Some design ideas for the electro-static drives (ESD) of the AEI-10m prototype

Holger Wittel & Stefan Hild

March 26, 2010

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:

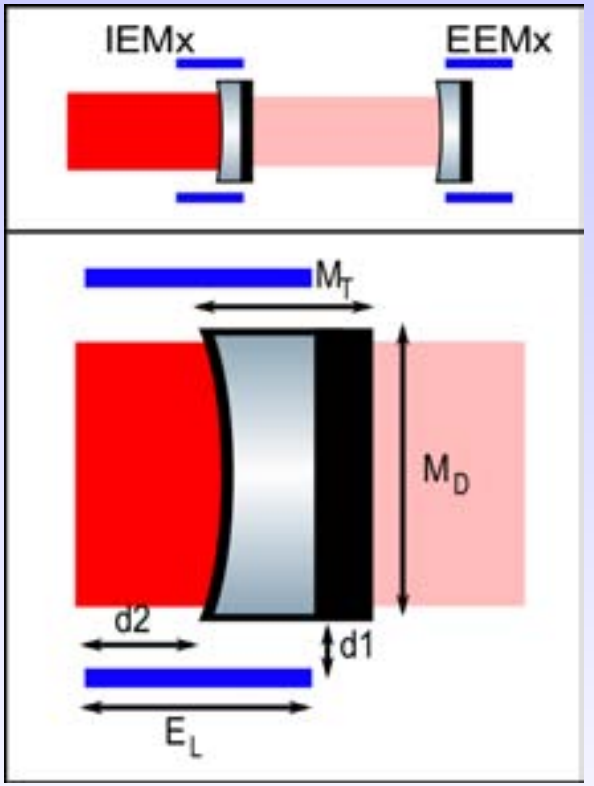
- Beam size at the test masses is driven by demanding thermal noise requirements.
- Beam uses the full mirror size (mirror is only 2.5 times larger than beam $\Rightarrow$ even for optimal centering we have 4 ppm clipping losses).
- Cannot make the mirror larger, because that would require heavier mirrors and thus make it harder to measure the SQL.
- 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

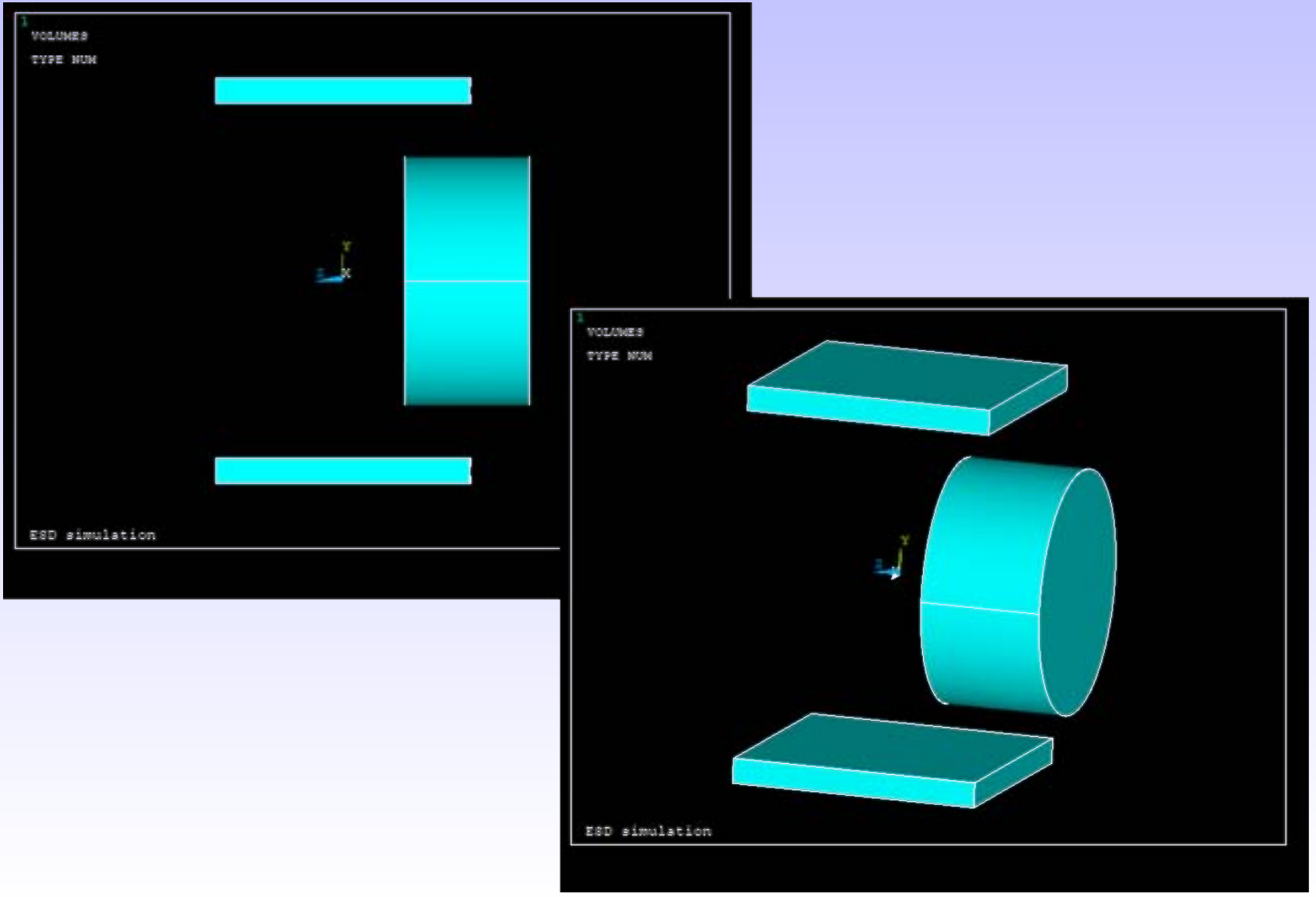
Figure: GEO ESDs

Motivation for a new ESD design

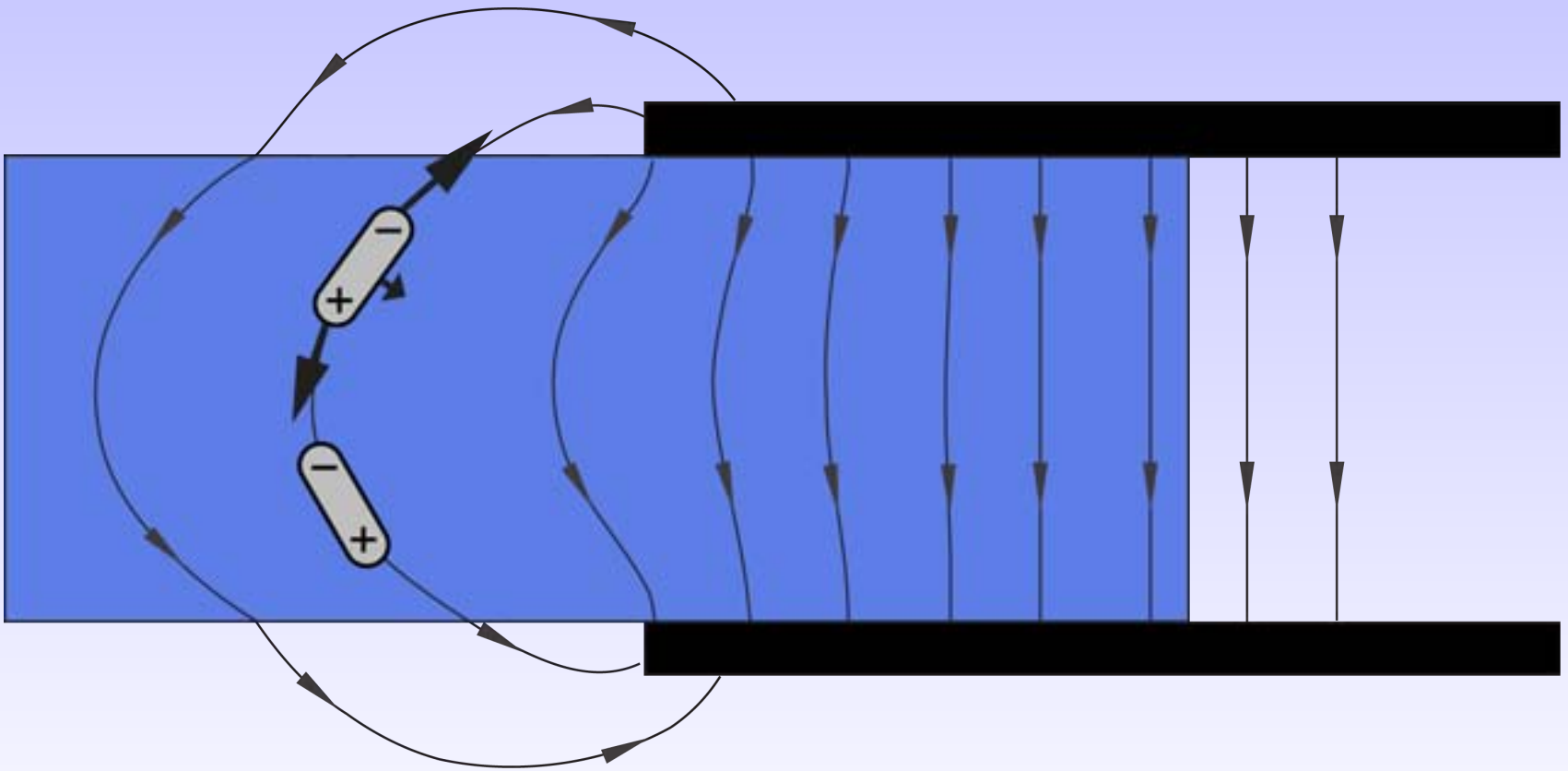
- IDEA: use ESDs made of two plates (see picture)
- Advantage: very large free aperature
- Advantage: There might be a setup where the force onto the mirror is independent of the relative position of ESD and mirror, but just depends on the voltage applied to the ESD.
- **This means very relaxed requirements for the seismic isolation of the ESDs.** Perhaps we could even just bold them down to the tables?



ESD Design


VOLUMES
TYPE NUM
ESD simulation
VOLUMES
TYPE NUM
ESD simulation

Origin of the force



Analytical approximation

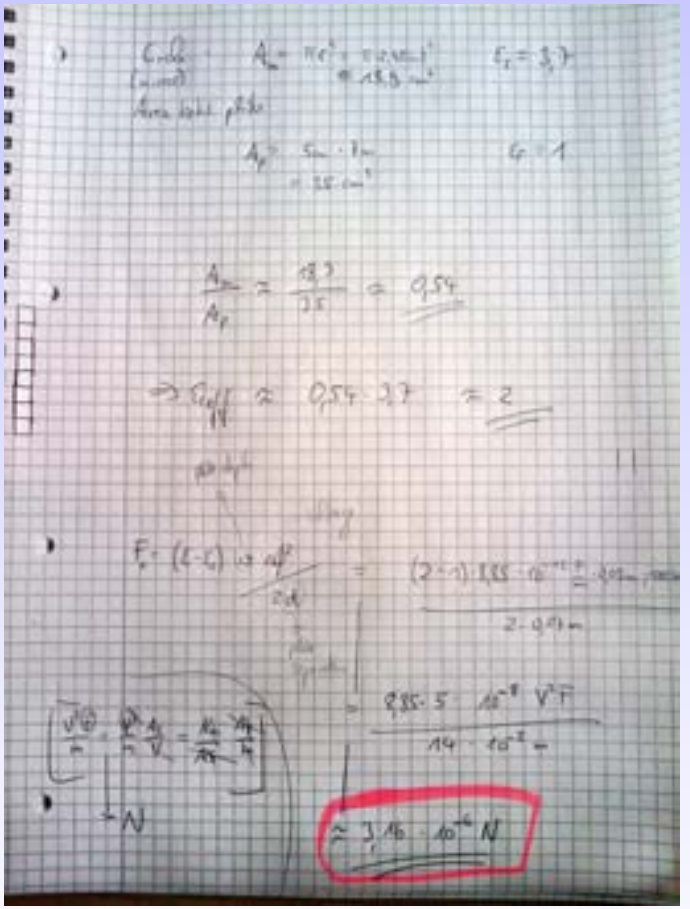
Assumption: big plates, small gap

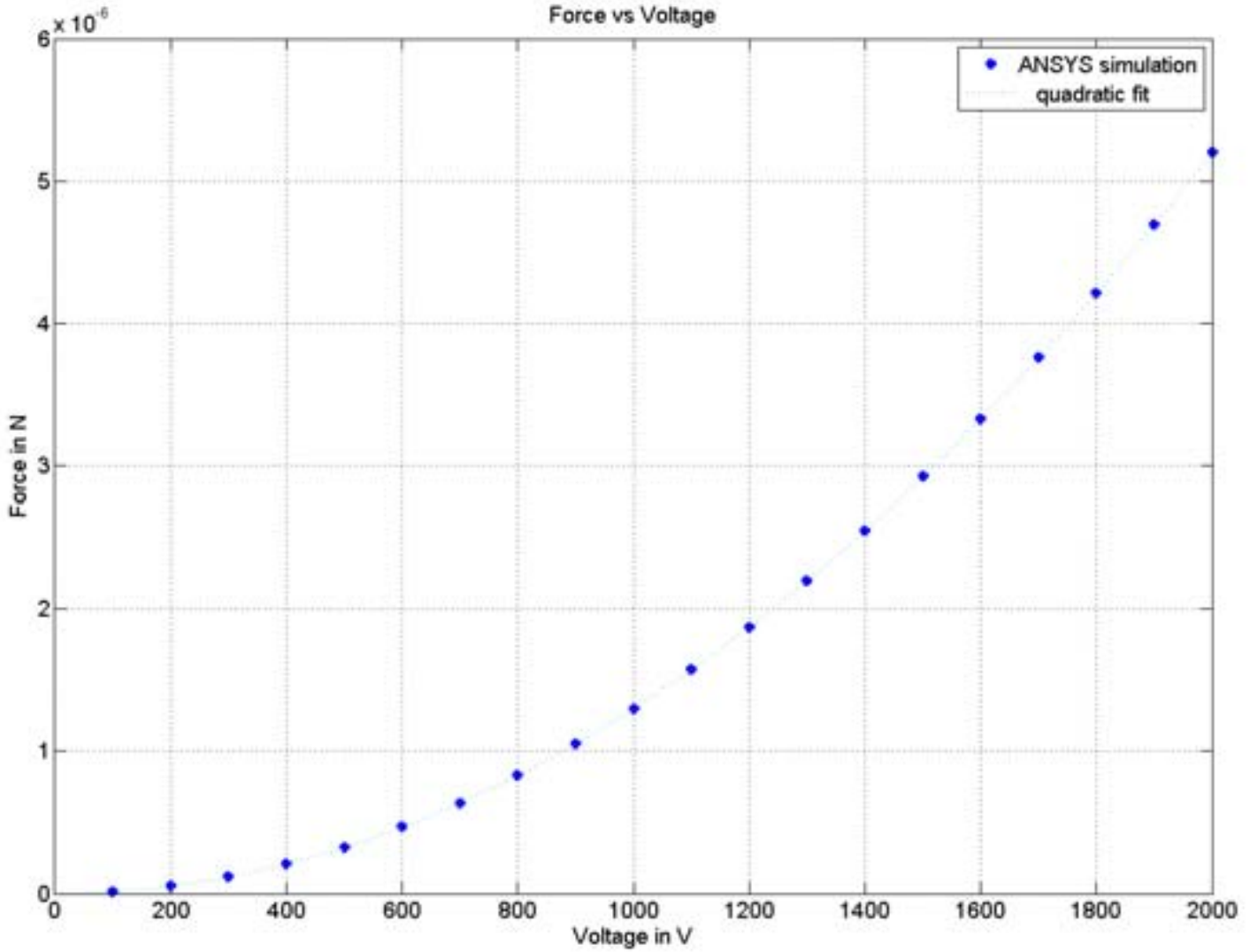
$$F = (\epsilon - \epsilon_0) \cdot \omega \cdot U^2 / 2d$$

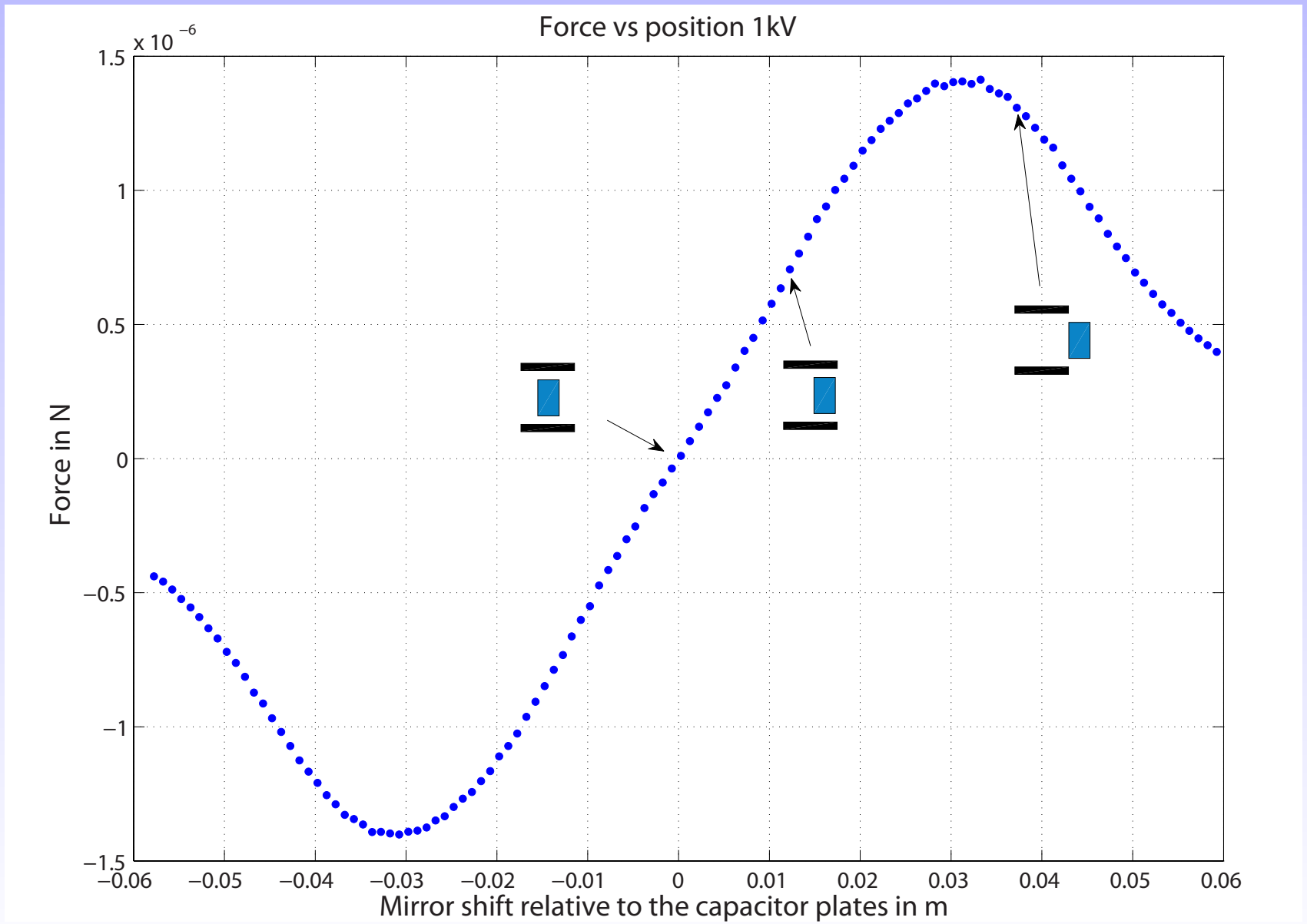
$U \hat{=}$ voltage

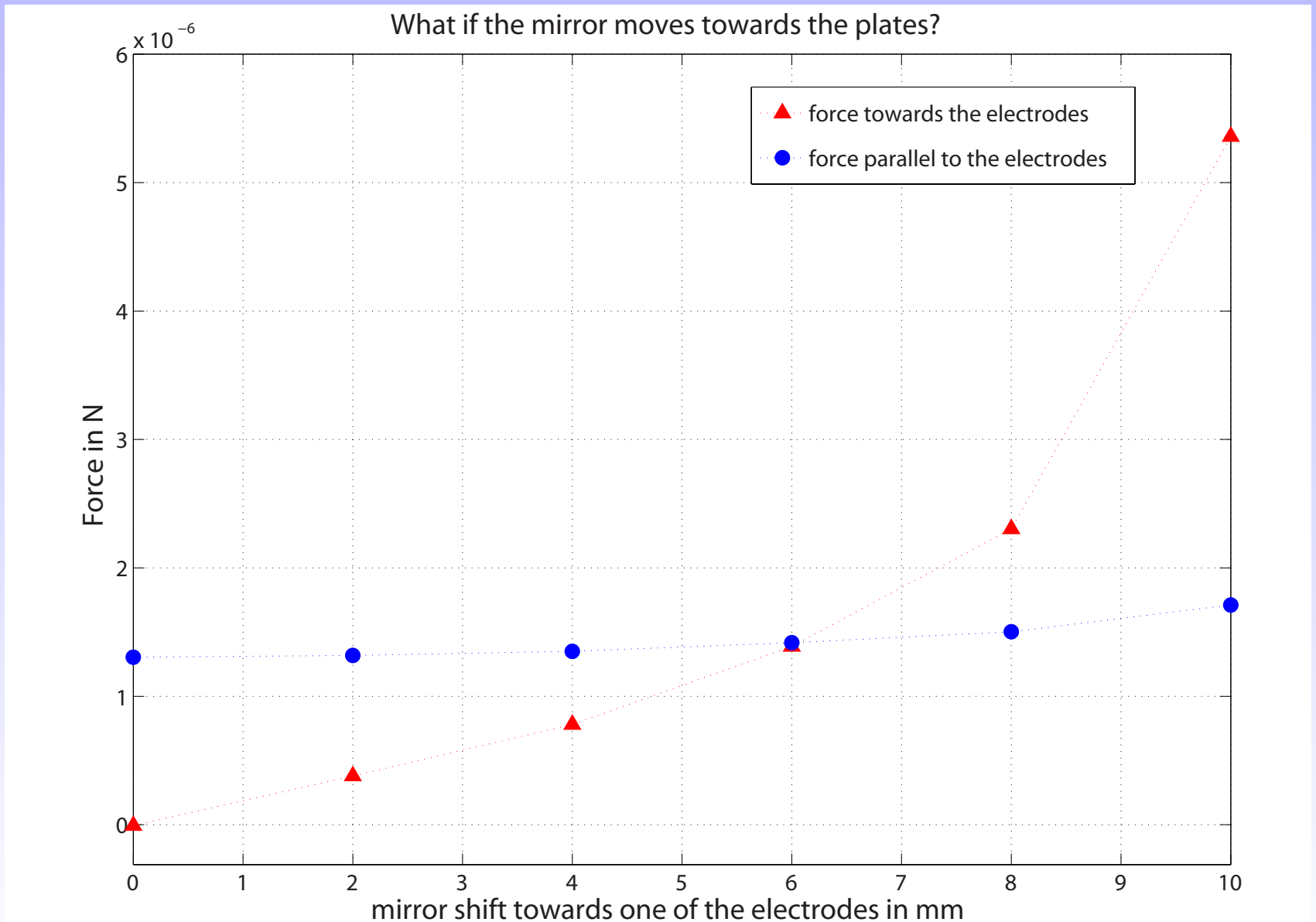
$\omega \hat{=}$ plate depth

$d \hat{=}$ plate distance



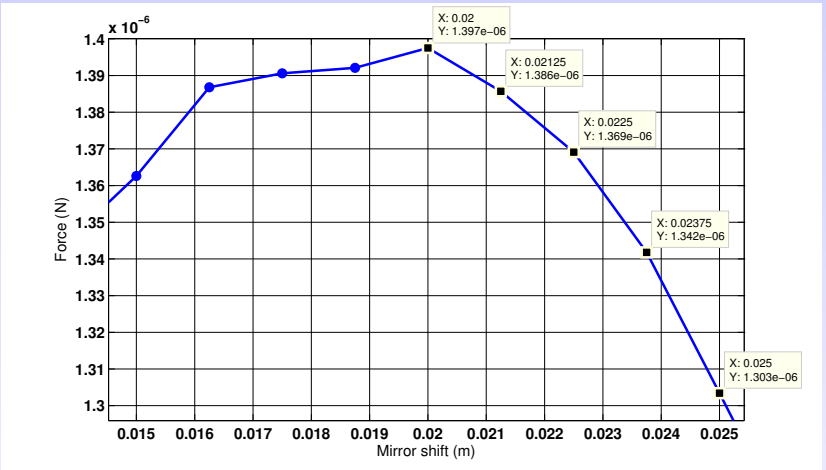

Force vs Voltage
x 10^-6
Force in N
Voltage in V
ANSYS simulation
quadratic fit
0
1
2
3
4
5
6
0
200
400
600
800
1000
1200
1400
1600
1800
2000

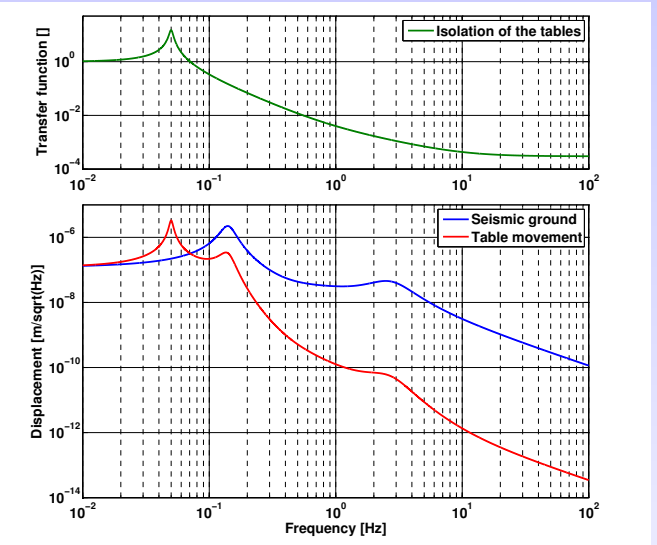

Force vs position 1kV
x 10 −6
1.5
1
0.5
0
−0.5
−1
−1.5
Force in N
−0.06
−0.05
−0.04
−0.03
−0.02
−0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
Mirror shift relative to the capacitor plates in m


What if the mirror moves towards the plates?
x 10 −6
6
5
4
3
2
1
0
Force in N
force towards the electrodes
force parallel to the electrodes
0
1
2
3
4
5
6
7
8
9
10
mirror shift towards one of the electrodes in mm

Coupling of seismic for mispositioned ESD

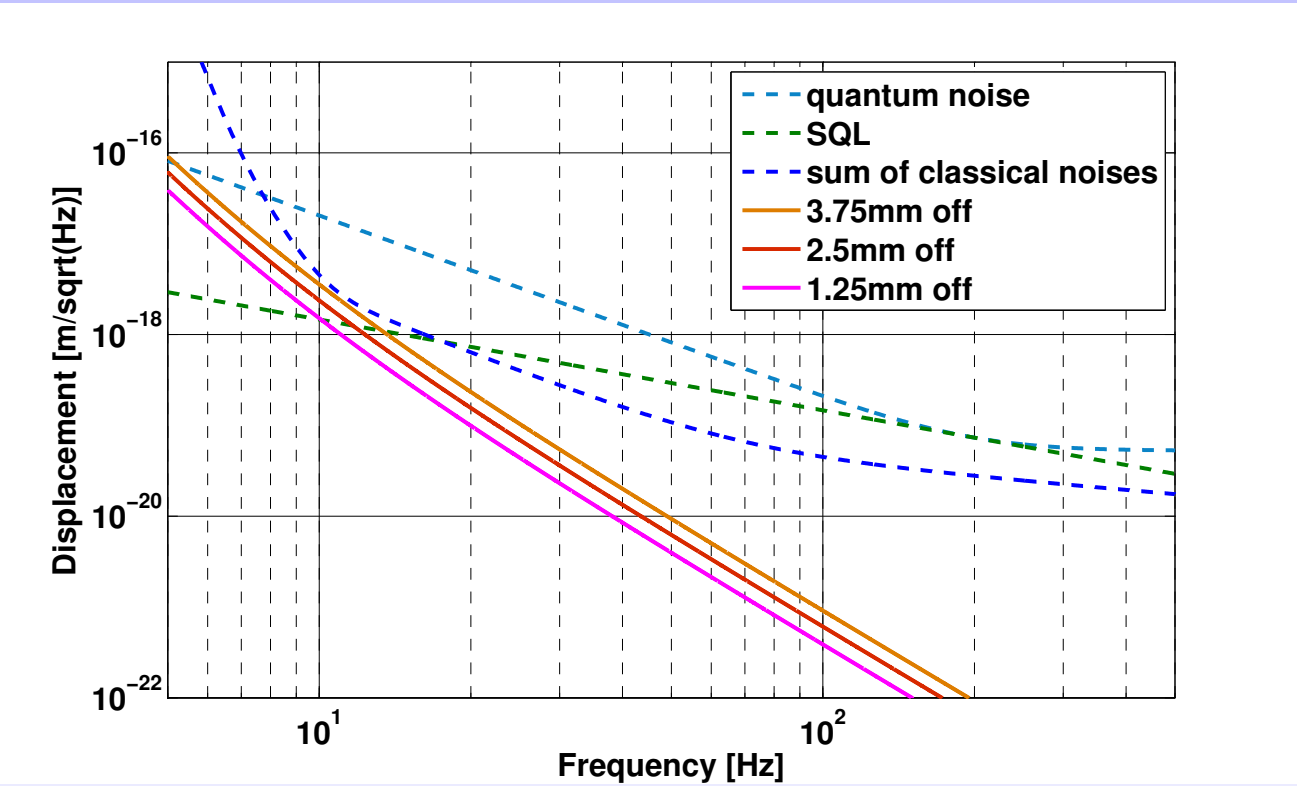
Key-Question: How accurately do we have to position ESD relative to the mirror in order to not spoil the sensitivity of the AEI-10m?





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.

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

Plenty things remain to be done:

- Stability of test mass position perpendicular to beam axis. Perhaps we can go for horizontal orientation of ESD plates? How would this work with the monolithic suspensions?
- Look at various type of tolerances ...
- Look test mass rotation and pitch ...
- Look at cross coupling from EETM to IETM and vice versa ...

Two important questions:

1. When do we have to settle on the design for the longitudinal actuators for the main test masses?
2. Would we dare to go for such a new concept without any 'prototype' or other form of previous demonstration?