- There are 3 basic interlock types:
  - Global orbit interlocks.
  - Global COD interlocks.
  - Local orbit interlocks : injection region, TOTEM, TCDQ
- All interlocks dump the corresponding beam, except the interlocks specific for injection:
  - Global orbit interlock at injection,
  - Global COD interlock at injection,
  - Local orbit interlock in the 2 injection regions.

  >> inhibit of injection
- The settings are stored in the LSA DB as critical settings (role MCS-LHC-SIS) and are filled from the steering application.
  - Can copy orbit readings/CODs to DB settings.

- Compare entire orbit with reference, by plane and by beam (4 sub-interlocks):

  - Reference and tolerance by BPM.

  - Global limit on max. number of out-of-tolerance BPMs.

  - BPMs was bad status are ignored.

Global orbit interlocks

Interlock / phase	Tol. ARC + IR3,4,6,7	Tol. IR1,2,5,8	BPMs to trigger	Action
Injection	1.2 mm (H+V) (≈1 sigma)	1.2 mm (H+V)	2	Inj. Inhibit
Injection to Adjust	1.8 mm (H)* 1.2 mm (V)	4 mm (H+V)**	10	Dump
Stable Beams	0.8 mm (H+V) (≈2 sigma)	1.6 mm (H+V)	10	Dump

- Remarks:
  - * Limited by Q' measurements.
  - ** Limited by separation bumps/Xing bump changes.

- Compare all CODs with reference, by plane and by beam (4 sub-interlocks):

  - COD kicks are reconstructed from PC currents (simple scale factor).
  - Reference and tolerance by COD.
  - CODs that are not powered are automatically ignored.
  - Global limit on max. number of out-of-tolerance CODs.

Global COD interlocks

Interlock / phase	Tol. ARC + IR3,4,6,7	Tol. IR1,2,5,8	CODs to trigger	Action
Injection	12 urad (H+V)	12 urad (H+V)	2	Inj. Inhibit
Injection to Adjust	30 urad (H+V)	40-60 urad (H+V)	2	Dump
Stable Beams	16 urad (H) 12 urad (V)	20-40 urad (H+V)	2	Dump

- Remarks:
  - The tolerance are partly limited by the need to keep some margin in case a (60 A) COD is lost and compensated by neighboring CODs. With tighter tolerances an immediate change of settings would be required in case of a loss of COD.

Local orbit interlock – injection

- Compare local orbit (4 BPMs) in injection regions with reference, by plane and by beam (4 sub-interlocks):
  - B2 : BPMYB.5R8.B2, BPMYB.4R8.B2, BPMWI.4R8.B2,BPMSX.4R8.B2
  - B1 : BPMYB.5L2.B1, BPMYB.4L2.B1, BPMWI.4L2.B1, BPMSX.4L2.B1
  - Tolerances fixed at 0.6 mm.
  - Injection inhibit if 2 BPMs out of tolerance.
- New interlock (~ 1 week) to avoid large orbit offsets around the TDI – important for high intensity injection.
  - Presently collecting (first) operational experience.
  - Still have to check if the interlock logic is fully adequate.
  - Issue with low and high intensity bunches – readings can differ by > 0.3 mm. Could solve with 2 distinct settings ….

Local orbit interlock – TOTEM

- Compare local orbit (3 BPMs) around TOTEM with reference, by plane and by beam (4 sub-interlocks):

  - 2 TOTEM BPMs (BPMWT) and 1 regular machine BPMs.
  - Tolerances 0.8 mm: 2 sigma in V, 4 sigma in H.
  - Dump if 2 BPMs out of tolerance.

- Experience over past months shows that the BPM readings do not change more than ± 0.2 mm around the reference.

  - Some room to tighten interlocks, in particular in H plane.

- One false dump triggered when one acquisition reported all BPMs as bad…

  - Fixed the logic to accept bad readings for 2 minutes.

Local orbit interlock – TCDQ

- Compare 2 BPMs (BPMSA/B) near TCDQ/TCSG.6 with center of the TCSG collimator.
  - Reference for center of the collimator and for each BPM.
  - Tolerance energy dependent (function):
    - 1 sigma (2 mm) at injection.
    - 1.4 sigma (1 mm) at 3.5 TeV.
  - Dump if any of the BPMs is out of tolerance.
- For nominal performance the tolerance must be pushed towards 0.5 sigma.
  - Interlock settings feed into the minimum b* - one of the tolerances.
  - From the stability of the BPMs (and the stability of the orbit), a tolerance of 1 sigma should be feasible in 2011.

Operational experience

- Some false dumps – mostly in April/May – most of them related to CMW issues.

- Above 450 GeV:
  - The COD interlocks never triggered.
  - Up to August, there have been a few justified triggers from the orbit interlocks: global orbit and TCDQ local orbit.
  - **No more orbit dumps by SIS since we switched to trains:**
    - **Very good orbit control.**
    - There is now so much beam in the tails that BLMs come first. Orbit interlocking now second line of defense.