

Experimental Detection of Charged Fusion Products in a Compact Electron-Catalyzed Fusion System Using Calibrated CR-39 Diagnostics

Key Results and Impact: This study presents a systematic investigation and experimental validation of charged fusion product detection using CR-39 solid-state nuclear track detectors (SSNTDs) in Alpha Ring's compact electron-catalyzed fusion (ECF) system. Over 1,400 CR-39 detectors—including both test and calibration coupons—were deployed and systematically calibrated using 5.486 MeV alpha particles from an Am-241 source, as well as an internally developed ion beam system¹ operating under known fusion reaction conditions. Observed tracks in fusion experiments showed consistent morphology, diameter (~8-9 μm), and depth (>25 μm) with Am-241 benchmarks, confirming the presence of energetic alpha particles and providing direct evidence for the electron-catalyzed fusion mechanism. This contributes to the field of fusion reactions in mild operating conditions and supports the viability of compact aneutronic fusion systems.

Background and Motivation: Electron screening has been proposed to reduce the Coulomb barrier in fusion reactions, but empirical validation in plasma systems has been scarce. Our study addresses this gap through the detection of p-B11 and D-D fusion products in an ECF reactor that uses LaB6 thermionic emission and electron-ion two-stream instability to form potential wells that enhance local fusion probability.

Methodology: TASL-manufactured CR-39 detectors (2.0×2.5 cm) were used and calibrated via a vacuum-compatible Am-241 source setup under matched experimental conditions. Calibration included direct and attenuated exposures (1.397–5.486 MeV) using aluminum foil and depth profiling through progressive etching in 6 M NaOH at 90 °C. Pre- and post-experiment alpha exposures on each coupon ensured detector stability. Semi-automated imaging using a TASL Auto Microscope and ImageJ software enabled large-scale image stitching, morphological analysis, and AI-assisted particle identification.

Principal Observations:

- Over 6000 fusion shots were performed. Track densities ranged from 50 to 700/cm².
- Post-etch diameters and depths from plasma-exposed CR-39 matched Am-241 calibration tracks.
- No comparable tracks were found in control or blank runs.
- Using rigorous controls—including surface artifact exclusion, background test, vacuum sensitivity tests, and calibration under matched etching conditions—effectively ruled out alternative explanations, supporting their origin as energetic charged fusion product.
- Thermocouples validated that CR-39 and Kapton remained structurally stable during plasma discharges.

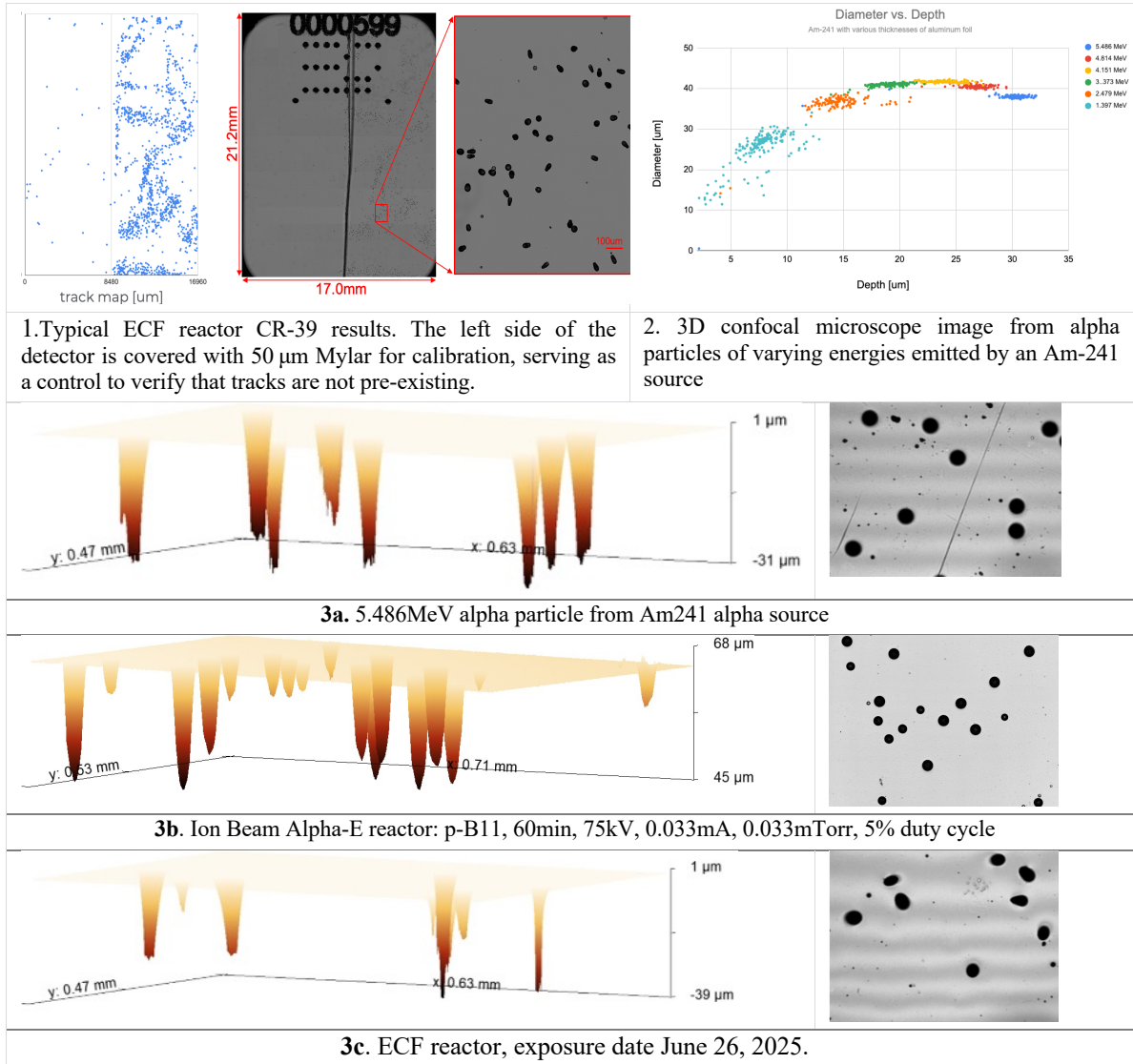
Additional Calibration Measures: A vacuum chamber with extension matched source-to-detector distances, replicating plasma conditions (~10⁻⁵ Torr). Dual-point Am-241 exposures on each coupon verified pre- and post-exposure morphology. Controlled angle-of-incidence studies further refined interpretation of non-normal tracks. Attenuation experiments showed a clear peak in track diameter at 4.151 MeV and consistent decrease at lower energies, supporting energy discrimination.

Vacuum Sensitivity and Thermal Tolerance: Vacuum exposure tests (0.5–160 hours) confirmed CR-39 stability under standard 4-hour experimental vacuum conditions. Thermal analysis using embedded thermocouples indicated <5 °C temperature rise at holders and confirmed no melting or structural degradation in CR-39 or Kapton.

AI-Based Track Classification: To address the large volume of image data, a deep learning model² was trained to distinguish alpha tracks from background with >94% accuracy. The model is capable of differentiating fusion species such as tritons, protons, and helions from D-D.

Conclusions and Significance: The systematic detection of energetic alpha particles using CR-39 diagnostics supports the presence of fusion events in the Alpha Ring ECF device. Through rigorous calibration, validation, and control experiments, this work offers a reproducible diagnostic platform for low-barrier fusion studies and invites the broader fusion research community to collaborate in advancing compact, aneutronic fusion approaches.

Figures:



3. 3D image captured using a Keyence confocal microscope. Comparison between 5.486 MeV alpha particles from an Am-241 source and those observed in Alpha-E fusion experiments.

References:

- [1] A.X. Chen, B. F. Sigal, J. Martinis, A.Y. Wong, A. Gunn, M. Salazar, N. Abdalla, K.J. Xiao. Performance Characteristics of the Battery-Operated Silicon PIN Diode Detector with an Integrated Preamplifier and Data Acquisition Module for Fusion Particle Detection. *Journal of Nuclear. Engineering*, 2025, 6(2), 15.
- [2] Y. Wang, A. X. Chen, M. Salazar, N. Abdalla, Z. Li, and B. Wrixon, "Deuterium–deuterium fusion charged particle detection using CR-39 and deep learning model," *Radiation Measurements*, vol. 185, p. 107444, 2025.