Modèles micromécaniques du dommage intra-laminaire dans les stratifiés avec couches fines

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Ultra-thin Fiber Reinforced Polymer Composite (FRPC) Laminates: an Introduction

Technological origins and applications

Solar Impulse 2, from [1].

Nuon Solar team's car, from [2].
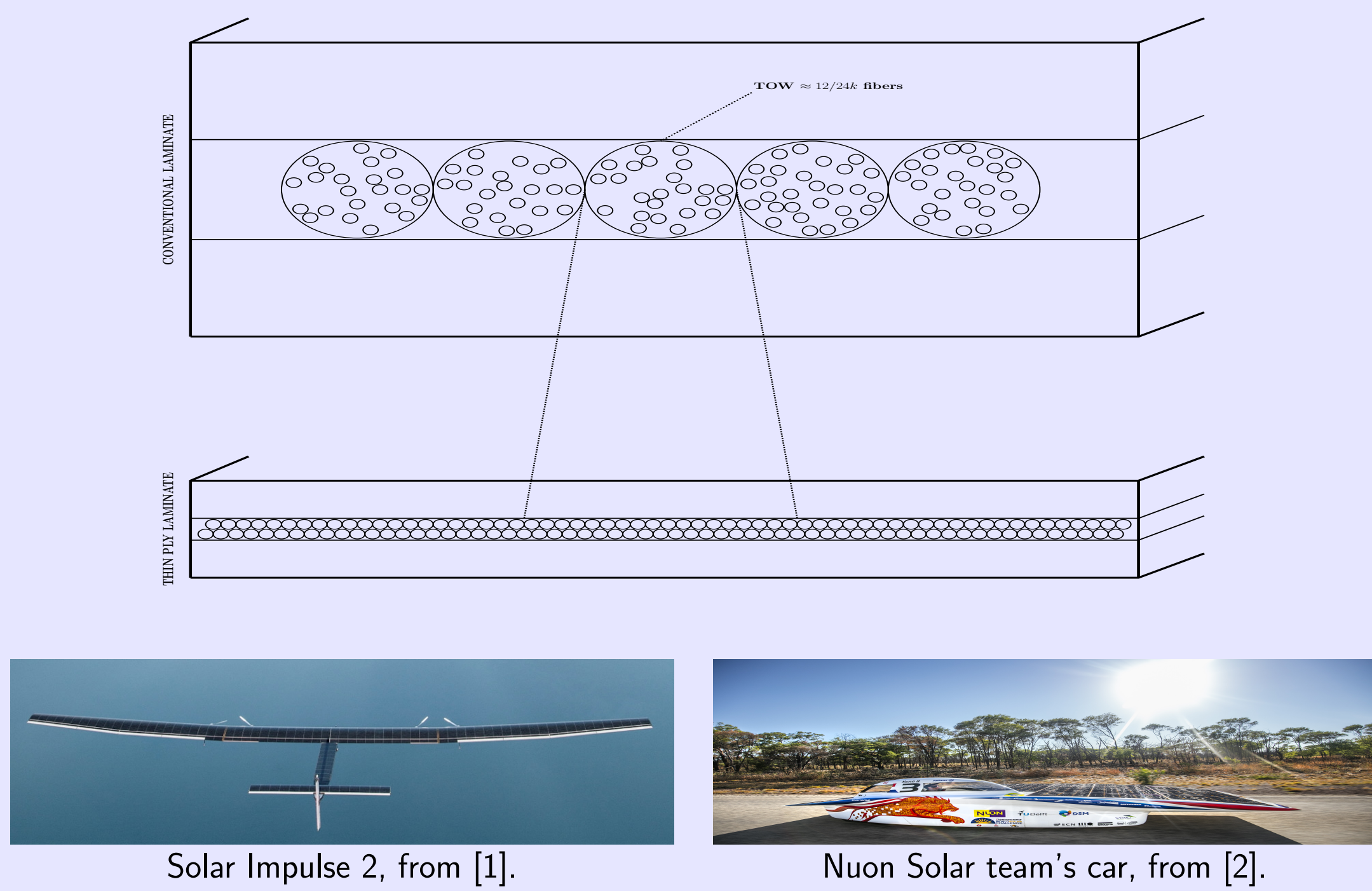
Damage in FRPCs: a visual introduction

matrix crack 90°

fibre fracture 0°

delamination

By Dr. R. Olsson, Swerea, SE.

By Prof. Dr. E. K. Gamstedt, KTH, SE.

20 µm

The thin ply effect

In situ transverse lamina strength Y_T as a function of thickness and ply orientation

Measurements of in-situ transverse strength from Flaggs & Kural, 1982 [3].
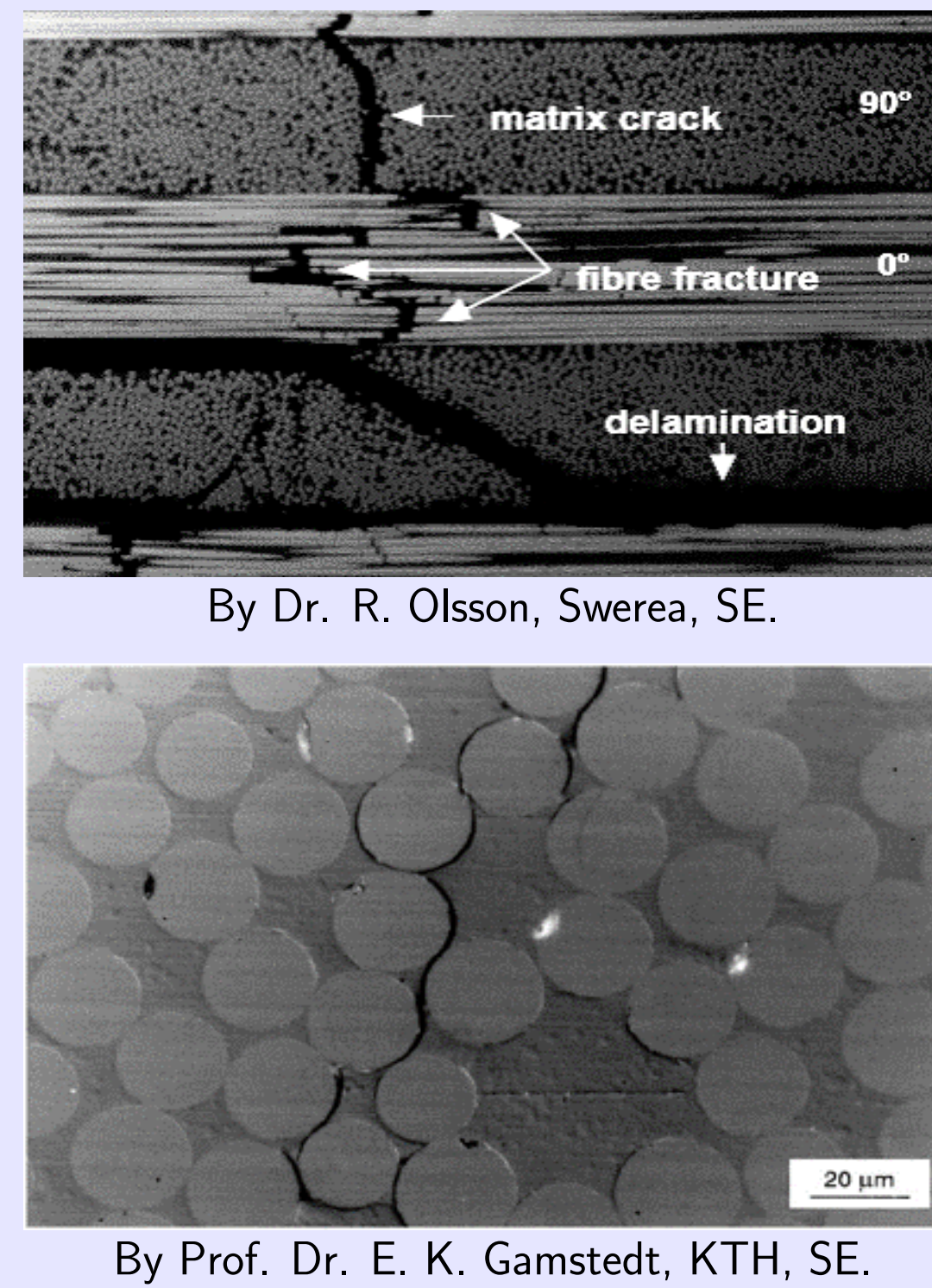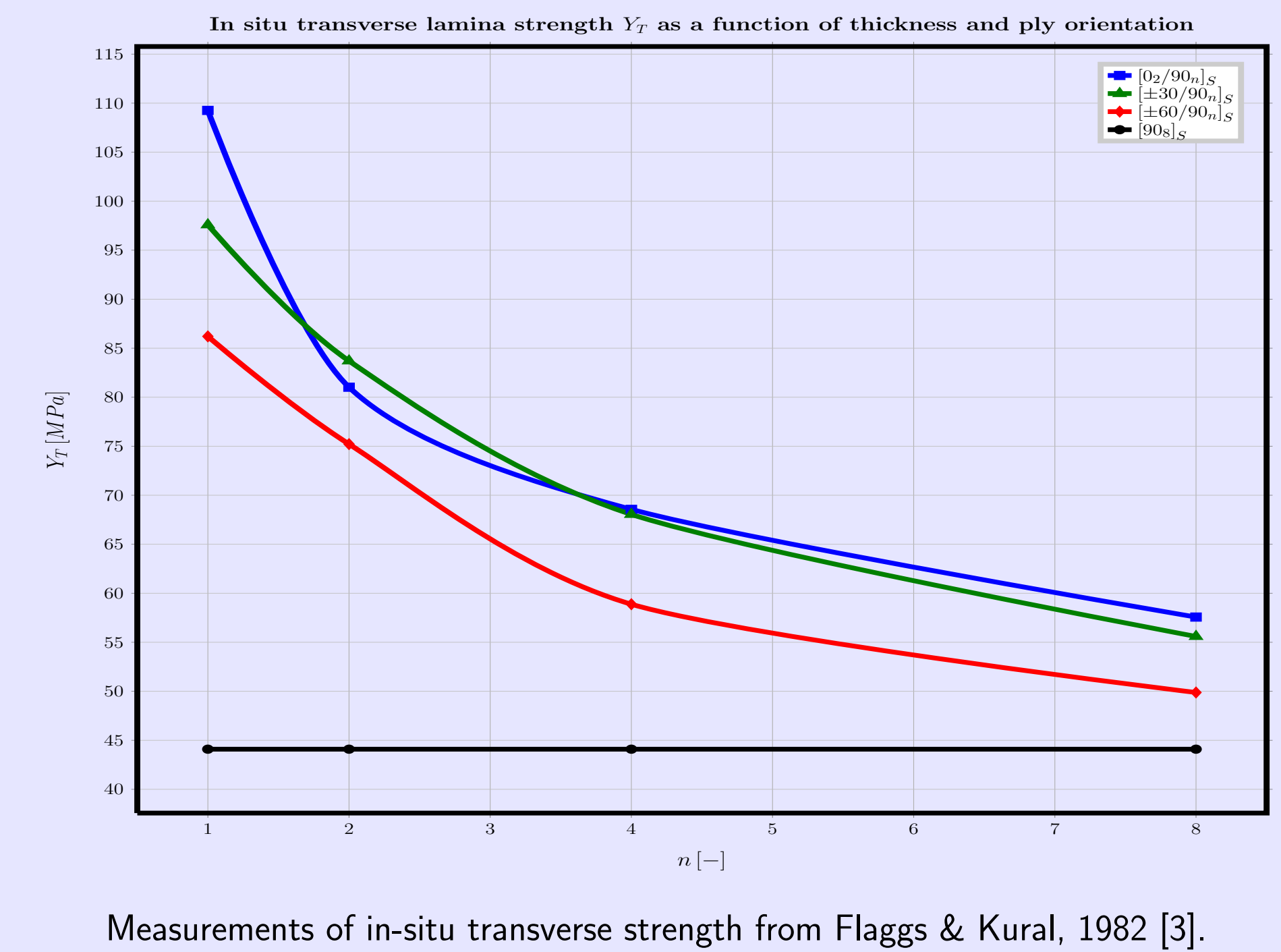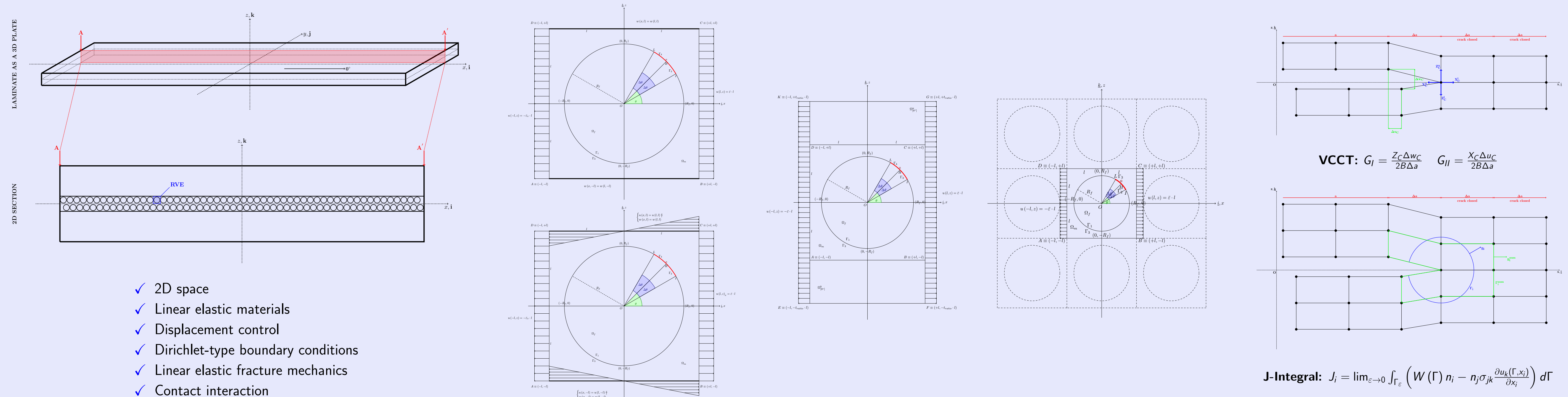
Objectives & Approach

What do we want to achieve?

► Investigate the influence of volume fraction, material properties, thin ply thickness and bounding plies' thicknesses on crack initiation

► $G_{*c} = G_{*c}\left(\theta_{debond}, \Delta\theta_{debond}, E_{(\cdot\cdot)}, \nu_{(\cdot\cdot)}, G_{()}, VF_f, t_{ply}, \frac{t_{ply}}{t_{bounding\ plies}}\right)$
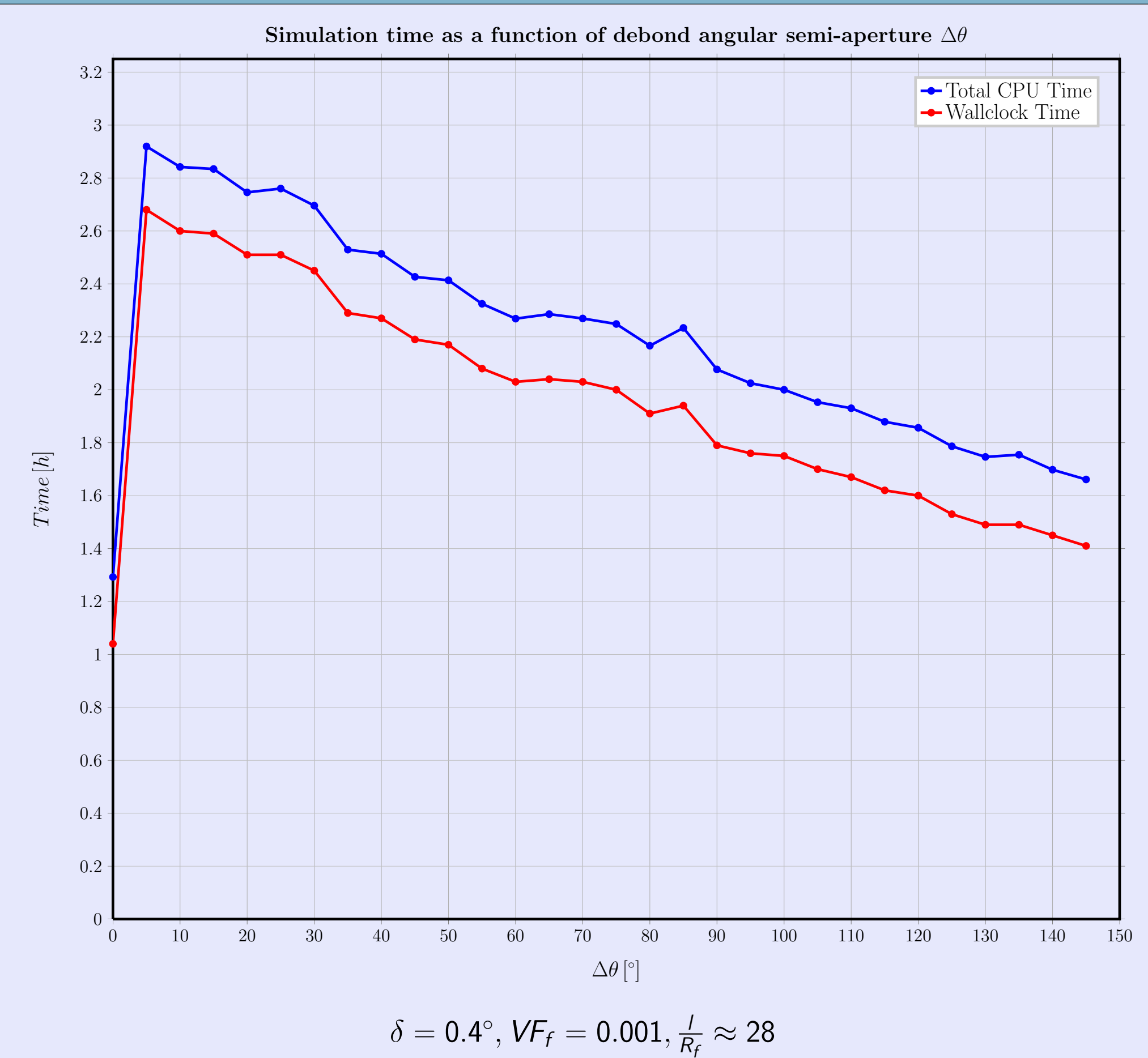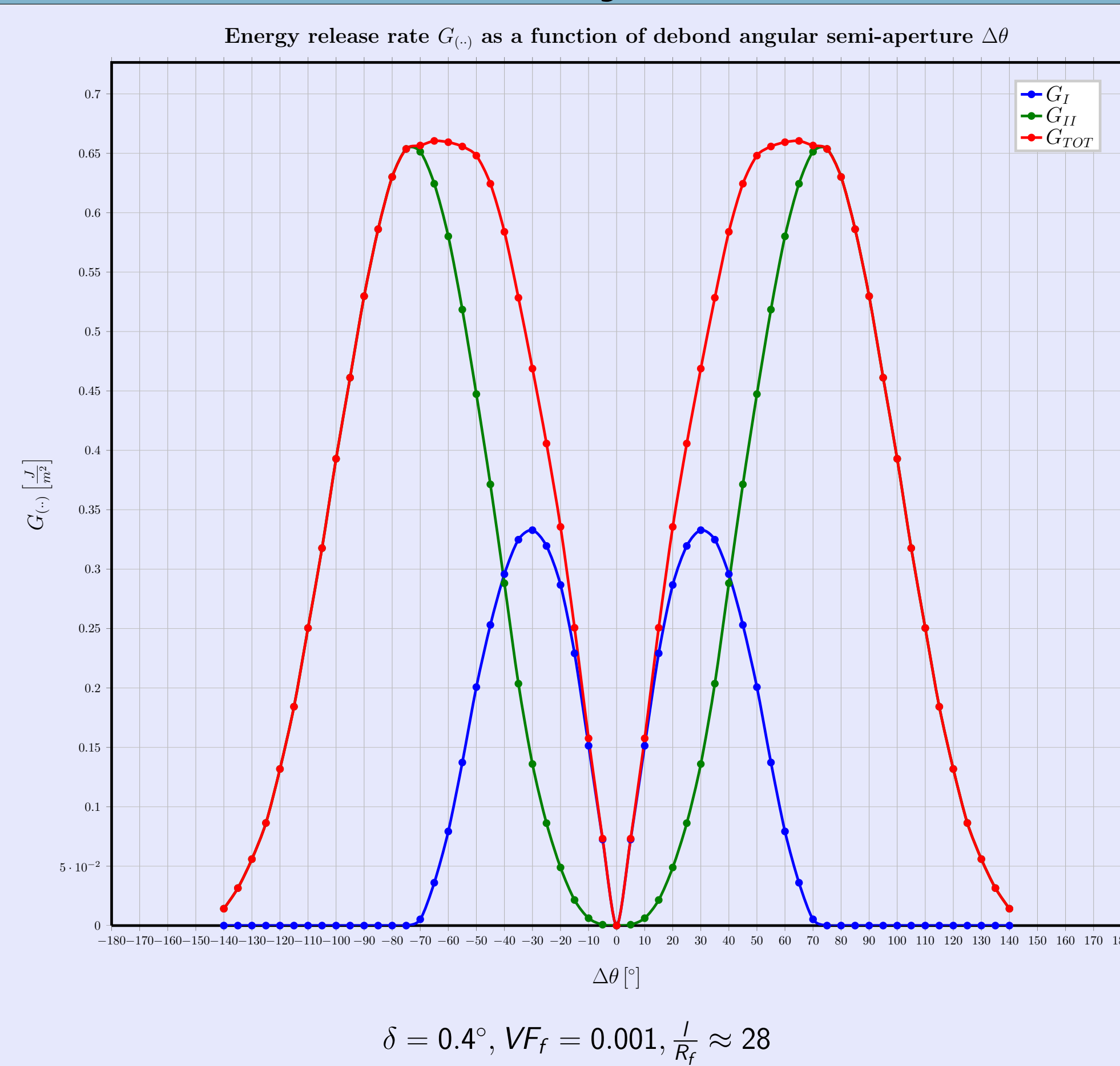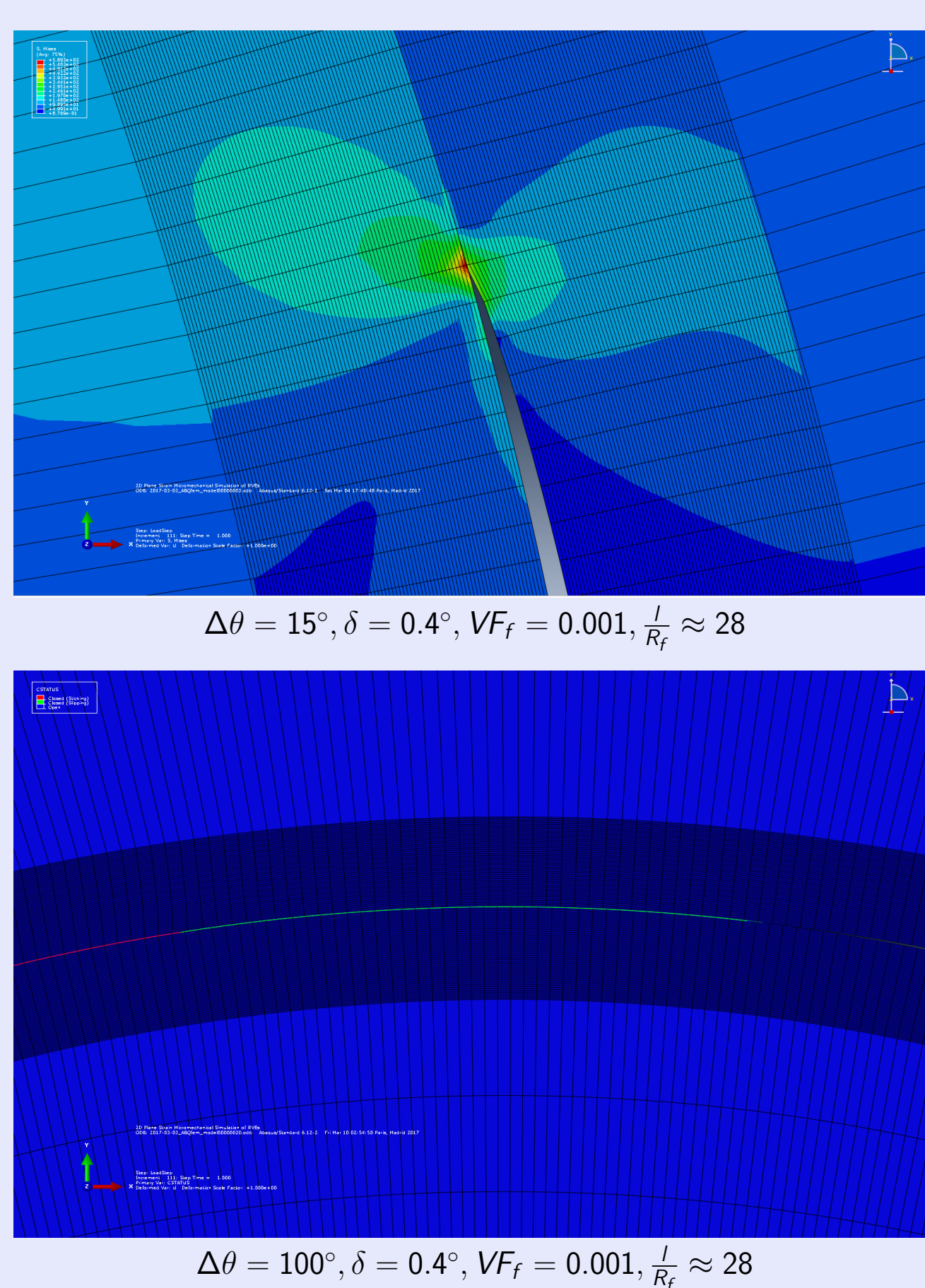
How do we want to achieve it?

► Design and categorization of several Representative Volume Elements (RVEs)
► Automated generation of RVEs geometry and FEM model
► Finite Element Simulations (in Abaqus)

Design & Analysis of Representative Volume Elements (RVEs)

✓ 2D space
✓ Linear elastic materials
✓ Displacement control
✓ Dirichlet-type boundary conditions
✓ Linear elastic fracture mechanics
✓ Contact interaction

VCCT: $G_I = \frac{Z_C \Delta w_C}{2B\Delta a}$ $G_{II} = \frac{X_C \Delta u_C}{2B\Delta a}$

J-Integral: $J_i = \lim_{\Gamma_i \to 0} \int_{\Gamma_i} \left(W(\Gamma) n_i - n_j \sigma_{jk} \frac{\partial u_k(\Gamma, x_i)}{\partial x_i} \right) d\Gamma$

Preliminary Results & Validation

$\Delta\theta = 15°, \delta = 0.4°, VF_f = 0.001, \frac{L}{R_f} \approx 28$

$\Delta\theta = 100°, \delta = 0.4°, VF_f = 0.001, \frac{L}{R_f} \approx 28$

Energy release rate $G_{(\cdot)}$ as a function of debond angular semi-aperture $\Delta\theta$

$\delta = 0.4°, VF_f = 0.001, \frac{L}{R_f} \approx 28$

Simulation time as a function of debond angular semi-aperture $\Delta\theta$

$\delta = 0.4°, VF_f = 0.001, \frac{L}{R_f} \approx 28$

Conclusions & Perspectives

What has been accomplished?

► 2D micromechanical models have been developed to investigate crack initiation in thin ply laminates
► A numerical procedure has been devised and implemented to automatize the creation of FEM models
► Validation for $VF_f \to 0$ (matrix dominated RVE) with respect to previous literature [4, 5]

What's next?

► Investigate the dependence on VF_f, t_{ply}, $t_{ply}/t_{bounding\ plies}$ and different material systems
► Study numerical performances with respect to model's parameters
► Repeat for different RVEs and compare

Merci á

Références

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[5] París, F., Cano, J., and Varna, J.; The fiber-matrix interface crack - a numerical analysis using boundary elements. Int. J. Fract., 1990; 82(1), pp. 11-29.

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