4 MW Targets for Neutrino Factory

A Reality Check!

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ISS - KEK - Jan 2006

OPTIONS

1 - Solid (stationary, rotating)

2 - Liquid (Hg)

3 - In-between (liquefied particle bed)

Solid Targets

4 MW ????

What do we need materials to possess to get us there:

- low elasticity modulus (remember stress limits ♦ ~ *E* ♋ 👎*T)*
- low thermal expansion
- high heat capacity
- good diffusivity to move heat away from hot spots
- high strength
- resilience to shock/fracture strength
- resilience to irradiation damage

- **Other than that, we are not asking for much!!!!**

What are we after on the way to 4 MW?

- Look for new alloys, composites, “smart” materials (low to high Z)
- Irradiation damage of these non-traditional materials
- Establish 4 MW-target feasibility by pushing the limits through state-of-art simulations (simulations based on physical models benchmarked on increasingly available experimental data)

Is there hope?

Several "smart" materials or new composites may be able to meet some of the desired requirements:

- **new graphite grades**
- **customized carbon-carbon composites**
- **Super-alloys (gum metal, albemet, super-invar, etc.)**

While calculations based on non-irradiated material properties may show that it is possible to achieve 2 or even 4 MW, irradiation effects may completely change the outlook of a material candidate

ONLY way is to test the material to conditions similar to those expected during its life time as target

Relevant Activity Status

- Beam on targets (E951)
- Material irradiation
- New activities
  - irradiation studies/beam on targets (BNL & FNAL's p-bar facility)
  - Laser-based shock studies
- Simulations and benchmarking
  - LS-DYNA (highly non-linear simulations which reflect on the 4-MW conditions)

Solid Targets – How far can they go?

1 MW ?	4 MW ?
Answer is **YES** for several materials Irradiation damage is of concern Material irradiation studies are still needed	**Answer dependant on 2 key parameters:** 1 – rep rate 2 - beam size compliant with the physics sought A1: for rep-rate > 50 Hz + spot > 2mm RMS ➔ 4 MW possible (see note below) A2: for rep-rate < 50 Hz + spot < 2mm RMS ➔ Not feasible (ONLY moving targets) **NOTE:** While thermo-mechanical shock may be manageable, removing heat from target at 4 MW might prove to be the challenge. CAN only be validated with experiments

Why so?

It is not ONLY the thermo-mechanical shock due to pulse intensities that prevents targets from operating at high power BUT also the ability to remove heat from target

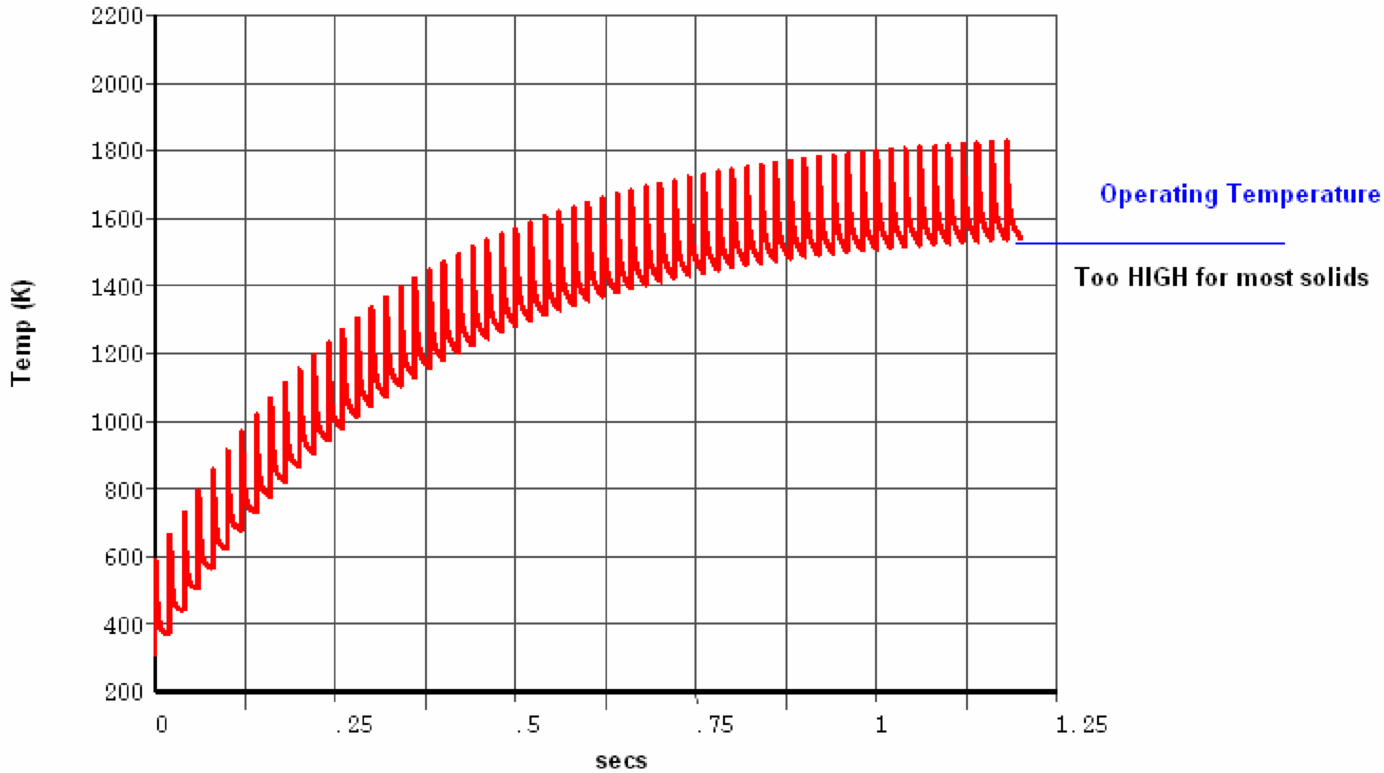
Even at 1 MW it is tough to keep a high-Z target operating within reasonable temperatures

2 MW is most likely the limit for low-Z stationary target (Carbon composite, graphite) operating at low rep rate and 2mm beam spot

Example: Challenge in Operating a Cu Target at 1 MW – 24 GeV

1 MW - 50 Hz Target Operating Temperature Assessment

- Primarily function of power and target geometry
- NOT a function of pulse length or rep rate
- Can be lowered with more cooling BUT there is saturation in cooling capacity for given target geometry



“Moving” Solid Targets

A number of scenarios have been studied

1 MW ?	4 MW ?
YES	LIKELY

Issues

Beam size

Irradiation damage

Operational challenges

A "Liquefied" Particle Bed Concept

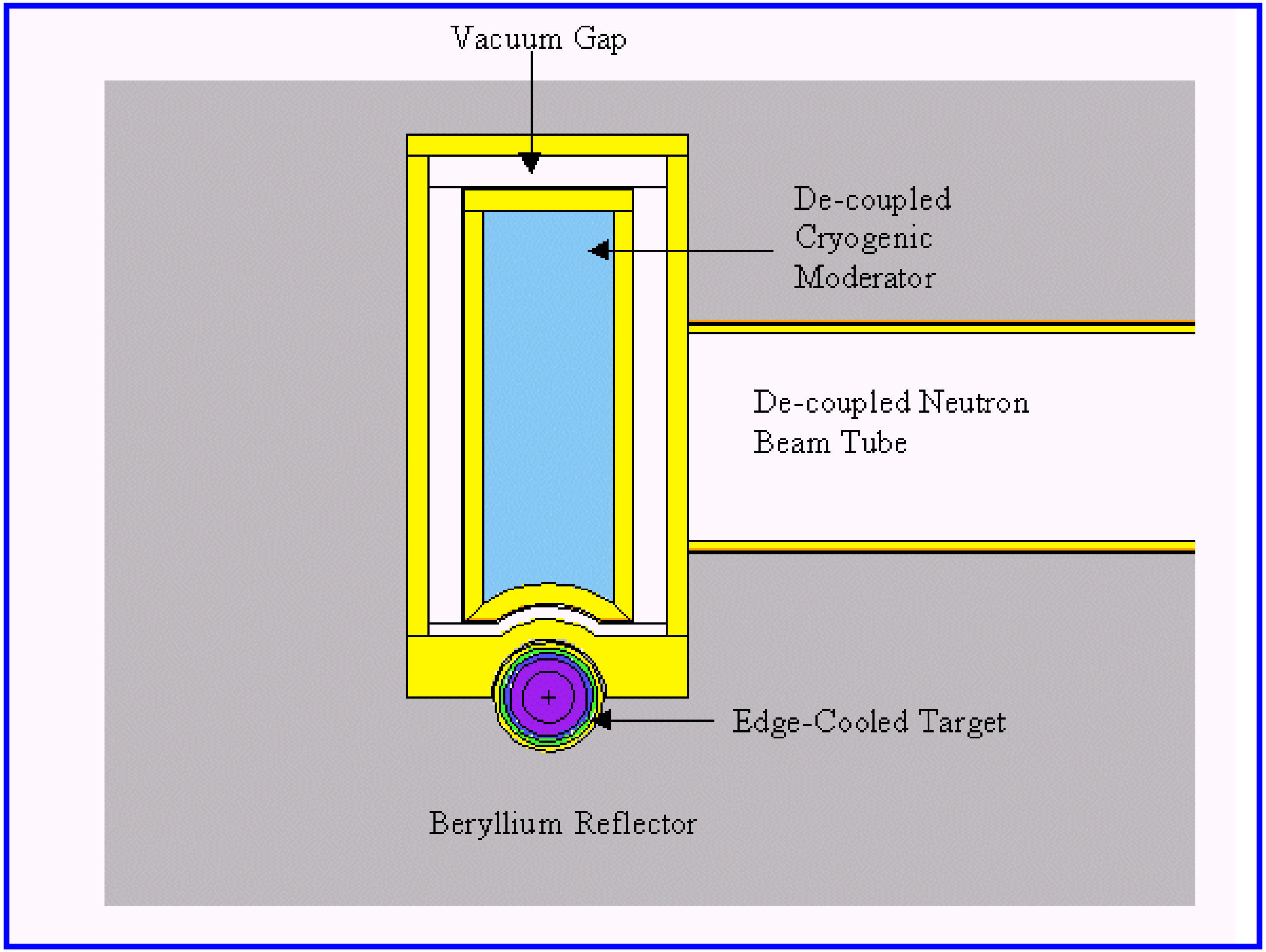
WHAT IS IT ?

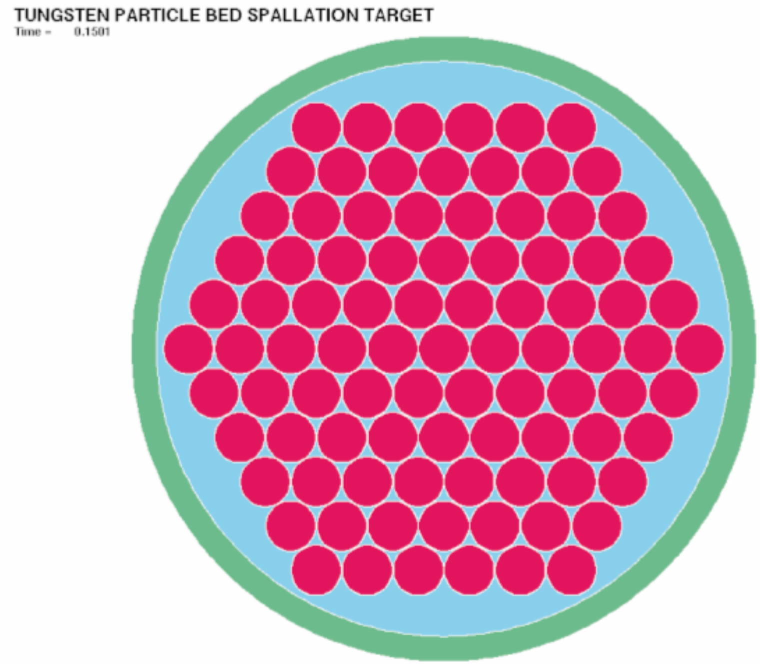
- A loosely packed particle bed wetted by a liquid metal (i.e. Hg)
- particle/liquid interaction ➔ "attenuate" the shock induced + provide yield
- Randomly packed particle beds have been considered in the past (BNL, CERN)

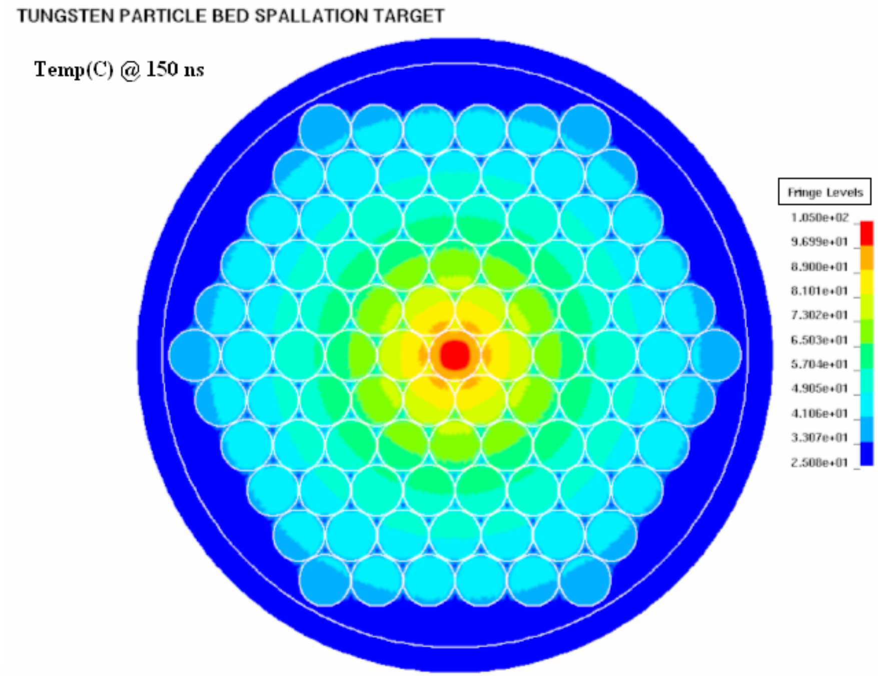
  - pebble bed reactor
  - neutron sources
  - SNS collimators/absorbers
  - Studies of poro-elasticity in granular media

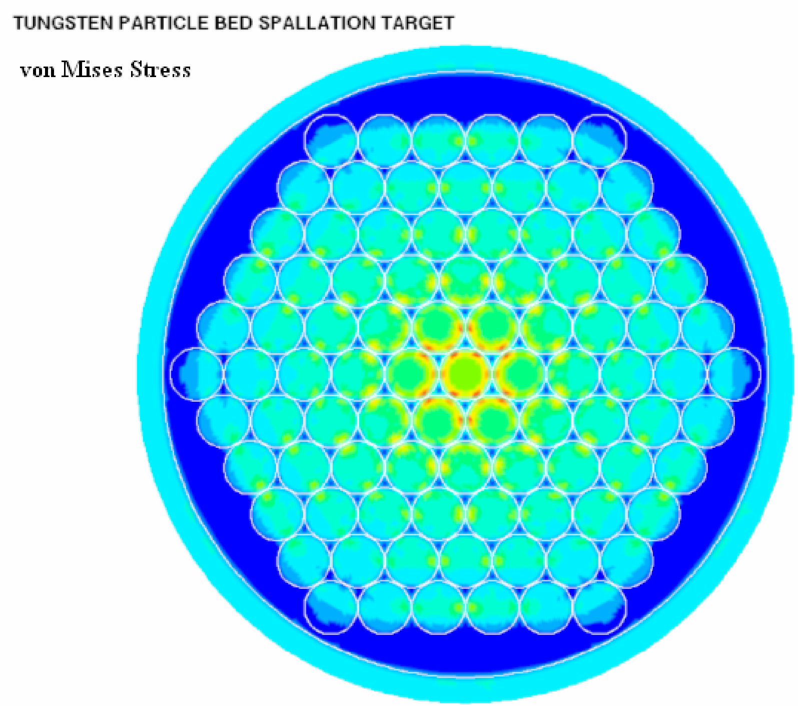
Concept for an Edge Cooled Target for Use at the BNL-AGS

H.Ludewig, N. Simos, J. Hastings, P. Montanez, and M. Todosow.



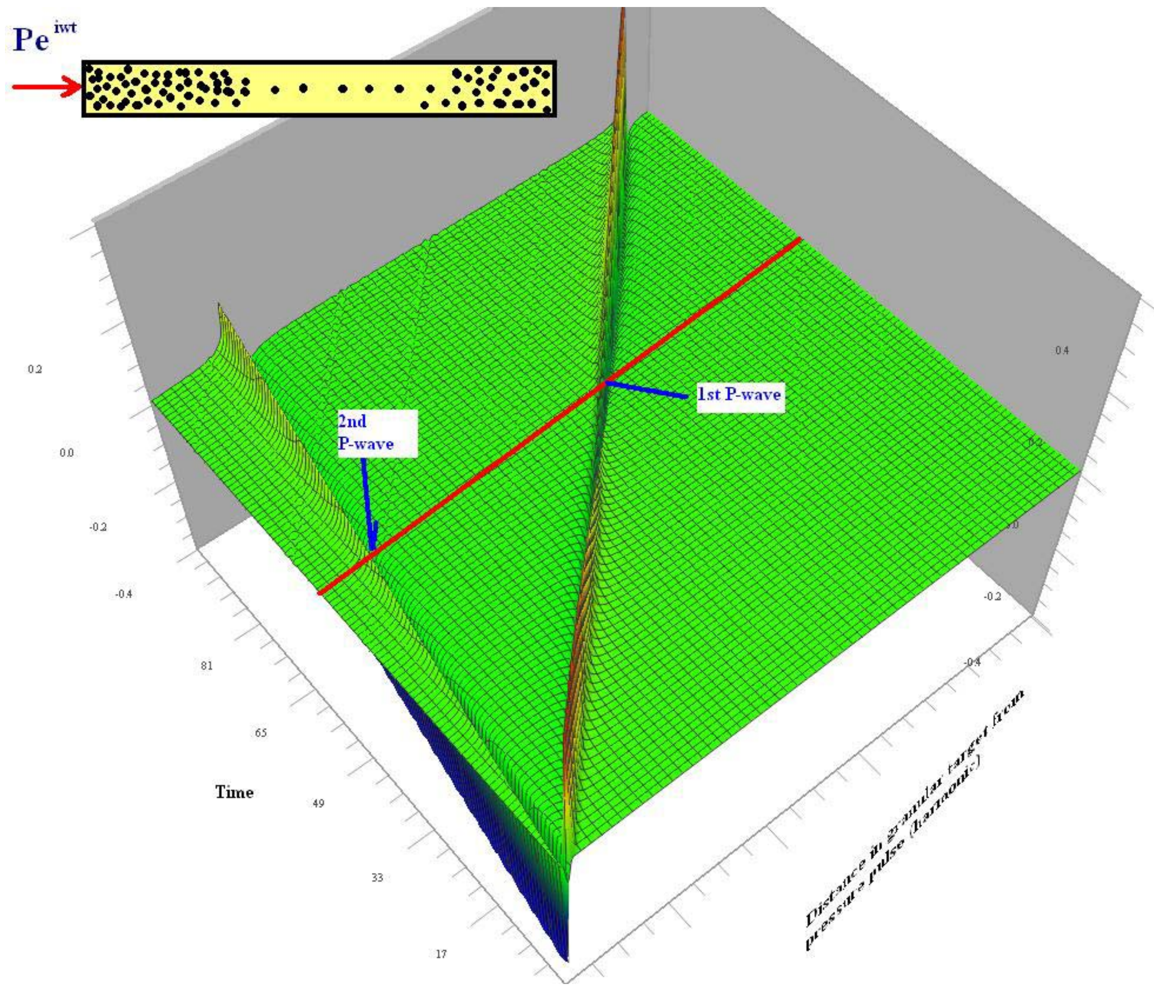

TUNGSTEN PARTICLE BED SPALLATION TARGET
Time = 0.1501


TUNGSTEN PARTICLE BED SPALLATION TARGET
Temp(C) @ 150 ns
Fringe Levels
1.050e+02
9.699e+01
8.900e+01
8.101e+01
7.302e+01
6.503e+01
5.704e+01
4.905e+01
4.106e+01
3.307e+01
2.508e+01


TUNGSTEN PARTICLE BED SPALLATION TARGET
von Mises Stress

Experimental + Theoretical work has been done in this area

Figure shows analytical results of a pulse propagating in the medium with two (2) velocities ➔ leading to sharing of energy



Proof of Principle by Experiment:

Use the E951 thimble experiment set-up at CERN to assess the potential benefit of “suspended” pebbles in Hg

Use simulations to predict the level of influence of suspended particles

Conceptualize/simulate a 4 MW target system based on the neutron source concept