UFOs, ULO, BLMs

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and the BLM Thresholds Working Group http://cern.ch/blmtwg

25. Jan. 2016, LHC Performance Workshop, Chamonix 2016

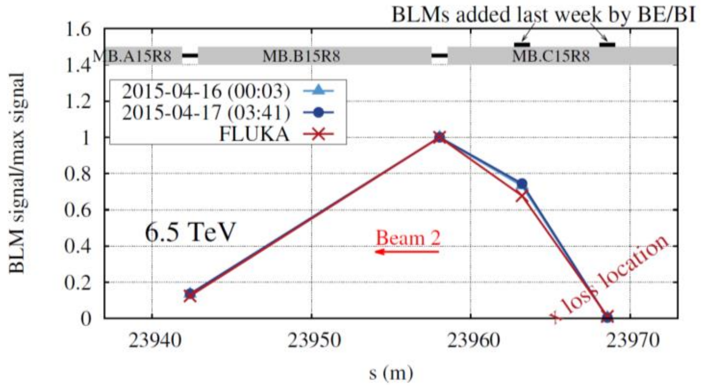
Overview

- ULO
- Run-2 UFOs Observations
- BLM Strategy vis-à-vis UFOs
- 2015 lessons on quench levels
- Overview of YETS BLM threshold changes

ULO Observations (1/2)

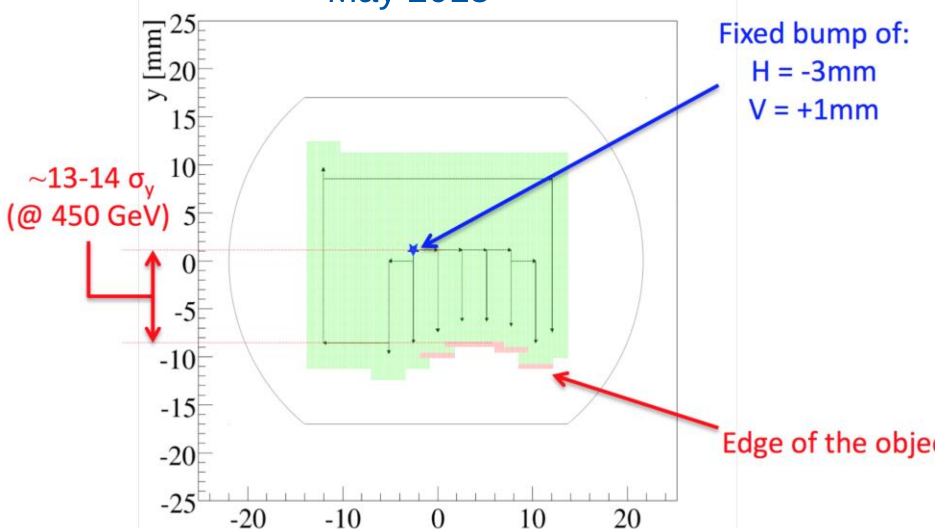
See Nov. 18th Extended LMC (S. Redaelli) and Evian (D. Mirarchi).

- Aperture restriction deep in MB.C15R8.
- Vertical restriction not constant; horizontal restriction stable.
- Not seen by conventional H- and V-loss maps.

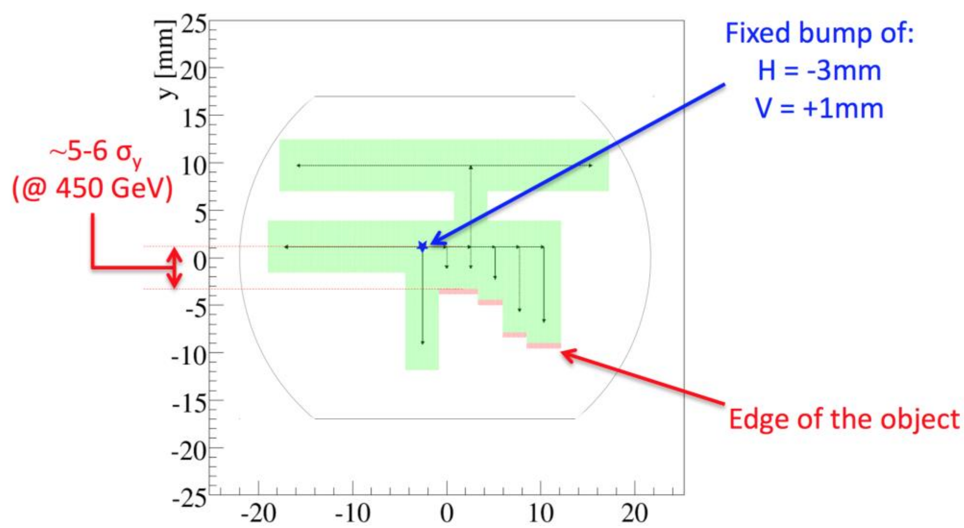


A. Lechner

May 2015



15/11 and 10/12



D. Mirarchi

ULO Observations (2/2)

- If the object grows further, there is room for increasing the orbit bump:
  - from currently H = -3 mm, V = 1 mm
  - we may increase to H = -6 mm, V = 3.5 mm
  - and reduce margin to 10 σ in both planes at 450 GeV in the nearby quad.
- ULO was there already at the beginning of Run 2.
  - In Run 1 there were no sensitive BLMs in the location.
- UFO@ULO signatures are correlated with beam movement – mostly injection and injection cleaning.
  - No correlation with intensity, energy, present or preceding beam mode was found.
- 3 ULO-induced quenches; BLM thresholds around 15R8 have been lowered so as to avoid quenches.
- No obvious limitation to operation in 2015 after orbit bump was deployed.
- Decision at Extended LMC: not to intervene at this point.

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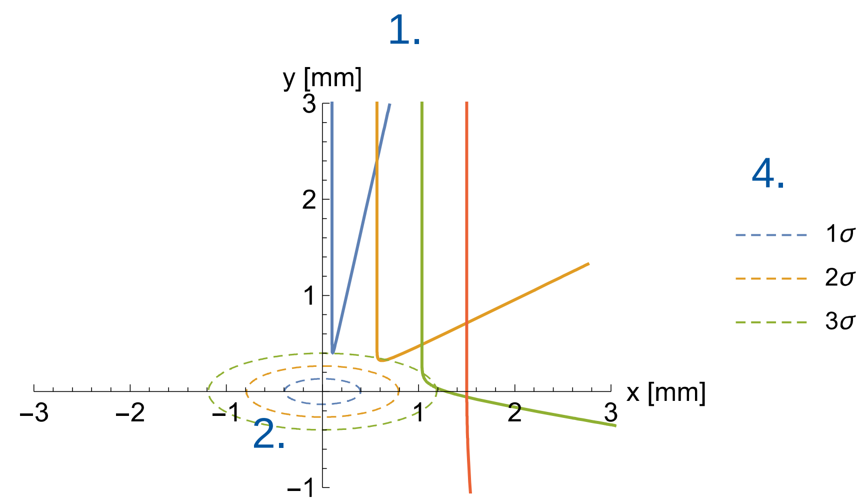
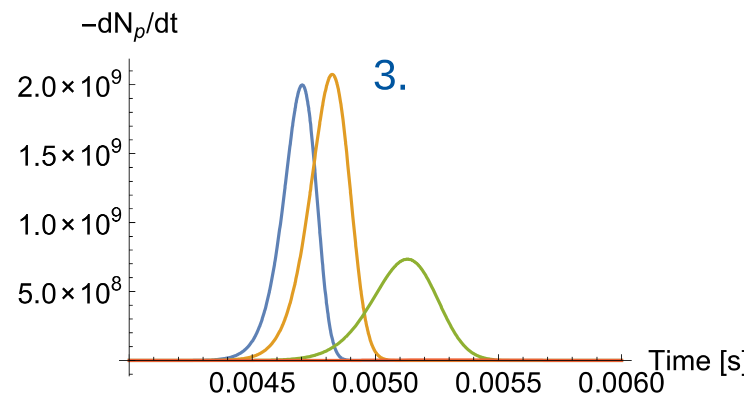
UFOs Introduction

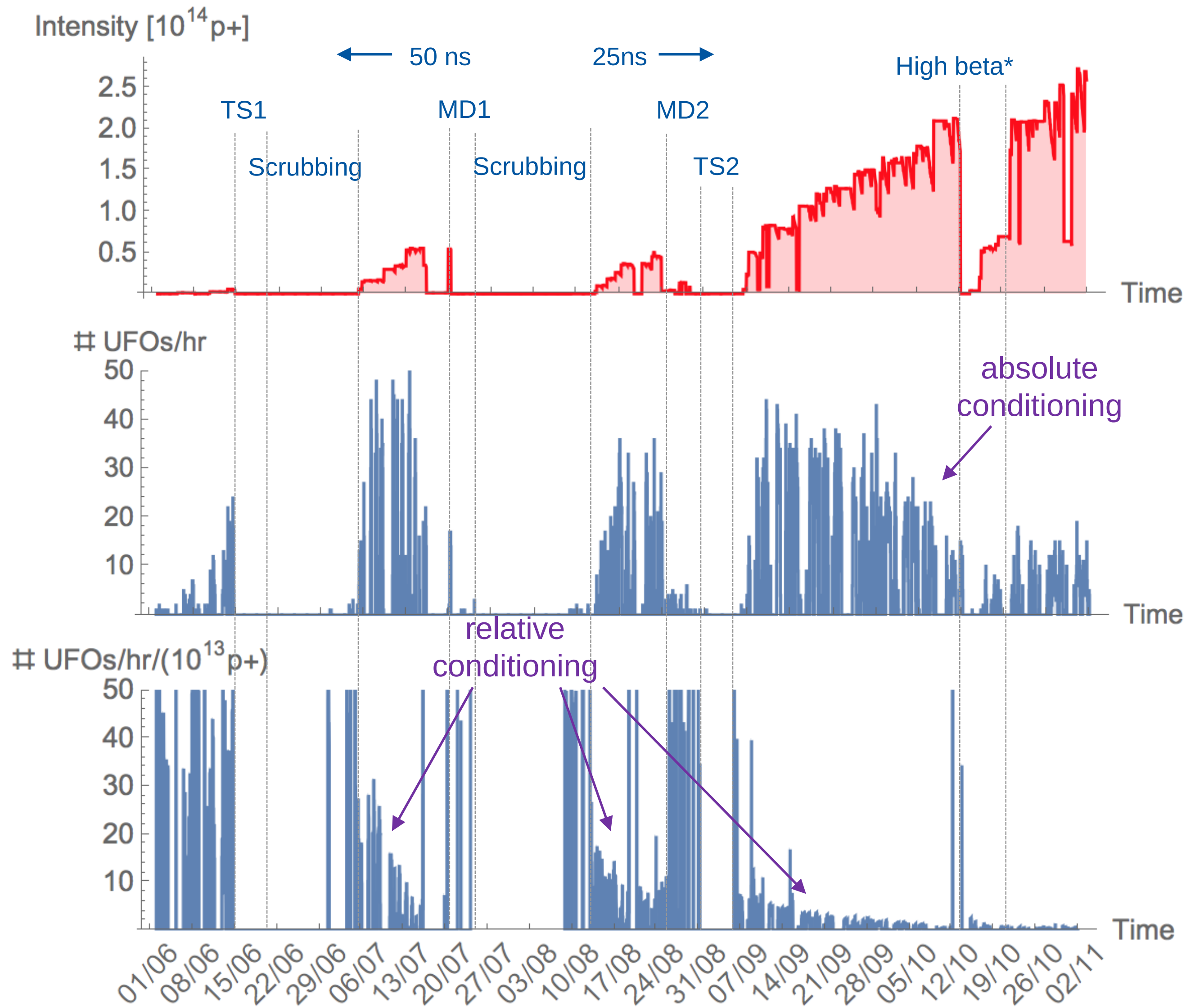
An explanation for UFO events is as follows:

1. A macroparticle falls from the top of the beam screen. The mechanism for the release of the particle is not well understood.
2. The macroparticle is ionized by the primary the protons in the beam.
3. At the same time, inelastic collisions result in particle showers that heat the SC coils and are registered in the BLMs.
4. The positively ionized macroparticle is subsequently repelled from the beam due to the beam electric field.





UFO Rates 2015 Proton Operation*

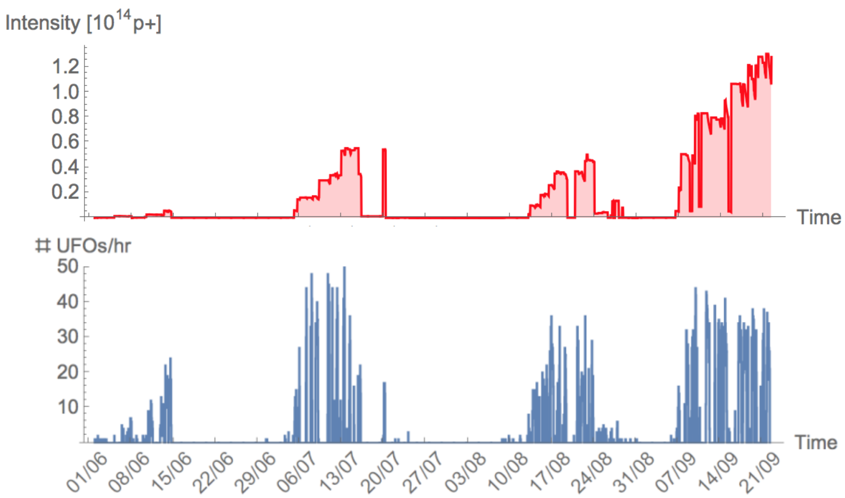


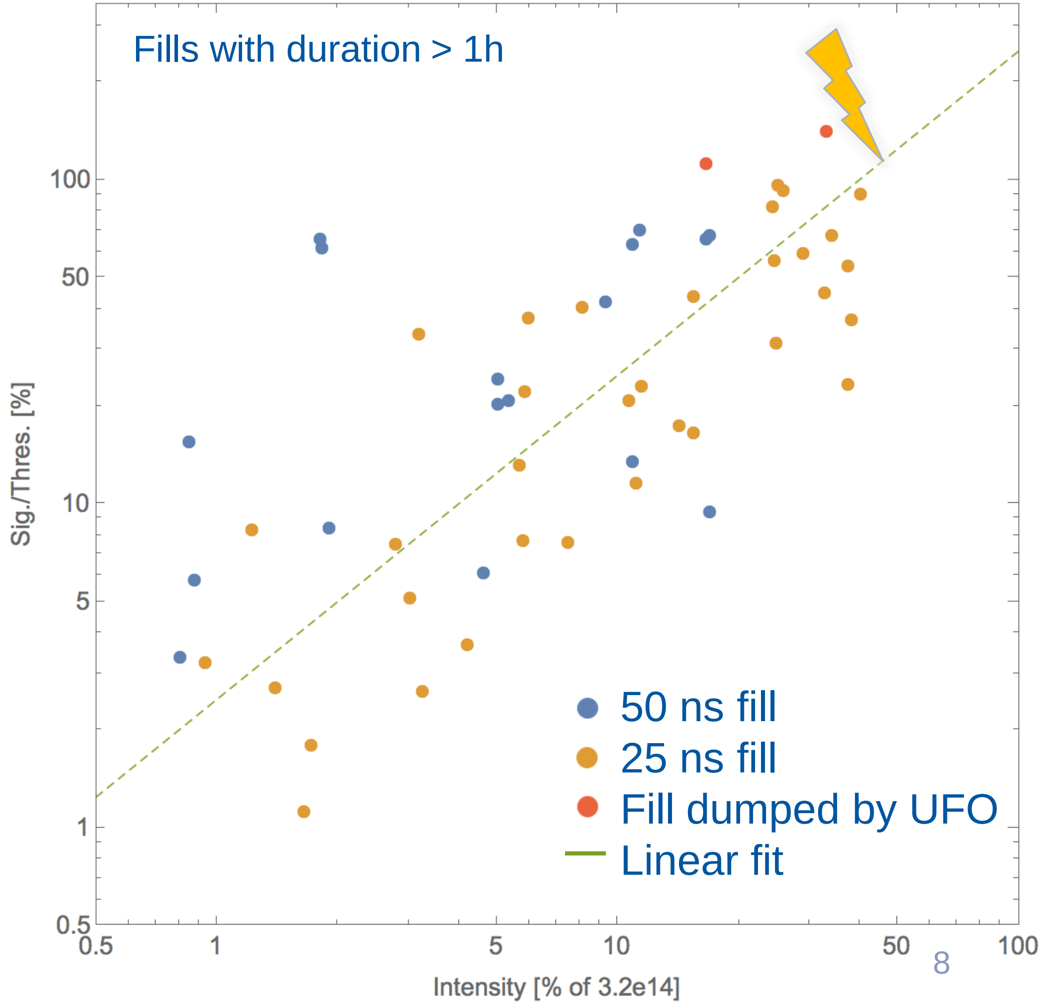
* … data at 6.5 TeV from Arc/DS, cell 12 and upwards.

BLM Signal vs. Intensity

Pessimistic outlook at LMC September 23, at first confirmed by

- 8 UFO dumps within 2 weeks (Sept. 20 to Oct. 5).
- 5 UFO dumps on Sept. 26-27 alone.

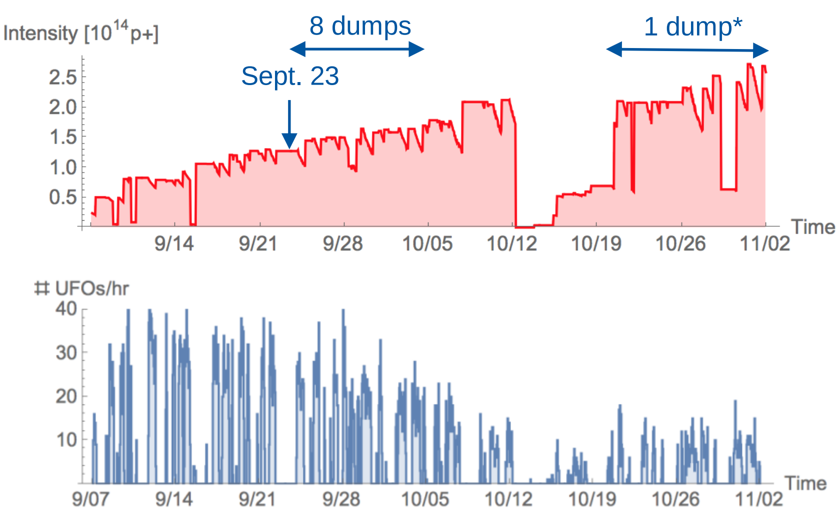


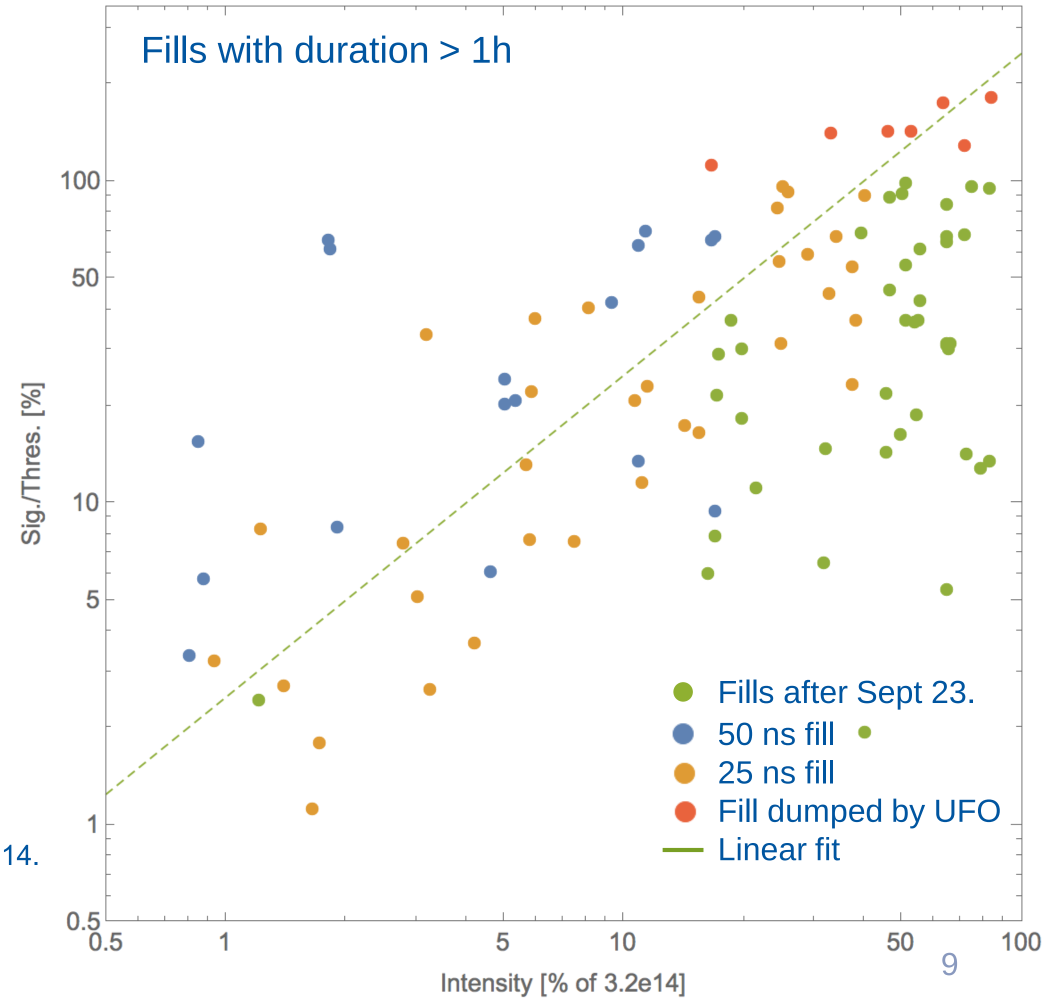


BLM Signal vs. Intensity – UPDATE

Since then, UFO rates dropped. Most fills now have lower peak losses.

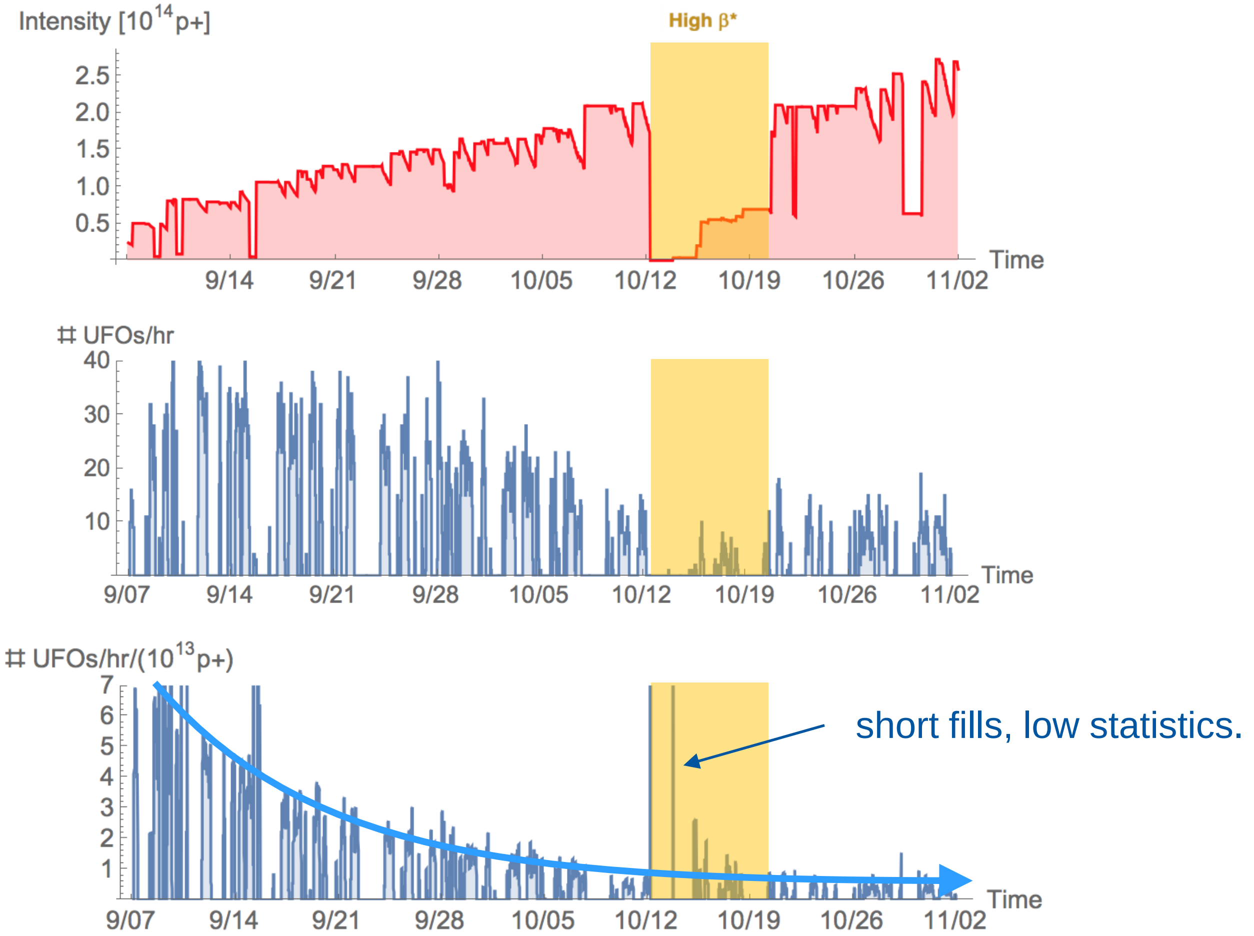
Only 1 UFO-related dump from 20.10. to 2.11.





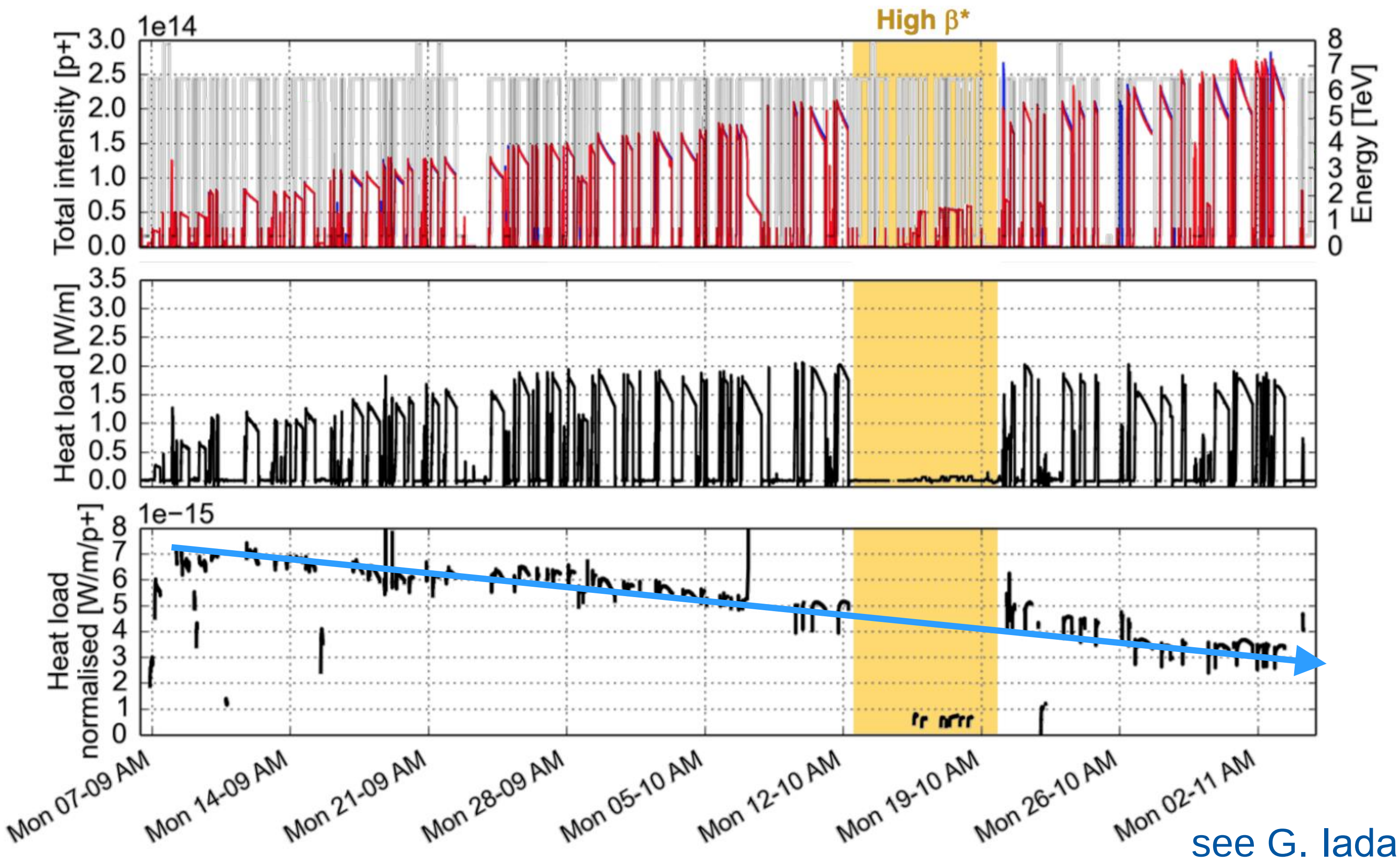
* … would be 2 dumps if thresholds had not been increased Oct. 14.

End of Conditioning?



UFO rates of ~10/h have been stable over the last 3 weeks.

Correlation with eCloud?



see G. Iadarola's talk

No direct correlation between UFO rate and eCloud heat load.

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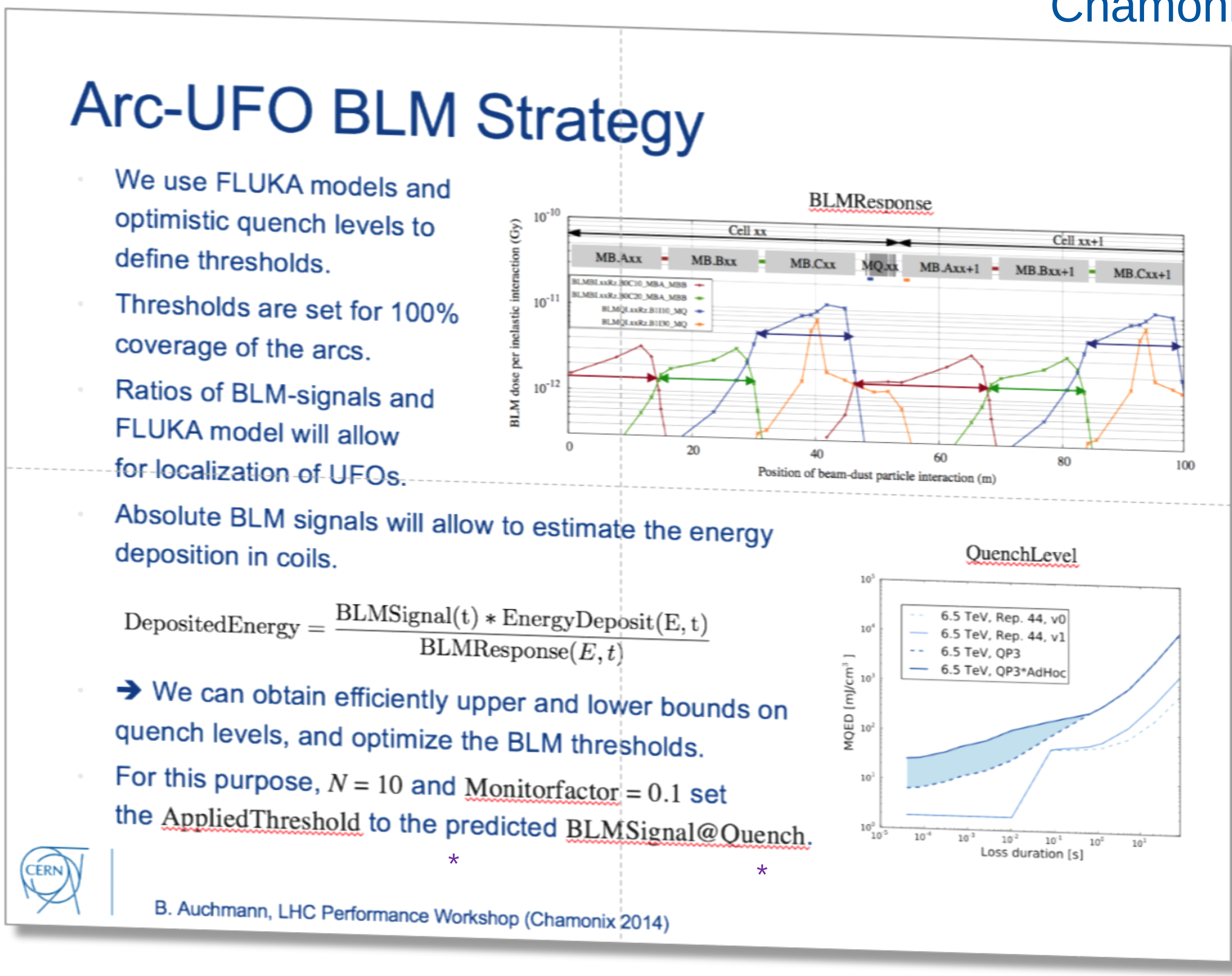
Initial Run 2 Thresholds Strategy vis-à-vis UFOs

Chamonix 2014



* .. .Eventually N=3 and Monitorfactor = 0.333 was implemented.

Strategy to prevent UFO-induced quenches by optimal BLM threshold setting.

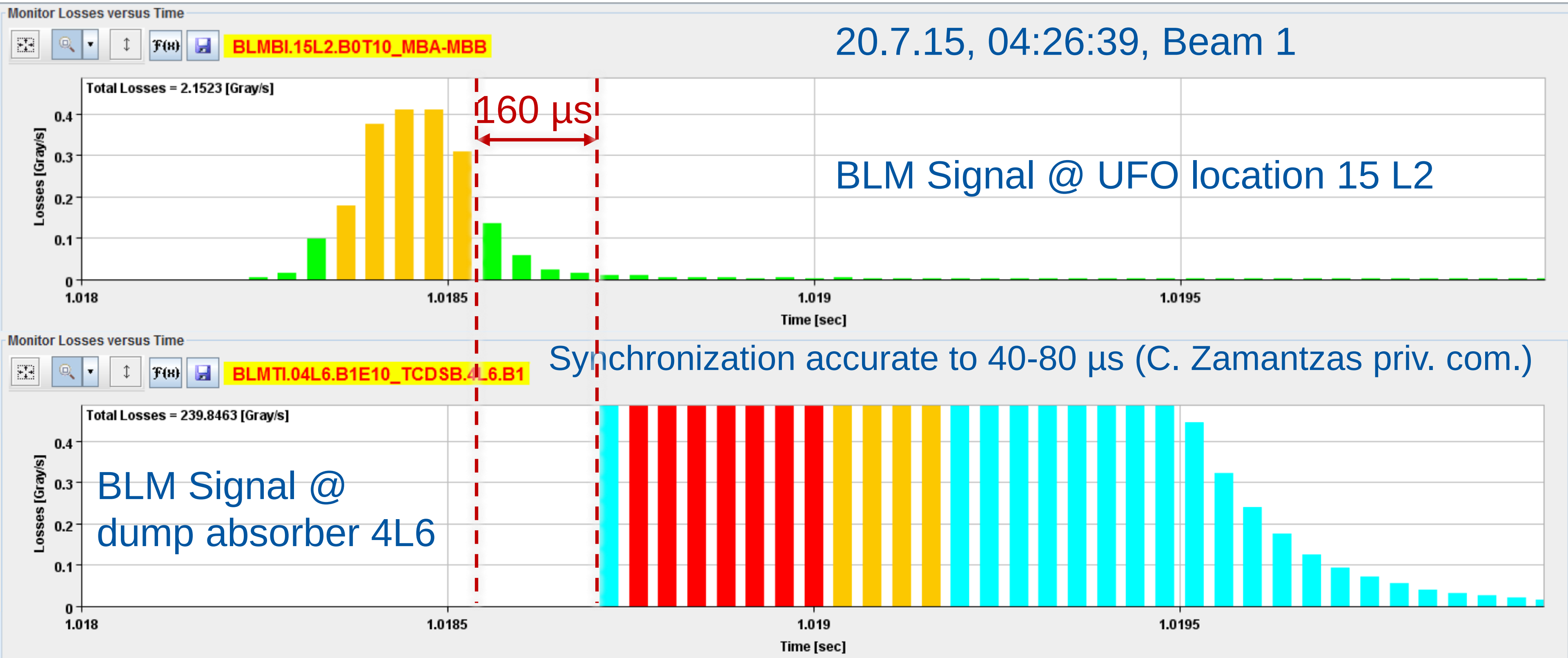
Quench Level and FLUKA model by and large confirmed by Run 2 observations.

Arc/DS Observations (1/2)

14 UFO-triggered beam dumps, 3 UFO-induced quenches not prevented.

Out of 11 dumps without quench:

- 9 were too late to significantly shorten the UFO.
- 1 may have shortened the UFO but there was no risk of quenching.
- 1 potentially avoided a quench.

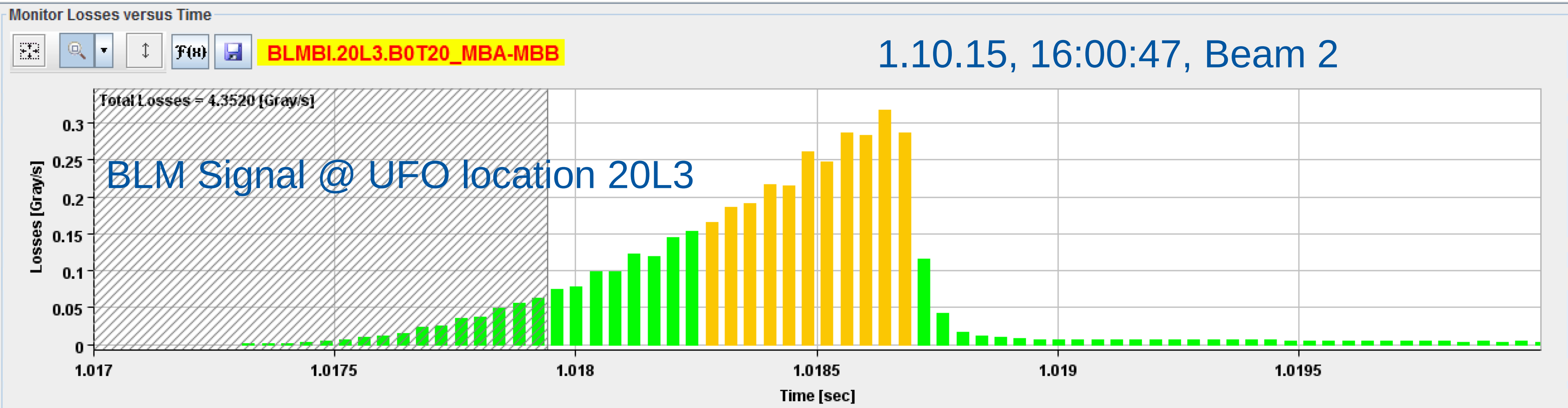


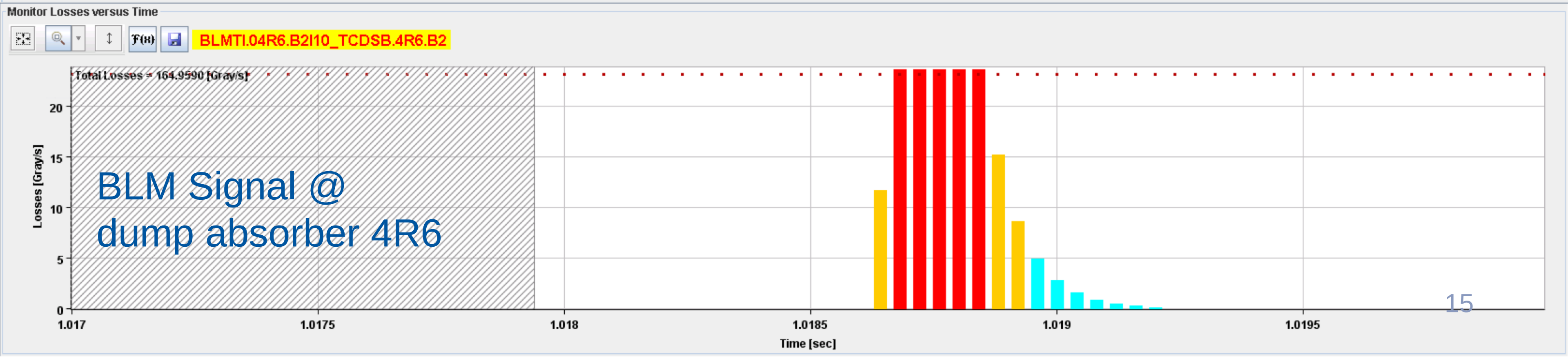
Arc/DS Observations (2/2)

Counter-example, 3rd UFO-induced quench: event shortened, but too late.

Reducing thresholds by 50% would have led to 20 additional unnecessary dumps!

Consider: ~3h lost-physics for beam dump, ~12h for quench (A. Apollonio, Evian).

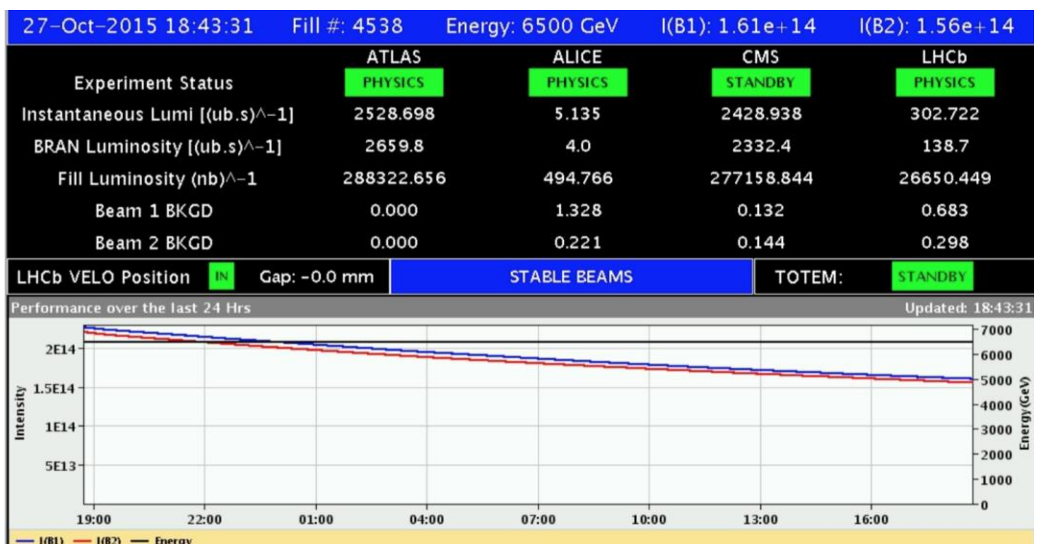




First Thresholds Increase

LMC, 14. 10. 2015, AOB: “BLM threshold mitigation strategy to avoid unnecessary UFO-related dumps”

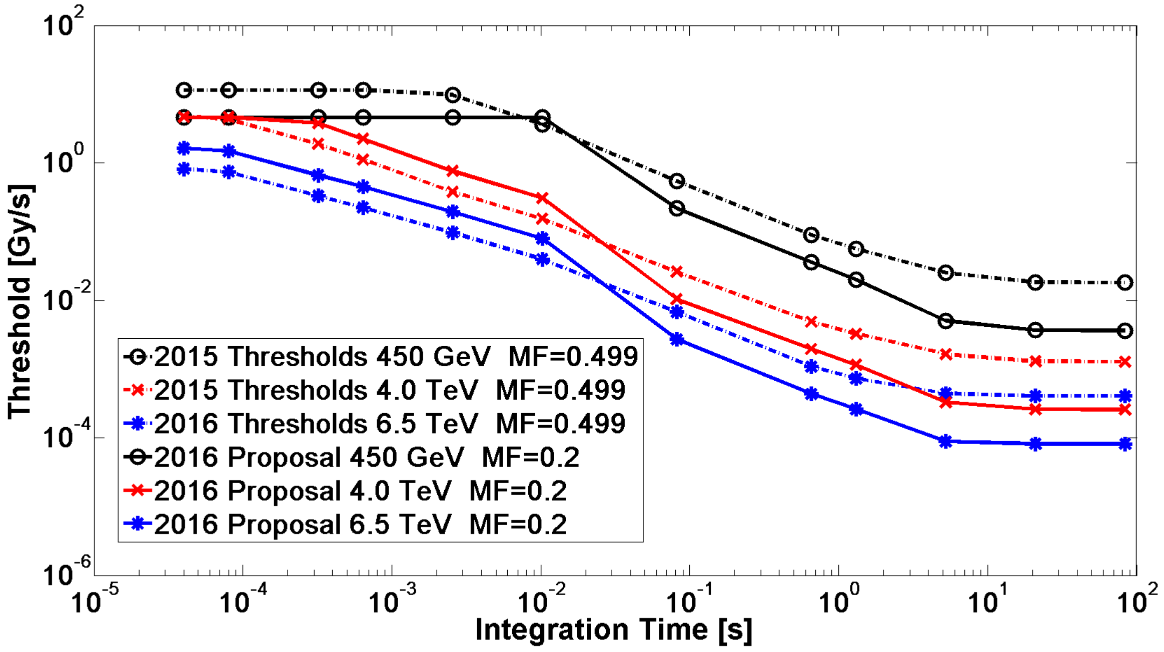
- ARC/DS thresholds were increased by 50%.
- First deviation from the initial strategy to avoid UFO-induced quenches by appropriate BLM thresholds.
- Without it, the 24-h record fill would have lasted only 16hs.
- Only 1 UFO dump (also unnecessary) during remaining 2 weeks.



Post-YETS Changes

BLMTWG proposes to continue to avoid dumping on UFOs as a strategy to maximize availability.

- increase the short Running Sums (RS 1-6) by another factor 2, while reducing the longer Running Sums to conservative values.



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- increase the short Running Sums (RS 1-6) by another factor 2, while reducing the longer Running Sums to conservative values.
- use conservative thresholds next to magnets with heater problems.
- re-discuss these settings if more than ~15 quenches per year.
  - rationale: 15 quenches is comparable to expected flattop training quenches, much fewer heater firings than spurious QPS triggers (resets, etc.).

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- use conservative thresholds next to magnets with heater problems.
- re-discuss these settings if more than ~15 quenches per year.
- How often will we quench due to UFOs in 2016?
  - 2015 saw 2 quenches with ~500 bunches, and 1 quench with 1500 bunches.
  - Lack of data, and uncertainty on UFO rates, do not allow for extrapolation.
    - Situation in weeks after YETS unclear (re-conditioning, scrubbing, intensity ramp).
  - However, the last 2 months of proton operation saw only 1 quench (with 0 quenches avoided by BLM-triggered beam dumps).

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    - Situation in weeks after YETS unclear (re-conditioning, scrubbing, intensity ramp).
  - However, the last 2 months of proton operation saw only 1 quench (with 0 quenches avoided by BLM-triggered beam dumps).
- Action: study if BLM triggers can be adjusted in LS2 to improve sensitivity to UFOs (e.g.: dI/dt threshold or ratios of RSs).

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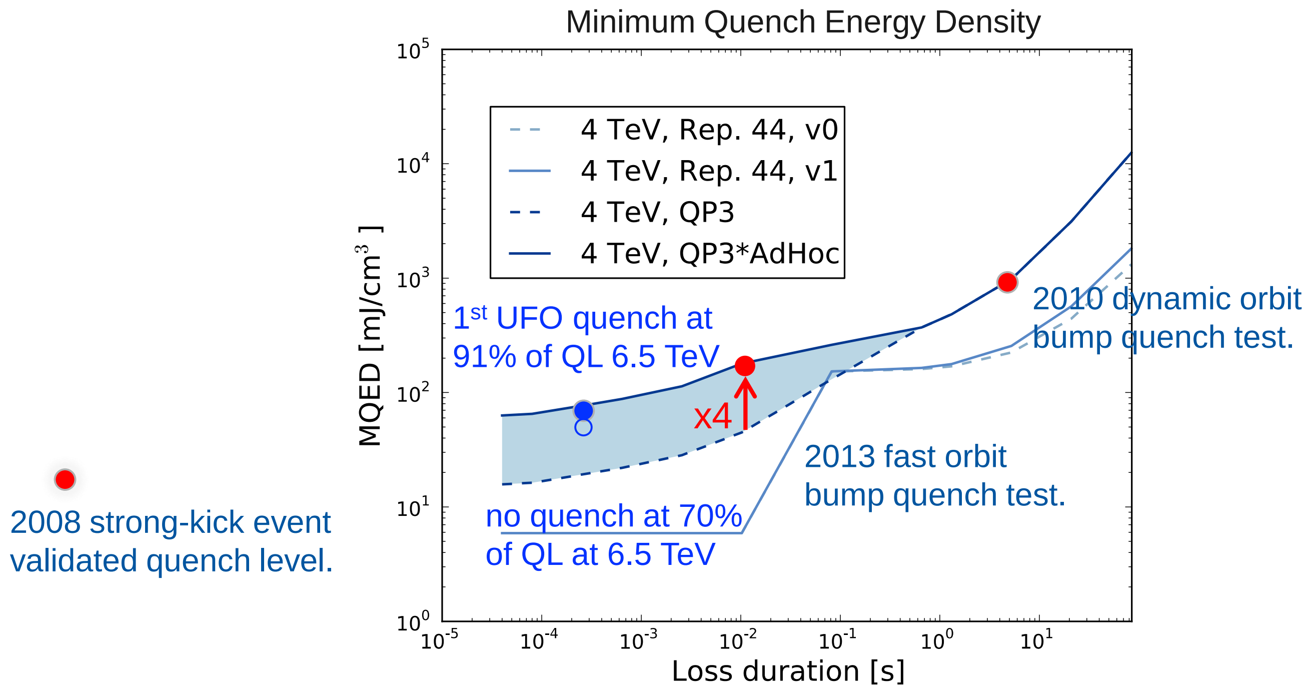
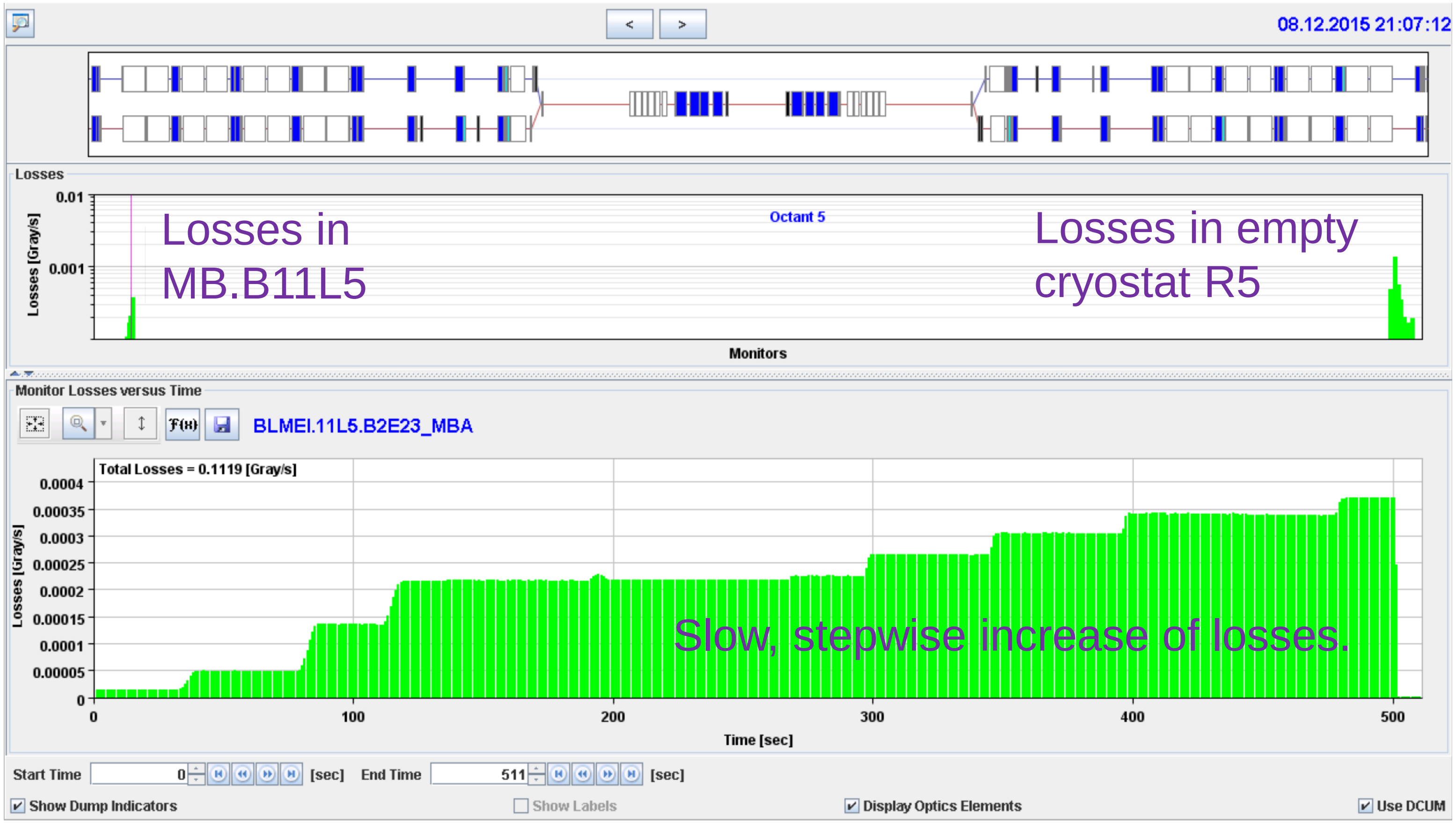
UFO-Time-Scale Quench Level (2/2)

Studied numerous UFO events for information on quench levels.
Quench at 91% of quench level by and large confirmed assumed limit.



Steady-State Quench Level (1/3)

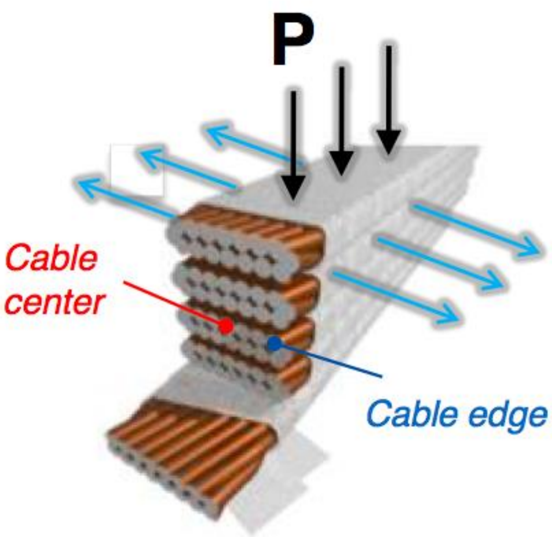
BFPP quench test. First direct measurement of steady-state quench level.

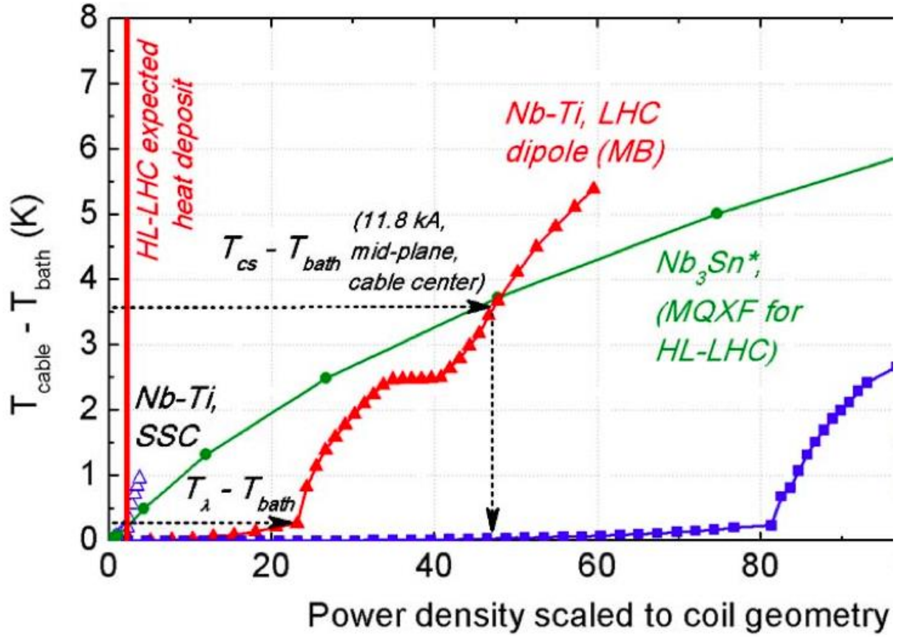


J. Jowett, T. Mertens, M. Schaumann

Steady-State Quench Level (2/3)

Previous assumptions on steady-state quench level were based on 10-stack measurement.



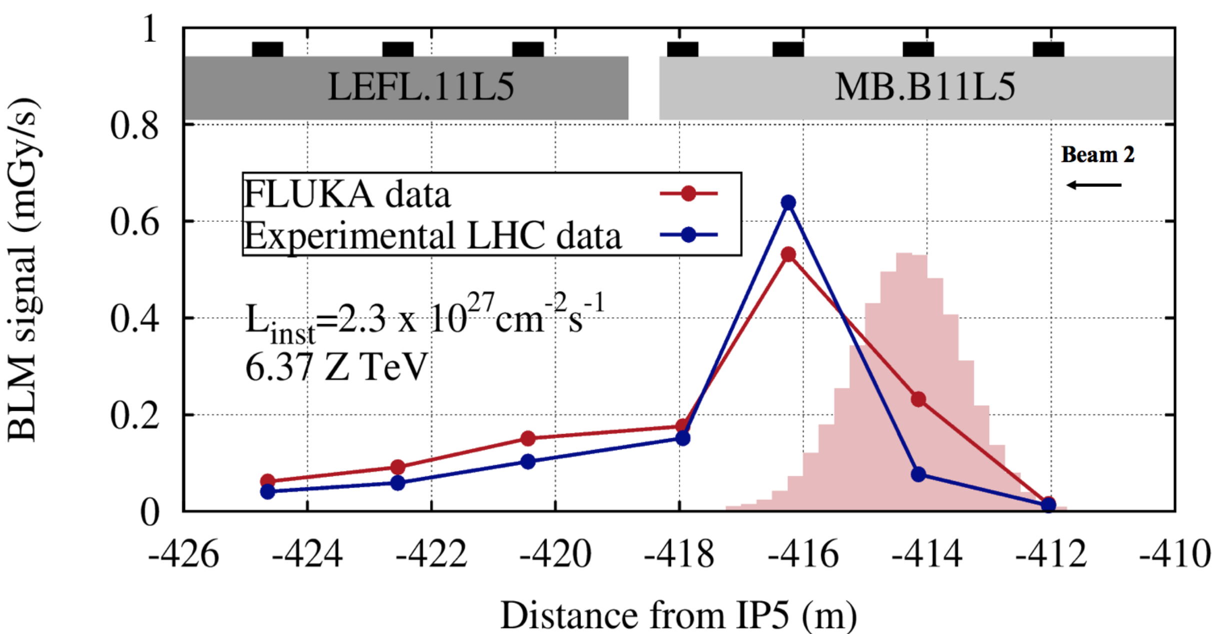


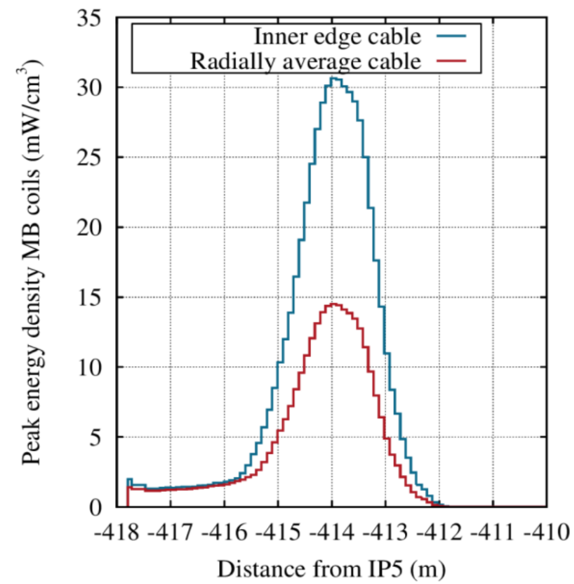
Graphs and drawings from P.P. Granieri et al., “Deduction of Steady-State Cable Quench Limits for Various Electrical Insulation Schemes With Application to LHC and HL-LHC Magnets”, IEEE Trans. on App. SC, Vol. 24(3), June 2014. “

Steady-State Quench Level (3/3)

Preliminary analysis of BFPP quench test by FLUKA team shows 2-3x lower quench level.

Analysis of collimation quench tests ongoing; see S. Redaelli's talk.





C. Bahamonde, A. Lechner
For more see talk by J. Jowett.

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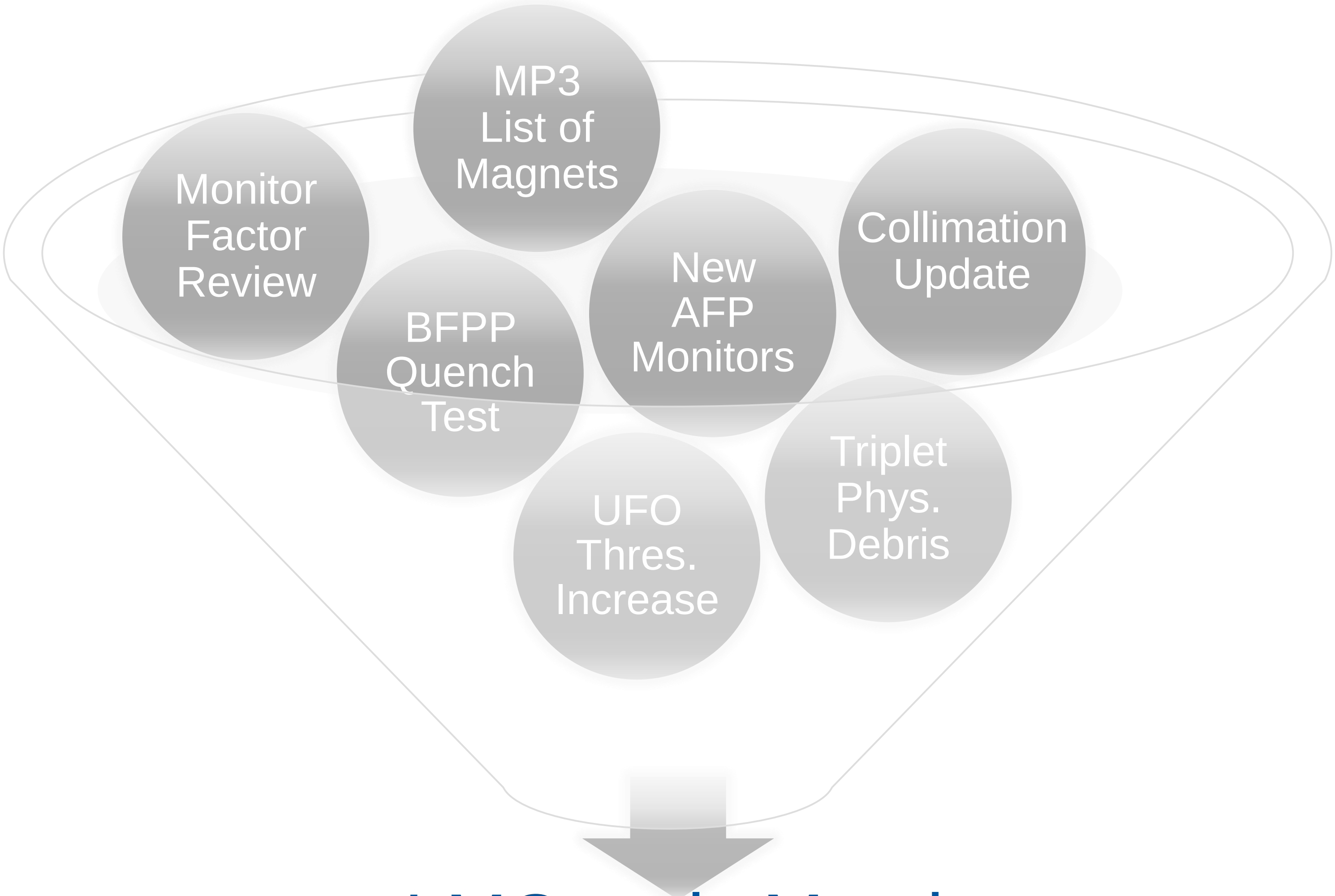
More YETS Thresholds Updates



LMC early March

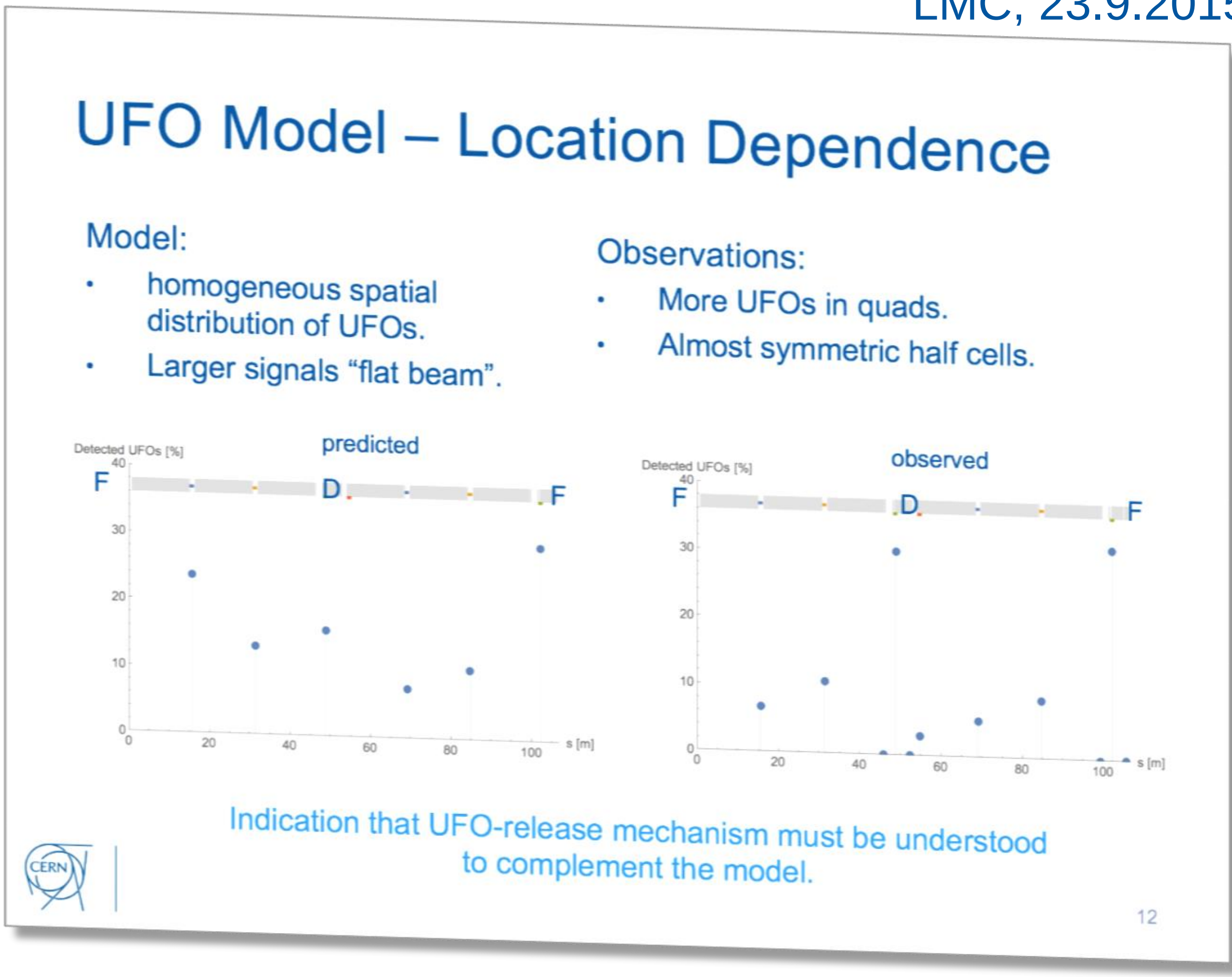
Summary

- The orbit bump around the ULO can be increased x2.
- UFO conditioning “saved the day” in 2015.
- More conditioning cannot necessarily be expected.
- BLM thresholds + beam dump not effective for prevention of UFO-induced quenches.
- UFO-induced quenches appear rare enough to propose a strategy that aims to avoid BLM triggers on UFOs.
- Improved knowledge on quench levels in the UFO time scale – they are close to the assumed values.
- Steady-state quench levels are 2-3x lower than assumed – see talks by J. Jowett and S. Redaelli.

EXTRA SLIDES

UFO Location Conundrum

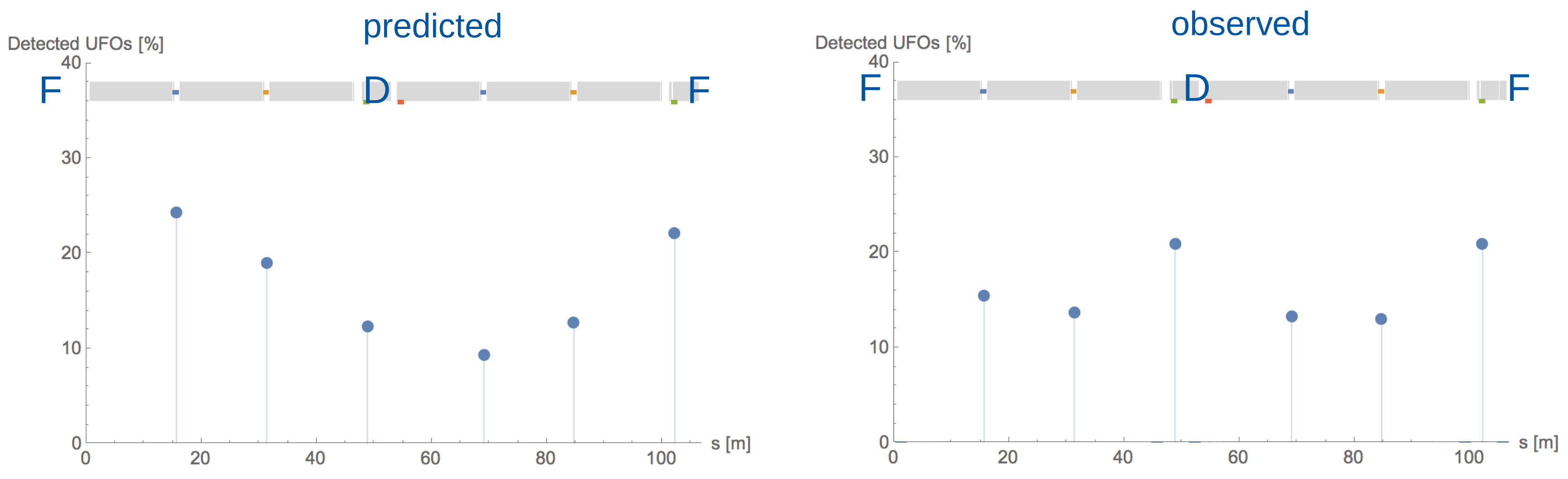
LMC, 23.9.2015



Initial analysis indicated: 62% of UFOs detected by monitors on quads, 38% on dipoles. ***No clear reason as to why this should be the case!***

UFO Location Conundrum (Partially) Resolved

- Re-examined the algorithm to compensate for UFO-buster bias.
- Cut on larger UFO events.
- Apparent predominance of quad monitors disproved, though significant differences to the UFO model remain.



Updated analysis yields 44% of UFOs detected by BLMs on quads and 56% on dipoles.

YETS BLM Thresholds Updates

Monitor factor review
- assign a default factor for each family.
- verify that deviations from default are temporary.
- no net changes to thresholds.

ARC/DS
- Increase in UFO time scale.
- Reduction for steady-state losses
(after completion of BFPP quench test analysis).

MP3 List of Magnets
- Heater issues, slow trainers, protection issues for symmetric quenches.

AFP
- new monitors, same thresholds as TOTEM.

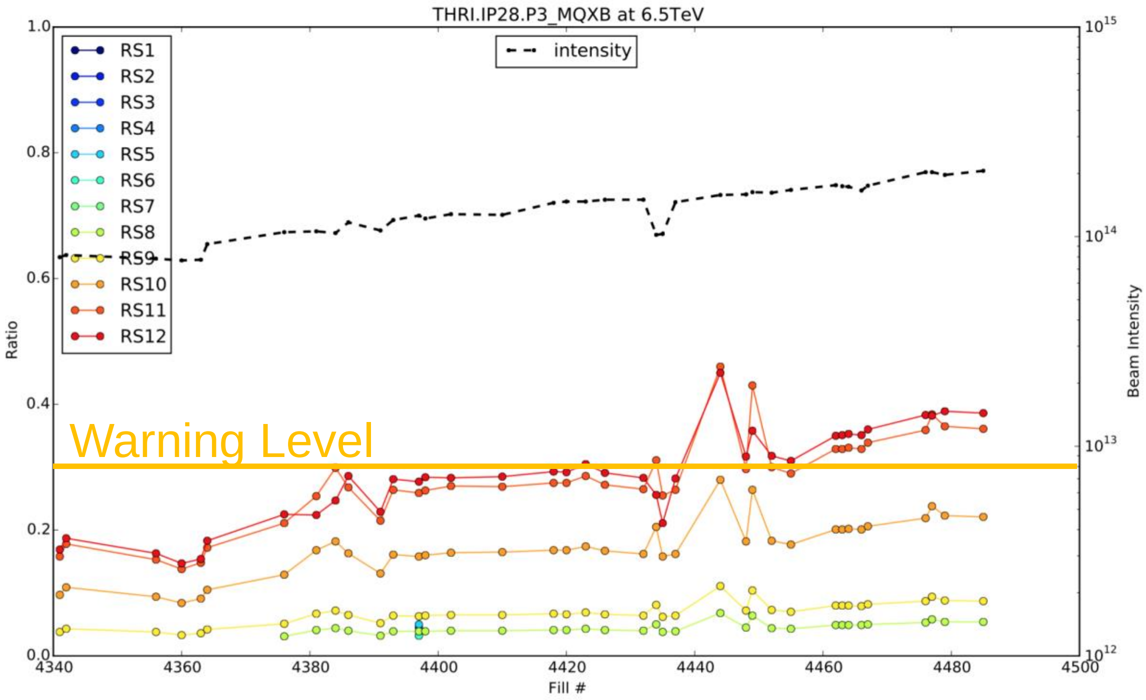
Triplets
- Corrections to long running sums to avoid operating constantly in warning level due to physics debris.

Collimation
- Larger update under preparation.
- Scope of YETS updates under study.

BLM Signal-to-Threshold Tracking

Goal: spot and analyze trends pro-actively.

- Python + Logging DB API (Chen Xu).
- Extract the largest Signal-to-Threshold ration per fill, monitor family, integration time window (running sum) and beam mode.
- Example: FLATTOP+SQUEEZE+ADJUST+10' STABLE BEAMS:



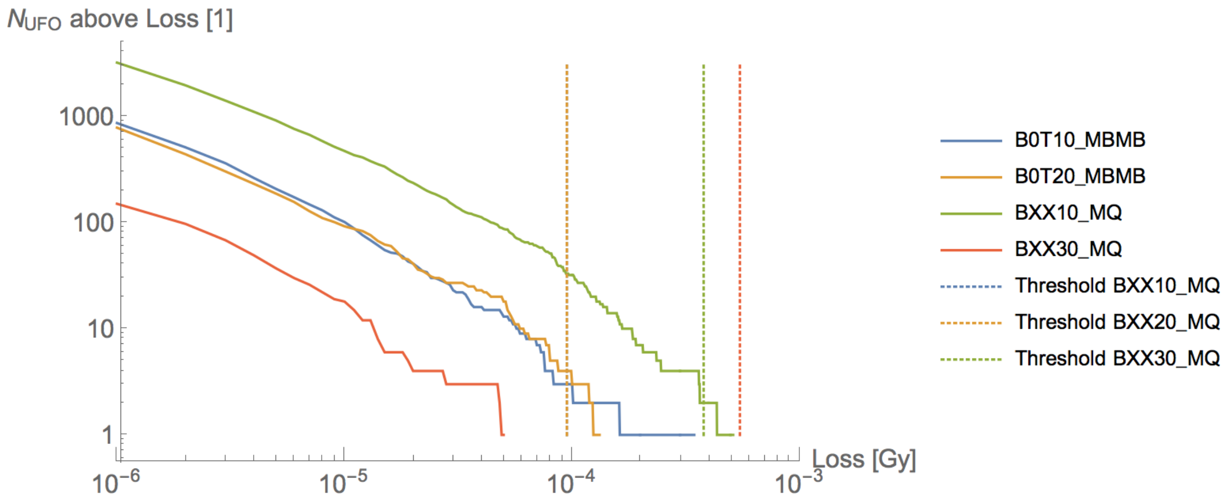
Detected erroneously low thresholds on specific triplet family.

UFOs at 7 TeV?

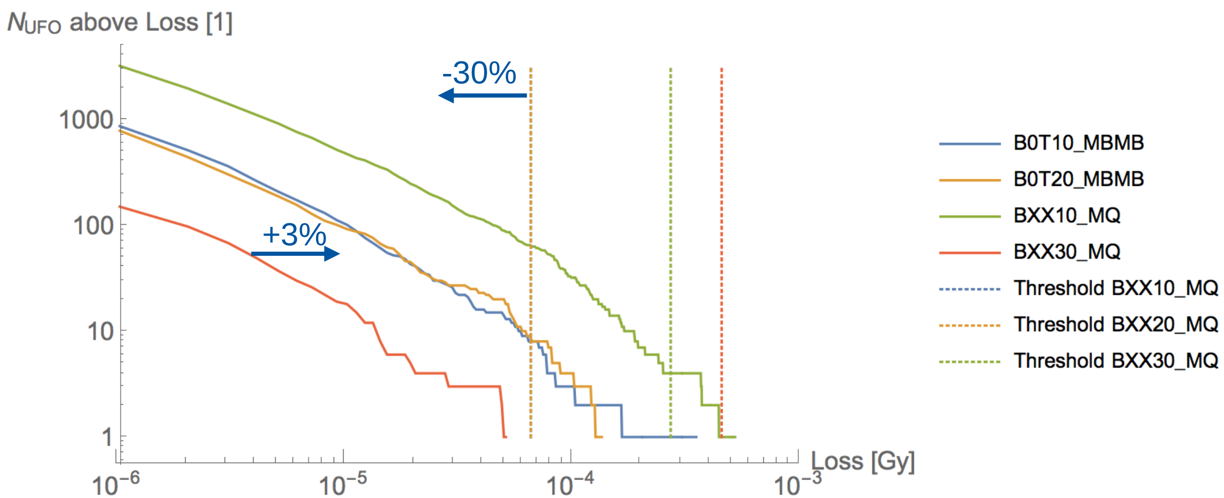
- We are not in a position to predict a UFO rate as a function of energy.
  - The reference run at 2.54 TeV would indicate that rates increase with energy; but there is not enough data for an extrapolation.
- To find an estimate on trends, we
  - use the UFO data from 2015 at 6.5 TeV in arc and DS cells 12 and above.
  - assume that the UFO dynamics remains roughly the same (same average number of inelastic collisions per interaction at 6.5 and 7 TeV),
  - make a cut on the observed events at the BLM signal strength that is compatible with a magnet quench. Events in this category only result in a quench if the UFO occurs in a position of low BLM sensitivity.
  - count **9 events in 2015** (with 2 actual quenches).
  - update the above cut in order to take into account the scaling from 6.5 to 7 TeV of quench levels (-25%), BLM response (+3%), and energy deposition per inelastic collision (+12%); which makes an overall reduction by 30%.
  - scale the observed BLM signals by the increase in BLM response.
  - count **21 events after** the two above **adjustments for 7 TeV**.
- In conclusion, the number of ***potential quenches*** appears to ***roughly double at 7 TeV***.
  - The error bars are relatively high (data taken from steep curve in loglog plot).

UFOs at 7 TeV?

6.5 TeV
RS 4



7 TeV
RS 4



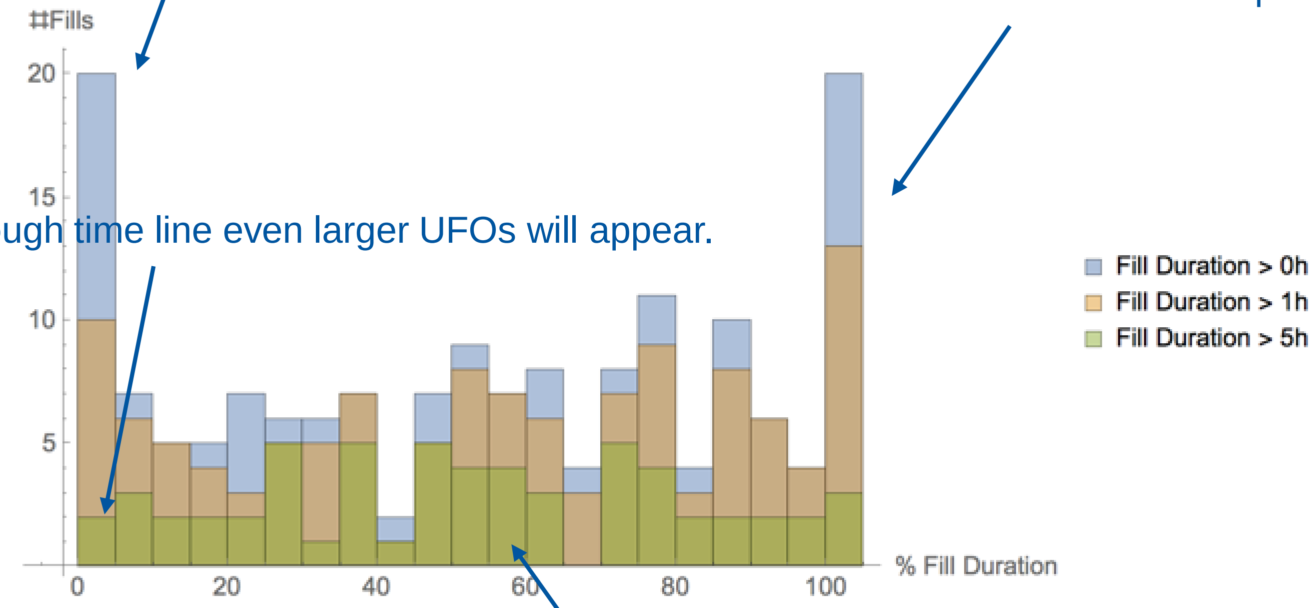
Timing of Peak Loss in Fill

- When is the maximal Signal/Threshold ratio registered over the flat-top duration of a fill?

Higher probability for larger events upon arrival on flattop.

Includes fills dumped by UFOs

On a long enough time line even larger UFOs will appear.

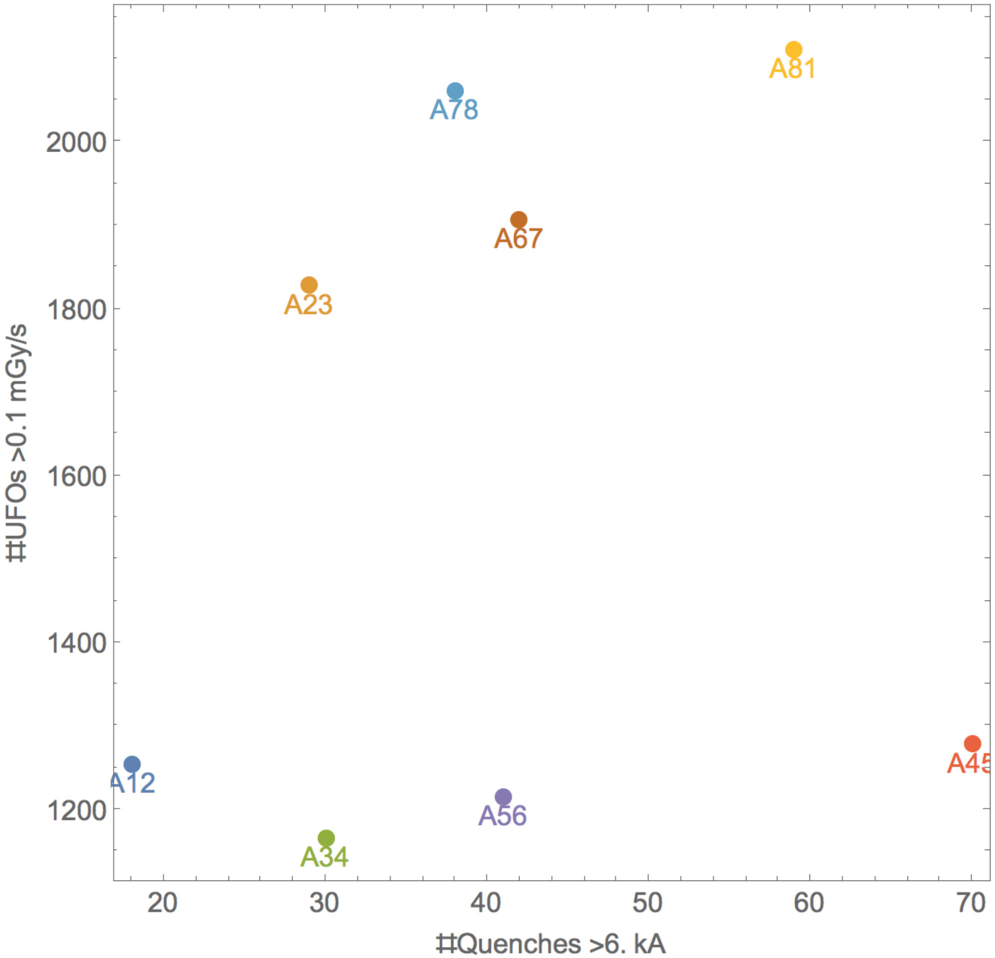


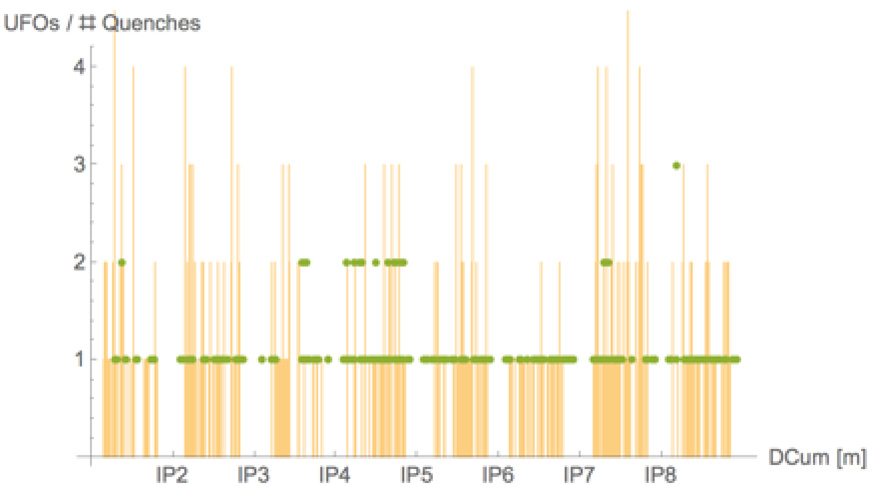
Distribution is flat for longer fills.

- For fills longer than 1h, the distribution basically is flat.

Other Studies: Training Quenches

Analysis per sector revealed no correlation.

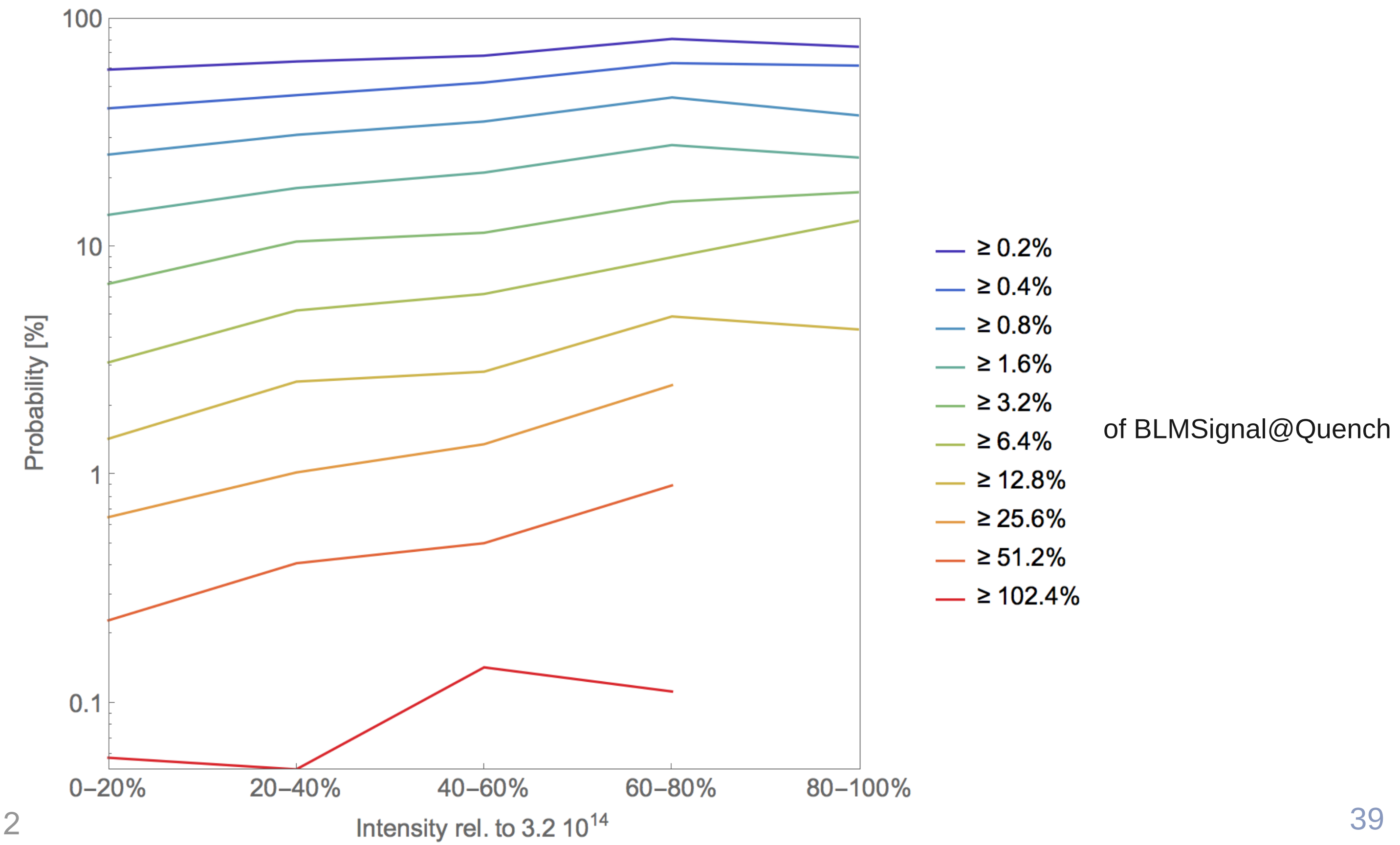




orange: UFOs
green: training quenches

BLM Signal vs. Intensity

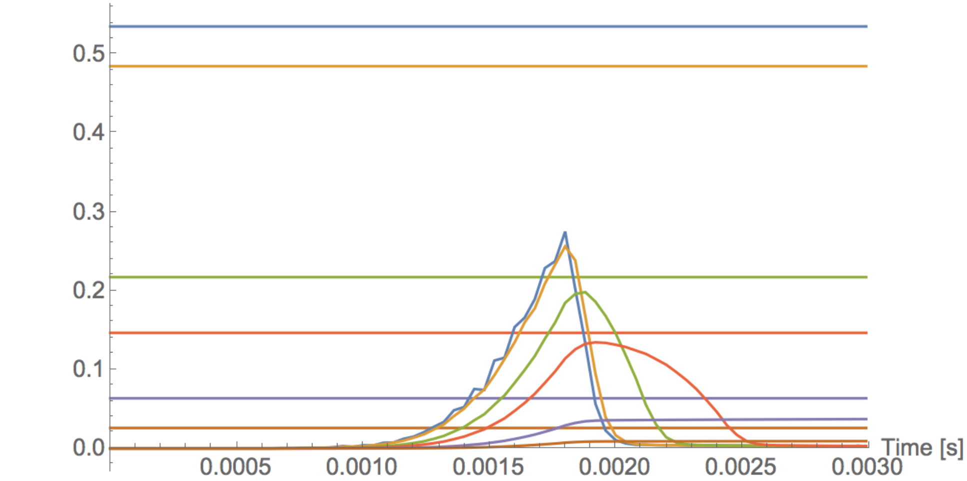
- Probability to reach percentage of BLMSignal@Quench (threshold up to Oct 14) as function of beam intensity.
- Plot shows correlation with intensity, irrespective of the UFO rate.



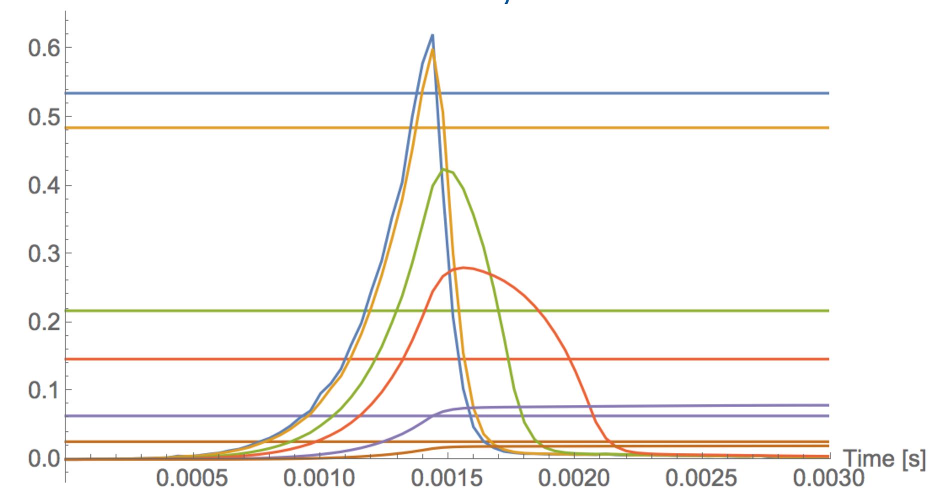
UFO Quenches

How much a reduction would it take to avoid these quenches?

2015.07.14, 00:05:03



2015.08.15, 00:56:49



Relatively slow quench-voltage rise indicates we just managed to quench.
Reducing 1/3 could reliably avoid this quench.

Step-function quench-voltage rise – large volume quench simultaneously.
Reduce at least 1/2 to avoid this quench.

- Thresholds have to allow for ~200 µs delay to dump the beam.
- The UFOs dropped in the least sensitive location of the BLM system.
- In most other UFO locations the thresholds are more than adequate.

Other Studies: BCMS, E-Cloud Effect

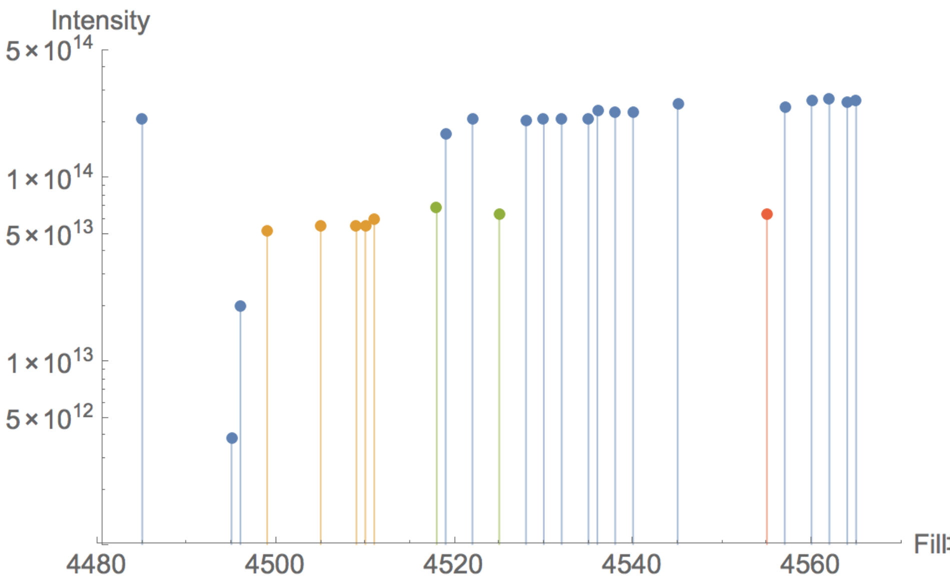
90-m run with ~1/5 e-cloud-related heat load (100 ns bunch spacing).

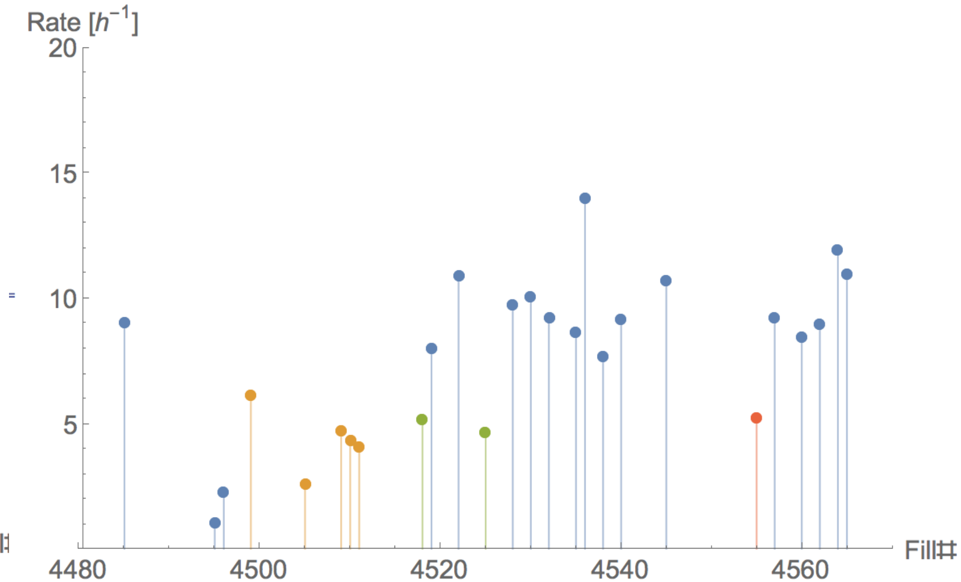
- UFO rate roughly the same.

BCMS fill with ~1/4 lower emittance.

- UFO rate roughly the same. (Only 1 fill.)

- 90-m run
- BCMS fill @ 6.5 TeV
- comparable intensity fills
- other fills





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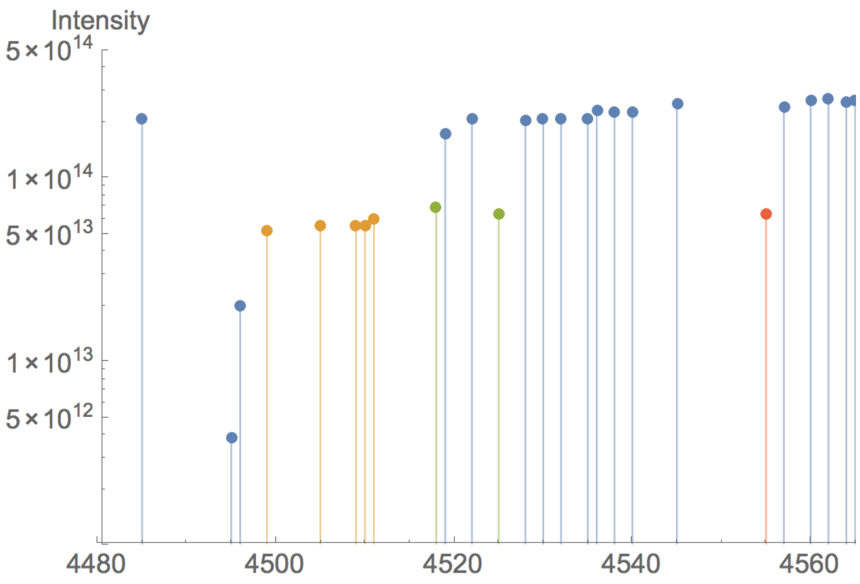
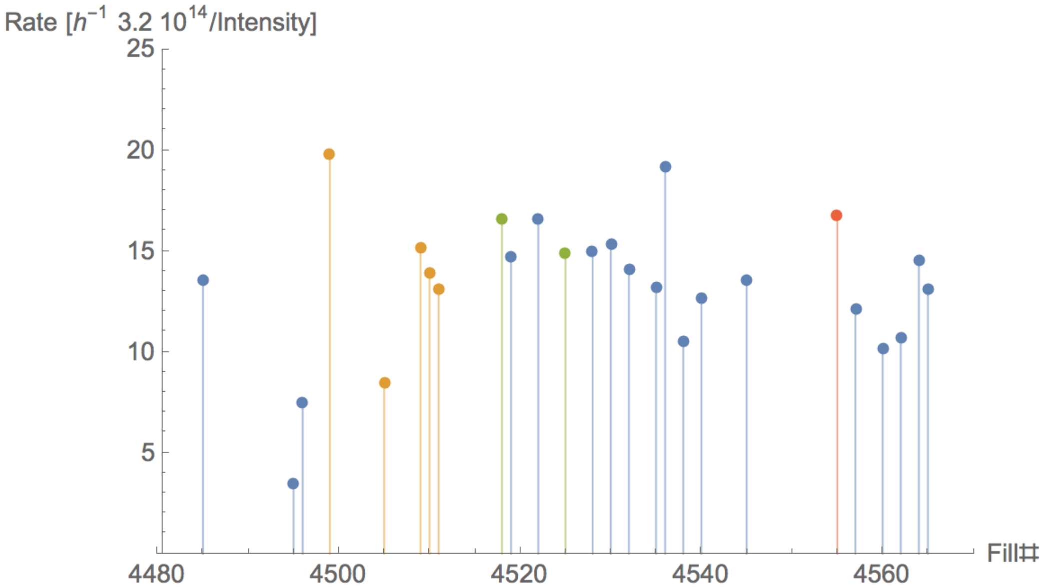
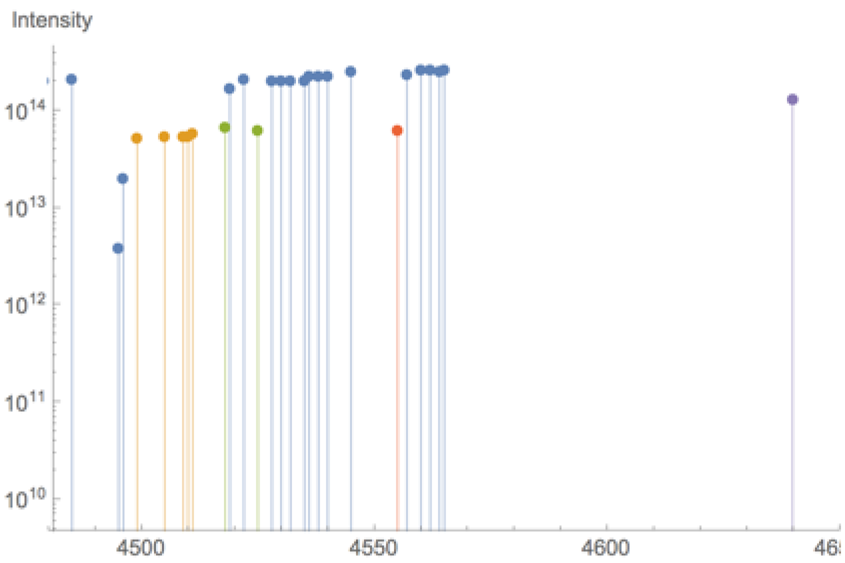
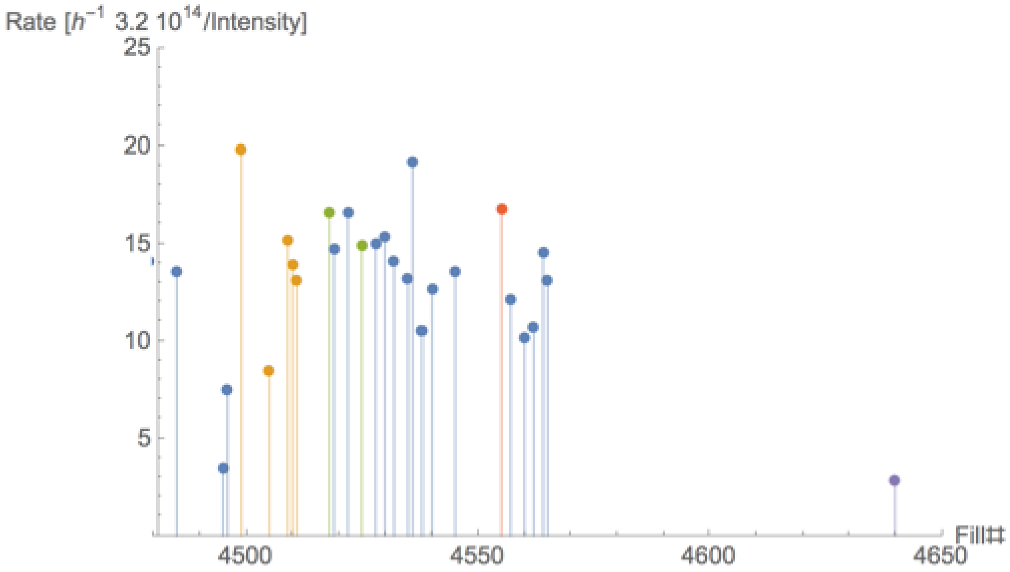




2.51 TeV Run

- Very few (8) registered UFOs during reference run.

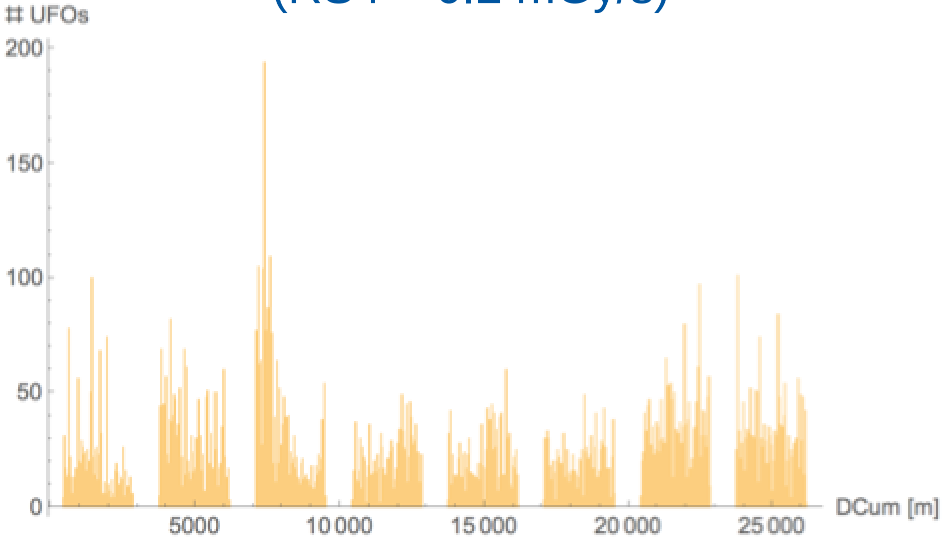




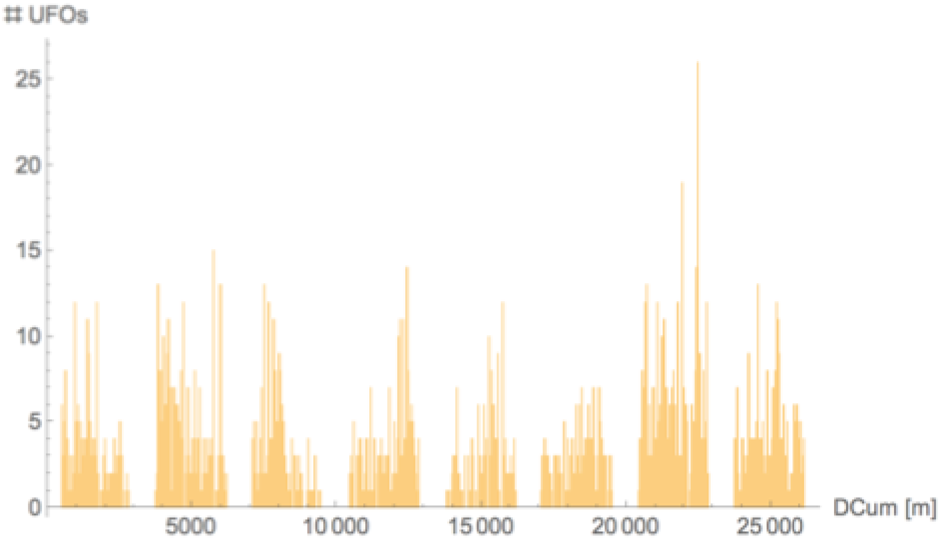
Location Around the Ring

The peak in Sector 34 disappears for larger UFOs.

All recorded UFOs
(RS4 > 0.2 mGy/s)

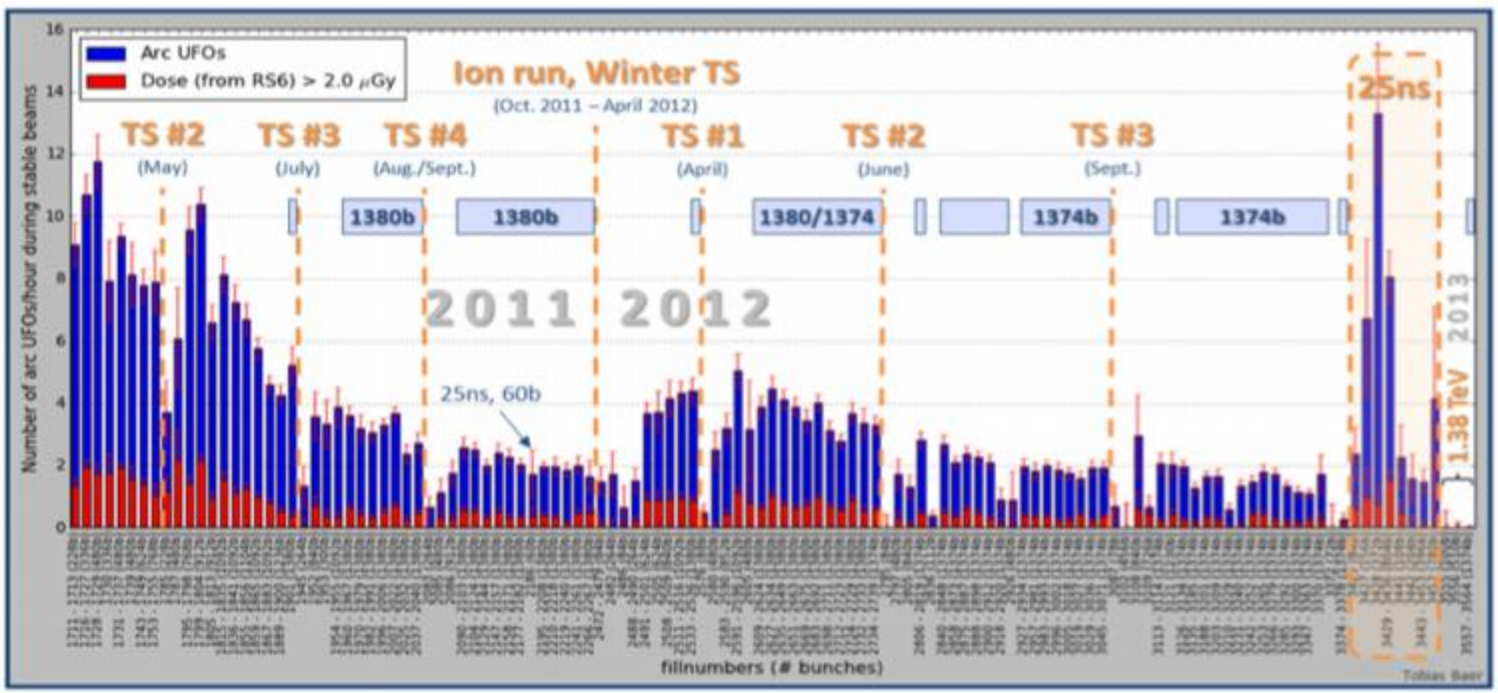


UFOs with RS4 > 10 mGy/s



2011-2012 Experience

- UFO buster in 2011 starts at 10/h and reaches an asymptote at 2/h.
- This was with a different BLM distribution in the arc/DS cells and at a different energy.
- We may expect an increase in rate after YETS.



T. Baer

Parasitic monitoring of beam losses

- Clear **loss spikes** (i.e. exp. decay and peak > 1e-6 Gy/s) looking at **1.3s BLM running sum**

*Most of them **synchronised** with **injection or inj. cleaning***