Tune shift and instabilities measurement at PSBooster

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thanks to F. Blas, K. Hanke, J. Tan and to all the PSB operators

CERN

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Outline

- Estimation of the impedances in the PSB (never done before)
- Trying to understand which kind of instabilities appears
- Trying to estimate the instability threshold in term of intensity
- Understand whether there are differences between the 4 rings

We have used 3 cycles at different kinetic energies

- MD2 [160 MeV]: with and without the second harmonic (C04) for tune shift measurements
- MD3 [1 GeV]: with only one harmonic (C02) for tune shift measurements
- NORMGPS [1.4 GeV]: with only one harmonic (C02) for tune shift and instabilities measurements

Outline

Ring 2 measurements for the MD2 cycle 1/3

Kinetic energy: 160 MeV

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Longitudinal phase space with the C02 and C04 on ($V \simeq 8$ KV)

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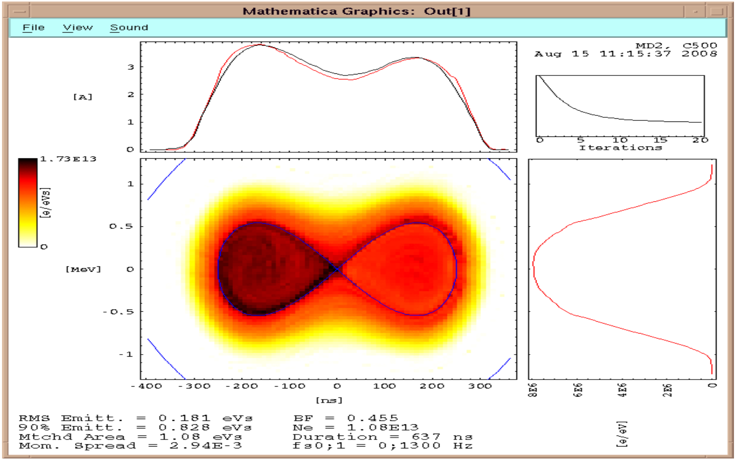
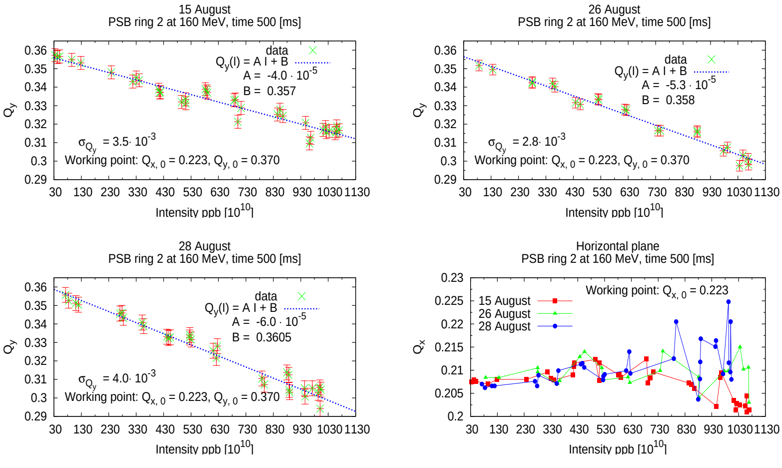
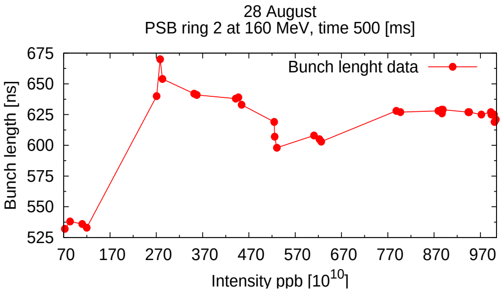


Ring 2 measurements for the MD2 cycle 2/3



Ring 2 measurements for the MD2 cycle 3/3

Bunch length from the tomoscope



Tune shift @ 160 MeV 1/4

MD2 cycle with single rf cavity (C02)

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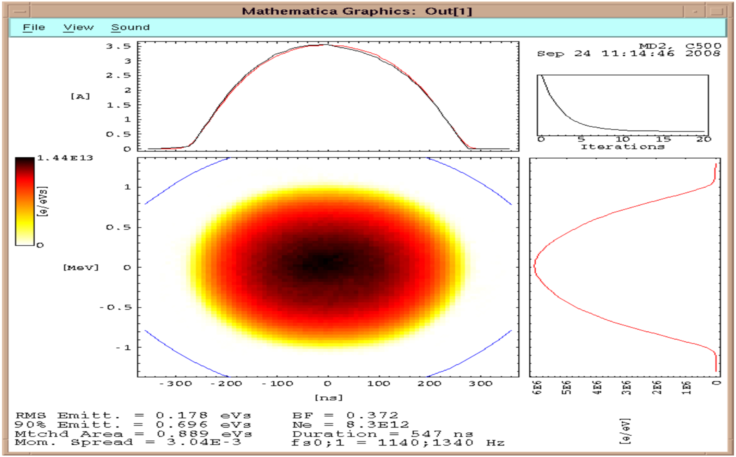

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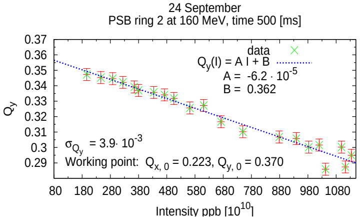

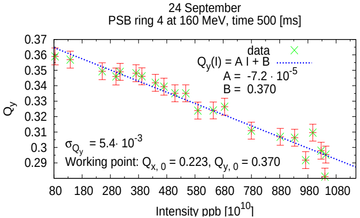

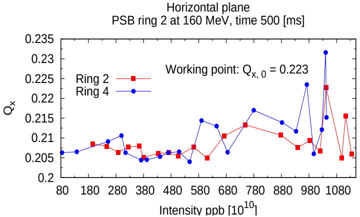

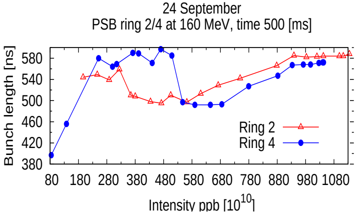

Tune shift @ 160 MeV 3/4

Tune shift for Gaussian beam

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Tune shift for Gaussian beam

$$\Omega - \omega_\beta \simeq -\frac{1}{4\sqrt{\pi}} \frac{N r_0 c^2}{\beta^2 \gamma T_0 \omega_\beta \sigma} i Z_{Eff}.$$

from the above formula we can obtain the total effective impedance.

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$$\Delta\Omega_{sc} = -\frac{N r_0 R}{\pi \gamma \beta^2 Q_y} \left(\underbrace{\frac{1}{B}}_{\text{electric image}} - \underbrace{\beta^2 \left(\frac{1}{B} - 1 \right)}_{\text{magnetic image}} \right) \frac{\xi^2}{h^2}, \quad \begin{cases} B = \dfrac{\sigma_t \beta c}{2\pi R} \\ \xi = \pi^2/16 \end{cases}$$

K. Y. NG, Physics of Intensity Dependent Beam Instabilities

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in the horizontal plane we didn't observe a clear shift and we should have seen

$$\Delta\Omega^H_{sc} \simeq \Delta\Omega^V_{sc}/4$$

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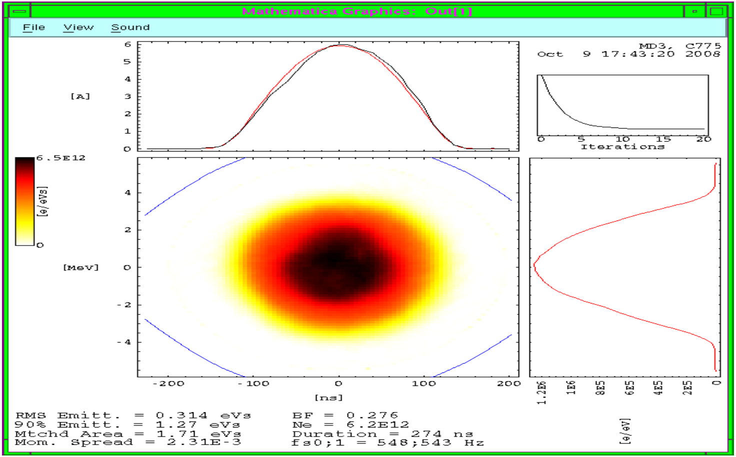

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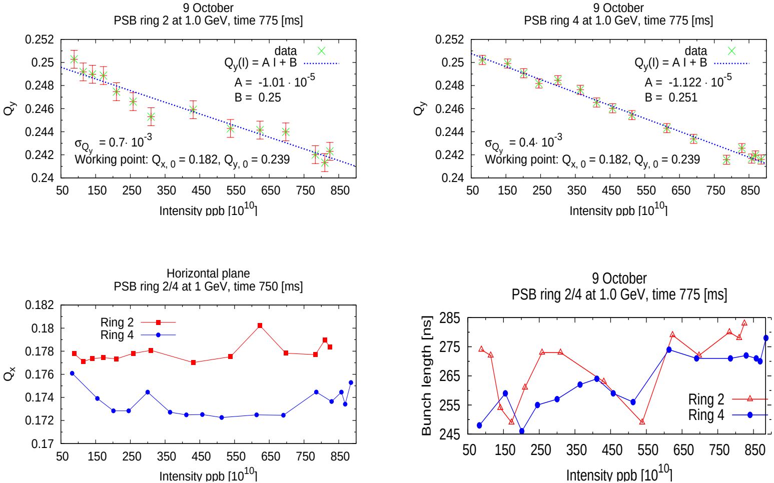

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it is not the case!
It is likely we are **overestimating** it, taking in account $h = 0.035$ m as pipe size.

The frequency range

For the $Z_{Eff.}$ we have

$$Z_{Eff.} = \frac{\sum_{-\infty}^{\infty} Z\left(\omega'\right) h(\omega' - \omega_\xi)}{\sum_{-\infty}^{\infty} h(\omega' - \omega_\xi)}, \quad \begin{cases} \omega' = \omega_0 p \\ \omega_\xi = \xi\omega_\beta/\eta \\ h(\omega) = exp(-\omega^2\sigma^2/c^2) \end{cases}$$

with

	160 MeV	1 GeV
$\omega_0[s^{-1}]$	$6.23 \cdot 10^6$	$10.5 \cdot 10^6$
η	-0.790	-0.295

we use the following range of the impedance

$$\begin{cases} 160\text{MeV} \rightarrow \omega' = 37.4\text{MHz} \\ 1\text{GeV} \rightarrow \omega' = 157\text{MHz} \end{cases}$$

Outline

The cycle and the losses 1/2

NORMGPS cycle @ 1.4 GeV

Losses mainly localized at two points throughout the cycle

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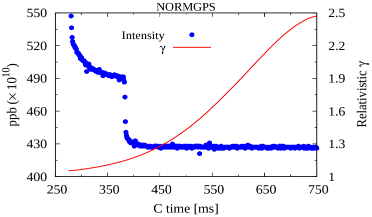

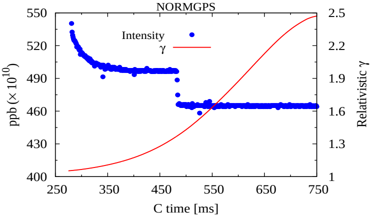

at $\approx$ 370 ms (left) and $\approx$ 470 ms (right)

The cycle and the losses 2/2

One rf cavity on (C02) and a Gaussian - like beam

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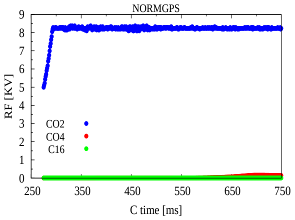

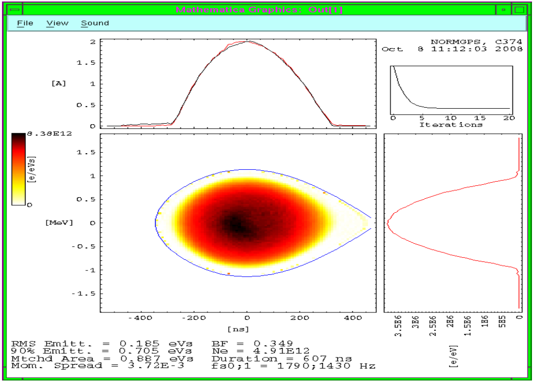

The two instabilities

The first at C time 378 ms

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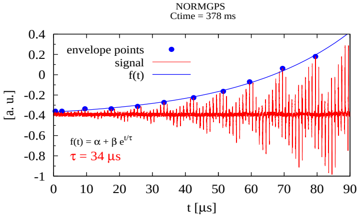

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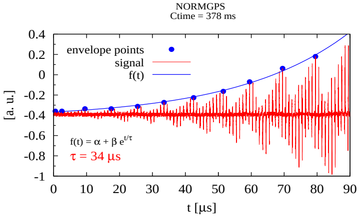

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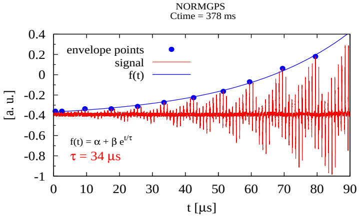

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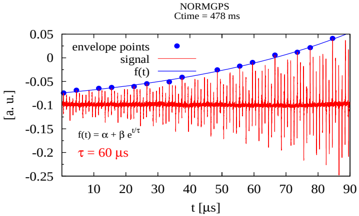

Growth rates

We have observed the following growth rates at $I \approx 490 \cdot 10^{10}$ ppb

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Ring 4 at 1.4 GeV, NORMGPS cycle

Ctime[ms]	378	478
τ [μs]	34	60

Outline

- Impedance estimated for ring 2 /4 both
- No big differences between the two
- Growth rates of the instabilities (ring 4) estimated
- The kind of instability is still to understand