Target activities at RAL

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Presented by Ottone Caretta

Fermilab October 09

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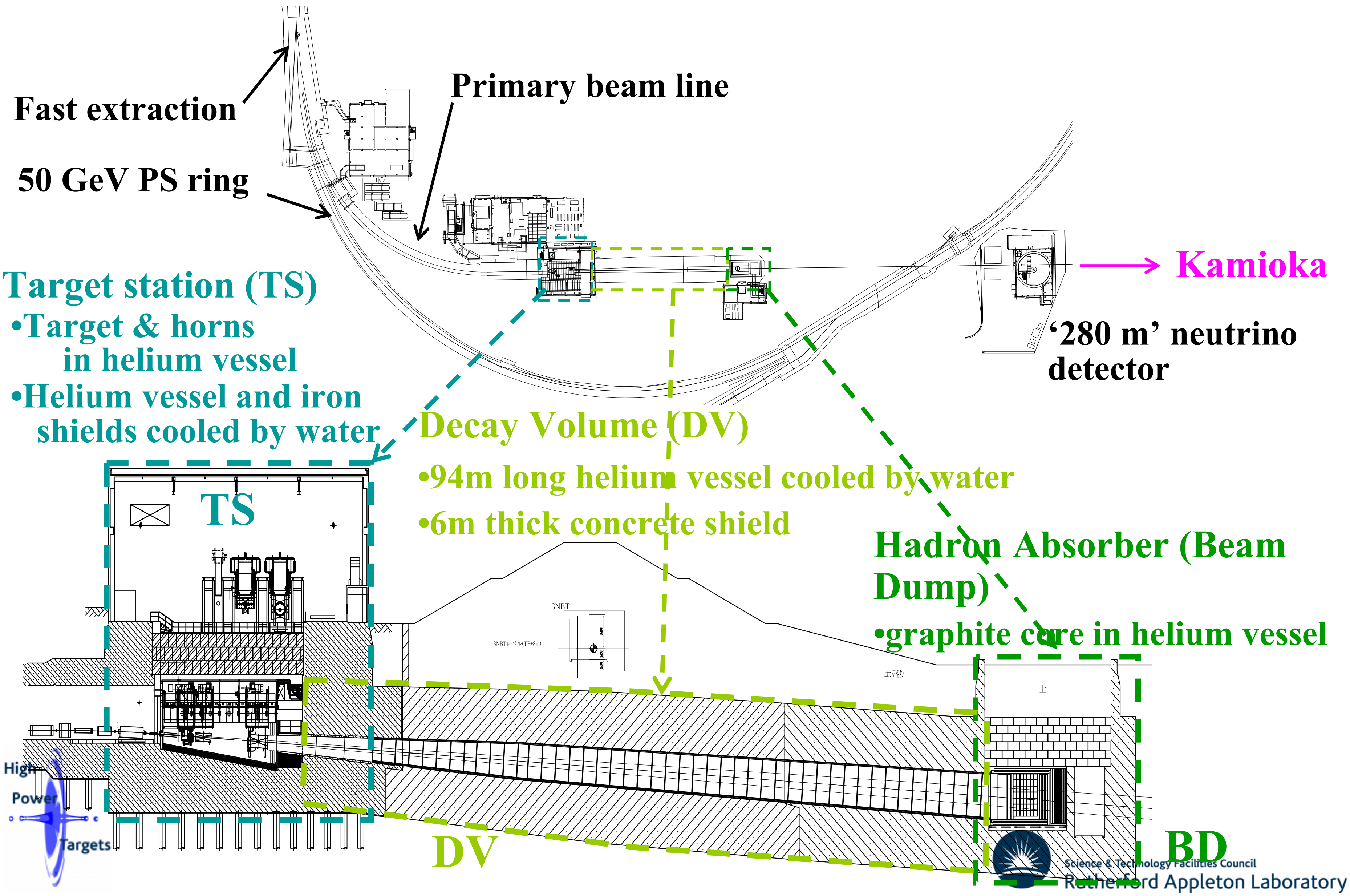
T2K Secondary Beam Line



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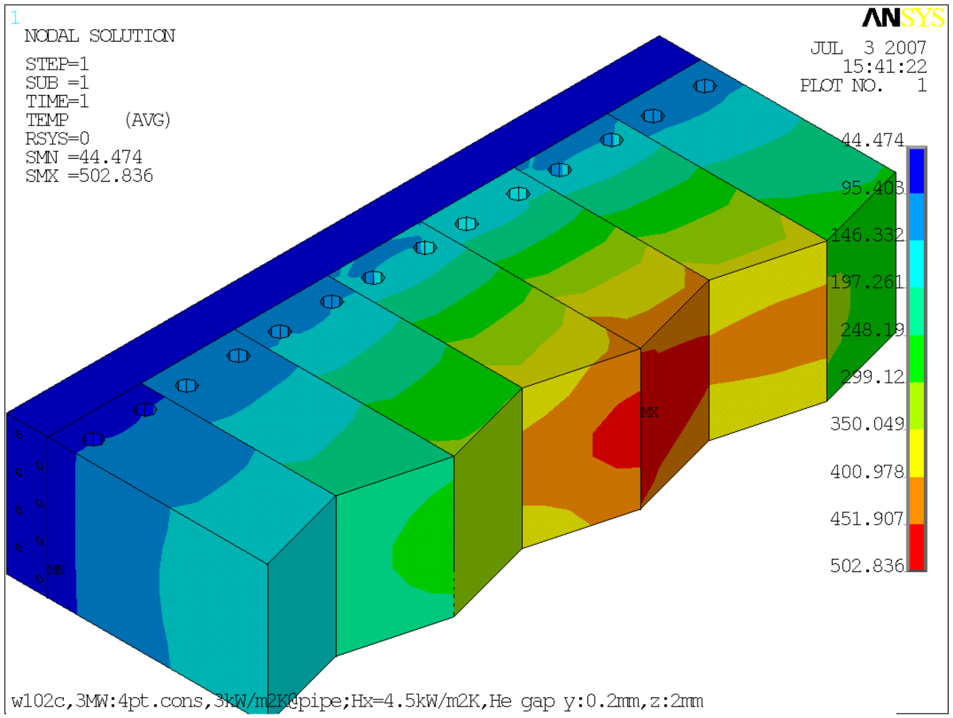
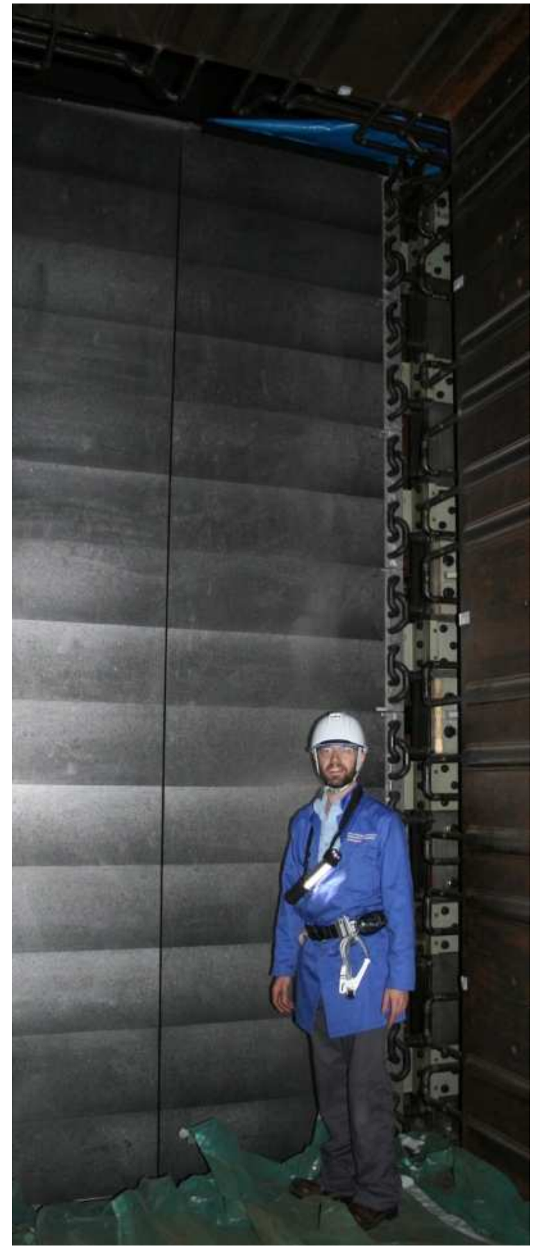
3-4 MW Beam Dump / Hadron Absorber



Beam

Temperature distribution in half layer of Beam Dump operating at 3MW



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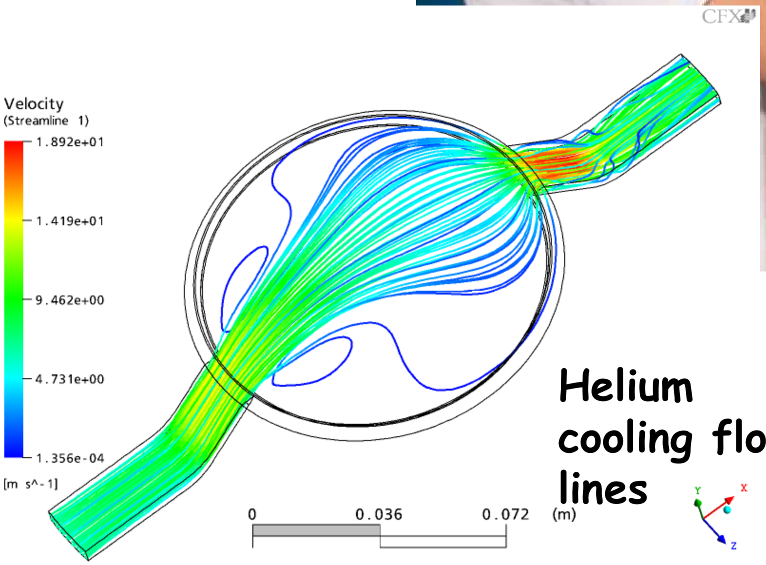
Proton Beam Window + pillow seals. Installed October 2008



Helium cooling flow lines

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Pillow vacuum seal and mating flange

- Successful leak test (3×10^{-9} mbar.l/s achieved November 2007)

Seal foils (surface roughness, Ra = 0.004 μm, Rt = 0.030 μm)

Polished flange (surface roughness, Ra = 0.020 μm)

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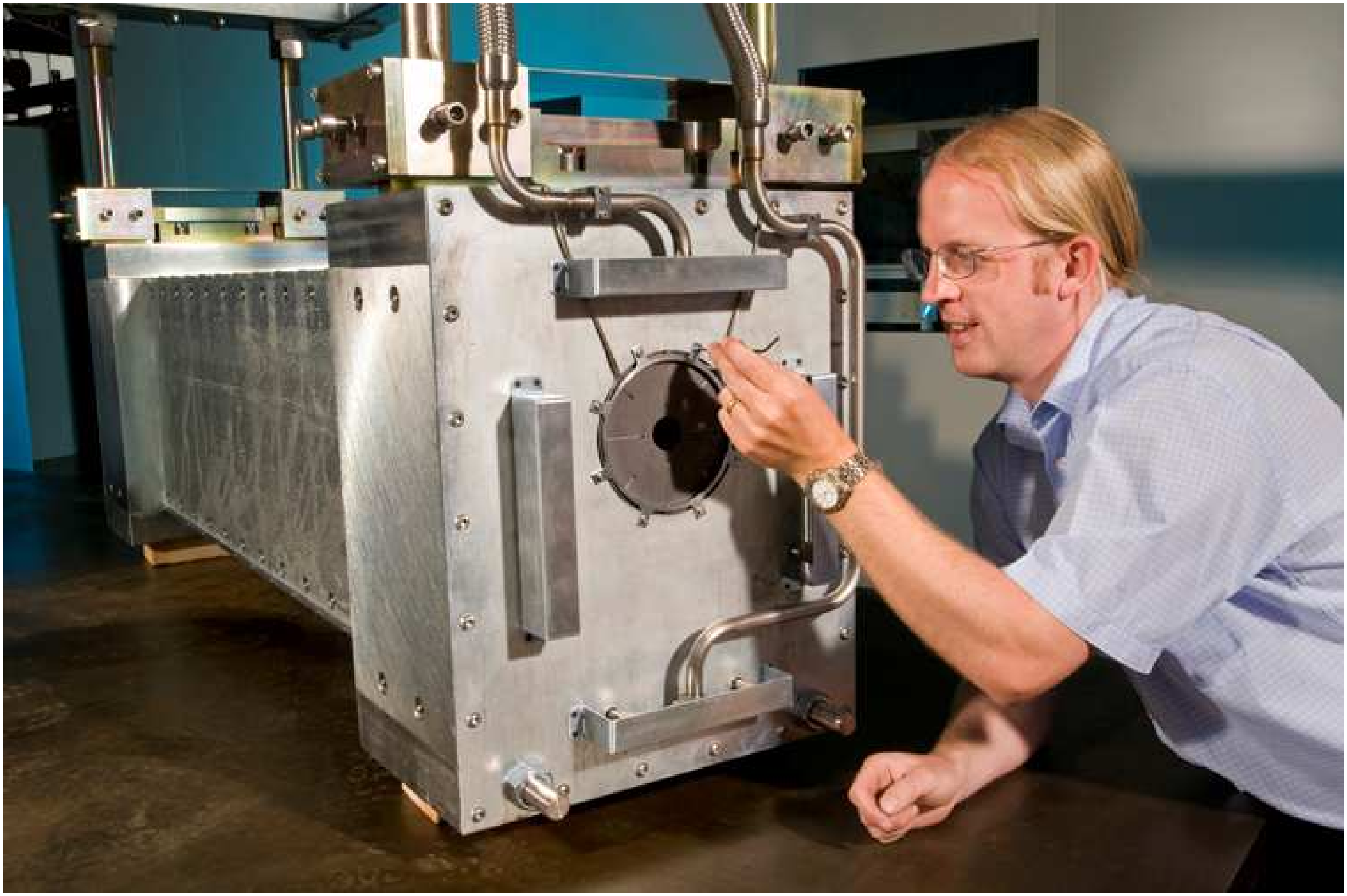
Baffle / Collimator -installation January 2009



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Specification of Phase 1 Target Design

- Graphite rod, 900 mm (2 interaction lengths) long, 26 mm (c.2σ) diameter
- **c.20 kW (3%)** of **750 kW** Beam Power dissipated in target as heat
- Helium cooled (i)to avoid shock waves from liquid coolants e.g. water and (ii)to allow higher operating temperature
- Target rod completely encased in titanium to prevent oxidation of the graphite
- Helium cools both upstream and downstream titanium window first before cooling the target due to Ti-6Al-4V material temperature limits
- Pressure drop in the system should be kept to a minimum due to high flow rate required (max. 0.8 bar available for target at required flow rate of 32 g/s (30% safety margin))
- Target to be uniformly cooled (but kept above 400°C to reduce radiation damage)
- It should be possible to remotely change the target in the first horn
- Start-up date: 1st April 2009

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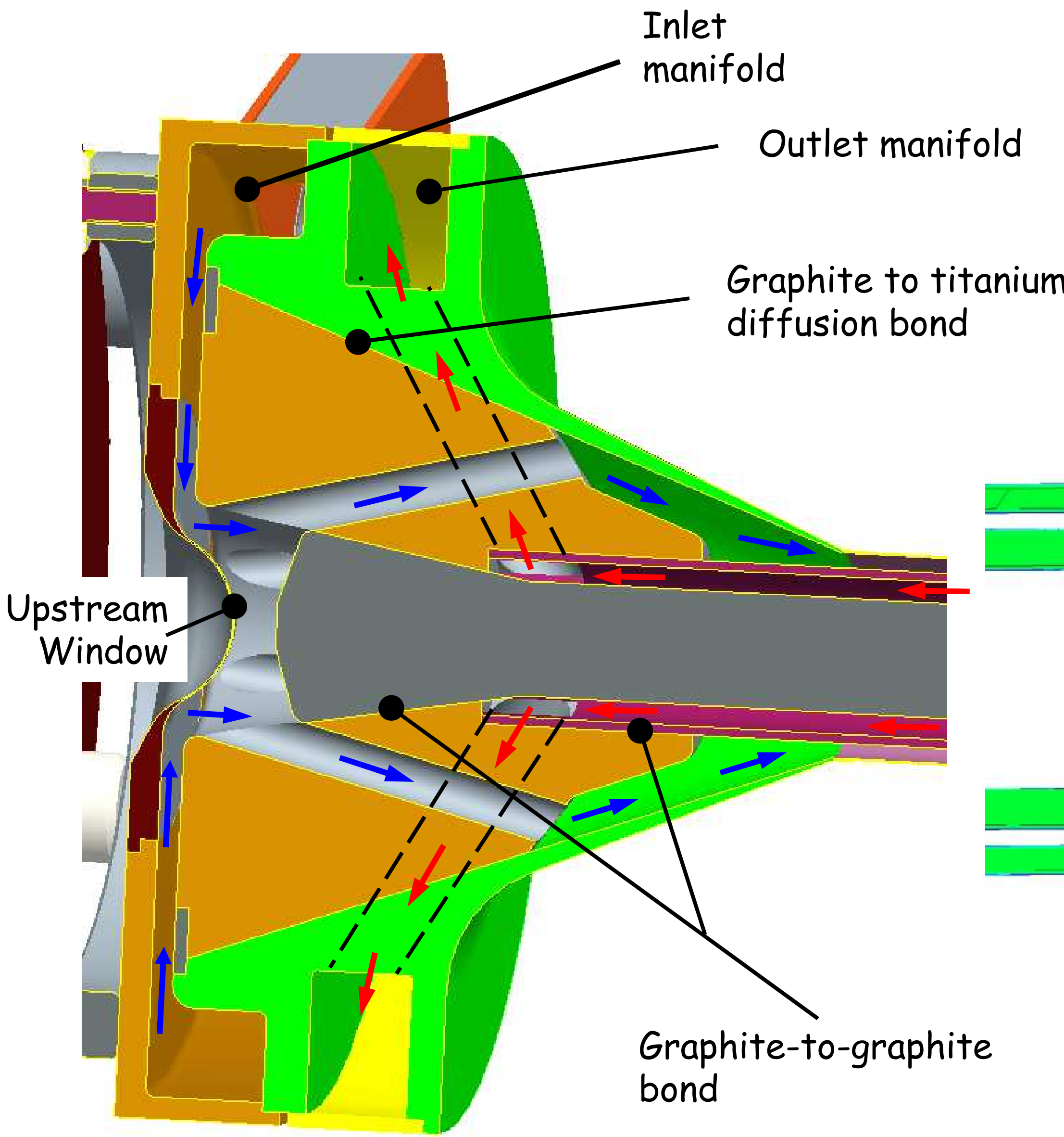
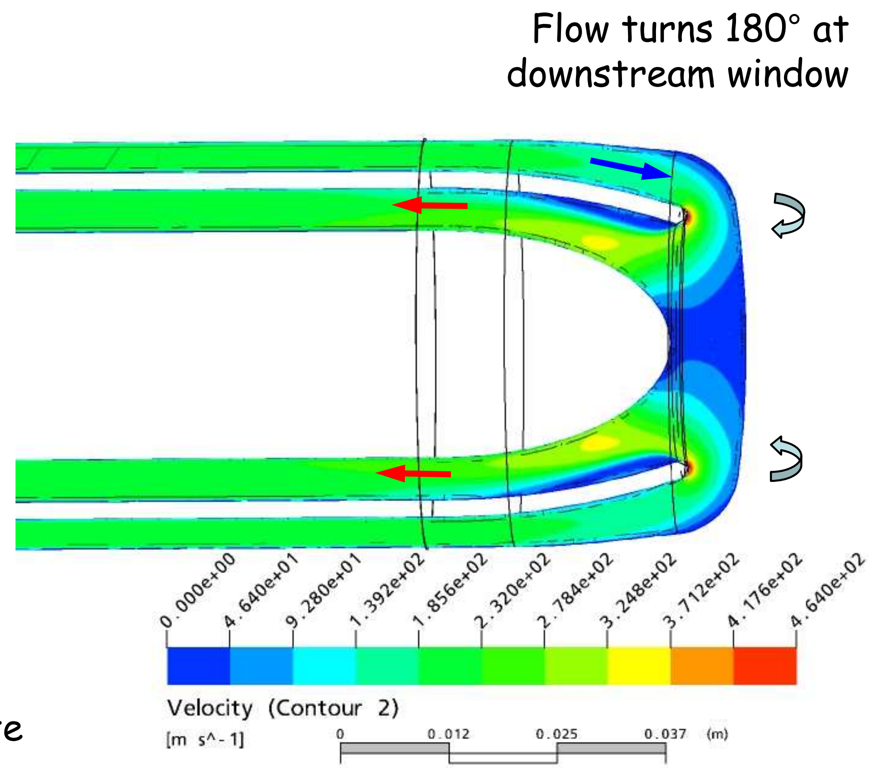
Target Design:

Helium cooling path

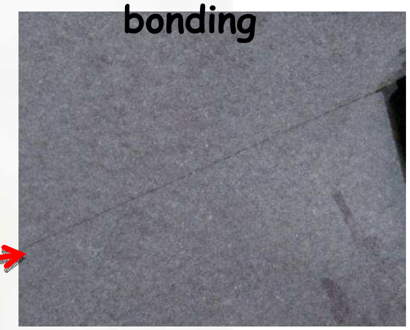




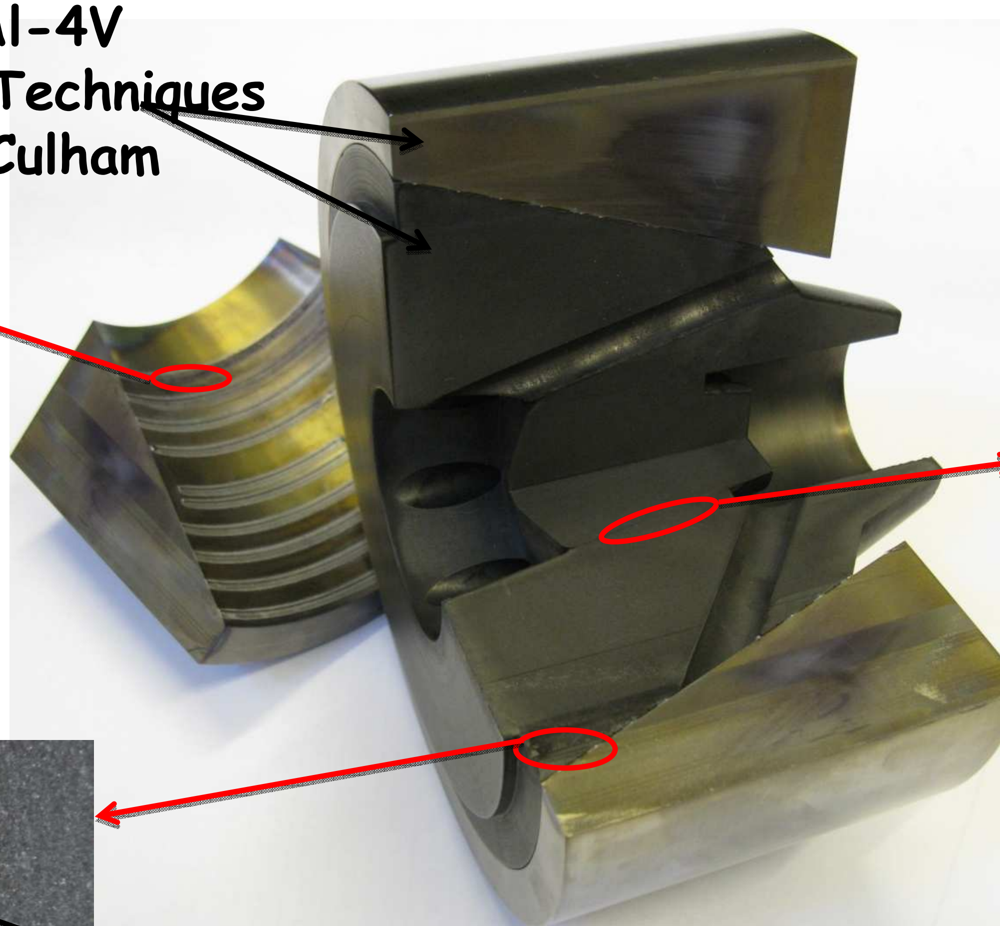
Diffusion Bond + Graphite-Graphite bonding test

IG43 Graphite diffusion bonded into Ti-6Al-4V titanium, Special Techniques Group at UKAEA Culham

Graphite transfer to Aluminium



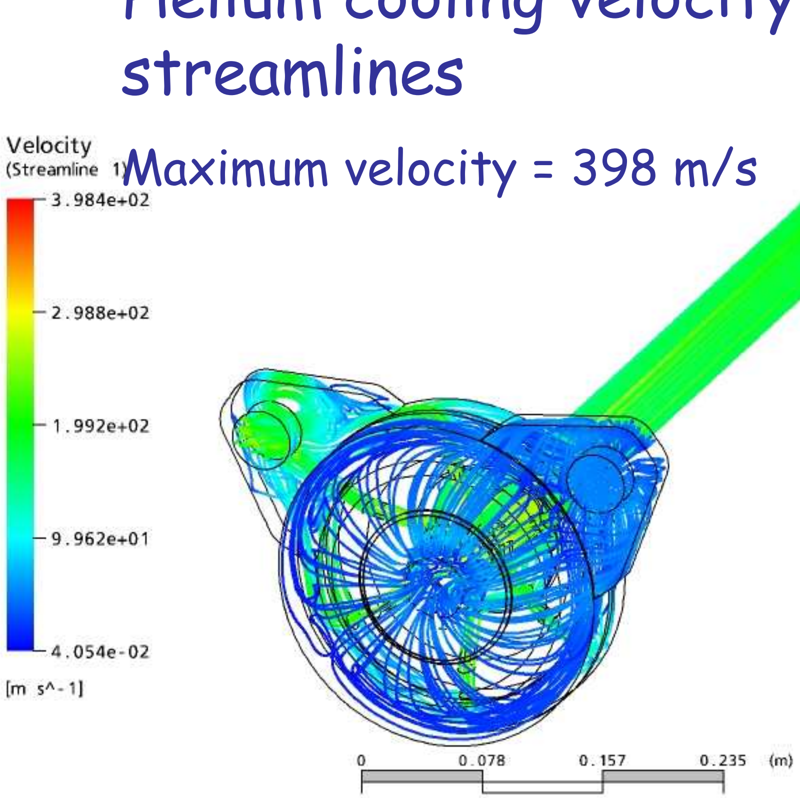
Graphite-Graphite bonding



Aluminium intermediate layer, bonding temperature 550°C
Soft aluminium layer reduces residual thermal stresses in the graphite

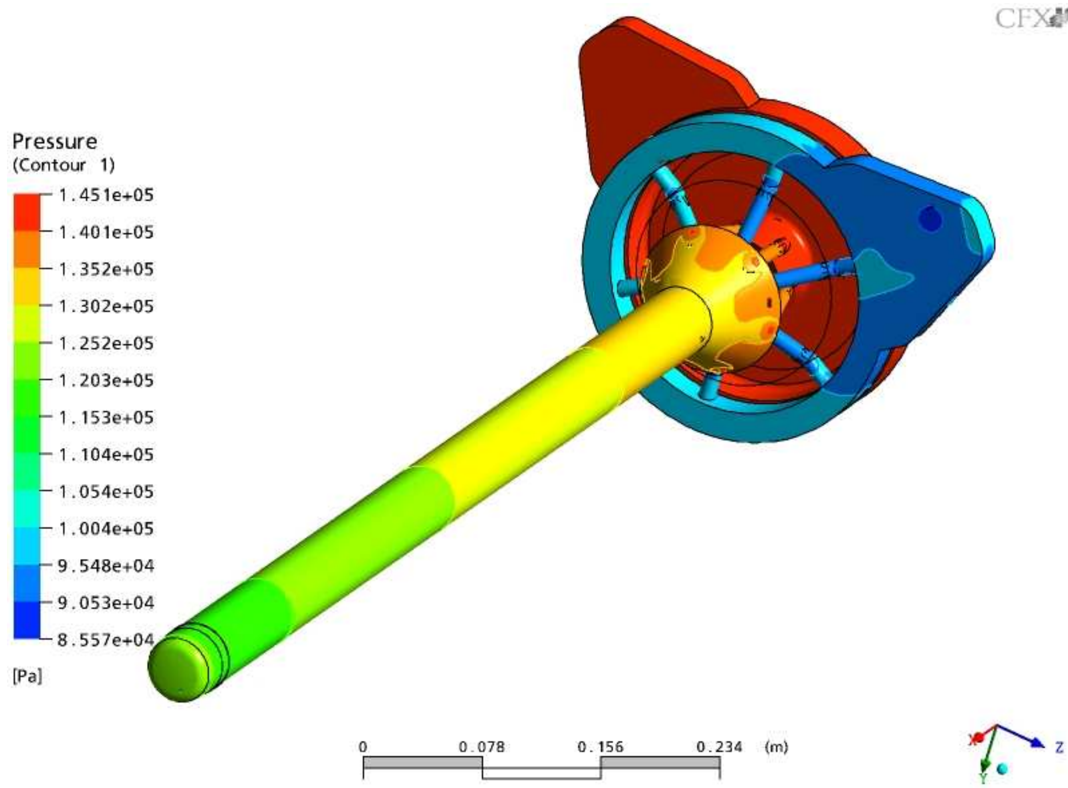
Helium cooling velocity streamlines

Maximum velocity = 398 m/s



Pressures (gauge)

Pressure drop = 0.792 bar



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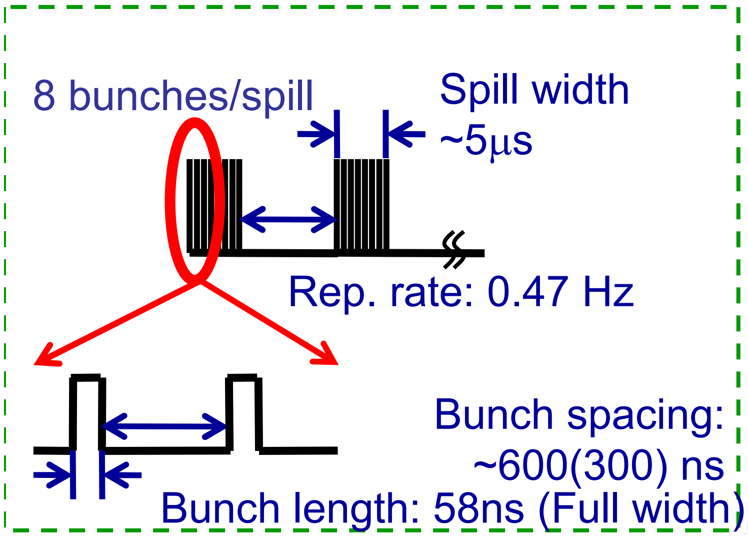
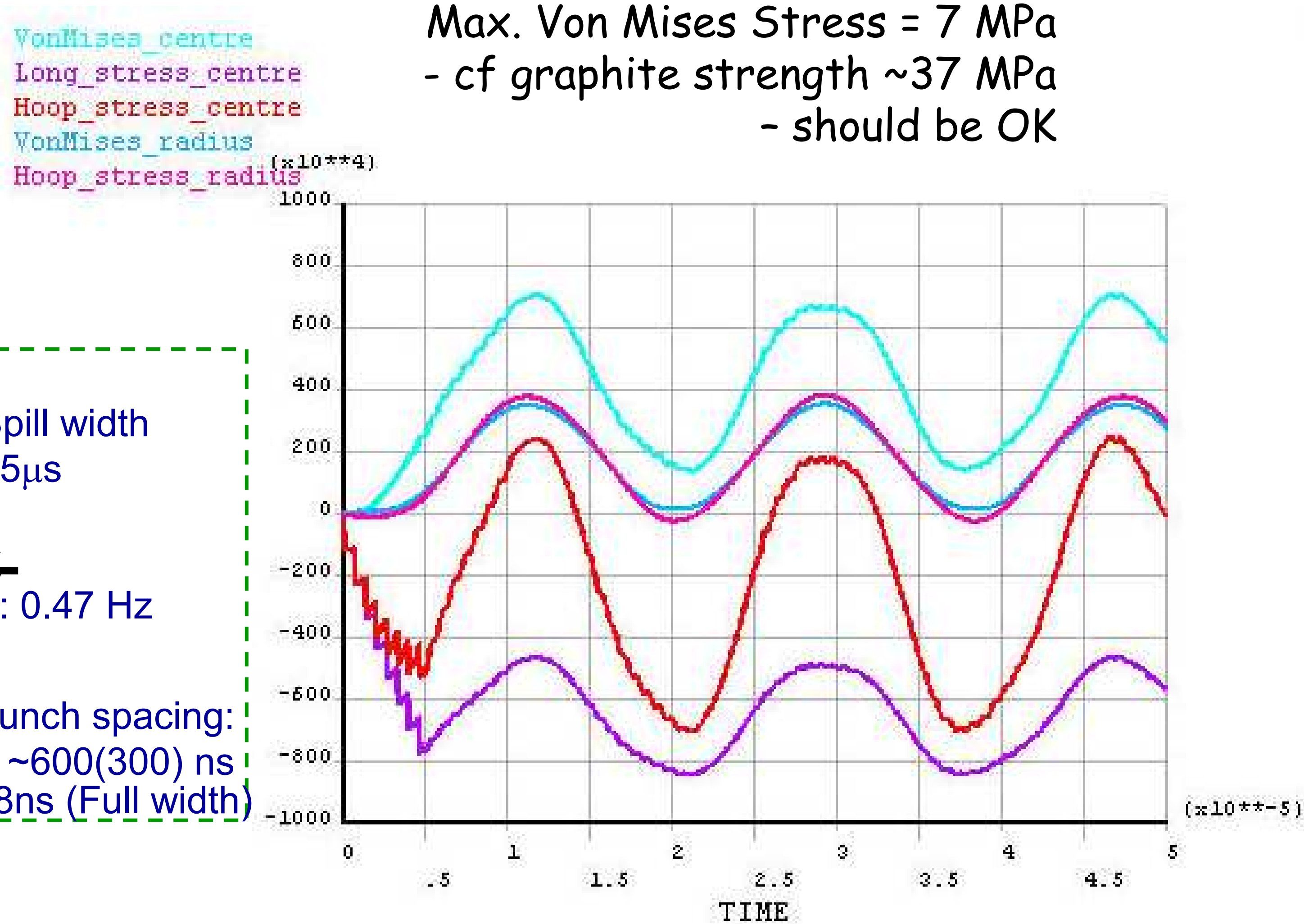
Pulsed beam induced thermal stress waves in target graphite

Max. Von Mises Stress = 7 MPa
- cf graphite strength ~37 MPa
– should be OK



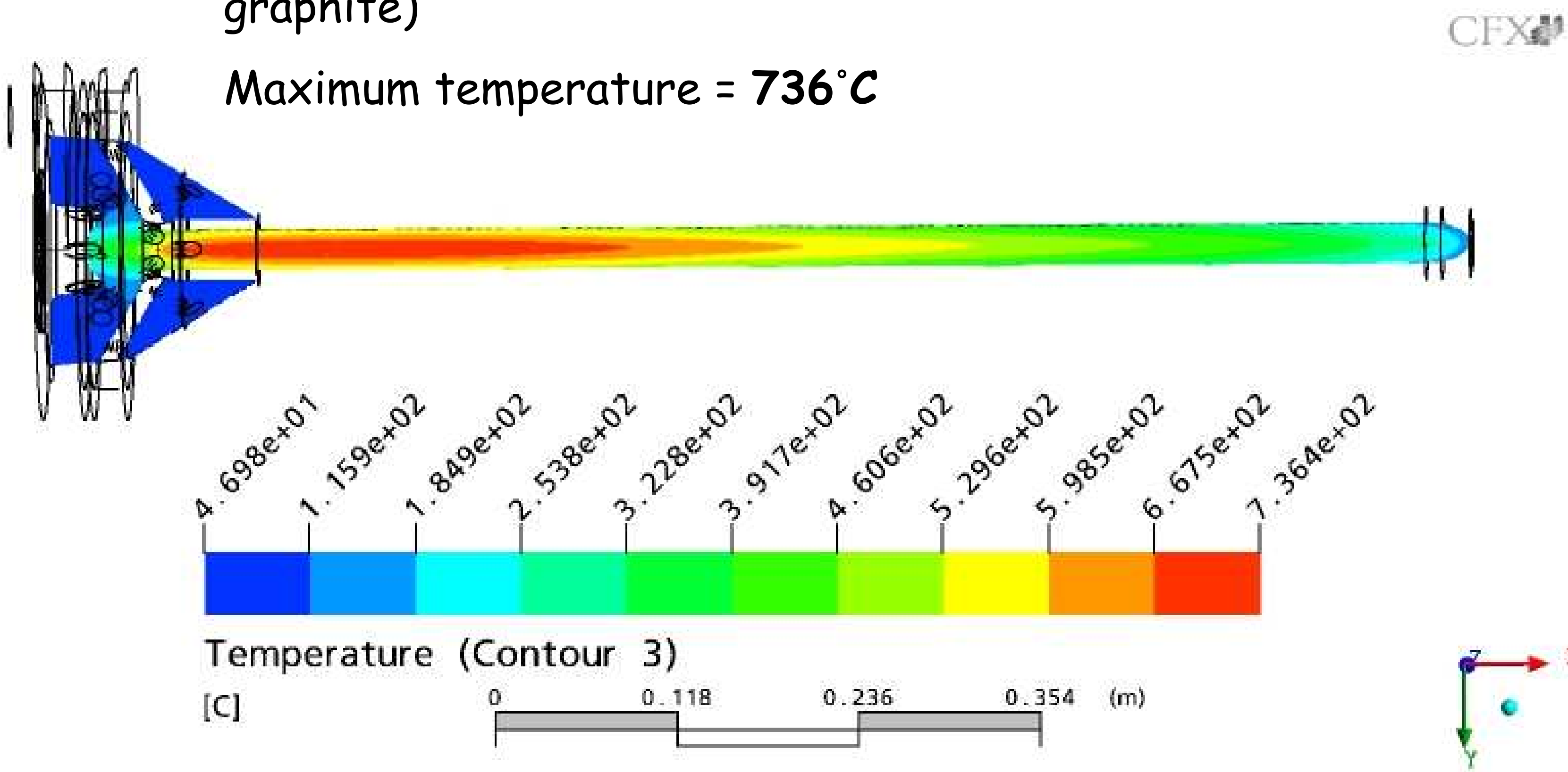


Steady state target temperature

30 GeV, 0.4735Hz, 750 kW beam

Radiation damaged graphite assumed (thermal conductivity 20 [W/m.K] at 1000K- approx 4 times lower than new graphite)

Maximum temperature = **736°C**



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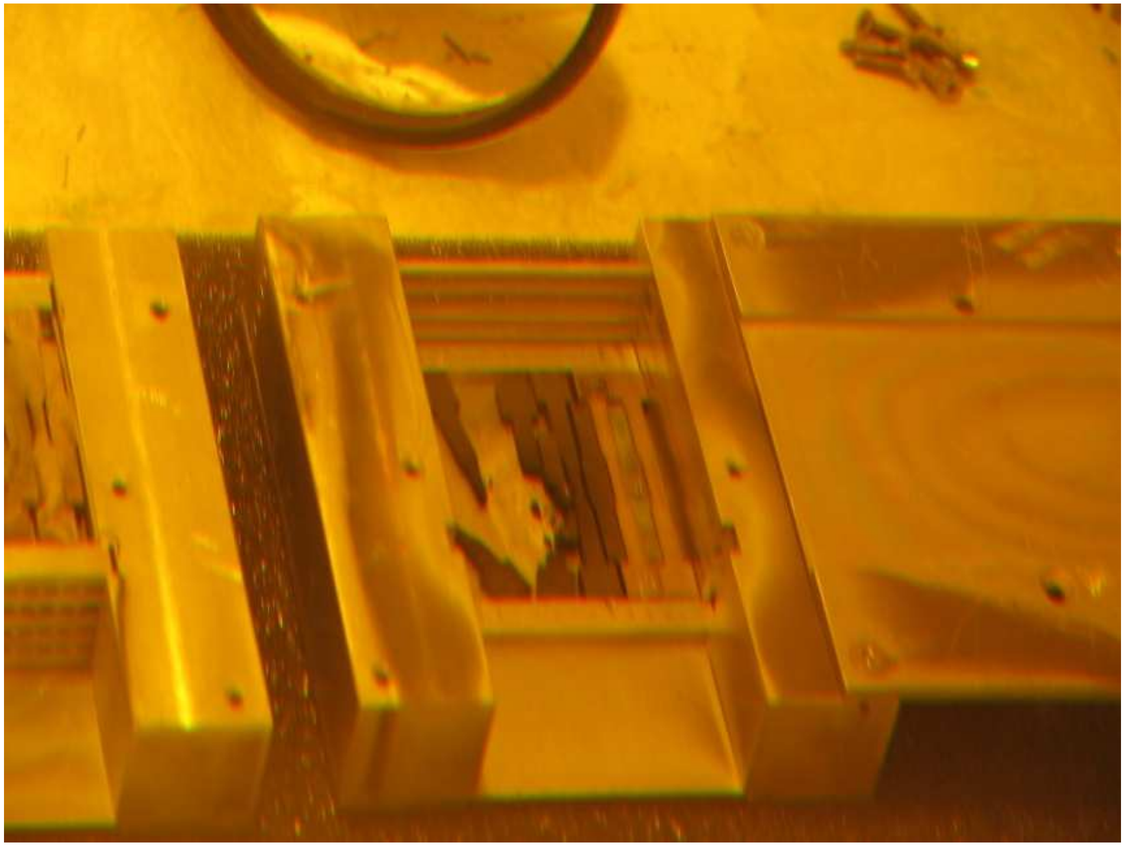
Radiation Damage in IG43 Graphite - data from Nick Simos, BNL



200 MeV proton fluence

~10^21 p/cm2

c. 1 year operation in T2K

IG 43 graphite

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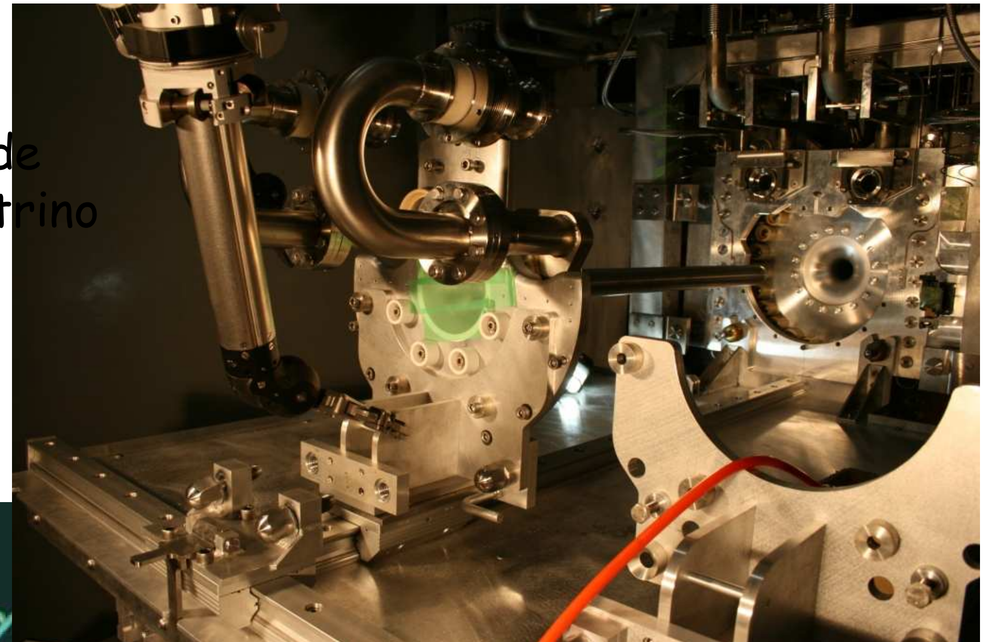
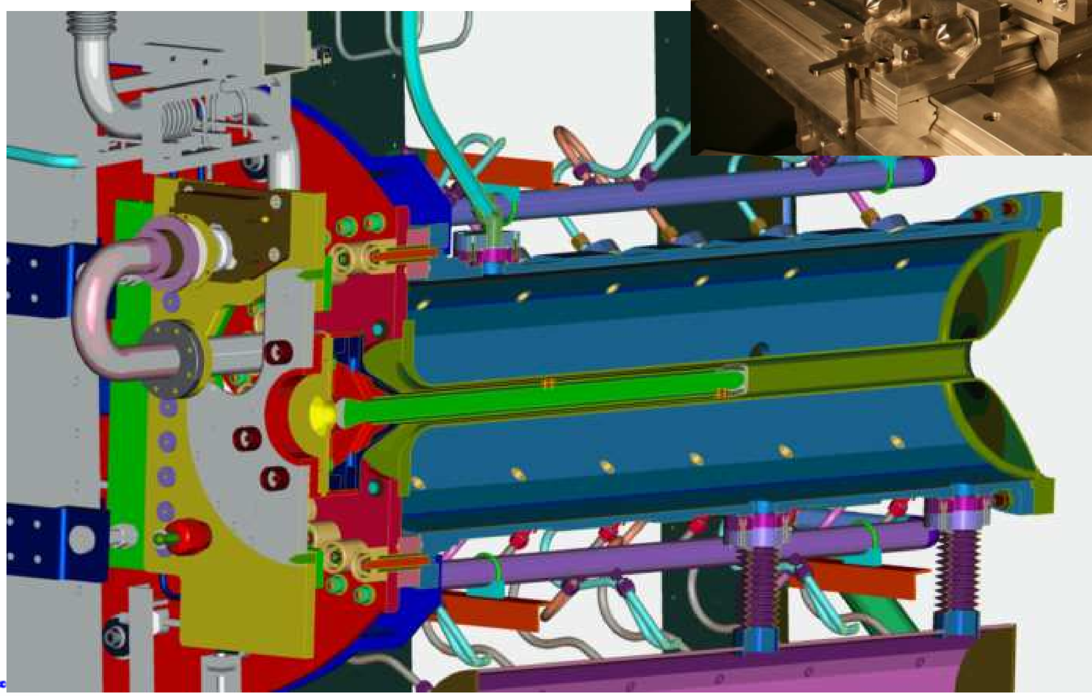
What are the limits for solid targets?

Pion production target installed inside magnetic horn for 'conventional' neutrino beam (ν_μ -> ν_e oscillations)

First Beam: 23rd April 2009

Phase I :30 GeV, 750 kW beam





5 year roadmap: 1.66 MW

Ultimate: 3-4 MW

Target options?

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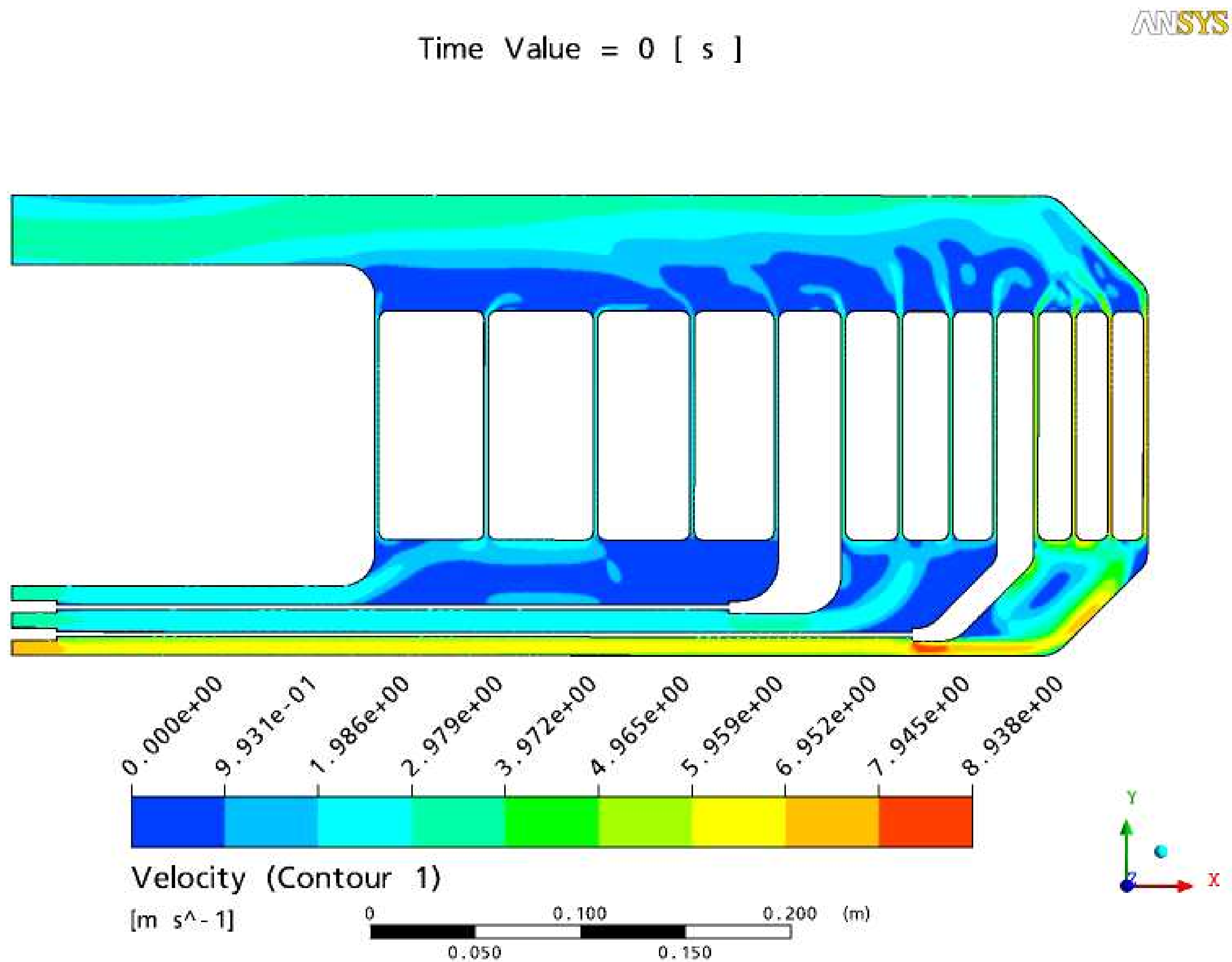

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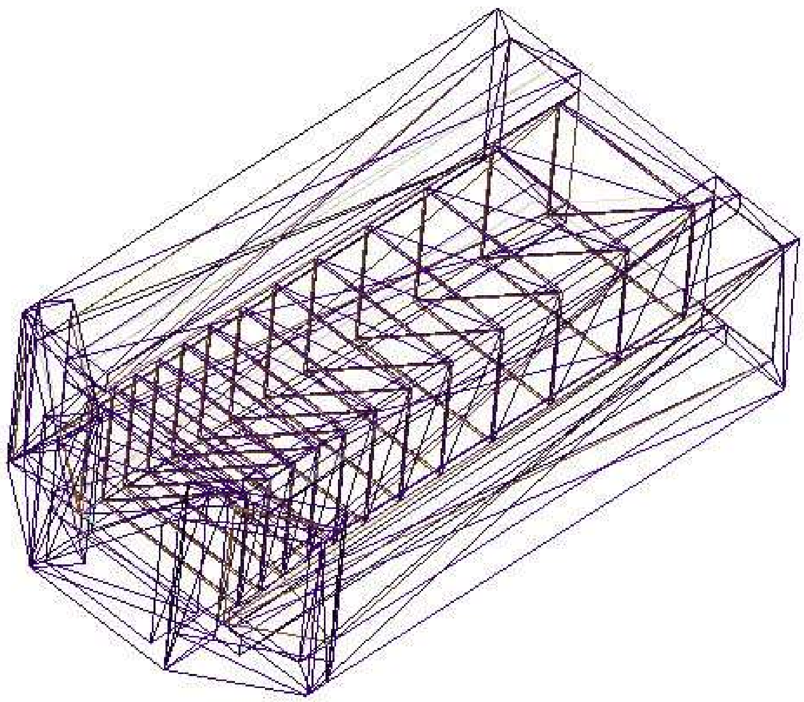
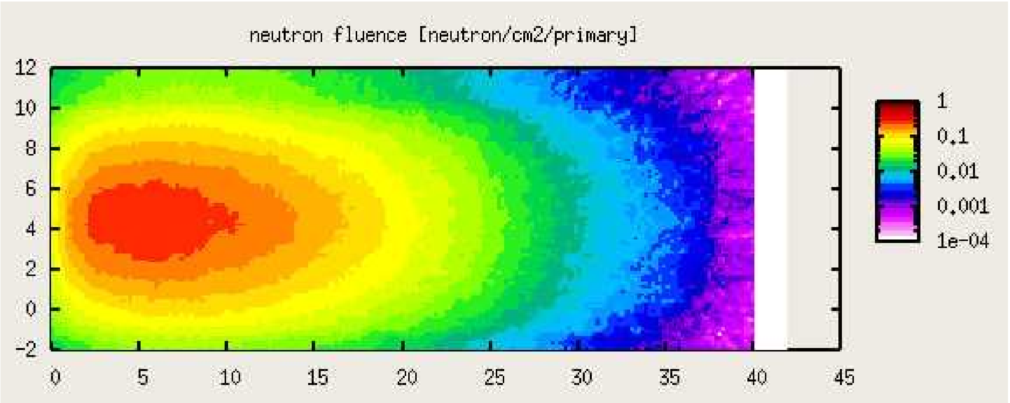
Fluka geometry of ISIS target





<u>Observations from Fluka model of ISIS target</u>

- More neutrons travelling back from target than going outwards.
- Water in manifolds reduces neutron flux.
- Energy deposition focused towards front end of target

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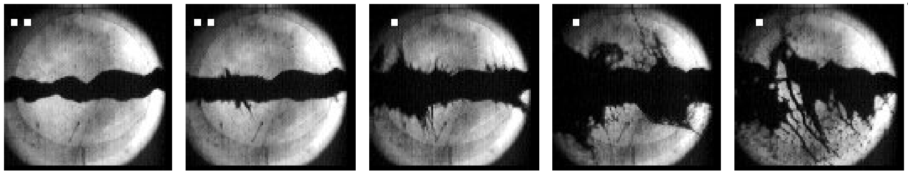
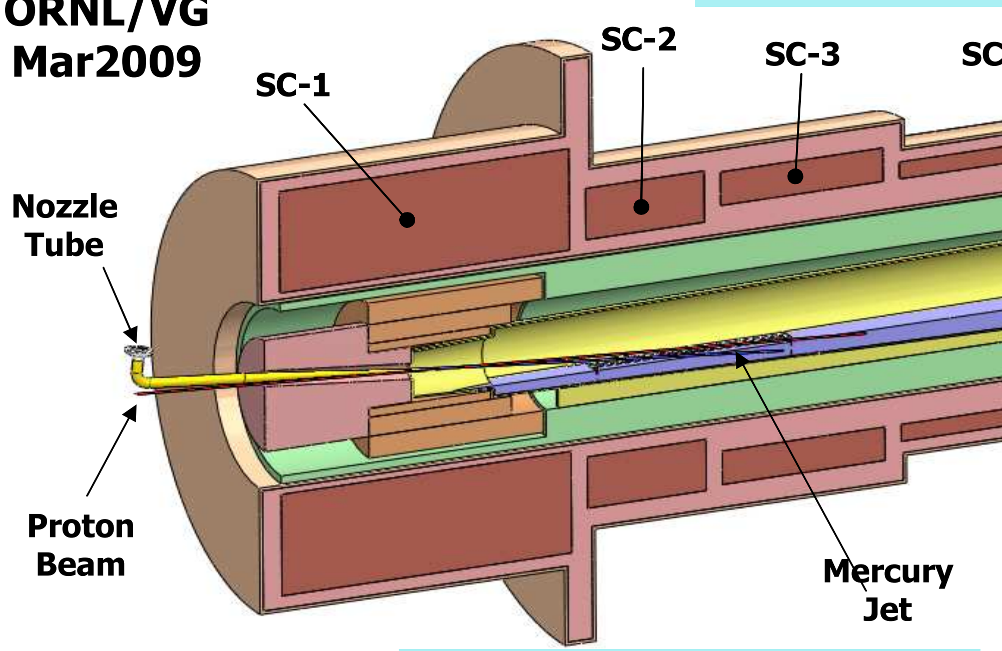
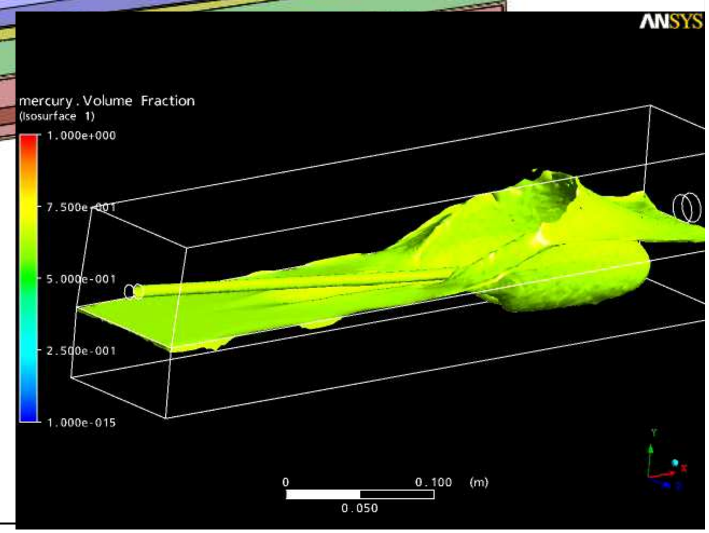
Mercury jet target is 'already broken' - Neutrino Factory / Muon Collider baseline



ORNL/VG Mar2009

... pulsed beam 'splash' mitigated by solenoidal magnetic field (ref. MERIT talk by Kirk MacDonald)





Some issues remain e.g. interaction of jet with mercury pool

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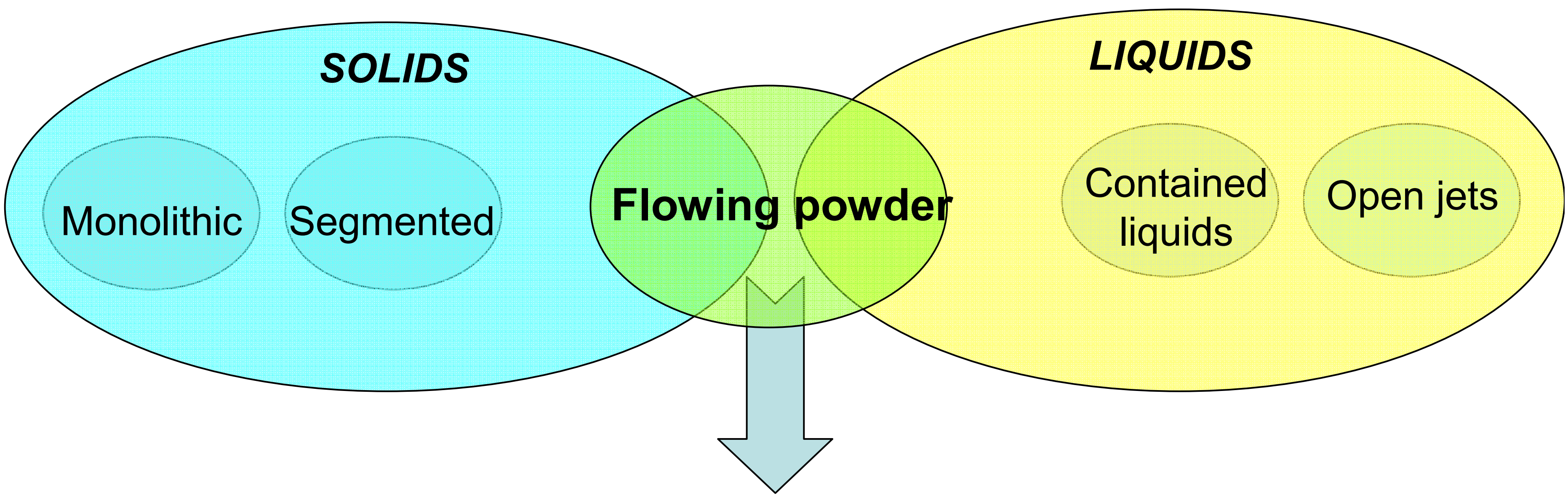
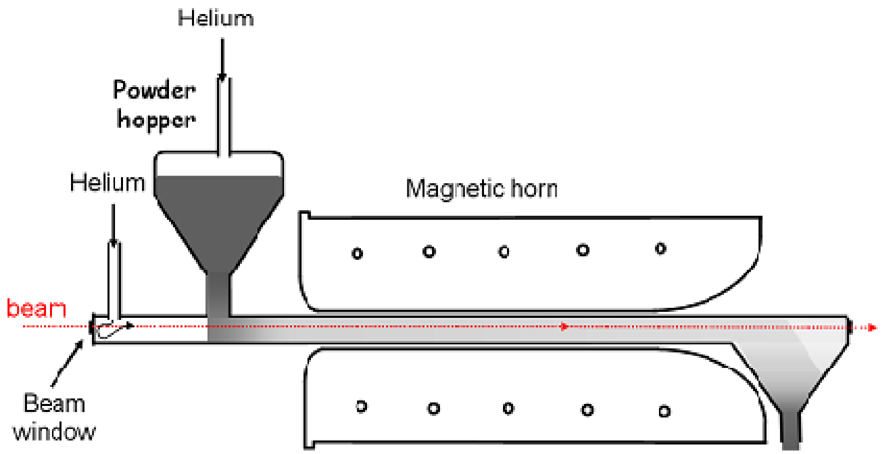
Is there a 'missing link' target technology?

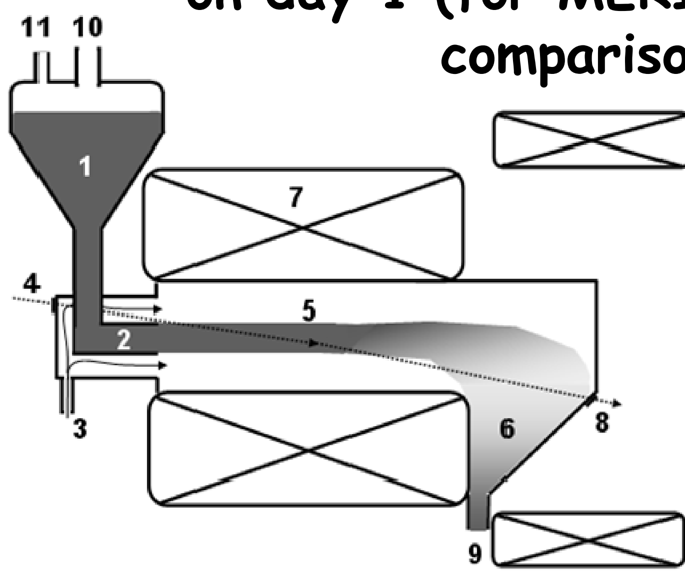


Schematic layouts of flowing powder targets for neutrino facilities

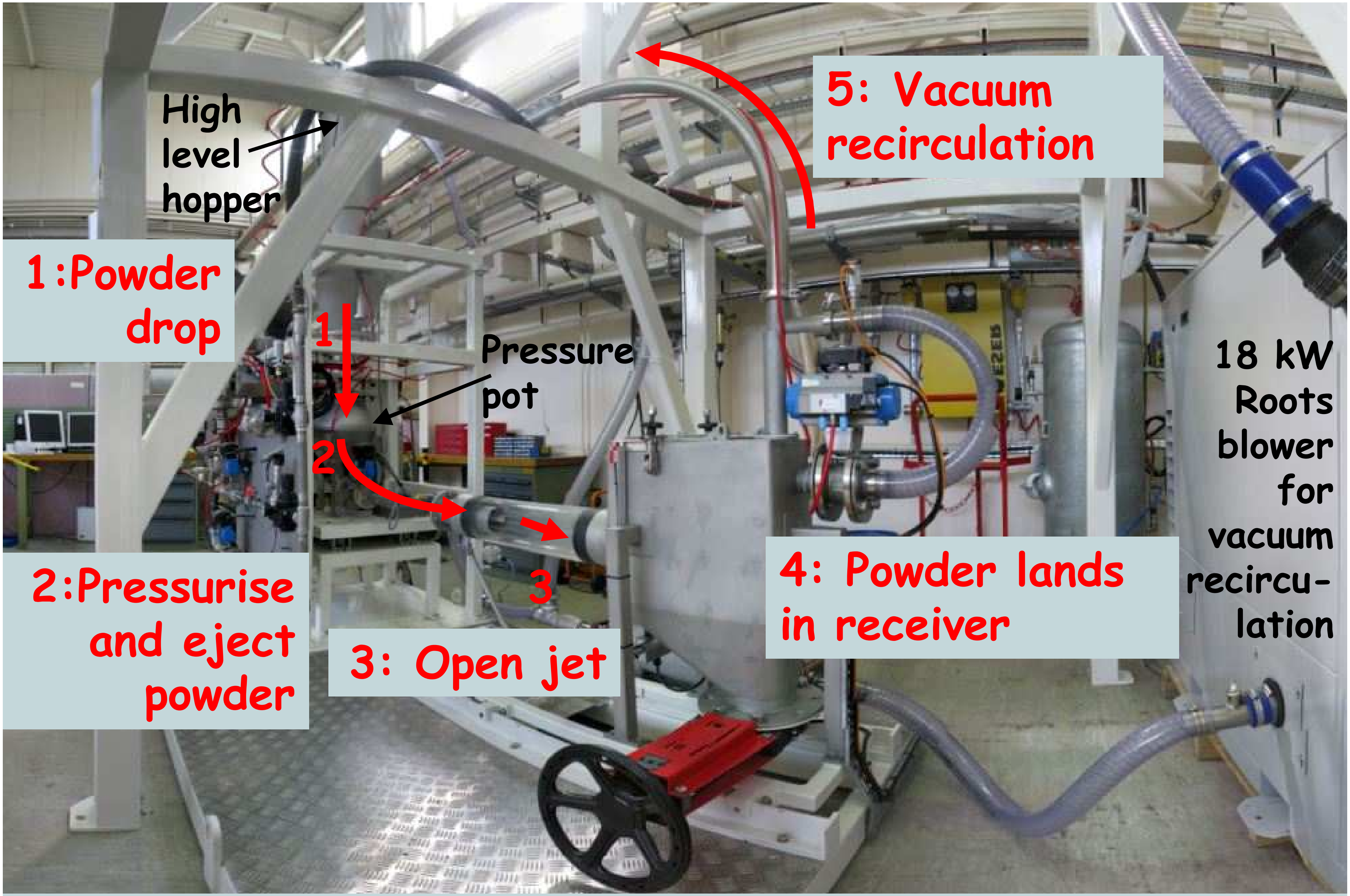
Superbeam target - contained within pipe



Neutrino factory target - open jet configuration used in test rig on day 1 (for MERIT comparison)

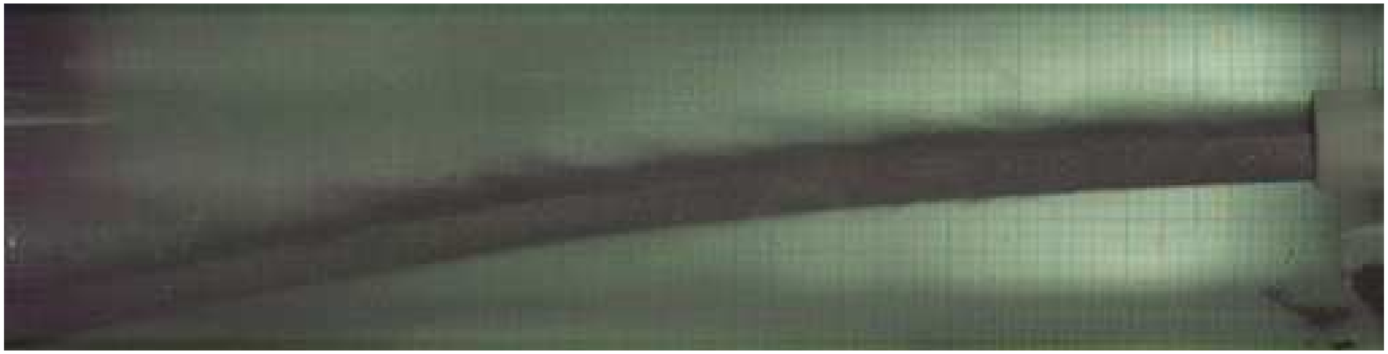


(1) pressurised powder hopper, (2) discharge nozzle, (3) recirculating helium to form coaxial flow around jet, (4) proton beam entry window, (5) open jet interaction region, (6) receiver, (7) pion capture solenoid, (8) beam exit window, (9) powder exit for recirculation, (10) return line for powder to hopper, (11) driver gas line



Powder test rig: open jet configuration

First data runs in March 2009



- 31 injection cycles – 3000 kg powder re-circulated
  - Driving pressure range 2 – 5 bar
- Best quality jet obtained for 2 bar driving pressure
  - Jet Velocity = 3.7 m/s
  - Stable Jet
    - Constant pressure in hopper throughout ejection
    - Constant velocity (top/bottom and over time)
    - Constant dimensions (with distance from nozzle and time)
  - Jet material fraction = **<u>42% ± 5%</u>** ~ bulk powder density at rest

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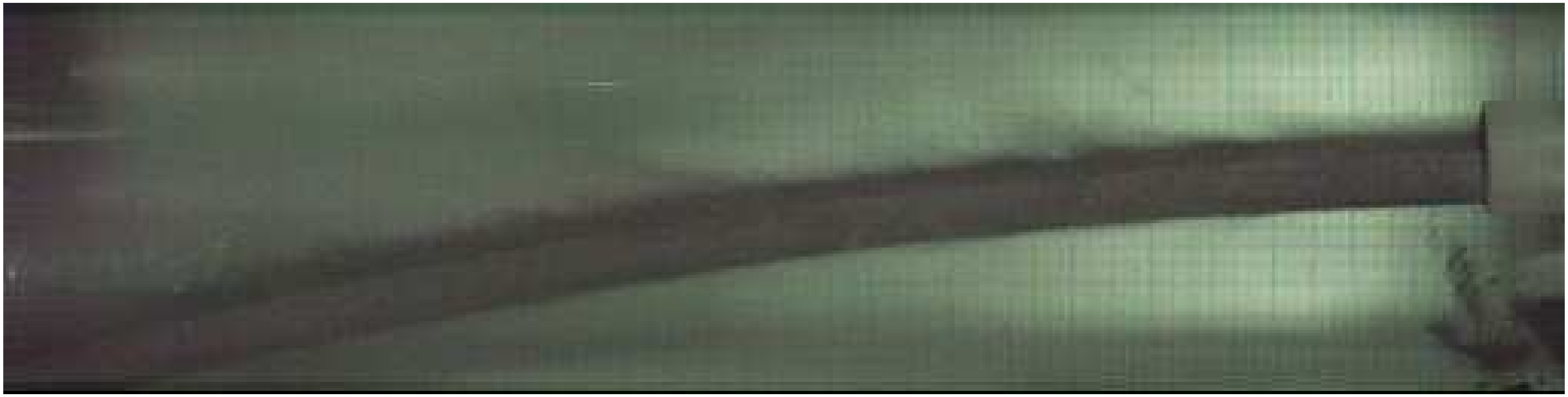
Driving pressure = 2 bar
Jet velocity = 3.7 m/s
Material fraction ~ 42%



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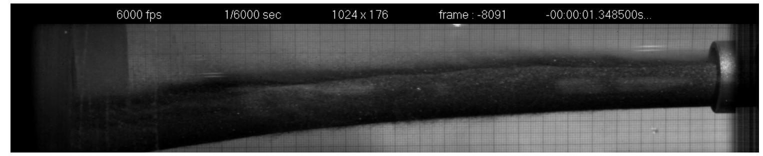
Powder experiments update

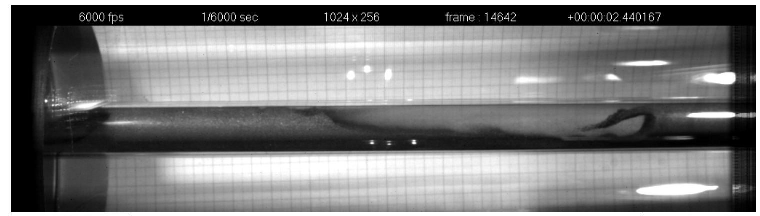
O.Caretta, P.Loveridge and C.J.Densham



High speed image: tungsten powder jet

Achieved a dense and coherent semi-cylindrical Jet:

estimated 42% +-5% v/v. I.E. ~8000 kg/m^3. With a 20mm diameter nozzle and over a 30 cm long jet.

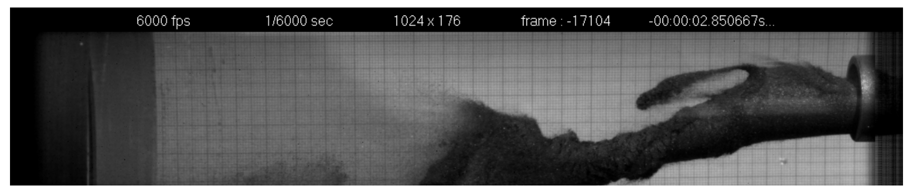


High speed image: tungsten powder flow in a pipe

Little erosion on dense phase conveying components:

the glass components did not scratch yet

Moving components were removed from the proximity of the beam line

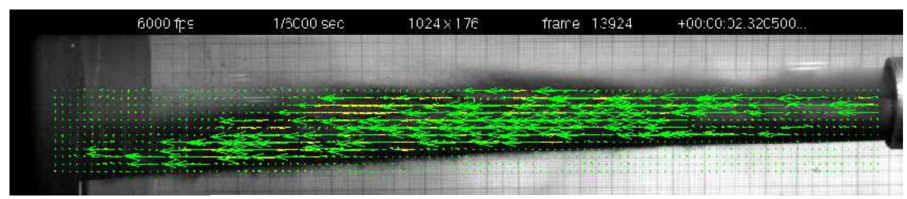


Unstable tungsten powder jet

Consistent dune flow was achieved in a pipe:

flow restarts even with a packed nozzle

Image analysis on the H.S. video of the jet is in progress



Particle Image Velocimetry applied to the jet

So far, the plant conveyed reliably 4.5 tonne of tungsten powder

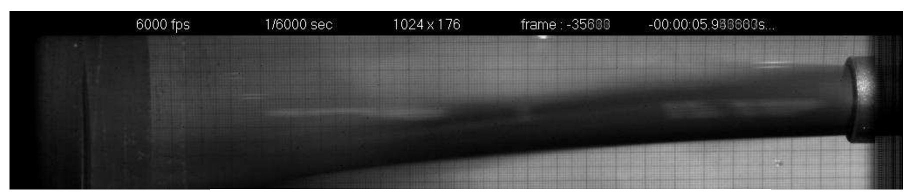


Image analysis: average jet

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