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Study of Mechanical Deformation of a Single Gas Electron Multiplier Foil using Finite Element Modelling

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Introduction

Gas Electron Multiplier (GEM) based detectors have been use in many applications since their introduction in 1997. Large areas of GEM are foreseen in several experiments such the future upgrade of the CMS muon detection system, where triple GEM based detectors will be used.

During the assembly and operation, GEM foils are stretched in order to keep the vertical distance between layers constant and uniform across the large area. This is a serious challenge for the assembly process. Indeed the deformation of the perforated holes in the Gas Electron Multiplier (GEM) are proven to have great effect on the electron gain. Numerical calculations are therefore required to optimize the stretching forces to ensure uniform GEM sheet assembly and consequently uniform detector gain.

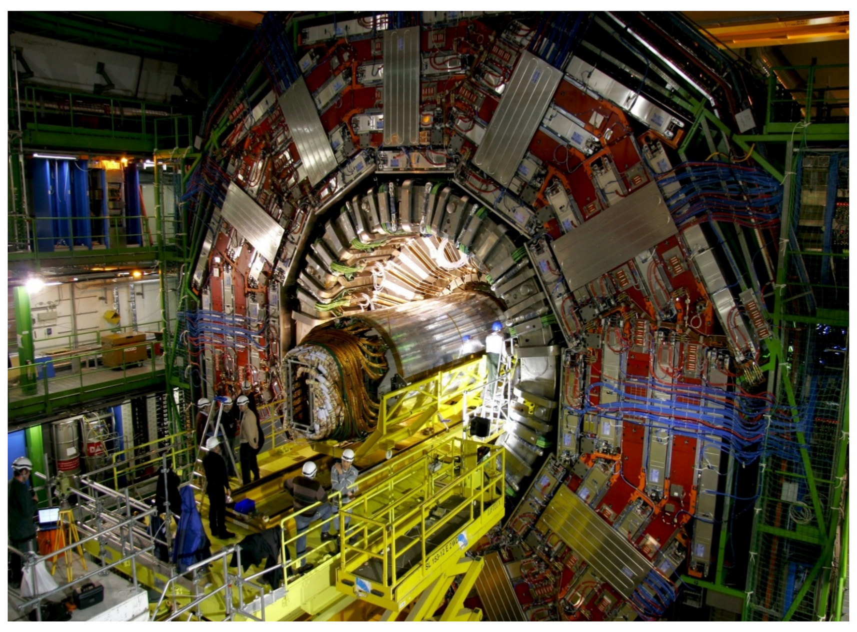


Fig 1: CMS detector

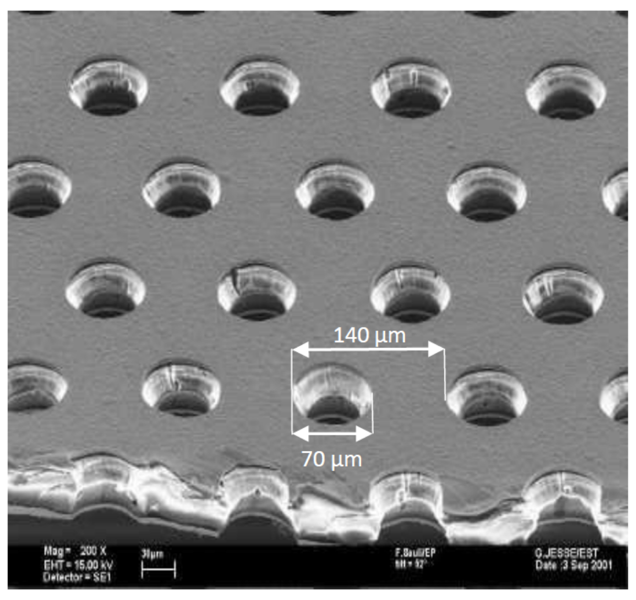


Fig 2: GEM foil with hole dimensions

Motivation

The deformed shape of the perforated holes in the GEM are proven to have great effect on the electron gain [1]. Numerical calculations are required to optimize the GEM sheet configuration for maximum gain. In this research, nonlinear mechanical properties of the GEM foil are predicted by:

- Linear elastic properties are predicted in the longitudinal and transvers alignment of the foil
- Plastic deformations predict the load limitations.

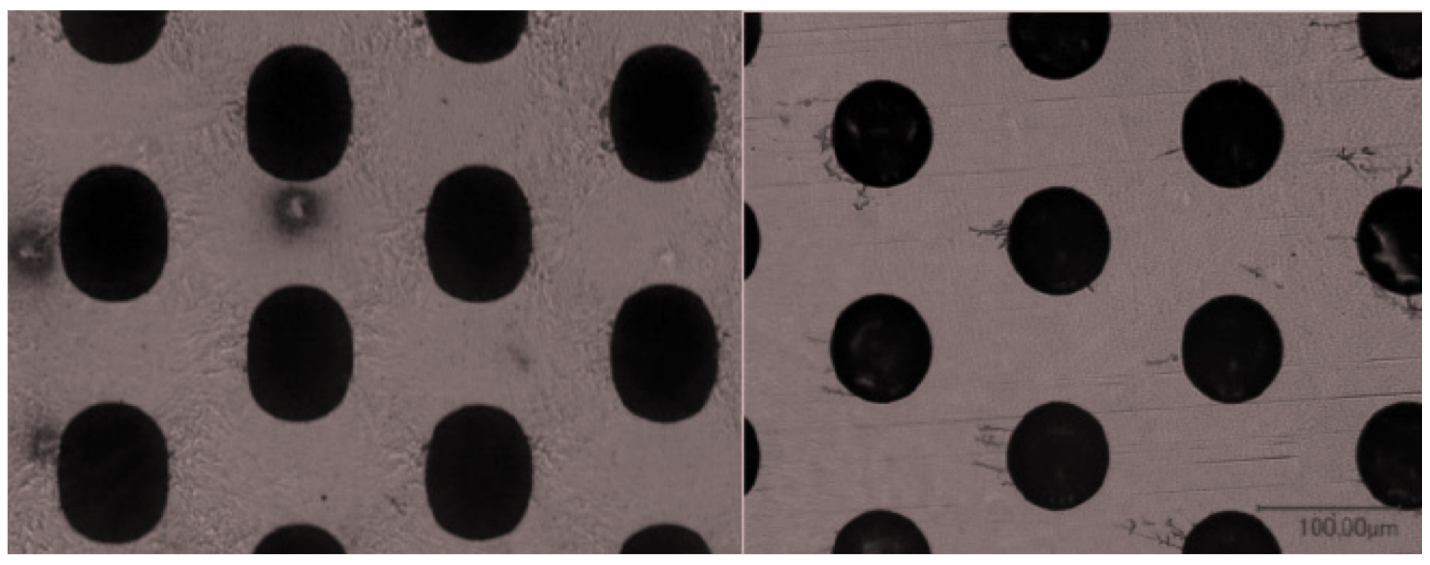


Fig 3: Effect of hole deformation on GEM foil

FEA model and stress-strain curve

The finite element [2] work will carry on the following steps:

- Creating the Finite Element Model (FEM) of a small GEM sheet (starting with 1mm*1mm sheet).
- Applying stress (stretching force), in X (or Y) direction.
- Measure the displacement (strain) on X and displacement on Y (Poisson effect), for both linear and nonlinear stresses.
- Estimate the deformation on the holes due to the stress.

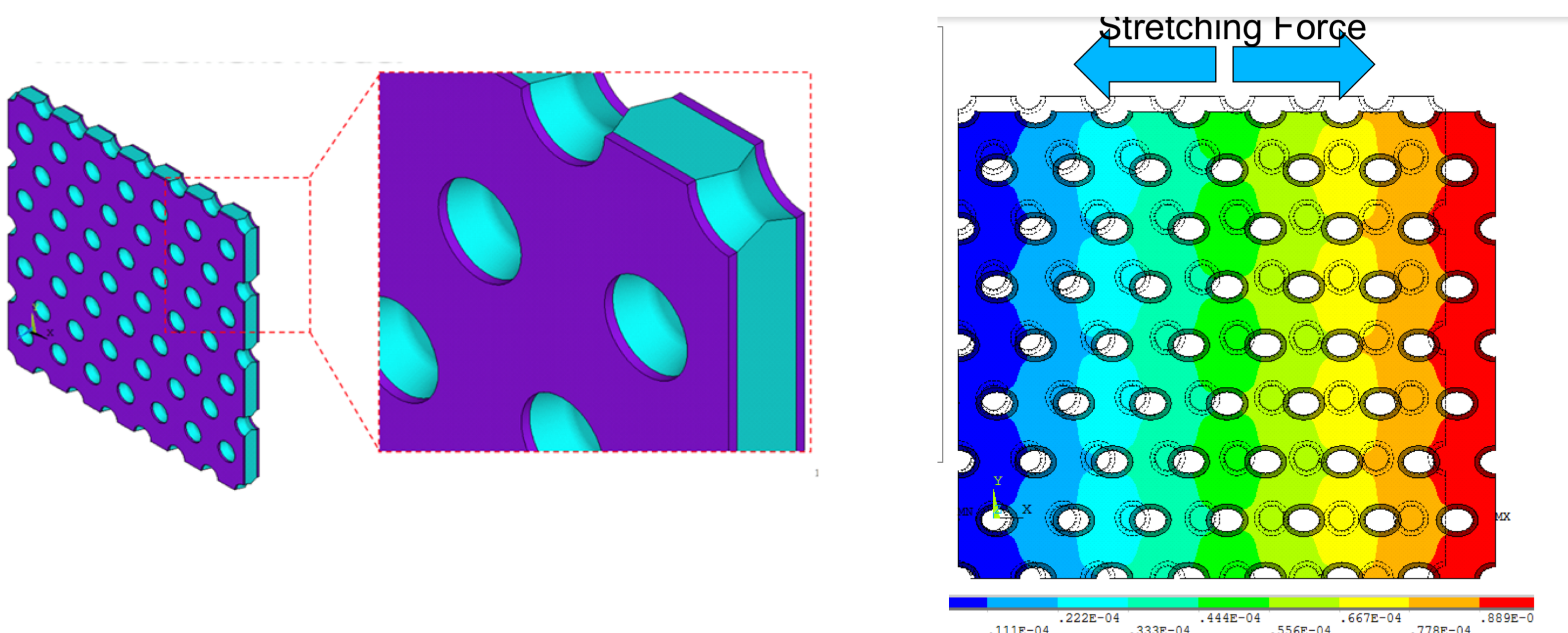
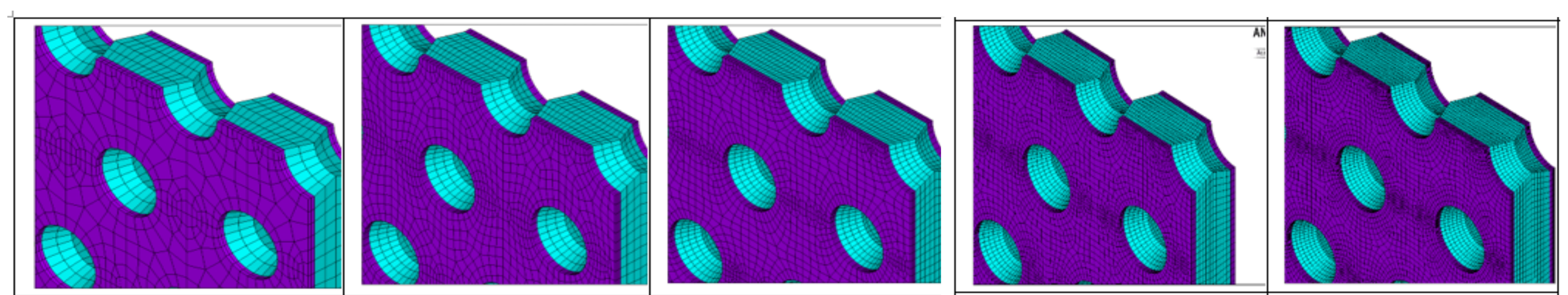


Fig 4: Geometrical and finite element models used for the present investigation

Mesh Density

The objective of mesh density sensitivity is to get the proper mesh density that will show insignificant change in the output results with higher density meshes. Five mesh densities are assessed; extreme coarse, coarse, medium, fine and extreme fine meshes. The meshes are shown in figure 5.



Extreme Coarse Mesh 28K nodes (84K DOF)	Coarse Mesh 81K nodes (243K DOF)	Normal Mesh 130K nodes (390K DOF)	Fine Mesh 262K nodes (786K DOF)	Extreme Fine Mesh 397K nodes (1,191K DOF)

Fig 5: Mesh densities used

Results and Discussion

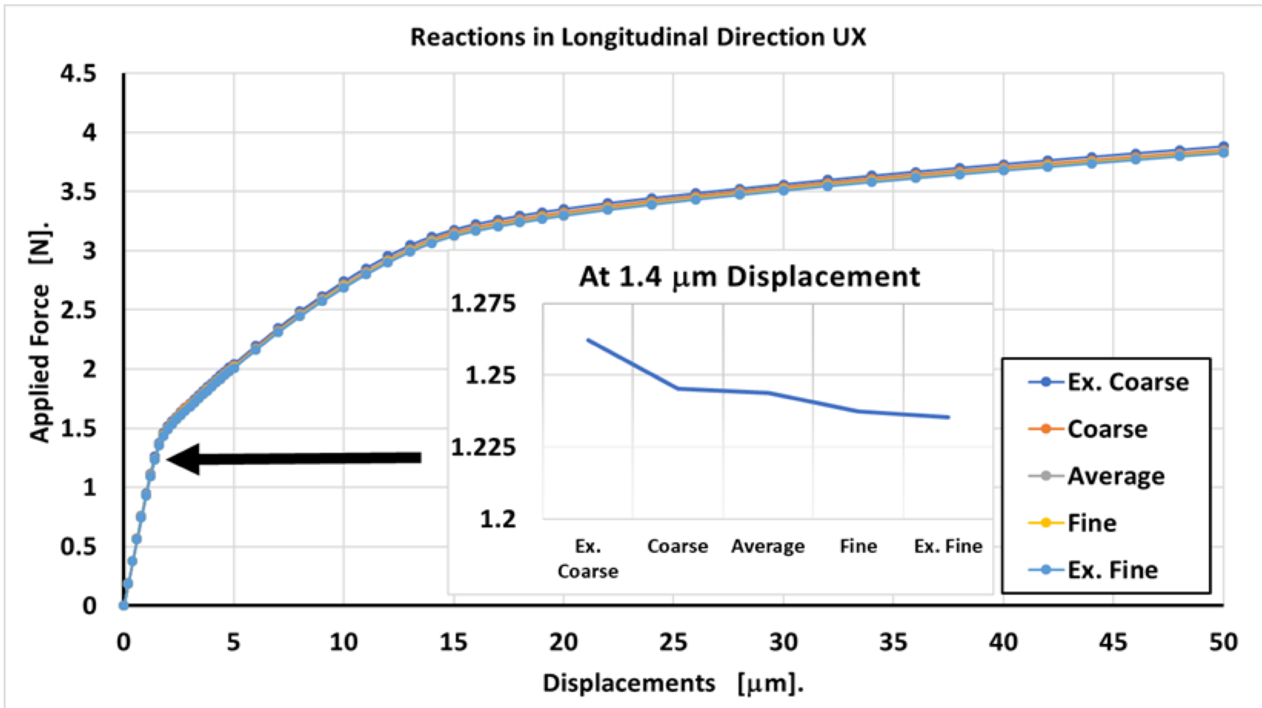


Fig 6: Reactions in Longitudinal Direction Ux

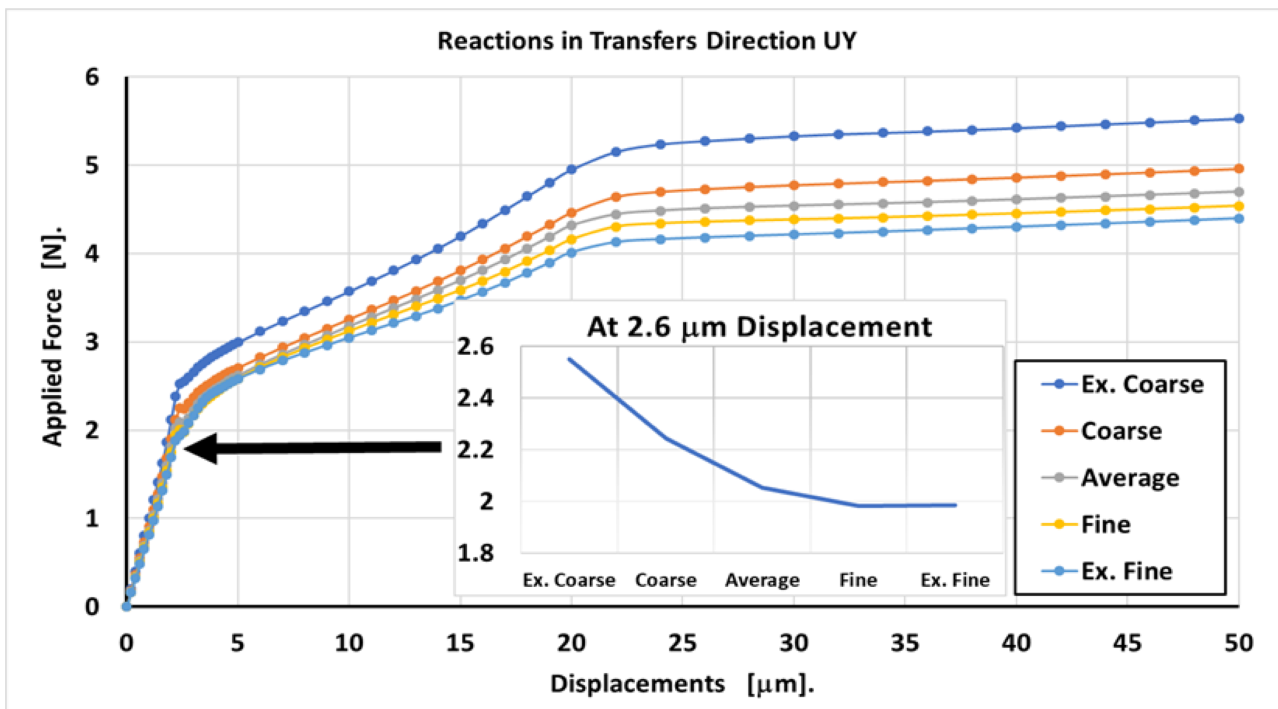
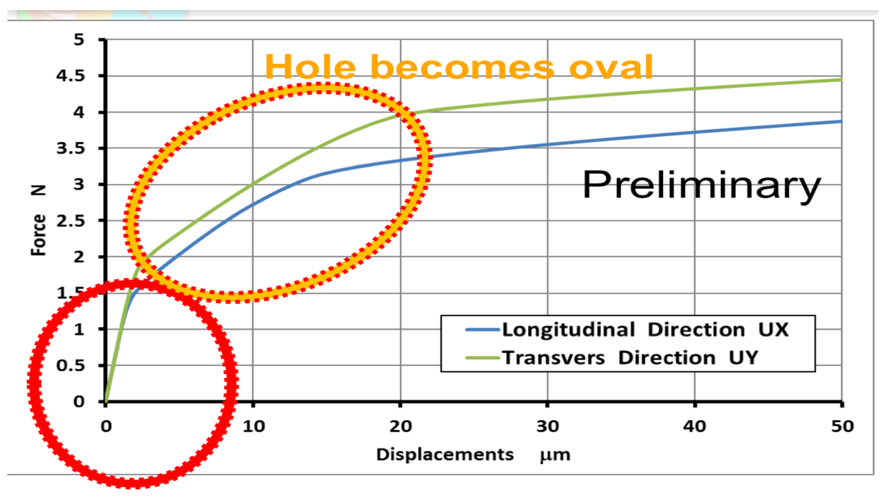


Fig 7: Reactions in Transfer Direction Uy



The hole shape stays circular

Fig 8: Stress-strain curve showing the displacement of the foil as a function of the stretching force applied in both directions

Conclusion

- The mesh density has no effect on the longitudinal loading.
- Three different model sizes were simulated. The results show no effect of the model size in both directions.
- Under linear regime there is no significant change in the GEM hole dimensions
- However in non-linear regime, the displacement is significantly different in both ways which might lead to an oval form of the holes.

References

1. M. Abi Akl et al., NIMA A832 (2016)
2. ANSYS Theory Manual, Release 8.0, ANSYS Inc., USA, 2003

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