Electro-static drives (ESD) for the AEI-10m prototype

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Original idea: Ken Strain

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Motivation for a new ESD design

The AEI-10m interferometer will face a new problem in terms of the required length actuators for the main optics:

- Beam size at the test masses is driven by demanding thermal noise requirements.
- Beam uses the full mirror size (mirror is only 2.5 times larger than beam $\Rightarrow$ even for optimal centering we have 4 ppm clipping losses).
- ITM and IETM have significant transmission. Therefore we need to have actuators featuring a free aperture of at least mirror size. $\Rightarrow$ **cannot use the GEO design**.

Motivation for a new ESD design

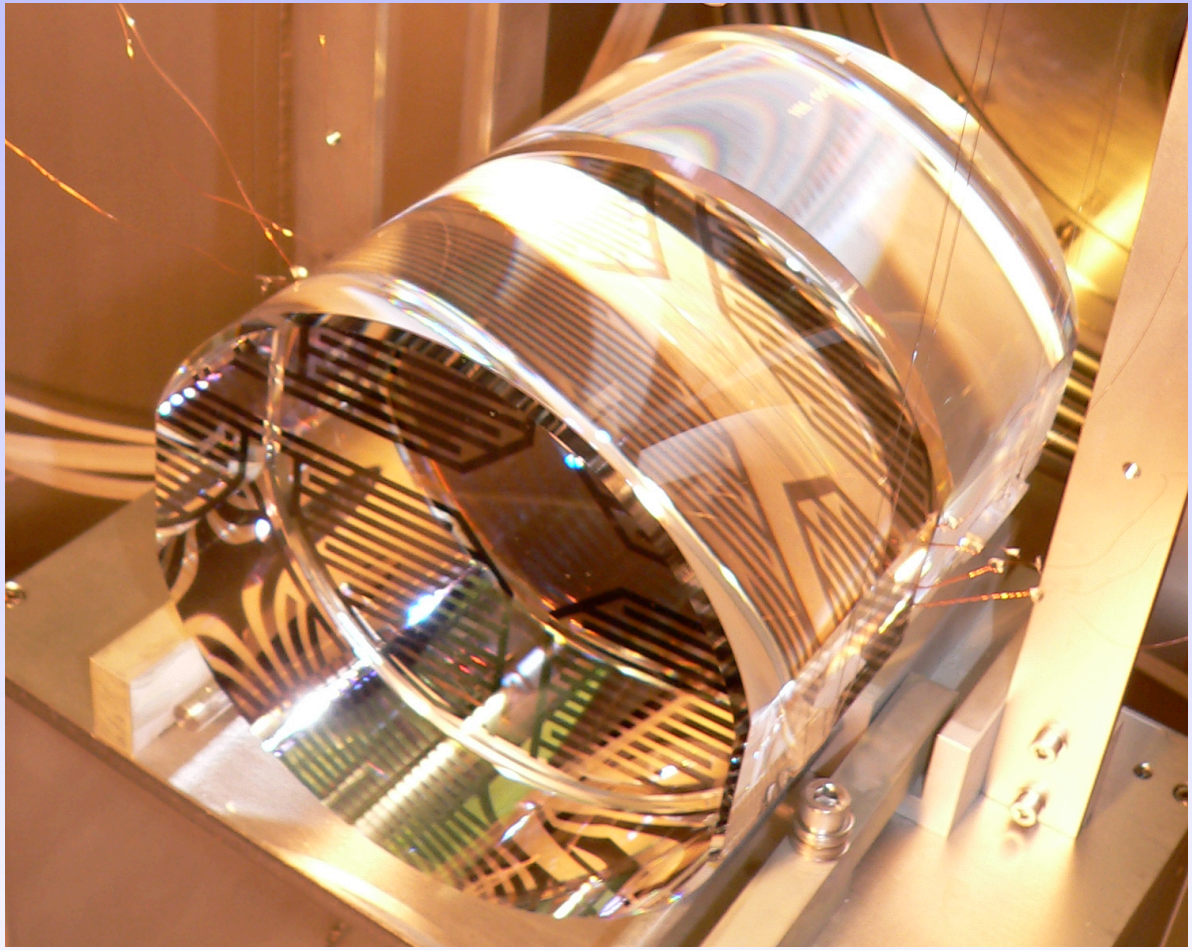


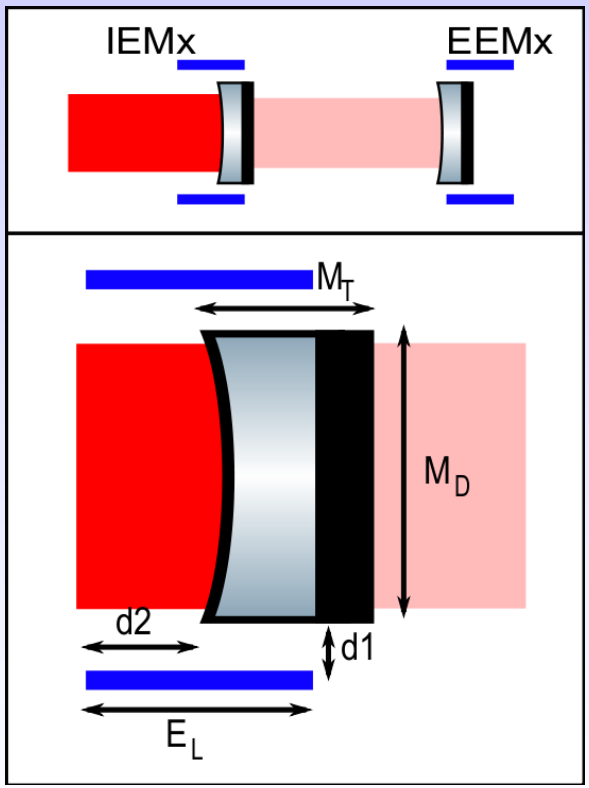
Figure: GEO ESDs

Motivation for a new ESD design

Idea

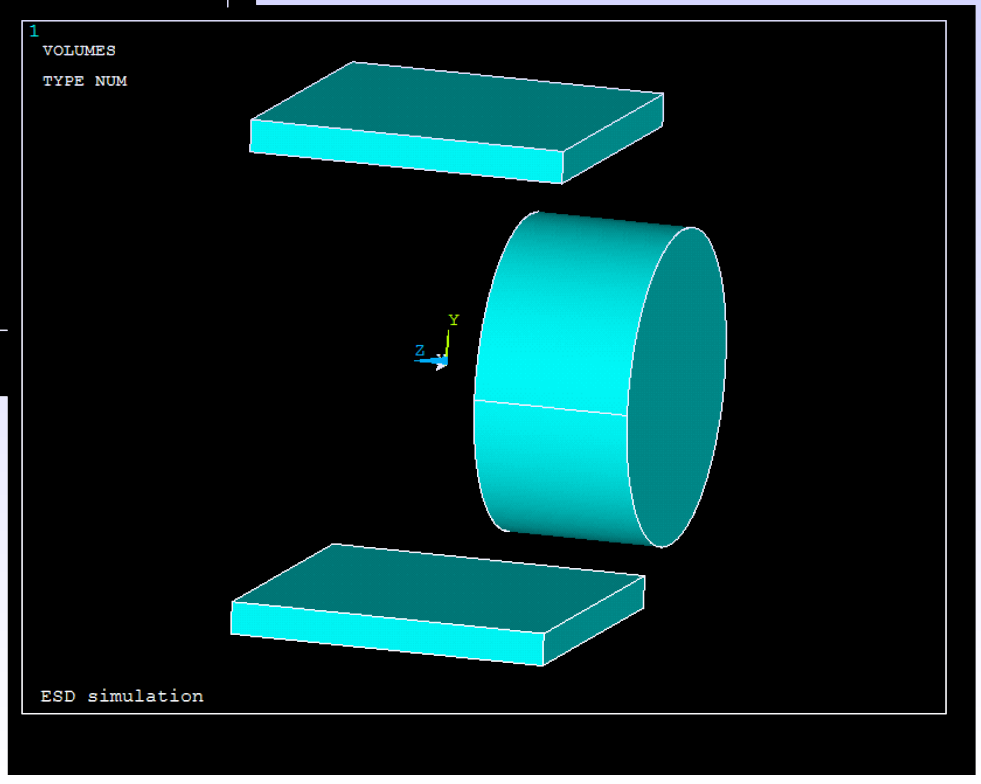
Use ESDs made of two plates (see picture)

- very large free aperture
- setup where the force is independent of the relative position of ESD and mirror, but just depends on the ESD voltage?!
- **This means very relaxed requirements for the seismic isolation of the ESDs.** Perhaps we could even just bold them down to the tables?

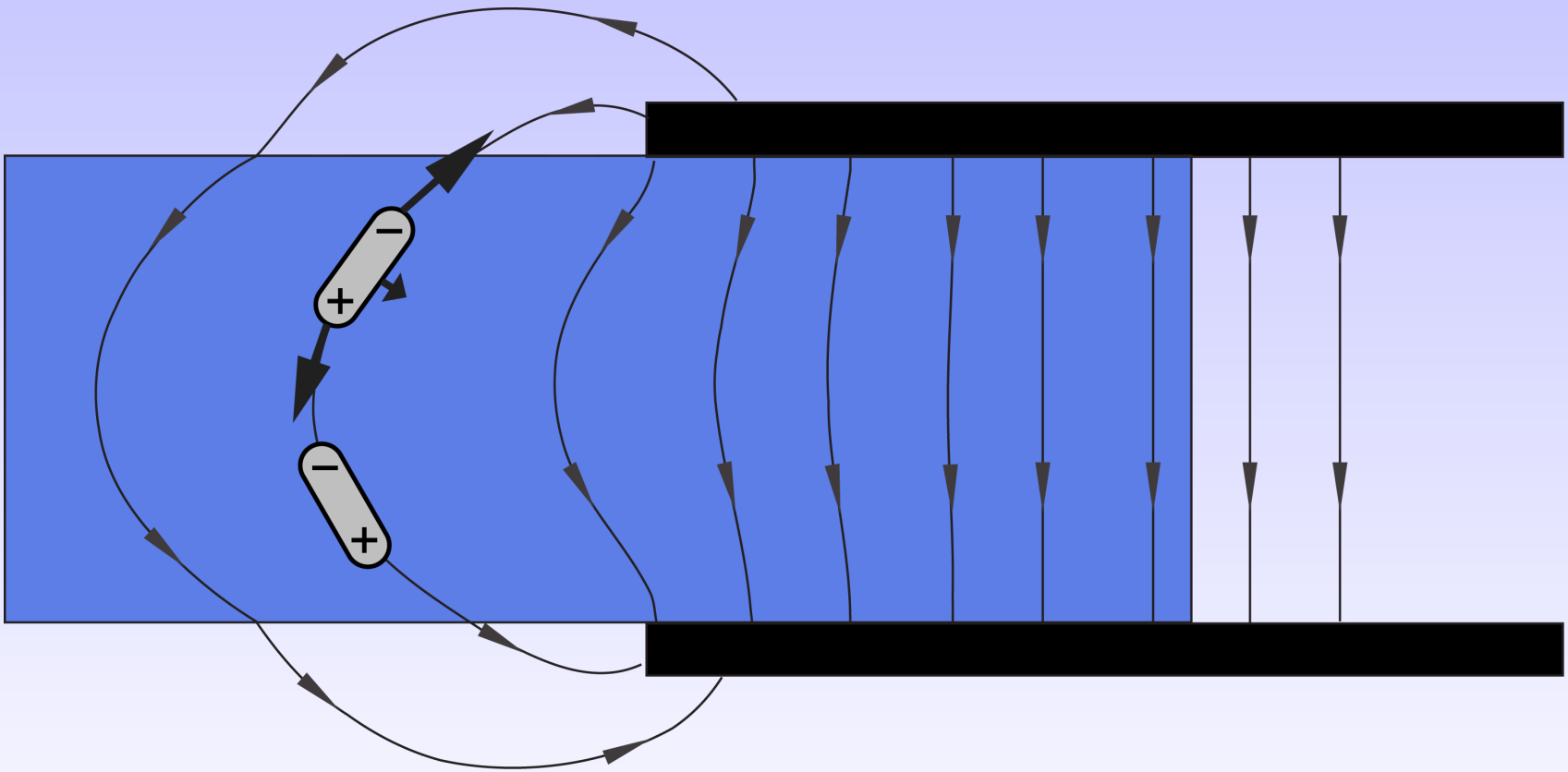


ESD Design


1
VOLUMES
TYPE NUM
Y
Z
X
ESD simulation


1
VOLUMES
TYPE NUM
Y
Z
ESD simulation

Origin of the force



Analytical approximation

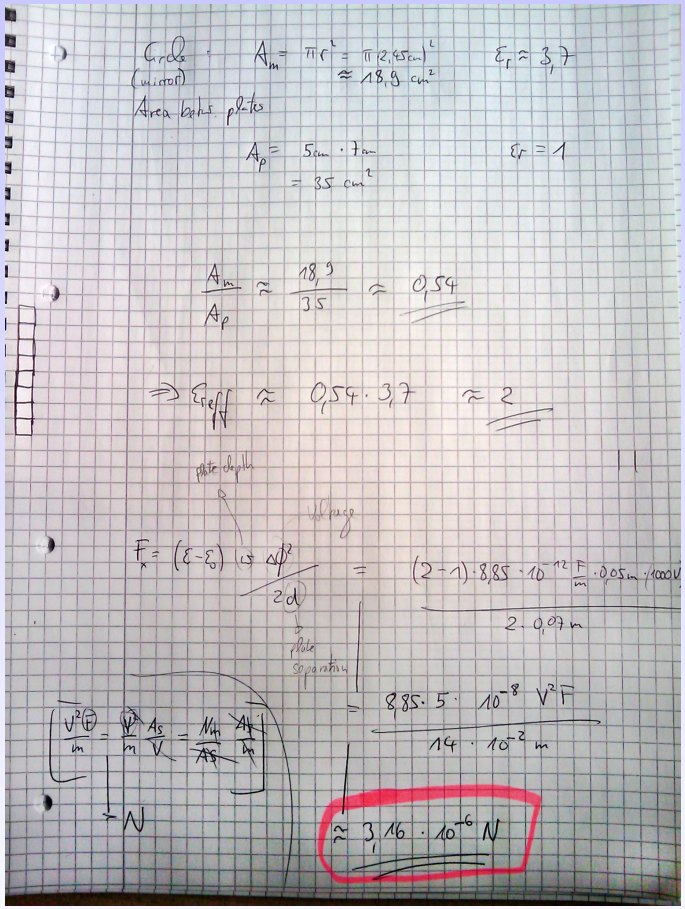
Assumption: big plates, small gap

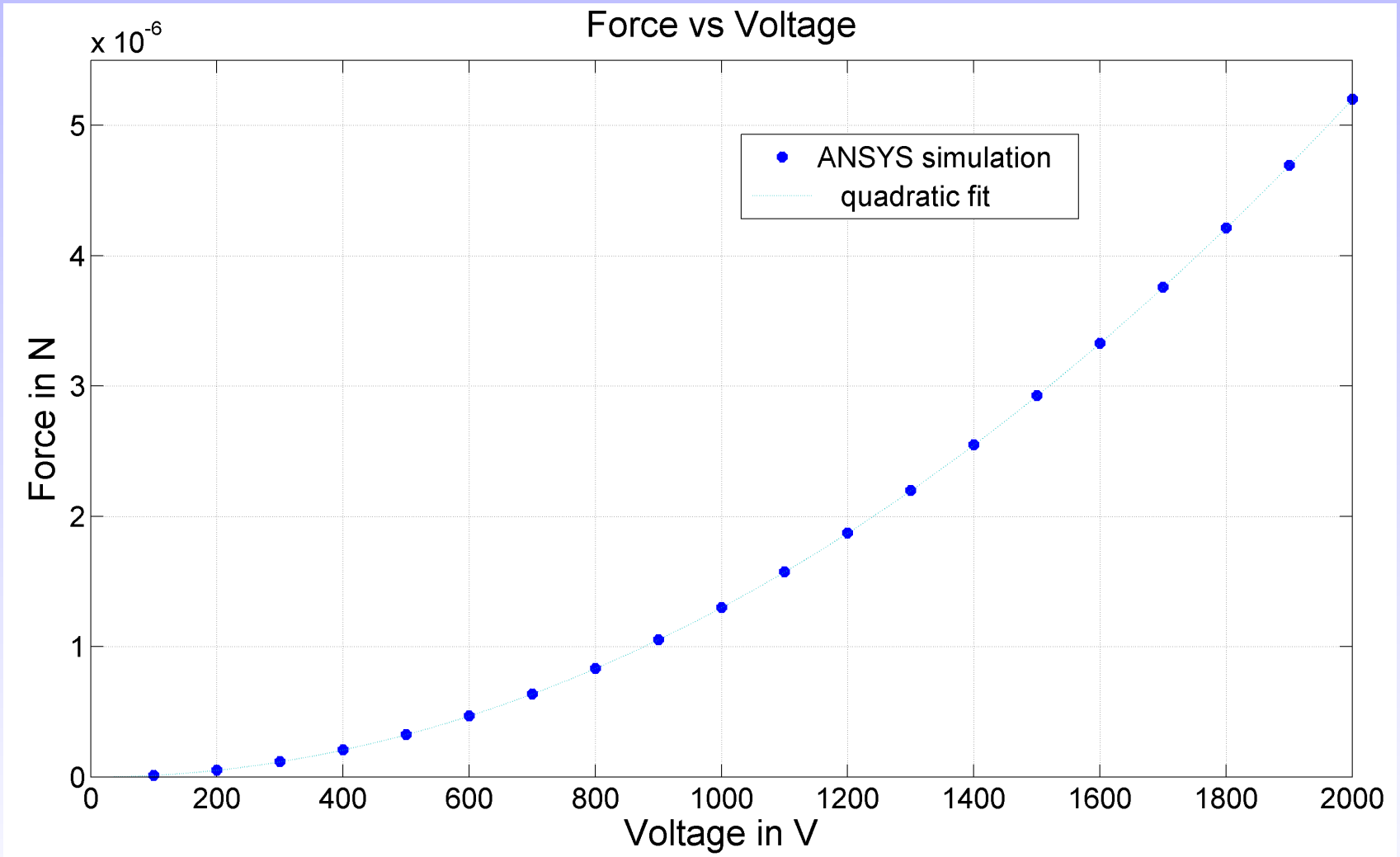
$$F = (\epsilon - \epsilon_0) \cdot \omega \cdot U^2/2d$$

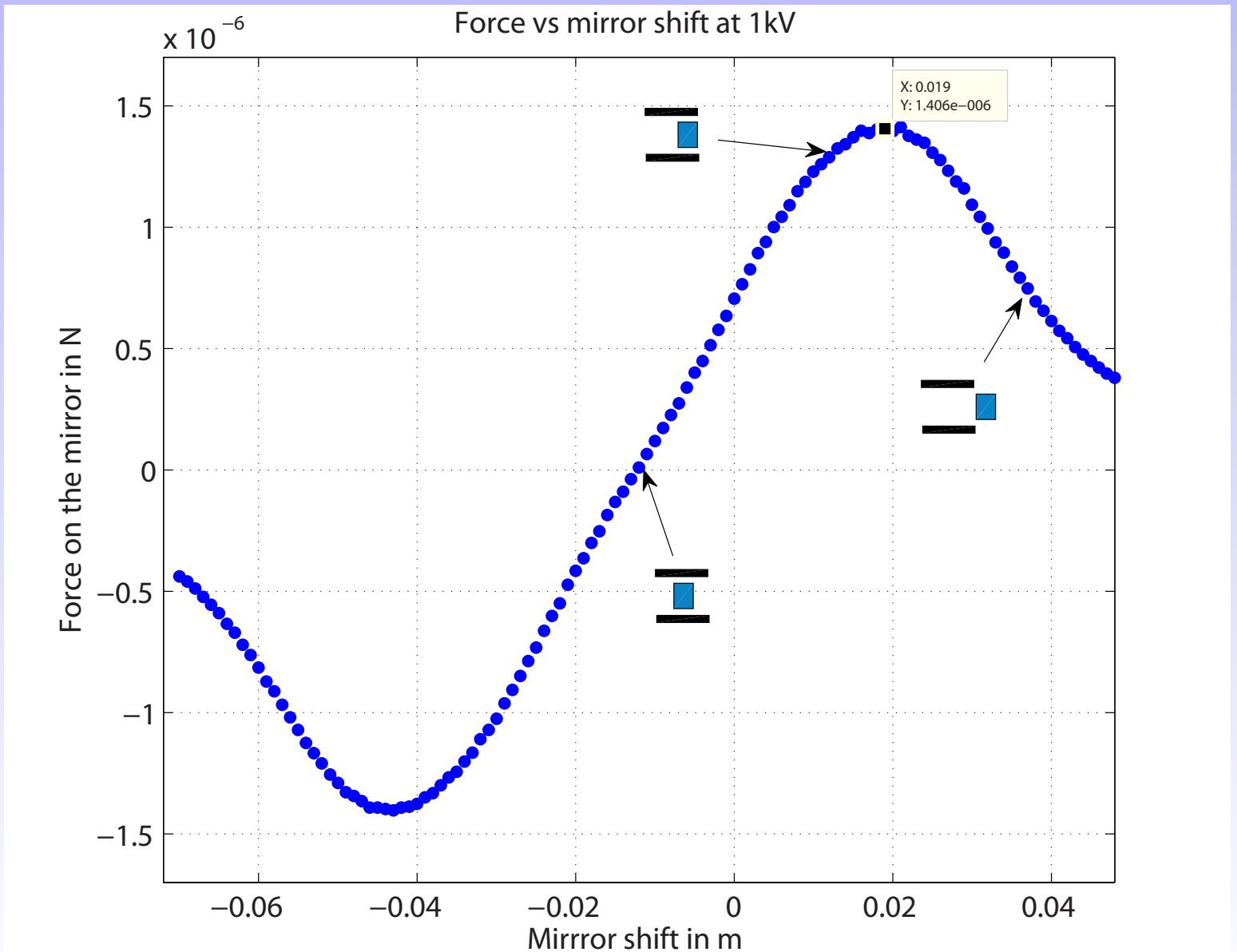
$U \hat{=}$ voltage

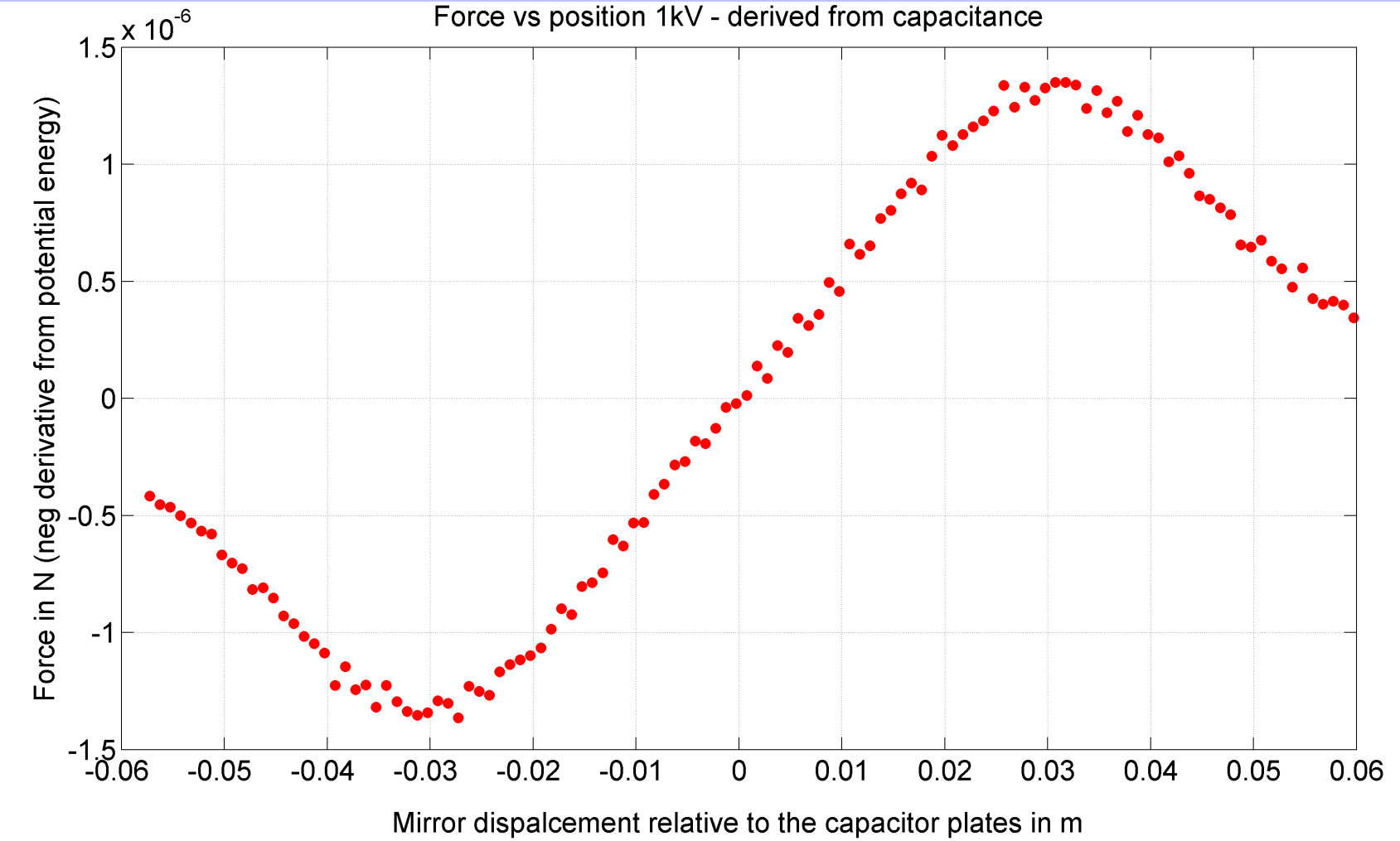
$\omega \hat{=}$ plate depth

$d \hat{=}$ plate distance



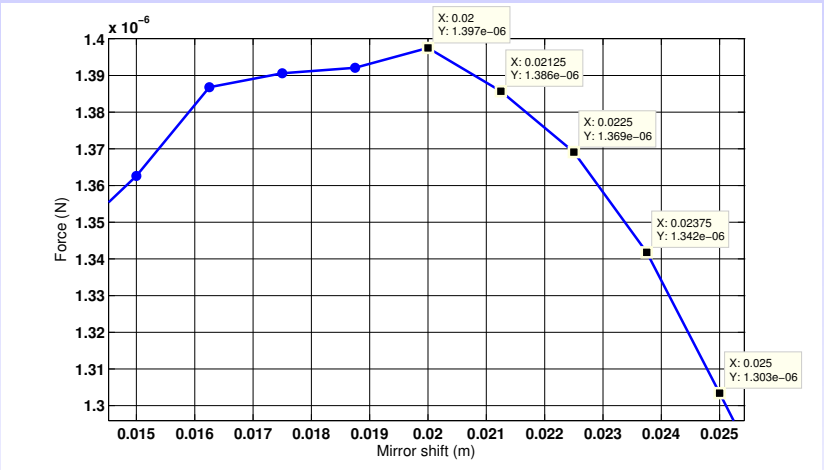

Force vs Voltage
x 10^-6
Force in N
Voltage in V
ANSYS simulation
quadratic fit
0
1
2
3
4
5
0
200
400
600
800
1000
1200
1400
1600
1800
2000

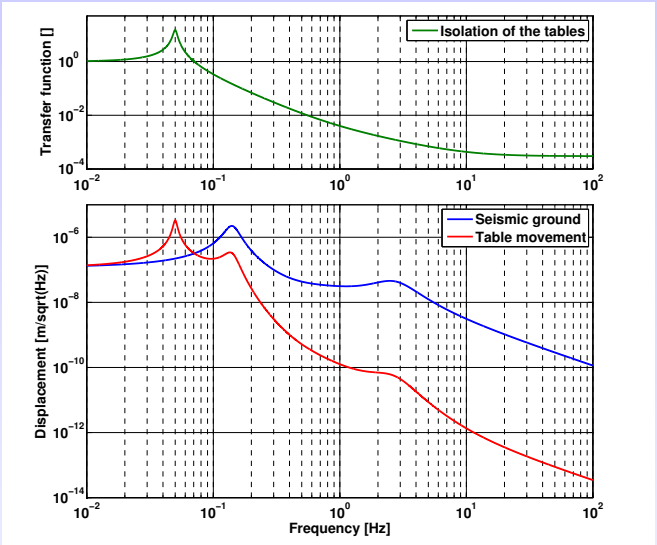

Force vs mirror shift at 1kV
x 10 −6
X: 0.019
Y: 1.406e−006
Force on the mirror in N
Mirrror shift in m
1.5
1
0.5
0
−0.5
−1
−1.5
−0.06
−0.04
−0.02
0
0.02
0.04


Force vs position 1kV - derived from capacitance
x 10^-6
1.5
1
0.5
0
-0.5
-1
-1.5
Force in N (neg derivative from potential energy)
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
Mirror dispalcement relative to the capacitor plates in m

Coupling of seismic for mispositioned ESD

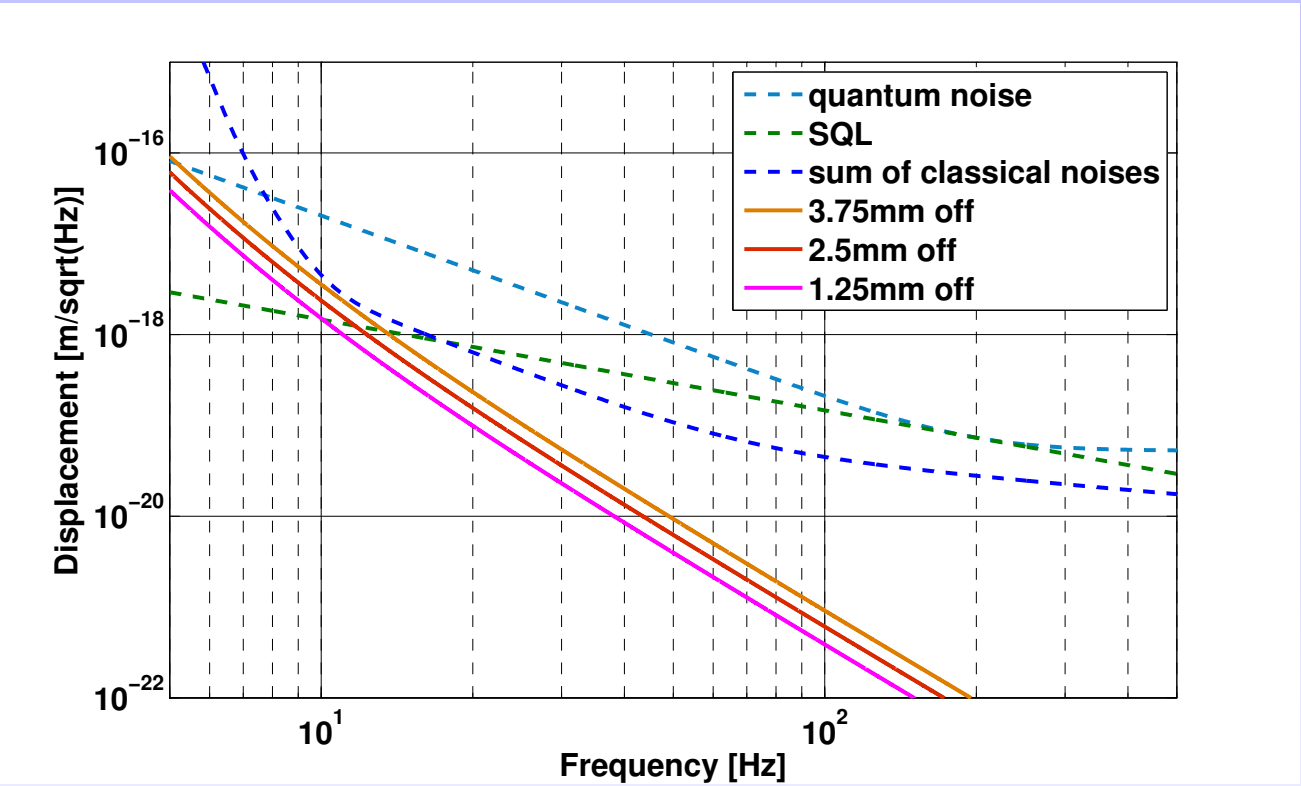
Key-Question: How accurately do we have to position the ESD relative to the mirror in order to not spoil the sensitivity of the AEI-10m?





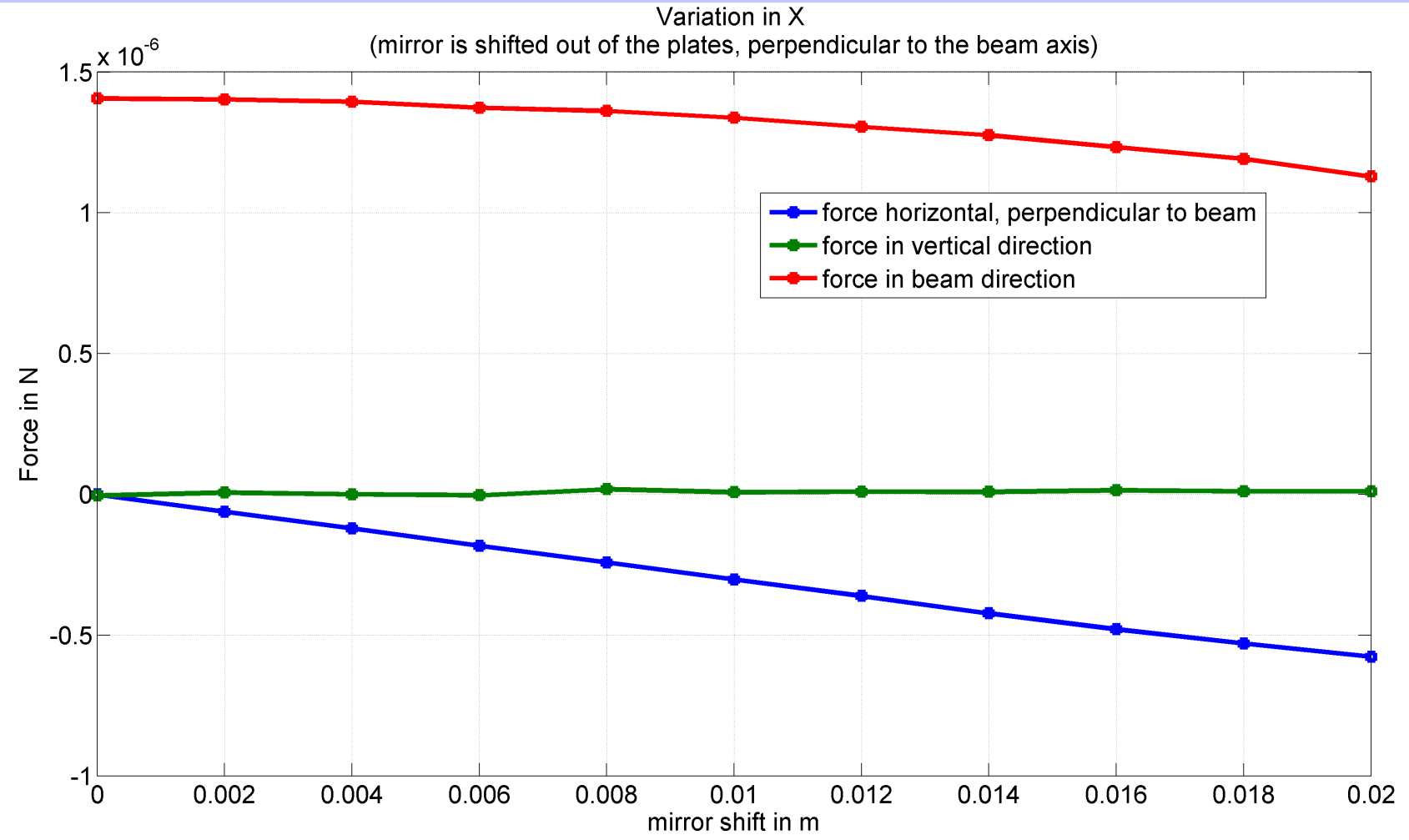
Calculation: Assume some deviation from optimal positions. Take corresponding slope from force vs position plot. Then fold it be the expected movement of the tables (seismic and table transferfunction taken from labbook 205).

Coupling of seismic for mispositioned ESD: Result

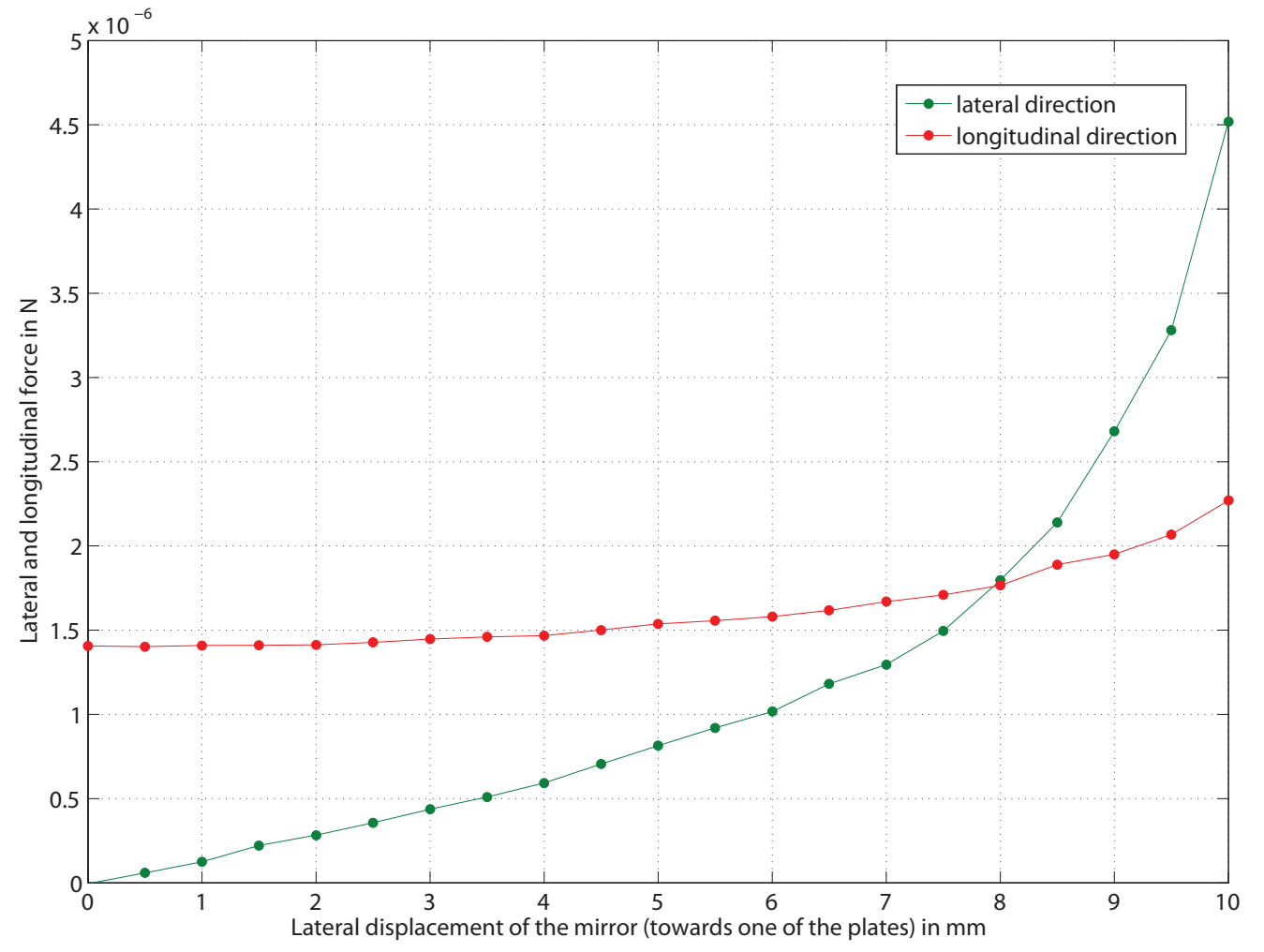


Assuming that the table performance will be achieved and that we are able to position the mirror and ESD in respect to each other within a few milimeter, noise wise it would be ok to mount the ESDs directly onto the tables.

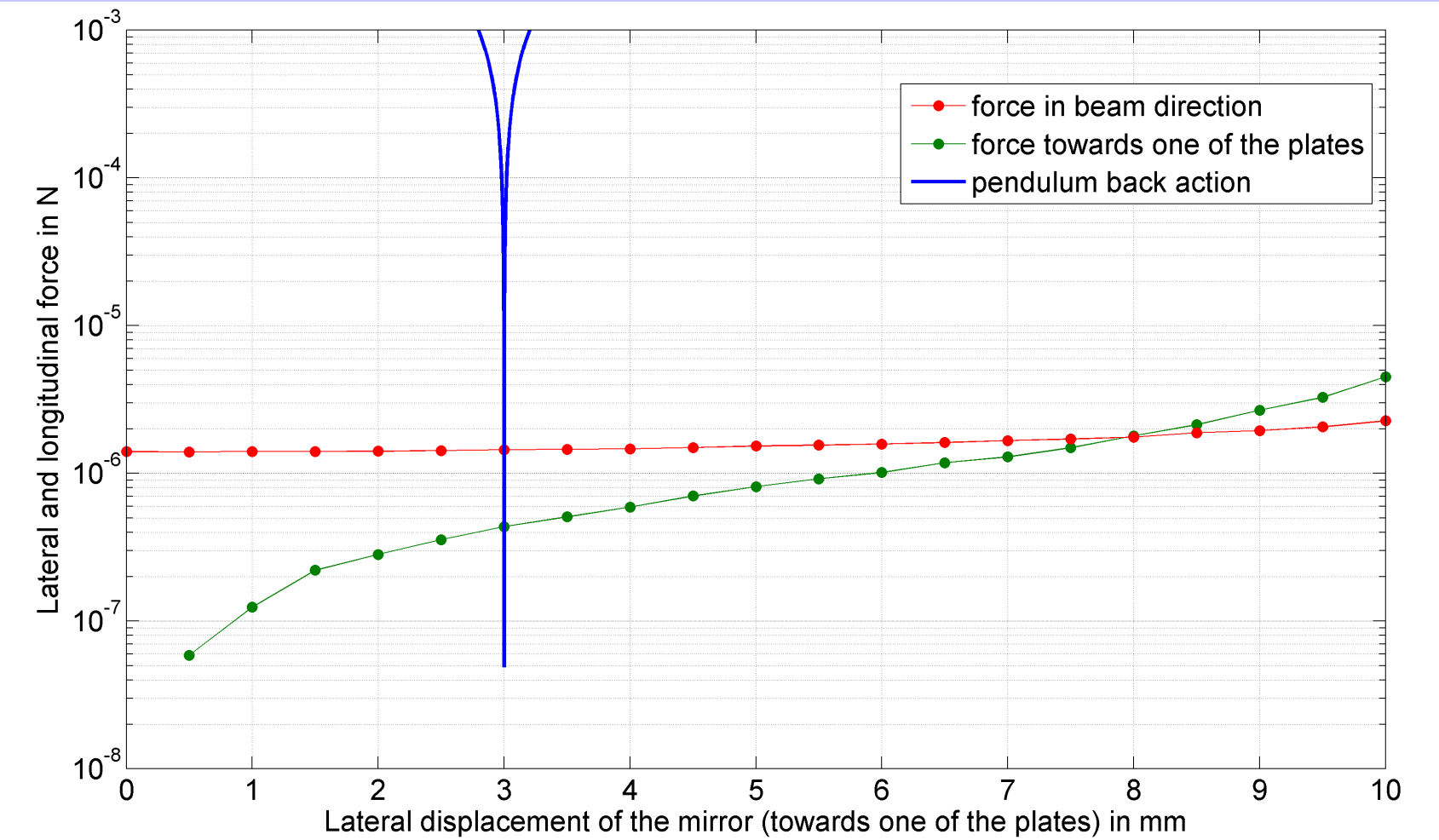
Miscentering out of the plates



Miscentering towards plates



Miscentering towards plates



Conclusion

Conclusion:

- GEO-style ESDs are not suitable for the prototype
  $\Rightarrow$ therefore we investigated a plate ESD design

Generally the force on the mirror depends on its position
But there is a maximum! $\Rightarrow$ Operating point

- Plate ESDs provide forces in the order of micro N
- They could be directly mounted onto the tables in terms of noise

Outlook

Things to be done:

- Look at various type of tolerances ...
- Look test mass rotation and tilt ...
- charged testmass ...