

Chamonix 2009 – LHC Performance Workshop

Injection and beam dump

B.Goddard TE/ABT

On behalf of everyone involved

Acknowledgement

The work described here is that of many people

In particular, the following were instrumental in preparing and commissioning the systems, and have also supplied material directly for this talk

**Etienne and team, Laurent and team, Eric, Ilya, Jan,
Jörg, Lars, Malika, Mike, Thomas, Verena**

The great efforts of the BI, CO and OP groups, together with all the other groups and teams involved at CERN, are also warmly acknowledged

Outline of talk

- Preamble
- Beam Injection
 - Strengths and synchronisation checks
 - Local aperture measurements
 - Injection stability
 - Beam losses on MKI and flashover
- Beam Dumping
 - Strengths and synchronisation
 - Local aperture measurements
 - Dump diagnostics
- SW, sequencing and operational aspects
- Lessons and changes for 2009 and beyond
- Conclusions

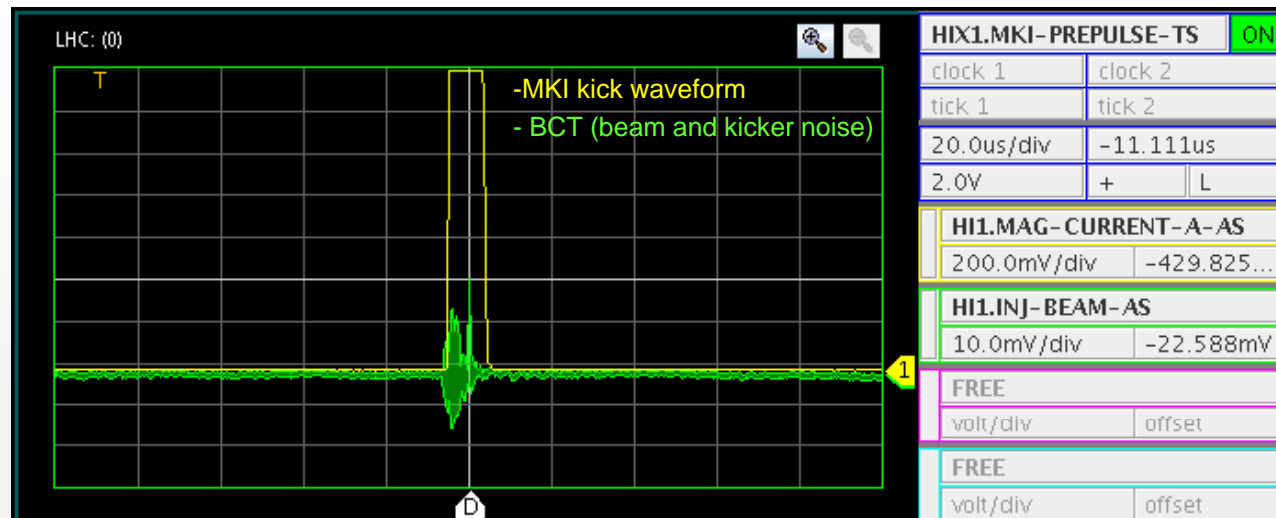
Injections – what was done

	Beam 1 (TI2/P2)	Beam 2 (TI8/P8)
Transfer line optics	OK	Still question of dispersion match
Injected beam aperture	OK (after vac. re-alignment)	OK
Kicker synchronisation	OK (rough)	OK (rough)
Injection element strengths	OK	OK
Beam instrumentation checks	OK	OK
Check injection stability	Started (data to evaluate)	OK
Interlocks	Started	Started
Circulating beam aperture	To do	To do (TDI moved in - OK)
Injection steering	To do	Started (rough)
Kicker waveform measurement	To do	To do
Detailed optics matching to LHC	To do	To do
Injection protection systems setup	To do	To do
Injecting onto Xing/sep bumps	To do	To do
Abort gap keeper	To do	To do

- Maybe 40-50% through initial (pilot) beam commissioning

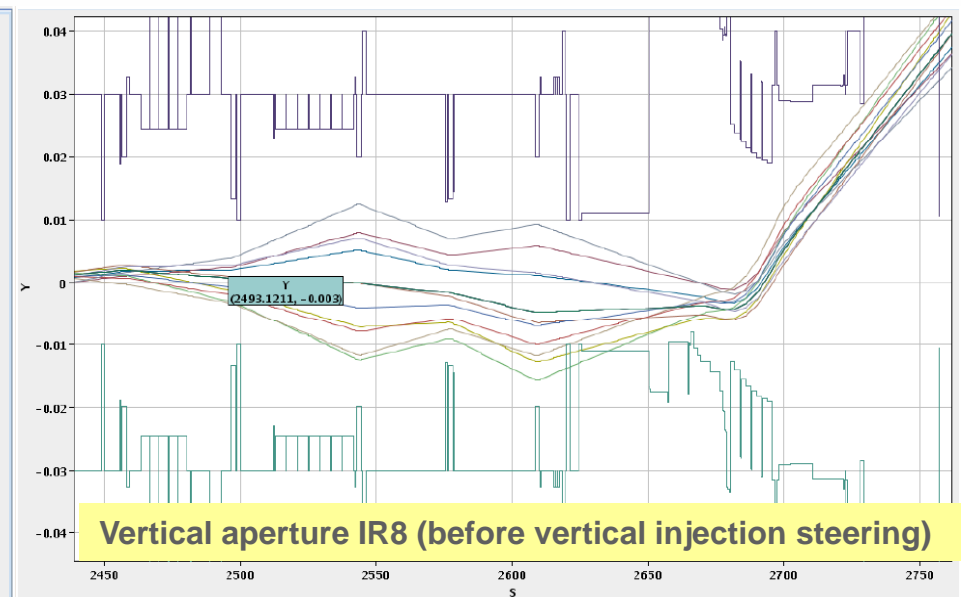
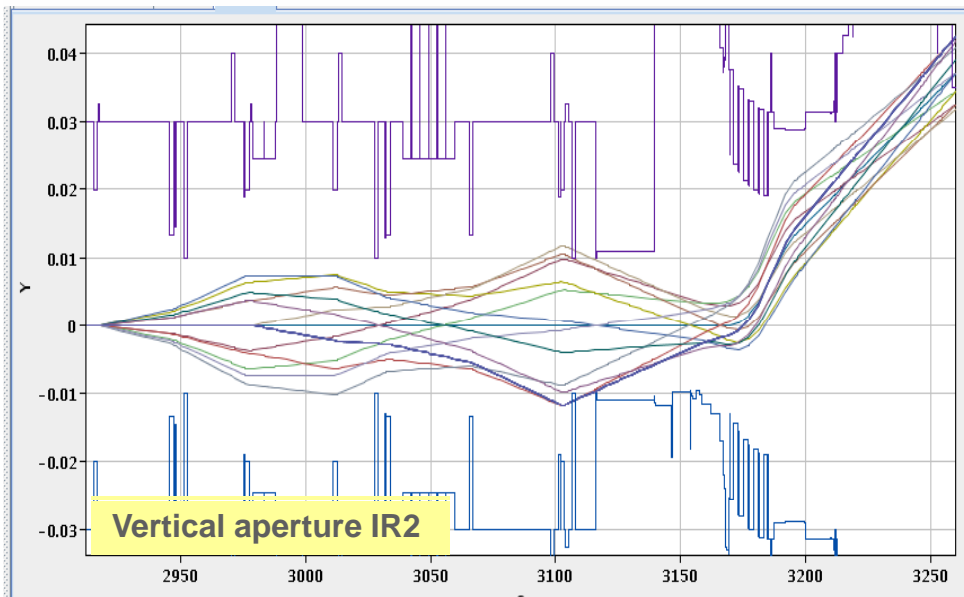
Injection element strengths and synchronisation

- MKI kicker strengths look perfect
 - No trims needed at this stage
- MSI septum strengths look perfect
 - But! Effect of pulsed leakage field found by Ralph S on circulating orbit (0.5 mm)
 - Investigating powering in MSI DC (magnet, PC, controls, interlocks, ...)
- SPS extraction and LHC injection kicker timing-in worked fine
 - Dynamic destination implemented
 - Rough injection kicker timing OK
 - Noise on TL BCT signal made adjustment procedure tricky - upgraded for 2009



Injection region aperture measurements

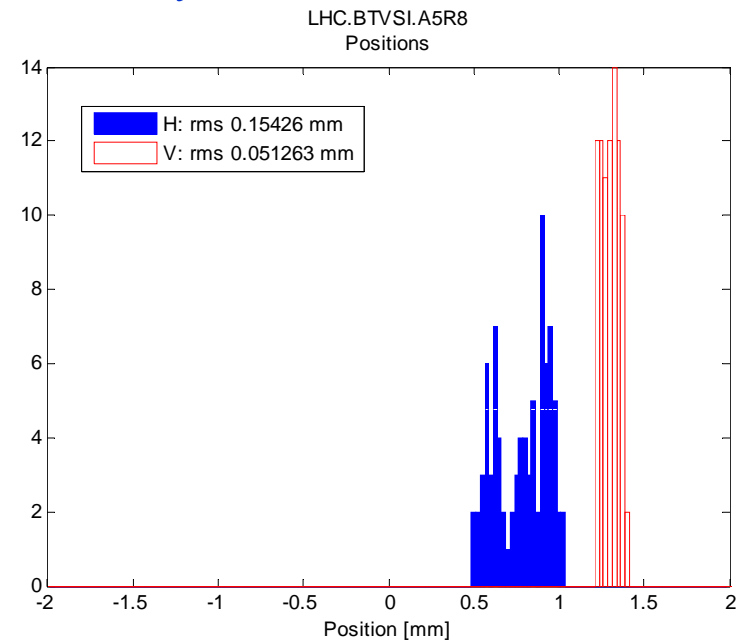
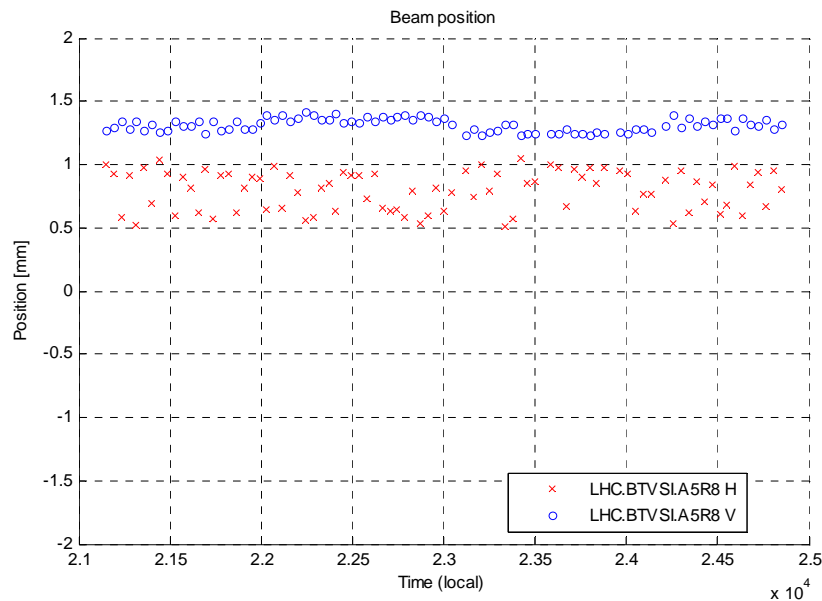
- Single pass measurement using unclosed oscillations at various phases
 - Very useful tools with madx online for preparation and visualisation
- All as expected, except at one location – VANMF.5L2 between MSI and Q5
 - Hot-spot with radiation survey ($3 \mu\text{Sv/h}$) - 10 mm vertical realignment made
 - 20/22 mm aperture of MSI protection device / MSI septa confirmed



- Still to check potential limits in vertical at D1 with MKI off (using RCBYV.4)
- Still to make circulating beam measurements at MSI & TDI

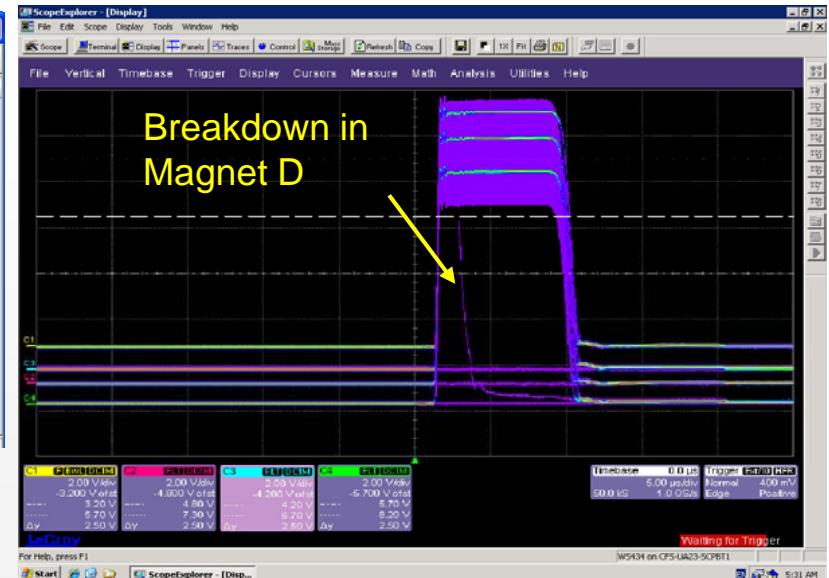
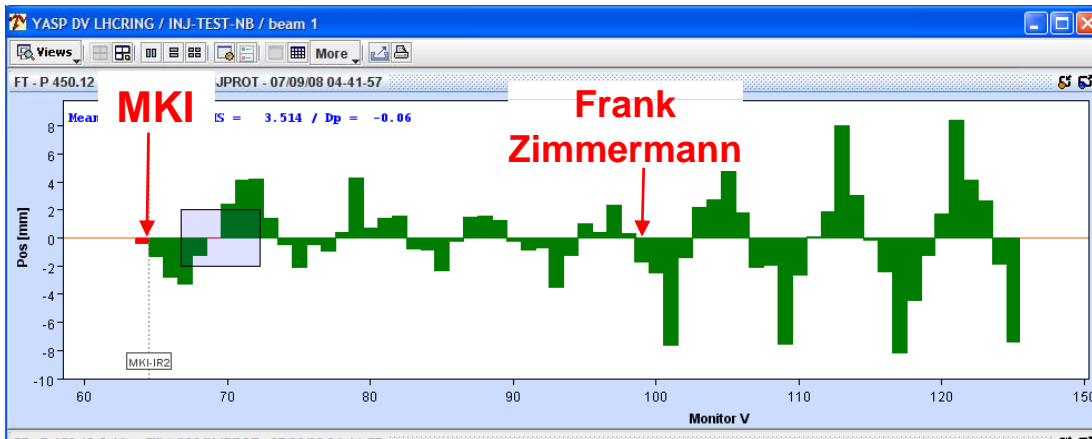
Injection steering and stability

- First steering done for B2, was initially several mm off in vertical (last slide)
 - Nice convergence of autopilot algorithm
 - To revisit including MSI and MKI strengths, and rechecking apertures
- Short-term (1 h) stability v. good at injection point (using screens in LHC)
 - P8: measured RMS jitter for B2 of 0.27 / 0.13 nominal σ H/V (c.f. ± 1.5 spec)
 - Upper limit on MKI kicker instability of about 1.7×10^{-3} (c.f. 5×10^{-4} spec)
- Still to measure MKI waveform with kick delay



MKI flashovers on MKI.C2 and MKI.D2

- First flashover during SoftStart, after aperture measurements (MKI off)
 - Pilot beam lost on aperture limit upstream Q5 (total of about $5e10$)
 - Subsequently added BLMs directly on MKIs
- Second flashover during beam passage (MKI on)
 - Different type of incident – no preceding beam loss in the region
 - Injected trajectory showed clear overkick of about 20% ($40 \mu\text{rad}$ or 10σ)
 - Demonstrates perfectly need for TDI....and for SoftStart
 - Breakdown about 60% along magnet consistent with observations
- Still to decide interlocking strategy with BLMs



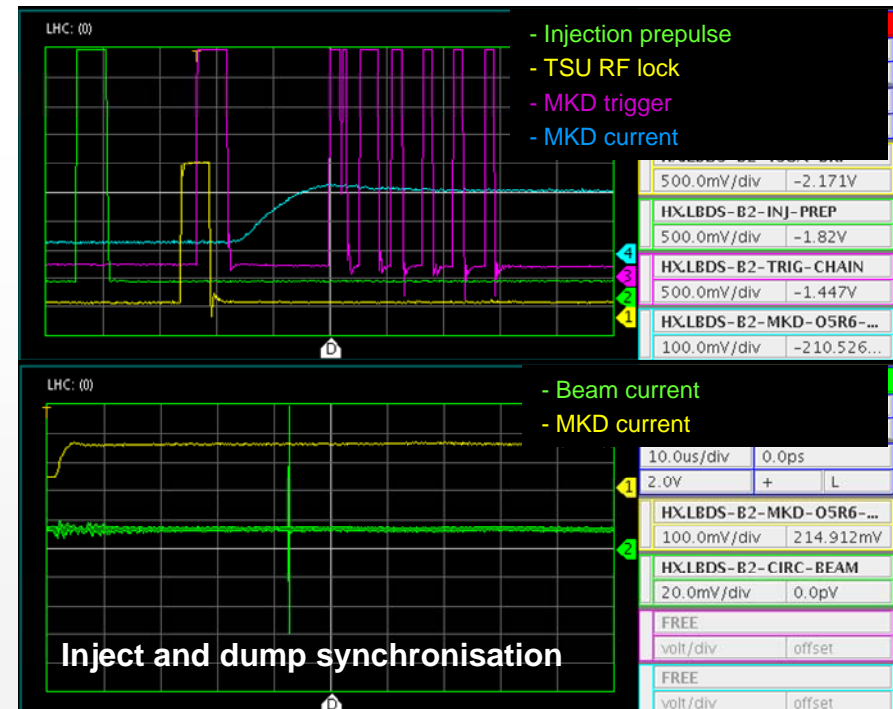
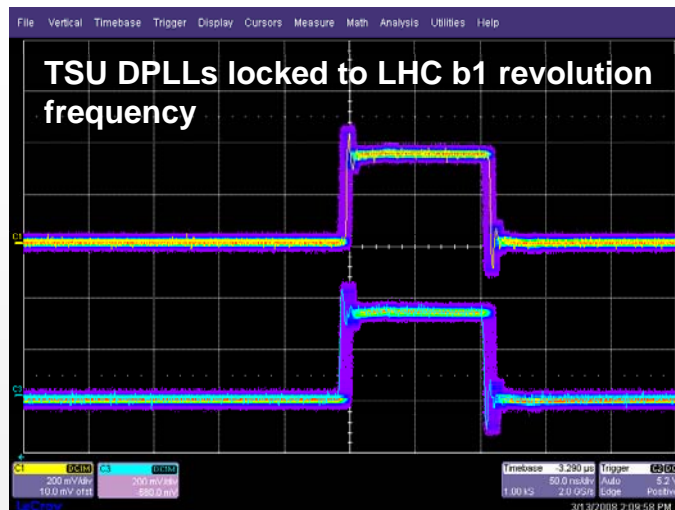
Dumps – what was done

	Beam 1 (TD/UD68)	Beam 2 (TD/UD62)
Inject and dump setup	OK	OK
Circulate and dump setup	To do	OK
Dump region aperture	To do	Started (some phases)
Detailed kicker synchronisation	To do	To do
Extraction element strengths	Started (corrected MSD)	Started (corrected MSD)
Beam instrumentation checks	Started	Started
Interlocks (BPMSA, TCDQ, ...)	To do	To do
Sweep waveform measurement	To do	To do (parasitic looks OK)
Dump protection systems setup	To do	To do
PM and XPOC	Started	Started
Tracking tests	Started (2 sectors only)	Started (2 sectors only)
Abort gap keeper	Started	Started

- Maybe 10-20% through initial (pilot) beam commissioning

Dump element strengths and synchronisation

- MSD septum strengths looked OK after initial 200 μ rad error corrected
 - Required tunnel access to update lookup tables in Energy Tracking System
- MKD kicker strengths looked OK
 - Extracted first attempts with correctors not MKD – but complexity for TD line BI
- MKB dilution kicker strengths looked OK
 - parasitic sweep data taken for many dumps
- TSU locking and arming fine
- Rough timing in and synch. done

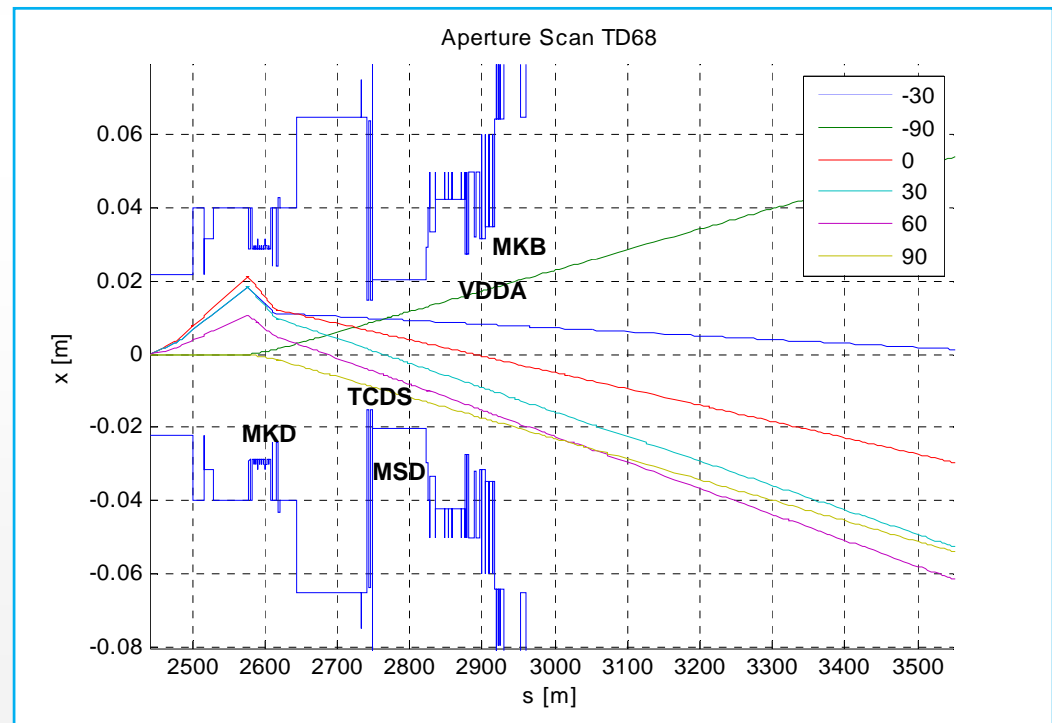


Dump region aperture measurements

- Performed first measurements from 00:00 to about 04:00 on 19/10
 - Did not finish them...problems with arming LBDS...then other problems
 - Only a few phases checked for B1
 - 6.5σ horizontal limit at TCDS to revisit (orbit, bunch timing in kick waveform)
- No obvious problems so far – and “loss free” extractions performed

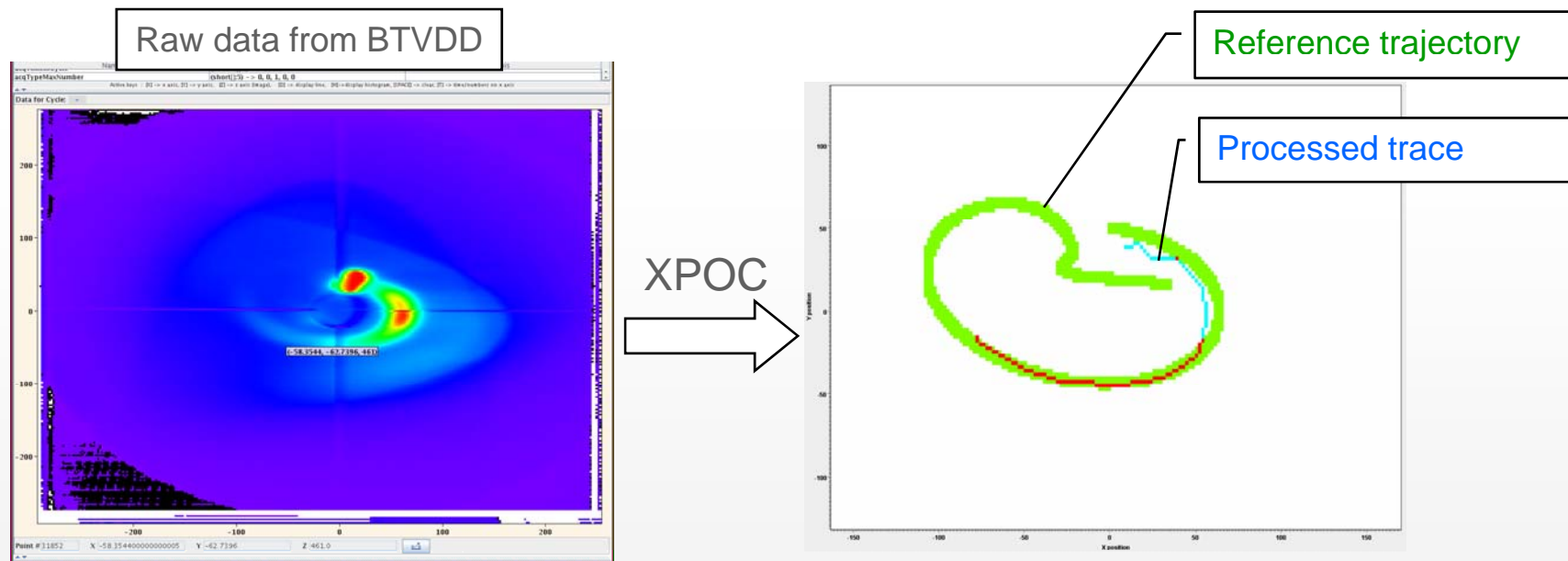
Phase	Vertical			
	+ve		-ve	
	sigma	location	sigma	location
0	12	Q4		
30				
60				
90	15	MKB	15	MKB

Phase	Horizontal			
	+ve		-ve	
	sigma	location	sigma	location
0	12.5	Q4	6.5	TCDS
30	13.5	Q4	6.5	TCDS
60	13.5	TCDS		
90	7.5	TCDS	13.5	MSDC



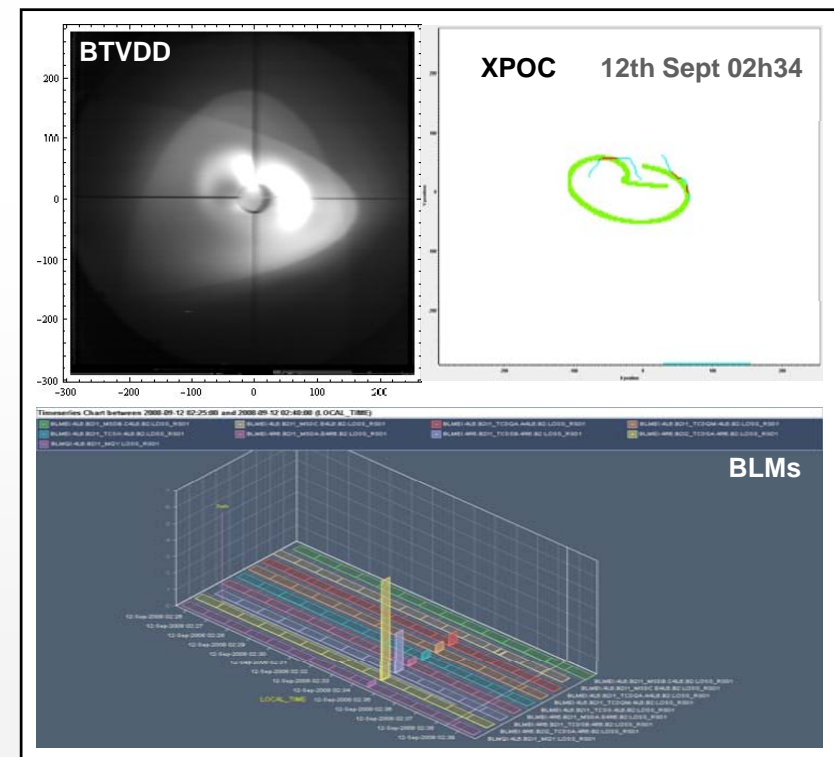
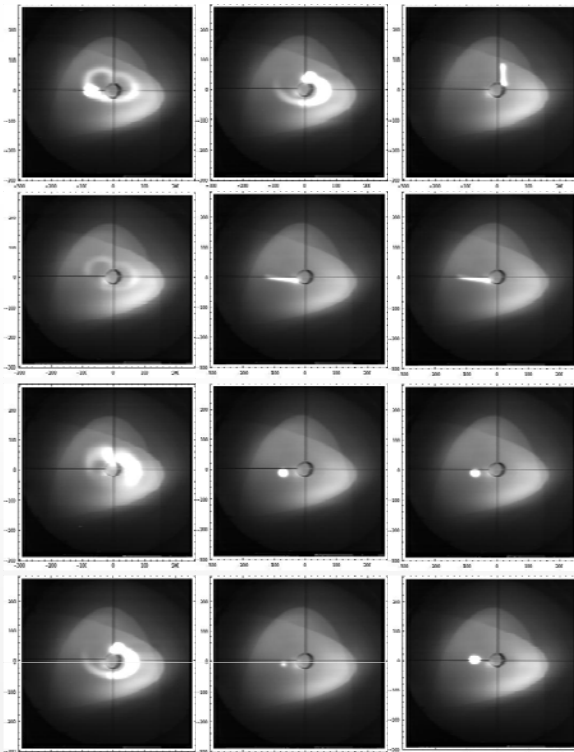
Dump diagnostics - XPOC Analysis

- Automatic XPOC analysis for MKD and MKB kickers now mature
 - Throughout 2008 for reliability run, dry runs and commissioning
 - Produced good results, including finding of some disconnected trigger cables
- Analysis of BI systems started with beam – mainly BTVDD screen
 - Analysis results and references agree well – MKD/MKB strengths look OK
 - Extended and updated for 2009 (see Jan's talk)



Sweep characterisation and “asynchronous” dumps

- Already an interesting rogues gallery of different dumps
 - Uncaptured beam, sweeps, different parts of kicker waveforms, unstable beams...
 - Used XPOC analysis to check MKB sweep
- In process of correlating with losses at extraction elements and around LHC
 - Will give experimental data for some of the simulations on failure cases
 - Huge data sets - available tools for browsing logged BLM data are not adequate



Sequencing and special machine modes

- All sequences developed and tested for injection and dump systems
 - Injection, SoftStart, arming, inject and dump, circulate and dump
 - Improved versions now available (exception handling and error messages)
 - Question of unskippable tasks etc. for MP critical systems to address
- Need to maintain, load and unload all required timing tables
 - susceptible to error – any way to improve this?
- Inject and dump mode worked well
 - Could dump both beams on 0th turn
 - OK for bunch 1 in batch 1 – needs testing for other bunch numbers (particularly b2)
 - Conceptual issue to fix on PM suppression (limits to ~20 turns instead of 1000)
 - All implications of RF prepulse to be tested (e.g. rephasing for bucket selection)
- Circulate and dump mode worked well
 - Dumped with timing event, up any time (in ms)
 - Find better way to adjust injection – dump delay (presently clunky)

Other operational aspects

- These are complicated systems with a lot of dependencies
- Injection requires a lot of preparation for OP
 - Injection kicker SoftStart
 - Beam permit loops
 - SPS and LHC modes
 - LBDS arming
 - Beam extraction from SPS
 - Kicker-beam synchronisation check
 - Beam to TED, TDI and into LHC
- OP frequently stressed or thwarted with SoftStart seconds running out
- Improved where possible for 2009 ('better' SoftStart - shorter, no 'cheats', improved arming and sequences, operator training planned)
- MKI application SW updated
- Will have first version of injection quality checks for 2009
 - Checking kickers, BLMs, filling pattern

Preparation in 2009

- In 2008 we hit the ground running in Sector Tests and finally on September 10th
- Need to repeat this in 2009
 - Changes to systems to be checked and rendered operational
 - Scheduling of TL beam tests already being discussed (June/July?)
 - Dry runs should already be starting – will be late compared to 2008
 - No reliability run in 2009 – but a lot of updates/modifications/new HW/SW to validate
 - Same people, teams and organisation (at our level...)
- Formalise interlock testing and/or acceptance?
 - Any proposals for this wrt 2008?
- Schedule time for critical systems tests (energy tracking, BIS→LBDS link)?
 - Machine checkout time for this evaporated under the 10/09 floodlights

More details in Jan's talk

Conclusions

- **LHC injection and beam dump systems so far perform as expected**
 - Some concern about MKI flashovers with beam – devise strategy for operation
 - Improvements made (sequencing, arming, SW) to make operations' life easier
 - Full XPOC and Injection quality check deployment needed
 - All HW/SW changes since 2008 need thorough validation
- **Commissioning measurement programs with beam started well**
 - To date no major issues found...but a lot of work here still to do
 - Increasing intensity, abort gap cleaning and setting up of protection devices will be some of the main challenges
- **Tools, techniques and teams have performed well**
 - Keep essentially same organisation for 2009
 - Some minor improvements of diagnostic and analysis tools needed
- **TL and injection beam tests in 2009 will speed up ring beam commissioning**
 - Get these in schedule now (many dependencies: sort out impact)
 - Systems Integration and Dry Runs being organised and scheduled
 - Presently behind schedule wrt 2008 preparation (shutdown work impact)