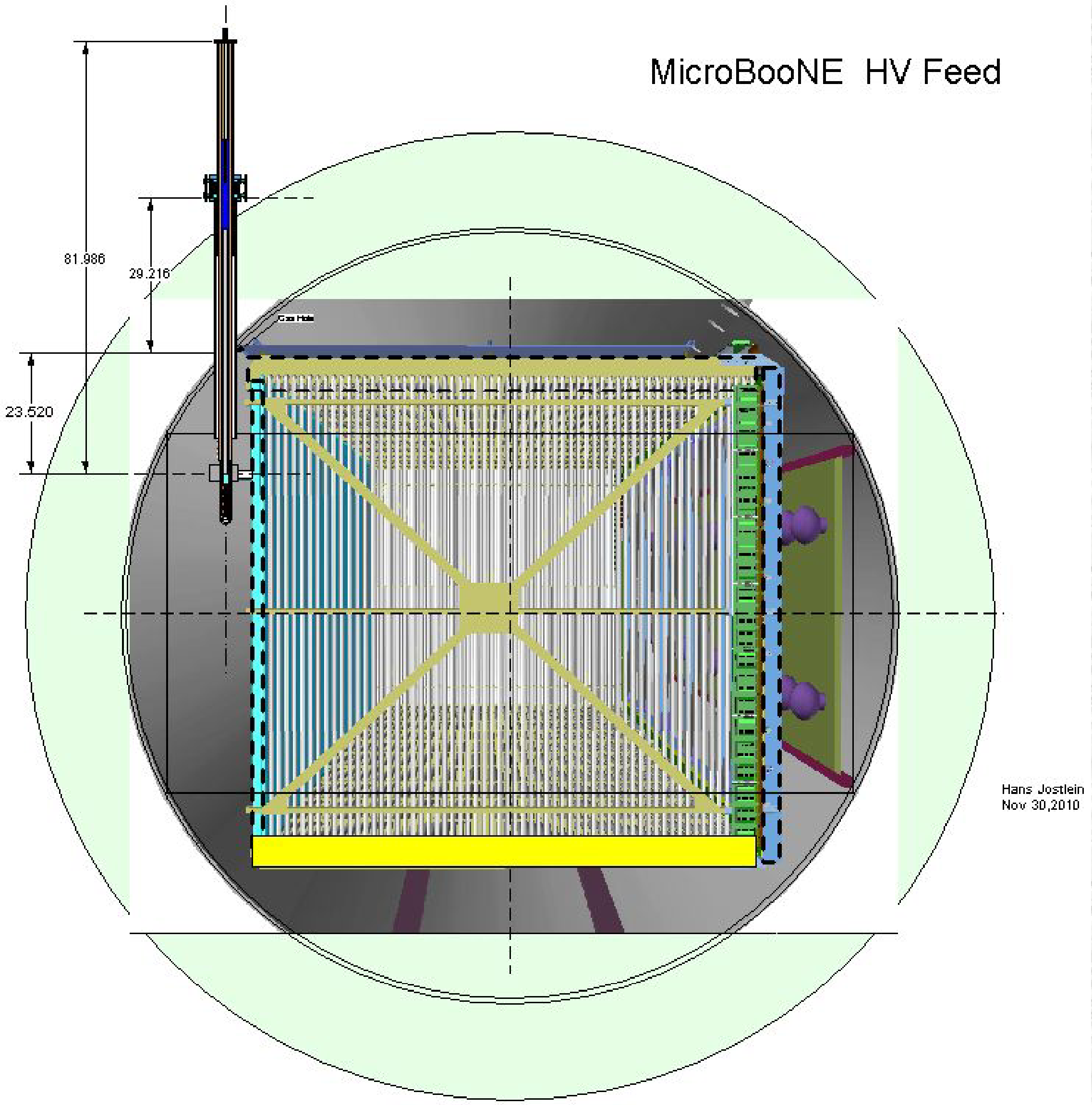
MicroBooNE High Voltage System and Feedthrough

MicroBooNE Collaboration Meeting
Hans Jostlein, December 3, 2010

Summary

- We present a conceptual design for the HV feedthrough for the MicroBooBNE Liquid Argon Time Projection Chamber.
- Starting with requirements, desirable properties, and challenges we proceed to develop a solution based on work by ICARUS and experience with similar feedthroughs we built in the past.

Design Overview



Power Supply Requirements

- Power supply requirements:
- --125 kV for operation
- -- up to 250 kV for testing
- --good Voltage stability (0.01%)
- --low noise (0.01% p-p)

We will to add a noise filter to reach

- --less than 500 electrons equivalent on sensing wires

The only suitable HVPS is the one defined earlier by Hanguo Wang and made by Heinzinger:

Heinzinger PNC 250000 -1 neg

Item	Description	Quantity		Unit Price
2 a	**Heinzinger® PNC 250000 - 1 pos** Precision – HighVoltage - Power Supply Positive output polarity	1 **2**	EUR **EUR**	41,800.- **39,900.-**
2 b	**Heinzinger® PNC 250000 - 1 neg** Precision – HighVoltage - Power Supply Negative output polarity	1 **2**	EUR **EUR**	41,800.- **39,900.-**

Output voltage:	approx. 0 up to 250,000 V DC adjustable
Output current:	approx. 0 up to 1 mA adjustable
Input voltage:	230V ±10% 47…63Hz or 110V ±10% 47…63Hz (please specify at order intake)

Voltage stabilization

Reproducibility:	≤0.1% U_{nom}
Stability:	≤0.01% U_{nom} over 8h
Ripple:	≤0.01%pp U_{nom} ±50mV
Temp. Coefficient:	≤0.01% U_{nom} /K

Current stabilization

Reproducibility:	≤0.1% I_{nom}
Stability:	≤0.05% I_{nom} over 8h
Ripple:	≤0.05%pp I_{nom} ± 500µA
Temp. Coefficient:	≤0.01% I_{nom} /K

Displays: 3.5 digits for voltage and current separately

Setting of output values:
by 10-turn-potentiometers, separately for voltage and current

Remotely controllable and extendable:
by means of the integrated analog interface 0…10V.
Voltage and current setup as well as indication and HV ON/OFF
(digital available as option)

Incl. 10m HV-cable HVC with HV-connector HVS

Enclosure: 19"-rack 600x2,000x800mm (wxhxd) with casters

All other technical details conform to Heinzinger series PNC (see datasheet).

Units of series PNC feature high precision in range of 0.01% or better. High voltage power supplies with even better accuracy (PNC*hp*), further options and customer's specific requirements are of course available.

Heinzinger Power Supplies

HV Noise reduction

- The selected power supply is of the switching type and has ripple noise of 0.01%, i.e.12.5 V p-p at 125 kV. Noise on the cathode potential couples into the sensing wires, although it will be attenuated by the internal grid.
- The sensing system is most sensitive to noise in the frequency range from 10 kHz to 10 MHz.
- We find (subject to checking) that the 12.5 V ripple is unacceptable.

HV Noise Filter

- We will use a passive external low pass RC filter , where the capacitance is provided by lengths of HV cable, provided by the power supply manufacturer, and the resistors are inside a Faraday capsule in an oil filled pot.
- The filter resistors must have a resistance low enough so as not to impair the DC voltage regulation, and large enough to provide a suitably low bandwidth cutoff for the low pass filter.
- We estimate (subject to verification) that a 2-stage RC filter will be needed to bring the ripple noise down to well below the amplifier noise.

HV Noise Monitoring

- The power supplies can be ordered with an optional scope output for noise monitoring.
- However we need to see the noise that gets to the cathode.
- To this end we are considering using the ground sheath of the last HV cable as a capacitive voltage sensing electrode.
- The sheath would have to be safely grounded, of course, but normally the grounding path would include a resistor across which one can monitor even very small noise superimposed on the DC voltage.
- If necessary an extra length of the HV cable can be integrated into the filter can to serve as a HV capacitor for the same purpose.
- This arrangement can also detect micro discharges, both outside and inside the Detector.

Choice of the Field Cage Divider Current

- The total cosmic rate current within the active volume of MicrobooNE is (see the paper by Gerstle and Pordes in the LArTPC –DocDB) is 0.8 nA.
- If we assume current from the total LAr volume ends up on the cathode we double the current estimate to 1.6 nA.
- Any additional leakage currents must be small, else they could create unacceptable noise if they are of a non-ohmic nature, e.g. act like micro discharges.

Cage Divider Current

- We will design for currents ten times larger than the cosmic ray current, i.e. 16 nA.
- In order to overcome unknown leakage currents, we design for a current that is 1000 times larger than that, i.e. 16 micro Amperes.
- This sets the maximum allowable resistance of the RC filter(s).
- We find we can reach an RC time constant in excess of 0.1 seonds

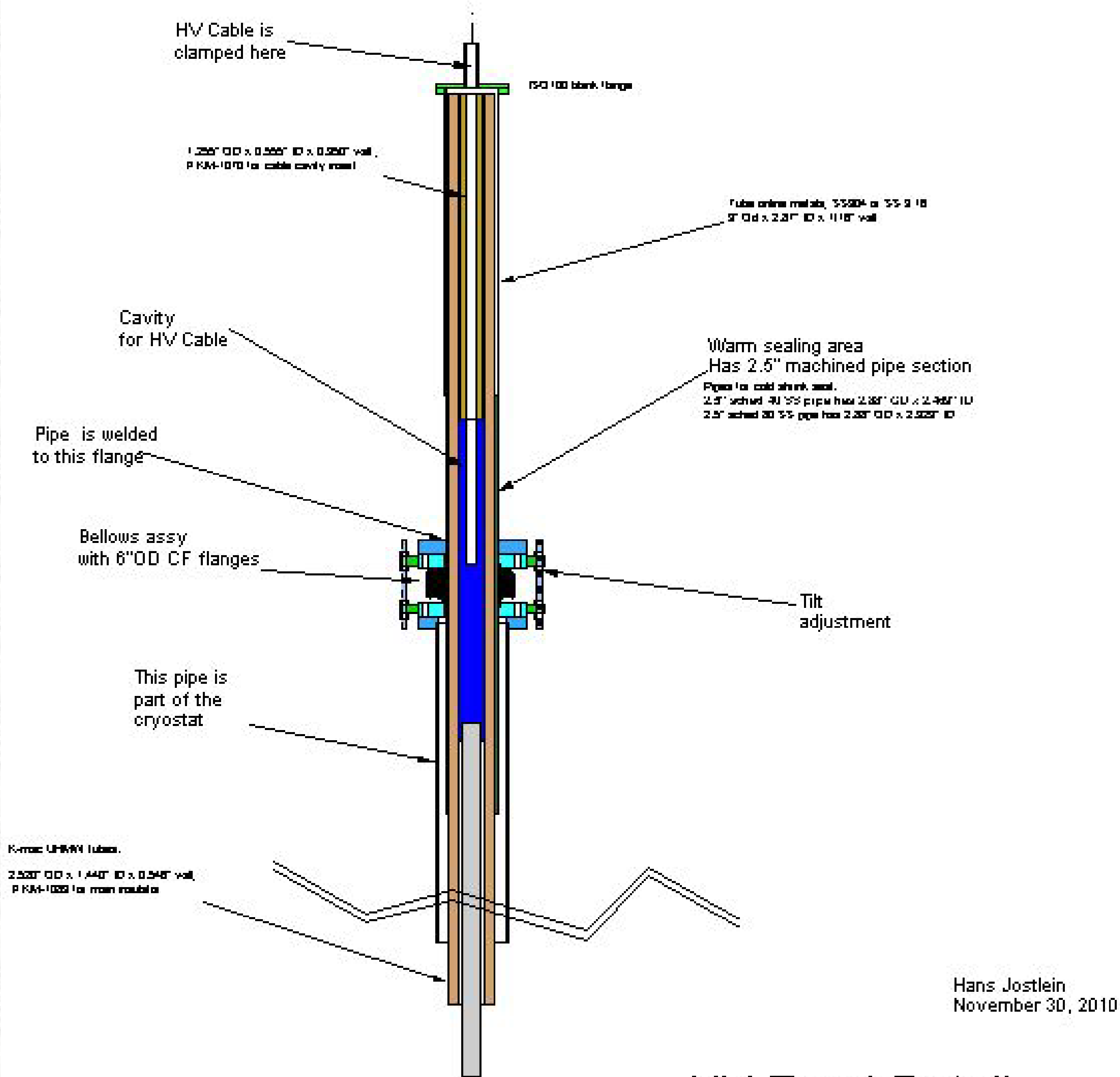
Sealing Requirements

- The feedthrough must prevent outside gas to enter the detector space.
- The FT will be checked with a helium leak detector.
- The HVFT must operate with a cold bottom end and a room temperature top end.

HV Feed Sealing

- The seals are made similar to those first used by ICARUS.
- We use a continuous insulating sleeve made of UHMW-PE (Ultra high molecular weight polyethylene) .
- The center conductor has a section of slightly larger diameter than the bore of the tube, and is forced in. This section is near the upper end and will remain at room temperature.
- It is forced into the PE sleeve.
- The rest of the center conductor of the feedthrough is a thin wall tube (to lower its thermal conductivity), welded to the larger section mentioned above. It is continuous all the way down to the connection receptacle on the cathode.

Feedthrough Design



HV Feed Detail

Design Details

- The top sealing area is about 8 inches long.
- The center conductor has a cavity, about 6 inches deep, and open to the top.
- On the outside it has rounded ends to reduce the electric field strength there.
- The HV cable (minus its ground braid and outer jacket) enters this cavity.
- A spring is attached to the center conductor to make contact inside the cavity. The spring is sized to be compressed when the top flange, with its clamped HV cable, is bolted on the top of the assembly.

More Design Details

- The cavity protects the spring area from breakdown by immersing it in zero electric field.
- The ground braid and outer jacket of the HV cable are clamped to a stub pipe welded to the top flange.
- A compression fitting allows nitrogen purge gas to enter the cavity space and the HV cable.

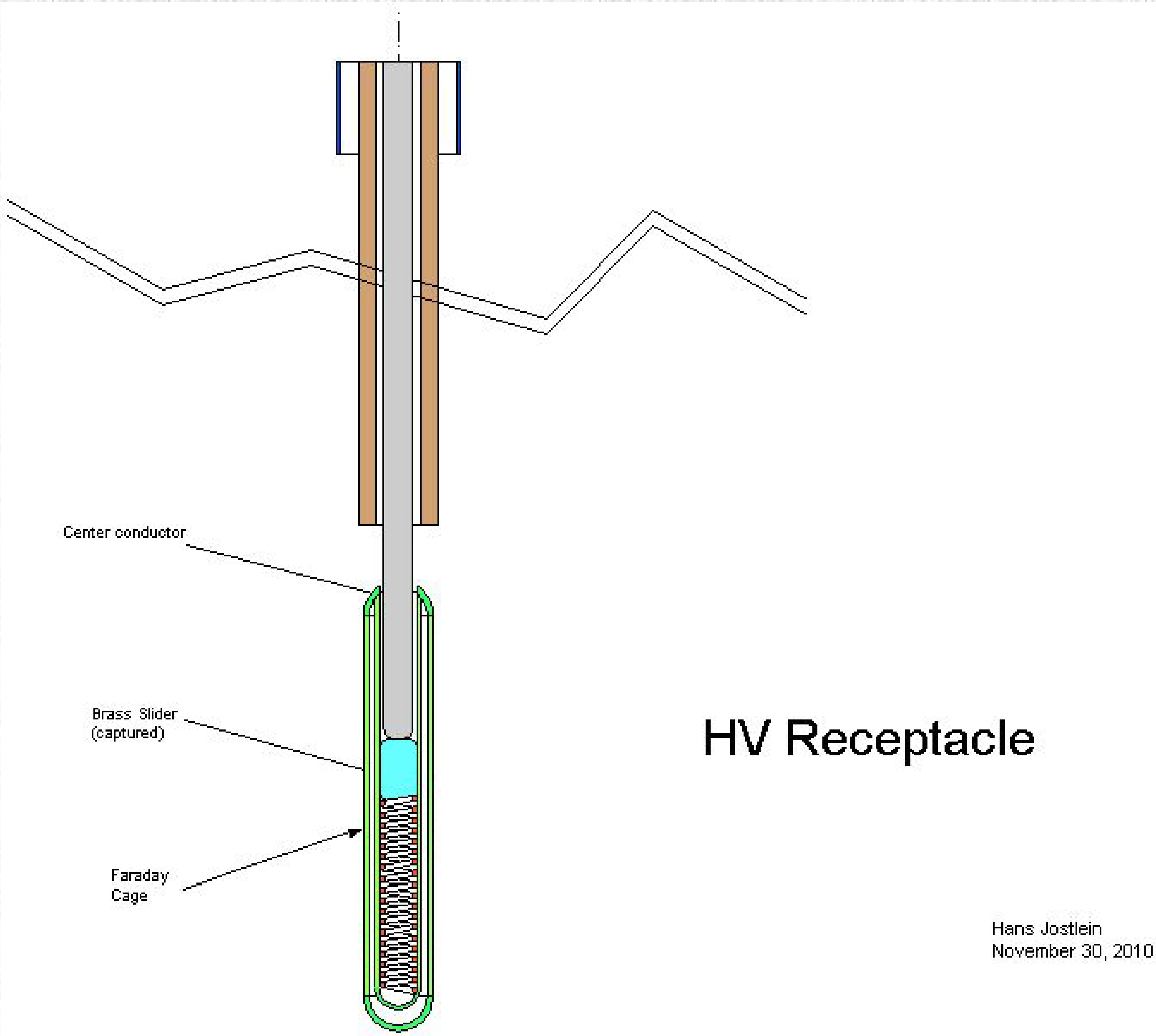
External Seal of the PE Sleeve

- Adapting an ICARUS design, the PE Sleeve,
- with its center conductor already forced in,
- Is cooled in a LN2 dewar to shrink the PE diameter, by about ½ mm.
- While cold it is inserted into a SS pipe machined to just slightly over the cold diameter of the PE Sleeve.
- When the assembly warms up, a vacuum tight fit is achieved.
- The compressed section is long enough to suppress plastic creep over the life of the assembly.

Installation and Alignment

- The HVFT will be installed after the TPC has been installed.
- The internal electrical connection will be made as in the ICARUS design: A spring loaded receptacle accepts the bottom end of the center conductor:

HV Feed Contact

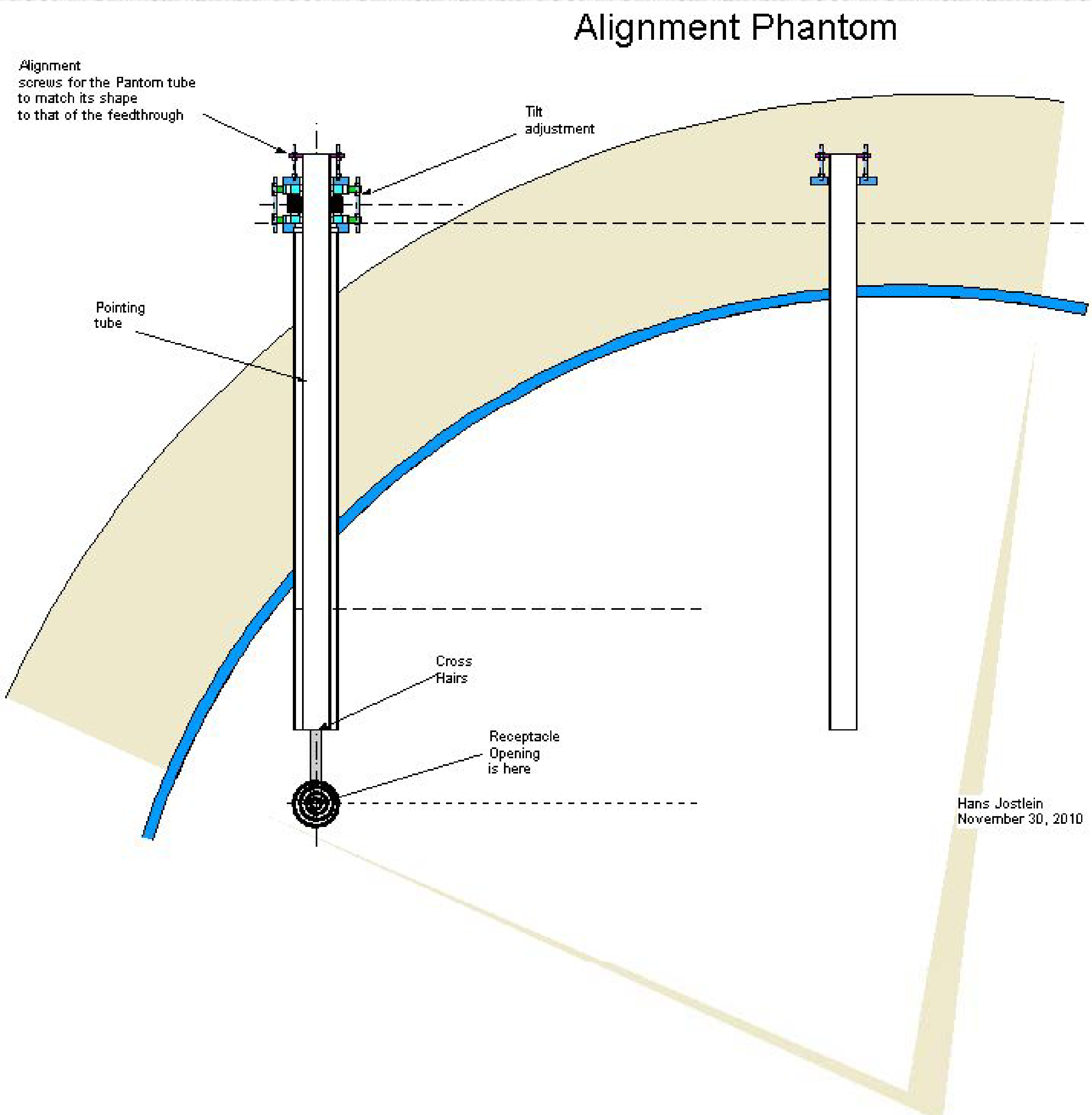


Alignment

- There is an alignment issue.
- We do not count on precision alignment between the HVFT flange and the HV receptacle.
- Visual alignment is not possible because the connection point is hidden at installation time.

A Two-Stage Alignment Process

- We will make a phantom consisting of a tube mounted (adjustably) on a flange that mates with the HVFT flange. The phantom will be adjusted on a fixture to match the shape of the HVFT. We aim for 3 mm accuracy at the bottom end when the phantom is bolted to the flange.
- The HVFT flange on the tank is mounted with a bellows insert and can be aimed using a set of adjustment screws.
- The phantom, when bolted to the tank flange, allows visual alignment of its bottom end to the electric receptacle using the alignment screws on the bellows. Adjustment is for two angles and depth (if needed).
- Once the bellows are well aligned, the HVFT is inserted and bolted to its flange.
- The design allows small variations in offset (+- 6 mm) and depth (+- 12 mm).



The Alignment Phantom

Breakdown Prevention in LAr

- LAr has an extremely high dielectric strength, 2 MV /cm.
- Nonetheless, care must be taken to avoid field concentration near sharp edges.
- For a sphere of radius R, the surface field from a faraway electrode at potential V is V / R.
- As an example, a 1.2 mm diameter sphere at a potential of 125 kV (the operating design voltage) has a surface field of 2.08 MV/cm, i.e. it can initiate breakdown.
- In another example, a cylinder of radius 0.1 mm at 125 kV at a distance of 10cm from ground has a surface field of 1.8 MV/cm, nearly enough to initiate breakdown.

LAr Breakdown

- Therefore, all edges inside the tank and out will have smooth rounded edges and corners.
- Parts having rough edges will be placed inside of well rounded corona shields.
- High electric fields attract small debris.
- Sharp filings are particularly effective in causing breakdown.
- Cleanliness of the tank and all its content is critically important

Breakdown Prevention in Ar Gas

- Gas breakdown can occur inside the tank if Ar gas (e.g. bubbles) passes through high electric field areas.
- Ar boiling can occur where the UHWPE sleeve and the center conductor of the HVFT enter the liquid.
- This point is just below the ground grid of the TPC.
- To prevent gas to enter the high field area there will be an opening in the tube surrounding the lower end of the FT, to direct the gas away .
- A short stub pipe may need to be added there to deliver the potential gas to a point above the liquid surface.

Breakdown Prevention at the Cable Connection

- Breakdown can also occur outside at the HV cable connection point along the insulated cable end to ground.
- To help prevent this breakdown, the path will be quite long (20 cm ?) and this space will be continuously purged with nitrogen gas.
- The gas purge will also remove any water in the gas and on the surfaces to an extremely low level, thus inhibiting flash-overs and micro discharges.

Conclusion

- We have started the design process for the MicroBooNE high voltage system.
- Much work remains to be done
- Prototype wok needs to start early next year.