

Preparing the Machine Protection System for the 2011 Run

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With contributions from

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Outline

- Changes to main players Machine Protection System
 - BIS, SMP, QPS, Collimators, BLMs, PIC/WIC/FMCM, SIS, Injection, Beam Dump
- Re-commissioning
- Impact on operational parameters
 - Energy, Beam Intensity
- Expected performance of the Machine Protection System in 2011

BIS

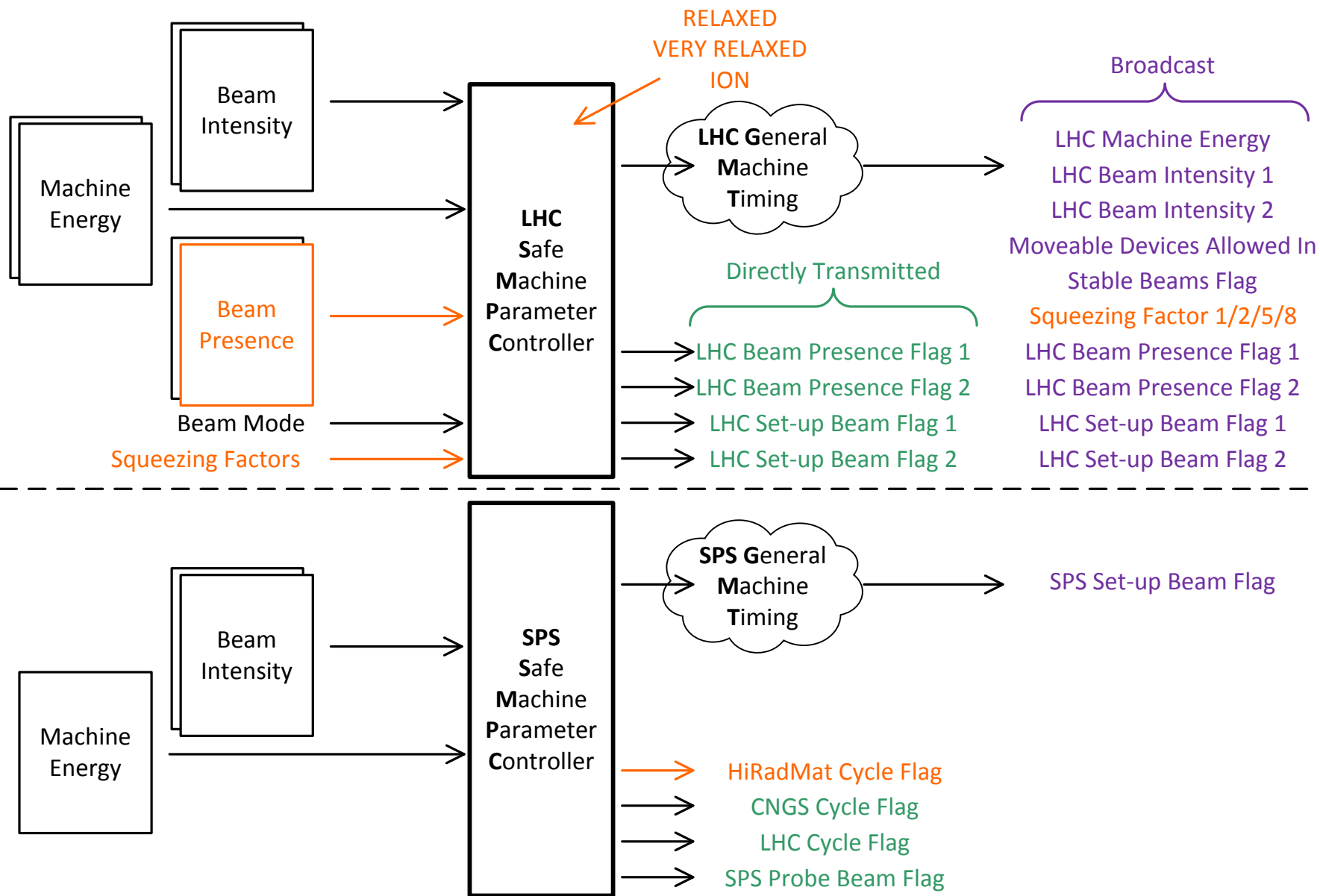
- Changes for 2011
 - Changes to the SPS Extraction BIS in BA6 with a new BIC to protect the TT66 line: **HiRadMat**
 - Consequently, the Master BIC managing Beam 1 will be updated in order to manage the new extraction conditions
- LHC-BIS not touched during this winter stop
- Time required for re-commissioning master BIC
 - Without beam: **few hours of commissioning time**
 - With beam: -
- Limitation of the system on operational parameters
 - **None**

B.Puccio

Safe Machine Parameters I

- Changes for 2011
 - Two **Beam Energy** sources of Beam Energy must be active (was one)
 - Both from beam dumping system but are calculated from different octants
 - Double source of **Beam Intensity**
 - Take signals from the two Fast BCTs
 - **Beam Presence Flag**
 - Dedicated hardware from BPM signal in addition to Fast BCT using a voting strategy
 - **Movable Device Flags**
 - New modes: Stable Beams, Unstable Beams, Beam Dump (new)
 - **Setup Beam Flag**
 - Normal, Relaxed, Very Relaxed (new), Ion (new)

At start-up the largest of the two BCT signals will be used for the SMP. Future plan dump the beam in case of disagreement: **BCT reliability !**



Safe Machine Parameters II

- Time required for re-commissioning
 - Without beam: Finished during Chamonix week
 - With beam: In the shadow of other work – need test ramps & different beam intensities
 - Tests are detailed in edms doc no. 1112187 B.Todd
- Limitation of the system on Operation Parameters
 - None

BLMs

- Changes for 2011
 - Several upgrades in the FPGA firmware, repairs and preventive actions on the tunnel installations
- Time required for re-commissioning
 - Without beam: In the shadow of other activities
 - With beam: about one shift at injection energy
- Limitation of the system on Operational Parameters
 - Limitation in energy between 4 and 5 TeV due to noise on some cables
 - Tests with double shielded cables for future operation

B. Dehning

Quench Protection System

- Changes for 2011
 - Installation of snubber capacitors on the 16 extraction switches of all Main Dipoles
 - Removal of 'old' global busbar protection; replaced everywhere by simplified detector + nQPS
 - Replacement of input power switches of all quadrupole quench heater power supplies: 900 units & broken ones on dipoles. **Should not break down any more!**
 - QPS of all Q8, Q9 and Q10: modified to be less sensitive to noise pick-up: change of voltage dividers & firmware modification
- Time required for re-commissioning
 - Without beam:
 - Snubber capacitors commissioned in 56 + 1 other sector. Commissioning will be required for all sectors if energy above 3.5 TeV. **One sector takes about 6 hours to commission – foreseen for mid February = close to beam start-up**
 - Busbar detectors: parasitic on first ramp(s)
 - Quad quench heaters: Individual System Tests – independent HC programme
 - QPS: parasitic during first ramps
 - With beam: -
- Limitation of the system on operational parameters: -

K.D.-Peterson

Collimators

- Changes for 2011
 - Squeeze factor, interlock logic, recalibration of sensors, ...
 - See talk S.Redaeli this morning
 - Time required for re-commissioning
 - Without beam: Shadow of other activities
 - With beam: Set-up and qualification at injection and full energy: 4 shifts @ 450 GeV, 5 shifts @ 4 TeV + 6 to 10 additional ramps... **a lot of time!**
- 2010 spent \approx 100 h \approx 12 shifts
- Limitation of the system on operational parameters
 - β^* , limited around 1.5 m (depending on β -beat, orbit feedback etc.)
 - No limit intensity
 - No direct limit on emittance

PIC/WIC/FMCM

- Changes for 2011
 - Firmware upgrade of PIC PLCs (diagnostics in case PLC gets stuck)
 - WIC of point 8 moved moved from UA83 to US85 - R2E study
 - TI8 WIC moved away form collimator position, unique SEU in 2009
- Time required for re-commissioning
 - Without beam: Most re-commissioning during hardware commissioning period. Re-commissioning PIC-BIS interface: 6 hours
 - With beam: Possible FMCM check for D1 and MSD for new β^* , but normally end of fill
- Limitation of the system on
 - Energy: FMCM will get more performing with higher energies!
 - Beam Intensity: Additional checks on reaction time for ultimate intensities, no limit
 - β^* : Few type tests for FMCMs to validate new β^* , no limit

M. Zerlauth

SIS

- Changes for 2011
 - β^* values produced by SIS, transit through SMP, distribute over timing
 - New injection oscillation interlock; forcing of intermediate intensity
 - More performing (=more complex) orbit interlocking to handle special conditions (special optics, Van der Meer scans)
 - Further improvement of settings management for special conditions
- Time required for re-commissioning
 - Without beam: Test link SIS – SMP (1 hour + ramp) – most tests parasitic
 - With beam: 1 -2 shift dedicated time
- Limitation of the system on operational parameters
 - No

J. Wenninger

Injection Systems I

- Changes for 2011
 - **New IQC.** Interlock on injection oscillations, B1 and B2 independent, change in functionalities & latching philosophy (see Evian follow-up meeting 19/01)
 - MKI operational settings with envelope to allow limited trim
 - New injection procedures with **intermediate beam intensity**
 - Tighten interlock gaps TCDIs, TDIs and TCLIs
 - New TCDI interlock logic (start-up) and automatic set-up (later during the year)
 - **Shielding of ring BLMs from TCDI** showers (first go installed TI2, to be installed TI8 in Technical Stop)
 - BLM interlock thresholds on TDI and TCLI under discussion
 - Possible TDI shielding
 - **Sunglasses** on the BLM during injection (after the summer)
 - **Sunglasses** for BCM at LHCb and ALICE
 - Abort gap and injection gap cleaning during injection

Injection Systems II

- Changes for 2011 – Hardware
 - Replaced MKI magnet (B Point 2) which sparked
 - Improved diagnostics, controls and interlocking of MKIs
 - Perform fine synchronisation of kicker modules and AGK
 - **New TI2 BPMs** and dual acquisition for all
 - Diamond BLMs in IP2 and IP8 for bunch by bunch diagnostics
- Time required for re-commissioning
 - Without beam: **About 1 shift with the loops closed**
 - With beam: **About 3.5 shifts for injection protection and 1.5 shifts for general injection set-up = 5 shifts.**
 - Maintenance & intensity increase: **3 shifts + 1 shift per 2 – 4 weeks**
- Limitation of the system on operational parameters
 - Injected beam intensity: **Last year injection of 48 nominal bunches was ok. Expect no problem up to 144 nominal bunches**, above this will need to optimise shielding, sunglasses and BLM thresholds

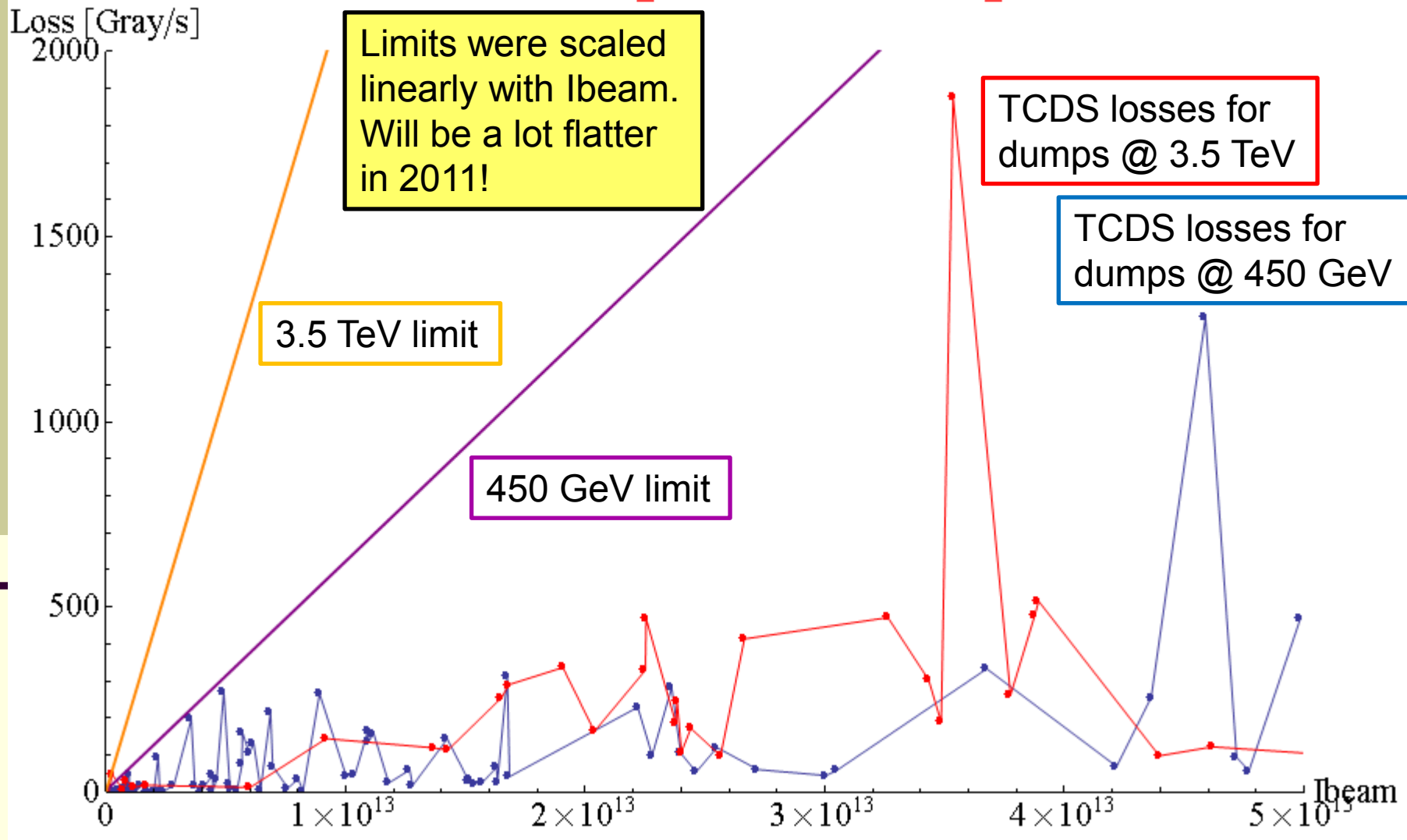
Beam Dumping System I

■ Changes for 2011

- Clamp MKD/MKB voltages at new maximum energy
- **MKD Trigger Fan Out (TFO) re-cabled** to minimise asynchronous dumps with multiple MKDs pre-triggering
- MKD generators new thermal working point to prepare for real high energy running (from 23 °C to 26 °C)
- TCDQ
 - General **controls and diagnostics improvements**: approach to collimator logic
 - Sequences separated from collimator sequences
 - Mechanical off-set to avoid 'orange TCDQ' during the ramp
 - Dependence of TCDQ setting on β^* for 2012
- **MSD settings** based on new MSD calibration at CERN to centre beam at lower energies & include degauss cycles
- XPOC
 - **Additional module**: Beam Position relative to TCDQ position
 - **BLM limits** calculated differently
 - Will be tighter for higher beam intensities, **include TCTs**

XPOC BLM limits will be tighter for larger beam intensities in 2011

BLME1.04L6.B1E10_TCDSA.4L6.B1:LOSS_RS01

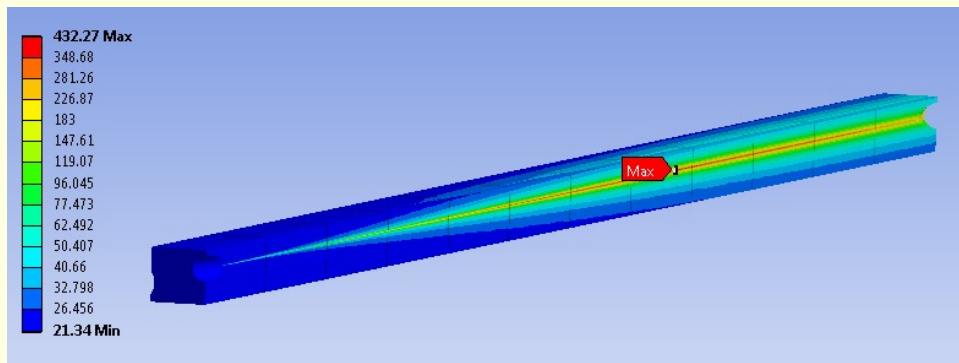


Beam Dumping System II

- Changes for 2011
 - Two MKD and two MKB generators replaced (contact erosion programme) -> regeneration of all settings and references
 - Trigger Synchronisation Unit firmware upgrade following external Audit
 - Improved controls and diagnostics
 - Update BEM firmware to correct communication errors between BETS – PLC
 - Abort gap monitoring and cleaning under development
- Time required for re-commissioning
 - Without beam: About 4 shifts, mainly with the loops closed
 - With beam: About 10 shifts: 3 shifts for basic checks, 3 shifts for TCDQ/TCT set-up including ramps full energy and 4 shifts for abort gap cleaning and monitoring
 - Maintenance: Depends on collimation set-up; asynch dump tests – about 30 minutes when already at full energy
 - Intensity increase & filling pattern: BPM interlock tests – about 30 minutes at injection

Beam Dumping System III

- Limitation of the system on
 - Energy
 - MKD generators HV break down along switch resulting in asynchronous dumps limit energy at 4.5 TeV
 - Awaiting isolators to be installed, can be installed for 2012 start-up
 - Total stored energy
 - TCDQ operational limit not known: Rough calculation for 28 bunches resulting in @ 25 ns @ 7 TeV: $7 \cdot 10^9$ p+/bunch < **SAFE LIMIT** < $7 \cdot 10^{10}$ p+/ bunch
 - Further studies needed / ongoing
 - Only an issue in case of an asynch dump; spare TCDQs exist...
 - Precise loss measurements to check possible TCDQ damage
 - Staged installation of diluters MKB, still 2 vertical diluters missing on each beam, ok for nominal intensity. All MKBs required for ultimate intensity



Presentation
V.Mertens

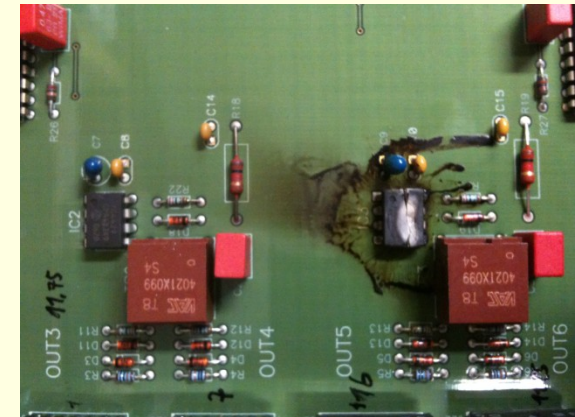
TCDQ studies ongoing

Σ Commissioning & Op. Limits

- Commissioning time as in other years
 - Cold check-out for: **about 8 shifts dedicated time** for MPS
 - QPS needs an extra 6 * 6 hours if energy > 3.5 TeV = **+5 shifts**
 - Re-use (better use) Web Based MPS checks
 - MPS checks with beam: **initial 28 shifts \approx 10 days**
 - Main players: **collimation, injection and beam dump**
 - Need to **revisit** during operation and intensity increase: **on average few shifts per week**
- Limit energy
 - **4 – 5 TeV** due to some noisy BLM cables
 - **4.5 TeV** due to break downs beam dump generator MKD
- Limit intensity
 - **Nominal**, but risk TCDQ damage in case of asynch dump; further studies needed
 - **144 bunches per injection** in present configuration
- Effect of **small emittances** on TCDQ unknown
- Limit **$\beta^* \approx 1.5$ m** due to collimation (with orbit, beta-beat etc.)

Performance 2011

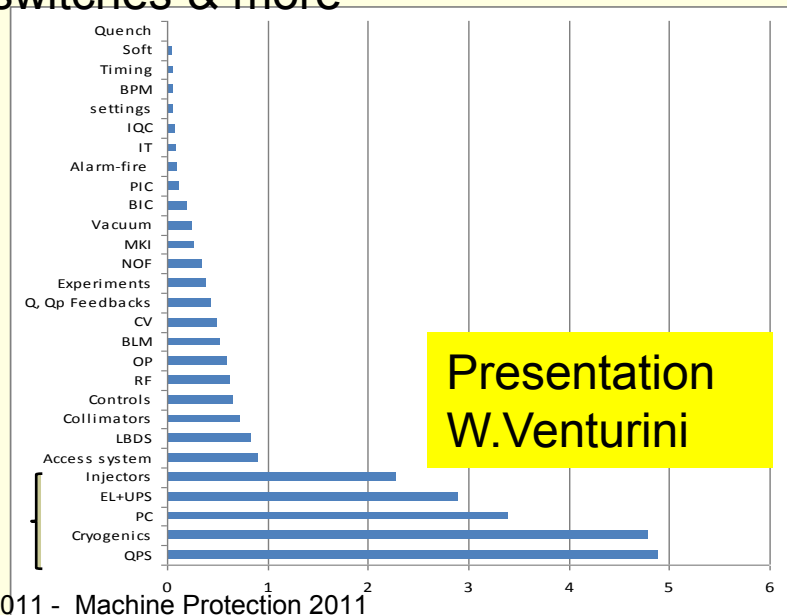
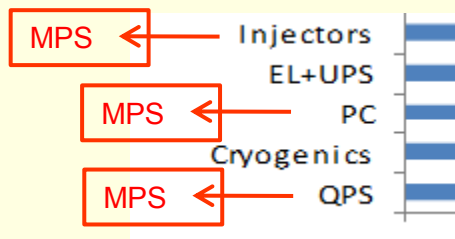
- MPS performance:
 - **Safety**: Limit damage to machine components
 - **Availability**: Limit impact on machine up time
- **Safety** 2010 was OK:
 - Generally no discussion point considering hardware
 - No damage, no **beam induced** quenches > 450 GeV
 - More discussions considering 'procedures'
 - 2010 'Safety Events'
 - MKD erratic with two magnets
 - **TFO logic modified for 2011**
 - Injection onto moving TCDQ
 - **TCDQ controls modifications (more conform)**
 - **Work on sequencer**
 - Other 2010 safety issues mainly operations / sequencer related and don't affect the Machine Protection hardware as such



Presentation of
L.Ponce

Expected Performance

- **Availability** for 2010 – see talk W.Venturini of Monday
 - Improved MPS at known weaknesses:
 - Injection losses due to TL collimator showers:
 - IQC upgrade, B1 and B2 independent
 - Shielding from TL losses and Sunglasses
 - Power Converters:
 - R2E - Moved electronics found to be sensitive
 - QPS: replaced 900 power switches & more



Conclusions

- LHC Machine Protection System is undergoing an impressive amount of changes in this short Technical Stop.
Changes \Rightarrow Improvements!
- Improvements focus on known weaknesses seen during 2010 operation and affect Safety & Availability
- Significant time required to test with and without beam – not new
- Expect a Safe and Available LHC in 2011
- Limits from MPS on operational parameters
 - 144 bunches per injection
but work ongoing to allow testing with more bunches
 - Beam energy limits 4 – 5 TeV
 - From BLMs and LBDS
 - $\beta^* \approx 1.5$ m