

# Statistical and Mechanistic Characterization of DDT Onset in Hydrogen–Air Explosions at Atmospheric Conditions

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## 1 Work-in-Progress Poster Synopsis

The experimental setup follows the geometry described in [1]. Homogeneous premixed hydrogen-air mixtures ( $\phi = 0.8 - 1.6$ ) at atmospheric conditions were ignited at the closed end by a low-energy spark source, and synchronized high-speed imaging together with four pressure transducers (PS1–PS4) recorded flame speeds and overpressures. This work contributes directly to hydrogen-safety research by providing pressure and flame-front analyses from a dataset of 200 experiments, aimed at improving understanding of deflagration-to-detonation transition (DDT) hazards in partially confined hydrogen–air systems.

Deflagration-to-detonation transition (DDT) occurred predominantly within a narrow equivalence-ratio window ( $\phi = 1.0 - 1.2$ ), peaking at  $\phi = 1.1$  with a 48% transition probability. Low-frequency DDT events were also recorded at  $\phi = 1.3$  and  $\phi = 1.4$  (each  $< 10\%$  probability). The inherently stochastic nature of the transition process is evident not only in the frequency statistics but also in the qualitative variations of the DDT mechanism captured by high-speed imaging. Outside this reactivity range, no sustained detonations were observed, highlighting the critical role of mixture reactivity in enabling the rapid energy release required for DDT. Run-up distances to detonation onset clustered between 620 mm and 800 mm, shortest at  $\phi = 1.1$ , reflecting induction-time sensitivity.

A non-parametric Mann–Whitney U test of peak pressures indicates that downstream sensors (PS3, PS4) robustly distinguish between DDT and non-DDT events ( $p < 10^{-4}$ , Cohen's  $d > 1.5$ , rank-biserial  $|r| > 0.8$ ), whereas PS1 provides moderate early indication ( $p \approx 10^{-5} - 10^{-4}$ ,  $d \approx 1.0$ ) and PS2 fails to separate the two regimes ( $p > 0.1$ ,  $d < 0.2$ ). Thus, PS3/PS4 serve as definitive confirmation of detonation, while PS1 offers limited pre-event warning.

High-speed shadowgraph and luminosity sequences reveal a multi-stage DDT mechanism: an initial central “hot spot” forms just downstream of the obstacle array and accelerates locally before decaying; a secondary ignition event near the channel walls generates transverse shock interactions and Mach stems; these coalesce into a planar, self-sustained detonation front.

## References

- [1] M. Henriksen et al. “Numerical Study of Premixed Gas Explosion in a 1-m Channel Partly Filled with 18650 Cell-like Cylinders with Experiments”. In: *Journal of Loss Prevention in the Process Industries* 77 (July 2022), p. 104761. ISSN: 09504230. DOI: 10.1016/j.jlp.2022.104761.