Calibration of liquid xenon detectors with ^{37}Ar

Zeuthen Workshop

Christopher Hils
chhils@students.uni-mainz.de

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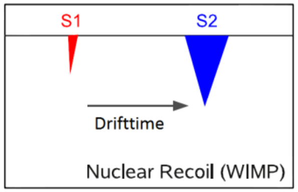
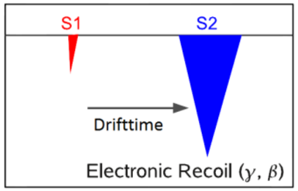
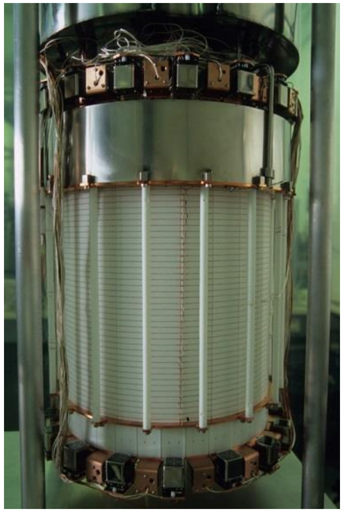
Motivation:

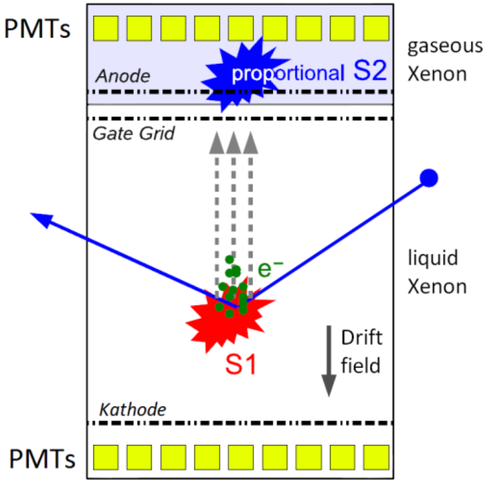
- standard calibration of liquid xenon Time Projection Chambers (TPC) uses external calibration sources
  - ^{137}**Cs**, ^{60}**Co**: γ source, electronic-recoil events
  - **AmBe:** neutron source, nuclear-recoil events





- positioned outside of the TPC vessel

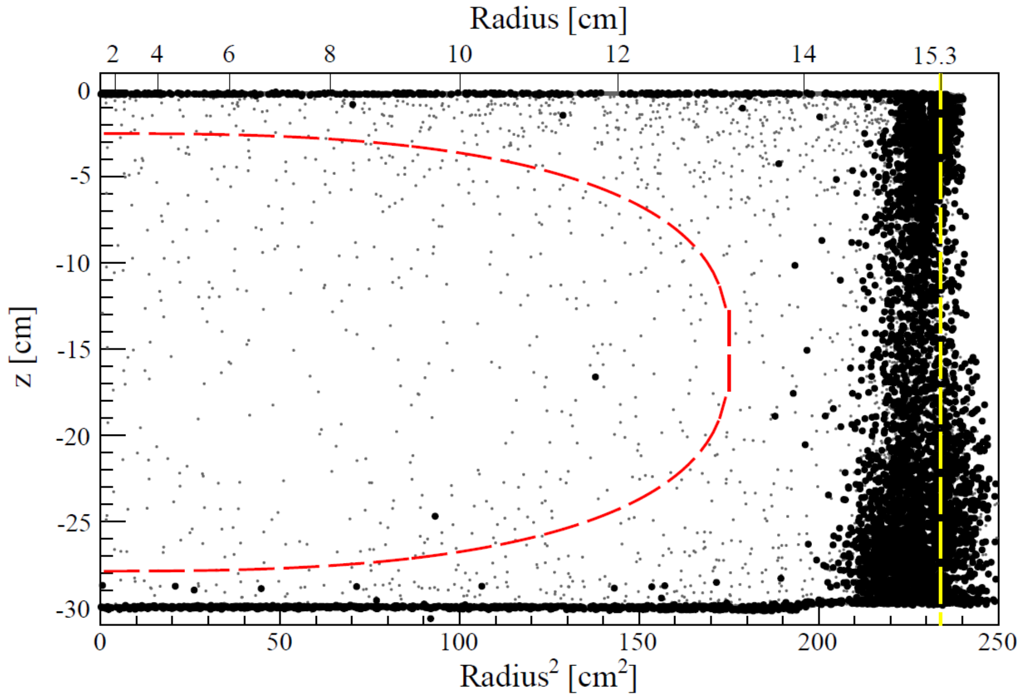




[Astropart. Phys. 35 (2012), 573-590]

Motivation:

- standard calibration of liquid xenon TPCs uses external calibration sources
- larger detectors are strongly influenced by the excellent self-shielding of xenon



Fiducial volume cut of XENON100 for backround-suppression. The same effect prevents external calibration radiation sources from reaching the inner region of larger detectors.
[Phys. Rev. Lett. 109, 181301]

Alternative calibration methods:

- **solid radiation source**, inserted via a tube, leading into the sensitive volume of the detector.

→ easy to remove.
→ can only be placed at certain locations of the detector.
→ insertion tube influences the light collection and the drift field.

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- **gaseous radiation source**, mixed with detector medium (xenon).

  → removal procedure needed.
  → homogeneously distributed throughout the medium.
  → does not influence light collection and drift field.

Alternative calibration methods:

Already used internal calibration sources:

Isotope	$T_{1/2}$	Decay Energy
^{129m}Xe	8.9 d	236 keV
^{131m}Xe	11.8 d	164 keV
^{83m}Kr	1.85 h	9.4 / 32.1 keV
CH_3T	12,32 y	< 18 keV

Calibration type:
- Energy calibration
- Spatial response

Usage of ^{37}Ar for Calibration:

Properties:

- noble gas → chemicaly inert.
- decay product (^{37}Cl) can be easily removed by a getter.
- remnants can be removed by cryo destillation ($T_{½}$(^{37}Ar)=35 d).

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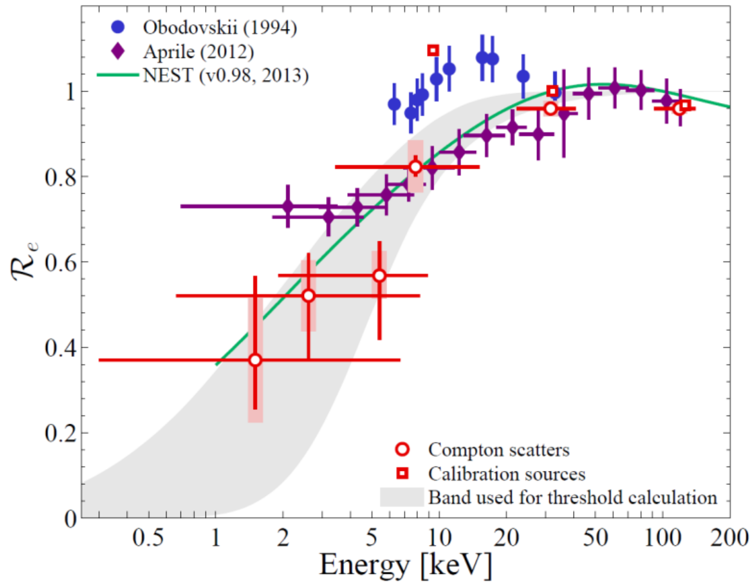
- decay product (^{37}Cl) can be easily removed by a getter.
- remnants can be removed by cryo destillation ($T_{½}(^{37}Ar)$=35 d).
- Low decay energy of 2.38 keV (Auger-electron) can be used for further examination of the low energy response of liquid xenon.



[Phys.Rev.D87:115015,2013]

Production of ^{37}Ar:

- $^{40}\mathrm{Ca} \xrightarrow{(\mathrm{n},\alpha)} {}^{37}\mathrm{Ar}$

- $^{36}\mathrm{Ar} \xrightarrow{(\mathrm{n},\gamma)} {}^{37}\mathrm{Ar}$

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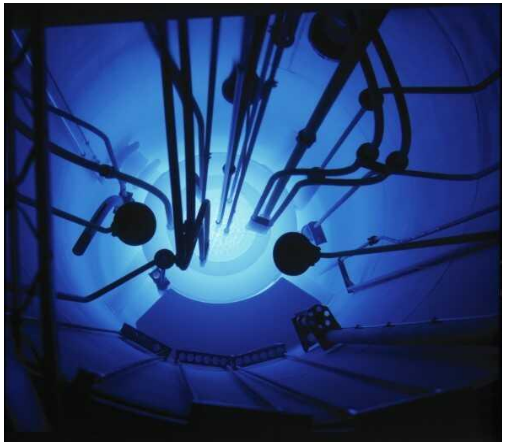
TRIGA Reactor Mainz



Properties of thermal neutrons:

E_n= 0,025 eV

F_n= 4.2 * 10^{12} $cm^{-2}s^{-1}$

Production of ^{37}Ar:

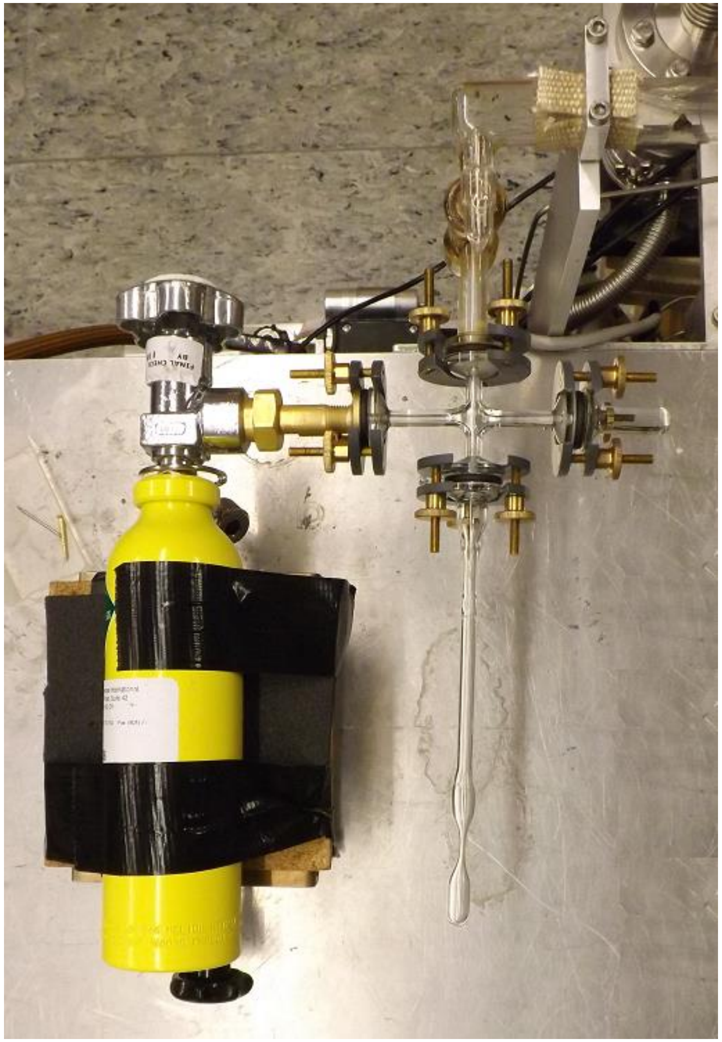
- $^{40}\mathrm{Ca} \xrightarrow{(n,\alpha)} {}^{37}\mathrm{Ar}$ σ=7.7*10^{-4} barn
  - solid target of calcium
  - to extract the gas calcium needs to be molten at temperatures > 842°C
- $^{36}\mathrm{Ar} \xrightarrow{(n,\gamma)} {}^{37}\mathrm{Ar}$ σ=1.64 barn
  - gaseous target
  - ^{36}Ar is part of natural argon, but natural abundance is only 0.34 %
  - besides ^{37}Ar, ^{41}Ar is produced out of ^{40}Ar (natural abundance 99.6 %)
    → γ-line (1294 keV) of ^{41}Ar can be used to determine ^{37}Ar activity

σ=1.64 barn (^{36}Ar) ⇔ σ=2.08 barn (^{40}Ar)

Production of ^{37}Ar:

Properties of the produced ampulla:

- Internal volume of approximately 1.6 cm³.
- Filled with low pressure argon at 0.13 bar.



Production of ^{37}Ar:

Use of enriched ^{36}Ar (>99,9%)

- Activation rate at TRIGA-Reactor Mainz increases (per mg gas at 1 bar)
  1 kBq/h (natural Argon) $\rightarrow$ 300 kBq/h (enriched ^{36}Ar)

- reduced argon contamination of the detector

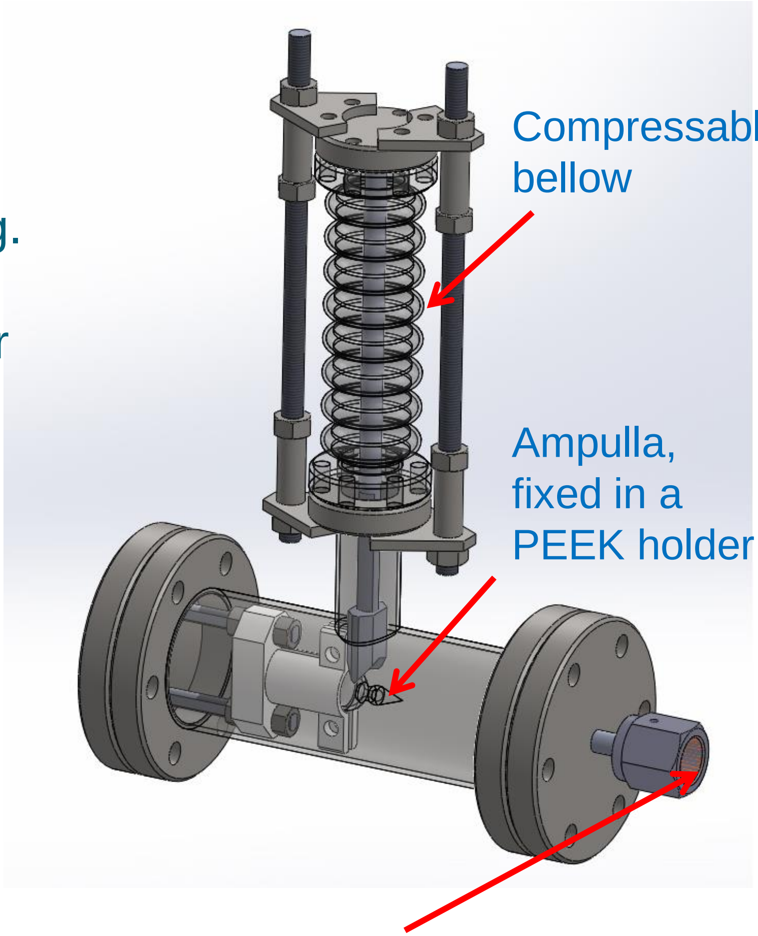
- enriched ^{36}Ar contains no ^{40}Ar $\rightarrow$ no indirect activity measurement with ^{41}Ar possible

- Calculated ^{37}Ar activity of 241±24 kBq.

Opening of the ampulla and storage of the ^{37}Ar:

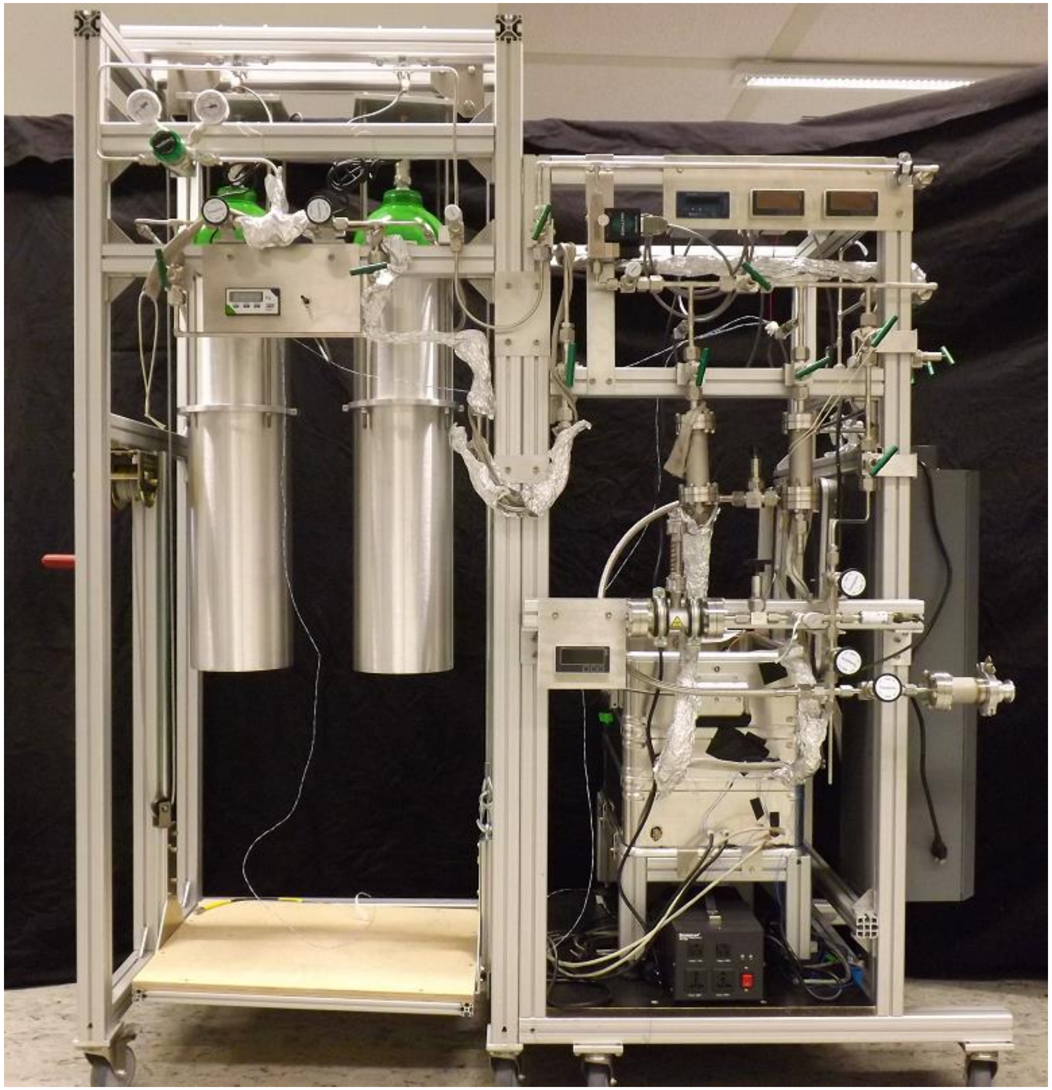
A device is needed to open the ampulla and keep the gas trapped after the opening.

- The bellow can be compressed, to lower the spline and open the ampulla.
- The device is sealed with a valve, so separation from the system and storage is possible.



A valve will be attached to close the device and allow separation.

Gas system:



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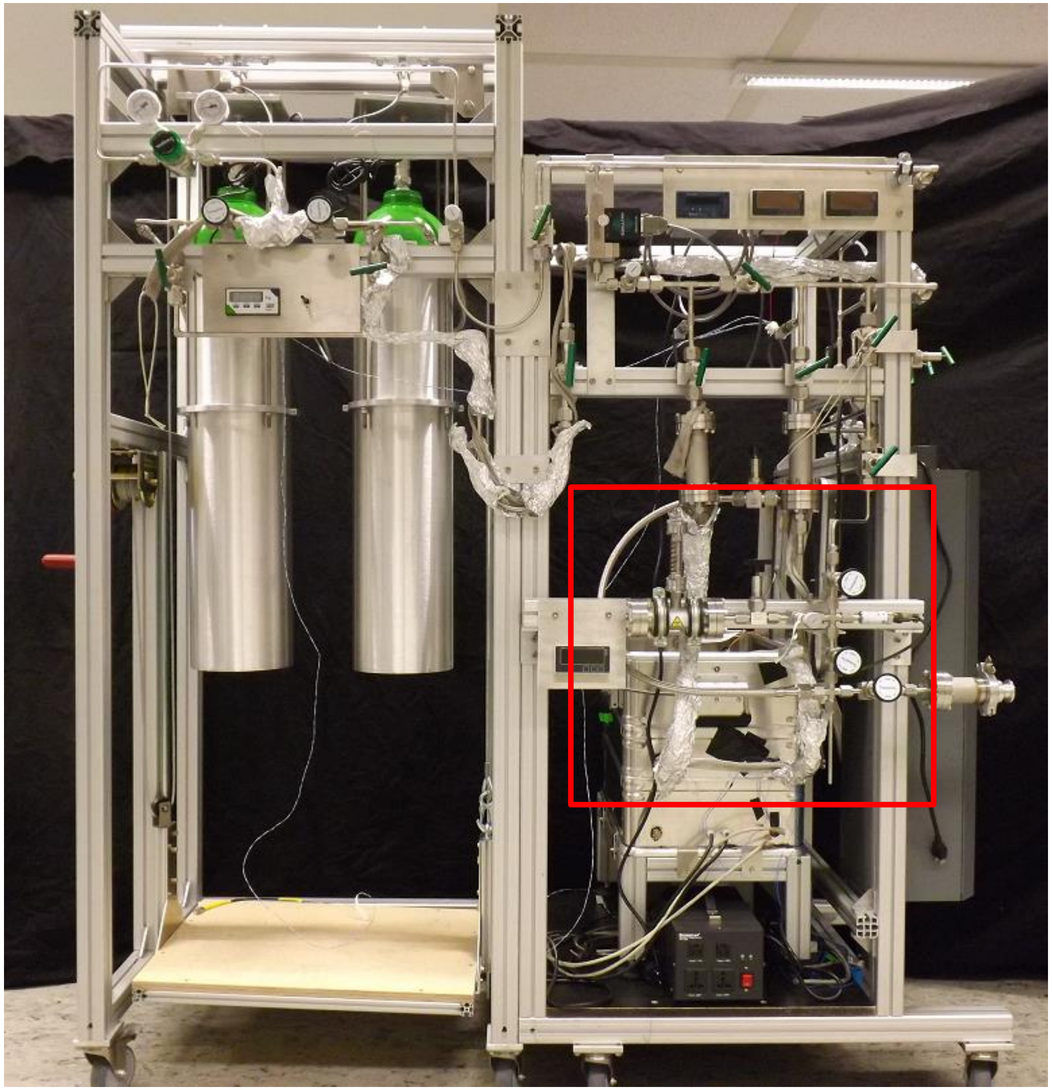
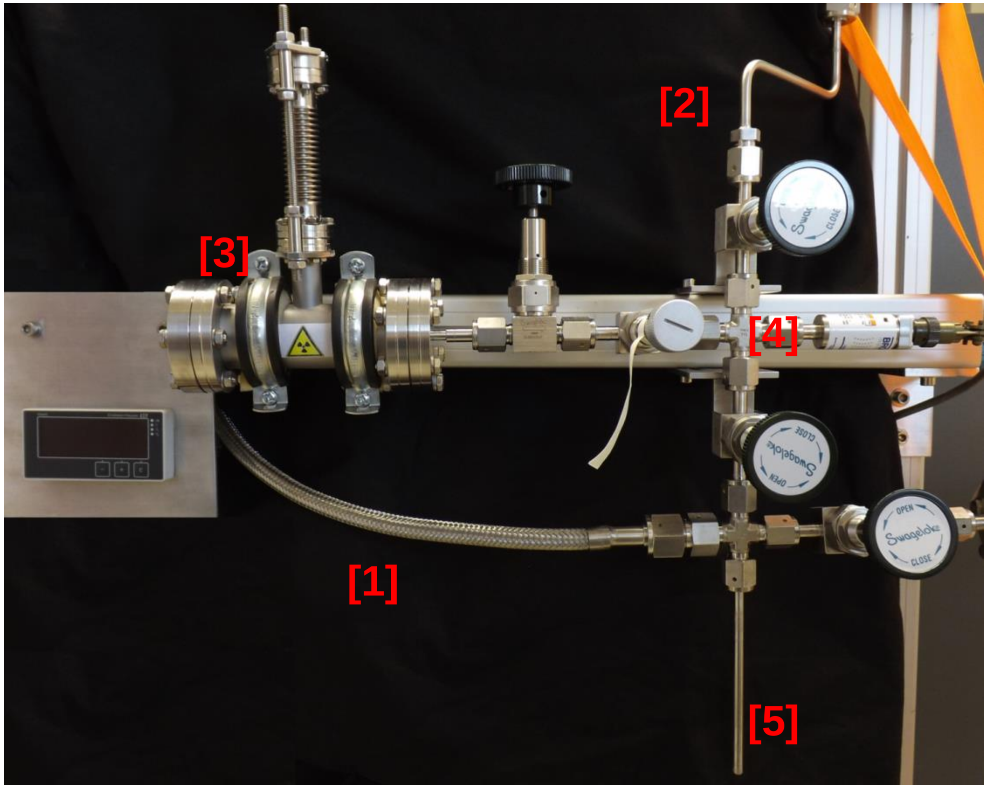


Dosing device for ^{37}Ar:

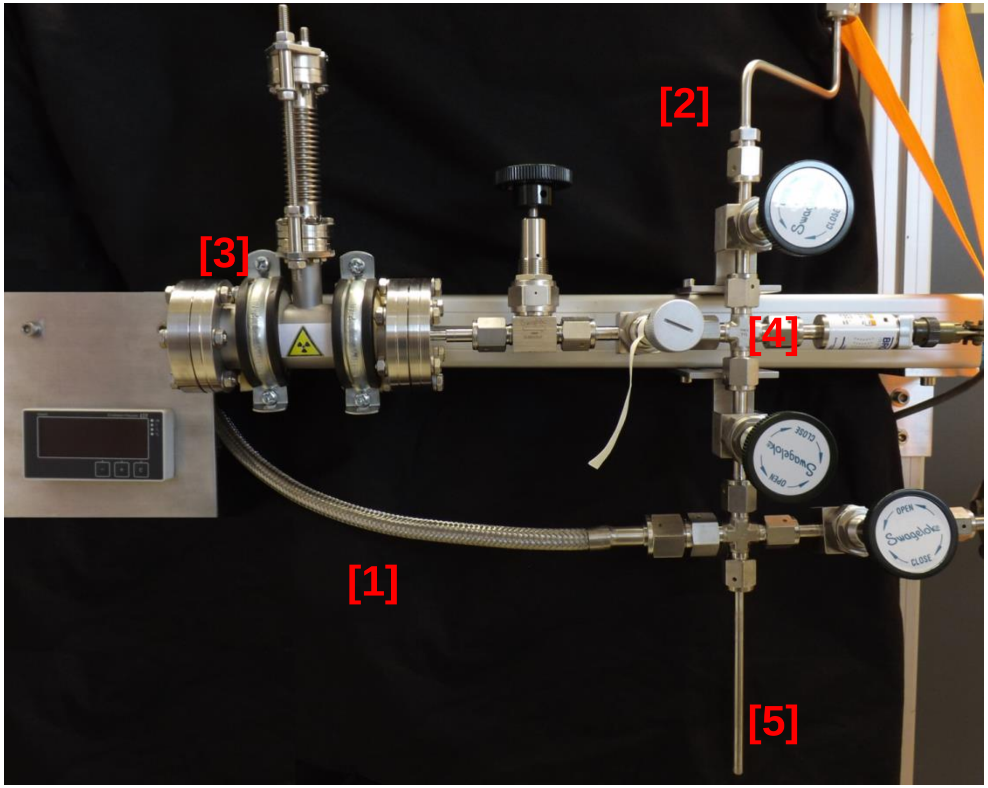


Components:

- Connected to recirculating gas system via [1] and [2].
- Gas container with the argon filled ampulla [3].
- Dosing volume with pressure sensor [4].
- Cold trap [5]

Dosing device for ^{37}Ar:

Gas container [3] filled with Xenon at 1 bar simplifies dosing.



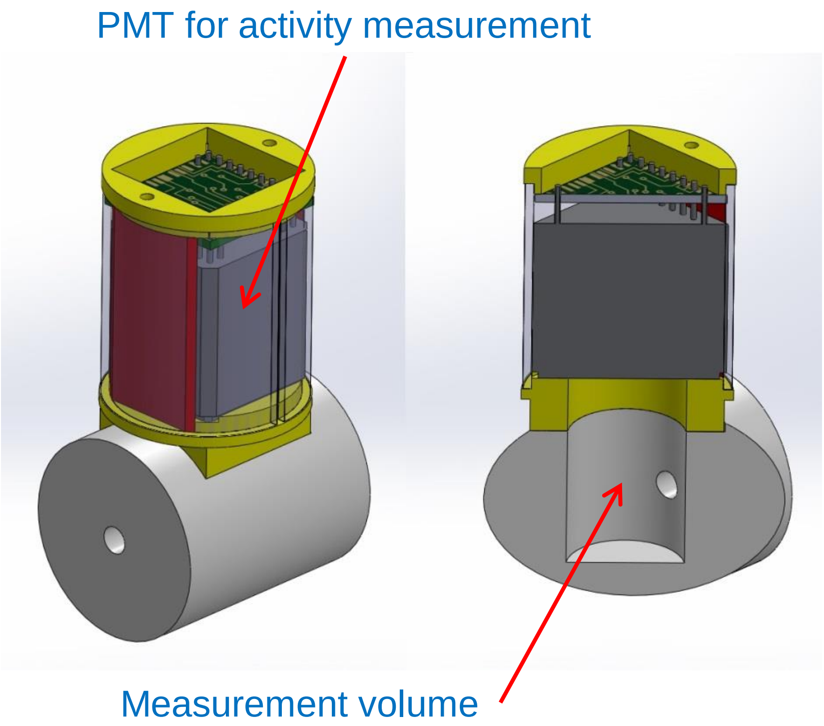
Procedure:

- Evacuate dosing volume [4].
- The dosing is accomplished over the known volume proportions of [3] and [4] and a pressure measurement in [4].
- An activity of approximately 10 kBq can be induced in the system in one step.
- Cold trap [5] can be used for repeated fillings.

Activity measurement:

Simple device for activity measurement:

- PTFE-Volume with high reflectivity for xenon scintillation light.
- 1“-PMT for event counting in the PTFE-volume.
- Standard CF-40-T act as housing for the setup.



Outlook

Activity measurement to confirm the predicted activity of the calibration gas.

Increase the efficiency of the ampulla filling process to reduce loses of ^{36}Ar.

Testing removal procedures with a destillation column.

Further measurements with the MainzTPC after its completion.