High Performance Computing Welding Analysis

with DynaWeld and Parallelized LS-DYNA Solvers

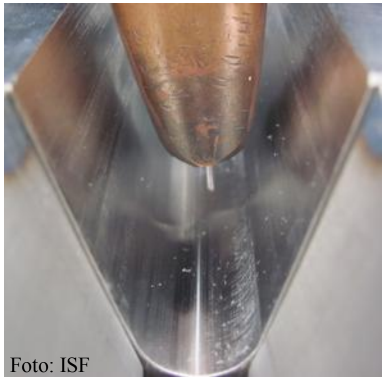
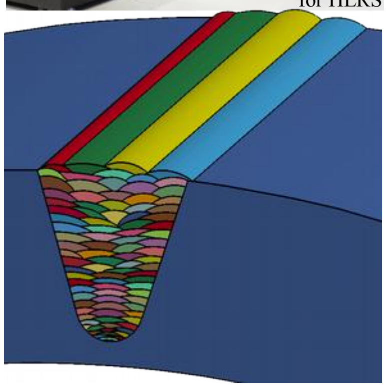


Foto: ISF

14. Deutsches LS-DYNA Forum

Bamberg 10.10.16 bis 12.10.16

Foto: Boris Lehner for HLRS



Tobias Loose

Ingenieurbüro Tobias Loose, Herdweg 13, D- 75045 Wössingen,
loose@tl-ing.de www.tl-ing.eu

Bärbel Große-Wöhrmann,

Martin Bernreuther,

Jörg Hertzer

Universität Stuttgart, Höchstleistungsrechenzentrum, Nobelstraße 19, D-70569 Stuttgart,
www.hlrs.de

Uli Göhner

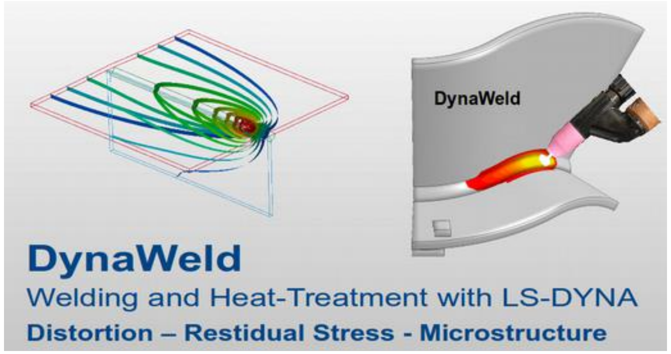
DYNAmore, Industriestraße 2, D-70565 Stuttgart,
www.dynamore.de

Foto: Edyta Łopatecka

INGENIEURBÜRO TOBIAS LOOSE
Herdweg 13, D-75045 Wössingen Lkr. Karlsruhe
E-Post: loose@tl-ing.de Mobil: +49 176 6126 8671

Numerical Simulation for Welding and Heat Treatment since 2004

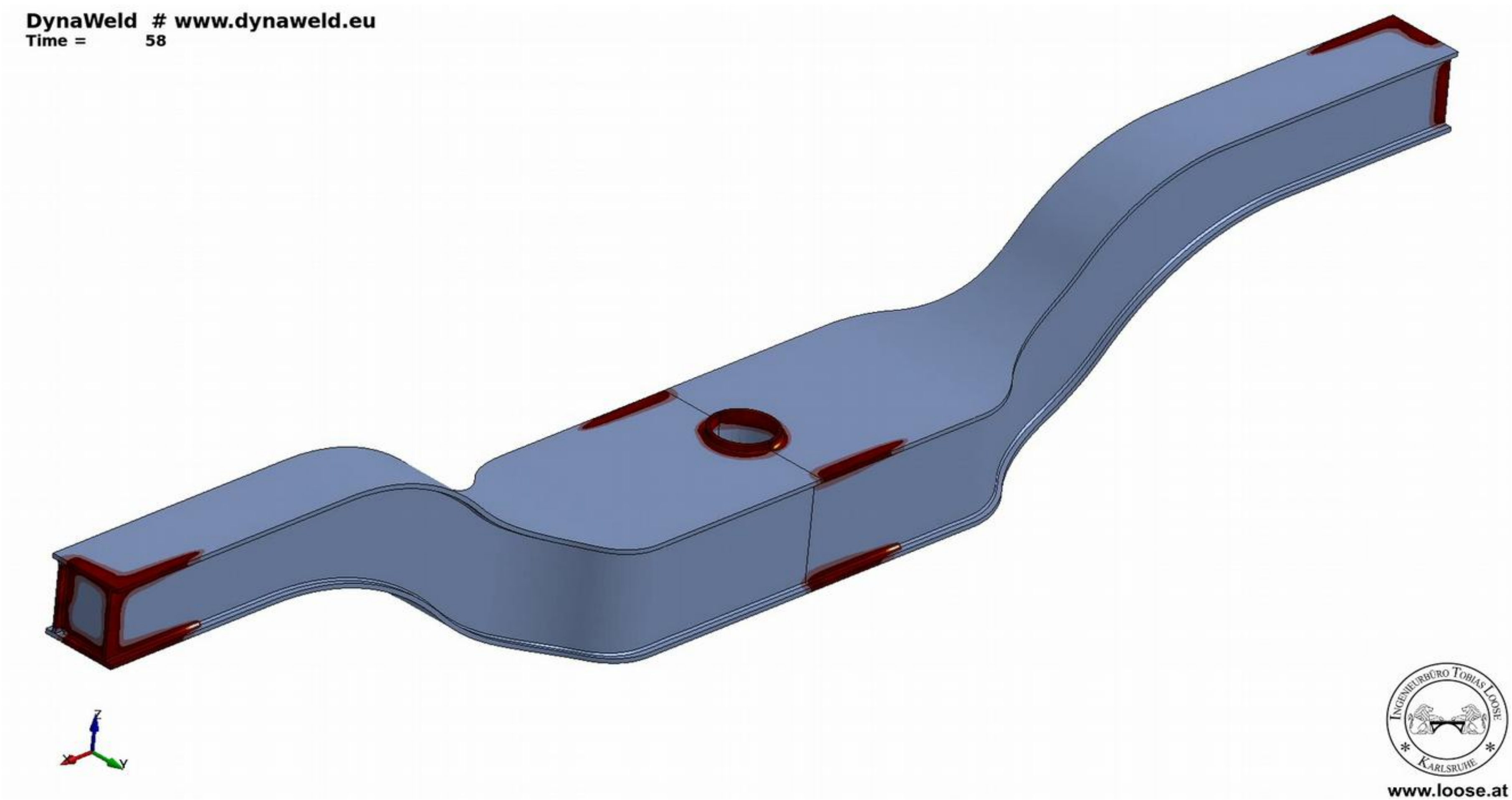
www.DynaWeld.eu **www.SimWeld.eu** **www.WeldWare.eu**



Consulting - Training - Support

Software Development and Distribution

Motivation



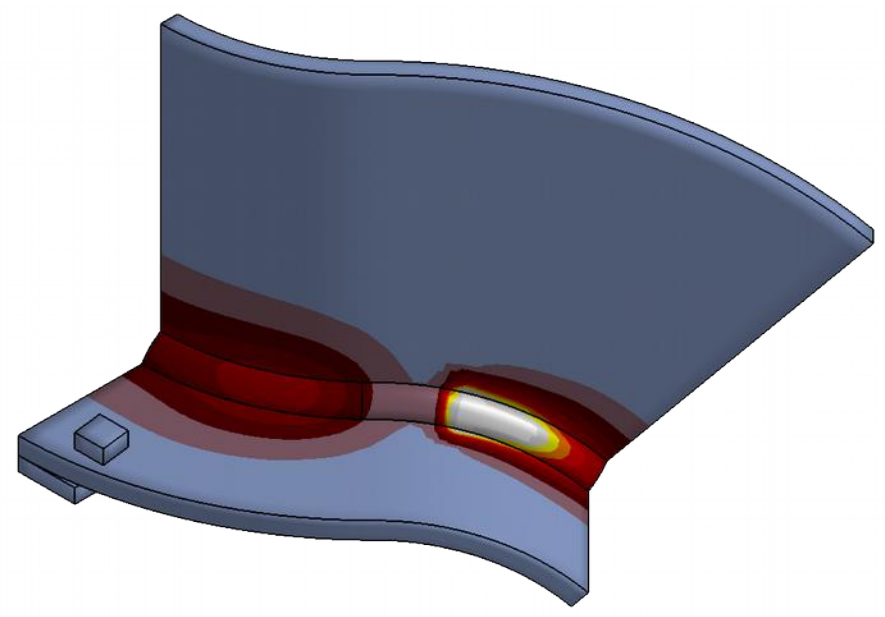
Welding simulations

Welding training simulation

Welding roboter simulation

Welding process simulation

- Predict weldpool and weldability
- Design process parameter



Welding structure simulation

- Predict distortion
- Predict residual stresses
- Predict state of assembly
- Design of distortion mitigation

Benefits of welding simulation

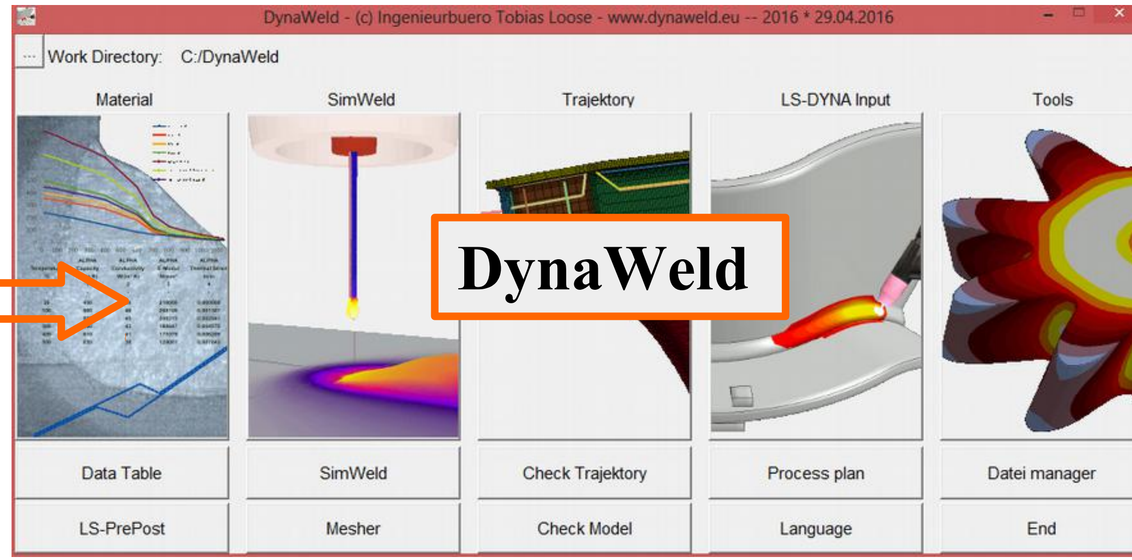
- complex high costly physical tests are replaced by low costly virtual tests,
- visualisation of states of work pieces which are not or hardly able to be measured,
- automatisation of analysis and evaluation which cannot be realised by physical tests,
- explanation of formation processes as basis for the design of optimisation tasks,
- training and education.

Software requirements for industrial welding simulation

High sofisticated Finite Element Application.
Welding covers a wide range of processes weld types and specimen dimensions.

Preprocessor and Environment

- approved for consultings
- easy work an quick setup
- automatisation as far as possible
- all weld types
- all specimem sizes
- several model techniques
- Model check and QA



DynaWeld

Solver

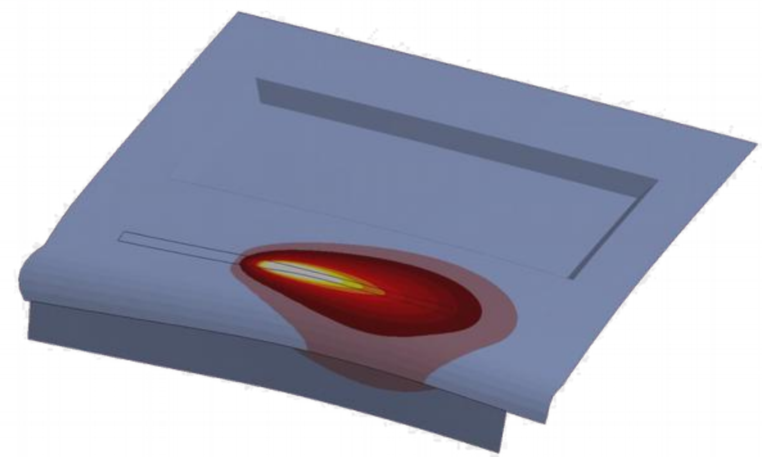
- special welding features
- special welding material
- robustness
- performance

LS-DYNA

Main issues of welding simulation and its solutions

Issue

- Large simulation time
- Requires experienced engineers for model setup
- Cost



Solution for SME

- High performance computing (HPC) on demand
- Use consulting from experts
- Pay only for the individual project
- Save investment costs for
  - supercomputer and its maintenance
  - manpower and training

HPC Welding with **DynaWeld** and **LS-DYNA** on **Hazel Hen** at **HLRS**

„Hazel Hen” Cray Cascade XC40 at HLRS

High Performance Computing Center Stuttgart

Foto: Boris Lehner for HLRS

„Hazel Hen" Cray Cascade XC40 at HLRS

High Performance Computing Center Stuttgart

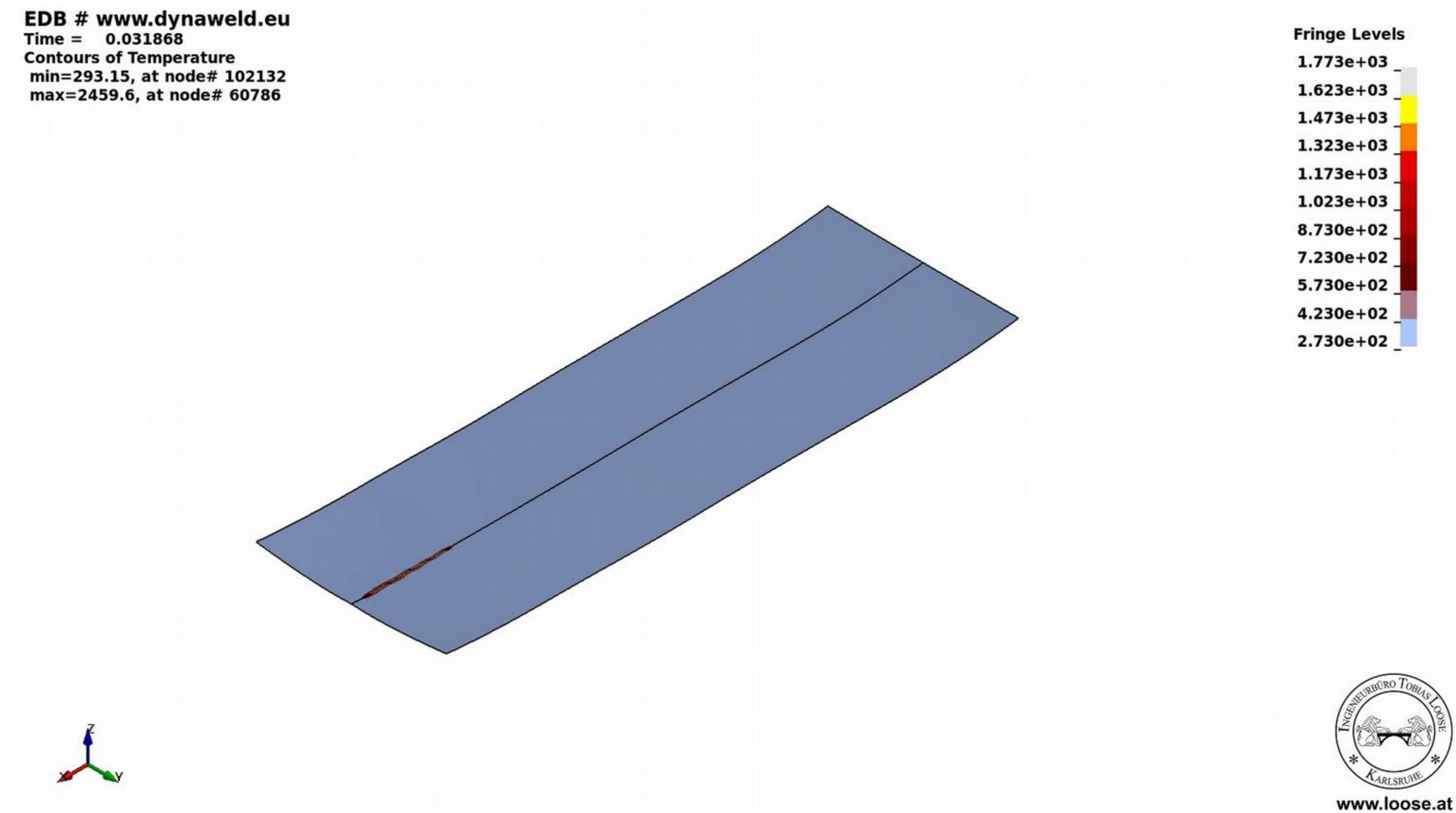
Main features of Hazel Hen:

- 7712 nodes
- 2 CPUs / node
- 12 cores / CPU → 24 cores / node
- 185088 cores totally
- Intel® Xeon® E5-2680 v3 CPUs with 2.50 GHz clock frequency
- 128 GB DDR4 memory / node
- Communication on the Cray XC runs over the Cray Interconnect
- Lustre based file system was used for input and output of data

Hazel Hen's LS-DYNA used for this project

- Cray-specific LS-DYNA mpp double precision (I8R8) version 103287
- Compiled by Cray using the Intel Fortran Compiler 13.1 with SSE2 enabled
- The Extreme Scalability Mode (ESM) was used

Testcases



EDB # www.dynaweld.eu
Time = 0.031868
Contours of Temperature
min=293.15, at node# 102132
max=2459.6, at node# 60786
Fringe Levels
1.773e+03
1.623e+03
1.473e+03
1.323e+03
1.173e+03
1.023e+03
8.730e+02
7.230e+02
5.730e+02
4.230e+02
2.730e+02
Z
X
Y
www.loose.at

Testcases

The testcases shall cover the range of industrial application

as wide as possible within several modelling techniques.

Categories:

- **Solid** element models - **shell** element models
- Models **with contact** formulation - models **without contact** formulation
- **Transient** method - **metatransient** method

Model size:

- **Small** models (100 000 .. 250 000 E.) - **large** models (> 1 000 000 E.)

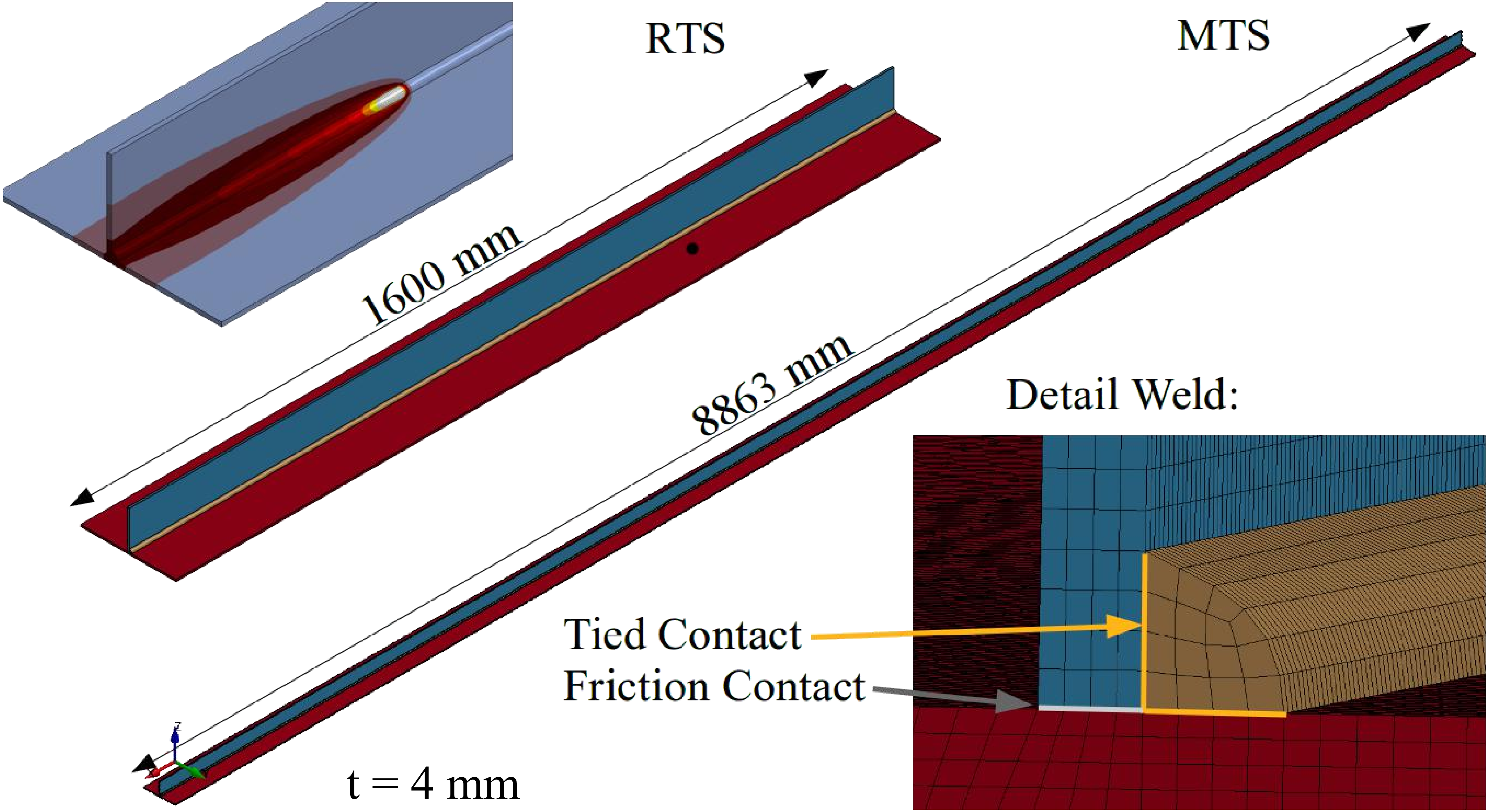
Time stepping scheme:

- **Implicit** analysis - **explicit** analysis

Feature	RTS	MTS	SHT	RUP	EDB	MDB
Process	GMAW	GMAW	GMAW	SAW	Laser	Laser
Model size	normal	large	normal	normal	normal	large
Element type	solid	solid	solid	solid	shell	shell
Method	transient	transient	metatransient	transient	transient	transient
Contact	yes	yes	yes	no	no	no
Weld time	320 s	1773 s	10 s	31225 s	0,21 s	0,21 s
Model time	50 s	50 s	5000 s	3000 s	0,21 s	0,1 s

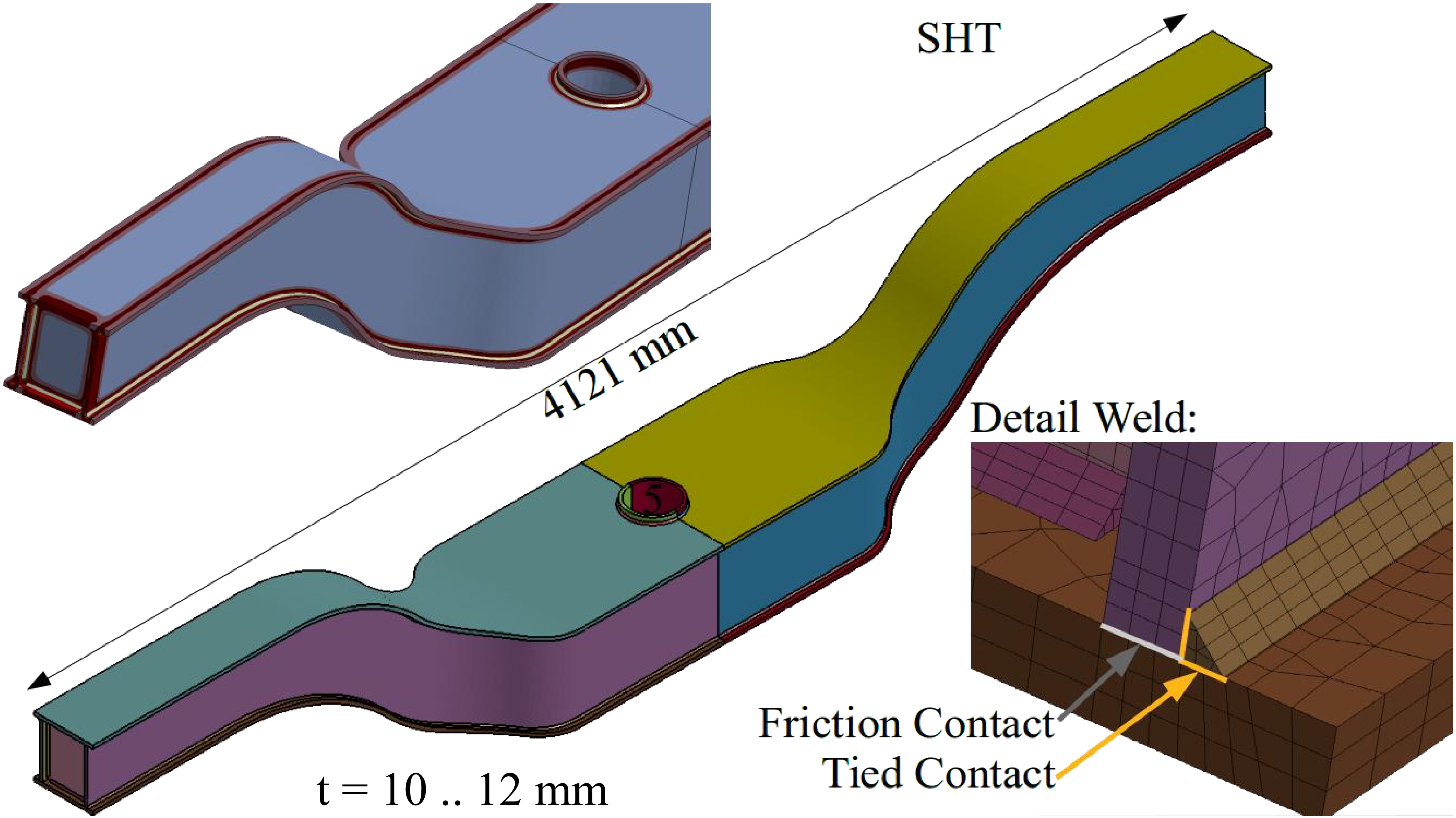
RTS and MTS - GMAW

solid model with contact transient



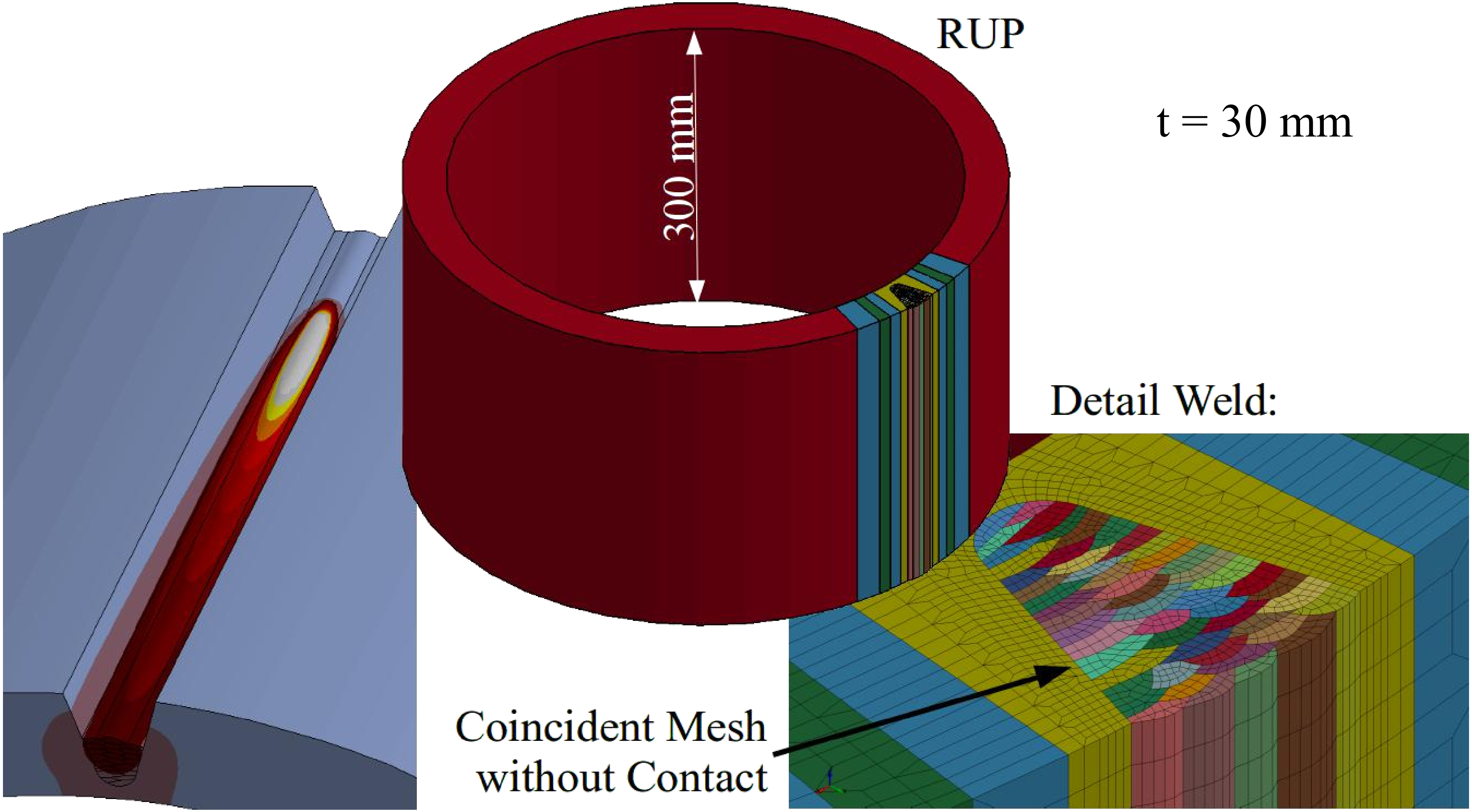
SHT - GMAW

solid model with contact metatransient



RUP - SAW

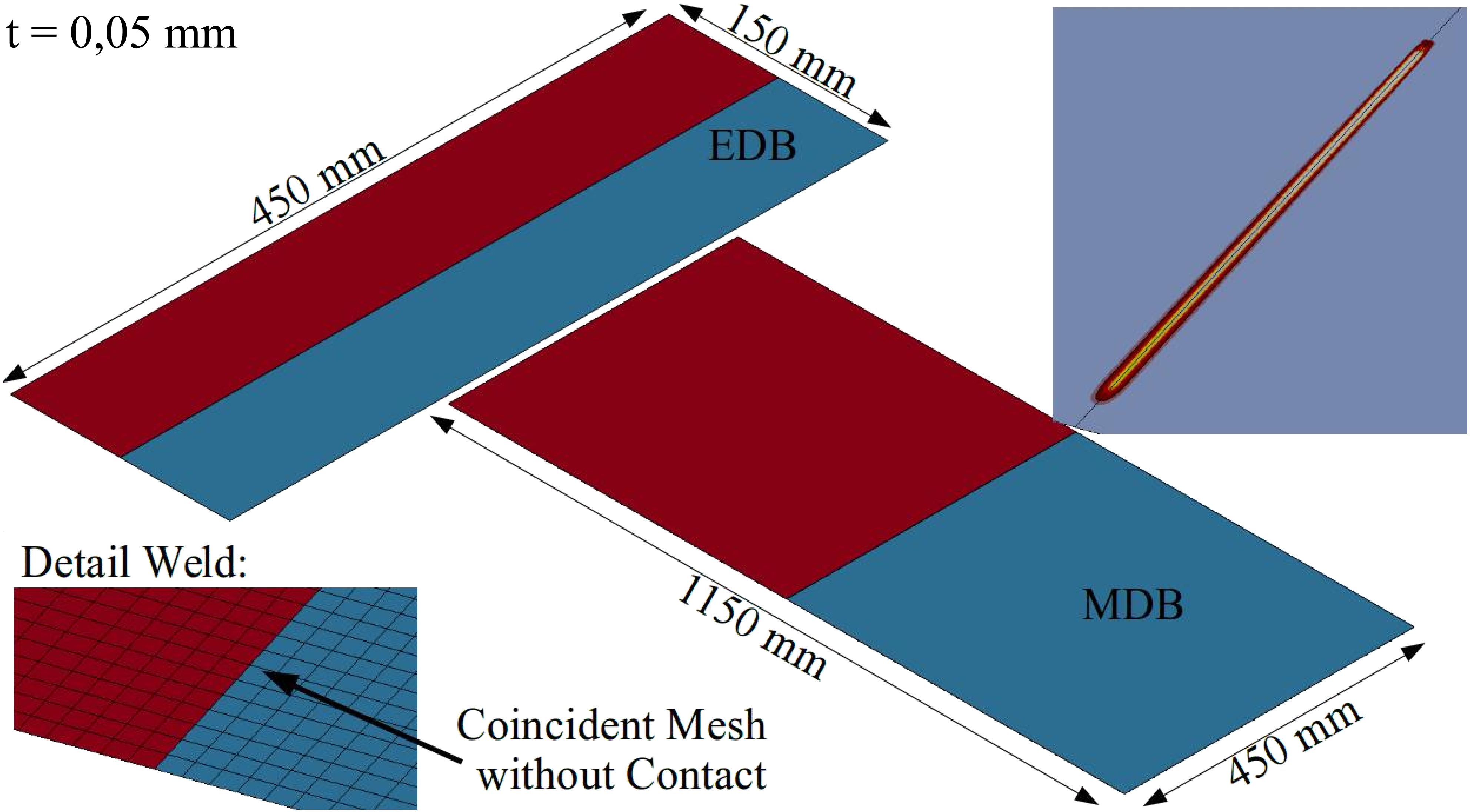
solid model without contact transient



EDB and MDB - highspeed laser

shell model without contact

t = 0,05 mm



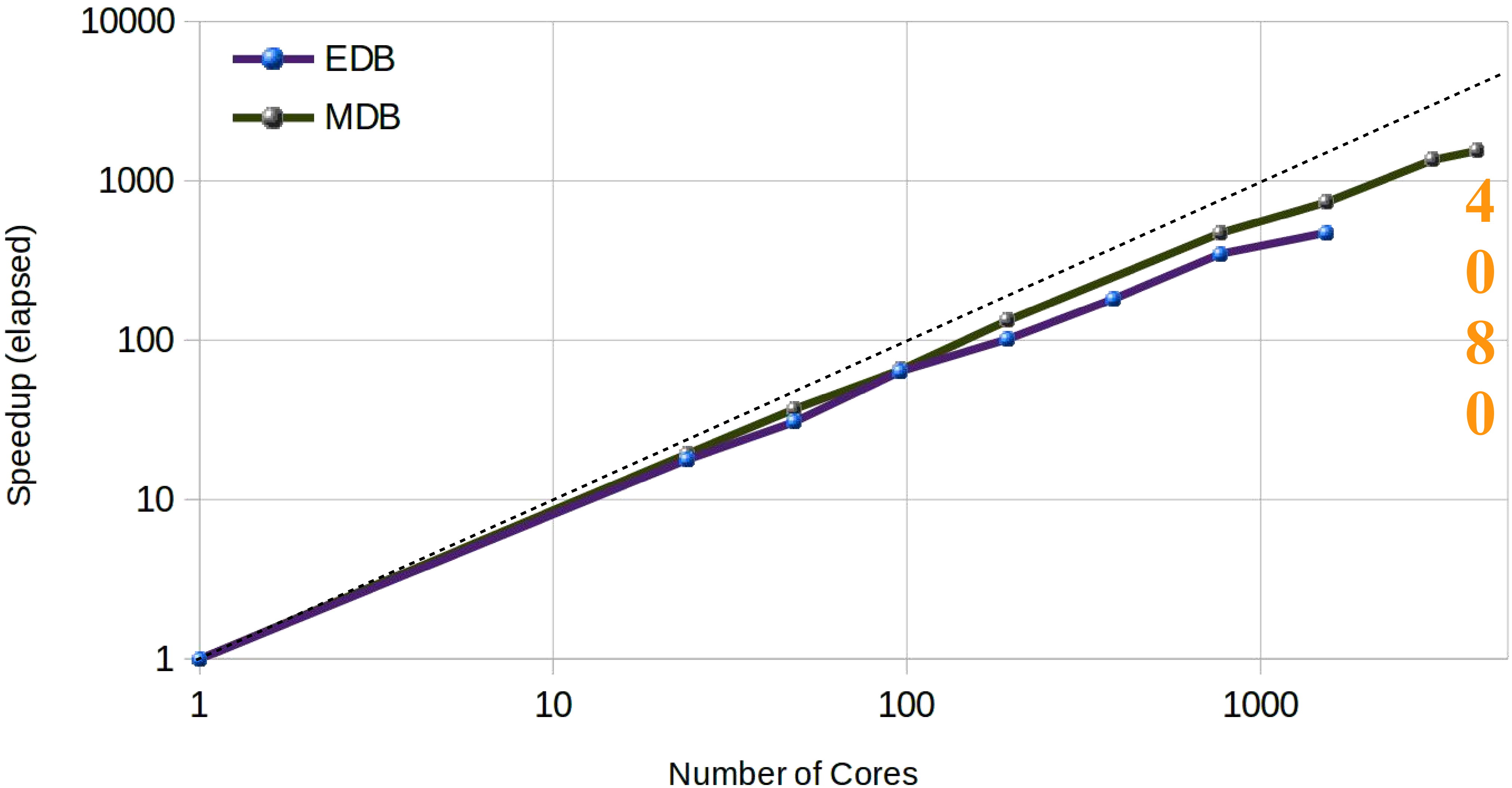
General remarks

- Decoupled thermal - mechanical analysis is used for all cases
- Focus of this project was on
  - feasability,
  - scalability,
  - performance.
- Scaling tests on following number of cores:
  - 1, 2, 4, 8 … or 1, 4, 16 ...
  - 1, 24, 48, 96 ... (full number of cores / node)
  - discrete jobs on 48, 72 and 96
- Explicit analysis only for mechanical solver.
- Explicit analysis requires smaller time steps than implicit analysis.
- Mass scaling methods are not used in this project.
- Computation time larger 24 h determined by extrapolation.
- Modular input using subdirectories and include files.

Results

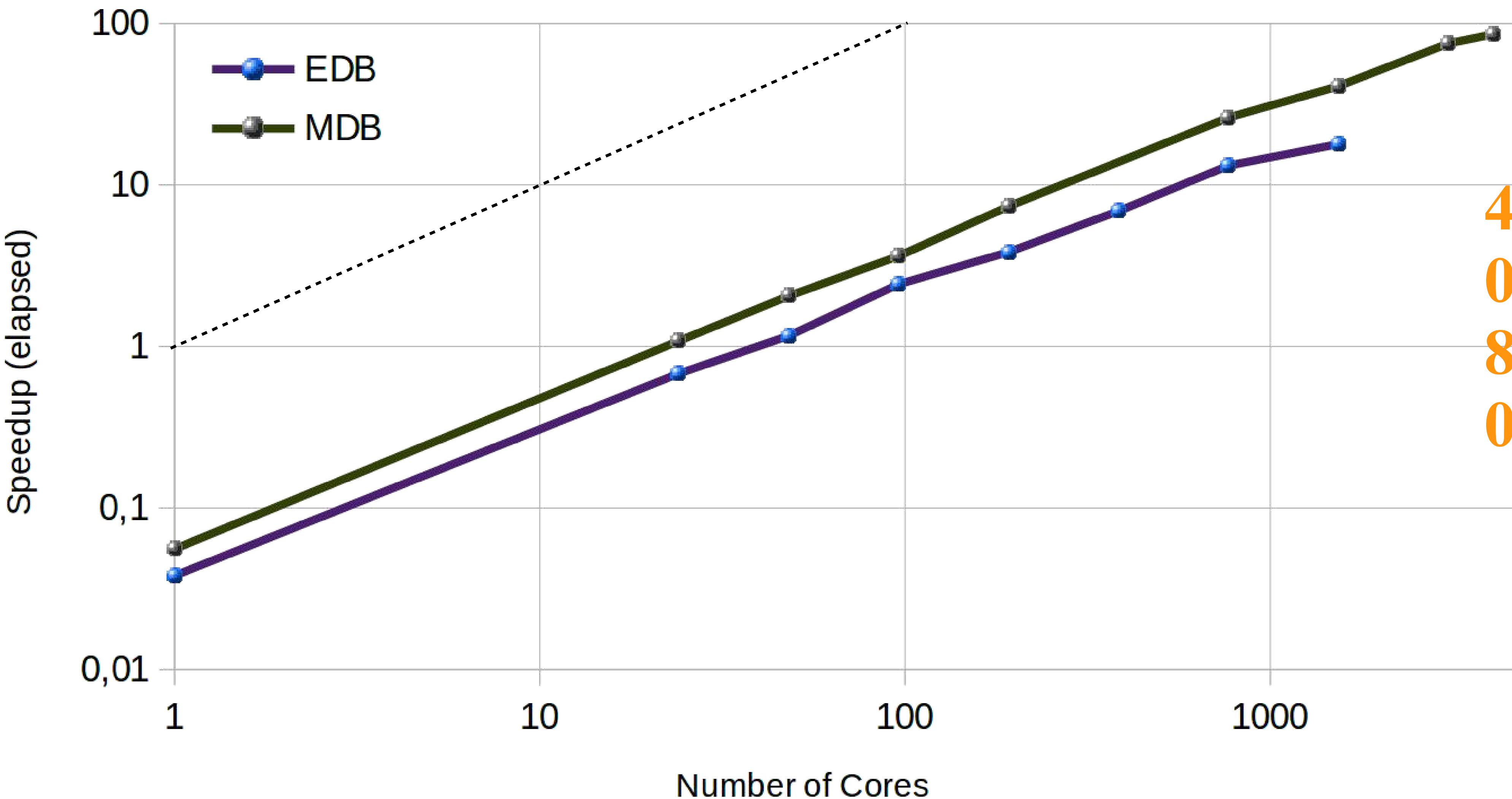
Foto: Edyta Łopatecka

Explicit analysis - mechanical solver
Speedup

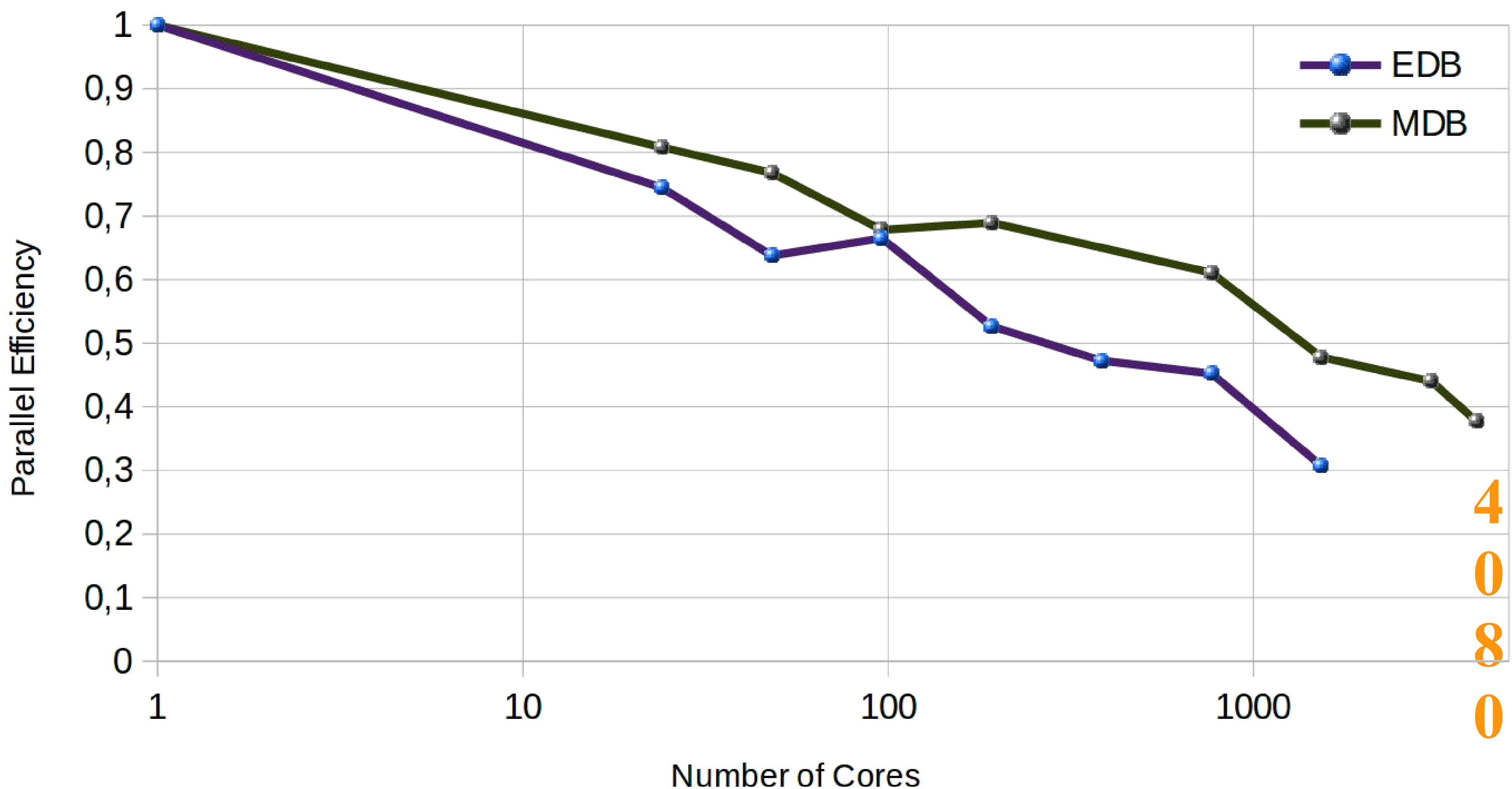


Explicit analysis - mechanical solver

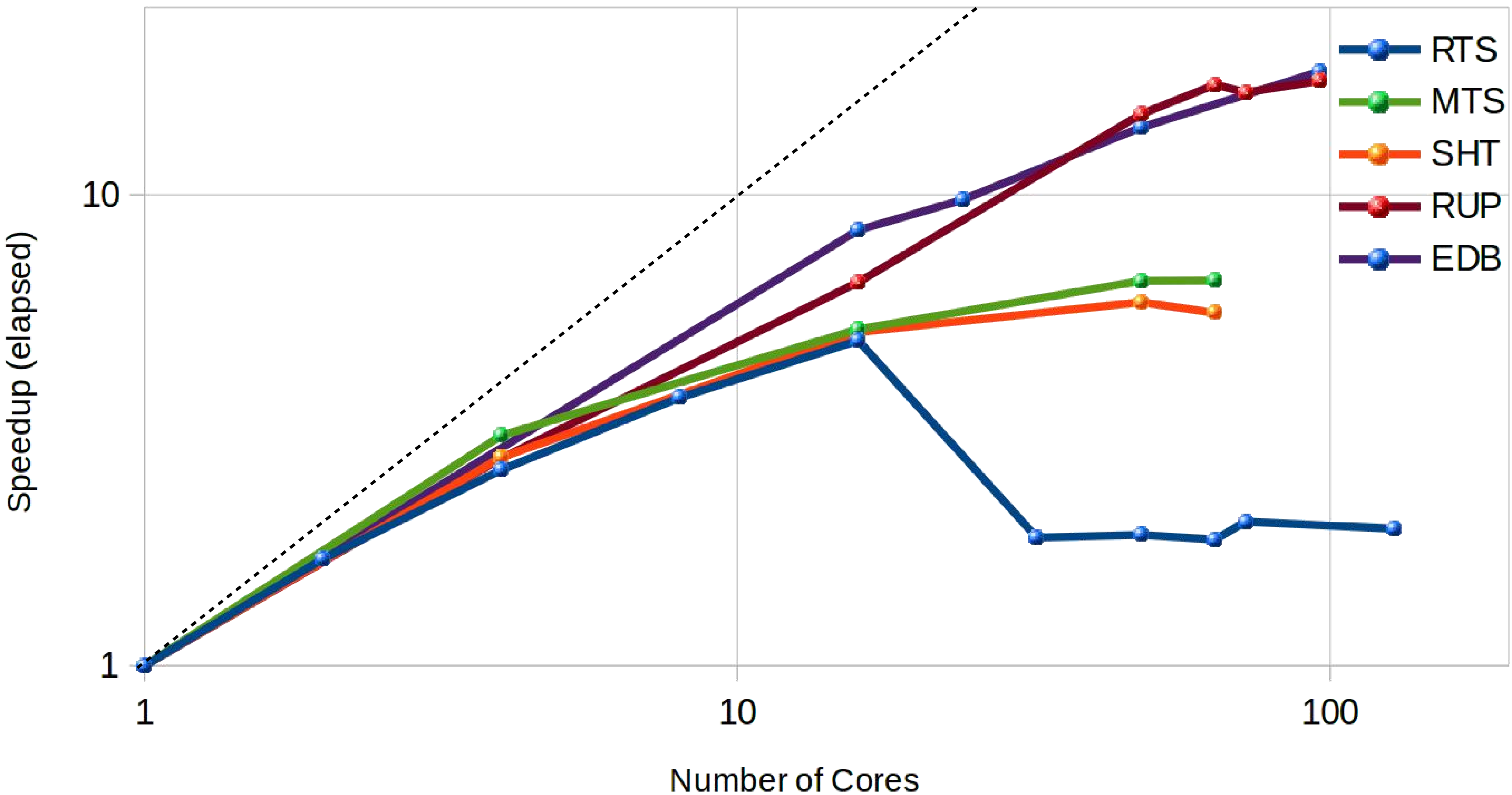
Speedup relativ to implicit analysis one core



Explicit analysis - mechanical solver
Parallel efficiency

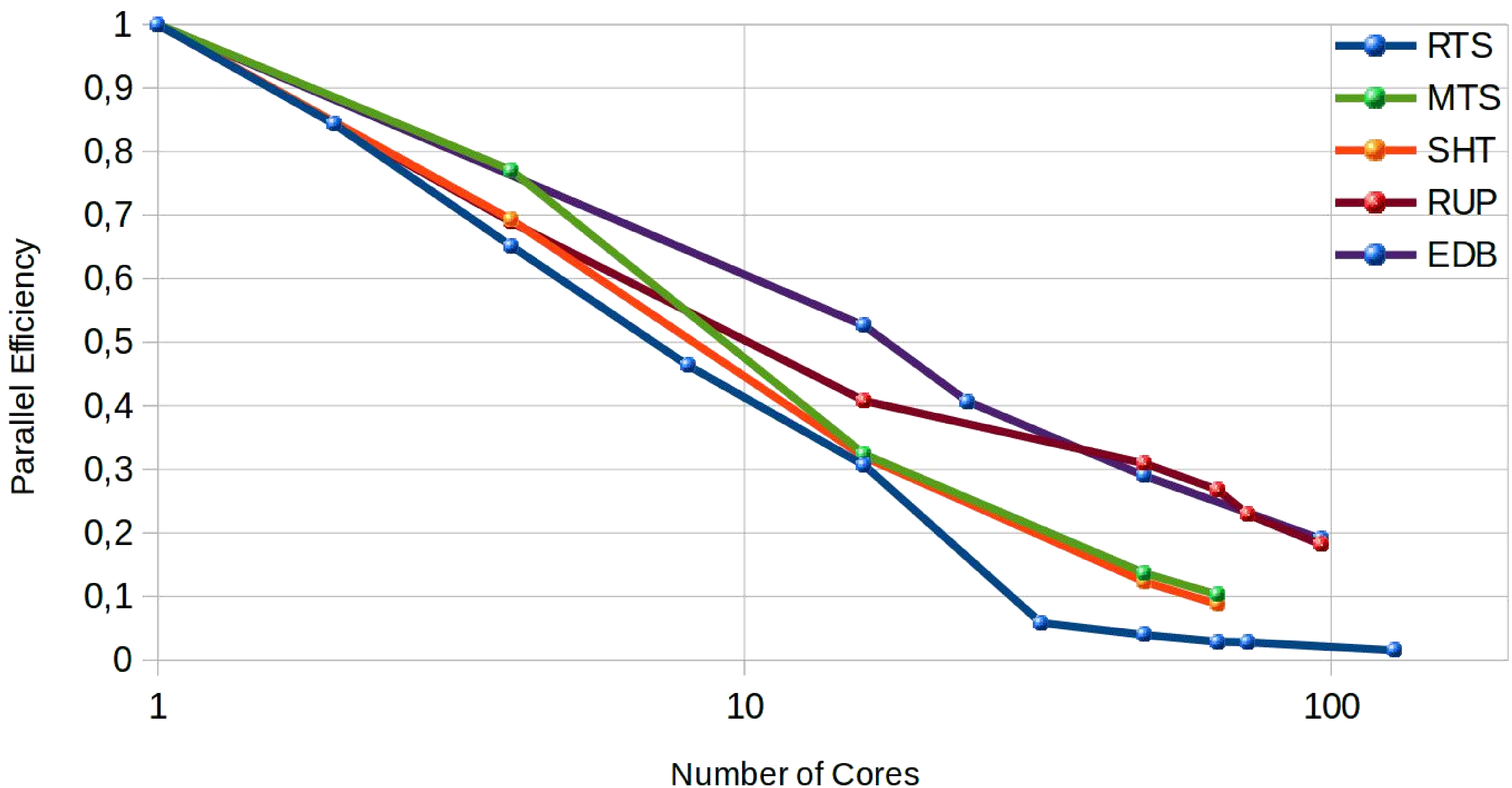


Implicit analysis - mechanical solver
Speedup



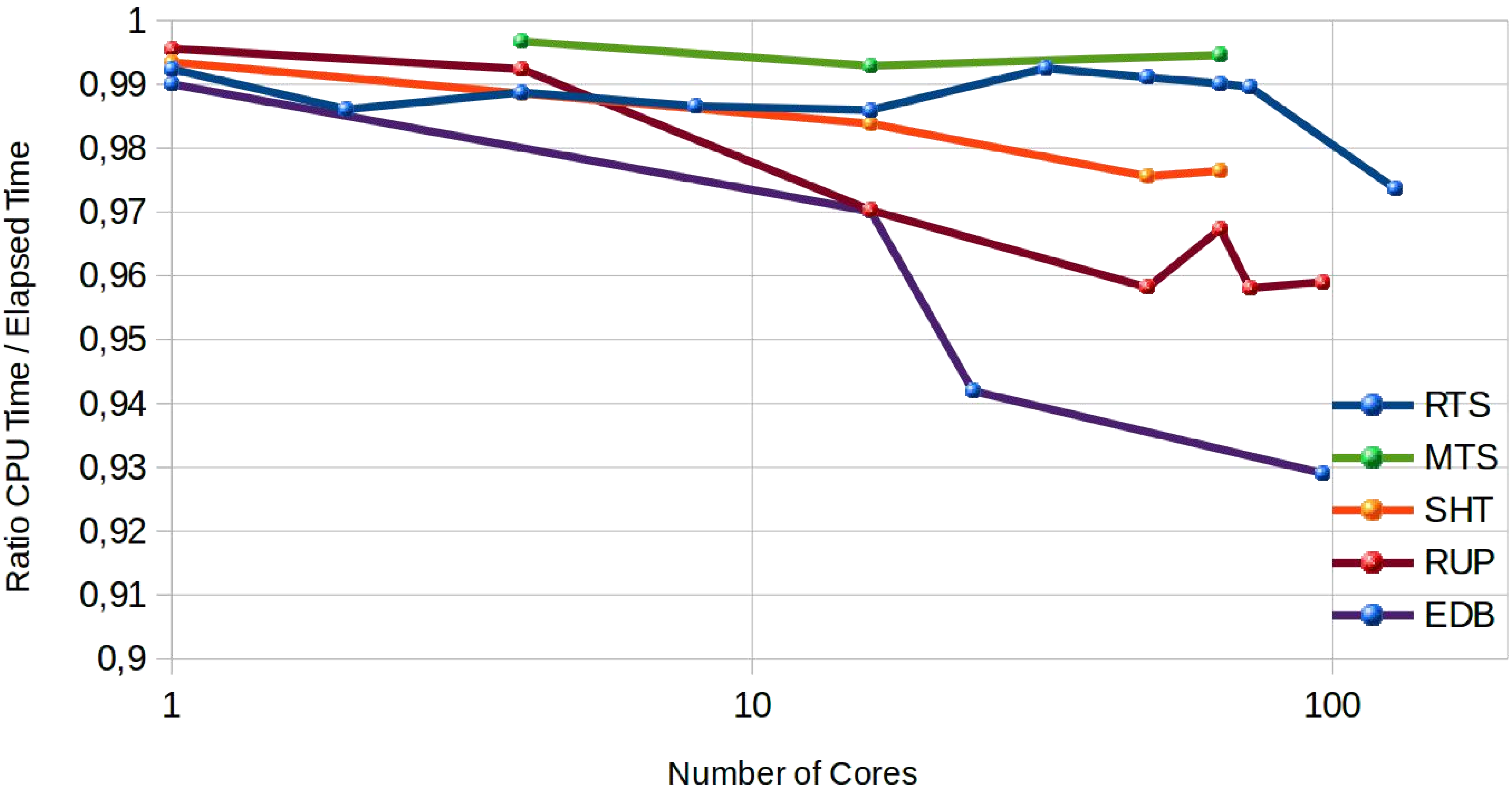
Implicit analysis - mechanical solver

Parallel efficiency

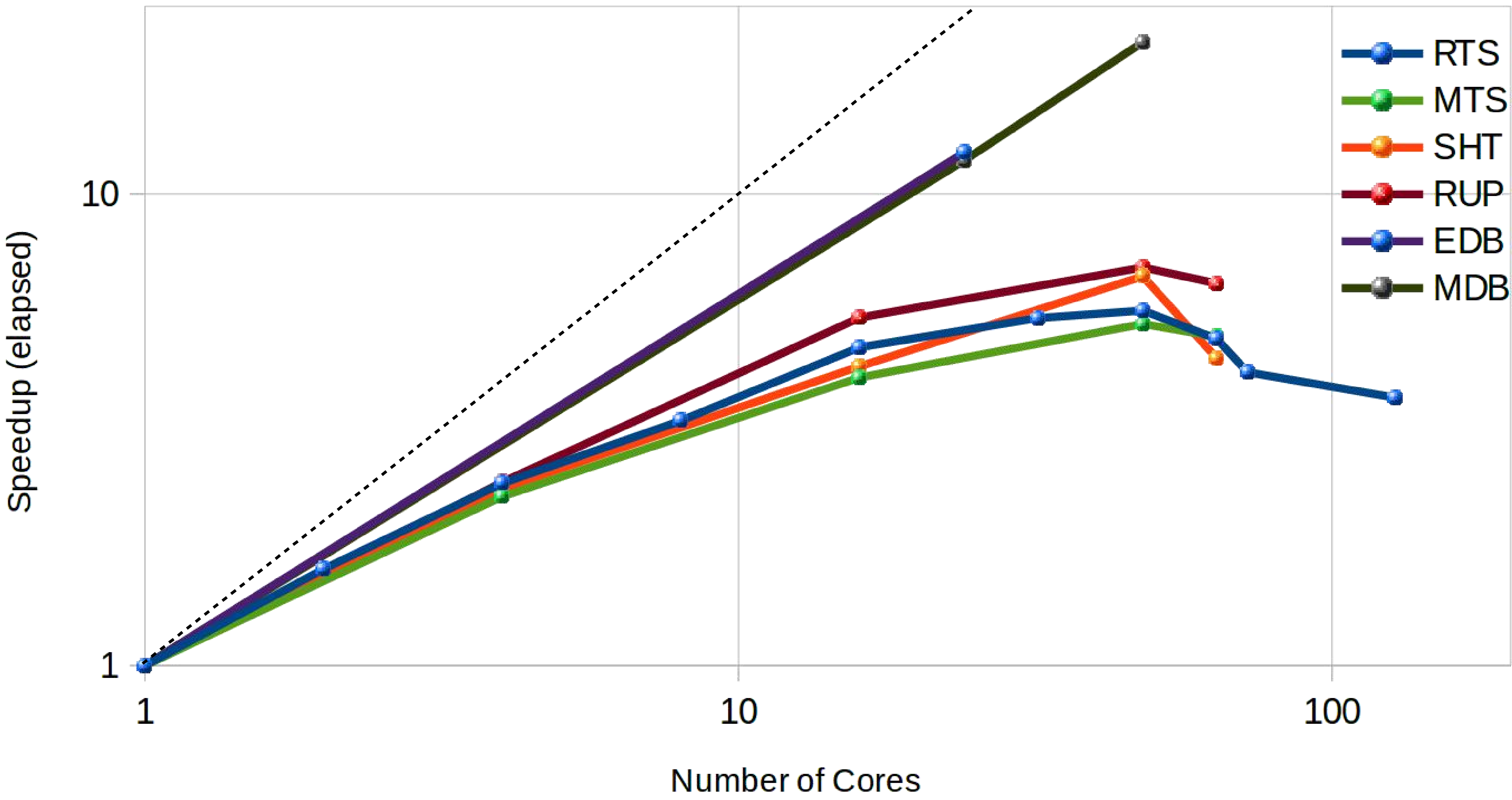


Implicit analysis - mechanical solver

Ratio cpu time / elapsed time



Implicit analysis - thermal solver
Speedup



Implicit analysis - thermal solver
Parallel efficiency

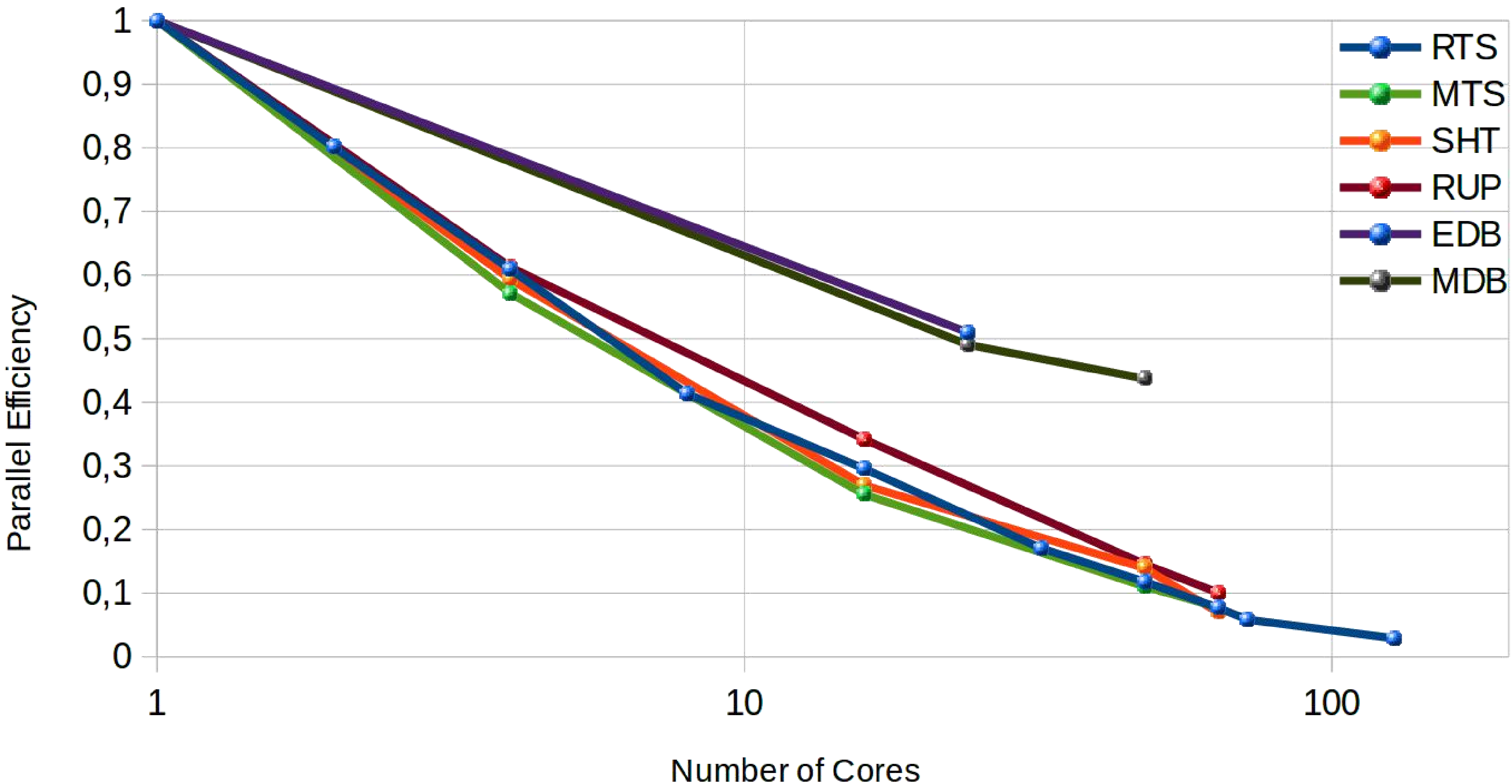


Foto: Edyta Łopatecka

Conclusion

Recommendation - Outlook

Results and recommendations

- Decoupled analysis recommend, mandatory for explicit analysis
- Shell element models show a better performance than solid element models,
- Models without contact show a better performance than models with contact,
- Large models show a better performance than small models.

	Thermal analysis		Mechanical analysis	
	Maximum number of cores	Speedup at max number of cores	Maximum number of cores	Speedup at max number of cores
Implicit				
SHELL model without contact	48 (or higher)	21	48	14 - 15
SOLID model without contact	16	4 - 5	16	5
SOLID model with contact	16	4 - 5	16	5
Explicit				
SHELL model without contact	n.a	n.a.	4080 (or higher)	1540

Conclusion and Outlook

- **Industrial welding structure simulation on HPC is feasible.**
- **DynaWeld** enables setup of industrial welding models for HPC.
- **LS-DYNA** guarants significant speedup and parallel efficiency
  - up to high number of cores
  - for explicit as well as for implicit analysis

- HPC on demand
- Excellent support of **HLRS** staff
- Consulting from experts

→ **HPC welding available for every company**

- The project is a good basement for further investigations in explicit HPC welding analysis on shell element models.
  - Speedup by mass scaling vs. result quality.
  - Efficiency on several welding processes.

Acknowledgement

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Foto: Martin Loose