UFO Update

Tobias Baer

Mini-Chamonix Workshop

July, 15th 2011

Acknowledgements: G. Arduini, W. Bartmann, M. Barnes, C. Bracco, M. Ferro-Luzzi, N. Garrel, B. Goddard, E.B. Holzer, M. Jimenez, V. Mertens, M. Misiowiec, E. Nebot, L. Norderhaug Drosdal, A. Nordt, J. Uythoven, J. Wenninger, C. Zamantzas, F. Zimmermann, …

Content

1. UFO related Beam Dumps
2. UFO Statistics
3. UFOs at MKIs

Content

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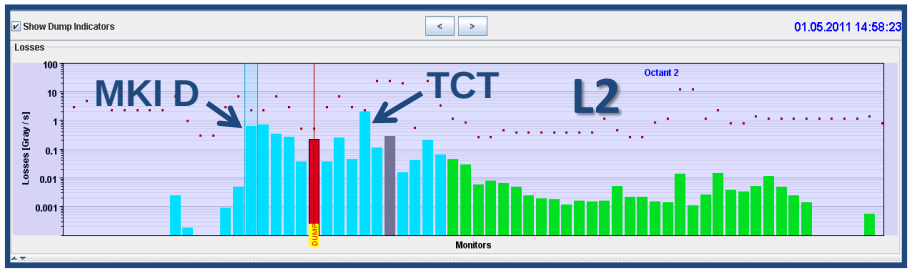
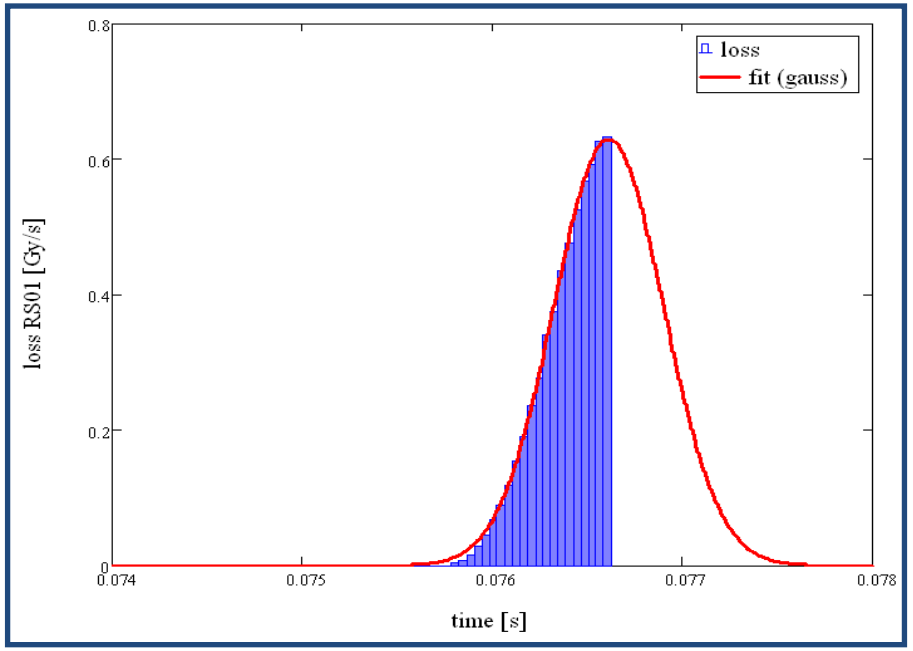
UFO related Beam Dumps

- **29 beam dumps** due to UFOs in 2010 (18) and 2011 (11).
  10 dumps around MKIs.
  1 dump at 450 GeV.
- Temporal width of a few turns.
  Dump often on running sum with 640µs or 2.5ms integration time.
- Max Loss amplitude (extrapolated): 7.7 Gy/s





Beam dump on 01.05.2011

Content

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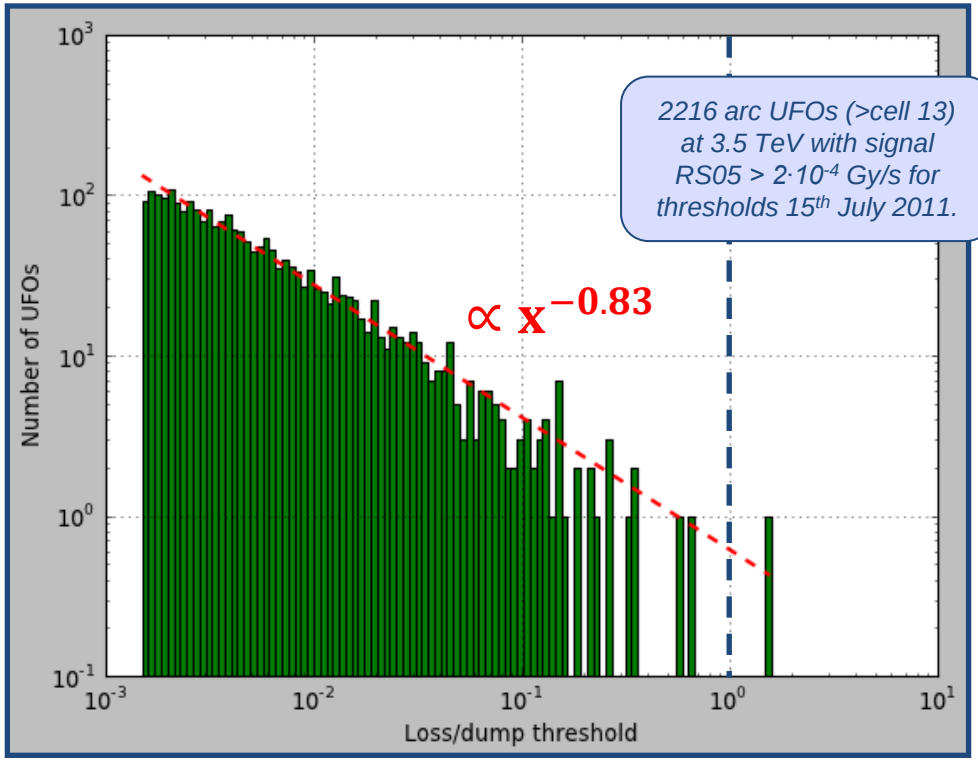
UFOs Below Dump Threshold

- For 2011: Online UFO detection by **UFO Buster.**

  Detects UFOs in BLM concentrator data (1Hz).

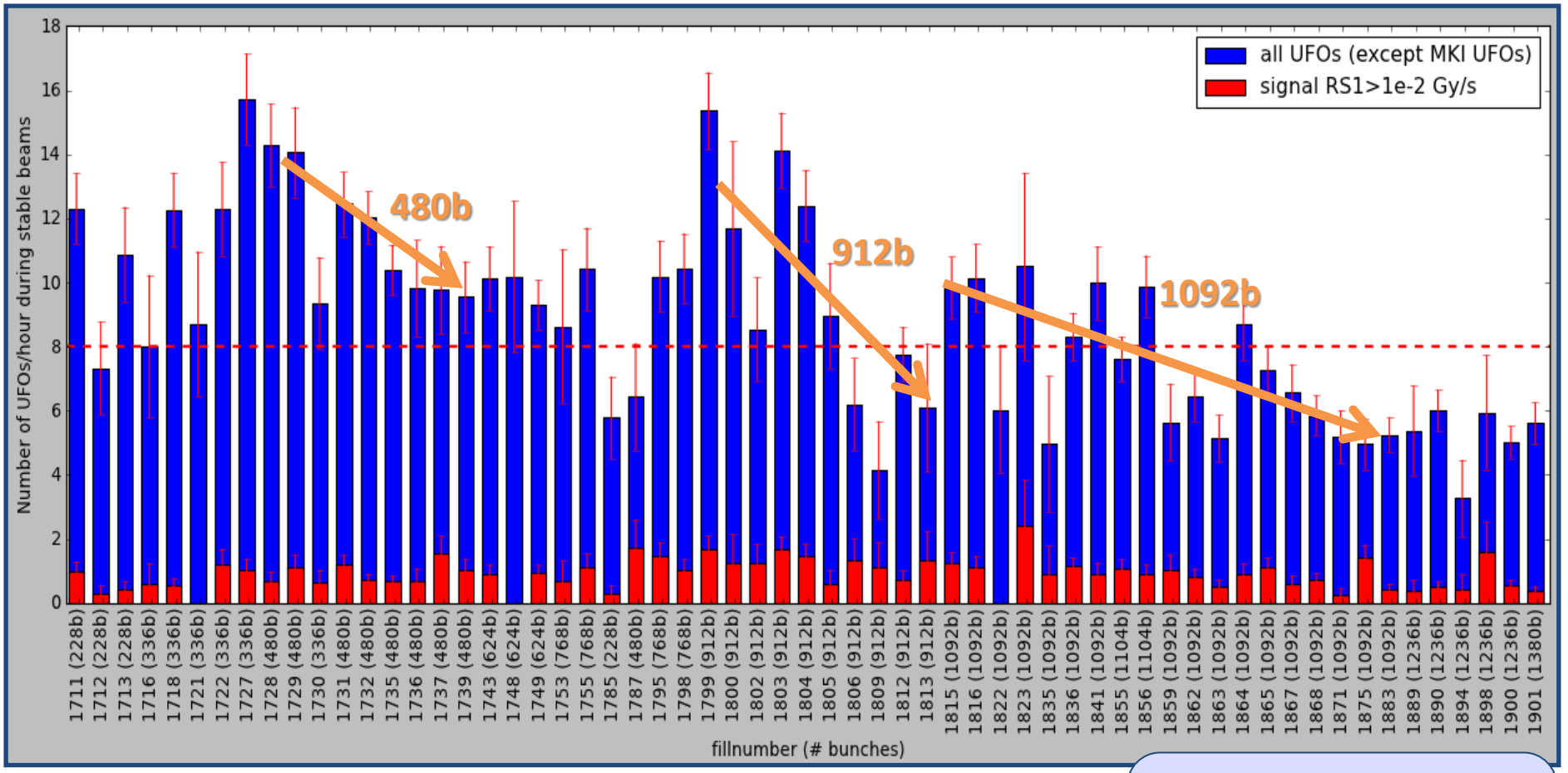
- Over **5000 UFOs** below threshold found so far.

Most events are much below threshold.



Amplitude of arc UFOs.

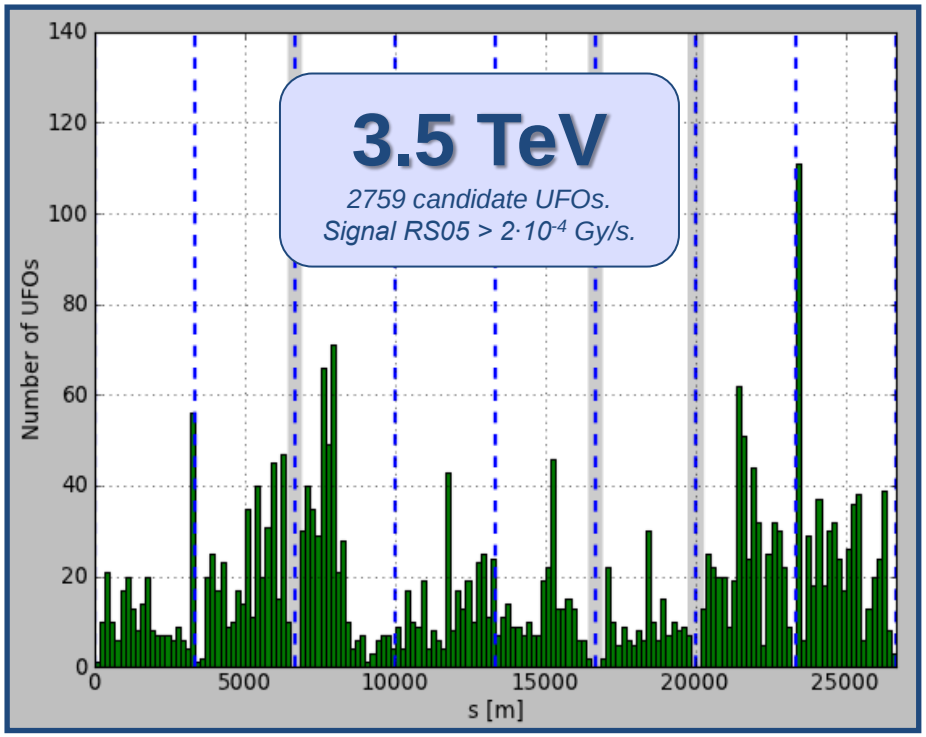
UFO rate

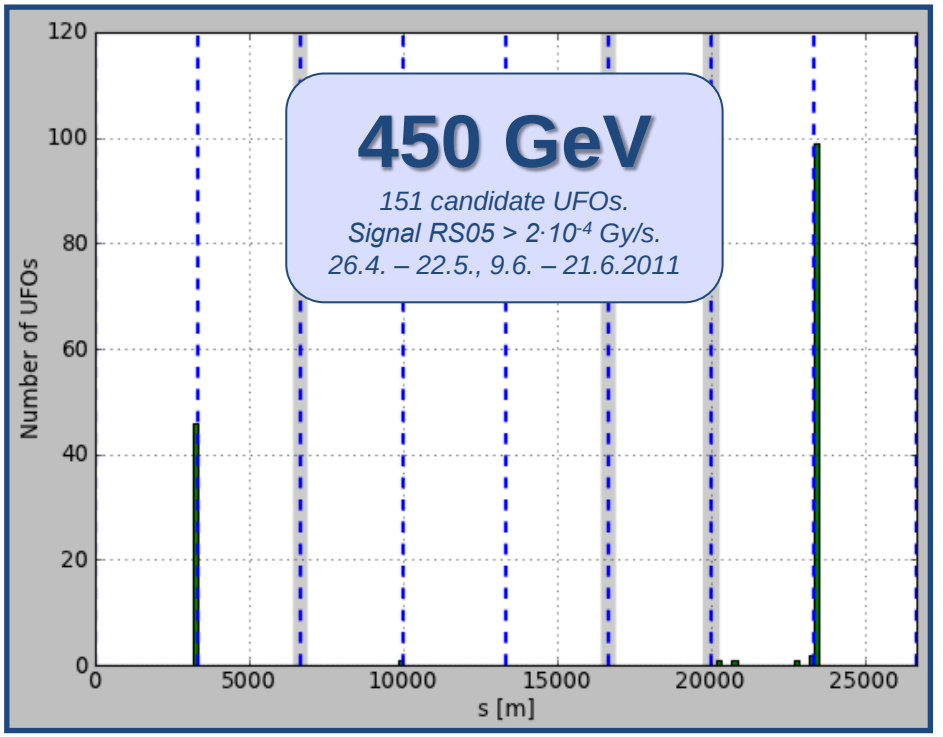


2301 candidate UFOs (excluding MKI UFOs) during stable beams in fills with at least 1 hour stable beams.
all UFOs: Signal RS05 > $2 \cdot 10^{-4}$ Gy/s.
Data scaled with 1.85 (detection efficiency from reference data)

On average 8 UFOs/hour.
Is there a conditioning effect?

Spatial UFO Distribution





- Many UFOs around ***MKIs***.
- Arc locations with many UFOs:

  BLMQI.19R3.B1I10_MQ: 50 UFOs.
  BLMQI.25R3.B2E10_MQ: 53 UFOs.
  BLMQI.28R7.B2I10_MQ: 47 UFOs.

Mainly UFOs around MKIs

gray areas around IRs are excluded from UFO detection.

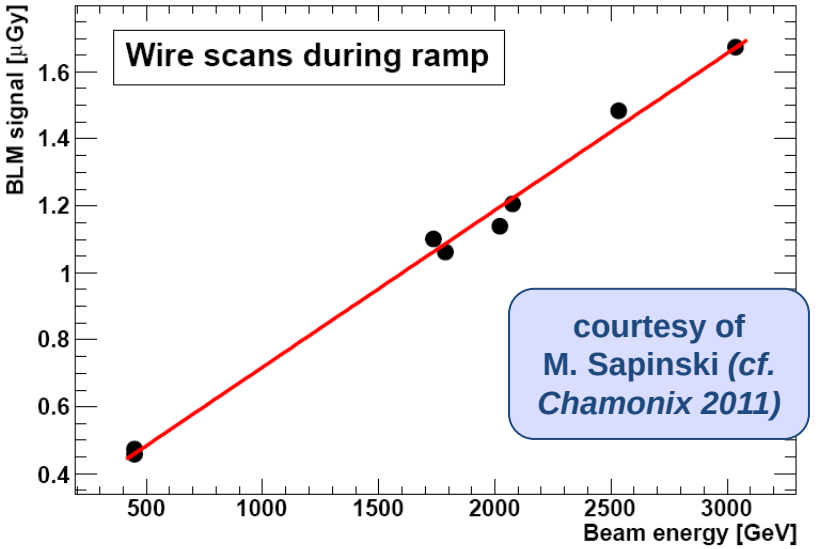
Energy Dependency

- **Ufo amplitude: Linear dependency** of BLM signal on beam energy observed (from wire scans).

  (cf. M. Sapinski at Chamonix 2011)

- **BLM Thresholds:** Arc Thresholds at 7 TeV are about a **factor 5 smaller** than at 3.5 TeV.

- **UFO rate:**
  - At 450 GeV: extremely rare.
  - During 1.38 TeV run: 3 UFOs in 36.5 h.
  - At 3.5 TeV: 8 UFOs/h.



Content

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2. UFO Statistics
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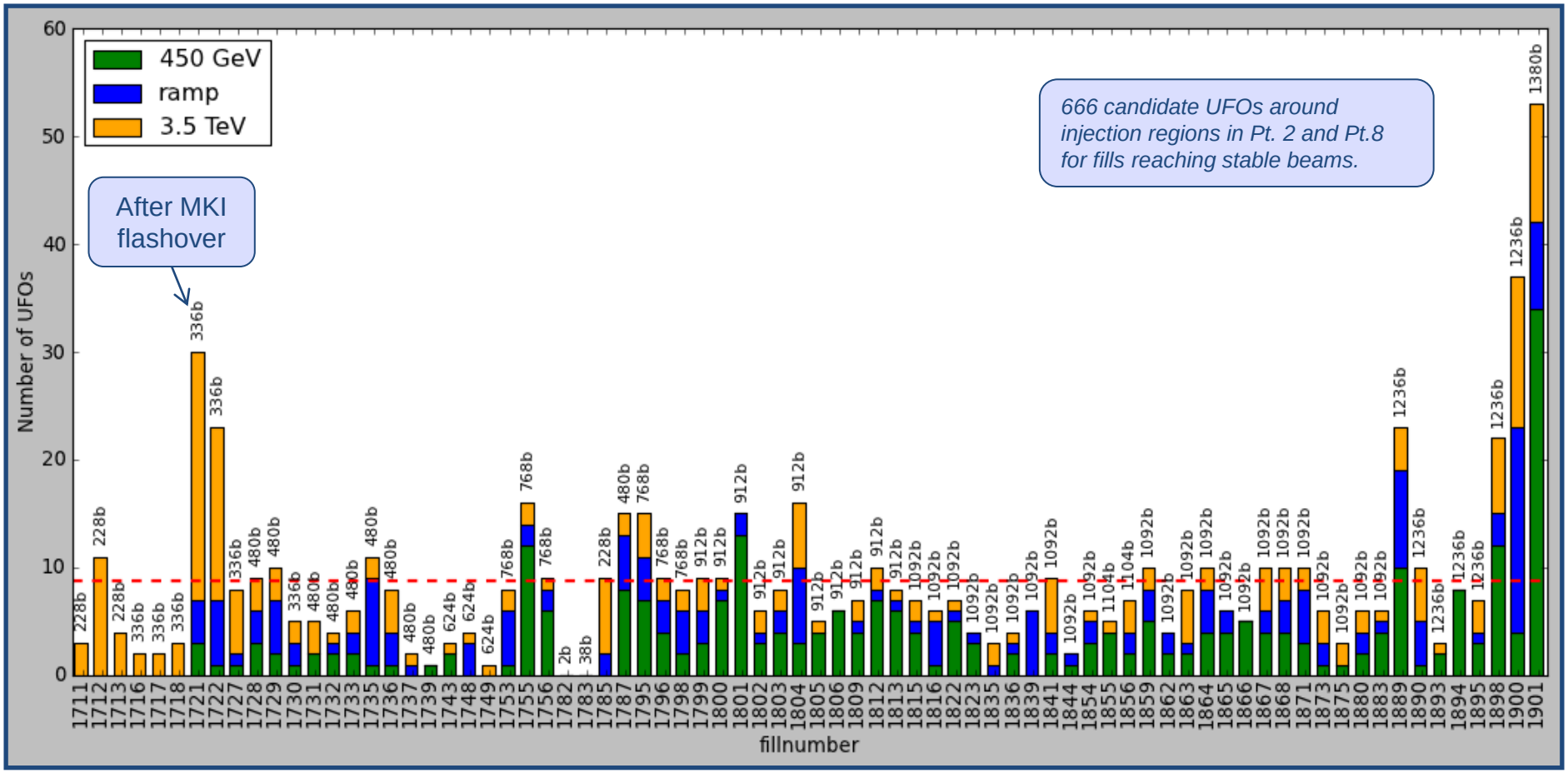
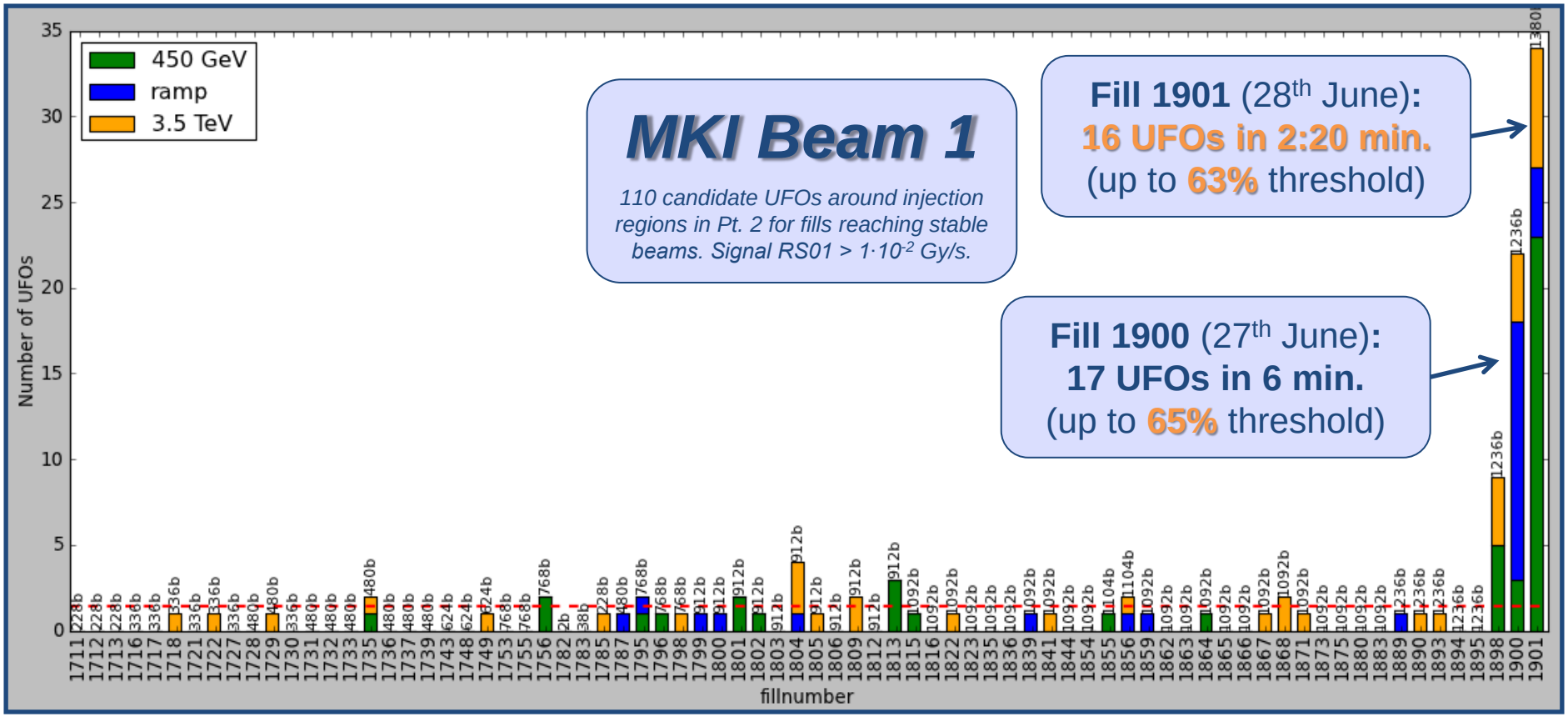
Number of MKI UFOs



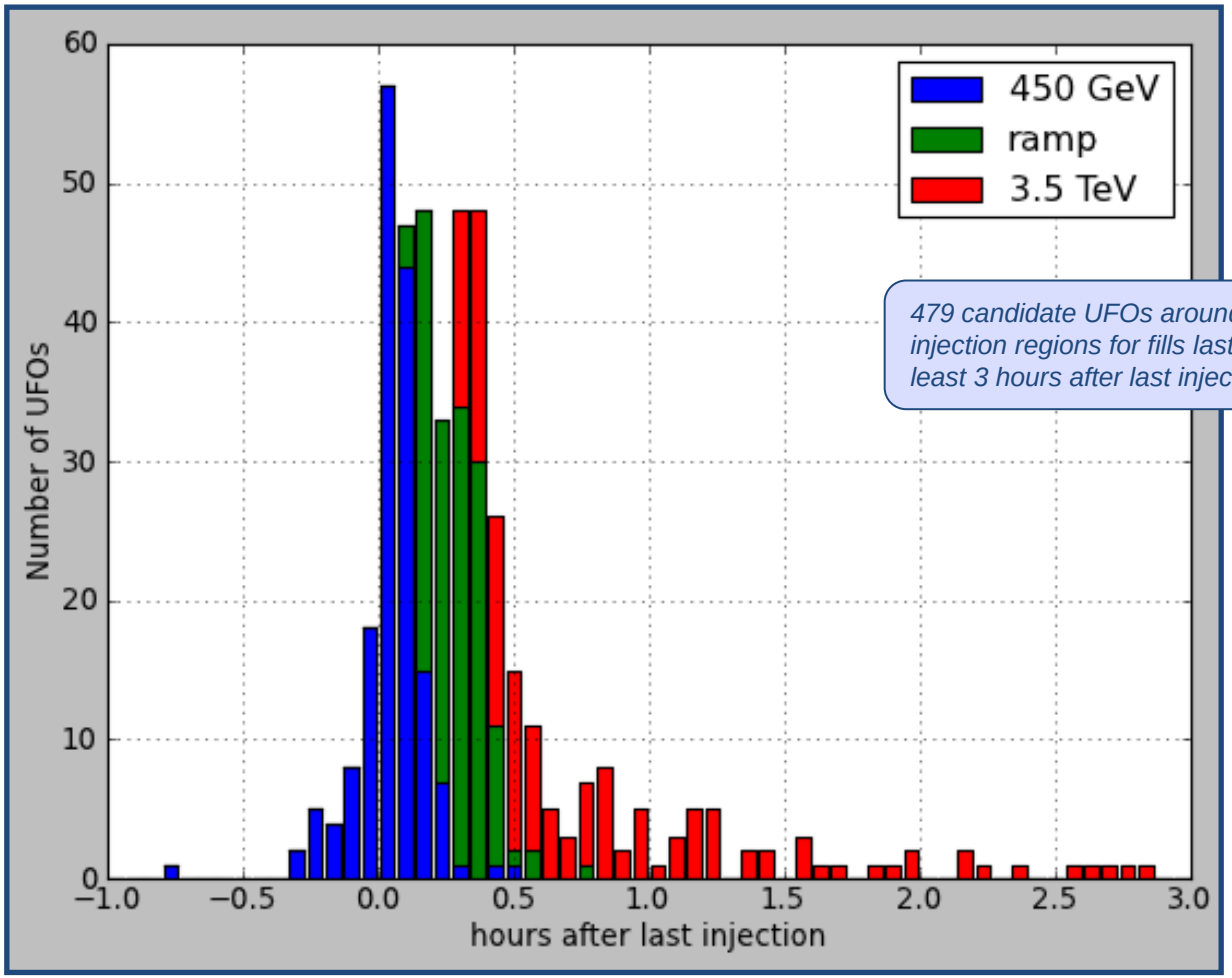
The number of MKI UFOs is much higher in Pt. 2 for the last few fills.

Number of Large MKI UFOs B1



In the last physics fills **many MKI UFOs** with **large amplitudes** occurred with a **high rate**. No obvious change found to explain this.

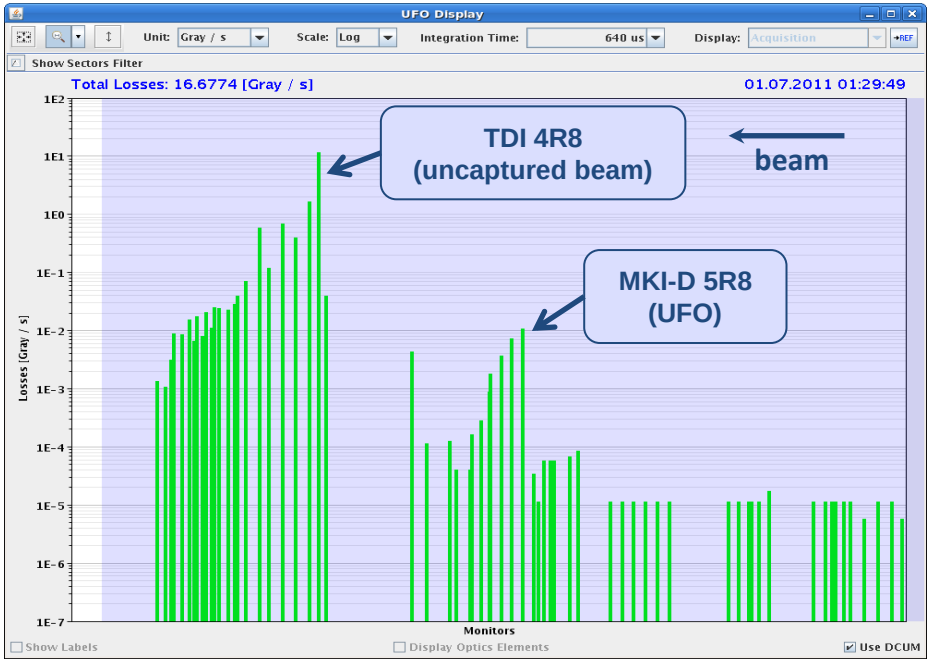
Time of MKI UFOs



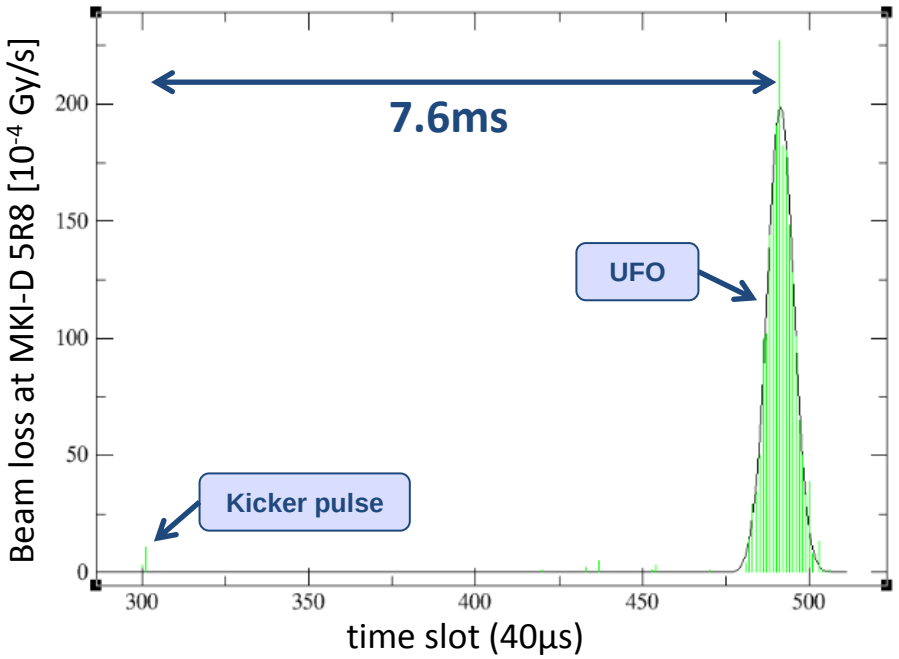
479 candidate UFOs around injection regions for fills lasting at least 3 hours after last injection.

Most MKI UFOs occur shortly after the last injections.

MKI UFO MD



Peak loss 640µs integration time in the second of the kicker pulse

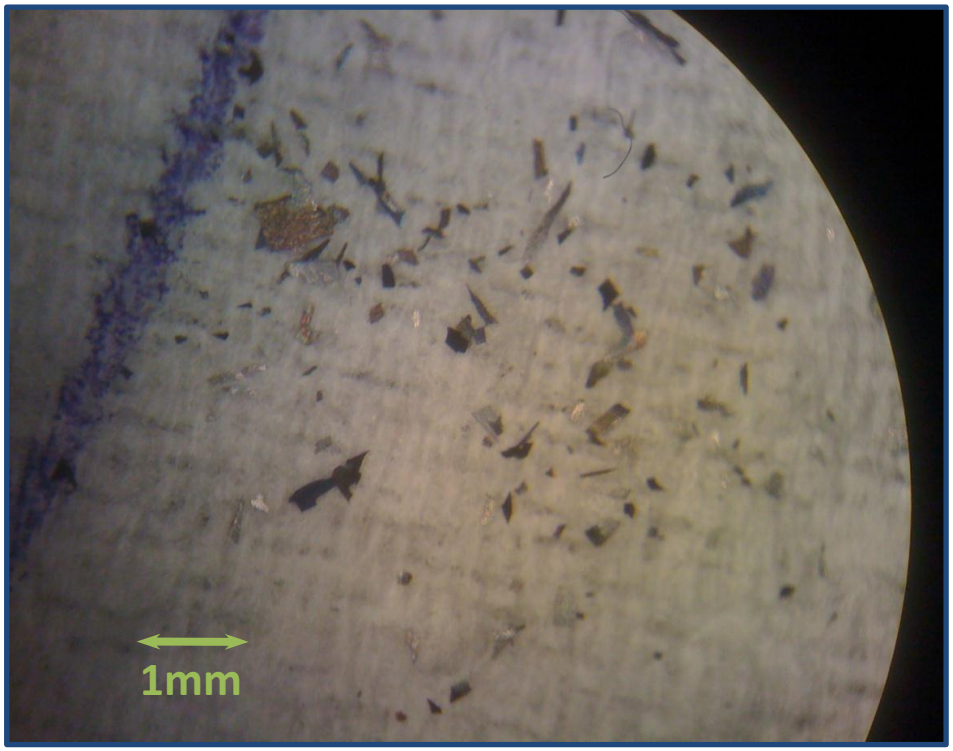


BLM injection capture buffer (512·40µs)

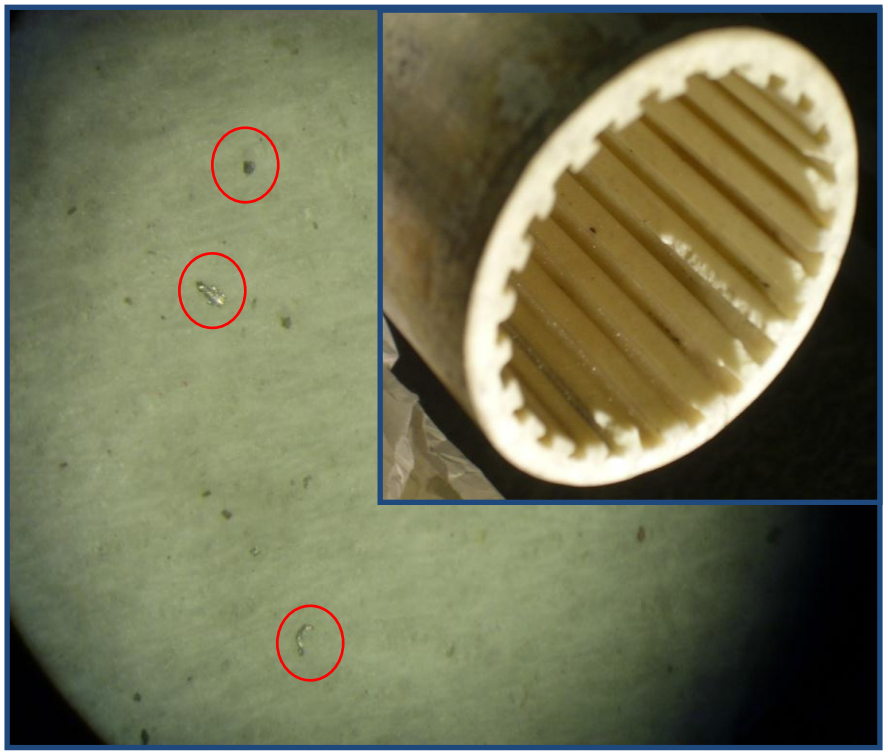
During the MD the MKIs were pulsed without injecting beam (1236b)

Several UFOs were observed directly after pulsing the MKIs.

Dust Particles in the LHC



Dust particles in Penning gauge from lab.



Dust particles in ceramic test beam tube.

Samples from non-operational and old equipment.
But not representative for the LHC…

courtesy of
N. Garrel and
V. Mertens

Next Steps

- Continuous improvement of diagnostics.
  - *Adjust injection capture buffer and BLM capture buffer for UFO events.*
  - *Analysis of additional BLMs around MKIs (installed during last TS).*
- Continue MKI UFO MD.
  - *Study UFO production mechanism (MKI UFO storms).*
  - *Study dust particle dynamics.*
- Search for dust particles in MKIs.
- MKI vibration measurements.
- Better understanding of Quench Limit.
- Additional Simulations
- ***Mitigation***: Further increase of BLM thresholds...

  But: For higher energies thresholds need to be decreased.

Conclusion

- **For 2011:**
  - **Arc UFOs: No sign that the situation will become worse.** Few dumps are expected.
  - MKI UFOs: **MKI UFO Storms might be critical.**
    Large effort underway to understand mechanism, in lab and in LHC.
- **Beyond 2011:**
  - Observations show an **aggressive scaling with beam energy!** Situation could be significantly worse above 3.5TeV.
    Intermediate energy step would be very helpful for extrapolations to nominal energy.

Thank you
for your Attention

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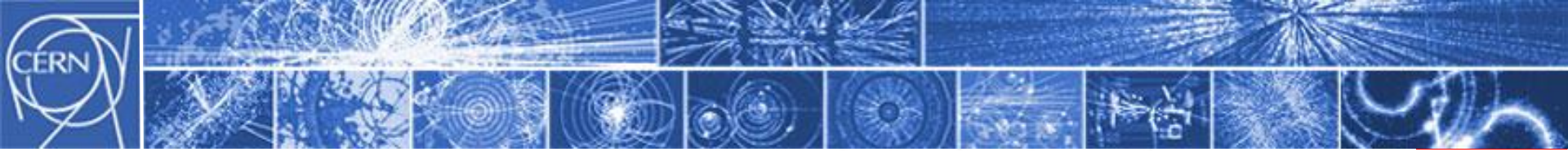
Further information:

- T. Baer, “Statistics on UFOs”, LHC UFO Study Working Group, June 2011.
- N. Garrel, V. Mertens, “MKI dust and other observations”, MKI UFO Meeting, July 2011.
- M. Sapinski, “Is the BLM system ready to go to higher intensities?”, Workshop on LHC Performance, Chamonix, Jan. 2011.
- F. Zimmermann, “Interaction of macro-particles with the LHC proton beam”, IPAC’10.

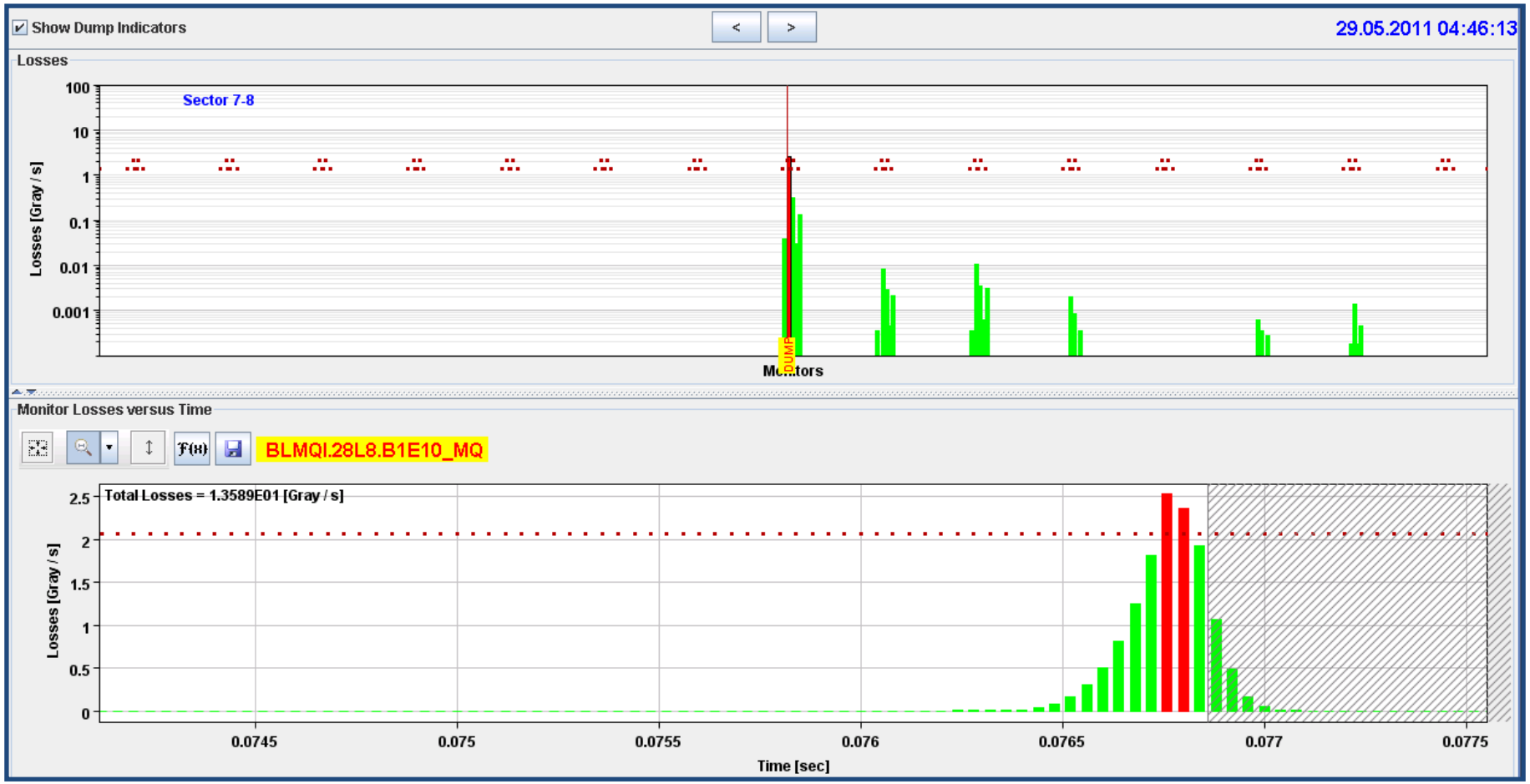


Backup slides

Content

1. UFO Dumps 2010/2011

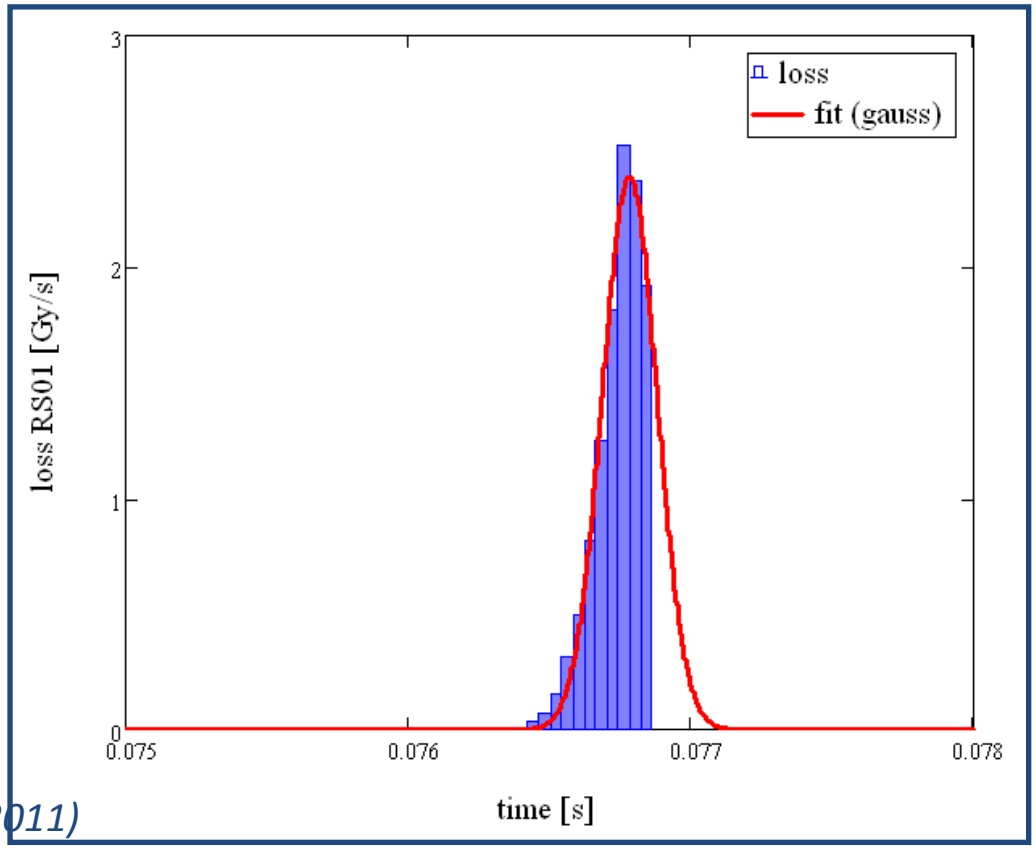
Beam dump on 29.05.2011



Dump on running sum 1-6.

Beam dump 29.05.2011

- From fit to losses (BLMQI.28L8.B1E10_MQ):
  - Amplitude: **2.4 Gy/s**
    (Threshold: 2.1 Gy/s)
  - Temporal Width: **97 µs**
    resulting speed of transiting dust particle = **3.6 m/s**.
    (assuming ϵ^n=2.5µm·rad)
    (also cf. J. Wenninger at MPP March 2011)



UFO Dumps in 2011

Timestamp (local)	Location	Loss RS1 [Gy/s]	Fillnumber	# bunches	Intensity
01.05.2011 14:58:23	MKI.D5L2	0.20	1752	762	9.00E+13
29.05.2011 04:46:13	Q28.L8	2.50	1813	912	1.11E+14
31.05.2011 06:22:03	MKI.D5L2	2.50	1822	1092	1.33E+14
31.05.2011 22:20:38	MKI.D5L2	2.00	1828	1092	1.24E+14
02.06.2011 21:50:17	MQXA.R8	0.50	1839	1092	1.24E+14
03.06.2011 18:24:50	MKI.D5R8	0.20	1843	1092	1.34E+14
04.06.2011 20:20:38	MKI.D5L2	0.10	1847	1092	1.29E+14
05.06.2011 06:56:37	MKI.D5L2	0.50	1851	1092	1.29E+14
06.06.2011 13:15:24	MKI.D5L2	3.49	1855	1104	1.31E+14
08.06.2011 19:04:29	MKI.D5L2	2.13	1858	1092	1.30E+14
16.06.2011 03:28:33	MQX.L8	0.50	1870	1092	1.27E+14

8 dumps due to UFO in injection region.

courtesy of J. Wenninger

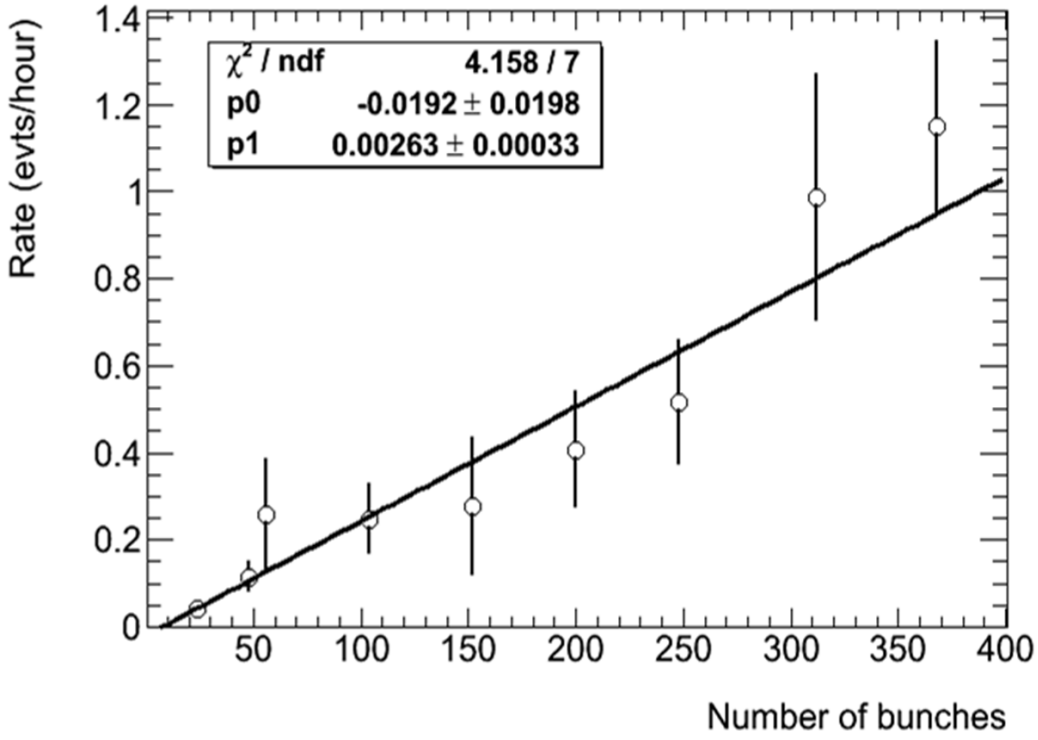
Content

2. Below Threshold UFOs

Event Rate 2010

- 113 events below threshold found in 2010.
  (E. Nebot)

- **UFO rate**: proportional to beam intensity.



courtesy of E. Nebot

UFOs Detection in 2011

- 2010: 113 UFOs below threshold found in logging database. (E. Nebot)
- 2011: Online UFO detection from live BLM data.

  *Losses (RS 4) of **two BLMs in 40m** are above **1E-4 Gy/s.***
  RS 2 / RS 1 > 0.55 (UFO average : 0.89).
  RS 3 / RS 2 > 0.45 (UFO average: 0.79).

- **Over 8000 triggers** so far.
  - From subset of about 300 manually verified triggers:

    About 65% are UFOs, 15% ambiguous cases, 20% are false triggers.

  - For most analysis additional cut. E.g.:

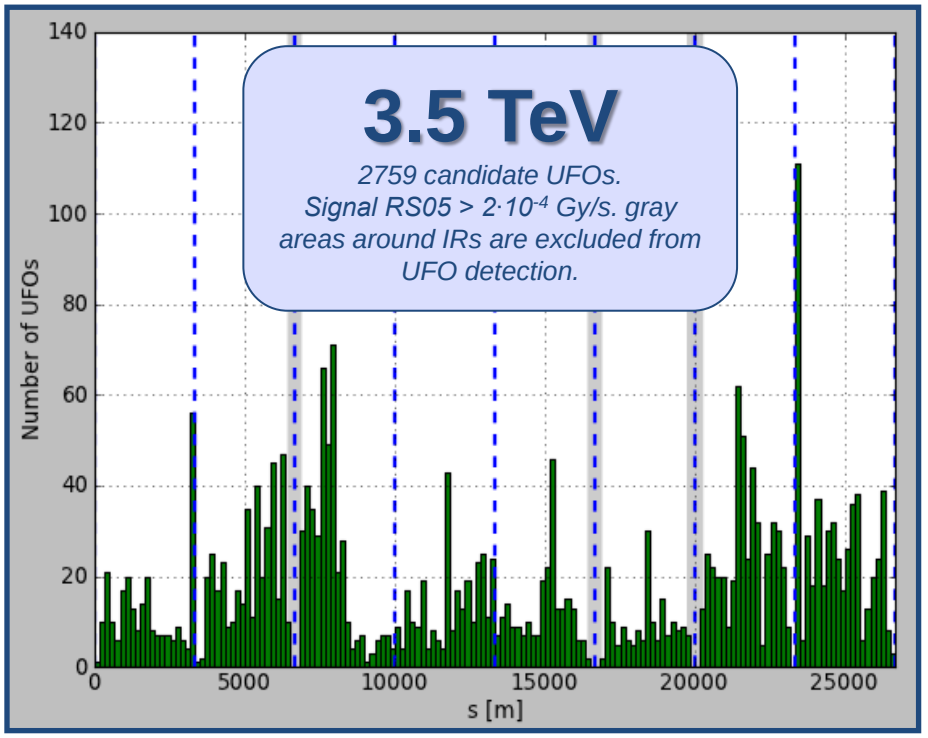
    Only flat top UFOs, loss of UFO BLM (RS05) > $2 \cdot 10^{-4}$ Gy/s (≈ 2 ‰ of threshold).

    74 events remain of subset, of which 71 are clear UFOs (96%) and 3 are ambiguous cases.

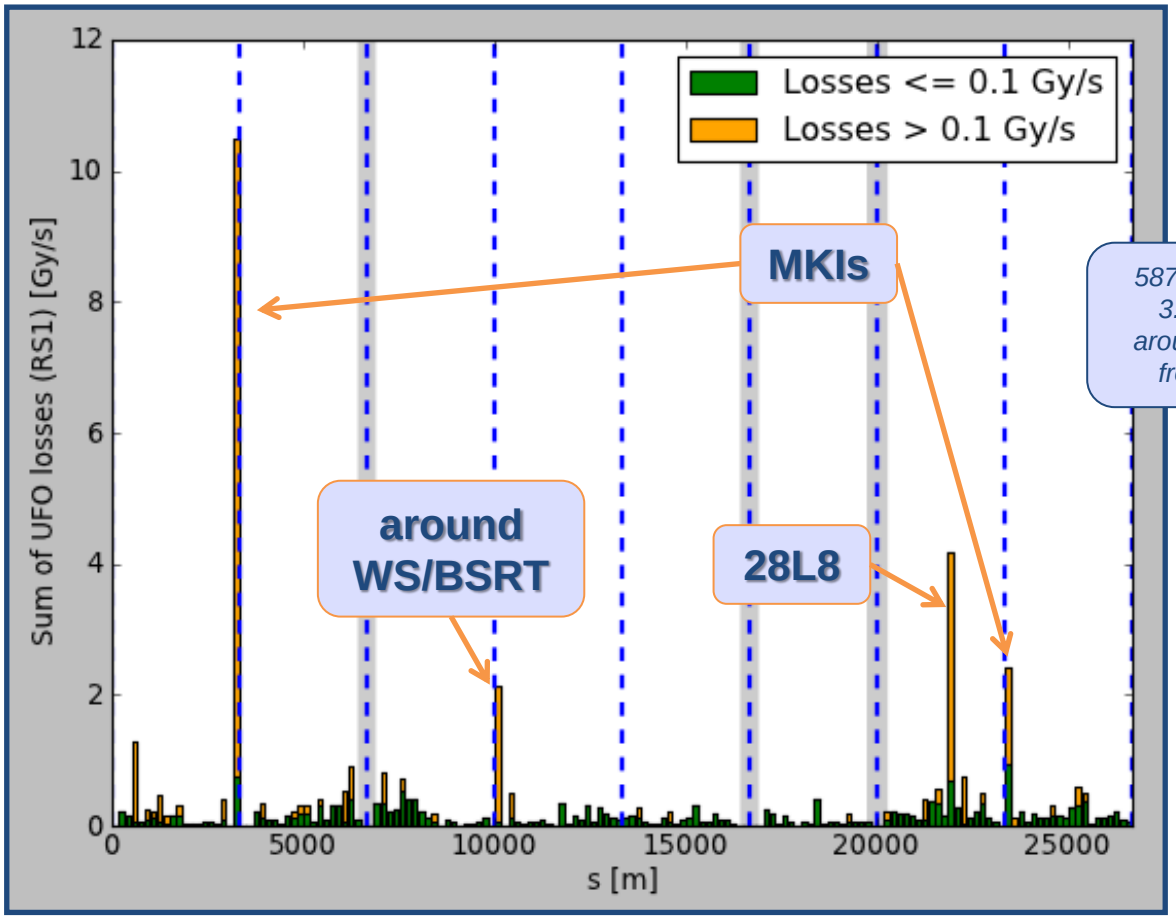
Spatial UFO Distribution

- Many UFOs around ***MKIs***.

- Arc locations with many UFOs:
  (on average ≈2.5 UFOs per cell and beam)
  - ***BLMQI.16L3.B2E10_MQ: 32 UFOs.***
  - ***BLMQI.19R3.B1I10_MQ: 50 UFOs.***
  - ***BLMQI.25R3.B2E10_MQ: 53 UFOs.***
  - ***BLMQI.32L5.B1I10_MQ: 34 UFOs.***
  - ***BLMQI.28L6.B2I10_MQ: 33 UFOs.***
  - ***BLMQI.28R7.B2I10_MQ: 47 UFOs.***
  - ***BLMQI.28L8.B1E10_MQ: 37 UFOs.***

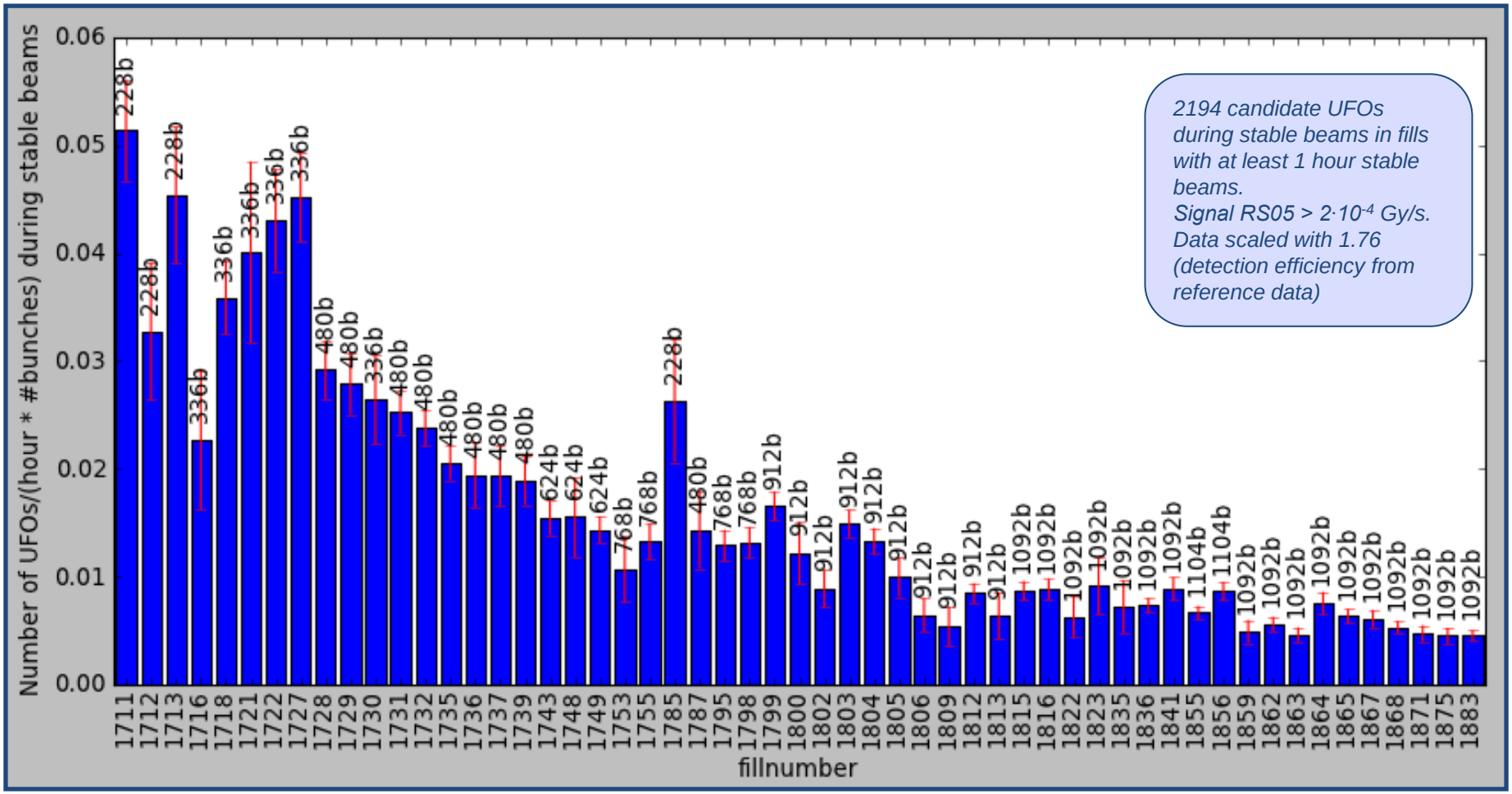


Weighted Spatial UFO Distribution

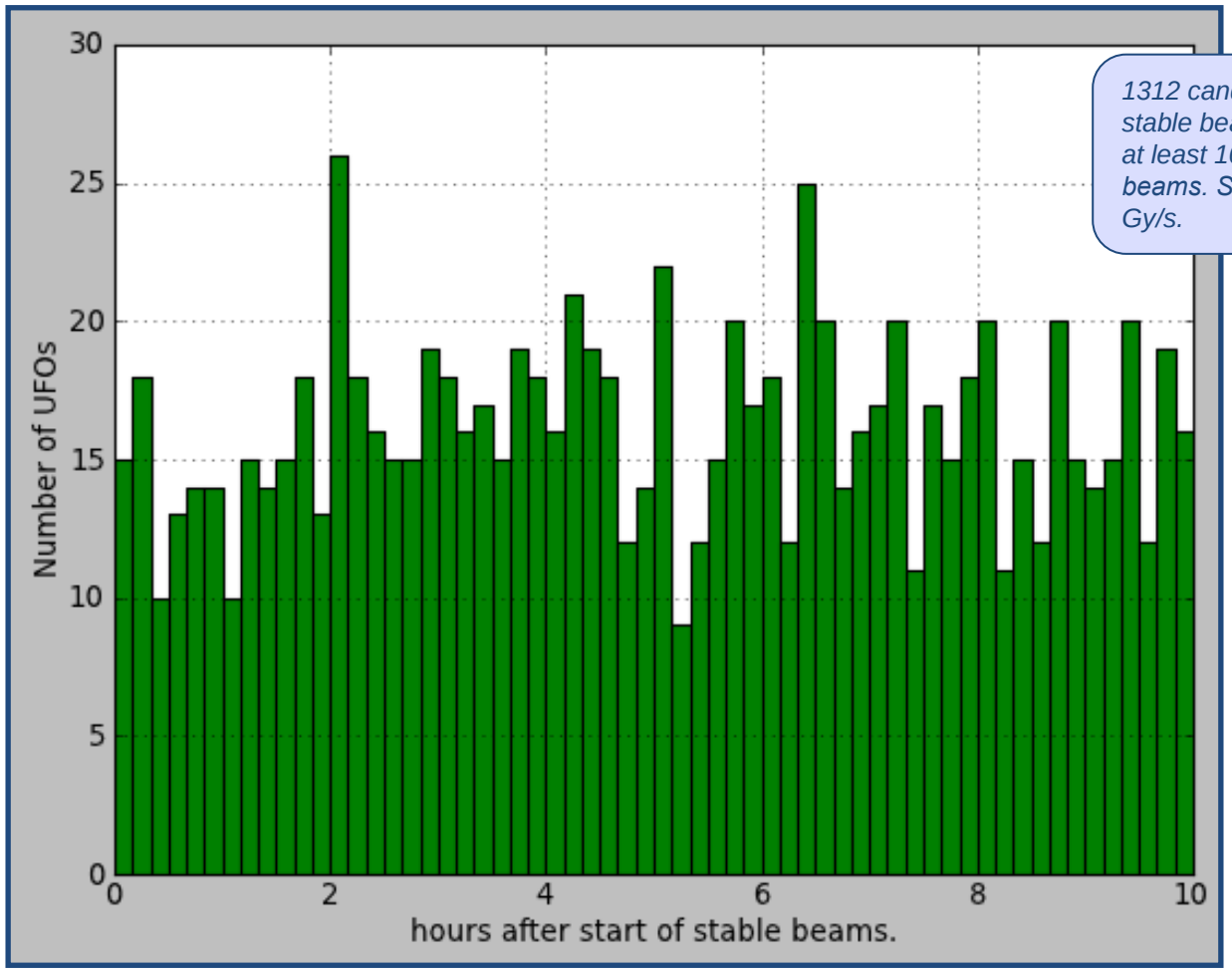


The weighted spatial distribution is dominated by a few large amplitude UFOs.

Normalized UFO rate



Intrafill UFO rate



1312 candidate UFOs during stable beams in 18 fills with at least 10 hours stable beams. Signal RS05 > $2 \cdot 10^{-4}$ Gy/s.

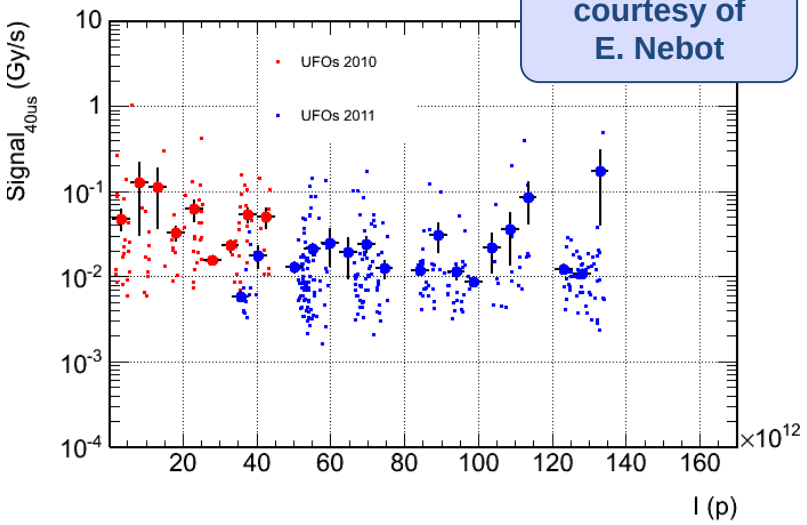
The UFO rate stays constant during a fill.

Peak Signal

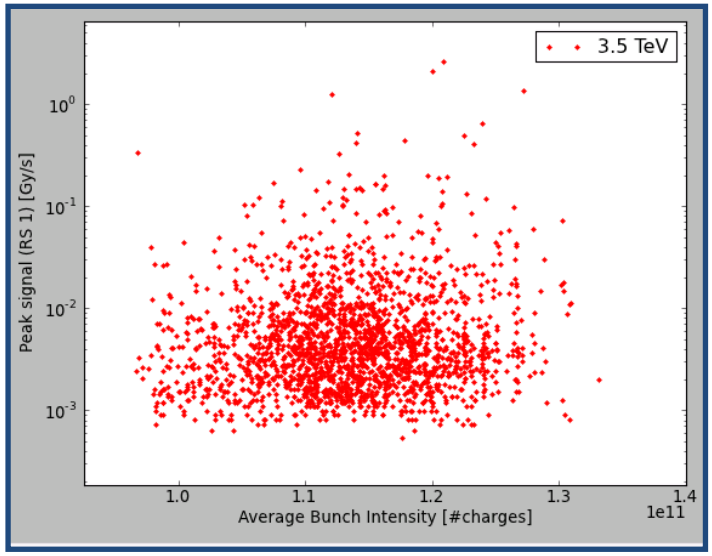
- No clear dependency of peak loss on intensity.

(cf. E.B. Holzer at Evian Dec. 2010)

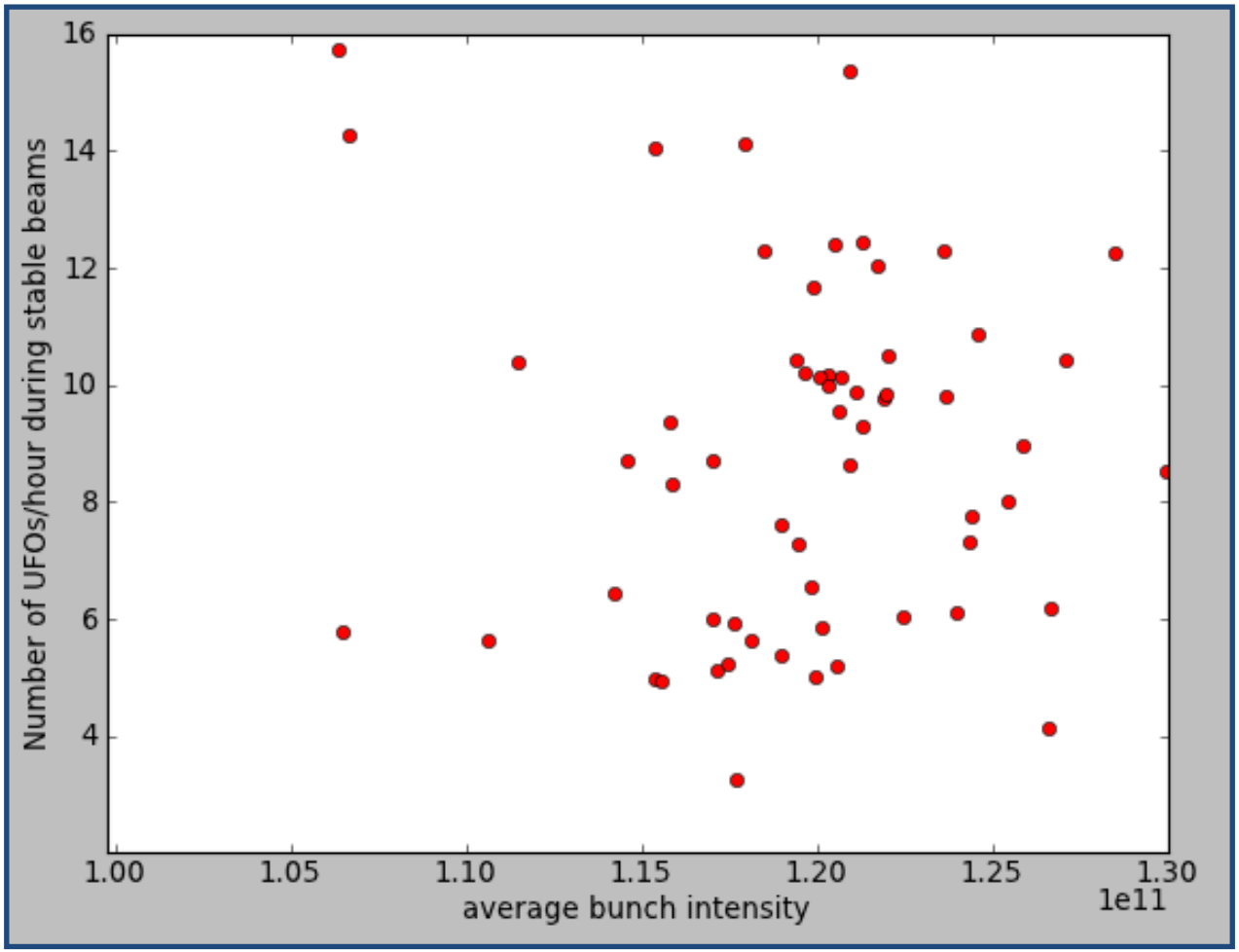
courtesy of E. Nebot



- No clear dependency of peak loss on bunch intensity.

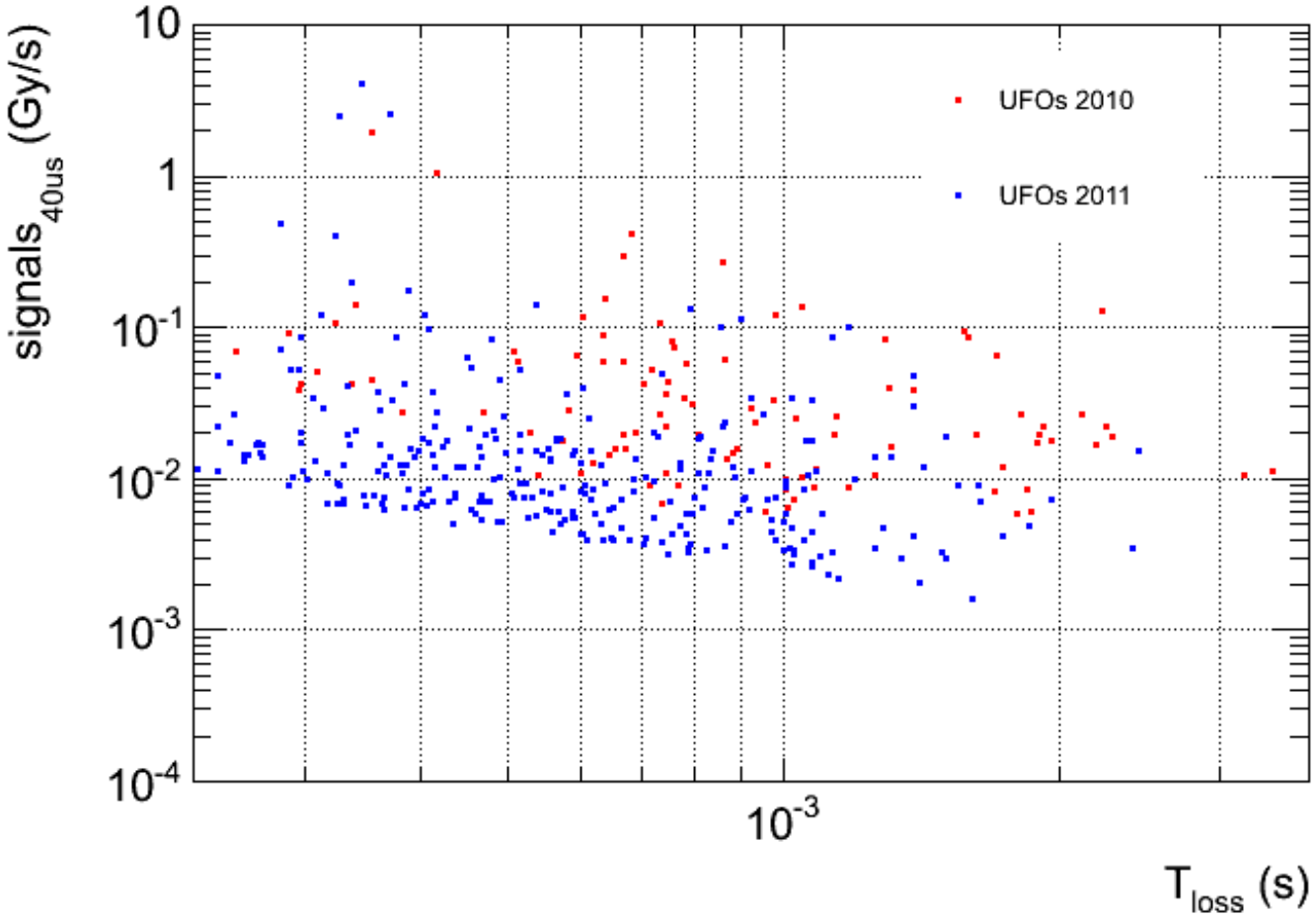


UFO rate vs Bunch Intensity



No dependency of UFO rate on buch intensity.

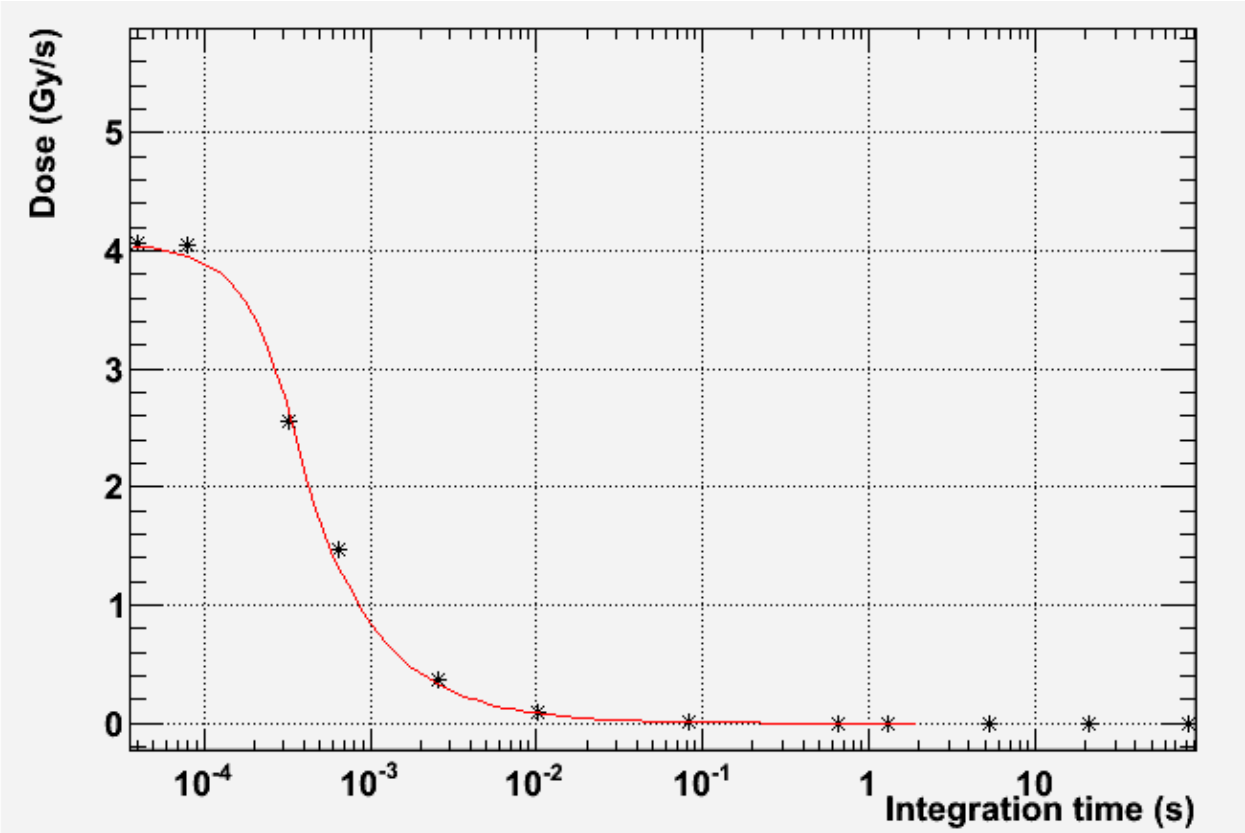
Peak Signal vs Loss Duration



courtesy of E. Nebot

Tendency that harder UFOs are faster.

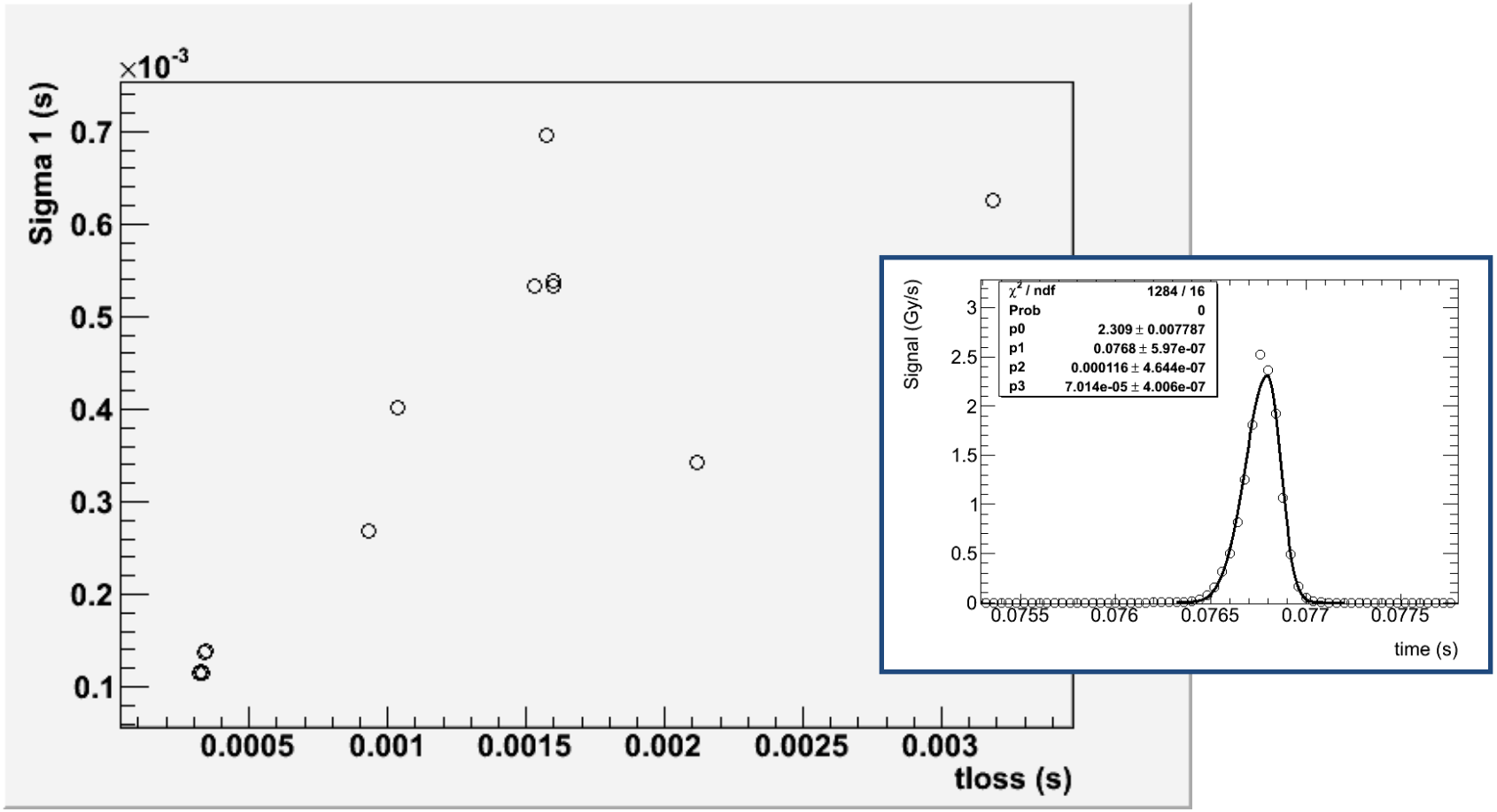
Loss Duration



T_{loss}: Given by fitting single function (Gaussian up to $t=T_{loss}$, 1/t afterwards) to data.

courtesy of E. Nebot

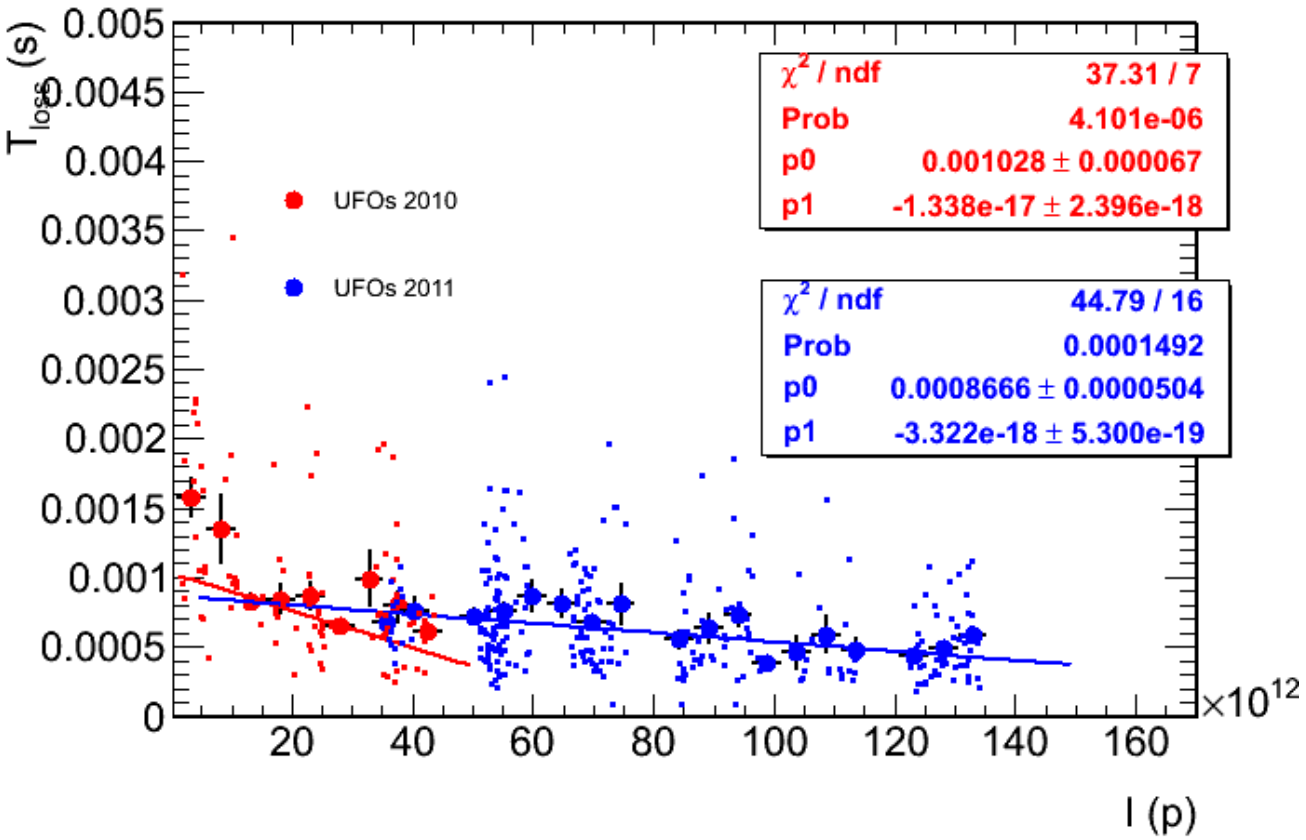
Calibration of T_{loss}



Correlation of T_{loss} and width of Gaussian fitted to post mortem turn-by-turn data.

courtesy of E. Nebot

Loss Duration

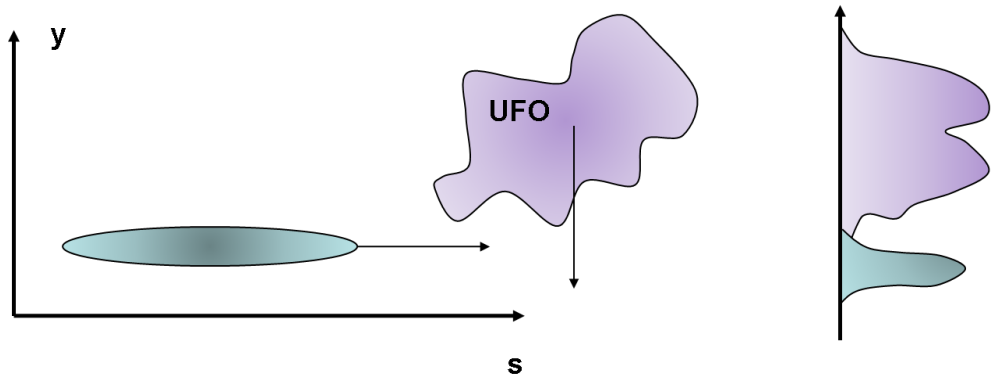


UFOs have the tendency to become faster with increasing intensity.

(cf. E.B. Holzer at Evian Dec. 2010)

courtesy of E. Nebot

UFO size



- Two extreme cases:
  - UFO much larger than beam: the beam is imaging the UFO.
  - UFO much smaller than beam: the UFO is imaging the beam.

Most UFO shapes are Gaussian, thus most UFOs are expected to be smaller than the beam.

- From FLUKA simulations: size ≈ 1 µm.

(cf. M. Sapinski, F. Zimmermann at Chamonix 2011)

courtesy of
J. Wenninger
(cf. MPP 25.03.2011)

UFO Speed

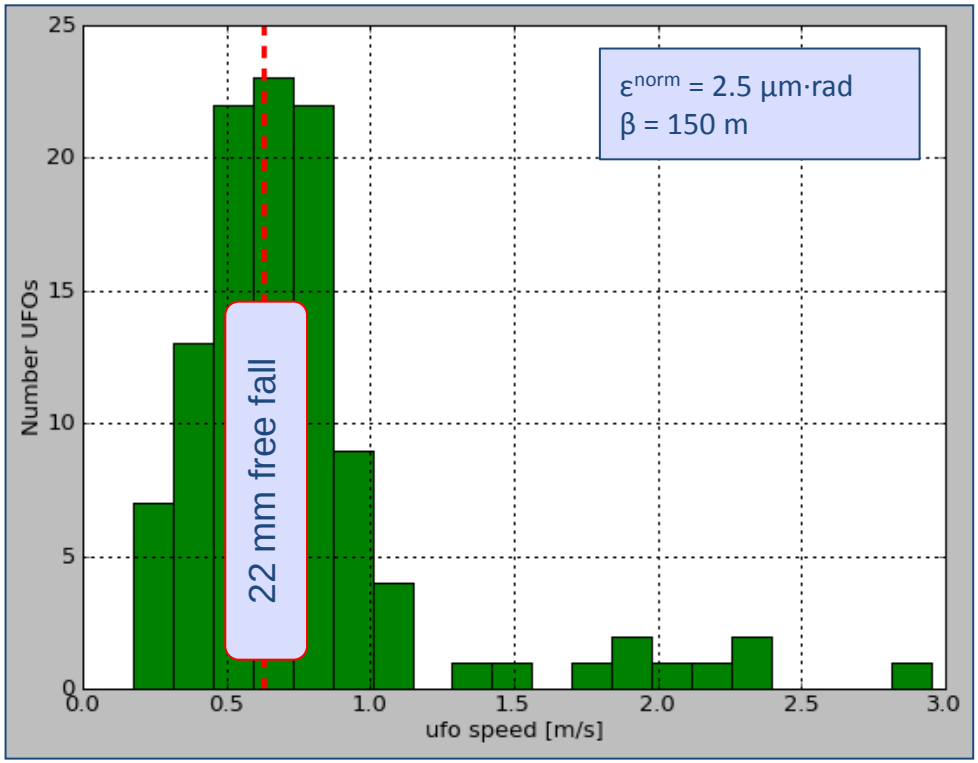
- UFO speed:

$$v_U = \frac{\sqrt{\sigma_b^2 + \sigma_U^2}}{\sigma_T} > \frac{\sigma_b}{\sigma_T}$$

v_u: UFO speed, σ_b: transverse beam size, σ_u: UFO size, σ_T: temporal width of loss.

- From free fall:

$$v_U = \sqrt{2 \cdot g \cdot h} = 0.63 \frac{m}{s}$$



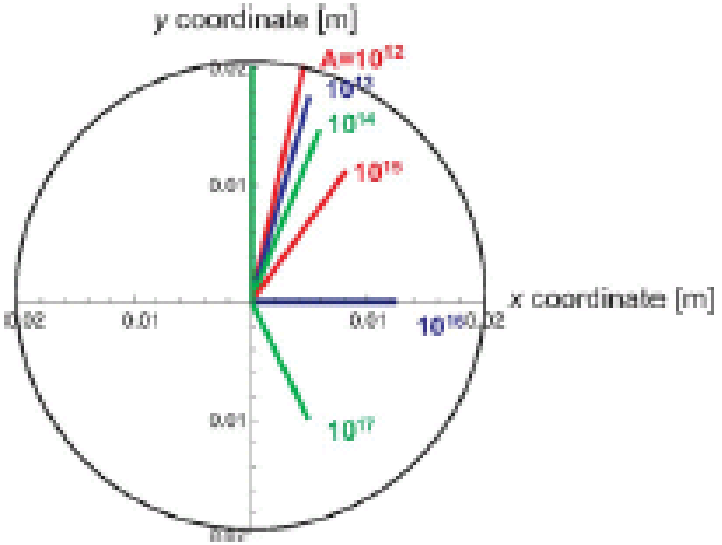
The UFO speed corresponds to the expected speed for a free fall from the aperture.

Dynamics of Dust Particles

From **simulations**:

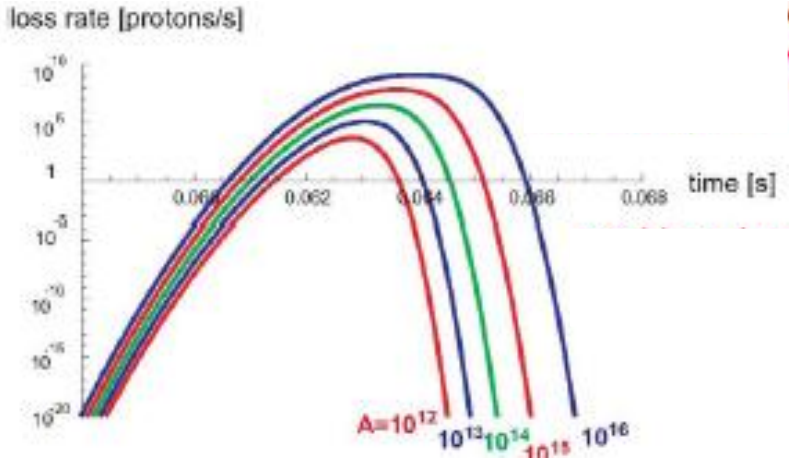
- Dust particle will be positively ionized and be repelled from the beam.

  Beam intensity: 2.3·10^{12} protons, Al object.



- Loss duration of a few ms.

  Losses become shorter for larger beam intensities.



courtesy of
F. Zimmermann

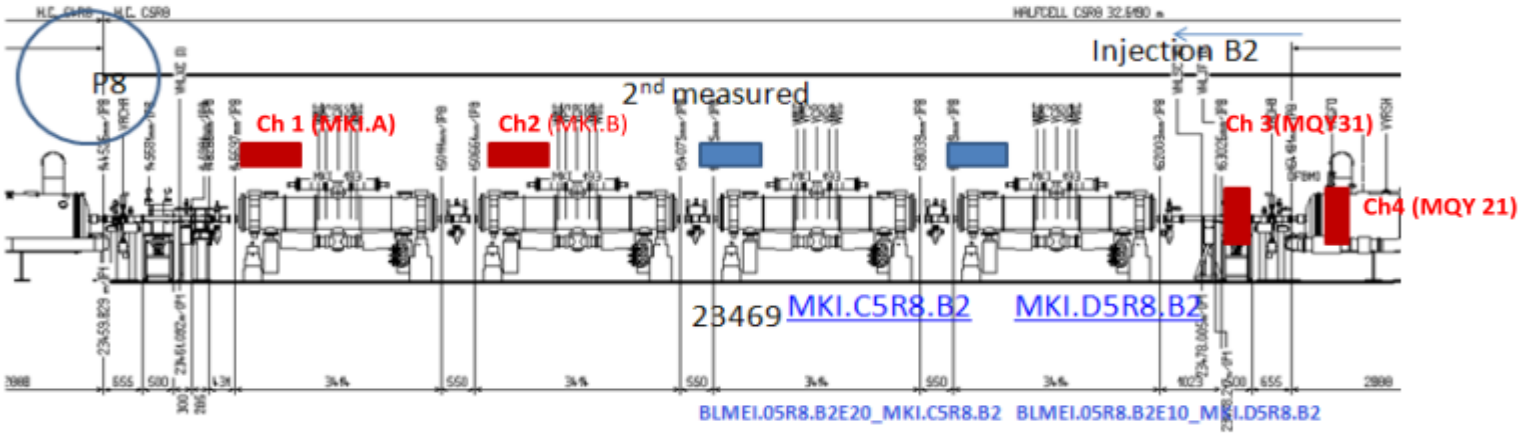
Content

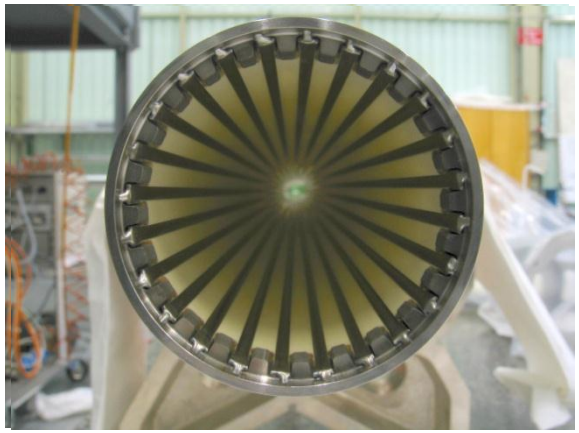
3. UFOs at MKIs

Layout of MKI Region

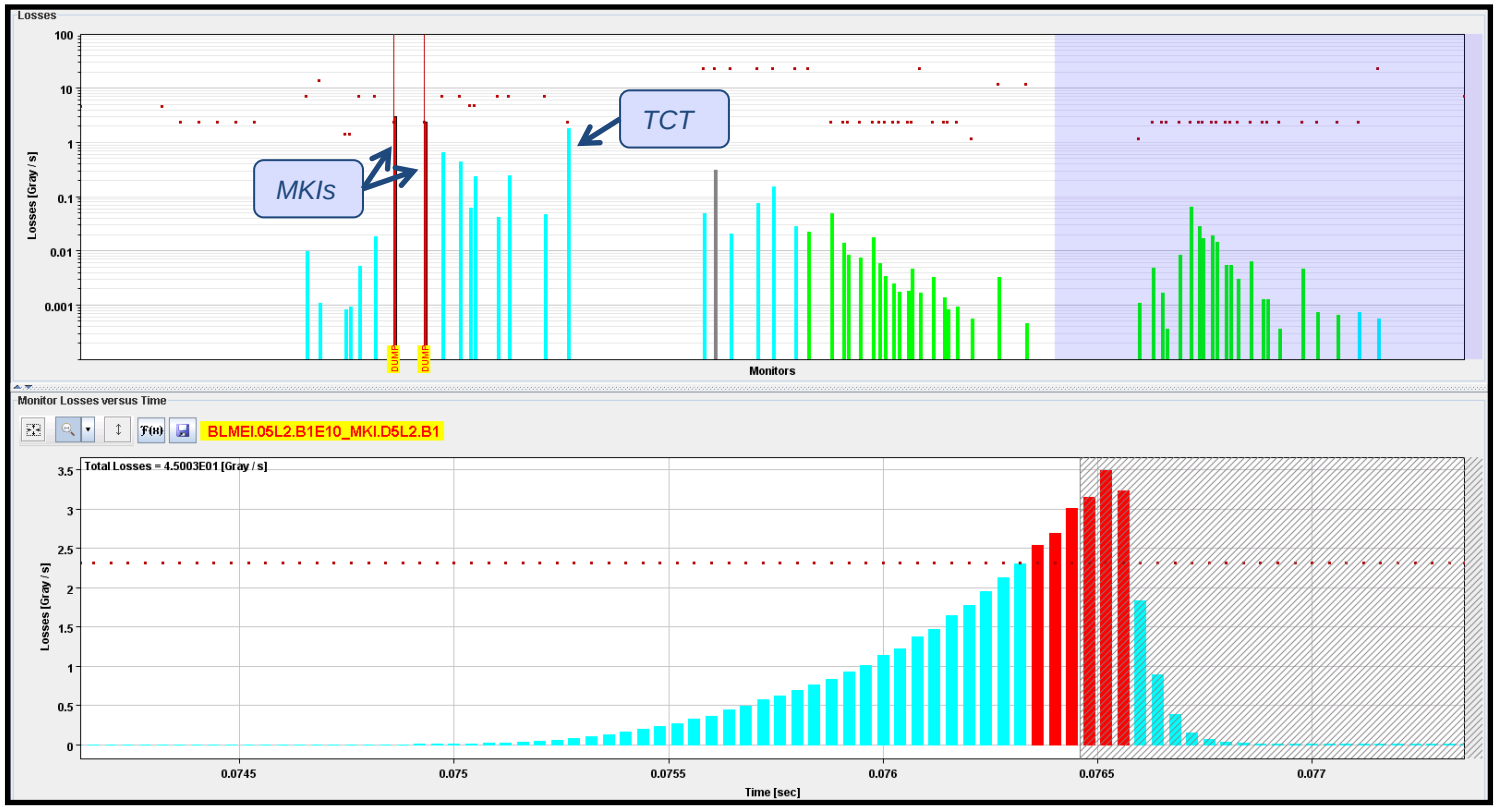
4 BLMMI.MKI P8 (installed 23.06.2011 right of point 8)

Thursday, June 23, 2011
4:48 PM





Beam dump on 6.6.2011



UFO at MKI in Pt. 2, at **450 GeV.**

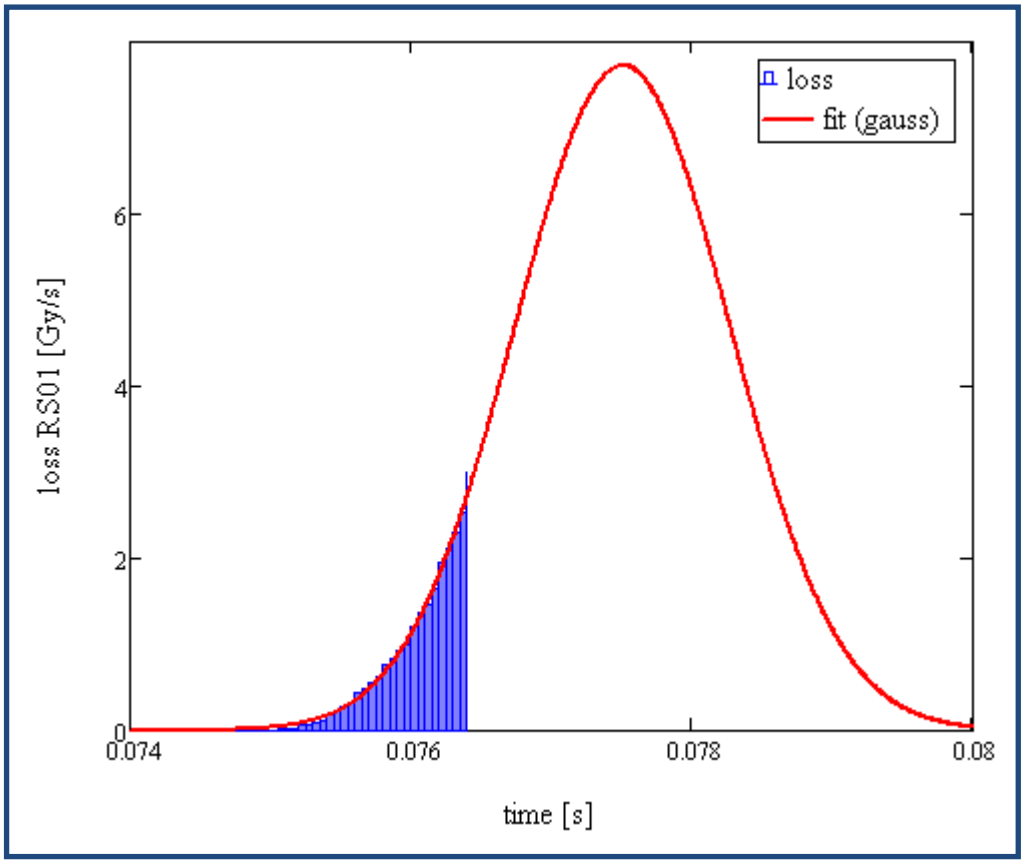
Small loss signal at Q5 (backscattering?).

Beam dump 06.06.2011

- From fit to losses (BLMEI.05L2.B1E10_MKI.D5L2.B1):
  - Amplitude: **7.73 Gy/s**
    (Threshold: 2.3 Gy/s)
  - Width: 0.77 ms

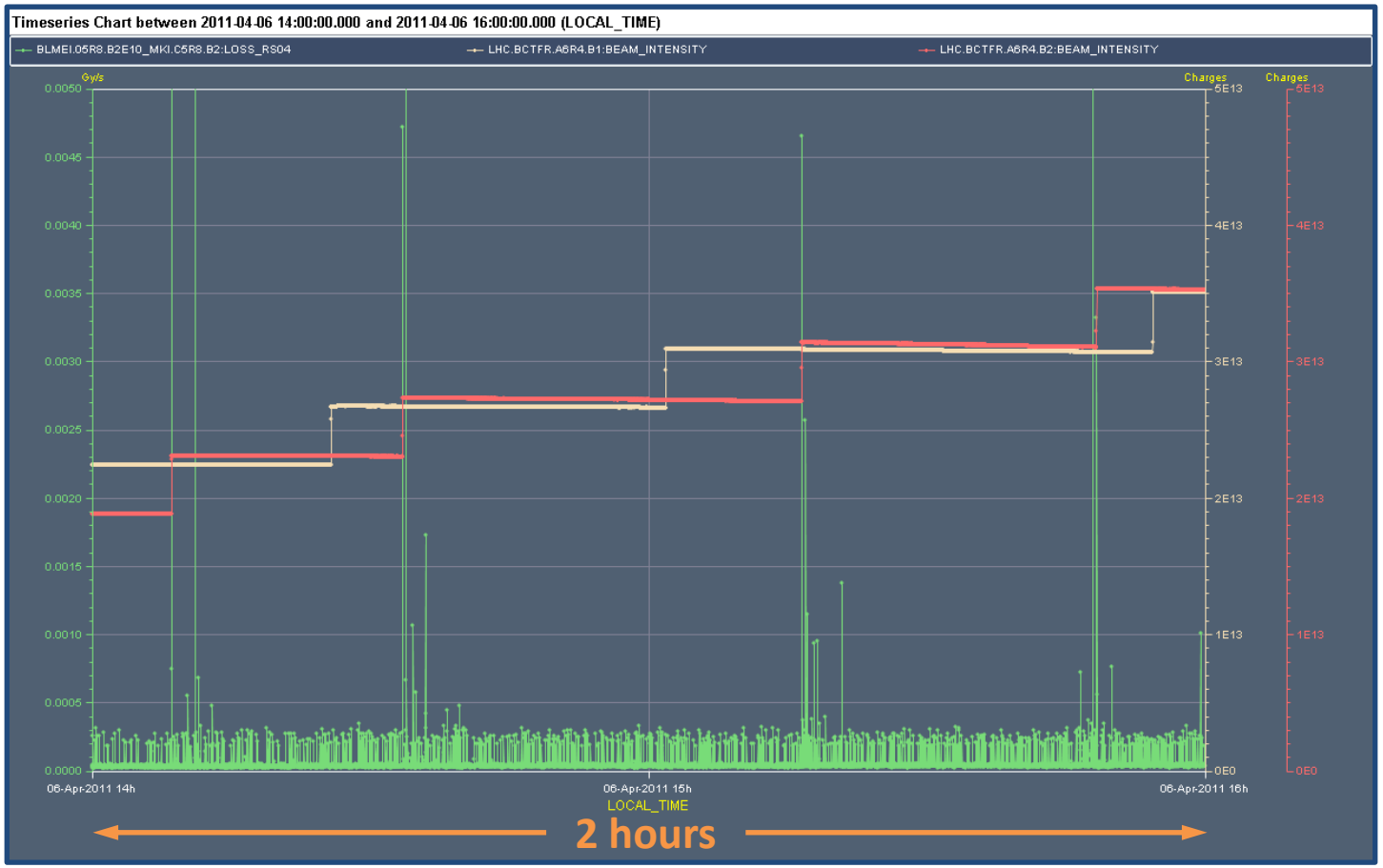
    resulting speed of transiting dust particle = **0.47 m/s**.
    (assuming ϵ^n=2.2µm·rad)

    (Brennan Goddard)



MKI UFOs During Scrubbing

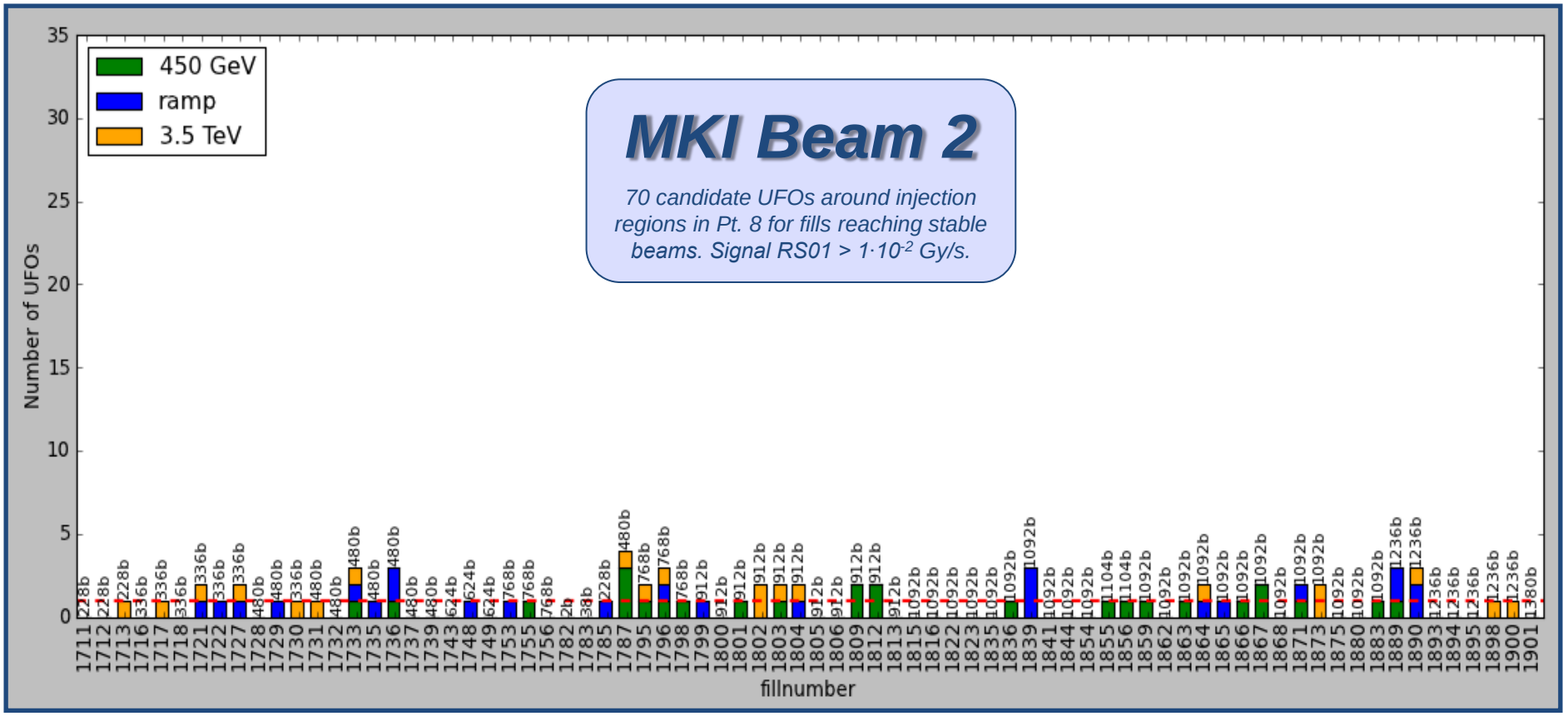
- Typical scenario for MKI UFOs during scrubbing: The MKI UFO rate is increased for about 10 minutes after each injection.



MKI UFO Storms

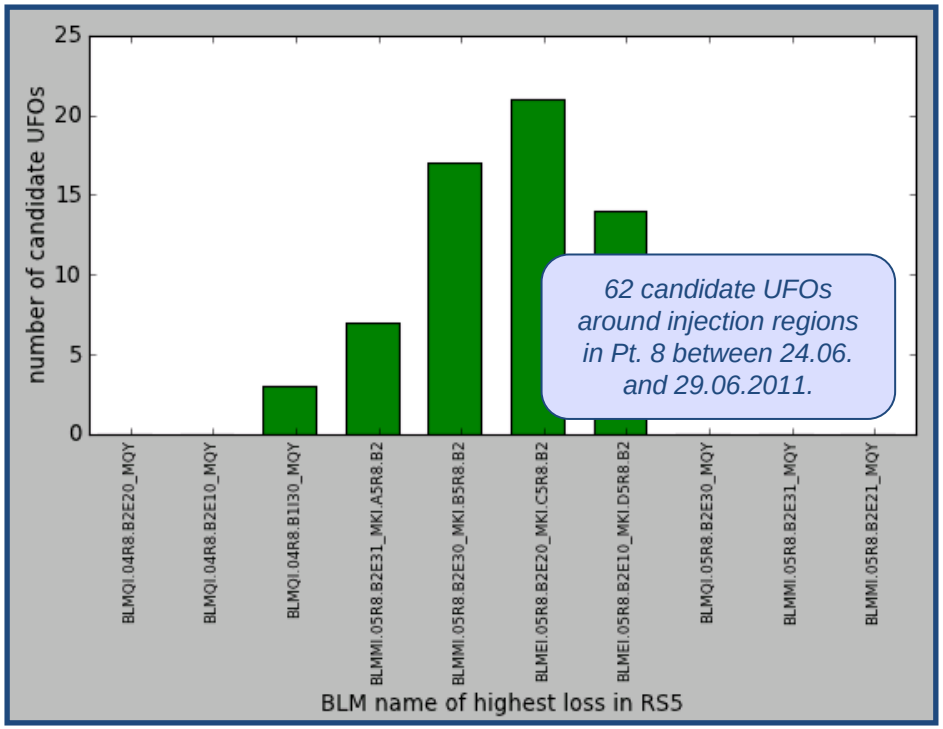
- Fill 1898 (26th June): 15 UFOs MKI B1, 7 UFOs MKI B2.
  - 14 UFOs at MKI B1 within 40 min.
  - Highest UFO: 34% of Threshold at TCTH.4L2 (RS1, RS2) at 3.5 TeV.
- Fill 1900 (27th June): 32 UFOs MKI B1, 5 UFOs MKI B2.
  - **17 UFOs at MKI B1 within 6 min.**
  - Highest UFO: **65%** of Threshold at MQY.04L2 (RS6) at 3.5 TeV.
- Fill 1901 (28th June): 41 UFOs MKI B1, 12 UFOs MKI B2.
  - **16 UFOs at MKI B1 in 2:20 min.**
  - Mostly at 450 GeV (12 min. at 450 GeV after last injection).
  - Highest UFO: **63%** of Threshold at TCTH.4L2 (RS8) at 450 GeV.

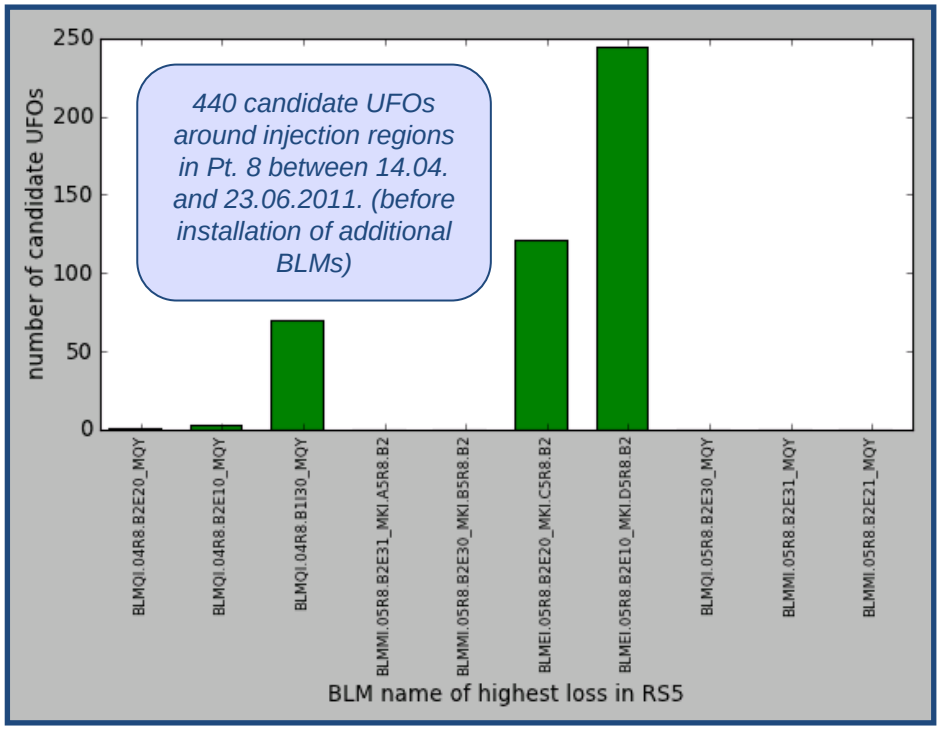
Number of large MKI UFOs B2



The number of large MKI UFOs in Pt. 8 did not increase.

BLM with Highest Loss

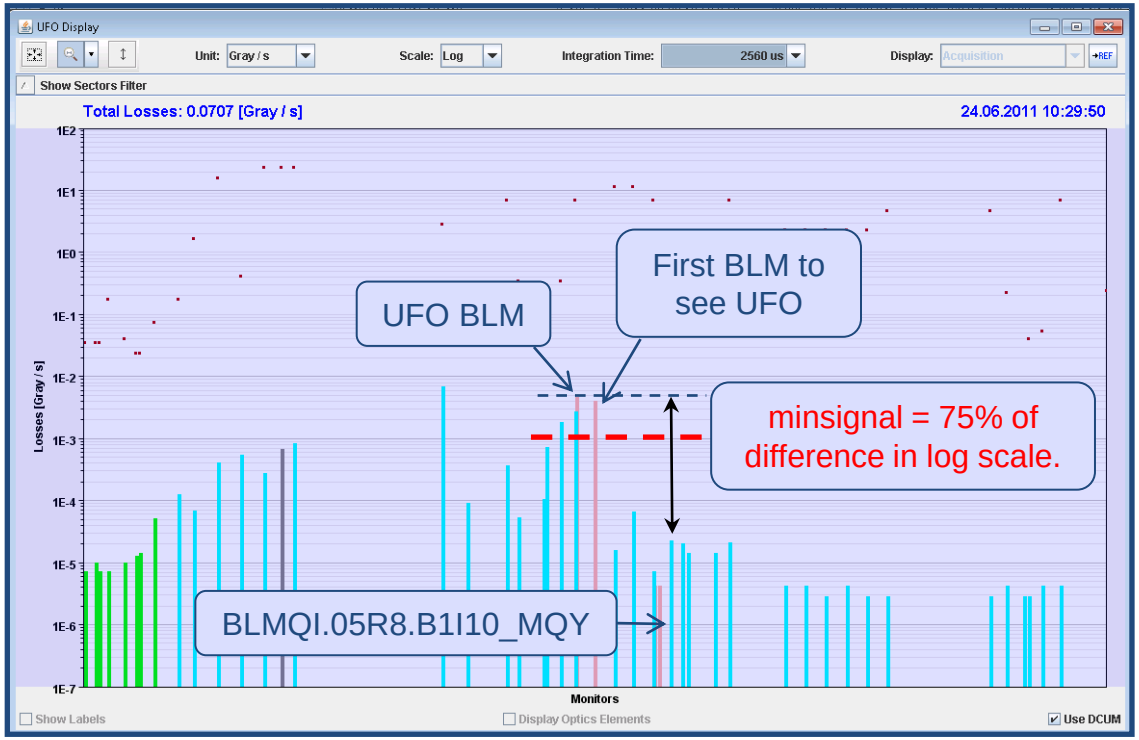




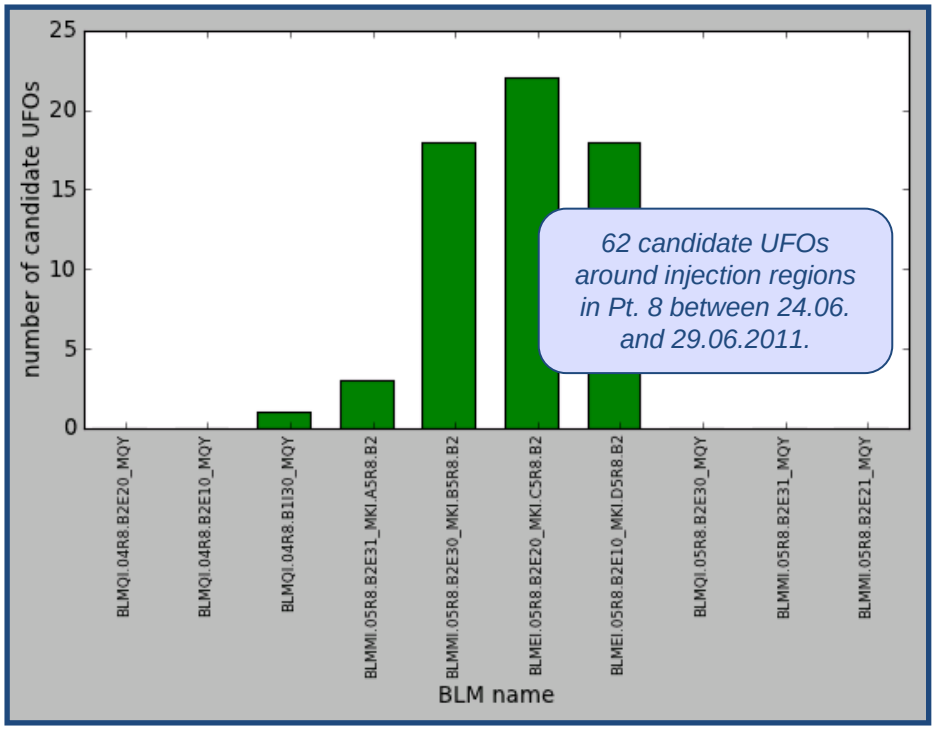
Distribution of BLM with the highest loss RS05.

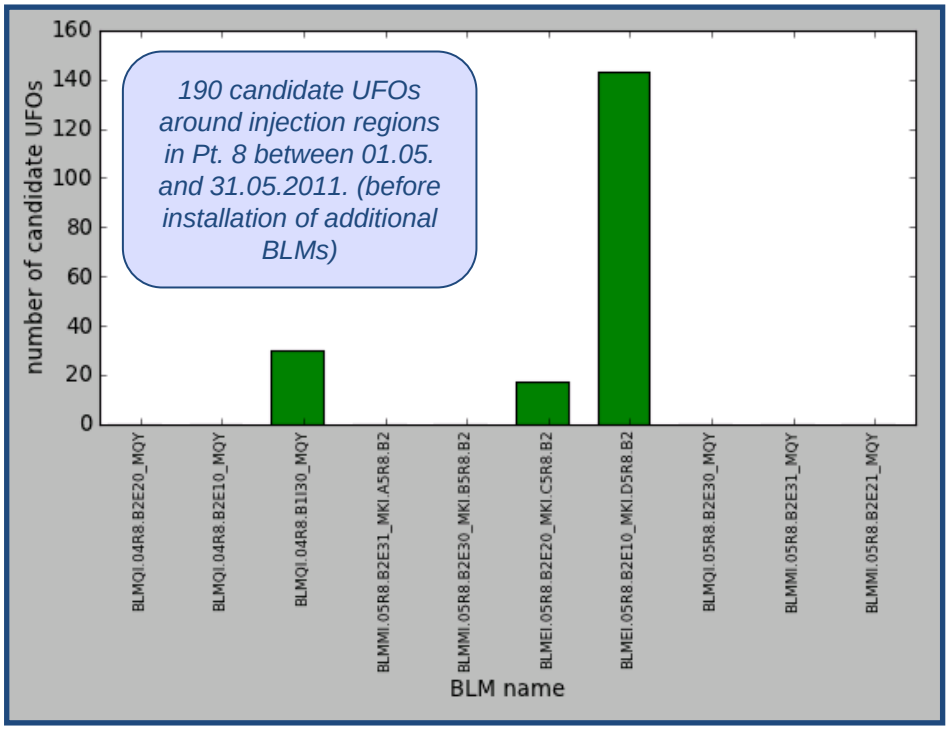
UFO Location

- Sometimes BLMs upstream of the BLM with the highest have only slighly smaller losses.
- → Analyzing first BLM above minsignal (as defined in plot)



Start of UFOs in Pt. 8





Distribution of first BLM to see UFO. Less UFOs are detected to start at MKI A.

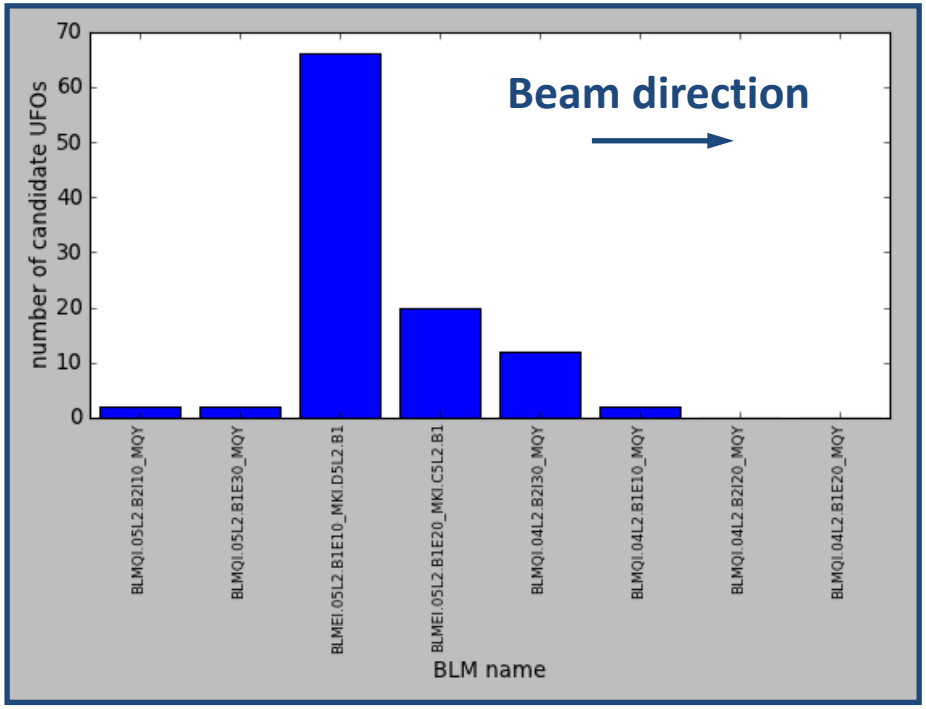
In the past most of the UFOs were observed to start at MKI D.

(cf. presentation at MPP, May 13th 2011)

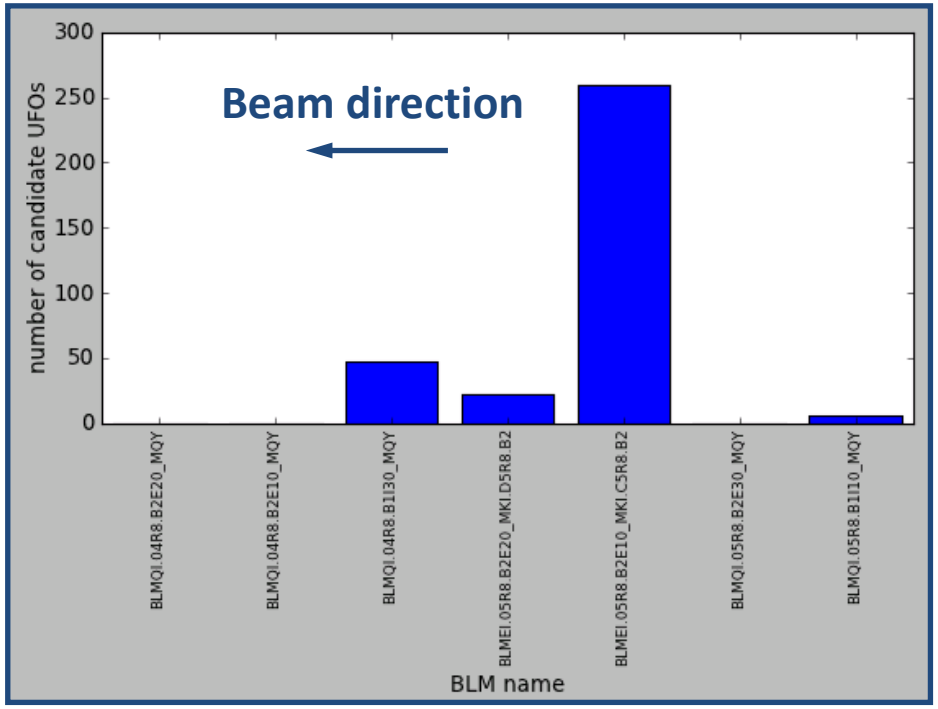
UFOs at MKIs

- 08.04. – 05.05. in total **460** fast loss events around MKIs.
  (**104** around MKI in IP2, **336** around MKI in IP8).

Distribution of first BLM which sees the loss:

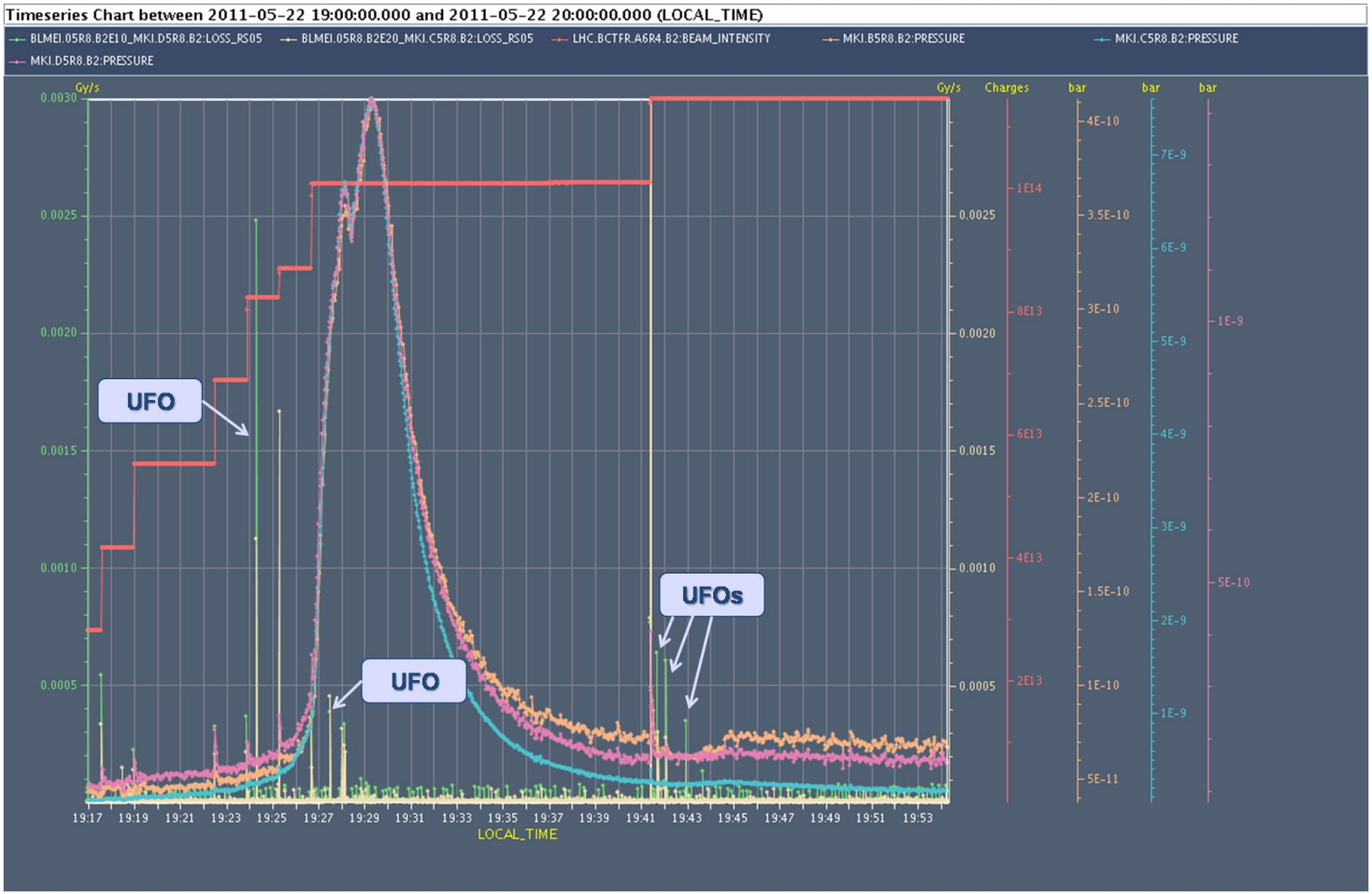


Left of IP2



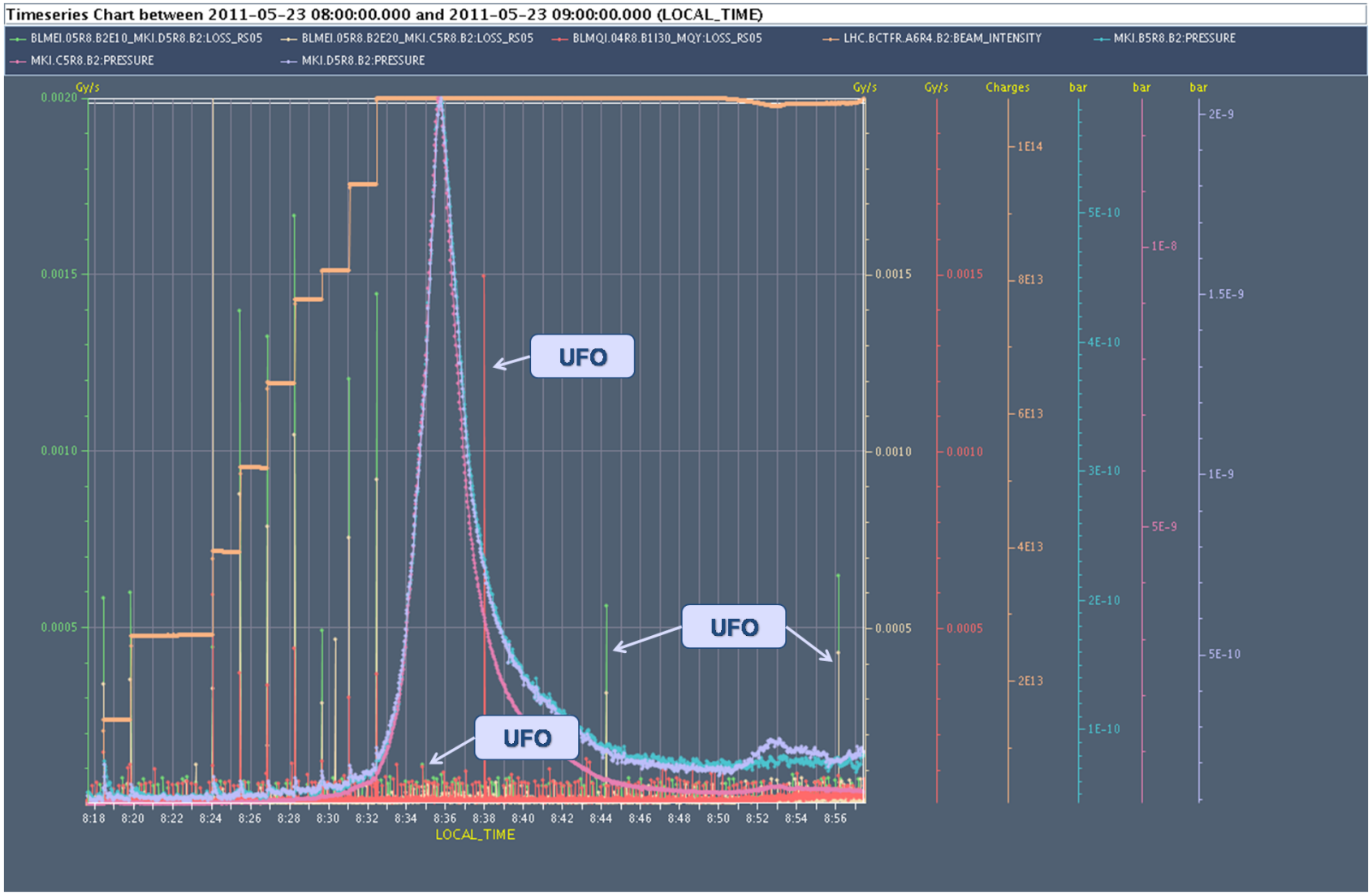
Right of IP8

Correlation with Vacuum

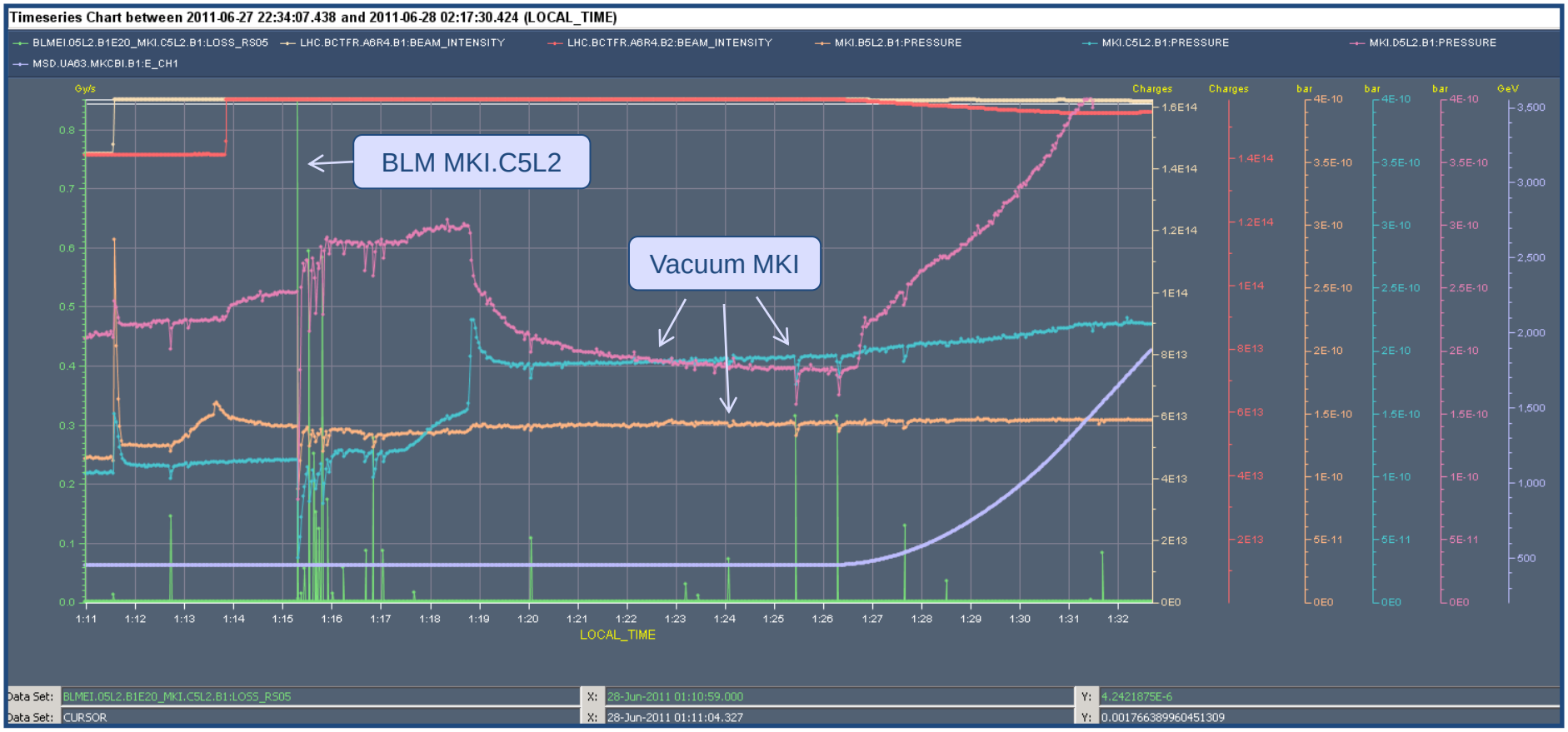


Despite a large vacuum spike, there is no clear correlation with UFOs

Correlation with Vacuum

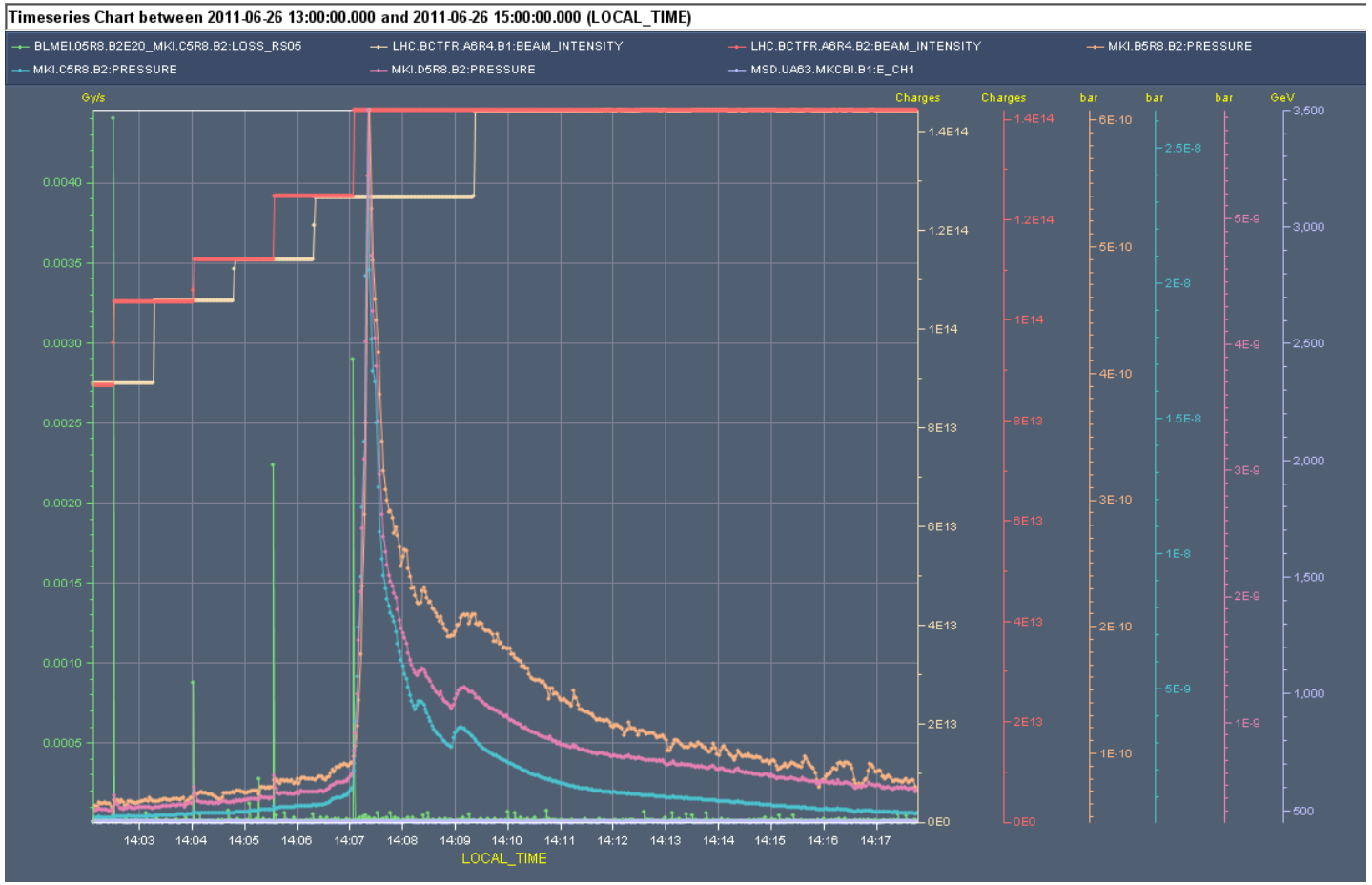


Vacuum Correlation



The pressure spike is seen on all MKI magnets.

Vacuum correlation (slow)



The slow vacuum spike is correlated to the last injection.

No correlation with UFOs

Content

3. Conclusion and Summary

Known Dust Particle Sources

- Distributed ion pumps (PF-AR, HERA).
  No ion pumps in LHC arcs.
- Electrical Discharges (PF-AR).
- Movable Devices (LHC).
- Particles frozen to or condensated at cold elements. (ANKA)

Summary

- **11 UFO related beam dumps** in 2011 so far (18 in 2010).
- **Over 5000 UFOs** below dump UFOs detected in 2011 so far.
  Strong energy dependency expected.
  First Indication that UFO rate might decrease over time.
- Many UFOs around injection kicker magnets
  Pulsing the injection kicker magnets directly induces UFOs.
  During scrubbing: increased UFO rate after each injection.
  Increased UFO rate after MKI Flashover.
- Continuous improvements of diagnostics are ongoing.