Dump protection

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MPS Review 17-June 2010

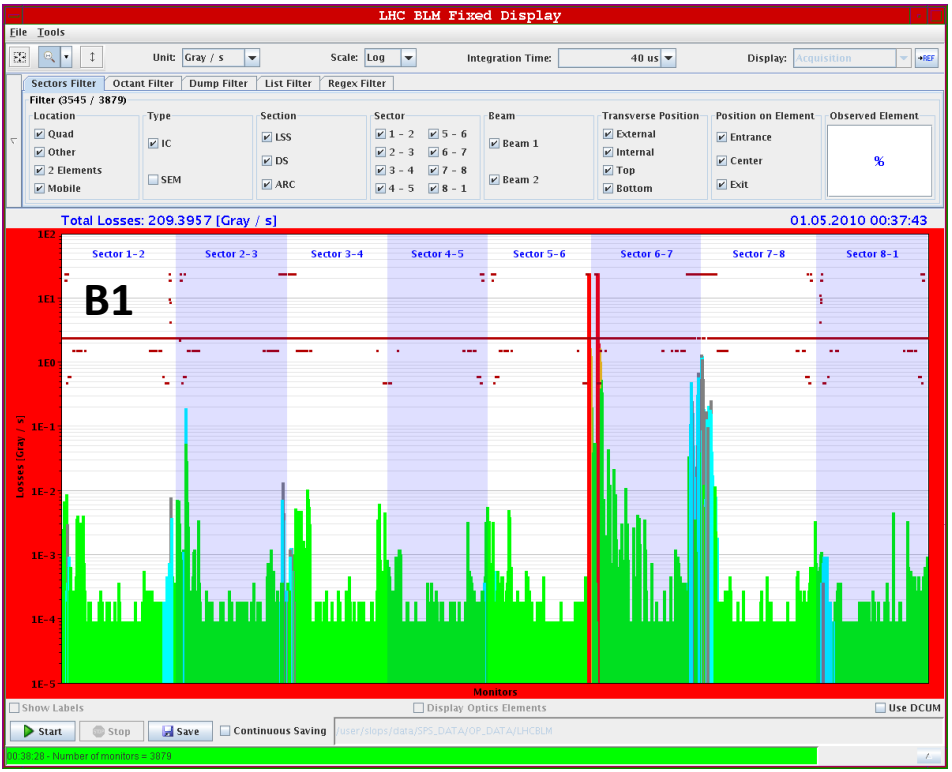
Outline

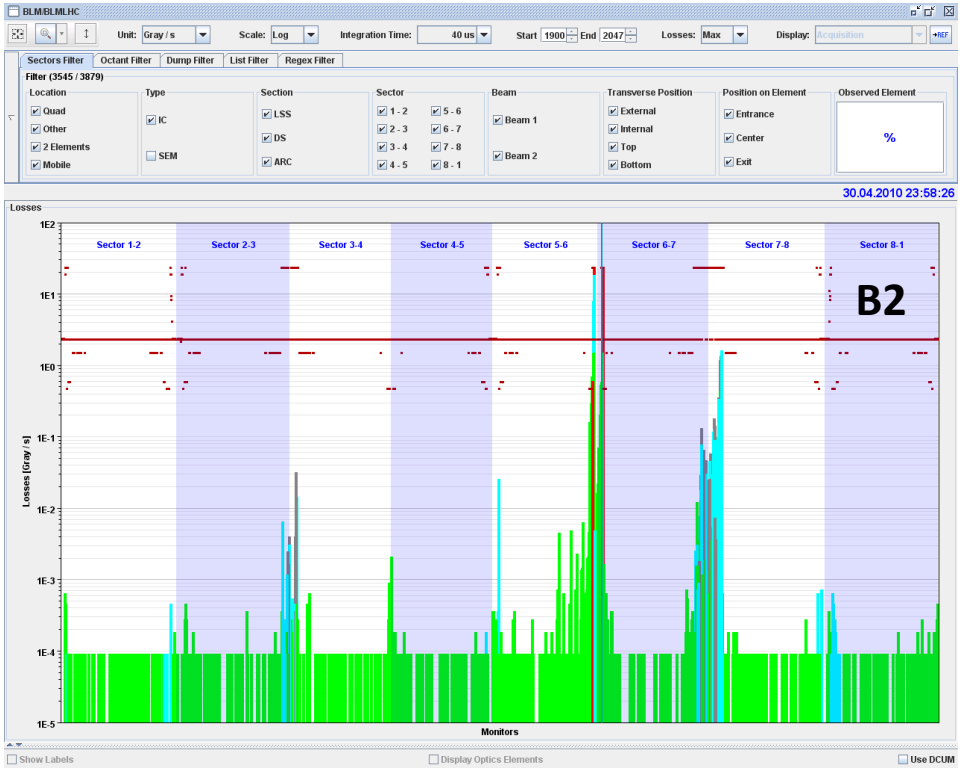
- TCDQ Performance
  - hw/sw issues
  - asynch dumps at 450 GeV and 3.5 TeV
  - orbit tolerance
- TCDQ leakage simulated with SixTrack
- Abort gap cleaning

TCDQ hw/sw issues

- TCDQ movement problems:
  - SW trigger problems, lost communication between FESA and PLC, fixed
  - SW trigger failed in coll application after CPU update at the low level, fixed
  - sequencer task problem, (e.g. sending TCDQ to position where it already is), management of states to be improved, at the next long shutdown (2010/2011) – requires a full recheck of the system after code modification!
  - applying angle settings out of tolerance possible – will be modified in low level SW, the compatibility with mid- and high level SW needs to be reviewed in general
- settings in LSA only low level for the moment (no nsigma deployment)
- TCDQ will be damaged by impact of full intensity 25 ns beam at 7 TeV – rebuild in 2012 shutdown - ongoing

Debunched dumps at 450 GeV, 1e11





→ Losses as expected

→ a small spike on the TCLIB R2 (inj.prot. in for this test to see the losses on these objects)

→ big saturation of BLMs in P6

→ Losses in P6, P7, P3 and very small amount (3e-6 Gy) on TCTH.4R5

→ no beam seen by B2 abort gap monitor

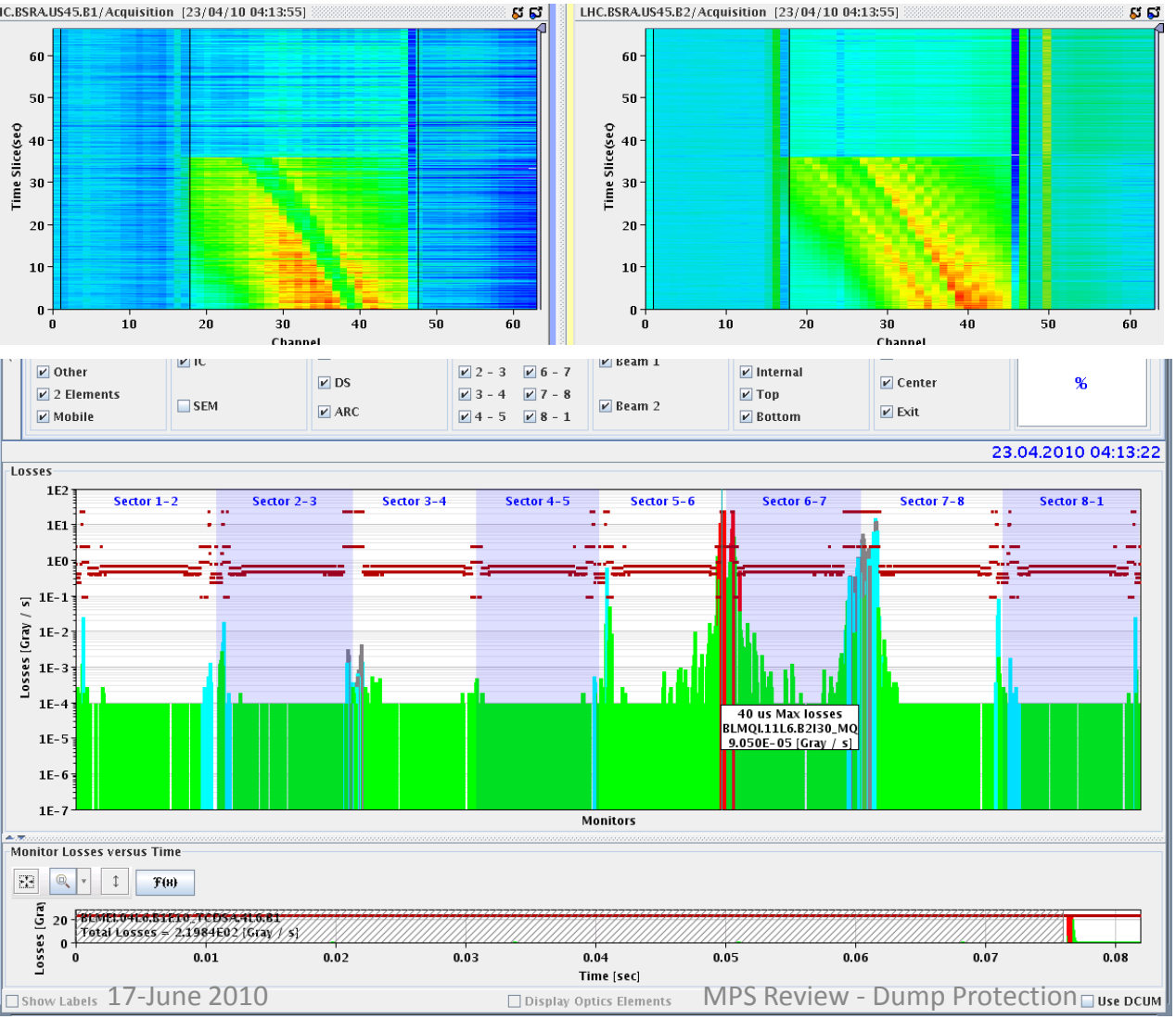
Asynch Dump at 450 GeV, 1e11 looks OK

Debunched dumps at 3.5 TeV

- 4 separate tests made to date
  - 1x 3.5 TeV unsqueezed
  - 2x 3.5 TeV squeezed, low intensity, centered
  - 1x 3.5 TeV squeezed, higher intensity, offset

- Assumptions
  - 36/120 of abort gap population impacts TCDQ
  - Uniform abort gap population (pending deeper analysis!)
  - 1e12 p+/Gy response for BLMs at TCTs and, TCSG, TCDS
  - Measured response at TCDQ: 1 – 5 e11 p+/Gy

Debunched dumps at 3.5 TeV squeezed, 1σ offset



- 1.6e10 in 2b in B1, 1.7e10 in 2b in B2,
- 90 s debunching, 1 σ offset
- Measured ~4e9 in abort gap at moment of dump

IR6 saturated
IR7 15Gy/s
TCTH.4R5.B2 0.6 Gy/s, 2e7 p+

Leakage from TCDQ ~2e-2 from BLMs (but saturated). Using abort gap population gives ~2e-3

Some other considerations

- Other observations
  - About 4-6e7 p+/m – 'limit' for abort gap at 7 TeV defined as 1e6 p+/m, for Q4 quench
  - No quench of Q4 (factor 10 above BLM threshold)
  - Structure on BSRA signal – what is this??
  - Analysis of various unsaturated BLM data and comparing signals gives estimates of between 0.03% and 0.3% leakage to P5.TCT – comparable to the other estimates
  - Cross-calibration of losses "v.difficult" because of BLM saturation at 40 us – should be better now with filters, to be tested
  - p+ on TCT calculated from assumed 1e12 p+/Gy scaling – to measure!
  - Main contribution to leakage probably from only a few σ impact parameter on TCDQ system – confirmed by simulations - increases leakage figure!
  - Abort gap population and distribution known more accurately when BSRA not saturated
- Actions, analysis ongoing to improve some of these unknowns – needs supporting measurements

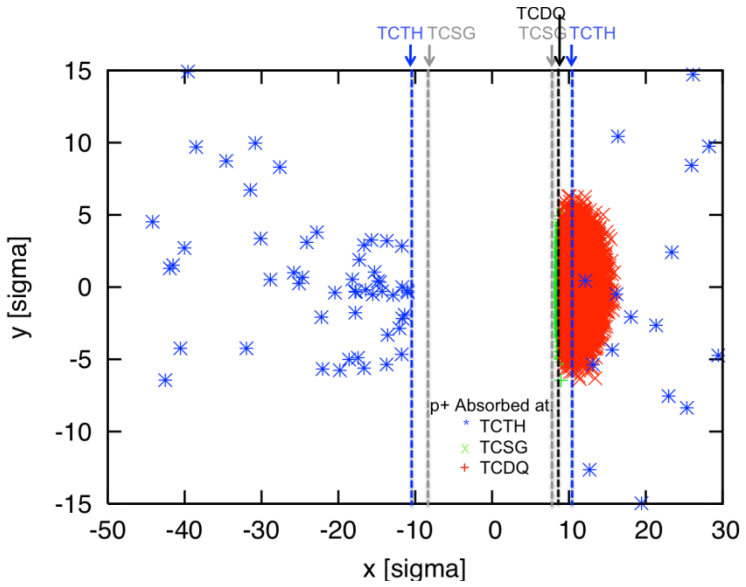
Orbit tolerance at TCDQ

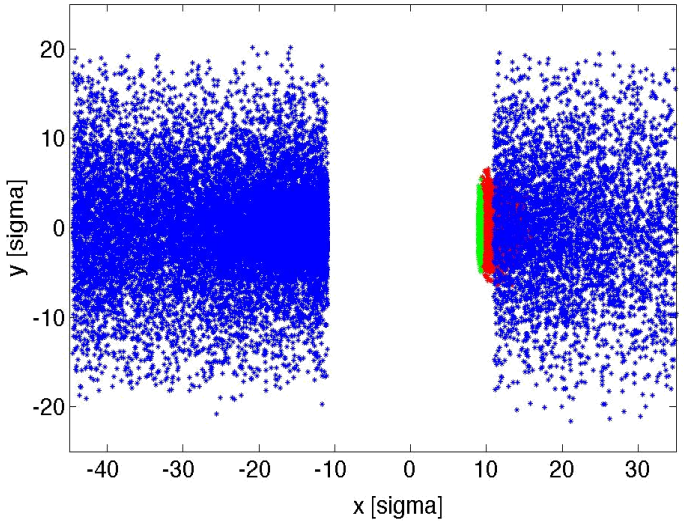
Retraction of TCT wrt TCDQ:

Contribution	[σ]
orbit measurement error at TCDQ	0.7
orbit change at TCDQ (SIS interlocked)	2.5-3.0
TCDQ setting up error	1.0
dynamic beta beat	0.5
TCT setting up error	0.5
total	**5.2 - 5.7**

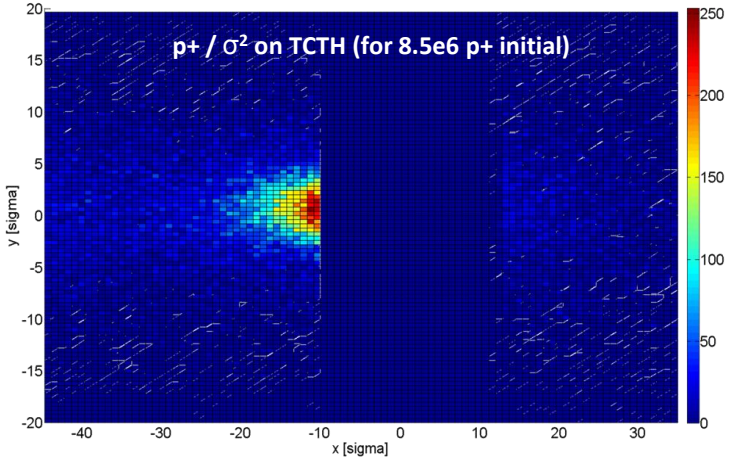
Agreement to 5σ retraction TCT-TCDQ

Leakage from dump protection – SixTrack simulations





- All losses come from p+ scattered through TCSG which fills acceptance with scattered primaries
- Total p+ on TCTH is 0.3% of single bunch (8% impacting TCSG in this simulation) or 3.4×10^8 p+
- Peak p+ density is about 0.016% of single bunch (equivalent to 2.5×10^6 p+ with nominal e_{xy})
- Consistent with expectations - full bunch on TCSG would be attenuated by $\times10$, and have $\times180$ emittance increase



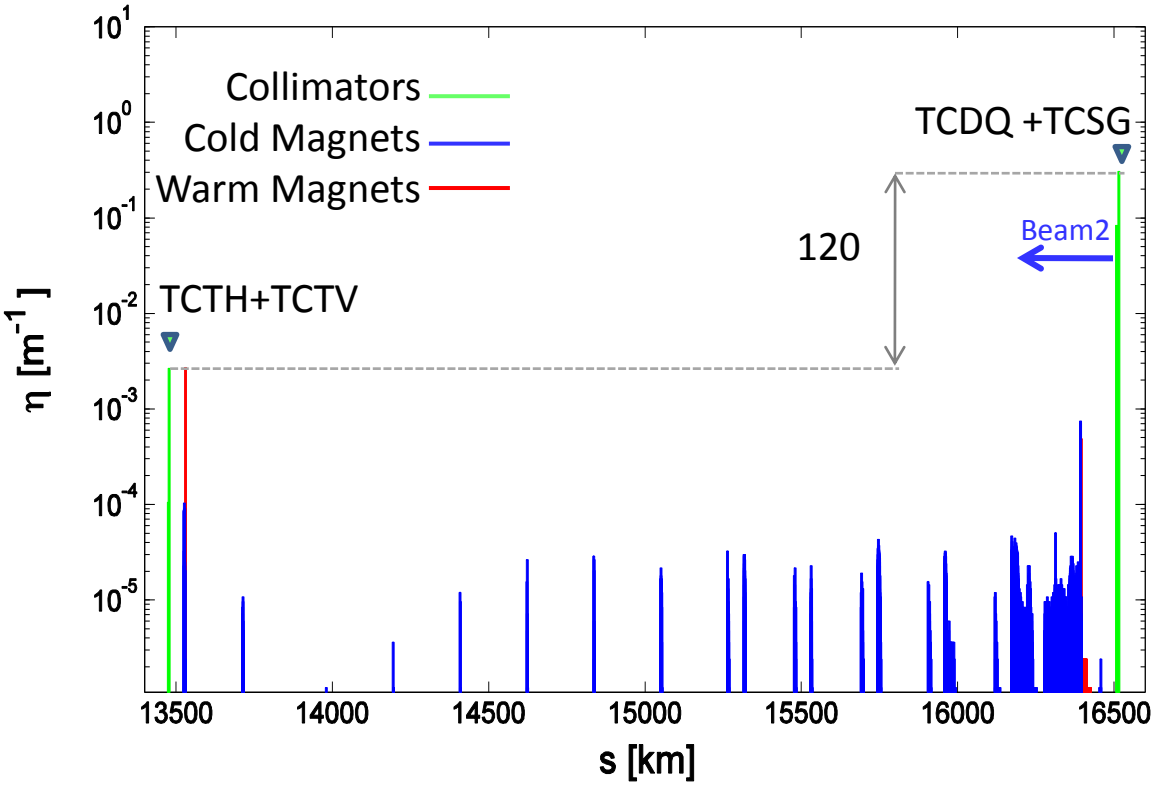
Loss Map for Beam 2, 3.5 TeV, 2m β* in IP5

From SixTrack simulations:

Local cleaning inefficiency:

$$\eta = \frac{\#\ \text{particles lost in } \Delta s}{\Delta s \times \text{Tot}_{abs}}$$

Δs = 10 cm @ magnets
Δs = 1 m @ collimators (jaw length)
Tot_{abs} = 8'463'489



1 bunch case

Collimator	N [p+]	% Tot_{abs}
TCDQ	7'639'643	90
TCSG	697'298	8
TCTH	22'186	0.3
TCTV	875	0.01

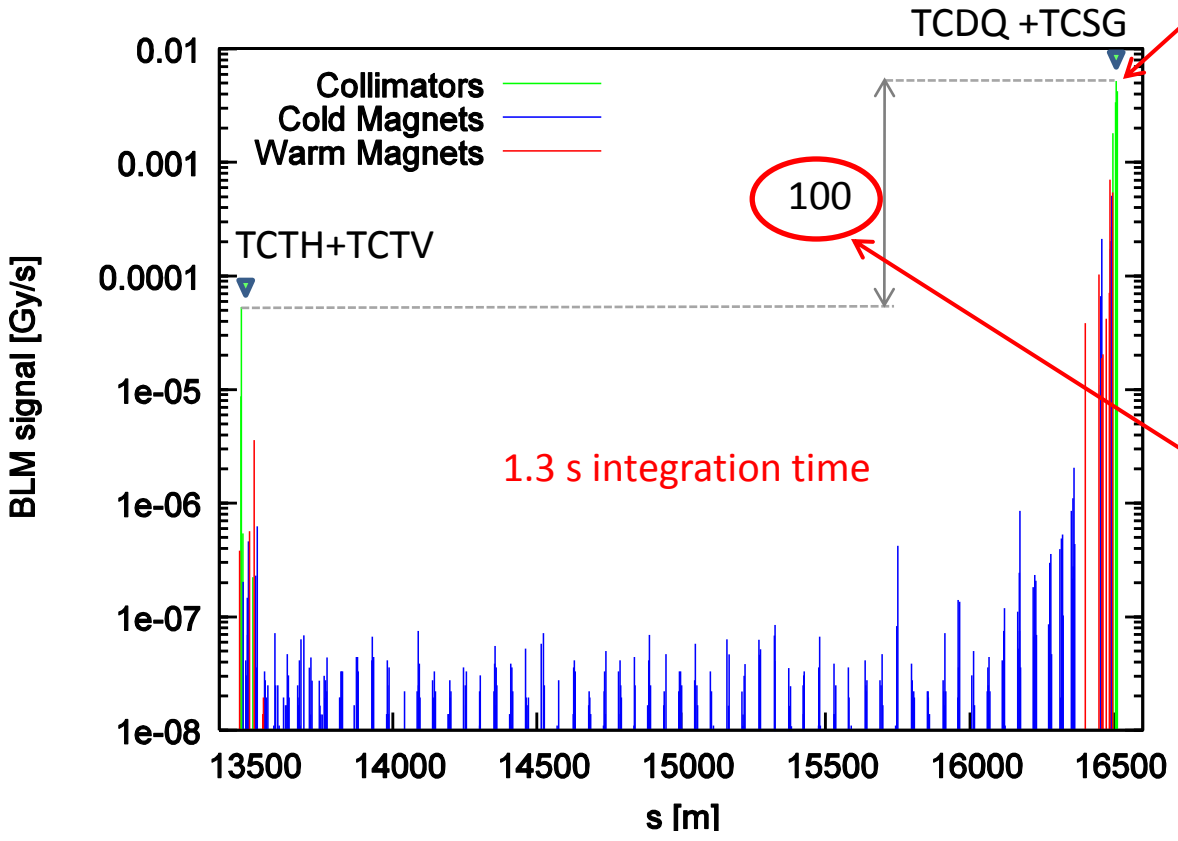
Statistical error = 1/√N ➔ max = 0.03

Nominal bunch (1.1E11 p+):
3.3E8 p+ on TCT

Only primary protons losses.

Loss Map for Beam 2, 3.5 TeV, 2m β* in IP5

From Measurements during asynchronous beam dump (23/04/2010):



BLM at TCDQ and TCSG saturated for 40 μs and 80 μs integration time!

At least a factor of 100 between losses in point 6 and TCT in point 5.

1) It seems to be consistent with simulations (not worse).
2) Filters added at BLM in point 6 ➔ repeat measure.

Showers included

Loss Map for Beam 2, 3.5 TeV, 2m β* in IP5

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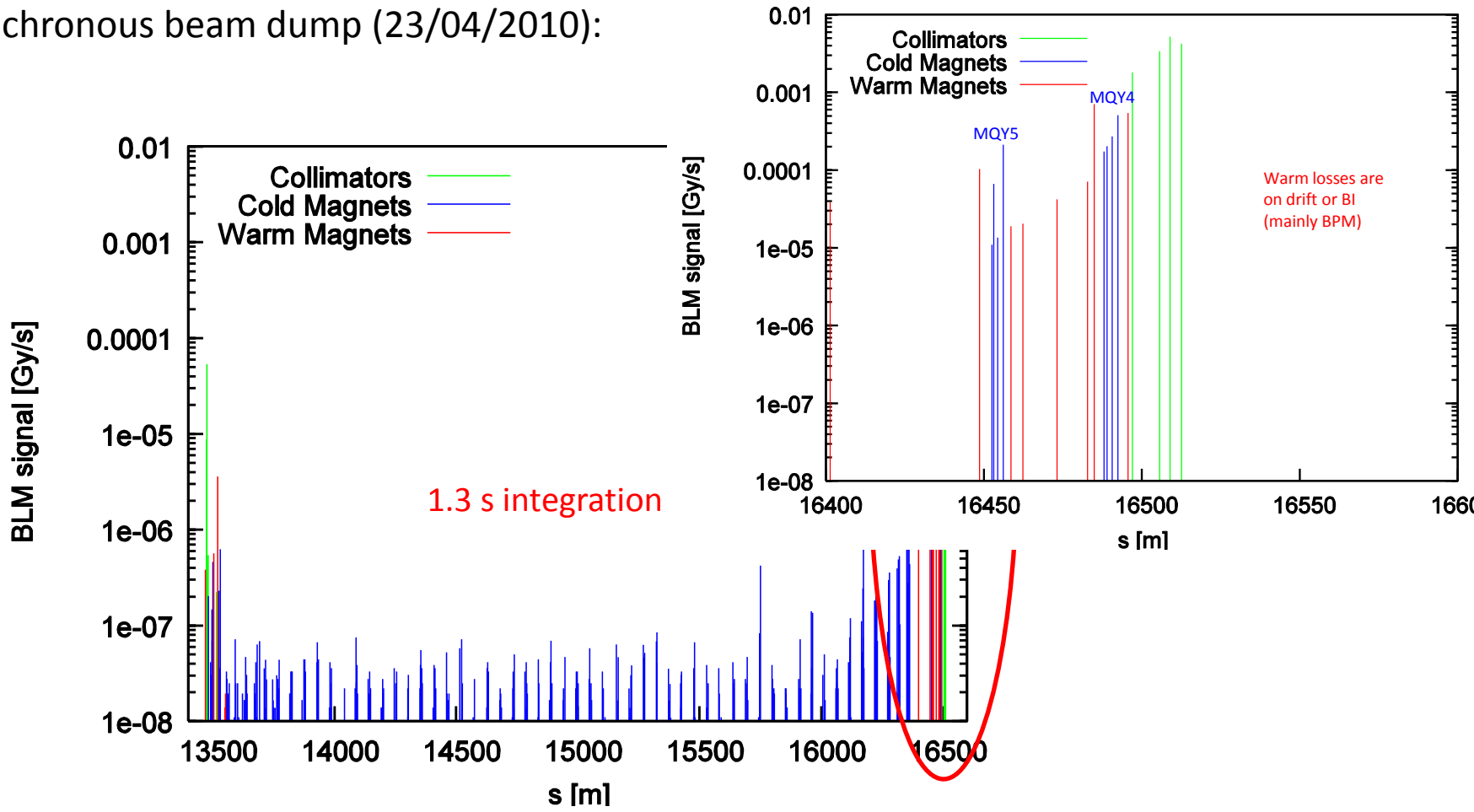

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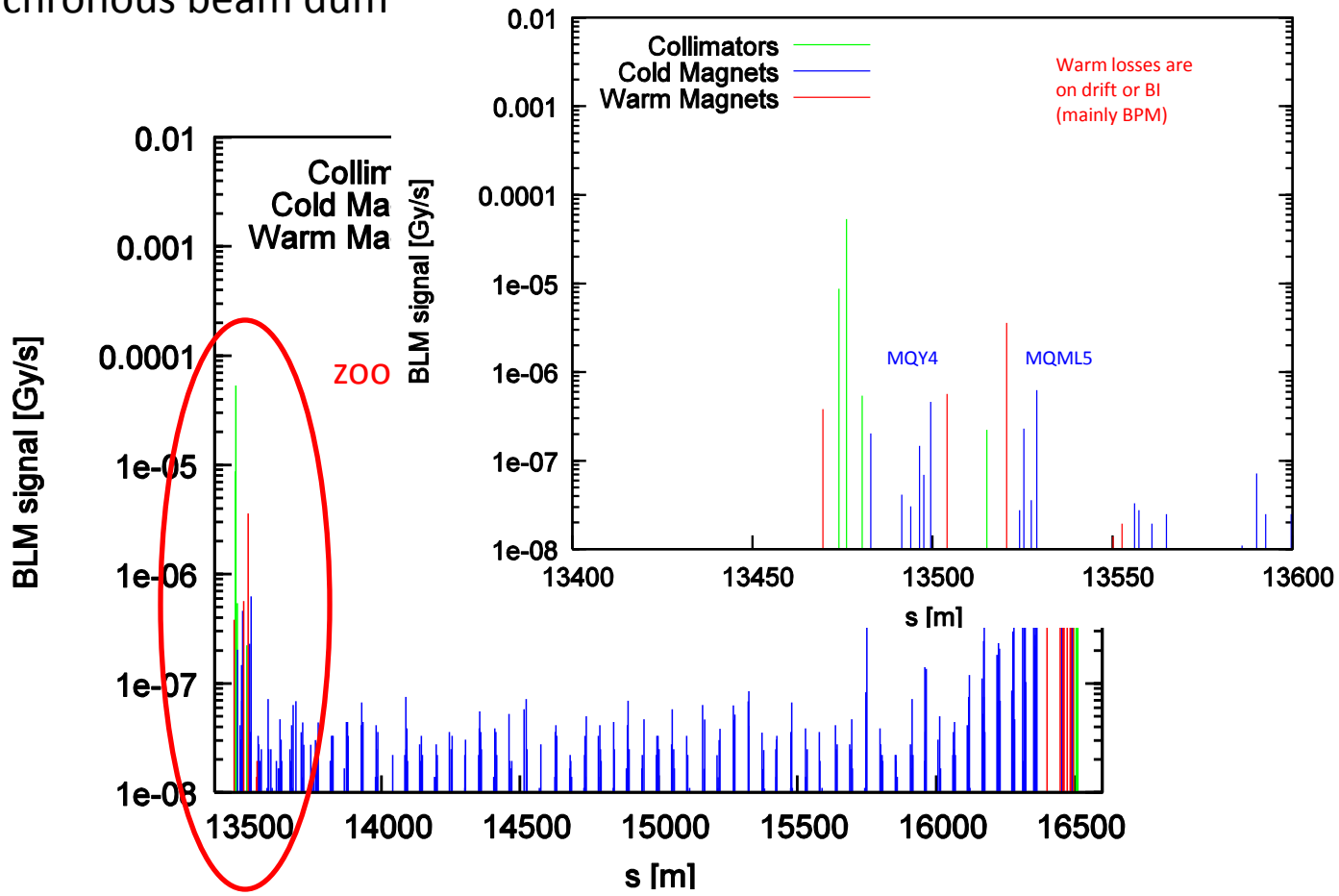


Showers included

Outcome of simulations

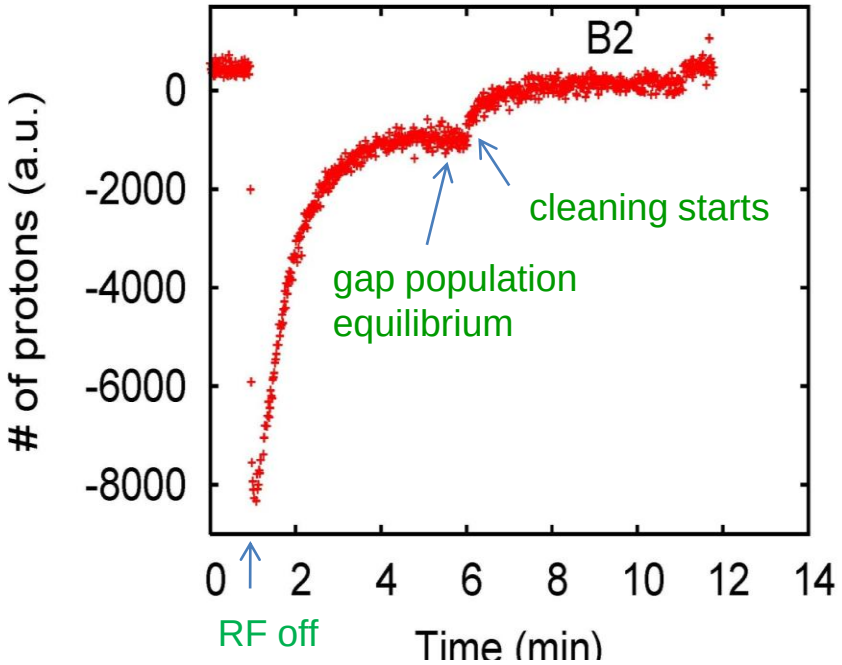
- Asynchronous beam dump simulations for a single bunch (worst case) at 3.5 TeV (2m β* in point 5) have been performed with SixTrack for beam 2.
- Simulations show that losses at the TCT come from particles scattered at the TCSG, no losses of primary protons are observed
- Simulations allow to visualize the distribution of particles absorbed at the TCT: peak density equivalent of 0.016% of full bunch with nominal emittance
- An asynchronous beam dump test has been performed for the same case (3.5 TeV, 2m β* in point 5) and losses (from PM) have been analyzed.
- BLM at the collimators in point 6 saturated (40-80 μs):
  - Difficult to quantify the ratio between losses in point 6 and point 5 (at the TCT)
  - Data at 1.3s show that measurements are consistent (not worse) than simulations
  - Filters applied at the TCDQ → new measurements needed for benchmarking

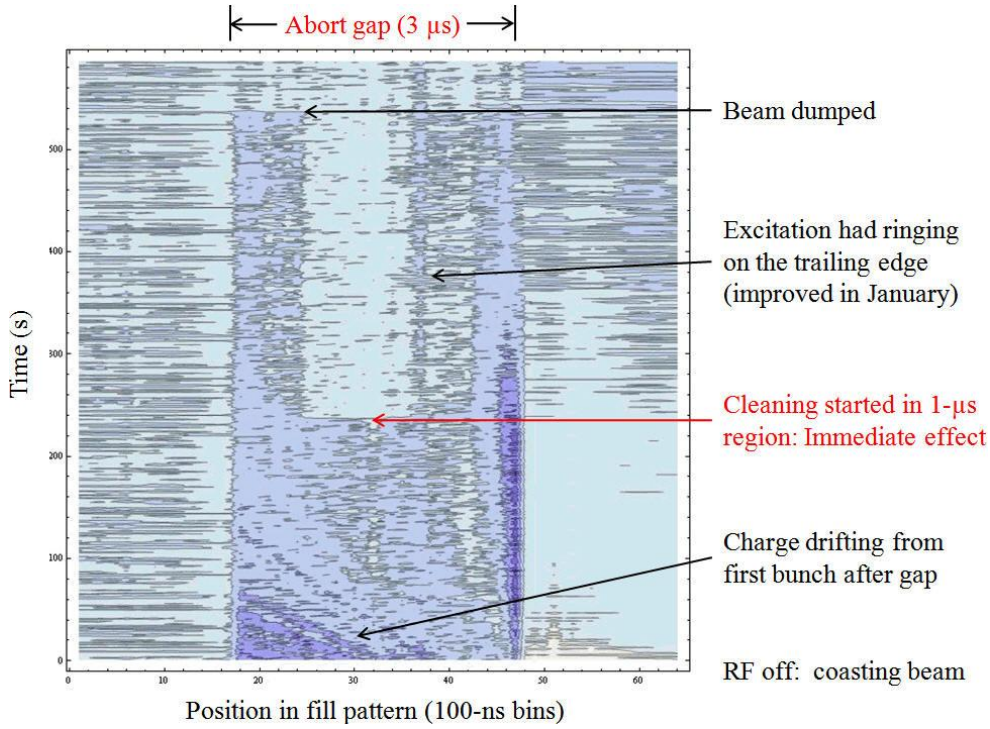
AGC: Results from cleaning test

(E. Gianfelice-Wendt, W. Höfle, T. Lefevre, ...)

Cleaning test of a costing beam done, on 16-17 Dec.'09

- 4 bunches of 2.5e10 protons
- RF switched off
- After 5 minutes, started cleaning using swept frequency around Q_v





Summary – TCDQ Performance

- Estimated 1e-4 leakage from TCDQ system unsqueezed, and around 2-4e-3 leakage squeezed.
  - Based on this, full sweep can let maybe 0.1 bunches through to TCT. However, almost certainly seeing scattering from TCSG/TCDQ and not 'primary' p+ (yet)

- Cannot yet conclude on effect of 1 s offset – not hugely different from beam centered

- Analysis to refine with abort gap population data

- BLM saturation in P6 - filters are installed

- Response measured for TCDQ – to be done for TCT and TCSG6

Summary – SixTrack Simulations

- Asynchronous beam dump simulated with SixTrack for a single bunch at 3.5 TeV
- Losses at the TCT come only from scattered particles at the TCSG - no losses of primary protons
- Peak density equivalent of 0.016% of full bunch with nominal emittance
- Simulations compared to measurement:
  - Data at 1.3s show that measurements are consistent (not worse) than simulations
  - Filters applied at the TCDQ BLMs → new measurements needed for benchmarking

Summary – Abort Gap Cleaning

- First AGC tests in Dec 09 with encouraging results
- In the 2009-2010 LHC shutdown, modifications on the damper system to improve the shape of the pulse
- Calibration of damper kicks to compare simulations with measurements
- The effect of all modifications has still to be demonstrated with beam
- NOT ready to include the abort gap population info to SIS
  - Abort gap monitoring almost operational
  - Need to define interlock level for abort gap population

What is still to do for high bunch intensity stable beams?

- LBDS MPS checks:
  - Beam excursion interlock window
  - TCSG/TCDQ settings cross-check with TCP scan
  - Normal dumps from extreme orbit positions
  - Checks of asynch dumps at 450 GeV with high bunch intensity, from extreme orbit positions
  - Dumps with maximum energy offset AND maximum orbit excursion (H plane only)
  - Verification of abort gap keeper settings and protection (only after all fine synch adjustments)

- Dump protection validation at 3.5 TeV and 3.5 m β^*
  - TCDQ hierarchy checks and settings checks
  - TCSG/TCDQ settings cross-check with TCP sigma scan (2 h)
  - Asynchronous dump tests with beam on- and off-axis (3 ramps)

- Abort gap cleaning tests – tbc when needed