MicroBooNE internal note: Prototype of a cryogenic UV laser feedthrough with a moveable mirror system to allow a hemispherical steering of the laser

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Abstract

This document describes the design and tests of a prototype UV laser feedthrough, designed to allow a steering of the UV laser beam in a cryostat filed with liquid argon.

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Introduction

The MicroBooNE neutrino experiment will investigate the LSND and MiniBooNE anomalies. This low energy excess can be due to either ν_e or γ interactions. As liquid scintillator does not allow to distinguish these two event types, a liquid argon time projection chambers (LAr TPC) is used. This TPC will be operated at surface, and due to the 100 times faster drift of the electrons with respect to the argon ions, space charge effects will occur. This space charge will be distributed non-uniformly in the TPC, as shown by calculations and can reach electric field strengths comparable to the applied drift field, thus distorting the time resolution of the TPC. If enough straight tracks can be collected, these distortions can be corrected. While the calibration van be done with cosmic tracks, it is preferable to calibrate the space charge effect using straight laser tracks, as they do not suffer from mis-identification of low energetic tracks, multiple scattering and hadronic re-interactions. This requires a steerable laser beam in the cryogenic environment of the TPC.

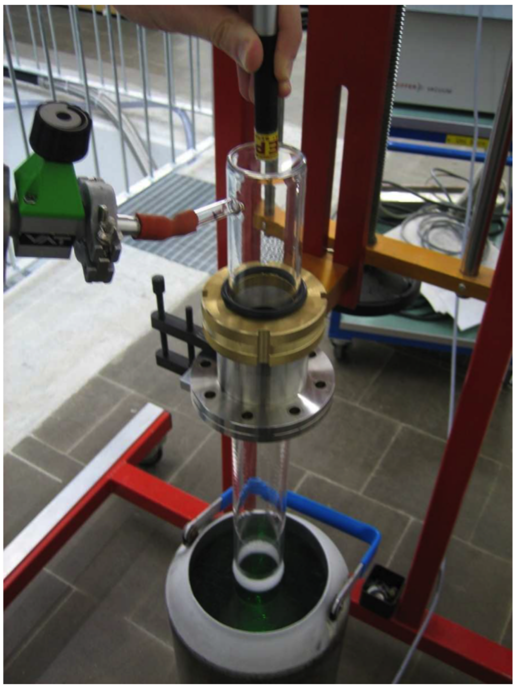

Figure 1: Fixed laser beam feedthrough developed at LHEP Bern.

In the laboratory for high energy physics (LHEP) in Bern a UV laser calibration system was developed and tested, wherein a pre-defined laser path was allowed with a fixed-mirror design by the feedthrough shown in Figure 1. In the following chapters we present the engineering effort to allow for a steerable mirror.

Flange design

Due to the experience in creating a UV laser feedthrough, the main design need for the flange was a vacuumed Quartz glass pipe with two flat windows, one where the laser beam enters in the warm, the other reaching below the liquid surface, to allow for the UV laser to enter the liquid argon without be deflected at the liquid/gas argon phase, see Part IV in Figure 2. The lower part of the flange is fitted to a CF100 connection (Part IX), the inner diameter of this flange size being the driving size limit for all mounting parts reaching into the inside of the detector. This space is filled with the pillars for the mirror support (Part X) and the Quartz glass pipe itself, reaching well below the liquid Argon surface.

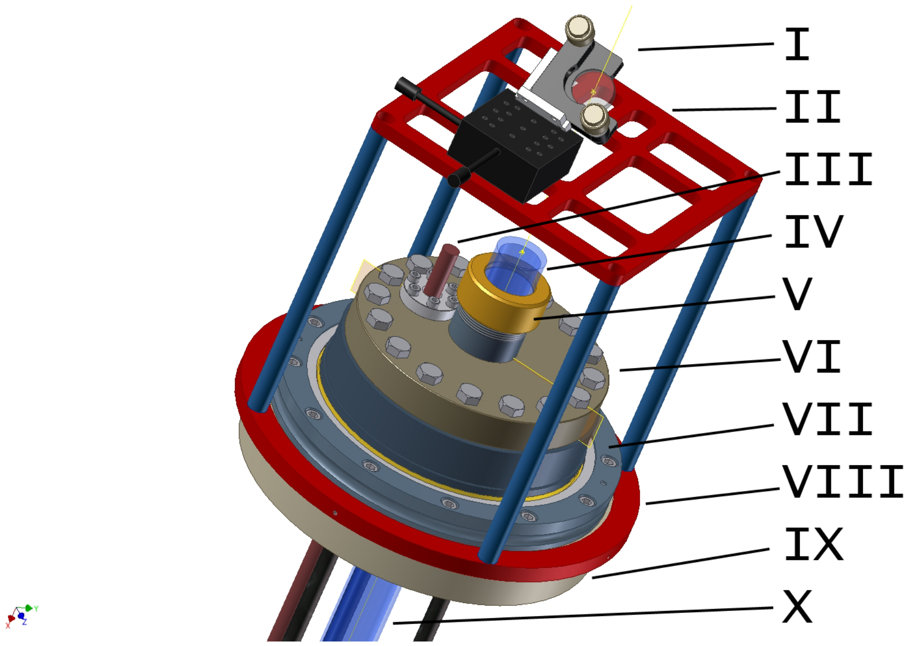

Figure 2: Shown here is the 3d drawing of the feedthrough. Part I is the top mirror to reflect the laser beam into the TPC. Part II is the optical table. Part III is the rod for the linear motion. Part IV is the Quartz glass pipe. Part V is the brass screw to vacuum tighten the Quartz glass pipe. Part VI is the top cap of the flange. Part VII is the rotational bearing. Part VIII is the optical table holder. Part IX is the CF100 flange. Part X indicates the inner structural support pillars.

As we wanted to steer the UV mirror in within a half hemispherical orbit, at least 2 degrees of freedom for a mirror were required. This was implemented by introducing one rotational (Part VII) and one linear degree (Part III) of freedom, thus centring the Quartz glass pipe in the symmetry axis of the flange, as shown in Figure 2.

1. Rotational degree of freedom

To allow the rotational degree of freedom, a dedicated rotational bearing was used, which is able to take the loads of the mounted flange. The vacuum tightness is realised by four silicon rubber sealing fitted into groves along the outer shaft of the feedthrough (Part VIII in Figure 3), which is mounted on the flange of the cryostat (Part IX). The inner part of the feedthrough (Part X) is closed with the top cap, wherein its mounting is fixed (Part V). Additionally to it the Quartz glass pipe (Part II) and the linear feed through (Part I) is mounted. The sealing of the Quartz glass pipe is done with smaller silicon rubber (Part IV), these small rings are alternating with steel O-rings which are pressed together by a brass screw (Part III).

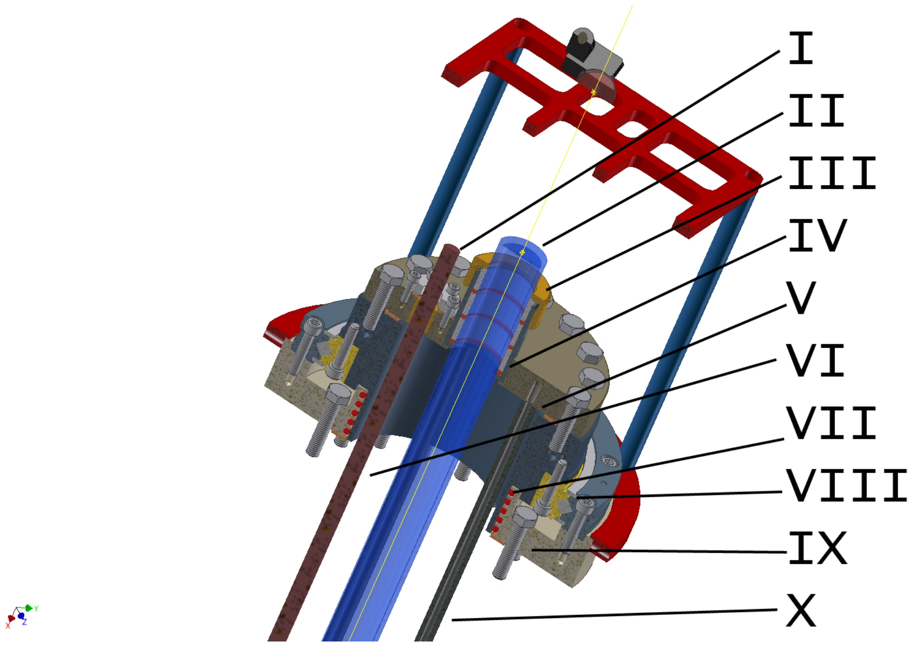

Figure 3: Shown here is the 3d cut drawing of the feedthrough. Part I is the feedthrough for the linear motion. Part II is the Quartz glass pipe. Part III is the brass screw to vacuum tighten the Quartz glass pipe. Part IV is the small silicon ring assembly for vacuum tightness. Part V is the support structure mounting. Part VI is the rod for the linear motion. Part VII shows the silicon rubber rings to allow for vacuum tightness during the rotational motion. Part VIII is the rotational bearing. Part IX is the CF100 flange. Part X indicates the inner structural support pillars.

2. Linear degree of freedom

The linear feed through (Part I in Figure 3) consist of a linear bearing, which guides a cylindrical rod (Part VI). The top of the rod is welded vacuum tight with a CF16 bellow, which is mounted on the top cap.

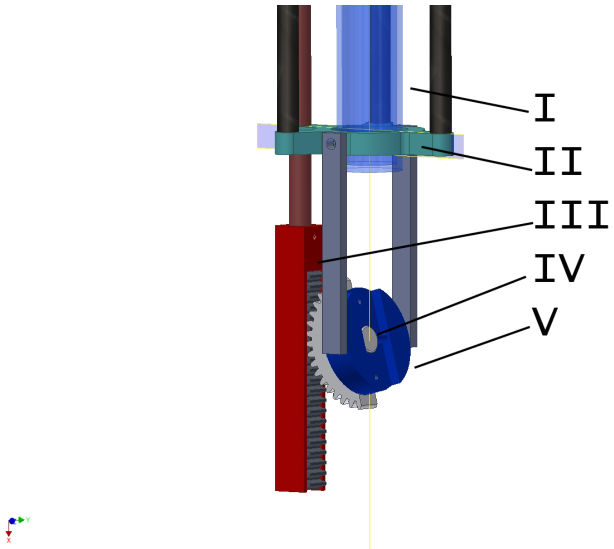

Figure 4: Shown here is the 3d drawing of the lower end of the support structure. Part I is the Quartz glass pipe with the structural support rods. Part II is the turtle shaped reinforcing ring to keep the structure stable. Part III is the linear gear-wheel of the linear rod, which turns the circular gear-wheel of the mirror support. Part IV is the mirror support. Part V is the UV reflecting mirror.

The linear rod extends into the liquid Argon and shown in Figure 4 is the lower part of the linaer stage. A gear-wheel mechanism connects the linaer motion into a circular motion of the mirror holder. Thus an angle of nearly 180° can be covered vertically.

Tests

1. Initial vacuum tightness

To confirm the vacuum tightness of the design, several tests were performed. First, the top cap of the feedthrough was closed on both the CF16 mount, and instead of the Quartz glass pipe, a blind flange fitting in the opening was installed. On the other side of the flange a CF100 flange was mounted which was equipped with a small vacuum pump. A vacuum of 10^{-4} mbar was reached in this quick test, proving that the tightening with the silicon rubber rings works, even while the feedthrough is being rotated. A second test was done, with a similar setup was performed after the linear cylindrical rod was welded on the CF16 Balg and mounted on the top cap. The same vacuum levels were reached. These first test showed, that a tight sealing with the silicon rubber rings could be achieved, while the rotational movement of the feedthrough was performed.

2. Test in a dewar

After mounting of the mirror support, the final feedthrough prototype was mounted on the medium ArgonTube dewar at AEC BErn. The top flange of the dewar was equipped

with three CF60 Quartz glass windows, the CF100 pumping flange and the CF100 UV laser feedthrough, all other ports were closed with blind flanges. After the installation, the dewar was pumped for several days, a vacuum of 10^{-5} mbar was reached. With the leak tester a leak rate of less than 10^{-8} mbar/(litre*s) was measured, and a manual movement of the linear and rotational stage performed. During these movements the leak rate did not change. The laser used in this test was a 4.5mW diode laser with a wave length of 544nm. The path was aligned from the top flange with a standard optical mount from Thorlabs, and with the moveable mirror the point of incidence on the dewar wall could be shifted at will. Several videos and images of the mirror movement were recorded with a cryogenic camera, developed by Sebastian Delequais of the Bernese EXO group.
Later the dewar was filled with liquid Argon, and the movement and tightness tests were repeated. Again the point of incidence could be shifted at will, and no leakage of the Argon gas to the outside at the feedthrough was observed.

Summary

We presented the first results of a hemispherical steerable UV laser feedthrough. The design allows a 3d movement of an incident laser beam, and can be used in a liquid argon TPC for the application of a UV laser calibration system. The sealing of the feedthrough was shown to be vacuum tight in both cold and warm, as well as vacuum conditions. In all conditions, the steerable mirror mount is working and allows for a precise positioning of a laser beam.