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Changing the World's Energy Future

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# Challenging Common Assumptions of Thick-Wall Chamber Dynamics in Inertial Fusion Systems Using MOOSE-based Multiphysics Simulations

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## Introduction

The breakthrough at the National Ignition Facility put the spotlight on the inertial fusion approach.

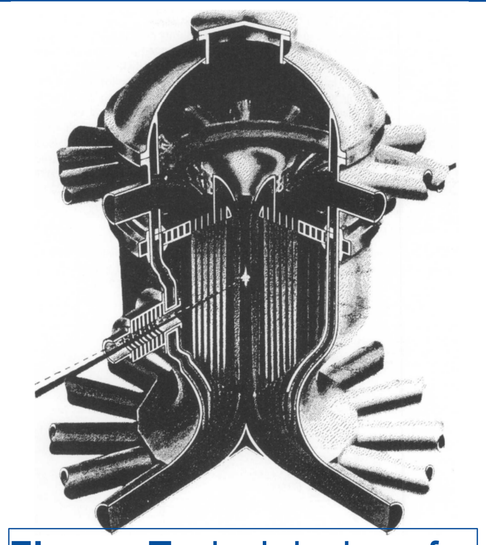


**Figure**: Typical design of a thick-wall chamber

This work focuses on a specific **Inertial Fusion Energy** (IFE) design and aims to **understand the physics of thick-wall chamber dynamics**.

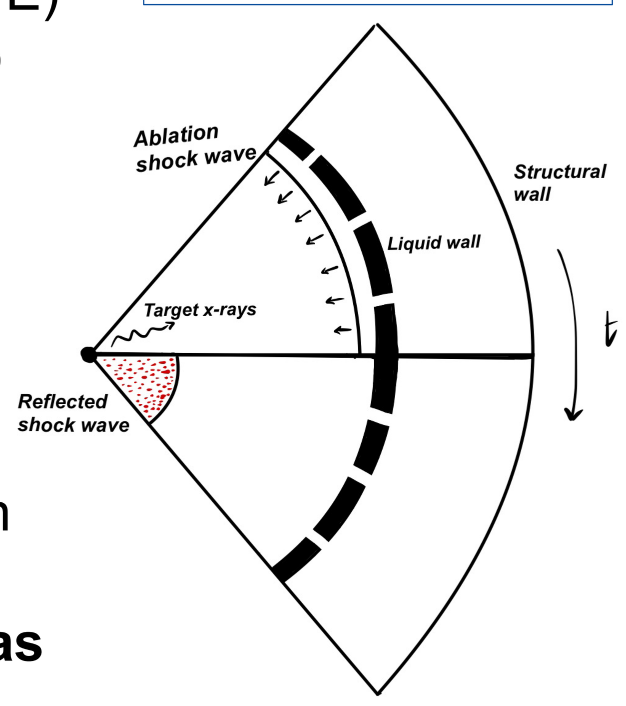



**Figure**: Schematics of the gas dynamics within the chamber

The modeling challenge stands in understanding the **behavior of the gas ablated off the liquid wall** by the x-rays emitted upon target ignition.

**Metrics of engineering significance**:
1. Momentum transfer to the liquid wall
2. Chamber clearing

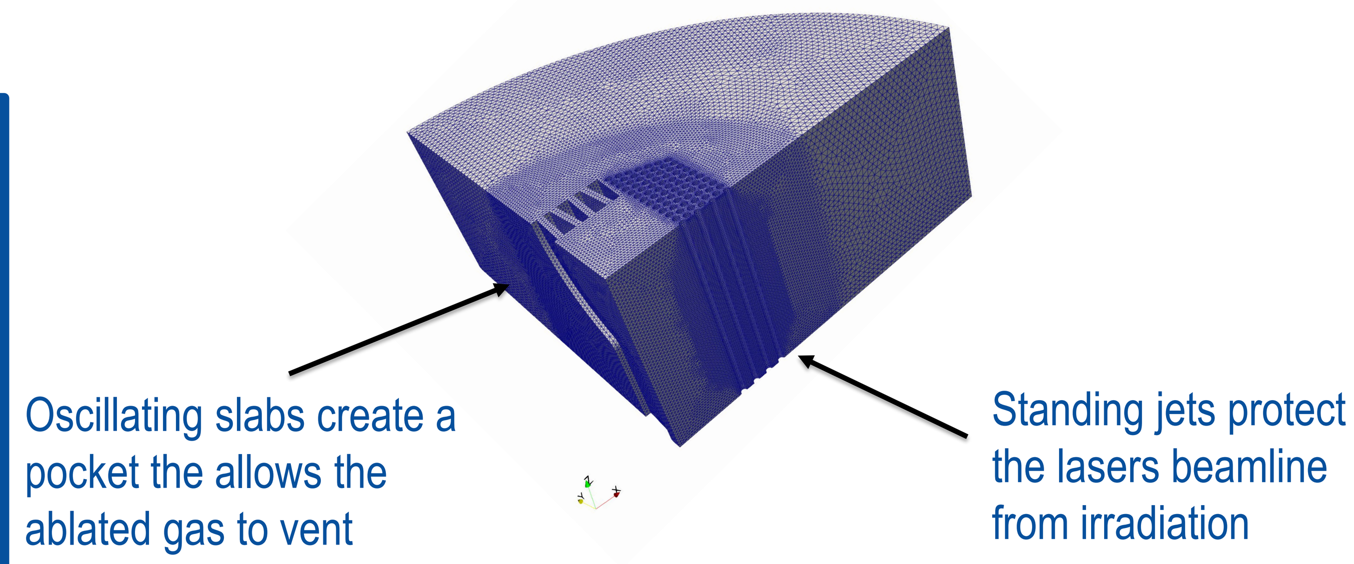



**Figure**: 3D mesh employed to represent 1/8th of the chamber.

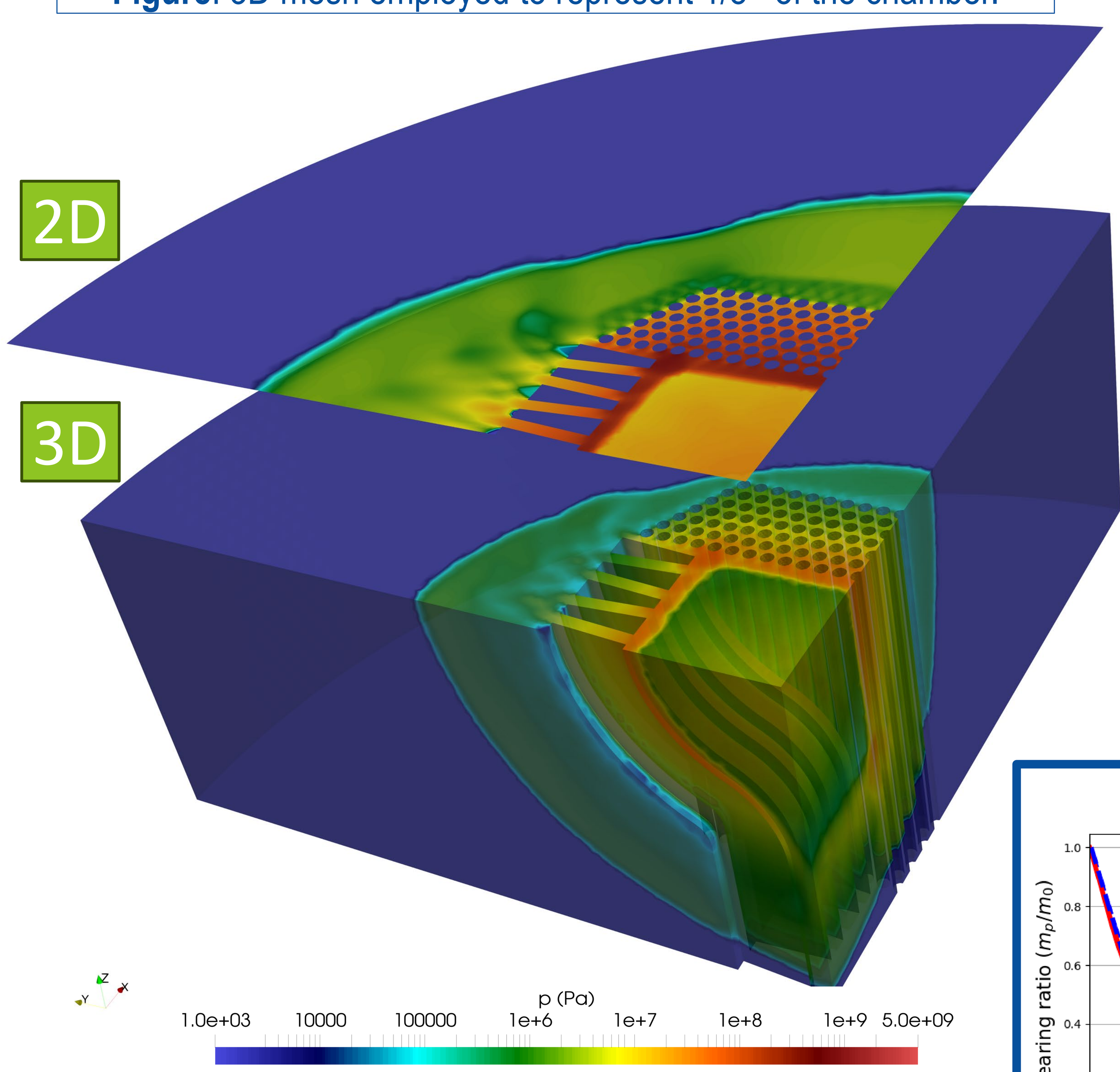
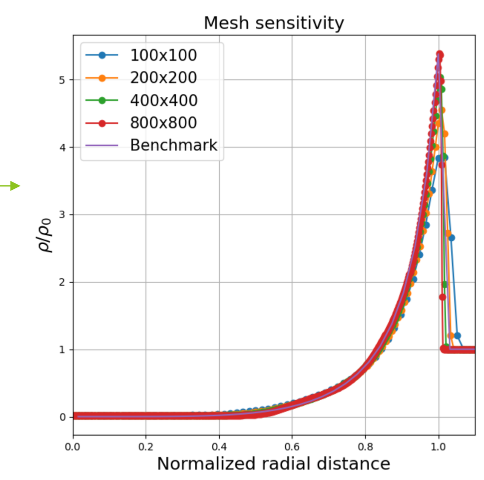



**Figure**: Comparison of pressure contour between a 2D and 3D case.

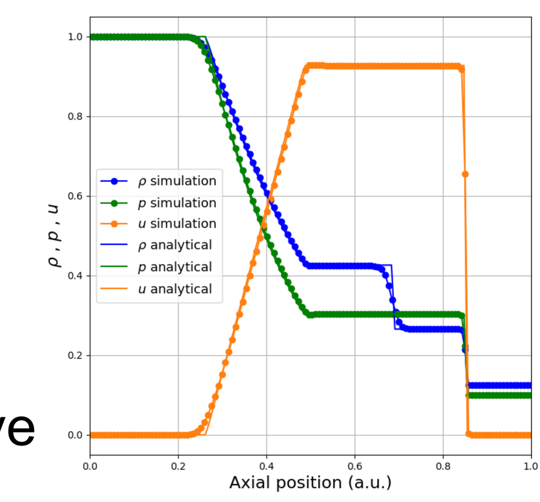
## Modeling approach and verification

Existing **MOOSE** capabilities were verified and extended.

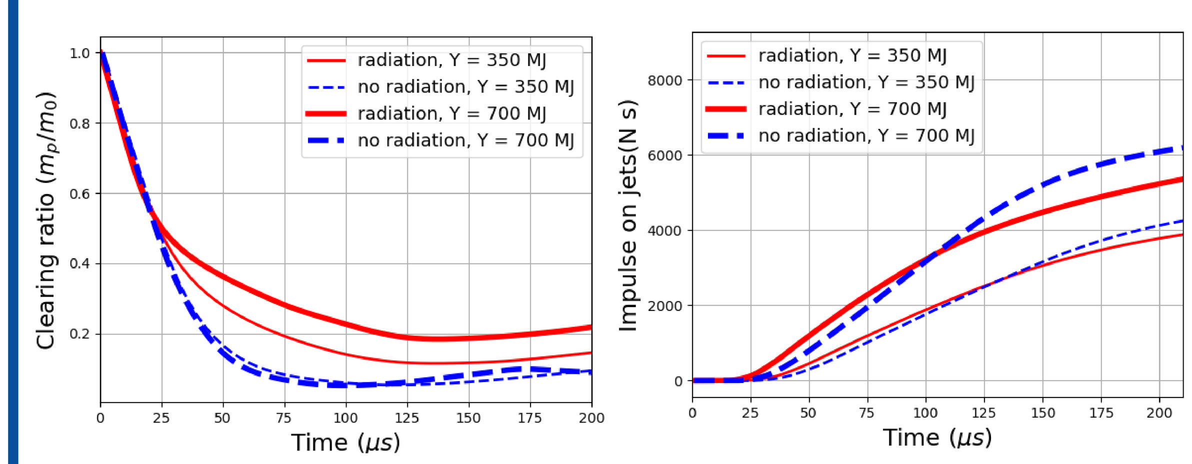
**Verification**
- Sedov blast-wave problem
- Sod shock-tube problem




**Coupling**
- Multi-App system within the MOOSE framework.
- Semi-implicit source/sink term to improve stability.

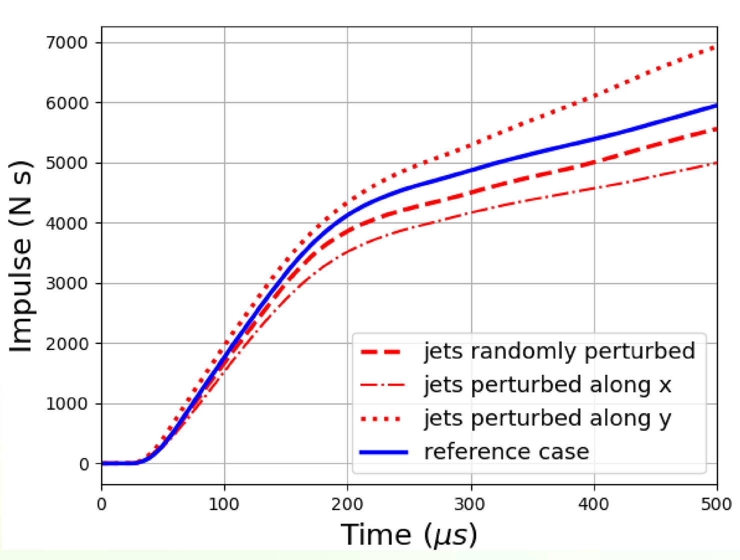


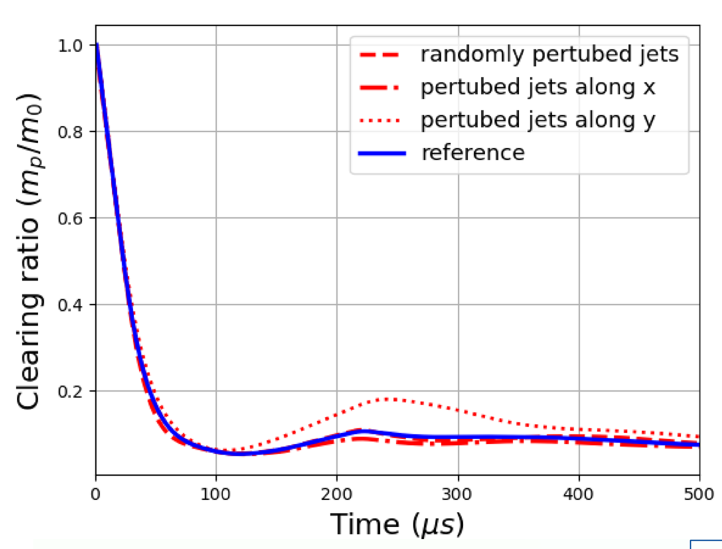

## Impact of radiation heat transfer

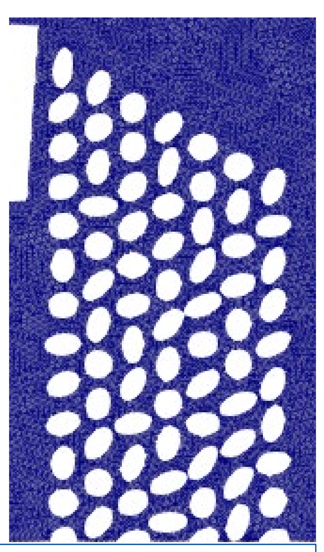



**Results:**
- Radiation slows down the chamber clearing process because of the additional energy dissipation mechanism.
- The lower temperature associated with an emitting gas leads to a lower speed of sound and a weaker shock-wave. The effects is larger when the target yield increases.

## Impact of model dimensionality and jet geometry perturbation

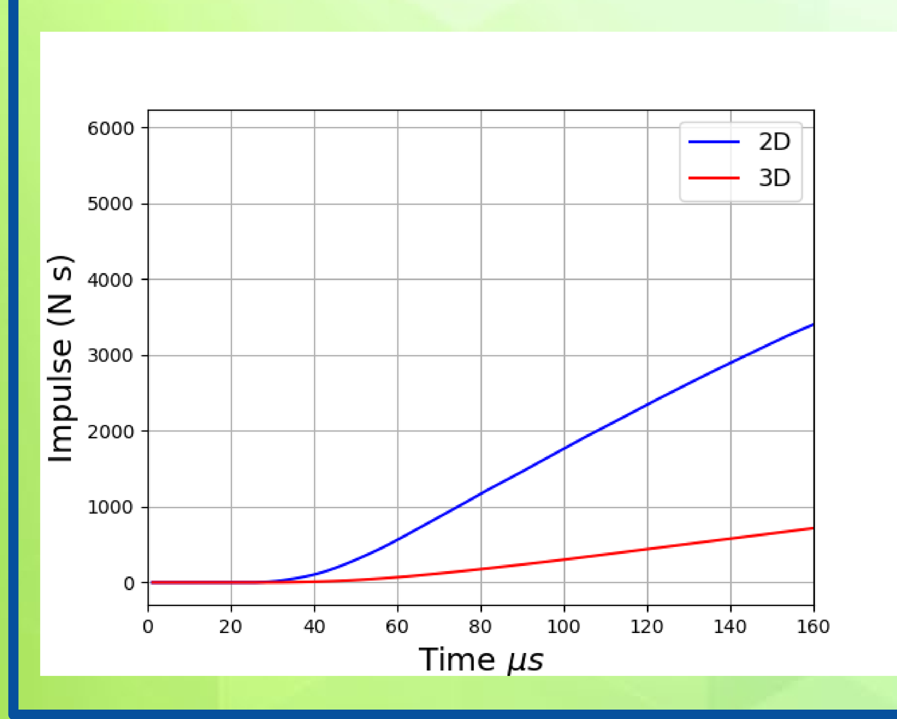


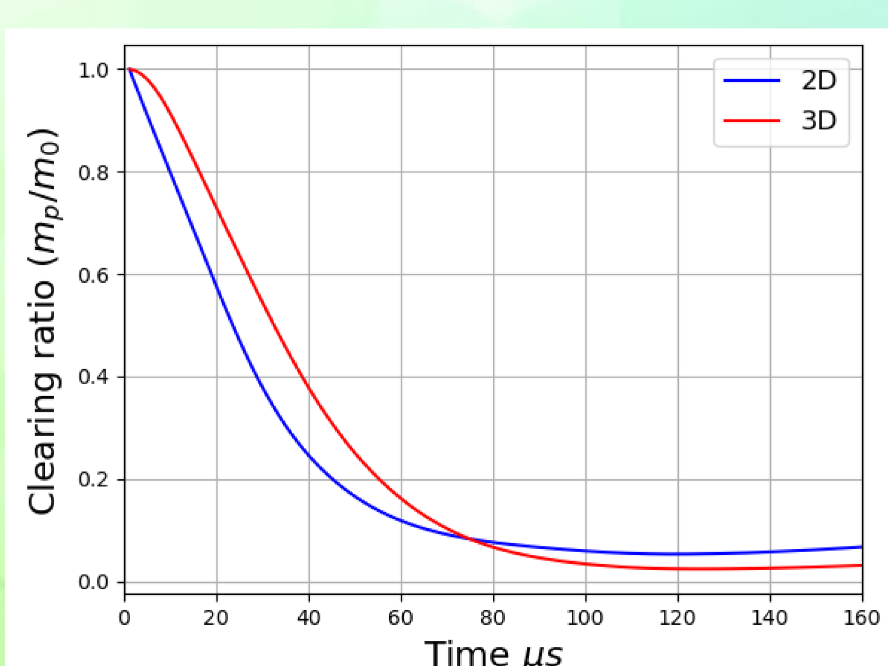



Zoom on the mesh employed for the case involving randomly perturbed jets.

**Results:**
- For **randomly perturbed** jets, **effects cancel out**.
- When the **jets are stretched in the direction of the flow** (x), the drag force decreases, and the **clearing is slightly more effective**.
- When the **perturbation is in the transversal direction** (y), the effective area of the jets increases, and the **clearing worsens**.
- 3D effects show that a **2D model is (overly) conservative**.




## Conclusion and future work

The following **assumptions**, commonly applied when studying chamber dynamics, were **challenged via MOOSE-based multiphysics simulations**:

1. Assumption of a fixed geometry: the jets array protecting the beam line was perturbed and the results show that the **change of shape can affect the metrics of engineering significance**.
2. A **2D model is not enough** to describe an inherently 3D problem.
3. Assuming the absence of radiation heat transfer is **not a conservative approach**.

Future work will focus on:
- Including the effect of **gas ionization** through a tabulated equation of state.
- Improving the **initial conditions** describing the reflected shock-wave.

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