Protecting TOTEM

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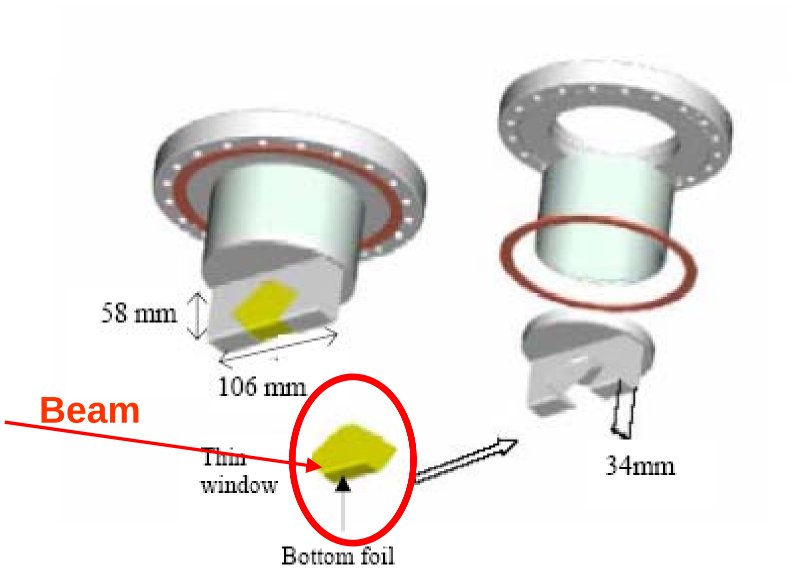
PH-TOT

12.06.2007

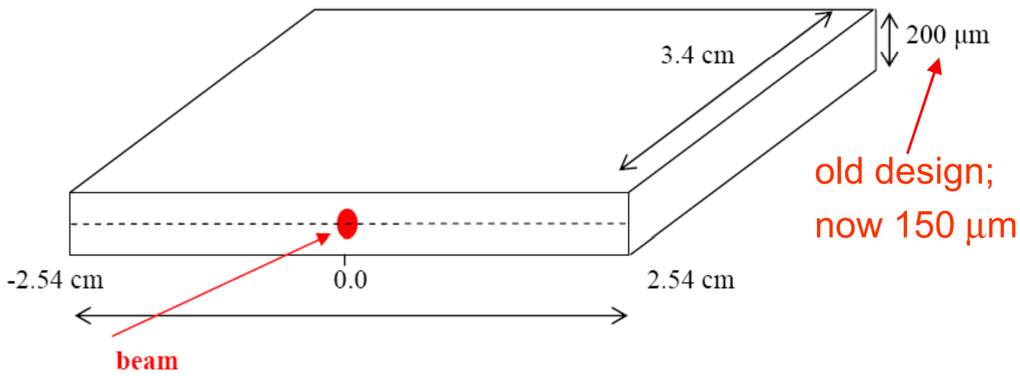
Damage Levels: Roman Pot: Window

Bottom foil of Roman Pot window

Fluka simulation by E. Dimovasili:

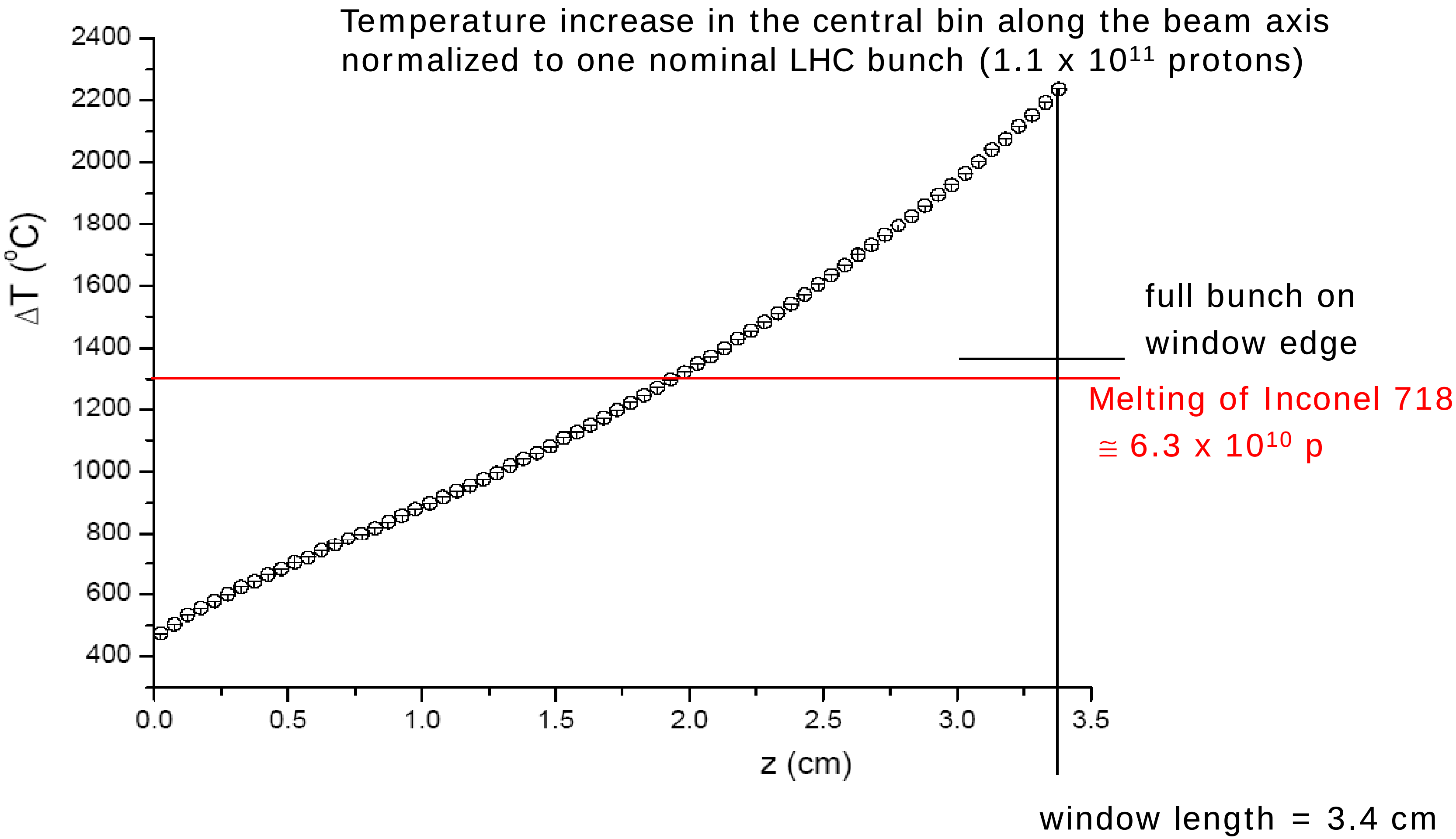


Accident Scenario:
A nominal bunch (1.1×10^{11} p) through the bottom RP window



Beam dimensions according to high beta optics at XRP3 (β^*=1540 m):
σ_x = 30 µm, σ_y = 80 µm
➔ worst case scenario

Damage Levels: Roman Pot: Window



Impact on transverse window: z = 150µm → no problem

Mechanical stress effects not included!

Damage Levels: Roman Pot: Window

•Normal running (7 TeV):

RP at 10 σ ;

- $\beta^* = 1540$ m: narrow beam: RP220: $\sigma_x = 0.03$ mm, $\sigma_y = 0.08$ mm (scenario of the study above)
  wider at RP147: $\sigma_x = 0.24$ mm, $\sigma_y = 0.17$ mm

  43 bunches: asynchronous beam dump: at most 1 bunch can hit the RP. (? To be checked)
  Seems OK for bunches up to 6 x 10^{10} p.

- $\beta^* = 90$ m: wide beam: RP147: $\sigma_x = 0.4$ mm, $\sigma_y = 0.3$ mm
  RP220: $\sigma_x = 0.4$ mm, $\sigma_y = 0.6$ mm → much less concentrated

  156 bunches: asynchronous beam dump: how many bunches can hit the RP ?

- $\beta^* = 2$ m, 0.5 m: wide beam: RP147: $\sigma_x = 0.3$ mm, $\sigma_y = 0.5$ mm
  RP220: $\sigma_x = 0.1$ mm, $\sigma_y = 0.3$ mm

  2808 bunches: asynchronous beam dump: at most 8 bunches can hit the RP. (?)
  Potentially dangerous even for small bunches.
  "Safe beam" (10^{10} p total): OK for RP window.

•Injection (450 GeV):

RP retracted → less risk

another Fluka simulation: 1 full bunch (1.1 x 10^{11} p) → $\Delta T \sim 200^\circ$C OK

"safe beam" (10^{12} p): $\Delta T \sim 2000^\circ$C ???

Problem: ΔT does not scale linearly with the charge (specific heat depends on T).

What is the impact of the bunching scheme ?

(1 big bunch vs. several small ones with distance Δt and same total charge)

Damage Levels: Roman Pot: Silicon Detectors

Thin detectors (300 µm): damage by heat very unlikely.

Displacement damage by non-ionising energy loss:

- independent of HV
- expected hardness at 450 GeV and 7 TeV: $\Phi_{max} \sim 5 \times 10^{14}$ p/cm^2
- Fluence of 1 full bunch (area within 3 σ_{beam}):

worst case scenario: thin beam at $\beta^* = 1540$ m: $\Phi_{1\ bunch} = 6 \times 10^{13}$ p/cm^2

damage limit: $\Phi_{max} / \Phi_{1\ bunch} = 8$ bunches

standard scenario: thick beam at $\beta^* = 0.5$ m: $\Phi_{1\ bunch} = 9 \times 10^{12}$ p/cm^2

damage limit: $\Phi_{max} / \Phi_{1\ bunch} = 58$ bunches

- Fluence of safe beam at injection (10^{12} p total), $\beta^* = 11$ m, E = 450 GeV:

$\Phi_{safe\ beam} \sim 3 \times 10^{13}$ p/cm^2 $< \Phi_{max}$

OK

RP detectors will be retracted with HV off at injection.

Damage Levels: T2 (GEMs)

- No dedicated accident studies available
- Melting: unlikely but not studied
- Ageing: GEMs were tested up to $\Phi = 1.4 \times 10^{13}$ p/cm^2 without performance loss.

Fluence of 1 full bunch at 14 m from IP5:
$\beta^* = 0.5$ m: $\Phi_{1\ \mathrm{bunch}} = 2.4 \times 10^{12}$ p/cm^2 : OK
$\beta^* = 1540$ m: $\Phi_{1\ \mathrm{bunch}} = 1.9 \times 10^{12}$ p/cm^2 : OK

Fluence of safe beam at injection: $\Phi_{\mathrm{safe\ beam}} \sim 10^{13}$ p/cm^2

T2 will be off during injection.

General problem for studies of injection phase: Optics properties for $\beta^* = 11$ m needed.

Damage Levels: T1 (CSCs)

- No dedicated accident studies available
- Melting: unlikely but not studied [main material: 30 mm honeycomb (Nomex)]
- Ageing: tested by CMS for same gas mixture (NIM A515: 226-233, 2003)
  up to 0.4 C/cm or 1.3×10^{12} p/cm^2 without significant performance deterioration.
  ➔ tested fluence is of same order of magnitude as the one of a full bunch.

Problem Diagnostics

- During injection:

all detectors off → diagnostics only from
- BLMs
- BPMs
- radiation monitors fixed in various places on the RP

- During normal running:

- trigger rates from T1, T2, RP (individual detectors and track coincidences)
  details of trigger scheme still in preparation;
  RP trigger rates to be calibrated w.r.t. BLM rates;
- detector currents (read-out frequency still unclear; not on kHz level);
- radiation monitors, BLMs, BPMs.

Protection Strategy

1. Protection of T1, T2
   - Detectors placed inside CMS → hopefully protected by CMS's BCMs at z = 1.9 m, r = 4 cm and z = 14.4 m, r = 5 – 29 cm (near T2);
   to be investigated and to be discussed with CMS

   - HV on → injection inhibit

2. Protection of RP
   - RP has to be out except for "stable beam" or "unstable beam": ensured by interlock system via "user_permit" (first CIBU)

   - HV on → injection inhibit

   - Wish: RP movement controlled by collimator supervisor system (agreement still to be concluded)
   ensures that RP stay always in the shadow of collimators

   - rate too high → retract RP: threshold still undefined;
   beam dump due to high detector rate not foreseen in the beginning.
   Option for beam dump via "user_permit" (second CIBU) reserved for later.

Expected Roman Pot Rates

Estimated signal + background rates → gives an idea about orders of magnitude of possible retraction thresholds

- $\beta^* = 1540$ m, $L = 10^{29}$ cm^{-2} s^{-1}:
  Single plane rate (2 vertical + 1 horizontal – overlap): ~ 100 kHz
- $\beta^* = 90$ m, $L = 10^{30}$ cm^{-2} s^{-1}:
  Single plane rate (2 vertical + 1 horizontal – overlap): ~ 400 kHz
- $\beta^* = 0.5$ m, $L = 10^{33}$ cm^{-2} s^{-1}:
  Single detector rate (1 horizontal): ~ 200 MHz (unusable)
  Local track coincidence rate: ~ 4 MHz

Background estimates difficult → Only experience will teach the real rates.

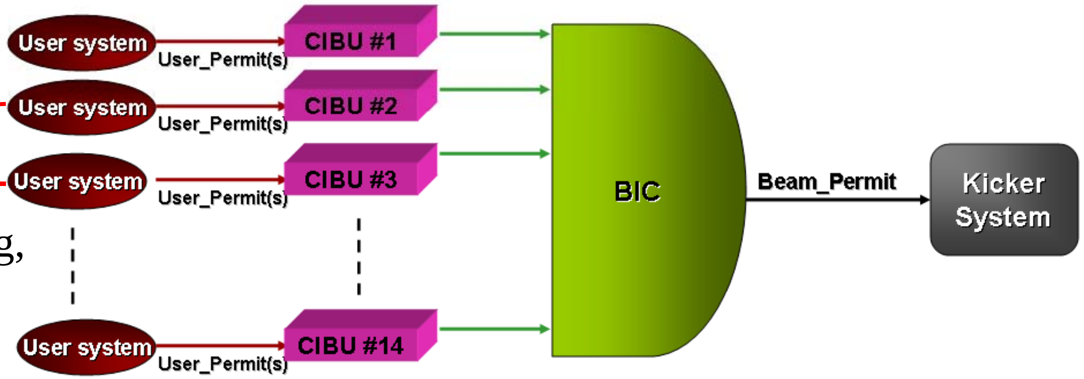
Interlock Actions

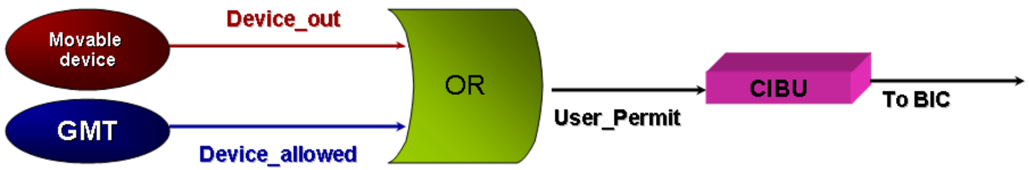
TOTEM has 2 CIBUs:

RP position

Detector information

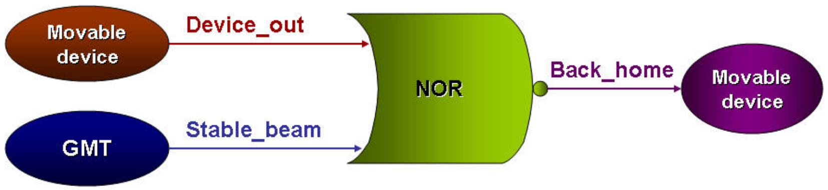
(e.g. rate), unused in the beginning, corresponding "user_permit" kept permanently "high" (UPS)





Device_out = TRUE only if device is in home position
Device_allowed = TRUE only if mode= stable or mode = unstable

Dumps the beam and inhibits injection if RP is IN and the mode forbids it.



Device_out = TRUE only if device is in home position
Stable_beam = TRUE only if mode = stable

Drives the RP out if it is IN and the beam is not stable.

Back_home = TRUE only if device NOT in garage and mode ≠ stable

[graphs © D. Macina]

Software Interlock: Injection Inhibit

Prevent injection when

•RP is IN and existing beam should not be dumped, e.g. during normal running;

•Detector HV is on.

To be implemented as a software interlock.

Total Fluence after 1 fb^{-1}

Charged Hadrons:

- Averaged over horizontal detector: $\langle F \rangle = 0.7 \times 10^{12}\ cm^{-2}$
- Maximum in the diffractive peak (protons with $E \approx 7$ TeV):

averaged over 2 x 2 mm^2 bin: $F_{max,\ 2x2} = 6 \times 10^{13}\ cm^{-2}$
extrapolated to detector edge (10 σ + 0.5 mm = 1.2 mm from beam centre):

$$\mathbf{F_{max} = 3 \times 10^{14}\ cm^{-2}}$$

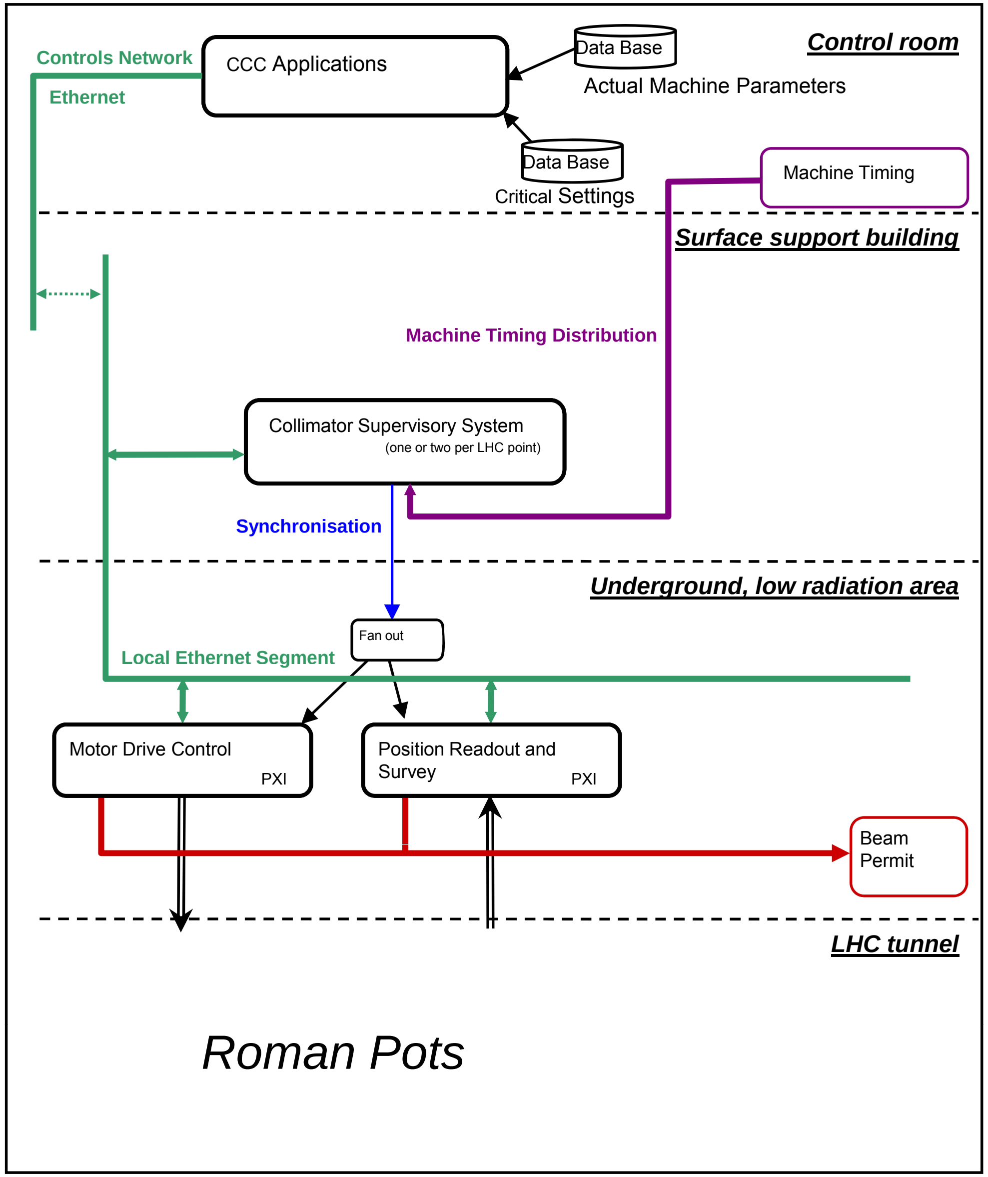
Damage factor of 7 TeV protons is 1/10 of 1 MeV neutrons
→ equivalent 1 MeV neutron fluence: $\mathbf{F_{equ} = 3 \times 10^{13}\ cm^{-2}}$

Detectors can survive $F_{equ,\ det} \sim 1 \times 10^{14}\ cm^{-2}$
corresponding to **3 fb^{-1}**

Neutrons: much lower than charged hadrons:

- Averaged over horizontal detector: $\langle F \rangle = 0.1 \times 10^{12}\ cm^{-2}$
- Maximum (over 4 x 2 mm^2): $F_{max} = 2 \times 10^{12}\ cm^{-2}$

Control of Roman Pots



Michel Jonker, 30.01.2007