Synthetik applied technologies
Protection Engineering CONSULTANTS

01/22/2026

# Advancing explosive safety projects through the application of computational modeling to quantify explosive effects for confined HD 1.3 events


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# Two-Briefing Overview

## What we will be covering

- Synthetik + PEC
- **Development of Enhanced Computational Modeling Tools for Confined HD 1.3 Events**
  - What you'll get: physics, numerics, validation path, readiness for safety workflows
- **Application of Enhanced Computational Modeling Tools for Confined HD 1.3 Events**
  - What you'll get: Validation examples, how this changes safety assessments and design choices

# EnergetiX: what it is (in one picture)

## Energy-to-hazard pipeline

- An open-source computational framework for **confined HD 1.3 event analysis**
- Built by extending blastFoam with models tailored to HD 1.3 phenomena
- Goal: improve predictive accuracy while staying computationally tractable

### Energy-to-hazard pipeline

Ignition → Flame Spread → Pressurization → Venting/Breach → Structural Loads

- Ignition: *+ How, where, what?*
- Flame Spread: *+ Rate of energy release*
- Pressurization: *+ Confinement matters*
- Venting/Breach: *+ Pressure relief*
- Structural Loads: *+ Time-dependent loads*

# EnergetiX: Core capability additions (high level)

## Energy-to-hazard pipeline

### Solid propellant regression modeling

- Temperature/Pressure-dependent burn laws
- Geometry-aware mass addition options
- Provides physically grounded burn-rate feedback into pressurization

### Multi-species afterburn chemistry

- Captures secondary combustion and delayed energy release
- Arrhenius-based kinetics for time-dependent chemical source terms
- Helps resolve scenarios where legacy tools under/over-predict late-time pressure

### Basic coupled structural interaction

- Simplified FSI capability for doors/hatches (rigid body dynamics)
- Predicts opening motion, changing vent area, changing pressure relief rate
- Connects internal blast to structural response timing

### 3D resolution + spatial adaptability

- Finite volume on unstructured 3D meshes
- Adaptive resolution near steep pressure gradients / flame fronts
- Practical deployment on desktop or clusters

# Workflow integration

## How engineers will use it

### 0D / 3D Options

- Select 0D (IVM) set-up
- Select full-3D simulation

### Flexible Inputs

- Structure geometry, vents, propellant, BCs

### Pre-processing Tools

- 'Default' settings
- Unique regression/afterburn

### Run Simulation

- CPU/GPU
- Desktop/cluster

### Post-processing Tools

- ParaView compatible
- Volume/surface p(t) histories for loading

# Inputs

## What matters?

- Vent size/shape + obstructions; door inertial properties + constraints
- Propellant type/ layout/geometry assumptions (regression surface area drives burn)
- Confinement leakage paths (small gaps can dominate relief)
- Chemistry settings (afterburn on/off; species set)

# Outputs

## Take into the design

- Pressure-time histories at critical locations
- Peak/impulse maps for structural load cases
- Vent performance: relief rates, choked vs unchoked flow regimes
- Breach timing & vent evolution (door motion curves)

# Where EnergetiX fits into the safety ecosystem

## Potential application to explosive safety projects

- Supports hazard classification inputs, and protective design load definition
- Built to inform defensible technical arguments aligned with DDESB expectations
- Answers “what-if” questions:
    - *“How big do vents need to be to prevent violent pressurization?”*
    - *“What loads should we design doors/walls/roof for?”*
    - *“How sensitive are outcomes to propellent type, packing density, geometry, obstructions?”*
    - *“What’s the credible envelope we can defend?”*

# EnergetiX vs. 0D/Control Volume (CV) Solvers (e.g., IVM[+])

## Key differences

- Solving compressible Navier–Stokes with additional source terms for combustion/regression/afterburn
- Resolving transient fields (mass / momentum / energy / species), not just compartment averages
- Enabling capture of "gradual-to-violent" pressure rise and mixed venting regimes
- When geometry is non-ideal, vents are asymmetric, or obstructions exist:
  - CV tools can miss localized overpressure gradients and load patterns
  - Afterburn/secondary combustion can change late-time loads
- Use EnergetiX to find "the actual hot spots" before designing mitigation

[+] https://ivm13.com/ [accessed Jan 17, 2026]

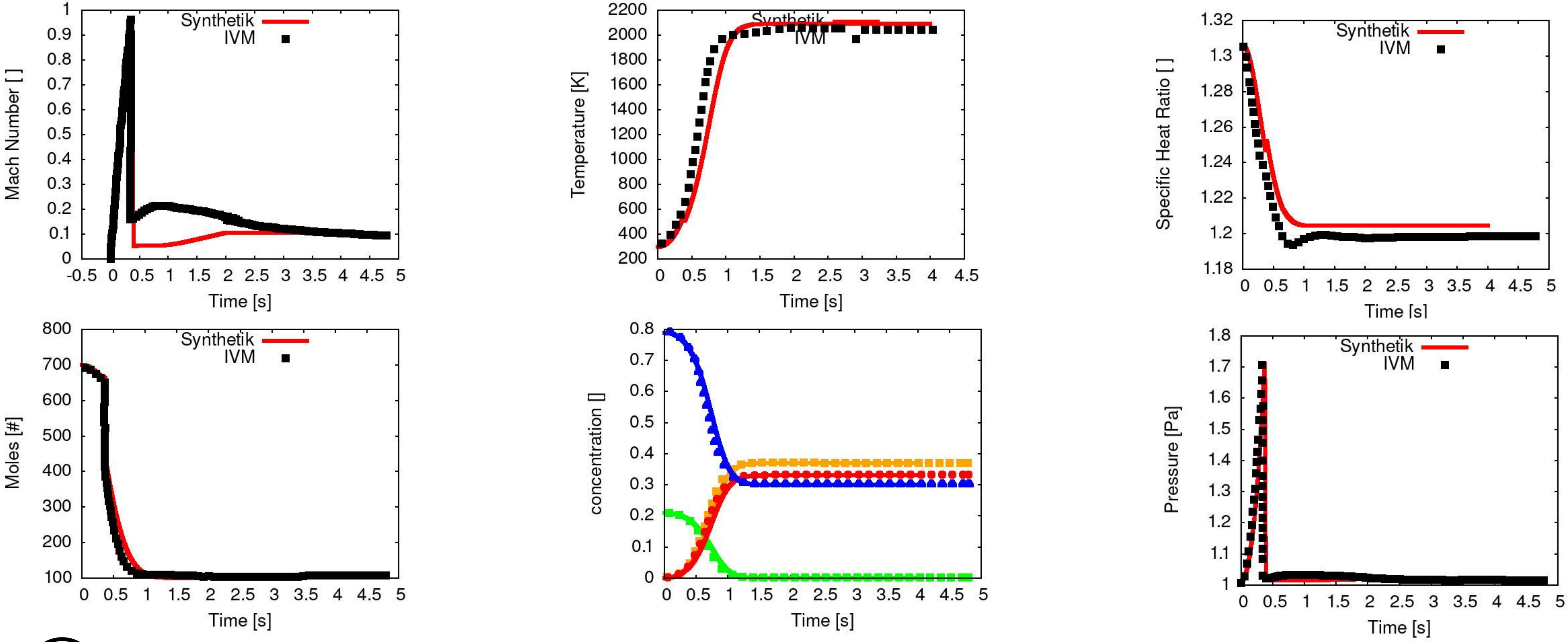
# Comparison /Benchmarking with the Integrated Violence Model (IVM)

## Can we match an 'accepted' 0D solver?

- Compare against control-volume approaches (IVM) on standard benchmark scenarios:
  - ISO container (10 barrels, 500 kg)
  - ECM (150 barrels, 7500 kg)
- **Metrics:**
  - Mach No.
  - Temperature
  - Specific Heat Ratio
  - No. of Moles
  - Specie Concentration
  - Pressure

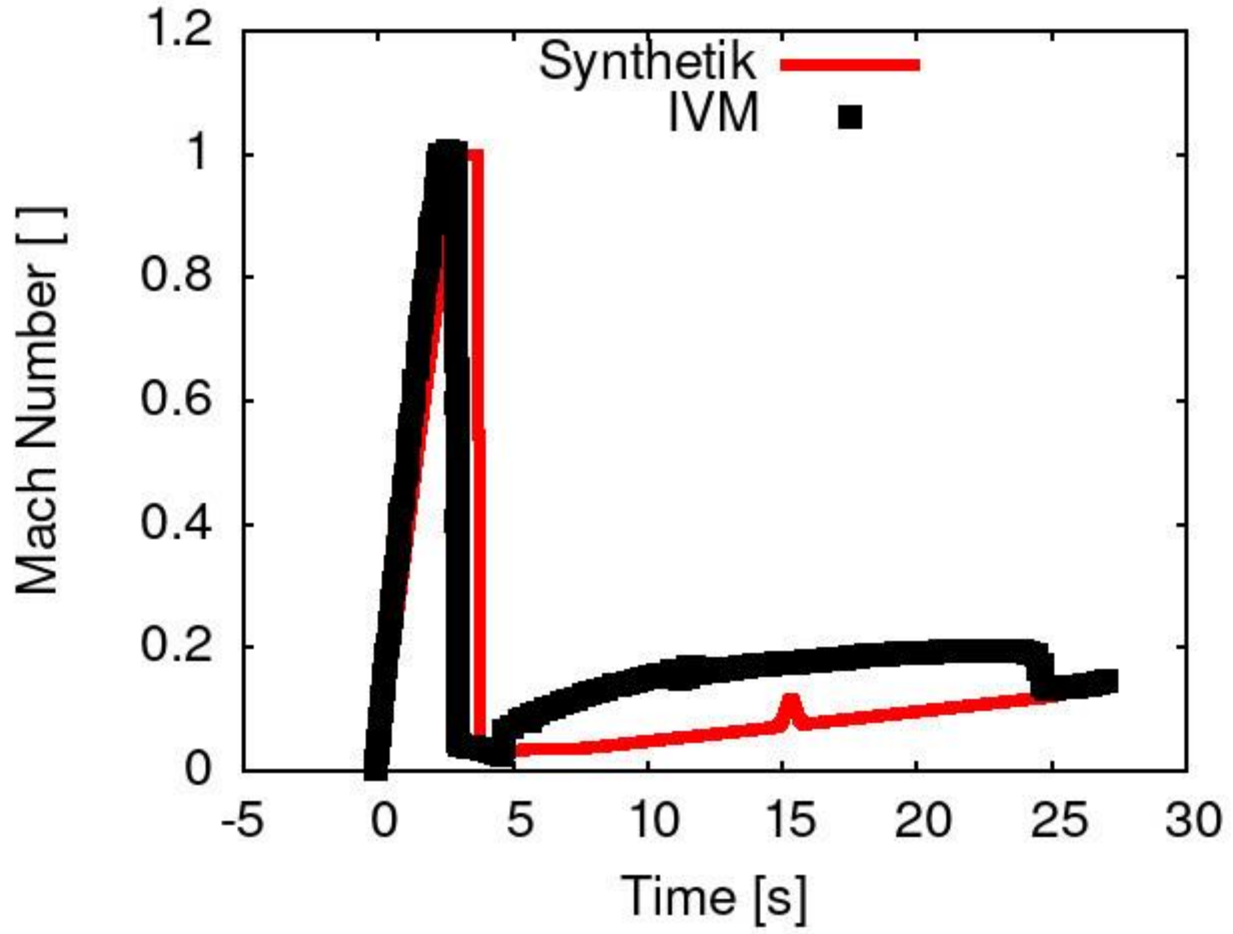
# Comparison with IVM – 0D Case

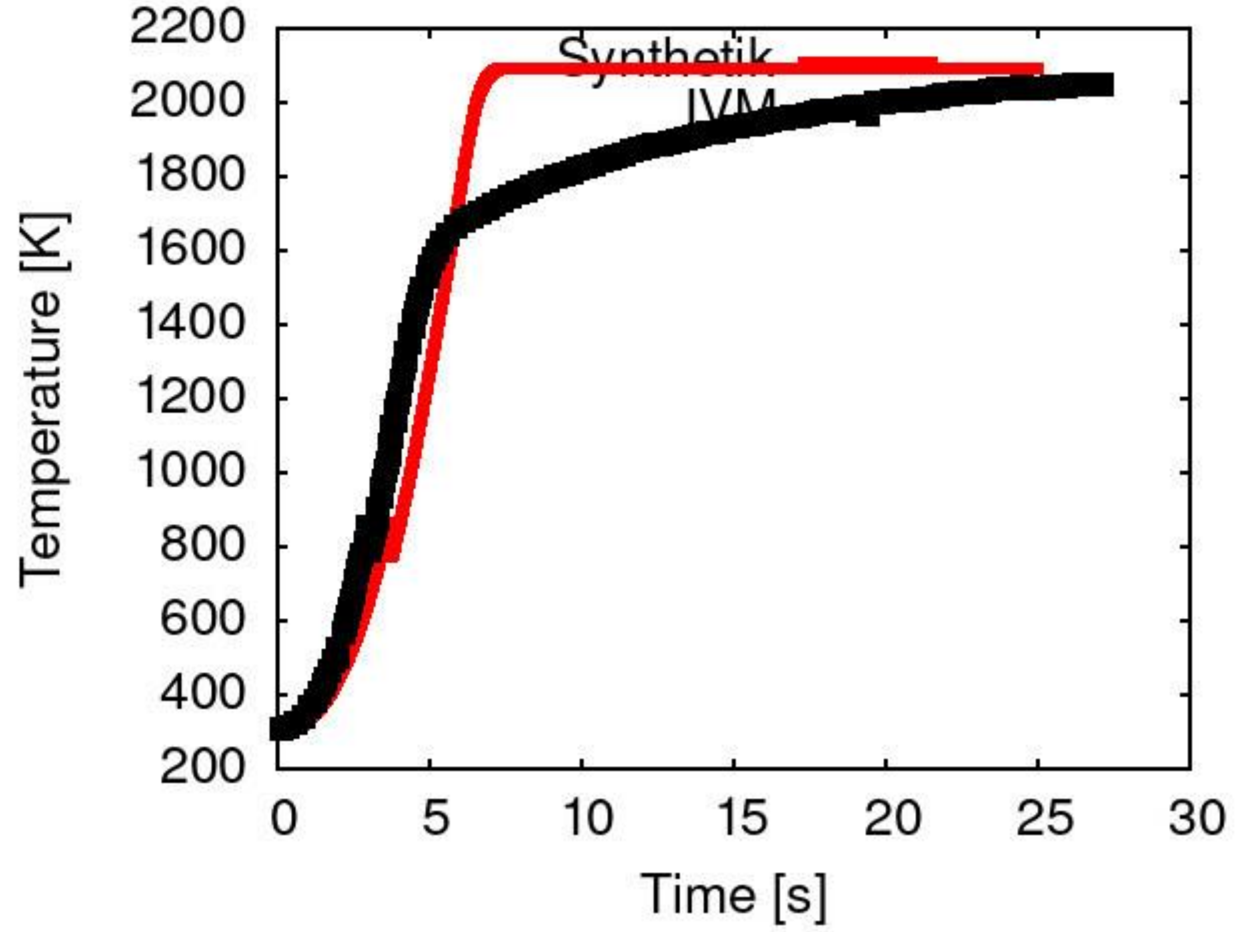
## ISO container (10 barrels, 500 kg)

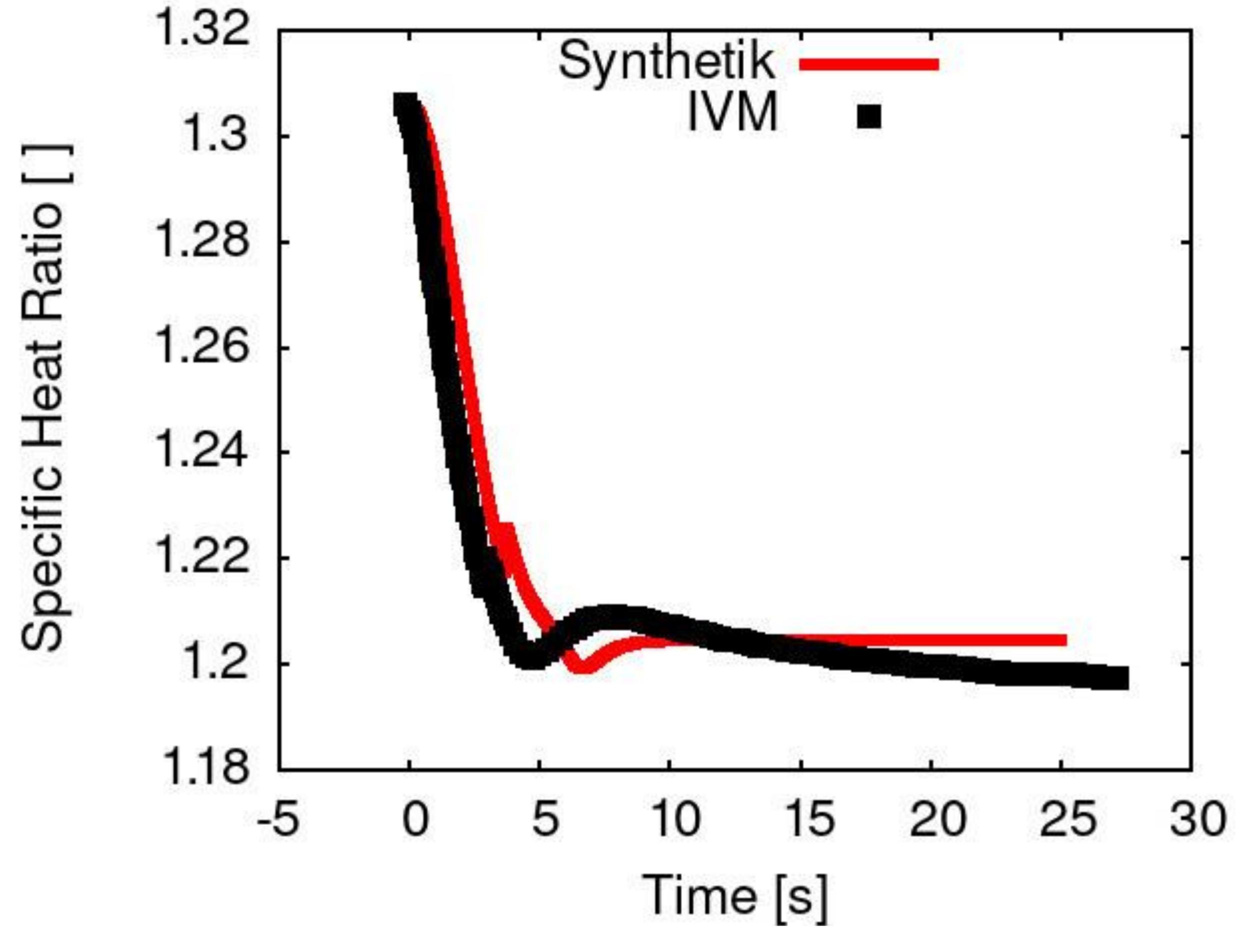


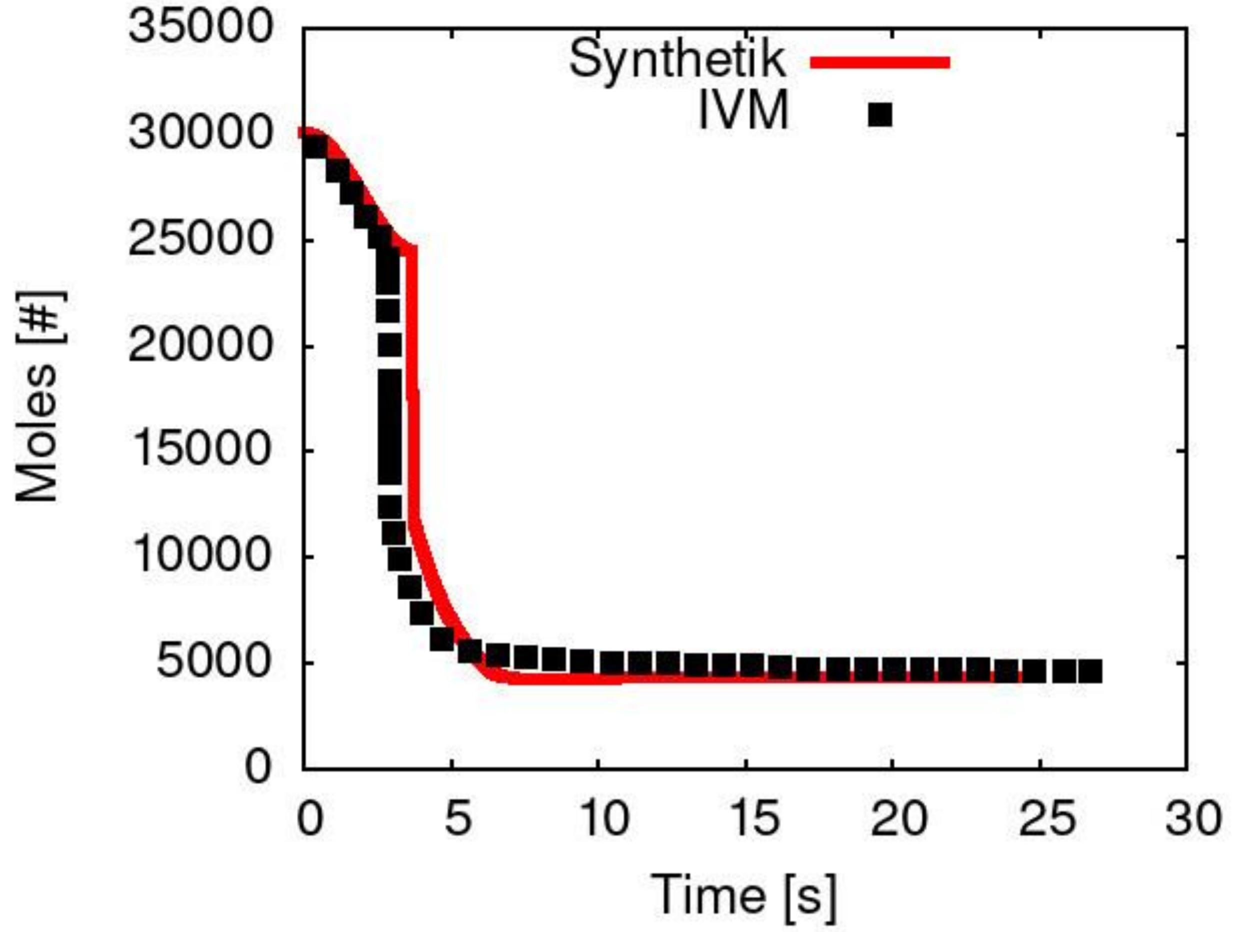
# Comparison with IVM – 0D Case

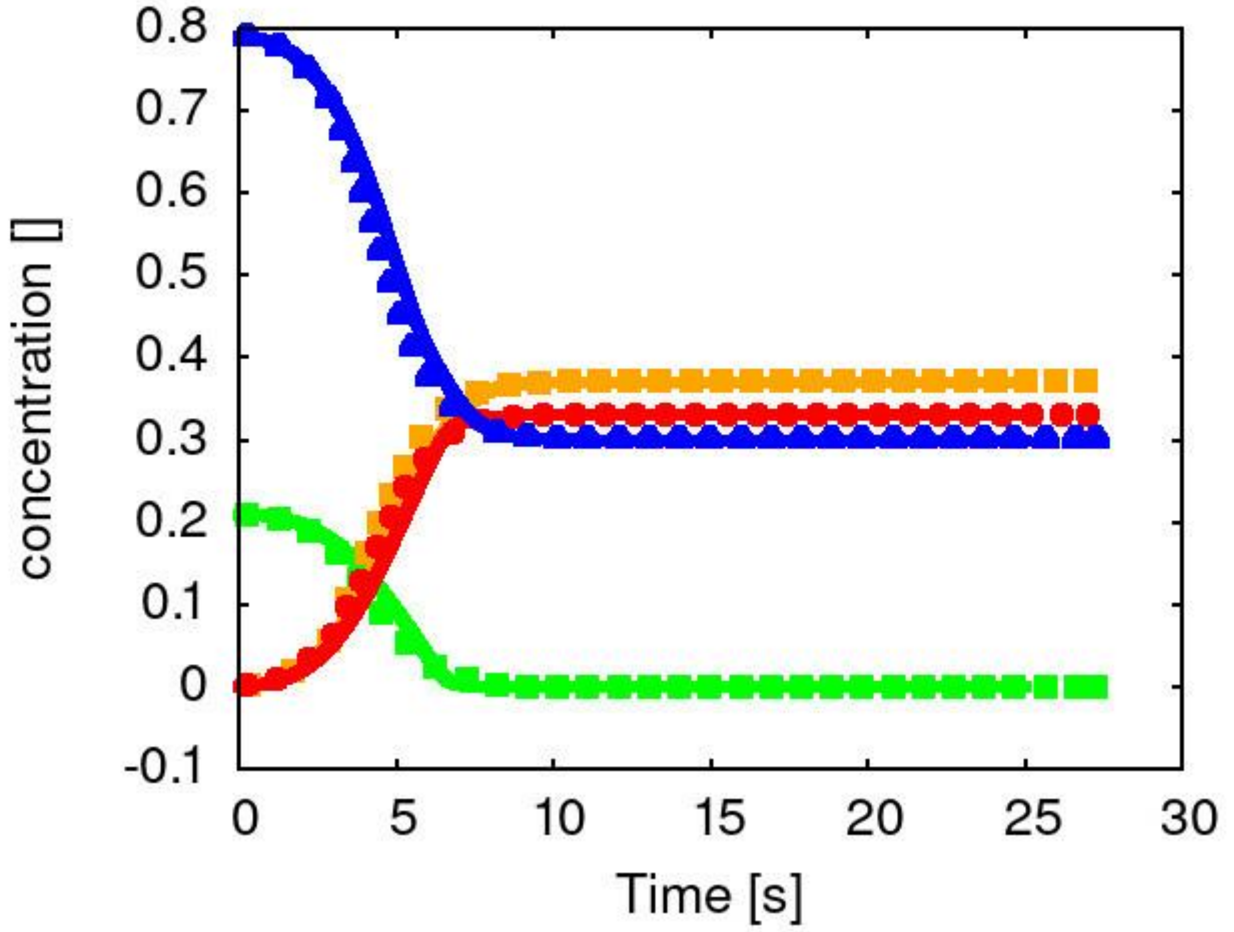
## ECM (150 barrels, 7500 kg)

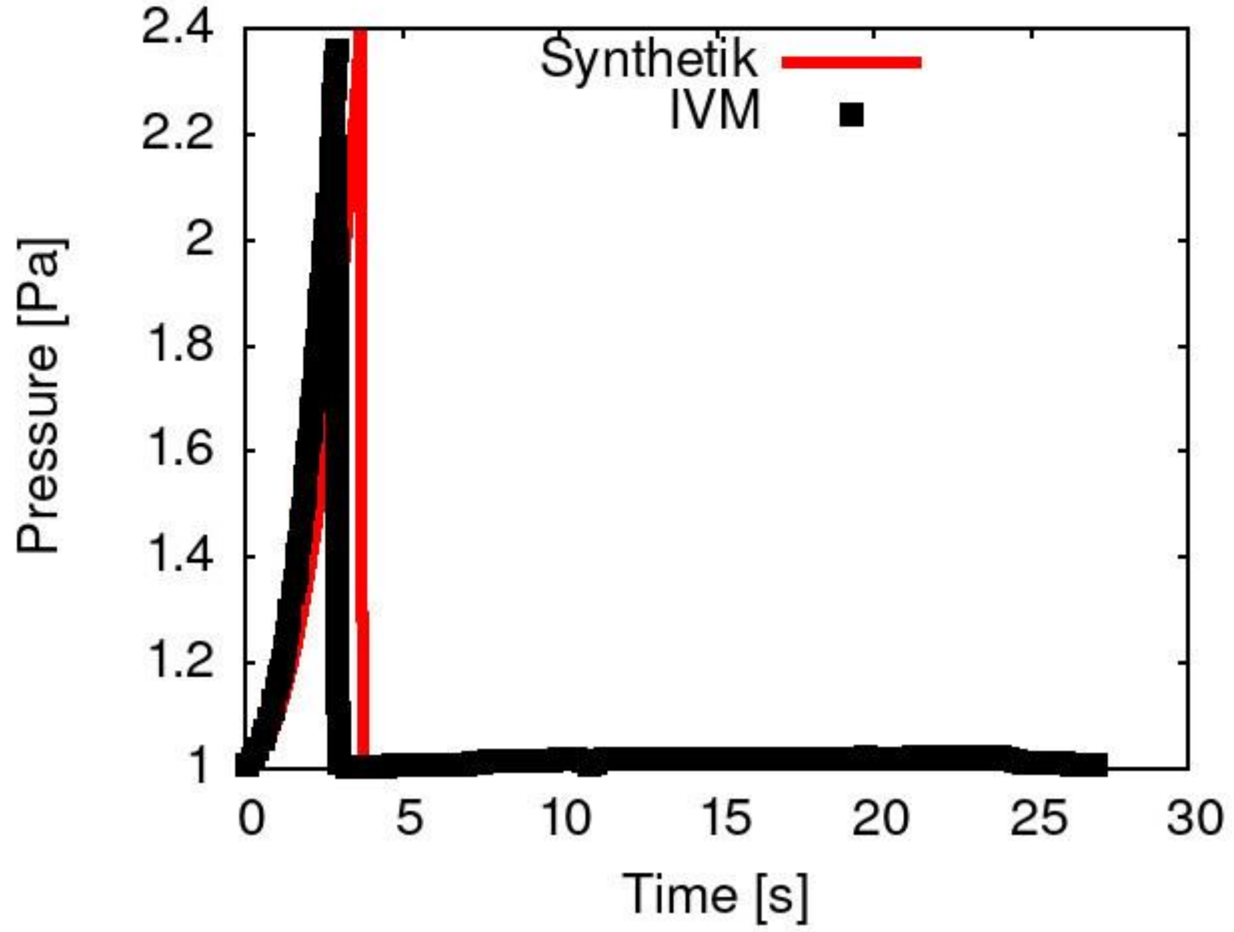


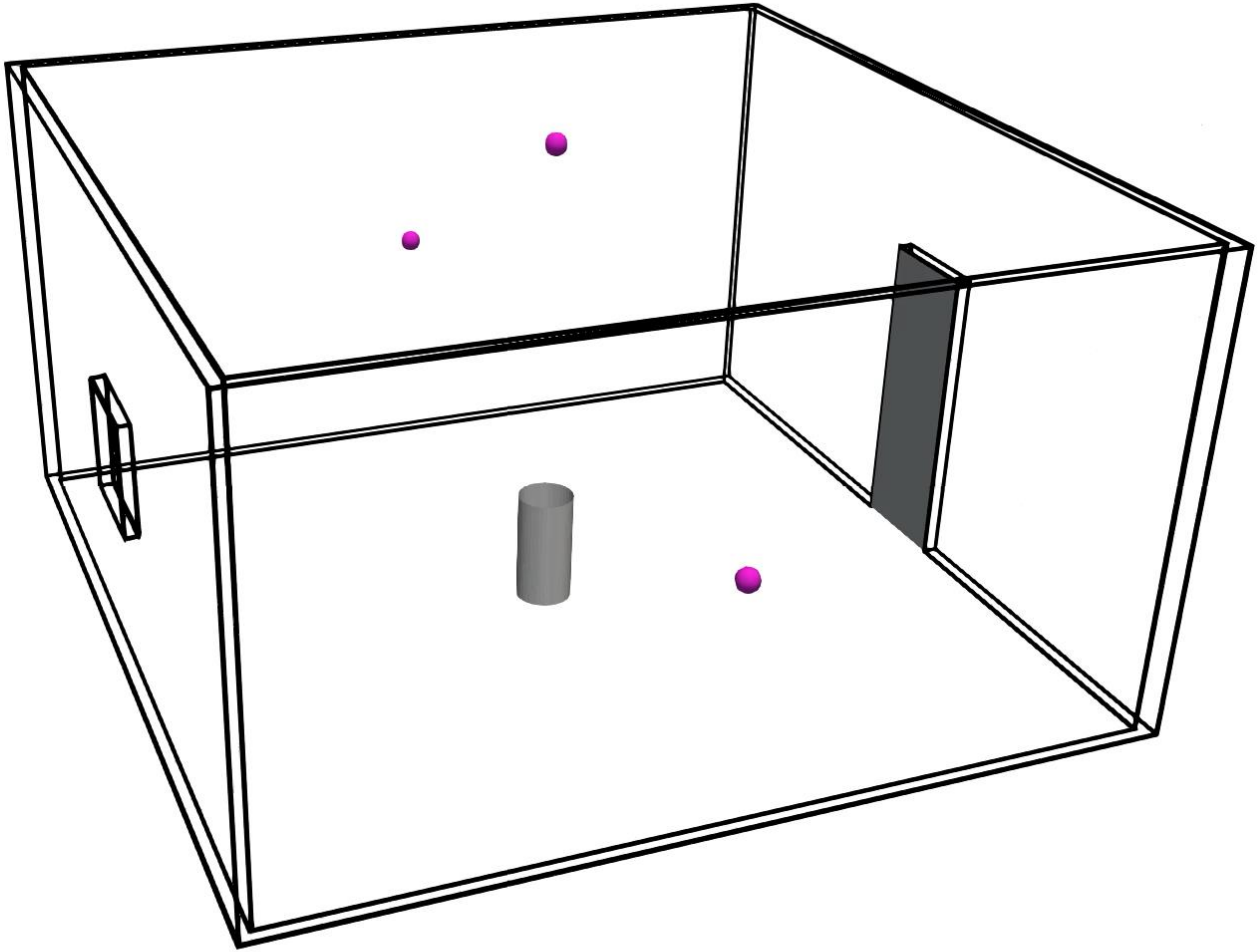





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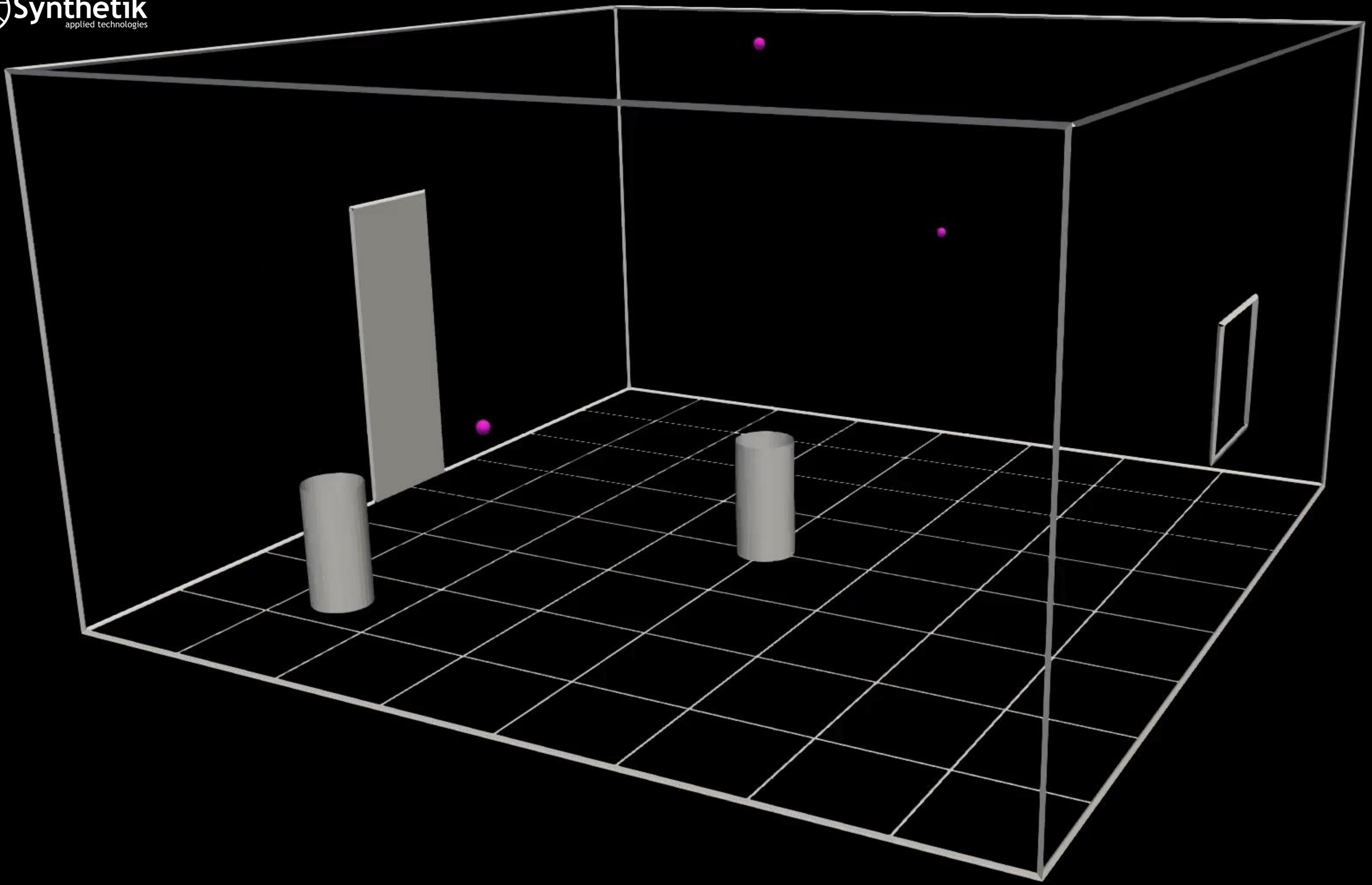

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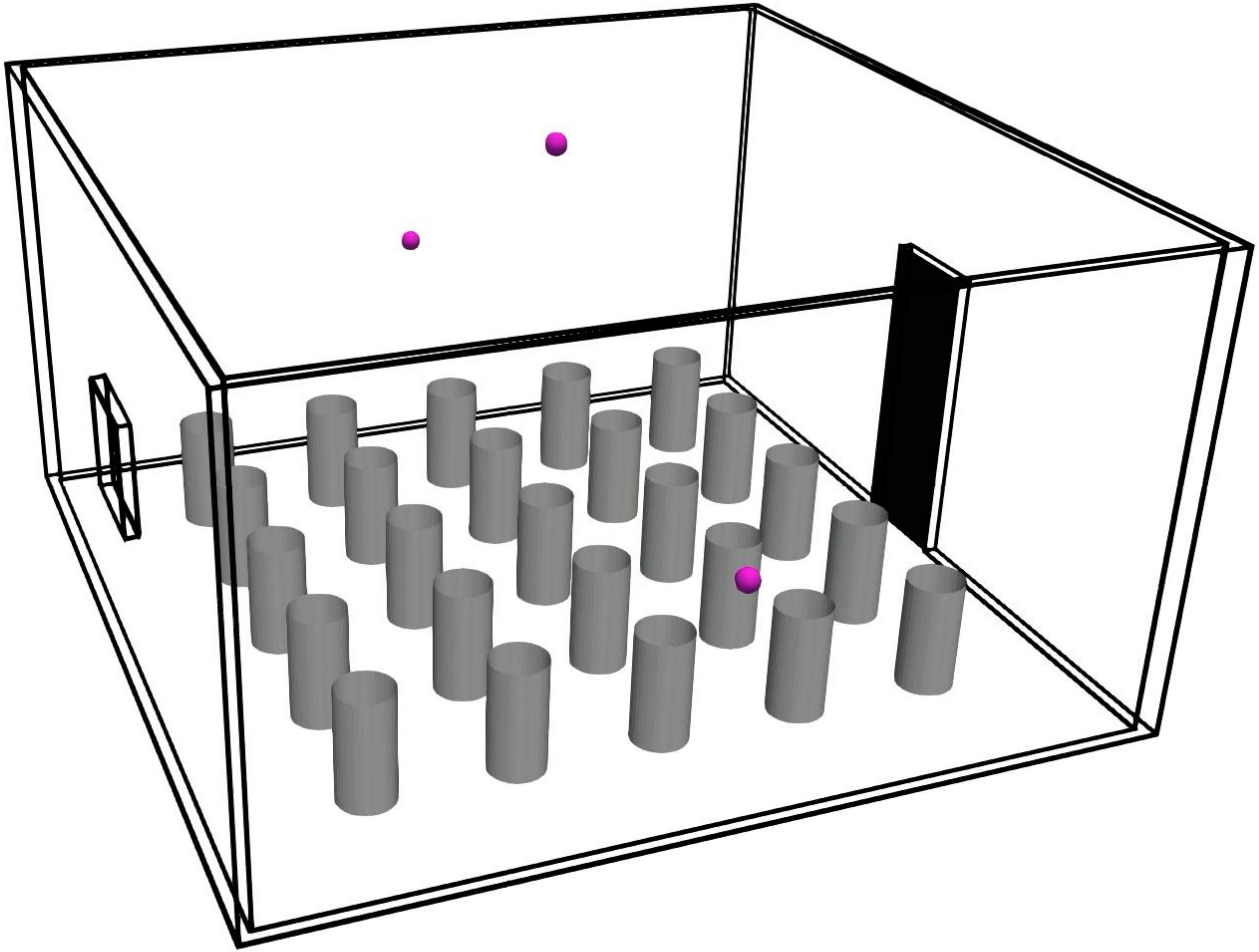
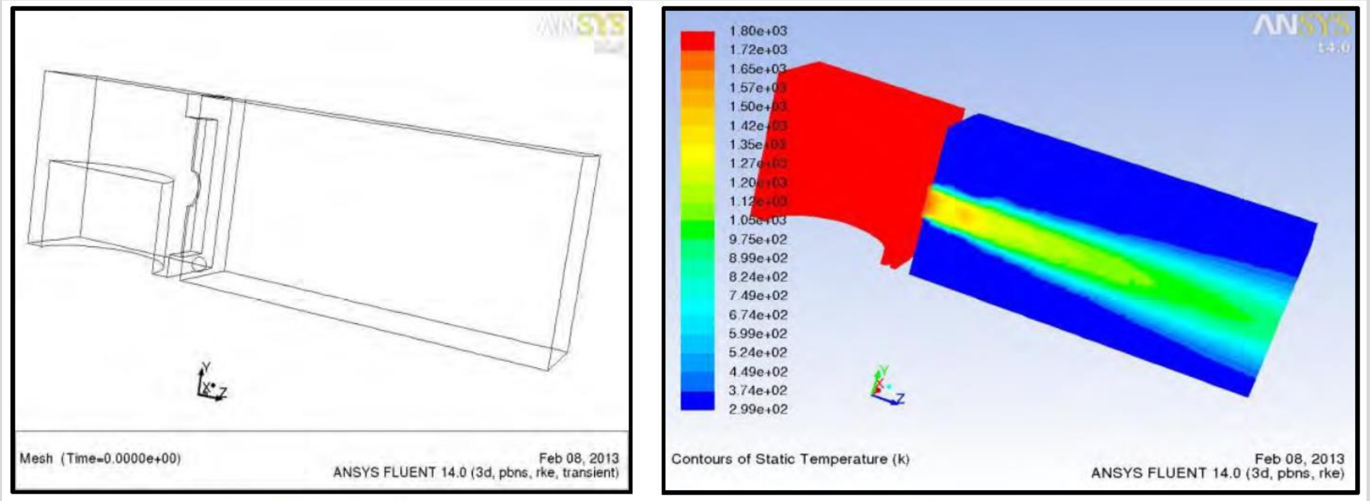


# NAWCWD TM 8742

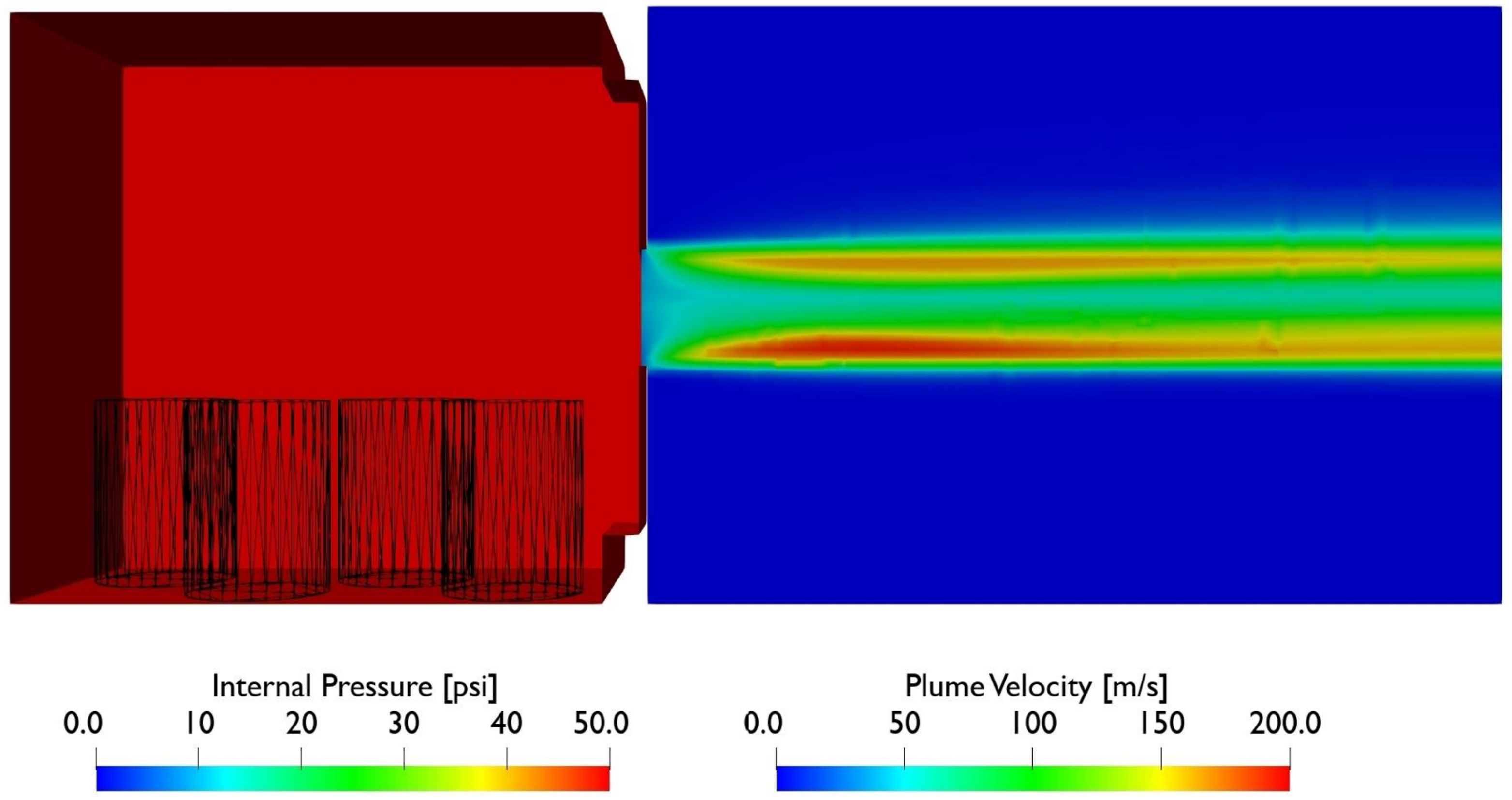
## Comparison with Large-scale tests

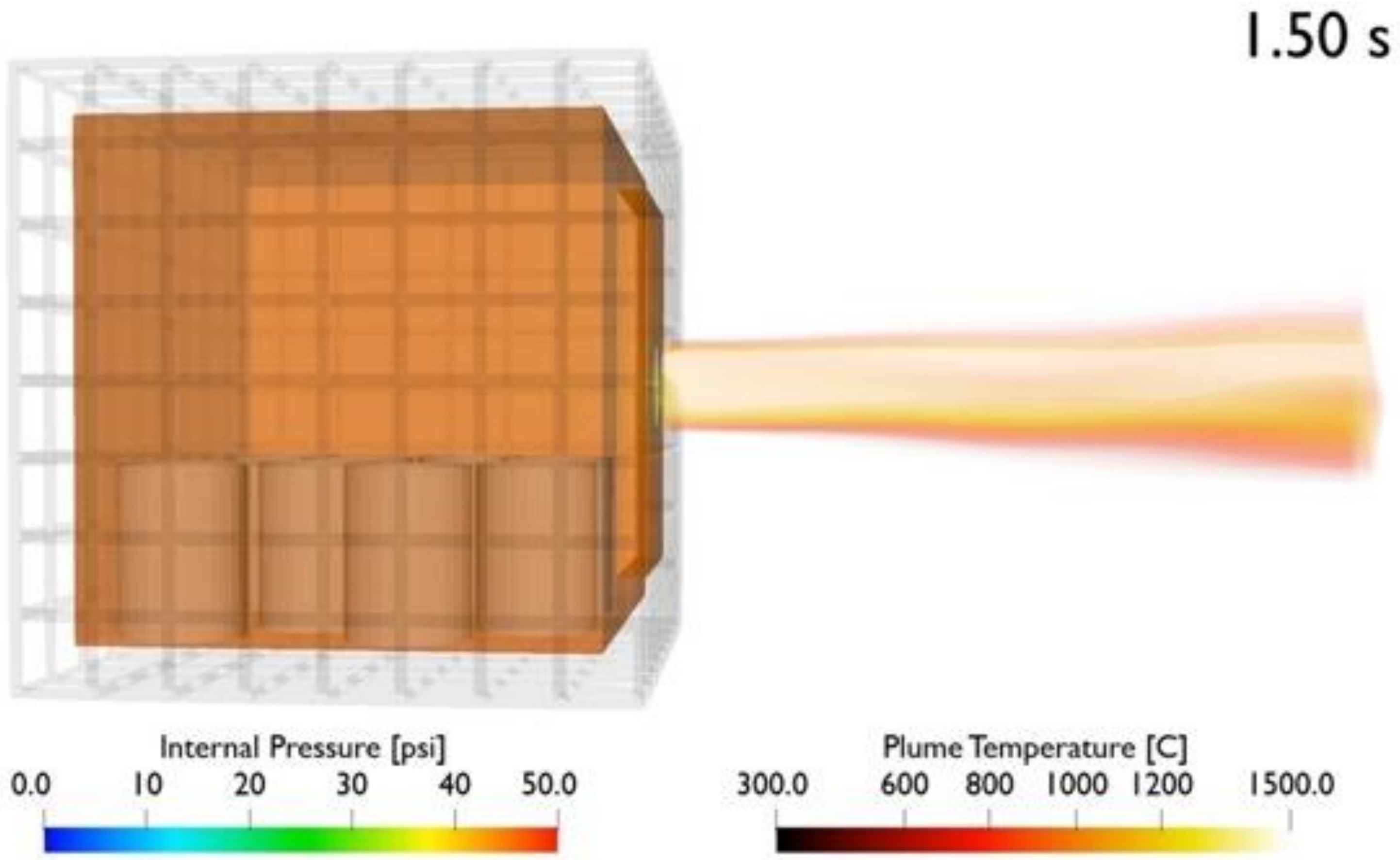
*"The Combustion Sciences Branch of NAWCWD used the ANSYS Fluent Computational Fluid Dynamics (CFD) models developed for Reference VI-6 and adapted them for the Kasun structure using M1 gun propellant."*



(a) CFD Mesh. (b) Plume Formation.

FIGURE VI-1. ANSYS Fluent Simulations.




Aubrey Farmer, A., , Ford, K., Atwood, A., Boggs, T., Covino, J., "Combustion of Hazard Division 1.3 M1 Gun Propellant in a Reinforced Concrete Structure (U)", NAWCWD TM 8742

# Roadmap: what's next (and why it matters to users)

## Seeking endorsement and support

- Validation (test data – and will need support/access obtaining)
- More complex structural interactions (fracture/spall/scab), coupling to nonlinear FE
- GUI + automation + standardized post-processing/reporting for submissions
- Expanded validation for edge cases (marginal venting, high energy density)

# Conclusion

## From Solver Development to Safety Decisions

- **What we built:** Open, extensible modeling tools for confined HD 1.3 events with regression, afterburn, venting, and breach dynamics.
- **How we apply it:** A 0D→3D workflow that matches accepted 0D behavior when appropriate, then resolves geometry driven hot spots when it matters.
- **What you get:** Defensible pressure time histories, impulse maps, vent performance, and breach timing to “take into the design.”
- **Why it matters:** Better predictions reduce both under design risk and over conservatism, while remaining aligned with DDESB expectations.
- **What we need next:** Validation datasets and pilot safety projects to mature automation, reporting, and structural coupling.

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