Science & Technology Facilities Council

Tungsten powder work update

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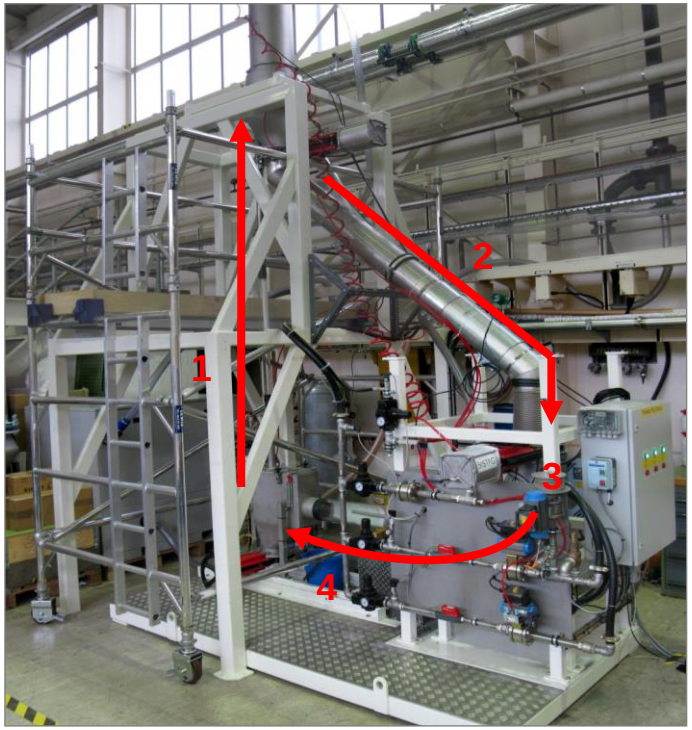
(RAL)

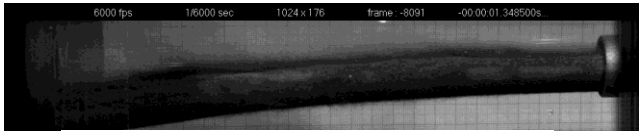
2014-09-09 PASI meeting at RAL

Fragmented high Z flowing target: W powder rig

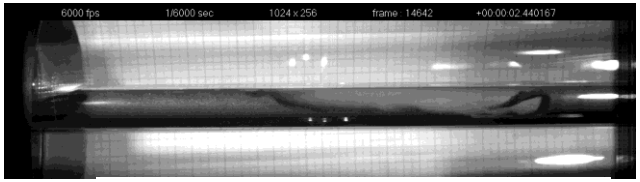
- Offline testing
  - Pneumatic conveying (dense-phase and lean-phase)
  - Containment / erosion
  - Heat transfer and cooling of powder



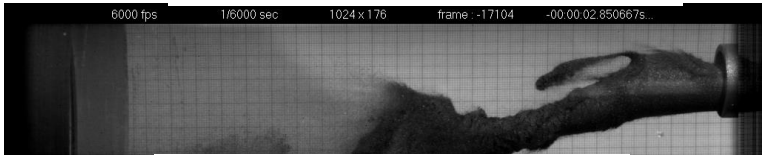
Dense-phase delivery



High speed image: tungsten powder jet

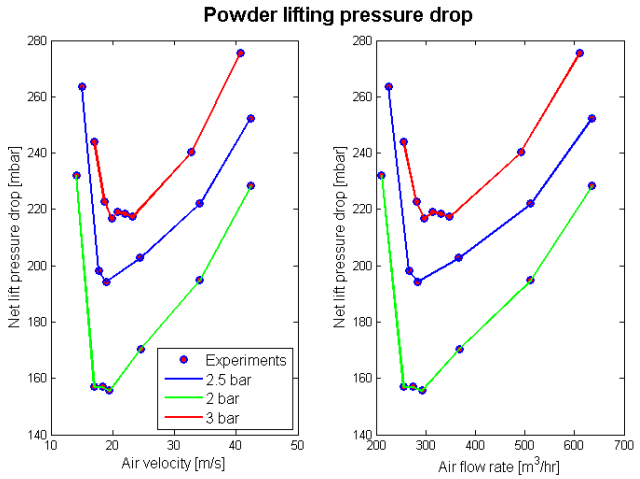


High speed image: tungsten powder flow in a pipe



Unstable tungsten powder jet

Lean-phase lift



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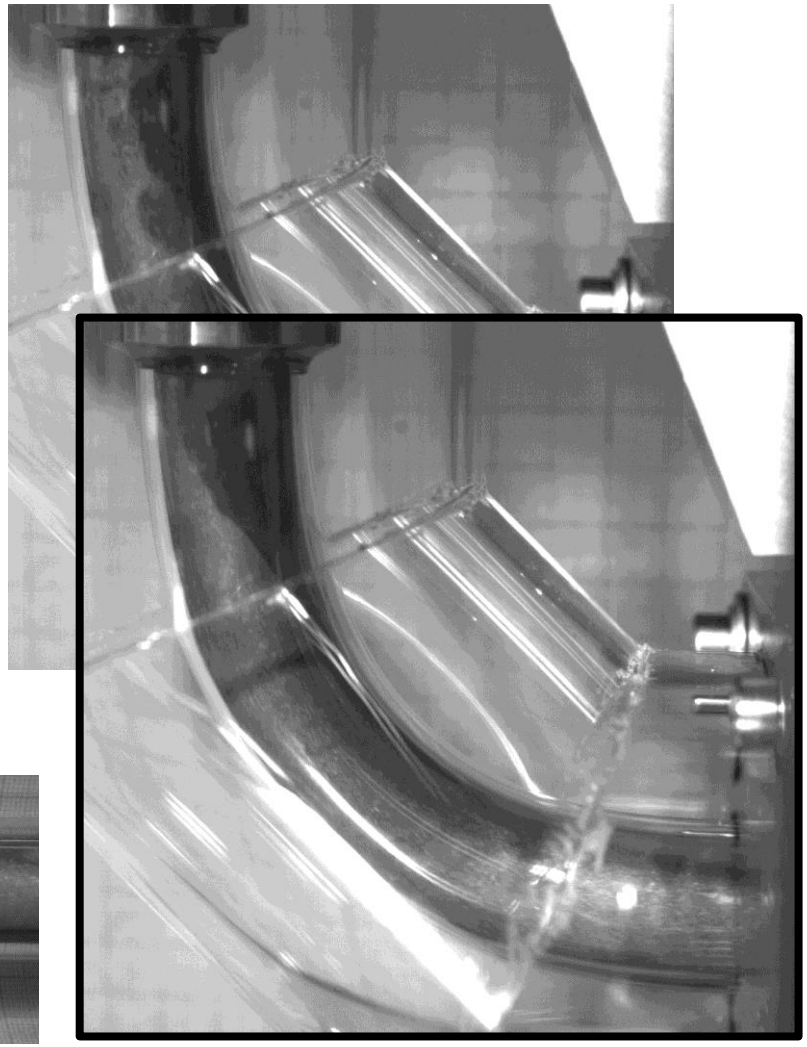
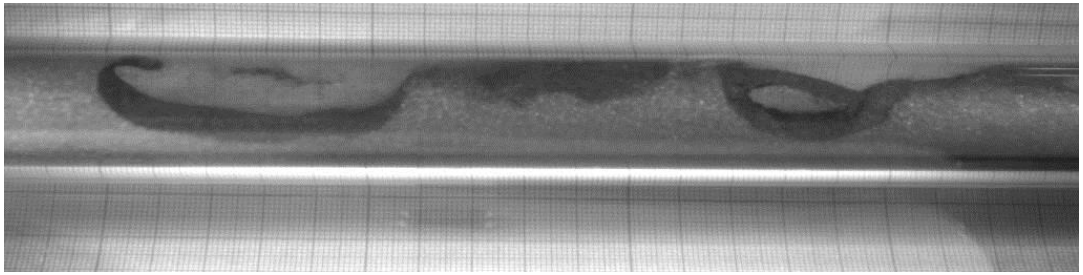
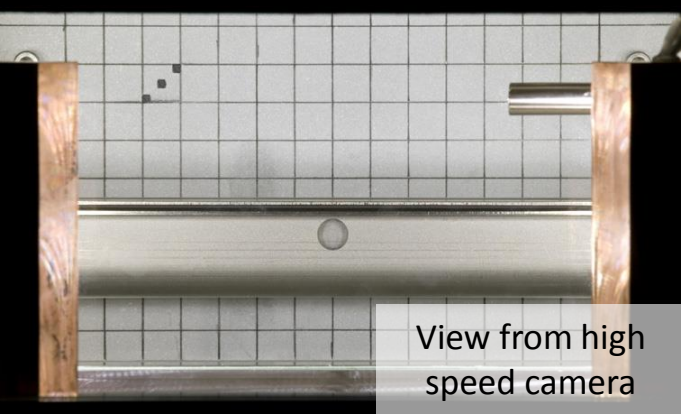
Improving diagnostics to increase the solid fraction

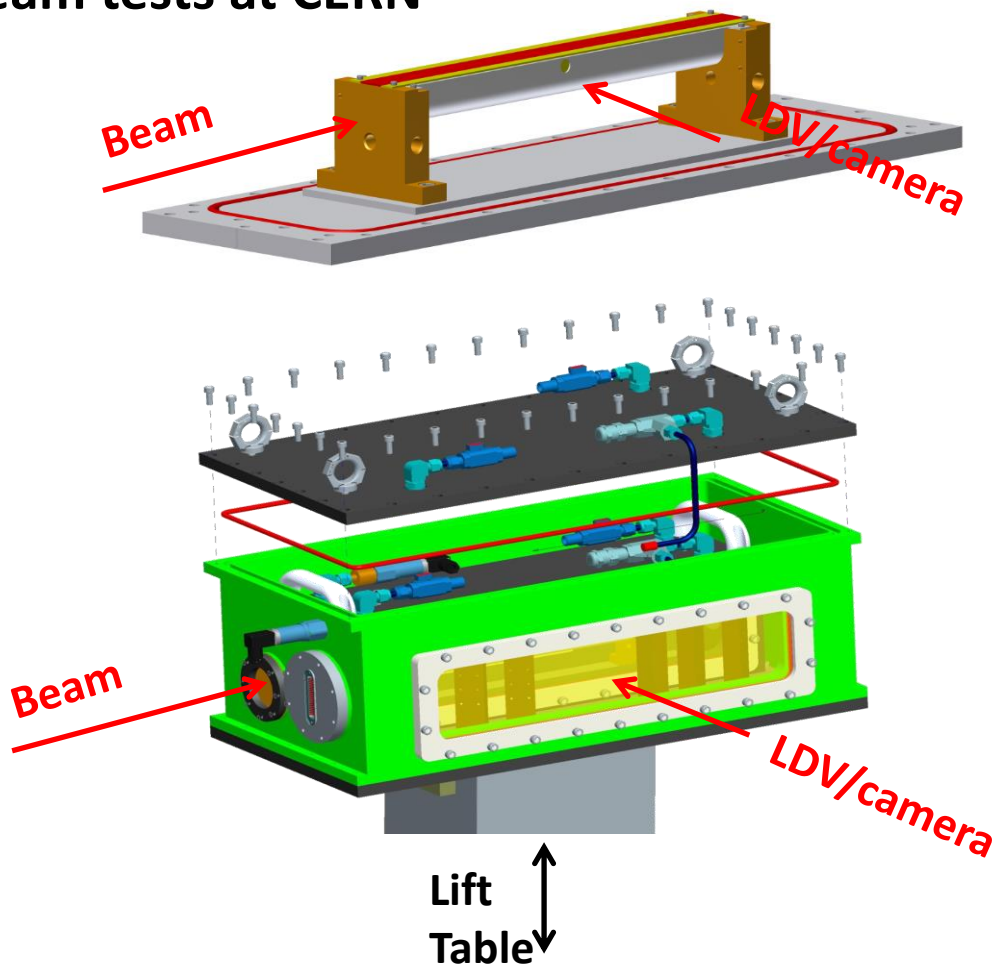




glass parts tube show early stages of phase separation

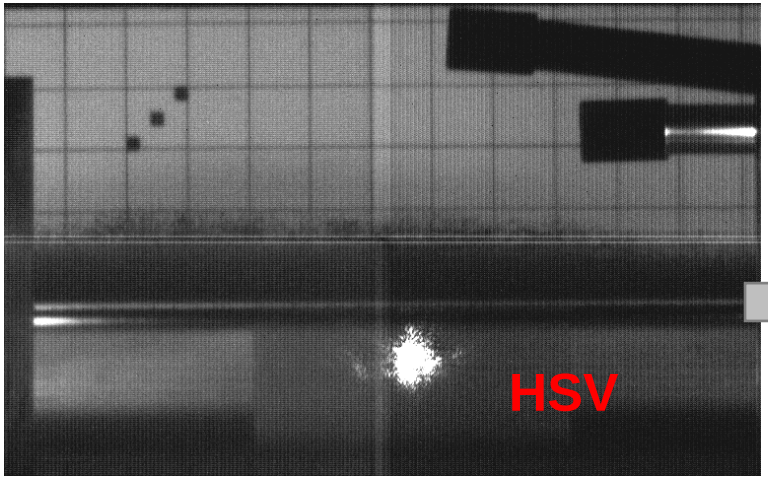
In beam tests at CERN





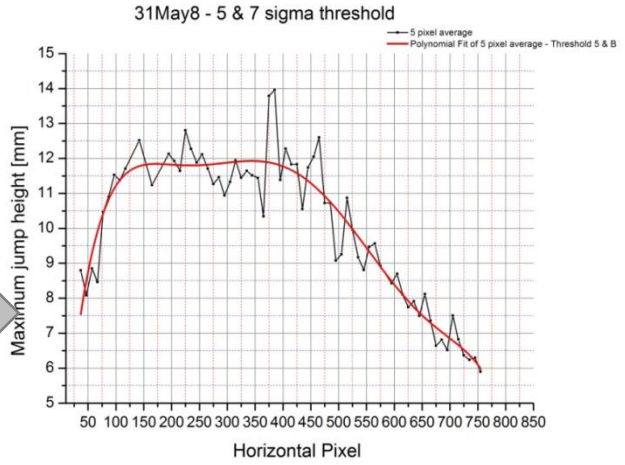
- Tungsten powder sample in an open trough configuration
- Helium environment
- Two layers of containment with optical windows to view the sample
- Remote diagnostics via LDV and high-speed camera

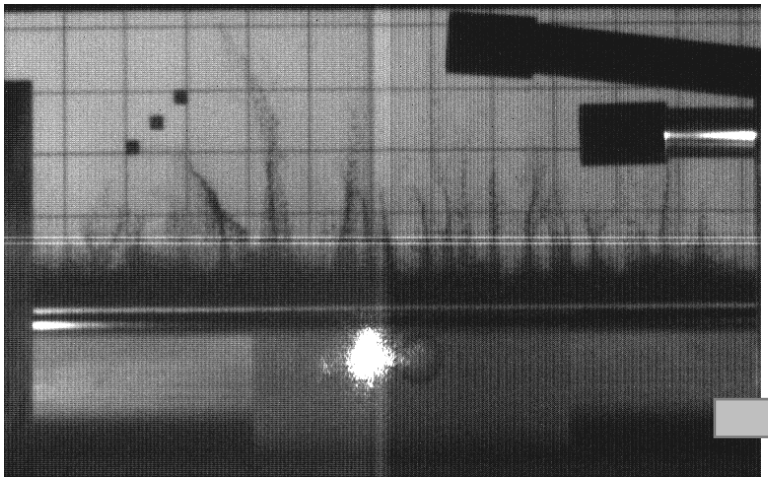
Charitonidis



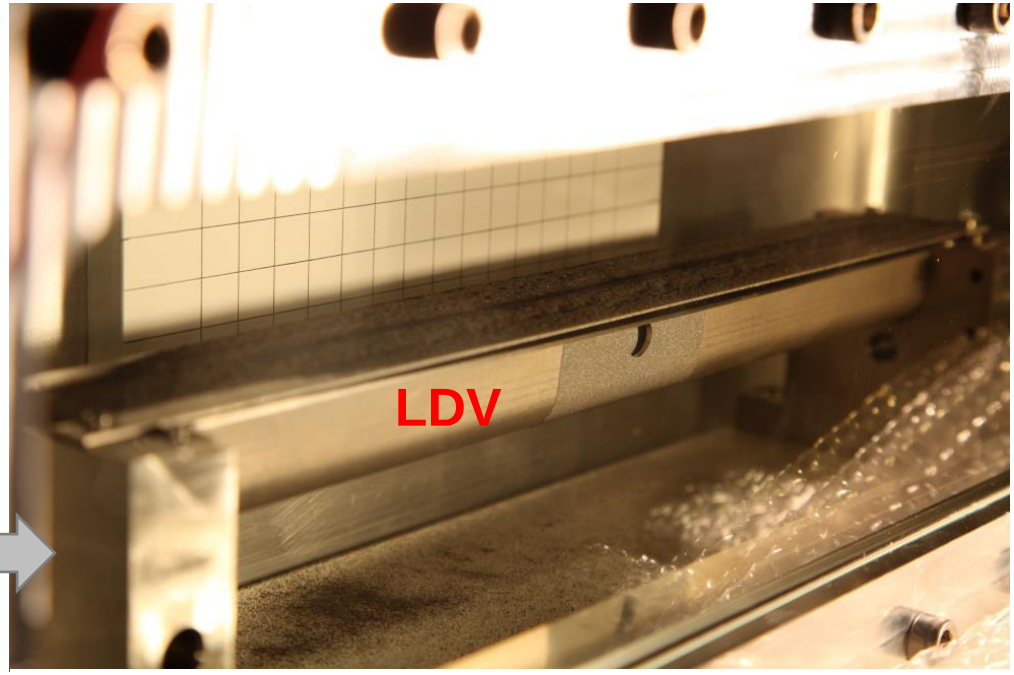
Shot #8, 1.75e11 protons
Note: nice uniform lift

Lift height correlates with deposited energy





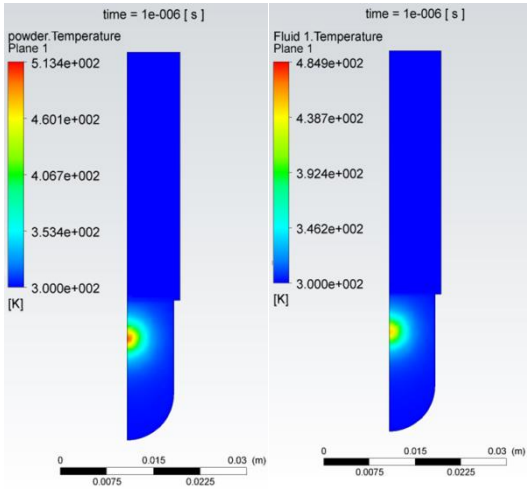
Shot #9, 1.85e11 protons
Note: filaments!

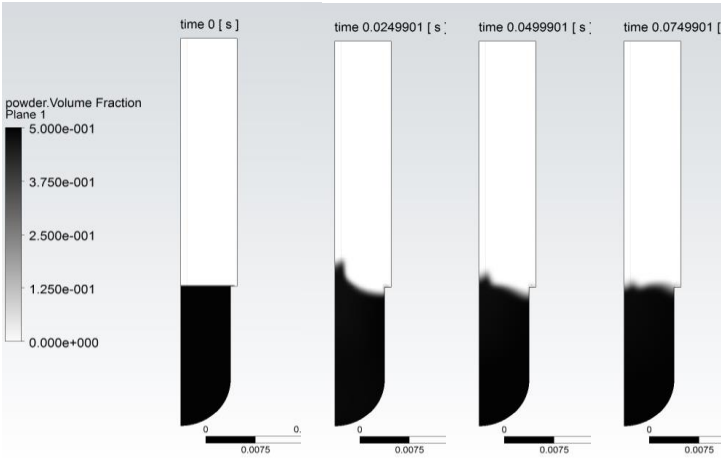


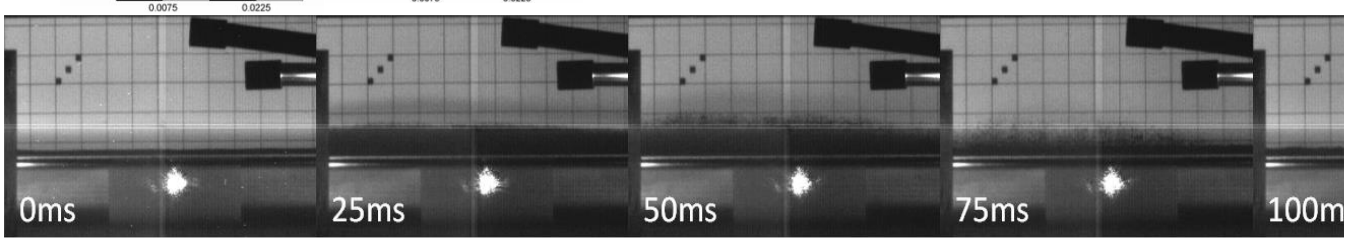
Trough photographed after the experiment.
Note: powder disruption

Davenne: CFD predictions/post fits

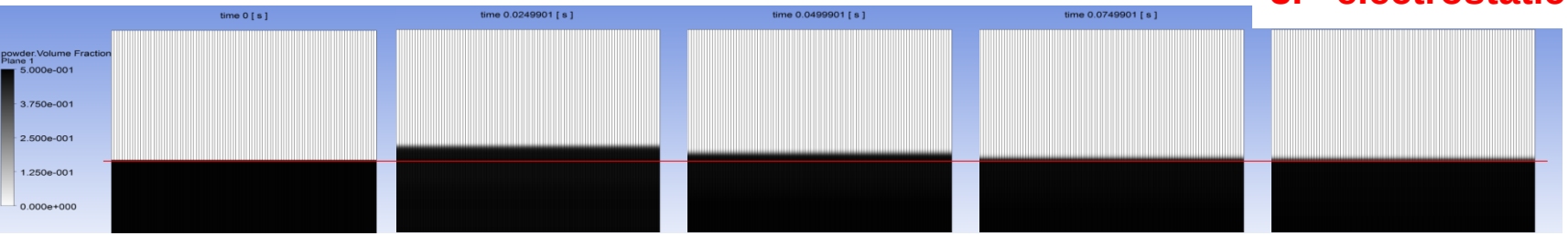
Beam heating







Test Results from Shot #8, 1.75e11 protons, beam sigma 0.75 mm x 1.1 r



CFD simulation of Shot #8, assuming 1 micron particle size
(n.b. no lift with 25 micron particles at this intensity)

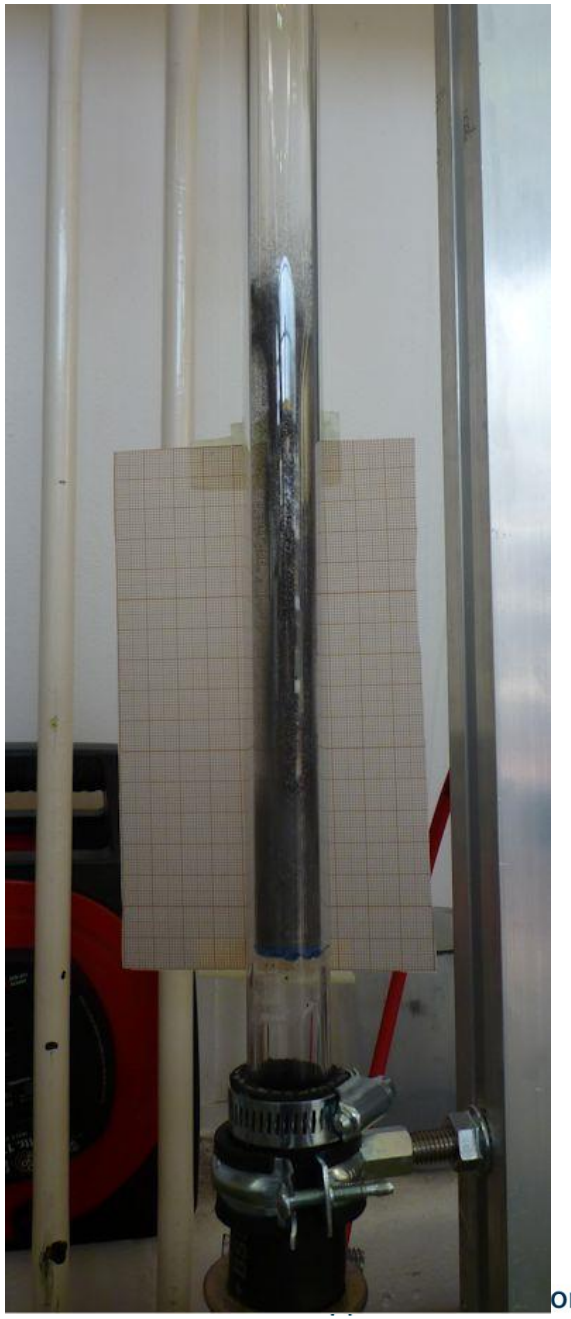
Powder lift was predicted by CFD

However the energy to lift the powder was found in the experiment to be an order of magnitude smaller than predicted

So is the lift:

1. **aerodynamic?**
2. **stress propagation?**
3. **electrostatic?**

Understanding powder lift



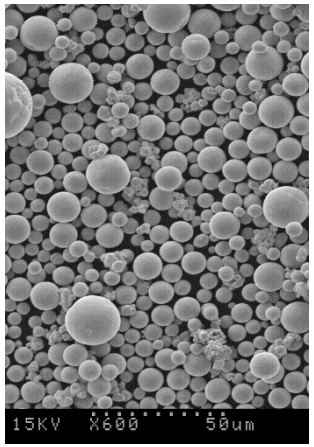
Pressure drop for air flowing through a bed of powder

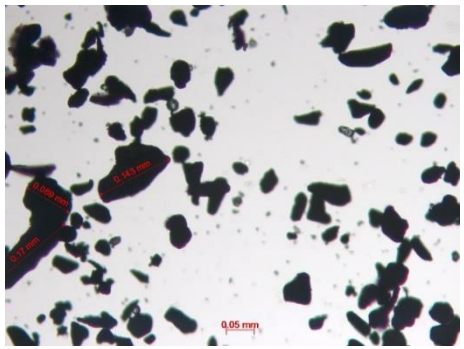
Atherton, Davenne

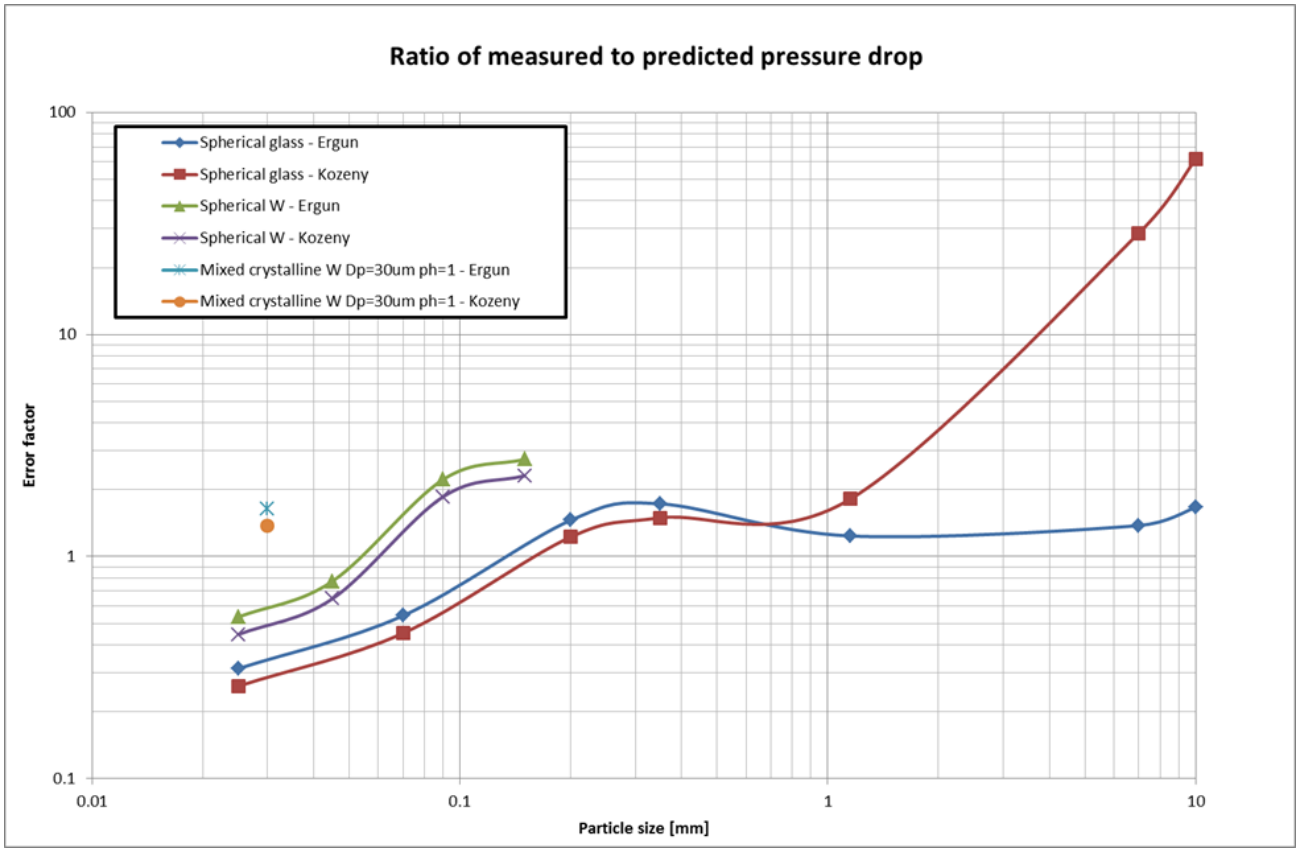
Packed bed experiment

Experimental pressure drop measured across a packed bed of W powder is in line with the analytical pressure drop given by Ergun (employed by CFX)

$$\frac{\Delta P}{h} = \rho_g U^2 \left[\frac{150(1-\varepsilon)}{Re_d \psi} + \frac{7}{4} \right] \frac{1-\varepsilon}{\psi \, d_p \, \varepsilon^3}$$

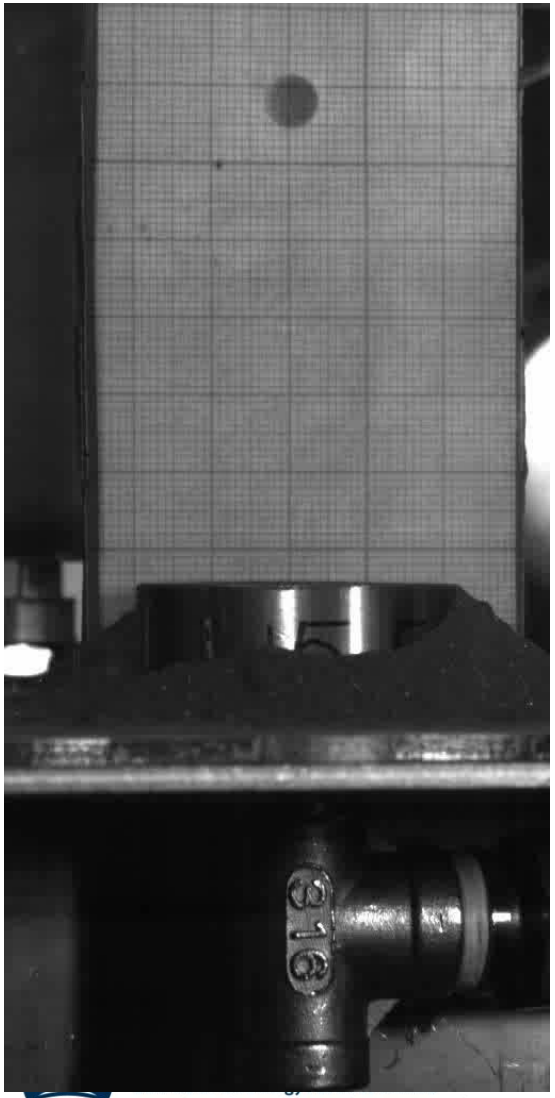




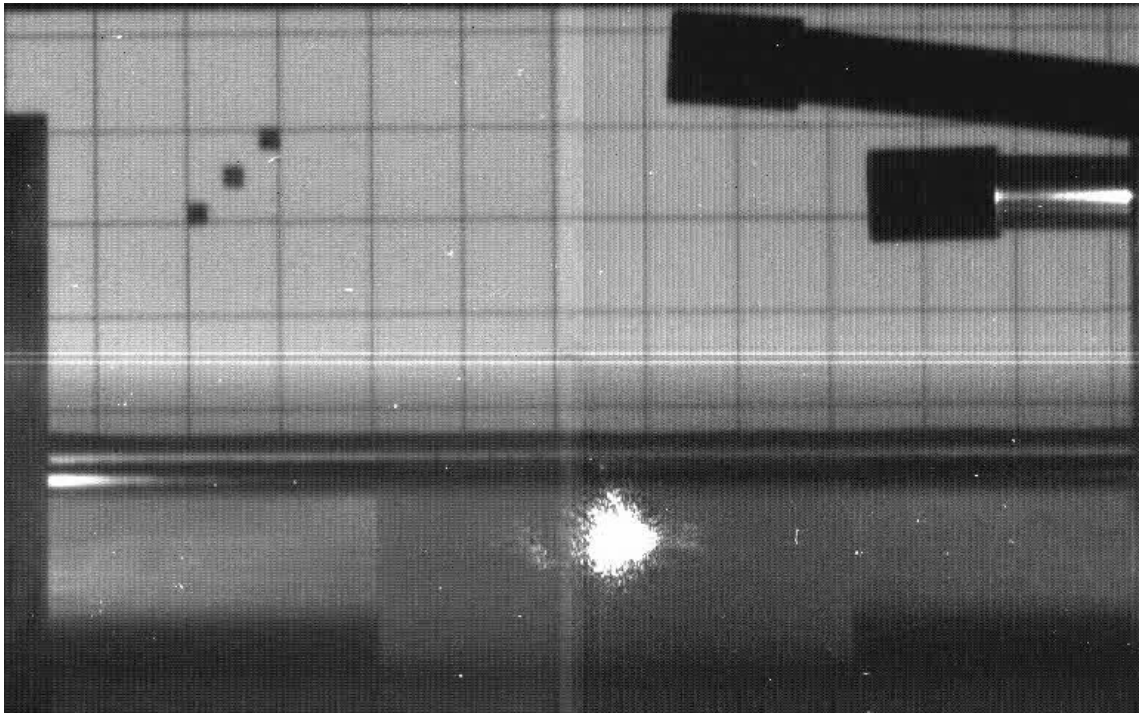


Tungsten powder puff experiment: understanding the powder lift

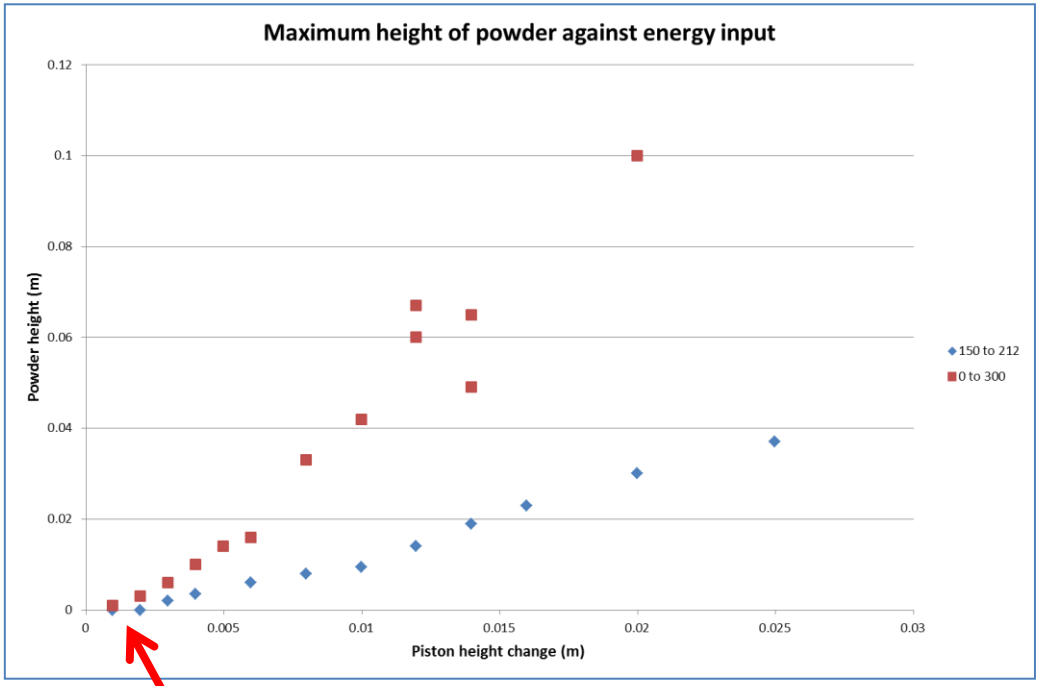
Tungsten powder puff experiment



- Aim: To compare behaviour of Tungsten powder after a short pressure spike against the behaviour in the HiRadMat experiment
- Method: Use a short pressure pulse to lift the powder



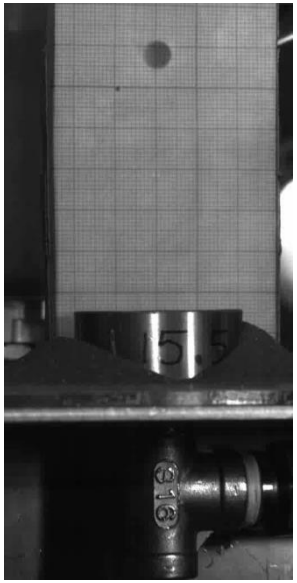
Tungsten powder puff experiment



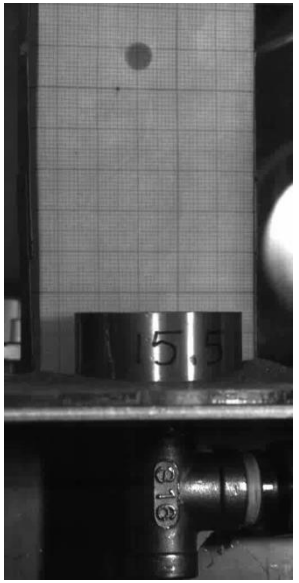
There is a threshold energy which has to be reached before the powder begins to lift. The threshold depends on the depth of the powder

- The maximum height reached by the powder is proportional to the energy put in by the compression of the piston
- The powder sample containing smaller particles was lifted higher than the sample containing only larger particles
- The acceleration is faster that can be captured with 1kHz HSV

0 to 300 um

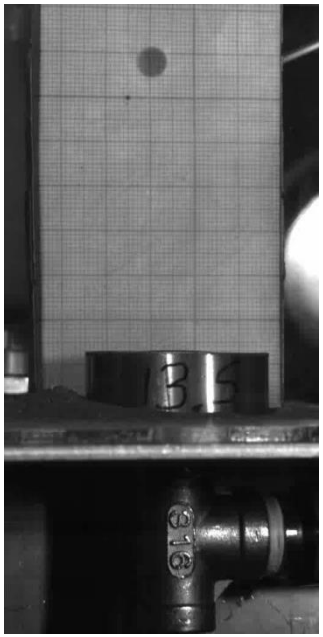


150 to 212 um

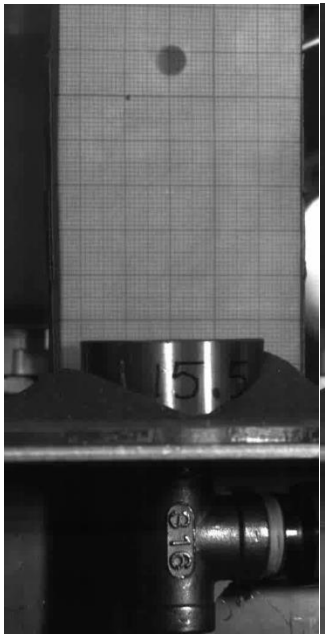


Tungsten powder puff experiment

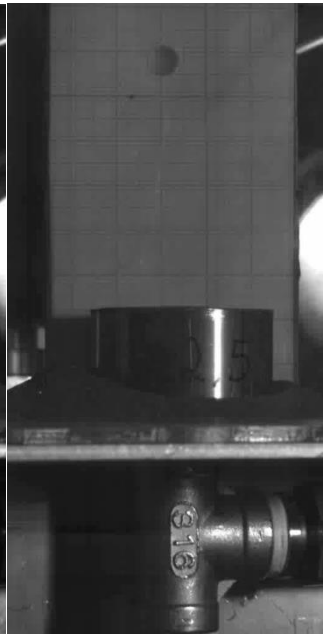
Powder depth = 13.5mm



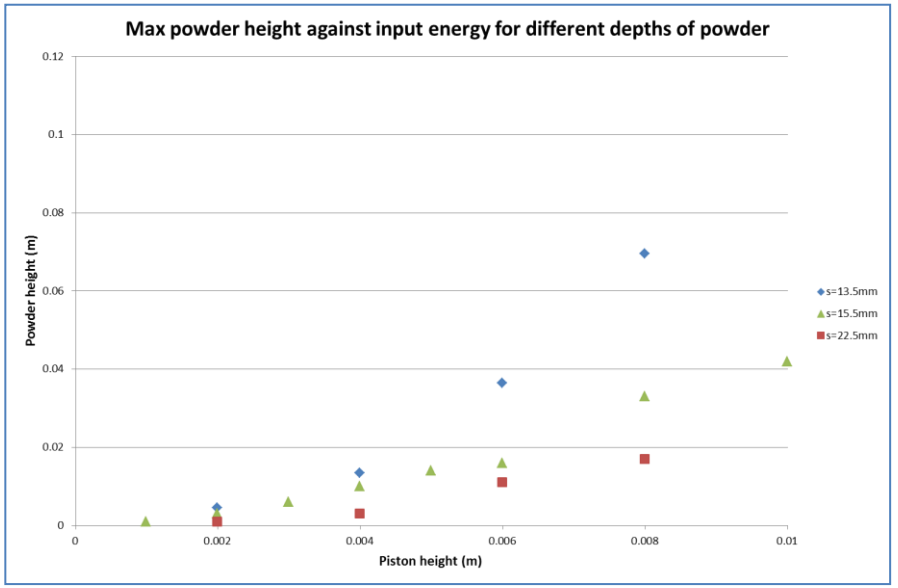
Powder depth = 15.5mm



Powder depth = 22.5mm



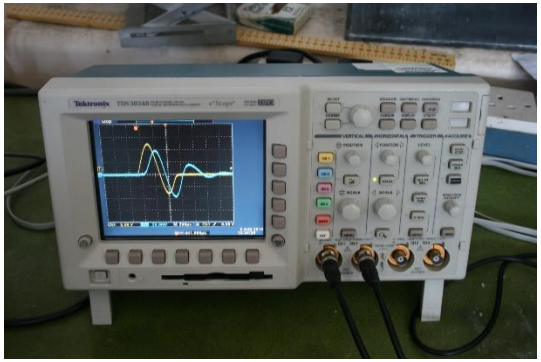
- The smaller the depth of powder, the larger the maximum powder height reached

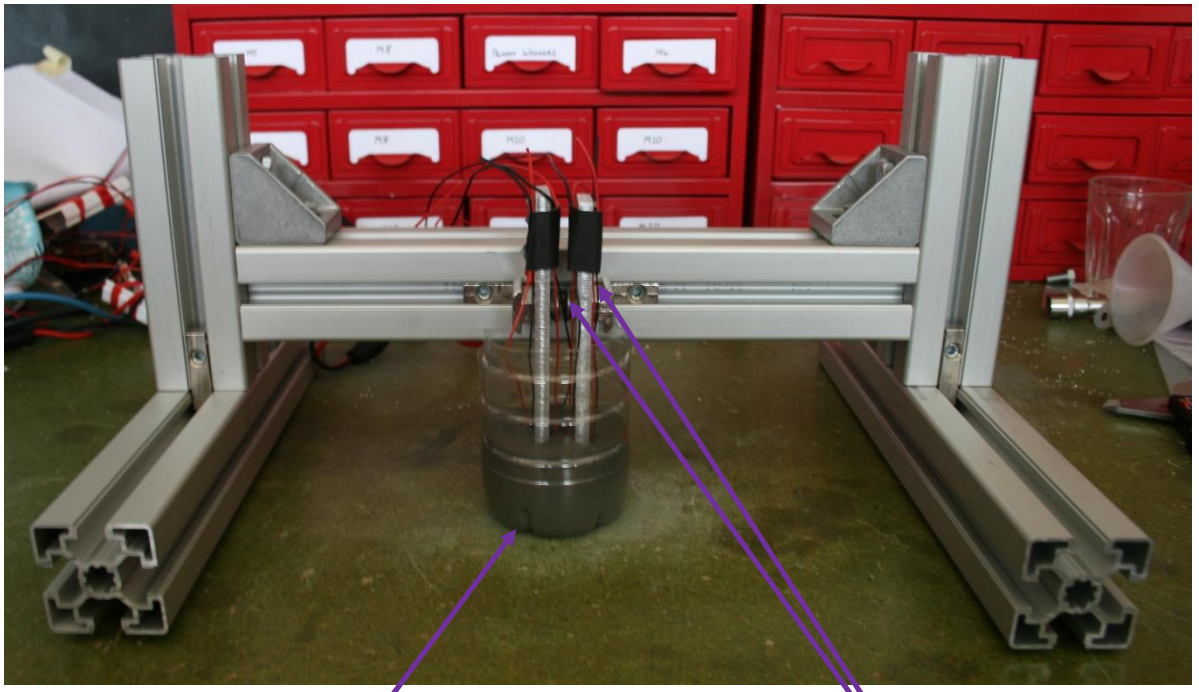


Propagation of stress through W powder
Sound propagation velocity and attenuation

12 V signal generator

oscilloscope

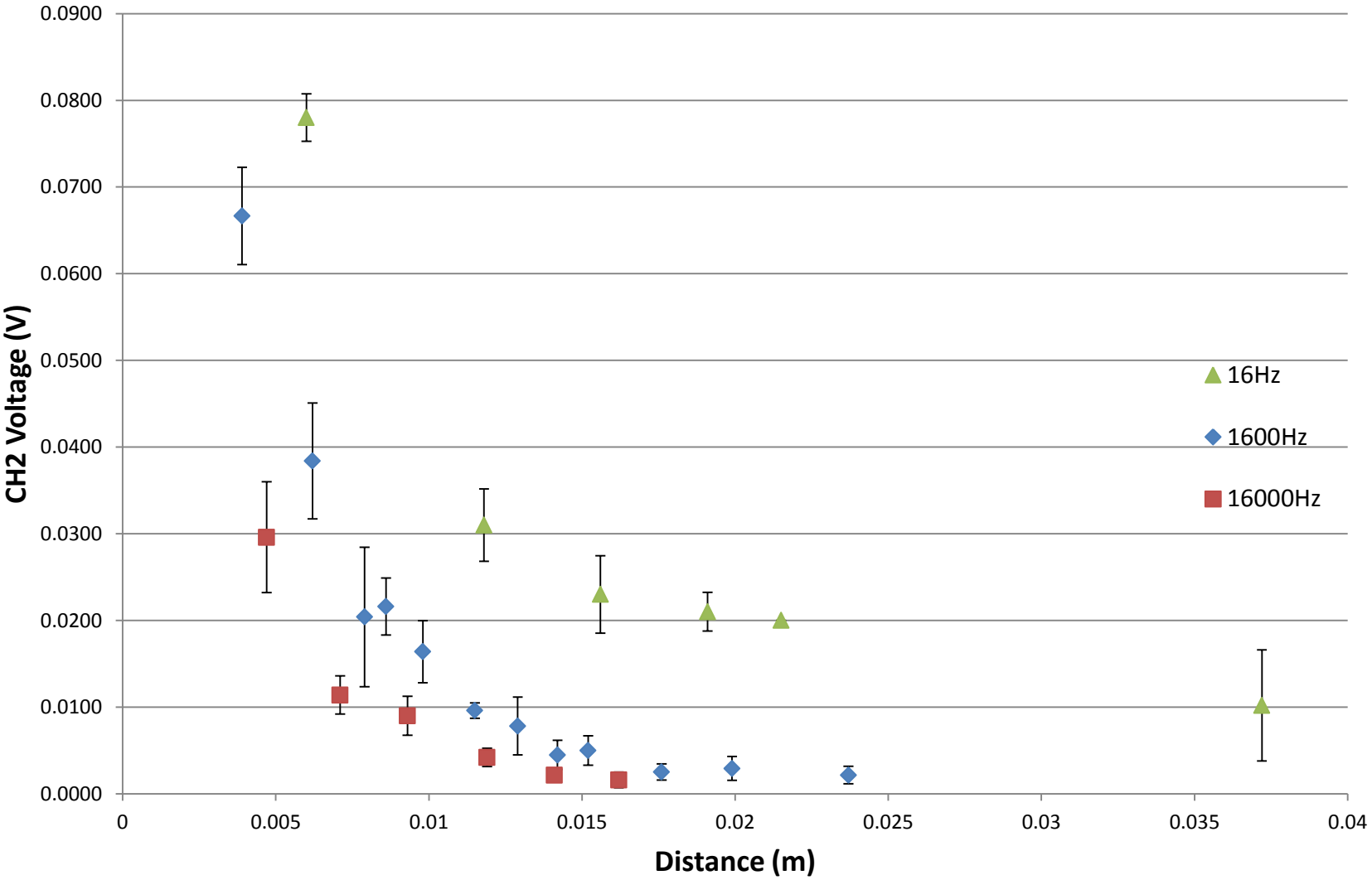




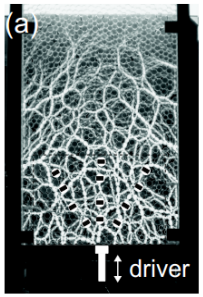
Piezo source and receiver

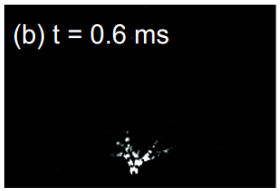
Powder sample

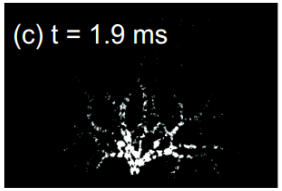
Attenuation of sound waves at different frequencies

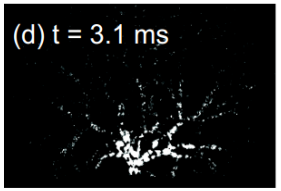


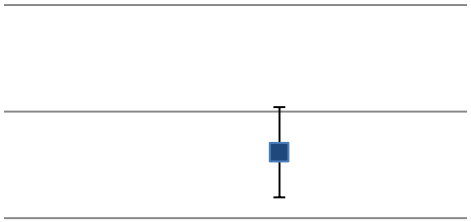
Tungsten Powder Average Velocity (m/s)

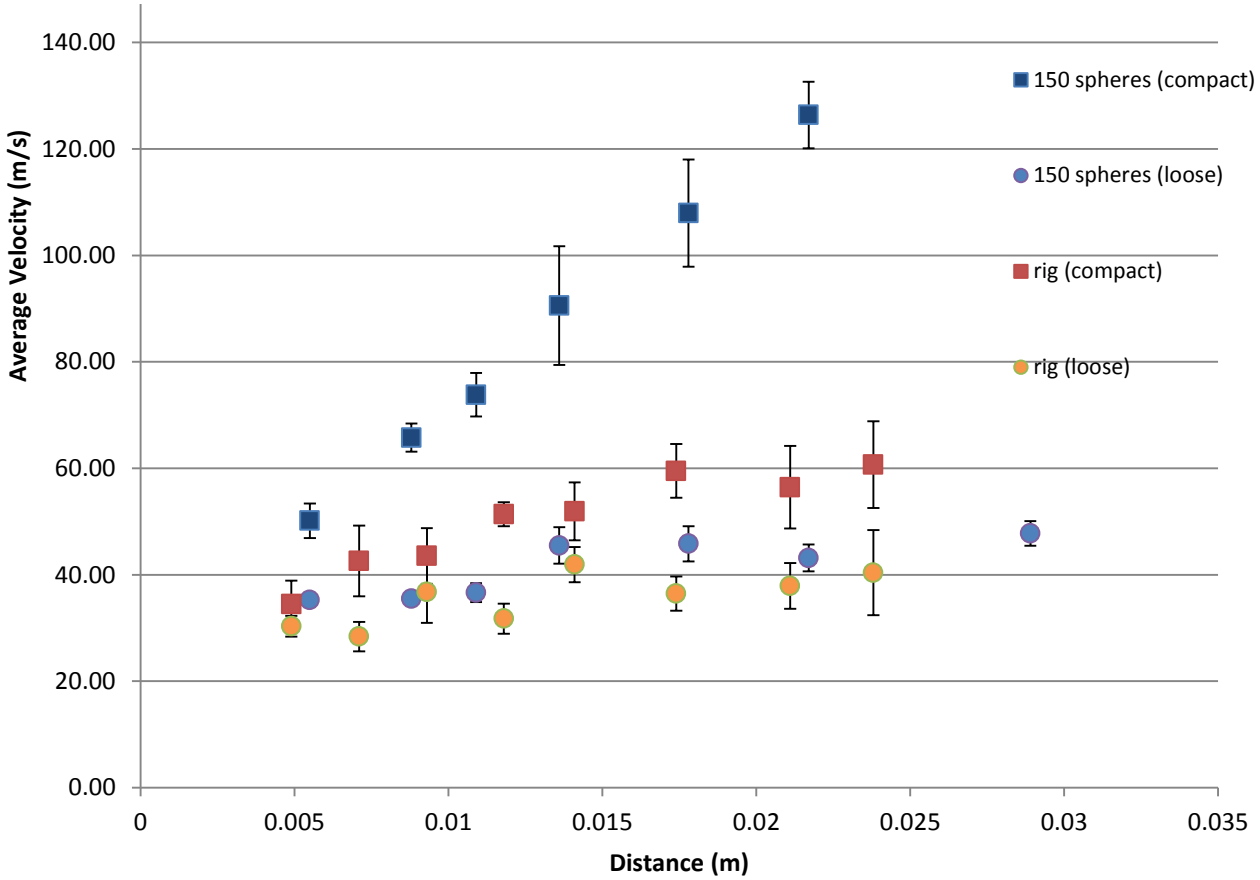












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Piezo crystal direct displacement tests

Investigate if it is possible to move a grain/grains with the rapid 1um displacement from a multi-layered piezo crystal

Packed bed experiment

Electrostatic Experiments:

High voltage powder charge using a Van Der Graaf generator

Test 1
Test 2

Initial test indicate that the powder can be charged and repels as expected.

More work is needed to investigate if rapidly charged powder would puff

Key Developments for the HRMT-22 Experiment **(Approved)**

1. ***Test in both vacuum and helium environments***

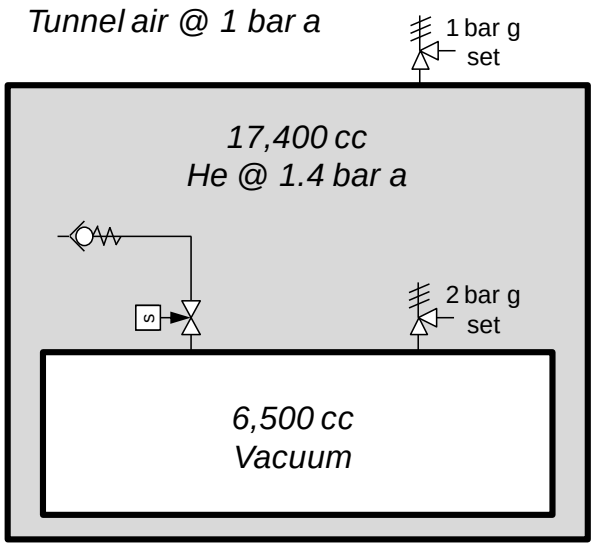
   If we see an eruption in vacuum then it cannot be due to an aerodynamic mechanism!

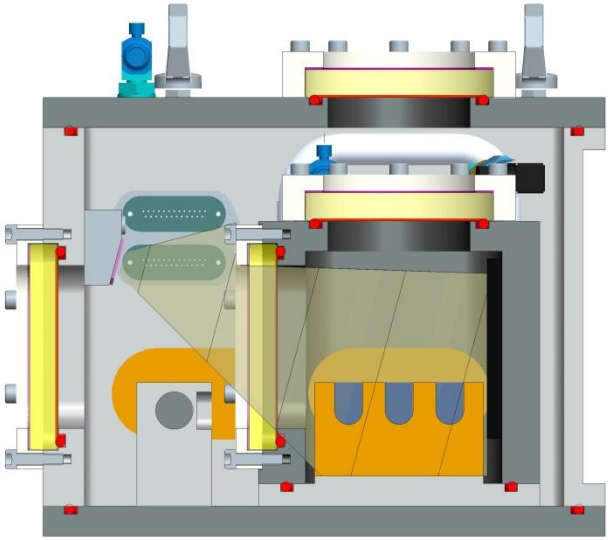
2. ***Vessel updates***

   Elongated beam windows to facilitate hitting multiple samples. Extra optical window in the lid permits a view of the disrupted sample from above.

3. ***New Trough Concept***

   multiple samples, stiff (high natural frequency) to separate trough/powder disruption effects.

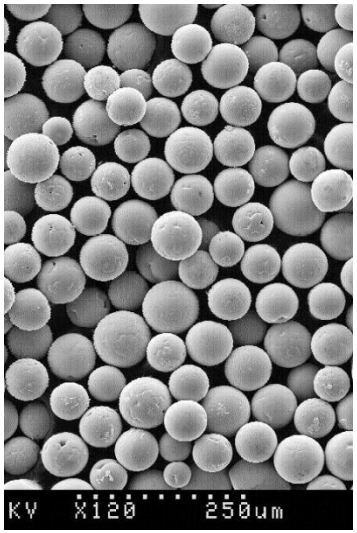


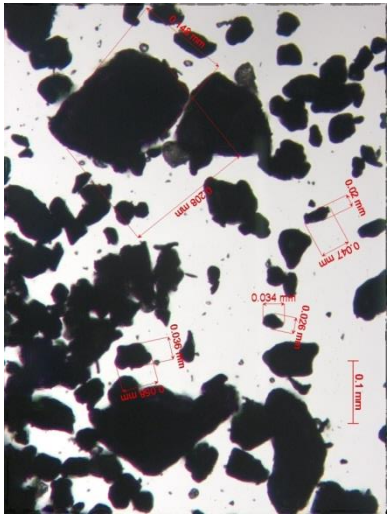


Key Developments for the HRMT-22 Experiment **(Approved)**

4. ***Use mono-dispersed spherical tungsten powder***

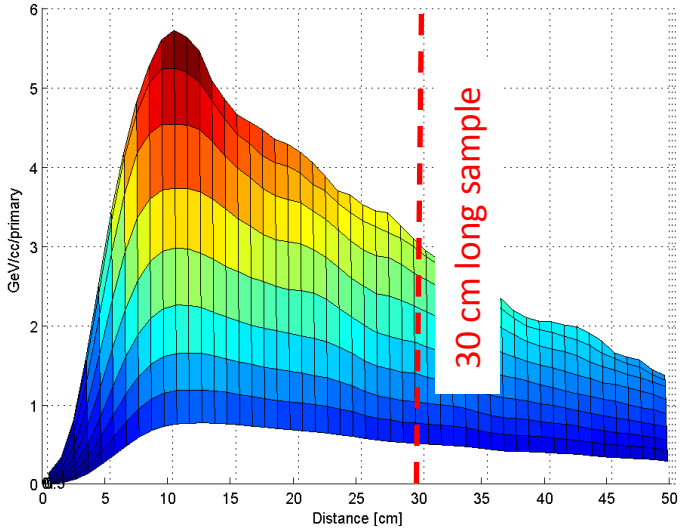
   To make the experiment fit the model(!)





5. ***Reconfigure the lighting rig to permit a view along the full length of the trough***

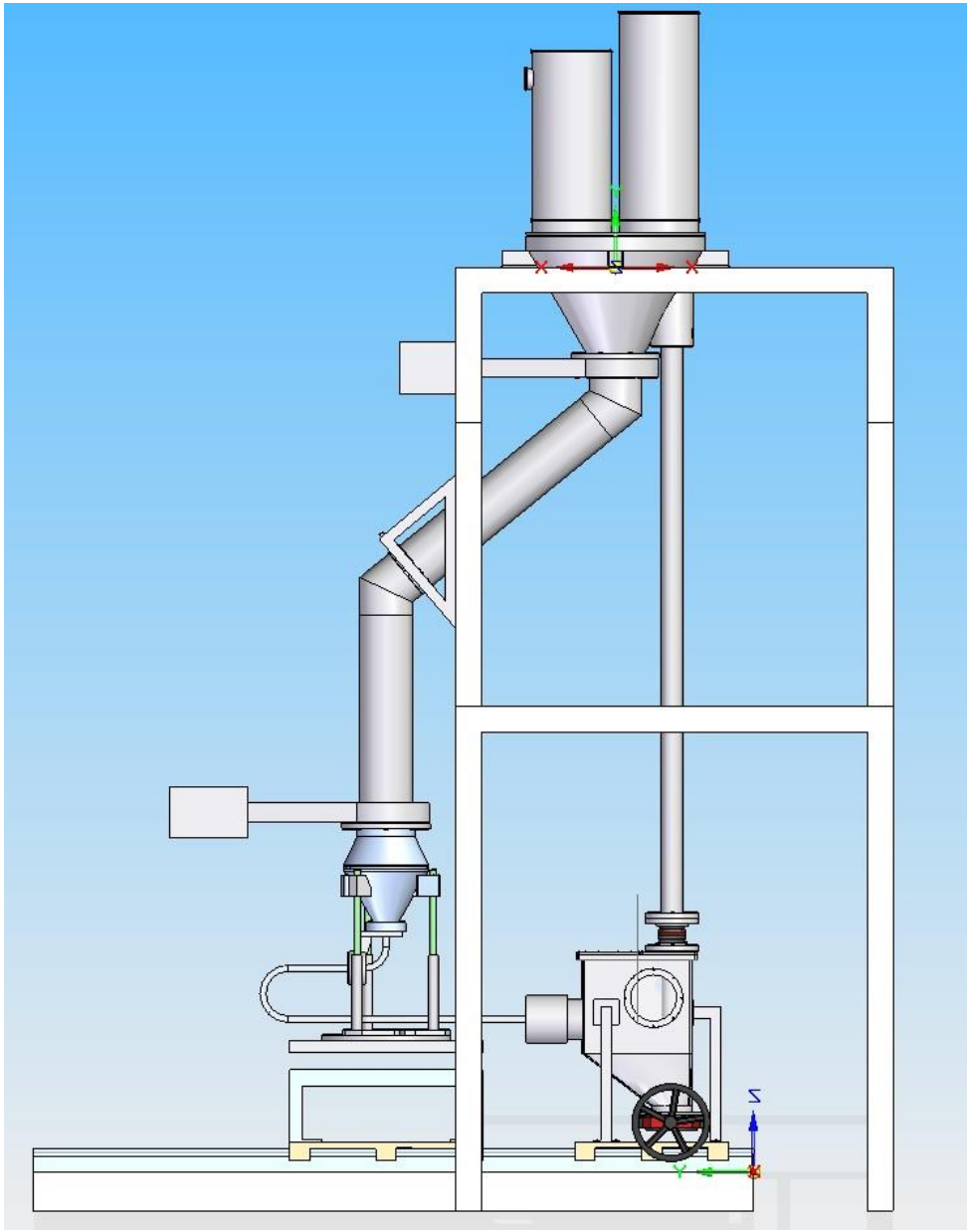
   To allow better correlation of lift vs energy deposition as the shower builds up along the sample



Energy deposited in a tungsten powder sample from FLUKA simulation

Fluidised powder test rig development

1. Improving density of the flow
2. Investigation of 180° re-entrant pipe geometry
3. CW upgrade
4. Calorimetry – heat transfer with pipe wall



Work to come

More work is needed to study electrostatic effects on the powder

HiRadMat round 2 is coming (the revenge) this will hopefully, ultimately shed some light on beam effects on powder (not severe)

Development on the powder rig is in progress. A new translation stage is being installed which will allow studying pressure drop vs flow density.

A flow and return experiment is also on its way

the rig will then be upgraded for continuous operation (it is now working batch mode)

A calorimetric experiment is being developed to study heat transfer between the powder flow and the containers walls. This will eventually be integrated into the large rig.