UFO observations with IC and diamond BLMs

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Study of UFO dynamics

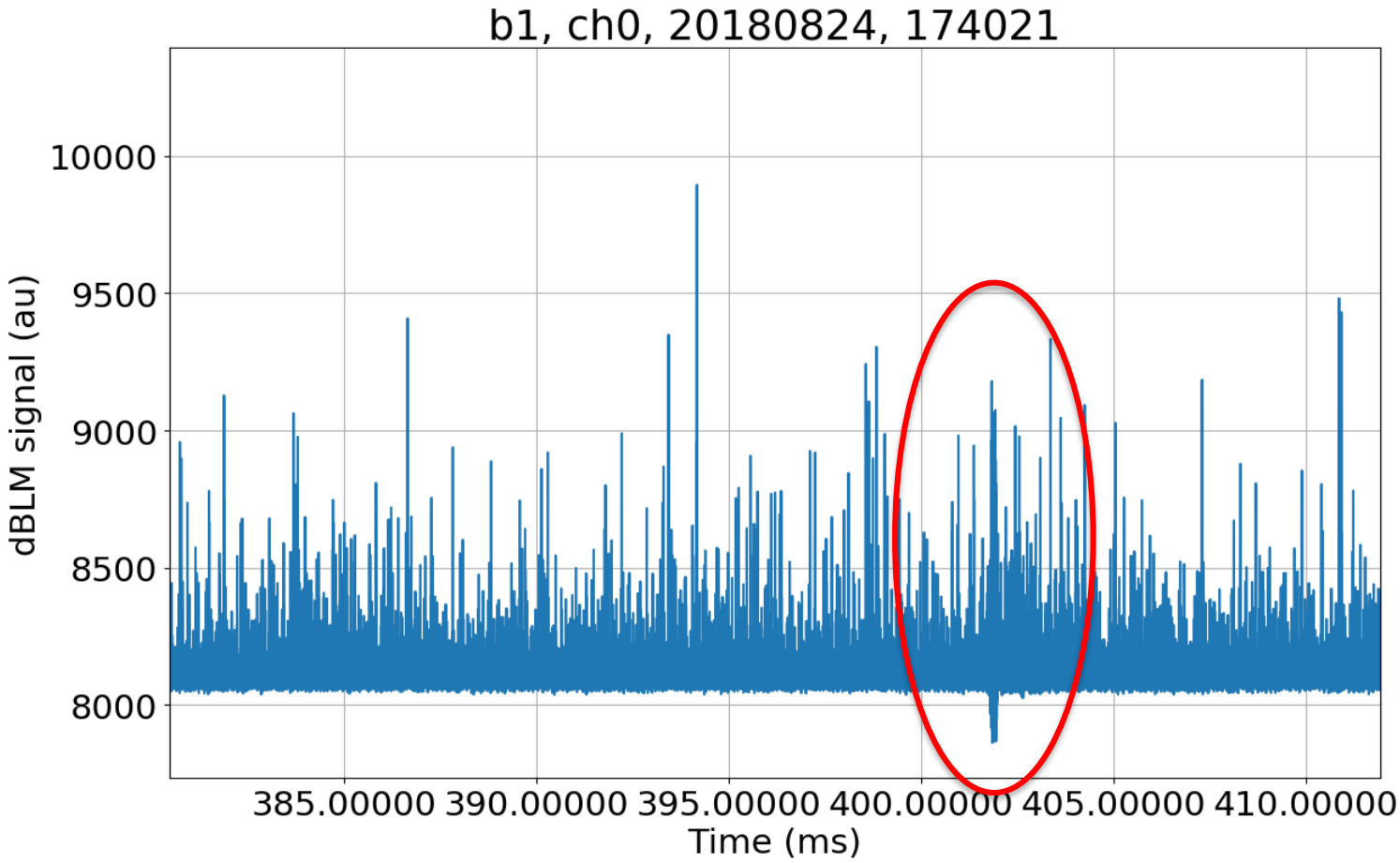
- Requires **blown-up** bunches, and ideally **displaced** bunches
- Goals:
  - Understand the **release mechanism**
    - Do UFOs **statistically drop** from the beam screen?
    - Can they be **charged** and **attracted** by the beam?
  - Benchmarking of the **dynamics simulation model**
  - Identifying dust particle **size and material** (benchmarked by measurements)
  - How **conditioning/deconditioning** mechanism works
  - Identify their **origin** and how to **best operate** in their presence
- **Triggering algorithm** for recording UFOs with **dBLMs** in IR7 was implemented and blown-up bunches used during standard operation

Readout system and Trigger algorithm

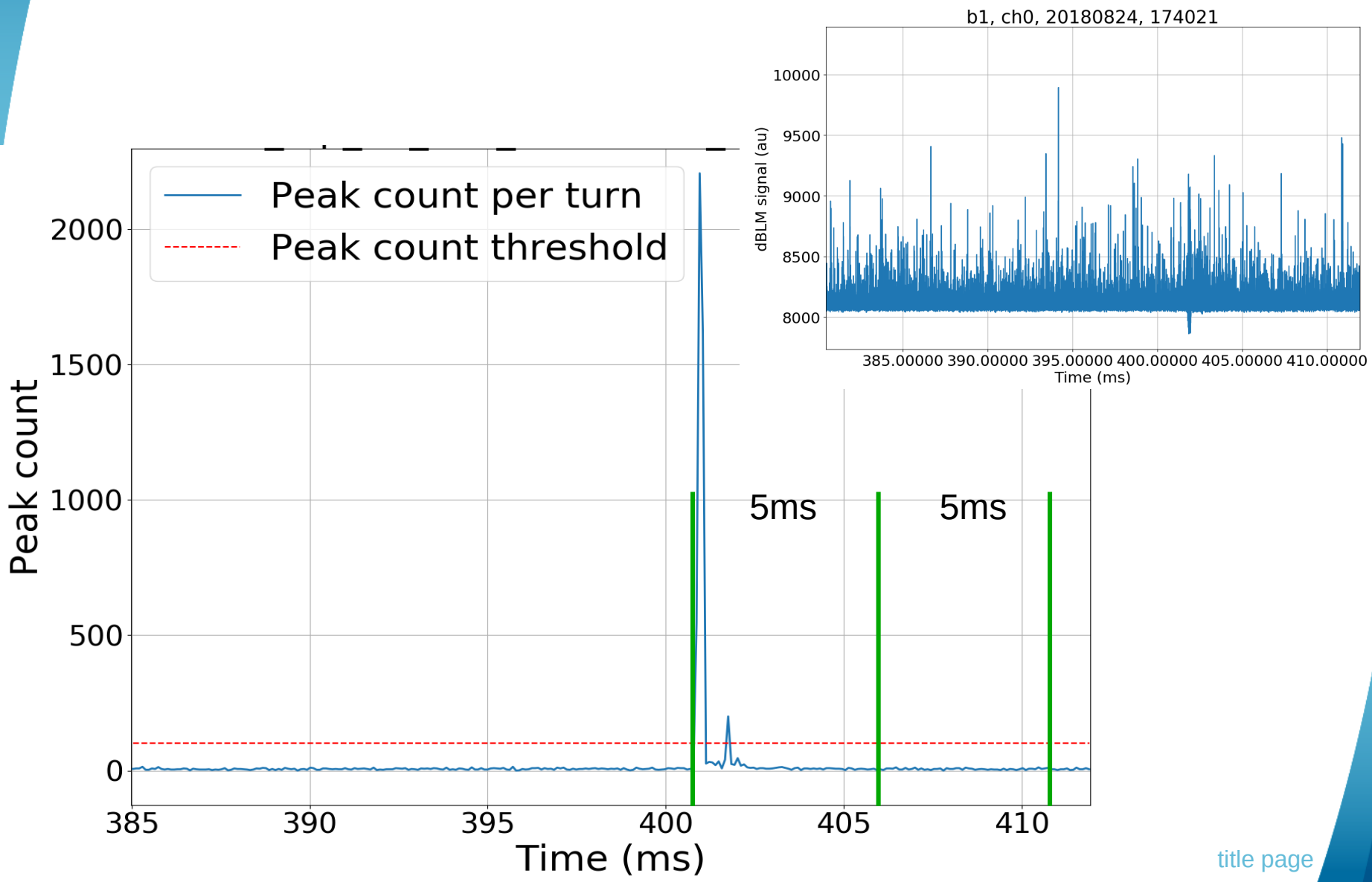
- **VFC FPGA** based readout system installed in parallel to ROSY in 2018
- Allows **flexible** and advanced **triggering**
- Two algorithms in parallel:
  - Signal above 8200 bits from min 100 bunches in one/several turns in a 5 ms window **AND** condition not fulfilled in the next 5 ms window
  - Total integrated signal in 5 ms window above threshold **AND** condition not fulfilled in preceding and following 5 ms windows
- ~1 UFO recorded per beam day *(~2 from UFO buster)*

Trigger example

- UFOs hidden by background losses in TCP region

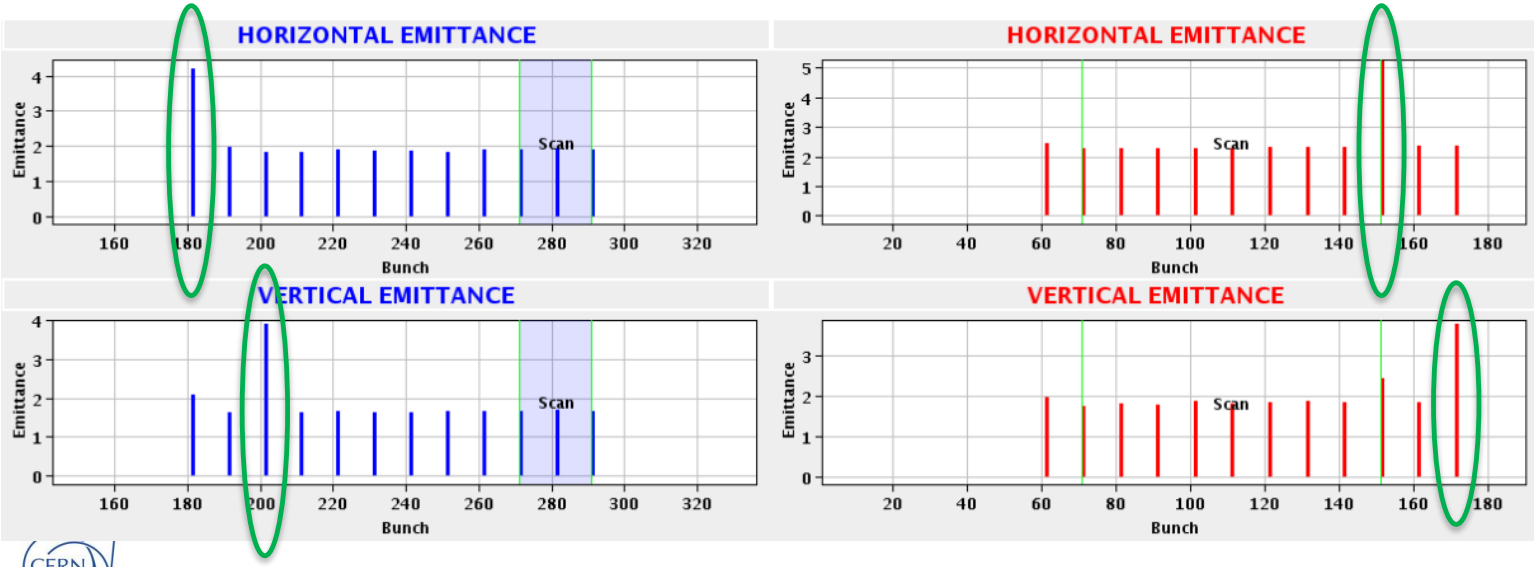


Trigger example



UFOs at end of run 2 proton physics

- **Automatic script** for blowing up bunches implemented by ADT expert
  - Manually triggered at injection, manual confirmation of successful result, no problems encountered
- Routinely used during physics fills from Sep 29 (f7234) until Oct 23 (f7334)
  - **24 fills** with blown-up bunches (2 oo 12 non-colliding)
  - 205.2 hours of SB, 16.9 hours of RAMP
  - **13* UFOs** detected by **dBLM** (2 during MD period)
  - 3 at top energy, **all others during ramp 1096-4522 GeV**
  - **6 coincident triggers** dBLM/UFO buster (out of 33 detected by UFO buster)
- **No issues** in machine operation due to ADT blow-up were observed



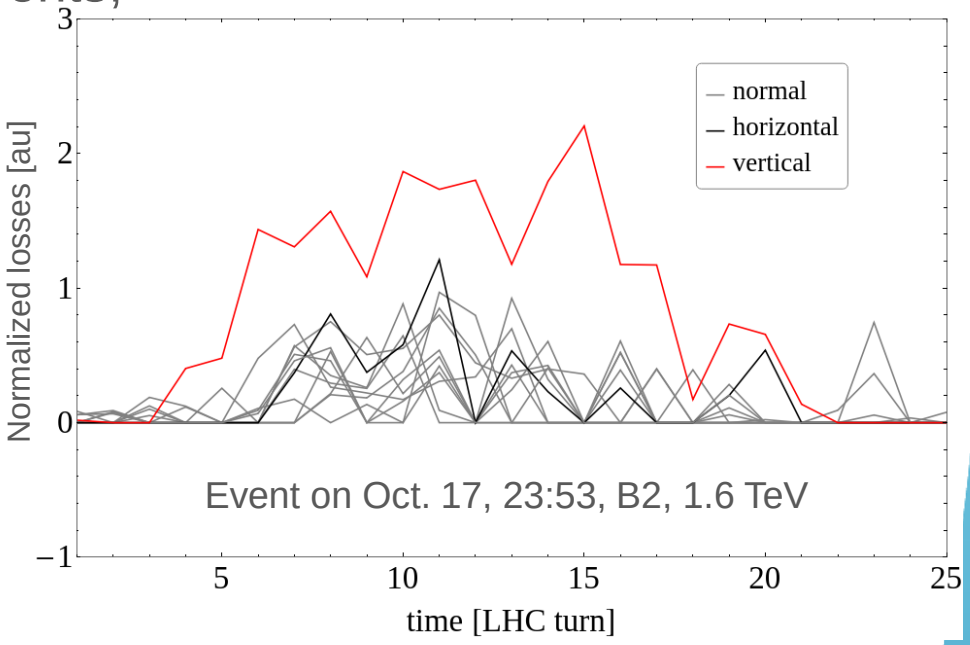
* detailed table below

dBLM UFO events with blown-up bunches

time (local)	fill	beam	location (ICBLM with max signal)	energy [TeV]
20180930_224752	7240	b2	BLMQI.15L1	6.5
20181003_121604	7252	b1	BLMAI.11R8	6.5
20181003_152726	7253	b2	n/a	2.9
20181007_012459	7264	b2	n/a	3.4
20181009_174201	7271	b1	n/a	1.1
20181016_095144	7308	b1	BLMBI.27L4	4.5
20181016_141328	7309	b1	n/a	2.1
20181017_235320	7314	b2	n/a	1.6
20181017_235320_2	7314	b2	n/a	1.6
20181019_143039	7319	b1	BLMQI.05L1	3.4
20181020_094316	7321	b1	BLMQI.08R3	2.6
20181026_231622	7365	b1	BLMMI.16L2	6.5
20181026_231623	7365	b1	BLMMI.16L2	6.5

Challenges of dBLM measurements

- Useful signal for **several turns** in only 4 events
  - 1 has **horizontal** preference / 2 have **vertical** preference
  - 1 was without blown-up bunches
- Useful signal during 2 turns in 3 events, and 1 turn in 5 events
  - Difficult to conclude about the dynamics in very fast events
- Even useful signal suffers from **fluctuations**
- Multi-turn losses in IR7 distort the falling edge

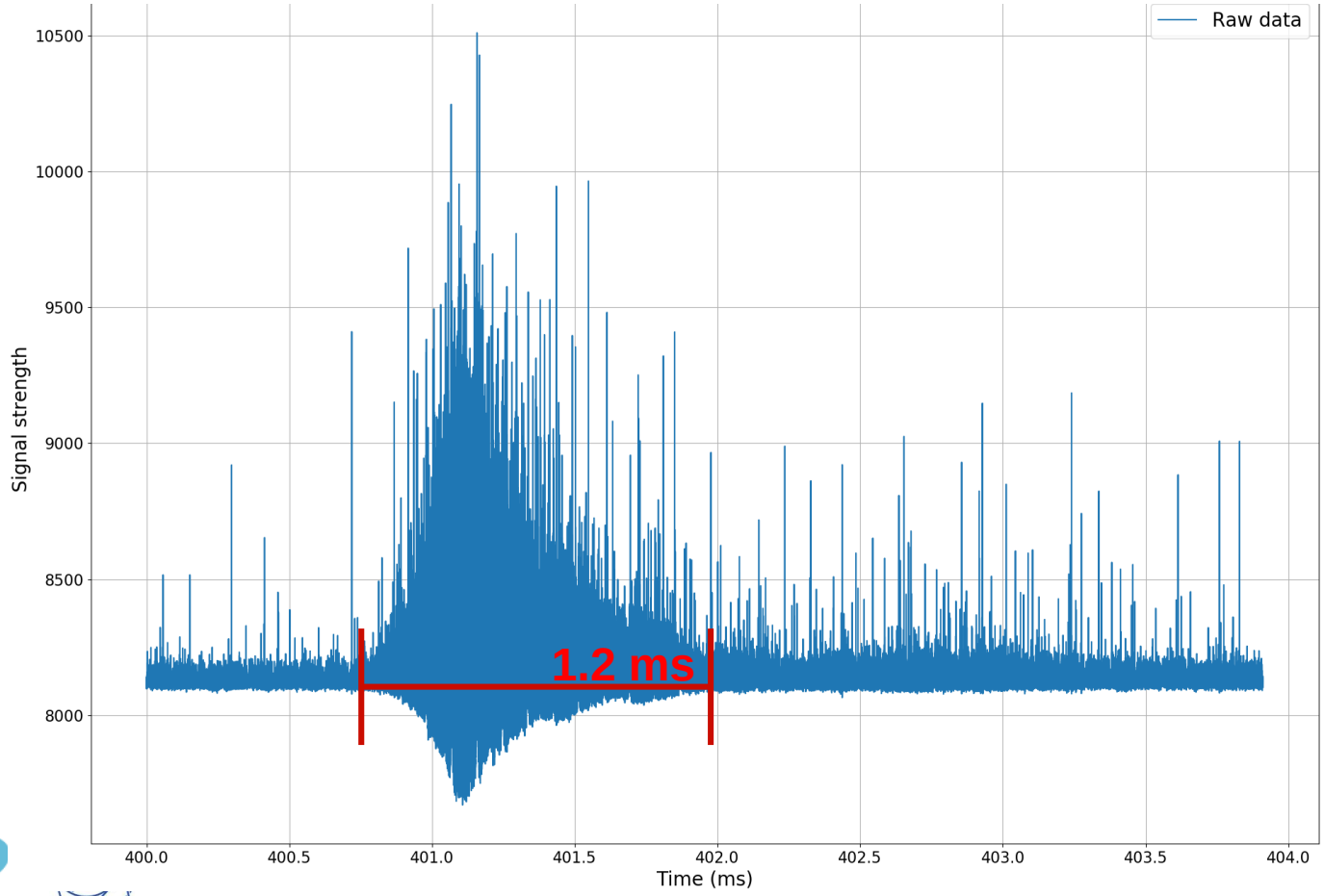


- 10 out of 13 events **during ramp**
  - Is there a detection bias or an increased UFO rate?
- During validation period, before blown-up bunches, 8 out of 16 events were at 6.5 TeV and consequently signal to noise ratio much better

To draw conclusions, need to analyse dBLM data, UFO buster recordings and perform simulations

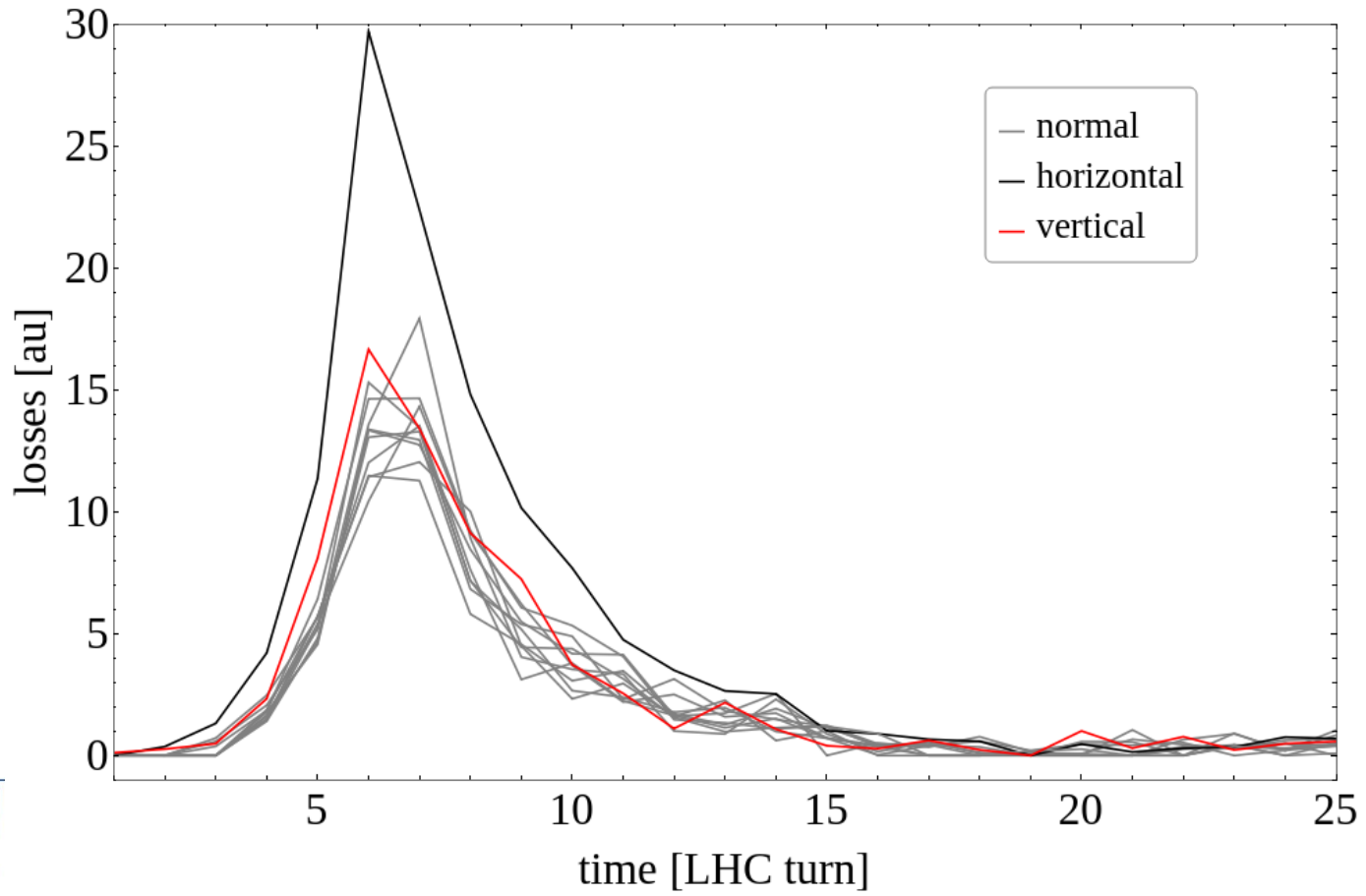
UFO measurement example

- Event on Sep 30, 22:47, (Q15L1), B2, 6.5 TeV
- **Raw waveform** as measured in IR7 by **dBLM**
- Best recording (with blown-up bunches)



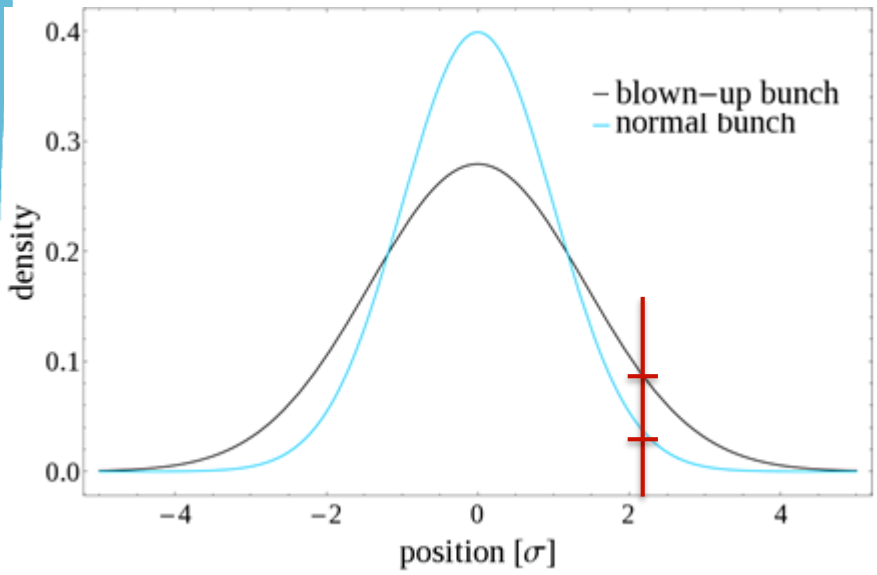
UFO measurement – 12b train

- Event on Sep 30, 22:47, (Q15L1), B2, 6.5 TeV
- 12b train (bunches shown separately)
- **Clear signal**, but significant **fluctuations** between similar bunches
- Bunch-by-bunch signals can be used to estimate UFO position

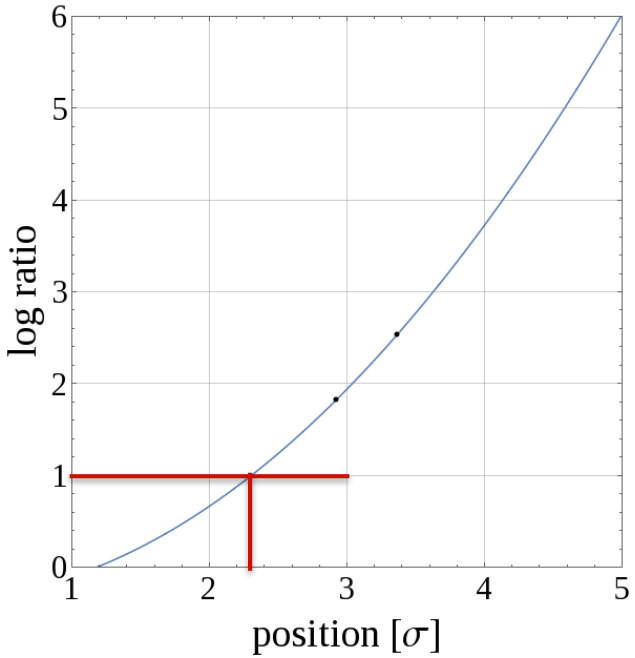


Ratio of bunches – Method

- Bunch profiles assumed gaussian
- Losses proportional to particle density at interaction point
- Ratio of bunch profiles ~= ratio of losses

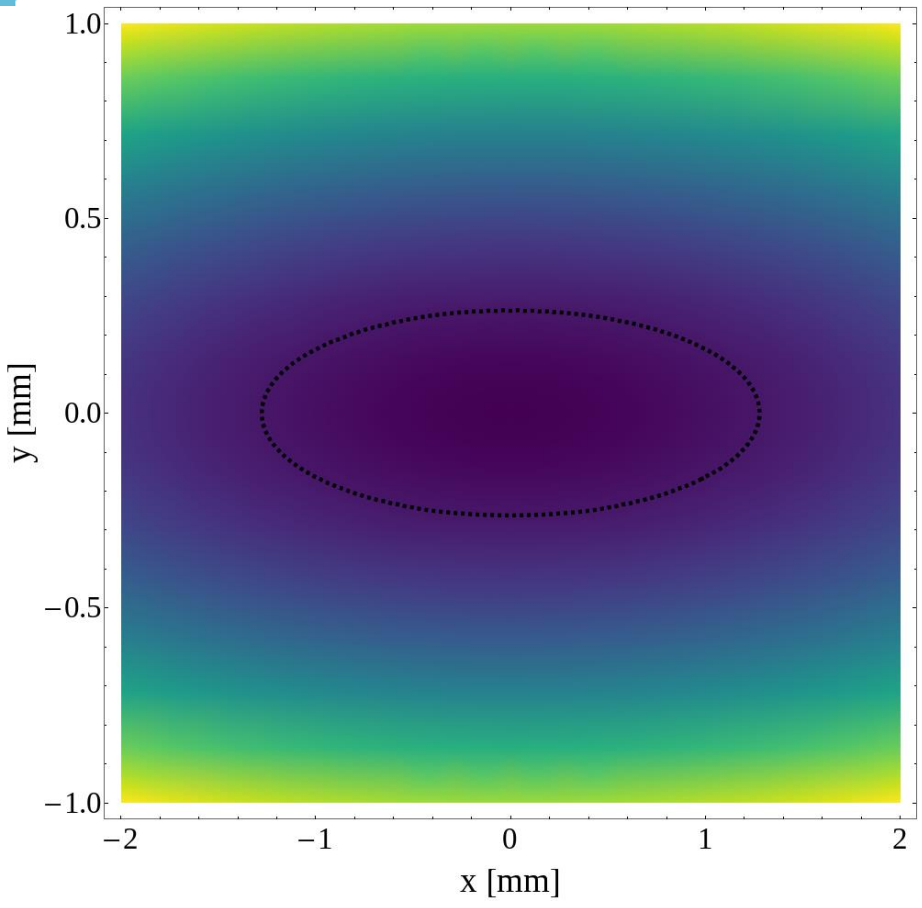


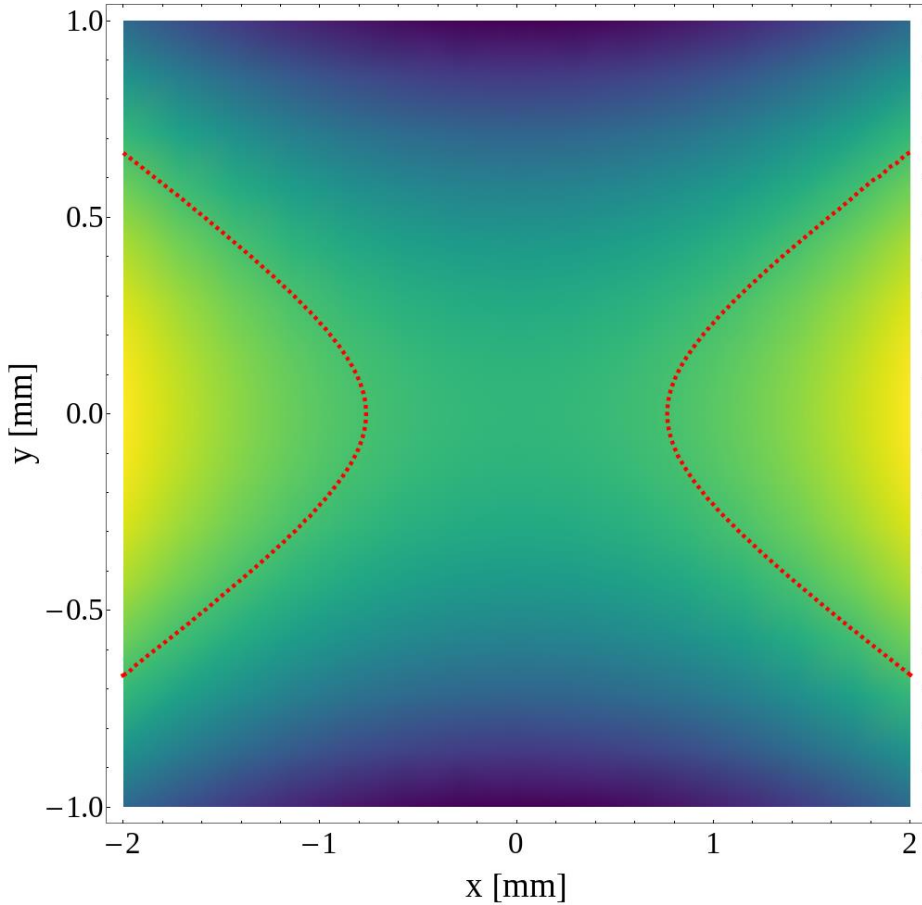
Ratio between bunch signals gives position



Ratio of bunches – Example

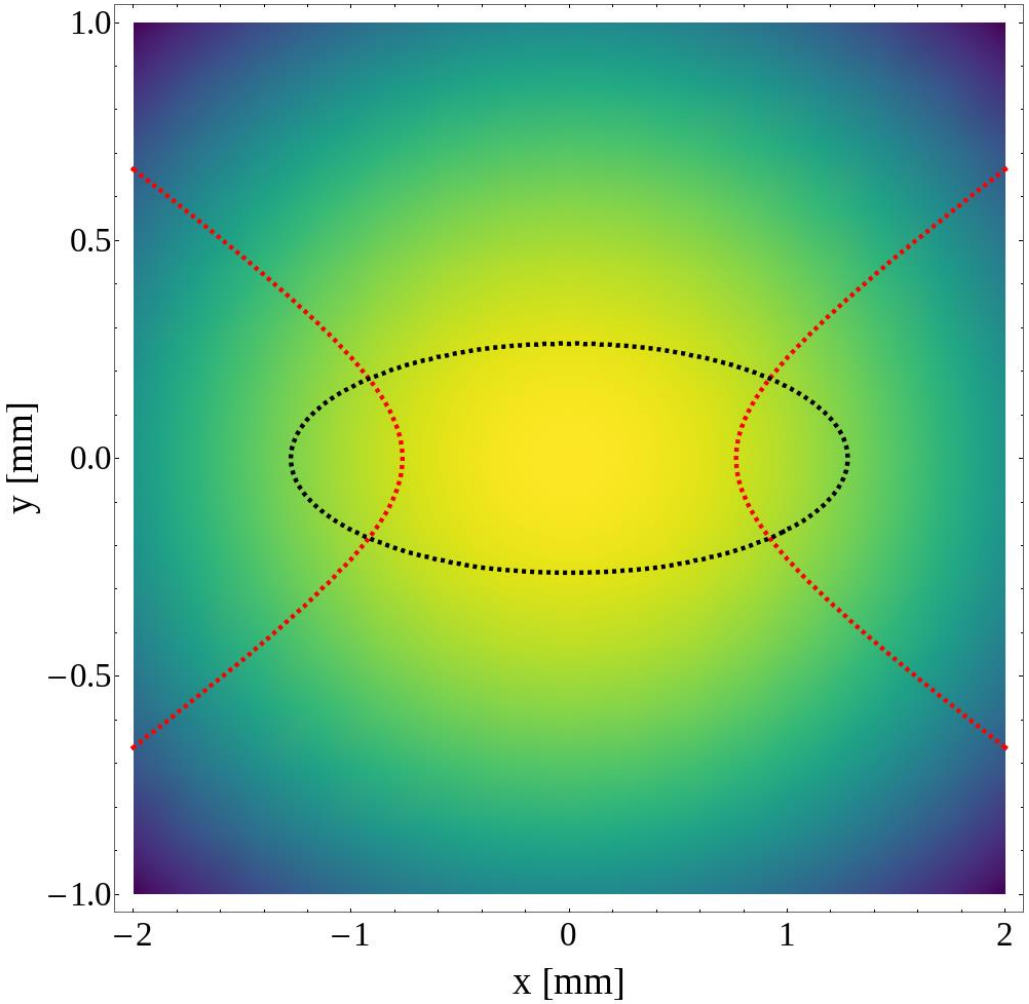
- Horizontally blown-up bunch divided by reference bunch (left)
- Horizontally blown-up bunch divided by Vertically blown-up bunch (right)
- Dashed lines are contours where horizontal bunch density 2 times reference and vertical bunches



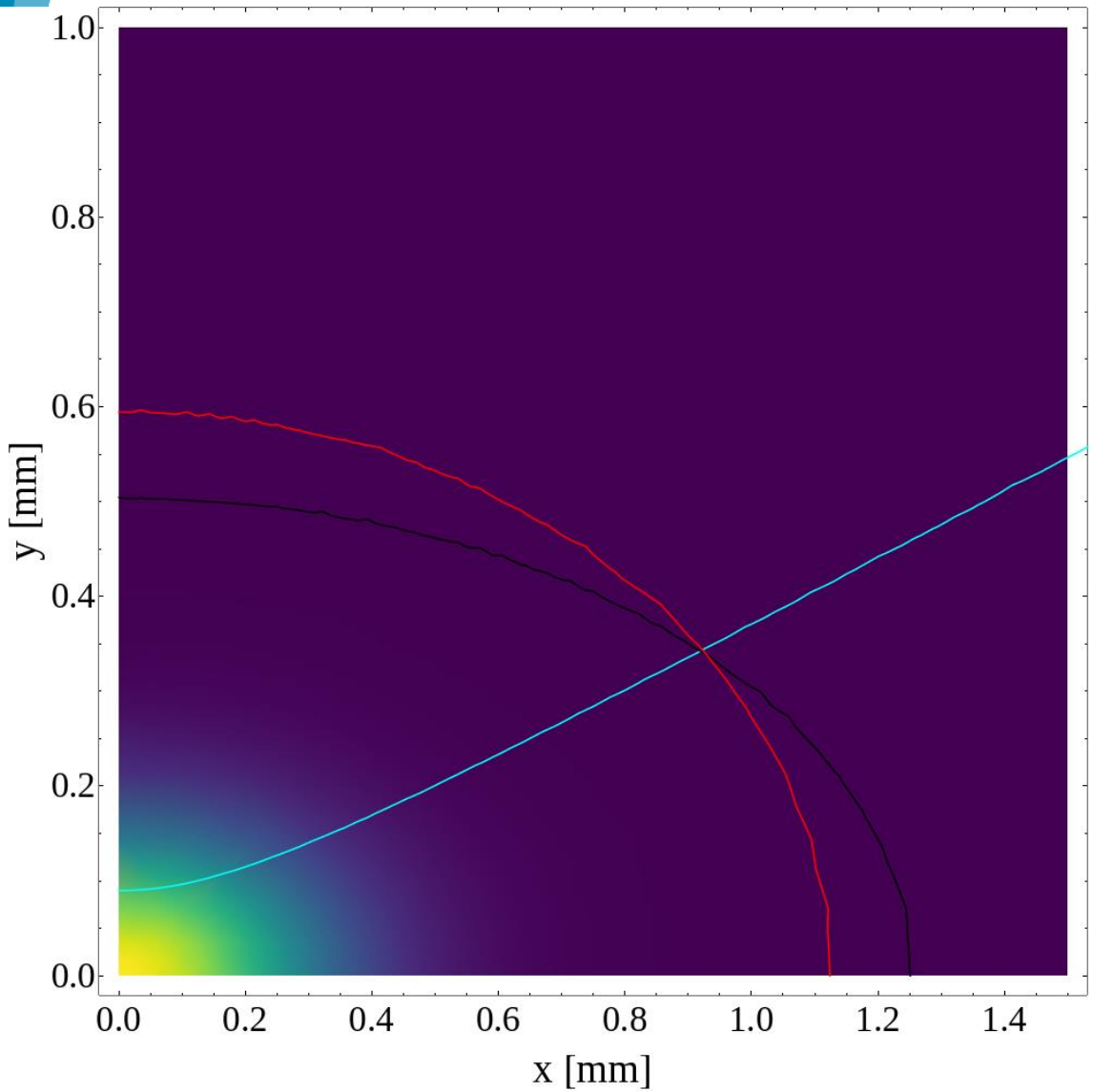


Ratio of bunches – Example

- Combining both ratios gives the estimated UFO position at the intersections
- UFO position is uniquely determined (with a four-fold symmetry)

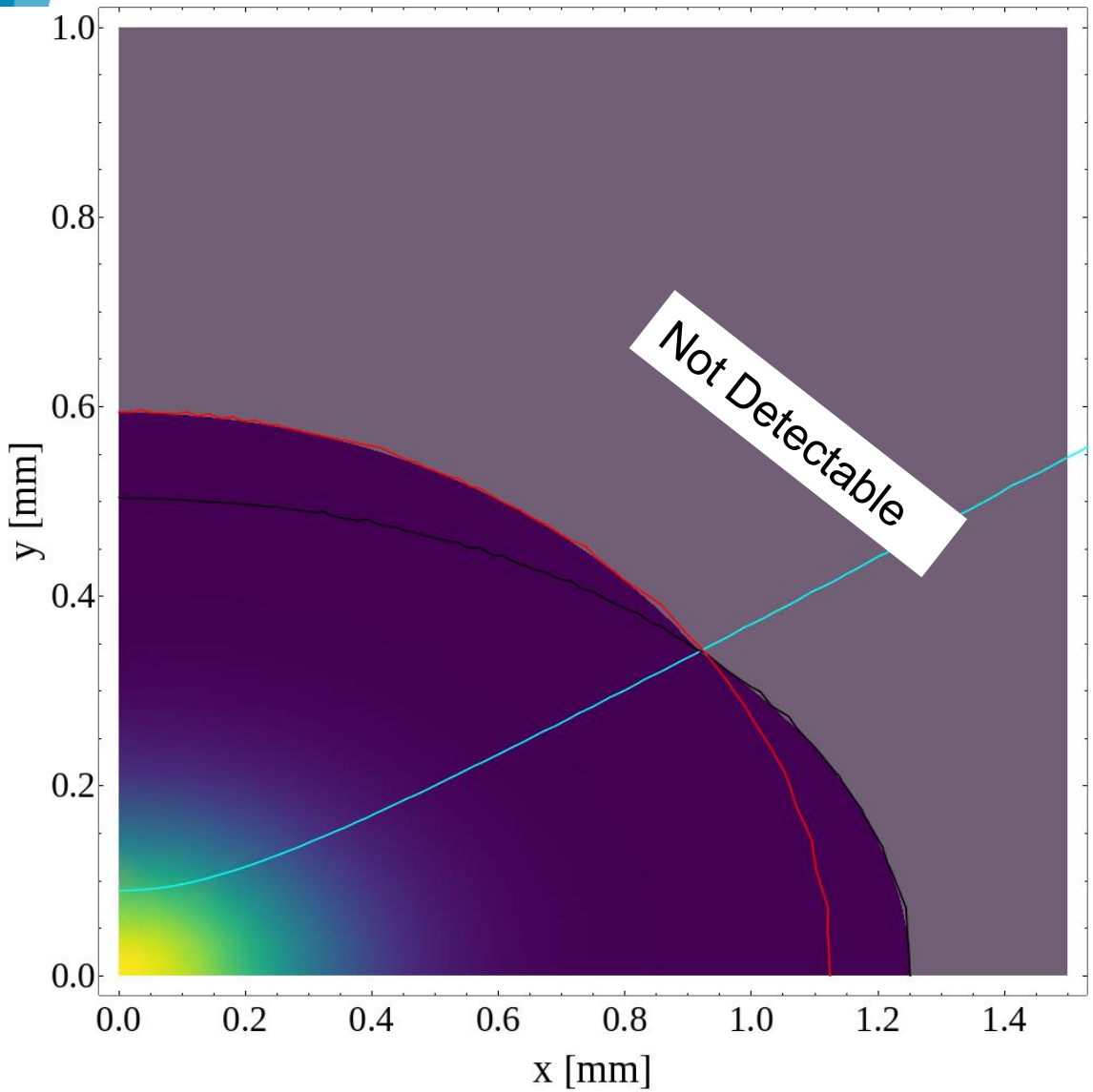


Exclusion regions



- Proton density necessary for visible losses within the red (ver. bunch) and black (hor. bunch) ellipses
  - includes pessimistic margin
- Cyan line: contour where ratio of horizontal and vertical bunch densities equal 1

Exclusion regions



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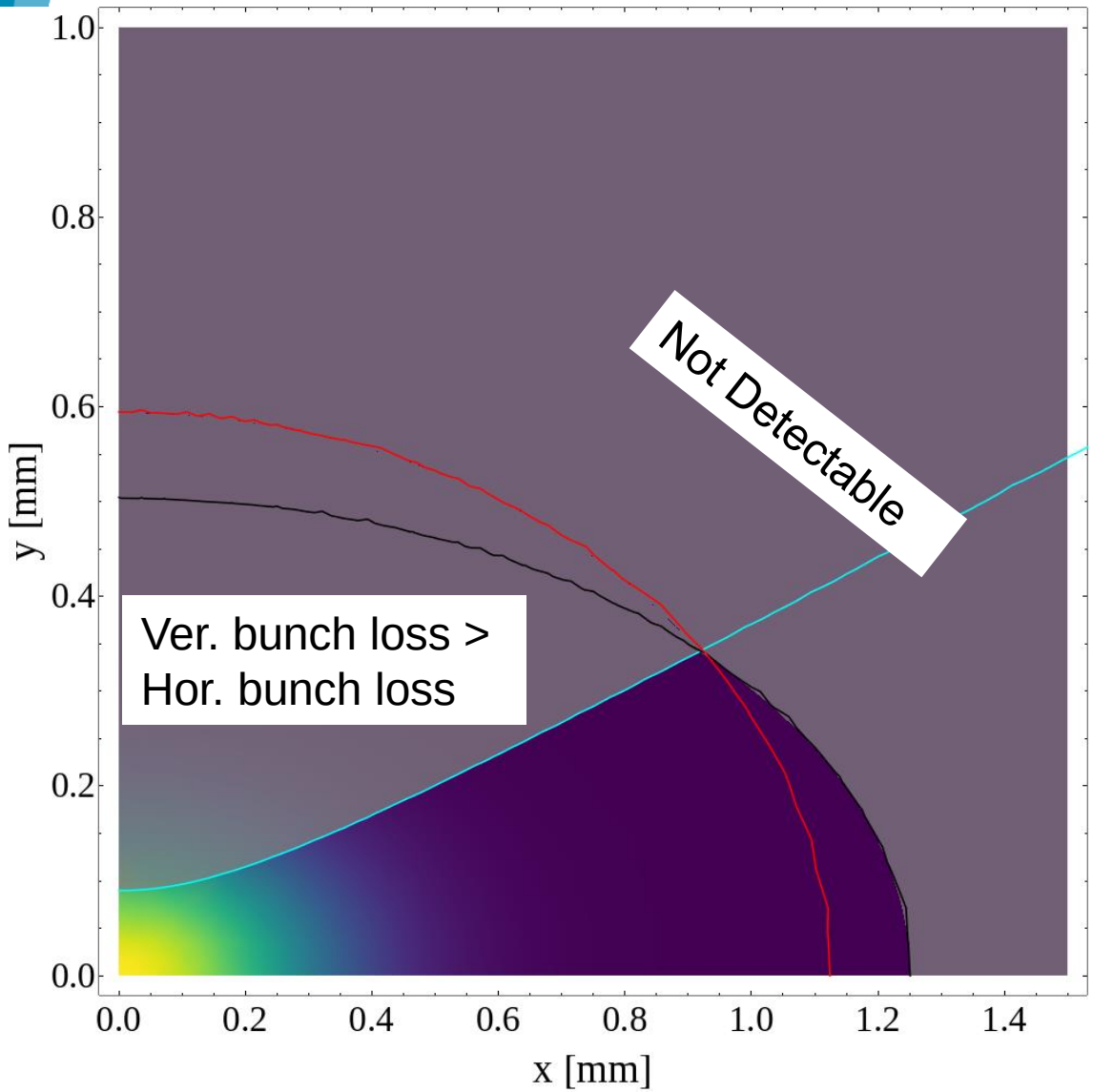

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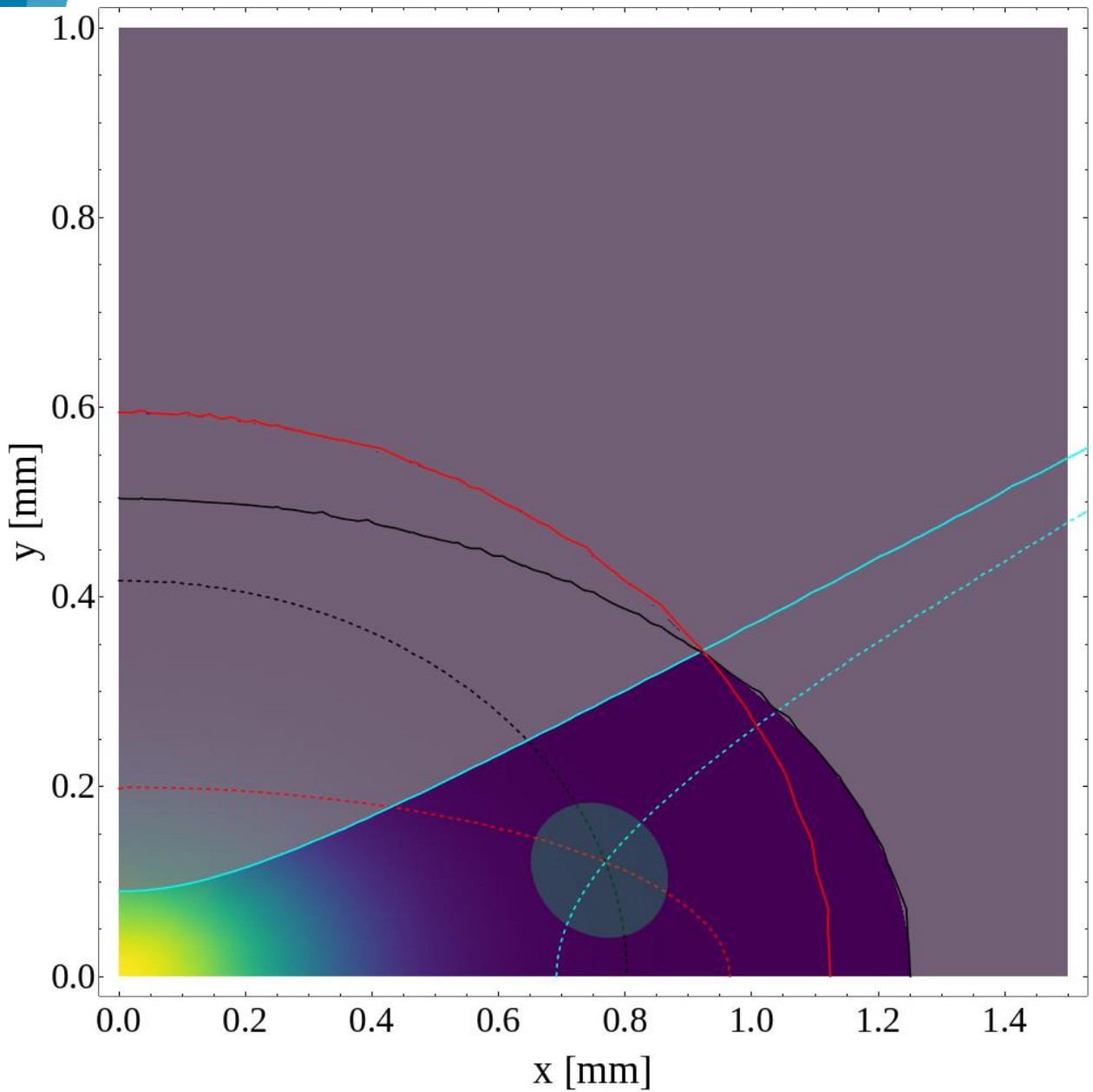
UFO position estimate

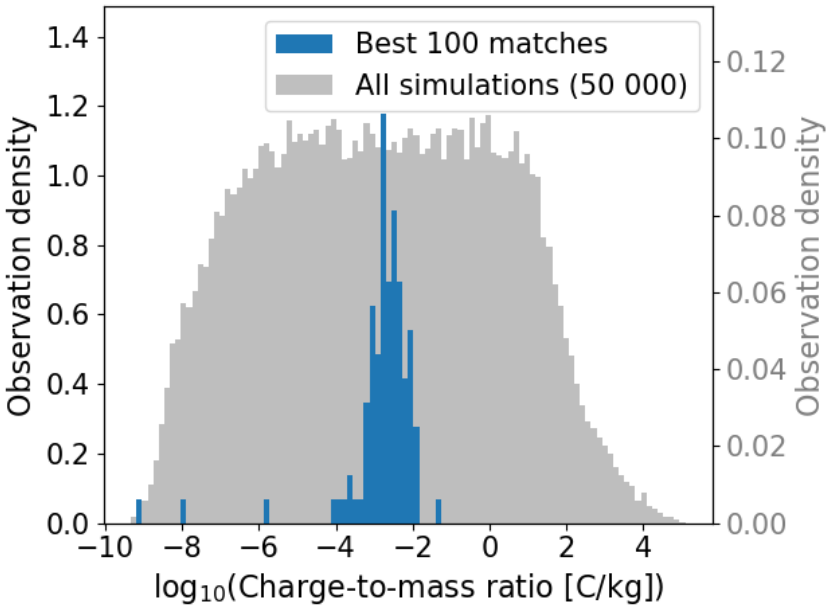


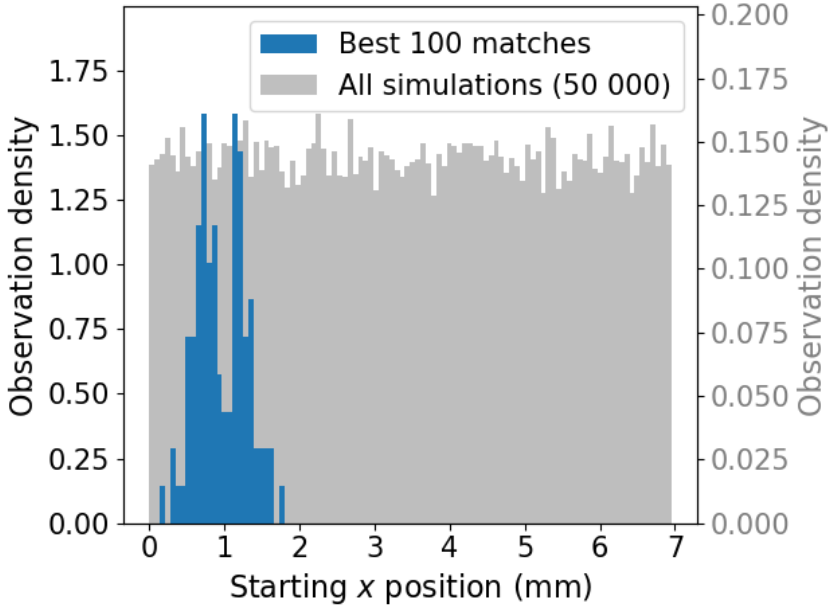
- Filled ellipse shows position during peak losses, with a $1\,\hat{\sigma}$ error on measurements
- Below the cyan line (more losses from hor. bunch)
- Consistently more losses from hor. bunch throughout the event

→ **Horizontal Movement**

Monte Carlo simulations

- Different UFO candidates could explain the measurements (ICBLM, dBLM)
  - **7 input** parameters → **1 output** signal, however many events
  - Different scenarios can lead to the same simulated output (ICBLM, dBLM)
- Nevertheless, the **important physical quantities** (in order to understand UFOs release mechanism) **converge** quite well

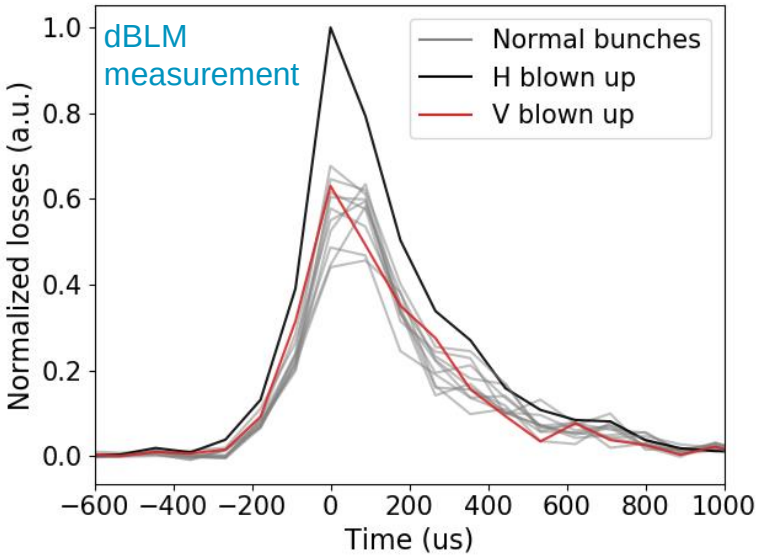


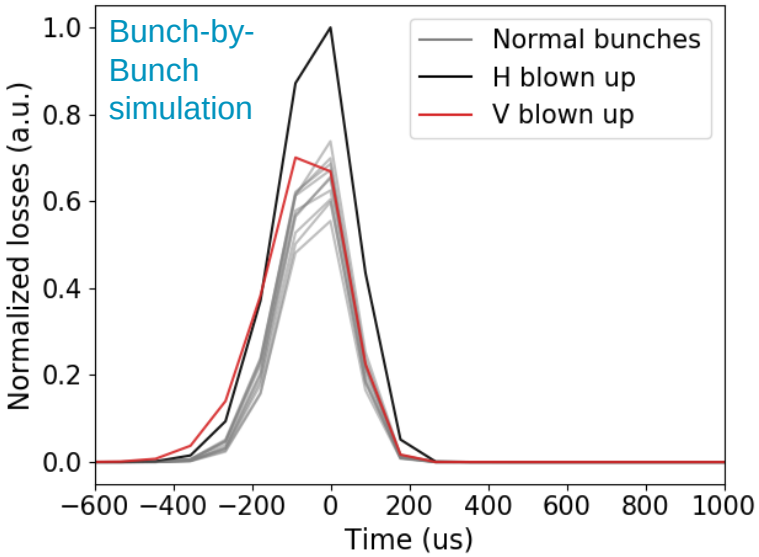


"Best matches" between simulations and the event presented on previous slides

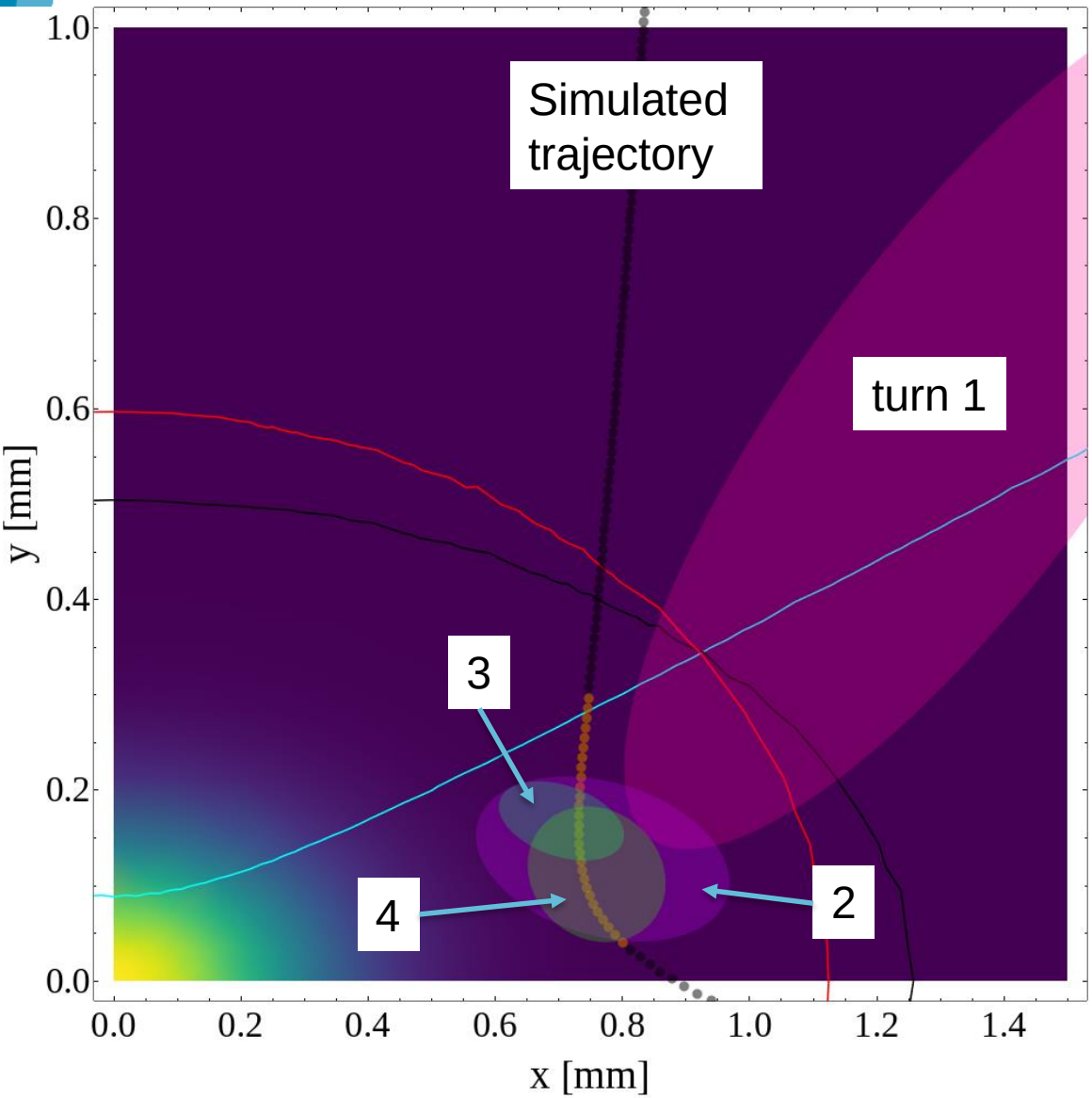
Comparison with simulations – Example

- Simulations were matched to local ICBLM measurements (**no bunch-by-bunch input!**)
- Good agreement of the rising edge for the blown-up bunches.
  - dBLM measurement suffers from delayed losses, distorting the falling edge
- Important for understanding the **simulated UFO trajectory**





Simulated vs Measured trajectory



- Orange dots correspond to the 4 peak turns in simulation
- Ellipses correspond to measured position, 4 is the turn of peak losses
- Closest approach fits well between simulation and measurement
- Simulated trajectory in region where Ver. bunch > Hor. bunch. This is not seen in measurements, better fit should exist

Conclusions

- Estimated UFO position together with consistently larger losses from horizontal bunches requires horizontal movement
  - UFOs are pre-charged or released with an initial speed
- Good agreement between simulations and measurements in center part, where resolution is best
  - Trajectory and Bunch-by-bunch losses
- Simulations fit despite only taking ICBLM measurements into account
  - Hints that overall time profiles are unique to certain trajectories

Outlook:

- Include bunch-by-bunch data to find a better fitting trajectory
- Combine simulations with loss tracking to “deconvolute” the delayed TCP losses
- Reiterate on the other recorded events

Acknowledgements

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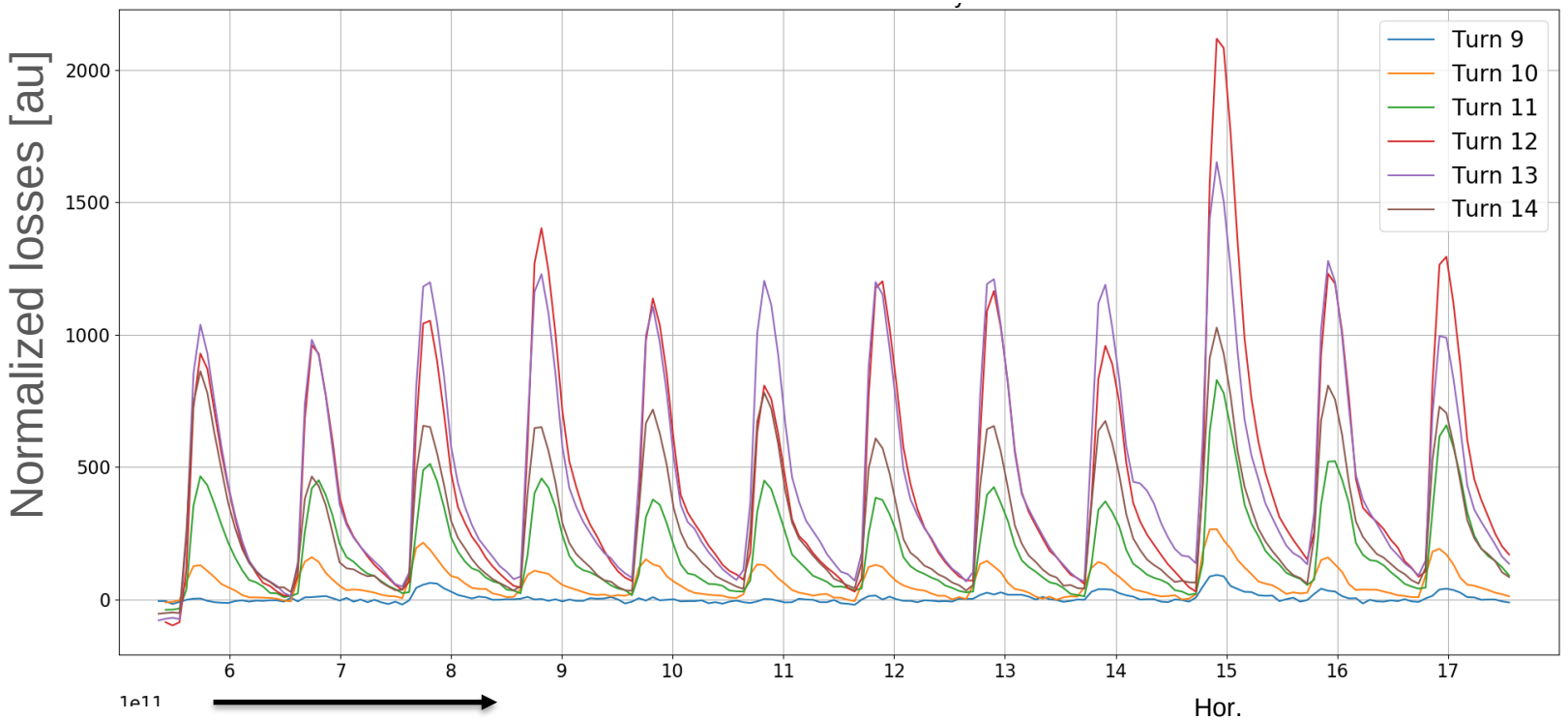
Many thanks to D. Valuch for implementation of bunch excitation and to OP team for consistent execution

UFO measurements zoom

- Event on Sep 30, 22:47, (Q15L1), B2, 6.5 TeV



dBLM UFO events without blown-up bunches

time (local)	fill	beam	confirmed by UFO buster	energy [TeV]
20180712_180259		b2	yes	6.5
20180716_004600		b1	yes	6.5
20180717_220721		b1	yes – 16L2	6.5
20180724_040228		b1	yes	2.732
20180728_024804		b1	no	6.5
20180806_220338		b1	yes	6.5
20180807_210027		b1	yes	6.5
20180814_045856		b1	no	1.211
20180823_150941		b2	no	6.5
20180824_152558		b2	yes	6.274
20180824_174021		b1	yes	6.5
20180830_110744		b1	no	1.263
20180831_052212		b2	no	2.651
20180903_080452		b1	no	3.501
20180903_181837		b2	yes	6.326
20180904_214859		b1	no	0.465

dBLM UFO events Ion Run

time (local)	fill	beam	confirmed by UFO buster	energy [TeV]
20181111_112533		b2	yes – 16L2	5.2
20181122_101510		b2	yes	6.4
20181123_031804		b2	no	6.4
20181123_060221		b2	no	6.4
20181123_234255		b2	no	6.4
20181128_033815		b2	yes	6.4

UFO position estimate error

- Red points show calculated position including error, turn with smallest error
- Error evaluated from std dev. $\hat{\sigma}$ of turn-by-turn loss value from reference bunches
- The points are calculated by varying the measured values by $\pm 1\ \hat{\sigma}$