T2K Target & Secondary Beamline - progress towards a neutrino Superbeam?

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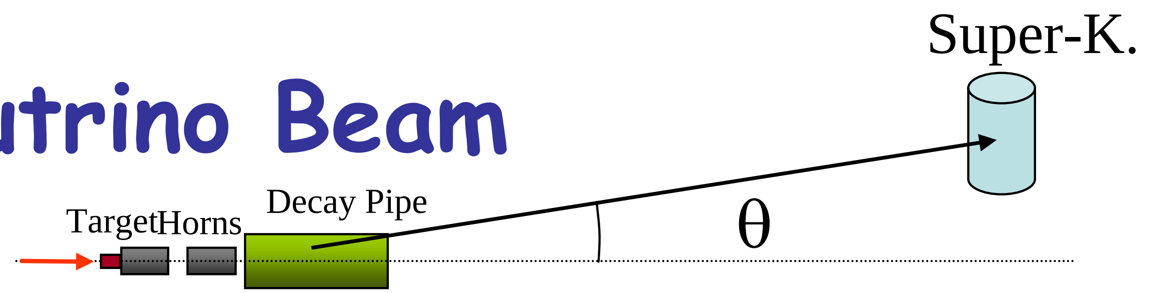
High Power Targets

Science & Technology Facilities Council
Rutherford Appleton Laboratory

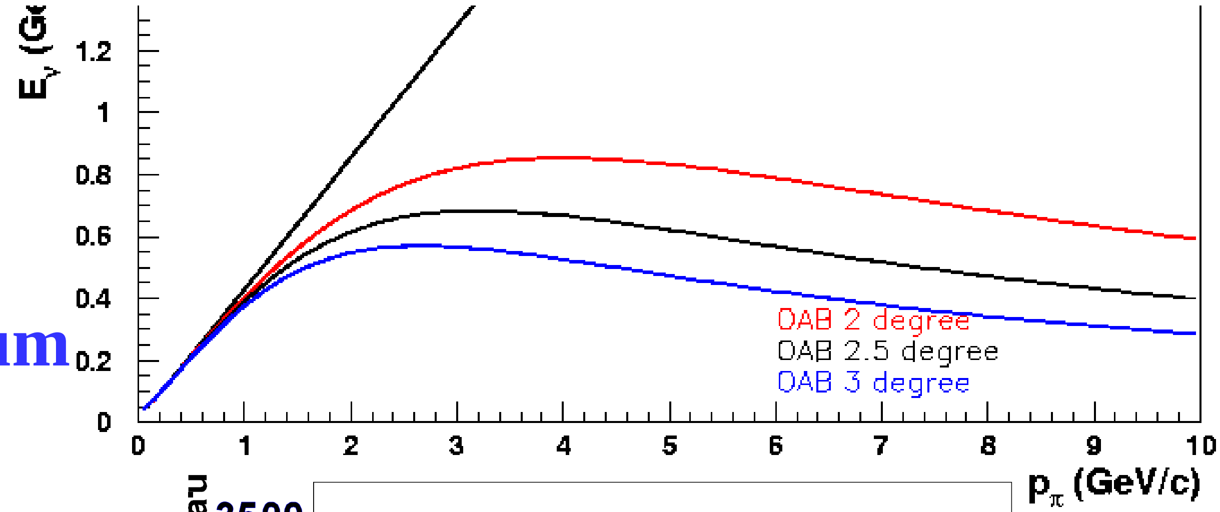
T2K: Off-Axis Neutrino Beam



(ref.: BNL-E889 Proposal)

- **Quasi Monochromatic Beam**
- **x 2~3 intense than NBB**

Tuned at oscillation maximum



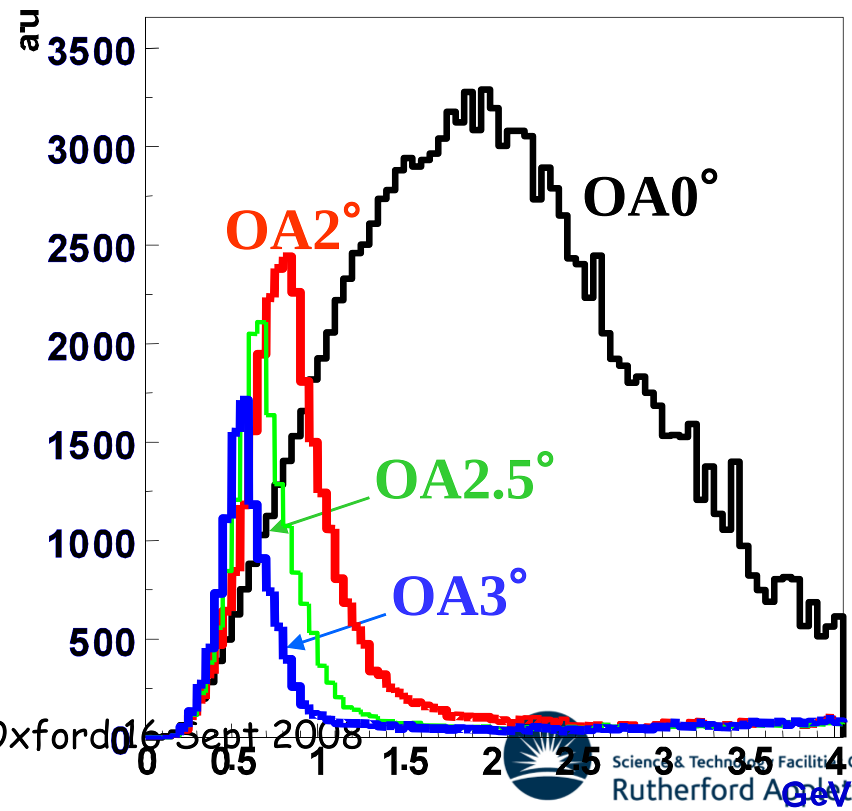
Statistics at SK

(OAB 2.5 deg,1 yr,22.5 kt)

~ 2200 ν_μ tot

~ 1600 ν_μ CC

ν_e ~0.4% at ν_μ peak



Neutrino energy spectrum σxΦ

$$\sigma \propto E$$

— 'Official' T2K Roadmap — (as quoted by Kobayashi-san 2 weeks ago at CARE)

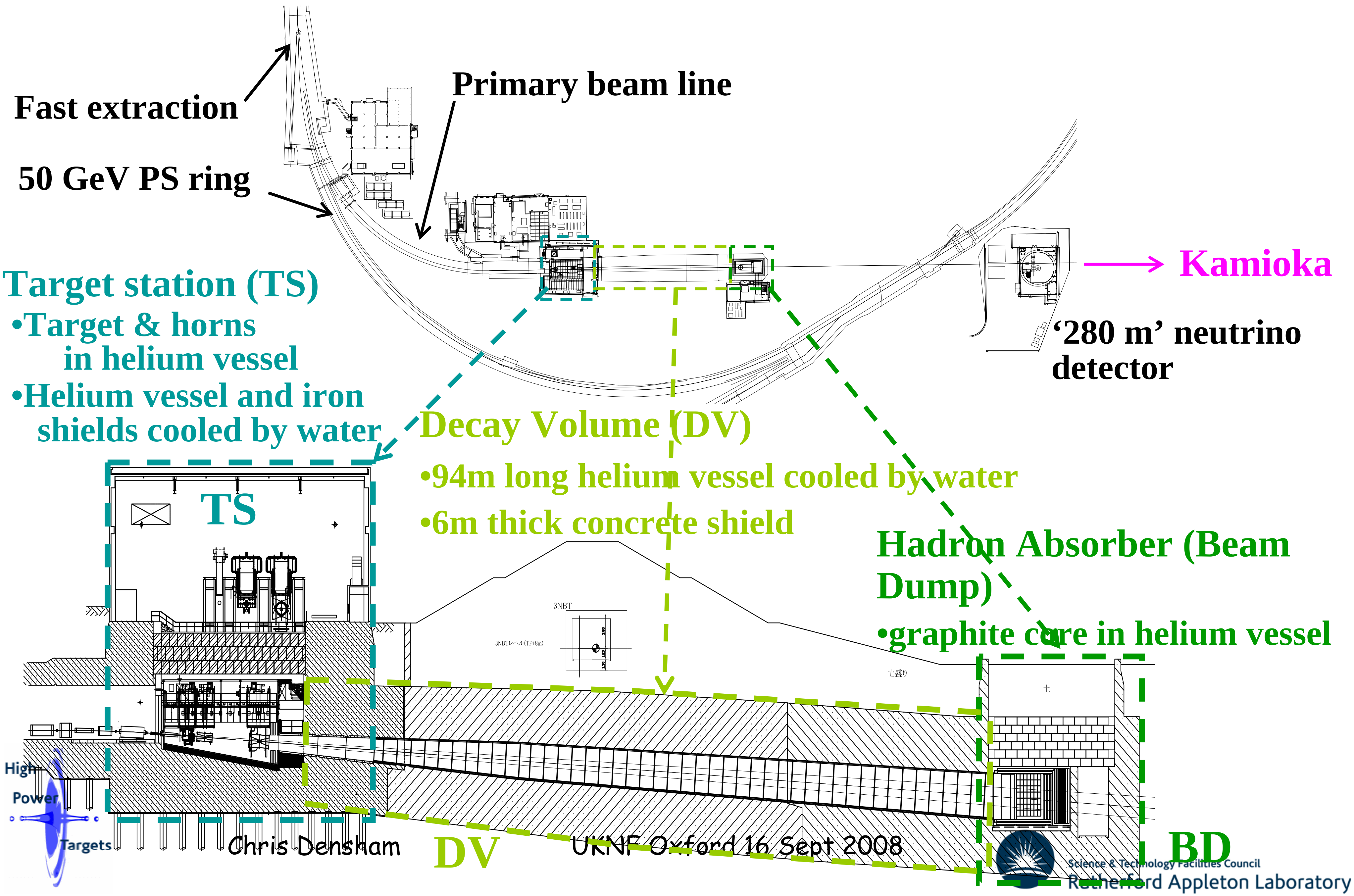
	Day1 (up to Jul.2010)	Next Step	KEK Roadmap	Ultimate? [Not official any more]
Power(MW)	0.1	0.45	1.66	[3-4 MW]? [Original objective]
Energy(GeV)	30	30	30	[50]
Rep Cycle(sec)	3.5	3-2	1.92	
No. of Bunch	6	8	8	[8]
Particle/Bunch	1.2×10^{13}	$<4.1\times10^{13}$	8.3×10^{13}	
Particle/Ring	7.2×10^{13}	$<3.3\times10^{14}$	6.7×10^{14}	
LINAC(MeV)	181	181	400	
RCS	h=2	h=2 or 1	h=1	

After 2010, plan depends on financial situation

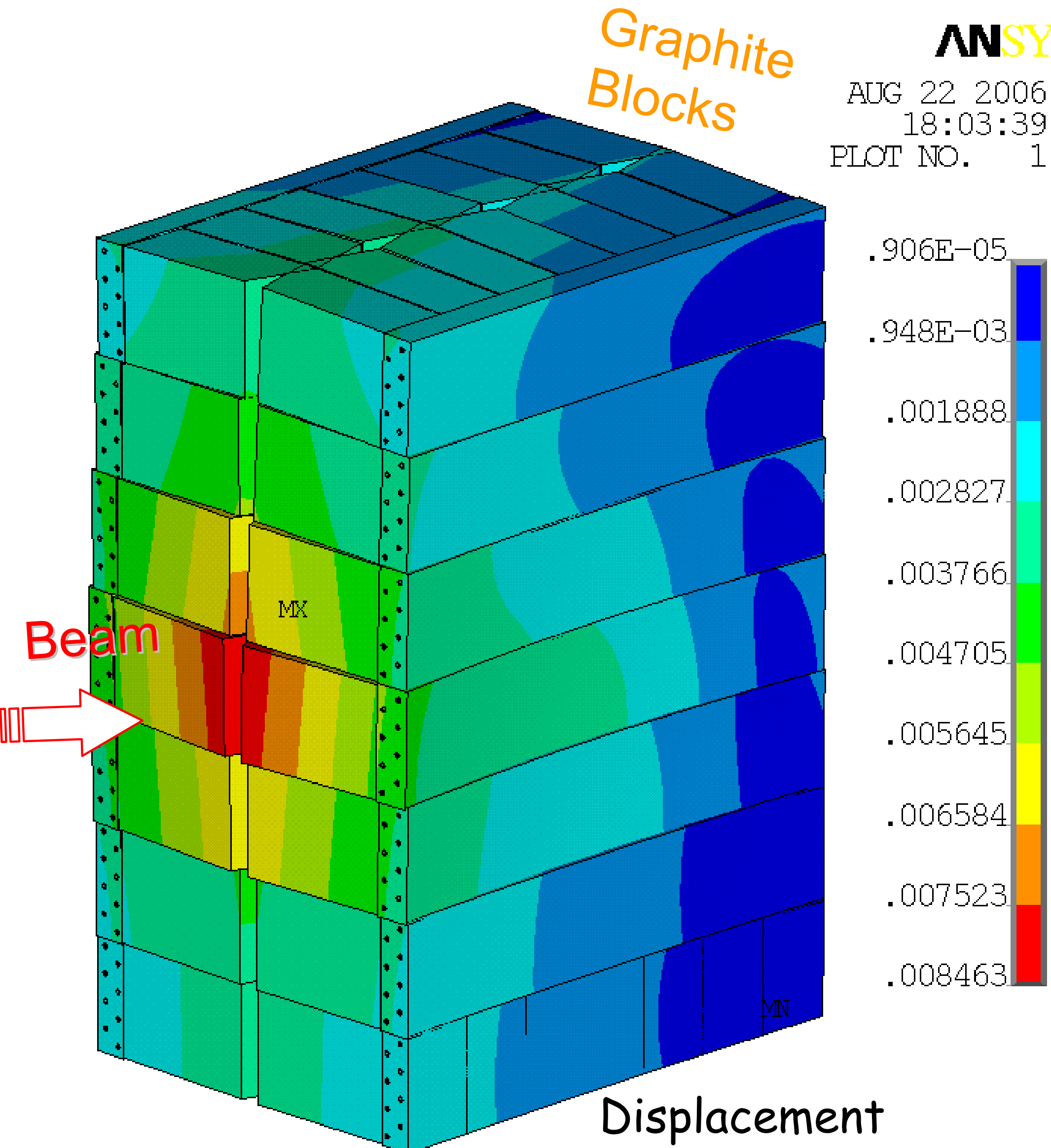
Specified Beam Powers for T2K Secondary Beamline design – towards a Superbeam

- Start-up date: 1st April 2009 (Japanese politics)
- Components built for Phase I: 0.75 MW
  - Beam window
  - Baffle (collimator)
  - Target + 1st horn
- Phase II power: 1.66 MW
  - Expected within 5 years
  - Need to start work on target + 1st horn system upgrade soon
- Components built for ultimate power: 3-4 MW
  - Target station
  - Decay volume
  - Hadron absorber (beam dump)

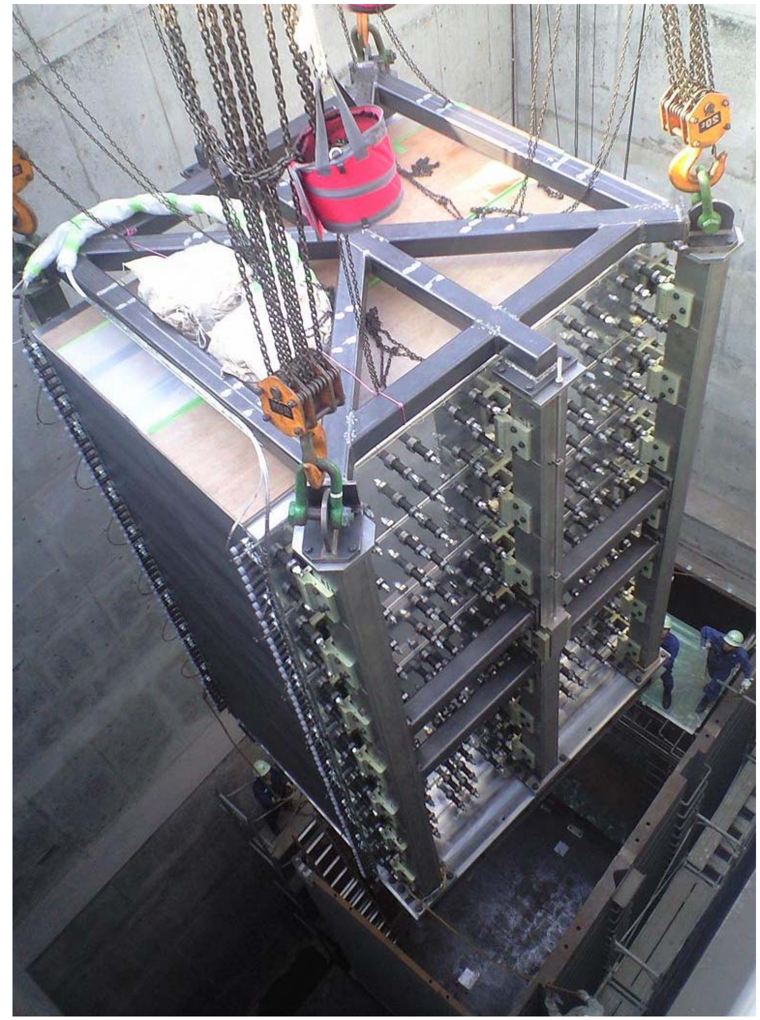
T2K Secondary Beam Line



4 MW Beam Dump / Hadron Absorber

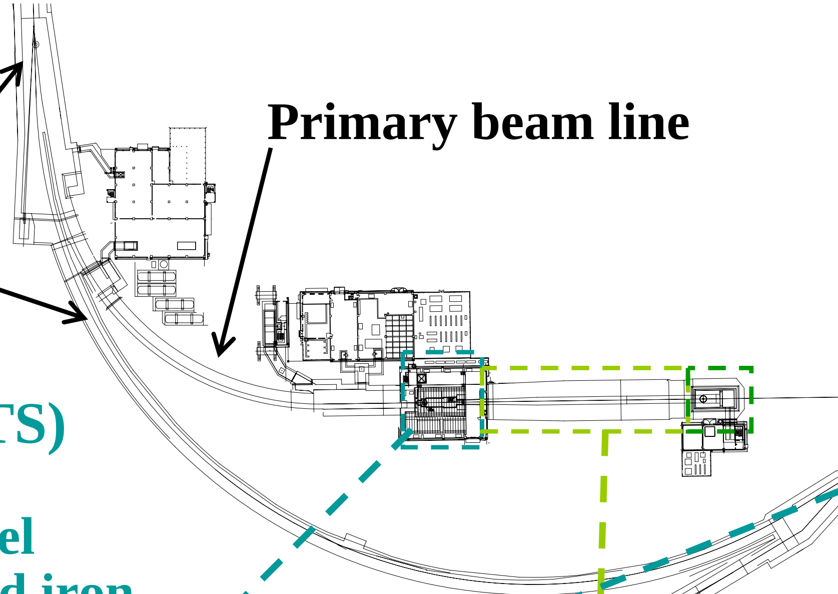


Displacement (max) = 8.5 mm at 4 MW



Hadron Absorber (November 2008)

T2K Target Station

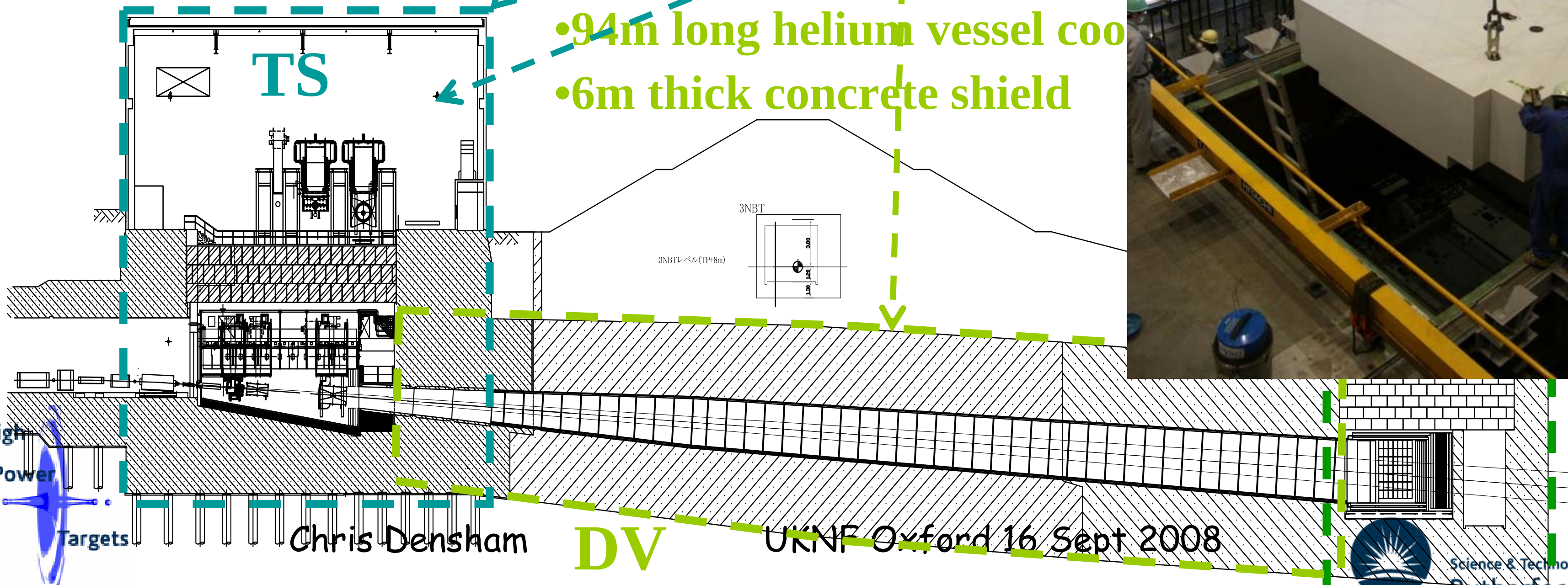


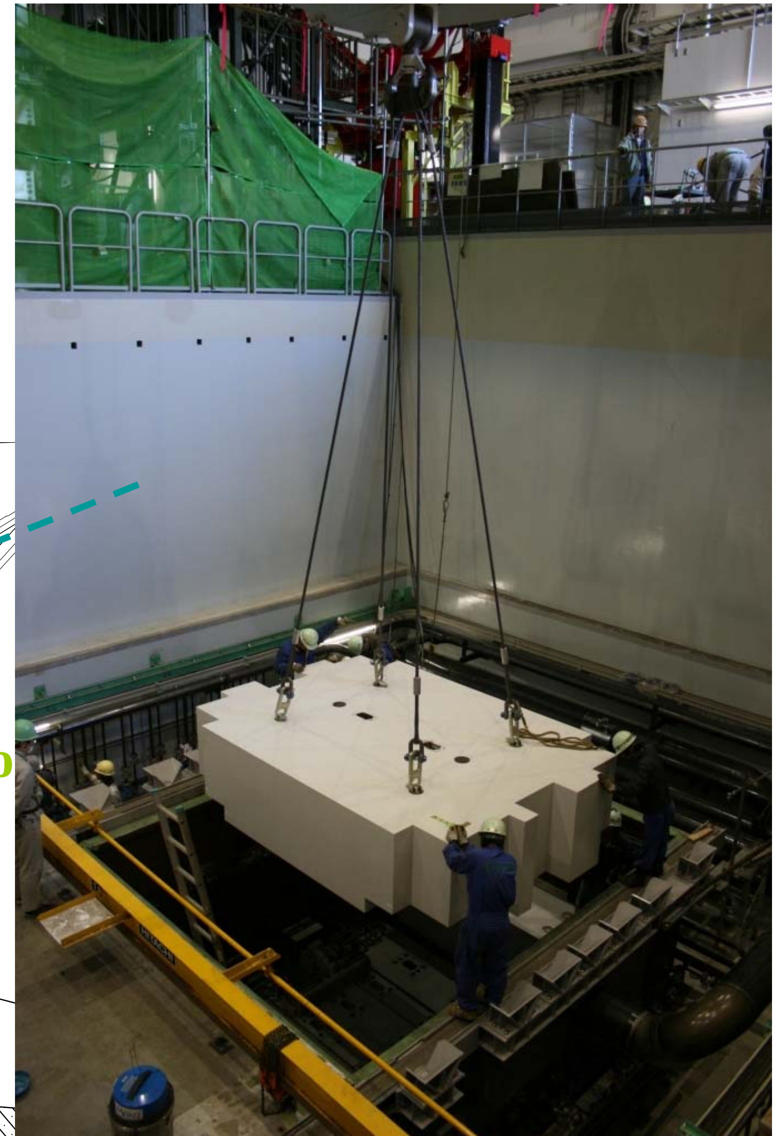
Target station (TS)

- Target & horns in helium vessel
- Helium vessel and iron shields cooled by water

Decay Volume (DV)

- 94m long helium vessel coo
- 6m thick concrete shield

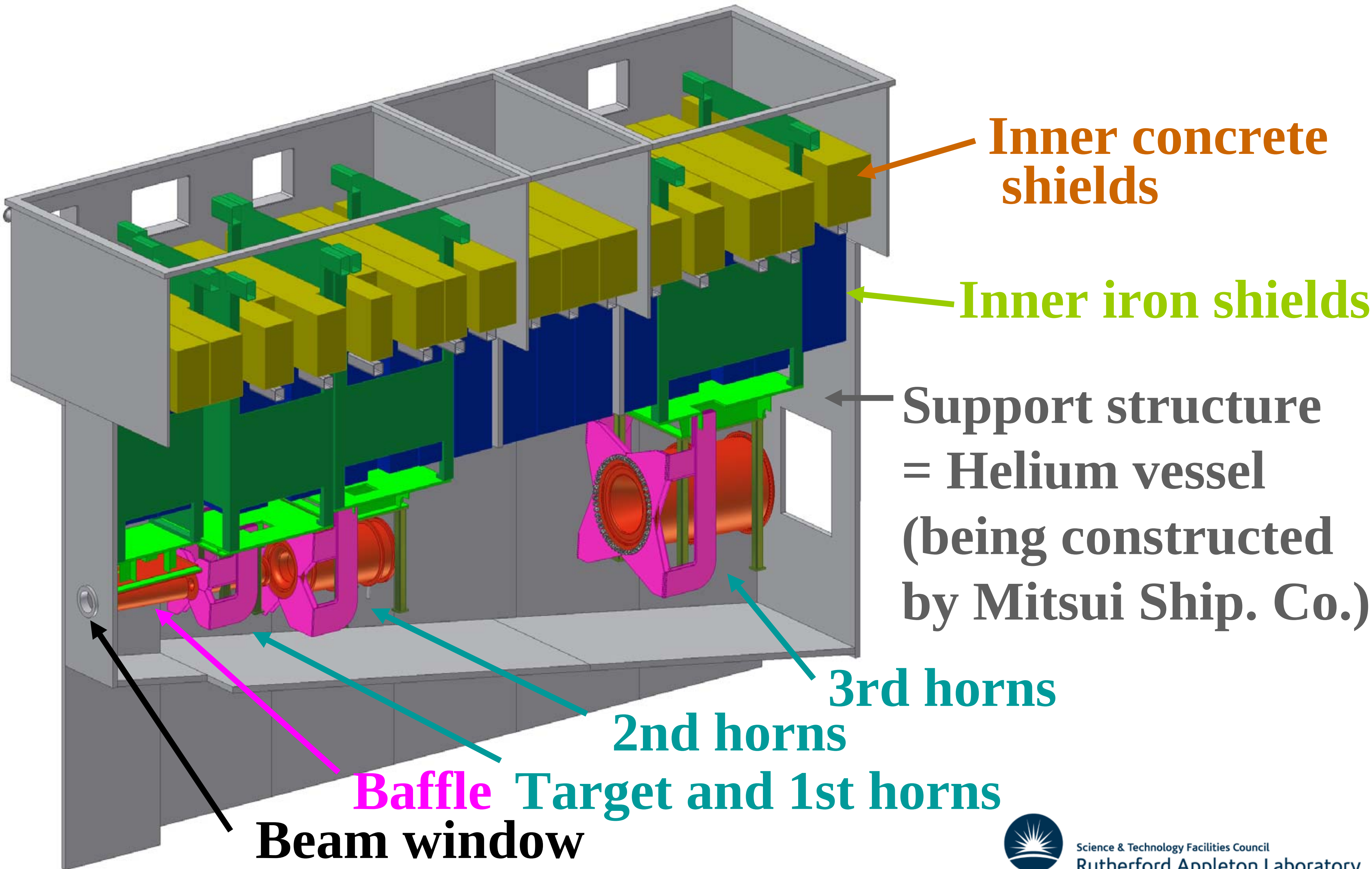




Proton Beam Window + pillow seals. Installed October 2008

Baffle / Collimator -installation imminent

T2K Target area



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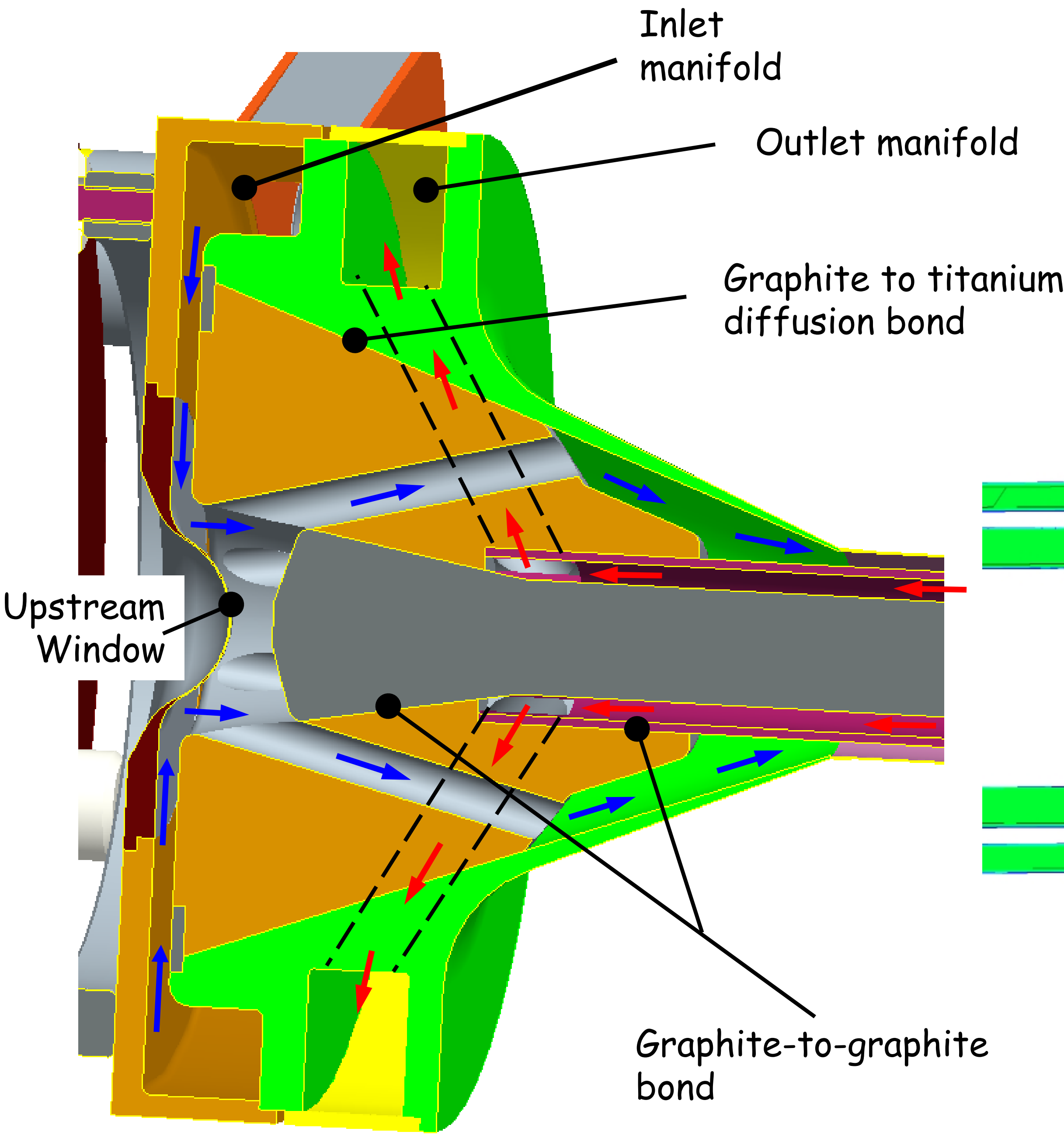
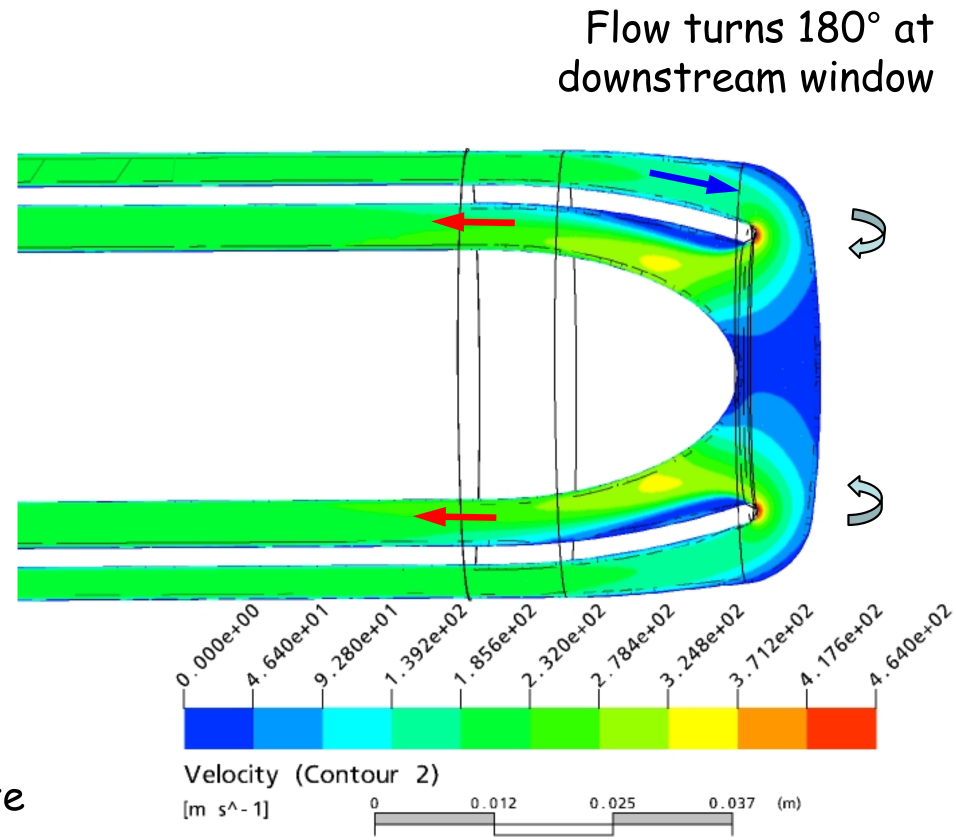
Specification of Phase 1 Target Design

- 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

Target Design:

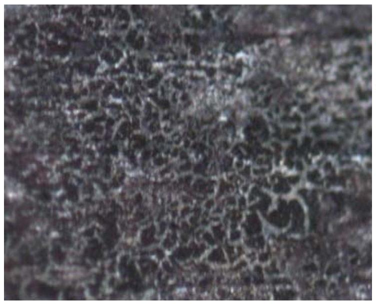
Helium cooling path



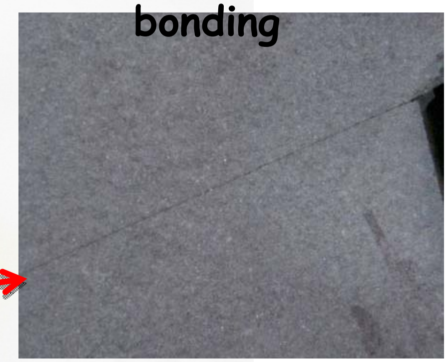


Diffusion Bond + Graphite-Graphite bonding test

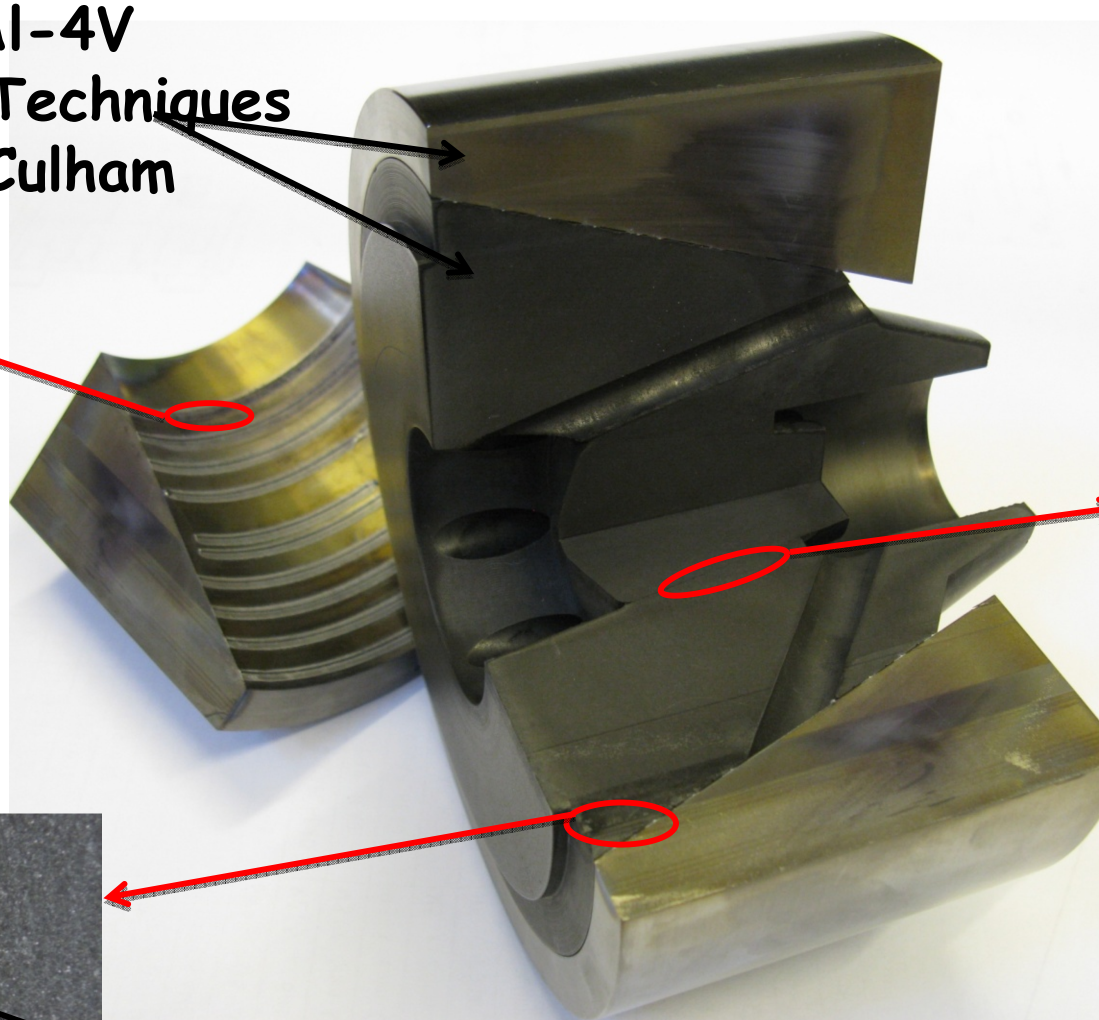
IG43 Graphite diffusion bonded into Ti-6Al-4V titanium, Special Techniques Group at UKAEA Culham



Graphite transfer to Aluminium



Graphite-Graphite bonding



Aluminium intermediate layer, bonding temperature 550°C

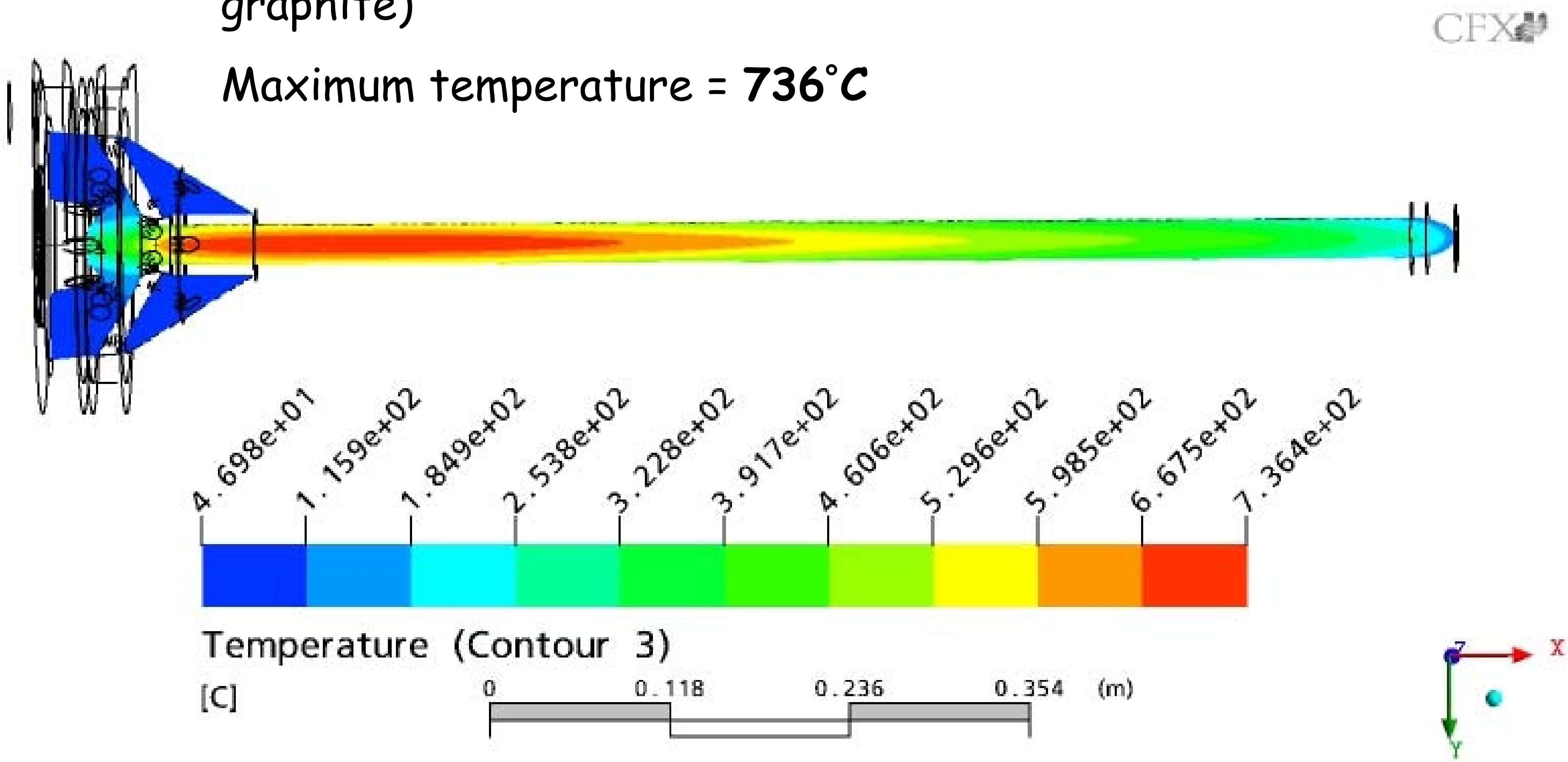
Soft aluminium layer reduces residual thermal stresses in the graphite

Steady state target temperature

30 GeV, 0.4735Hz, 750 kW beam

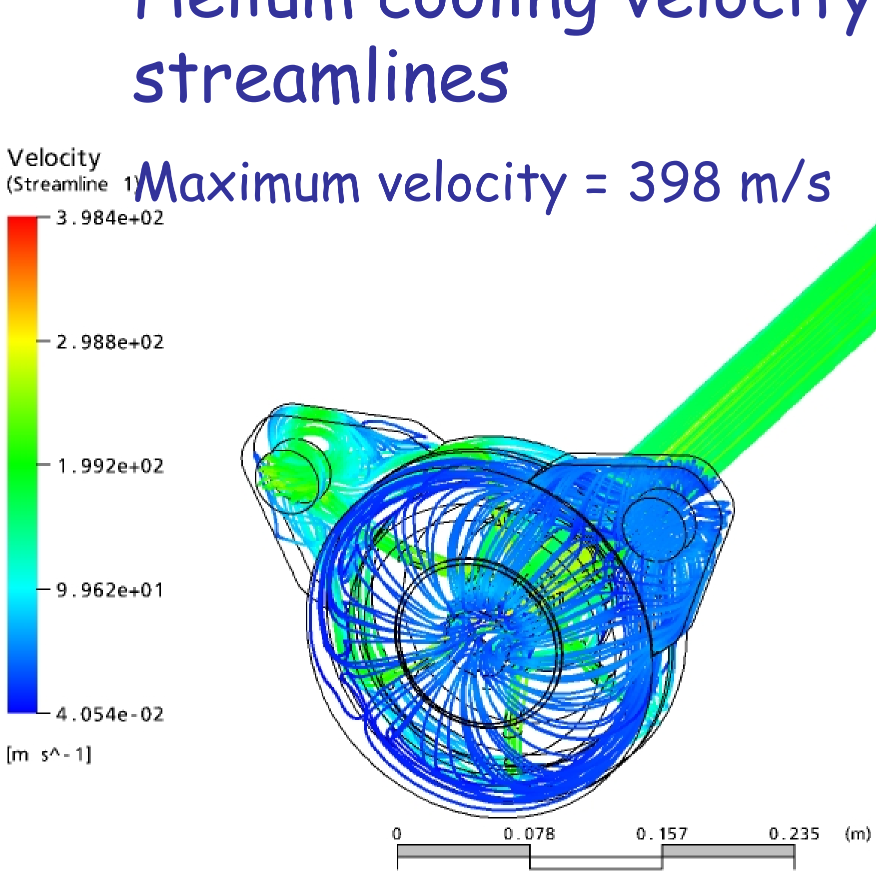
Radiation damaged graphite assumed (thermal conductivity 20 [W/m.K] at 1000K- approx 4 times lower than new graphite)

Maximum temperature = **736°C**



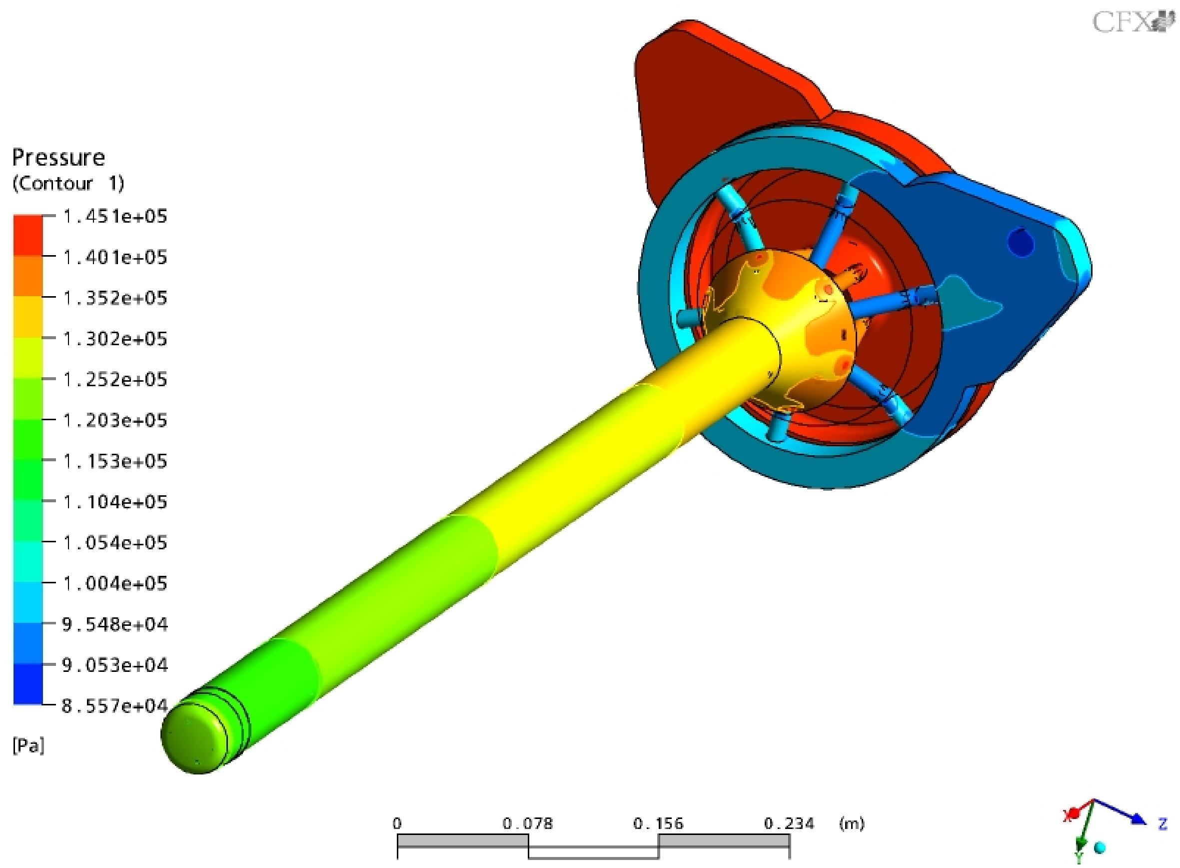
Helium cooling velocity streamlines

Maximum velocity = 398 m/s

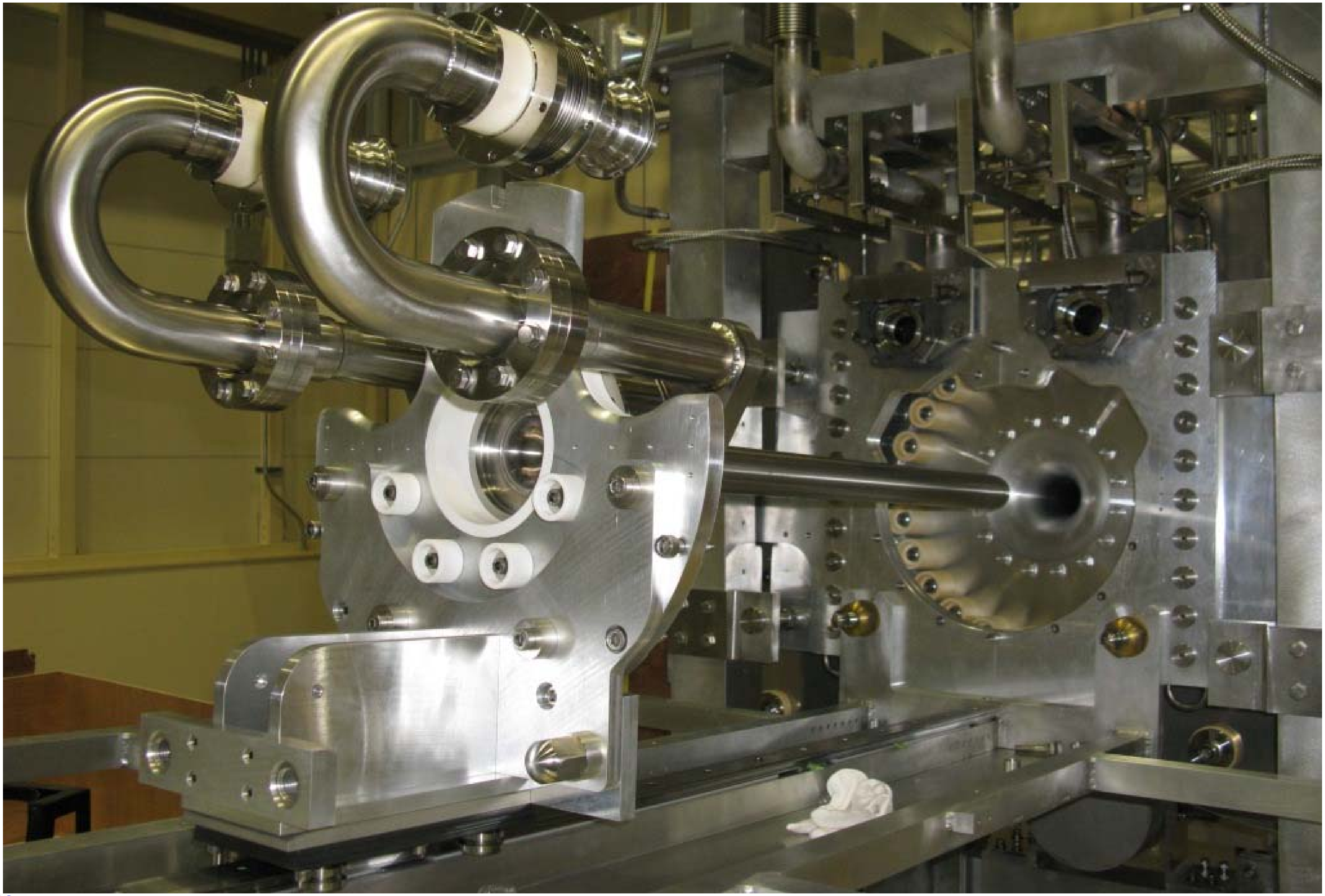


Pressures (gauge)

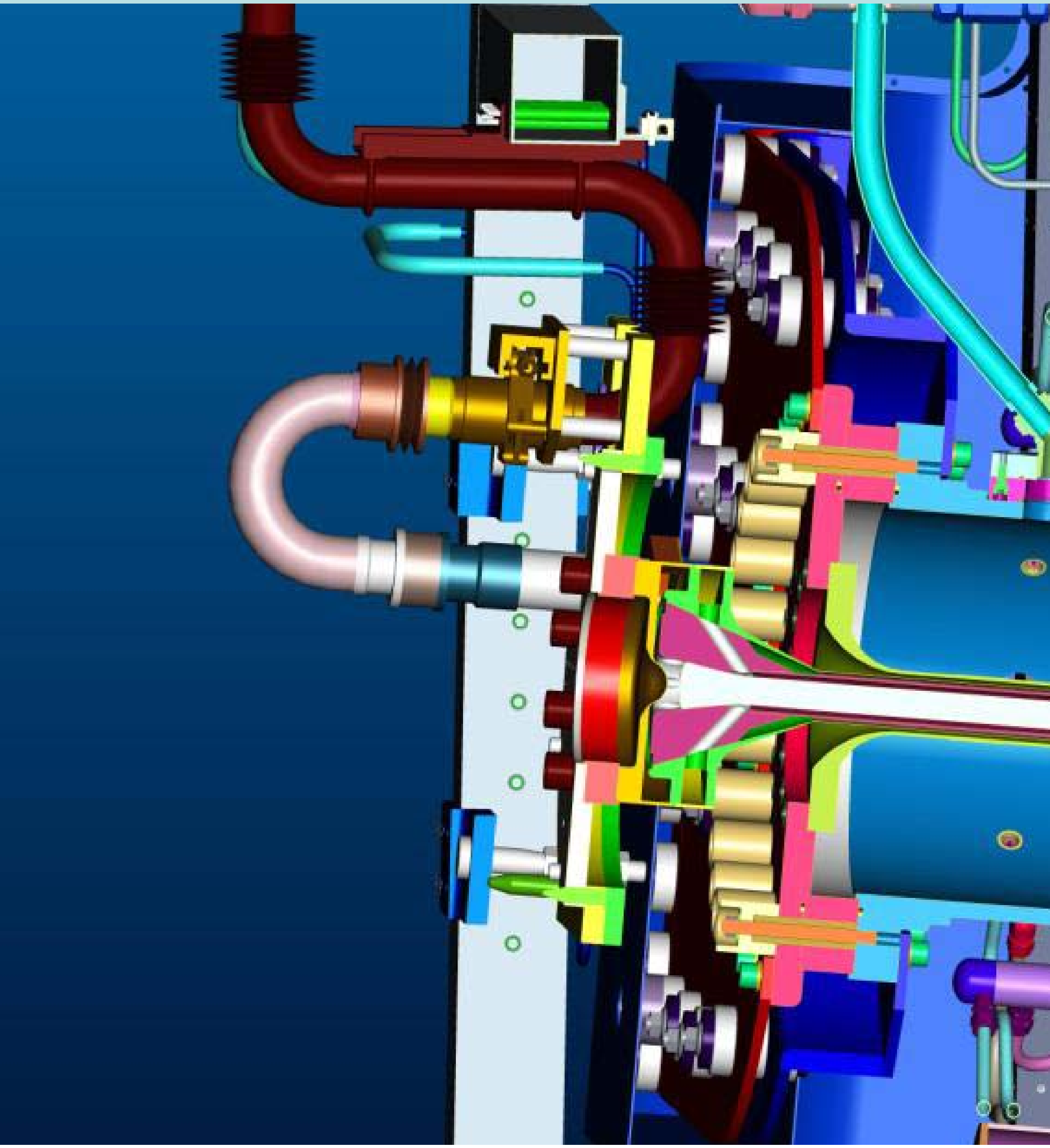
Pressure drop = 0.792 bar



Prototype Target Integration with 1st Magnetic Horn – August 2008

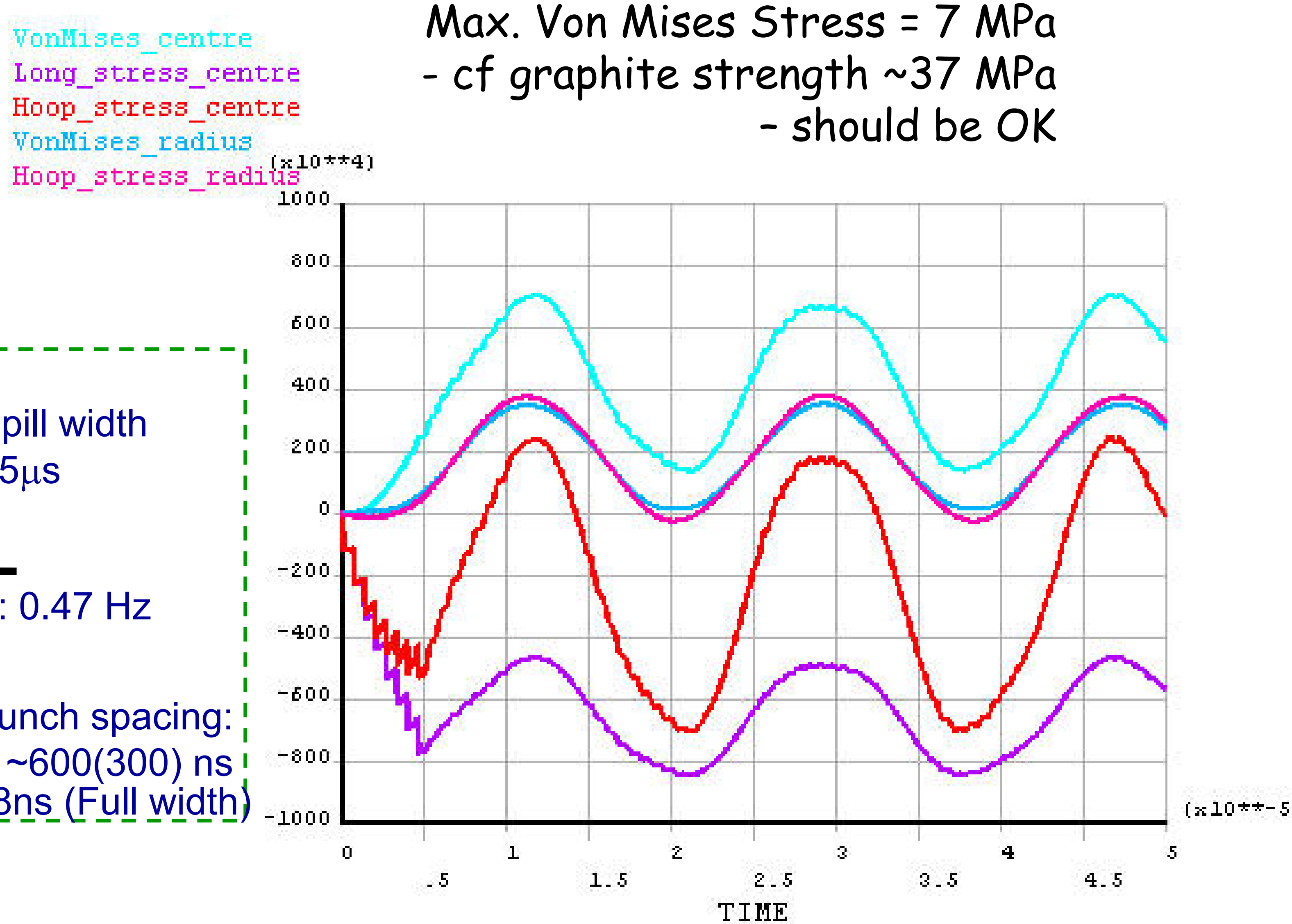


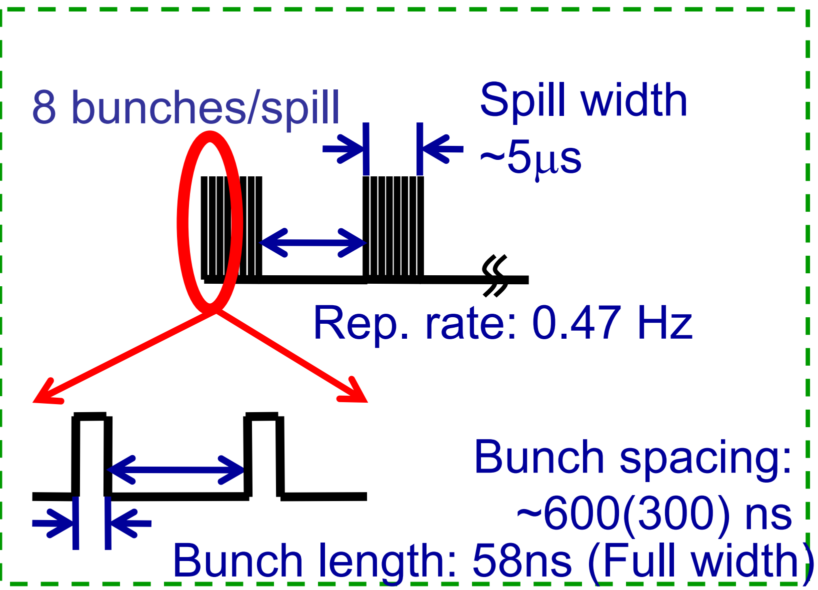
Target installed within 1st magnetic horn



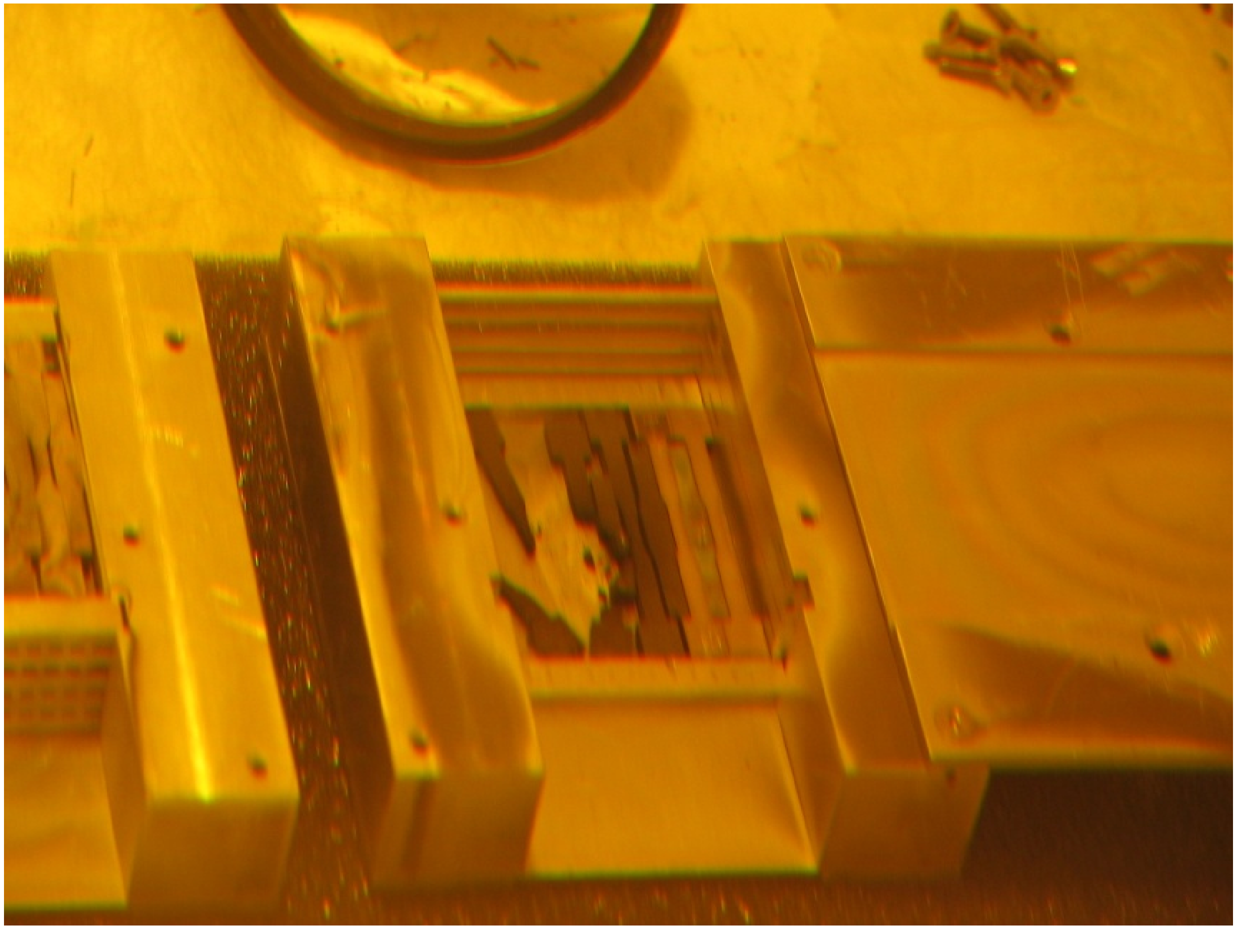
Pulsed beam induced thermal stress waves in target graphite

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





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



200 MeV proton fluence

~10^21 p/cm2

c. 1 year operation in T2K

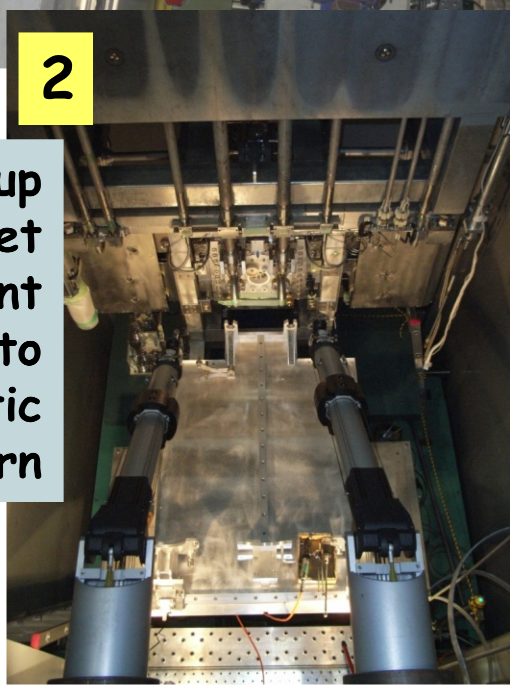
(phase 1, 750 kW)

We don’t expect targets to last long!

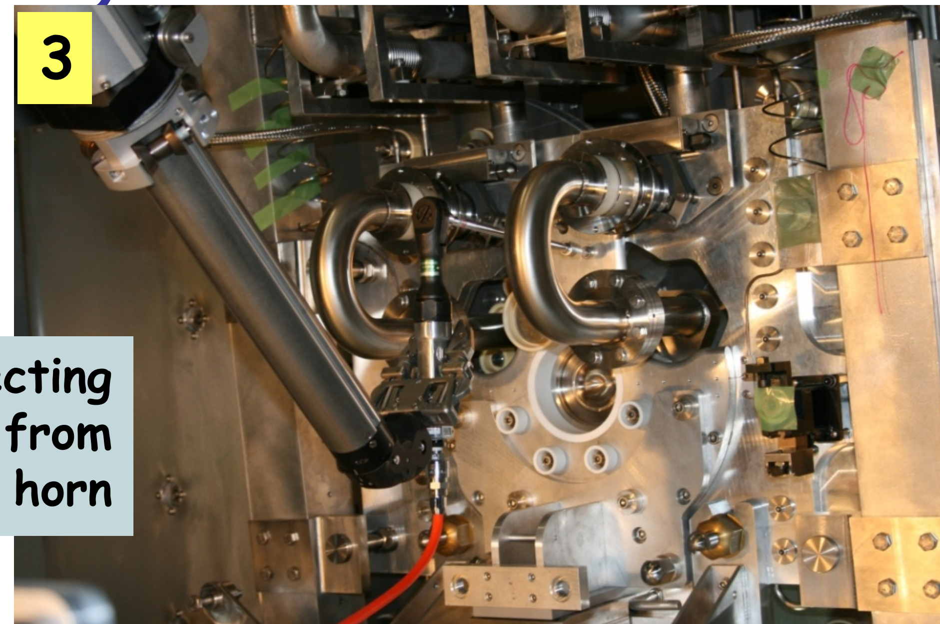
Targets can be changed within magnetic horn

Target Remote Replacement Commissioning (Nov 2008)

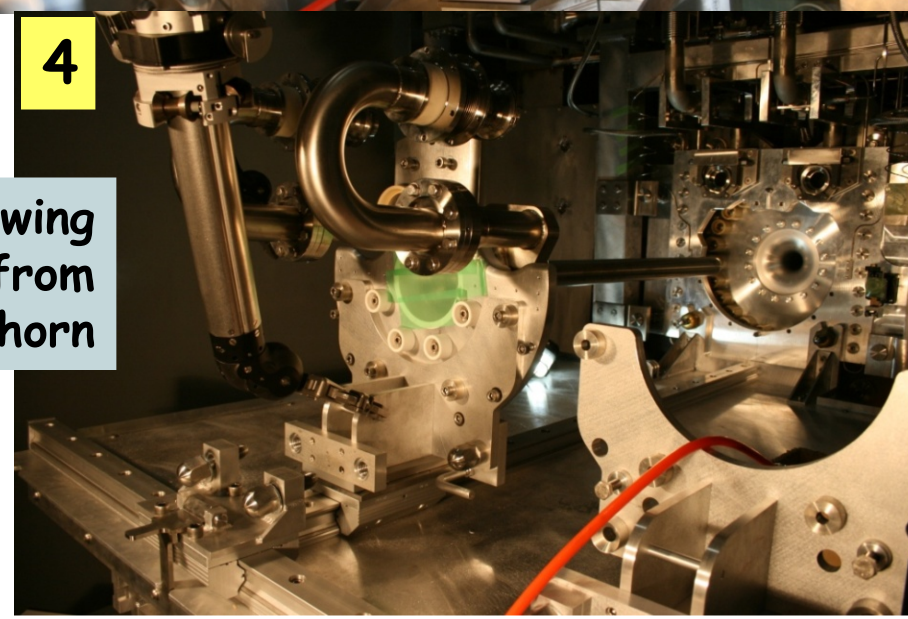
Installation of manipulators into hot cell



Offering up target replacement system to magnetic horn



Disconnecting target from horn



Withdrawing target from horn

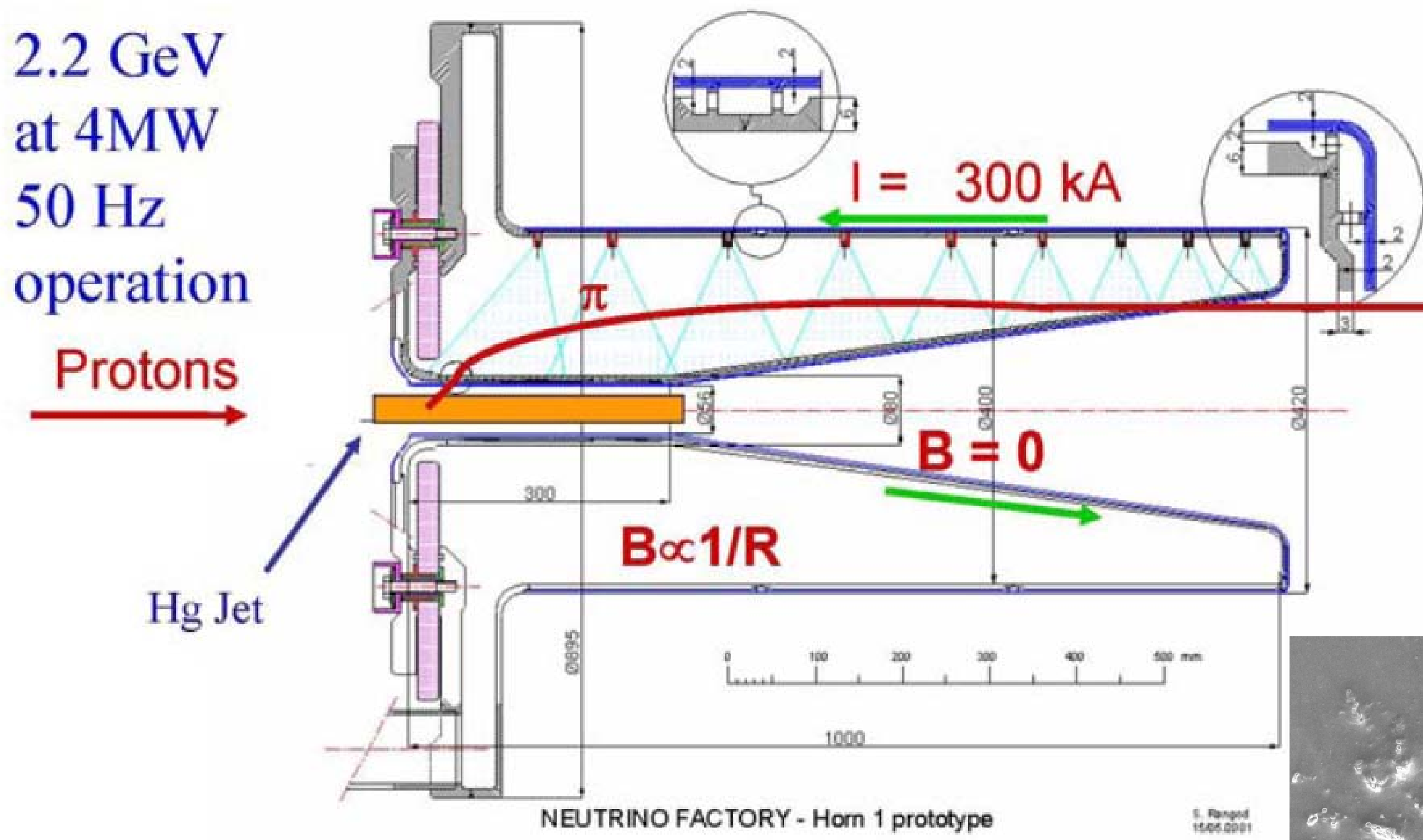
Options for Neutrino Superbeams

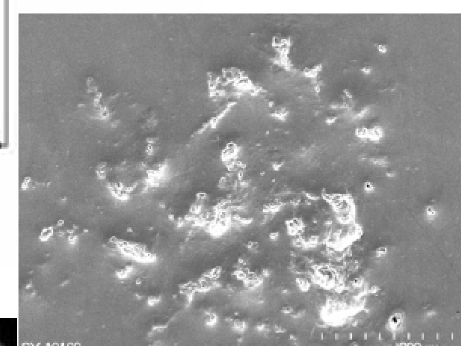
- Static target difficult beyond 1 MW beam power – problems include:
  - Power dissipation
  - Thermal stress
  - Radiation damage
  - High helium flow rate, large pressure drops or high temperatures
- Expect to replace target increasingly often as beam power increases
- Is it possible to combine a moving target with a magnetic horn?
- New target technology may be necessary above c. 1 MW beam power

Liquid mercury jets for neutrino facilities

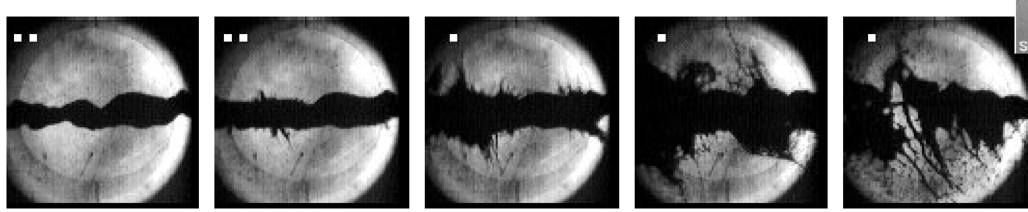
- In principle, the problem of pulsed beam interactions with a mercury target may be solved for an open jet injected into a high-field (c.20 T) solenoid
- However, many difficult engineering, materials and radiochemistry issues remain to be solved
- What candidates are there for a neutrino Superbeam target, e.g. T2HK (T2K Phase 2) or at the SPL at CERN?

EUROnu proposal for CERN SPL Superbeam forsees mercury jet (a la MERIT)…

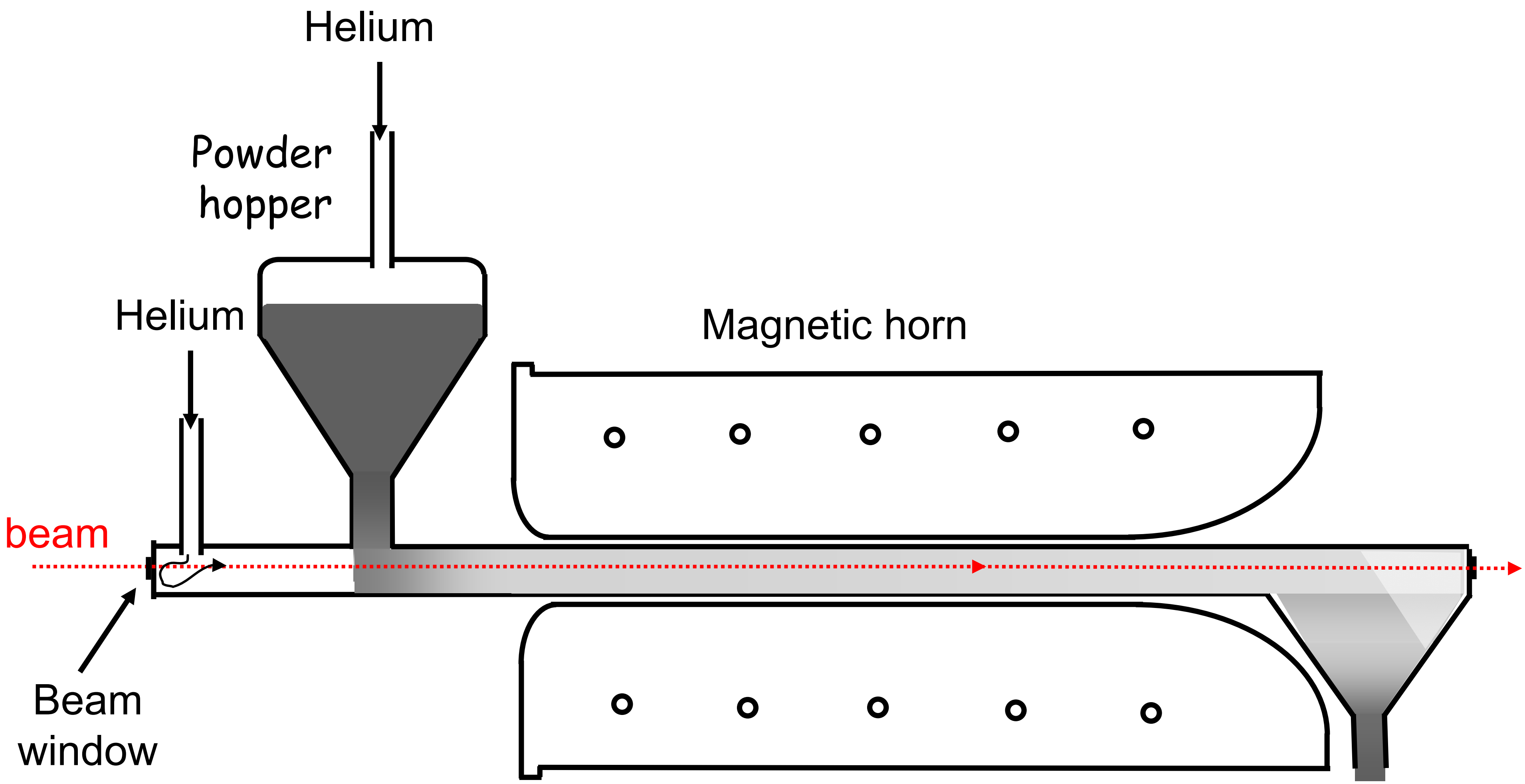




But…



A flowing powder target for a Superbeam or Neutrino Factory? See Otto Caretta's talk



Summary: Targets for a Neutrino Superbeam

- Yield ~ target production & capture efficiency × **reliability**
- Target efficiency much simulated/optimised, however system reliability is generally unknown
- Graphite targets achievable for deposited powers up to ≈ 30 kW for multi-GeV proton beams
- Limits of solid target technology not yet demonstrated
- Important to distinguish between beam power (750 kW for T2K) with beam power deposited in target (20 kW for T2K)
- Open liquid metal jets may be feasible for a future neutrino factory or muon collider, but not necessarily for a Superbeam
- New ideas probably required for Superbeam targets e.g. different materials (Be?), flowing powders?