**Specifications Sheet: High Voltage Feedthrough**

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**Functional specifications:**

The high voltage feedthrough is required to deliver ±250 kV @ ±200 µA from an atmospheric R24 plug with a P3 cable to the vacuum environment through one of the center ISO 200 flange of the vacuum chamber. The vacuum system will probably operate at $\~1×10^{-3}mbar$ of helium to protect against sparks. The feedthrough requires to pass through the ground shell in vacuum and interface with the side of the HV electrode.

**Feedthrough dimensions:**

The feedthrough requires to be placed on a central flange on the vacuum chamber. This flange has an internal diameter of ~ 200 mm (ISO K 200). The central electrode is about 1 m in diameter, leaving a distance to the vacuum chamber wall of less than 500 mm. The external dimensions of the vacuum chamber are 1.5 m height, 1.9 m wide, and 1.9 m in length. The dimensions of the inner mu-metal walls are approximately 2.9 × 2.9 × 2.9 m3. This will only give ~ 500 mm distance in which to install anything onto the vacuum chamber flanges from the outside. Hence, the feedthroughs absolute length has to be < 500 mm in order to be installed onto the flange. On the atmospheric side requires > 72 mm for the minimum bending radius of the cable into the feedthrough receptacle. Ideally the cable should be installed independently of the feedthrough to maximize the feedthrough length.

**Leakage current:**

Leakage current can flow along the outside of the feedthrough insulator surface. Magnetic fields due to this current will practically cancel since they are compensated by the leakage current flowing on the feedthrough conductor (two counter flowing currents, about 500 mm away from the precession chamber). Hence, magnetic field contributions from this leakage current are negligible.

However, if we considered only the leakage path occurring along the upper most surface of the insulator (not considering the castellations or compensation effect from the conductor of the feedthrough), this would generate a larger magnetic field in the top precession chamber compared to the bottom. In order to control the systematic effect due to uncompensated field drifts below $3×10^{-28}e∙cm$, we need to be able to detect small correlation between the electric field and magnetic field gradient (compared to the TDR). Therefore, a requirement on short term stability (< 5 minutes) variations in the gradient should be:

$$σG<50 fT/cm$$

This is associated with polarity reversal, therefore, if a leakage path is formed the path the current takes would be correlated with polarity being applied. Assuming a worst case, where the leakage path is a straight line along the insulator surface, a leakage current of $<100 nA$ at 200 mm would meet this gradient stability limit.

**Vacuum tightness:**

The vacuum chamber target pressure is a water partial pressure of below $5×10^{-6}$ mbar. However, any gas leaking along the feedthrough via a non-perfect seal, could cause unexpected sparking which at 250 kV could cause critical damage to the device. Therefore, the gas leak rate of the feedthrough must be minimized in order to avoid such a problem. A value for the maximum tolerable gas leakage still needs to be determined, however, it is reasonable to assume a value equal or better than the leak rate/out-gasing rate of the vacuum chamber (the latter is however not given in the vacuum tank specifications).

**Magnetic properties of the construction material:**

Construction material of the conductor and insulator has to be non-magnetic, measured fields on the surface has to be $<200 pT$ peak-peak, at a distance of 10 cm from the dipole, after magnetization with 30 mT field.

**Outgassing:**

High outgassing rate could cause local regions of higher pressures on the feedthrough which would cause discharging and higher leakage current to occur. Either careful vacuum pumping needs to be considered or materials with little to no outgassing rate are required for construction. Plastics in general tend to have a high outgassing rate, hence where possible ceramics and metals will be used. The same will apply for the vacuum sealing method.

**Ballast resistor:**

A ballast resistor is used to limit the discharge current during a HV spark in the precession chamber of the previous nEDM experiment. However, the HV cable contributes the largest capacitance to the system. In order for the ballast resistor to properly work it would need to be placed very close to the central electrode/HV feedthrough. This is not possible for n2EDM as there is limited space in the mu-metal shield to place such a device. The available HV resistors that would be used to construct this device are also very magnetic which is unacceptable for our magnetic requirements. Therefore, it was decided at the collaboration meeting in Berlin (in 2018) that for n2EDM, no ballast resistor will be employed. If the ballast resistor is determined at a later date to be required, this can be revisited.