Overview of LHC Beam Loss Measurements

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IPAC 2011

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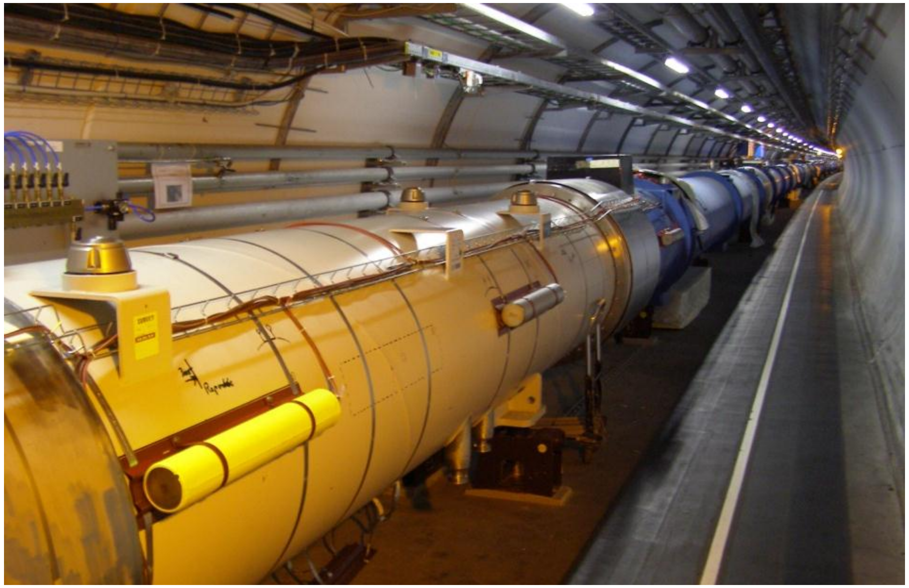
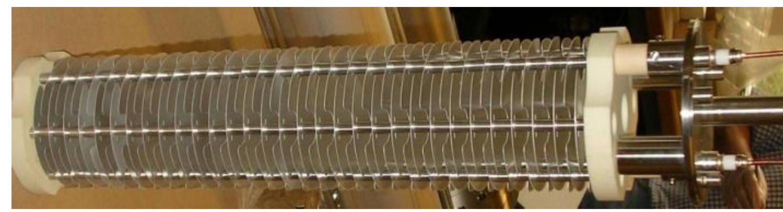
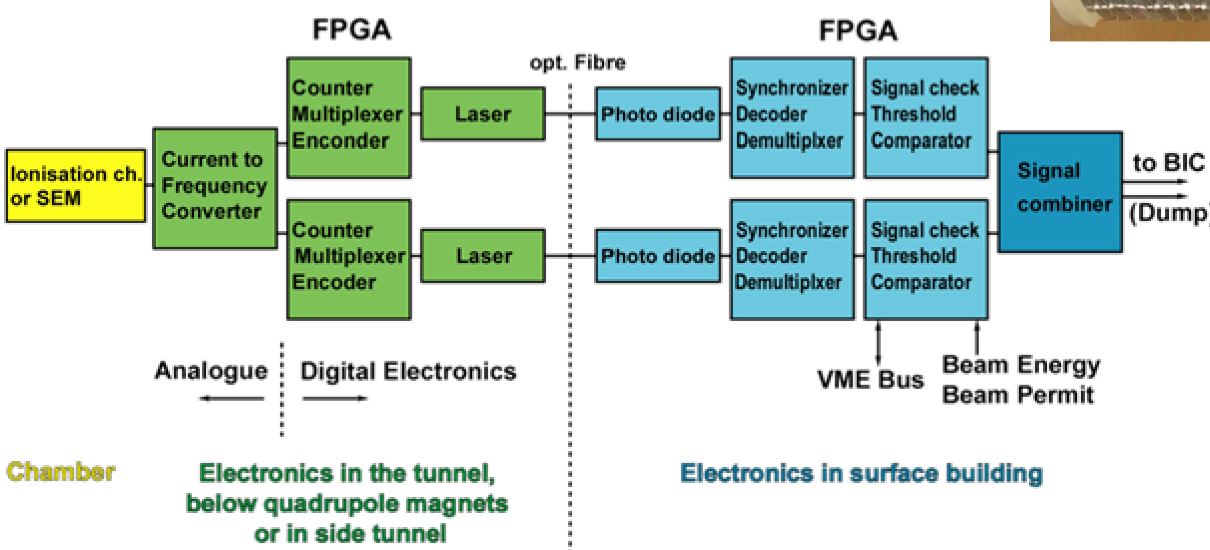
Introduction to the BLM System

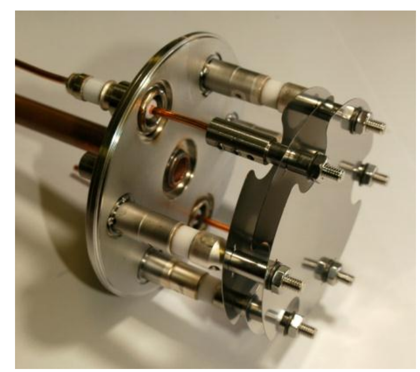
Beam Loss Measurement System Layout



- **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:
  - One of 12 integration intervals over threshold
  - Internal test failed

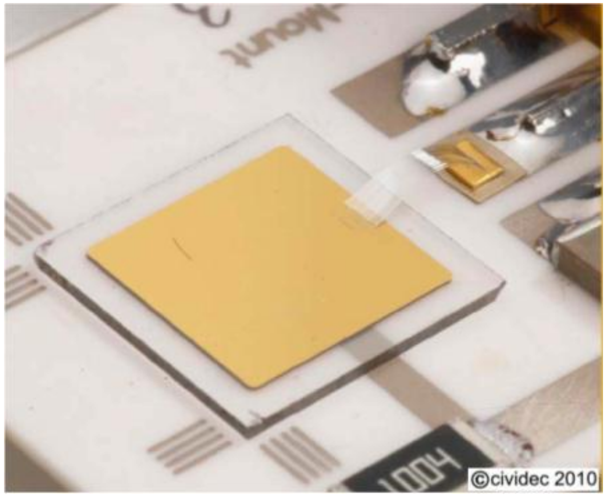
Stored Energy	
Beam 7 TeV	2 x 362 MJ
2011 Beam 3.5 TeV	up to 2 x 100 MJ
Magnets 7 TeV	10 GJ

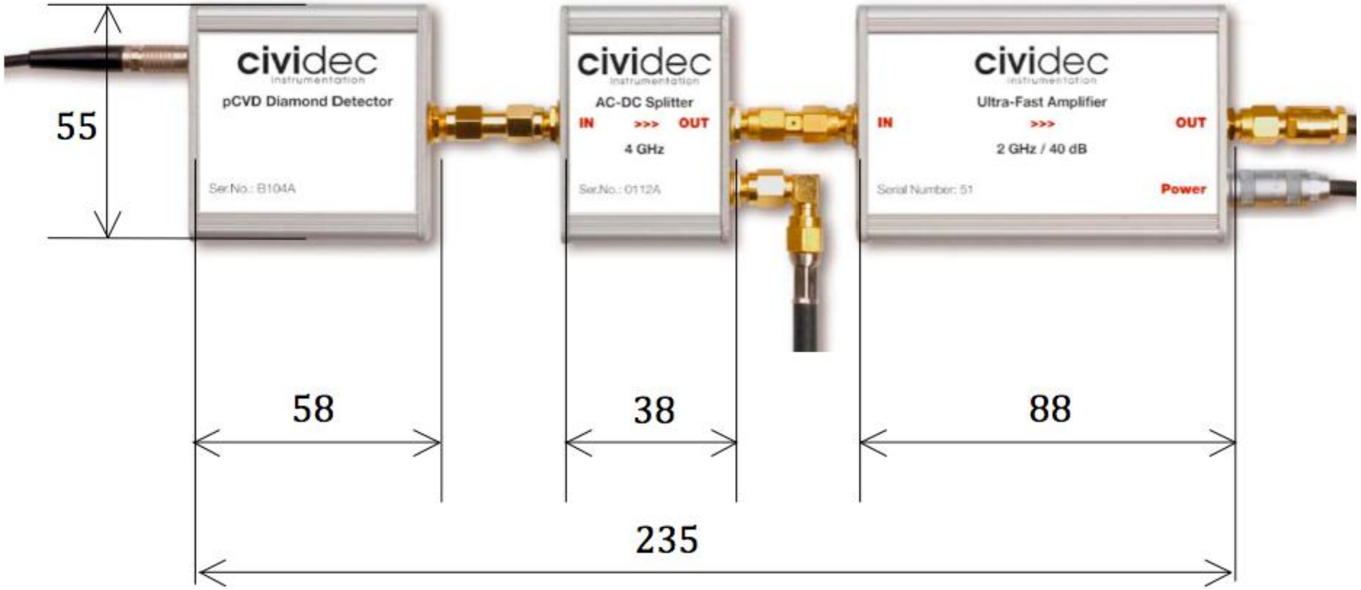
Quench and Damage at 7 TeV	
Quench level	≈ 1mJ/cm^3
Damage level	≈ 1 J/cm^3

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)

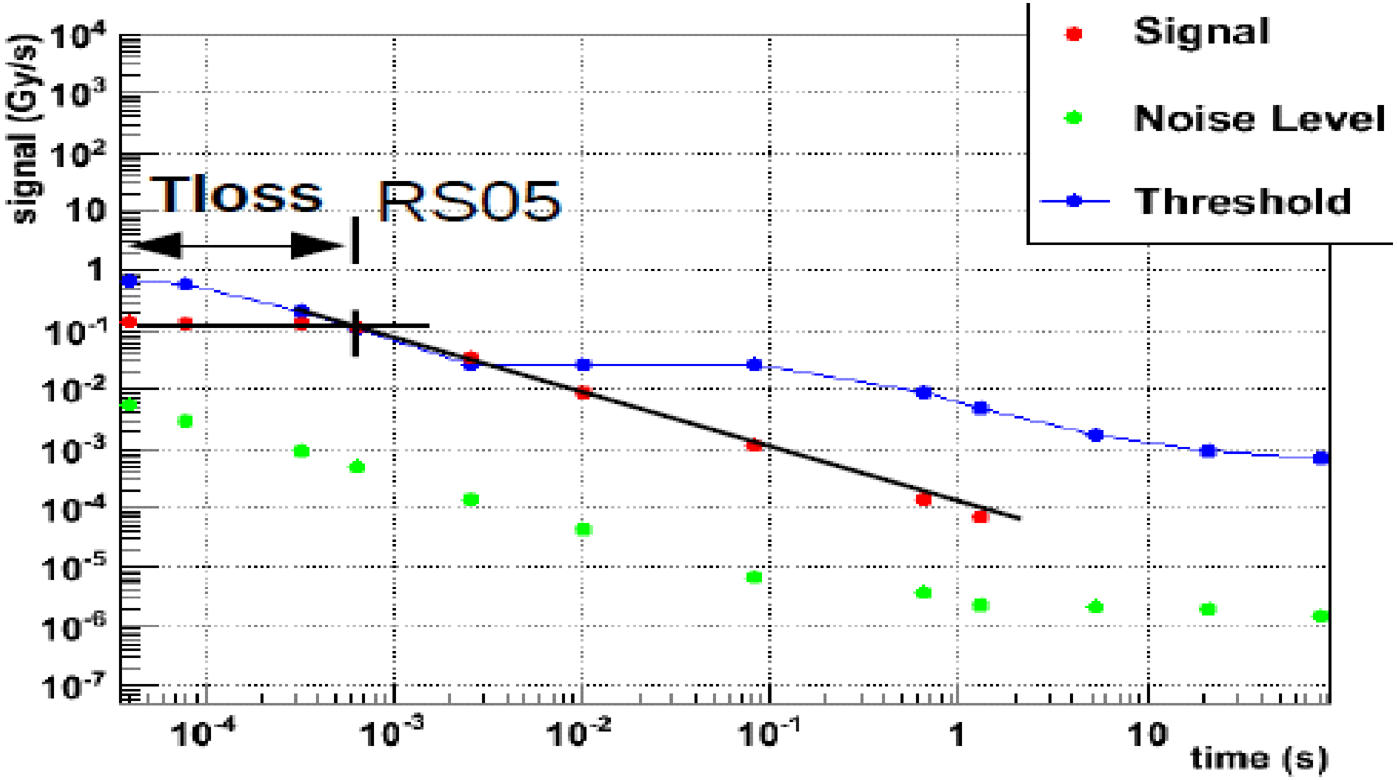




BLM Published Data – Logging Data

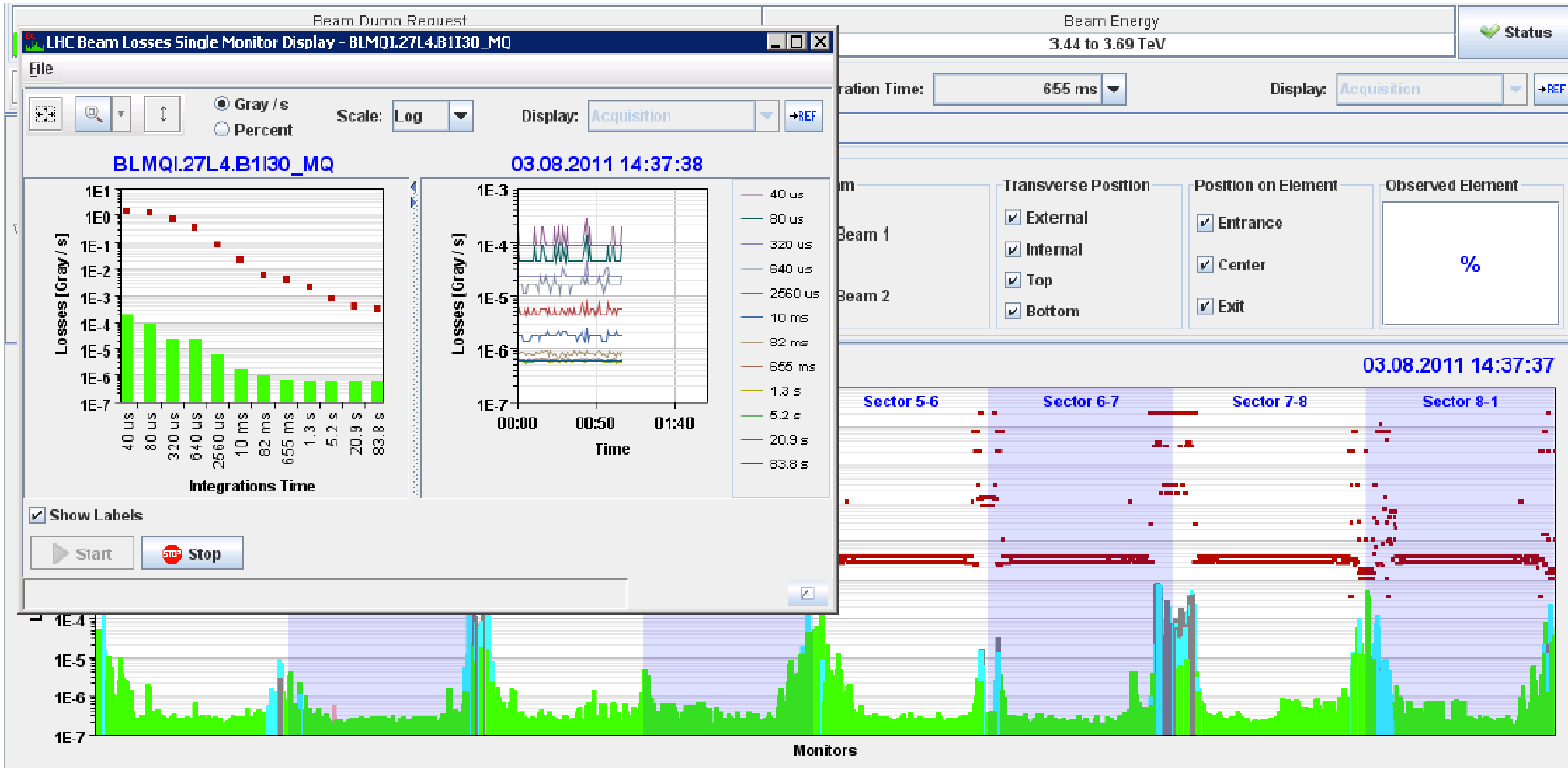
- Extensively used for operation verification and machine tuning
- Logging once per second (all 12 integration intervals)
  - Integration times < 1s: maximum during the last second is published

    → 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

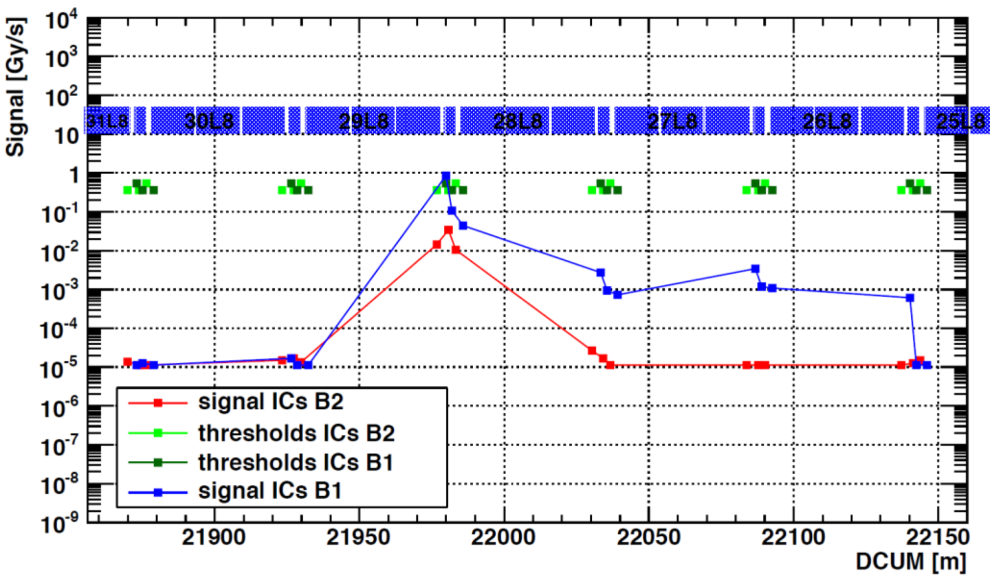
Fast (ms-time-scale) Losses
UFO: Unidentified Falling Object

- MOPS017 *Simulation Studies of Macro-particles Falling into the LHC Proton Beam*, F. Zimmermann 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 UFO's

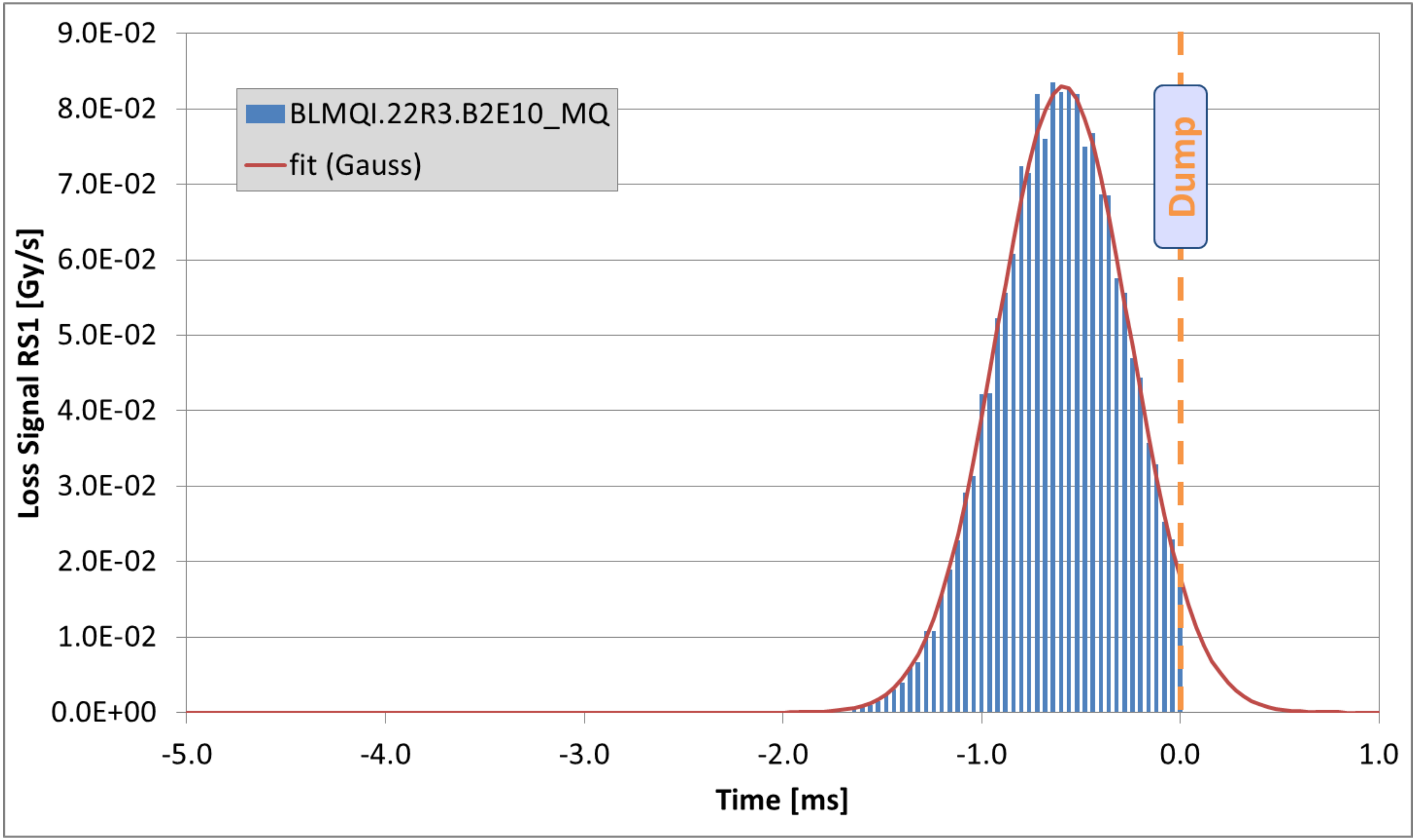
- Fast and localized losses all around the ring believed to be caused by macro particles intercepting the beam
- Stepwise increase of BLM thresholds at the end of 2010 run
- New BLM thresholds on cold magnets for 2011 start-up
- Always detected by > 6 local monitors and at all aperture limits (collimators)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

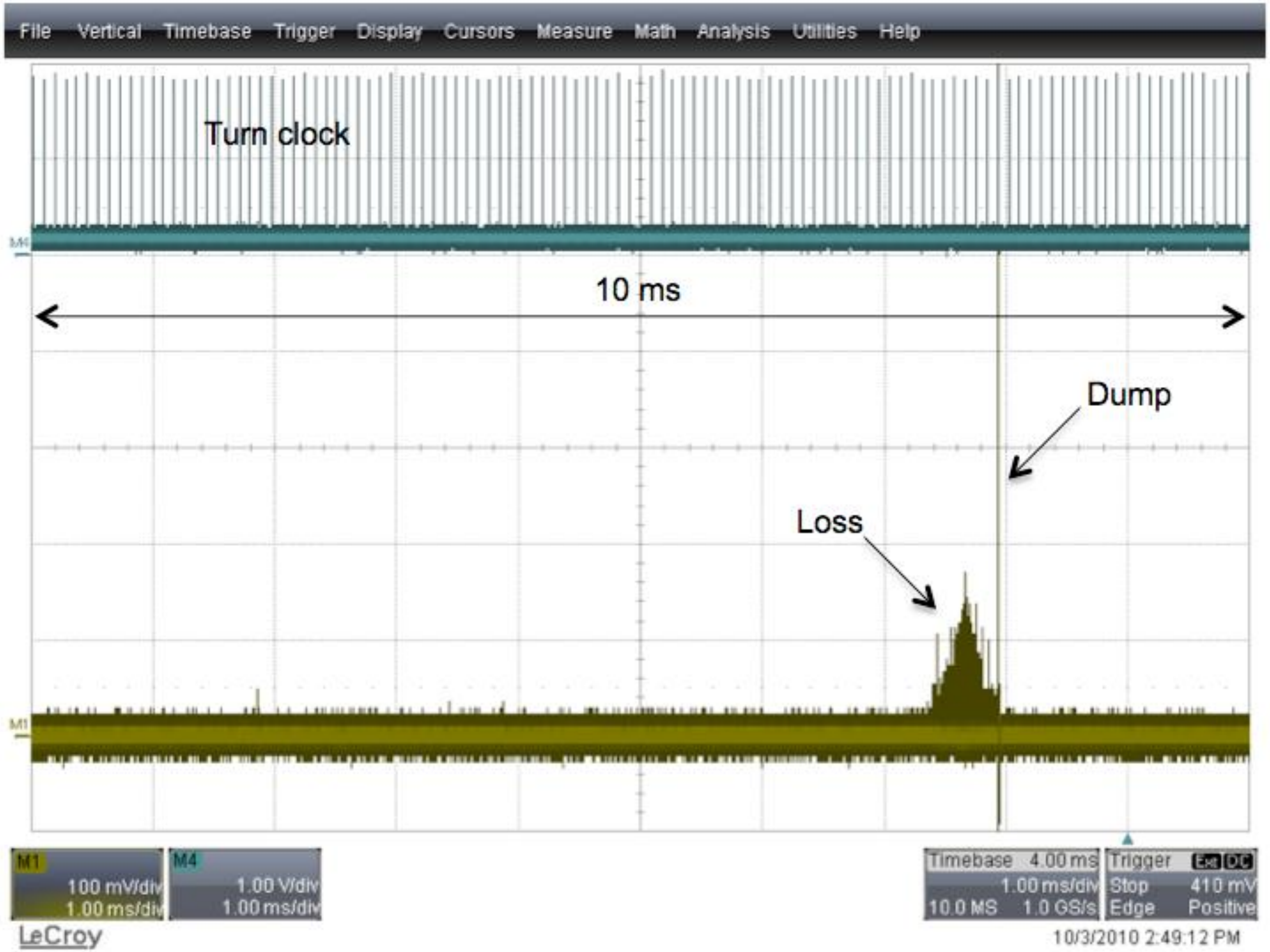


Gaussian Fit to UFO Time Distribution

PhD thesis T. Baer

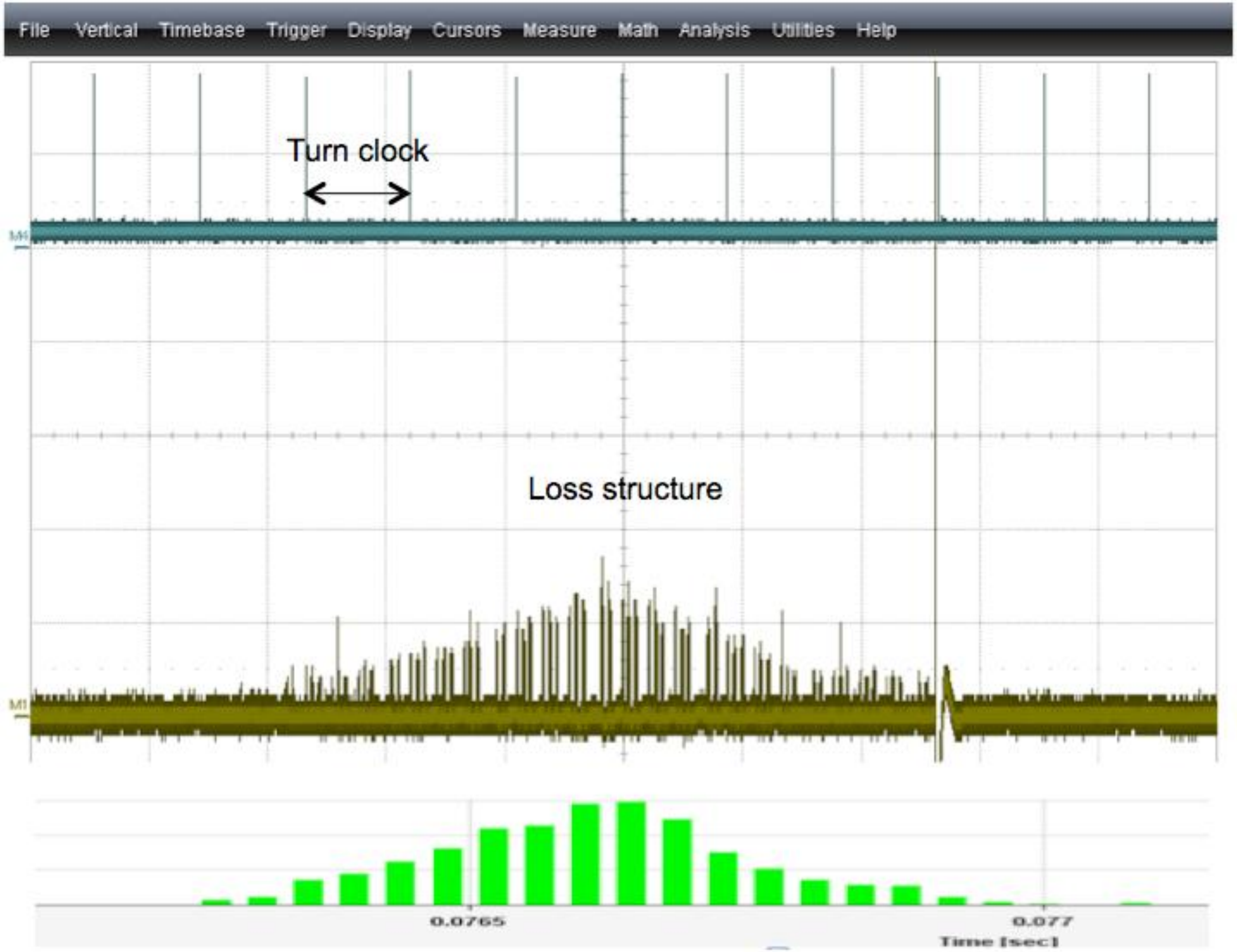


Diamond BLM Signals



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

Diamond BLM Signals



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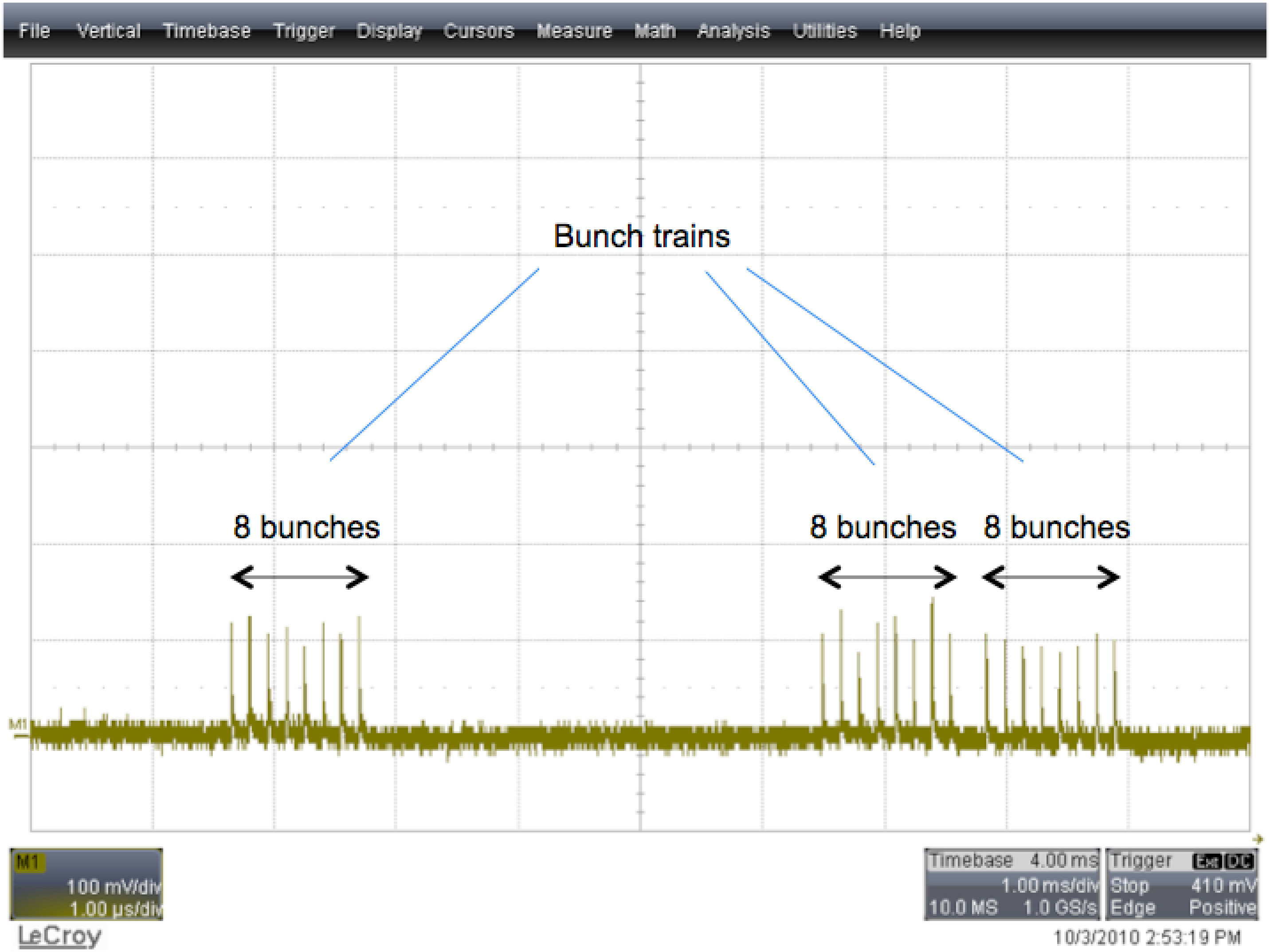

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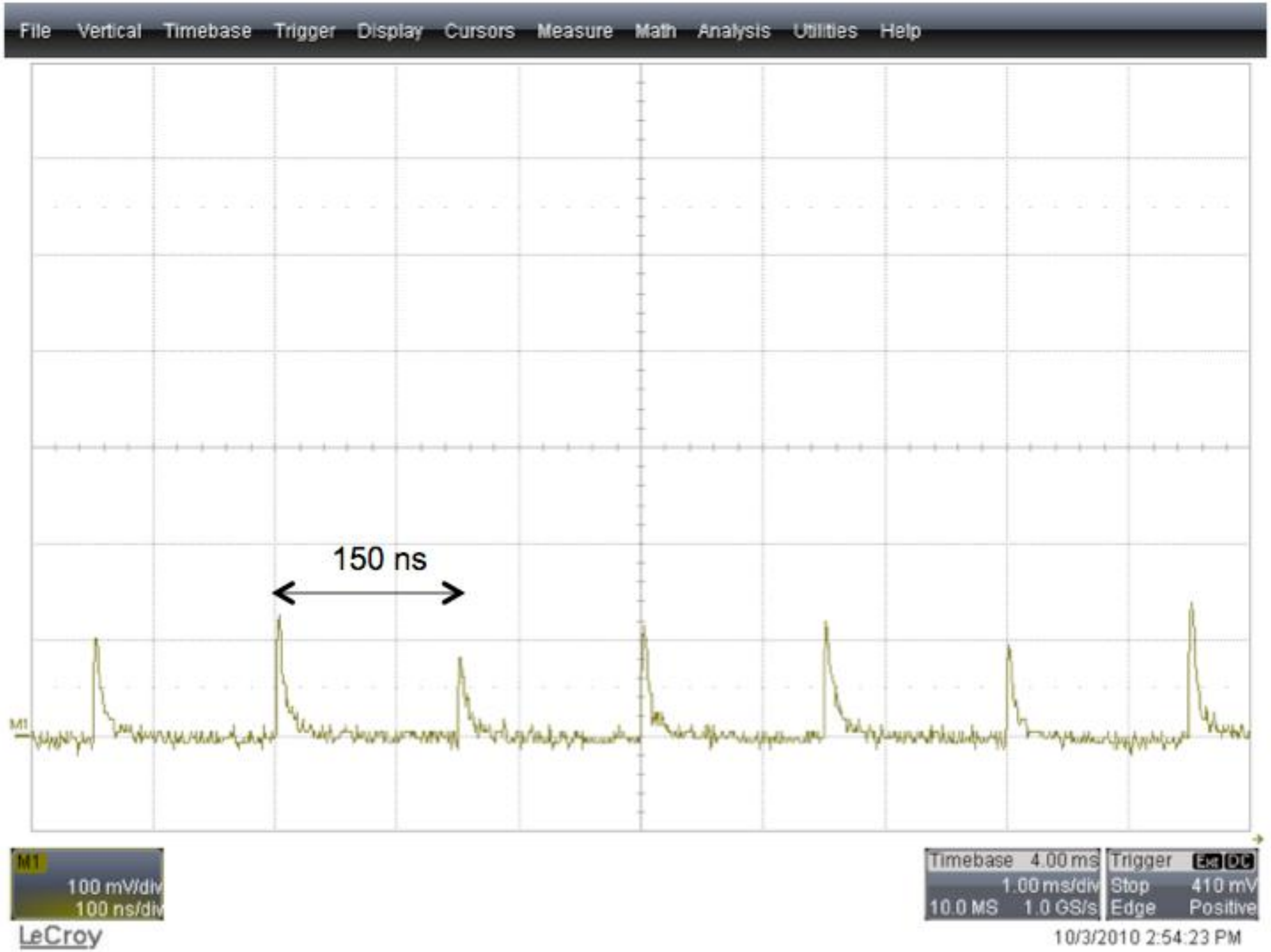
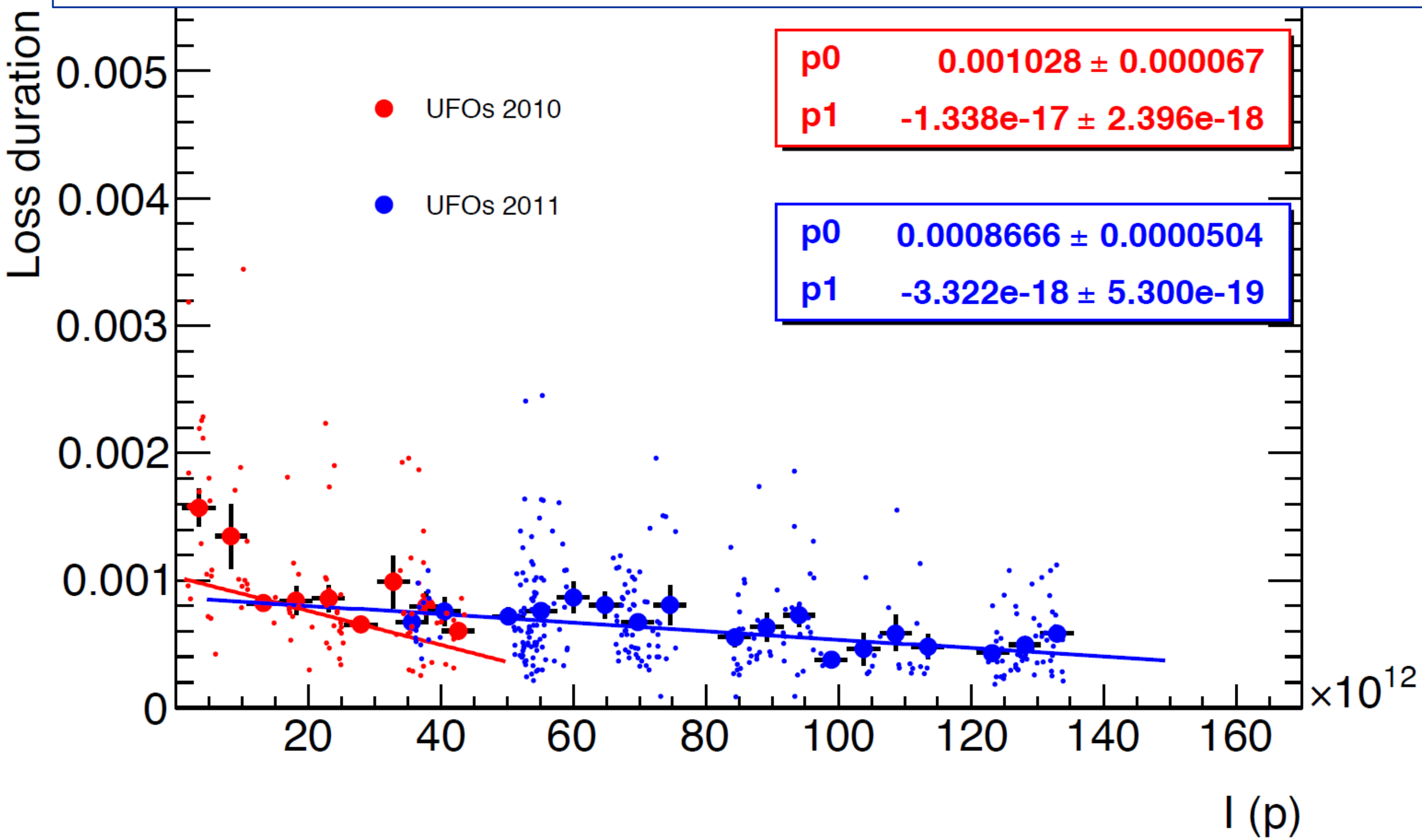


3/10/2010 12h48, 152 bunches, 150ns bunch spacing

UFO Duration 2010 and 2011

E. Nebot

Average duration: 130 μs at nominal intensity
Average maximum signal ≈ 5 10^{-2} Gy/s
Estimate on signal increase at 7TeV compared to 3.5 TeV (from wire scanner measurements): factor 2 – 3.5

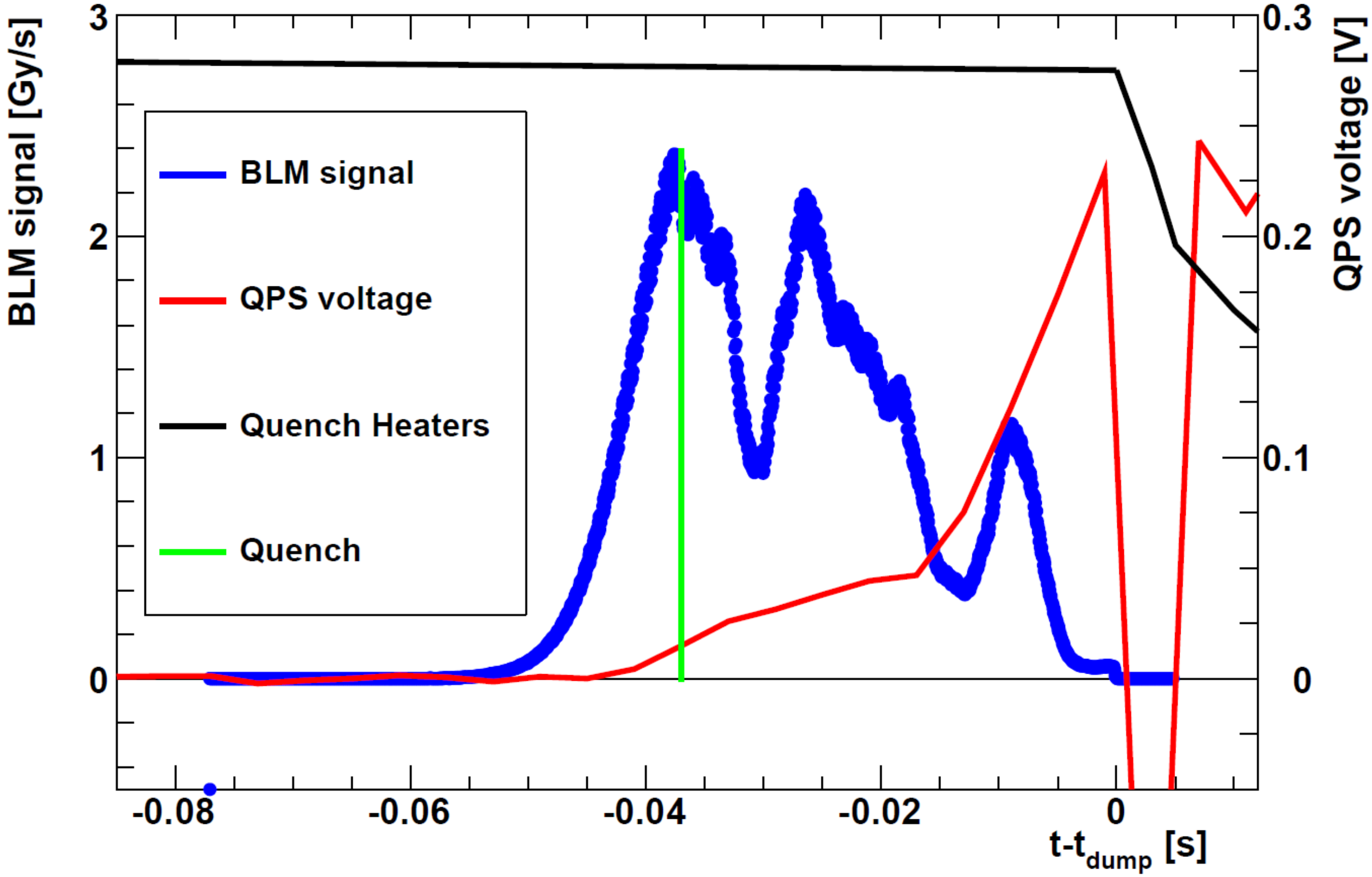


BLM Thresholds and Magnet Quench Levels

- 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.

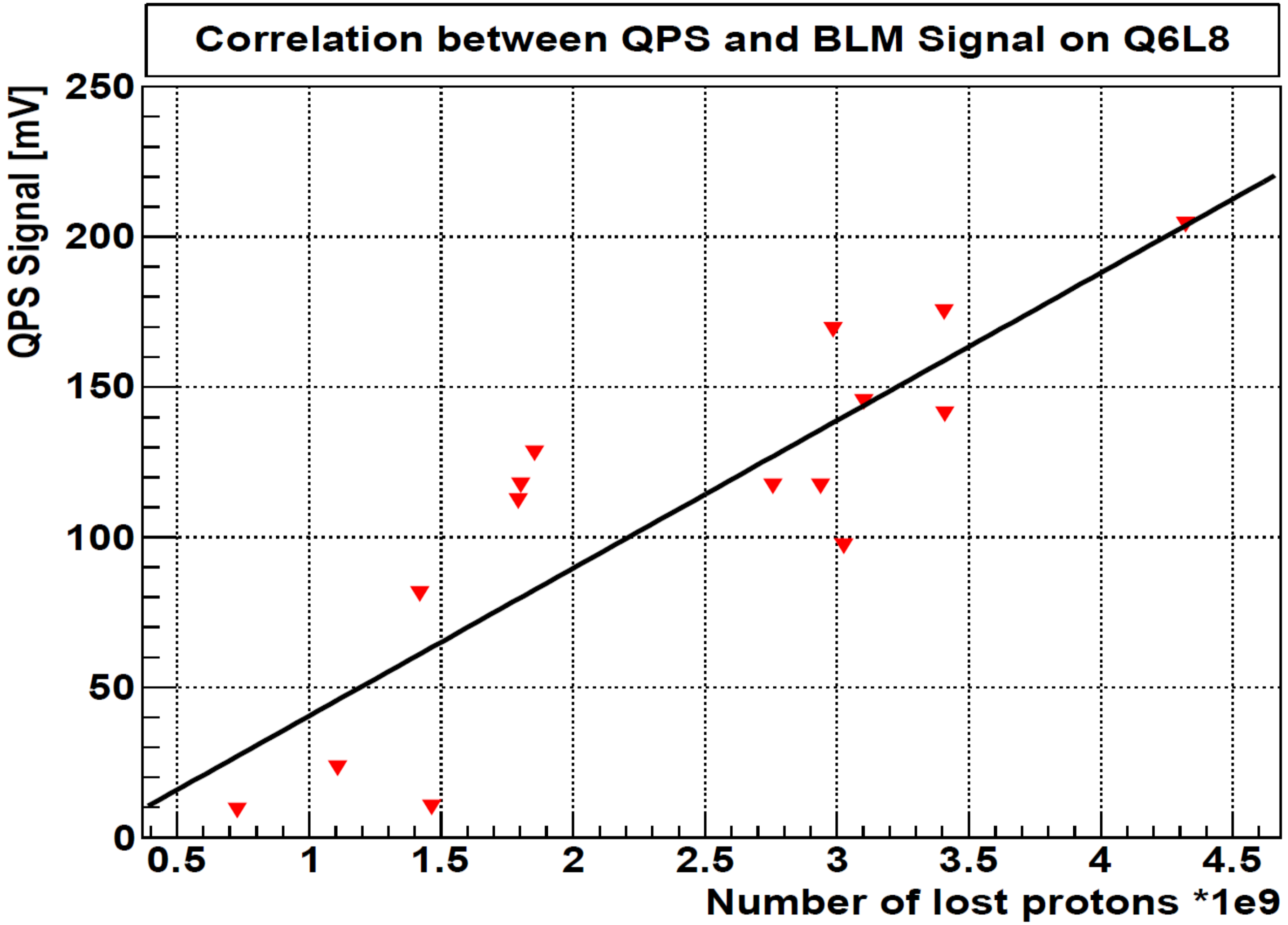
Quench Test: Wire Scanner Induced Losses

- 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

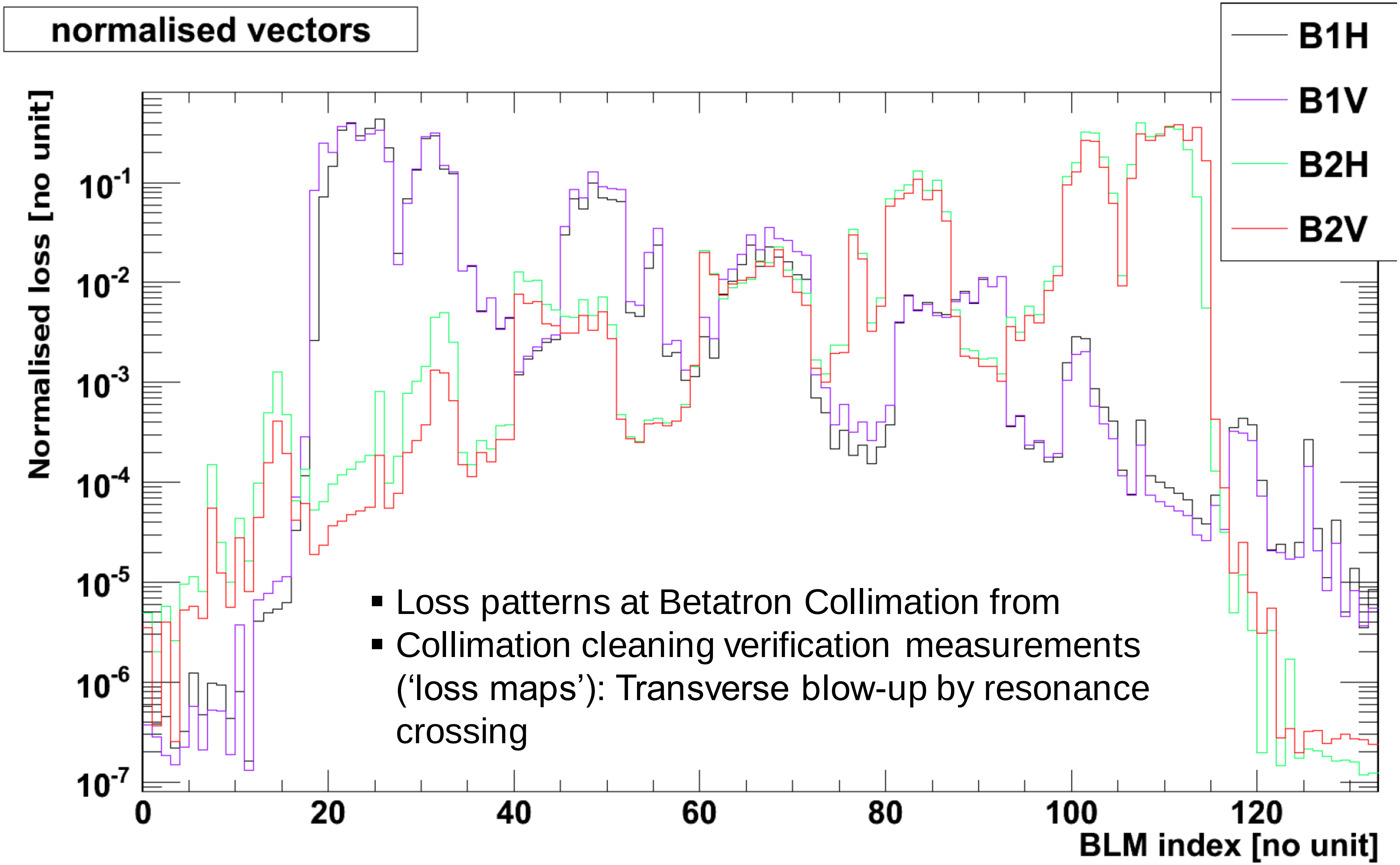


Beam Loss Patterns

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

Decomposition of Losses

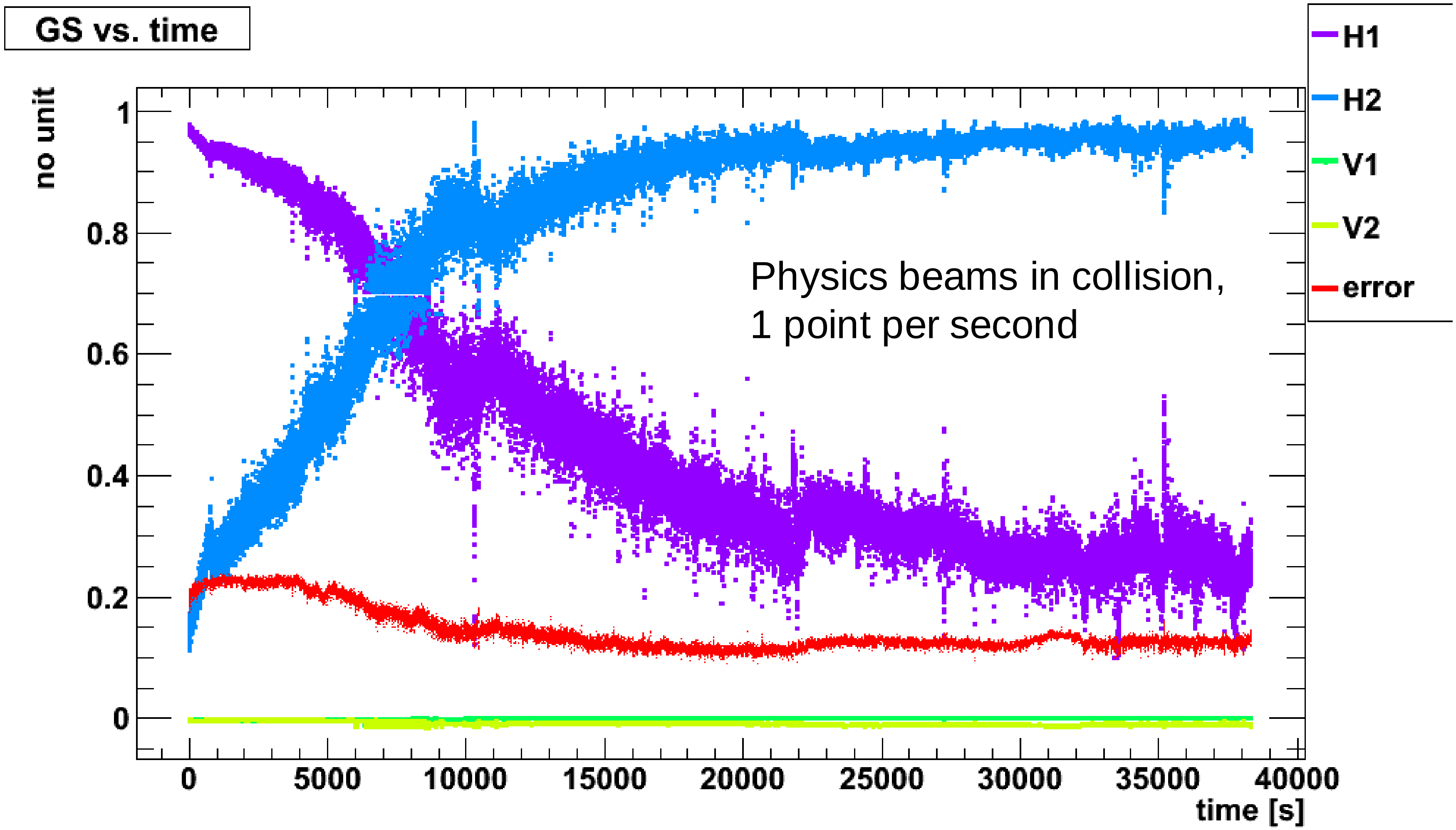
PhD A. Marsili



- Loss patterns at Betatron Collimation from
- Collimation cleaning verification measurements ('loss maps'): Transverse blow-up by resonance crossing

Decomposition Prelim. Results

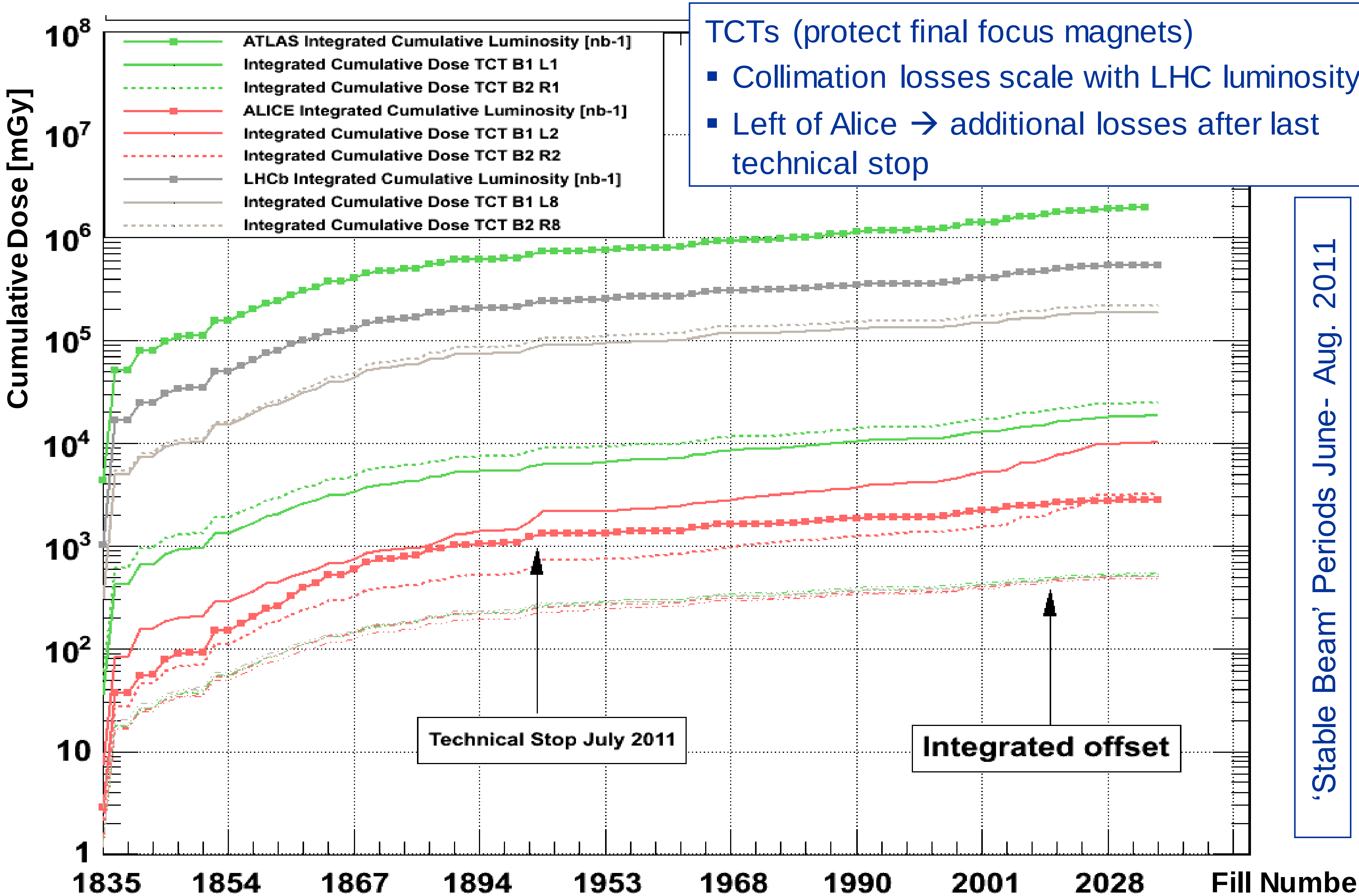
PhD thesis A. Marsili



Losses on Tertiary Collimators (TCT) and Luminosity

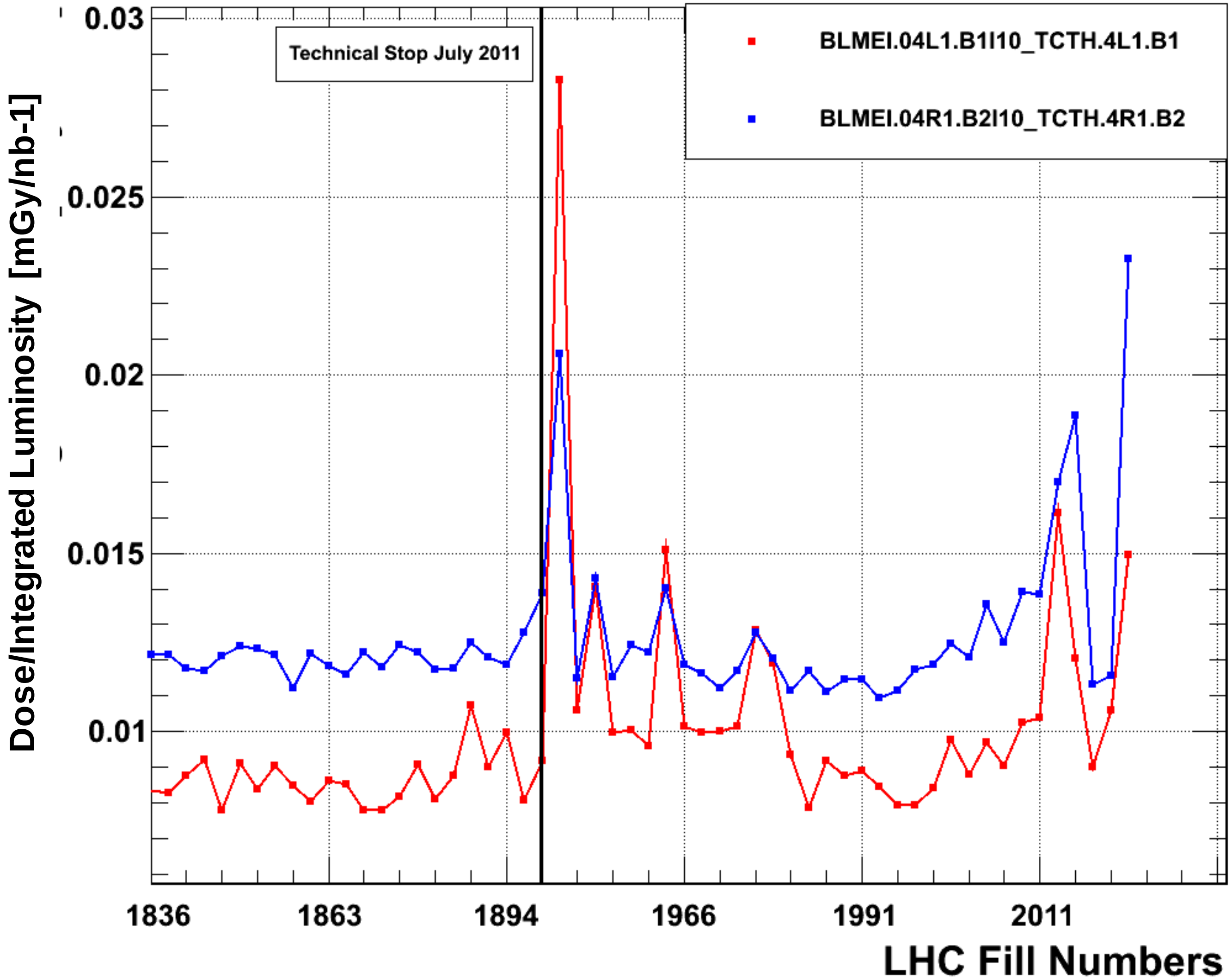
TCTs (protect final focus magnets)

- 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

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