Mechanical Design and Stress Analysis of a Large-Area Gas Electron Multiplier

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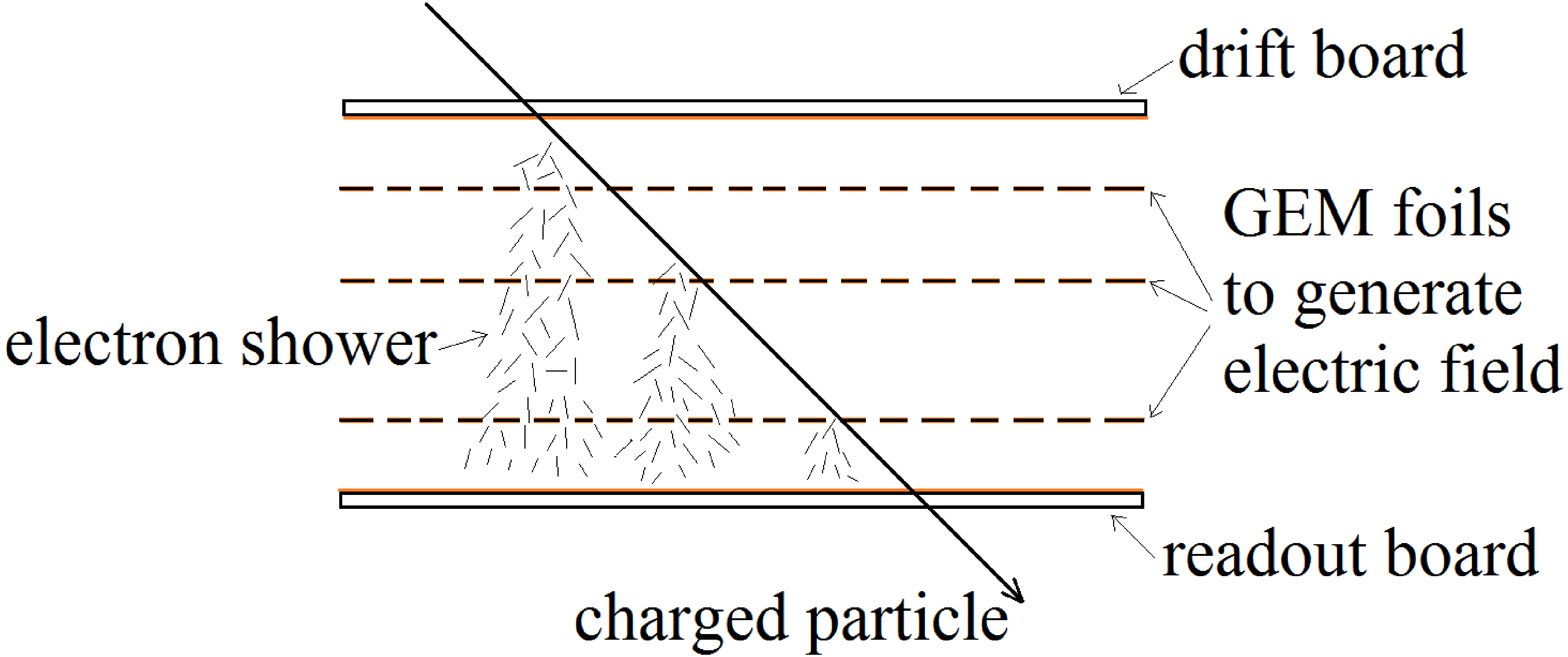
81st Annual Conference of Florida Academy of Sciences

t Florida Polytechnic University

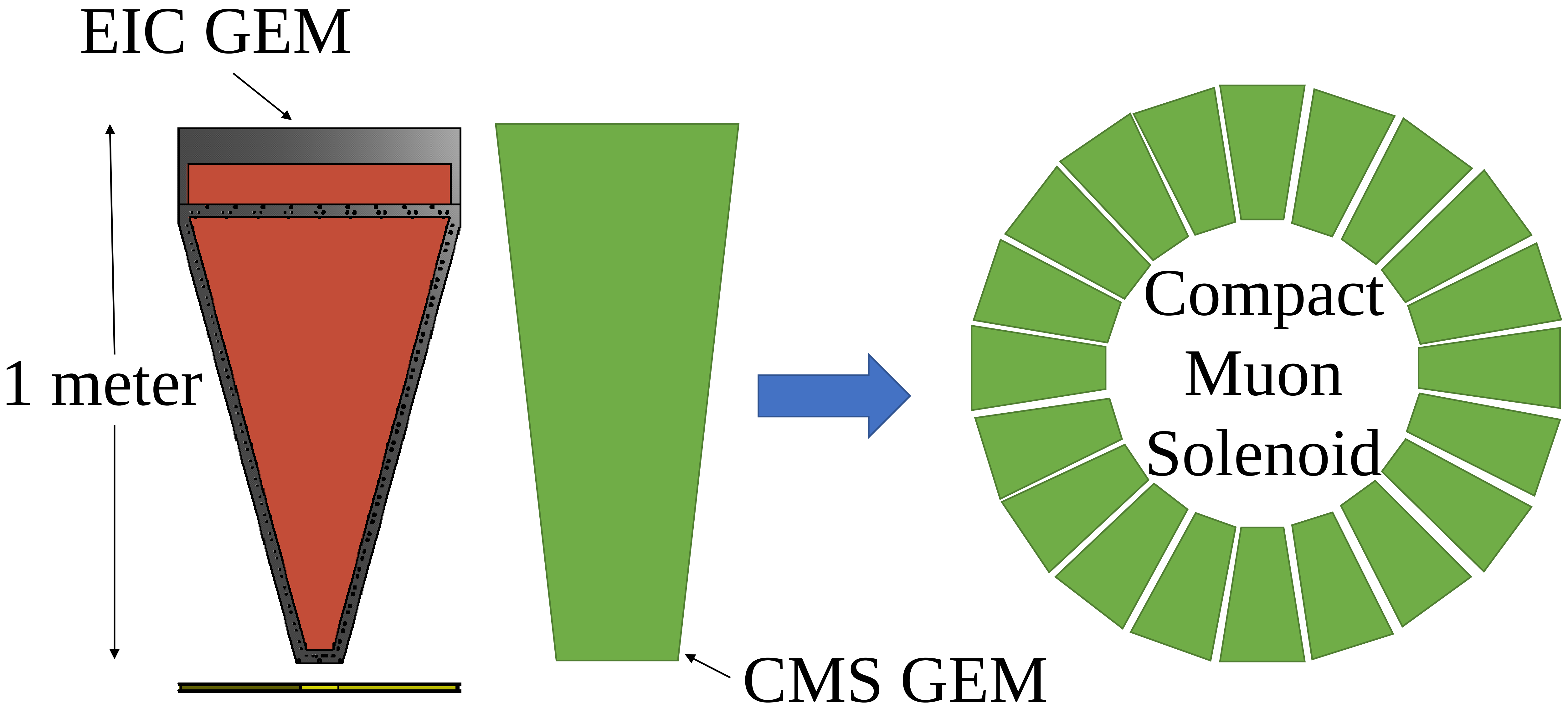
March 11, 2017

Introduction to Micropattern Gaseous Detectors

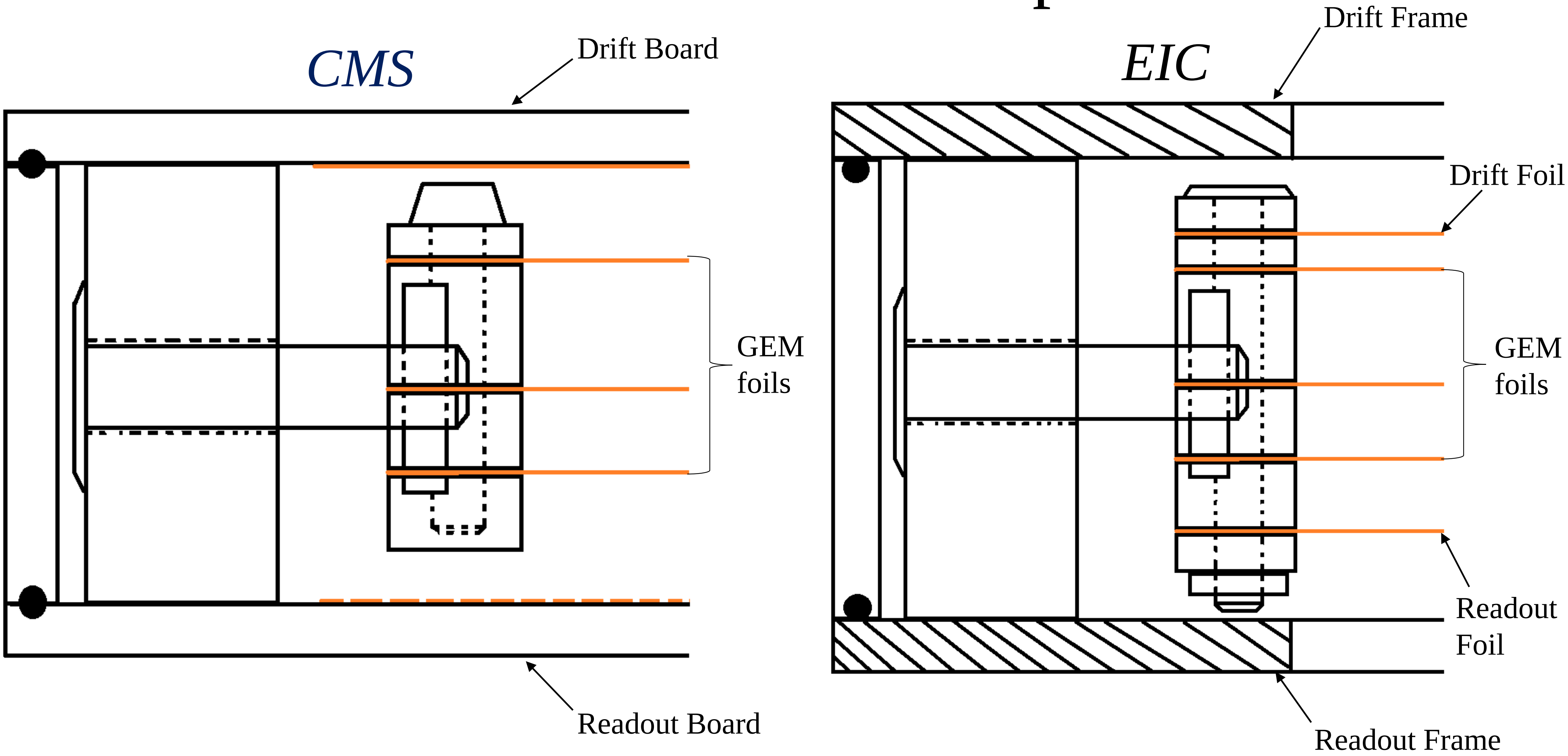
Note: Gas-filled region between drift and readout boards



Purpose of the Detector



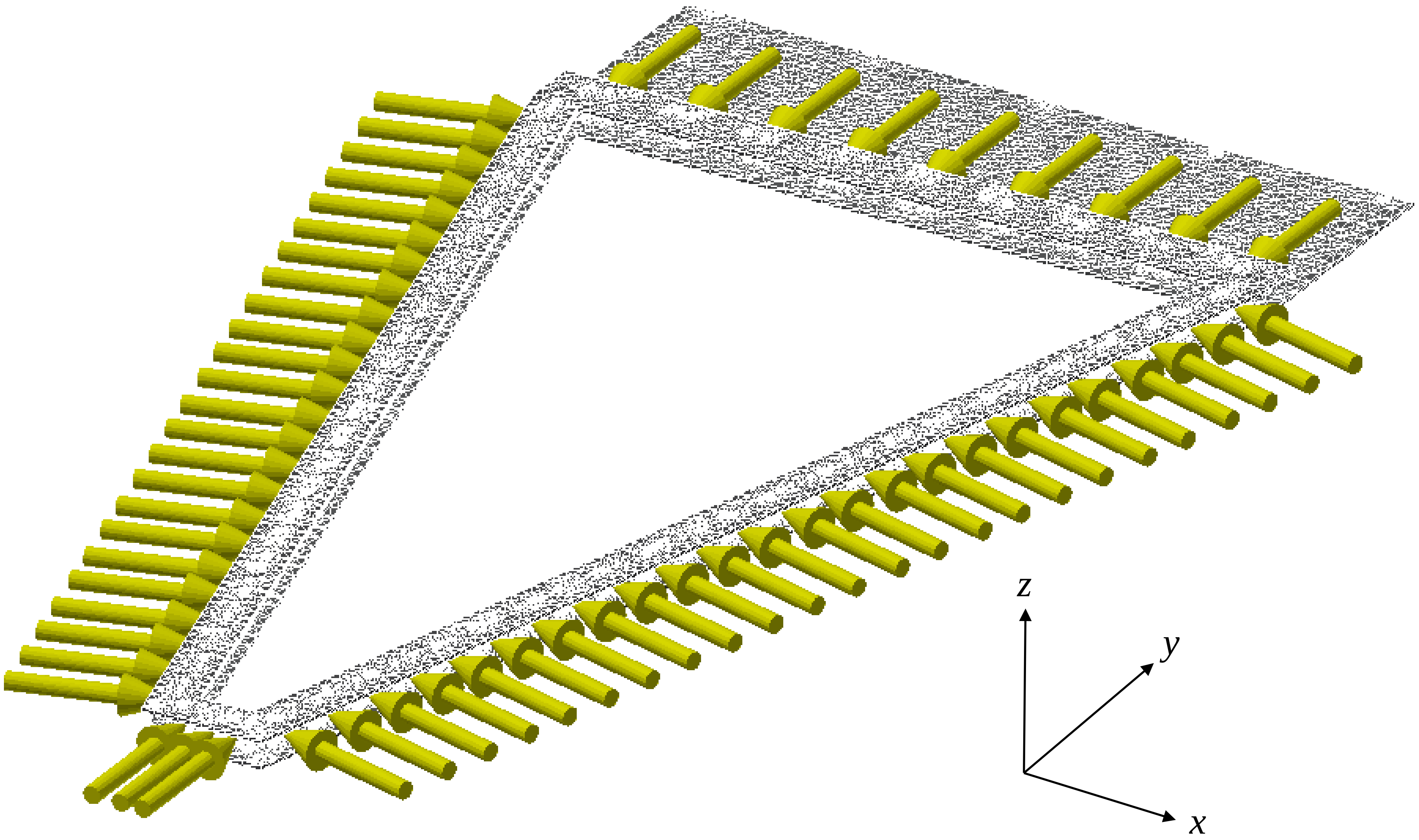
CMS and EIC GEM Comparison



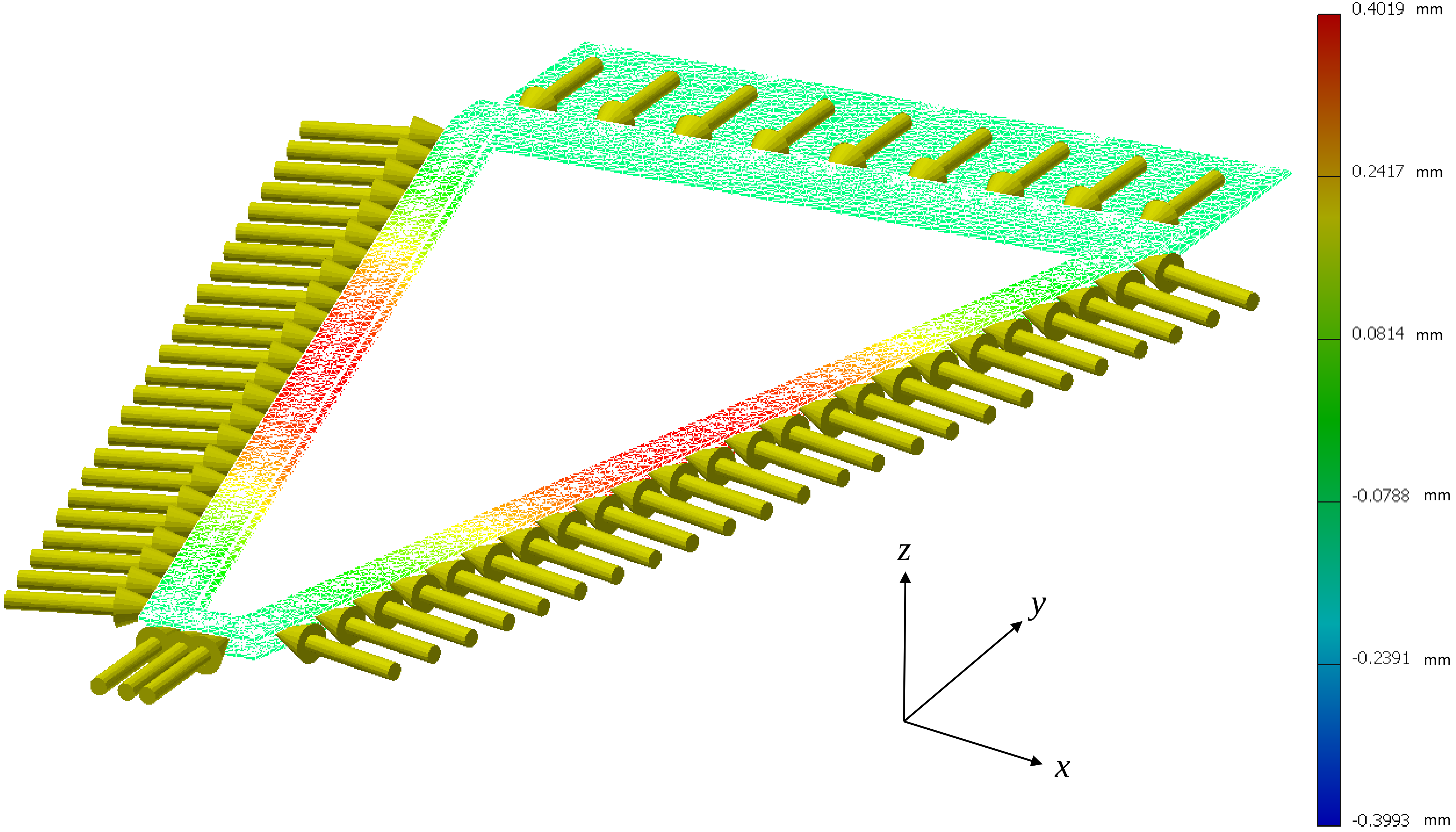
EIC GEM Design Criteria

1. Deformation of the frames must be less than 2 millimeters
2. Material must have high Young’s Modulus
3. Material must have low density

Introduction to Stress Analyses in Inventor Professional

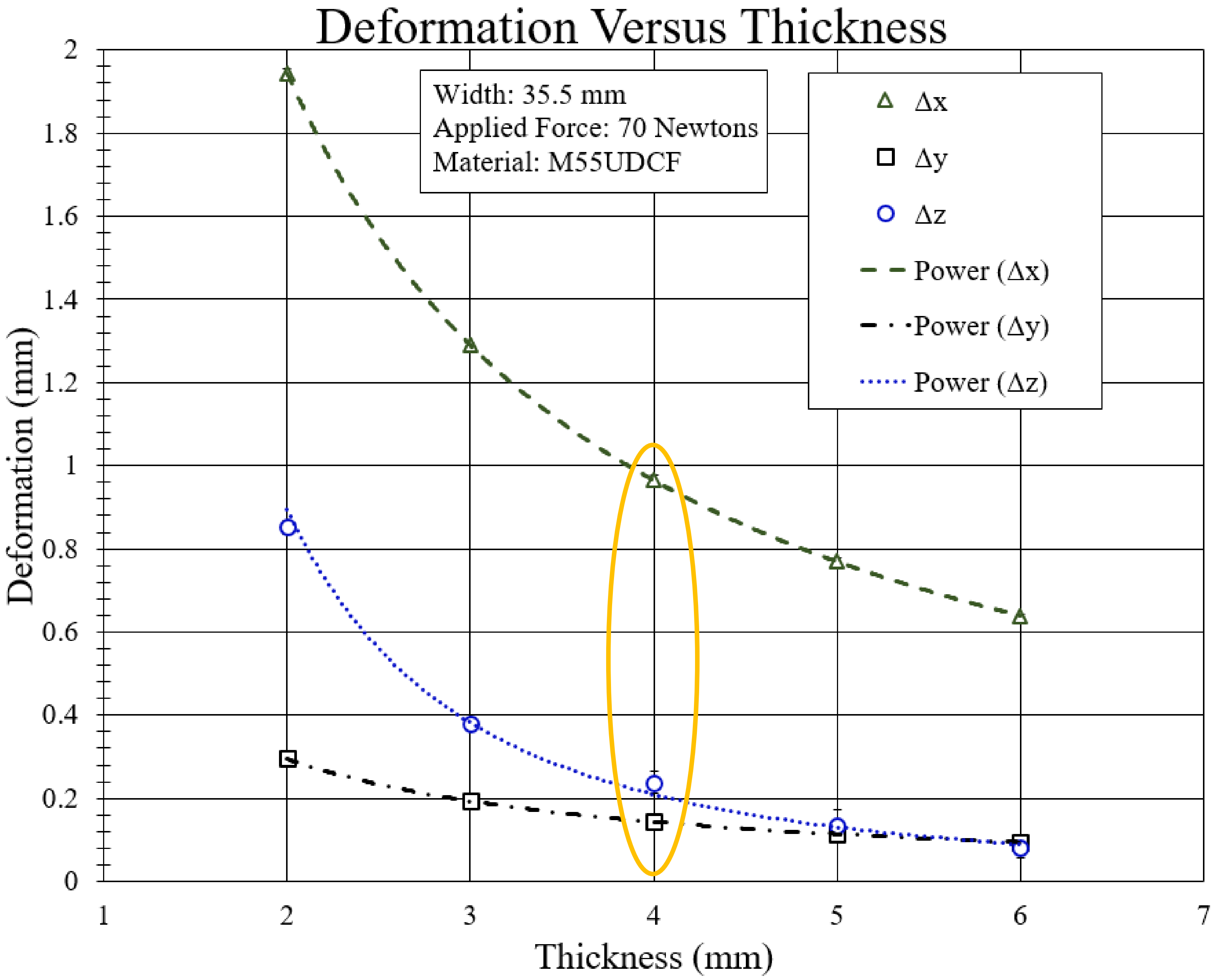


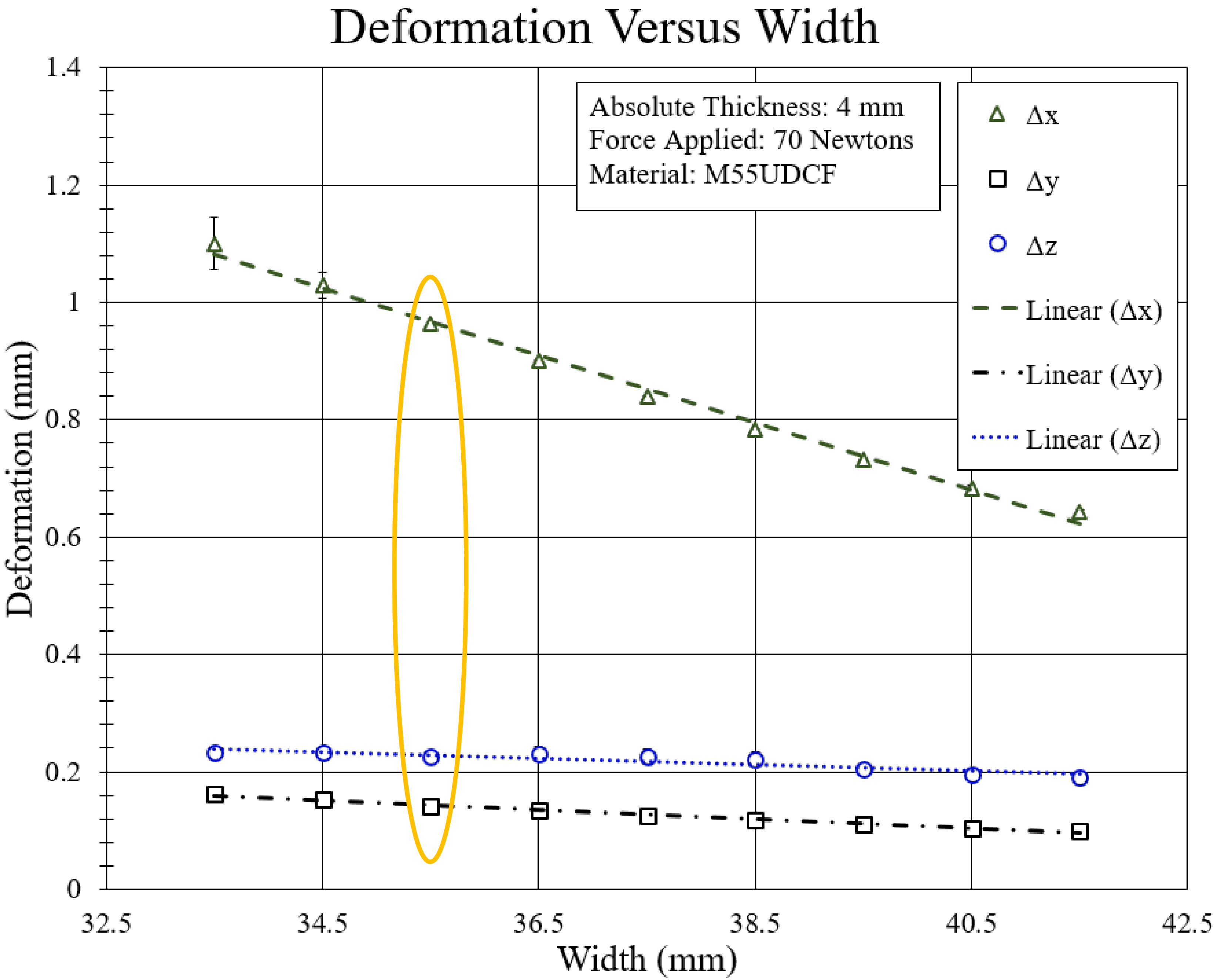
Introduction to Stress Analyses in Inventor Professional



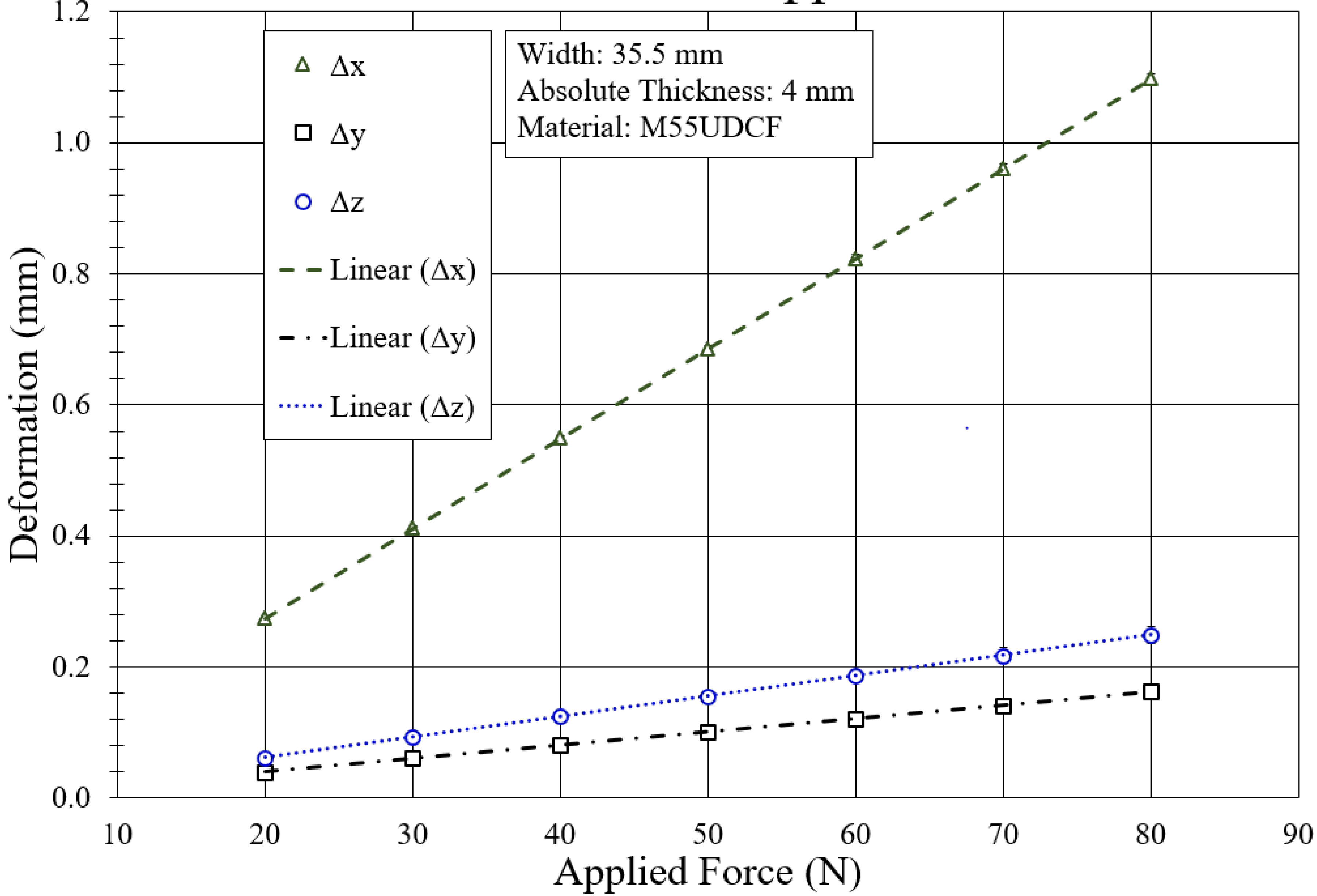
Performance of Candidates for Frame Material

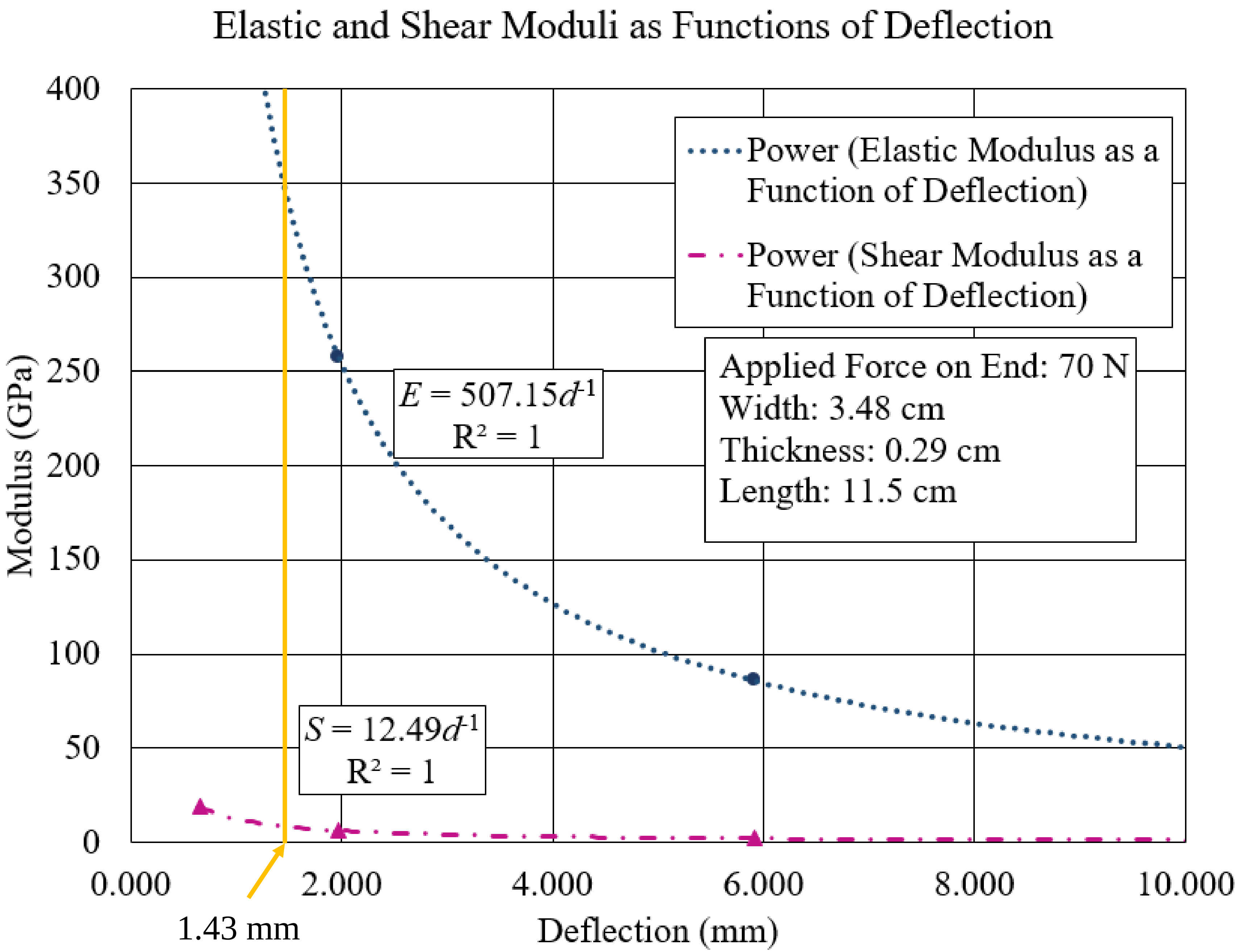
	Deformation (mm)				
Material	**Δx**	**Δy**	**Δz**	**Young's Modulus (GPa)**	**Density (g/cm^3)**
Acrylonitrile Butadiene Styrene Plastic	61.330	9.233	3.990	2.240	1.052
Epoxy Resin	37.230	5.591	2.926	4.940	1.135
FR-4 (Fiberglass with Epoxy Resin Binder)	10.403	1.555	1.107	24.132	1.855
Thermoplastic Resin	48.840	7.343	3.474	3.300	1.273
Carbon Fiber Reinforced E Glass (Fiberglass)	10.078	1.507	1.110	25.001	1.910
Carbon Fiber Reinforced Kevlar	8.549	1.277	1.013	30.000	1.412
Carbon Fiber Reinforced Plastic (2000 w/ 2060)	4.768	0.711	0.709	56.332	1.107
Carbon Fiber Reinforced Plastic (Dragonplate)	1.231	0.183	0.274	230.292	1.661
Carbon Fiber Reinforced Plastic (LBL)	4.200	0.627	0.815	113.836	1.661
High-Modulus Carbon Fiber	3.225	0.480	0.521	85.015	1.606
High-Modulus Uni-Directional Carbon Fiber	2.841	0.424	0.625	174.994	1.606
M55 Uni-Directional Carbon Fiber	0.951	0.141	0.202	300.000	1.661
Standard Carbon Fiber	3.881	0.578	0.594	69.984	1.606
Standard Uni-Directional Carbon Fiber	2.068	0.307	0.406	135.003	1.606
Aluminum 6061	3.935	0.587	0.650	68.901	2.713
Brass	2.842	0.423	0.515	97.012	8.499
Stainless Steel	1.463	0.217	0.310	192.990	8.000
Titanium	2.686	0.400	0.501	102.804	4.512
Silicon Nitride	0.673	0.100	0.160	427.212	3.184


Deformation Versus Thickness
Width: 35.5 mm
Applied Force: 70 Newtons
Material: M55UDCF
Δx
Δy
Δz
Power (Δx)
Power (Δy)
Power (Δz)
Deformation (mm)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
Thickness (mm)


Deformation Versus Width
Absolute Thickness: 4 mm
Force Applied: 70 Newtons
Material: M55UDCF
Δx
Δy
Δz
Linear (Δx)
Linear (Δy)
Linear (Δz)
Deformation (mm)
Width (mm)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
32.5
34.5
36.5
38.5
40.5
42.5

Deformation Versus Applied Force





IM7 with Araldite:

$E(1.43\text{ mm}) = 354\text{ GPa}$

$S(1.43\text{ mm}) = 9\text{ GPa}$

Conclusion

1. The theoretical model determined the material, thickness, and width of the frames to be M55 unidirectional carbon fiber, 4 mm, and 35.5 mm, respectively
2. The material used to manufacture the frames seems to perform better than that used in the Inventor model

References

[1] Sauli, F., 1997, “GEM: A new concept for electron amplification in gas detectors,” Nuclear Instruments and Methods in Physics Research A, **386**(2-3), pp531-534.

[2] C. Altunbas, et al., 2002, “Construction, test and commissioning of the triple-GEM tracking detector for compass,” Nuclear Instruments and Methods in Physics Research A, **490**(1-2), pp 177-203.

[3] CMS GEM collaboration, 2015, “CMS Technical Design Report for the Muon Endcap GEM Upgrade,” CERN-LHCC-2015-012, CMS-TDR-013, ISBN 978-92-9083-396-2.

[4] A. Accardi, et al., 2012, “Electron Ion Collider: The Next QCD Frontier – Understanding the glue that binds us all,” Also known as the EIC White Paper, arXiv:1212.1701 (https://arxiv.org/abs/1212.1701).

[5] A. Zhang, et al., “R&D on GEM detectors for forward tracking at a future Electron-Ion Collider,” Proc. Of IEEE Nuclear Science Symposium, Nov. 24, 2015, San Diego, CA, arXiv:1511.07913.