Analysis of 2008 Beam Instability Data

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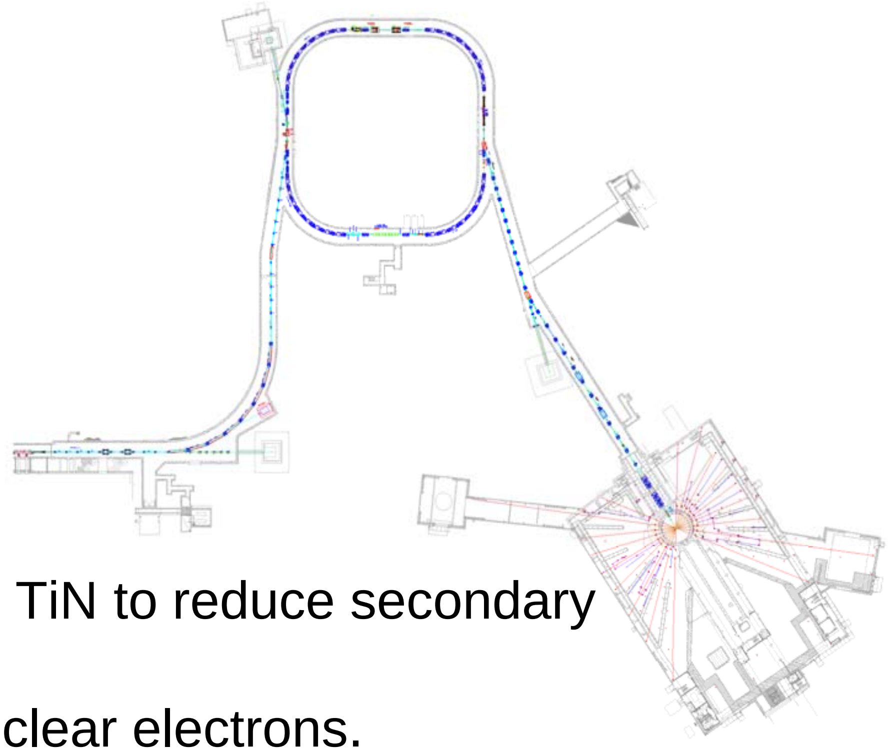
HB2008

The SNS Accumulator Ring

Design ring parameters:

- 1 GeV beam
- Intensity: 1.4×10^{14} ppp
- Working point (6.23,6.20)
- Ring circumference – 248 m
- Space charge tune shift – 0.15



e-P mitigating factors at SNS:

- ✓ Most of vacuum chamber coated with TiN to reduce secondary electron yield.
- ✓ Solenoids in the collimation region to clear electrons.
- ✓ Clearing electrode near the stripper foil.
- ✓ Robust dual harmonic RF system which can help keep the gap clean.
- ✓ BPMs can be biased to use as clearing electrodes.

Status: Production beam with up to ~6.2e13 ppp (May 2008).
No instabilities observed.

Summary of 2008 e-P Data

In 2008 we began exploring bunched beam instabilities. Almost all were e-p.

Studies Performed:

1) 2006 - 2007: Studies focused on coasting beam (no gap, no RF).
   Instabilities observed: e-p, transverse impedance instability, resistive wall instability.

2) February 2008: Accumulated 20 uC of bunched beam, nominal config.

3) April 2008: Accumulated 10 uC of bunched beam, varied tune, intensity.

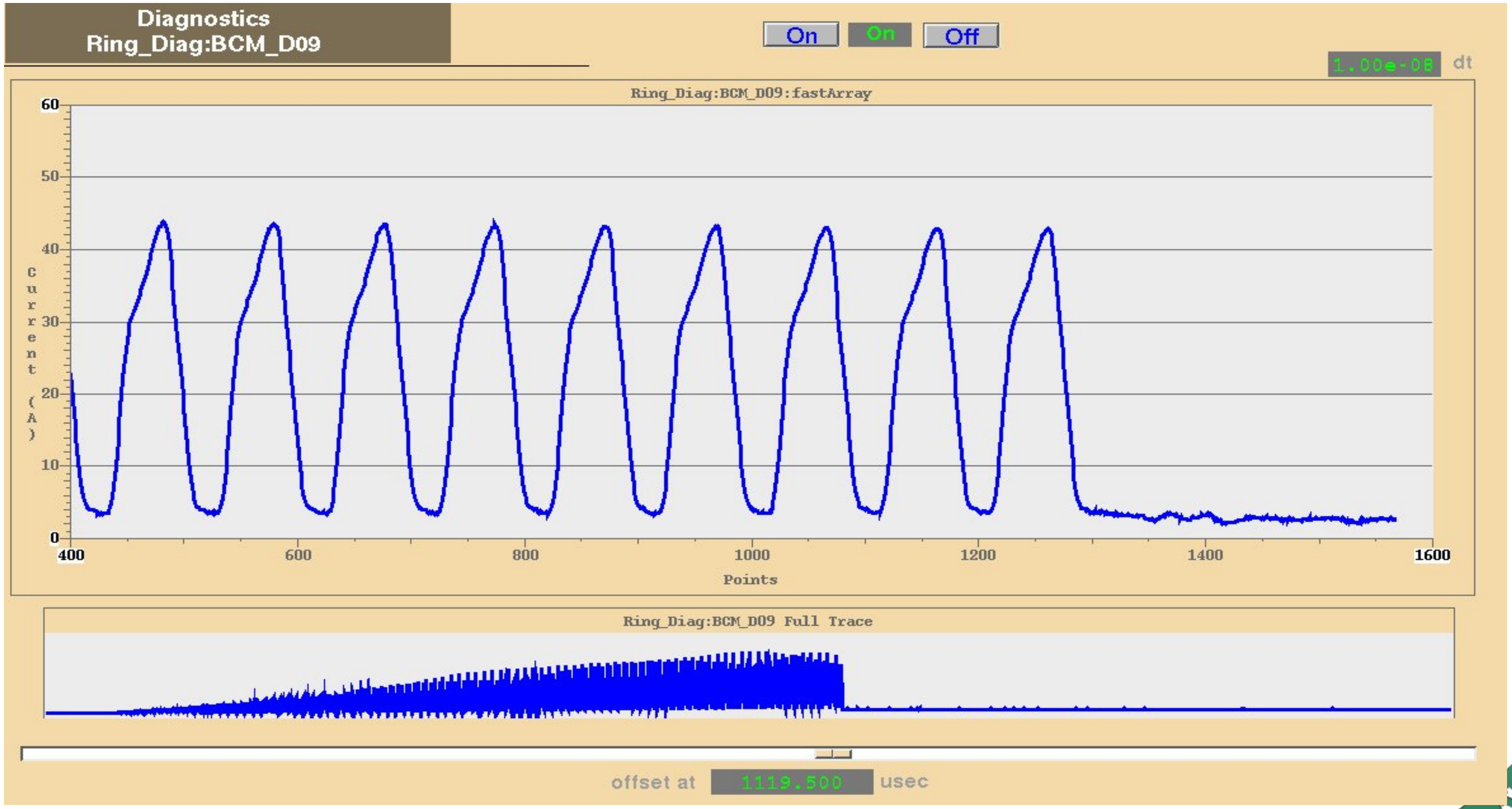
4) July 2008: Accumulated 8.5 uC of beam and varied the RF.

February – 20 uC beam in 1000 turns. All RF on. Nominal tune, natural chromaticity.

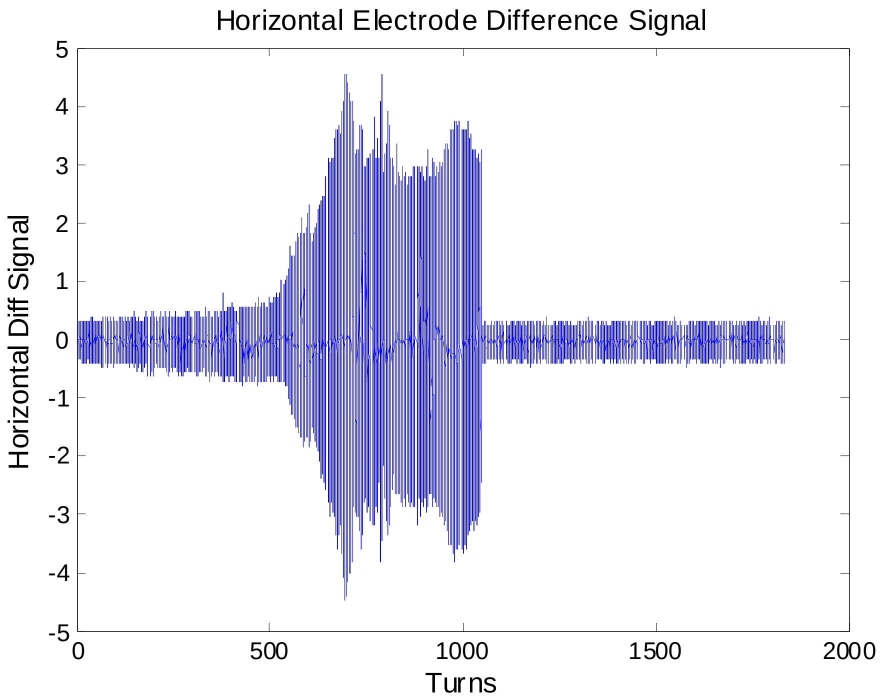
February 2008: New Intensity Record In Ring.

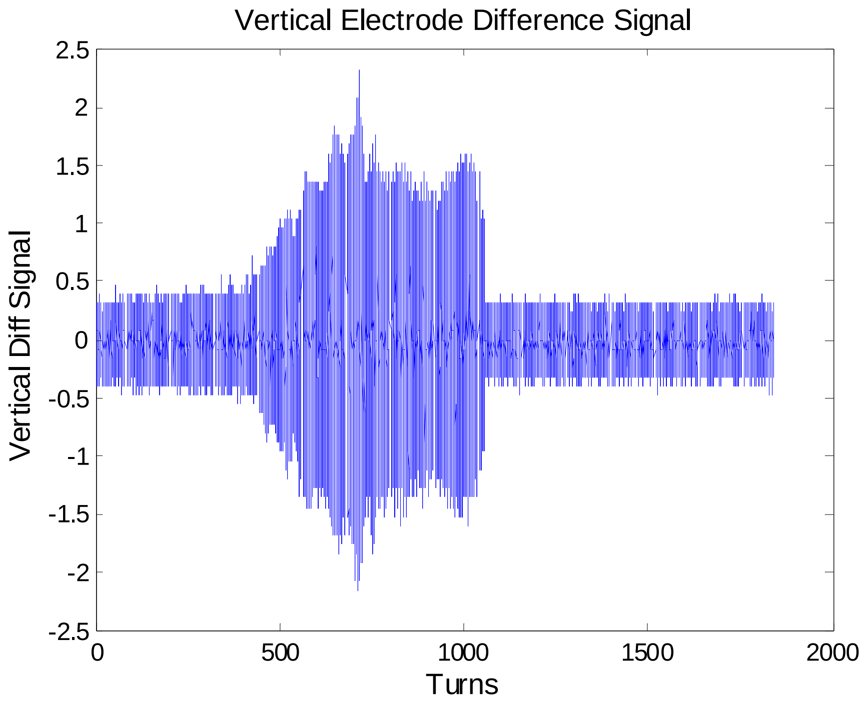
In Feb 2008, SCL pulse length extended to 1000us and **1.3e14 ppp** accumulated in ring. **Equivalent of 1 MW @ 60 Hz.**

Ring losses were very high, no real tuning was performed. All ring BLMs bypassed.



February 2008: 20 uC in 1000 turns of accum.

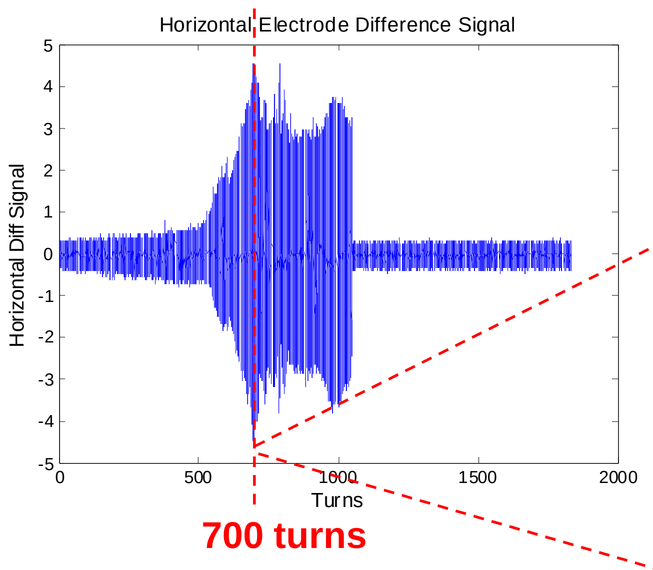


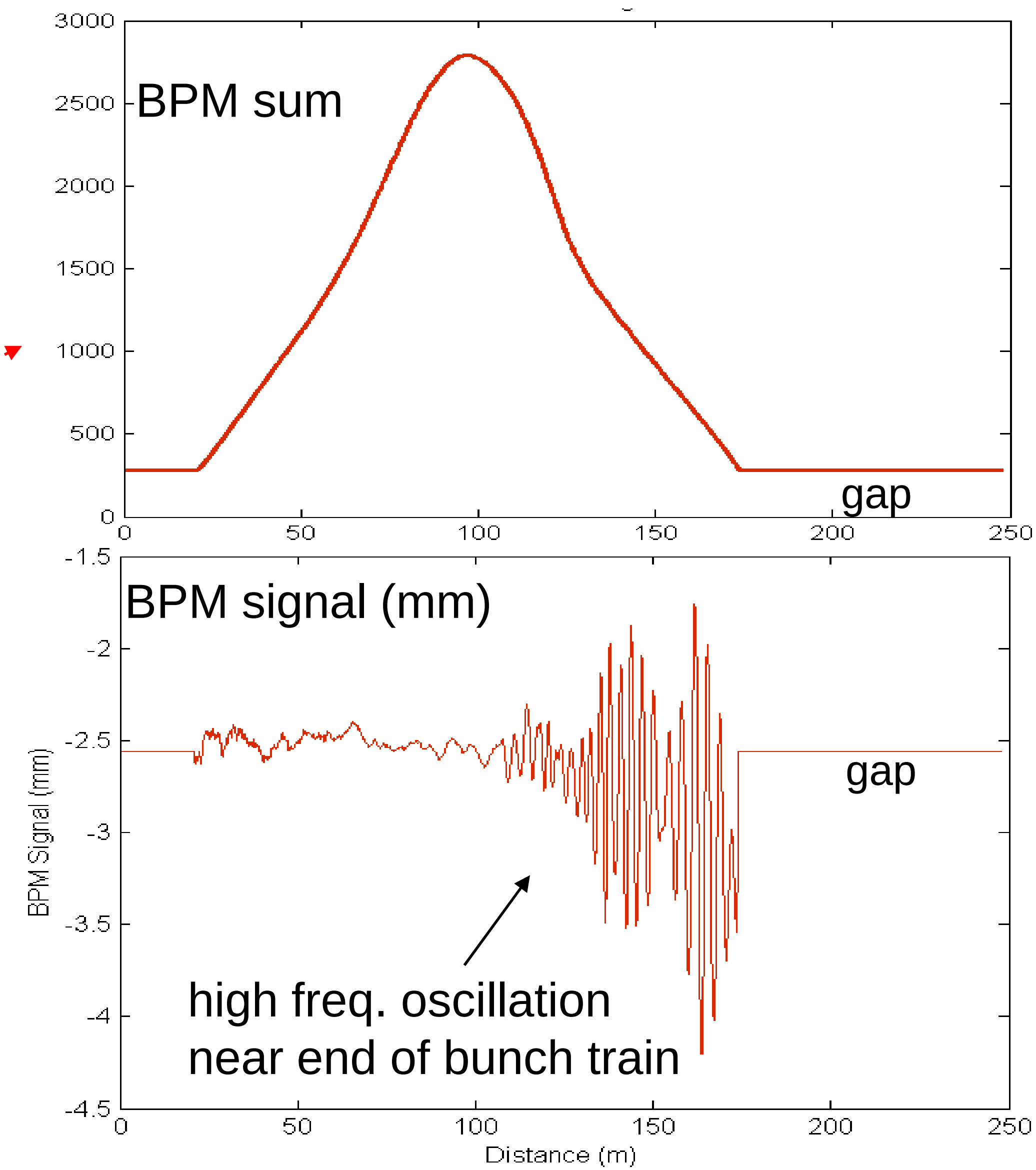


e-p instabilities were observed in both planes. Time to panic? Not yet.

When we rapidly alter the configuration of the machine without performing a clean loss tune-up, we often see instabilities.

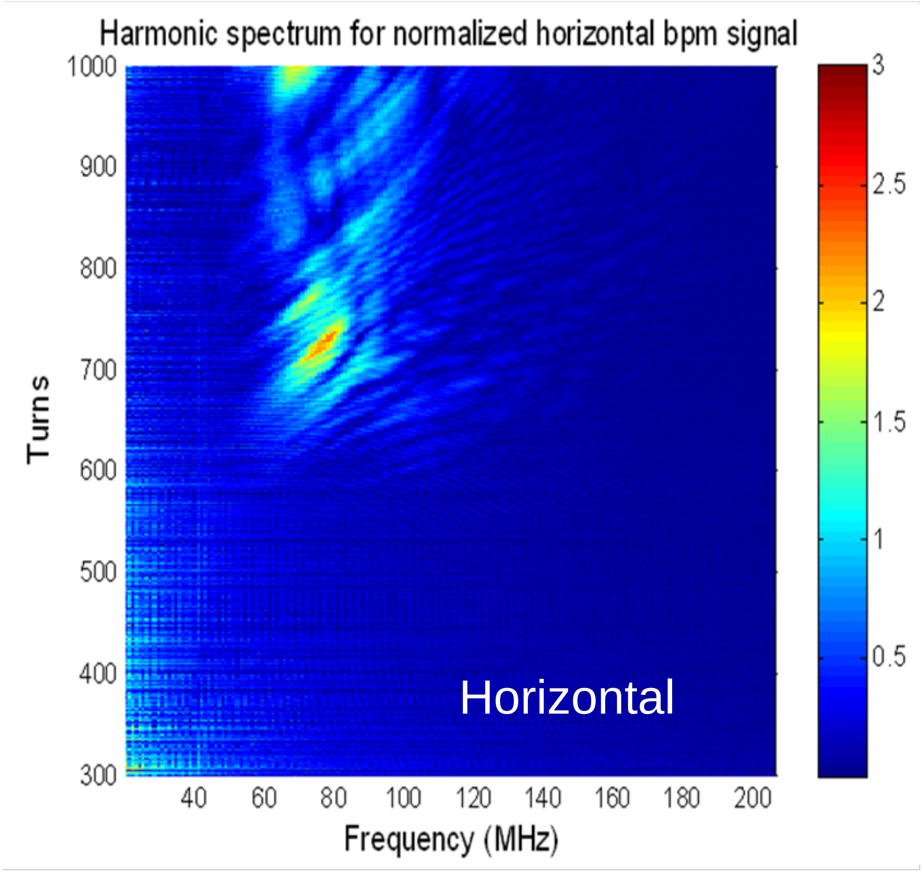
February 2008: Beam signal oscillation.

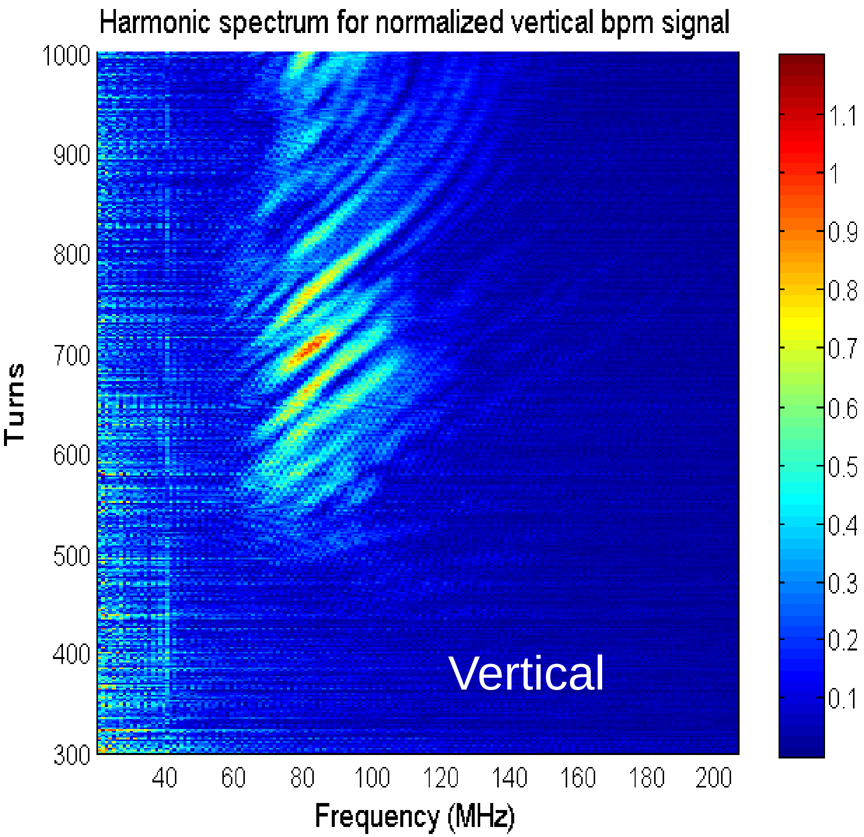




- Converting the BPM signal to mm is useful for tracking e-p trends, from one experiment to the next.

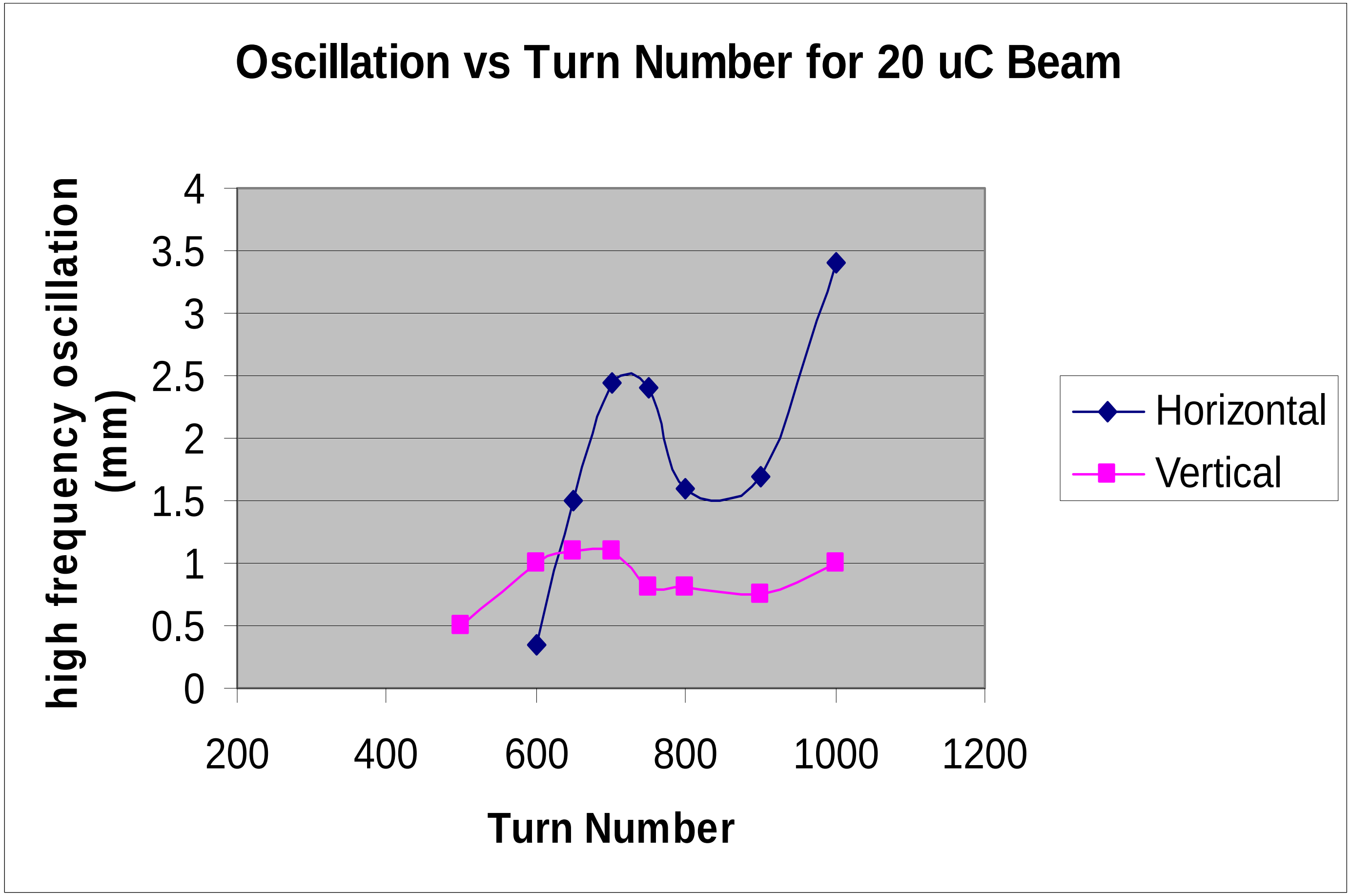
February 2008: Instability Frequency





- Instability frequency: 60 – 100 MHz.
- Vertical preceded horizontal by ~200 turns.

February 2008: Beam Oscillation Amplitude



- Amplitude gets to about 2.5 mm before 1st saturation.

April – 10 uC beam in 1000 turns. All RF on. Varied tune, intensity.

April 2008: Tune Scan of 10 uC Beam

QV03 was scanned from 650 to 643 Amps.

Tune range: **(6.22, 6.24) @ 650 Amps**

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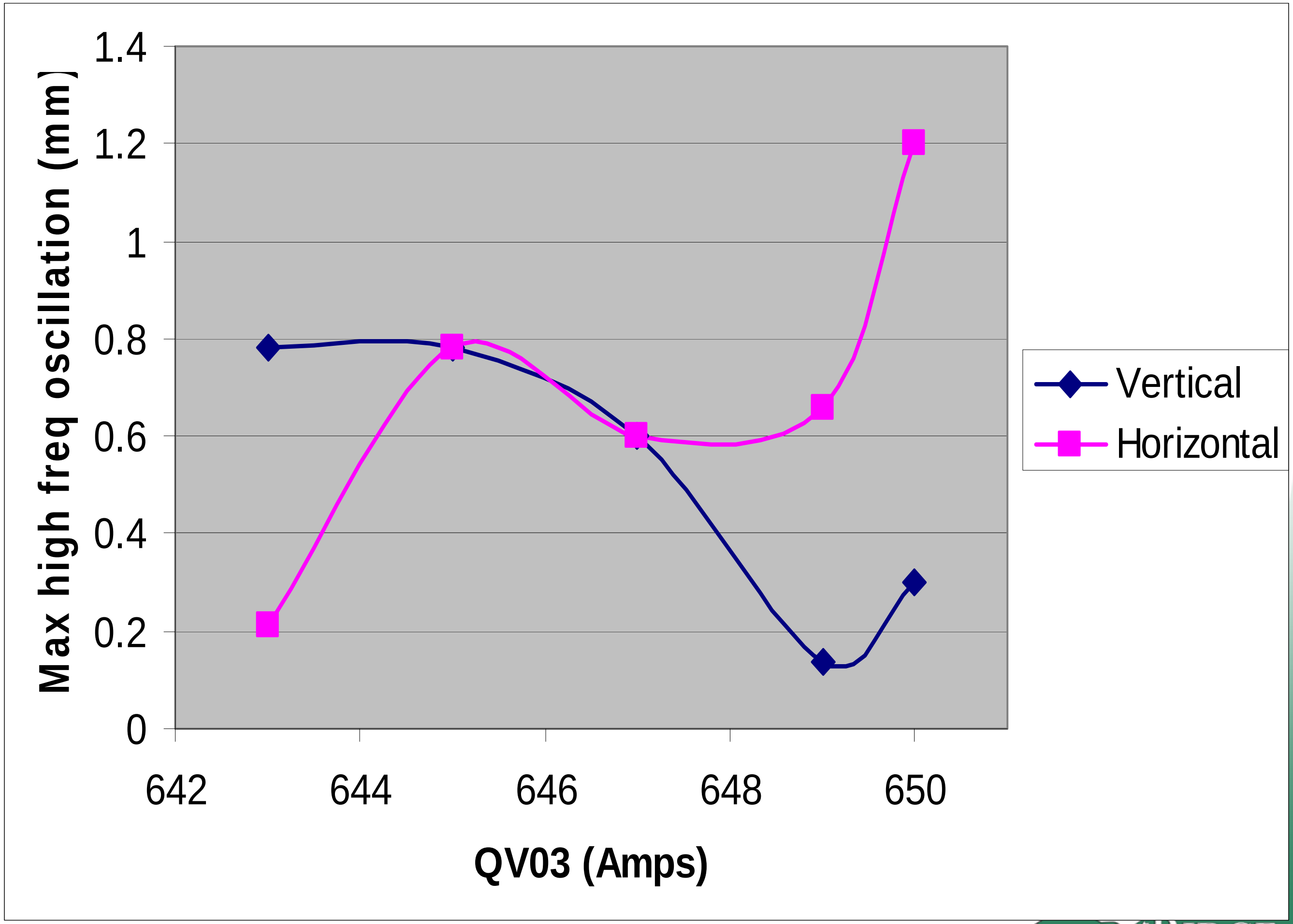
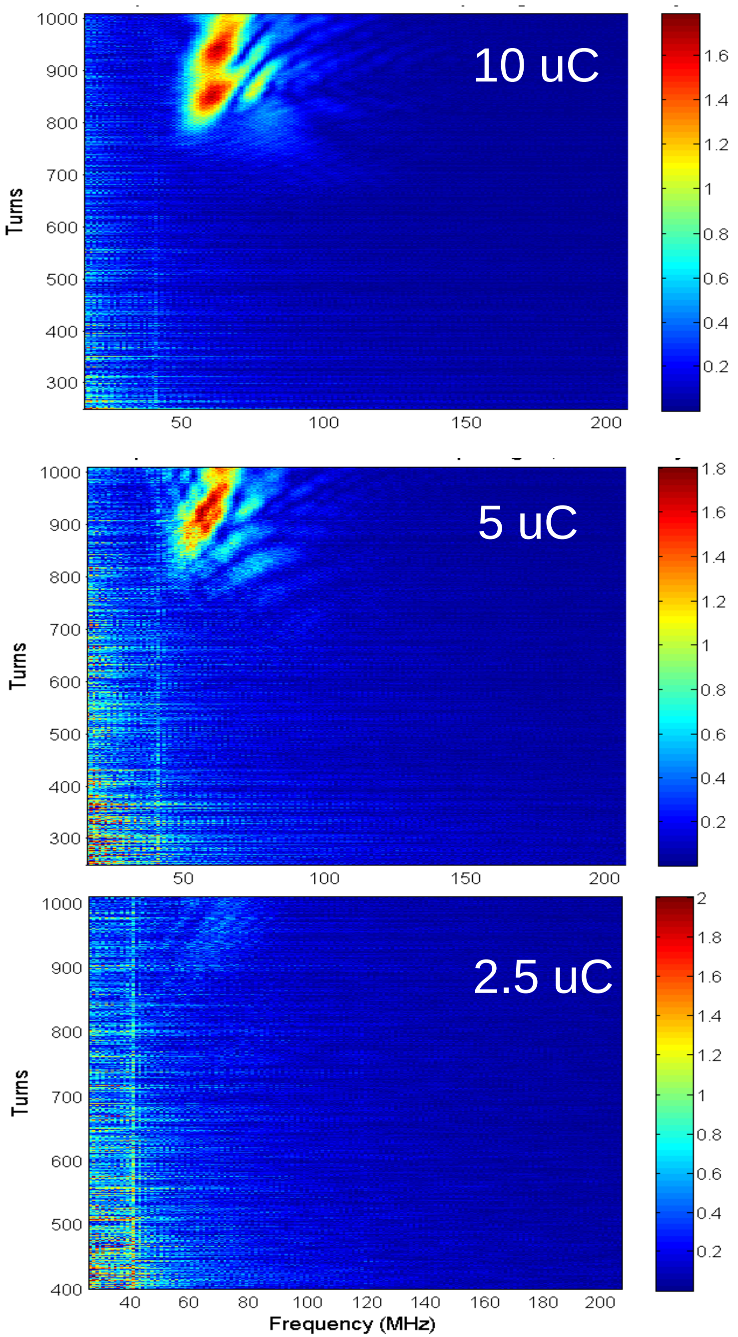
(6.23, 6.16) @ 643 Amps

- Instabilities small.
- No systematic tune dependence.



April 2008: Beam Intensity Study - Frequency

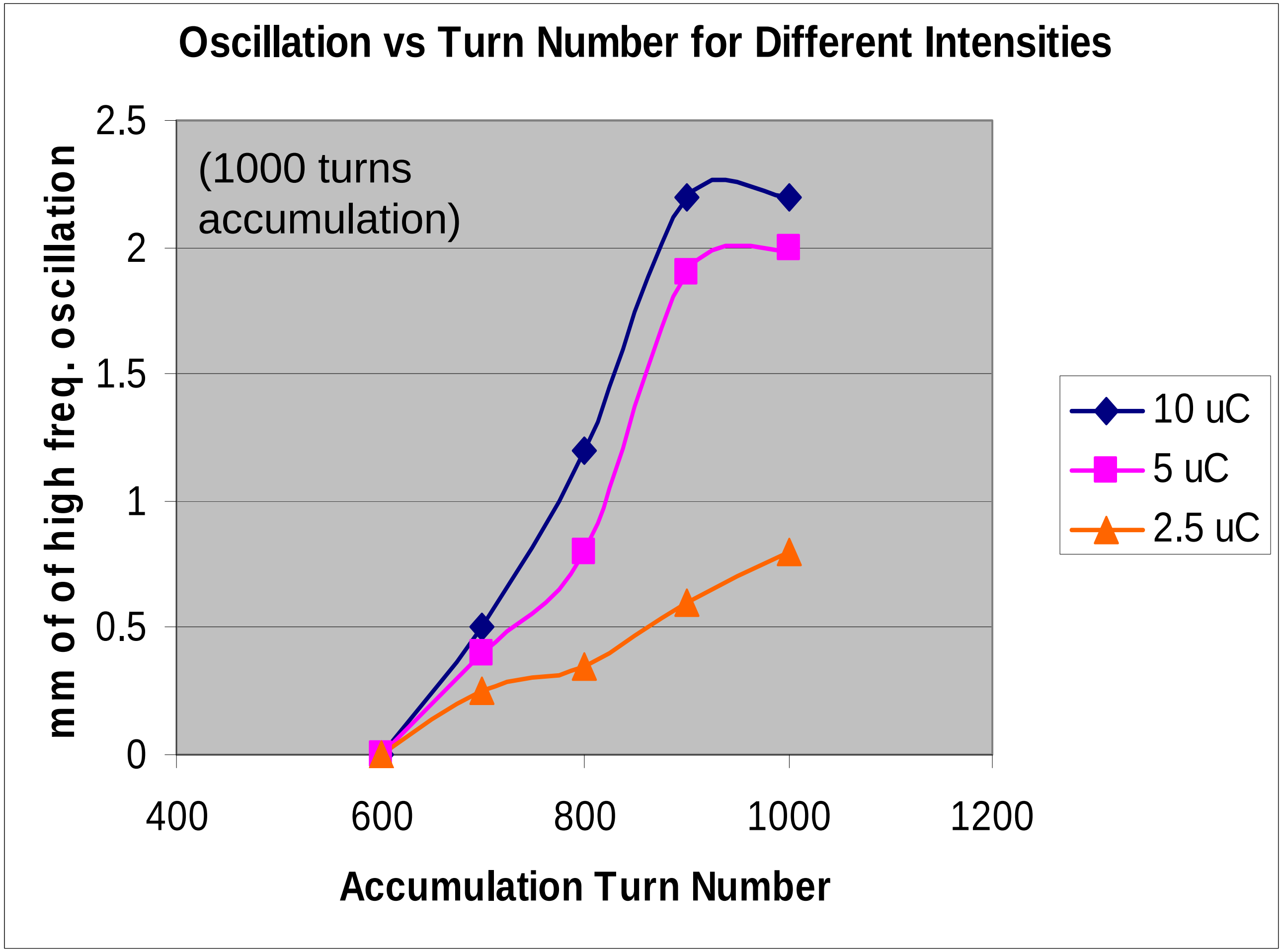


Ring beam pipe was vented during maintenance shutdown before April beam run.

- Pulse length extended to 1000 us, almost no tuning performed.
- 10.6 uC of beam accumulated in ring.
- Vertical instabilities stronger (shown here).
- Frequency of instability does not change with intensity.

•Some activity seen at very low intensity.

April 2008: Beam Intensity Study - Amplitude



Instabilities are seen even at low beam intensity, well below production beam intensities.

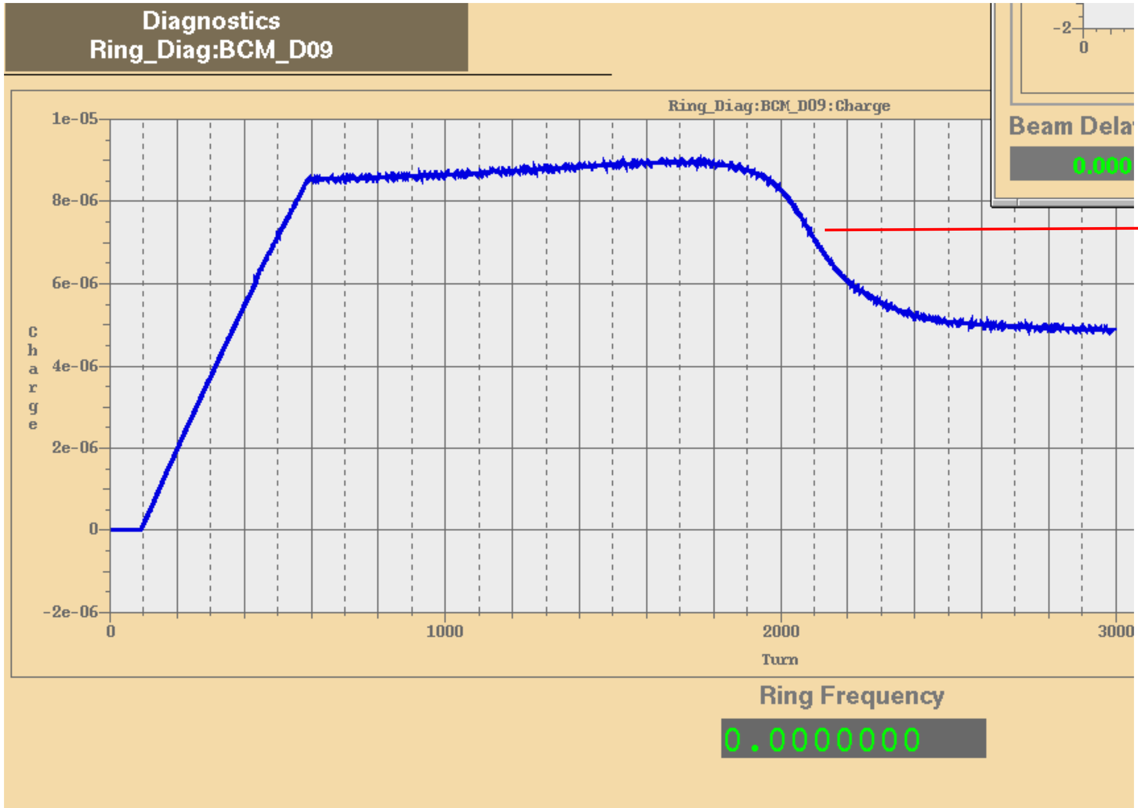
July – 8.5 uC beam in 500 turns + 2000 storage. RF varied.

July 2008: 8.5uC Production Run Beam, Vary RF

Stored the 8.5 uC production run for 2000 turns while lowing RF voltage.

Looked for gross signature of instability (more than saturating the BLMs).

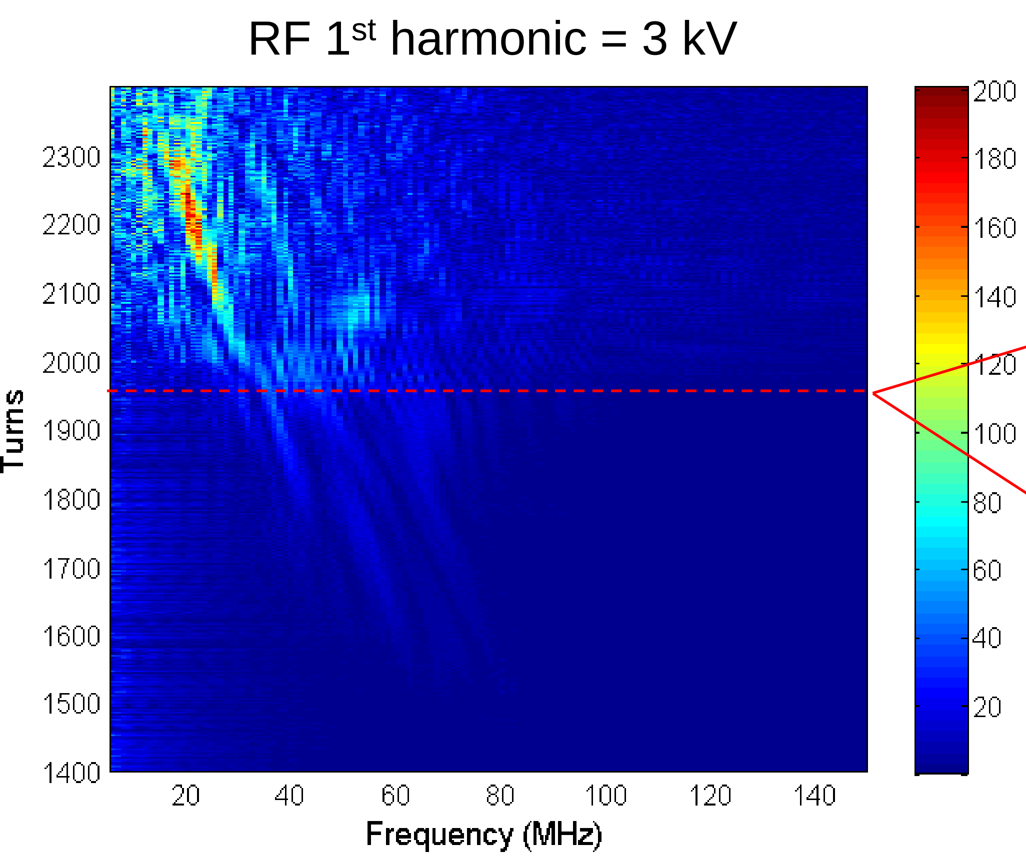
Found it at : RF 1st harmonic = 4 kV, RF 2nd harmonic = 0 kV (off).

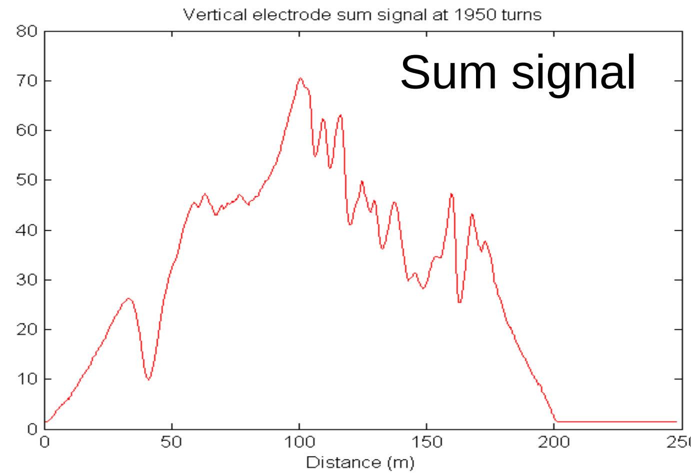


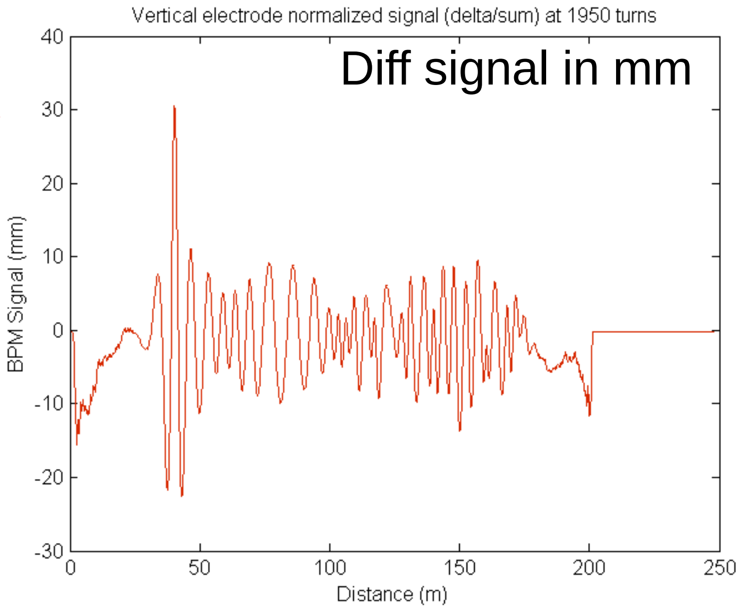
This is a signature that we can recognize as an instability in the control room.

However smaller e-P instabilities (~2.5mm of oscillation) do not display this signature.

July 2008: 8.5 uC in 500 turns, then store

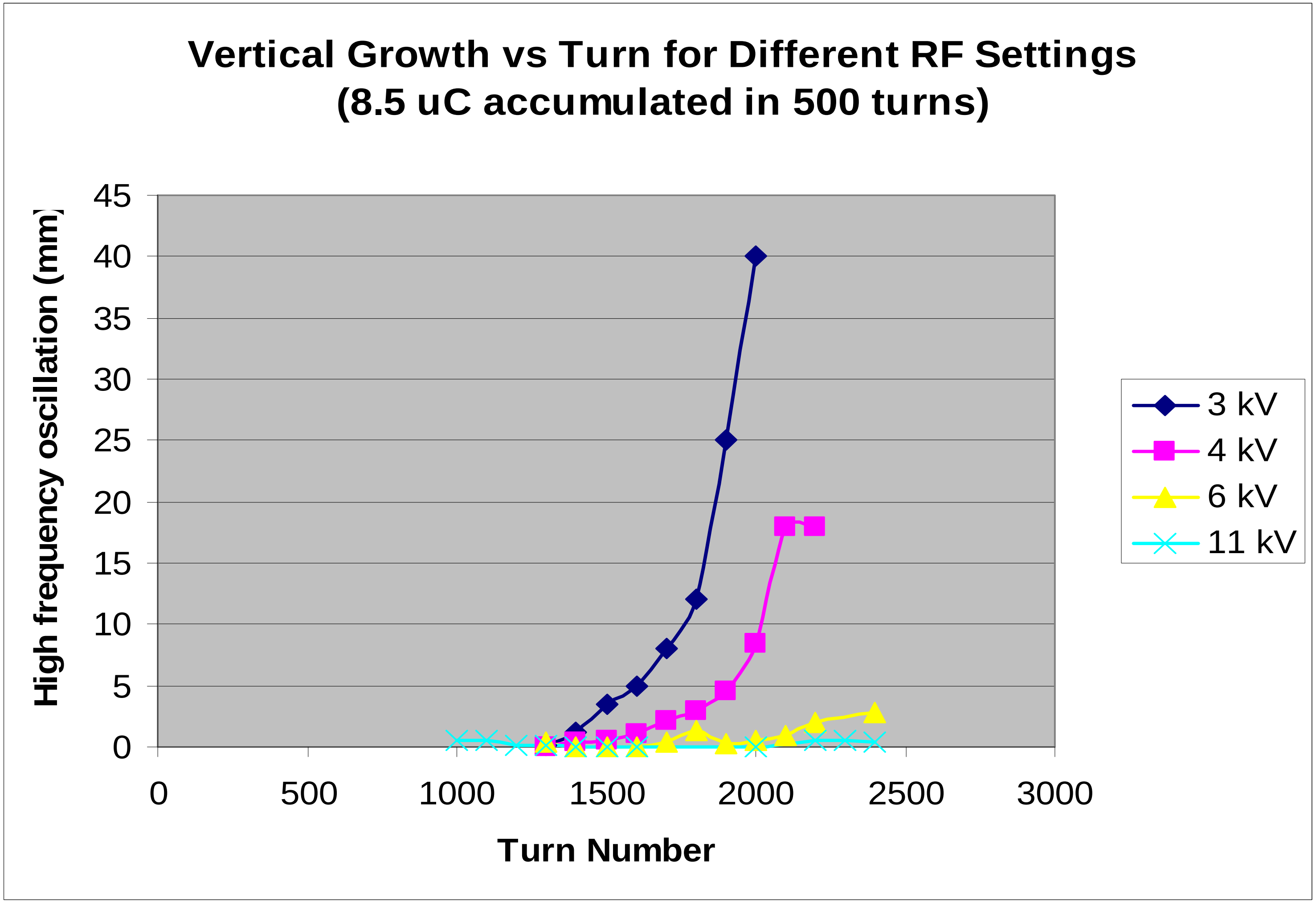






Instabilities seen in both planes, vertical was always a little stronger (shown above).

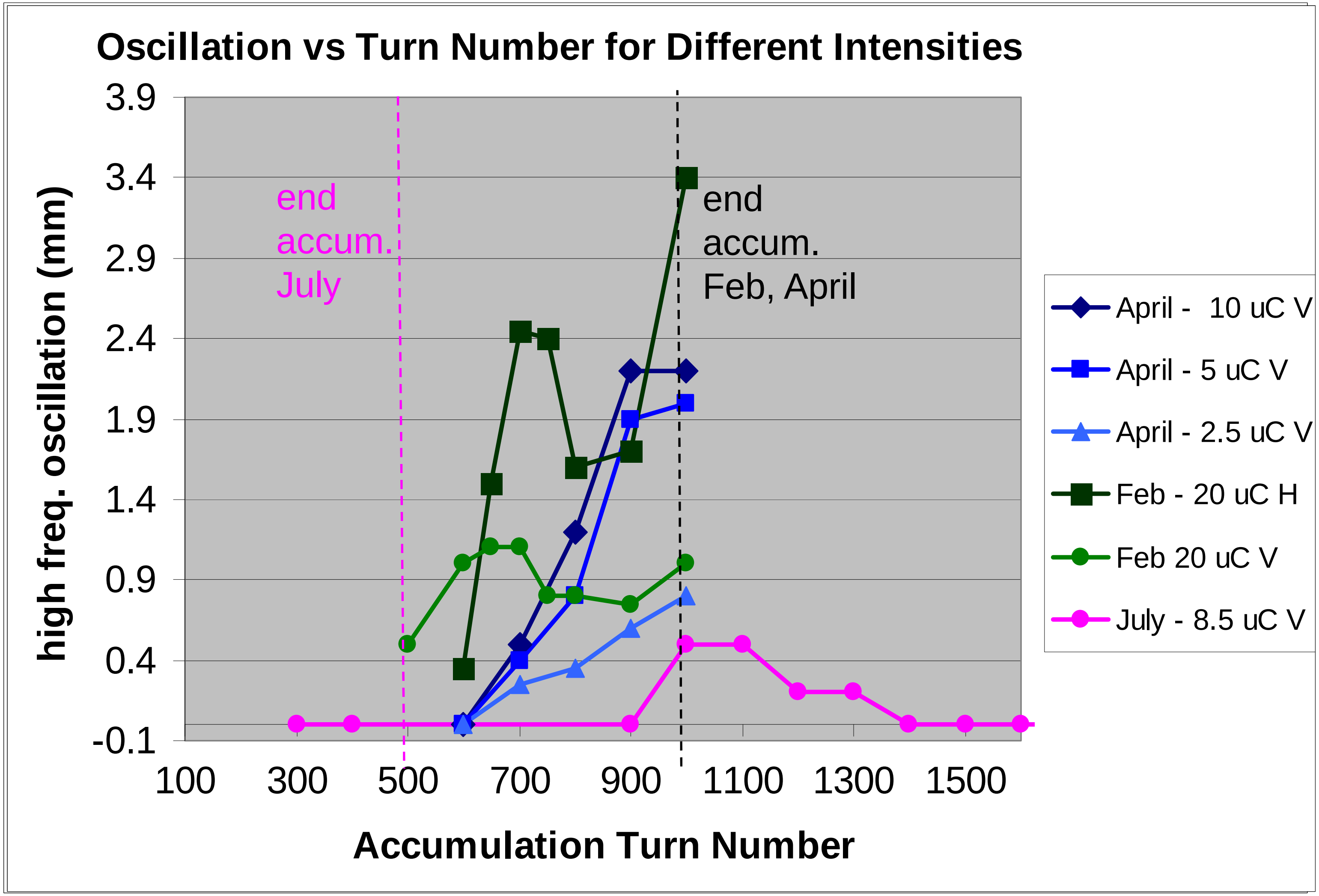
Oscillation Amplitude versus 1st Harmonic RF



- 1st harmonic RF knob was very strong.
- No sign of saturation at lowest RF setting.
- Here about 11 kV to suppress instability.
- Total 1st harmonic RF available is 20 + 20 + 20 = 60kV.

Comparison of Experiments – Looking for Trends

Comparison of the Different Experiments



There seems to be a dependence on accumulation turn number rather than intensity.

Further Evidence of Accumulation Turn Limit

- On May 9th we successfully ran 10 uC (520 kW) of beam using 600 minipulses.

- On June 5th, the available pulse length was extended to 700 us. A "limit" was hit around 640 minipulses for 9 uC and we were unable to put the last ~30 pulses in due rapidly escalating beam loss.

- We didn't stay at 700 us long enough to explore this problem. Under time pressure, we ran production at 640 minipulses.

Open Questions

1. What is the phenomenon which triggered the onset of instability at ~650 turns?

2. Is this phenomenon still going to exist when we extend to 700us this winter?

3. At what level do we begin to call the high freq. oscillation an ***instability***? At 0.5 mm? At 20 mm? Is there a community standard?

4. How much e-p activity does it take to cause intolerable beam loss for SNS?

5. Can we use our BLMs to diagnose the cause of instability onset or is the saturation level too low?

6. Is there better diagnostic that we aren't looking at yet?

Summary and SNS Path Forward

Observations:

- Still no e-p that interferes with routine beam operation, up to 540 kW.
- Found e-p instabilities at intensities from 2.5uC to 20 uC.
- Appears to be a trigger for instability related to accumulation turn number.
- Instability is very sensitive to RF, and we have plenty of RF available.

Path Forward:

✓SNS will be heading to 700 us pulse lengths and beyond this winter.

✓Plan to routinely investigate e-p instability at every beam power step.

✓Feedback system will be implemented this fall/winter (talk by C. Deibele tomorrow).