# Beam Transfer Lines, Injection and Extraction

## Some highlights from LHC commissioning

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and many, many other dedicated colleagues.

# Outline

- Highlights from 2009 LHC commissioning
  - Transfer lines
  - Injection
  - Beam dump
- Known issues and outlook for 2010

# Transfer lines

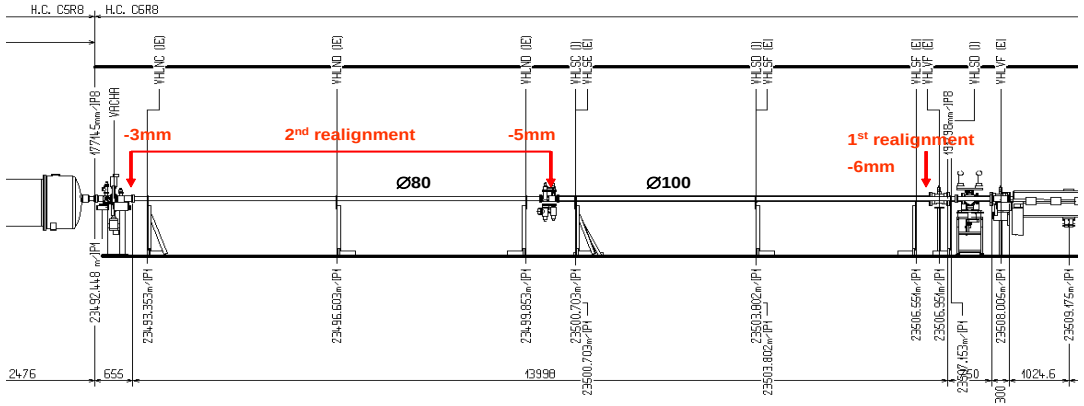
- Nearly all commissioning work completed in TL beam tests in previous years, and in 2008/2009 sector tests
  - Some subtle effects from tilt mismatch at LHC understood and remeasured for confirmation
- Big effort since 2008 to understand and correct dispersion mismatch
  - Caused by combination of strong MB.B3 and MQ calibration curve error (as suggested by S.Fartoukh)
  - Models updated and now agree well with measurement
- No more detail here, as this has been presented to the LMC already

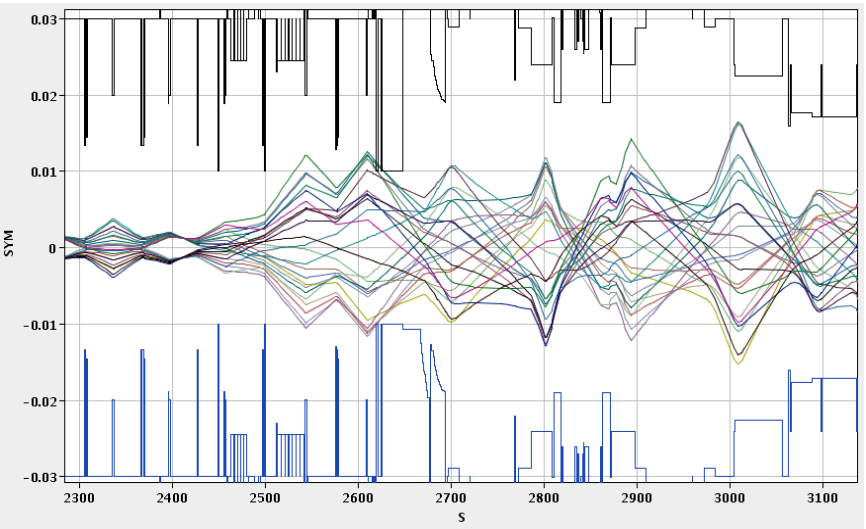
# Injection

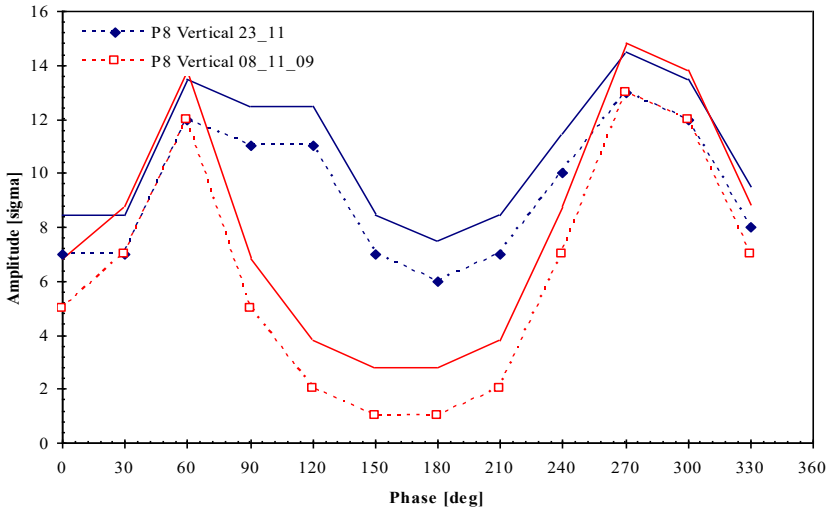
- Now almost ‘routine operation’ (for present simple filling schemes)
- Nearly all commissioning measurements completed for single bunch per injection

# Injection aperture

- Vacuum chamber alignment between MSI and Q5 again gave problems with vertical aperture (2008 P2/B1, 2009 P8/B2)
  - Realigned in P8 twice to remove the problem - now as designed.
  - Improving documentation and procedures with VSC and SU

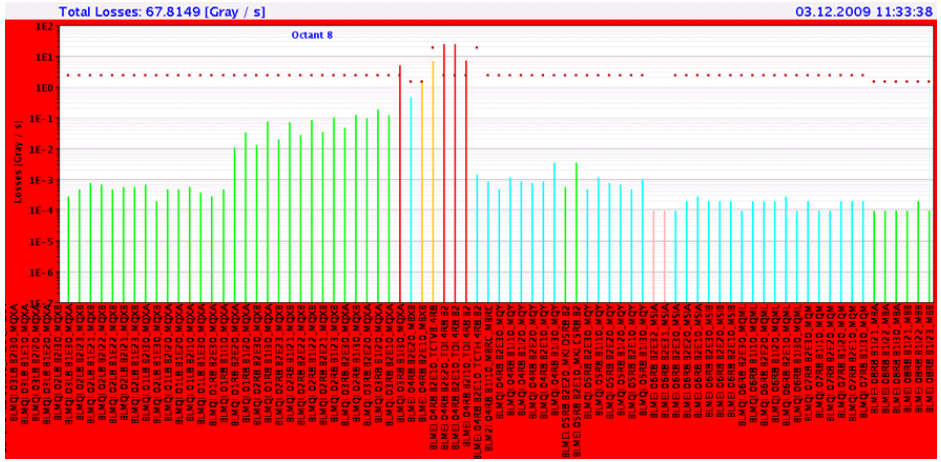


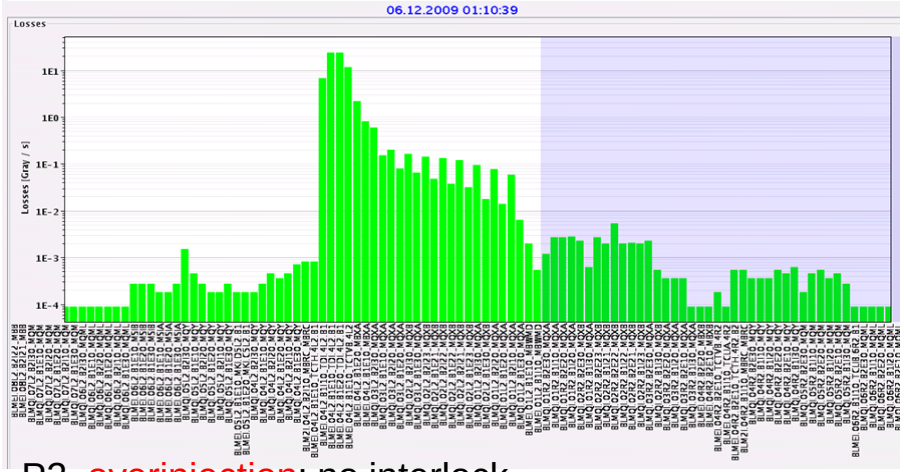



# TDI setup and losses

- Setup with beam no major problem (few mm jaw asymmetry to understand for B2)
  - TDI already protected LHC from overinjection or missing injection kick.
- Losses and scraping studied, also with Beam Condition Monitors from LHCb and ALICE.
  - Overinjection is problematic – now works for B1 but not B2 (losses on MQXA (Q3) R8 which triggers BLMs)



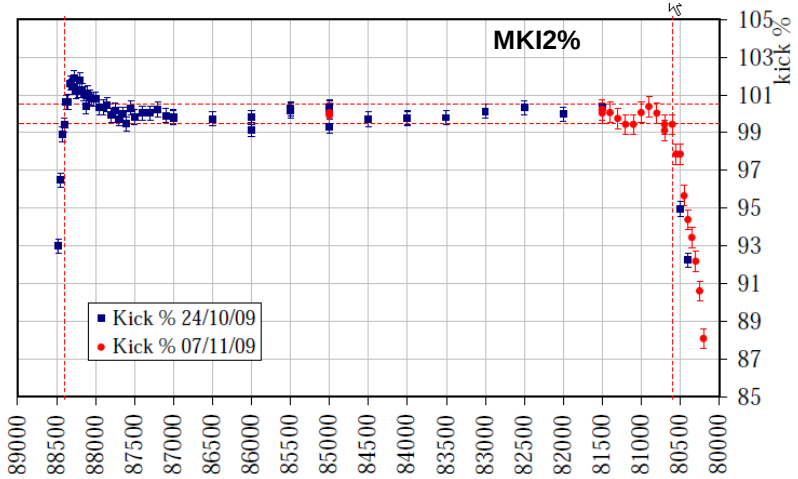

P8, overinjection: MQXA (Q3) interlock

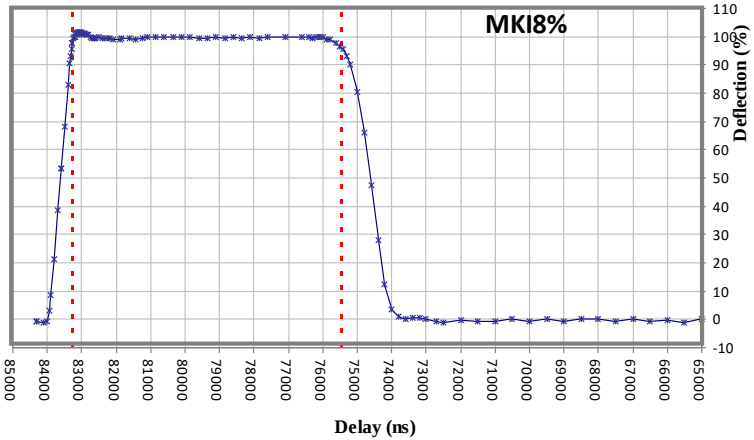


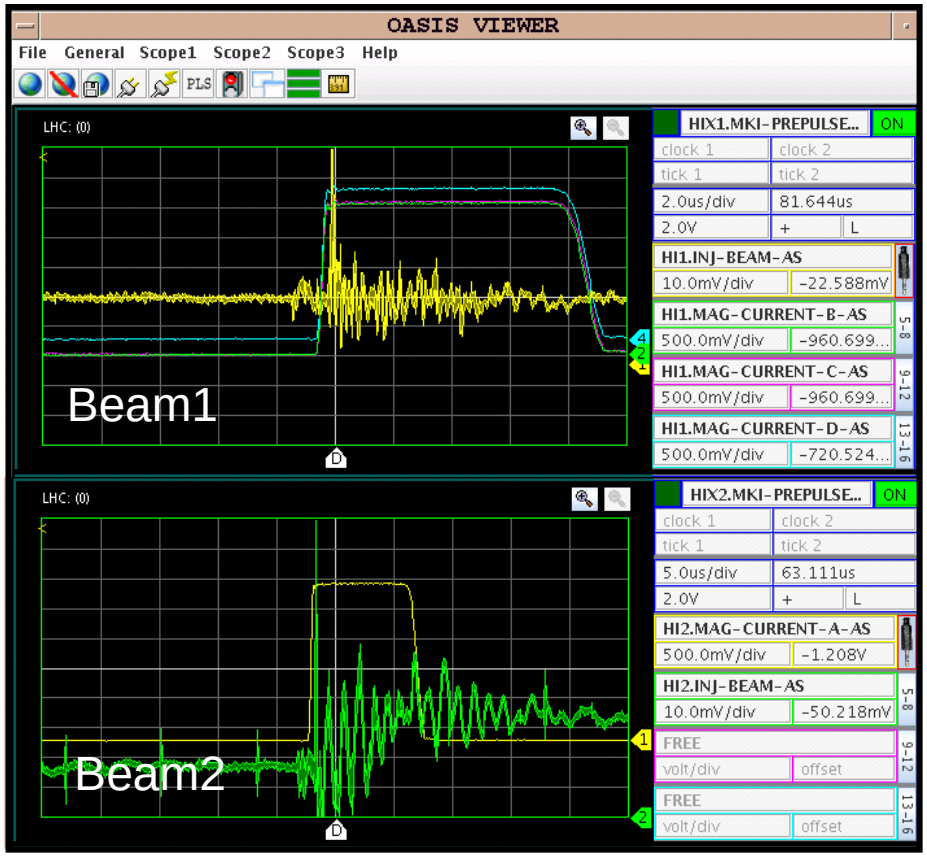

P2, overinjection: no interlock

# Injection kickers

- Waveforms measured already during sector tests
  - Overshoot slightly out of tolerance at pulse start – shutdown correction
- Several MKI “missings” from low-level logic – understood and fixed
- Fine kicker timing-in with beam done

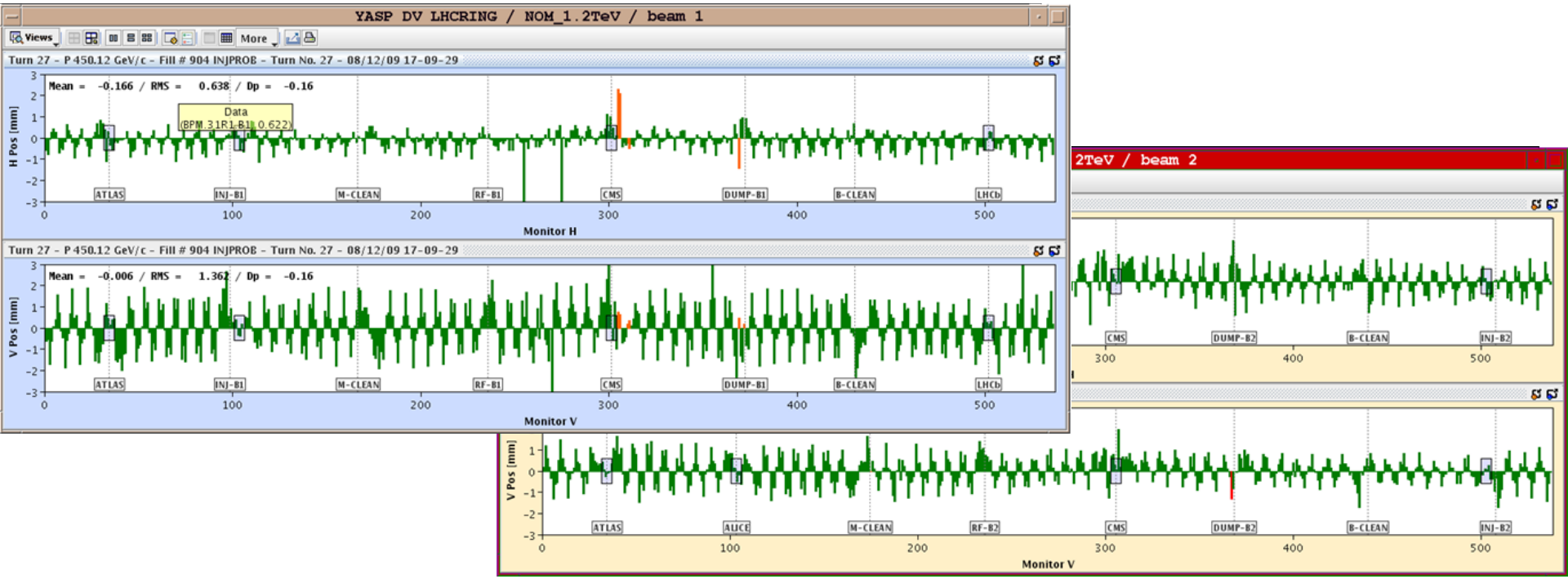


# Injection oscillations and losses

- Injection oscillations typically about 2mm peak in both planes
  - Already near specified value – more optimisation possible
- Losses on first turn(s) can be large (>10%?) - needs optimisation
  - wait until setup of injection protection in transfer lines & injection damper

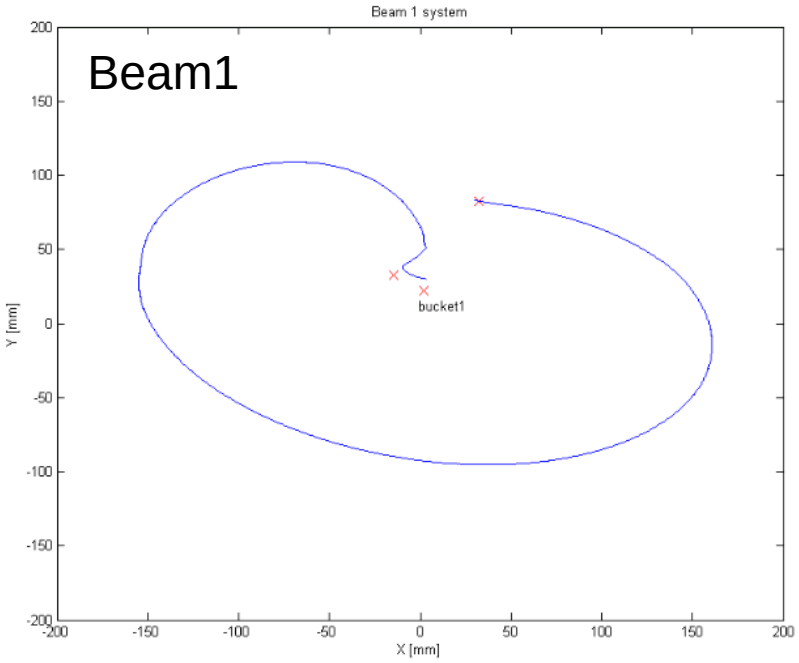


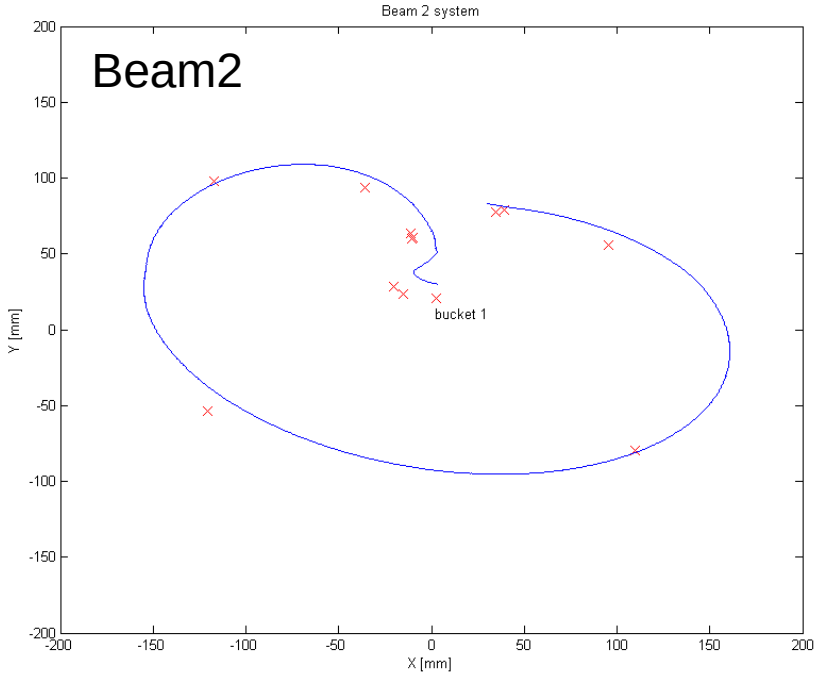
# Beam dump

- First adjustments and checks have been finished
- Dumps now working well with 4 pilot bunches per extraction
- Some early issues have been found and solved
  - TCDQ movement sense inverted for B2
  - Asynchronous dumps from feature in the Trigger Synchronisation Unit logic. Needed firmware upgrade and testing

# Kicker synchronisation

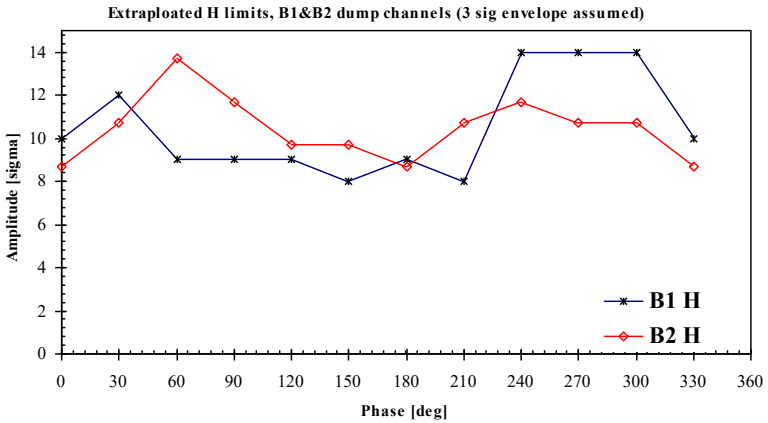
- Adjusted and checked for B1 and B2 – bucket 1 now at the right place in the extraction sweep

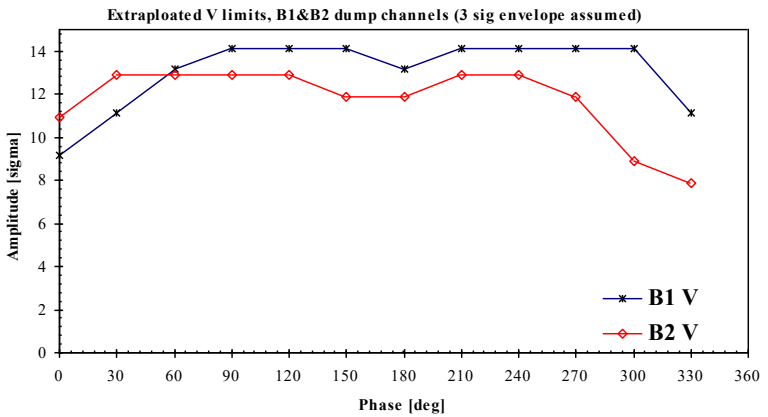


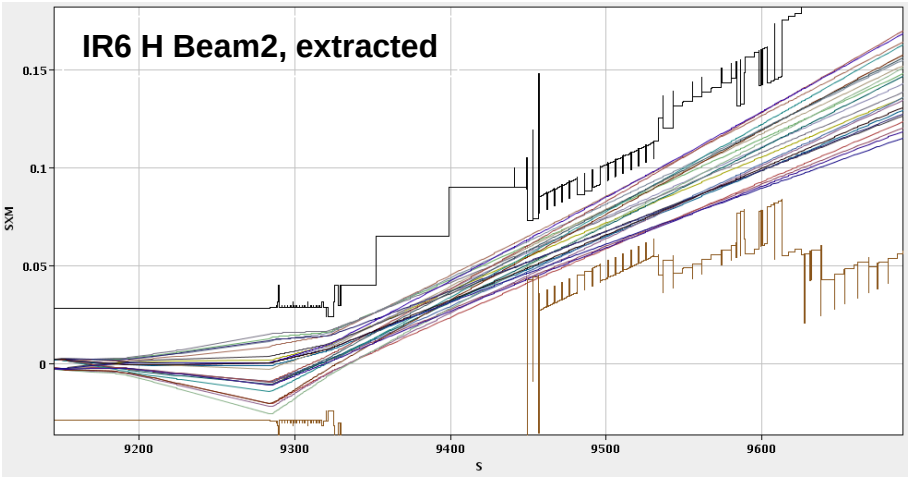



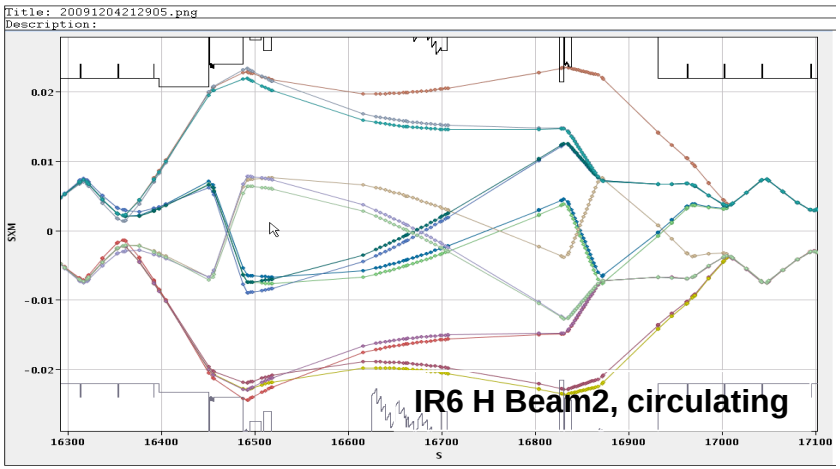
# Dump aperture

- Extracted beam aperture measured with all phases in H&V
- Circulating beam H aperture checked carefully at TCDS, TCDQM, MSDC and MKD, with bumps through the region
- All looks to be in agreement with expectation



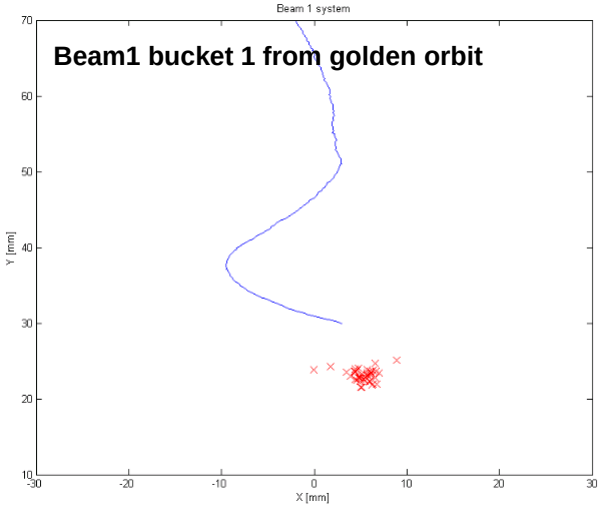



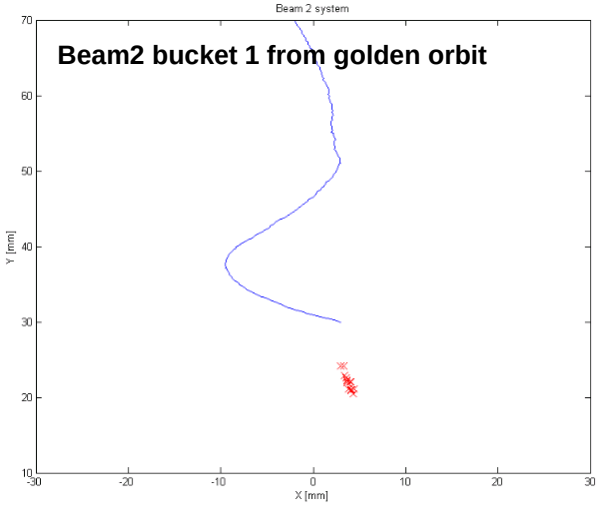



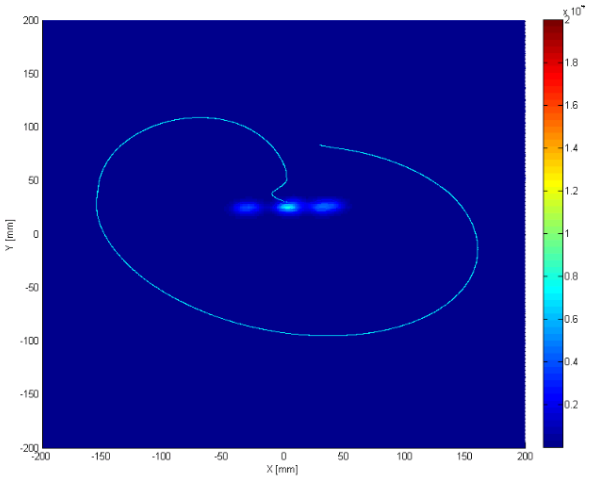



# Dump checks from golden orbit

- Extracted beam trajectory looks very good for both beams
  - Maybe 7-8 mm vertical error at the TDE for both beams (total MSD strength could be about 11 μad too weak – not an issue)
- Can dump without losses with ±1.67 MKD for B1, +1.333 and -1.67 MKD for B2
  - Good result for the dump channel aperture



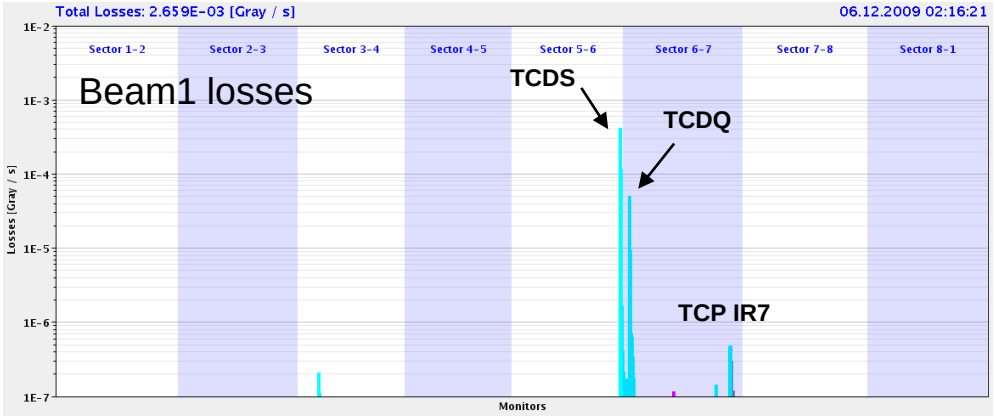



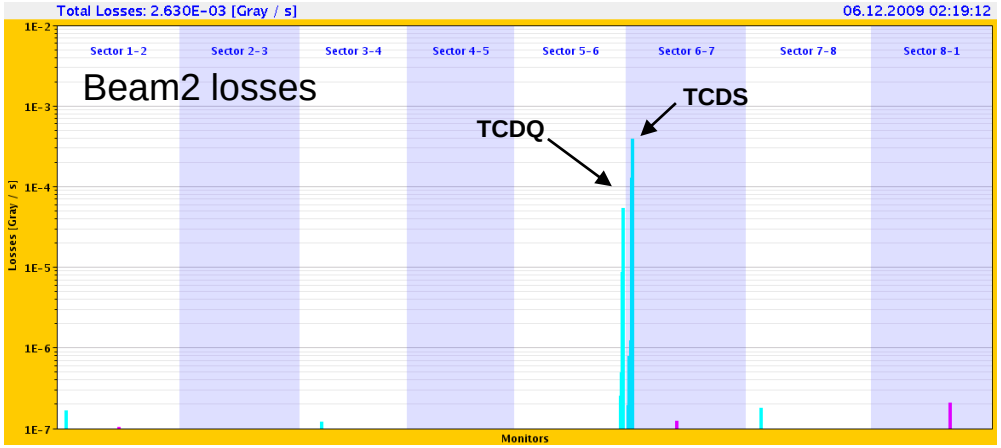




**Beam1 with 13.33 – 16.67 MKD**

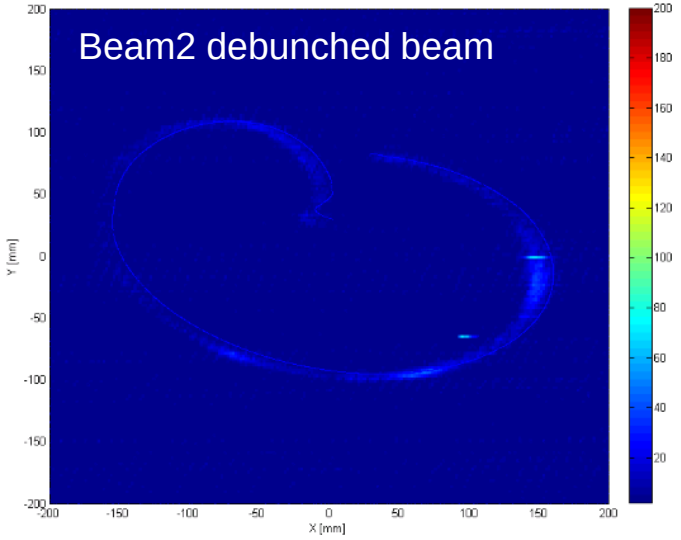
# Dump protection setup and tests

- Setup and tested by debunching beam and tiggering dump
  - Losses concentrated on dump protection devices, with ~0.1% on collimators as expected



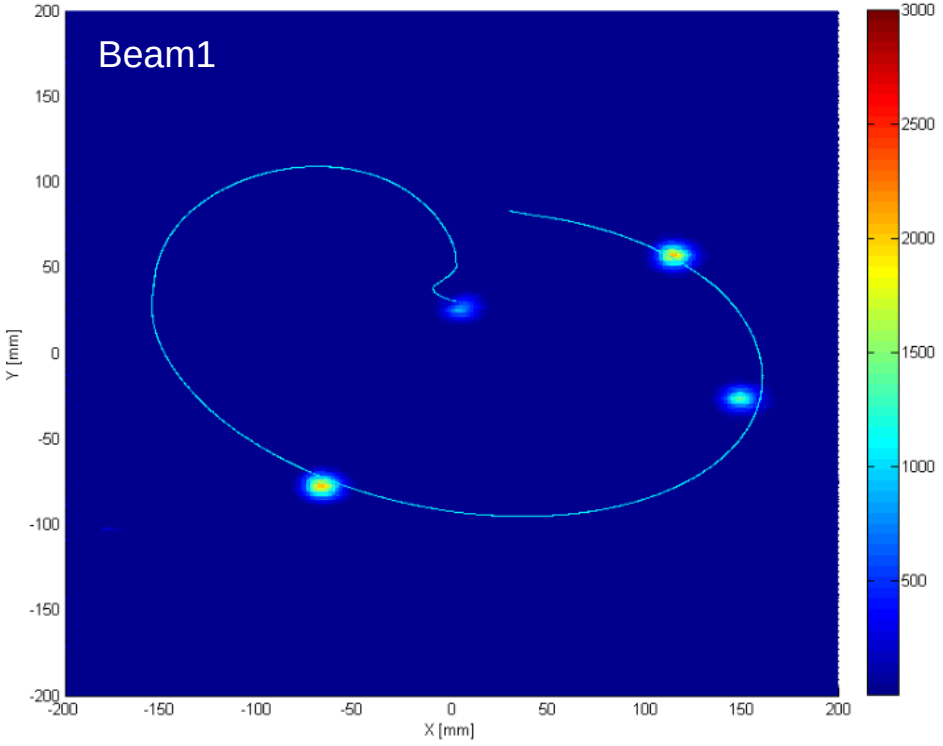



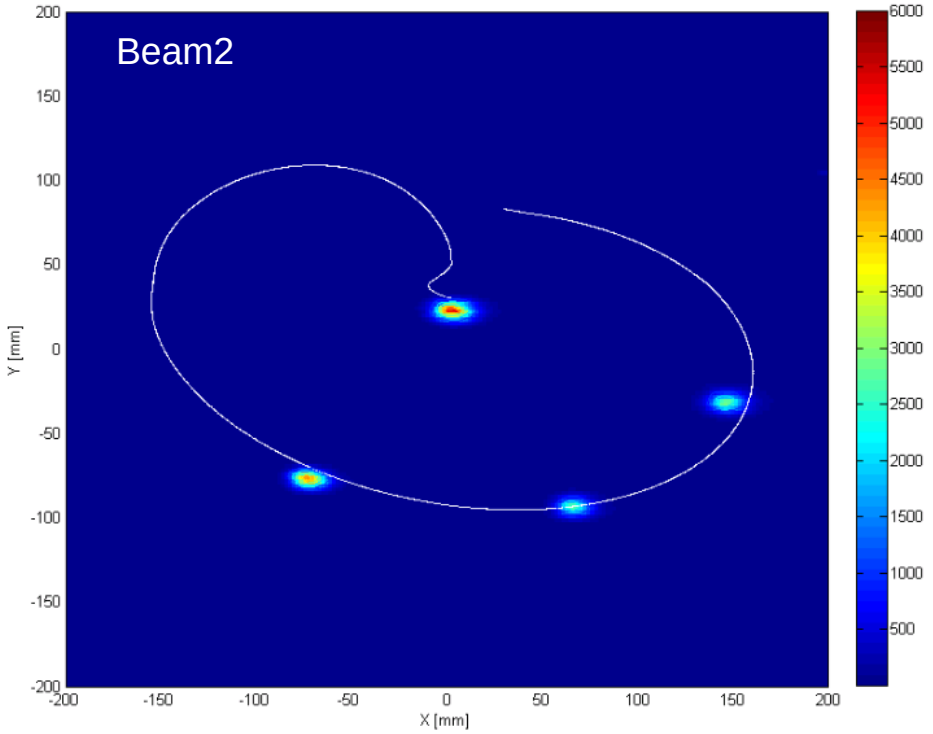

Asynchronous dump tests, 4 bunches



# Multiple bunch extraction

- Checks of trajectory and losses with 4 bunches
  - Also full scan through RF buckets for both beam with 1 bunch
- Both beam extracted correctly
  - No losses in extraction channel
  - Bunches where they should be on TDE and on sweep



# Present issues

- Still investigating how to overinject B2 without interlocking
  - Puzzle of losses in P8 on MQXA
- Losses on TCDQ/TCSG for B1 at injection – (more) checks to make
- Some sequence problems to solve (e.g. can start arming LBDS while “arm permitted” is false
- TCDQ alignment for B1
  - 7 mm difference with respect to beam calibration – probably mechanical calibration hangover from sense inversion
- TCDQ LVDT sensor problem
  - Small mechanical fix to make in shutdown

# 2009 outlook

- Setting up of injection protection devices TCDIs and TCLIA/Bs for higher intensity
- Activation of Abort Gap Keeper to prevent injection into abort gap
- Switching on of beam position interlock in IR6
- Tests of injection and dumping with higher intensity
- Tests of dumping beam at 1.17 TeV (so far 1 dump with 1 bunch)
- Dump protection setup at 1.17 TeV, with collimation
- Tests of abort gap monitor and abort gap cleaning with damper

# Conclusion

- Beam Transfer looks in good shape so far
  - A great head start from sector tests in past ~year
  - So far performance basically as specified
  - Some issues already seen and solved
  - No major problems apparent
- Now started the steps and tests for increasing intensity at 450 GeV

*Thanks to everyone who has been involved for making this such an efficient startup*