Measurement of the SPS low frequency longitudinal impedance: second attempt

12 December 2007

Results of MD on 1.11.2007 and their comparison with measurements done on 20.07.2007 and in 2006

Part I: measurements based on PD signal

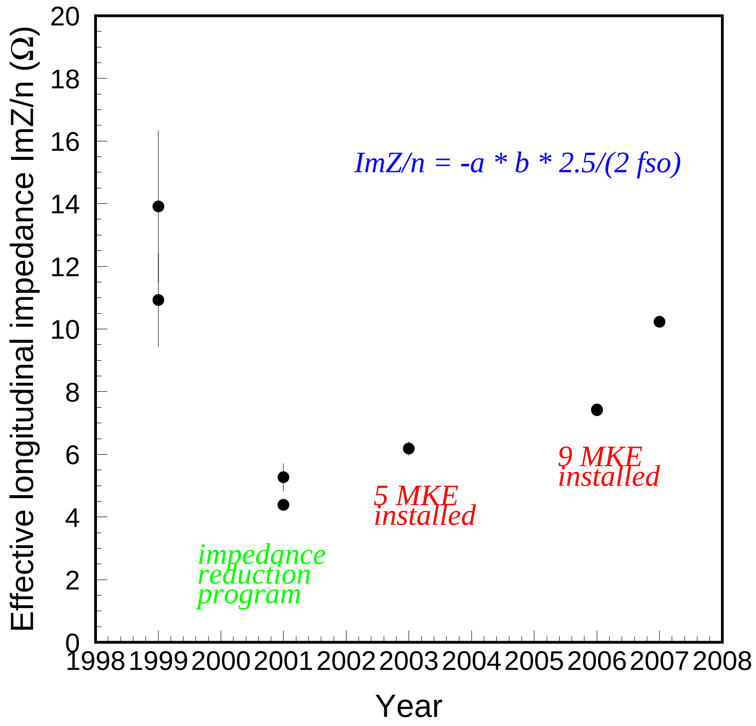
Part II: measurements based on MR data $\rightarrow$ Thomas

MD participants: T. Bohl, H. Damerau, T. Linnecar, M. Schokker, E. Shaposhnikova and J. Tuckmantel

Acknowledgments: G. Arduini, E. Metral and OP shift

History and motivation

Low frequency longitudinal inductive effective impedance



• Reduction in impedance, expected in 2007 due to removal of one MKE kicker and partial shielding of another one, was not observed during MD on 20.07.2007 $\longrightarrow$ second attempt on 1.11.2007

Estimation of impedance from quadrupole frequency shift:

$$\omega_2(N) = \Delta\omega_{inc}(N) + \Delta\omega_{coh}(N) + 2\omega_s^{(0)}$$

$$\omega_2(\tau, N) = 2\omega_{s0}\{1 - \frac{(\omega_{rf}\tau)^2}{64} + \frac{Ne\omega_0}{4\pi h V_0} Z_1 + (\frac{2}{\pi})^{1/2} \frac{16 N e\omega_0 h^2}{V_0(\omega_{rf}\tau)^3} [(\frac{\mathrm{Im}Z}{n})_0 - \frac{3}{16\sqrt{2}} (\frac{\mathrm{Im}Z}{n})_{eff}^{m=2}]\},$$

where ($\omega_p = p\omega_0$)

$$Z_1 \simeq \sum_{p=-\infty}^{\infty} p\,\mathrm{Im}Z(\omega_p) e^{-\omega_p^2\sigma^2/2},$$

and

$$\mathrm{Im}(Z/\omega)_{eff}^{m} = \frac{\sum_{p=-\infty}^{\infty} h_m(\omega_p) Z(\omega_p)/\omega_p}{\sum_{p=-\infty}^{\infty} h_m(\omega_p)},$$

The spectral density for a Gaussian bunch: $h_m(\omega) = (\omega\sigma)^{2m} e^{-\omega^2\sigma^2}$

- Complicated dependence on bunch length $\Rightarrow$ the same experimental conditions are essential for comparison

Experimental conditions

Requirements: single bunch with variable intensity and constant longitudinal parameters

- 26 GeV/c, mismatched capture in 900 kV at 200 MHz
- measurements of quadrupole oscillation frequency from

  (I) bunch profiles (Thomas)

  $\longrightarrow$ peak amplitude oscillations

  $\longrightarrow$ bunch length

  $+$ intensity measurement from BCT and calibrated peak amplitude

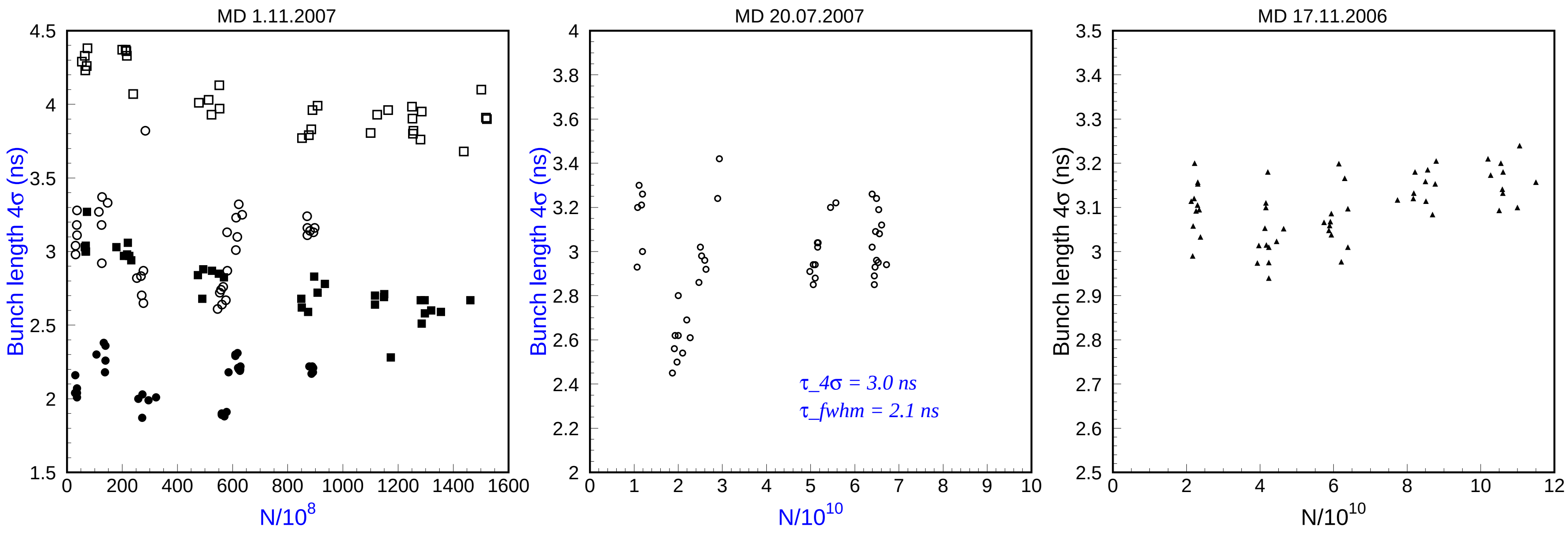
  (II) peak detected signal

  $\longrightarrow$ peak amplitude oscillations

  $+$ intensity measurement from BCT

  $+$ simultaneous bunch length measurement

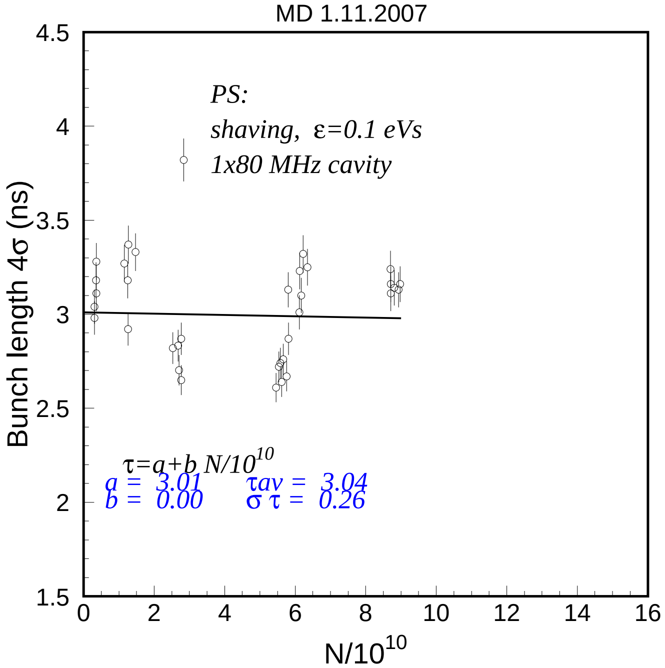
(II) Bunch length (4σ Gaussian fit) as a function of intensity (measured in the PS)

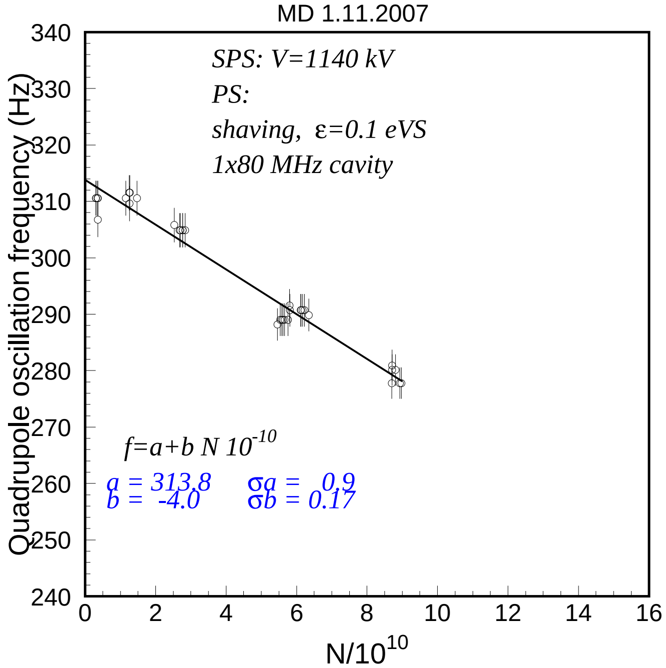


- 2006: $\tau_{av} = 3.1$ ns and $\varepsilon \sim 0.2$ eVs (long. shaving in PS from 0.3 eVs)
- 20.07.2007: $\tau_{av} = 3.0$ ns and $\varepsilon \sim 0.1$ eVs - long. shaving in PS (V dip)
- 1.11.2007: with long. shaving in PS: $\varepsilon \sim 0.1$ eVs, no shaving: $\varepsilon \sim 0.2$ eVs; with 1x80 MHz cavity - long bunches and 2x80 MHz - short $\rightarrow$ 4 data sets

$2Q_s$ and bunch length as a function of intensity on 1.11.2007:

Set (11): small emittance (shaving) and long bunches (1x80 MHz)

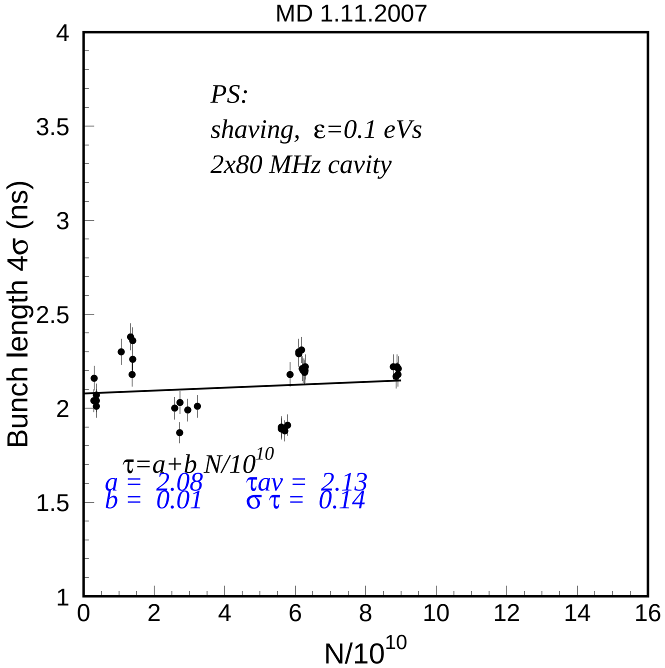


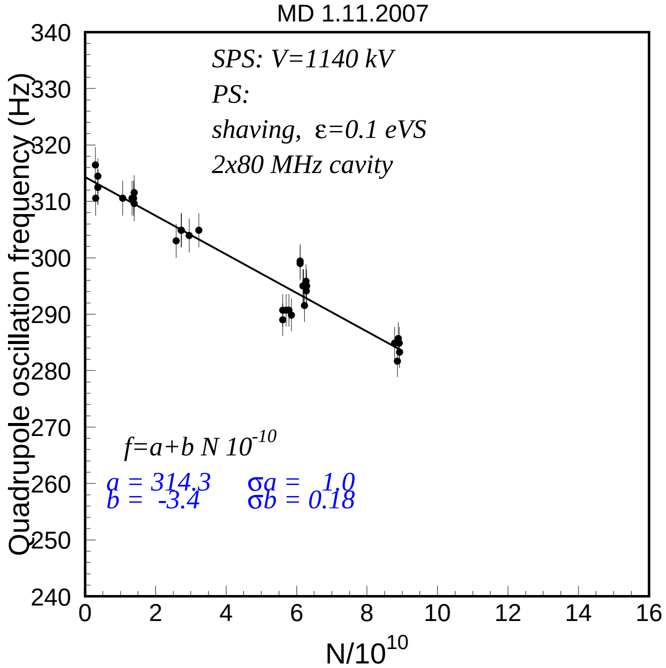


$\Rightarrow \tau = 3.04 \pm 0.26$ ns and $b = -4.0 \pm 0.2$ - close to 2007

$2Q_s$ and bunch length as a function of intensity on 1.11.2007

Set (12): small emittance (shaving) and short bunches (2x80 MHz)

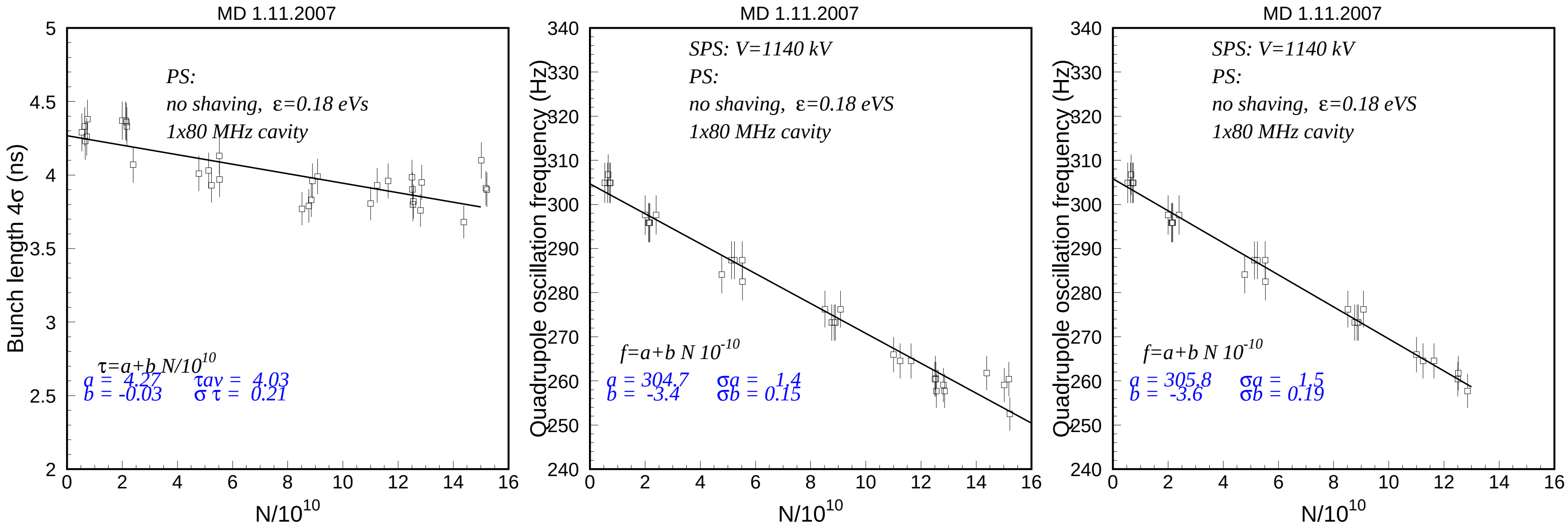




$\Rightarrow \tau = 2.13 \pm 0.14$ ns and $b = -3.4 \pm 0.18$

$2Q_s$ and bunch length as a function of intensity on 1.11.2007

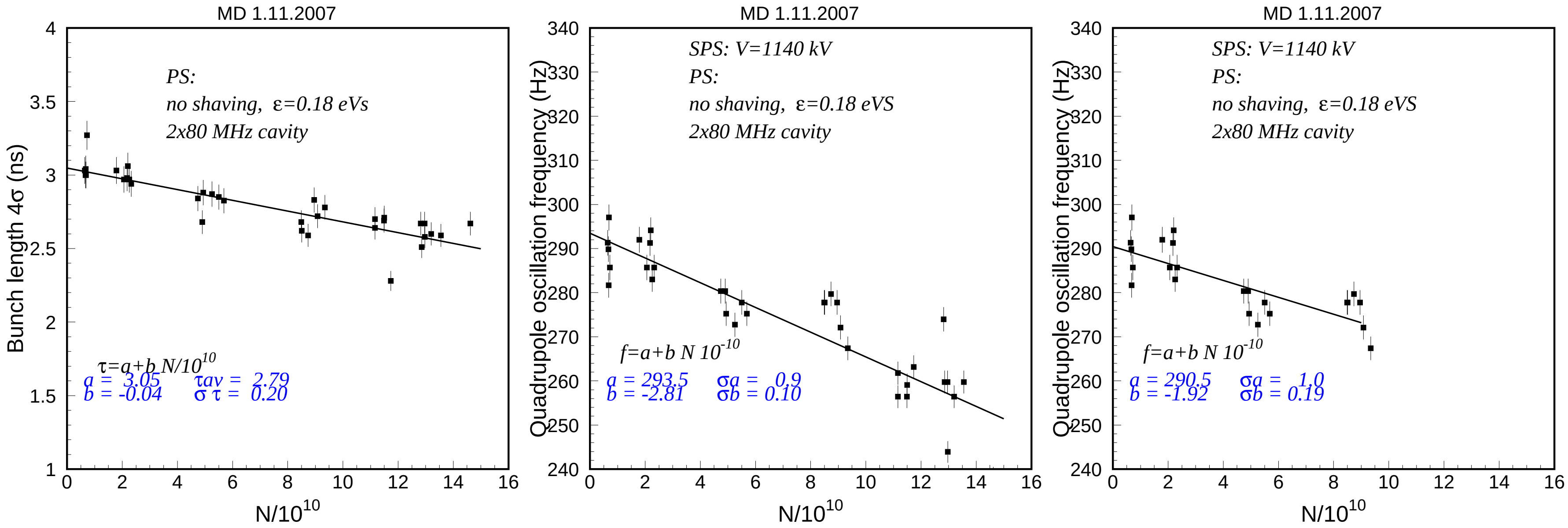
Set (21): large emittance (no shaving) and long bunches (1x80 MHz)



$\Rightarrow \tau = 4.03 \pm 0.21$ ns and $b = -3.4 \pm 0.15$

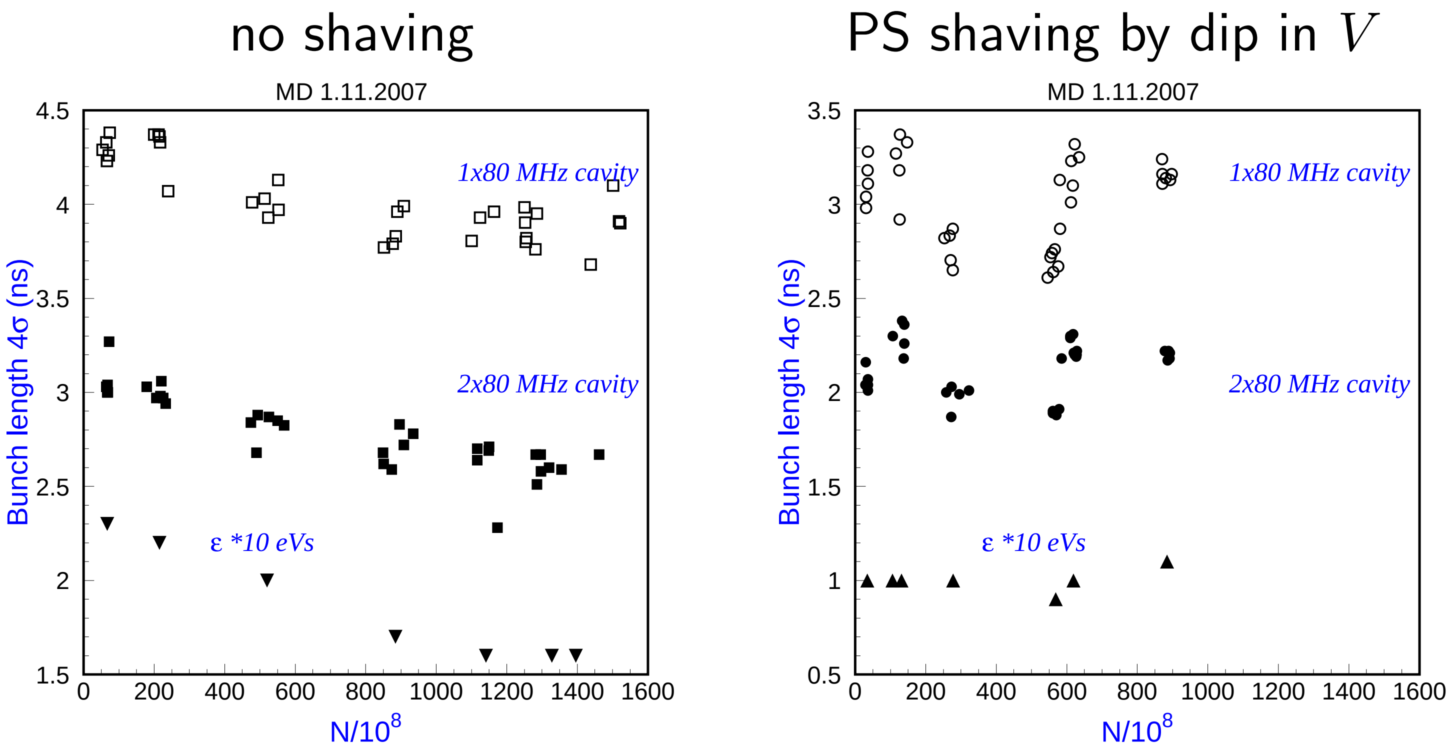
$2Q_s$ and bunch length as a function of intensity on 1.11.2007

Set (22): large emittance (no shaving) and short bunches (2x80 MHz)



$\Rightarrow \tau = 2.8 \pm 0.2$ ns and $b = -2.8 \pm 0.1$ - most close to 2006 (bunch length and emittance), but large negative (!) slope and scatter

ε_L and τ measured in the PS as a function of intensity



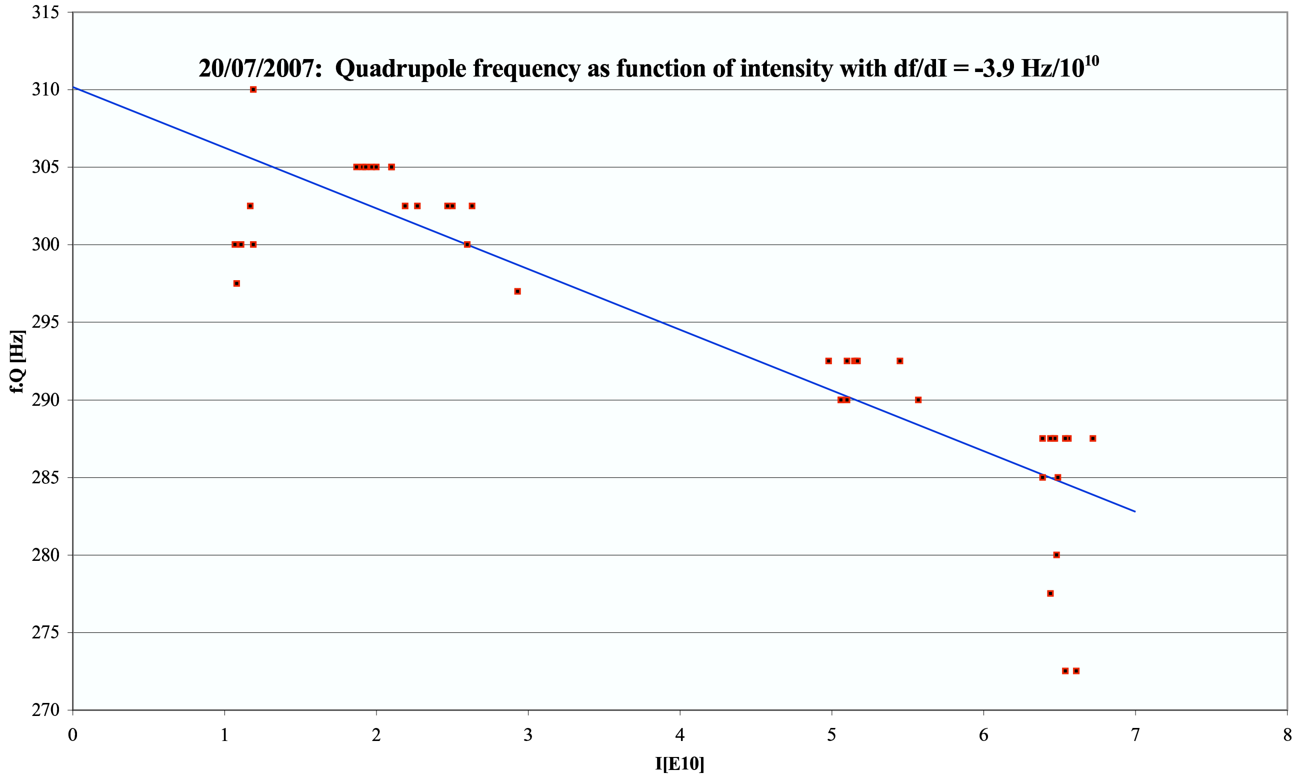
⇒ Longitudinal emittance in the PS is decreasing with intensity - why?

⇒ Shaving reduces the slope but increases the scatter

(II) Measurements of quadrupole frequency shift

PD signal - FFT with dynamic signal analyzer

(measurements start 1 s after injection, acquisition time 400 ms)

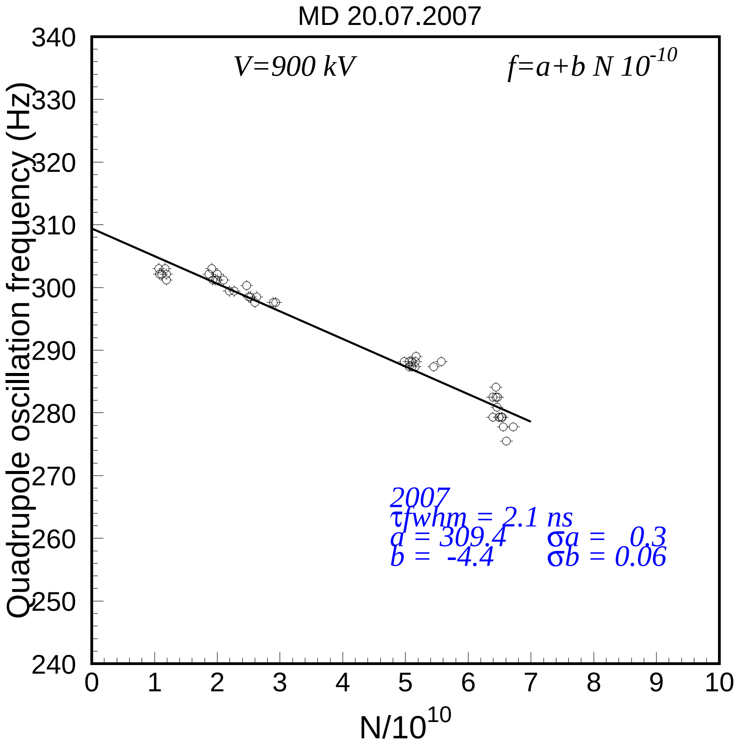


$a = 310$ Hz, $b = -3.9 \pm 0.07$ Hz

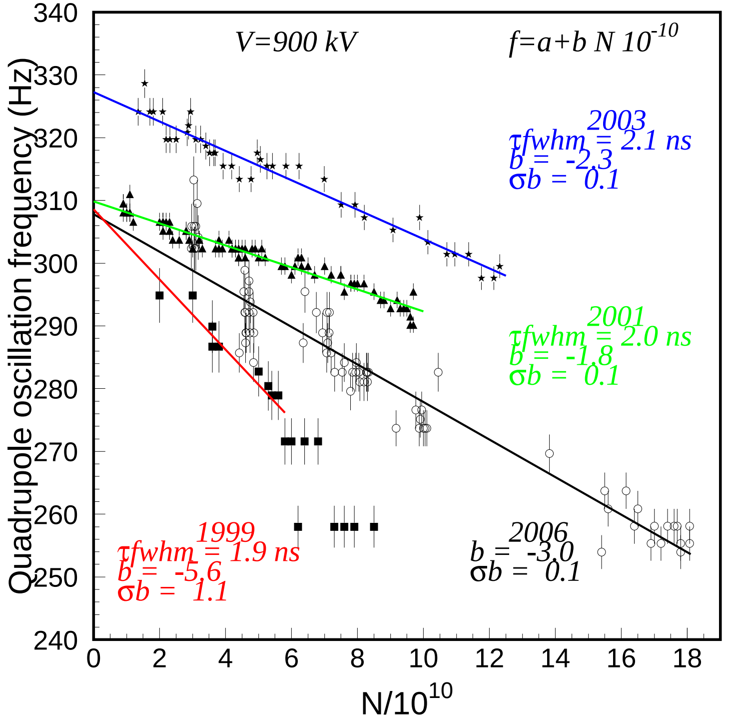
(II) Measurements of quadrupole frequency shift

PD signal: first 5-10 oscillations on the scope

2007



1999-2006



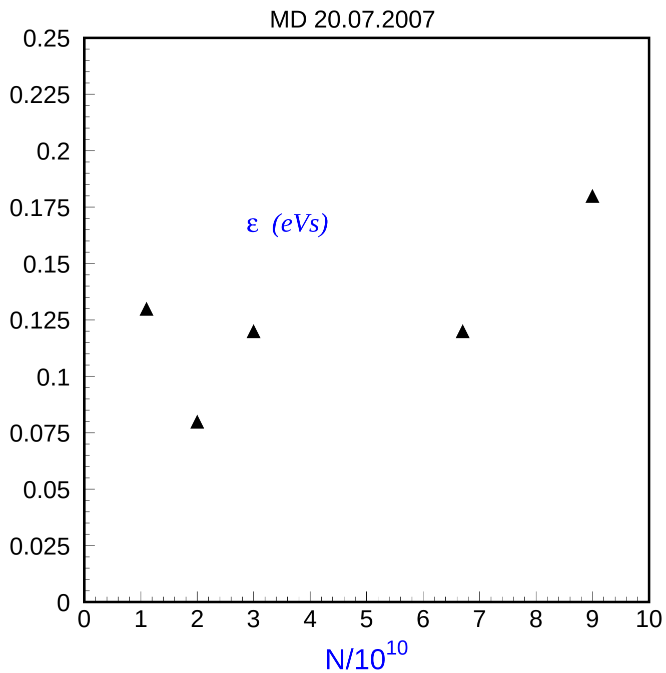
Measurements in 2006 and 2007

MD date	ε [eVs]	n_{cav} in PS	τ_{av} [ns]	$\|b\|$ from MR inj.	$\|b\|$ from PD inj.	$\|b\|$ from PD 1 s
27.10.06	0.2-0.3	2	3.1?	3.0	2.9	3.0
17.11.06	0.25	2	3.1	3.0	3.0	3.0
20.07.07	0.08-0.18	1&2	3.0	4.5	4.4	3.8

MD on 1.11.2007

data set	ε [eVs]	n_{cav} in PS	bunch length [ns] $\tau_{av} \pm D\tau$	bunch length [ns] slope	$\|b\|$ from PD at inj. (scope)	$\|b\|$ from PD at 1 s (FFT)
S11	0.1	1	3.04 ± 0.26	0.00	4.0 ± 0.2	3.5 ± 0.3
S12	0.1	2	2.13 ± 0.14	0.01	3.4 ± 0.2	3.5 ± 0.1
S21	0.19	1	4.03 ± 0.21	- 0.03	3.4 ± 0.2	2.3 ± 0.2
S22	0.19	2	2.8 ± 0.12	- 0.04	2.8 ± 0.1	2.1 ± 0.2

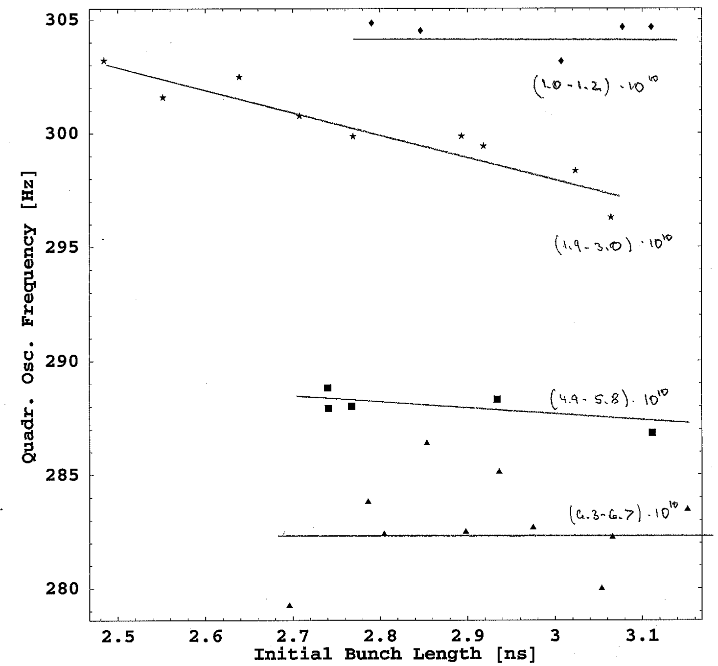
ε_L measured in the PS as a function of intensity MD on 20.07.2007



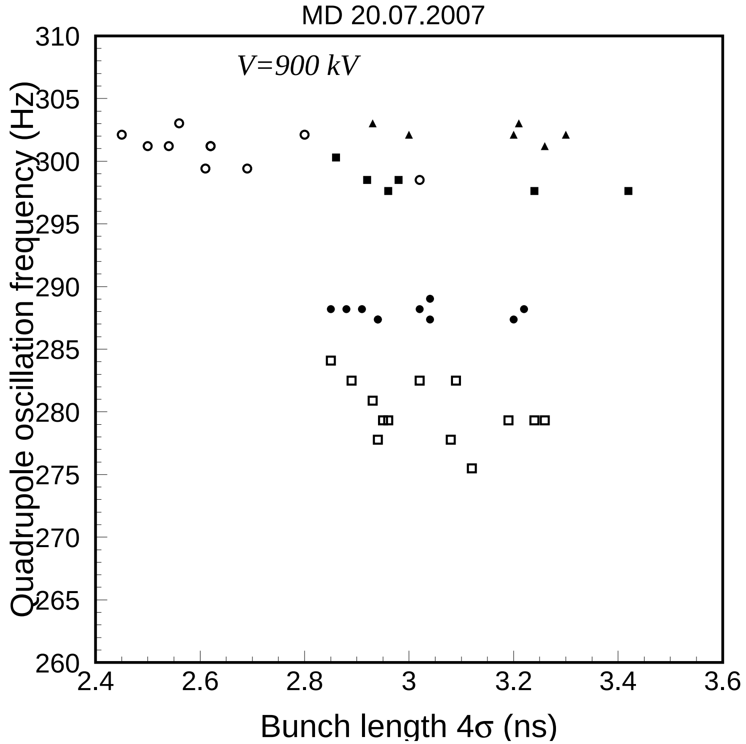
- With shaving in the PS by voltage dip

Dependence of quadrupole frequency on bunch length

(I) - bunch profile



(II) - PD signal



⇒ No significant dependence of quadrupole frequency on bunch length for fixed intensity (and emittance?)

Summary of $2Q_s$ measurements at the last MD (1.11.2007)

data set	ε [eVs]	n_{cav} in PS	$\tau_{av} \pm D\tau$ [ns]	$\lvert b \rvert$ at inj. (scope)	inj (MR)	1 s (FFT)
S11	0.1	1	3.04 ± 0.26	4.0 ± 0.2	4.1 ± 0.1	3.5 ± 0.3
S12	0.1	2	2.13 ± 0.14	3.4 ± 0.2	3.4 ± 0.2	3.5 ± 0.1
S21	0.19	1	4.03 ± 0.21	3.4 ± 0.2	3.1 ± 0.1	2.3 ± 0.2
S22	0.19	2	2.8 ± 0.12	2.8 ± 0.2	2.2 ± 0.3	2.1 ± 0.2

$\Rightarrow$ Results of measurements (b) depend

- at injection - on bunch length and emittance
- at 1 s - on emittance

Conclusions

- Results of measurements are sensitive to both bunch length and emittance
- Single bunch production changed from 2003:
  - PSB: $h = 2 \rightarrow h = 1$
  - PS: additional longitudinal scraping needed to reduce ε_L (to see quadrupole oscillations with 900 kV in the SPS)
- Beam recently used for quadrupole frequency measurements did not satisfy requirements of constant ε_L and τ
- Measurements in 2006 and on 20.07.2007 were done with different ε_L
- Accurate comparison with 2006 and 2001 could be done in 2008 with corresponding ε_L and τ. Requires careful production and monitoring.