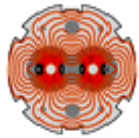


Automatic Coupling Corrections in the LHC

-Present status and outlook towards 2015

Tobias Persson, Rogelio Tomas

Outline

- Introduction
- Motivation
- Approach to control coupling in the LHC
- Measuring the coupling
- Coupling corrections using injection oscillation
- Outlook towards 2015

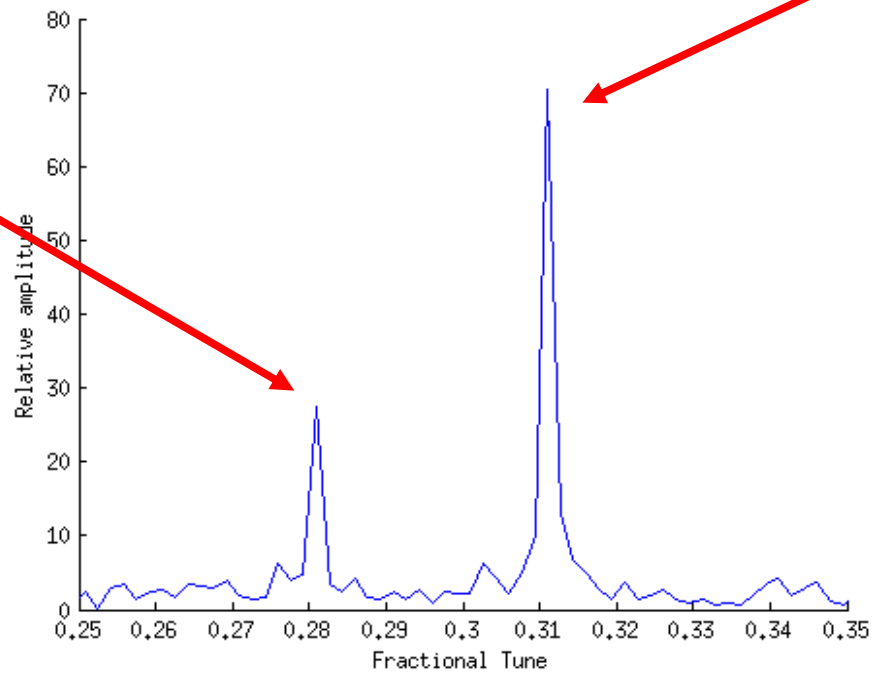
Motivation for coupling corrections

- Important for the tune feedback
- Can reduce the dynamic aperture
- An automatic correction of the coupling saves time (no need for manual corrections)

Introduction to coupling

Tune peak

Coupling peak



From the spectra of two BPMs we can calculate the “sum” and “difference” resonance driving terms

“sum” = f1010
“difference” =f1001

We measure the coupling from the turn-by-turn data

Introduction to the terminology

In LHC the f1001 is larger than f1010 since Qx-Qy is much closer to an integer than Qx+Qy

- f1001 is related to C- according to:

$$\left|C^{-}\right| = 4\Delta_Q |\overline{f_{1001}}|$$

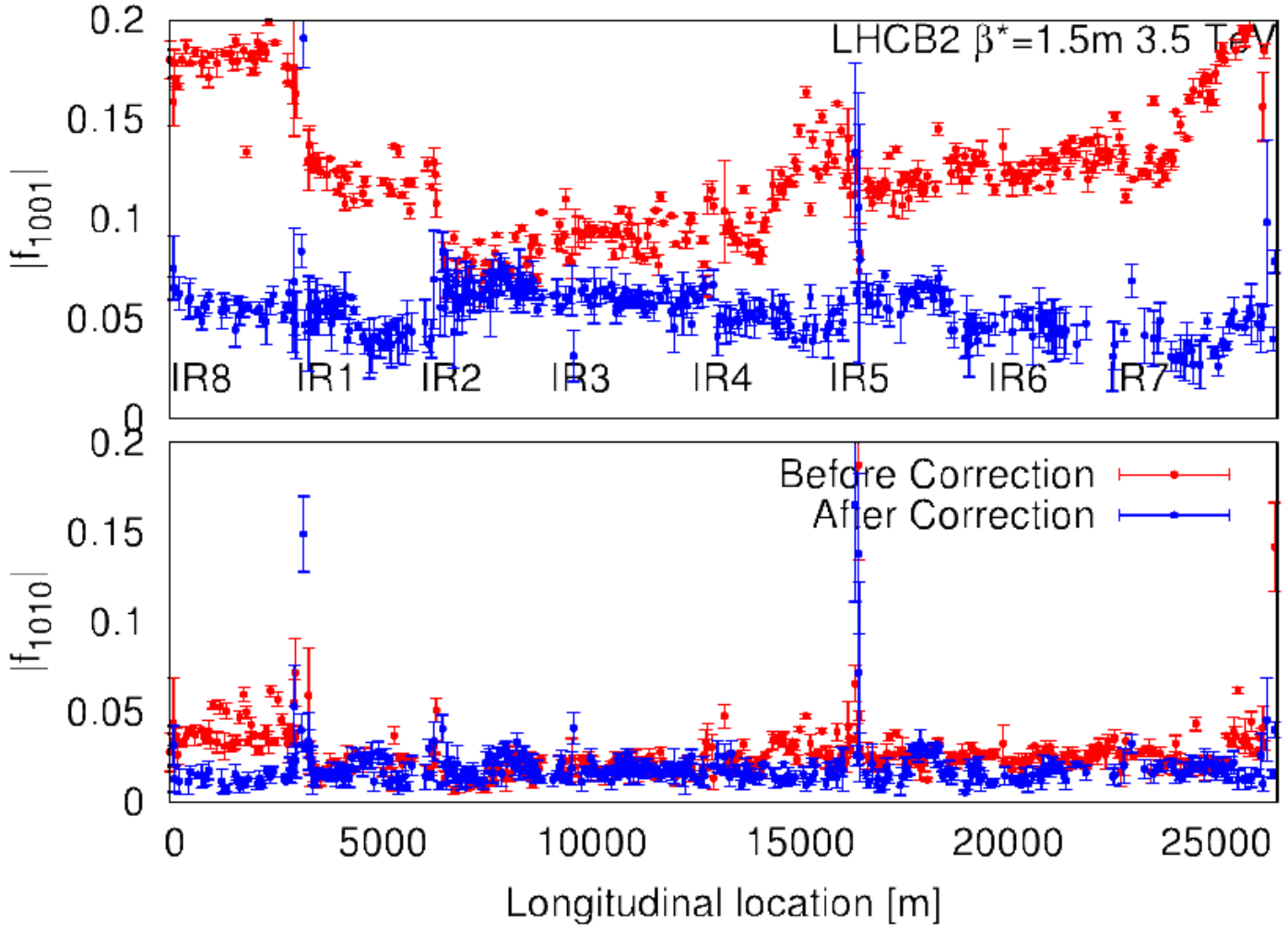
- |C-| is also the same as the closest you can approach the two tunes

$$\left|C^{-}\right| \equiv \Delta Q_{min}$$

Approach to correct coupling in the LHC

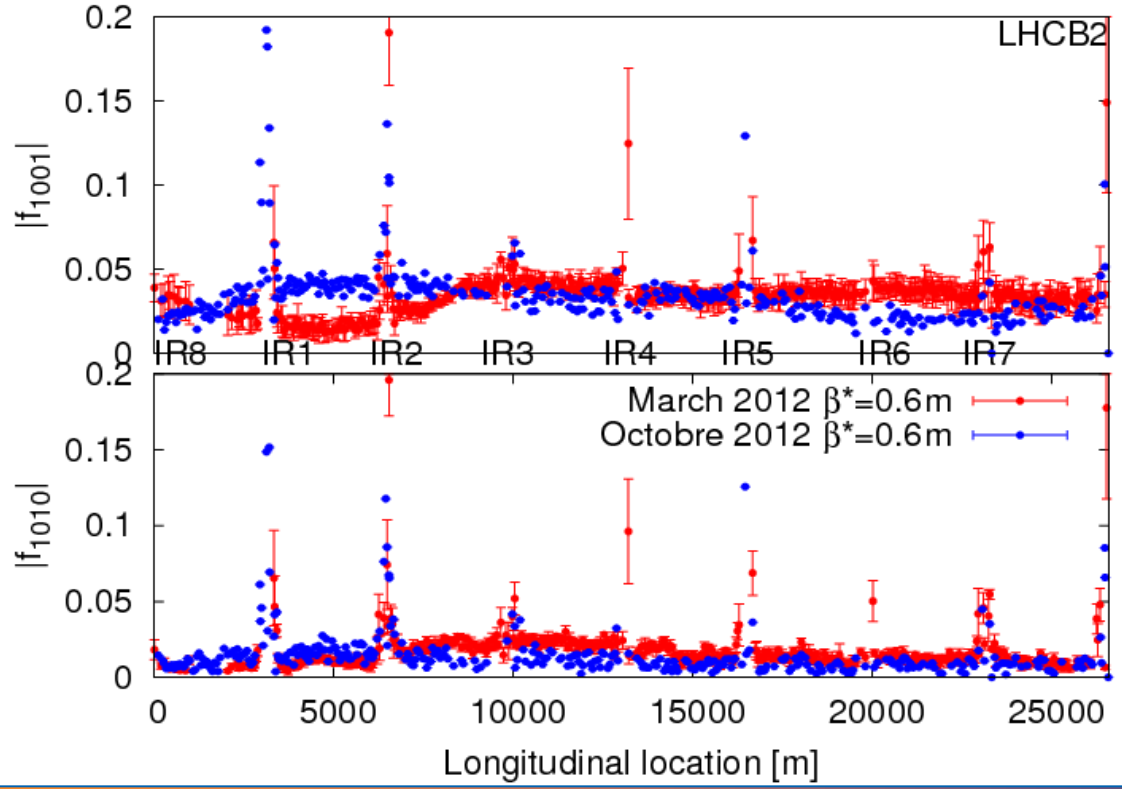
1. During commissioning the strong local coupling sources were corrected.
2. Correct the global coupling with two knobs.
   - Im {C-}
   - Re {C-}

Local corrections

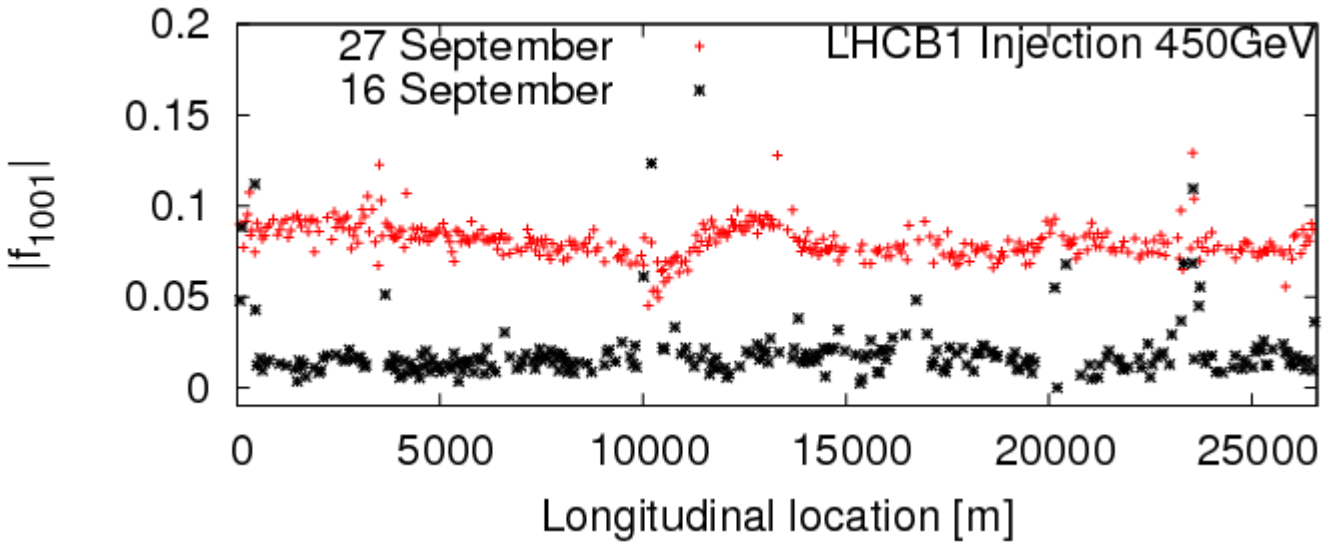


Local corrections

Same corrections for the entire cycle.
Corrections have remained valid throughout 2012!



Global coupling can still change!



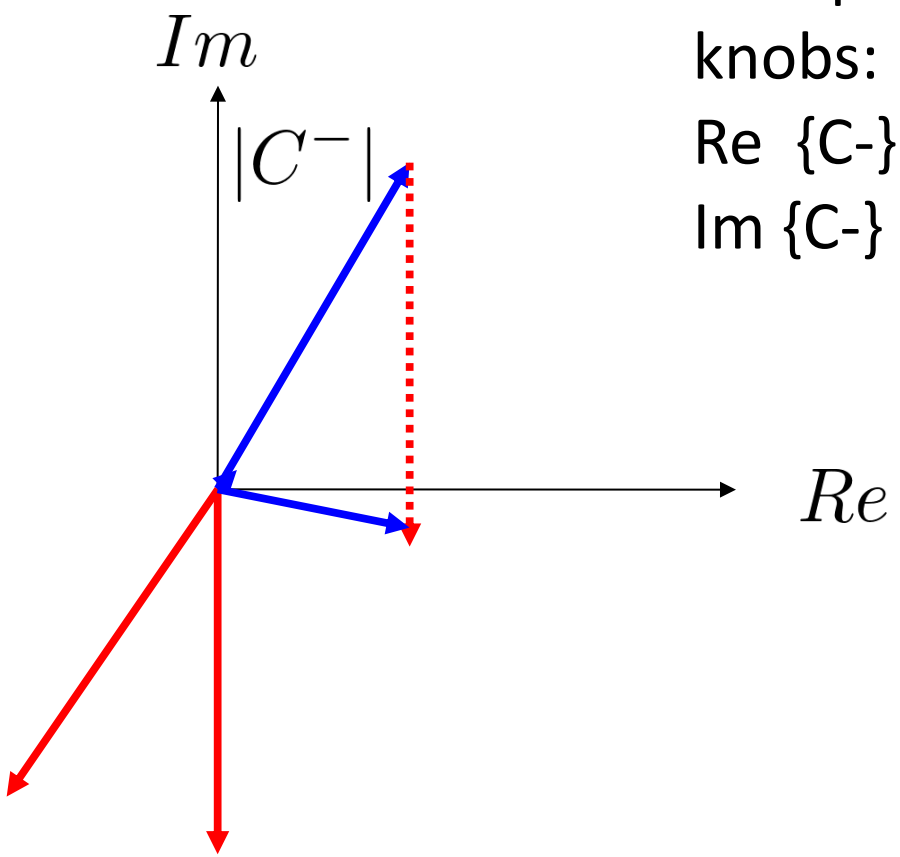
Intermediate conclusion

- The local corrections remained valid over the 2012 run
  → Enough to correct them during commissioning
- Drift of the global coupling
  → Need to measure and correct the global coupling during normal operation

Correction

Coupling

Correction



Correct the global coupling with two knobs:

Re {C-}

Im {C-}

What is needed to measure the global coupling?

Only need to measure f1001 at a single location.

- Since the strong local sources are corrected.
  - –> We know how the coupling propagates.

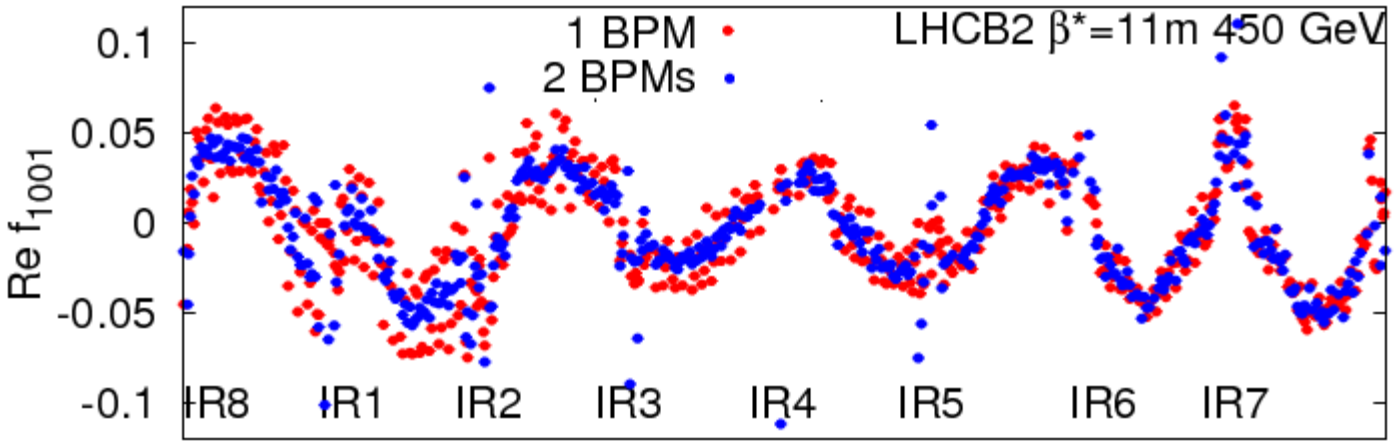
However, very profitable to use at least 2BPMs!

Why not only 1 BPM?

We can't separate f1001 from f1010.

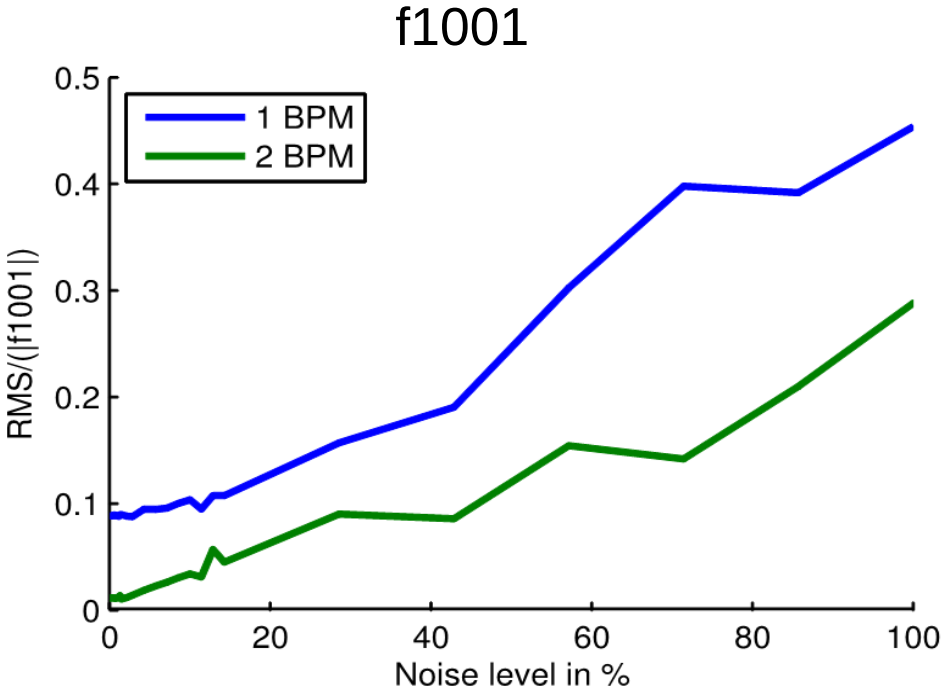
- Have to assume f1001 >> f1010

Less precise measurement



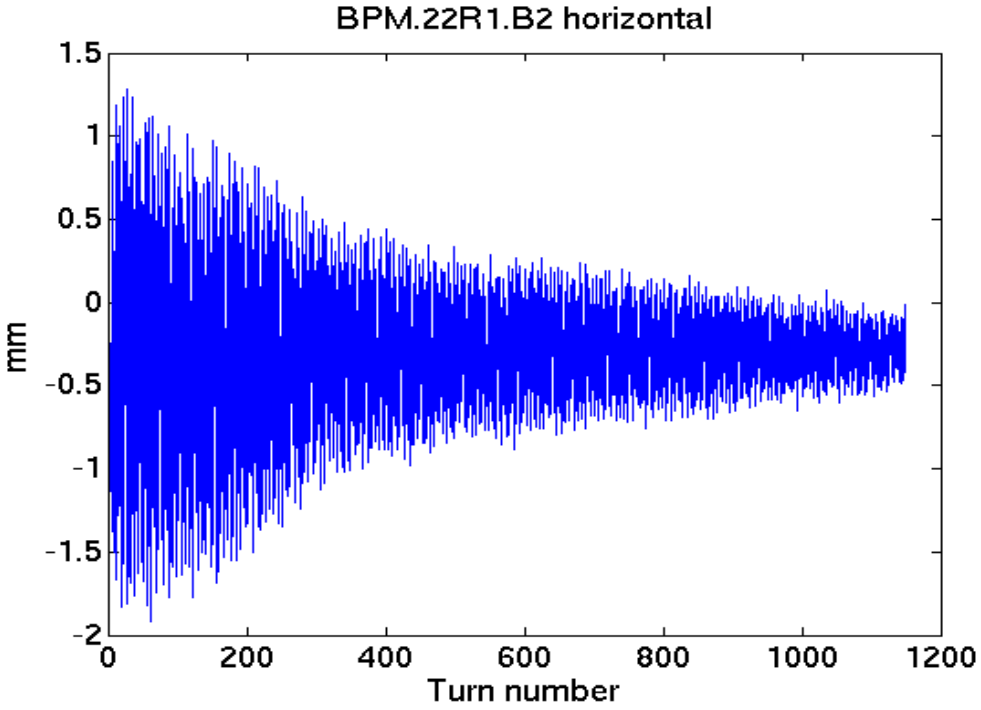
1 Vs 2 BPM

Tracking with a realistic coupling situation (Reproduce real measurements)



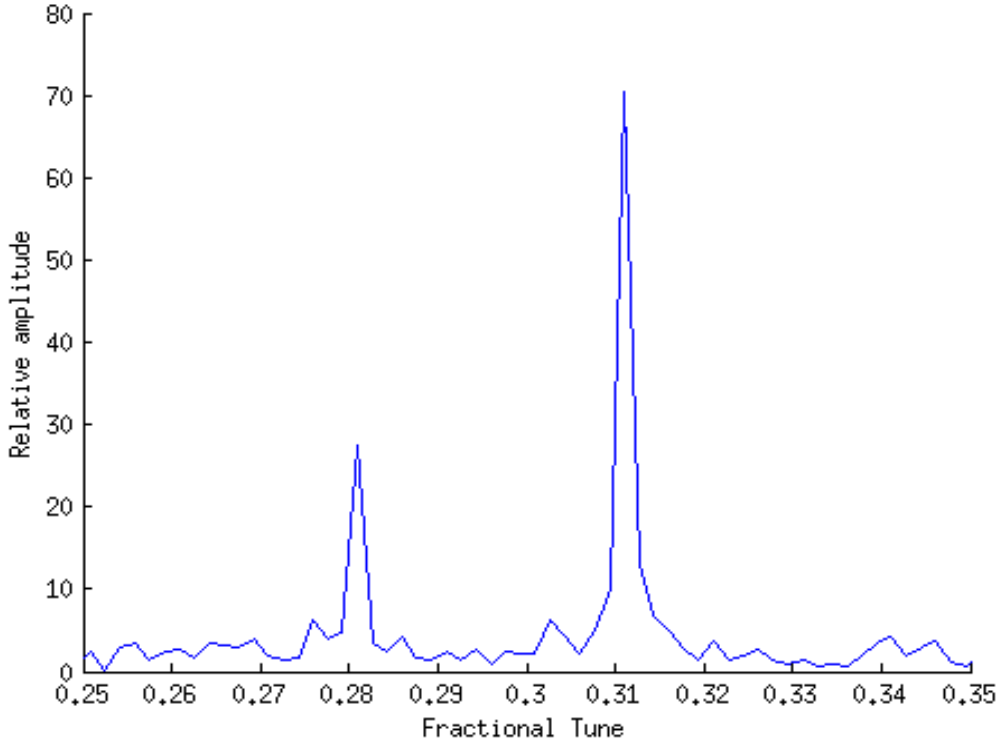
Injection oscillations from pilot

Thanks to Verena Kain and Delphine Jacquet, all the BPMs are now recorded for every injection.



Record Turn-by-turn data from the injection → Calculate the coupling amp and phase → Calculate correction based on our model → Apply correction

Calculate coupling



Record Turn-by-turn data from the injection → **Calculate the coupling amp and phase** → Calculate correction based on our model → Apply correction

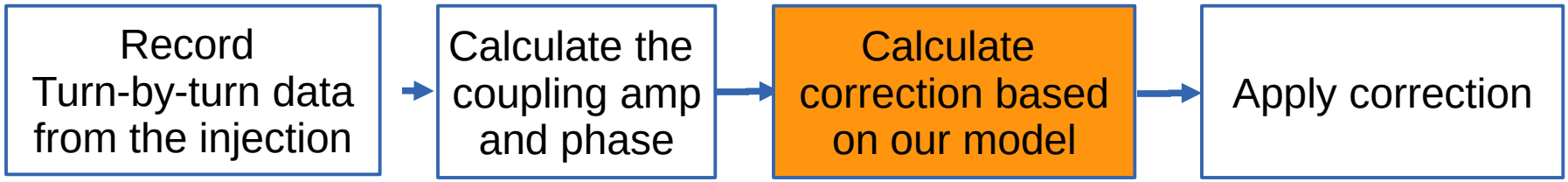
Correction (2)

- We know the influence of each skew quadrupole on the phase and amplitude of the coupling.

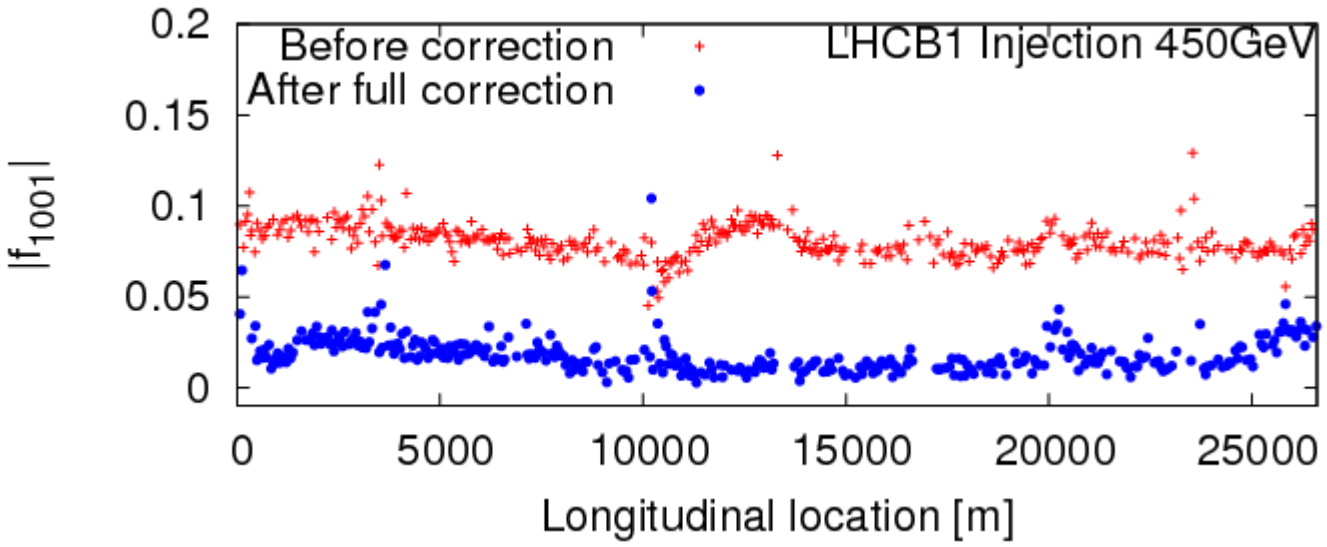
$$\mathbf{R}\Delta\vec{K}_{knobs} = (Re\{\vec{f}_{1001}\}, Im\{\vec{f}_{1001}\})$$

- The best setting of the knobs is found by a SVD solution of the system.

$$\Delta\vec{K}_{knobs} = \mathbf{R}^{-1}(Re\{\vec{f}_{1001}\}, Im\{\vec{f}_{1001}\})$$



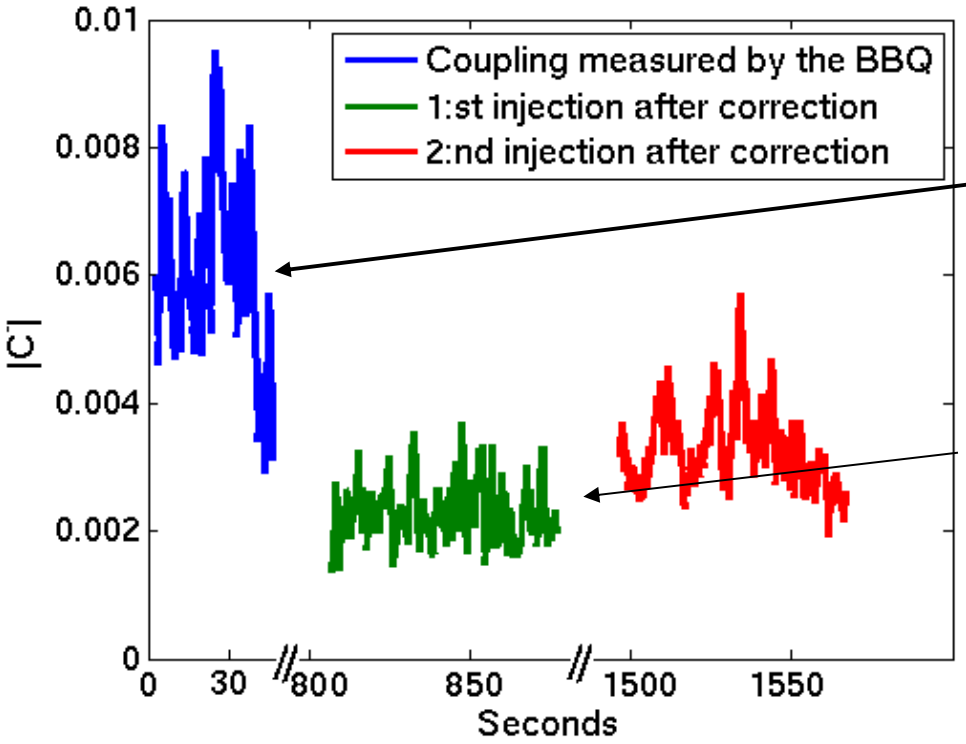
Results



Record Turn-by-turn data from the injection → Calculate the coupling amp and phase → Calculate correction based on our model → Apply correction

Results (beam 2)

Measured with the BBQ-system

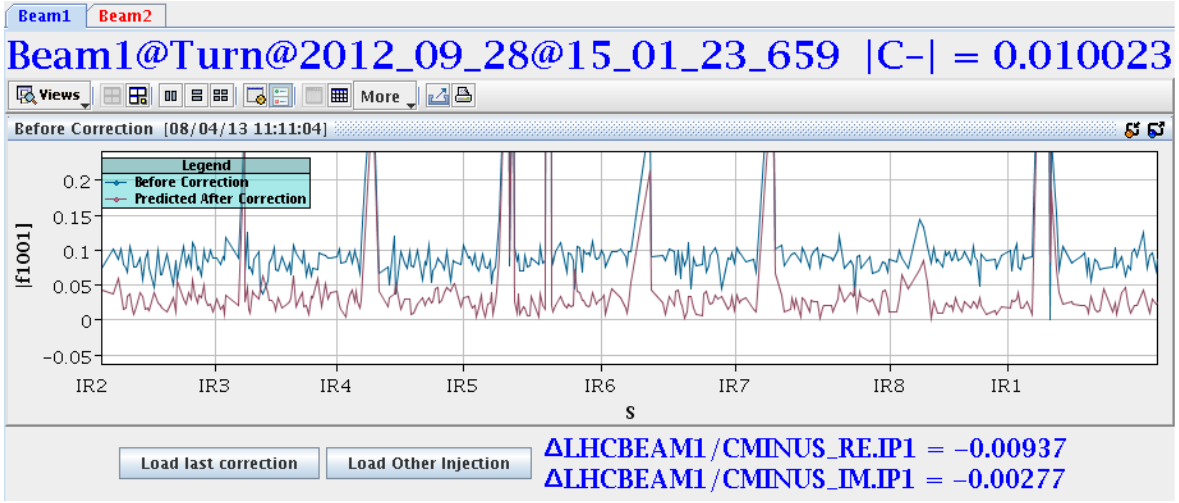


Correction applied here

Beam dumped due to unmasked RF

Injection oscillations from pilot

- This method has been used in normal operation
- Is implemented and ready to use for the 2015 run



Semi-automatic Coupling correction at injection ✓

Correction throughout the cycle

Can't use the same method as for injection

We have tried two different systems:

ADTs - damper BPMs

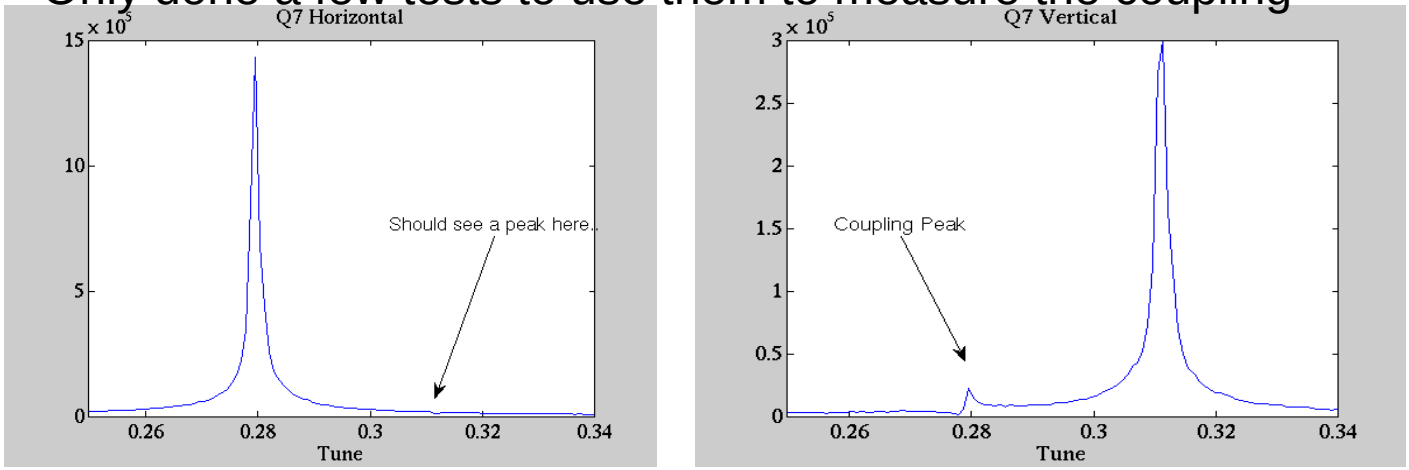
BBQ – system

Important to keep in mind that these systems were not designed for this.

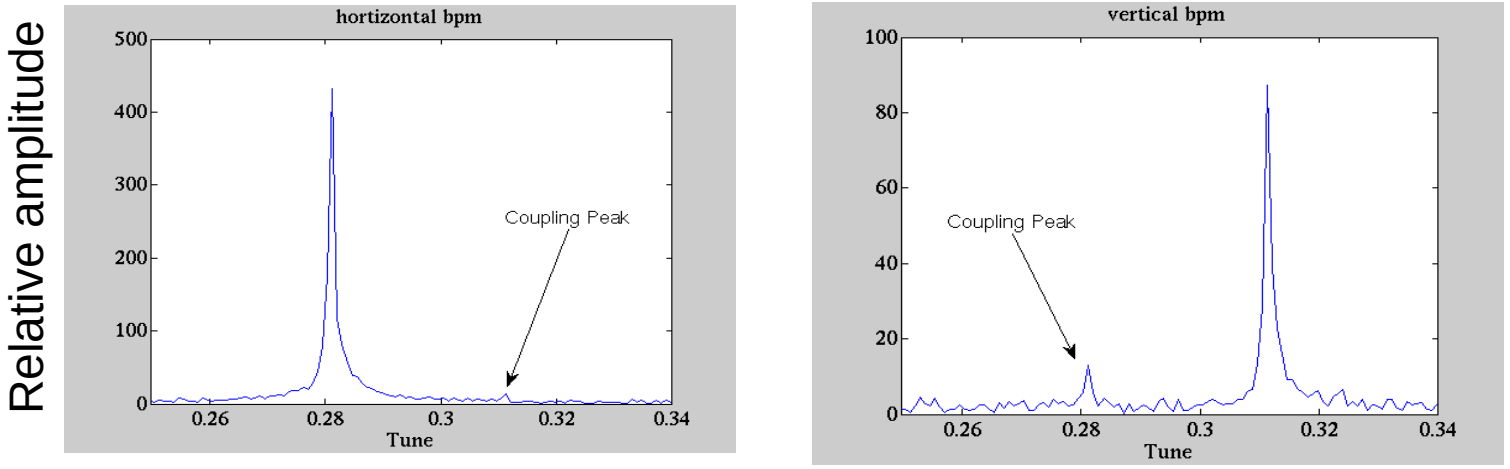
Placed at positions with high beta-function for that plane.

ADTs

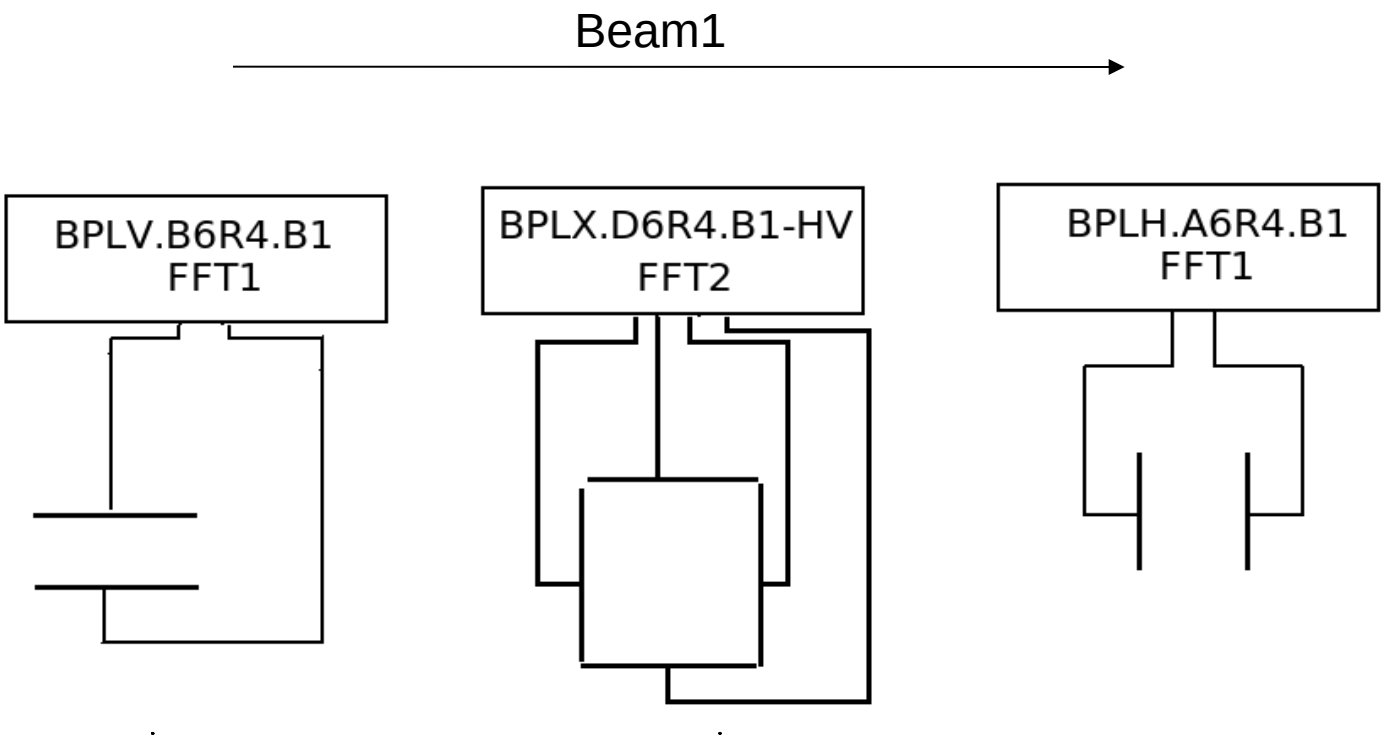
Only done a few tests to use them to measure the coupling



Same injection but recorded with the normal BPMs.
Looks more noisy but the coupling peak is visible in both planes.



BBQ (beam 1)



Δy =2.8°

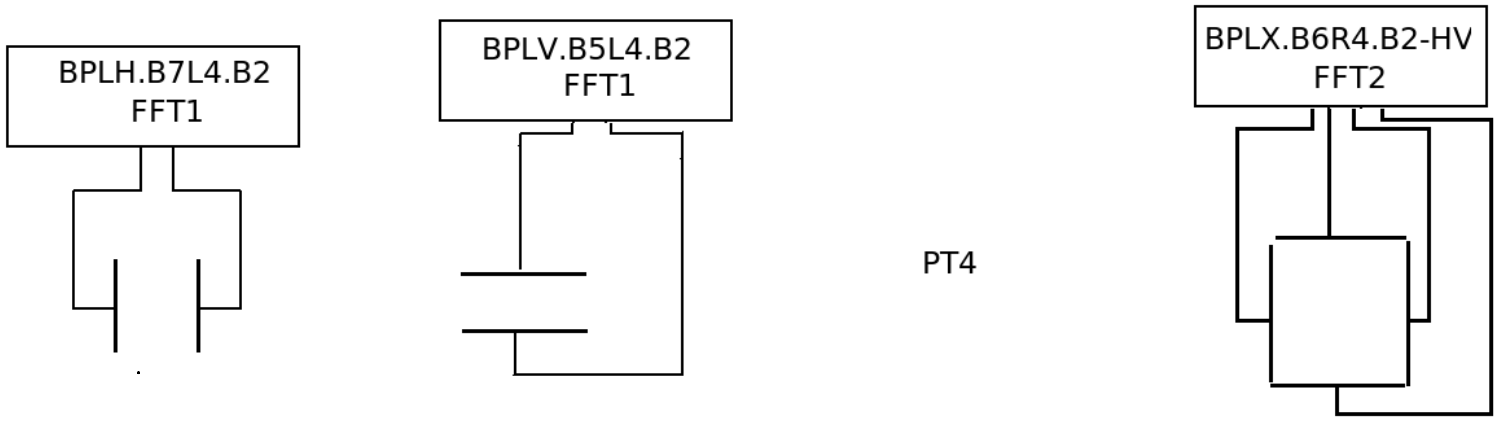
Δx =3.6°

Very small phase advance.

BBQ (beam 2)

Beam 2

- Nice phase advance!
- However, not synchronized



$\Delta x = 15.3°, \Delta y = 10.7°$

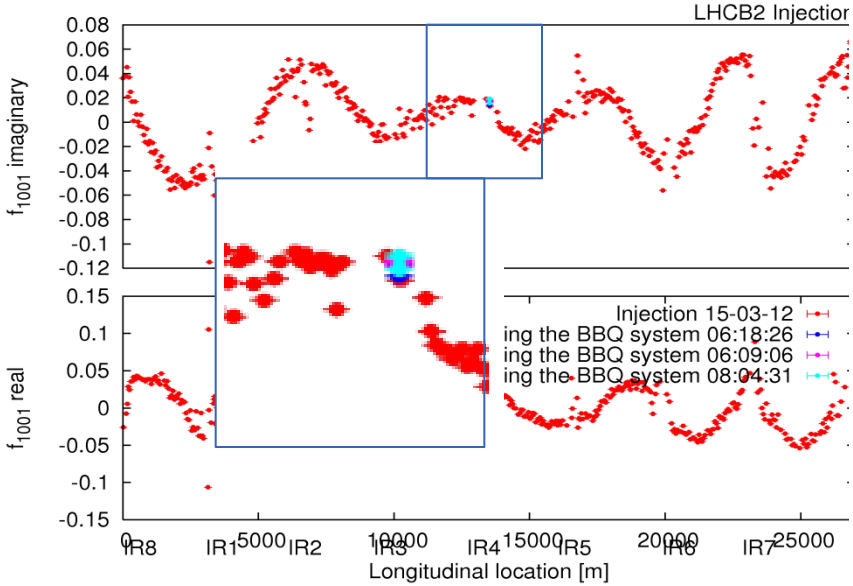
$\Delta x = 98.4°$
$\Delta y = 57.8°$

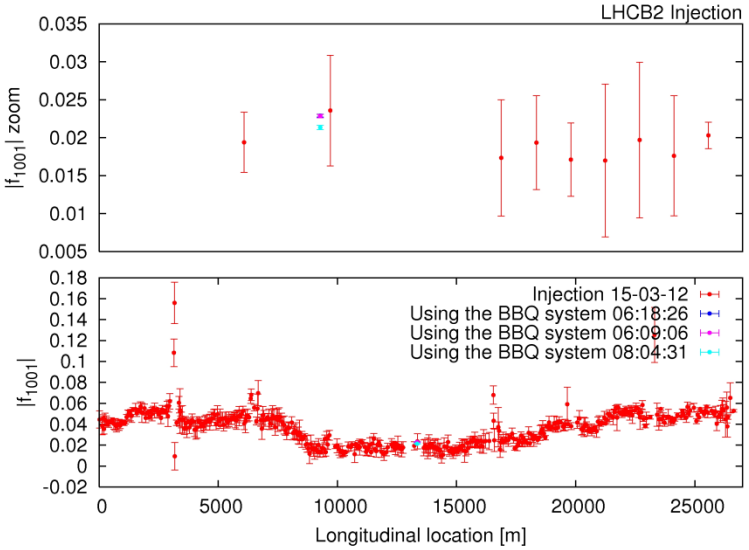
Coupling Measurements with BBQ

We had some successful measurements of the f1001 with the BBQ.

The synchronization of the two pick-ups had to be done through **extensive** post analysis of the data.

Need a clear point for the synchronization (like a kick)





Outlook / Proposal

- A “pilot” or “witness” bunch injected with every physic fill.
- Excite it with for example the tune kicker if the signal to noise ratio is to low.
- A scheduled excitation and correction.

<u>Record it with:</u>

BBQ – Need synchronization. The post analysis synchronization is not reliable. One pickup would need to be moved for Beam 1.

ADT – Need more tests to say if possible.

Normal BPMs – Most likely too low resolution even with the filtering we can do (SVD).

New LHC Diode ORbit and OScillation System (DOROS)

Seems very promising from the specifications!

System Requirements

What we would need to use it for coupling corrections:

- At least 2 pickups synchronized
- Phase advance between two pickups > 30 degrees

What we would wish for:

- Phase advance ~ 90 degrees
- Dual plane
- Gated
- Large signal to noise ratio

Conclusion

- The strong local sources has remained well corrected throughout the 2012-2013 run.
- A method based on the injection oscillations to measure and correct the coupling has been used in operation and will be available for the 2015 run
- “The New LHC Diode ORbit and OScillation System (DOROS)” seems to provide a good option for coupling measurements throughout the cycle for the 2015 run.

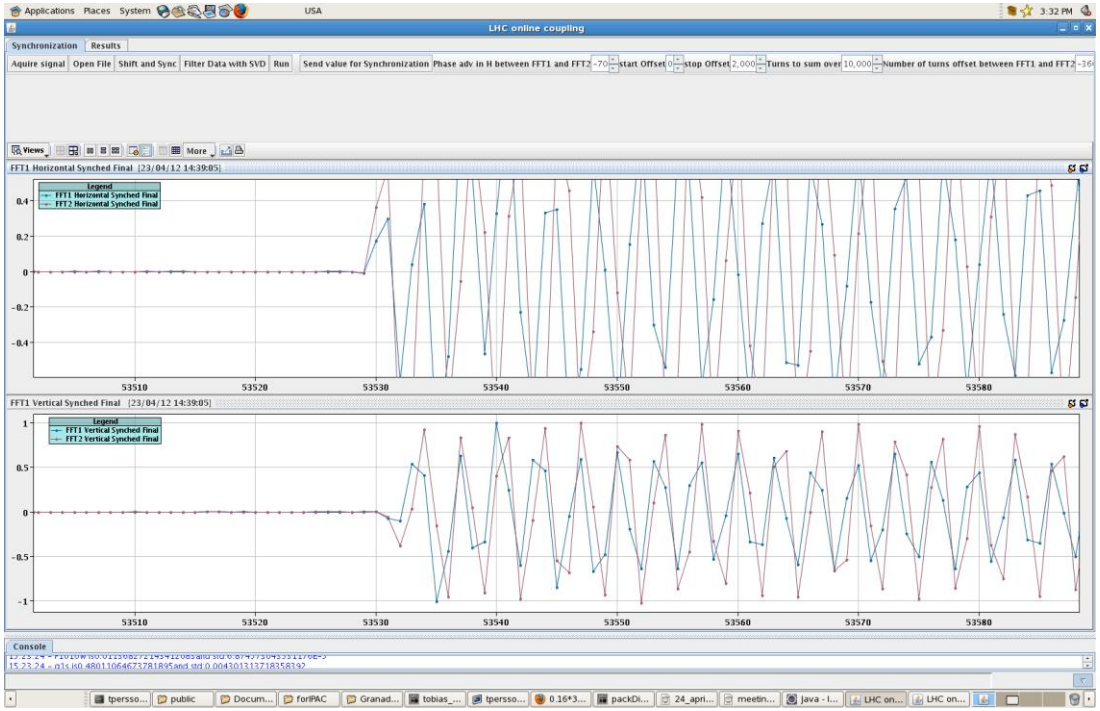
Thank you for your attention!

*Thanks to Ralph Steinhagen and Marek Gasior for discussions and comments about this presentation

Backup slides

Synchronization of the BBQ

Have to find a starting point for the synchronization.
A kick or something similar



Some of the data is read in twice.

This enable us to construct the turn by turn data.