

LHC Beam Operation workshop - Evian 2011



Injection and Dump System

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Outline

- ▶ LBDS:
 - ▶ 2010/2011 performance
 - ▶ TCDQ induced beam dumps and HW problems
- ▶ Injection System:
 - ▶ 2010/2011 performance
 - ▶ MKI problems:
 - Flashover
 - Erratic
 - Vacuum
 - Temperature
 - ▶ Other observations
- ▶ XPOC
- ▶ IQC
- ▶ Summary

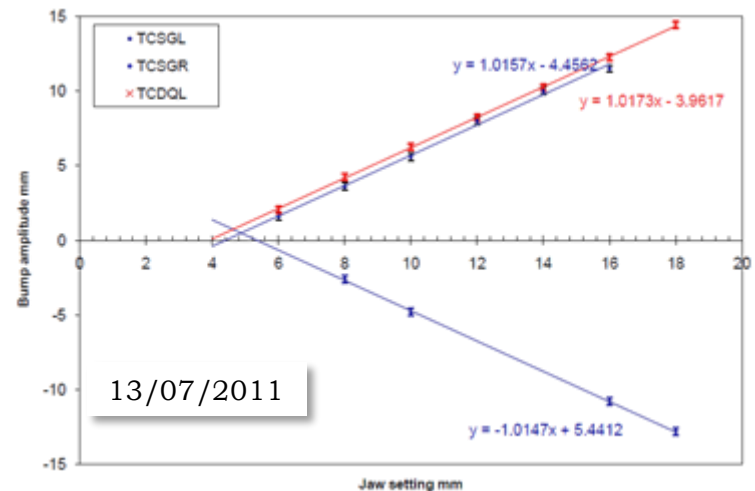
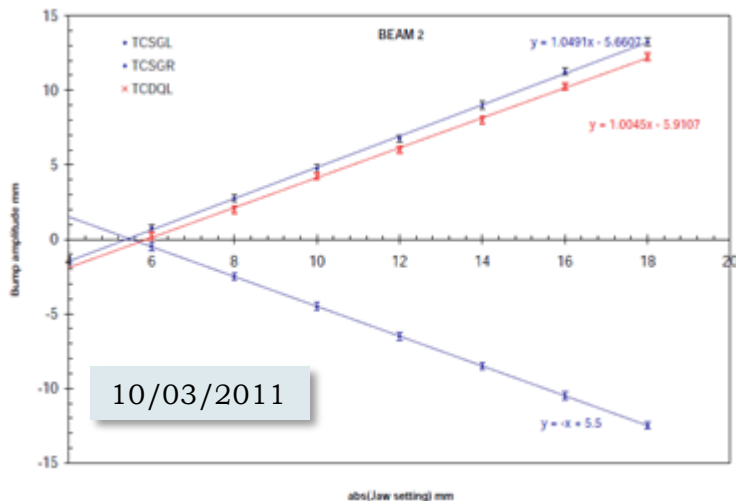
- ▶ **Asynchronous beam dump**, during energy scan **without beam** (due to spark on the outside of the gate turn-off GTO thyristor):
 - ▶ **1 at 5 TeV**
 - ▶ **2 at 7 TeV**
- ▶ **5 internal triggers: 1** due to BETS and **4** due to vacuum interlocks on the MKB for B2 (FALSE vacuum pressure reading)
- ▶ **1 Asynchronous beam dump with beam:**
 - ▶ Failure of a **single power driver** in one Trigger Fan-Out unit (TFO) → LBDS self-triggering of **two generators** for Beam 1: MKD C and D → IPOC fault and XPOC fault
 - ▶ Subsequent retriggering of remaining 13 generators worked perfectly
- ▶ **2 beam dumps induced by TCDQ faults:**
 - ▶ timing event sent TCDQ and thresholds to 3.5 TeV setting ($< 4 \sigma$ at 450 GeV) → beam then was injected and dumped due to losses in point 6.
 - ▶ beam 1 dumped due to a glitch in position readings (resolver read injection values) at end of ramp (out of thresholds).

2011 LBDS

- ▶ **No asynchronous beam dump**
- ▶ **7 internal triggers with beam** (BETS, PLC, *vacuum pump off in the dump line ...*)
- ▶ **Internal triggers without beam** due to:
 - ▶ TSU new firmware → back to 2010 version
 - ▶ PXI failures → N.I. digitizer fuses replaced on all boards
 - ▶ GTO switches } Mainly during ramp down, 2-3 h access required
- ▶ **10 Beam dumps induced by TCDQ:**
 - ▶ **Retraction TCSG/TCDQ SIS** interlock (90 m β^* ALPHA roman pots setup, tight collimators settings)
 - ▶ TCDQ at wrong position when injecting pilot (after previous test to check TCDQ offset)
 - ▶ **SIS interlock on beam position at TCDQ** during ramp and at flattop
 - ▶ **2 energy interlocks** at the beginning of the ramp (glitch in energy limit) → relaxed limits
 - ▶ **Position interlock** at the end of the ramp (server problem)
- ▶ BPMS interlock still reading wrong number of bunches, HW interlock based on another signal so we can leave with that

Other problems with TCDQ

- ▶ Problems with running **TCDQ sequence**, **loading settings** and **thresholds** → generally solved repeating sequence and/or running ramp (in some cases the beam had to be dumped)
- ▶ **Mechanical offset:**
 - ▶ Measured on 10/03/2011 and compensated by adding:
 - ▶ B1: -0.25 mm for all settings
 - ▶ B2: +0.5 mm at 3.5 TeV setting and +1 mm at 450 GeV
 - ▶ B2 TCDQ offset “Corrected” during TS → previously defined settings non more valid → TCDQ offset put back **but** in the wrong direction → offset had to be re-measured (2 hours) → new settings
 - ▶ B2: -0.6 mm for all settings



2010 Injection System

Chamonix 2011

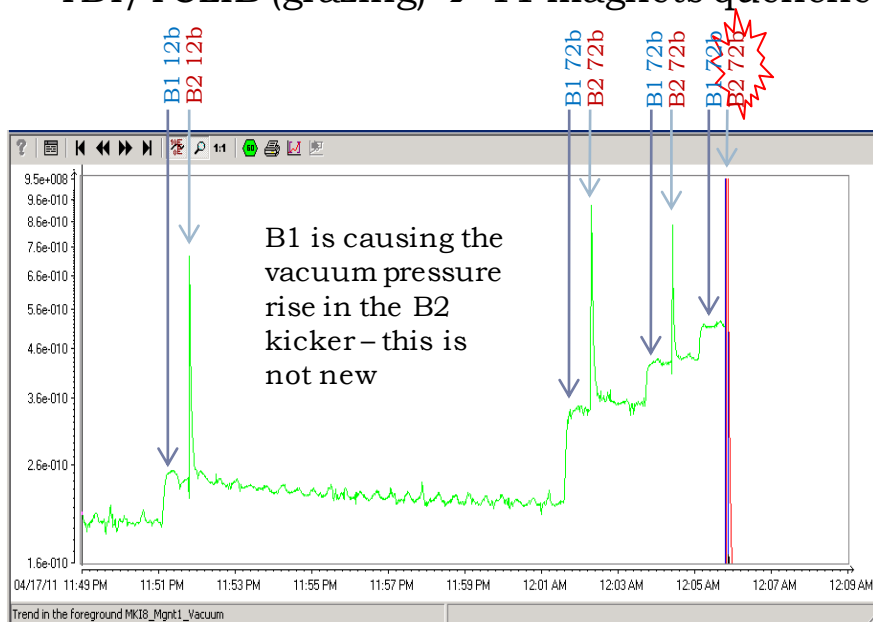
- ▶ Abort Gap Keeper (AGK) prevented MKI from firing → Train of **32 bunches dumped on upper TDI jaw** → showers to ALICE
- ▶ Losses in ALICE in agreement with simulations (further benchmarking data from TDI grazing tests) → **ALICE ready for 288 bunches on TDI**
- ▶ LHCb, only grazing tests with TDI



No indication of limits on injected intensity: 288 bunches OK! **BUT TDI must be correctly set up!!**

MKI Flashover 18/04/2011

- Injection of 2×36 bunches spaced by $2.2 \mu\text{s}$
 \rightarrow Breakdown after $\sim 2 \mu\text{s}$ \rightarrow All 36b of 2nd batch were kicked with 110-125% nominal MKI deflection
- Beam was on LOWER TDI jaw and over-kicked, i.e. breakdown in second half of magnet (LHCb signals support this)
- Nearly all p+ of the 36b impacted on the TDI/TCLIB (grazing) \rightarrow 11 magnets quenched

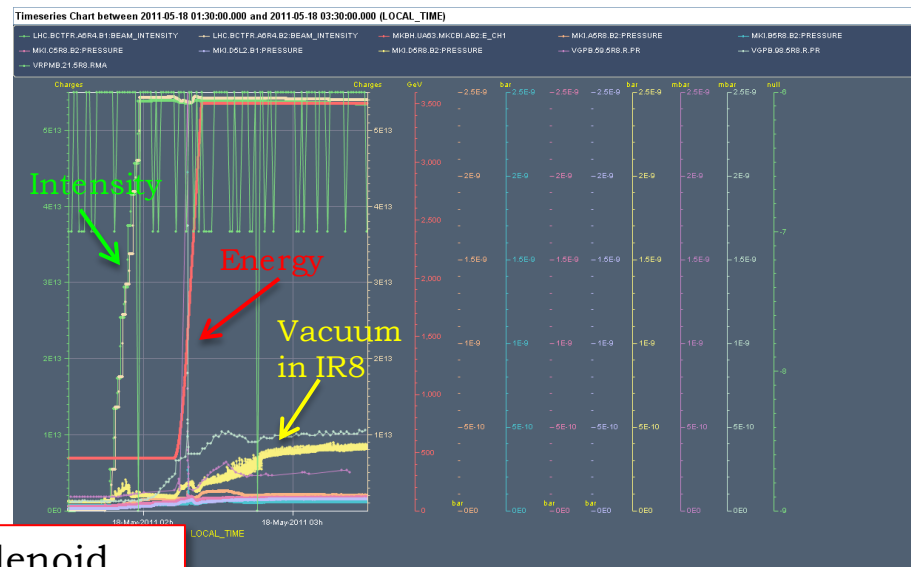
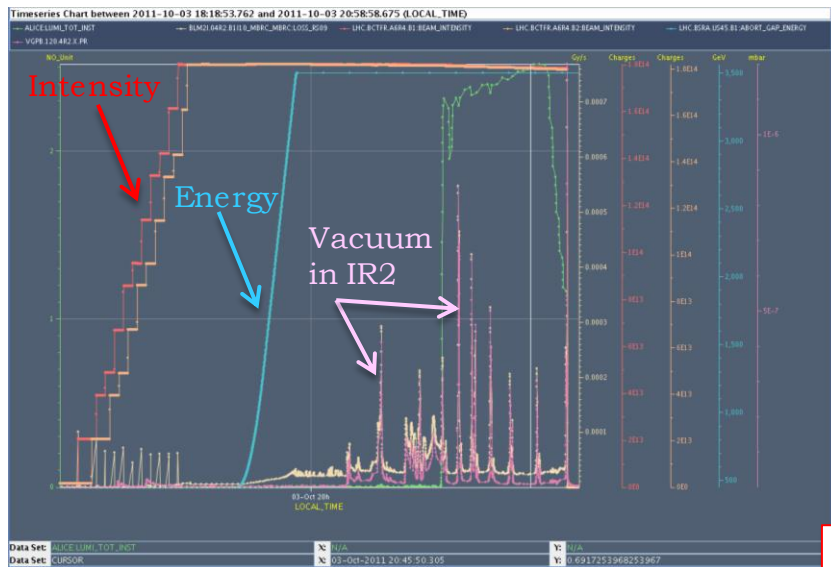


- MKI HW vacuum interlock** reduced from $5\text{e-}8$ mbar to **$2\text{e-}8$ mbar**
- New **SIS** to **prevent injection** if **MKI pressure** **$>2\text{e-}9$ mbar** for 50 ns beam (temporary **$>2.5\text{e-}9$ mbar** for scrubbing with 25 ns beam)
- Checked carefully **TDI angular alignments** in IR2 and IR8

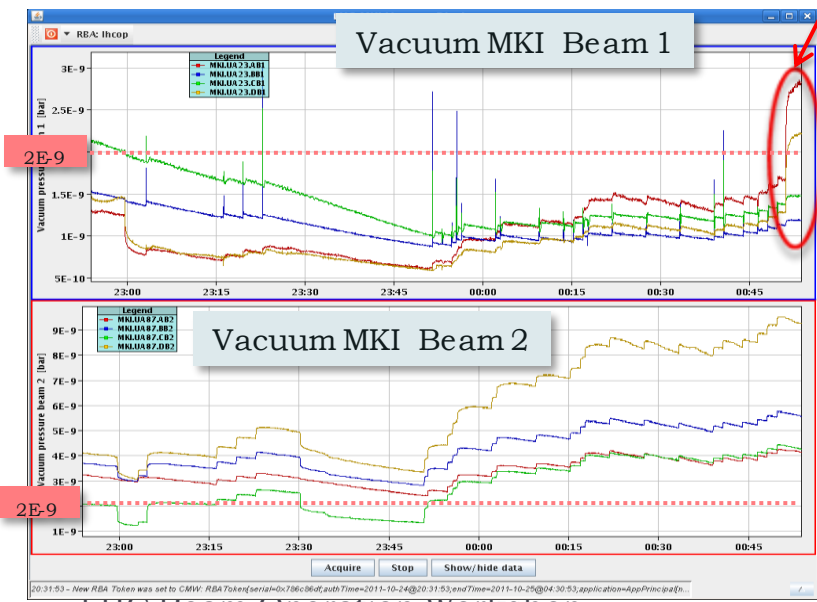
ALICE Polarity	B1 left [μrad]	B1 right [μrad]	B2 left [μrad]	B2 right [μrad]
Old	-70	-750	-190	-110
New	+86	-1035	-190	-110

- TCLI openings** \rightarrow **TCLIB to 8.3σ**
- New Fixed Display in CCC with MKI pressures
- Solenoids between MKI and Q4/A5 switched ON

MKI Vacuum Activity



Solenoid switched off



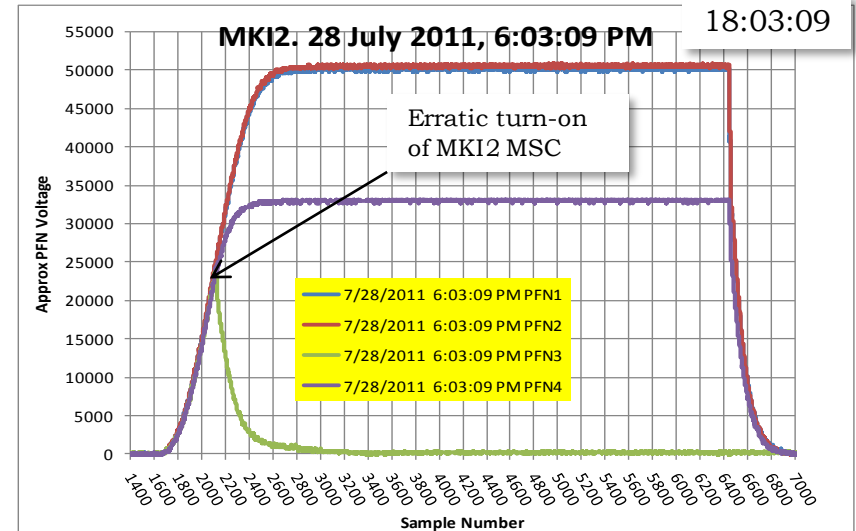
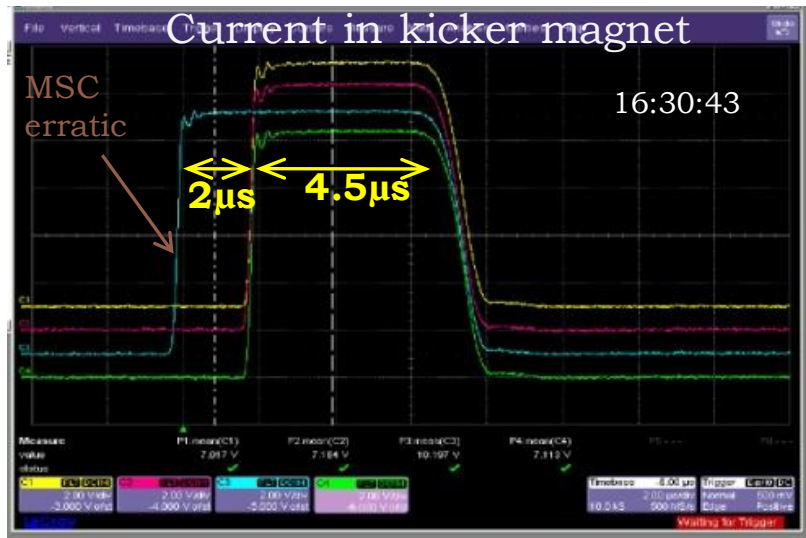
To avoid possible vacuum/breakdown problems with the MKIs, solenoids:

- ▶ ON during normal operation
- ▶ OFF during scrubbing provided pressure does not become too high (respect SIS injection interlock)
- ▶ In future, possible to include a $\int P \cdot dt$ interlock (under study)

M.J. Barnes

Evian, 12/12/2011

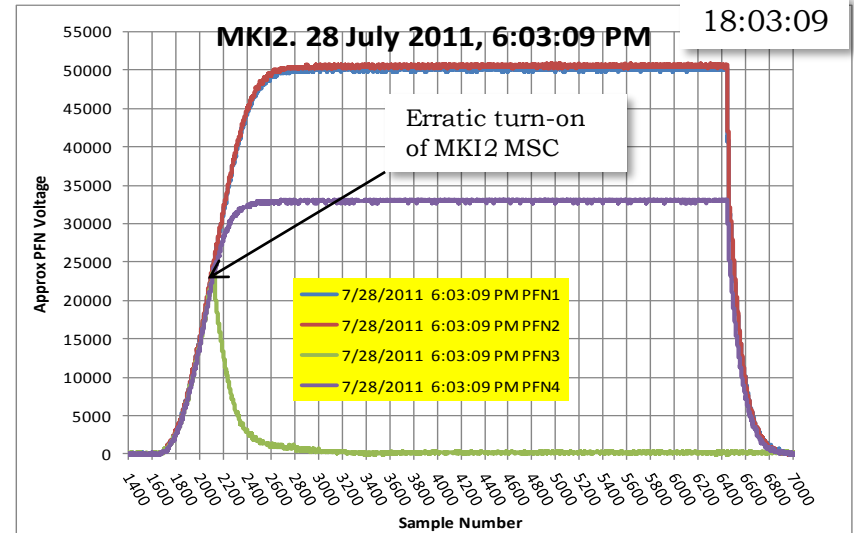
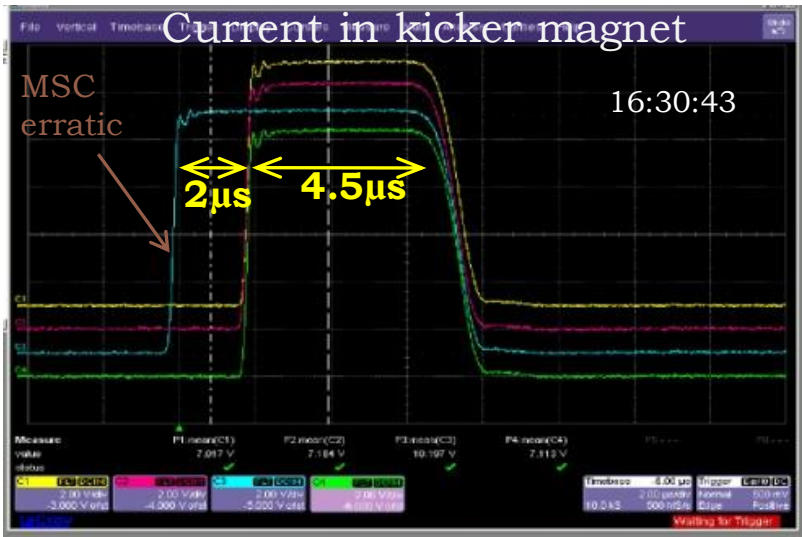
MKI Erratics on 28/7/2011



- Interlocks detected an MSC erratic and correctly triggered MS's and DS's of system (within $2\mu\text{s}$), emptying PFN via both ends.
- Hence **kicker-C** pulsed for **$6.5\mu\text{s}$** and **3 other kicker magnets pulsed** for up to **$4.5\mu\text{s}$** , emptying PFNs of energy.
- **Circulating beam was not in IP2** and therefore not disturbed.
- **Batch was extracted from SPS** but saw no kick at MKI2 (current already back to zero in all magnets) and went **straight into the TDI upper jaw**.

- Erratic of MKI2 MSC at 33kV **during resonant charging** – sending current to one of the four kicker magnets
- **Interlocks did NOT detect erratic** of MS3: hence no immediate action was taken to turn-on other thyratrons → **full $9\mu\text{s}$ PFN pulse length to kicker C**.
- Failure $\sim 500\mu\text{s}$ into charging process: **extraction from SPS correctly inhibited**;
- Circulating beam was swept over aperture and grazed TDI (**$\sim 17\%$ of normal kick**) for **$\sim 8-9\mu\text{s}$** → **150-190 bunches**

MKI Erratics on 28/7/2011



- Interlocks detected an MSC erratic and triggered MS's and DS's of system (with emptying PFN via both ends.
- Hence **kicker-C** pulsed for **6.5µs** and **kicker magnets pulsed** for up to **4.5µs** of energy.
- **Circulating beam was not in IP2** and therefore not disturbed.
- **Batch was extracted from SPS** but saw no kick at MKI2 (current already back to zero in all magnets) and went **straight into the TDI upper jaw**.

Hardware problem → faulty components exchanged + additional diagnostic + faster detection electronics with lower voltage threshold

- Erratic of MKI2 MSC at 33kV **during resonant charging** – sending current to one of the four magnets
- **did NOT detect erratic** of MS3: reaction was taken to turn-on **all 9 µs PFN pulse length**
- **SPS correctly inhibited;**
- Circulating beam was swept over aperture and grazed TDI (**~17% of normal kick**) for **~8-9µs → 150-190 bunches**

MKI Erratic Effects

- ▶ 173 bunches - **2.15e13 p+ lost** (not dumped)
- ▶ **3 magnets quenched**
- ▶ **ALICE:**
 - ▶ The values of BCM threshold for beam background were exceeded:
 - 16:30 - **80 times**
 - 18:03 - **3559 times**
 - ▶ 9 / 17 sub-detectors were affected during second erratic event
 - ▶ All subsystems **except** Silicon Drift Detector (SDD) recovered using standard procedures
 - ▶ **20% of modules with good drift speed** from injector on layer 3 and 60% on layer 4 (**permanent effect**)

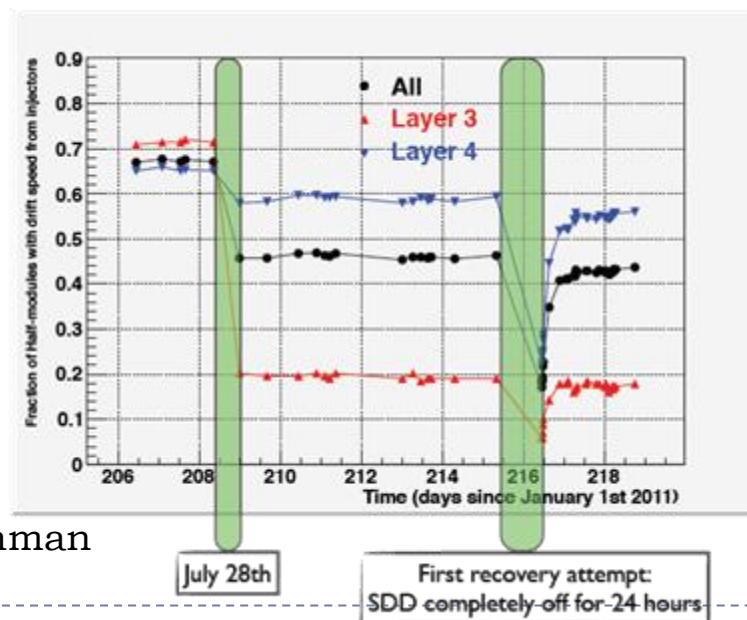
intensity and #bunches will still increase

(slightly) worse impact parameter possible

Up to a factor of 2-4 higher losses might occur in future years!

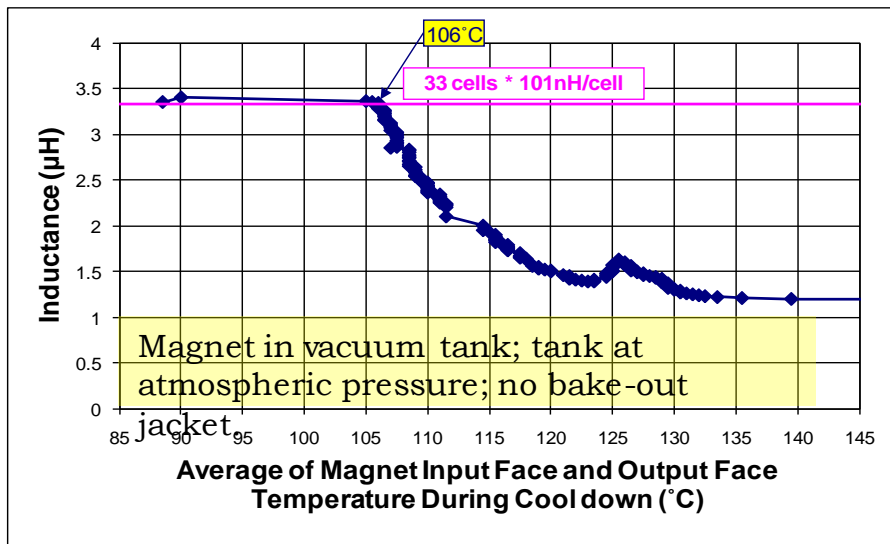
OK for machine, but main concern is safety for ALICE/LHCb.

Detectors must be off during injection!



M.Lechman

MKI Temperature Interlock



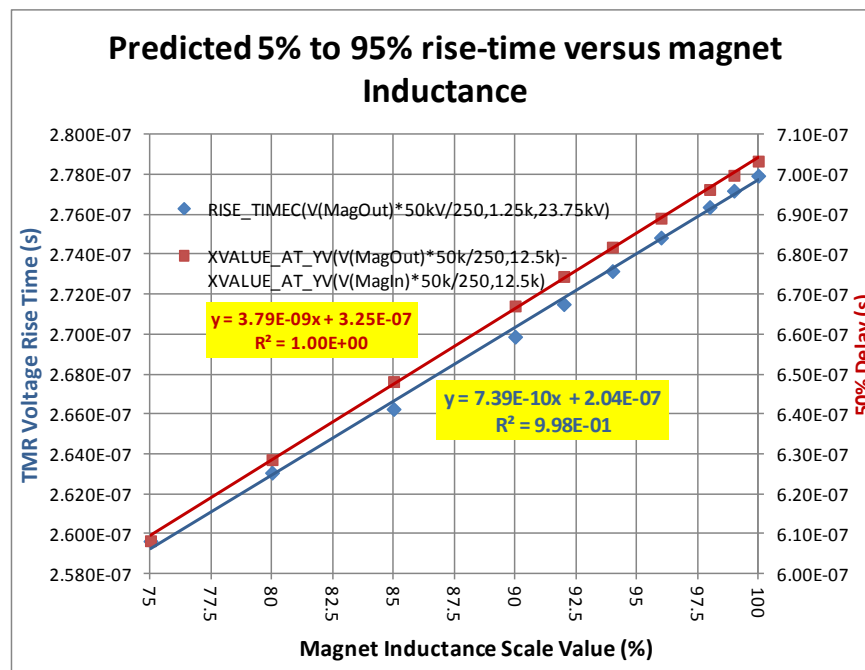
Ferrite Heating Measurements in Clean Room:
Curie point of ferrite corresponds to 106 $^{\circ}\text{C}$ measured on ground plates

M.J. Barnes

- ✓ Magnet **inductance** decreases with reducing ferrite permeability \rightarrow magnet strength decrease
- ✓ **Rise-time** decreases with reducing inductance and/or capacitance
- ✓ **Delay** decreases with reducing inductance and/or capacitance

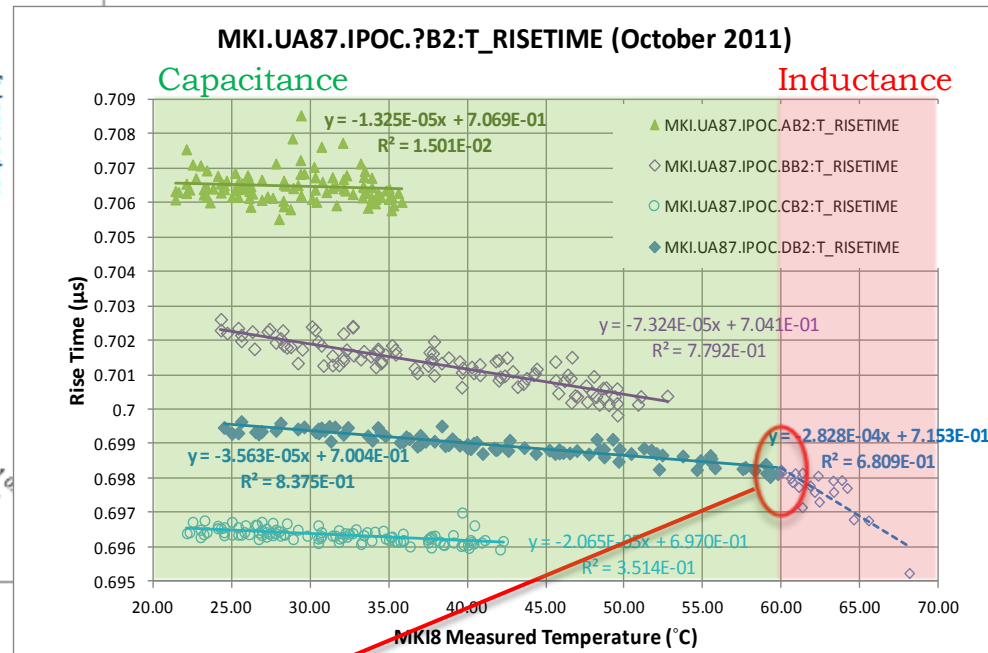
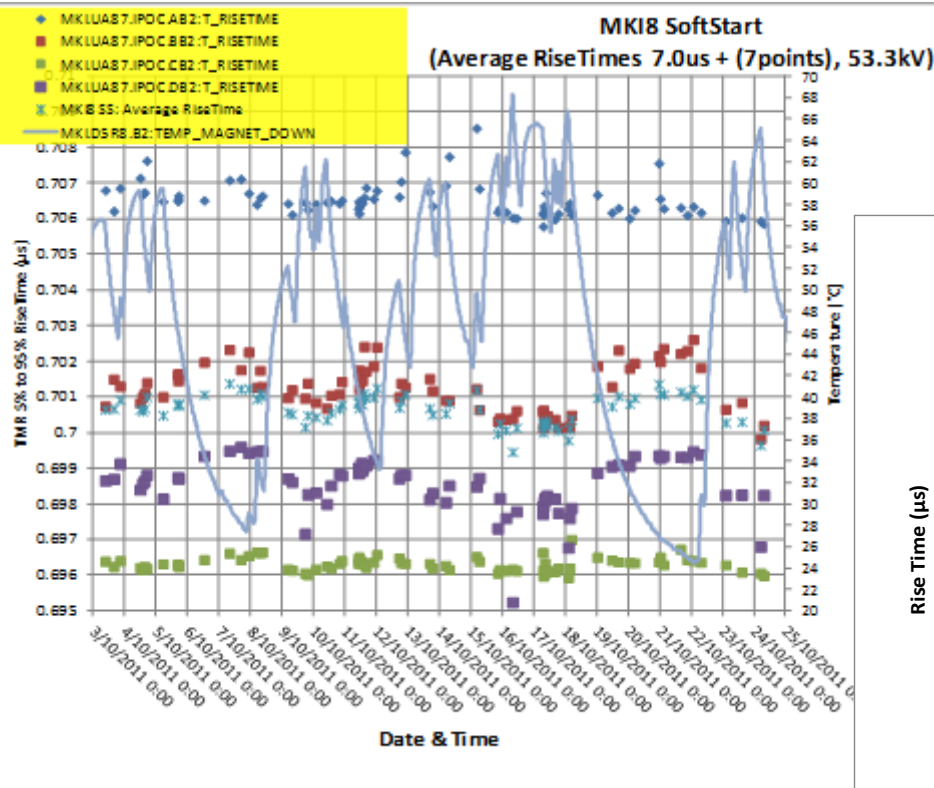
Softstart \rightarrow measure rise-time \rightarrow indirect measurement of inductance (temperature)

During Xmas stop: new diagnostic to measure delay (more sensitive)



MKI Temperature Interlock

M.J. Barnes



- ✓ **SIS interlock presently 62 °C (originally 55 °C) cannot be further increased !**
- ✓ MKI Temperature is < 68 °C and lags real temperature (ferrite thermal capacity)
- ✓ Softstart: OK → injection
not Ok → wait for MKI cooling

Other Problems Related to Injection System

- ▶ UFOs at MKI → several beam dumps at the beginning of the run (T. Baer's talk)
- ▶ Problems with kicker delay (ions run)
- ▶ Beam on TDI (32 and 144 bunches) due to operational error (AGK inhibited MKI from pulsing as it should)
- ▶ Vacuum pressure increase at TDI in IR2 and IR8 when at parking position (± 20 mm) → High background in ALICE (shielding?) → new parking position ± 55 mm (B. Salvant's talk)

- ▶ TDI.4L2 controls problem:
 - ▶ required setting different from measured motor position
 - ▶ Noise in the measurement of jaw positions → gap opening outside limits → TDI.4L2 gap interlocks changed by $100\mu\text{m}$ to avoid interlocks due to drift of the position reading triggered by electromagnetic noise



- ▶ Wrong settings of injection protection collimators (TCDI, TCLI and TDI):
 - ▶ Association with “bad” beam process (during MD)
 - ▶ Solution: injection protection collimators on an independent beam process

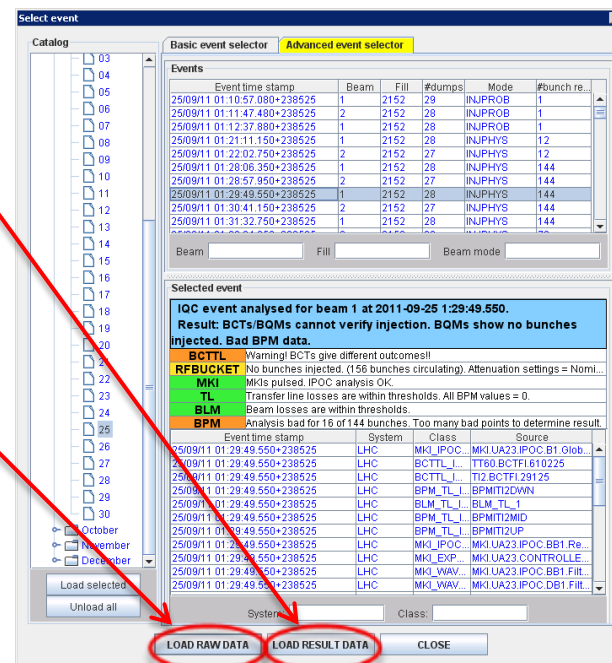
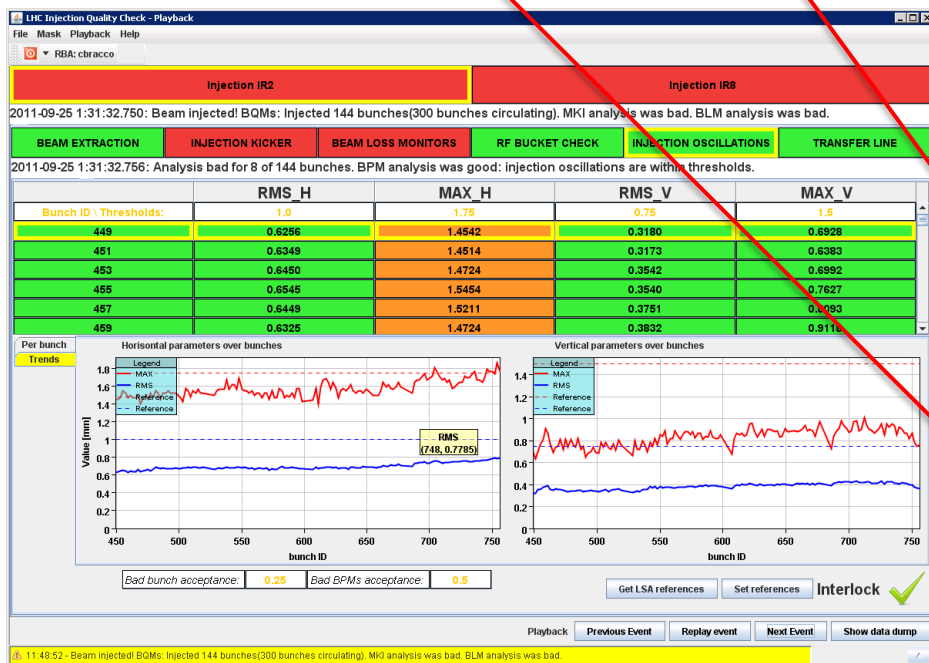
XPOC

- ▶ Encountered problems
 - ▶ Data missing (BLM, BCT, BSRA, Vacuum)
 - ▶ Wrong filling patterns and faults on MKB waveforms → new release and filters to reduce noise due to high bunch intensities (not completely solved)
 - ▶ Problems with inject and dump (late BLM data) → new BIS interface card installed
- ▶ Acknowledgment logic:
 - ▶ EIC-MPS can reset errors in Context and BLM modules
 - ▶ LBDS-EXPERT can reset all modules.
 - ▶ No evident reason to change it in 2012!

IQC

▶ New features:

- ▶ Injection oscillations max/rms vs bunch number;
- ▶ Playback: actual or of the date reference thresholds



IQC

- ▶ New features:
 - ▶ Injection oscillations max/rms vs bunch number;
 - ▶ Playback: actual or of the date reference thresholds
- ▶ Problems:
 - ▶ Injection of 144 bunches not seen by the IQC and the injection sequencer → **danger of overinjection** (server communication problem?)
 - ▶ Missing MKI data and BCT from TL
- ▶ Acknowledgment and Improvements:
 - ▶ Phase error integration
 - ▶ Limits at TL BPM (MD to define them) → easier steering
 - ▶ Clear warning level at critical BLMs depending on number of bunches injected (i.e. MSI \geq 5% with 12 bunches → steering needed)
 - ▶ Injection oscillations interlock → still maskable in 2012?

Summary 1 / 2

Equipment	Problems in 2011	Applied Solution	2012 Operation
LBDS	Internal triggers	Electronics, faulty components exchanged	Ok, new power supplies. Testing time during machine checkout for new HW/SW/FW
	No async. dump		Ok
TCDQ	Load thresholds/settings, energy limits and position interlocks	Repeat sequence	Ok, β^* interlock + new potentiometer electronic → more precise position reading
	Mechanical Offset	Compensation with beam based alignment	Ok
MKI	Flashover	SIS interlock to inhibit injection in case of vacuum exceeding thresholds	Ok if injection protection collimators correctly set up and detectors off during injection
	Erratic	Faulty components replaced + diagnostic + faster electronics with lower voltage threshold	Ok if injection protection collimators correctly set up and detectors off during injection
	Temperature	SIS at 62°C + softstart to measure rise-time (inductance)	Ok if T does not increase further since close to Curie limit. New diagnostic to measure delay
	Vacuum	HW interlock + MKI cond. + e-cloud solenoids	Ok but waiting time between injections, conditioning (25 ns more critical)

Summary 2/2

Equipment	Problems in 2011	Applied Solution	2012 Operation
TDI	Angular offset	Compensation with beam based alignment	Ok
	Vacuum and ALICE background	Parking position to $\pm 55\text{mm}$	Ok
	Controls (LVDT noise)	Relaxed gap interlock	Ok, if noise not worse
TDI/TCLI/TCDI	Association to "bad" beam process → wrong position		Not Ok, Separate beam process needed
XPOC	Missing data, faults	New release, filters, cards....	Ok, stronger filters + BI data collection improvements (directly into PM system)
IQC	Missing data, injection not detected	New release	Ok but needs to become clearer (closer to operation, easier steering). Risk of 144 bunches overinjection must be eliminated

Ready for 2012 operation but:

- Dedicate enough time w/wo beam to properly test components (new electronics, SW, FW...) and set up (collimators, IQC references for steering...)
- Respect safety instructions (Experiments off during injection, MKI vacuum and temperature interlocks)

Safe operation and reduce downtime!!!

Thank you!





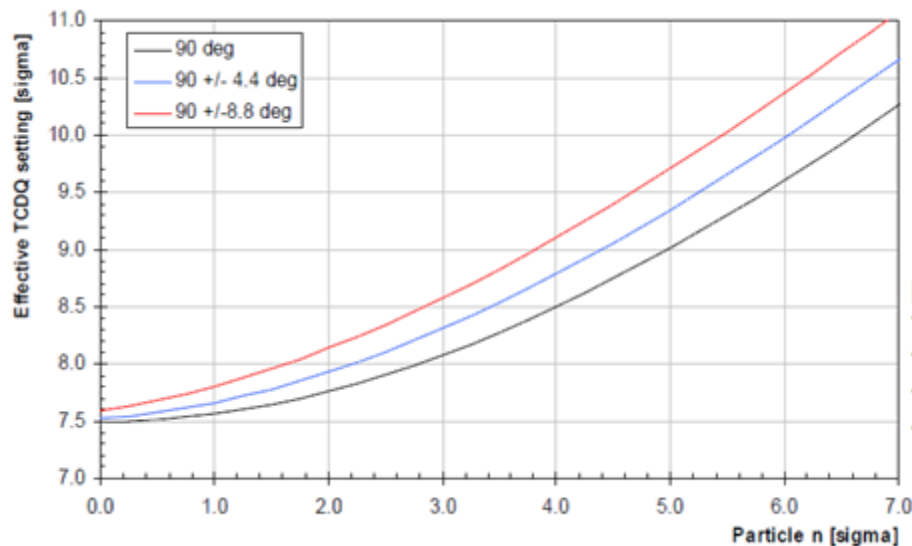
Backup



TCDQ Upgrade (LS1)

▶ Upgrades for IR6 dump protection

- ▶ TCDQ upgrade for robustness: graded Carbon Composite (1.4g/cc and 1.65 g/cc), absorber length 6m -> 9m (1 more module)
- ▶ TCDQ controls: collimation stepping motor system and low-level (to be decided)
- ▶ New improved TCDQ bellows
- ▶ TCSG with BPM buttons
- ▶ Additional TCLA – to be decided after FLUKA studies
- ▶ Phase advance MKD-TCDQ exactly 90° to reduce # of escaping particles → rematch the optics (R. Bruce's talk)



T. Kramer

Nominal $\Delta\psi$

MKD to...	Deg B1	Deg B2
TCDQ entr	93.55	93.75
TCDQ exit	94.47	94.65
TCSG entr	94.60	94.78
TCSG exit	94.71	94.89

Two More Erratics.....

Two more erratics happened during softstart on 30/07/2011

Hardware problem → Actions:

- Replaced MS3– damaged current regulator on bias board
- Remote current monitoring added
- New G1 trigger cards installed
- Damaged thyatron switch replaced
- Fiber optic read-back to better monitor thyatron and bias-board G1 current ??

Trigger units for MS3 replaced.



Power supply and crate for MS3

heater/reservoir replaced.

Diagnostics added