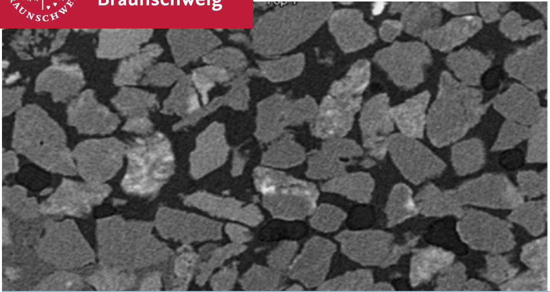
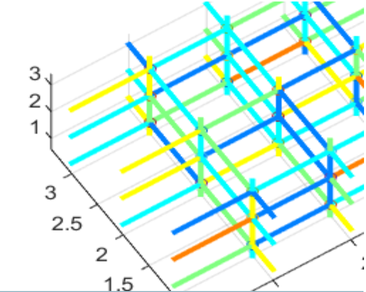
Technische Universität Braunschweig

IGEP TU Braunschweig
Institut für Geophysik und extraterrestrische Physik





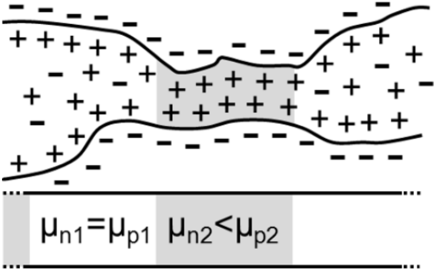
Simulation of membrane polarization for 2D and 3D pore networks

4th International Workshop on Induced Polarization

Hermann Stebner, Andreas Hördt, 07.06.2016

Membrane polarisation

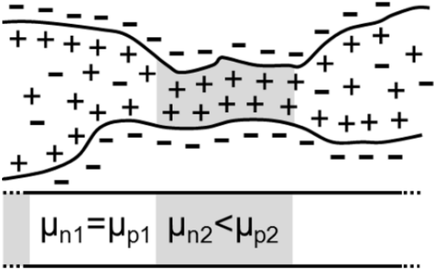
Marshall und Madden (1959)

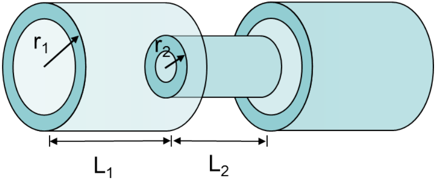


- cations bound to mineral surface
- decrased effective anion mobility in bottlenecks

Membrane polarisation

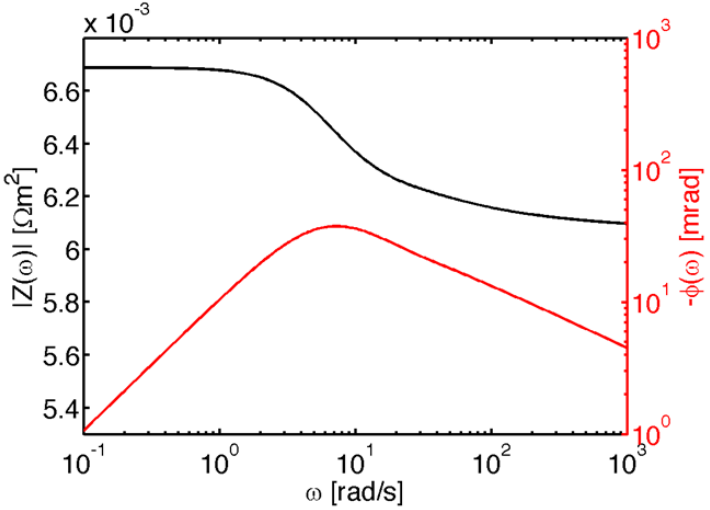
Marshall und Madden (1959)





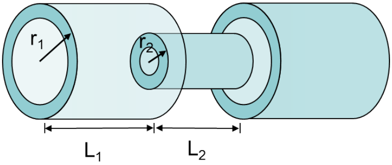
- cations bound to mineral surface
- decrased effective anion mobility in bottlenecks
- 2D-expansion (Bücker and Hördt, 2013a) with geometric parameters: r_1, r_2, L_1, L_2

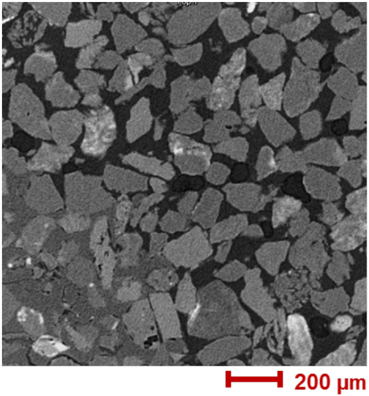
Membrane polarisation



Networks

Aim

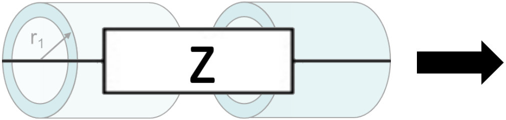


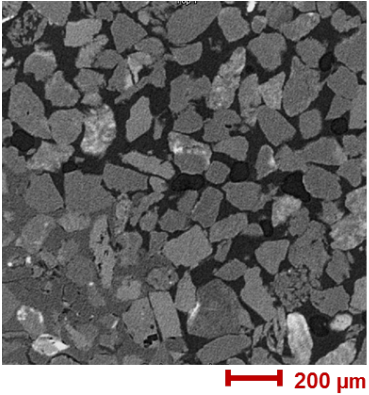


Networks

Aim

impedance component





Networks

Aim

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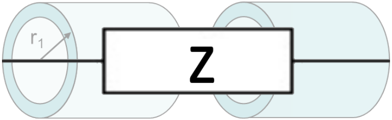
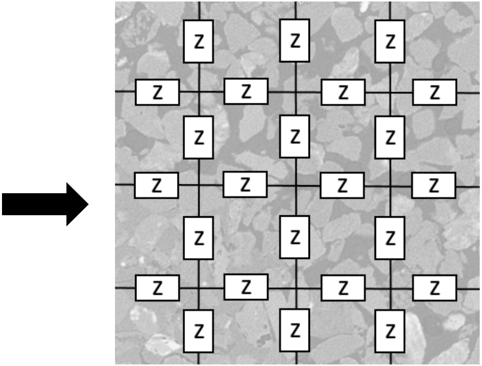
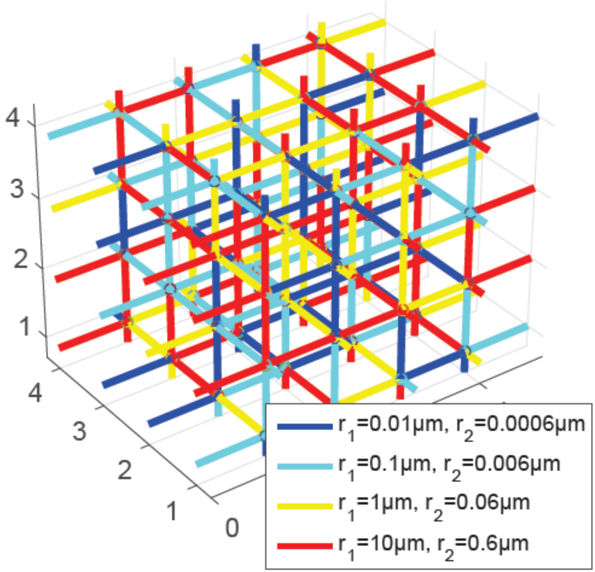
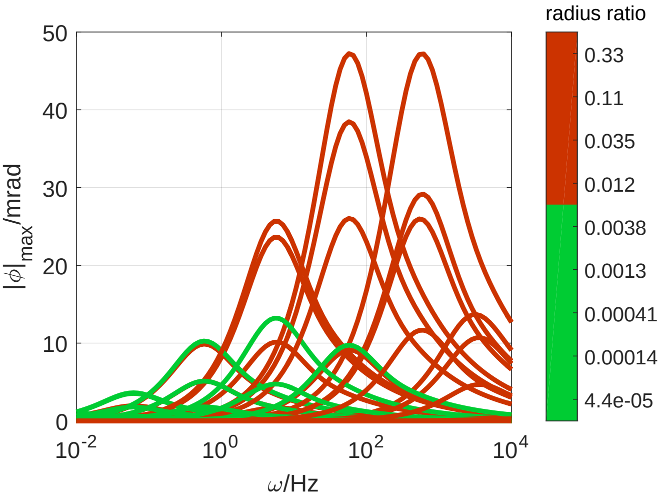




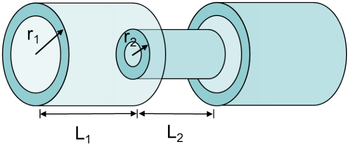


4
3
2
1
4
3
2
1
0
r1=0.01μm, r2=0.0006μm
r1=0.1μm, r2=0.006μm
r1=1μm, r2=0.06μm
r1=10μm, r2=0.6μm

Pore combinations



Choosing geometric parameters



Pore lengths

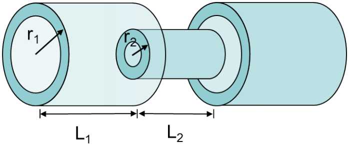
$$\mathbf{L_i} = (c \cdot \mathbf{r_i})^d$$

r_i, pore radii

c, **L-r** ratio parameter

d, exponent parameter

Choosing geometric parameters



Pore lengths

$$\mathbf{L_i} = (c \cdot \mathbf{r_i})^d$$

r_i, pore radii

c, **L-r** ratio parameter

d, exponent parameter

d = 2 → maximum phase shift (Hördt et. al, B11, late afternoon)

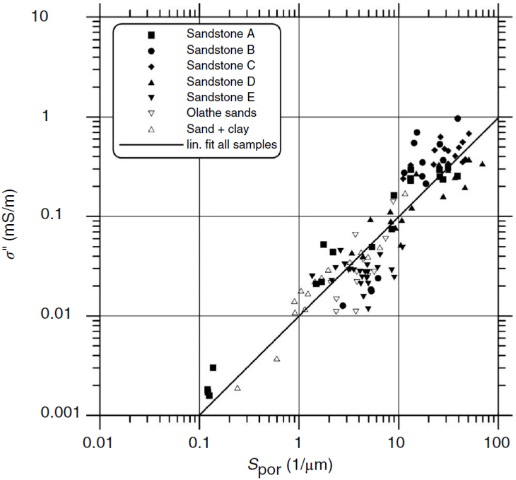
c = ?

σ'' vs S_{por}

Imaginary conductivity σ'' at 1Hz vs specific inner surface S_{por}.

with $\sigma'' = a \cdot {S_{por}}^b$
and $b \approx 1$

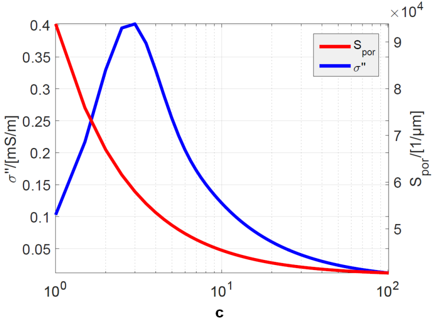
(from Weller et. al., 2010)



σ'' vs S_{por}

$$\mathbf{L_i} = (c \cdot \mathbf{r_i})^d, \quad \mathbf{r_1} = 0.5\mu\text{m}, \mathbf{r_2} = 50\mu\text{m}$$

with d=1.5



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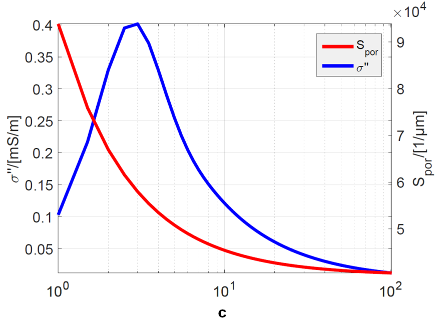
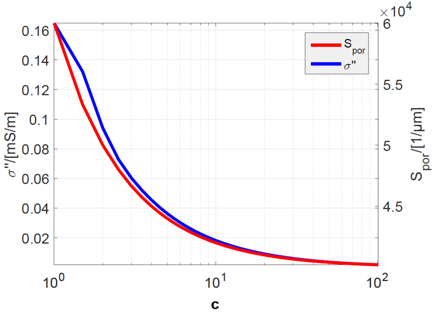
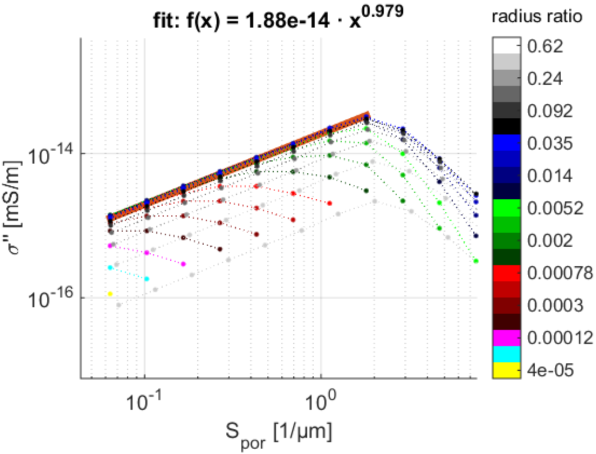


with d=1

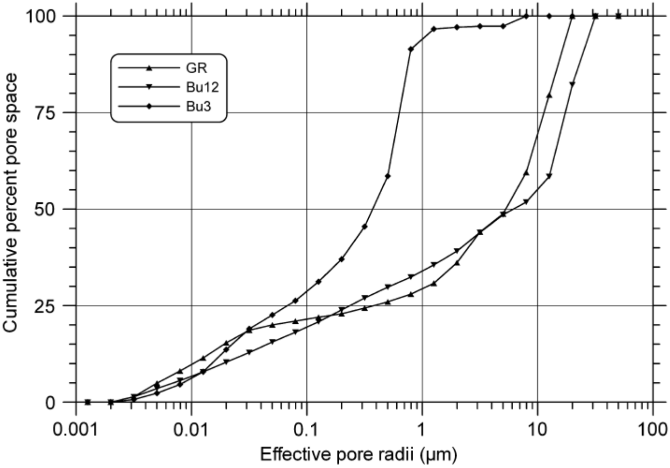


Lengths-radii relation



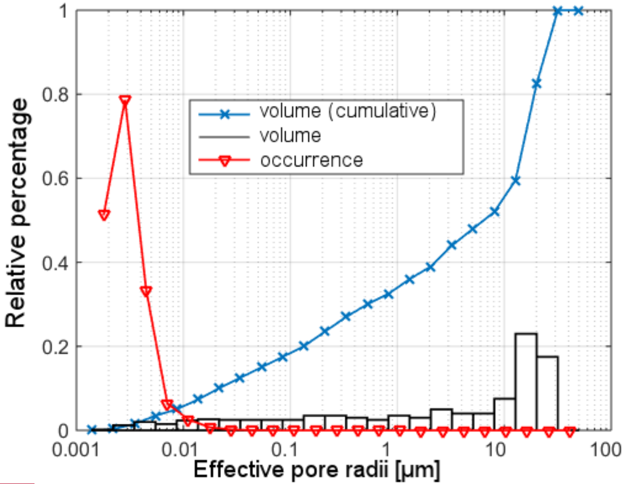
With L-r relation $\mathbf{L_i} = 50 \cdot \mathbf{r_i}$.

Real pore distribution

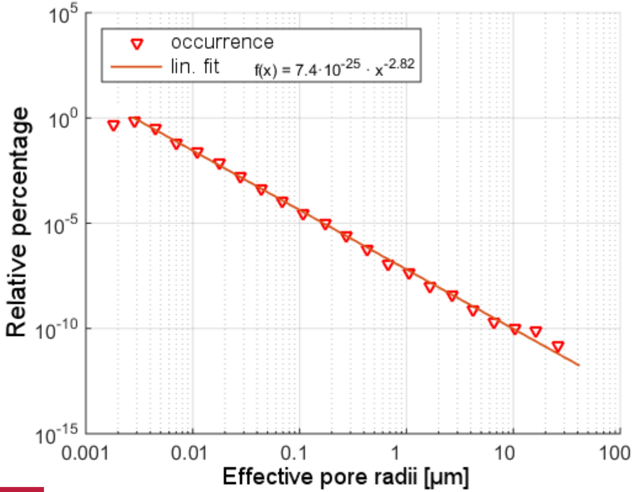


(from Weller et. al., 2011)

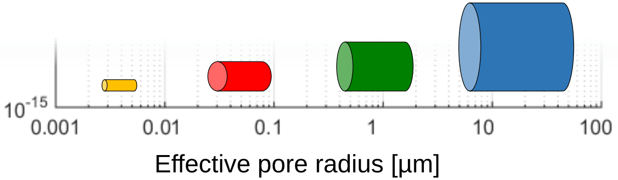
Real pore distribution



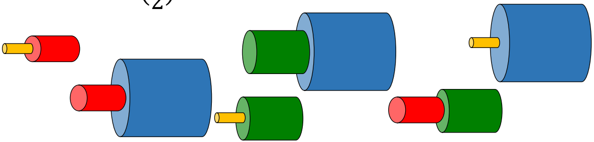
Real pore distribution



Pore combinations



$\binom{n}{2}$ combinations



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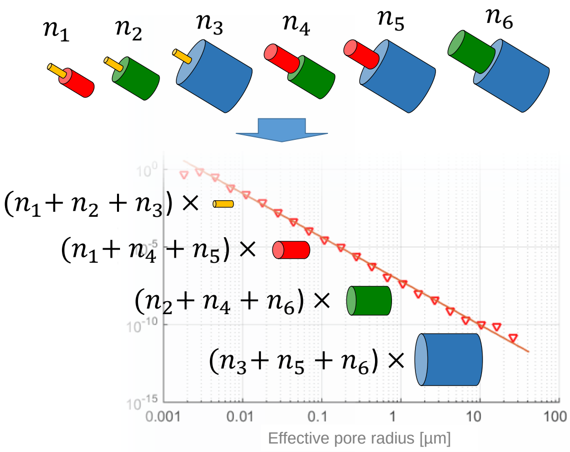
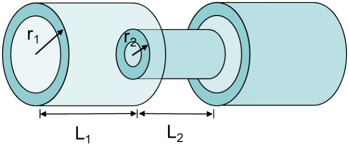
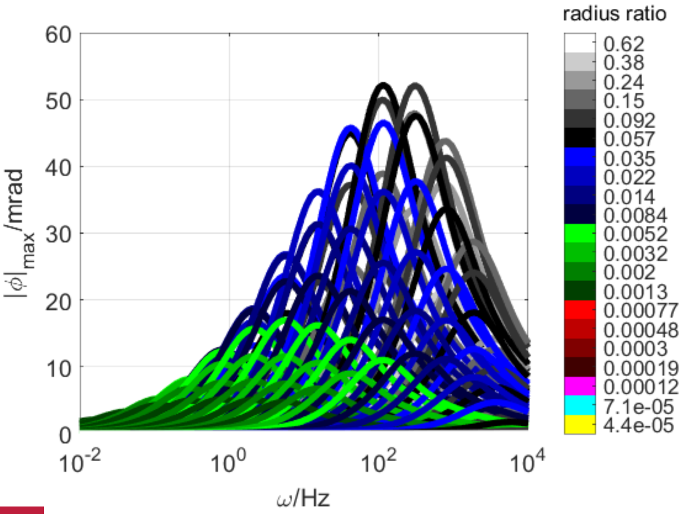


Choosing geometric parameters

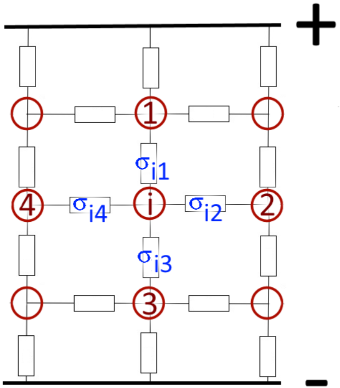


- σ'' - S_{por} - relation → **Pore lengths** $L_i = 50 \cdot r_i$
- Real pore radii distribution → **Pore radii combinations**

Spectra used for network



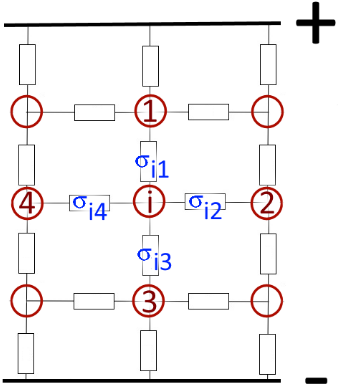
Networks - Total impedance



Finite difference method (FDM)

- potential electrodes

Networks - Total impedance



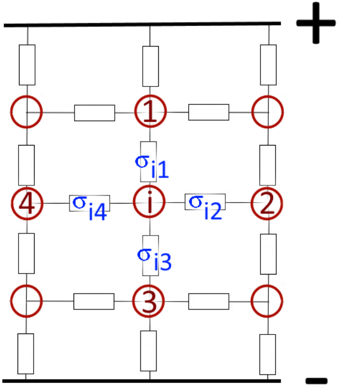
Finite difference method (FDM)

- potential electrodes
- Kirchhoff's circuit law:
  conductivities $\sigma = 1/\rho$

$$\sum_j \sigma_{ij} \left(V_i - V_j \right) = 0 \quad \longrightarrow \quad \mathbf{D} \cdot \mathbf{V} = \mathbf{B}$$

D matrix from pore conductivities
B vector from edge nodes potentials
V vector from inner nodes potential drops

Networks - Total impedance



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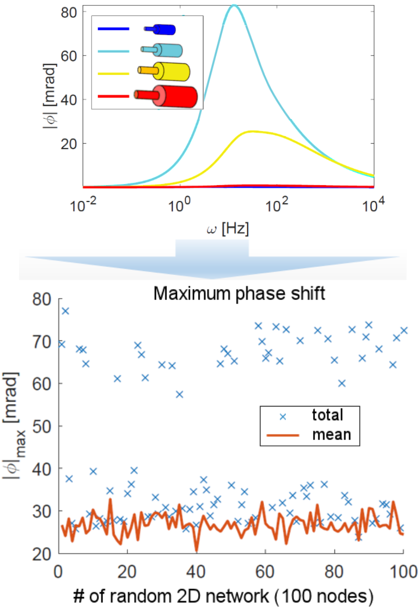
D matrix from pore conductivities
B vector from edge nodes potentials
V vector from inner nodes potential drops

- **V** $\Rightarrow$ total impedance from edge pores currents

Results | Small networks

equally distrib. pore combinations



Results | Small networks

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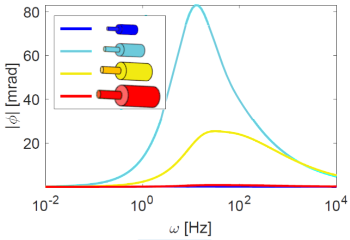
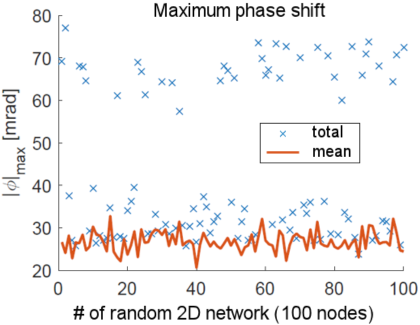
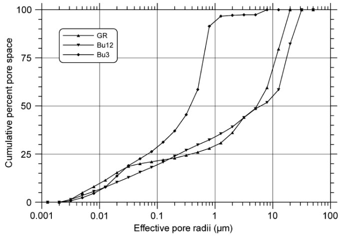
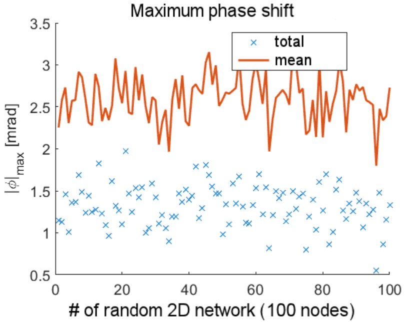




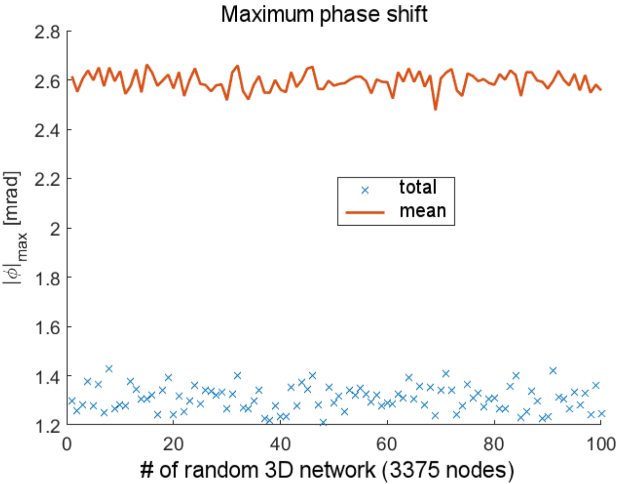
real pore distribution





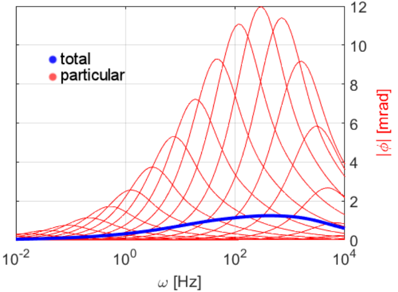
Results | Big networks

real pore combinations



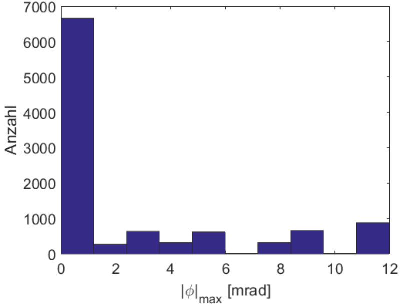
Results | Big networks

phase shift



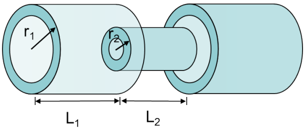
- 276 various impedances
- mean: 2.6 mrad
- network total: 1.3 mrad

maximum phase shift distribution



- 3375 nodes
- 10350 edges (impedances)
- biggest bin: [0 - 1.4] mrad

Conclusions



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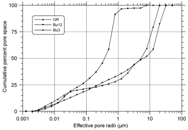

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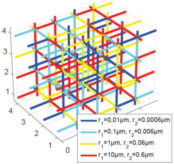
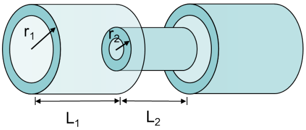


- SIP-Model: Combination of big and small pore
- Network of impedance components $\rightarrow$ FDM $\rightarrow$ total impedance
- Network matches real radii distribution and σ'' vs S_{por} relation

Conclusions



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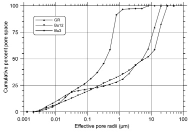

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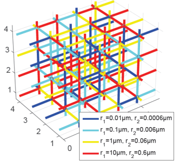

- SIP-Model: Combination of big and small pore
- Network of impedance components → FDM → total impedance
- Network matches real radii distribution and σ'' vs S_{por} relation

- Total impedance does not match the mean impedance
- Real pore distribution with pore length = 50×pore radius
  → Realistic SIP spectra possible

Outlook

- Choosing the porelengths
- Characteristic time τ
- Constraints for possible pore combinations

Thank you for your attention!