Experience with the 1.7 GHz Schottky Pick-ups in the Tevatron

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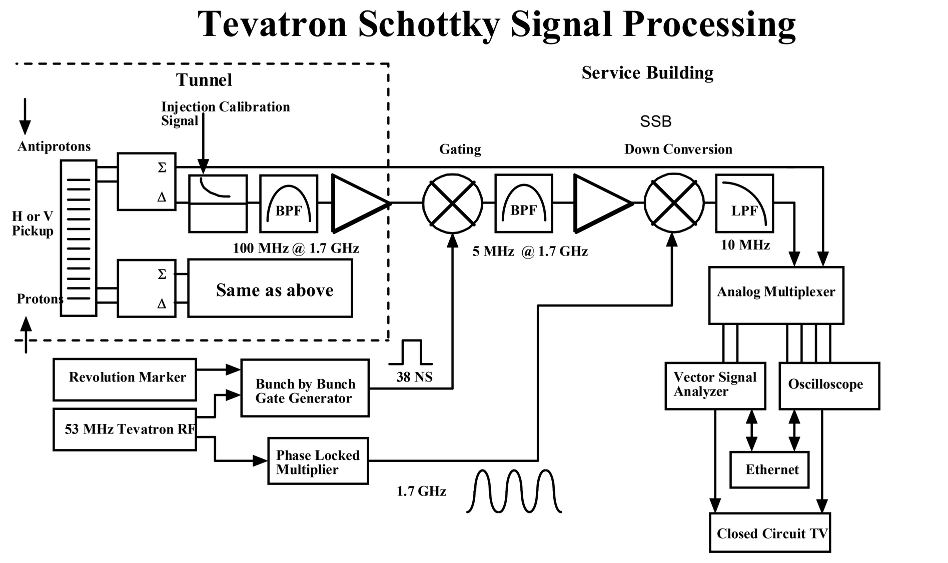
Abstract

During a 2003 shutdown, new high-frequency Schottky pick-ups were installed in the Tevatron. These devices operate at 1.7 GHz (harmonic ~36000 of the revolution frequency) and can in principle be used to measure tunes, chromaticities, momentum spread and transverse emittances of individual bunches. Only the transverse signal is used, as the longitudinal is dominated by coherent signal. The default mode of operation during a store is to sequentially acquire and analyze frequency data from different sets of bunches in the machine. This function is performed by an open access client written in Java/C++, running in the background. The resulting fit parameters are datalogged and can also be plotted in "real time" during the store. With an alternative setup, data from select bunches can be acquired continuously during the entire ramp (and squeeze), for analysis off-line. This paper describes the evolution, current status and performance of the acquisition and analysis software, and presents measurements with comparison to predictions and other measurement techniques. One example of such a measurement is the variation of beam-beam tune shift as a function of intensity and bunch position within a train.

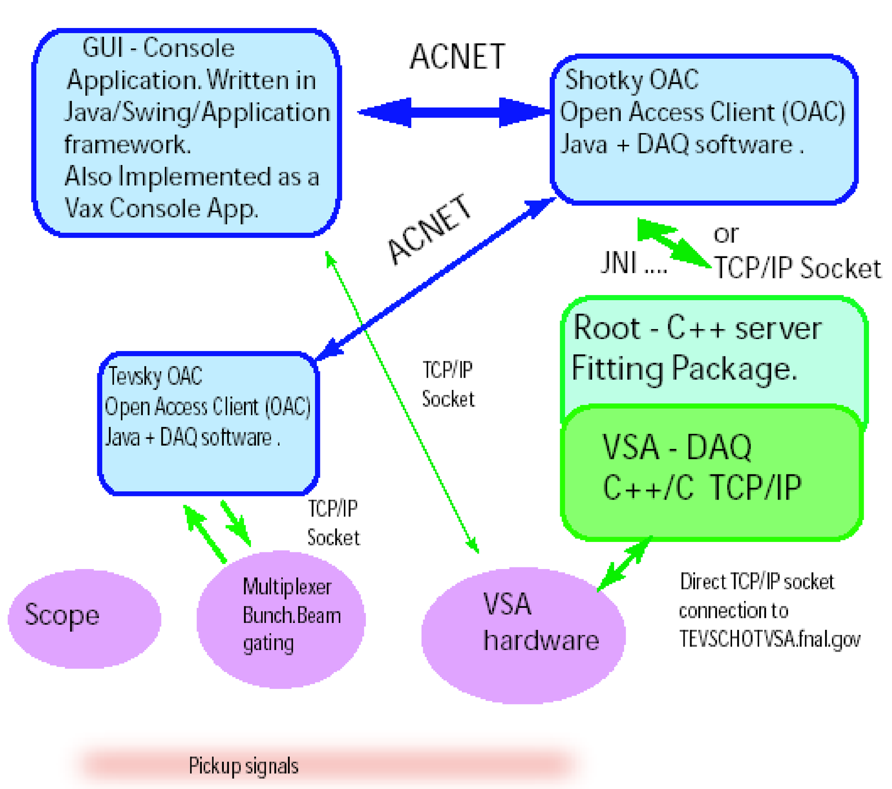
Hardware layout

Tevatron Schottky Signal Processing



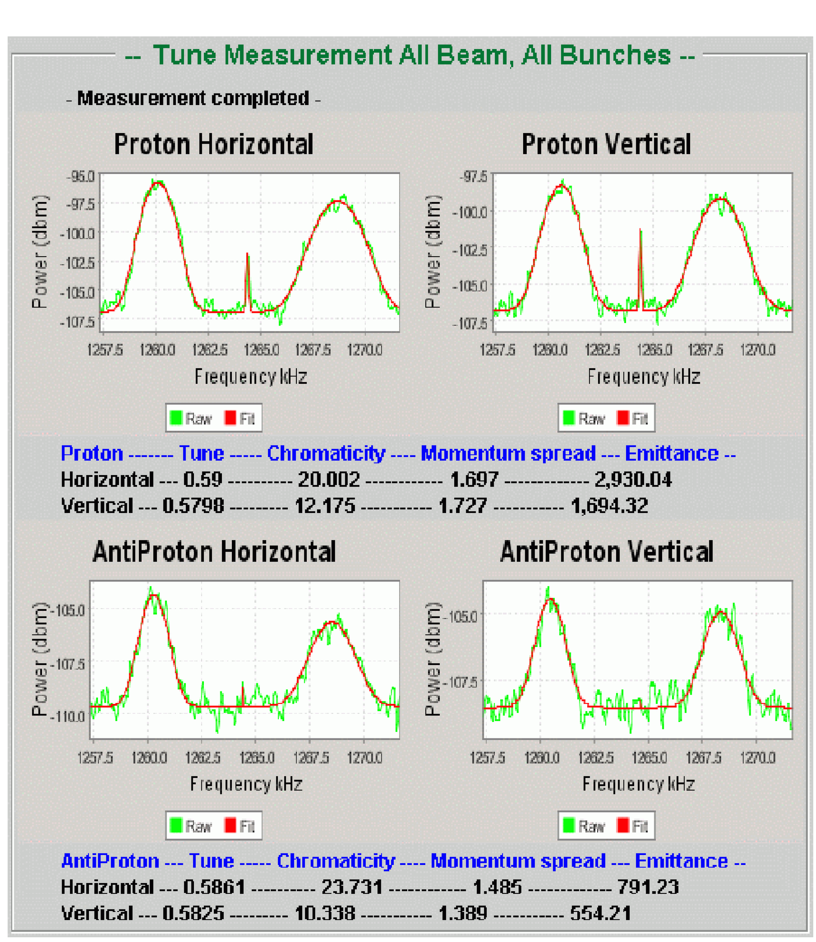
Schematic of the data acquisition system. The directivity of the pick-up combined with the time gating provides excellent separation between proton and pbar signals. Due to the ample signal, band pass filters are used to avoid saturation of the active components. The down-conversion is single side band (SSB) to preserve chromaticity information in the spectrum.

Software architechture



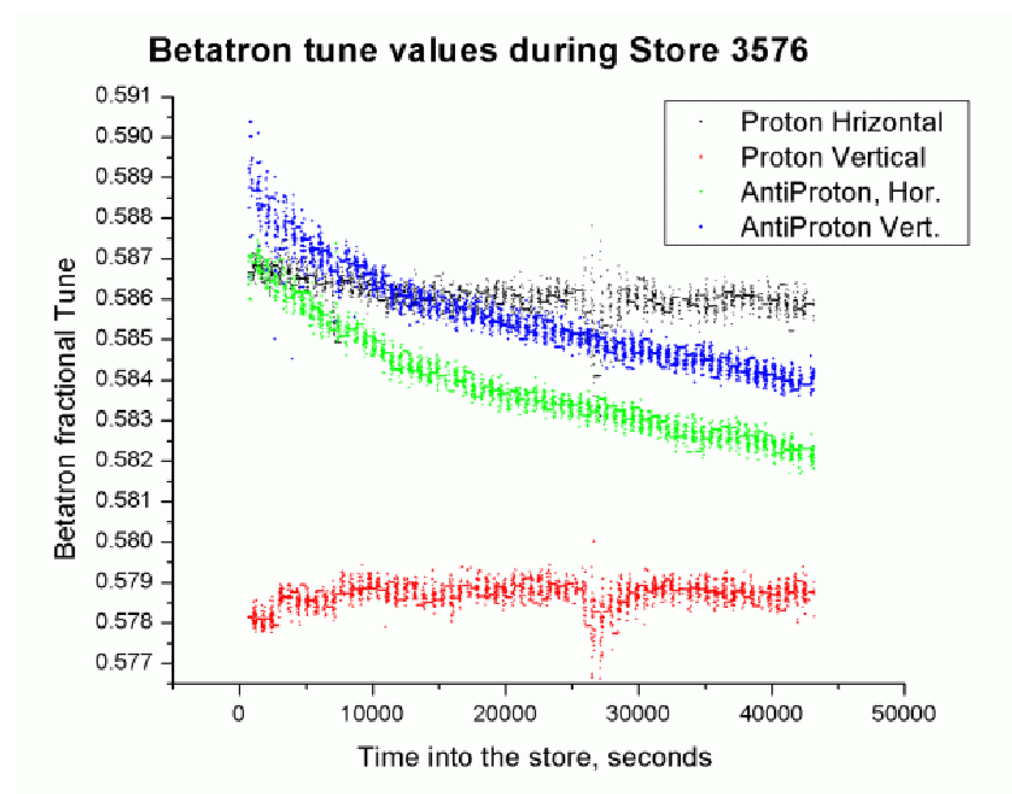
Schematic of the data acquisition system. An Open Access Client (OAC) written in Java handles the communication with the Vector Signal Analyser (VSA), and publishes results to the ACNET control system. A ROOT/C++ subprocess does the computing-intensive fitting. The gating is handled thru a second OAC.

User interface

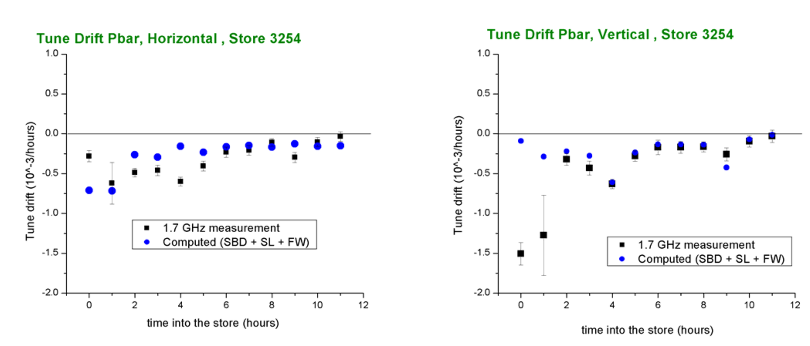


The Open Access Client can be controlled from a Java GUI, which also provides an online display of the raw frequency data and fits.

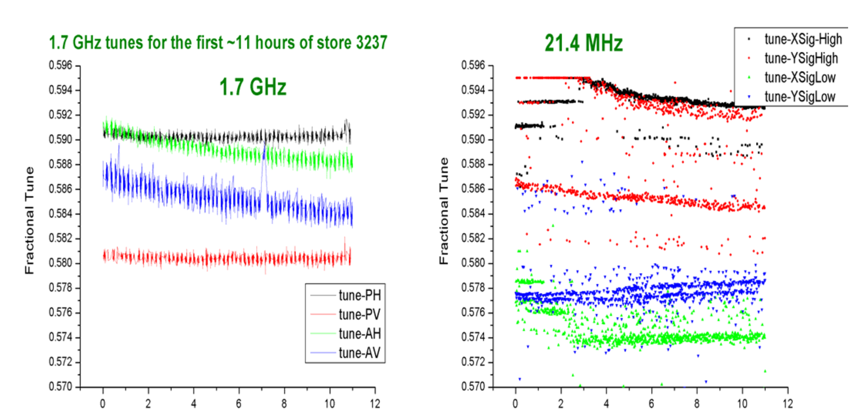
Tune during store



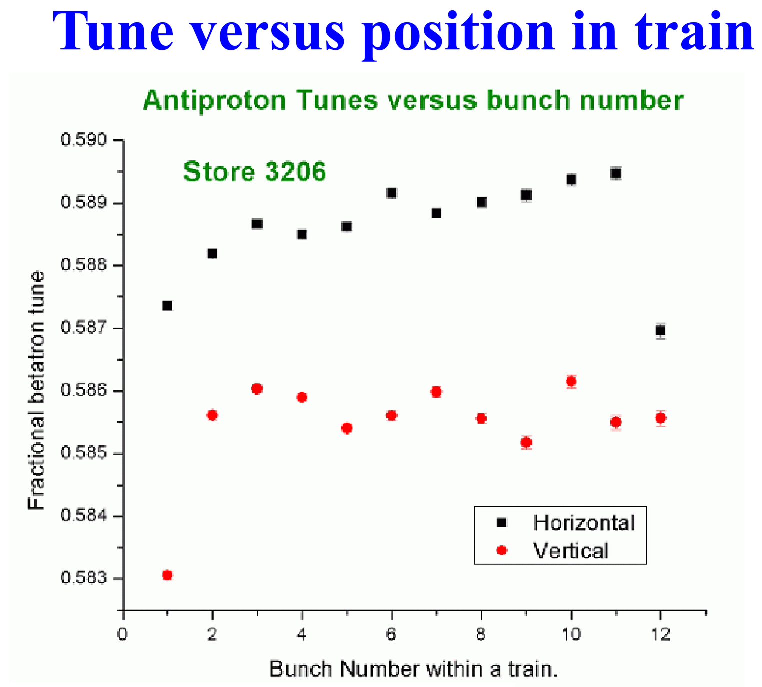
Tune evolution during a typical store. There distinct steps in the tune due to operators tuning to e.g. minimize losses. Also, the pbar tune is decreasing due to the change in beam beam force, as the proton intensity decreases and proton emittance increases. The observed decrease compares well with calculations using measured beam parameters (plot below).

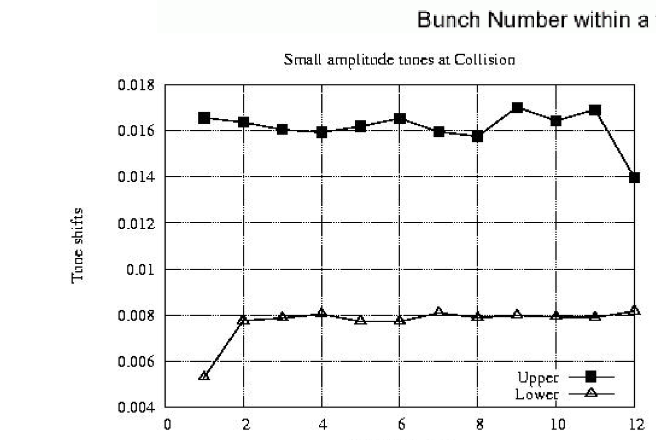


The typical r.m.s. fluctuation in the measured tune is of order **2 10^{-4}**, so changes of this order can be detected. However, there are systematic differences between the 1.7 GHz Schottky tune and the tune measured with the 21 MHz Schottky. In the low frequency Schottky, the betatron lines are much sharper, protons signals can not be sepaarated from pbars, and there sometimes an ambiguity in locating the central synchro-betatron line.



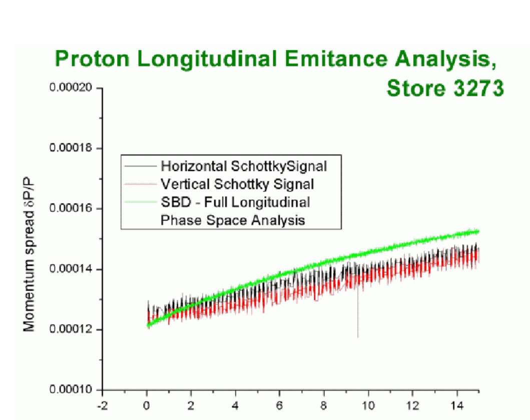
Tune versus position in train





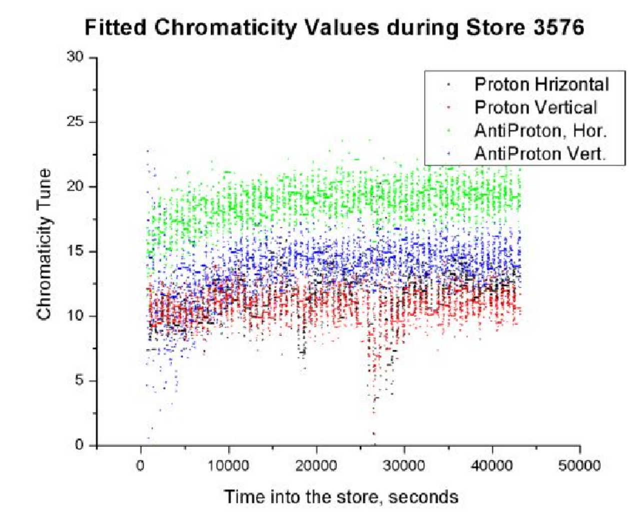
Measured tune versus position in the bunch train, averaged over the three bunch trains (by gating on three bunches at the time). The significantly lower horizontal tune for the last bunch and vertical tune for first bunch agree with theoretical predictions for the long-range beam beam tune shift (left).

Momentum spread measurement



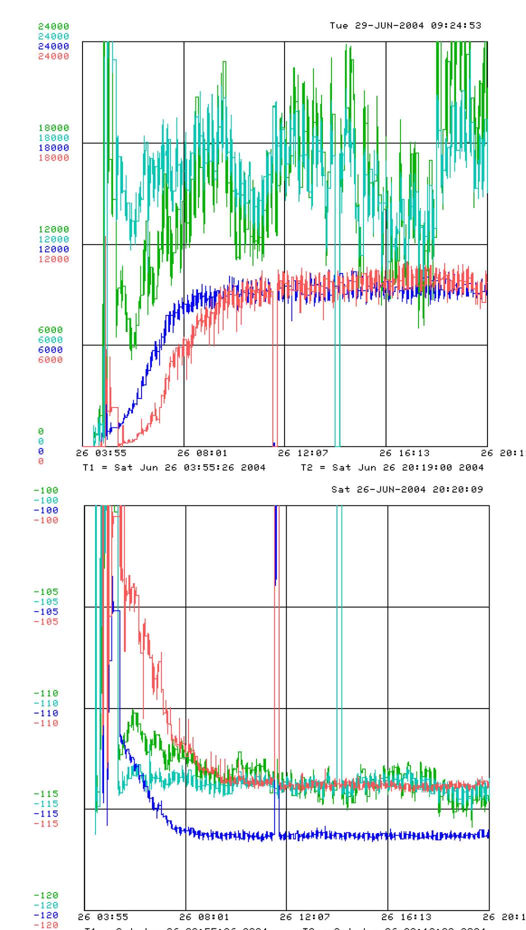
The momentum spread, calculated from the average width of upper and lower betatron lines, agrees to within 5% with the same quantity measured by the Sample Bunch Display, which calculates momentum spread from the longitudinal bunch distribution.

Chromaticity measurement



The measured chromaticity during a store is consistent with predictions from lattice studies. There is no other measurement of chromaticity during stores.

Emittance measurement and related problems

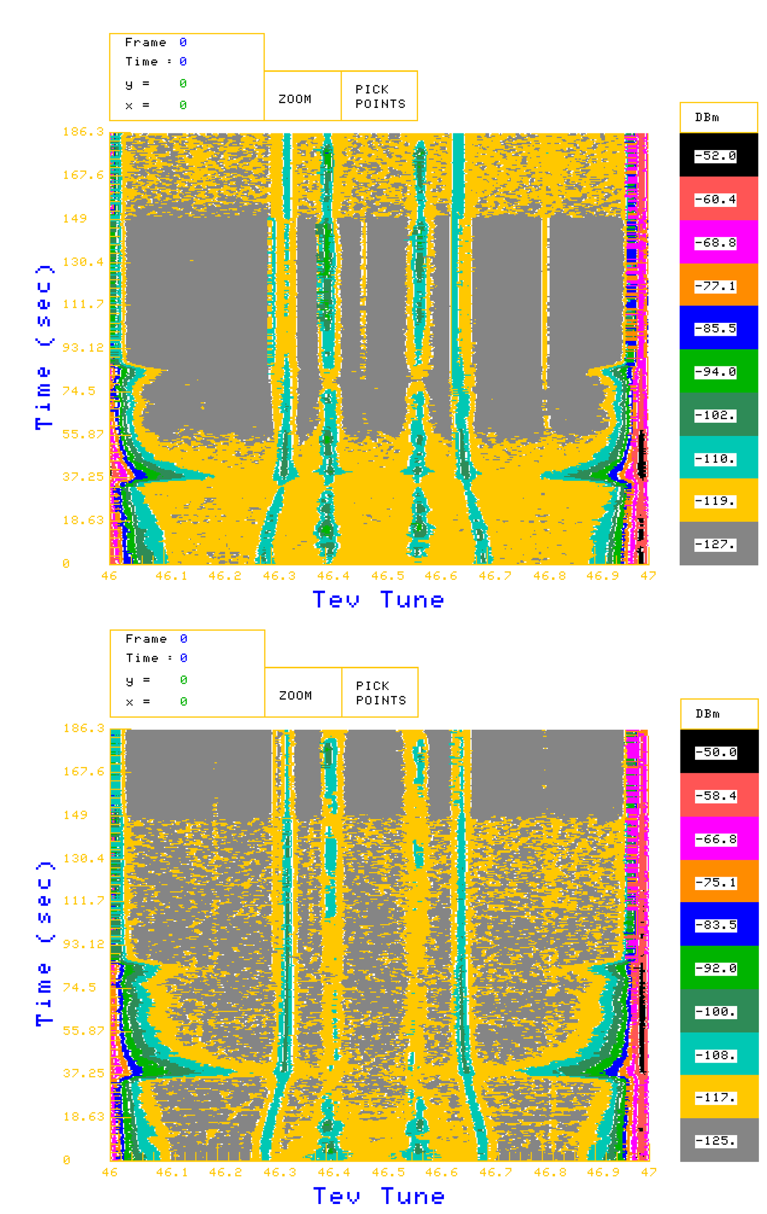


Proton Horizontal
Proton Vertical
Pbar Horizontal
Pbar Vertical

The measured betatron band power, which should be proportional to emittanec (top plot) shows strong fluctuations during a store for protons. For pbars, the signal is less fluctuating, but starts at zero and reaches its 'equilibrium' value only after a few hours.

In both cases, the change in measured emittance is strongly correlated with the observed baseline of the measured spectrum (bottom plot). It is not clear what causes the fluctuation of the proton base-line, or why it is correlated between horizontal and vertical plane (completely separate instruments). The long 'settling time' of the pbar baseline is also a puzzle.

Measurements during ramp



Horizontal (top) and vertical (bottom) Schottky spectrum during ramp and squeeze.

The outer lines that move during ramp have appeared recently and are due to parasitic sidebands in the RF signal used for down-conversion.

There is significant activity at the revolution line during the ramp, and the baseline not constant. Most of these features are reproducible from store to store.

Summary

- The 1.7 GHz Schottky has become routinely used in operation, mainly as a tune monitoring device.
- The momentums spread measured from the Schottky signal agrees well with other measurements
- The chromaticity measurement agrees with expectations from lattice studies.
- Emittance measurement has been hampered by fluctuations, which seem related to a shifting baseline.
- The spectra on the ramp has yet to be understood.