LHC Injectors Upgrade

CERN

LHC Injectors Upgrade

PS-MD transverse plane studies for LIU MD review

S. Gilardoni, N. Biancacci, S. Persichelli, G. Sterbini,
G. Rumolo, G. Iadarola, A. Blas, C. Yin Vallgren,
J. Borbough, C. Yu, W. Bartmann, R. Steerenberg, A. Huschauer

M. Pivi - SLAC
V. Kornilov, S. Aumon - GSI

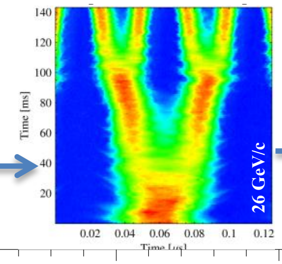
Ack. to the OP crews for they help/support and patience …

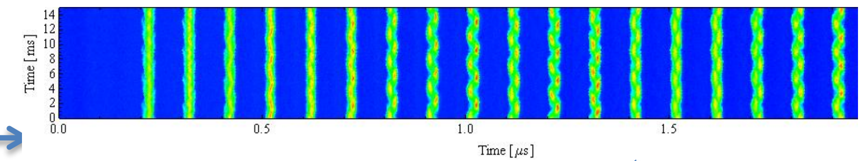
Todays known limitations

Acceleration/Bunch splittings

Longitudinal beam stability

Transient beam loading

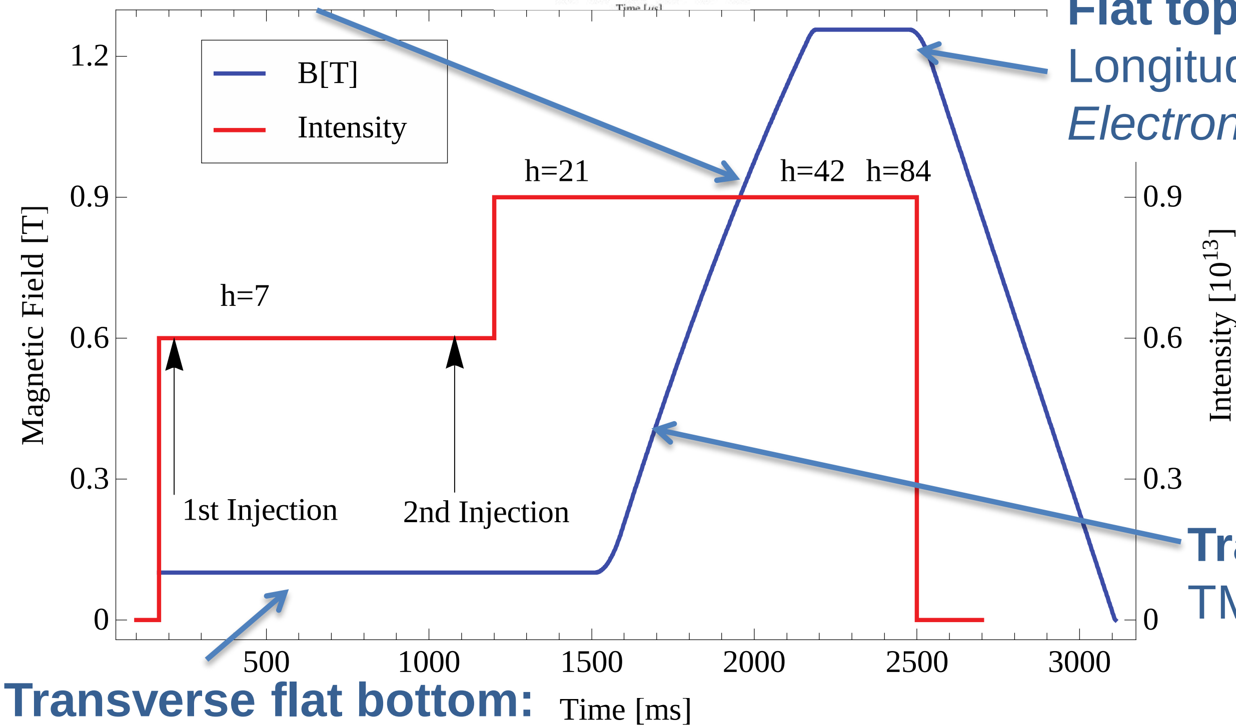




Flat top:

Longitudinal beam stability

Electron cloud



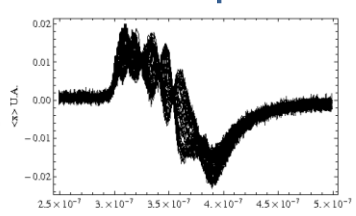
Transition crossing:

TMCI

Injection Transverse flat bottom:

Transverse emittance blow-up due to space charge if beam density too high

Headtail instability

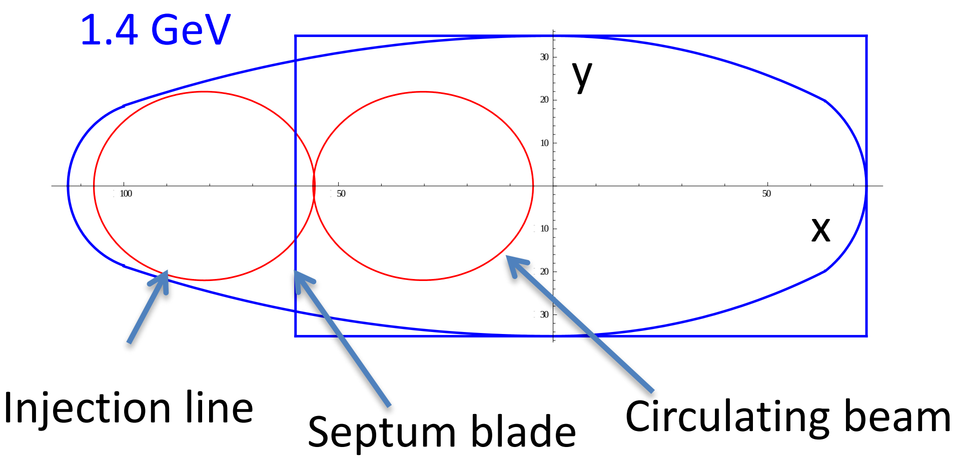


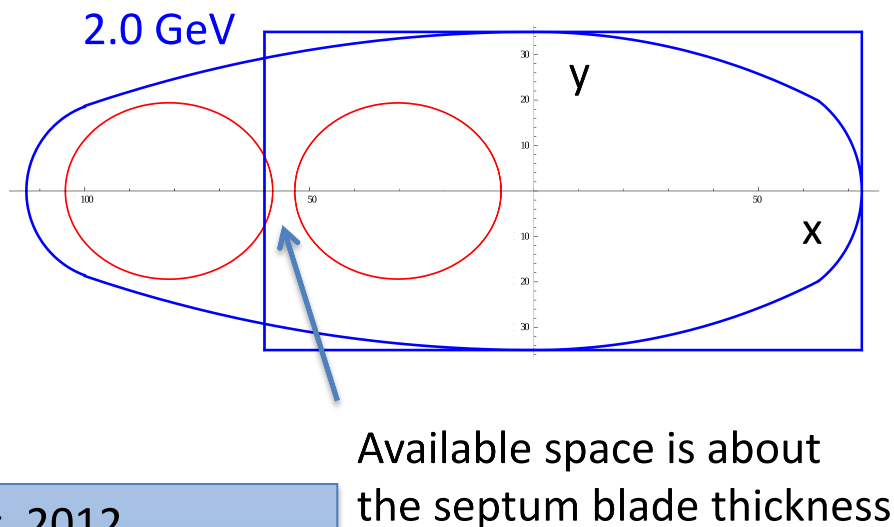
Outline

- New injection optics for high intensity beams
- Headtail instabilities on injection flat bottom
- Transverse damper status
- Transition crossing instabilities
- *Instability at flat-top arrival (new 2012)*
- Transverse instability at extraction
- e-cloud measurements
- Transverse impedance studies

New injection optics

New injection optics defined for high intensity beams to improve available aperture in the injection region.



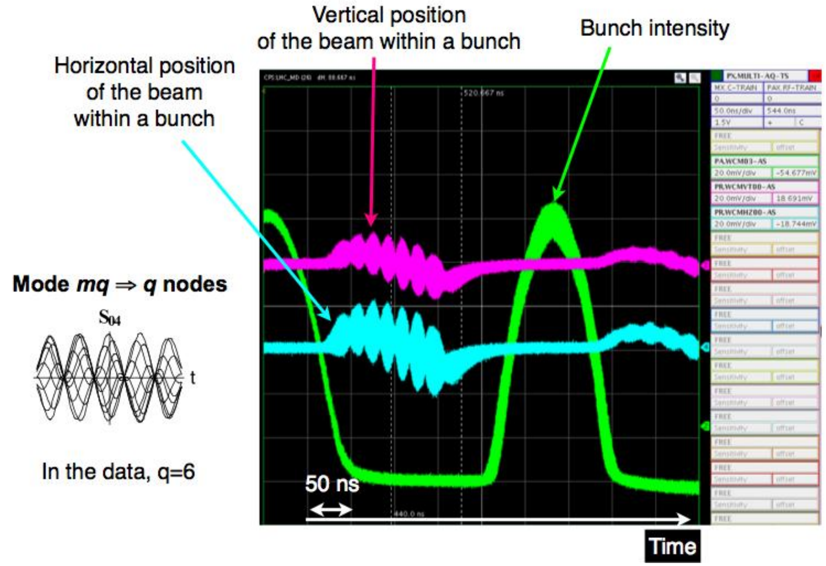


MD data	Sept. 2012
HW ready	Yes
Theor. Studies status	Concluded
Has implication on HW construction	Yes (new quads)
Impact on LHC future beam	Medium
Could be postponed to 2014	No

Headtail studies

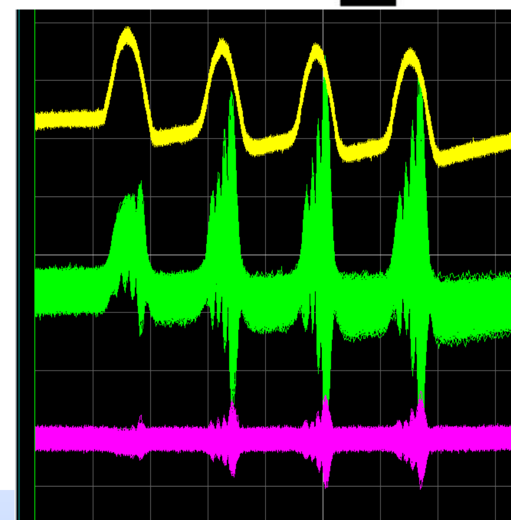
Studies on HEADTAIL to better determine

- Rise time
- Intensity Thresholds



Possibility to cure it by:

- Linear coupling (as done today)
- T-damper w/wo chromaticity control
- Octupoles



Last week meas.
50 ns nominal beam

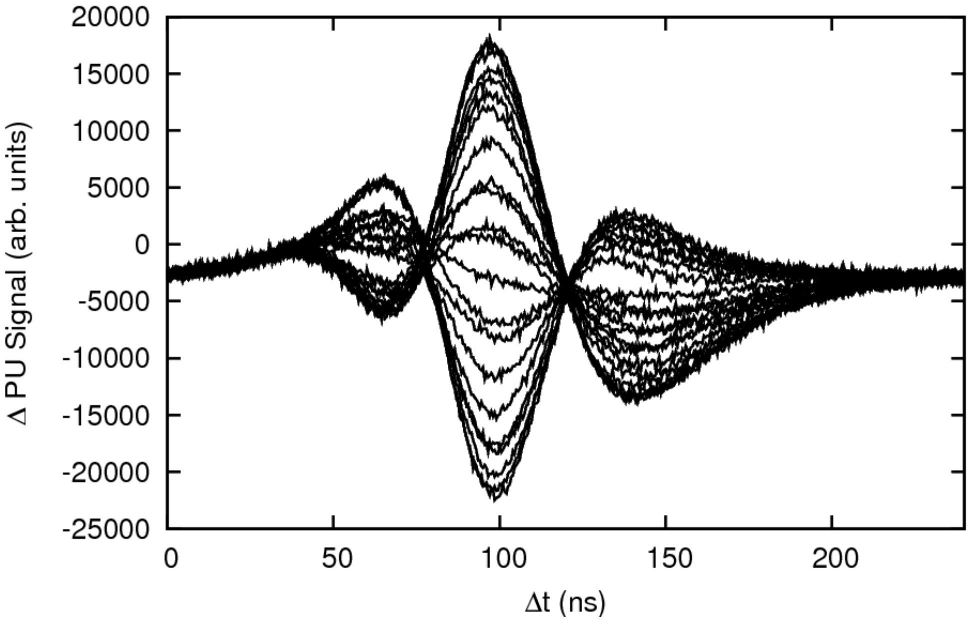
MD data	During the year
HW ready	Yes (skew quad., T. damper, Octupoles)
Theor. Studies status	Theory well known, new simulations in 2013
Has implication on HW construction	Yes (skew quad., T. damper upgrades)
Impact on LHC future beam	High
Could be postponed to 2014	No

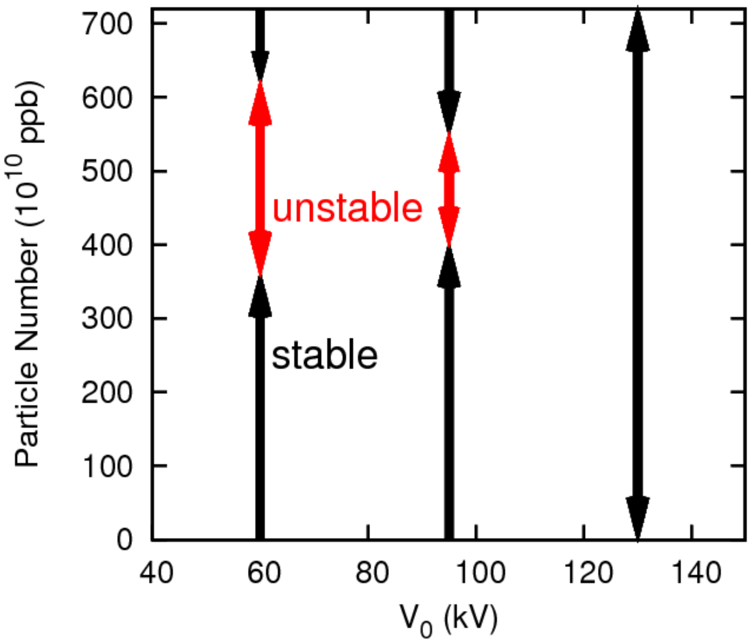
MD in June 2012, V.Kornilov (GSI), Machine Operation: S.Aumon, S.Gilardoni

Head-Tail Instability at the Injection Plateau

With the chromaticity compensated ξ_x=-0.1, unstable k=2 head-tail mode observed, here 440e10, the growth time 5.6ms.

The instability has two thresholds: the lower and the upper intensity, depending on the rf voltage





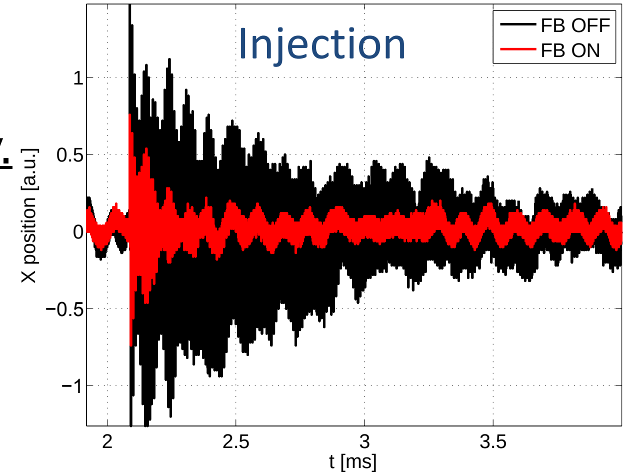
- The intensity thresholds are due to space-charge related Landau damping
  - ✔ important contribution to understanding of transv. dynamics with strong space charge
- The driving impedance is probably not the Resistive-Wall impedance but a narrowband impedance around 6MHz

Detailed discussion tomorrow on Wednesday at 14:00, Room 864-2-B14 - SALLE J.B.ADAMS

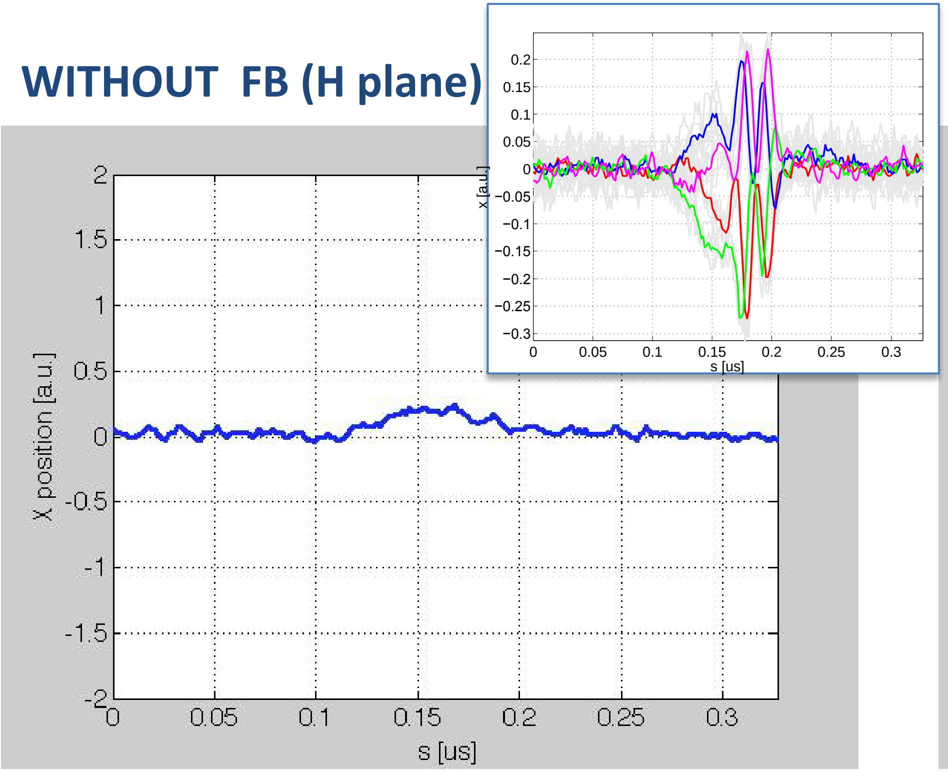
PS Transverse Dampers Commissioning

Obtained:

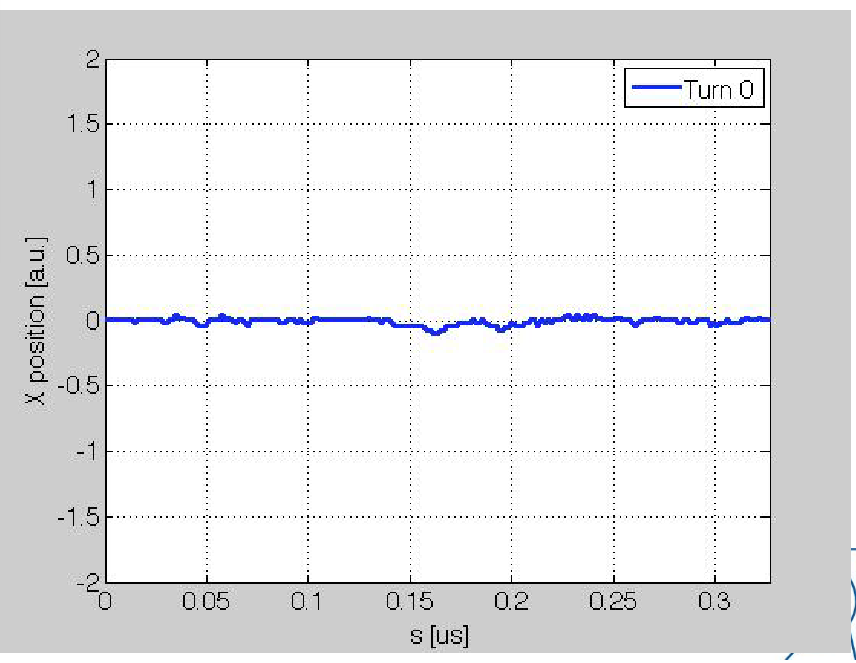
- Results as expected in H and V plane <u>at fixed energy.</u>
- Damping of injection errors
- 50 MHz instability observed in the H plane.
  It seems to be triggered by the rigid oscillation due to injection errors and vanish when it is damped.



WITHOUT FB (H plane)



WITH FB (H plane)



PS Transverse Dampers Commissioning

To be done:

-“Transverse tune to Betatron phase set-point” table to be adjusted (the present machine model being used is slightly incomplete)

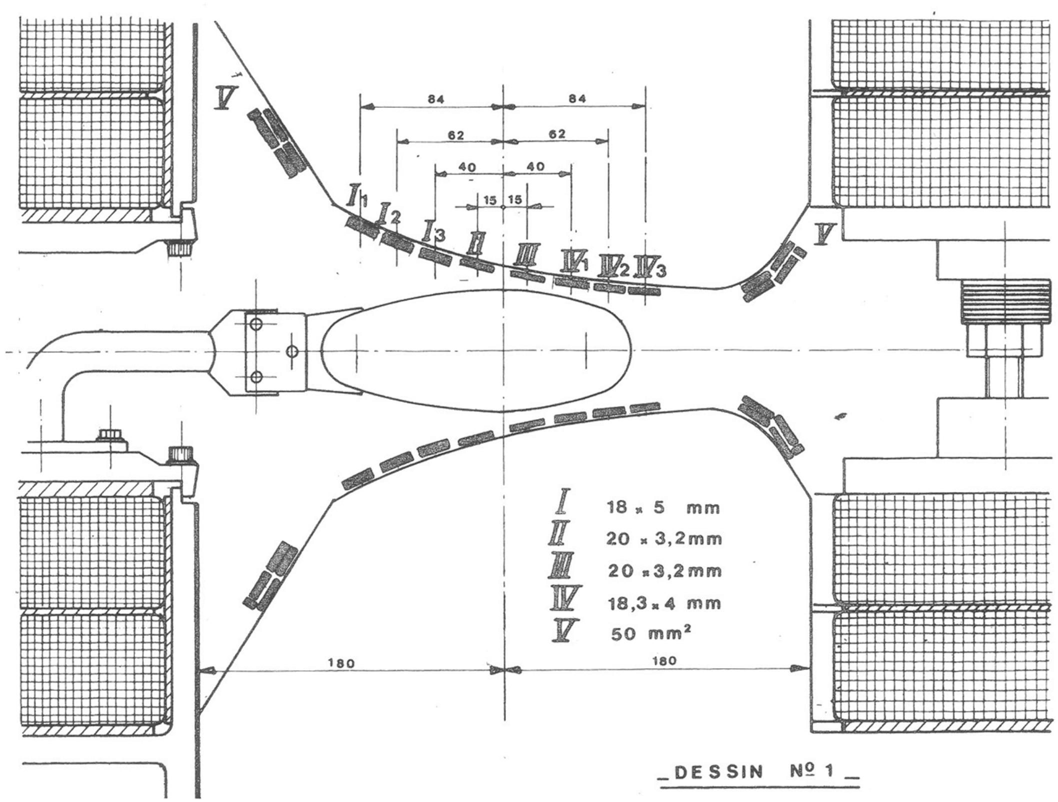
-Test during acceleration using the above mentioned table and the Q(t) GFA

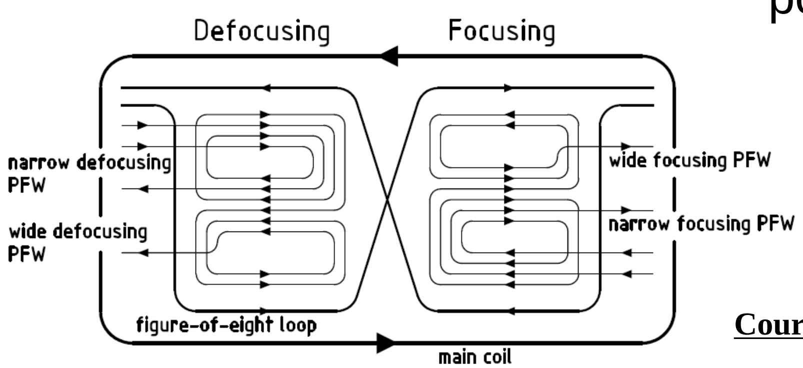
-Analysis of the 50 MHz instability (intensity threshold with different machine parameters (coupling and chroma), with and without damper

-Define the required characteristics for the Damper in the L4 era

-Repair Pick Up in section 98 (ΔH channel)

Pole Face Windings, working point control





- Four circuits mounted on top of the magnet poles
- F8L crossing between two magnet half units
- Used in the past to control working point during high intensity tests
- Since 2007 five separate power supplies

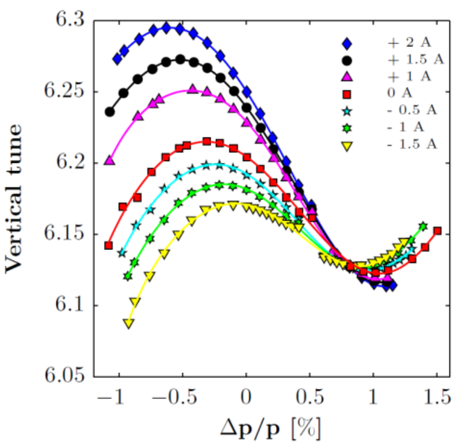
Courtesy M. Juchno

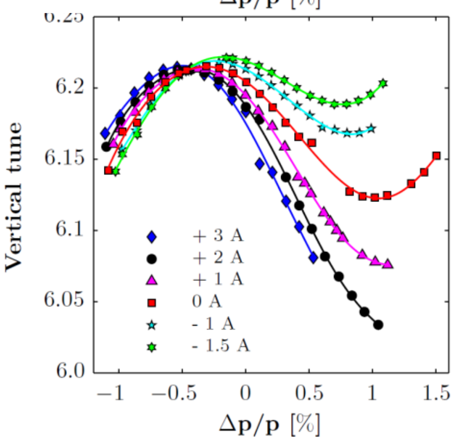
Towards chromaticity control @ PS injection

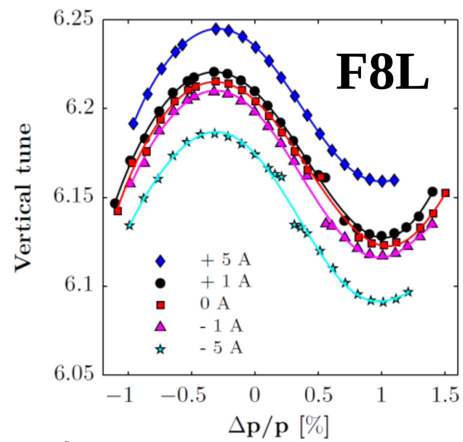
For the second time in PS history (see late ’90), study to correct injection chromaticities (linear) and study control of non-linear working point

Extensive experimental studies of non-linearities at injection to optimise chromaticity control and dynamical aperture (here example of V. plane)

PFW narrow



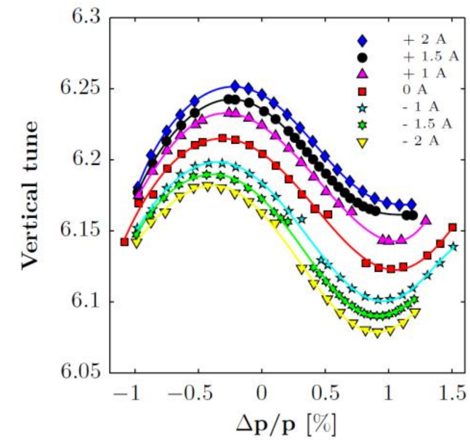


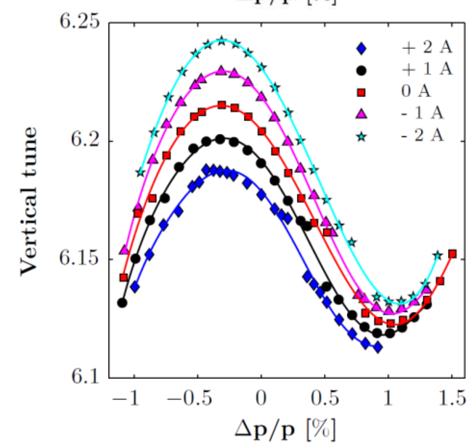


$$\begin{pmatrix} \Delta Q_x \\ \Delta Q_y \\ \Delta \xi_x \\ \Delta \xi_y \\ \Delta Q''_{x,y} \end{pmatrix} = \mathbf{M}_{x,y(5x5)} \begin{pmatrix} \Delta I_{FN} \\ \Delta I_{FW} \\ \Delta I_{DN} \\ \Delta I_{DW} \\ \Delta I_{F8L} \end{pmatrix}$$

Different curves corresponds to different ΔI in the different circuits to define matrices and control the WP.

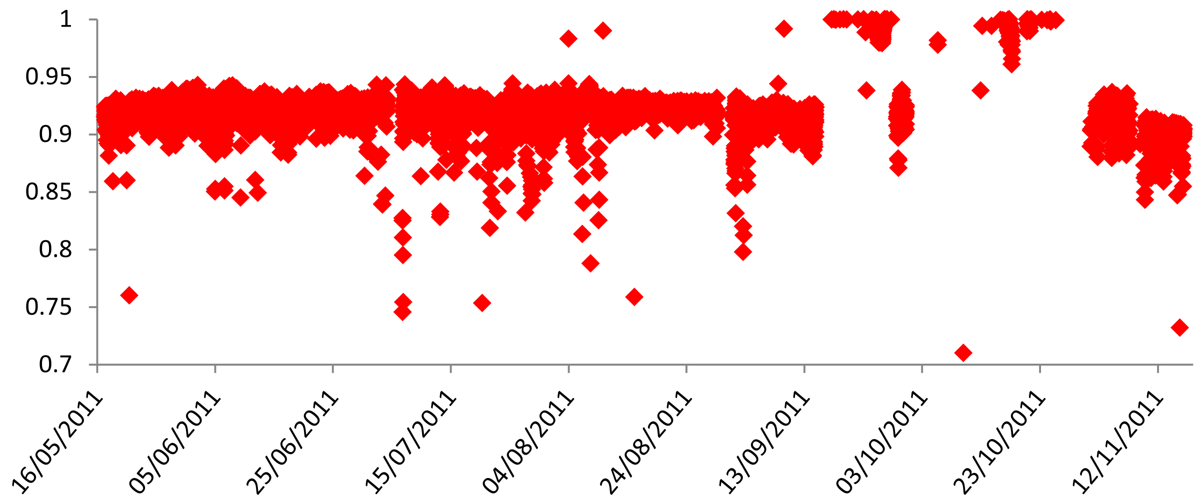
PFW wide





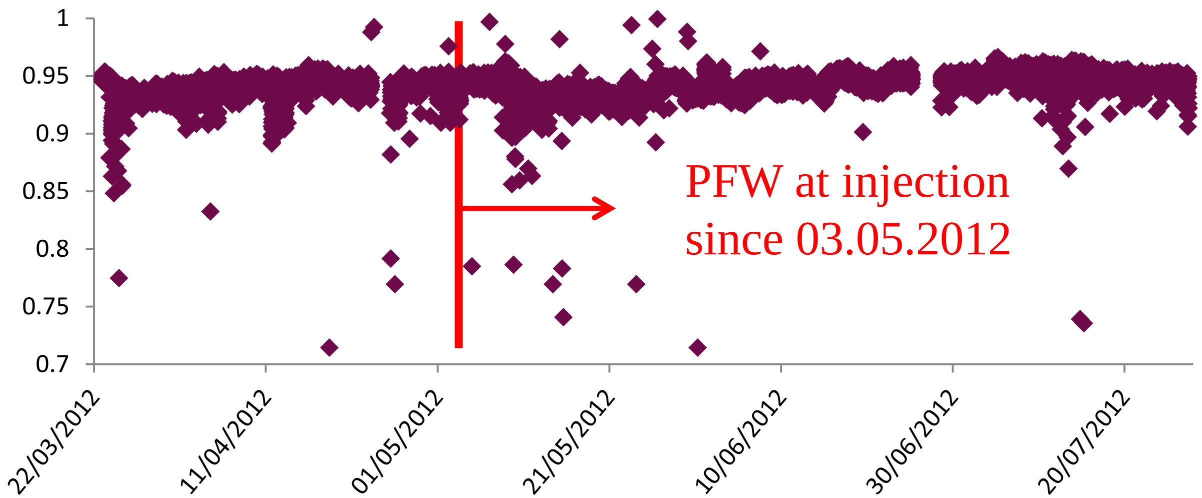
TOF beam: Inj. WP control only with PFW

Inj. efficiencies: 2011 (only tune control with quadrupoles) vs.
2012 (tune + chromaticity control with PFW)



2011

92,1%
$I_p=800\cdot10^{10}$



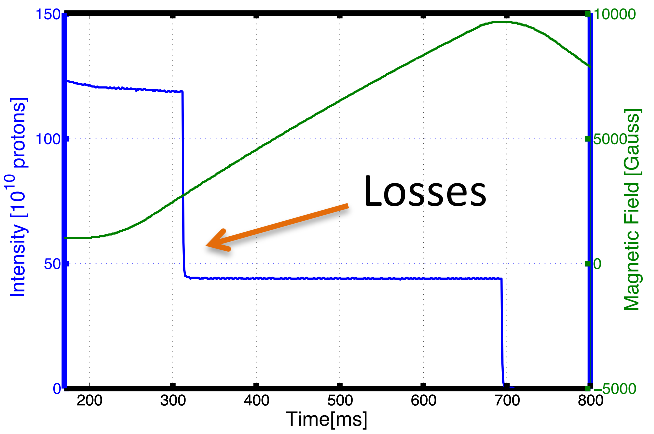
2012

94,1%
$I_p=650 \cdot 10^{10}$

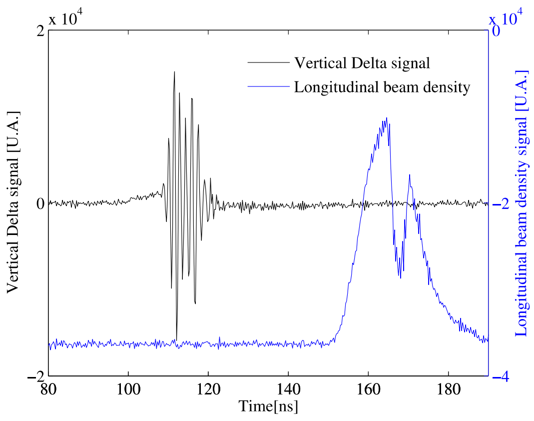
Transition crossing

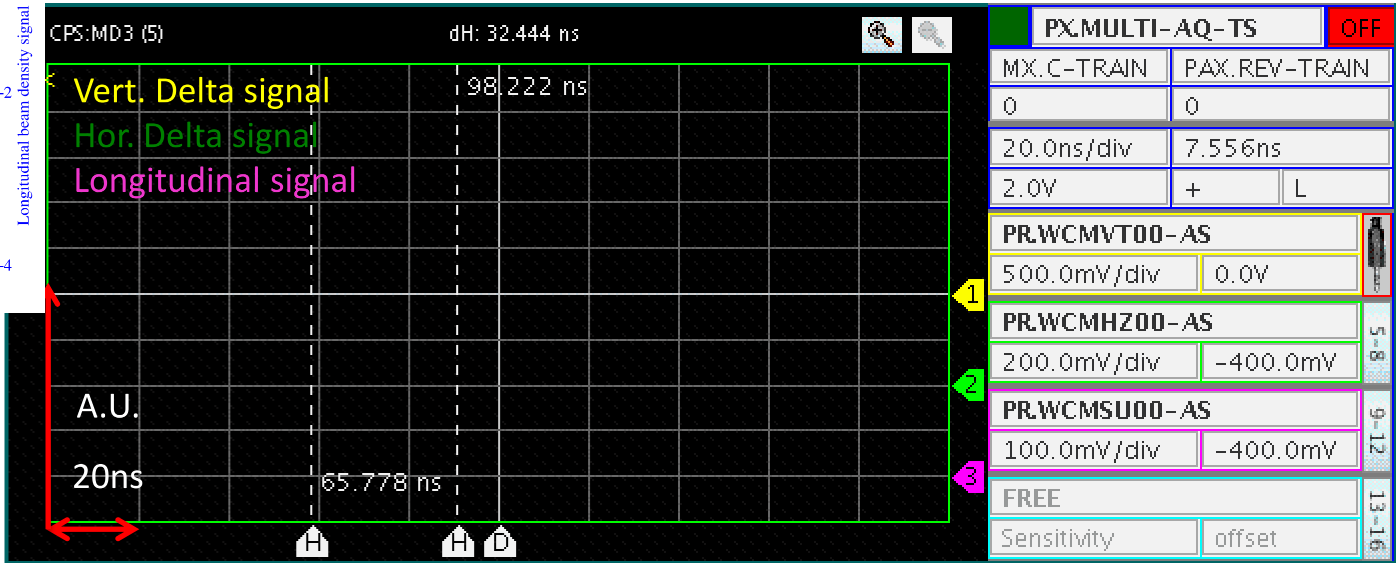
Fast vertical instability extensively studied in S. Aumon's during thesis

- LHC-type beams should be stable at transition
- Collaboration with GSI progressing



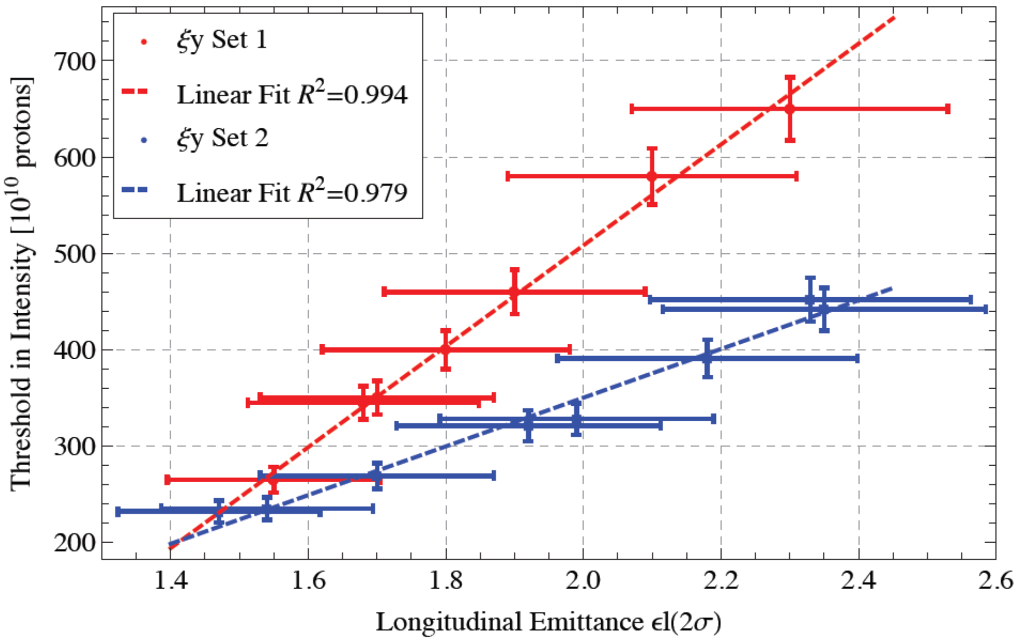
Probably no need of other MDs for 2012





Intensity threshold with gamma jump

- Use of a gamma jump allows to increase considerably I_{th} by factor 3.
- "Chromaticity-jump" allows to push the factor to 5.
- η_{th} is increased by a factor 10
- High Luminosity LHC beam stable



- Gamma jump+ Quick change in chromaticity "Chromaticity jump"

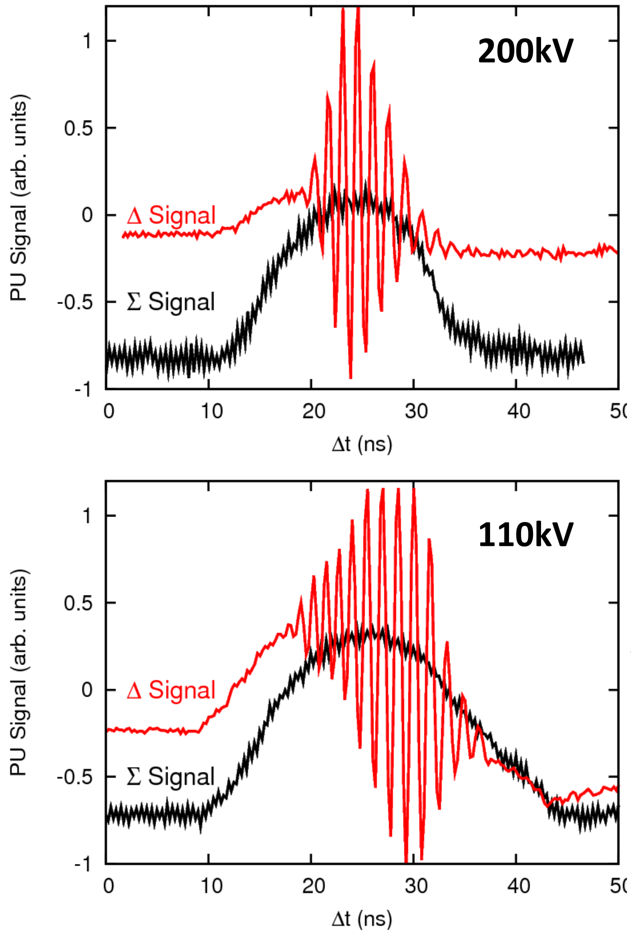
Chromaticity jump, if required, would need new HW

MD in June 2012, V.Kornilov (GSI), Machine Operation: S.Aumon, S.Gilardoni

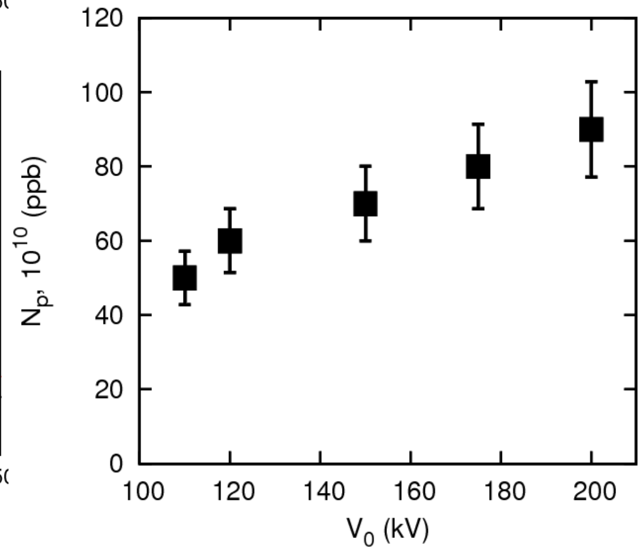
High-Frequency Transverse Instability at the Transition

The 0.7 GHz instability at the transition (no γ-jump)

- explanation for the intensity thresholds according to usual Landau damping
- strong stabilizing effects due to the bunch length and due to the synchrotron motion

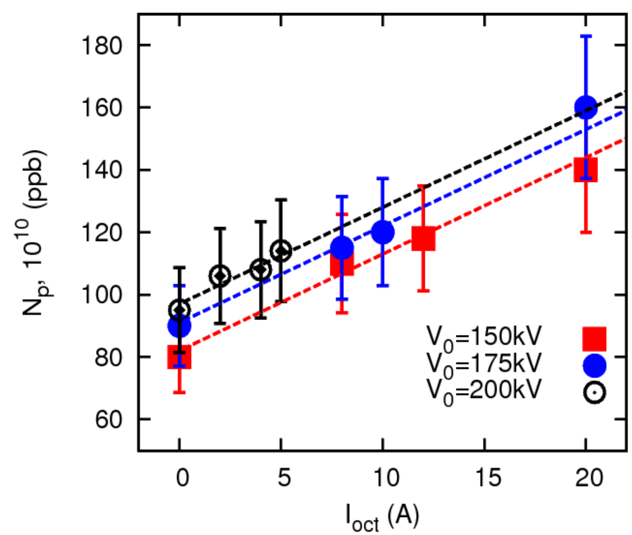


Strong effect of the bunch length on the instability threshold



Instability threshold for different rf voltage

Stability due to octupoles: linear contribution to Landau damping



Instability thresholds as functions of the octupole current

Detailed discussion Wednesday at 14:00, Room 864-2-B14 - SALLE J.B.ADAMS

Recent instability observation at FT arrival

Emittance growth observed for LHC50 ns operational beams prior to arrival on FT in 08/2012:

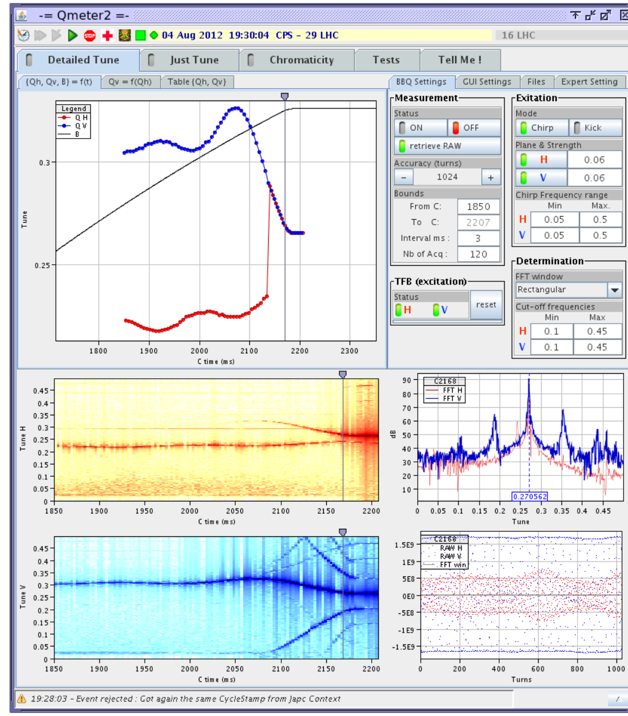
-Large tails in V-plane

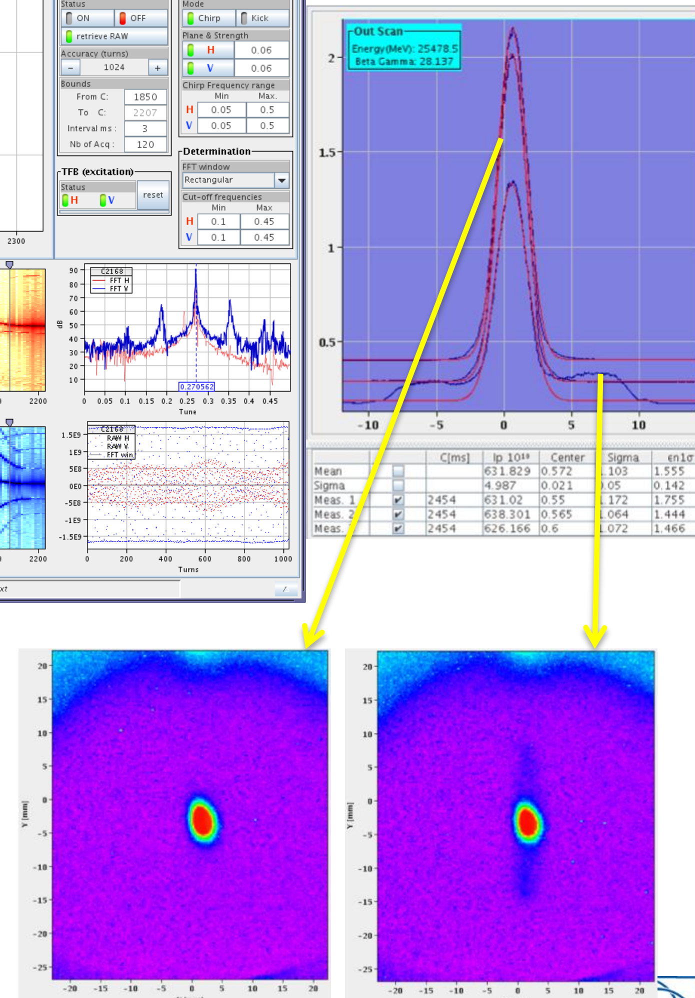
-Emittance growth

Cured by:

- Moving the tune away from 1/3 resonance
- Changing linear chromaticity

Further studies to understand better the source (1/3 resonance, missing Landau damping, …)



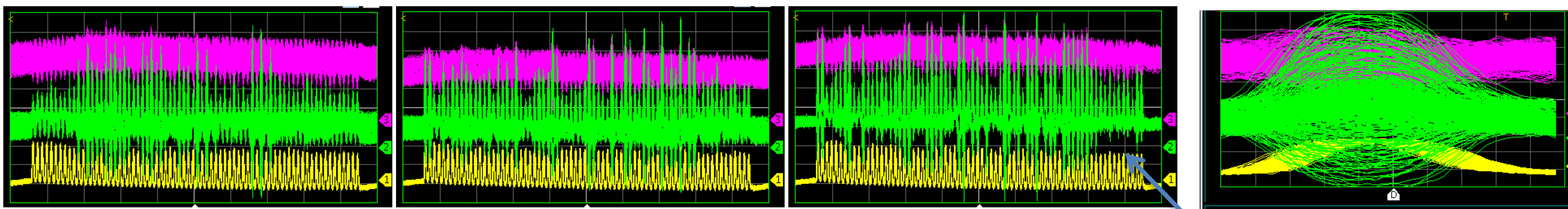


OTRs TT2

Measurement along flat top, nominal 25 ns

Instability observed at FT in the past if bunch length before last rotation shorter than ~ 13-14 ns (*shorter than nominal*).

Not fully clear if e-cloud driven. A signature that electron cloud might be the cause of instability is positive tune shift along the train bunches (*to be done*)



2419 ms

2426 ms

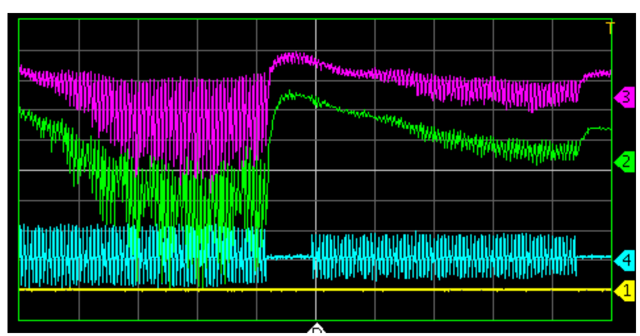
2436 ms

Instability

-- Wall current monitor
-- Sum
-- Horizontal
-- Vertical

- 1.15e11 ppb
- bunch length ~13.5 ns

e-cloud signal now available in CCC



-- e- cloud pickup 1
-- e- cloud pickup 1
-- e- cloud strip-line
-- pressure

FT instabilities

FT transverse instability appearing in non-nominal longitudinal conditions

- Instability observed together with e-cloud but no evidence that e-cloud is the cause of the instability.
    - Threshold for bunch length already identified in the past
    - e-cloud always there for operational beams but not causing beam quality degradation
- Missing resources in 2012 to finalize the studies but not on critical path (new student arriving soon to reinforce the team…)

MD data	Already taken
HW ready	Yes
Theor. Studies status	To be done (simulation and analysis in 2013)
Has implication on HW construction	Yes (T-damper, Wideband damper, coating)
Impact on LHC future beam	High
Could be postponed to 2014	Yes

Electron cloud studies

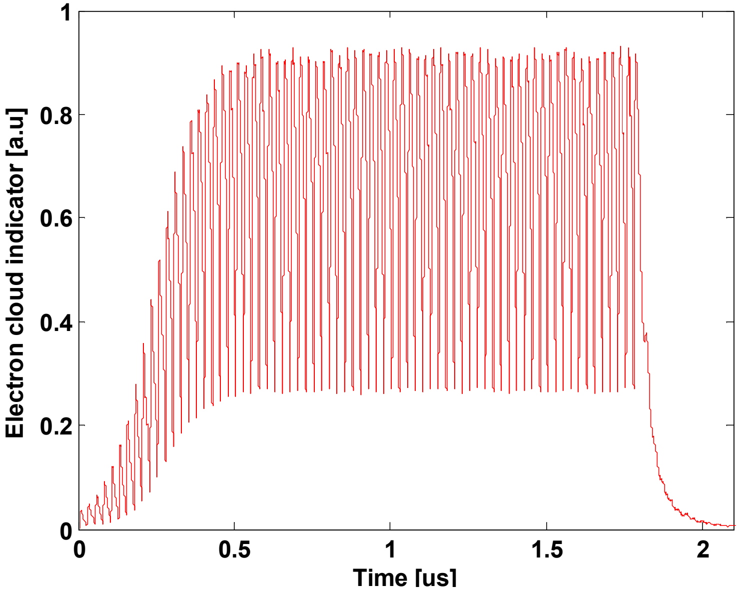
Measurements taken to qualify vacuum chamber

Simulations ongoing with the build up code ***PyECLOUD (same as LHC/SPS)***

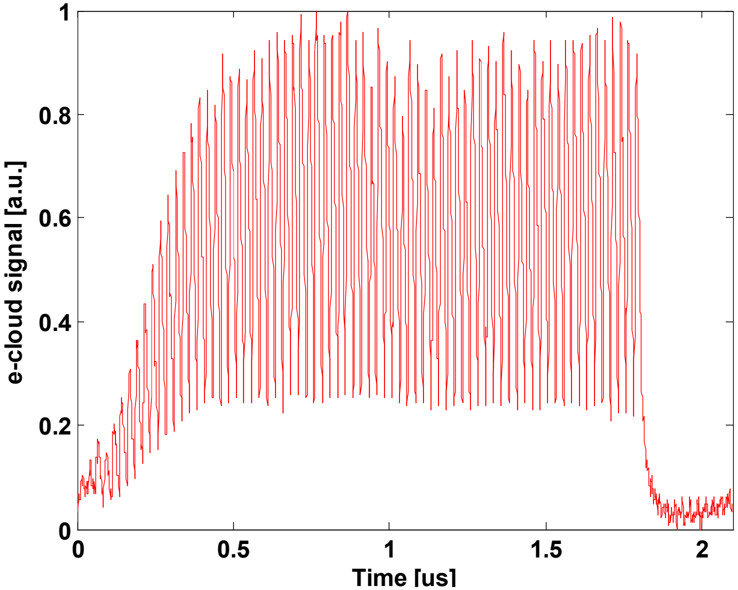
⇒ Flux to the wall for a 25 ns case (N_b=1.33 x 10^{11} ppb, bunch length=4 ns)

⇒ First estimation of the inner surface properties of the PS beam chamber

Simulation



Measurement

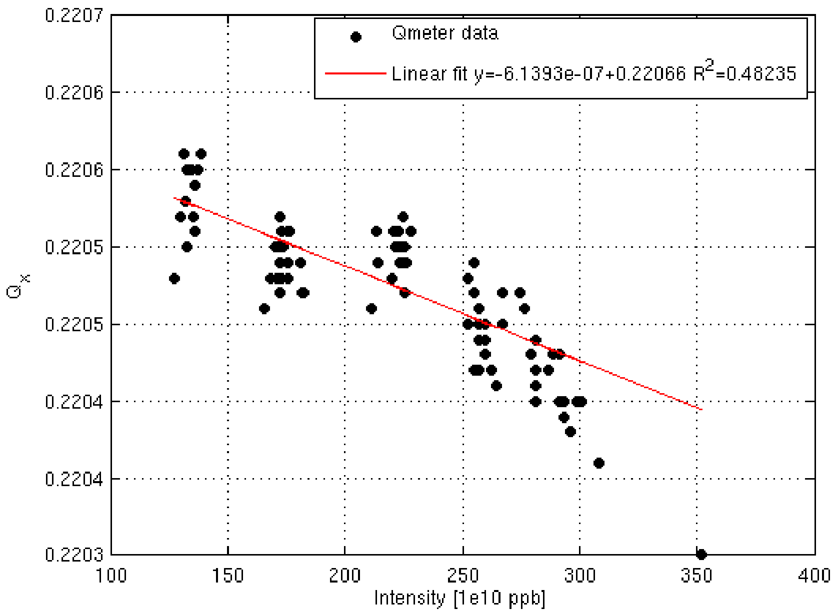


	δ_{max}	R_0	Beam in the gap
Simulation	1.6	0.5	5%

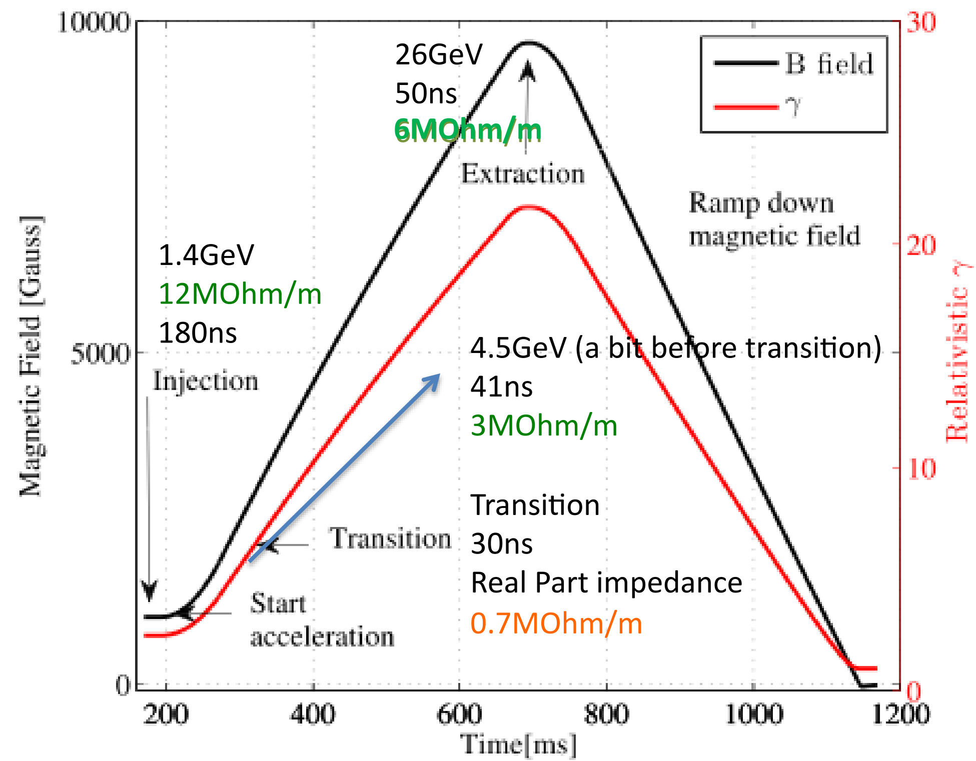
Recent transverse impedance measurements

First global impedance model measured at different energies:
- Deduced from intensity dependent tune shift
- Transverse beam instabilities

Improvement of the model needed to better understand known (and not yet observed) instabilities



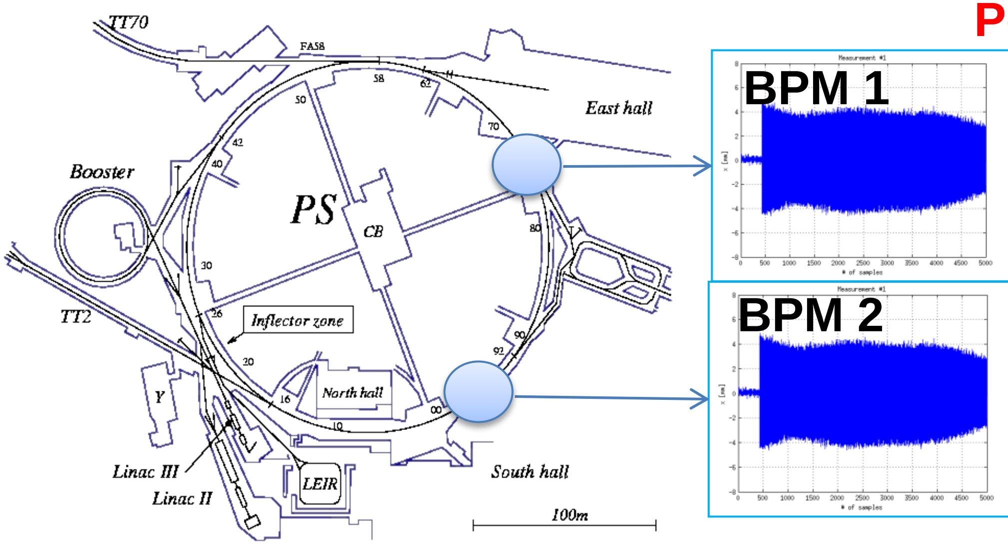
Real Part meas. Z_y
Imaginary Part meas. Z_y



Transverse impedance measurements

The transverse beam coupling impedance can be measured both globally and locally:

Possible thanks to new orbit system



In the local coupling impedance measurements we measure the variation of phase advance between BPMs with intensity.

$$\Delta\varphi(N_b)_{1\to 2} \propto Z_{\perp(TOT)1\to 2}$$

A beam based method to localize impedances was proposed and applied by G. Arduini et al. in 2004 and 2009 in SPS [1,2]. The aim of the measurement is correlating the phase advance beating variation with intensity with a local source of impedance. In "optical" terms, an impedance would behave as a (de)focusing intensity dependent quadrupole.

In the global coupling impedance measurements we measure the variation of tune frequency with intensity.

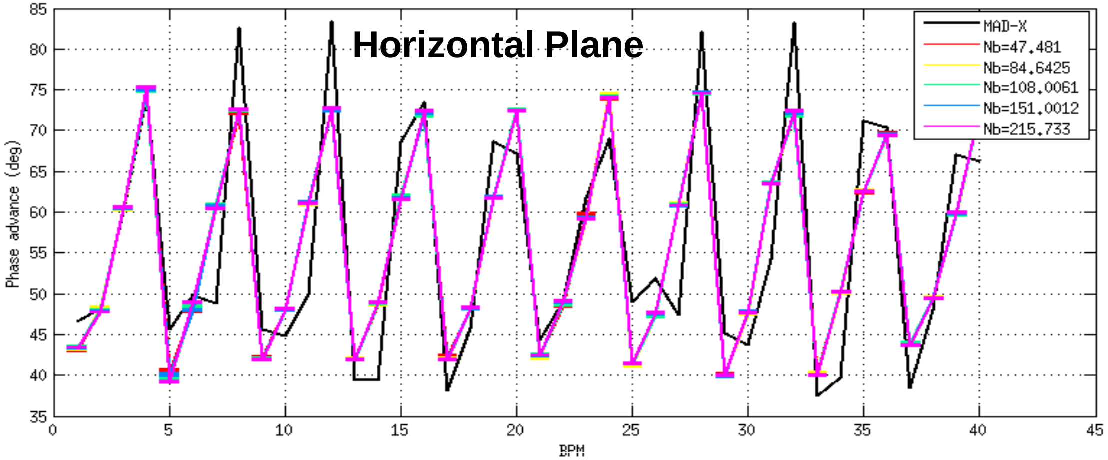
$$\Delta Q(N_b) \propto Z_{\perp(TOT)}$$

The method for local measurements was proposed and applied by G. Arduini et al. in 2004 and 2009 in SPS [1,2] and benchmarked with HEADTAIL.

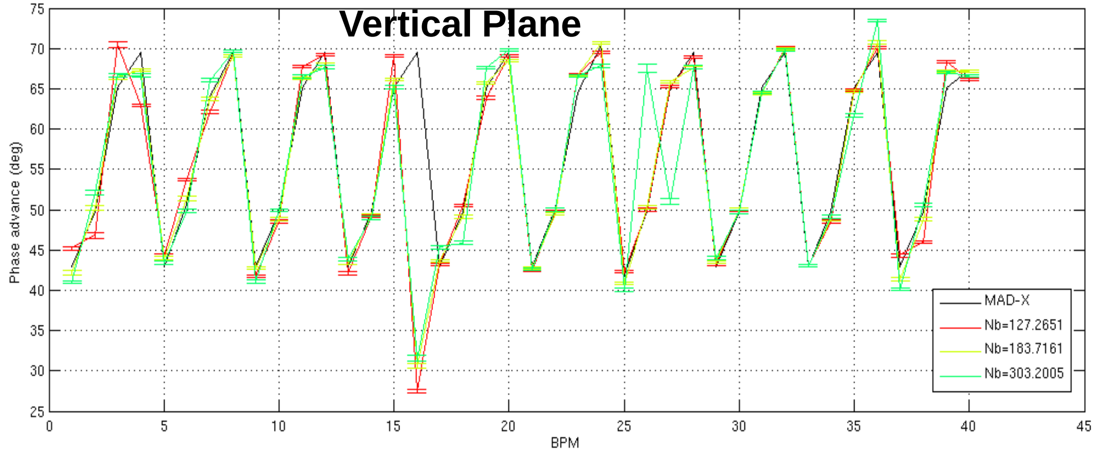
[1] "Localizing impedance sources from betatron-phase beating in the CERN SPS", G. Arduini, C. Carli , F. Zimmermann EPAC'04.
[2] "Transverse Impedance Localization Using dependent Optics" R.Calaga et al., PAC'09.

June-July MD results

Local impedance measurements



Excitation: **kicker**
Average noise/signal ratio: **5%.**
Phase accuracy: **0.1deg .**
Estimated impedance: **<1MΩ/m**
Tune shift in degree: **0.07deg**

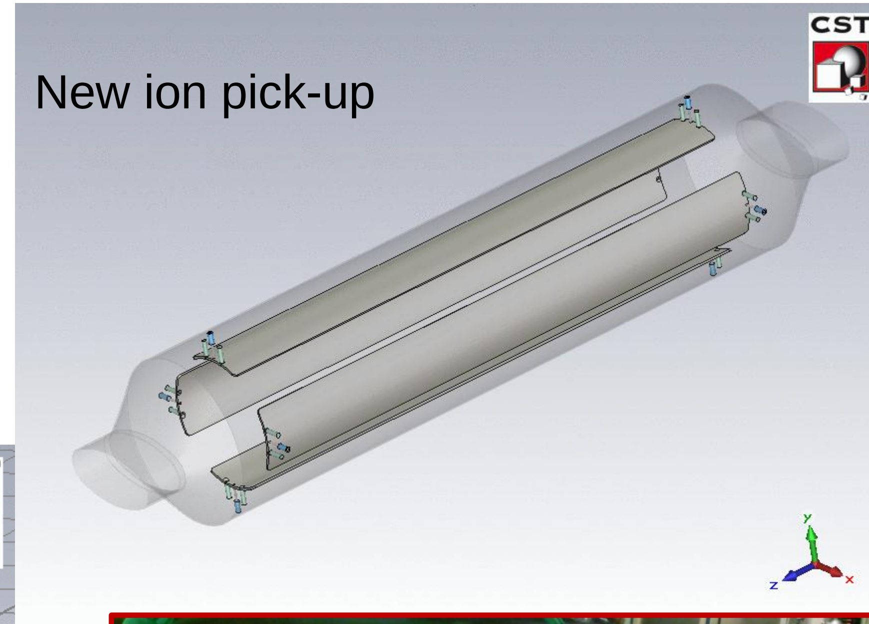


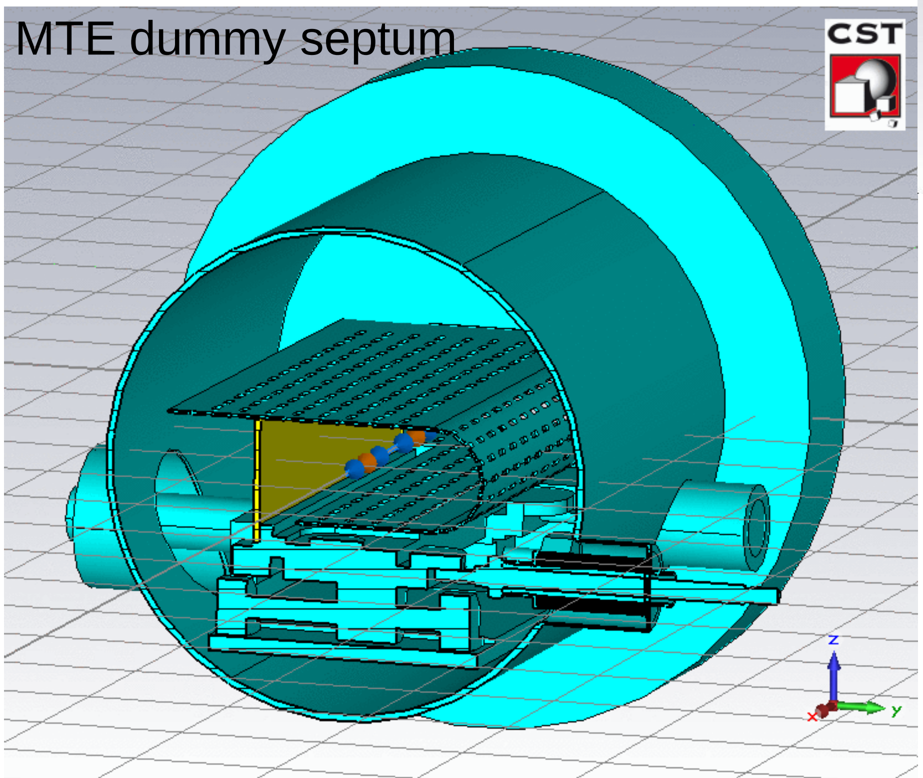
Excitation: **Qmeter kick / coupling**
Average noise/signal ratio:>**50%.**
Phase accuracy: **0.1-0.2deg .**
Estimated impedance: **>4MΩ/m**
Tune shift in degree: **0.5deg**

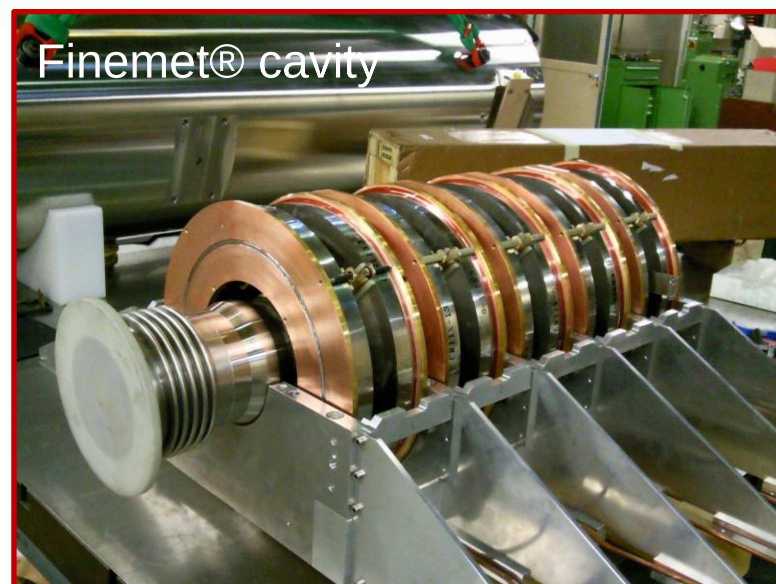
- While in the horizontal plane the impedance is much lower than the accuracy we can get, in the vertical plane it seems to be possible for big lumped sources.
- More measurements are ongoing, especially at injection in vertical plane where impedance is higher.
- **The absence of a vertical kicker strongly limits the capabilities of this measurement.**

Impedance evaluation of new elements

Determination of Impedance model of new/old elements to be compared with beam-based measurements







Summary I/II

#	Subject	Beam Instrum.	HW available	HW avail. before LS1
1	New injection optics for high intensity beams	Check injection grids	✓	
2	Headtail instabilities on injection flat bottom	✓	Finish damper comm.	✓
3	Transverse damper	✓	One plane missing	✓
4	Transition crossing instabilities	✓	✓	
5	*Instability at flat-top arrival (new 2012)*	✓	✓	
6	Transverse instability at extraction	✓	Finish damper comm.	Power upgrade during LS1
7	e-cloud measurements	✓	✓	
8	Transverse impedance studies	Performance Orbit system	✓	

Summary II/II (as conclusion …)

#	Subject	
1	New injection optics for high intensity beams	Ongoing / To be done before LS1
2	Headtail instabilities on injection flat bottom	Ongoing
3	Transverse damper commissioning	Ongoing / To be done before LS1
4	Transition crossing instabilities	Completed
5	*Instability at flat-top arrival (new 2012)*	Ongoing
6	Transverse instability at extraction	Ongoing
7	e-cloud measurements	Ongoing
8	Transverse impedance studies	Ongoing

Completed — Ongoing — To be done before LS1

All activities are progressing at a reasonably good pace but it will be important to being able to have MD time also during the run after Xmas.