NuMI-B-800

Ionization Chambers used at the Fermilab Booster Test Beam

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1. Review of the Test

The Beam Monitoring group wished to test ionization chambers for its beam monitoring subsystem. The RDF committee slotted us for a November, 2001, run of these tests, which ran for 11 8-hour shifts of run time.

The goal of the test was to provide rigorous testing of the Pad Ionization Chamber (PIC) technology and to prototype various components and methods to be used in the production system.

The beam monitoring chambers are parallel-plate ionization chambers consisting of Al_2O_3 ceramic wafers coated with Platinum electrodes. The ion chambers are placed under He or He(98%)-H_2(2%) gas flow inside a stainless gas vessel which also has thin Ti or stainless windows. The beam impinges on the ceramic wafers at normal incidence, ionizing the He (or He-H) gas in the 1 or 2 mm gap between electrodes. We instrumented the ceramic wafer chambers with external stripped ionization chambers so we could read out the beam profile. We felt it critical to have beam profile instrumentation in this test at the Booster.

The gas vessel was designed to be hermetically sealed and to be resistant to radiation. A radiation-hard dielectric was used for high voltage and signal feedthroughs, as well as gas-tight fittings throughout.

The feedthroughs, ion chamber, and beam profile detectors are described in pictures in the proceeding sections of this memo. More details on the ion chambers can be found in [1].

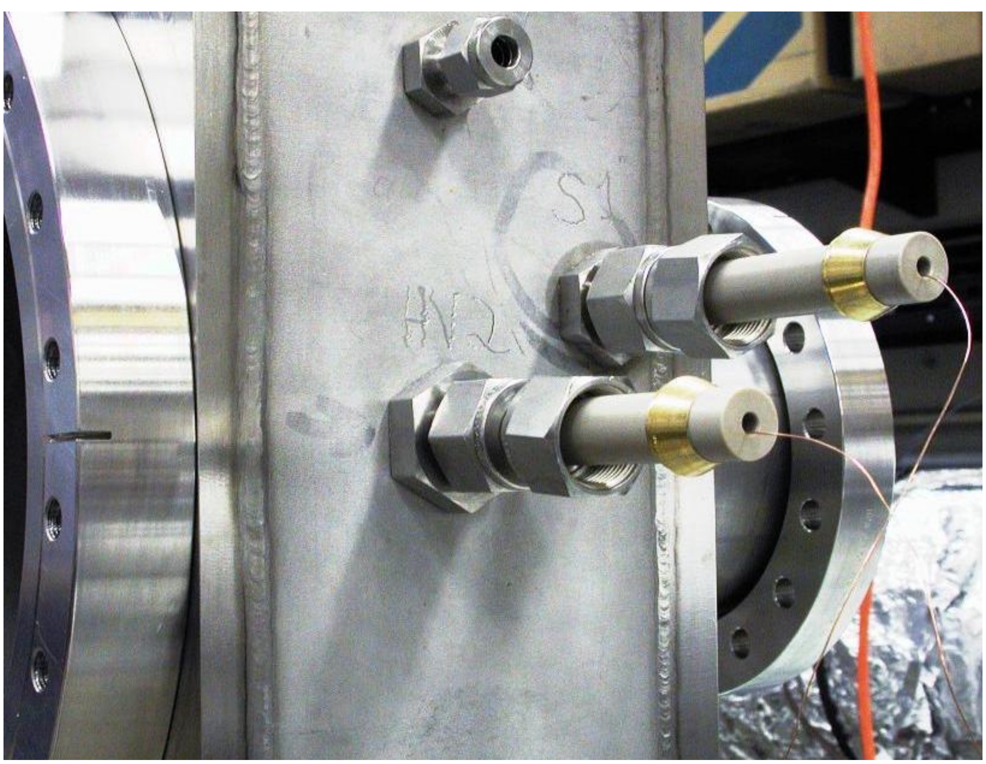
2. Radiation Hard Electrical Feedthroughs

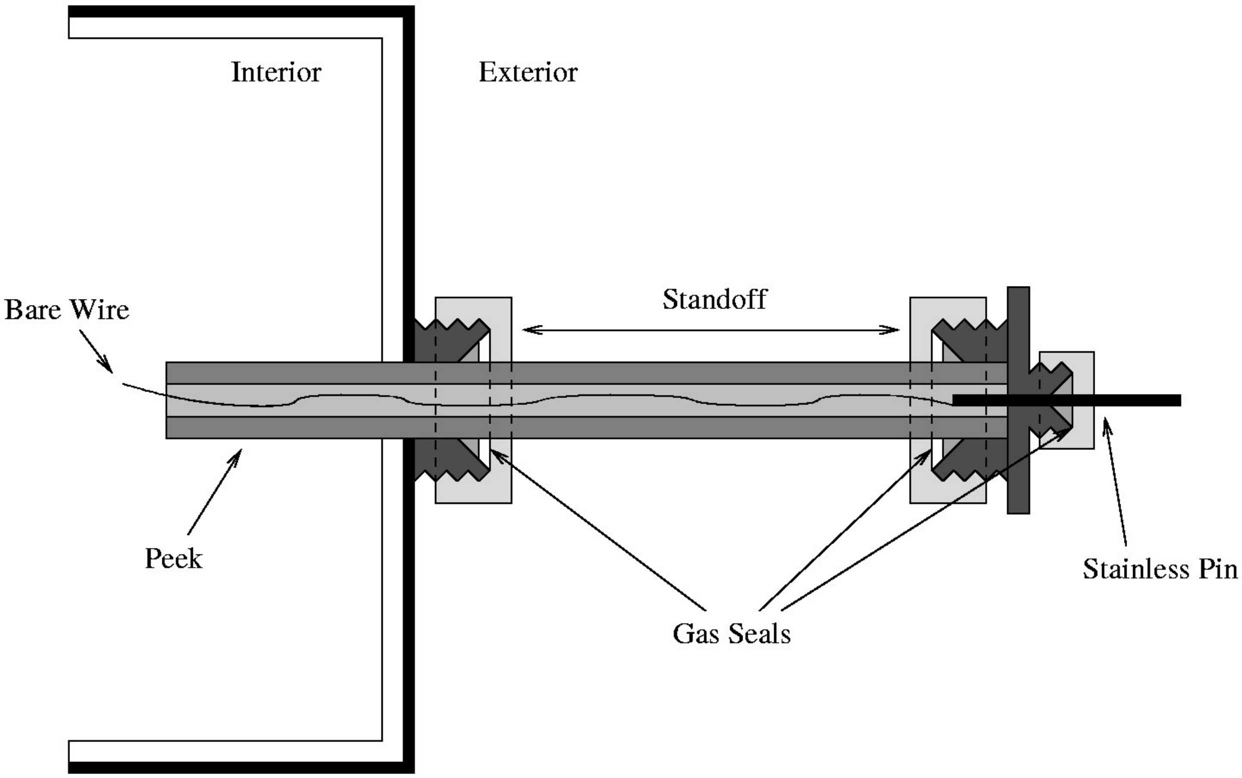
The gas-purity requirements, high radiation operating environment, and electrical sensitivity of the ion chamber system necessitate a custom feedthrough method for high voltage and signal lines. Mike May earlier adopted a similar design for use with the Hadronic Hose [2].

To maximize the dynamic range of our chambers it is necessary to have a high-purity gas system. Impurities tend to add a significant electronegative component to the gas, which fosters recombination of ions and prevents ionization from being measured. To this end, it is necessary to minimize the use of epoxies, standard dielectrics, solder, and other materials that may not resist radiation. Particularly, standard cables could not be used for electrical connections within the vessel.

Additionally, the signal and HV wires must be reasonably isolated from the rest of the environment. The HV and signal wires will attract charge along their lengths, and the geometry of a wire can cause the field along the wire to be even higher than that in the chamber. Thus, the leads must still be isolated and shielded within the vessel, but stock cables are not acceptable.

Our method is to use a solid radiation-hard dielectric with Swagelok compression fittings to create a coaxial cable while also preserving hermeticity. The dielectric we used was Peek plastic, which is thermally stable and radiation resistant. Other possibilities include ceramics, such as Aluminum-Oxide or Zirconium-Oxide. The ceramics are further hardened to radiation, but are more brittle.

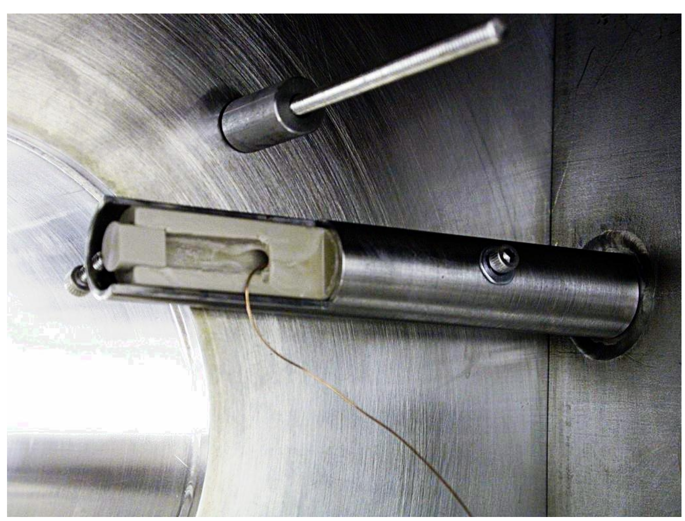




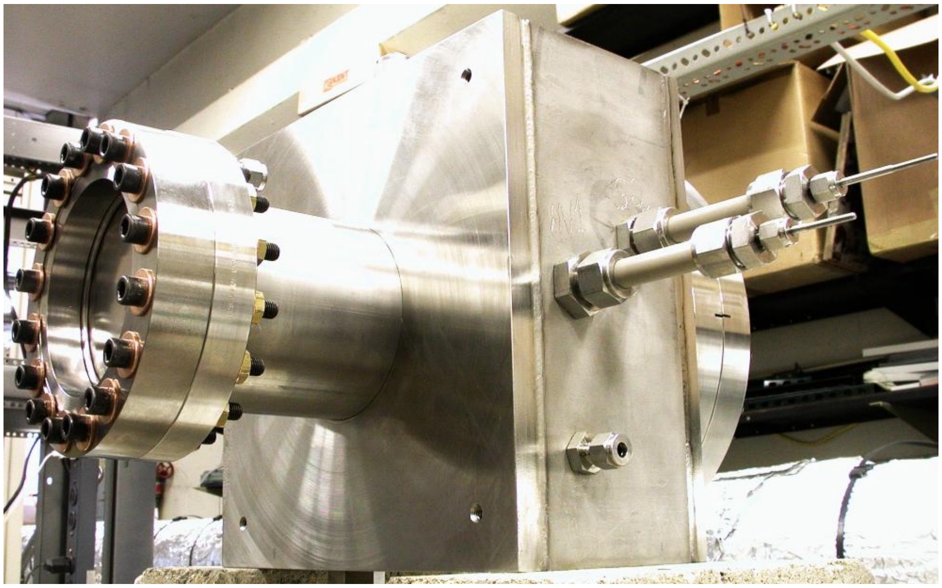
We used ½" rounds of Peek, though we are investigating a 3/8" size. The round was hollowed out to allow a wire to pass through. A steel pin of 1/8" diameter was fashioned to fit inside the Peek and be soldered to the wire, larger pins are possible if a portion is turned down to fit inside of the Peek. Two Swagelok fittings were used to make the gas seal. One was welded to the vessel and swaged to the peek. A few inches of Peek act as a standoff from ground, and then a reducer is placed at the end of the Peek and swaged on to the Peek and the stainless pin.

This system of three gas seals isolates the inside and outside volumes. Notice now than the entire reducer at the end of the Peek is part of the HV or signal line, and thus must be isolated.

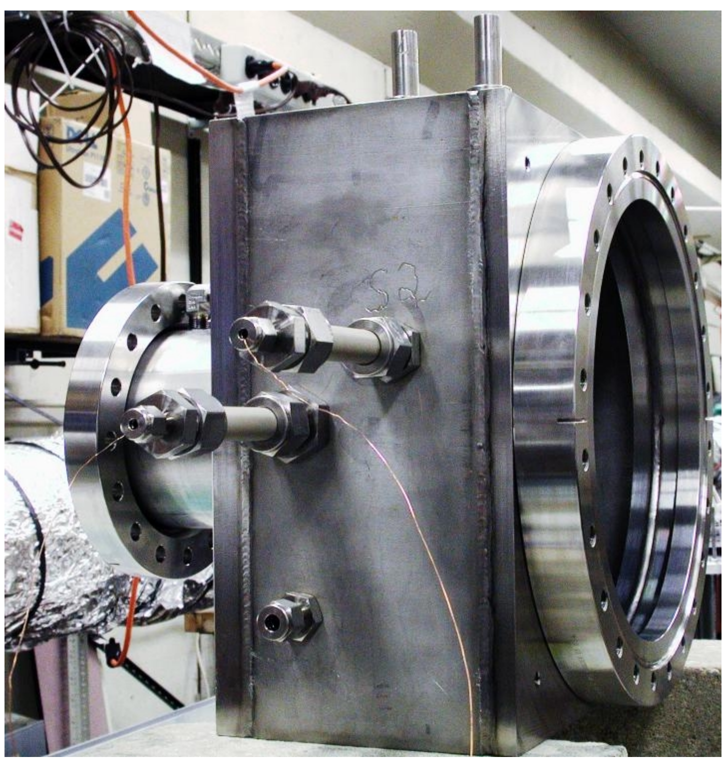
Inside the vessel a stainless steel shroud was placed about the Peek to act as a ground shield. The wire was soldered to the ceramic PIC and well cleaned. The PIC was placed over threaded rods and fit against a flattened portion of the peek. The feedthrough fit closely over the solder pad to minimize the air exchange between the main volume and the smaller that contained the copper signal wire and solder.

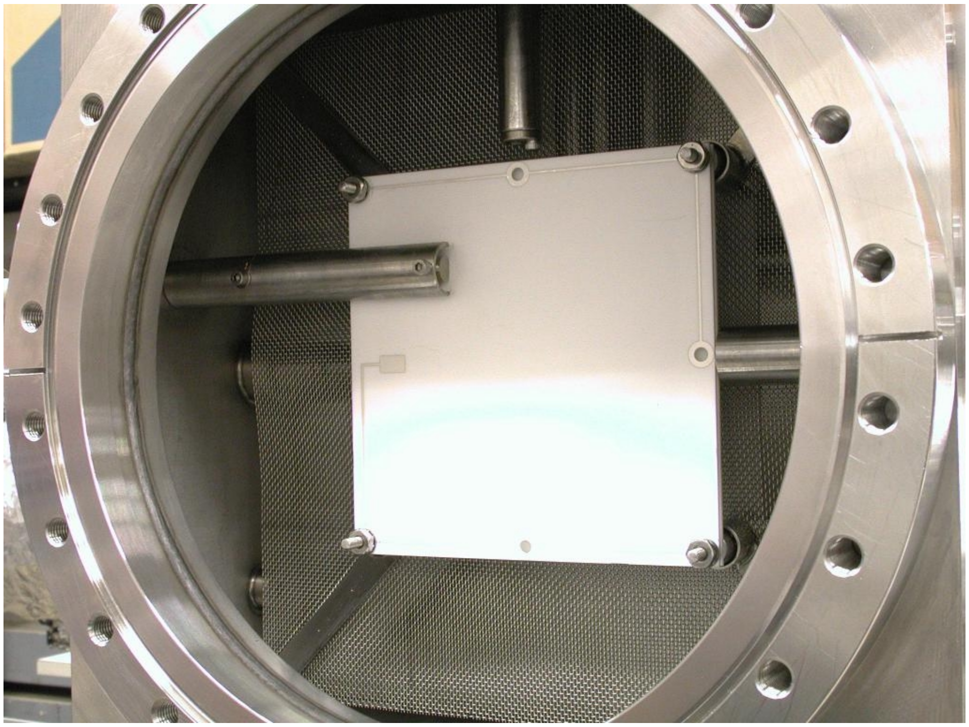


3. Beam Monitoring Chambers

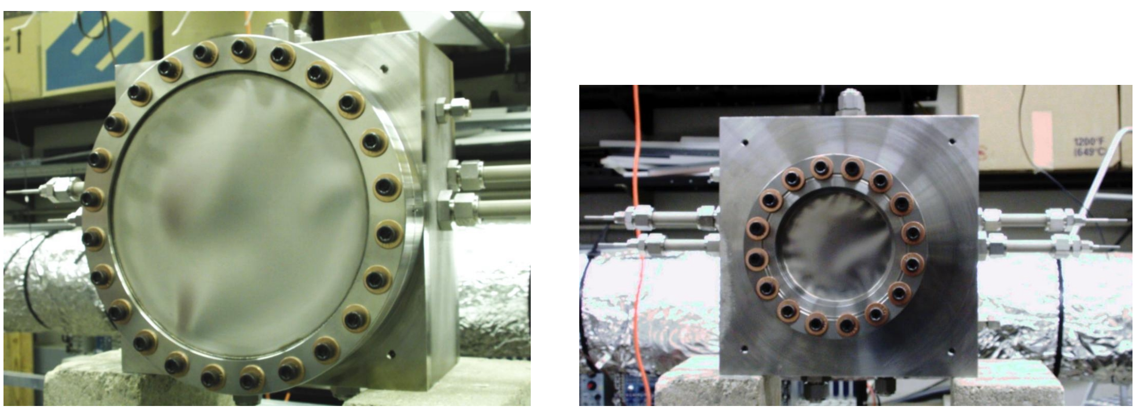


This is the beam box that was mounted directly in the beamline. It is 10”x10”x4” in size. Shown to the front is the double-sided Titanium conflat flange with a 0.002” foil window welded inside to act as a beam entrance window. To the rear of the box is visible the edge of the 10” OD conflat flange with 0.005” stainless beam exit window. To the side of the box are visible the HV and signal feedthroughs for a ceramic ion chamber and also a Swagelok feedthrough for delivering gas to the box.





The ion chambers are mounted at their four corners on threaded rods that thread into the beam box and are spaced from one another by stainless washers. A stainless steel 0.005" wire mesh screen is suspended between the two chambers to minimize stray electric fields from the two ion chambers from interfering with one another. From the left and right are visible the HV and signal feedthroughs which slip over and behind the ceramic wafers. Inside the Peek plastic is the signal or HV wire that is soldered to the backsides of the ceramic (see previous photos). The feedthrough coming in from the top was used to insert and positions a 0.9 μCi Americium alpha source for calibration.



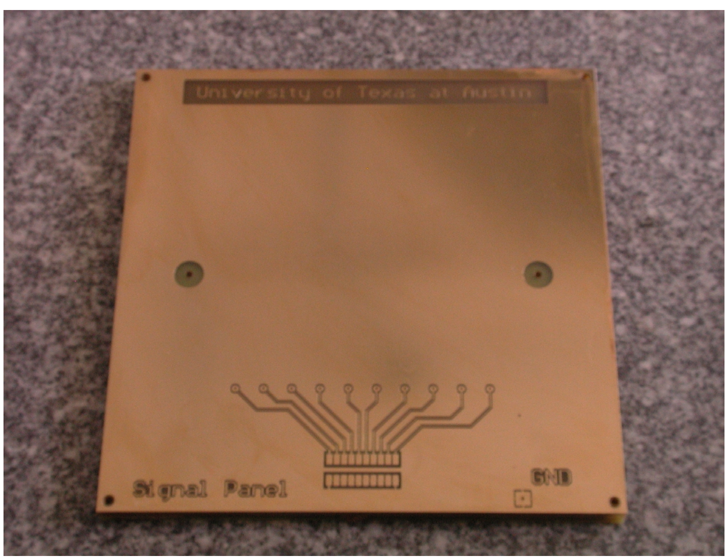
(left) Stainless beam exit window of the ion chamber beam box. (right) Ti entrance window of the ion chamber beam box. This window is welded inside a 6" OD Ti double-sided conflat flange, and will simultaneously serve as the exit window for the vacuum bell jar. Visible at the top and bottom are capped off Swagelok feedthroughs.

4. Beam Profile Ionization Chamber

These were necessary to measure the beam profile and ensure that ‘most’ of the beam goes through our ceramic wafer chambers in Section 2. The Booster beam at the dump is ~1” in size, which is not insignificant compared to the 3” square sense pad of the ceramic ionization chambers in Section 2. Therefore, beam profile measurement is appropriate.

This photo shows the interior side of one of two printed circuit boards, 8”x8” in size, with gold-plated copper electrodes on the inside. The sense pads are segmented into 1cm wide strips for beam profile measurement. The circuit board is 0.063” thick and the copper 0.005”.

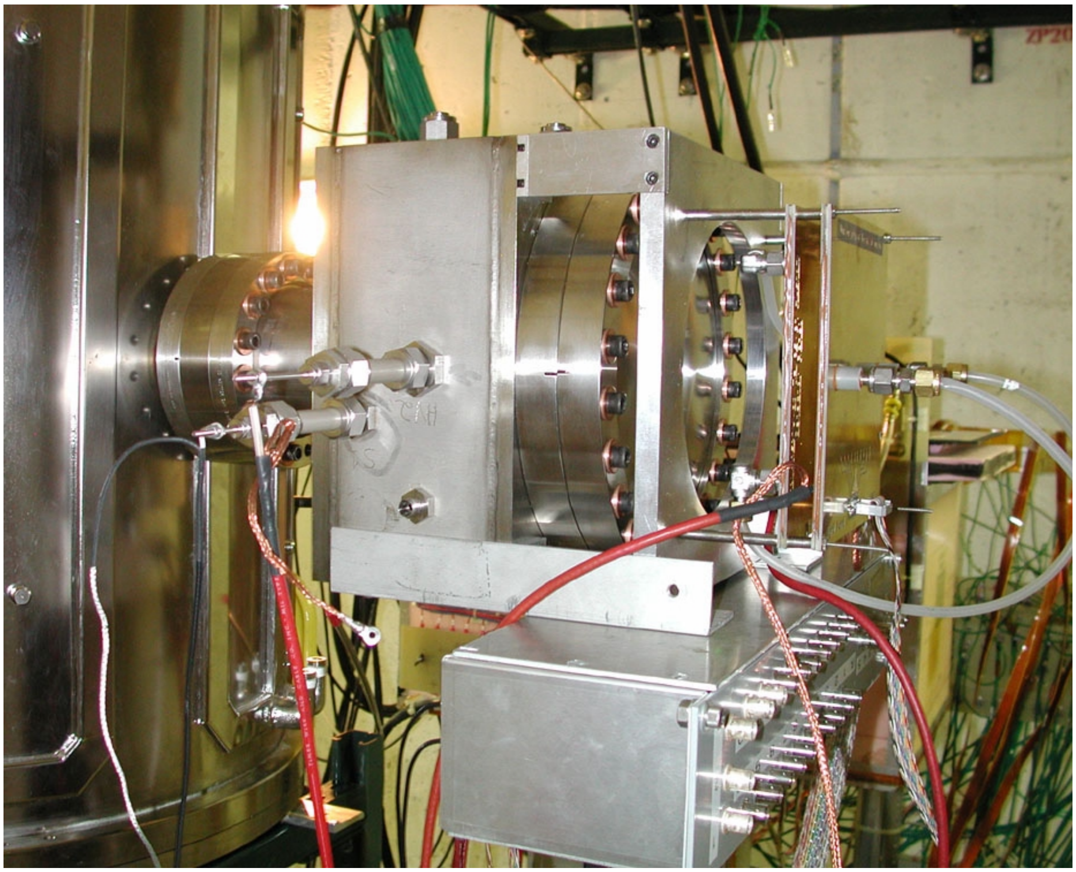
This and the HV circuit board are glued together using Armstrong A-12 epoxy and spaced from one another by 1.5 mm G10 shims.



The exterior side of the same sense pad circuit board. The exterior side is also coated with 0.005” copper to act as a ground shield for the ionization chamber. Visible in this photo are two holes for gas inlet and outlet (He gas flow is assumed). Also visible are traces which bring the signals from via’s on the sense strips to solder pads for a surface mount ribbon-cable connector.

We built a simple transition box to go from the ribbon cable to coax RG58 cables that come upstairs through the shielding to a SWIC scanner located upstairs.

The profile chambers were mounted rigidly to an Aluminum base and fastened to the exterior of the gas vessel. This procedure ensured that they were well aligned to the ceramic ionization chambers inside, within machining tolerances.

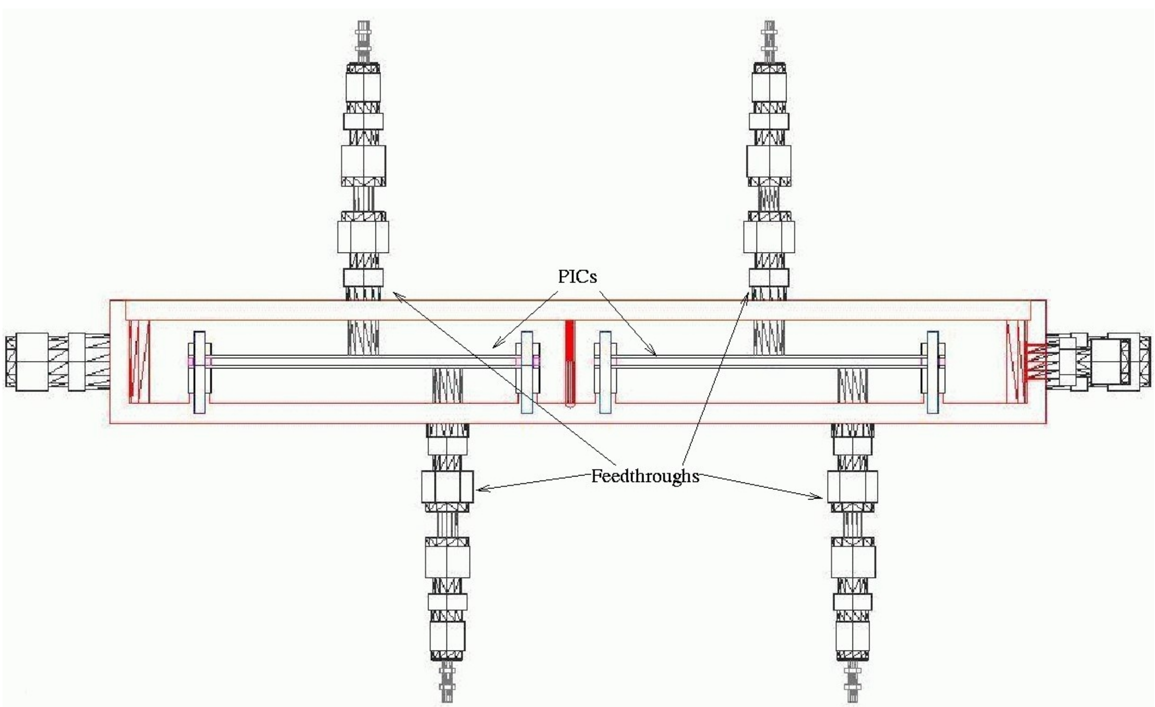


Two separate gas lines were used, one for the ionization chambers, and one for the profile chambers. The chambers, while being separate volumes, were daisy-chained onto a single line.

5. Production Feedthroughs

The particular geometry of the feedthroughs used for this test is somewhat different than that to be used for the monitoring system. At the Booster the beam is perpendicularly incident on the chambers, and we wished to minimize the amount of radioactivated material produced in the test. As such, we specialized our design of the feedthroughs to allow the to approach from the side and minimize their beam exposure. This required flattening a portion of the peek rounds and resulted in tight tolerances on fitting placement.

The planned approach is a more straightforward design where the feedthroughs approach directly on the face, and simplifies the construction process. A diagram is shown of the design for a future test with a neutron source.



References

[1] D. Naples et al., *Pad Ionization Chamber Design*, NuMI-B-769, (2001).

[2] J. Hylen et al., *NuMI Hadronic Hose Technical Design Report*, NuMI-B-700, (2000).