Results of UFO dynamics studies with beam in the LHC

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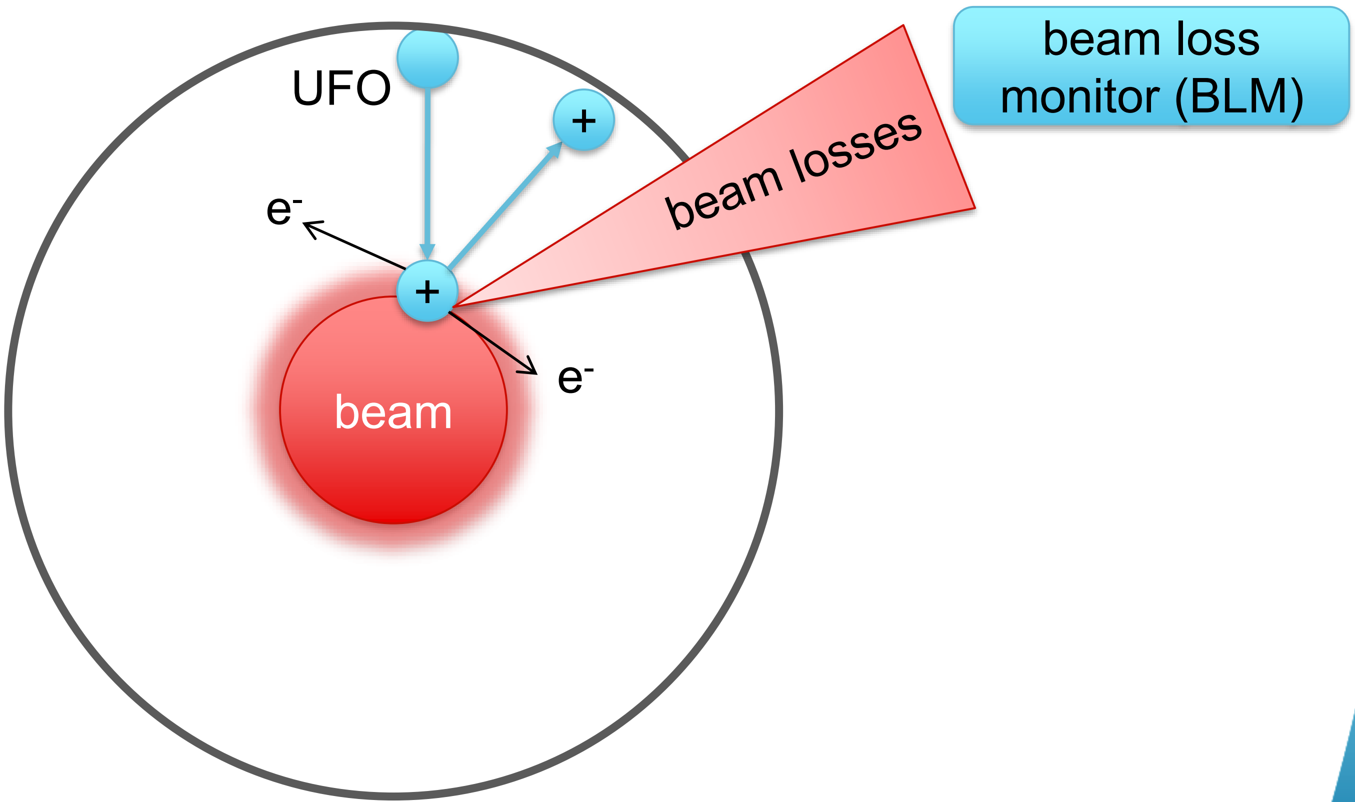
Unidentified Falling Objects (UFO)

Beam-Macroparticle interaction

- Intense Beam losses, duration < 1 ms
- Premature beam dumps and superconducting magnet quenches
  - **-> up to 12 hours downtime!**



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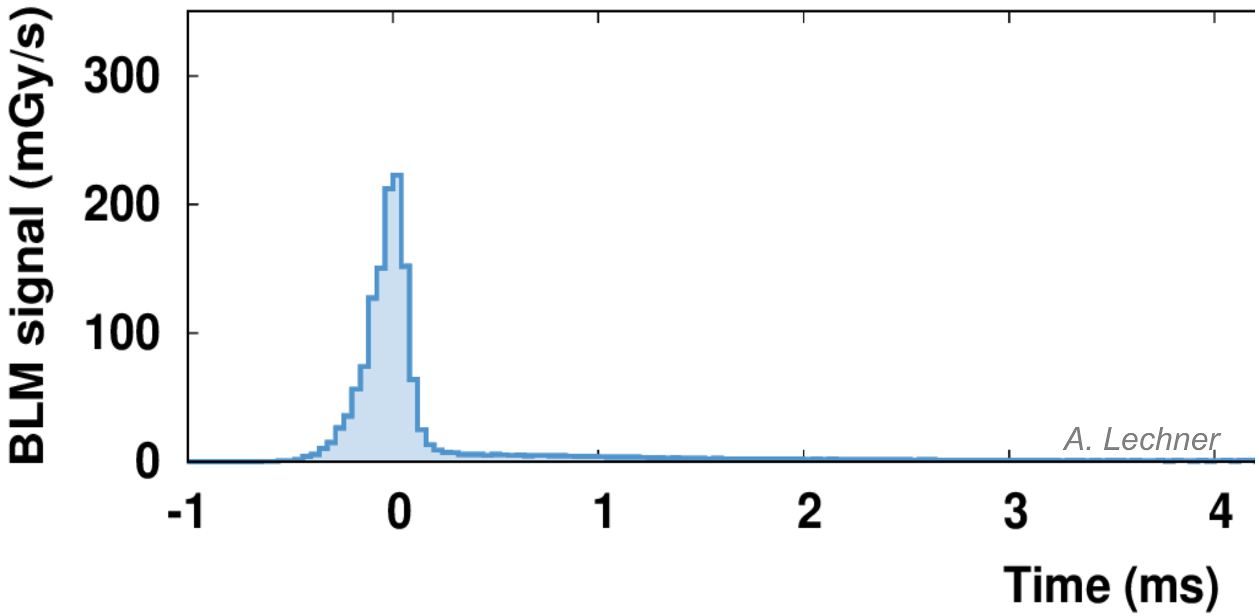
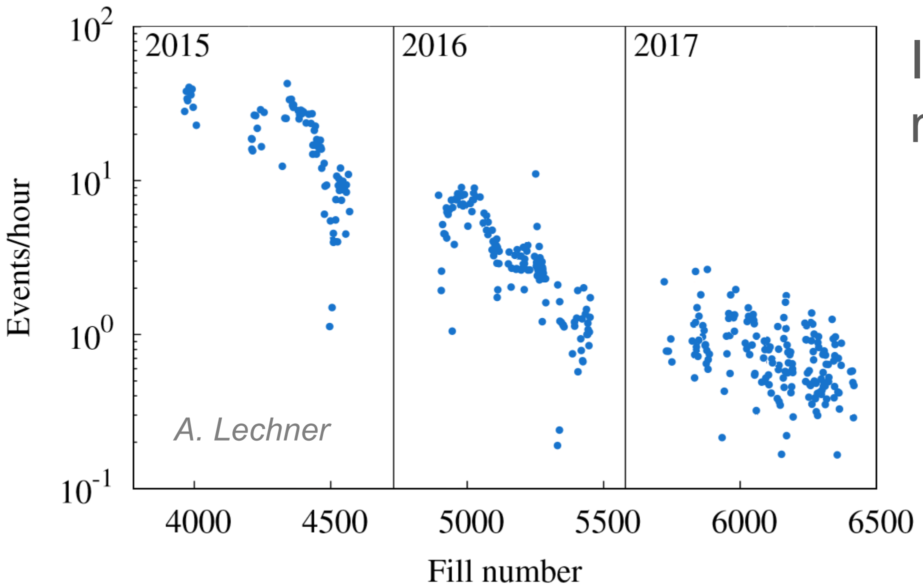


Unidentified Falling Objects (UFO)

LHC first proton accelerator to suffer from their impact



In 2017, new type of UFO at specific magnet interconnect

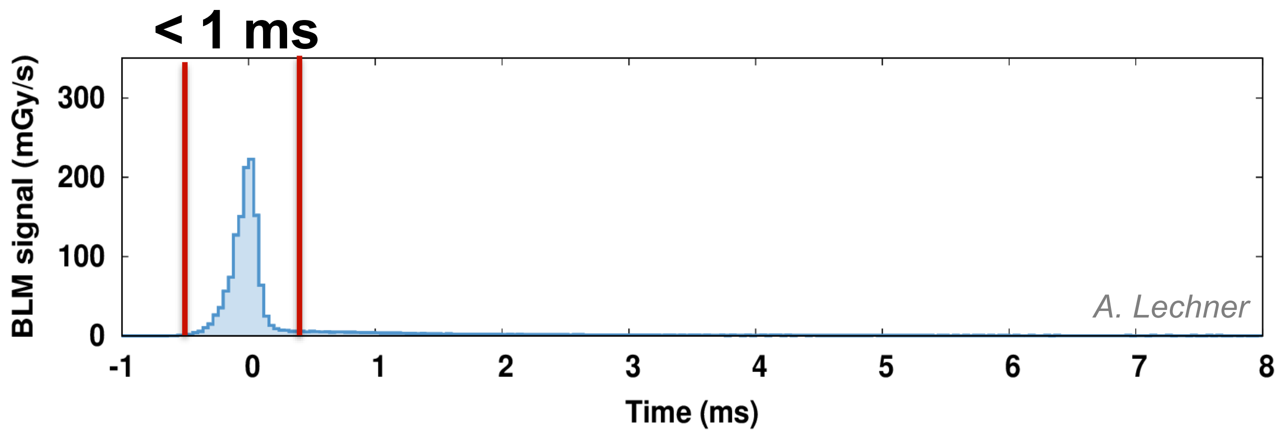
- different loss pattern
- **67** premature beam dumps (out of **~350** total)
- **significant impact on availability**

Still many unknowns, impact expected to increase in future (higher beam energy, higher beam intensity...)

Understanding their dynamics is important for employing countermeasures

UFO types

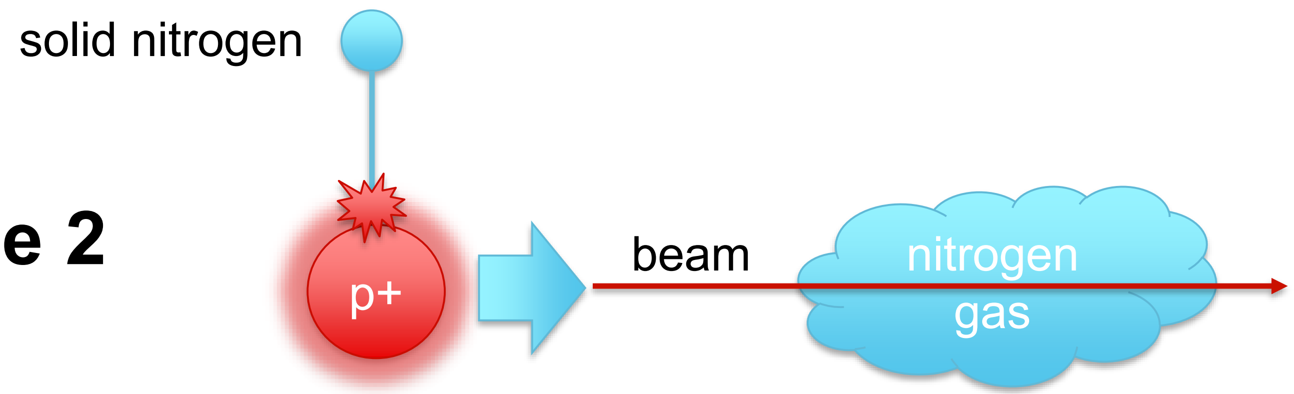
Type 1

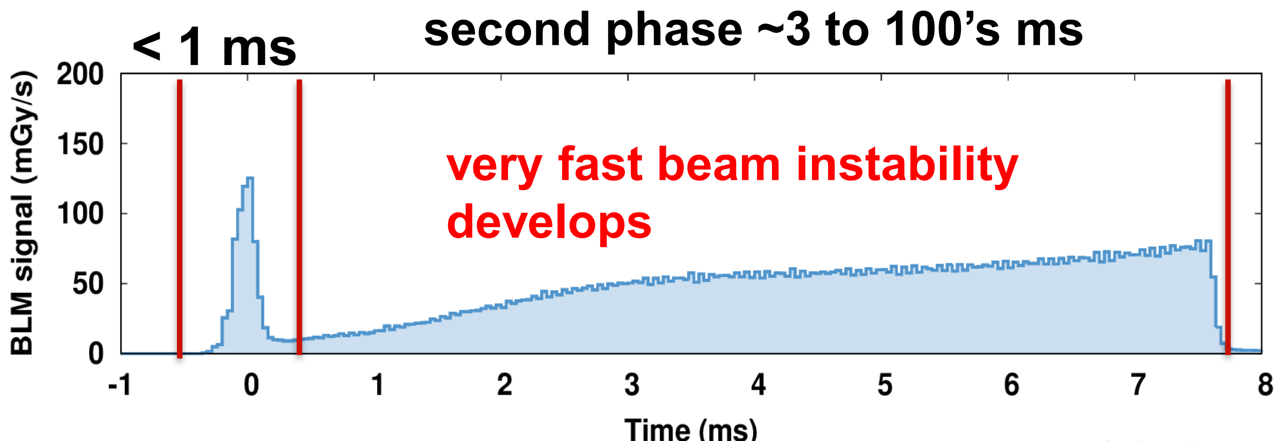


- Traditional type, present since high-intensity operations
- Sporadic
- Along the entire length of the LHC

UFO types

Type 2



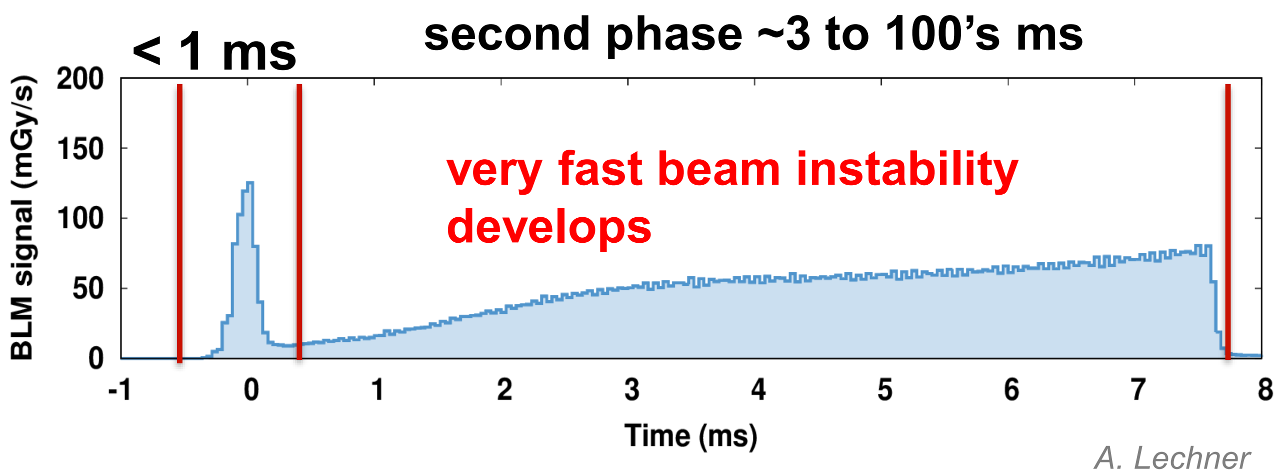


A. Lechner

UFO types

- Present at specific magnet interconnect (16L2)
- Hypothesis: caused by frozen nitrogen macroparticle
  - Contamination of beam vacuum by air at 16L2 confirmed
- Rate is correlated to beam parameters (e.g. beam intensity) and well-defined location
  - **-> Unique opportunity to study dynamics of real macroparticles, 'UFOs on demand'**

Type 2

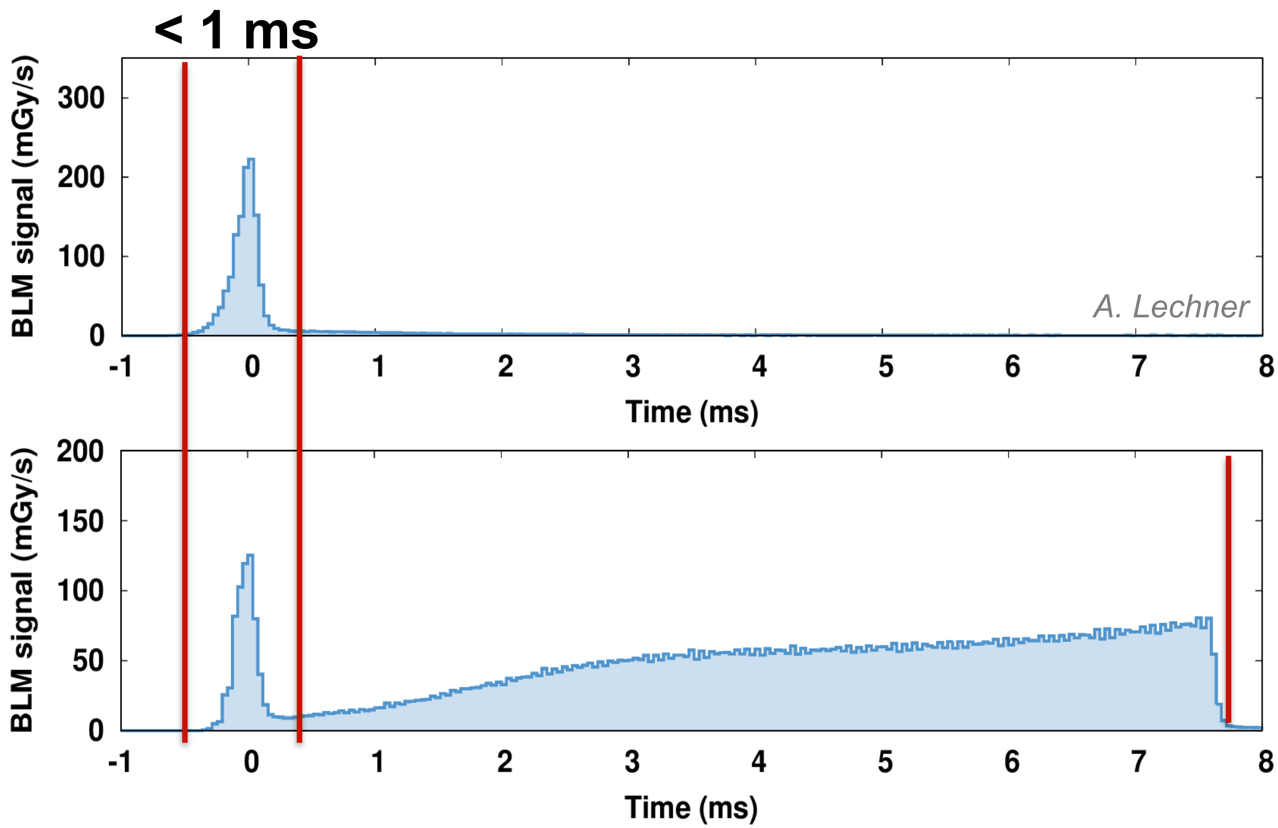


A. Lechner

UFO types

Type 1

Type 2

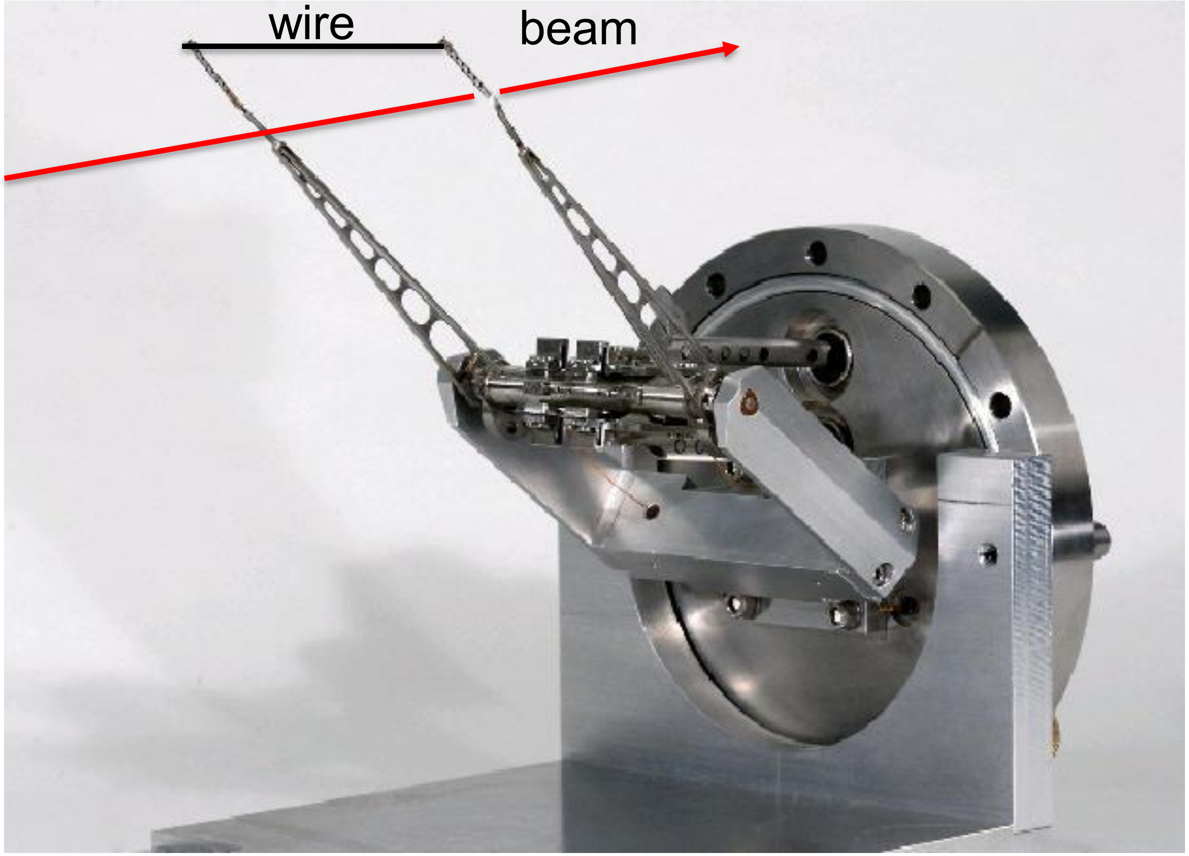


How to study them?

Wire-scanner experiment

Wire-scanner: Thin carbon wire, **~30 µm**, similar dimension to UFO

Beam losses detected by fast **diamond beam loss monitor (dBLM)**



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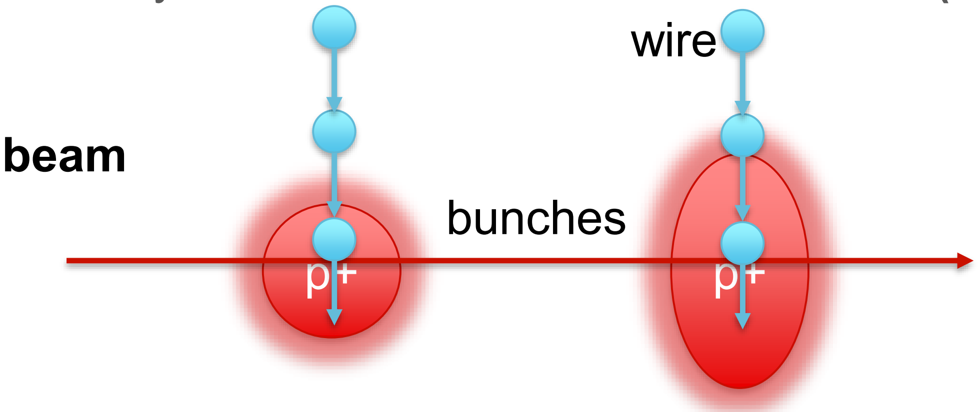
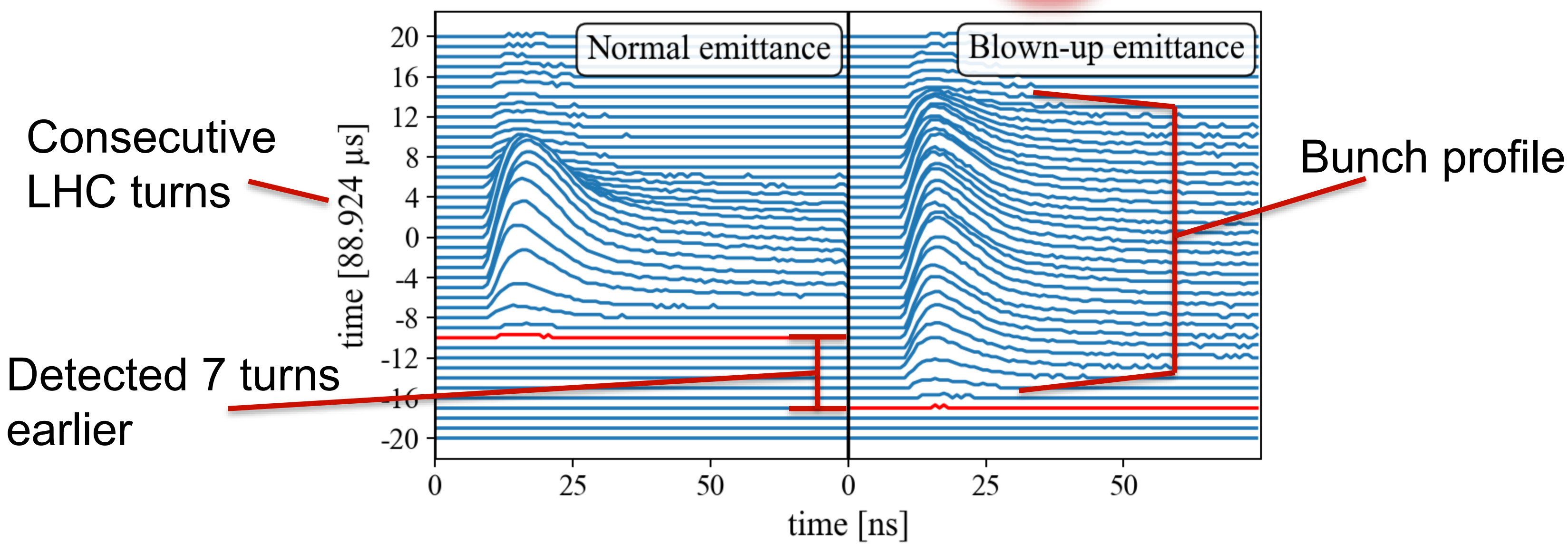
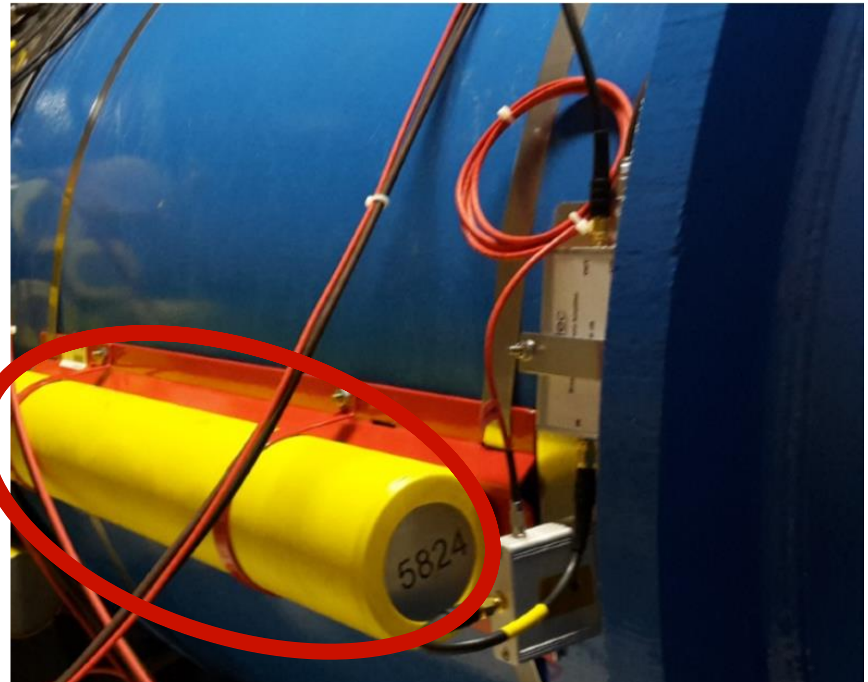




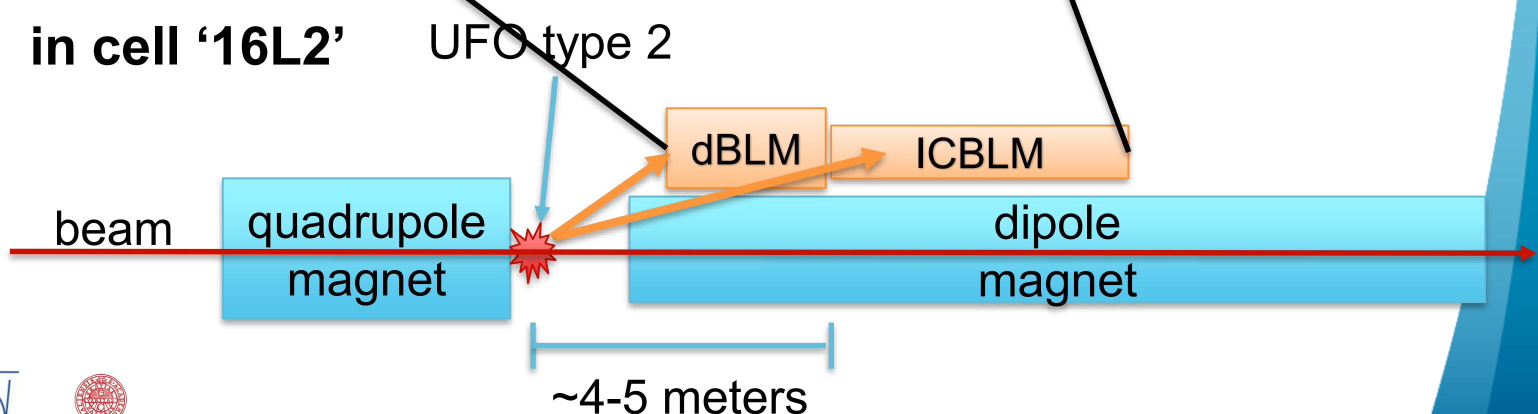
Can study movement of matter intercepting the beam

ICBLM:
Large acceptance -> good signal to noise

40 μs time resolution (half LHC turn)



in cell ‘16L2’



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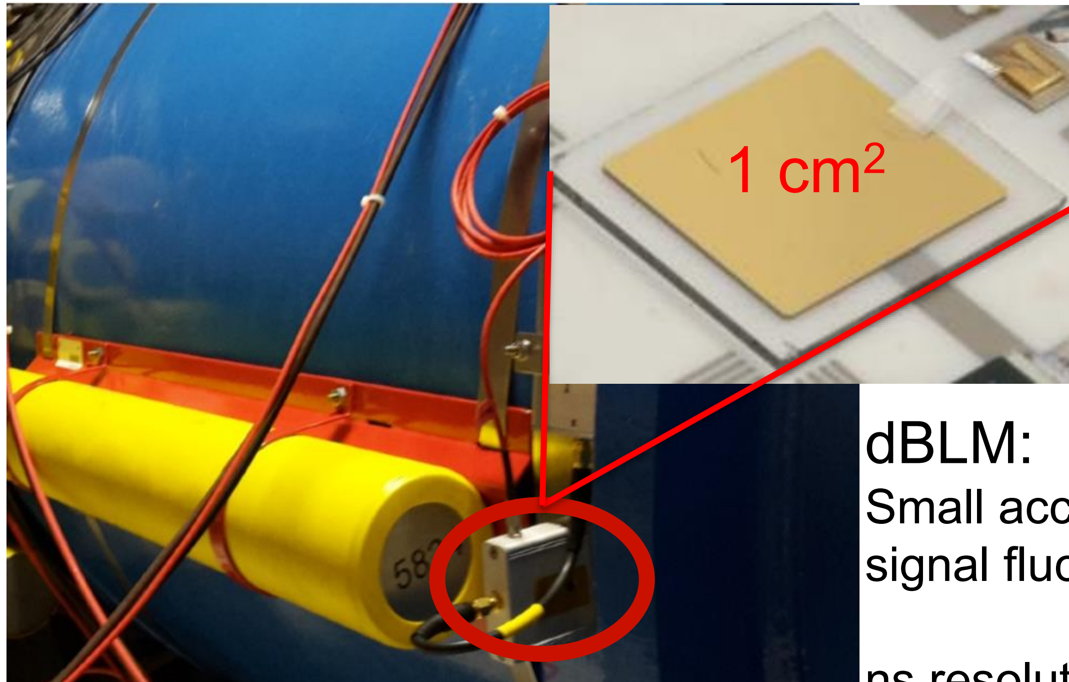
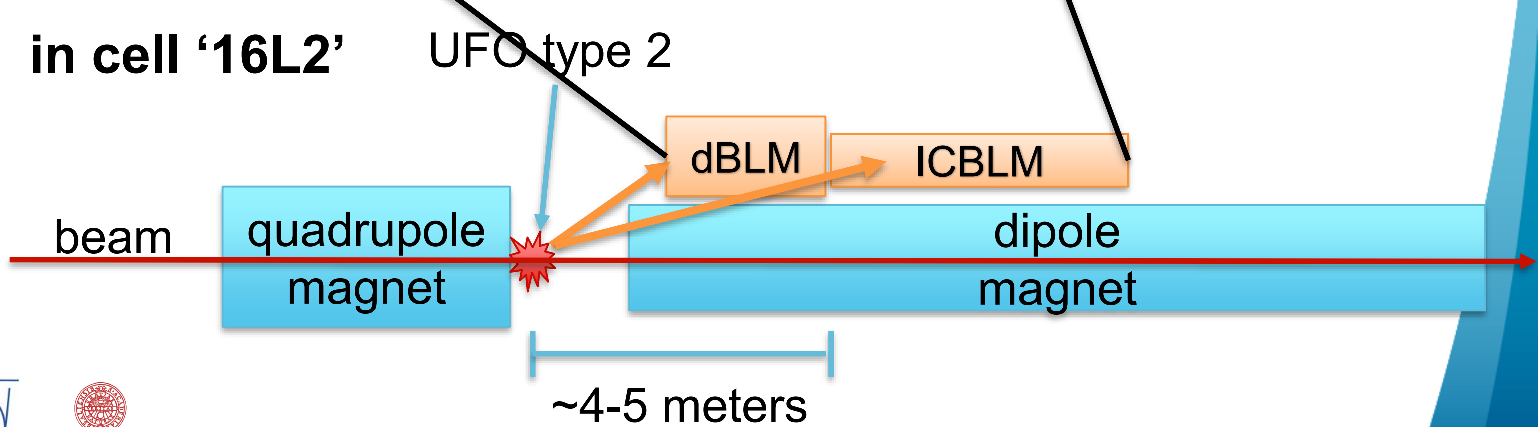


dBLM:
Small acceptance -> signal fluctuations

ns resolution (bunch-by-bunch, 25 ns)

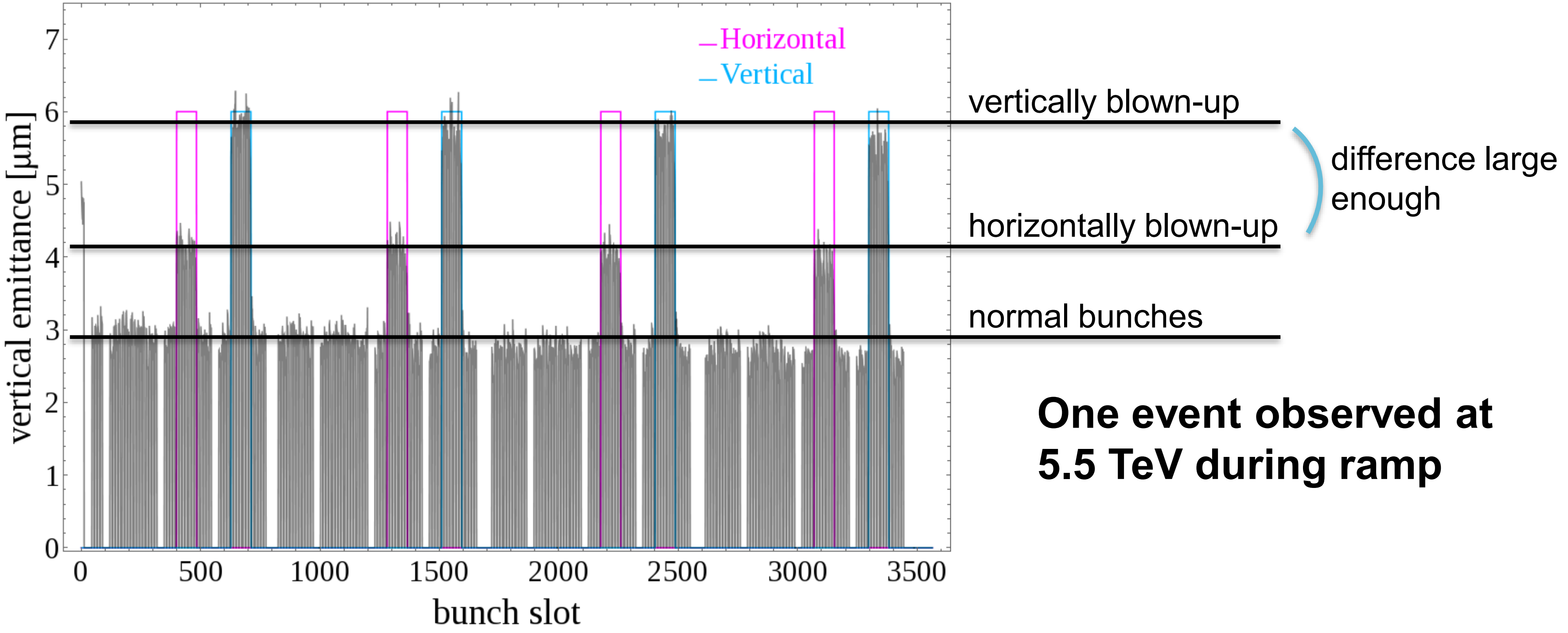
in cell '16L2'



UFO type 2 experiment

Beam: **1868** bunches, **1.25e11** protons/bunch *(high probability of triggering event)*

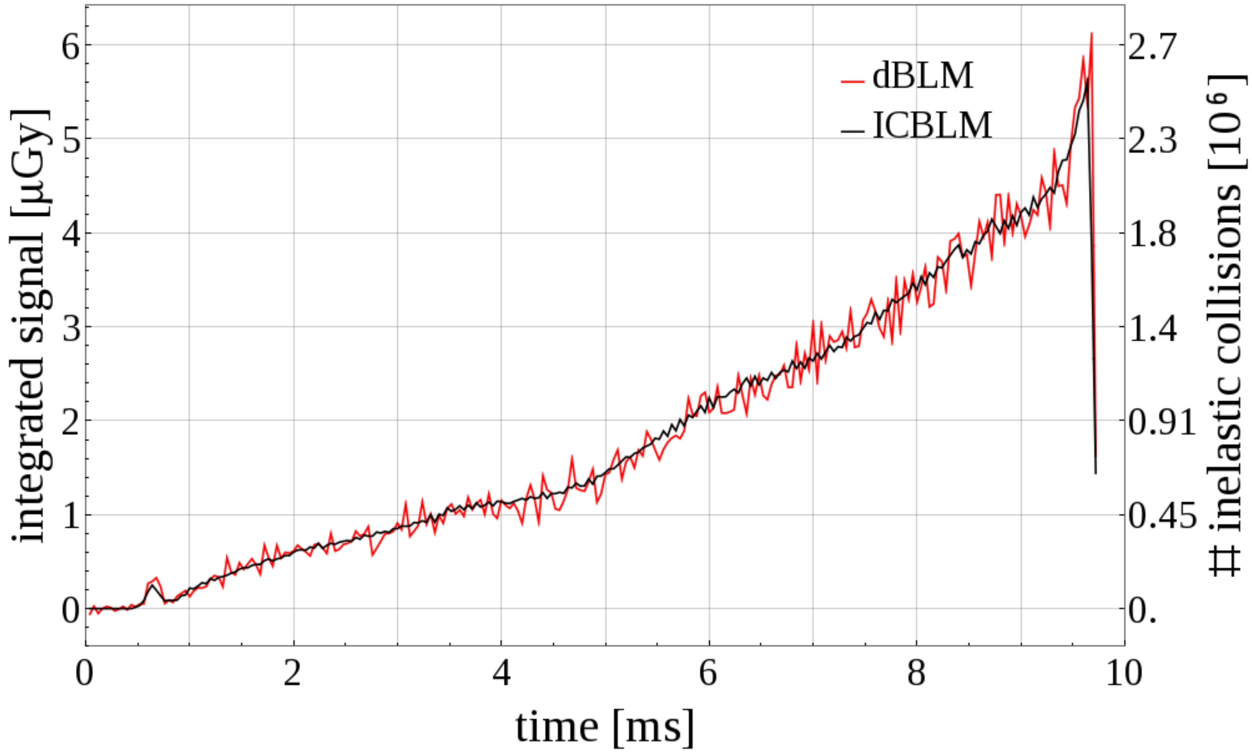
- **448 blown-up** bunches (horizontal and vertical separately)
- Horizontally blown-up bunches slightly blown-up vertically and vice versa due to coupling



One event observed at 5.5 TeV during ramp

UFO type 2 - signal

- Integrating dBLM in 40 μs and comparing to ICBLM
  - -> good linear correlation
- Allows estimating statistical error



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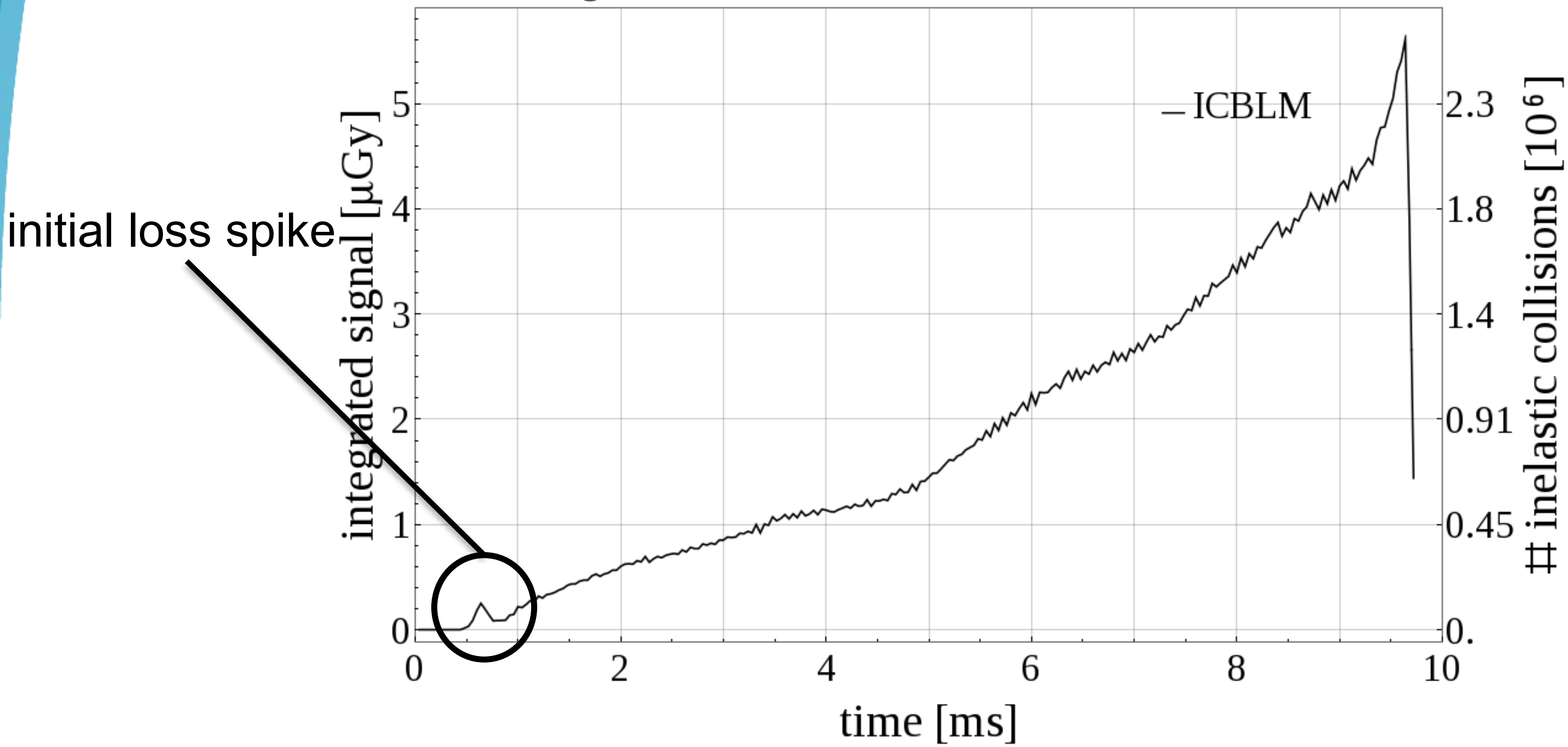

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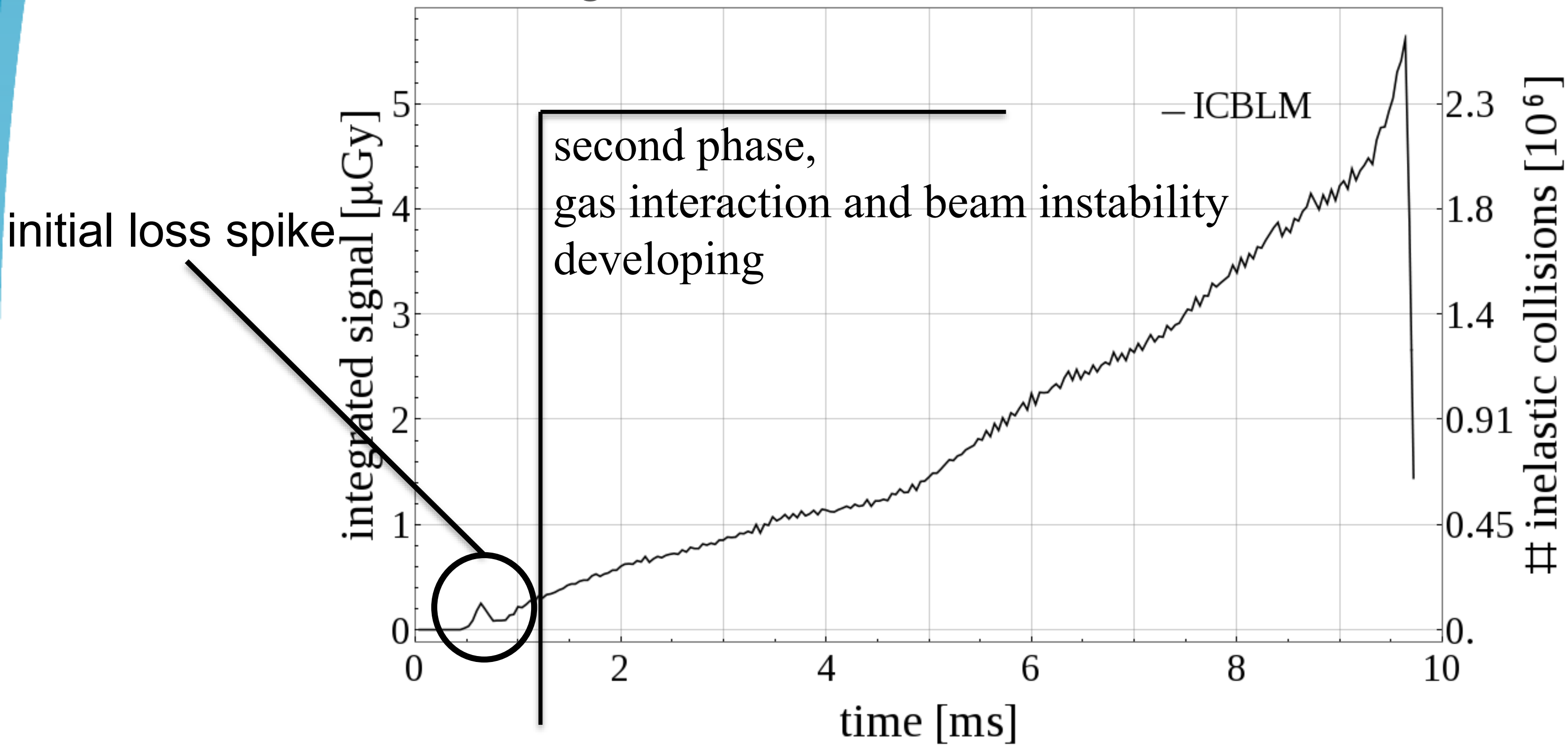

dBLM equivalent to ICBLM

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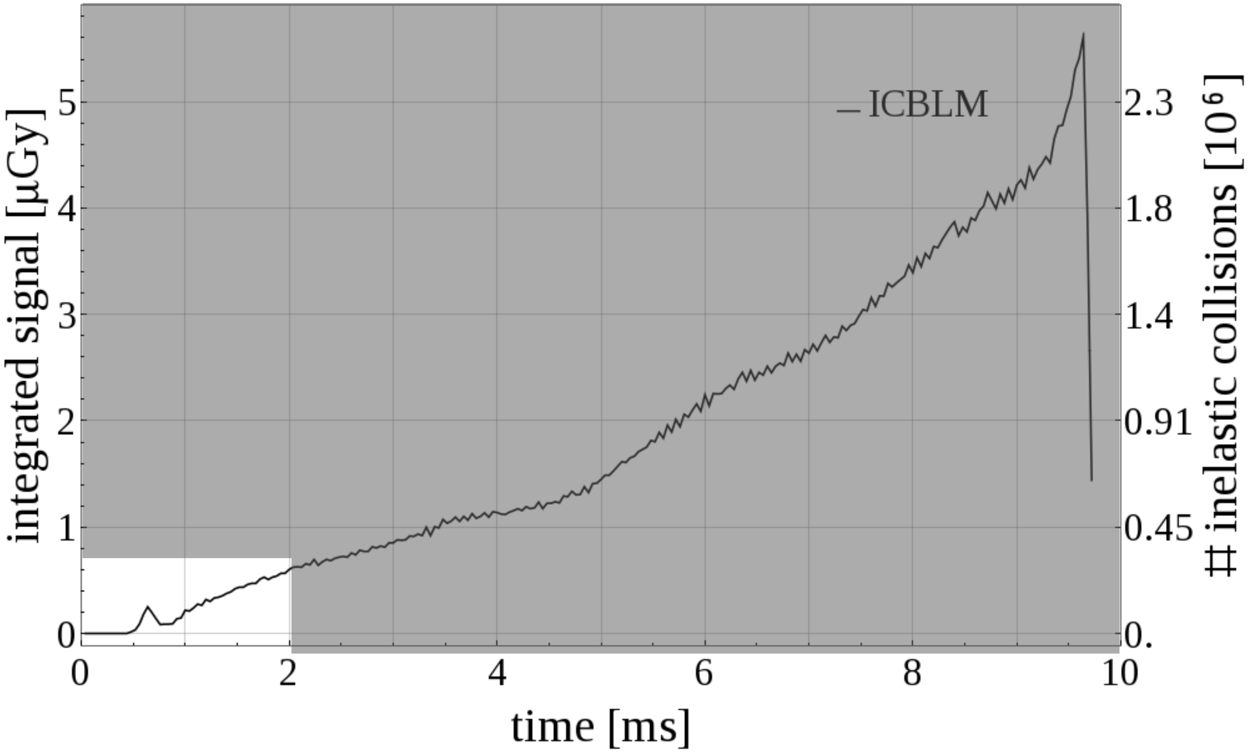
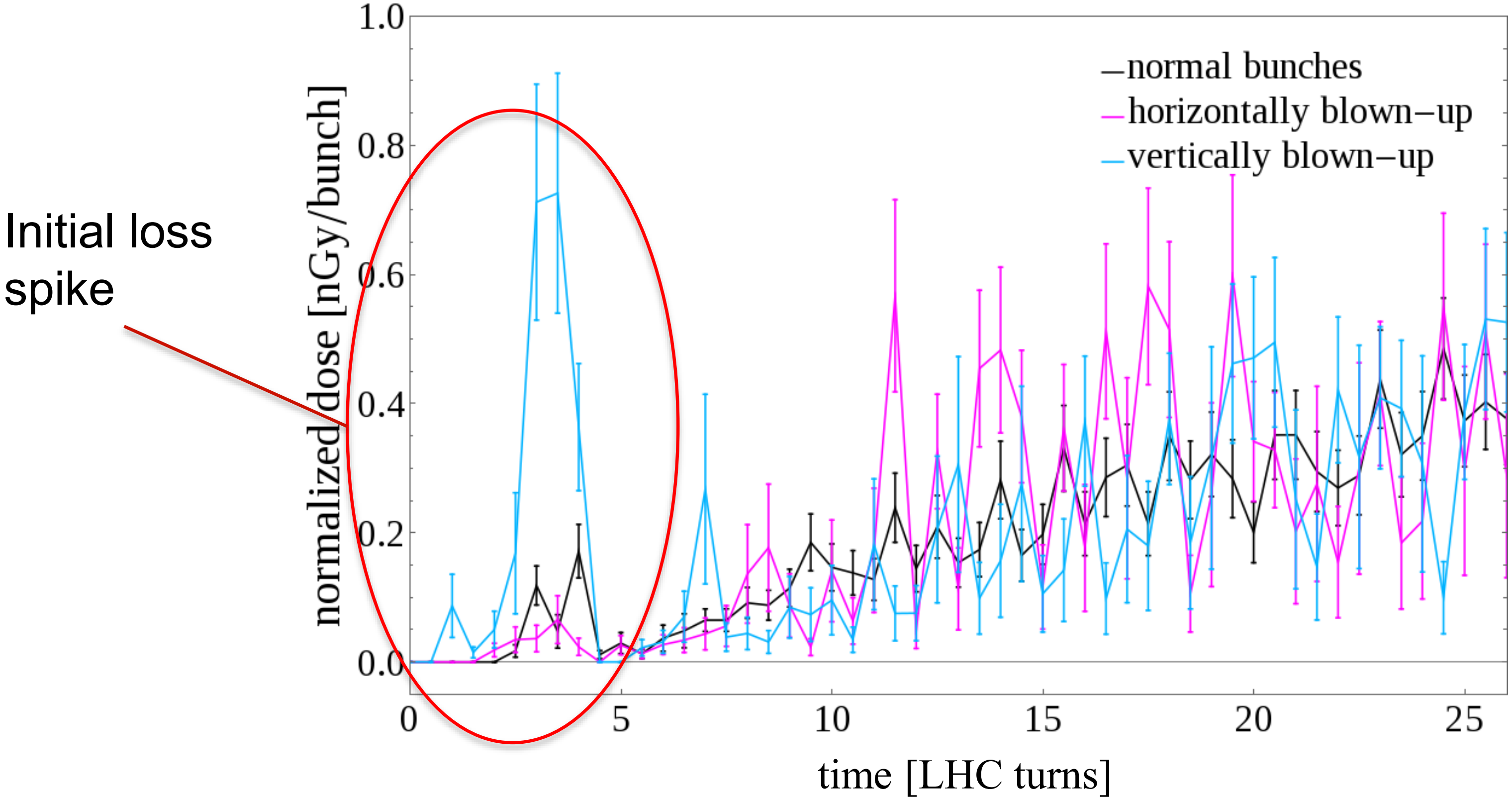


dBLM equivalent to ICBLM

UFO type 2 dynamics

- Splitting integration into the three different bunch groups:
  - Significantly more signal from vertically blown-up throughout whole loss spike
  - In second phase, no difference between bunches



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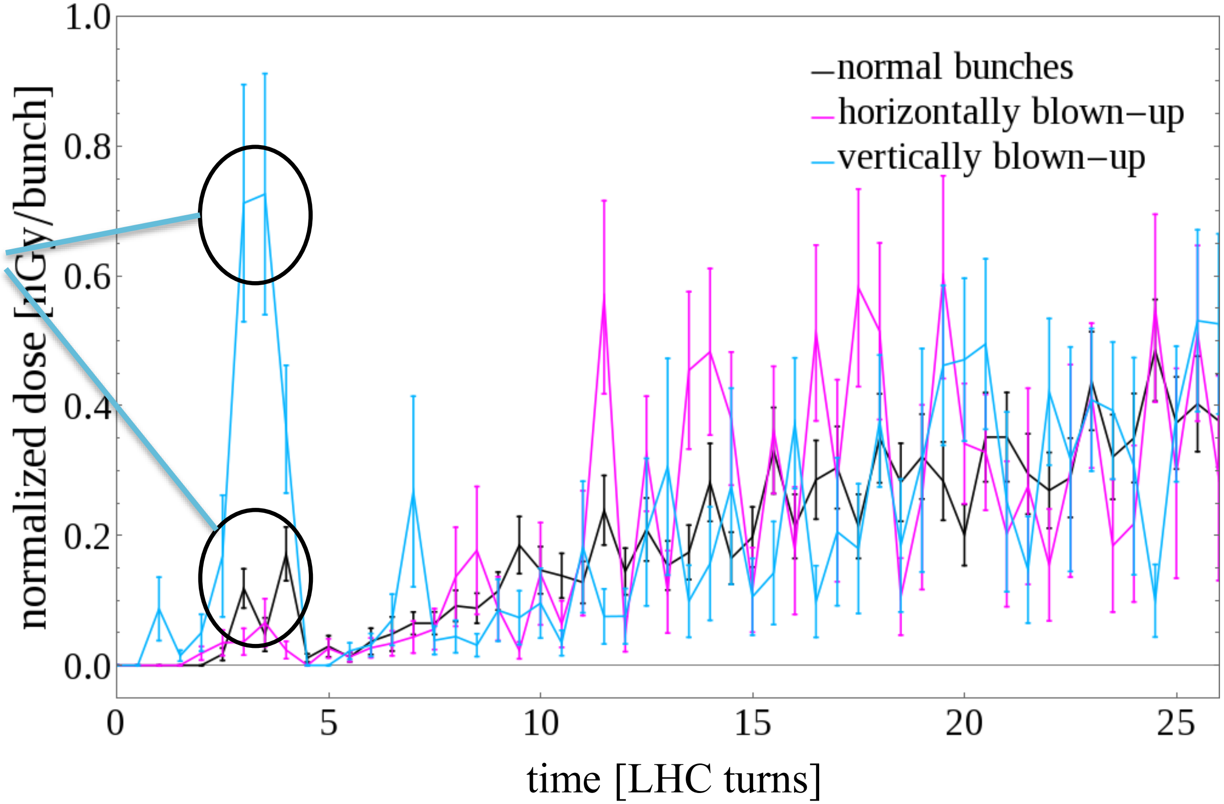
ratio of signals estimates position to 2.9-3.4 sigma

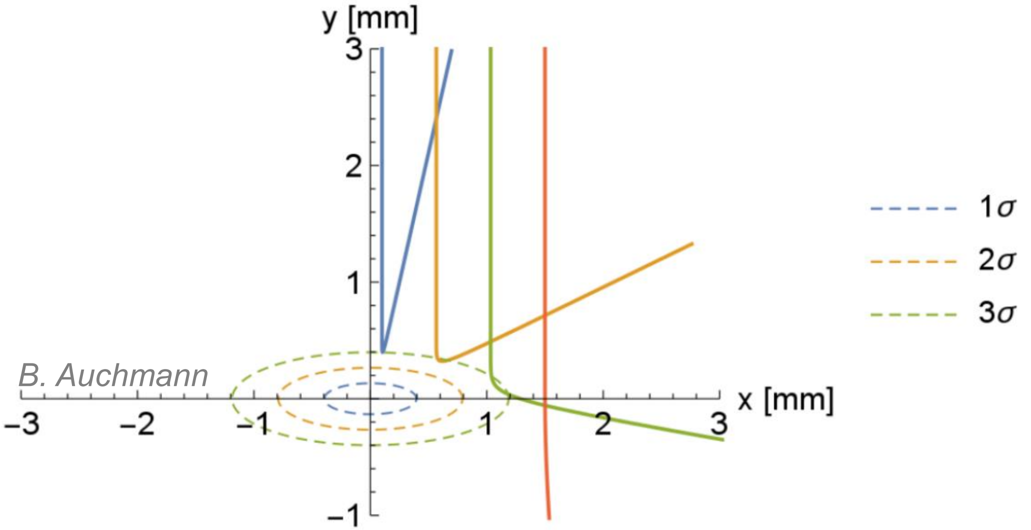


UFO intercepts beam in vertical plane and remains in the halo (2.9-3.4 sigma)

Simulation Model

Physical model of beam-macroparticle interaction to study UFOs

- **Partially validated against UFO type 1 events** (temporal loss pattern, # inelastic collisions; assuming ~20-30 μm particles, Cu, C)



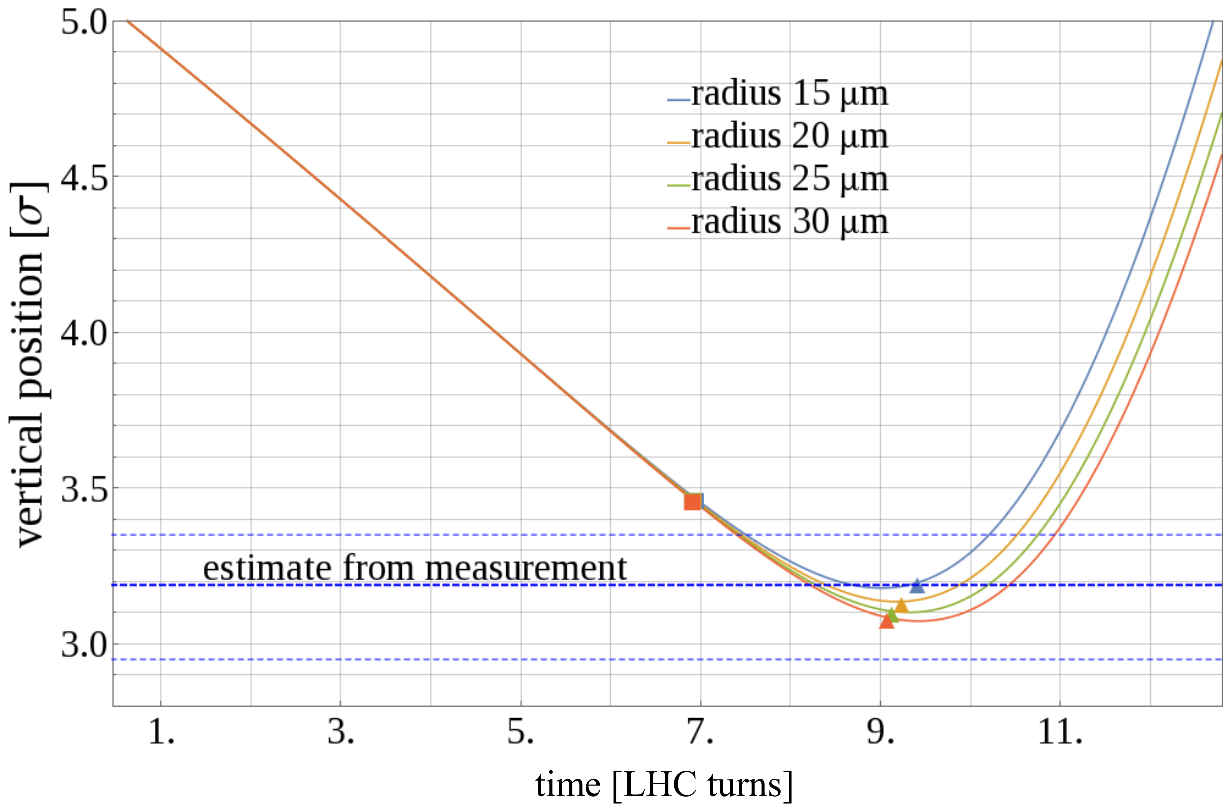
Comparing measured # of inelastic collisions with simulated:

- Estimate of macroparticle size -> radius **15-30 μm** (nitrogen, density 1.029 g/cm^3)

Simulation Results

- Nitrogen particles assumed negatively charged (possibly from electron clouds), and **attracted from bottom**

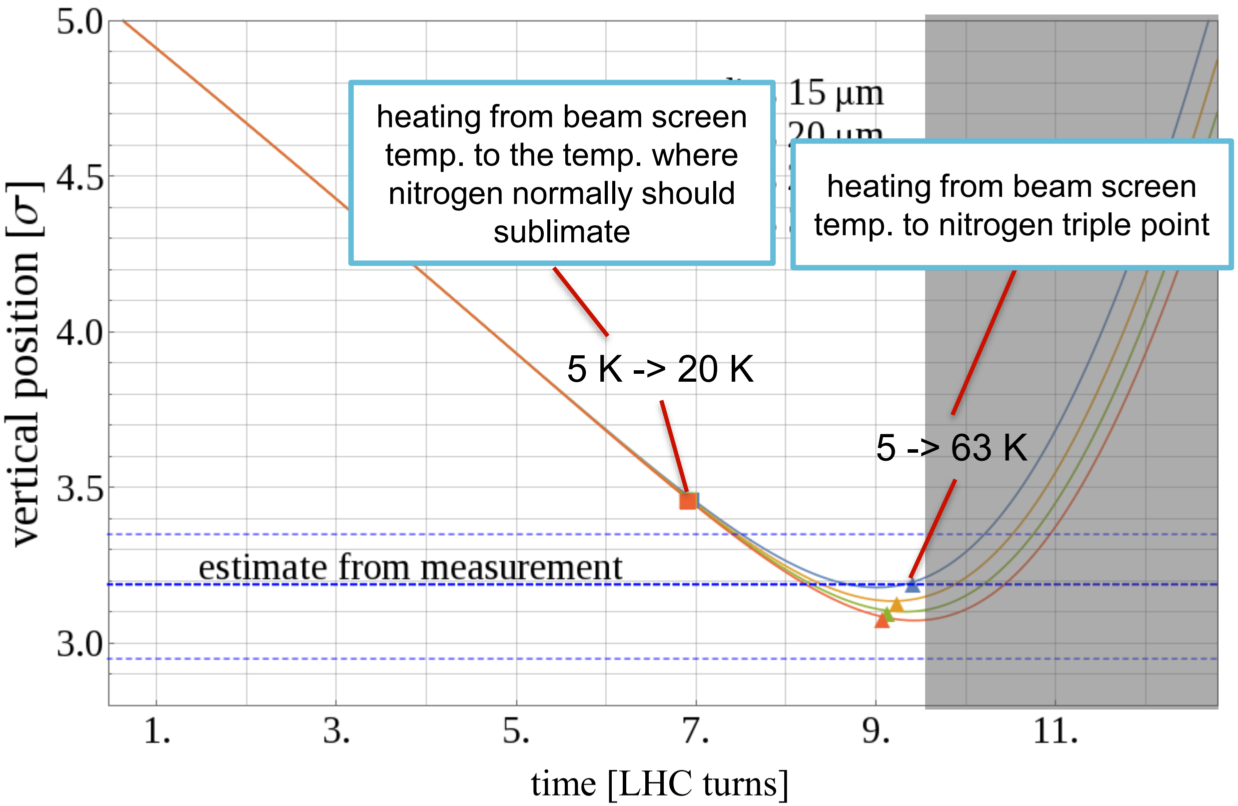
$1\ \sigma = 0.3\ mm$



Simulation Results

- Nitrogen particles assumed negatively charged (possibly from electron clouds), and **attracted from bottom**
- Phase change suspected, temperature increase simulated

$1\,\sigma = 0.3\,mm$



Good agreement with measurements

Conclusions

- We have successfully studied dynamics of beam-macroparticle interactions using method of blown-up bunches and fast diamond BLMs
- The macroparticle intercepted the beam in the vertical plane and remained in the halo for a short time
- Small (µm) object interacted with the beam in the first part, and then indication of a homogenous cloud in second part
- This allows confirming our simulation models and opens the door for further studies on UFOs

Other papers on 16L2/UFO type 2 this conference:
J.M.Jiménez,"Observations, analysis and mitigation of recurrent LHC beam dumps caused by fast losses in arc half-cell16L2",
A. Lechner, "Beam loss measurements for recurring fast loss events during 2017 LHC operation possibly caused by macroparticles",
L.Grob,"Analysis of Loss Signatures of Unidentified Falling Objects in the LHC and Related Dust Samples",