LHC Orbit FB for IR6

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- Motivations for an orbit feedback @ LHC
- Anticipated orbit changes
- Estimated feedback parameters / limitations / performance
- Conclusion

Orbit Feedback @ LHC : why ?

Some reasons why a real-time orbit feedback is required for the LHC :

- Need good orbit control over whole ring at all stages of operation due to the tight aperture. A well controlled orbit also greatly simplifies operation, in particular during ramp and squeeze.

- Tight orbit tolerances around collimators :
  fraction of a beam sigma → stabilization to better than 0.1 mm.

- LHC has 2 rings : orbit movements (due to ground motion…) will separate the beams at the IPs → minimize this effect !

- Bad LEP experience : we suffered a lot during ramp & squeeze from the absence of real-time orbit feedback. Large (few mm rms) orbit changes to the un-anticipated movements of the low-beta quadrupoles.

Expected Orbit Perturbations

Effect	Source	RMS orbit change (mm)	Time scale	Reproducible
Ground motion	quads	~ 0.2 - 0.5 (LEP)	5-12 hours	No
Persistent cur. decay	dipoles	~ 0.3	~15 min	~ "YES"
Snapback	dipoles	~ 0.3	~1 min	~ "YES"
Squeeze	IR1,2,5,8 quads	~ 2-10	few mins	~ "YES"

No significant motion (above ~ few μm) observed at freq. > 0.5 Hz at LEP.

Reproducible effects can be **'anticipated'** after a learning period :

→ included into the PC functions (snapback, ramp, squeeze).

→ reduces the load for the FB.

Orbit Feedback Limitations

Some feedback limits are set by the orbit system sampling rate of 10 Hz.

For a closed loop feedback, the highest frequency of a perturbation that can be well corrected is ~ sampling rate / 20 :

→ feedback will only be efficient below ~ 0.5 Hz.

The feedback is also limited by the long time-constants (~ 200 sec) of most of the cold orbit correctors → PCs cannot drive them much above ~ 1 Hz.

For the anticipated effects → perfectly adequate !

…but we must beware of magnet vibrations inducing orbit movements above 0.5 Hz etc

Design Ideas

Possible work-horse for the LHC : a **global orbit feedback**.

- It can correct the **anticipated effects** to < 0.2 mm rms over the whole machine, except possibly IR1,2,5,8 (squeeze, more studies required).

  → Stabilization of IR6 to < 1 mm is not a problem.

- Little sensitivity to isolated bad/missing BPMs, missing correctors.

- Assuming a 100 ms delay (acquisition, correction algorithm, network, PCs…) the system achieves a gain of ~ 10 at 0.1 Hz, no gain at 1 Hz.

- To improve the orbit at special locations (collimators..) :
  → add a local correction – multiple design options.

Note that the FB maintains the orbit around a given reference, but it does not find this optimum reference orbit !

Orbit @ TCDQ Absorber

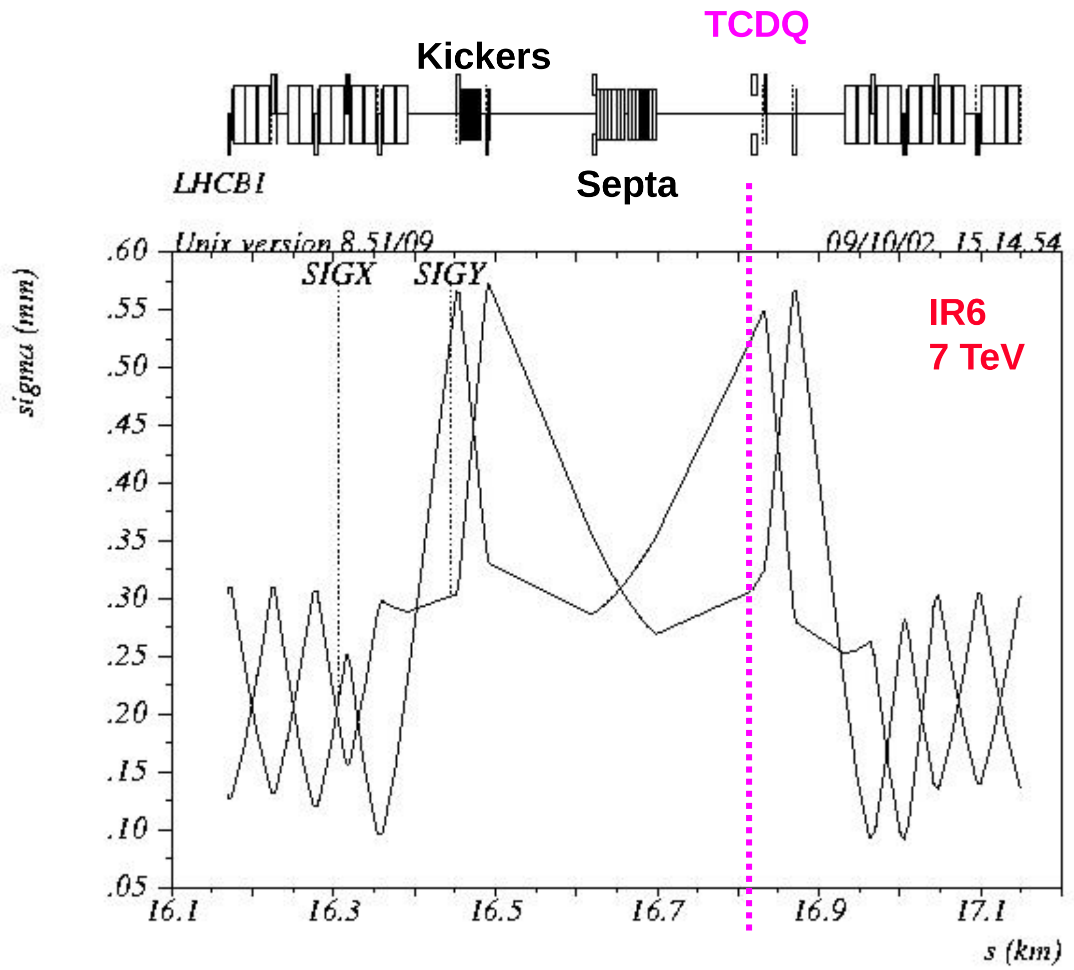
At the TCDQ **absorber** :

Must stabilize the horizontal orbit to better than

$\sigma_x/2$ ~ 0.2 mm at 7 TeV

to ensure a correct distance to the beam for protection.

Tighter than aperture tolerance !



Reliability

The orbit feedback depends on distributed systems and is **not failsafe** :

- up to 500 orbit monitors per plane and ring.
- up to 300 orbit correctors per plane and ring.
- fast network connections.

→ Its reliability will be limited by those elements
(not sensitive to isolated problems !).

Some strategies have to be defined, to be refined with **operational experience** :

- What do we do if we cannot access BPMs around IR6 ?
- What do we do if the the BPMs around IR6 are "faulty" ?
- What do we do if we cannot access orbit correctors around IR6 ?
- …

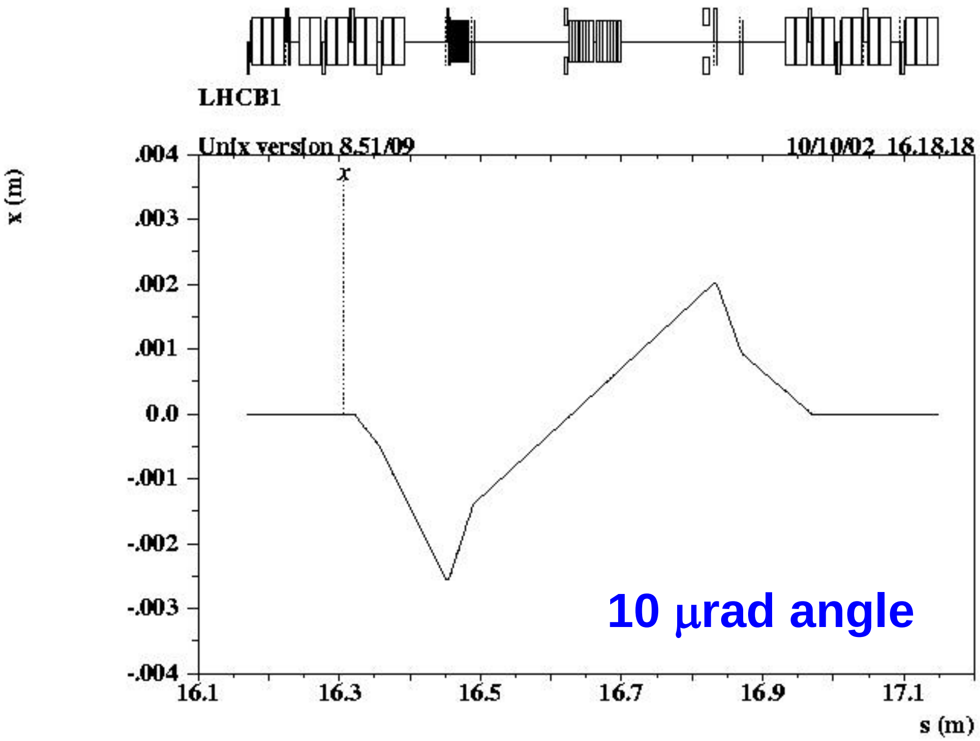
Conclusion

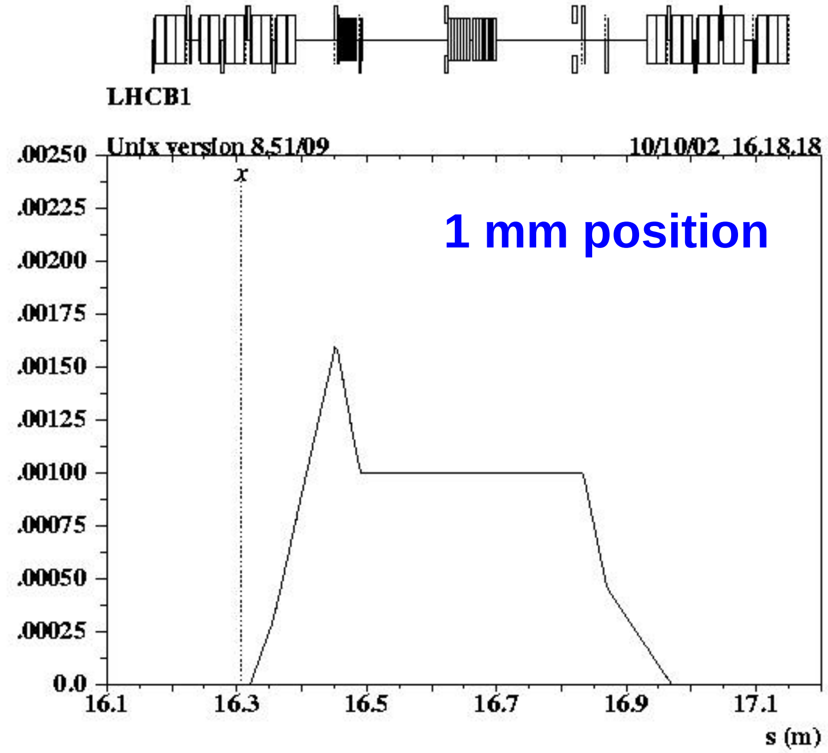
With the orbit feedback :

- the orbit in IR6 can be stabilized to < 1 mm for frequencies < 0.5 Hz during all phases for the anticipated orbit movements.
- the orbit cannot be stabilized in case of failures inducing fast orbit changes on the time scale of few turns or few msec.
- the requirements for the feedback may be even tighter than 1 mm at the TCDQ absorber : ~ 0.2 mm at 7 TeV.
- the orbit FB maintains the orbit around a reference, which must be defined when setting up the whole extraction process in IR6.

Bump shapes @ IR6

4 corrector bumps using nearest orbit correctors

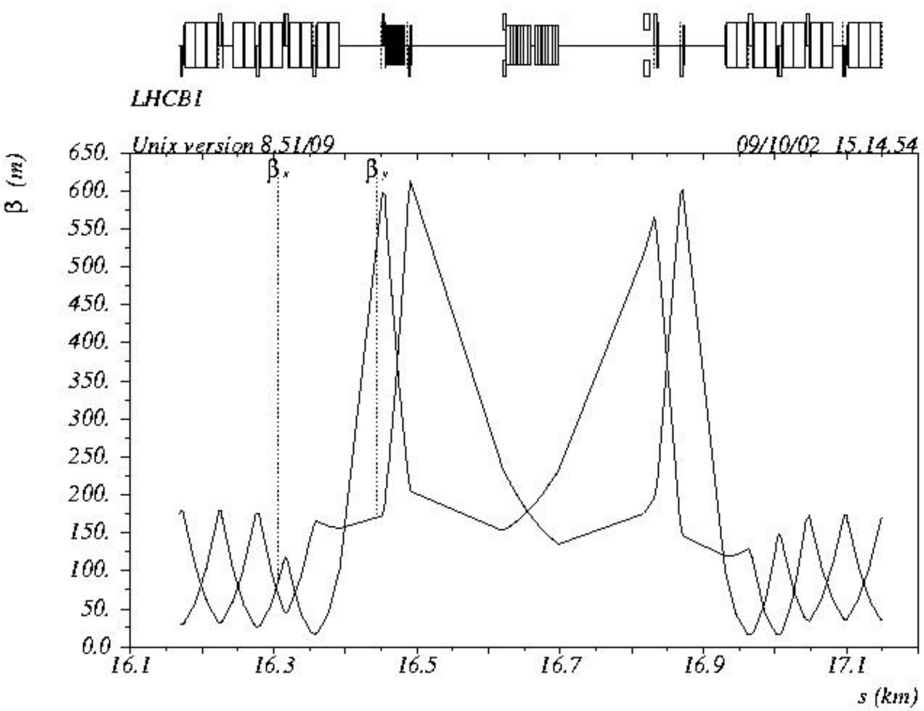




To ramp the correctors for a
1 mm /10 μrad bump takes ~ 4 sec @ 7 TeV

Optics in IR6

β functions



dispersion