NOvA: Accelerator Upgrades

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Fermilab Institutional Review
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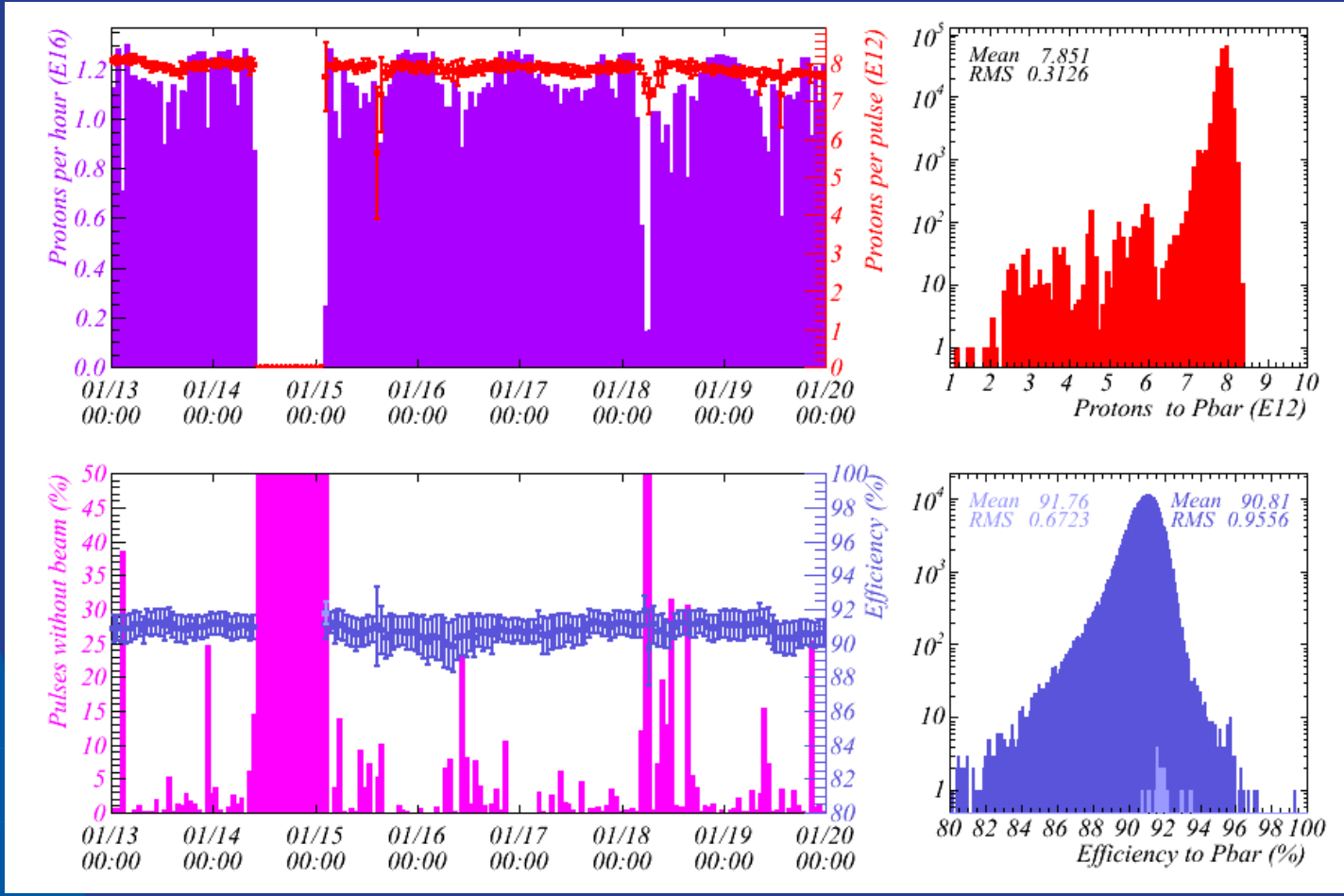
Accelerator Upgrades for NOvA

- Increase power on ν target to 700 kW
  - Slip Stacking in Recycler
  - 1.33 second cycle in Main Injector
  - Target station upgrades
    - ν energy configuration
    - to handle increased power
- Element of NOvA Project: J. Cooper
  - 14 kton detector in Ash River MN
  - CD-3b Oct 2009
  - CD-4 Nov 2014

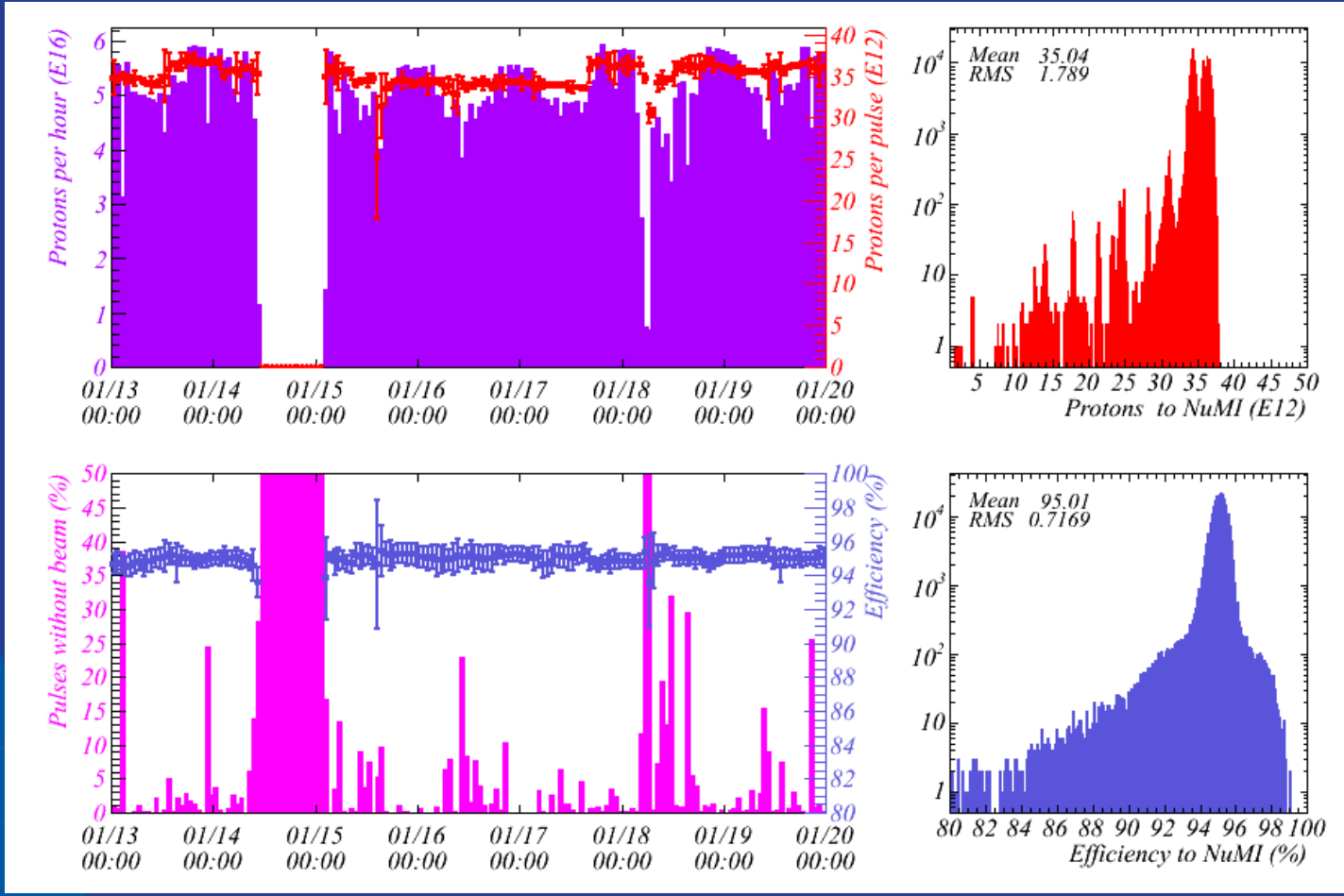
Operations for NuMI

- 11 batch injection into Main Injector & slip stacking
  - $^{10}/_{15}$ second to accumulate beam in MI
- Ramp to 120 GeV and extract
  - 1.533 seconds
  - 2 for pbar production ~8e12 70 kW
  - 9 to NuMI target ~3.5e13 305 kW
- 2.2 second cycle
  - 5 Hz demand on Booster

Main Injector Beam Performance to Pbar



Main Injector Beam Performance to NuMI



NOvA ANU

- Injection and Slip Stacking in Recycler Ring
  - Cut $^{2}/_{3}$ second for injection from cycle
  - 12 batches from Booster instead of 11
- Single turn transfer to MI
- Ramp to 120 GeV
  - Faster ramp: 1.333 second
  - All 12 to NOvA target: ~4.9e13 706 kW
- 1.333 second cycle
  - 9 Hz demand on Booster
  - 12 consecutive pulses
  - 1.4e17/hour
- Target Station:
  - New target design
  - New Horn configuration

NOvA ANU: Recycler

- Recycler Upgrades: from a pbar storage ring to a proton slip stacking ring
  - MI 10, MI 20, MI 30 — Decommission pbar cooling and transfer lines
  - 2 new transfer lines
    - MI 8 and MI 10 — Injection: Booster to RR
    - Preserve Booster Neutrino Beam and MI capabilities
    - MI 30 — Extraction: Recycler to MI
  - New fast kickers 12 vs 11 injected 57 nsec rise/fall
    - MI 10, MI 30, MI 40 — 5 different kicker systems
  - New magnets
    - New/modified designs PDS MLAW
    - Existing Designs PDD RQN
  - Refurbished Magnets ADCW

NOvA ANU: Magnet List

Type	Comment	Total Required	From Tunnel	Available From Storage	Construct New	Modify Existing	Status
PDS	New SmCo5 style double dipole	2	0	0	2	0	DONE
PDD	PDD 8 GeV style double dipole, existing style	5	0	0	5	0	DONE
PDDW	PDD dipole design, reduced field	2	0	0	2	0	DONE
RQNx	Recycler style 20 in. permanent magnet quad	48	0*	5	43	5	In progress, most parts in hand
MGS	Recycler dispersion suppressor mirror magnet	2	1	1	0	0	Need measurement
ADCW	Modified B1 style to open aperture	3	0	0	0	3	Almost Done (waiting on cooled beam pipe)
MLAW	MI style injection Lambertson, new, modified	2	0	0	2	0	Probably this fall
ILA	MI style Lambertson	1	1	0	0	0	
MQT	Old MR style quad trim	23	10	13	0	0	
HDC	Old MR style horizontal corrector used in Recycler	8	8	0	0	0	
VDC	Old MR style vertical corrector used in Recycler	9	9	0	0	0	
MCH	LEP Horizontal corrector	2	2	0	0	0	
MCV	LEP vertical corrector	2	2	0	0	0	

NOvA ANU: PDD Installation, March 2011

NOvA ANU: Recycler

- Recycler Upgrades:
  - 53 MHz RF for Capture and Slip Stacking — MI 60
    - New cavities, under construction
  - Instrumentation Upgrades
    - BPMs — everywhere — cabling and electronics for 53 MHz
    - MultiWires — MI 10 and MI 30 — in transfer lines
    - DCCT — MI 60 — for intensity measurements

NOvA ANU: Main Injector

MI 60

- To handle faster ramp:
  - 2 “New” RF stations 18 -> 20
    - Cavities from existing MI spares
    - New modulators, ferrite bias supplies, power amplifiers
  - Power upgrades
    - New transformer for quad bus
    - Move Tevatron Anode Power supply for RF

NOvA ANU: NuMI

A1 line, MI50, NuMI line

- Transfer Line:
  - Magnet & PS upgrades: faster cycle time
  - Instrumentation & Diagnostics: intensity

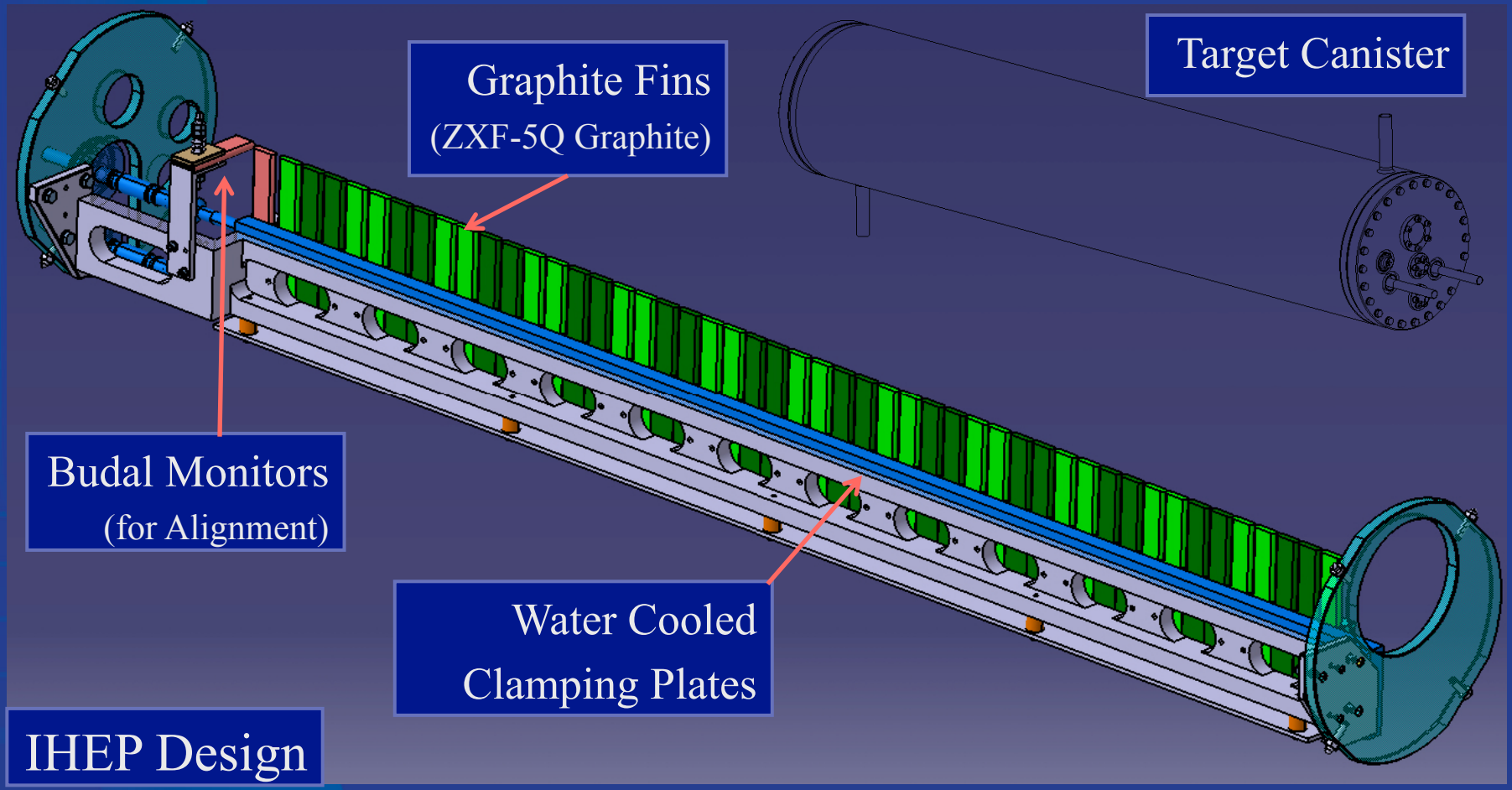
NuMI Target hall

- New Target Design Medium Energy position
  - No motion
  - Not constrained inside horn
  - Lessons learned from NuMI targets have been applied to design
  - IHEP design
  - IHEP & STFC/RAL construction

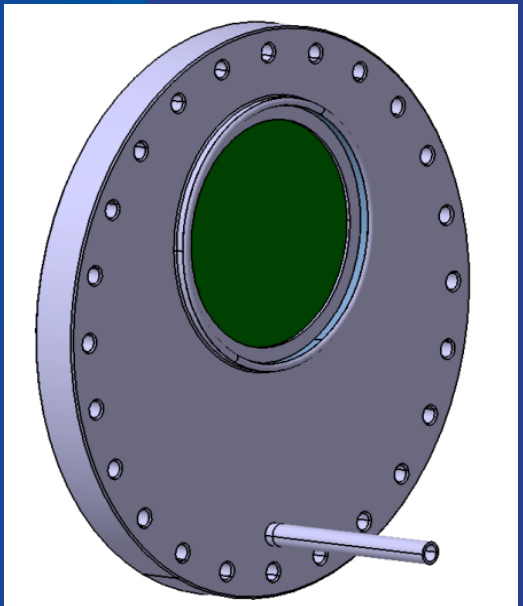
NuMI Target hall

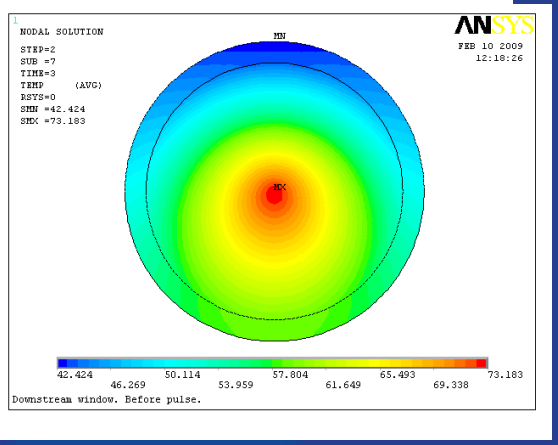
- Relocate Horn 2
  - ~9 m downstream
  - Utility upgrades

NOvA ANU: Target



NOvA ANU: Beryllium Window

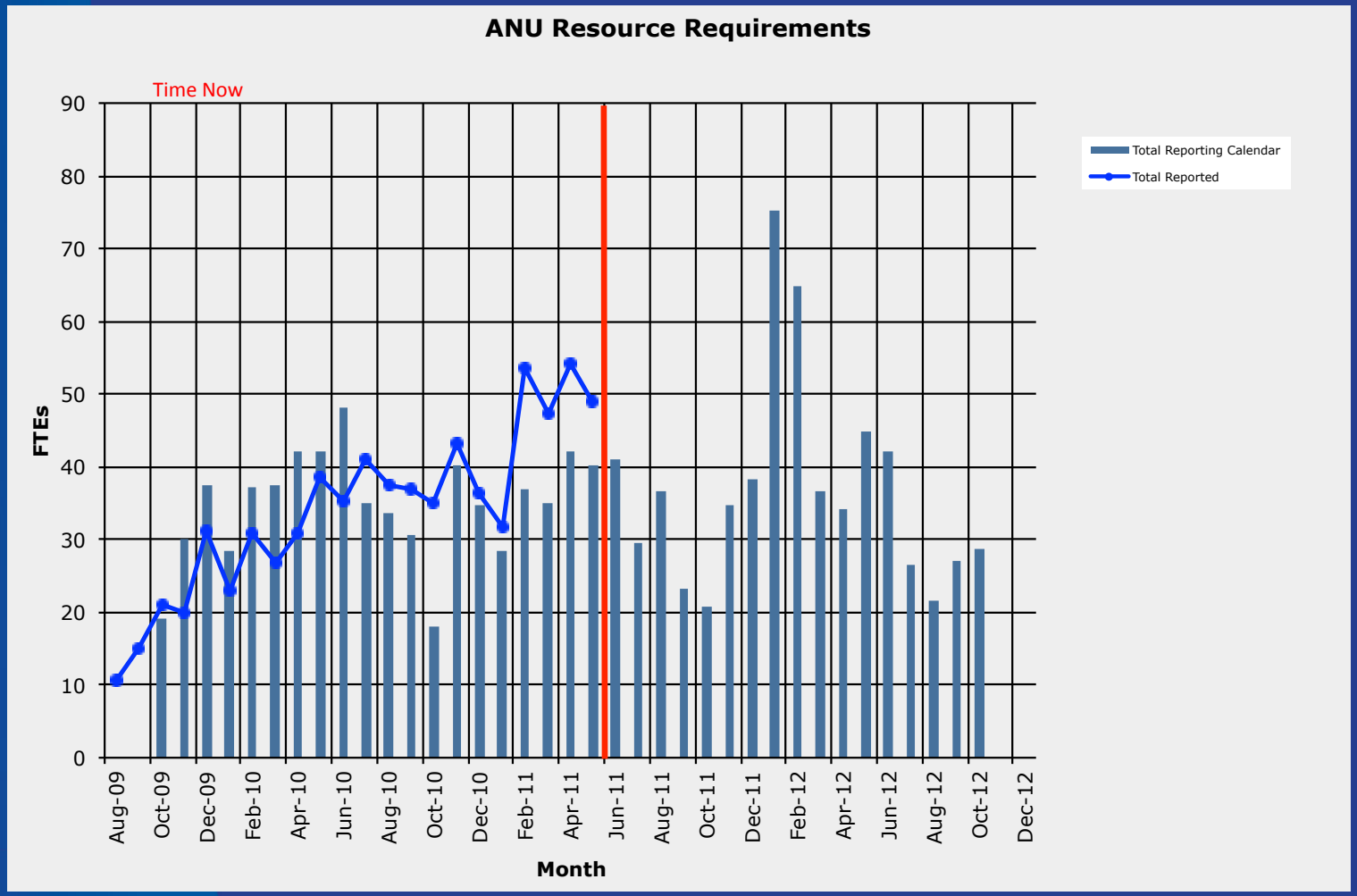




- 135 mm dia X 1.25 mm thick
- PF-60 grade beryllium window.
- Diffusion bonding technique.
- Can withstand vacuum w/o beam and 3 psig with beam.

- IHEP to prototype, test, and build (3) windows
  - Prototype successful, 8.5 atm
- Brush-Wellman will build one window.

NOvA ANU: Resources

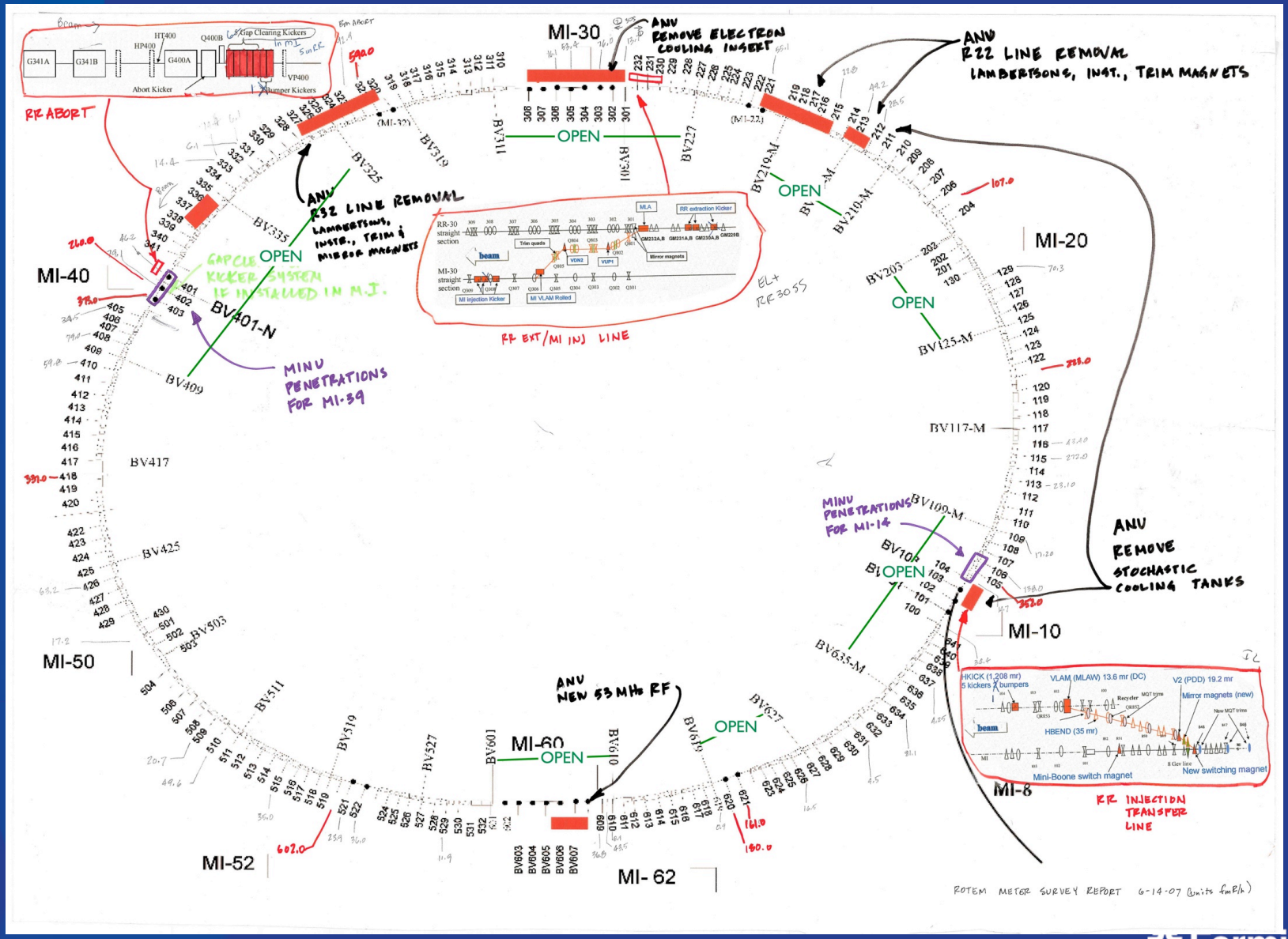


Project has priority and available resources for work

NOvA ANU: Shutdown

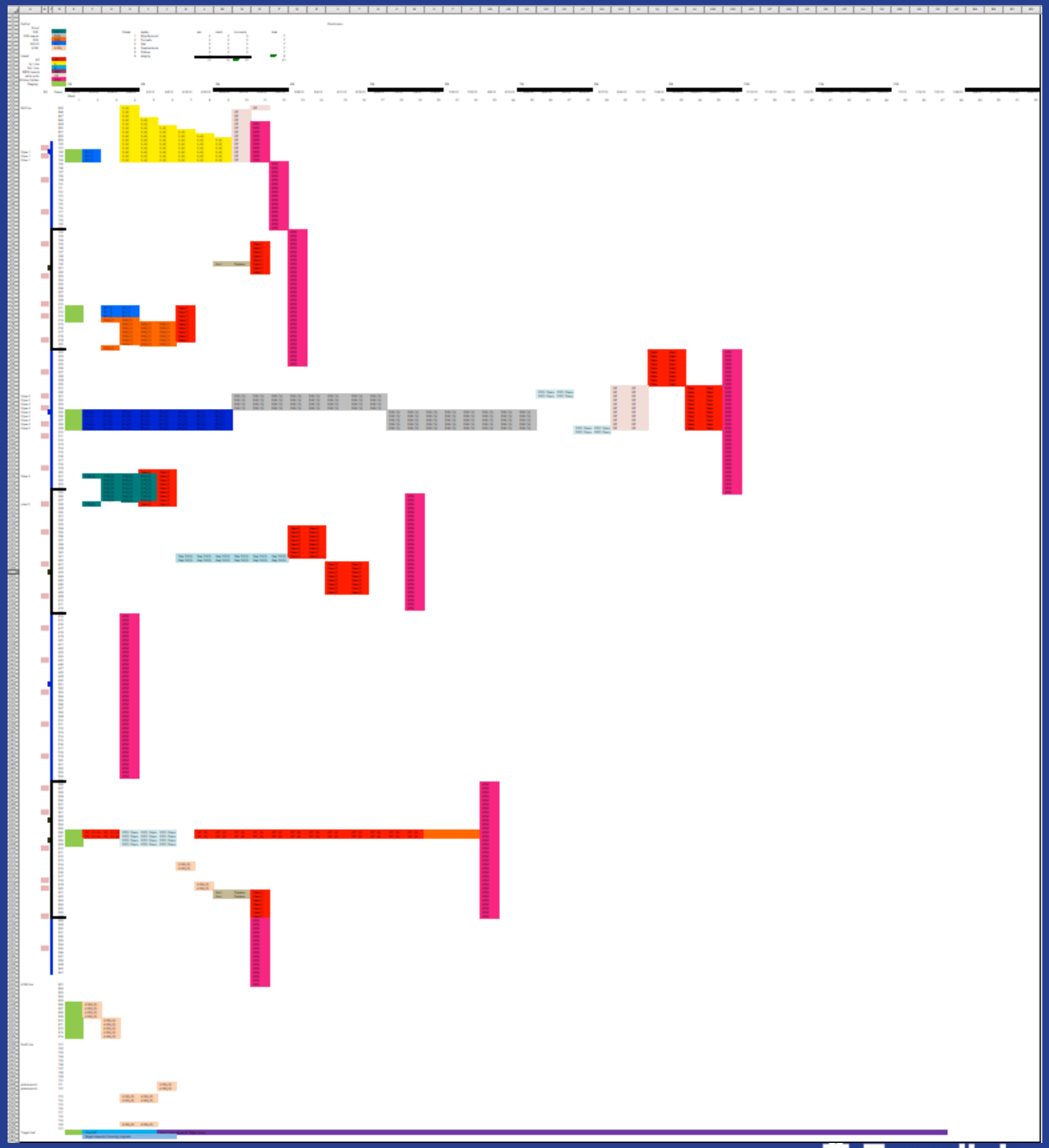
- Scheduled 11 month shutdown
  - Recycler and MI upgrades
  - NuMI Target Hall upgrades
  - 1 Mar 2012 – 1 Feb 2013
- Working on coordination since September 2010
  - Balancing of time, traffic, and tasks
    - Radiation and ALARA
      - MI 30 is hot
      - NuMI Target Hall is hot
    - Traffic: MI 60 is access point
    - Resources: people and equipment

NOvA ANU: Shutdown work



NOvA ANU: Shutdown scheduling

- Time: x axis (weeks)
- Location: y axis (vacuum sector)
- Color: crew
  - AD Installation
  - Electricians
  - Riggers
  - Pipefitters



NOvA ANU: Commissioning

- Plan under development
  - Hardware testing as part of installation
  - Beam Commissioning
    - Expect ~100 kW in weeks time frame
    - Anticipate ready with RR slip stacking and 1.33 second MI ramp in 6 months

NOvA Accelerator & NuMI Upgrades

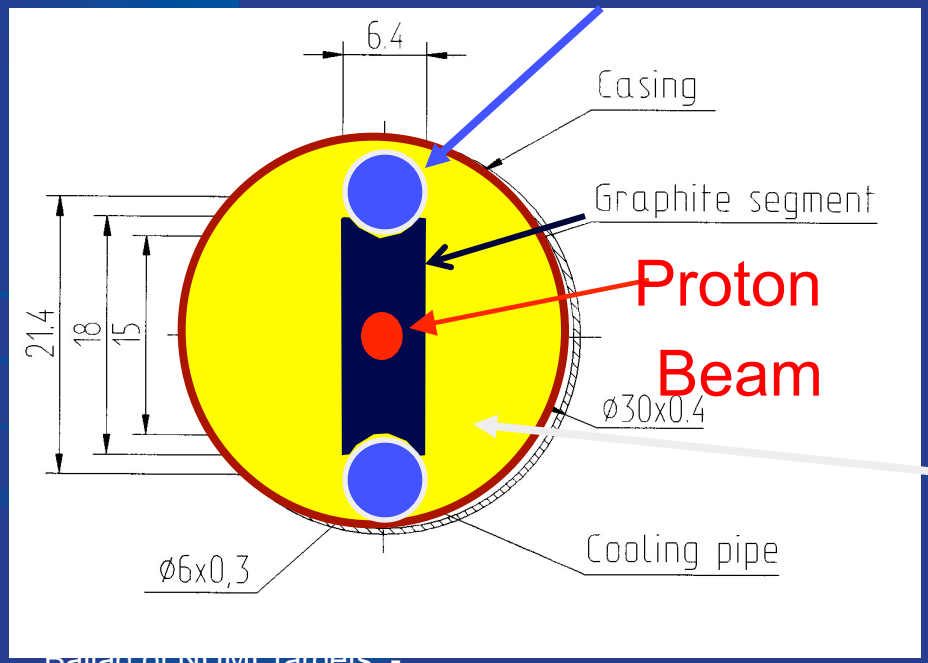
- Plan to deliver 700 kW to NOvA target
  - Series of upgrades to:
    - Recycler
    - Main Injector
    - NuMI Target Hall
  - Resources in place to execute the plan
- CD-4 Requirement: Complex capable of delivering 700 kW
- On schedule for shutdown
  - 1 Mar 2012 – 1 Feb 2013

Backups

NuMI Target

- NOVA target water line is much further from target
  - Will very likely fail in some different manner

Water cooling pipe

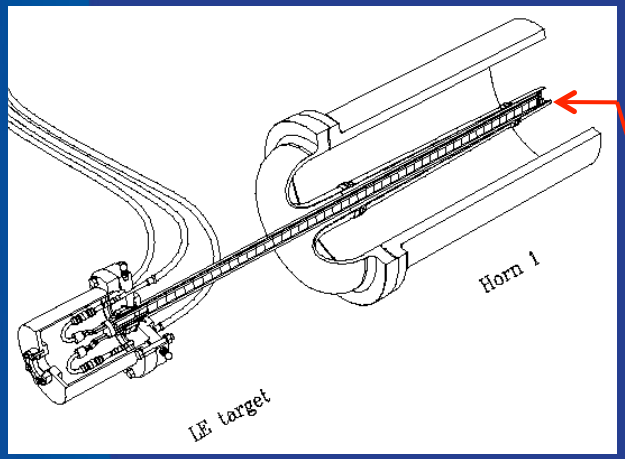


Aluminum tube for helium containment

MINOS LE target

All units mm

- *water-cooled target must fit inside small radius of focusing horn*
- *intense beam; center of graphite $\Delta T = 270\ ^{o}C$ each 9 μs pulse*



Target life-time history

Design goal	*12 months*
1st target	16 months
2nd target	33 months
3rd target	10 months
4th target	< 1 month
5th target	4 months

After two targets quickly failed with water line leaks (downstream water turnaround):

-- Did autopsy on highly radio-activated target 5 to confirm location of leak

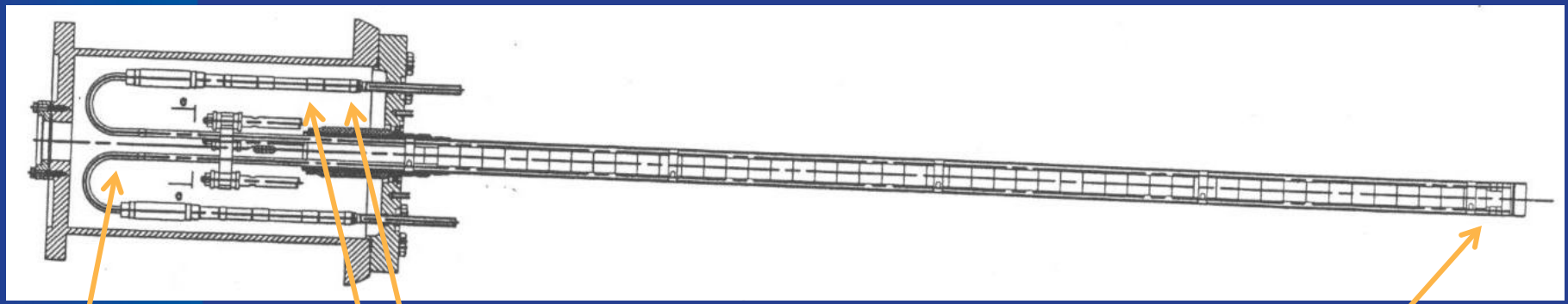
-- Then modified target 6 (more robust weld and geometry) before putting it in beam

← Old design

New design →

Problematic laser weld – will TIG weld

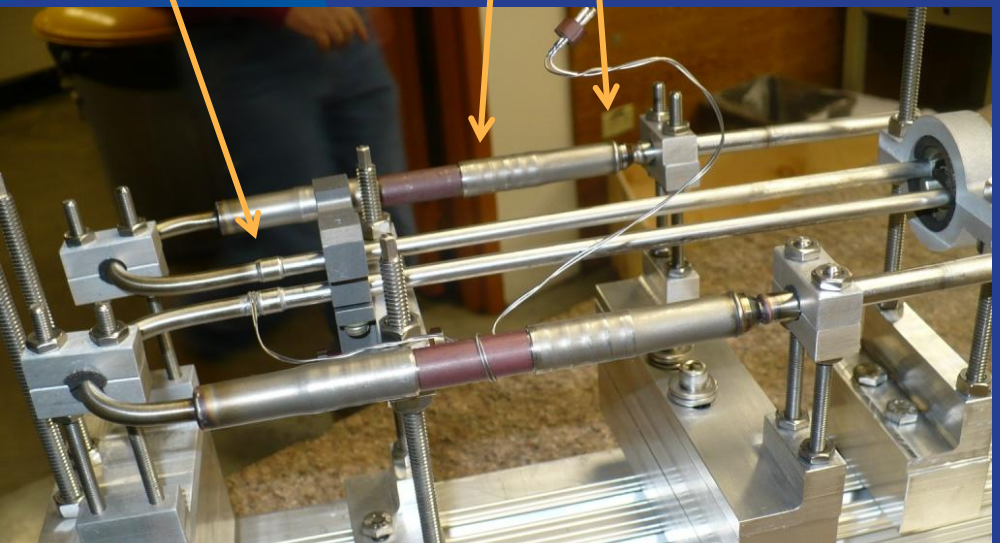
So, usual suspects



Weld sleeve

Ceramic transitions

Water turn-around

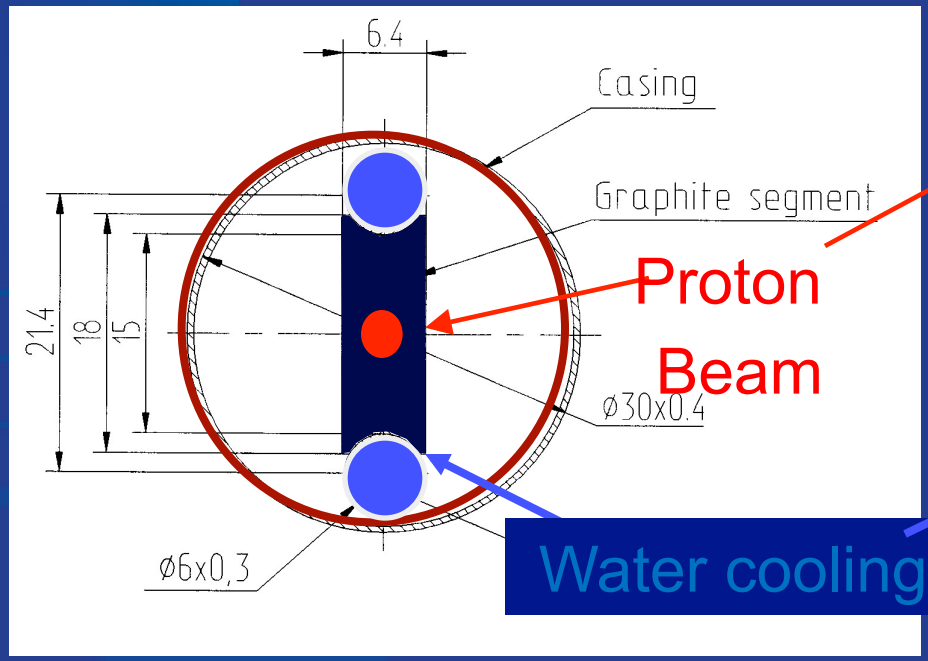


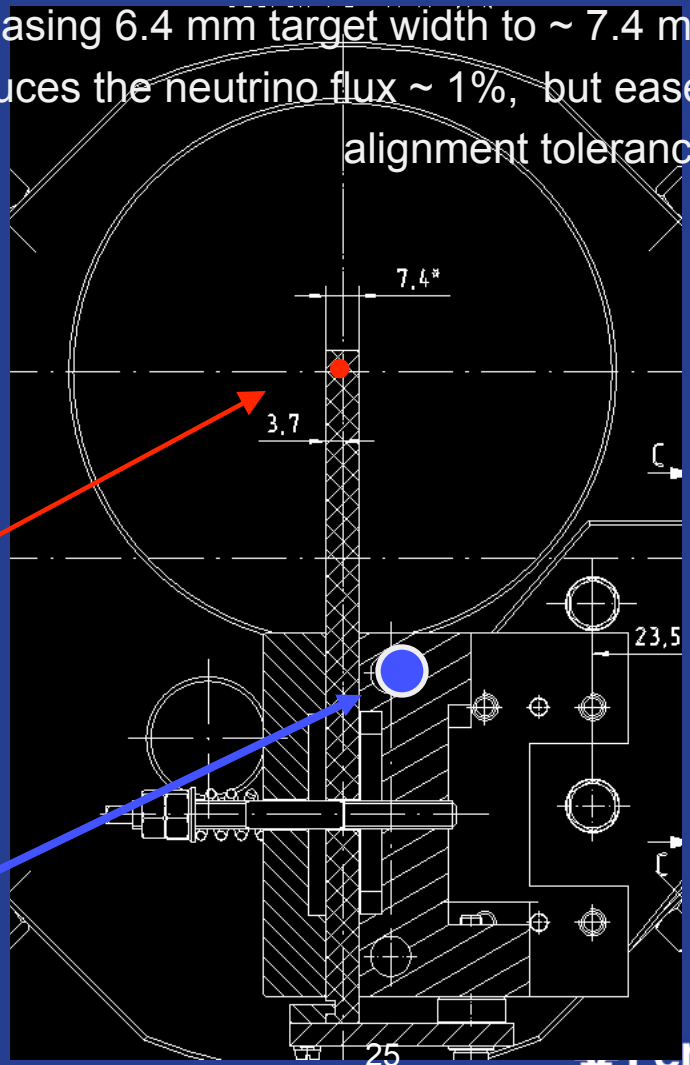
Target cross section comparison

water cooling 8 times as far away, 0.1 x the water hammer

MINOS beam spot size of 1.1 mm RMS is increasing to 1.3 mm for NOVA, increasing 6.4 mm target width to ~ 7.4 mm - reduces the neutrino flux ~ 1%, but eases alignment tolerance.

Spacing between fins
0.5 mm / 24 mm versus 0.2 mm / 20 mm





All units mm