Aluminum structures exposed to blast loading

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Outline

- Blast loading
- Challenges in urban environments
- Research approach at CASA
- Blast-load research at CASA
- Computer simulations

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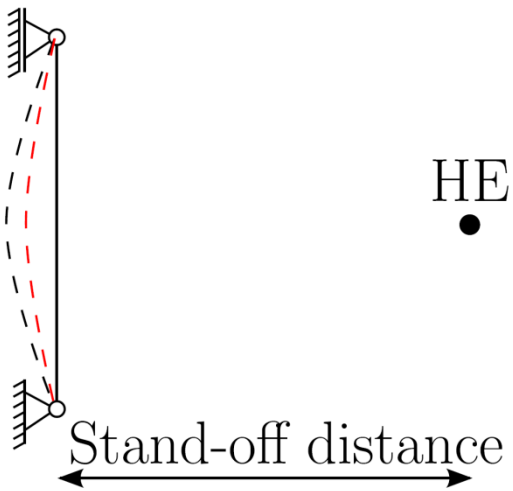
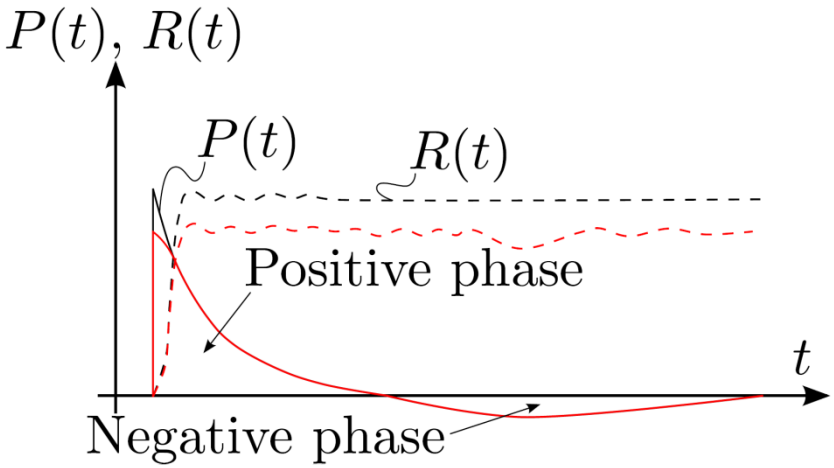
Brief intro to blast loading

- Typical scenario in blast-resistant design of civilian buildings
- Spherical blast wave propagation
- Structure loaded by the blast overpressure
- Response dependent on the structural and loading properties





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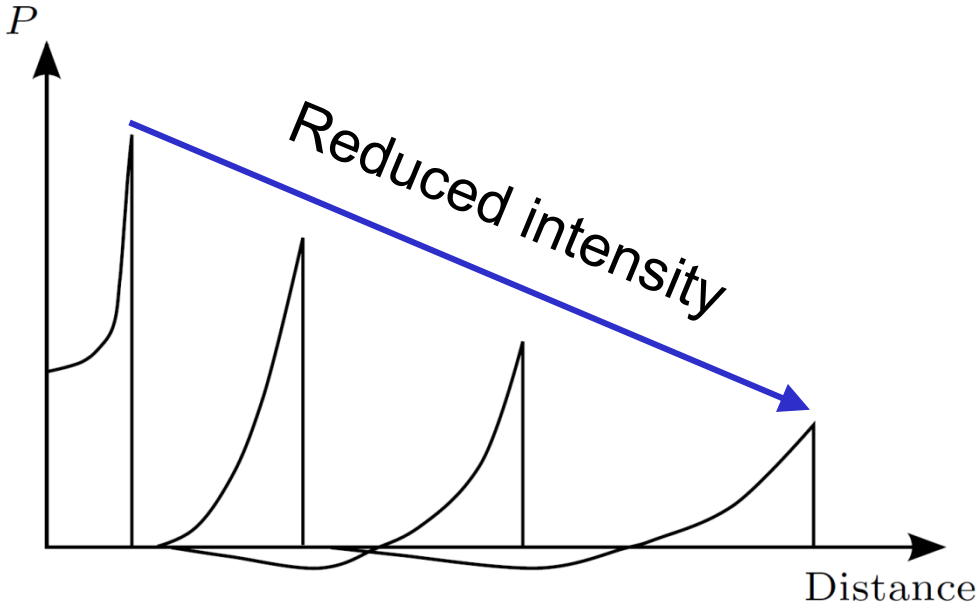
Blast mitigation

- Protection = reduce the effect of the action
- Blast mitigation = increased distance



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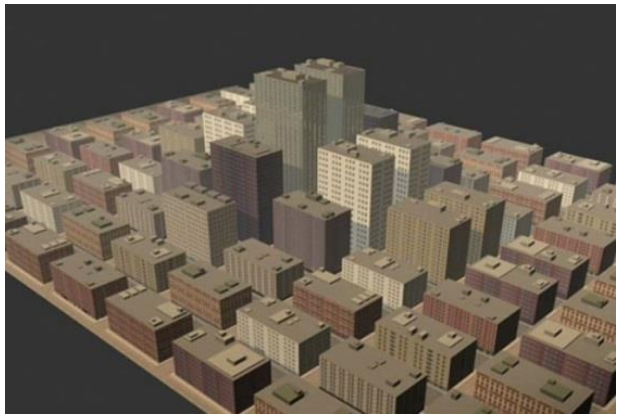
Challenges in urban environments



Team Urbis' concept «Adapt»

Mye glass og høye bygg i det nye regjeringskvartalet

- Space limitations
- Utilize the capacity of architectural materials and components
- Mitigate the effect of blast loading on buildings

Blast mitigation

Pictures from Oslo Bombings 22 July 2011, NOU (2012)

Objective:

- Avoid total structural collapse
- Protect people and critical infrastructure

Understanding the underlying physics

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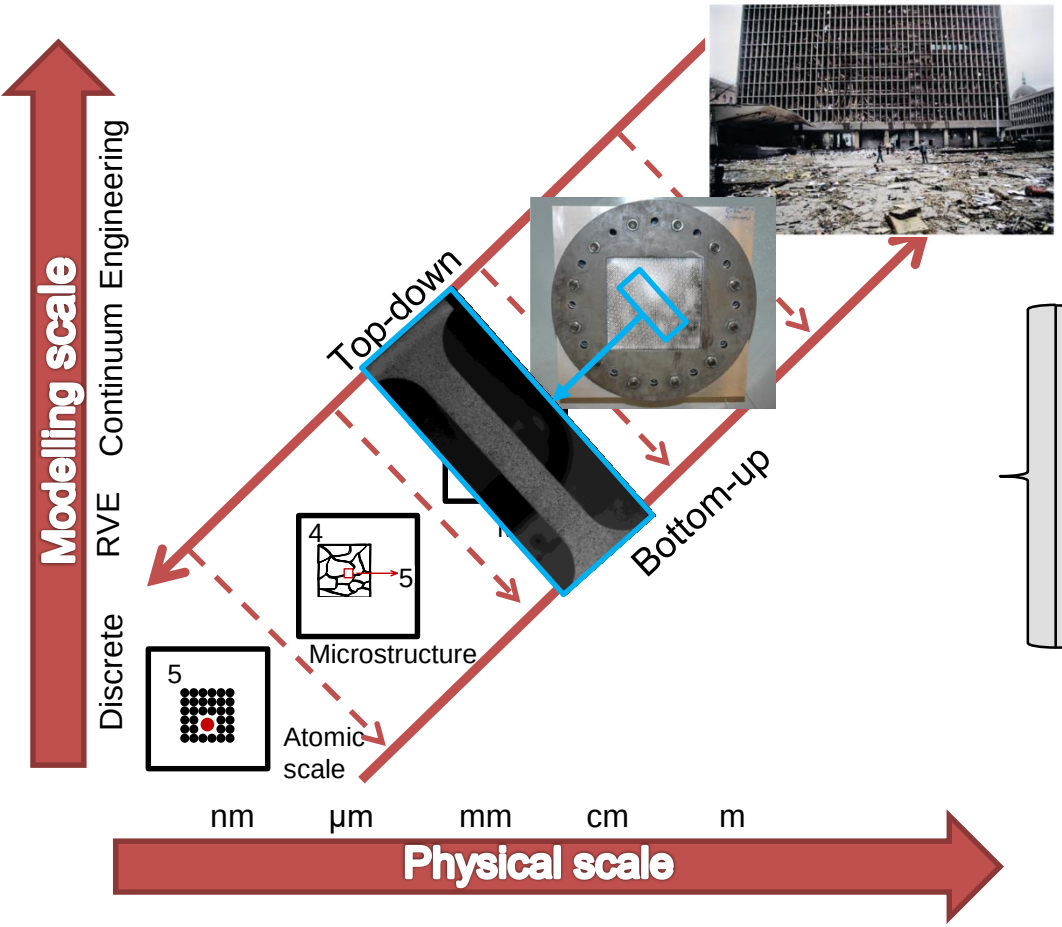
Research approach



- Detailed analyses of complex full scale problems.

- Validate computational methods (material and FSI)
- Material testing and controllable small-scale experiments

⇨ Establish reliable experimental and computational frameworks

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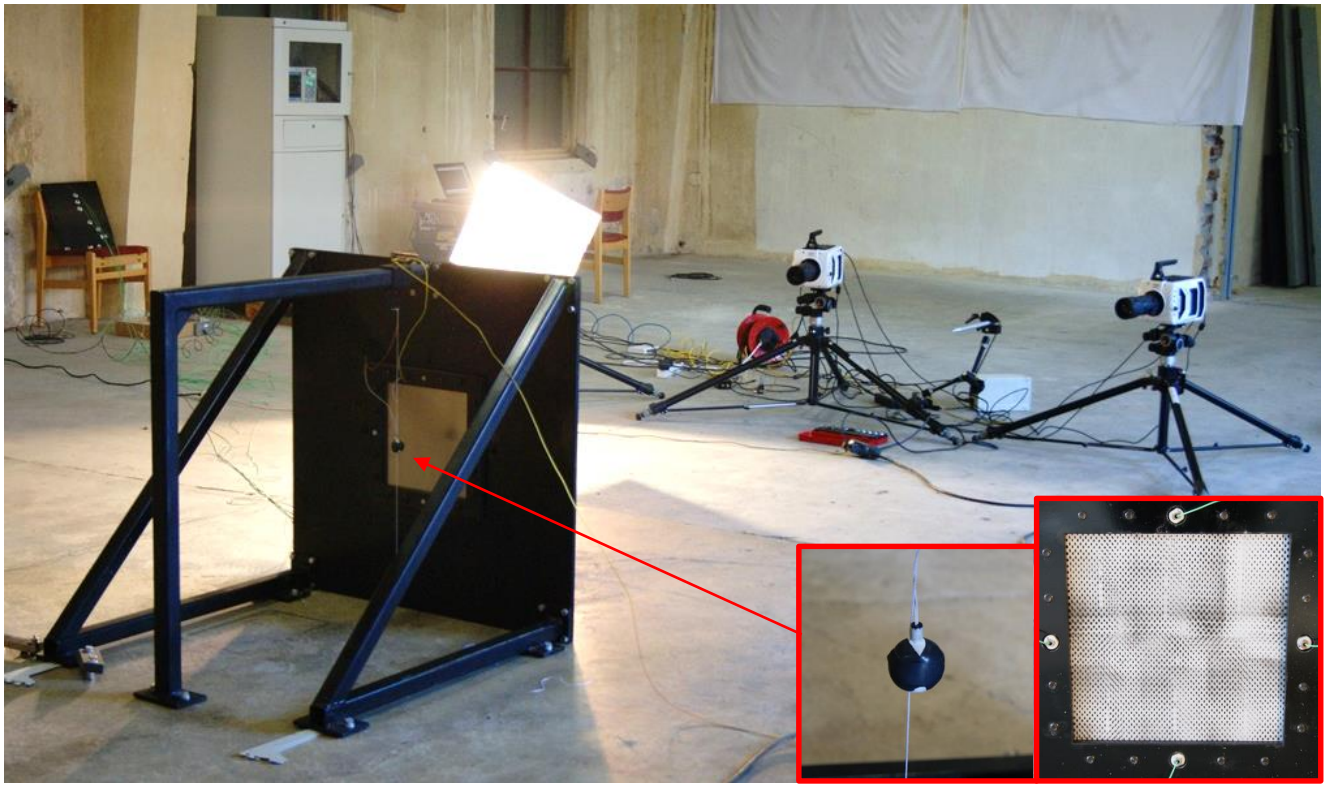
What about explosive detonations?



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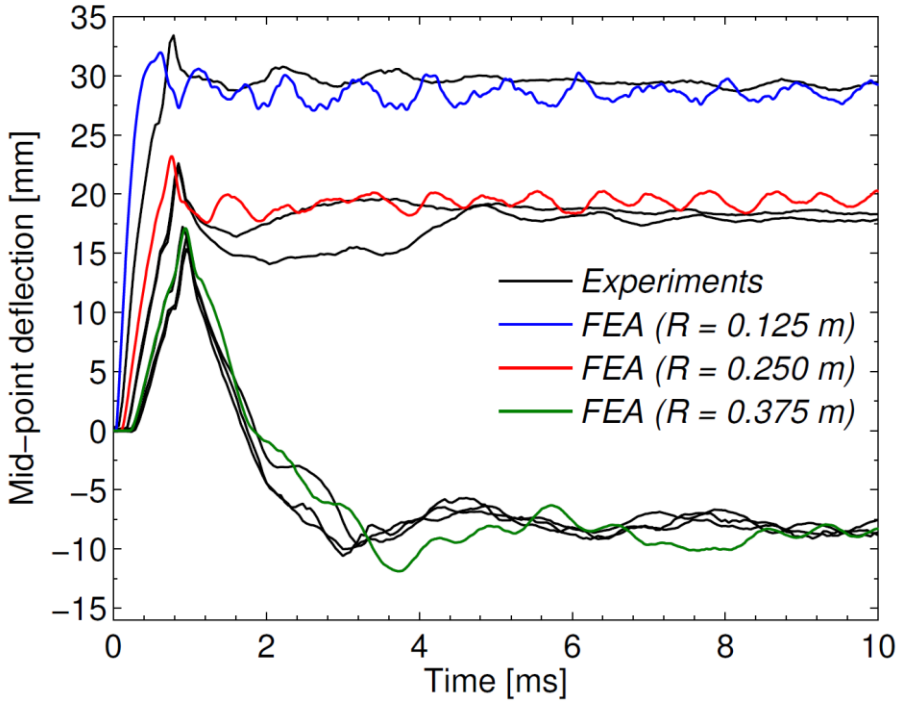
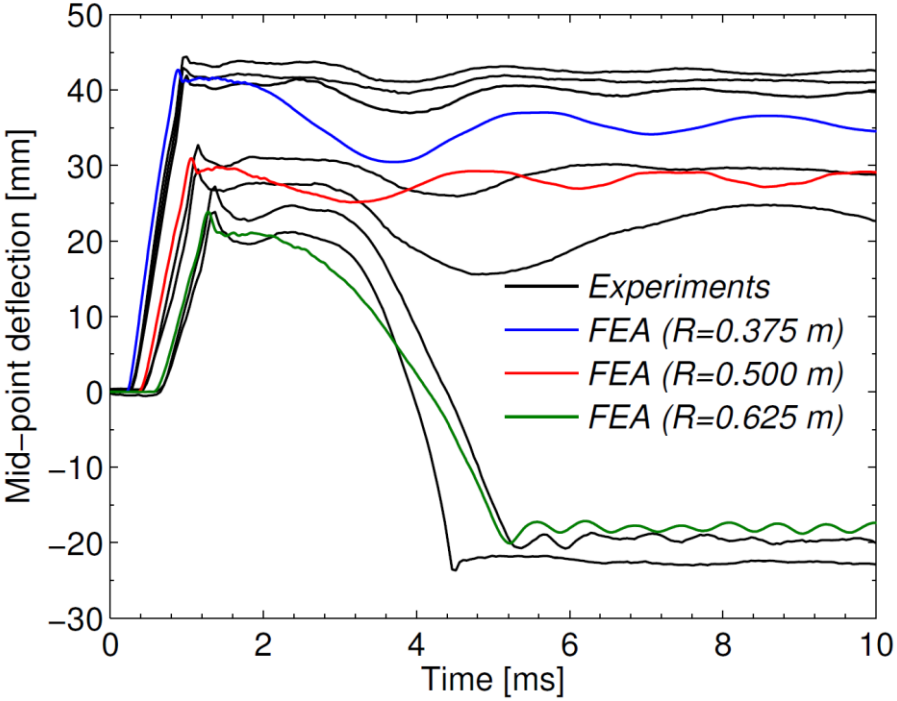
Experimental and numerical results

Steel



Aluminium



Numerical results in good agreement with experimental data

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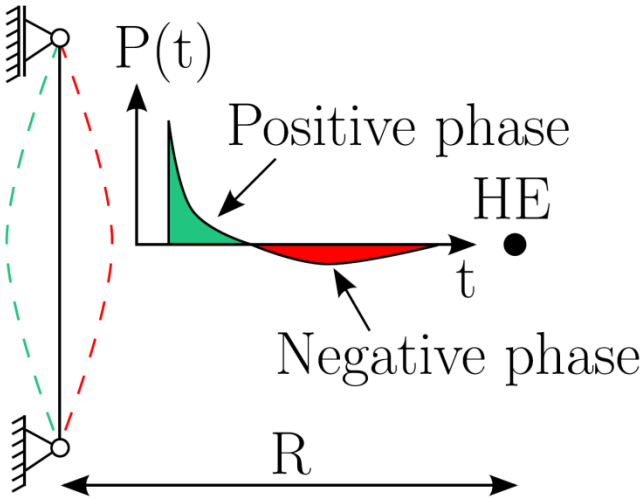
What did we actually observe?



- Reversed snap buckling (unexpected behaviour)
- Characteristic loading domain often determined based on the ratio t_{d+}/T_n
- Severe blast-structure interaction effects during the negative phase

Loading domain should not be determined solely based on the positive phase

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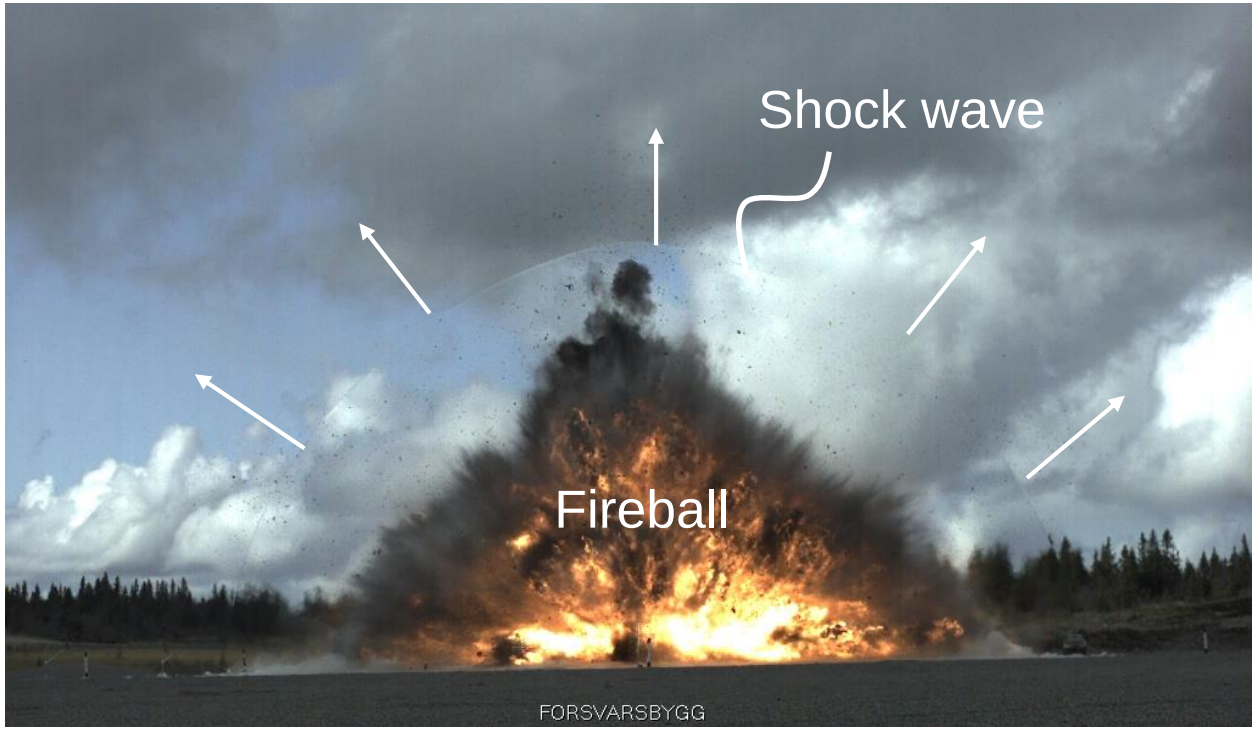
Experience with high explosives



Picture from the detonation of a VBIED (400 kg TNT)

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SIMLab Shock Tube Facility

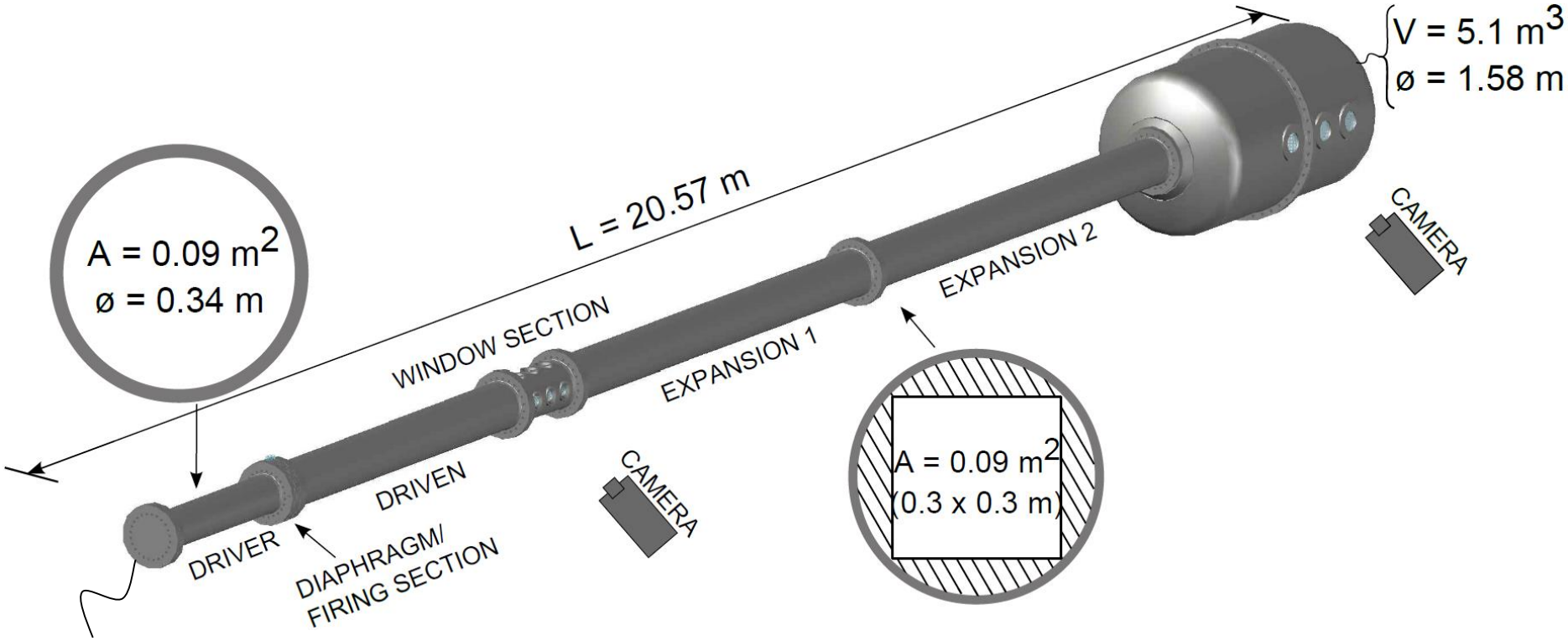

Figure: Sketch of SIMLab Shock Tube Facility.

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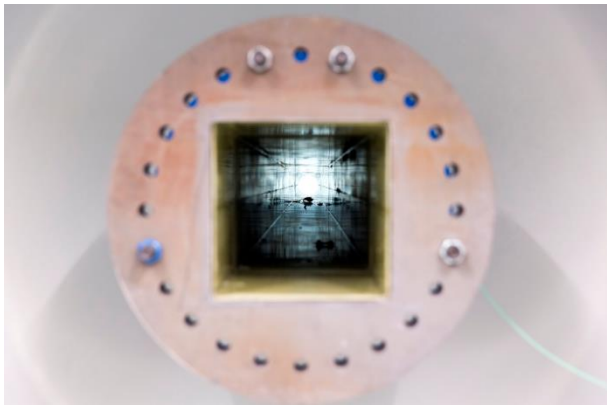
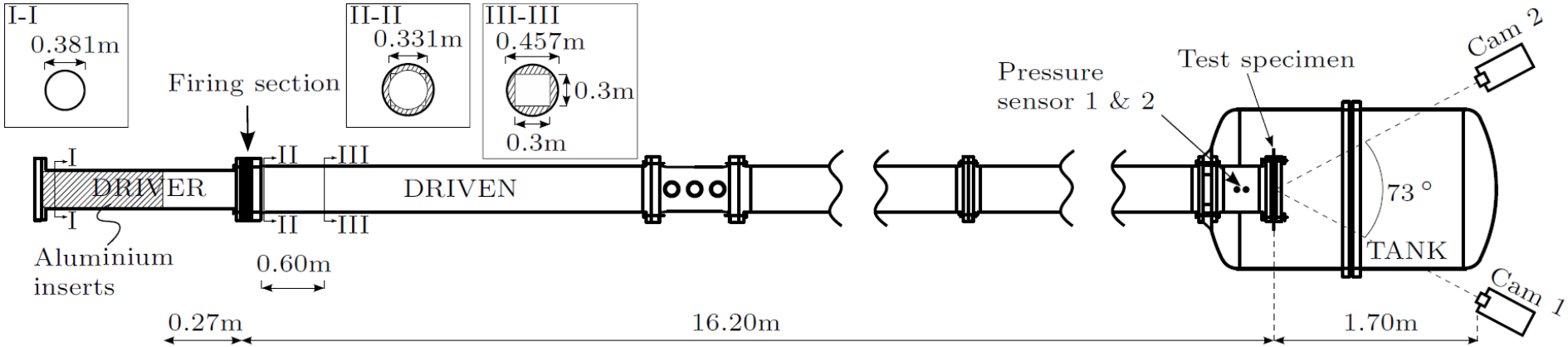
SIMLab Shock Tube Facility



- Alternative to explosive detonations
- Controlled, repeatable blast environment
- Planar shock wave
- Dynamic response of blast-loaded structures



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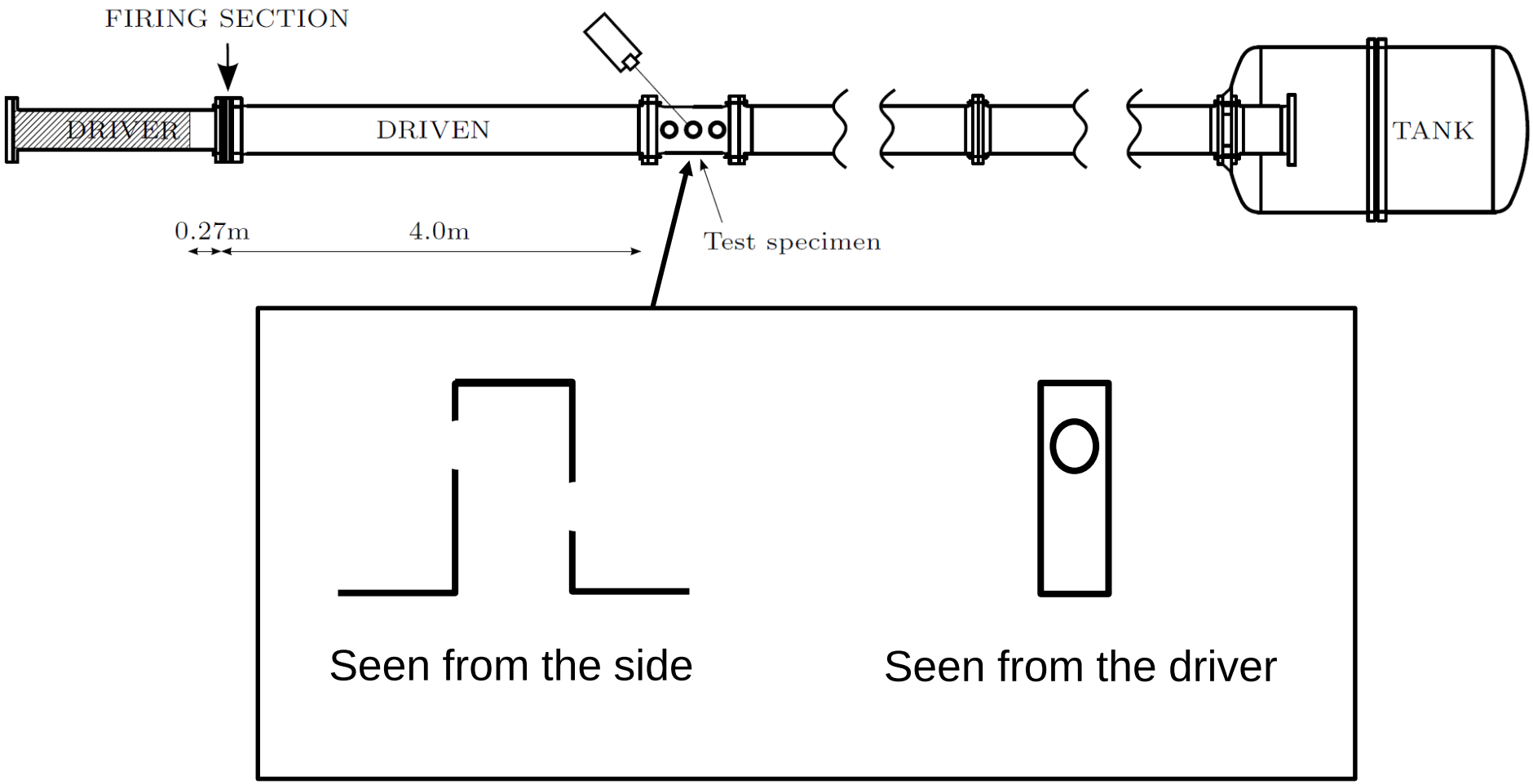
Blast-load research at CASA



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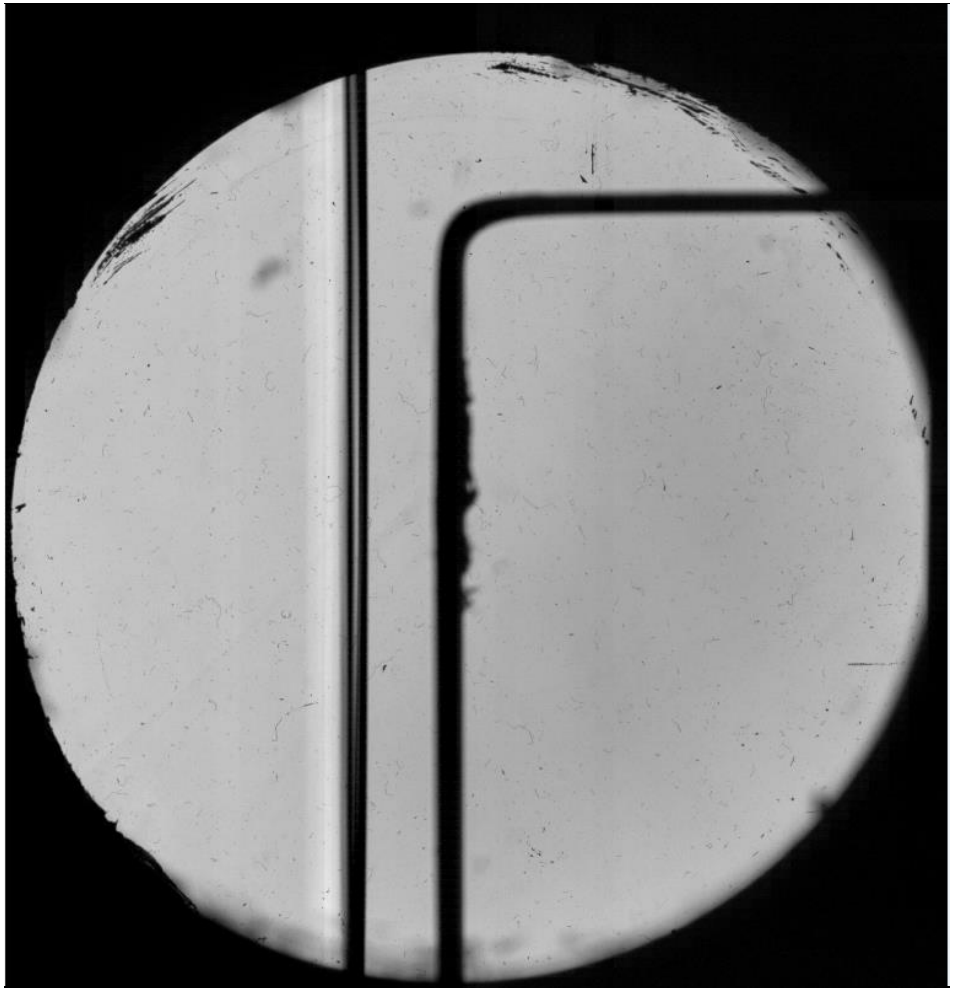

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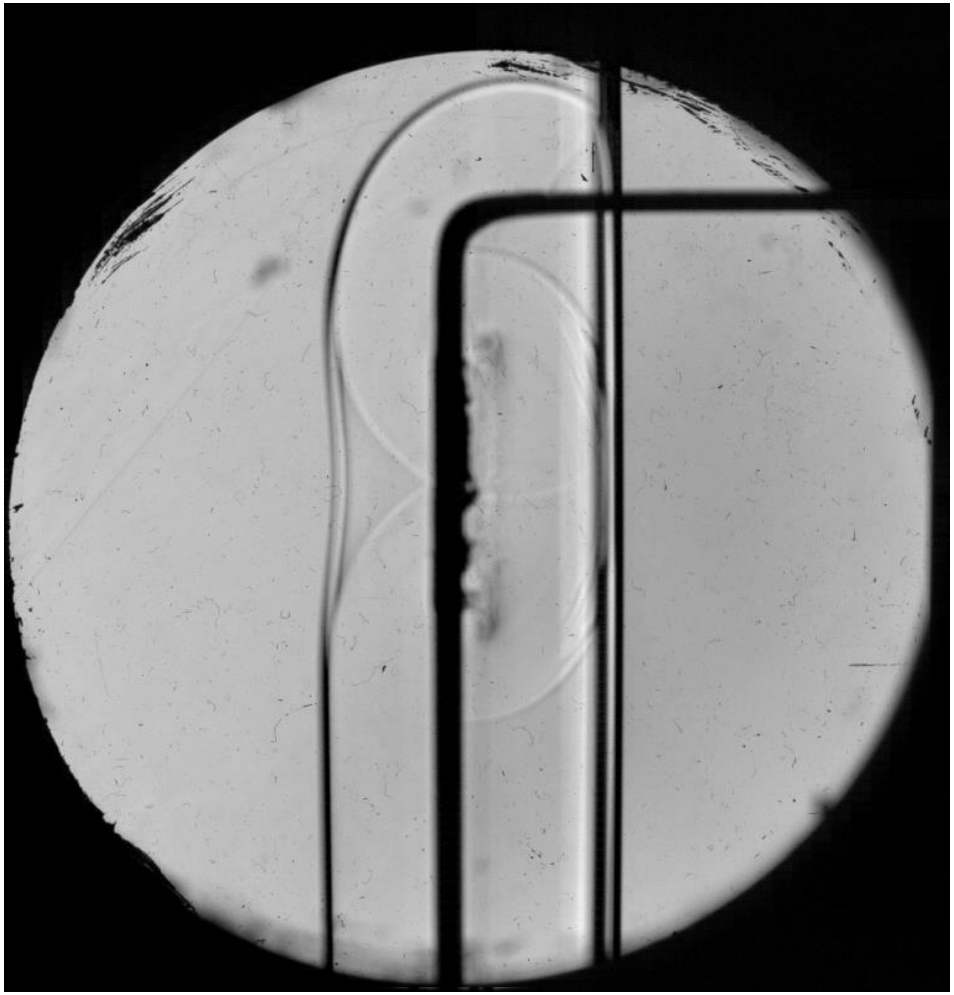

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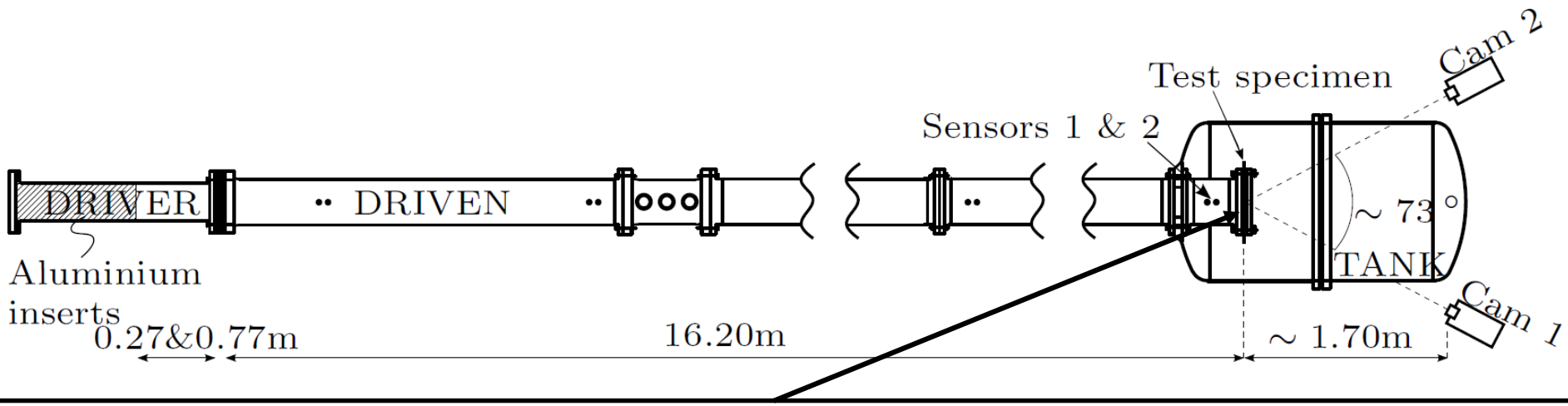
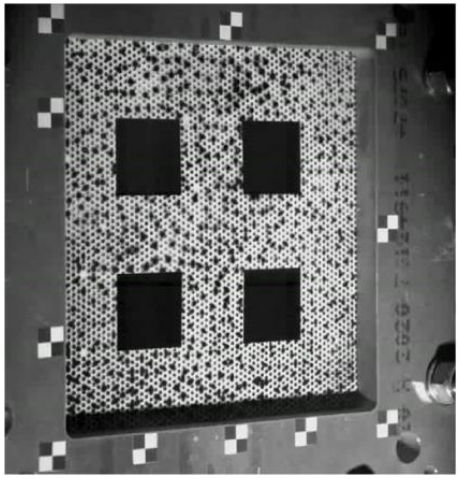
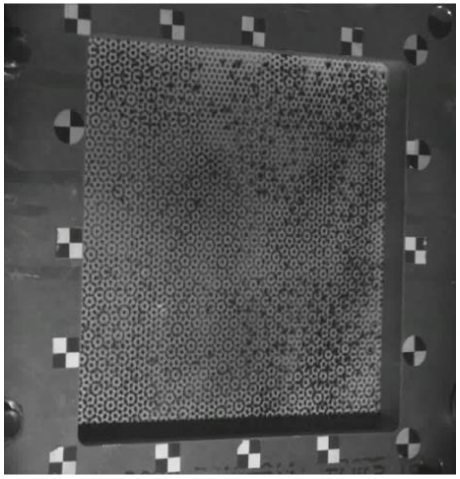


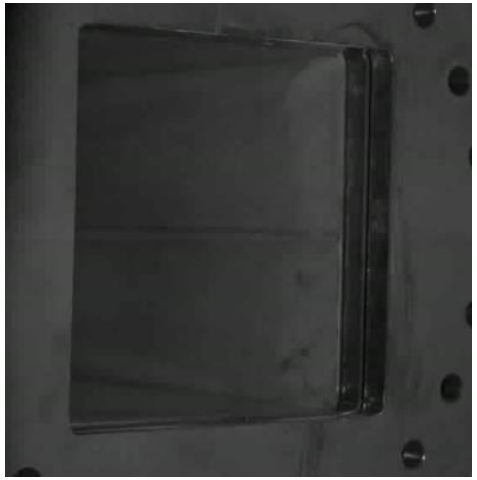


Steel



Aluminium

Concrete



Glass

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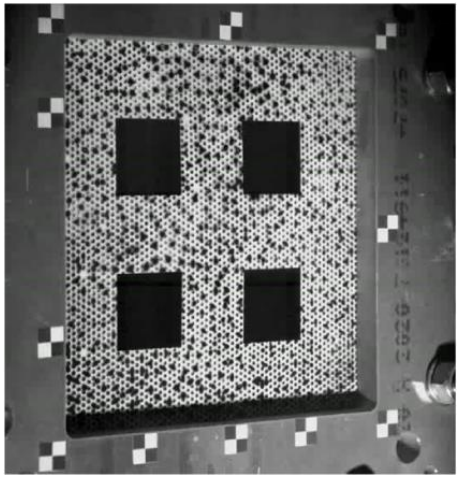
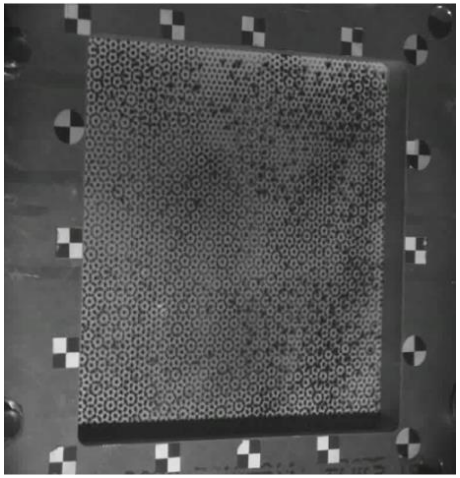
Blast-load research at CASA

Study the dynamic response of blast-loaded structures

- Material vs geometry
- Fluid-structure interaction
- Evaluation of computational methods



Steel



Aluminium

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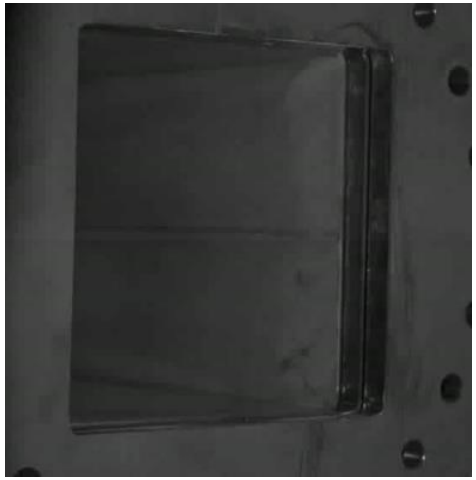

Glass

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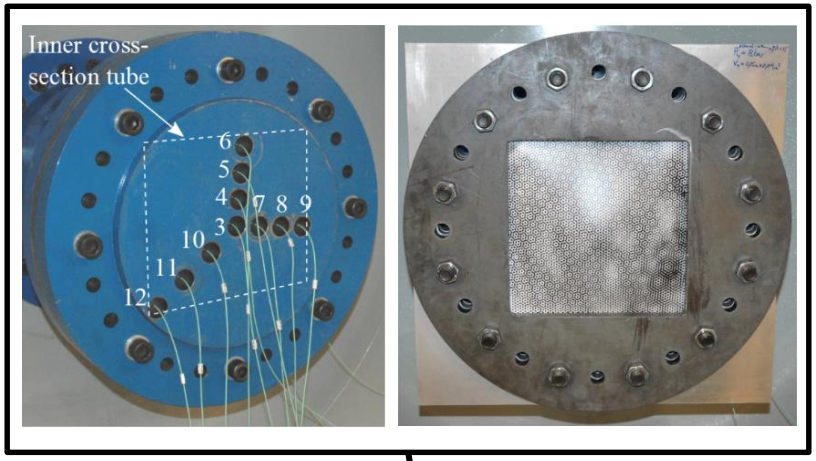
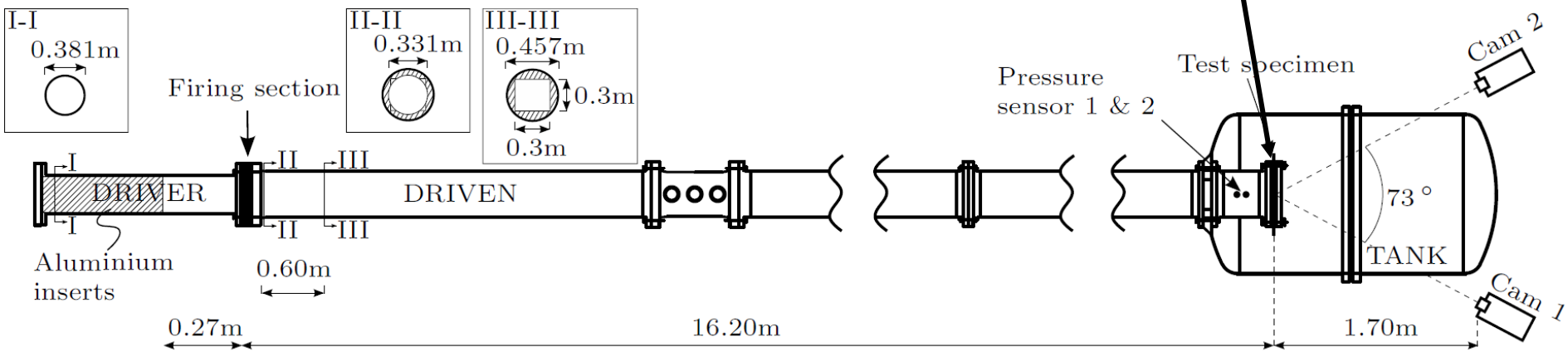
Aluminium plates

Study dynamic response of blast-loaded plates

- Massive plate (loading, FSI effects)
- Various blast intensities
- Evaluation of computational methods





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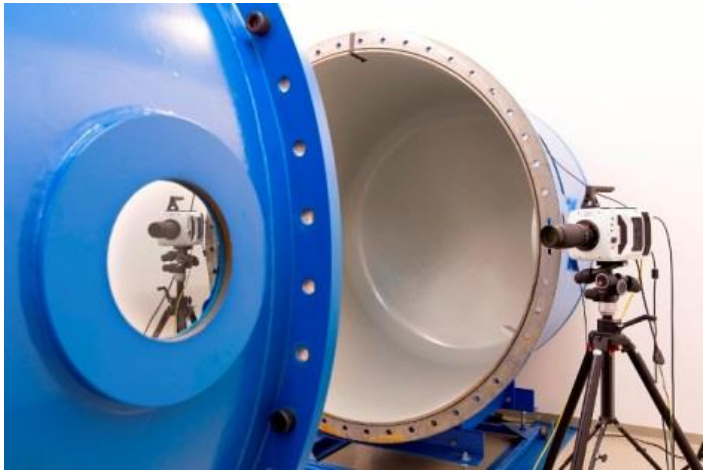
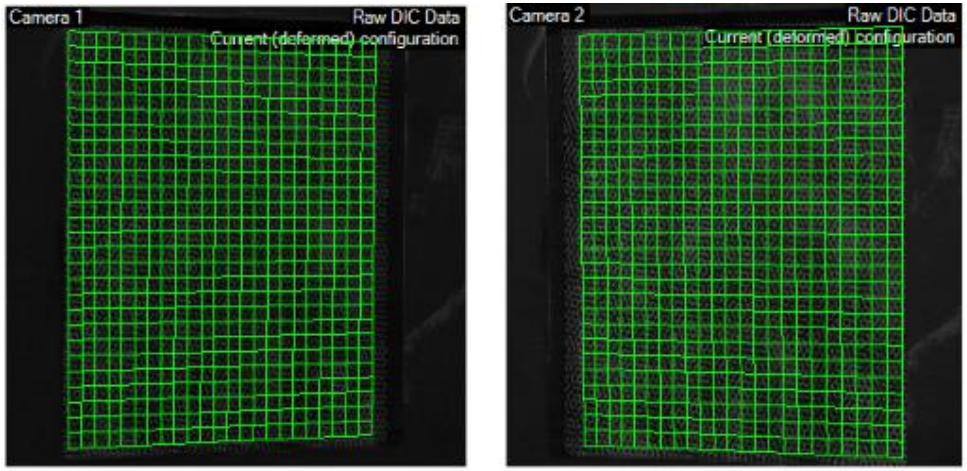
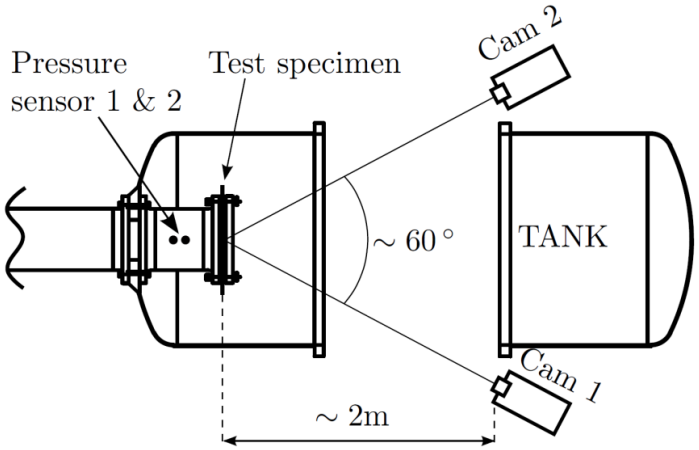
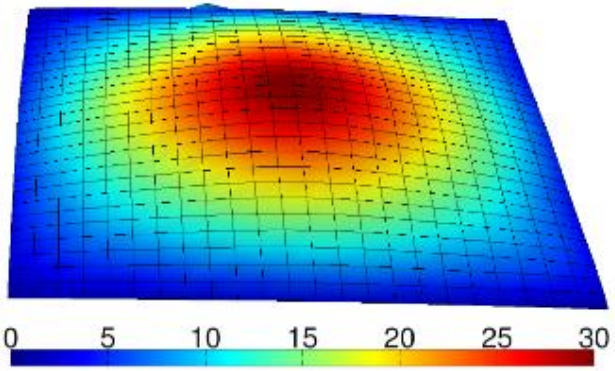
High-speed cameras and 3D-DIC (eCorr)









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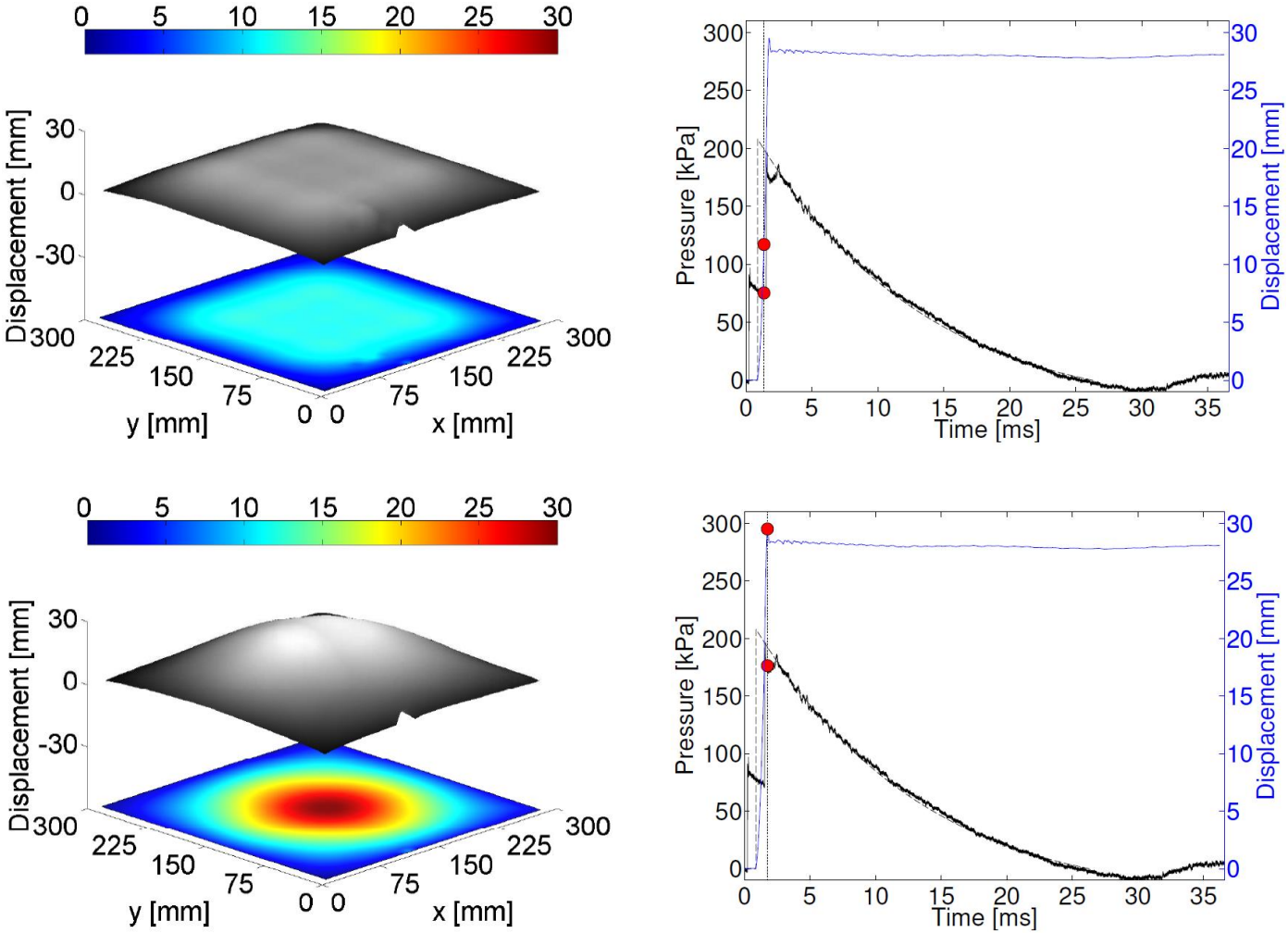
Synchronized pressure and response



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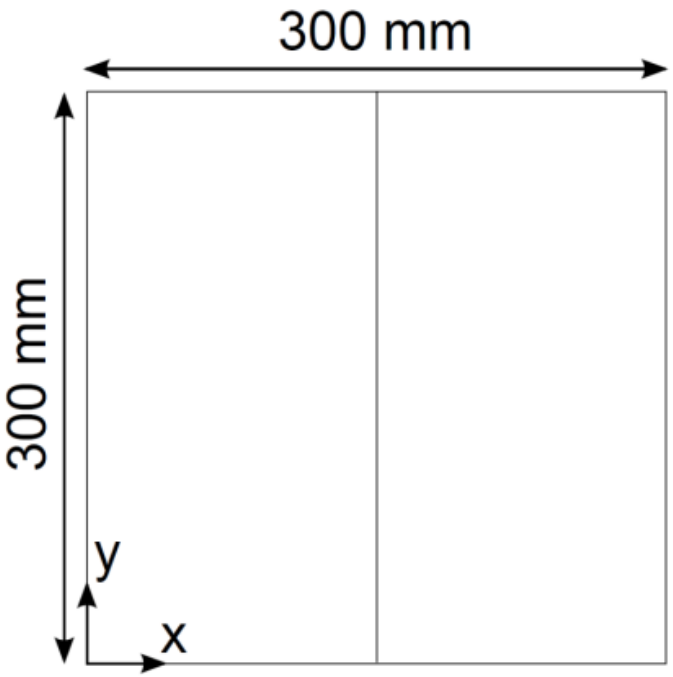
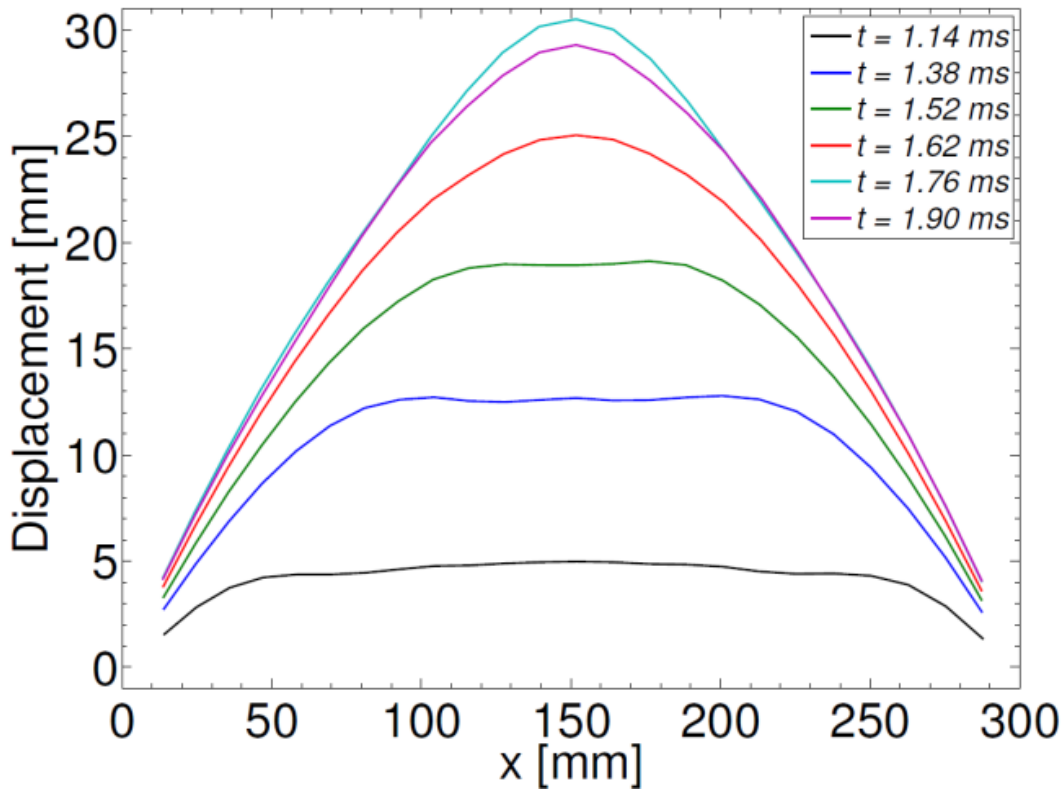
Possibilities with 3D-DIC (eCorr)





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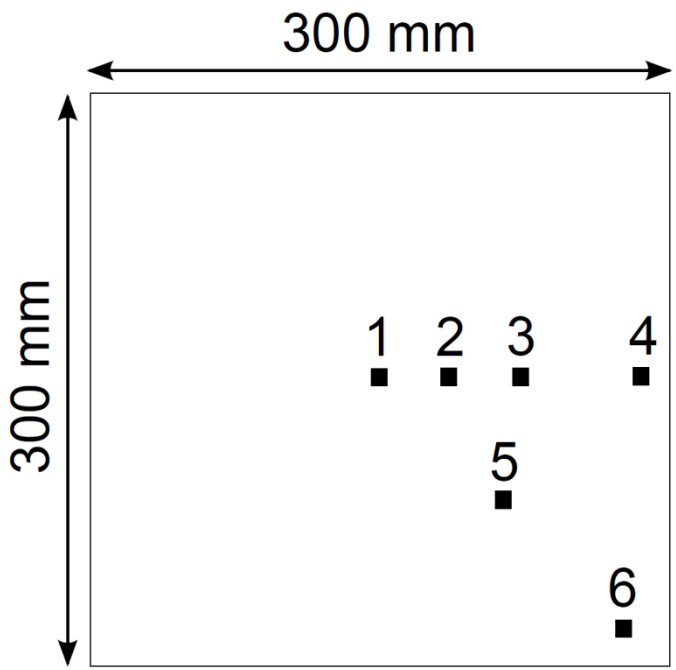

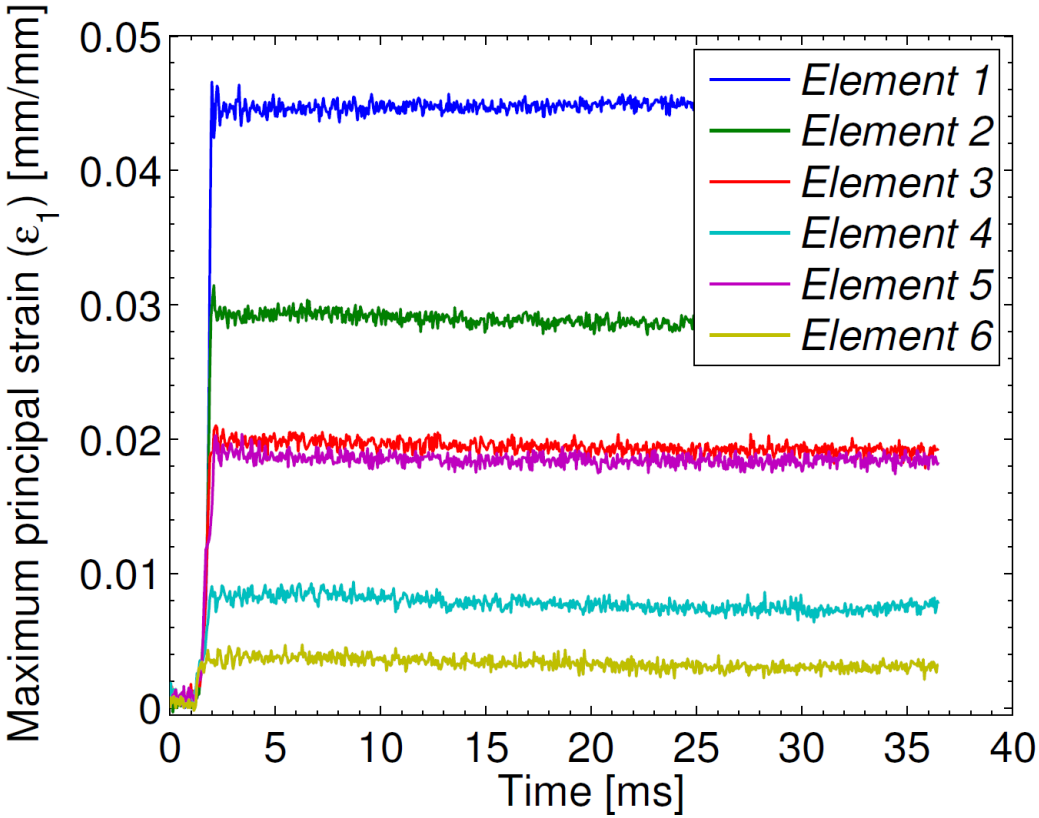

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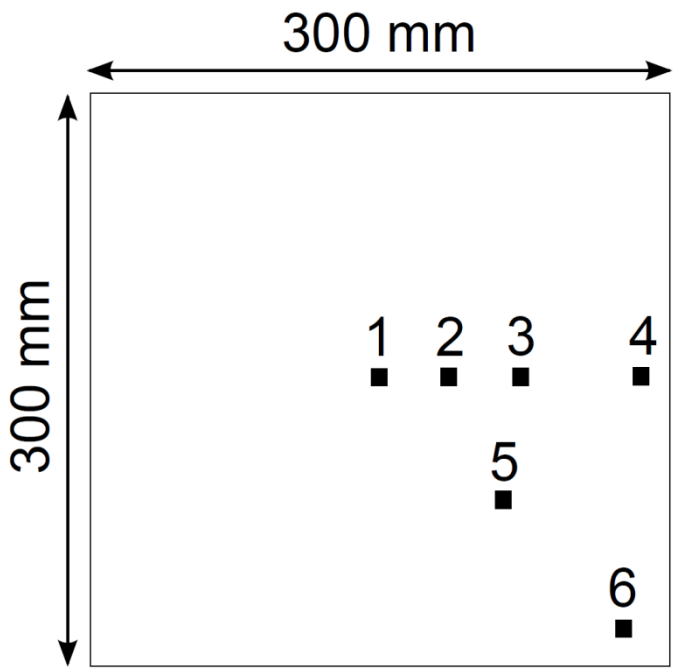

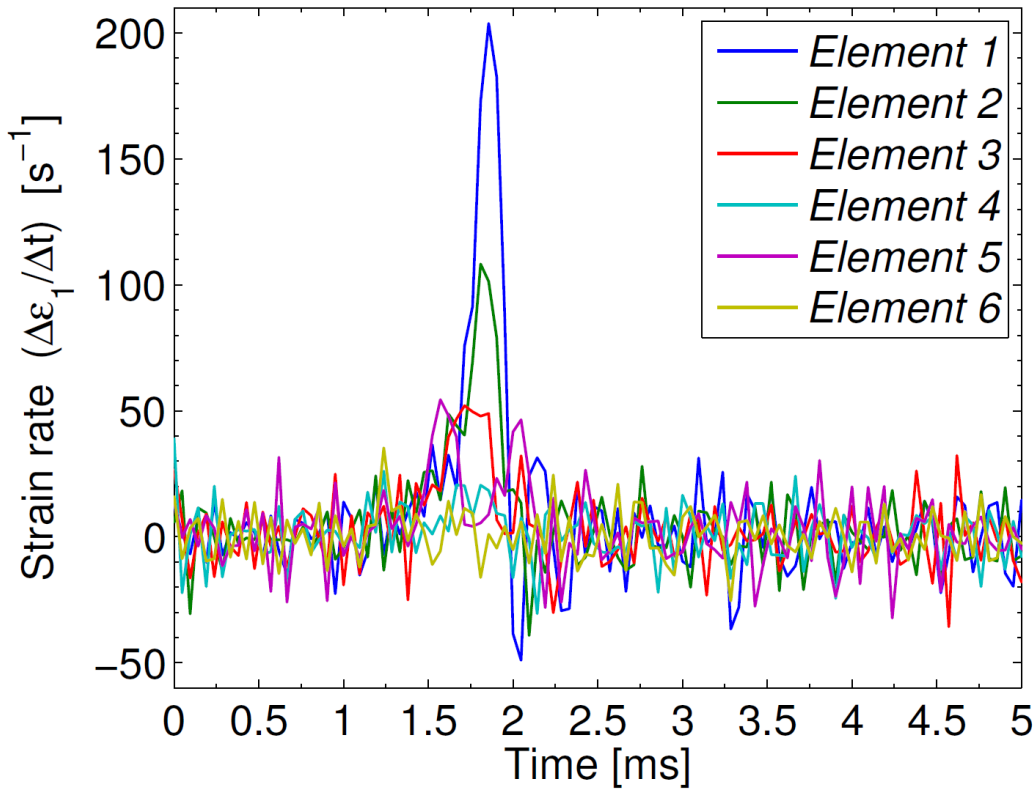

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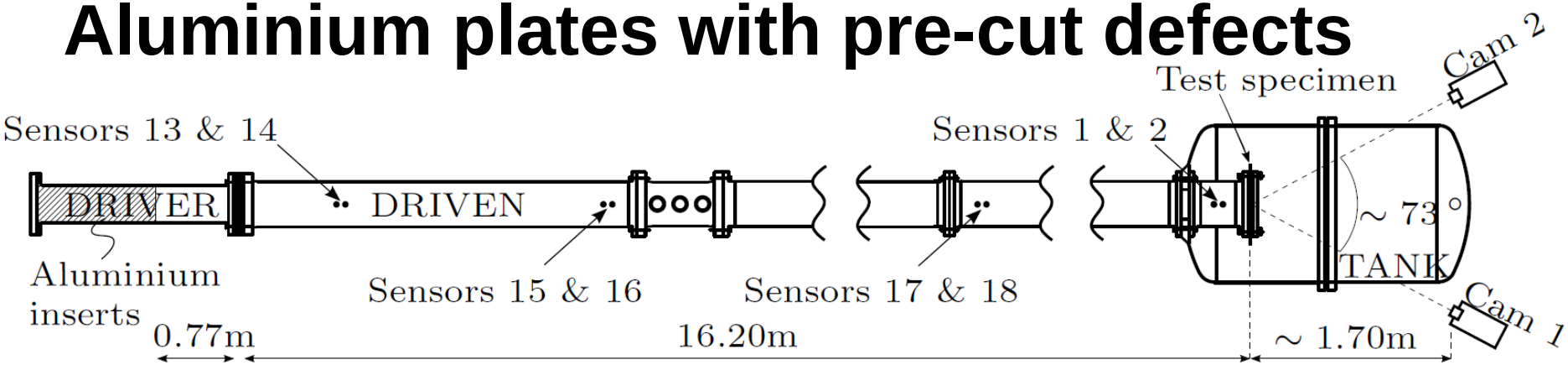
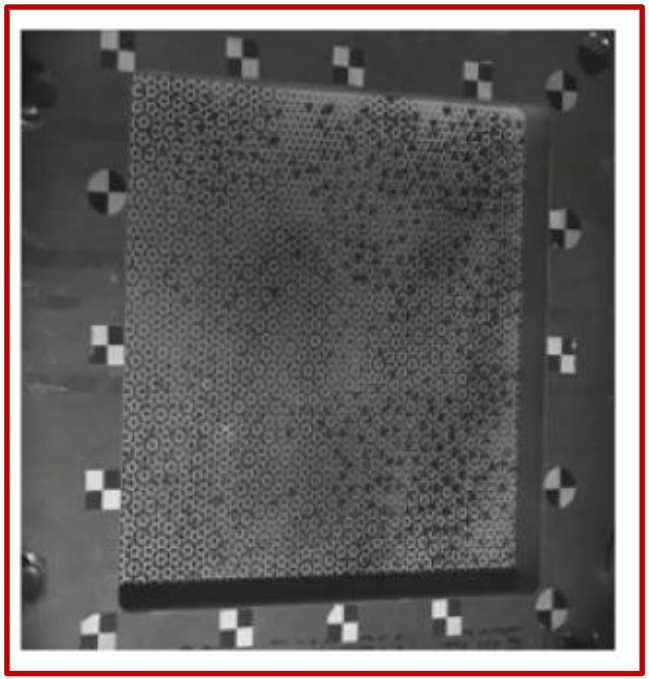
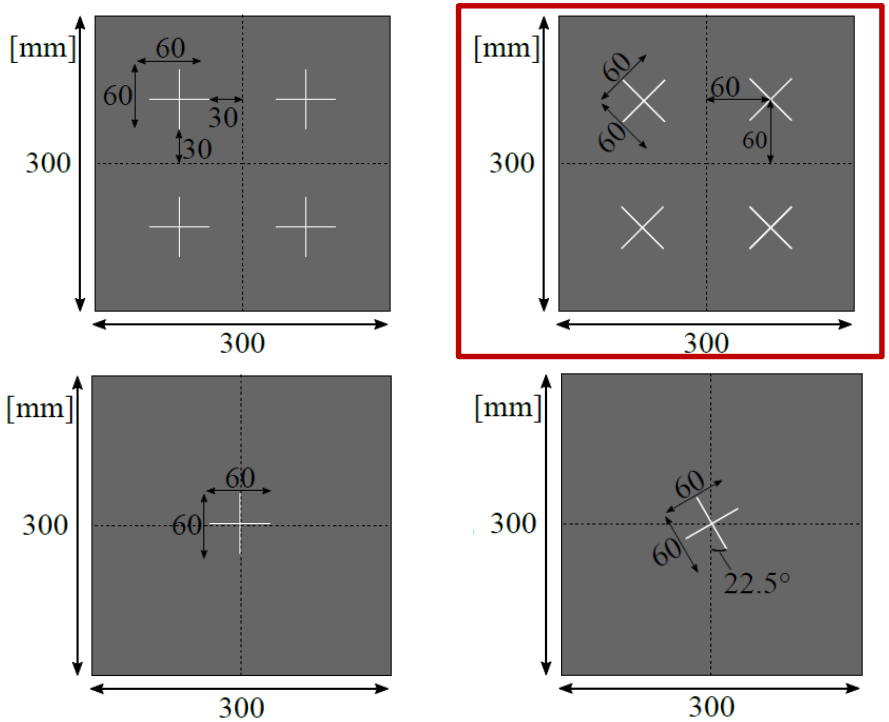
Aluminium plates with pre-cut defects







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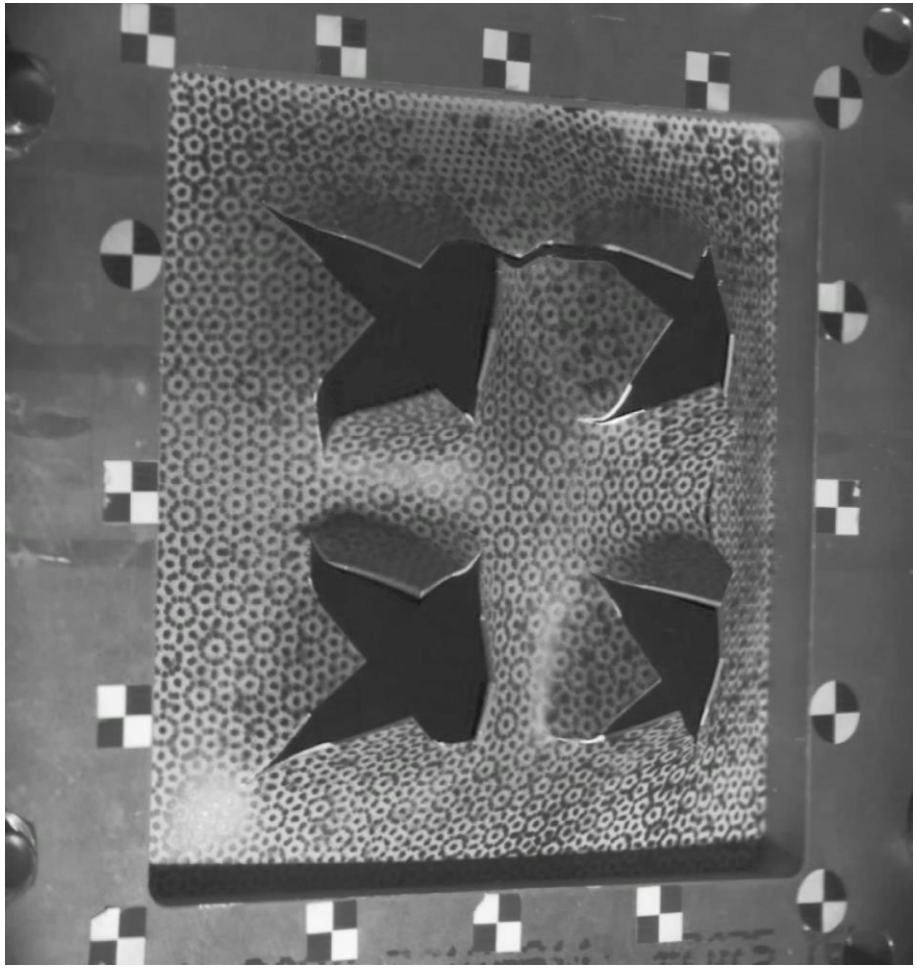
Aluminiumsplate with pre-cut defects



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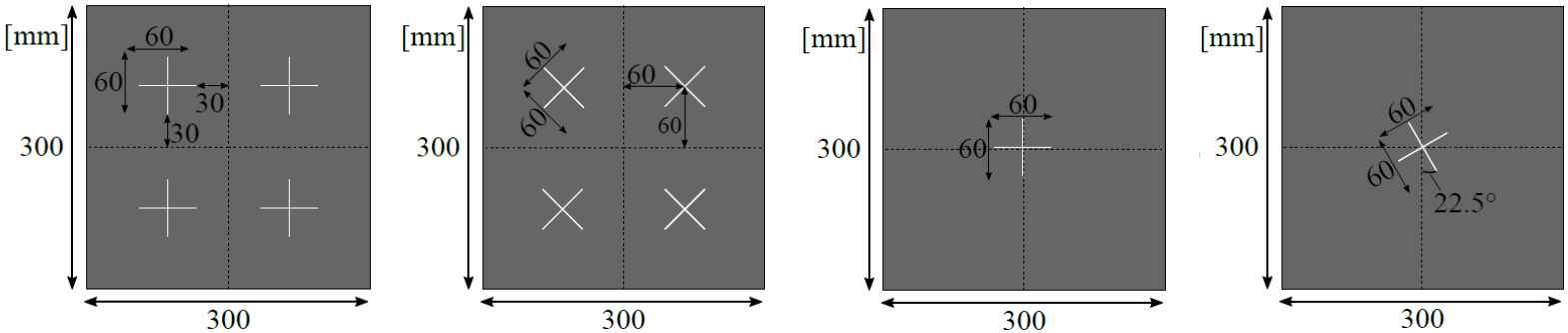
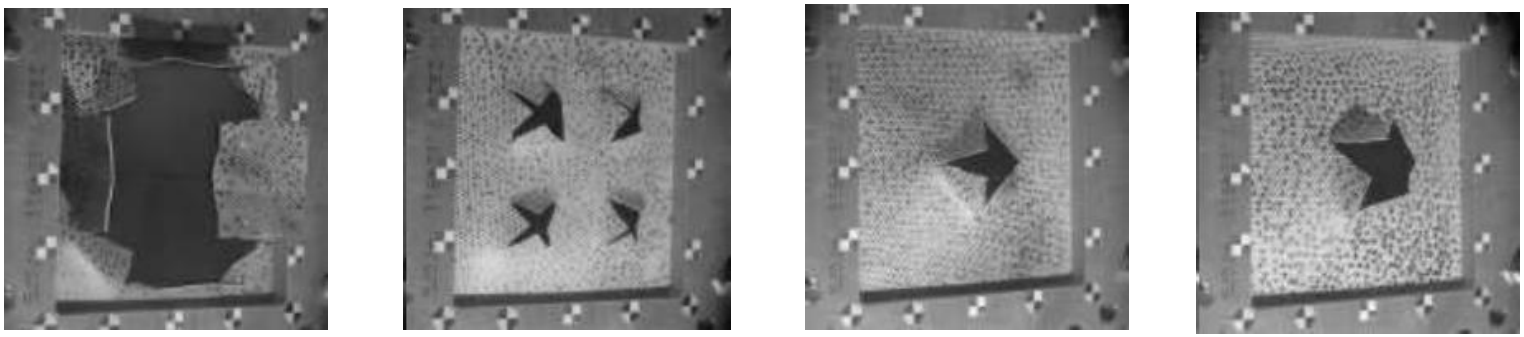
Aluminium plates with pre-cut defects

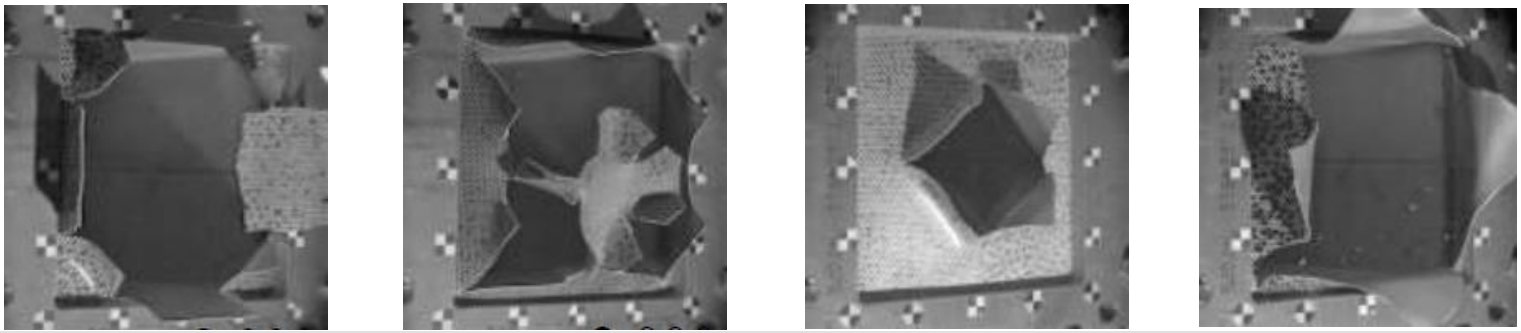
6016 – T4



$P_{r,max}$ = 460 kPa



$P_{r,max}$ = 620 kPa



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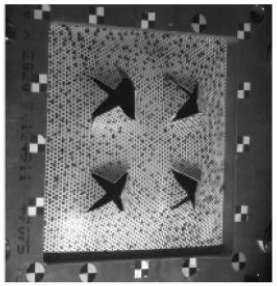
$P_{r,max}$ = 460 kPa

6016 - TX

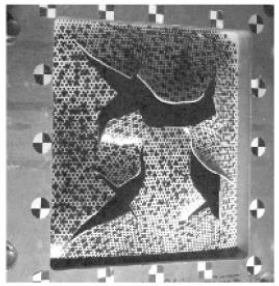
Aluminium plates with pre-cut defects

T4



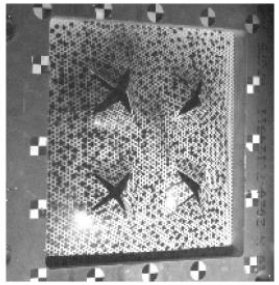
t = 1.50 ms

T6

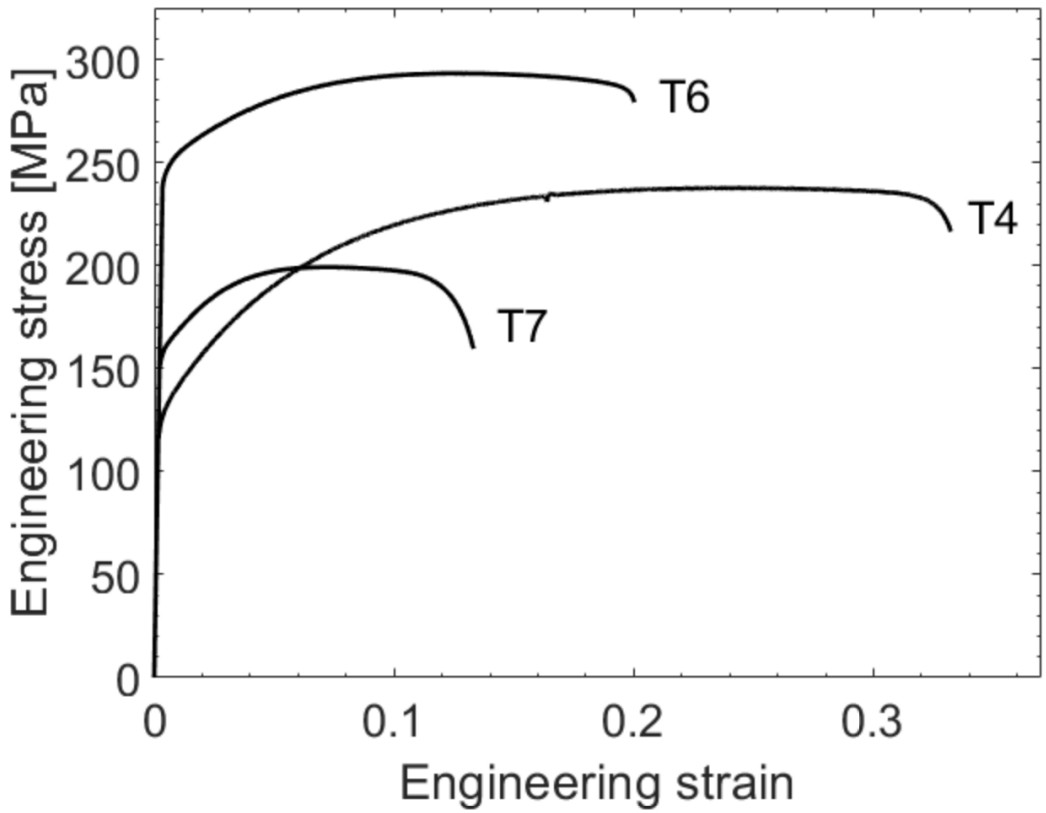


t = 1.50 ms

T7



t = 1.50 ms



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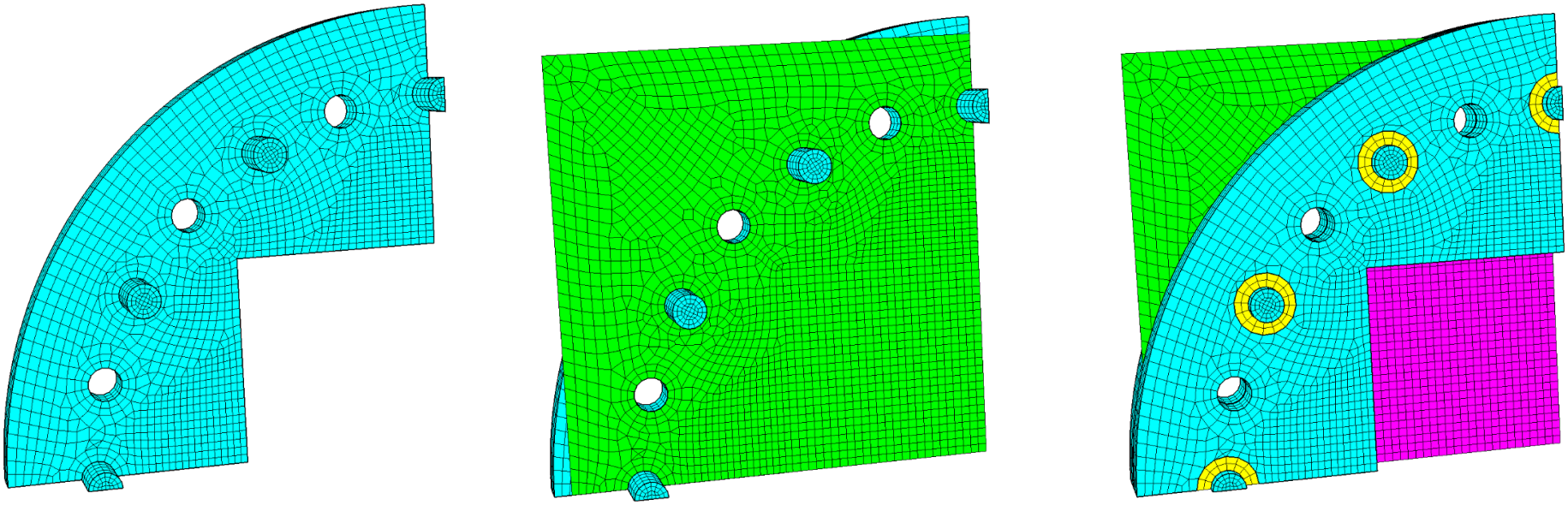
Computer simulations

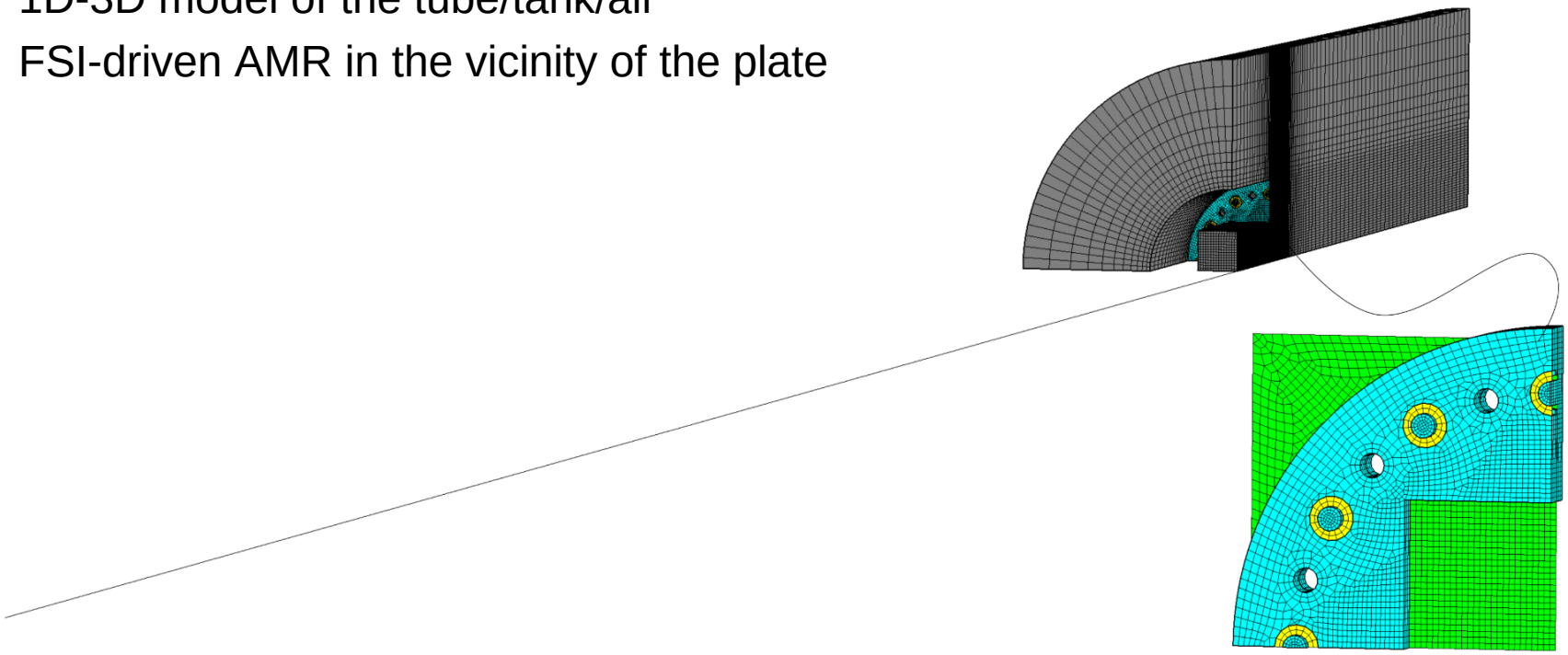
Use the FE code EUROPLEXUS (EPX)



- Assuming symmetry (1/4 model)
- 4-node shell elements (6 mm x 6 mm)
- 3 blast intensities
- Uncoupled vs. coupled FSI approach

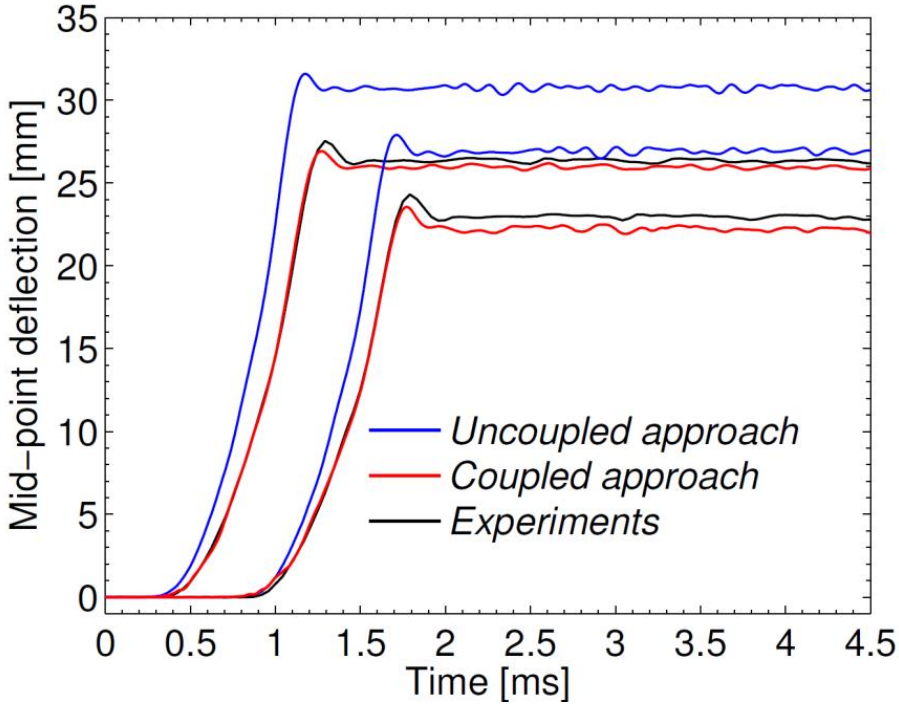
Coupled FSI approach

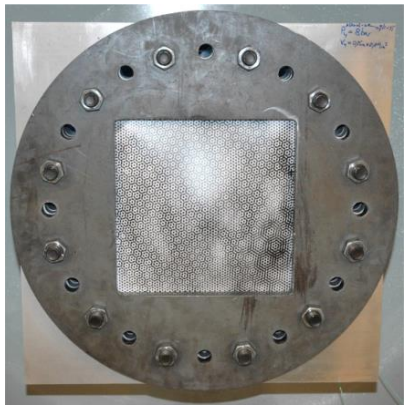
- Assuming symmetry (1/4 model)
- 1D-3D model of the tube/tank/air
- FSI-driven AMR in the vicinity of the plate



Validation of model

Test	HS images	3D-DIC
A5		
A7		
A10		





Numerical results in **good agreement** with experimental data

6-mm mesh size **not able** to predict failure

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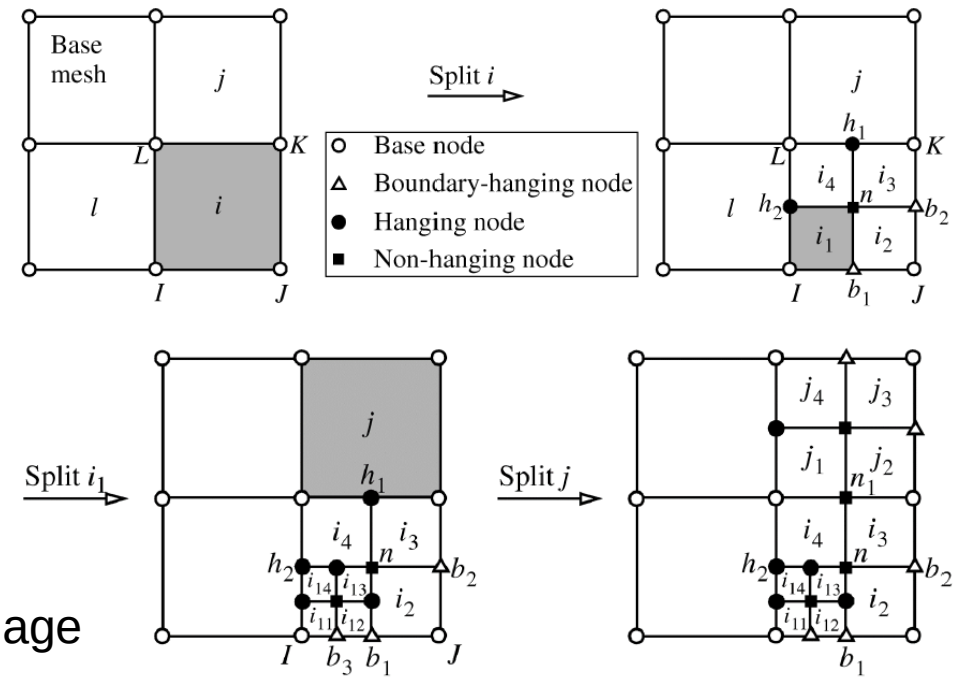
Adaptive mesh refinement (AMR)

- AMR using a threshold criterion
- Based on damage parameter

$$D = \frac{1}{W_c}\int_0^p \langle \sigma_1 \rangle \, dp$$

- Refine mesh when $D_{min} < D < D_{max}$
- Refinements until a user-defined level
- Maximum refinement when $D > D_{max}$
- Controlled by GPs with the largest damage



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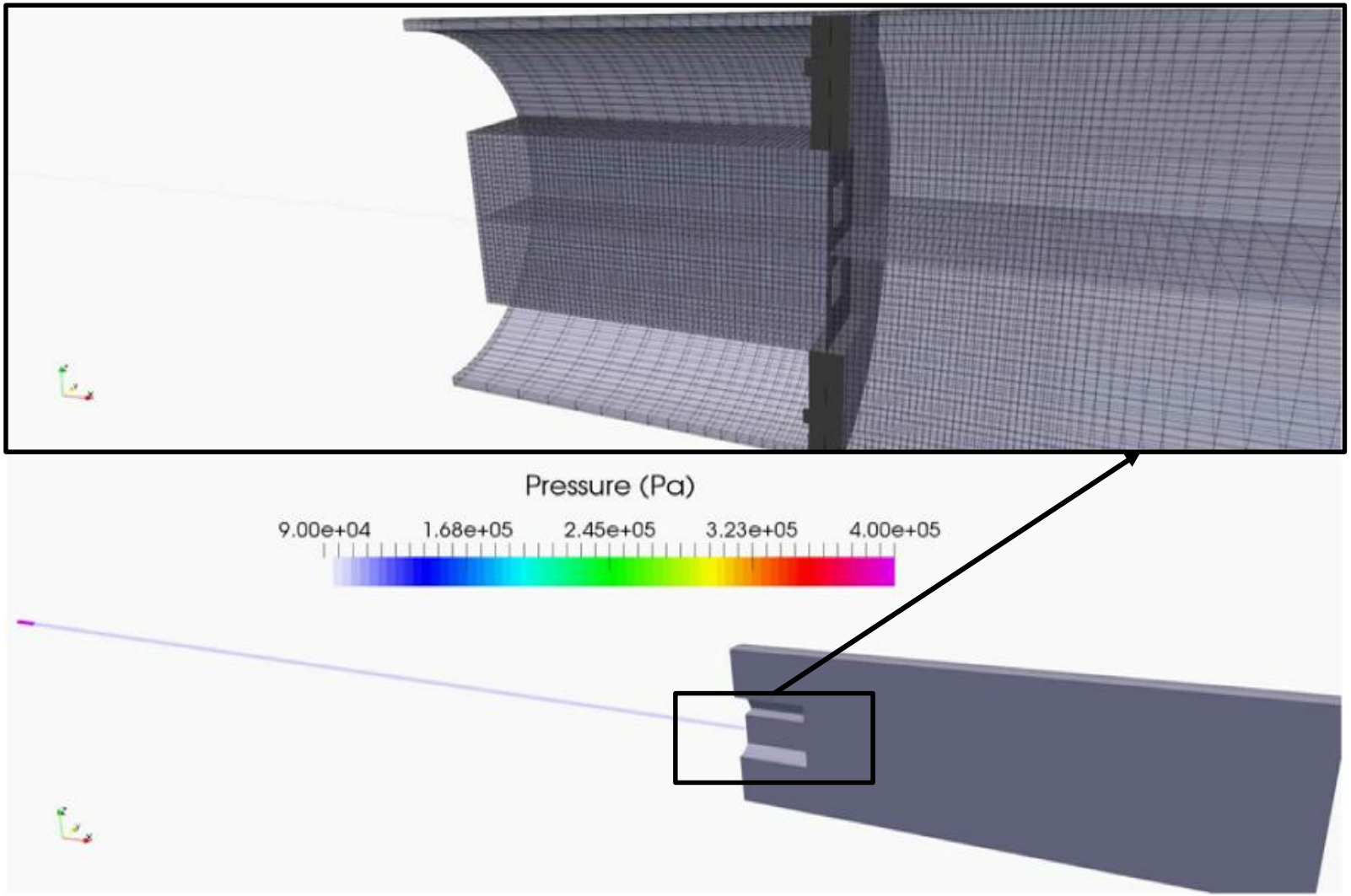

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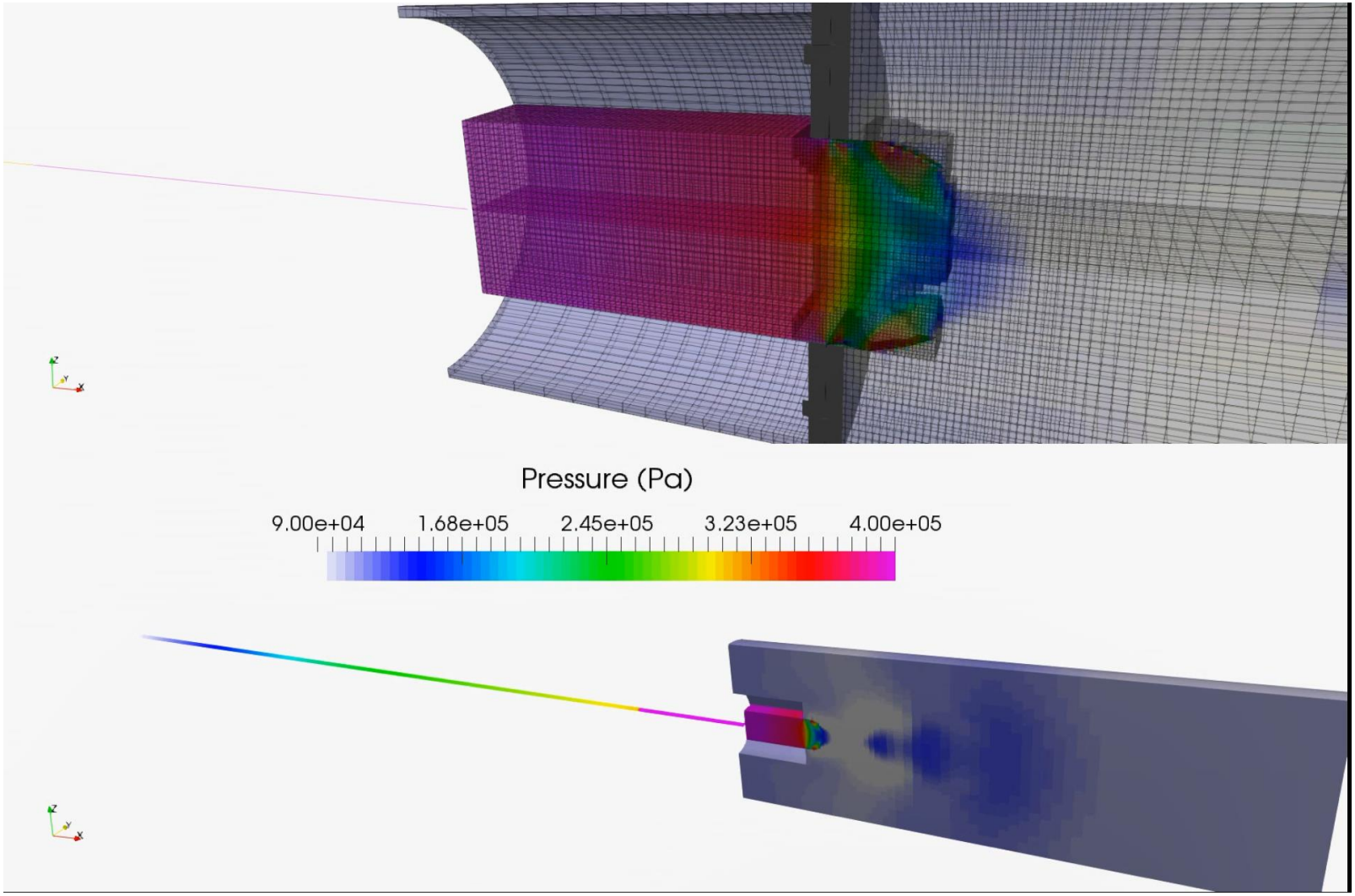

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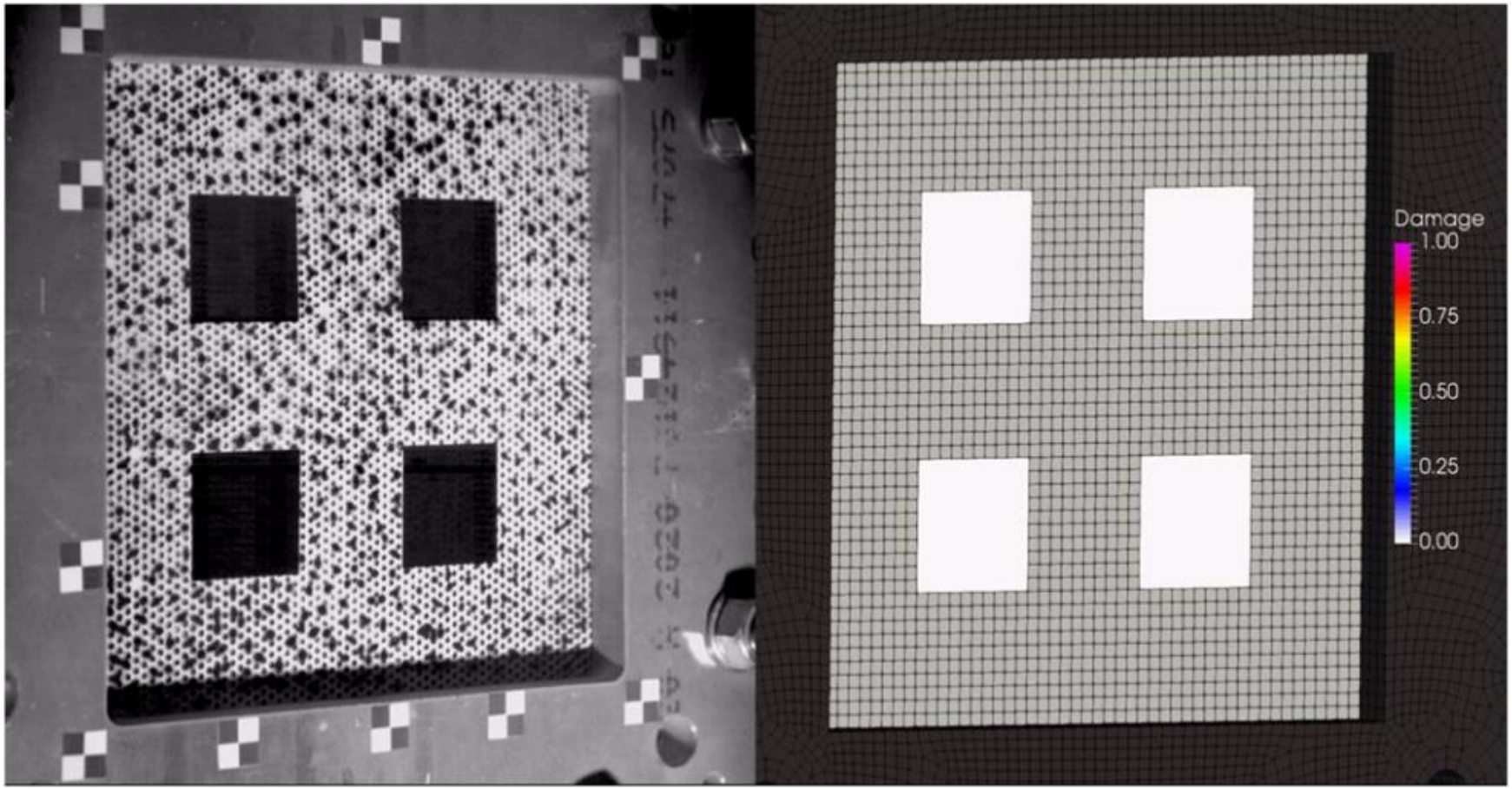
Comparison to experiment (qualitative)



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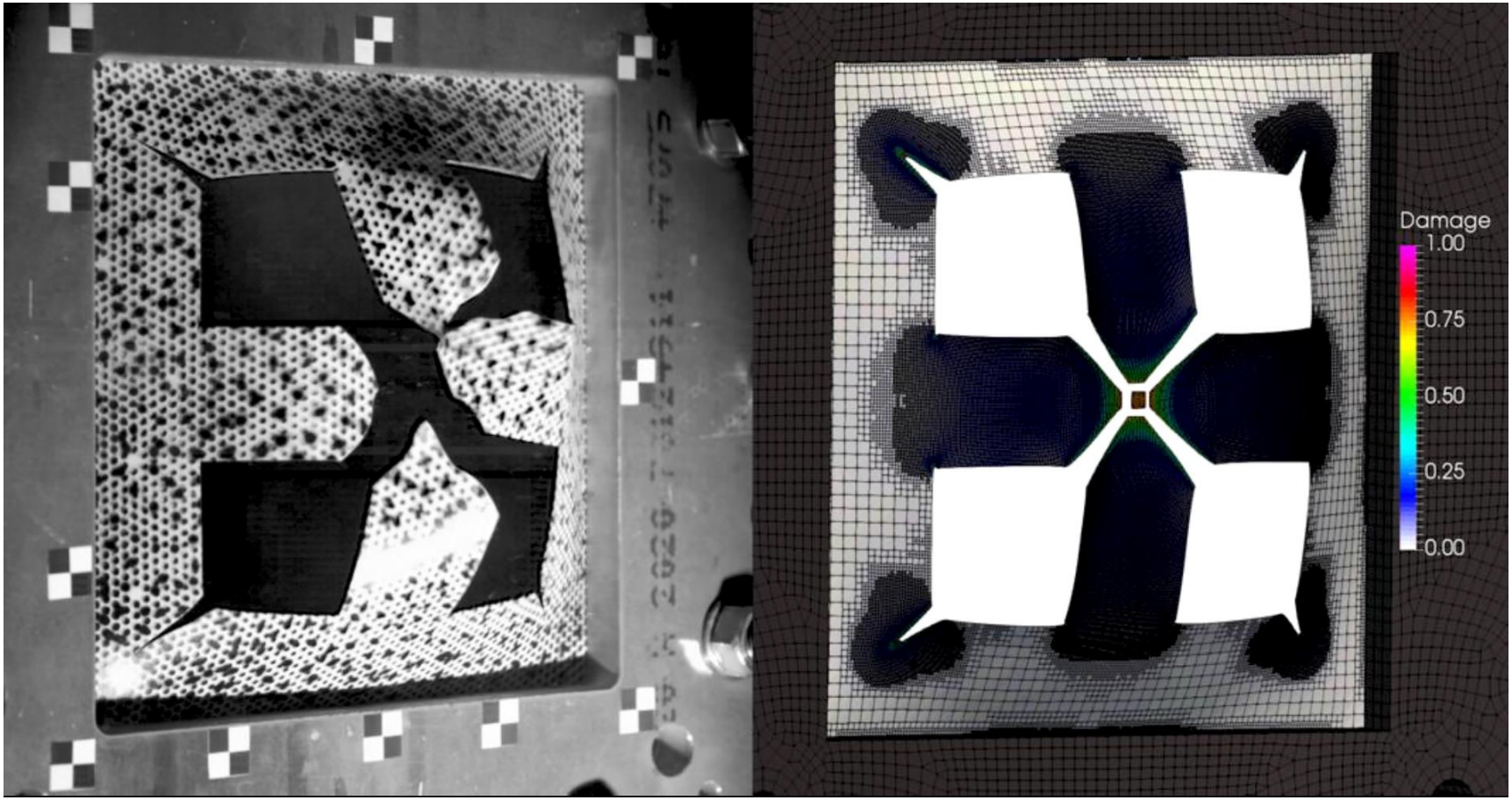

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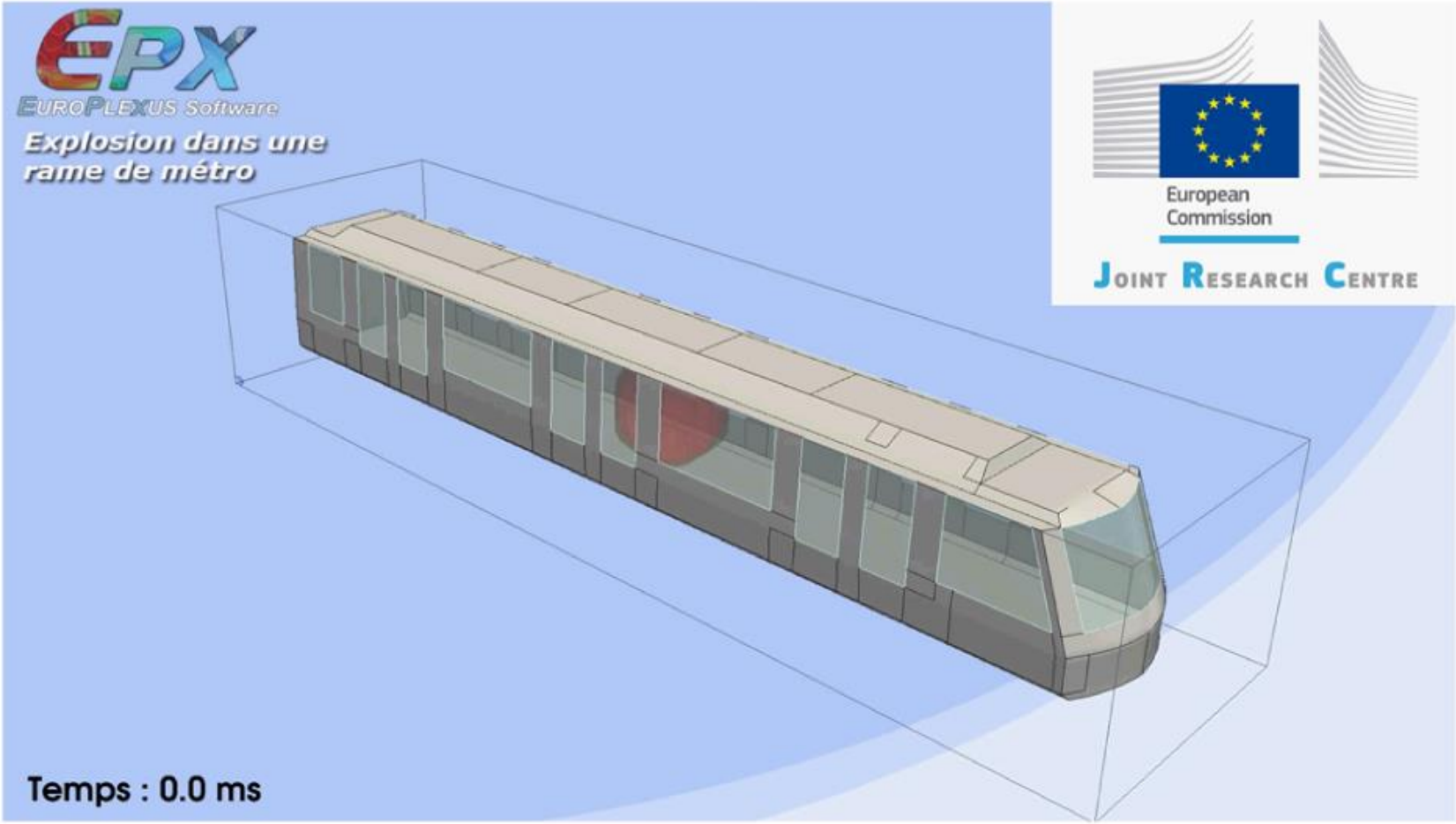
Application in realistic scenarios



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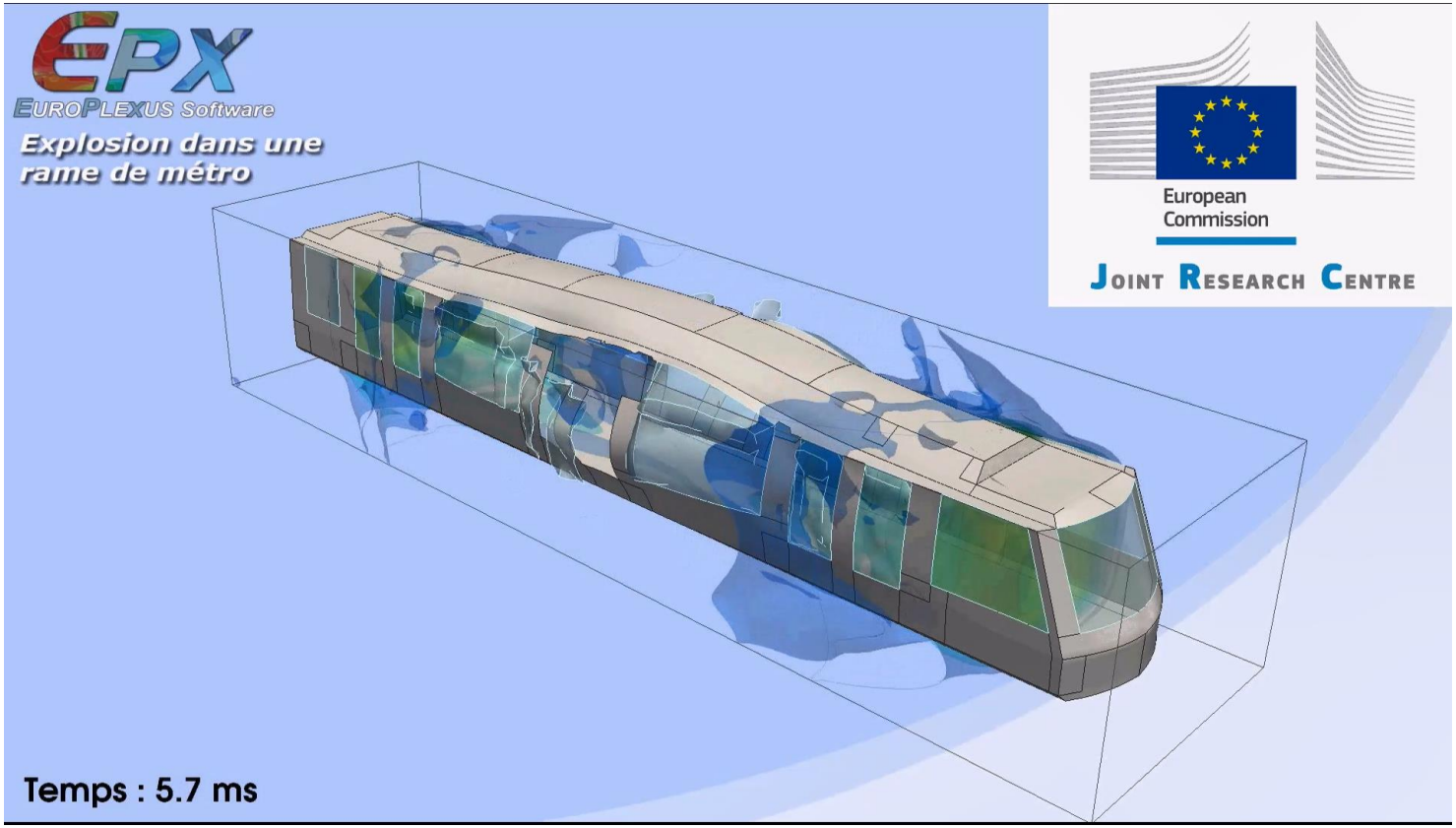
Application in realistic scenarios



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