Schottkys

Experience from an ICE member…

An instrument from BI+ Fritz +Tevatron

A lot of material and help from Mathilde Favier

Reference : F. Casper CAS 2008

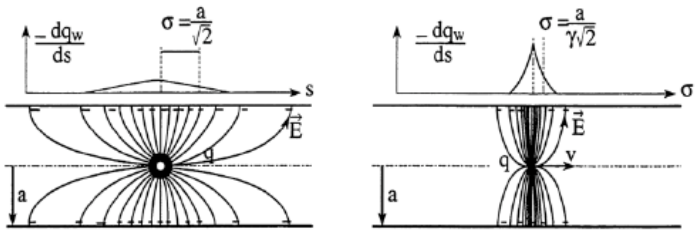


Fig. 4: Electromagnetic field of slow and fast beams (from Ref. [8])

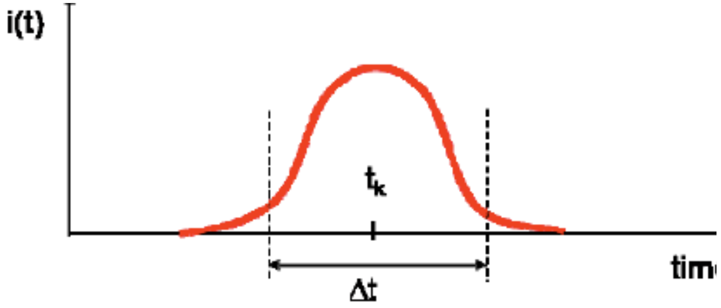
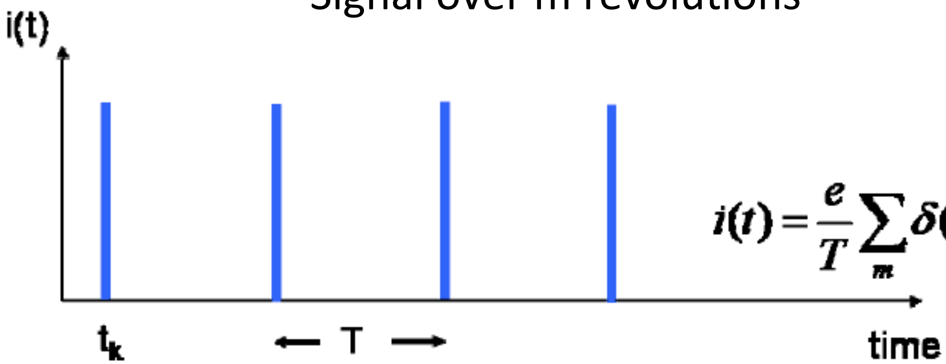


Fig 5: Pick-up signal of a single particle

Coasting beams

Single particle circulating with constant freq will induce a certain signal on a pick-up at its passage t_k

Signal over m revolutions



$$i(t) = \frac{e}{T}\sum_m \delta(t - t_k - mT)$$

Second particle at a slightly different frequency will give a signal at

Δf with Δf increasing at each harmonic of the revolution frequency f0

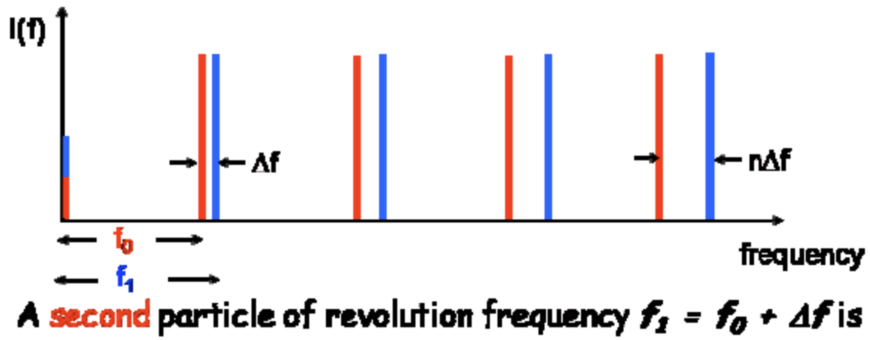


Fig. 6: A single particle and two particles with a slight frequency offset Δf

For a large number of particles the signal will give:

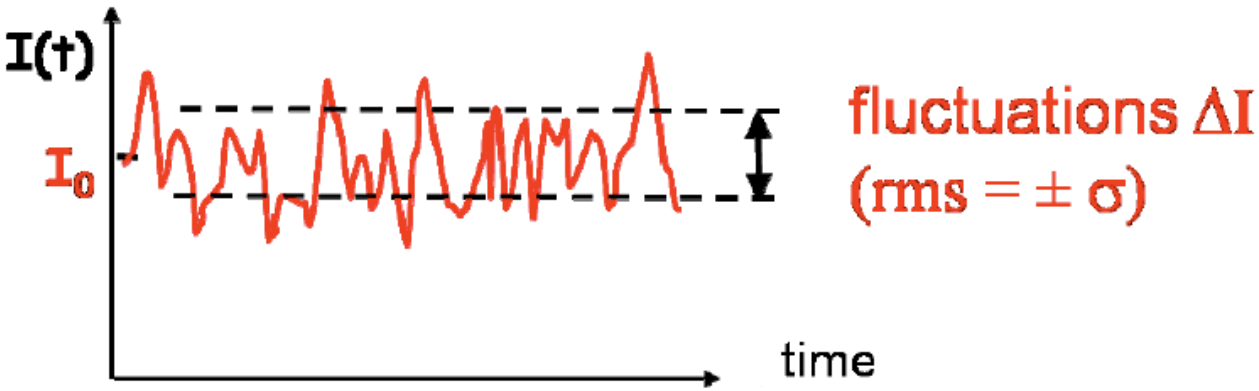


Fig. 7: Illustration of mean current I_0 and fluctuations ΔI

For Gaussian and non-Gaussian distributions

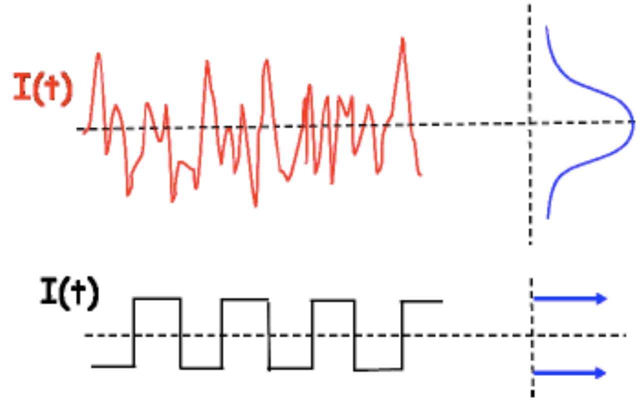


Fig. 9: Illustration of Gaussian amplitude density distribution and non-Gaussian case

For a large number of particles with non-Gaussian distribution the signal will be of the type:

Schottky bands

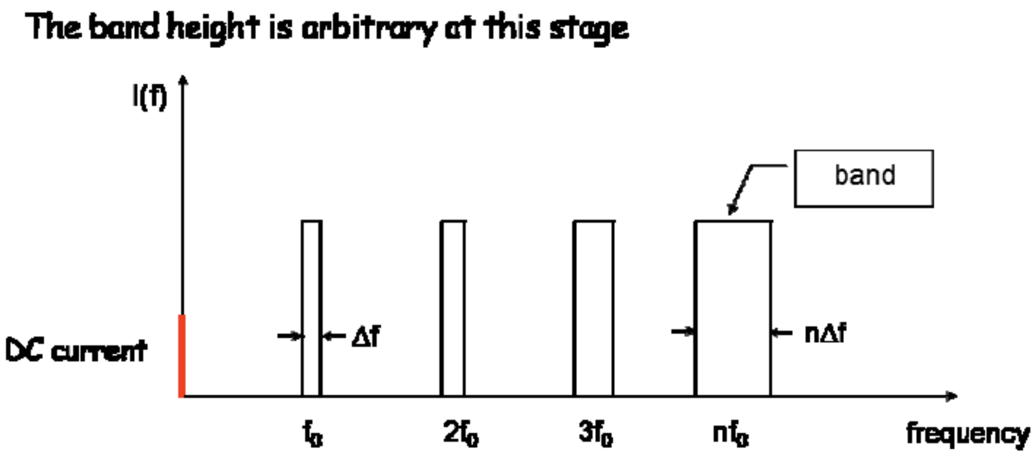


Fig. 8: Spectral density distribution for a large number of mono-energetic particles

One can determine:

- **Mean revolution freq**
- **Freq distribution of particles**
- **Momentum spread**
- **Number of Particles N**

Trasverse plane signal

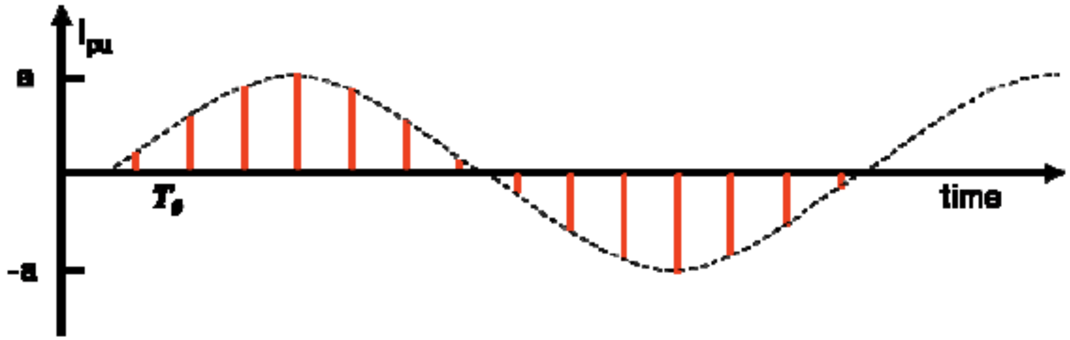


Fig. 11: A single particle with betatron oscillation of amplitude a as seen by a transverse pick-up

The betatron motion results in the particle's wobbling around some reference orbit and thus the transverse position changes every turn. This transverse signal is not seen in the sum output of any pick-up structure (e.g. a pair of strip-lines) but is observed in the Delta, or difference, output. The output signal of such a pick-up has two contributions, one related to the longitudinal phase space and another related to the betatron oscillations.

$$i_{pu}(t) = \frac{e}{T}\sum_{n}^{\infty}\delta(t - nT + \varphi_k)\times a_k\cos(q\omega t + \phi_k) \quad . \tag{16}$$

The first term under the sum sign is just the same as already seen in the longitudinal phase space discussion. In addition, however, there is an amplitude modulation of this signal due to the betatron motion. This has a frequency of $q\omega/(2\pi)$, with q being the non-integer part of the betatron frequency and an amplitude a_k representing the oscillation amplitude. The difference response of the pick-up, Δi_{pu}, can therefore be written as

$$\Delta i_{pu} = S_\Delta \times a_k(t)\times i_k(t) = S_\Delta \times a_k\cos(q\omega_0 t + \phi_k)\cdot\left[i_0 + 2i_0\sum_{n=1}^{\infty}\cos(n\omega_0 t + n\varphi_k)\right] \tag{17}$$

7 Bunched beams

So far the discussion has been limited to the Schottky noise properties of coasting, i.e., unbunched beams. For bunched beams it is necessary to convolute the transverse spectra obtained in the case of an unbunched beam with the synchrotron spectrum related to the motion of particles in the RF bucket.

It can be seen from Eq. (19) that the total power in each band is constant and proportional to the term a^2_{rms} , which for an ensemble of particles is nothing more than the rms transverse beam size and is proportional to the transverse emittance. The width of the sidebands is given by

$$\Delta f_{\pm} = (n \pm q) \times df \pm f_0 dq \tag{20}$$

where q stand for the fractional tune and $dq\ /Q$ is the tune spread.

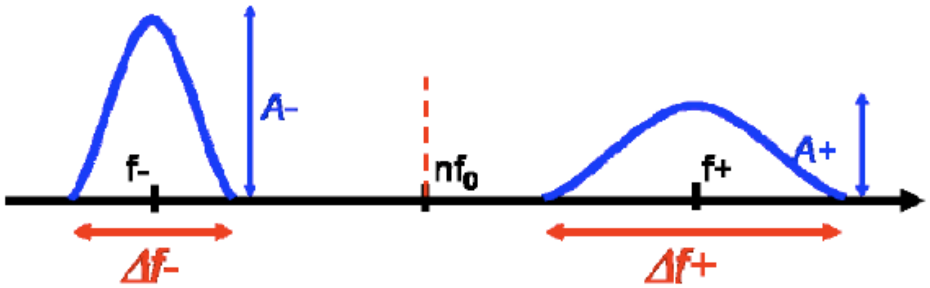


Fig. 13: Example of a Schottky signal with non-zero chromaticity

What can be measured?

$$q = \frac{1}{2} + \frac{f_2 - f_1}{2 f_{rev}}$$

$$\frac{\Delta p}{p} = \frac{1}{\eta} \cdot \frac{W_1 + W_2}{2 n f_0}$$

$$\xi \propto \frac{W_1 - W_2}{W_1 + W_2}$$

$$\varepsilon \propto A_1 W_1 + A_2 W_2$$

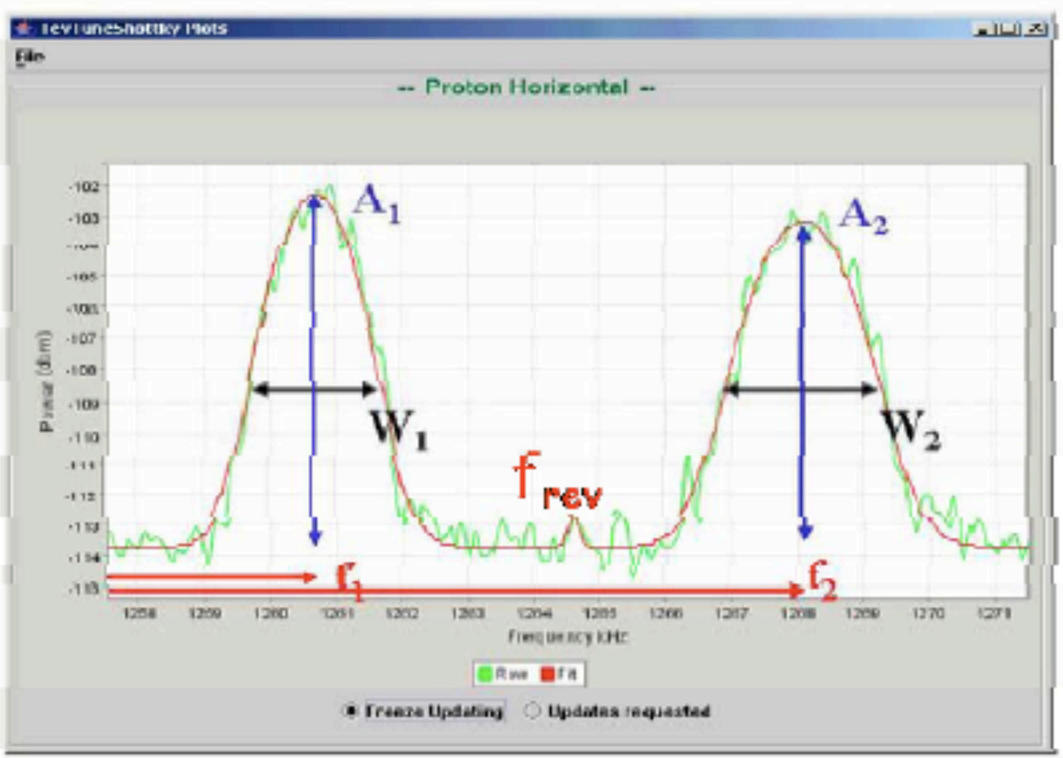
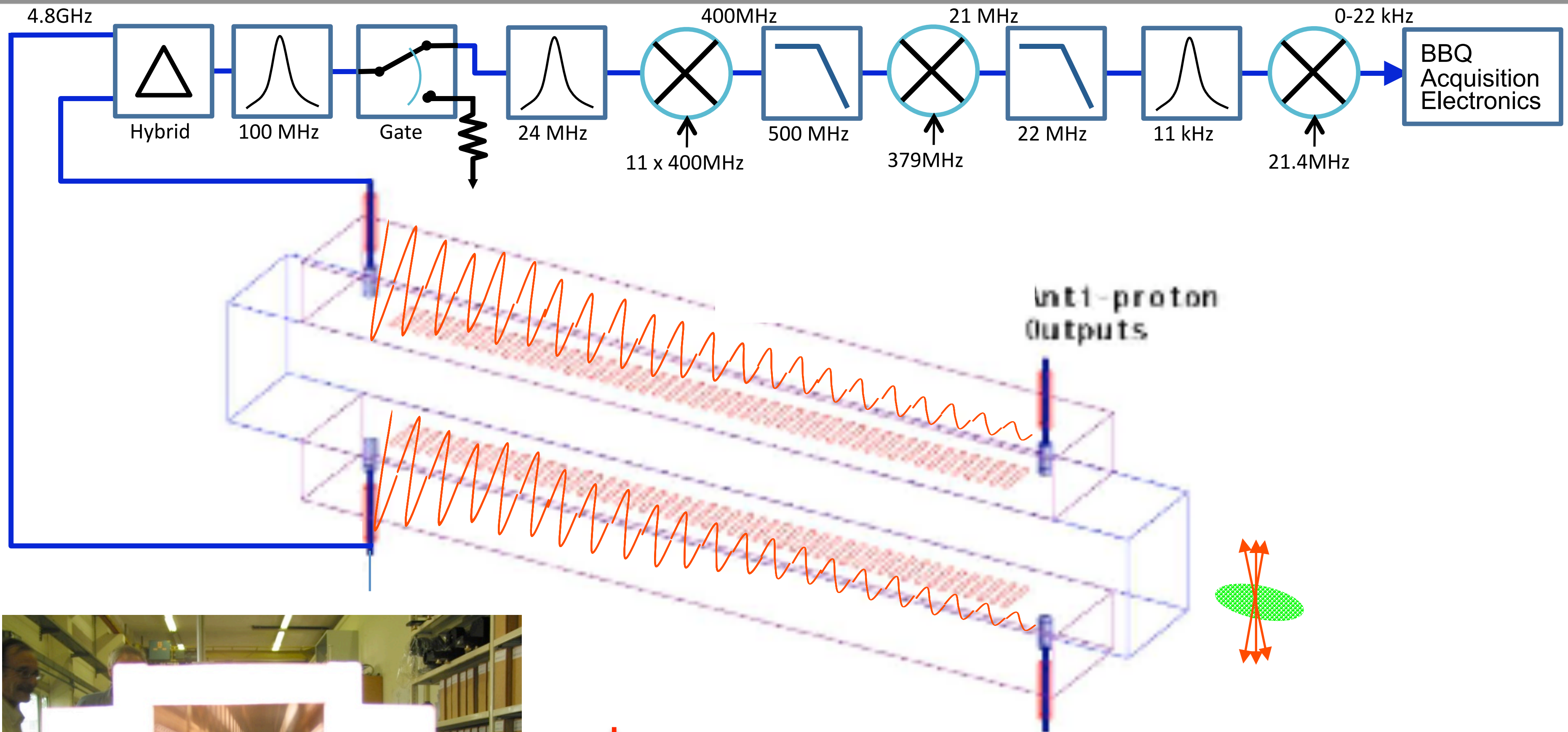
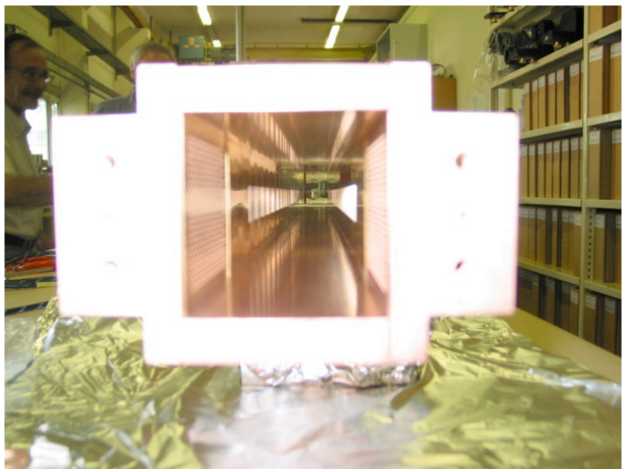


Fig. 23: Measurement example in transverse phase space from the Tevatron [18]

Powerful tool parassitic DOES NOT PERTURB THE BEAMS!!!

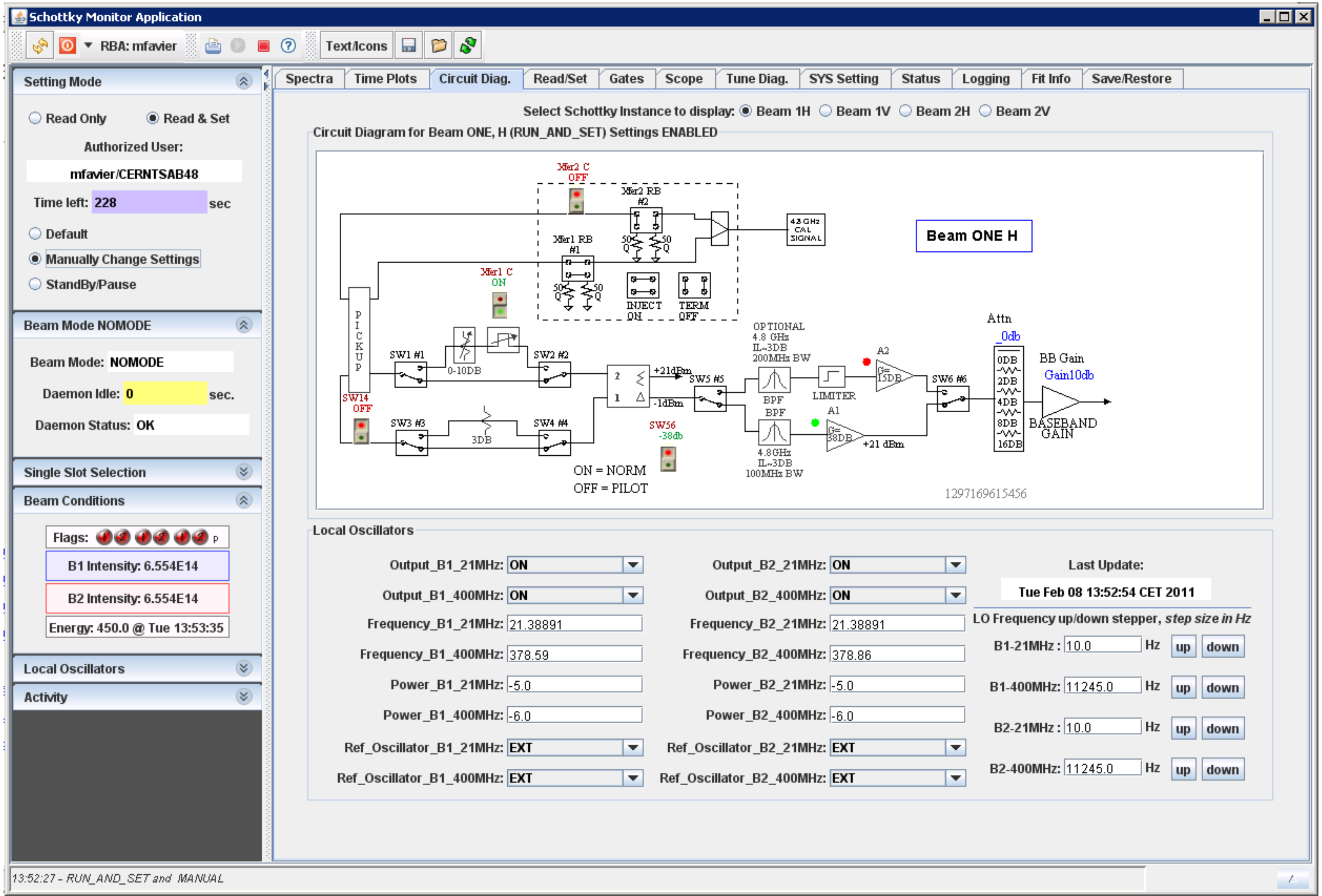
Schottky Monitoring LHC



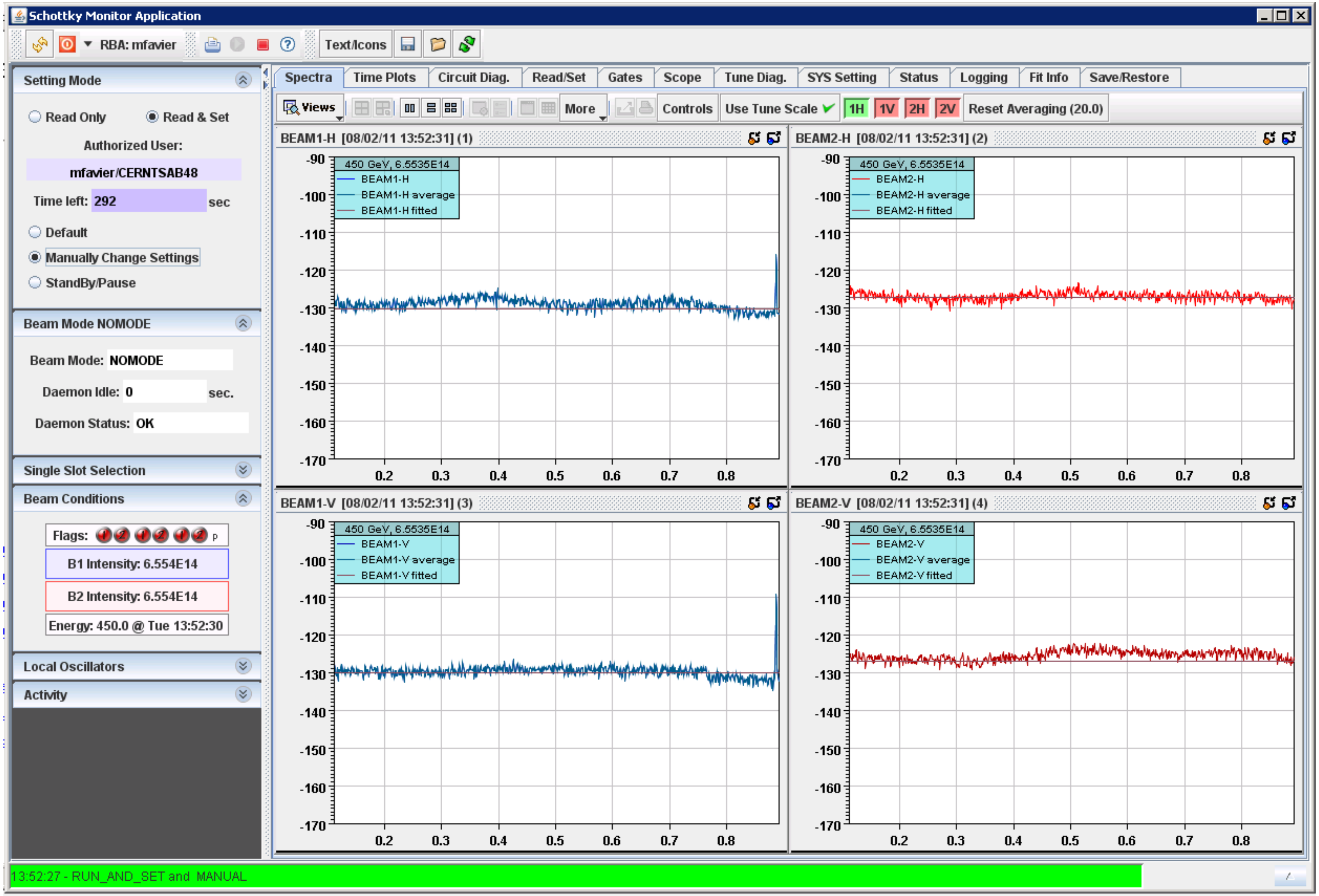


4.8 GHz Slotted Waveguide Structure
60 x 60 mm aperture x 1.5 meters long
Gated, triple down-mixing scheme to baseband
Successive filtering from bandwidth of 100MHz to 11kHz
Capable of Bunch by Bunch Measurement

The data flow

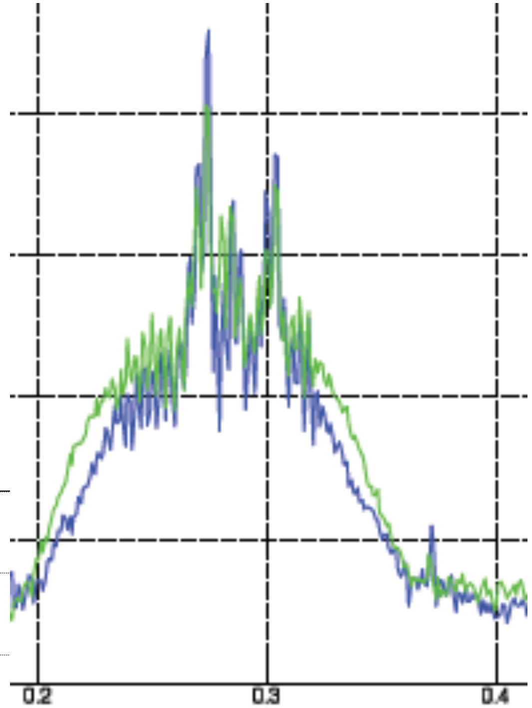


Bunch spectra

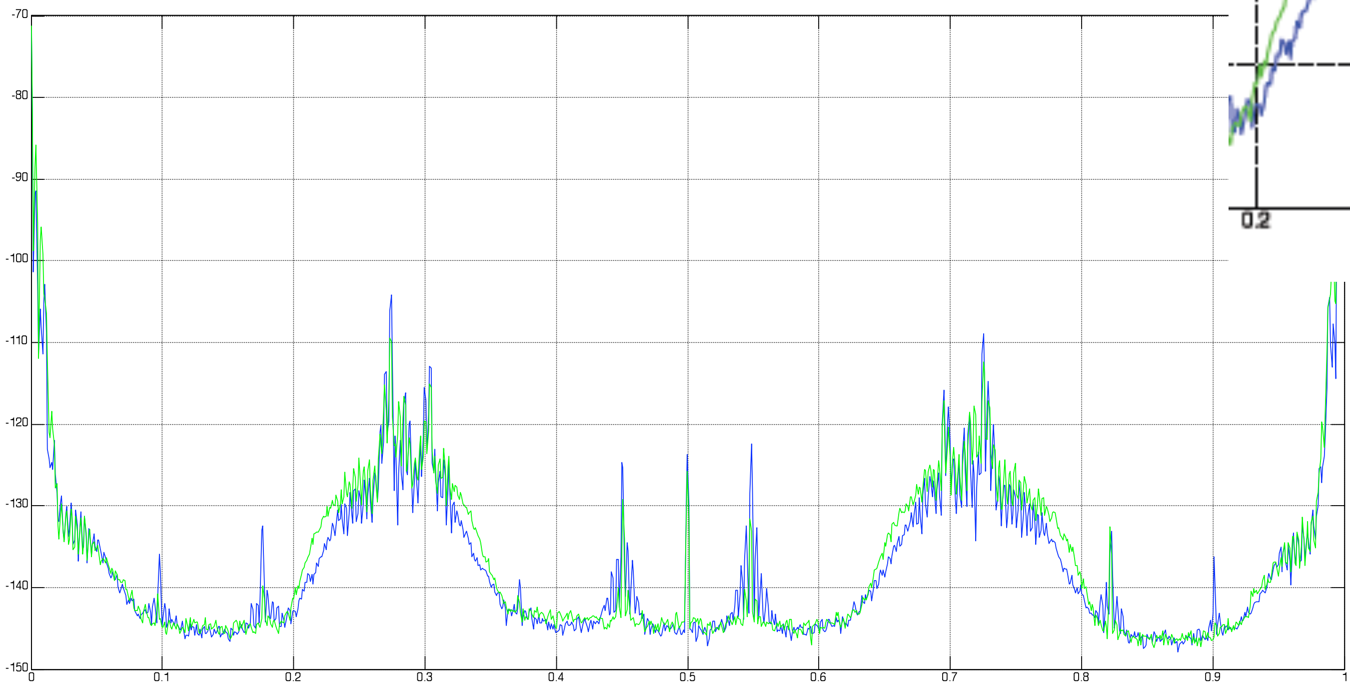


90 sec integration time per bunch needed: takes some time to go through a train

Tunes of two bunches during e-cloud MDs last November 200

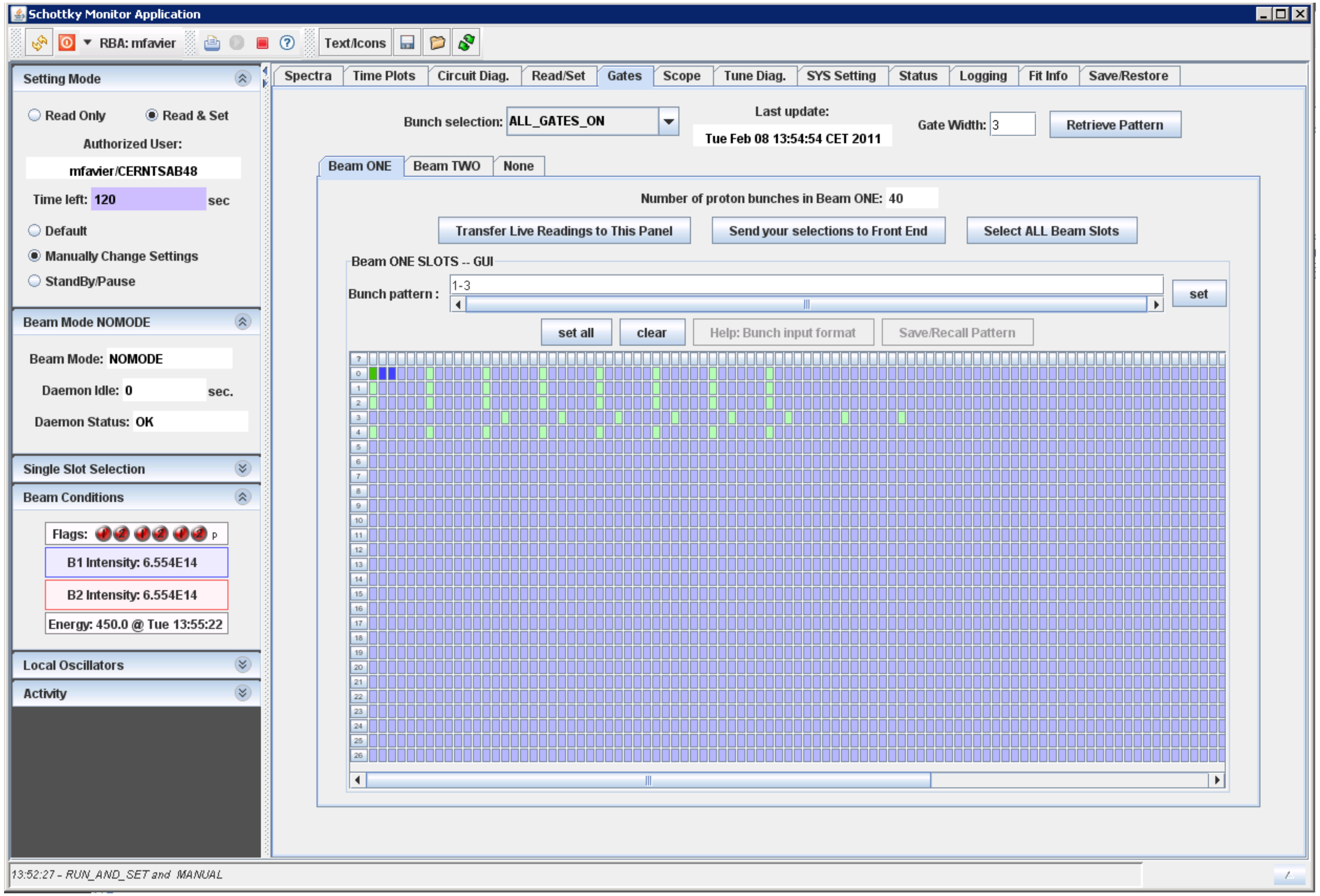


GUI working for IONS after many problems with application!
Some measurements with protons but no "instability" observed



Mathilde Favier

Bunch selection, FBCT defines filled slots then clicking technique….



Bunch selection with play-list from E. Bravin : external application still to be implemented in GUI but working well also like this

90 sec integration time per bunch needed: takes some time to go through a train

Which other data can be interesting?

Non-integer tunes
Emittances
Chromaticity
Momentum spread

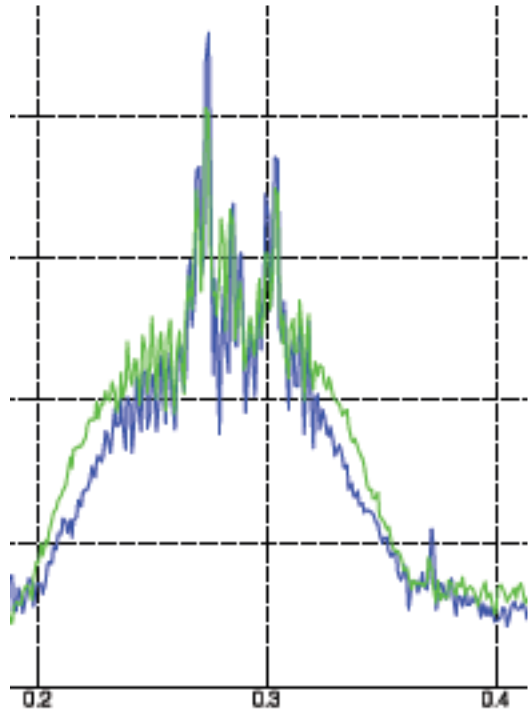
To be "checked/compared" with other instruments to define limits

An extra application: ROSALI

JJ Gras, using Mathematica Library

It records the data one need (the same that the one records in Timber) then some analysis can be done.

Mathilde is providing a script to plot the tune spectra for multiple bunches on site for straight comparison of bch to bch .



Schottky Monitoring

- Status in 2010
  - Schottky made operational towards the end of the year
  - GUI & calculation daemon provided by FNAL
  - Now logging tune, chroma, emittance & dp/p
    - Consistency of emittance & dp/p still to be verified
  - Proton signals not useable during ramp
    - Longitudinal blow-up wreaks havoc!
  - Ion signals text book beautiful!

- Plans for 2011
  - Incorporate automatic bunch cycling on selected bunches in GUI (currently via expert program)