

Machine Protection System response

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LHC Beam Operation Workshop

December 2011

Thanks to : rMPP and MPP members, K.Fuchsberger, M.Galetzka,
B.Goddard, R.Schmidt J.Wenninger, et al

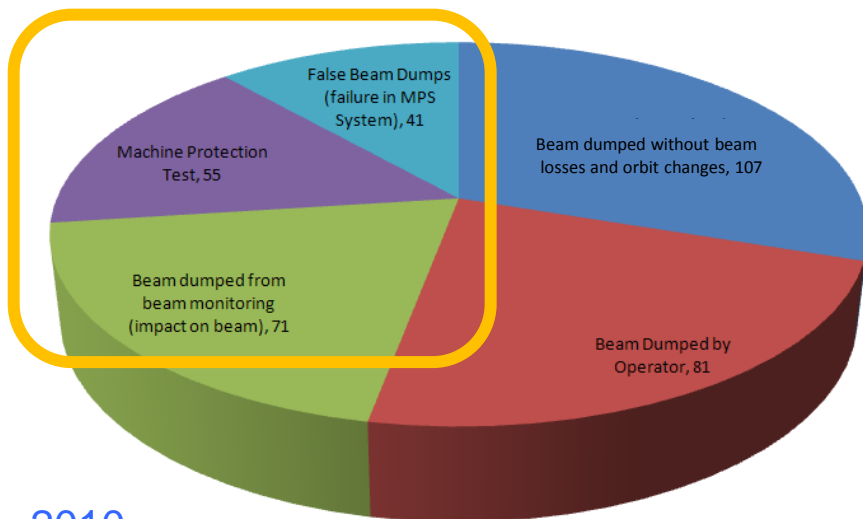
- MPS response in 2011
- Dependability of MPS backbone
- Issues and areas of upcoming improvements
- Commissioning and validation procedures
- Change management (incl. SW release)

1200 beam dumps were cleanly executed during 2011 (-10% wrt to 2010)

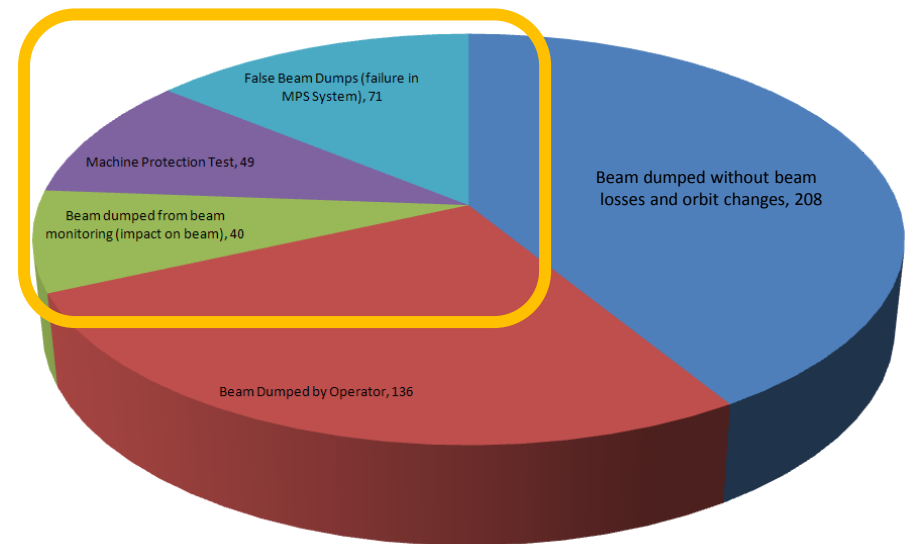
No beam induced quench with >100MJ beams @ 3.5TeV in 2011 (including all 'quench' tests)

No equipment damage observed (apart from kicker erratic causing damage in SDD calibration of ALICE)

MPS response of all dumps from 3.5TeV meticulously analyzed and validated – Initiating system always identified, but sometimes not fully clear why it triggered ('spurious' triggers, SEUs,...)



2010

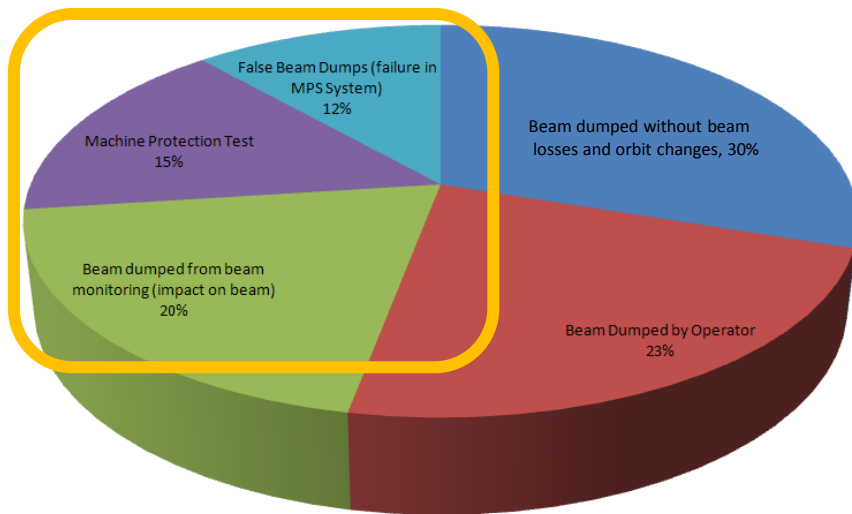


2011

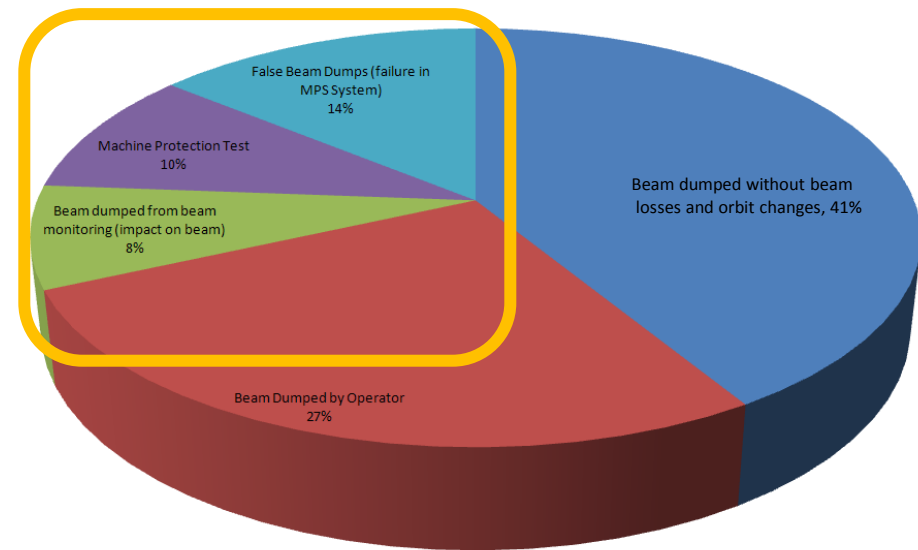
Nota bene: All statistics only counting fills > injection

During 2011 run we counted

- 40% more successful ramps to 3.5TeV
- Relatively speaking less MPS tests (commissioning, ramp-up after TS, loss-maps,...)
- ~ **Factor of 3 less dumps by beam monitoring** (beam losses, orbit changes,...) -> 2010/11 improvements do their job
- A small relative increase of false triggers of MPS system



2010

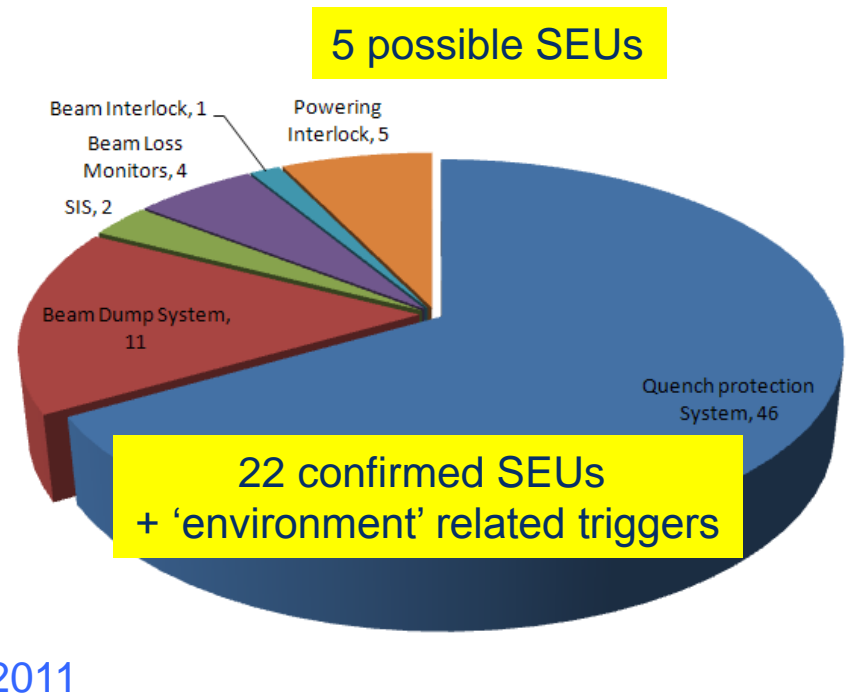
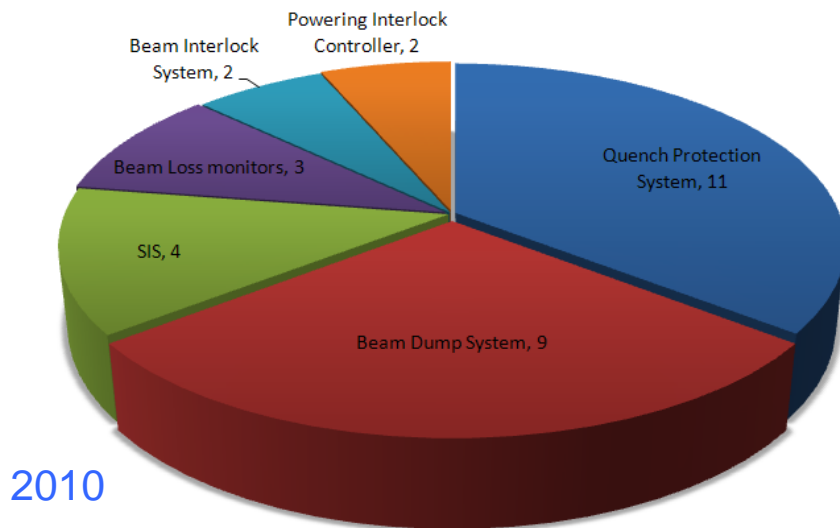


2011

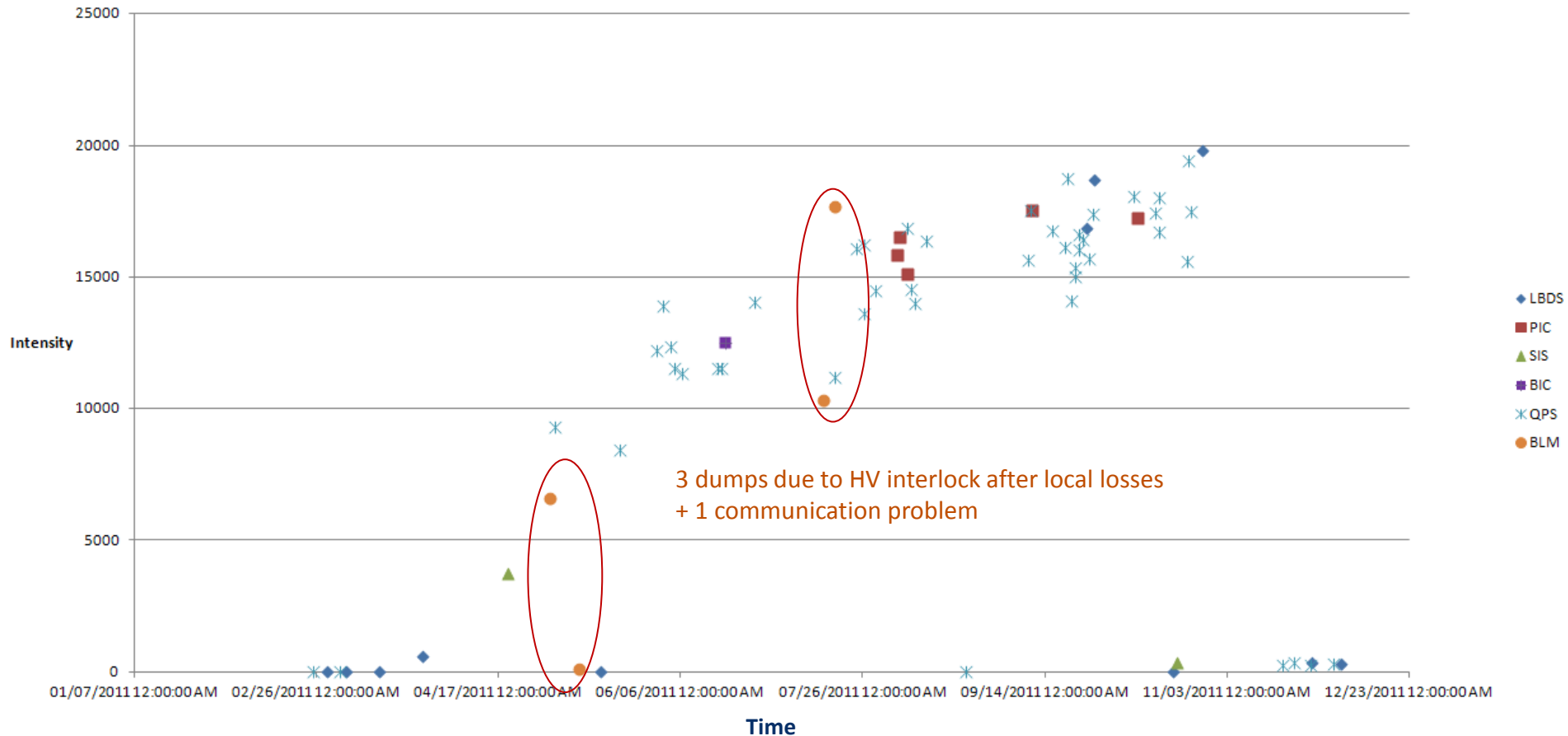
False triggers of most MPS backbone systems remained (surprisingly) constant

95% of false dumps in 2011 above injection energy

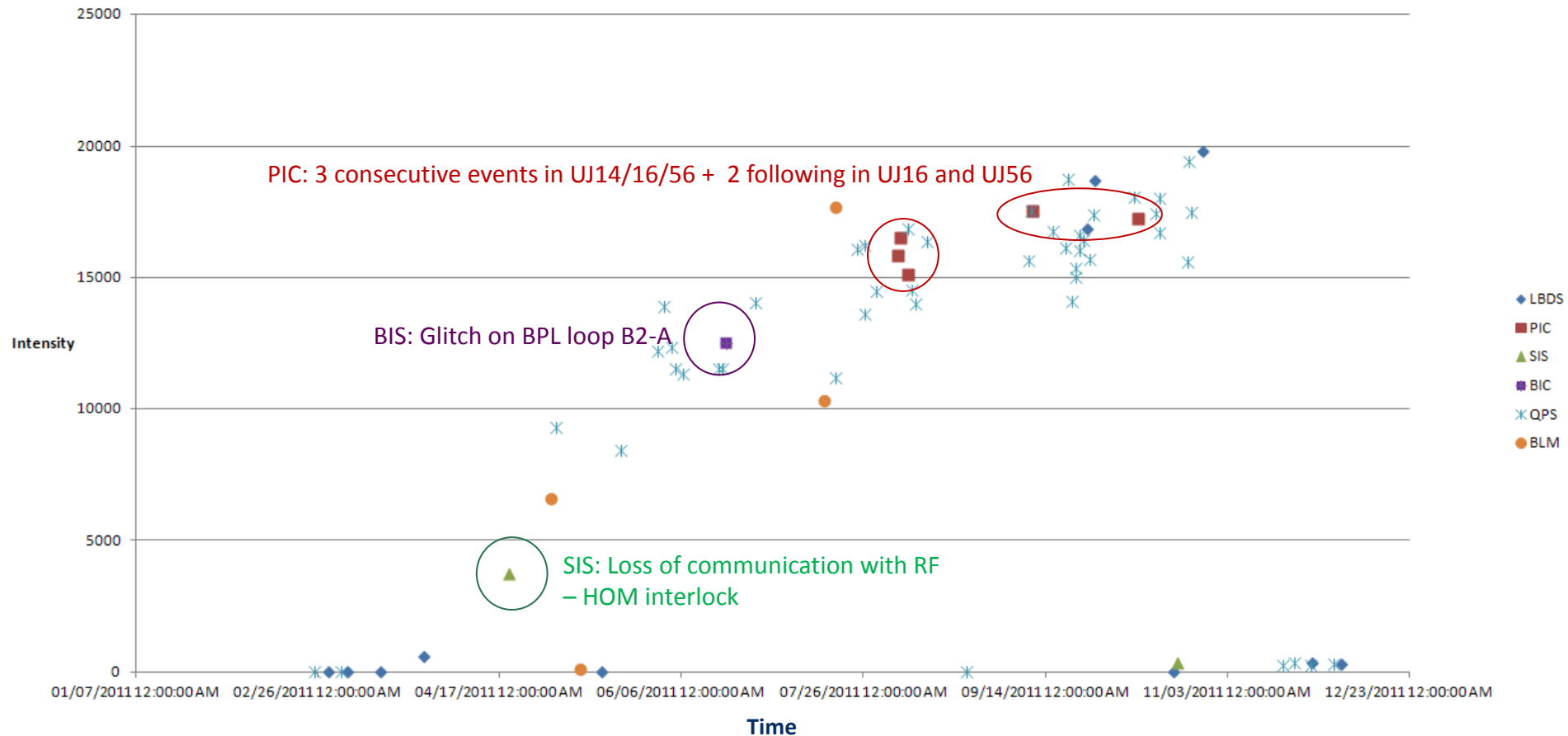
4-fold increase of QPS dumps (half of which confirmed or possible SEUs) -> See R.Denz



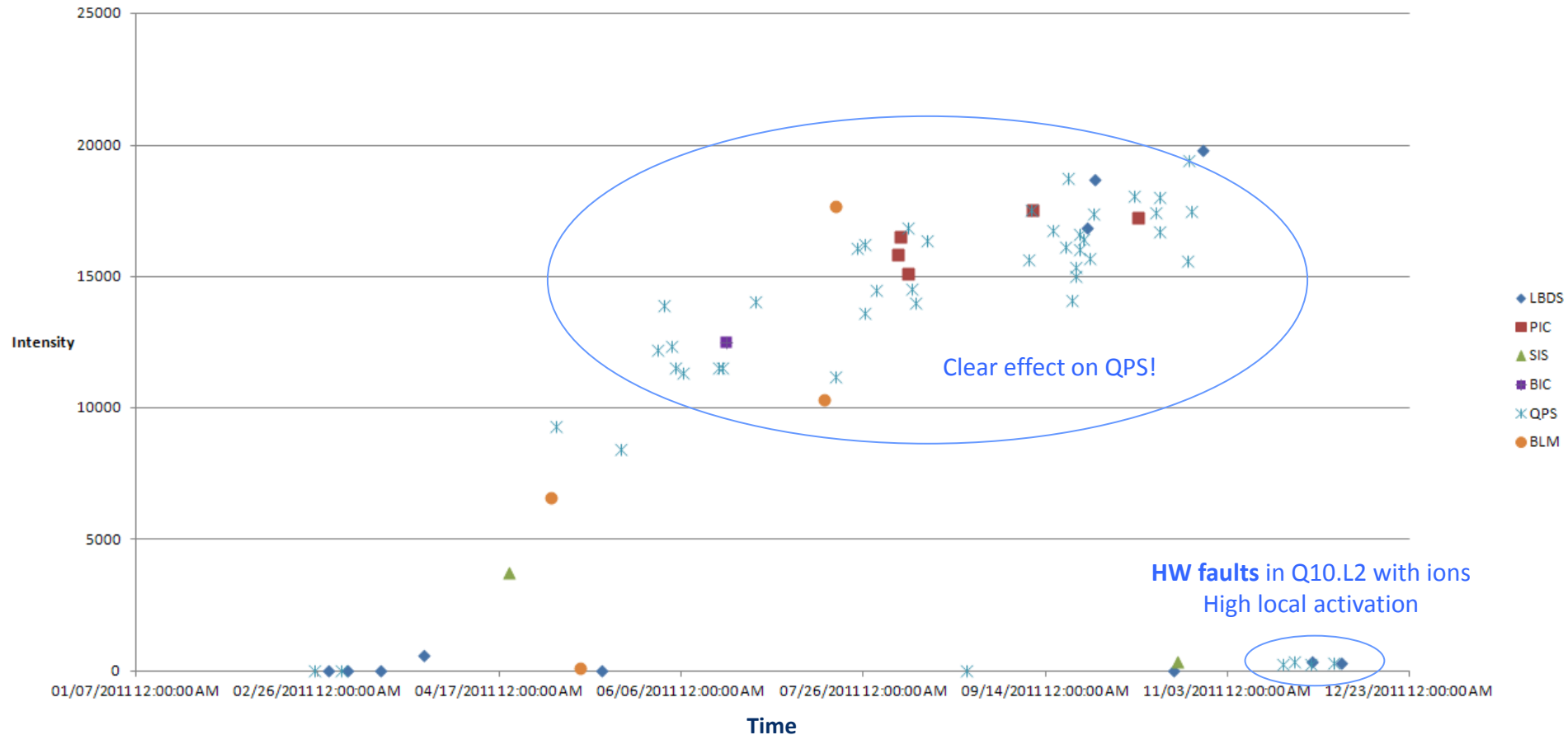
Occurrence of false dumps of some systems clearly related to increasing beam intensities



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Occurrence of false dumps of some systems clearly related to increasing beam intensities



Beam dumps by beam monitoring

Some 40 dumps by beam monitoring indicate possible improvements of redundant active detection

Mostly slow losses, caused by Vacuum activities, Feedback issues and beam instabilities

Very well protected by BLMs (and QPS), but $E>$, $<\beta^*$ means tight collimator settings, lower BLM threshold

Maintain current good level of orbit stability -> additional interlocks for orbit corrector current and DDT

EVENT_TIMESTAMP	ENERGY	MPS_DUMP_CAUSE	MPS_DETECTION	COMMENT
21-NOV-11 08.53.39	3499920	Orbit Feedback	BLM	Unstable OFB in squeeze with gain increase by a factor of 10
04-NOV-11 10.00.29	726600	Orbit Feedback	OP dump	Wrong OFB Parameter ORBIT_REF CHANGING_TIME (1s instead of 680s)
03-NOV-11 02.57.45	3500040	Beam Loss	BLM	Beam Loss during aperture measurements
17-OCT-11 06.58.51	3500040	Transv. beam instability	SIS	High Losses due to bad tune signal (end of ramp and squeeze without QFB)
28-SEP-11 08.56.30	1773720	Transv. beam instability	SIS	OFB problems during ramp
28-SEP-11 08.52.30	629280	Transv. beam instability	SIS	OFB not sending correct trims
20-SEP-11 07.44.34	3500040	Beam Loss	BLM	QFB dragged tune of B2H on resonance
11-SEP-11 04.50.52	3500040	Beam Loss	BLM	Vacuum spike
11-SEP-11 02.56.59	3500040	Beam Loss	BLM	Vacuum spike
25-JUL-11 02.32.30	3500040	Beam Loss	BLM	Orbit oscillations and consequent losses during optimisation
24-JUL-11 03.12.35	3500040	Beam Loss	BLM	Vacuum spike
23-JUL-11 10.14.12	3500040	Beam Loss	BLM	Vacuum spike
09-MAY-11 01.07.45	3500040	Transv. beam instability	BLM	Beam instability after quench test (ADT picking up wrong tune)
08-MAY-11 06.22.17	3500160	Beam Loss	BLM	Beam instability in B2V at end of coupled bunch instability MD
28-APR-11 09.20.22	3500160	Beam Loss	BLM	Vacuum spike
25-APR-11 08.40.04	3500040	Beam Loss	BLM	Vacuum spike
20-APR-11 02.26.26	2930880	Transv. beam instability	BLM	Horizontal beam instability with 2-3 s risetime
16-APR-11 11.58.41	3500040	FB 2	SIS	Orbit reference change applied in 1s instead of 385s, excursion in B2H
14-APR-11 05.37.30	3500160	Transv. beam instability	BPM6	Beam instability during IP scan

Nota bene: Not showing dumps of BPM in IR6 following too low bunch intensity (x4) & UFO dumps (x17 - see T.Baer)

Beam Current Change Monitor was vital part of MPS systems for e.g. HERA

Proposed for use in LHC MPS in 2005 (EDMS Doc. 359172)

With HERA like system, changes of $< 0.1\%$ of total beam current could be captured in 10 turns

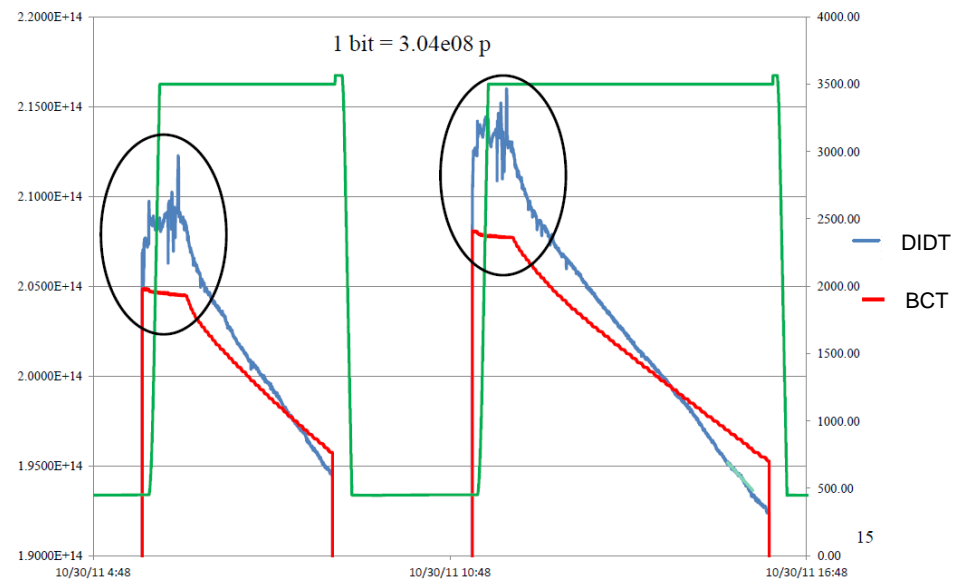
BI started development (with DESY consultancy) mid 2010, for deployment end 2011 + 2012 run

First system installed and data recorded, but showing not understood effects of bunch length, ...?

Important to validate and finish soon to eventually re-design during LS1?



First system now installed in IR4



First measurements during proton runs

Courtesy of M.Pfauwadel, D.Belohrad

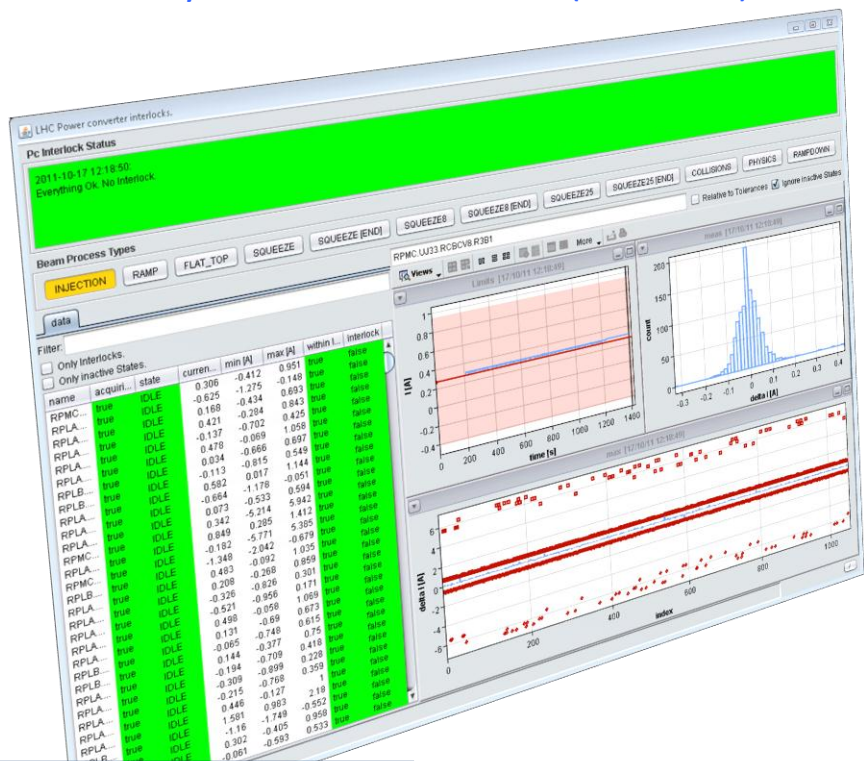


Work ongoing: Novel PC Interlock System

In addition to existing SIS interlocks at injection and SB, new SW interlock system monitoring PC currents to protect against operations- and feedback- failures

Redundant to SIS for arcs, adds protection for LSS 1/2/5/8 due to capability of tracking bump shape amplitude/variations

Key interest for all other (non-COD) converters where currently no current racking is done

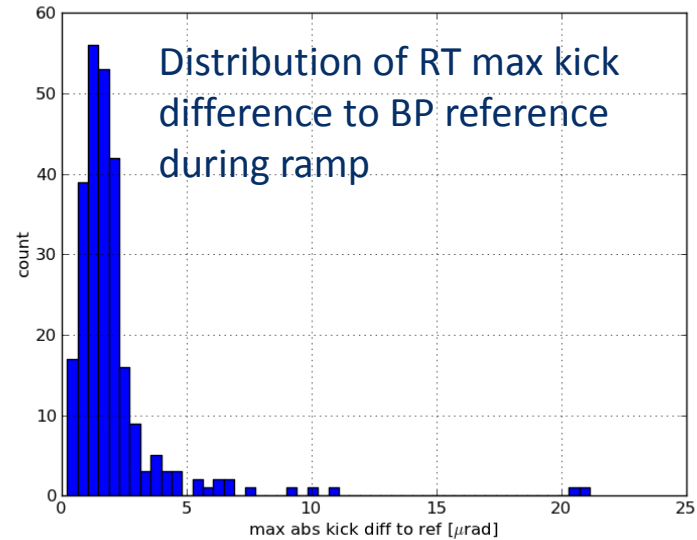
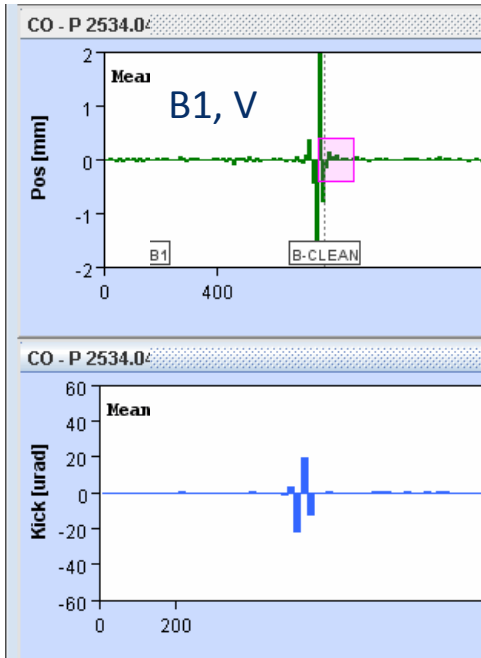


Status:

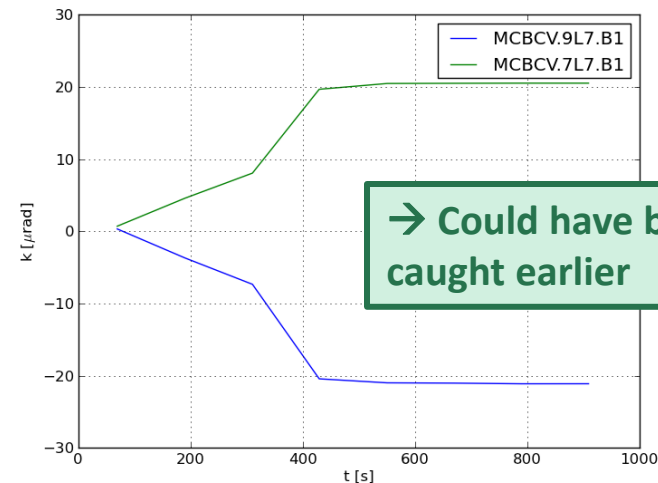
- Server and GUI application in place.
- Tracking of LHC status (beam process, time within beam process) works.
- Acquisition & Decision-taking works.
- Configuration-management (storing tolerances in LSA + reusing GUI from YASP): in preparation.
- Currently Commissioning and Testing
 - a) in first phase to provide warnings
 - b) after gaining experience, possibly to connect it to the BIS

Courtesy of K.Fuchsberger

Fill 1717: Bump >2mm during ramp in IR7



Only two kicks > e.g. 15 μrad :



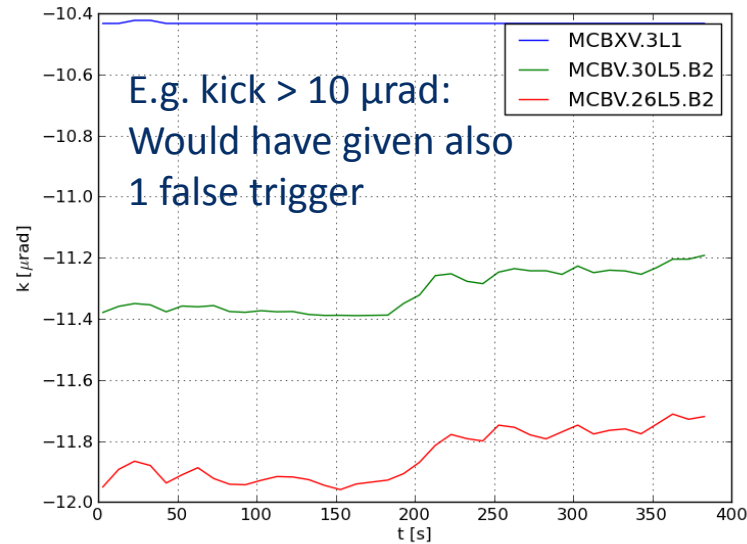
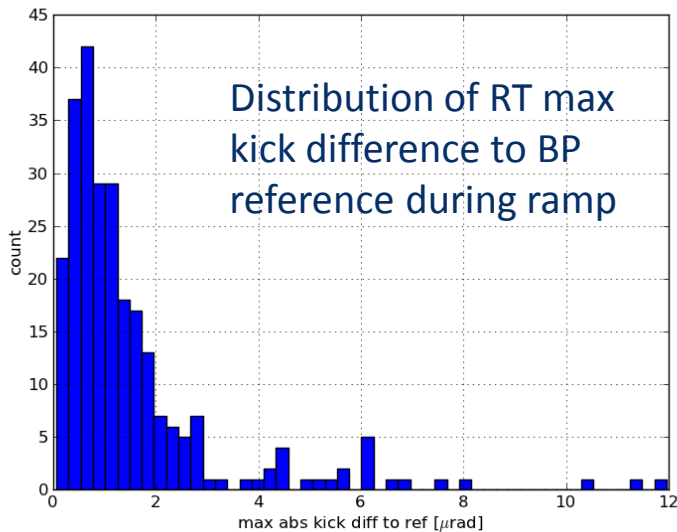
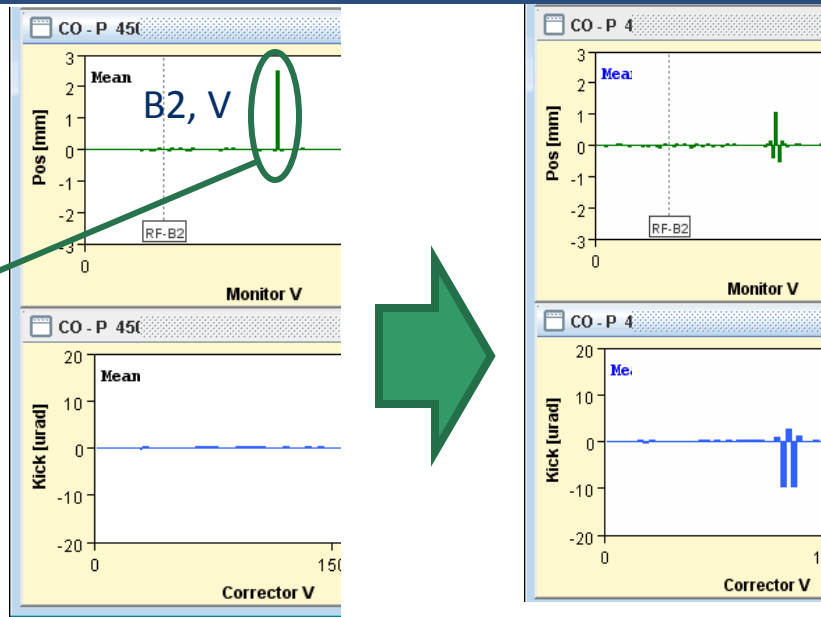
Eventually dumped by SIS in physics. Tolerances in μrad :

Corr name	Inj/Rmp/Sqz	Physics
MCBCV.9L7.B1	30	16
MCBCV.7L7.B1	30	16

Courtesy of K.Fuchsberger

Fill 1614: Pi-Bump (~1mm) in arc at injection

1 bad BPM



→ Bump of this size is at the limit for simple detection by ref functions and tolerances.

Courtesy of K.Fuchsberger

- BLM HV checks implemented at HW level
- New (shorter) BLMs in injection lines, providing > dynamic range
- New LBDS TSU firmware (including recommendations of external audit)
 - Increase re-trigger delay to avoid asynchronous dumps following internal TSU failures
- Started work on redundant BIS-LBDS trigger interface
- SMP-GMT hardware cross-checker
- First draft of operational procedure in case of non-working dump ready
- Operational procedure for abort gap cleaning
- Improvements of Roman Pot Controls
- ...

- MPS commissioning and validation well established and performed according to EDMS procedures (tracking done in SharePoint site)
- Profit from HWC re-factoring to introduce more formal approach and tools including representation of dependencies and sequencing as well for beam commissioning

The screenshot displays the 'Accelerator testing' software interface. On the left, there is a sidebar with 'Table actions' (Systems filter, Refresh table data), 'System actions' (Select all systems, Deselect all systems, Unlock systems, Lock systems), and 'Selected tests actions' (Run selected tests, Sign selected tests). Below this is a 'Displayed Test Filter' with checkboxes for Successful, Failed, Not started, Executing, Excluded, and Analysis pending.

The main area features a table with columns: 'Sel.', 'System name', 'Active locks', and 'The tests for the system'. The table lists systems RB.A12 through RB.A81, each with a lock icon and a grid of test buttons (e.g., 8 HOUR H., 24 HOUR H., PIC1 PC P., PIC1 POW., PIC1 CIR., PIC1 FAST., PIC1 DISC.).

On the right, a 'Type of plan' section offers 'Union of all tests' and 'Intersection of all tests'. Below it are 'Test plan actions' (Refresh test plan, Run selected tests, Sign selected tests) and 'Manage phases size' (Expand all phases, Collapse all phases). Another 'Displayed Test Filter' is present.

The rightmost part of the screenshot shows a dependency flowchart. It starts with an '8 Hour Heat run' box (8 HOUR HEAT, # Systems: 8), which leads to a '24 Hour Heat run' box (24 HOUR HEA, # Systems: 8). This leads to a 'PIC1' box containing six sub-phases: PIC1 PC PER., PIC1 POWER., PIC1 CIRCUIT., PIC1 FAST AB., PIC1 DISCHA., and PIC1 DISCHA., each with '# Systems: 8'. This PIC1 box leads to a 'PCL-CRYO OK' box containing 'PIC2 CRYO-OK' and 'PCL', both with '# Systems: 8'.

Courtesy of M.Galetzka, K.Fuchsberger

- Machine Developments per definition explore new machine and machine protection territory!
- MD requestors demonstrated responsibility in proactively providing the required MP documents
- More than 20 documents approved through EDMS for MD periods in 2011
- Preparation phase has proven very useful for MD and Machine Protection teams and often increased the efficiency of the MDs

To be made better for 2012:

- rMPP classification of requests + preparations of documents tbd more timely before the MD
- Certain flexibility wrt to agreed procedure was useful to increase efficiency (BFPP test, ion quench tests,...) but must not become the default

The screenshot shows the EDMS Web Navigator interface. The main content area displays a document titled "LHC MD Test Program - MD Class C & D" with a sub-section "DS QUENCH TEST".

Abstract:
This note summarises the detailed program proposed for the qualification of single diffractive scattering to the DS region of R7, which will be evaluated during an MD on 6th of May 2011. The detailed program along with the necessary modifications of the machine protection systems is presented and responsibilities for the latter are defined.

Prepared by:	Checked by:	Approved by:
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Distribution list:
LHC Engineers in charge, LHC operators

The right-hand side of the interface shows a list of documents with their status (Released) and size (KB):

- nge Beam-Beam Limit MD
- beam-long-range **docx** (120 KB)
- V Quench Margin at Injection
- k-10-00 **docx** (249 KB)
- 0GeV-QuenchMargin **doc** (249 KB)
- n studies and MKI UFOs
- nStudies **docx** (18 KB)
- dsx (13 KB)
- SI_UFO **doc** (179 KB)
- ych Test
- nchTest **doc** (293 KB)
- fill study on collimator tight settings
- igs **doc** (297 KB)
- ych Test #2
- R-2 **doc** (117 KB)
- duced Quench Measurement #2
- dsocx (46 KB)
- JANGE BEAM-BEAM LIMIT MD
- im **docx** (121 KB)
- Slow up with ADT
- MD3-Transverse-Blowup-ADT **docx** (46 KB)
- 1158394 v.1 MD3 - Aperture Measurement MQX
- MD3-Aperture-Measurement-MQX **DOC** (144 KB)
- 1158957 v.1 MD3 - MKI UFOs at injection #2

- Some improvements to track changes in MPS systems during 2011 run
- > 90 HW and MPS SW changes tracked in MPS commissioning SharePoint Site, however...
- Requires corresponding culture and level of responsibility of equipment experts
- Even more so for SW deliverables -> Culture of best practice
 - Good design
 - Unit Testing
 - Integration Testing
 - Functional Testing
- Replaying (BI) data from the Logging DB would allow testing on test-beds without beam (e.g. during LS1)
- Tools for intelligent rollback
- Tools to centralize information on deployments/ server reboots,...
- RBAC like protection against changes on operational machines

Title	Assigned To	Status	Criticality	Modification Date	% Complete
Exchange of PCB managing circuit protection in PIC AR8	Markus Zerlauth	Completed	(2) Normal	16/12/2010	100 %
Firmware Upgrade of PIC PLCs	Markus Zerlauth	Completed	(3) Low	11/01/2011	100 %
Exchange of CIBOs in both LBDS TSUs	Benjamin Todd	Completed	(2) Normal	09/03/2011	100 %
Upgrade of MTG due to bug in UTC distribution	Javier Serrano	Completed	(4) No direct impact on MPS	17/03/2011	100 %
Bug in FGC software tripping RF supplies	Quentin King	Completed	(4) No direct impact on MPS	21/03/2011	100 %
BLM Threshold Changes on cold magnets	Eva Barbara Holzer	Completed	(1) High	18/02/2011	100 %
Change of TDI, MBX and MQX thresholds and BIS connections	Eva Barbara Holzer	Completed	(1) High	29/03/2011	100 %
BLM firmware update	Christos Zamanitzas	Completed	(2) Normal	08/03/2011	100 %
Upgrade of low level collimator controls software	Ralph Wolfgang Assmann	Completed	(2) Normal	21/03/2011	100 %
Upgrade of TSU firmware	Brennan Goddard	In Progress	(1) High	03/03/2011	70 %
Adding direct BLMs in IR6	Eva Barbara Holzer	Completed	(2) Normal	01/09/2011	100 %
Interlock from energy-dependent gap for collimator TCLA.A7L7.B2 during 1.38TeV run	Ralph Wolfgang Assmann	Completed	(3) Low	24/03/2011	100 %
Change of Broadcasted Beam Intensity to 100Z logic	Benjamin Todd	Completed	(4) No direct impact on MPS	28/03/2011	100 %
Change of NI card in LBDS (Problem of missing Rogowski coil readings)	Nicolas Magnin	Completed	(3) Low	24/03/2011	100 %
FGC update to fix bug in PM data for RT_REF	Stephen Page	Completed	(4) No direct impact on MPS	28/03/2011	100 %
Change of IR6 interlock BPM settings for 1.38TeV run	Brennan Goddard	Completed	(2) Normal	26/03/2011	100 %
SMP 3v1	Benjamin Todd	Completed	(3) Low	30/03/2011	100 %
Changes to Magnet Powering System during TS end of March	Hugues Thiesen	Completed	(2) Normal	29/03/2011	100 %
Threshold of the new BPF raised by a factor of 3	Marek Gasior	Completed	(3) Low	31/03/2011	100 %
Optical Fibre connections in UA63/JA67 have been moved	Benjamin Todd	Completed	(2) Normal	30/03/2011	100 %
Exchange of MKB_HB.B2 generator, HV pc issue	Jan Uythoven	Completed	(2) Normal	31/03/2011	100 %
Re-alignment of TCLA.A7R7.B1, TCTH.4L2.B1, TCSG.A5L3.B2 during TS	Ralph Wolfgang Assmann	Completed	(2) Normal	01/04/2011	100 %
Update of Beta* interlock logic	Alessandro Masi	Completed	(2) Normal	28/03/2011	100 %
LBDS exchange MKD B1 generator K	Jan Uythoven	Completed	(2) Normal	01/04/2011	100 %
LBDS MKB vacuum pumps	Jan Uythoven	Completed	(2) Normal	01/04/2011	100 %
LBDS MKB Ti resistances in generators	Jan Uythoven	Completed	(2) Normal	01/04/2011	100 %
LBDS MKB magnet entrance box	Jan Uythoven	Completed	(2) Normal	01/04/2011	100 %
Interlock on interlock BPMs in TS	Benjamin Todd	Completed	(2) Normal	01/04/2011	100 %

LHC Machine Protection Systems have been working well during 2011 run thanks to a lot of loving care and rigor of operation crews and MPS experts

Most failures are captured before effects on beam are seen (no losses or orbit movements)

Still no quenches with circulating beam (with $\sim 100\text{MJ}$ per beam and 10mJ for quenching a magnet)

No evidence of major loopholes or uncovered risks, additional active protection will provide further redundancy

Maintaining present good level of orbit stability is a primary importance

Still **we have to remain vigilant to maintain current level of safety of MPS systems** while increasing efforts on increasing MPS availability

Thanks a lot for your attention