MATH 2 MARKET

SIMULATION-BASED OPTIMIZATION FOR FILTER MEDIA DESIGN

FILTREX ASIA

FILTREX™ Asia 2018

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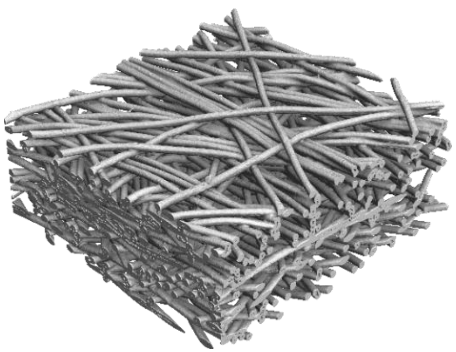
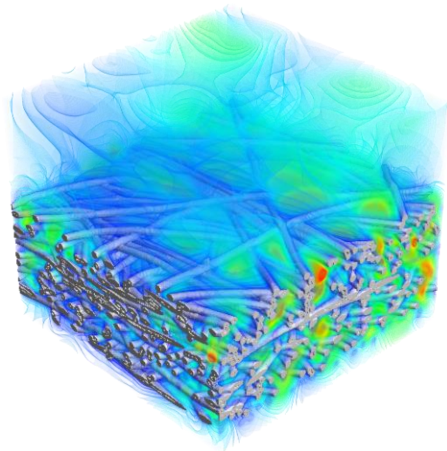
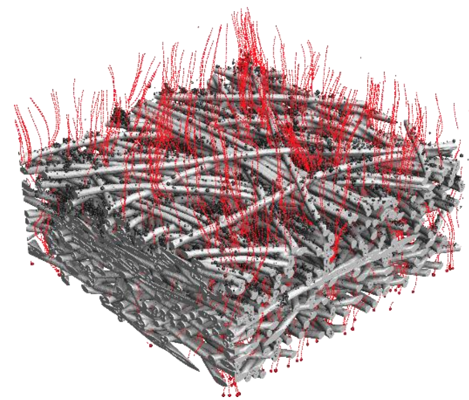
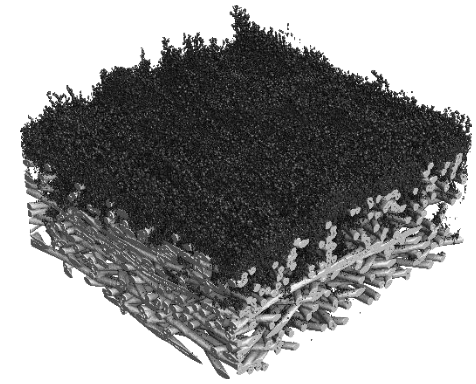
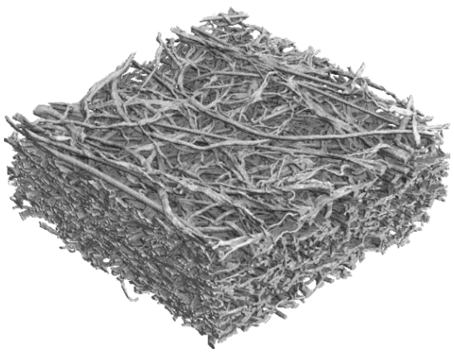
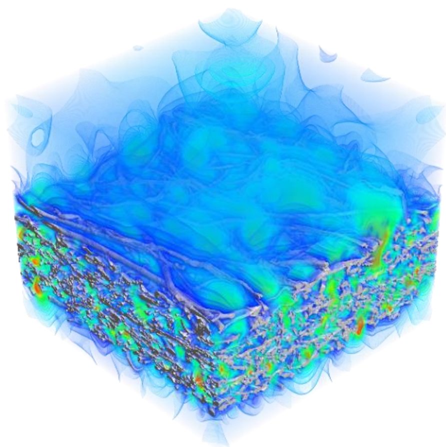
GeoDict for Filtration: Gas Filtration Portfolio

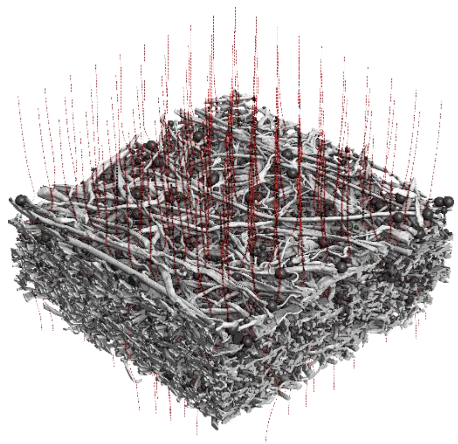





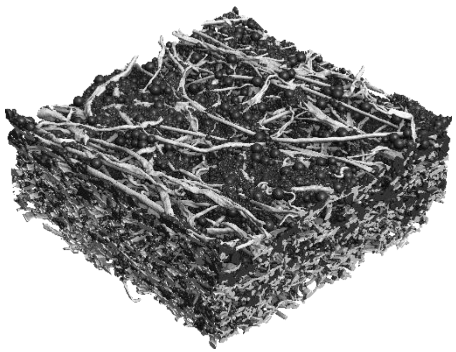
Filter Media	Clean Filter Parameters	Gas Filtration Experiments	Gas Filtration Results
■ Nonwoven fabrics	■ Media thickness	■ Single pass tests	■ Initial pressure drop
■ Woven fabrics	■ Fiber diameters	■ Diesel soot test dust	■ Pressure drop evolution
■ Foams	■ Fiber orientation	■ Standard aerosol test dusts	■ Initial filter efficiency
■ Sintered ceramics	■ Grammage		■ Fractional efficiencies
■ Pleats and support meshes	■ Pore size distribution		■ Filter capacity
	■ Bubble point		■ Filter class
	■ Percolation path		■ Most penetrating particle size

GeoDict for Filtration: Liquid Filtration Portfolio



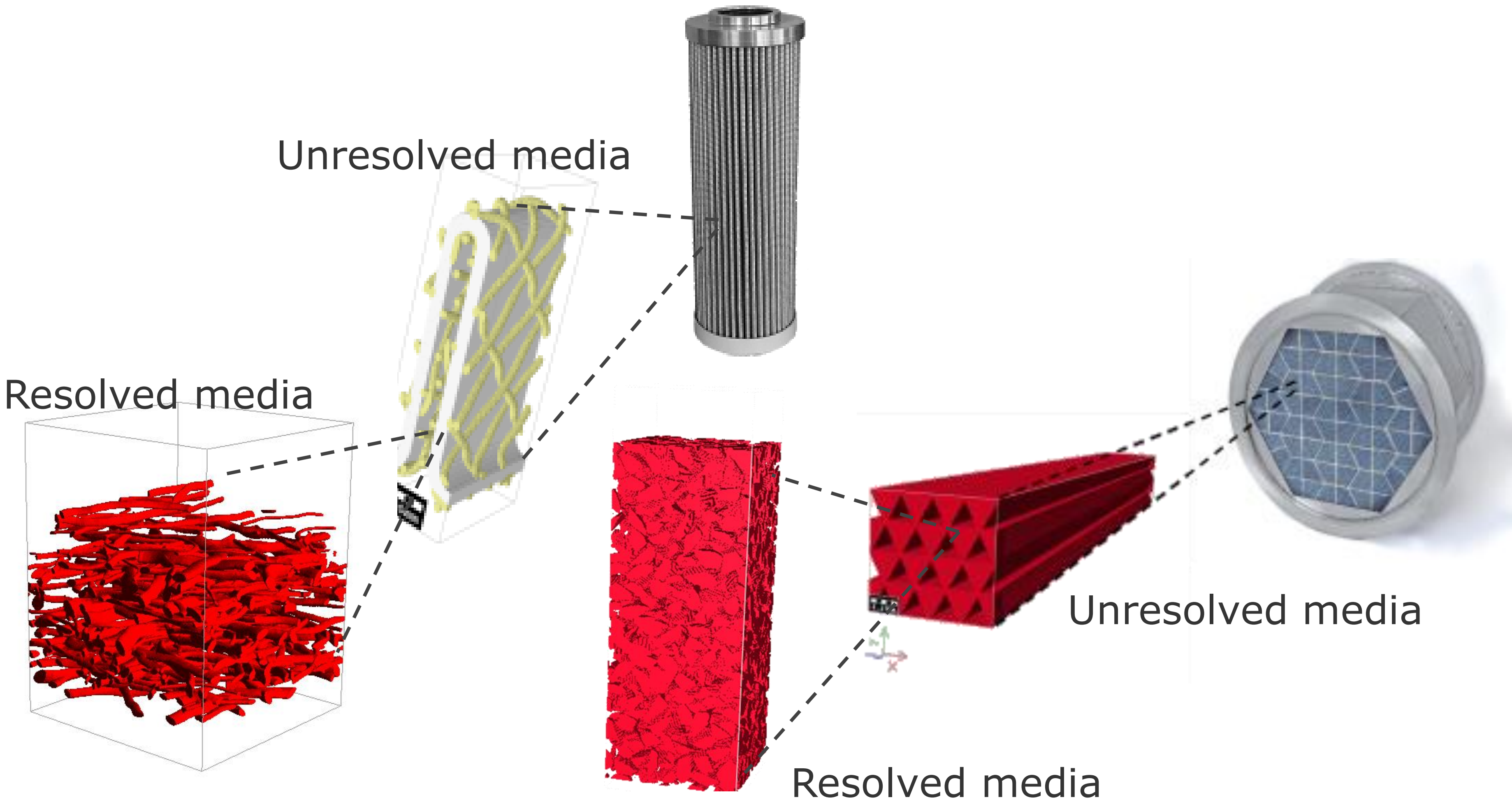




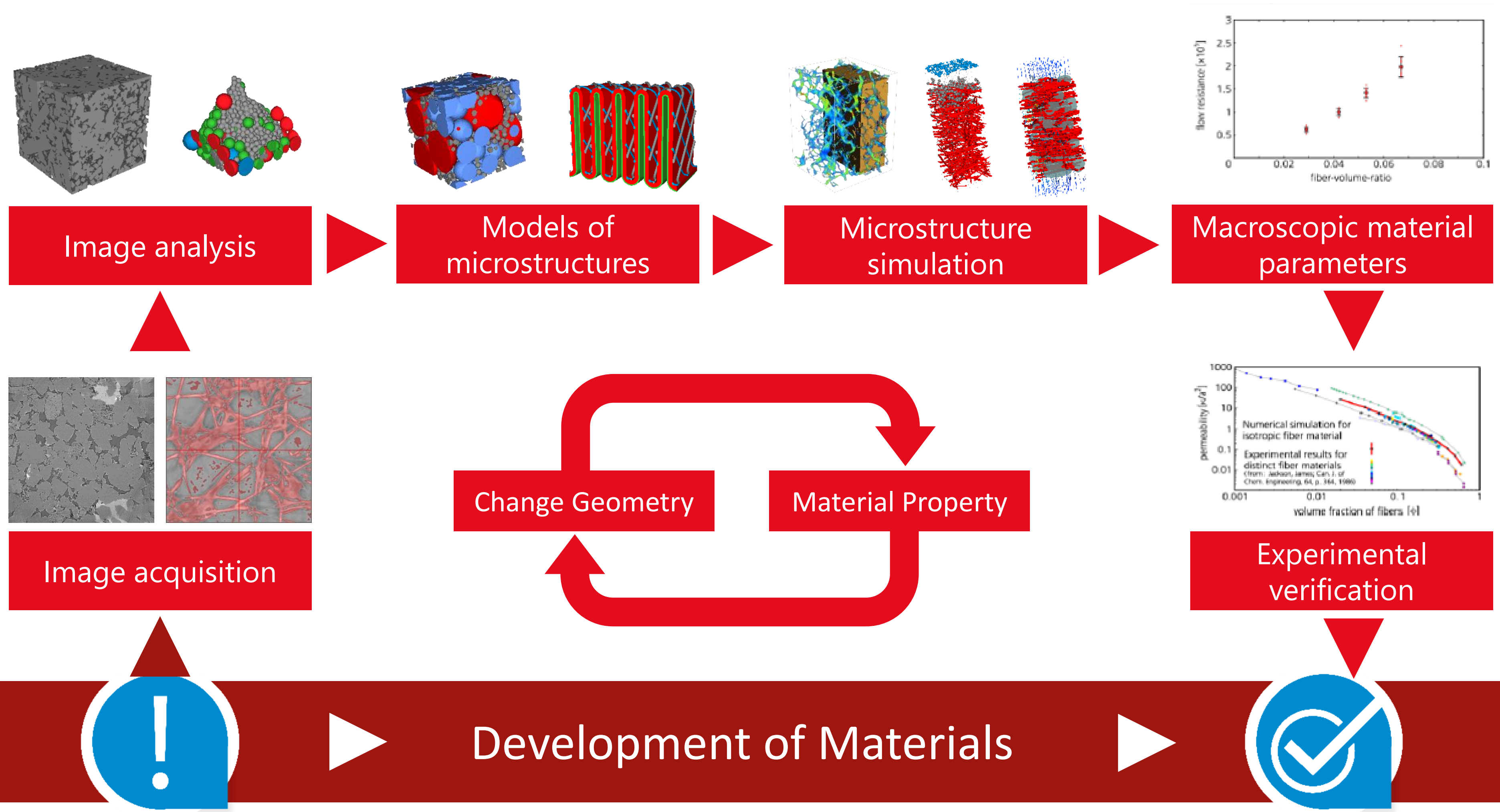


Filter Media	Clean Filter Parameters	Liquid Filtration Experiments	Liquid Filtration Results
■ Nonwoven fabrics	■ Media thickness	■ Multi pass tests	■ Initial pressure drop
■ Woven fabrics	■ Fiber diameters	■ Standard test dusts	■ Pressure drop evolution
■ Foams	■ Fiber orientation		■ Initial filter efficiency
■ Membranes	■ Grammage		■ Fractional efficiencies
■ Metal wire meshes	■ Pore size distribution		■ Filter capacity
■ Pleats & support meshes	■ Bubble point		■ Filter class
	■ Percolation path		■ Filter clogging behavior

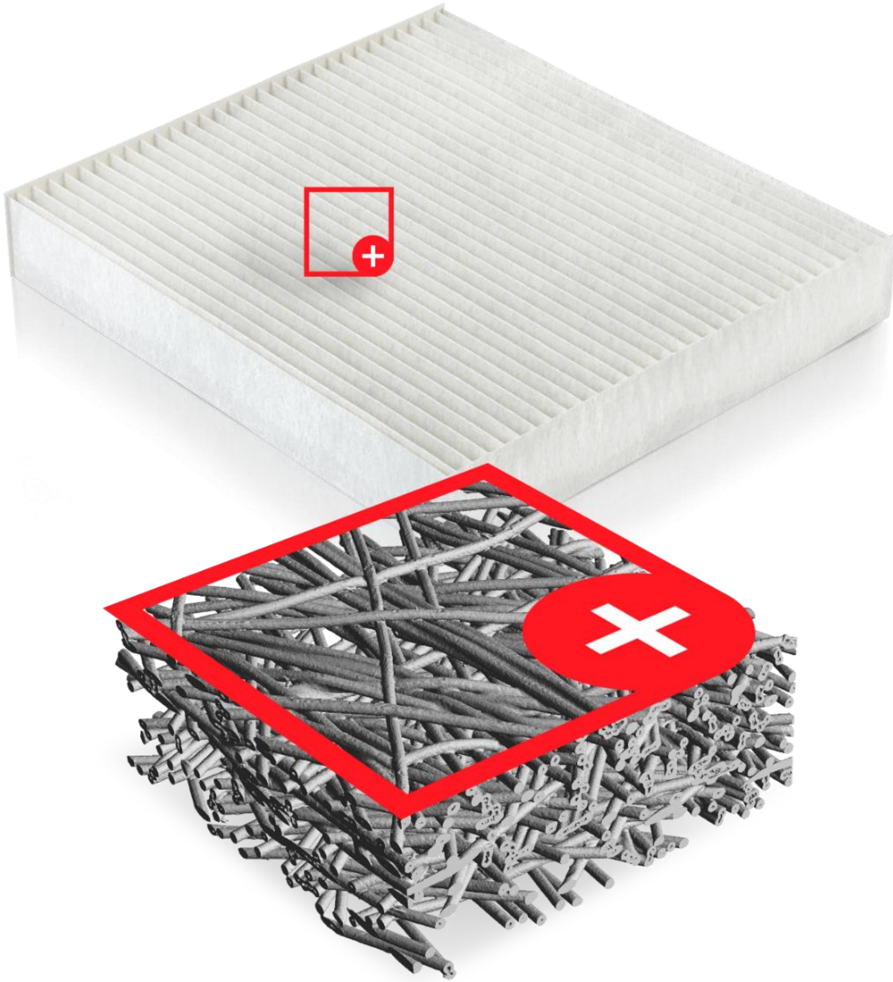
Simulate filtration at different scales



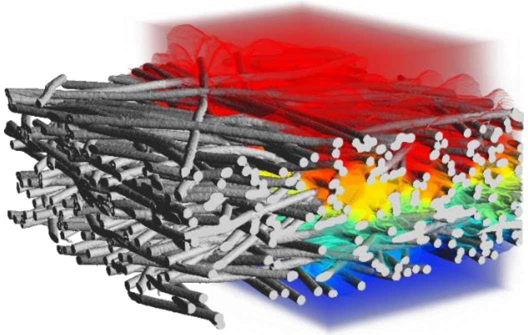
Digital Material Design



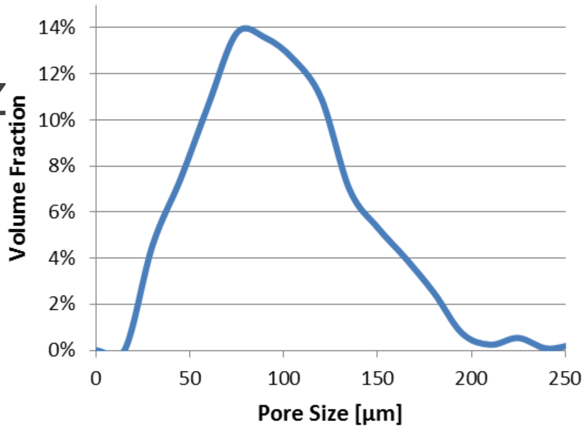
μCT-SCAN OF CABIN AIR FILTER SAMPLE



- Flow and pressure drop

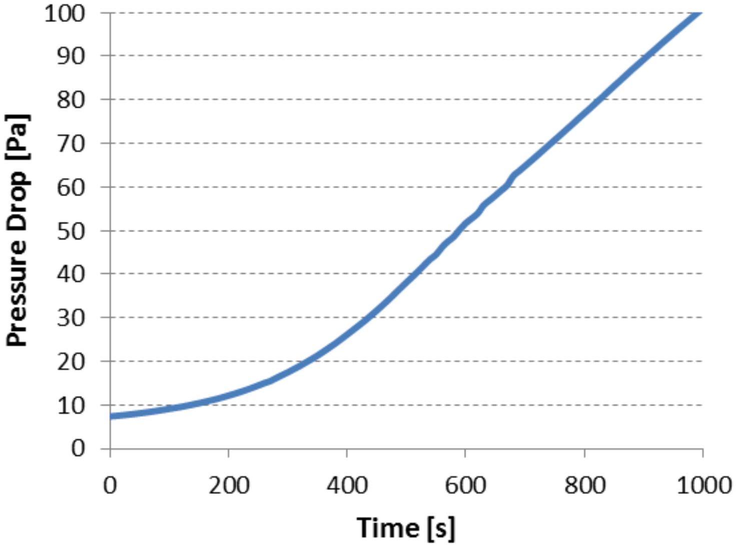


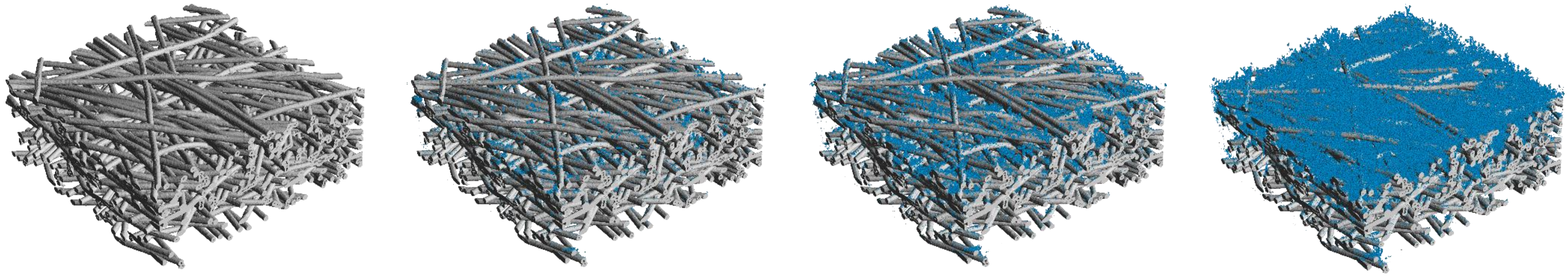
- Pore Siz



Filter Life Time simulation

Initial pressure drop	7 Pa
Pressure drop after 1000s	101 Pa
Total deposited dust after 1000s	93 g/m²
Total filter efficiency	93% (weight)



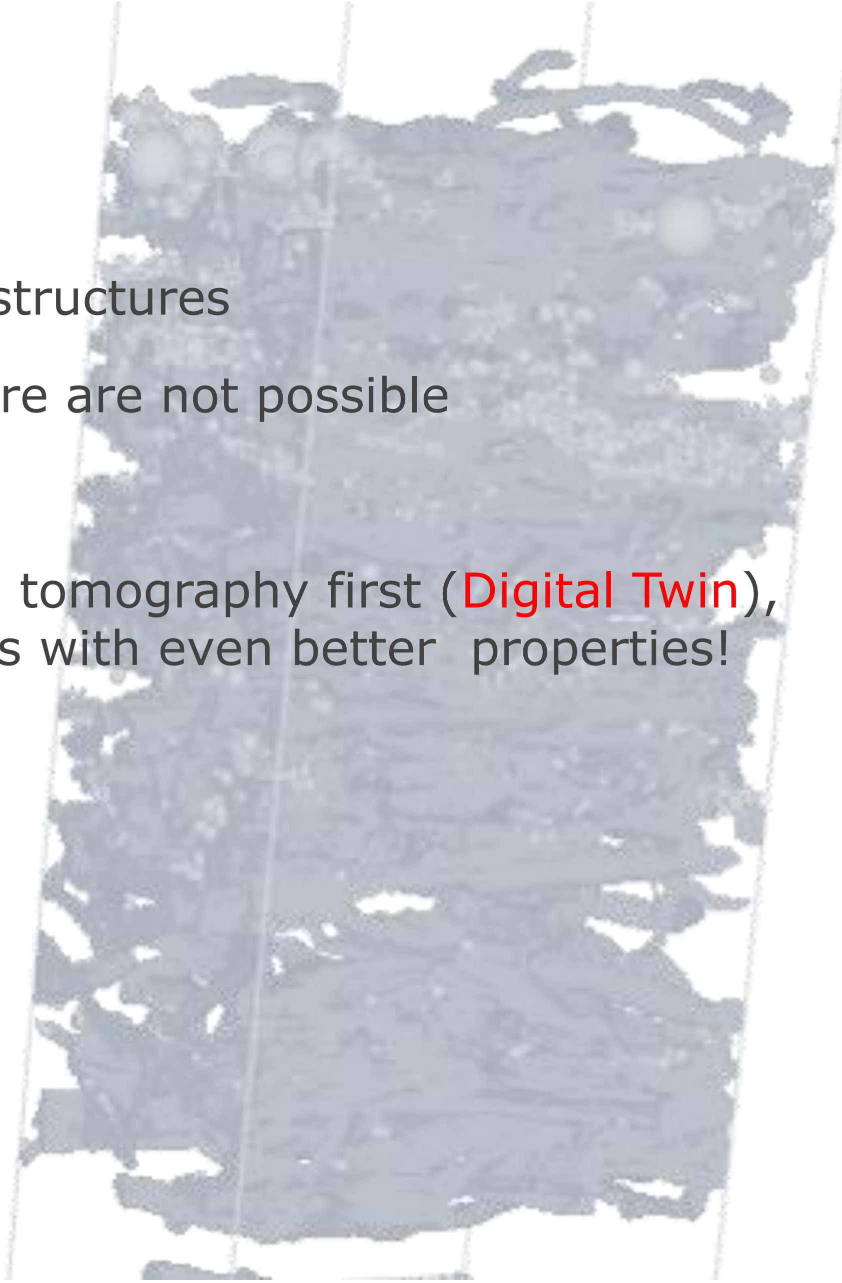


Simulate on μCT scans

(+) Allows simulations on real filter structures

(-) Modifications of the filter structure are not possible

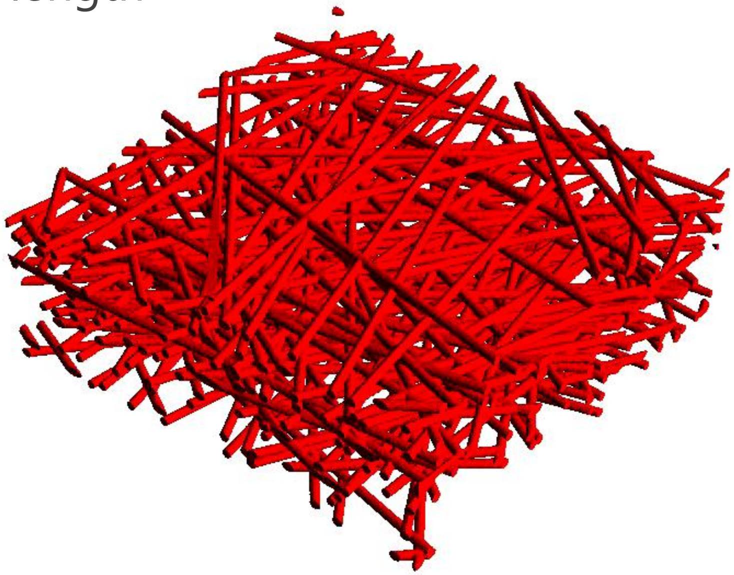
Aim: create a model that mimics the tomography first (Digital Twin), then modify it to find structures with even better properties!



CREATE 3D STRUCTURE MODELS

Input parameters needed (straight fibers):

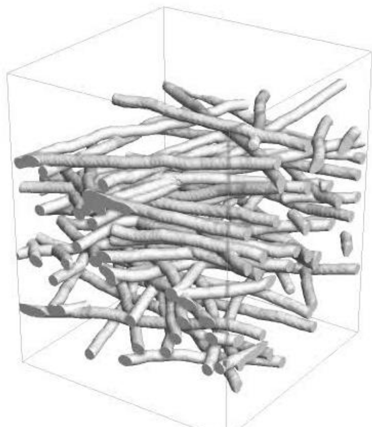
- Porosity
- Fiber type: cross sectional shape, diameter, length
- Fiber orientation tensor
- Thickness (height) of the filter media



Parameters might be

- known from manufacturing process
- measured experimentally
- measured from CT image

Filter life-time simulations



1. Filter model

2. Flow field

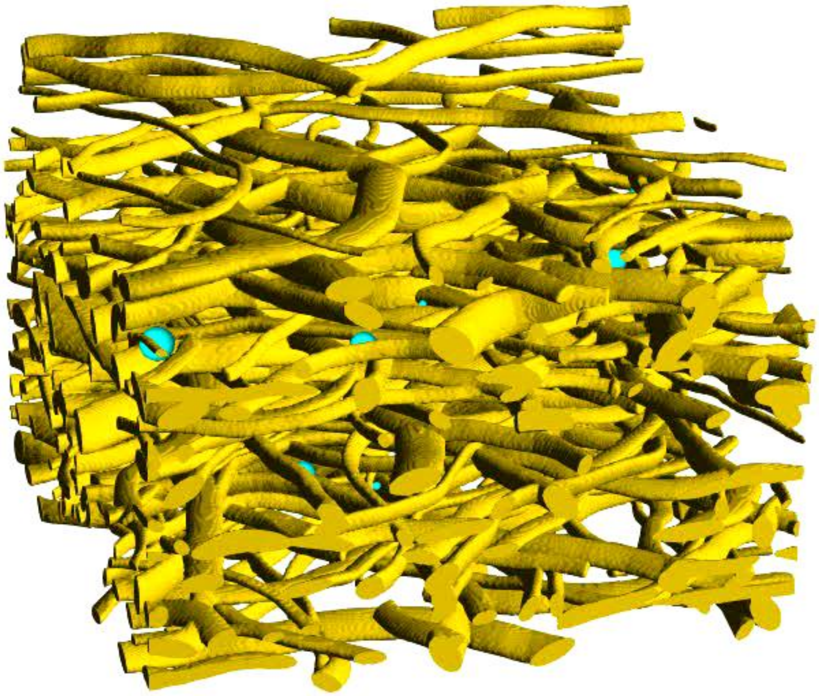
3. Track particles

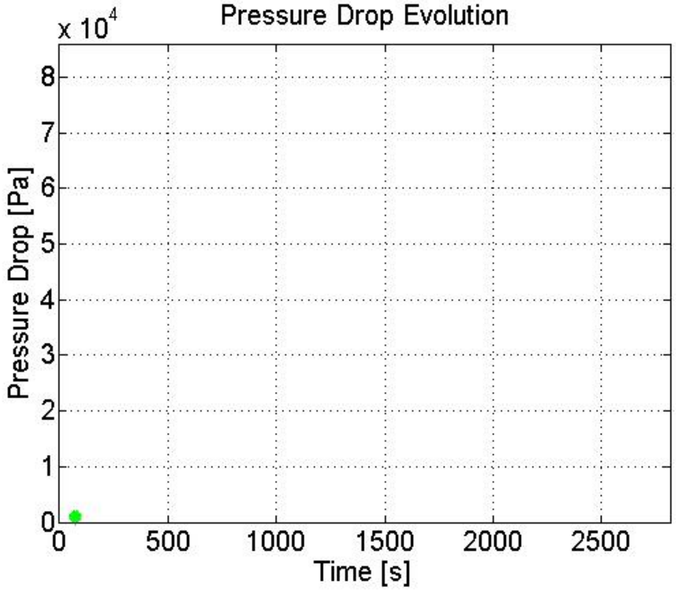
4. Deposit particles

5. Flow field

6. Repeat …

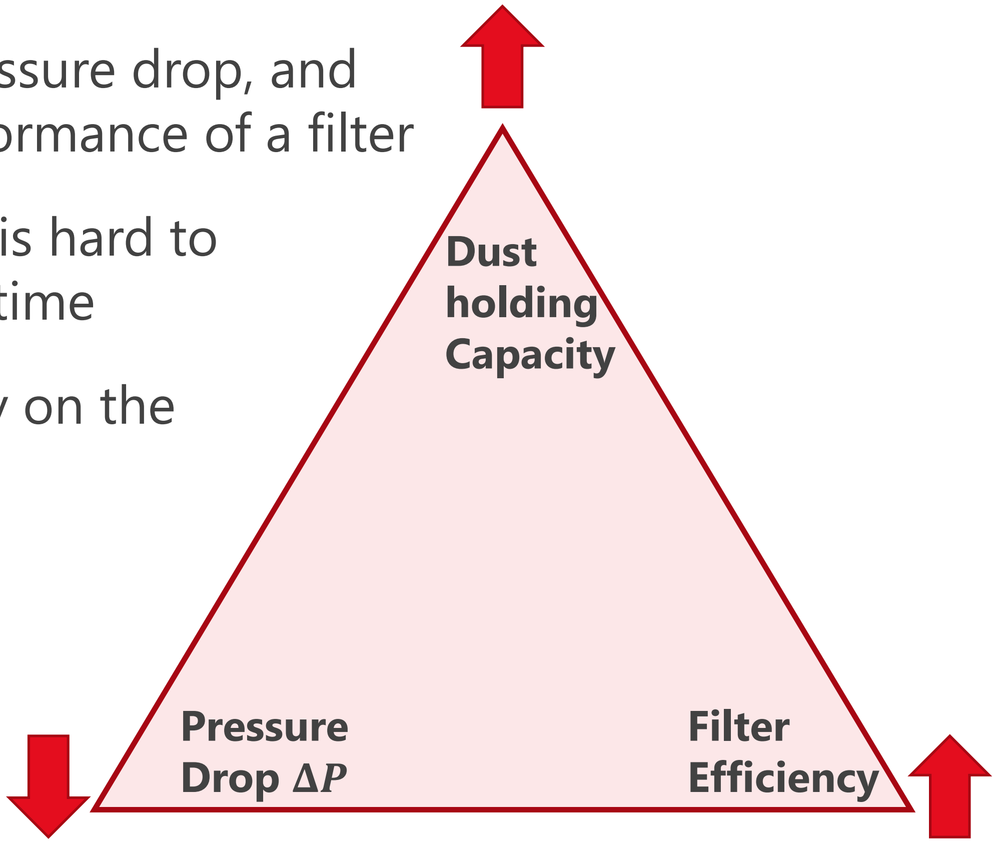
Filter Capacity and Life Time





Filter Media Design

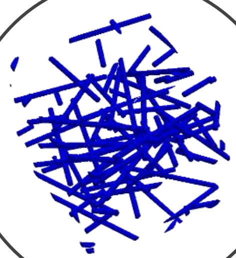
- Dust holding capacity (DHC), pressure drop, and filter efficiency describe the performance of a filter
- They influence each other and it is hard to improve all of them at the same time
- These parameters depend mainly on the porous microstructure
(e.g. pore size distribution)



- In this presentation we want to optimize the DHC
while keeping initial pressure drop and clean filter efficiency the same

Modeling of coarse/fine mixed media filter

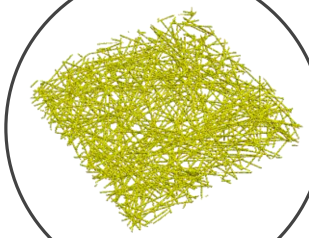
Thick glass fibers



Homogeneous

+

Thin glass fibers



Homogeneous

Linear

Exponential

=

Three various structures

Same inital pressure-drop

Same β ratio

Thick fibers (blue):

Diameter:	20 µm
Orientation:	Anisotropic 8/1
Material:	Glass
Vol. ratio:	60%

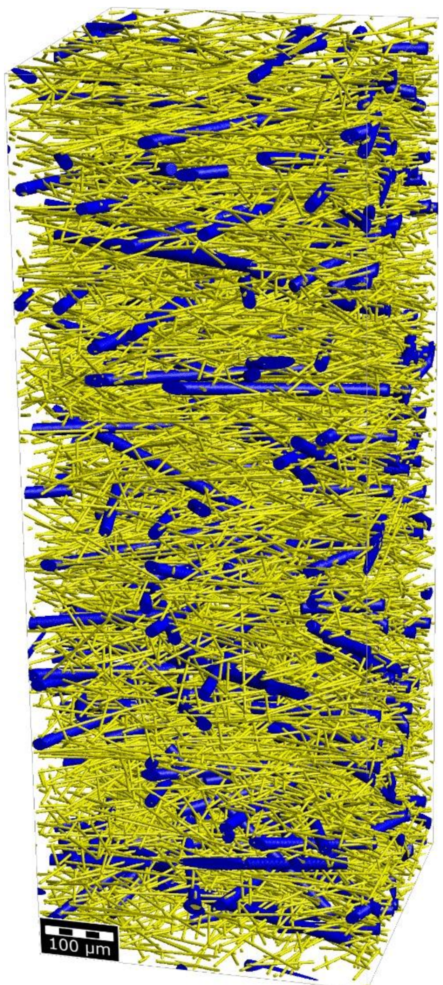
Thin fibers (Yellow):

Diameter:	4 µm
Orientation:	Anisotropic 8/1
Material:	Glass
Vol. ratio:	40%

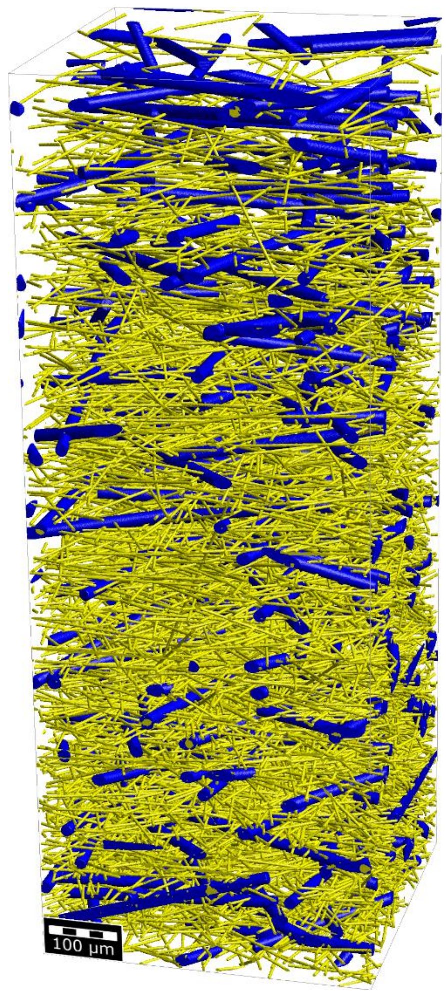
$$\beta_d = \frac{n_{\geq d,Upstream}}{n_{\geq d,Downstream}}$$

Modeling of three filter media structures

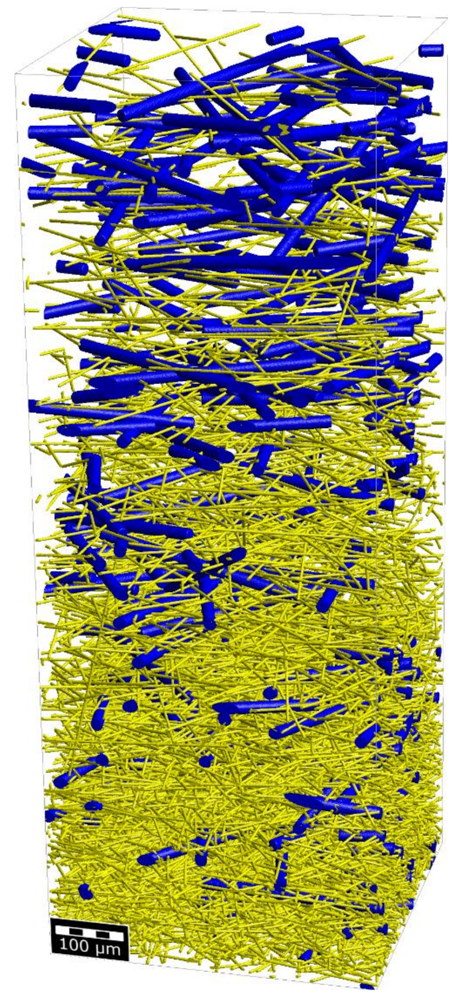
Homogeneous



Linear



Exponential

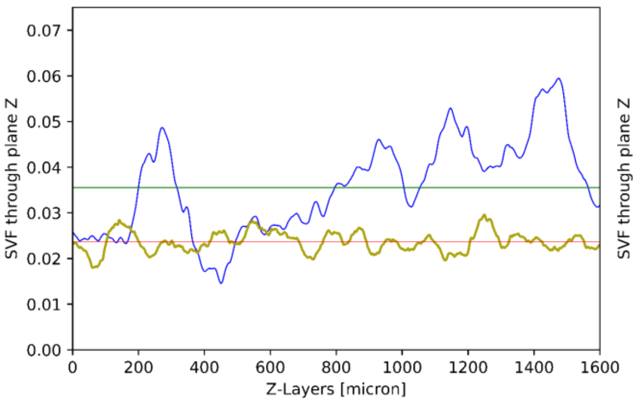


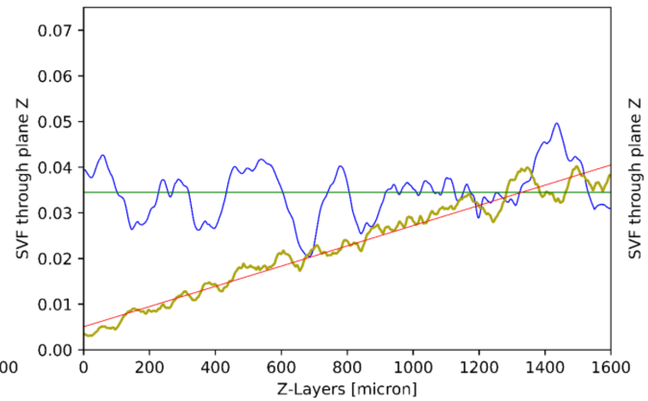
Modeling of three filter media structures

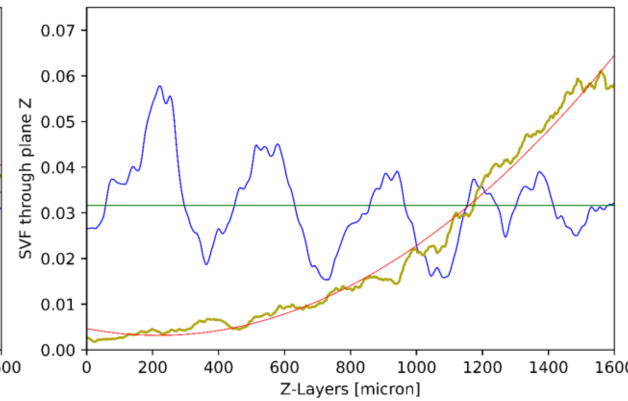
Homogeneous

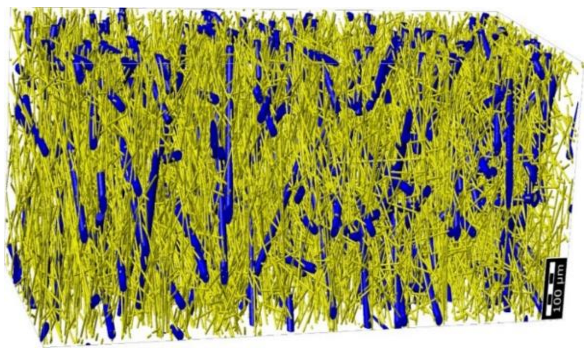
Linear

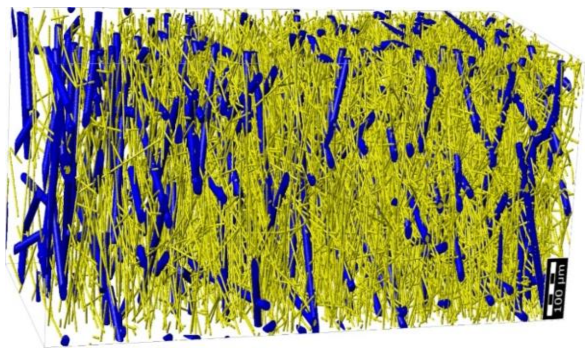
Exponential

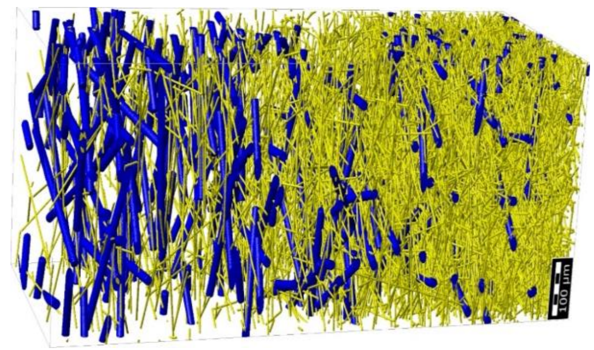












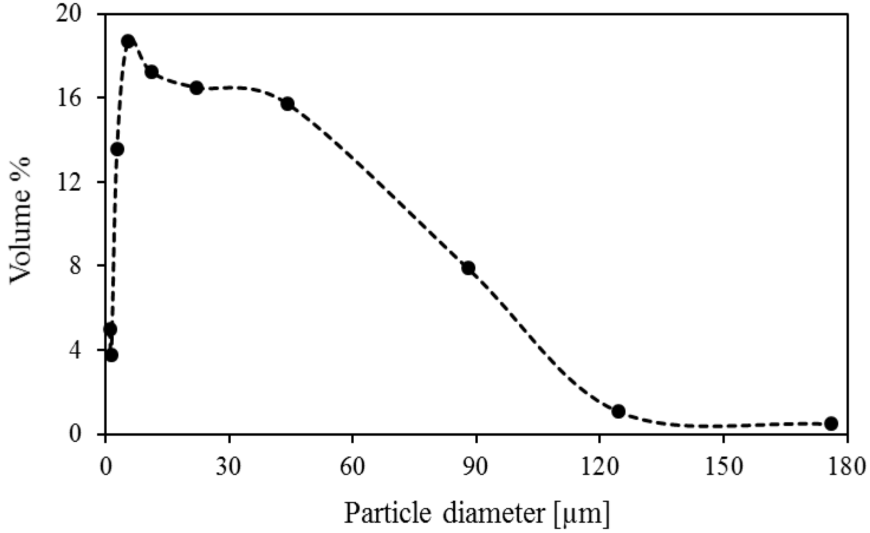
Flow direction

Structural comparison

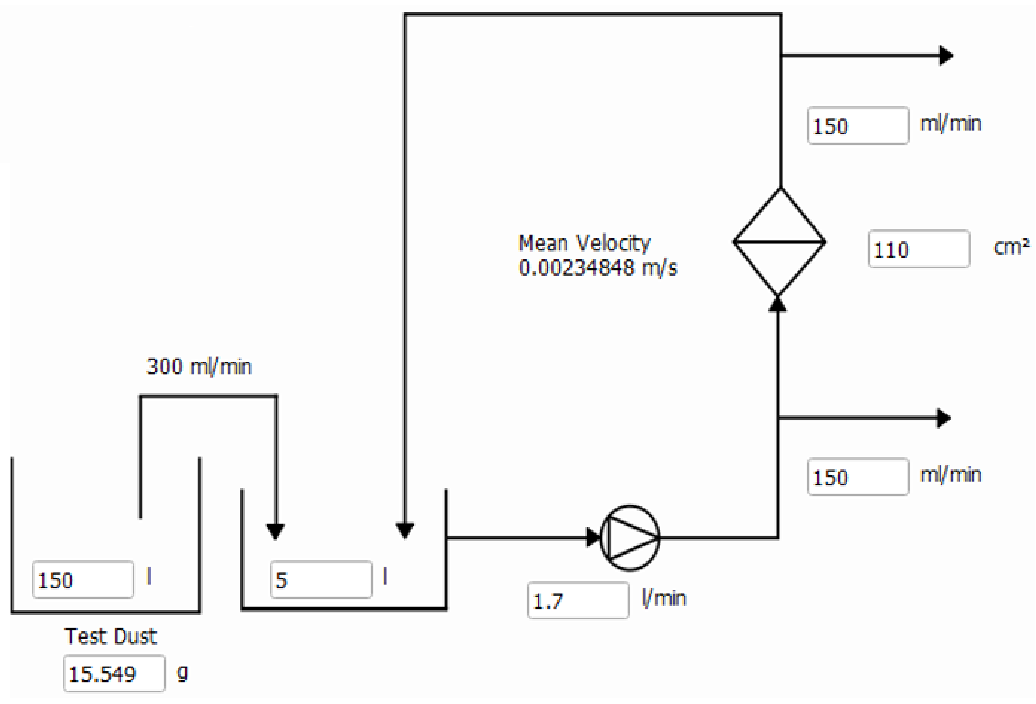
Structure	Homogeneous	Linear	Exponential
Size [μm]	600x600x1600	600x600x1600	600x600x1600
Distribution of coarse fiber / fine fiber	Uniform / Uniform	Uniform / Linear(1,2,3,4,5,6,......)	Uniform / Exponential(1,2,4,8,16,......)
Permeability [m^2]	5.47E-11	5.48E-11	5.53E-11
$\beta_{22\mu m}$	200	200	200
Object solid volume percentage in domain (porosity in %)	6.11 (93.89 %)	5.9 (94.1 %)	5.43 (94.57 %)
Volume coarse fiber / Volume fine fiber	60/40	60/40	60/40

EXPERIMENTAL SETUP

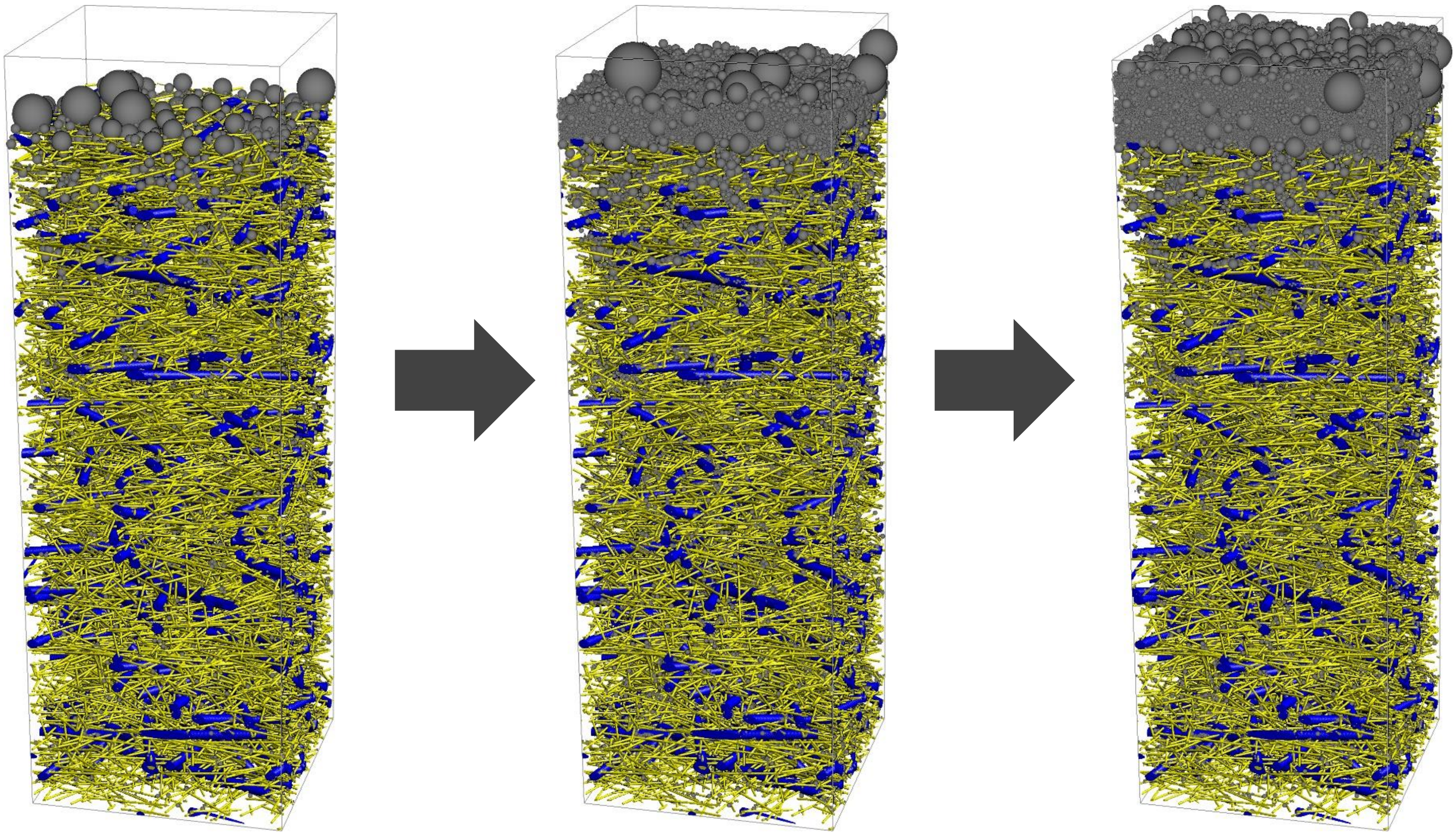
Used Fluid:	Oil
Temperature:	20 °C
Used Particles:	ISO Fine A2 test dust
Particle Density:	2560 kg/m^3
Particle Collision Model:	Sieving
Flow regime:	Laminar



Multi-pass filter test schematic based on ISO 4548-12

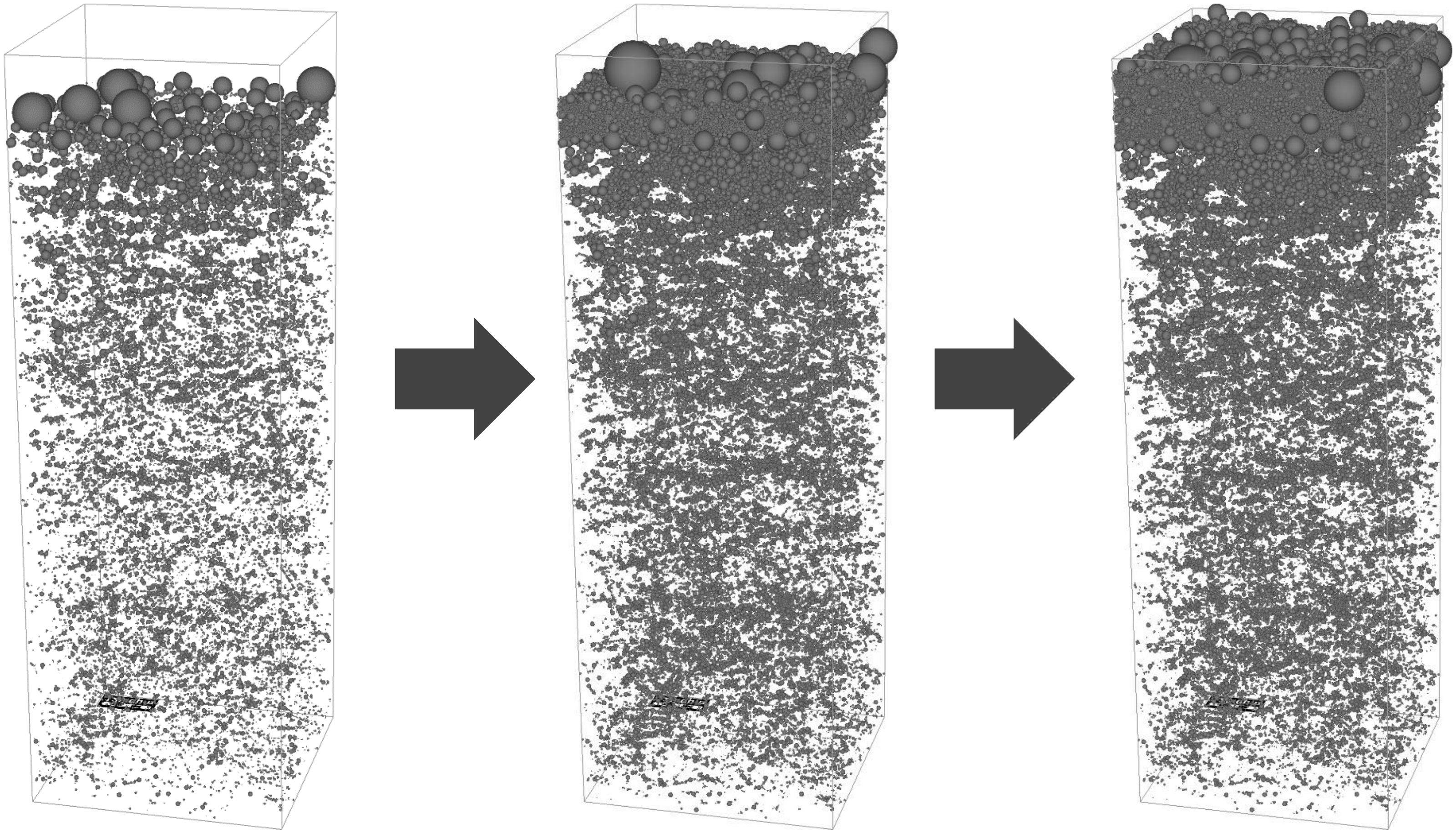


Transient filtration simulation (Homogeneous structure)



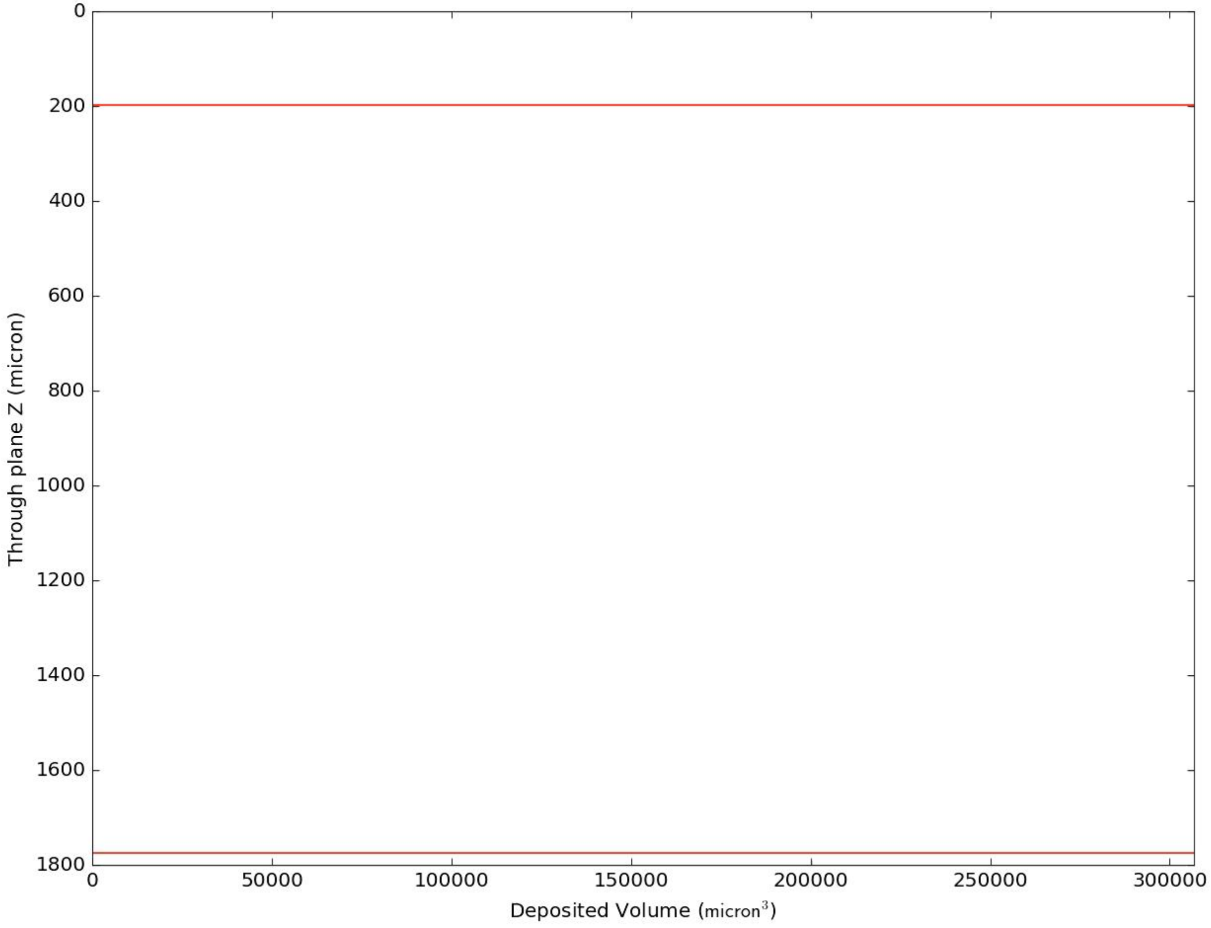
45 min | 2 hr 25 min | 3 hr 10 min

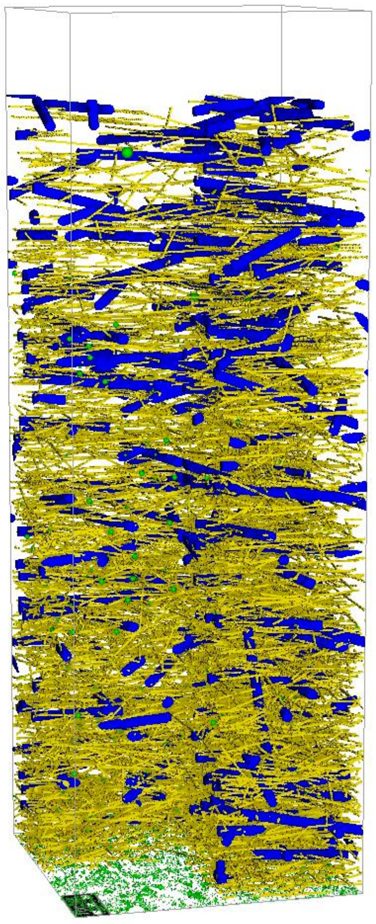
Transient filtration simulation (Homogeneous structure)



45 min | 2 hr 25 min | 3 hr 10 min

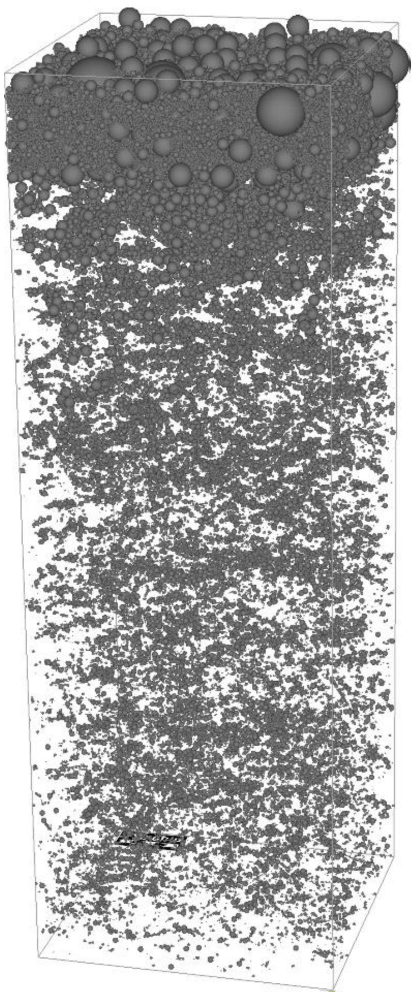
ANIMATION OF THE FILTRATION SIMULATION (LINEAR STRUCTURE)



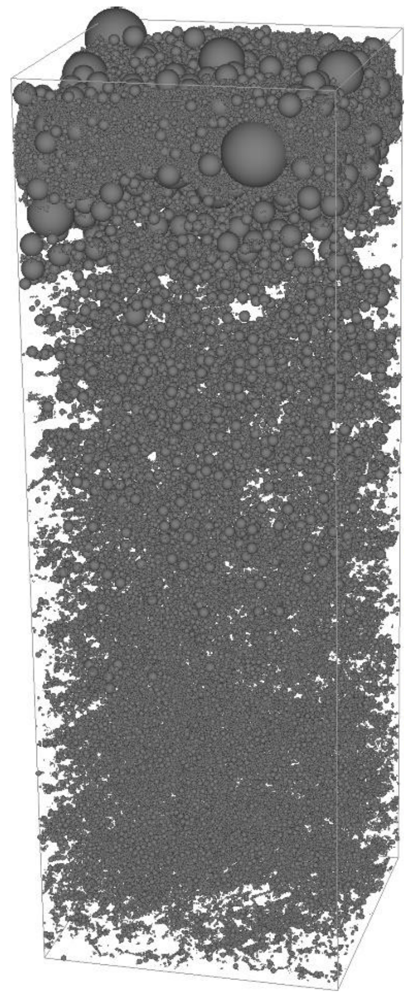


COMPARISON OF PARTICLE DEPOSITIONS

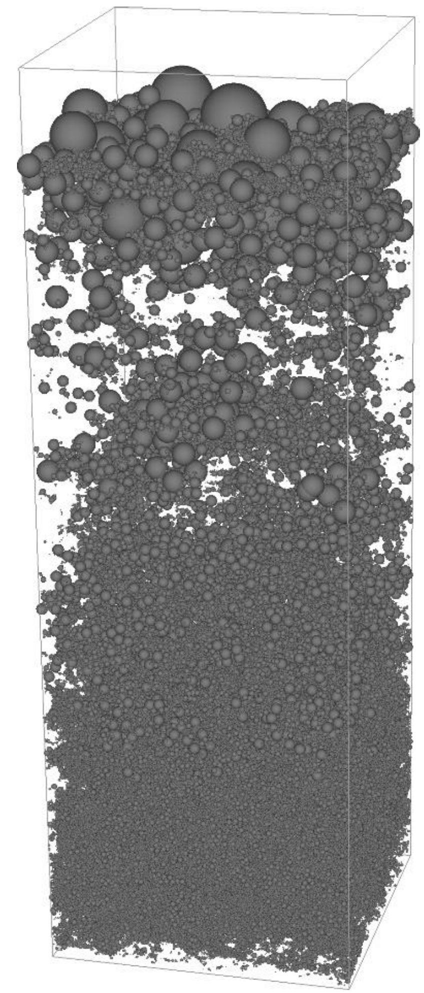
Homogeneous



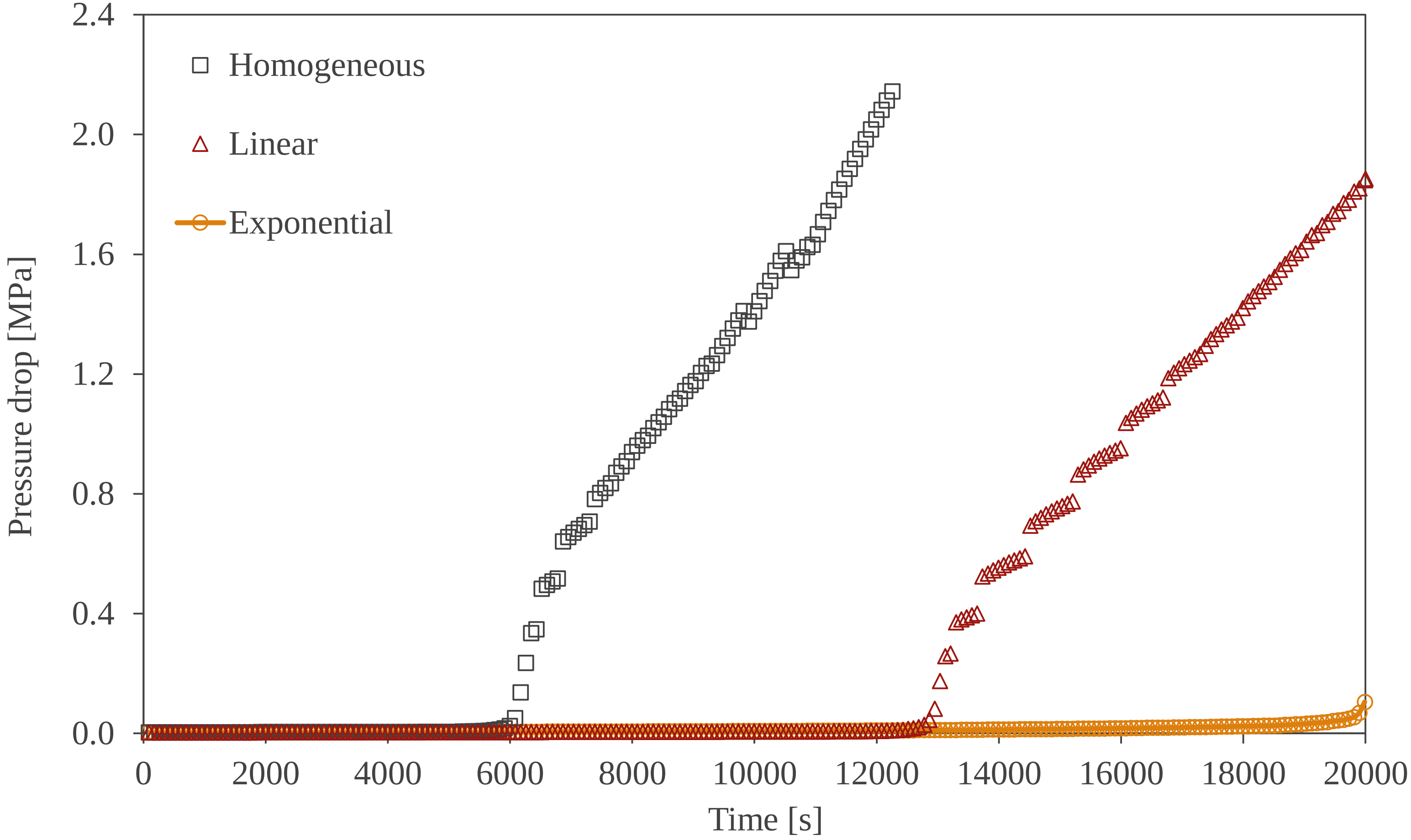
Linear



Exponential



Multipass simulation results: Pressure-drop over time



- The exponentially increasing media shows the lowest pressure-drop increase through the life-time simulations.

CONCLUSIONS

- ✓ The simulations of filter and filtration can be done in different scales.
- ✓ By modification of the micro-structure of filter media, the macroscopic properties can be optimized.
- ✓ The gradient distribution of fibers through the medium thickness, can improve the filtration characteristics.
- ✓ The exponential media shows the lowest pressure-drop increase & the highest DHC through the life-time simulations.
- ✓ The computer simulation helps to find the best performed filter media without being physically produced.

Thank you for your attention.

GeoDict
The Digital Material Laboratory