TRANSITION CROSSING REQUIREMENTS FOR PS2

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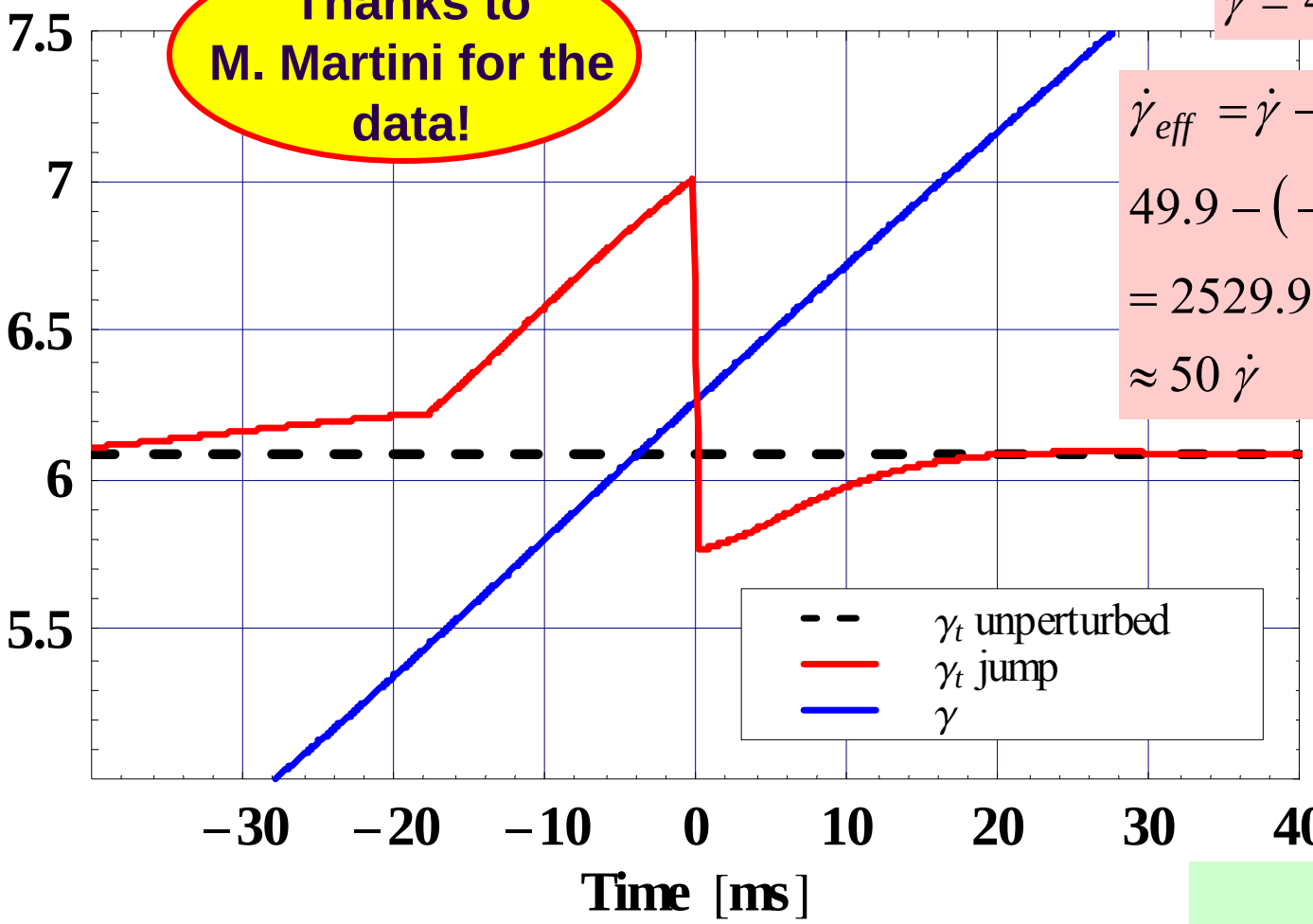
(30 min, 14 slides)

- Introduction with the case of the PS & PS2 beam parameters
- General result for the nonadiabatic transition region without collective effects (and nonlinearities) Space Charge
- (Asymmetric) γ_t jump for nTOF in the PS with long. SC & impedances
- Computation of the instability rise-times near transition for nTOF
- Application to the different beams considered for PS2
- Conclusions and outlooks

Introduction with the case of the PS (1/2)

Thanks to M. Martini for the data!



$$\dot{\gamma} = 49.9\ \mathrm{s}^{-1}$$

$$\dot{\gamma}_{eff} = \dot{\gamma} - \dot{\gamma}_t = 49.9 - (-2480)\ \mathrm{s}^{-1} = 2529.9\ \mathrm{s}^{-1} \approx 50\ \dot{\gamma}$$

$$\eta = \frac{1}{\gamma_t^2} - \frac{1}{\gamma^2}$$

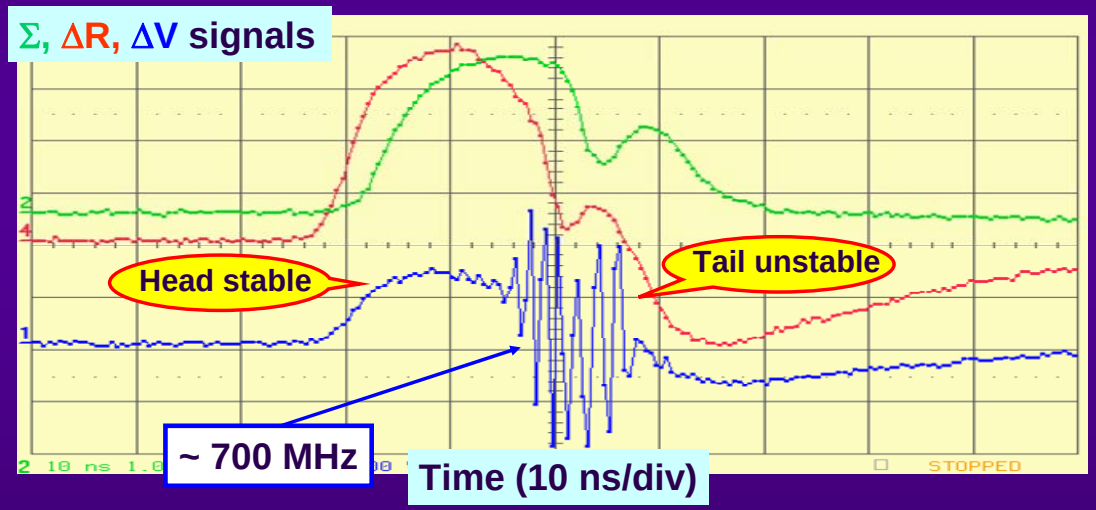
$\Longrightarrow$ $\Delta\gamma_t$ = - 1.24 in Δt_{jump} = 500 μs

Introduction with the case of the PS (2/2)

$\Longrightarrow$ Currently, the nTOF bunch is the most critical at transition due to a TMCI which develops near transition crossing

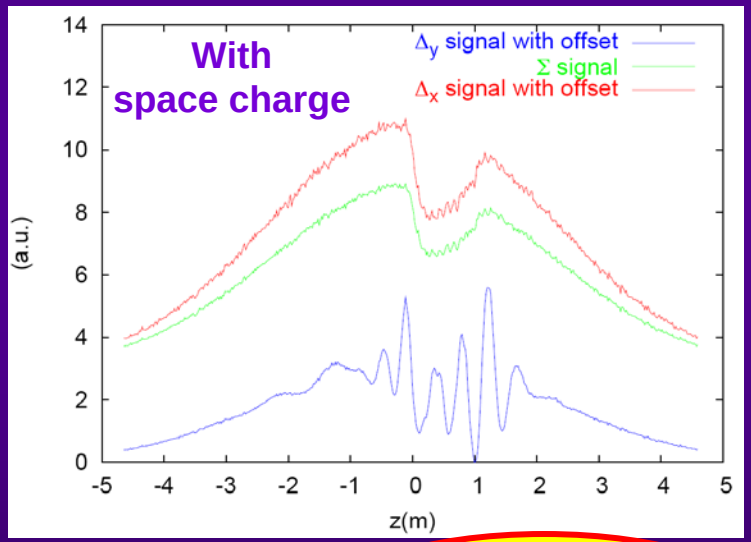
Transverse Mode Coupling Instability

Measurements in 2000



$\Longrightarrow$ Instability suppressed by increasing the longitudinal emittance

Simulation by Giovanni with HEADTAIL (ICAP06)



Broad-Band (BB) impedance

$\Longrightarrow$ > 2.1 eVs are needed for ~ 7×10^{12} p/b (PS/RF Note 2002-198)

$f_r = 1\,\mathrm{GHz}$ $\quad Q = 1$ $\quad Z_y^{BB} = 3\,\mathrm{M\Omega/m}$

PS2 beam parameters (1/2)

	PS	PS2				
	nTOF	nTOF 10 MHz	FT 10 MHz	LHC 10 MHz	FT 40 MHz	LHC 40 MHz
R [m]	100	214.3				
ρ [m]	70	100				
Bdot [T/s]	2.2	1.5				
Vrf [kV]	200	500	500	500	1500	1500
h	8	15	45	45	180	180
α_p	0.027	0.0076				
ϵ_L [eVs]	2/2.3/2.5	2.5	1.5	1.5	0.4	0.6
N_b [10^{10} p/b]	800	1000	320	190	80	48
ϵ_t (1σ, norm.) [μm]	5	6	6	2.5	6	2.5
β_t average [m]	16*	15*				
Pipe [cm × cm]	3.5 / 7	3.5 / 7				
Q_t	6.25	11.25**				

* R / Q_t

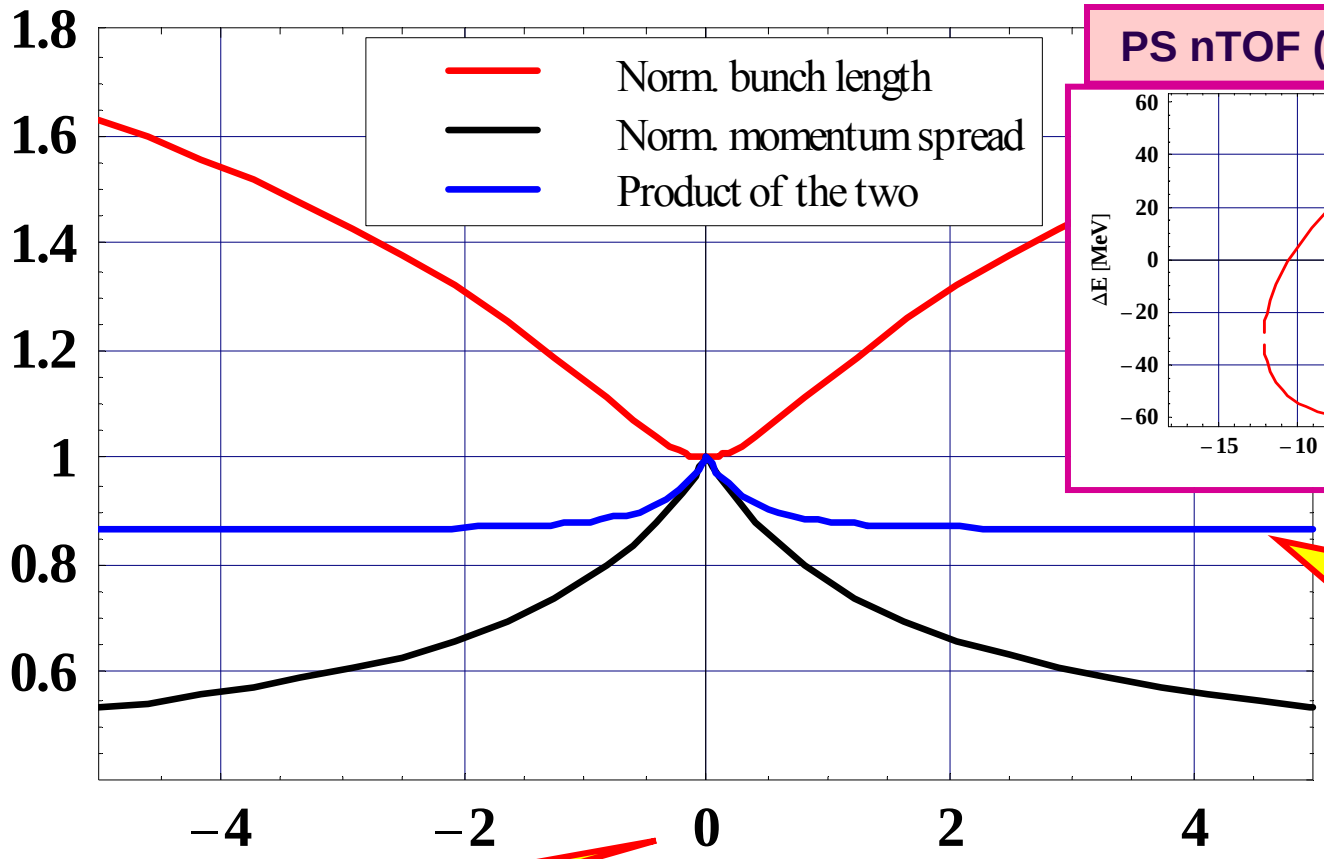
** Assumption: $Q_t \sim \gamma_t = 1 / \sqrt{\alpha_p} = 11.47$

PS2 beam parameters (2/2)

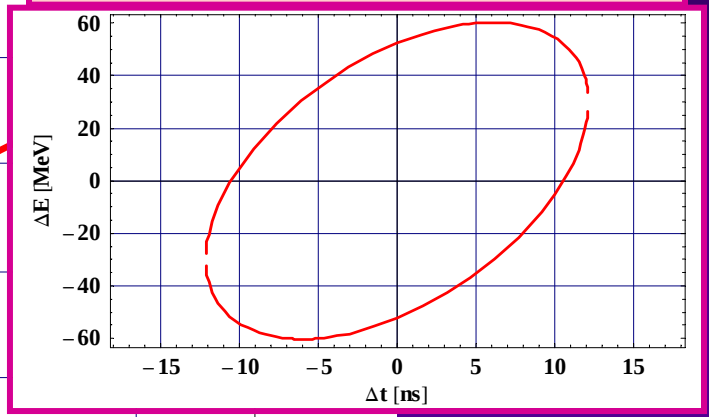
	PS2			
	LHC bis 10 MHz	LHC bis 40 MHz	LHC 50ns 20 MHz	nTOF 20 MHz
R [m]				
ρ [m]				
Bdot [T/s]				
Vrf [kV]	500	1500	1500	1500
h	45	180	90	90
α_p				
ϵ_L [eVs]	1.5	0.6	0.7	1.5
N_b [10^{10} p/b]	170	42	62	160
ϵ_t (1σ, norm.) [μm]	2.5	2.5	2.5	6
β_t average [m]				
Pipe [cm × cm]				
Q_t				

Question: Which $\Delta\gamma_t$ and Δt_{jump} are needed in the PS2?

General analytical result for the nonadiabatic transition region (with neither SC, or BB imp., nor γ_t jump)



PS nTOF (2 eVs) at transition



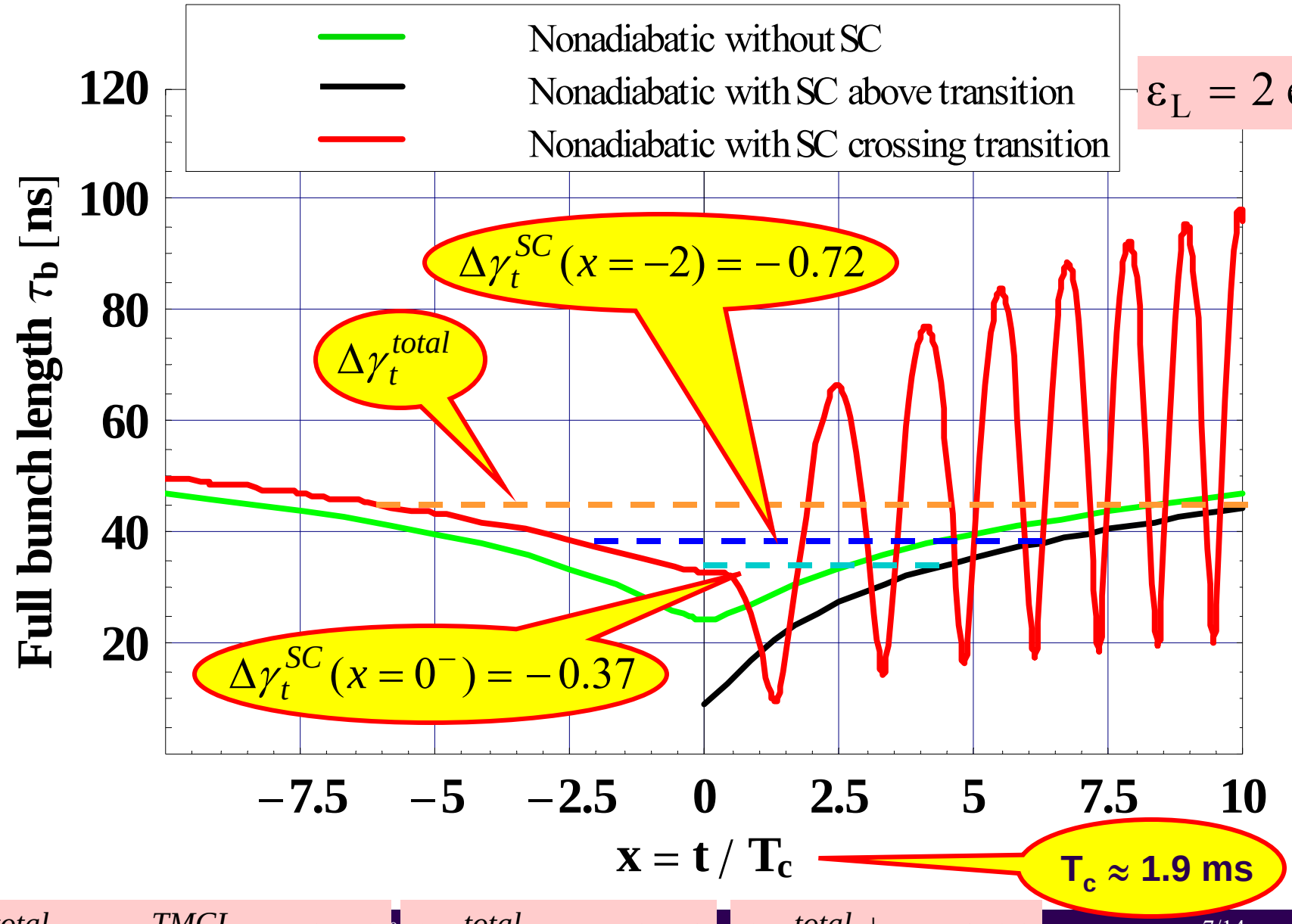
⟹ The bunch is tilted near transition

Transition

Nonadiabatic time

⟹ Same picture as the one obtained by K.Y. Ng in his book "Physics of Intensity Dependent Beam Instabilities" (2006), p. 707

(Asymmetric) γ_t jump for nTOF in the PS (considering SC & L & TMCI)



$\Delta\gamma_t^{total} = \Delta\gamma_t^{TMCI} \approx -1.58$ $\Delta\gamma_t^{total,-} = -0.58$ $\Delta\gamma_t^{total,+} = -1.00$

Summary table for PS and PS2 (considering SC & L & TMCI) (1/2)

Assuming the same BB impedances as in the current PS

$$\frac{Z_l^{BB}}{n} = 20\,\Omega$$

$$f_r = 1\,\text{GHz}$$

$$Q = 1$$

	PS			PS2				
	nTOF (2 eVs)	nTOF (2.3 eVs)	nTOF (2.5 eVs)	nTOF (10 MHz)	FT (10 MHz)	LHC (10 MHz)	FT (40 MHz)	LHC (40 MHz)
Tc [ms]	1.86	1.86	1.86	4.29	2.97	2.97	1.27	1.27
SC imp. [Ω]	- 19.85 × j	- 19.85 × j	- 19.85 × j	- 5.36 × j	- 5.36 × j	- 6.62 × j	- 5.36 × j	- 6.62 × j
$\Delta\gamma_t$ with SC from x = - 2	-0.72	-0.65	-0.61	-1.50	-0.88	-0.79	-0.50	-0.34
$\Delta\gamma_t$ with SC & L & TMCI	-1.58	-1.35	-1.23	-6.85	-2.91	-2.97	-2.68	-1.08

It is the $\Delta\gamma_t$ of the present PS

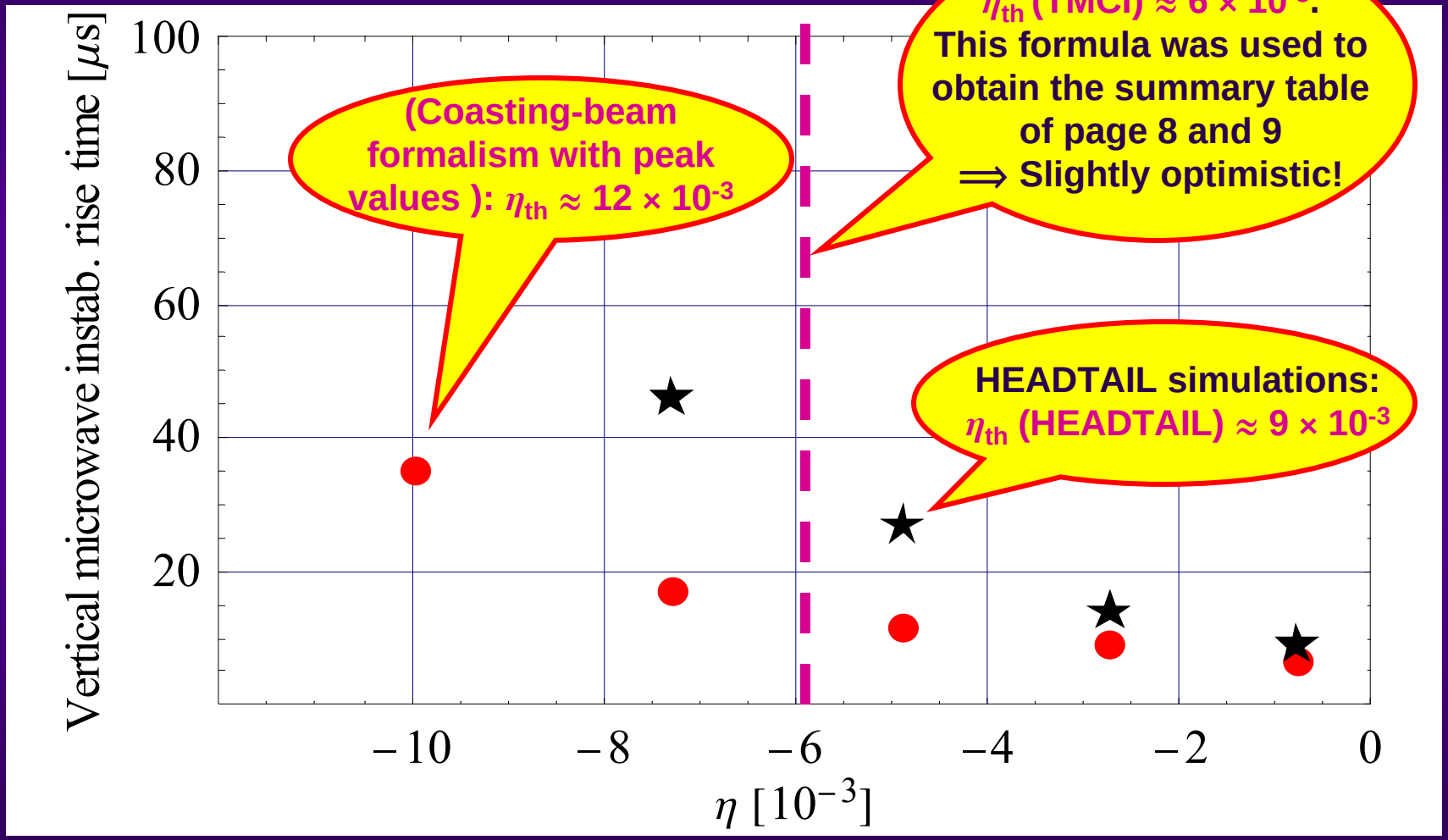
= -1.50 if PS2 BB imp. ~ 6 times smaller than PS

Summary table for PS and PS2 (considering SC & L & TMCI) (2/2)

	PS2			
	LHC bis (10 MHz)	LHC bis (40 MHz)	LHC 50ns (40 MHz)	nTOF (40 MHz)
Tc [ms]	2.97	1.27	1.59	1.59
SC imp. [Ω]	- 6.62 × j	- 6.62 × j	- 6.62 × j	- 5.36 × j
$\Delta\gamma_t$ with SC from x = - 2	-0.77	-0.33	-0.43	-0.39
$\Delta\gamma_t$ with SC & L & TMCI	-2.44	-0.95	-1.41	-1.36

Vertical microwave (BB) instability rise-times (without acceleration)

PS nTOF (2 eVs)



Conclusions and outlooks (1/4)

- Transition crossing with a γ_t jump looks possible in PS2 for the densities foreseen with the FT and LHC beams
- It its more difficult for conditions corresponding to the present nTOF bunch (10 MHz option). In this case a strong reduction of the Broad-Band impedance is necessary to keep the required γ_t jump $\leq$ ~ - 2 *
- Further improvement of the longitudinal density beyond that of nTOF seems excluded, even if only the (unavoidable!) space-charge impedance of the beam is taken into account

* - It is believed that $\Delta\gamma_t$ until ~ - 2 can be performed

- It should be done with $\Delta Q_t \approx 0$

- During the γ_t jump the dispersion has the tendency to increase $\Longrightarrow$ This can lead to an increase of the horizontal beam size and subsequent beam losses

Conclusions and outlooks (2/4)

- Reminder on the vertical BB impedance in the PS and SPS (measured from coherent vertical tune shift vs. intensity):
  - PS: ~ 3 MΩ/m
  - SPS: ~ 22 MΩ/m in 2007 (i.e. ~ 7 times higher for a machine 11 times bigger)

~ half is coming from the numerous kickers

  - The PS2 will be more than 2 times bigger than the present PS and will operate at higher energy (more powerful kickers needed etc.)

$\Longrightarrow$ Will be challenging to build the PS2 machine within the required (transverse) impedance budget (~ 6 times smaller than the present PS!)

Conclusions and outlooks (3/4)

- Concerning the time Δt_{jump} needed to perform the γ_t jump in PS2
  - Vertical microwave (BB) instability rise-times are larger in the PS2 compared to the present PS, where the shortest rise-time is ~ 10 μs (by at least a factor ~ 3)
  - Longitudinal negative-mass (SC) instability rise-times are larger in the PS2 compared to the present PS, where the shortest rise-time is ~ 20 μs (also by at least a factor ~ 3)

$\Longrightarrow$ The time Δt_{jump} needed to perform the γ_t jump of the present PS (i.e. ~ 500 μs) should be enough for the PS2

Conclusions and outlooks (4/4)

- Proposed MDs in the PS in 2008 to check our estimates (fast analog signals are available in the CCC since the end of 2007)

S. Aumon and W. Bartmann will be the contact persons for these studies

- Perspectives with HEADTAIL (which was upgraded recently for these studies) $\Longrightarrow$ Possibility to
  - Compute the transverse instability rise-time with acceleration
  - Include a γ_t jump
  - Include SC
  - Take into account the high-order components of the momentum-compaction factor
  - …

$\Longrightarrow$ It should be possible to benchmark all the measurements (which will be performed in 2008) against HEADTAIL