Welcome to the 7th European Bifurcation Club 14-15 October 2011 - LISBON

John Doe LM flow dynamics before, during and after stenting

European Bifurcation Club

EBC

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Politecnico di Milano

Milan, Italy

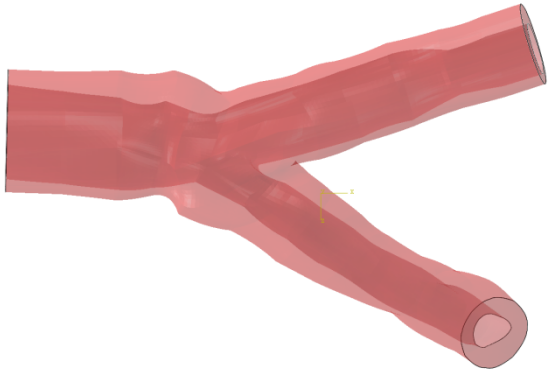
European Bifurcation Club

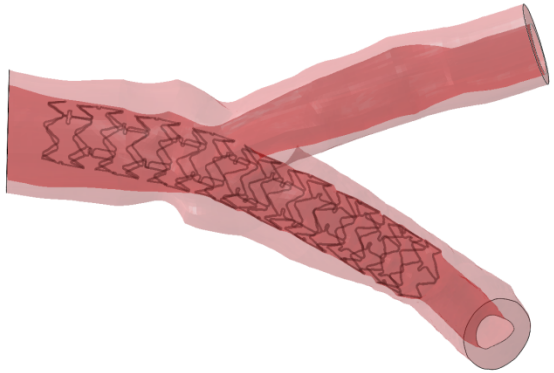
EBC

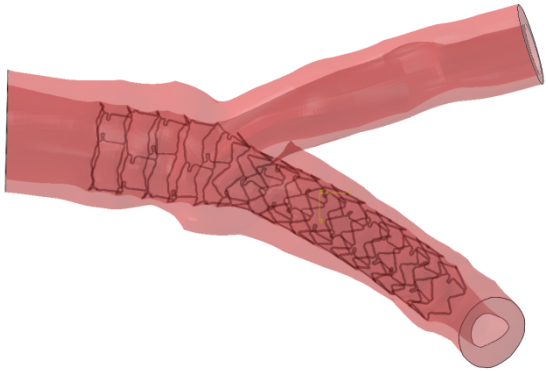
From structural to fluid dynamic model

- **Pre Expansion**
- **MB Expansion**
- **Proximal Optimisation Technique (POT)**

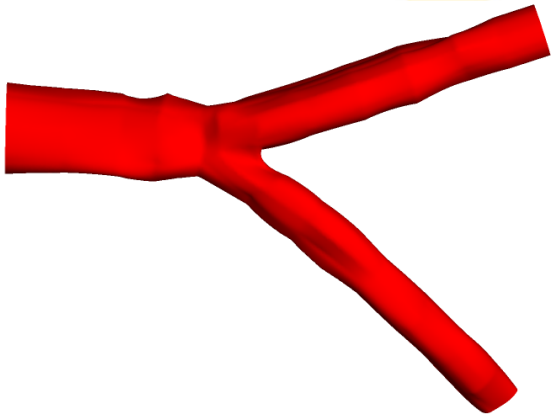
STRUCTURAL MODEL *(from Ghent University)*

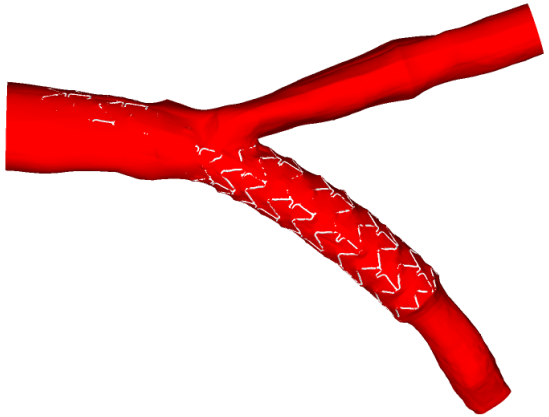


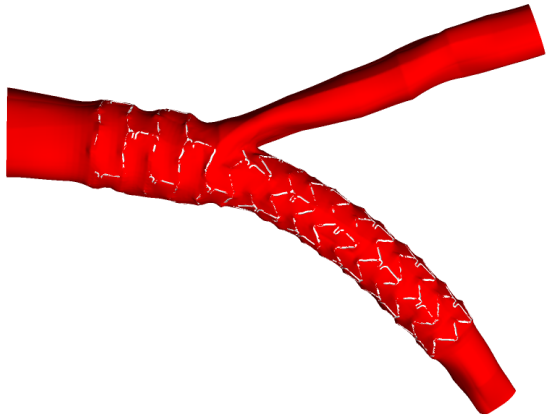




FLUID DYNAMIC MODEL



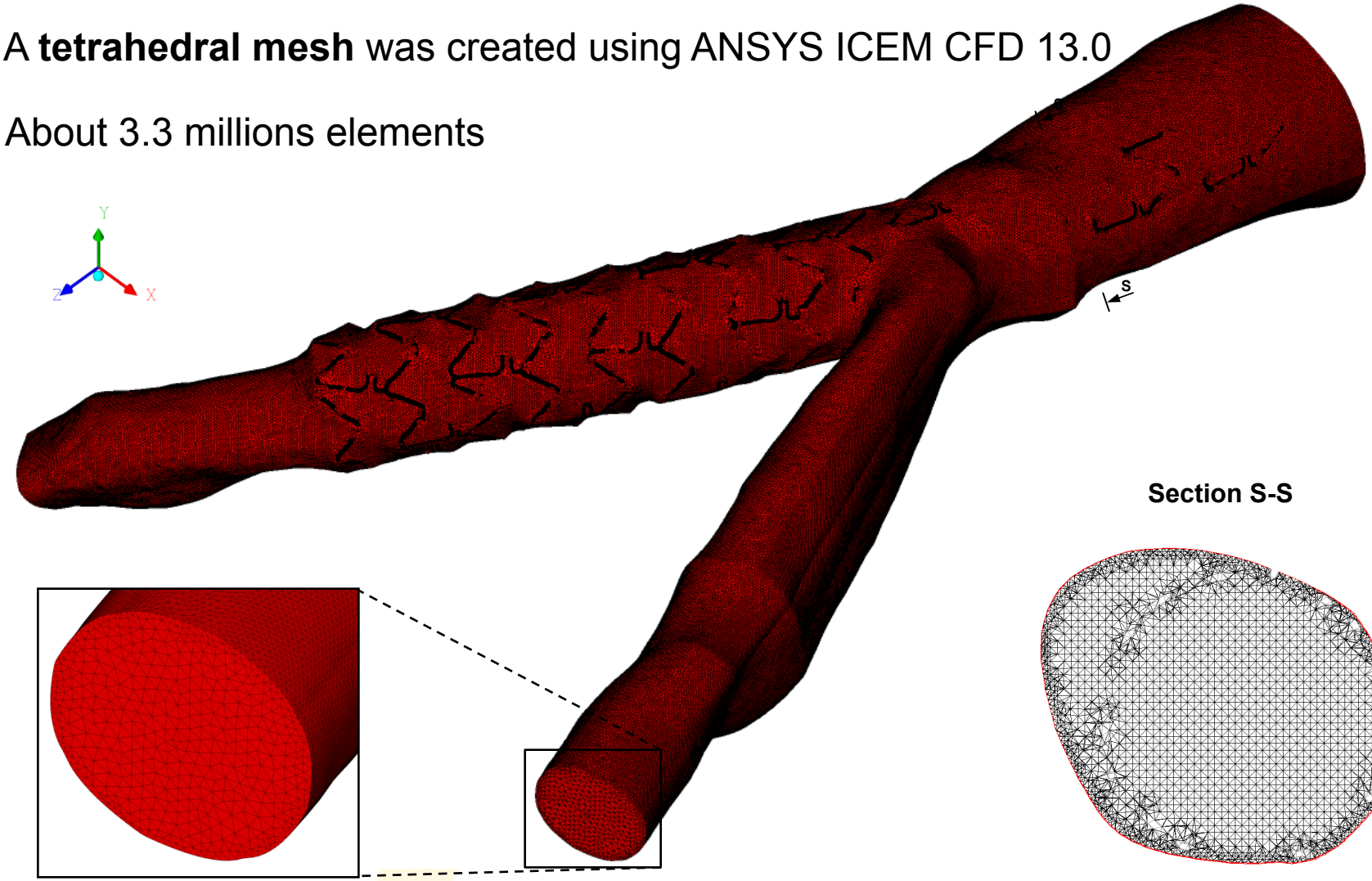




(Xience Prime stent)

Fluid dynamic model: mesh

- A **tetrahedral mesh** was created using ANSYS ICEM CFD 13.0
- About 3.3 millions elements



Section S-S

Fluid dynamic model: methods

- **Fluid model**: non-Newtonian blood (Carreau model)

  μ_∞ = 0.0035 Pa·s λ = 25 s

  μ_0 = 0.25 Pa·s n = 0.25

  $$\mu = \mu_\infty + (\mu_\infty + \mu_0)[1 + (\lambda S)^2]^{n-1/2}$$

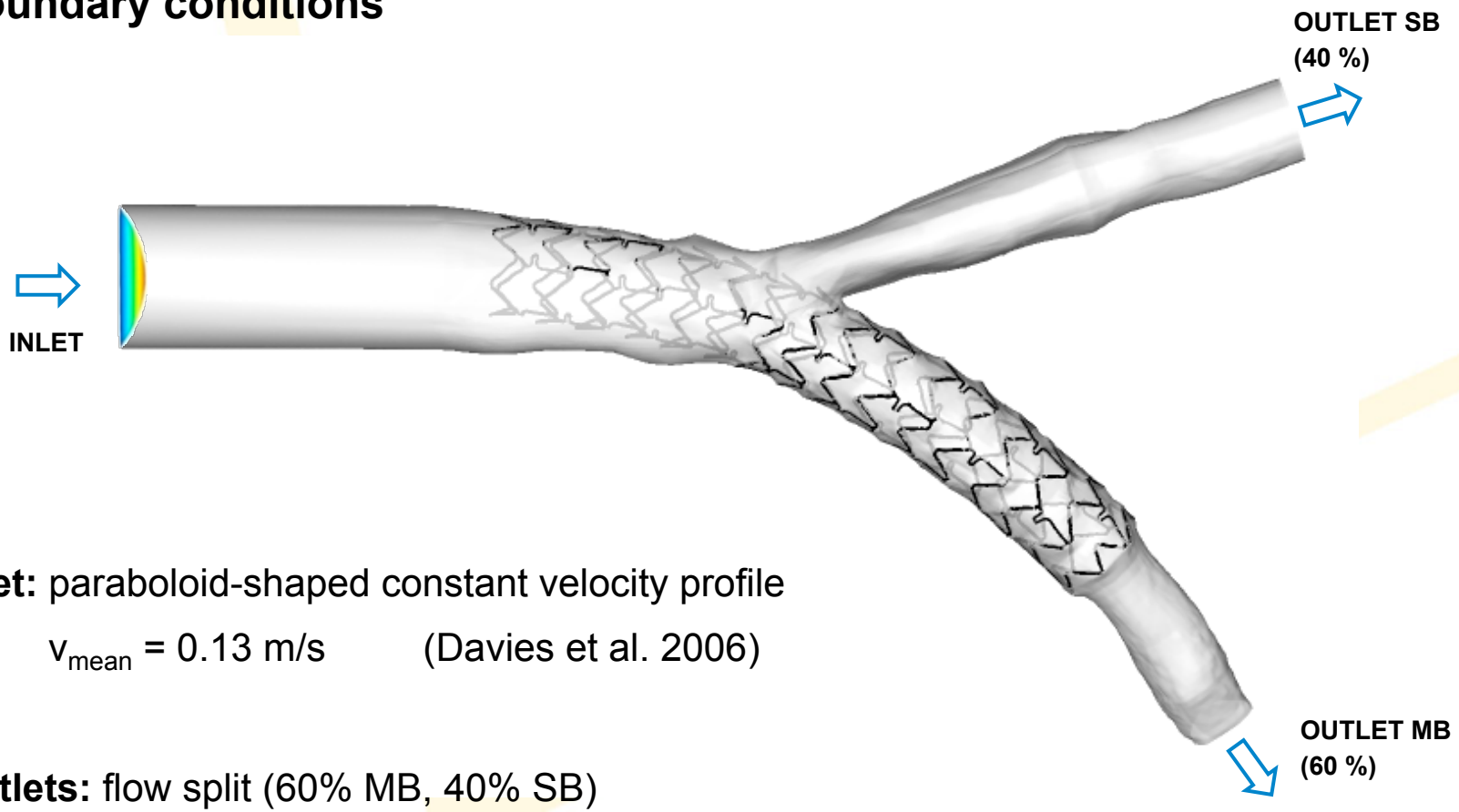
  ρ = 1060 kg/m^3 (Seo et al. 2005)

- **Solver**: ANSYS FLUENT 13.0 coupled – steady state

  - **Momentum spatial discretization:** second-order upwind scheme
  - **Courant number:** 50
  - **Under relaxation factors:** 0.3 for pressure and momentum
    1 for density
  - **Convergence criterion:** 10^{-7} for continuity and velocity residuals

Fluid dynamic model: methods

Boundary conditions



- **Inlet:** paraboloid-shaped constant velocity profile

  v_{mean} = 0.13 m/s (Davies et al. 2006)

- **Outlets:** flow split (60% MB, 40% SB)

- **Wall:** no-slip condition

Fluid dynamic model: methods

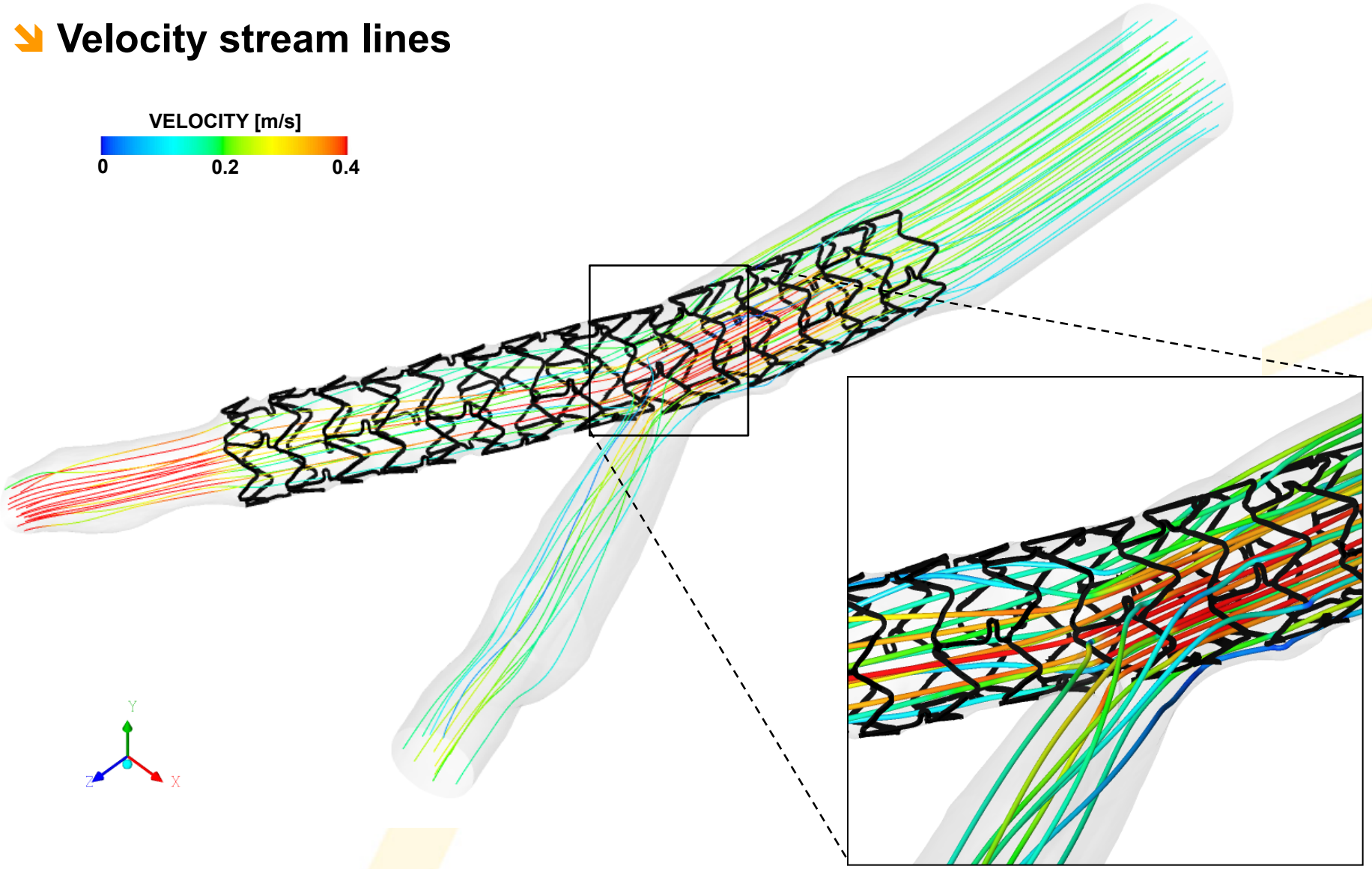
- **CFD simulations were made on a desktop PC using 2 parallel cores.**
  The computer is equipped with a 2,93 GHz quad-core processor with 16 GB RAM

- **Wall clock time for CFD a steady simulation:** about 4 hours
  (with a mesh of 3.3 million elements)

- **Estimate wall clock time for a CFD transient simulation:** 2 days (on a cluster)

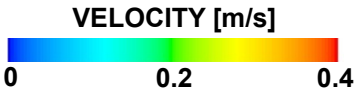
Fluid dynamic model: results

- **Velocity stream lines**

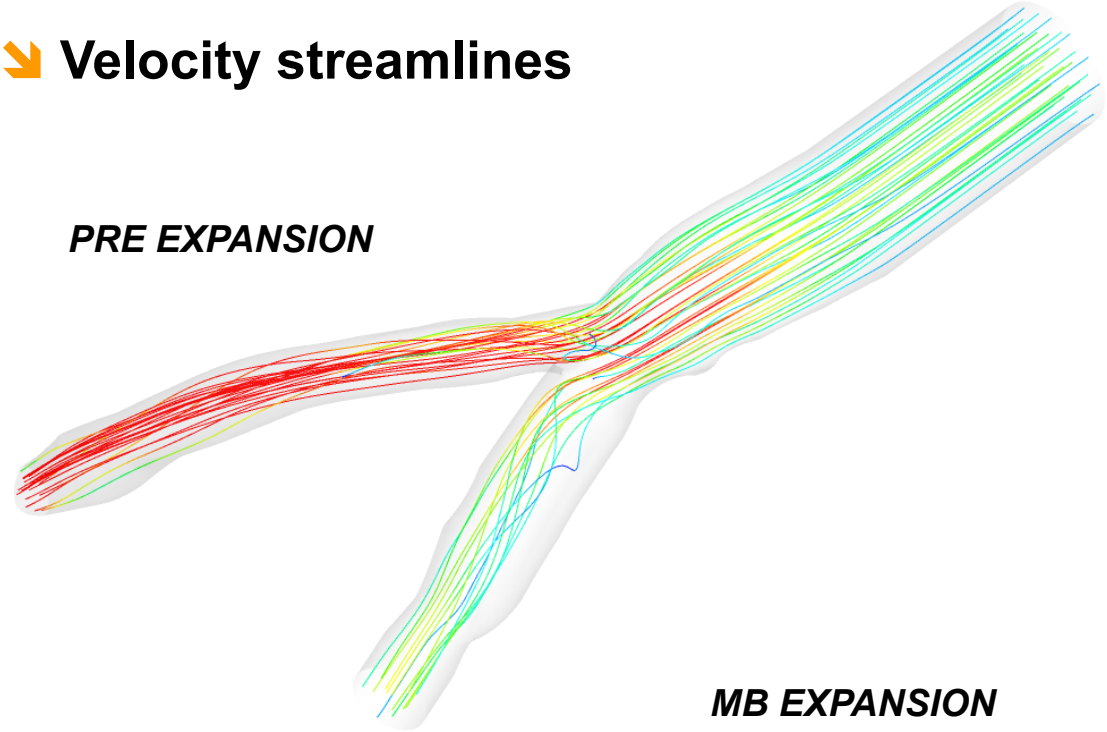


Fluid dynamic model: results

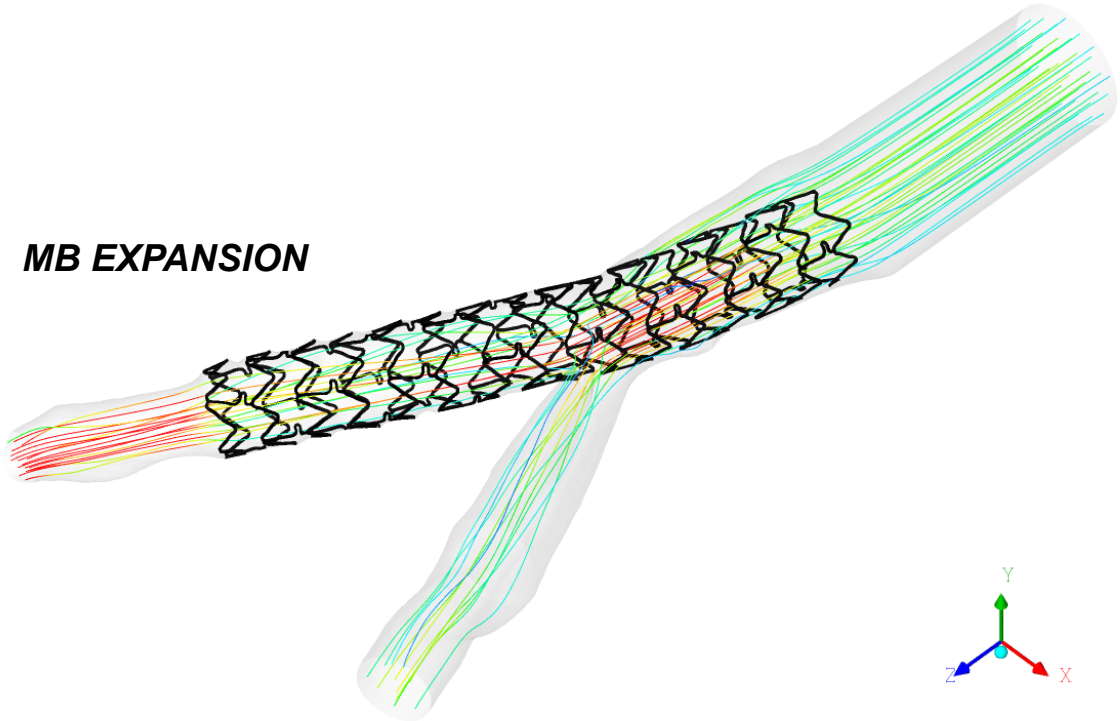
- **Velocity streamlines**



PRE EXPANSION

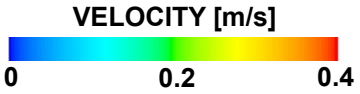


MB EXPANSION



Fluid dynamic results: comparison

- **Velocity contours**



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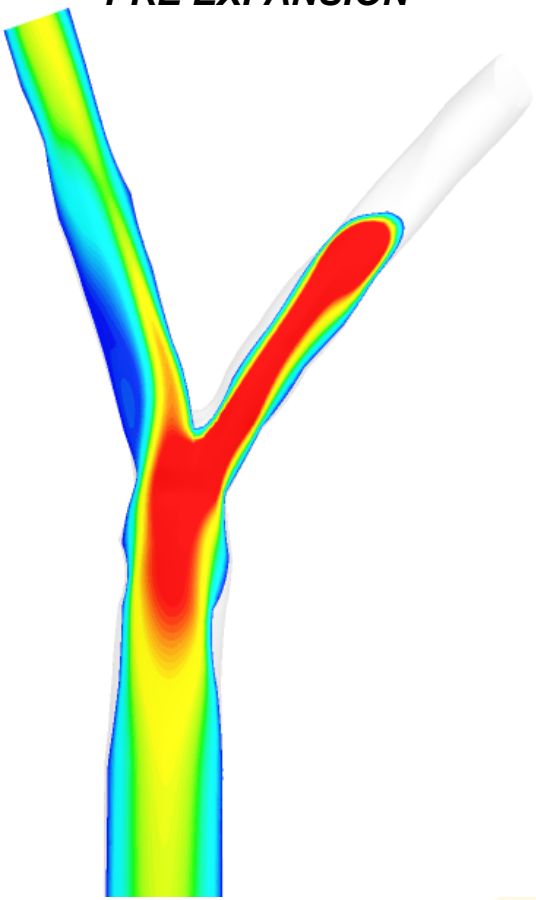
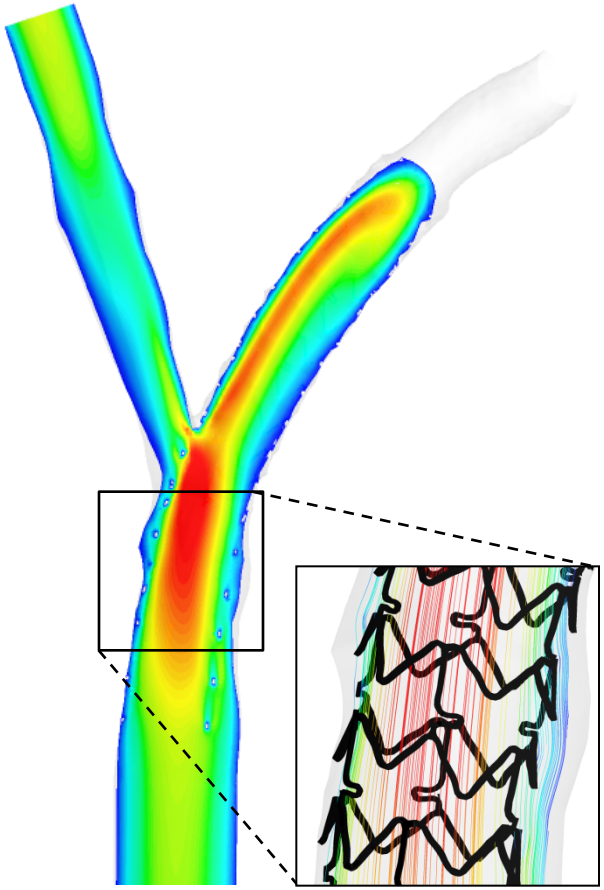
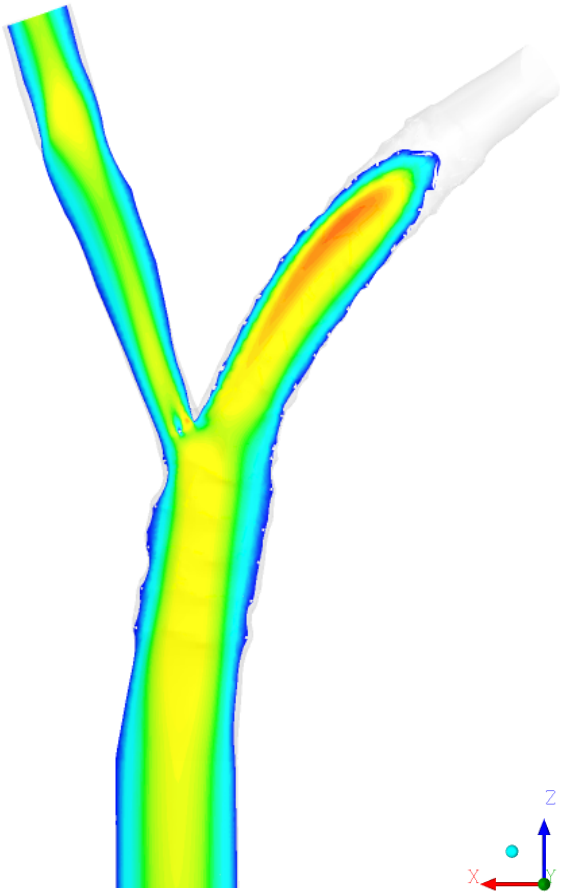


MB EXPANSION



POT

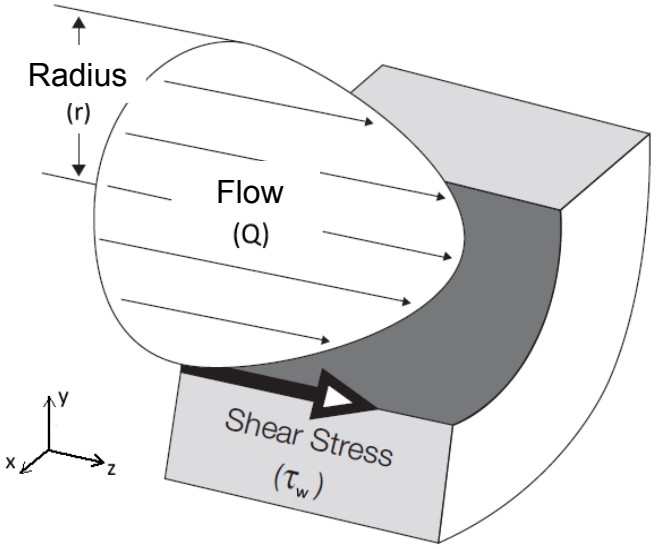


Local fluid dynamics

- **Wall Shear Stress (WSS) and WSS gradients**

- **Oscillatory Shear Index (OSI)**

$$OSI = \frac{1}{2}\left(1 - \frac{\left|\int_0^T \vec{\tau}_w dt\right|}{\int_0^T \left|\vec{\tau}_w\right| dt}\right)$$



T = duration of cardiac cycle and τ_w = instantaneous wall shear stress vector

OSI > 0.1 ÷ 0.2

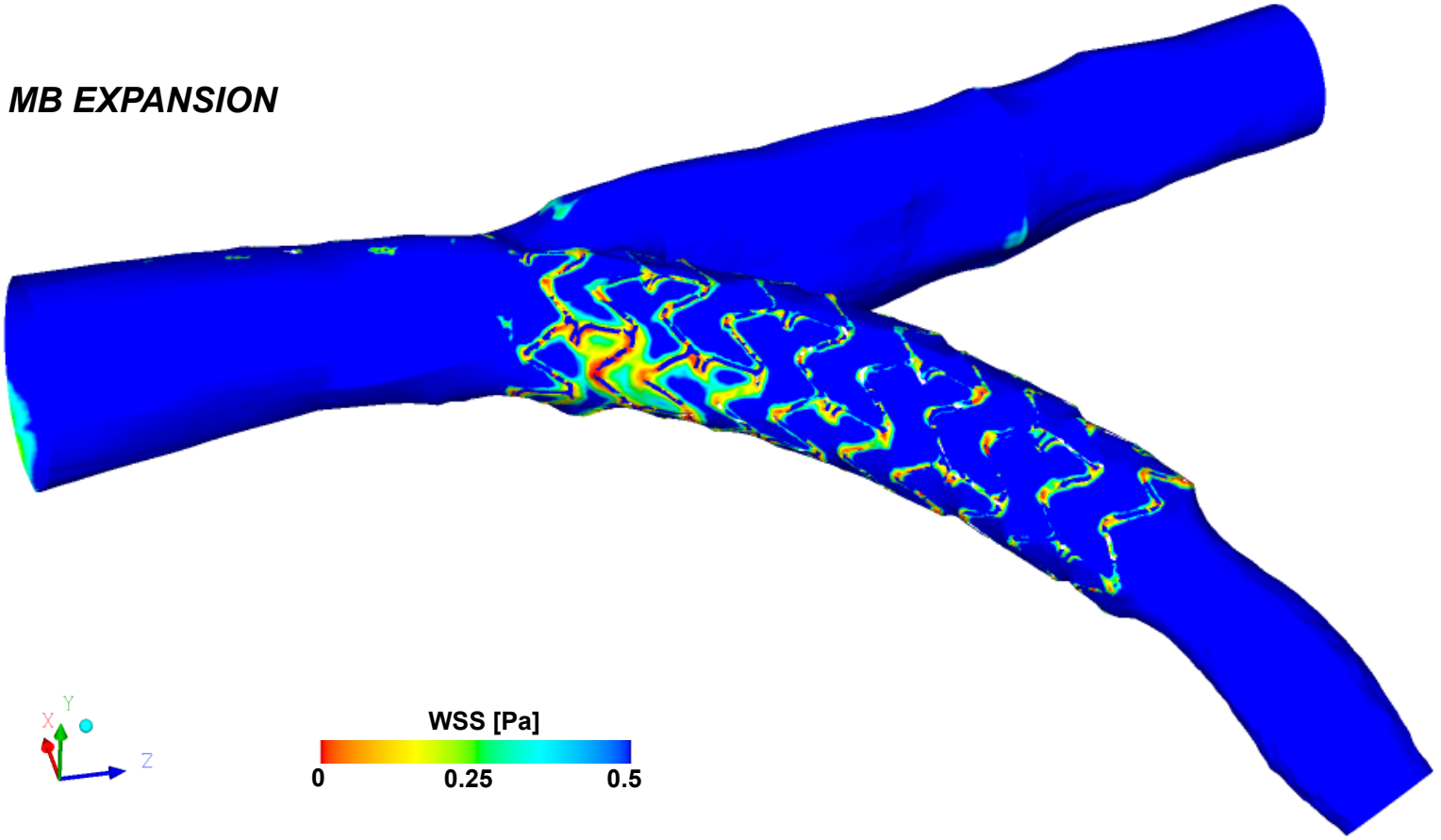
WSS < 0.5 Pa

⇨ associated with cellular proliferation, intimal thickening, and inflammation

Fluid dynamic results

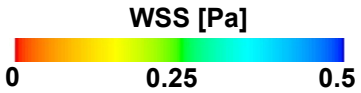
- **Wall Shear Stress (WSS)**

WSS < 0.5 Pa ⇨ risk of restenosis (Ku 1997, Malek et al. 1999)

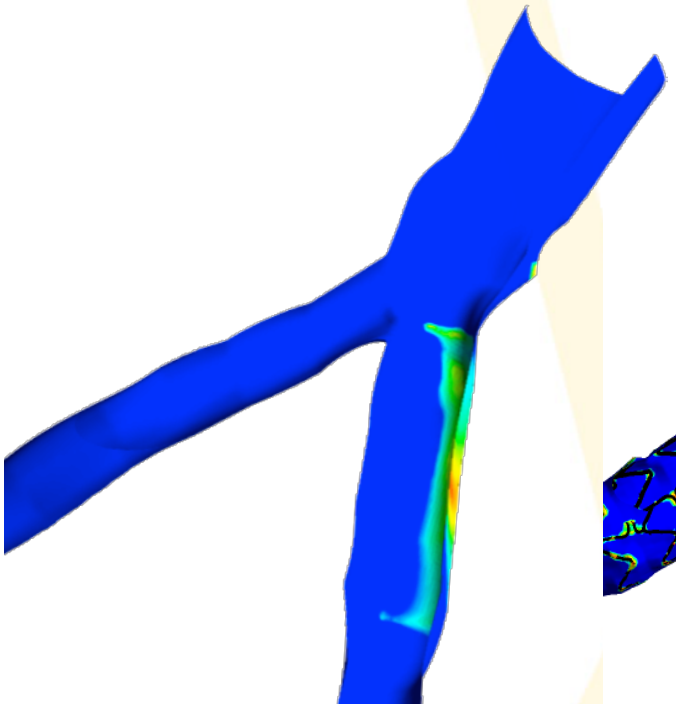


Fluid dynamic results: comparison

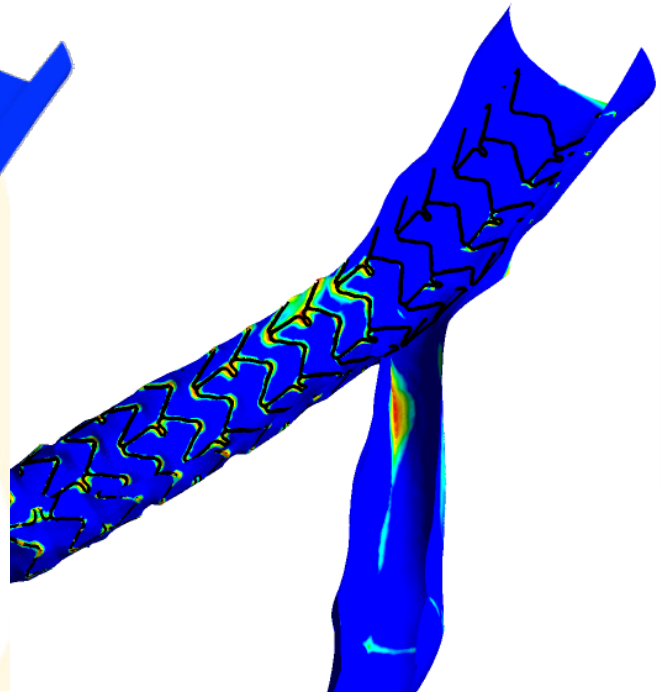
- **Wall Shear Stress (WSS)**



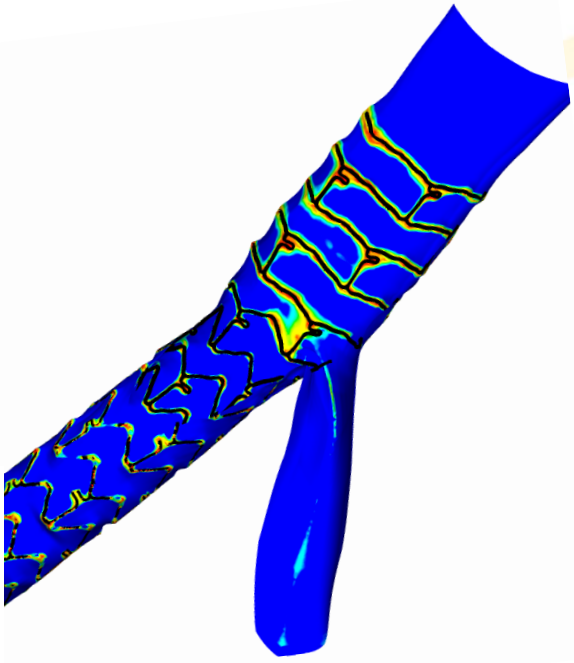
PRE EXPANSION



MB EXPANSION



POT

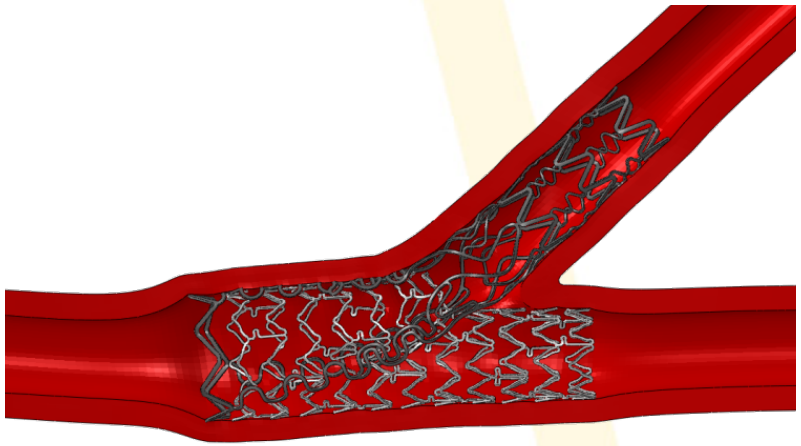


Conclusions (from EBC 2010)

Towards (patient-specific) virtual interventional planning - *i.e. open problems for engineers*:

- Material properties of the arterial wall and plaque
- Detailed anatomy from routine visualisation techniques – i.e. beyond fluoroscopy
- Inlet flow curve and outlet pressure/flow split
- Short term prediction
- How to smoothly fit in the clinical workflow?

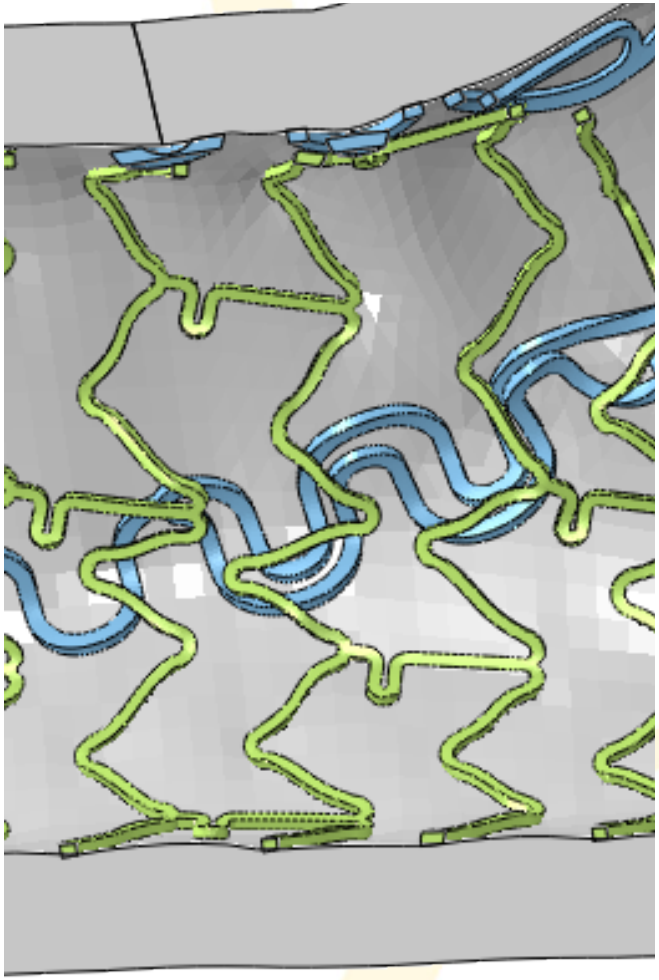
Dedicated vs standard devices

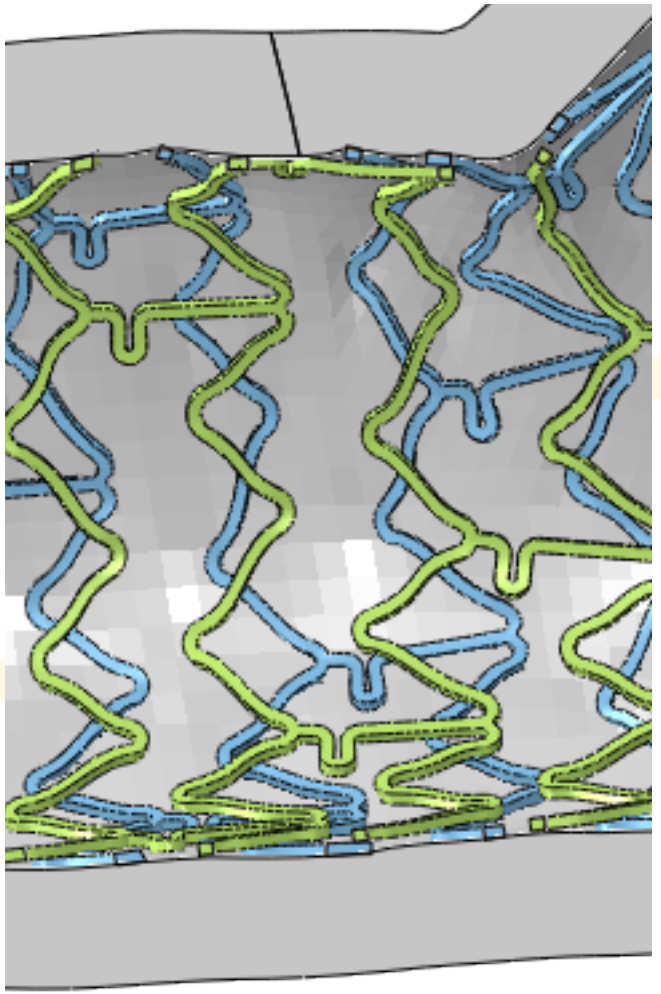


Dedicated device

Standard device

Dedicated vs standard devices





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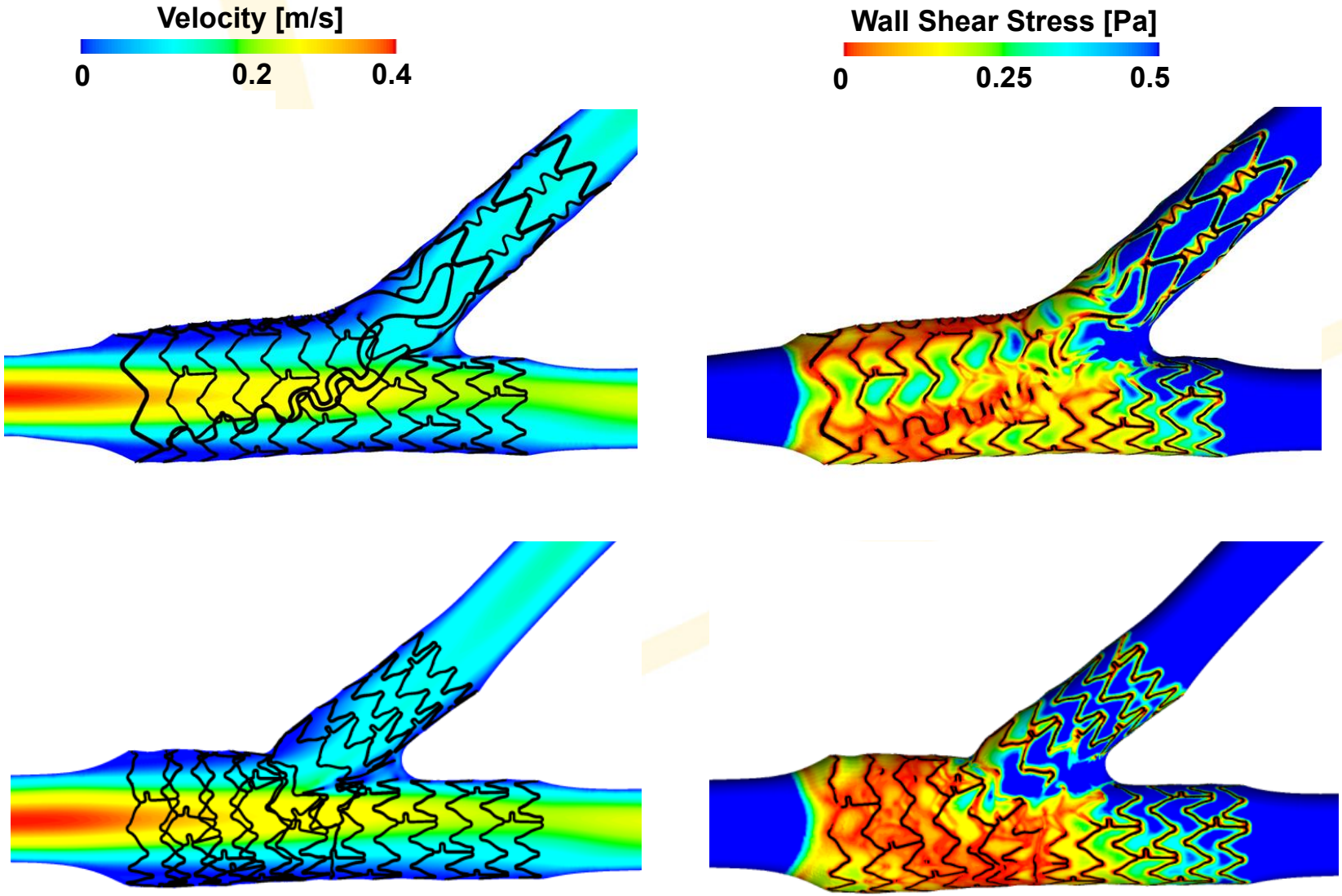

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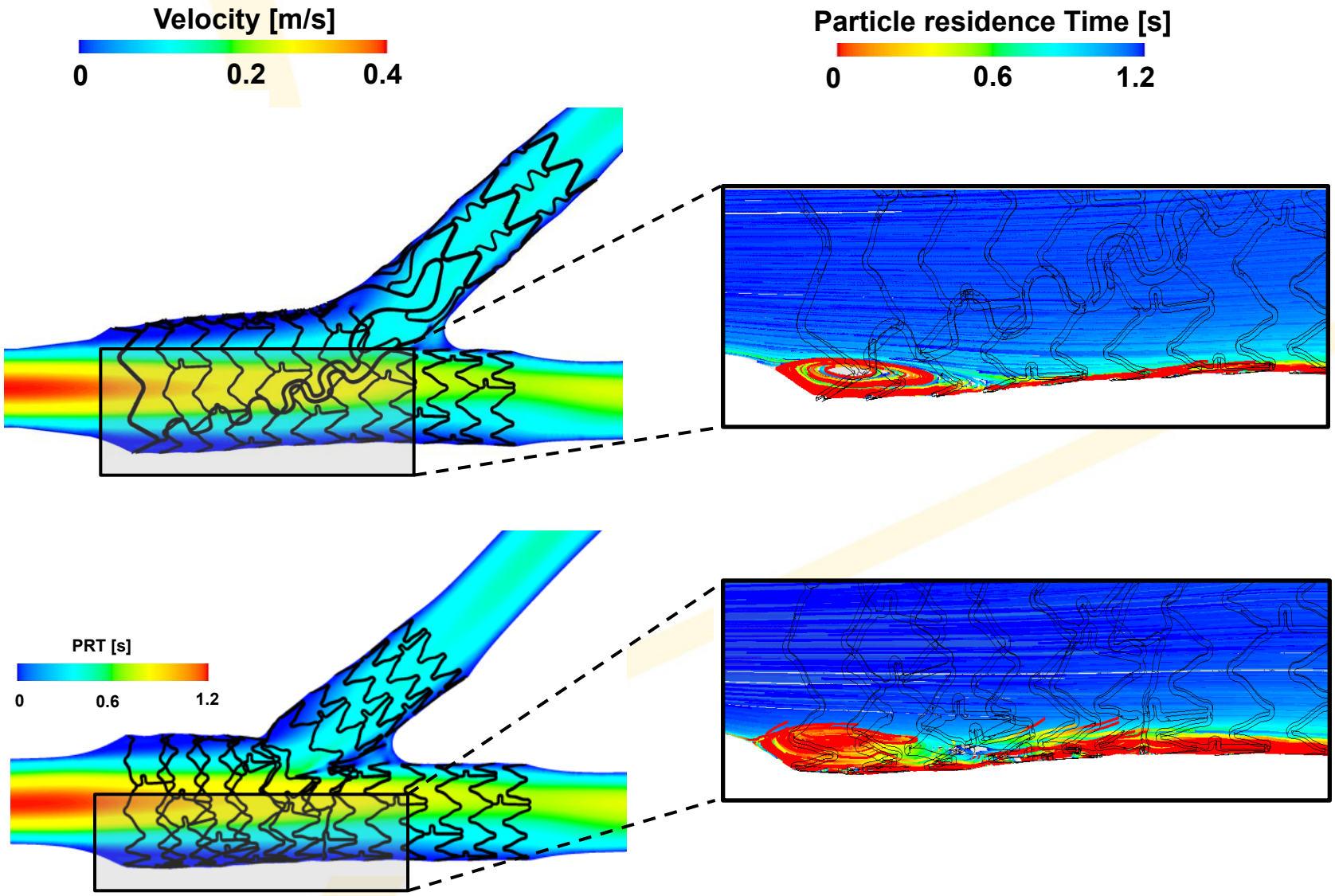

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