Accelerator R&D: Horn R&D Opportunities

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ICFA Neutrino Panel Mini-Workshop

January 31, 2014

- Detailed optimization to particular experiments
- How to handle higher beam power

How does a horn work ?

→ What are the upcoming challenges ?

→ What R&D issues ?

Apologies in advance for LBNE-centricity

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

Downside as general R&D activity– optimized shape is rather experiment specific

- Must iterate with engineering (and depends on target design as well)
- Depends on physics goals of an experiment, baseline, and accelerator beam structure
- May even be different for phase 1 and phase 2 of LBNE (importance of 2nd oscillation max.)

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 need.

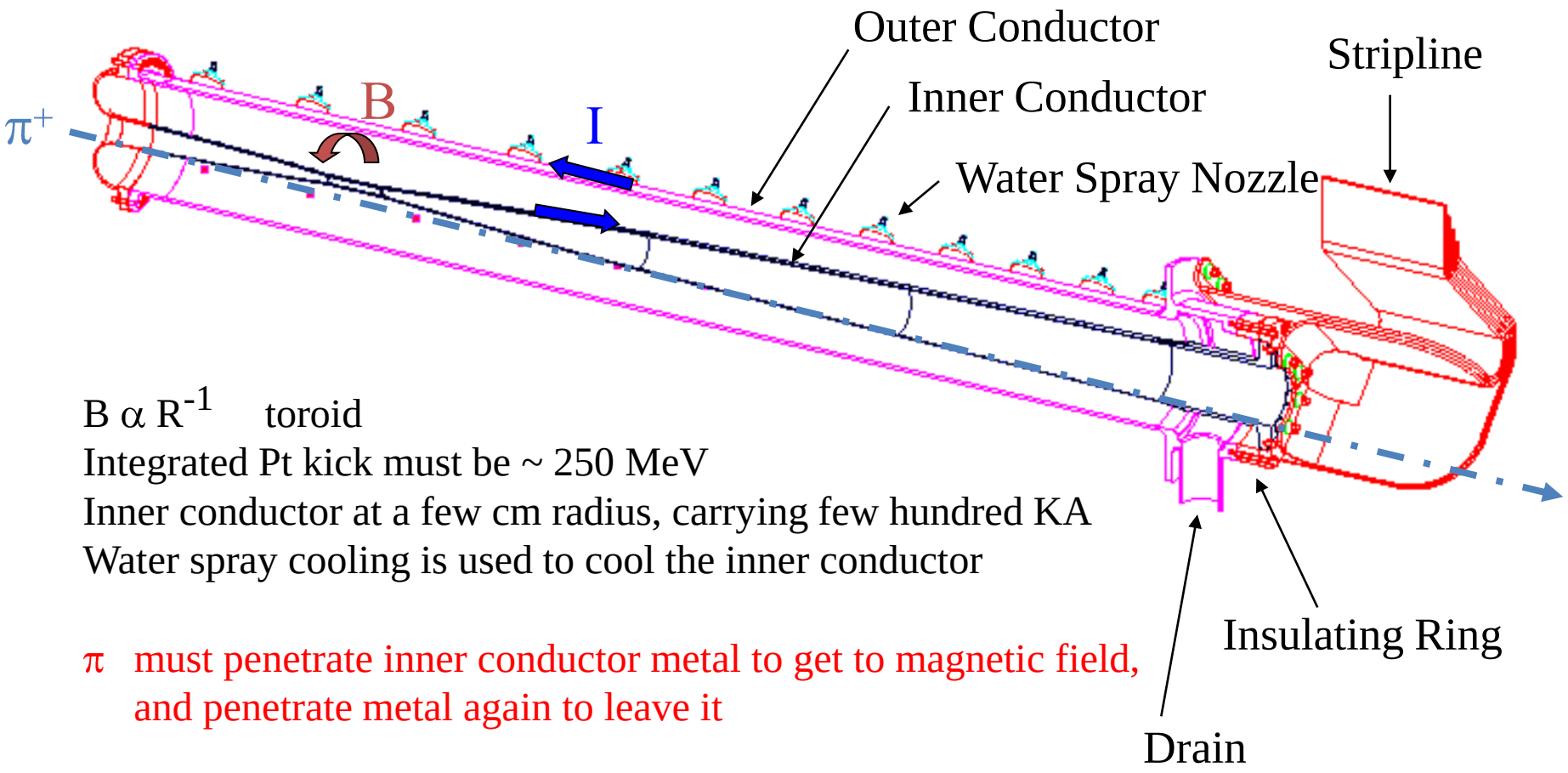
In fact, current baseline is re-use of NUMI style horns to keep cost under control.

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

International 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.

Horn: π focused by toroidal field between conductors

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



$B \alpha R^{-1}$ 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

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:

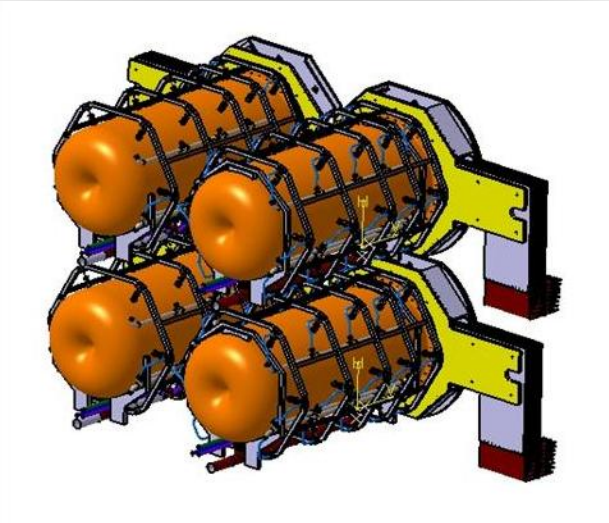
- Beam power going up
- Desired neutrino spectrum is low energy, focusing features drive target into horn, maximizing beam heating of horn inner conductor
- Generally, target gets "fatter" (spread out beam to withstand shock, more cooling), and showering in target adds energy to horn beam heating (x2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

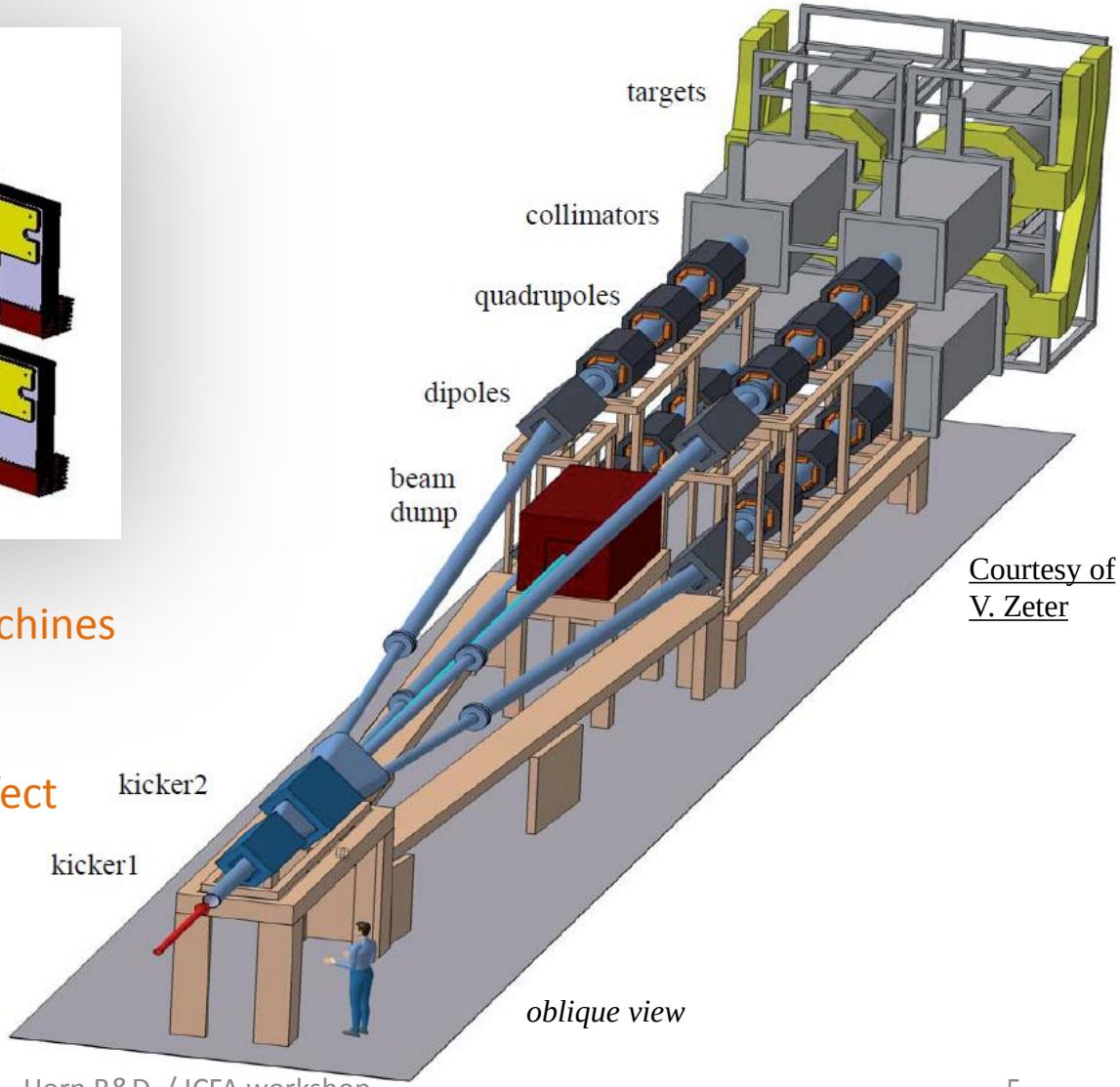
The NuMI style target/horn works at 700 KW, with minor modifications for LBNE.

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 need major modifications because of beam heating

One proposal from Euroν Superbeam studies: 4 primary beams into four horn systems in parallel for 4 MW beam





Courtesy of V. Zeter

Scalable for high repetition rate machines
But
For LBNE (and T2K) with slow rep., single pulse beam heating is big effect

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

--> 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**

BACKUP

NuMI Neutrino beam-line