



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

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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.

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

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

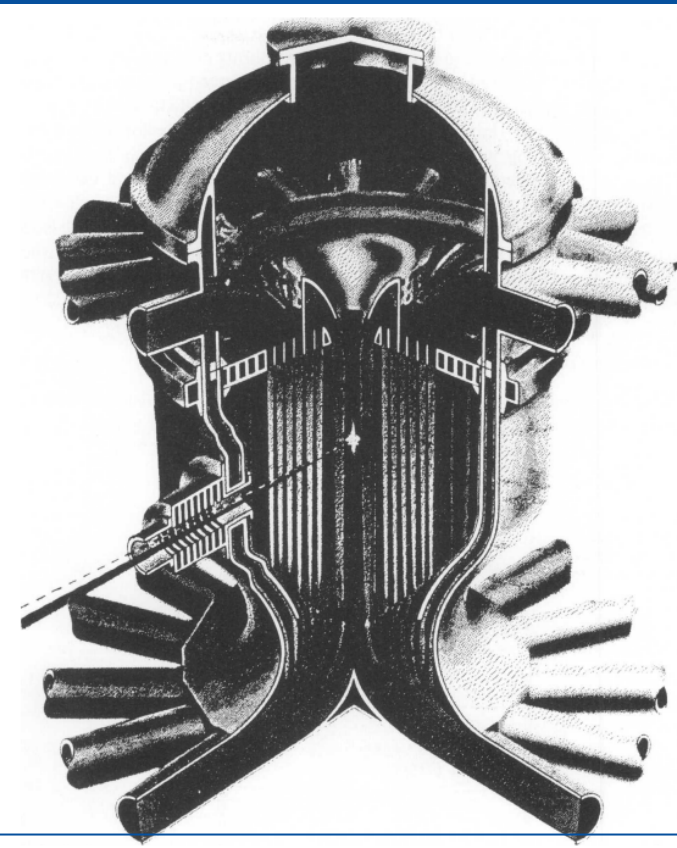


Figure: Typical design of a thick-wall chamber

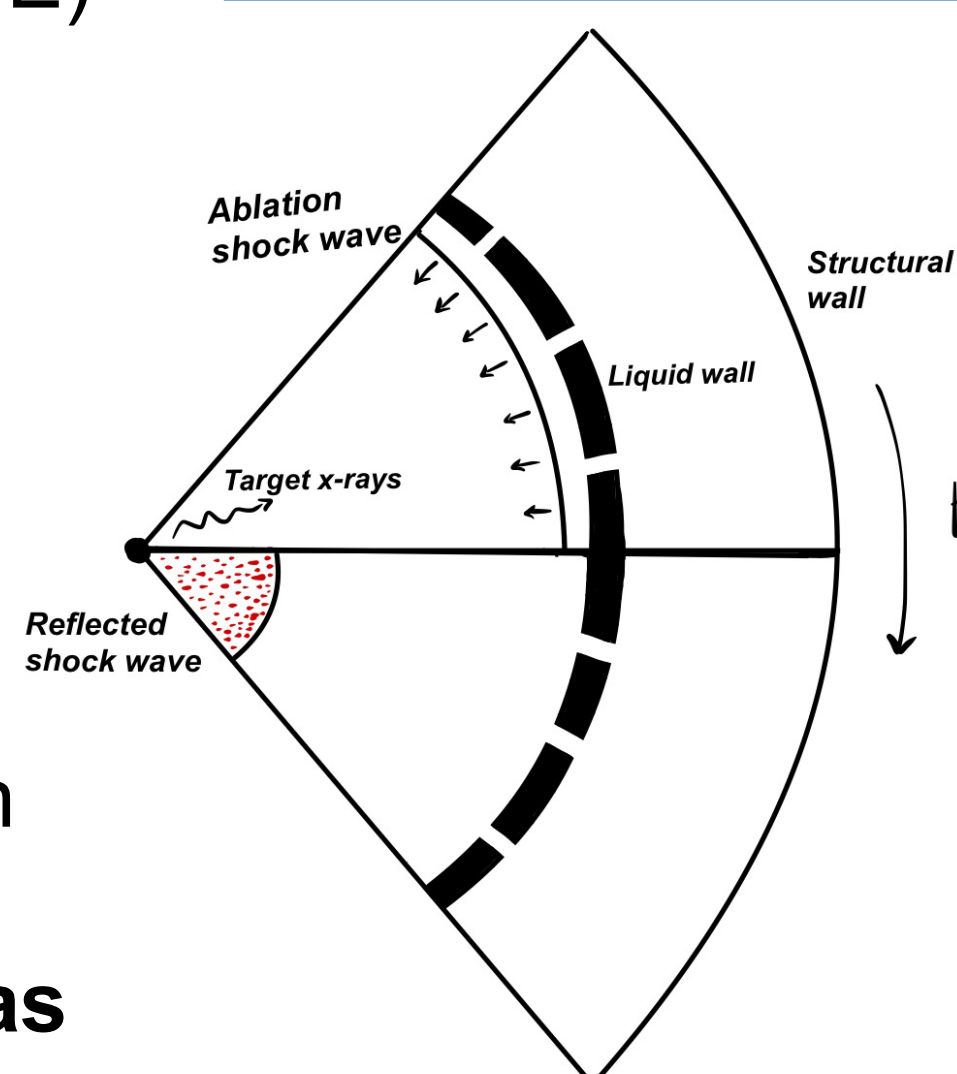
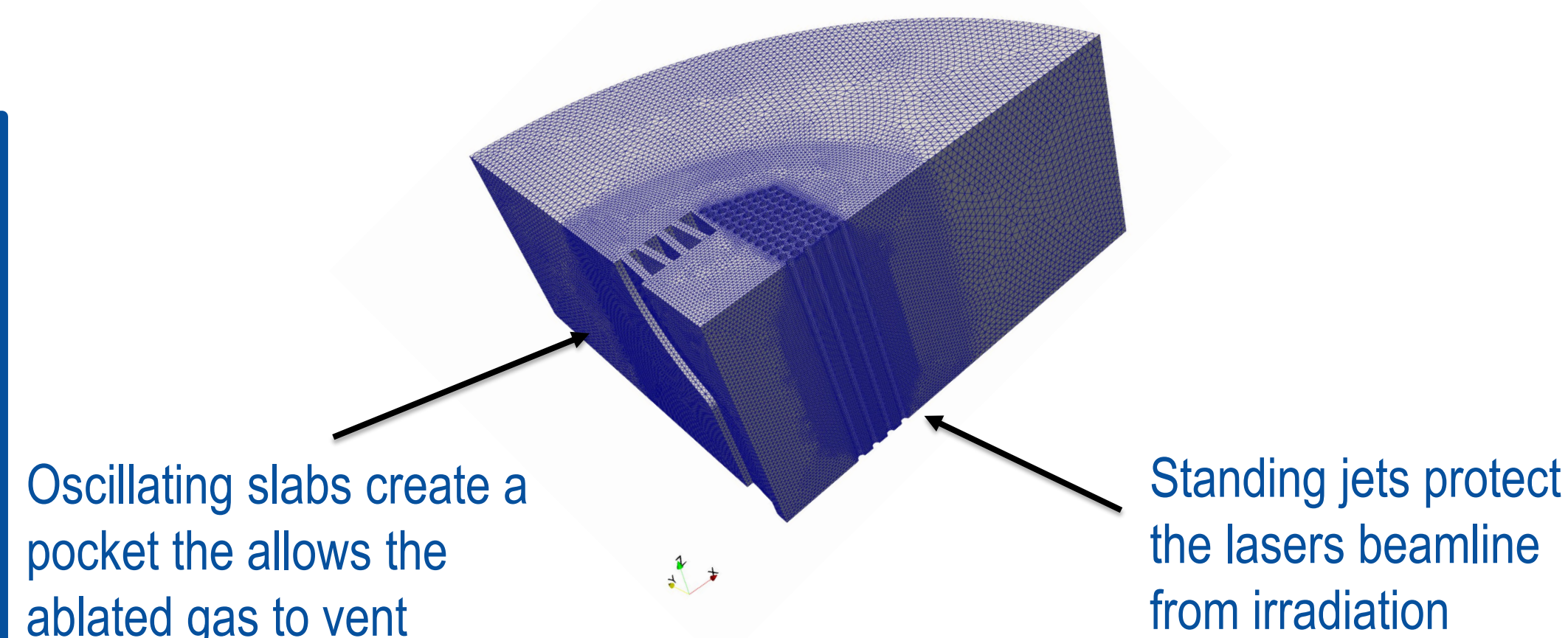


Figure: Schematics of the gas dynamics within the chamber



Oscillating slabs create a pocket that allows the ablated gas to vent

Standing jets protect the lasers beamline from irradiation

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

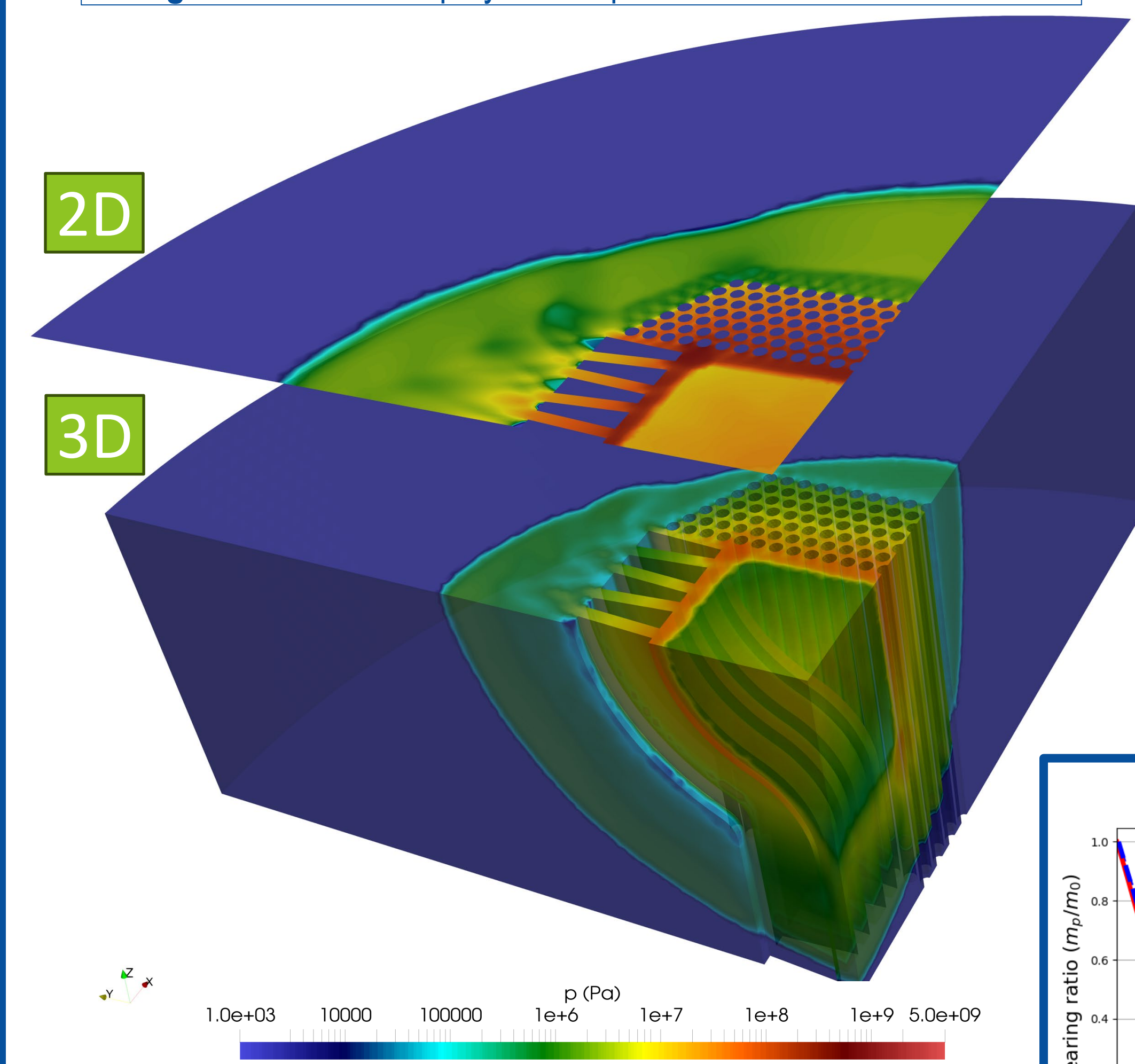


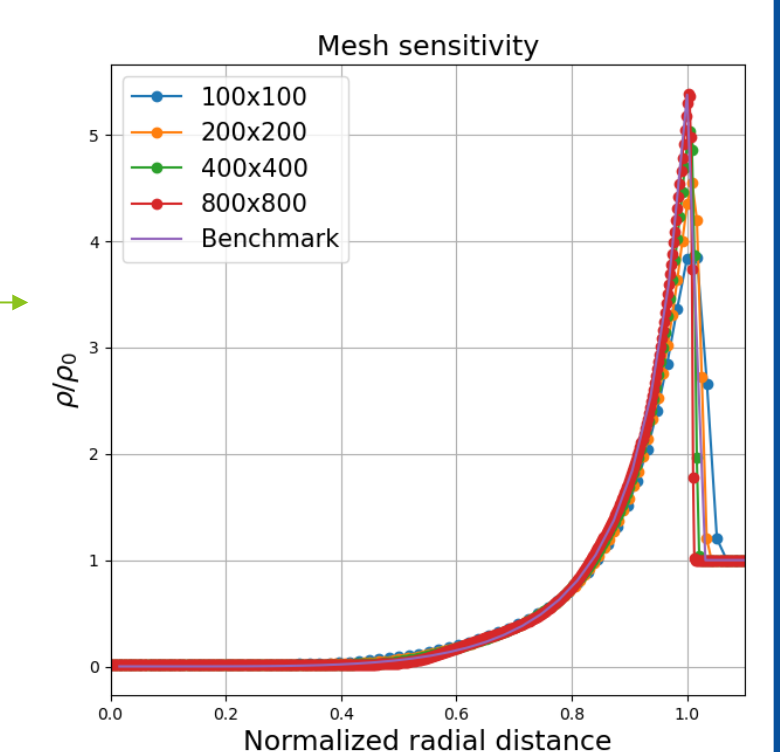
Figure: Comparison of pressure contour between a 2D and 3D case.

## Modeling approach and verification

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

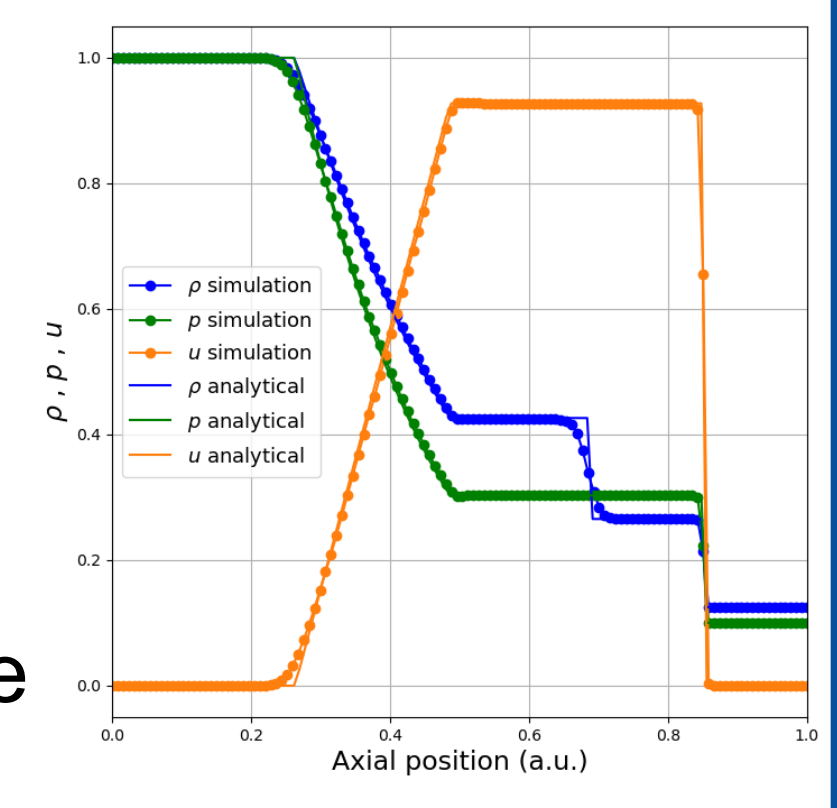
### Verification

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

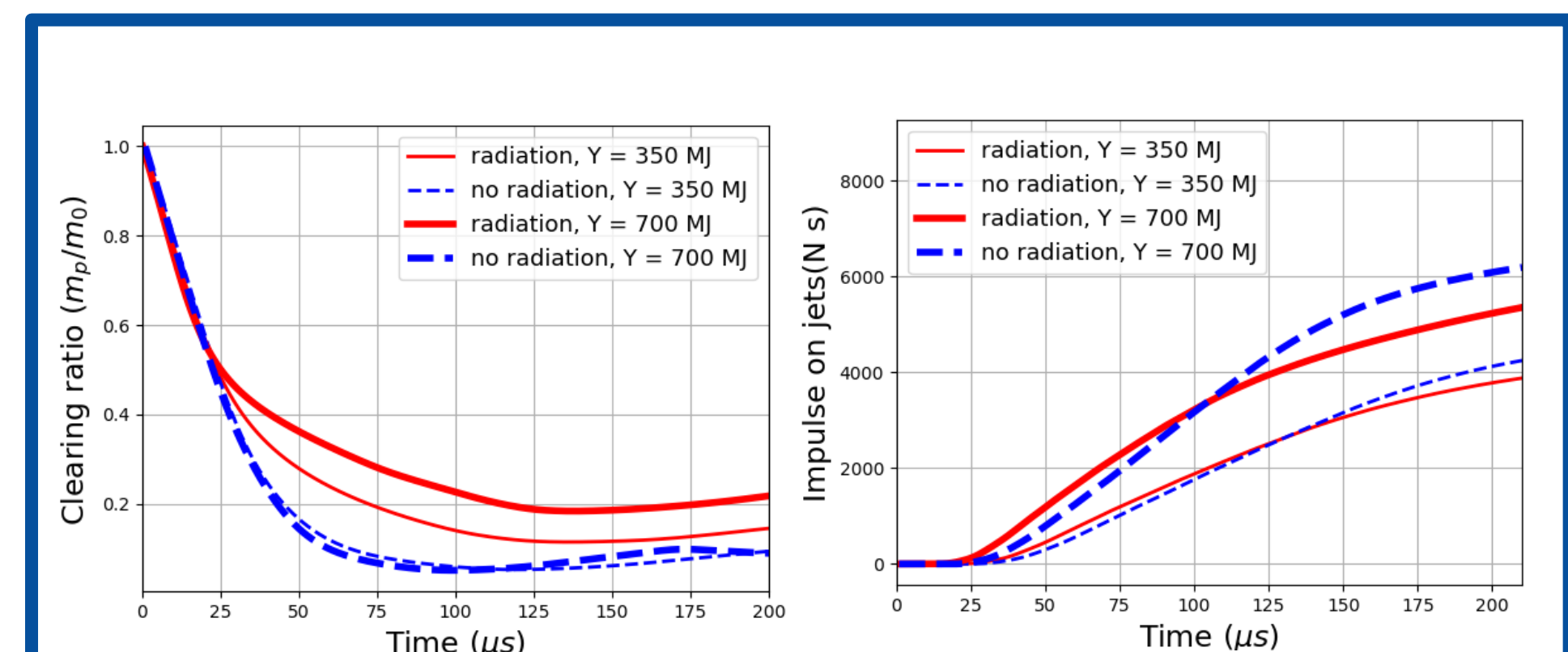


### Coupling

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



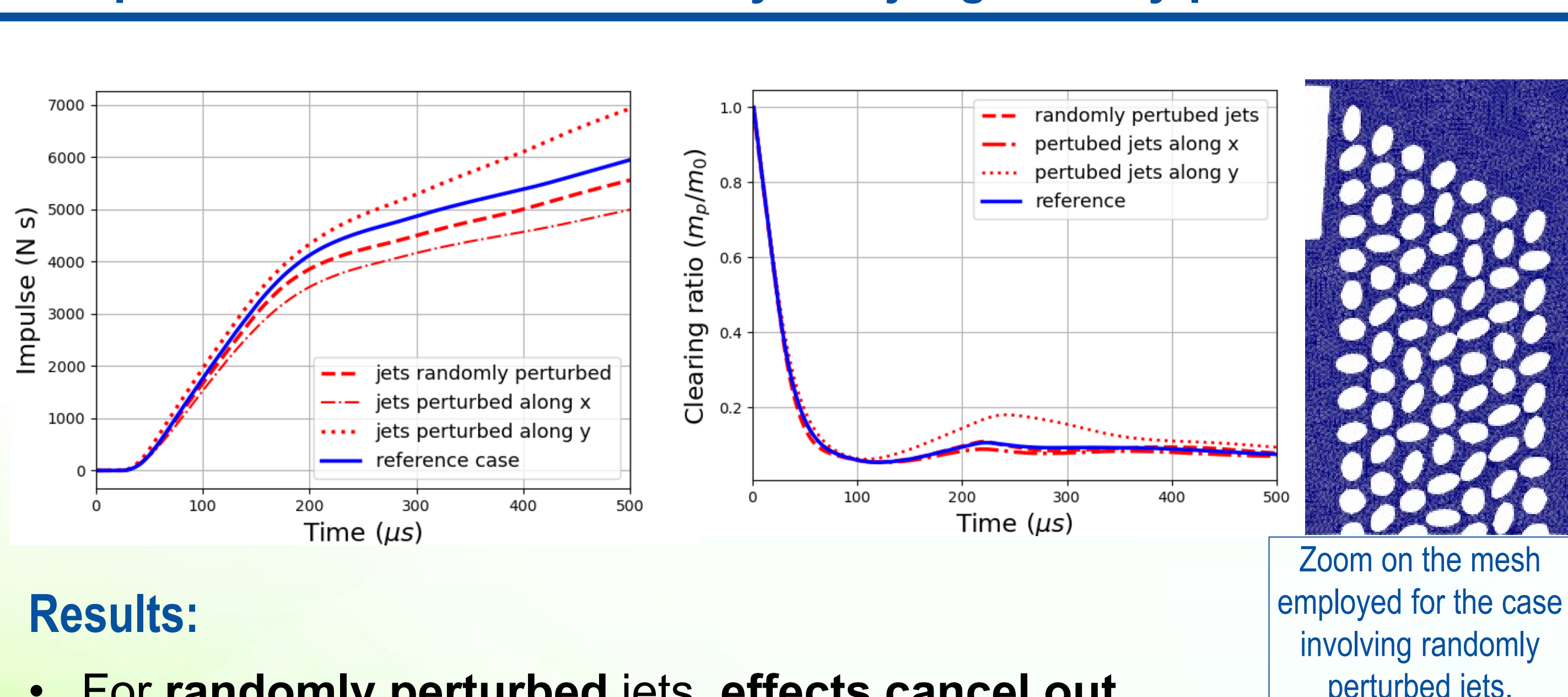
## Impact of radiation heat transfer



### 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.

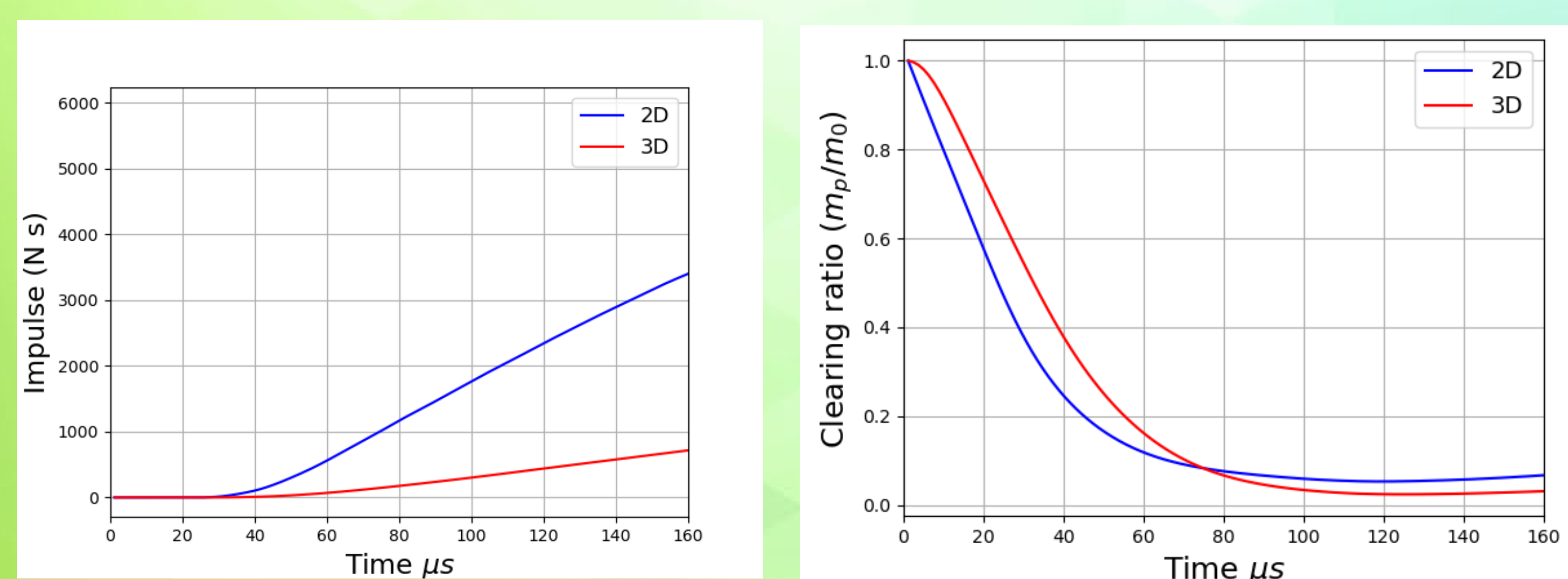
## Impact of model dimensionality and jet geometry perturbation



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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