Modeling extracellular potentials in a cortical slice preparation

Chaitanya Chintaluri
c.chintaluri@nencki.gov.pl

Supervisor: Daniel Wójcik

Nencki Institute of Experimental Biology, Warsaw, Poland.
Open Source Brain meeting, Sardinia, 15th May, 2014

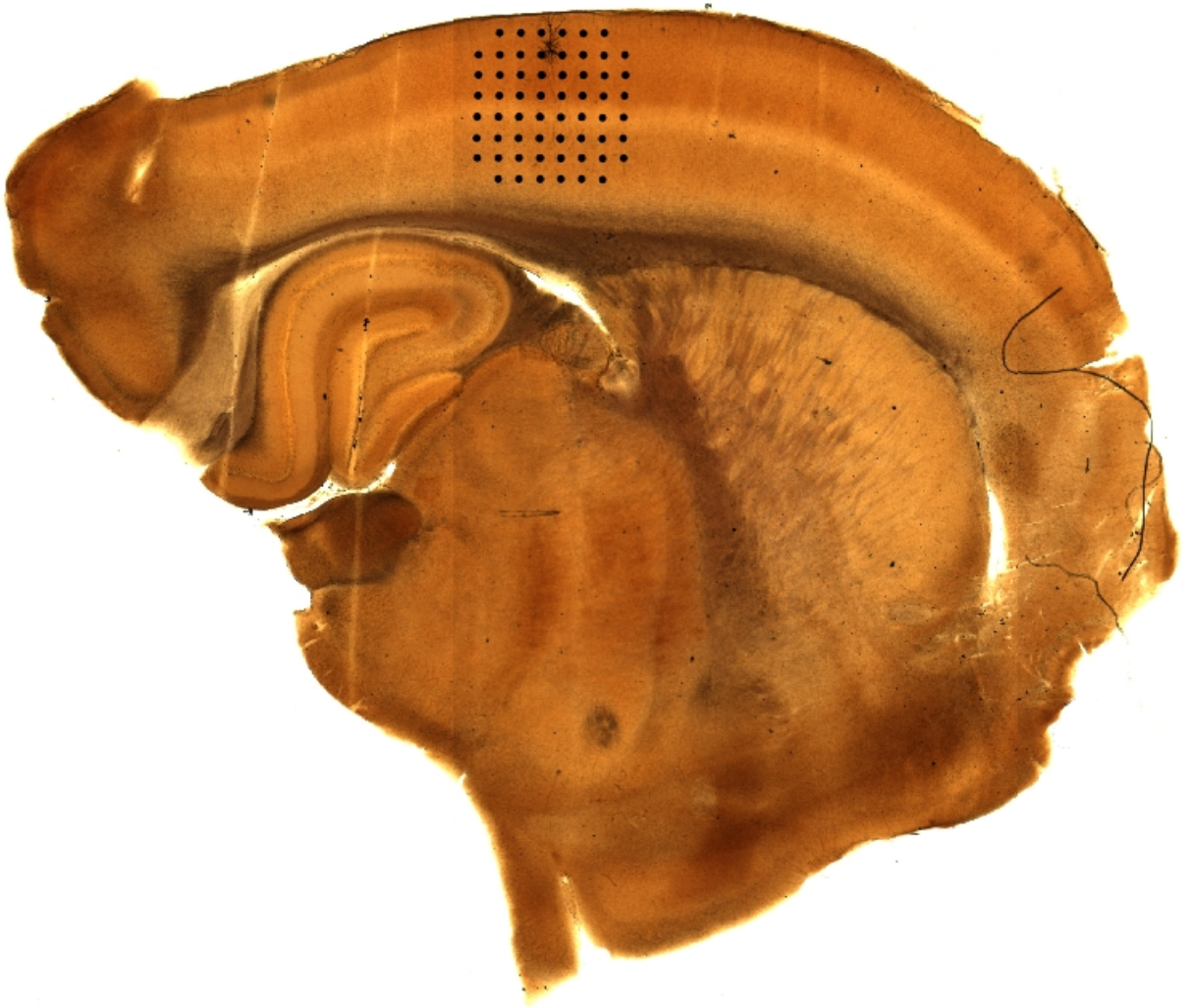
Cortical slice preparation

*

- Acute brain slices
- MEA – Multielectrode Arrays
- Applications

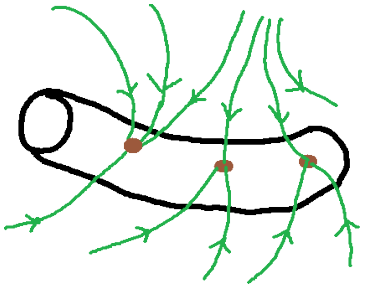
* wikimedia commons, source Dr. Steven M. Potter

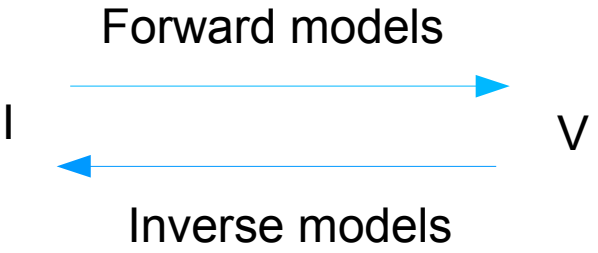
Barrel cortical slices*

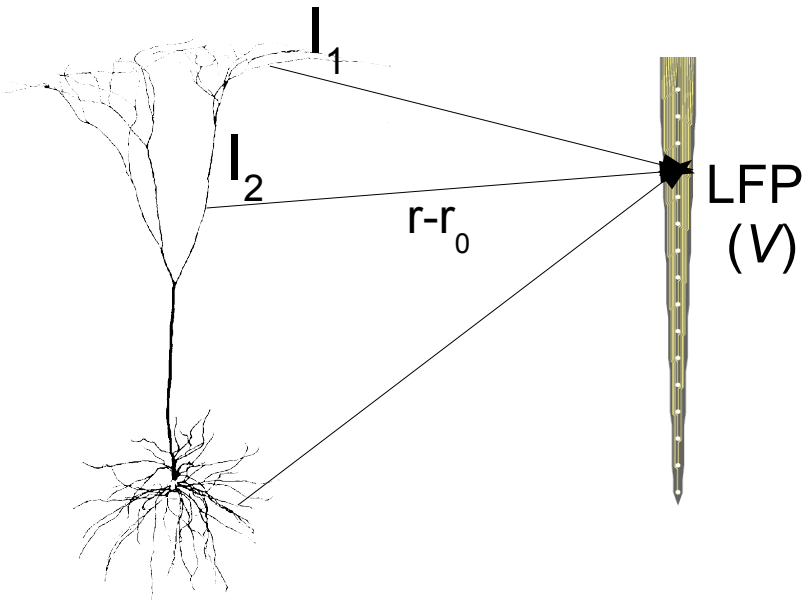


* Dirk Schubert's lab, Donders Institute, Nijmegen

Neural activity – Electrical potentials



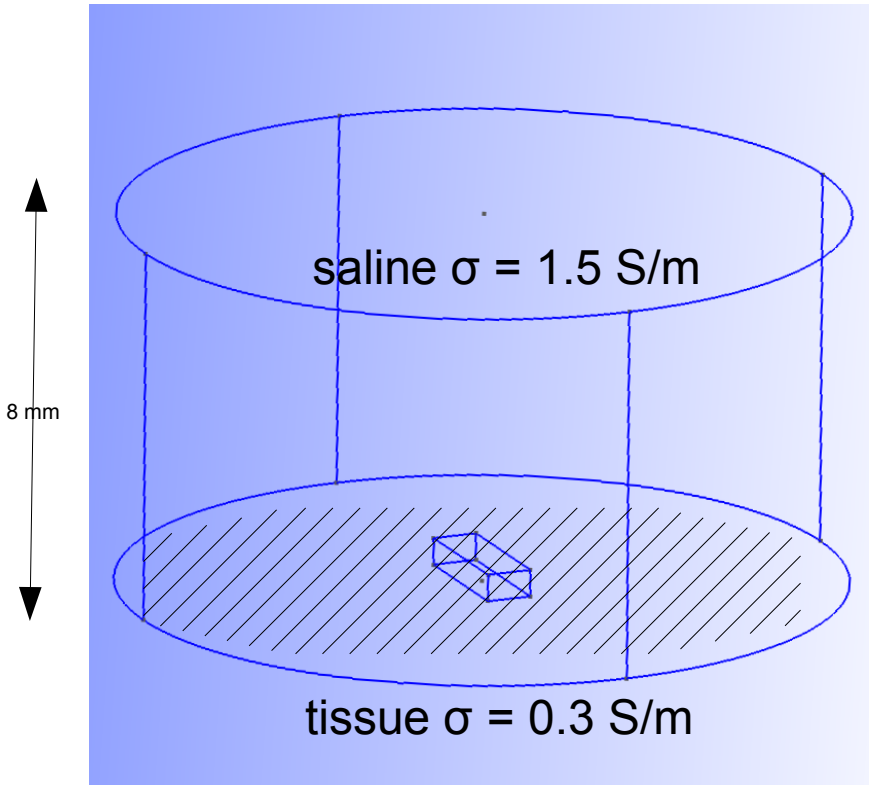




$$\phi(\mathbf{r},t) = \frac{1}{4\pi\sigma}\frac{I_0(t)}{|\mathbf{r}-\mathbf{r}_0|} \quad .$$

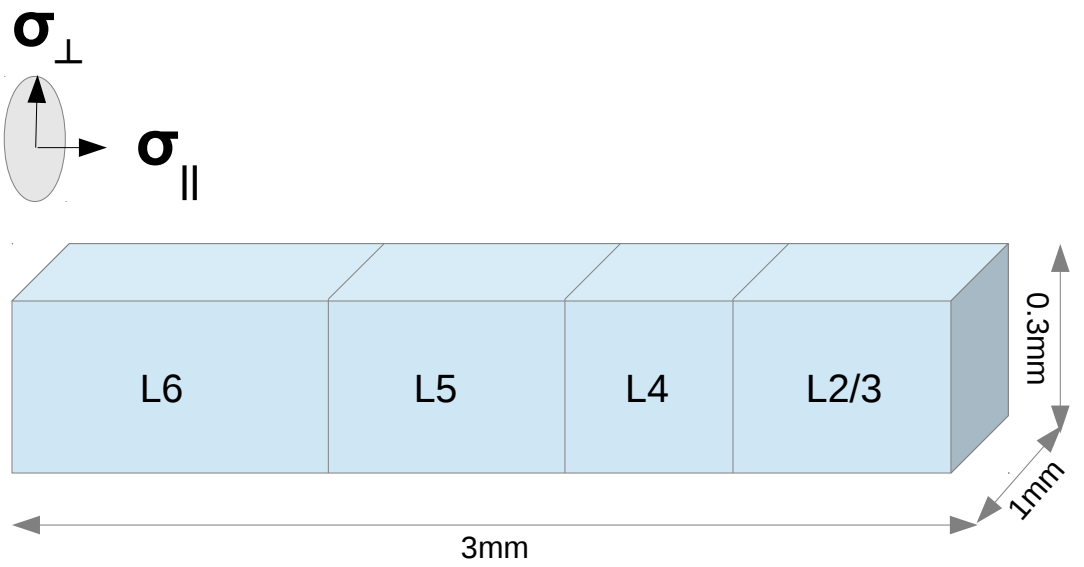
Some assumptions

Conductivity profile of the setup



- Finite volume
- Changing conductivity
- Plane of electrodes (MEA)

Conductivity profile of a cortical slice

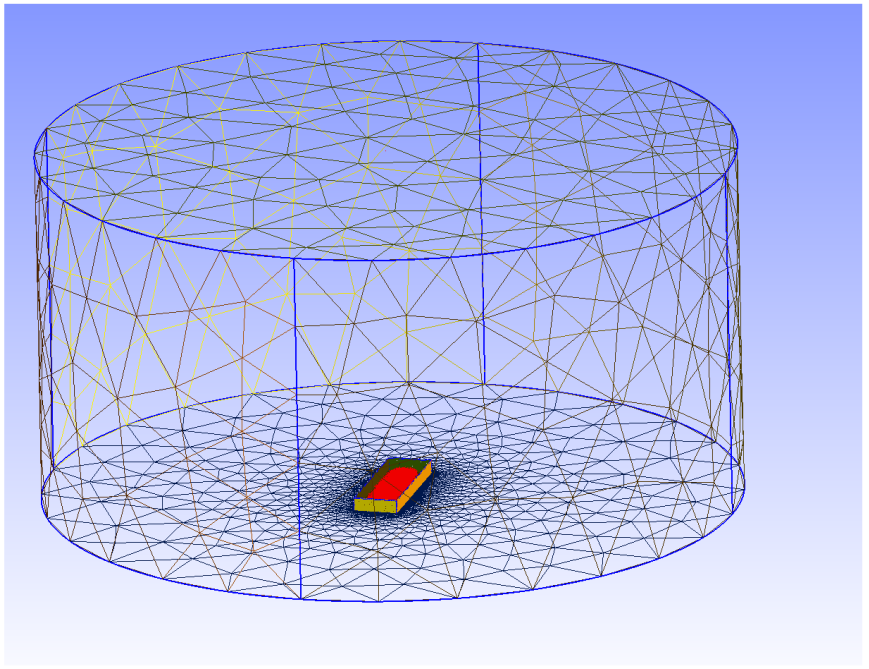


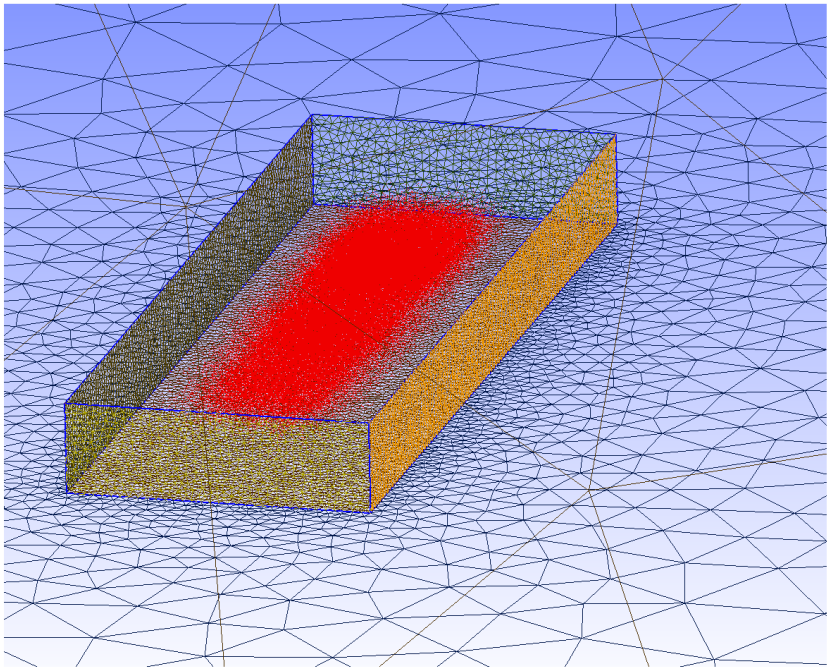
layer	layer depth (μm)	$\sigma_{\parallel}$ (S/m)	$\sigma_{\perp}$ (S/m)
2/3	-400 to 0	0.319 ± 0.043	0.231 ± 0.056
4	-700 to -400	0.325 ± 0.067	0.240 ± 0.093
5	-1200 to -700	0.353 ± 0.063	0.228 ± 0.047
6	-1700 to -1200	0.294 ± 0.062	0.268 ± 0.067

*

* T.Goto et.al. 2010, J. Neurophysiol

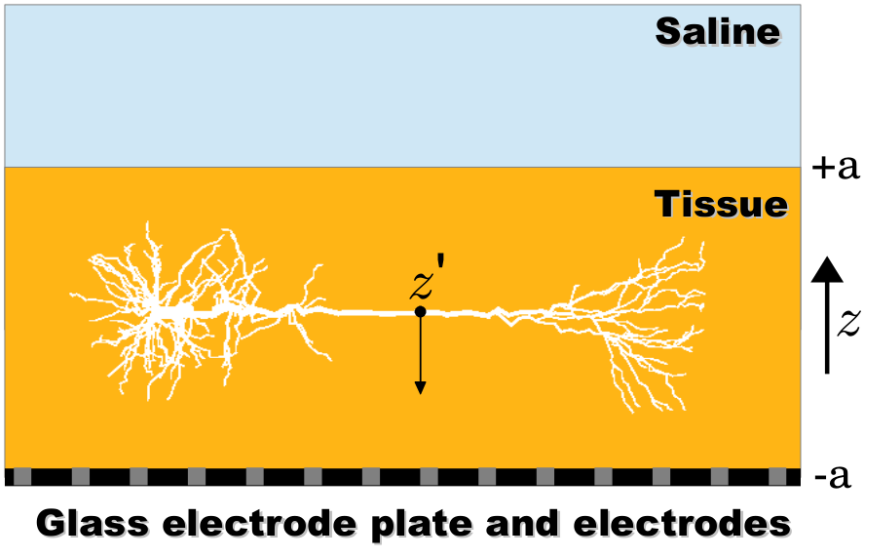
Finite Element Method (FEM)





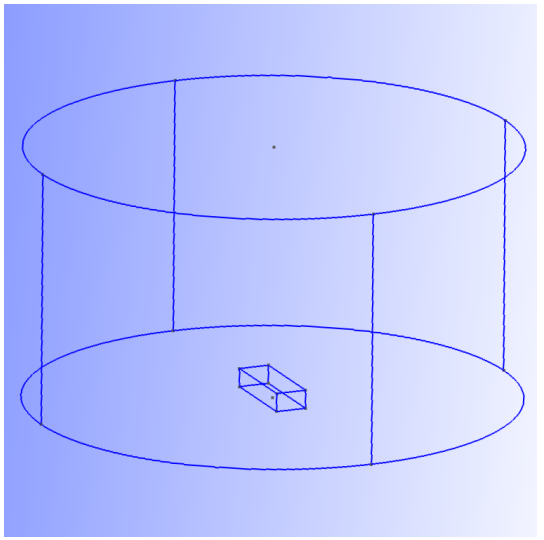
- Gmsh – for defining volume and generating the mesh
- FeniCS – to define conductivity profile, boundary conditions and solve for Maxwell's equation – electrostatic approximation.

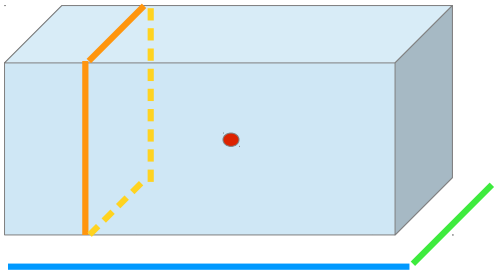
Method of Images (MOI)

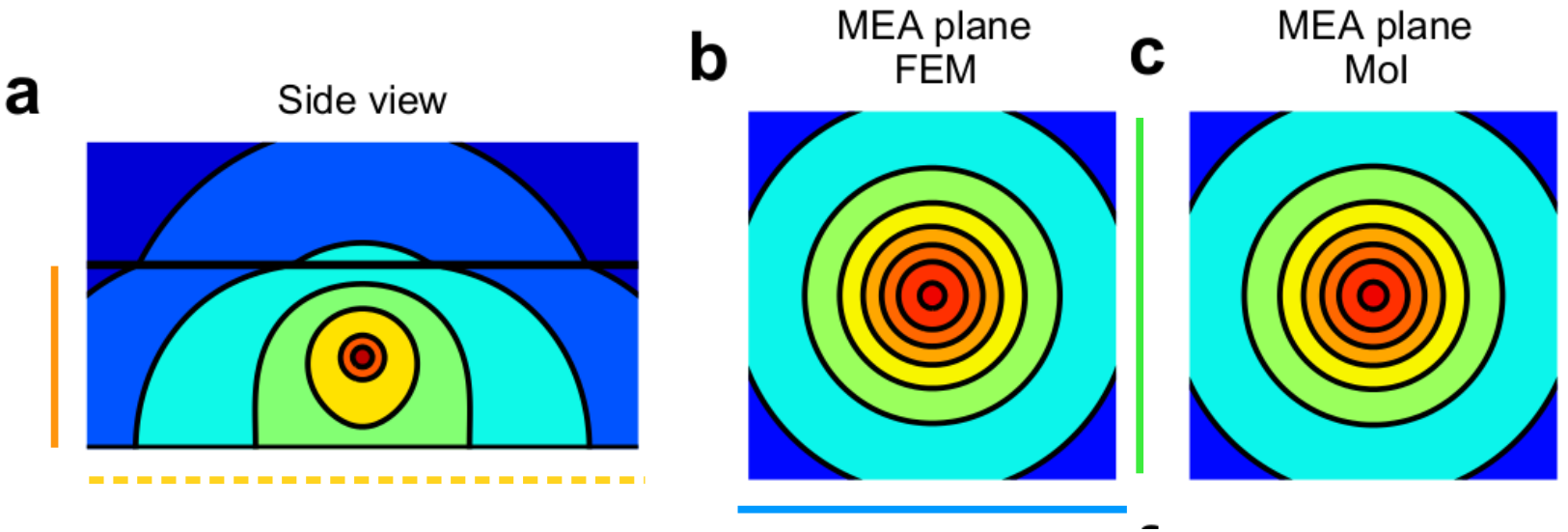


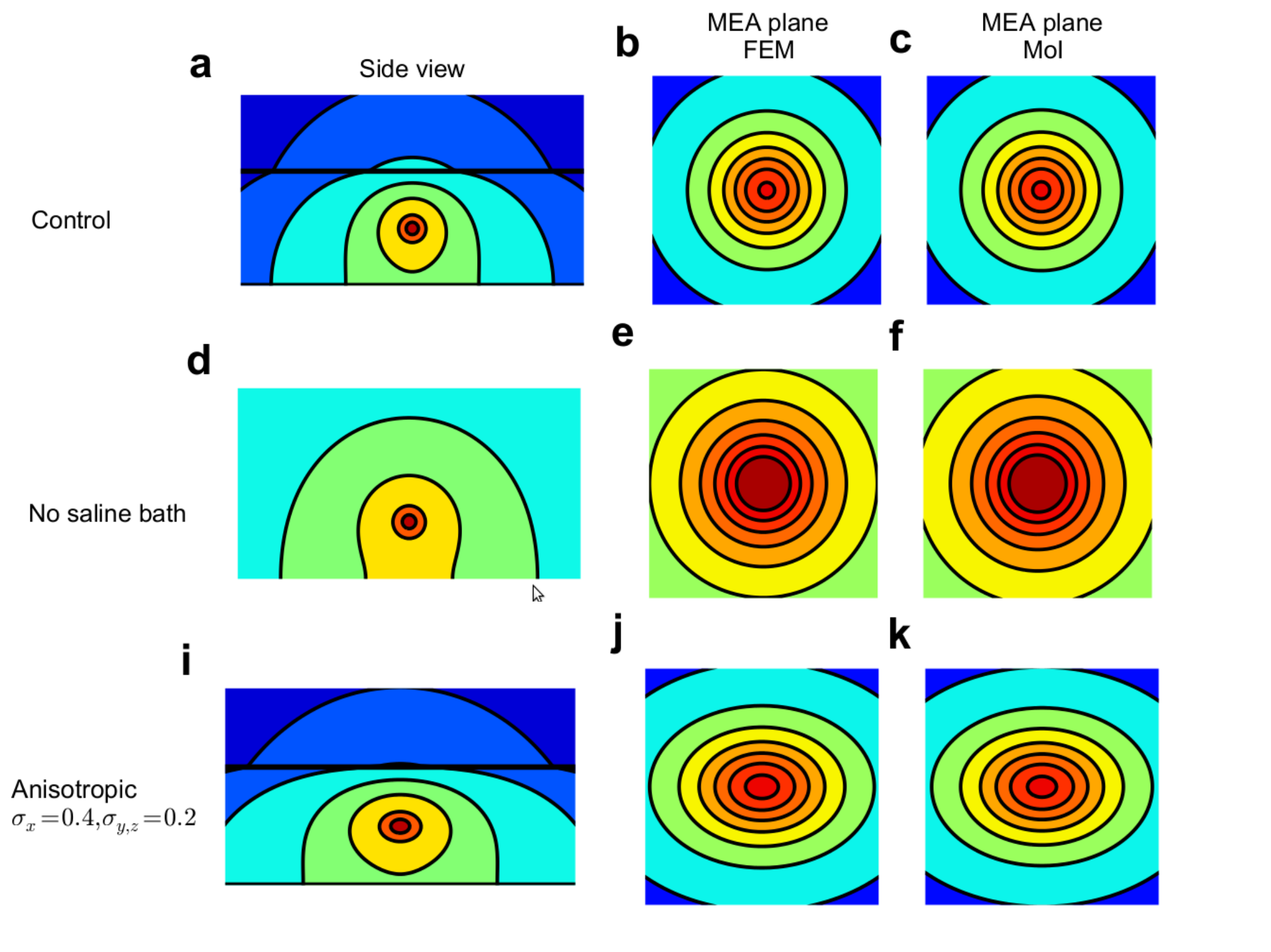
- Simple geometry – most relevant aspect of setup.
- Approximate solution.

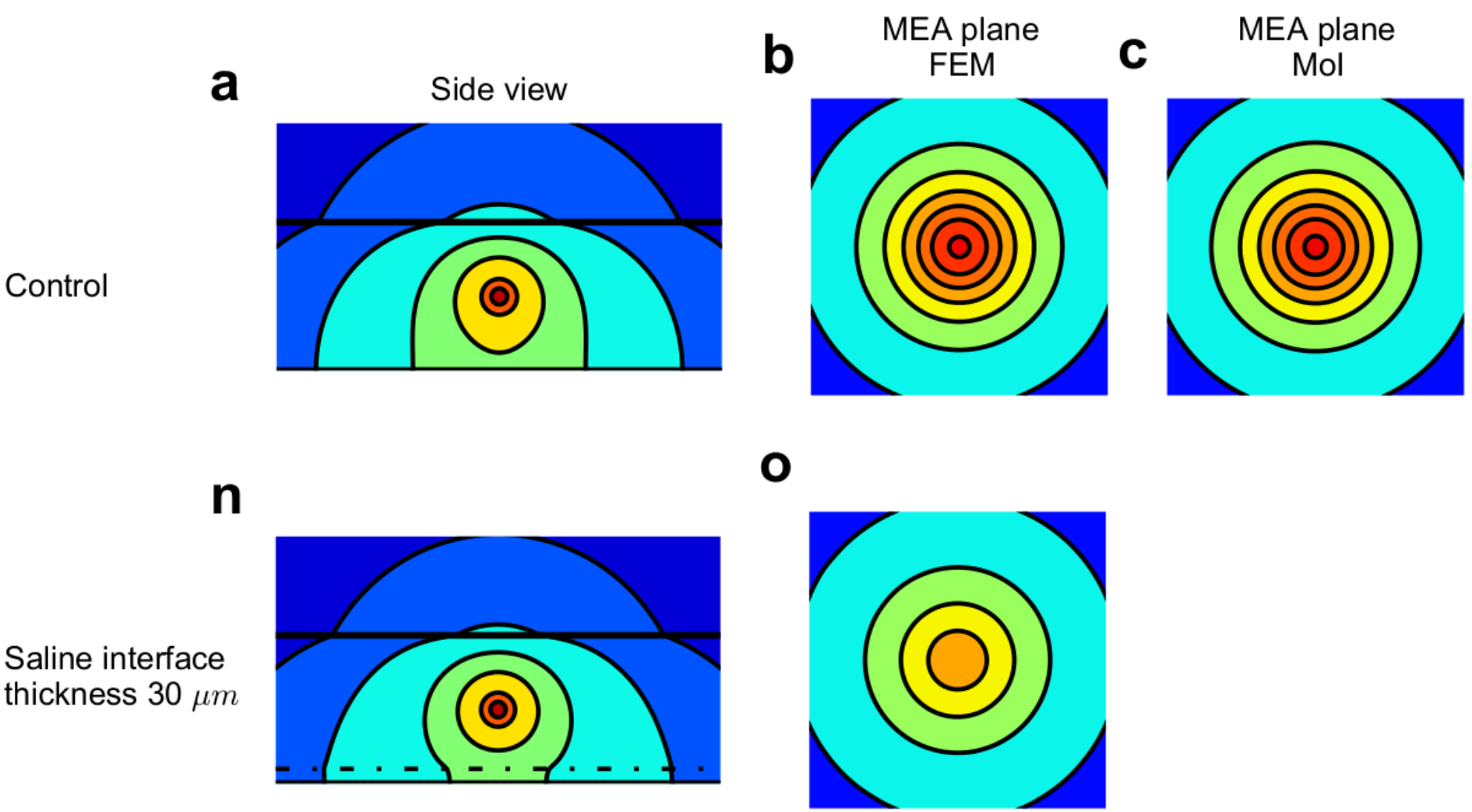
Point current source



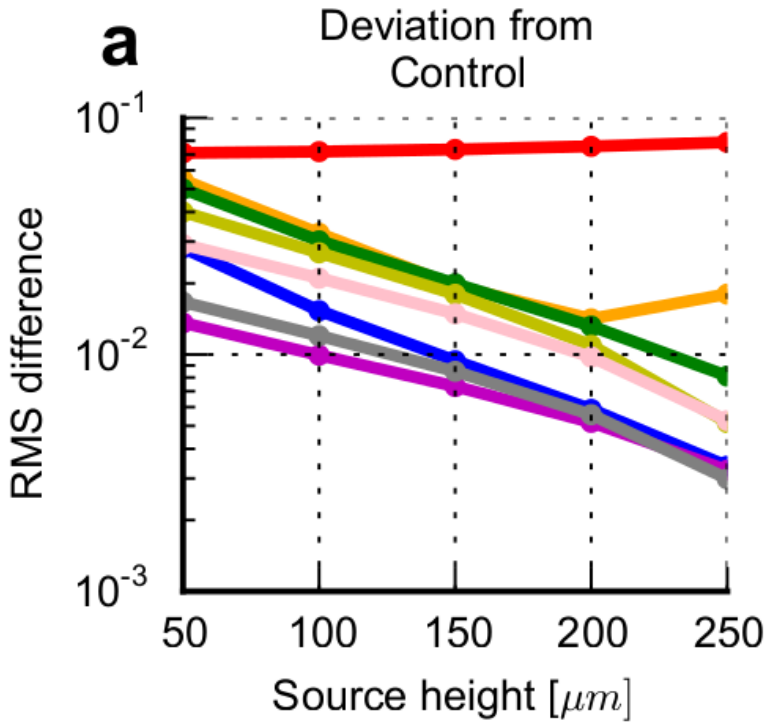


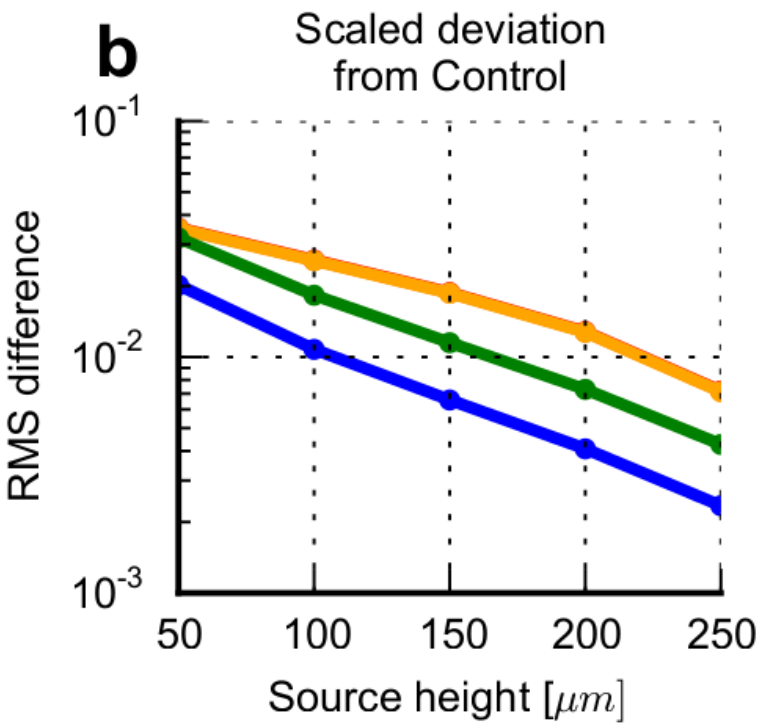



a
Side view
b
MEA plane
FEM
c
MEA plane
MoI
Control
d
e
f
No saline bath
i
j
k
Anisotropic
$\sigma_x = 0.4, \sigma_{y,z} = 0.2$


a
Side view
b
MEA plane
FEM
c
MEA plane
MoI
Control
n
o
Saline interface
thickness 30 μm

What changed? And by how much?





No saline bath

Infinite homogeneous

Saline interface thickness 10 μm

Saline interface thickness 30 μm

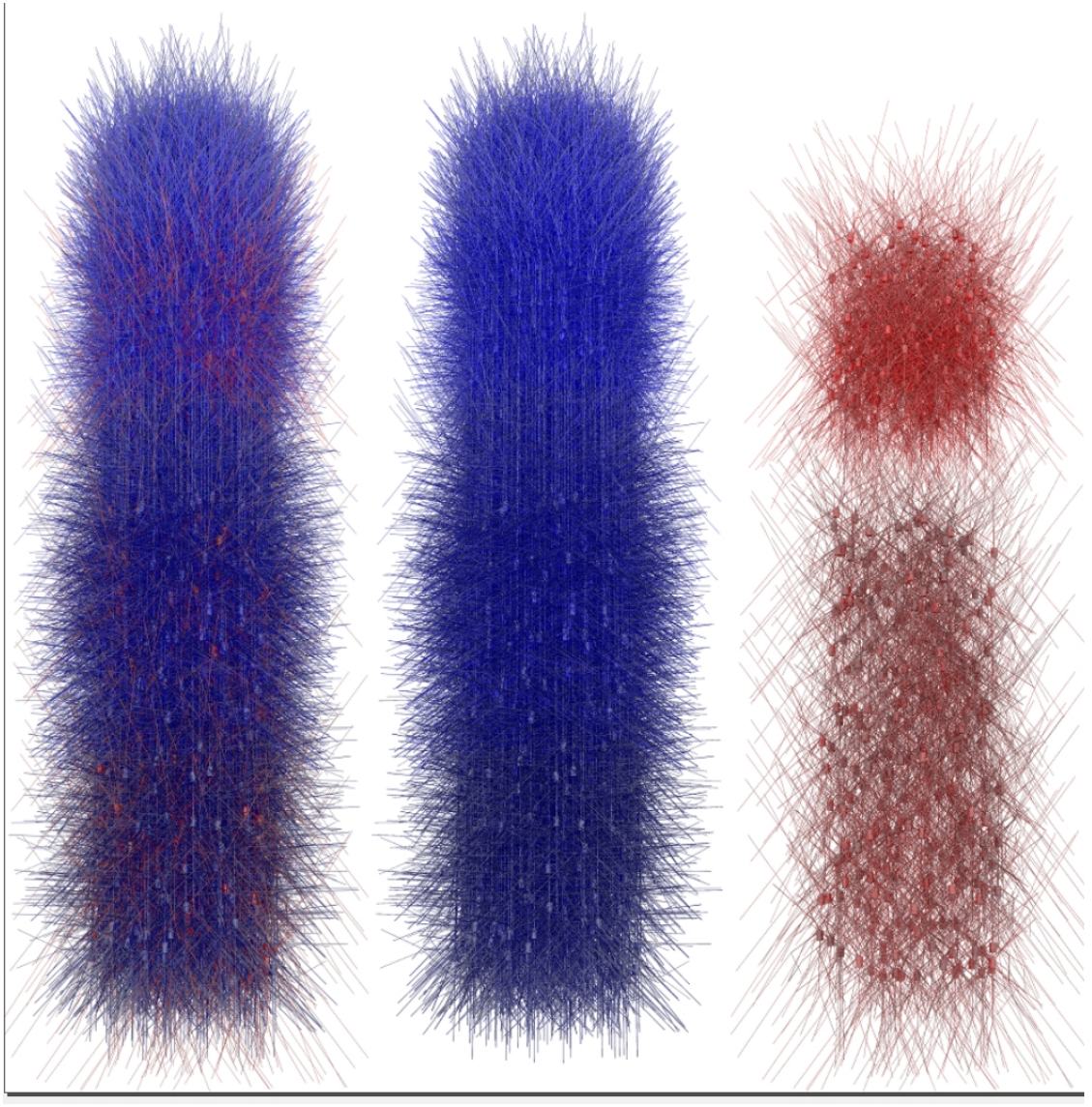
Anisotropic $\sigma_x = 0.4, \sigma_{y,z} = 0.3$

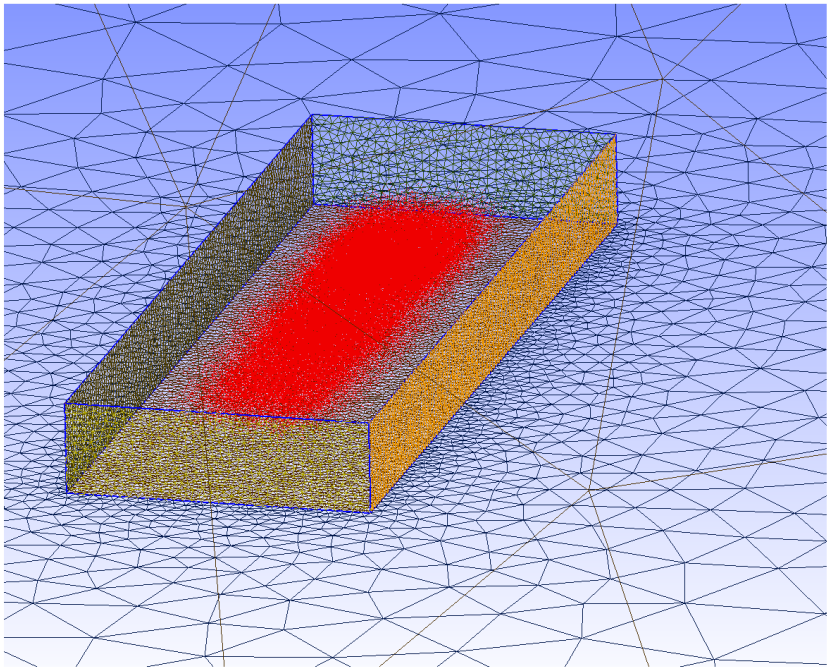
Anisotropic $\sigma_x = 0.4, \sigma_{y,z} = 0.2$

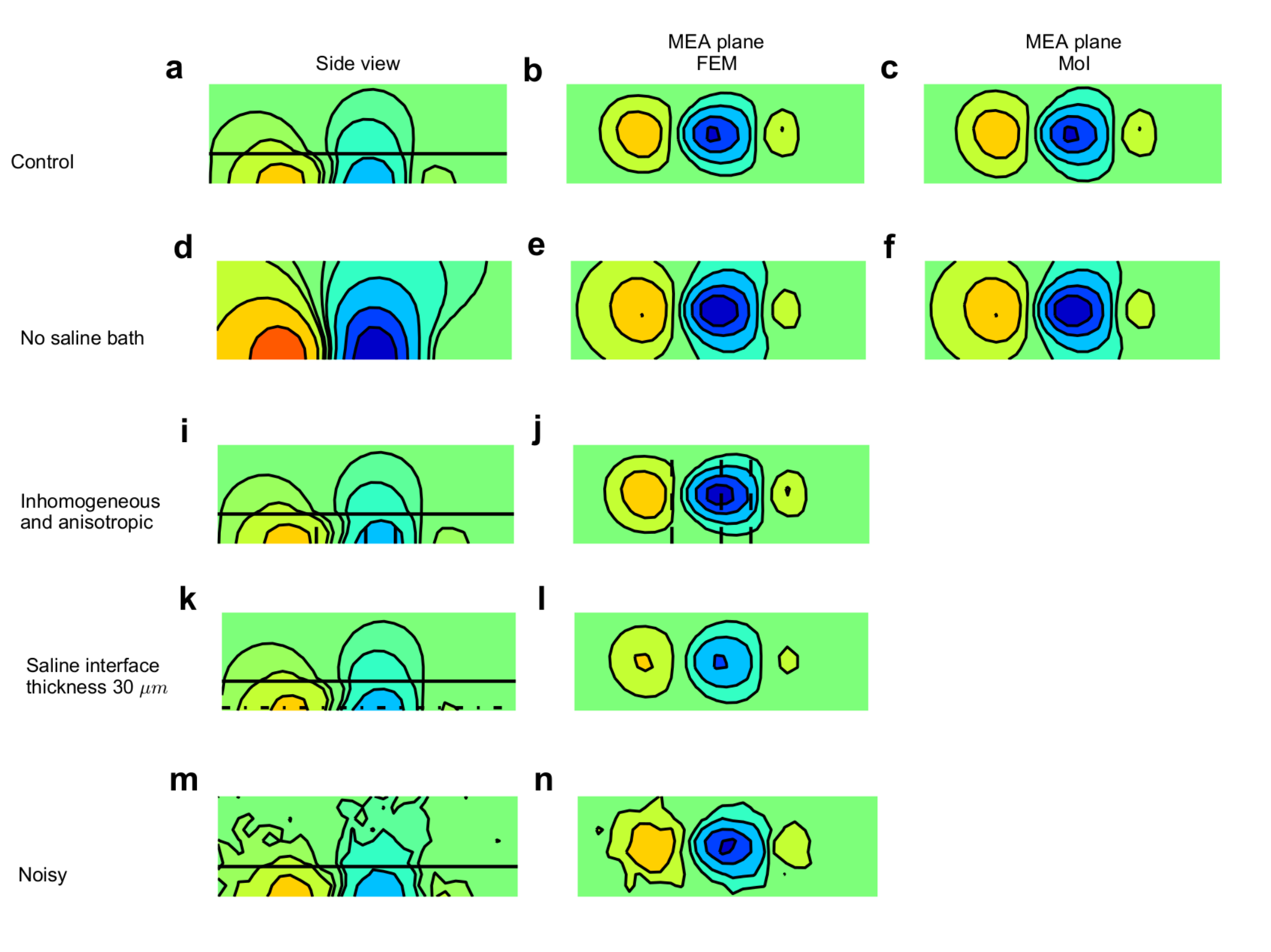
Inhomogeneous $\sigma_{T1} = 0.3, \sigma_{T2} = 0.4$

Inhomogeneous $\sigma_{T1} = 0.3, \sigma_{T2} = 0.5$

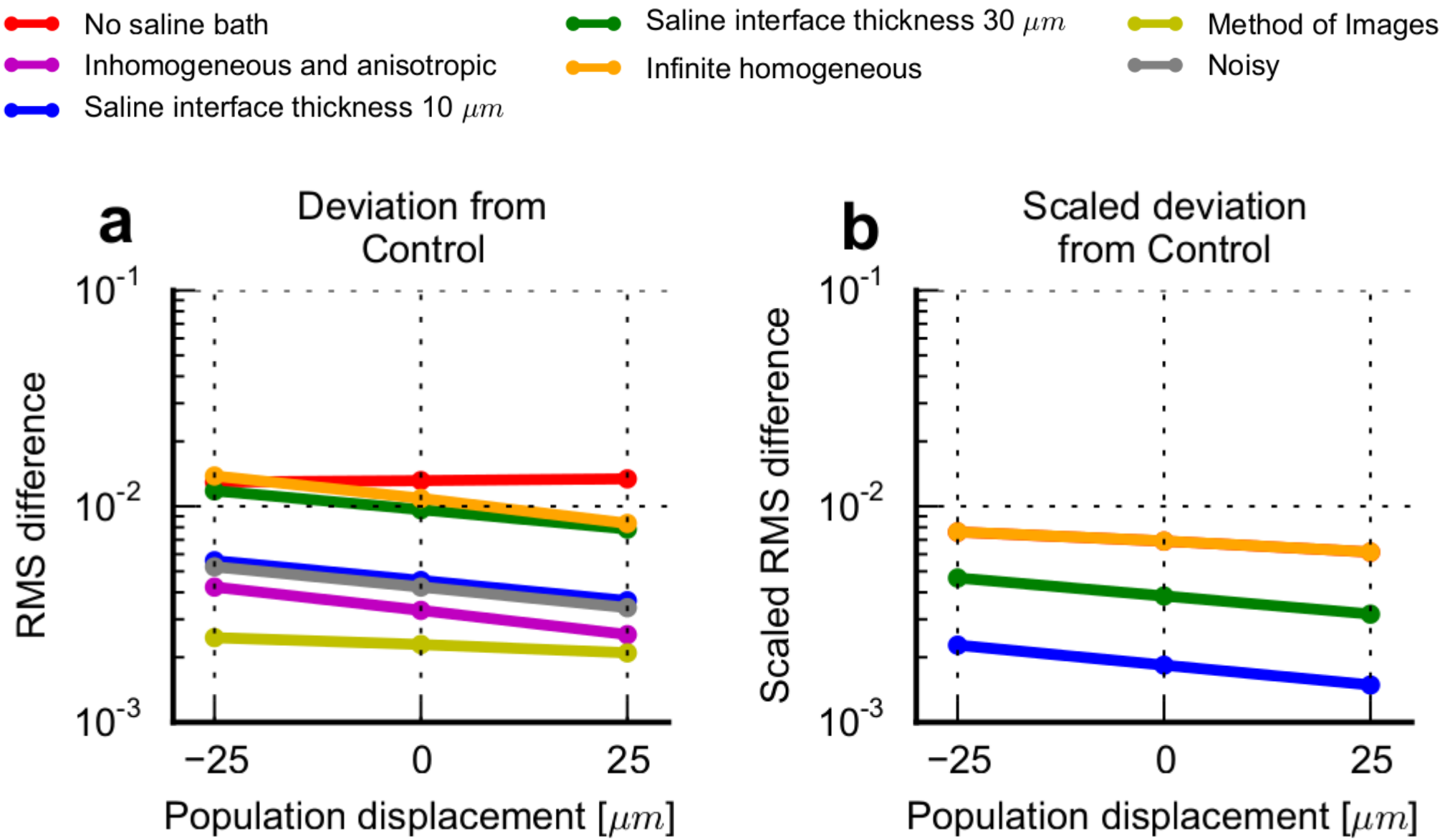
Traub's single column model





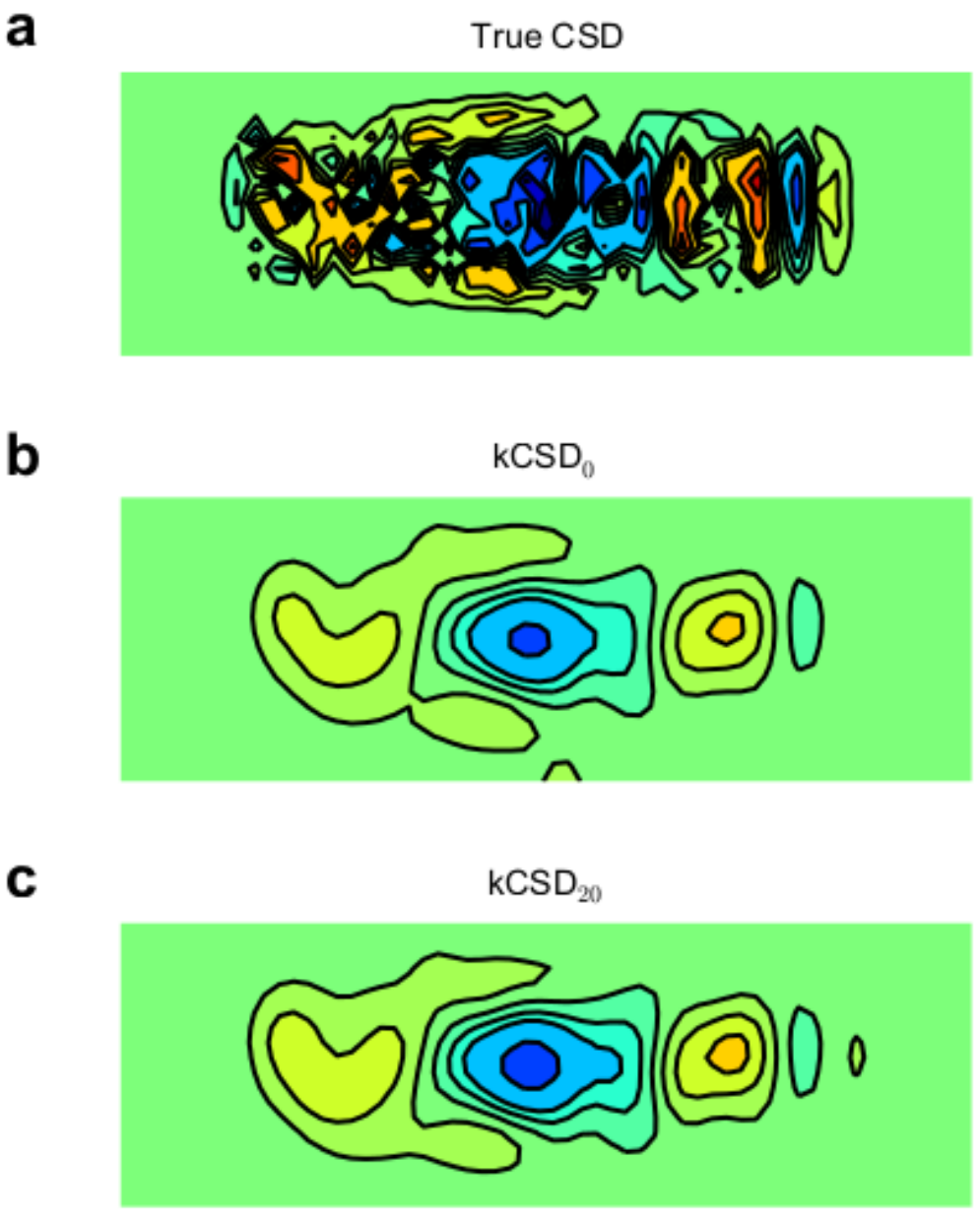

a
Side view
b
MEA plane
FEM
c
MEA plane
MoI
Control
d
e
f
No saline bath
i
j
Inhomogeneous
and anisotropic
k
l
Saline interface
thickness 30 μm
m
n
Noisy

Position within the slice

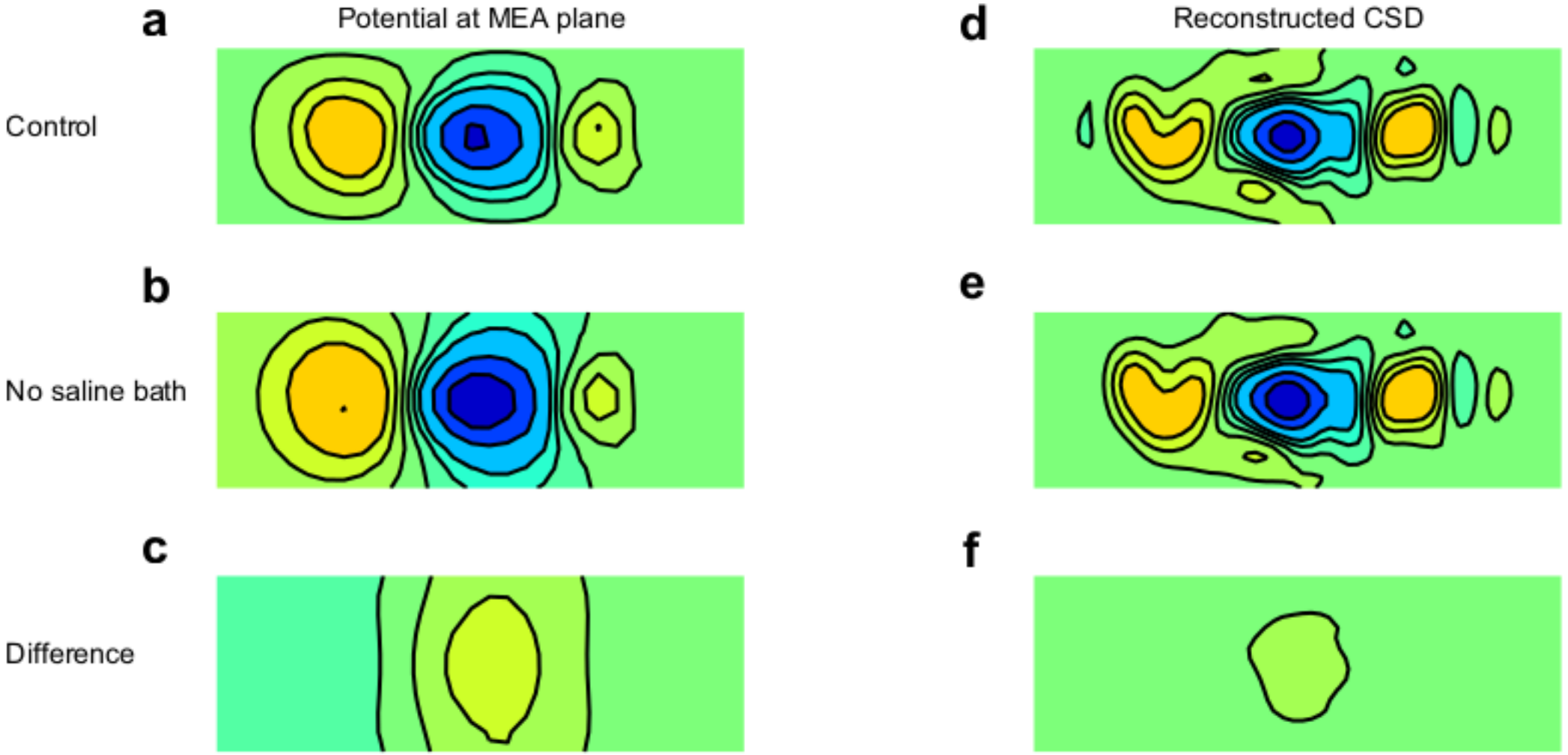


FEM	MOI
Sophisticated conductivity profiles - Inhomogeneity + Anisotropy - Saline interface between MEA and slice - Non trivial geometry	Simple conductivity profile - Two interface (MEA+Saline) - Anisotropy - Simple geometry
Computationally expensive. Not easily portable to other software.	Computationally cheap, and easily portable.
Can be verified independently to existing methods of calculations	Needs FEM like method to estimate accuracy
Inhomogeneity in forward models does not add new information.	The most contributing factor of Saline can be accounted for.

Inverse models



Inverse models – why?



Conclusions

- Modeling saline - important for forward models.
- Modeling inhomogeneity does not add new information.
- MOI versus FEM – which is better, and when.
- Modeling saline for inverse models - CSD reconstructions - does not add new information.

Acknowledgments

Norwegian University of Life Sciences, Aas, Norway

Gaute T. Einevoll

Torbjørn B. Ness

Nencki Institute of Experimental Biology, Warsaw, Poland.

Daniel Wójcik

Jan Potworowski

Szymon Łęski

Helena Głąbska

Laboratory of Neuroinformatics

nencki institute of experimental biology

MARIE CURIE ACTIONS

EC-FP7 NAMASEN ITN

NAMASEN, EC-FP7 PEOPLE Initial Training Network

NSDF – Neuroscience Simulation Data Format

(Subhasis, Chaitanya, Upinder Bhalla, Daniel)

Informal discussion ~ 30 minutes

Relevant to:

- Simulator / Tool developers
- Distribute / save simulation data
- Tests for solvers / simulators

Cheers!