HiPER – Case Study

NUCLEAR TECHNOLOGIES

Shielding Support to the HiPER Business Case

HiPER is a proposed European High Power Laser Energy Research facility dedicated to demonstrating the feasibility of laser driven fusion as a future energy source (http://www.hiper-laser.org).

The Nuclear Technologies shielding team were contracted by the HiPER project, to provide expert shielding design advice in support of a feasibility study for the facility.

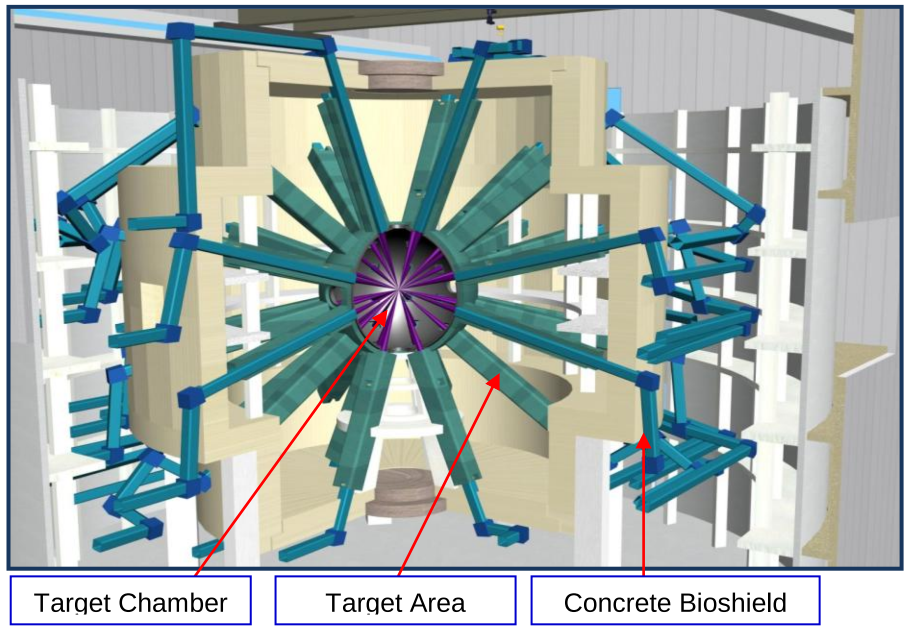
A facility such as HiPER will essentially consist of 3 key areas:

The Target Chamber: an evacuated spherical chamber of around 10 metres diameter where fusion reactions are initiated. The shielding of the Target Chamber is limited to containing the fusion reaction. Some local neutron shielding may be present to reduce doses to electronic equipment mounting on, or close to, the chamber.

The Target Area: the room in which the Target Chamber is located. This room will contain the support structure for the Target Chamber and will direct services to the Target Chamber, including vacuum pumps, laser power and diagnostics. The Target Area will be contained by the bulk of the concrete biological shielding.

Everywhere else: outside the Target Area will be the laser switchyard and beyond that, laser compressor rooms and the control room. Further concrete bulk shielding may be required for the switchyard if the Target Area biological concrete shielding is not solely sufficient.

Concept Layout of the HiPER Target Area, by Steve Saunders of Oxford Technologies



The assessment demonstrated that there is significant scope for providing high levels of shielding for personnel access doors through the use of labyrinths in combination with shield doors based on a

Preliminary Activation Analysis of Materials in the HiPER Target Area

Although the Target Area will be evacuated during fusion initiation exercises, it is still expected that occupancy within this area (for maintenance, diagnostics etc) will be the most significant driver for dose uptake on the plant. This will be due to activation of the Target Chamber, the hot-side of the Target Area Biological shielding and of equipment within the Target Area.

This calculation undertook a preliminary activation analysis of the primary materials likely to be found in the Target Area in significant amounts, for example mild steel, stainless steel, air and concrete. The results presented radionuclide yield and gamma energy spectra for specified materials and cooling intervals. A sensitivity analysis of concrete composition was undertaken for the activation assessment of the biological shielding.

SPECTRUM			DOMINANT RADIONUCLIDES					
Energy Bin (MeV)	Gamma Spectrum MeV/Second	Gamma/Second/cc	Nuclide	Activity (Bq/kg)	% Activity	Nuclide	S-IP Dose Rate (Sv/h)	% Dose Rate
0.0-0.01	4.06E+05	6.39E+05	Total	1.24E+09		Total	4.74E-01	
0.01-0.02	7.91E+04	4.14E+04	Al28	3.48E+08	28.2	Al28	1.97E-01	41.7
0.02-0.05	2.10E+04	4.72E+03	Mn56	3.11E+08	25.1	Mn56	1.55E-01	32.6
0.05-0.1	8.04E+05	8.43E+04	V52	1.89E+08	15.3	V52	8.02E-02	16.9
0.1-0.2	1.30E+06	6.84E+04	Co60m	1.43E+08	11.6	Al30	1.53E-02	3.2
0.2-0.3	9.23E+04	2.90E+03	Cr55	9.30E+07	7.5	V53	6.62E-03	1.4
0.3-0.4	6.72E+05	1.51E+04	Mn57	2.60E+07	2.1	Mo101	4.77E-03	1.0
0.4-0.6	6.29E+06	9.88E+04	V53	2.29E+07	1.9	Zr90m	4.71E-03	1.0
0.6-0.8	4.23E+06	4.75E+04	Cu66	1.98E+07	1.6	V54	3.14E-03	0.7
0.8-1.0	2.71E+08	2.37E+06	Al30	1.36E+07	1.1	Mg27	1.61E-03	0.3
1.0-1.22	3.15E+07	2.23E+05	Mo101	1.25E+07	1.0	Co62	1.11E-03	0.2
1.22-1.44	2.90E+08	1.71E+06	Mn58m	1.01E+07	0.8	Mn57	5.29E-04	0.1
1.44-1.66	4.14E+06	2.10E+04	V183m	6.84E+06	0.6	Nb100m	5.10E-04	0.1
1.66-2.0	7.79E+08	3.34E+06	Mg27	6.82E+06	0.6	Nb98	4.59E-04	0.1
2.0-2.5	1.39E+08	4.85E+05	Zr90m	6.30E+06	0.5	Cu66	4.30E-04	0.1
2.5-3.0	2.04E+07	5.83E+04	Nb98	5.40E+06	0.4	Al29	3.72E-04	0.1
3.0-4.0	1.79E+07	4.03E+04	Co58m	3.24E+06	0.3	Mn58m	3.37E-04	0.1
4.0-5.0	1.50E+06	2.62E+03	V54	2.61E+06	0.2	Ni65	3.02E-04	0.1
5.0-6.5	0.00E+00	0.00E+00	Co62	2.37E+06	0.2	Mn58	2.46E-04	0.1
6.5-8.0	0.00E+00	0.00E+00	Ni65	1.89E+06	0.2	Mo91m	2.26E-04	0.0
8.0-10.0	0.00E+00	0.00E+00	Co64	1.36E+06	0.1	Co60m	1.95E-04	0.0
10.0-12.0	0.00E+00	0.00E+00	Rest	9.37E+06	0.8	Rest	1.09E-03	0.2
12.0-14.0	0.00E+00	0.00E+00						
14.0--->	0.00E+00	0.00E+00						
Total	1.57E+09	9.26E+06						

Source Geometry	Width (cm)	Height (cm)	Distance (cm)	Gamma Dose Rate in microSv/h	
Box Side	10	10	1	3.9E+05	microSv/h
			10	6.1E+04	microSv/h
			30	8.2E+03	microSv/h
			50	3.0E+03	microSv/h
			100	7.5E+02	microSv/h
			300	8.4E+01	microSv/h
			500	3.0E+01	microSv/h

Source Geometry	Radius (cm)	Height (cm)	Distance (cm)	Gamma Dose Rate in microSv/h	
Cylinder Side	10	10	1	4.3E+05	microSv/h
			10	1.6E+05	microSv/h
			30	3.0E+04	microSv/h
			50	1.2E+04	microSv/h
			100	3.0E+03	microSv/h
			300	3.4E+02	microSv/h
			500	1.2E+02	microSv/h

Furthermore, the activation analysis of damp air allowed an estimate of the amount of tritium produced in the air by neutron activation and also the radionuclide population which may be important when considering internal dose uptake.

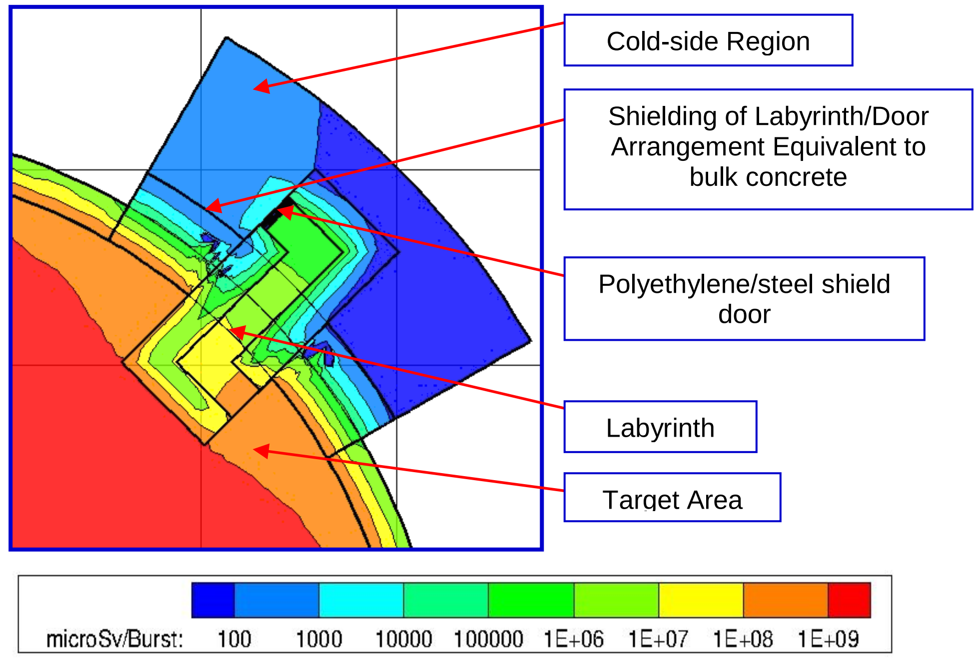
Shielding Assessment of Door Penetration within the Target Area Wall:

This assessment considered the feasibility of shielding for a large penetration, such as an access door, through the Target Area shield wall.

It was proposed that a bulk shield door, constructed using standard shielding material such as concrete, steel, lead and polyethylene could be designed to achieve similar levels of shielding performance to that of the shield wall within in which it is placed. The drawback of using such large shield doors is that they can often be very heavy requiring significant engineering effort to ensure that reliable door mechanisms capable of opening and closing the door can be produced.

This assessment however considered the use of a labyrinth shielding arrangement to reduce the shielding requirements on a door into the Target Area. This would facilitate easier access into the Target Area through the provision of a much lighter door designed for personnel access.

Dose Contour through Access Labyrinth & Shield Door



The assessment demonstrated that there is significant scope for providing high levels of shielding for personnel access doors through the use of labyrinths in combination with shield doors based on a compound polyethylene (neutron) and steel (gamma) shielding construction.

Activation Analysis over 30 Years of HiPER Operation:

This assessment was undertaken to determine levels of activation in the biological shielding and in any Target Area structures/materials over a 30-year operational lifetime.

The levels of activation were calculated immediately after each burst of successful fusion events and the 7 cooling days thereafter; each burst was spaced a week apart, for 30 years. The activation levels were calculated for a period of up to 5 years after the cessation of operations at the HiPER facility in order to aid waste characterisation for decommissioning.

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For further information please contact: Tel: **01847 805070**
Email: **info@nuclear.co.uk**