# Recent progress of LIBRA project and new TBR measurements

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The LIBRA (Liquid Immersion Blanket Robust Accountancy) project seeks to develop the liquid immersion blanket concept (LIB) as a viable solution to achieve tritium self-sufficiency in fusion power plants [1]. As part of this effort, the BABY experiment has undergone a significant upgrade to study tritium breeding and transport at the 1L scale. This upgrade marks an essential milestone in the project's progression, providing valuable insights into the behaviour of molten salts under neutron irradiation.

The BABY (Build A Better Yield) 100 ml setup was upgraded by increasing the salt volume to 1L, allowing more representative testing of tritium breeding in larger systems. Tritium is produced in the experiment by neutron interactions with the lithium in the molten salt (ClLiF). 14 MeV neutrons are produced by a Deuterium-Tritium neutron generator. As the previous BABY setup only collected the tritium that was released from the top surface of the salt, an outer vessel was added to the setup to allow the collection of tritium permeating through the walls of the crucible (see Figure 1). In addition, the heating system was improved by incorporating an external furnace along with the central heating. The tritium collection system and the neutron detection apparatus remained consistent with those used in the 100 ml setup. Neutrons were detected using diamond detectors and activation foil analysis. Tritium was collected in bubblers and then counted with Liquid Scintillation Counting. Two experimental runs were conducted for reproducibility. Experimental data and analysis are available on Zenodo [2, 3]. The setups for both runs were identical, except that the second run was conducted with a neutron fluence five times greater than the first.

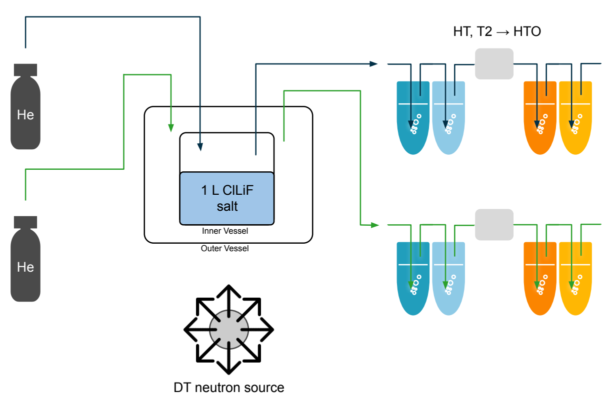
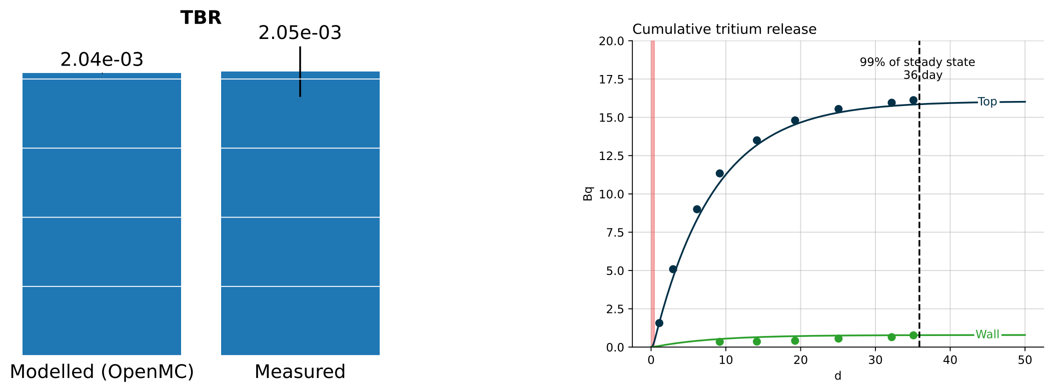



Figure 1: Experiment principle

OpenMC [4] was employed for neutronics simulations to calculate the TBR, providing a predictive framework for experimental validation. A 0D tritium transport model was used to simulate tritium release dynamics, offering insights into the transport and release mechanisms.

The measured Tritium Breeding Ratio (TBR) in the upgraded BABY experiment was approximately $2 \times 10^{-3}$. This represents a sixfold increase compared to the TBR measured in the previous 100 mL scale experiment, which was $3.57 \times 10^{-4}$ [5]. The measured TBR showed excellent agreement with predictions from OpenMC neutronics simulations (see Figure 2a). This is a great improvement compared to the previous experiment where there was a relative error of about 20 % between theory and measurements. This alignment provides confidence in the experimental setup and modelling approaches, reinforcing the feasibility of achieving a TBR of one in future scaled-up experiments such as LIBRA-Pi and LIBRA-XL.

The release dynamics of tritium from the free surface of the molten salt showed good agreement between experimental data and the 0D transport model (see Figure 2b). However, no permeated tritium was conclusively detected in the outer vessel. This absence of detection is under investigation and may be attributed to several factors, including the formation of a permeation barrier, such as an oxide layer, on the inner surfaces of the crucible, or the trapping of tritium within the outer vessel, possibly through adsorption, or secondary permeation losses. The reproducibility of the setup was demonstrated by modelling tritium release in both low-fluence and high-fluence experiments using the same transport parameters.




(a) TBR validation

(b) Cumulative tritium release

Figure 2: Results of the BABY 1L low fluence experiment

Future experiments will introduce other breeders such as FLiBe, LiPb and LiOx. Additional studies will include redox control experiments to better understand the chemical behaviour of tritium in molten salts and investigations into the effects of varying purge gas compositions. These findings will provide critical data for informing the design of LIBRA-Pi, the next-generation experimental platform, which aims to further scale up the LIB concept and move closer to achieving tritium self-sufficiency in fusion power plants.

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