# Near Term Strategy for Development of 1.2 MW Target & Horn for LBNE

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LBNE collaboration meeting

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| *Plan for beam power:* | start at | eventually upgrade to |
|---|---|---|
| As of last summer | **0.7 MW** | --> 2.3 MW |
| Current plan | **1.2 MW** | --> 2.3 MW |

LBNE Beam Project, permanent elements designed for 2.3 MW:

- transfer line
- radiation shielding
- Decay Pipe
- Absorber (Dump)

Elements designed for 0.7 MW, needing reexamination or re-design for 1.2 MW:

- Target profile monitor
- Beam window from transfer line to target hall
- Baffle
- Target
- Horns
- Horn power supply
- Hadron monitor at end of decay pipe
- Water cooling panels for target hall shield pile (were to run dry at 0.7 MW)

Some history:

- Had developed a 0.7 MW target + horn design more optimized for LBNE
- When LBNE re-configured to save money, reverted to NuMI style target/horn which is excellent at 1st oscillation maximum, but not as good at 2nd osc. max.; expected to produce a horn with more emphasis on 2$^{nd}$ osc. max. later

- At 0.7 MW, both target and horn were pushed to stress limits with reasonable but not excessive safety factor. (The headroom we had with the horn we used up increasing the current to 230 kA as compared to the existing run at 200 kA)

- For 1.2 MW beam, we need some modifications to handle higher beam power

Plan: see if modest modifications can get us to 1.2 MW.

Try minimal redesign and thus hopefully minimal cost increase.

If that does not work, will look at major modifications in design.

- A 2.3 MW target/horn system may well be less efficient at neutrino production, due to some tradeoffs to handle higher power. It probably requires major modifications, and significant R&D and prototyping.
  - Doing the system in two steps can make sense.

# The attempt at modest TARGET modification

Reduce stress by increasing the beam spot size, spread out beam

- Implies making target wider so protons don't miss target
- For higher power, also must increase size of water cooling line
- Scoping calc.: for same proton flux at center, 1.3 mm RMS -> 1.7 mm RMS.

  But limit may be outer edge of target (tension) rather than center (compression)

  ***Detailed MARS + ANSYS simulation needed to see what size increase required***

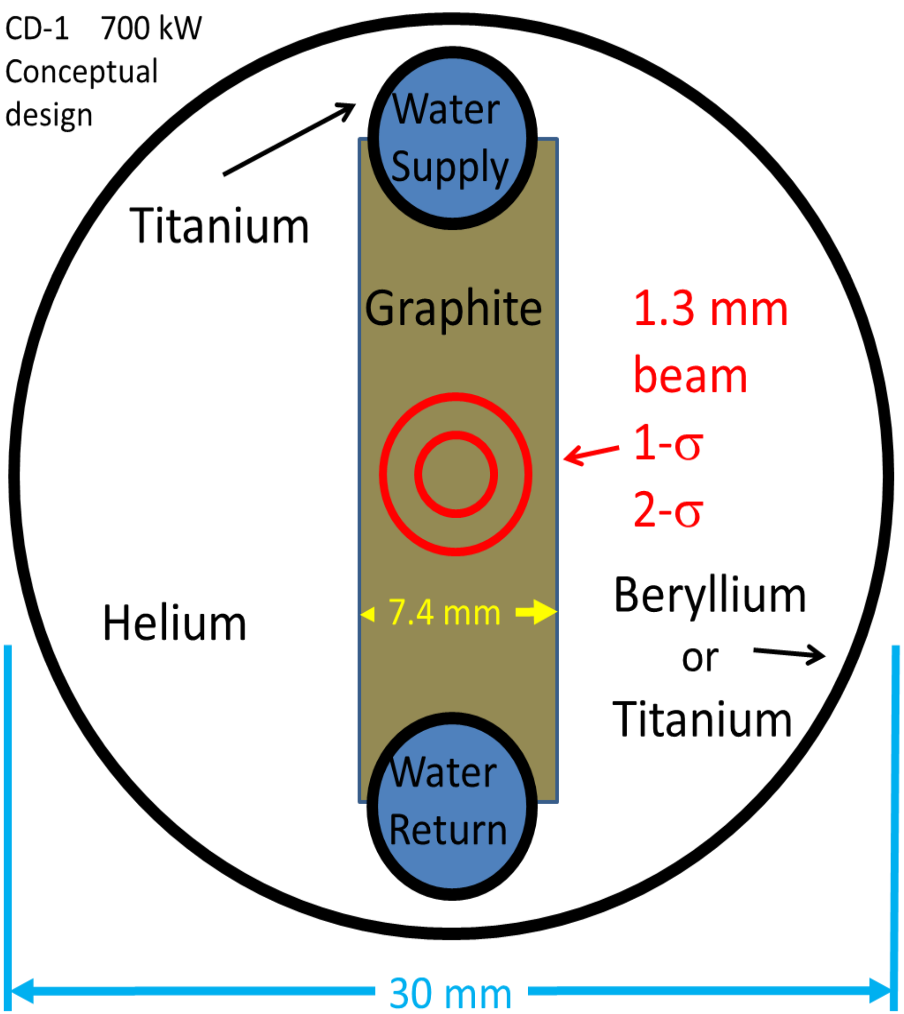
Some expected advantages of increasing beam/target size

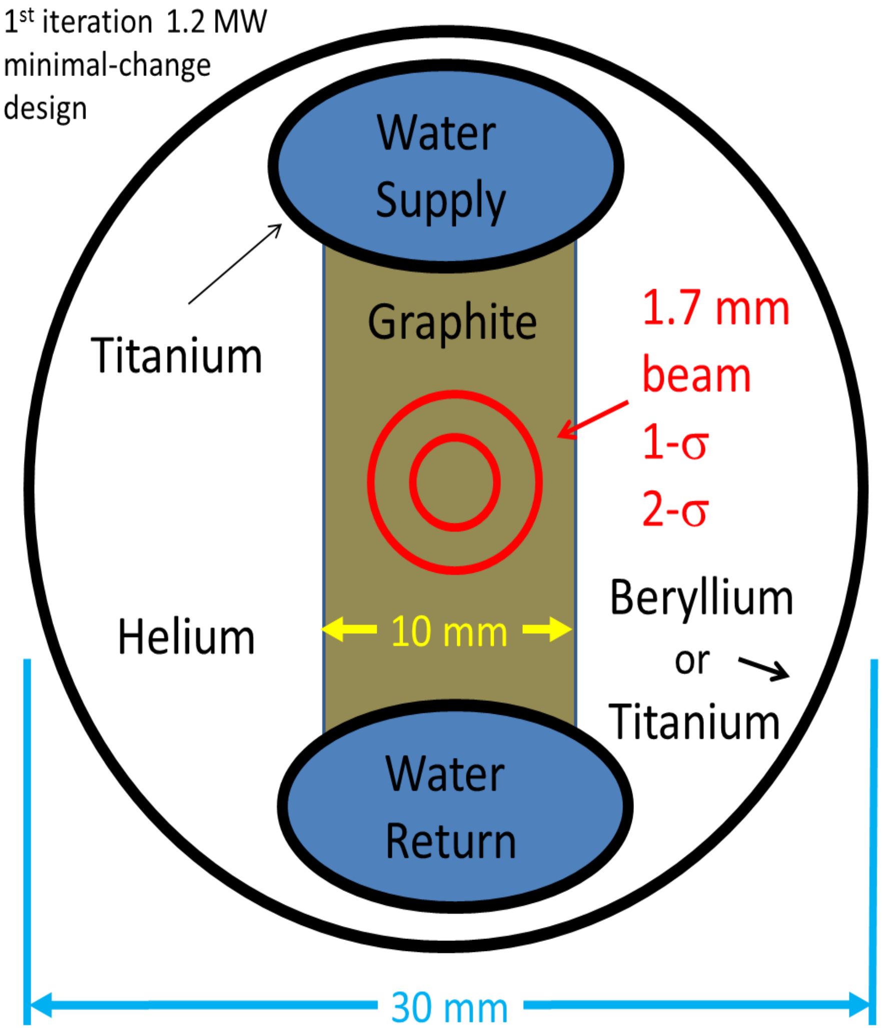
- Reduces stress in center of target
- Reduces radiation damage rate at center of target
- Extra showering in target may gain some flux at 2nd osc. max.

Some expected dis-advantages of increasing beam/target size

- Extra showering in target may lose some flux at 1st osc. max.
- Extra showering deposits more beam heating in horn inner conductor
- If target cooling lines get too large, would need to increase radius of horn

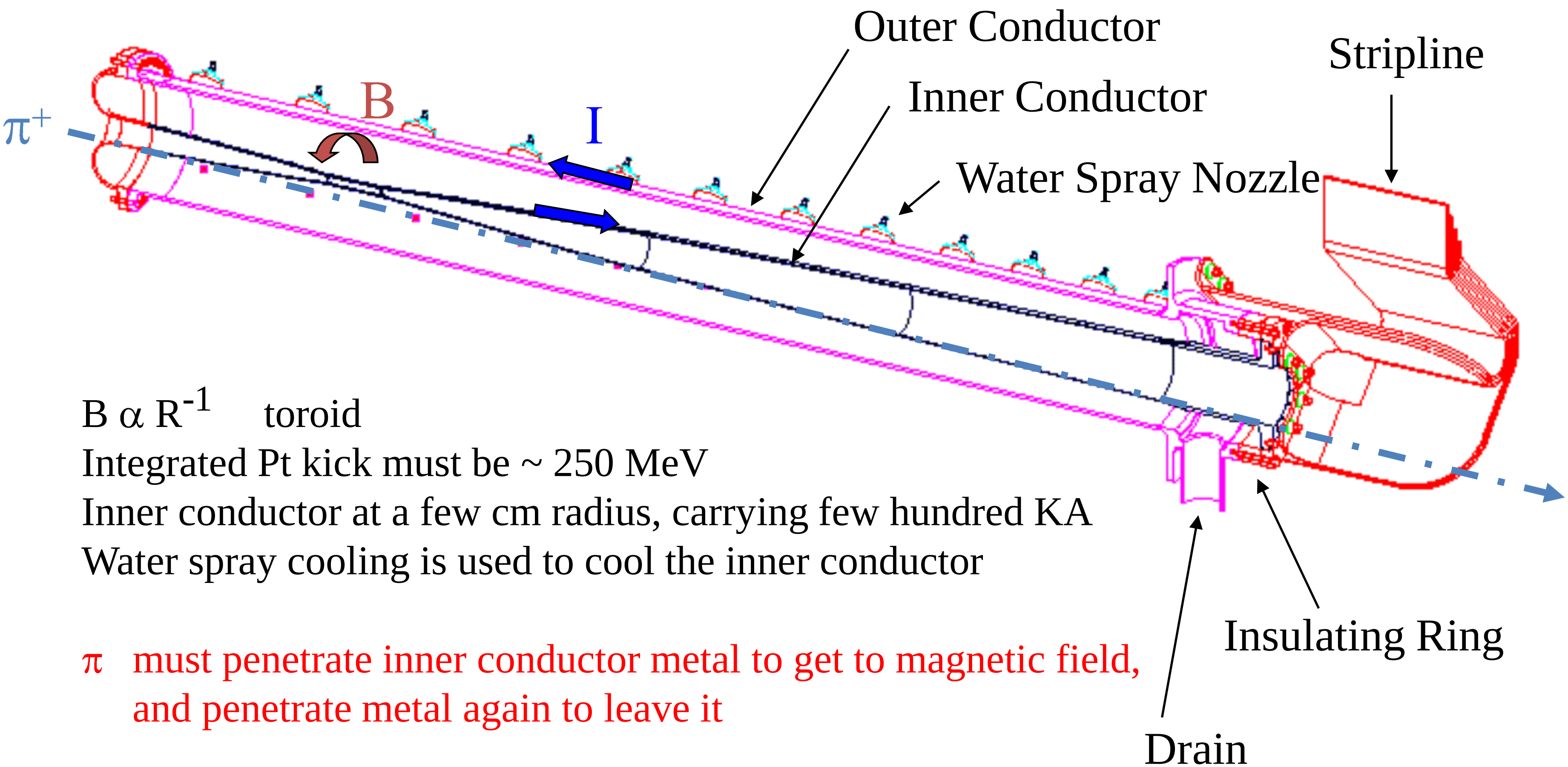
| LBNE CD-1 0.7 MW target | LBNE Zero-th iteration 1.2 MW target |
| --- | --- |



# Horn: π focused by toroidal field between conductors

Beam-lines use 1, 2, or 3 horns in series




B α $R^{-1}$ toroid

Integrated Pt kick must be ~ 250 MeV

Inner conductor at a few cm radius, carrying few hundred KA

Water spray cooling is used to cool the inner conductor

π must penetrate inner conductor metal to get to magnetic field, and penetrate metal again to leave it

Inner conductor is a few mm aluminum, but penetrated at small angles

# The attempt at modest HORN modification

Horn limits come from STRESS and TEMPERATURE that ALUMINUM Inner Conductor can take

- at 0.7 Mw, beam heating : joule heating is 44% : 56%
- at 1.2 MW, make more room for beam heating by reducing joule heating with shorter pulse
  changing 2.1 msec half-sin-wave -> 0.8 ms gives same overall heating
  ( insufficient flat top across beam spill would start around 0.2 ms )

Have to first see what target profile may work

- Target modifications will further increase beam heating
- Modified target might not fit in NUMI horn profile

Then input beam heating from that target into horn analysis

- Stresses are combination of magnetic field, beam heating profile, and joule heating profile

If this strategy succeeds, still requires new power supply & stripline

- We had planned to recycle the NuMI power supply to save money
- Note the pre-reconfiguration power supply was designed for 1.0 ms pulse width, similar to what we may need, so we essentially already have a design / cost estimate for that

We are months away from seeing if this minimal modification strategy works or we need substantial re-design to accomplish good neutrino efficiency at 1.2 MW.

# *Possible R&D Opportunity*
# Horn shape studies for Neutrino optimization

Simulation effort to optimize target/horn geometry

Many shapes, horn currents possible, very large phase space to study

Compute intensive, needs extensive resources

different for phase 1 and phase 2 of LBNE (importance of $2^{nd}$ oscillation max., beam heating)

When cost for an experiment + beam approaches $1 Billion,
worth optimizing for the last several percent

For LBNE, have not done extensive optimization, so significant oppertunity.

In fact, current baseline is re-use of NUMI style horns to keep cost under control.

Excellent at $1^{st}$ osc. Max., but not particularly good for $2^{nd}$ osc. max. (~ 30% available gain ?)

collaboration on horn shape design would expand phase space one could look at,

and would be very useful, as we are people-limited. Especially true for phase 2 horn and target.

Not clear how this iterates with expensive engineering.

0.4 MW -> 0.7 MW -> 1.2 MW - > 2.3 MW

MINOS -> NOVA/LBNE phase 1 -> LBNE proposed phase 1 -> LBNE phase 2

Up to 0.7 MW, magnetic / joule heating / beam heating stresses were comparable

Going forward, beam heating becomes dominant:

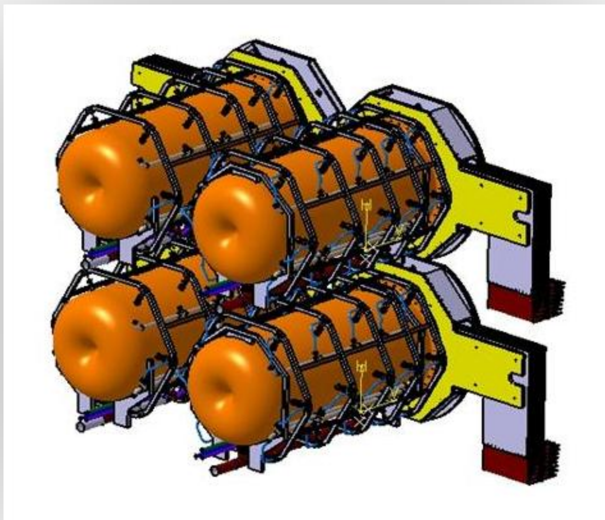
- Beam power going up
- Desired neutrino spectrum is low energy, focusing features drive target into horn, maximizing beam heating of horn inner conductor
- Generally, target gets "fatter" (spread out beam to withstand shock, more cooling), and showering in target adds energy to horn beam heating (x2 for two LBNE targets)

The NuMI style target/horn works at 700 KW, with minor modifications for LBNE.

Under study right now is whether reasonable tweaks can get this to 1.2 MW, results not yet in.

By 2.3 MW, NuMI horns probably need major modifications because of beam heating

# One proposal from Euro$\nu$ Superbeam studies:
# 4 primary beams into four horn systems in parallel for 4 MW beam

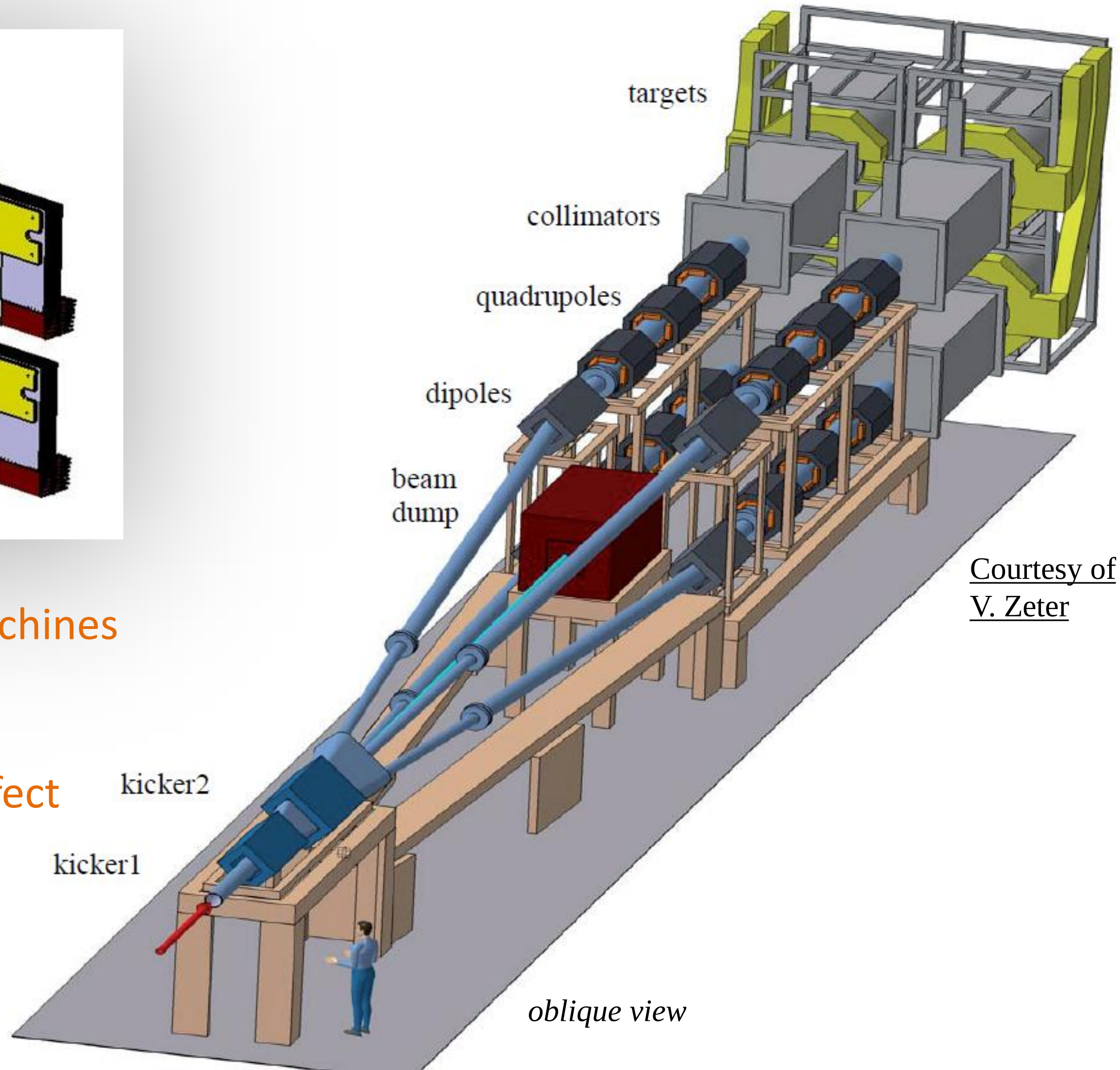


Scalable for high repetition rate machines

But

For LBNE (and T2K) with slow rep.,

single pulse beam heating is big effect




Courtesy of V. Zeter

# *Possible Hardware R&D Opportunity*

## Horn for higher power: Beryllium inner conductor ?

Somewhere between 1 and 2 MW, beam heating makes Aluminum inner conductor problematic – creep limits what temperature aluminum can take, and stresses are also daunting. *Time for a new material?*

The list of possible replacement materials are limited, need:

- Good Electrical Conductivity
- Large radiation and interaction lengths
- High Strength, resistant to creep
- Corrosion resistant

--> Beryllium ( or Albemet = alloy of Beryllium and aluminum )

The first challenge for Beryllium will be connecting to it, and connecting pieces of beryllium together.

To pursue this, need complete engineering design of a beryllium inner conductor horn.

This could be useful for any future high power neutrino beam; option for **generic R&D**

# *Possible Hardware R&D Opportunity*
# Target

Several Target R&D opportunities are covered in Patrick Hurh's talk in this session.

Bob Zwaska has pointed out that some facilities add a few percent CO2 or Methane or Carbon monoxide around graphite to help mitigate radiation damage; issues like this may also present R&D opportunities.