Measuring the gamma-ray-to-neutron branching ratio in the deuterium-tritium reaction

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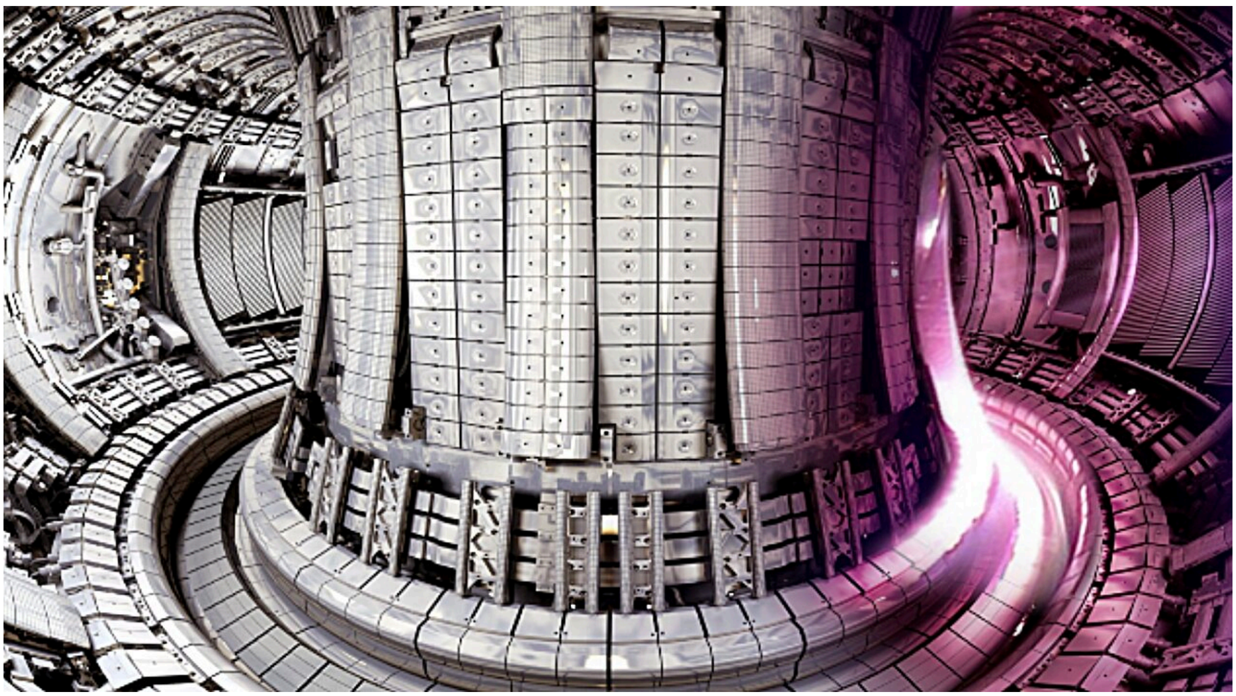


Image taken inside the vessel of the Joint European Torus experiment. Credit: Dal Molin et al

Magnetic confinement fusion devices are technologies that can attain controlled nuclear fusion reactions, using magnetic fields to confine hot plasmas. These devices could contribute to the ongoing transition towards more sustainable energy production methods.

The optimal operation of these devices relies on the ability to accurately measure fusion power. Existing devices achieve this solely via absolute neutron counting, a technique to measure the total number of neutrons produced in a plasma discharge, which in turn gathers insight about the rate and yield of the reactions.

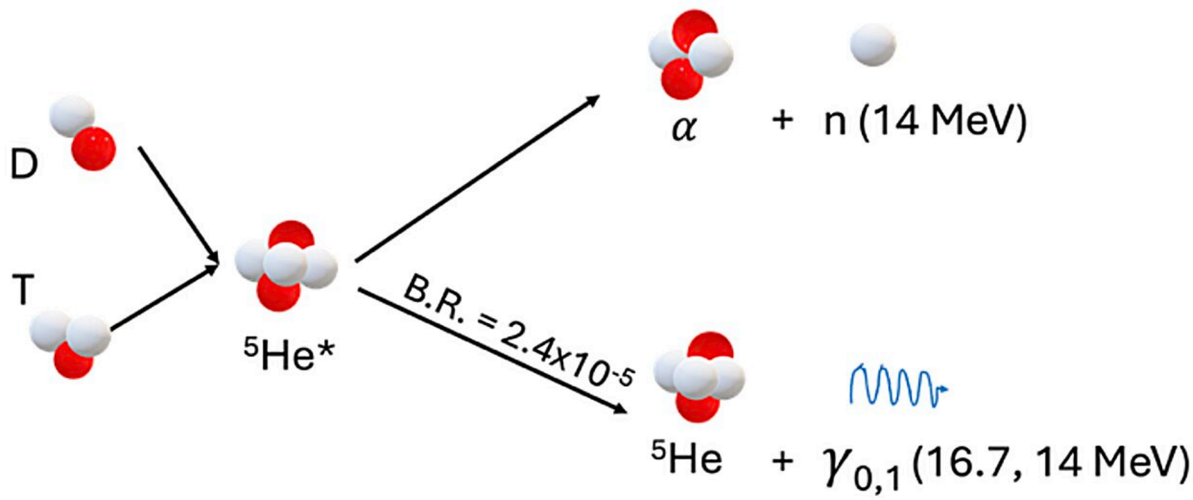
Researchers at Consiglio Nazionale delle Richerche (CNR-ISTP), University of Milano-Bicocca and other institutes worldwide, under the coordination of Dr. Marco Tardocchi, recently identified an additional measurement that could offer valuable information about fusion power.

This measurement, outlined in a paper published in *Physical Review Letters*, is the gamma-ray-to-neutron branching ratio in the deuterium-tritium reaction.

"Our project started with ITER, the next-generation International Thermonuclear Experimental Reactor, which aims to demonstrate the feasibility of producing electrical power from nuclear fusion," Andrea Dal Molin, first author of the paper, told Phys.org.

"One of the key technical challenges of ITER is that the fusion power is measured using two independent methods. The first one, absolute neutron counting, is a well-established technique already adopted in current fusion experiments like the Joint European Torus (JET). The second method was yet to be identified."

Dal Molin and his colleagues set out to explore the possibility of using the rare gamma rays emitted during the deuterium-tritium reaction to measure fusion power. Their proposed method of collecting this measurement entails counting the two gamma rays emitted by the electromagnetic channel of the deuterium-tritium nuclear fusion reaction, in which a ^{5}He nucleus produced in an excited state decays in lower levels.



A schematic representation of the deuterium-tritium fusion reaction. Credit: Dal Molin et al

"This reaction channel is much less probable (2.4×10^{-5}) than the nuclear reaction channel producing a neutron and an alpha particle," explained Davide Rigamonti, co-author of the paper. "This translates into a significant neutron flux which is a source of unwanted background for the gamma ray measurements. The use of an efficient neutron attenuator was one of the primary requirements which enabled this measurement."

Dal Molin, Rigamonti and their colleagues invested significant efforts in trying to accurately identify the energies and relative intensities of the two emitted gamma rays, which were previously unknown. They then utilized the absolute measurement of the number of neutrons produced by the JET magnetic confinement device to determine the gamma-ray-to-neutron branching ratio.

"The accurate determination of the gamma-ray-to-neutron branching ratio for the deuterium-tritium reaction paves the way for using absolute gamma ray counting as a secondary and neutron-independent technique to measure the fusion power in the next-generation fusion experiments," said Dal Molin. "Our work thus provides an essential tool to directly validate results and improve accuracy in the measurements."

This recent study by Dal Molin, Rigamonti and their colleagues opens interesting possibilities for the accurate measurement of fusion power during future nuclear fusion experiments. Notably, the method used by this team to measure the gamma-ray-to-neutron branching ratio could also be adapted and applied to other fusion reactions that do not produce neutrons, such as proton-boron or deuterium-helium-3 reactions.

"Fusion energy research is currently experiencing a significant surge of interest from both public and private sectors," added Rigamonti. "New tokamaks able to operate with a deuterium-tritium mixture, such as ITER, are being in development. Our plan is to provide the fusion power measurements on the next magnetic confinement reactors by using the gamma ray method."

More information: A. Dal Molin et al, Measurement of the Gamma-Ray-to-Neutron Branching Ratio for the Deuterium-Tritium Reaction in Magnetic Confinement Fusion Plasmas, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.133.055102.