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Verification of Energetic and Angular Distributions of Nuclear Fusion Products in Plasmas

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ABSTRACT

- Yields and spectra of neutrons belong to central subjects of physics of controlled fusion neutron sources and energy reactors.
- Flux densities of primary neutrons from plasma are the key parameters for the design of a fusion device.
- New analytical results have been obtained for integral angular distributions and integral energetic distributions of nuclear fusion products in plasmas with general anisotropic distributions of fuel nuclei velocities.

BACKGROUND

- An important component of the ongoing works on the physics basis of controlled fusion systems, including neutron sources, is the development of verification methods for all mathematical models involved.
- Analytical results concerning the calculated quantities and the underlying mathematical relationships can serve as reliable verification methods.
- New analytical results have been obtained representing an independent formula for the total angular distribution of fusion product particles in plasma, integrated over all kinetic energies, as well as an independent formula for the total energetic distribution of fusion product particles in plasma, integrated over all emission angles.

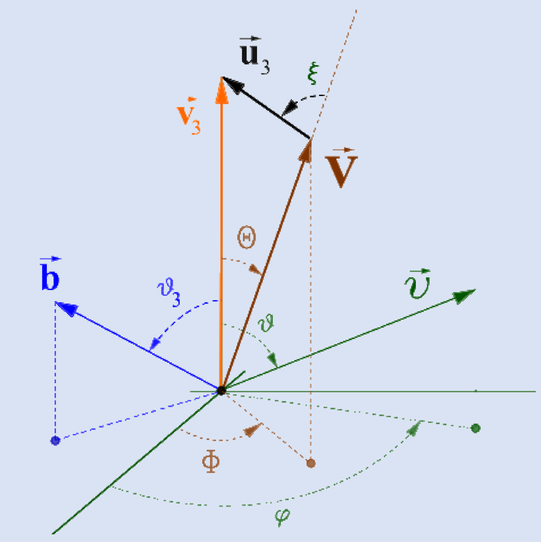
METHODS / IMPLEMENTATION

TOTAL ANGULAR DISTRIBUTION

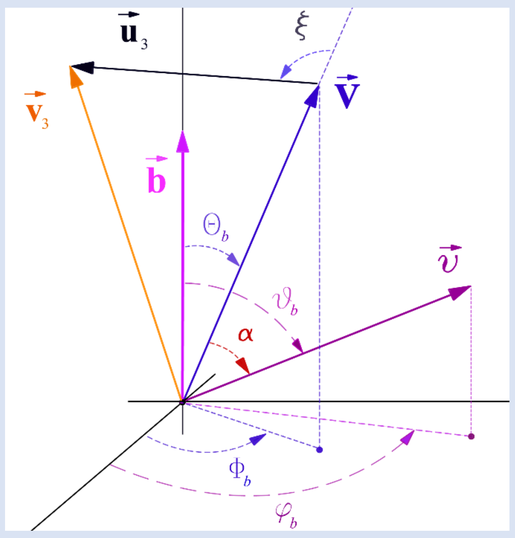
$$\frac{d\mathcal{R}_{12}}{d\Omega_3}=\int_0^{\infty}\upsilon^3 d\upsilon\int_0^{\pi}\frac{d\sigma(\upsilon,\xi)}{d\Omega_{C.M.}}\sin\xi d\xi\int_0^{\infty}\mathrm{V}^2 d\mathrm{V}\int_0^{\pi}\sin\vartheta d\vartheta\int_0^{2\pi}d\varphi\int_0^{2\pi}d\Phi\ f_1(\mathrm{v}_1,\vartheta_1)f_2(\mathrm{v}_2,\vartheta_2)$$

TOTAL ENERGETIC DISTRIBUTION

$$\frac{d\mathcal{R}_{12}}{dE_3}=\frac{4\pi^2}{m_3}\int_0^{\infty}\mathrm{V}d\mathrm{V}\int_0^{\infty}\frac{\upsilon^3 J(\mathrm{V},\upsilon)}{\mathcal{L}(\upsilon)}\frac{d\sigma(\upsilon,\xi)}{d\Omega_{C.M.}}d\upsilon\int_0^{\pi}\sin\Theta_b d\Theta_b\int_0^{\pi}\sin\vartheta_b d\vartheta_b\int_0^{2\pi}f_1(\mathrm{v}_1,\vartheta_1)f_2(\mathrm{v}_2,\vartheta_2)d\varphi_b$$



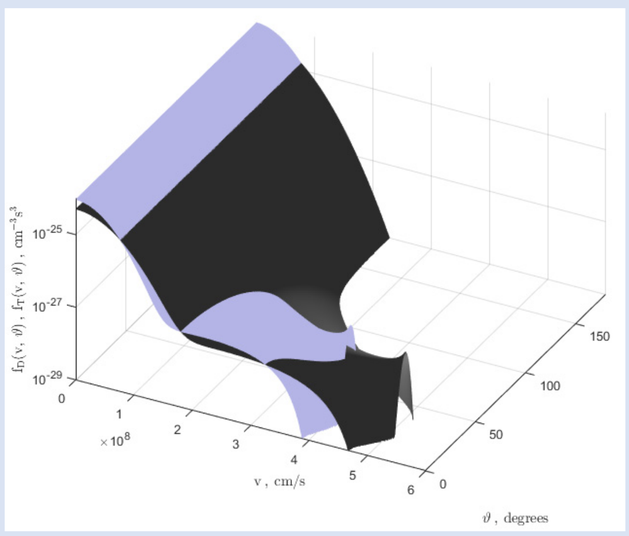
Integration variables in velocity space for the total angular distribution



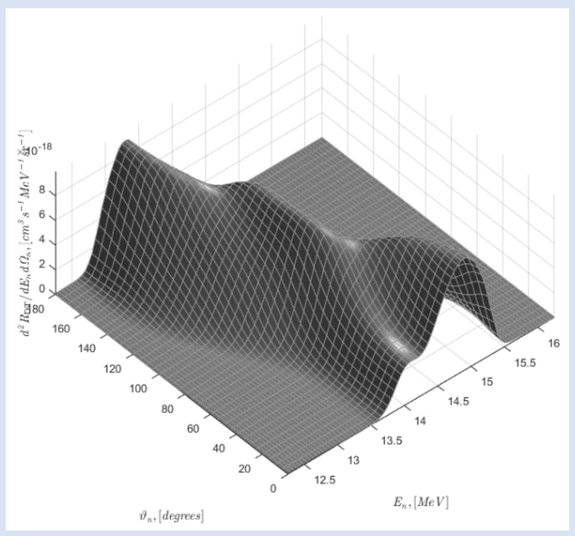
Calculation of the total energy distribution of fusion products

OUTCOME

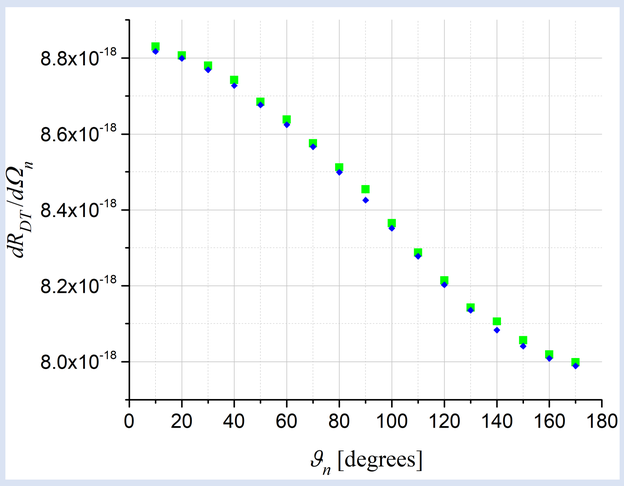
The essence of the achieved verification capability is that the total angular distribution of fusion products, calculated using the obtained independent formula, should coincide with the result of numerical integration of the calculated double differential reaction rate coefficient over the entire range of kinetic energies of fusion products. Analogously, the total energetic distribution of fusion products, e.g. the integral neutron spectrum, calculated using the obtained independent formula, should coincide with the result of numerical integration of the calculated double differential reaction rate coefficient over the entire range of emission angles of fusion products.



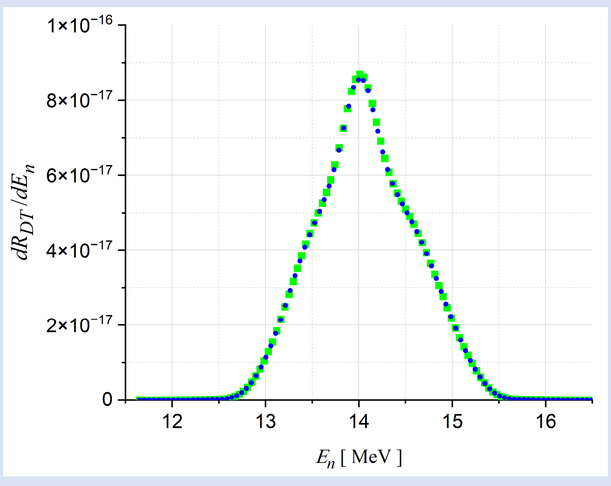
Velocity distributions of deuterons (dark) and tritons (light)



Double differential rate coefficient of the DT reaction



Verification of the integral angular distribution of neutrons



Verification of the integral energy spectrum of neutrons

CONCLUSION

- Verifications of the double differential nuclear fusion reaction rate coefficients have been performed using independent explicit general analytical formulae for the integral angular distribution and for the integral energetic distribution of nuclear fusion products in plasma.
- The obtained general results primarily described for the case of neutral beam heated tokamak plasmas are readily applicable for the modelling of fusion products in other configurations including stellarator/heliotron plasmas and inertially confined plasmas.

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