Status of T2K Target

2nd Oxford-Princeton High-Power Target Workshop
6-7th November 2008

Mike Fitton
RAL
Contents of Talk

• T2K target station
• Aims of target design
• Current target design
• CFD analysis
• Remote target exchange concept
• Future upgrade plans
Inner iron shields

Inner concrete shields

Support structure = Helium vessel

Baffle

Beam window

2nd horns

3rd horns

Target and 1st horns
Baffle / Collimator

Test install into Target station October 2008

High power target group, RAL
4MW Hadron Absorber

T. Ishida, KEK & C. Densham, RAL
Aims of Target Design

• Target is graphite rod, 900mm long and 26mm diameter

• Target should be Helium cooled to allow higher operating temperature and to avoid shock waves from liquid coolants

• Target rod to be completely encased in titanium and cooled using high purity helium to prevent oxidation of the graphite

• The Helium should cool both upstream and downstream titanium window first, before cooling the target due to material 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 rod to be uniformly cooled, but kept above 400°C to reduce radiation damage effects

• It should be possible to remotely change the target in the first horn
Current Target Design

Helium cooling

Titanium target body

Graphite (ToyoTanso IG-43)

Graphite to titanium diffusion bond

Ti-6Al-4V tube and windows (0.3 mm thick)

~940 mm
2\textsuperscript{nd} Oxford-Princeton High-Power Target Workshop

Mike Fitton

Target Design: Helium cooling path

Flow turns 180° at downstream window

Graphite-to-graphite bond (Nissinbo ST-201)
Target v.0 – September 2008

Target manufactured by Toshiba, Japan
Pipes, Isolators, remote connectors and remote handling/alignment systems by RAL
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 550ºC. Soft aluminium layer reduces residual thermal stresses in the graphite.
Testing of graphite bonding

Adhesive cured and fired to 1000°C
Fracture strength ~40MPa
Failure through substrate, not bondline
CFD Analysis outline

Boundary conditions
- Inlet Mass flow rate = 25g/s and 32g/s
- Helium Inlet temperature = 300K
- Outlet Pressure = 0.9 bar (gauge)

Heat deposition from MARS simulation
- On target as a function in r and z
- On upstream and downstream window as radial function
- On Inner graphite tube as a function of z
- On Outer tube as a total source
- TOTAL HEAT LOAD = 22kW
Velocity streamlines & Pressure drop

Maximum velocity = 476 m/s @ 32g/s
Maximum velocity = 398 m/s @ 25g/s

Pressure drop = 0.545 bar @ 25g/s
Pressure drop = 0.792 bar @ 32g/s
Steady state target temperature

30 GeV, 0.4735Hz, 750 kW beam

Helium mass flow rate = 32g/s

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

Maximum temperature = 736°C
Target window temperatures

Upstream Window

Max Steady State Temperature = 95°C

Downstream Window

Max Steady State Temperature = 92°C
He flow test with actual target

Pressure drop is consistent with the Expectation by CFD simulation by M. Fitton.

Achieved mass flow is 650 [Nm³/h] ... requirement + 27%
(Requirement for 750kW beam = 510 [Nm³/h])

2nd Oxford-Princeton High-Power Target Workshop
Mike Fitton

T. Nakadaira, KEK
Target helium compressor

- Power consumption: 34kW
- Helium gas leak rate < $1.1 \times 10^{-5}[\text{Pa} \cdot \text{m/s}]$
Target installed within 1st magnetic horn

Proton beam

Clearance between target and horn is only 3mm
Prototype Target remote exchange system
Target remote exchange system
Future upgrade plans

1st April 2009 – Start operation
2010 – Power to 750kW
2014 – Power to 1.66MW
20?? – Power to 3-4MW

Only Hadron absorber and DV currently designed for this power

Only approximately 50kW deposited in target, however

• With current setup helium ΔT too high (350°C)
• Need to increase flow rate → Higher pressure
  • May need to modify target and HX to lower ΔP
Radiation damage likely to be limiting factor for target life

IG 43 graphite

200 MeV proton fluence
~$10^{21}$ p/cm$^2$
c. 1 year operation in T2K
Water cooled

Nick Simos, BNL
Irradiation effects on Graphite

Expected radiation damage of the target

- The approximation formula used by NuMI target group: \( 0.25 \text{dpa/year} \)
- MARS simulation: \( 0.15~0.20 \text{ dpa/year} \)

Dimension change: shrinkage by \(~5\text{mm in length in 5 years at maximum.} \)

- \(~75\mu\text{m in radius} \)

Degradation of thermal conductivity ... decreased by 97% @ 200 °C
- 70~80% @400°C

Magnitude of the damage strongly depends on the irradiation temperature.
- It is better to keep the temperature of target around \( 400 \sim 800 \text{ °C} \)

![Graph showing irradiation effects on Graphite](image-url)

Toyo-Tanso Co Ltd. IG-11

JAERI report (1991)

2nd Oxford-Princeton High-Power Target Workshop
Mike Fitton