Strategy for intensity increase

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Machine Protection Organization

- Machine Protection Panel (MPP):
  - 'Open' committee responsible for dealing with all aspects of LHC Beam related Machine Protection (not magnet protection).
- Restricted Machine Protection Panel (RMPP):
  - Small committee with representatives of the main MP systems, responsible for defining the safe intensity limits for beam operation on a weekly basis (9 members),
  - Represented systems: Beam Dump and Injection, BLM System, Collimation, Powering, Magnets.

The general strategy for intensity increase was discussed and agreed upon in the MPP, presented and approved by the LHC Machine Committee (LMC).

Basic strategy

- The intensity increase strategy is based on the following observations:
  - Even moderate luminosities (~$10^{30\text{-}31}$) require beams with a significant damage potential.
  - Magnet damage may imply a lengthy stop (months…).
  - The MPS is brand new.
- The proposed strategy for intensity increase should allow for enough time to observe and detect problems.
  - Splice problem may have been detected if we had operated the magnets some time at lower current.

Intensity increase – general criteria

- Maximum intensity increase versus stored energy:

○ Up to 0.25 MJ	typical factor ~2, max 4	*Approved by LMC*
○ Up to 1-2 MJ	max. factor ~2	
○ Above 1-2 MJ	≤ ~2 MJ per step	*Wait and see*

Intensity increase – special criteria

- Machine Protection System tests:
  - All specified tests must be passed *~ 10 shifts to go*
    - Vast majority must be passed for ‘unsafe beam’.
- Stability tolerances (> 0.25 MJ) - depend on collimator settings and aperture:
  - Optics must be reproducible (≤ ~10%) *on track*
  - Orbit must be stabilized to ~0.5-1 sigma in all phases. *coming soon*
    - Locally tighter for injection of unsafe beam (~0.2 mm/sigma).
- The ~1-2 MJ beam:
  - Operate for a longer (see later) period at this intensity.
  - Review of the MPS performance after running at this intensity.

Injected intensity

- 50 ns trains:
  - First trains must be based on 6 or 12 bunches / train (and not 36) to limit the total injected intensity and to match intensity steps.

- Injection – based on progression.
  - Single bunch < Setup Beam intensity = 1E12 p.
  - 4 bunches < Setup Beam intensity
  - 6 bunches (50 ns) < Setup Beam intensity
  - 12 bunches (50 ns) ≤ Setup Beam intensity

‘Green light’ for intensity increase

- Operation time:
  - Minimum time ~10 days with at least 10 fills / dumps.
    - time to evaluate conditions and analyze data (post-mortem).
  - **Exception**: at least 3-4 weeks with intensities in the 1-2 MJ range, possibly in 2 different configurations (43, trains..).
- Beam cleaning & losses:
  - Cleaning adequate and no quenches, losses under control – Coll. Team.
  - Losses scaled by intensity should be << BLM thresholds
    - essential for efficiency
  - Abort gap population under control.
    - no Q4 quenches (quad. downstream from beam dumping system).
- Restricted MPP:
  - Review issues (if any) before approval of intensity increase.
  - Document decision.

The first step…

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the Large Hadron Collider project

LHC Project Document No.
LHC-MPS-IL-0001

CERN Div./Group or Supplier/Contractor Document No.
LHC restricted MPP

EDMS Document No.
XXX

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Restricted MPP

PERFORMANCE OF THE LHC MACHINE PROTECTION SYSTEM

INTENSITY LIMITS AT 3.5 TEV FOR THE MEDIA DAY AND EASTER WEEK

Abstract

This document describes the status of the LHC Machine Protection System end of March 2010 – before the 3.5 TeV Media Day. For the current commissioning status of the Machine Protection Systems (MPS) and of the LHC in general, **the recommended total intensity limit at 3.5 TeV is 2E10 protons per beam. At 450 GeV the intensity limit is set to 2E11 protons per beam and a maximum bunch charge of 5E10 protons per bunch.**

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Intensity increase - verification

- Tests / verifications after intensity increase:
  - Diagnostics operational (BLMs, BPMs, BCTs, BSRT/A).
    - Sounds trivial but…
  - Beam cleaning adequate, possibly re-optimized – Collimation Team.
  - Test beam dump at injection.

- NB: optics (or Xing angle) changes require additional verifications.
  - Collimation setup.
  - Dump of de-bunched beam (asynch. dump failure check).
  - …

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To reach such an integrated luminosity,

we must run flat out at $L=2x10^{32}$ $cm^{-2}s^{-1}$ in 2011

- Corollary: we must reach ~1-2$10^{32}$ $cm^{-2}s^{-1}$ by the end of 2010.
- Beam requirements: Ib = 8E10 p, Nb ~700 bunches, ~35 MJ.

Yet Another Model

- Assumptions:
  - 2 weeks between energy steps = 10 days + margin for MD, access, …
  - Follow rules for intensity increase (slide 2).
  - Move to ≥8E10 p/bunch ‘asap’: in this case when starting with trains.
  - To respect 2 MJ/step, max 48 bunches of 8E10 more per step (2.1 MJ).

- Running time 2010:
  - Max 7 months : ~32 weeks between April and end October.

Progression (1)

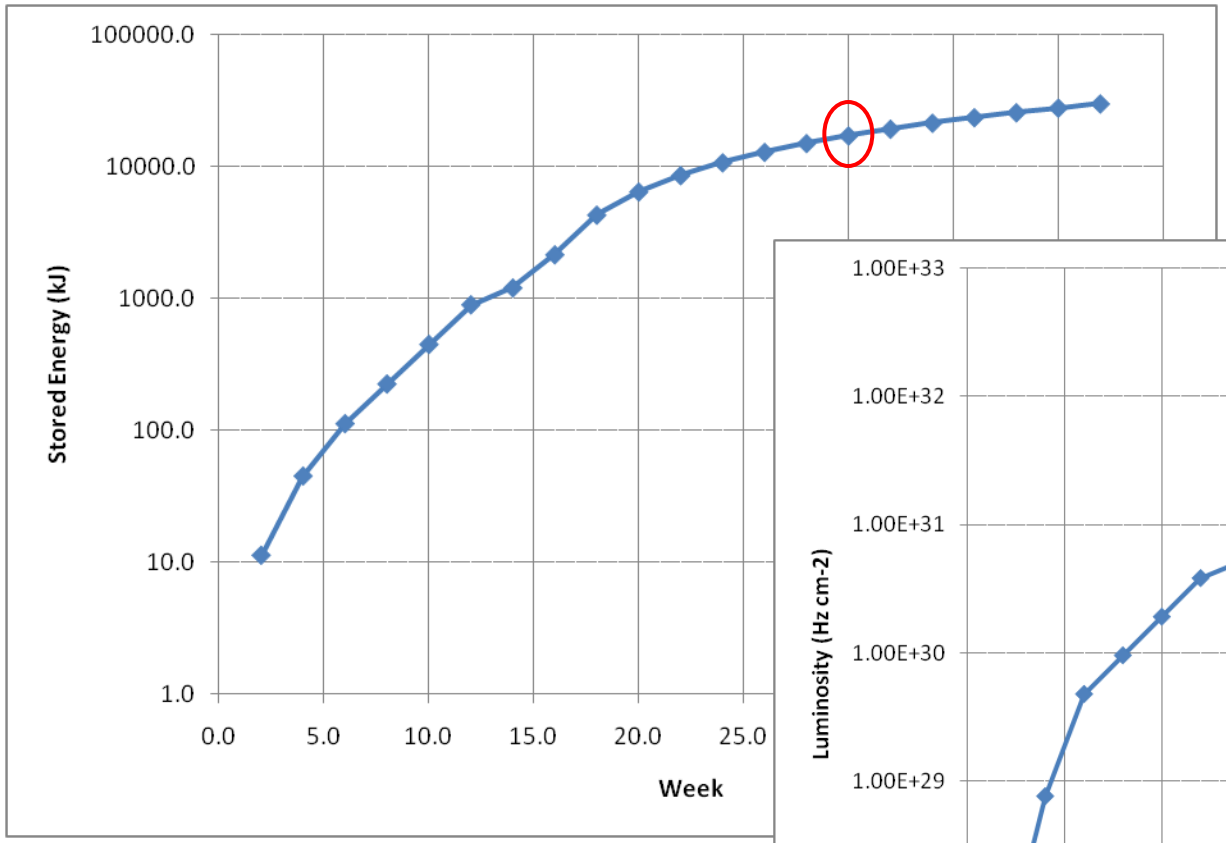
Stage	Ib (protons)	Nb	Stored E (kJ)	Stored E step	Peak L (Hz cm-2)
3 fat pilots (*)	1.00E+10	3	17	1.00	1.34E+28
4 bunches	2.00E+10	4	44.8	2.60	7.63E+28
4 bunches	5.00E+10	4	112.0	2.50	4.77E+29
8 bunches	5.00E+10	8	224.0	2.00	9.54E+29
4x4 bunches	5.00E+10	16	448.0	2.00	1.91E+30
8x4 bunches	5.00E+10	32	896.0	2.00	3.81E+30
43x43	5.00E+10	43	1204.0	1.34	5.13E+30
8 trains of 6 b	8.00E+10	48	2150.4	1.79	1.33E+31
50 ns trains	8.00E+10	96	4300.8	2.00	2.67E+31

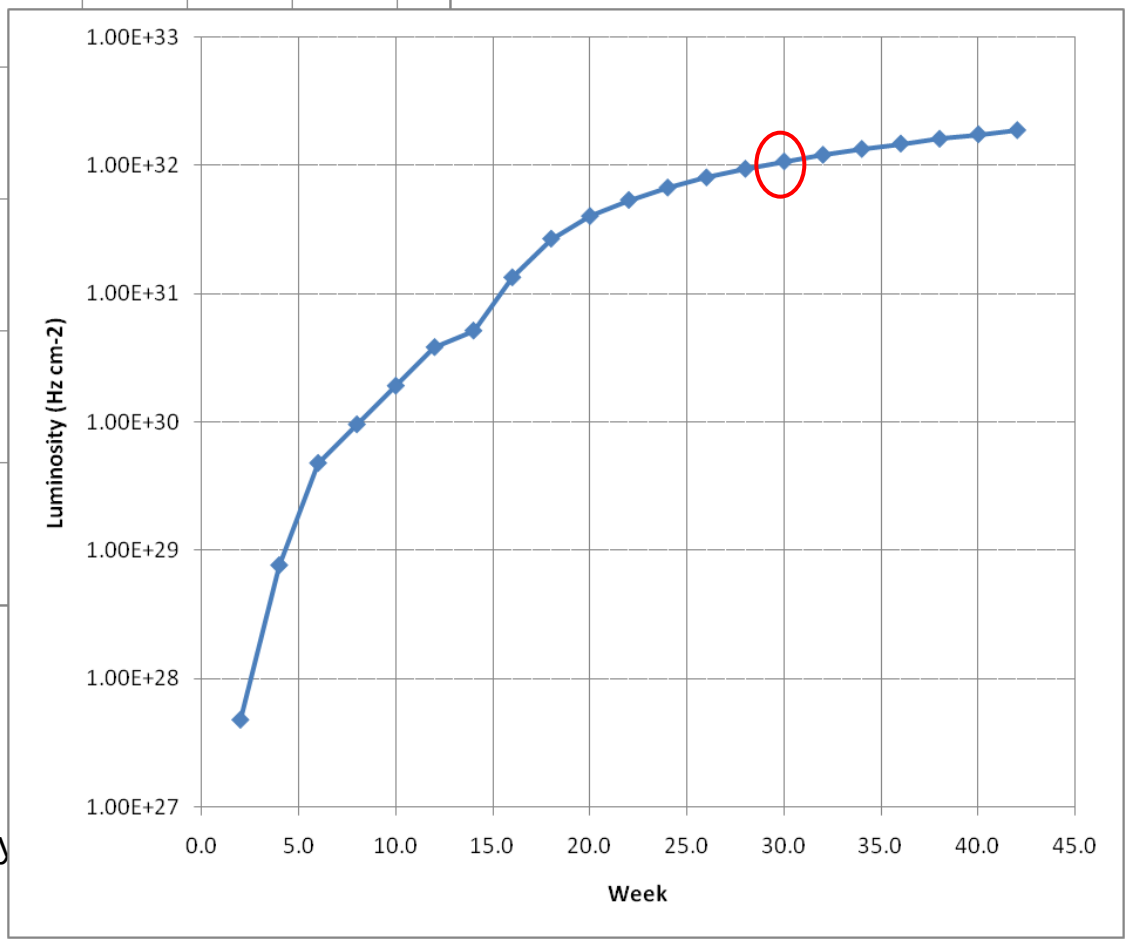
β^* = 2 m, nominal emittance

(*) Initial plan was with 4 bunches of 5E9, L ~ 4E27

Progression (2)

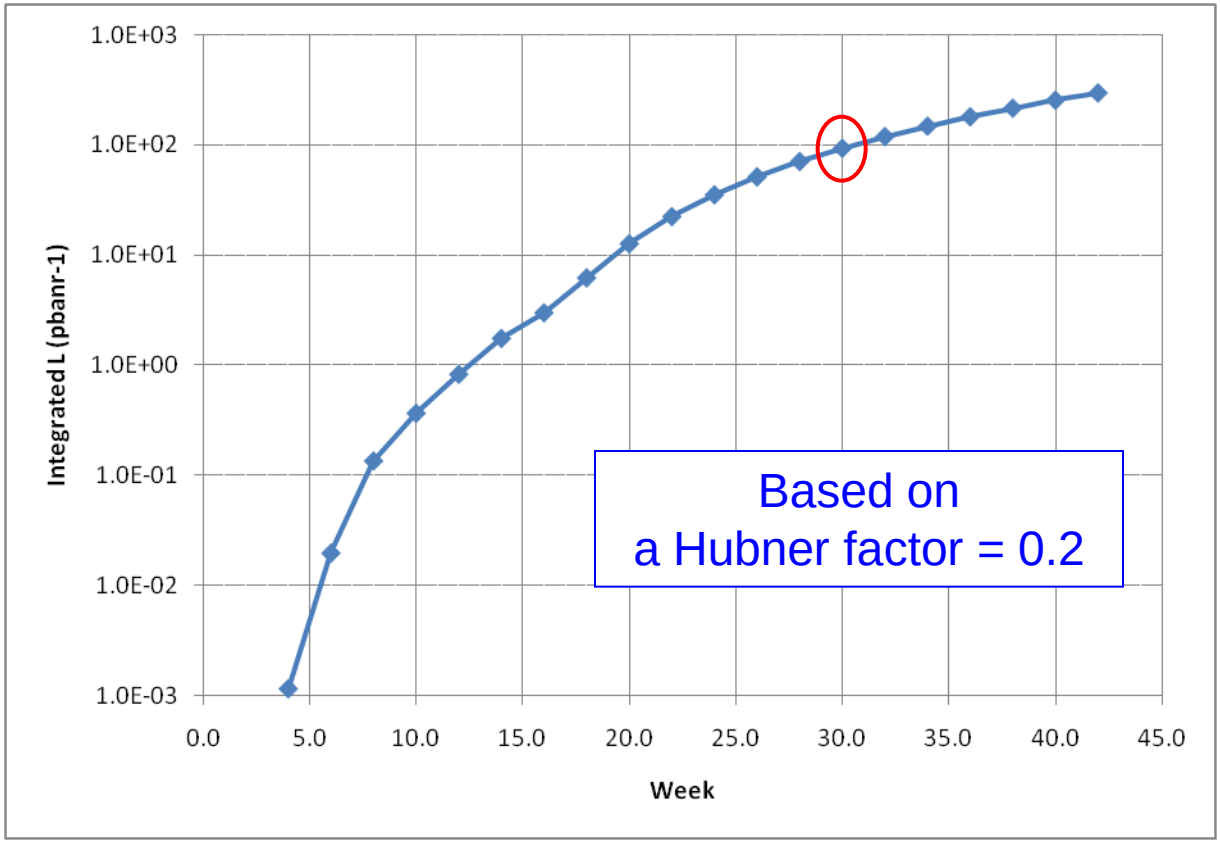
- After 30 weeks: ~1E32 cm-2s-1, 12 MJ.





Progression (3)

- After 30 weeks: ~100 pbarn-1



Remember: it's just a plan – and not a pessimistic one !

The Setup Beam (Flag)

- The LHC beam interlock system (BIS) has two types of input signals:
  - Non-maskable: active in all phases of operation.
    - Criticial circuit powering, vacuum, experiments, dump system, BLMs on SC elements, …
  - Maskable: inputs may be masked if the beam intensity is below the setup beam intensity
    - BLMs on collimators, collimator positions, 'uncritical' circuit powering, RF, …
- The setup beam intensity defines the transition between a 'safe' beam (where masking is possible) and 'unsafe' beam.
  - Enforced in the BIS HW (energy & intensity information).
  - Intensity scaling with energy: $1/E^{1.7}$
    - At 450 GeV: limit is 1E12 protons ~ 70 kJ
    - At 3.5 TeV: limit is 3E10 protons ~ 17 kJ