Design and Manufacture of a TCAP Scattering Chamber

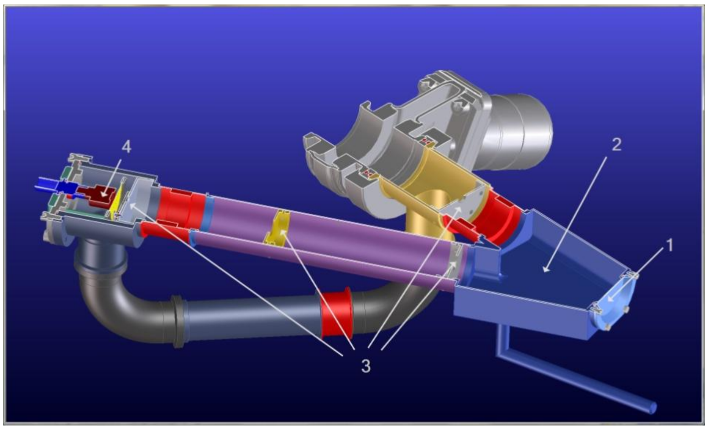
To determine the fluence of monoenergetic neutrons by means of the time-correlated associated particles method (TCAP), a low-mass scattering chamber has been developed and manufactured. It is intended to be operated at PTB's ion accelerator PIAF.

PTB's primary and secondary standards for determining the fluence of monoenergetic neutrons are based on neutron-proton scattering or on the fission of the isotopes ^{235}U and ^{238}U. These measuring instruments contain artefacts such as, for example, layers of a hydrogen-containing material or of uranium, and the assessment requires their properties to be taken into account. To ensure the stability of these instruments it is, therefore, important to perform comparisons with methods for which knowledge of the properties of artefacts is, at least generally, not required.

Within the scope of a research project funded by the Federal Ministry for Education and Research, a new measuring facility – which uses the time-correlated associated particle method – has, therefore, been established at PTB. For this purpose, neutrons with a mean energy E_n of approx. 14 MeV have been generated with the nuclear reaction T(d,n)^{4}He at a deuteron energy E_d of 150 keV and marked by coincident detection of the kinematically correlated second product particle ^{4}He (alpha particle). The target material is Ti(T), in which tritium (T) is bound in a titanium layer (Ti). By counting the alpha particles emitted into a specific solid angle range, the fluence of the associated neutrons can then be determined without having to refer to reference cross-sections.

For this purpose, a low-mass scattering chamber had to be designed which can be flanged to the beamlines of PTB's accelerator facility PIAF with a positioning uncertainty of a few 100 µm. The chamber consists of one arm for the incident deuteron beam and a second arm for the emitted alpha particles. This arm contains a semiconductor detector and a diaphragm system which defines the solid angle for alpha particle detection and blocks scattered alpha particles.

The challenges for the technical realization of the scattering chamber were the low-mass design of all components (i.e with walls as thin as possible) and the distortion-free welding.



1. Ti(T) Target
2. Target chamber
3. Diaphragm system
4. Semiconductor detector

Figure 1: Sectional representation of the chamber (CAD model)

Here, compliance with the required tolerances of less than 100 µm with respect to the angular position of the deuterium and of the alpha arm had to be taken into account as well as the position of the firmly mounted diaphragms in the overall system. After being put into use, subsequent changes to the chamber are not possible due to the radioactive contamination.

To comply with the mentioned requirements, the target chamber was prefabricated from a thick-walled material, annealed with minimum stress and subsequently finished with electro-erosive procedures to obtain the desired wall thickness of 1 mm. Then all thin-walled components were connected – without distortion and in a vacuum-tight way – by means of laser-welding procedures. These procedures made the manufacturing of the chamber very demanding.

The finished chamber was measured to check the dimensions with respect to their tolerances. In particular, the dimensions and positions of the diaphragms enter into a simulation calculation with which the experimental measurements on the accelerator are compared.

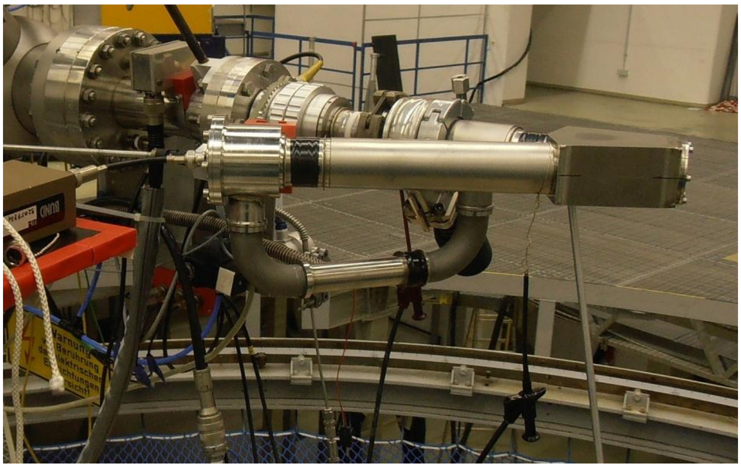


Figure 2: TCAP scattering chamber used at PTB's accelerator PIAF

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