UFOs in the LHC

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BE-BI-BL (Beam Loss Monitors)

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The Beam Loss Monitoring System

- Around 3600 Beam Loss Monitors (BLMs) are installed around the LHC to check for high radiation losses from the beam that could quench the superconducting magnets or damage other equipment.

The Beam Loss Monitoring System

- The BLMs measure average dose (energy per unit mass per second) over 12 different time intervals (from 40 μs to 83.9 s).
- If the dose measured is above a specified abort threshold a protective beam dump is triggered.

What are UFOs?

- During 2010, the BLM system recorded unexpected losses occurring over a timescale of a few ms. These were a limiting factor in the machine availability.
- These losses are caused by micrometer sized dust particles - “Unidentified Falling Objects”- falling into the beam and interacting with the circulating protons.

Why do UFOs matter?

- Between 7th July 2010 and the end of 2011, there were 35 beam dumps due to UFOs.
- From mid-2011, the impact of UFOs was mitigated by increasing the BLM abort thresholds.

Why do UFOs matter?

- Average UFO dose is expected to increase with beam energy.
- Due to higher currents, the magnet quench limits are lower at higher beam energy, and so the BLM abort thresholds must be decreased.
- Therefore beam dumps due to UFOs could be a significant luminosity limitation during 7 TeV operation.

Project Aims

Analyze data from candidate UFO events recorded by the BLMs:

- Understand more about the causes of UFOs
- Explore mitigation possibilities

What do we already know?

- Average UFO dose is expected to increase with beam energy.
- UFO rate increases with beam intensity up to a few hundred bunches.
- Loss duration decreases as intensity increases.

How to measure UFO "size"

- For each UFO, the BLM gives the maximum average dose integrated over 12 different time intervals.

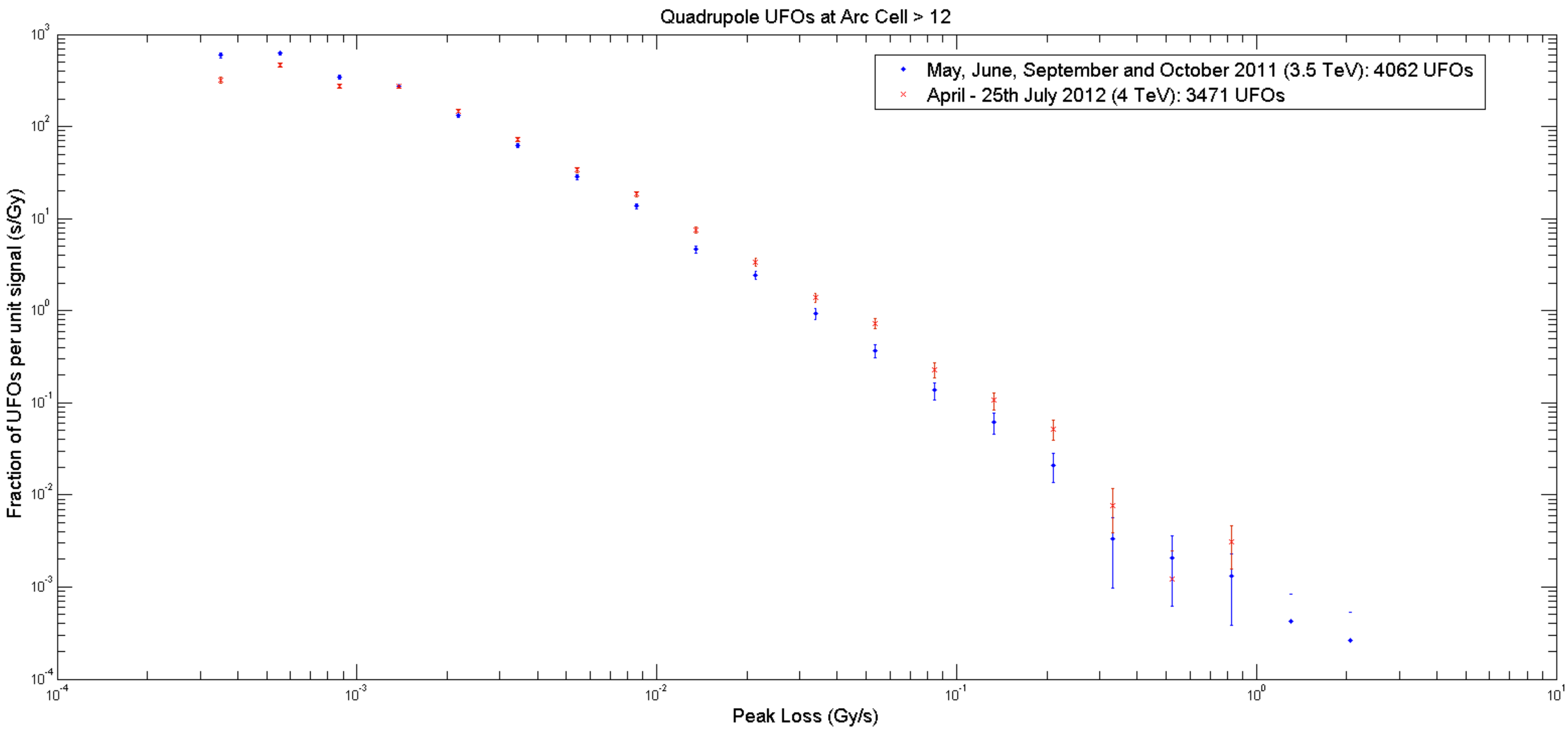
Two intervals used here:

Peak Loss = Highest average dose over 40 μs

Integrated Dose = Highest average dose over 10.24 ms

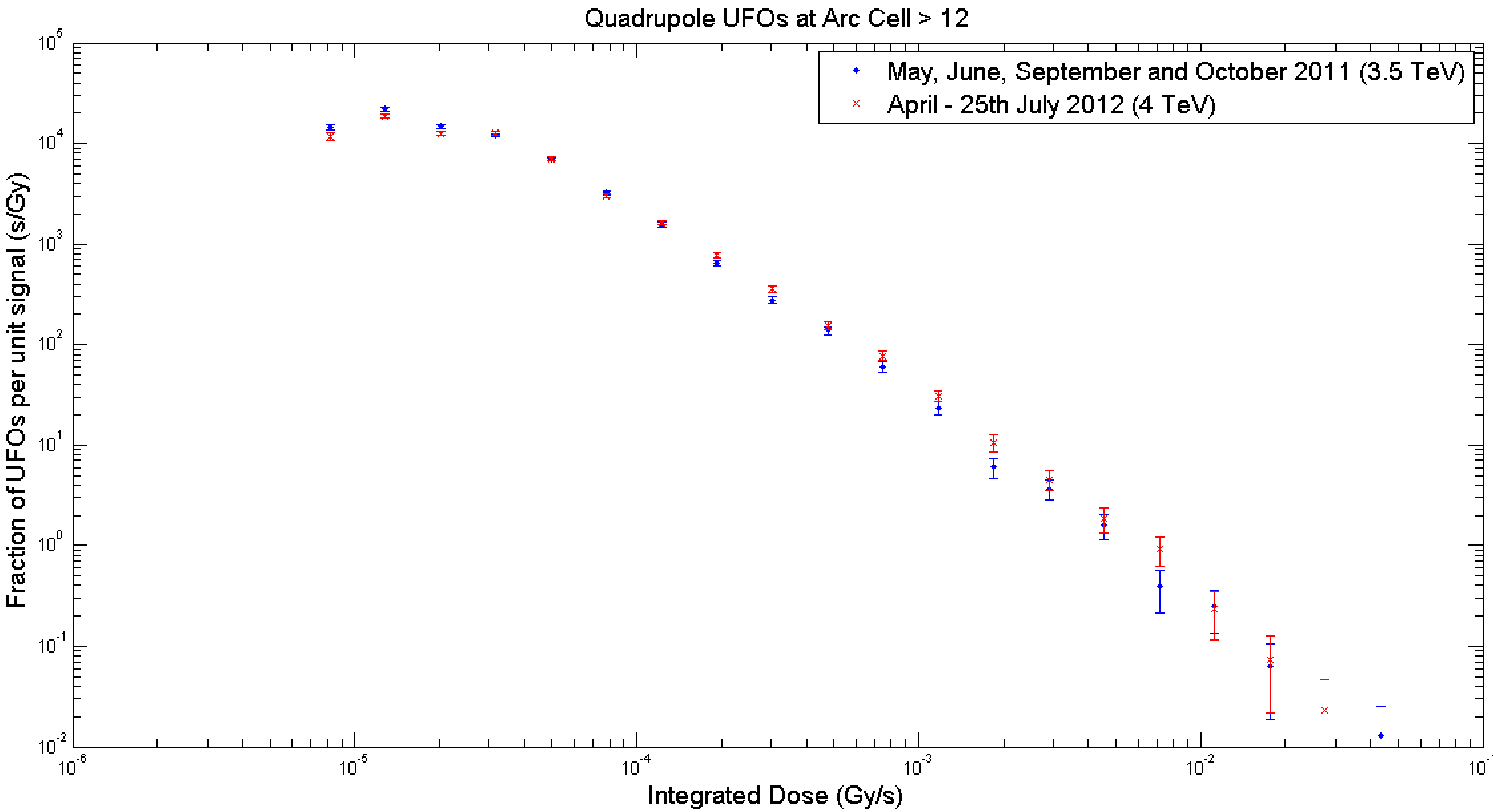
- Similar results obtained whichever integration window is used

UFO dose distributions in 2011 and 2012

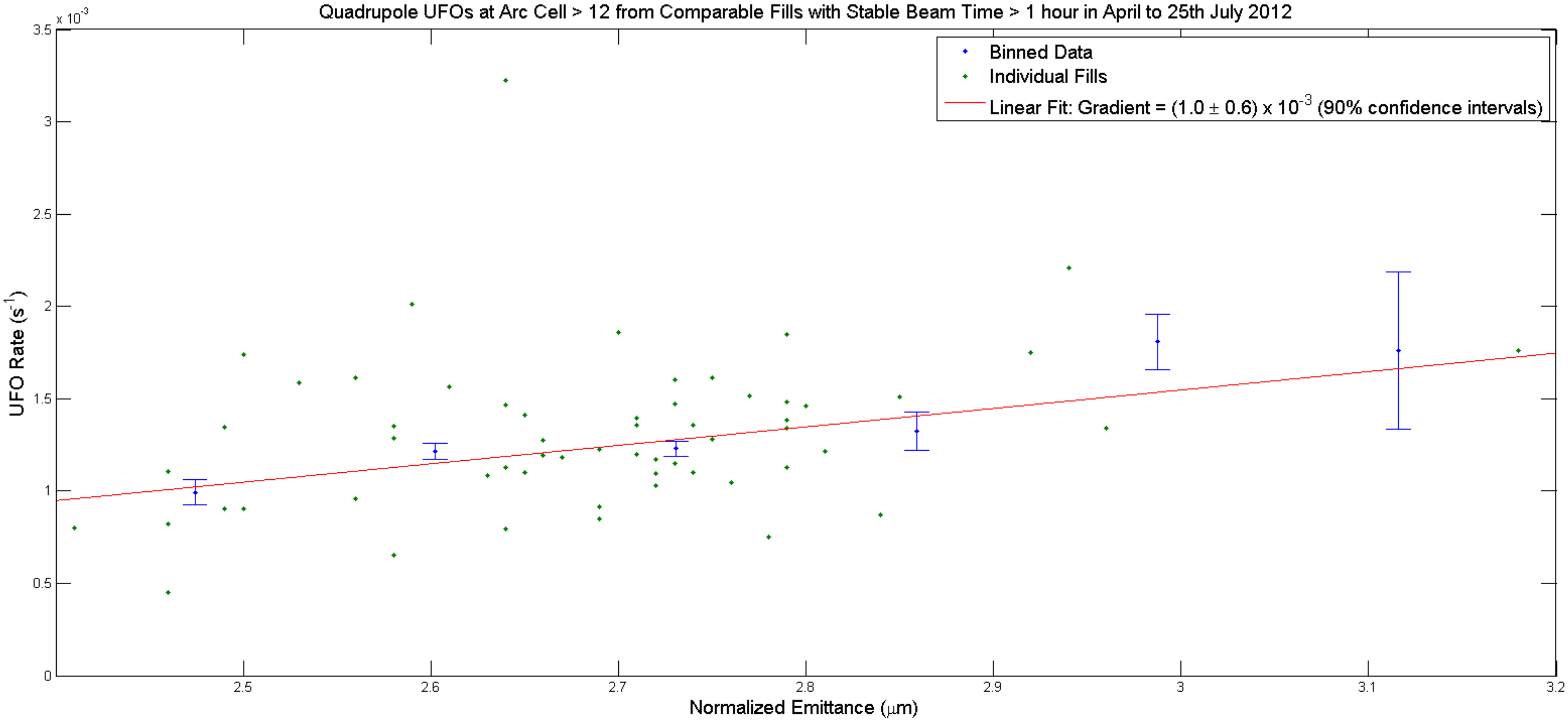


- More UFOs in 2011
- Similar distributions in 2011 and 2012
- Greater proportion of higher dose UFOs in 2012 as expected from increase in energy

Integrated Dose Distributions



Effect of Beam Emittance

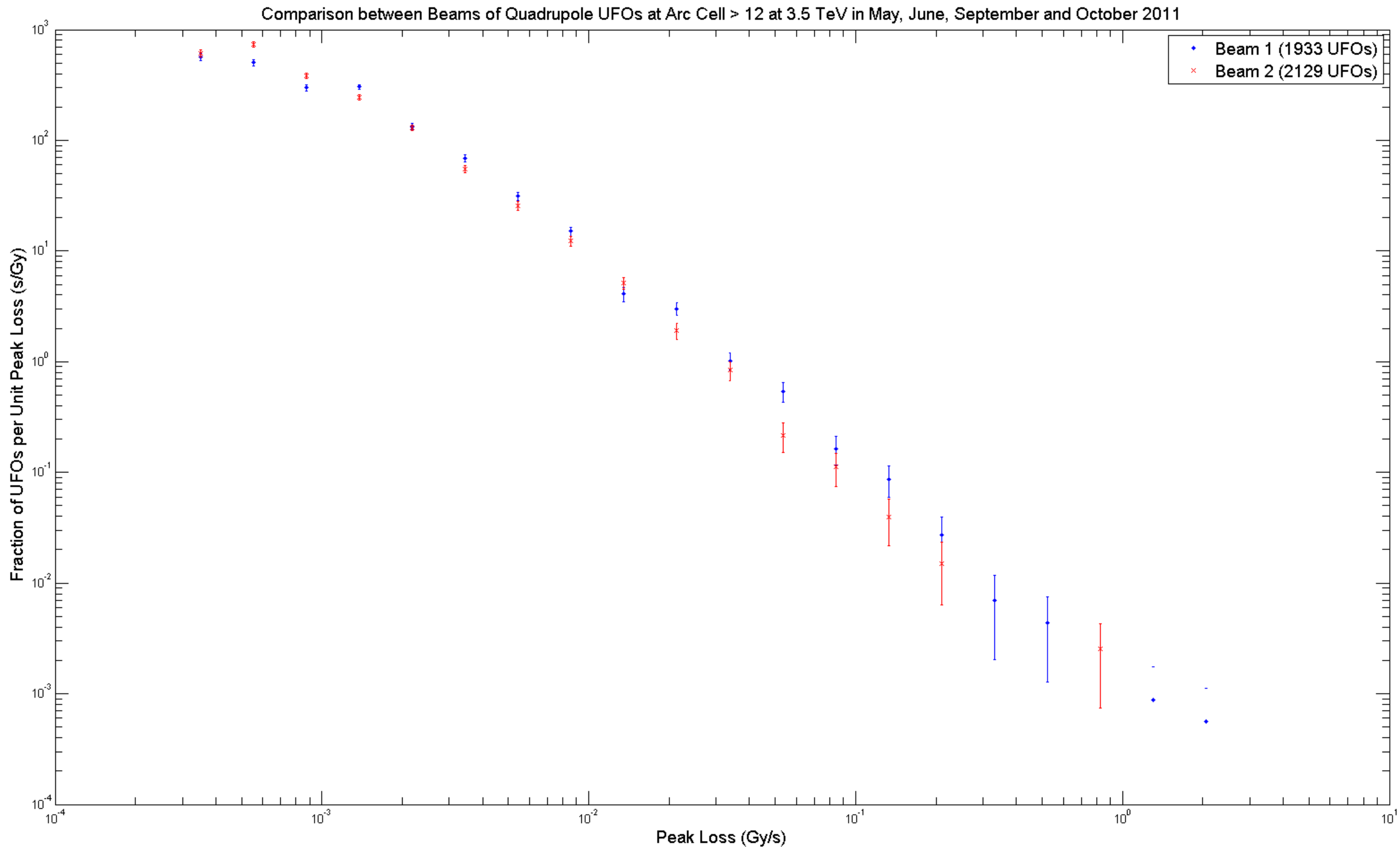


Effect of Beam Emittance

- Over the normalized emittance range 2.5 – 3 μm, we see a broad increase in UFO rate with emittance
- However, even some low emittance fills have a very high rate

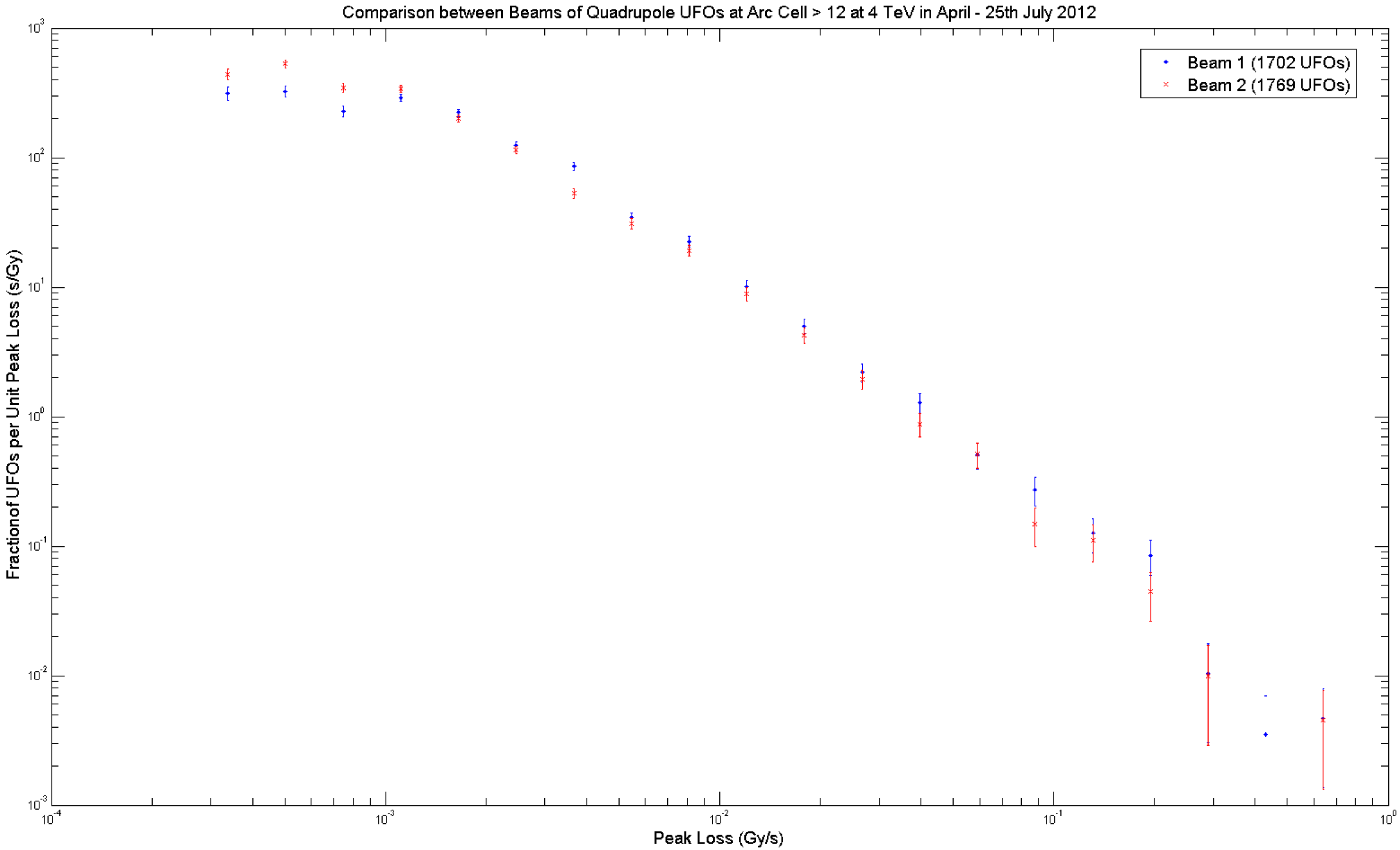
UFOs in each Beam

- No a priori reason to expect a different UFO distribution in beam 1 and beam 2
- Have a look anyway…



<u>2011</u>

- More UFOs in total in Beam 2
- A greater proportion of low dose UFOs in Beam 2
- Neglecting UFOs with peak signal < 10^{-3} Gy/s: 1272 in Beam 1, 1170 in Beam 2



<u>2012</u>

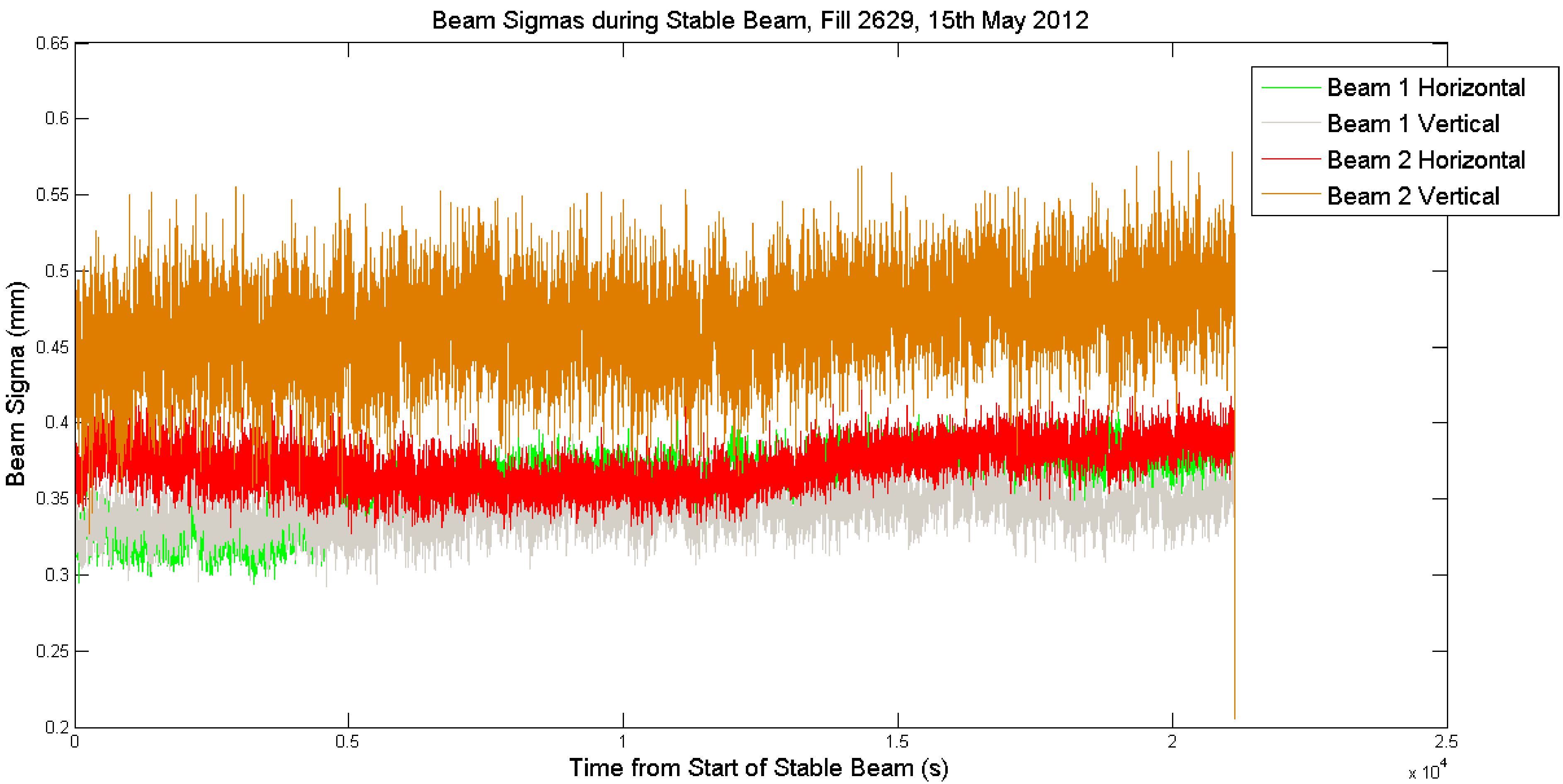
- A few more UFOs in Beam 2
- A much greater fraction of the Beam 2 UFOs have low dose
- Neglecting UFOs with peak signal < 10^{-3} Gy/s: 1319 in Beam 1, 1176 in Beam 2

UFOs in each Beam

- Look for other differences between beams that might explain the difference in their UFO distributions
- UFOs results from a range of very complex process, so cannot claim a causal connection

Beam Sizes

In 2012, the Beam 2 vertical size is consistently higher than the others



Conclusions and Outlook

- UFOs in 2011 tended to have lower dose than those in 2012 (as expected from increase in beam energy) but the shape of the dose distribution is similar for both years
- In 2012, UFO rate tended to increase with beam emittance
- An abundance of low dose UFOs is seen in Beam 2
- UFO mitigation, for example by trying to keep emittance low is likely to become a greater concern for LHC operation at 7 TeV

References

- T. Baer et al., “UFOs: Observations, Studies and Extrapolations”, proc. of Evian 2011
- E. Nebot del Busto et al., “Analysis of Fast Losses in the LHC with the BLM System”, IPAC 2011 San Sebastian
- B. Dehning, et al., “The Beam Loss Monitoring System”, Chamonix 2004