New Setup Beam Flag definition in the view of Run1 operational experience and the results of material damage experiments

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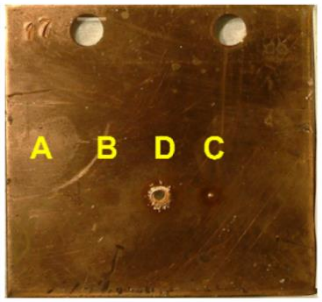
Definition of SBF

- The intensity limit as a function of energy at which damage* of Cu occurs in case of transient beam loss
  - “SET-UP BEAM FLAG = .TRUE.” : beam intensity and energy **below** the Cu transient damage limit.
  - “SET-UP BEAM FLAG = .FALSE.” : beam intensity and energy **above** the Cu transient damage limit.

* Damage = “clear sign of melting”.

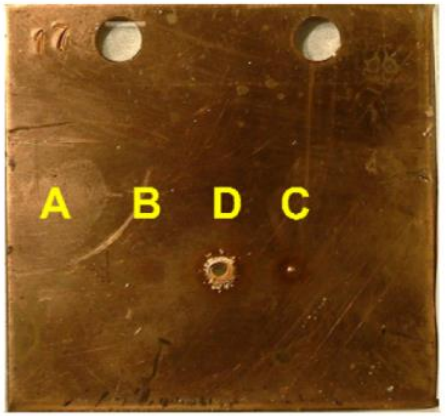


One of the Cu plates of the TT40 Material Damage Test target after the irradiation.

[V.Kain “Machine Protection and Beam Quality during the LHC Injection Process” CERN-THESIS-2005-047 Vienna Tech. U., 2005].

Background of SBF

- TT40 material damage test (2005): 1e12 lost protons having 450 GeV do not produce any damage.



- FLUKA: scaling law for SBF

  (adiabatic damping, orthogonal impact)

$$\left(\frac{E\left[GeV\right]}{450\left[GeV\right]}\right)^{1.7} \times I\left[p\right] \leq 1\times 10^{12}$$

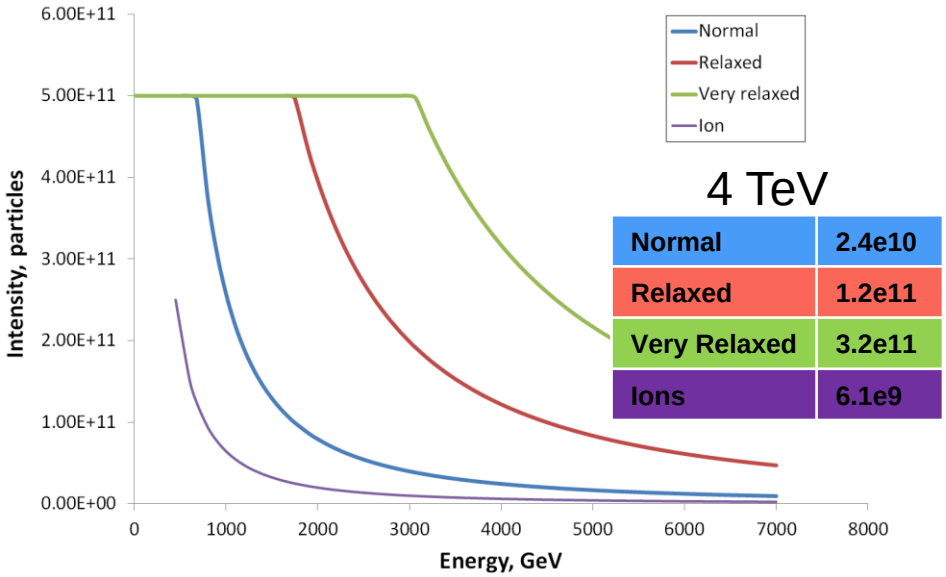
Intensity	# protons	Comments
A	1.3e12	No effect
B	2.6e12	Decolouration
C	5.3e12	Melting
D	7.9e12	Fragment ejection

SBF levels during Run 1

- Probability of orthogonal impact in the machine is low.
- Losses are mostly not instantaneous.
- Damage limit for Cu is lower than for stainless steel.

⇩

Three different SBFs were defined.



4 TeV

Normal	2.4e10
Relaxed	1.2e11
Very Relaxed	3.2e11
Ions	6.1e9

The intensity of ~1e12 p was considered safe; factor 2 was applied to this intensity value, due to lower emittance used during operation => 5e11 p

NORMAL: Considered to be safe.

RELAXED: was established to allow 1 nominal bunch at 4 TeV.

VERY RELAXED: was established to allow 3 nominal bunches at 4 TeV.

SBF mission

- Interlocks in the LHC to ensure protection:
  - RF; BLM; BPM; Vacuum; FMCM; Collimation; SIS; PIC; WIC; QPS; etc.
- SBF allows masking some of the BIS channels to allow for efficient beam setups:
  - BLMs on collimators
  - Collimation interlocks
  - RF interlock
  - BPM IP6 orbit excursion
  - Etc.
- Masking is not possible above the intensity as function of the beam energy defined in the SBF.

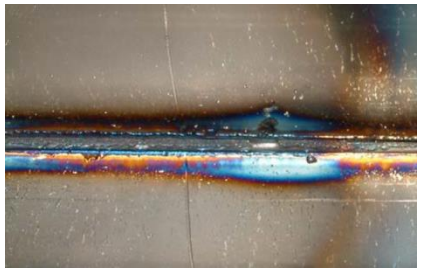
Users

- During Run 1:
  - Beam setup (orbit, collision, …).
  - Collimation setup and qualification.
  - MDs.
  - Optics measurements.
  - etc.

Very Relaxed SBF: 3.2e11p @ 4TeV

Normal SBF: 2.4e10 @ 4 TeV

Run 1 Experience

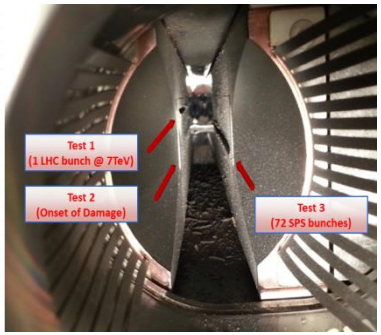


- TT40 Damage during HI SPS Extraction
  - Cutting the vacuum chamber open by 3.4e13 p @ 450 GeV

- TT40 Material damage test with 450 GeV
  - Safe beam intensity at 450 GeV: $1x10^{12}$ p

- TCT Damage Tests (HRMT09, HRMT14):
  - Onset of plastic damage : $5x10^{9}$ p
  - Limit for fragment ejection: $2x10^{10}$ p

Acceptable?

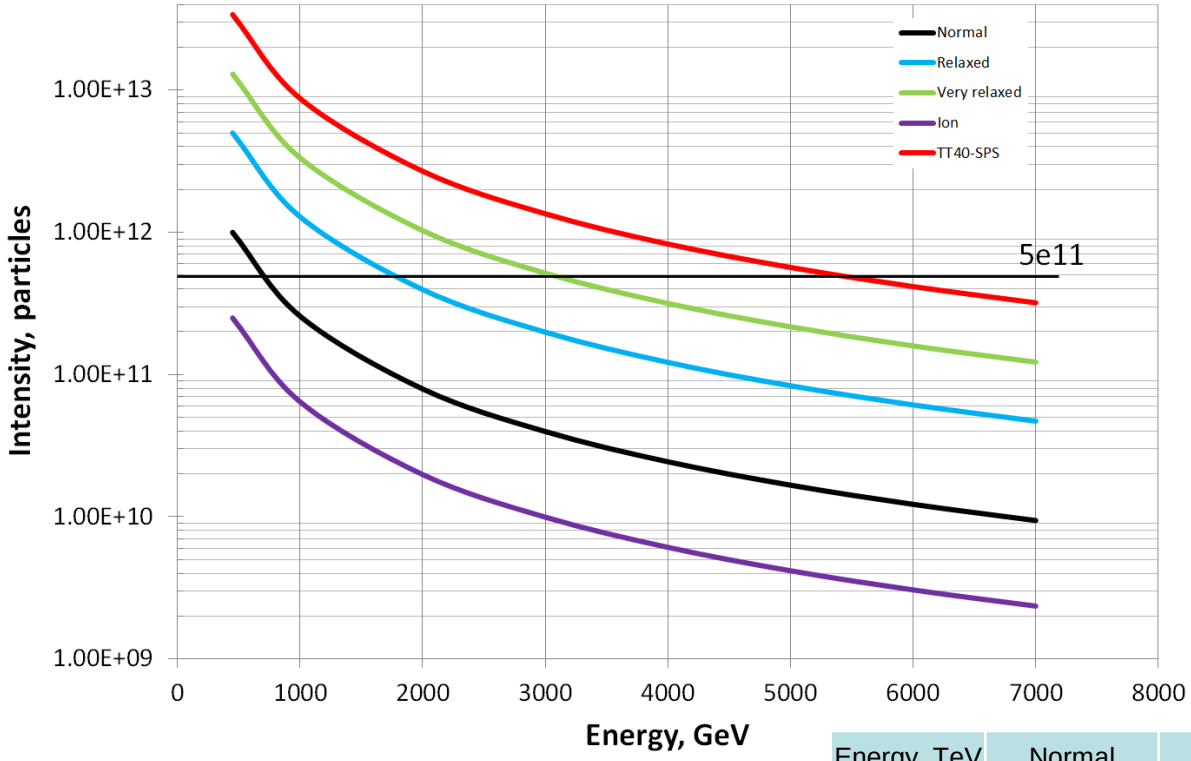


  - Limit requiring replacement of device (with fragment ejection): $1x10^{11}$ p

Not acceptable?

- Smaller beams during Run1. Emittance ~2 um instead of 3.75 um

Experience of TT40 Damage during 2004 High Intensity SPS Extraction

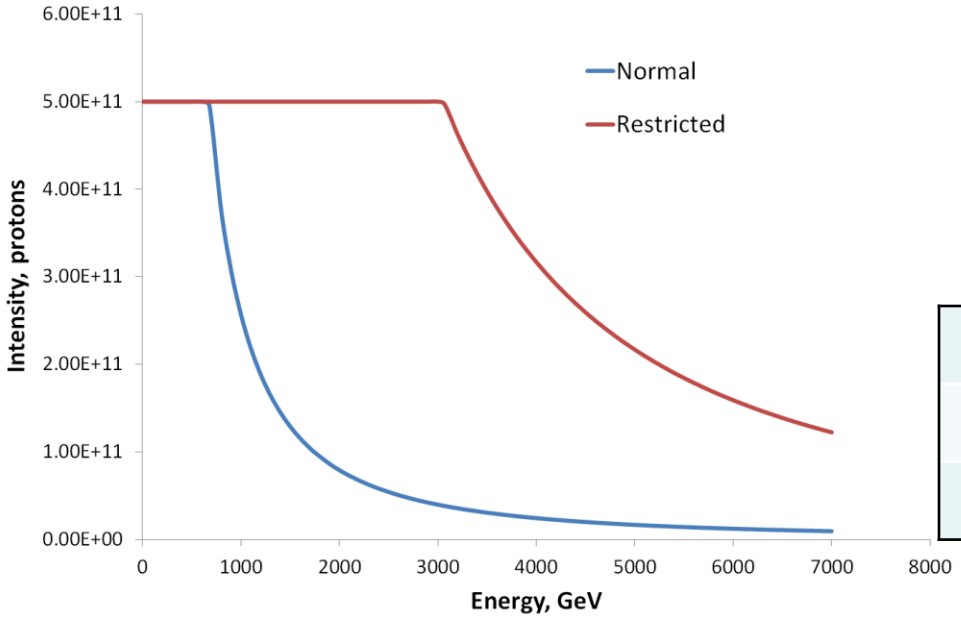


Number of protons that will melt stainless steel at 7 TeV (calculated using TT40 experience and scaling law): 3.2e11 p

Energy, TeV	Normal	Relaxed	Very relaxed	Ion	TT40-SPS
0.45	1.00E+12	5.00E+12	1.30E+13	2.50E+11	3.4E+13
1	2.57E+11	1.29E+12	3.35E+12	6.43E+10	8.75E+12
2	7.92E+10	3.96E+11	1.03E+12	1.98E+10	2.69E+12
3	3.98E+10	1.99E+11	5.17E+11	9.94E+09	1.35E+12
4	2.44E+10	1.22E+11	3.17E+11	6.09E+09	8.29E+11
5	1.67E+10	8.34E+10	2.17E+11	4.17E+09	5.67E+11
6	1.22E+10	6.12E+10	1.59E+11	3.06E+09	4.16E+11
7	9.41E+09	4.71E+10	1.22E+11	2.35E+09	3.2E+11

Proposal to ensure adequate protection and an efficient setup

1) Normal SBF: 1.1e10 [ALL]
2) Restricted SBF: 1.4e11 x 1 bunch [Only Special Users]
3) Restricted SBF: 1.1e10 x 12 bunches [MDs with MP doc.]
   - SIS interlock on bunch intensity



Limiting intensities for different-level SBFs at 6.5 TeV and 7 TeV

	6.5 TeV	7 TeV
Normal	1.1e10	9.4e9
Restricted	1.4e11	1.2e11

Discussion

Is it feasible with these limits to

- Set up collisions.
- Set up collimation system (assuming the “golden” orbit can also be achieved for pilot bunches).
- Perform loss maps.
- Perform Asynchronous Beam Dump tests.
- …

Ions: to be continued…