Computer Simulation of Flow and Mass Transfer in a Bioprinted *In-Vitro* Device of Human Cancer Cells for Optimizing Oxygen Supply - a Progress Report

Peter Farber, Simone Marasso

The Team

- National Research Council (CNR) Institute of Materials for Electronics and Magnetism (IMEM), IMEM Laboratory Torino
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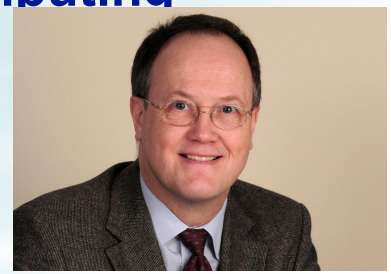

Agenda

- A Few Words about the Labs at PoliTO
- A Few Words about IMH
- The Real Process
- First Results of Numerical Simulations
- Future Steps

A Few Words about the Labs at PoliTO - 1

- **Project members:**
  - **Nanoscience Lab**
  - **PolitoBIOMed Lab**

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  - **Chi-Lab**
  - **Piquet Lab**

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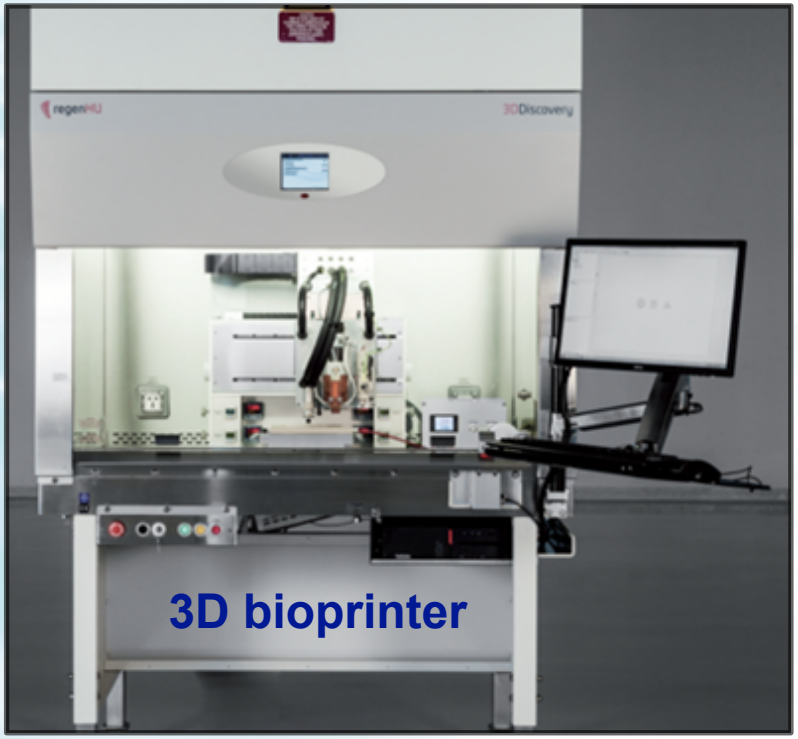
A Few Words about the Labs at PoliTO - 2

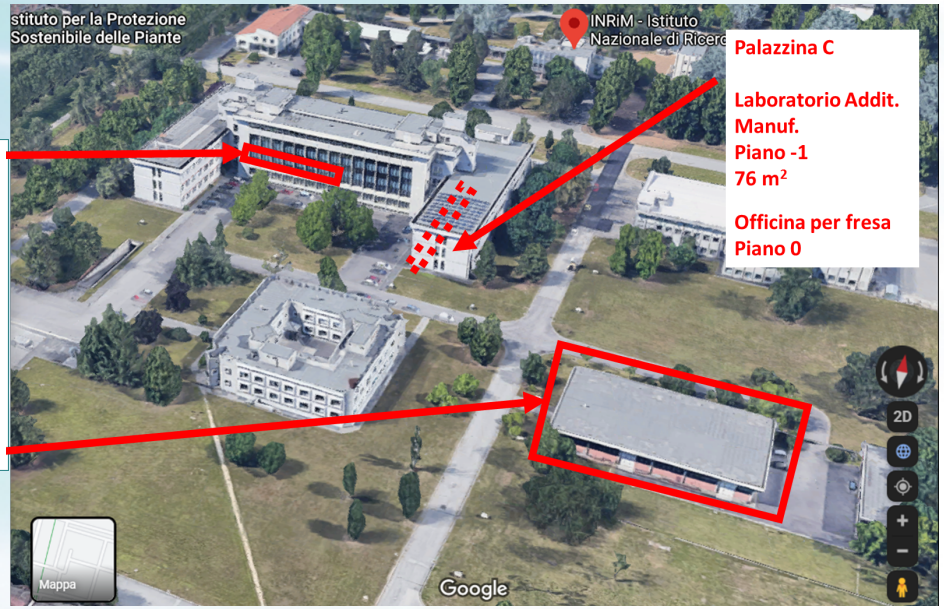
- Polito^{Bio}Med - biological field
  - Lab Cell culture & cell biology
  - Imaging Bioprinting
  - Biochemistry & molecular biology
  - Biomatrix preparation



3D bioprinter

A Few Words about the Labs at PoliTO - 3

- ChiLab - Micro&Nano Technological field
  - Lab class 100 - 15 m²
  - Lab class 1000 - 45 m²
  - Lab class 10 000 - 90 m²
  - Biomatrix preparation
- PiQuET - Micro&Nano Technological field



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A Few Words about IMH - 1

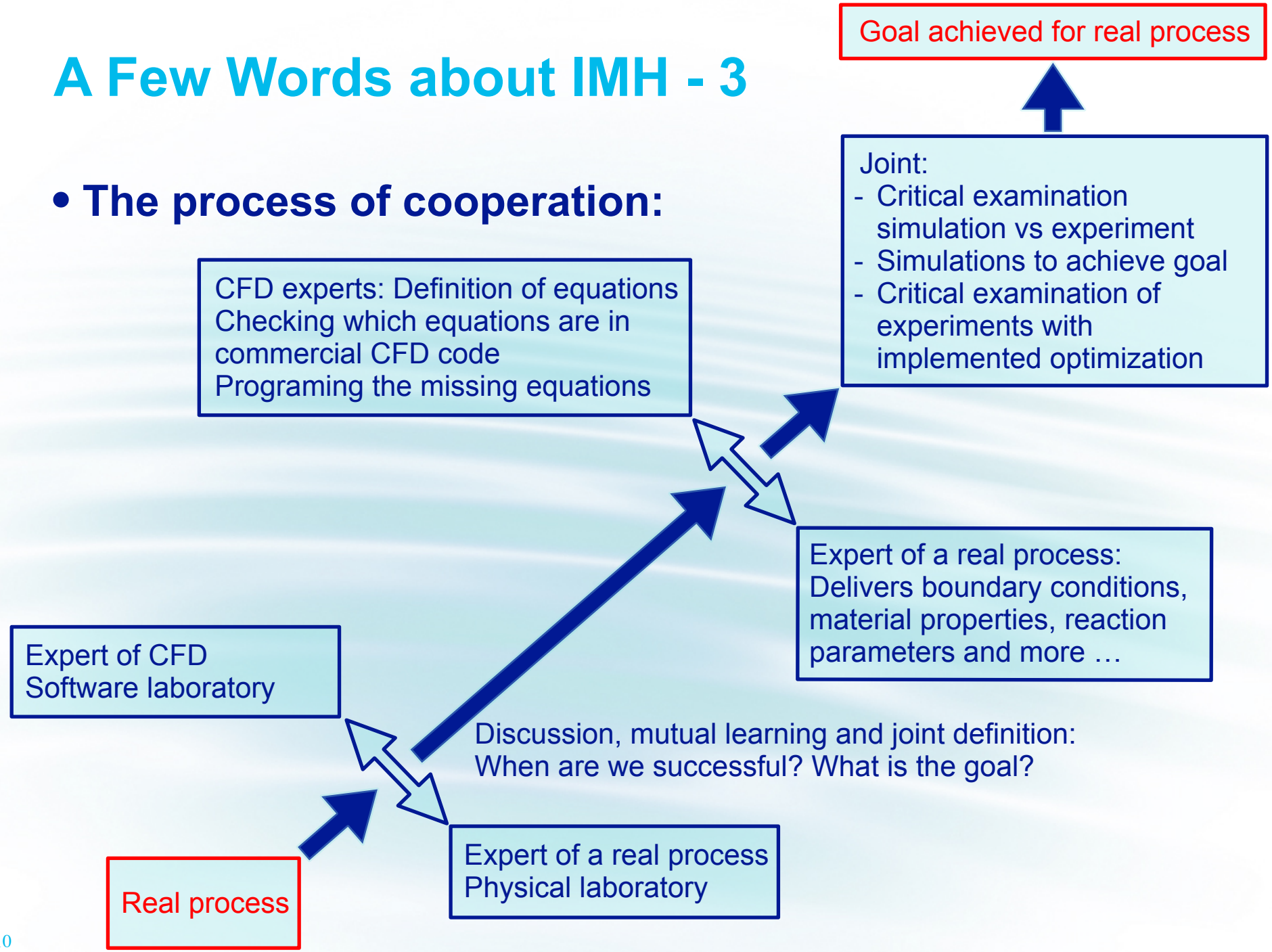
- Members:
  - 4 professors
    - Computer Science, Parallel Systems
    - Robust Design Optimization, Mathematics, Optimization
    - Computer Simulation of Fluid Flow (Computational Fluid Dynamics, CFD)
  - 7 scientific assistants
  - 1 assistant for finance and organization

A Few Words about IMH - 2

- CPU-cluster „Europa“ - 512 cores / 2,0 TB RAM
- Cluster „fornix“:
    - CPU-cluster - 1.216 cores / 9,7 TB RAM
    - GPU-cluster - 38 Nvidia A100 / 1,5 TB RAM
- 9 workstation (together 122 cores and 544 GB RAM)
- 75 permanent licenses Ansys Multiphysics
- 512 permanent parallel licenses Ansys Multiphysics
- DSMC OpenFOAM, software for coupling to Ansys
- And more …

A Few Words about IMH - 3

- **The process of cooperation:**



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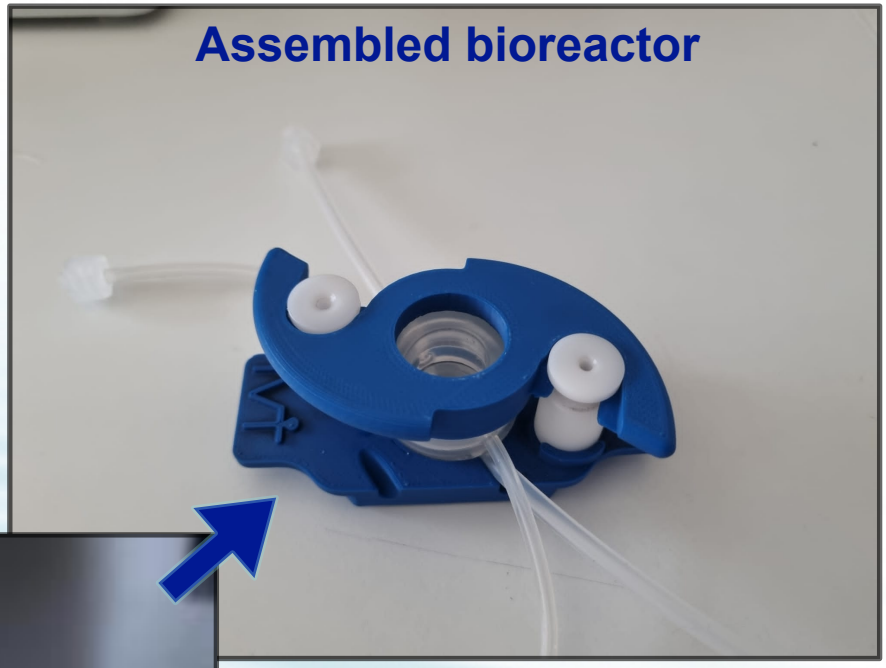
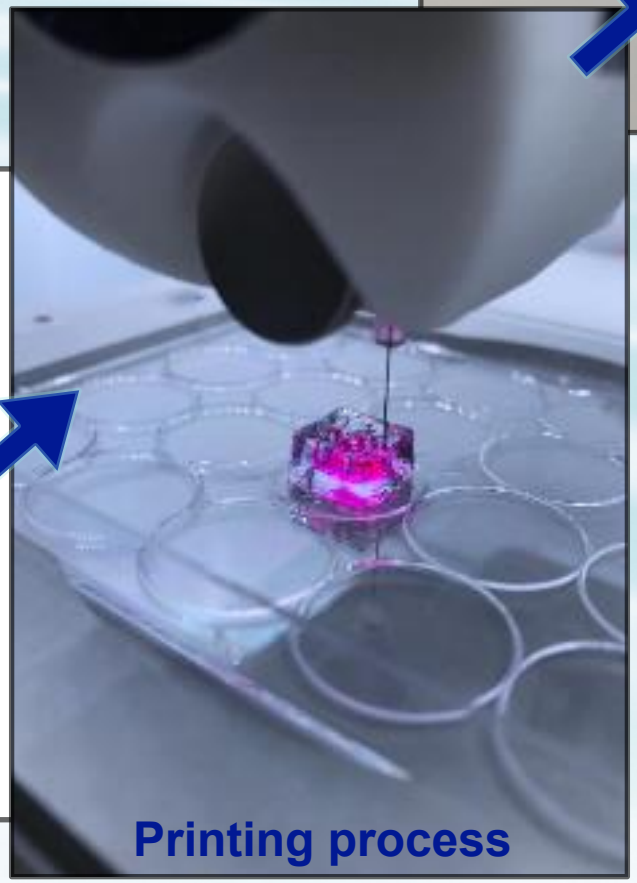
The Real Process - 1

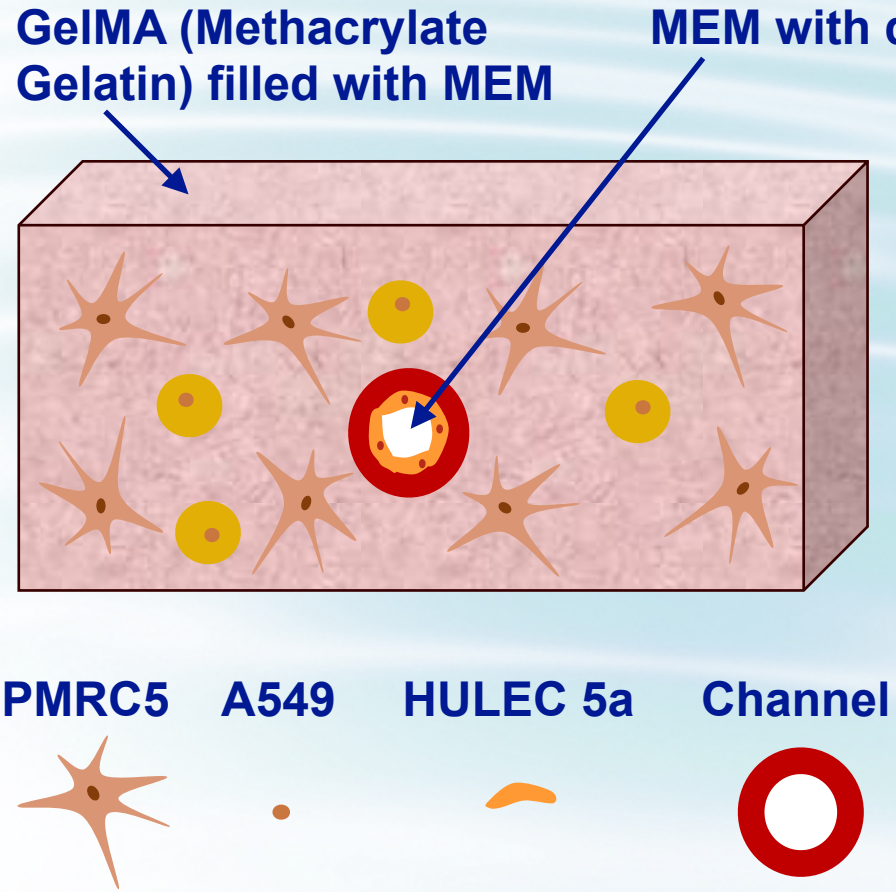
- **Organ-on-a-Chip study for tumoral cells bioprinting**

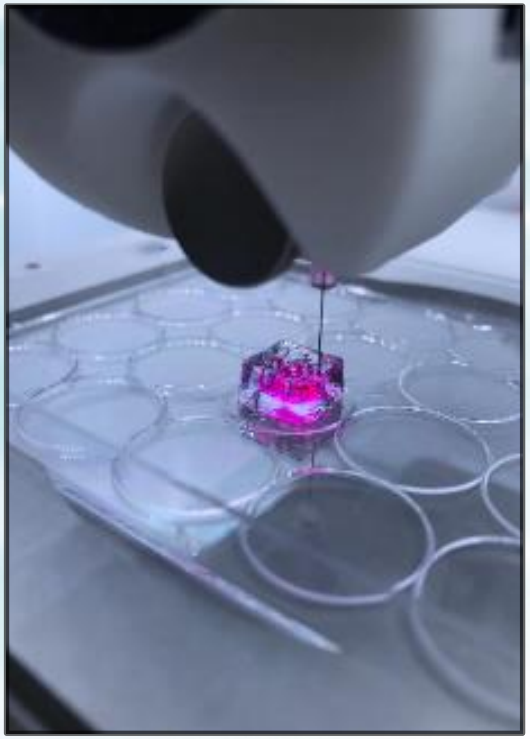




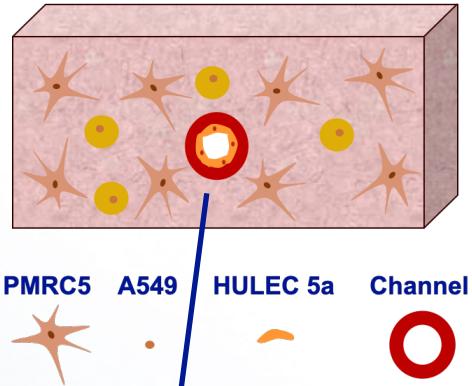
The Real Process - 2

- **Sketch of the bioprinted in-vitro device of human lung-cancer**

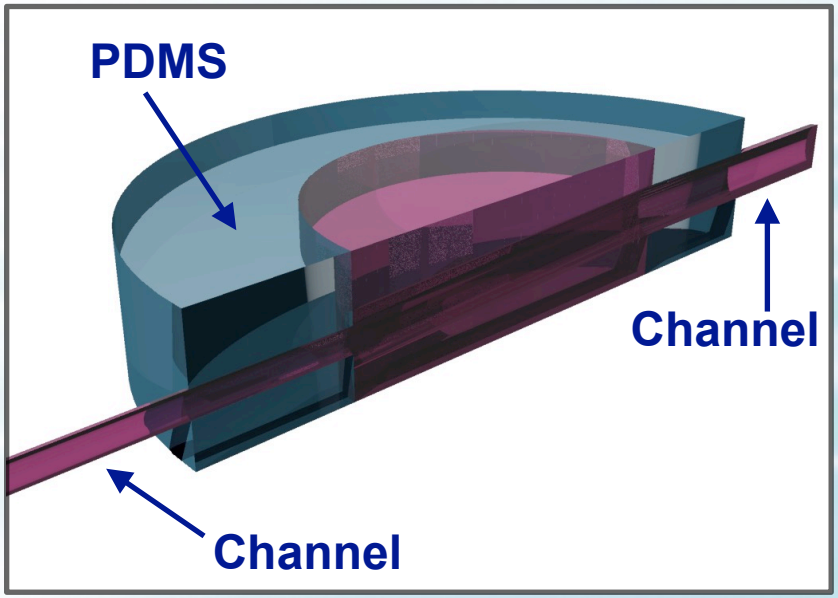


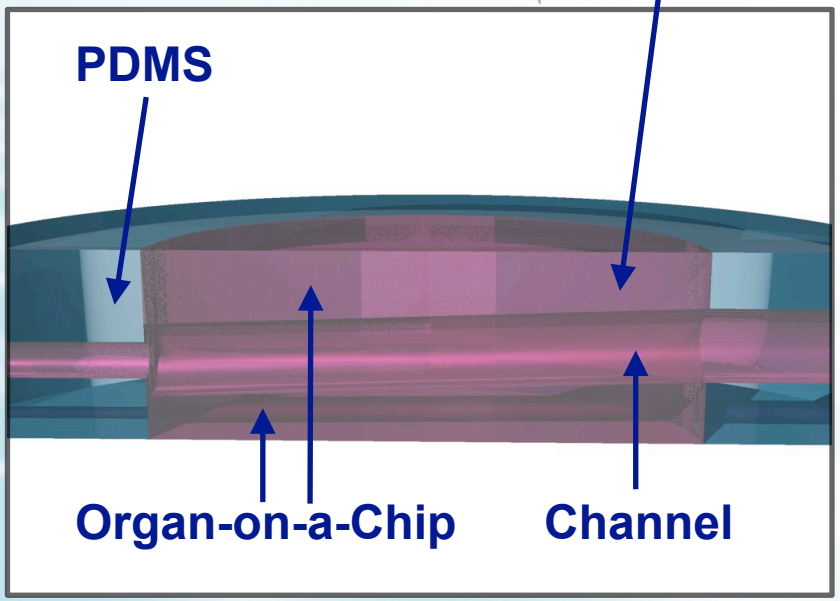


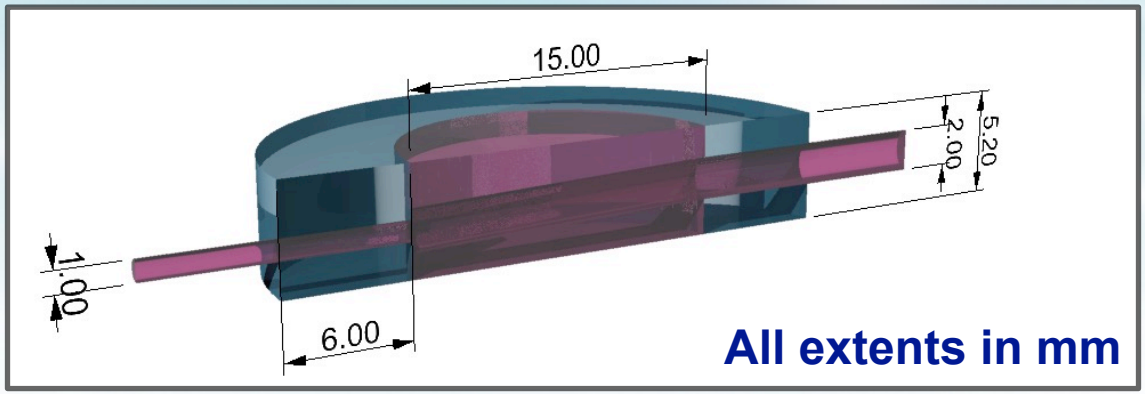
The Real Process - 3



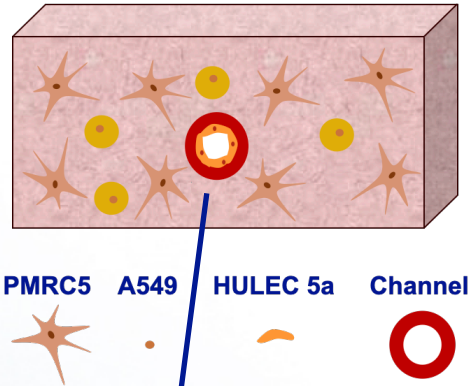
- **Solution domain: 3D CAD rendering**



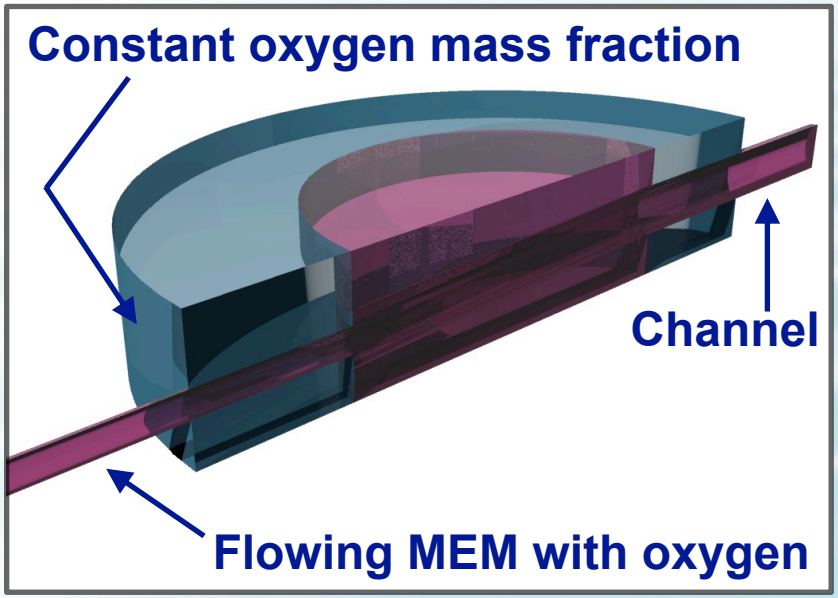


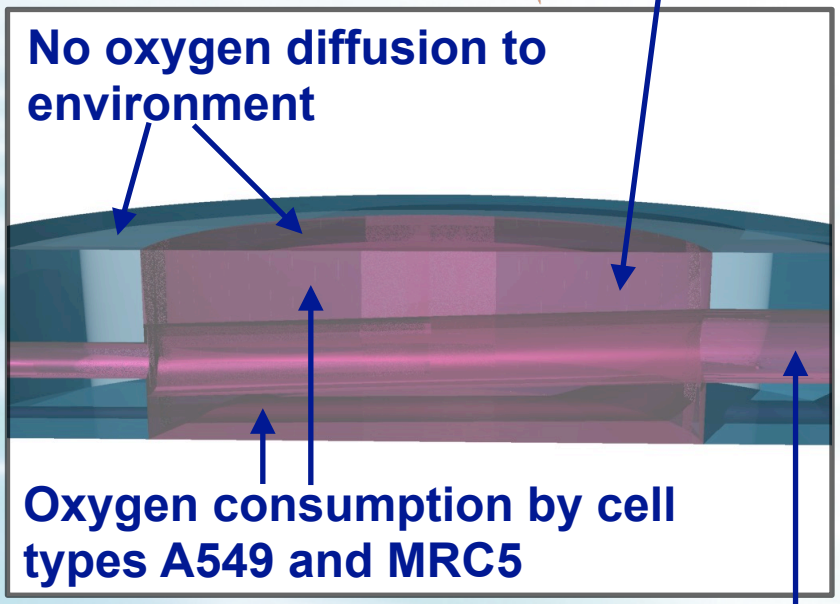


The Real Process - 4



- **Boundary conditions**





Flowing MEM with oxygen

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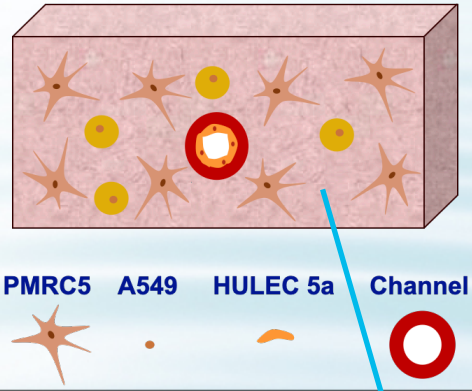
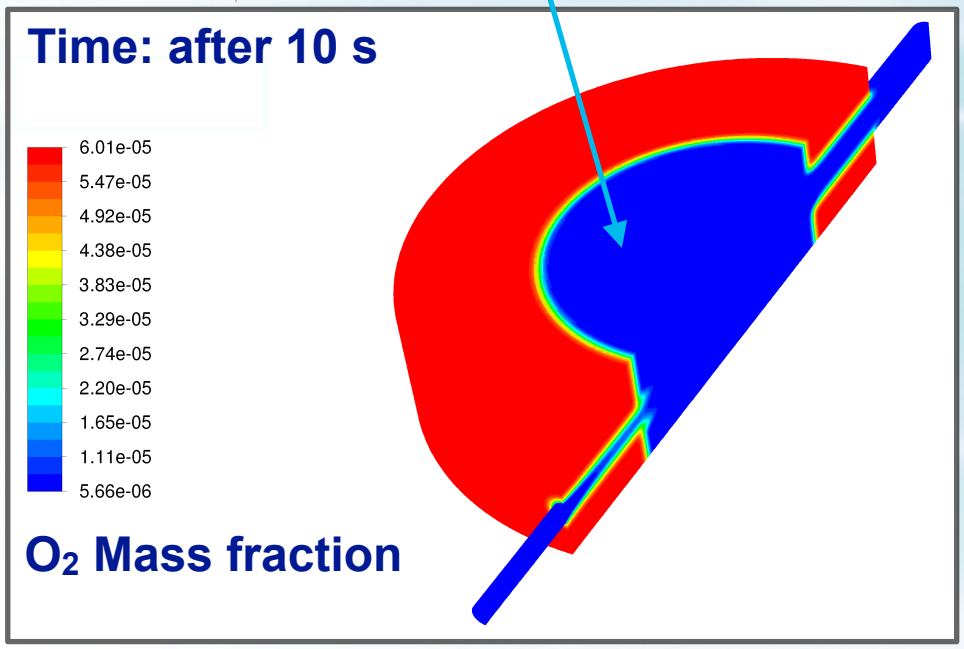
First Results of Numerical Simulations - 1

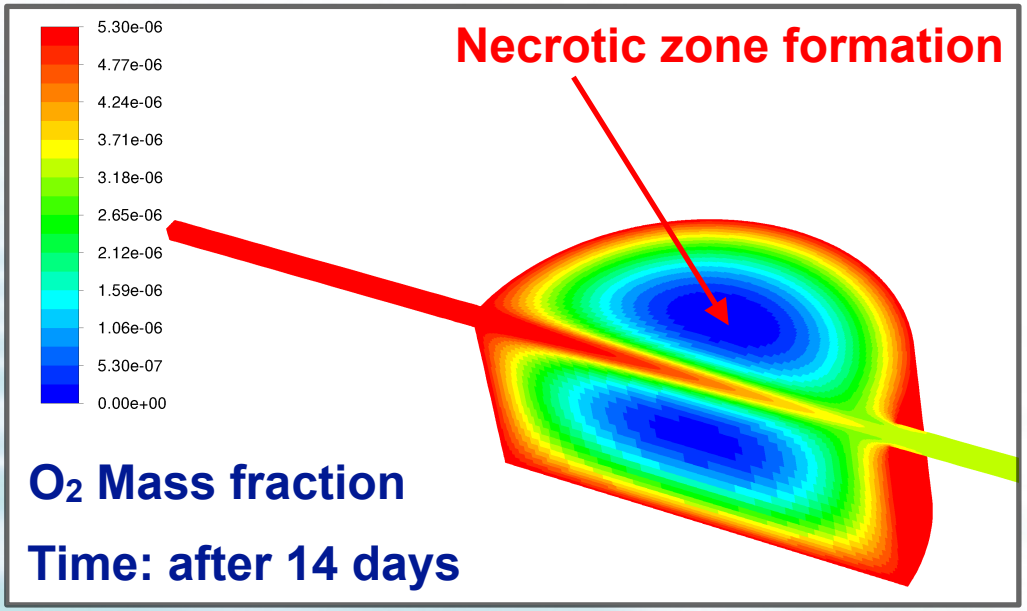
- O_2 Mass fraction evolution





First Results of Numerical Simulations - 2

- Benefits of Computer simulation:
  - One can look inside a volume of a liquid or gas - at every point
  - This generates new insights into the process
  - and an increase of quality
  - as well as a shortening development time and cost



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Future Steps

- Implementation of additional program in Ansys Fluent to consider physical O_2 max fraction in MEM
- Check of iteration convergence and mesh convergence (i.e. check of numerical accuracy)
- Comparison with the O_2 evolution in the experimental model
- Avoid necrotic zones:
  - Optimization of the flow rate to obtain O_2 optimal mass consumption with respect to MEM renewal in the OoC

References

Reference values

- MEM

	Density [kg/ m3]	Viscosity [Pa s]	Flow rate [µl/ min]
MEM	1.01E+03	9.30E-04[1]	200

- O2 mass fraction in mem

	D COEF. O2 [m2/s]	Molarity in Medium	%wt of O2 in MEM
O2 mass fraction in MEM	2.88E-09	1.67E-04[1]	5.30E-06

- O2 consumption per cell (Kg/s)

	Cell Type	#cell/ml	O2 consumption per cell [Kg/s]
O2 consumption	A549	1.50E+06	2.66E-18[2]
	MRC5	1.50E+06	1.06E-17[3]

[1] https://www.pnas.org/doi/pdf/10.1073/pnas.91.25.12248https://www.pnas.org/doi/pdf/10.1073/pnas.91.25.12248
[2] https://www.pnas.org/doi/pdf/10.1073/pnas.91.25.12248
[3]https://www.nature.com/articles/s41598-017-00130-x