



---

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

---

# Recent operational experiences at NuMI

Jim Hysten / FNAL AD Target Systems Dept.

NoVA PASI Workshop

November 11, 2015

# NuMI History

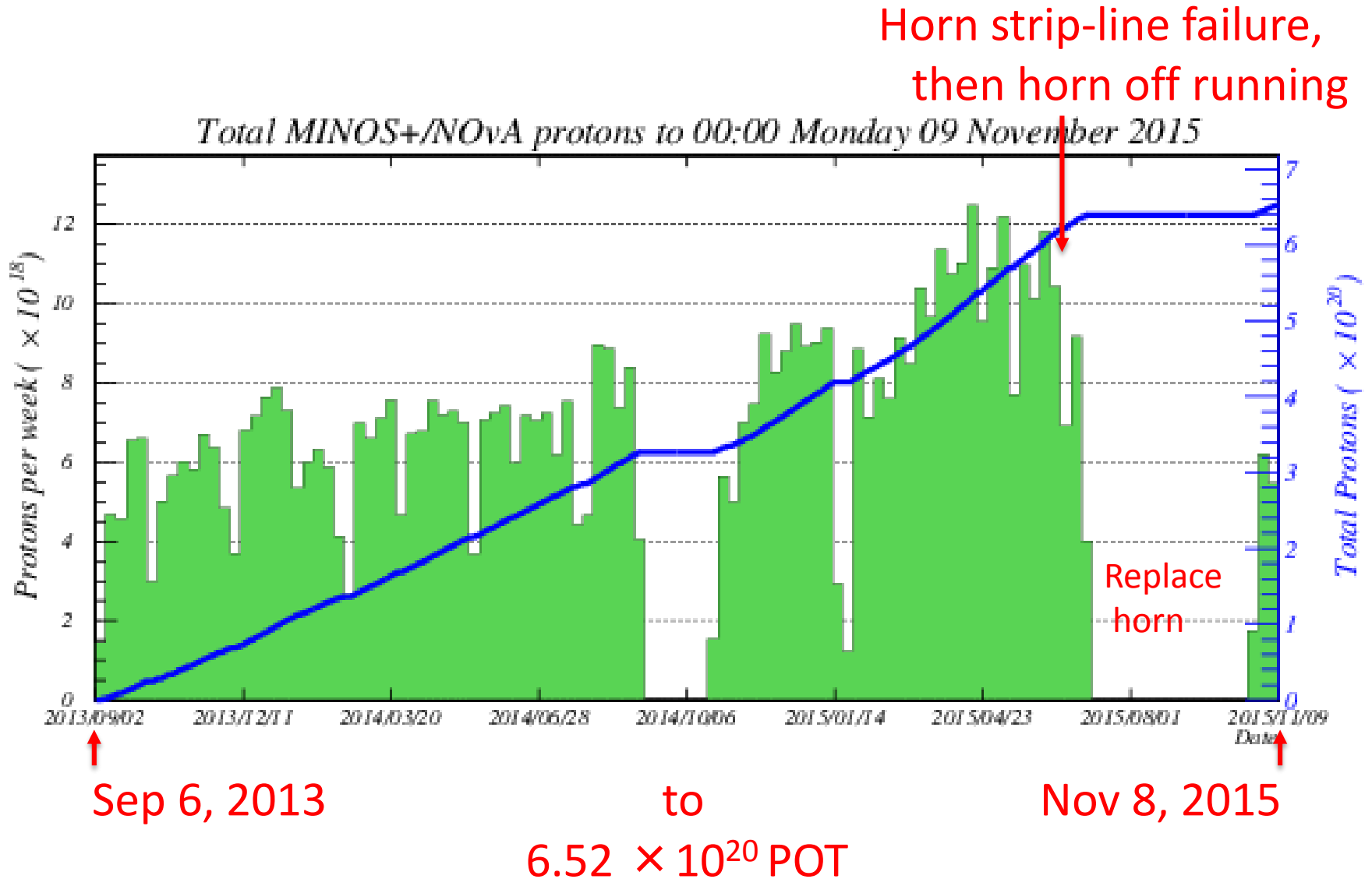
---

- May 2005 – April 2012      Run for MINOS, then also for MINERVA
  - 400 kW beam power design
  - Moveable target; mostly run with target stuck into horn - “Low E” neutrino beam
- May 2012 – Aug 2013      Shutdown for upgrade - enable 700 kW beam power
  - Switched to “NOVA” optimized target; no longer fits in horn
  - Replaced horn 1 with one upgraded for better cooling, able to take 700 kW beam
  - Moved horn 2 downstream by 9 meters to optimize for NOVA off-axis experiment
- September 2013 – present      Run for NOVA, also MINERVA and MINOS+
  - Target fixed upstream of horn – “Medium E” neutrino beam

This talk will focus on experience with new style target and upgraded horn

- Other than a **horn strip-line failure**, only a few target hall related down-time shifts: dehumidifier repairs, leaking water cooling coil, temperature interlocks

# Protons for ME Run



# Proton beam parameters

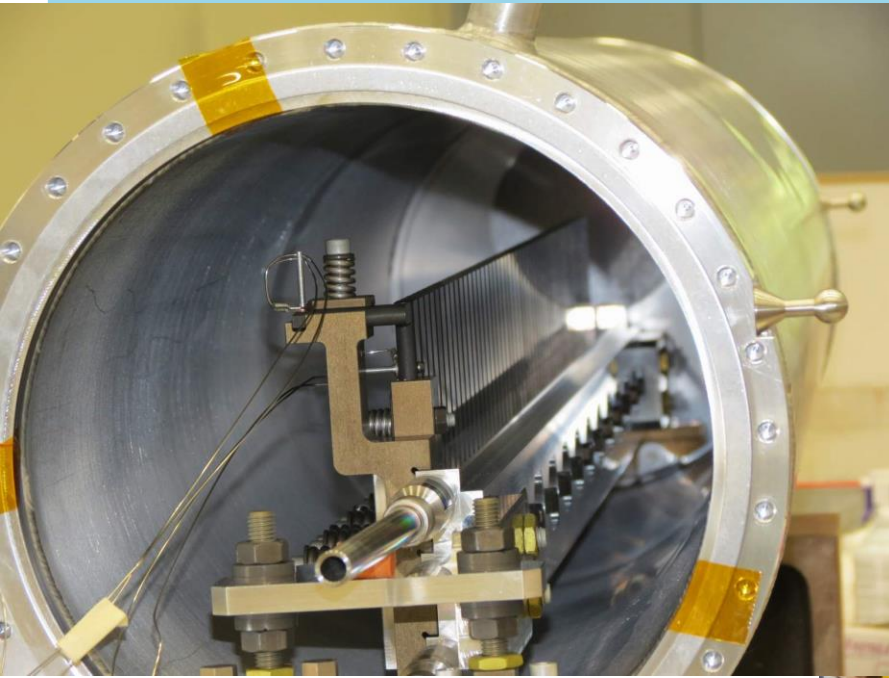
	Current design	Achieved so far
Proton beam power	700 kW	521 kW demonstrated 420 kW normal operation
Proton beam energy	120 GeV	120 GeV
Protons / pulse	4.9e13	3.3e13 recent (4.4e13 peak before upgrades)
Pulse cycle time	1.33 sec	1.33 sec
Spill time per pulse	10 μsec	10 μsec
Proton beam spot size	1.3 mm RMS	Mostly 1.2 mm RMS

Accelerator upgrades are still in progress;

700 kW beam may be delivered towards end of 2016

# NOVA-era target

# MET-01



Graphite fins: 50 x 24 mm; 7.4mm wide  
Helium atmosphere  
Beryllium windows  
Water cooled aluminum pressing plates  
*fins not brazed to cooling (vs. NT-series)*  
Water cooled outer can

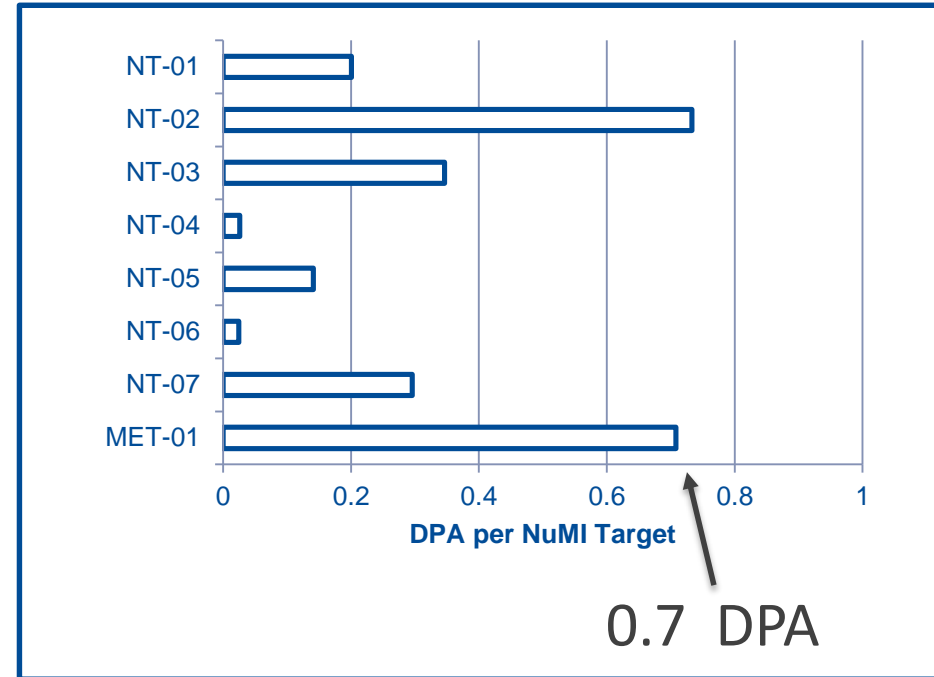
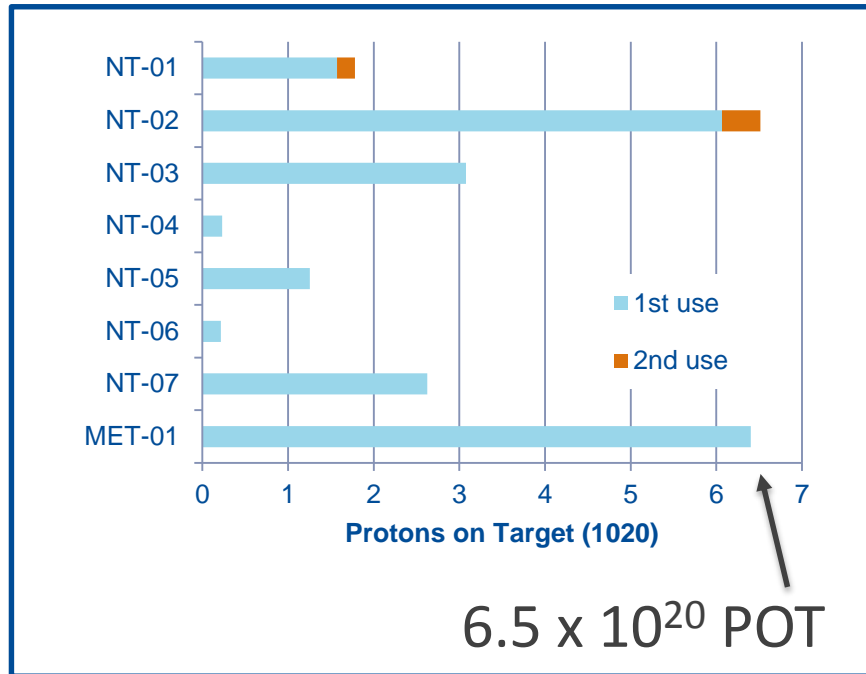
IHEP Protvino (Russia)  
did initial design

STFC-RAL / FNAL  
did final design

Constructed by STFC-RAL  
*Thanks, Chris !*



Target status: MET-01 is two years old,  
has taken 0.4 MW-year integrated beam power, no problems

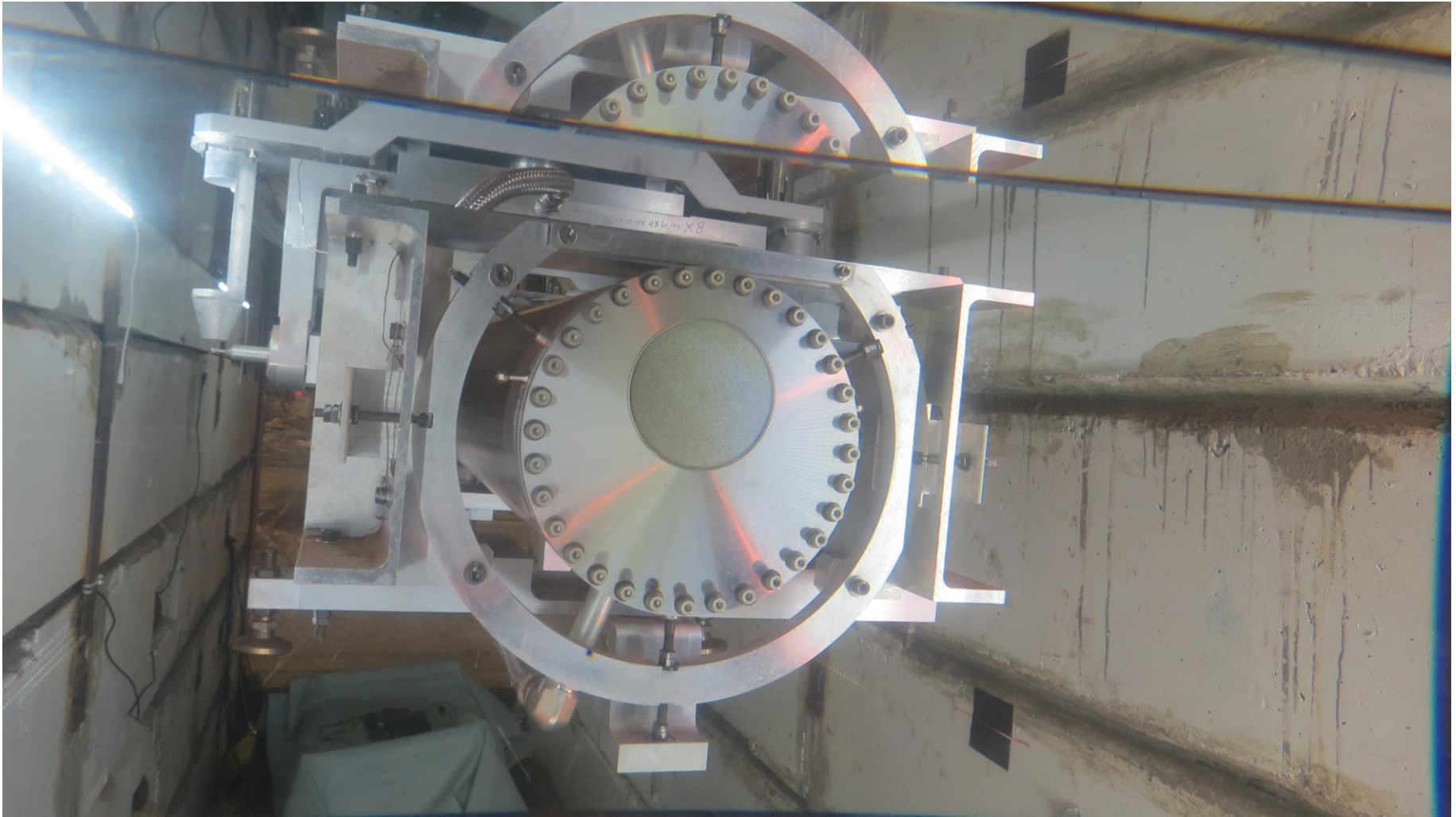


- MET-01 Exhibits No Sign of Neutrino Yield Degradation (despite rumors last spring to the contrary; was *neutrino pile-up* in detector).
- MET-01 continued good performance brings into question whether the NT-02 degradation was due to radiation damage

# Downstream end of MET-01

in work-cell

*after two years operation*



Looks very good !

# Horn PH1-04 strip-line problem

Saturday June 13, 2015 imbalance of horn current trips beam permit.  
Problem at horn, not power supply – decide to run *horn-off* until summer shutdown

Wednesday June 17

Stop beam, let cool

Open target pile

Find and remotely photograph  
cracked strip-line at horn

Close up, beam back in < 58 hours

Run beam horn-off through July 3,  
(start of scheduled  
summer shutdown)

Useful for study of systematics



Piece of strip-line that cracked is permanently attached to horn,  
so had to replace horn



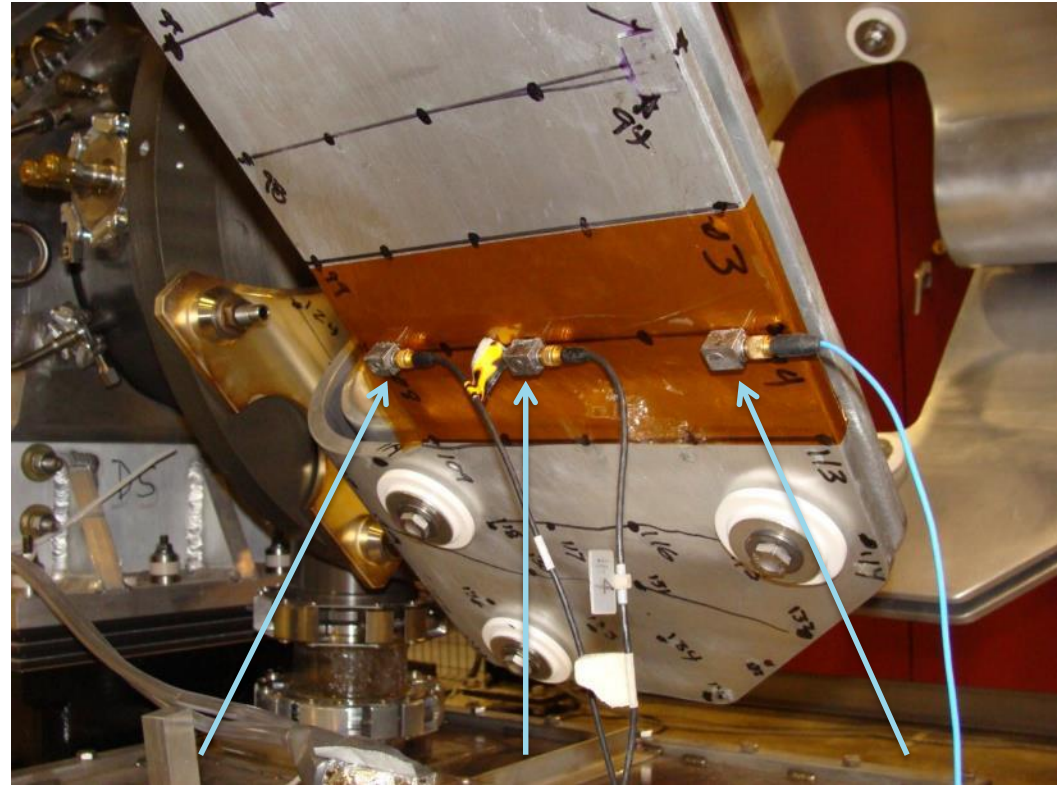
# Choice of horn replacement – 2 spares ? Really ??

---

- For the upgrade to 700 kW beam, had re-designed the strip-line
  - Moved strip-line to larger radius to control temperature
    - Lower beam energy deposition
    - Into better air stream, not blocked by horn body
- Had 1 old style spare (PH1-03) and 1 new style spare (PH1-05)
- Would like to get more than 2 years out of PH1-05
  - Consider using PH1-03 while re-designing PH1-05 strip-line

# Horn replacement work

## Horn strip-line vibration measurements



PH1-04 style strip-line has **larger motion,**  
**longer ring-down (more fatigue cycles)** than PH1-03 style

# *Horn replacement work*

## Horn wind tunnel heat transfer coefficient measurements



How badly would PH1-03 strip-line overheat ?

# *Horn replacement work*

## PH1-03 Modifications for higher beam power

- Air duct added (wind tunnel result)
- Al cross-hair replaced with Be
- Water cooling of DS flange added
- Bdot coils removed



# PH1-03 analysis

---

- Based on modifications, wind tunnel tests, vibration tests:
  - *PRELIMINARY: FEA shows some safety factor for 50 million pulses at 200 kA current and 700 kW beam power*
- Work is on-going, will be refining analysis this fall
- PH1-03 is modified, installed and running now
- PH1-05 strip-line will be redesign and replaced ~ next summer

# Horn life-time summary

NuMI horns since 2005 start	Pulses	Start date	End date
PH1-01 failed water line	24,200,000	2005	Jun-2008
PH2-01 HS steel washer caused stripline failure	28,100,000	2005	Dec-2008
PH1-04 Stripline fatigue (?)	26,960,000	Aug-2013	Jun-2015
PH1-02 removed to make way for PH1-04	45,900,000	Jun-2008	Jun-2012
PH2-02 still operating	68,960,000	Dec-2008	running
PH1-03 operating	745,000	Oct-2015	running

Shortest  
2 years



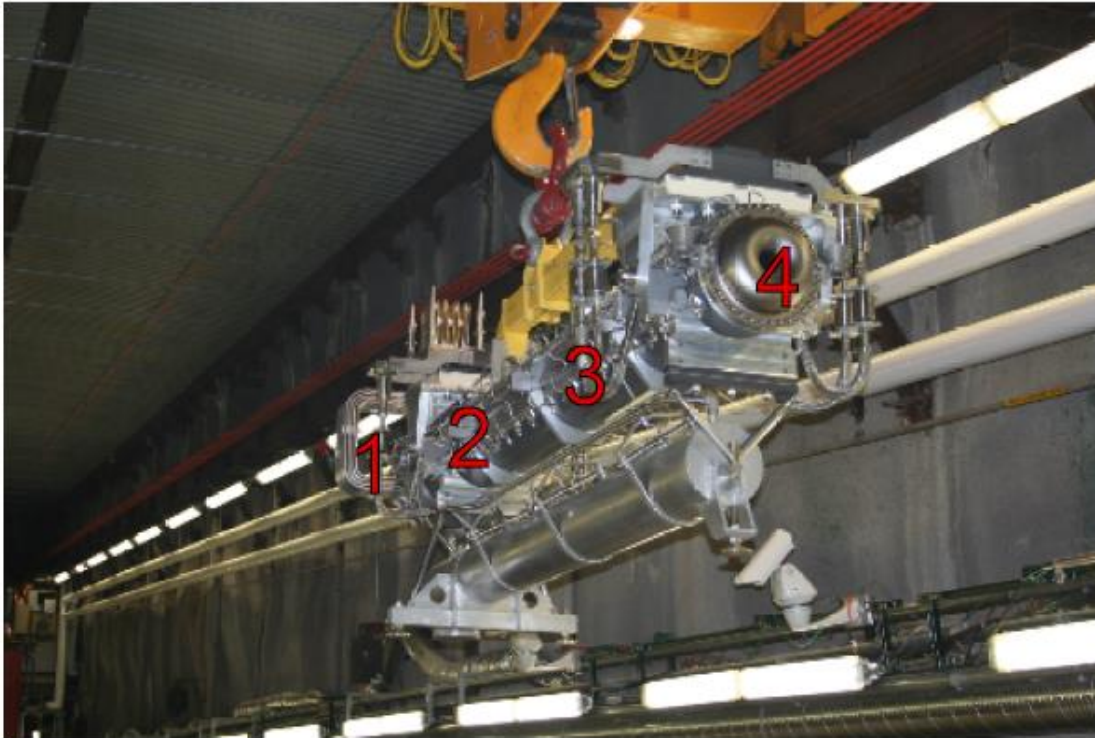
Longest  
7 years



# Residual radiation getting high



DATE: 9/3/15 TIME: 1000 PURPOSE: replacement survey RWP # \_\_\_\_\_



NuMI Horn PH1-04  
After 2 month cool-down

Point	Doserate @ 1 foot (mr/hour)
1	50000
2	100000
3	110000
4	80000



- Worker would accumulate weekly dose limit in 2 seconds

# Horn Argon injection system upgrade

---

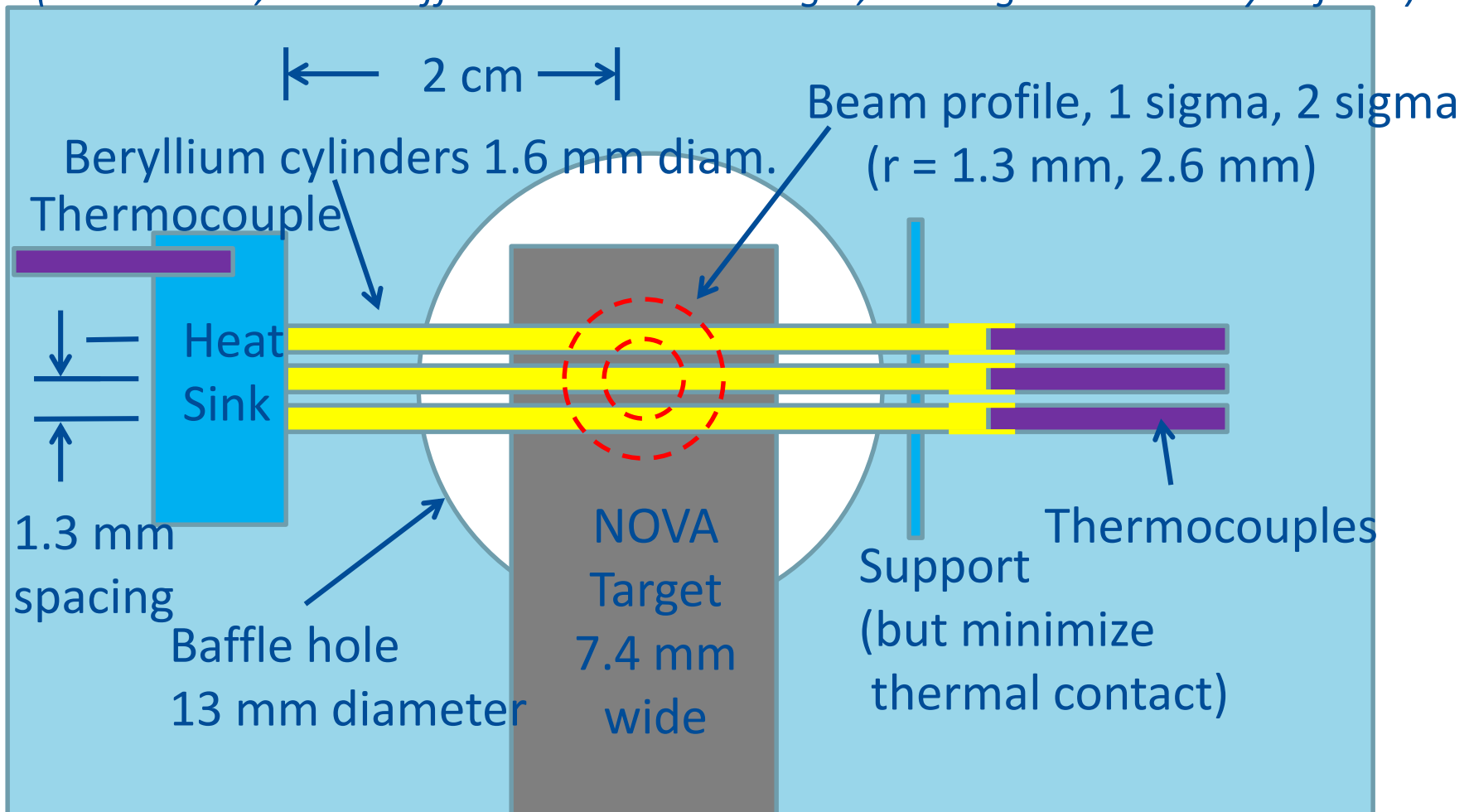
- Horn interior should be constantly flushed with an inert gas
  - Beam breaks water down to Hydrogen and Oxygen, need to push this out to prevent explosion
  - Air + water + beam -> nitric acid, don't want nitrogen producing corrosive
- Previously injected 0.5 liter/minute Argon into horn RAW expansion tank
  - Letting ejector pump and pressure equalization line do circulation
- Last run, injected 0.4 liter/minute Argon into horn water spray line,
  - Where it goes directly into horn, then to expansion tank
    - *Better job of flushing horn*
- New system has worked with no problems



# Concept of Target Vertical Position Thermometer

Measures position of beam on MET-01 to  $\sim 0.1$  mm

(not to scale; note baffle drawn behind target, although it is actually in front)



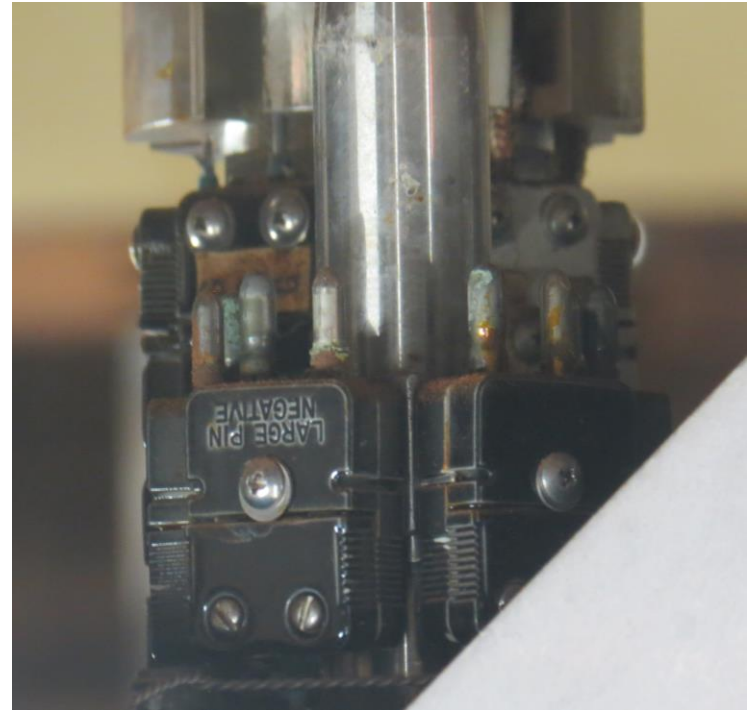
# TVPT connector problem on MET-01

Lost contact with sink thermocouple  
last run

*(Note could still tell beam position  
from ratio of other thermocouples)*

Corrosion of remote connection  
thermocouple pins

Recovered connection during  
summer shutdown,  
sink thermocouple is working again



Need to better protect the connection – grease helps

May be better to use type K thermocouple (we have type J)

Best would be to have plug connection accessible/repairable