Design of a Gas System and Study of an Internal Calibration Source for Liquid Xenon TPCs

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Gas system

For the operation of the MainzTPC, a two-phase liquid Xenon time projection chamber, a new gas system was designed and constructed. Main purpose of the system is recirculation and purification of Xenon gas. The system consists of two major modular parts. The recirculation and the storage device, which can be de-coupled.

Major parts of the recirculation device are a double membrane pump, a mass flow controller to set a xenon flow up to 20 standard liters per minute and a noble gas getter to purify the detector gas.

The storage device contains two aluminum gas cylinders with a capacity of 20 l each. A pressure reducer sets the operating pressure to typical values up to 3 bars. The cylinders can be submerged in liquid nitrogen, to recuperate the xenon from any attached setup.

In addition, the system is designed to offer the possibility of inducing calibration gases into the gas cycle.

Therefore the gas flow can be redirected after the pump through a device containing a calibration gas. This gas mixture can be fed back to the recirculation cycle before or after the getter, in case the gas would be removed by the getter.

Calibration

Compact TPCs like XENON100 (30 cm diameter, 30 cm height) are calibrated with external radiation sources and measurement of the radiation reaching the inside of the detector.

This is increasingly problematic with larger detectors like XENON1T [1] or DARWIN [2], due to the excellent self shielding of xenon. Therefore internal sources are needed to reach the inner regions of large detectors.

In the case of dark matter direct detection the calibration for two different types of particles is interesting: particles with electromagnetic interaction, like electrons or gamma-rays (electronic recoils, ER), and particles interacting with the xenon nucleus (nuclear recoils, NR), for which neutrons are used.

Calibration of electronic recoils is done with isotopes decaying under emission of an electron or gamma. Internal isotopes used for this purpose are for example $^{129m}\mathrm{Xe}$ and $^{131m}\mathrm{Xe}$ with decay energies of 236 keV and 164 keV [3].

For calibration of the ER band, high-energy gamma-rays are typically used to produce a Compton continuum.

Calibration using $^{37}\mathrm{Ar}$

For dark matter searches, the low energy response of xenon needs to be explored in more detail, so an absolute energy calibration for low energy is useful, for example with $^{83m}\mathrm{Kr}$ at 9.4 keV and 32.1 keV [4]. Here we study $^{37}\mathrm{Ar}$, which emits low-energy Auger-electrons with an energy of 2.38 keV during its decay process. The half life of $^{37}\mathrm{Ar}$ is 35 days [5], which is relatively long for this purpose compared to other calibration gases in use, but still too short for longer storage. Therefore its production needs to be established.

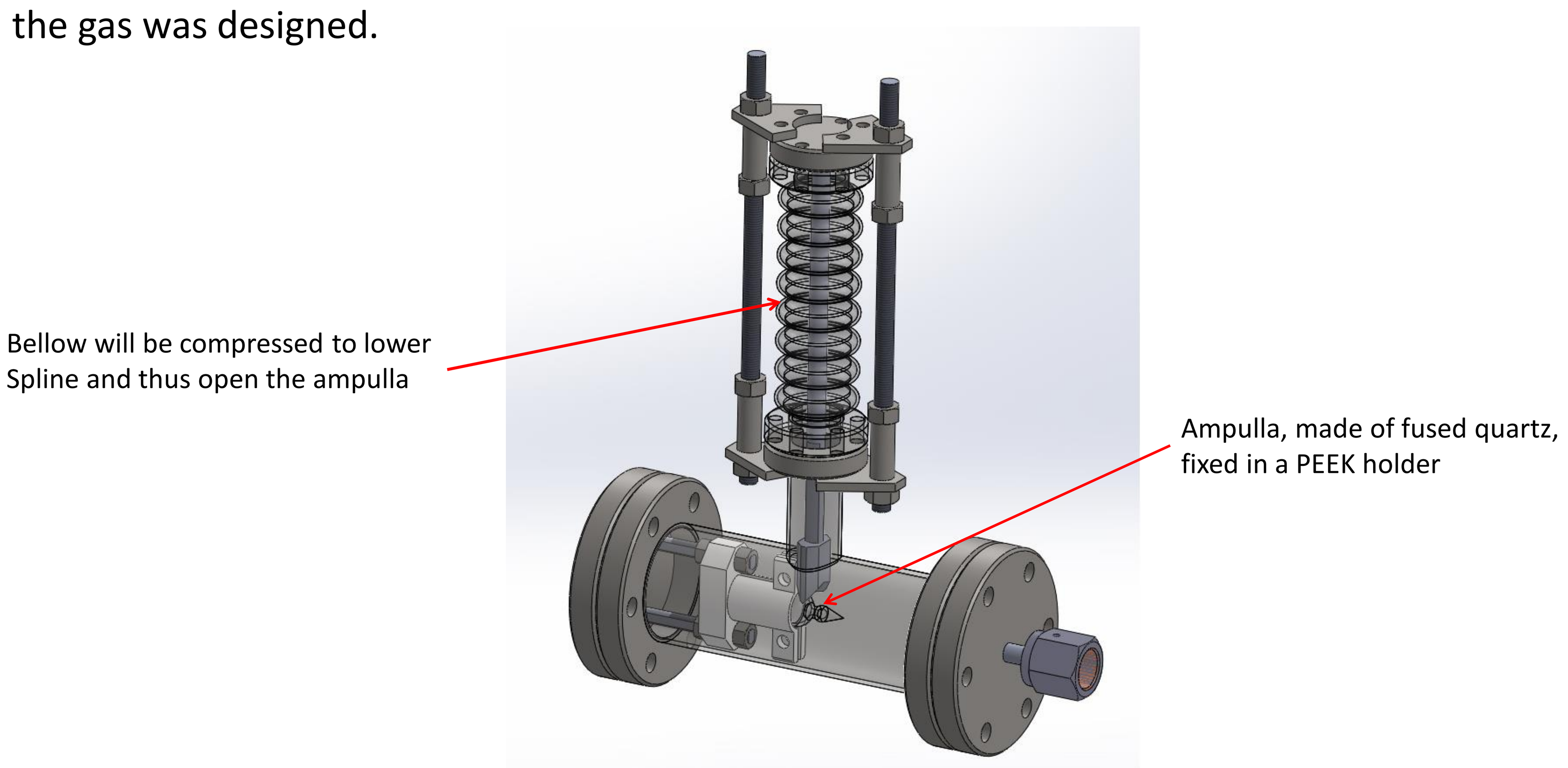
Production of $^{37}\mathrm{Ar}$

We have produced a $^{37}\mathrm{Ar}$ source at the Mainz TRIGA Reactor through capture of thermal neutrons of an enriched amount of the Argon isotope $^{36}\mathrm{Ar}$.

For the irradiation, the Argon needs to be filled into an ampulla consistent of fused quartz. A picture of the ampulla before filling and with KF-16 compatible flange is seen on the left. The detail shows the filled, separated ampulla.

Opening of the ampulla and storing the gas

To release the irradiated gas from the ampulla, a device for opening the ampulla and storage of the gas was designed.

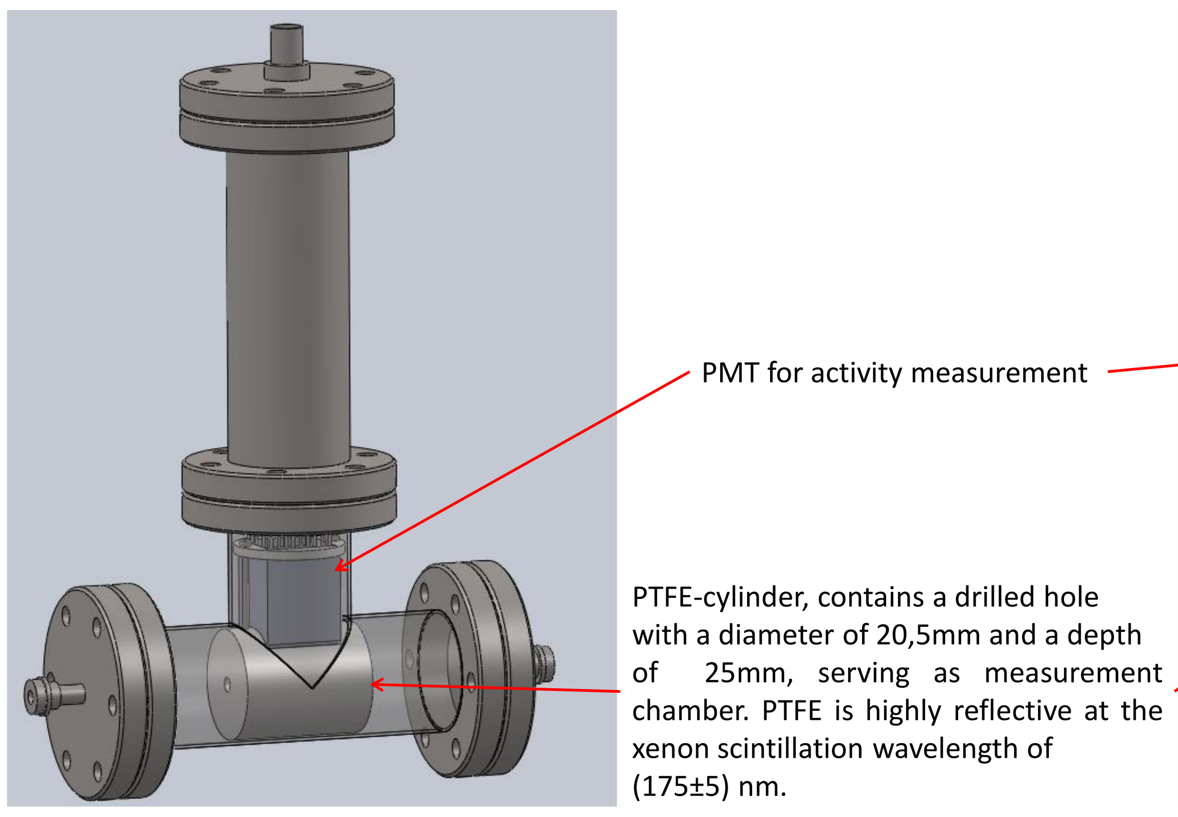


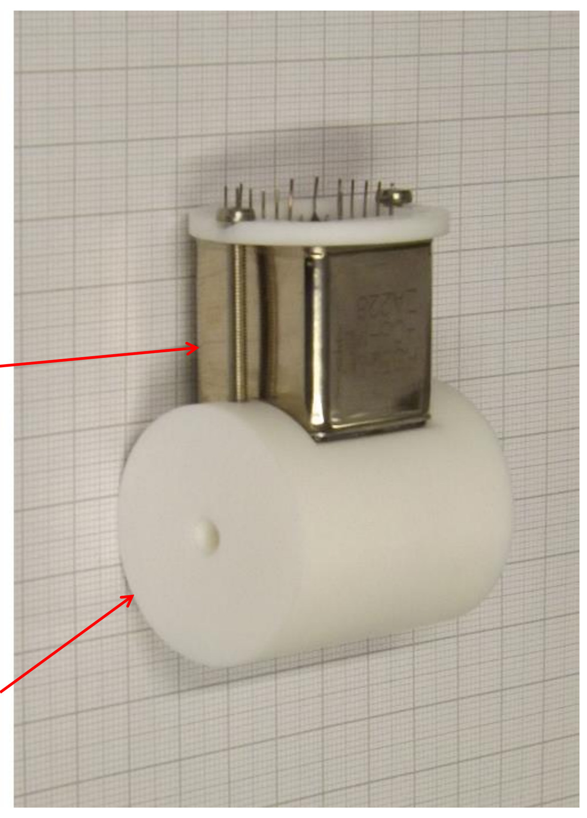
Dosing device

The produced activity is around 87 kBq for the used ampulla per hour of irradiation. The activity produced in the first ampulla was expected to be 241 kBq, which is too much for a calibration run, therefore a dosing device was built, capable of inducing the activity into the detector gas in steps of approximately 10 kBq.

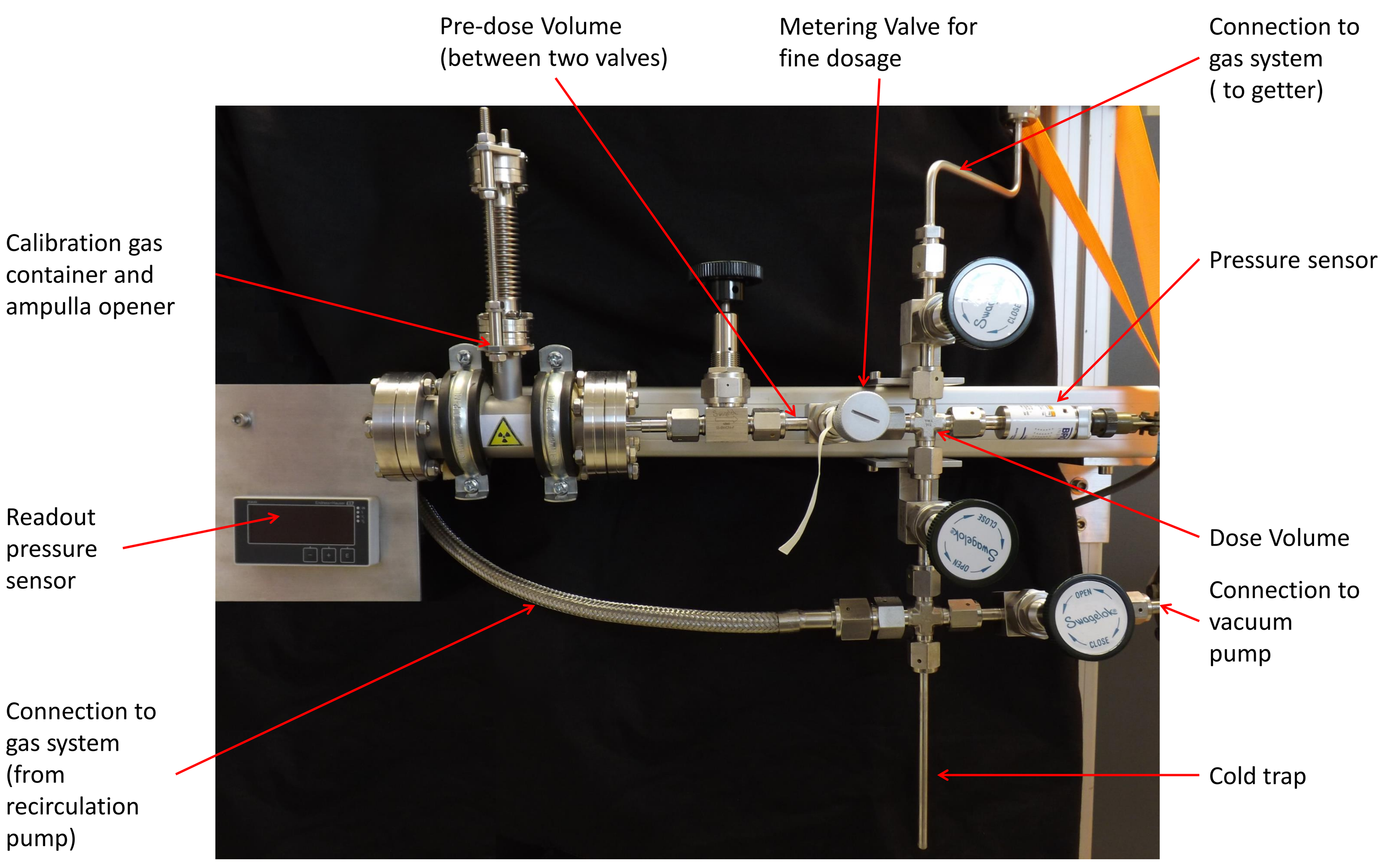
Measurement device

Since the MainzTPC was not operational yet, a simple activity measurement device was built. It consists of a small cylindrical PTFE chamber, in which the activity will be measured with a PMT.





Calibration setup



The complete calibration setup is shown on the left. The calibration gas will be pre-dosed between the closing valve and the metering valve. The dose infused can be determined with the volume proportions between pre-dose volume and dose volume and the pressure in the dose volume, as the pressure in the gas container is 1 bar.

The cold trap is used to evacuate the dose volume between repeated calibration processes.

Acknowledgement

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