Overview of LHC Beam Loss Measurements

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- BLMs for Collimation
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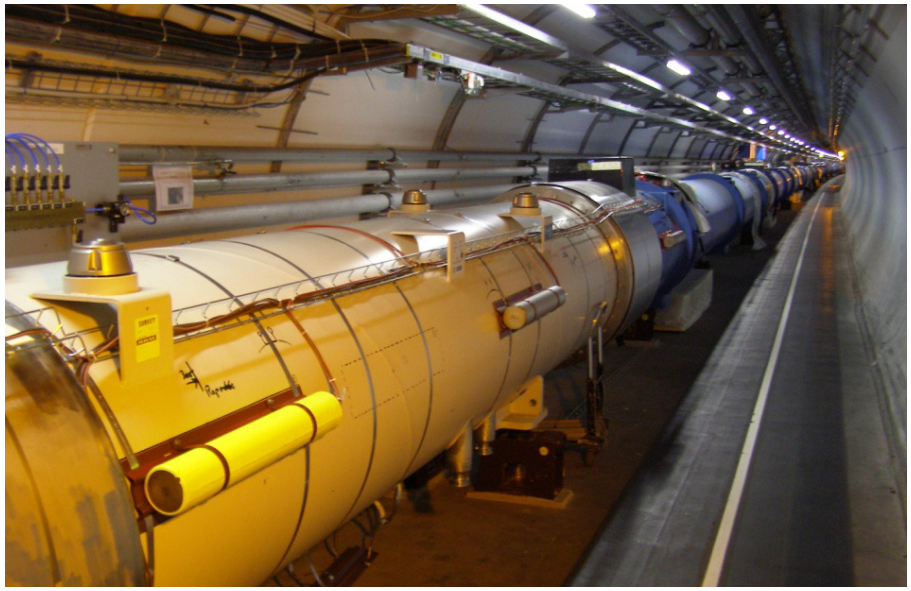
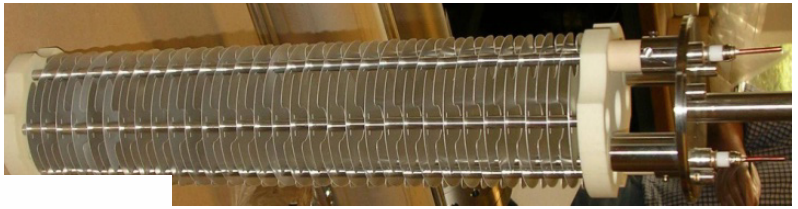
  - Tertiary collimator losses and LHC Luminosity

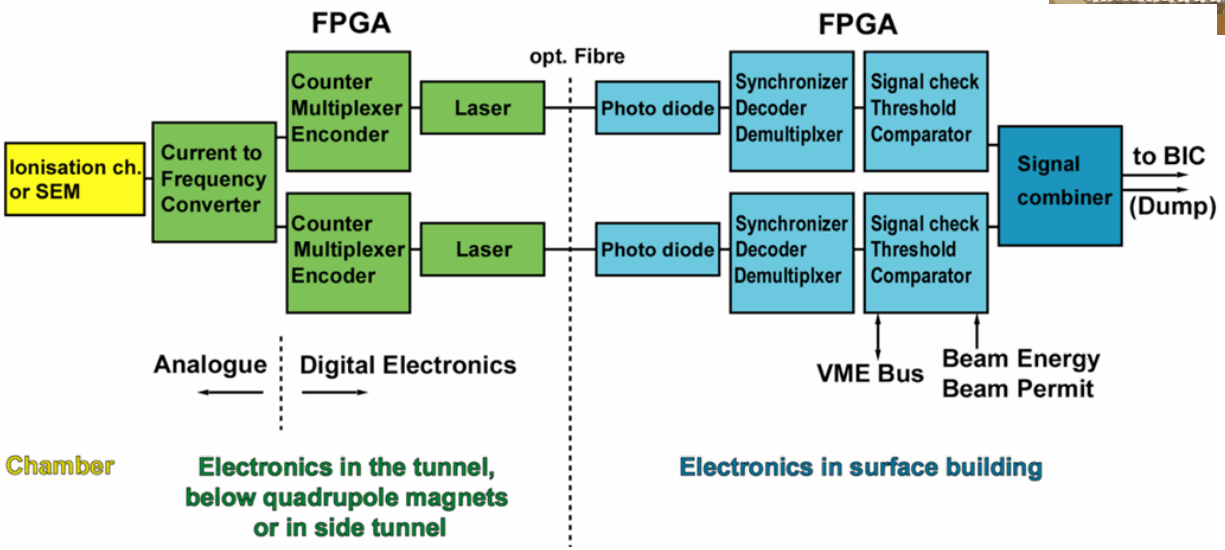
Introduction to the BLM System

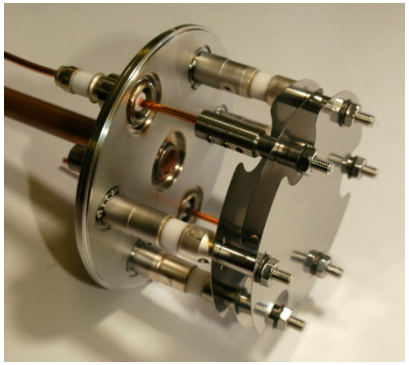
Beam Loss Measurement System Layout



- **Main purpose: prevent damage and quench**
- 3600 Ionization chambers (**IC**) **interlock** (97%) and observation
- 300 Secondary emission monitors (**SEM**) for observation







Integration Times and Beam Abort Thresholds

- 12 integration intervals: 40μs (≈1/2 turn) to 84s (32 energy levels)
- **Each monitor** (connected to interlock system BIS) aborts beam if
  - One of 12 integration intervals over threshold
  - Internal test failed

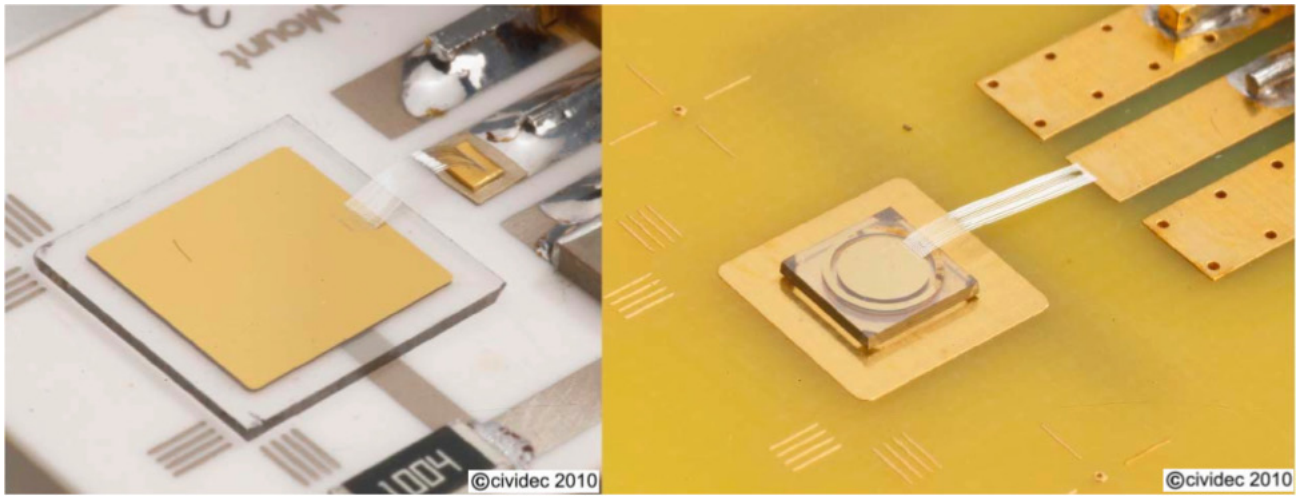
Stored Energy	
Beam 7 TeV	2 x 362 MJ
2011 Beam 3.5 TeV	up to 2 x 100 MJ
Magnets 7 TeV	10 GJ

Quench and Damage at 7 TeV	
Quench level	≈ 1mJ/cm^3
Damage level	≈ 1 J/cm^3

4 Diamond BLMs for High Time Resolution

ATS/Note/2011/048 (TECH), B. Dehning et al.

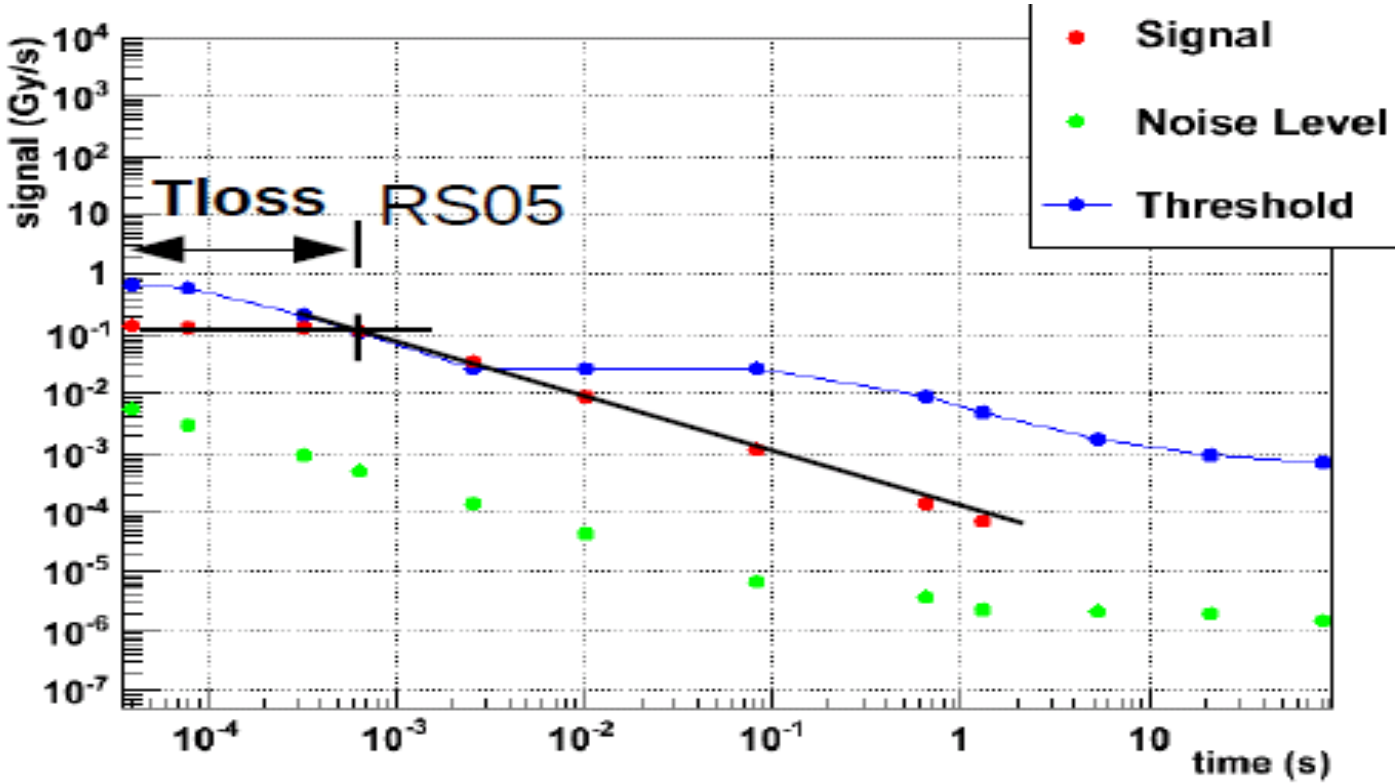
- Chemical Vapour Deposition (CVD) diamond for observation
- Betatron collimators (one per beam)
  - All sizable local losses also seen at collimators
- Injection regions (one per beam)



BLM Published Data – Logging Data

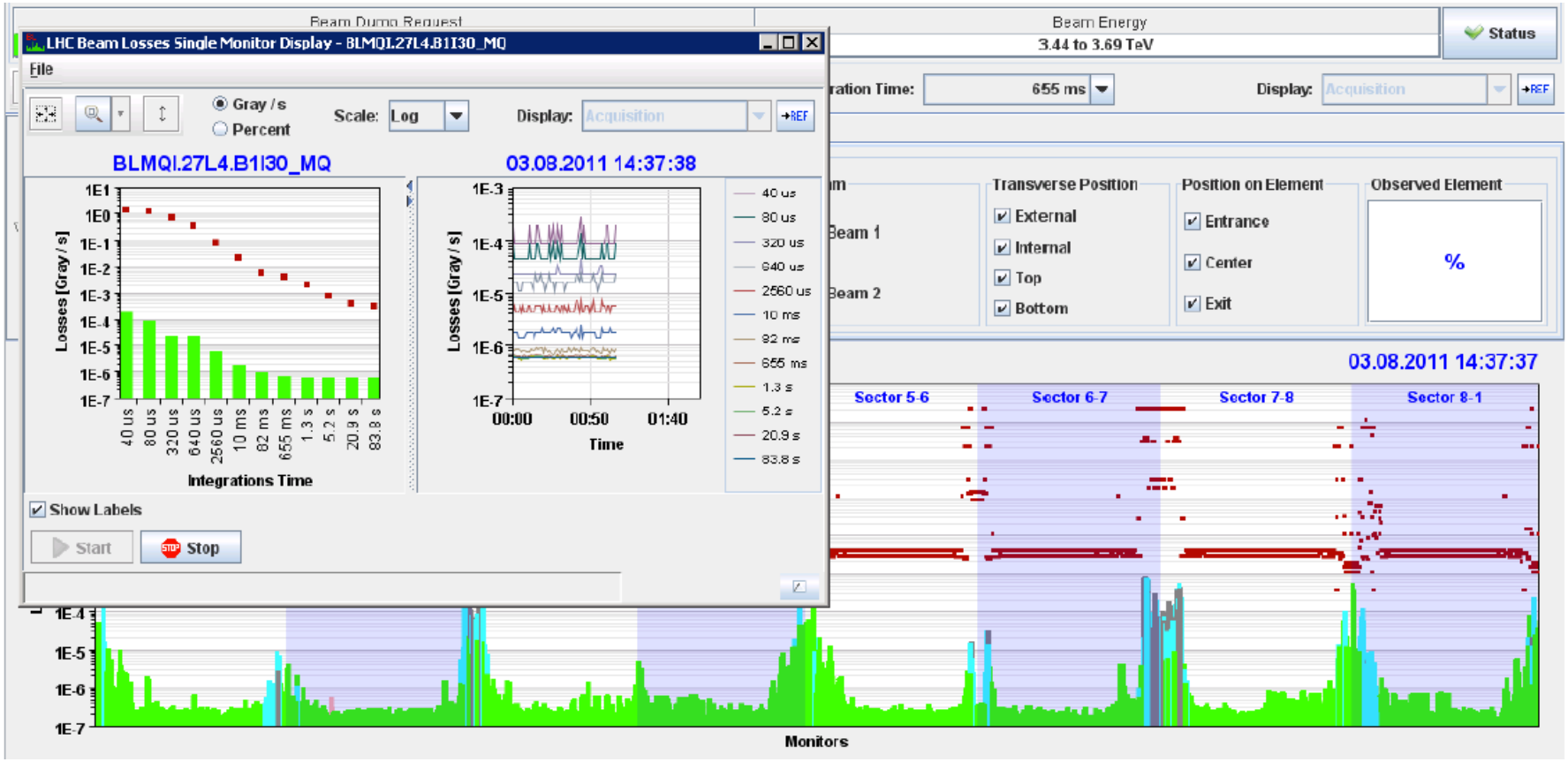
- Extensively used for operation verification and machine tuning
- Logging once per second (all 12 integration intervals)
  - Integration times < 1s: maximum during the last second is published

    → short losses are recorded and loss duration can be reconstructed (≈20% accuracy for UFOs)



BLM Published Data – Logging Data

- Logging Data also used for Online Display



BLM Published Data – Event triggered Data Buffers

- Event triggered BLM Data (40µs, 80µs or 2.6ms):

BLM Buffer (IC & SEM)		Integration Time	Buffer Length
Post Mortem		40µs	80ms online 1.72s offline
Collimation Buffer		2.6ms	80ms
Extraction Validation Buffer		40µs	80ms
Capture Data (2 modes)	Injection Quality Check (IQC) – 8 crates only	40µs	20ms
	Study (event triggered: for example UFO study)	80µs	Dynamical, currently up to 350ms

- CVD Diamond high resolution loss data (2ns):

Event triggered	Sampling Rate	Integration Time	Buffer Length
Post Mortem	0.2 ns	≈ 2ns	1ms

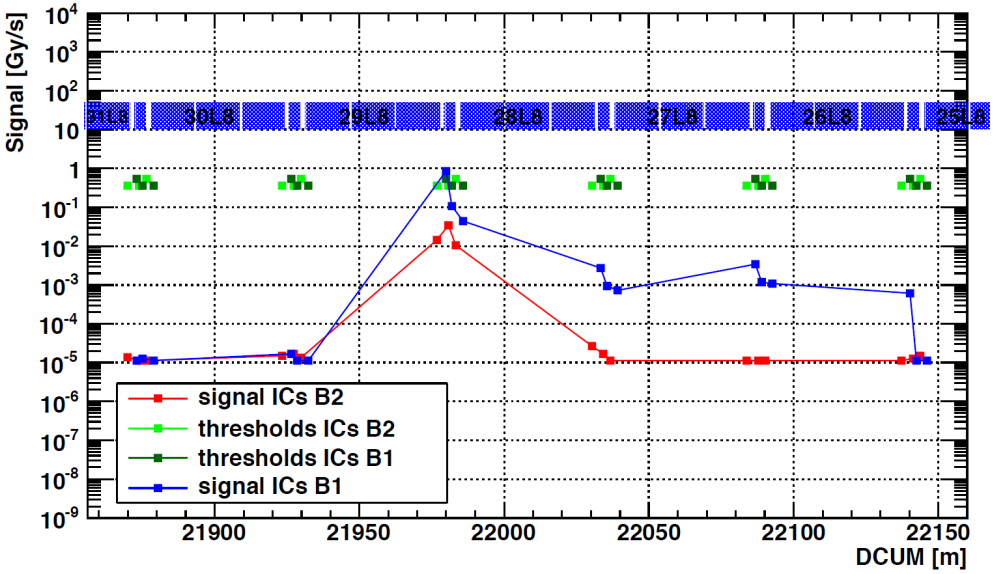
Fast (ms-time-scale) Losses
UFO: Unidentified Falling Object

- MOPS017 *Simulation Studies of Macro-particles Falling into the LHC Proton Beam*, N. Fuster Martinez et al.
- TUPC136 *Analysis of Fast Losses in the LHC with the BLM System*, E. Nebot et al.
- TUPC137 *UFOs in the LHC*, T. Baer et al.

Beam Aborts due to UFOs

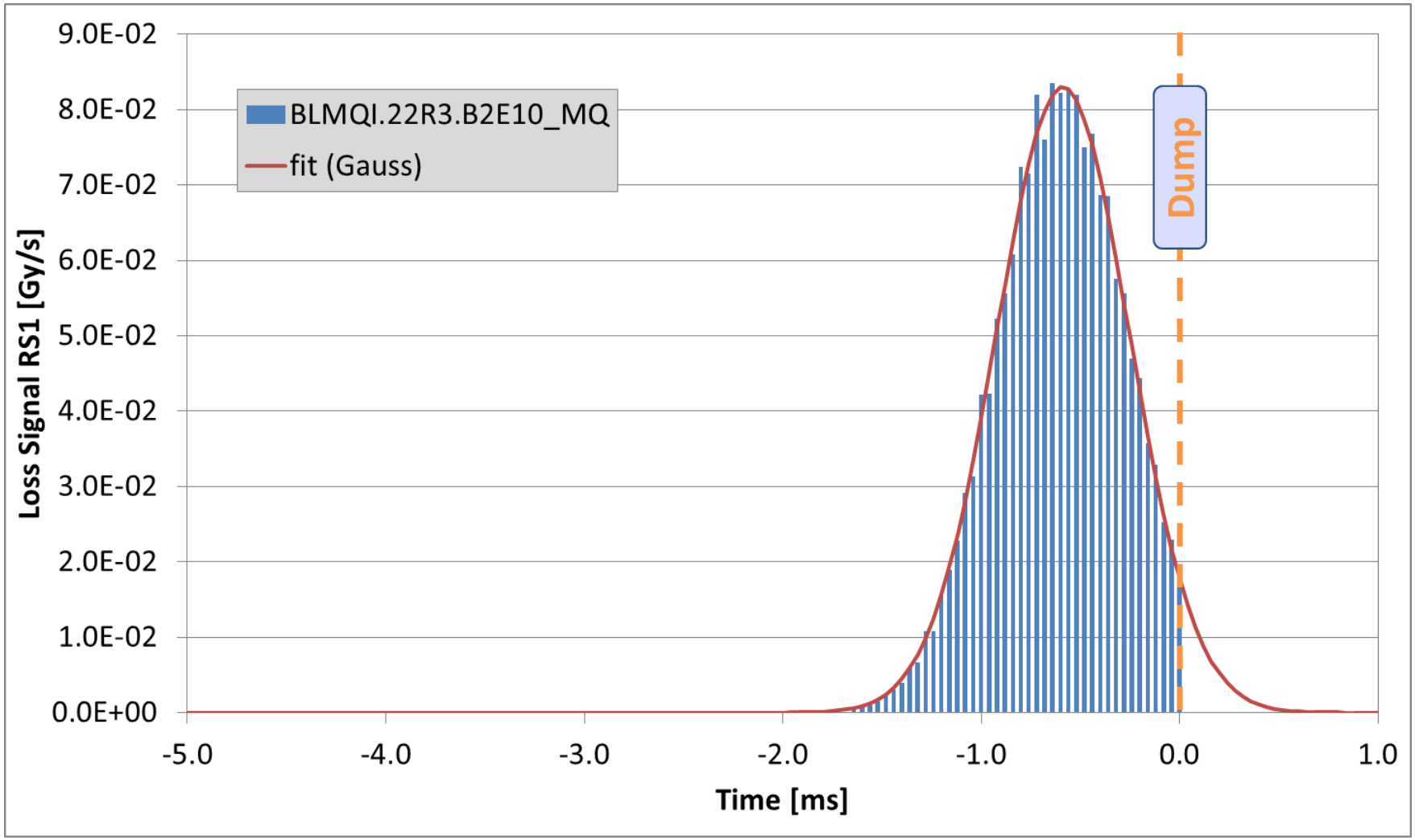
- Fast and localized losses all around the ring believed to be caused by macro particles interacting with the beam
- Stepwise increase of BLM thresholds at the end of 2010 run
- New BLM thresholds on cold magnets for 2011 start-up
- Always detected by > 6 local monitors and at all aperture limits (collimators)
- most UFOs far from dump threshold

UFO Beam Aborts	35
of which:	
2010	17
2011	18
Around injection kickers (MKI)	13
Experiments	6
At 450 GeV	1

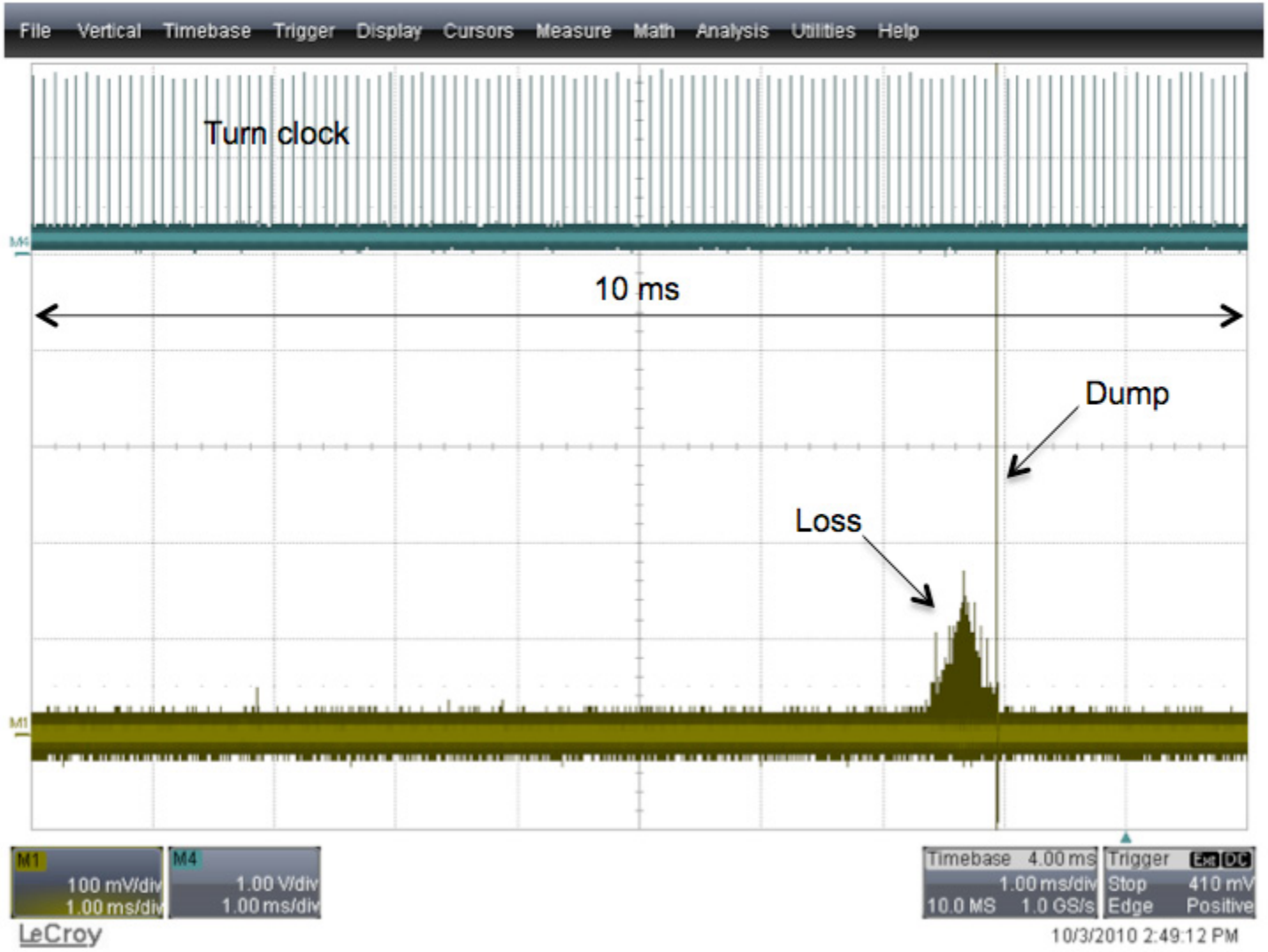


Gaussian Fit to UFO Time Distribution

TUPC137, T. Baer

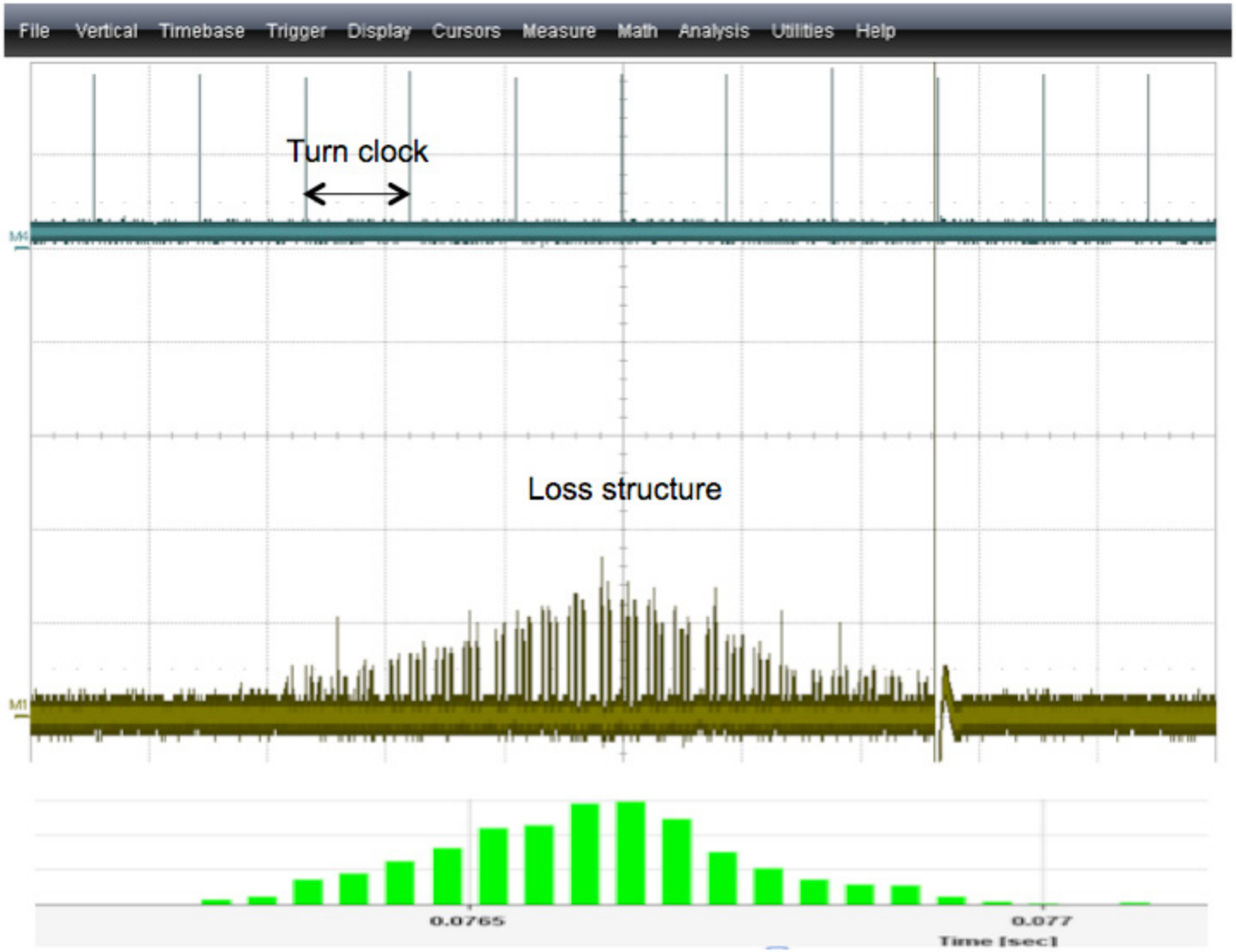


Diamond BLM Signals



3/10/2010 12h48, 152 bunches, 150ns bunch spacing

Diamond BLM Signals



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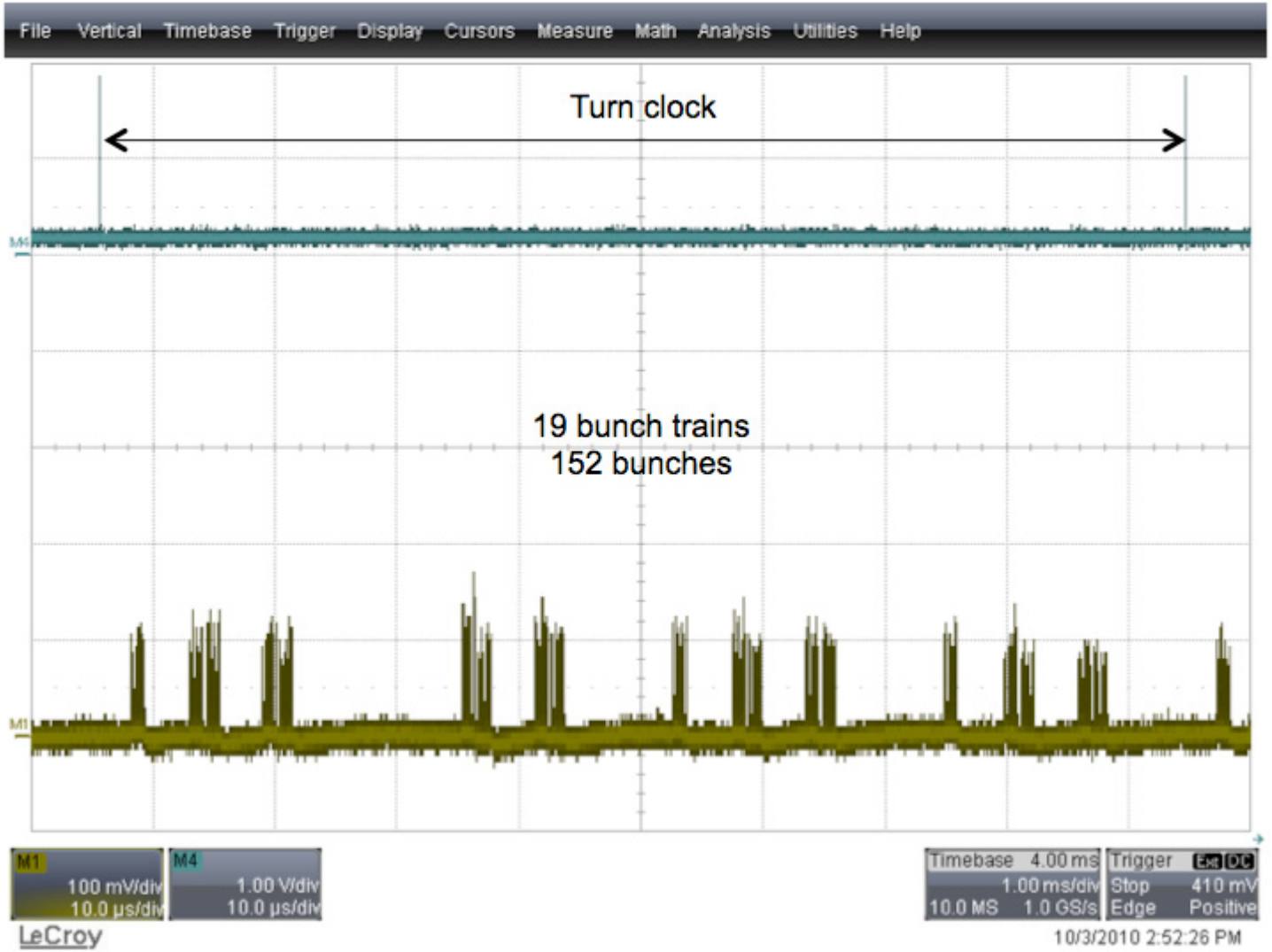

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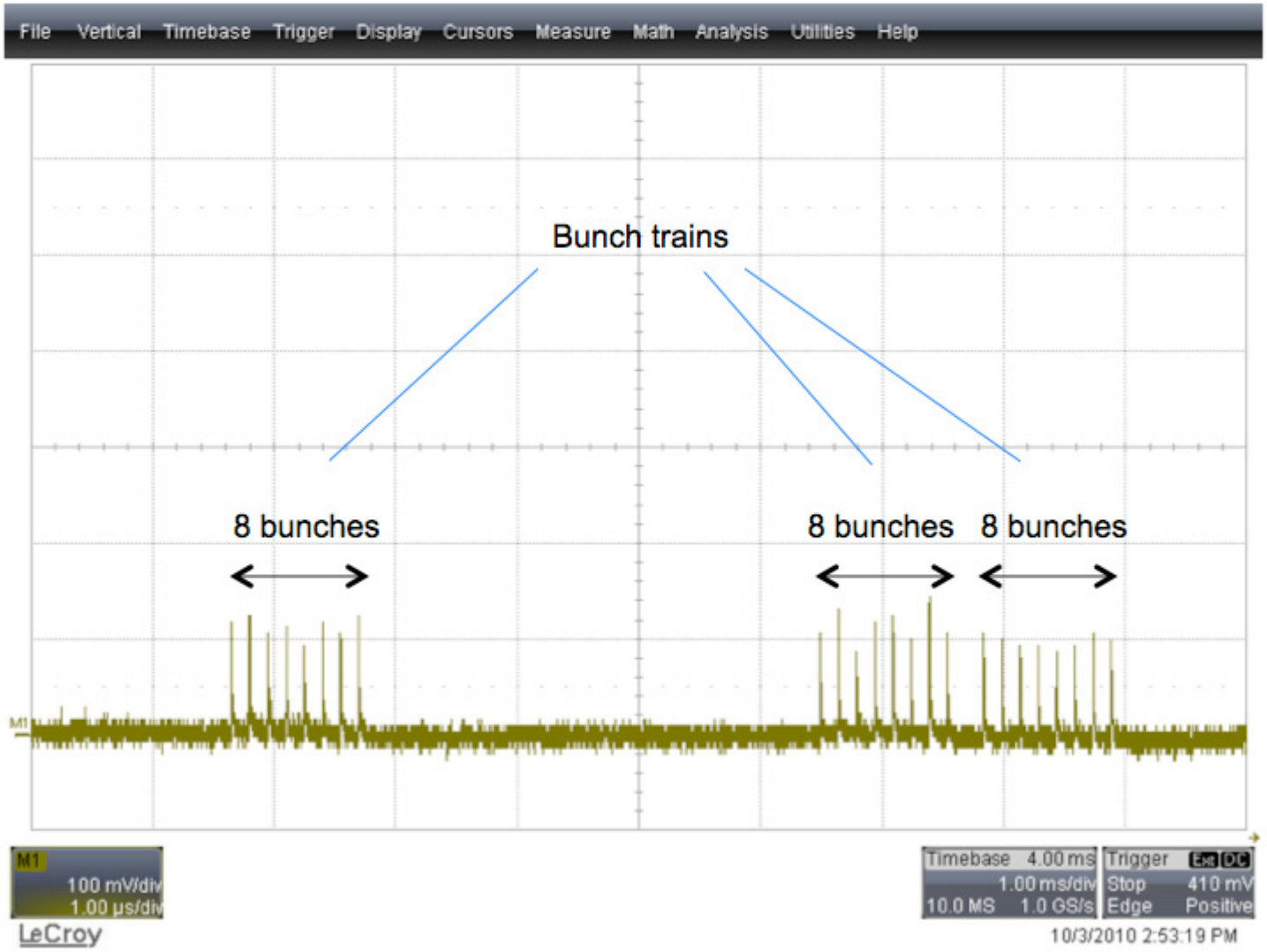

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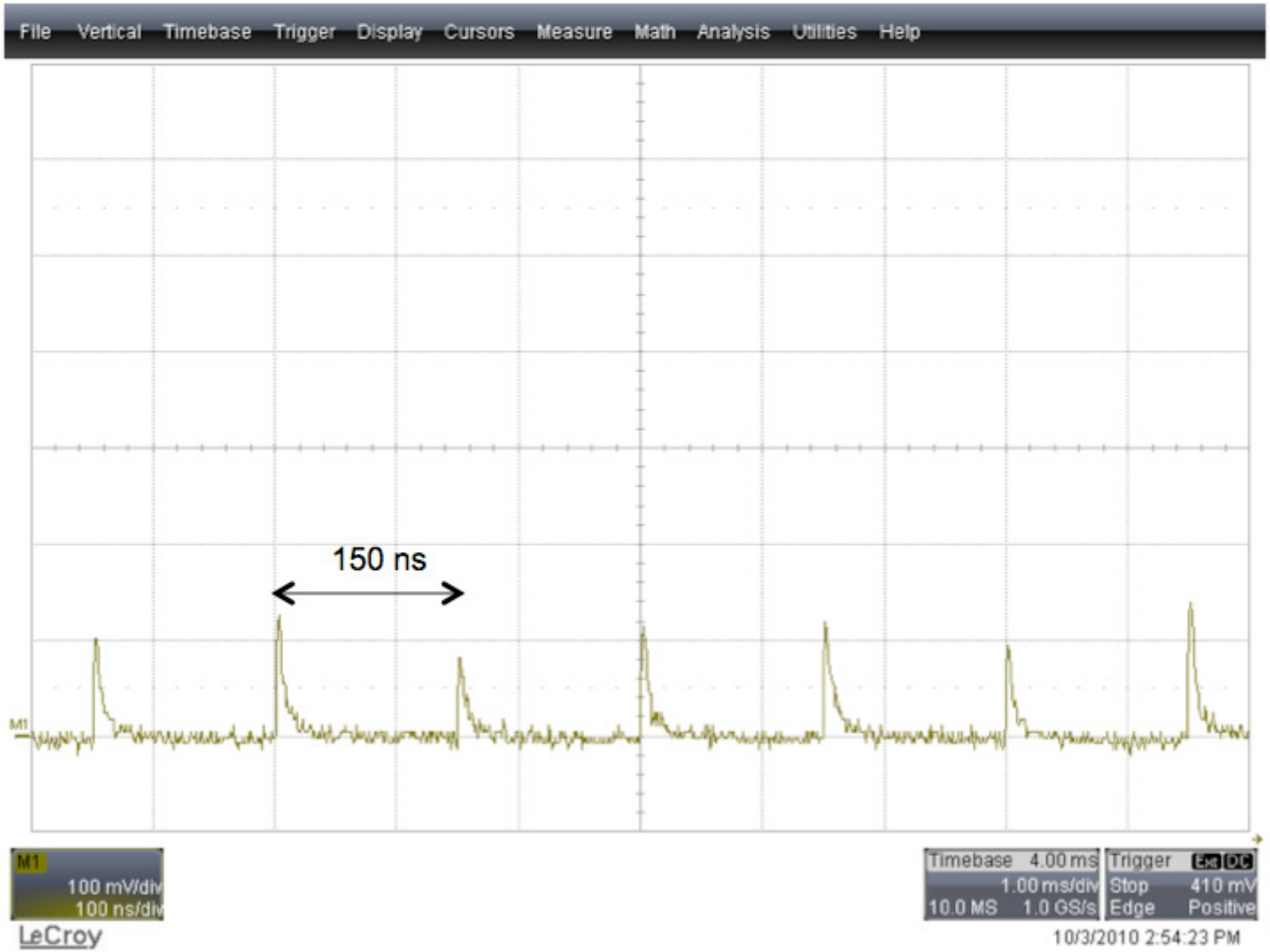
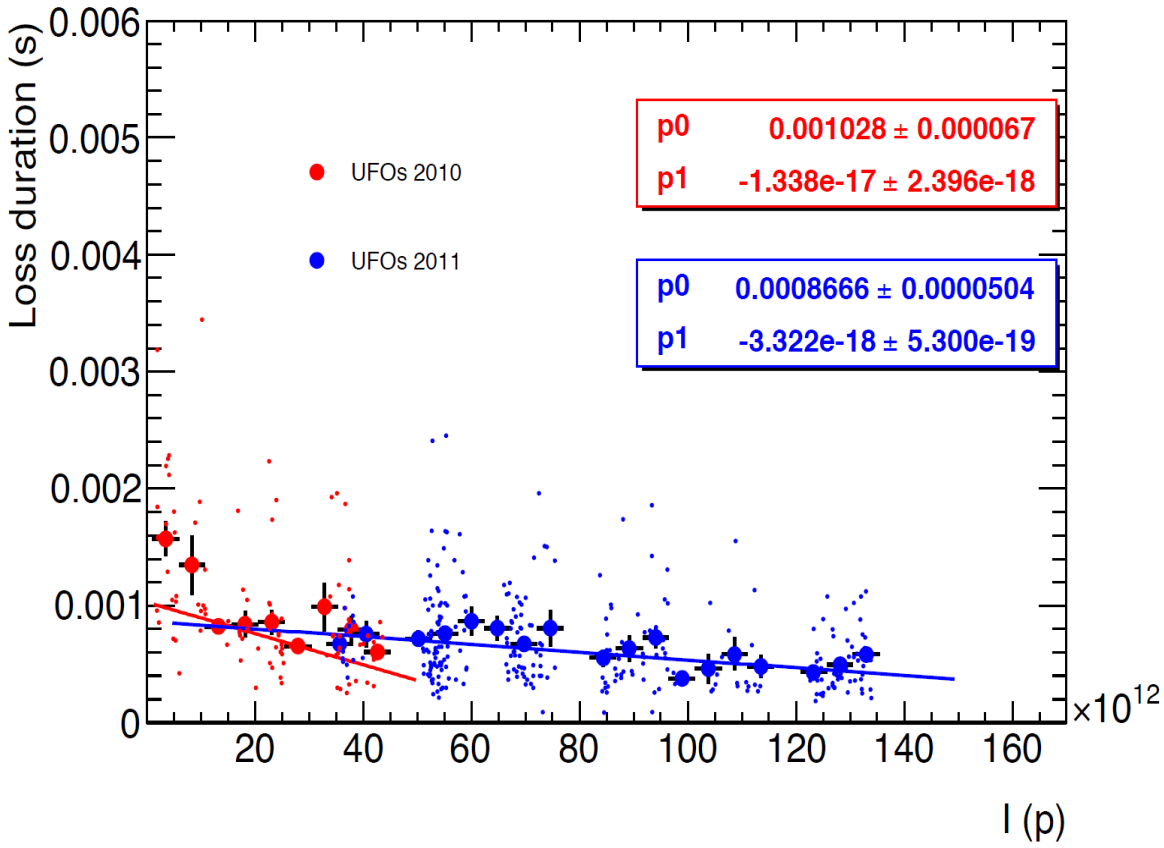


3/10/2010 12h48, 152 bunches, 150ns bunch spacing

UFO Duration 2010 and 2011

E. Nebot and T. Baer

- Average duration: 130 µs at nominal intensity
- The maximum signal does not depend on intensity
- Estimate on signal increase at 7 TeV compared to 3.5 TeV (from wire scanner measurements): factor 2 – 3.5
- 2011 rate decreased from 10 UFOs/h to 5 UFOs/h during ‘stable beams’

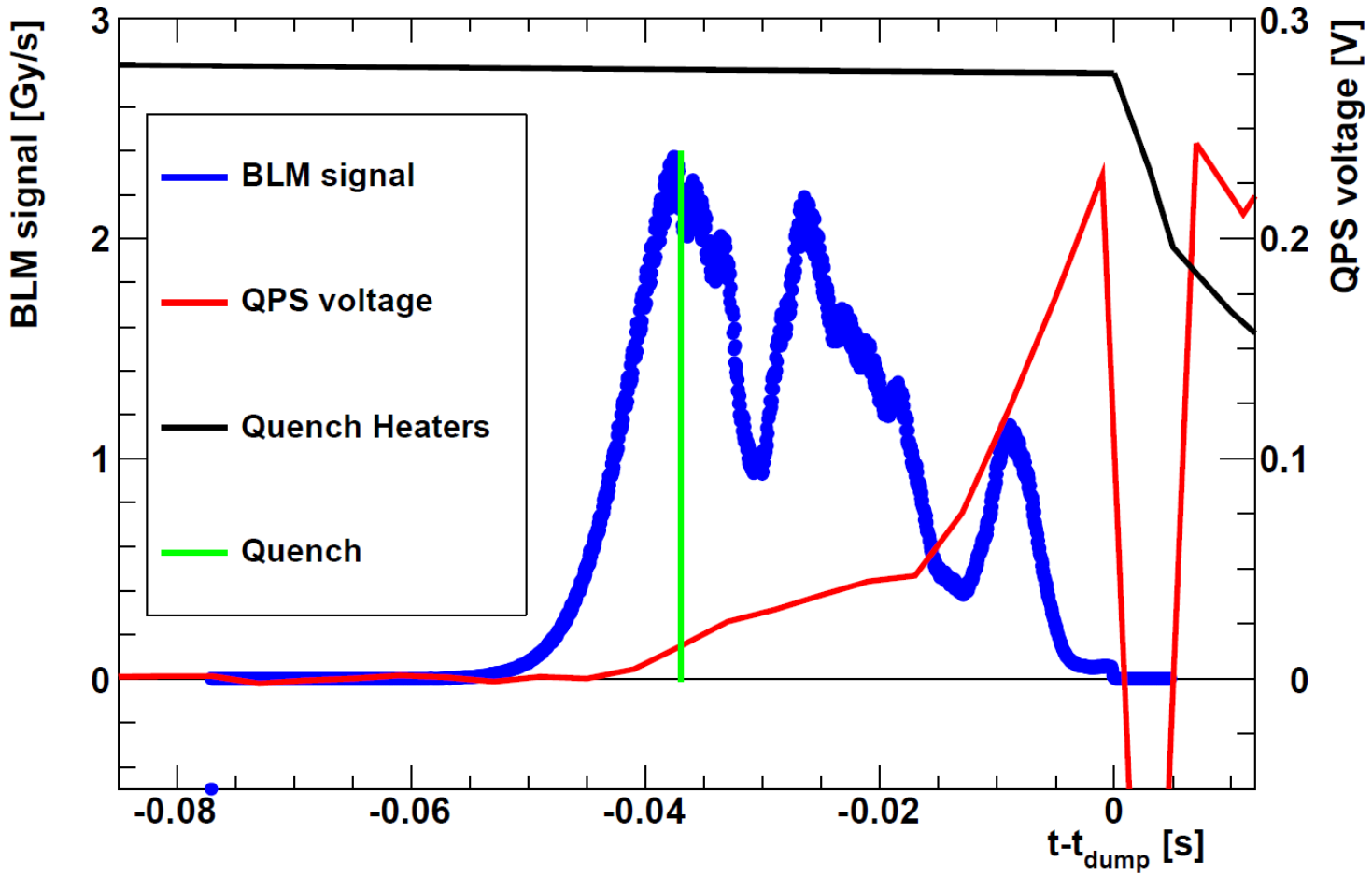


BLM Thresholds and Magnet Quench Levels

- WEPC172 *Beam-induced Quench Test of LHC Main Quadrupole*, A. Priebe et al.
- WEPC173 *LHC Magnet Quench Test with Beam Loss Generated by Wire Scan*, M. Sapinski et al.

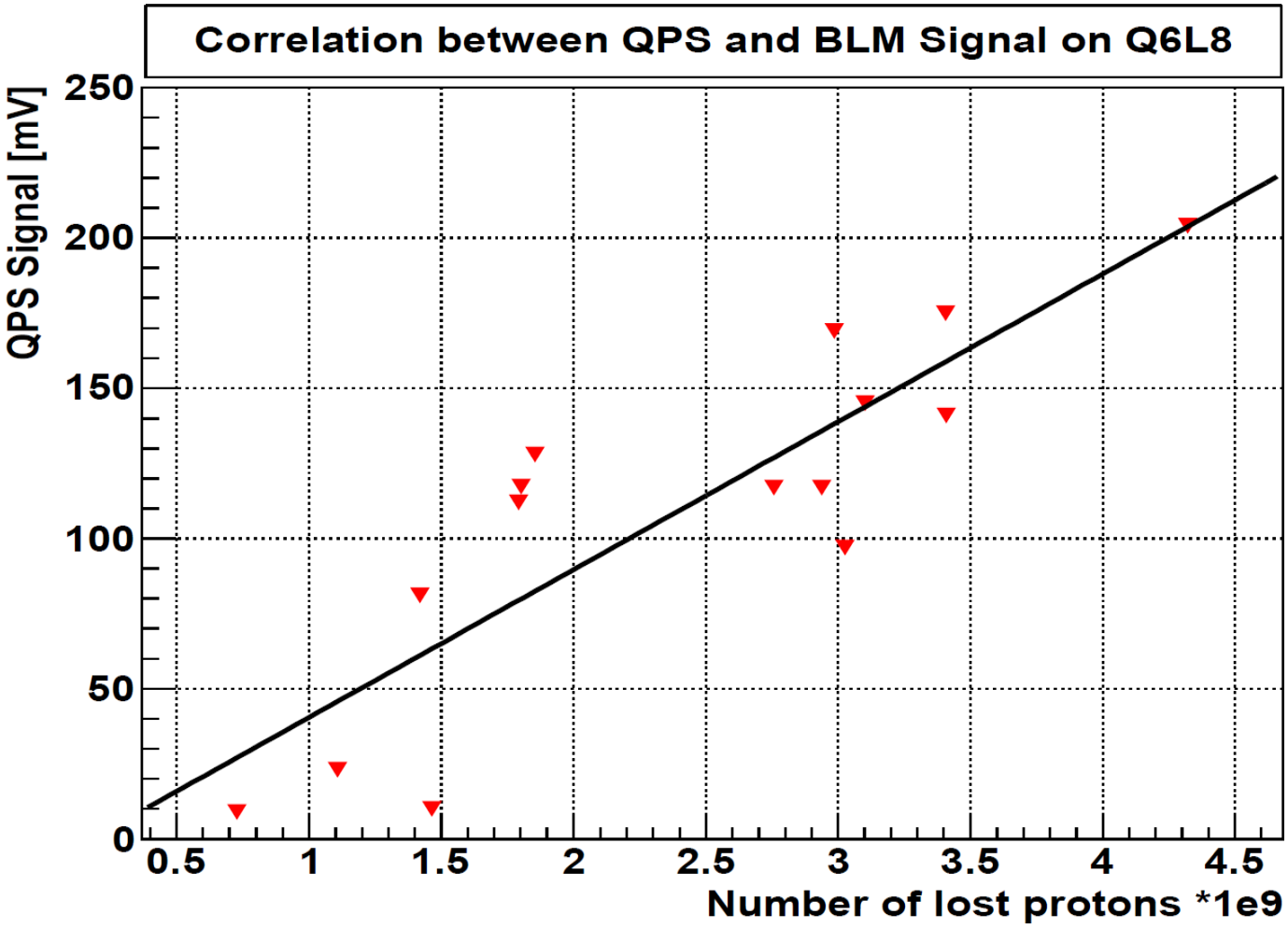
Quench Test: Wire Scanner Induced Losses

- BLM signal deviation from Gaussian: wire vibrations, sublimation of 50% of wire diameter (from 34 µm to about 18 µm)
- Voltage drop over the magnet coil (drop below zero due to signal disturbance)



Showers on Magnet from Losses on Collimator

- Maximum voltage drop on superconducting magnet coil scales with BLM signal

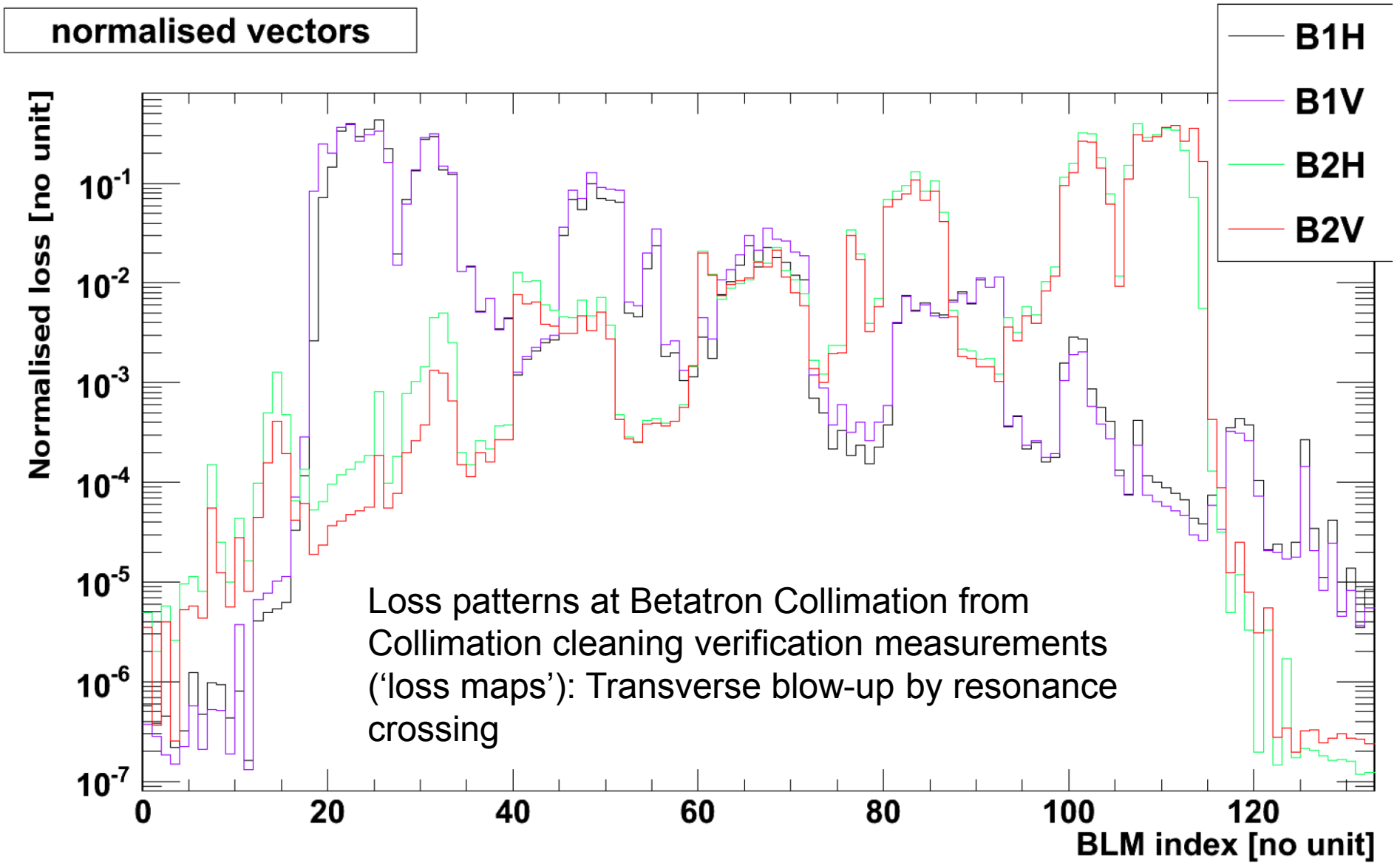


Beam Loss Patterns at Collimators

- Decomposing losses into known scenarios
  - TUPC141 *LHC Beam Loss Pattern Recognition*, A. Marsili et.al.
- Losses on Tertiary Collimators and Luminosity

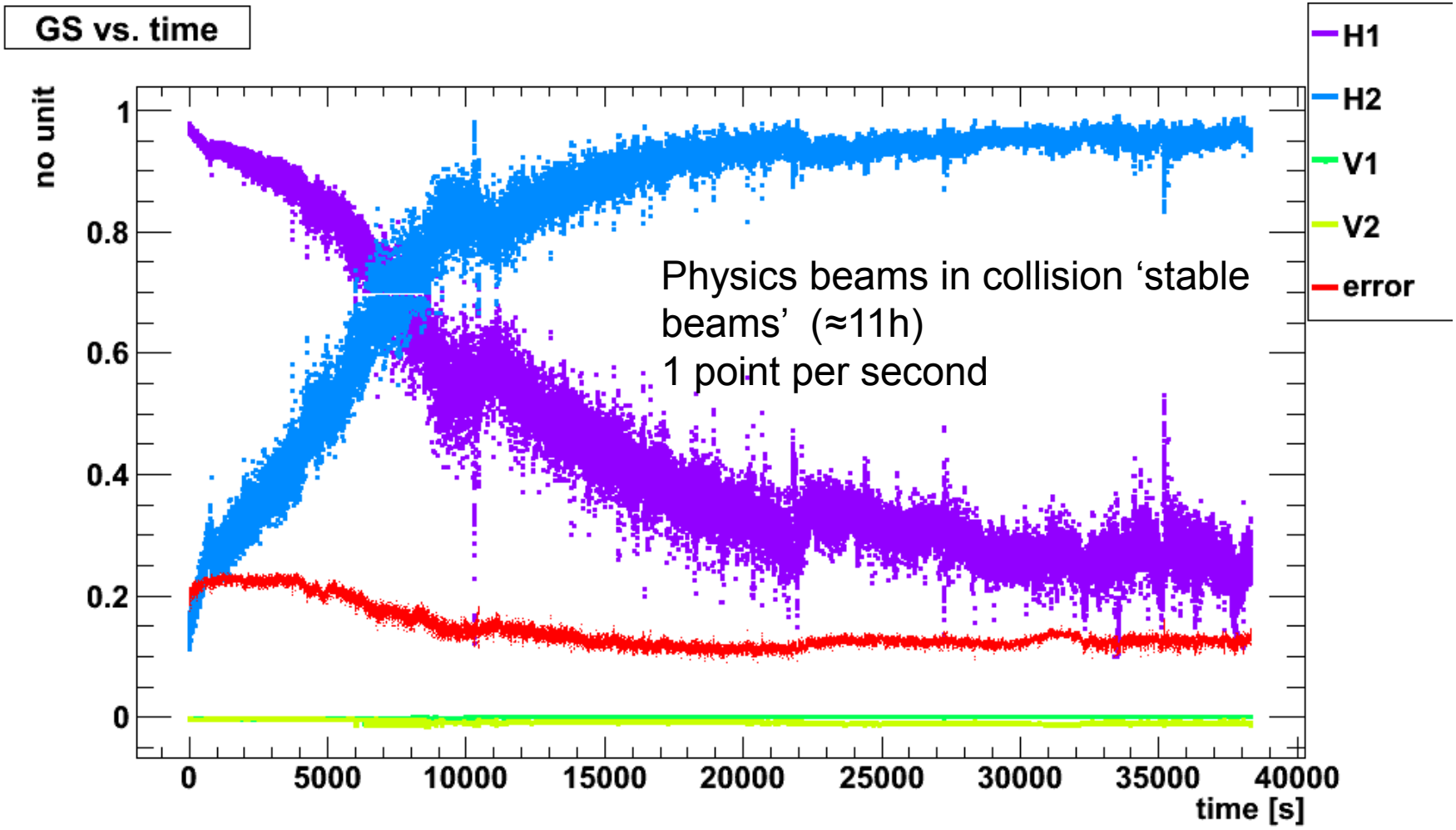
Decomposition of Losses

PhD thesis A. Marsili

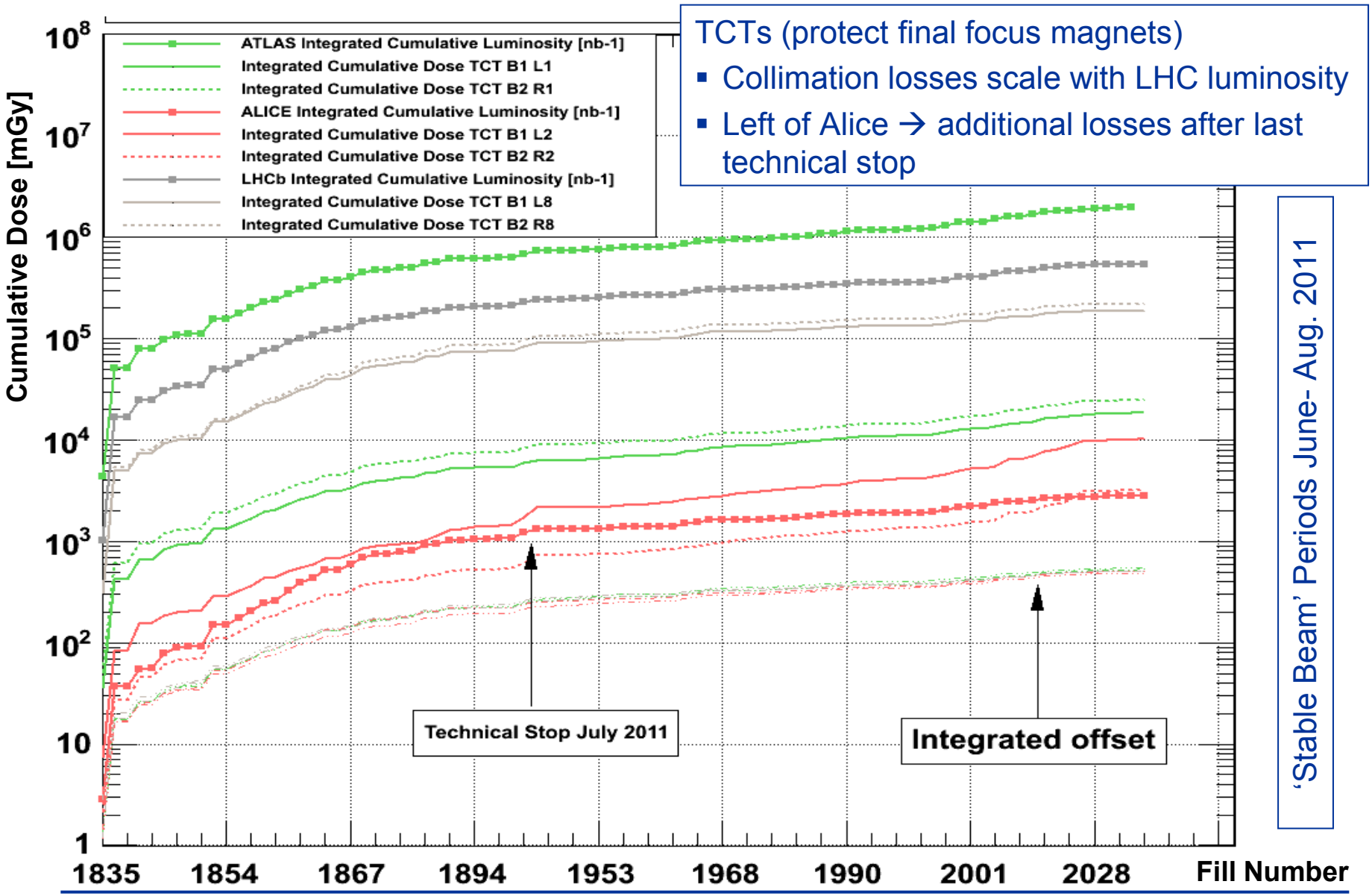


Decomposition Prelim. Results

PhD thesis A. Marsili



Losses on Tertiary Collimators (TCT) and Luminosity

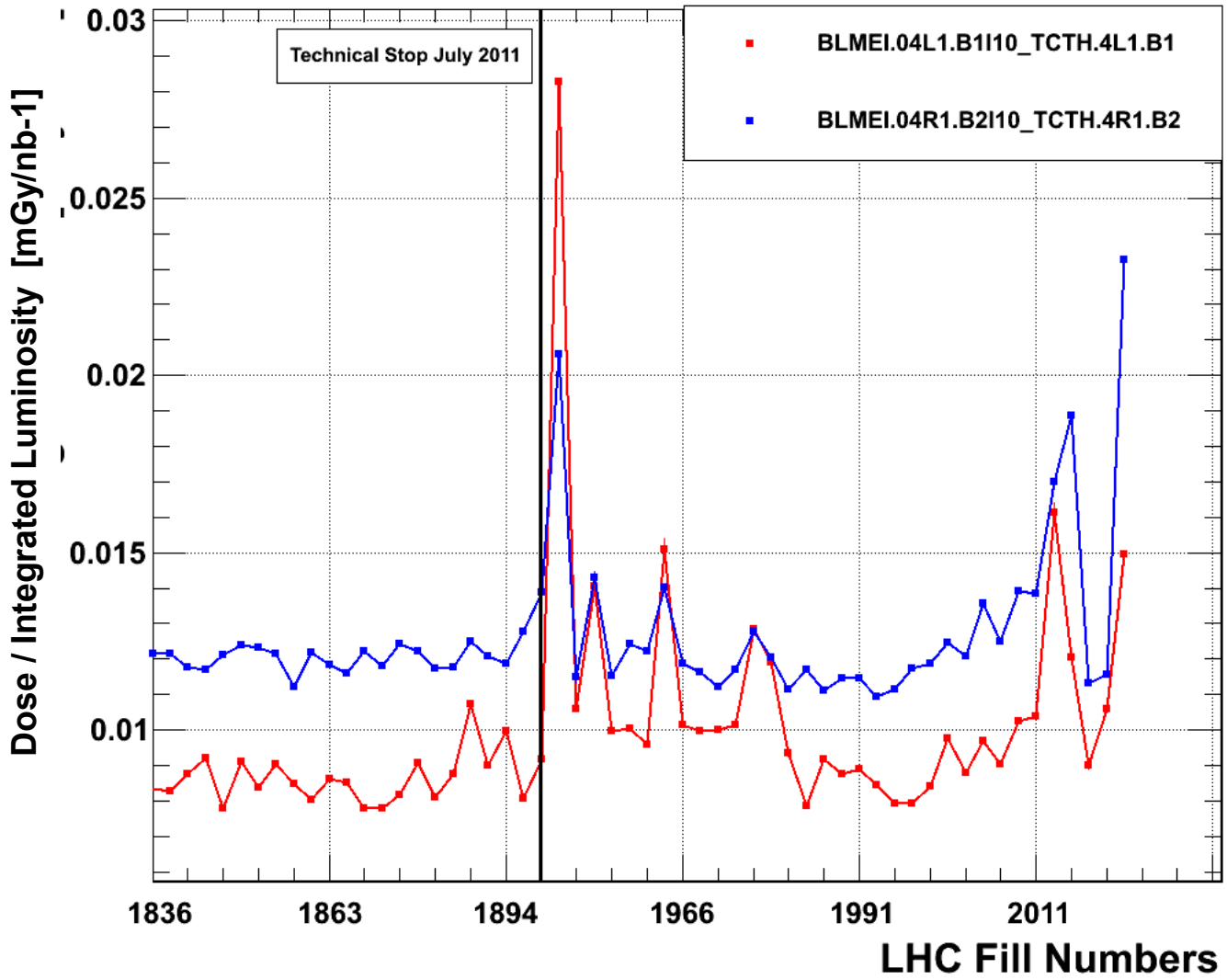


TCTs (protect final focus magnets)

- Collimation losses scale with LHC luminosity
- Left of Alice → additional losses after last technical stop

'Stable Beam' Periods June- Aug. 2011

Dose divided by Integrated Luminosity at Atlas TCT



'Stable Beam' Periods >2h June- Aug. 2011

Summary

Summary

- Four Examples of the usage of BLM data:
  - Analysis of fast ms-time scale local losses (UFOs)
  - Analysis of magnet quench levels for threshold determinations
    - Measurement of magnet coil voltage drop
  - Beam Loss Pattern recognition at collimators
  - Fill to Fill variations of losses