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# **Recent Operational Experience at the Booster Neutrino Beamline**

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Proton Accelerators for Science and Innovation

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# Booster Neutrino Beamline and Detectors



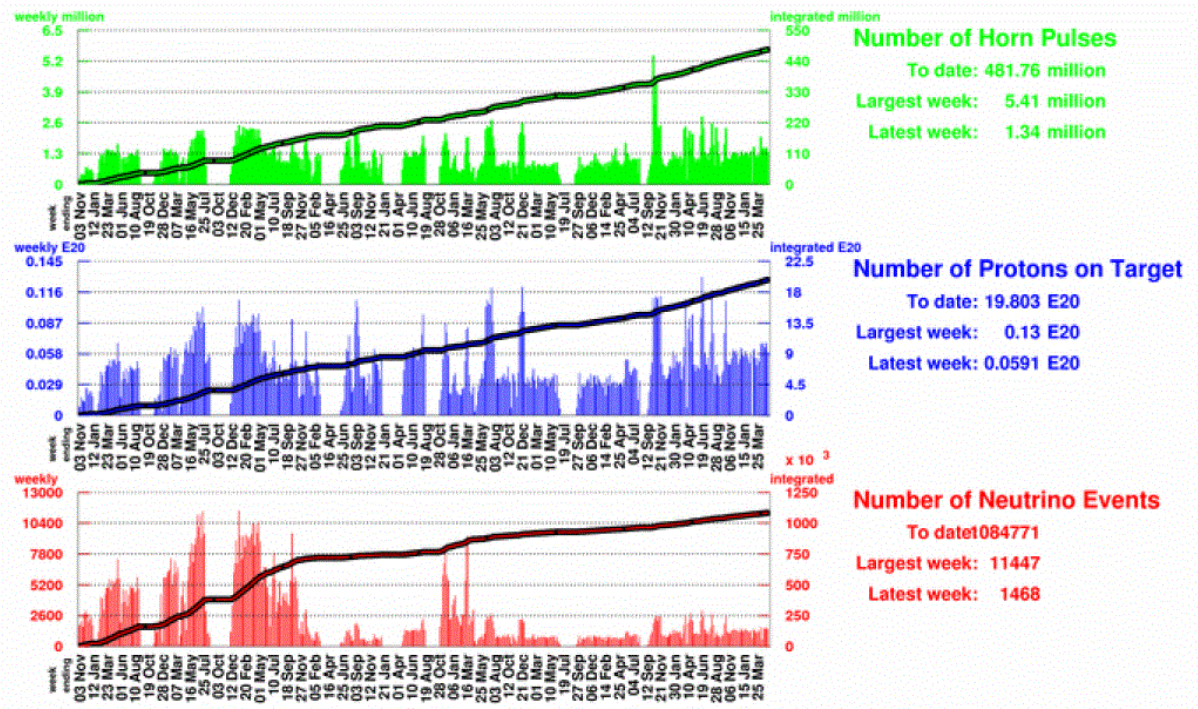
MiniBooNE

MicroBooNE

Booster

SciBooNE

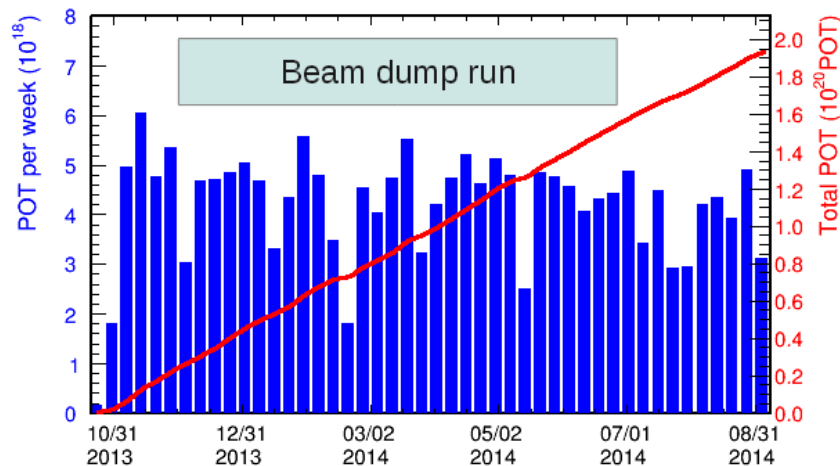
Booster Neutrino Beamline



Since turning on, BNB has transported 2.1E21 protons.

The horns have pulsed half-a-billion times.

BNB is assessed for greater than  $5 \times 10^{12}$  protons per pulse at 5 Hz average.

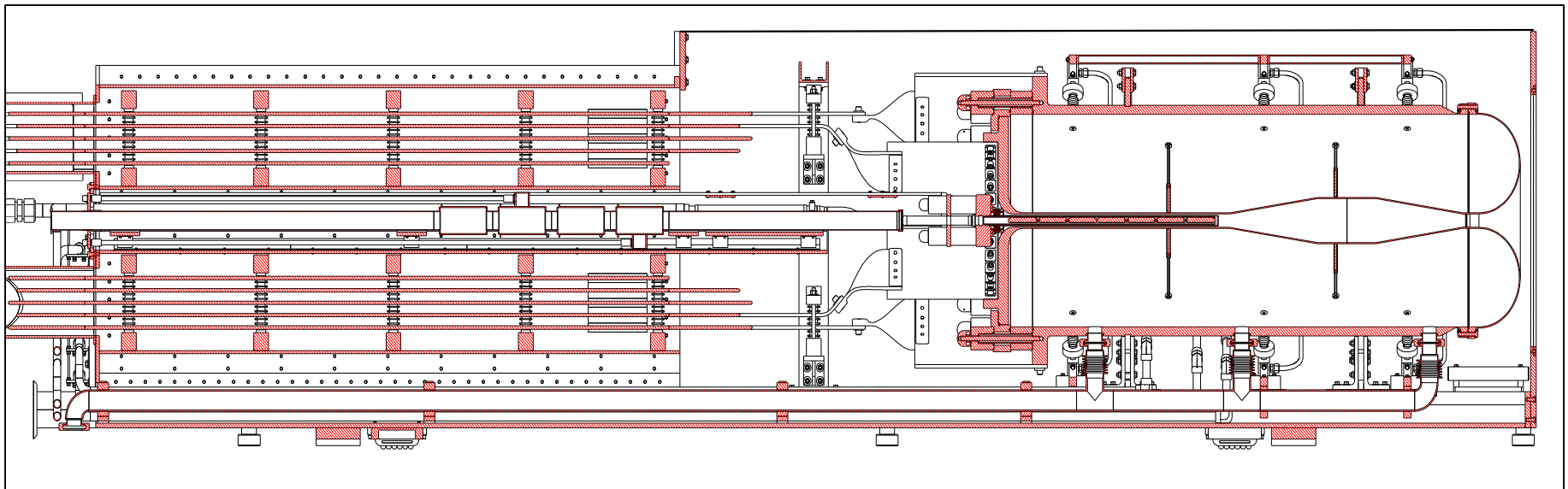




# Target and Horn Assembly



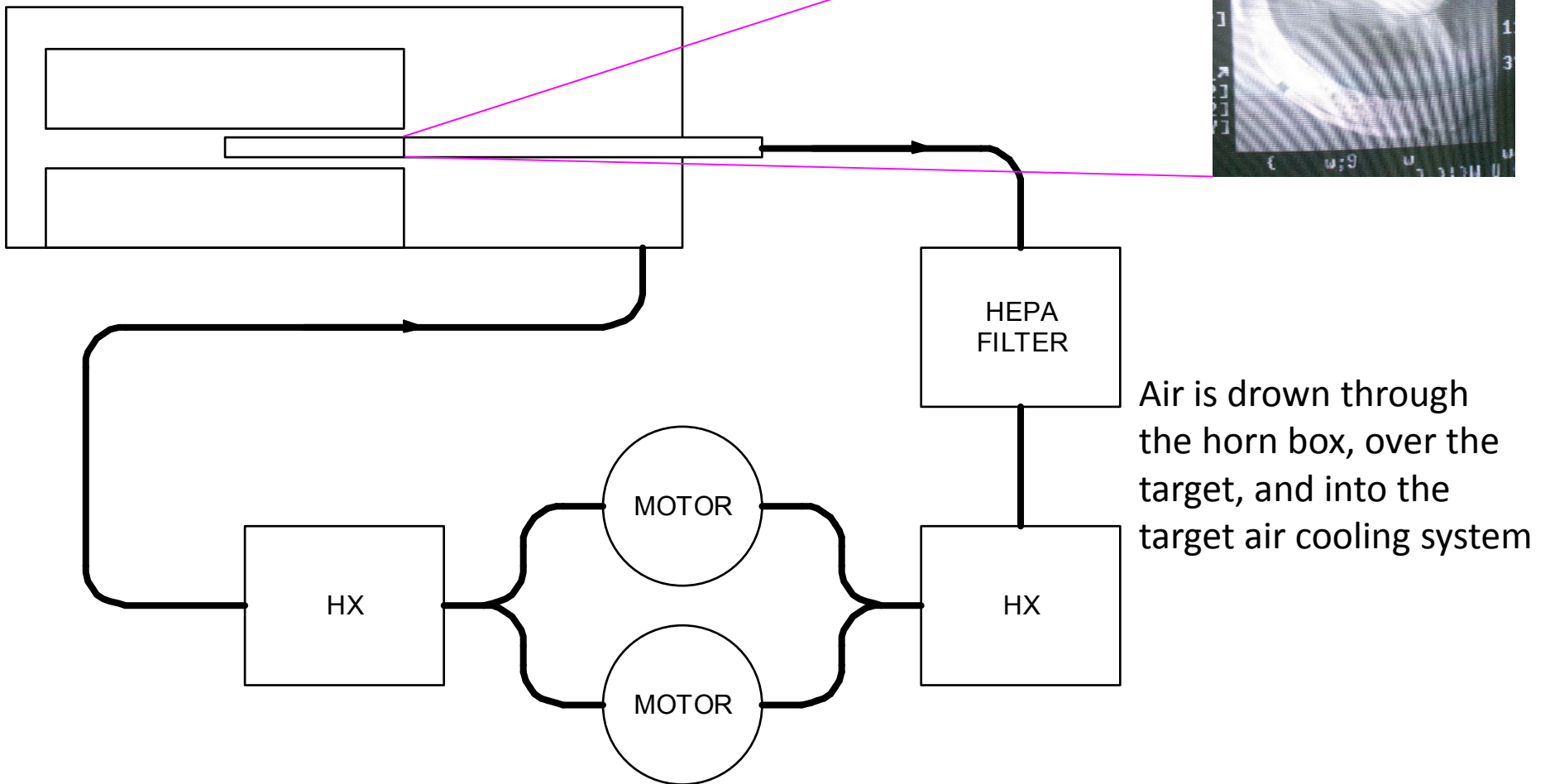
Designed by Larry Bartoszek  
Built by AD Mechanical Support Target Group  
Present engineer is Vladimir Sidorov



Target and horn are built and installed as a single unit, although it is possible to change only the target.

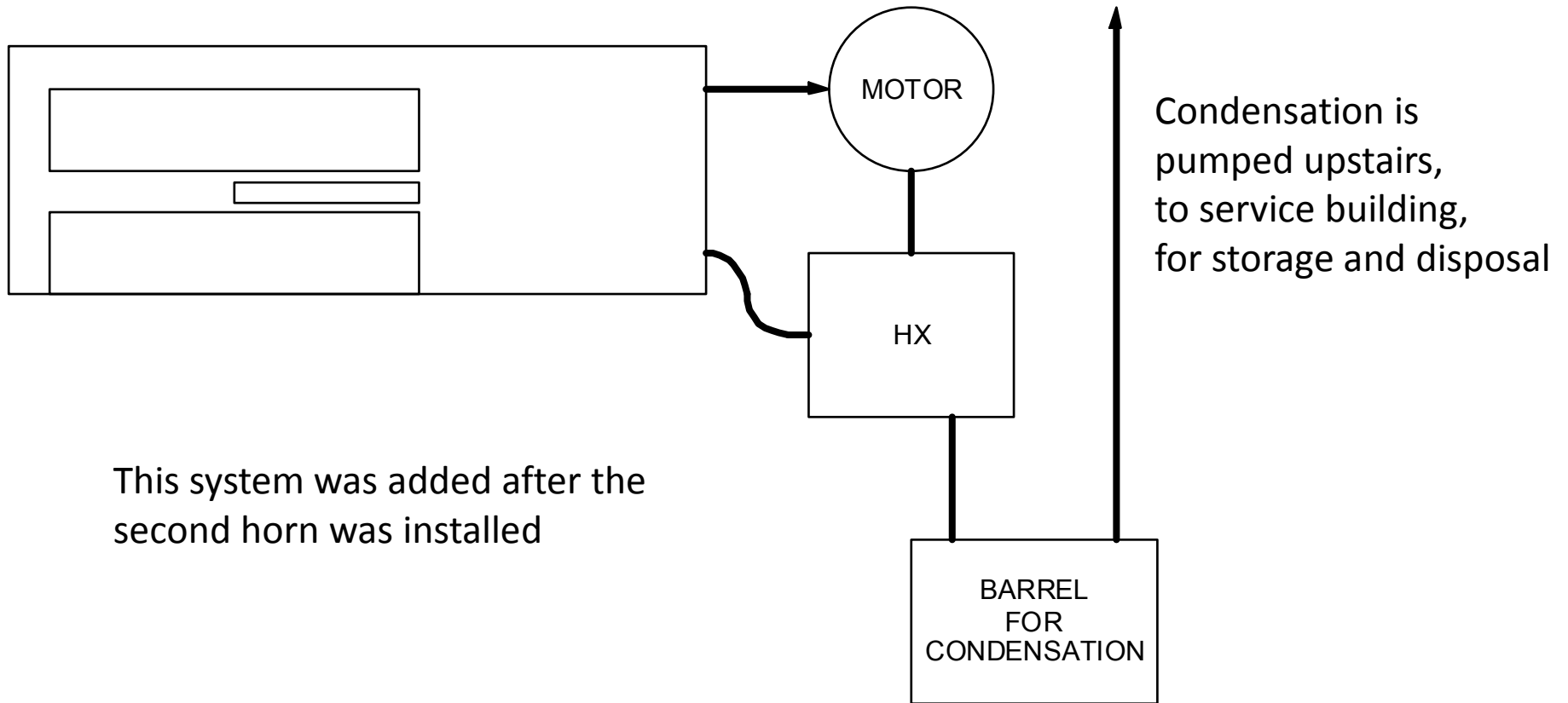


# Target Air Cooling System



Air is drawn through the horn box, over the target, and into the target air cooling system

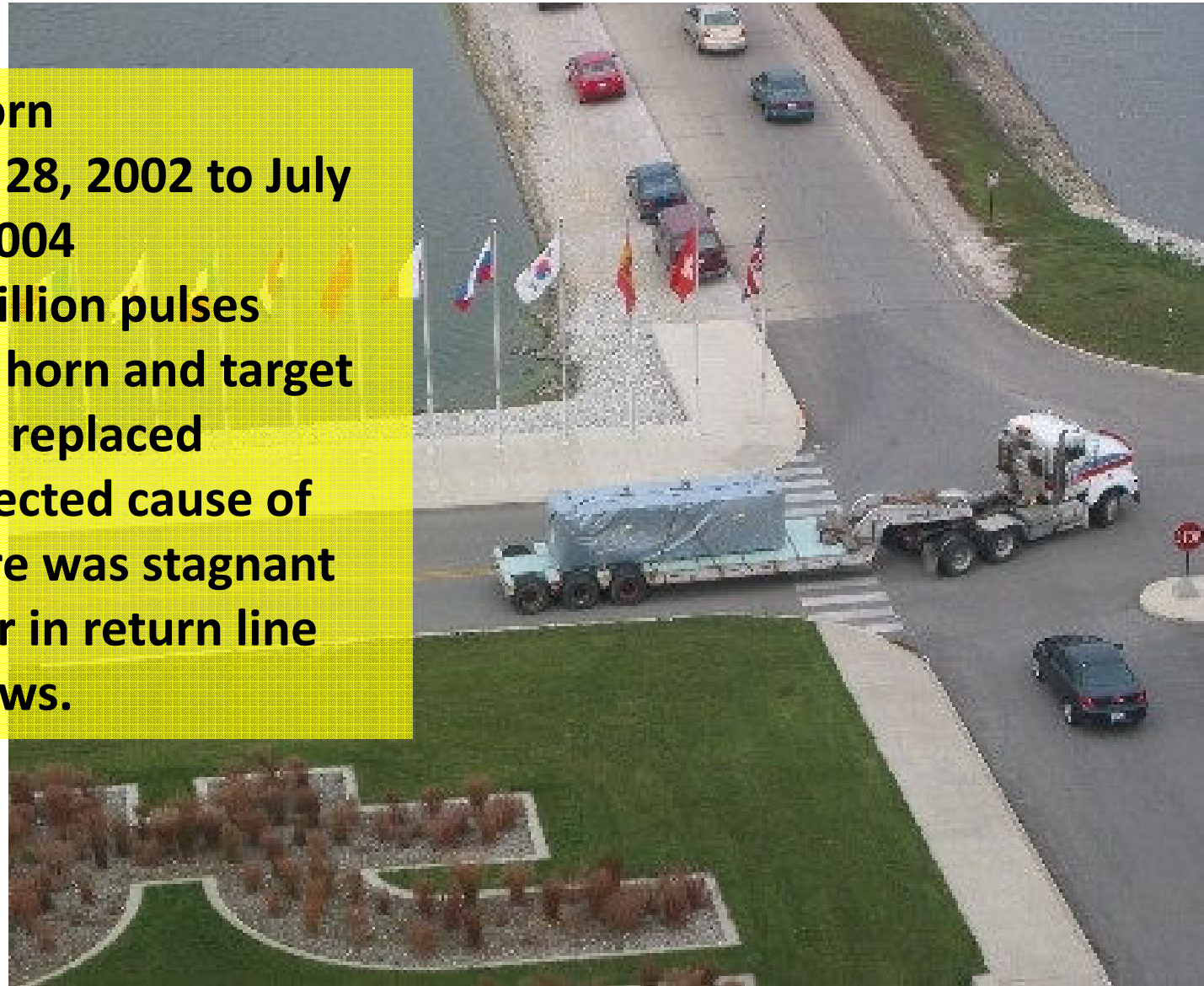
# Horn Box Dehumidifier



This system was added after the second horn was installed

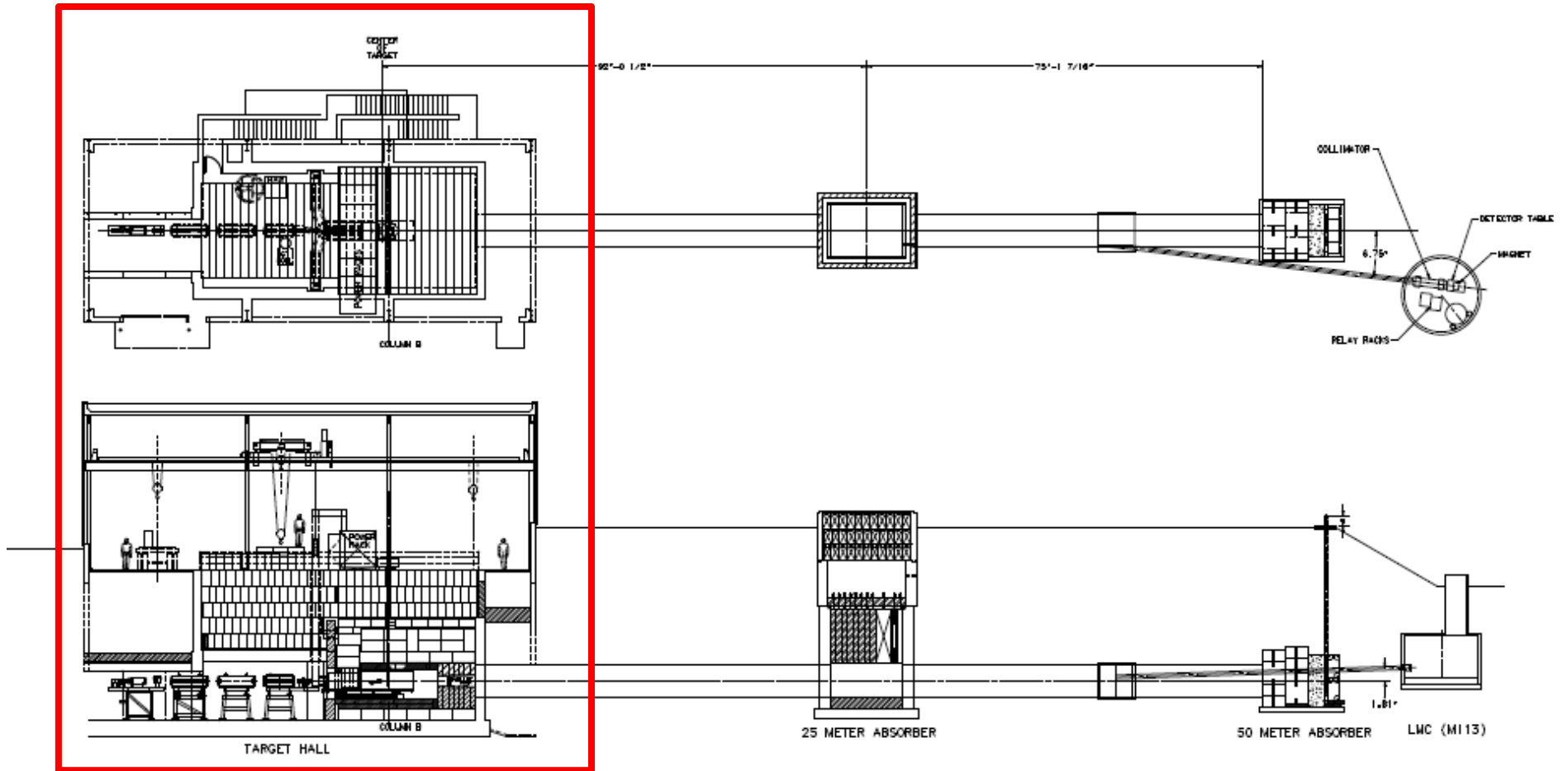
## First Horn

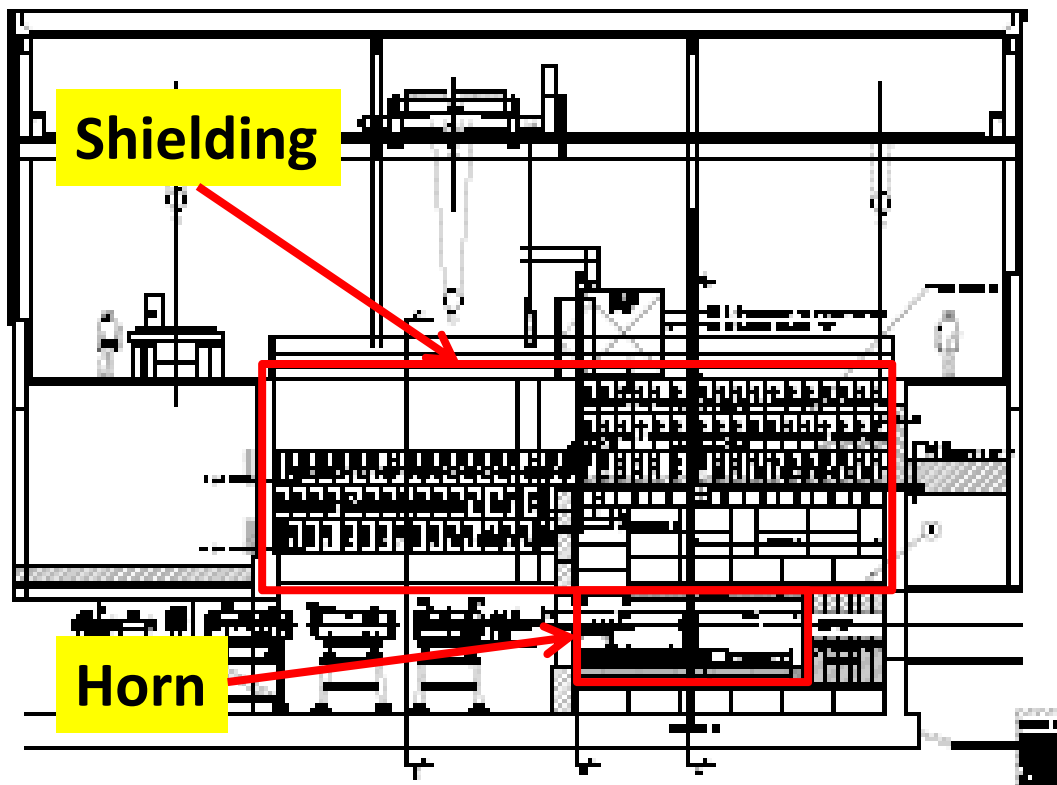
- April 28, 2002 to July 28, 2004
- 97 million pulses
- Both horn and target were replaced
- Suspected cause of failure was stagnant water in return line bellows.





# Changing a Horn





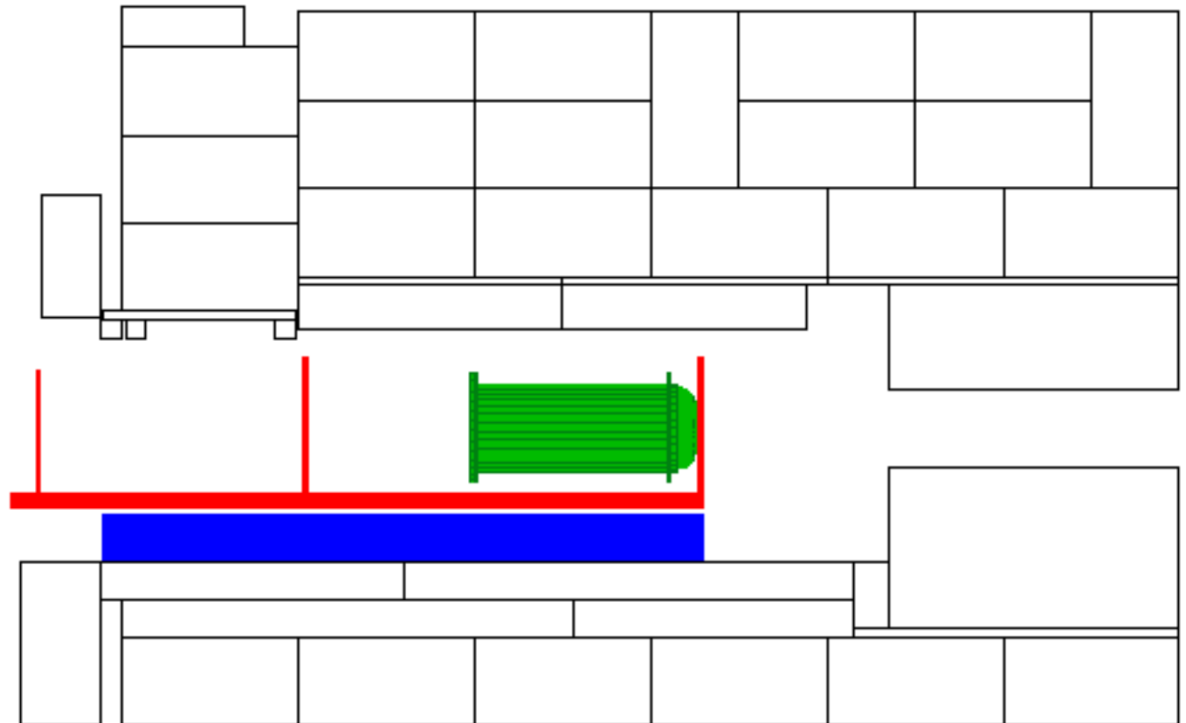
- Unstack 6x15 shielding blocks.
- Remove final focus triplet.
- Lower coffin.
- Remove horn.
- Reverse procedure.

Target and Horn are buried in shielding.  
Target can be changed independently of horn.

The horn (green) is mounted on the carrier assembly (red). It is supported by the adjuster module (blue).

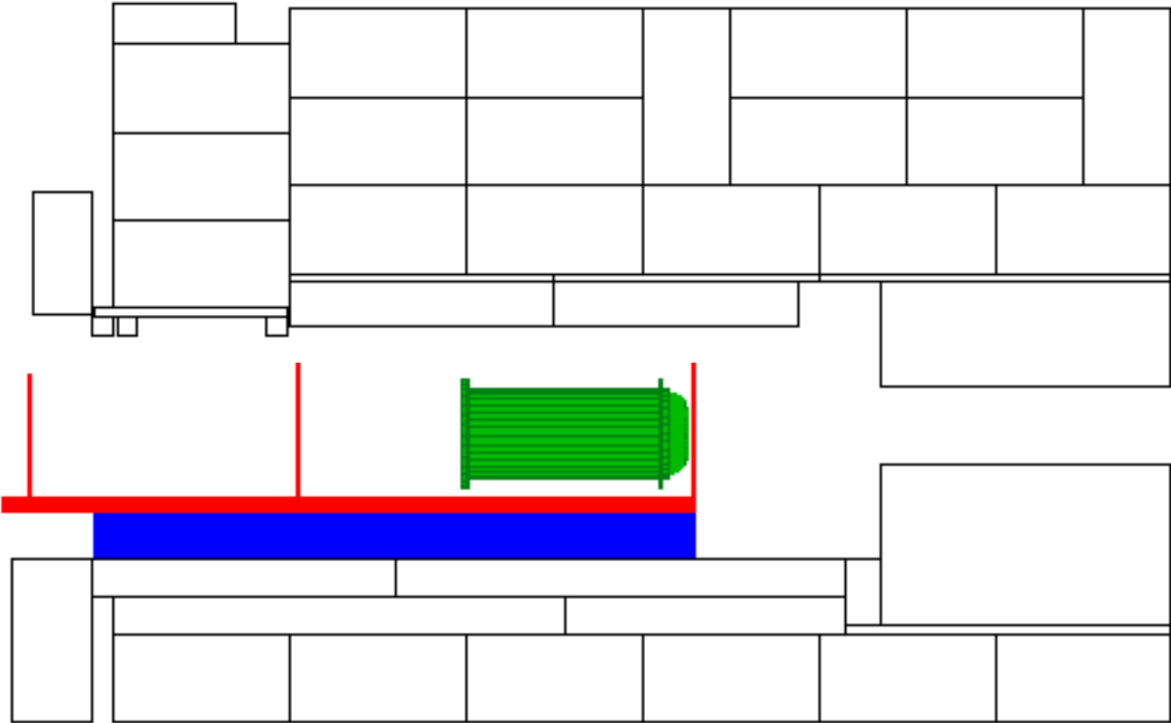
There are rails on either side of the adjuster module. For simplicity, the rails are not shown. Also, the adjuster is a lot more complicated than what is drawn.

All this is located in a cave in the target pile.



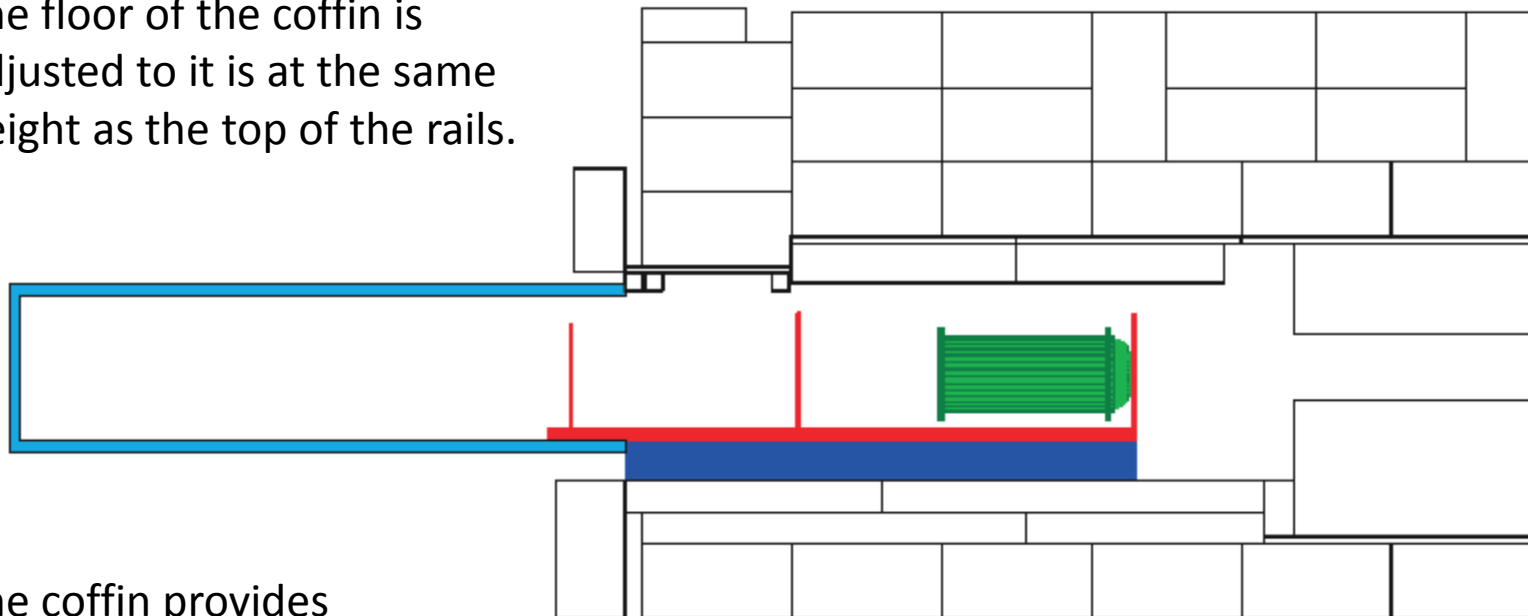


The carrier is lowered so it rests on rails. The carrier has rollers on it, but these are not shown.



A steel “coffin” is lower into the target hall and partially inserted into the target pile.

The floor of the coffin is adjusted so it is at the same height as the top of the rails.



The coffin provides shielding for when the horn and assembly are removed.



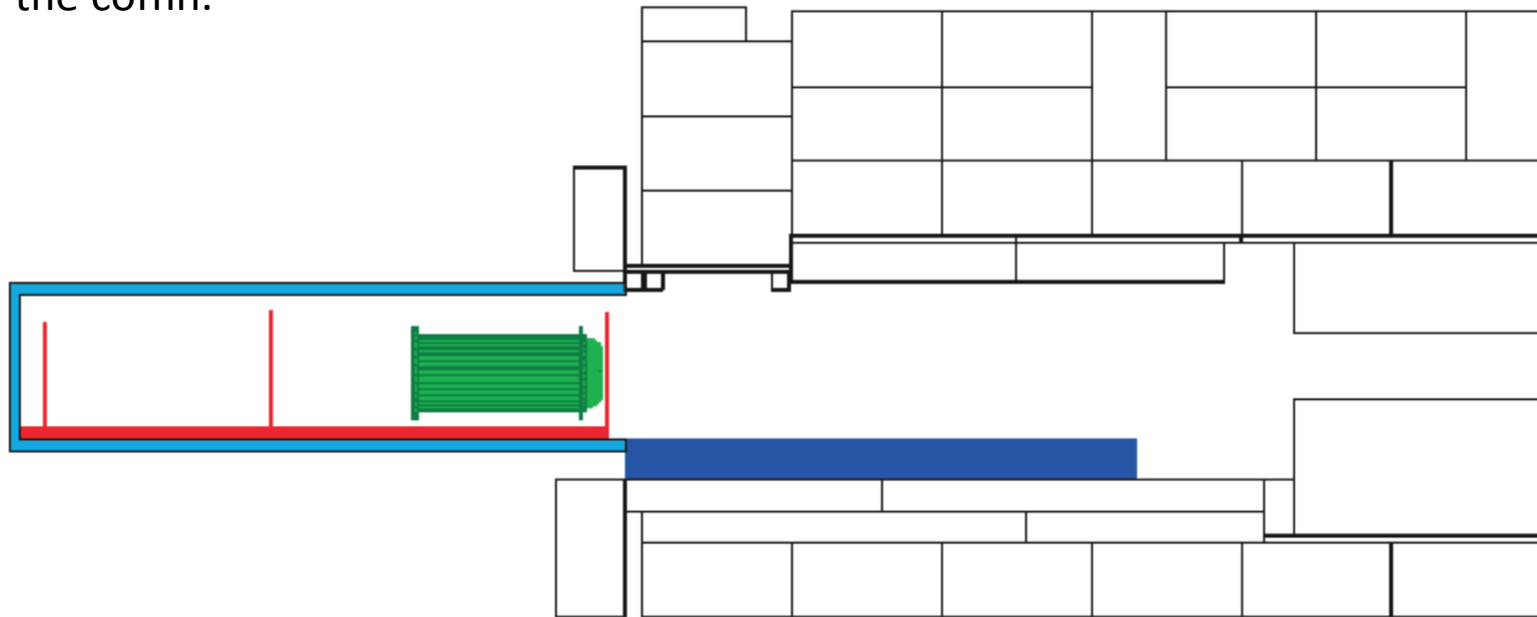
This is what it looks like.

The coffin is almost in place. It still needs to be pushed into the target pile. First, however, the door must be removed.

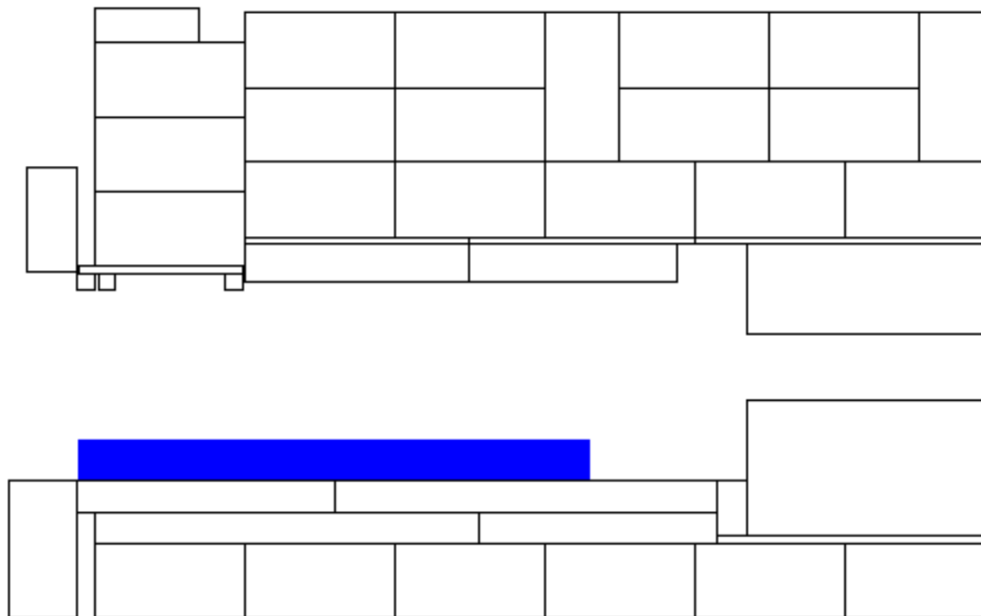
The door is heavy enough to significantly affect the center of mass, so it needs to be in place when the coffin is moved using a crane.

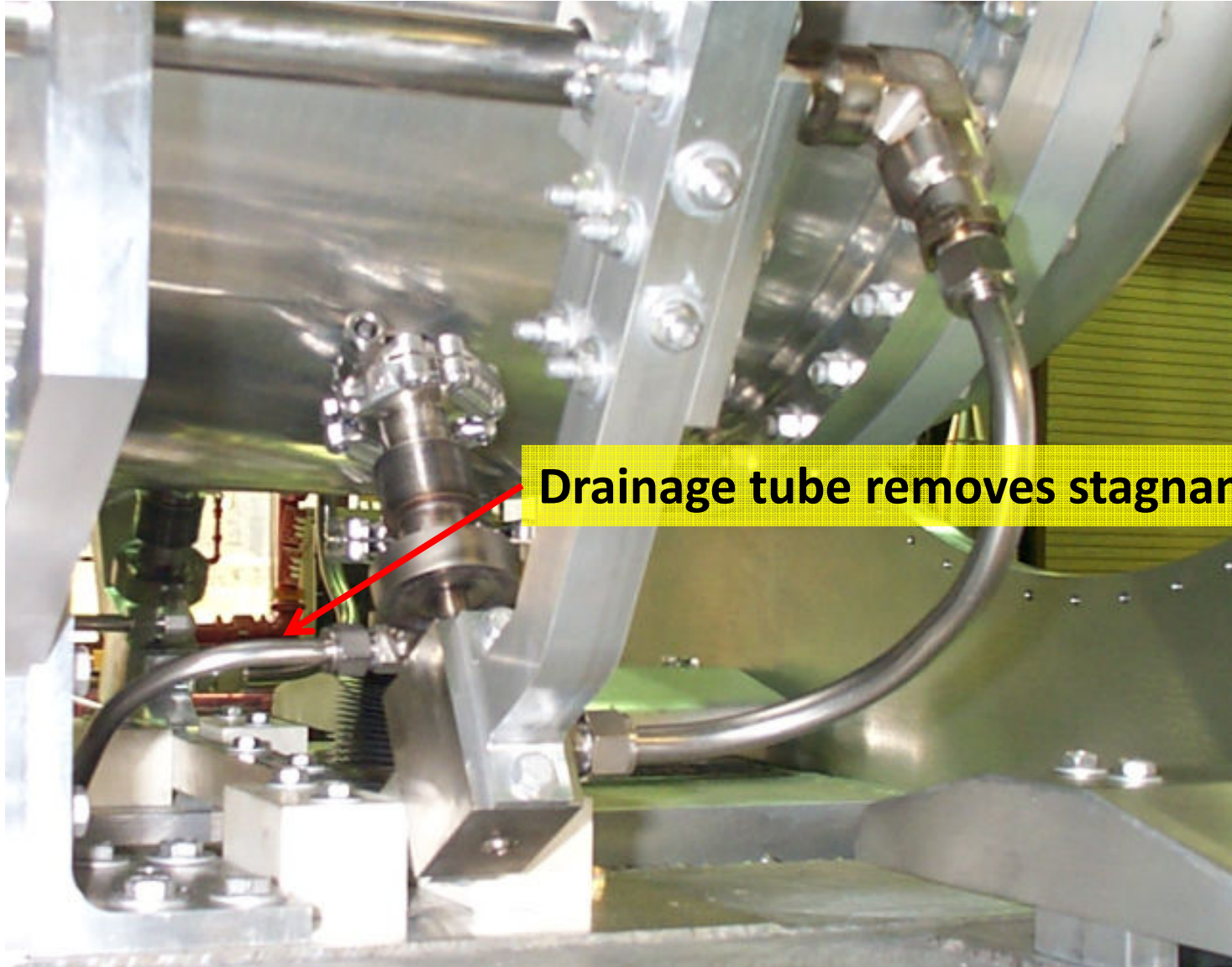


The horn is pulled into the coffin. Not shown is the steel door that will be lowered to block the front of the coffin.



The coffin is lifted out of the target hall.

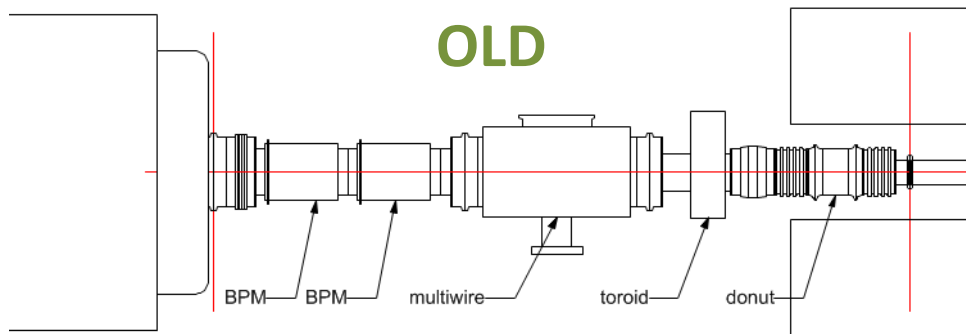




**Drainage tube removes stagnant water**

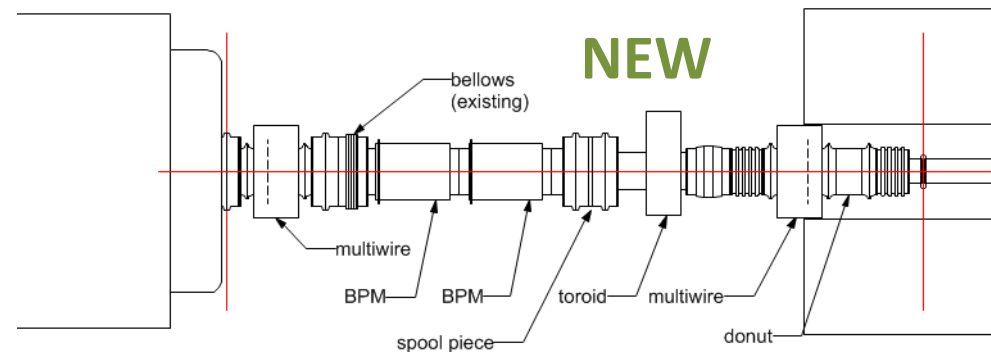


# Updated Target Hall Instrumentation in 2013



Old instrumentation was able to keep beam on target, measure intensity, and measure beam width when needed.

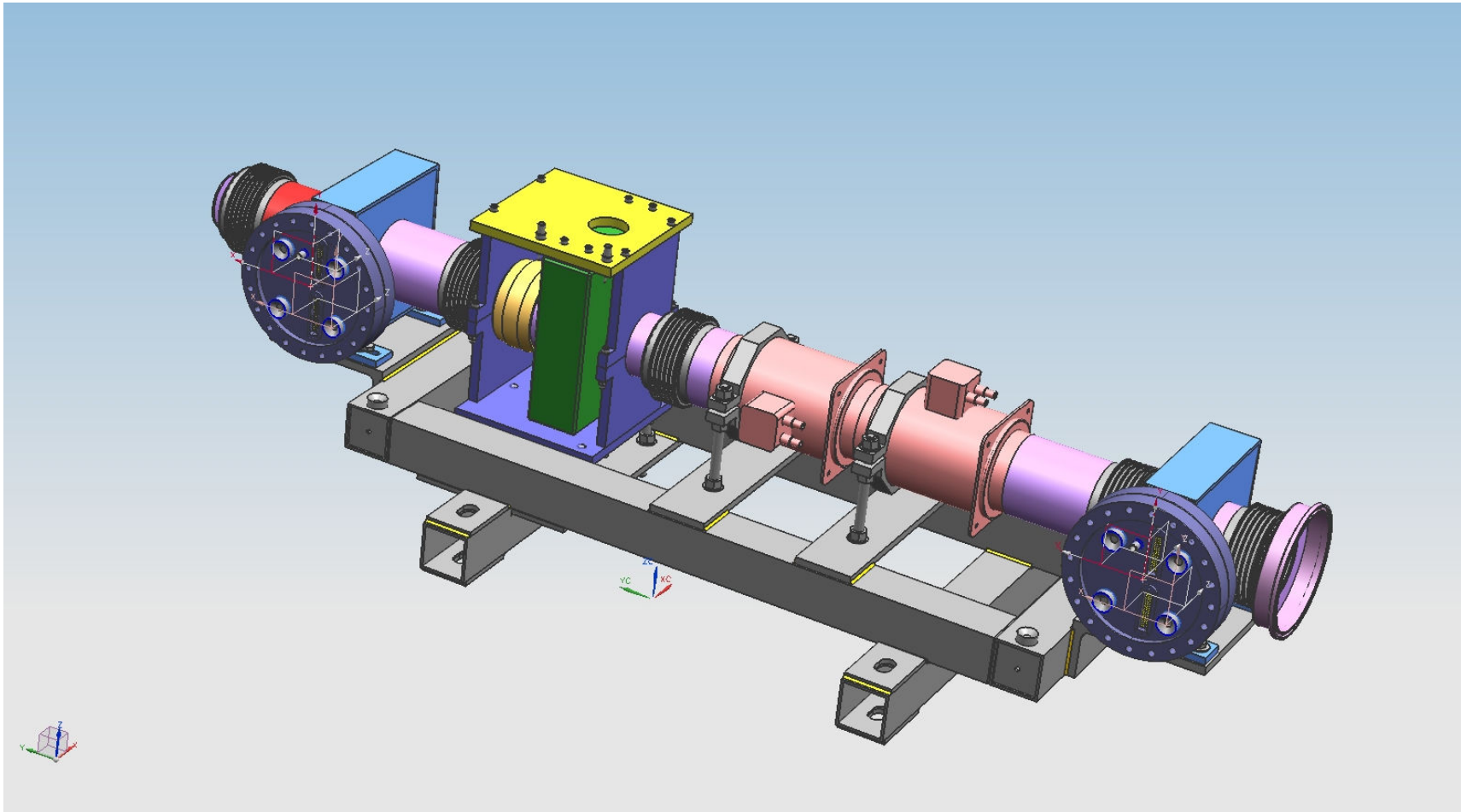
New instrumentation employs low-mass multiwires, allowing continual monitoring of beam shape.



Additionally, we are able to reference multiwires to external coordinate system, allowing us to locate beam position and trajectory in site coordinate system.

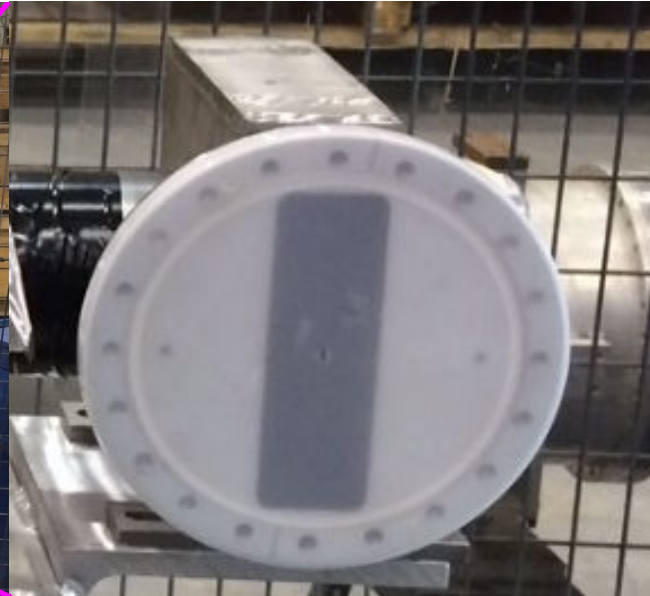
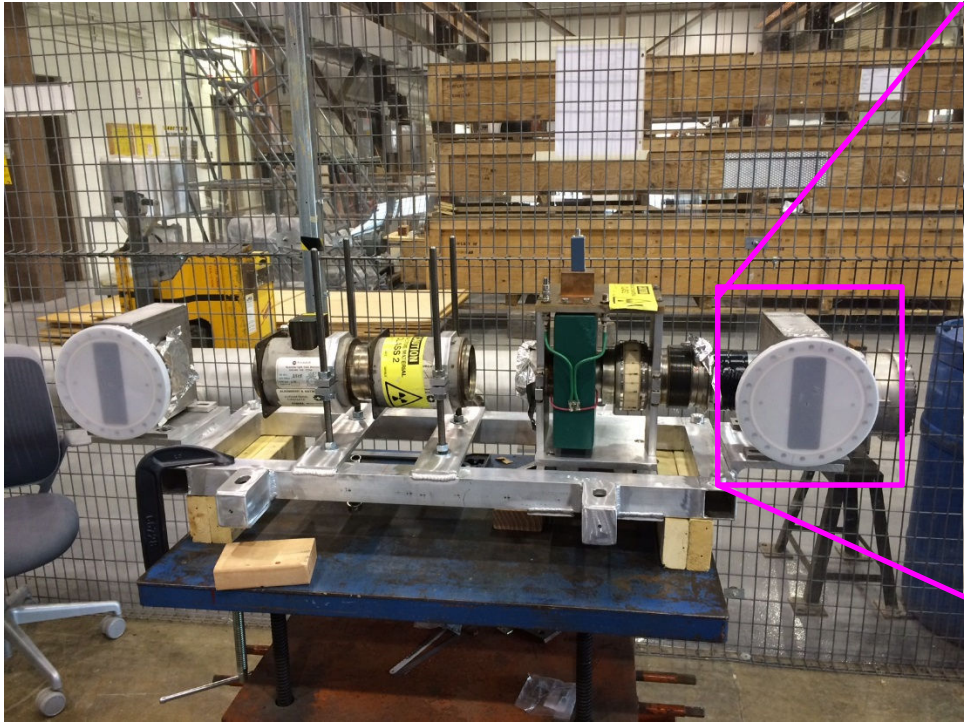


Due to the many flanges this assembly was very difficult to install. In spite of this, the idea was shown to work.

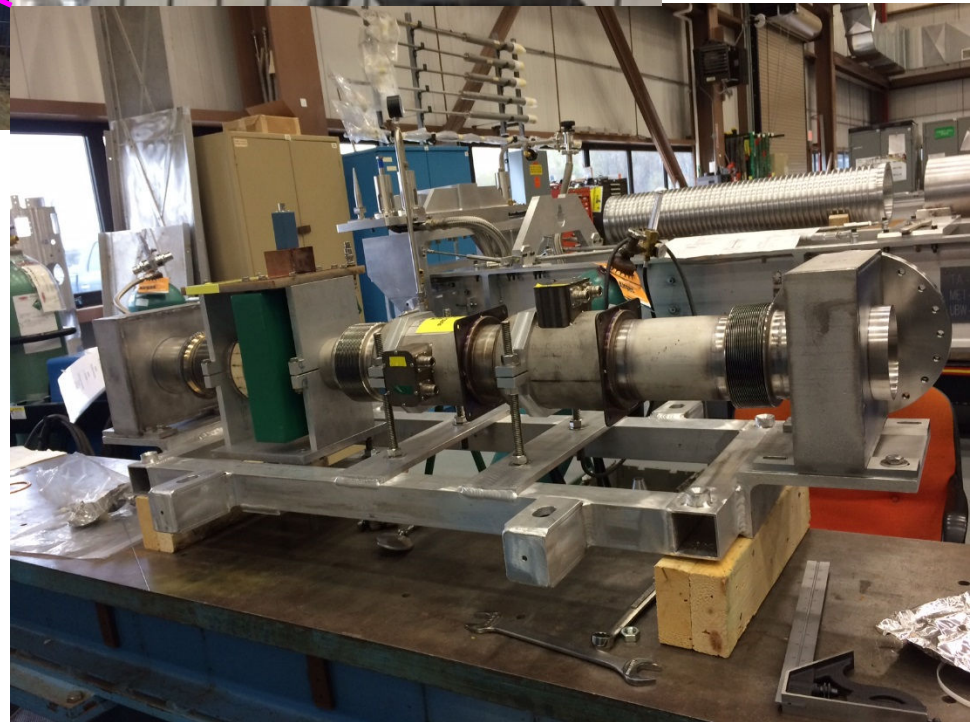


Second generation low-mass multiwires. Welded joints, easy access to wire plane, more robust mechanical design. Separation between planes remains at 110 cm and planes retain 0.5 mm pitch. New instrumentation package was installed when horn was changed.



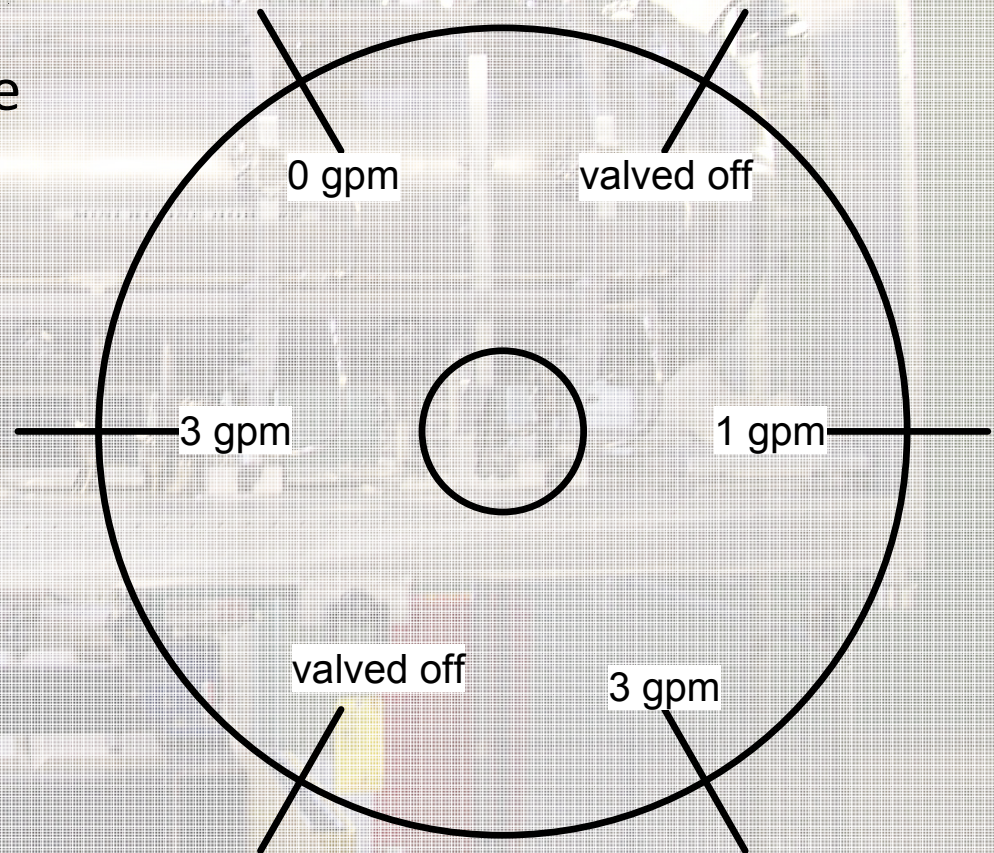


New multiwire wire assembly has welded joints.  
Flanges allow for easy mounting and replacement of ceramic planes.





- December 2004 to September 2014.
- 1/3 of a billion pulses.
- Two of the six water lines had been valved out due to leakage, but still had adequate cooling.
- Water was continually circulated, even during shutdowns and off-target running, to avoid stagnation.



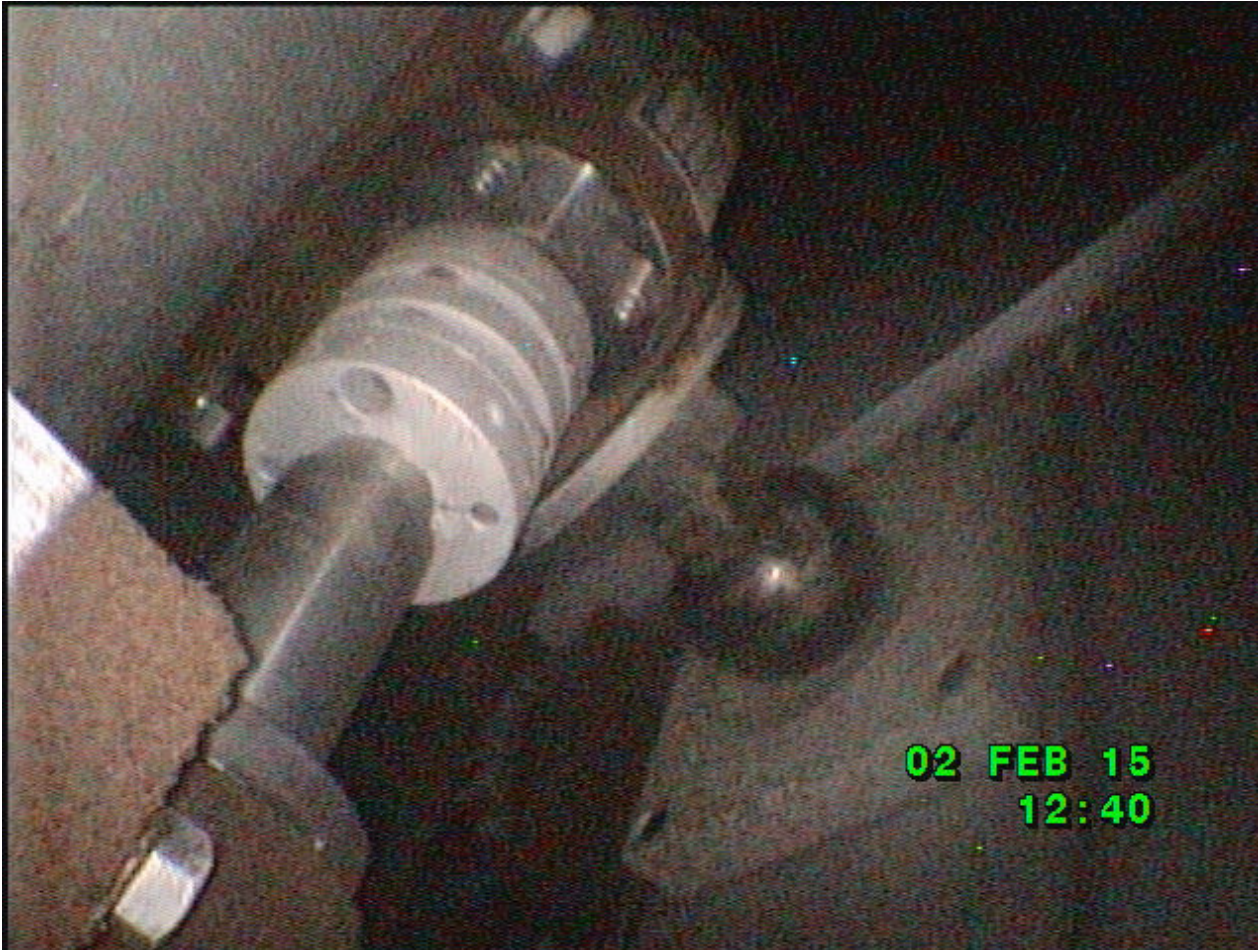




This is the bottom plate of the adjuster module installed in the target pile cave. The bottom plate provides lateral adjustment and yaw.

The rails that the horn rolls on are the brown I-beams on either side. Vertical guides are attached to the horn does not wander off to one side.

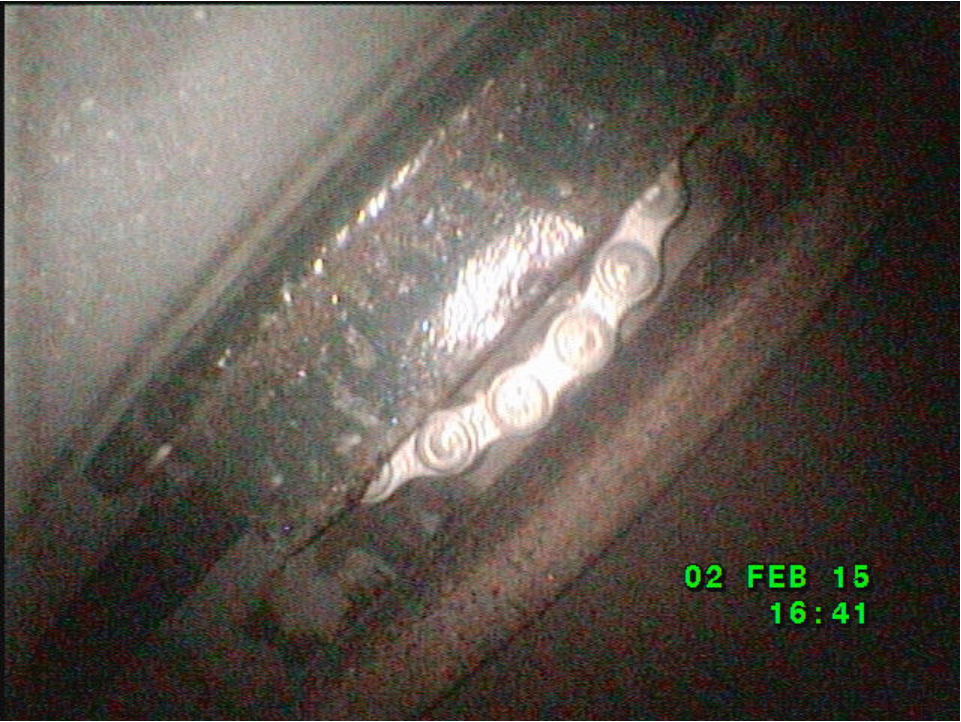
After 12 years, the mechanism no longer worked.



The set screws on the couplers were high-strength steel, and sheared (hydrogen embrittlement?).

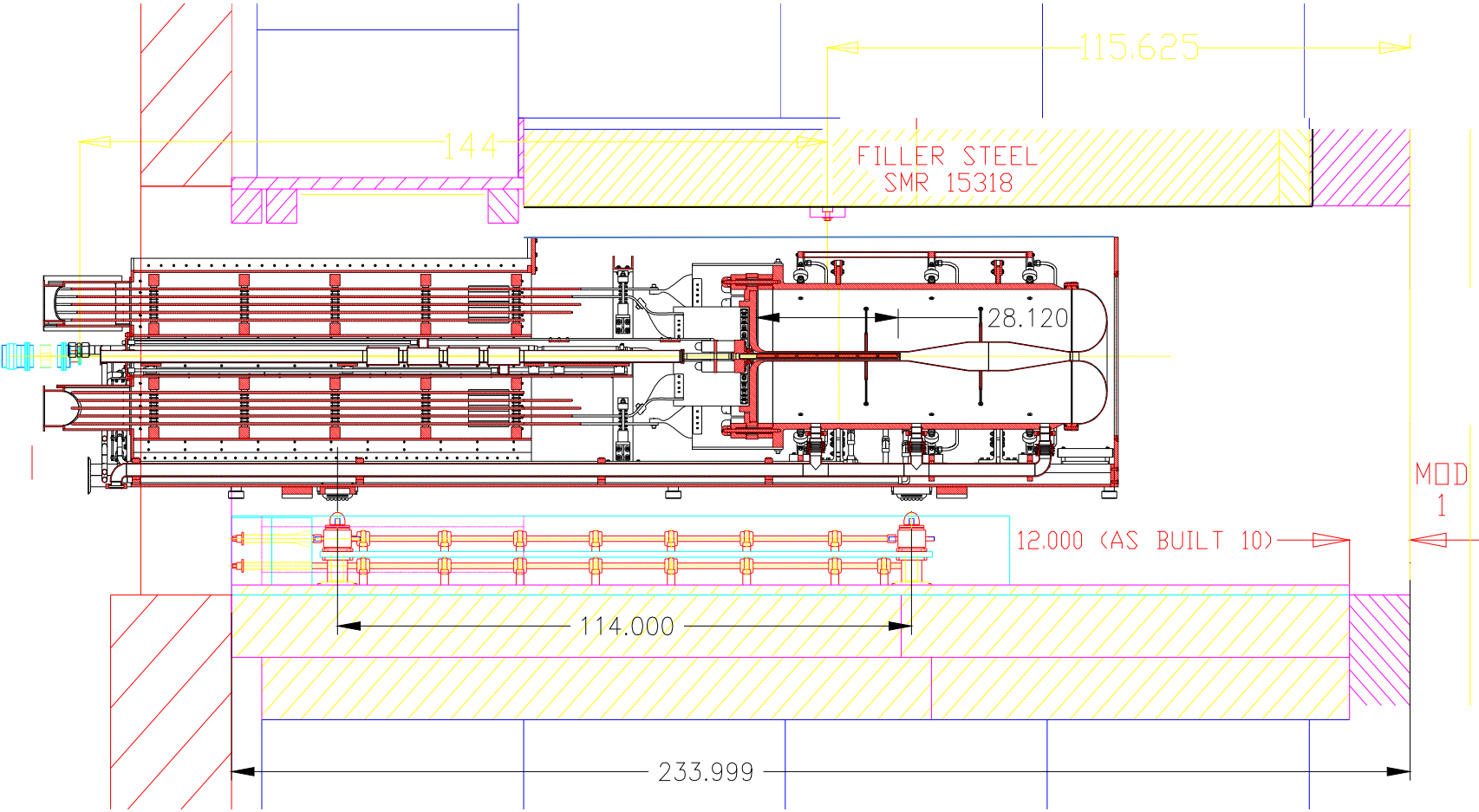
Another adjuster seized completely. The adjuster had been packed with grease – gummed up from radiation or just age?





Two more photos showing corrosion.

Luckily, there was enough space between the horn box and shielding cave to lift the horn off the adjuster module.  
Horn was lifted using an air bag.  
New rails were slid under the horn.  
Horn was removed.

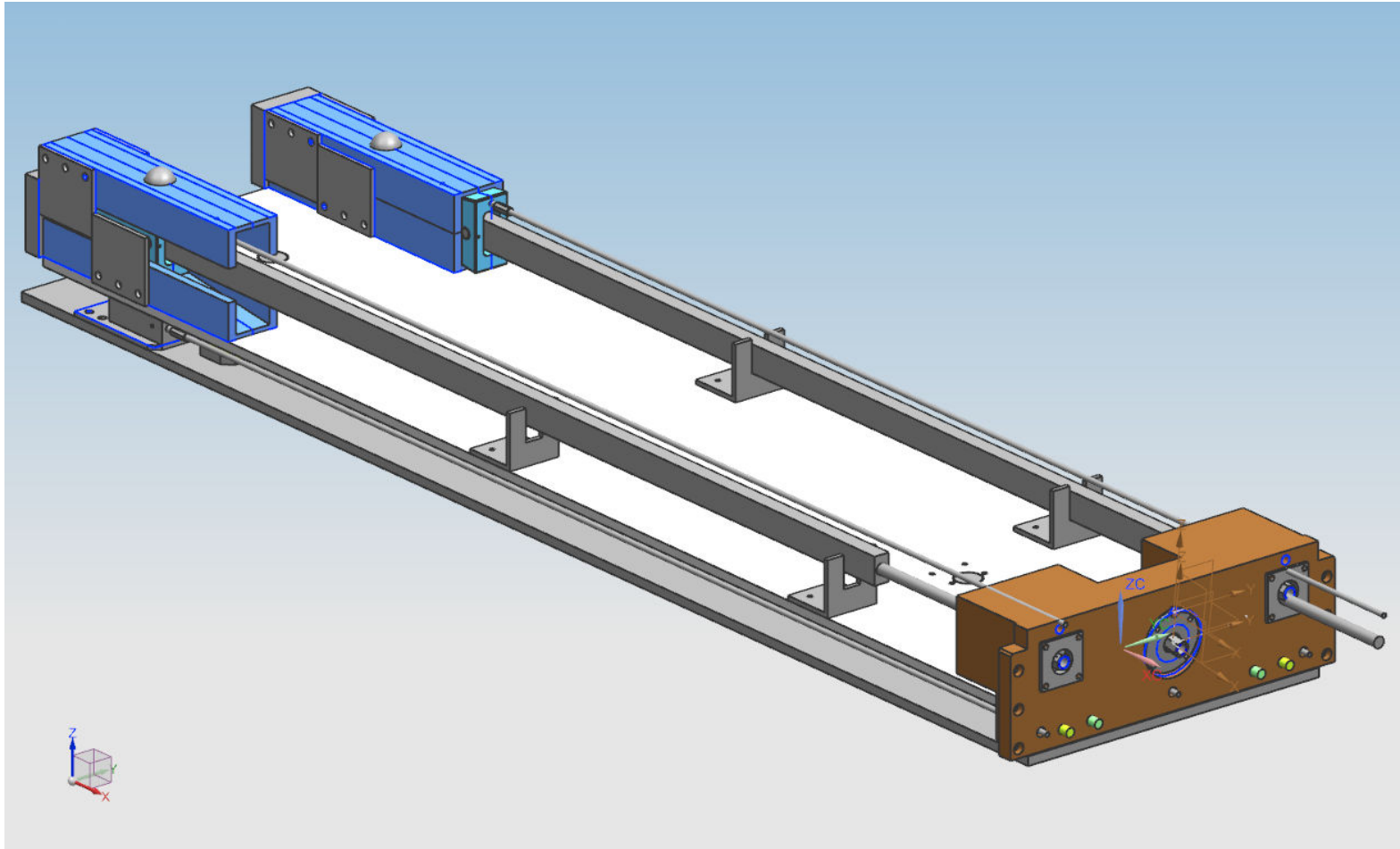




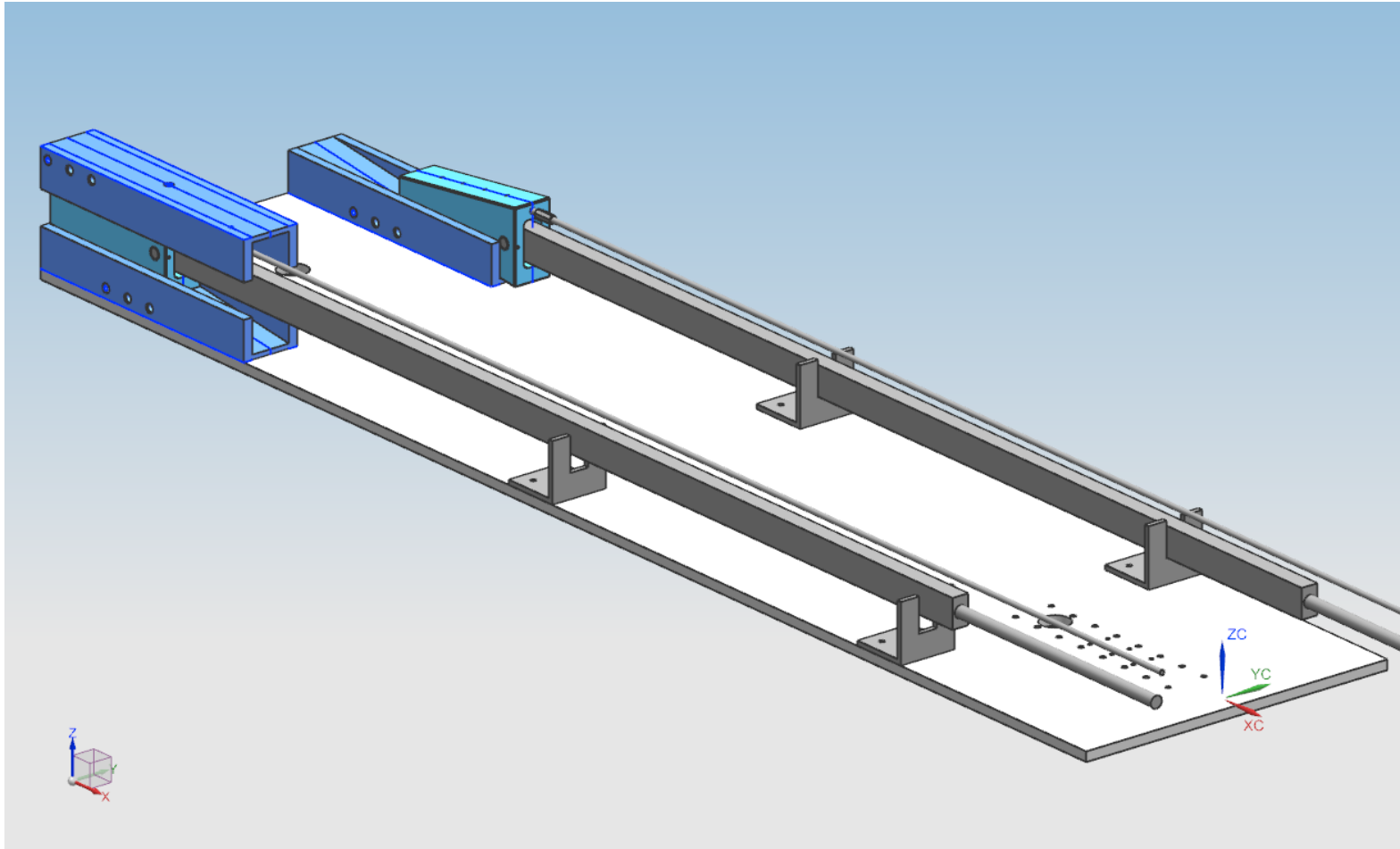
The old adjuster module was removed.



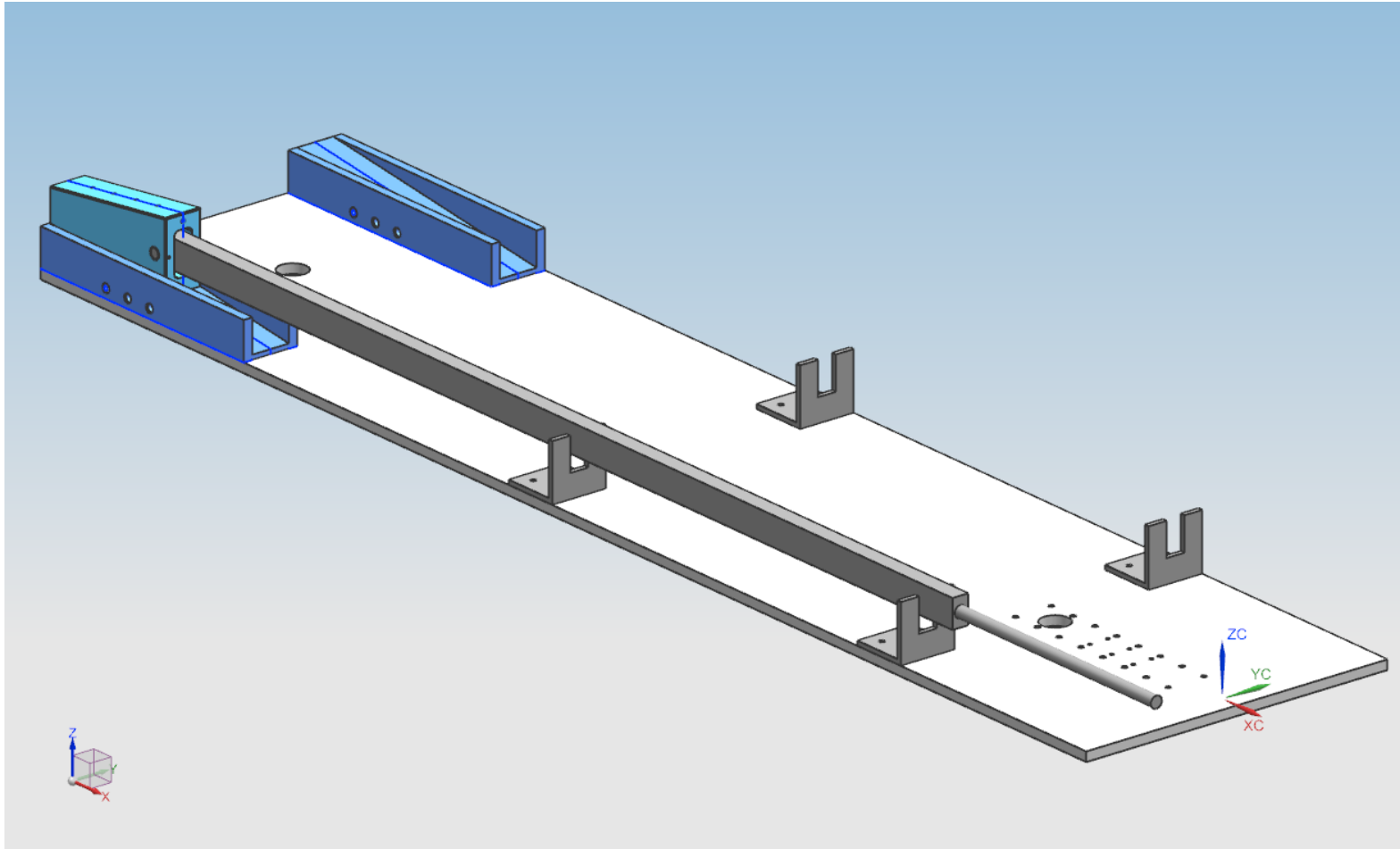
This is what the new adjuster will look like. There are two plates stacked on top of each other. The top plate adjusts the pitch, roll, and elevation, while the bottom plate adjusts the yaw and lateral position. (Design by Dave Pushka)



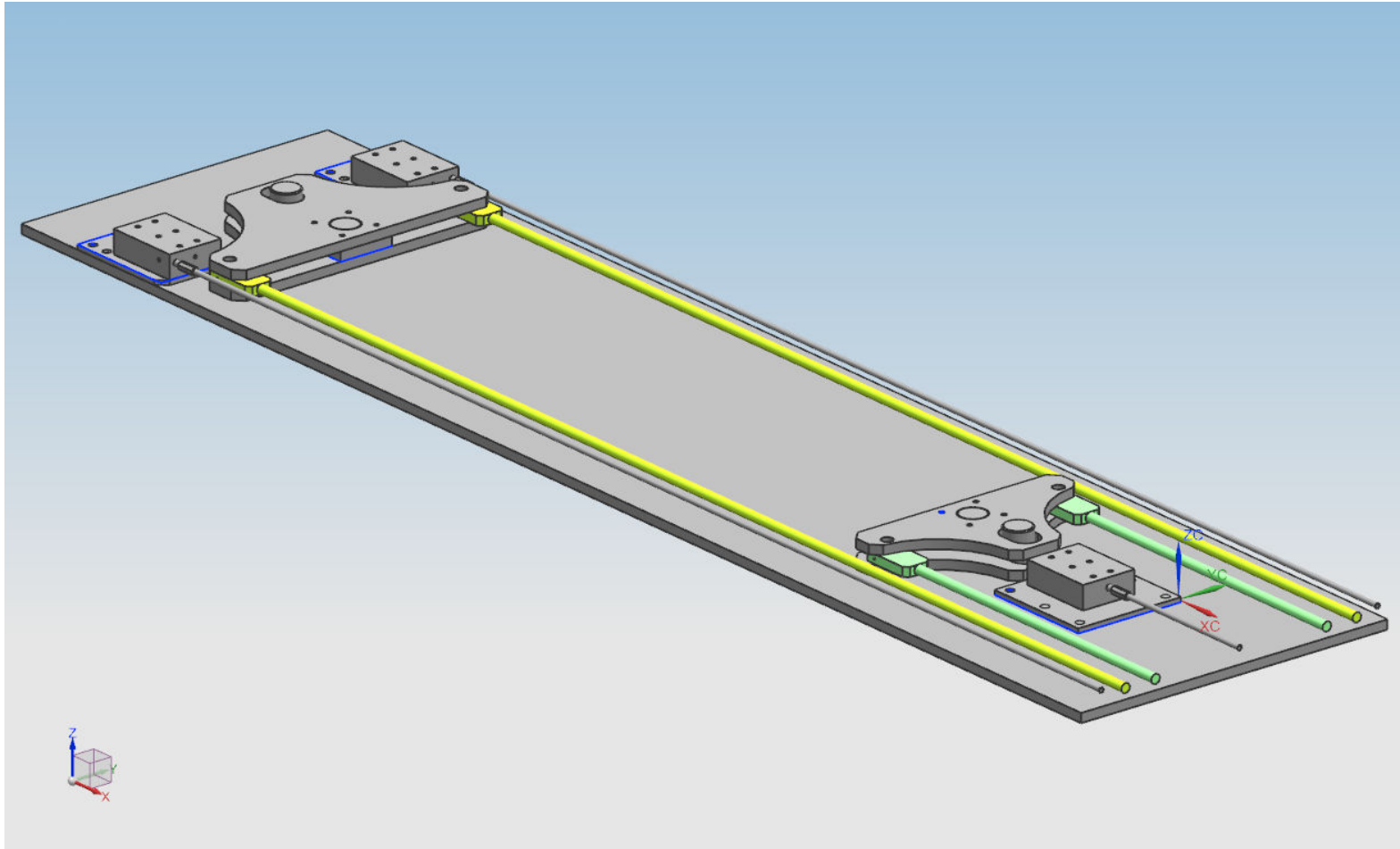
There will be push-rods with wedges attached to the ends. The wedges ride ramps on their top and bottom. When you push in, the ramps separate.



This has some more items removed.



A pin is attached to either end of the top plate. Each pin runs into a slot in a “bell-crank” mechanism. By pulling on either arm of the bell-crank, you can adjust the location of the pin.





New adjuster module during assembly



Checking for fit of Horn 3 to new adjuster module prior to installation.

Any parts which slide are anodized.





Horn 3 being installed.

Installation procedure was modified.

Previously, horn was placed in coffin, and horn/coffin was placed on fixture.

In new procedure, plate is placed on fixture and horn is placed on plate.

Advantage of new procedure: you can see what you are doing!



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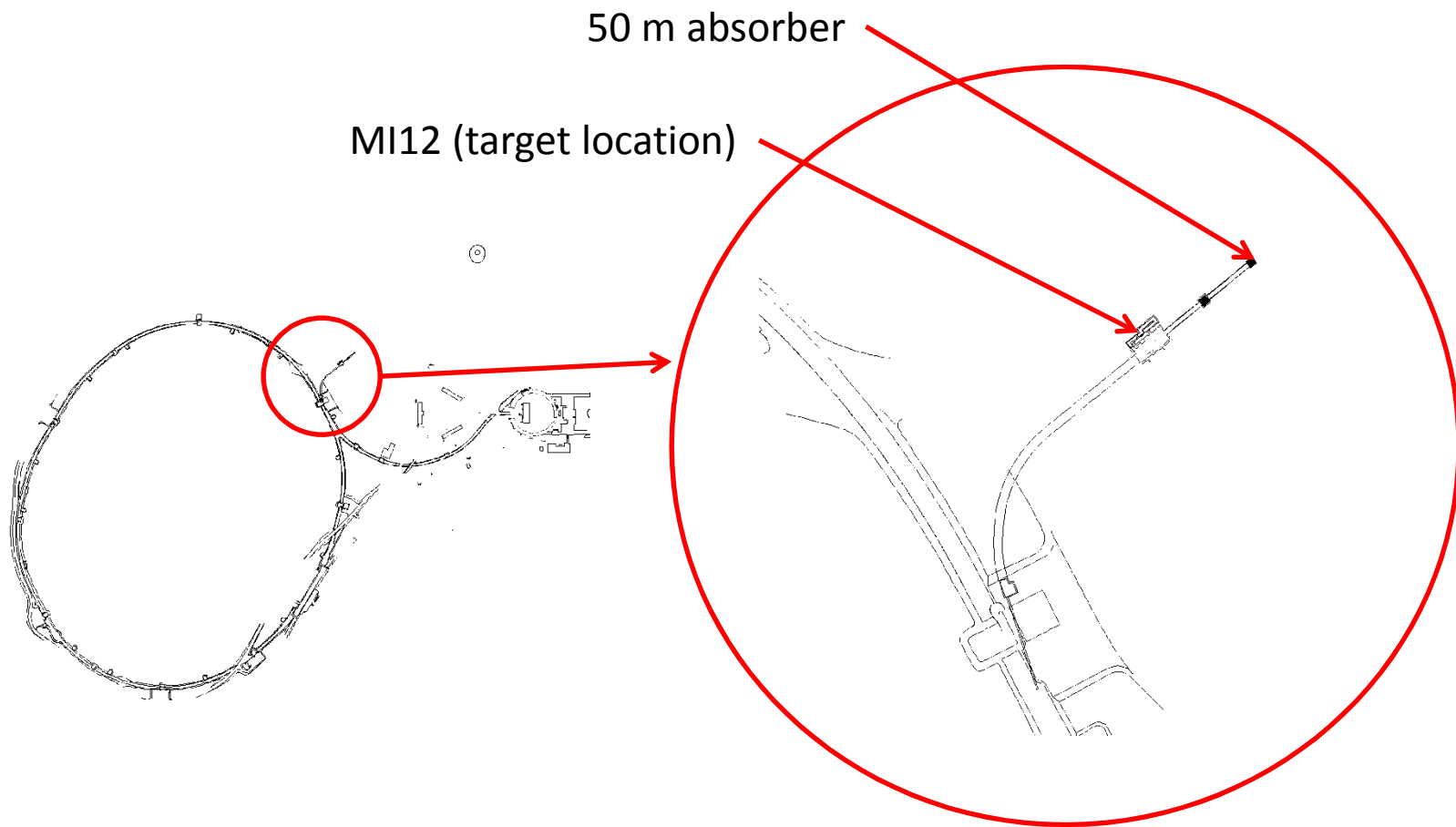
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The End

# Backup Slides

# Location





# Keeping Beam on Target -- AutoTune

- Change the current on a trim magnet and measure the movement on downstream BPMs:

$$\begin{aligned}\Delta i_1 &\rightarrow \Delta x_1, \Delta x_2, \Delta x_3 \\ \Delta i_2 &\rightarrow \Delta x_2, \Delta x_3\end{aligned}$$

- Leads to a linear equation:

$$\Delta \vec{x} = \begin{pmatrix} \frac{\Delta x_1}{\Delta i_1} & \dots & \frac{\Delta x_1}{\Delta i_n} \\ \vdots & \ddots & \vdots \\ 0 & \dots & \Delta x_n / \Delta i_n \end{pmatrix} \Delta \vec{i}$$

or

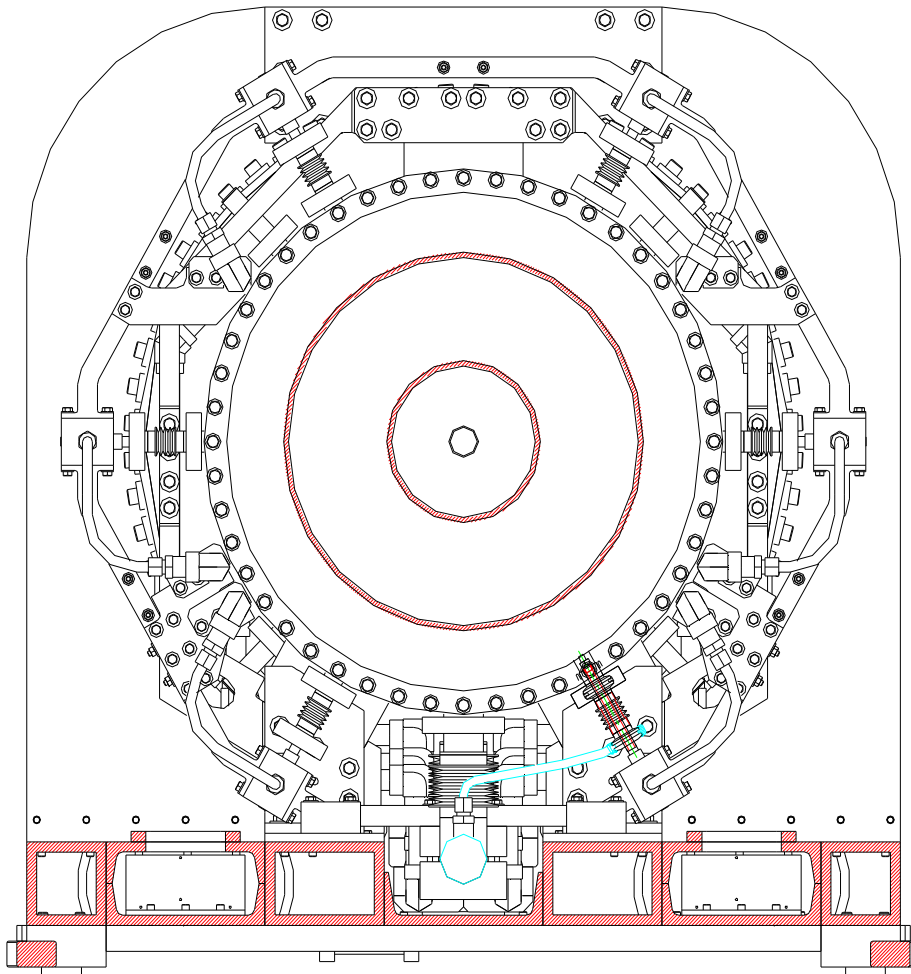
$$\Delta \vec{x} = \mathbf{M} \Delta \vec{i}$$

- $\mathbf{M}$  is invertible.  
to positions:

o positions:

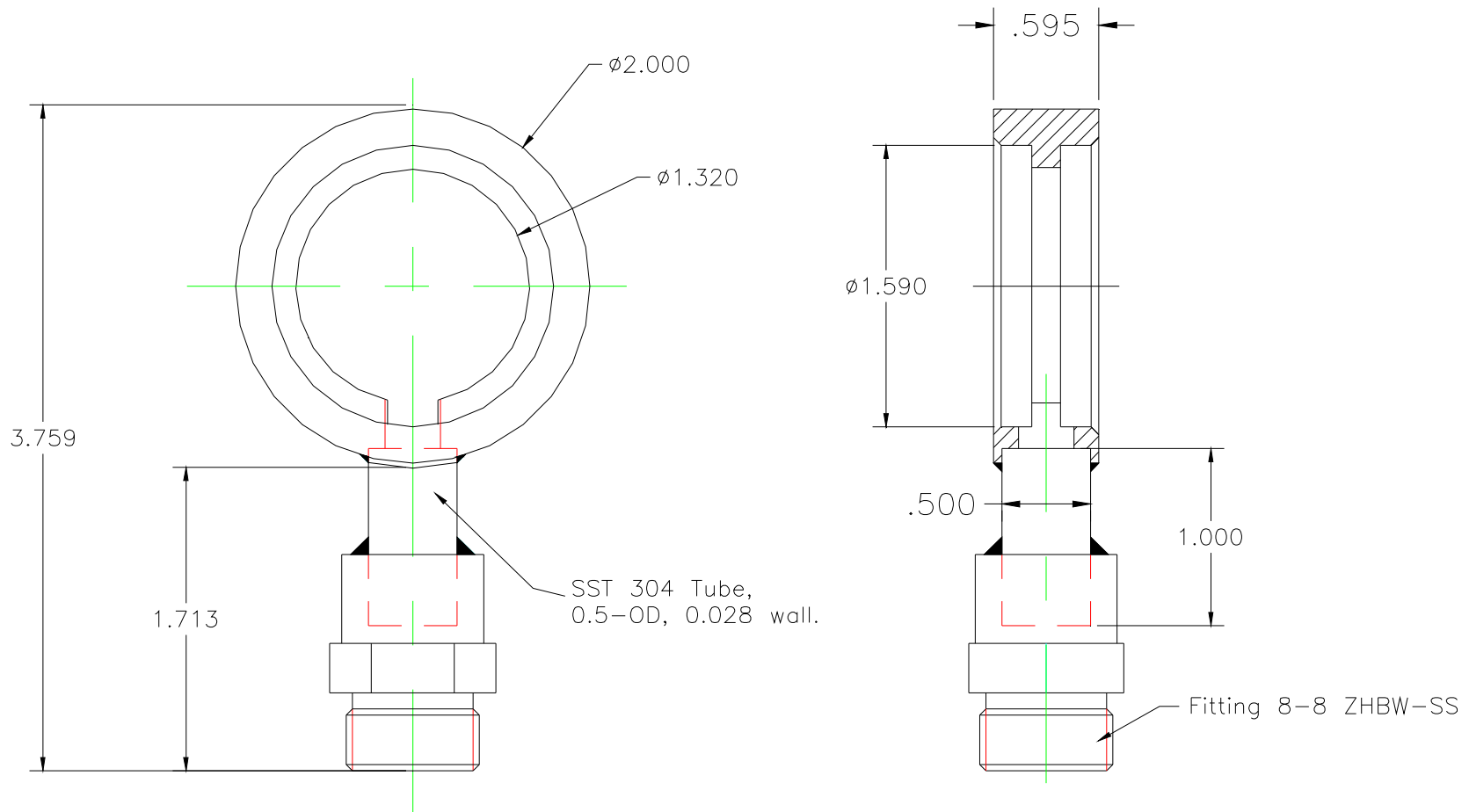
- convergence:  
– real position.

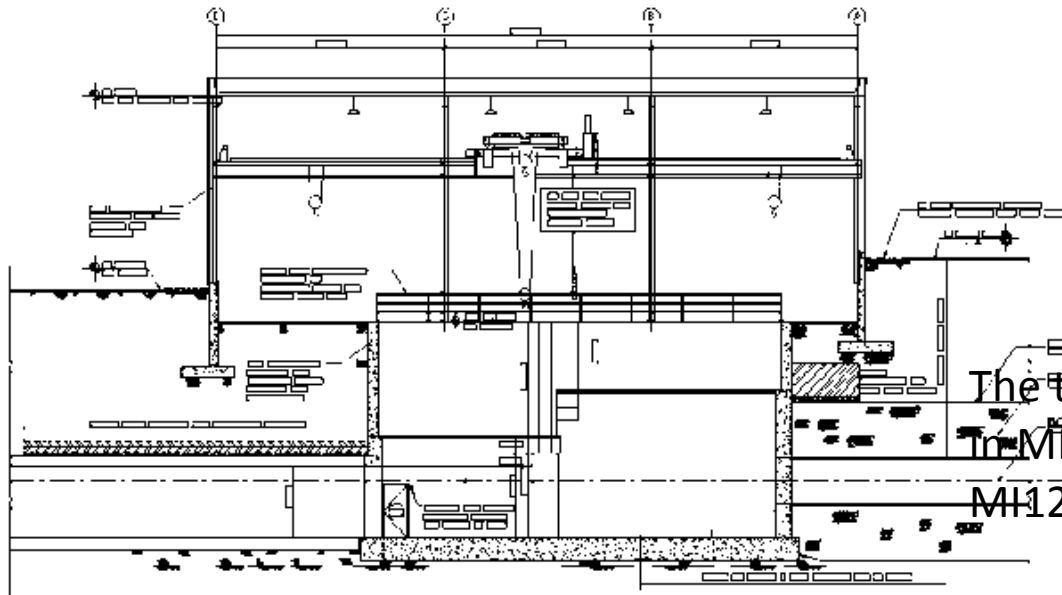
# Modification



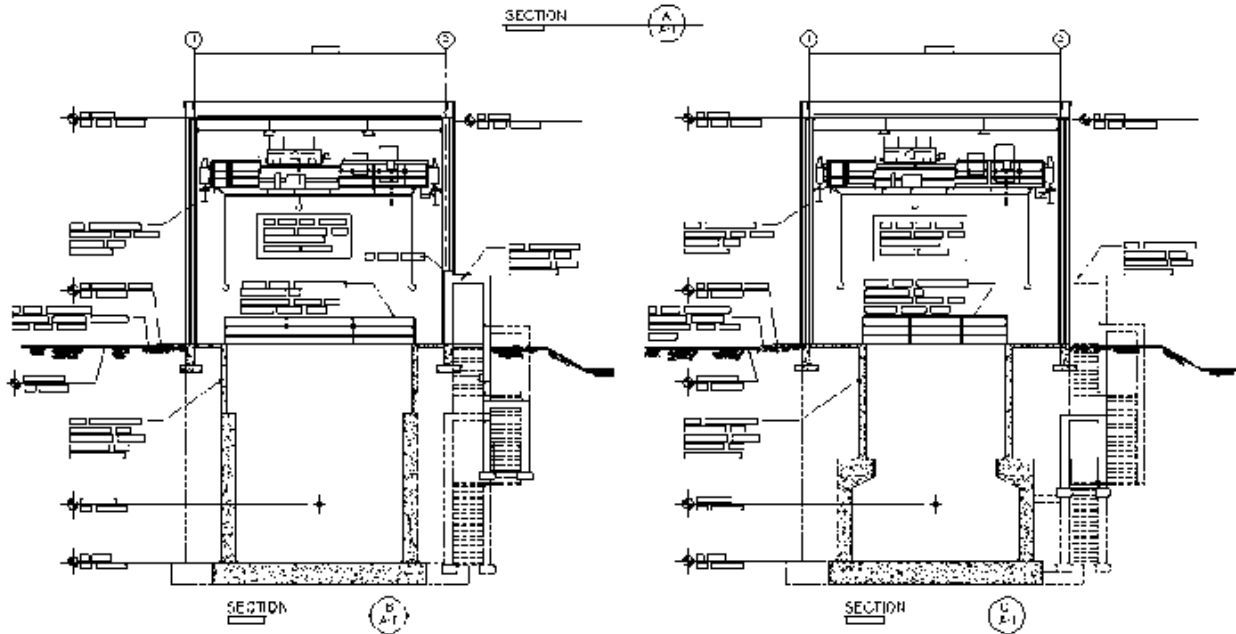
- Added drainage tube to return lines at five o'clock and seven o'clock position.
- Minimizes stagnant water.

# Modification



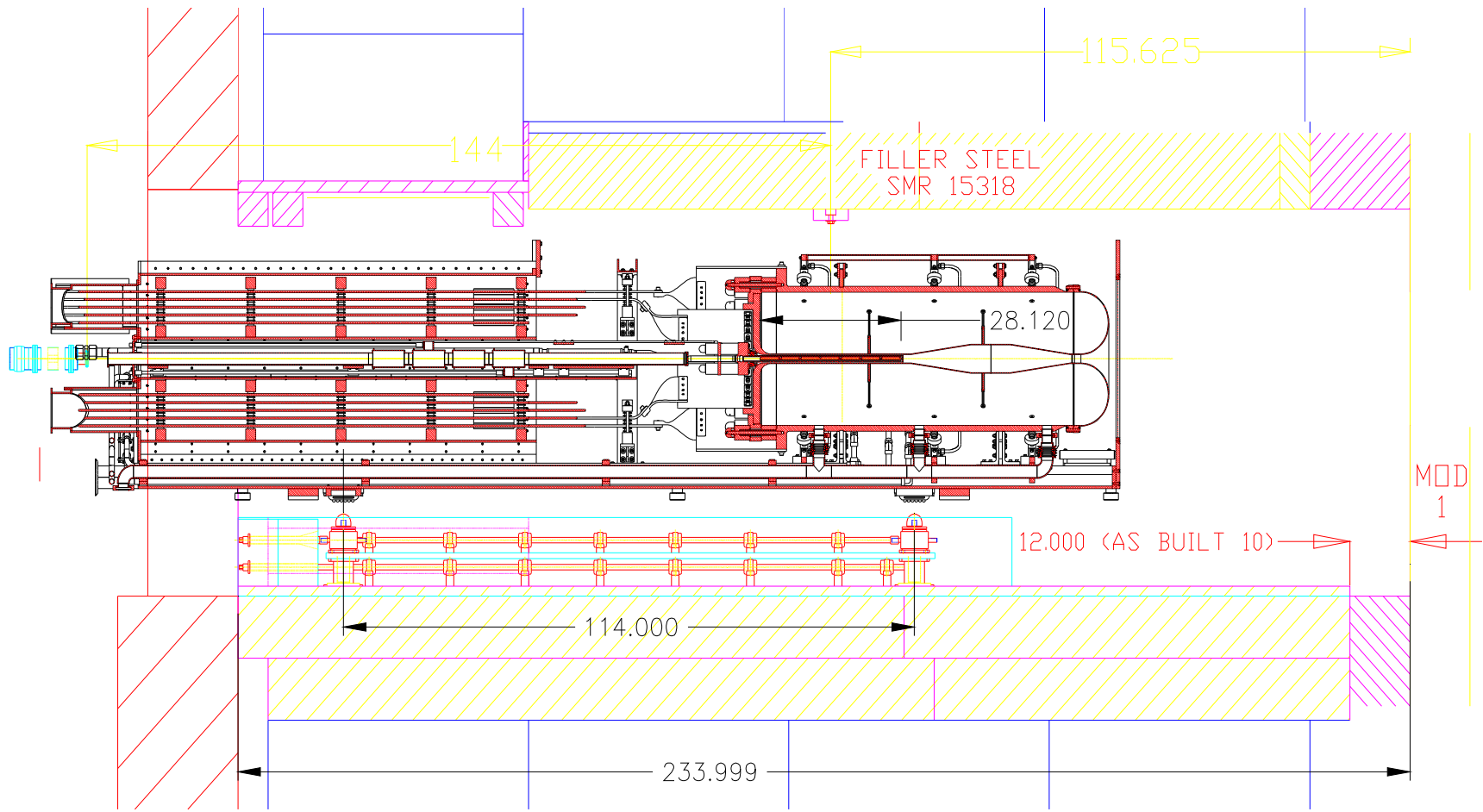


The target and horn are located in MI12B, accessed through the MI12 service building.

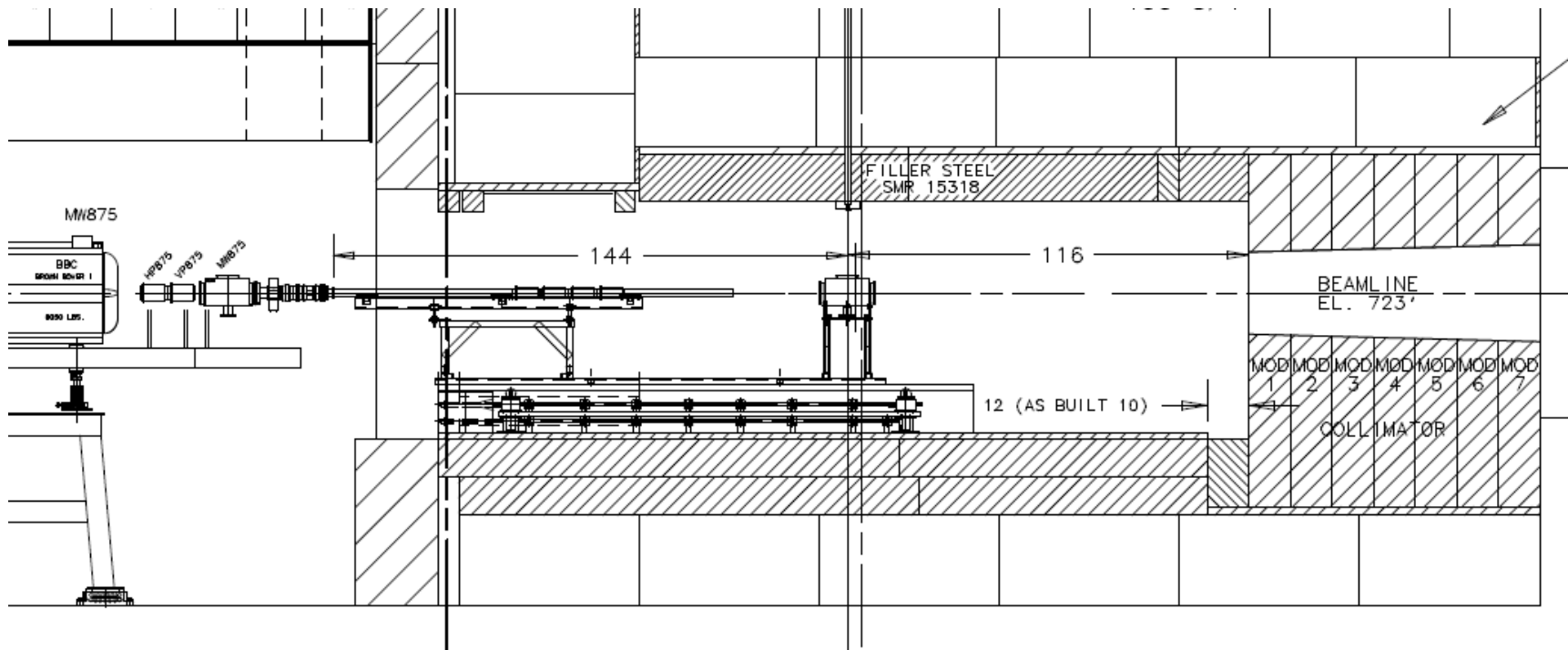




# Target/Horn in Target Pile



# Target Pile





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