Target activities at RAL

Work by: C.J Densham, P. Loveridge, M Rooney, M Fitton, T Davenne, O Caretta

Presented by Ottone Caretta

Fermilab, October 20, 2009
T2K Secondary Beam Line

Fast extraction
50 GeV PS ring

Target station (TS)
- Target & horns in helium vessel
- Helium vessel and iron shields cooled by water

Decay Volume (DV)
- 94m long helium vessel cooled by water
- 6m thick concrete shield

Hadron Absorber (Beam Dump)
- Graphite core in helium vessel

Kamioka
‘280 m’ neutrino detector
3-4 MW Beam Dump / Hadron Absorber

Temperature distribution in half layer of Beam Dump operating at 3MW
Proton Beam Window + pillow seals. Installed October 2008

Helium cooling flow lines
Pillow vacuum seal and mating flange

- Successful leak test (3 x 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)
Baffle / Collimator - installation January 2009
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
Graphite to titanium diffusion bond

Graphite-to-graphite bond

Flow turns 180° at downstream window

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

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
Pulsed beam induced thermal stress waves in target graphite

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

8 bunches/spill
Spill width
\( \sim 5\mu s \)
Rep. rate: 0.47 Hz
Bunch spacing:
\( \sim 600(300) \text{ ns} \)
Bunch length: 58ns (Full width)
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 = $736^\circ C$
Radiation Damage in IG43 Graphite
- data from Nick Simos, BNL

200 MeV proton fluence
~10^{21} p/cm^2

c. 1 year operation in T2K

IG 43 graphite
What are the limits for solid targets?

Pion production target installed inside magnetic horn for ‘conventional’ neutrino beam ($\nu_\mu \rightarrow \nu_e$ 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?
Observations from Fluka model of ISIS target
• More neutrons travelling back from target than going outwards.
• Water in manifolds reduces neutron flux.
• Energy deposition focused towards front end of target
Mercury jet target is ‘already broken’ - Neutrino Factory / Muon Collider baseline

... 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
Is there a 'missing link' target technology?

**SOLIDS**
- Monolithic
- Segmented

**LIQUIDS**
- Contained liquids
- Open jets

**Flowing powder**
Schematic layouts of flowing powder targets for neutrino facilities

Superbeam target - contained within pipe

- Pressurised powder hopper
- Discharge nozzle
- Recirculating helium to form coaxial flow around jet
- Proton beam entry window
- Open jet interaction region
- Receiver
- Pion capture solenoid
- Beam exit window
- Powder exit for recirculation
- Return line for powder to hopper
- Driver gas line

Neutrino factory target - open jet configuration used in test rig on day 1 (for MERIT comparison)
1: Powder drop
2: Pressurise and eject powder
3: Open jet
4: Powder lands in receiver
5: Vacuum recirculation

Powder test rig: open jet configuration

18 kW Roots blower for vacuum recirculation

High level hopper

Pressure pot
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 = 42% ± 5% ~ bulk powder density at rest
Driving pressure = 2 bar
Jet velocity = 3.7 m/s
Material fraction ~ 42%
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.

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

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

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