Solid Target Options

- The choice of a primary beam target for the neutrino factory, with beam power of 1 - 4 MW, is challenging - with target integrity a serious concern.
- Much of the recent focus has been toward a liquid heavy metal jet target - a 'disposable" target for long-term viability with intense radiation, and using Hg for high pion yield.
- However, a new set of issues must now be addressed.
- Concerns with a liquid metal jet target include
  - viability in 20- T solenoid field
  - jet integrity with pressure wave effect induced by proton beam
  - potential severe contamination problems
  - complexity of target system design in a very difficult radiation environment
- Perhaps most important
  - requirement for costly, lengthy and challenging R & D program to demonstrate basic feasibility

Case for a Solid Target

- A neutrino source can provide substantial physics capability with 1 - 1.5 MW beams.
- This level of beam power is higher than for existing solid target designs - but not by a large factor.
- NuMI graphite target design (400 kW beam) has similar energy deposition density as a 1 MW neutrino source. Recent successful beam testing.
- A great deal of experience exists with solid targets of different materials exposed for long duration to high beam power. Includes
  - CERN & FNAL p-Bar production
  - RAL: Spallation neutron source
- Simpler system design
- Readily compatible with high magnetic field environment
- Easier replacement capability
  - several months is a viable target lifetime
- R & D questions more readily addressable

Case for Solid Target (cont)

- Perhaps the most important point in favor of an approach toward initial 1 - 1.5 MW operation using a solid target:
  substantial physics capability & target feasibility issues can be credibly addressed with modest resources in a short time.
- **This type of approach is very important (and may be crucial) in progress toward a real facility**

- How to proceed:

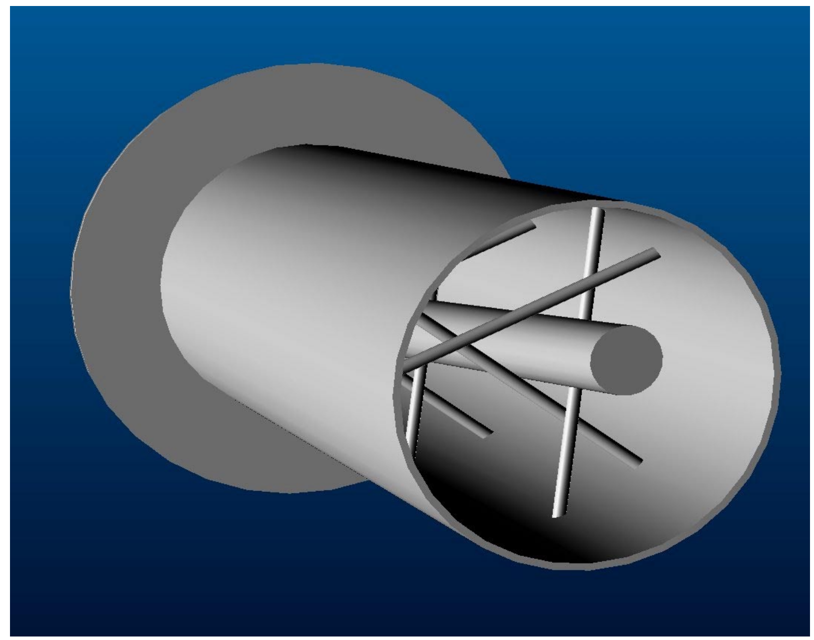
- Design target facility and support services for full 4 MW capability. Upgrade here is very difficult.
  (P. Spampinato - ORNL)
- Timely pursuit of R & D - both modeling and beam studies - to understand solid target limits and design optimization.

Target Material Choice

- Particle yields improve with higher z targets
  - N. Mokhov - FNAL (MARS) At 16 GeV, flux yield for Hg / C ~ 1.7 / 1.
- However, For low z target, <u>much</u> less power is deposited in the target for the same pion yield
  - power deposited in target = 5 / 1 for Hg / C. Only ~ 37 kW in C target with 1.5 MW beam
- A factor of 3 net gain to C in target power deposition for the same yield (but higher beam power)
- High beam power solid targets frequently use higher z materials for increased yield plus other techniques to compensate for high power deposition
  - FNAL p-Bar: rotating disks (CuNi)
  - CERN: Ti target encased in graphite
- New proposed concepts also
  - B. King - BNL considers a rotating band target geometry to spread energy deposition over a large target area

Target Material Choice (cont)

- For neutrino source (16 - 24 GeV) and given target material in a solenoid capture field, yield is optimized using a simple bare suspended target
  - figure shows J. Chesser -ORNL concept for a graphite target
- Most promising solid target material considering combined effects of yield, survivability and initial design simplicity is carbon (graphite).



NuMI Graphite Target

- NuMI Beam:
  - 4 × 10^{13} 120 GeV protons / 1.9 sec (400 kW) 8 _s spill
  - 1 mm beam size (σ) at target, max. deposition density ~ 0.11 GeV/cc/p
  - Similar beam energy deposition density as a 1 MW Neutrino Source but with different time structure
- Target design criteria include:
  - Maximal neutrino yield
  - Reliability for > ten million pulses (1 year, with peak deposition about 5 dpa / year)
  - Module replacement capability
- Target design by IHEP, Protvino (V. Garkusha Group)
  - water cooled graphite
  - http://www.numi.fnal.gov.8875/numi/beam/beam.html
- Graphite 3.2 mm width, 0.96 m length
- Fin design with slots to form 'teeth'
- Successful initial beam test
  - FNAL p-Bar facility, 1 × 10^{13} per pulse, 0.25 mm sigma beam to reach > 1 dpa.

Challenge of nsec Beam Spill

- One of the most challenging parameters for target survival is intense energy deposition in a few nsec beam spill
  - A. Hassanein - ANL calculation of pressure wave dependence on energy deposition time (HEIGHTS code)

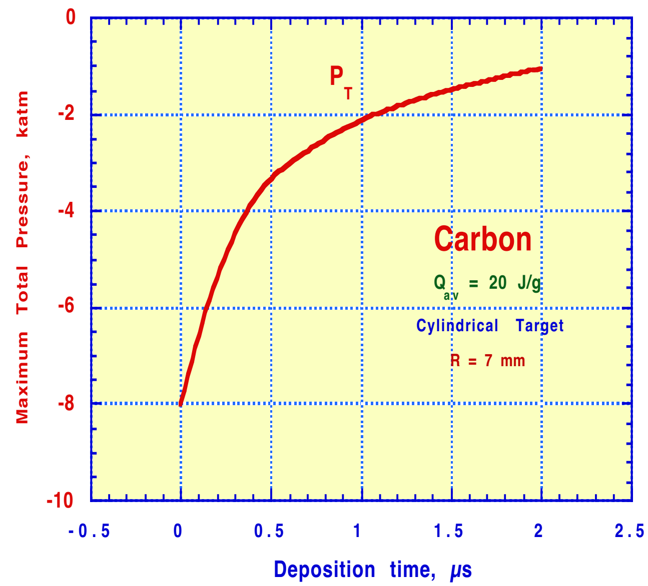


Fig. 1 HEIGHTS Calculations of Dependence of Total Pressure on Energy Deposition Time

Pressure Wave Modeling

- Neutrino source parameters
  - graphite target with 7.5 mm radius, 80 cm length
  - 16 GeV proton beam with σ(x,y) of 3 mm. RMS bunch length 3 nsec. 1.5 MW incident beam power. 15 Hz

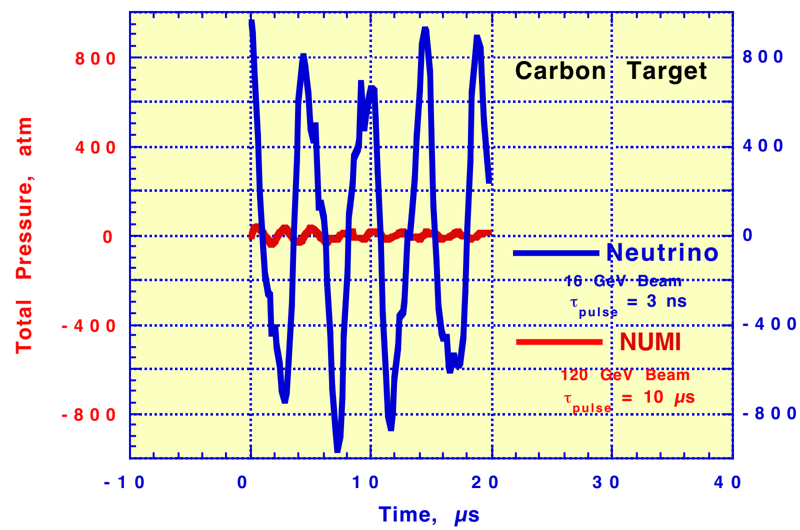
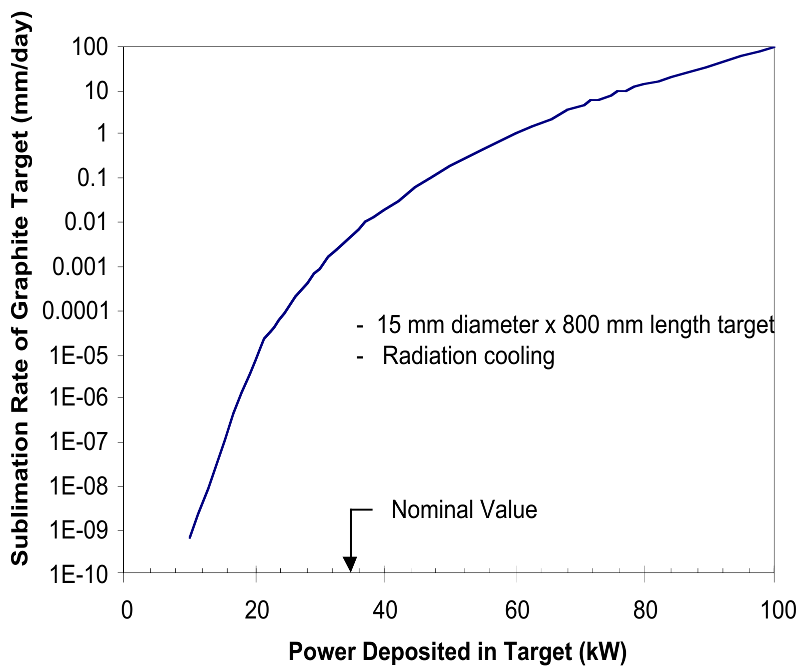


Fig. 3 HEIGHTS Calculations of NUMI and Neutrino Target Total Pressure Oscillations Following Beam Deposition

Target Cooling

- Radiative cooling for graphite target appears feasible
  - J. Haines - ORNL calculations
  - Surface temp ave. ~1850 deg. C
- Water cooling complicates flux optimization & must also be aware of survival for cooling tubes



Graphite Target R & D

- Priorities:
  - Detailed understanding of shock effects vs. target shape, material configuration - Model comparison and cross-checks
  - Single pulse high intensity beam testing in new BNL A-3 beam
  - Measurement of radiation degradation effects - High power short spill beam - Los Alamos
  - Optimize cooling approach & target design based on model & beam test feedback

- Near term R & D efforts (during the upcoming year) can give strong evidence toward a viable graphite target design for a Neutrino Source
- See how far we can go with the most simple type of target design - it may well be a very long way.