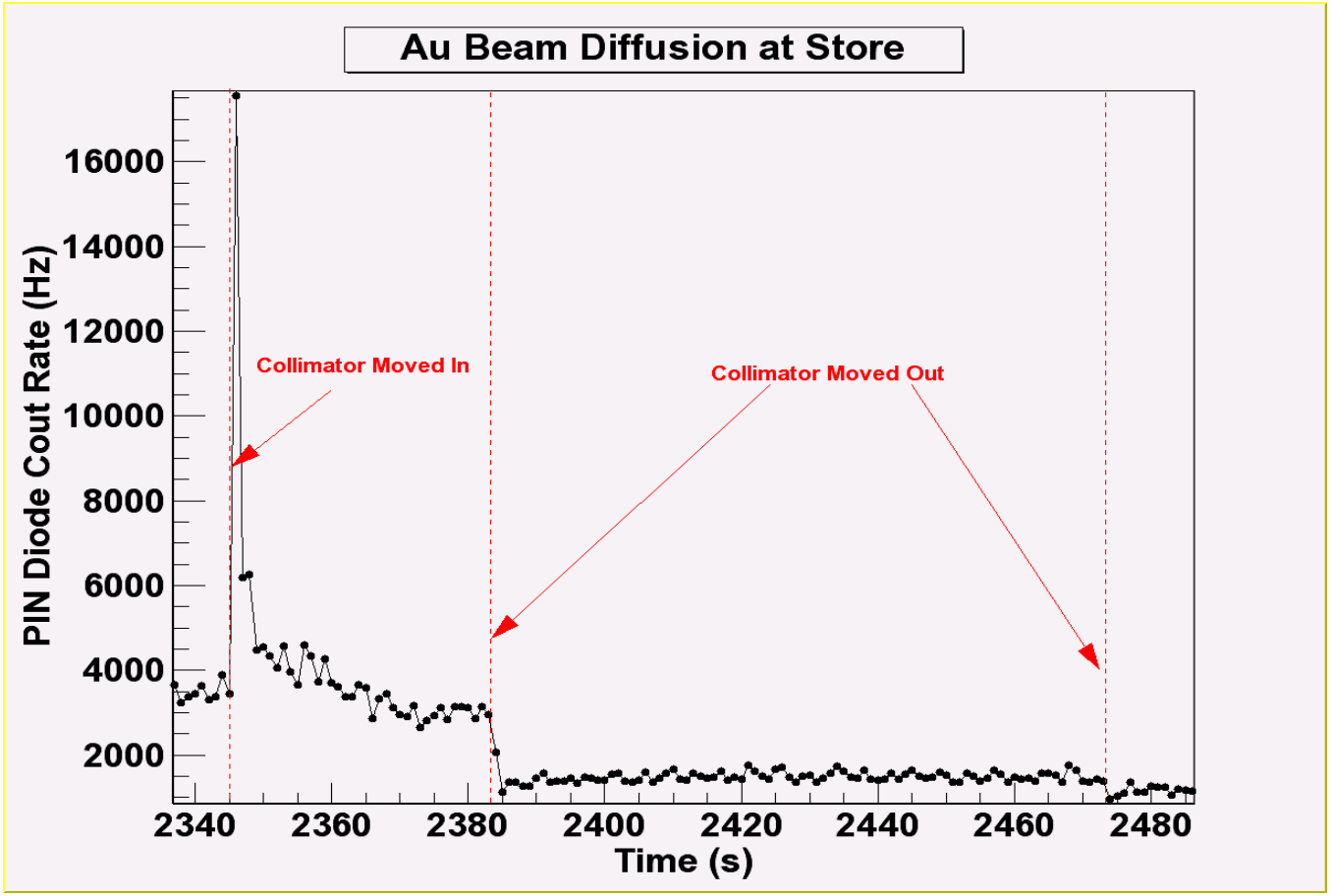
- By moving the collimator into and away from the beam and measuring the beam loss rate as a function of time → diffusion coefficient
- compare to calculations → find the driving factor(s) of emittance growth



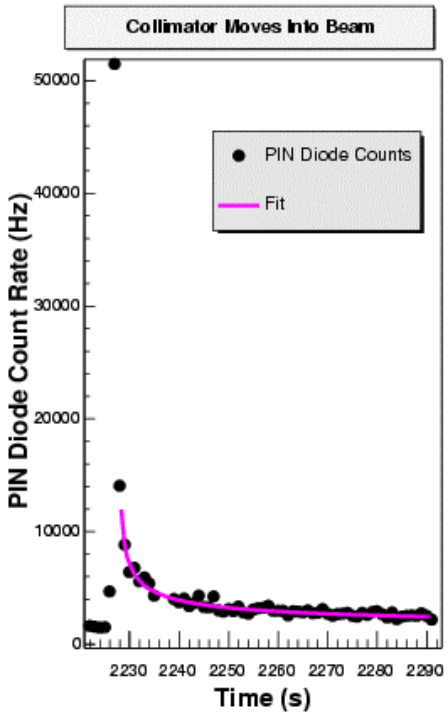
Diffusion at store

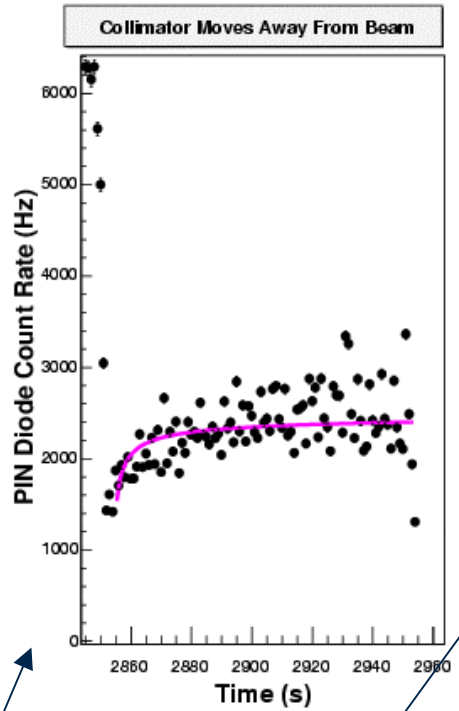
Good data→ analysis→ diffusion coefficients

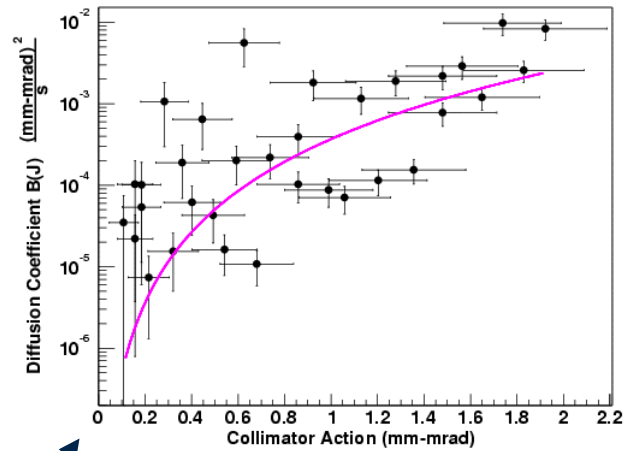
➢Compare to injection, beginning to end of store at flattop

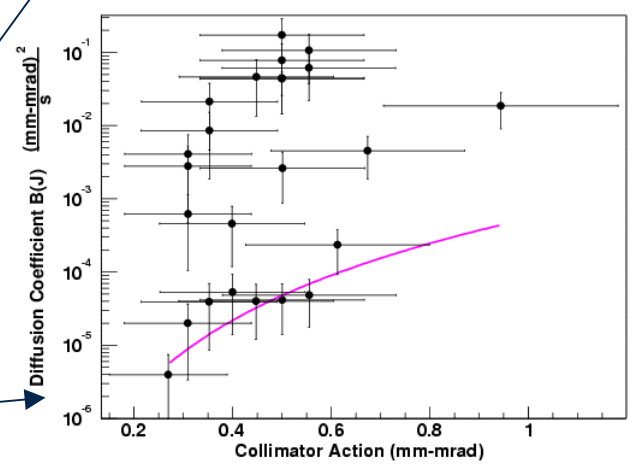


Diffusion - results









Fit of diffusion data
Diffusion coefficients as a function of J

large variation in the coefficients
of this data set to be understood

Diffusion coefficients - summary

Results of fit to $B(J) = bJ^n$

Store	Year	Ring	Beam	B ($\mu m^{2-n} s^{-1}$)	n
01413	2001	yellow	Au	0.17 (0.009)	10.3
02797 inj	2003	yellow	Au	0.00036 (0.0008)	2.8
02959	2003	yellow	Au	0.0081 (0.0014)	8.3
03155 – 01	2003	yellow	Au	0.00053 (0.00044)	3.5
03155 – 02	2003	yellow	Au	*1.8 (1.12)*	*8.7*
01874 inj	2002	yellow	p	0.045 (0.026)	8.5
01924 inj	2002	blue	p	0.06 (0.02)	7.0
02136	2002	yellow	p	*7.8 (5.5)*	*5.7*
02175	2002	blue	p	0.0036 (0.0005)	3.0

after Vernier scan
& orbit bumps

2003 fitting method slightly different from 2002 and 01

Data being re-analized
Data next run (dedicated experiments)

Halo stochastic cooling IBS

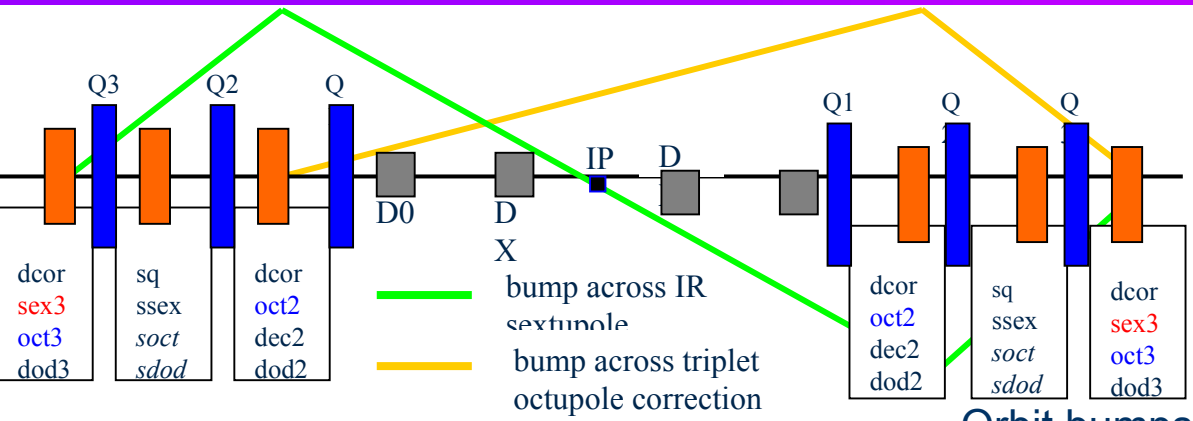
Brennan, Blaskiewicz

If the goal is to keep the beam bunched then we don't really want to cool the core, just keep the beam from crossing the separatrix

- Cooling of the hot part of beam goes faster
  - Better mixing
  - Better signal to noise ratio
- For a full bucket (J. Wei) coasting beam theory gives the correct results for cooling rate and stability limits
- With a full bucket the synchrotron satellites completely overlap, giving good mixing

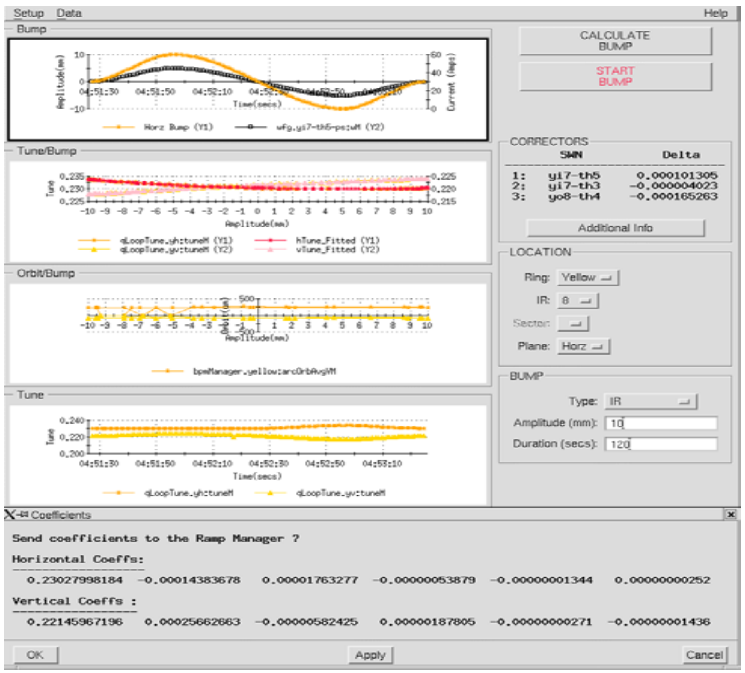
- We're not really looking to cool the beam (electron cooling), just to keep it from getting too hot ("stochastic refrigeration")
- **Test of the pickup signals done this year** (injection and store) positive – good transverse and longitudinal signal
- Plans for a cooling test next year

IR nonlinear (triplet) corrections



Motivation:

- Dynamic aperture
- Operations (closure of steering bumps)



Orbit bumps at triplets and across IR

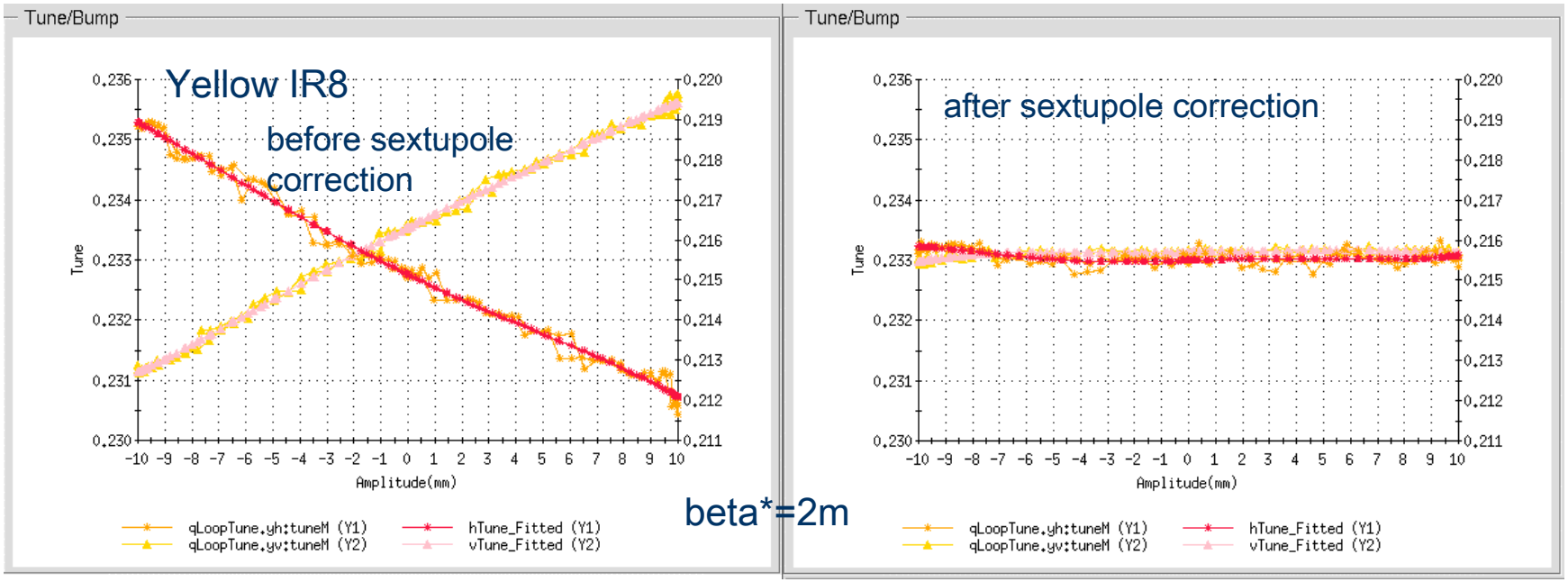
→rms **orbit** and **tunes** vs. bump amplitude

PLL ~10^{-5} resolution

IRbump application:

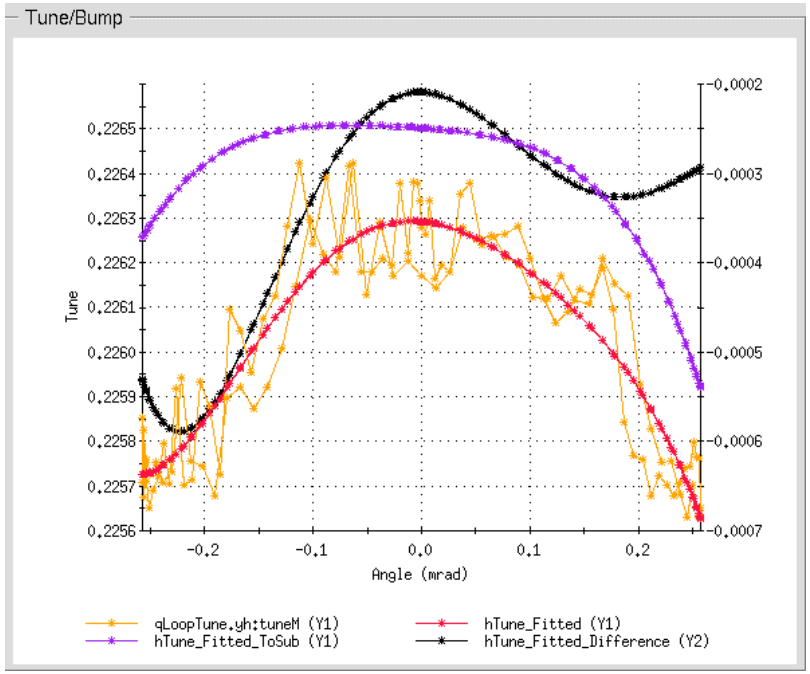
- **set-up** and **ramp-up** of IR and triplet bumps in specified time (1-2 minutes)
- Tune and power supply monitoring
- Plot orbit rms and tunes as a function of bump amplitude
- Polynomial fitting up to 5th order of tunes versus amplitude → **coefficients**→nonlinear **corrector settings**

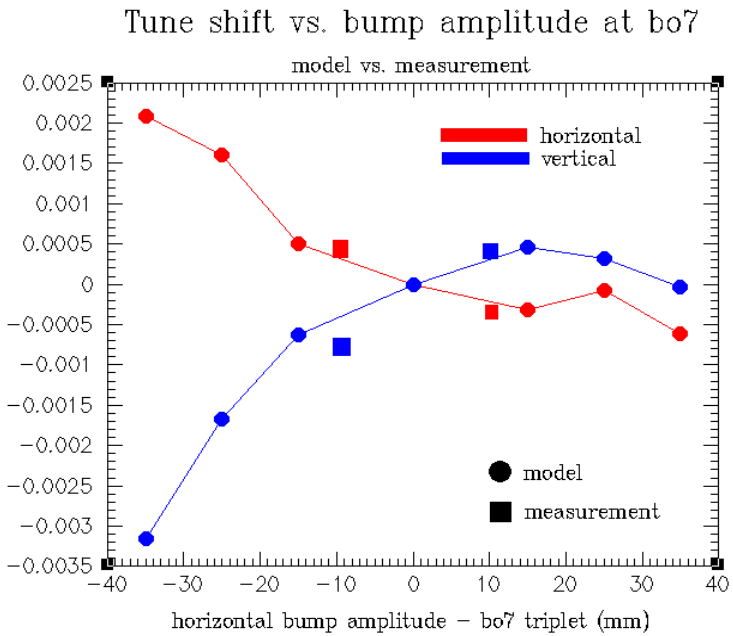
IR corrections - results



- Sextupole correction at the low beta* IR's (IR6 and IR8) – blue and yellow rings
  - beta* = 2m (deuteron-gold run)
  - beta* = 1m (polarized proton run)
- test of octupole correction at YIR8 (2 octupoles allow individual triplet correction) feed-down octupole→sextupole, to be repeated: octupole first, then sextupole (next week beam ex session….)

IR correction – work in progress





- Test of using the IRbump application to speed up the measurement of tune shift vs. crossing angle at the IP. (compare cogged vs. un-cogged beams)
- Promising – to be repeated with beams better centered in the triplets

- Started systematic comparison of experimental data with RHIC model (including measured individual field errors in triplet cold masses and alignment errors)

Nonlinear chromaticity - 1

Ptitsyn, Cameron, Tepikian

- Correct **linear chromaticity** to 0
- **Separate tunes** (reduce coupling effects)
- Compare radial steering shift to bpm
- Tried various radial steering ramps

Radial steps

5 and 10 steps

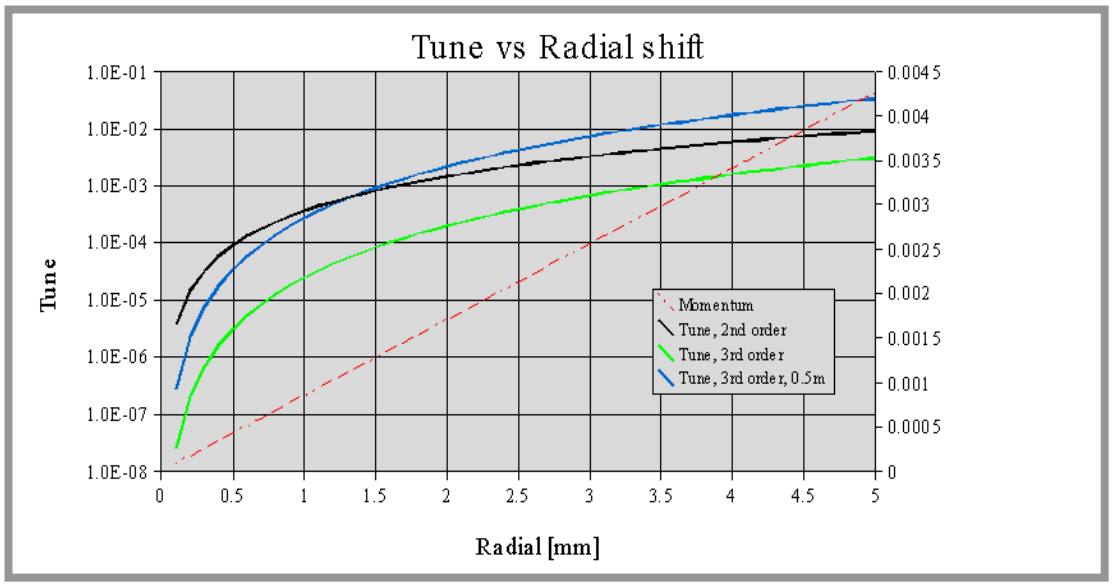
Radial modulation

0.4mm amplitude at 1Hz

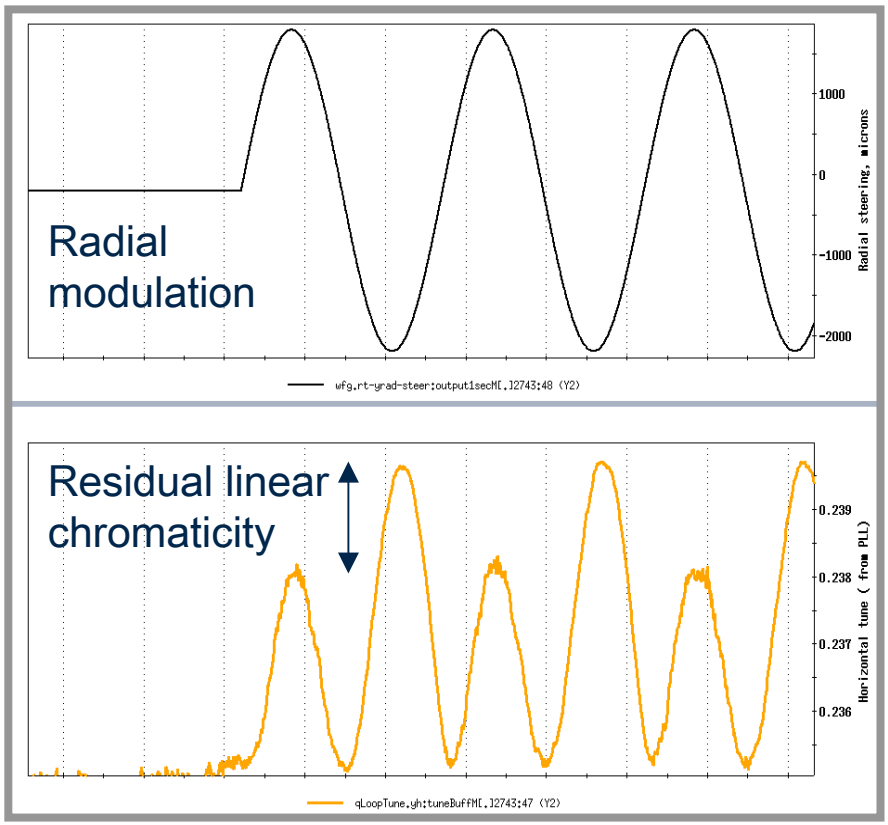
1mm amplitude at 0.4Hz

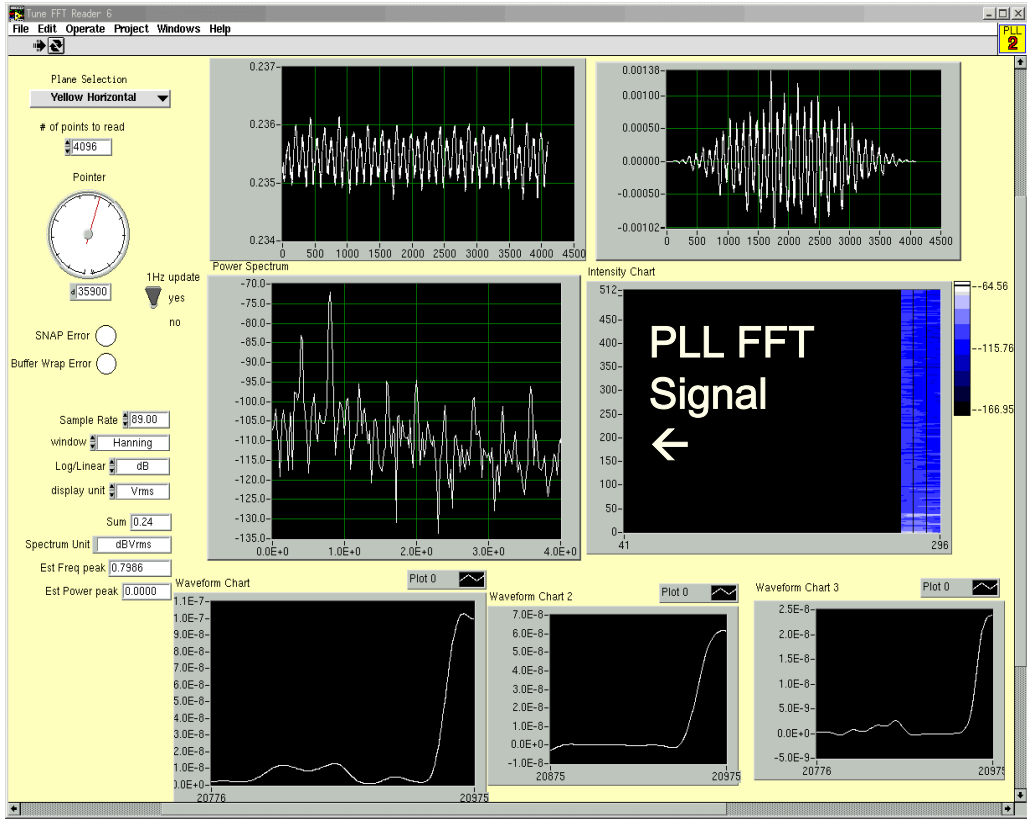
2mm amplitude at 0.2Hz

Prediction from model:



Nonlinear chromaticity - 2

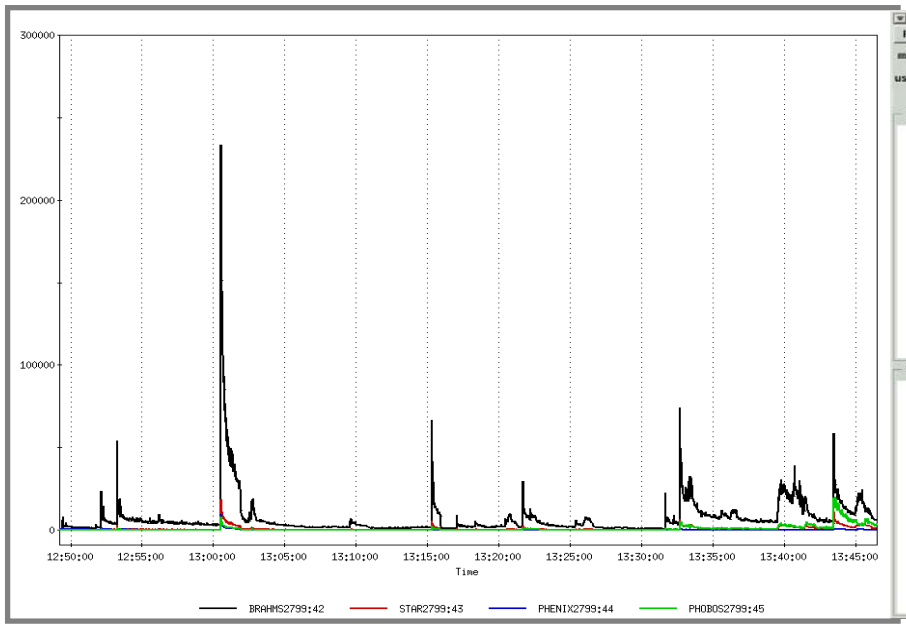


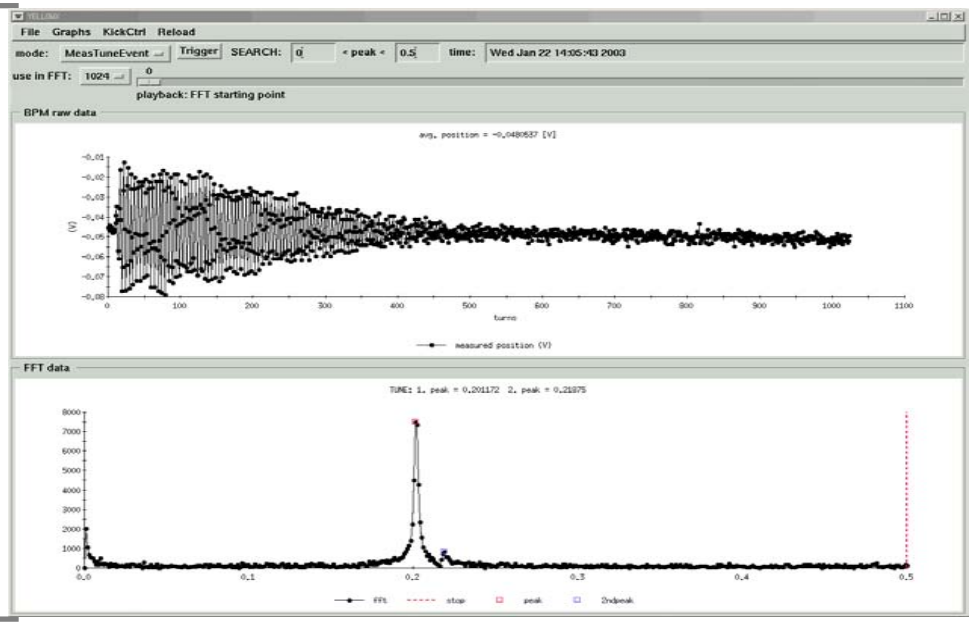


Good result for horizontal measurement
ξ_2~1340 chromaticity application compare well calculation from the raw PLL tune signal

Next step:
- Use octupoles to compensate

Resonance compensation





Goal: compensation of resonance lines **5Qx** (decapoles) and **4Qx** (octupoles)
useful at **store** and **transition**

Tools: BTF spectra, Schottky, then **TBT BPM + AC dipole** (res.driving terms)

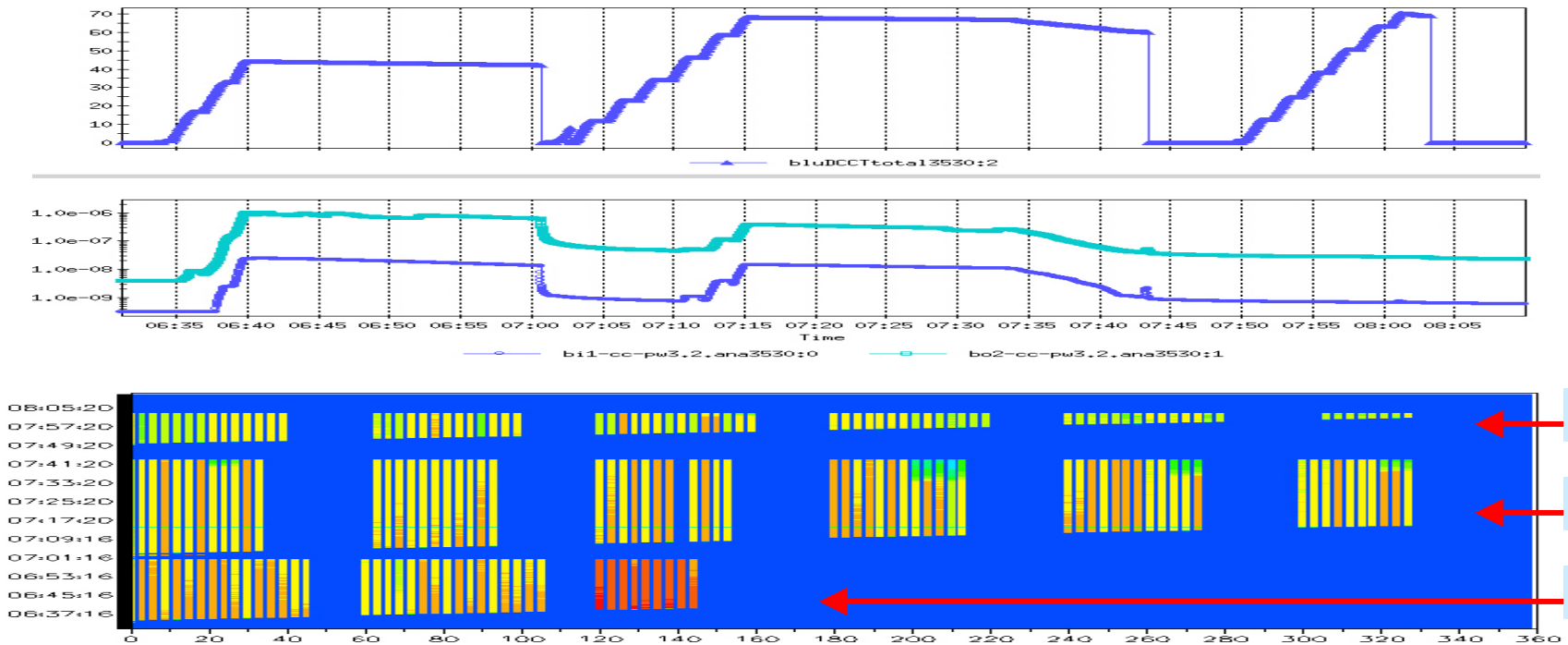
First test 2003: store, approached 0.2 tuning on background and decapoles in IRs

Second test 03: injection, beam in island (beam in island does not survive but is reproducible)

Ideas for 04: create and populate stable islands

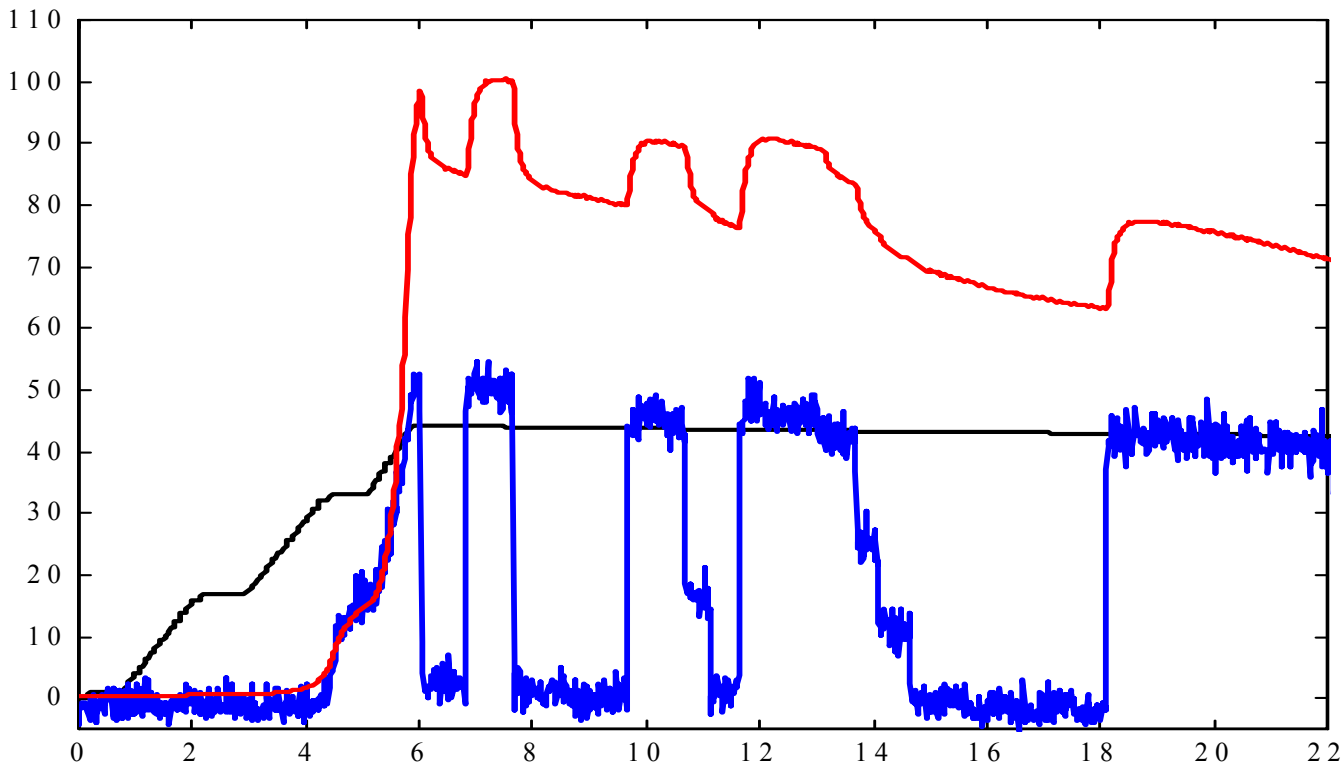
Pressure rise – beam gap study

Zhang, Iriso-Ariz, Fischer +…..



- Fill 1: 16 bunches+[4 empty]+..., Fill 2: 12+[8]+..., Fill 3: 14+[6]+...
- Pressure rise of Fill 2 is lower than Fill 1.
- Fill 3: bunch length is longer and intensity is lower.

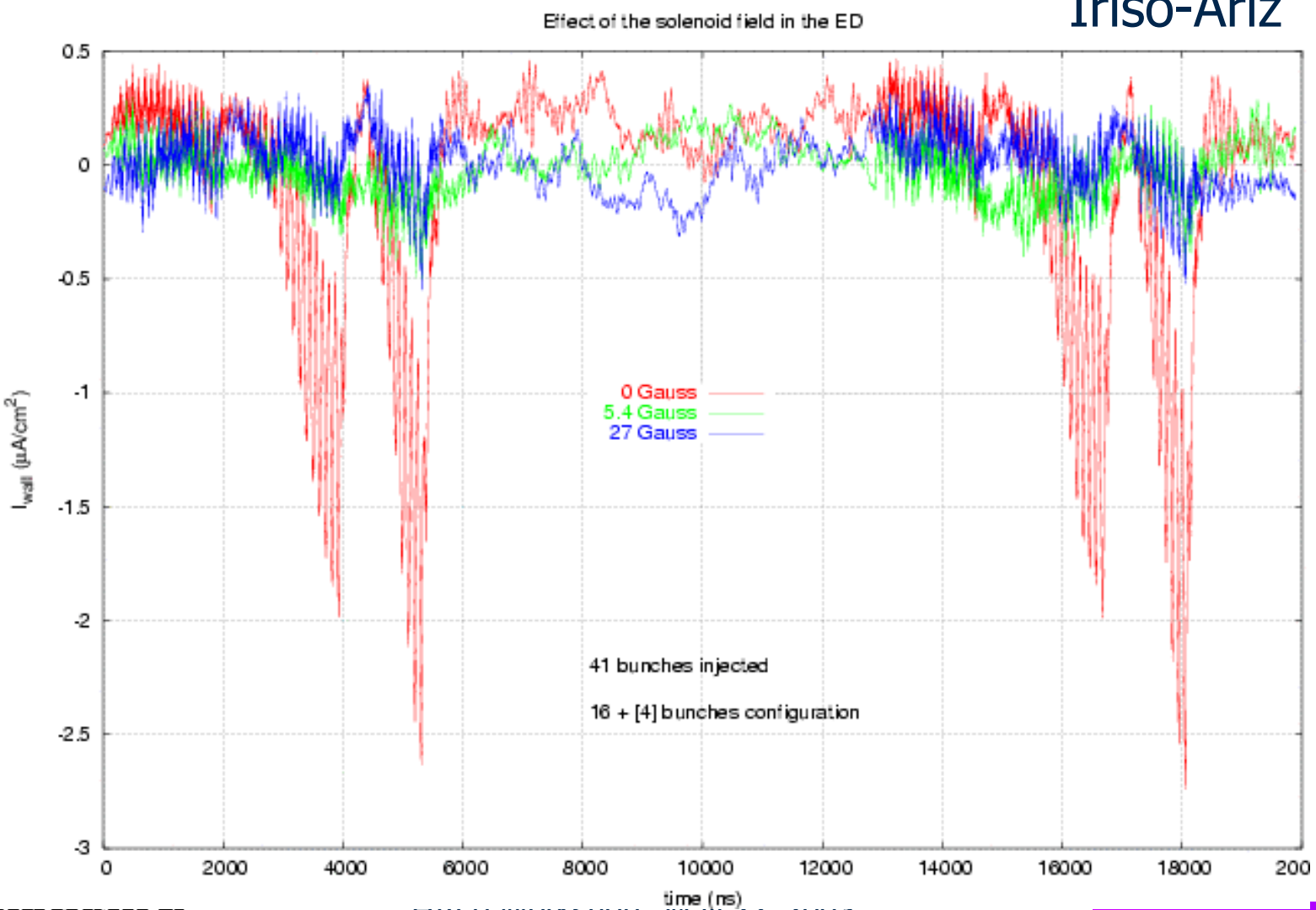
Solenoid effect on e-signal and pressure



- Electron signal was reduced by the solenoid at the fields less than 27 Gauss.
- Pressure rise was also reduced by the solenoid, from 1e-6 to 8e-7 Torr, solenoid covered 4 m over 35 m long pipe.

Effect of solenoid on e- signal

Iriso-Ariz



Plans for run 2004 and beyond

RHIC run 2004:

- Modeling effort during shutdown (compare model-experiment)

  does RHIC follow the "20% law" on dynamic aperture?
- Collaborative experiments of larger scale

  (TeV, LHC,..) including "class-2" experiments, approved and possibly with standing collaborations
- Address luminosity increase and RHIC upgrade

Beyond:

- Workshop on machine commissioning, development, experiments

ICFA sponsored? – mid/late 2004? (RHIC TeV Hera→ SNS LHC…LC)

- Remote operations/GAN – test experiments

  (ICFA working group on remote accelerator physics experiments has been recently created – chaired by David Rice – to coordinate efforts in this domain)