This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

Simulations results

Overview of results collected at ELI-NP and POLITO

Progress meeting for P219 Experiment in PHELIX

Lorenzo Peroni
Martina Scapin and Alberto Morena

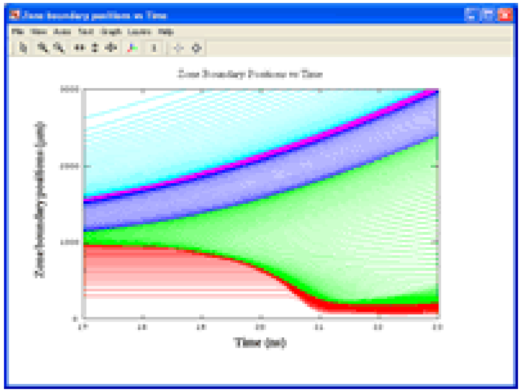
Summary

- ELI-NP simulations (HELIOS)
- POLITO methodology
- Benchmark and calibration
- GSI experiments predictions
- Conclusions and outcomes

HELIOS code

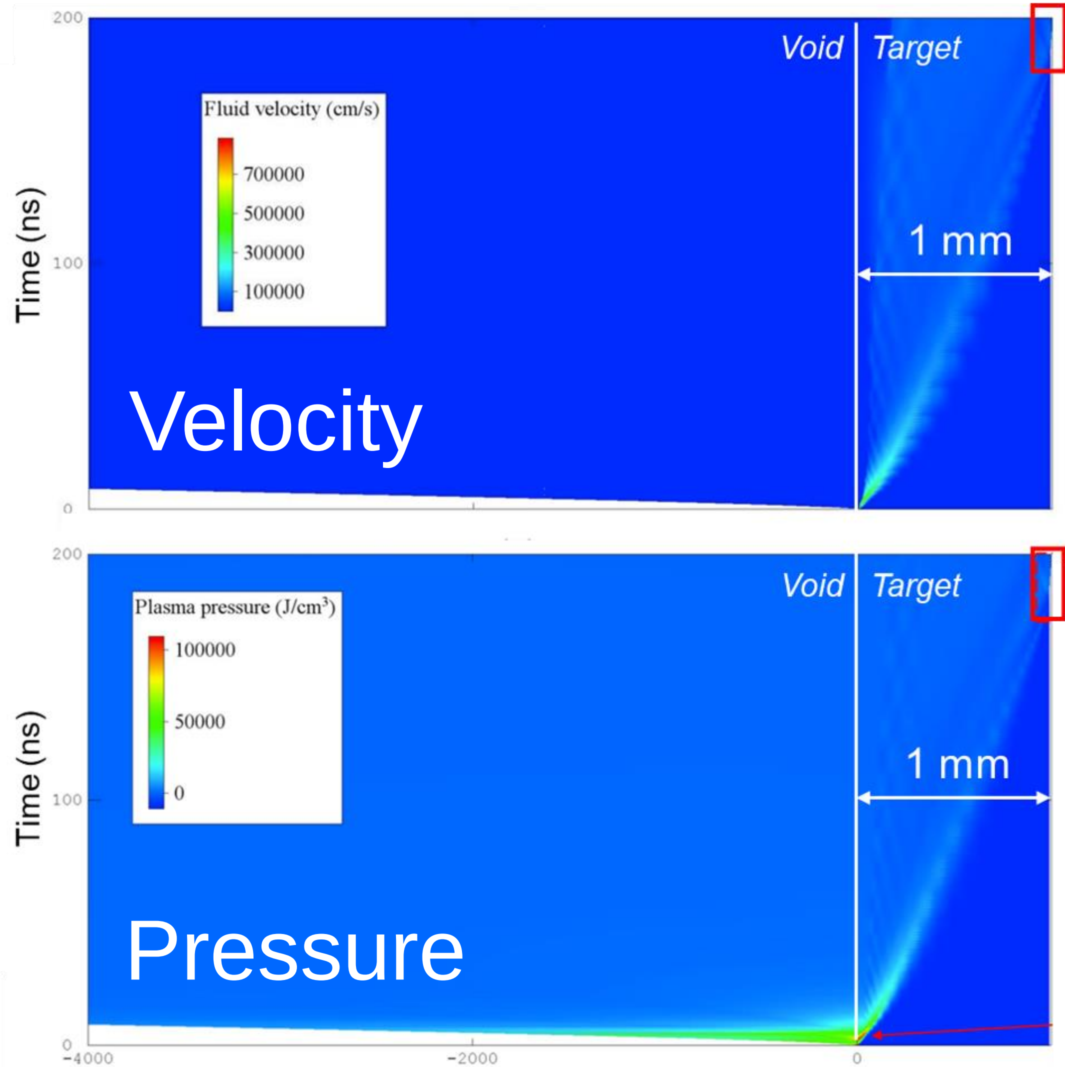
- The high-power lasers produce a surface plasma condition which acts as high-pressure loading source condition for the material in the rear portion of the sample.

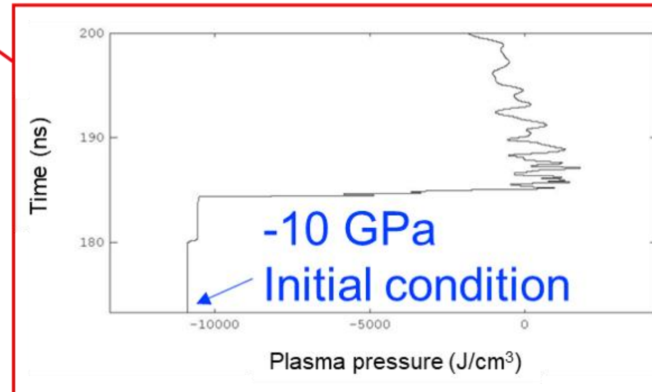
HELIOS is a 1-D radiation-hydrodynamics code designed to study the hydrodynamic evolution of radiating plasmas. It can be used to study the evolution of **planar**, cylindrical, or spherical plasmas heated by laser beams.
The code updates energy and momentum conservation equations in a **Lagrangian** reference frame (i.e., grid moves with fluid).



Target → SESAME equation of state, thermal conductivity, and electrical resistivity data.
Laser → Irradiance (W/m^2); pulse time history

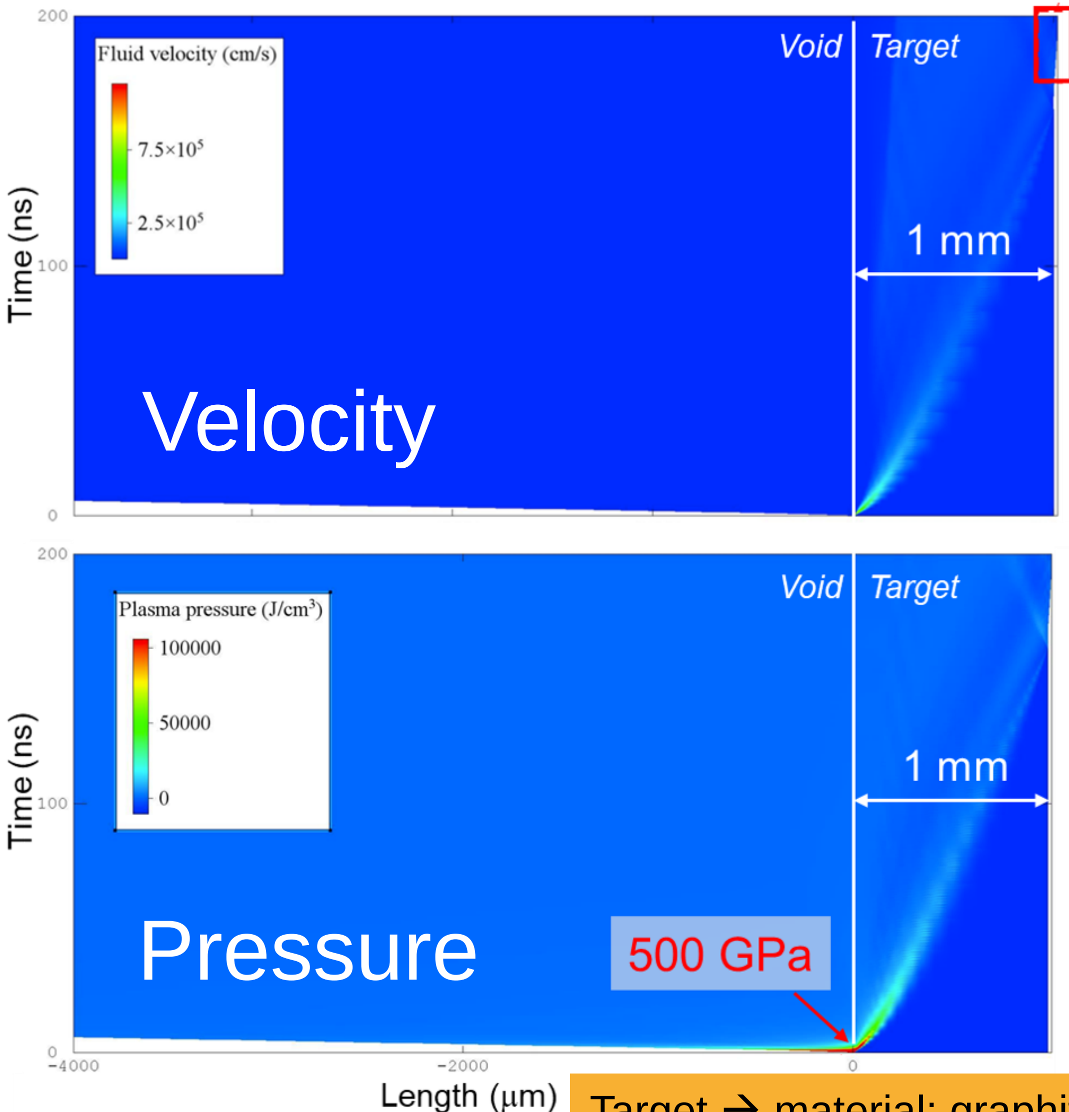
ELI-NP preliminary results

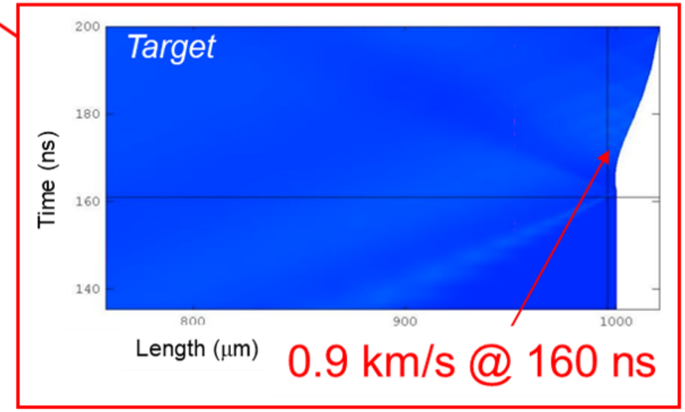




Target → material: graphite 1.77 g/cm^3; thickness: 1 mm
Laser → energy: 180 J; spot diameter: 1 mm; pulse duration: **5 ns**

ELI-NP preliminary results





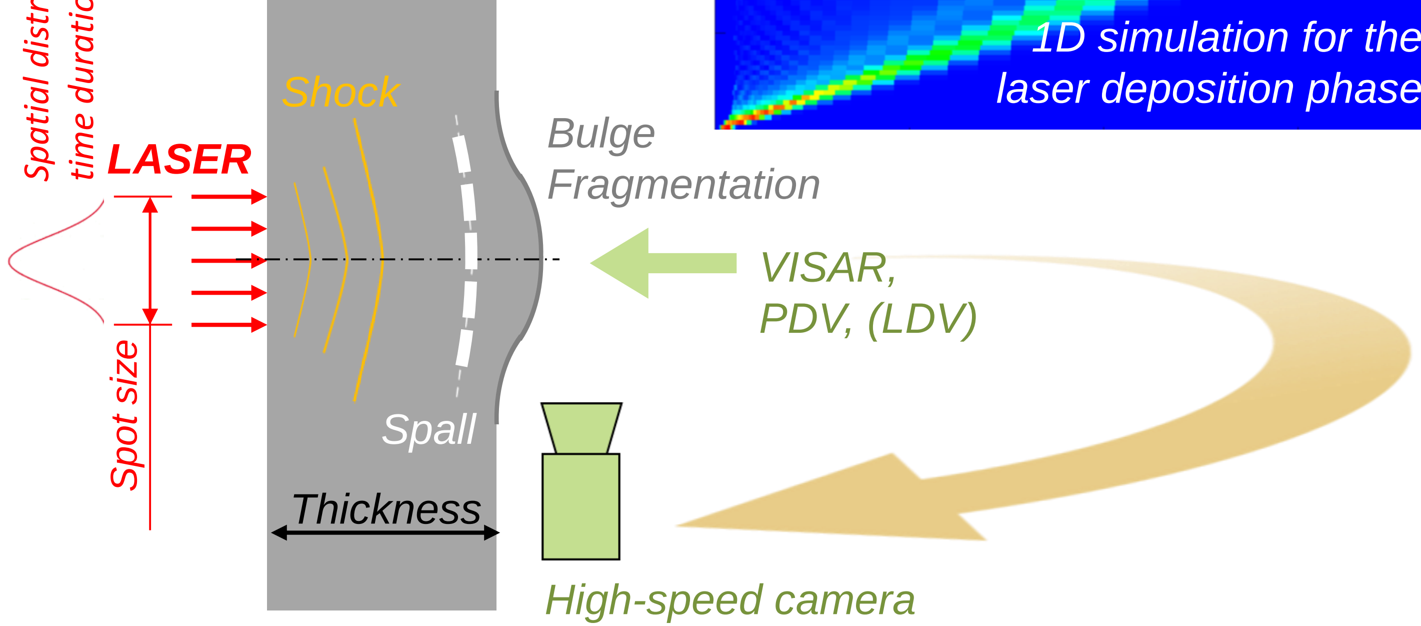
ELI-NP Conclusion:

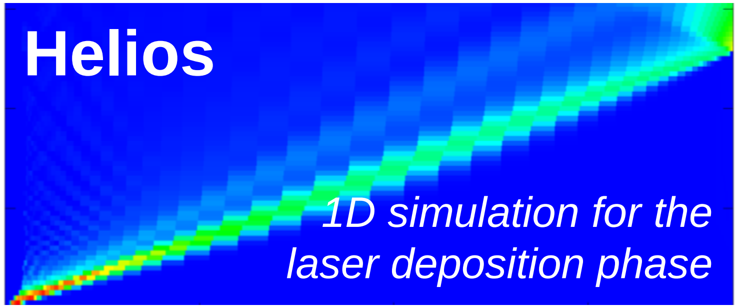
- Pure hydrodynamic simulations (no mechanical strength of the target)
- 1D code: overestimation of the results on the back surface

Target → material: graphite 1.77 g/cm^3; thickness: 1 mm
Laser → energy: 180 J; spot diameter: 1 mm; pulse duration: **1 ns**

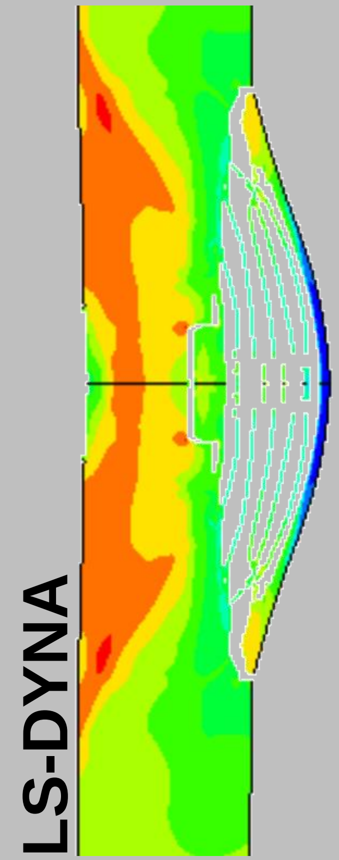
The experiment methodology

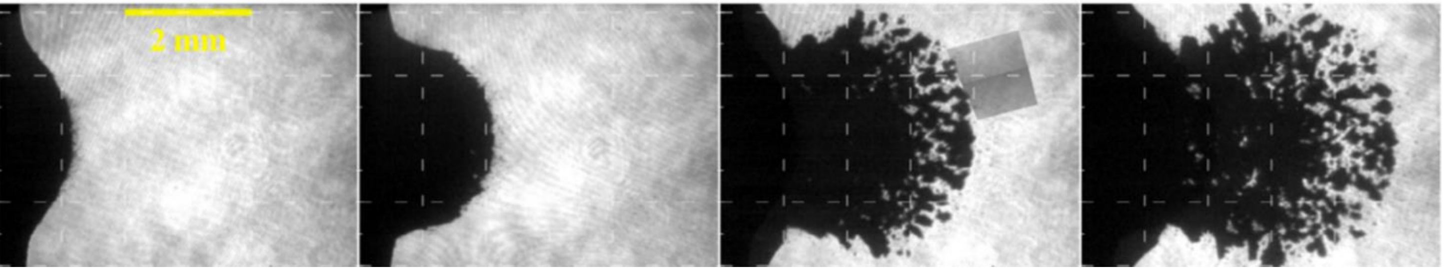
Design of the experiment





3D/2D axisymmetric simulation of the shock propagation and the target failure





Comparison of the results and model validation

Benchmark

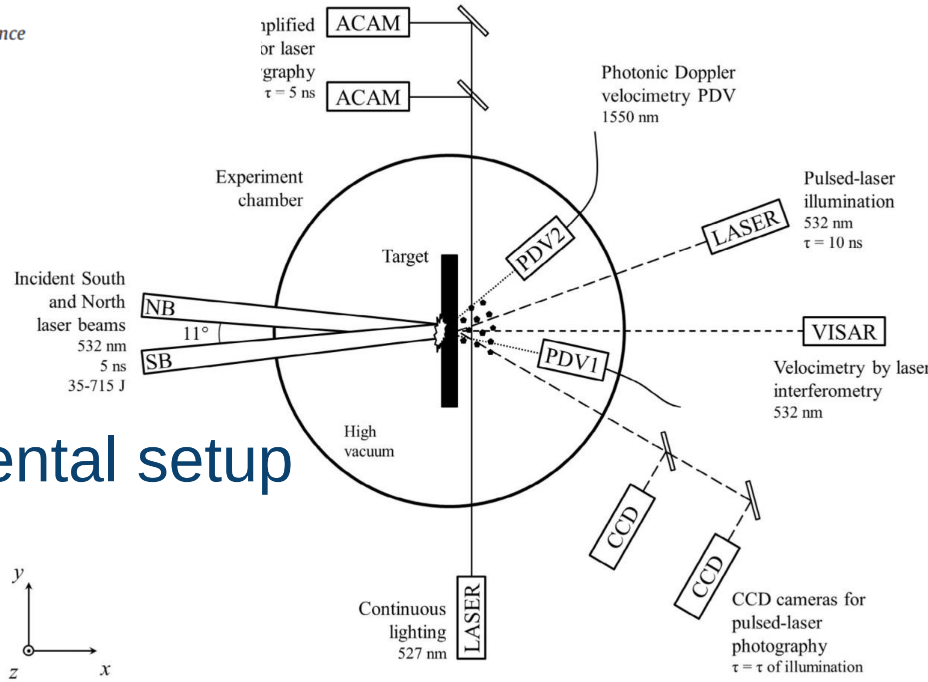
Dynamic fragmentation of graphite under laser-driven shocks: Identification of four damage regimes

G. Seisson [a,*], G. Prudhomme [a], P.-A. Frugier [a], D. Hébert [b], E. Lescoute [a], A. Sollier [a], L. Videau [a], P. Mercier [a], M. Boustie [c], L. Berthe [d]

[a] CEA DIF, Bruyères-le-Châtel, 91297 Arpajon Cedex, France
[b] CEA CESTA, 15 avenue des Sablières CS60001, 33116 Le Barp Cedex, France
[c] Institut P' – UPR3346 CNRS-ENSMA-Université de Poitiers, 1 avenue Clément Ader, 86961 Futuroscope Cedex, France
[d] Laboratoire PIMM – UPR8006 CNRS-Arts et Métiers ParisTech, 151 boulevard de l'Hôpital, 75013 Paris, France

Validation and tuning of FE simulations based on CEA experiments

Experimental setup



Target → material: graphite (ρ_0=1.754 g/cm^3)
Laser → spot diameter: 4 mm; pulse duration: 5 ns

Shot number	05	06	07	08	09	10	11	12	13	14	15*	16	17	18	26*	27*
Laser beam	S	N	S	N	N	S	N	S	N	S	S	N	S	N	N	S
Thickness (mm)	2.5	2.5	0.75	0.75	1	1	1.5	1.5	2	0.75	0.75	0.75	0.75	1	1	1
U_m (m/s)	51	77	169	511	332	201	163	78	99	97	272	162	564	194	190	320
P_m (MPa)	99	149	327	991	644	390	316	151	192	188	528	314	1094	376	369	621
I_m (TW/cm^2)	1.57	3.94	0.89	3.59	3.50	1.72	3.35	1.38	3.11	0.26	1.89	0.92	4.00	1.88	2.29	3.42
P_{ab} (GPa)	43.5	90.6	27.4	84.2	82.5	46.7	79.6	39.2	74.9	10.2	50.4	28.3	91.7	50.2	58.6	80.8

Shot conditions

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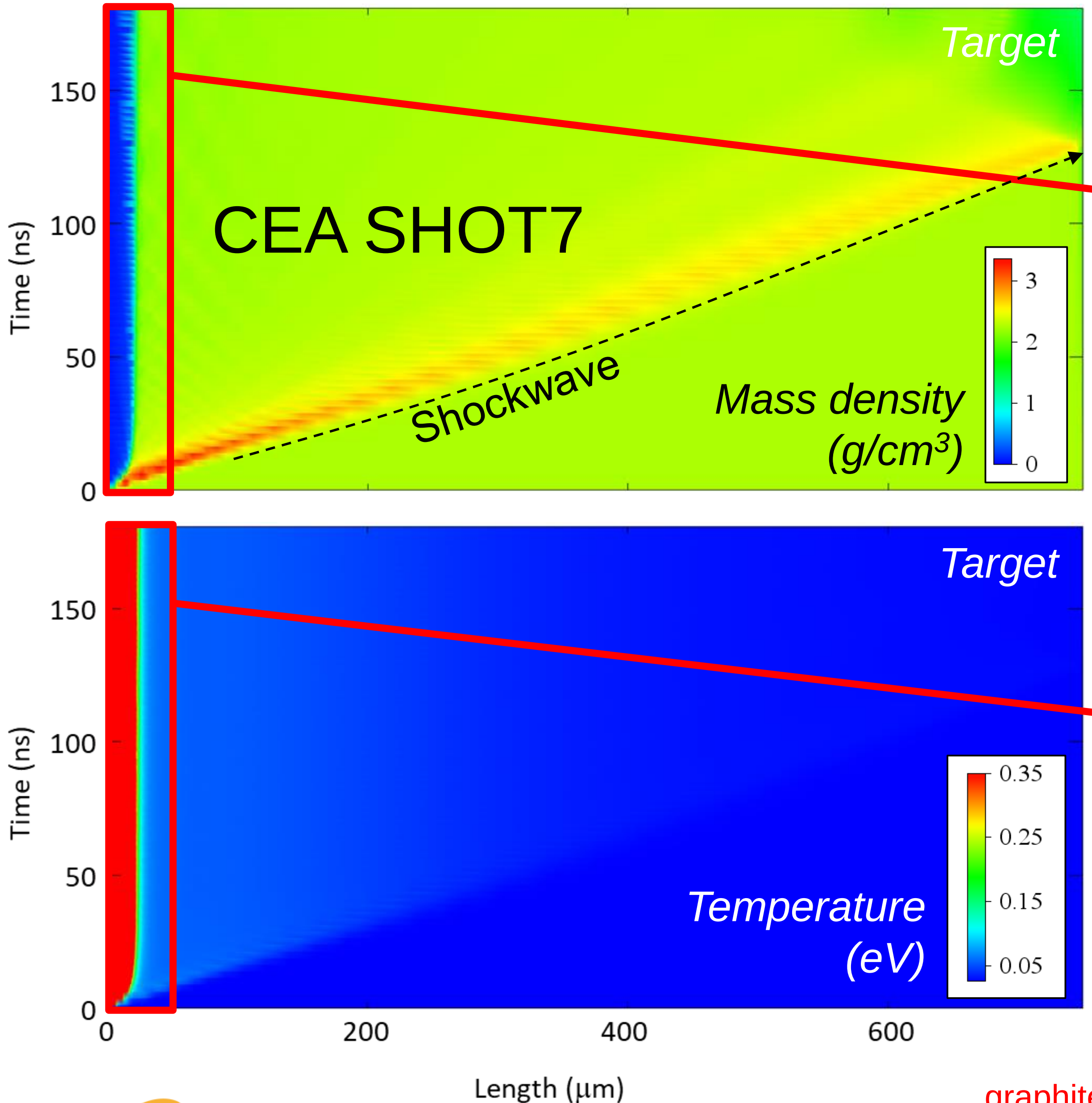
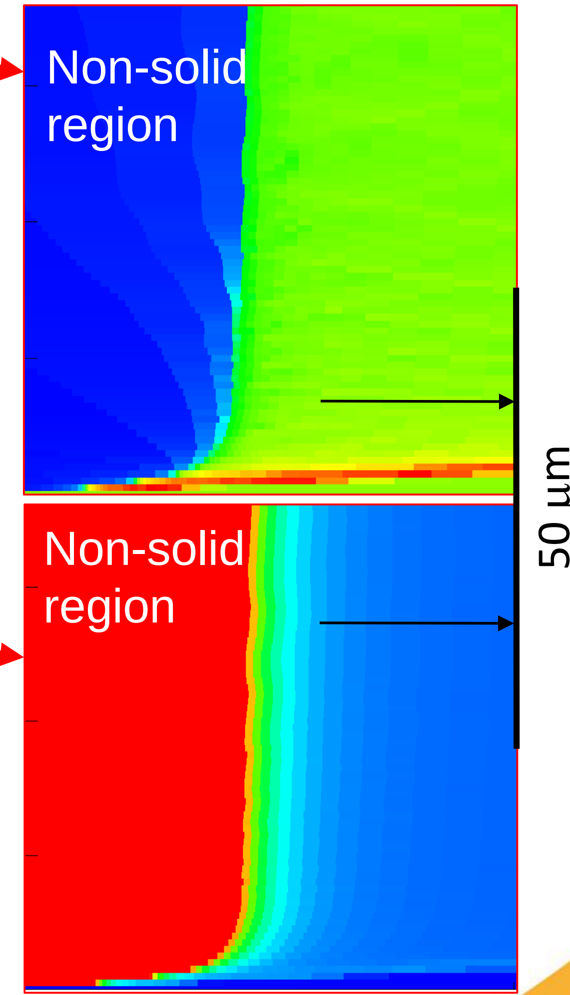
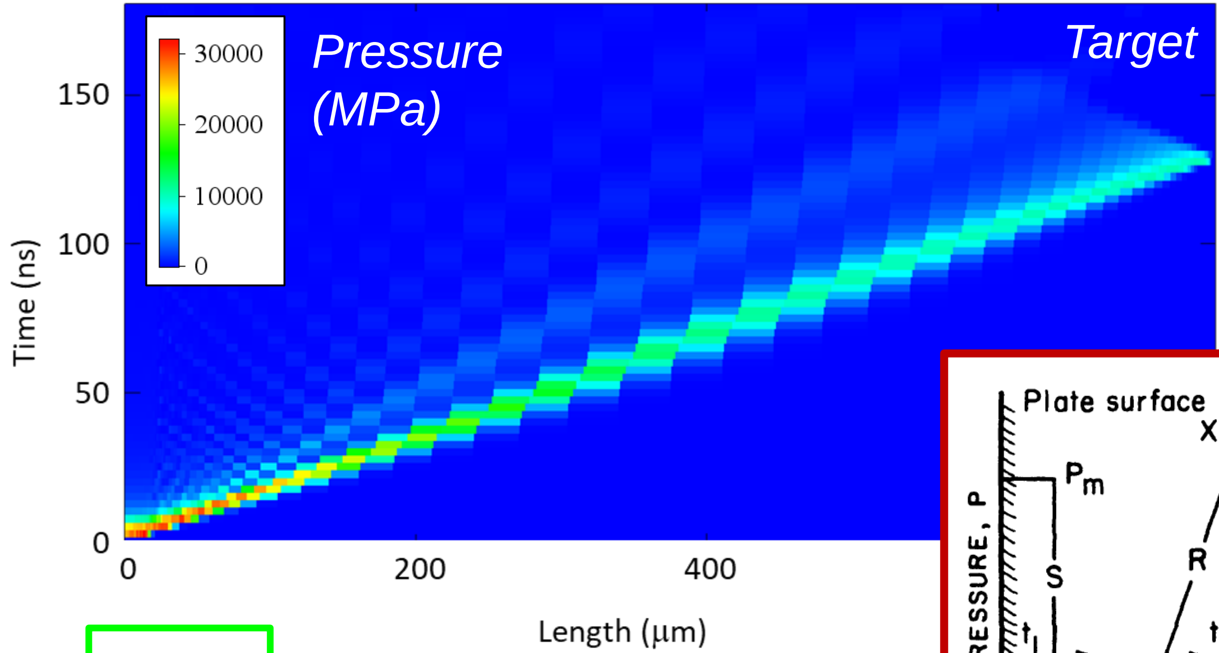
Helios results





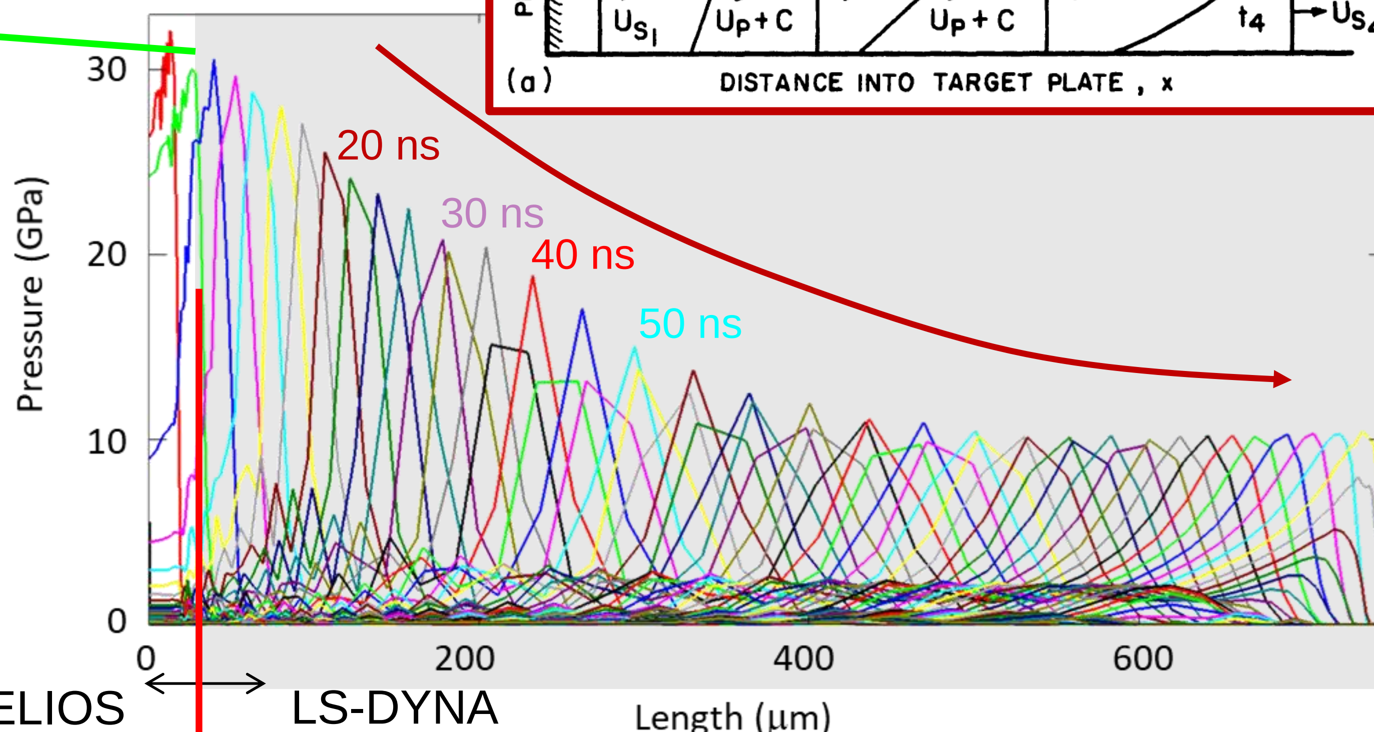
0.35 eV ≈ 4000 K
graphite melting temperature

HELIOS results

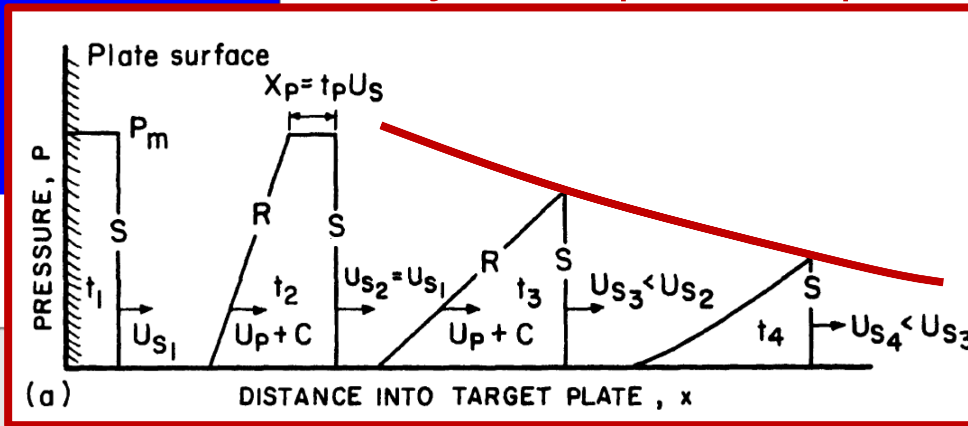


5 ns

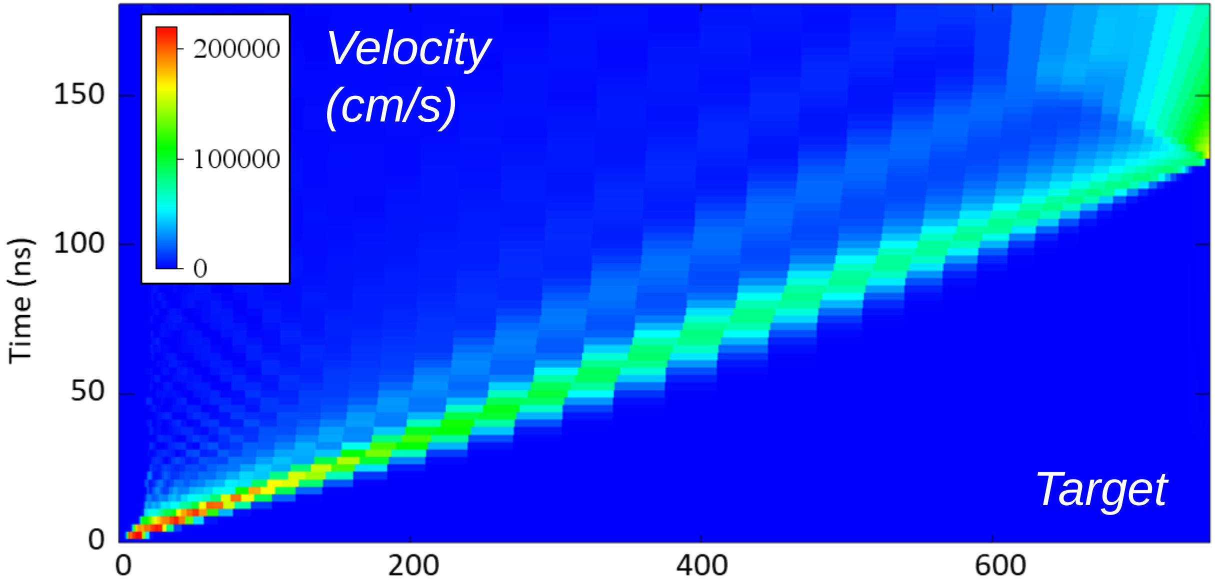
At the end deposition time of 5 ns the shock wave front is at 35 microns far from the front surface

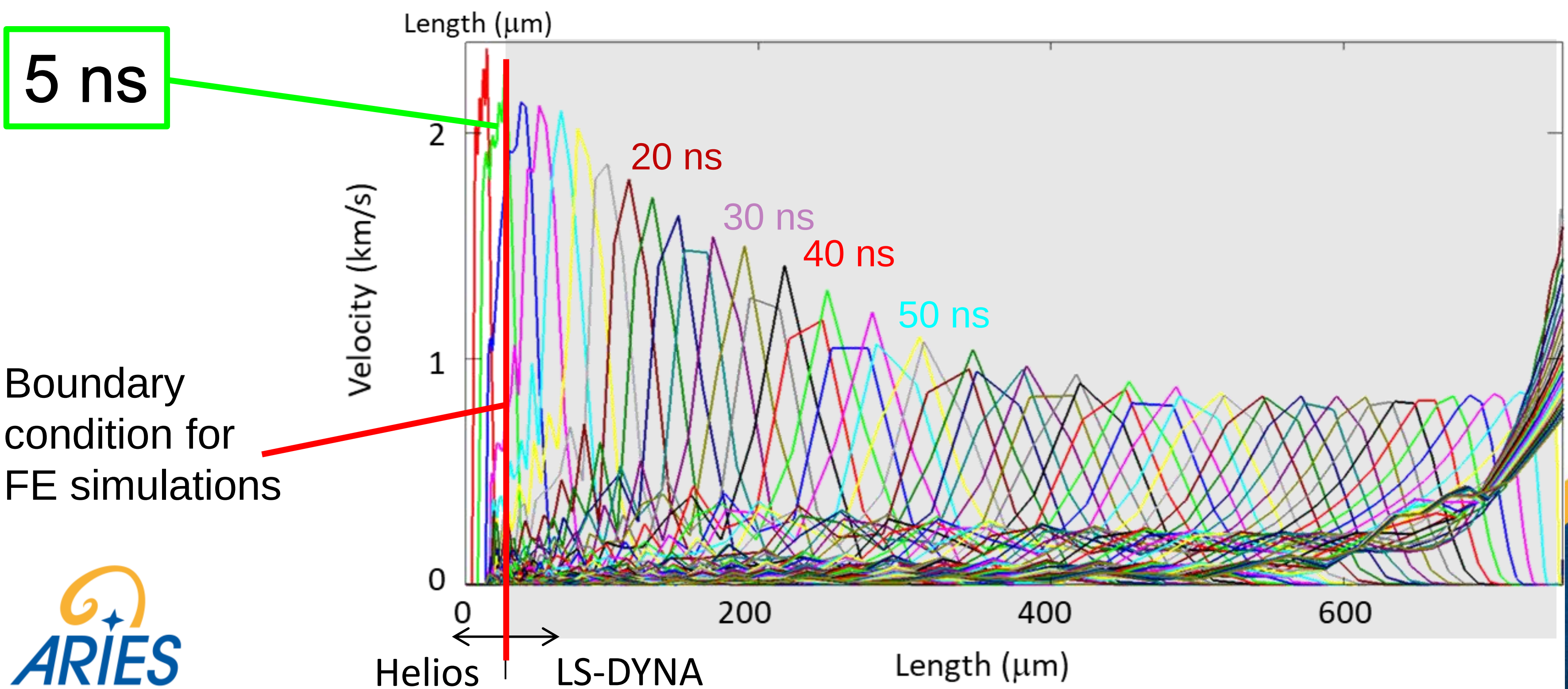


Decay of the pressure peak

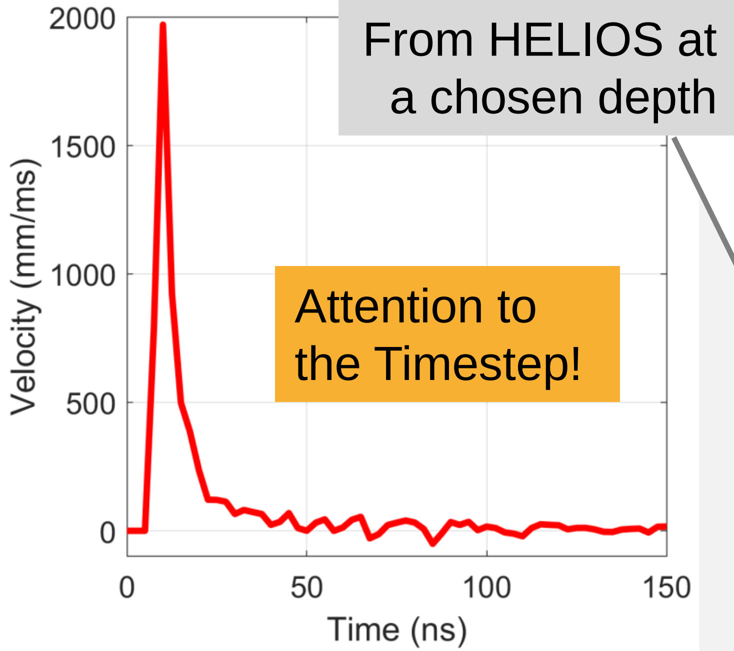


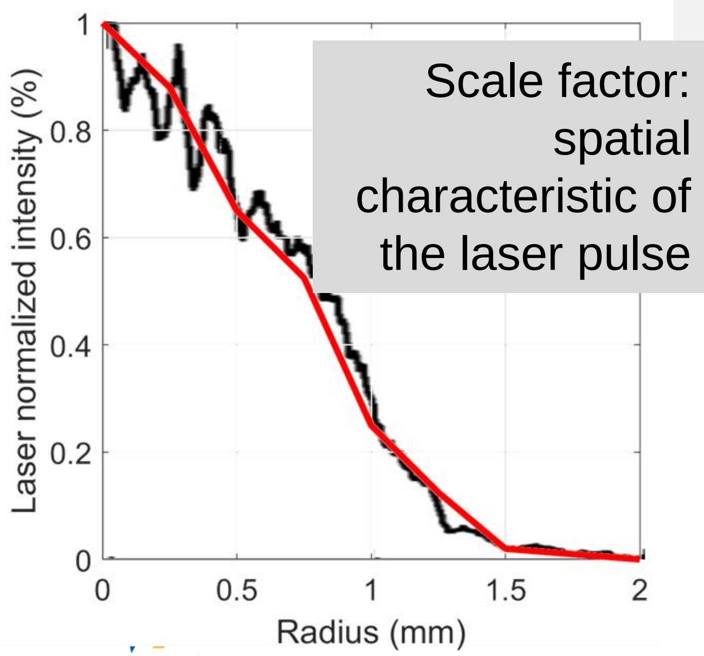
HELIOS results

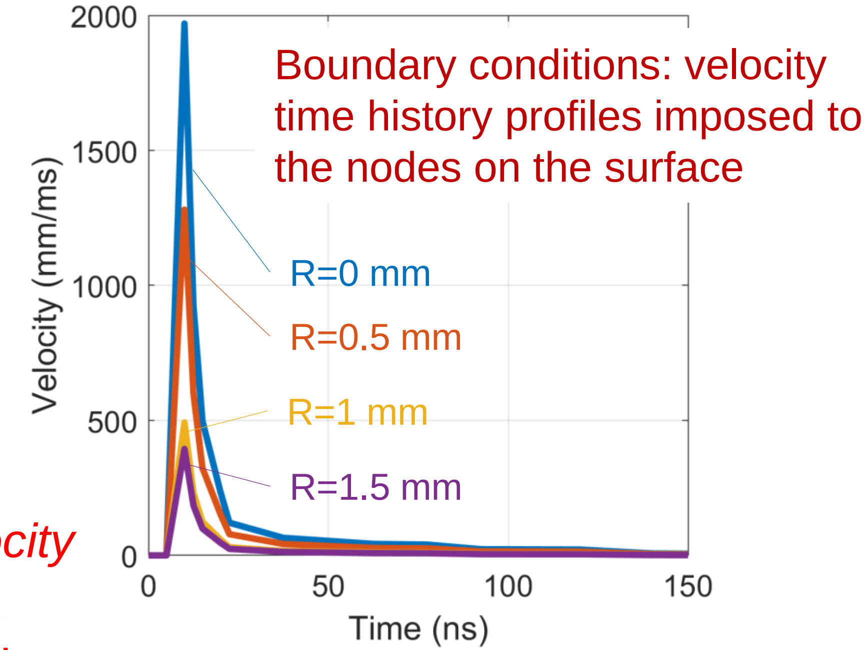


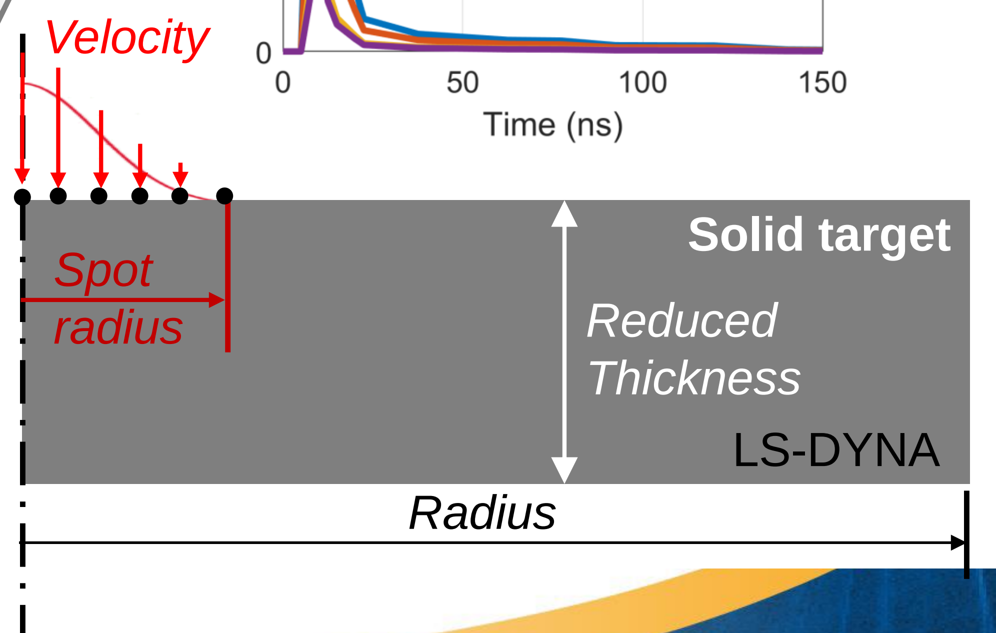


HELIOS to LS-DYNA

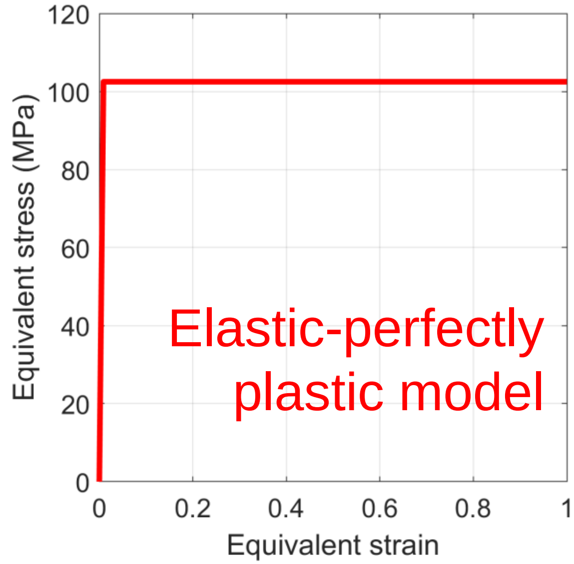


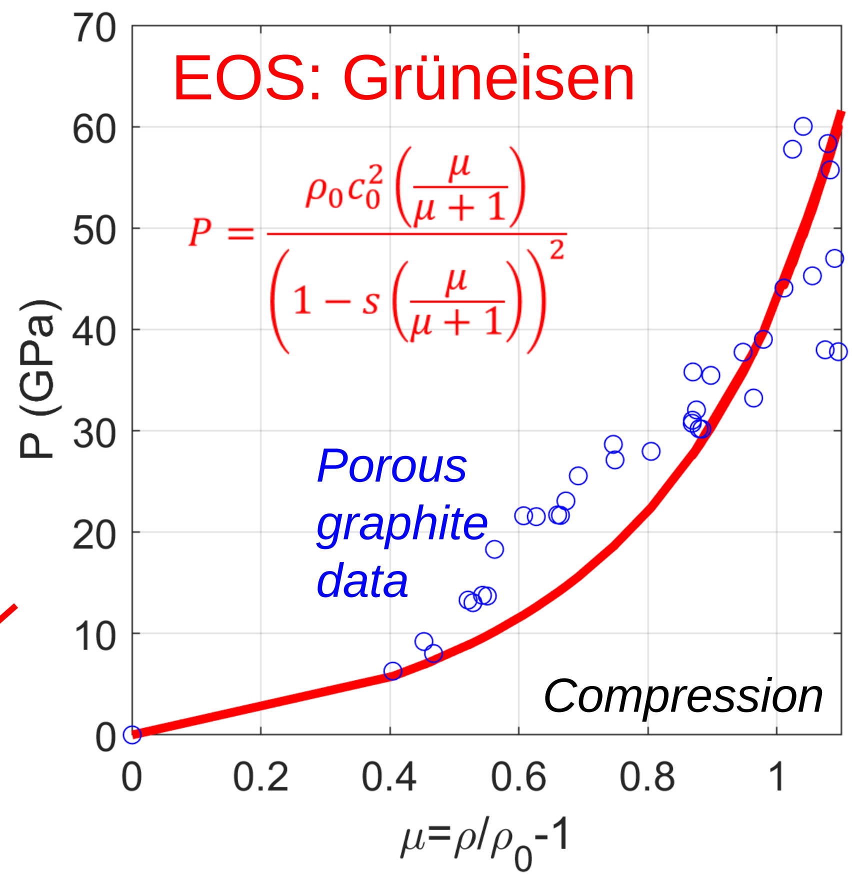






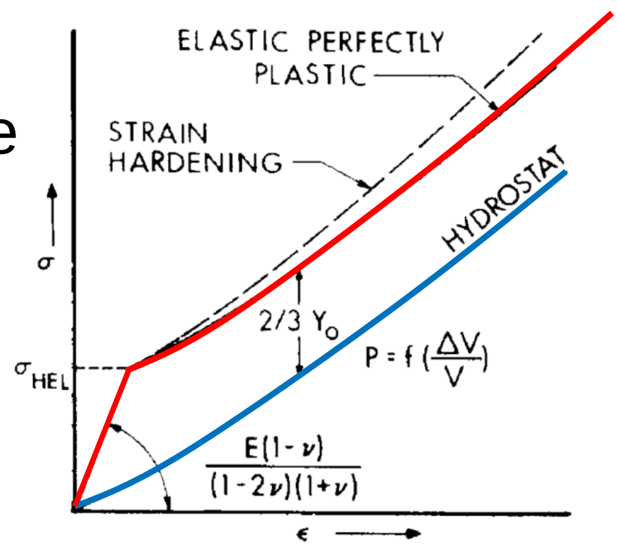
LS-DYNA material model





In uniaxial strain case

(Compression)



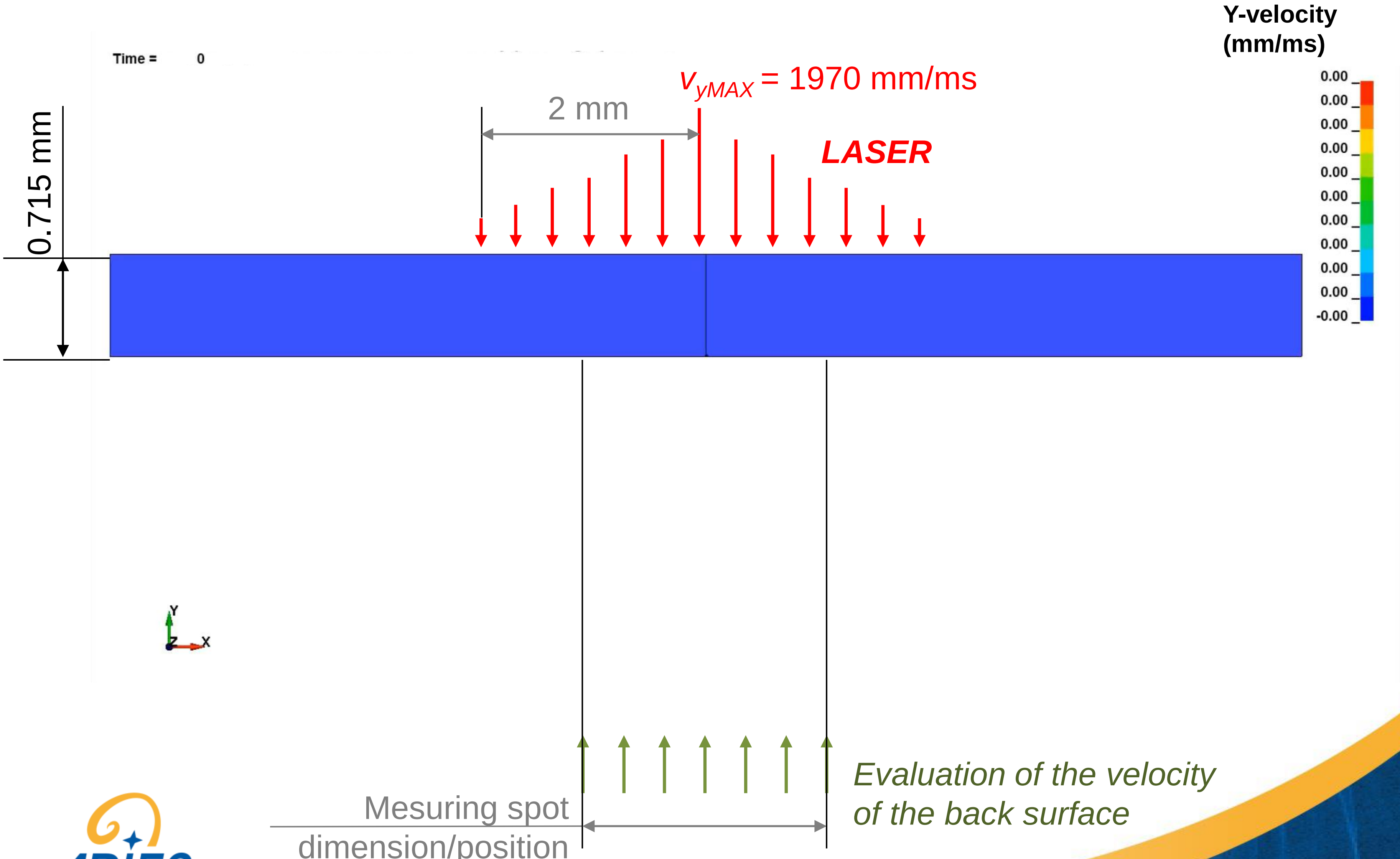
FAILURE CONDITIONS

- σ_{MAX}
- ε_{MAX}

In tension!!

LS-DYNA results

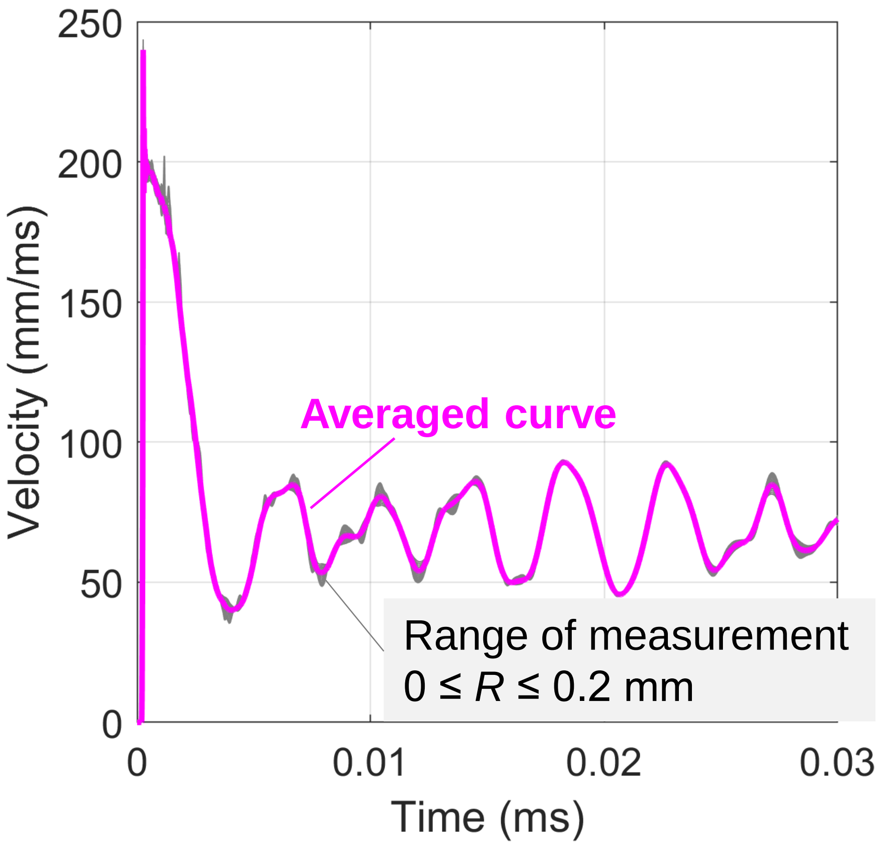
SHOT 7 @ CEA
Target → material: porous graphite; thickness: 0.75 mm
Laser → energy: 121 J; pulse duration: 5 ns



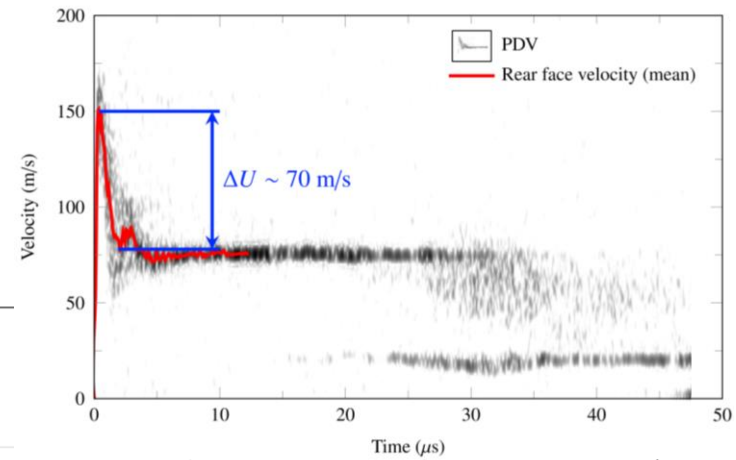
LS-DYNA results

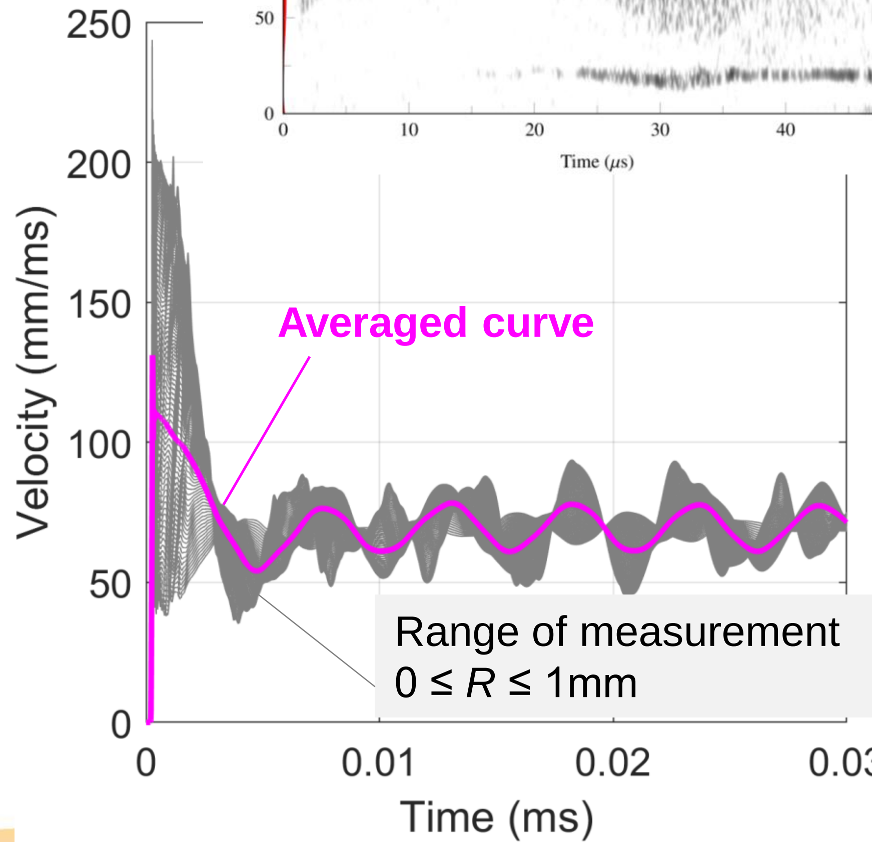
SHOT 7 @ CEA
Target → material: porous graphite; thickness: 0.75 mm
Laser → energy: 121 J; pulse duration: 5 ns

v_{yMAX} = 1970 mm/ms



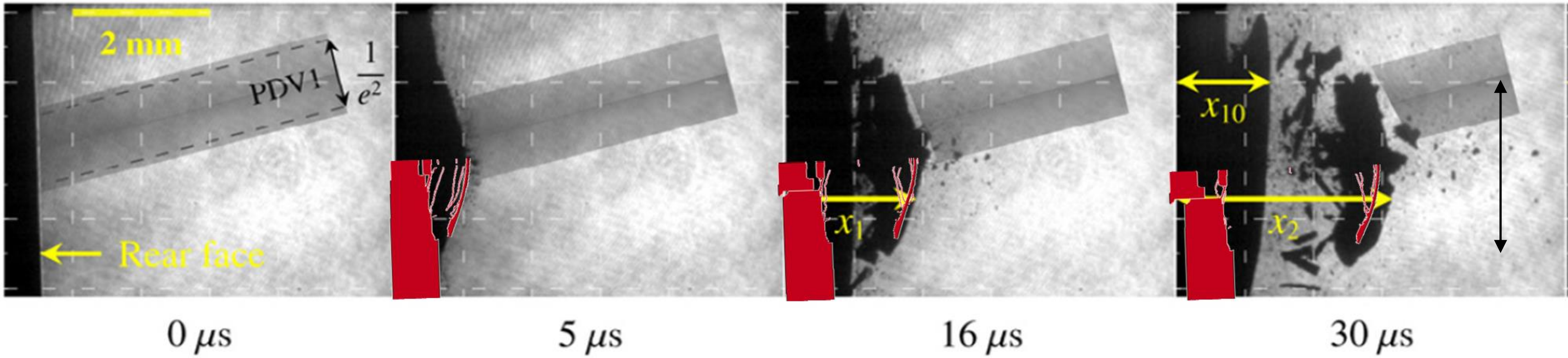
Comparison with experimental results

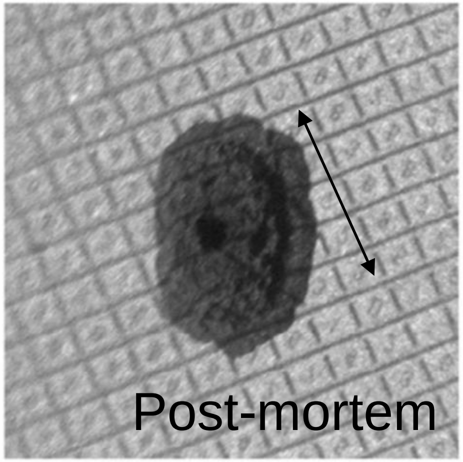




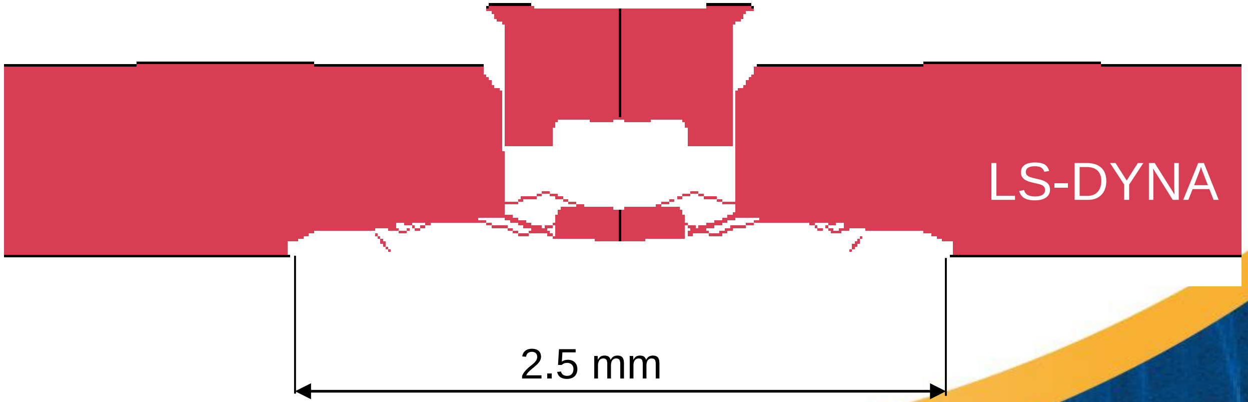
LS-DYNA results

Comparison with experimental results





SHOT 7 @ CEA
Target → material: porous graphite; thickness: 0.75 mm
Laser → energy: 121 J; pulse duration: 5 ns

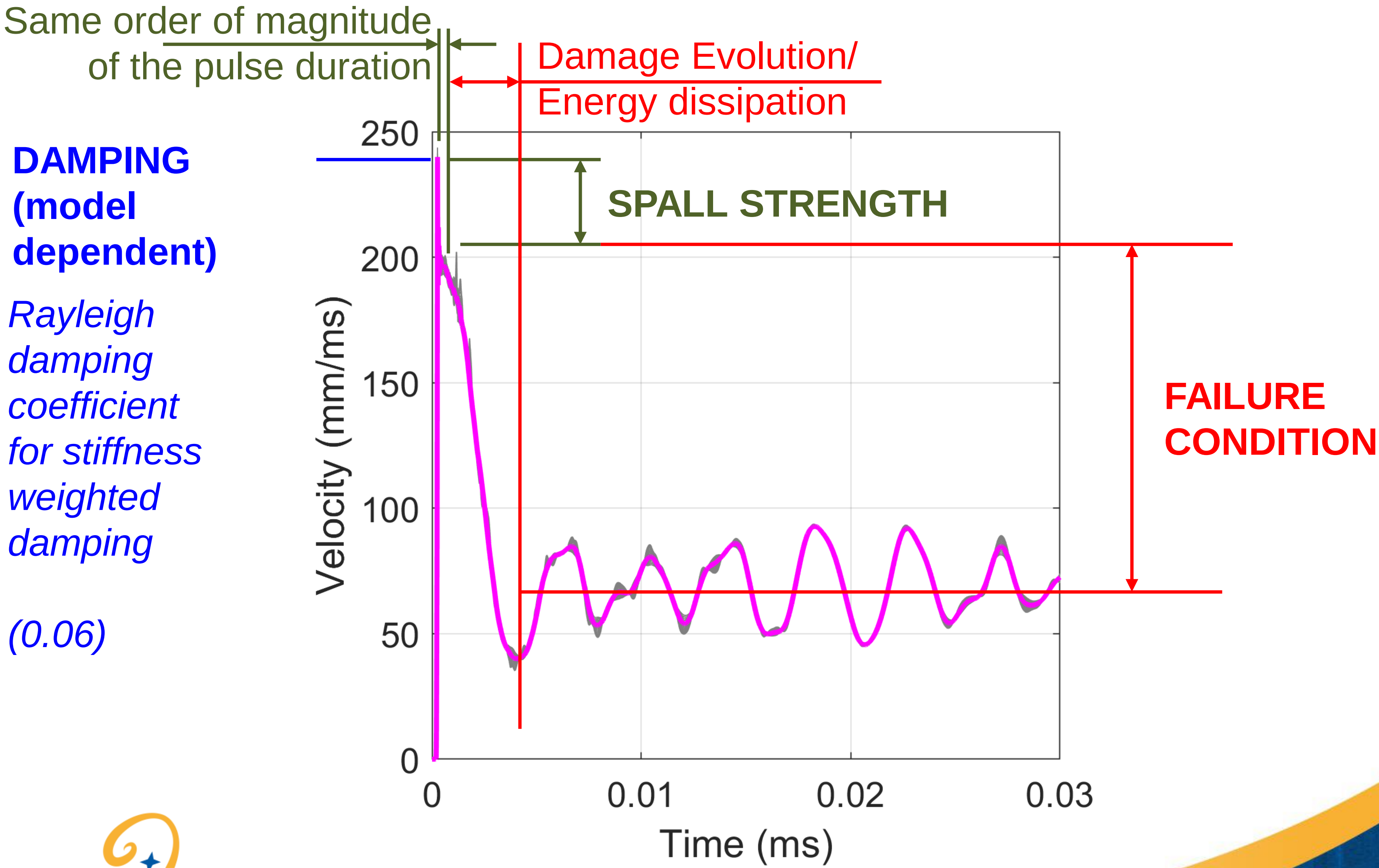


Results analysis: back surface velocity

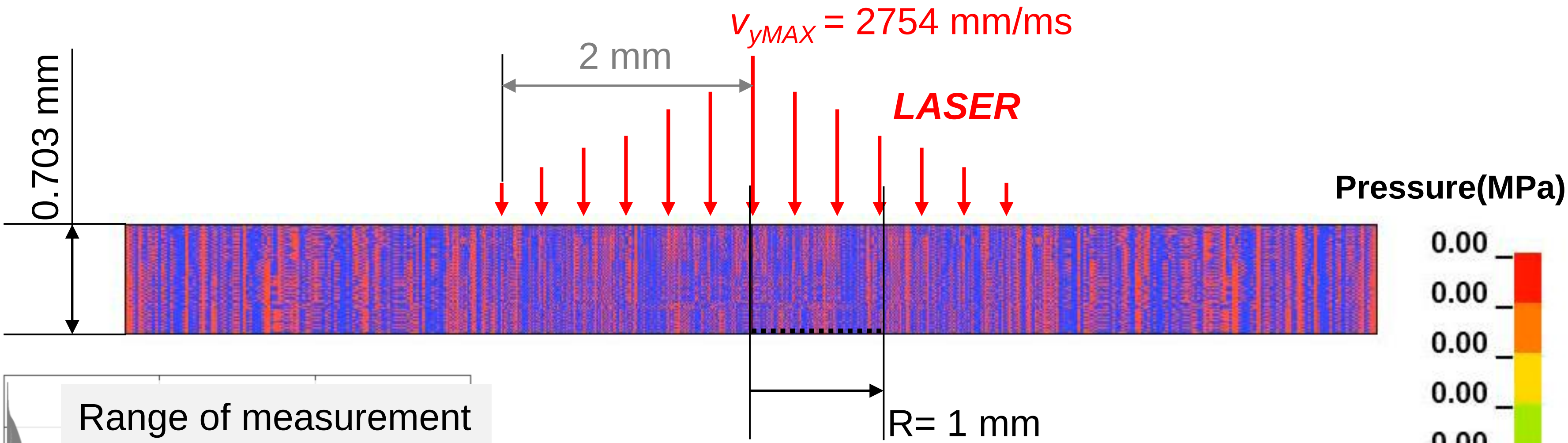
DAMPING (model dependent)

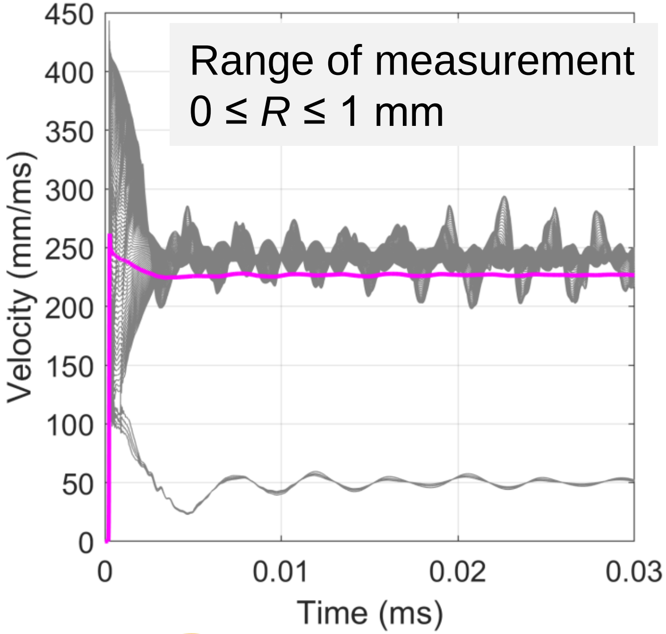
Rayleigh damping coefficient for stiffness weighted damping

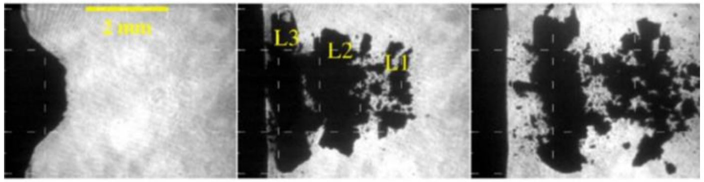
(0.06)



LS-DYNA results



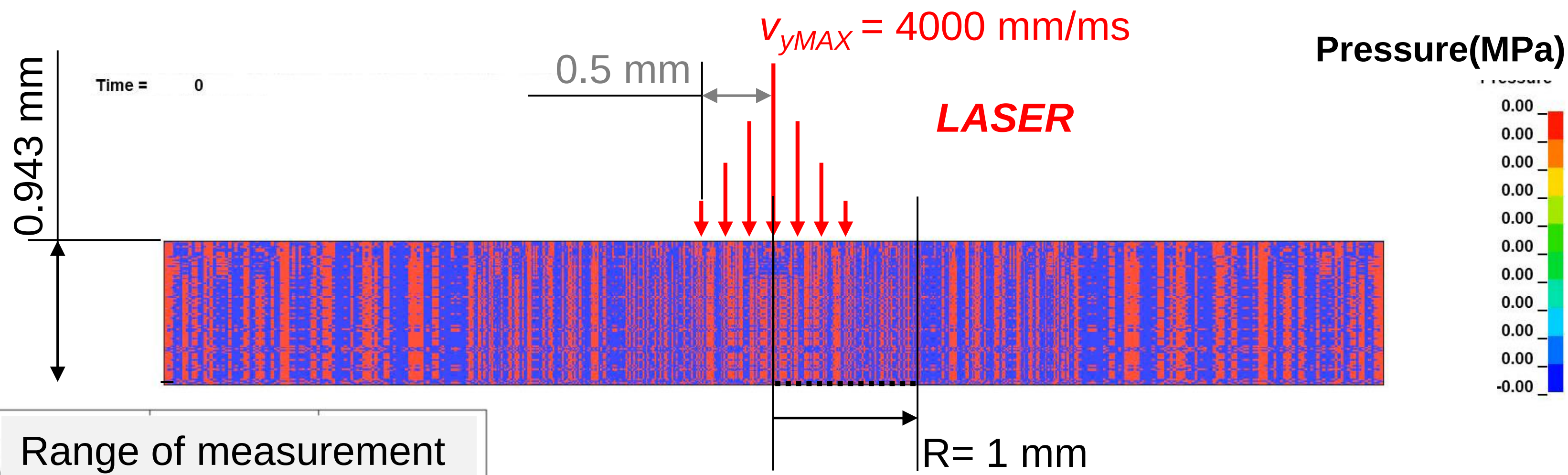


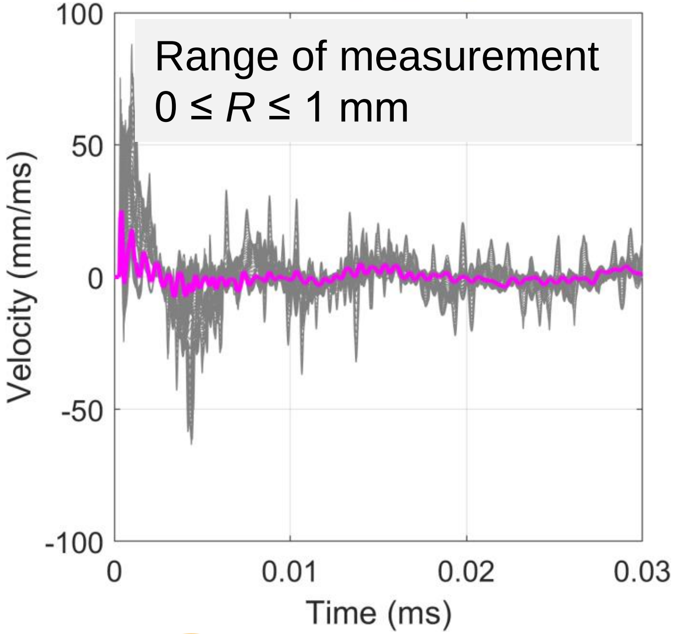


5 μs 16 μs 30 μs

SHOT 15 @ CEA
Target → material: porous graphite; thickness: 0.75 mm
Laser → energy: 259 J; pulse duration: 5 ns

LS-DYNA GSI Prediction 5 ns

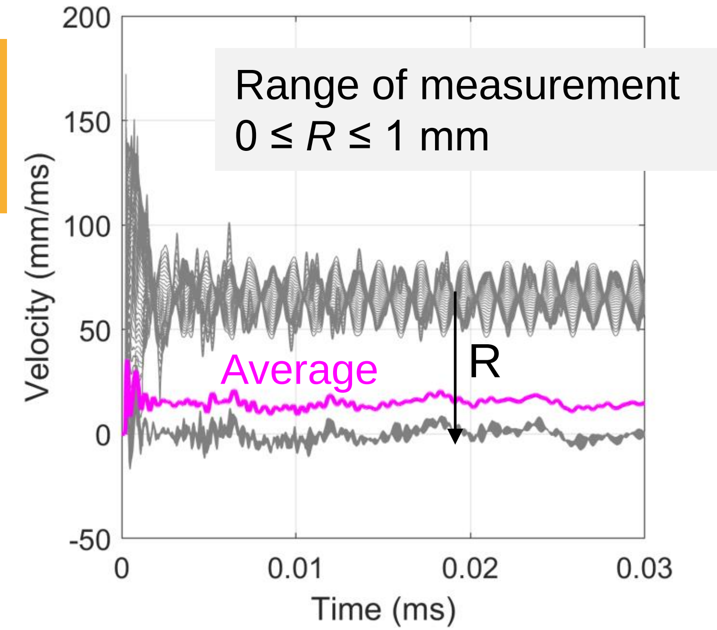


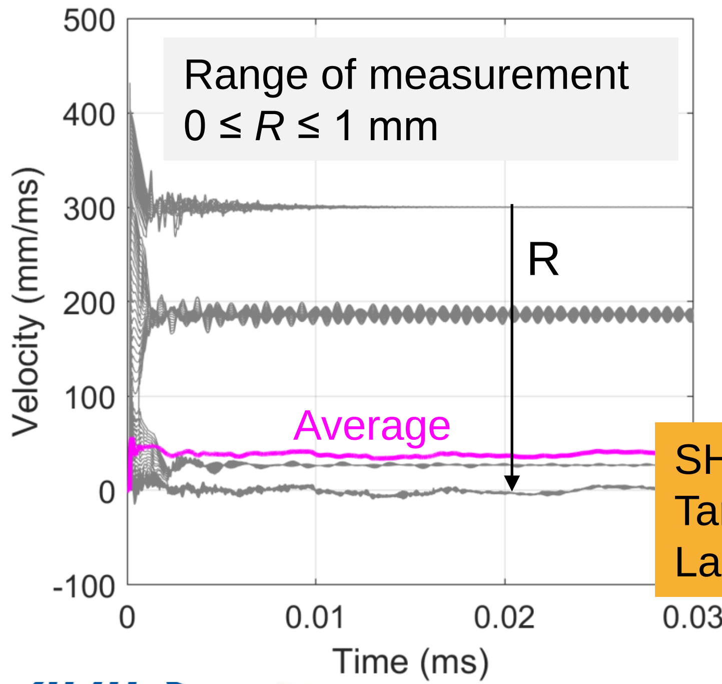


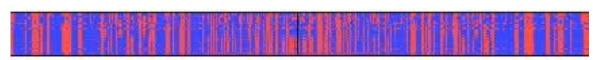
SHOT LOW @ GSI
Target → material: porous graphite; thickness: 1 mm
Laser → energy: 180 J; pulse duration: 5 ns

LS-DYNA GSI Prediction 5 ns

SHOT LOW @ GSI
Target → material: porous graphite; thickness: **0.75 mm**
Laser → energy: 180 J; pulse duration: 5

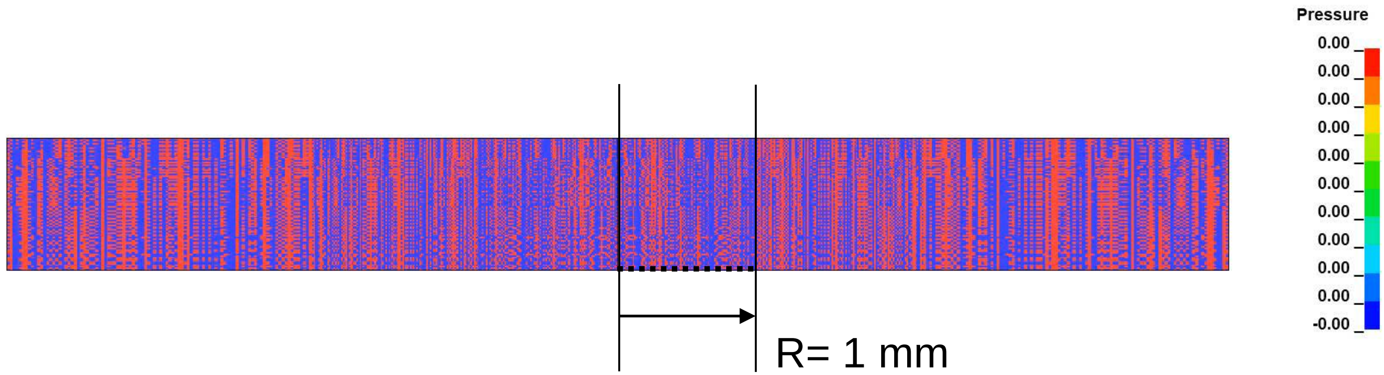


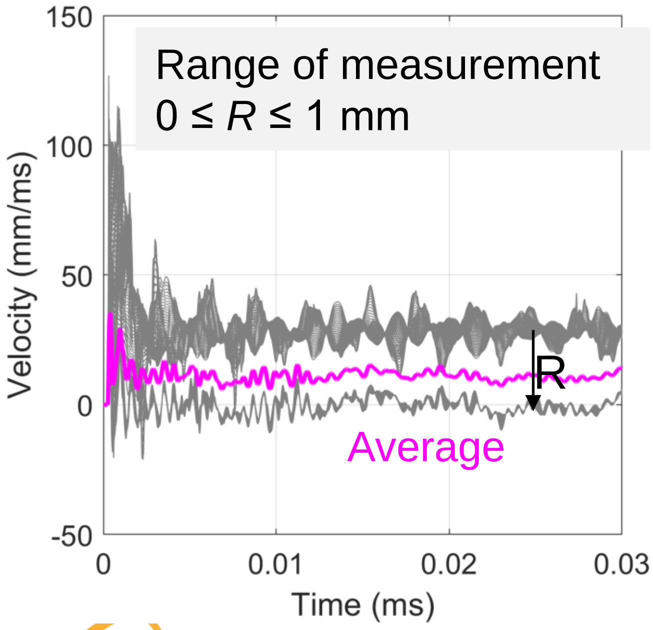




SHOT LOW @ GSI
Target → material: porous graphite; thickness: **0.5 mm**
Laser → energy: 180 J; pulse duration: 5

LS-DYNA GSI Prediction 1 ns





SHOT HIGH @ GSI
Target → material: porous graphite; thickness: **1 mm**
Laser → energy: 180 J; pulse duration: 1 ns

Conclusions and outcomes

- Following the preliminary ELI-NP results the laser deposition phase could be simulated with 1D code HELIOS
- The obtained velocity at the plasma-solid interface could be used as boundary condition for the LS-DYNA model in order to assess the conditions at the back surface tacking into account the strength and failure model of the material
- Different modelling techniques were tested (2D FE, 3D FE, SPH, FE-SPH) and 2D axisymmetric model results as the much effective solution (fast and enough accurate)
- The results are strongly dependent from the adopted damping and failure model
- Velocity measurements on the back surface could strongly vary in function of the portion of the sample considered and the dimensions of the measuring spot

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

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Thank you for your attention!