



Bunch shaping in the LHC

A quick look

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Acknowledgements

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F. Caspers, E. Shaposhnikova, S. Gilardoni, T. Argyropoulos, and H. M.
Cuna ...



Motivation

- Gaussian or nearly Gaussian bunches are great! But, we hit intensity limits
 - IBS – single bunch effect
 - e-cloud effects ← bunch spacing, filling pattern
 - And other instability issues

← now nominal bunch intensity (BI) = $1.15E11$ ppb, ultimate = $1.7E11$ ppb
- It is highly desirable to explore other possible paths to
 - Increase the bunch intensity ($\geq 3.4E11$ ppb, O. Brüning, Chamonix '11)
 - And eliminate/ minimize Instability.

← Say, by shaping the bunch (using double harmonic rf system).



Some Previous Work

- Beam dynamics in a double harmonic rf system (**Hofmann & S. Myers, CERN ISR-TH-RF/80-26**) ← realized that addition of higher harmonic rf can be used to increase the synchrotron frequency spread. This in turn increases Landau damping against coupled bunch instability
- RF system for Landau Damping in the LHC (**T. Linnecar & Elena Shaposhnikova, LHC project Note 394**) ← Studied the possibility of using h=2 & 3 of the main LHC 400MHZ rf system. Their analysis is on bunch shortening mode, based on SPS experiences, which uses h=1 and 4 rf systems.
- Diagnosis of Longitudinal Instability in the PS Booster (**A. Blas, S. Koscielniak and F. Pedersen PS/RF/Note 97-23 MD**) ← Studied instability involved while using h=2 system in the PSB. But in their study was carried out with

$$k = \frac{V_2}{V_1} > 0.5$$



Bunch shapes: Three scenarios

- Address bunches of different shapes in longitudinal phase space

□ By varying $V(h=2)/V(h=1)=0.2-0.6$, BLM & BSM

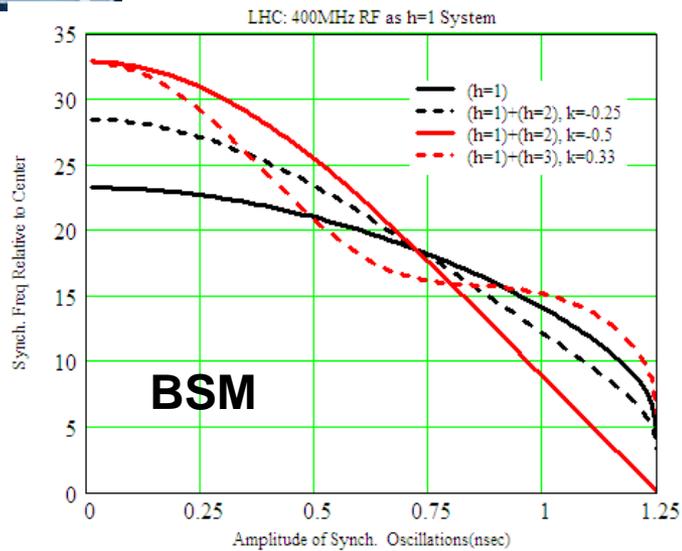


BSM= Bunch shortening mode

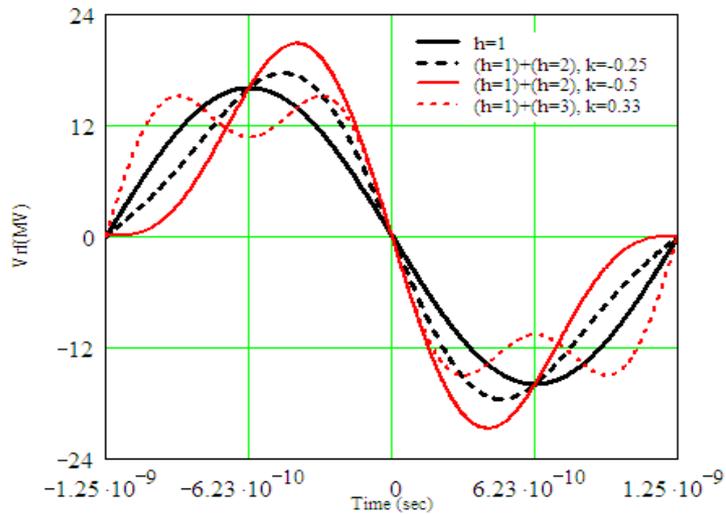
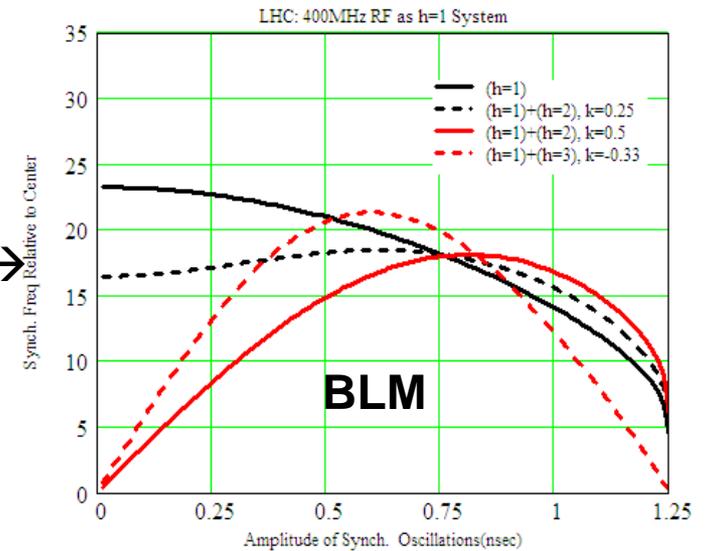
BLM= Bunch lengthening mode



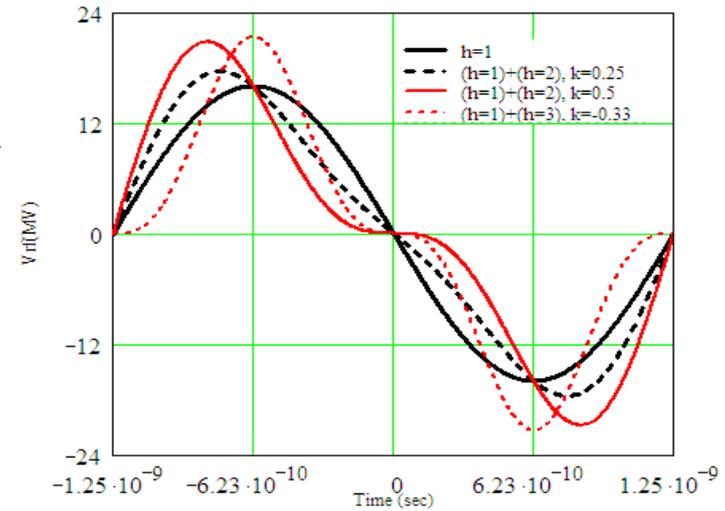
Bunch Shaping: BSM and BLM



←fs vs Amplitude→

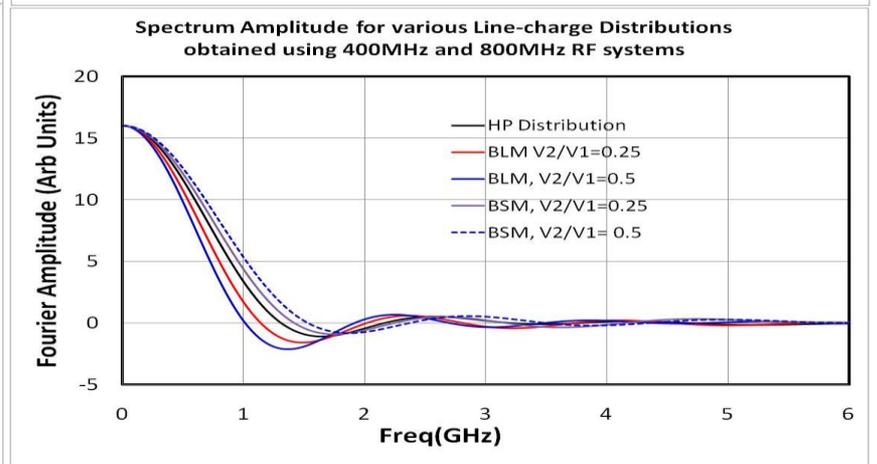
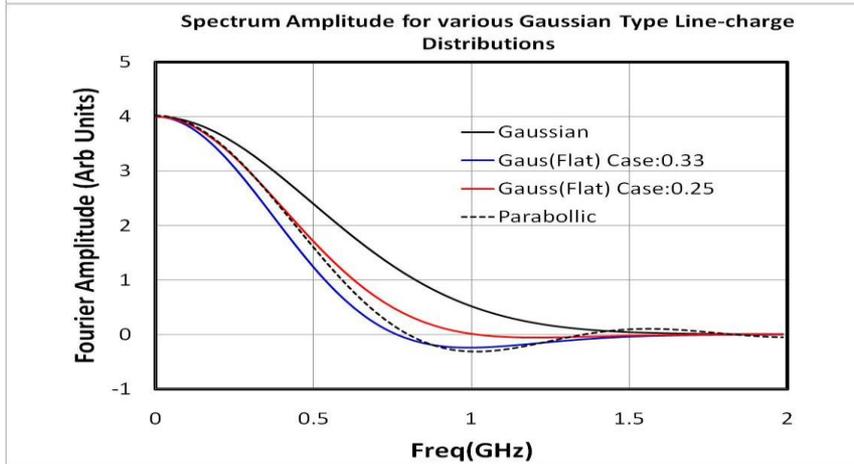
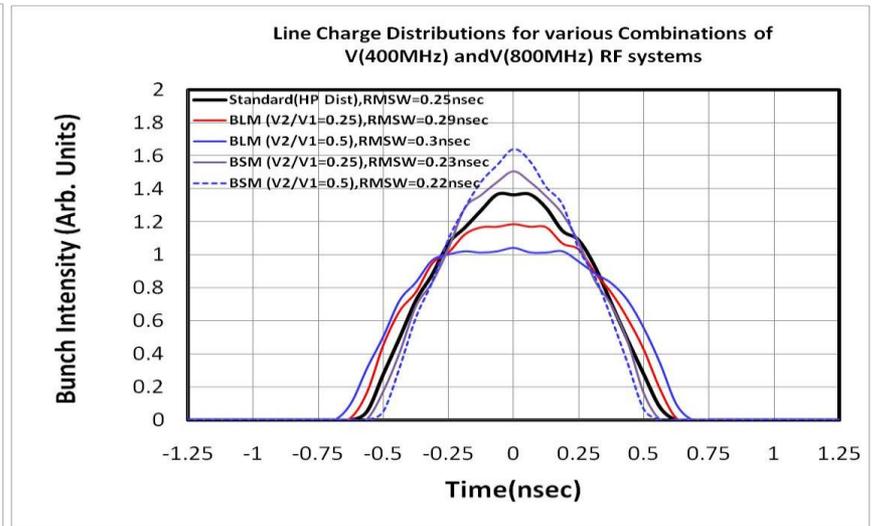
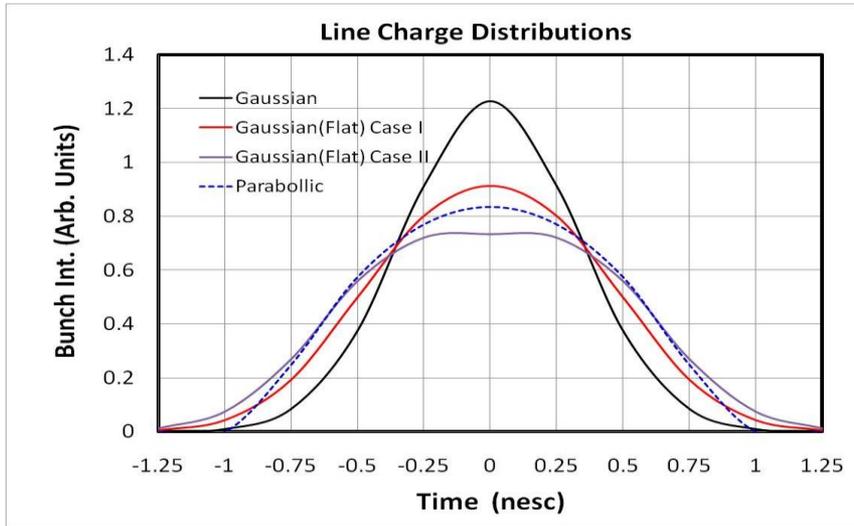


←RF Waves→





Line Charge Distributions & Fourier Spectra





Studies in Progress

- Characterize e-cloud effects on the **LHC-type** beam with bunches of different shapes
 - bunch spacing of 25nsec and 50nsec.
 - Bunch intensities: Nominal → ultimate → beyond

An **experiment is proposed** (now being carried out) in the **PS** at 26 GeV using LHC25 and LHC50

Collaborators: C. Bhat, H. Damerau, S. Hancock, E. Mahner, F. Caspers, F. Zimmermann, H. Cuna and T. Argyropoulos

& extend the findings to the **LHC/SLHC high luminosity** upgrade ← investigate the possibility for bunch shaping at higher bunch intensities in the LHC



PS e-cloud Measurements (cont.)

Without 80 MHz RF Last 40 msec before Ejection

LHC25 BI 1.3-1.5E11ppb

Signals from

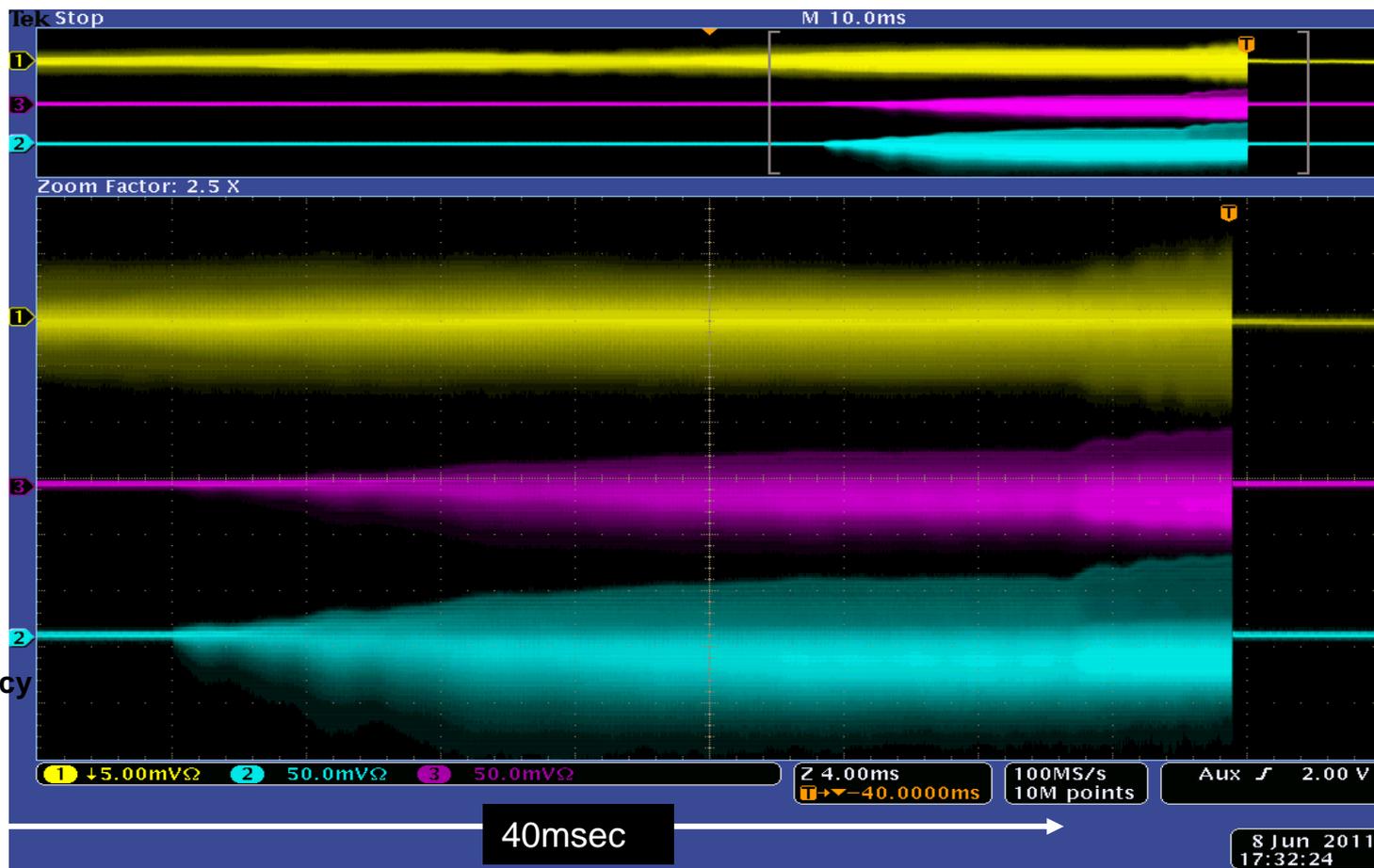
Strip-line Det.

BPU1

10% transparency

BPU2

37% and 23% transparency

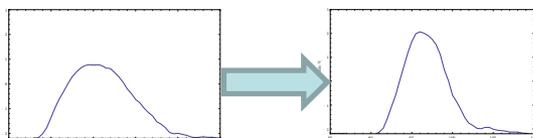
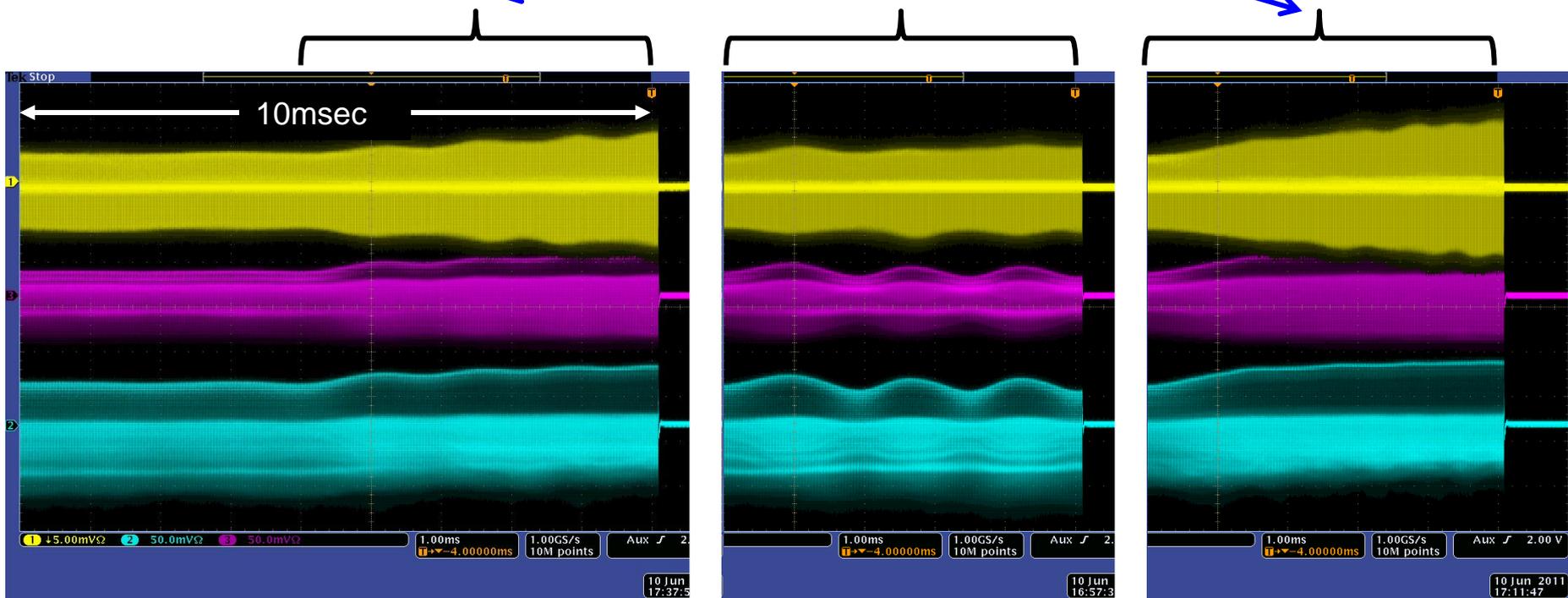




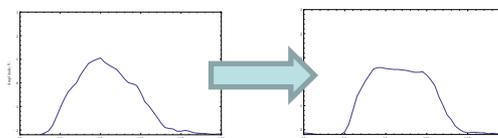
PS e-cloud Measurements (cont.)

V(80MHz): **0 to 50 kV**, V(40MHz): 40kV to 100 kV

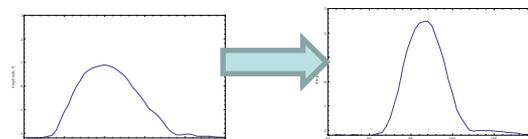
Last 5 msec
Region of Interest



Without 80MHz



Counter Phase(BLM)



In Phase (BSM)



Summary

- We are studying the possibility of bunch shaping to help bunch intensity in the LHC for luminosity upgrade.
- Some preliminary studies have been done in PS to understand effects of **ECLLOUD**.
- We have also studied beam instability issues in the PS using $h=1$ and $h=2$ systems for bunch lengthening mode.
- Hope to have some recommendations on the LHC rf upgrades based on our findings of the ongoing studies in a few months time