Low-Energy DD Fusion in Metallic Targets: Role of the 0^+ Resonance and Background Characterization in Terrestrial-Laboratory Measurements*

Gokul Das H[1], Sreelakshmi T[1], R. Dubey[1], K. Czerski[1], M. Kaczmarski [1], A. Kowalska [2], N. Targosz–Ślęczka [1], and M. Valat[1]
[1] *Institute of Physics, University of Szczecin, 70-451 Szczecin, Poland and*
[2] *Institute of Mathematics, Physics and Chemistry, Maritime University of Szczecin, Poland*

Deuteron-deuteron fusion is important for both future energy applications and understanding energy production in dense astrophysical environments such as giant planets, brown dwarfs, and white dwarf supernova progenitors [1]. The charged particle-induced nuclear reaction cross sections at lower energies drop exponentially due to the Coulomb barrier. However, systematic experimental studies have demonstrated that DD fusion cross-sections are significantly enhanced in metallic environments, especially below 10 keV. This enhancement is attributed to strong electron screening effects in metals [2]. Recent studies further suggest that lattice defects and the presence of impurities, such as oxygen and carbon, in the metallic substrate can significantly influence the magnitude of this electron screening energy [3][4].

It was recently shown that, in addition to electron screening, a narrow 0^+ threshold resonance in the ^{4}He nucleus significantly enhances the DD fusion reaction rate at very low energies [5]. This single-particle resonance decays via Internal Pair Creation (IPC), emitting e^- - e^+ pairs with energies up to 22.84 MeV. In experiments at the Ultra High Vacuum (UHV) accelerator facility of the University of Szczecin, these electrons were detected using thin silicon detectors [6]. Additionally, 511 keV annihilation photons and bremsstrahlung radiation from the pairs were observed using HPGe and large-volume NaI(Tl) detectors [7]. The partial absorption peak produced by these high-energy e^- - e^+ pairs in silicon detectors was compared with detector response functions generated using Geant4 Monte Carlo simulations and the electron-to-proton branching ratio was determined for projectile energies down to 6keV. These results indicate a ratio of 15 at thermal energies, emphasizing the need for measurements at extremely low projectile energies, close to the reaction threshold.

At very low projectile energies, the exponentially falling DD fusion cross section leads to a significant reduction in the number of fusion and hence IPC events. In this scenario, the precise background characterisation in the detector response function is crucial for the branching ratio calculations. Natural radiation and cosmic ray showers were identified as dominant sources and simulated using Geant4, with cosmic rays modelled via the Cosmic RaY (CRY) library. Thin silicon detectors in a Δ E -E configuration were used to suppress the background. This work offers a benchmark for surface-laboratory experiments and supports future underground measurements.

[1] S. Ichimaru *et al.*, Physics of plasmas **6** (1999) 2649.
[2] F. Raiola *et al.*, Eur. Phys. J. **B 624** (2005) 181.
[3] A. Kowalska *et al.*, Materials **16** (2023) 6255.
[4] A. Kowalska *et al.*, Materials **18** (2025) 1331.
[5] K. Czerski *et al.*, Phys. Rev. C (Letters) **L011601** (2022) 106.
[6] K. Czerski *et al.*, Phys. Rev. C (Letters) **L021601** (2024) 109.
[7] R.Dubey *et al.*, arXiv:**2408.07567** (2024) [nucl-ex]
[8] H.Gokul Das *et al.*, Measurement **114392** (2024) 228.

*This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 951974.