**Nuclear data need for spherical tokamak**

**1. Overview and Motivation**

Spherical tokamaks (STs) are a promising path forward for achieving commercial fusion energy, combining compact design with high operational efficiency. A key innovation in their development is the use of high-temperature superconducting (HTS) magnets, which support steady-state plasma operation and offer reduced material requirements compared to conventional tokamaks. Despite these advantages, STs present unique nuclear engineering challenges. Their geometry, component proximity, and material selection result in intense neutron exposure, requiring precise nuclear data for accurate simulations and safe, efficient design.

**2. Key Requirements for ST Development**

The use of HTS magnets is fundamental to ST performance. These magnets operate at cryogenic temperatures around 20K and must endure high levels of neutron flux without performance degradation. Neutron-induced heating, displacement damage (measured in displacements per atom or dpa), and gas production within the composite structure of HTS tapes—consisting of rare earth copper oxides, silver, and buffer layers—must be carefully modelled. This requires detailed and validated nuclear data for each constituent material.

Shielding performance is another critical aspect of ST development. The limited space between the plasma and the HTS magnets places stringent constraints on shielding design. Effective attenuation of both fast and thermal neutrons is essential to protect core components and extend their operational lifetimes. Materials such as tungsten carbide, tungsten borides, boron carbide, and hafnium hydride are under consideration for these roles, but their effectiveness depends heavily on accurate neutron interaction cross sections. Uncertainty in these data can lead to affect design predictions and undermine reactor performance.

In addition to magnet protection, STs must support efficient tritium breeding to achieve fuel self-sufficiency. Lithium-based materials, especially liquid lithium, are potential candidates for breeding blankets. For these to function optimally, the structural materials must allow effective neutron penetration while maintaining mechanical integrity. Vanadium, iron, and chromium alloys are being proposed. Accurate prediction of TBR and in-blanket heating depends on precise nuclear data, particularly for high-energy neutron interactions.

**3. Critical Nuclear Data Needs**

Accurate cross section data are the foundation of reliable simulation and design in spherical tokamaks. These include data for neutron scattering, absorption, activation, transmutation, and gas production. A notable gap exists in reaction channels such as 12C(n,n’2α)4He, which significantly affects helium inventory predictions and impacts simulation accuracy for diagnostic tools like diamond detectors. Furthermore, inconsistencies in widely used libraries like FENDL-3.1, ENDF-VIII, and TENDL-19 highlight the need for better alignment with experimental data.

Composite materials used in HTS magnets and advanced shielding solutions also require comprehensive nuclear data. For example, the boron and hafnium-based materials currently being evaluated show cross section discrepancies in the 1 to 12 MeV range. These inconsistencies can alter the predicted performance of shielding structures and necessitate further experimental validation.

Post-shutdown analysis, including decay heat and activity levels, is another domain reliant on accurate nuclear data. Disparate results between data libraries can lead to inconsistent waste categorization and maintenance planning. A major limitation is that the FENDL library is not currently available in a format compatible with the FISPACT simulation tool, which creates further challenges in uniform assessment and planning.

**4. Future Directions and Considerations**

There is a need to enhance the nuclear data infrastructure supporting spherical tokamak development. This includes improvements in the processing of raw nuclear data for predicting dpa, gas production, and heating using tools like NJOY, which can impact the accuracy of design predictions. There is also potential to expand existing libraries to include high-energy electron cross sections, enabling simulation of phenomena such as runaway electron impacts within the ST environment.

**5. Conclusion**

The development of spherical tokamaks as a practical fusion energy solution depends on the availability of high-fidelity nuclear data. Every major design decision—from shielding selection to tritium breeding and HTS magnet protection—relies on precise understanding of neutron interactions. Addressing the current data gaps and improving cross section validation will play a decisive role in achieving reliable, safe, and efficient operation of next-generation fusion reactors.