Blast wave propagation:
A comparative study of two numerical solvers

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50th UKELG Anniversary Meeting on 'Explosion Safety – Assessment and Challenges'

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Outline

- Motivation
- Blast solver & Flacs solver
- Open air field simulations
- Dense explosives in confined geometries
- Urban canyon
- Prospects
- Conclusions

Hazards related to blast waves

- Accidental explosions
  - Deflagrations
  - Detonations!
- Malicious attacks
  - Condensed explosives

Buncefield, 11 December 2005, Northgate building

Oslo, 22 July 2011, Regjeringskvartalet

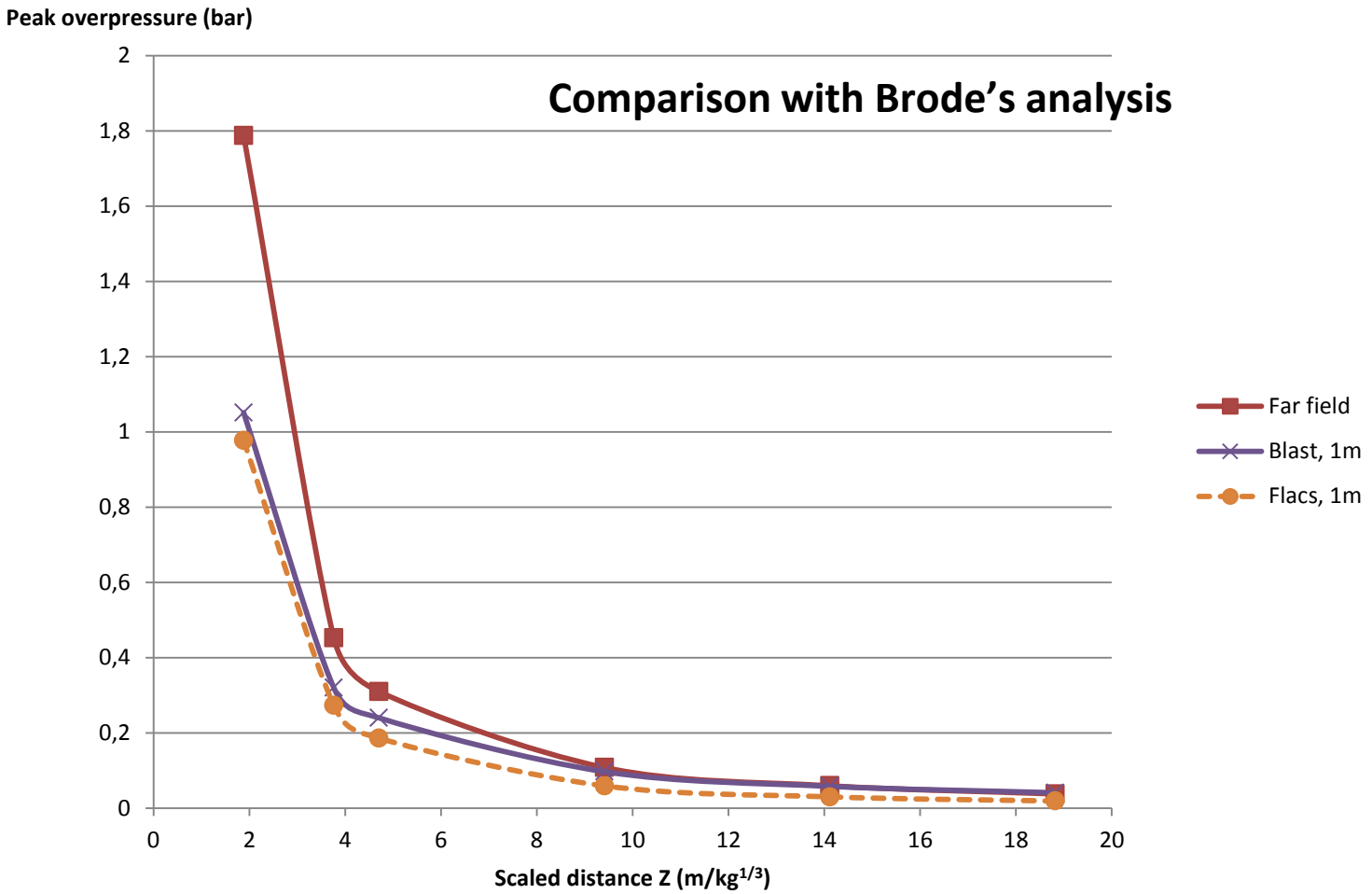
Solvers

Blast Solver	Flacs solver
• **Euler** equations (no turbulence) • **ICE**: Implicit Continuous Eulerian • 2nd order upwind convection scheme (**van Leer**) • Relatively small memory footprint	• **Navier-Stokes** equations • Standard *k*-*ε* turbulence model • **SIMPLE**: Pressure-correction method • 2nd order blended upwind+central convection scheme (**kappa**) • Quite large memory footprint

Improvements to Blast

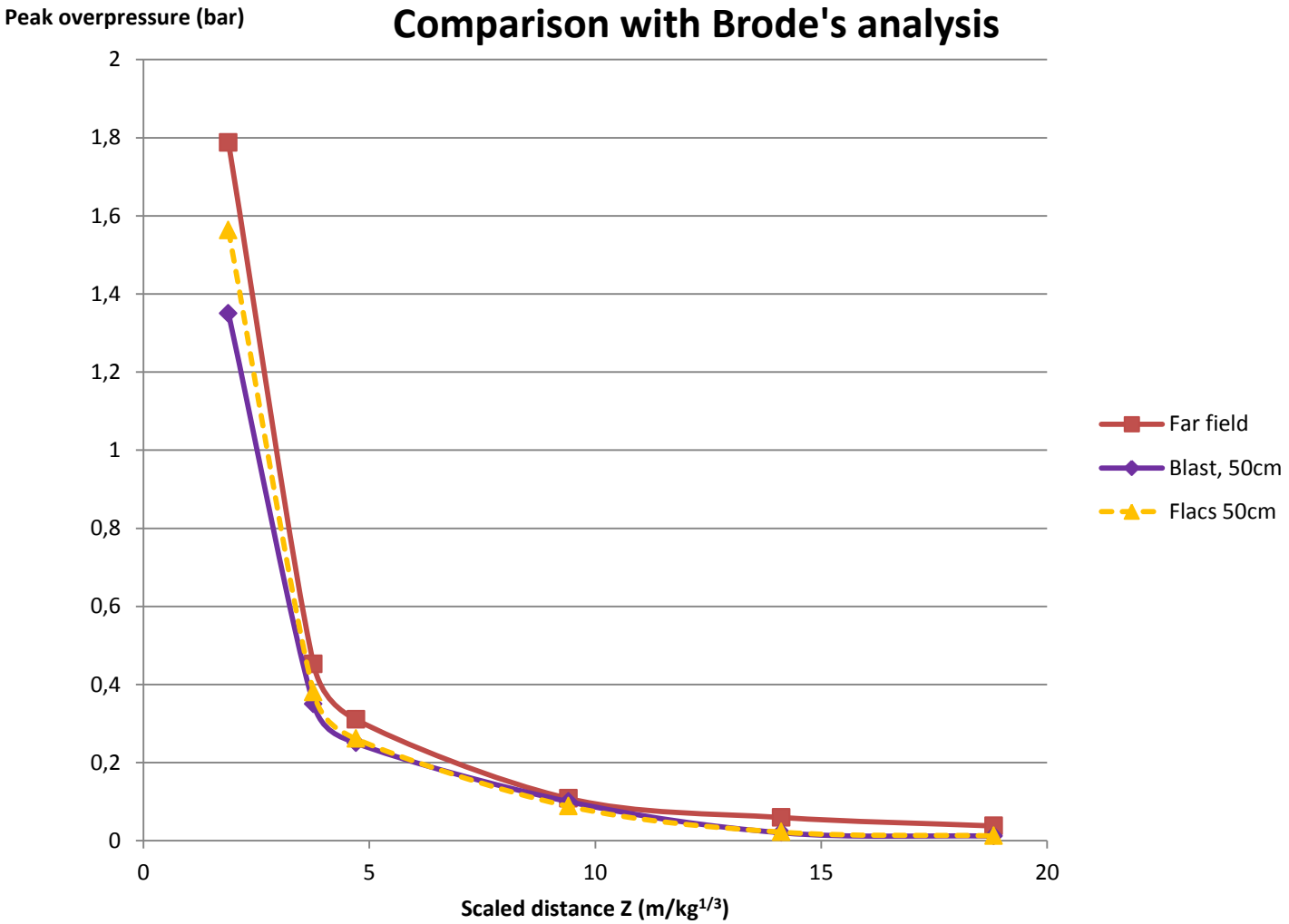
- Open MP parallelization
  - Run up to 40 million grid cells simulation on 4 CPU
- Improved symmetry in the solution
- Improved loop optimizations

Open air field simulation



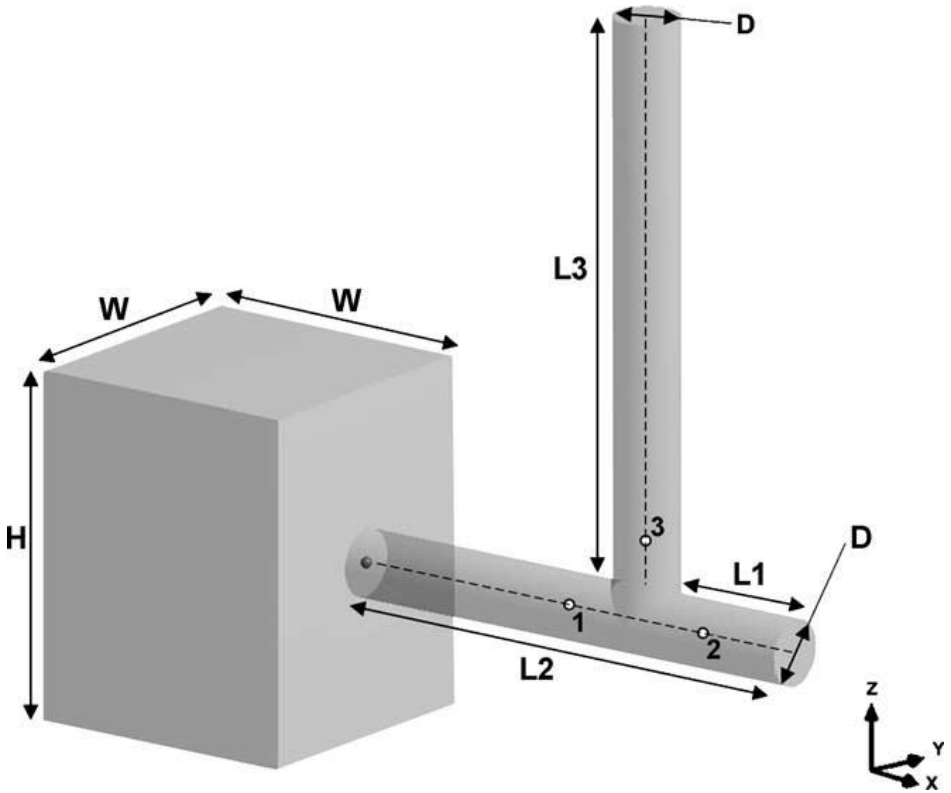
Brode, H.L. Numerical solution of spherical blast waves. *Journal of Applied Physics*, 1955, No. 6, 26, 766-775.

Open air field simulation



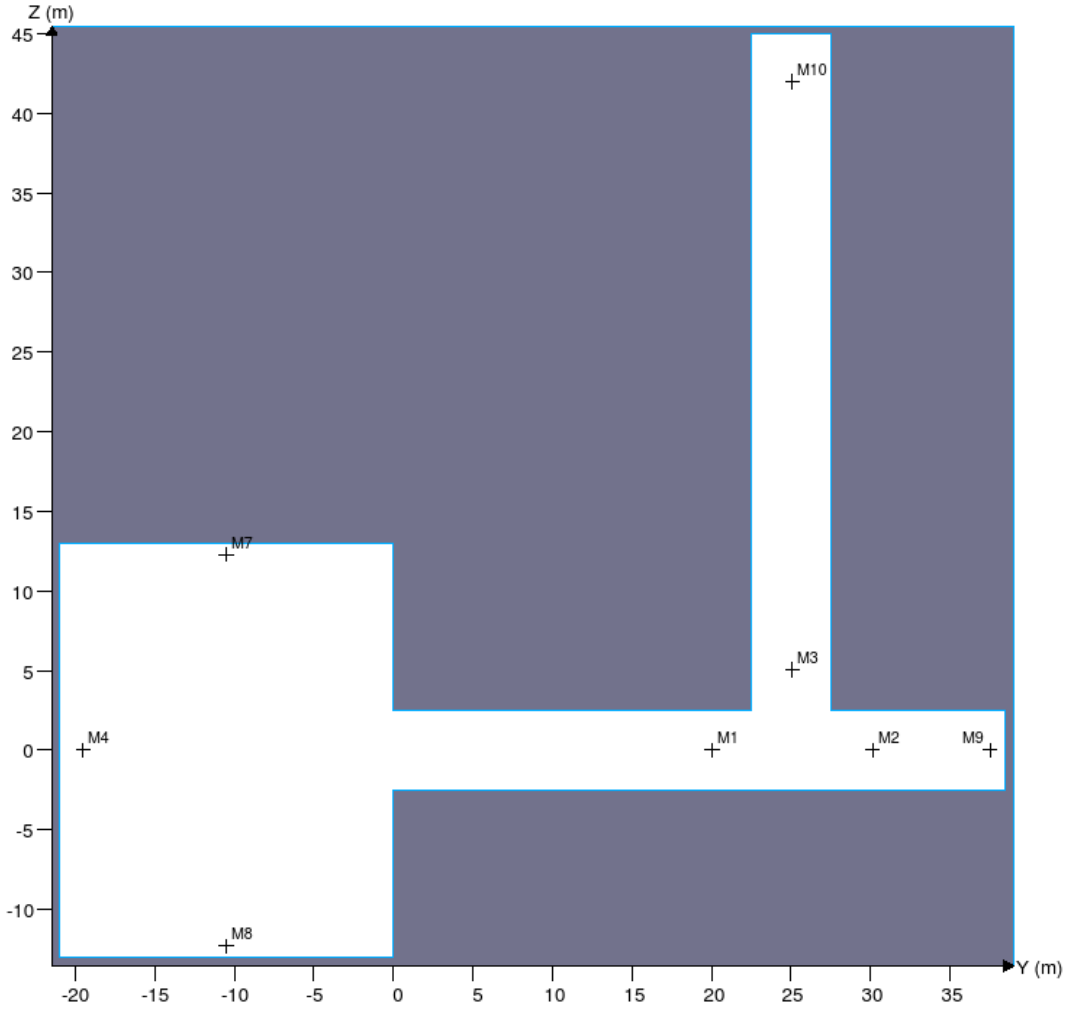
Dense explosives in confined geometry

- Rigas,F. & Sklavounos, S. Experimentally validated 3-D simulation of shock waves generated by dense explosives in confined complex geometries. *Journal of Hazardous Materials*, A121 (2005) 23-30



Small scale:	Full scale:
L1= 0.360m	L1= 10.8m
L2= 1.280m	L2= 38.4m
L3= 1.416m	L3= 42.48m
D= 0.168m	D= 5m
W= 0.7m	W= 21m
H= 0.868m	H= 26.04m
18,5g of Plastit	500kg of Plastit

Dense explosives in confined geometry



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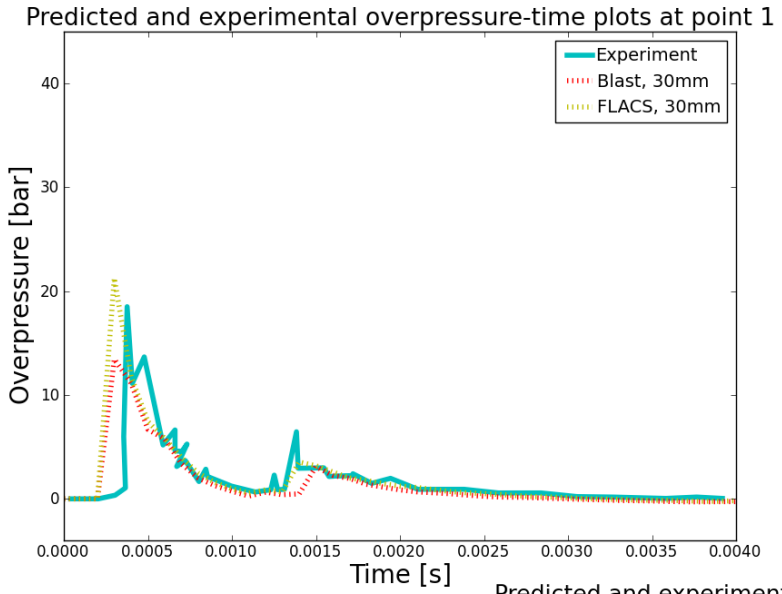
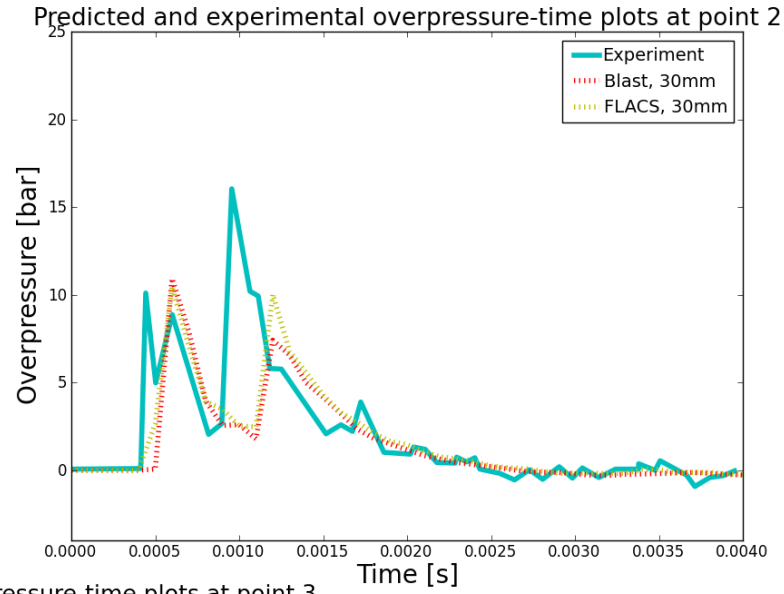
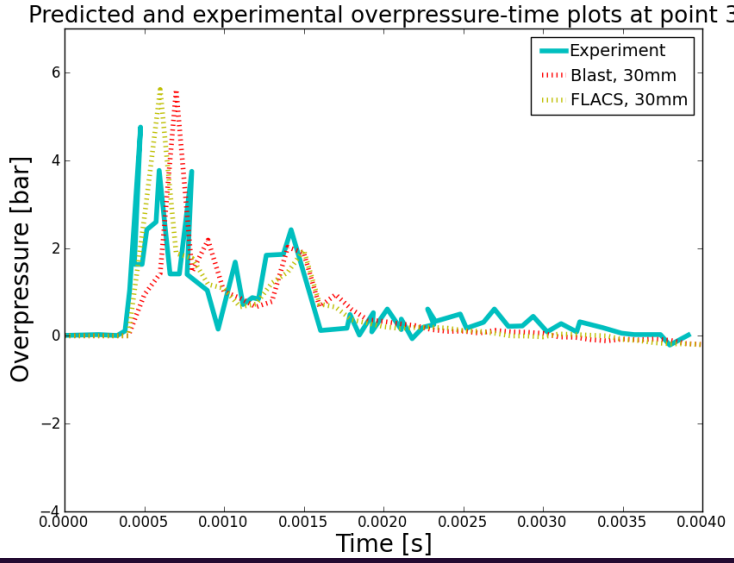
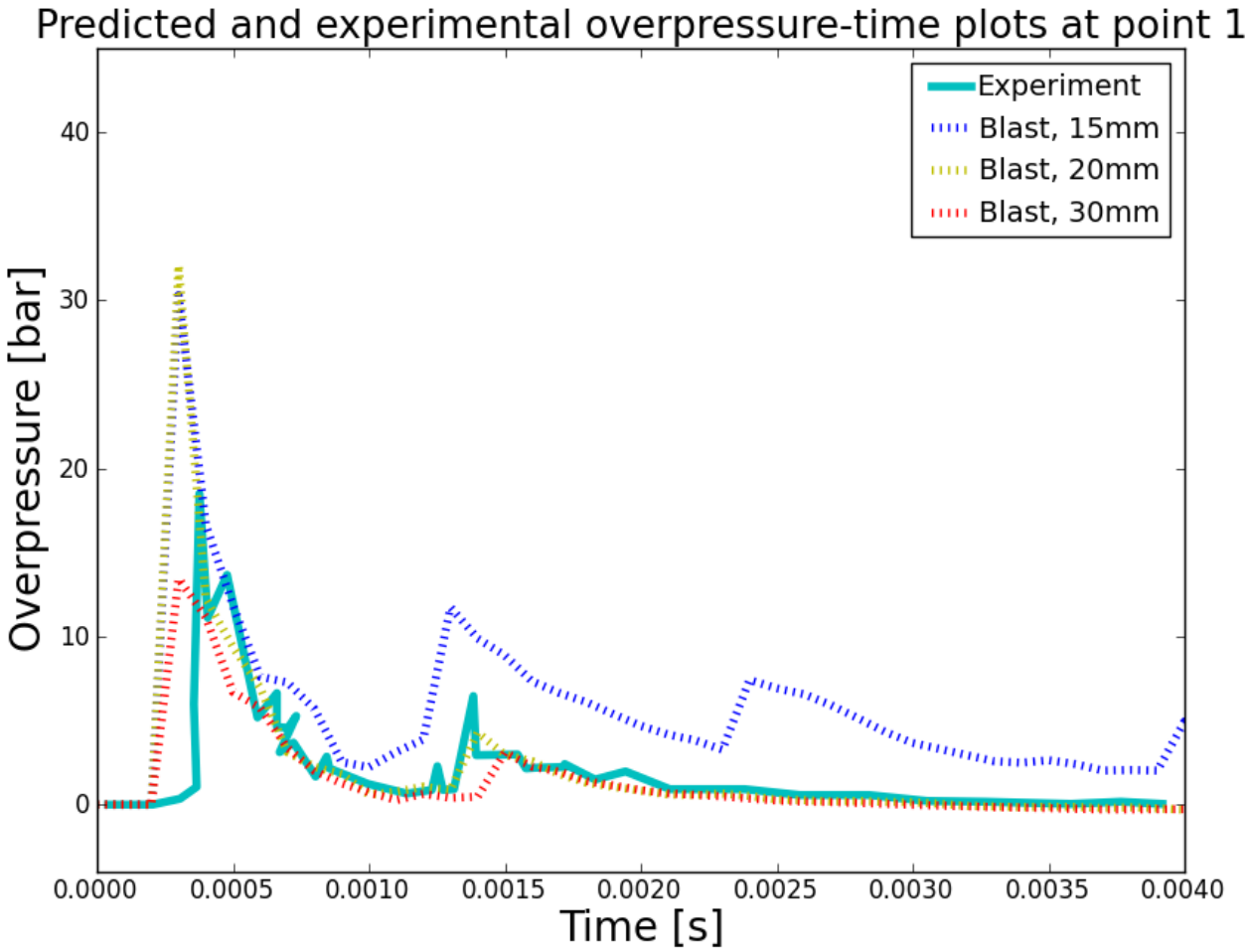
Dense explosives in confined geometry







Dense explosives in confined geometry



Dense explosives in confined geometry

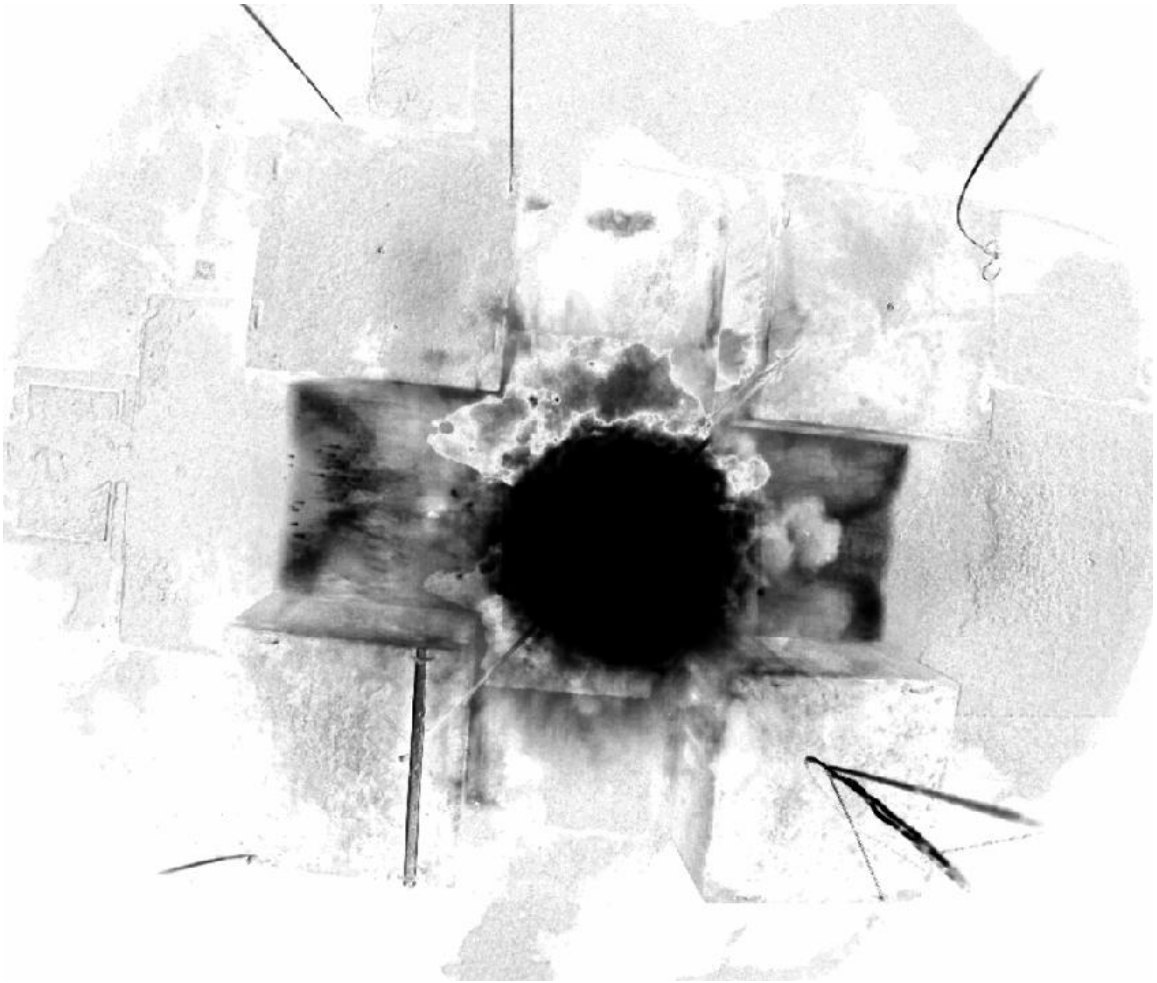
Arrival times (s)

	Measurement points	Experimental value (ms)	Computational value (ms)		Error with Blast (%)	Error with Flacs (%)
			BLAST code	FLACS code		
Grid 1.5cm	Point 1	0,3	0,25	0,27	-16,7	-10,0
	Point 2	0,44	0,46	0,46	4,5	4,5
	Point 3	0,43	0,43	0,4	0,0	-7,0
Grid 2cm	Point 1	0,3	0,27	0,26	-10,0	-13,3
	Point 2	0,44	0,48	0,46	9,1	4,5
	Point 3	0,43	0,45	0,41	4,7	-4,7
Grid 3cm	Point 1	0,3	0,27	0,25	-10,0	-16,7
	Point 2	0,44	0,51	0,48	15,9	9,1
	Point 3	0,43	0,47	0,43	9,3	0,0

Selected results

- 12.5 cm Blast solver
- 50 cm Blast solver
- 50 cm Flacs solver

Urban Canyon Blast Load Calculations



Experiments

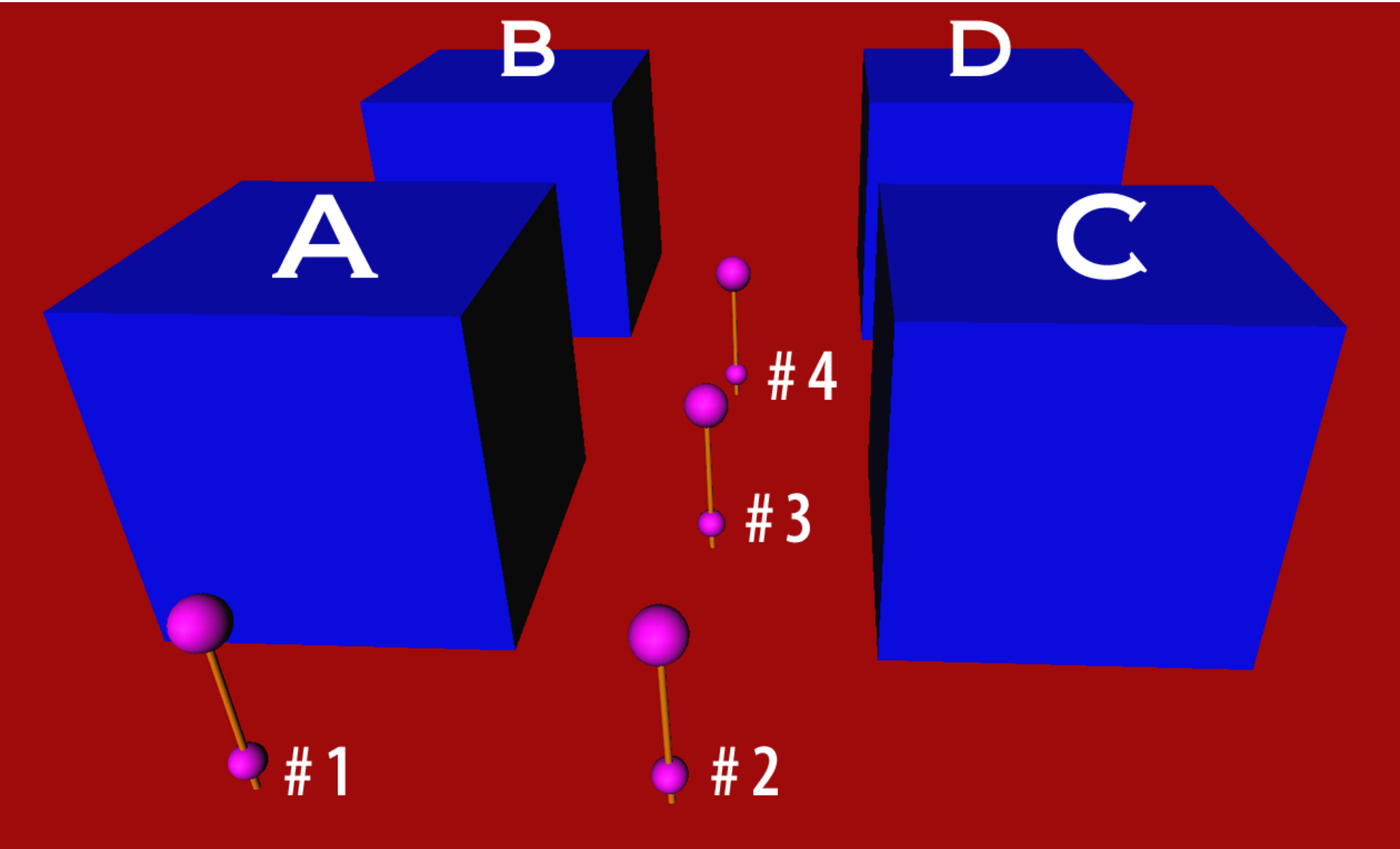
- Tests performed by Norwegian Defence Estates Agency (NDEA) and Swedish Defence Research Agency (FOI) during spring 2006.
- Geometry consisting of four 2.3-metre cubical concrete blocks, representing buildings in an intersection at scale 1:5.
- Simulated 8 experiments with PETN with FLACS-Explo (Blast solver)

Experiments

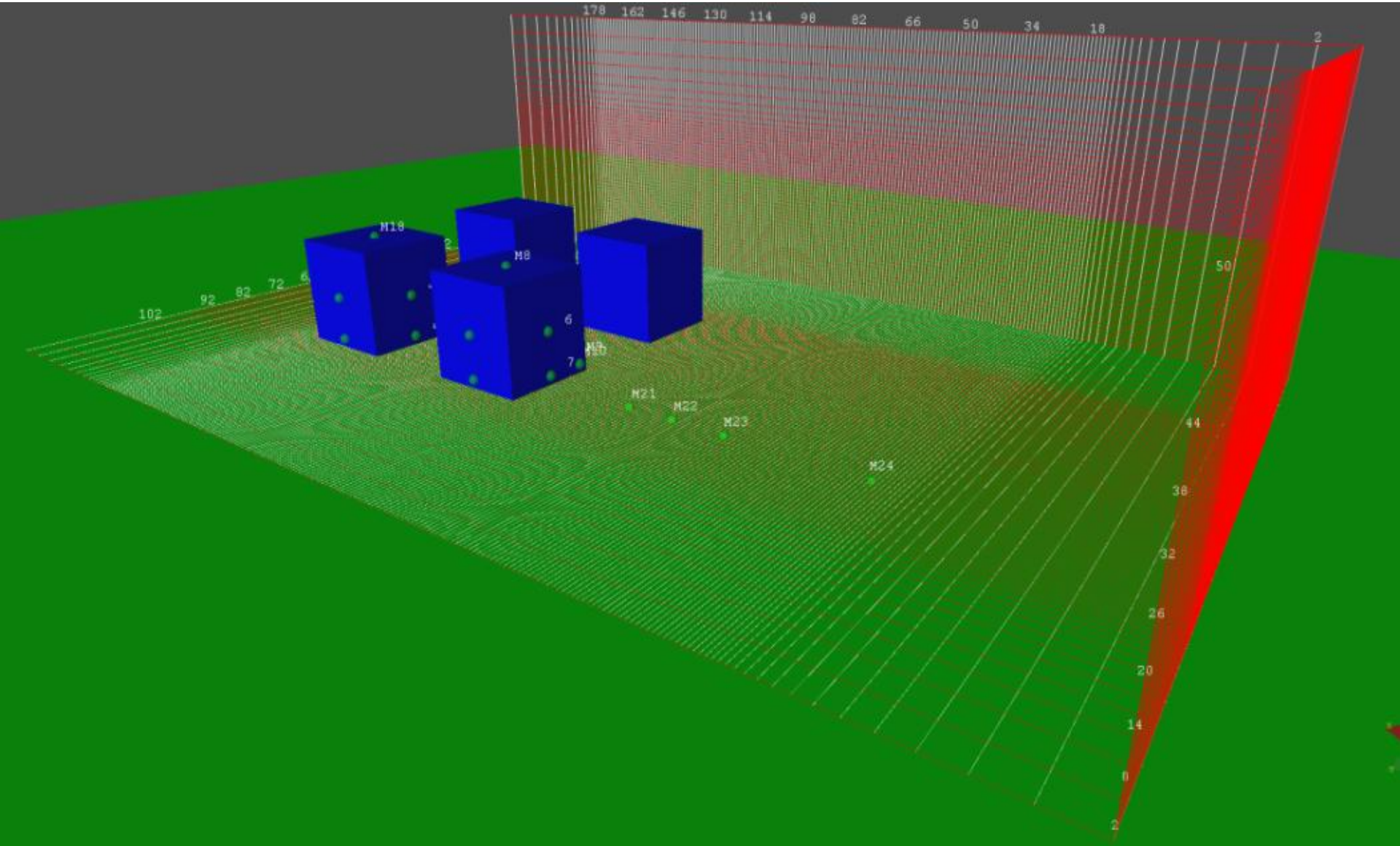
Simulated tests

No.	Charge (kg_{PETN})	Equivalent charge (kg_{TNT})	Location #	HOB (m)
1	0.40	0.44	1	0.20
2	1.60	1.76	1	1.15
4	0.40	0.44	2	0.20
5	1.60	1.76	2	1.15
7	0.40	0.44	3	0.20
8	1.60	1.76	3	1.15
10	0.40	0.44	4	0.20
11	1.60	1.76	4	1.15

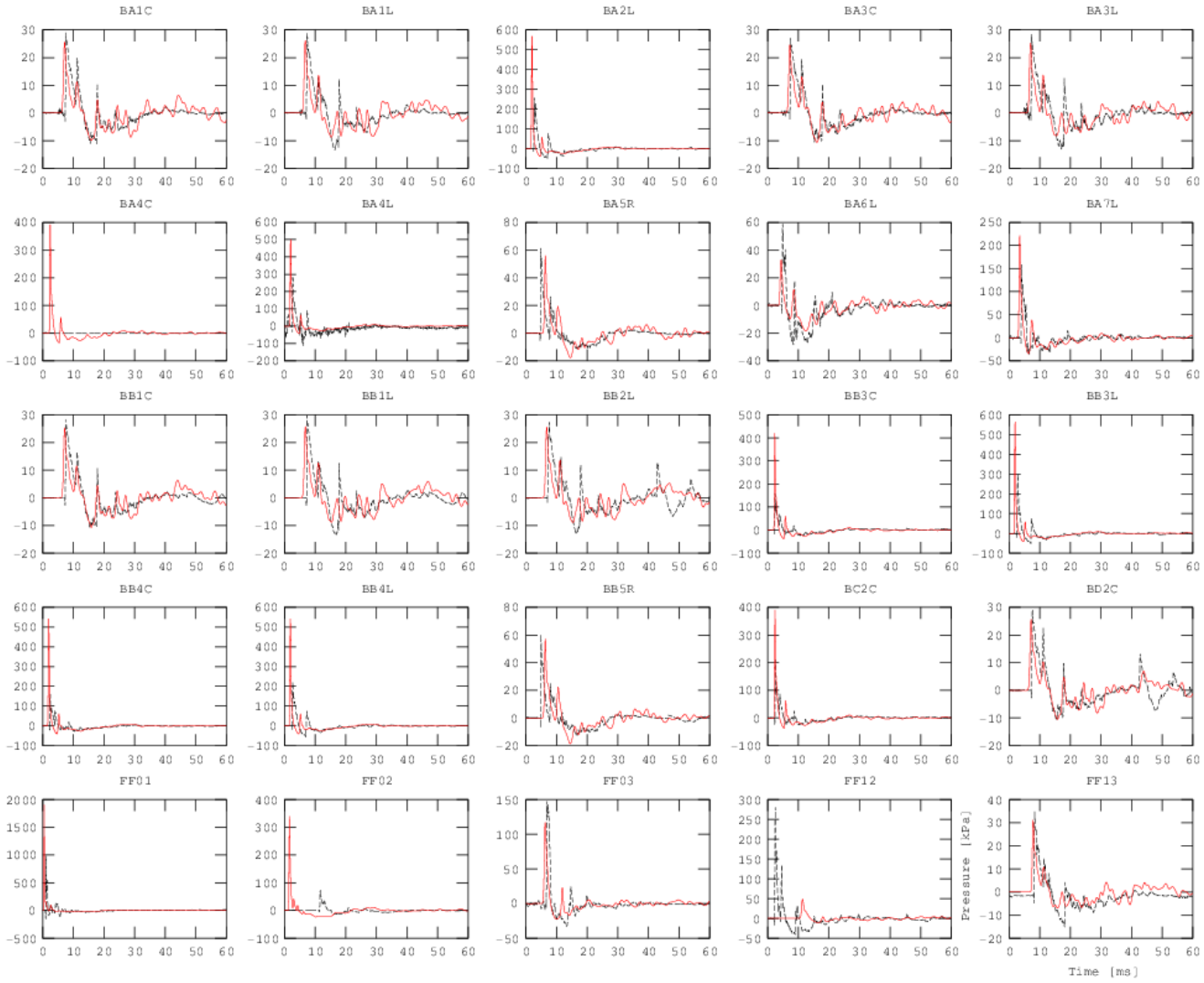
Eight scenarios



Geometry and grid



Pressure results for Blast v1



25 monitor points

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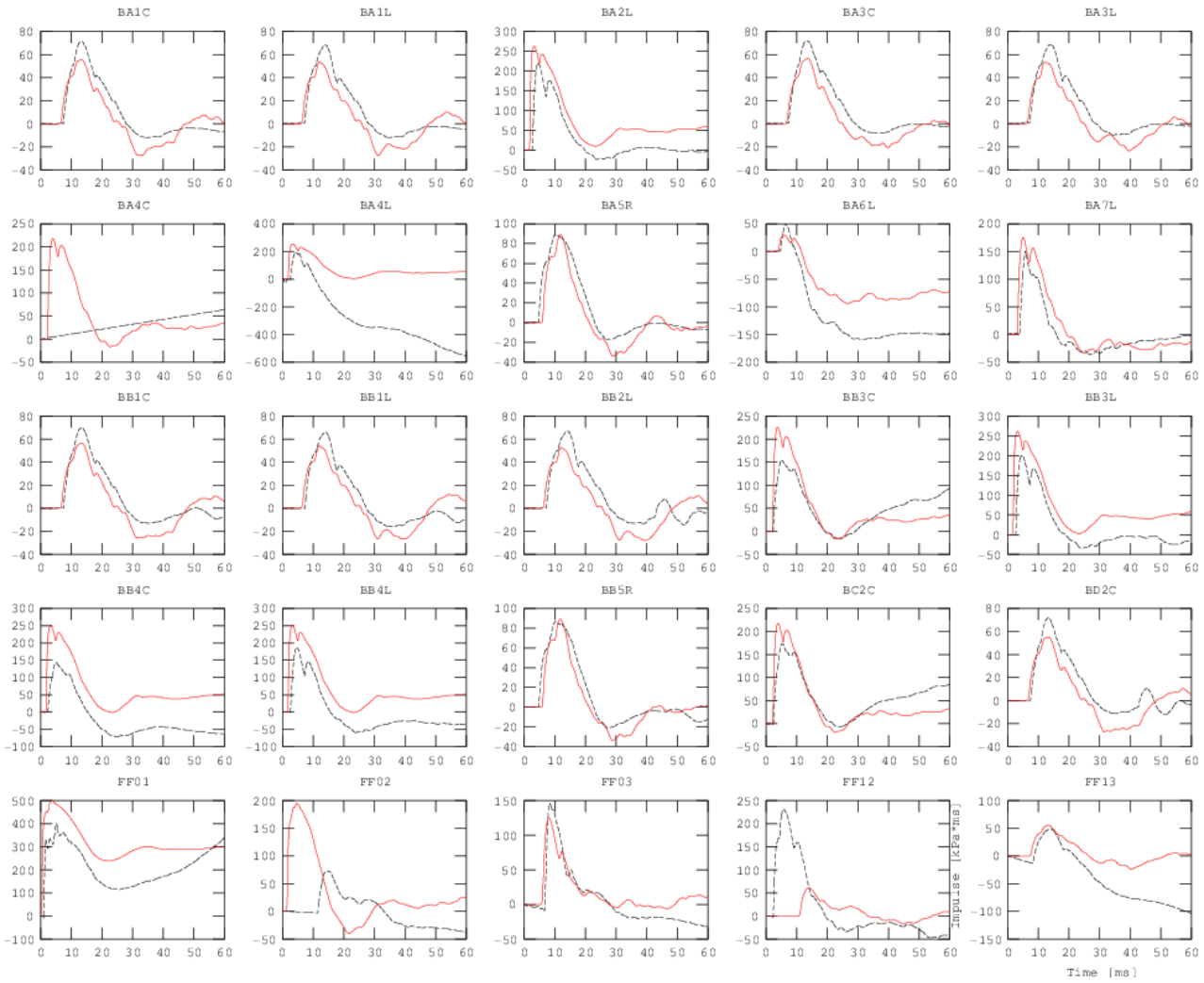
Impulse results for Blast v1



25 monitor points

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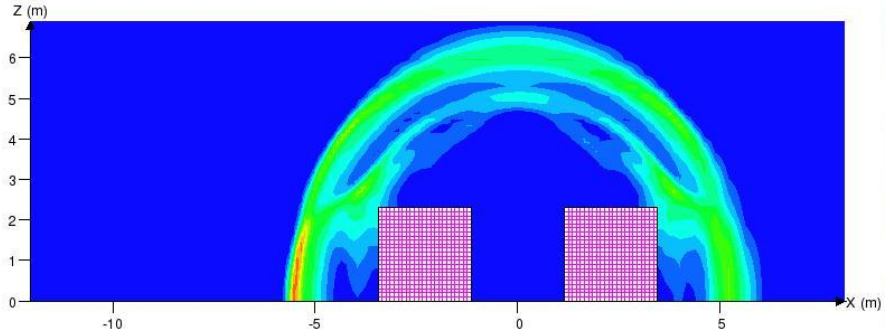
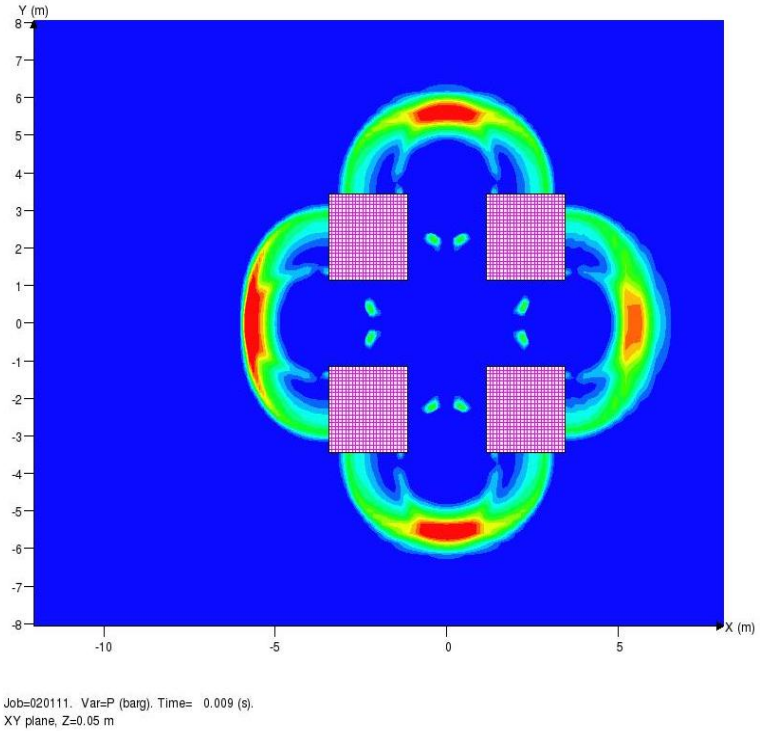
Blast wave propagation

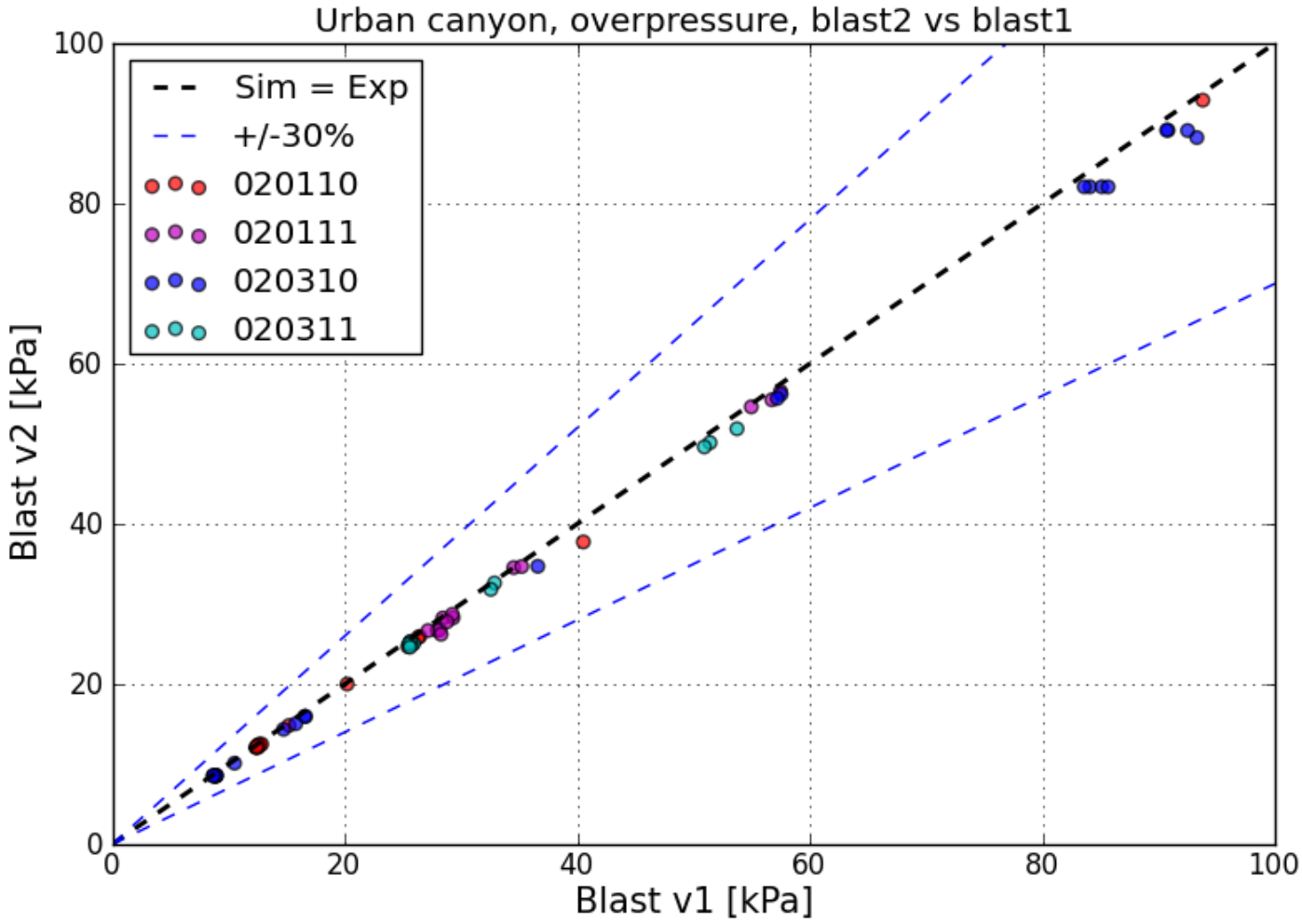
From the side



From the top



Solver comparison: Pressure



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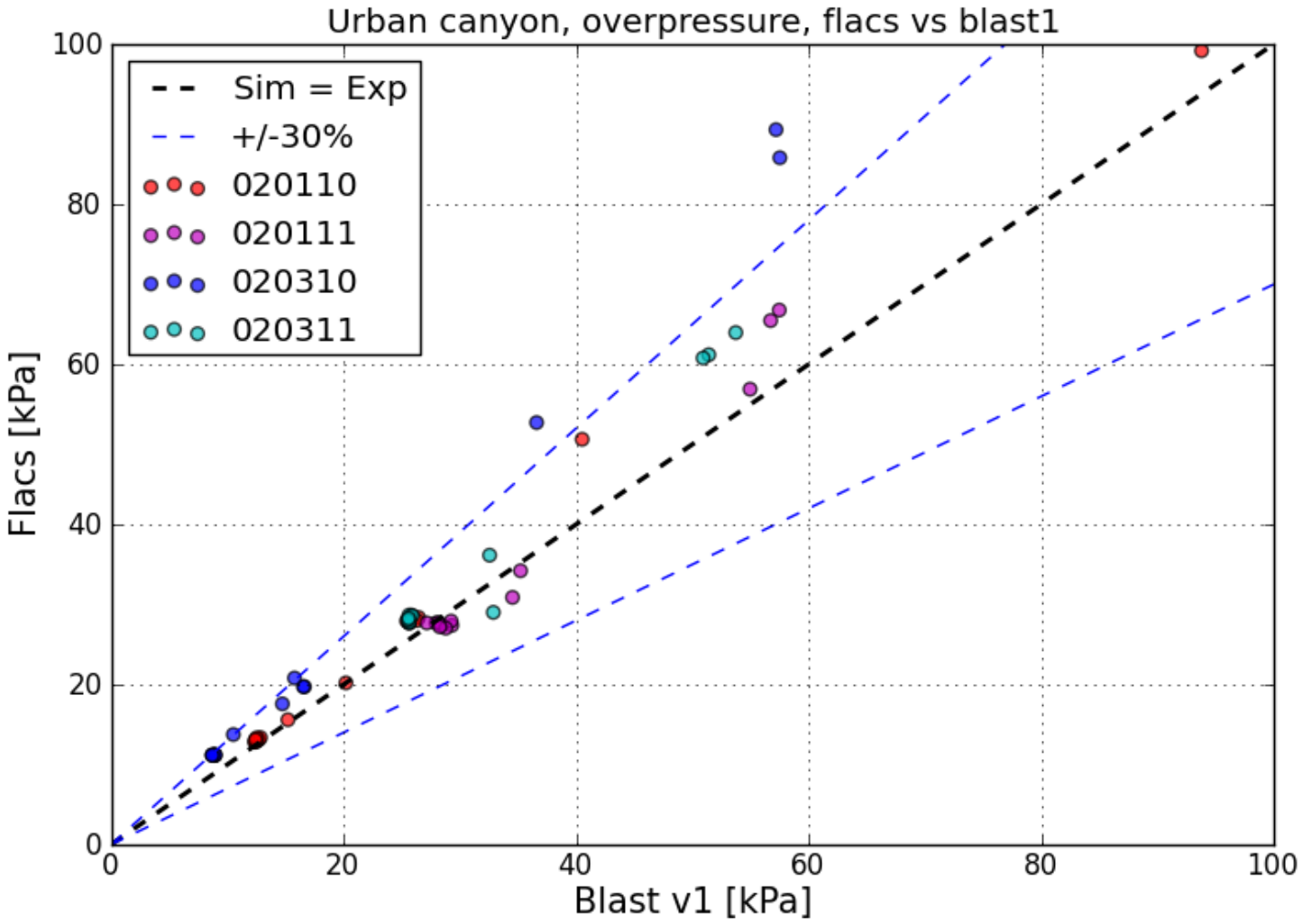
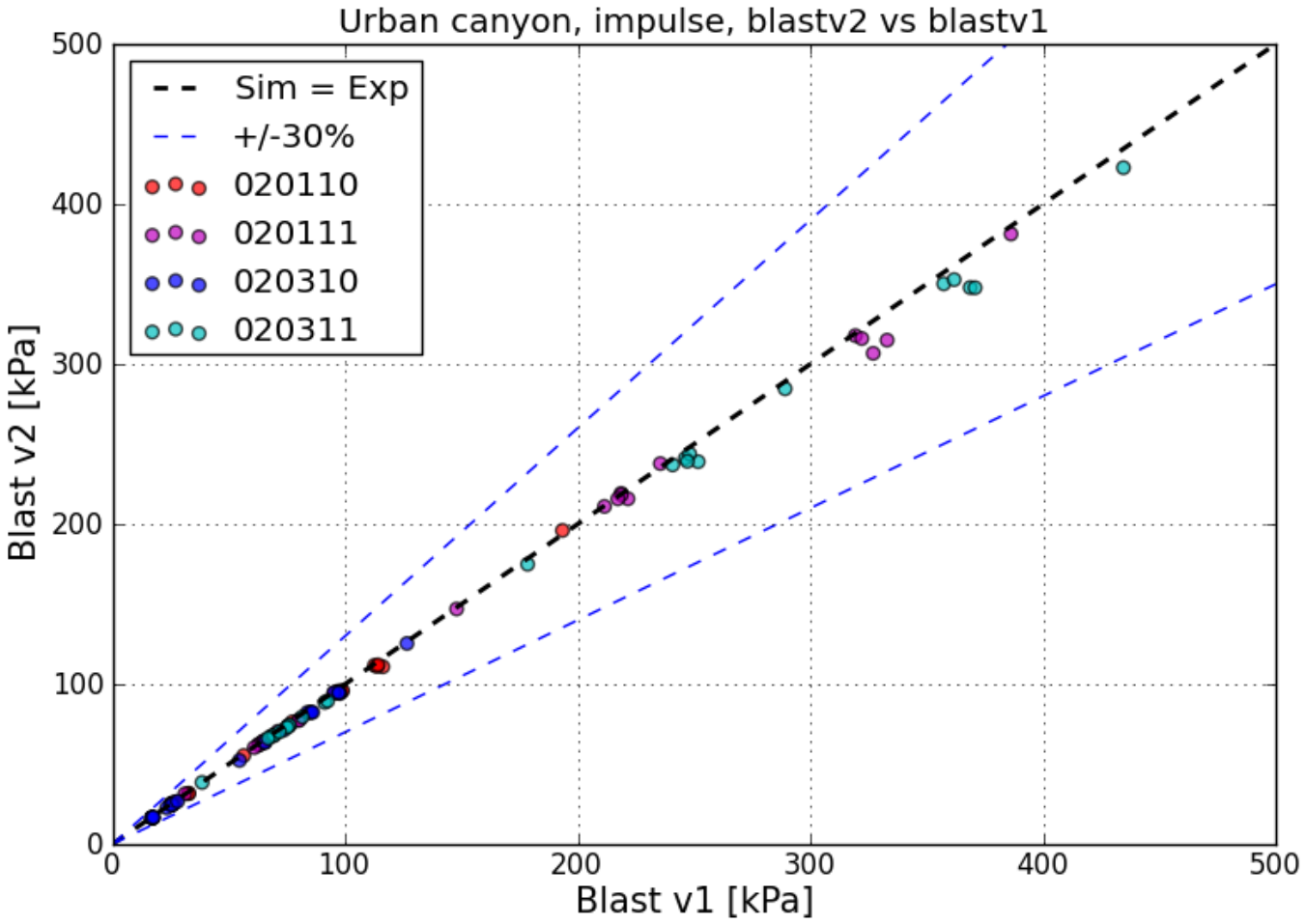
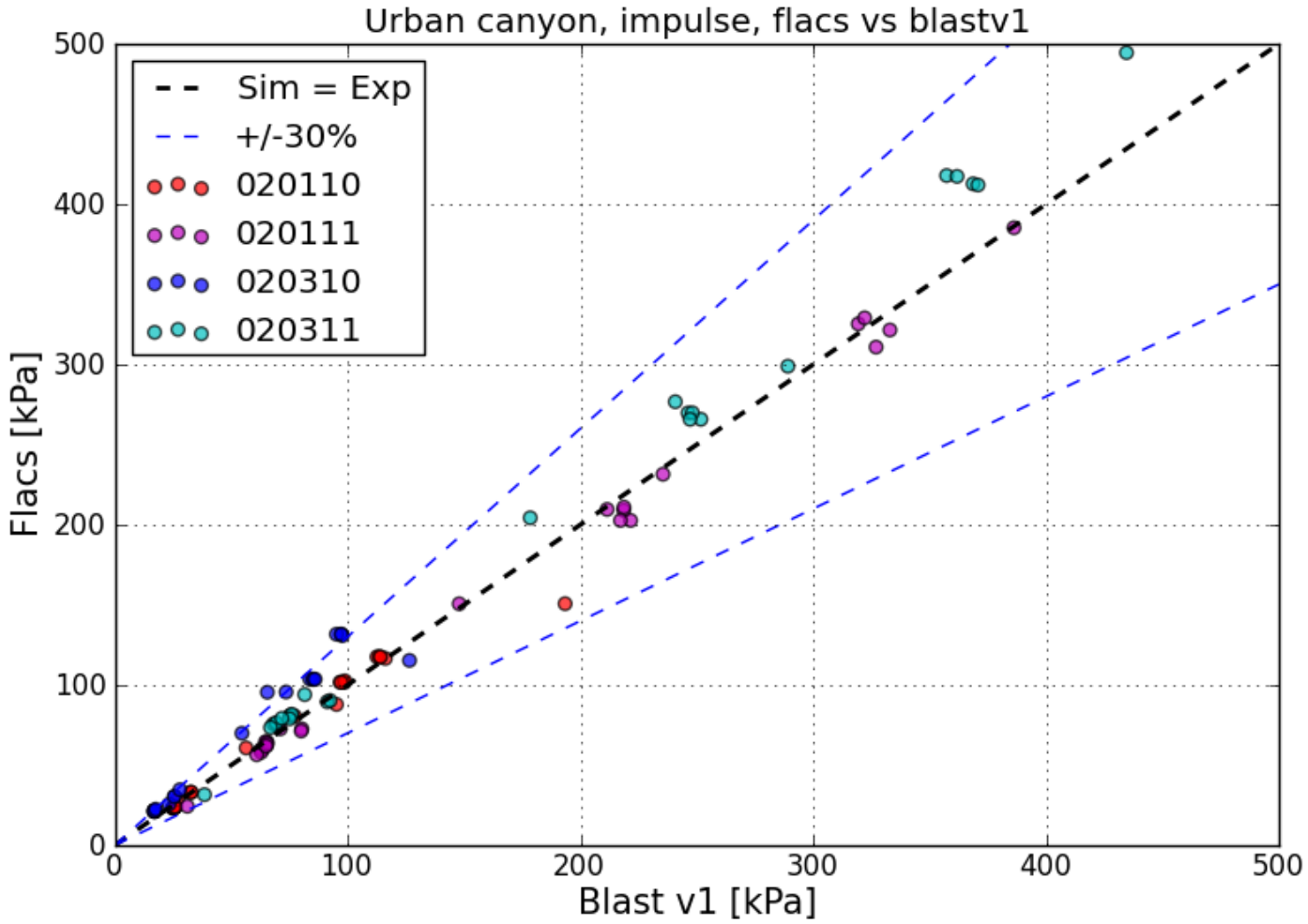


Solver comparison: Impulse

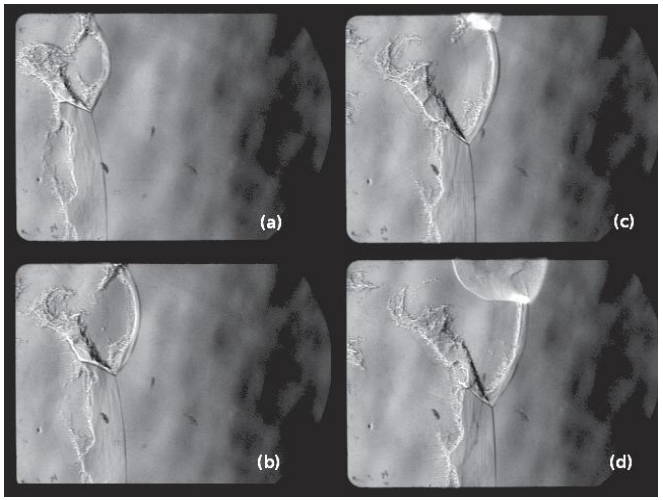


Solver comparison: Impulse



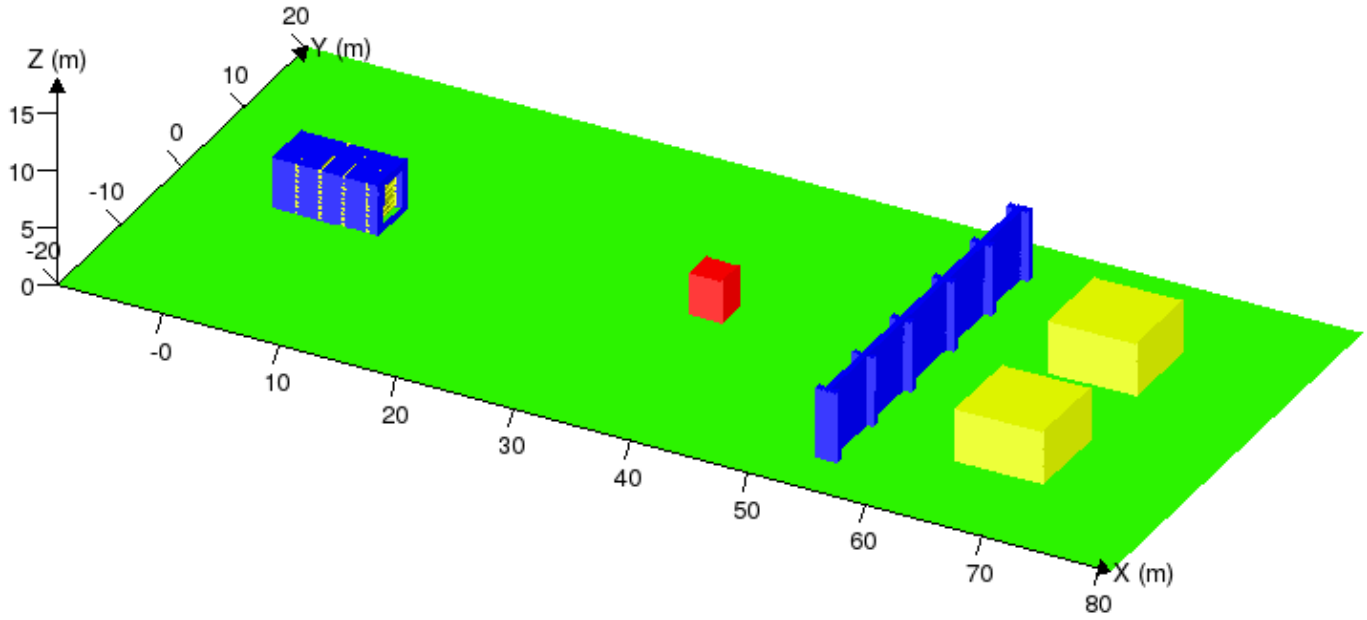
Prospects

- Increasingly important to predict DDT and detonations
- Adaptive mesh refinement will allow for increased precision
- Structural response



BangBox simulations

- 180 m^3 Bang-Box Experiment Shell Global Solution Performed at Spadeadam
- Configuration 3: 40 pipes, diameter 0.18 m
- Stoichiometric methane-air mixtures
- Internal overpressure about 2 bar
- Cubical target structure (2.5 m) with hypothetical blast wall and buildings
- 2.43 million 0.3 m cubical grid cells



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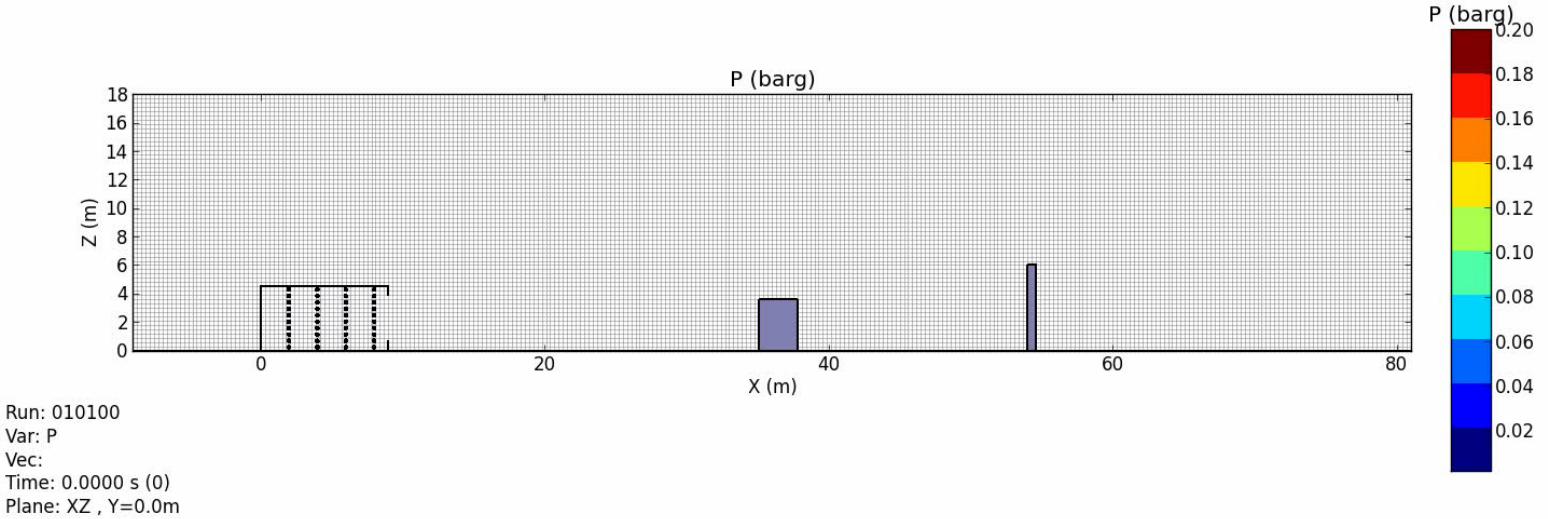

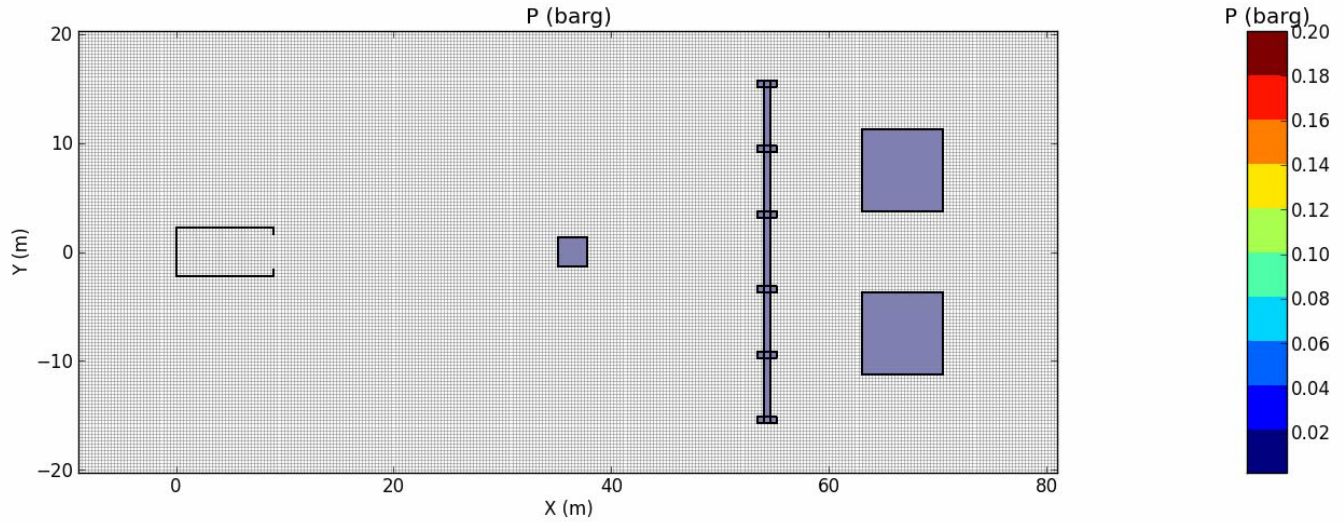

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Conclusions

- Good predictions for blast wave in unconfined geometries with or without simple obstacles
- Improvements for confined geometries
- Blast: less CPU demanding and memory consuming than Flacs

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Tenth International Seminar on

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10-14 June 2014

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Thanks for your attention