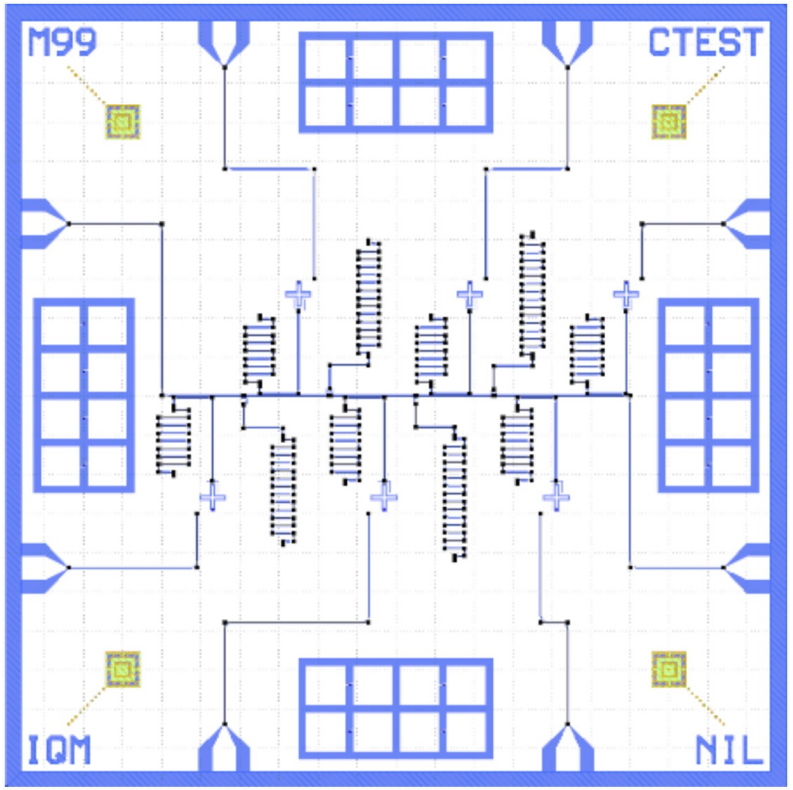
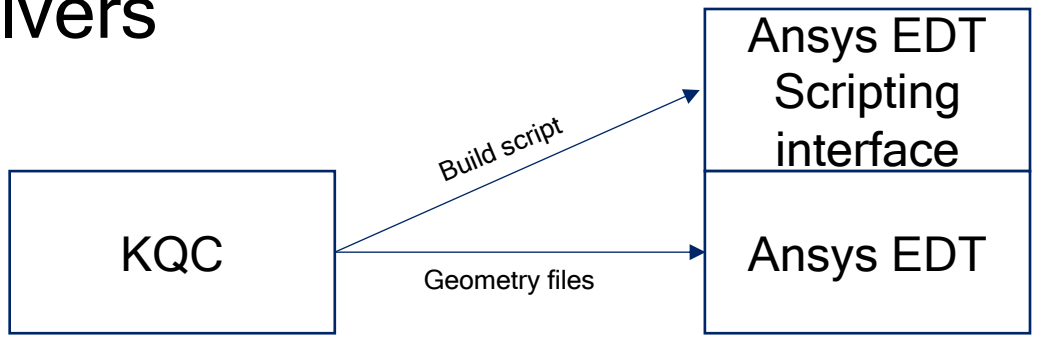
KQC-HPC FEM Integration

KQCircuits

- Multi-layer 2-dimensional geometry representation of common QPU structures
- Parametrized geometrical objects
- Framework for assembling QPU as composition of elements
- Mask creation: optical layout, EBL patterns
- Simulation export to numerical PDE solvers
  - Sonnet
  - Ansys

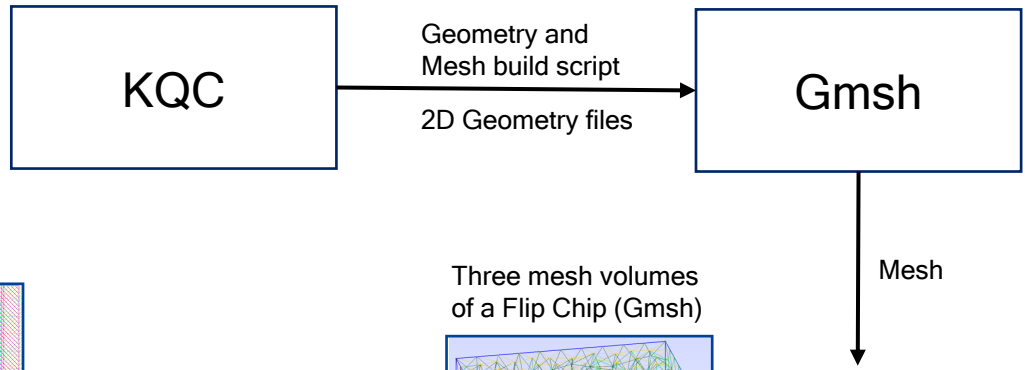
1. Capacitance extraction
2. Full microwave simulation

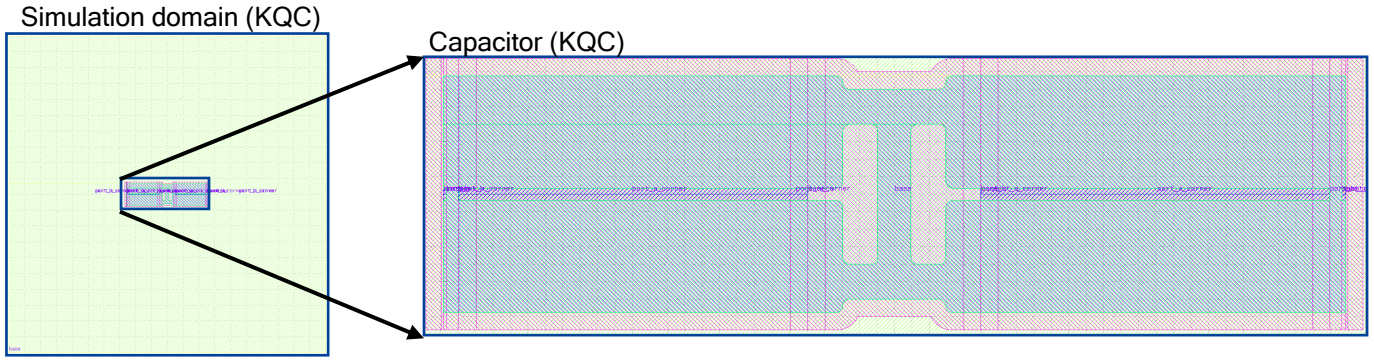


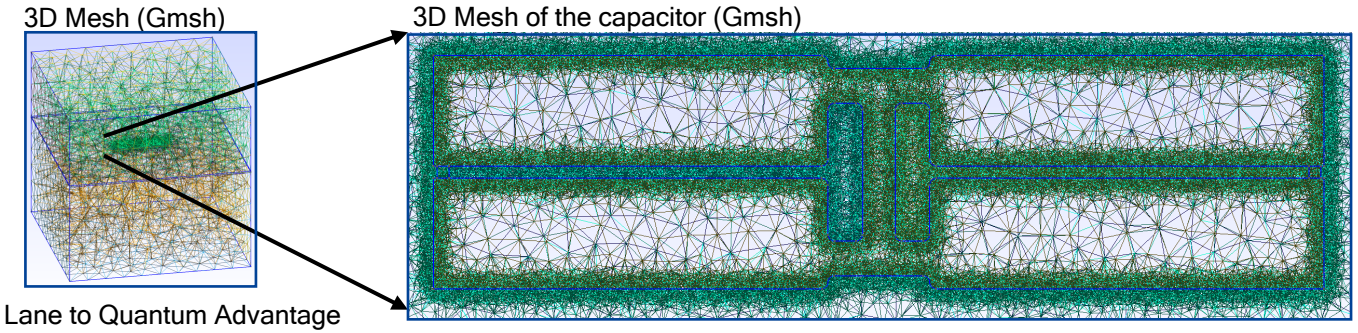


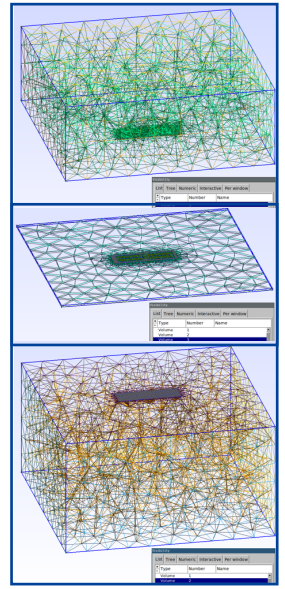
KQCircuits – HPC FEM Integration

- Gmsh (https://gmsh.info/) is used for creating the (3D) mesh from the 2D multi-layer geometry representation



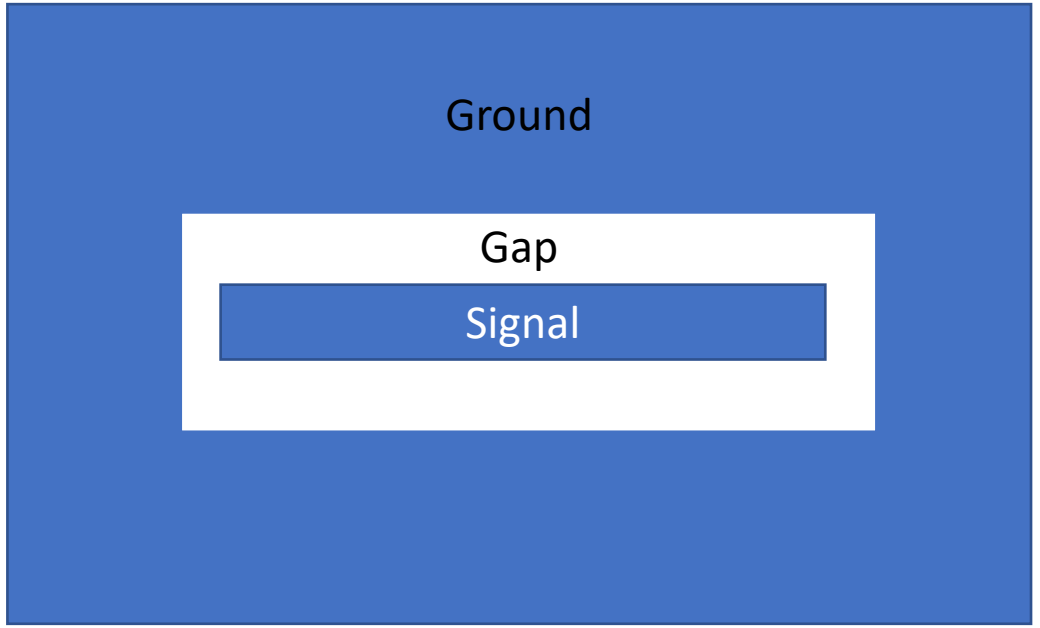




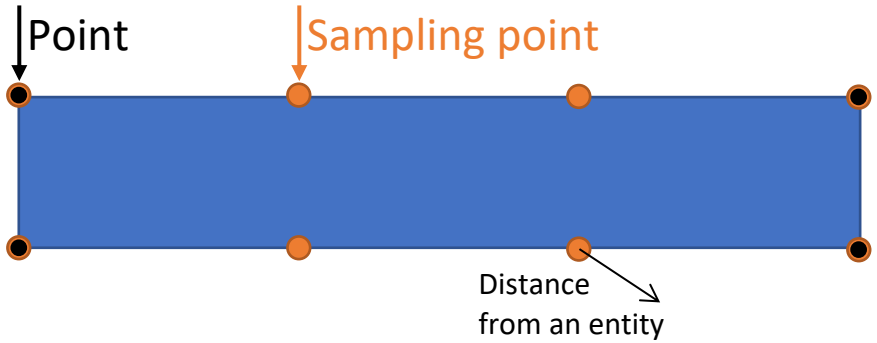


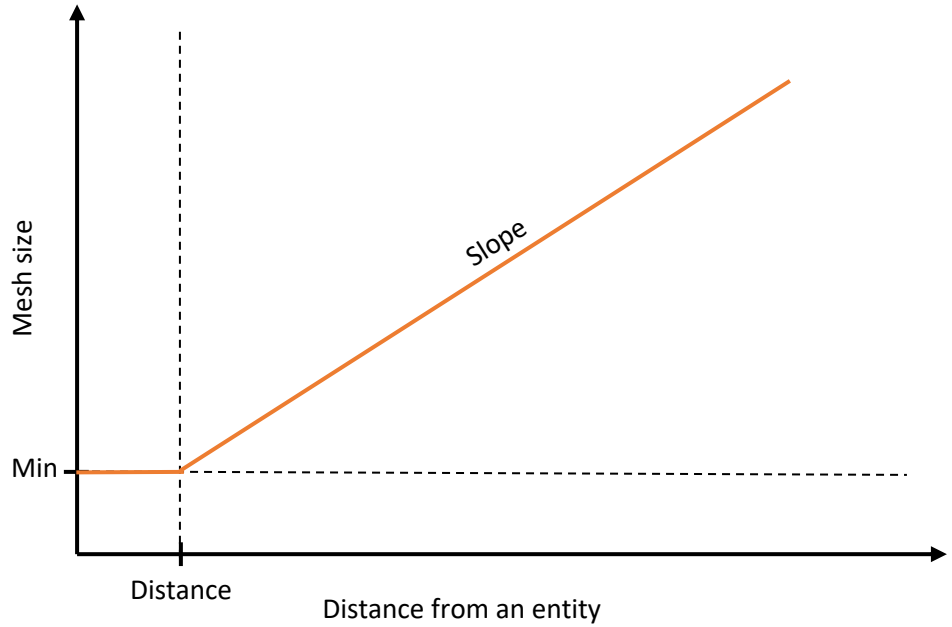
Meshing can be controlled via names

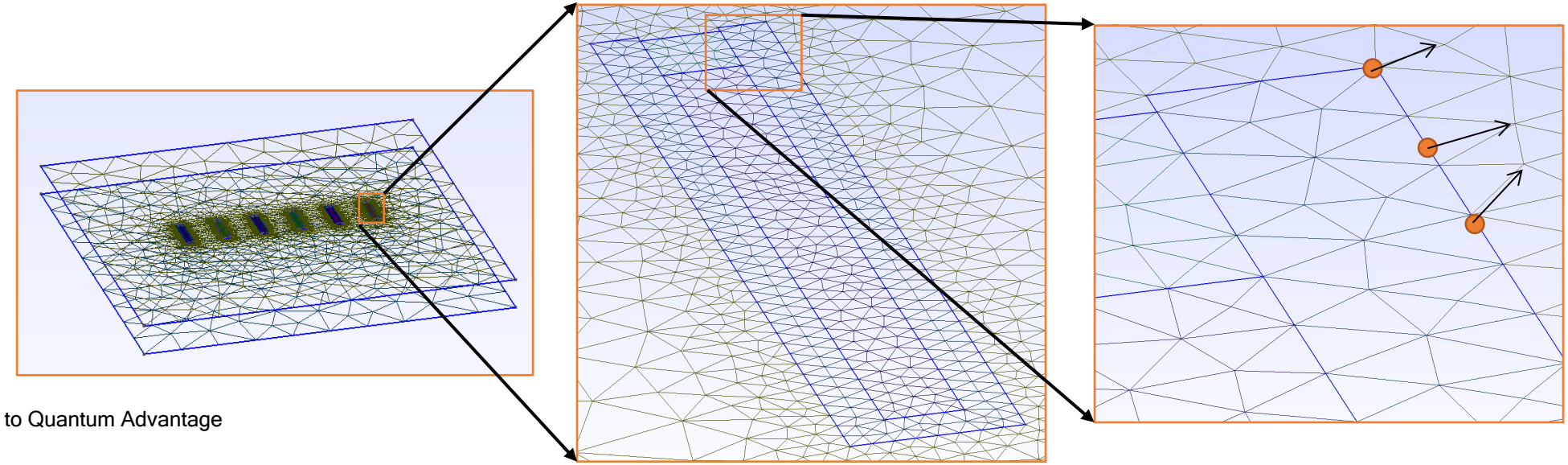
- Ground, Gap, Signal (also port)
  - Mesh can be refined at geometric entities or their intersection
    - “gap”: 1.
    - “gap&signal”: 0.1
    - “gap&ground”: 0.1
- Mesh size vector can be given
  - [size, slope, distance]
  - “gap”:[1.,0.2,0.1]



About mesh sizes

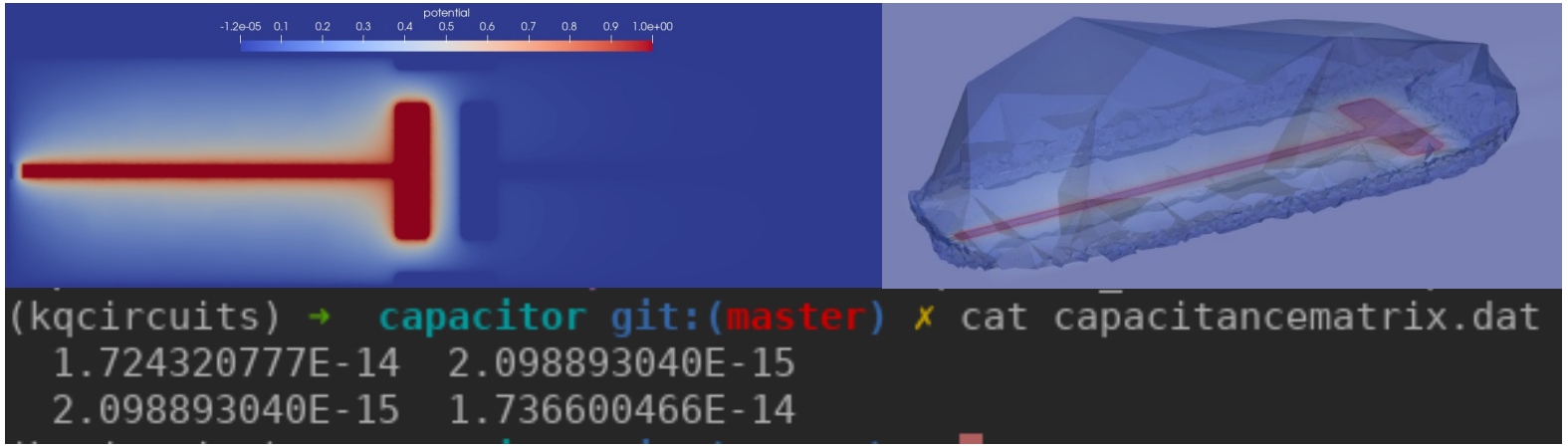


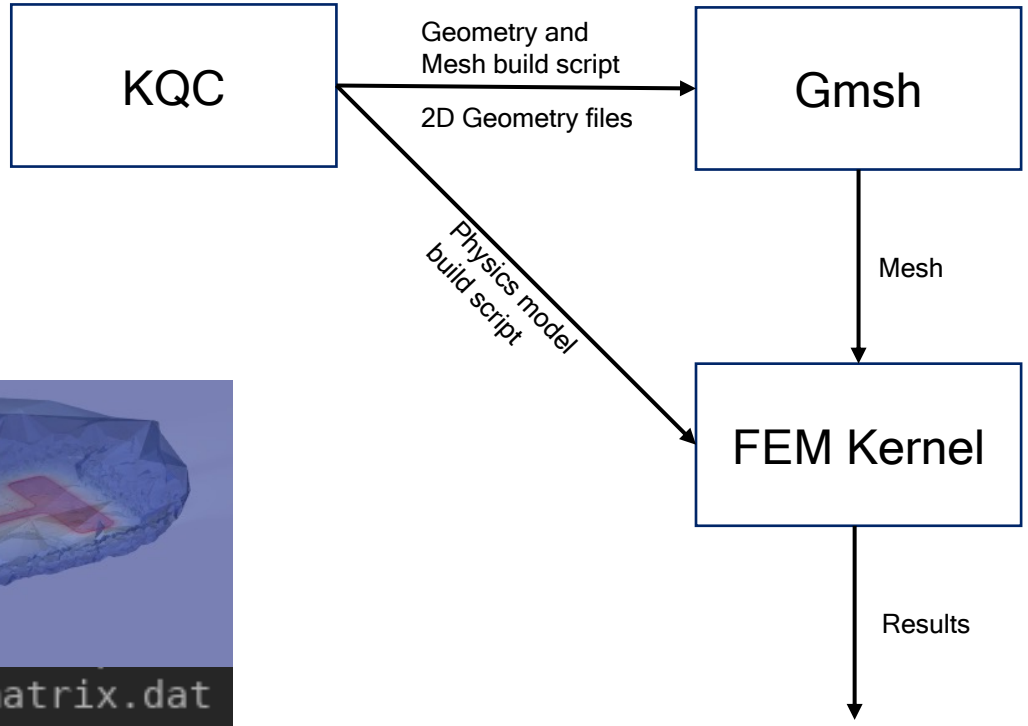




KQCircuits – HPC FEM Integration

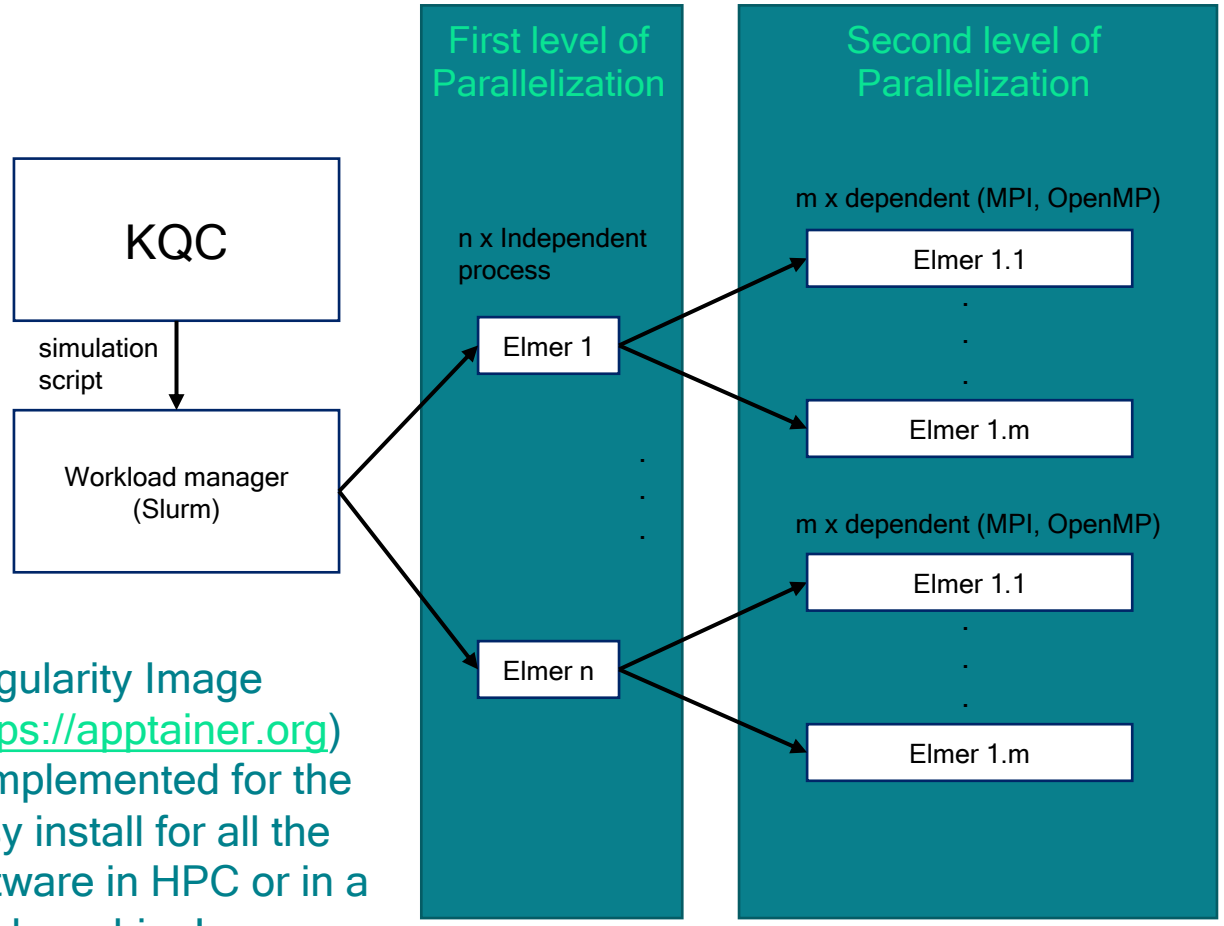
- The mesh can be used in a separate FEM Kernel
- The KQC physics model for Elmer FEM (https://www.csc.fi/web/elmer) is implemented
- Paraview (https://www.paraview.org) can be used to visualize the results





HPC FEM Integration - Parallelization using CSC infrastructure

- KQC can export simulation sweeps
  - Many independent simulations
    - For example, capacitance extraction for a component library
  - Workload manager script (Slurm batch)
    - First level of parallelization – independent simulations can always be run at the same time (linear speed-up)
- Elmer is run as a distributed process using MPI
  - Dependent processes
  - Second level of parallelization
    - Can achieve close to linear speed-ups
- Gmsh is sped-up using OpenMP
  - Elmer can use OpenMP in addition to MPI



Singularity Image (https://apptainer.org) is implemented for the easy install for all the software in HPC or in a local machine!