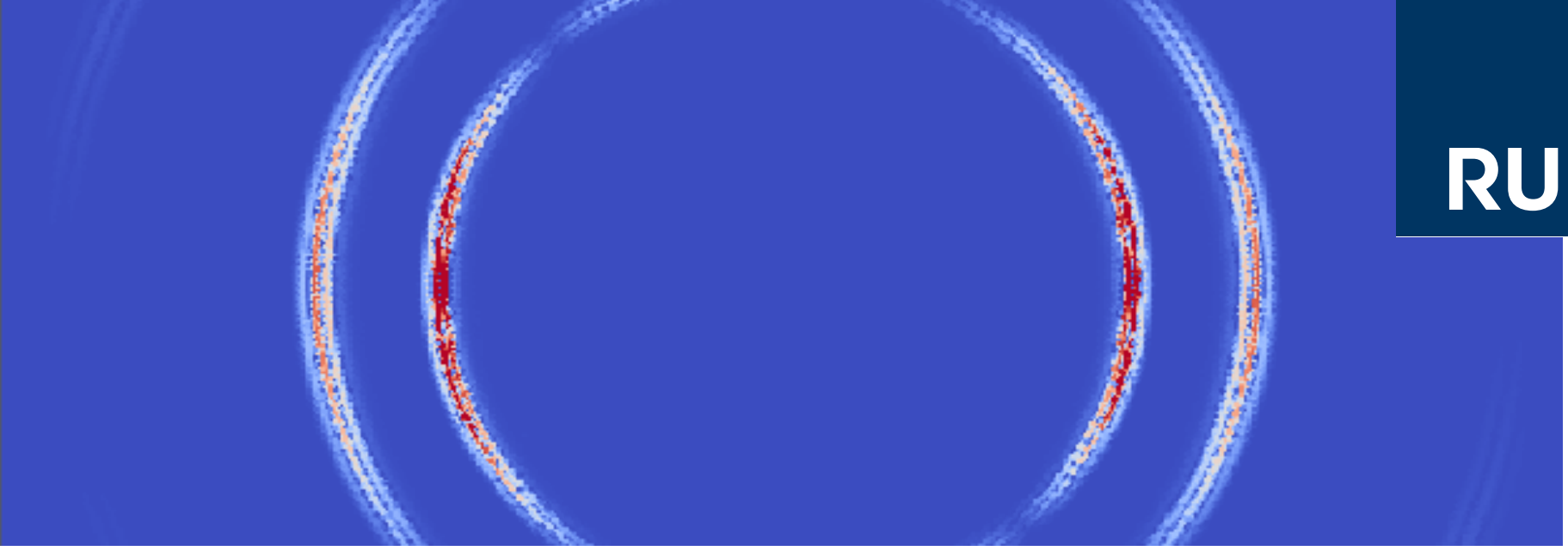

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NEXD: A Software Package for High Order Simulation of Seismic Waves using the Nodal Discontinuous Galerkin Method

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Features of NEXD

Feature	1D	2D	3D
Material			
elastic	✓	✓	✓
viscoelastic	✗	✓	✓
poroelastic	✓	✓	(✓)
fractures	✓	✓	✗
Boundary conditions			
reflecting	✓	✓	✓
periodic	✓	✗	✗
absorbing	✓	✓	✓
absorbing (PML)	✗	✓	✓
Other			
adjoint methods	✗	✓	(✓)
Cubit meshs	✗	✓	✓
MPI (parallel computing)	✗	✓	✓

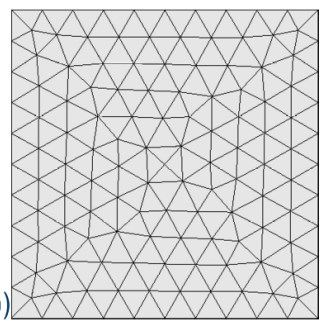
Top: Overview of current features and development
✓: implemented and published, ✓: implemented, (✓): work in progress, ✗: not implemented (yet)

Nodal Discontinuous Galerkin Method

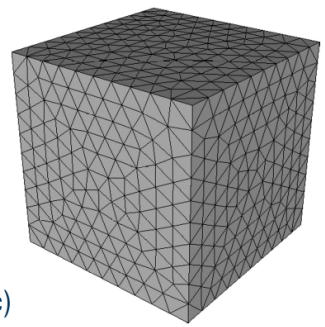
Space discretization

a) Linear meshes (1D)
b) Triangular meshes (2D)
c) Tetrahedral meshes (3D)

a)

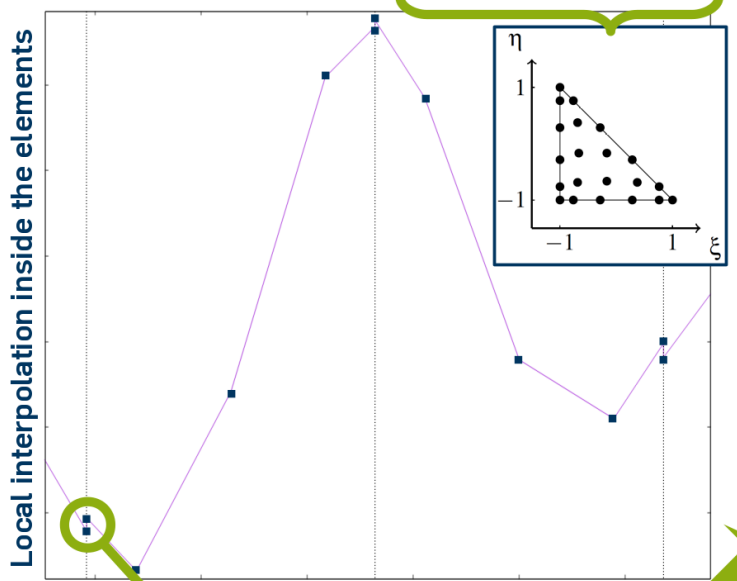


b)



c)

Interpolation points: GLL (1D), warp & blending (2D, 3D)



Riemann-Problem
(initial value problem for piecewise constant data with a single discontinuity)

Numerical Flux

wave equation in velocity-stress formulation (here: 1D)

$$\partial_t \vec{Q} + \mathbf{A}\partial_x \vec{Q} = \mathbf{E}\vec{Q} + \mathbf{F}\vec{s}$$

weak form
(multiplied with test functions & integrated)

$$\int_{D^k} \left(\partial_t \vec{Q}_h^k + \mathbf{A}\partial_x \vec{Q}_h^k - \mathbf{E}\vec{Q}_h^k - \mathbf{F}\vec{s}_h^k\right) \psi_n dx$$
$$= \int_{\partial D^k} n_x \left[\mathbf{A}\vec{Q}_h^k - \left(\mathbf{A}\vec{Q}_h\right)^*\right] \psi_n dx$$

semi-discrete numerical scheme for the weak form

$$\partial_t \vec{Q}^k = -J^{k^{-1}} \mathbf{A} D_{r,(i,j)} \vec{Q}^k + \mathbf{E}\vec{Q}^k + \mathbf{F}\vec{s} - \mathbf{Flux}$$

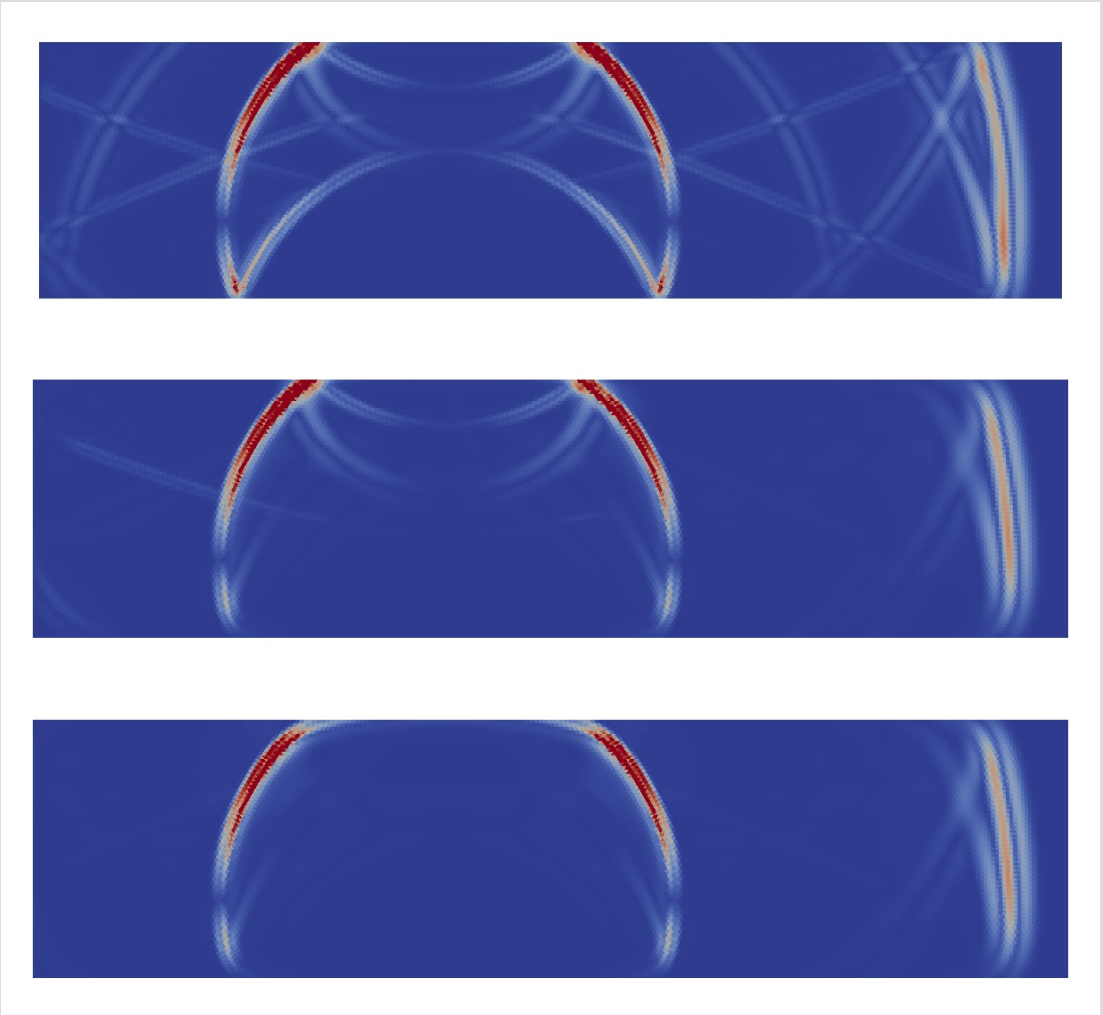
(Galerkin Principle used)

Time stepping scheme

$$\partial_t \vec{Q}^k \rightarrow ?$$

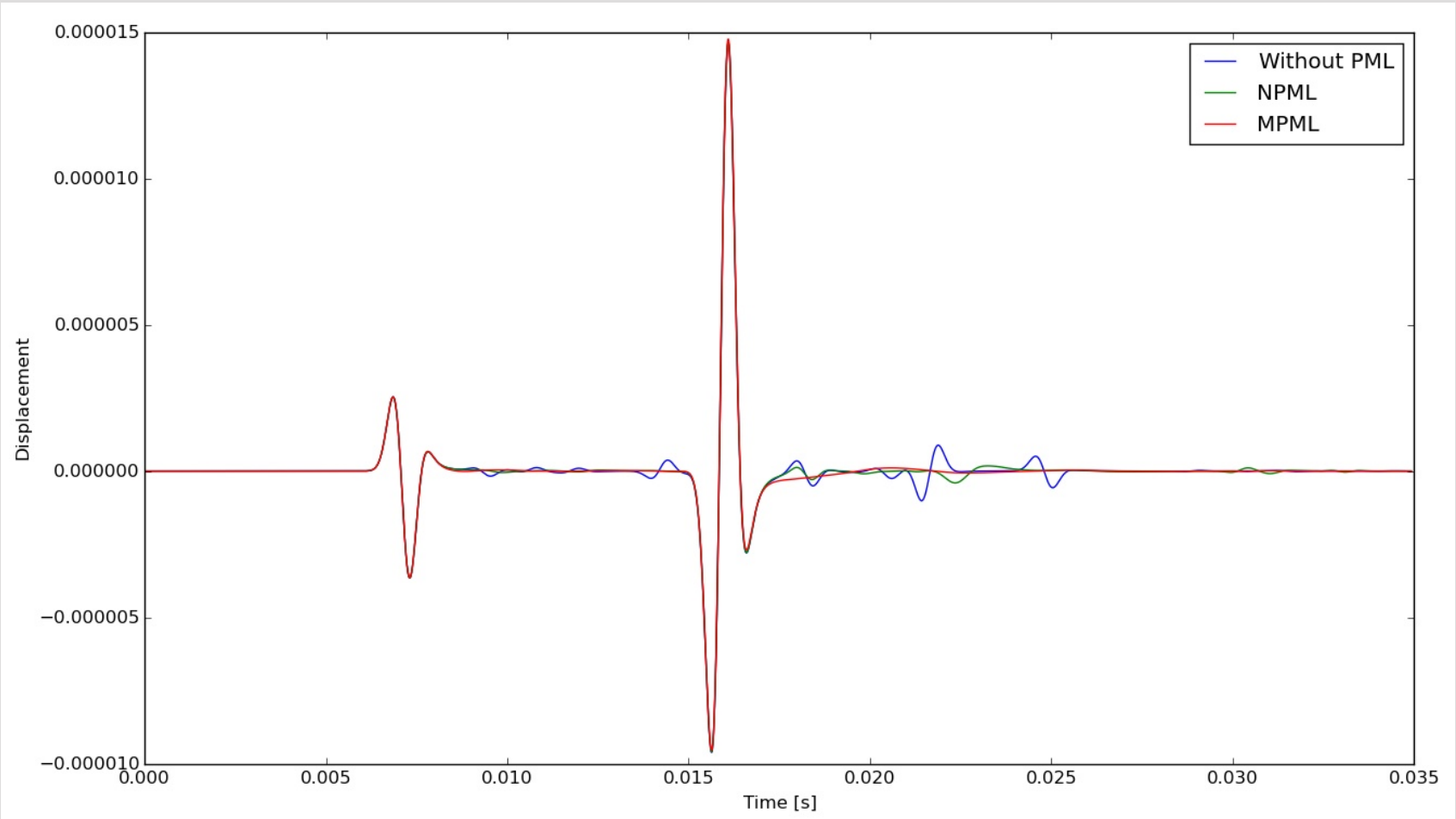
a) Euler method
b) different Runge-Kutta implementations

Absorbing Boundaries: PML

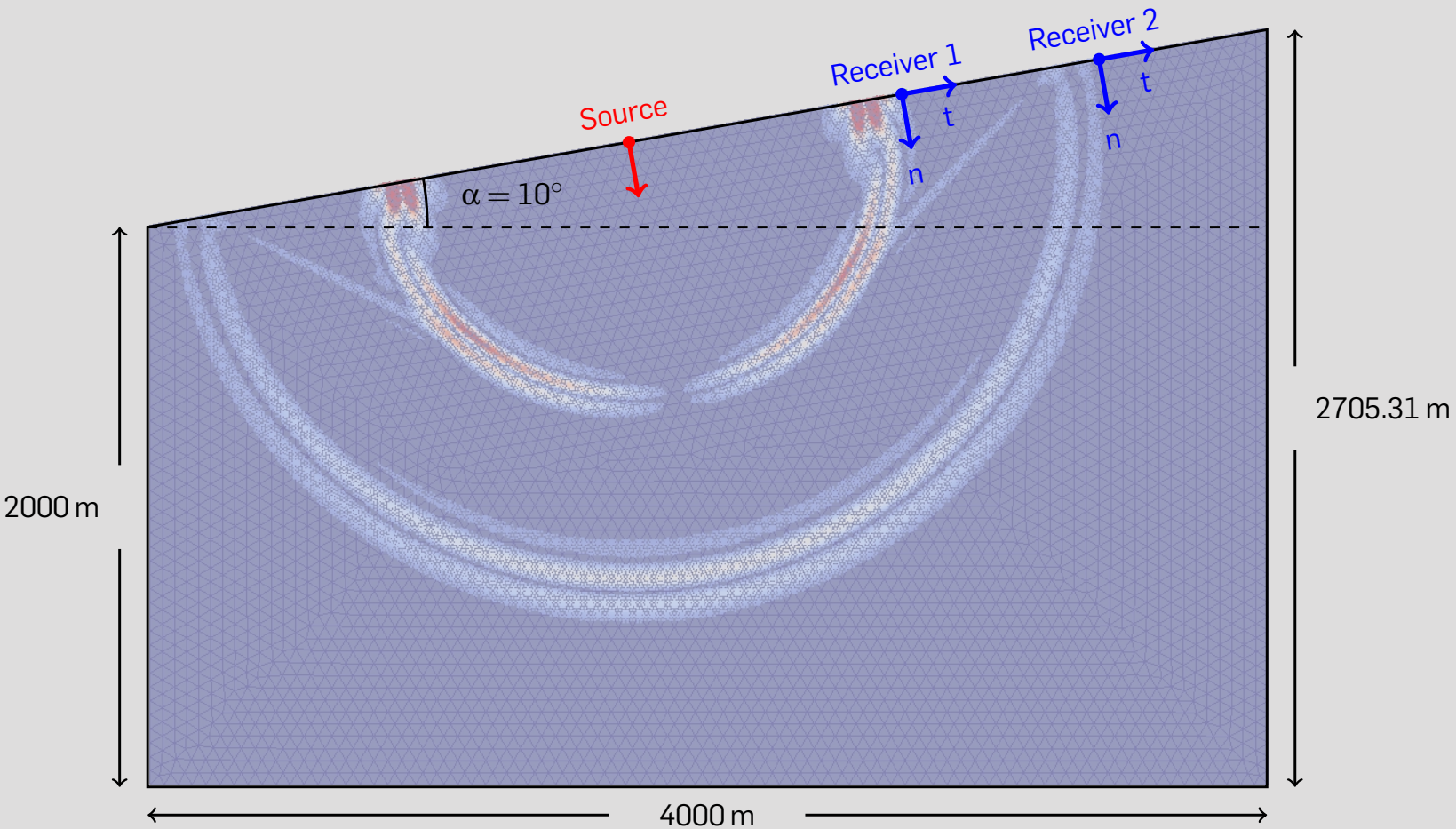


- without PML
- NPML
- MPML

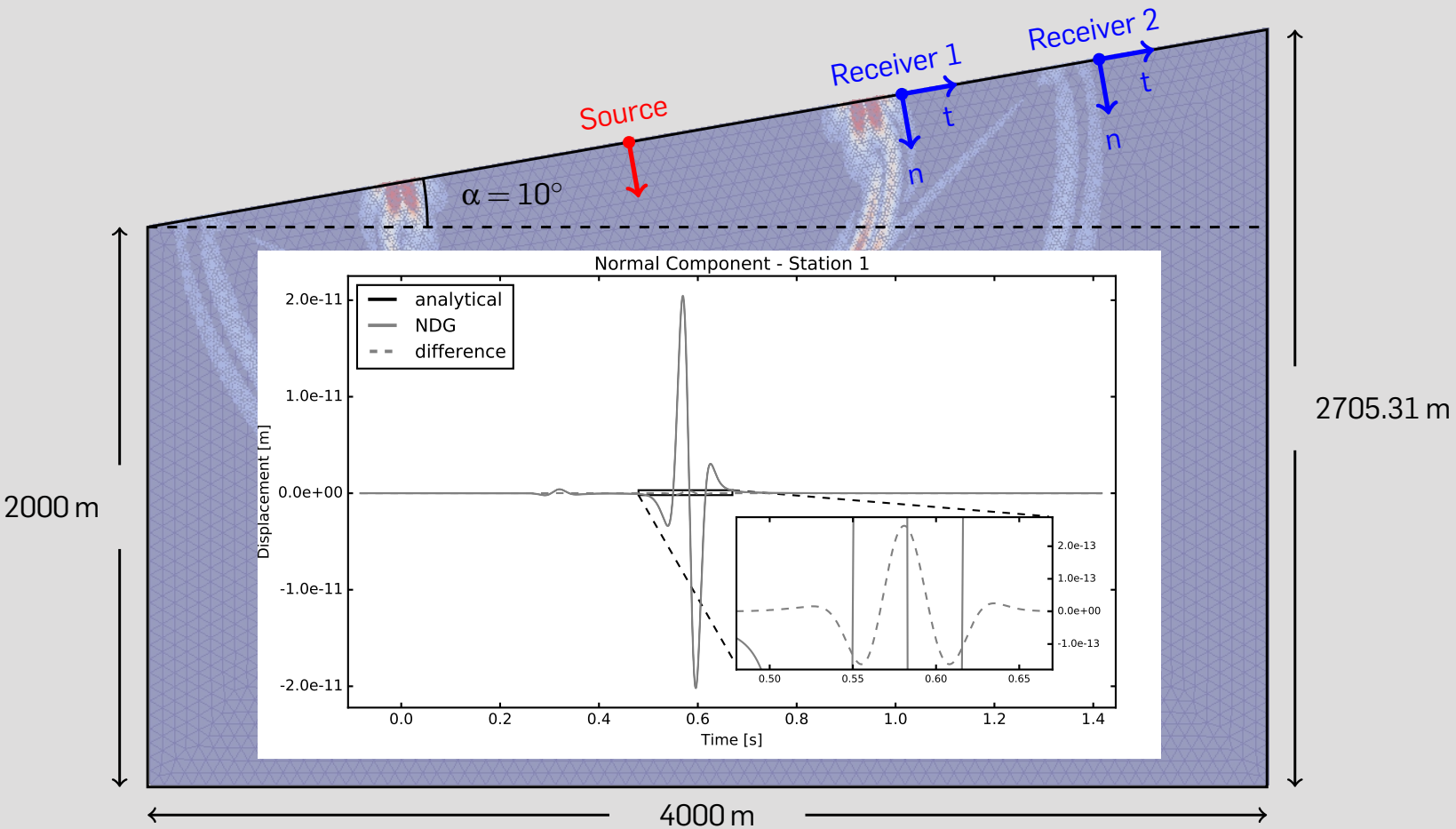
Absorbing Boundaries: PML



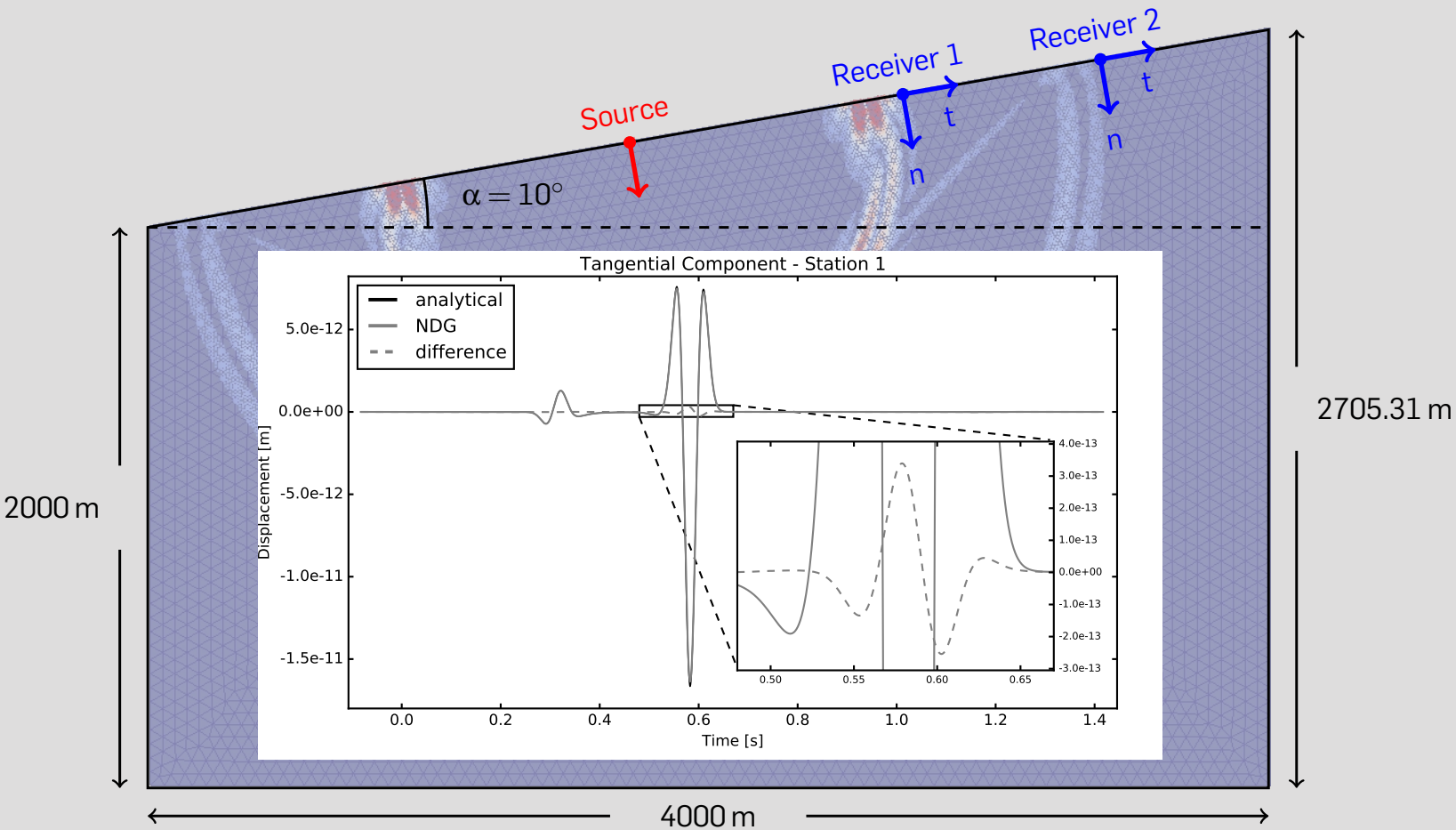
Lamb's problem



Lamb's problem

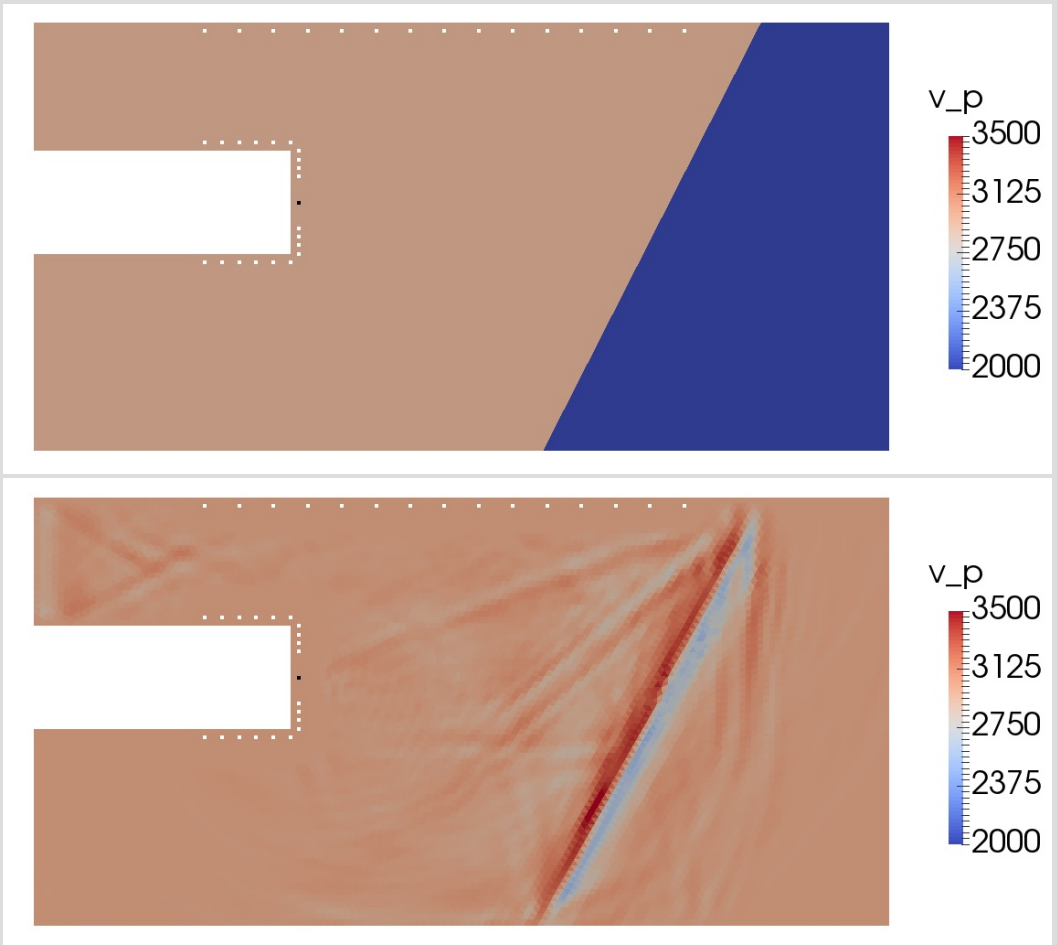


Lamb's problem

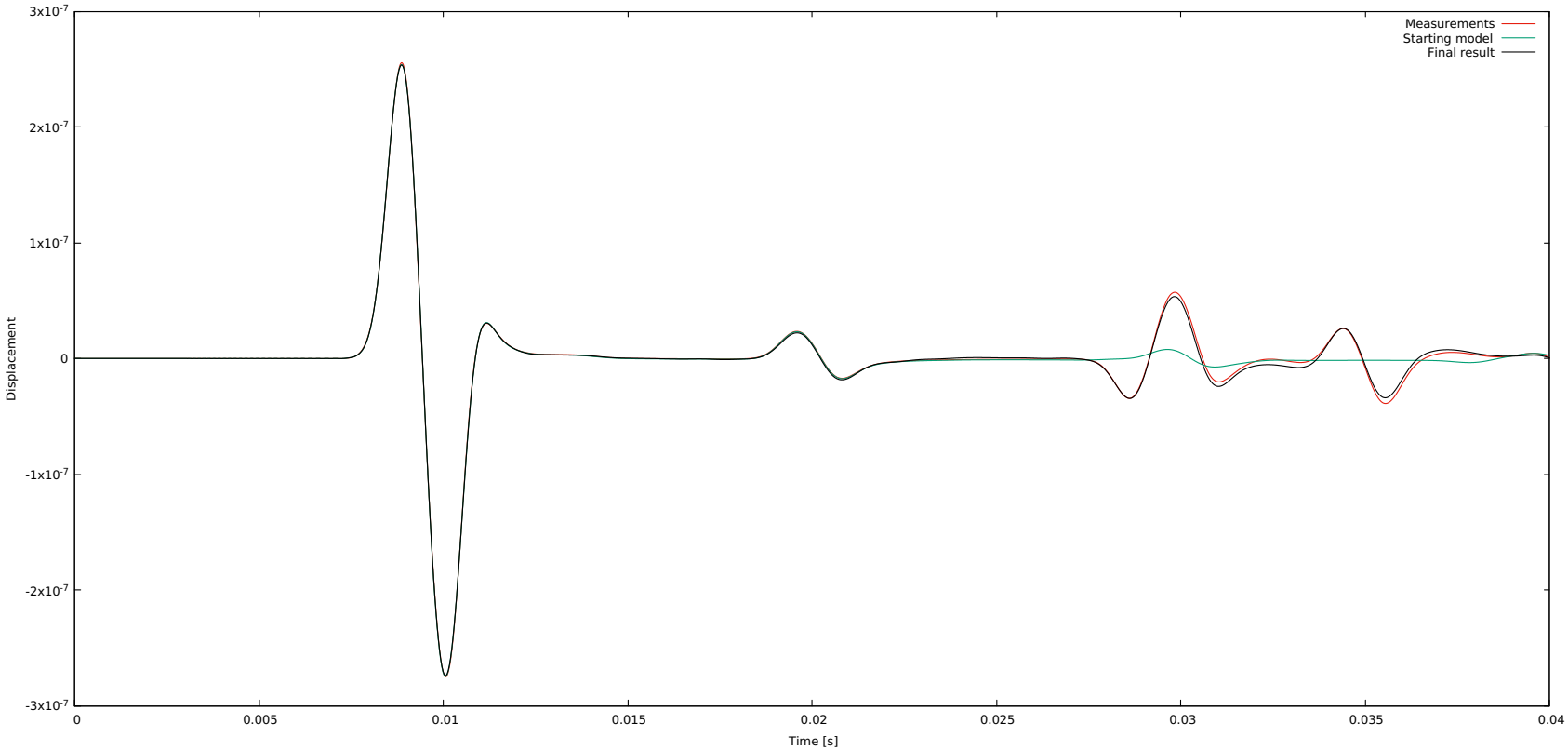


Full Waveform Inversion for Mechanized Tunneling

- Full Waveform Inversion (acoustic) using adjoint and conjugate gradient method
- 500 Hz Ricker source at tunnel face
- Receivers at tunnel face, tunnel walls and surface
- Reflecting interface well recovered



Full Waveform Inversion for Mechanized Tunneling



Station at surface

GitHub

- NEXD is open source software (GNU GPL v3.0)
- Download at `http://github.com/seismology-RUB`
- More information at `http://www.rub.de/nexd`

- More on poroelastic solver: **EGU2017-12821**
  Poster, Mon, 17:30-19:00, X3.98
- More on fractures: **EGU2017-15012**
  Poster, Thu, 17:30-19:00, X1.57