NuMI Horn
Construction and Testing

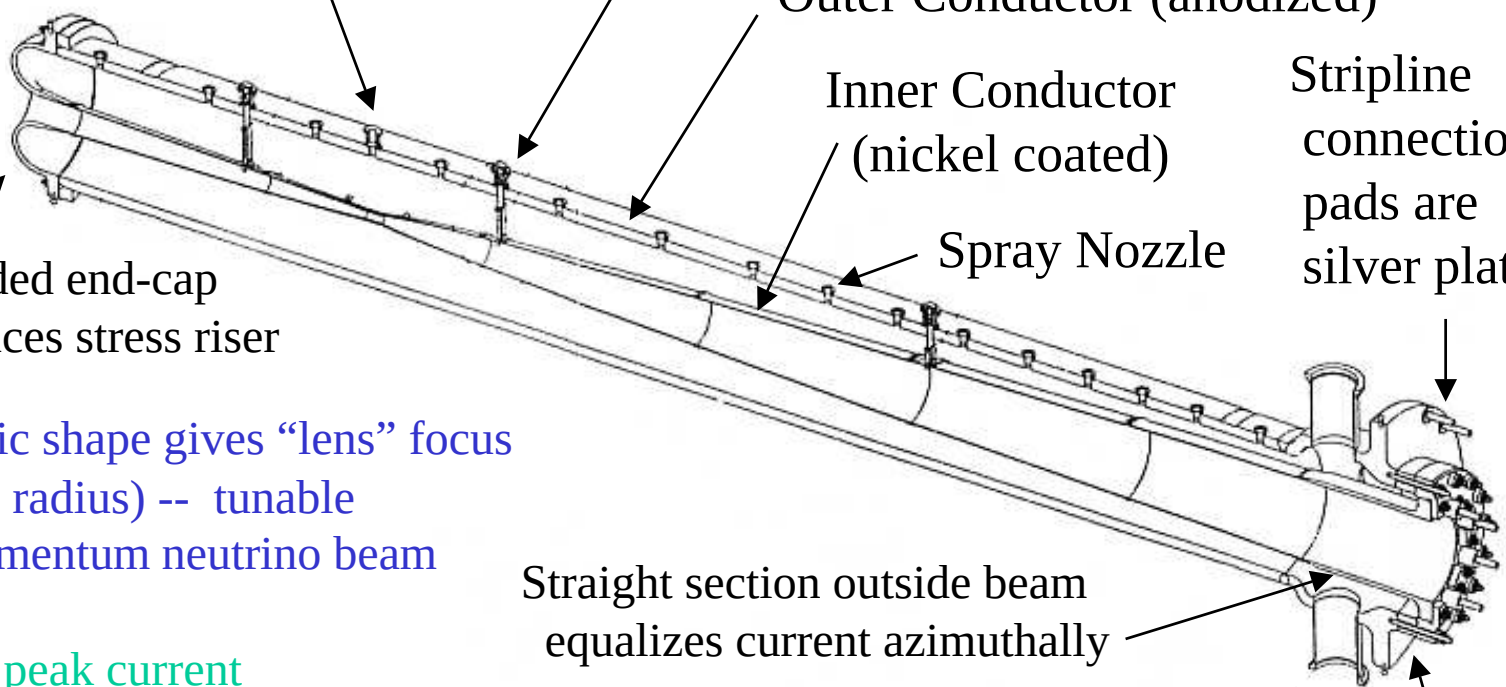
At NBI'02
- Just finishing testing of prototype horn

Since NBI'02
- Constructed and tested production horns 1 & 2

Will also mention
- Cross Hair Alignment System
- Remote survey rod
- Field Monitoring Bdot Coils
- Remote electrical connection, stripline flex test
- Decay Pipe Magnetic Field Check

ANL has collaborated on horn testing and monitoring

NuMI Horn
General Design Features



Parabolic shape gives "lens" focus
(Bdl α radius) -- tunable
momentum neutrino beam

205 kA peak current
3.0 Tesla peak field
2.6 milli-sec half-sine wave pulse
1.87 sec repetition rate

Production Horn 1 is complete

Horn remote stripline connection

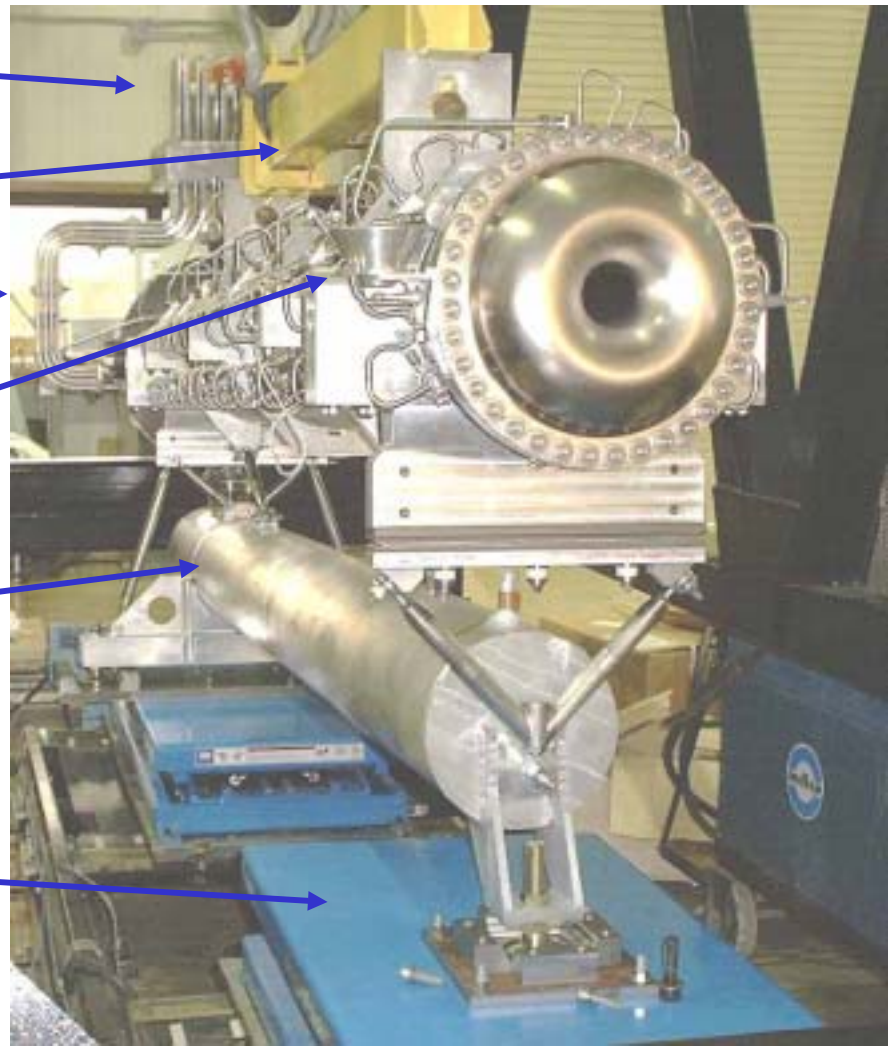
Horn remote lifting fixture

Stripline flex section

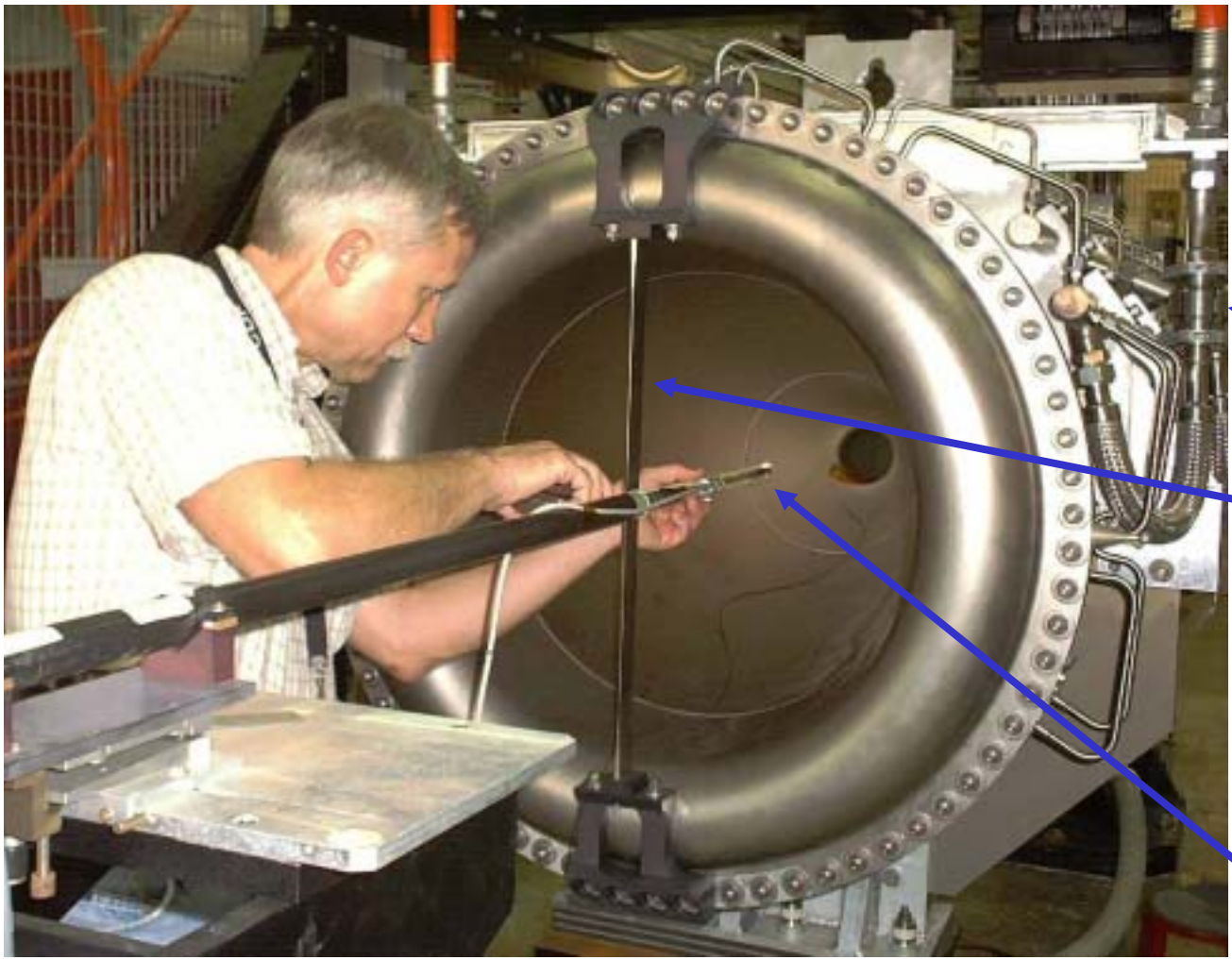
Cone to guide survey pole onto tooling ball

Water drain tank

Lift tables to remotely plug horn up onto module



Production Horn 2 is complete



Water line
electric break
– rad-hard ceramic
in compression

"Cross Hair"
precision check of
horn position via
beam scan scatter
to ion chamber

Magnetic field
mapping
Hall probe

Test Pulsing
and problems found

Prototype Horn 1: 10 million pulses (1 "NuMI year") *described at NBI'02*

- *Water drips at quick-disconnects, fixed by making water lines less stiff*
- *Flaking of nickel at nickel-to-anodize coating transition at inner conductor straight section (for production, nickel coat entire inner conductor, eliminate interface)*

Production Horn 1: 0.4 million pulses *No problems found*

Production Horn 2: 0.4 million pulses *No problems found*

Remote electrical clamp: 1.8 million pulses *No problems found*

Flex joint at maximum flex: 0.2 million pulses *No problems found*

Bdot field monitor upper prototype: 10 million pulses

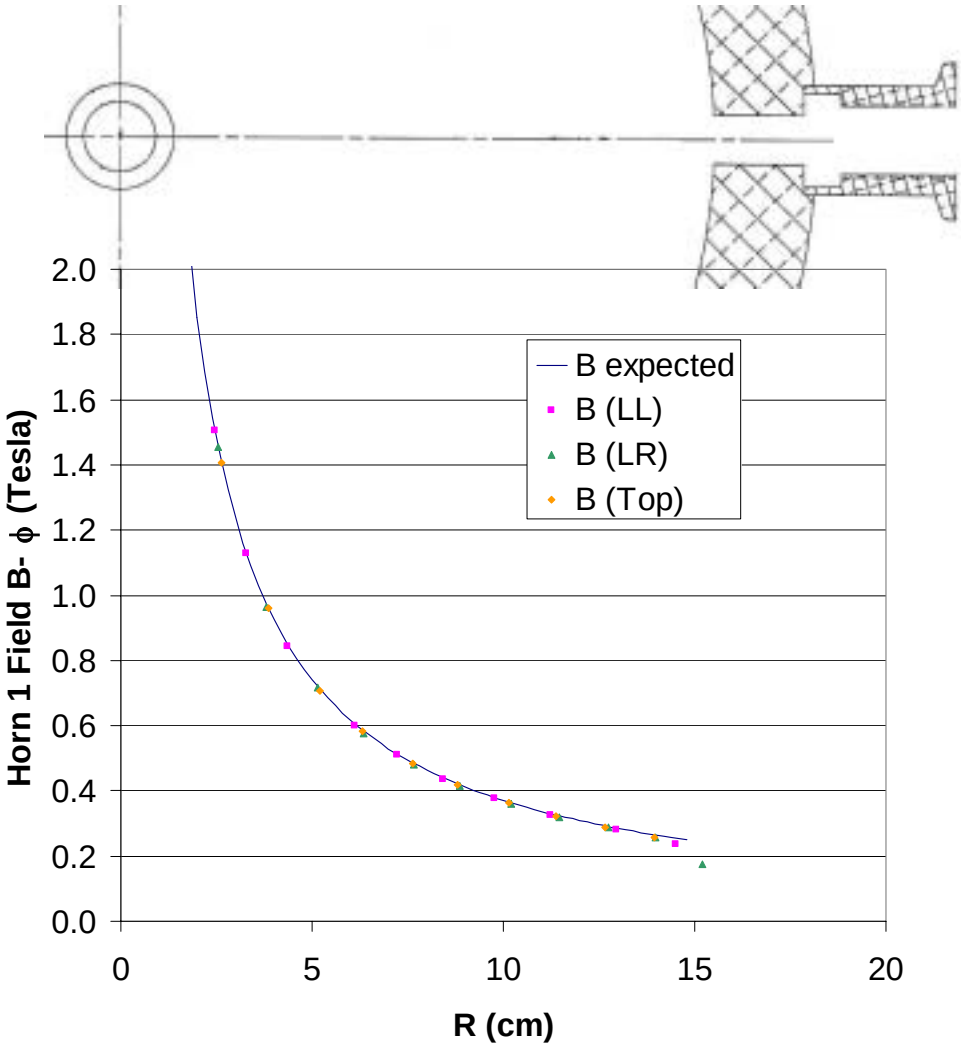
Temperature fluctuations at connector cause baseline drift – do baseline subtraction

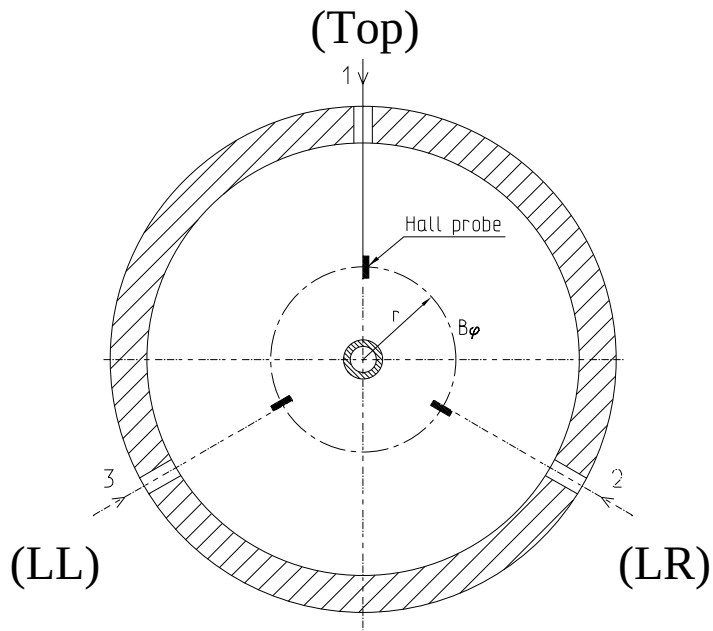
Bdot field monitor lower prototype: 0.2 million pulses

Water collecting at lower feed-through becomes conducting – add drain line

Horn Field Measurement

Main horn field between conductors of NuMI Production Horn 1





NuMI Horn 1

Measured September 2003

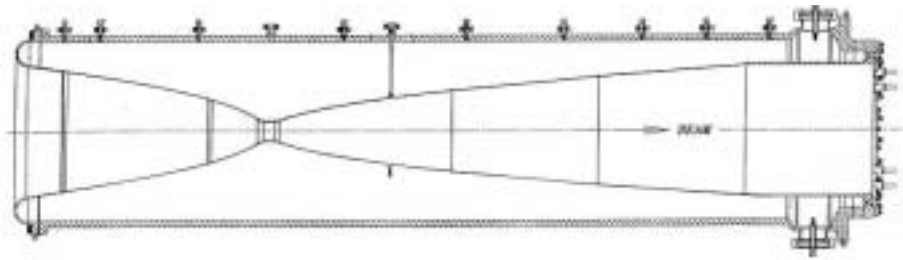
Field between conductors:

- α 1/R
- symmetrical and
- matches current better than 1%

Horn Field Measurement

in 'field-free' region through center of horn

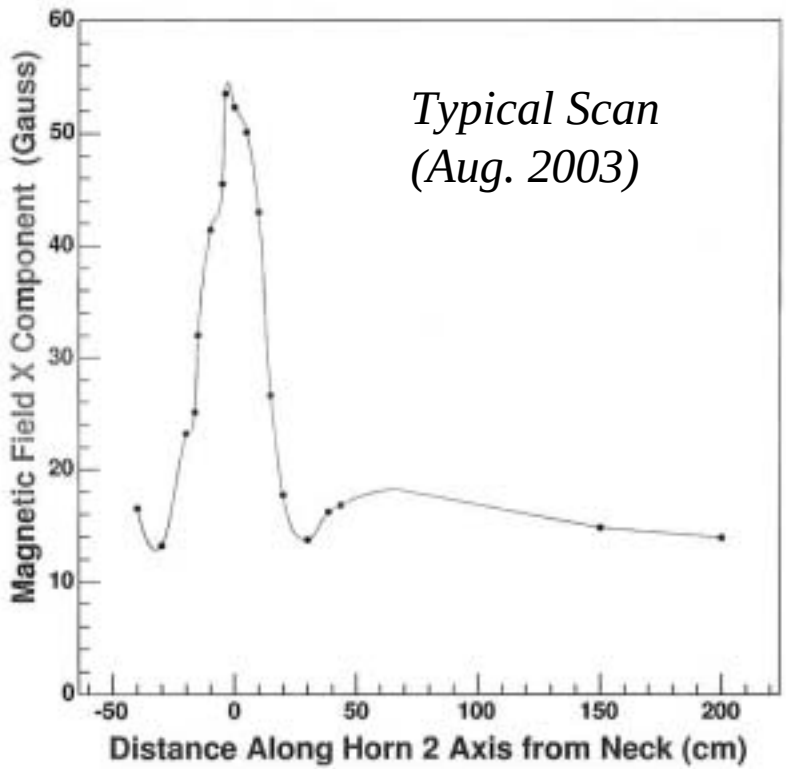
Measurement with probe moving along horn axis →



For all three horns
- Prototype Horn 1
- Production Horn 1
- Production Horn 2

fringe field in "field-free" region down center of horn is small (~0.01 Tesla max.)

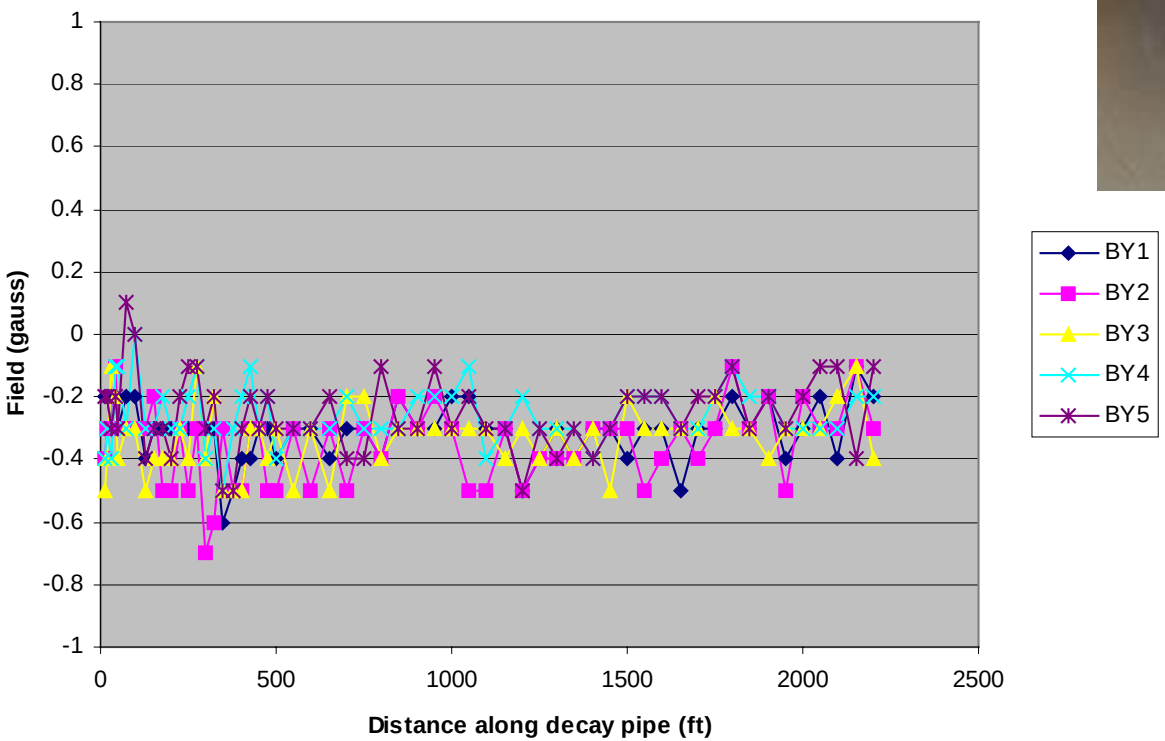
Have not put this field in Monte Carlo yet; previous studies indicate effect on Far/Near neutrino flux ratio should be small

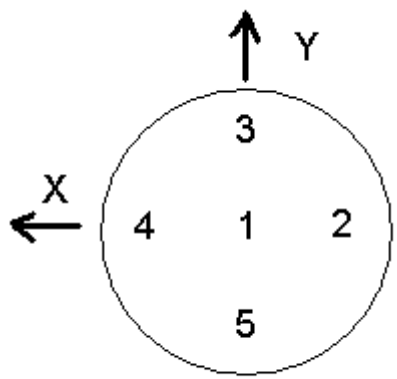


Decay Pipe as Third Horn? (Shades of Hadron Hose!)

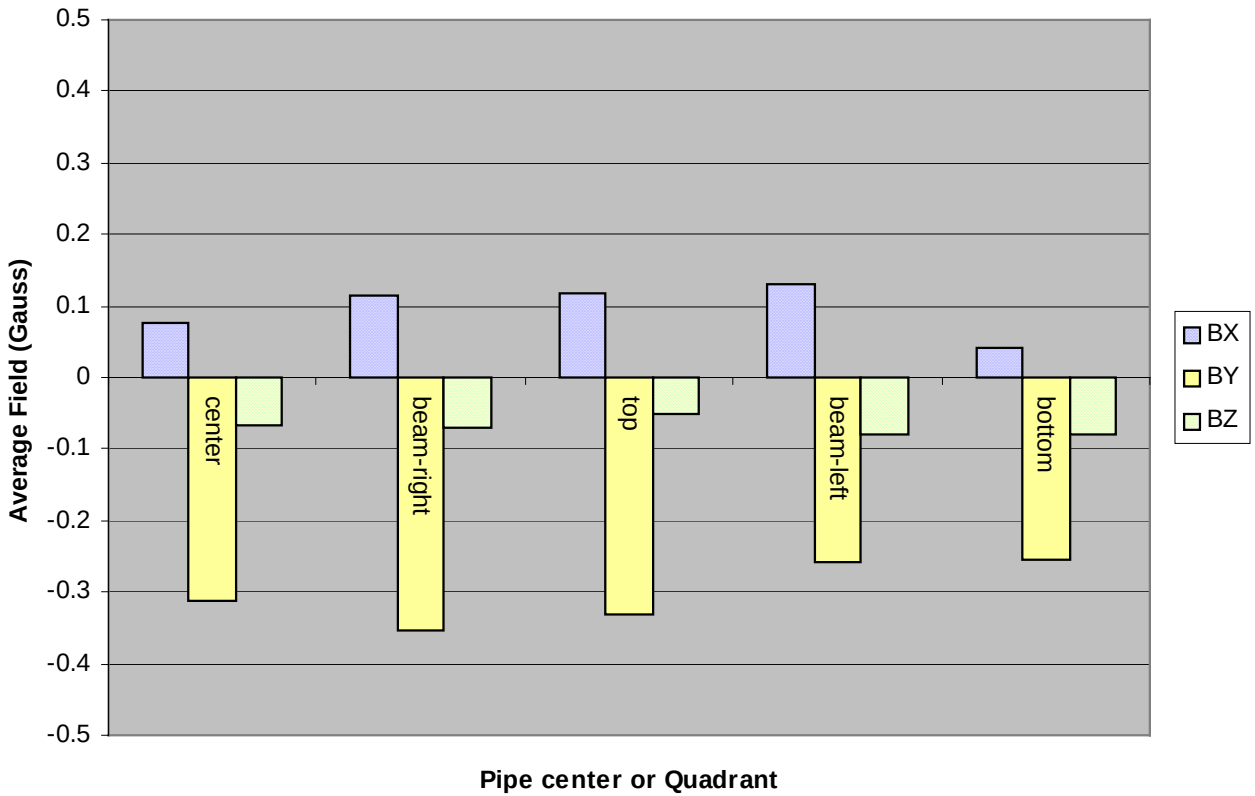
Just a couple gauss will affect neutrino spectrum
if field aligned along whole 675 m of decay pipe

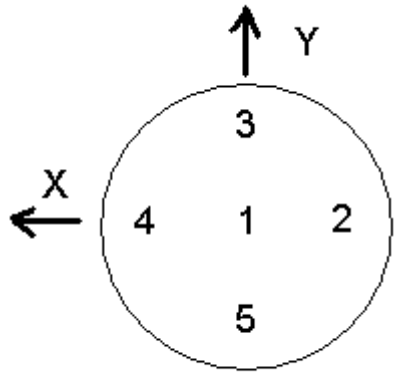
so measured field Oct. 2003





Measured Decay Pipe Magnetic Field is Negligible



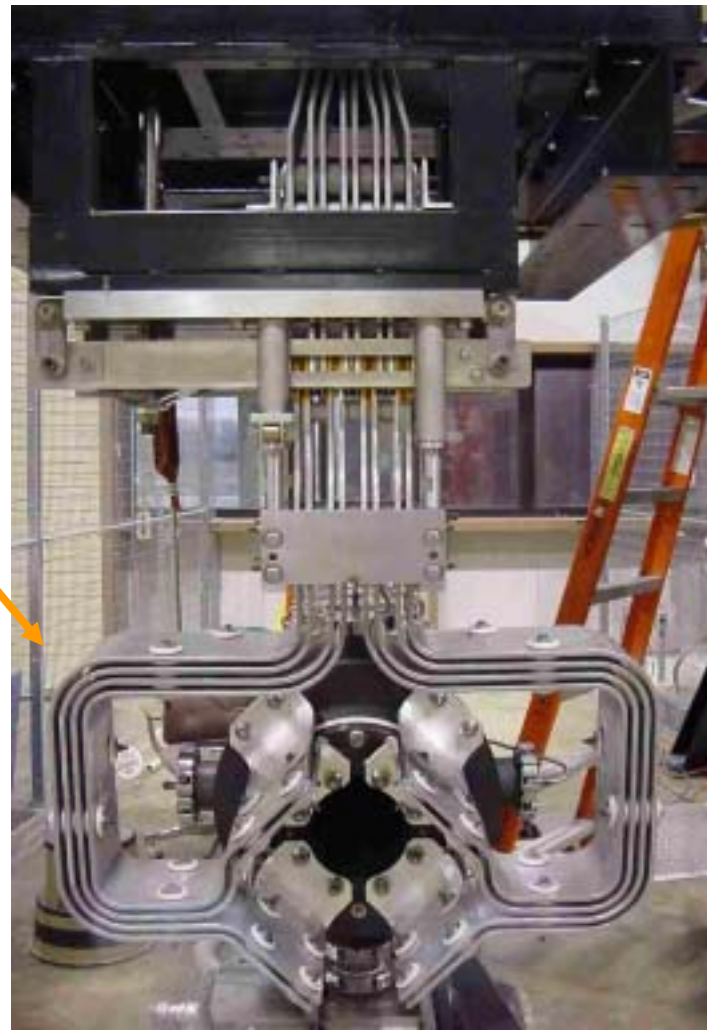


Field measured is only 0.3 Gauss, fairly uniform

Stripline flex test

Stripline flex region allows horn to move relative to remote clamp for:

- Remote motor controlled horn alignment
- Thermal expansion of stripline from beam and electrical heating



0.2 million horn pulses taken with stripline flexed to maximum specification 3mm horz. + 3mm vert.

No problems found

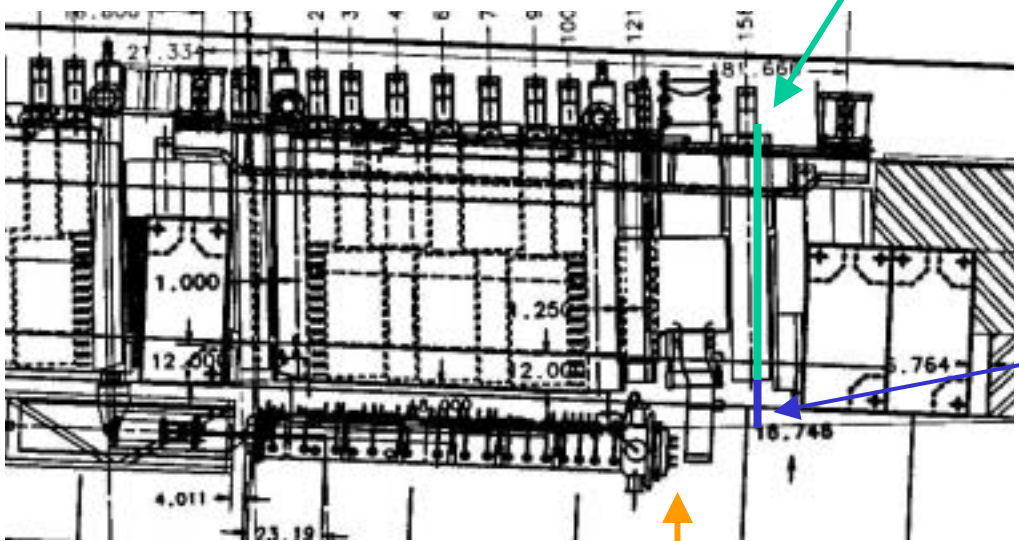
Remote stripline clamp test

How to hook and unhook horn from power stripline remotely in radiation area?
Shaft toggles clamp to provide pressure for good electrical connection

Contact surfaces fine after
two plug/unplug cycles
1.8 million pulses total

Cross Hair Horn Alignment System

Hole in shield to insert beam loss monitor



Function: Check position of horn w.r.t. beam by beam scan (target-out)

Scan: (1) horn 1 neck
(2) horn 1 downstream
(3) horn 2 upstream
(4) horn 2 downstream

Beam loss monitor ion chamber

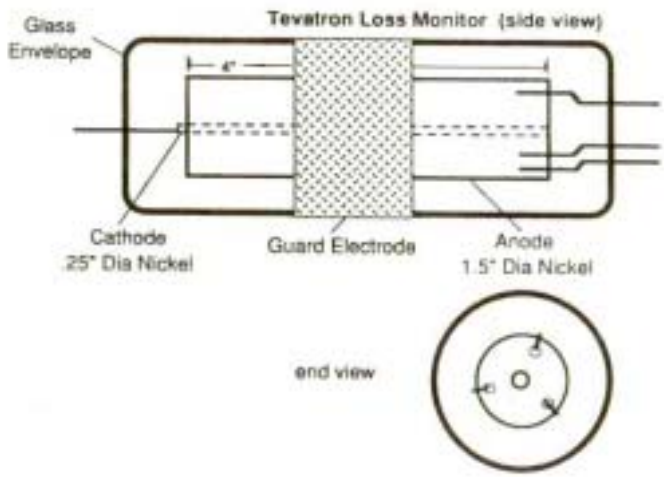
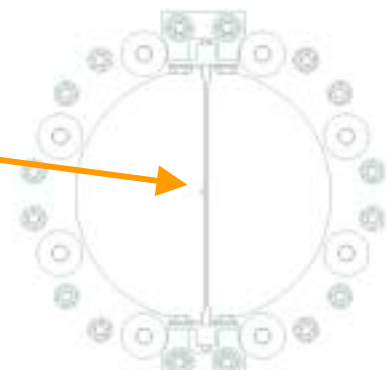


Figure 9. Schematic of Tevatron loss monitor. The monitor is filled with argon gas at 725 mm of Hg. The guard electrode reduces the leakage curren

12 mm x 1 mm
Aluminum cross hairs
mounted on horn

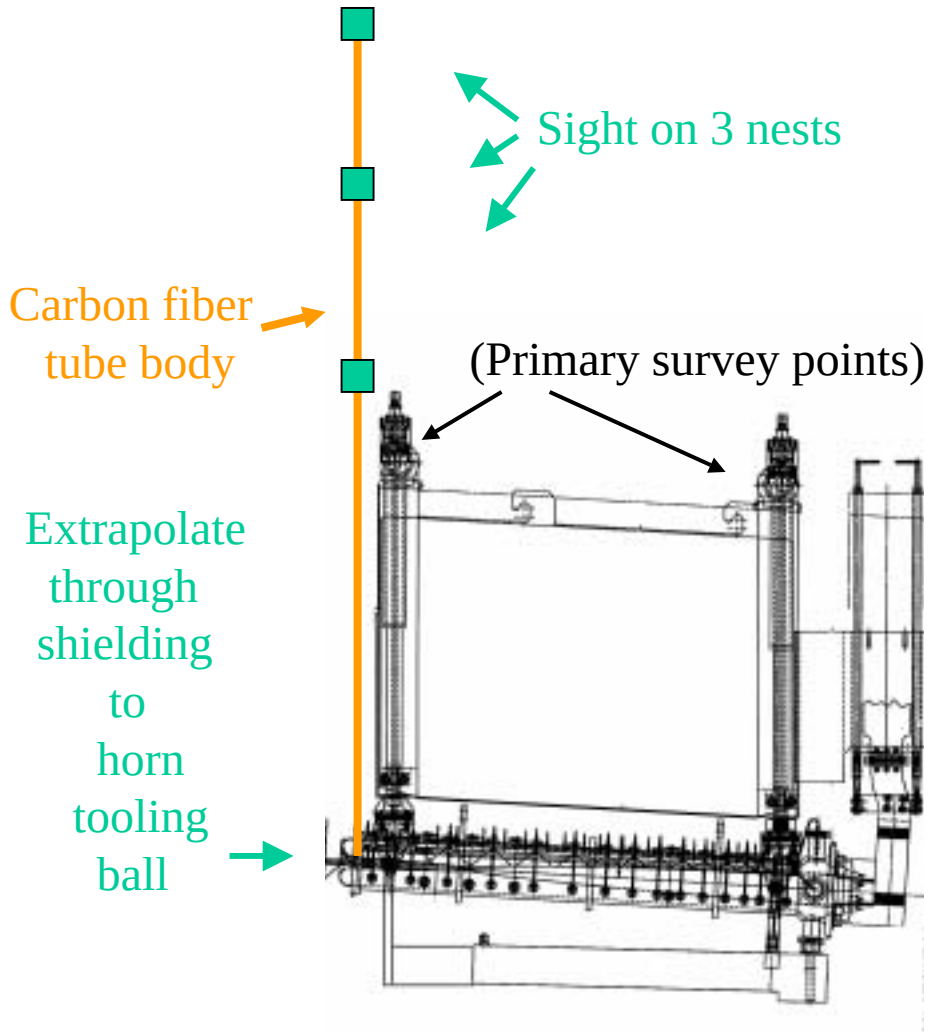


(36 mm x 1 mm for
horn 2 upstream)

Horn survey rod

for cross check

Tests give ~ 0.01” transverse accuracy



Bdot Coil
Horn Magnetic Field Monitor

Three bdot coil units per horn to monitor magnetic field each pulse

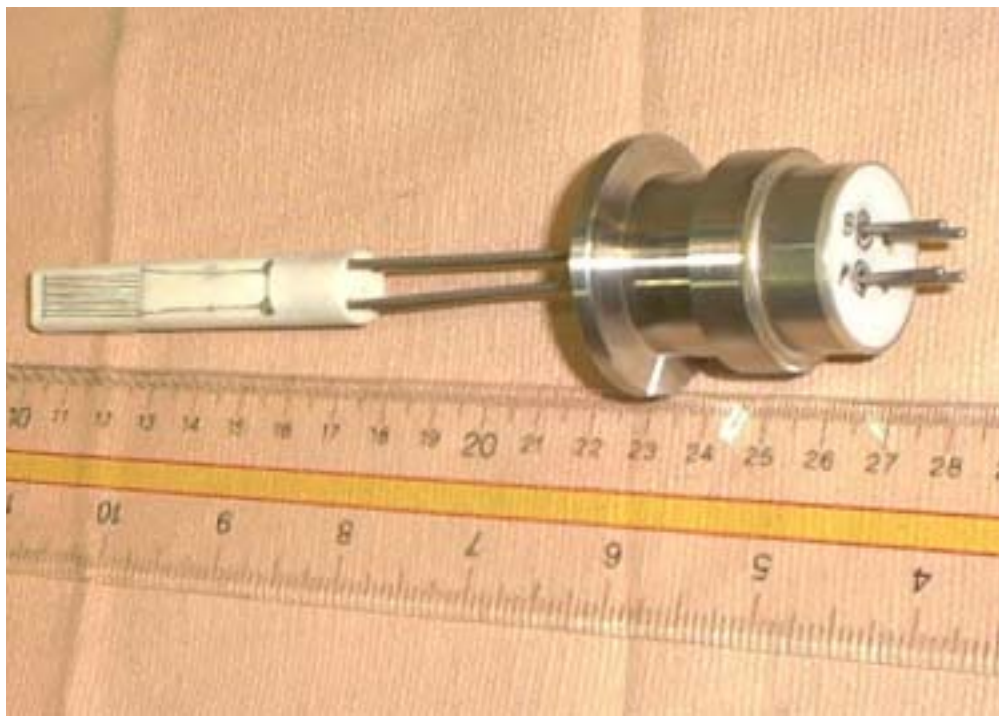
First prototype: 8 turns of 0.01 inch diameter 304 stainless steel wire
wrapped on MACOR form, 1.010 x 0.363 sq inch per turn
mounted to Aluminum Oxide ceramic feedthrough

Problems:

MACOR was borderline for required radiation-hardness, but holes for coil were easy to produce

Significant thermo-electric effects found at wire to pin solder joints, caused readout drift

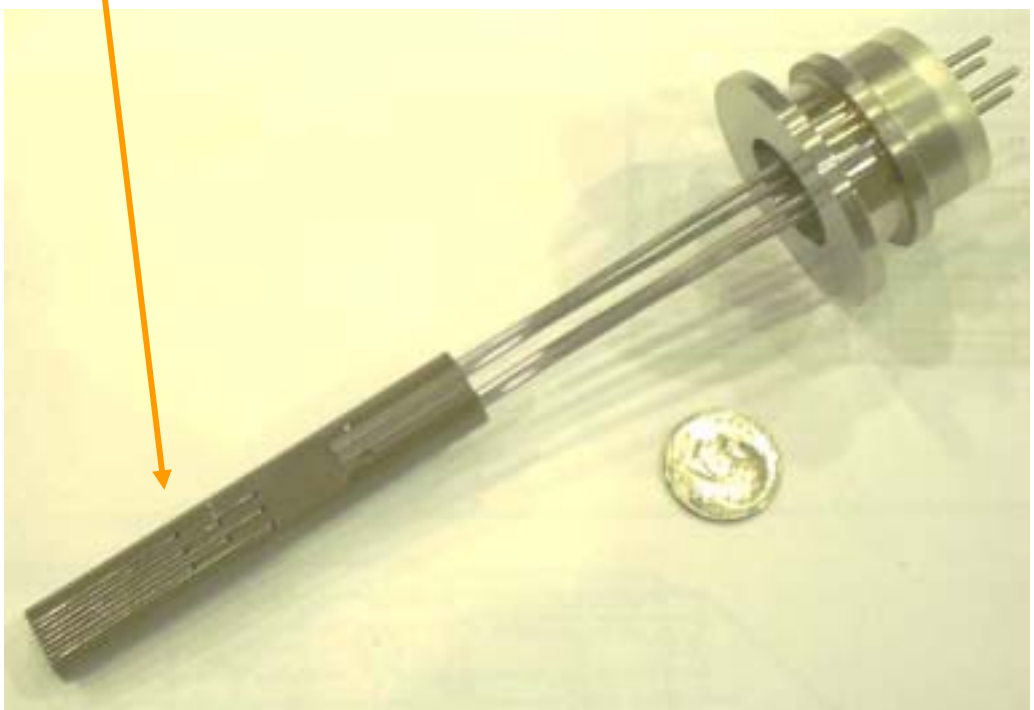
Puddling water at lower probe feed-through became conductive, affecting readout



Bdot field monitoring coil solutions

Yt Partially Stabilized Zirconia: high impact resistance rad-hard insulator

Manufacturer managed to produce 0.03" diameter holes for coil wire



Water drain being added to lower feed-through - pipe to water drain tank

DC-baseline subtraction done each pulse to compensate thermo-electric effect

When tested, three coils on horn agreed on field to 1%

Summary and outlook

NuMI Horns constructed and pulse tested – look good!

Next steps:

- Practice remote mounting of horns to modules (December/January 2003)
- Install in target hall (May/June 2004)
- Practice remote handling in target hall
- Commission with beam (December 2004)