Experience with Longitudinal and Transverse Instability Dampers in Tevatron

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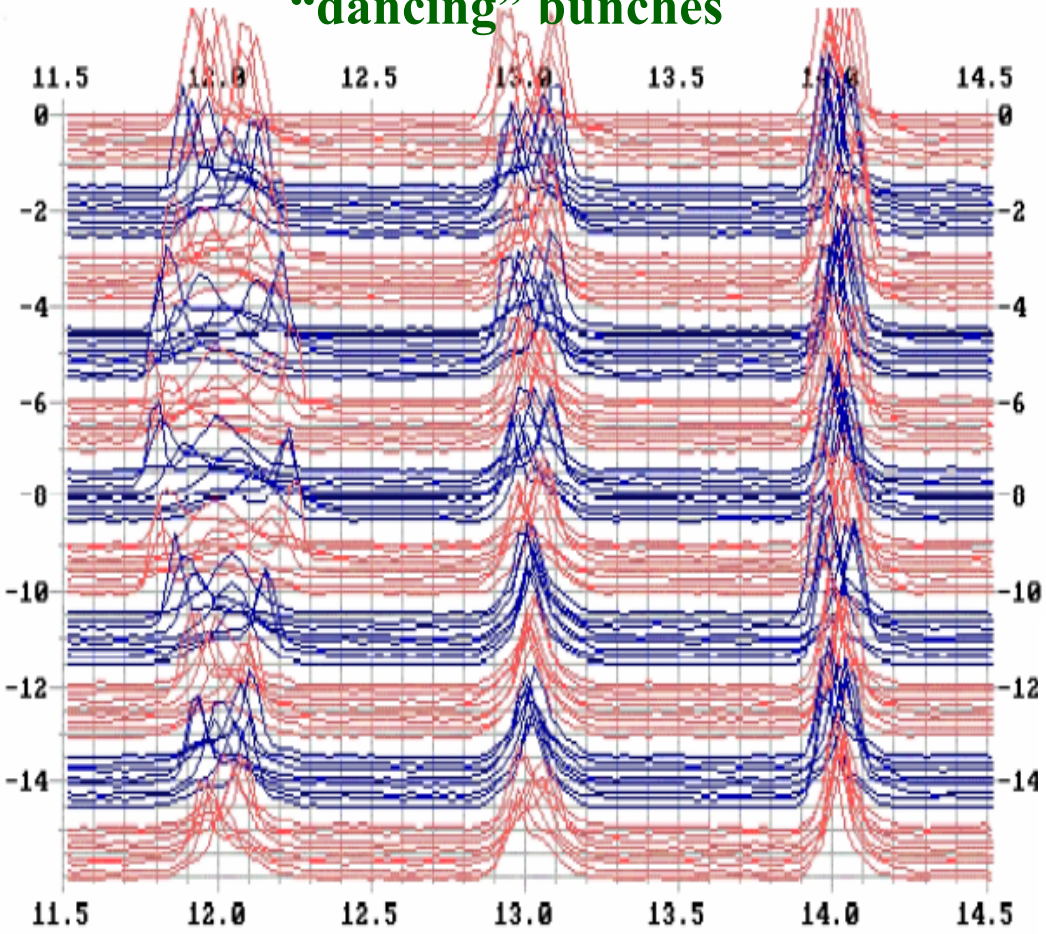
Short Longitudinal-Damper Story

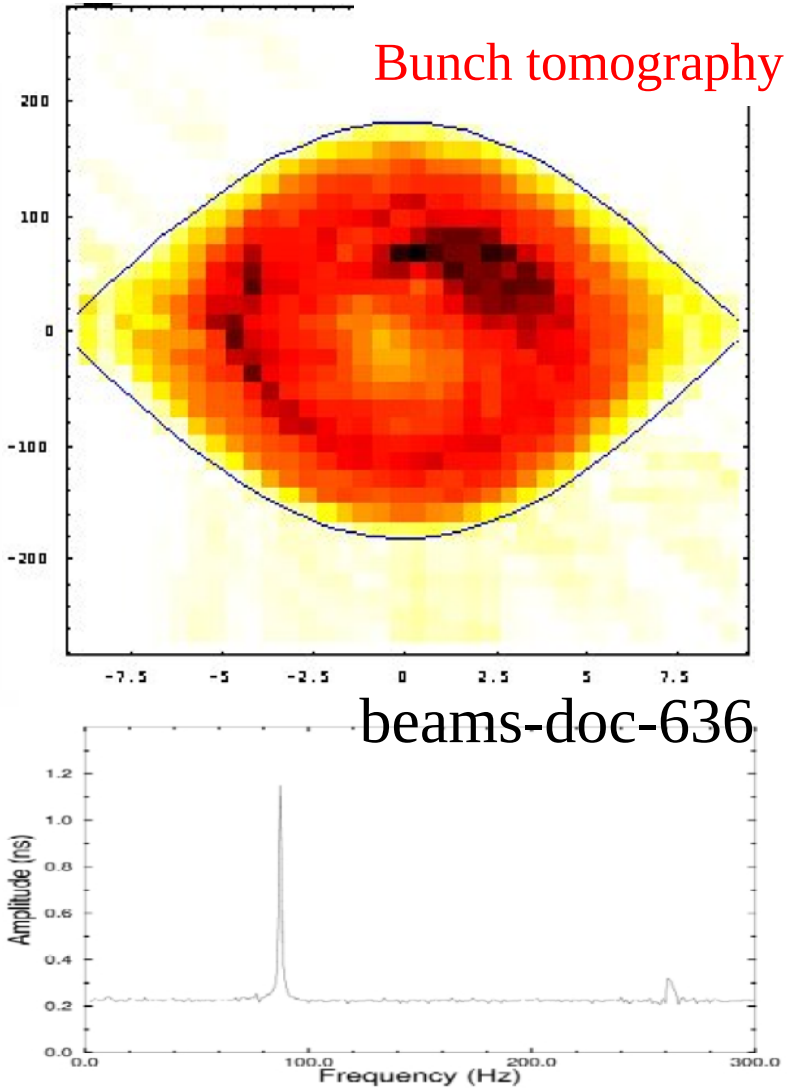
- **Had dancing bunches @150 GeV and long.instability at 980 GeV**
- **Long. bunch-by-bunch damper built and commissioned (2002)**
  - C.Y.Tan and J.Steimel, 150 & 980 GeV
  - acts thru main RF ! (anti-Q filter)
- **In operation since then**
  - rare occurances of instability
  - don't understand why
  - lower the gain with N/sigma_s
- **Est. dEmm_l/dt < 0.013 eVs/hr**

Dancing Bunches at 150 and 980 GeV

No instability, continuously "dancing" bunches



Bunch tomography

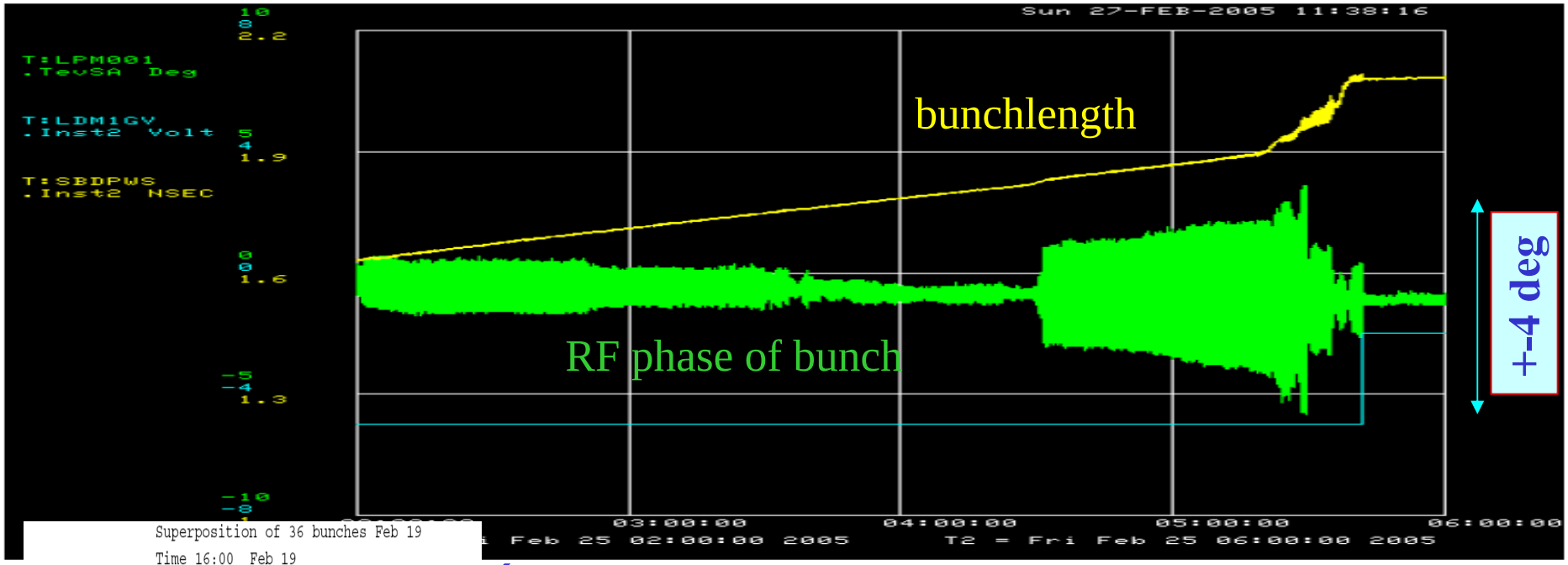


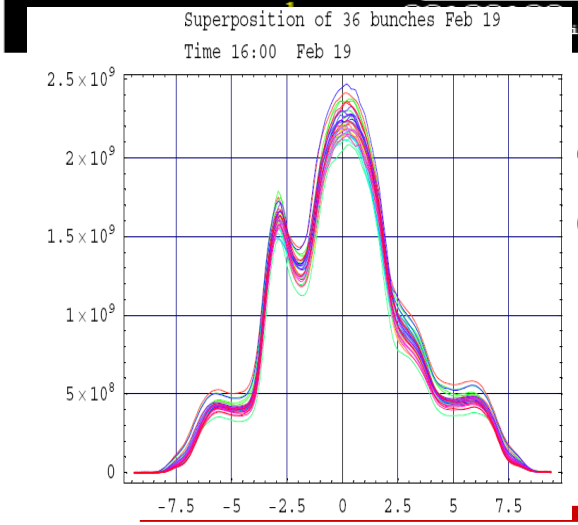
beams-doc-636

Figure 2: FFT of an oscillating proton bunch centroid.

N~30e9/bunch dt=19ns

Longitudinal Instability in Store





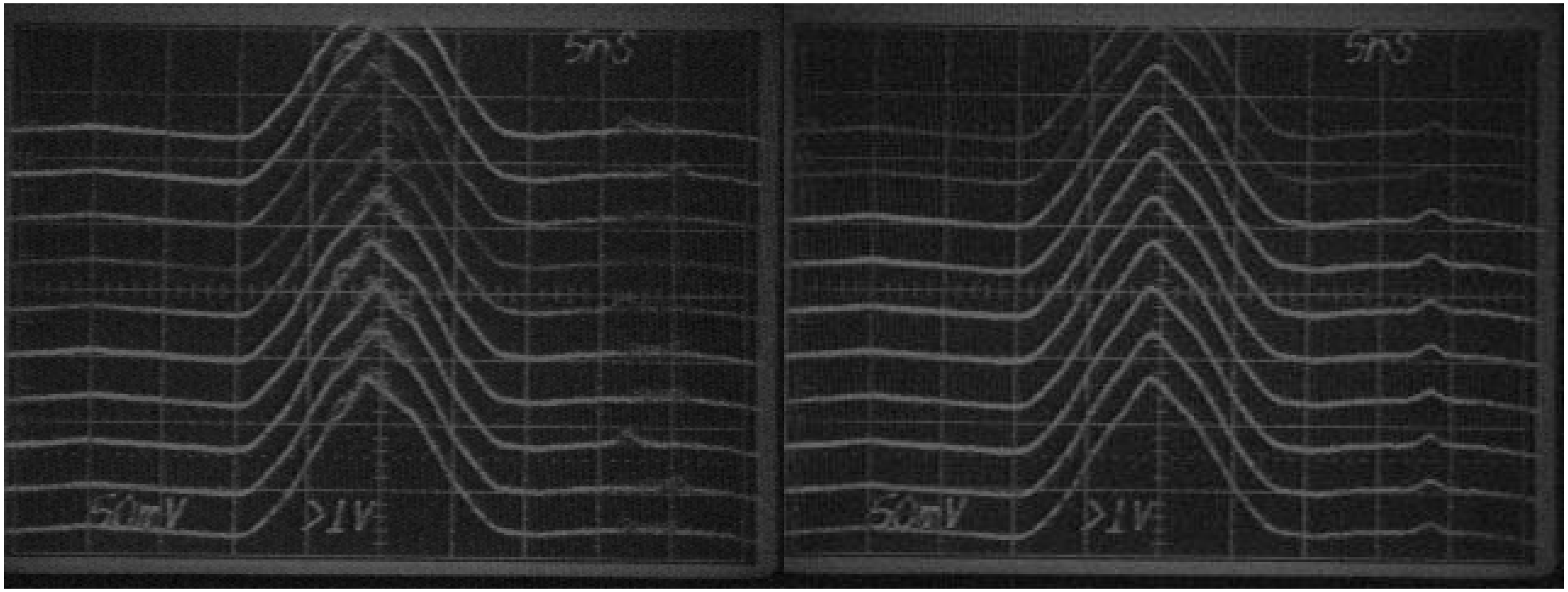
←**Weird bunch shapes during instability burst (snapshop taken by SBD)**

No instability, continuously "dancing" bunches (RWM) →

Fast (200Hz) longitudinal phase monitor is under development

Oscillations Suppressed

July 27, 2002



N=2.6e11 damper OFF …and… damper ON

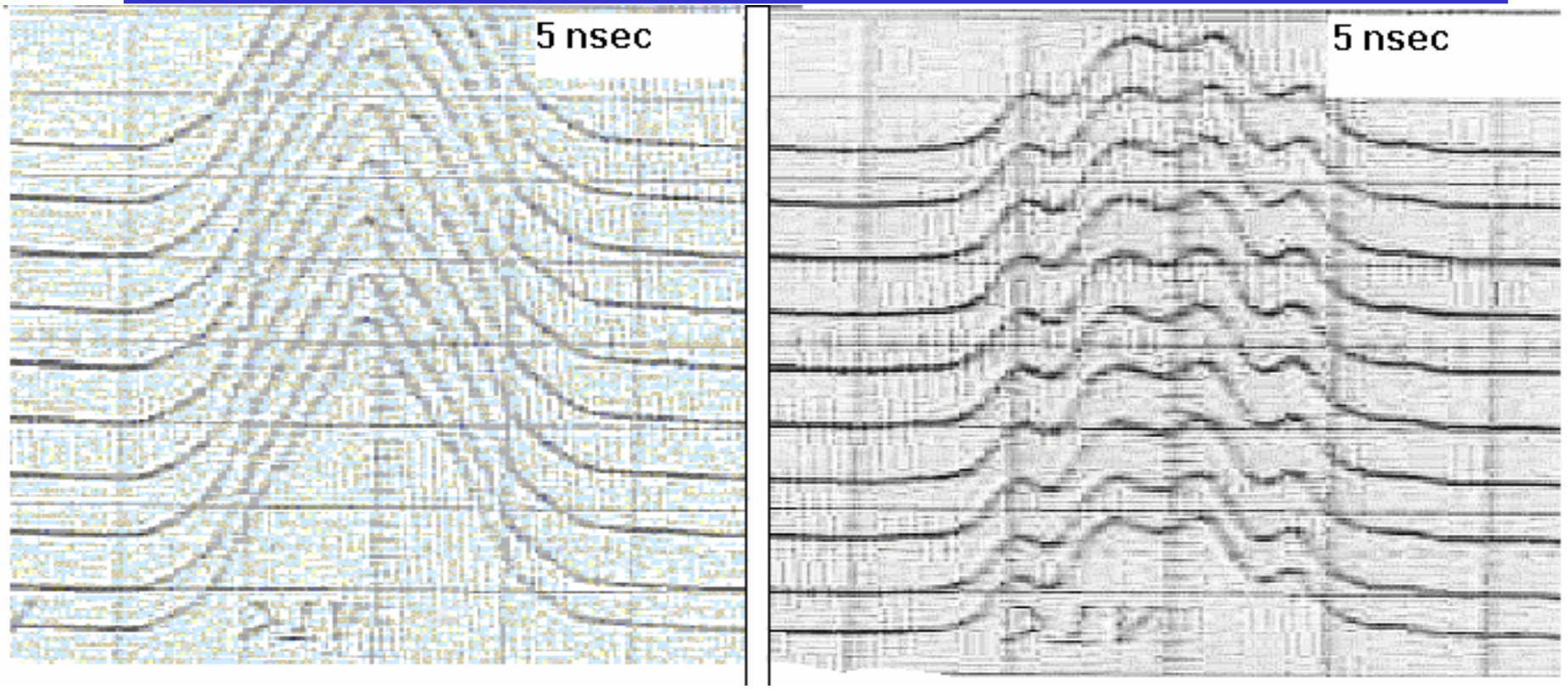
Transverse-Damper Story (I)

- **Single and coupled bunch instabilities at 150 and 980 GeV and during collissions dQ_bb ~ 0.01**

  @ N/bunch>200e9, N_b=1...36

- **Chromaticity helps, but lifetime suffers**
- **Transv. bunch-by-bunch damper built and commissioned (2002-3)**
  - C.Y.Tan and J.Steimel, 150 GeV ONLY!
  - see FNAL-TM-2204 (2003)

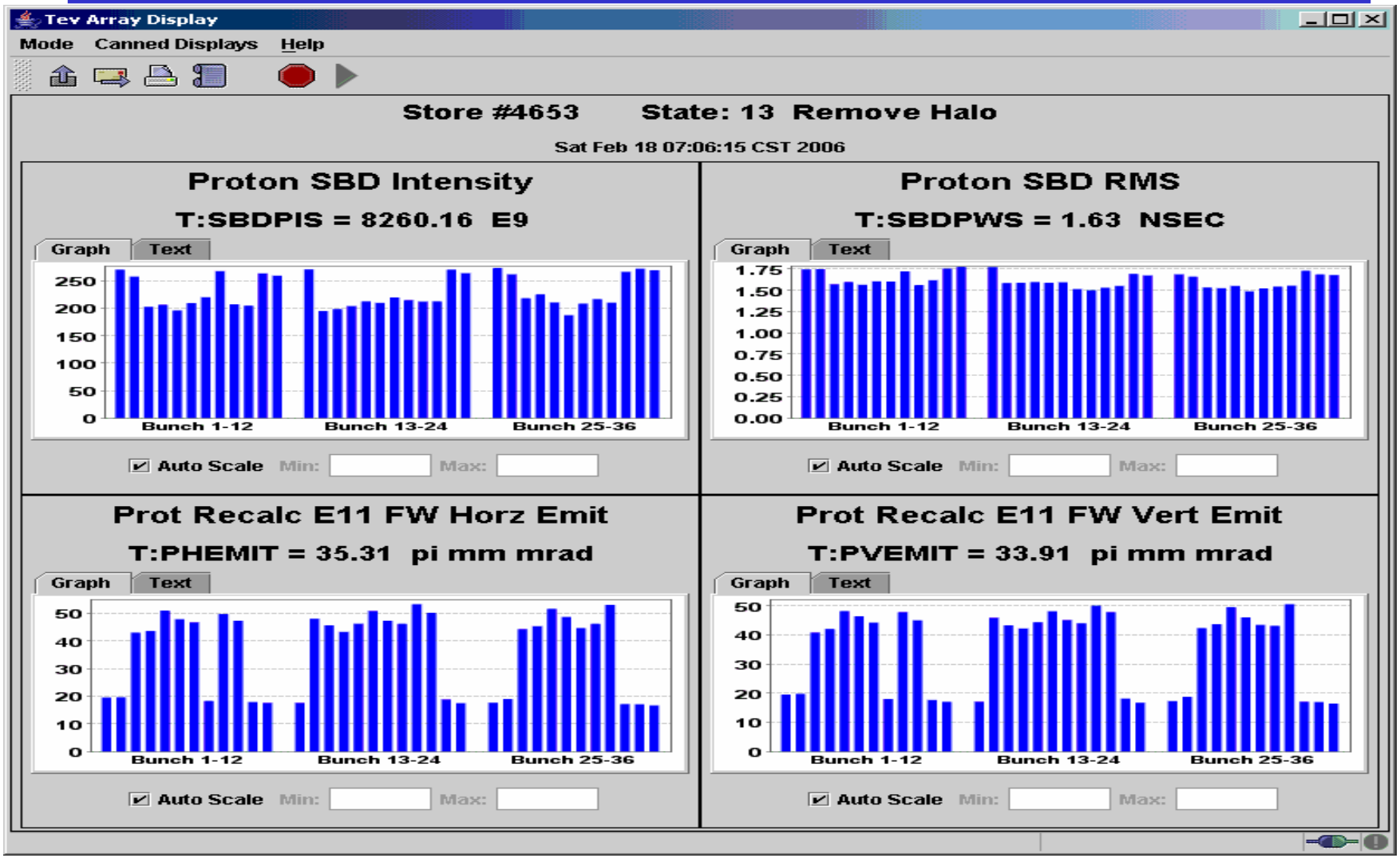
Weak Head Tail-Instability



***l*=2** head-tail instability: N=2.6→1.3e11

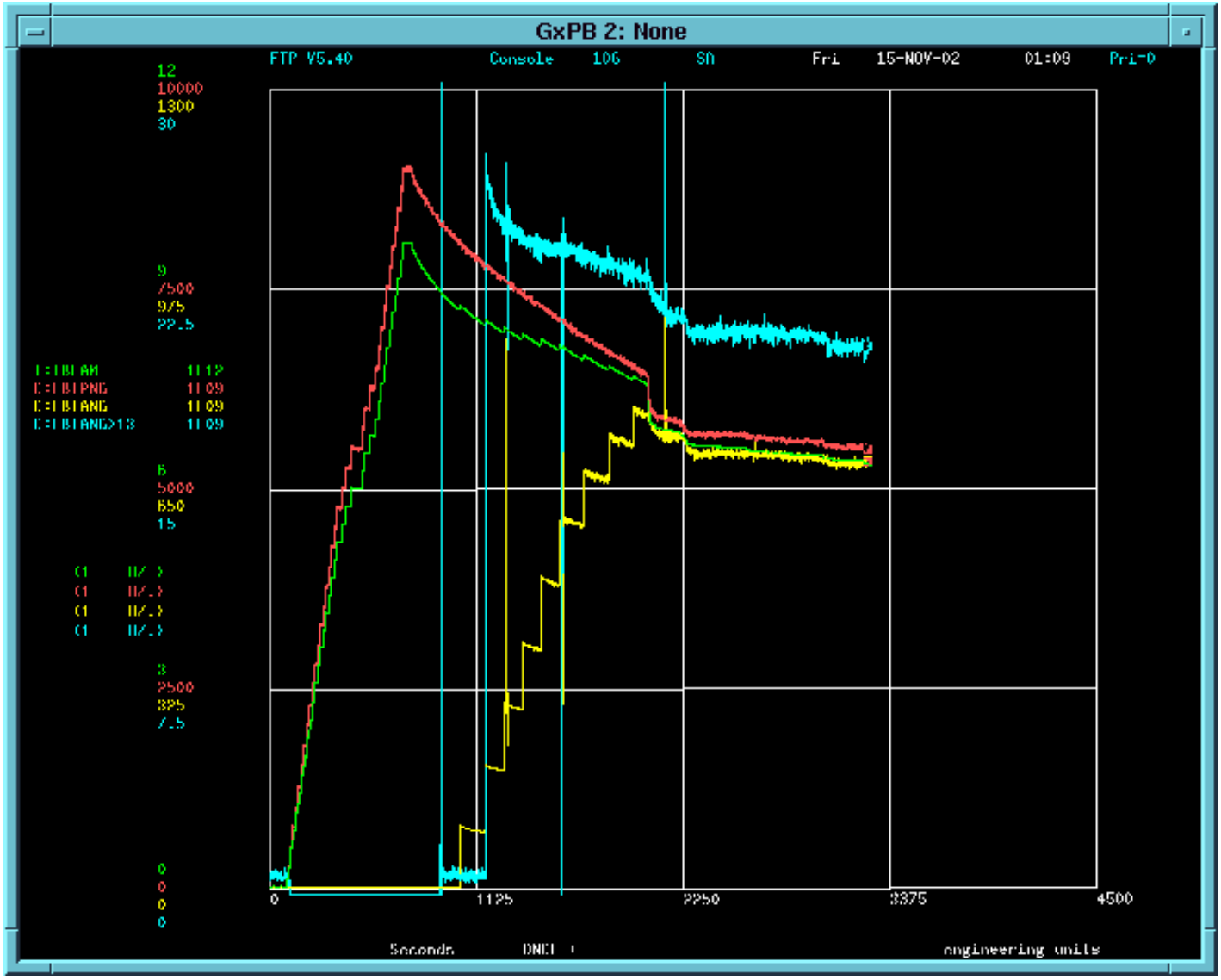
Growth rate ~300-1000 turns at Q' ~ (6…8)

Transverse Instability at 150 GeV



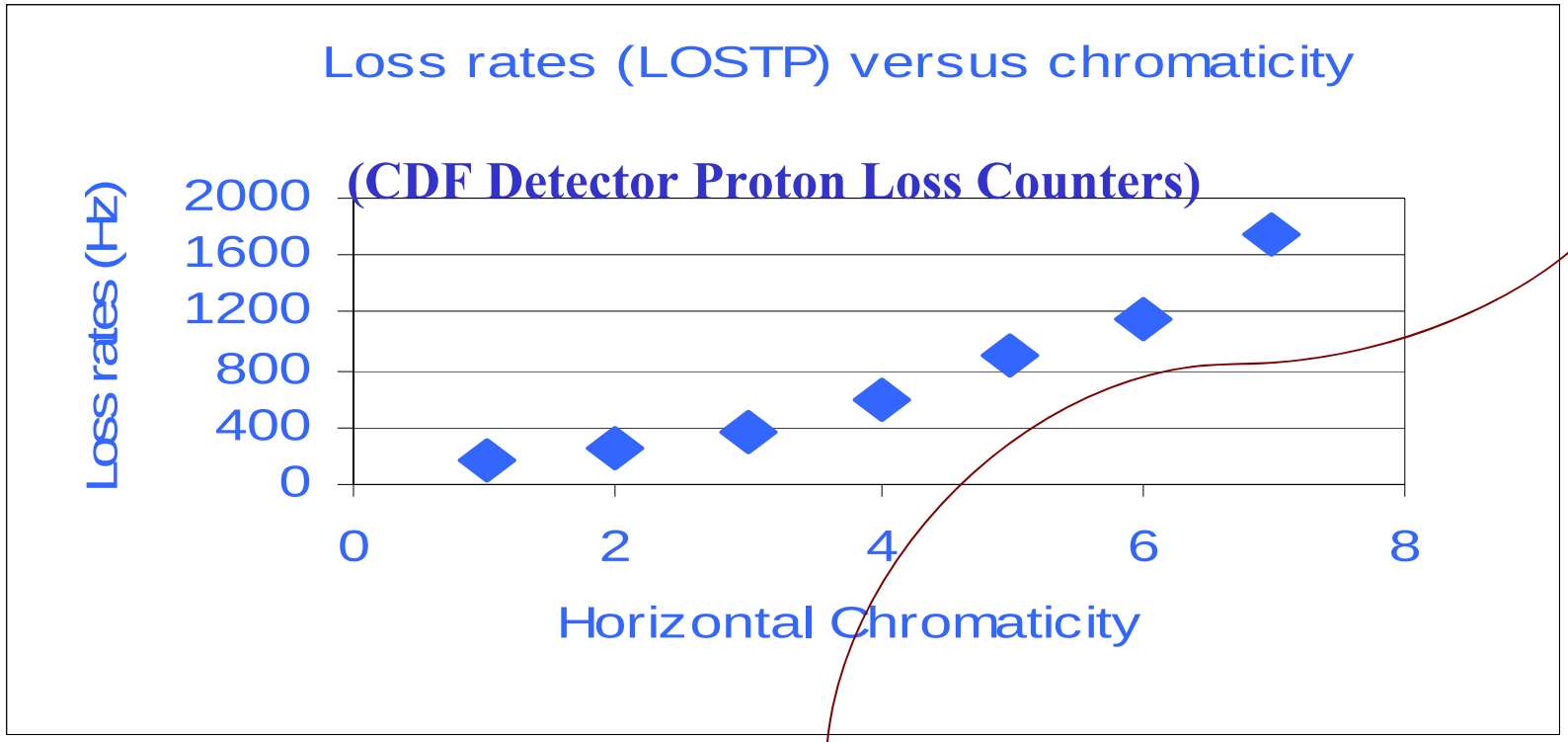
instability occurrence at 150 GeV

Beam Lifetime Depends on Chromaticity



Nov'02

Beam Lifetime Depends on Chromaticity



$$\frac{\Delta N_{a,p}}{N_{a,p}} = 1 - \frac{N(t)}{N(t=0)} \propto \sqrt{t} \cdot \varepsilon_{a,p}^{2} N_{p,a} Q'^{2}{}_{a,p} \cdot F(\varepsilon_L, Q_{x,y}, S_{a-p})$$

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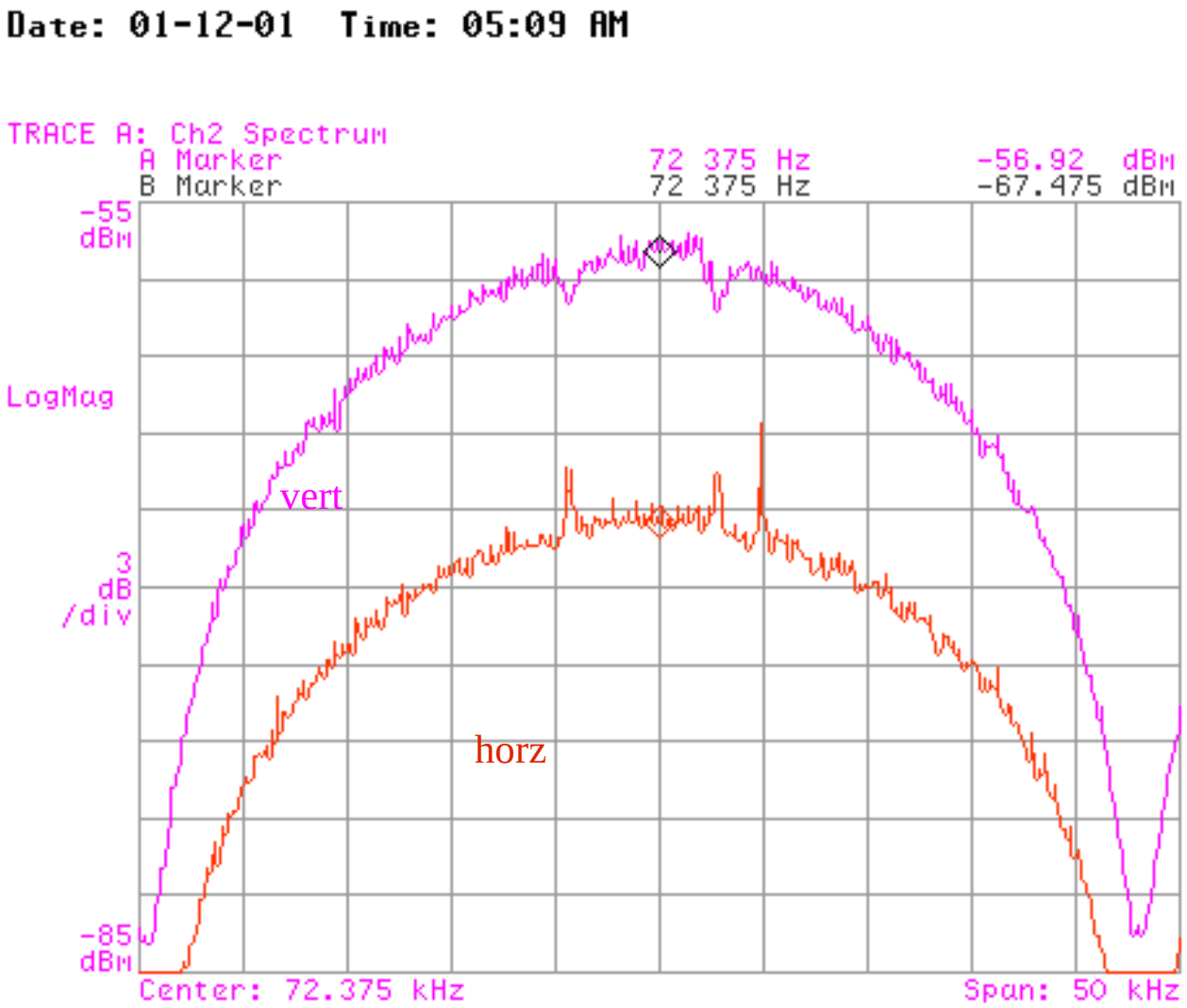
Transverse-Damper Story (II)

chromaticity

Originally	~2002	Q'~10-16
V/H dampers work	'03	Q'~5-8
Lambertson lined	'04	Q'~3-5
V fights H damper	Dec'04	Q'~8-10
Octupoles comms'd	Feb'05	Q'~0-3

no problems since then... (fingers crossed)

Coupling Causing Instabilities



Both dampers are ON. Notice that the vertical damper is suppressing the tune. BUT the vert damper is causing excitation in the horizontal plane. Note that horz dampers are OFF. (Logbook entry Dec11 2002 0811214)

Transverse Dampers Story (III)

- **150 GeV beam fifetime improved since 2002: from ~1-2 hrs to ~15-25 hrs now**
- **At least one factor was known to affect damper's effectiveness – local coupling – but our best efforts did not help, no stability after decoupling – still a mystery why**
- **Emittance growth due to dampers was small, not easy to separate from vac+noise**

~~**estimate dEmm_rms/dt~0.1+-0.1 π μm/hr**~~