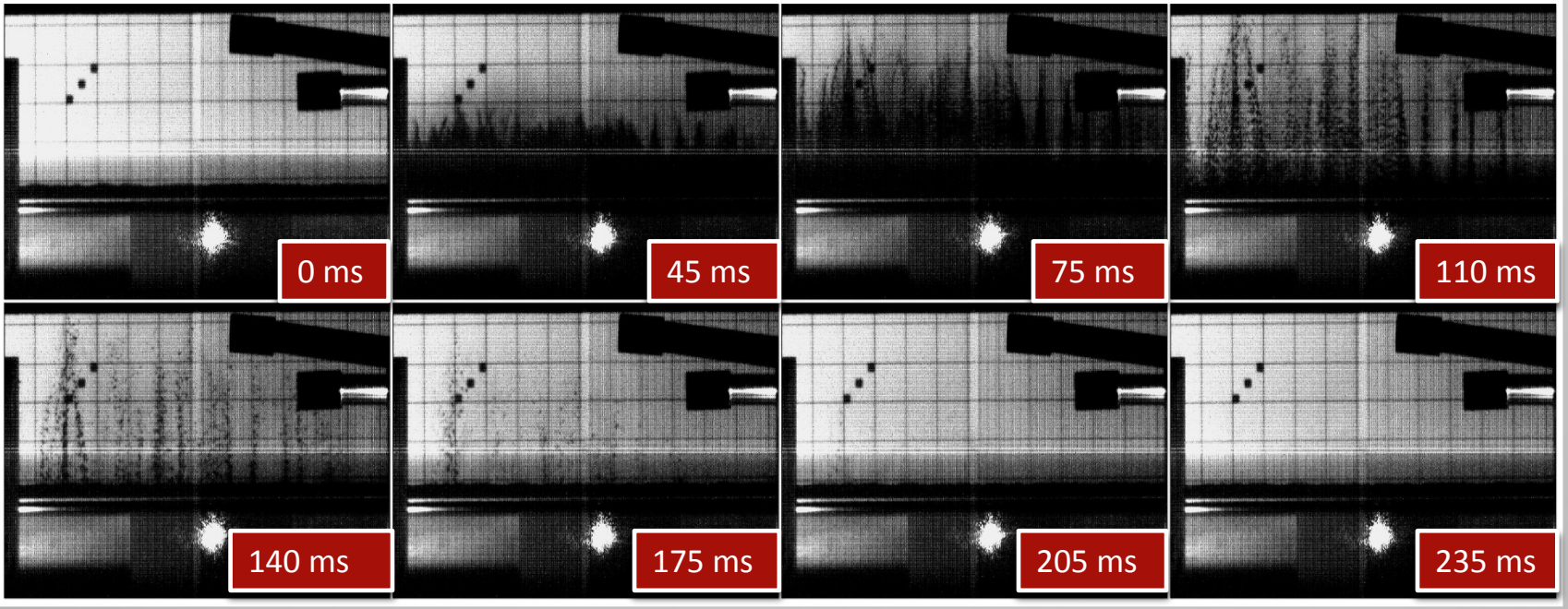
First observations from the HRM-10 tungsten powder experiment at HiRadMat

N. Charitonidis [CERN, EPFL], I. Efthymiopoulos [CERN], C. Densham, O. Caretta, M. Fitton, P. Loveridge, T. Davenne & Joe O'Dell [RAL-STFC]

File Name 31MAY20_5fps.avi
File Size 286MB (299,712,880 Bytes)
Resolution 768x480
Play Time 00:00:54

2.64x10^{11} protons @ 440GeV/c



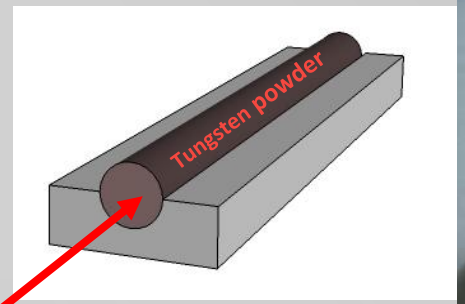
Objective – Scientific motivation

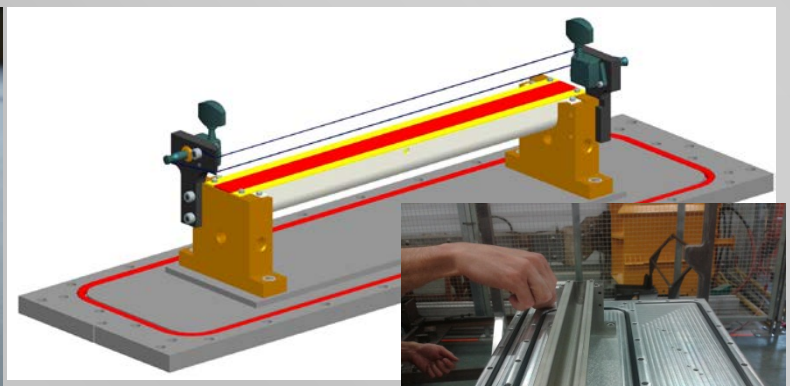
- **Tungsten powder:**
  - Candidate solution for high power targets
    - *Pneumatic conveyance demonstrated @ RAL* ☺
    - *Response to proton beam : **UNTESTED***

HRM10 to fill this experimental gap ! !

Experimental setup of HRM10

- **A double Ti Trough, containing static powder target , <u>settled</u> but <u>not compressed</u>**

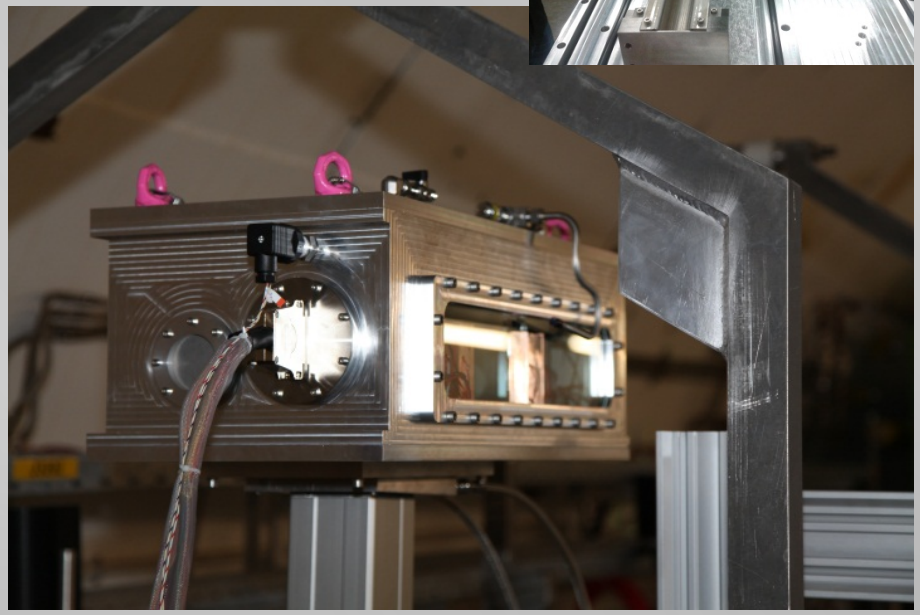




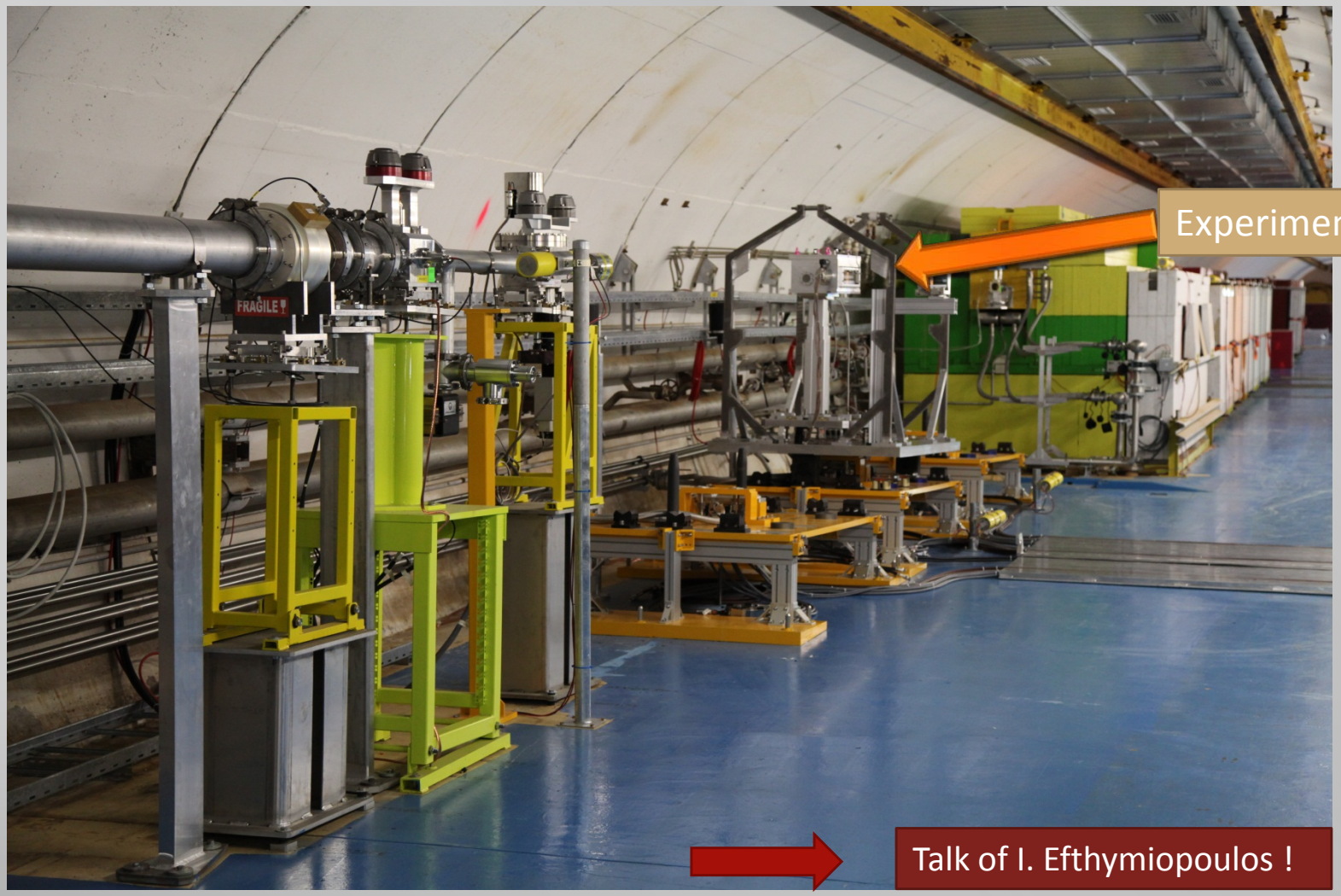
Proton beam

Length 30cm, Diameter ~ 1.6 cm

Containers with He-Gas



Experiment placed & ready for beam @ HiRadMat

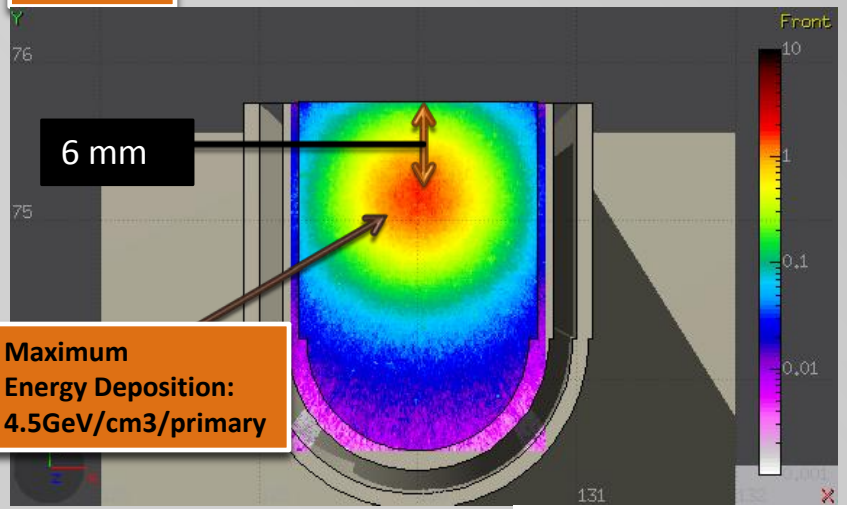


Instrumentation

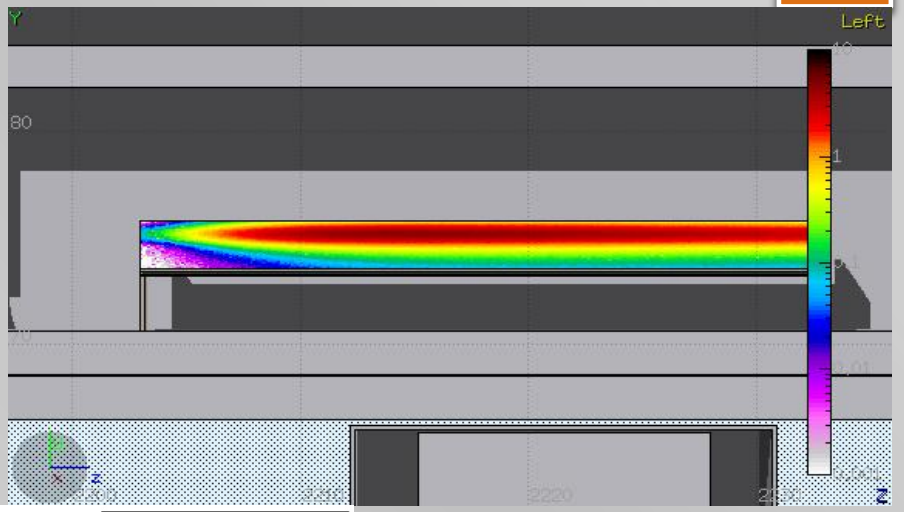
- **Possible effects**
  - Gas expansion (or implosion)
  - Melting of the beads
  - Shock Wave propagation
- **Two main diagnostic tools**
  - High Speed Camera (Redlake MotionXtra HG-100K)
    - ***Frame rates used in the experiment: 2kfps & 1kfps***
  - Laser – Doppler Vibrometer (Polytec OFV-505)
    - ***Pointing on the container(s) of the powder – Evaluation of the vibrations of the containers due to the beam impact***

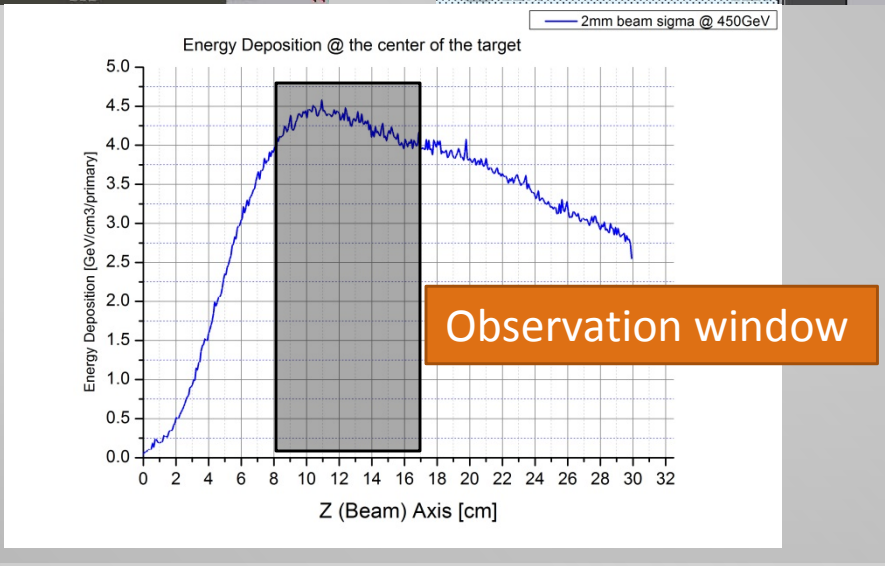
Prompt energy deposition/radiation (FLUKA® Monte – Carlo Code)

Front



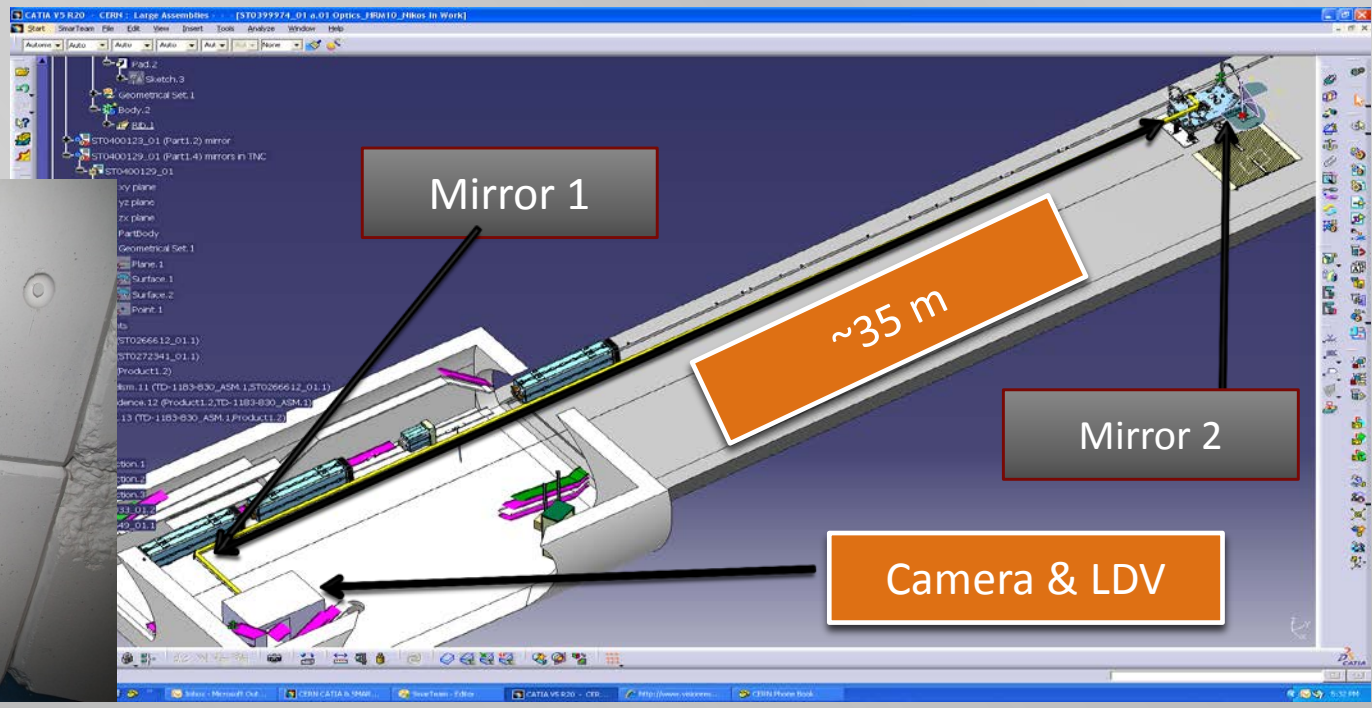
Top



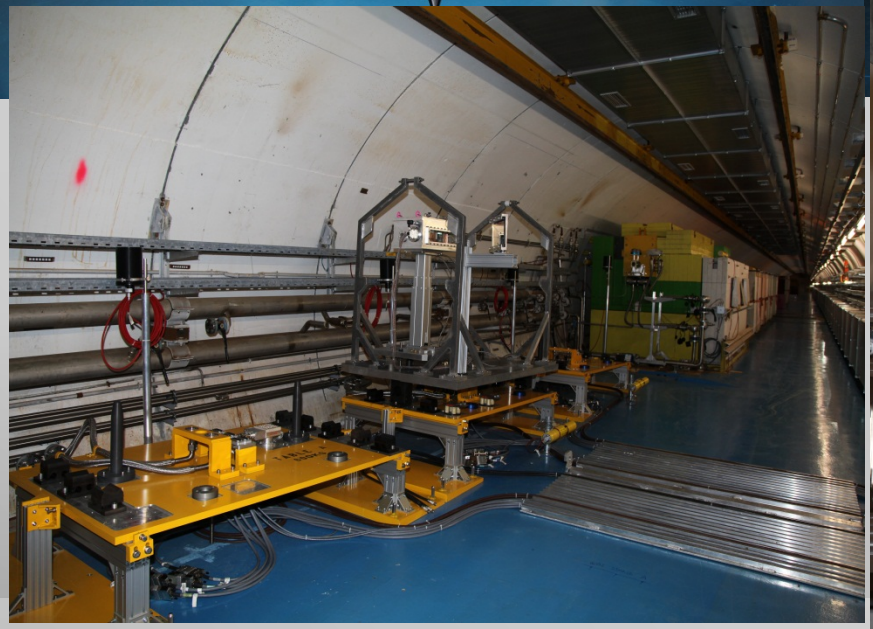


Experimental Layout

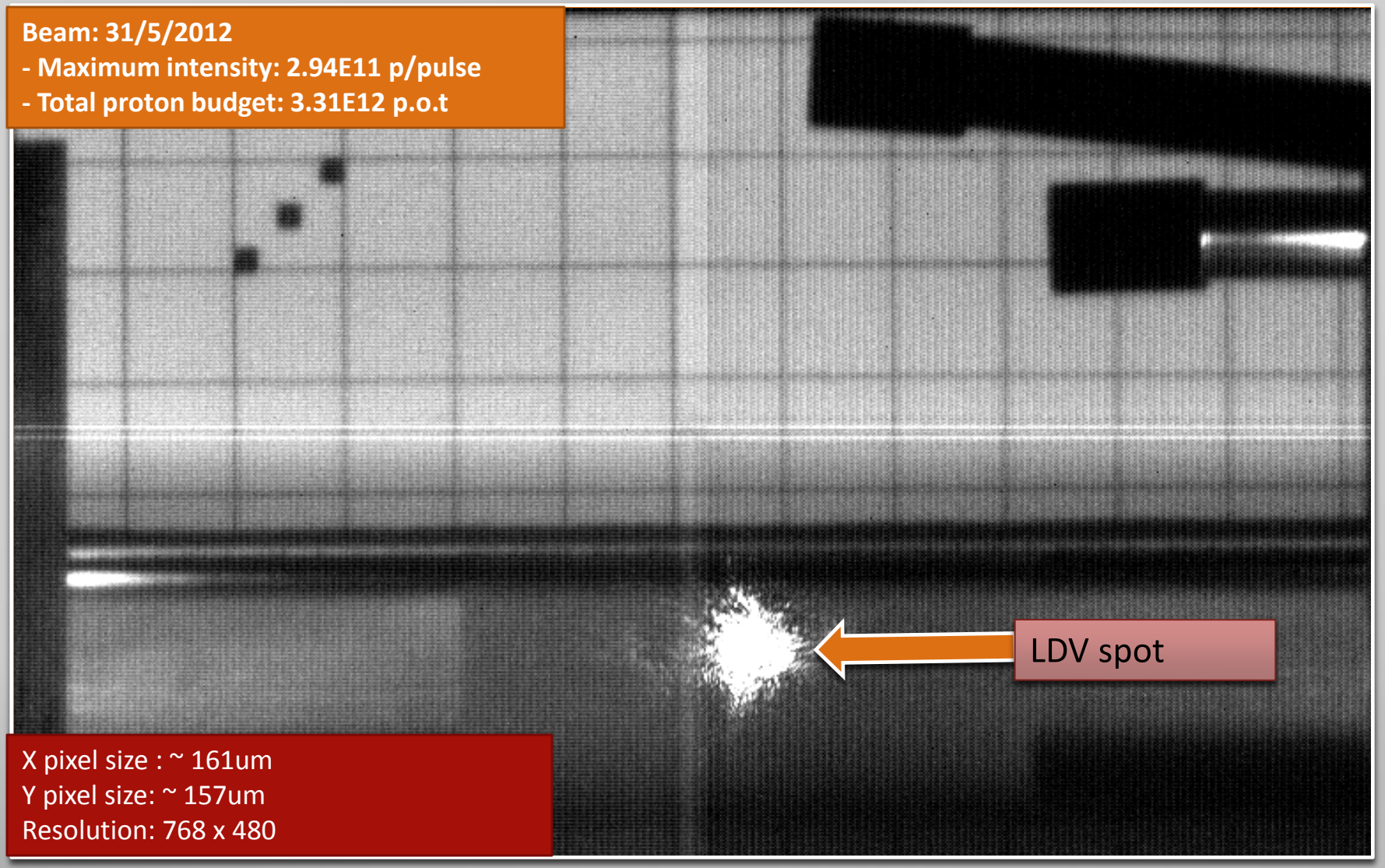
- **Remote observation for both LDV & High Speed Camera**
  - The only way for the equipment to survive the prompt radiation
- **Concrete bunker built at TJ7 tunnel & two mirrors (1 in TJ7 and one near the sampler holder, at TNC tunnel)**



Experimental Setup



Field of view



Beam parameters of HRM-10

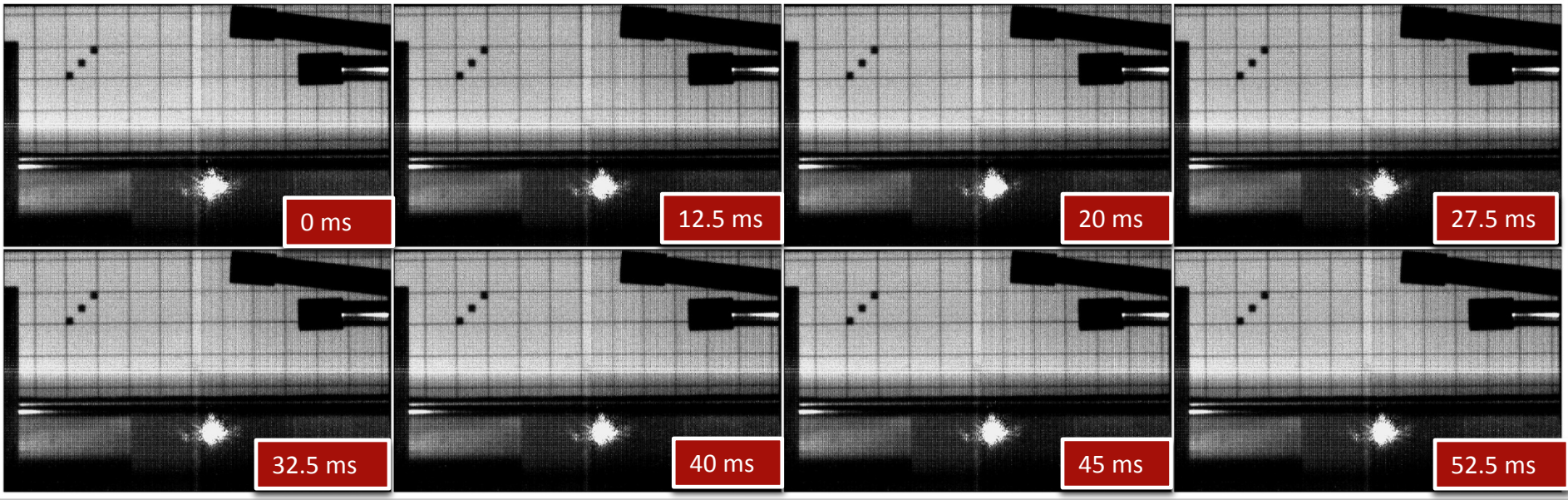
- **p= 440 GeV/c protons**
  - Sigma^2: variable, around 4mm^2
  - Intensities: From 6.8E9 up to 2.94E11 p/pulse
  - Bunches / pulse: 1 (6 shots), 6 (11 shots), 36 (5 shots)
- **In total: 22 shots on target**

Low intensity shots

- **Intensities from 7E9 to 4.6E10**
- **No visible effect noticed ! (No disruption, no movement) !**

File Name 31MAY4_5fps.avi
File Size 128MB (133,821,280 Bytes)
Resolution 768x480
Play Time 00:00:24

4.6x10^{11} protons @ 440GeV/c



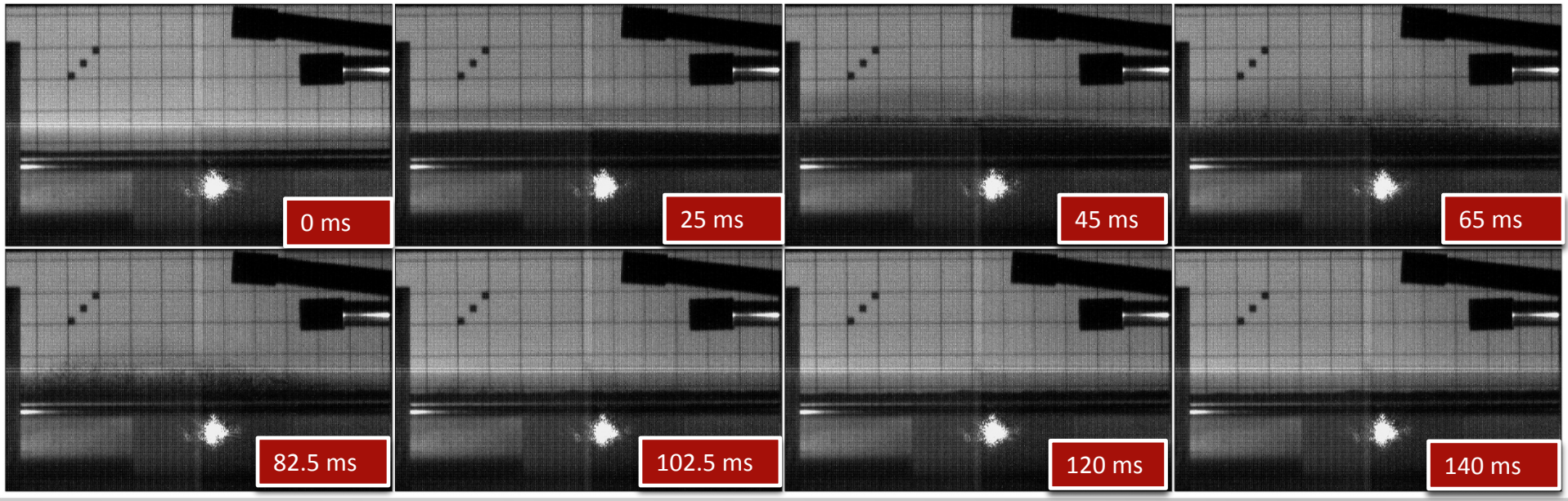
Medium Intensities – 8.1E10 to 2E11 p/pulse

- **440 GeV/c**
- **Sigma^2 ~ 4mm^2**
- **6 bunches / pulse , 50 ns spacing**

Shot # 8 – 1.75E11 p.o.t

File Name 31MAY8_5fps.avi
File Size 339MB (355,10,80 Bytes)
Resolution 768x480
Play Time 00:01:04

1.75x10^{11} protons @ 440GeV/c

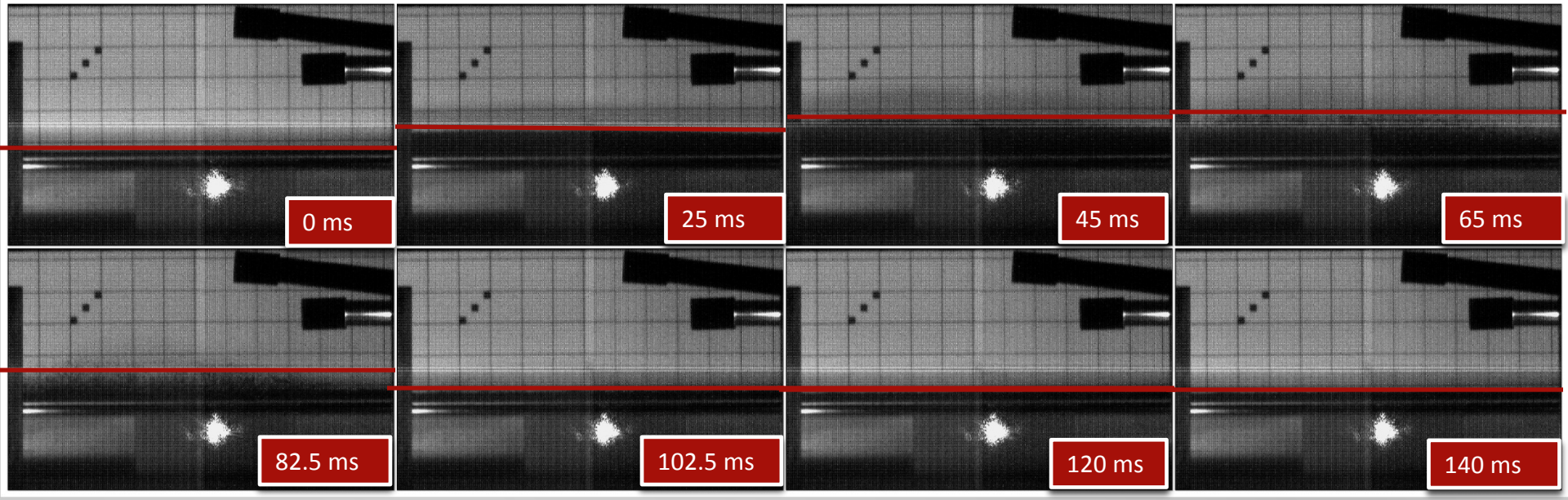


- **First major disruption !**

Shot # 8 – 1.75E11 p.o.t

File Name 31MAY8_5fps.avi
File Size 339MB (355,10,80 Bytes)
Resolution 768x480
Play Time 00:01:04

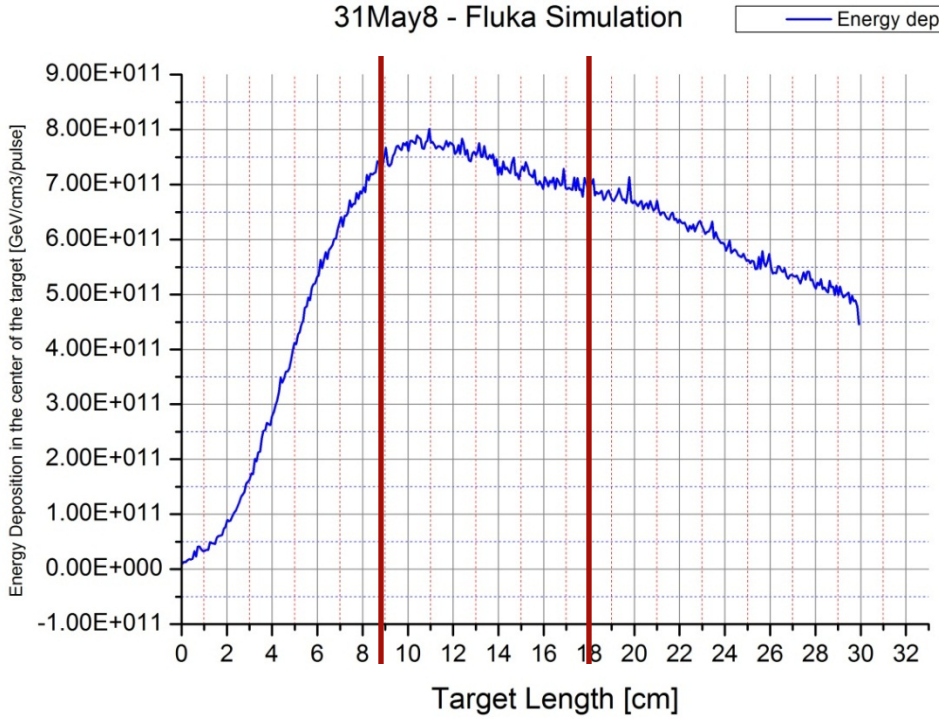
1.75x10^{11} protons @ 440GeV/c

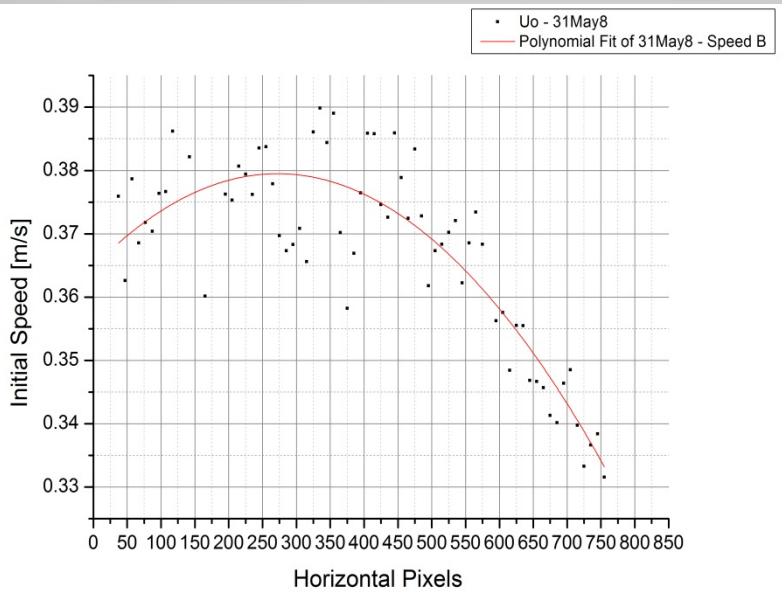


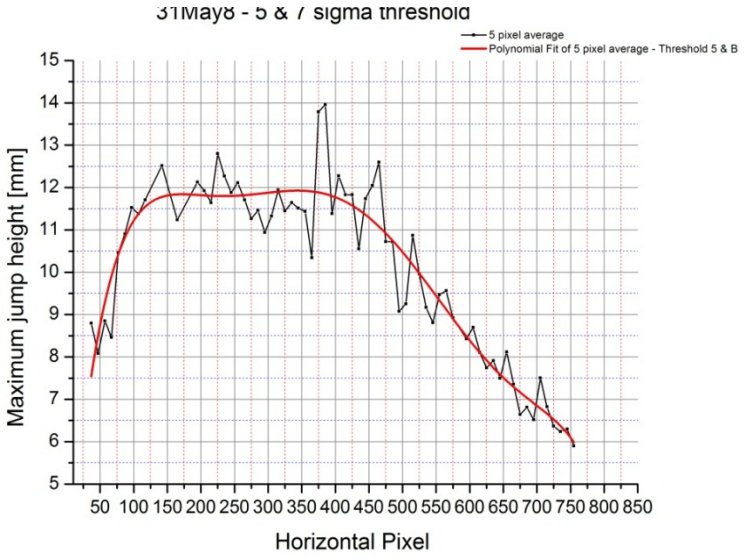
- **First major disruption !**

Shot # 8 – 1.75E11 p.o.t

50 horizontal pixels = 0.8 cm





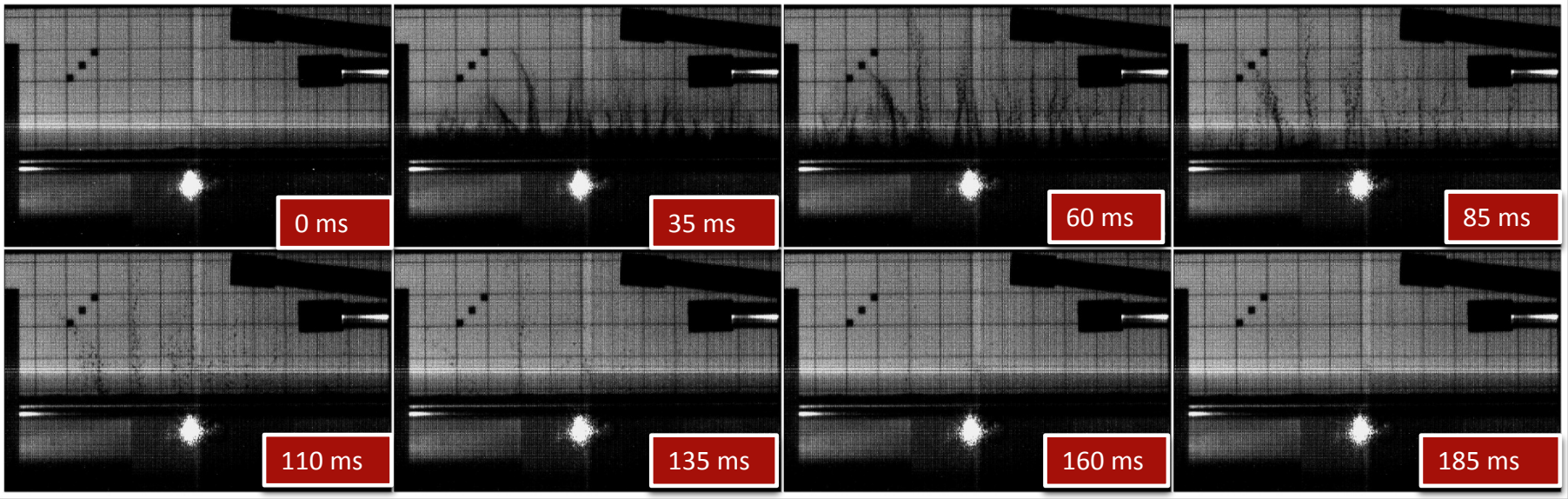


- **Maximum height jump & speed consistent with the energy deposition distribution !**

Shot # 9 – 1.85E11 p.o.t

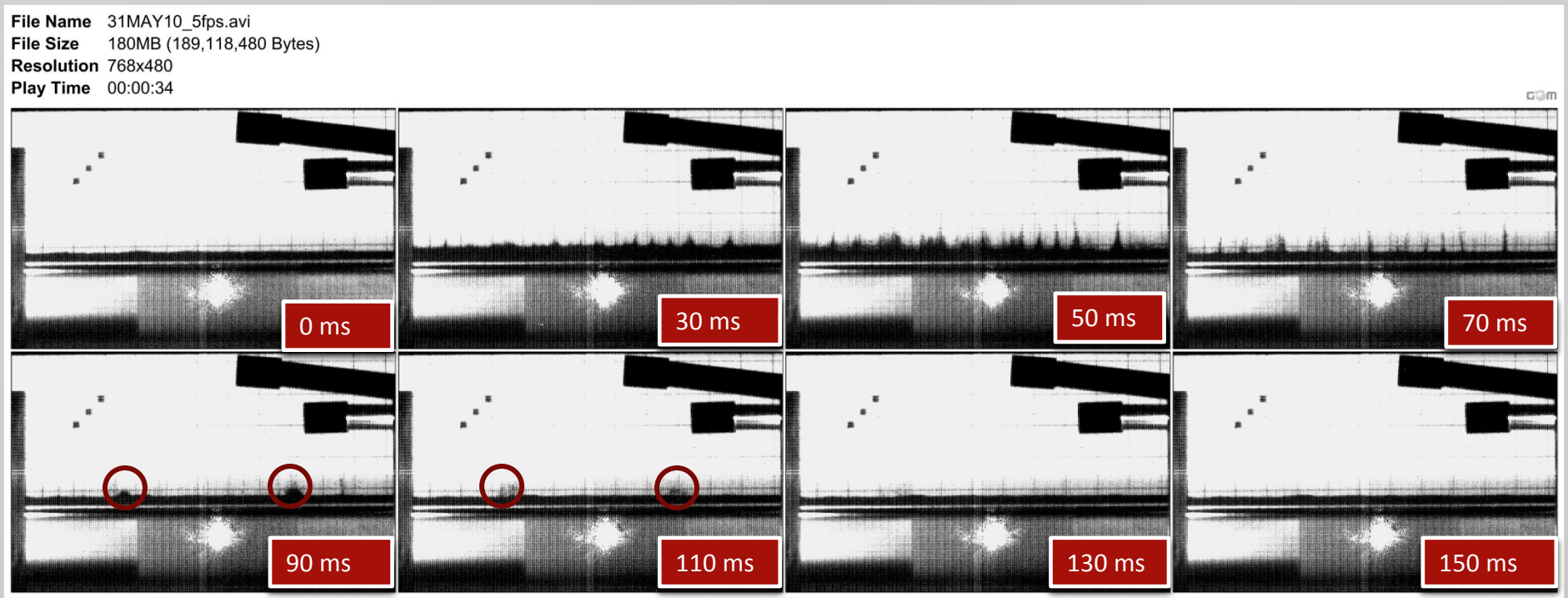
File Name 31MAY9_5fps.avi
File Size 444MB (465,604,480 Bytes)
Resolution 768x480
Play Time 00:01:24

1.85x10^{11} protons @ 440GeV/c



- **Similar intensity & beam sigma with shot #8, but totally different reaction. Possible explanations :**
  - **Beam impact in slightly different height**
  - **Different surface density (due to previous disruption)**

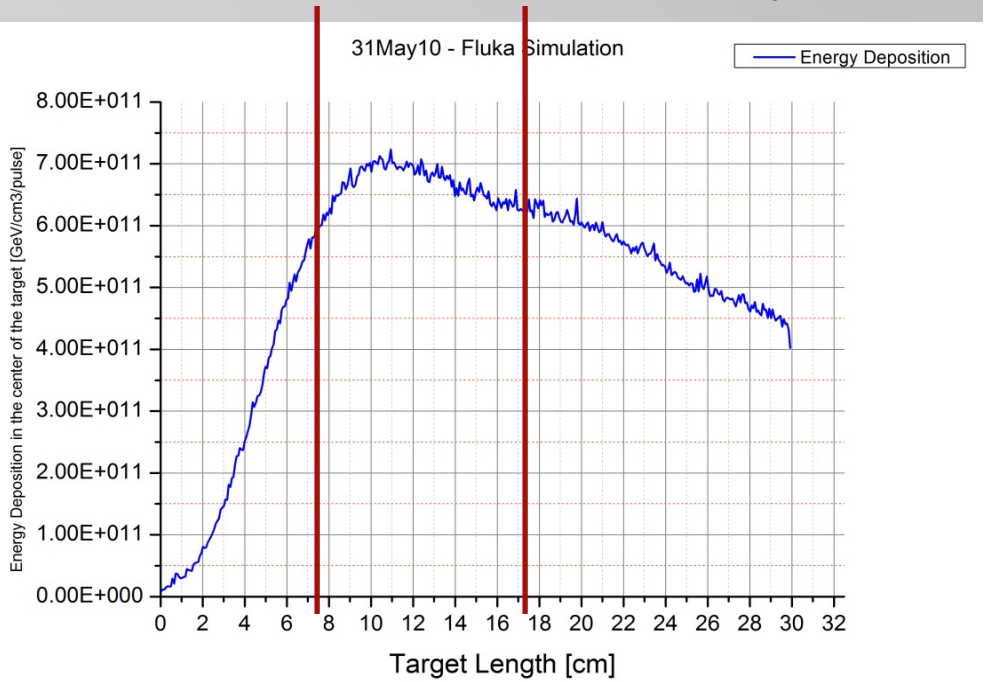
Shot #10 – 1.58E11 p.o.t

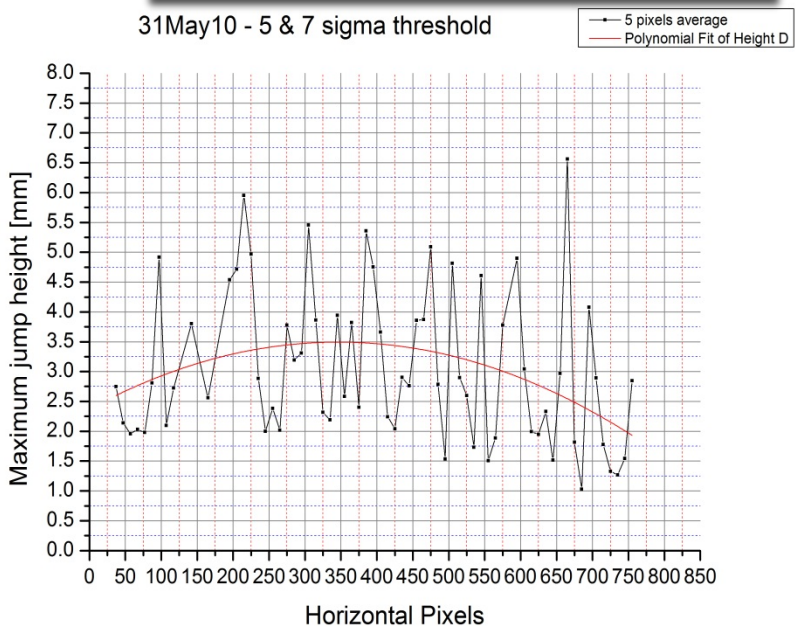


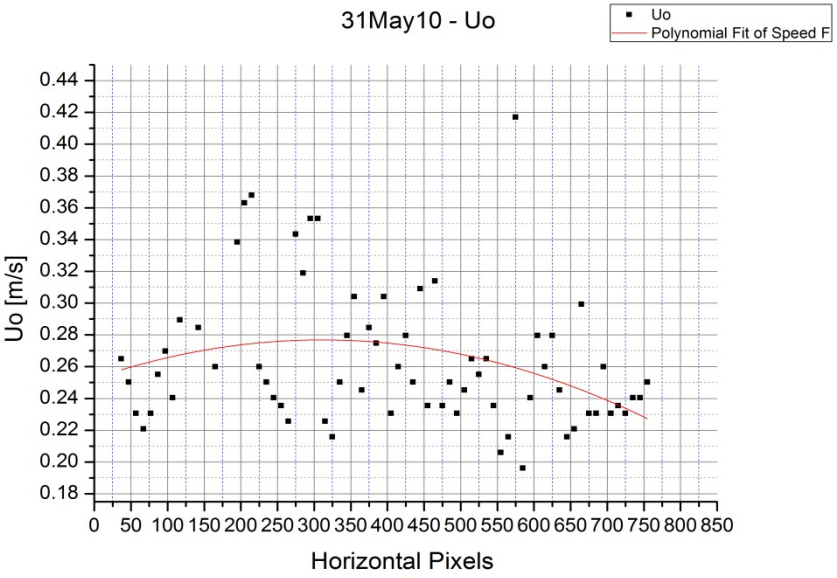
- **Secondary & delayed disruptions appear for first time !**

Shot #10 – 1.58E11 p.o.t

50 horizontal pixels = 0.8 cm





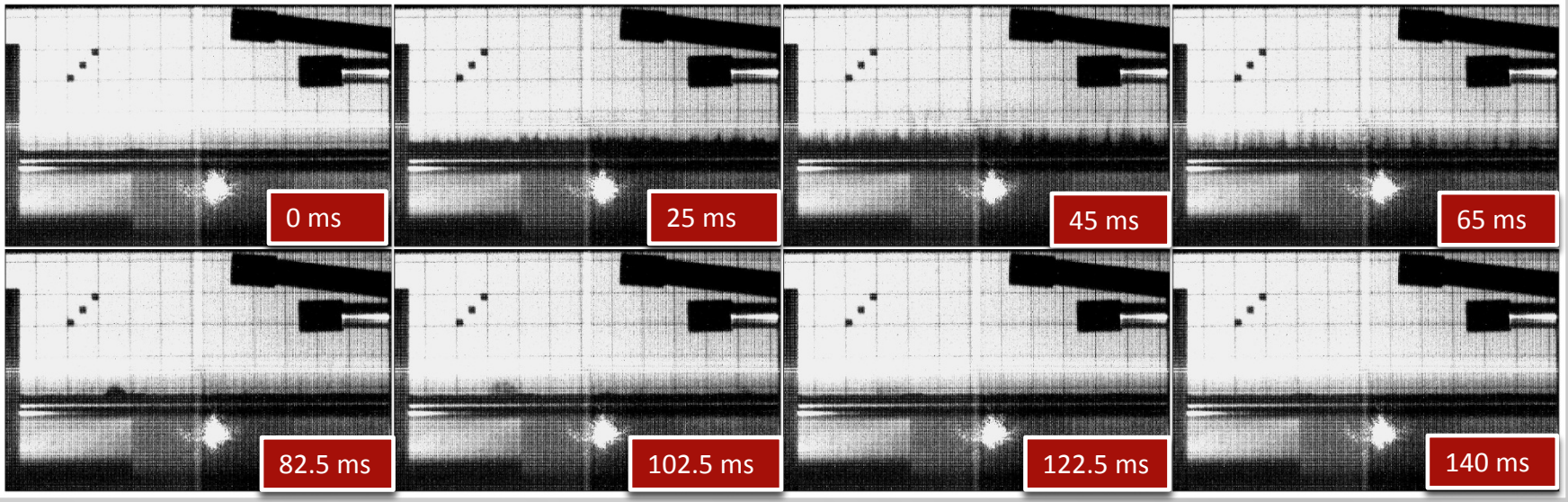


- **Lower maximum height, and lower speed**
  - **Filaments appear.**

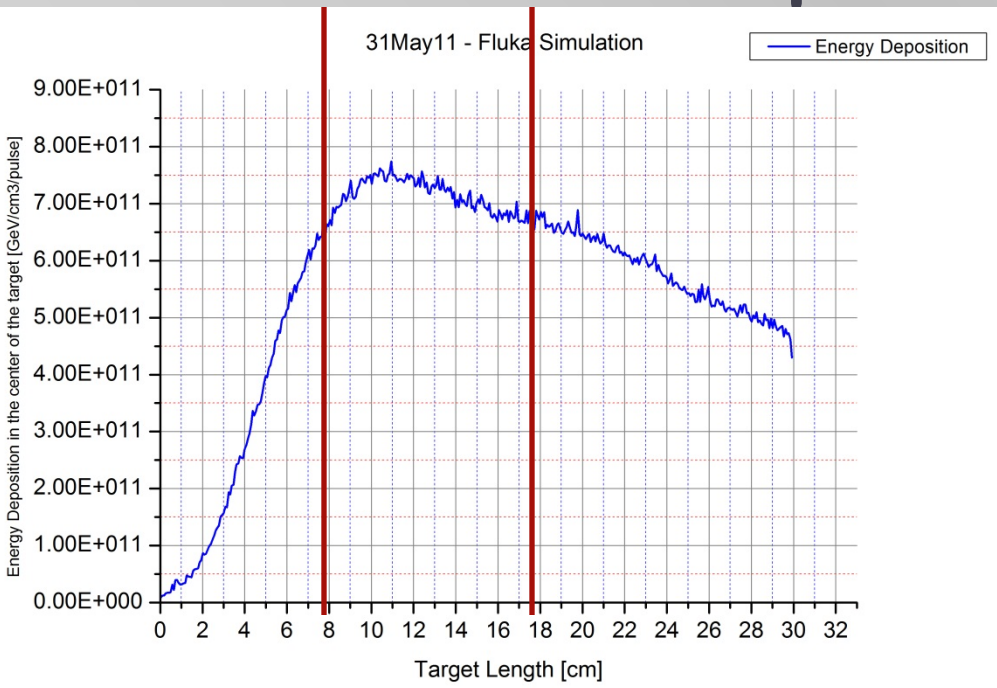
Shot #11 – 1.69E11 p.o.t

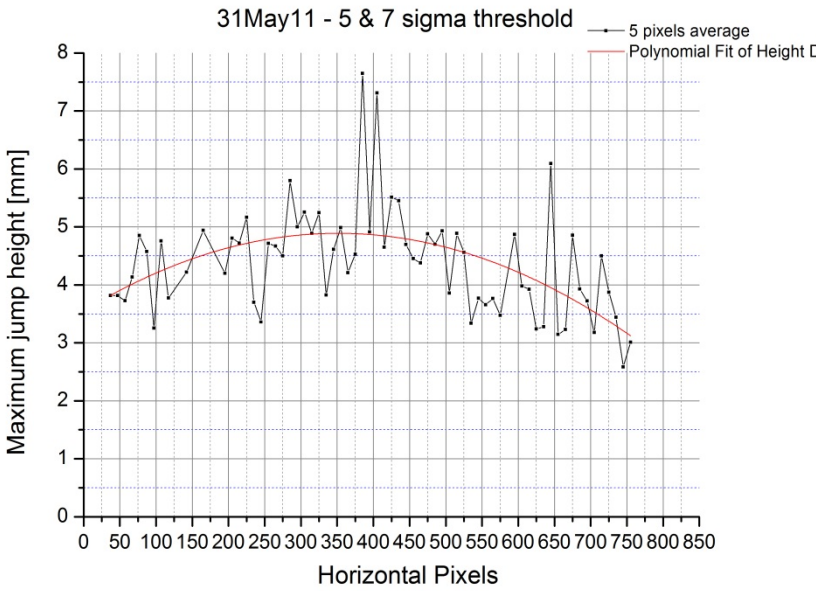
File Name 31MAY11_5fps.avi
File Size 339MB (355,10,80 Bytes)
Resolution 768x480
Play Time 00:01:04

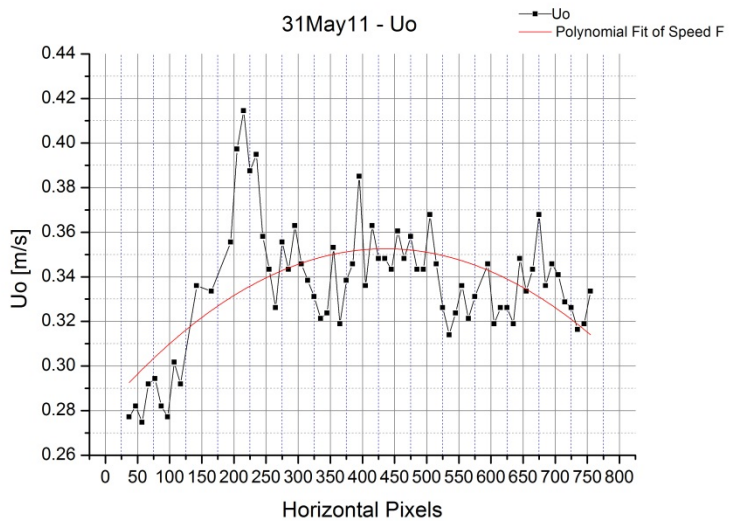
1.69x10^{11} protons @ 440GeV/c



Shot #11 – 1.69E11 p.o.t



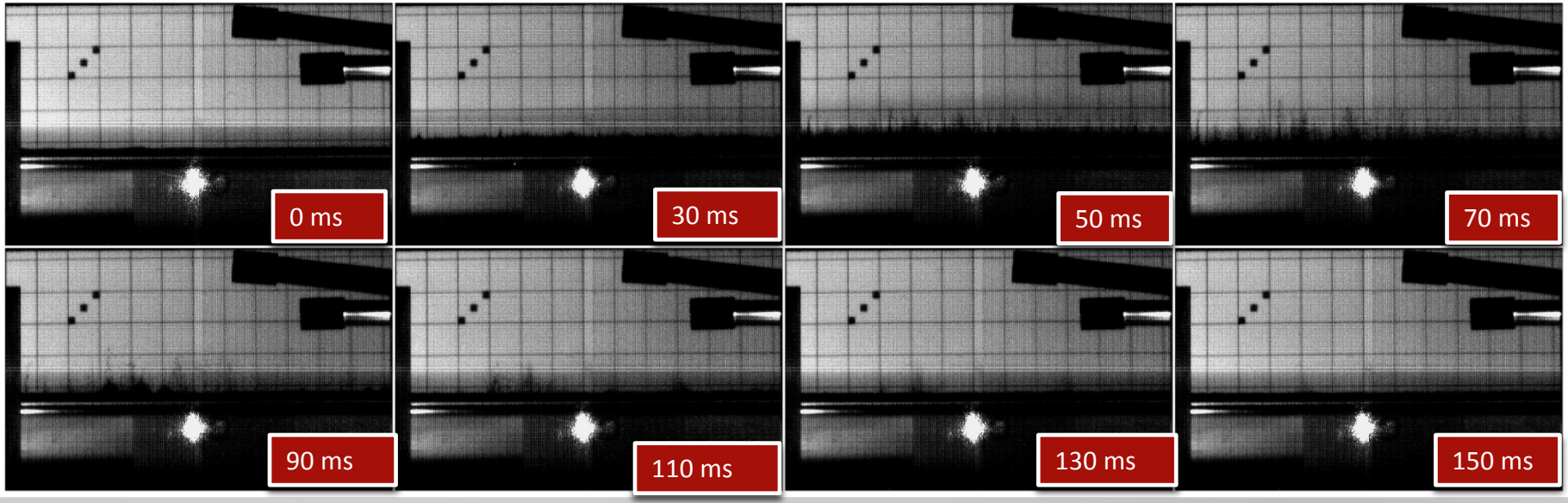




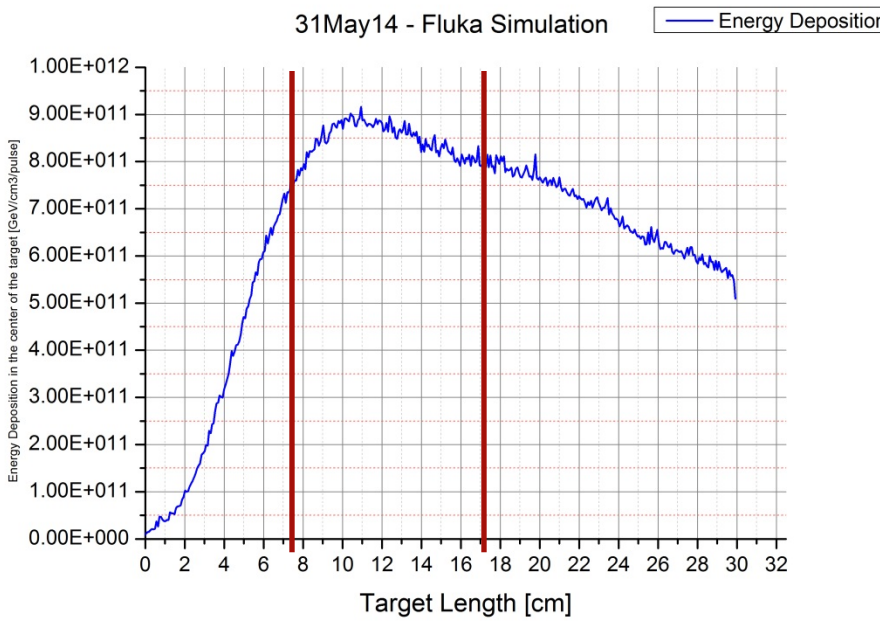
Shot #14 – 2E11 p.o.t

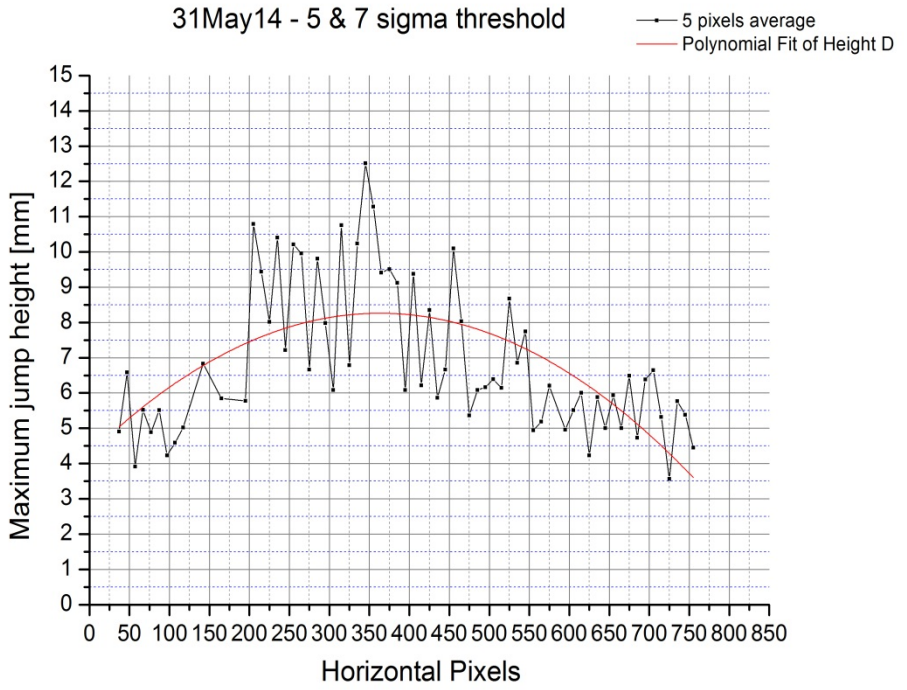
File Name 31MAY14_5fps.avi
File Size 180MB (189,118,480 Bytes)
Resolution 768x480
Play Time 00:00:34

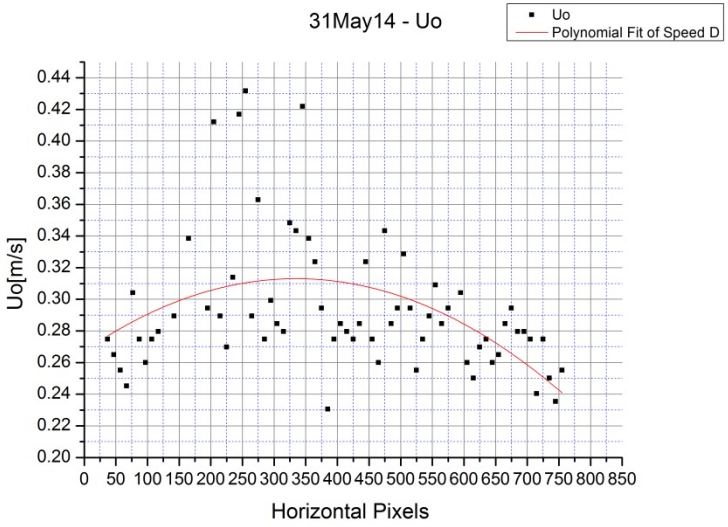
2x10^{11} protons @ 440GeV/c



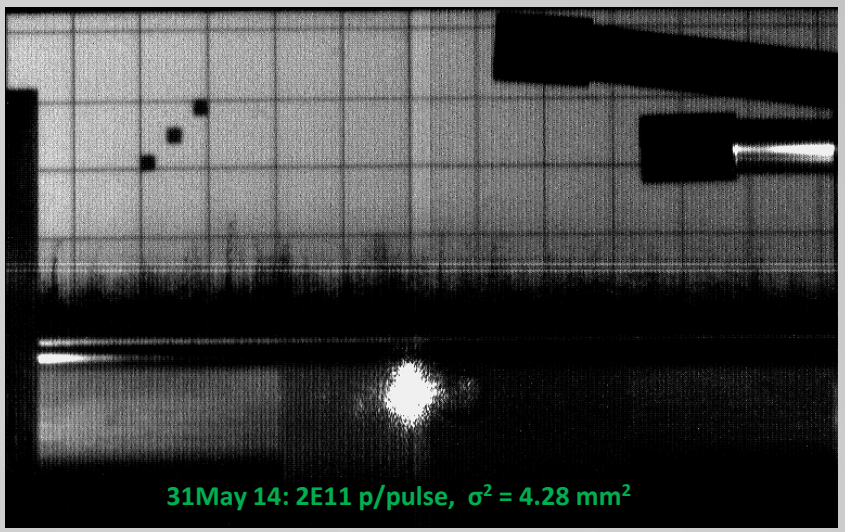
31May14 – 2E11 p/pulse

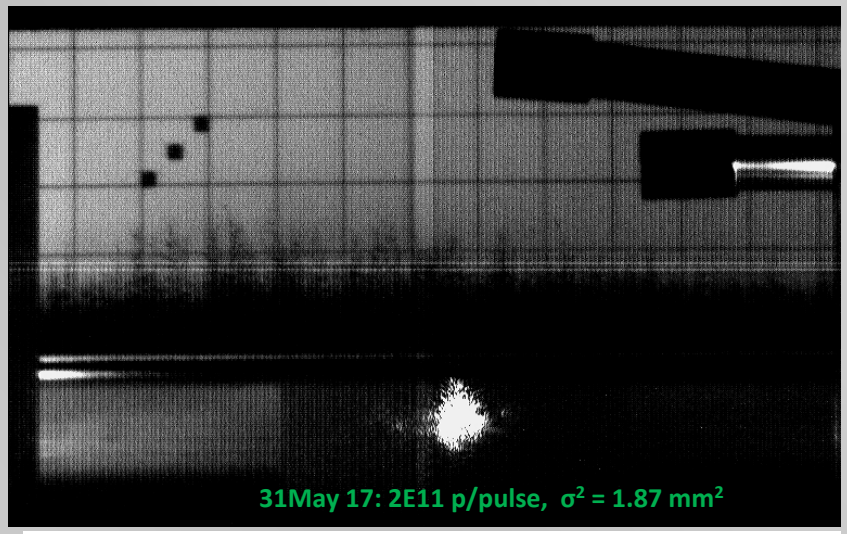


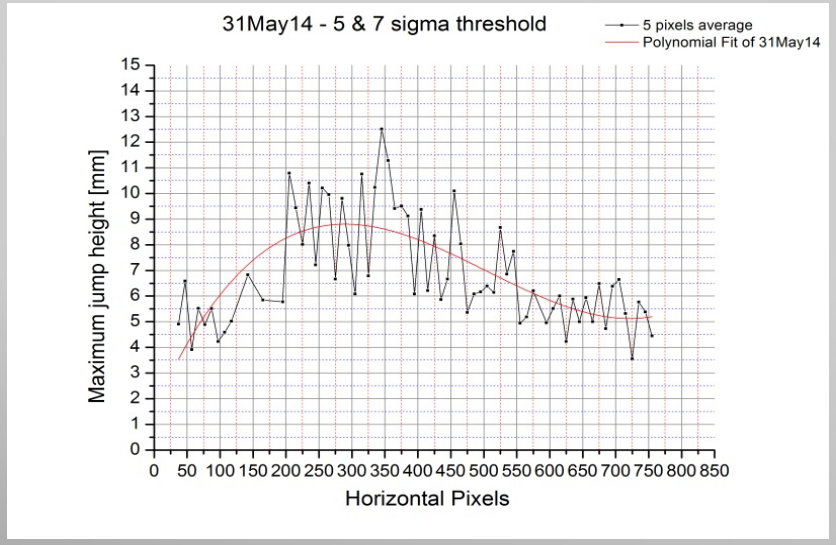


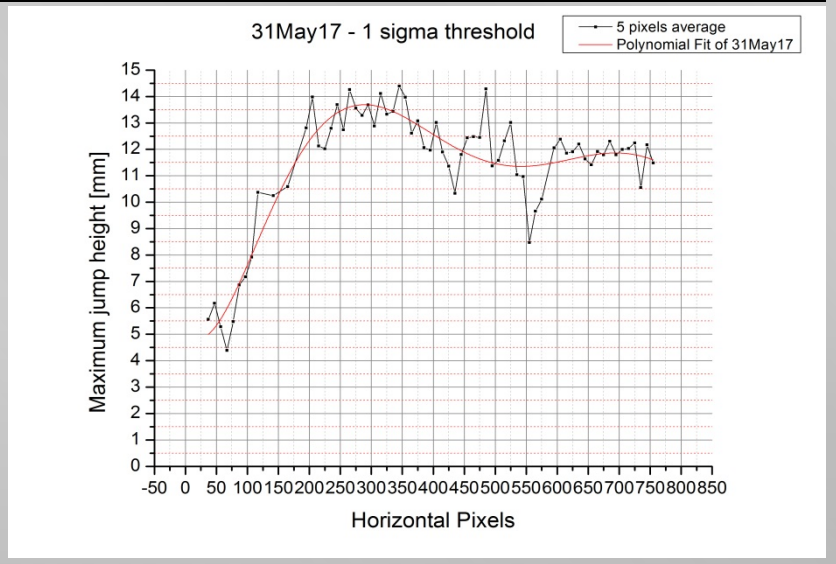


Shot #14 & Shot #17: Same intensity, different beam sigma





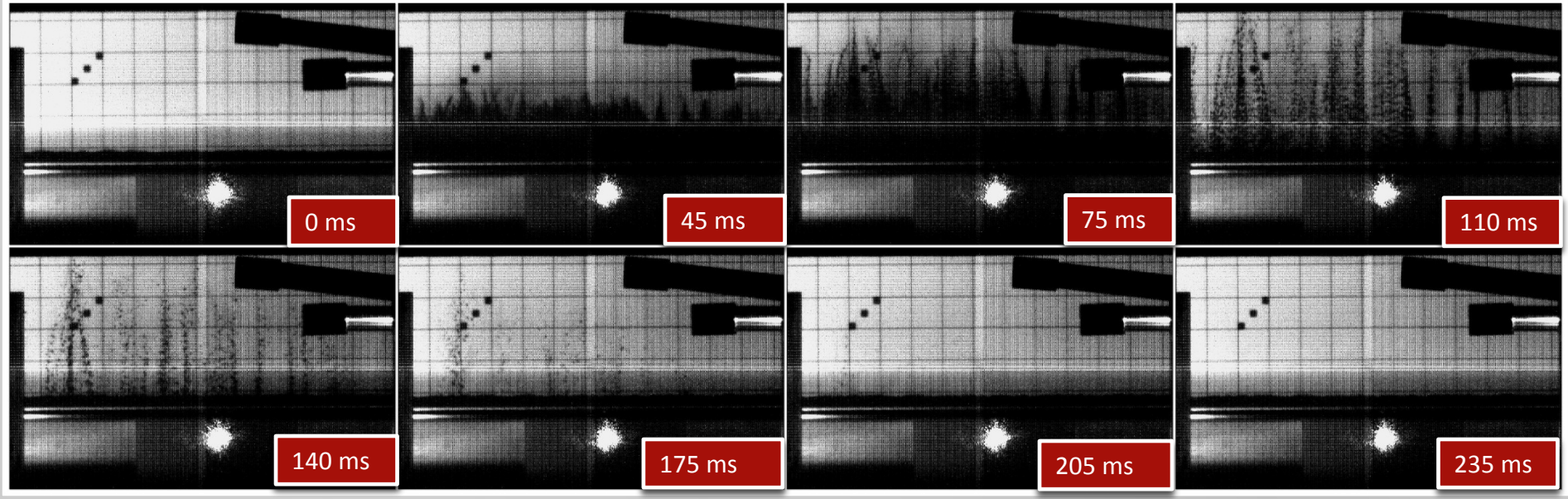




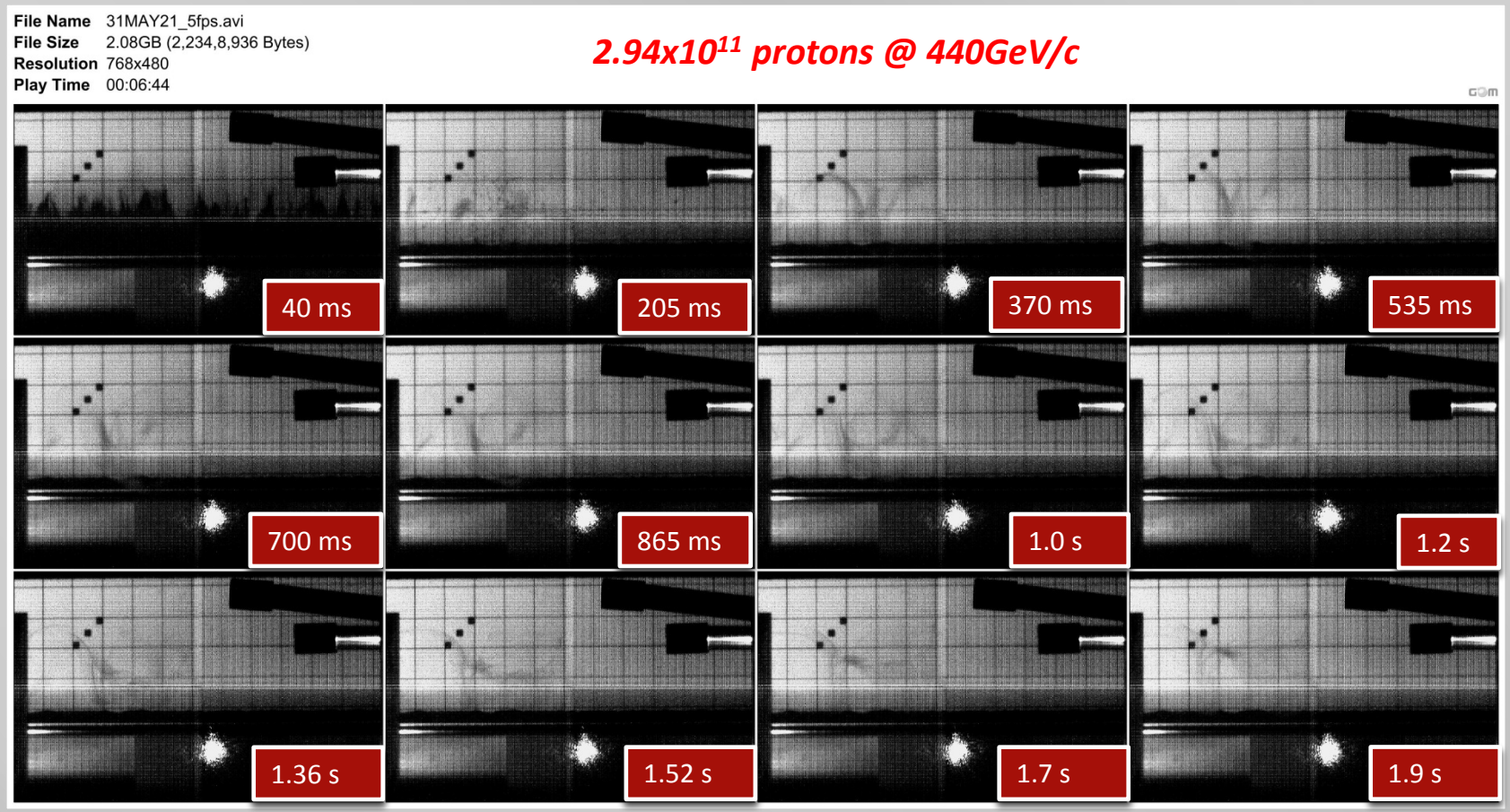
Shot #20 : More violent disruption

File Name 31MAY20_5fps.avi
File Size 286MB (299,712,880 Bytes)
Resolution 768x480
Play Time 00:00:54

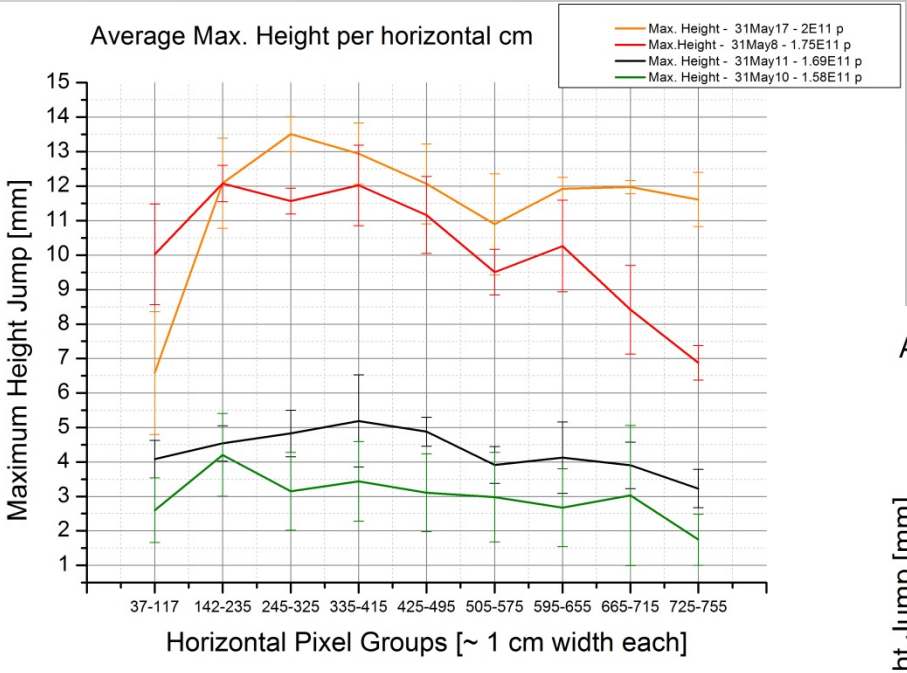
2.64x10^{11} protons @ 440GeV/c



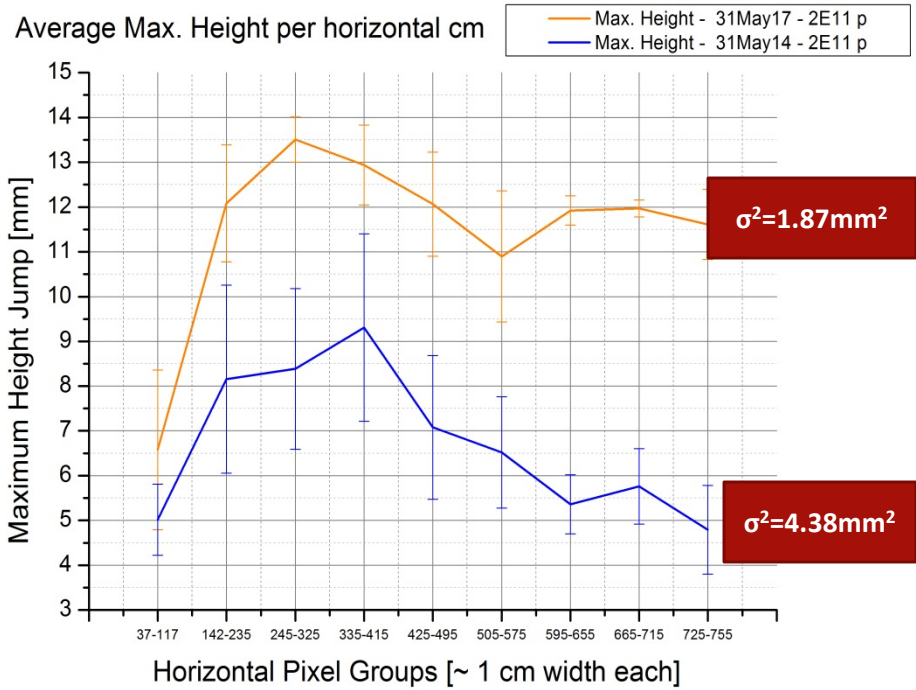
Shot #21 : Powder dust ?



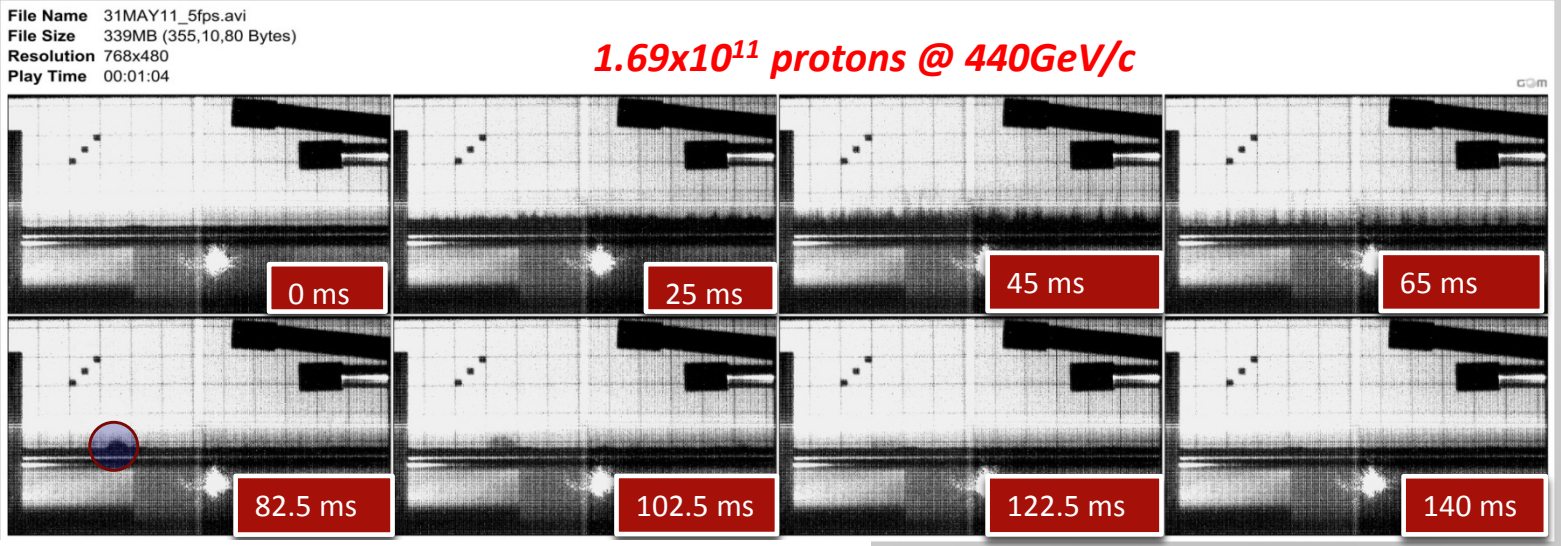
Average Height

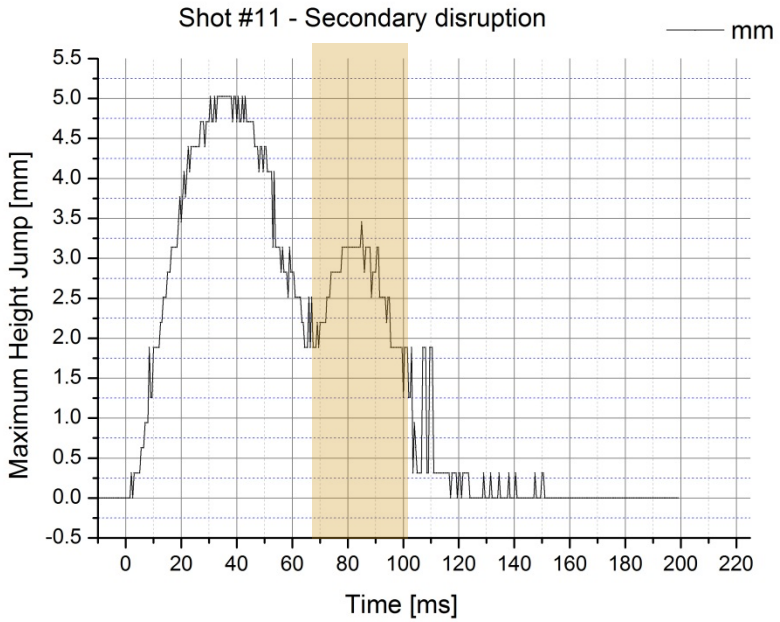


- **Maximum height appears to scale with the *intensity* as well as with the *beam sigma***



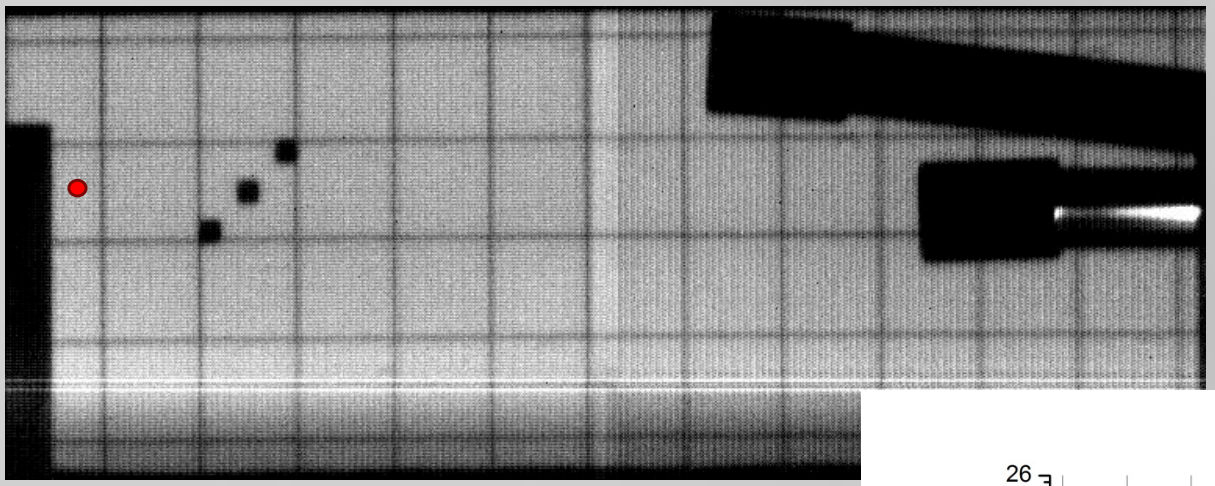
Secondary disruption – Shot #11



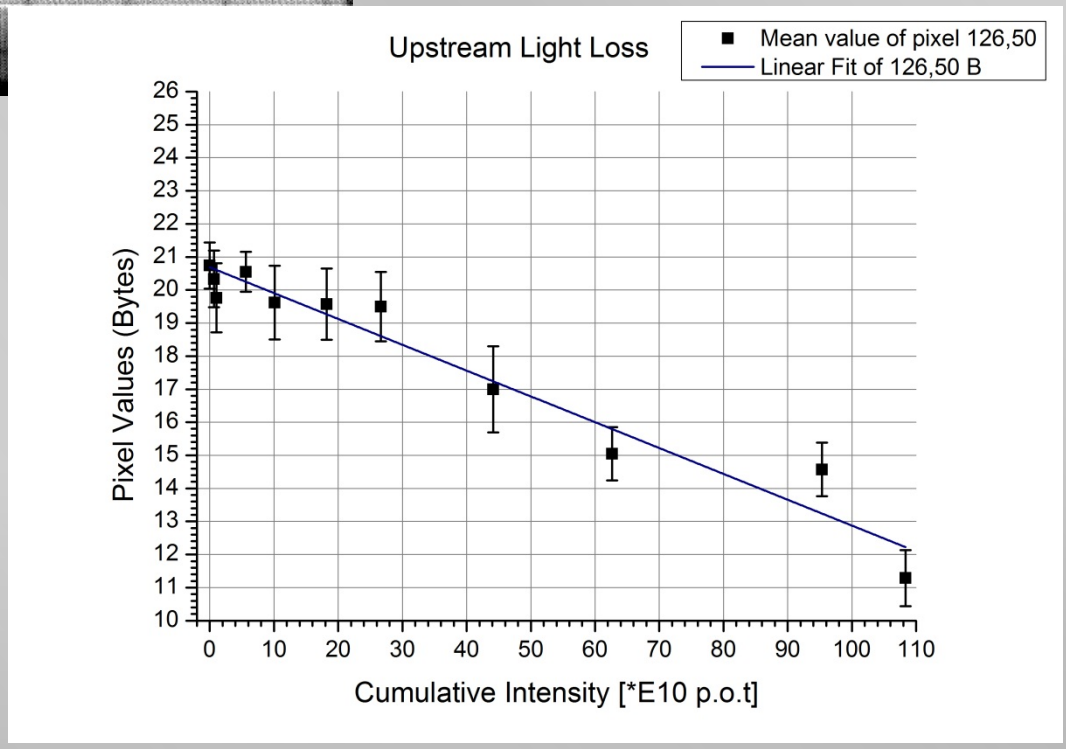


- **The main disruption finishes at ~ 65 ms and immediately after the secondary disruption starts.**
  - **Duration: ~ 30 ms**
  - **Max. Height : ~ 3.5 mm**

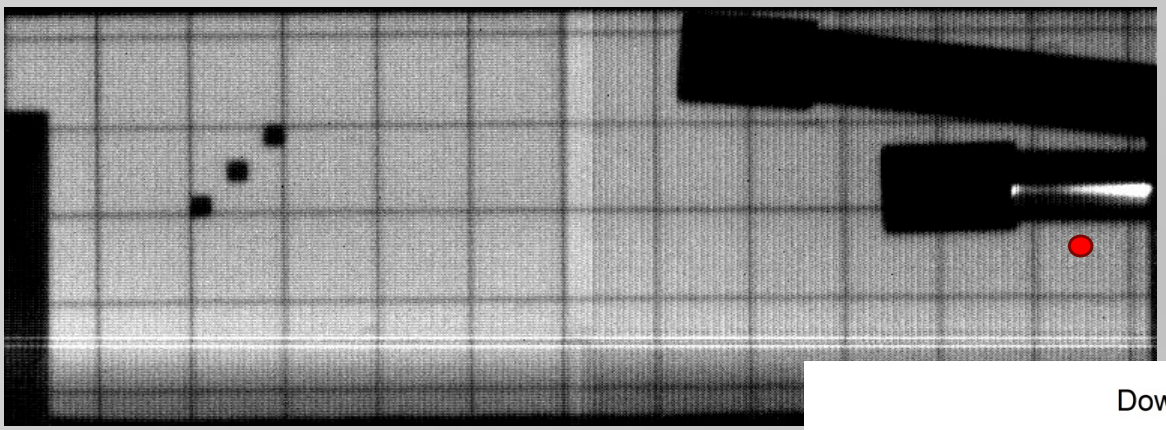
LED Degradation - Upstream



- **After ~ 6E11 p.o.t**
  - More than 25% light loss !
- **After ~ 1E12 p.o.t**
  - More than 50% light loss

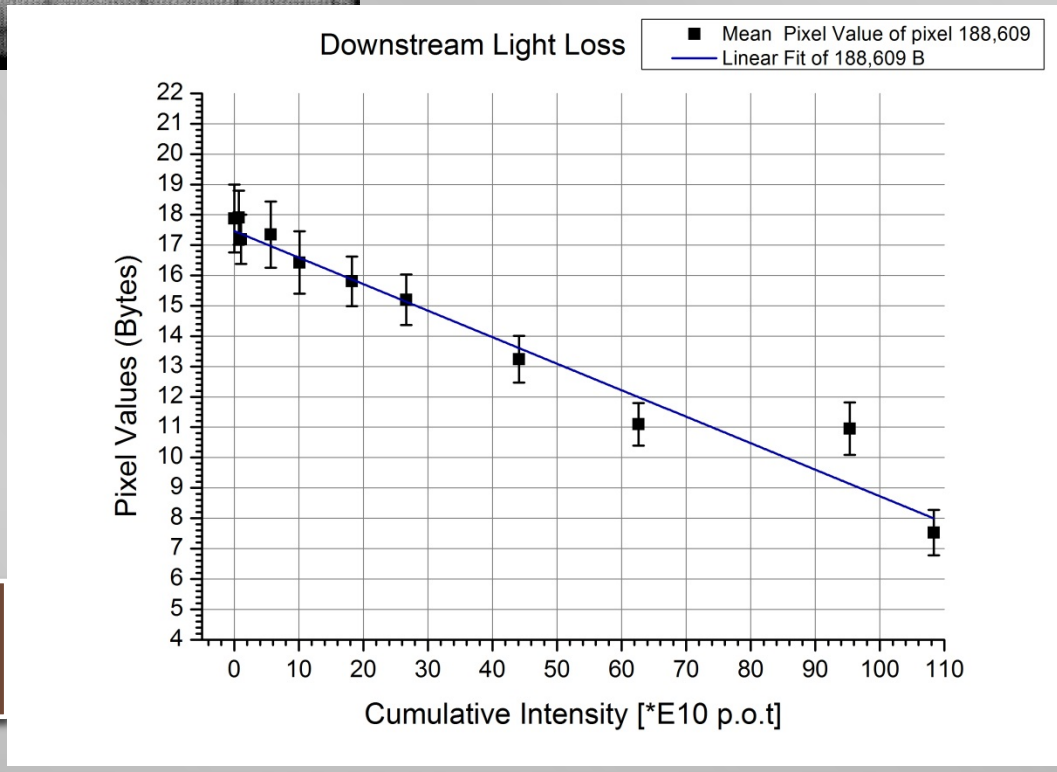


LED Degradation - Downstream



- **After ~ 4E11 p.o.t**
  - More than 25% light loss !
- **After ~ 1E12 p.o.t**
  - More than 50% light loss

No change in the lighting appears for proton doses < 1E11 p.o.t

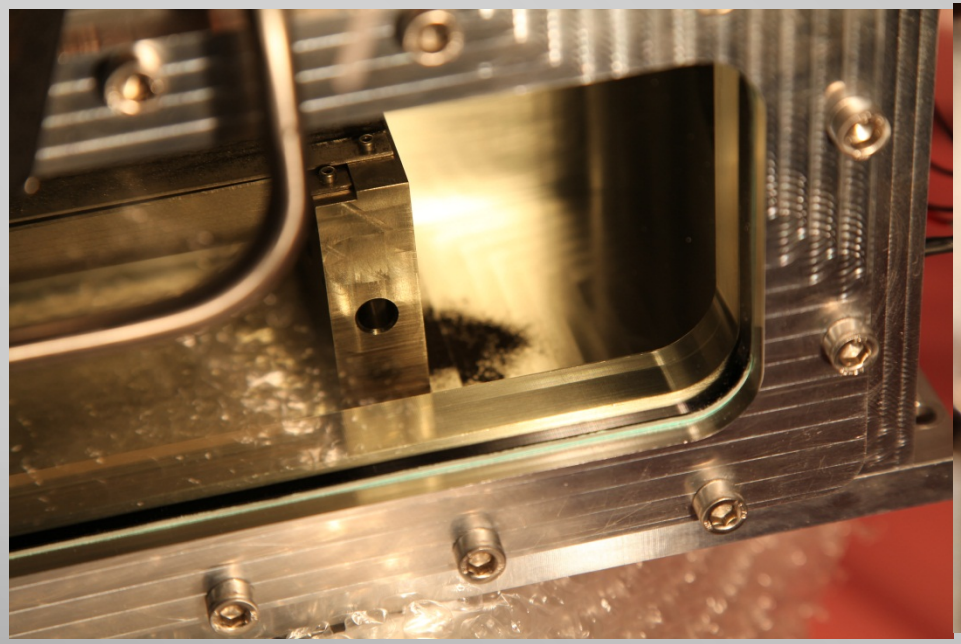


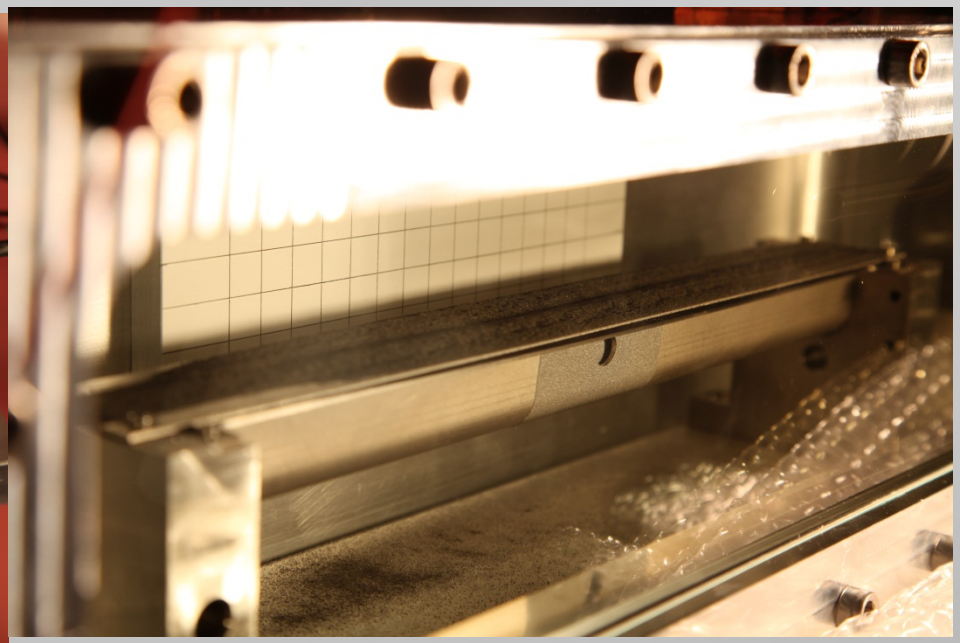
Conclusions

- **W - powder disruptions under the effect of the beam appears to be consistent with the energy distribution predicted by Monte – Carlo simulations**
- **Maximum height of the disruption for beam intensities up to 2E11 p/pulse : ~ 14mm**
- **Disruption speeds < 0.5 m/s**

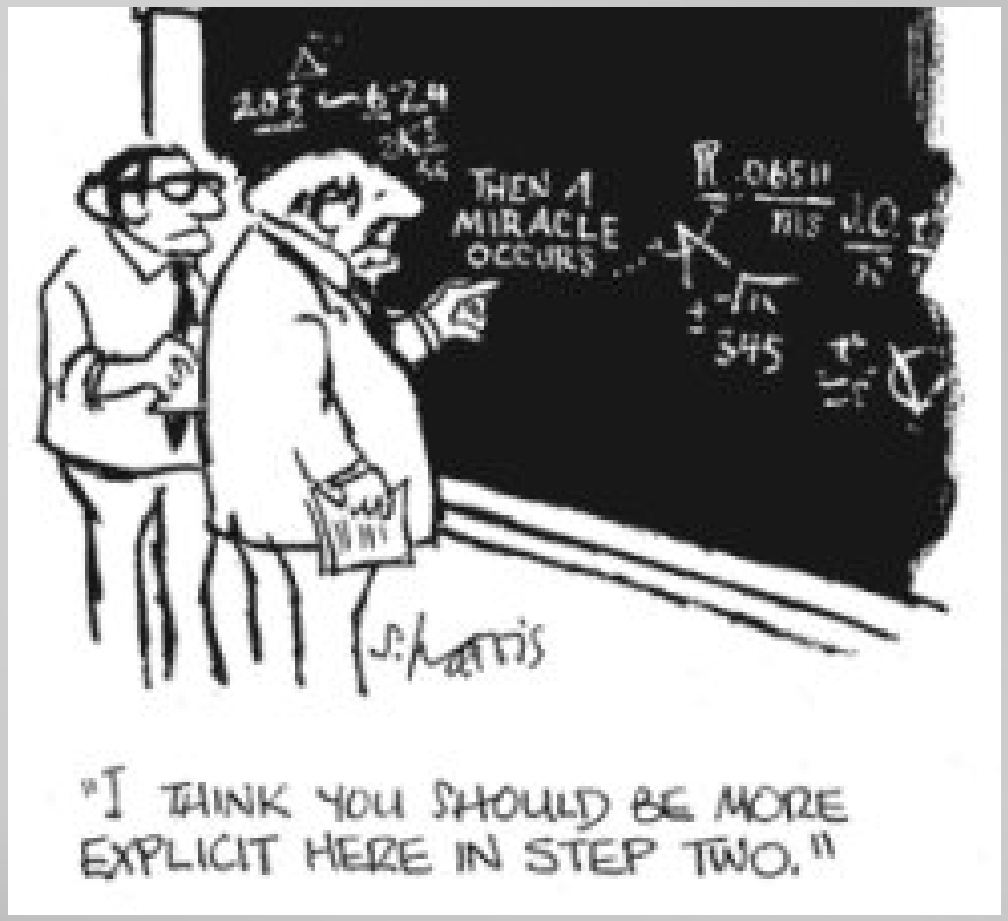
Next steps

- **Fine-tuning of the analysis algorithms for the photos**
- **Continuation of the analysis of the LDV data**
- **Post Irradiation analysis ?**



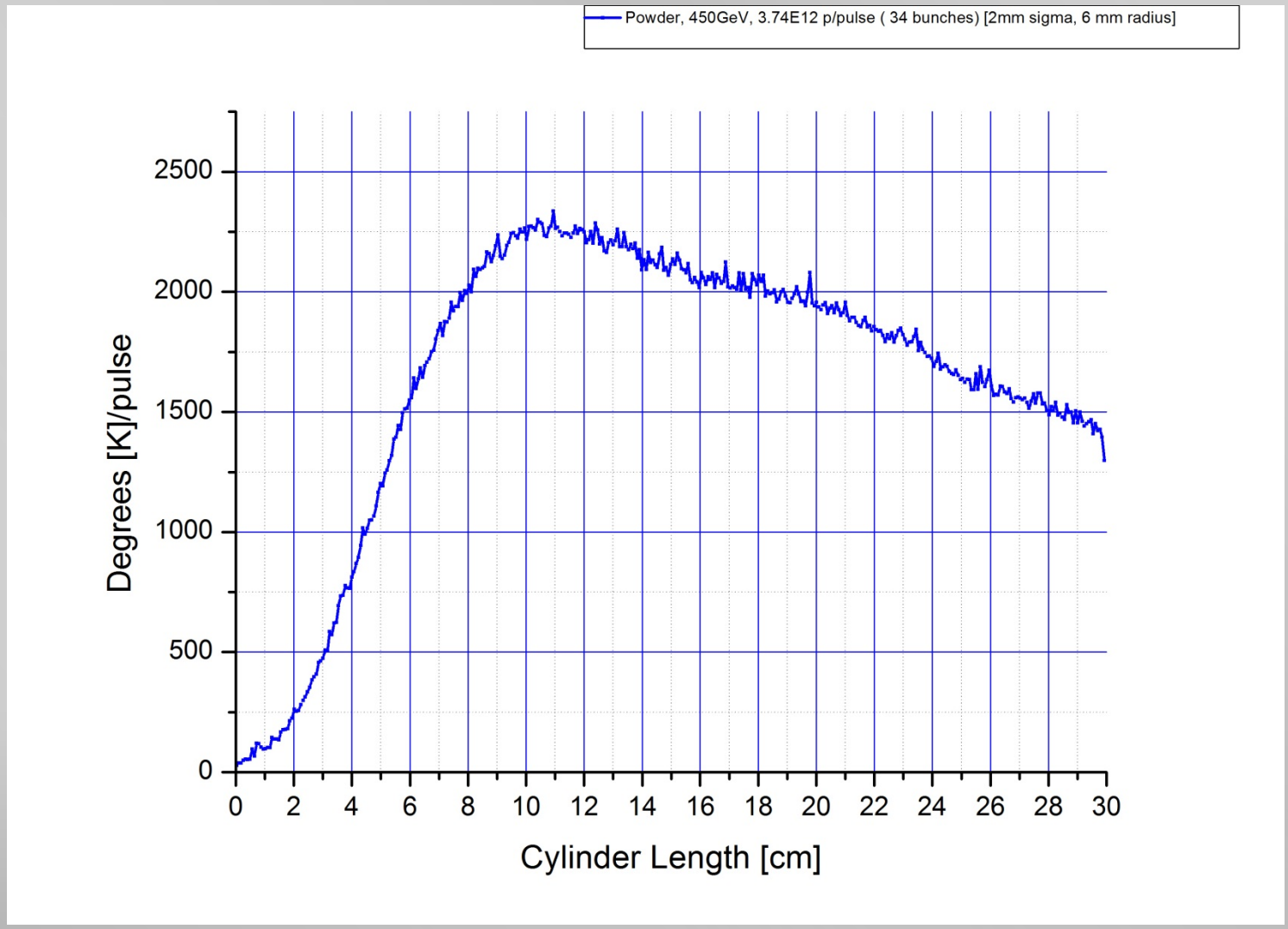


Thank you !

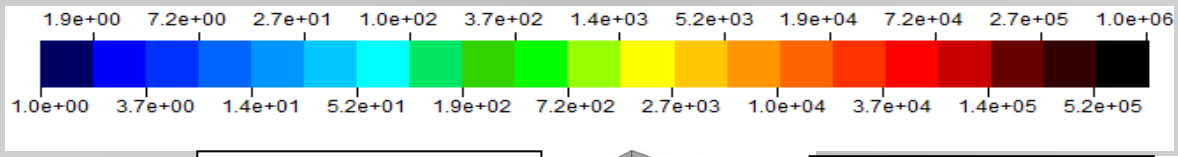

THEN A MIRACLE OCCURS...
"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

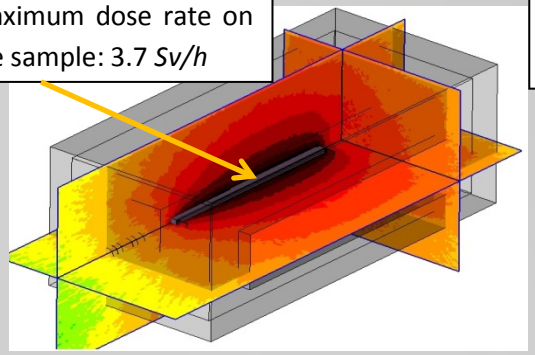

© Original Artist
Reproduction rights obtainable from
www.CartoonStock.com
Okay... ready? O three,... THROW!
search ID: bstn331
Before the linear accelerator

Extra 1 : Temperature

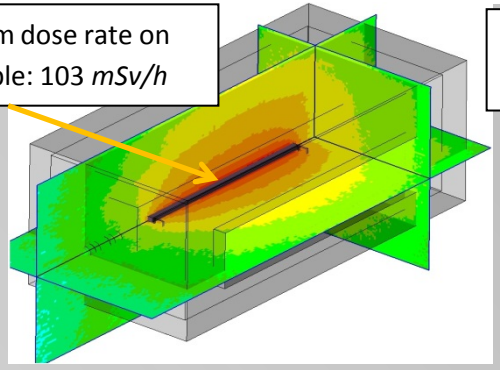


Extra 2: Activation Dose Rates (uSv/h) – For 1E13 p

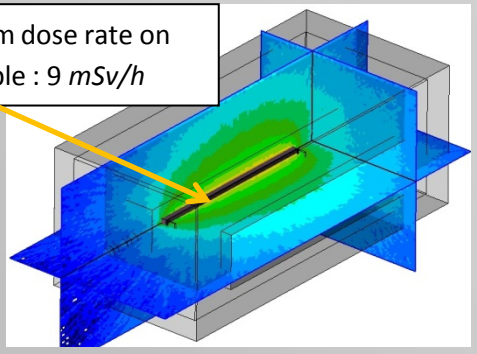




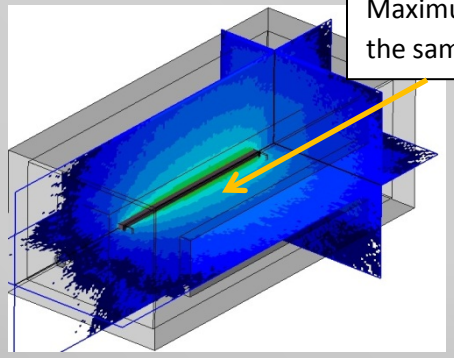
1 hour



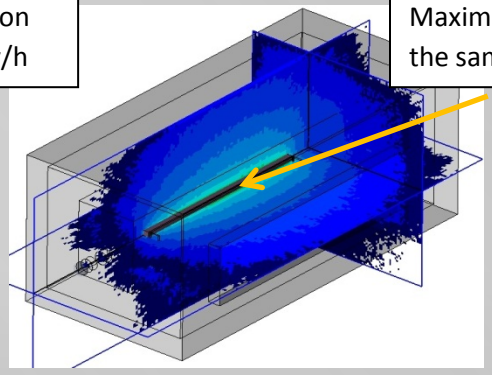
1 day



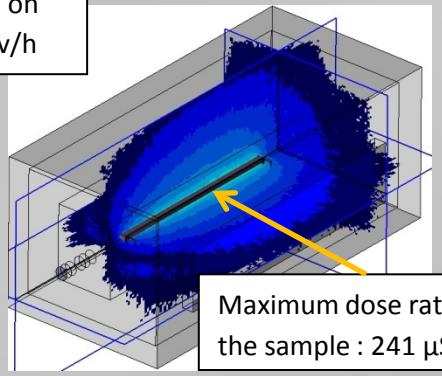
1 week



1 month



2 months



4 months

Loss of LED power [%] due to irradiation