

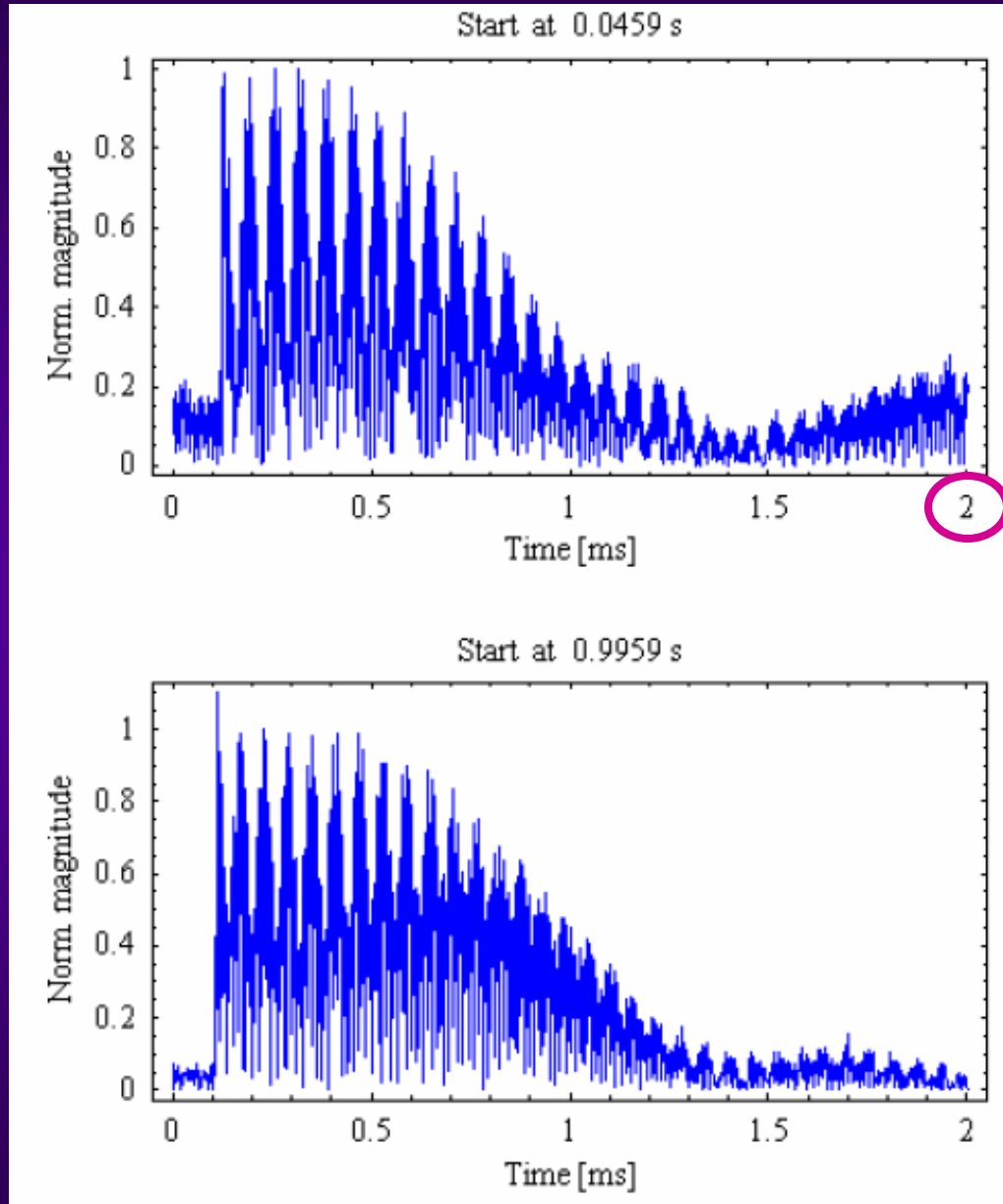
DECOHERENCE FROM CHROMATICITY & NONLINEAR DETUNING OR SPACE CHARGE AT PS INJECTION

E. Métral

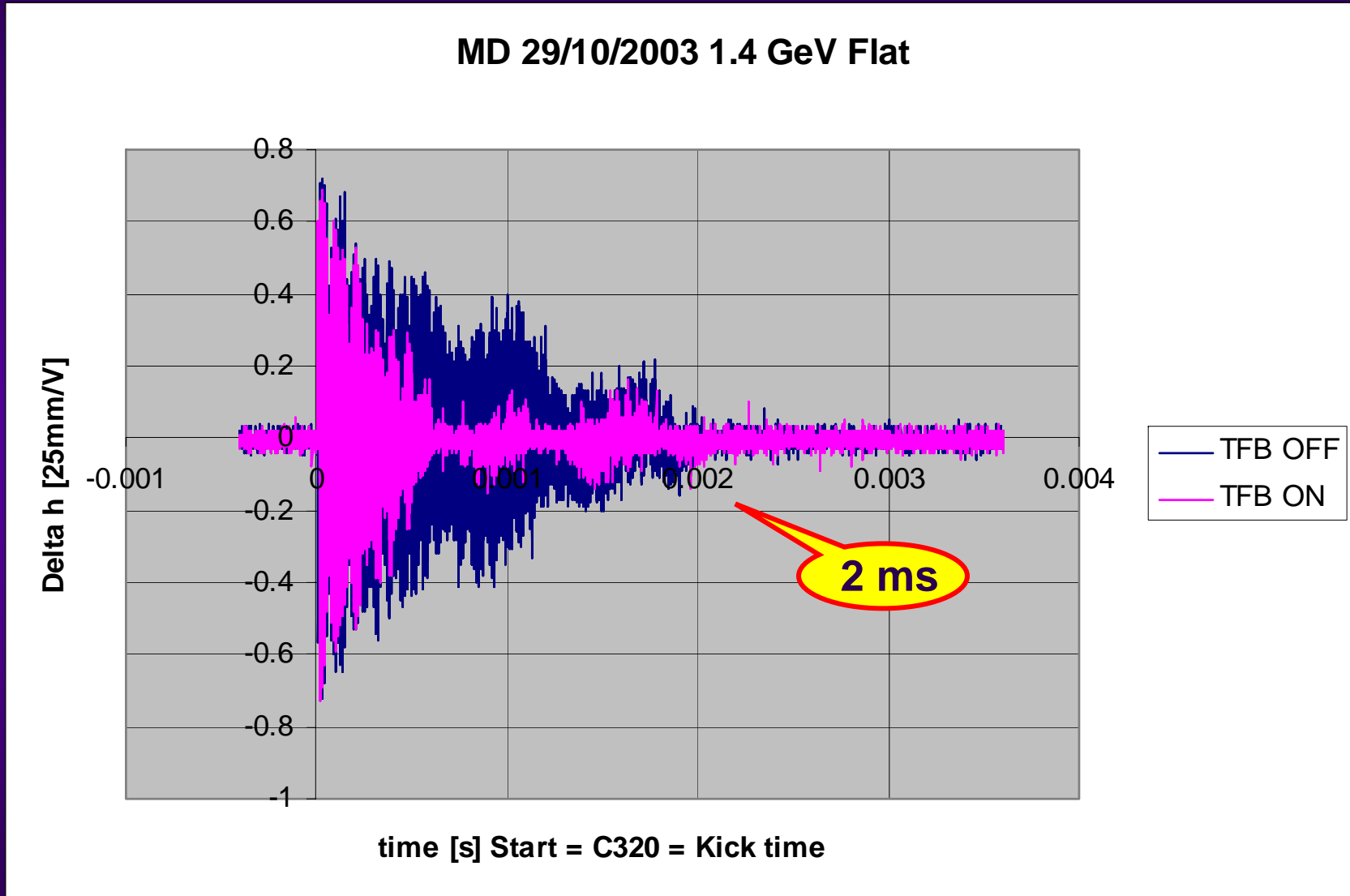
(Study with F. Blas, E. Benedetto and F. Zimmermann)

- ◆ **Measurements by M. Gasior and F. Blas**
- ◆ **Chromaticity and nonlinear detuning \Rightarrow Analytical formulae**
- ◆ **Space charge ONLY \Rightarrow L. Vos' approach ...**
- ◆ **Head-tail damping**
- ◆ **Comparison between analytical formulae and HEADTAIL simulations by Elena (with chromaticity only)**

MEASUREMENTS ON THE LHC BEAM BY M.GASIOR (15/11/04)



MEASUREMENTS ON A BUNCH SIMILAR TO LHC BY F.BLAS (29/10/03) (1/2)



MEASUREMENTS ON A BUNCH SIMILAR TO LHC BY F.BLAS (29/10/03) (2/2)

parameter	symbol	PS	
bunch population	N_b	2×10^{12}	
beta function	$\beta_{x,y}$	16 m	
rms beam size	$\sigma_{x,y}$	4.186 mm	(normalized emittance= $2.5\mu m$)
rms bunch length	σ_z	11.24 m	(bunch full length= $150ns$)
rms momentum spread	δ_{rms}	1.132×10^{-4}	
synchrotron tune	Q_s	0.0266	($f=650Hz$)
circumference	C	628m	
nominal tunes	$Q_{x,y}$	6.22	
chromaticity	ξ	-1	
relativistic factor	γ	2.49211	(kinetic energy= $1.4GeV$)
cavity voltage	V	25kV	
cavity harmonic number	h	8	
wakefield (Broad Band Resonator)			
resonator frequency	f_r	1.4GHz	
quality factor		1	
transverse impedance	Z_x	1MΩ/m	

Cf. Elena's talk on 11/02/05

10^{-3} instead of 10^{-4} for the momentum spread (typo)

Maximum tune shift due to space charge:

$\Delta Q \approx 0.35$ ← Good agreement with HEADTAIL

With $D_x \approx 2.6$ m I find

$$\Delta Q_x^{SC,max} \approx -0.3$$

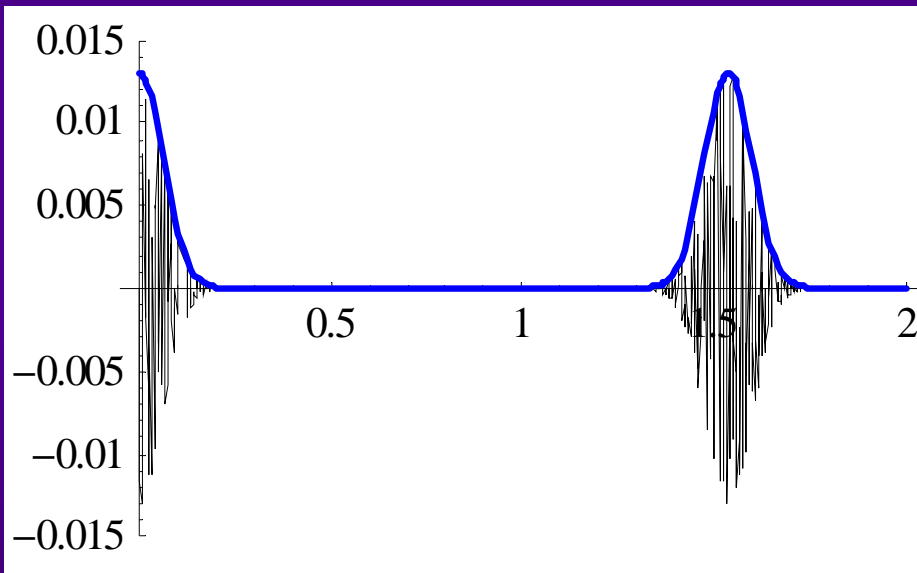
$$\Delta Q_y^{SC,max} \approx -0.35$$

I suspect wrong data from F. Blas' measurements...

CHROMATICITY AND NONLINEAR DETUNING (1/2)

- ◆ Analytical formulae by Minty & Chao & Spence (SLAC-PUB-95-6815) \Rightarrow Application to the PS without nonlinear detuning (full recoherence)

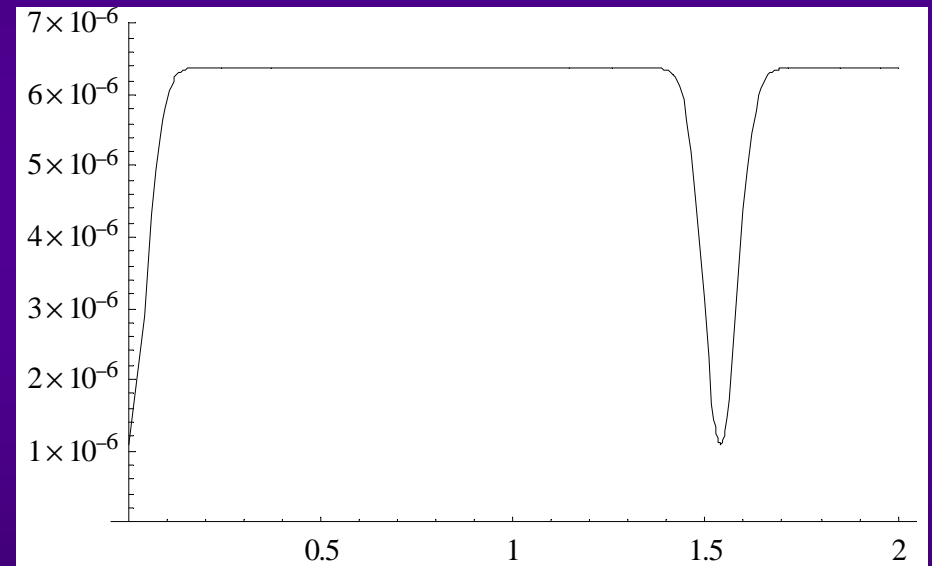
Bunch centroid motion [m]



Time [ms]

$$T_s \approx 1.5 \text{ ms}$$

Bunch rms emittance [m]

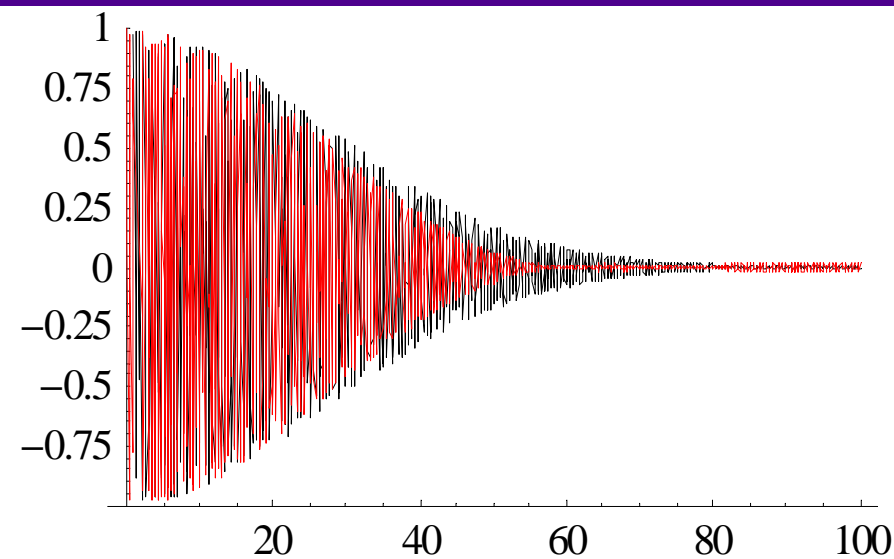


Time [ms]

CHROMATICITY AND NONLINEAR DETUNING (2/2)

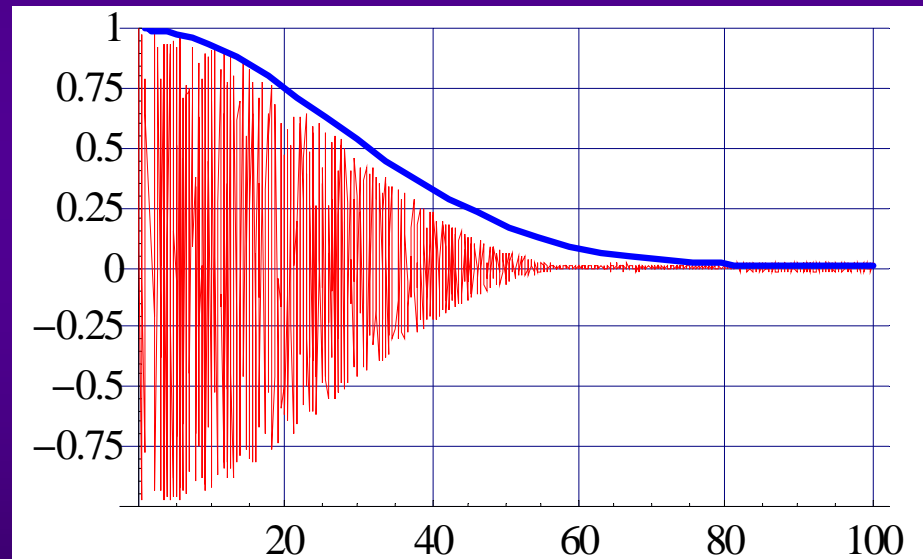
- ◆ Comparison between (1) the analytical formulae and (2) the inverse Fourier transform of the betatron frequency distribution = the response to a δ -pulse excitation = Green function

Normalised bunch centroid motion



Time [turns]

Normalised bunch centroid motion



Time [turns]

⇒ Good agreement !

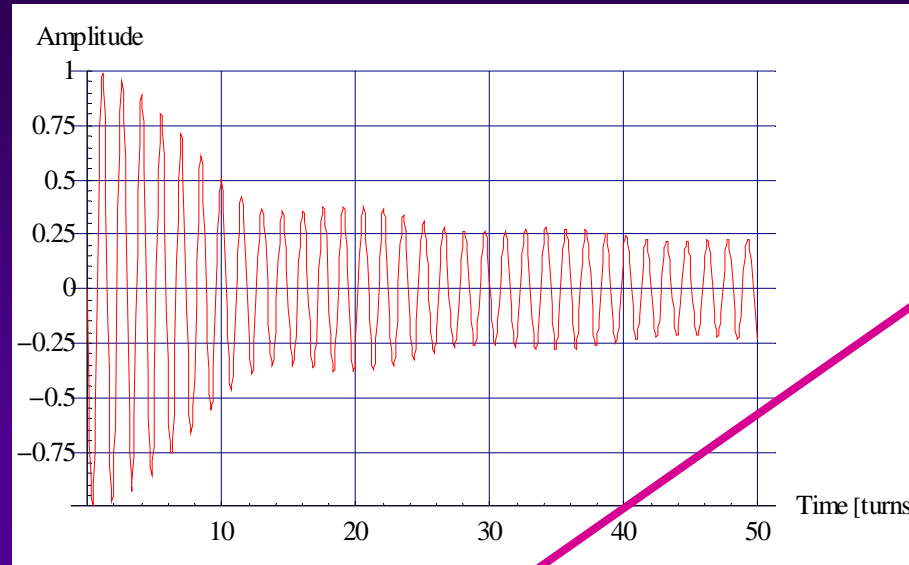
SPACE CHARGE ONLY

- ◆ **L. Vos' approach (CERN-SL-98-056 AP) = Inverse Fourier transform of the betatron frequency distribution**
⇒ Seems correct to me if applied to chromaticity or nonlinear detuning but not for the space charge...

⇒ **No decoherence expected theoretically (contrary to his result)... as confirmed by HEADTAIL simulations !!!**

- ◆ First I recovered Vos' result for the SPS example given in his paper

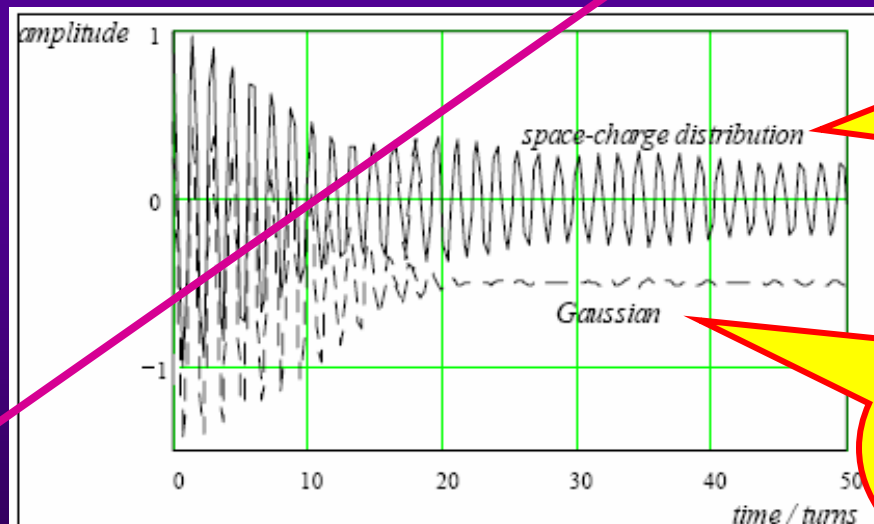
My result



$$q_0 = 0.73$$

$$\Delta Q = -0.067$$

Vos' result



Gaussian longitudinal density profile

Approximation of the tune distribution by a Gaussian (which is not...)

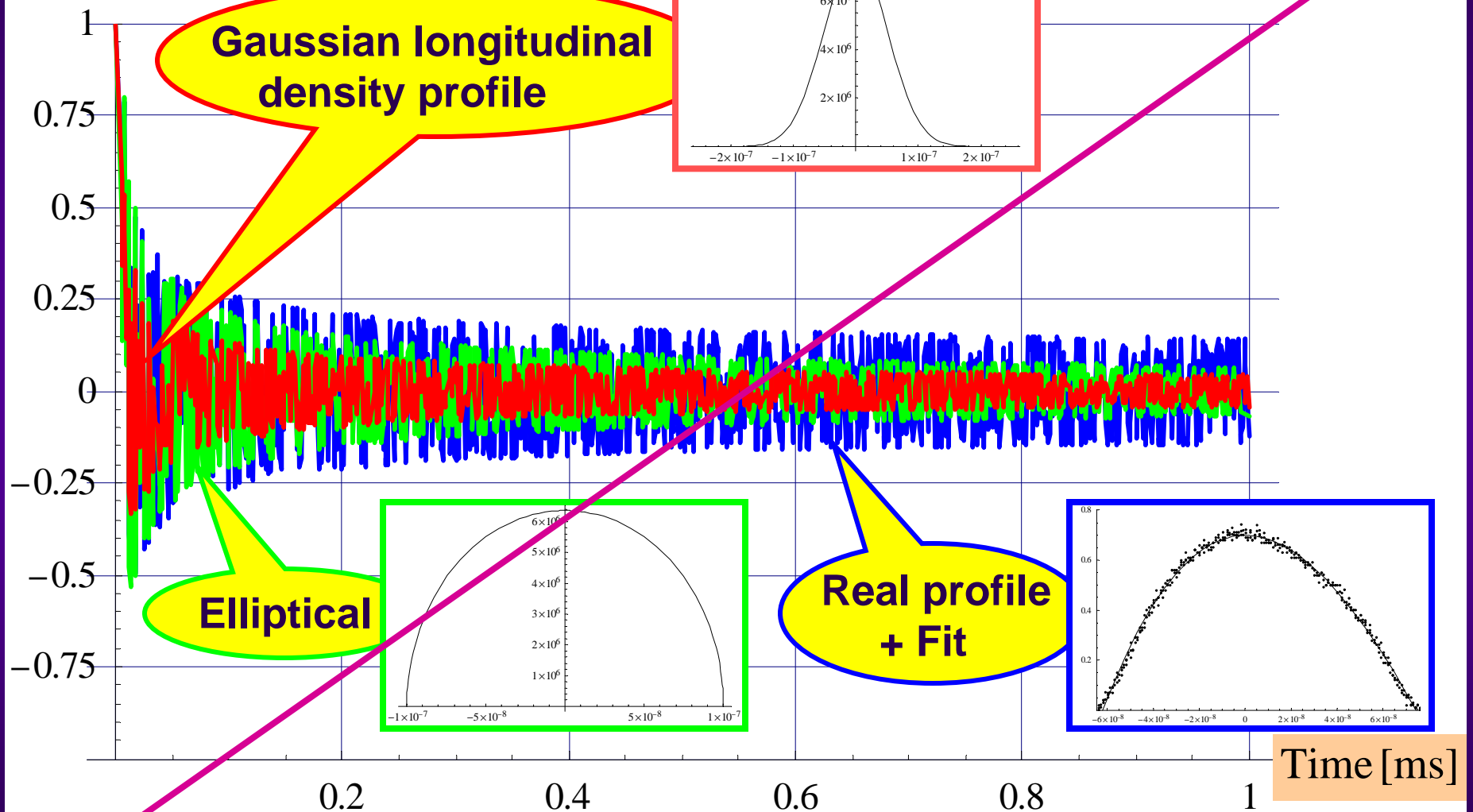
Figure 4 : Time response of space charge distribution and approximate Gaussian distribution

◆ Application to the PS

$Q_x = 6.22$

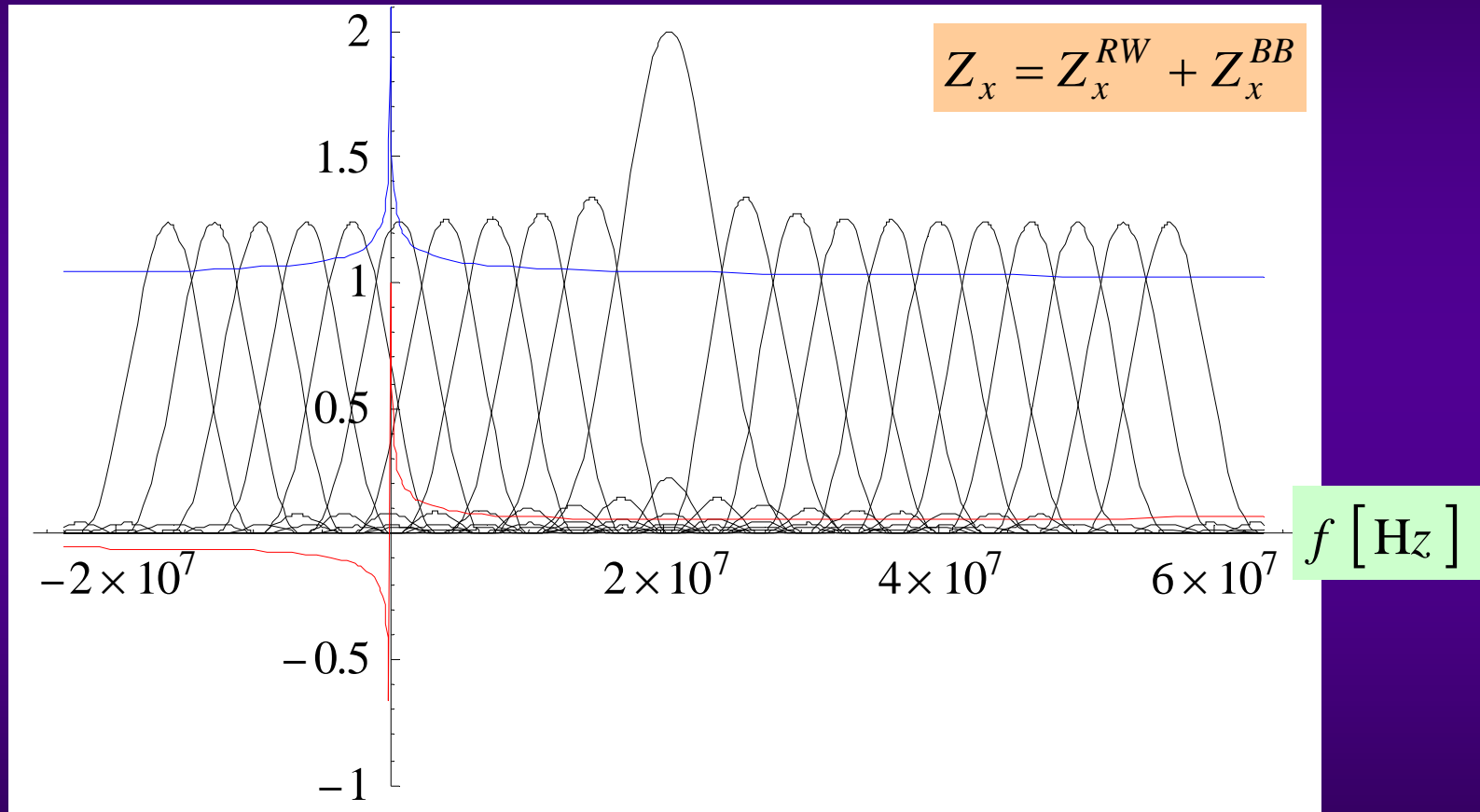
$\Delta Q_x = -0.2$

Normalised bunch centroid motion



HEAD-TAIL DAMPING

In Head-Tail damping, the coherent motion damps, rather than decoheres \Rightarrow Smaller emittance growth if faster than decoherence

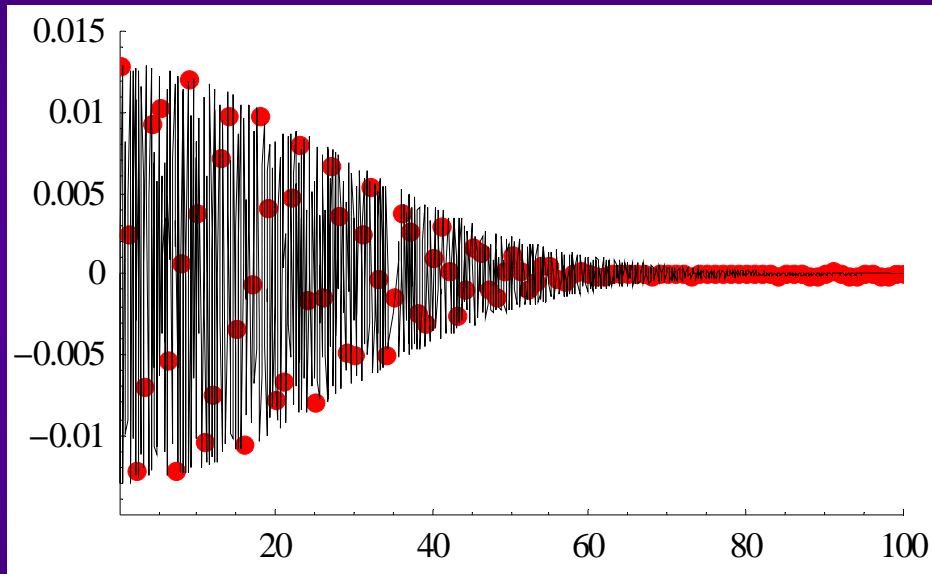


\Rightarrow Head-tail damping time ($m=0$) = 5 ms

COMPARISON BETWEEN ANALYTICAL FORMULAE AND HEADTAIL SIMULATIONS (WITH CHROMATICITY ONLY)

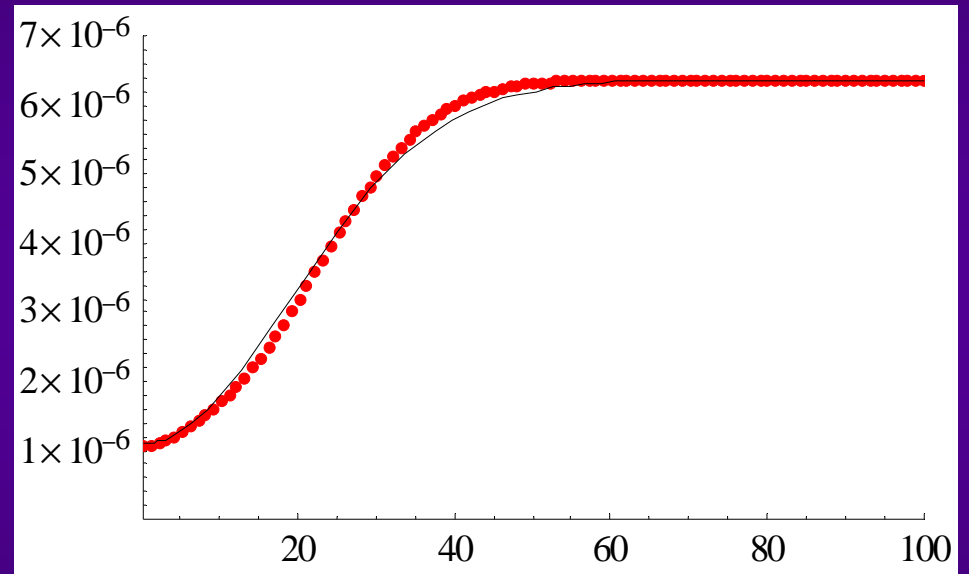
In red

Bunch centroid motion [m]



Time [turns]

Bunch rms emittance [m]



Time [turns]

⇒ Very good agreement !

NEXT STEPS

- ◆ **HEADTAIL simulations show a beneficial effect of space charge on decoherence, which goes in the good direction to explain the larger decoherence time measured in the PS compared to the case with chromaticity only**
- ◆ **HEADTAIL simulations seem to predict even larger decoherence time than measured, but I suspect that the data from F. Blas are wrong (too large tune shift) ⇒ To be checked with F. Blas**
 - ⇒ **May explain some differences between the HEADTAIL simulations and the measurements...**
- ◆ **Analytical predictions with BOTH chromaticity and space charge**