

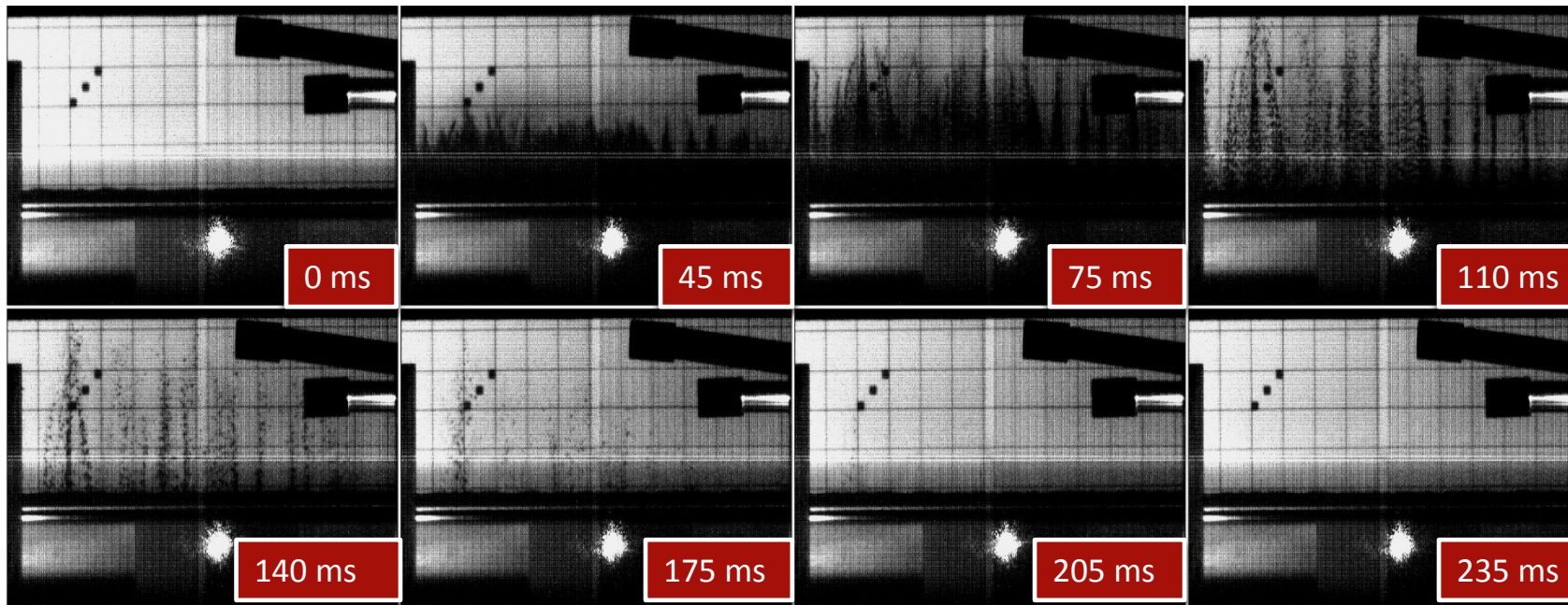
# First observations from the HRM-10 tungsten powder experiment at HiRadMat

*N. Charitonidis [CERN, EPFL], I. Eftymiopoulos [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

**$2.64 \times 10^{11}$  protons @ 440 GeV/c**

gcm



# 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 ! !**

**4th HIGH POWER TARGETRY WORKSHOP**

EUROPEAN SPALLATION SOURCE (ESS) | DTU | LUND UNIVERSITY

Hilton Malmö City Hotel, Malmö, Sweden  
2nd May - 6th June

**EXTENDED ABSTRACTS SUBMISSION DEADLINE 21st MARCH**

The 4th high-power targetry workshop will be held at the Hilton Malmö City Hotel in Malmö, Sweden. The workshop is organized by the major laboratories operating or designing high-power targetry facilities, including ESS, DTU, and LUND University. The workshop is intended for scientists and engineers from the design phase to the operation phase of high-power targetry facilities. Through the workshop, participants will have an opportunity to discuss and exchange with a balanced sharing of views on the challenges and solutions in the design and construction of high-power targetry facilities.

**Proposed Topics:**  
Operational experience of high-power target facilities  
Resonance targets  
Spallation neutron sources  
Radiation shielding  
Simulation tools and modelling  
Industrious safety issues  
Ballistic damage material properties  
Design principles for high-power targetry

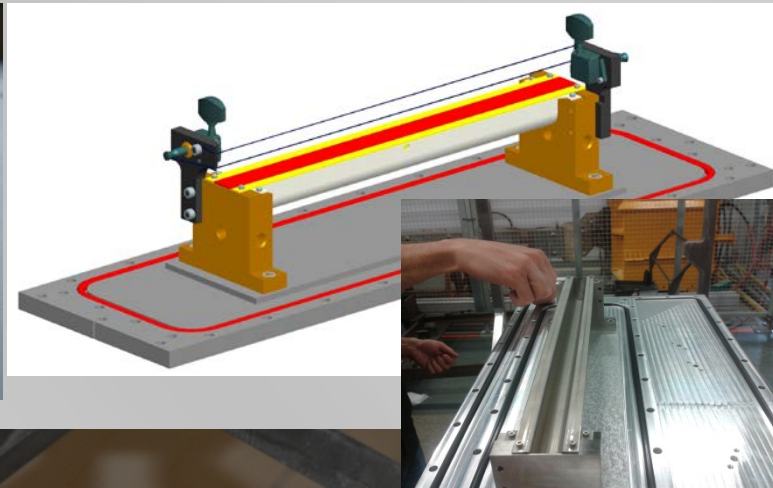
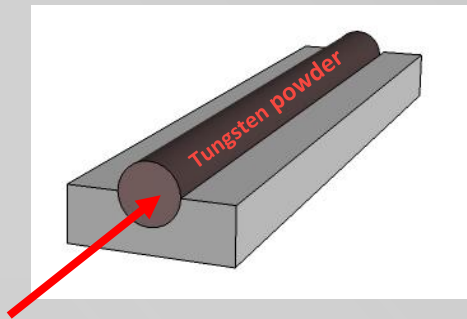
**The Venue:**  
Hilton Malmö City Hotel is the venue of Malmö City 15 Minutes to Park, from Copenhagen Airport.

**Important Dates:**  
March 15, 2011: Abstracts submission deadline  
March 21, 2011: Extended Abstracts submission deadline  
March 30, 2011: Notification of abstract acceptance  
April 3, 2011: Deadline registration for the workshop  
May 2, 2011: Workshop at ESS in Malmö, Sweden  
June 4, 2011: Manuscript submission

Register on  
<http://ess-scandinavia.eu/hptw>

# Experimental setup of HRM10

- A double Ti Trough, containing static powder target, settled but not compressed



Proton beam

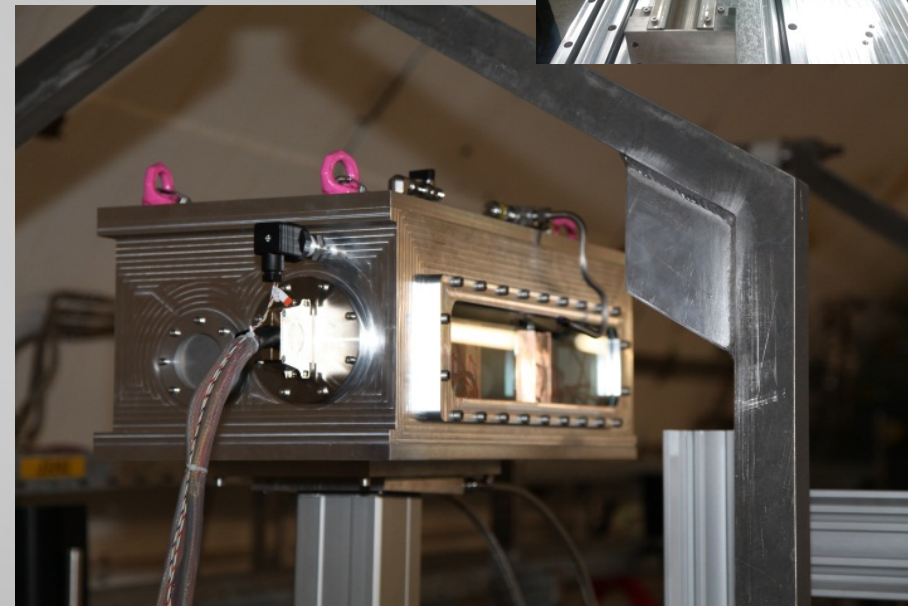
Length 30cm, Diameter ~ 1.6 cm



Outer container

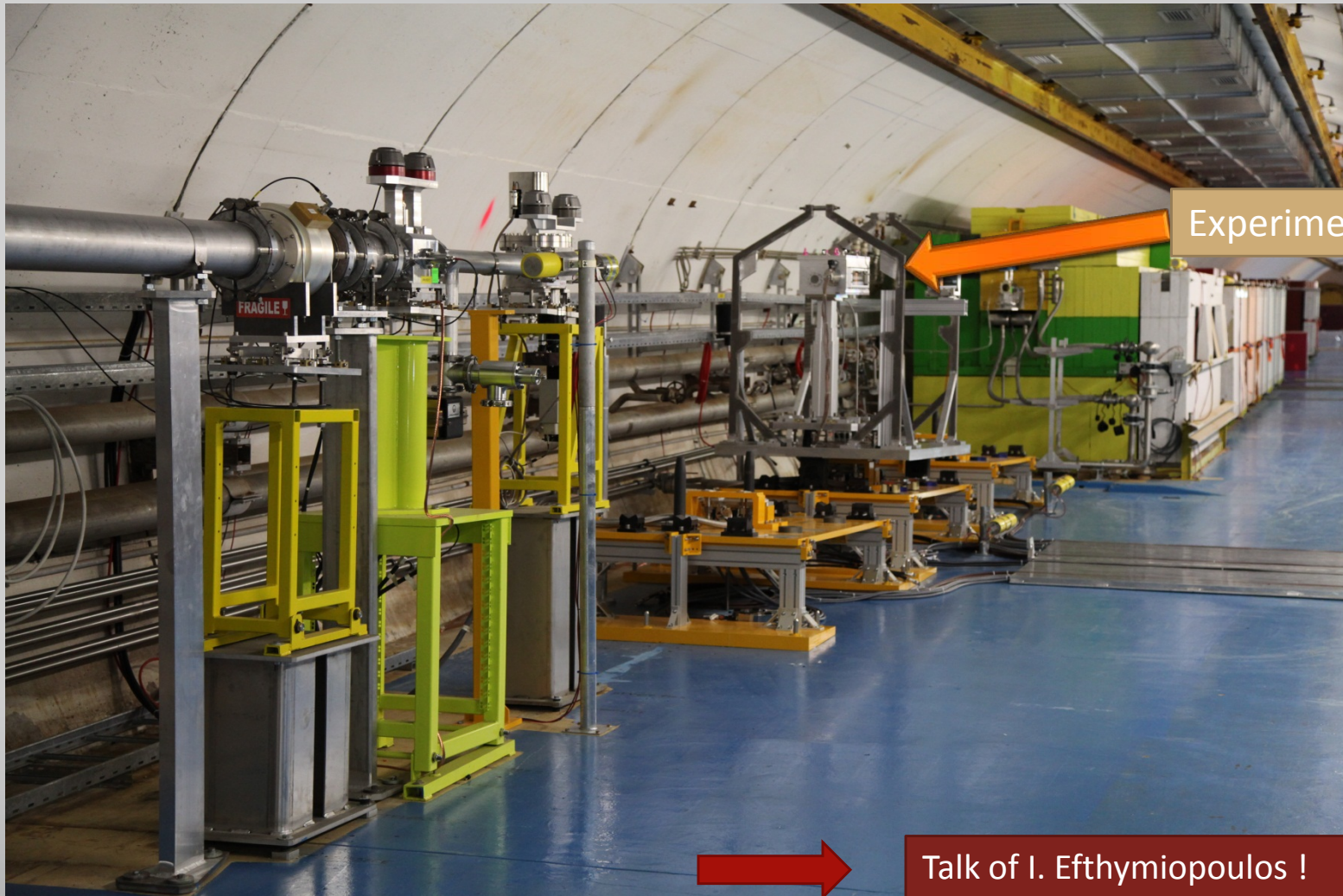
Inner container

Containers with He-Gas





# Experiment placed & ready for beam @ HiRadMat



Experiment

Talk of I. Efthymiopoulos !





# Instrumentation

## ■ Possible effects

- Gas expansion (or implosion)
- Melting of the beads
- Shock Wave propagation

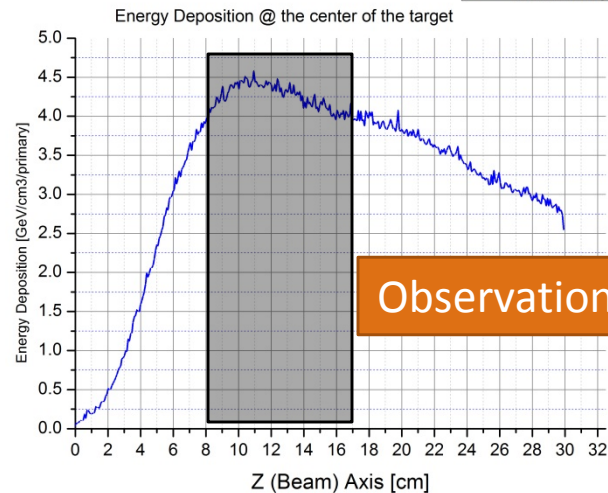
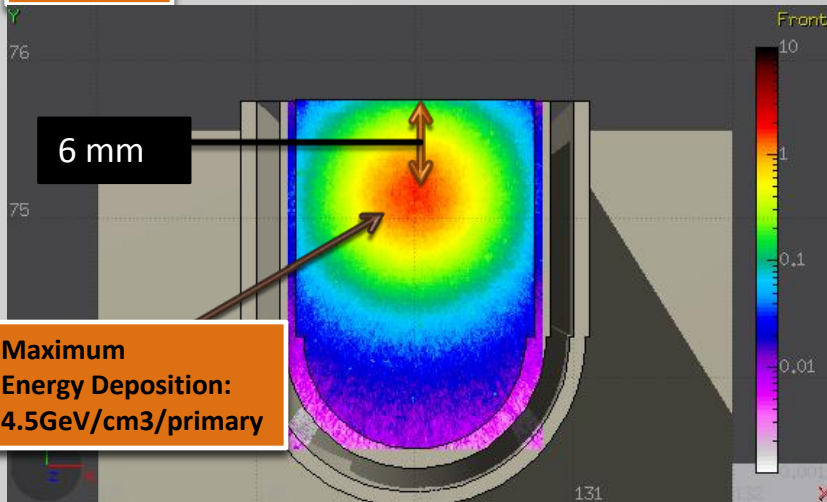
## ■ Two main diagnostic tools

- 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<sup>®</sup> Monte – Carlo Code )

Front

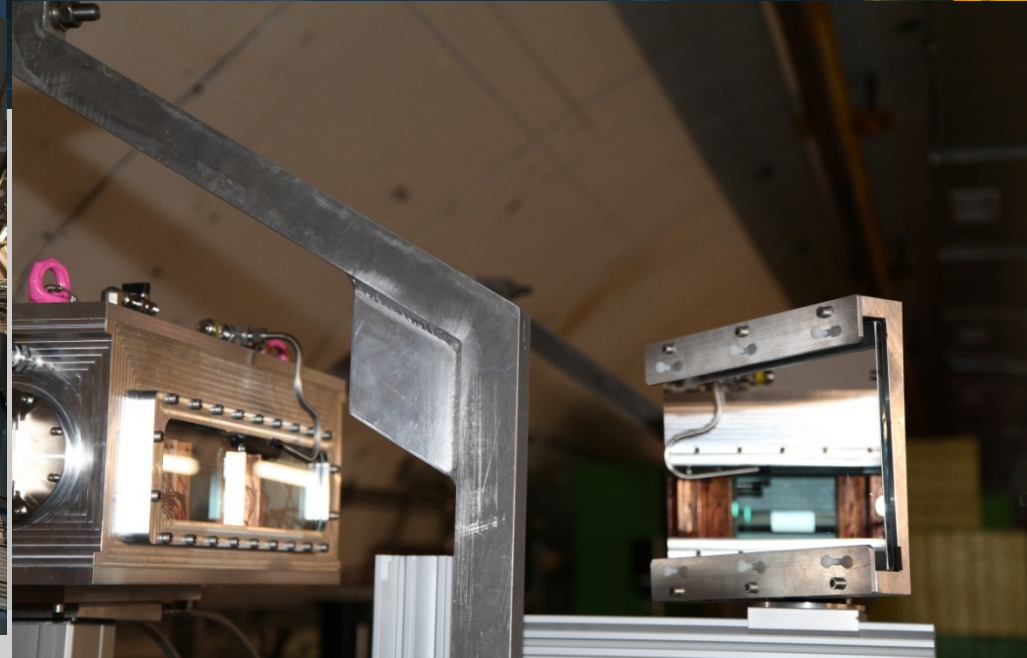
Top







# Experimental Setup

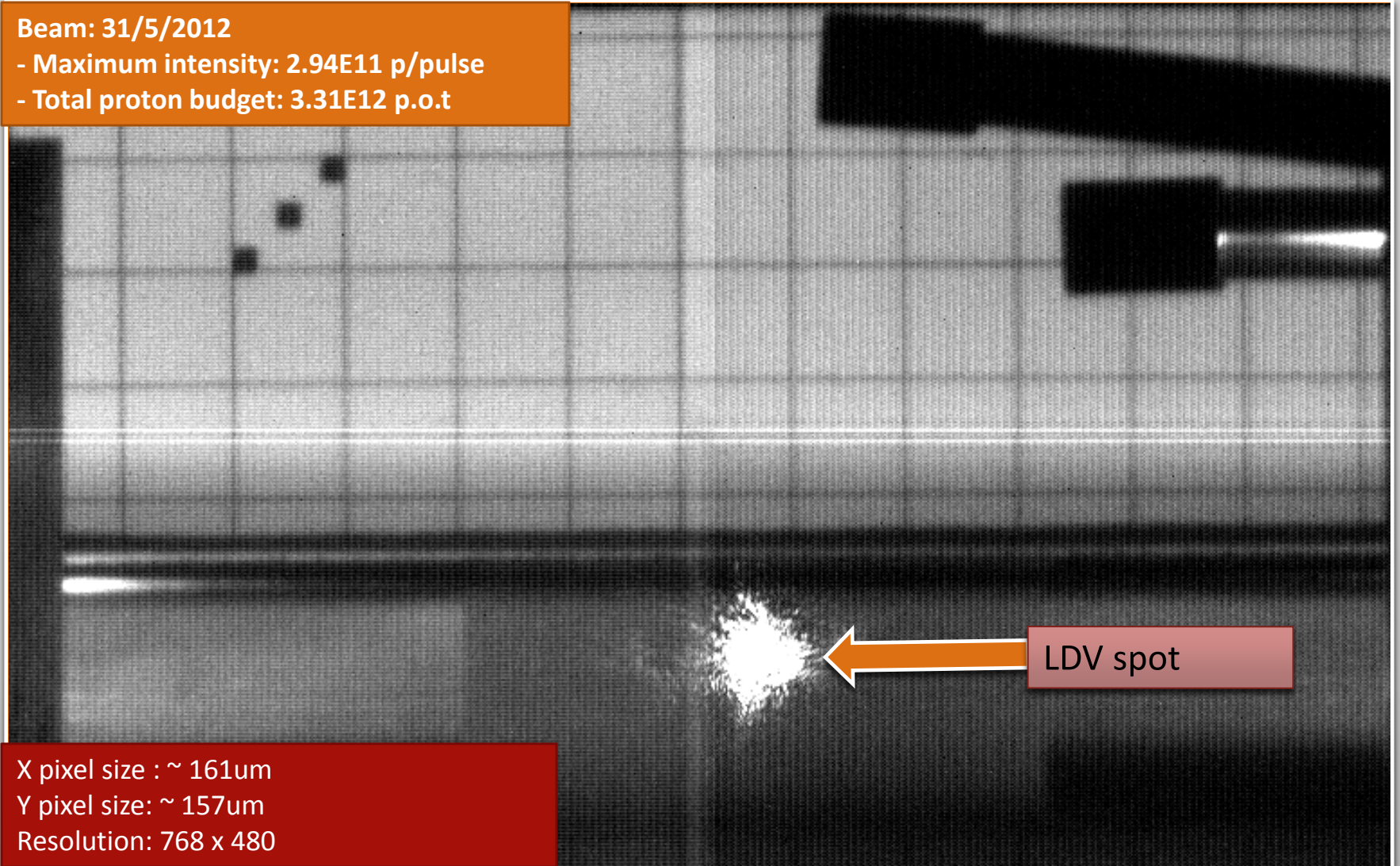




# Field of view

Beam: 31/5/2012

- Maximum intensity:  $2.94E11$  p/pulse
- Total proton budget:  $3.31E12$  p.o.t



X pixel size :  $\sim 161\mu\text{m}$   
Y pixel size:  $\sim 157\mu\text{m}$   
Resolution: 768 x 480

# Beam parameters of HRM-10

- **p= 440 GeV/c protons**
  - $\text{Sigma}^2$ : variable, around  $4\text{mm}^2$
  - Intensities: From  $6.8\text{E}9$  up to  $2.94\text{E}11$  p/pulse
  - Bunches / pulse: 1 (6 shots), 6 (11 shots), 36 (5 shots)
- **In total: 22 shots on target**

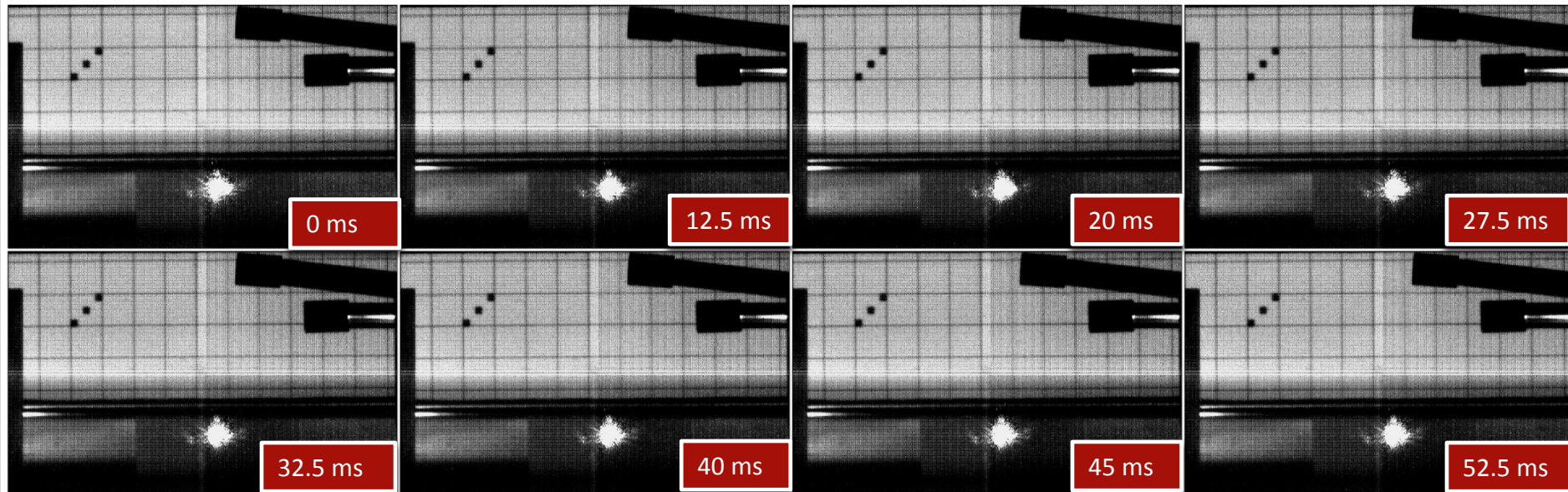


# Low intensity shots

- 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

*$4.6 \times 10^{11}$  protons @ 440 GeV/c*





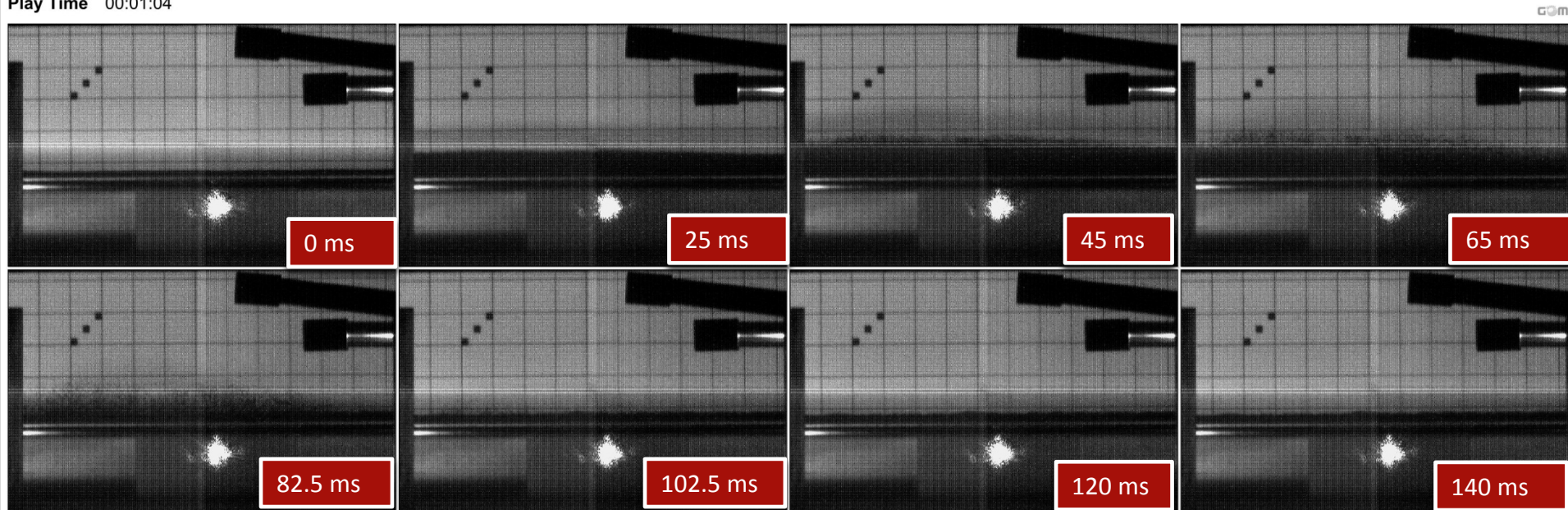
## Medium Intensities – $8.1E10$ to $2E11$ p/pulse

- **440 GeV/c**
- **$\Sigma^2 \sim 4\text{mm}^2$**
- **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<sup>11</sup> protons @ 440GeV/c*



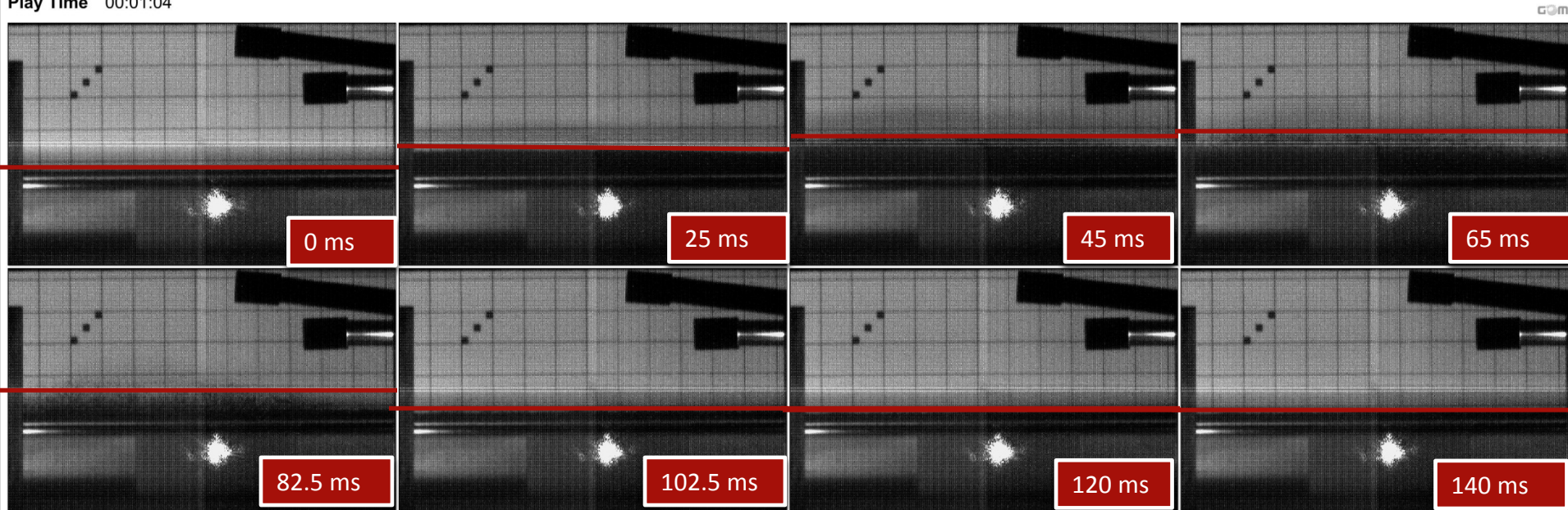
- **First major disruption !**



# 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<sup>11</sup> protons @ 440GeV/c*



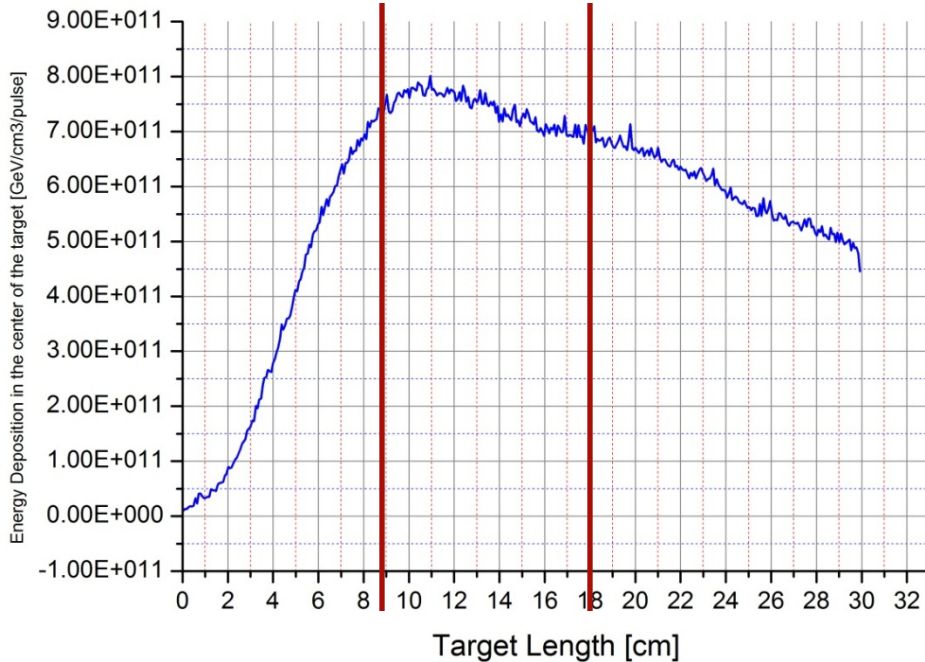
- **First major disruption !**

# Shot # 8 – 1.75E11 p.o.t

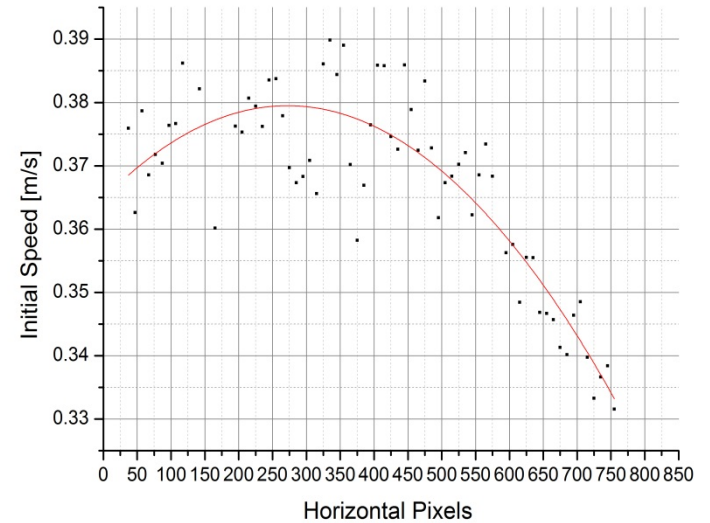
50 horizontal pixels = 0.8 cm

31May8 - Fluka Simulation

— Energy deposition

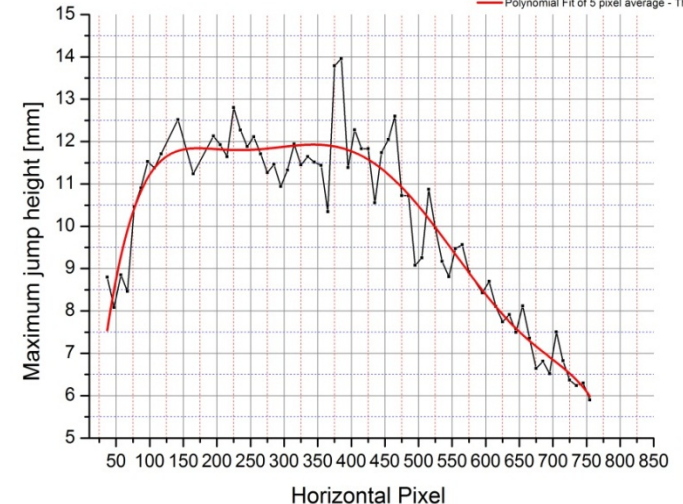


• U<sub>0</sub> - 31May8  
— Polynomial Fit of 31May8 - Speed B



31May8 - 5 & 7 sigma threshold

— 5 pixel average  
— Polynomial Fit of 5 pixel average - Threshold 5 & B



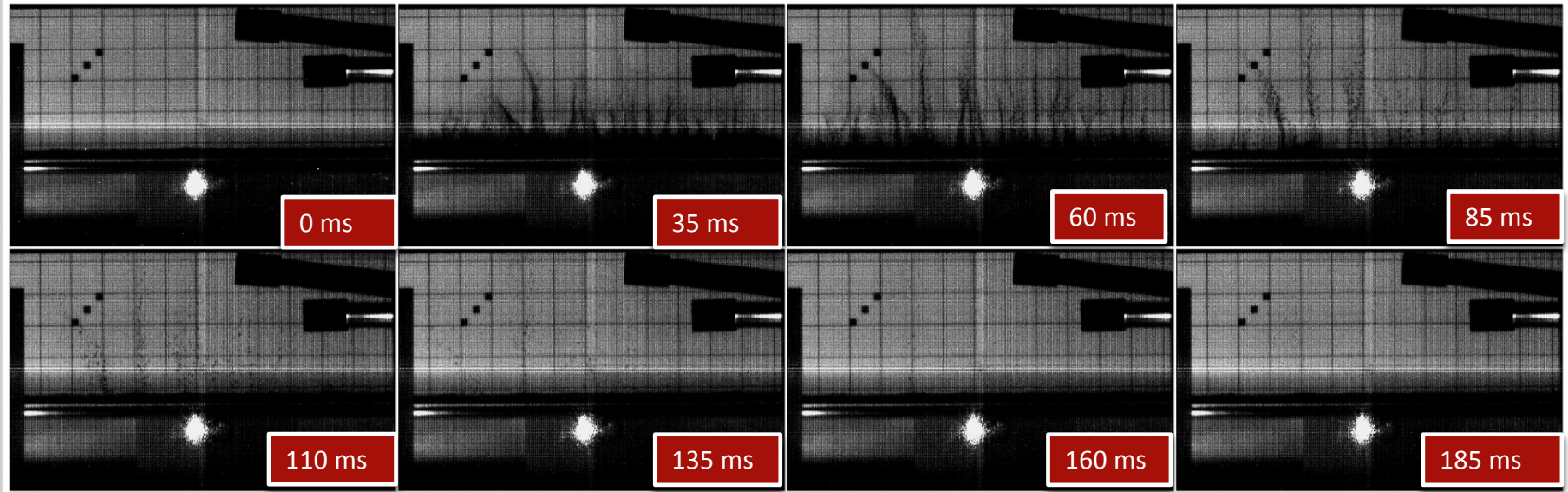
- **Maximum height jump & speed consistent with the energy deposition distribution !**



# 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

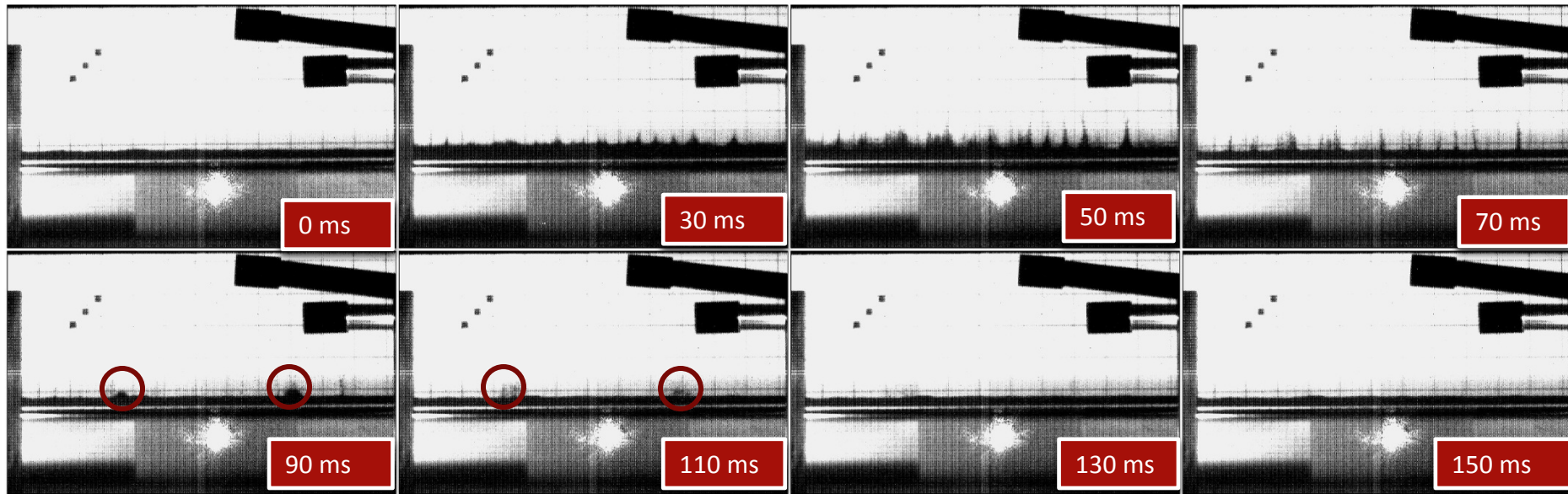
*1.85x10<sup>11</sup> protons @ 440GeV/c*



- 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

File Name 31MAY10\_5fps.avi  
File Size 180MB (189,118,480 Bytes)  
Resolution 768x480  
Play Time 00:00:34

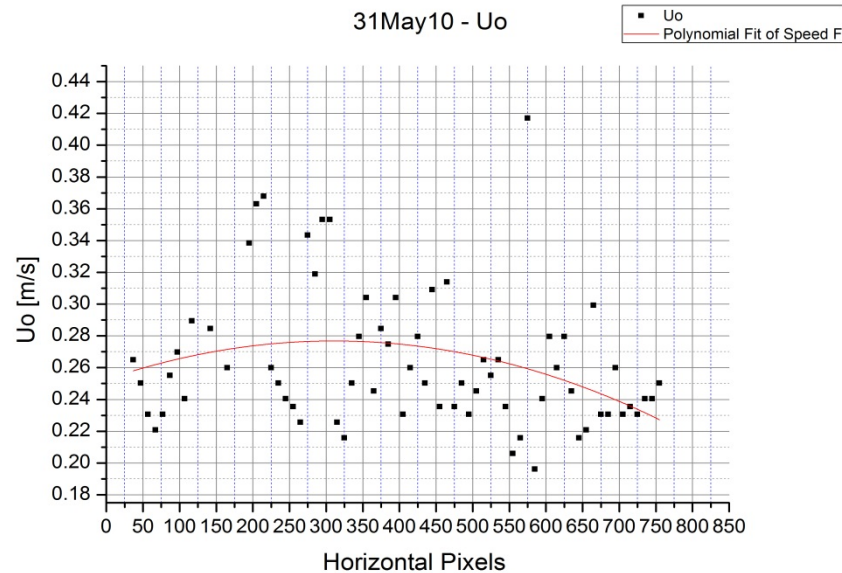
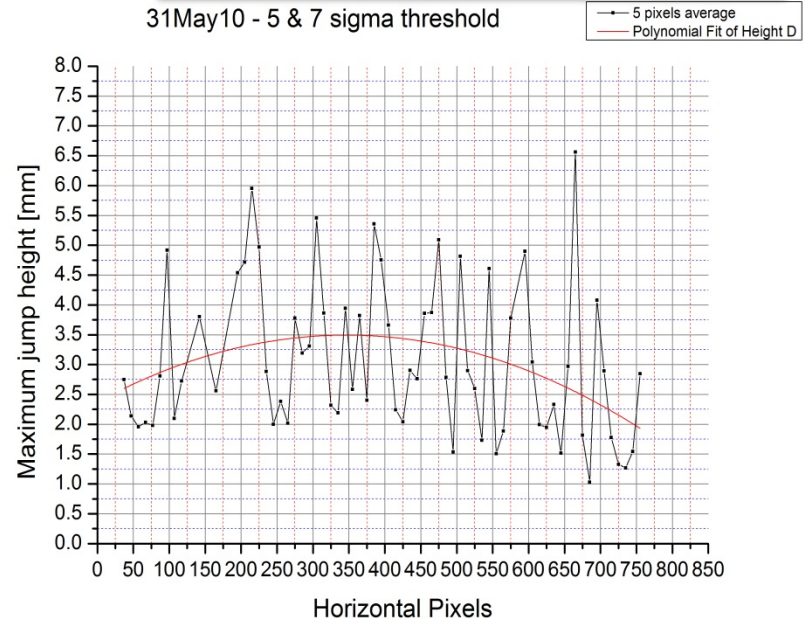
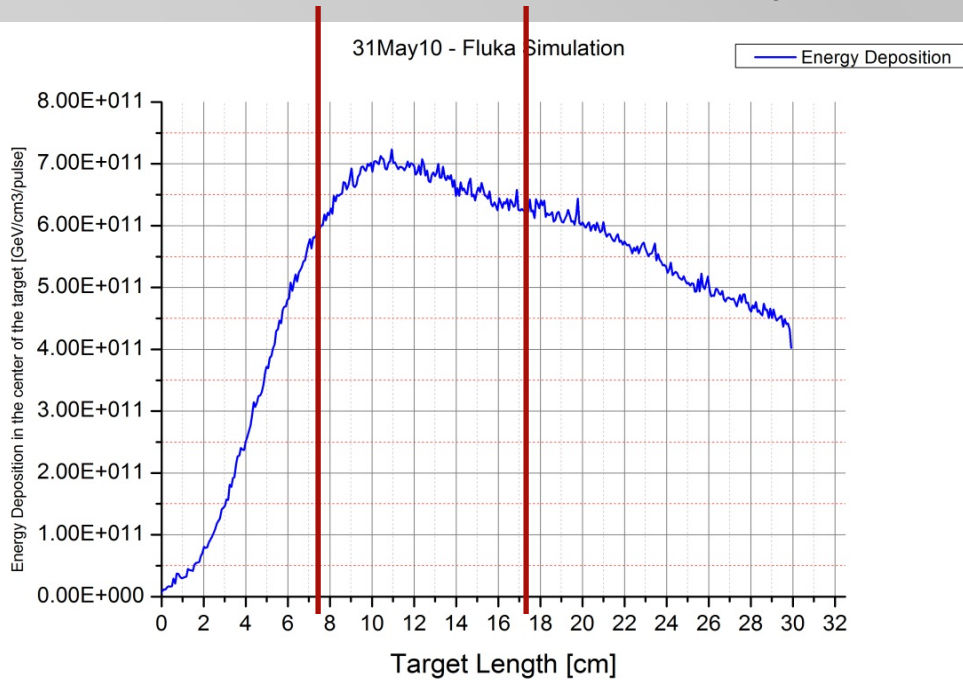


- Secondary & delayed disruptions appear for first time !



# Shot #10 – 1.58E11 p.o.t

50 horizontal pixels = 0.8 cm

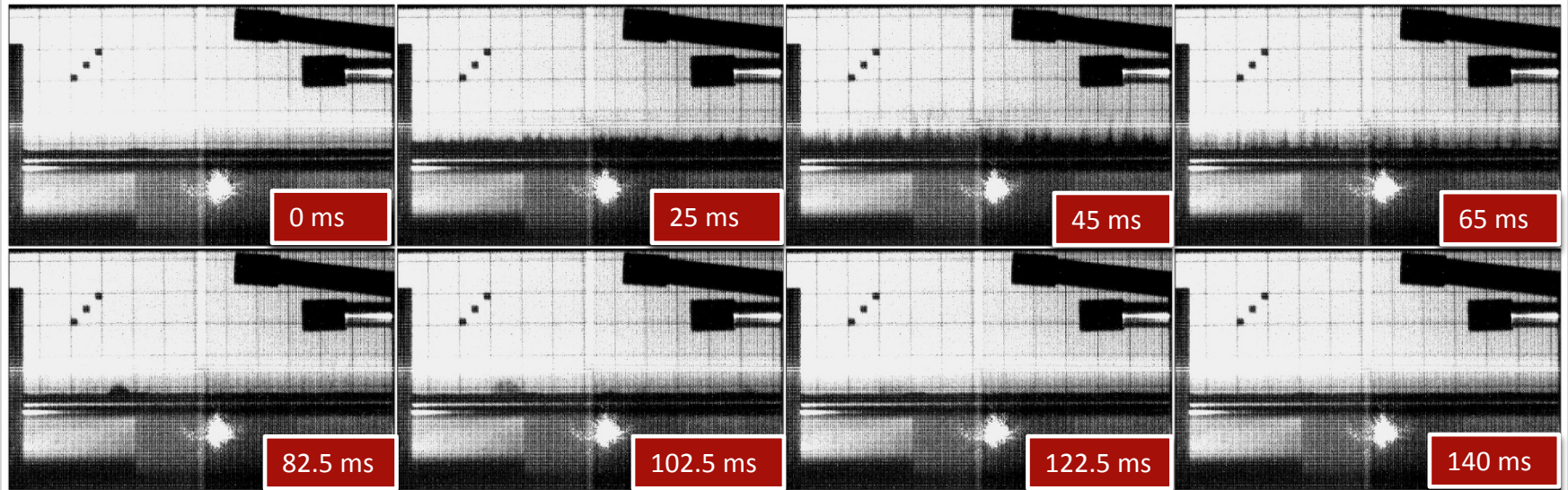


- Lower maximum height, and lower speed
  - Filaments appear.

# Shot #11 – 1.69E11 p.o.t

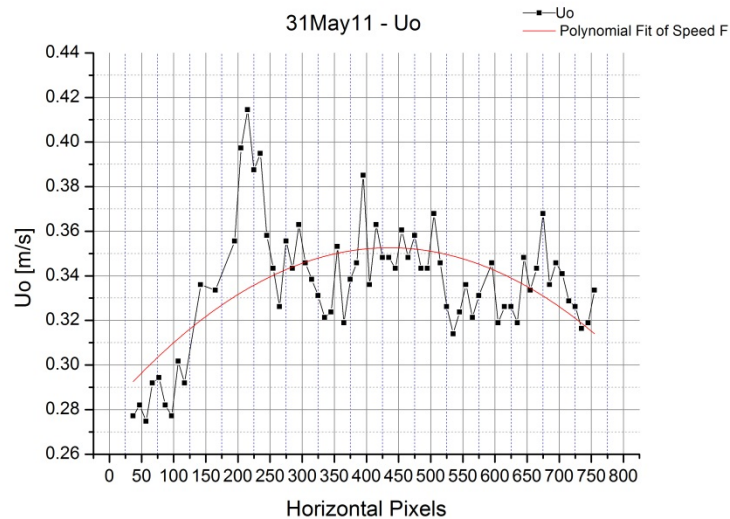
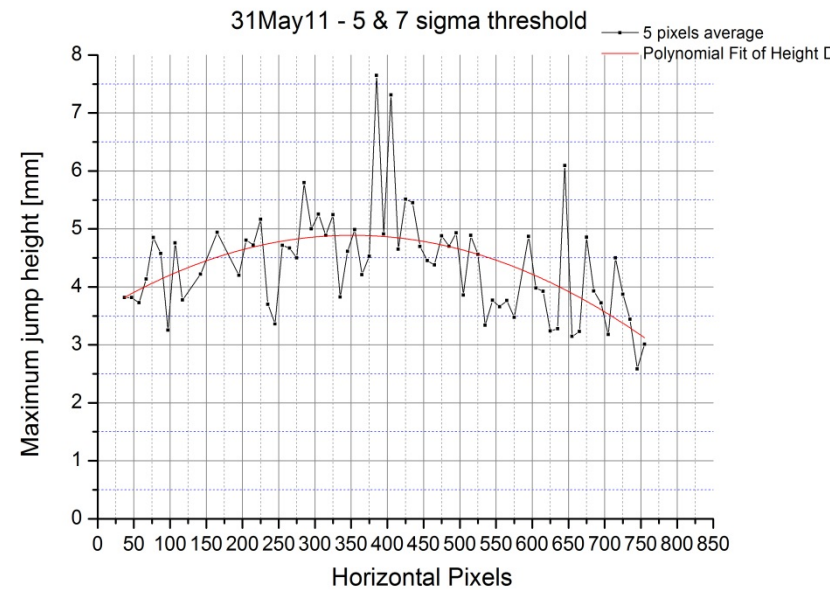
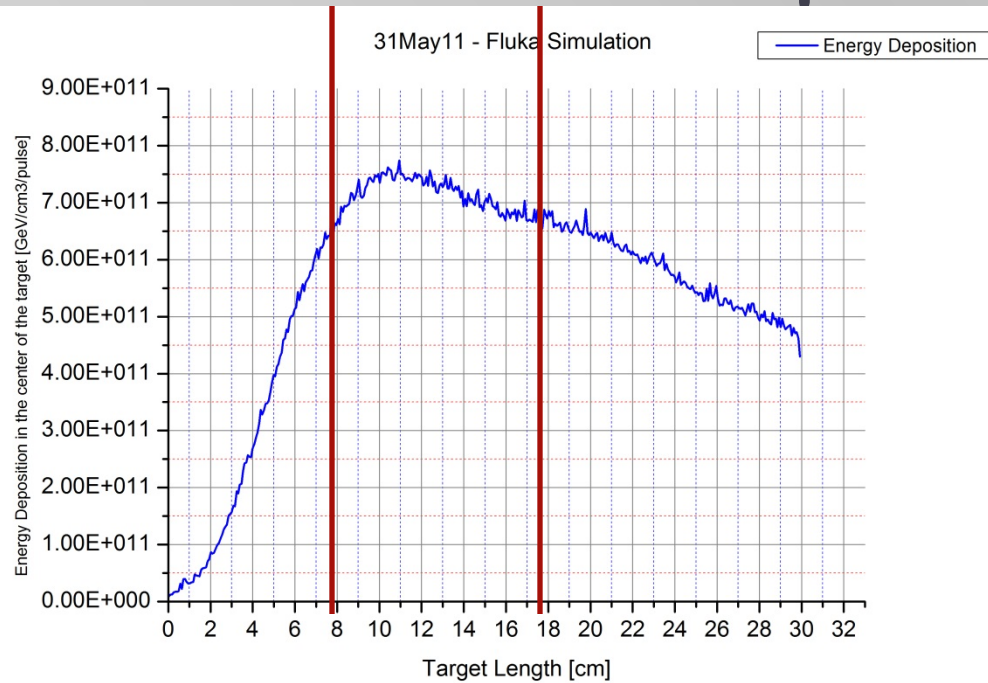
File Name 31MAY11\_5fps.avi  
File Size 339MB (355,10,80 Bytes)  
Resolution 768x480  
Play Time 00:01:04

*1.69x10<sup>11</sup> protons @ 440GeV/c*





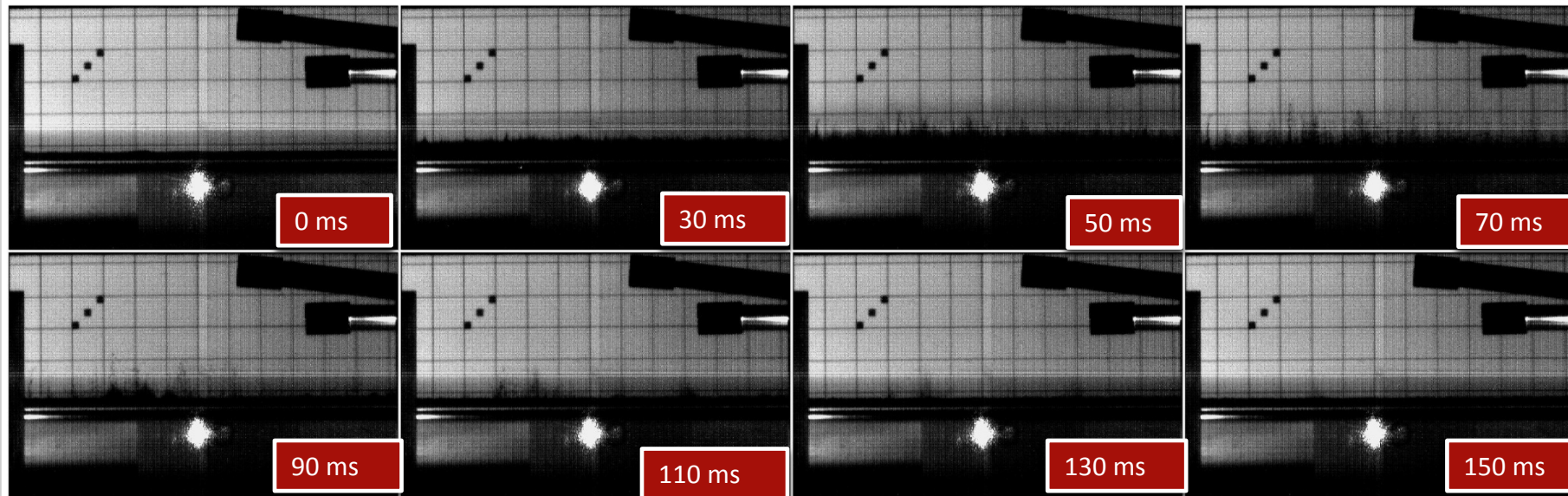
# Shot #11 – 1.69E11 p.o.t



# Shot #14 – 2E11 p.o.t

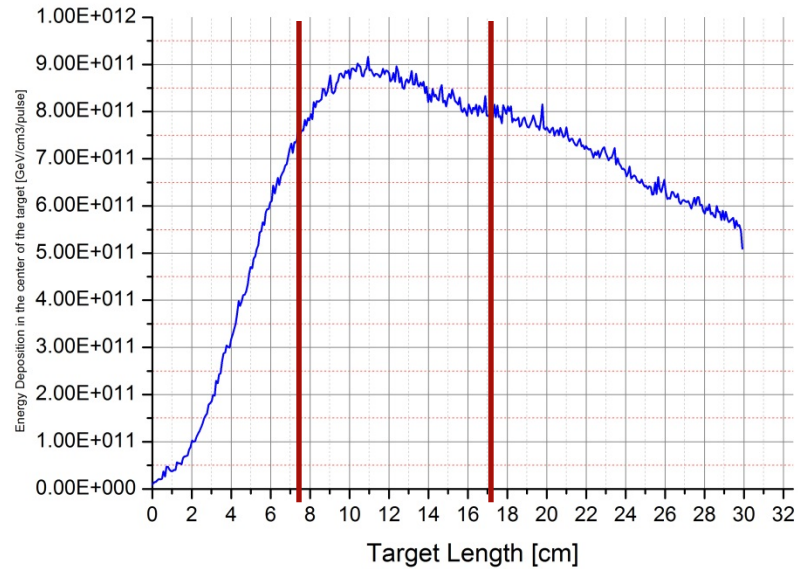
File Name 31MAY14\_5fps.avi  
File Size 180MB (189,118,480 Bytes)  
Resolution 768x480  
Play Time 00:00:34

*2x10<sup>11</sup> protons @ 440GeV/c*

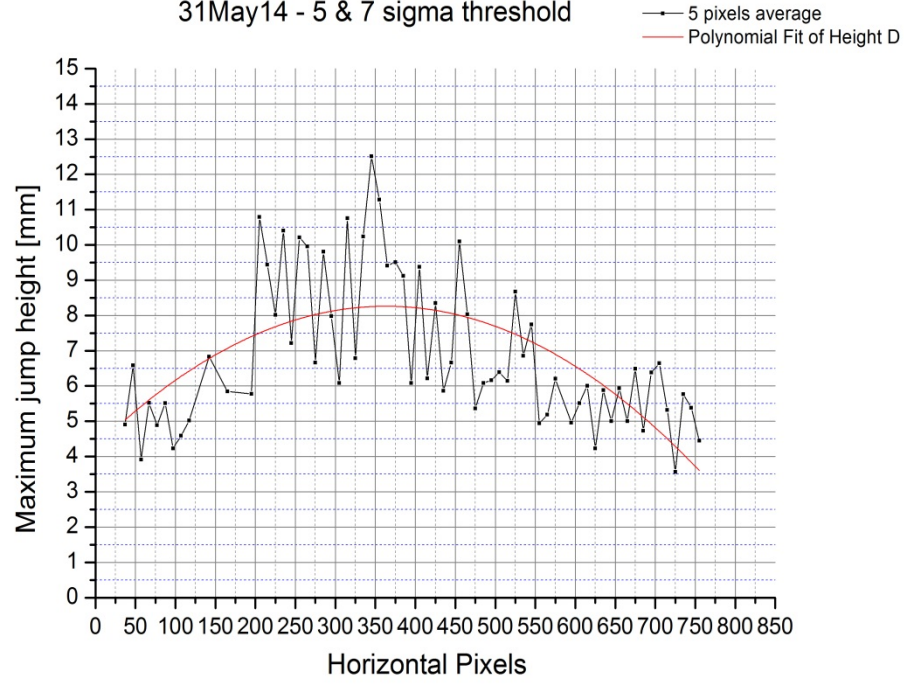


# 31May14 – 2E11 p/pulse

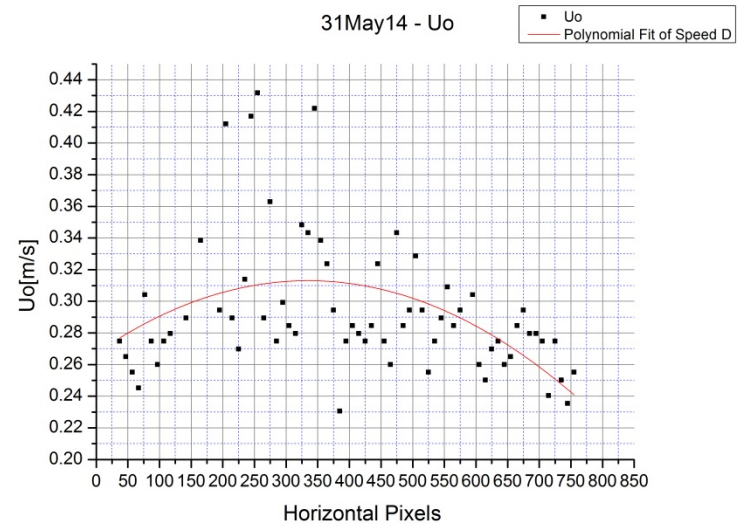
31May14 - Fluka Simulation Energy Depositor



31May14 - 5 & 7 sigma threshold

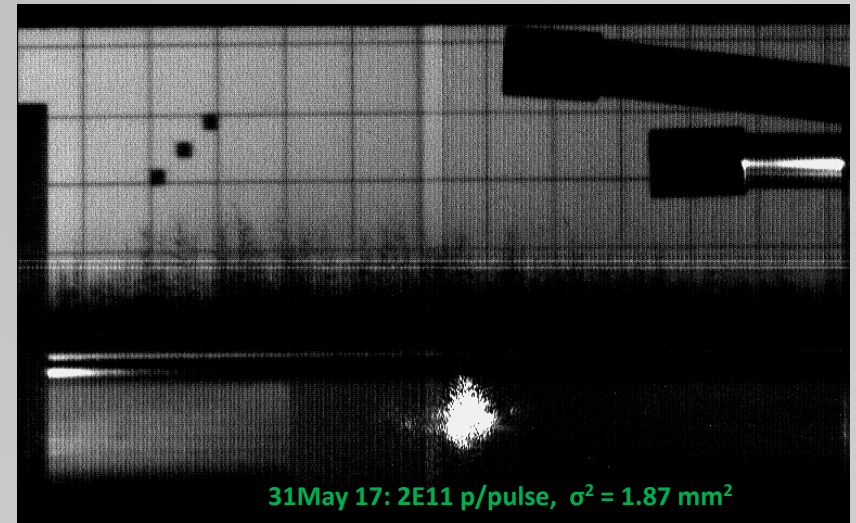
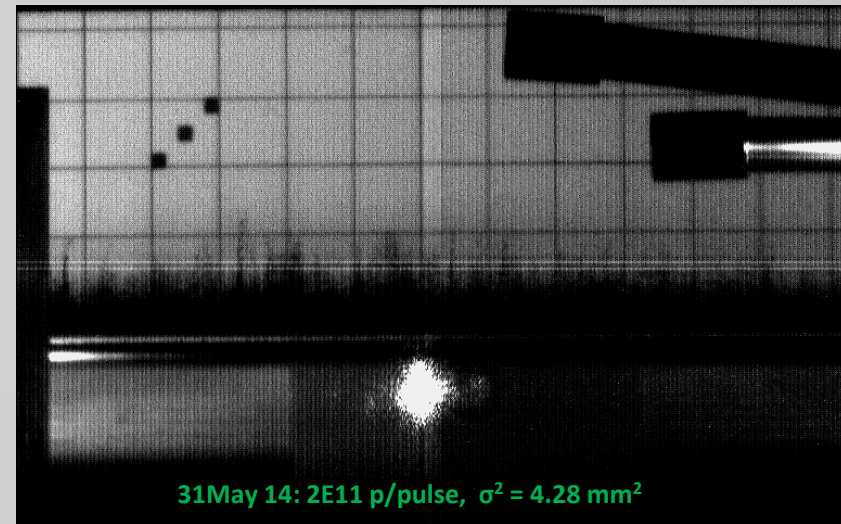


31May14 - Uo

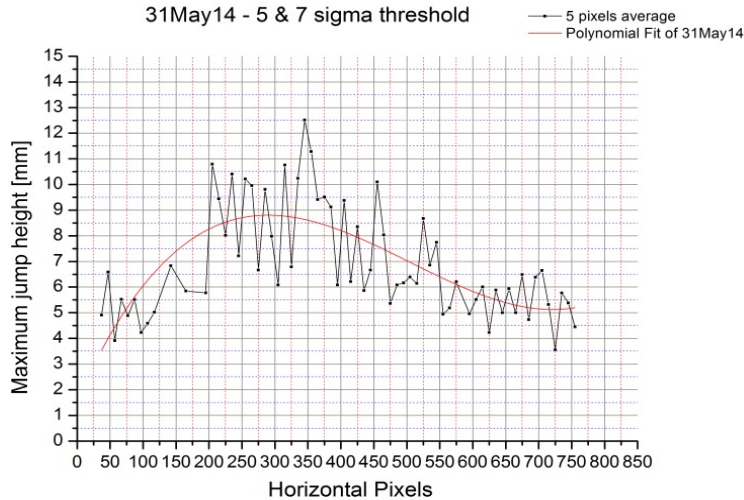




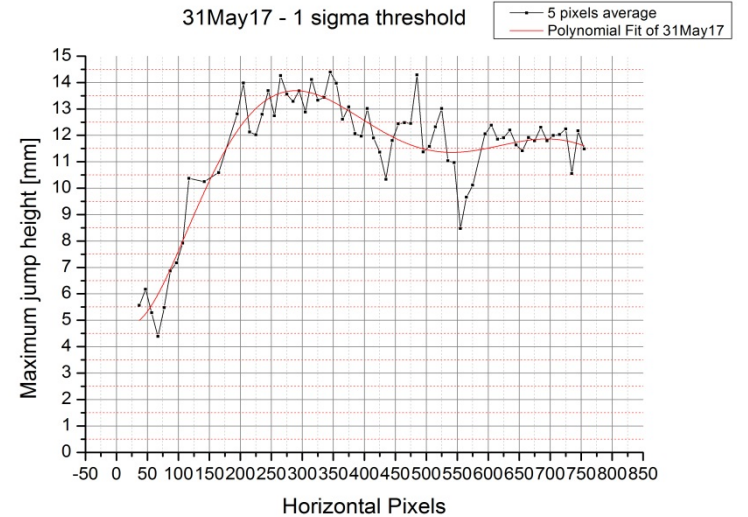
# Shot #14 & Shot #17: Same intensity, different beam sigma



31May14 - 5 & 7 sigma threshold



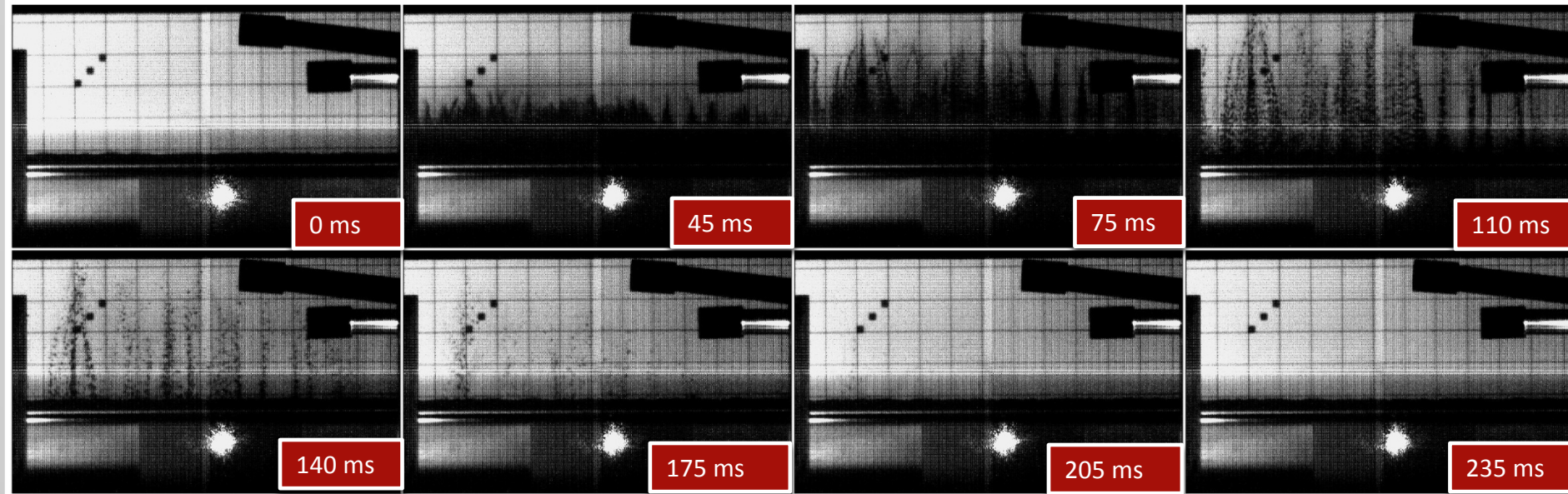
31May17 - 1 sigma threshold



# Shot #20 : More violent disruption

File Name 31MAY20\_5fps.avi  
File Size 286MB (299,712,880 Bytes)  
Resolution 768x480  
Play Time 00:00:54

*$2.64 \times 10^{11}$  protons @ 440 GeV/c*

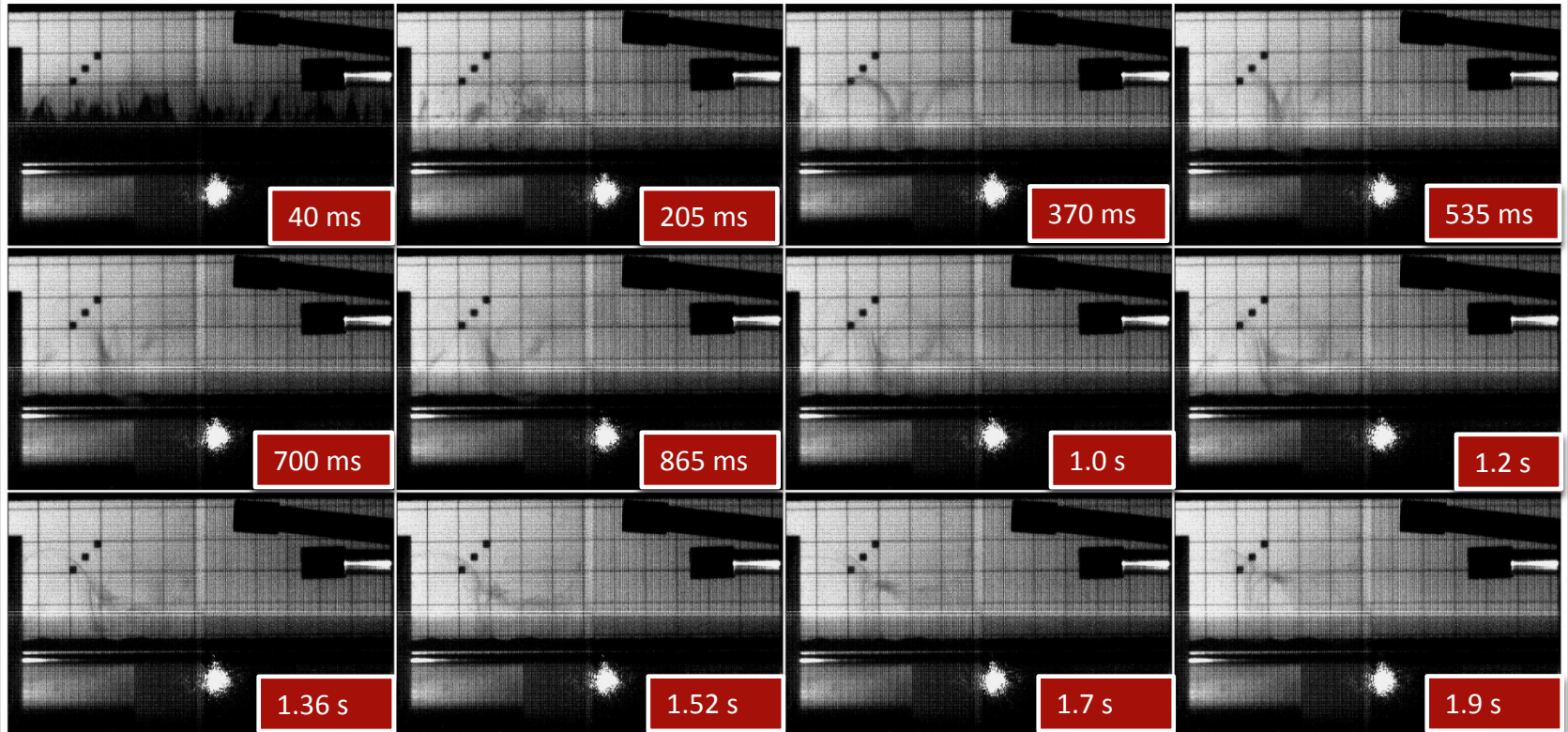




# Shot #21 : Powder dust ?

File Name 31MAY21\_5fps.avi  
File Size 2.08GB (2,234,8,936 Bytes)  
Resolution 768x480  
Play Time 00:06:44

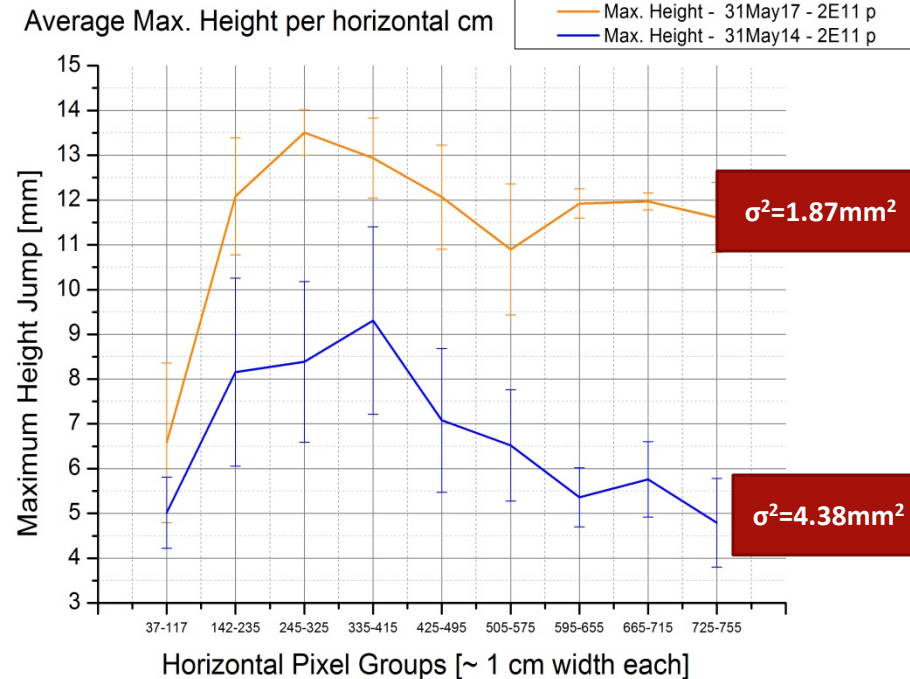
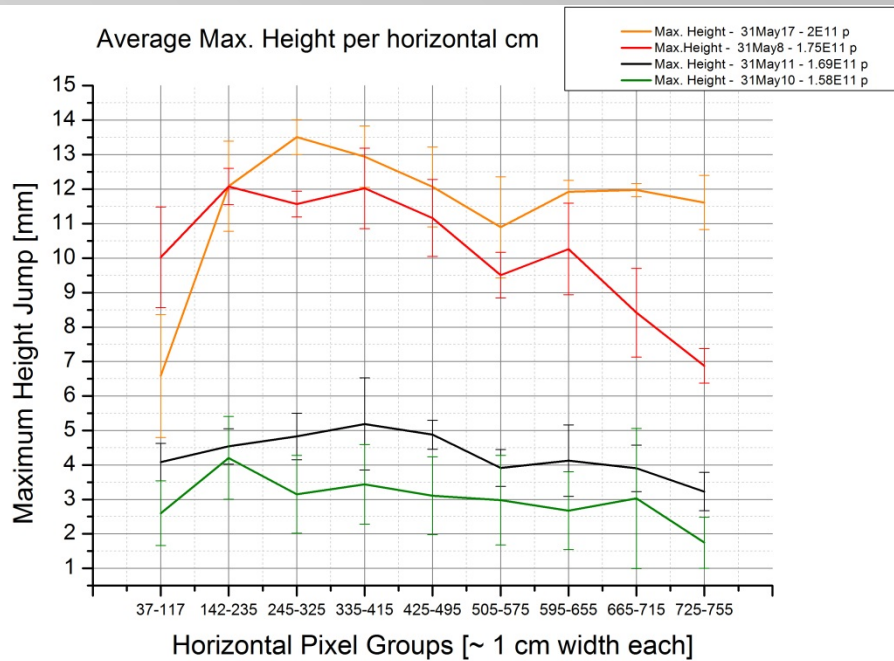
*2.94x10<sup>11</sup> protons @ 440GeV/c*





# Average Height

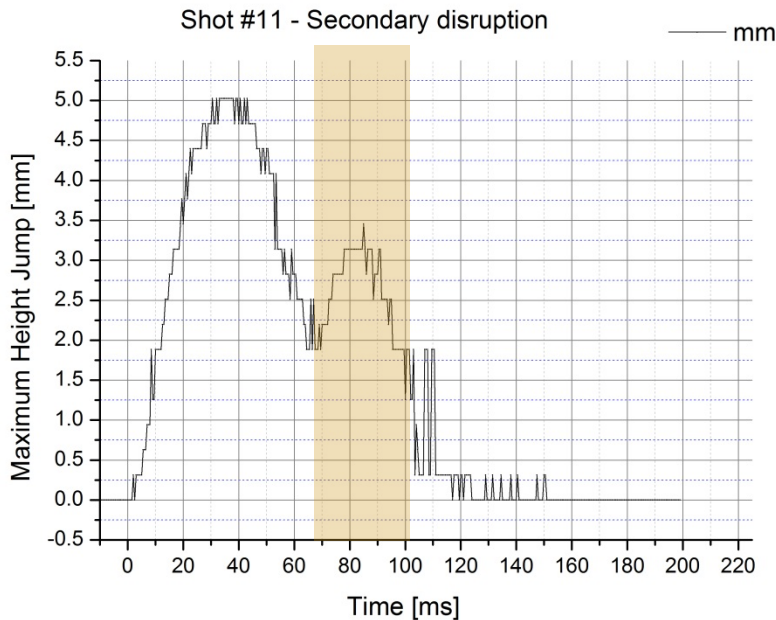
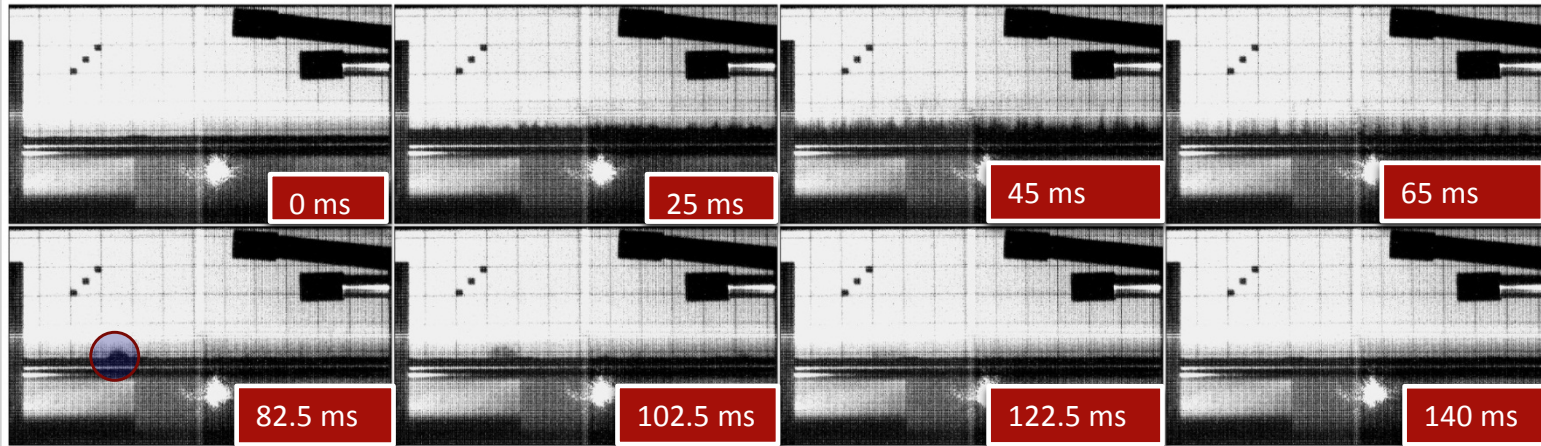
- Maximum height appears to scale with the *intensity* as well as with the *beam sigma*



# Secondary disruption – Shot #11

File Name 31MAY11\_5fps.avi  
File Size 339MB (355,10,80 Bytes)  
Resolution 768x480  
Play Time 00:01:04

**$1.69 \times 10^{11}$  protons @ 440 GeV/c**

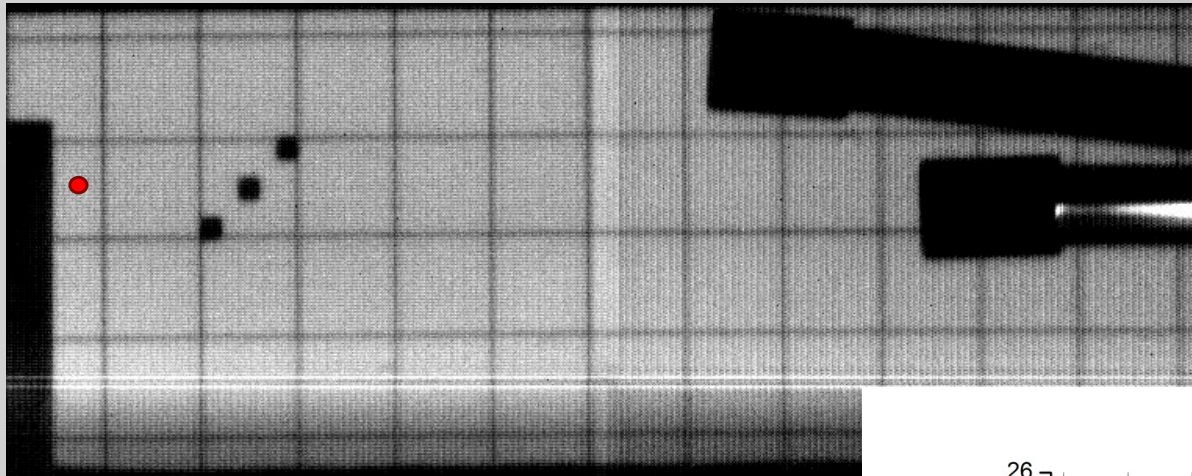


- The main disruption finishes at  $\sim 65$  ms and immediately after the secondary disruption starts.

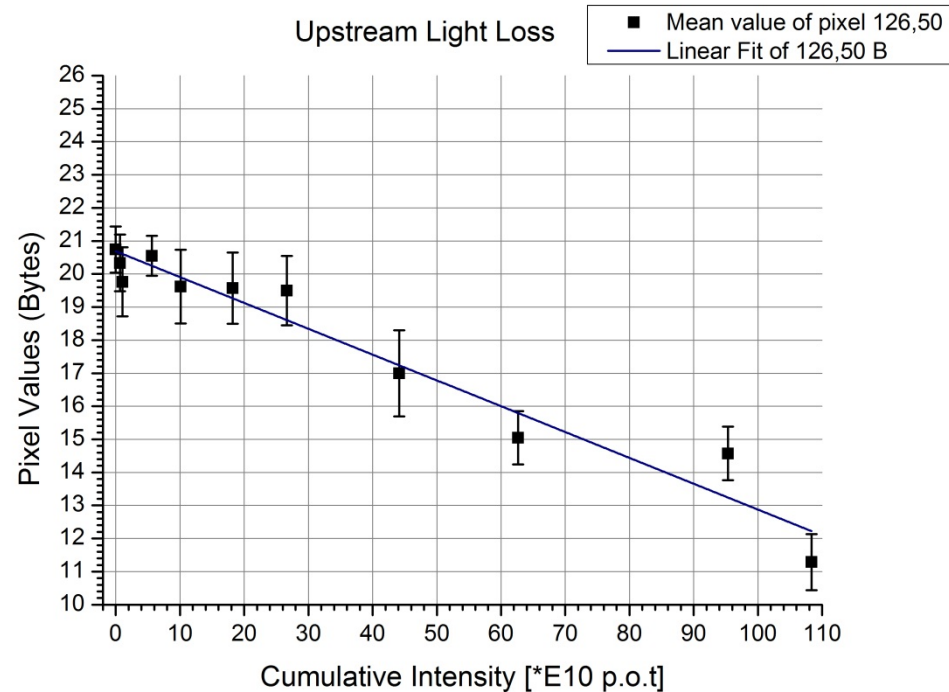
- Duration:  $\sim 30$  ms
- Max. Height :  $\sim 3.5$  mm



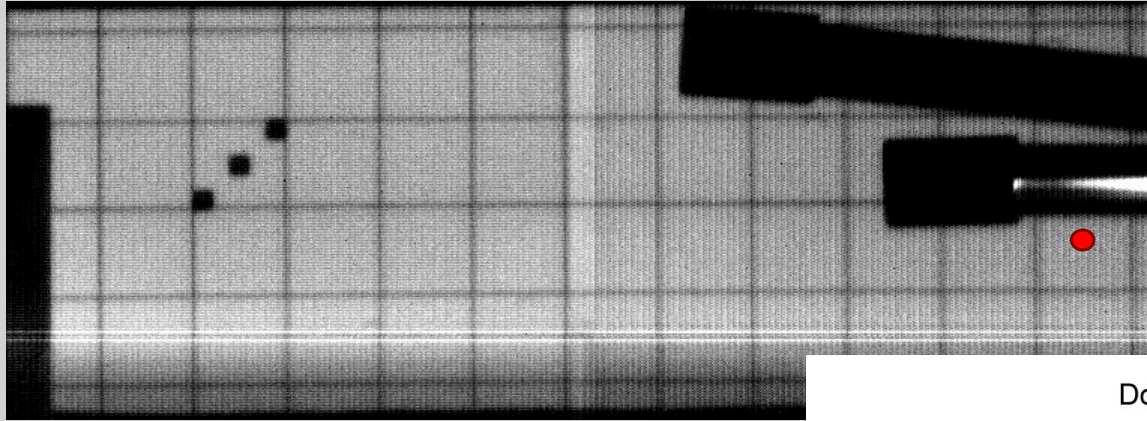
# LED Degradation - Upstream



- After  $\sim 6E11$  p.o.t
  - More than 25% light loss !
- After  $\sim 1E12$  p.o.t
  - More than 50% light loss

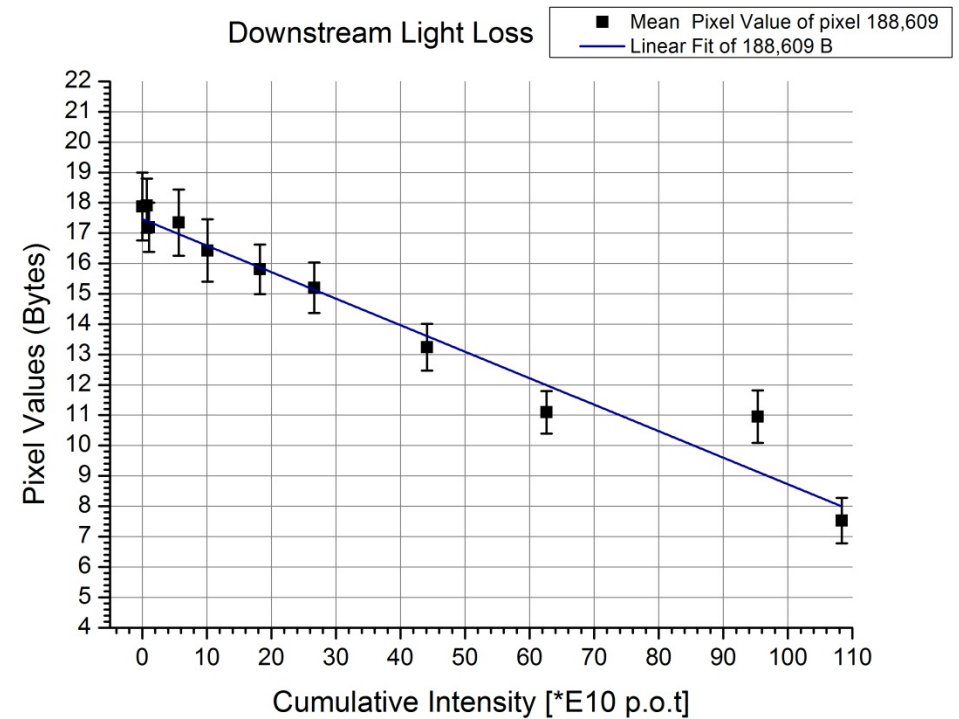


# LED Degradation - Downstream



- After  $\sim 4E11$  p.o.t
  - More than 25% light loss !
- After  $\sim 1E12$  p.o.t
  - More than 50% light loss

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





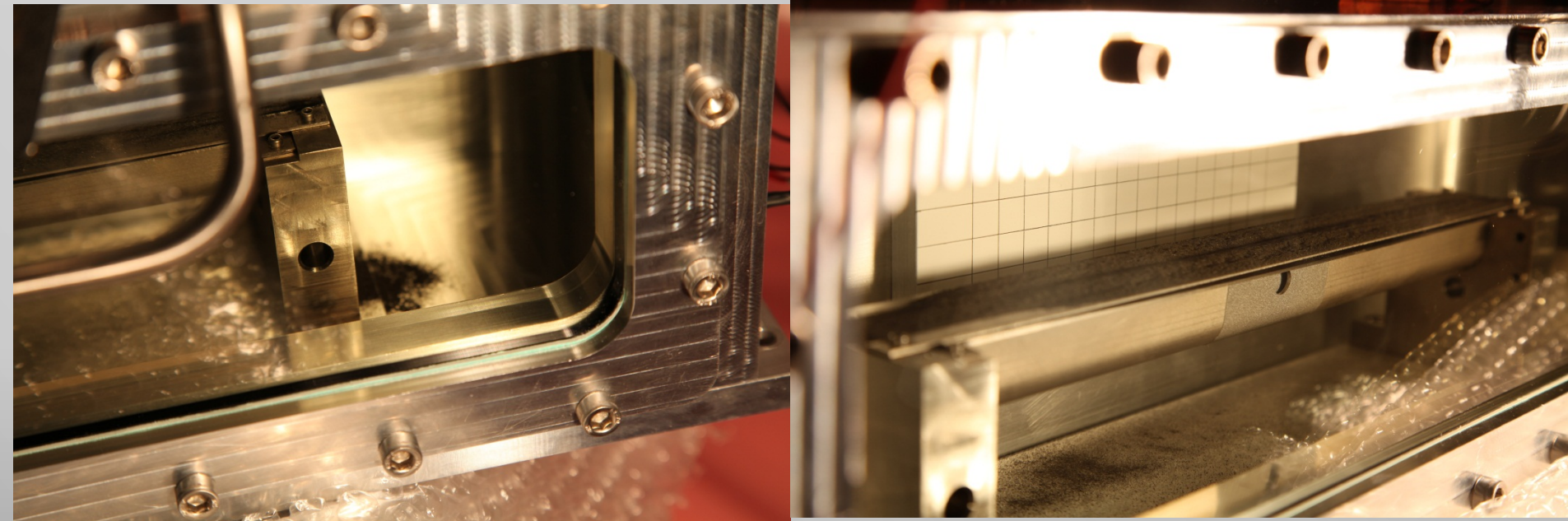


# Conclusions

- **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 :  $\sim 14\text{mm}$**
- **Disruption speeds  $< 0.5$  m/s**

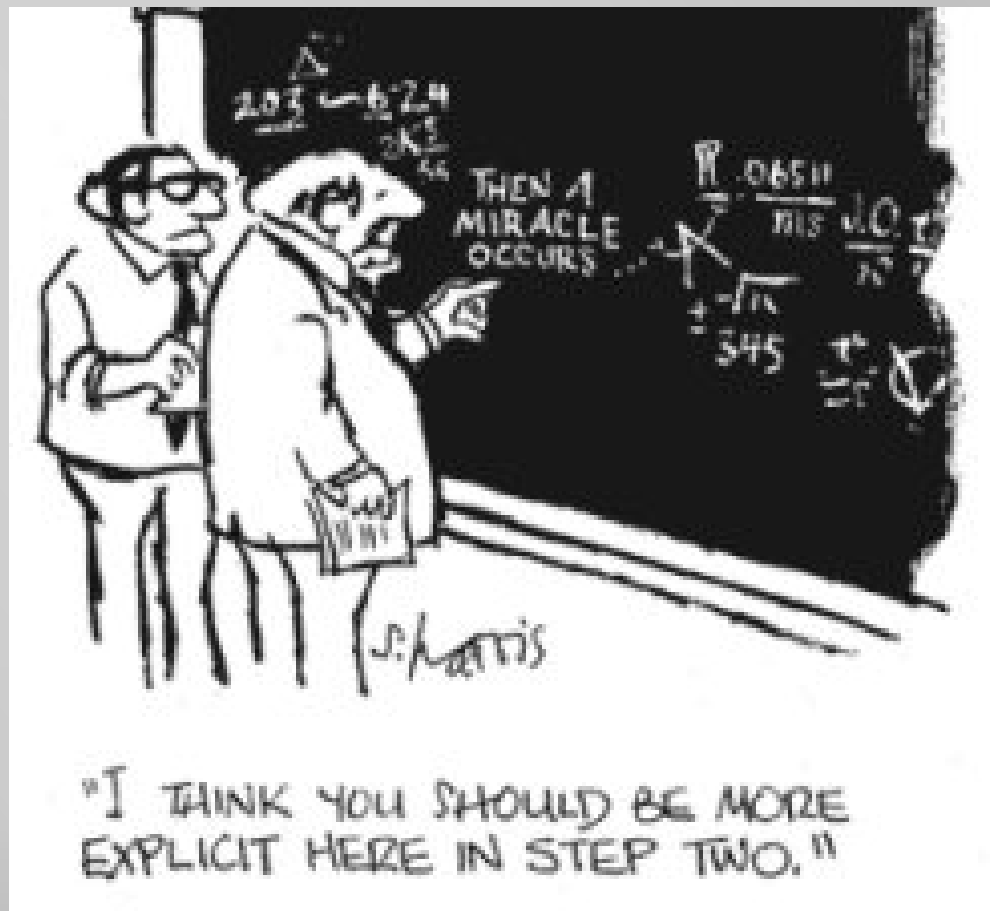
# Next steps

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

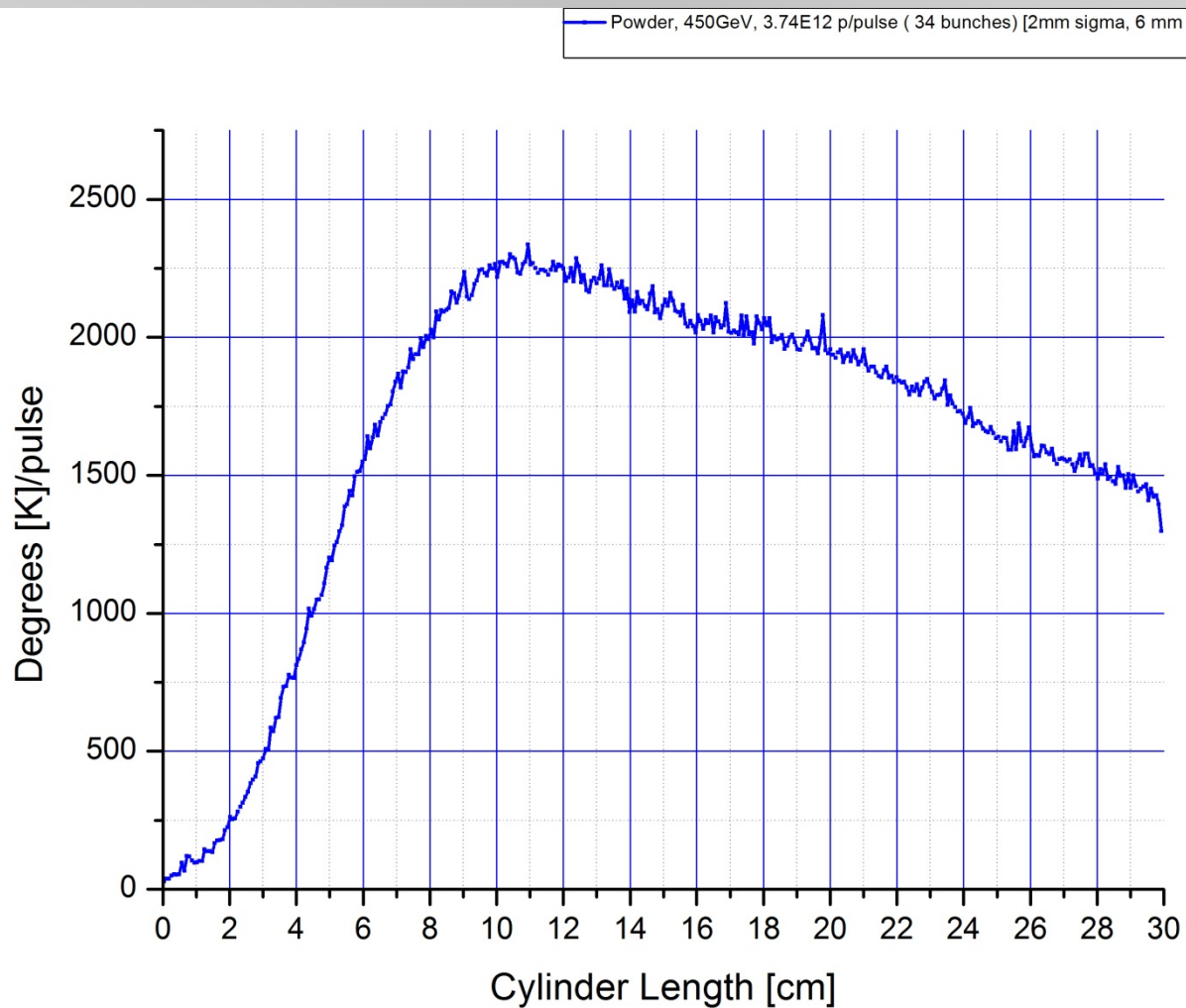




# Thank you !



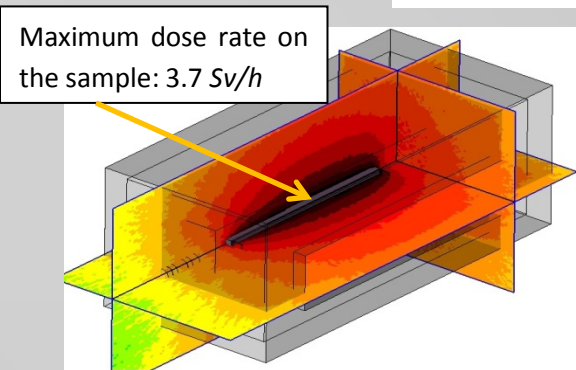
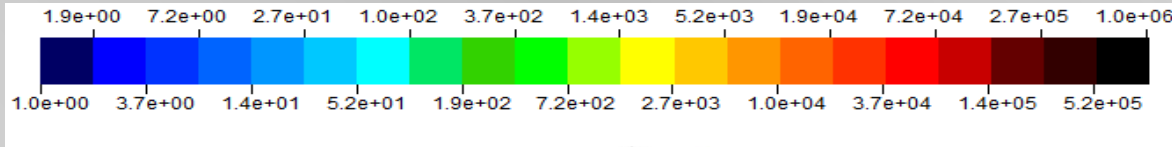
# Extra 1 : Temperature





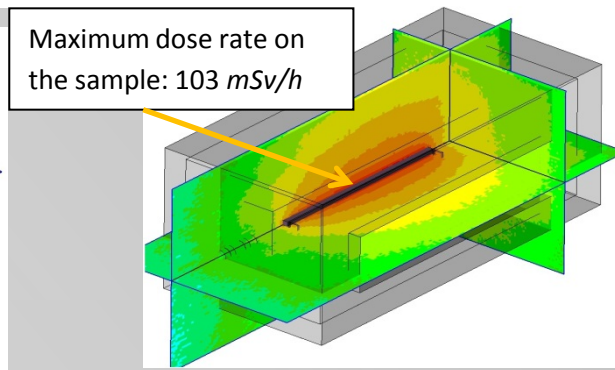
# Extra 2: Activation Dose Rates ( $\mu\text{Sv/h}$ ) – For $1\text{E}13$

p



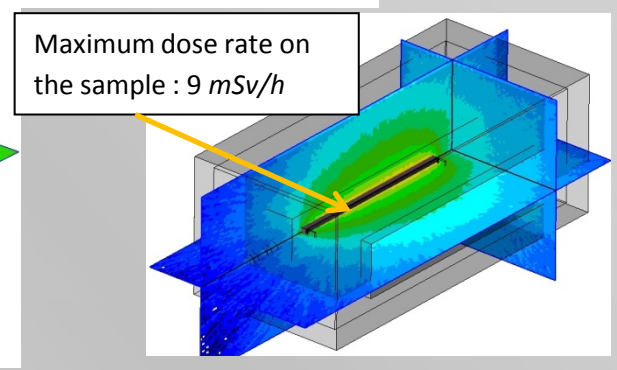
Maximum dose rate on the sample: 3.7 Sv/h

1 hour



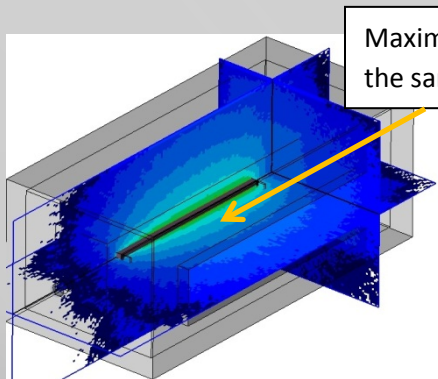
Maximum dose rate on the sample: 103 mSv/h

1 day



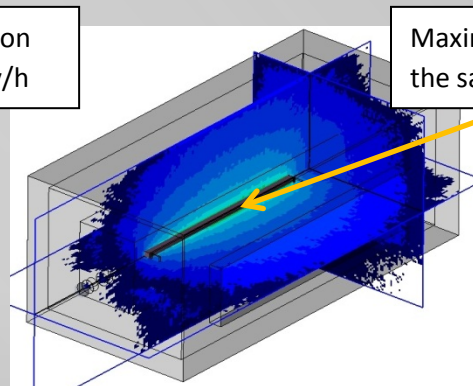
Maximum dose rate on the sample: 9 mSv/h

1 week



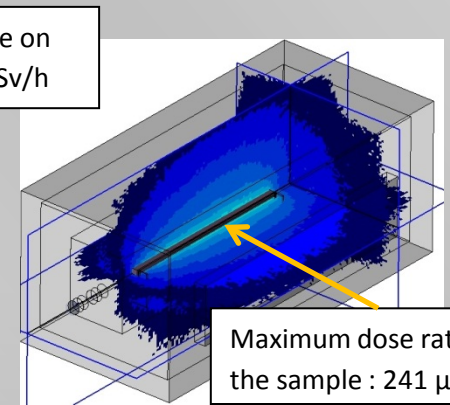
Maximum dose rate on the sample: 925  $\mu\text{Sv/h}$

1 month



Maximum dose rate on the sample: 476  $\mu\text{Sv/h}$

2 months



Maximum dose rate on the sample: 241  $\mu\text{Sv/h}$

4 months

# Loss of LED power [%] due to irradiation

