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Experimental study of behavior of fiber in wall bounded turbulent flow

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• Motivation

✓ **The knowledge of the behavior of Fiber-laden turbulent flows covers a wide range of applications:**

- Paper making
- Fiber-reinforced composites processing
- Long distance fluid transport
- Aerosols in the atmosphere
- …

• Objective

✓ **The objective of this talk is reporting the motion statistics of fiber in wall turbulence in order to understand fiber behavior and the size effect.**

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• Experimental facility and methodology

✓ Experiment setup

-Experiments were conducted on the water table at Linne´ Flow Centre, KTH Mechanics.

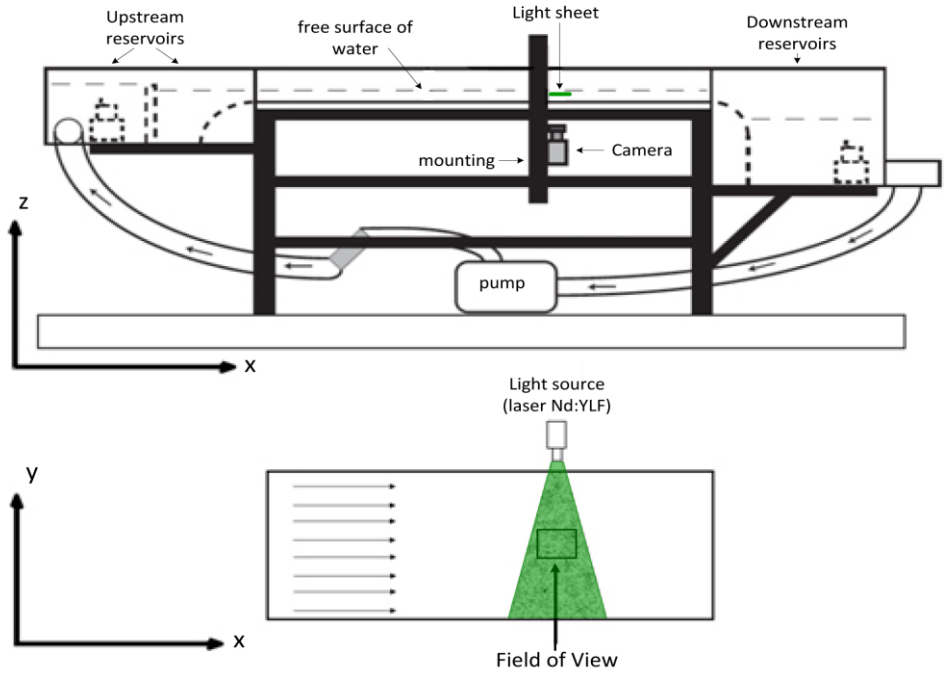
-A dilute suspension of cellulose acetate fibers into tap water.

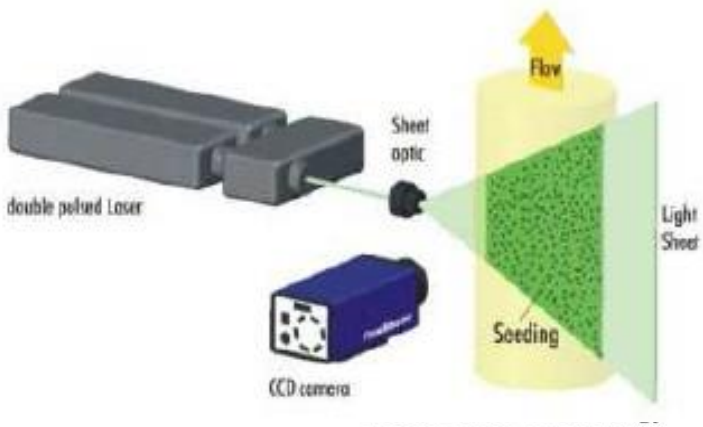
-The film of suspension flowed down, derived by gravity, on the slightly inclined flat glass plate:

-Thickness of film: h=11.5±0.5 mm

-Angle of slope: α=0.081±0.005 deg

✓ Combined PIV/PTV Measurement of Fiber Suspension Flow





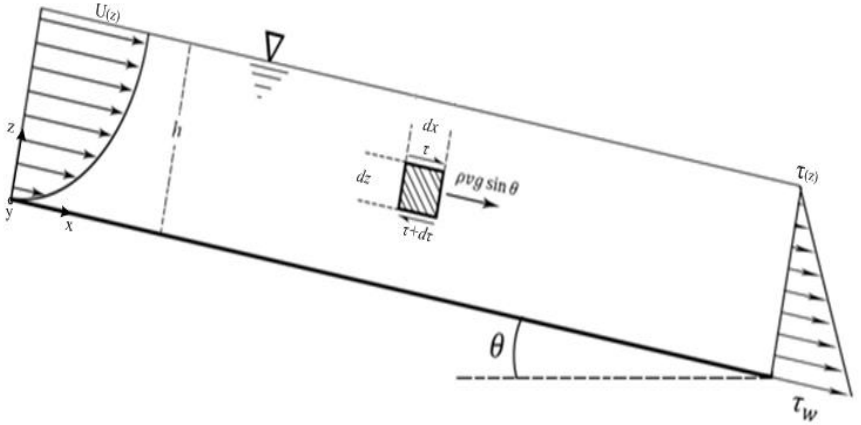
✓ Flow condition:

$$\tau = \rho g(h - z)\sin\theta$$

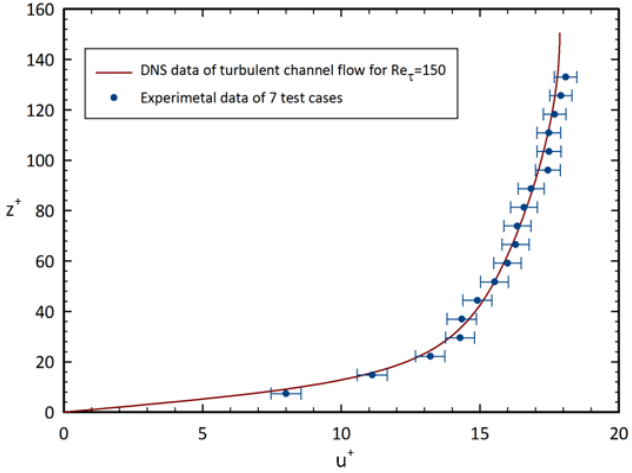
$$\tau_w = \rho g h \sin\theta$$

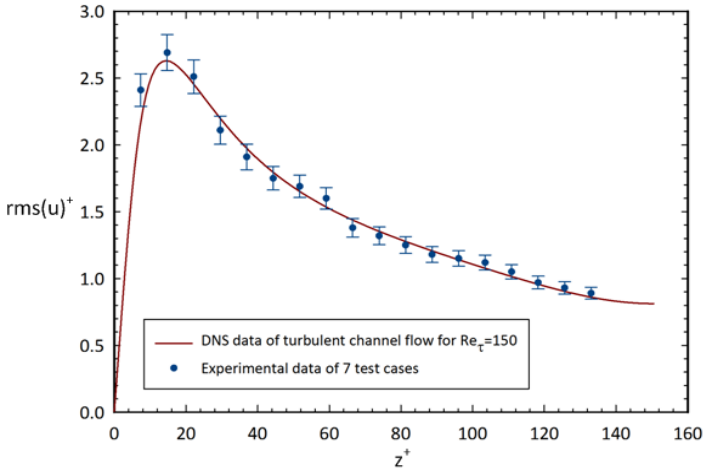
$$u_\tau = \sqrt{\tau_w/\rho} = \sqrt{gh\sin\theta}$$

$$Re_\tau = \frac{h.u_\tau}{\nu} = \frac{h.\sqrt{gh\sin\theta}}{\nu}$$



✓ Flow quality on the water table setup:





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✓ Experiment Conditions:

-Cellulose acetate fibers with density of 1300 kg/m3 and diameter of 70 μm;

-Three different types of fibers in length: 0.5 mm (λ≈7), 1mm (λ≈14) & 2 mm (λ≈28);

- Experiments was conducted in three different distances from the bottom wall of water table: z+=14, 43 & 72 (in viscous wall unit) ;

-Reτ≈170

	Fiber specification			Measurement position		
	length (mm)	aspect ratio (λ)	response time(τ^+)	Z^+=14	Z^+=43	Z^+=72
Case 1	0.5	7	0.2	√	√	√
Case 2	1.0	14	0.24	√	√	√
Case 3	2.0	28	0.3	√	√	√

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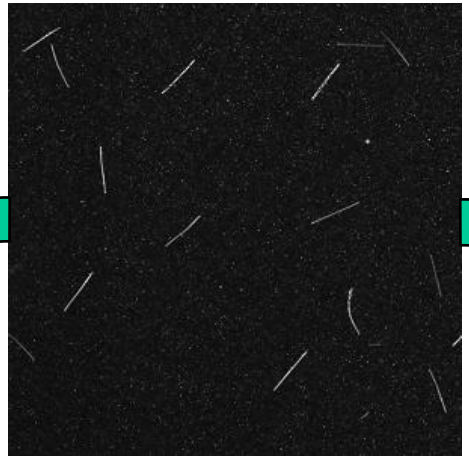
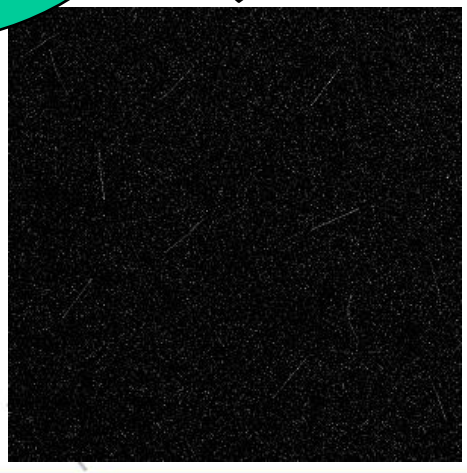
• Image Processing

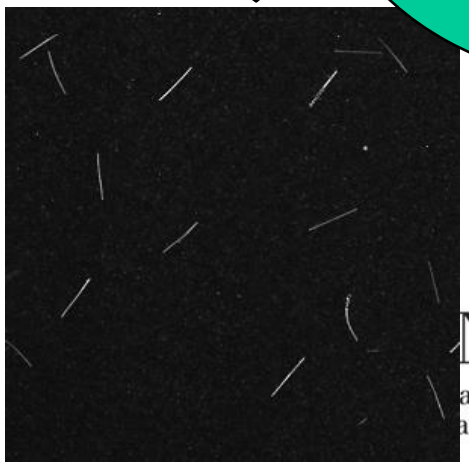
✓ **Phases separation:**



PIV Processing on tracer images



Fiber Tracking (PTV processing)



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• Fiber Tracking

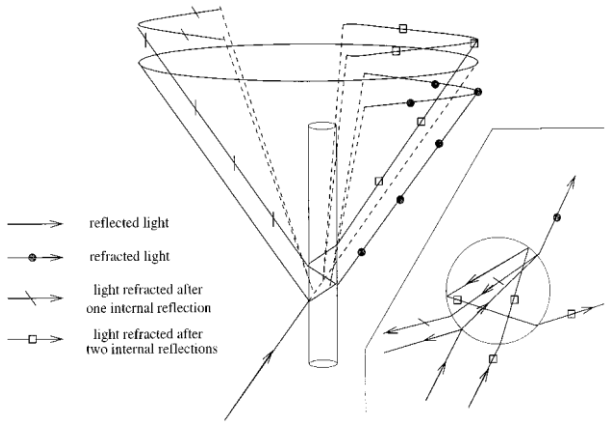
✓ **Precisely identifying fibers in images**

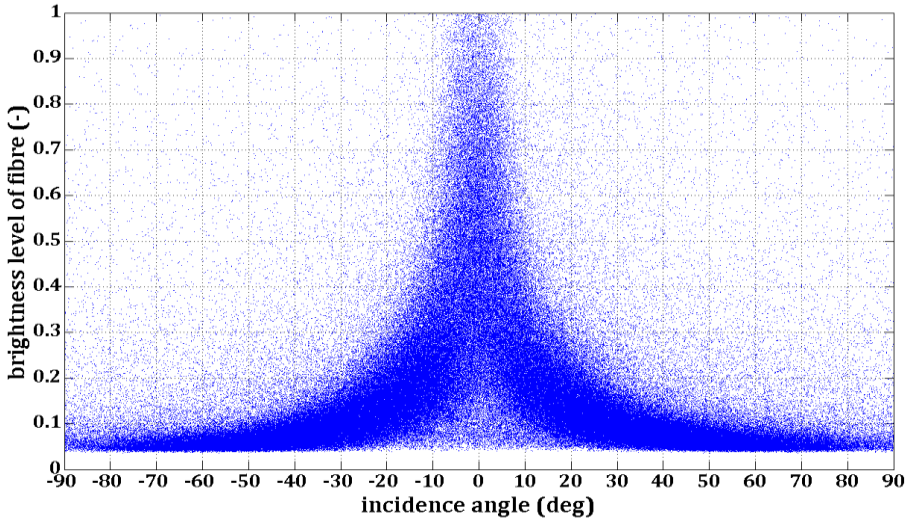
-A filter in class of steerable filters for ridge detection was proposed by Jacob &Unser (2004) and was developed by Carlsson, Lundell & Soderberg (2007).

-The ability of this filter in order to determine the position and orientation of fibers in images has been found to be excellent with acceptable accuracy (Carlsson 2011).

✓ **Fiber recognition in visualization volume-Dynamic Threshold**

-Light scattering from finite fibers in oblique incidence light



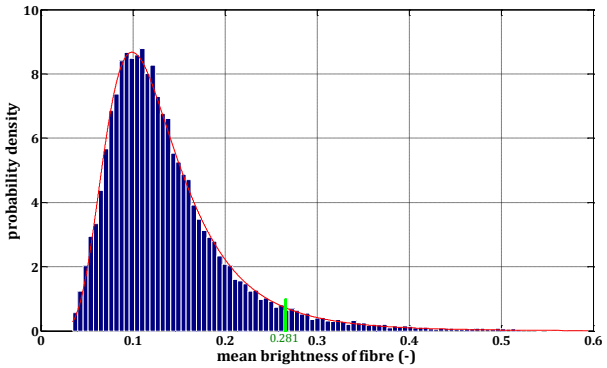


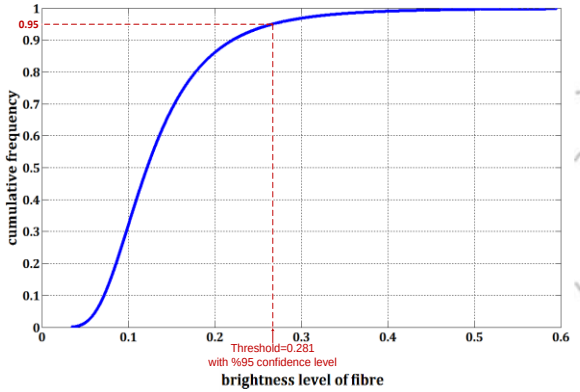
-Dynamic Threshold :

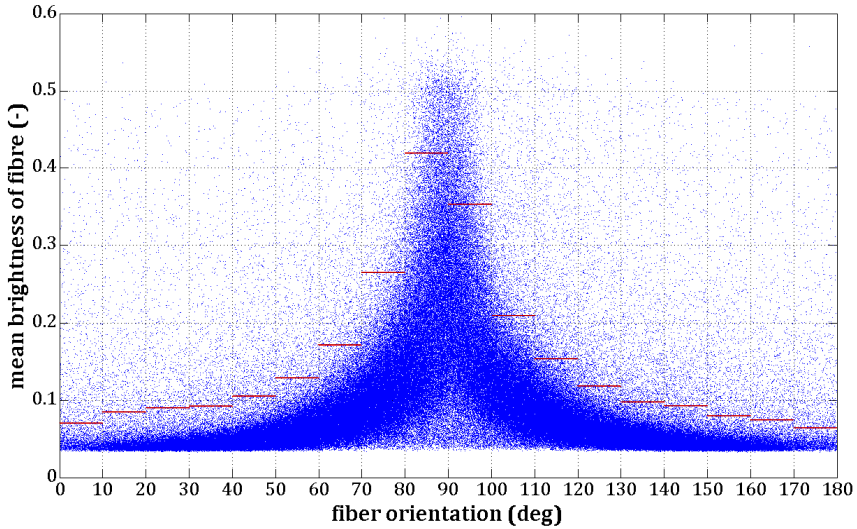
- We reached briefly the two principals:

1- Of the fibers that are at the same direction, those that have the highest intensity are in light sheet.

2- For the fibers that are in light sheet, the more oriented to the normal direction to light beam, the higher intensity of light scattered.







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- ✓ **Fiber matching algorithm:**

-Matching algorithm proposed is based on the SOM neural network that finds most likely matching link in images on the basis of feature extraction and clustering.

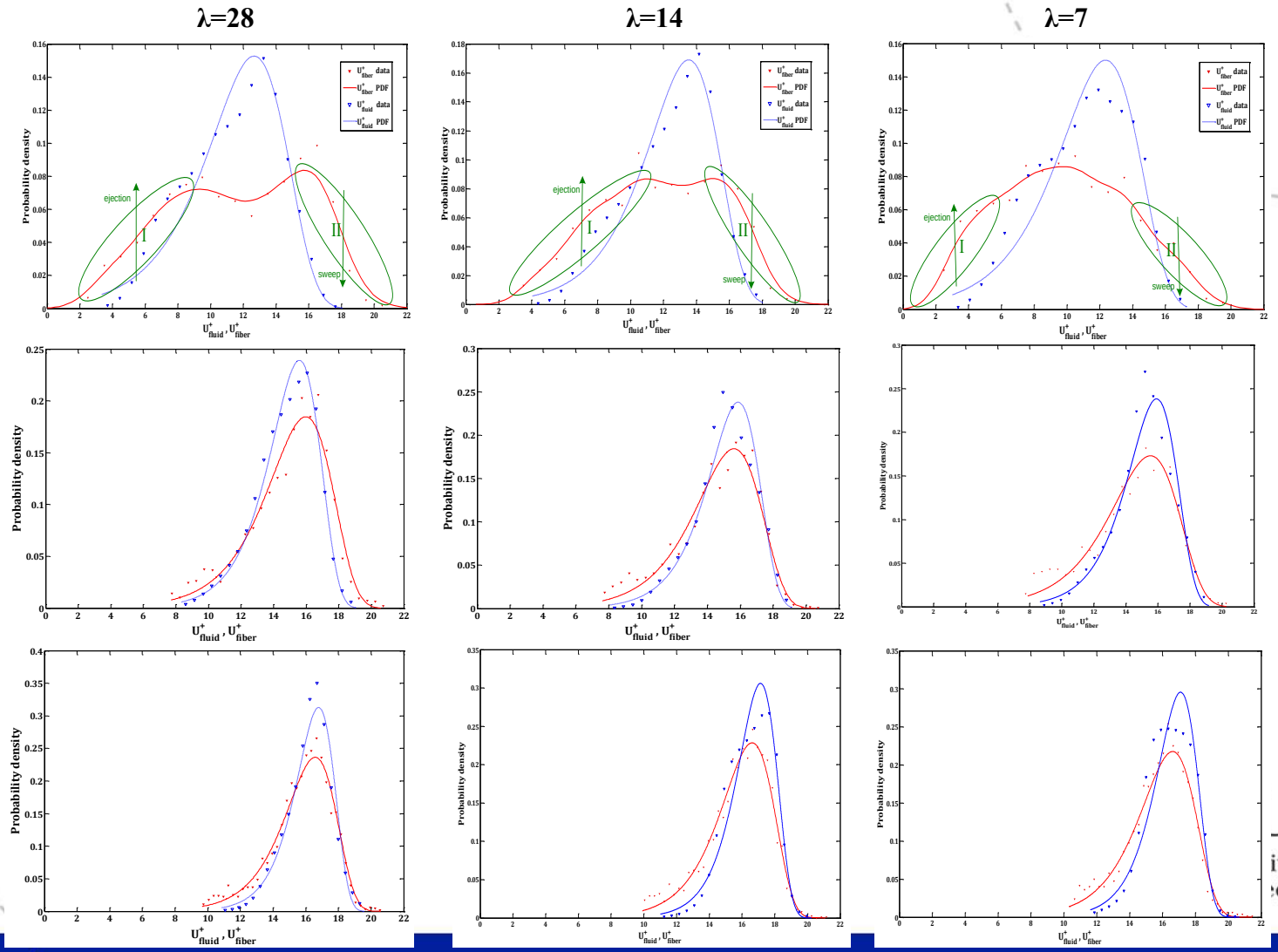
-Using one more characteristics of fibers in images, namely its angel, improves the pairing both for more reliable matching at higher fiber concentration and for more robustness against loss-of-pair fiber between images.

-The fundamental concept is finding the corresponding fibers with the nearest characteristics, position and angel in images.

(Afshin Abbasi Hoseini et al., ICNAAM 2013)

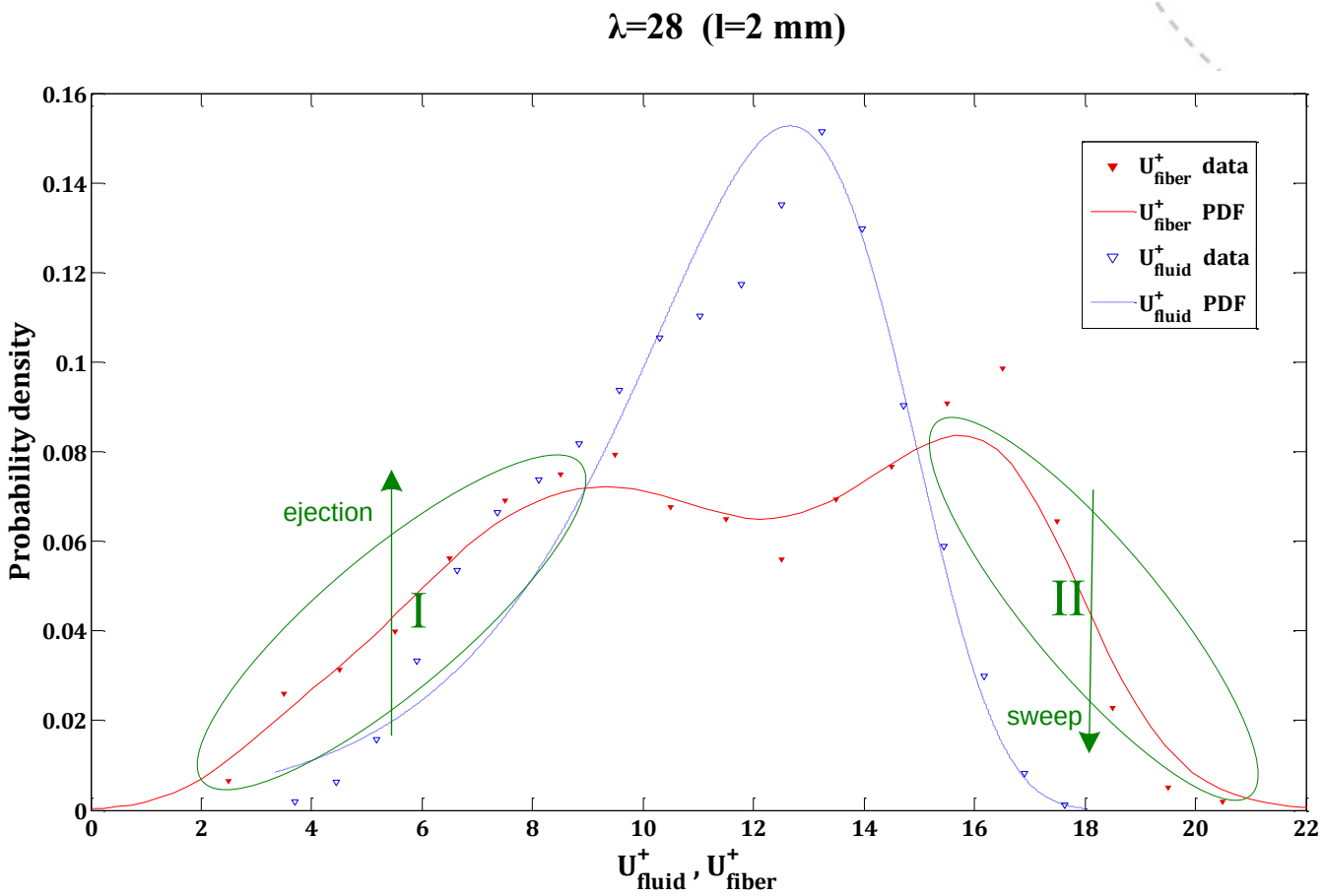
• Results and discussion:

- The fiber and fluid velocity distribution



- The fiber and fluid velocity distribution

$z^+=14$



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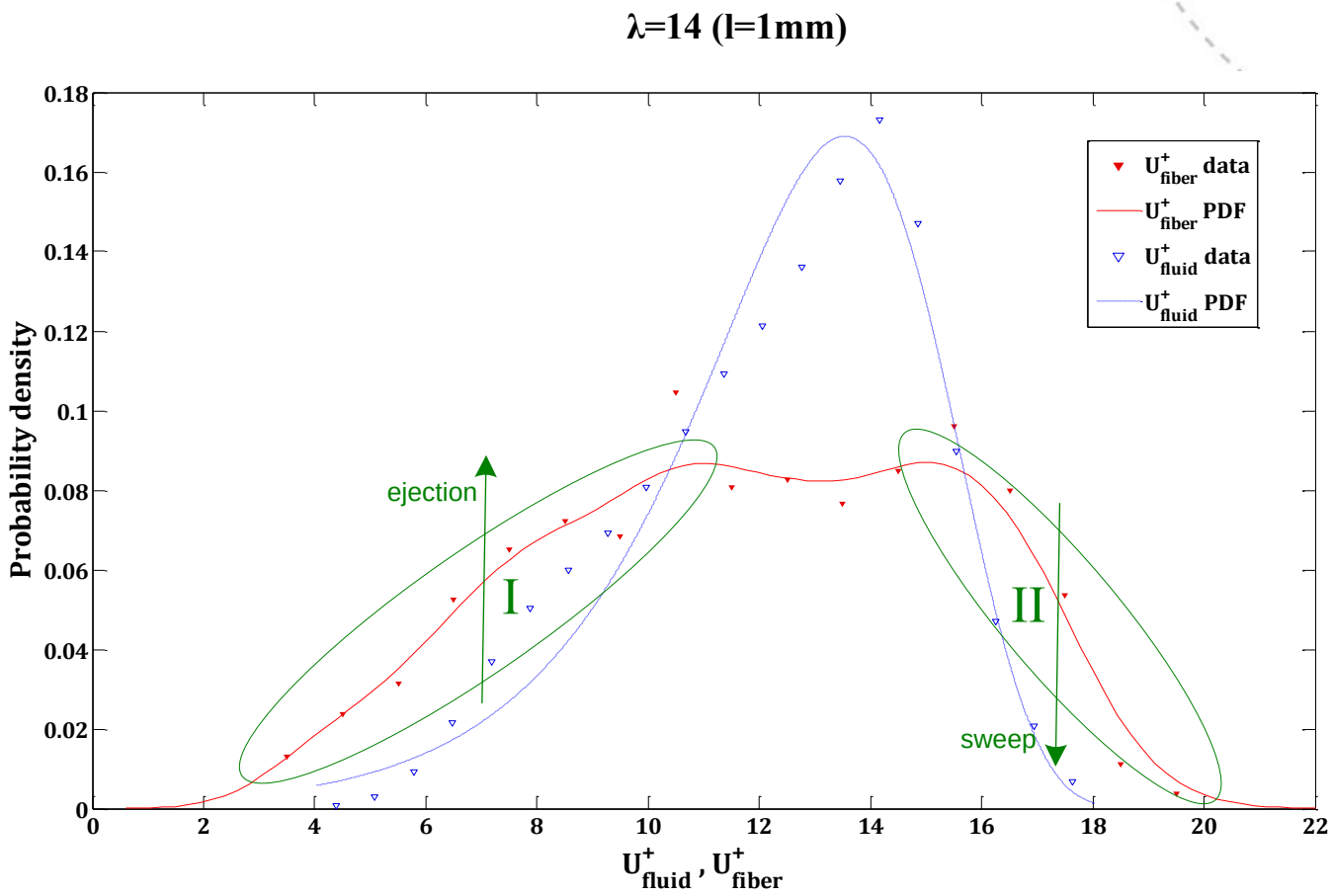

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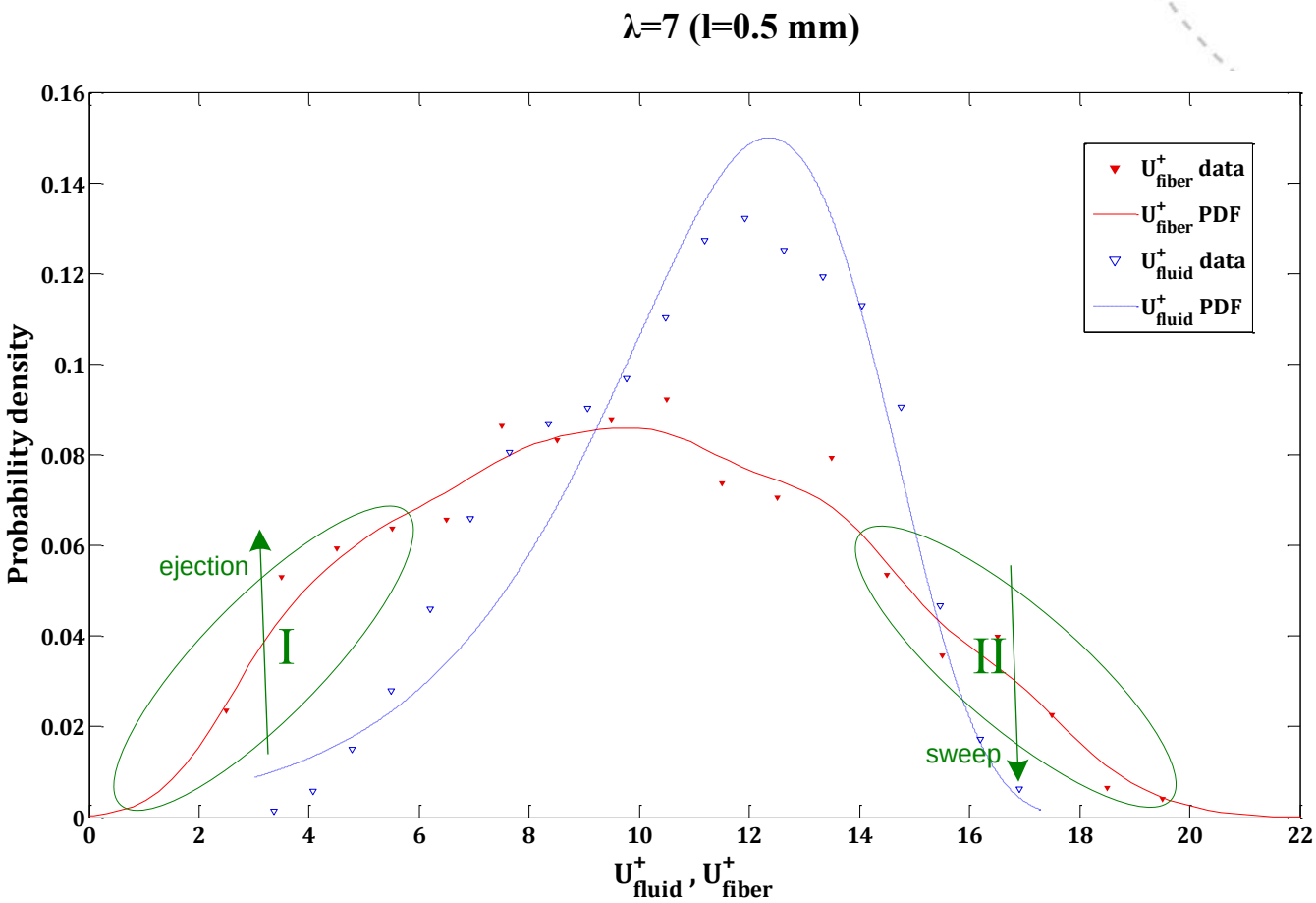
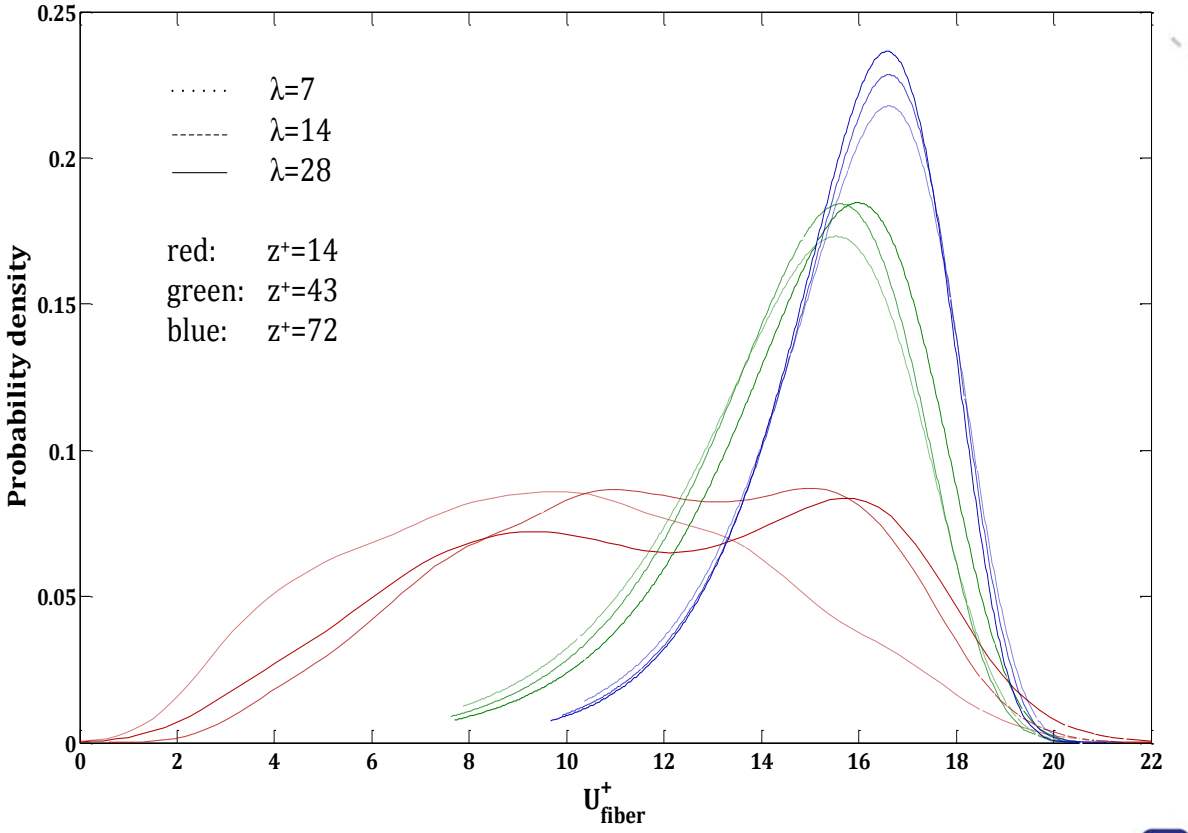


- The fiber streamwise velocity distribution assembled for all cases



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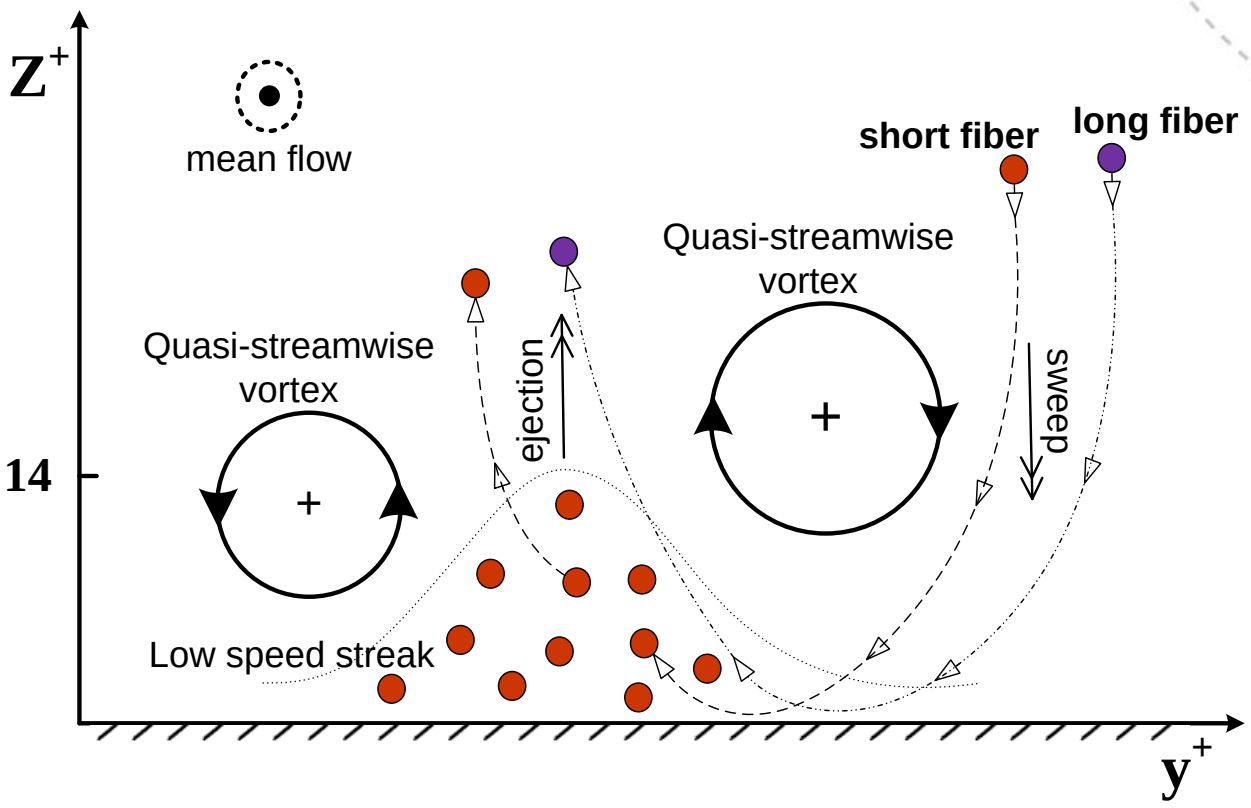
- The size effect on the mechanism of fiber transfer and segregation



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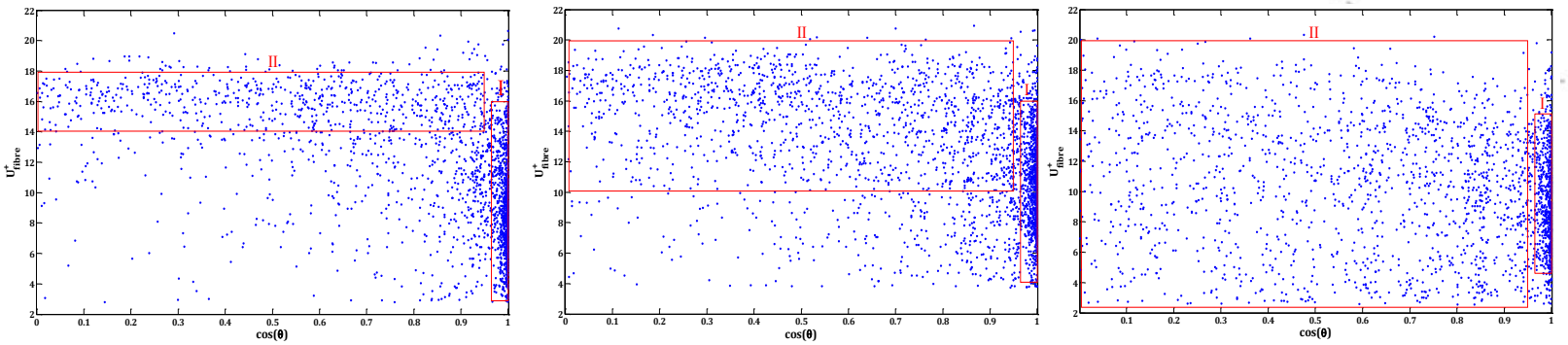
- The distribution of the fiber streamwise velocity versus fiber orientation, @ $z^+=14$

$\lambda=28$ $\lambda=14$ $\lambda=7$



• Conclusion:

✓ **Experimental methodology:**

- We found the light scattering pattern from fibers in light sheet depends on fiber orientation relative to light beam, We propose **Dynamic threshold**;

✓ **Fiber behavior in wall turbulence:**

- The probability of presence of the long fibers (λ=28) in the Low-speed and high-speed streaks of the flow is equal;

- The short fibers (λ=7) experience a long residence time into the low-speed areas;

- In the far-wall regions, the translational motion of fiber is practically unaffected by the aspect ratio and size, whereas it depends crucially on the distance from the wall;

- In the case of long fibers near the wall, there is no preferential orientation for high-speed fibers. On the other hand, the fibers with lower velocity are mostly orientated in streamwise direction;

- The ratio of fiber length to fiber distance from the solid wall is important for fiber behavior in the vicinity of the wall;

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This work benefited from COST Action FP1005 to be presented here.

Thanks for your Attention

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