Beam instabilities in the PSB

presented by G. Rumolo

in collaboration with A. Findlay, B. Mikulec, M. Chanel, D. Quatraro

→ Observations of **high-intensity phenomena** in the PSB
- Head-tail instabilities along the cycle
- Ring 4 losses before extraction

→ 2010 MDs on **Ring 4 losses**
- Observation
- Correction

The PSB instabilities….

→ The beam is transversely stabilized in the PSB by a transverse feedback system

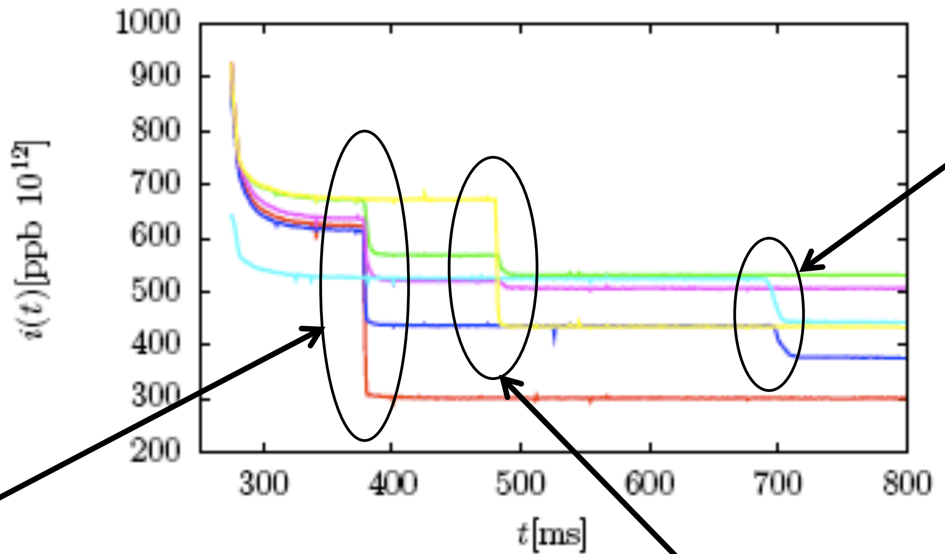
→ In particular, the feedback is necessary in the horizontal plane for high intensity beams (both h=1 and h=2)

→ In normal operation, the feedback is off in the vertical plane

→ What happens if the feedback system is switched off also in H?

Depending on the injected intensity, the beam can become unstable at different points along the cycle!

N.B. Measurements were done on Ring 4, but actually these instabilities were seen to equally occur on all 4 rings



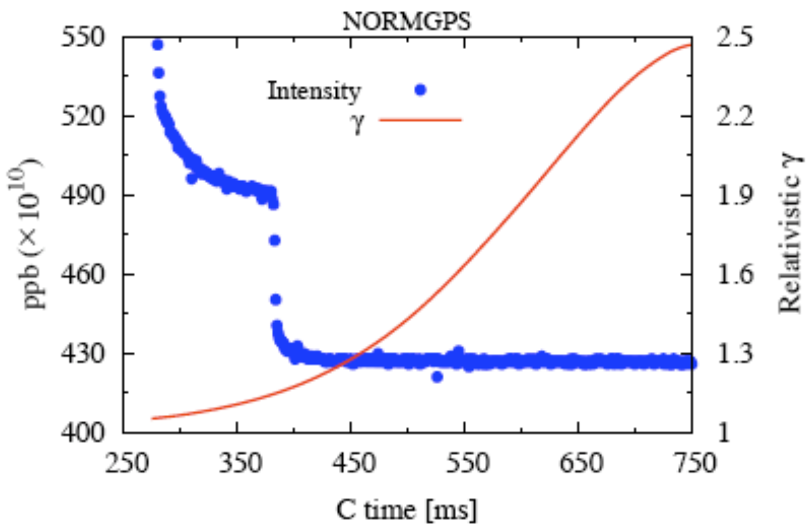
Instability @ c=690ms
$I_{thr} \approx 400 \times 10^{10}$ p (?)

Instability @ c=378ms
$I_{thr} \approx 300 \times 10^{10}$ p

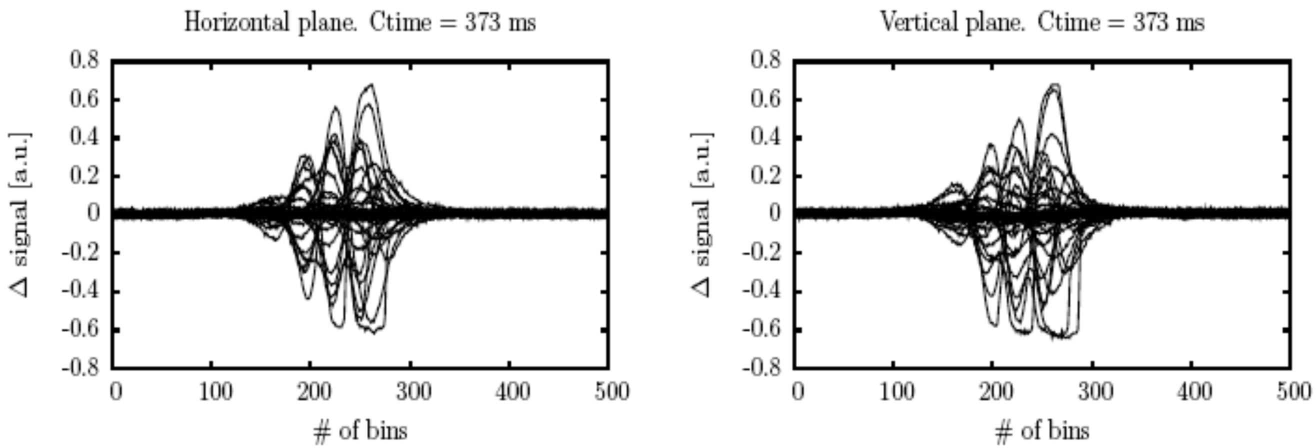
Instability @ c=478ms
$I_{thr} \approx 500 \times 10^{10}$ p

From D. Quatraro's talk in MSWG, 06/11/2009

Instability at c=370ms (I)

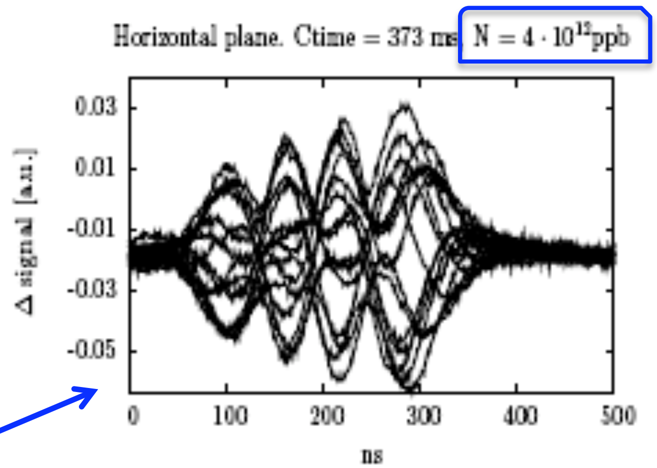


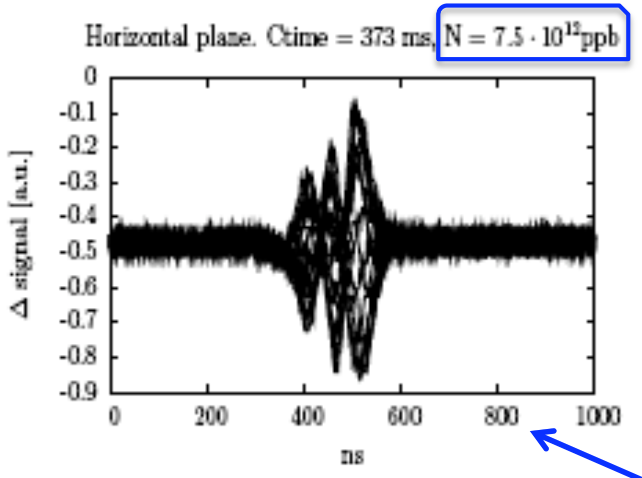
Taking snapshots of the $\Delta_{x,y}$ signal along the bunch while the instability is developing, we can see **3 nodes**



Instability at c=370ms (II)

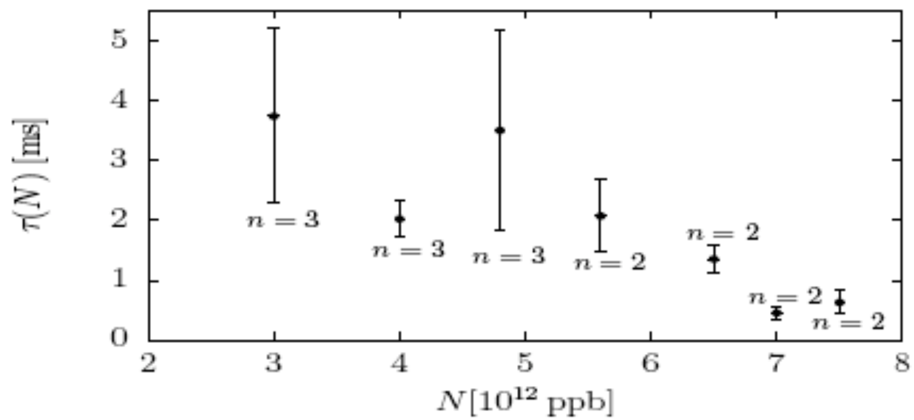
→ In fact, the number of nodes has been found to depend on the beam intensity





Lower intensity, 3 nodes

Higher intensity,
2 nodes

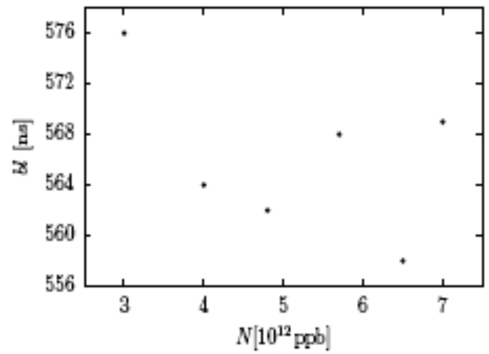


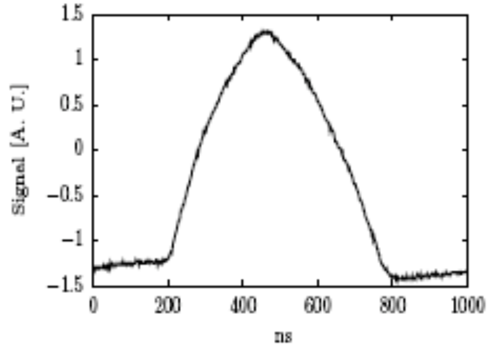
Decreasing trend of rise times
with the bunch intensity

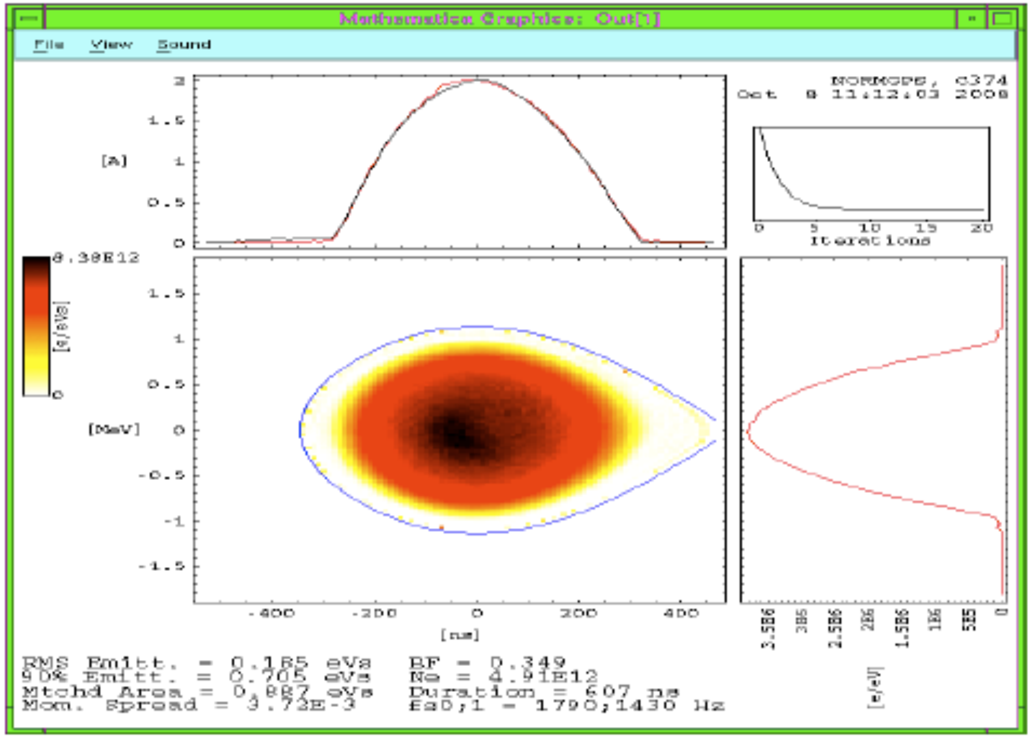
Instability at c=370ms (III)

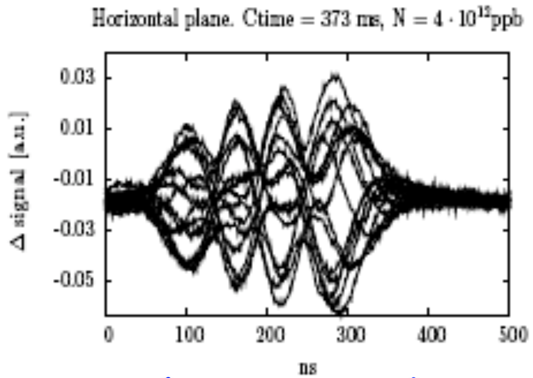
→ Unexplained observations….

The bunch is ~600ns long at c=370ms









Why do we see a Δ signal extending only over ~300ns?

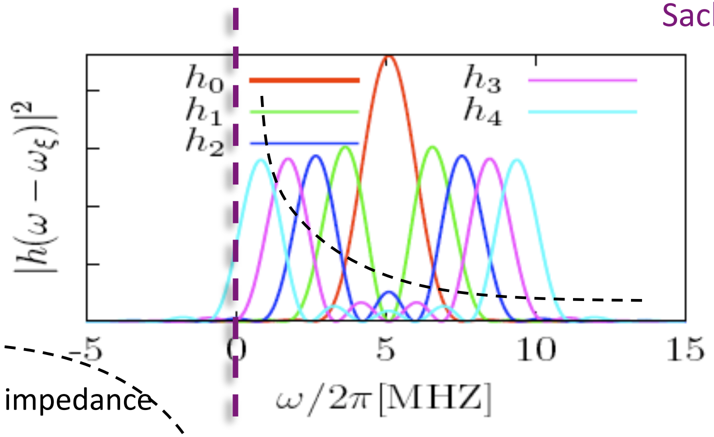
The signal comes from a wideband PU (the same used for the feedback) and goes through a BOSS unit

Instability at c=370ms (IV)

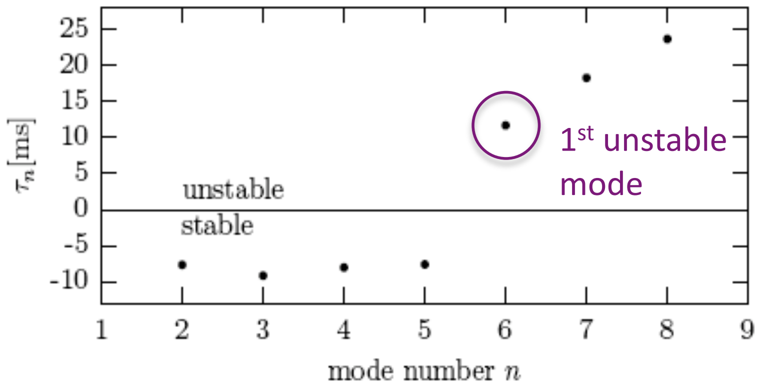
→ Both theory and simulations (not including space charge) would predict that, with a chromatic shift of 5 MHz ($\xi_x \approx$-1), the first unstable mode is n=6 and has a rise time of ~12ms for 500 x 10^{10} p

→ This mode would appear due to resistive wall, as any other impedance source would excite even higher order modes (n>6)

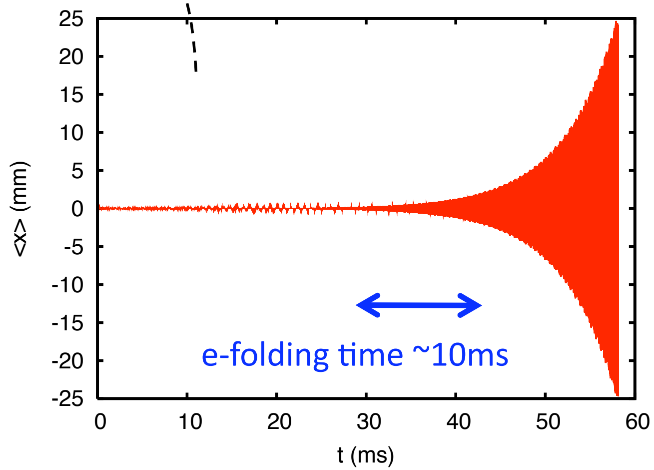
Sacherer theory

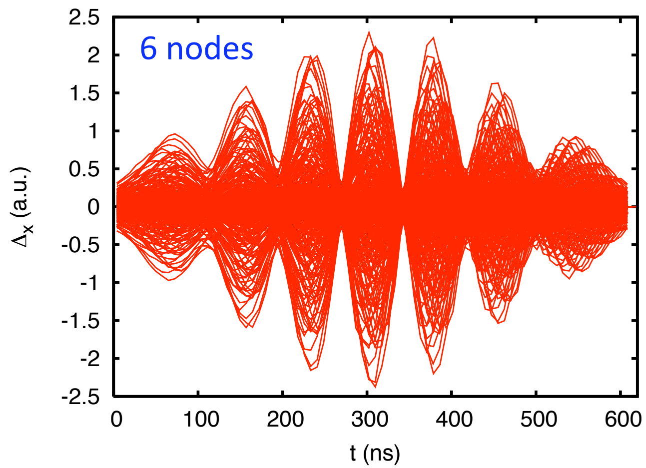


Resistive wall impedance



HEADTAIL simulations with multi-turn

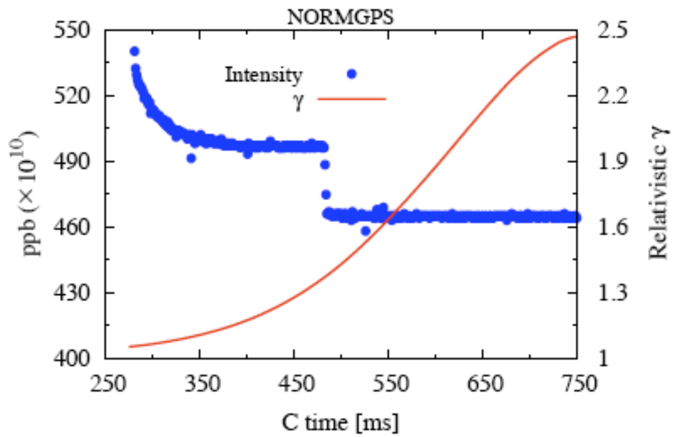




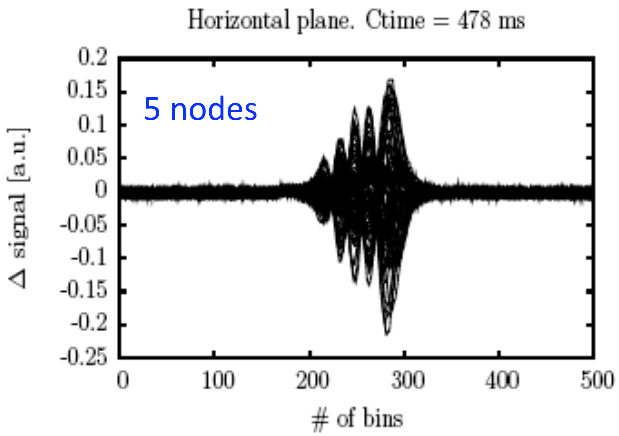
Instability at c=470ms

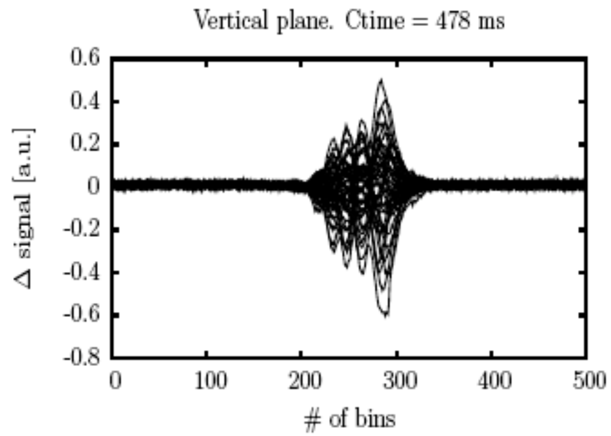
→ Also the second instability has the typical head-tail features
→ The number of nodes is higher (usually 4)
→ The rise time of this instability is typically longer than for the first instability

The losses



Getting the following Δ signal profiles

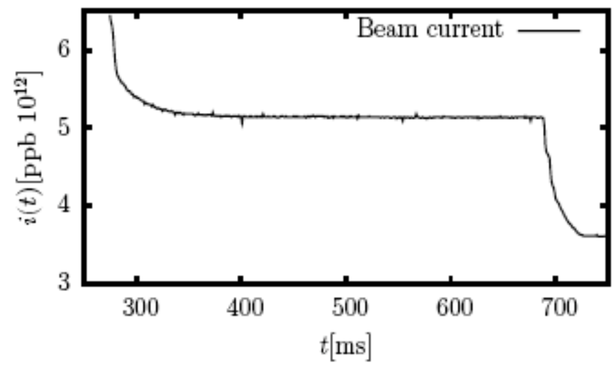




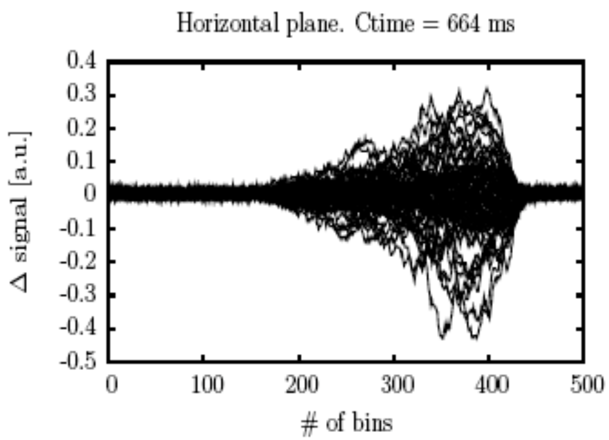
Instability at c=690ms

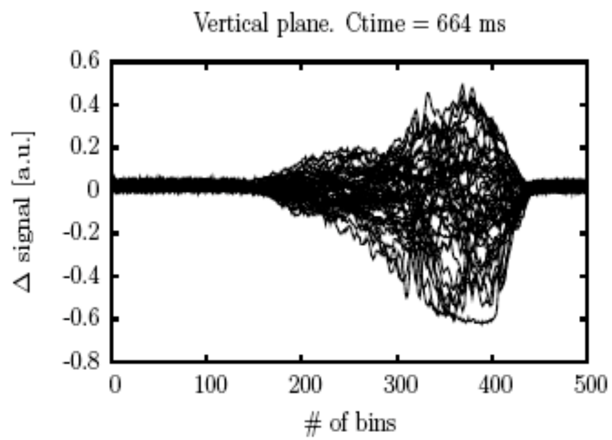
→ Hard to recognize a specific head-tail mode from the Δ signal
→ The rise time of this instability is comparable to that of the first instability

The losses



Getting the following Δ signal profiles

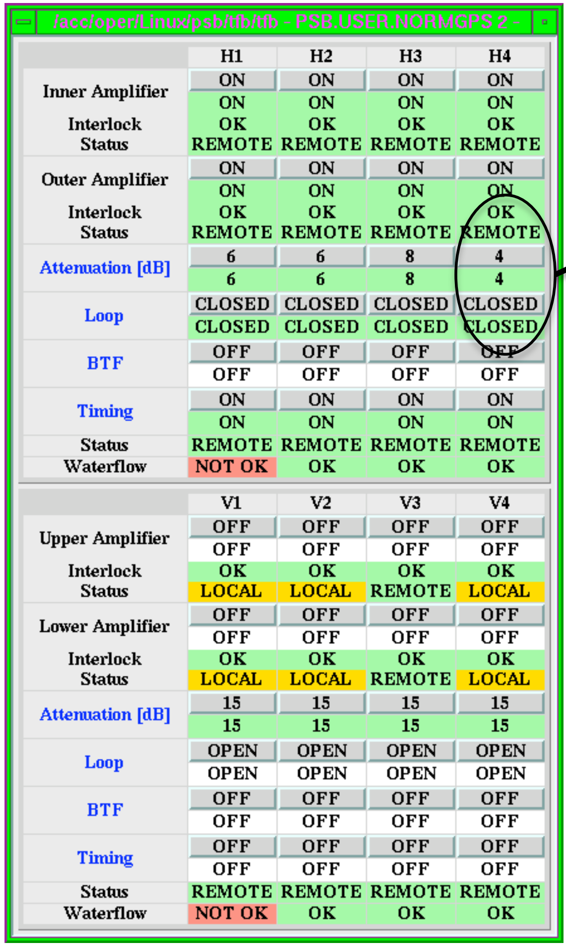




Instability at c=690ms

→ Losses at around the same time in the cycle were also observed in Ring 4 at the beginning of our **MD on July 1st**

→ They could be efficiently suppressed by reducing the gain of the phase loop between the cavities (non-ppm hardware change), and increasing the gain of the TFB.



/acc/oper/Linux/psb/tfb/tfb - PSB.USER.NORMGPS 2 -

	H1	H2	H3	H4
Inner Amplifier	ON	ON	ON	ON
	ON	ON	ON	ON
Interlock	OK	OK	OK	OK
Status	REMOTE	REMOTE	REMOTE	REMOTE
Outer Amplifier	ON	ON	ON	ON
	ON	ON	ON	ON
Interlock	OK	OK	OK	OK
Status	REMOTE	REMOTE	REMOTE	REMOTE
Attenuation [dB]	6	6	8	4
	6	6	8	4
Loop	CLOSED	CLOSED	CLOSED	CLOSED
	CLOSED	CLOSED	CLOSED	CLOSED
BTF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF
Timing	ON	ON	ON	ON
	ON	ON	ON	ON
Status	REMOTE	REMOTE	REMOTE	REMOTE
Waterflow	NOT OK	OK	OK	OK

	V1	V2	V3	V4
Upper Amplifier	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF
Interlock	OK	OK	OK	OK
Status	LOCAL	LOCAL	REMOTE	LOCAL
Lower Amplifier	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF
Interlock	OK	OK	OK	OK
Status	LOCAL	LOCAL	REMOTE	LOCAL
Attenuation [dB]	15	15	15	15
	15	15	15	15
Loop	OPEN	OPEN	OPEN	OPEN
	OPEN	OPEN	OPEN	OPEN
BTF	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF
Timing	OFF	OFF	OFF	OFF
	OFF	OFF	OFF	OFF
Status	REMOTE	REMOTE	REMOTE	REMOTE
Waterflow	NOT OK	OK	OK	OK

Attenuation reduced on the Ring 4

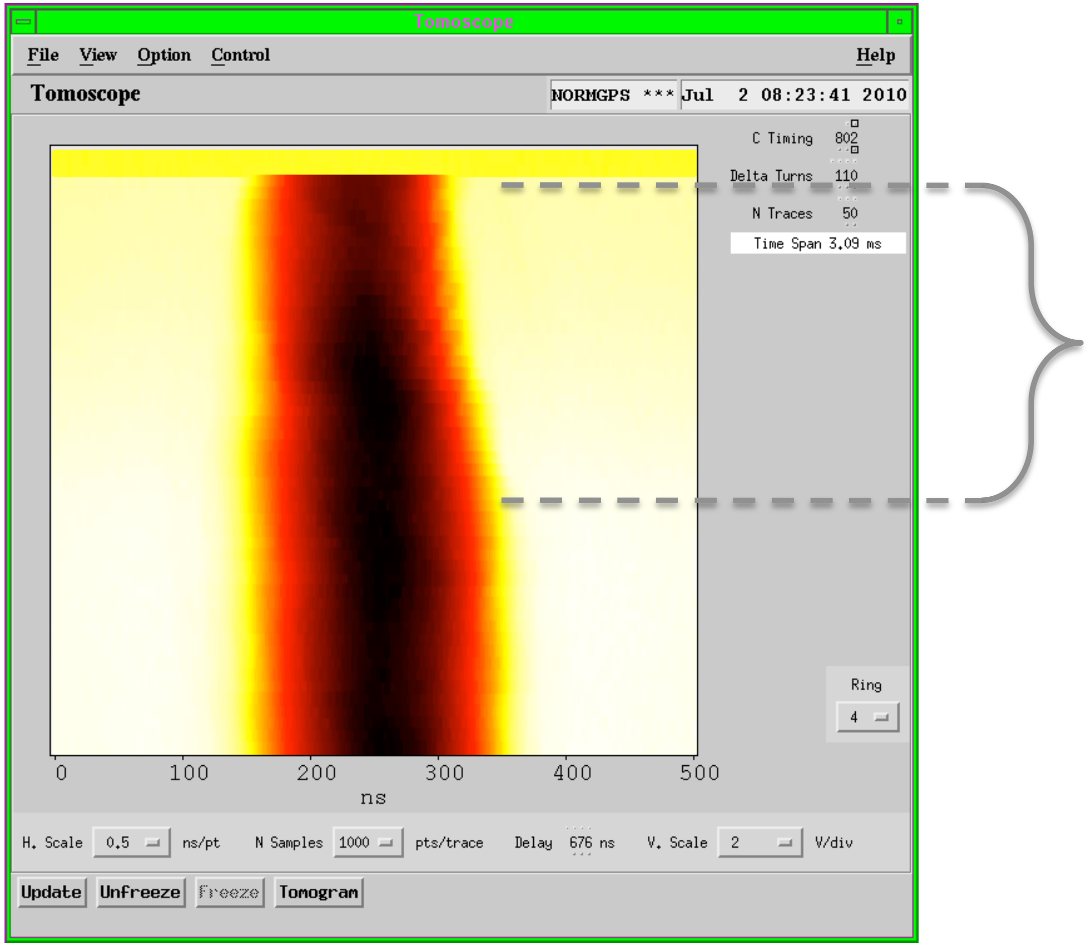
Once the problem of these losses was solved, the beam could be accelerated up until the last few ms. At this point our old friend, **the loss during the last ms**, re-appeared (From the PSB e-logbook July 1st Morning)

See next slides….

Ring 4 losses before extraction

→ Even with the feedback system on, Ring 4 has suffered for years from an **instability appearing right before extraction** for intensities above 800 x 10^{10} p

→This instability would trigger the BLMs on the ejection line and stop the beam to ISOLDE

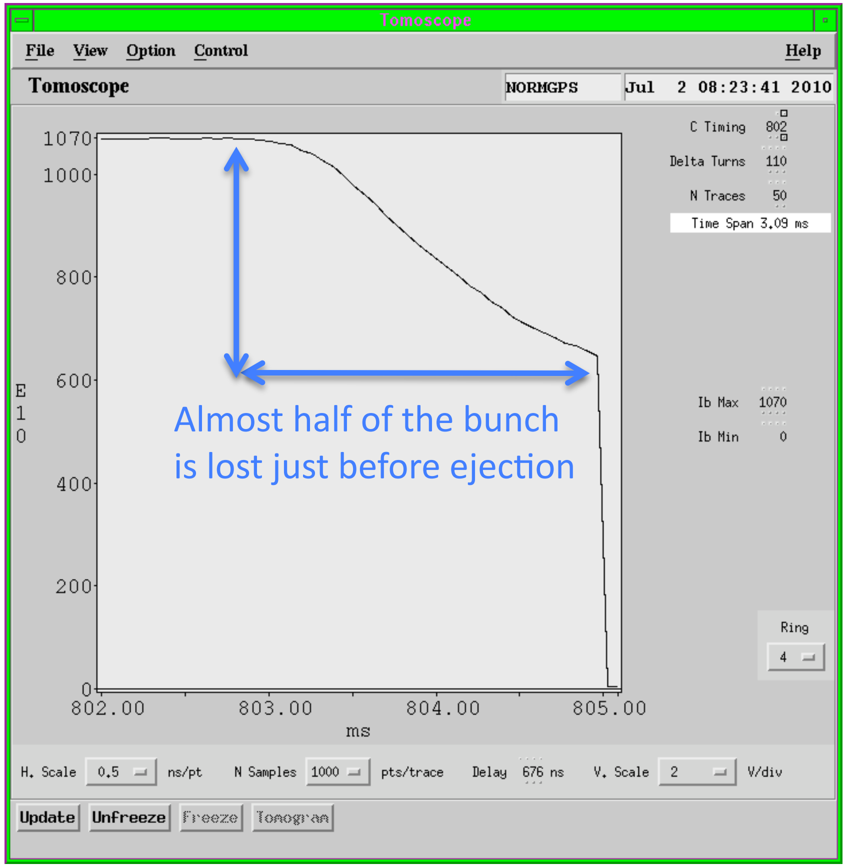


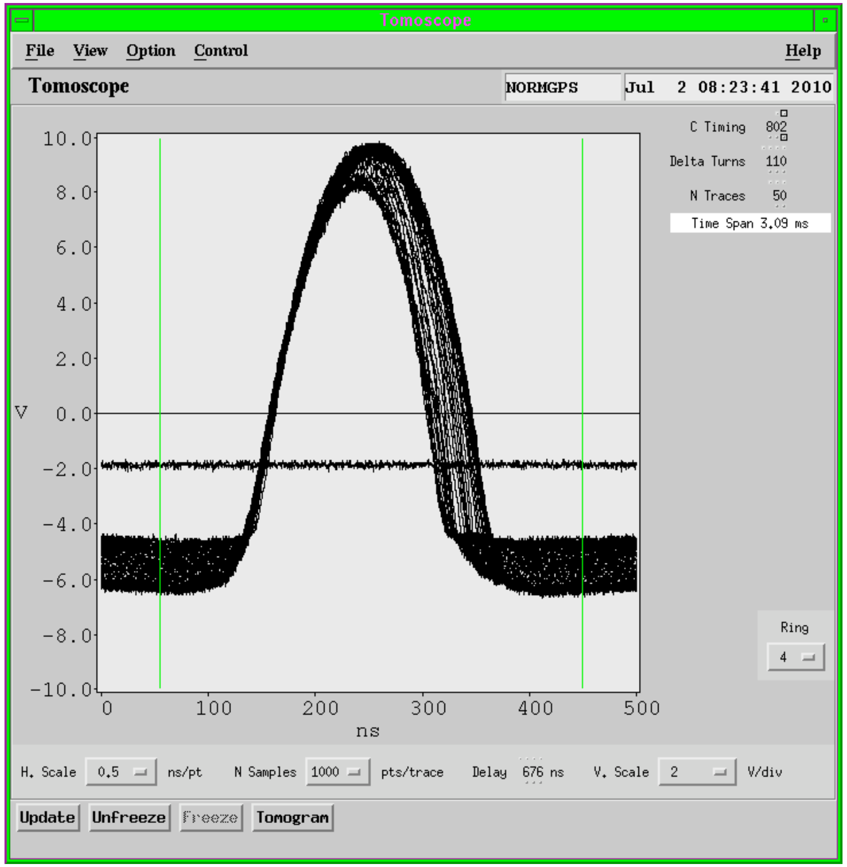
Losses take place during the last 2 ms. They are associated to bunch shortening, but particles are also lost from the core

Ring 4 losses before extraction

→ The maximum **intensity in Ring 4 was limited in operation to 800 x 10^{10} p**

→ **C04 beam-loading**, considered a potential responsible, was excluded during a dedicated MD last February, when C04 was short-circuited and the loss was not cured



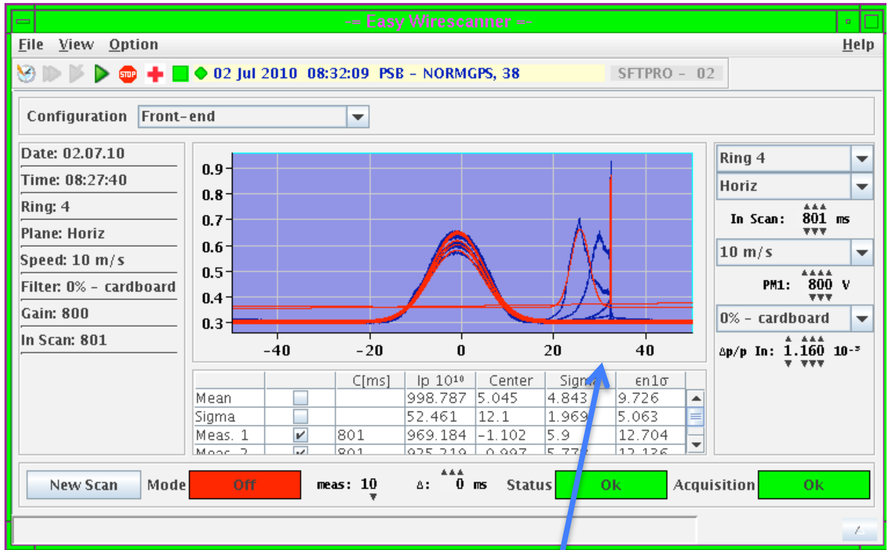


Ring 4 losses before extraction

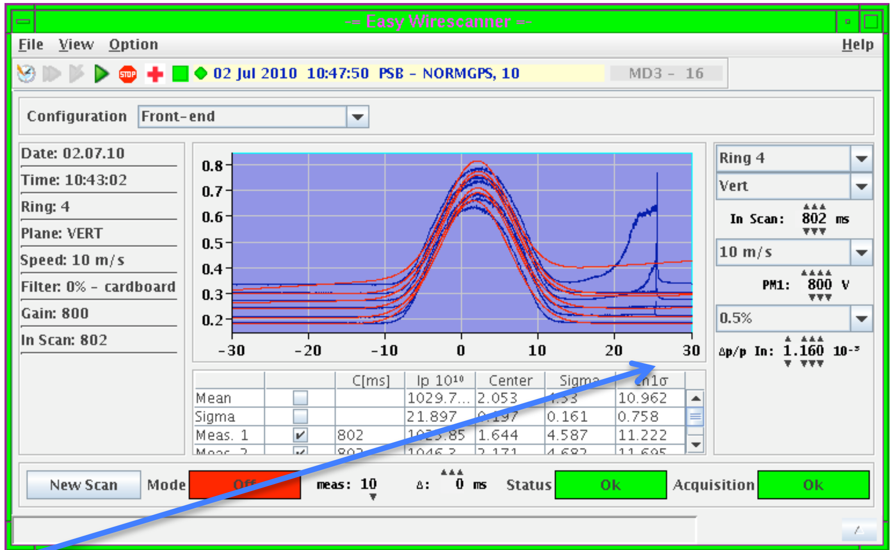
→ The Wire Scanner measurements show some bizarre profiles during the instability in both transverse planes

→ The ‘second’ signal on the right side is measured shortly before extraction and could be a sign of instability or emittance blow up

H profile



V profile

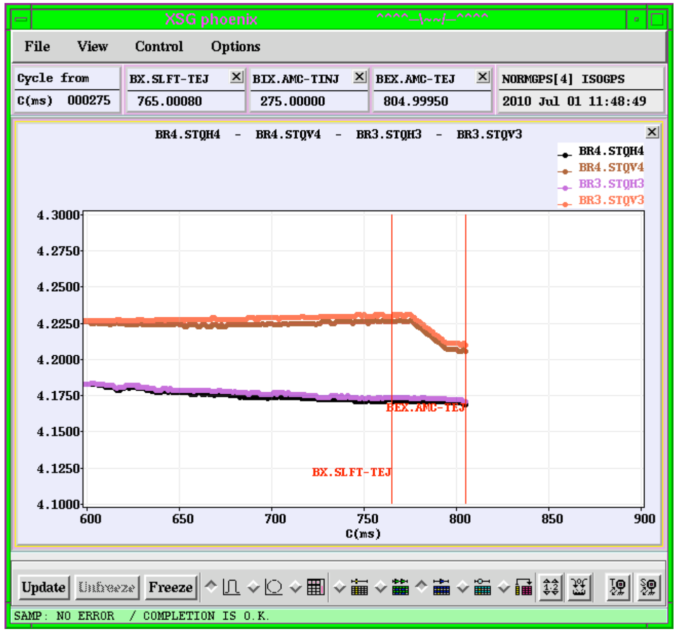


Extraction, the scan takes ~8ms to get to this point. The measurement of the ‘extra-beam’ starts ~2ms before.

Ring 4 losses before extraction

→ During the **MD session on July 1st**, after an adjustment of the beam radial position close to extraction (which removed a transient before the synchro), we attempted to **change the working point at extraction** in order to possibly cure the unstable motion that causes the beam loss

- ✓ If the loss is caused by some resonance crossing enhanced by the space charge with high intensity, we can hope to move farther away from this resonance
- ✓ If it is a coherent instability in the horizontal plane, we could suppress it by coupling more to the stable vertical plane (setting the tunes closer together)

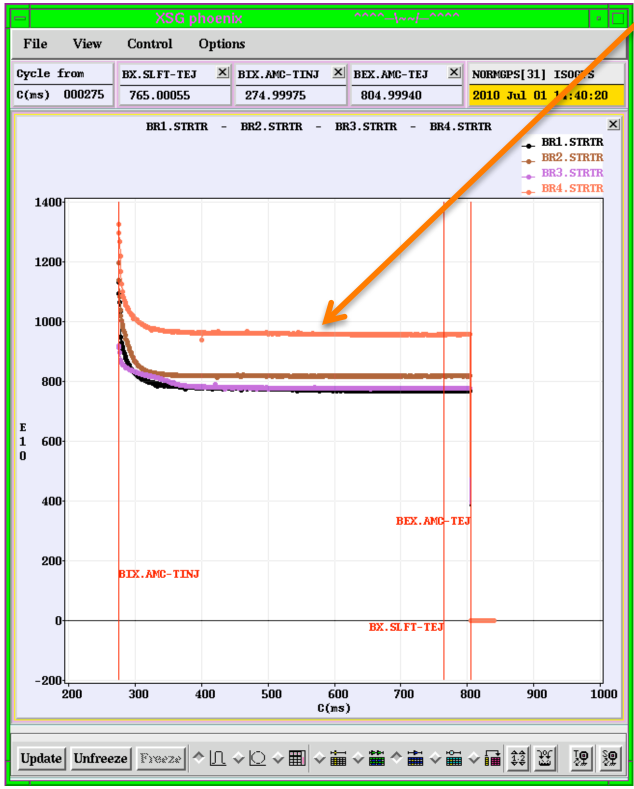


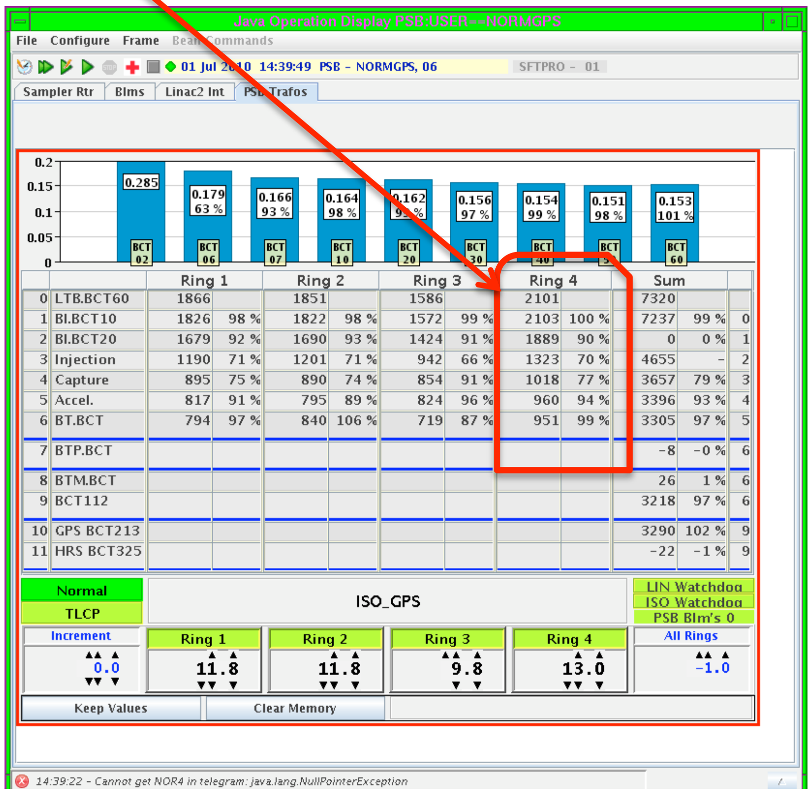
The GFA of the Ring 4 Q-strips (BR4.GSQCF) was extended and pulsed close to the end of the cycle. This had the effect of moving the tunes closer together

Ring 4 losses before extraction

→ And voilà!

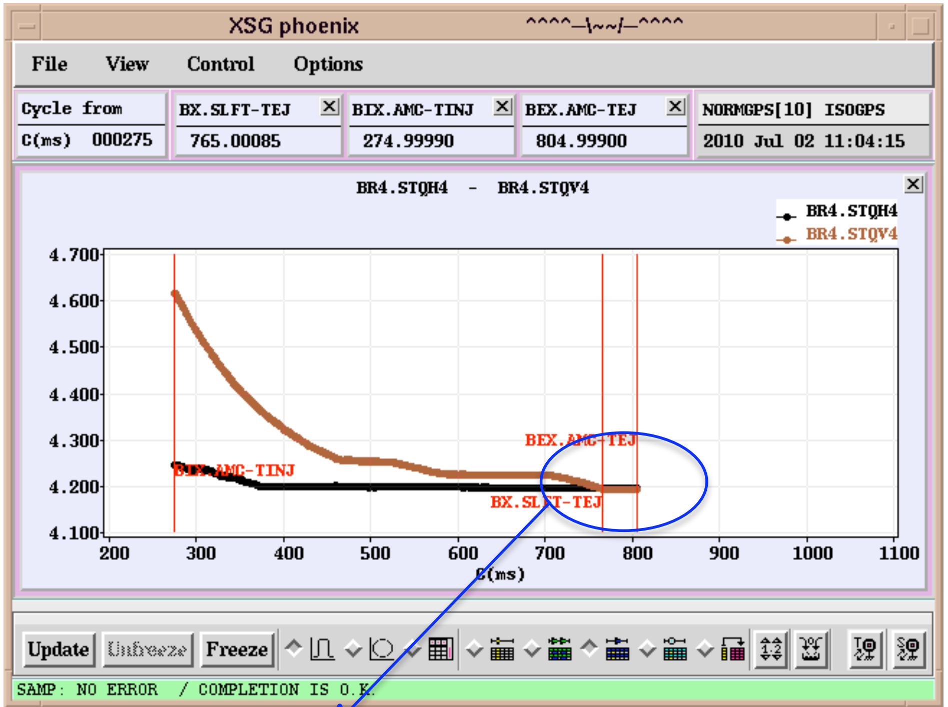
→ Finally we could accelerate up to almost 1000 x 10^{10} p in Ring 4 without the BLMs being triggered



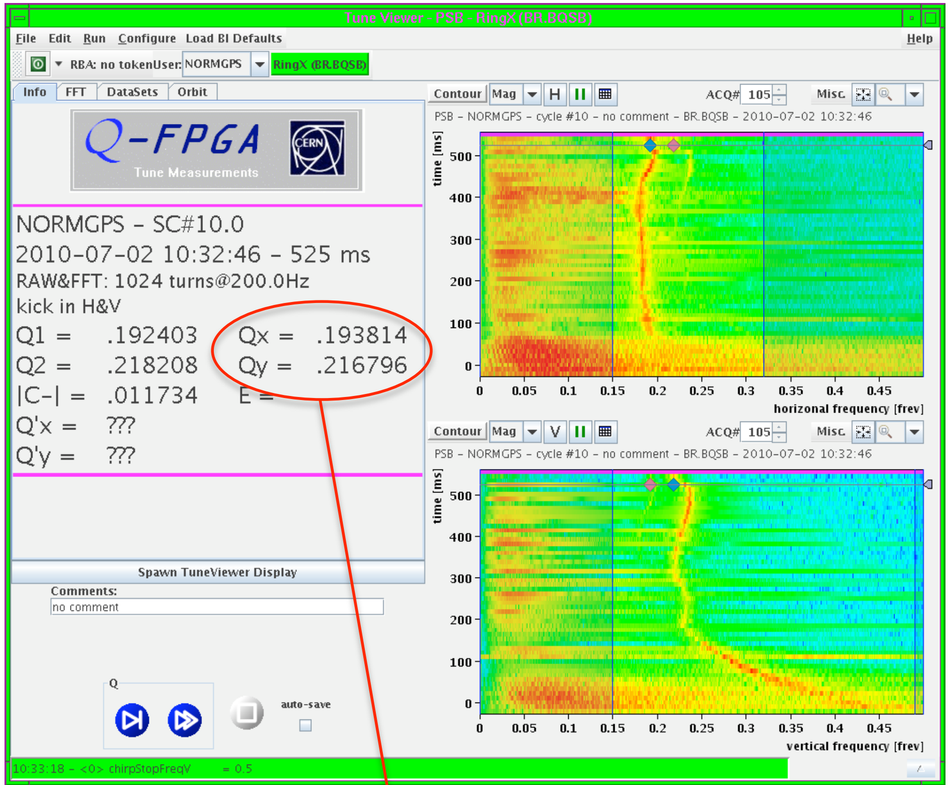


Ring 4 losses before extraction

→ We decided to adjust the working point at extraction in all 4 rings using the tune editor instead of the Q-strips
→ We basically programmed the H and V tunes to be equal at extraction (4.200) to enhance the coupling (they were before Q_x=4.17 and Q_y=4.23)
→ This could stabilize the beam in Ring 4 and allowed **extraction of up to 1100 x 10^{10} p** !!!



Programmed tunes



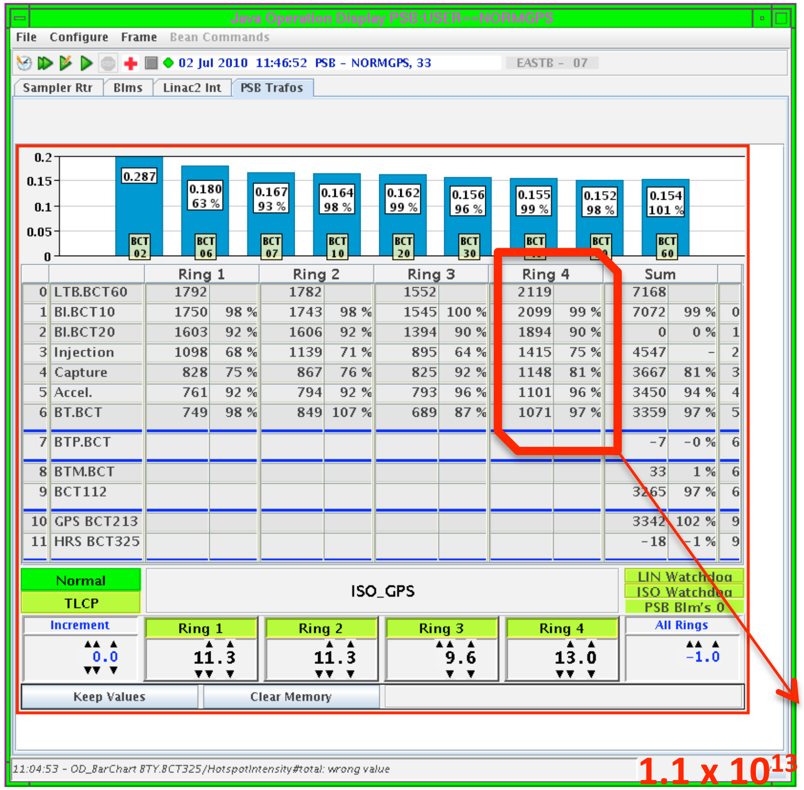
Measured tunes

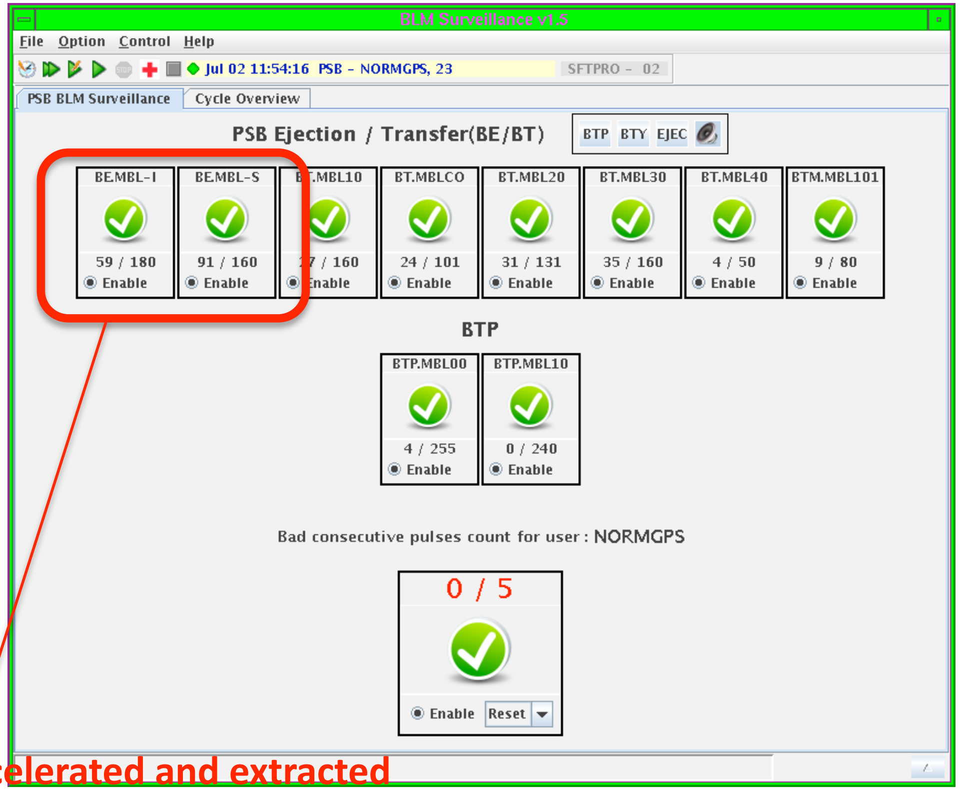
Ring 4 losses before extraction

→ M. Chanel went then back to the original working points at extraction and enhanced the coupling at extraction by using the skew quadrupole BR4.QSKH0 in Ring 4

→ This setting proved to cure the losses at extraction, too. However, we are presently running with the modified working point at extraction and BR4.QSKH0 set to its original 0.78A

→ Consequently, we tend to believe that by bringing the tunes closer together we have actually stabilized the horizontal plane by coupling it to the stable vertical plane.





1.1 x 10^{13} p accelerated and extracted with low losses in the ejection line