LPT with random walk model And interPhaseChangeFoam with non-homogeneous nuclei distribution.

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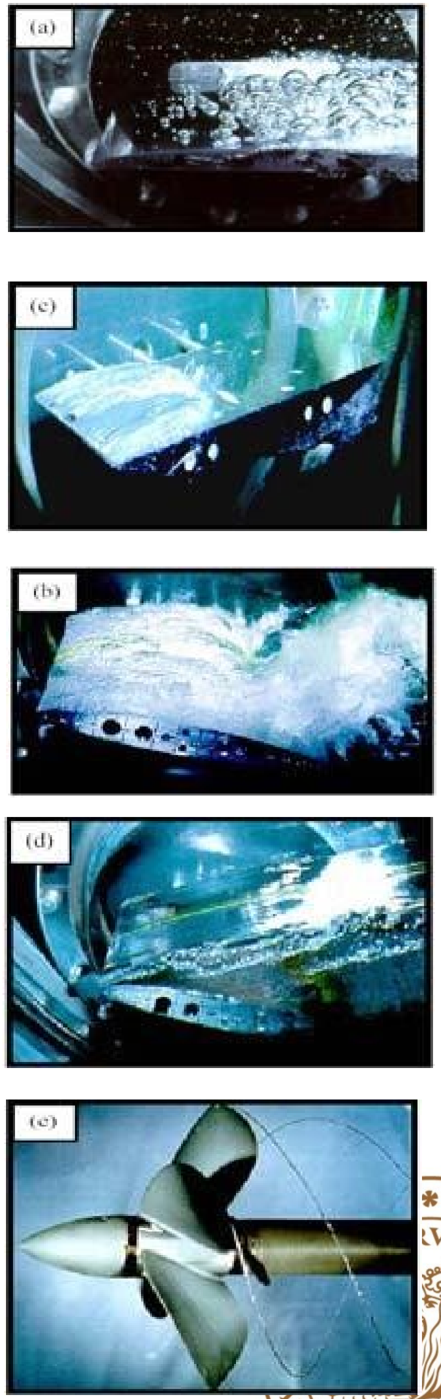
INTRODUCTION

Cavitation in hydro-turbines

- Travelling bubble
- Attached cavitation
    - Sheet cavitation
    - Cloud cavitation
- Supercavitation
- Vortex cavitation

→ interPhaseChangeFoam (based on Sauer model)



OUTLINE

- **Sauer model**
- **Nuclei distribution**
- **Sauer model with a non-uniform nuclei distribution**

SAUER MODEL

Pressure drop	Cavitation number	$\sigma = \frac{p_\infty - p_v}{1/2\rho u_\infty^2}$
Nuclei	Nuclei density n0 Nuclei radius R	$\alpha = \frac{n_0 \cdot \frac{4}{3}\pi R^3}{1 + n_0 \cdot \frac{4}{3}\pi R^3}$
Two phase flow	Interface tracking Transport equation Mass transfert	Volume Of Fluid $\rho = \rho_v \alpha + \rho_l (1-\alpha)$ $\mu = \mu_v \alpha + \mu_l (1-\alpha)$ $\frac{\partial \alpha}{\partial t} + \nabla . \alpha \vec{U} = \frac{\dot{m}}{\rho_l}$
Turbulence	Turbulence model	RANS (2D) LES(3D)
Bubble dynamics	Rayleght-Plesset equation	$\frac{dR}{dt} = \sqrt{\frac{2}{3} \frac{p(R) - p_\infty}{\rho_l}}$

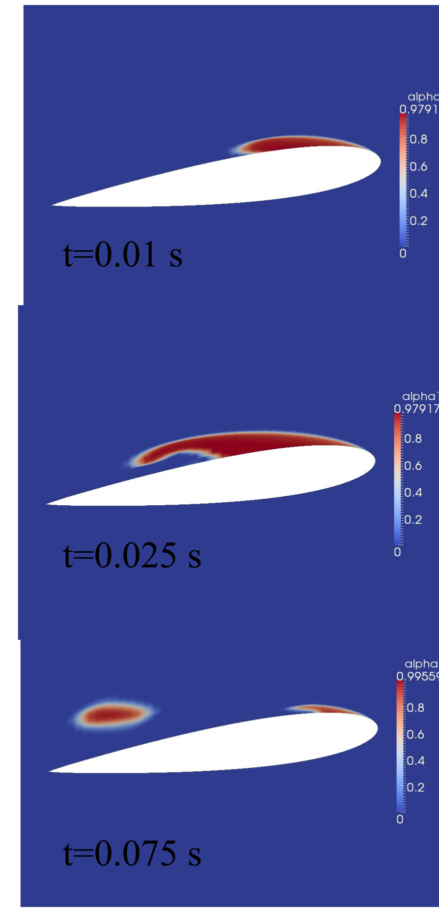
SAUER MODEL - Achievements

The mechanisms of the unsteady behavior are well simulated.

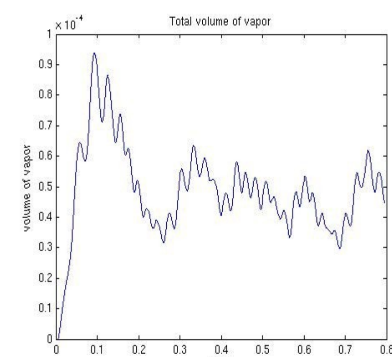
. Attached cavity

. Re-entrant jet

. Cloud transported downstream

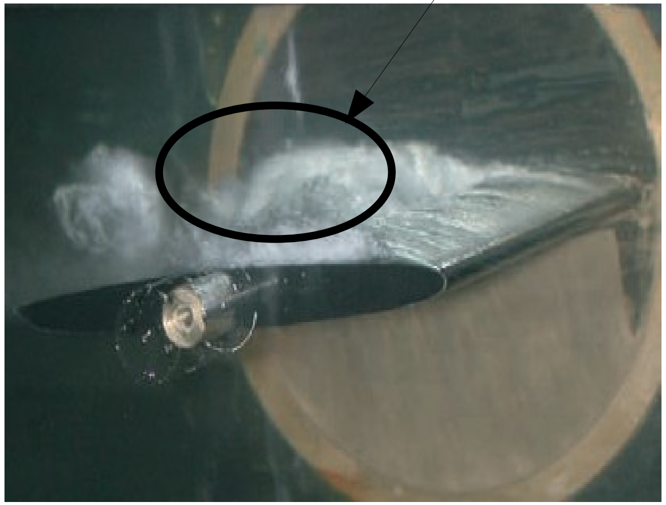


. Vapor shedding

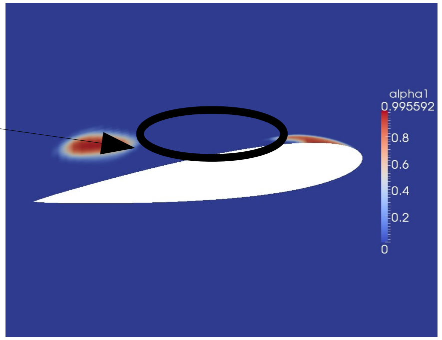


SAUER MODEL - Limitations

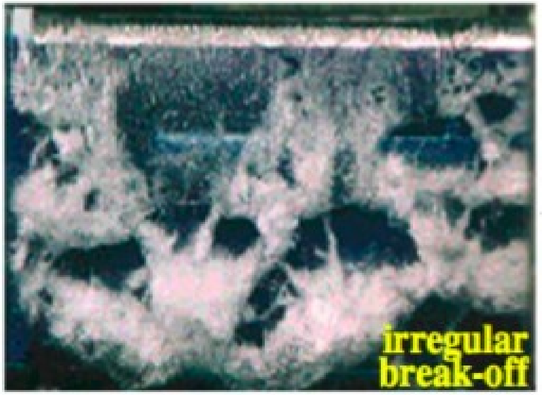
The region with low void fraction is not reproduced correctly.

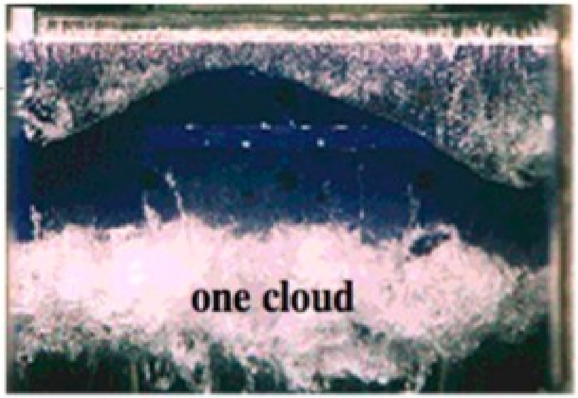


. Transition between the attached cavity and the cloud of vapor



. The break-off with many small structures





. Compressibility → collapse, shock wave, erosion

SAUER MODEL

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Nuclei distribution?

Assumption: uniform
Experiments : non uniform

→ **numerical simulations?**

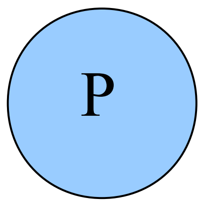
OUTLINE

- Sauer model
- **Nuclei distribution**
- Sauer model with a non-uniform nuclei distribution

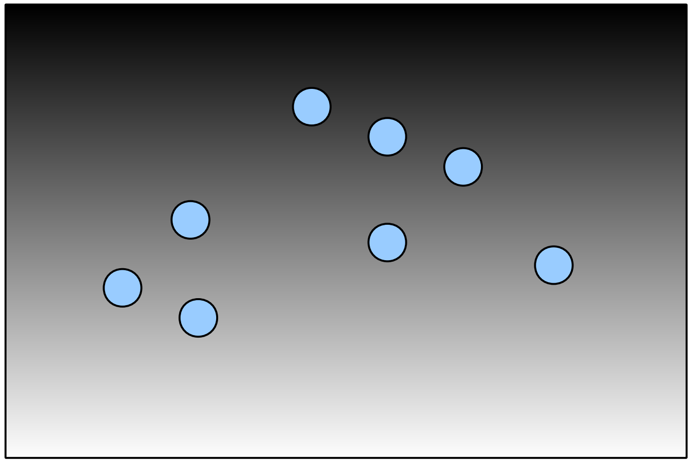
NUCLEI DISTRIBUTION - LPT

Mean flow data (Converged, steady state solution – RANS) ➡ U

Particles (Lagrangian Particle Tracking LPT)



x_p, D_p, U_p, m_p



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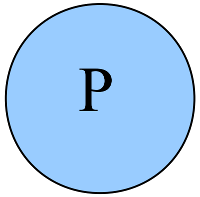
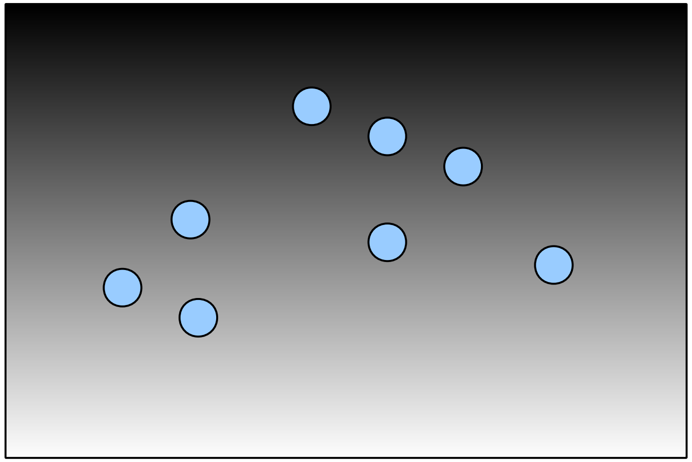


x_p, D_p, U_p, m_p



$$\begin{cases} \dfrac{d\mathbf{x_P}}{dt} = \mathbf{U_P} \\ m_p \dfrac{d\mathbf{U_P}}{dt} = \mathbf{F_D} = -m_p \dfrac{\mathbf{U_p} - \mathbf{U}}{\tau_P} \end{cases}$$

$$\tau_p = \frac{4}{3} \frac{\rho_p D_p}{\rho_f C_D |\mathbf{U} - \mathbf{U_p}|}$$

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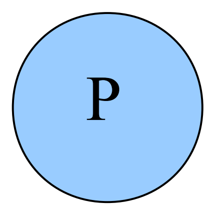
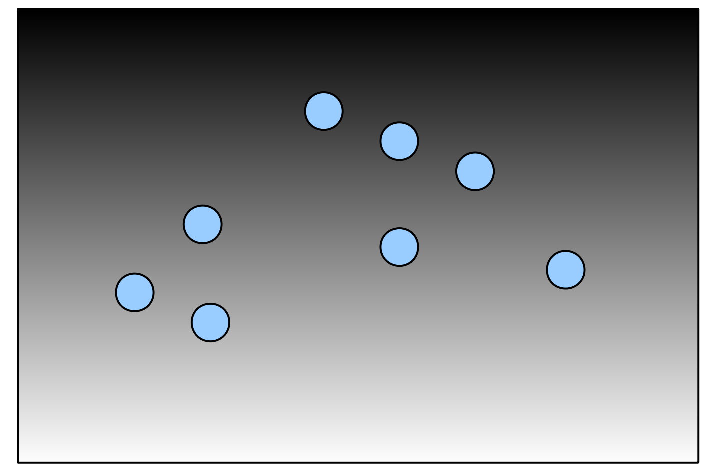
Mean flow data (Converged, steady state solution – RANS) ➡ U

Particles (Lagrangian Particle Tracking LPT)



x_p, D_p, U_p, m_p



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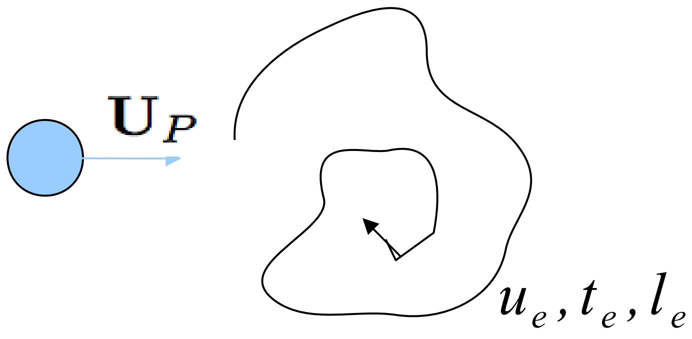
Turbulence inhomogeneities ➡ Random Walk model

NUCLEI DISTRIBUTION - Random walk model



$$U \Rightarrow \tilde{U} = U + U^{fluct}$$

$$U^{fluct} = \psi \sqrt{2k/3}$$

N(0, 1)

NUCLEI DISTRIBUTION - Random walk model

$$U \Rightarrow \tilde{U} = U + U^{fluct}$$

$$U^{fluct} = \psi \sqrt{2k/3}$$

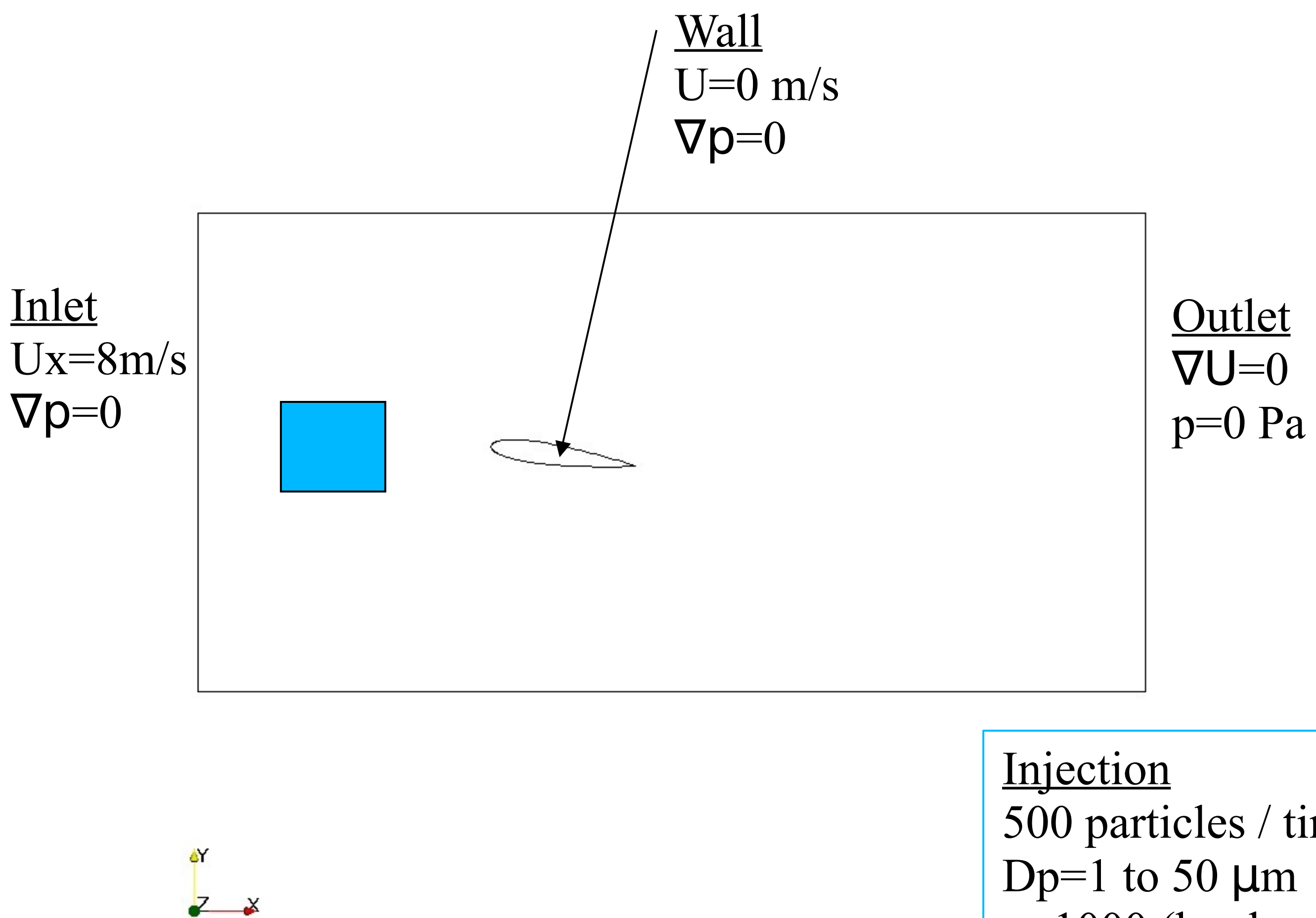
$\psi \rightarrow$ N(0, 1)

Eddy life time $$t_e = \frac{l_e}{u_e} = \frac{C_\mu^{0.63} k^{3/2} / \epsilon}{\sqrt{2k/3}}$$

Particle transit time $$t_{tr} = -\tau_P \ln\left(1 - \frac{l_e}{\tau_P |U - U_P|}\right)$$

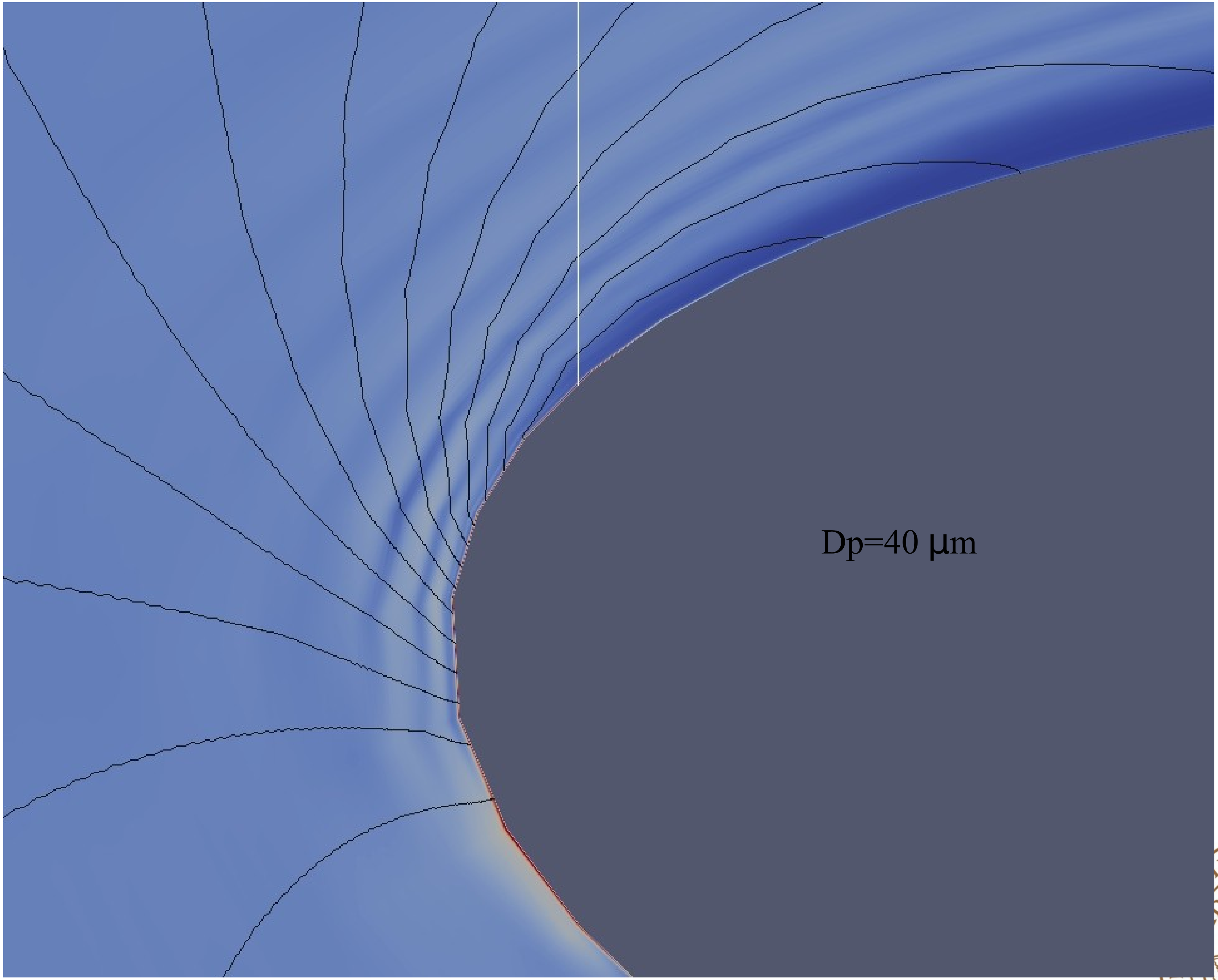
➡ Interaction time $$t_{inter} = min(t_e, t_{tr})$$

NUCLEI DISTRIBUTION – Problem Set Up

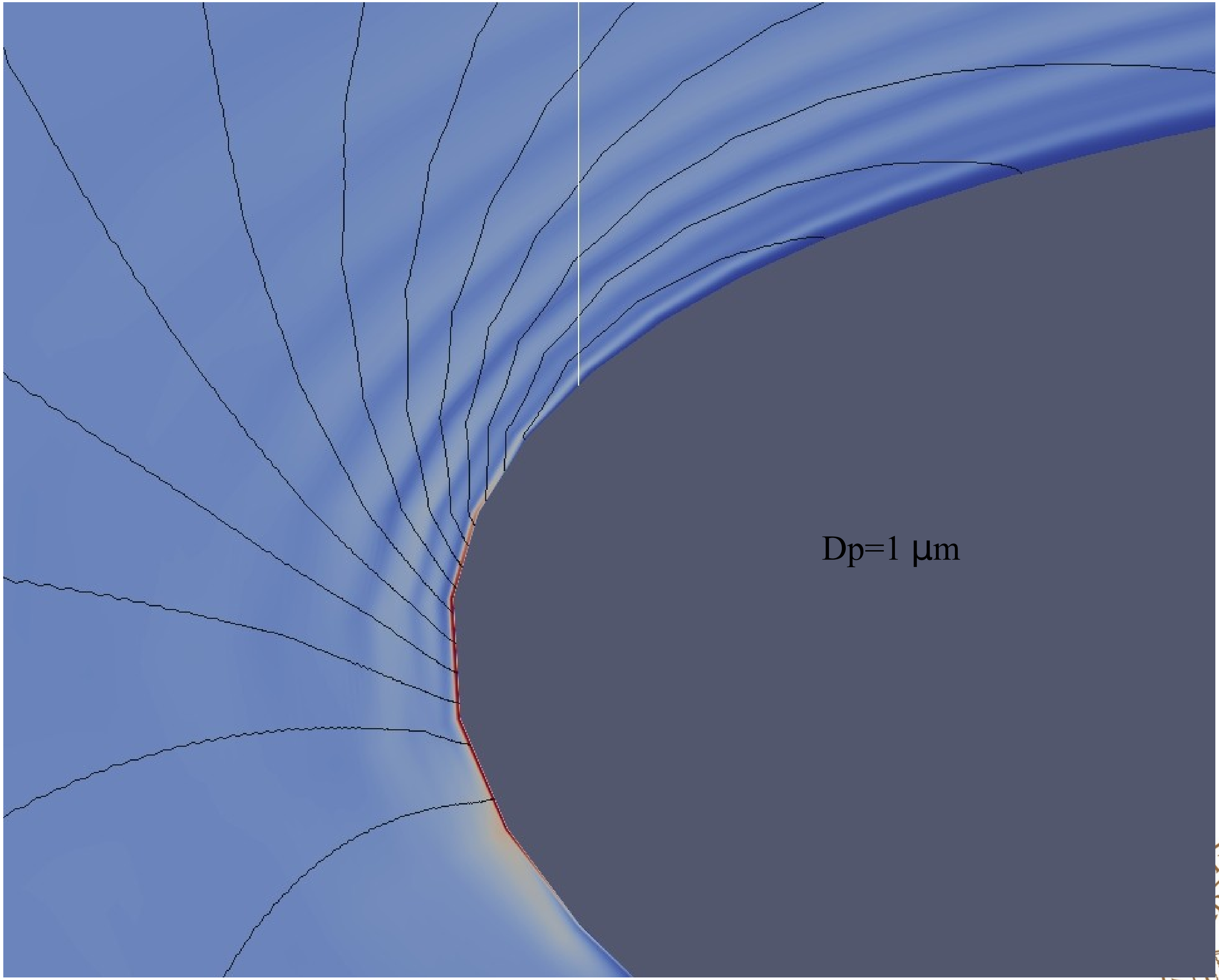


Injection
500 particles / time step
Dp=1 to 50 µm
ρ=1000 (hard particle)
Up=0
Solution method
LPT one way coupling
with/without Random Walk
Average on 50 flow-through periods

NUCLEI DISTRIBUTION - Results



NUCLEI DISTRIBUTION - Results



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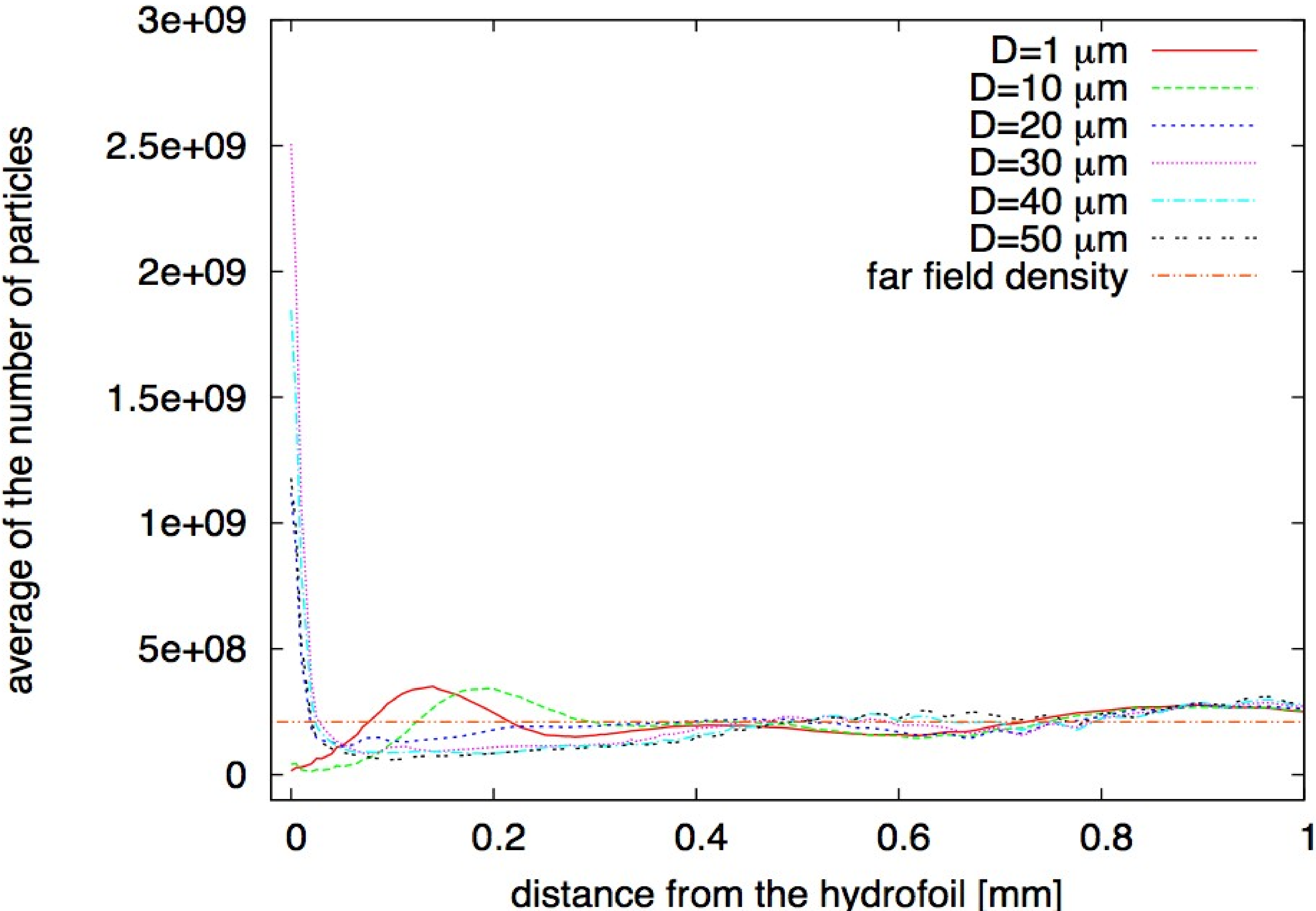
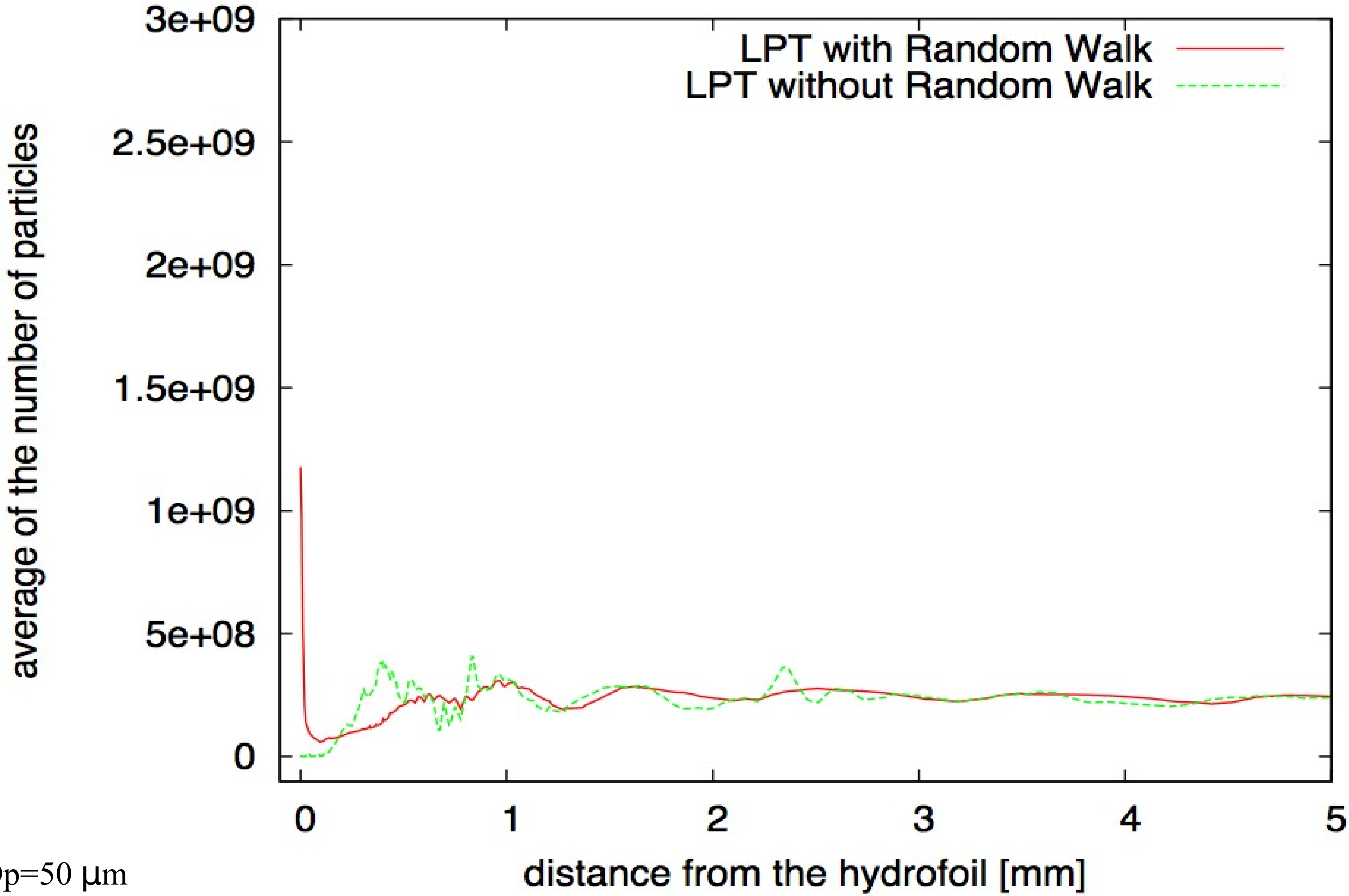


NUCLEI DISTRIBUTION - Results



Dp=50 μm

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Nuclei distribution?

Assumption: uniform
Experiment: non uniform
LPT simulations: non uniform

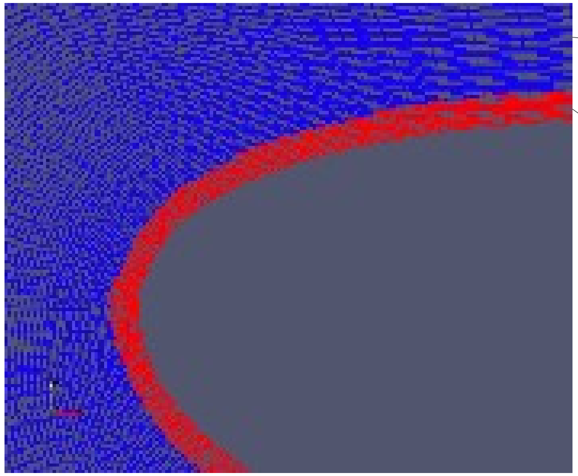
→ sensitivity of Sauer model to a non uniform nuclei content?

OUTLINE

- Sauer model
- Nuclei distribution
- **Sauer model with a non-uniform nuclei distribution**

NON UNIFORM NUCLEI CONTENT

- InterPhaseChangeFoam n0=1e8
- Nuclei density



Smaller nuclei density
N=1e2 or 1e4

Large nuclei density n0=1e8
Thickness of the layer =0.5, 1, 2 or 4 mm

- MyInterPhaseChangeFoam

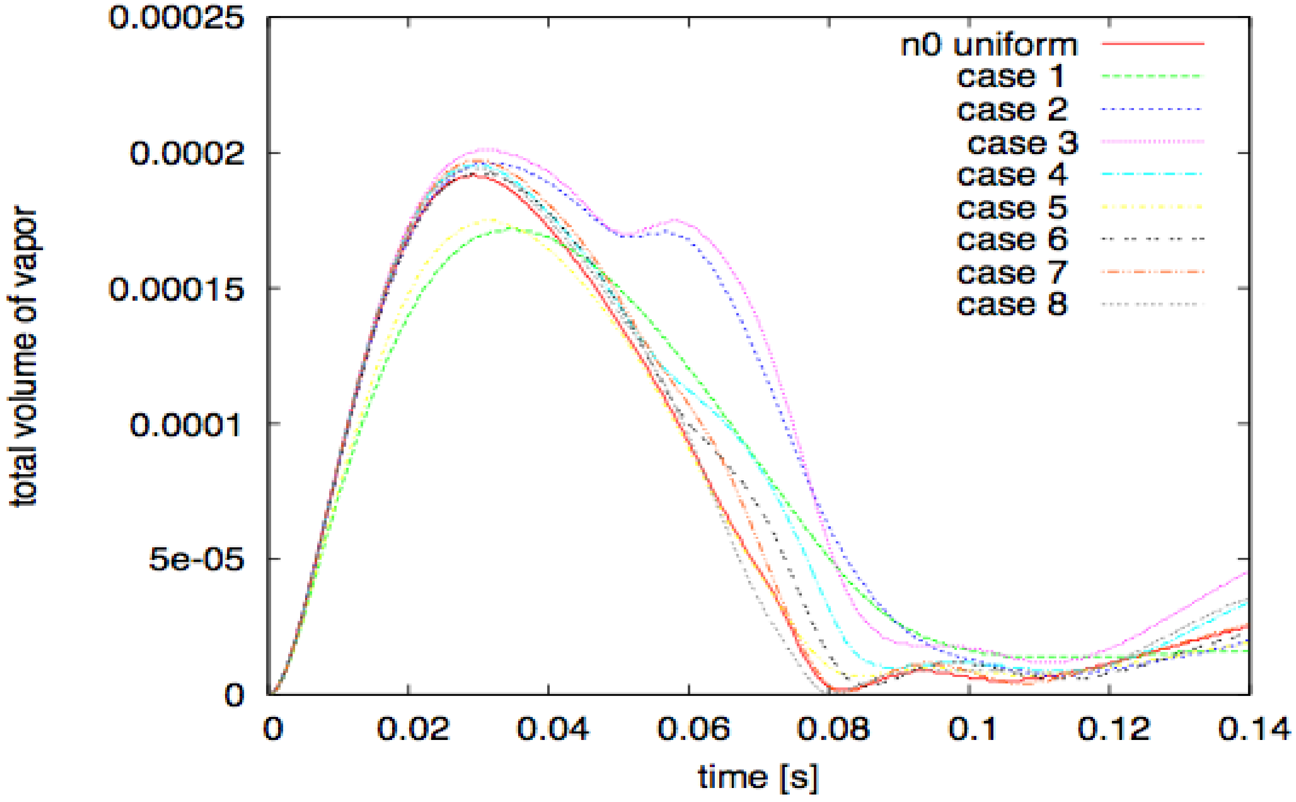
  - volScalarField n0nonunif

  - funkySetField (1e-6 or 1e-4 in the domain, and 1 in the layer)

  - n0 → n0nonunif . n0

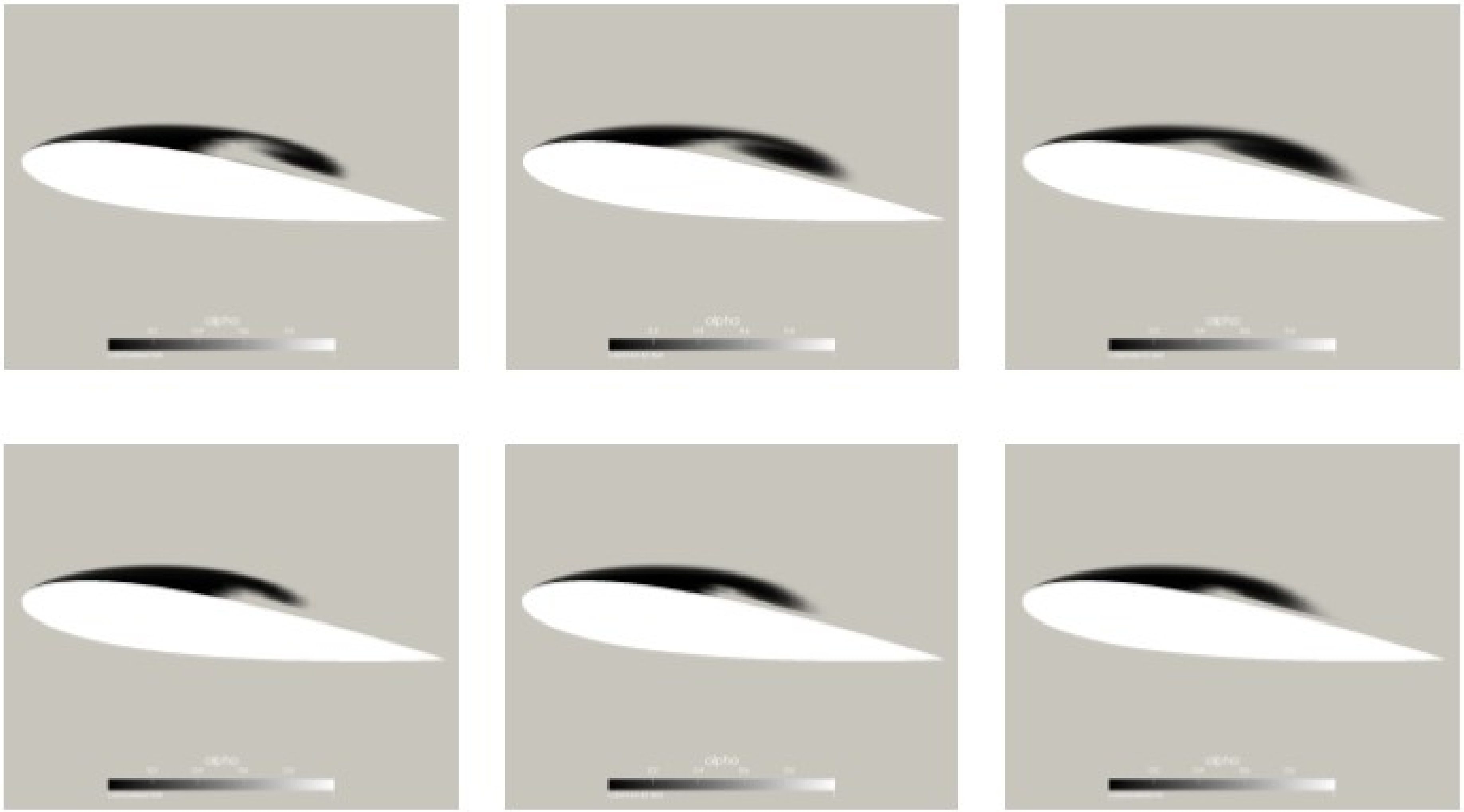
NON UNIFORM NUCLEI CONTENT

	δ_N=0.5	δ_N=1	δ_N=2	δ_N=4
N=10^2	case 1	case 2	case 3	case 4
N=10^4	case 5	case 6	case 7	case 8



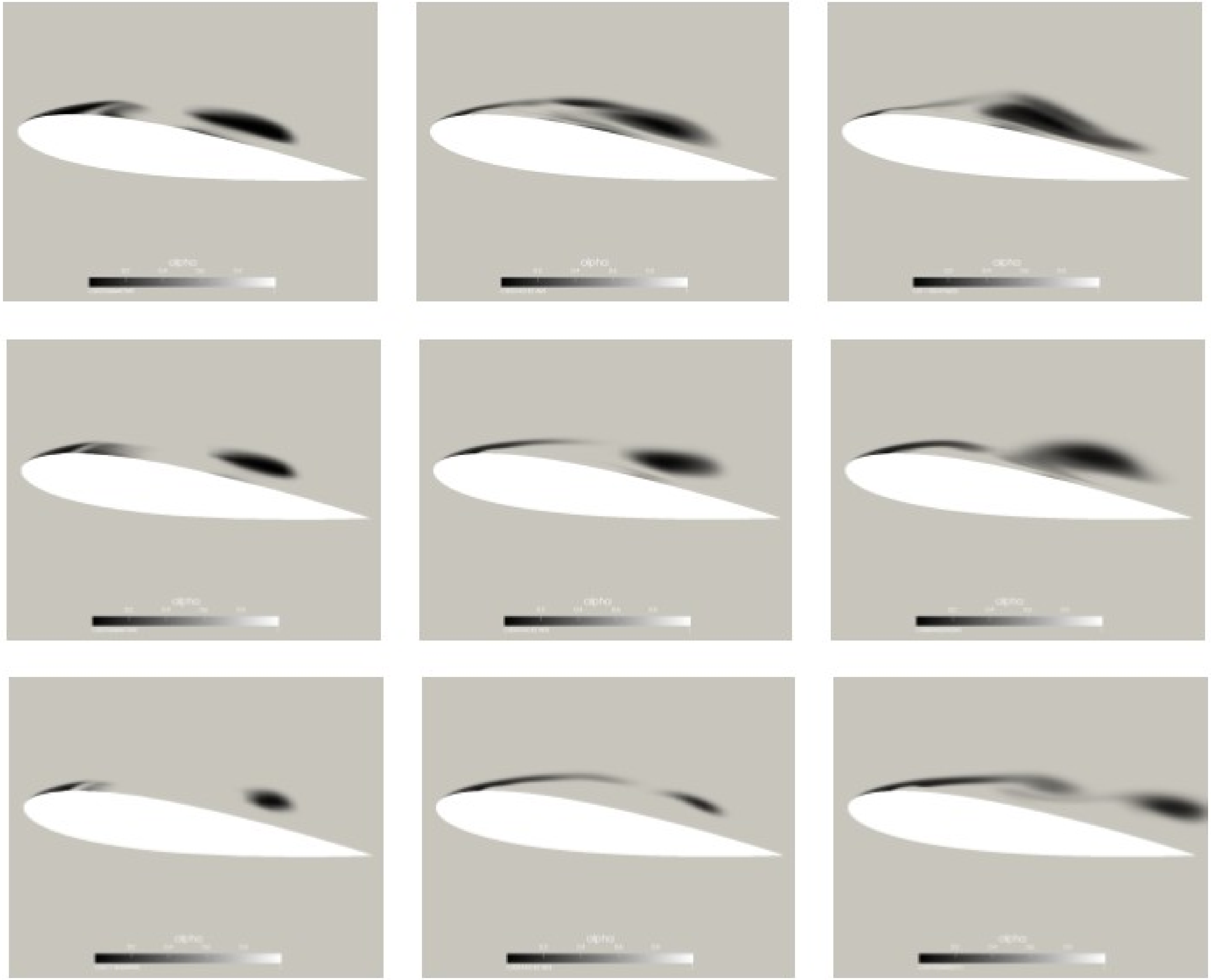
NON UNIFORM NUCLEI CONTENT

Uniform $N = 10^8$ | $N = 10^4, \delta_N$=2 mm | $N = 10^2, \delta_N$=2 mm



t=0.02s

t=0.03s



t=0.05s

t=0.06s

t=0.07s

CONCLUSIONS

- Performances/limitations of Sauer model

- Non uniform nuclei content

→ inception,

→ thickness and velocity of the re-entrant jet,

→ shape of the cavitating structures and volume of vapor.