# FY08 RHIC Schottky

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# Schottky Systems (1002)

- Low Frequency (LF) system (245 MHz)
  - ✓ narrow line widths
  - ✓ good resolution of synchrotron lines ($\nu_s$ measure)
  - ✓ good resolution of coupling
  - ✓ low Q system, signal levels for pp around 15 dB (at best) with >5 dB noise background
- High Frequency (HF) system (2.07 GHz)
  - ✓ large line widths
  - ✓ clean signals (20-30 dB signal with <1 dB noise)
  - ✓ with proper fitting, good resolution of Q & Q'
  - ✓ not as sensitive to coupling, since line widths are large relative to dQmin
  - ✓ High Q system with HF (so low noise); lots of signal

# Schottky Systems (1010)

- Traveling Wave (TW) system (1.70 GHz)
  - ✓ line widths (slightly) narrower than HF
  - ✓ Is able to give bunch by bunch Schottky spectra (tune, chrom., emittance, … anything HF can do).
  - ✓ Low Q system; signal levels are lower than HF
  - ✓ Main value: gives spectra for both bunched and debunched particle distributions within a 28 MHz bucket period = useful as an *abort gap monitor*!

# Parameters

| Parameter | LF system | HF system | TW system |
|---|---|---|---|
| Freq. | 245 MHz | 2.07 GHz | 1.70 GHz |
| n | ~3133 | ~26473 | ~21740 |
| Line Widths | ~440 Hz | ~3700 Hz | ~3000 Hz |

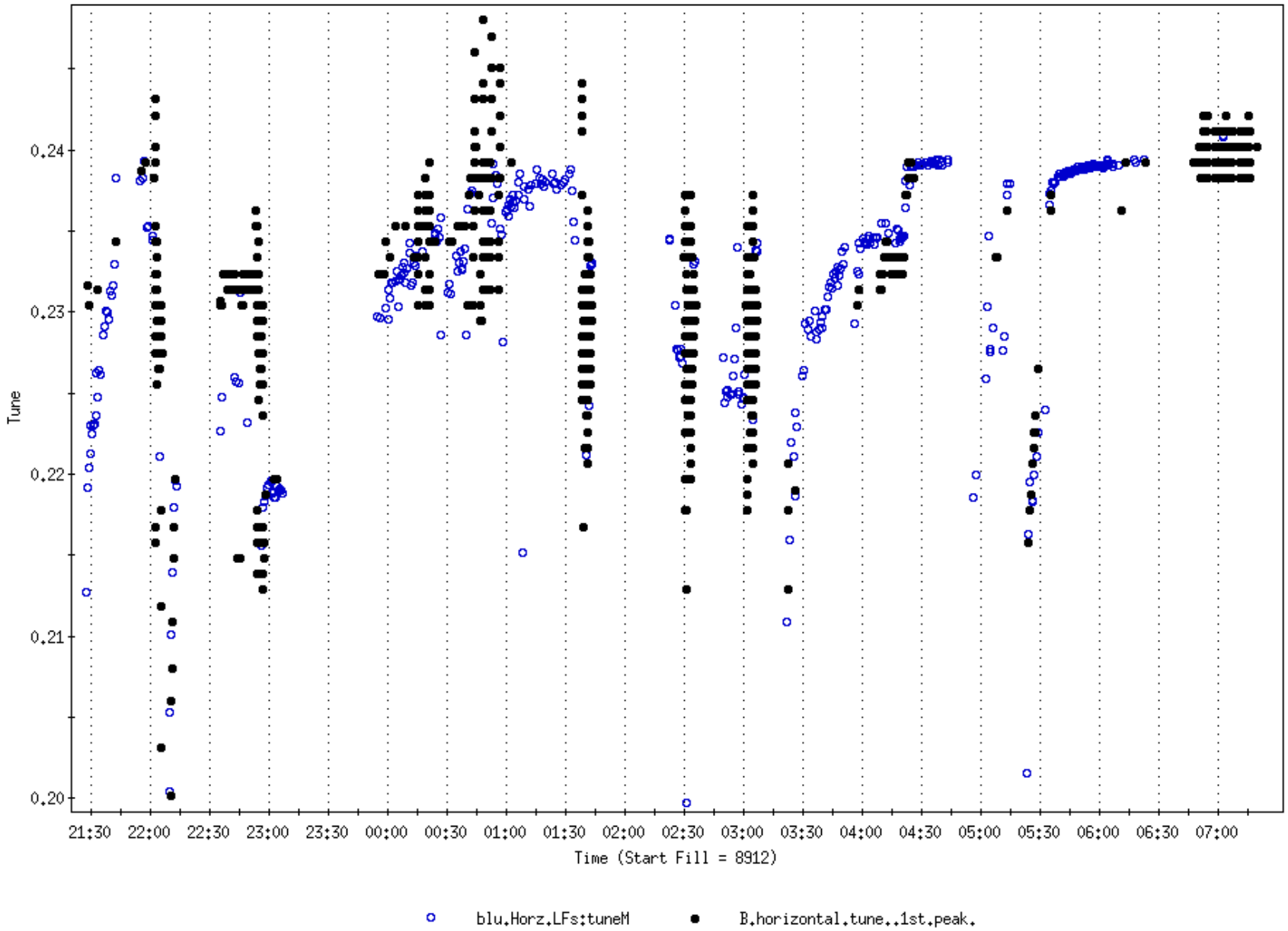
# Schottky Systems Status

Main focus of work is to move away from LabView interfaces and into the control system, allowing more control of data acquisition and more flexible remote instrument control.

- LF
  - ✓ New software – analysis & control from manager
  - ✓ new, narrow BW, higher gain amplifiers (40 db gain)
  - ✓ Data acquisition w/o labview (complete!)
  - ✓ control of mux from manager
  - ✓ control of bpm position feedback through manager
- HF
  - ✓ Data analysis in manager
  - ✓ labview used only for data acquisition
  - ✓ e.g., emittance calibration/studies via gpm

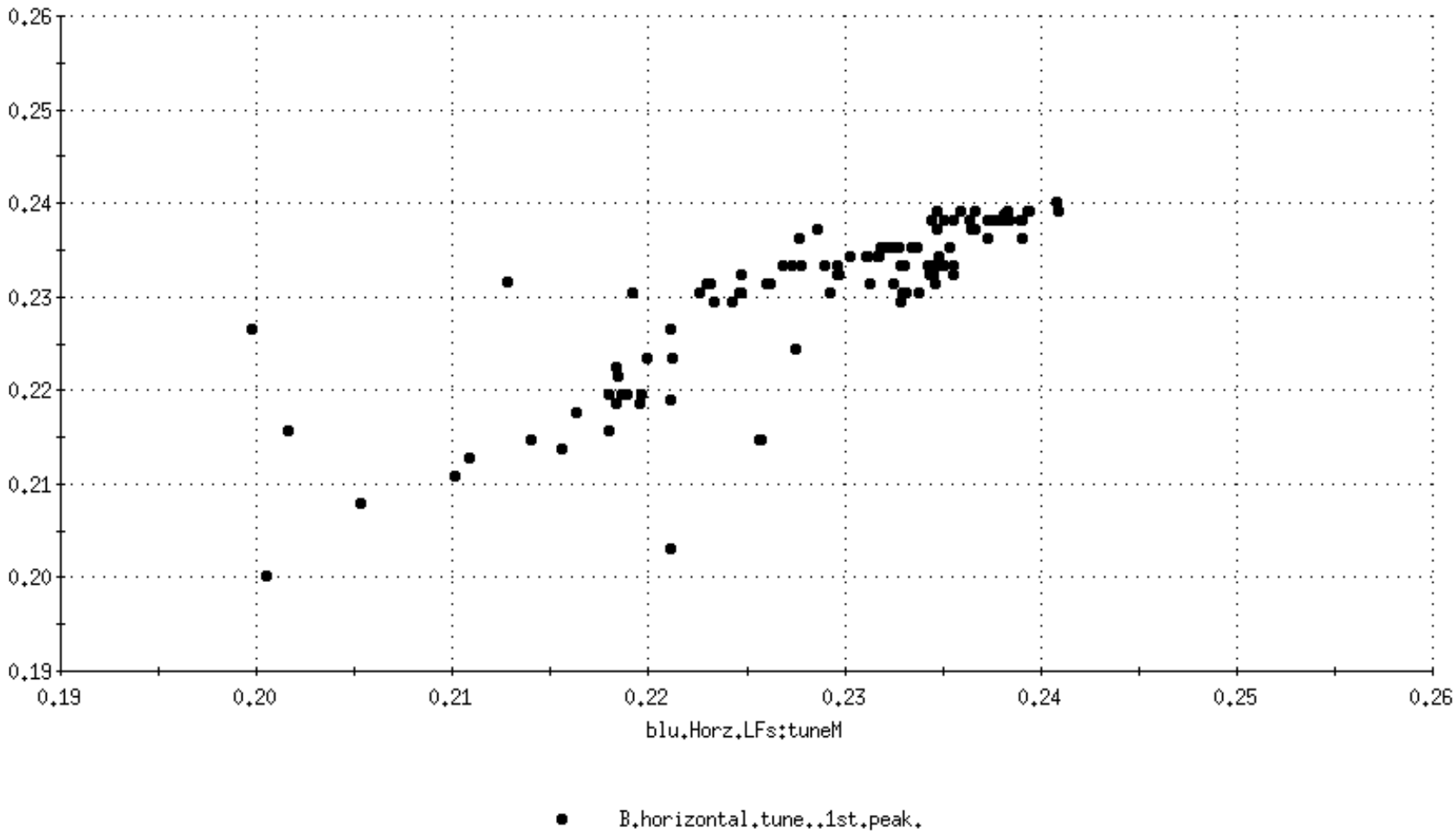
Tue Jun 05 16:50:15 - Wed Jun 06 07:19:40

Window Event Analysis



sddsview

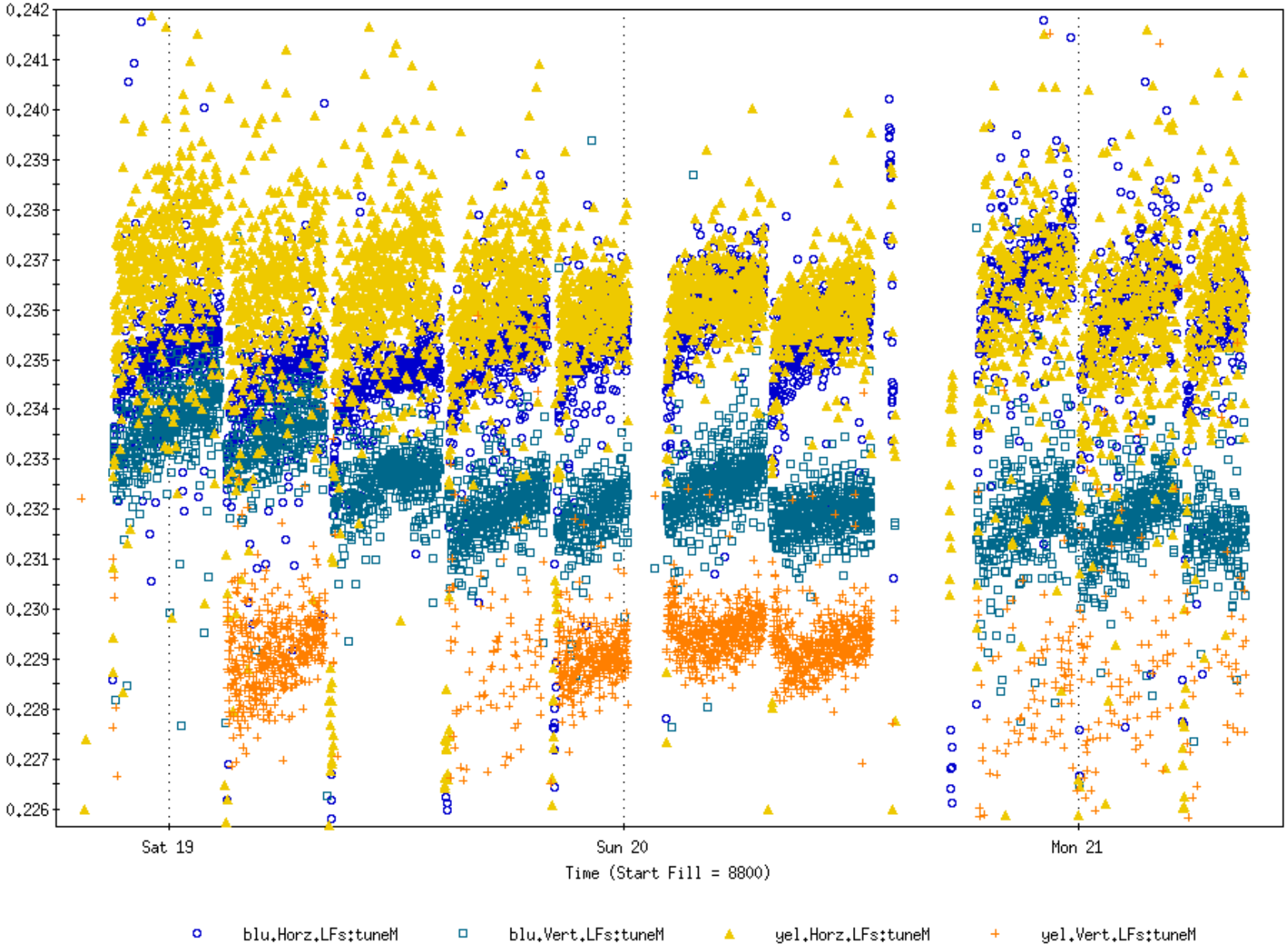
File Options Data Help



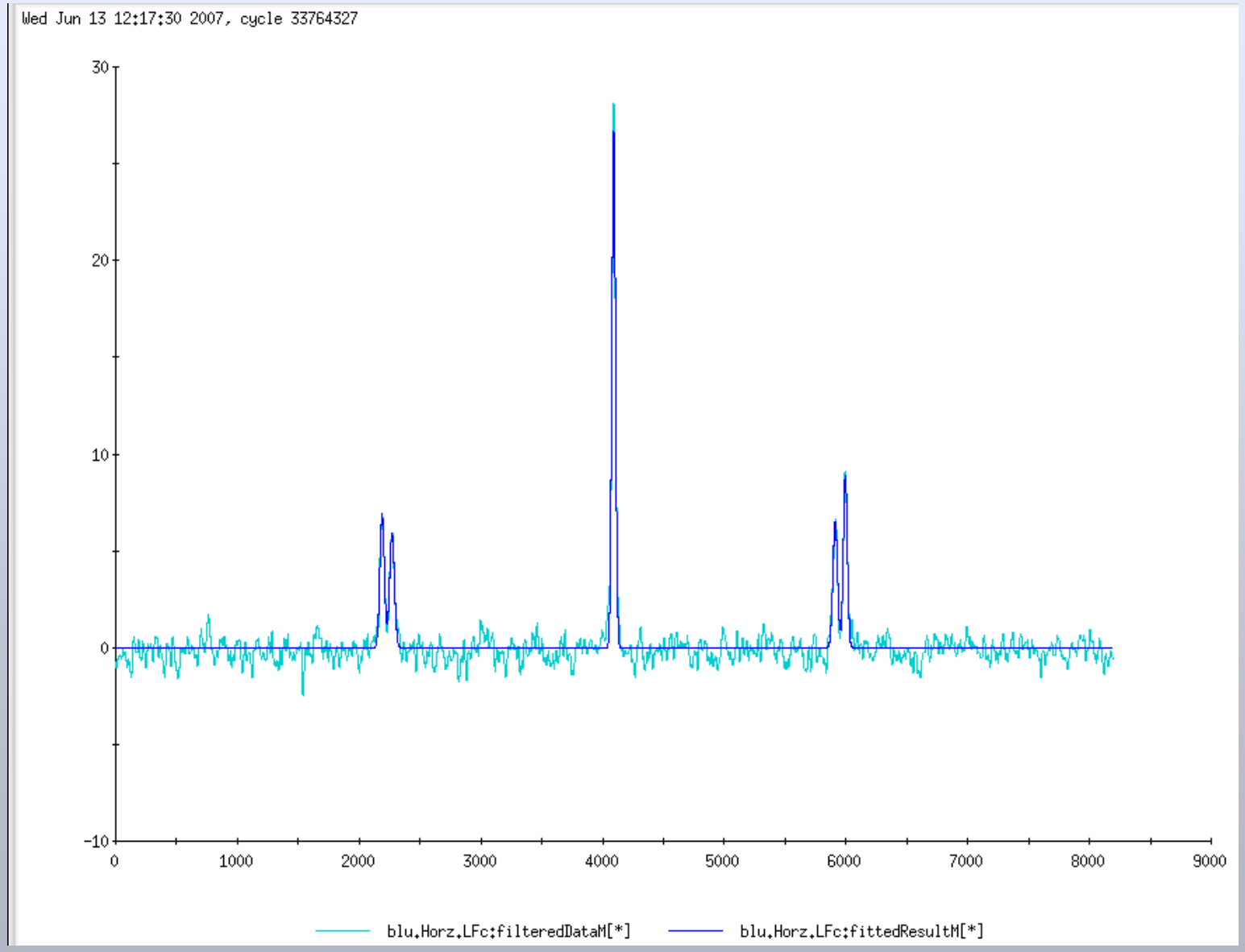

| Index | blu.Horz.LFs:tuneM | B.horizontal.tune..1st.peak. |
|---|---|---|
| 0 | 0.212706 | 0.231689 |
| 1 | 0.219095 | 0.230469 |
| 2 | 0.222958 | 0.231445 |

Fri May 18 19:26:20 - Mon May 21 08:48:30

Window Event Analysis

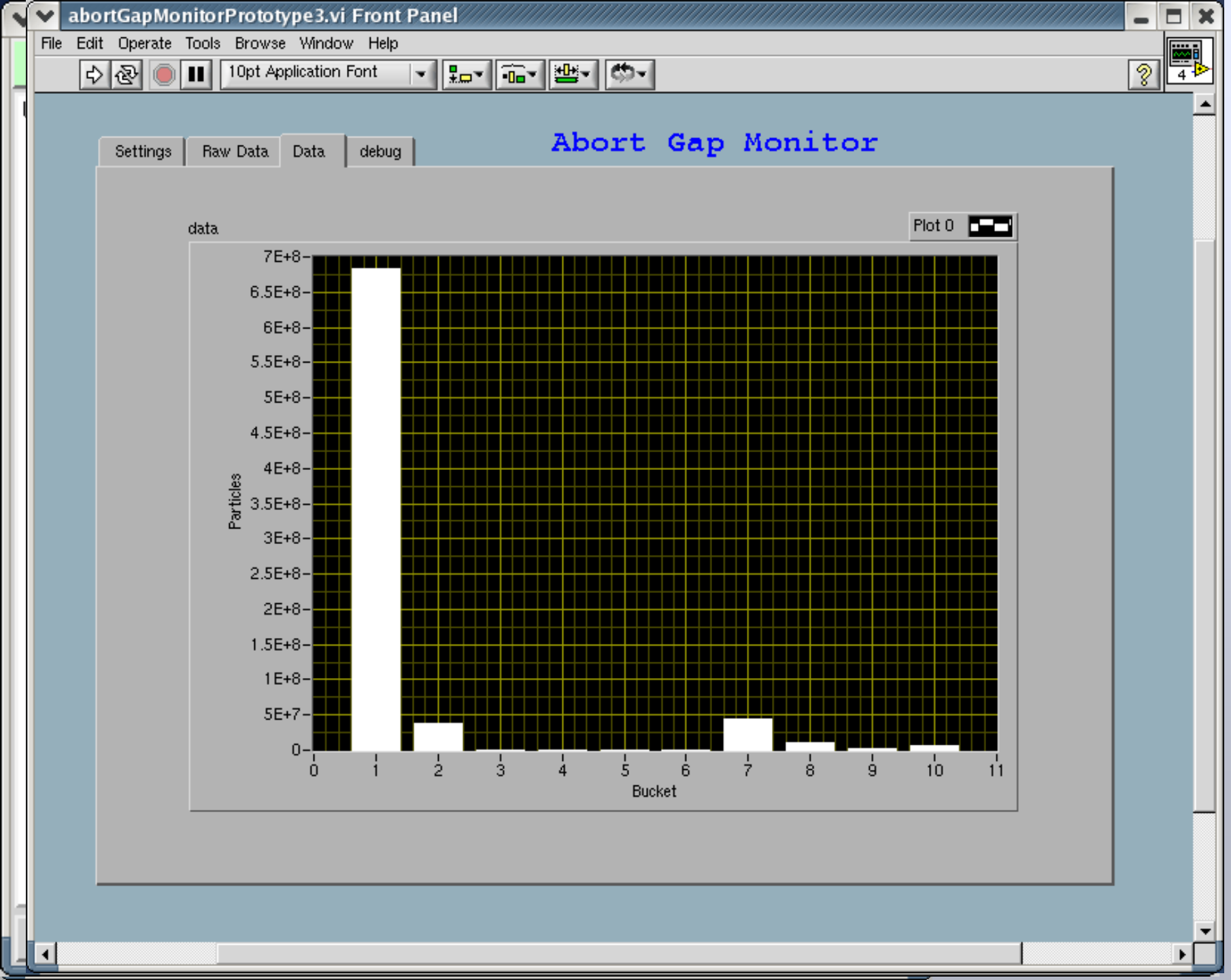


# LF Analysis w/ coupling (new)



# Schottky Systems Status

- TW
  - ✓ Main focus = Abort Gap Monitor.
  - ✓ Cavities were carefully checked out over the shutdown and compared to data from FNAL.
  - ✓ New amplifiers, filters, diodes, …
  - ✓ New 3.5 GHz Tektronix scope (for group)
  - ✓ Two pickups are now on higher quality cables
    - ❑ all cables are now better matched
  - ✓ All signal processing will be outside the tunnel, in old Phobos trailer (1010).
  - ✓ BPM signal routed to trailer, for timing.


abortGapMonitorPrototype3.vi Front Panel
File Edit Operate Tools Browse Window Help
10pt Application Font
Abort Gap Monitor
Settings
Raw Data
Data
debug
data
Plot 0
7E+8
6.5E+8
6E+8
5.5E+8
5E+8
4.5E+8
4E+8
3.5E+8
3E+8
2.5E+8
2E+8
1.5E+8
1E+8
5E+7
0
Particles
0 1 2 3 4 5 6 7 8 9 10 11
Bucket

# Schottky Plans

- LF & HF
  - ✓ Documentation is improving = web pages.
    - ❑ http://www.cadops.bnl.gov/RHIC/Instrumentation/schottky/
  - ✓ tracking center freq. through acceleration cycle
  - ✓ improving data analysis and software development
  - ✓ Generally, both are working systems, but we need to develop greater trust in the results, improve the quality of the data, and simplify the analysis.

# Schottky Plans

- TW
  - ✓ initially, data analysis in LabView
  - ✓ LabView used only for development = will need to migrate to a manager
  - ✓ Still a lot of development = new system
  - ✓ studies (mainly parasitic) to develop a good abort gap monitor system
  - ✓ commission to be useful for operations

# A few things I learned at FNAL

- Operators use dedicated scope on LF Schottky system = no interest in TW system. They look at spectra!
- Tune space display program does not display tune spread! It shows tune measurements with persistence, and so shows amount of variation in tune over many measurements.
- High level of integration in application and data acquisition system to controls.

# Tune Ripple

Run7 (Jun-20-2007) measurements have put an upper limit on the level of 60 Hz tune ripple in RHIC; $< 2 \times 10^{-5}$.

# AC Quadrupole

Based on magnetic measurements

$$\Delta \boldsymbol{Q}_{x,y} = \frac{1}{4\pi}\int \frac{\beta(\boldsymbol{s})\boldsymbol{B}'(\boldsymbol{s})}{\boldsymbol{B}\rho}\boldsymbol{ds} = 0.2895\frac{\beta(\boldsymbol{s})\boldsymbol{I}}{\boldsymbol{B}\rho}$$

Where $\boldsymbol{I}$ is in kA, $\beta$ in m, $\boldsymbol{B}\rho$ in Tm.

At injection with +/- 10 amp, $\Delta Q \sim 3\times10^{-4}$

On the Schottky spectra this is about 45 Hz.

For LF Schottky this is not easily measurable (much smaller than a line width). It is easily measurable with BBQ.

But, increase in tune spread will be reflected in collision rates (polarized protons), if run in a CW mode.

# Schottky Experiments

- Strong focus on abort gap monitor and TW system
- Lots of parasitic looking at signals.
- Continue to make Comparisons of Schottky (HF/LF) tunes and tune spreads to other measurements.
- Continue development of emittance measurement
- Tune Ripple measurements, with polarized protons, need to be done with normal stored beams (beginning of a collisions and at end of store), to observe change in collision rates for different excitations of the AC-quadrupole.

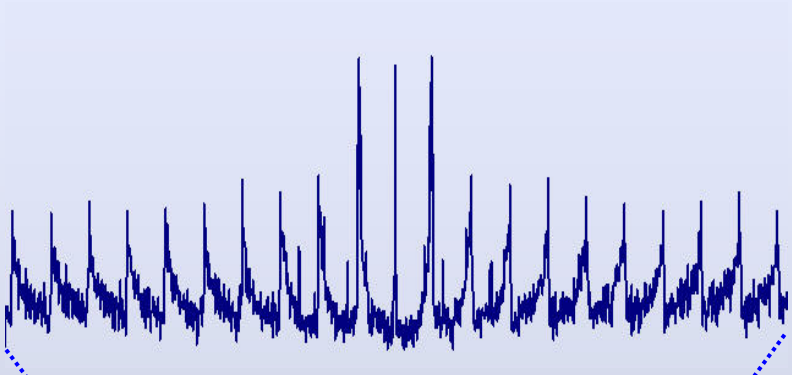
# Backup, Reference material,,,,

# Standard References

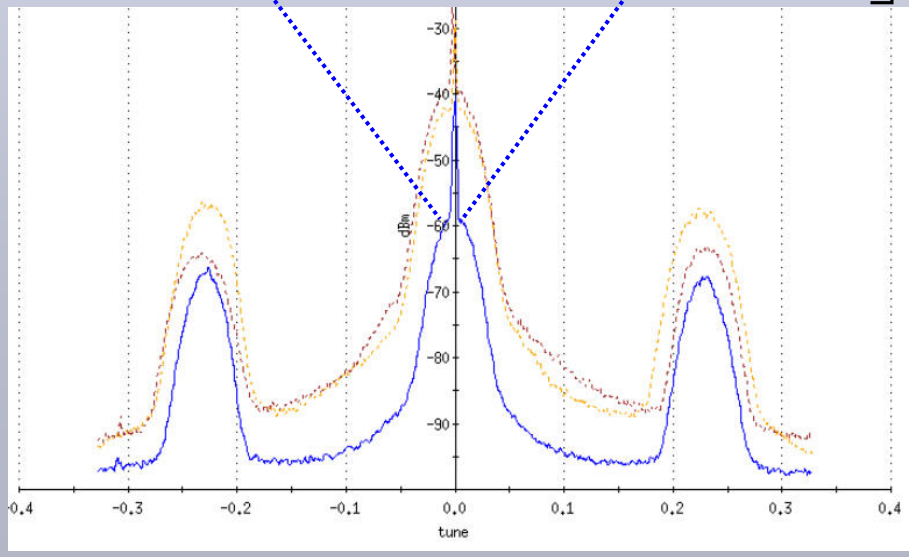
- D. Boussard lectures: http://preprints.cern.ch/cernrep/1987/1987-003_v2/1987-003_v2.html
- R.Siemann USPAS lectures: (1992S) Topics in Experimental Accelerator Physics
- M. Blaskiewicz Lecture notes (BNL, 2006)
- W. Mackay USPAC lectures: (2005S) Accelerator Physics Supplementary Notes
- D.A.Goldberg & G.R. Lambertson: Schottky Monitors for the Tevatron Collider, LBL internal tech. note no. BECON-61, LBID-1129

# Line Locations and Widths

- Bunched beams: each revolution line splits into an infinite number of synchrotron satellites separated by synchrotron frequency with amplitudes proportional to Bessel functions.



$$d_n = e f_0 a_i \,\mathrm{Re}\left[ \sum_{p=-\infty}^{\infty} J_p\left(\left[(n \pm q) - Q\xi/\eta\right]\omega_0 \hat{\tau}_i\right) e^{j\left[\left(\left[(n\pm q) - Q\xi/\eta\right]\omega_0 + p\Omega_s\right)t + p\Psi_i + \varphi_i\right]} \right]$$




- Harmonic bands at $nf_0$ with betatron bands split into pairs of sidebands at frequencies $(m+-q)f_0$
- Betatron sidebands have similar structure of synchrotron satellites

# Line Locations and Widths

- Total line widths (bunched or unbunched)

$$\Delta f = n\eta f_0 \frac{\Delta p}{p} \quad \text{Longitudinal} \quad \Delta f = \left|-(n \pm q)\eta \pm \xi\right| f_0 \frac{\Delta p}{p} \quad \text{Transverse}$$

- Individual Lines in bunched beam spectra

$$\Delta f_{\parallel}^{0} = \Delta f_{random} \quad \text{Central line width in longitudinal}$$

$$\Delta f_{\parallel} = \Delta f_{\parallel}^{0} + \mu \Delta f_s \quad \mu^{\text{th}} \text{ satellite line width in longitudinal}$$

$\Delta f_s =$ spread of synchrotron frequency due to non-linear synchrotron oscillations (dependent on fraction RF bucket is filled by beam)

$$\Delta f_{\perp}^{0} = \Delta f_{\parallel}^{0} + f_0 \Delta Q_0 \quad \text{Central line width in Transverse}$$

$\Delta Q_0$ is due to non-linear betatron oscillations, beam-beam tune spread.

$$\Delta f_{\perp} = \Delta f_{\perp}^{0} + \mu \Delta f_s$$

Table 5: Factors Affecting "Usefulness" of Schottky Spectra

Input signal-to-noise ratio high enough to observe signals in a "reasonable" time.

Frequencies low enough that bands don't overlap.

Frequencies high enough that at least one satellite line observed.

Ability to resolve at least the central satellite lines.

Ability to determine band center.

Ability to determine overall bandwidth.

Ability to detect both longitudinal and transverse signals.

Freedom from coherent signals to avoid

a) spectral contaminants

b) detector damage

Ability to read total incoherent power to determine N and $N\sigma_{\perp}^{2}$.

Reasonable data acquisition time/hardware

Response either directional or rapid enough to permit separation of p and $\bar{p}$ signals.