ISIS Target studies

Could a used ISIS target provide fusion relevant irradiated tungsten material properties?

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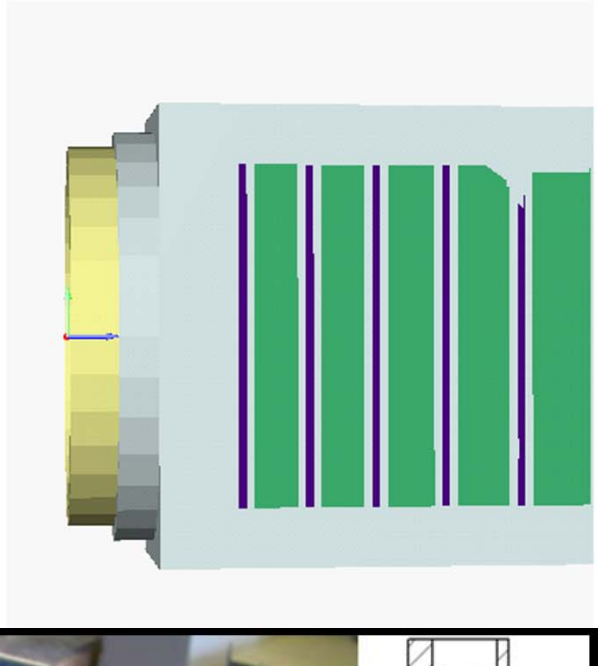
20th May 2015

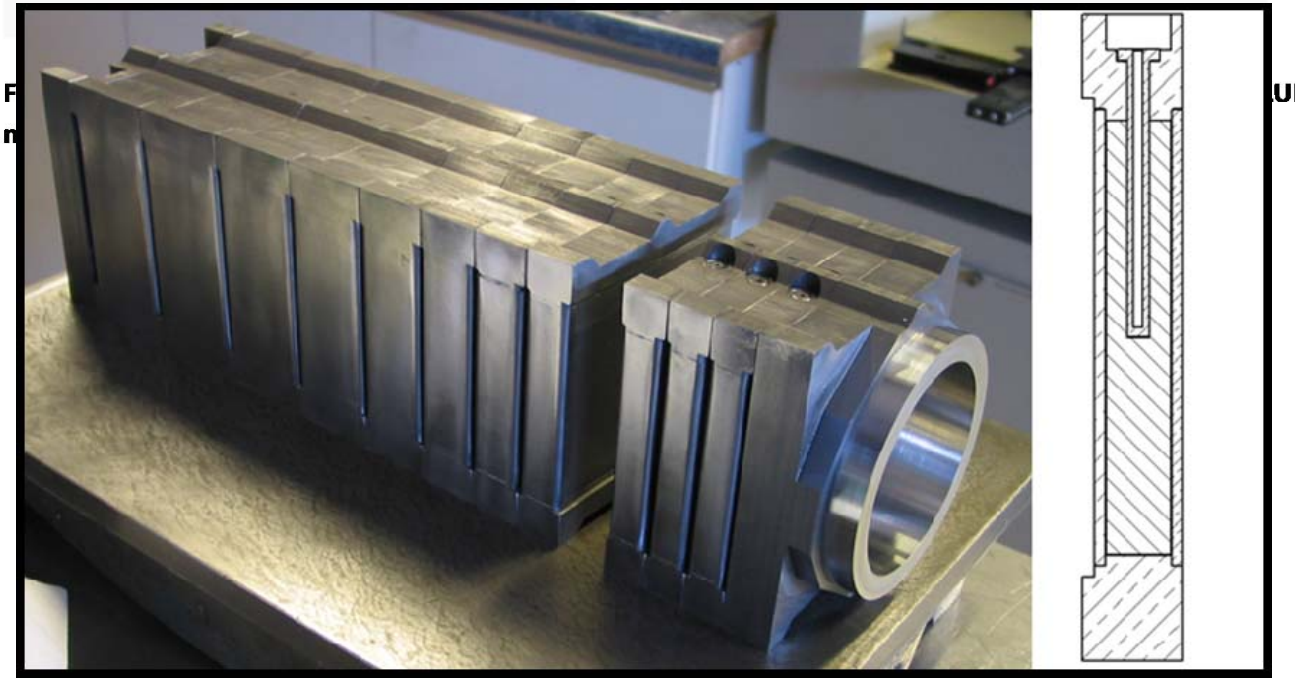
2nd Radiate Meeting

Oxford University

TS1 core FLUKA geometry

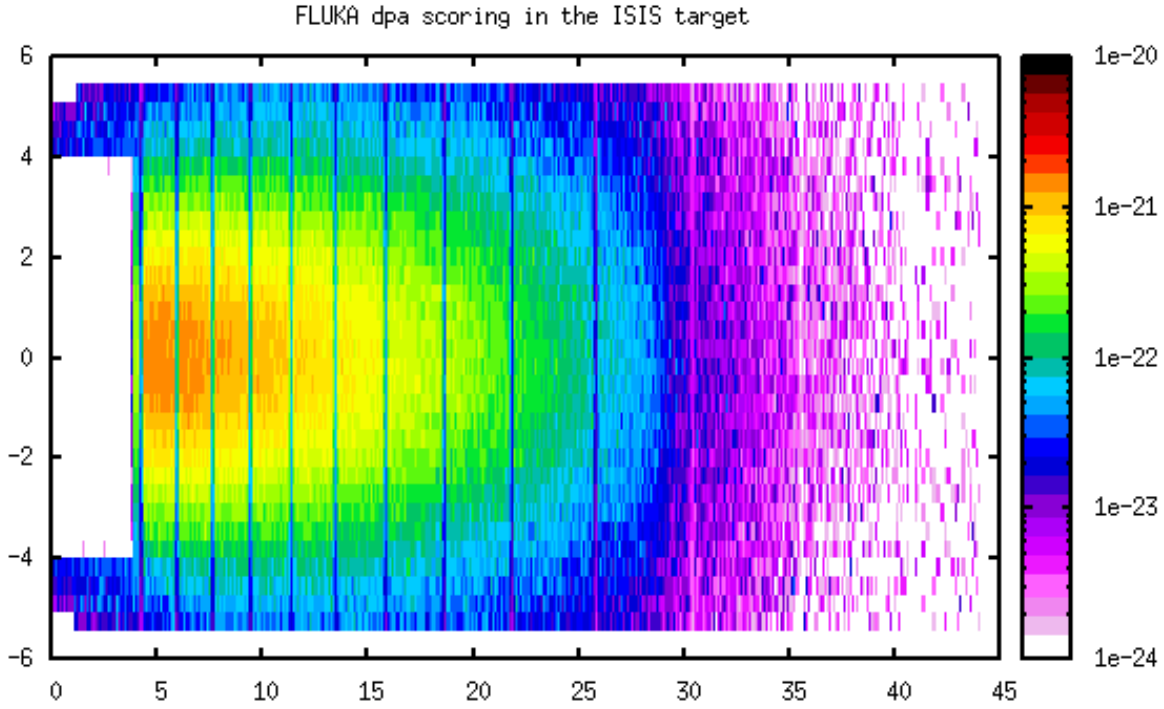
Geometry includes 12 tantalum clad tungsten plates and heavy water channels in between. Does not include stainless steel water manifolds on side of target.



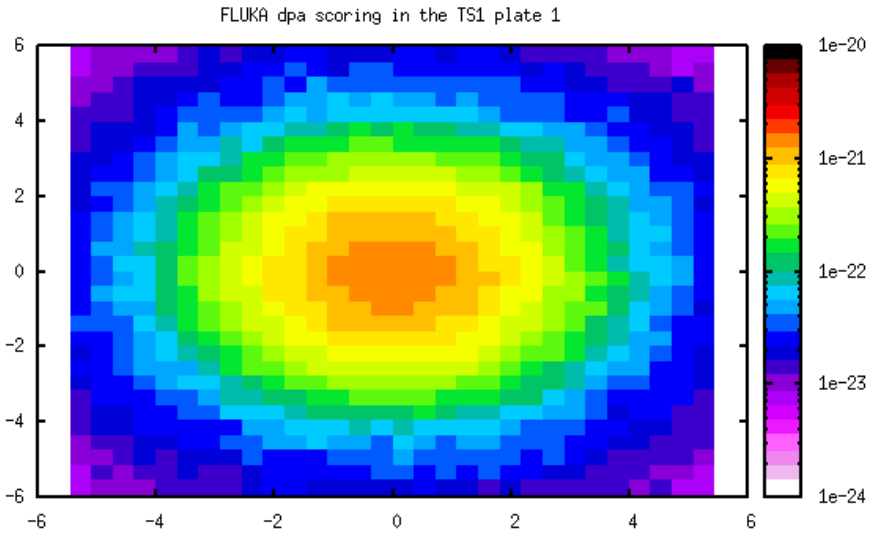


TS1 energy deposition and FLUKA dpa

Target Plate [800MeV sigx=16.3mm sigy=16.3mm]	max dpa/proton	dpa/s at 210µamps (equivalent to 1.31e15protons/s)	dpa per year 2e7s	Total Power deposited at 210µamps [kW]	Peak energy density at 210µamps [W/m3]	max temp calculated with CFX at 210µamps [°C]
1	1.90E-21	2.49E-06	49.8	11.76	4.79E+08	207
2	1.67E-21	2.19E-06	43.8	12.14	4.64E+08	205
3	1.26E-21	1.65E-06	33.0	12.18	4.11E+08	199
4	1.19E-21	1.56E-06	31.2	11.97	3.67E+08	200
5	9.40E-22	1.23E-06	24.6	11.3	3.21E+08	191
6	7.10E-22	9.30E-07	18.6	10.96	2.46E+08	179
7	5.20E-22	6.81E-07	13.6	9.99	1.86E+08	161
8	4.00E-22	5.24E-07	10.5	9.11	1.32E+08	151
9	3.00E-22	3.93E-07	7.9	8.32	9.01E+07	146
10	1.38E-22	1.81E-07	3.6	5.38	6.34E+07	109
11	2.30E-23	3.01E-08	0.6	0.24	5.15E+06	33
12	1.77E-23	2.32E-08	0.5	0.11	4.18E+06	31



Variation of dpa through out target



Variation of dpa across a target plate

Target Activity

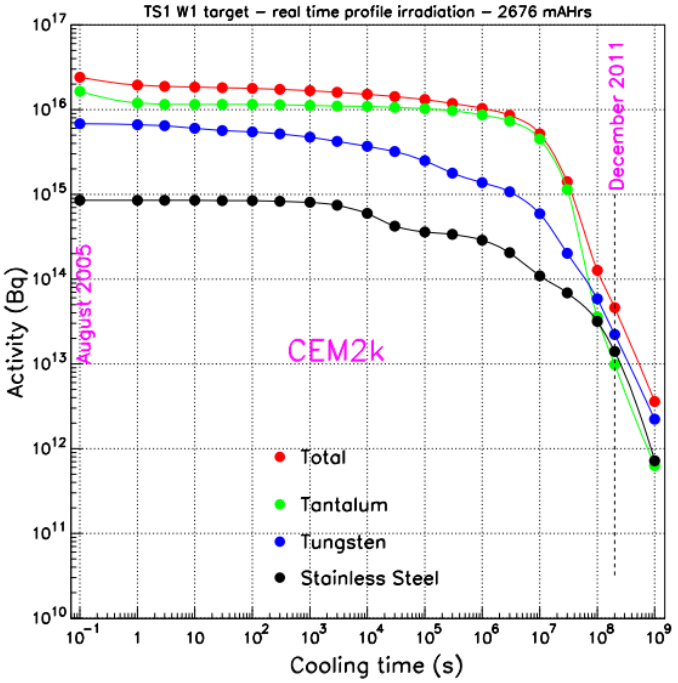
Irradiation profile of TS1-W1 from Goran Skoro's report

Table 1. Irradiation time profile for the TS1-W1 target.

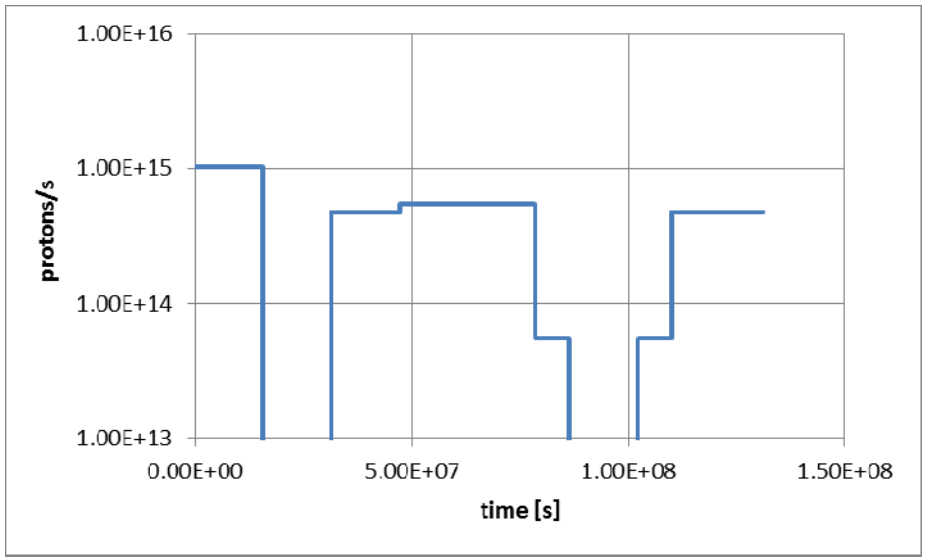
Time period	Protons on target (mAHrs)
May-Dec 2001	722.703
Jun-Dec 2002	338.293
2003	777.057
Jan-Mar; Oct-Dec 2004	387.844
Jan-Aug 2005	450.368

http://hepunx.rl.ac.uk/uknf/wp3/hidden/goran/ISIS_jobs/01_TrgtInven/ts1_w1_act.pdf

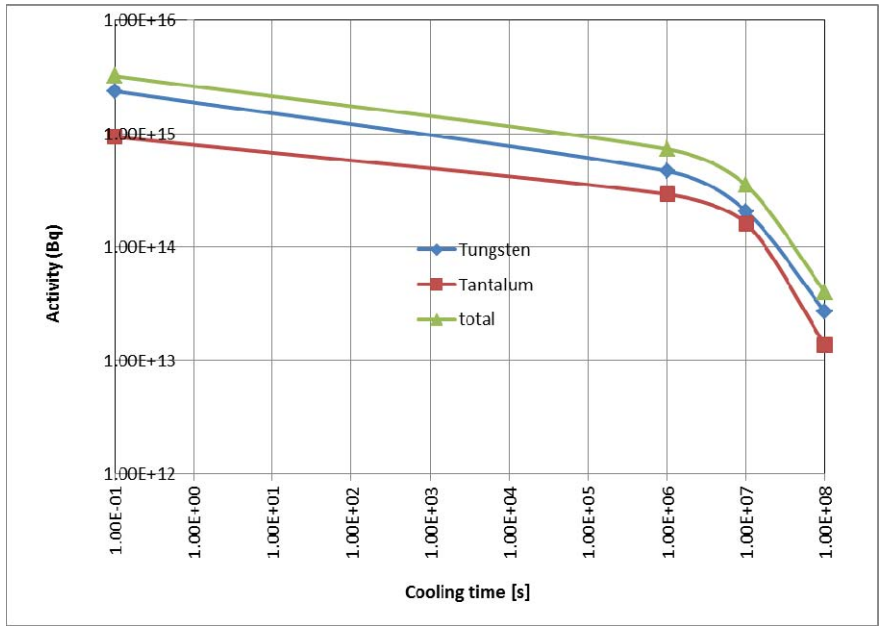
Total target activity from Goran Skoro's report



Irradiation profile interpreted for FLUKA

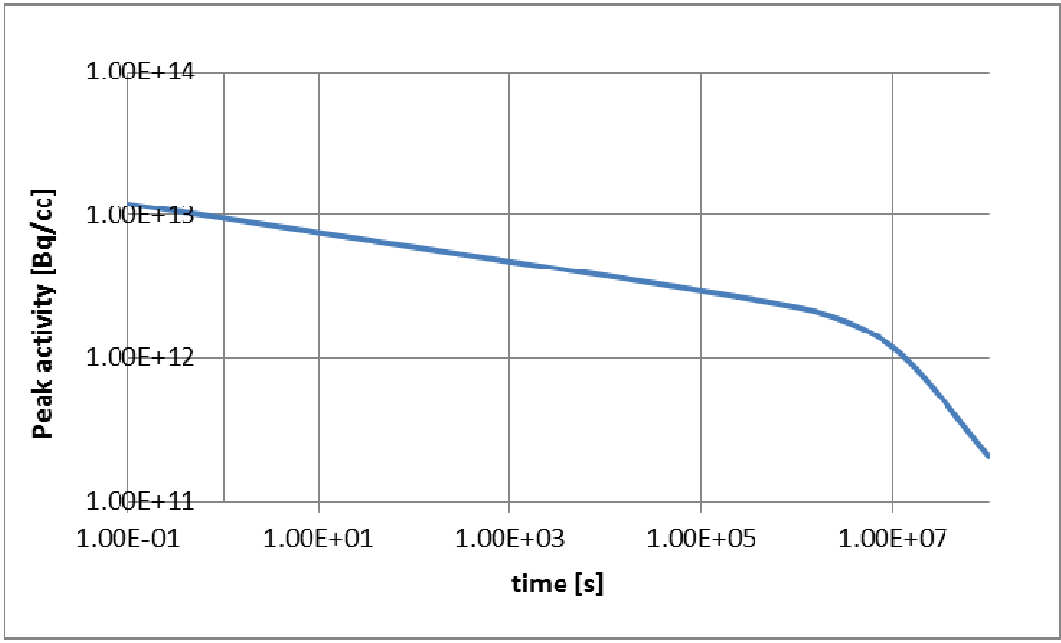


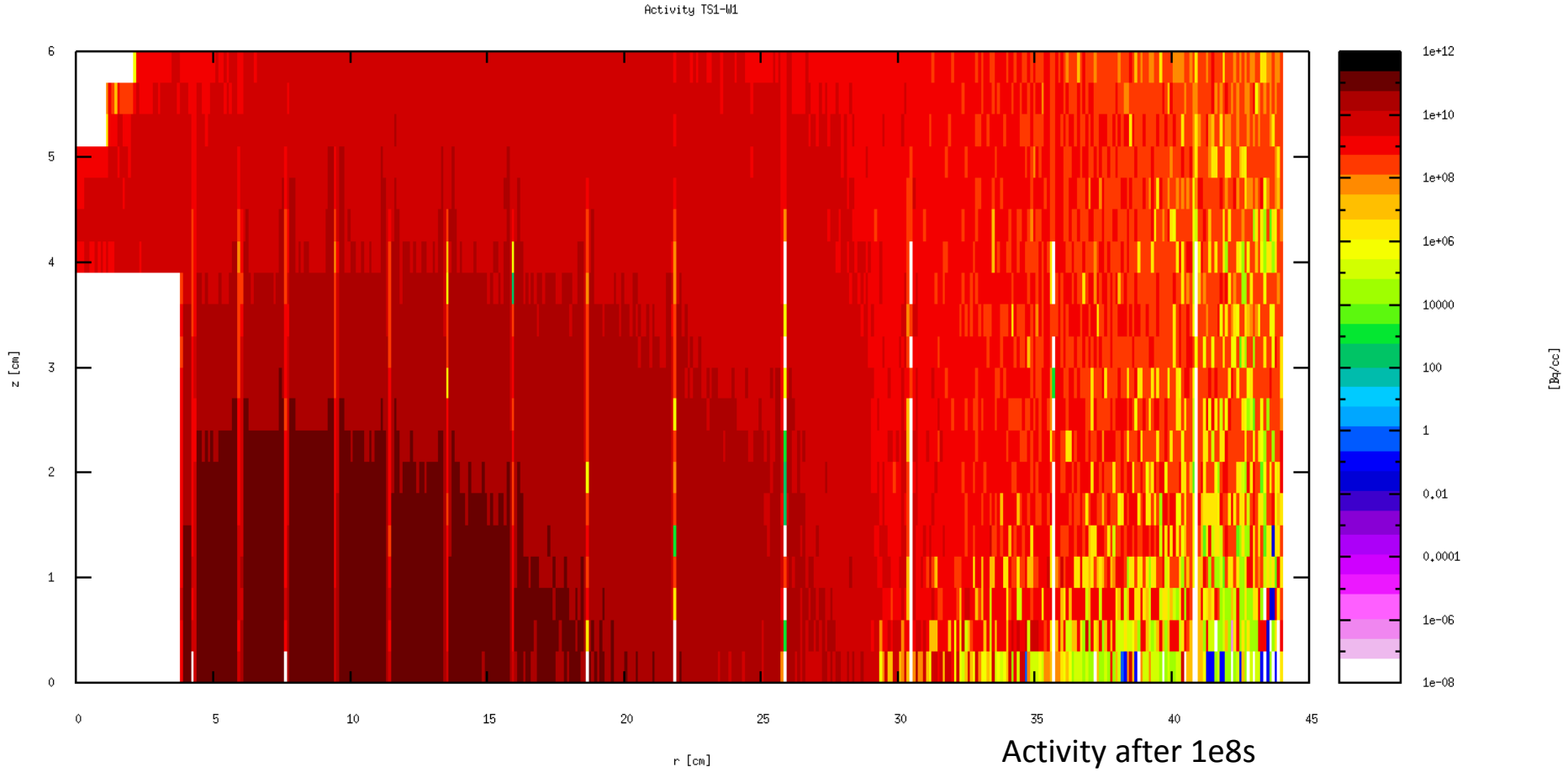
Total target activity calculated from simple FLUKA model



Peak Target Activity

Maximum activity in target
1.2e13 Bq/cc imeadiately after irradiation
2.1e11 Bq/cc after 1e8s
or for tungsten
1.1e10Bq/gram after 1e8s (i.e. 10GBq/gram)





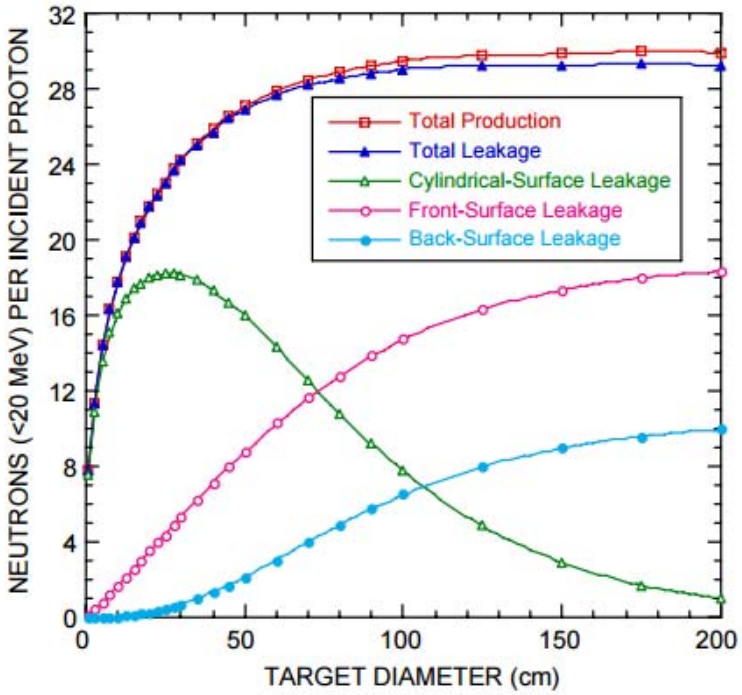
Activity after 1e8s

How many neutrons can you get per incident proton from a spallation target?

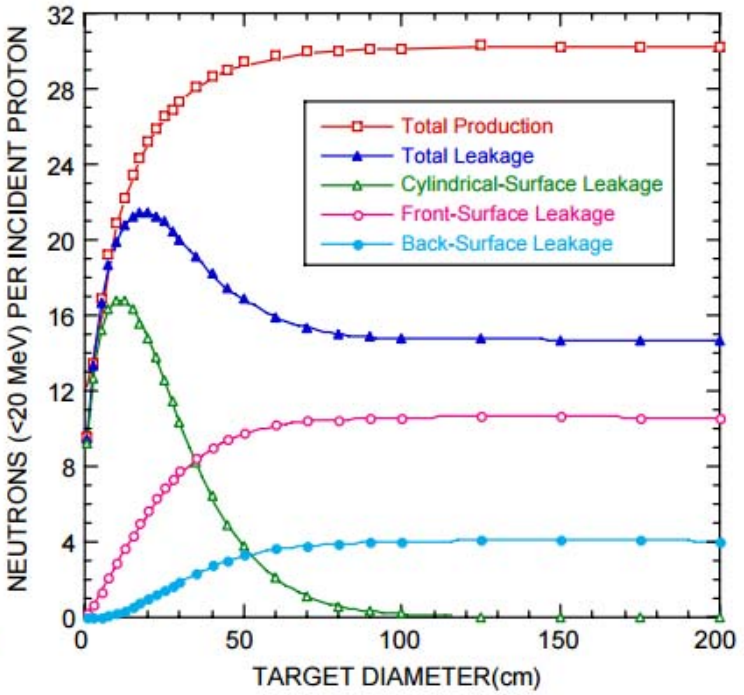
≈ 18 neutrons/proton for a 30cm long 10cm diameter tungsten cylinder

Neutronic Performance of Lead and Tungsten Targets

(Stopping-length targets bombarded on axis by 1-GeV protons)



55-cm-long Natural Lead



30-cm-long Natural Tungsten

Viewgraph courtesy of Phil Ferguson,SNS

Fusion neutron spectra according to Mark Gilbert et al. J Nuc Fusion 2012

In fusion reactor DEMO expect 1e15 neutrons/cm^2/s/lethargy interval in first wall tungsten armour

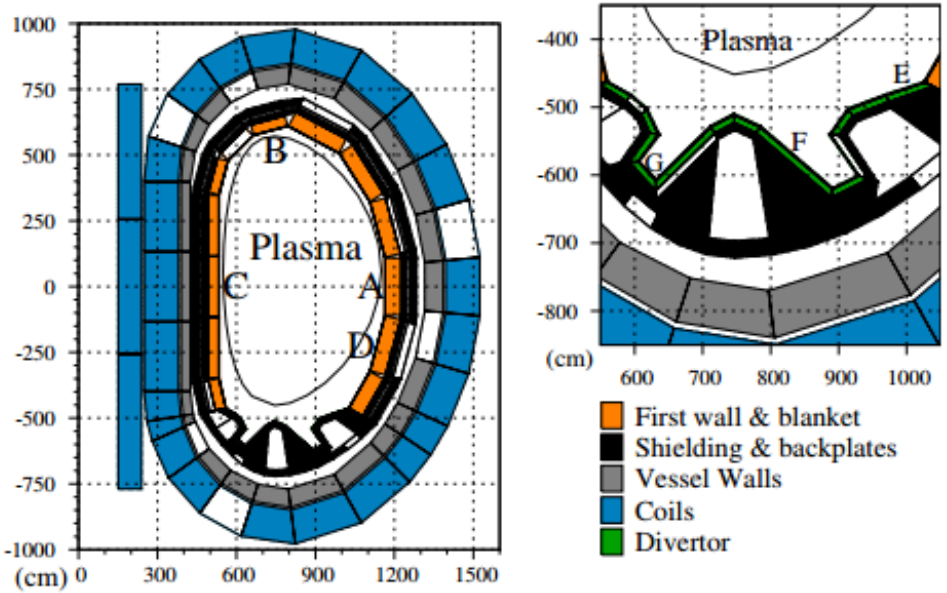


Figure 2. A toroidal section through the simplified, homogeneous, DEMO model used in MCNP simulations to obtain neutron fluxes and spectra.

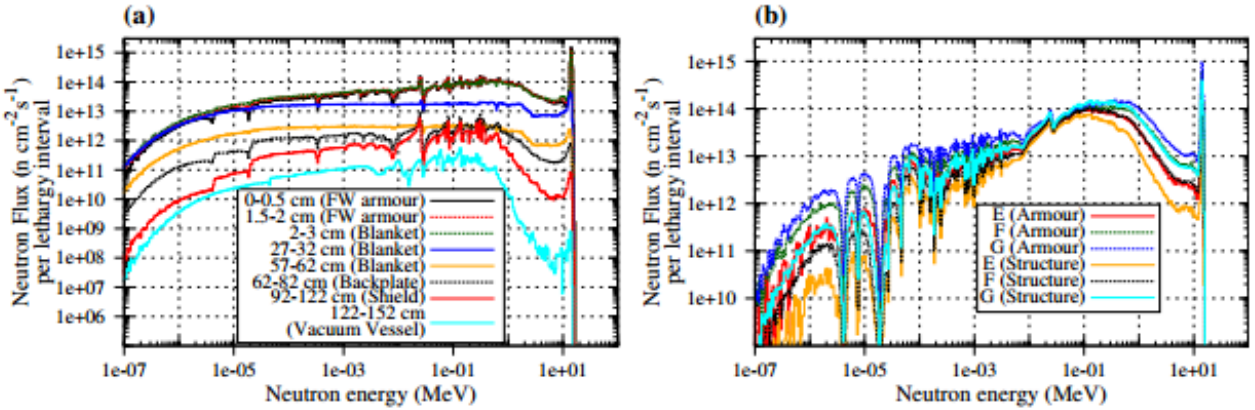
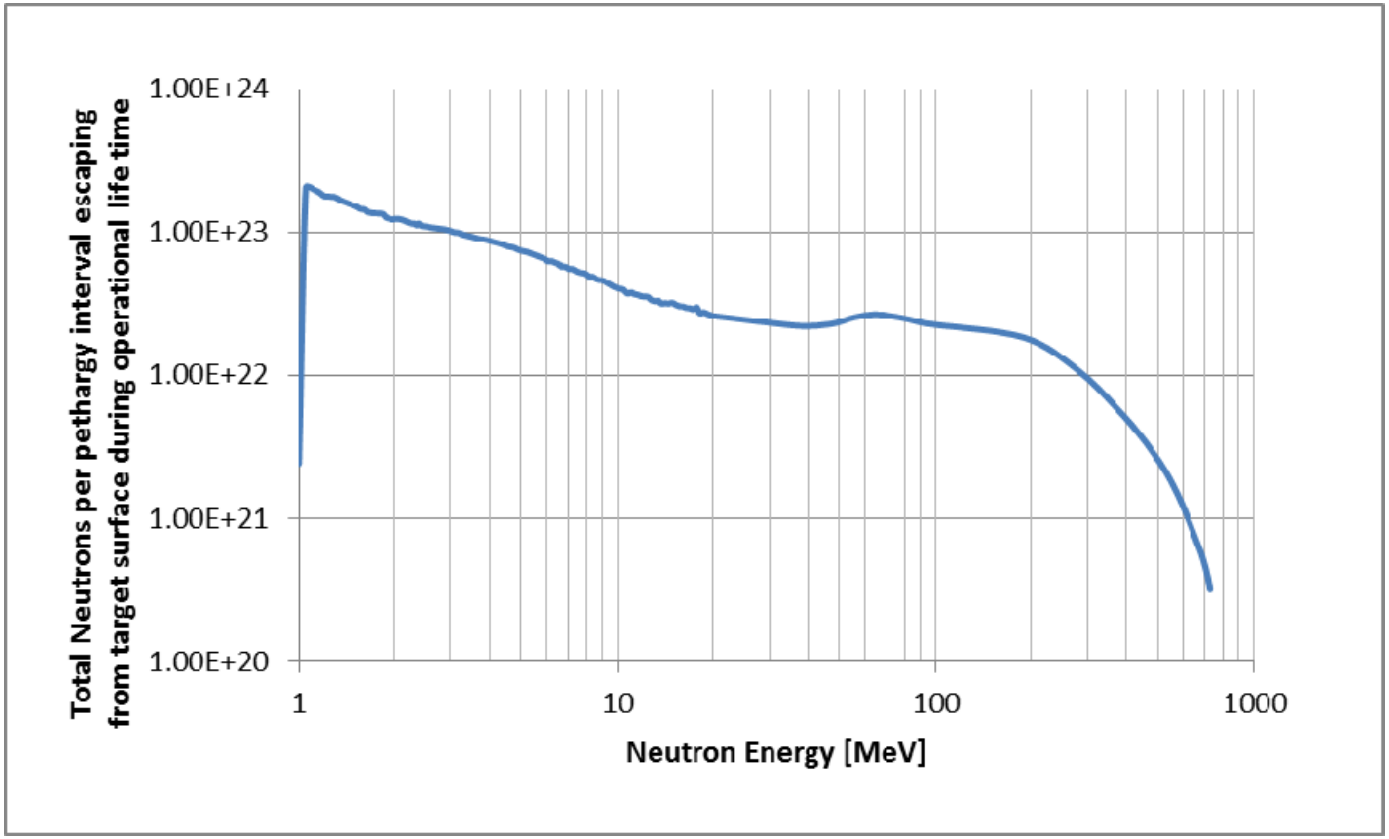


Figure 3. Comparison of the neutron-energy spectra in DEMO; (*a*) as a function of depth into the vessel from the plasma-facing wall at the equatorial position A in figure 2; and (*b*) in the first two layers of the divertor as a function of position (E–G in figure 2).

FLUKA simulation of neutron yield from ISIS target core

TS1 yields 3 neutrons per proton above 1MeV

TS1 W1 ran with 1e15 protons/s for 1e8s , i.e. 1e23protons, so about 3e23 neutrons produced



Compare with expected neutron spectrum in a fusion reactor

At 14MeV

TS1 W1 had 2e22 neutrons/lethargy interval

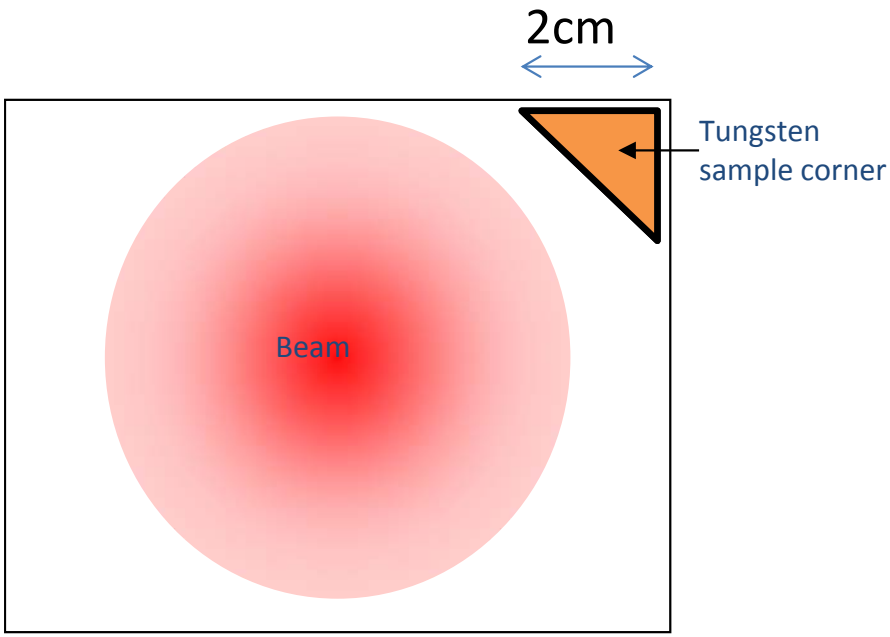
Assume neutrons uniformly spread over Target surface of 2000cm2

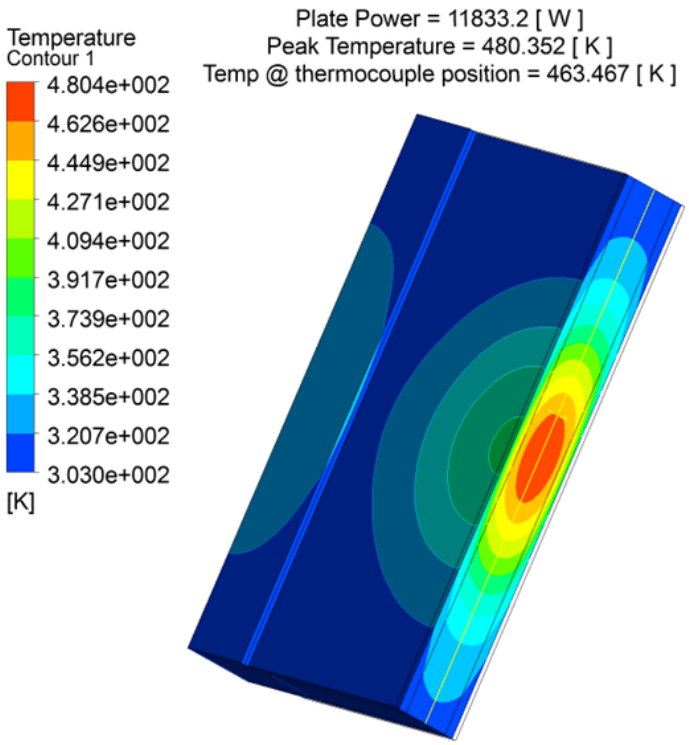
Gives 1e19 neutrons/cm2/lethargy interval

In fusion reactor DEMO expect up to

1e15 neutrons/cm2/s/lethargy interval

Consider neutron flux through a corner of plate 1 of TS1

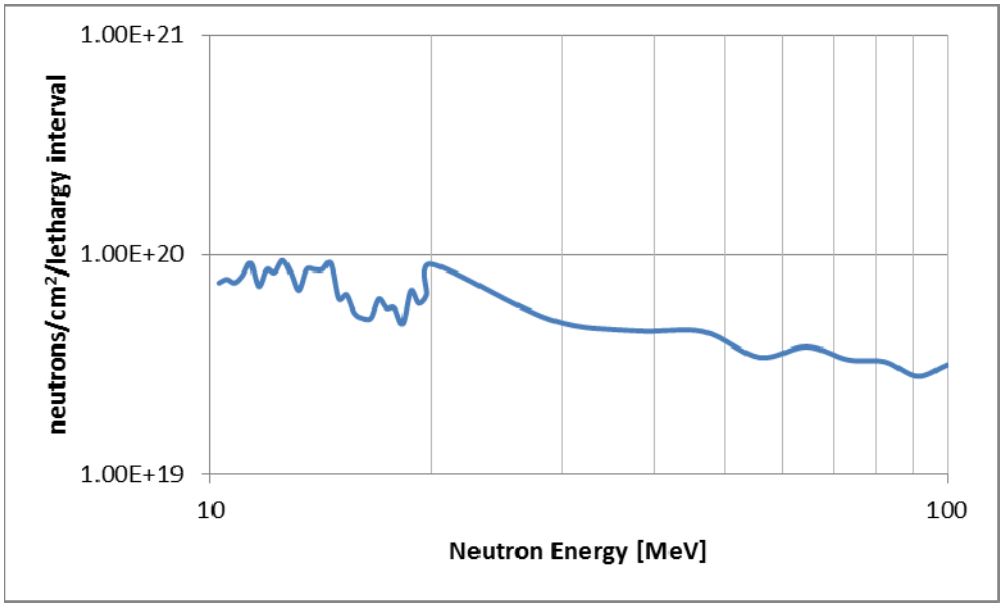




At 14MeV

TS1 W1 plate 1 sample corner has seen
1e20 neutrons/cm^2
(Irradiated at about 330K)
First wall armour tungsten exposed to
1e15 neutrons/cm^2/s

integrated flux in sample corner equivalent to 1e5s of operation – 28hours



Next calculation – helium and hydrogen production through out target

PNNL have made an offer to do PIE on TS1 W1 and TS2

-Container or cask for receipt of target, size and cost depends on activity of target
-Initial size reduction requiring band saw capability in hot cell
-Visual examination with cameras (routine)
-Precision sectioning requiring installation of an EDM
-Waste disposal

PIE then to include
-Thermal conductivity
-Mechanical properties
-Microscopy