Fluidised powder as a new target technology:

COMMISSIONING OF A NEW RIG

Work by Chris Densham, Peter Loveridge
& Ottone Caretta (RAL),
Tom Davies (Exeter University) and Richard Woods (Gericke LTD)

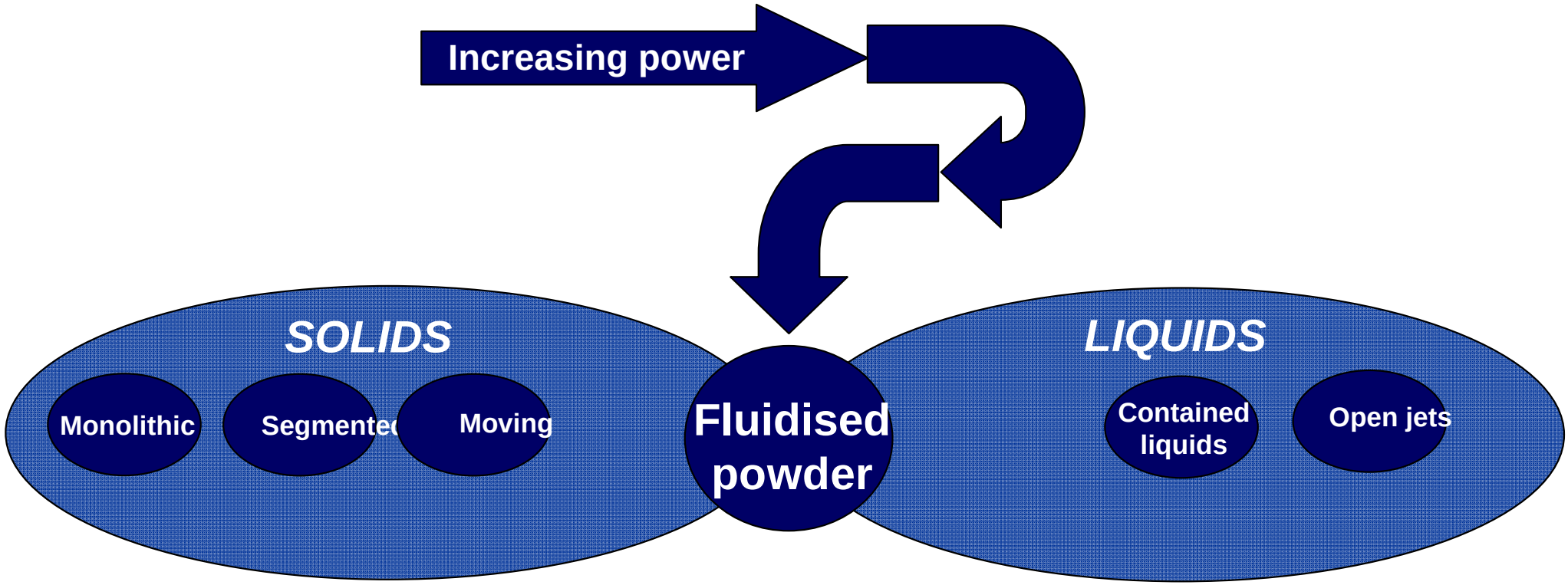
Presented by Ottone Caretta

EUROnu-IDS kick-off meeting 2008

CERN December 2008

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Is there a 'missing link' target technology?



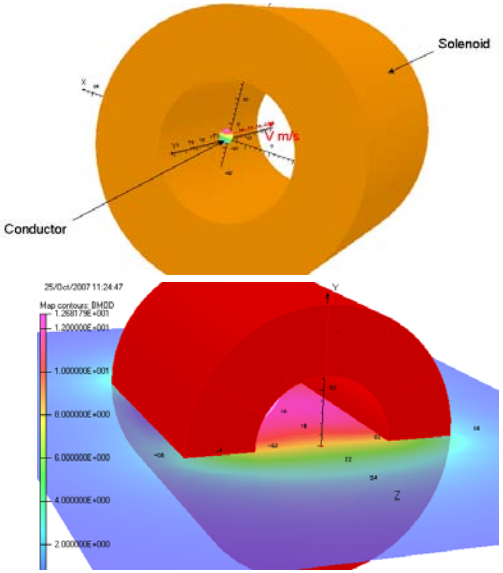
has some of the advantages of both solids and liquids

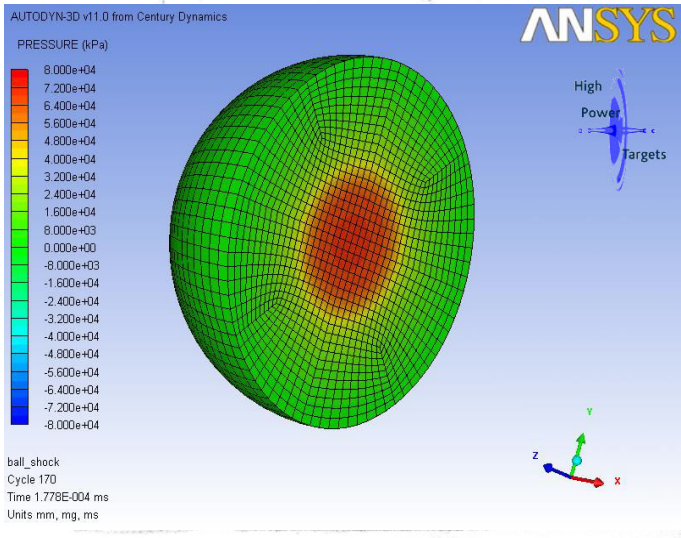
Powder jet targets: some potential advantages

- **Solid**
  - Shock waves constrained within material – no splashing, jets or cavitation as for liquids
  - Material is already broken
  - Reduced chemistry problems compared with the liquid
- **Fragmented**
  - a near hydrostatic stress field develops in the particles so high pulsed energies can be absorbed before material damage
  - Better for eddy currents ?
  - Favourable (activated) material disposal through verification
- **Moving/flowing**
  - Replenishable
  - Favourable heat transfer
  - Decoupled cooling
  - Metamorphic (can be shaped to convenience)
- **Engineering considerations:**
  - Could offer favourable conditions for beam windows?
  - It is a mature technology with ready solutions for most issues
  - Few moving parts away from the beam!

Some questions/issues:

- Electrical charge (Lorentz force)
  - Frictional electrostatic charge
  - Beam charge
- Eddy currents
  - lower the conductivity of the material
  - break the conductor into smaller parts
- Elastic stress waves and thermal expansion
- Erosion + wear
  - Can be tamed with careful design
- Disposal and radiological hazard

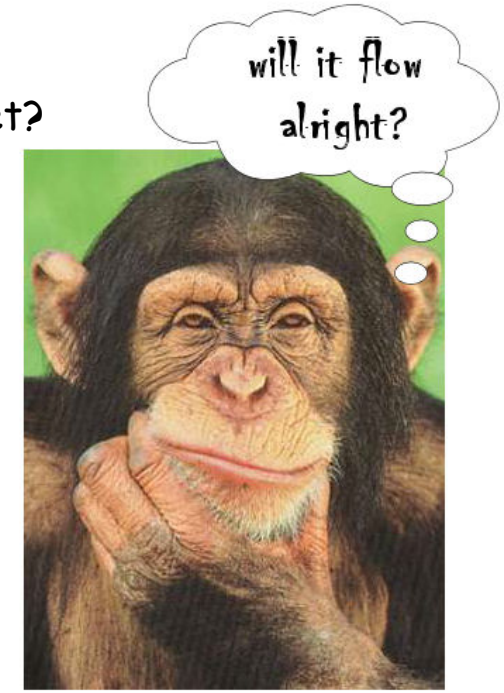




Science & Technology Facilities Council
Rutherford Appleton Laboratory

A tungsten jet as a target for NuFact?

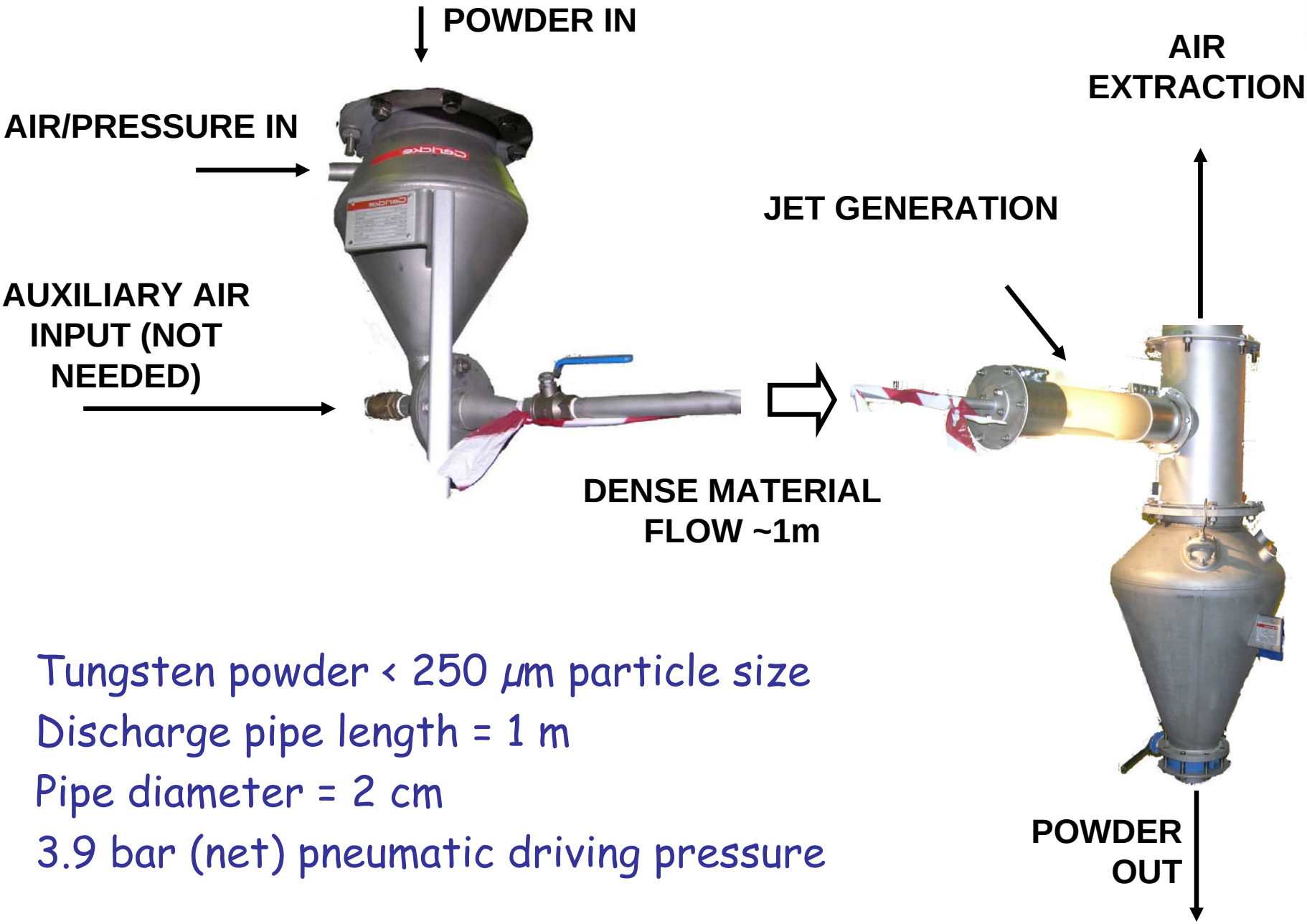
Arising questions:



- Is it applicable to a geometry similar to that sketched for the mercury jet?
- is W flowable?
- Is it fluidisable?
  (its much heavier than any material studied in the literature)
- Is it possible to convey it
  - in the dense phase?
  - in the lean phase?
- What solid fraction is it possible to achieve?
  (a typical loading fraction of 90% w/w solid to air ratio is not good enough!)
- How does a **dense**, dense powder jet behave like?

→ Preliminary tests at Gericke ltd

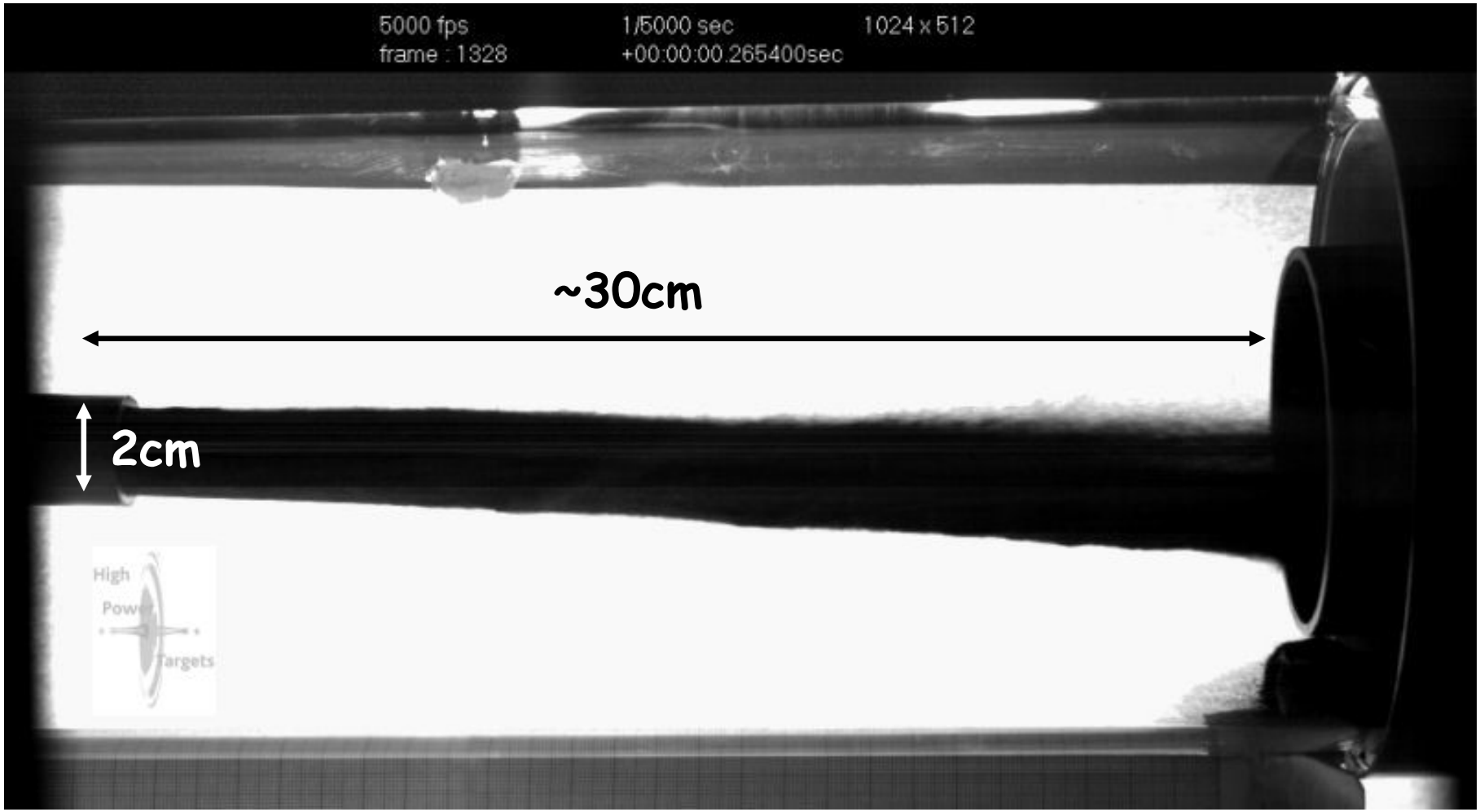
The rig



- Tungsten powder < 250 μm particle size
- Discharge pipe length = 1 m
- Pipe diameter = 2 cm
- 3.9 bar (net) pneumatic driving pressure

Science & Technology Facilities Council
Rutherford Appleton Laboratory

3 days test campaign

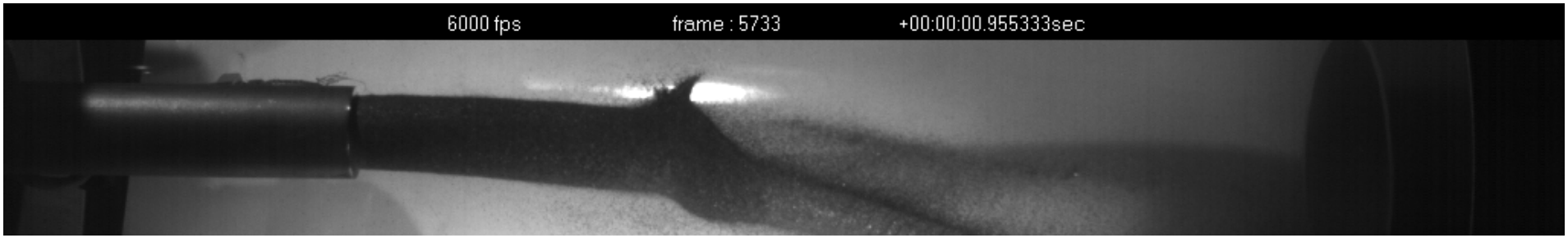


Thank you to EIP at RAL for providing the video equipment used for these experiments

Science & Technology Facilities Council
Rutherford Appleton Laboratory

High speed videos: some of the tests

propelled by Helium 1.5 bar

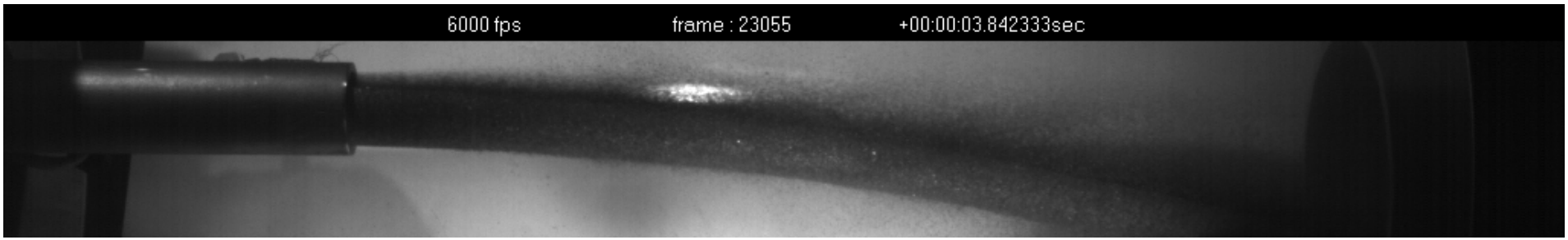


Thank you to EIP at RAL for providing the video equipment used for these experiments

Science & Technology Facilities Council
Rutherford Appleton Laboratory

High speed videos: some of the tests

propelled by Helium 2.5 bar

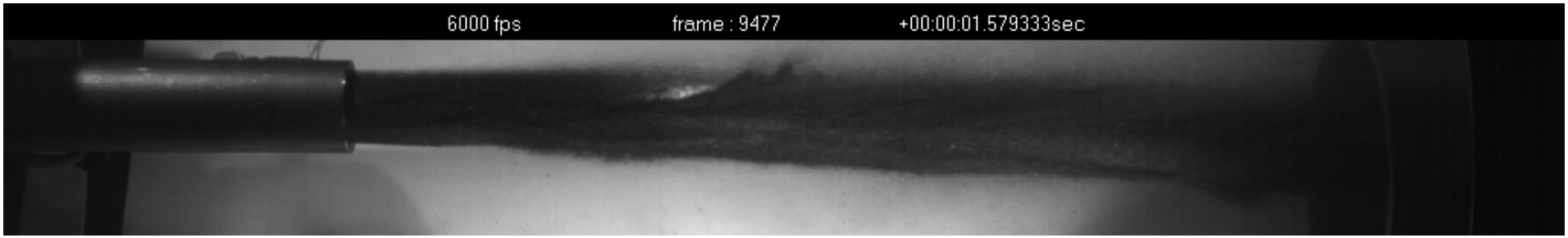


Thank you to EIP at RAL for providing the video equipment used for these experiments

Science & Technology Facilities Council
Rutherford Appleton Laboratory

High speed videos: some of the tests

propelled by Helium 3.5 bar

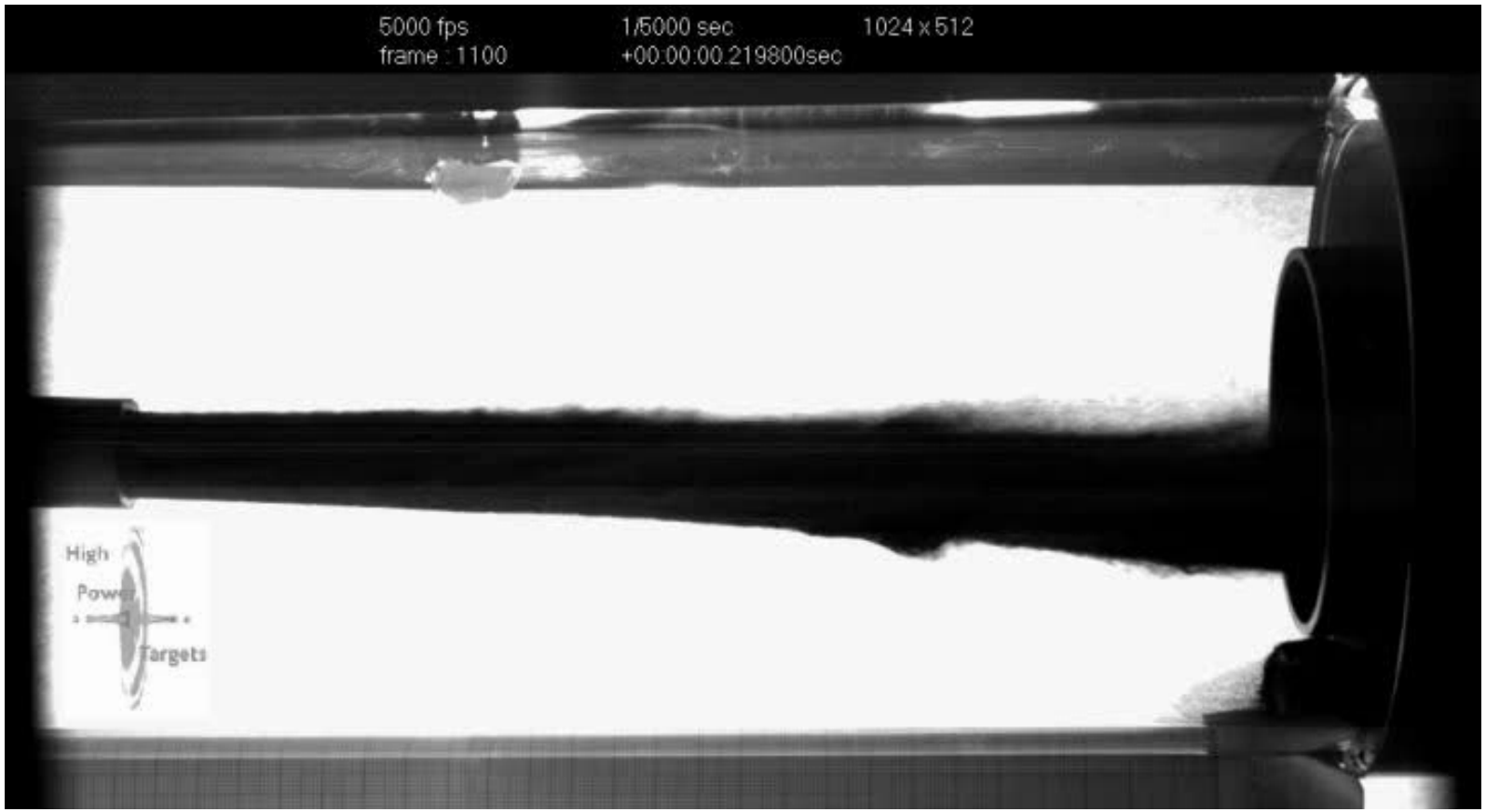


Thank you to EIP at RAL for providing the video equipment used for these experiments

Science & Technology Facilities Council
Rutherford Appleton Laboratory

High speed videos: some of the tests

propelled by air ~3 bar



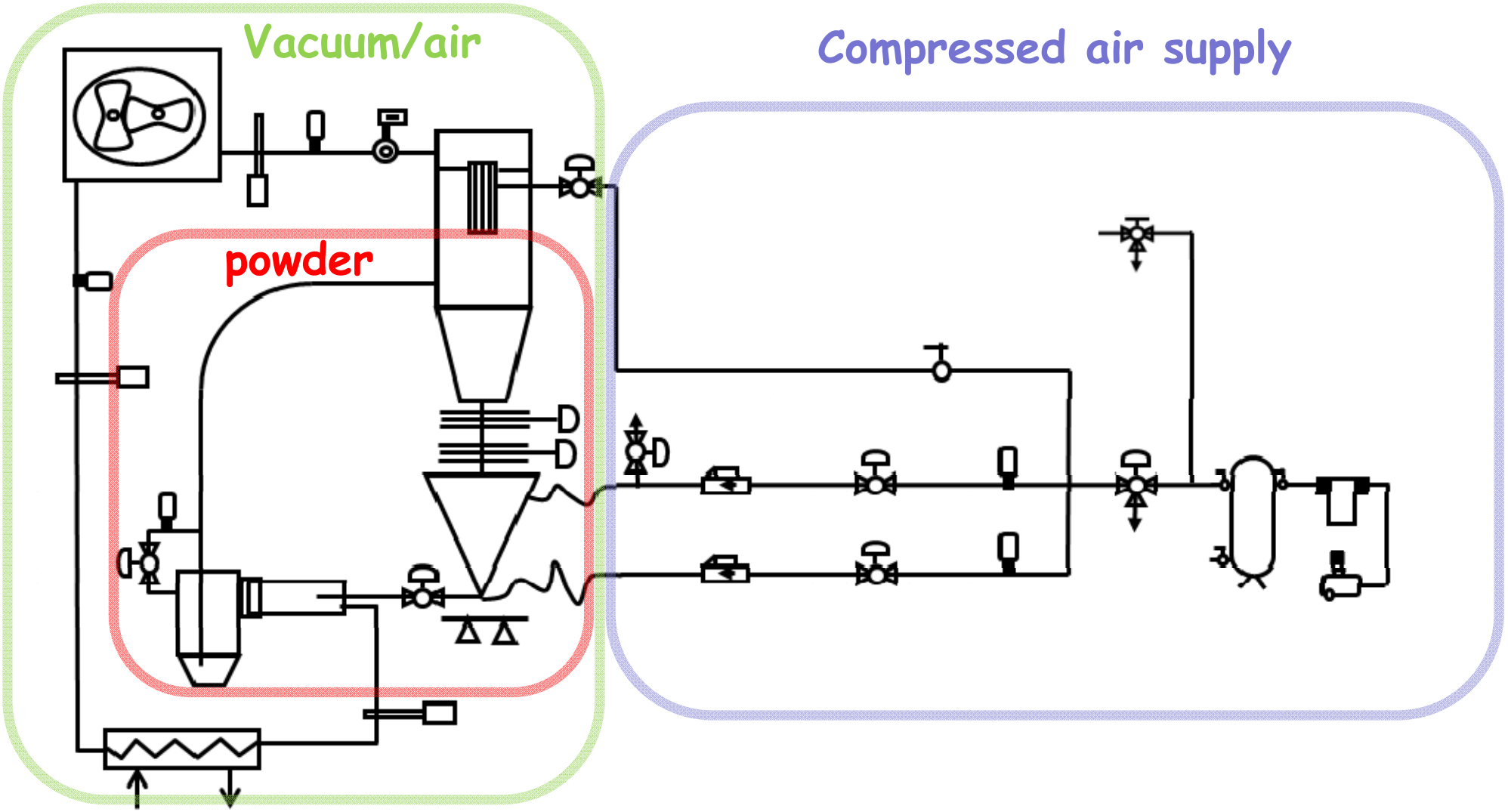
Thank you to EIP at RAL for providing the video equipment used for these experiments

Tests results:

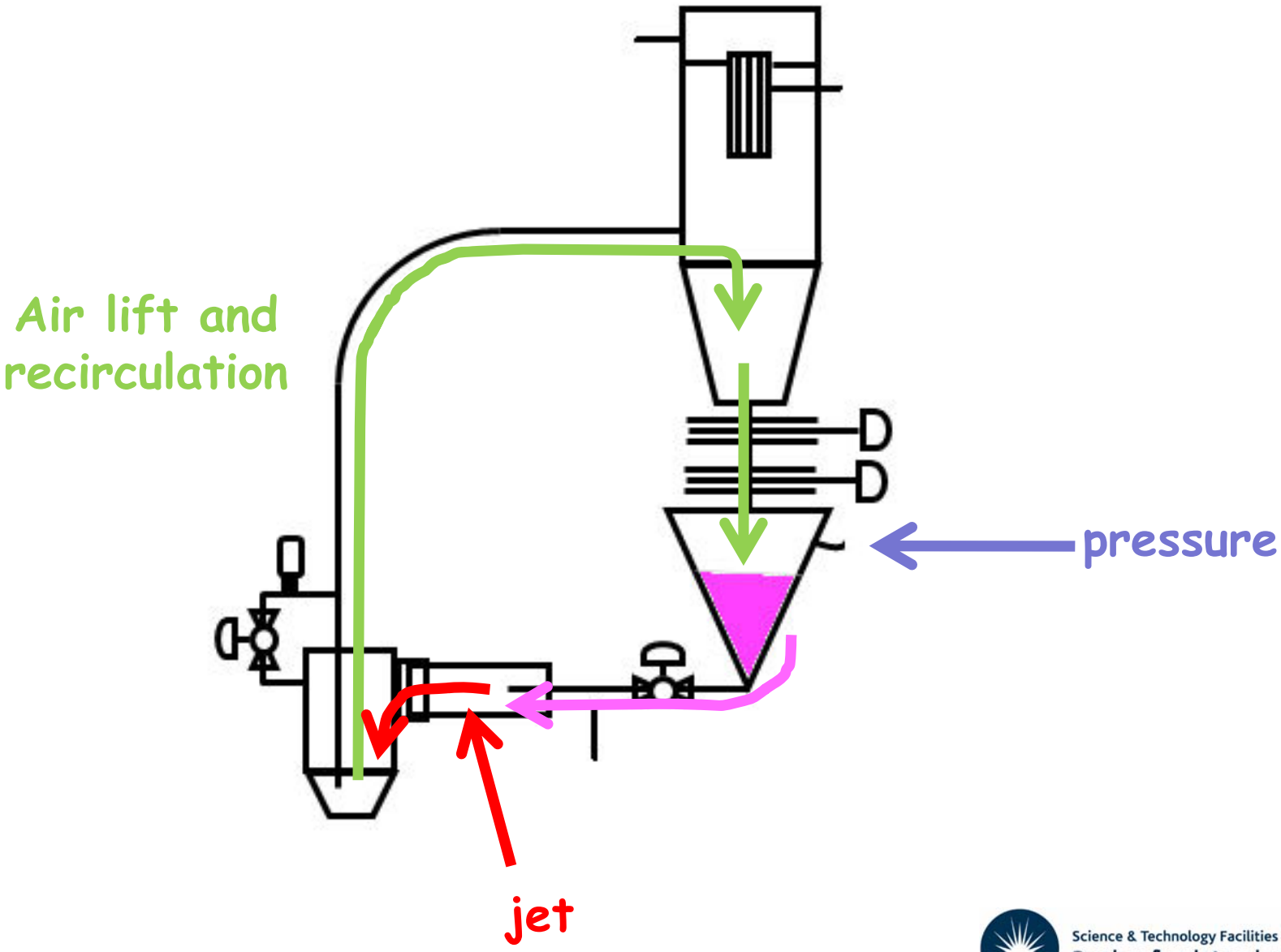
- Tungsten has extremely good flowability
- It is fluidisable in the dense and lean phase
- **The dense phase was successfully propelled both with air and He**
- W can produce a coherent high density jet (so far ~= 28.75 % v/v ; max ~=50% v/v)
- The jet looks similar to a liquid jet and is strongly dependent on the surrounding environment
- We encountered different jet flow regimes

→ **scope for a rig**

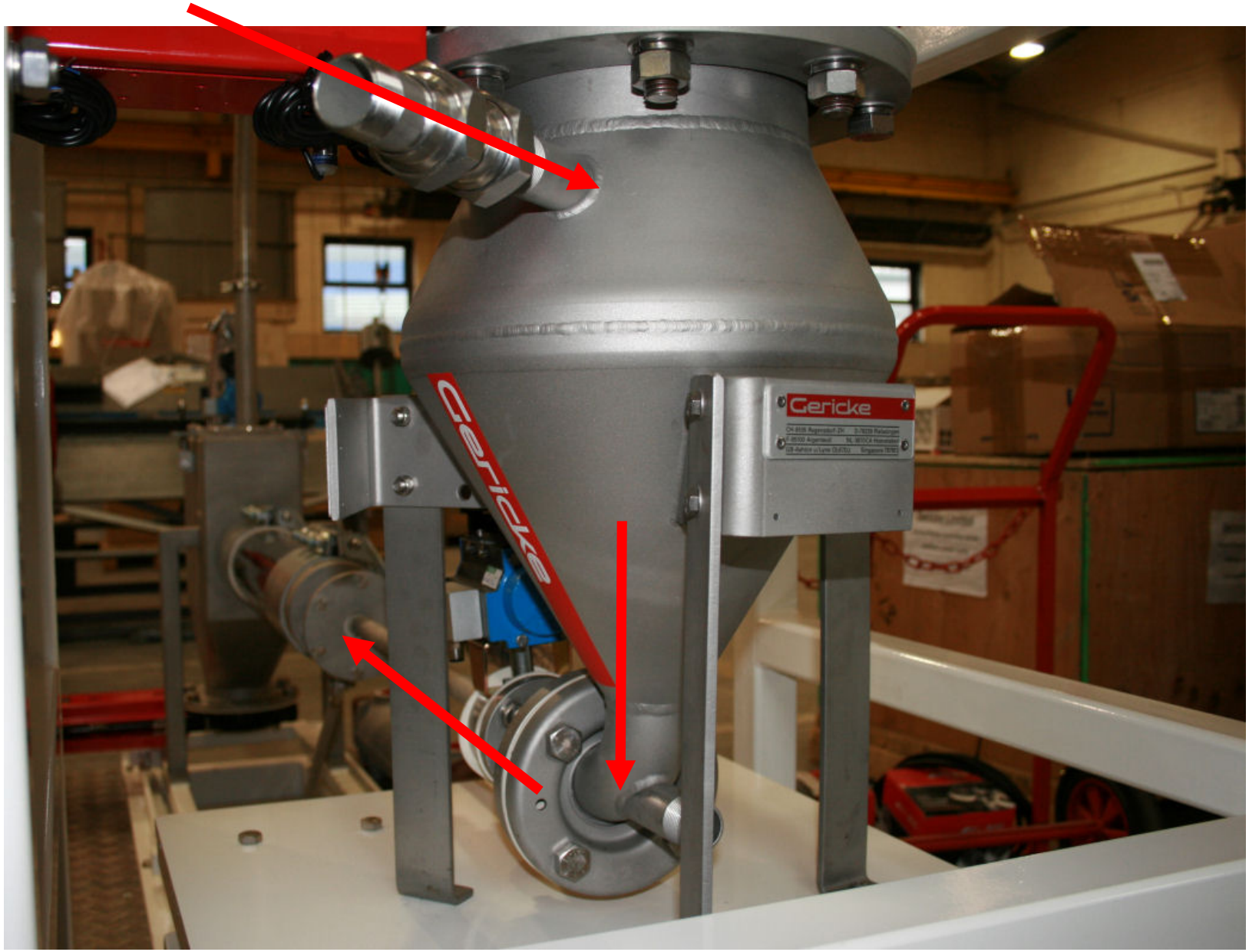
Powder jet test plant layout



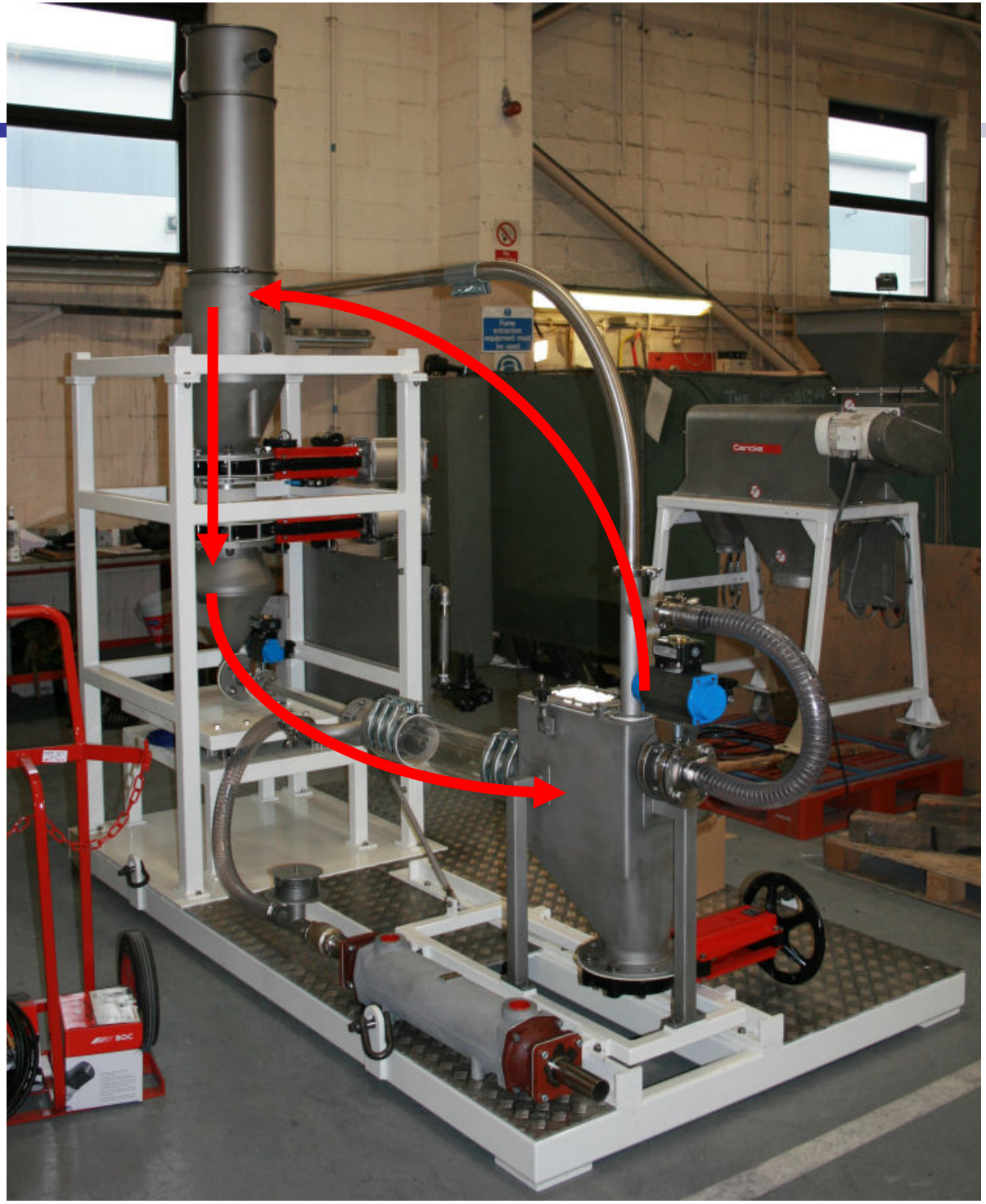
Powder jet test plant layout: the powder cycle



The rig



The rig

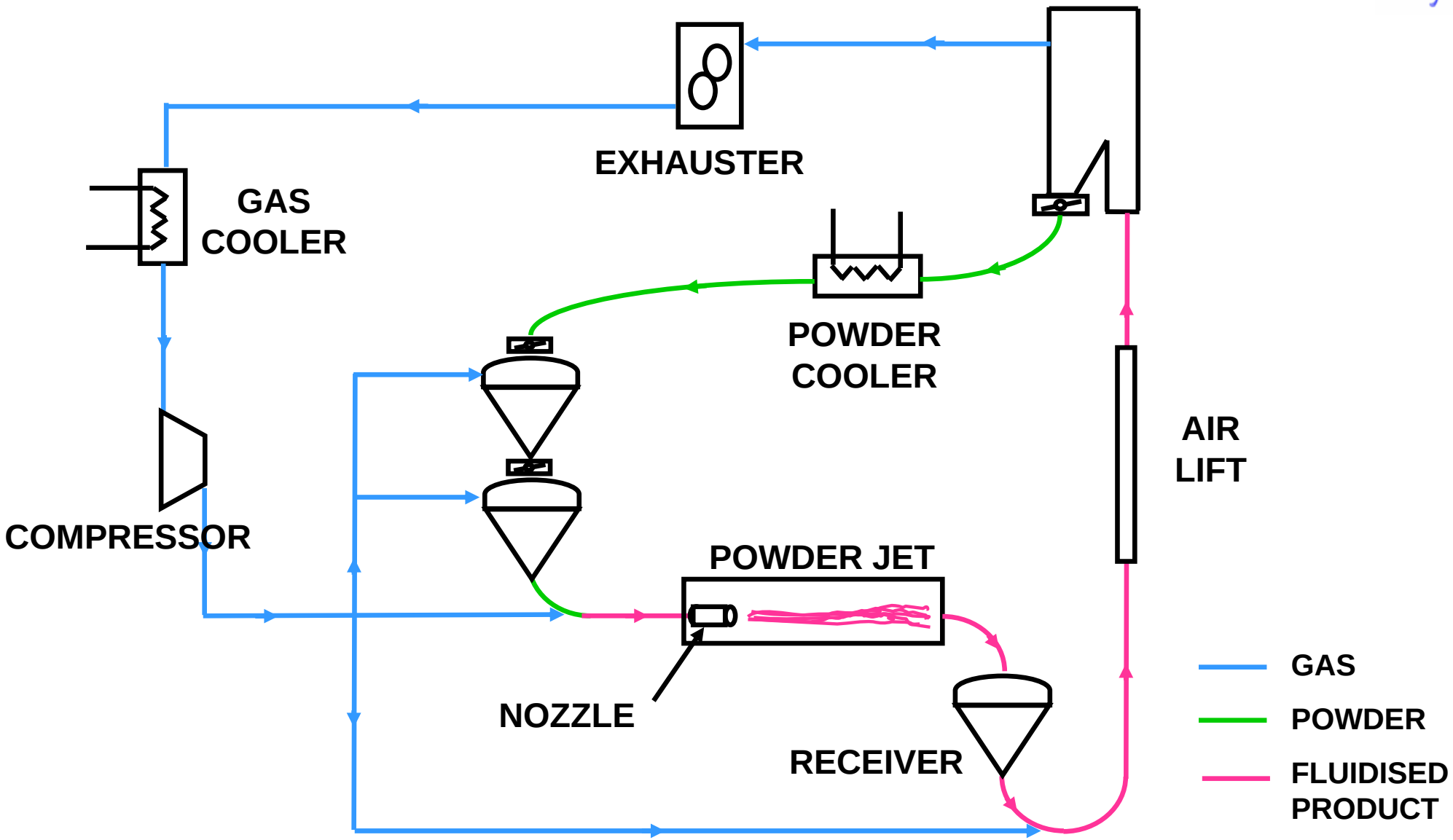


High Power Targets

Science & Technology Facilities Council
Rutherford Appleton Laboratory

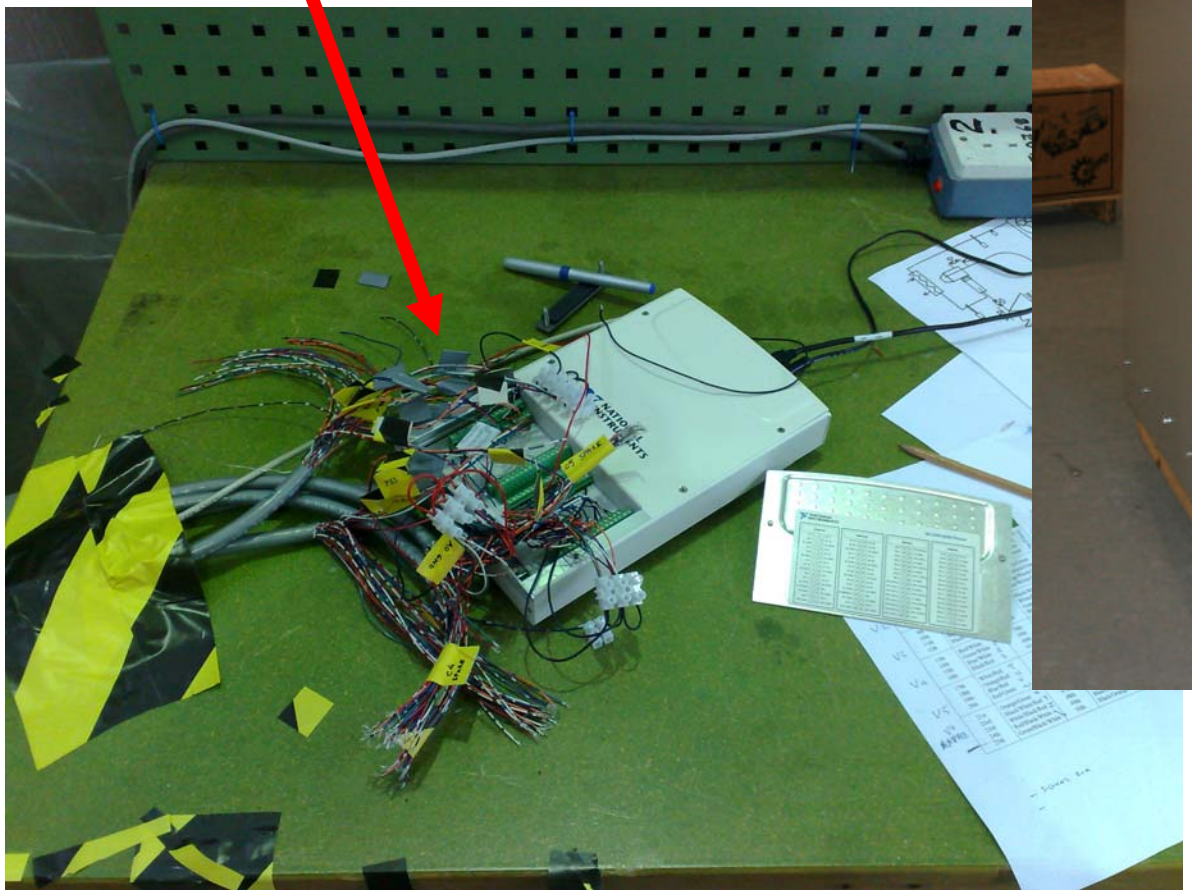
The rig

Powder jet prototype test plant

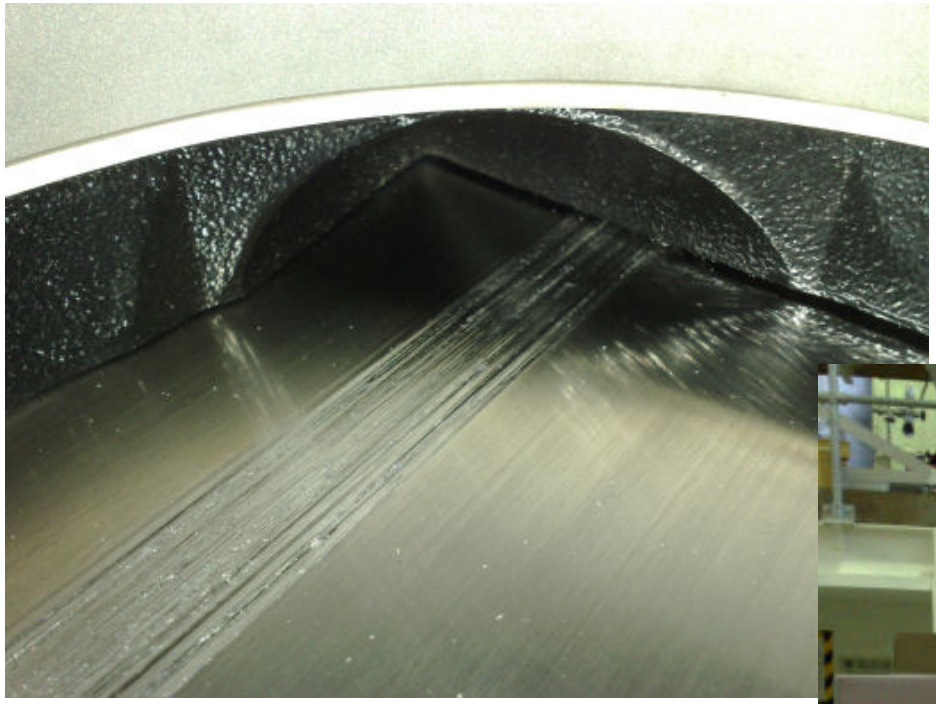


Commissioning of the rig

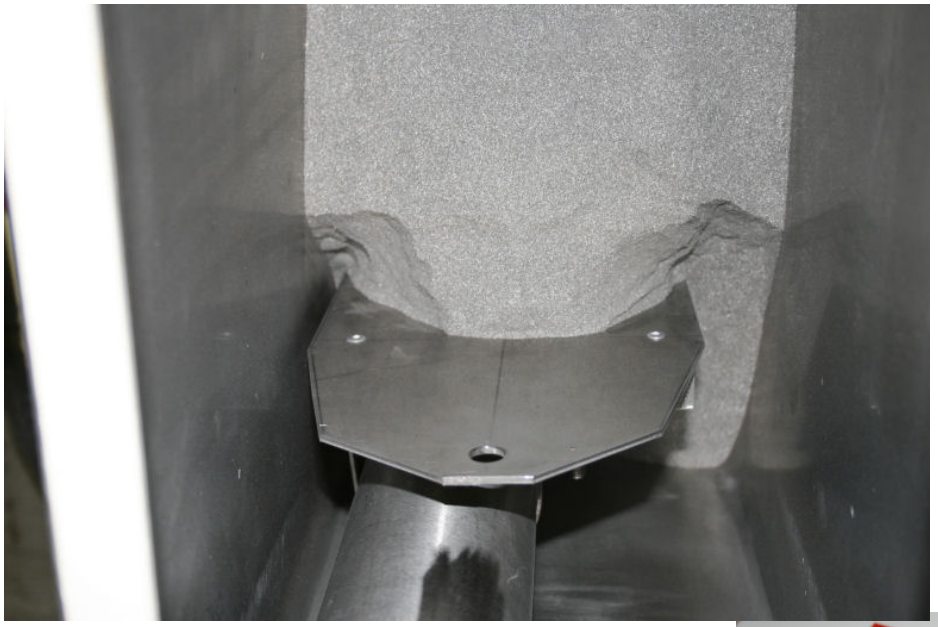
Commissioning of the rig



Commissioning of the rig



Commissioning of the rig



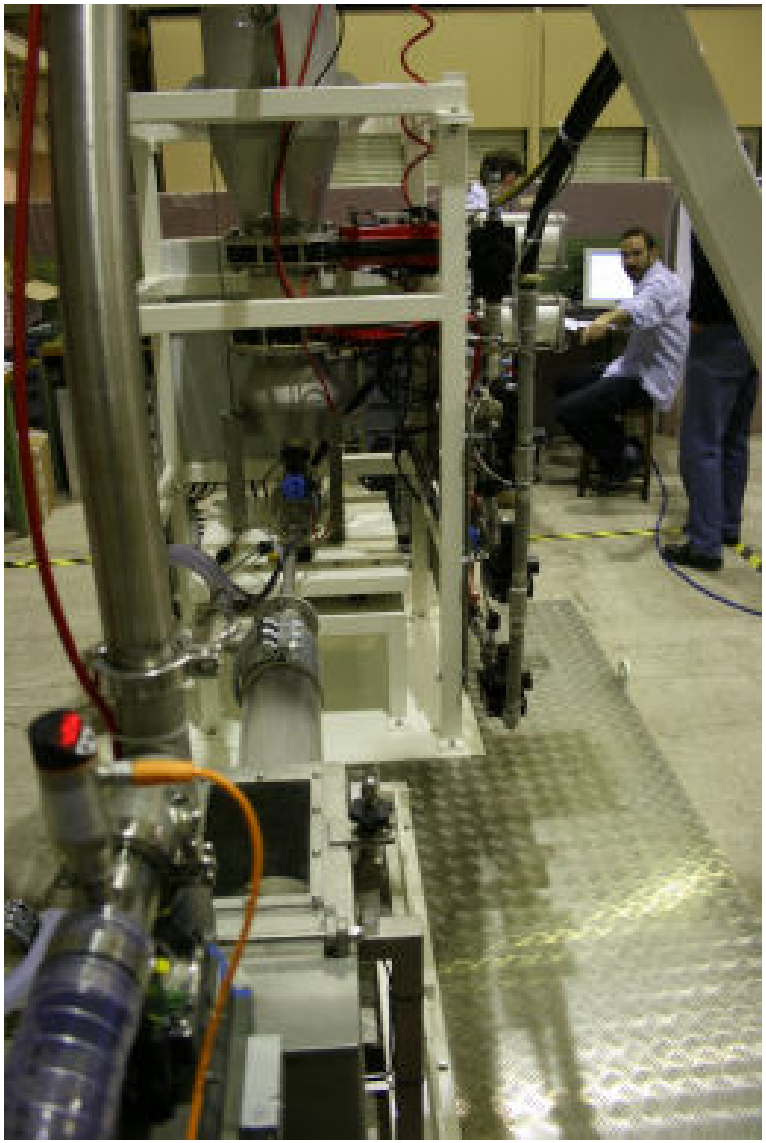
Protons+

Tungsten powder+

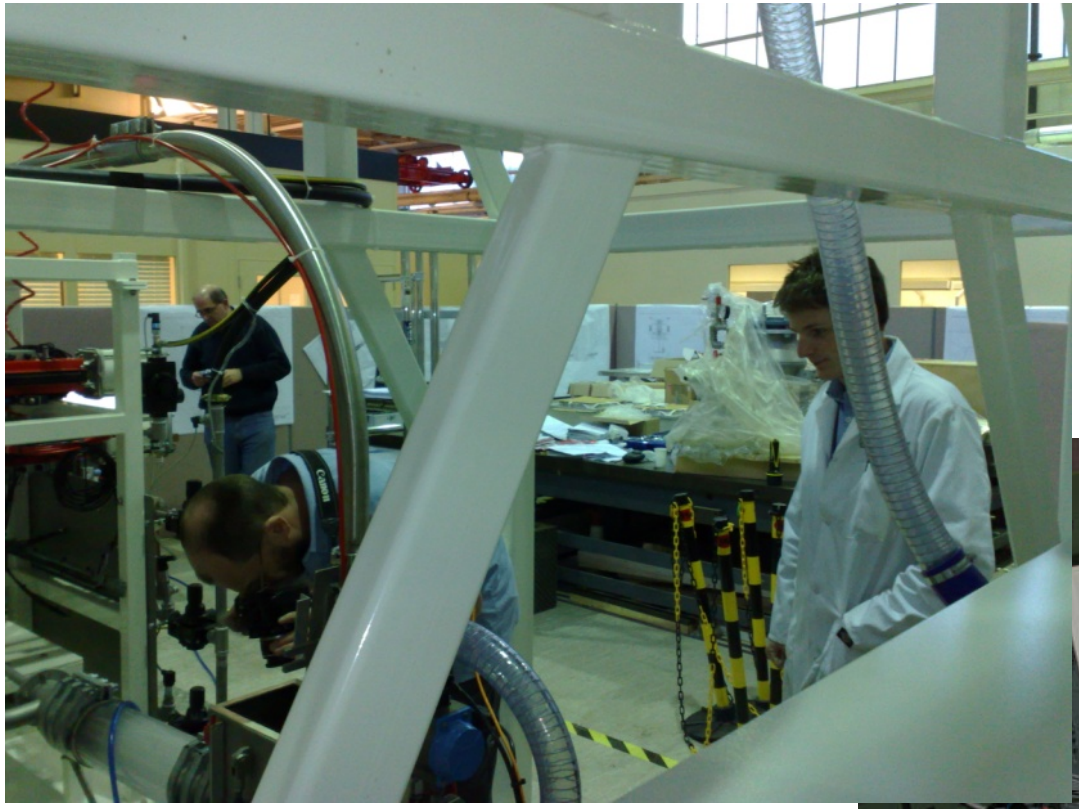
Chocolate=

What flavour neutrinos?!

Commissioning of the rig

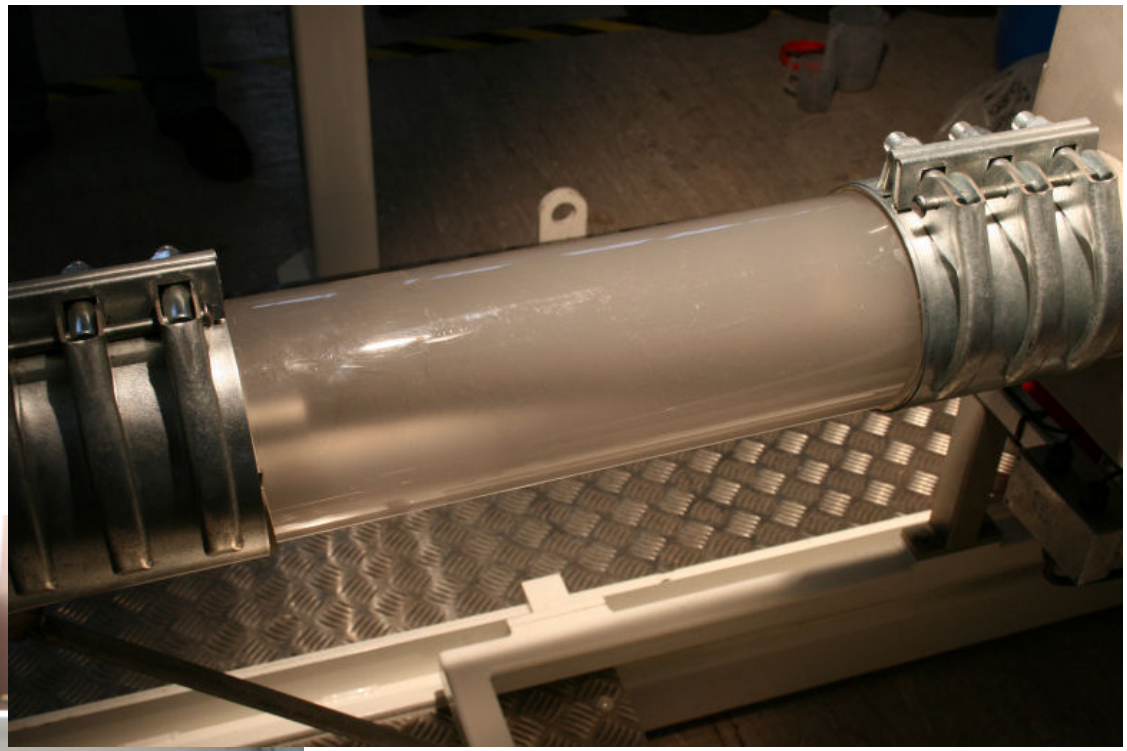


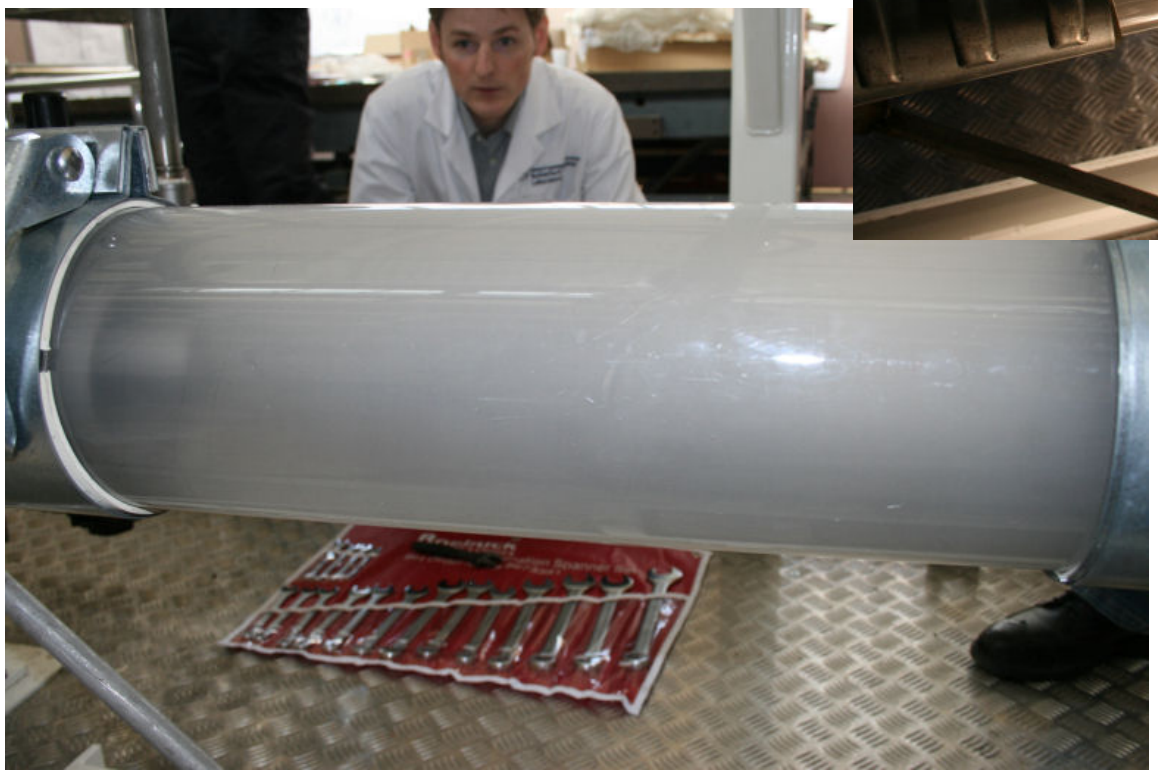
Commissioning of the rig



To go boldly where no one has ever been!

Commissioning of the rig





Future work (with the rig)

- Optimisation of the jet flow
- Particle Image Velocimetry (PIV) to determine the density
- Identification of the parameters affecting the jet and the overall performance of the system
- Erosion & wear
  (e.g. life of standard SS components and ceramics parts)
- Test different powders (e.g. TiO2? and C)
- Test different powder based target geometries
- Heat transfer

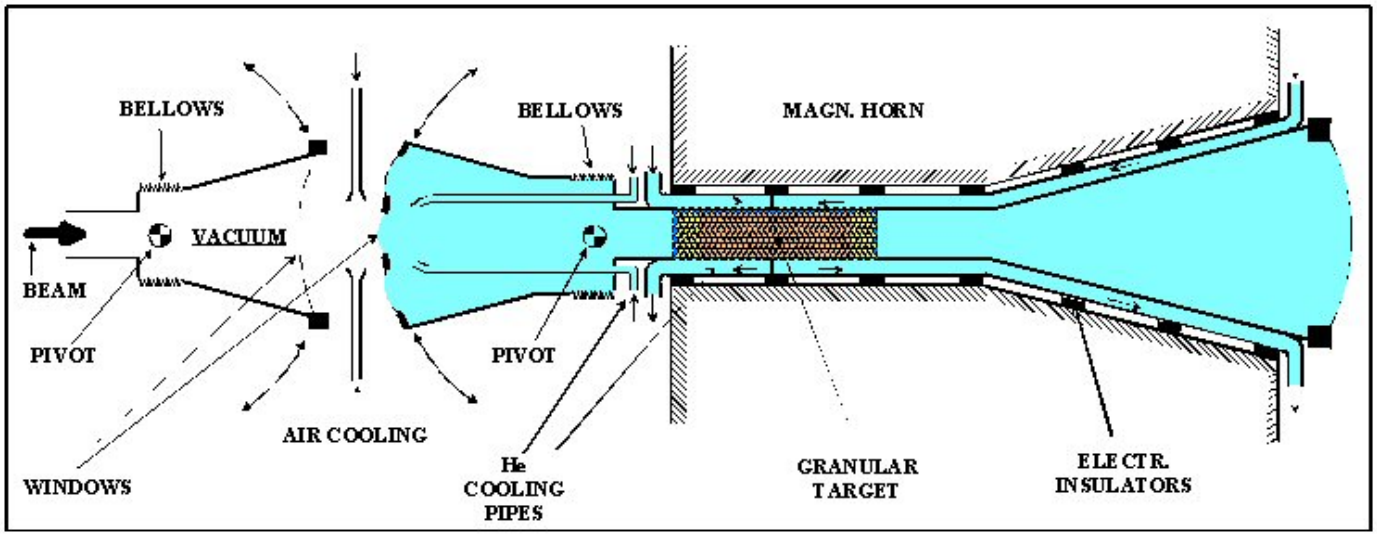
High Power Targets

Q & A

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Not a totally new idea:
packed bed have been proposed and used before

e.g. Sievers proposes a packed bed as a NuFact target:
Tantalum grains (2mm) in flowing helium

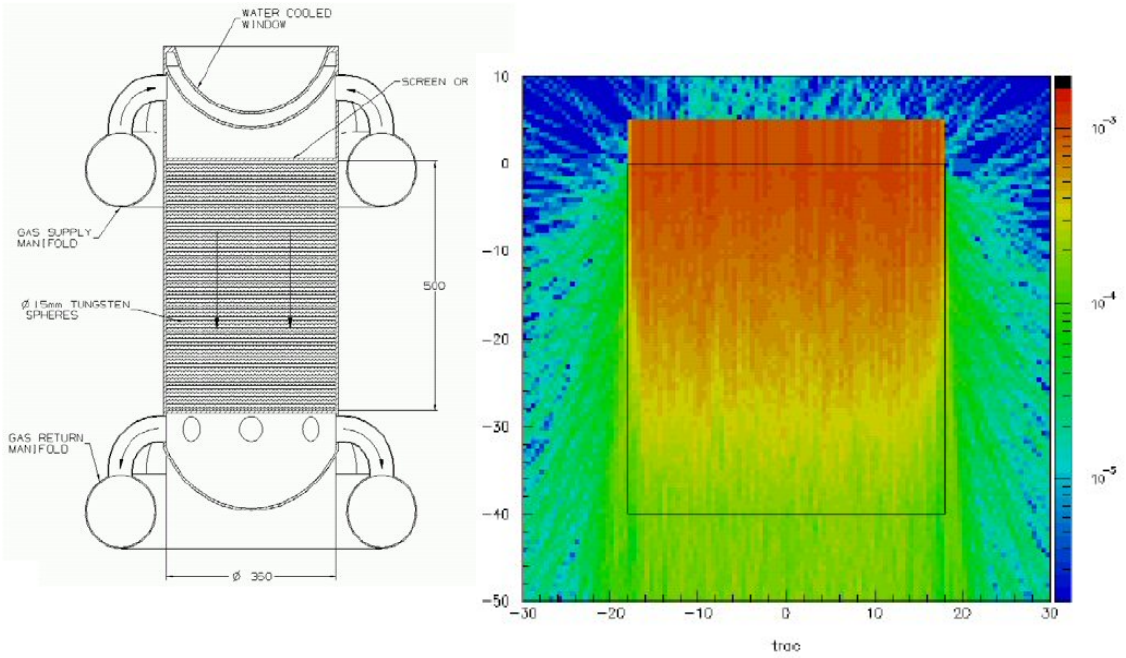


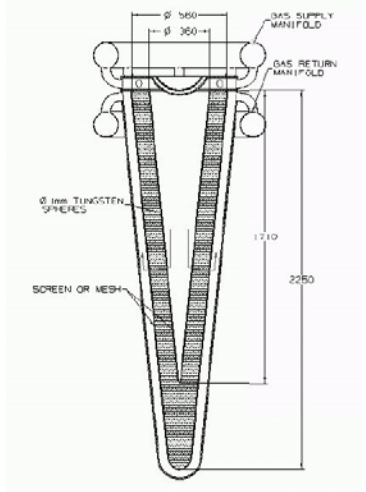
Others who worked with powders: Nick Simos and Kirk McDonald?

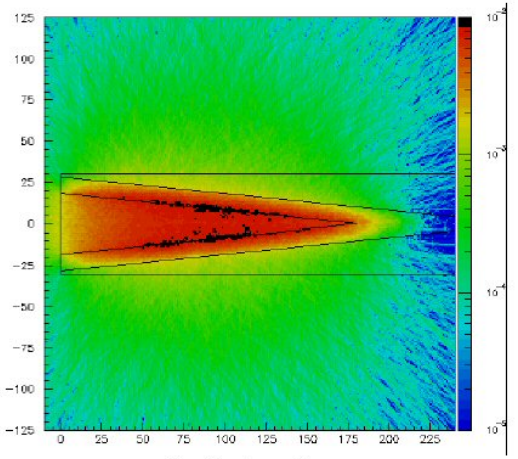
Not a totally new idea:
packed bed have been proposed and used before

High Power Targets

e.g. Ammerman proposes a packed bed of tungsten particles in flowing helium as a feature for the ATW







8a. Neutron Flux

Fig. 8. Proton and Neutron Flux for the Concentric Cone Target.

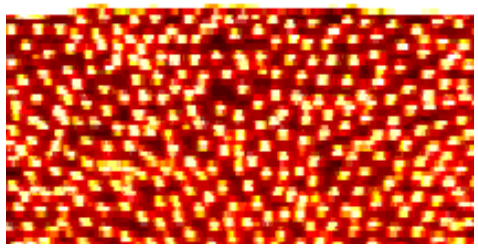
Science & Technology Facilities Council
Rutherford Appleton Laboratory

Powder technology
(such as fluidised beds, jets and pneumatic bulk transport)

High Power Targets

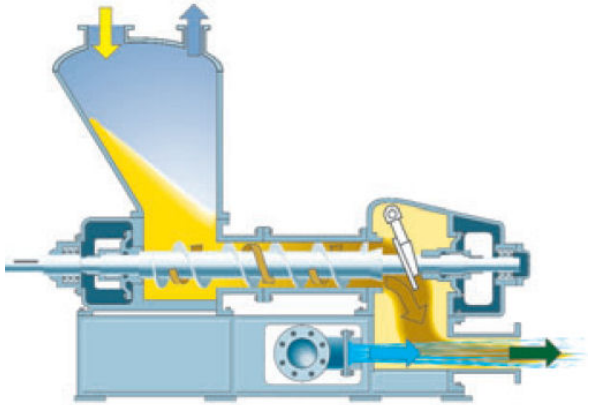
Is standard technology and is used daily in many different fields:

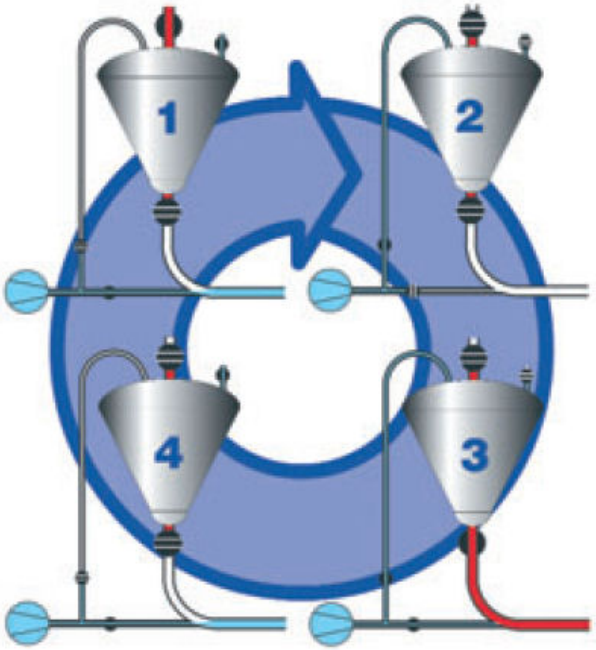
Transport of corn flakes, plastics, ores, to jet cutting, to sand blasting, to fluidised bed furnaces

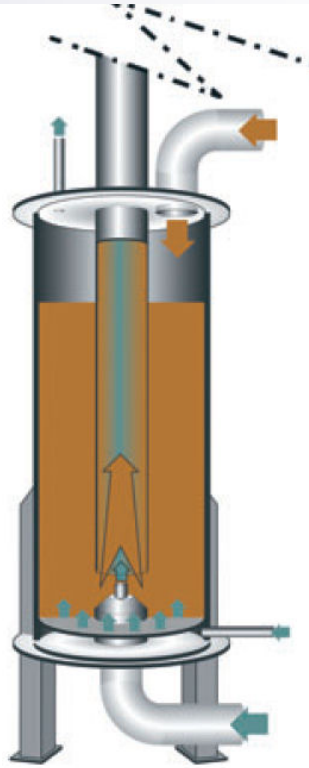


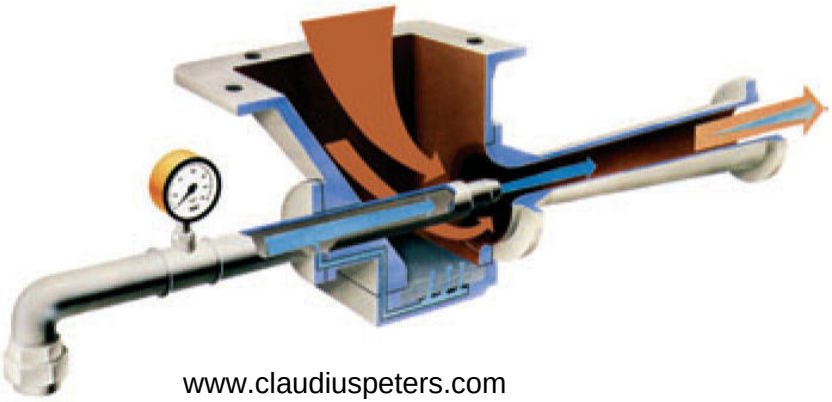
Science & Technology Facilities Council
Rutherford Appleton Laboratory

Different fluidising technologies

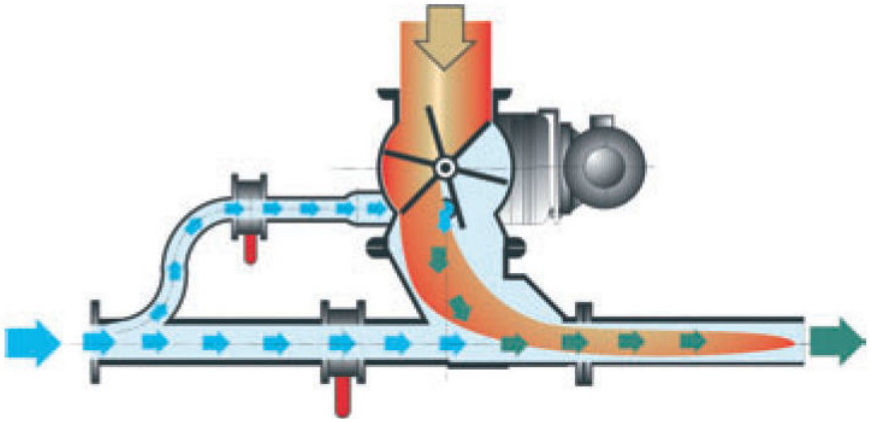








www.claudiuspeters.com



Science & Technology Facilities Council
Rutherford Appleton Laboratory

Tungsten powder jet – first results

Initial bulk density

= 8660 kg/m^3

= 45 % W (by volume)

Jet bulk density

~= 28.75 % W by vol.

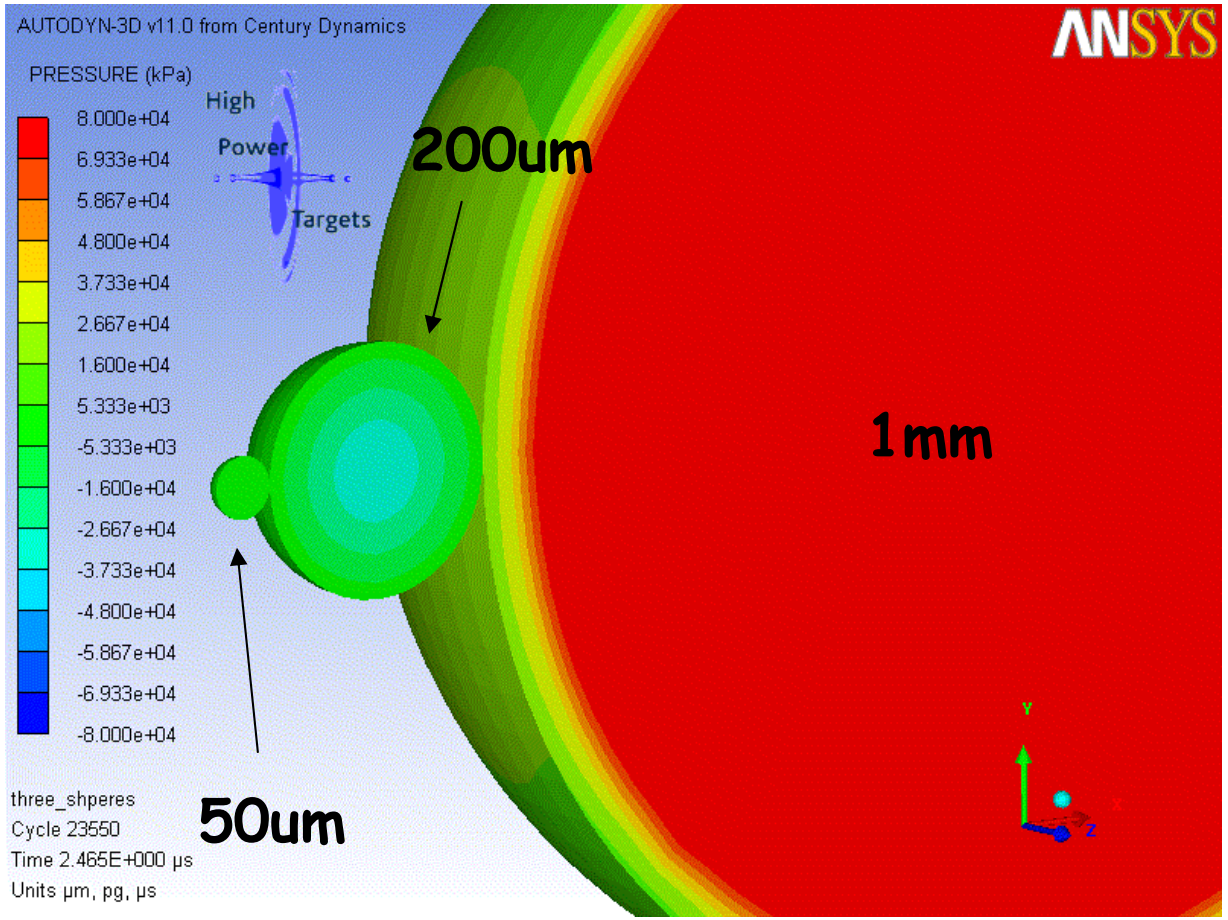
Jet velocity = 10 m/s

(100 kg in 8 seconds)

Difficult to measure!

Elastic stress waves and thermal expansion

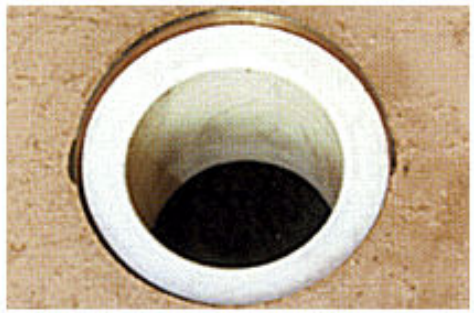
The simulations show that smaller particles have higher resonance frequencies and dissipate their energy faster than bigger particles

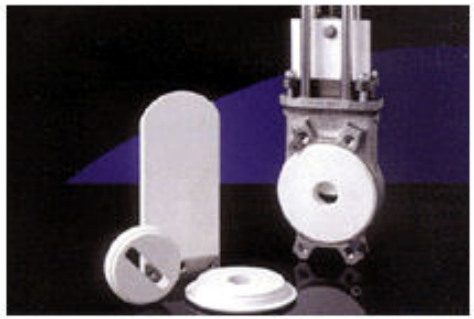


Erosion

Is a standard issue encountered in certain flow regimes

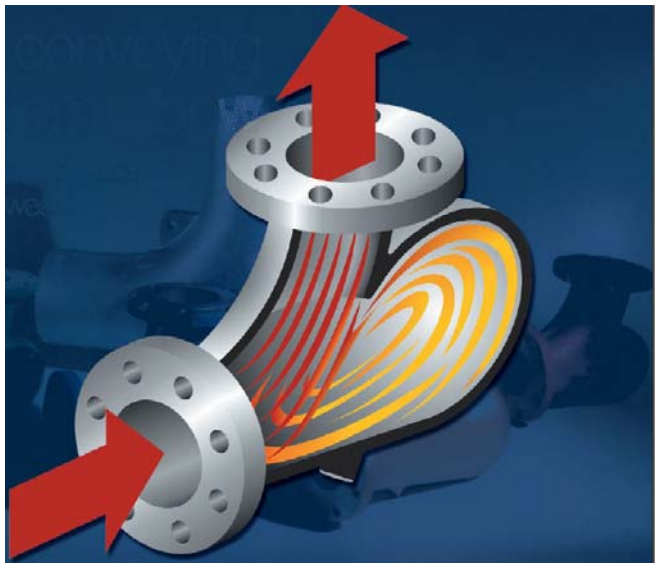
There are solutions available and most problems can be avoided by careful engineering design of the plant

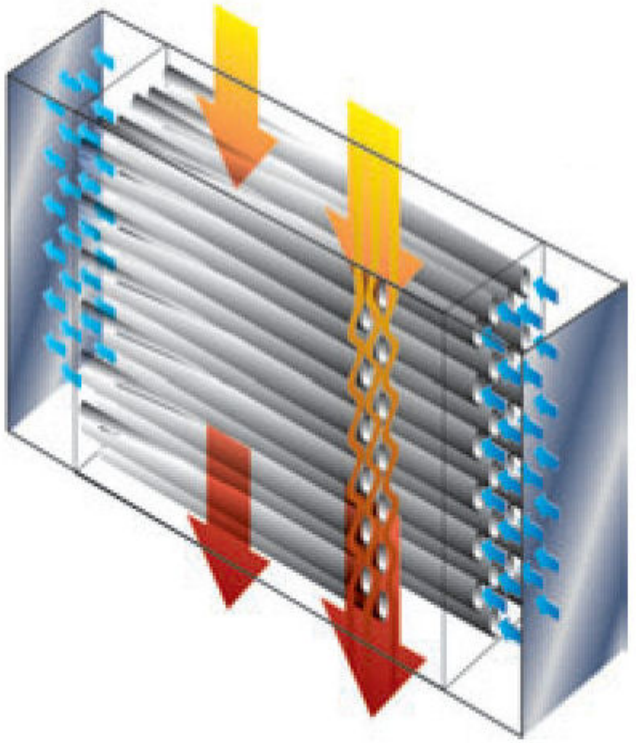




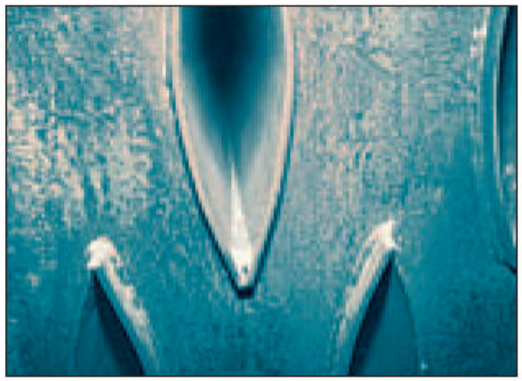
Ceramic linings →

Erosion: some existing solutions





Turbulent energy dissipation



Specially designed gravity fed heat exchangers

Disposal and radiological hazard

High-level radioactive waste from the nuclear industry is currently turned into powder before vitrification (using boro-silicates)!