Multiscale quasicontinuum approaches for beam lattices

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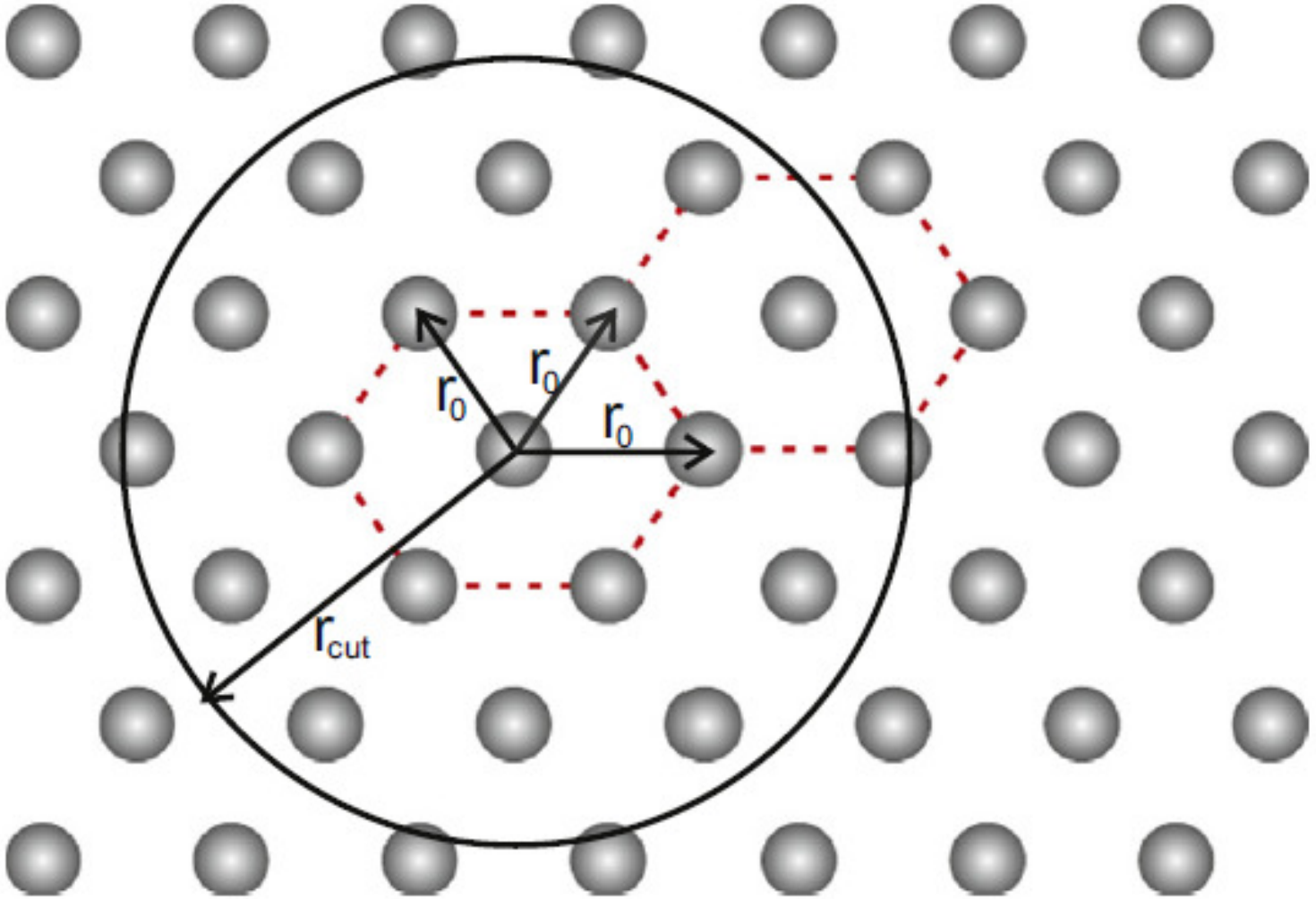
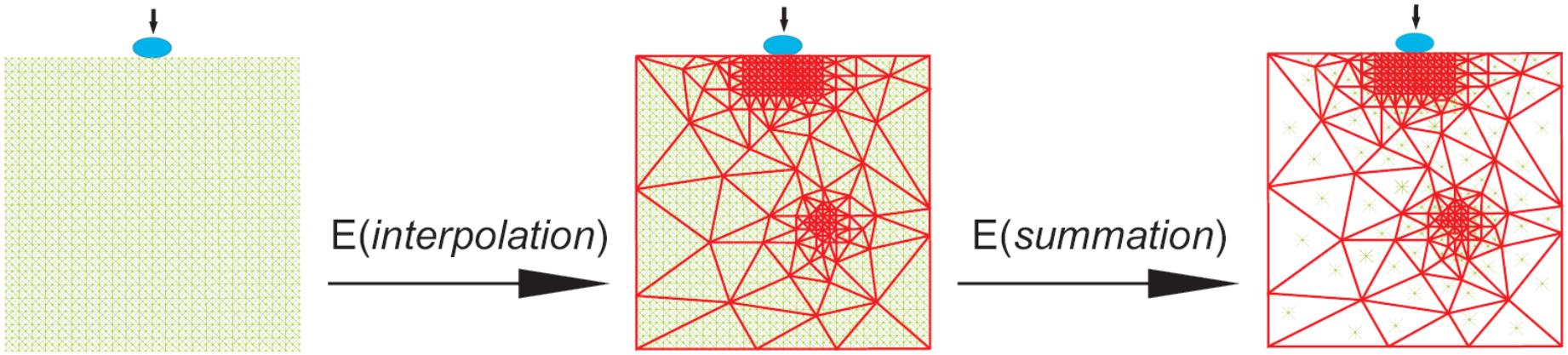
Atomistic lattices

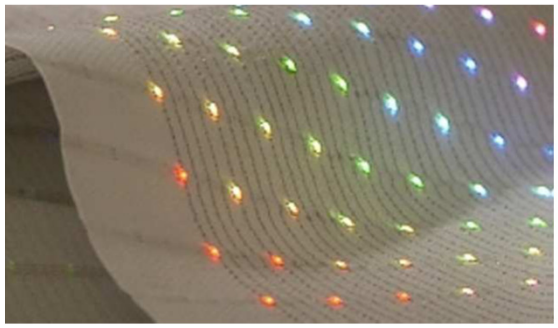


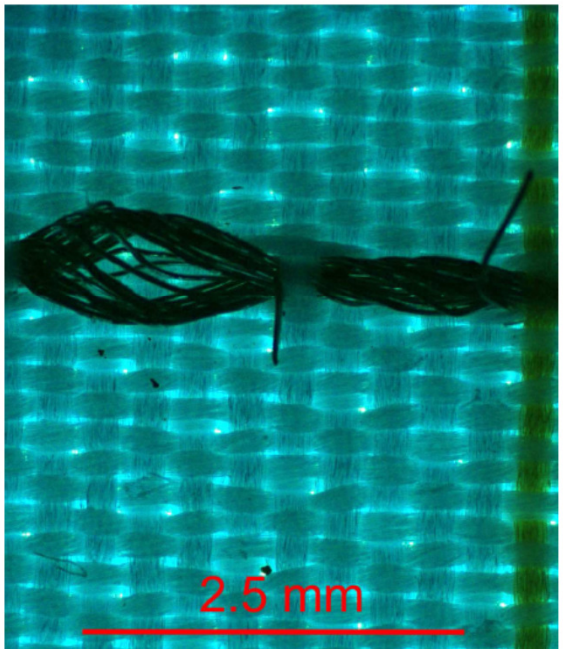
Quasicontinuum method (Tadmor et al, 1996)

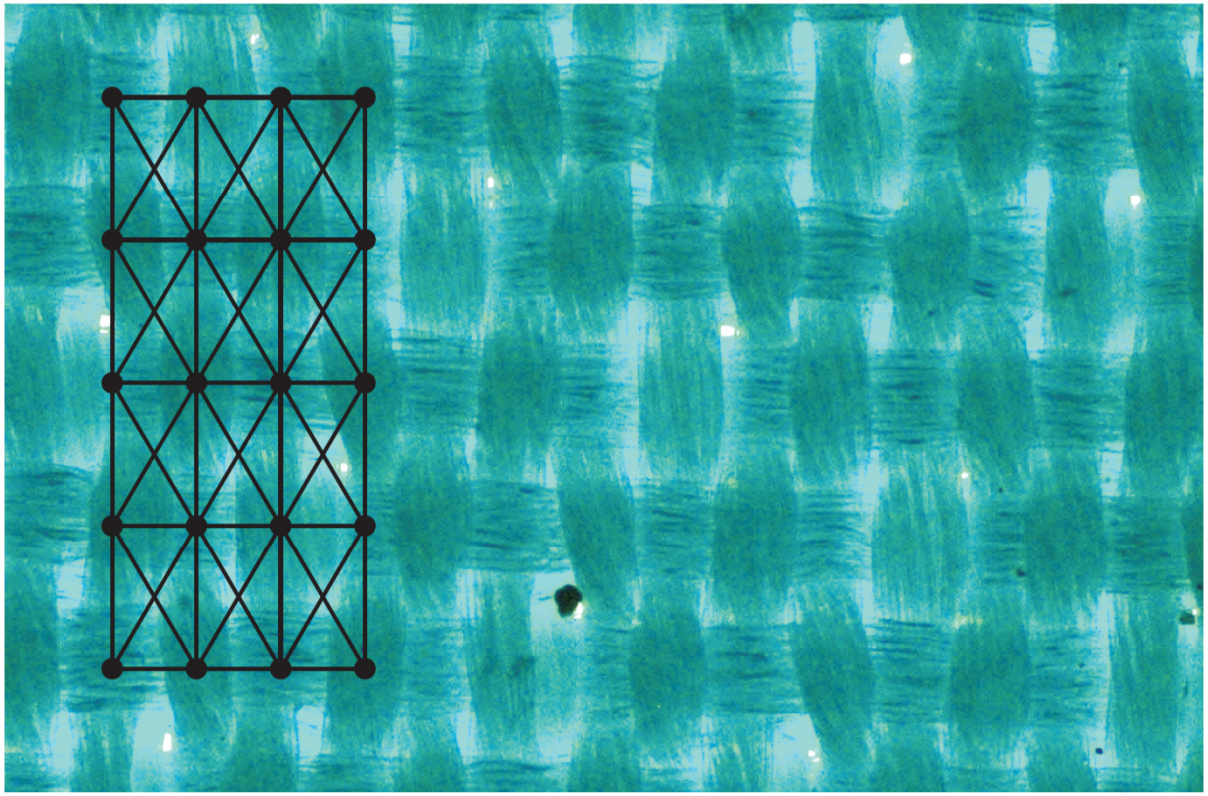


- Ideal for local events in large-scale lattice computations
- Underlying lattice fully resolved where needed
- No continuum/constitutive assumptions

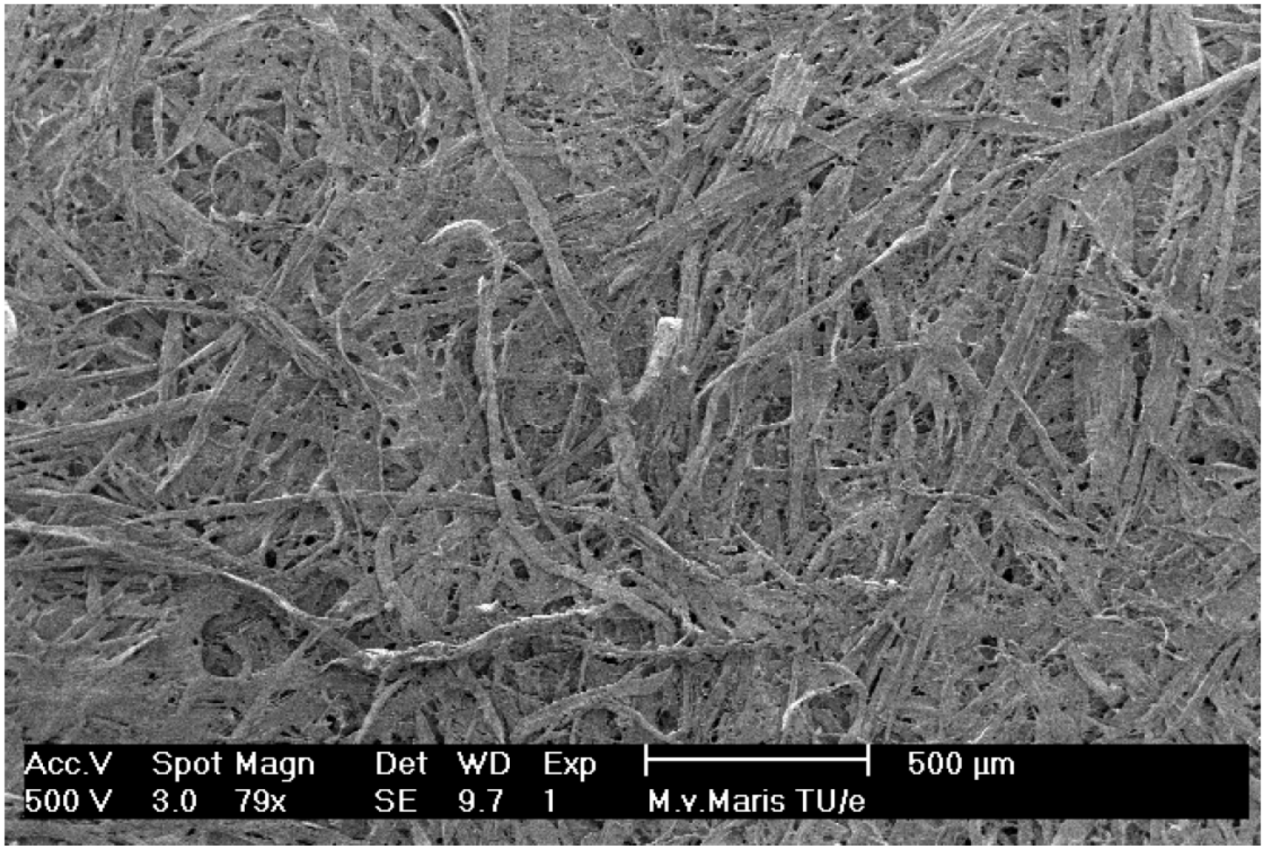
Truss/spring lattice for electronic textile



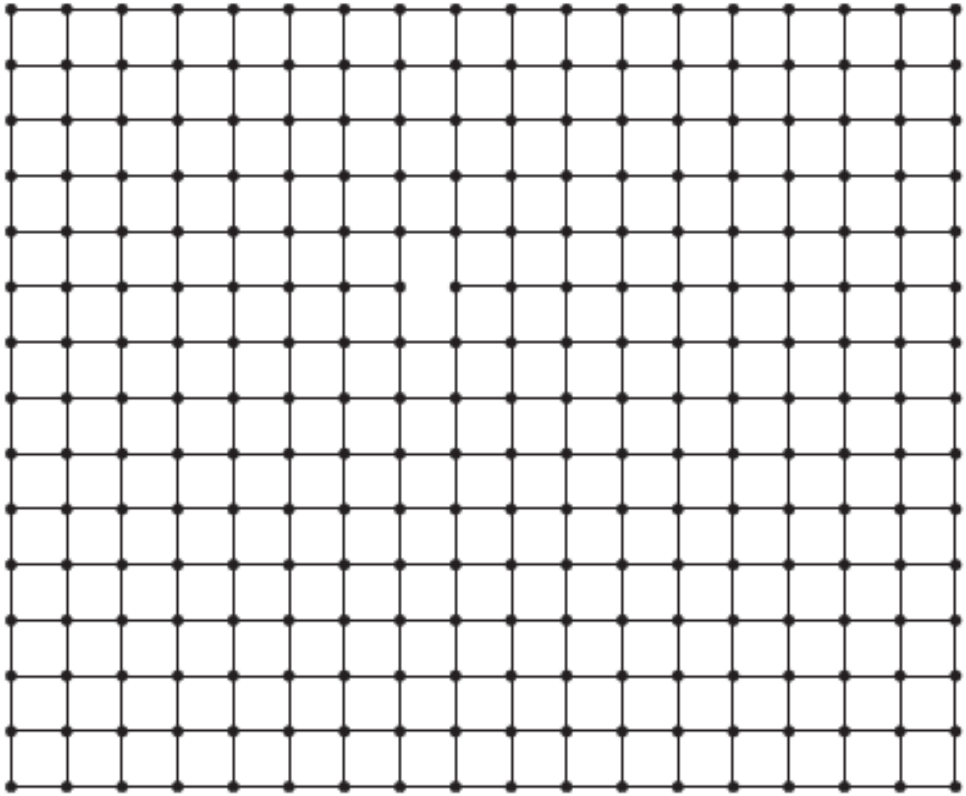




Truss/spring lattice for paper materials



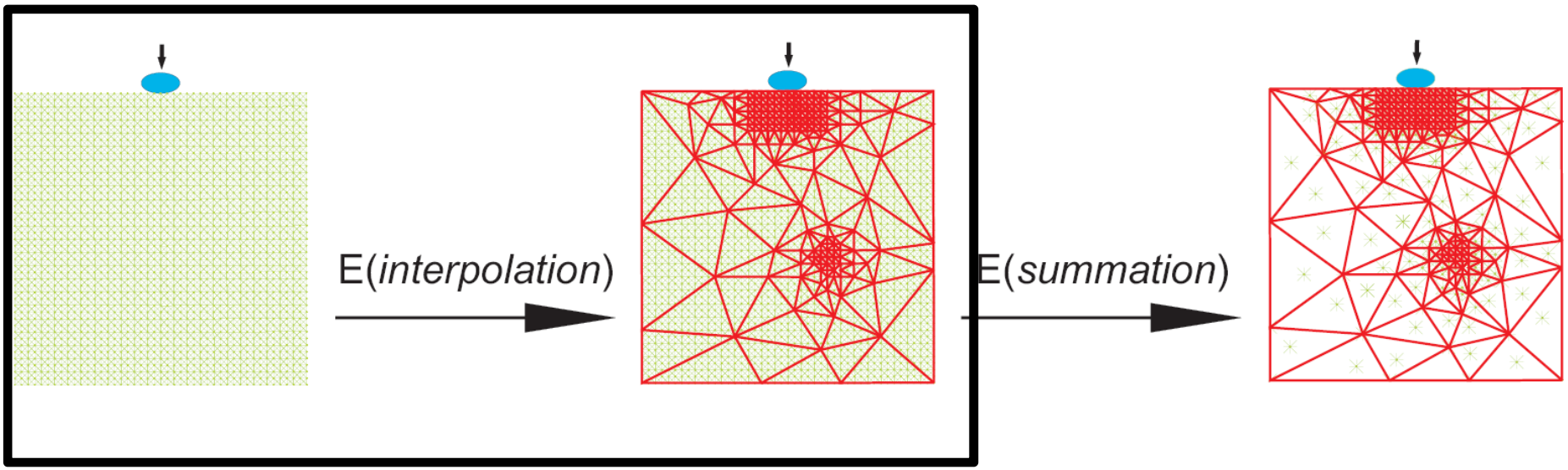
Beam lattices



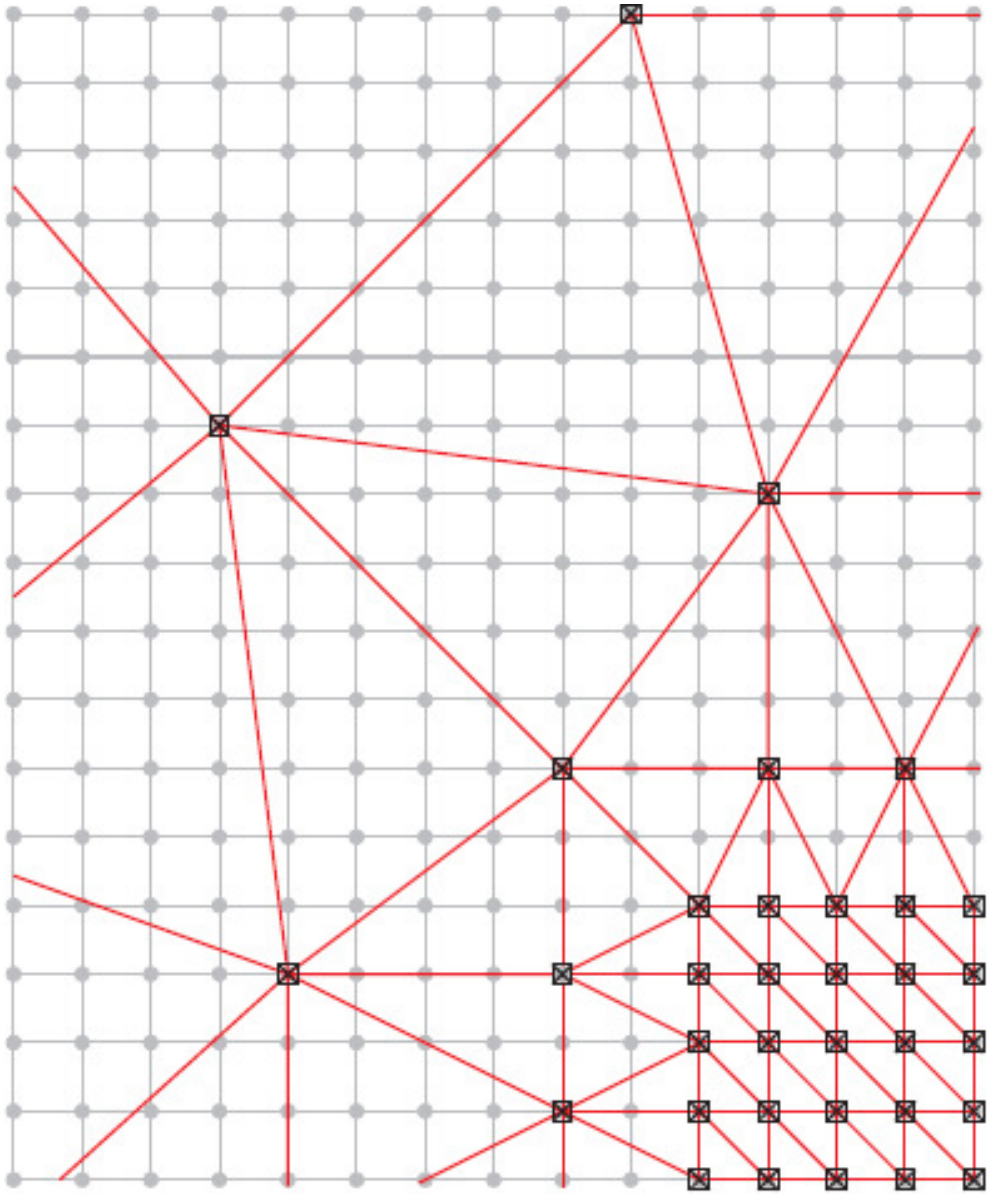
Euler Bernoulli beams:

- **Hermite interpolation in each beam**
- **nodal displacements**
- **nodal rotations**

Beam lattices: interpolation



Beam lattices: interpolation



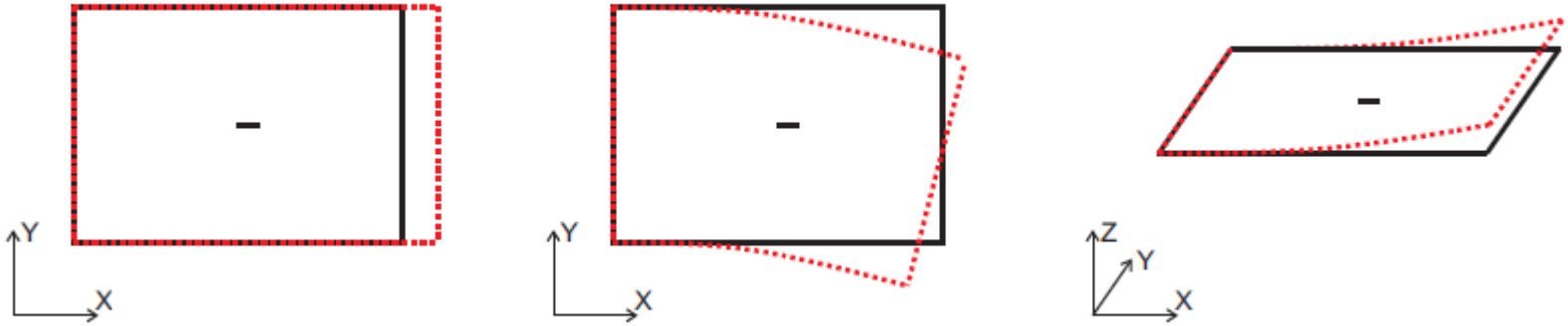
Nodal displacements: Linear

Nodal rotations: Linear

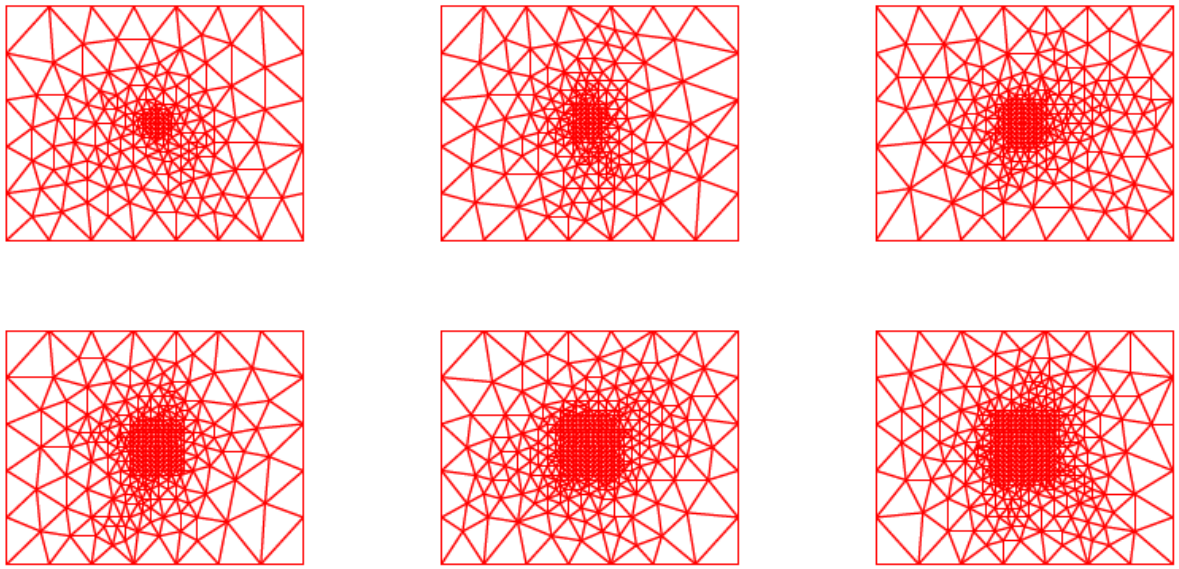
Conforming triangulations

Beam lattices: interpolation

Test cases

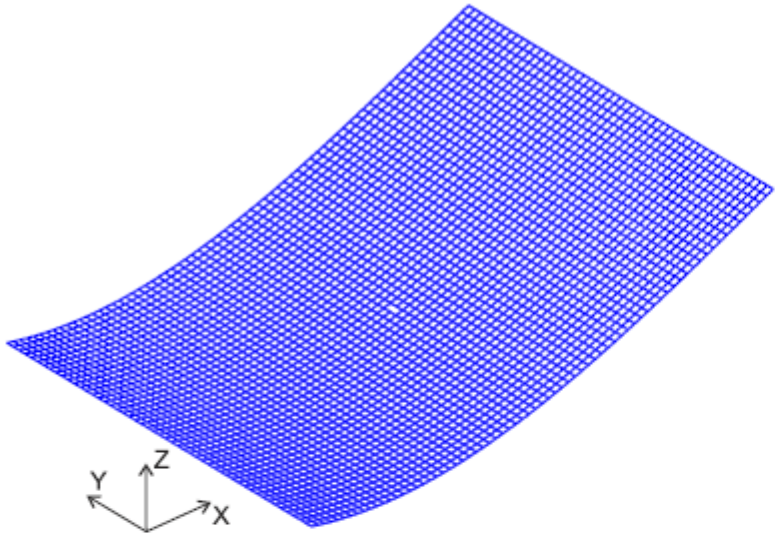


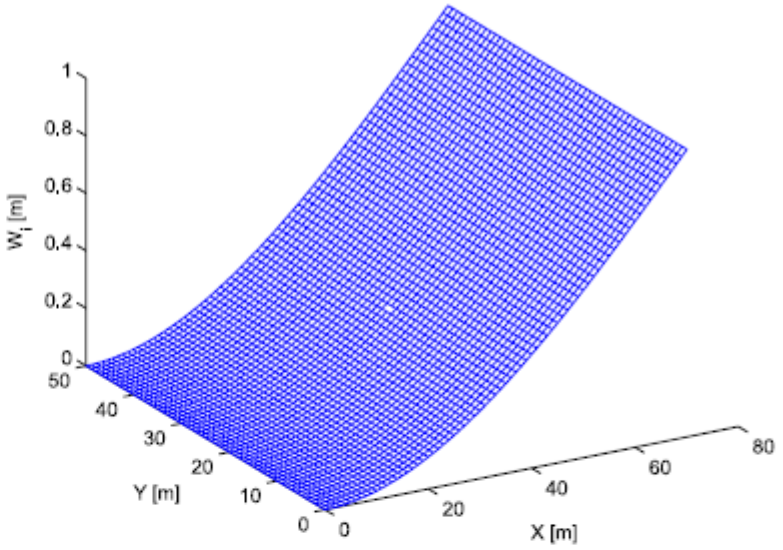
Meshes

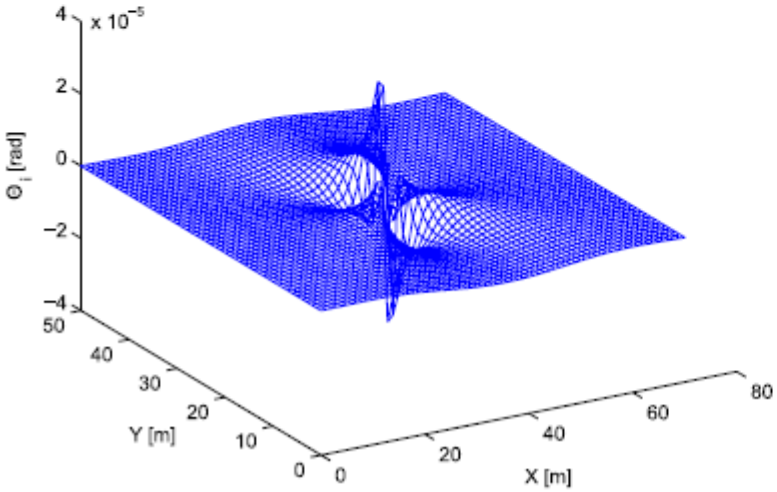


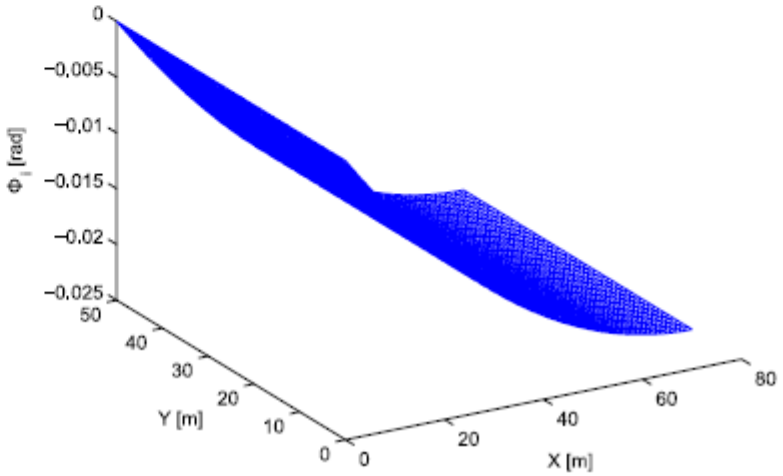
Beam lattices: interpolation

Reference results for case 3: out-of-plane bending



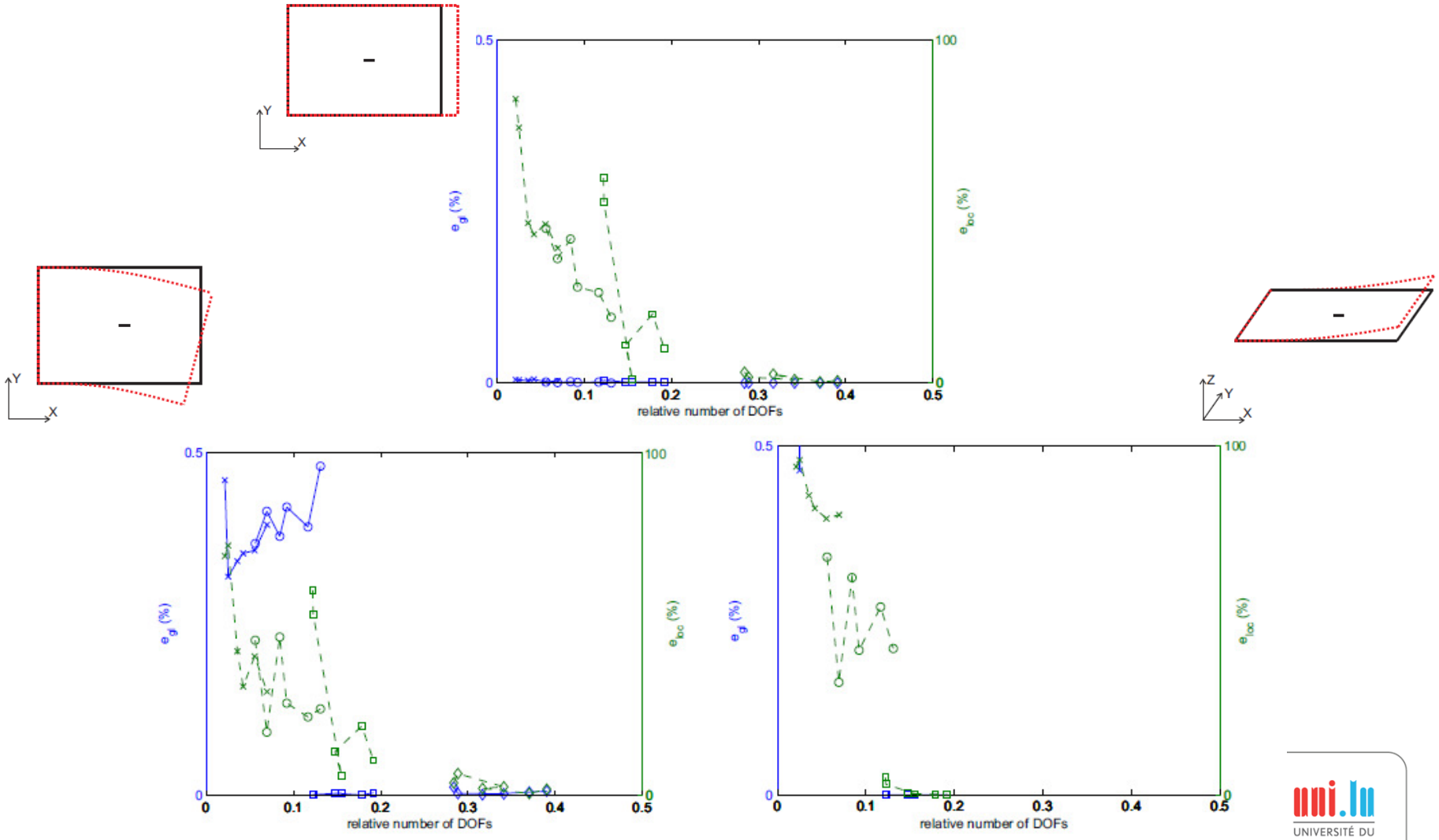




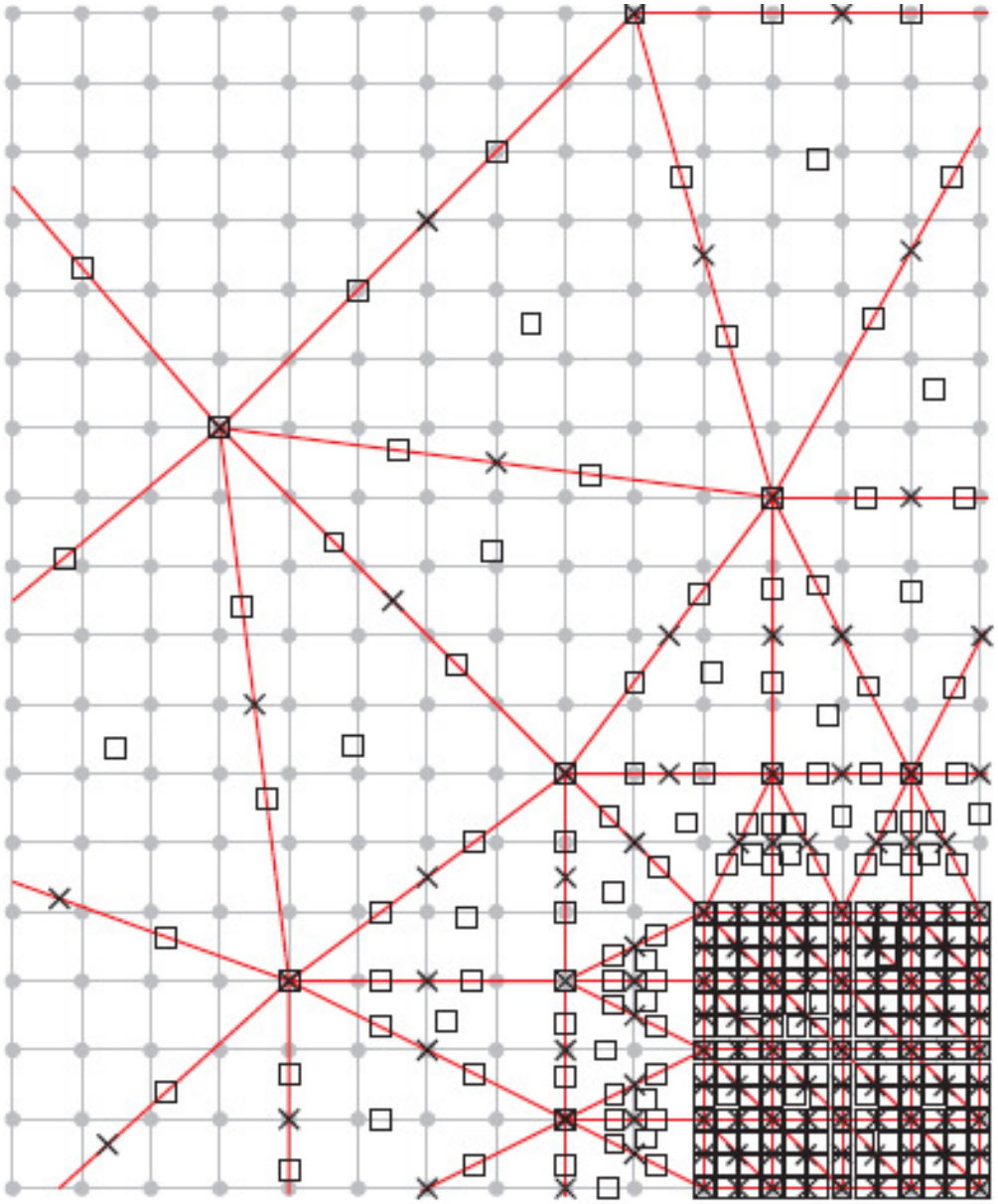


Beam lattices: interpolation

Error: 0



Beam lattices: interpolation

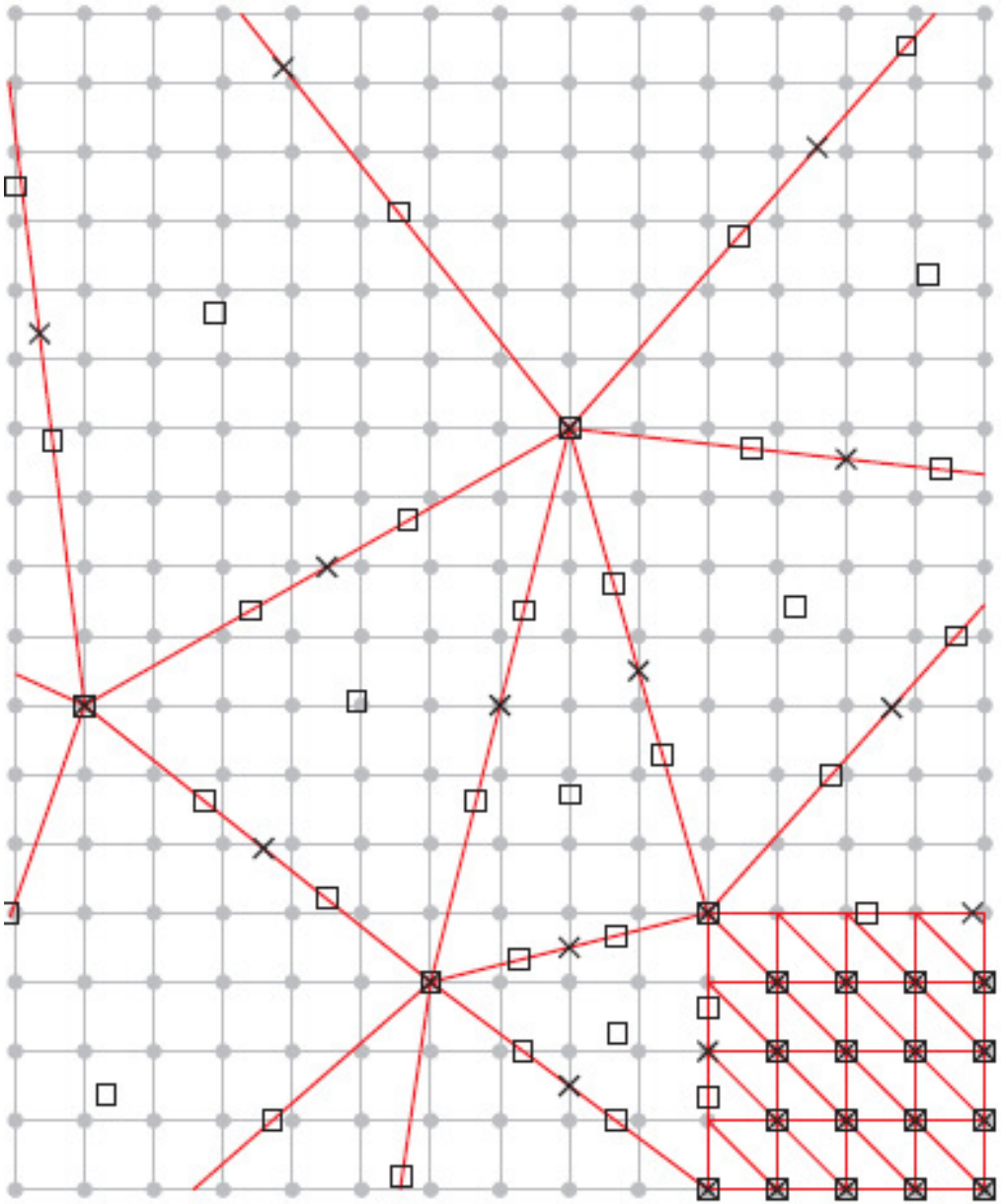


Nodal displacements: **Cubic**

Nodal rotations: **Quadratic**

Conforming triangulations

Beam lattices: interpolation



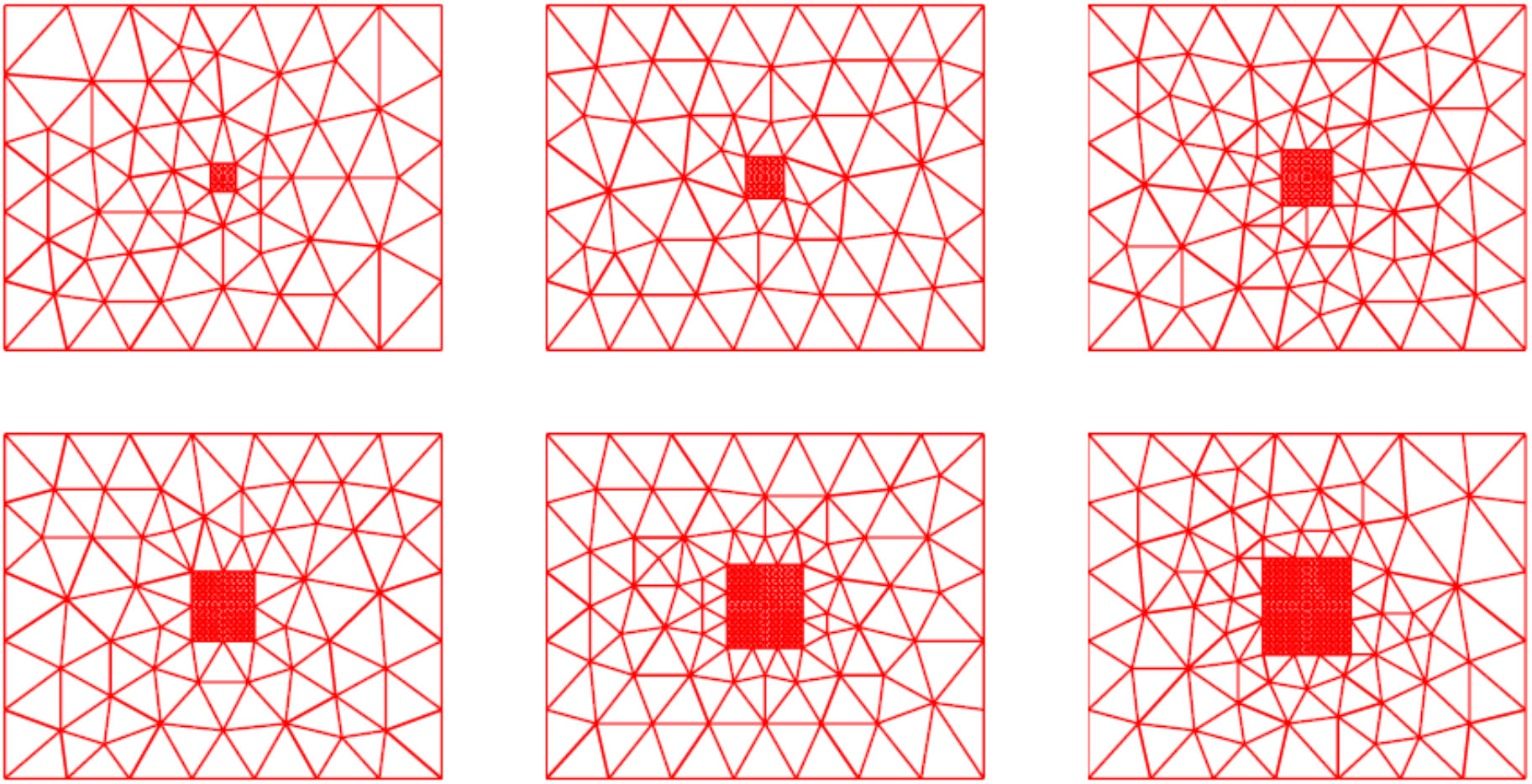
Nodal displacements: **Cubic**

Nodal rotations: **Quadratic**

Non-conforming triangulations

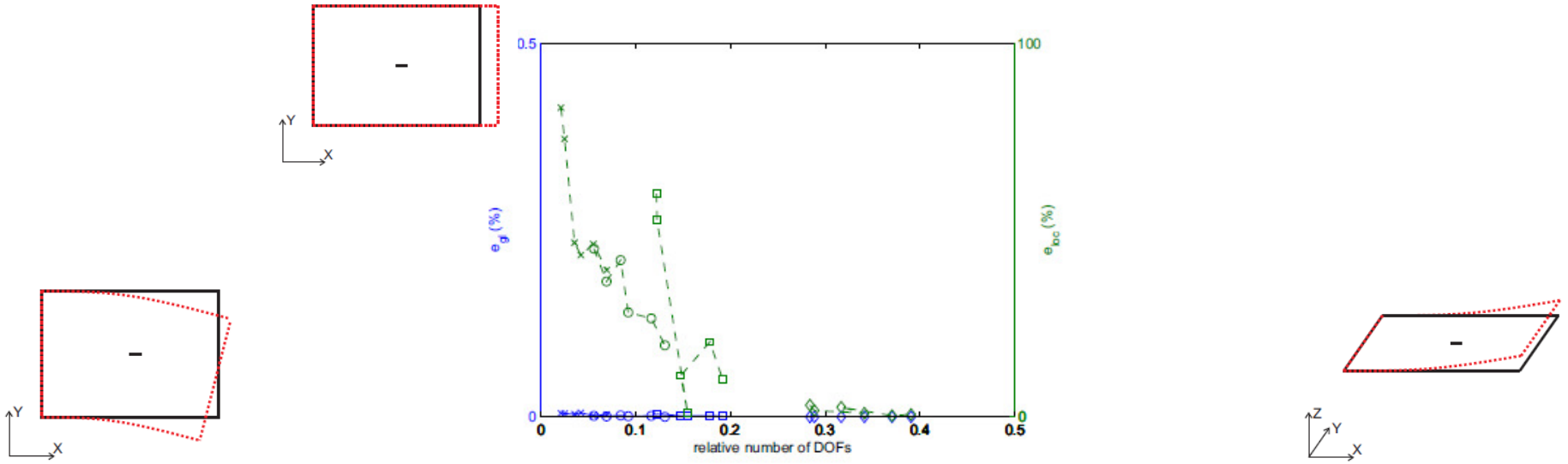
Beam lattices: interpolation

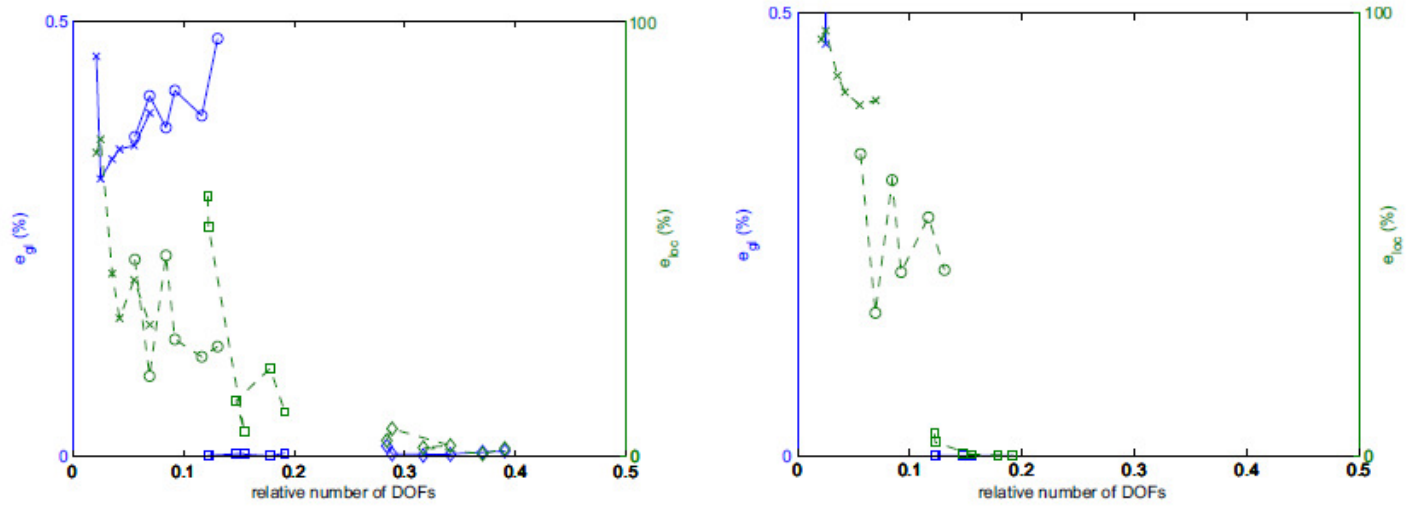
Non-conforming meshes



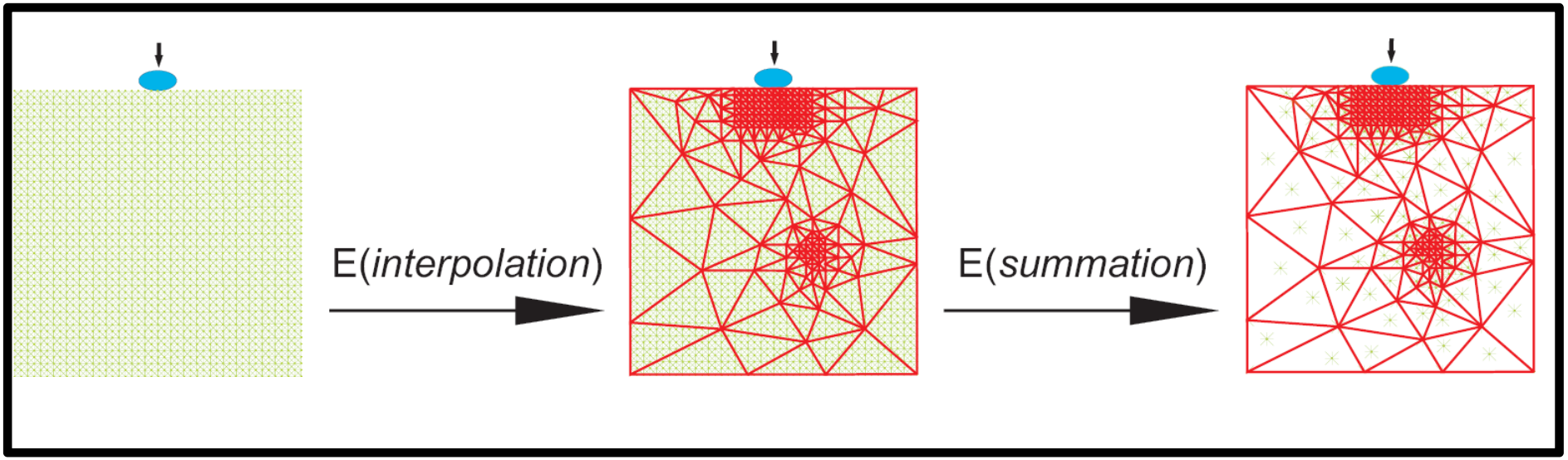
Beam lattices: interpolation

Error conforming: ◊ Error non-conforming: □

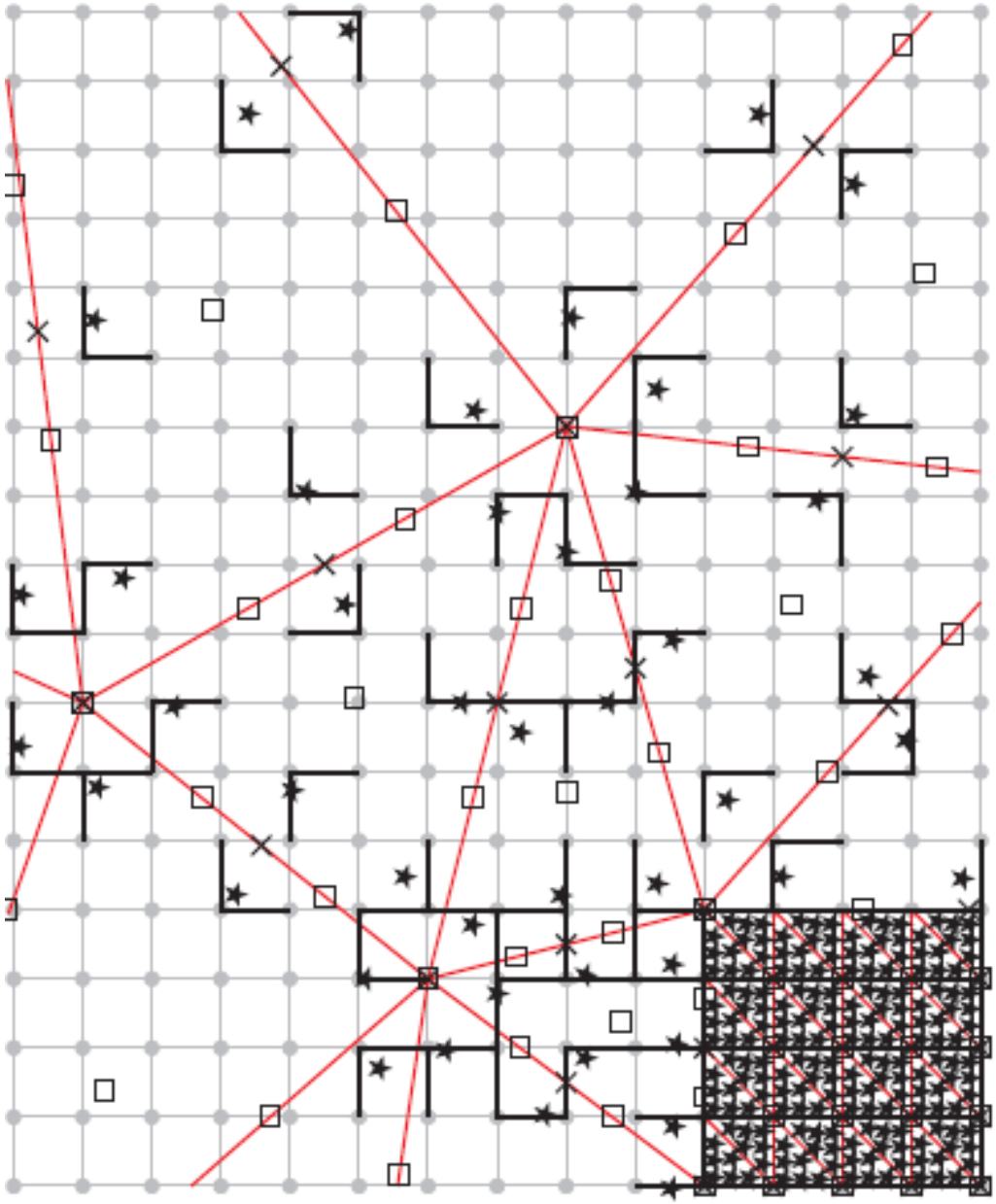




Beam lattices: interpolation & summation (full QC)



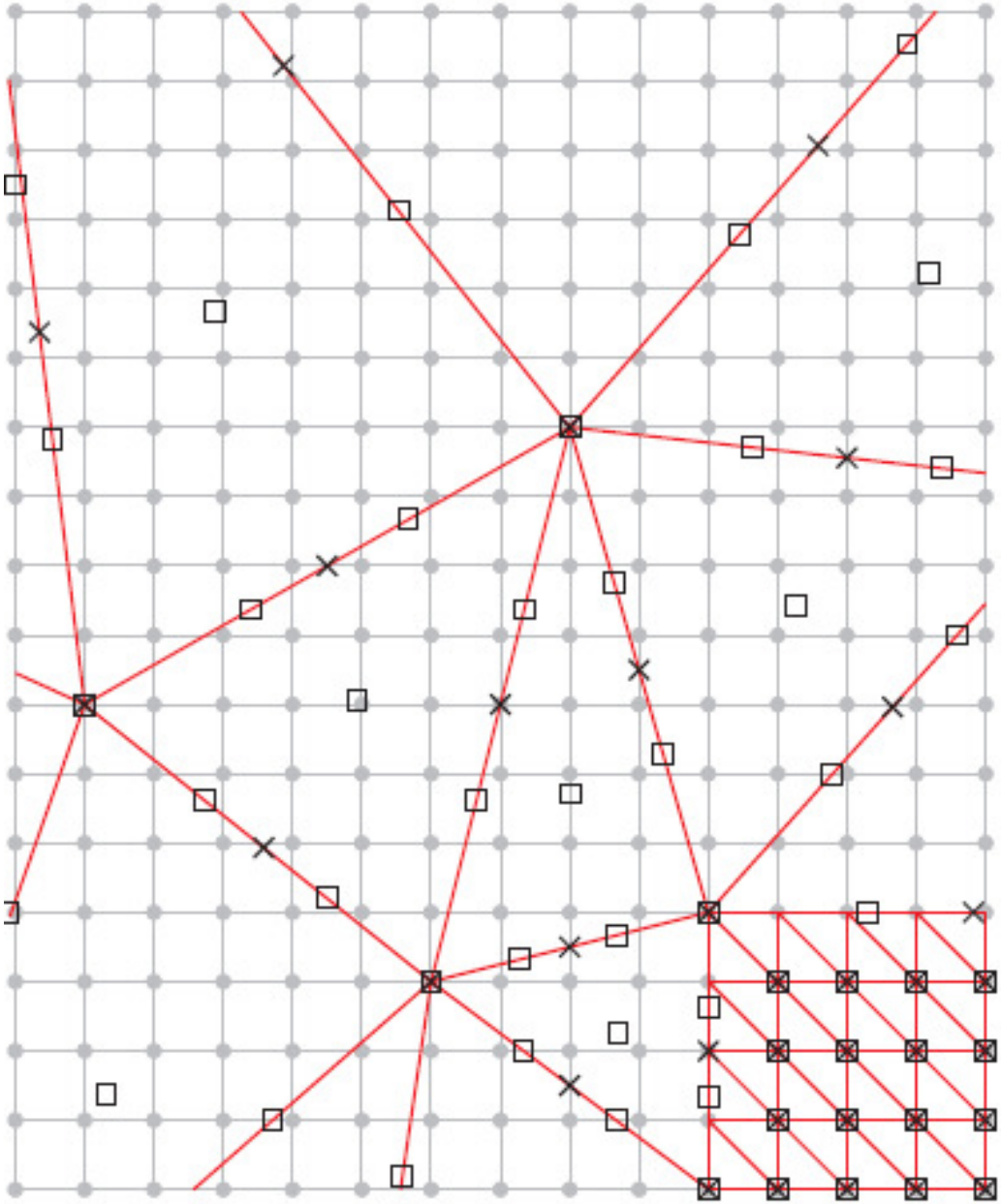
Beam lattices: interpolation & summation (full QC)



Sampling beams near

Gauss points

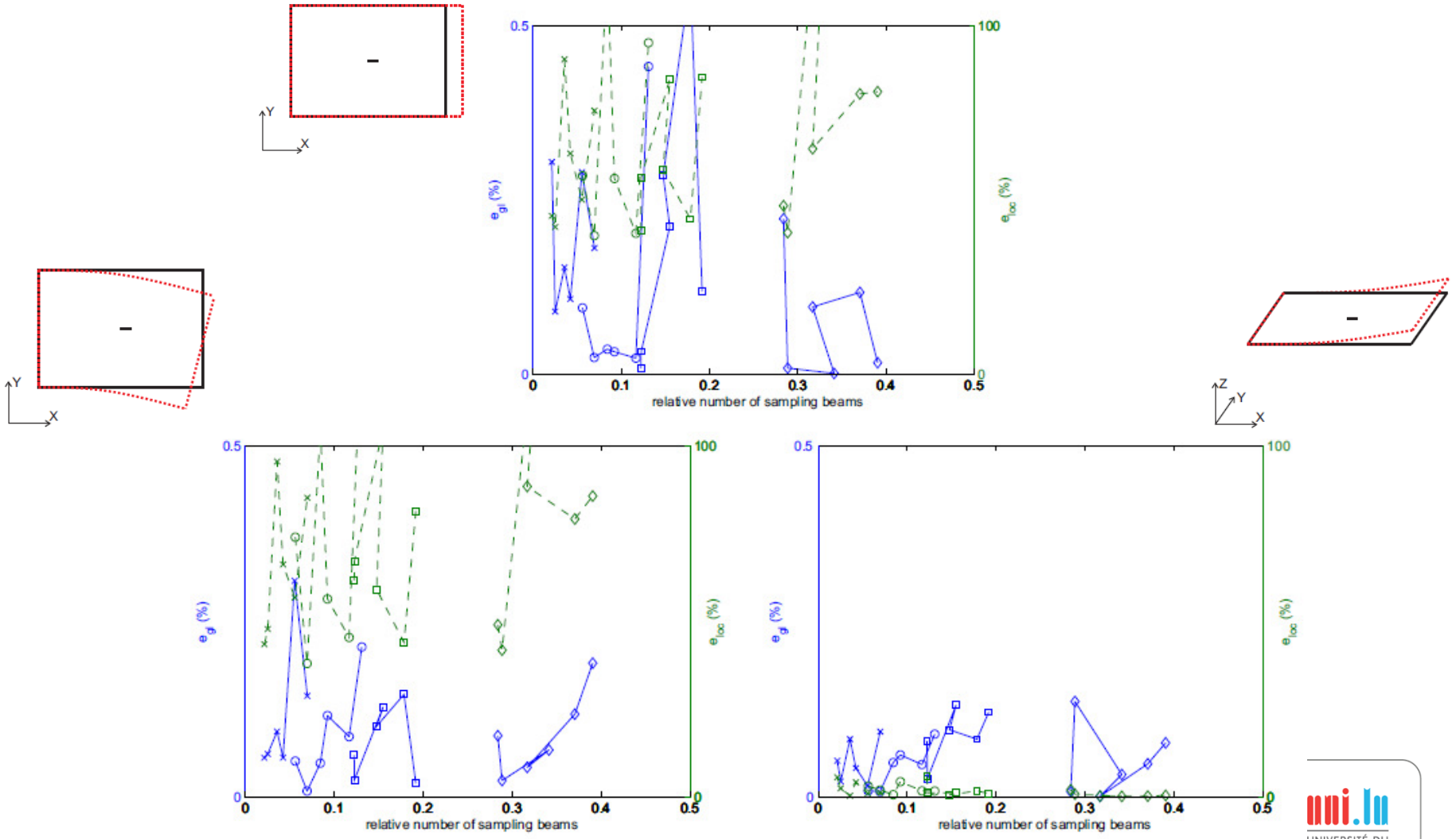
Beam lattices: interpolation & summation (full QC)



4 Gauss points leads to poor results

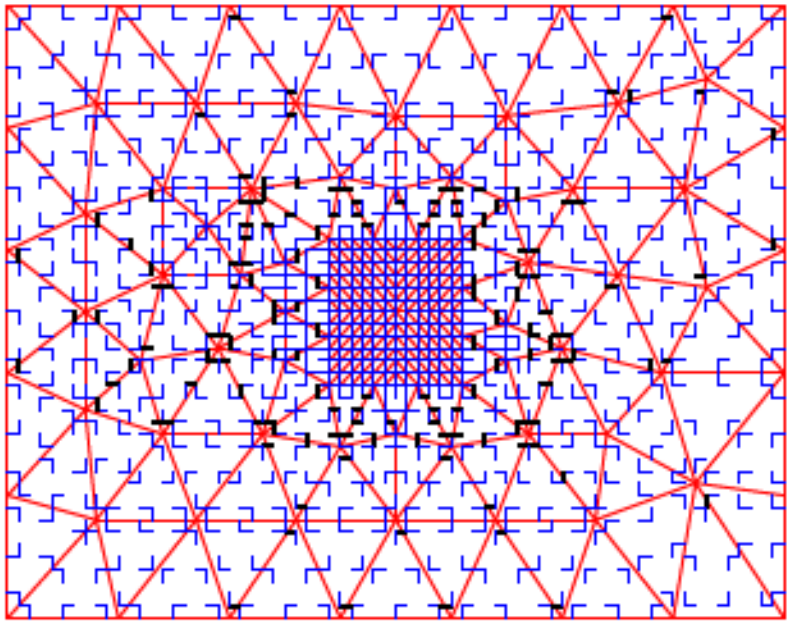
Beam lattices: interpolation & summation (full QC)

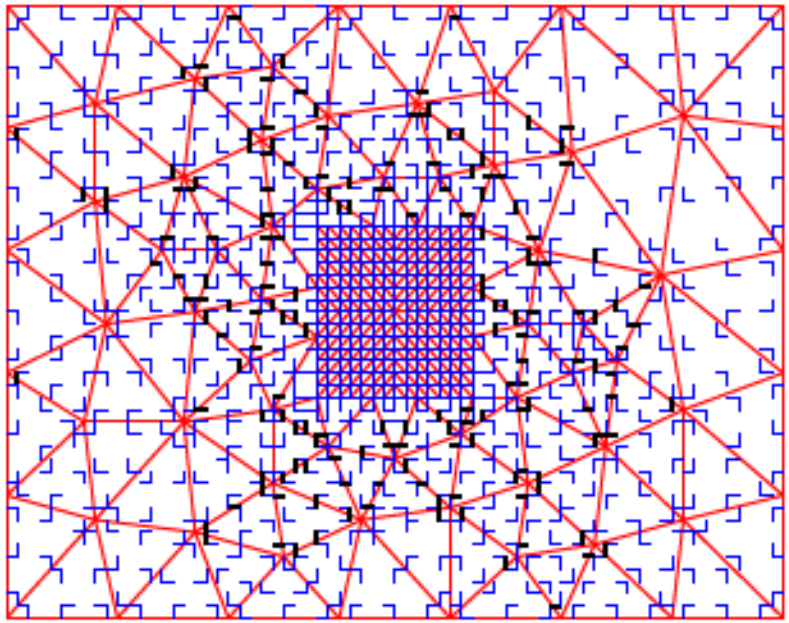
Error Gauss points: 6 O 7 X 9 ◊ 12 □



Beam lattices: interpolation & summation (full QC)

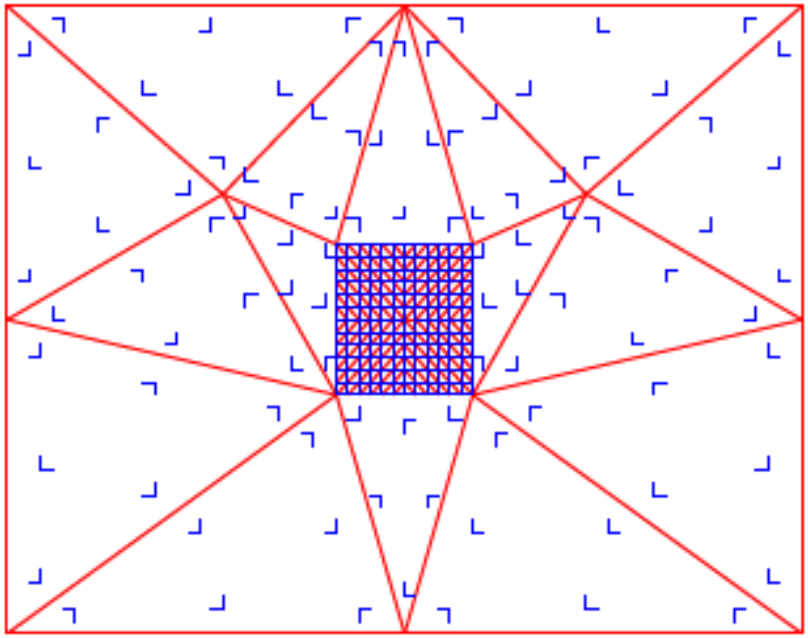
6 Gauss points is optimal

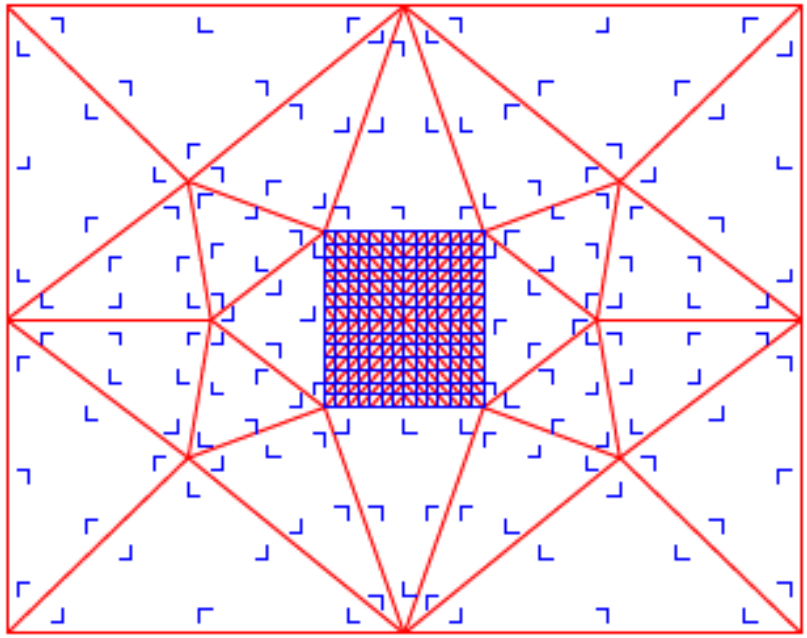




Beam lattices: interpolation & summation (full QC)

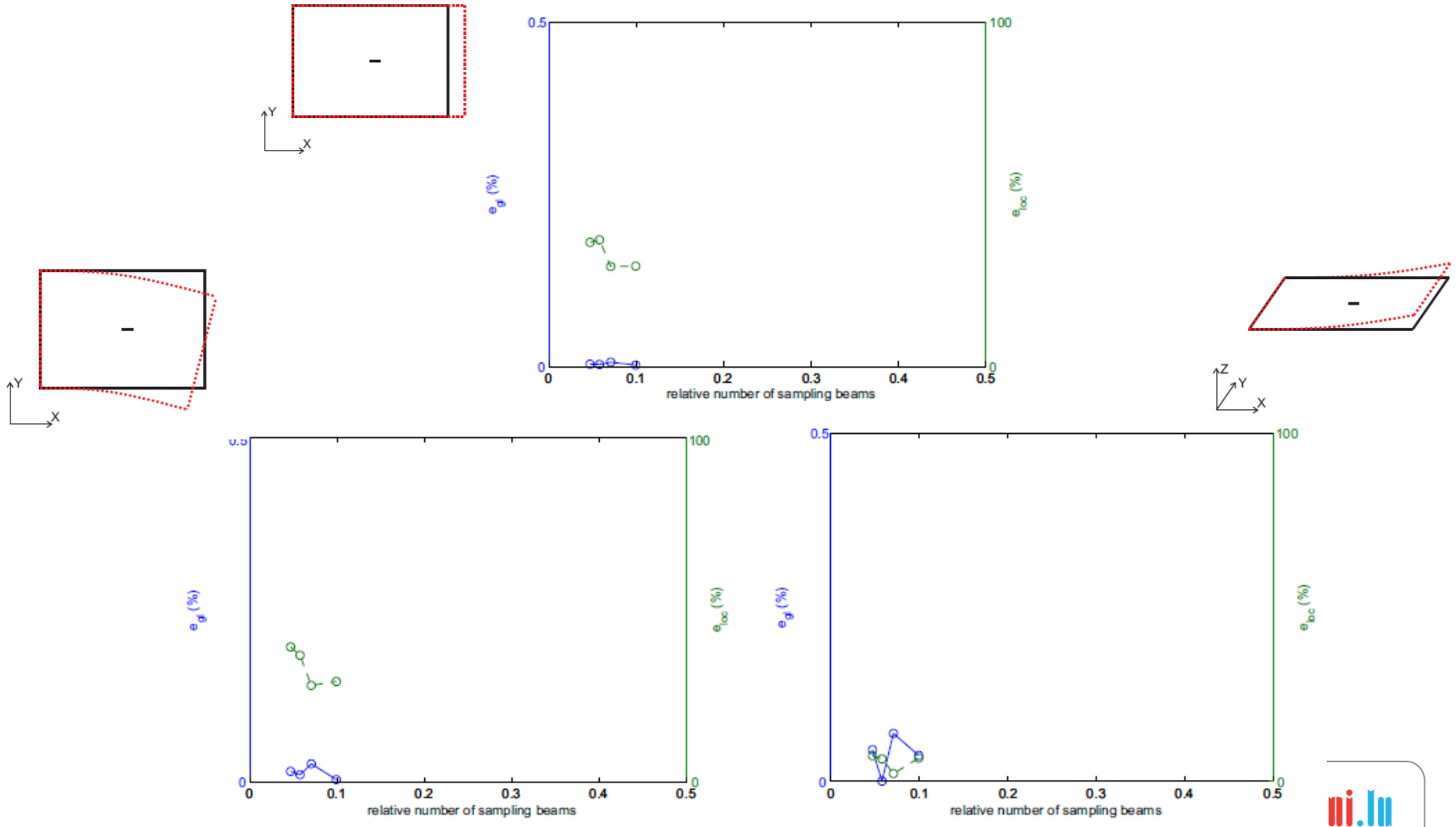
6 Gauss points is optimal with large triangles





Beam lattices: interpolation & summation (full QC)

6 Gauss points is optimal with large triangles



Beam lattices: interpolation & summation (full QC)

6 Gauss points is optimal with large triangles OR

LOCAL shape function evaluation is

in progress

Summary

QC methodologies for beam lattices

Most accurate: - Nodal displacements: Cubic

- Nodal rotations: Quadratic

- Non-conforming triangulations

- Sampling beam selection near 6 Gauss points

- Large triangles OR local shape function evaluation

Future research

- Irregularity
- Adaptivity
- Fracture
- Applications:
  1. Collagen networks
  2. Networks with matrix material
  3. CNT sheets/graphene sheets
  4. Nanofibers by electrospinning
  5. ……