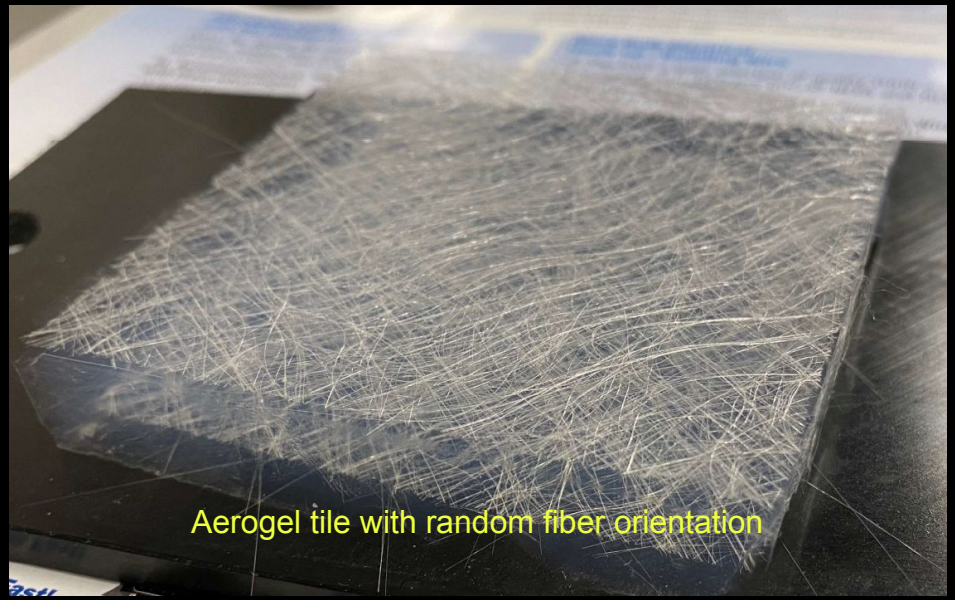
A.I.-supported Research and Development

Novel composite Aerogel materials for nuclear Physics Detectors



Aerogel tile with random fiber orientation

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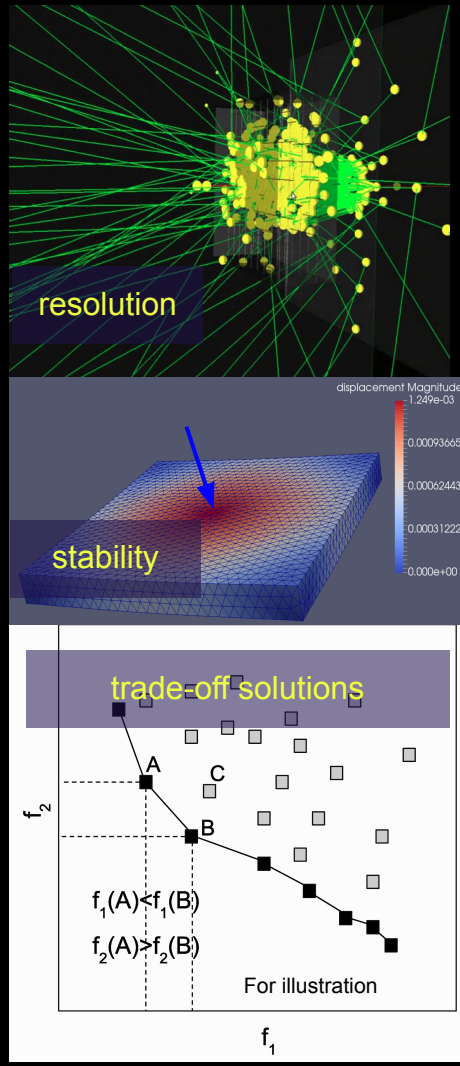
E. Cisbani, CF,
T. Horn, R. Trotta

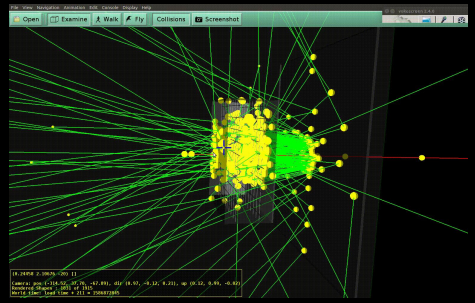
The Problem

- Aerogels with low refractive indices are very fragile tiles break during production and handling, and their installation in detectors.
- To improve the mechanical strength of aerogels, Scintilex developed a reinforcement strategy. The general concept consists of introducing fibers into the aerogel that increase mechanical strength, but do not affect the optical properties of the aerogel.
- The R&D of these composite aerogel materials is supported by Artificial Intelligence, which provided an automated and highly parallelized framework used to explore a multi-dimensional objective space and determine the Pareto optimality of the problem.
- This allowed to make decisions on the trade-off between the angular resolution and the mechanical strength, two essential features to build an optimized and robust aerogel detector.
- Our optimization is based on evolutionary algorithms.

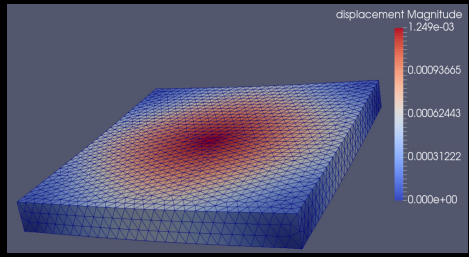


The Simulation Framework aefib

Simple Ring Imaging CHerenkov Geant4 based simulation
Aerogel + Optical Fibers



Gmsh - define geometry and produce mesh
ElmerGrid - convert the gmsh mesh to elmer compatible mesh
ElmerSolver - do modeling (solve linear and nonlinear equation)
Paraview - visualize Elmer Solver and provide a python interface to automate



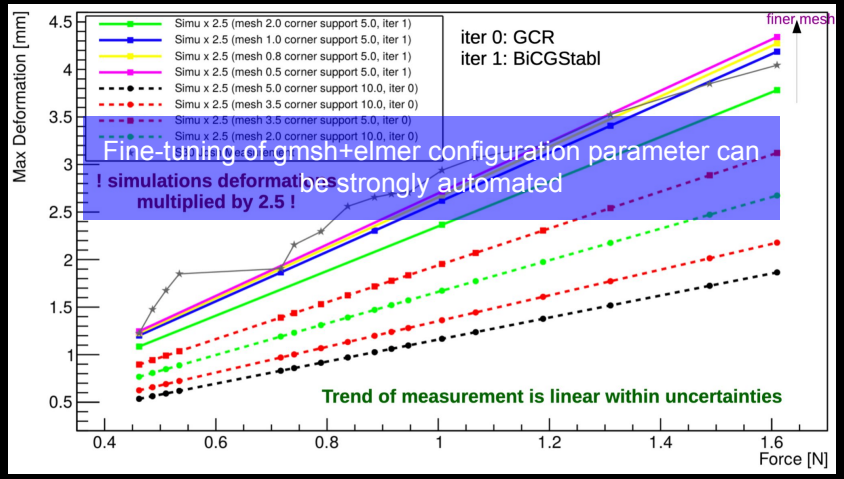
- gmsh version 4.8.2 (https://gmsh.info/)
- elmer version 9.0 (https://www.csc.fi/web/elmer)
- paraview 5.4.1 (https://www.paraview.org/)

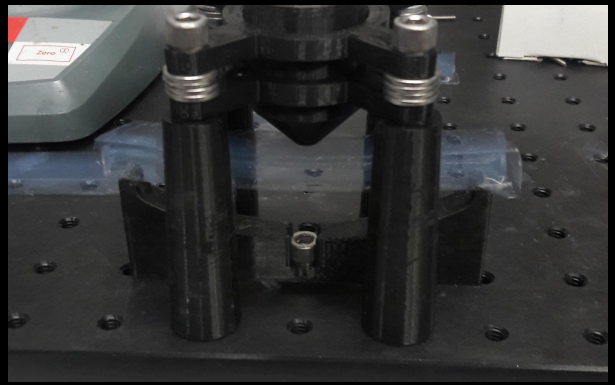
Gmsh+Elmer benchmarked against Inventor

Credits: E. Cisbani

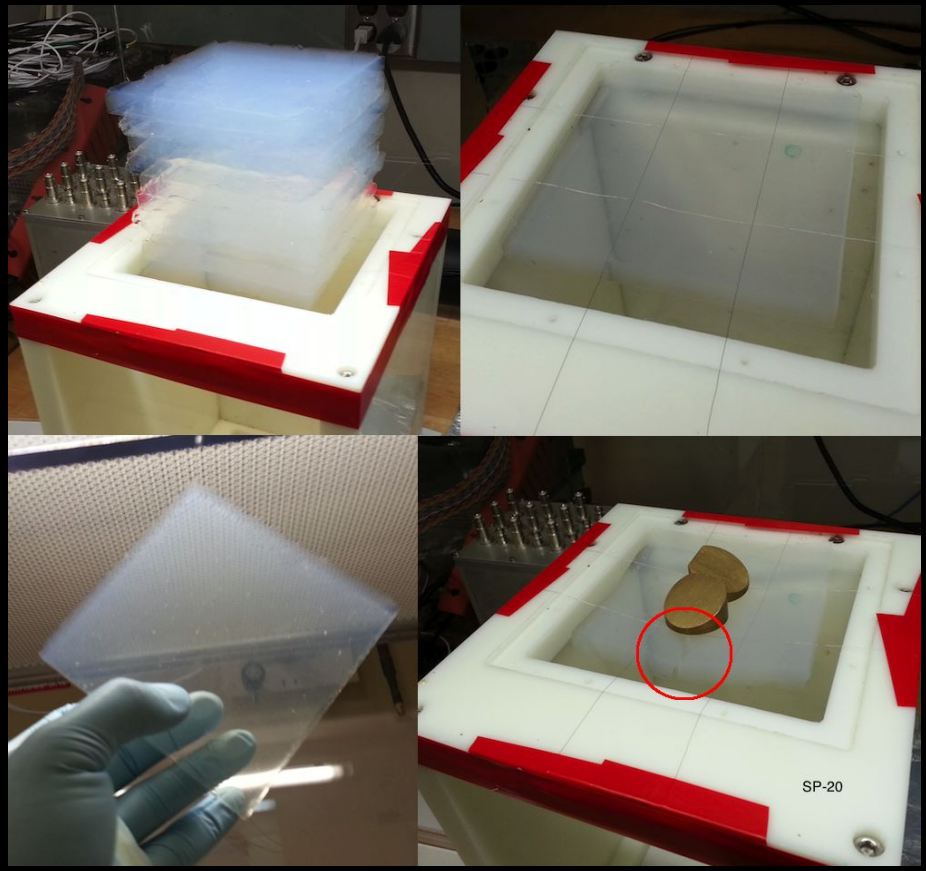
Measurement Vs Simulations

Credits: J. Crafts and CUA 07/13/2021





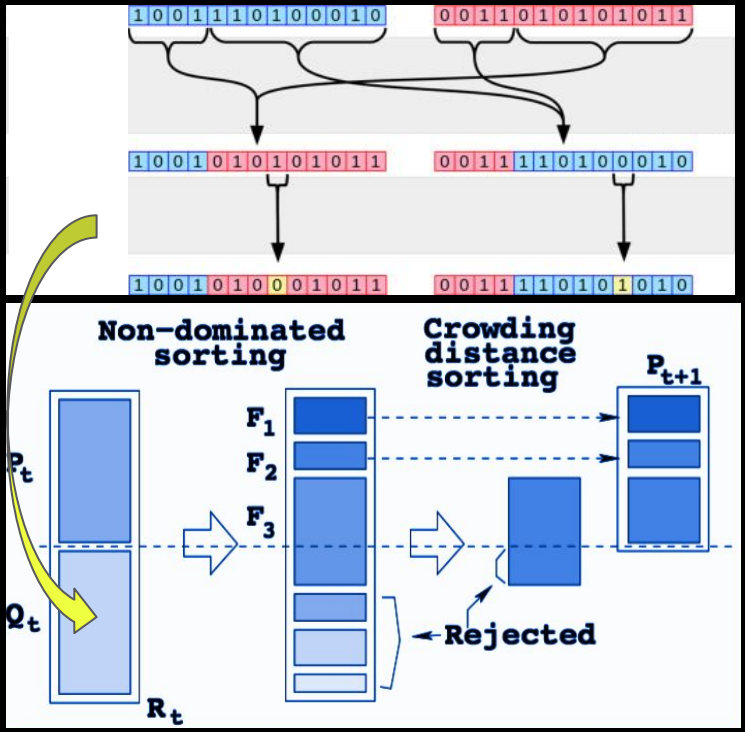
Aerogel tiles of 10x1x1 cm^3.
Deflection measurements to calculate Young's modulus



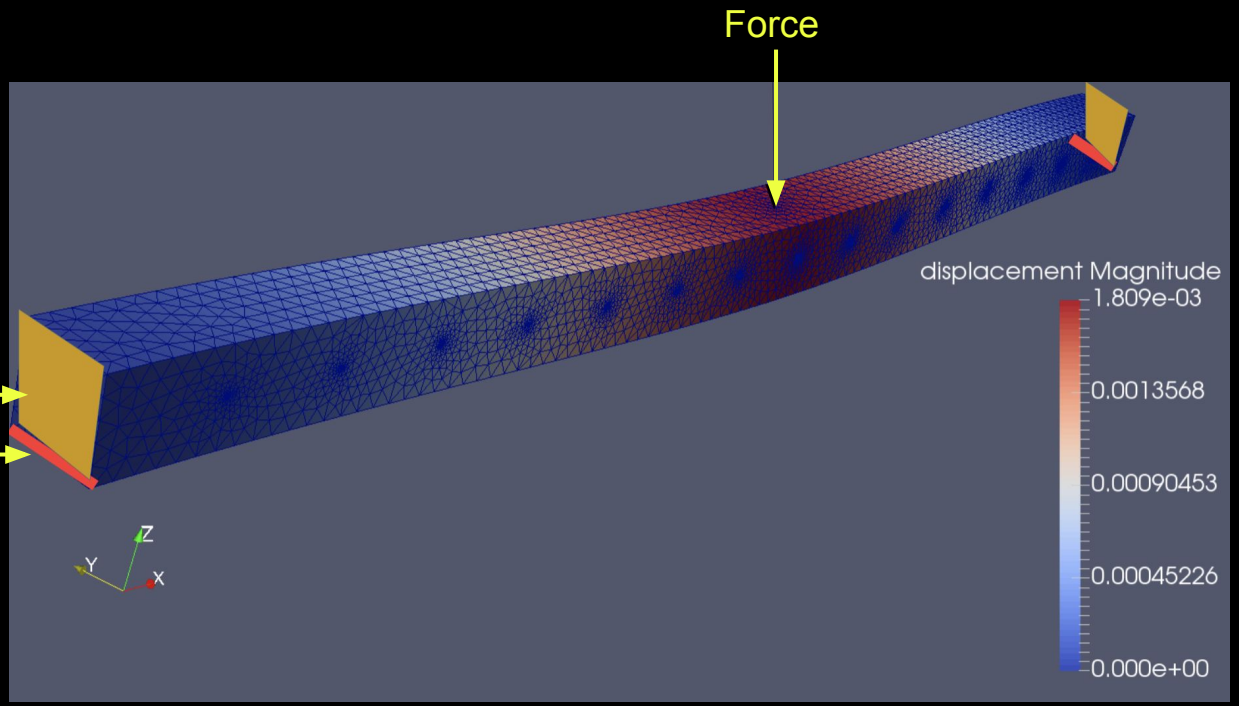
Conclusions

- Aerogels of very low refractive index (<1.011) are needed to reach the highest momenta up to 8 GeV/c. Such aerogels are very fragile and break easily, which is a concern for detector construction and operation.
- Low refractive index aerogels with mechanical reinforcement have recently been developed by Scintilex/Aspen.
- In this study we developed an AI-supported framework for the R&D of novel composite aerogel materials to optimize simultaneously the resolution on the Cherenkov angle, light yields, and the mechanical stability of the aerogel tile.
- A software stack which includes Geant4 + Gmsh + Elmer has been developed to evaluate the properties of the aerogel, which are compared to measurements during the R&D process for validation.
- New reinforced designs with promising performance are suggested by AI.
- They will be evaluated with prototype detectors.
- We are close to submit a paper.

AI Workflow



Simulation of Aerogel with block of Fibers



Boundary conditions:

- end surface
- bottom edges