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WALLENBERG WOOD SCIENCE CENTER

KTH VETENSKAP OCH KONST
CHALMERS

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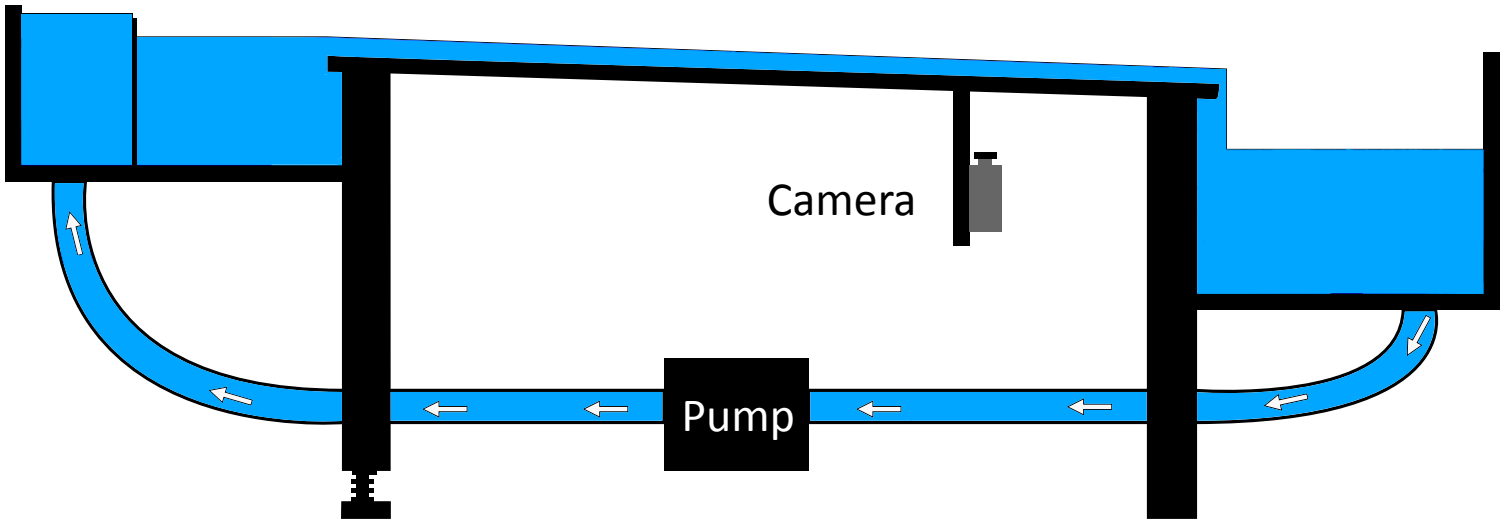
Streak formation and fibre orientation in near wall turbulent fibre suspension flow

WWSC is a joint research center at KTH and Chalmers

Experimental setup

- KTH water-table
- Recirculating suspension
- Camera

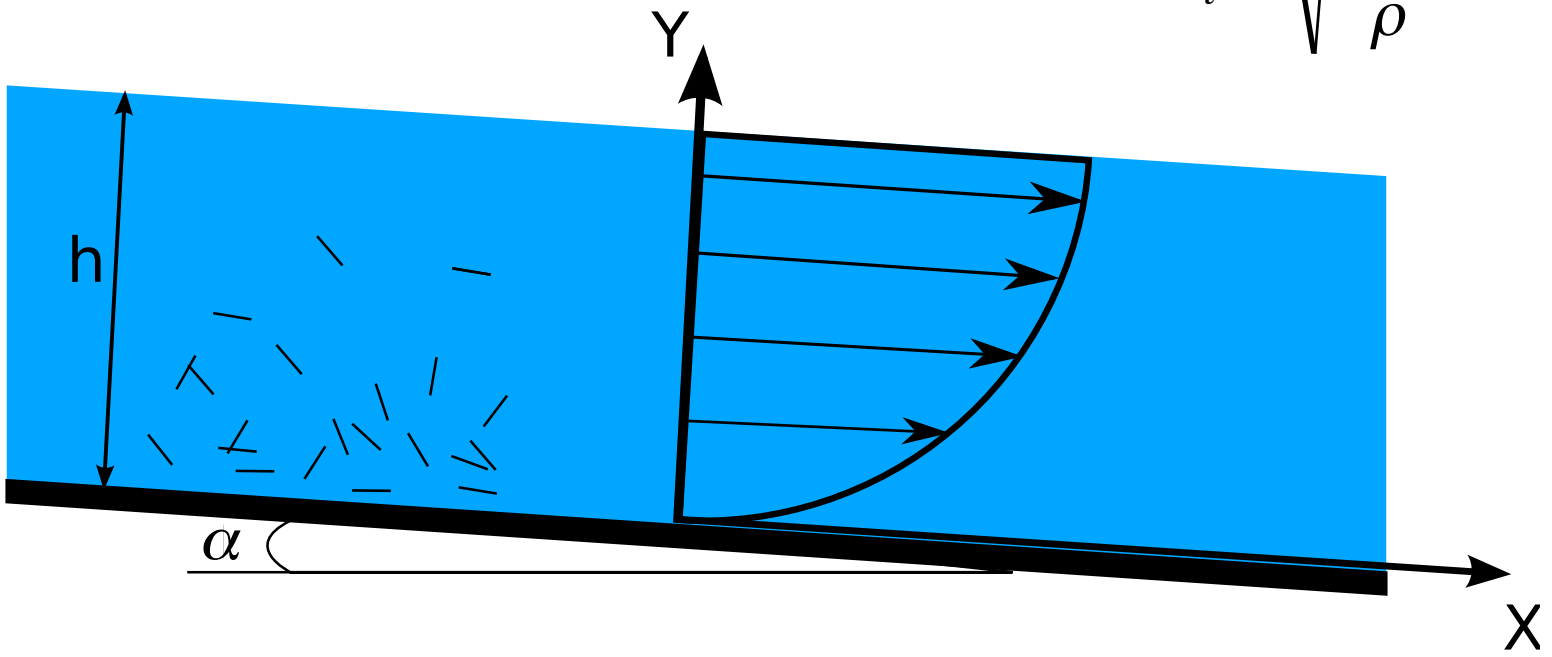


Inclined plate

- Only a boundary layer
- Fully developed turbulent flow
- Wall shear stress (τ_{wall}) is known

$$\tau_{wall} = \rho g h \sin\alpha$$

$$u_\tau = \sqrt{\frac{\tau_{wall}}{\rho}}$$



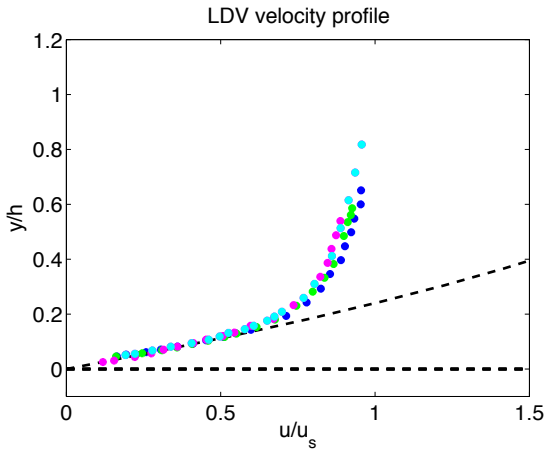
LDV measurements

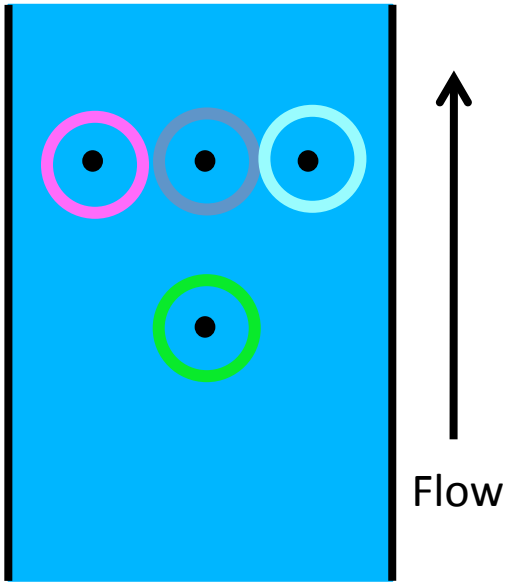
- Used to verify fully developed turbulence.
- Measured velocity profiles upstream and spanwise of data acquisition position.
- Without fibres.
- Measurements for several $\mathrm{Re}_\tau = \frac{u_\tau h}{\nu}$.

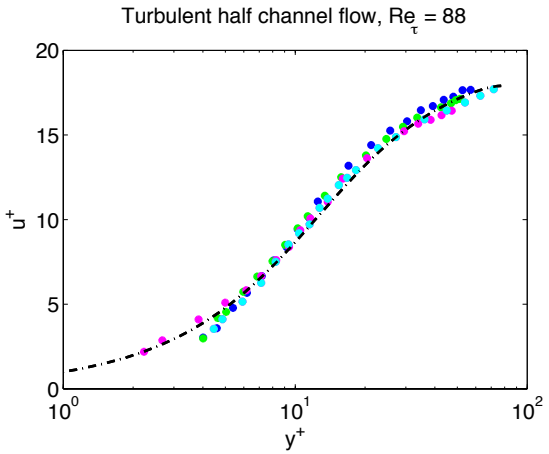
- Comparison with DNS.

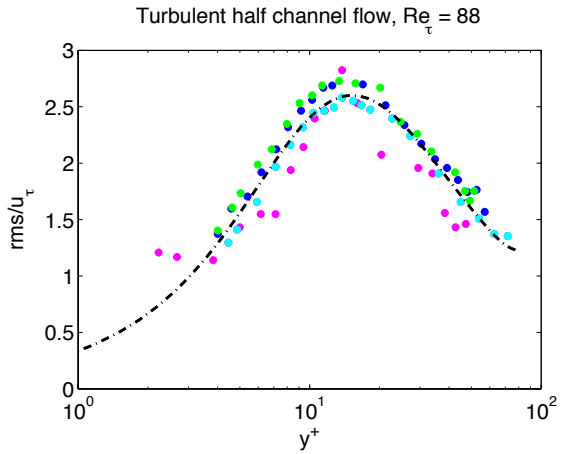
LDV measurements

$Re_\tau = 88$









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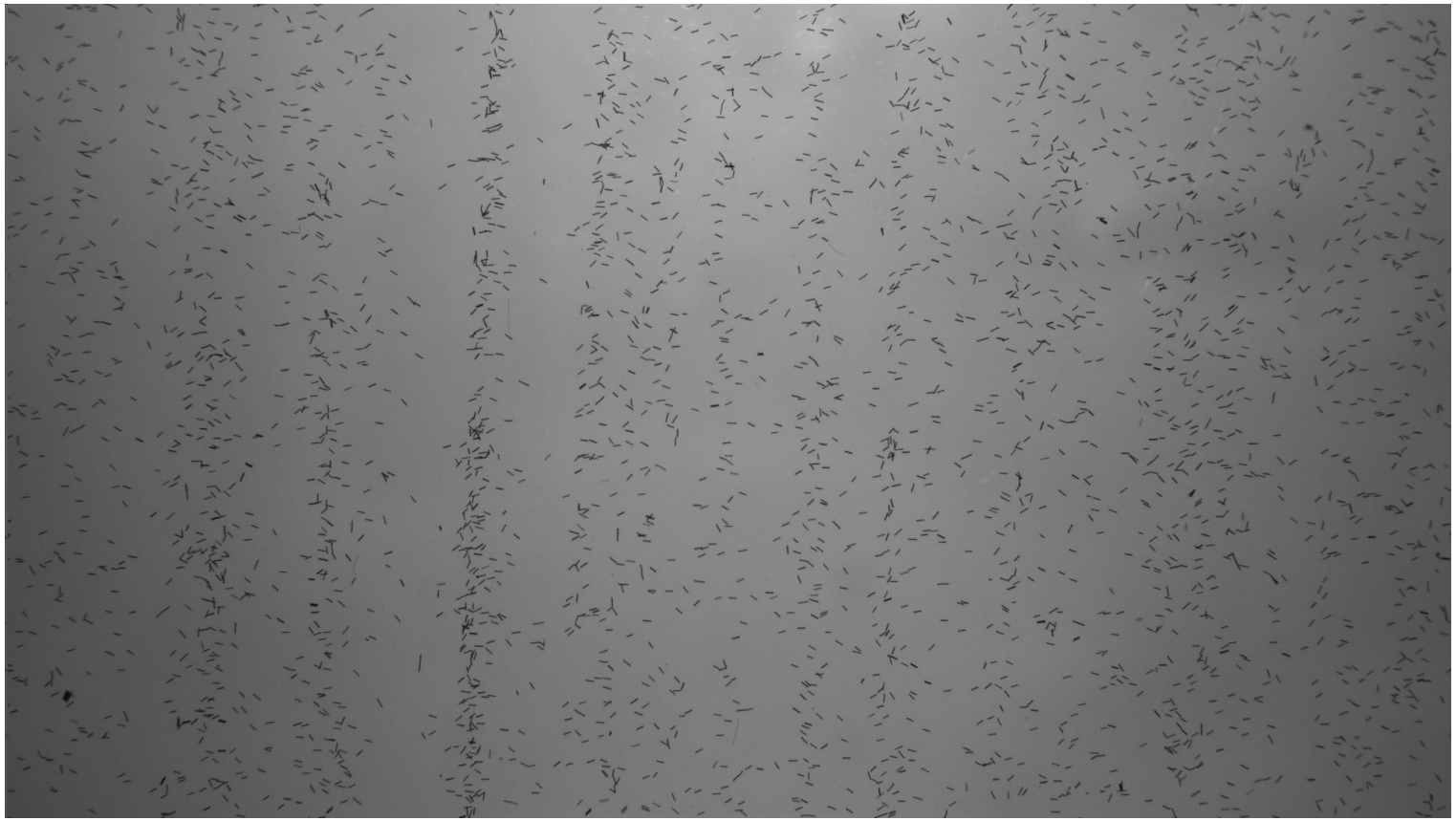
Fibre suspension

l= 0.5 mm, d=70 µm, ρ = 1300 kg/m³
r_p = 7, c_m= 0.033 %



~5 cm

~10 cm

Flow

Fibre suspension

- *Cellulose acetate fibres:*
  l = 2, 1, 0.5 mm, d =70 µm, ρ = 1300 kg/m³
  Aspect ratios r_p = 28, 14, 7.

- *Water*: 120 litres.

- *Concentrations:*
  nl^3 = 0.0008 – 0.0066
  c_m = 0.0041 – 0.033 %

- *Surface velocities:* 0.15 – 0.3 m/s.

Dimensionless parameters

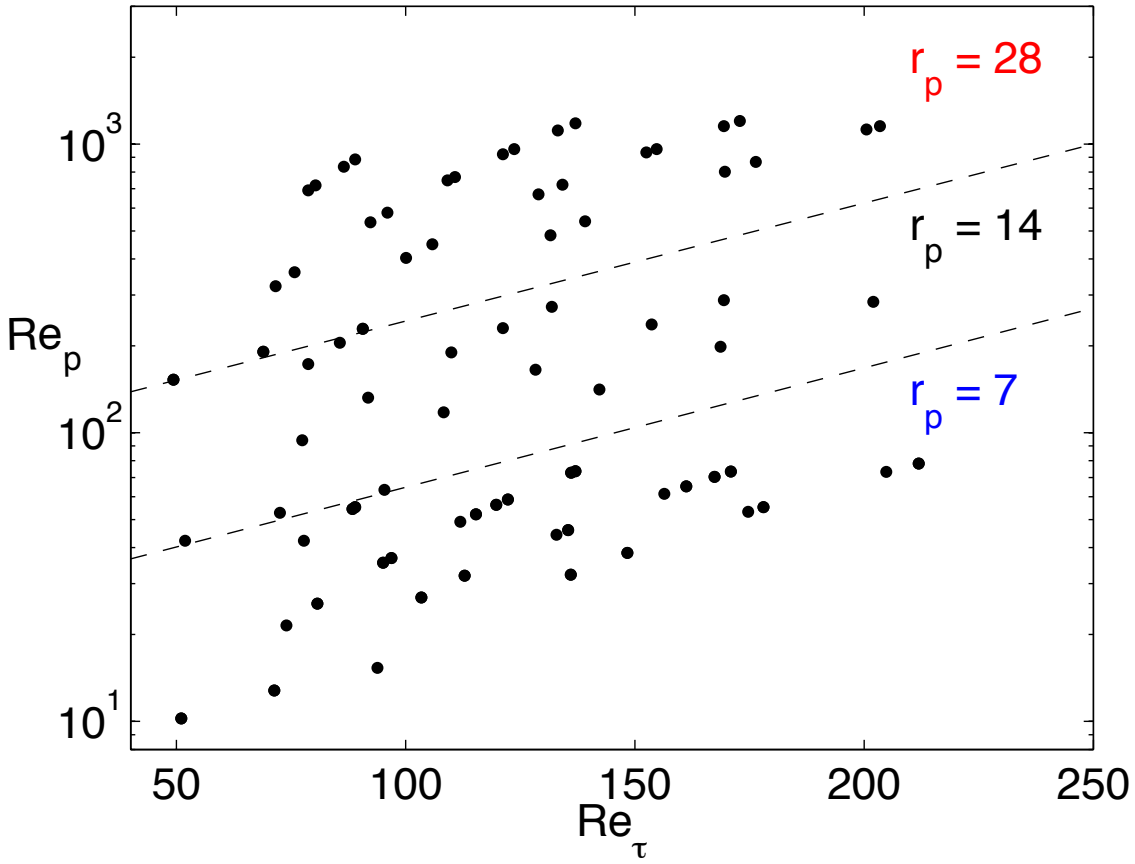
- Particle Reynolds number:

$$\mathrm{Re}_p = \left(\frac{\tau_{wall}}{\rho \nu} \right) \frac{l^2}{\nu}$$

- Friction Reynolds number:

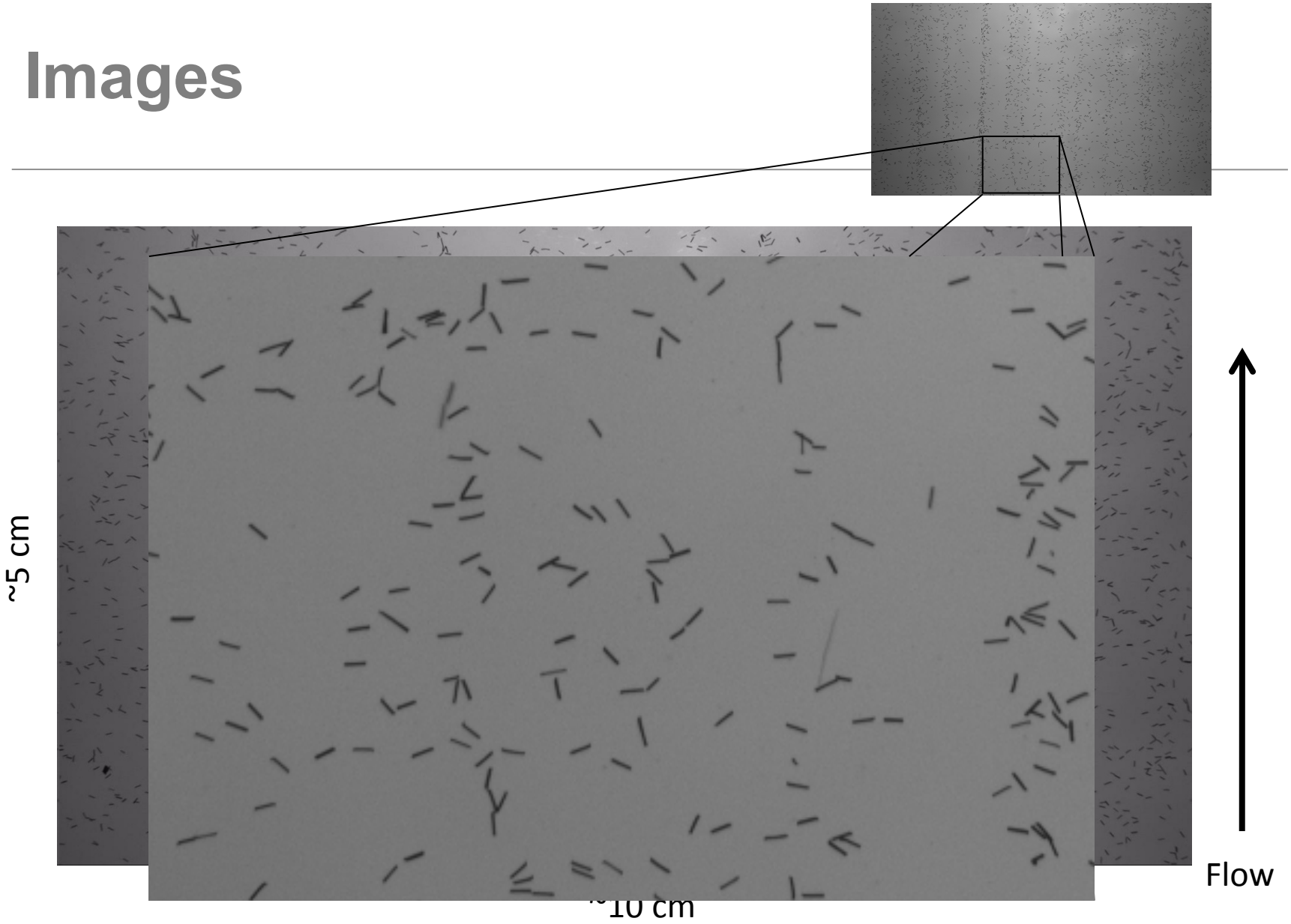
$$\mathrm{Re}_\tau = \frac{u_\tau h}{\nu}$$

Parameter space

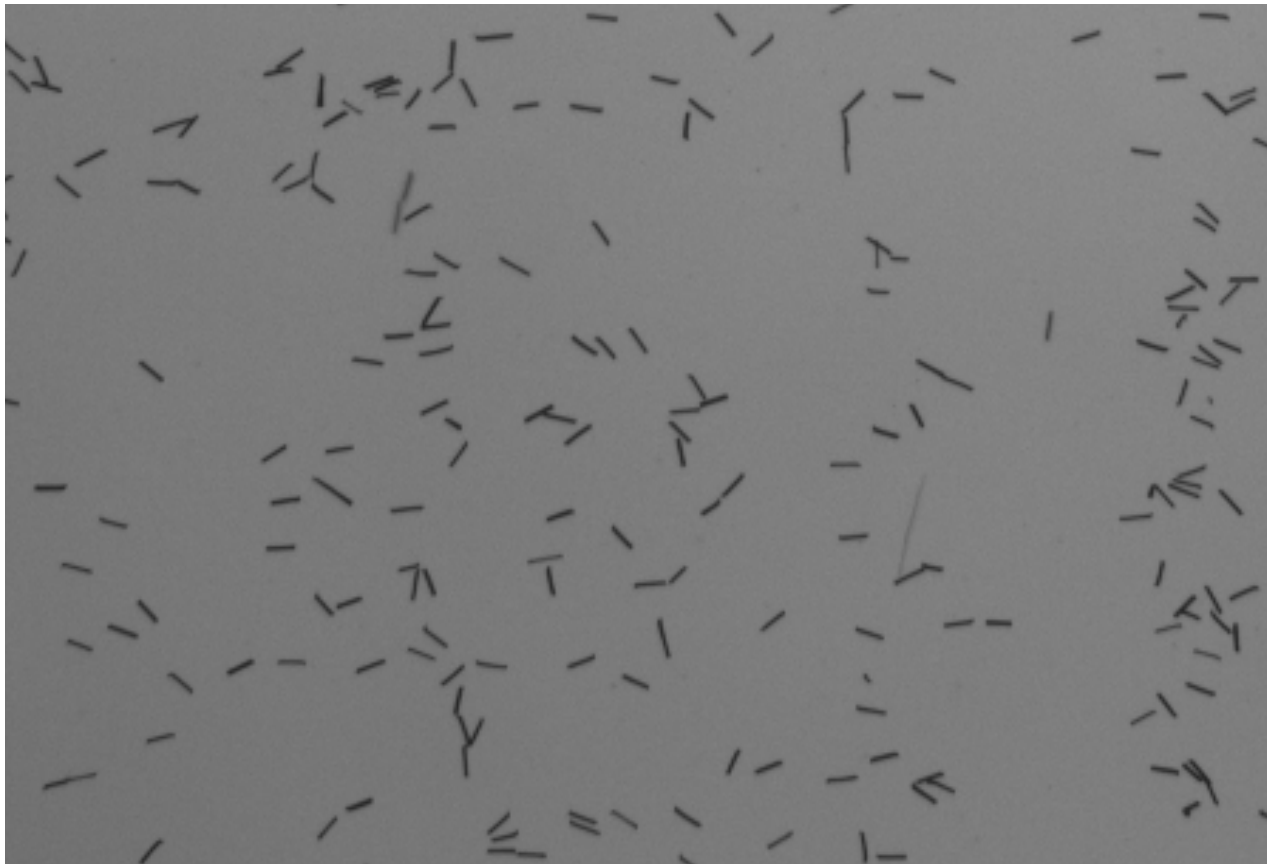


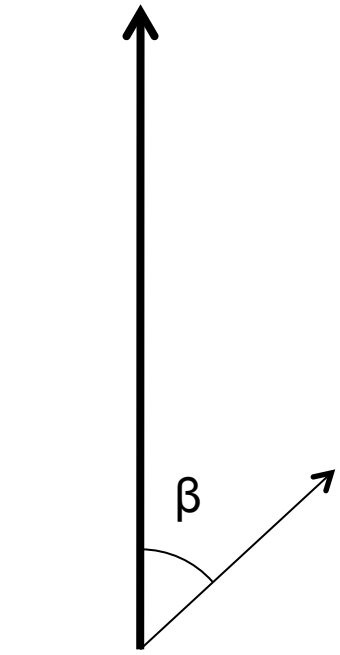
Re_τ = 50 – 230 and Re_p= 10 – 1000.

Images

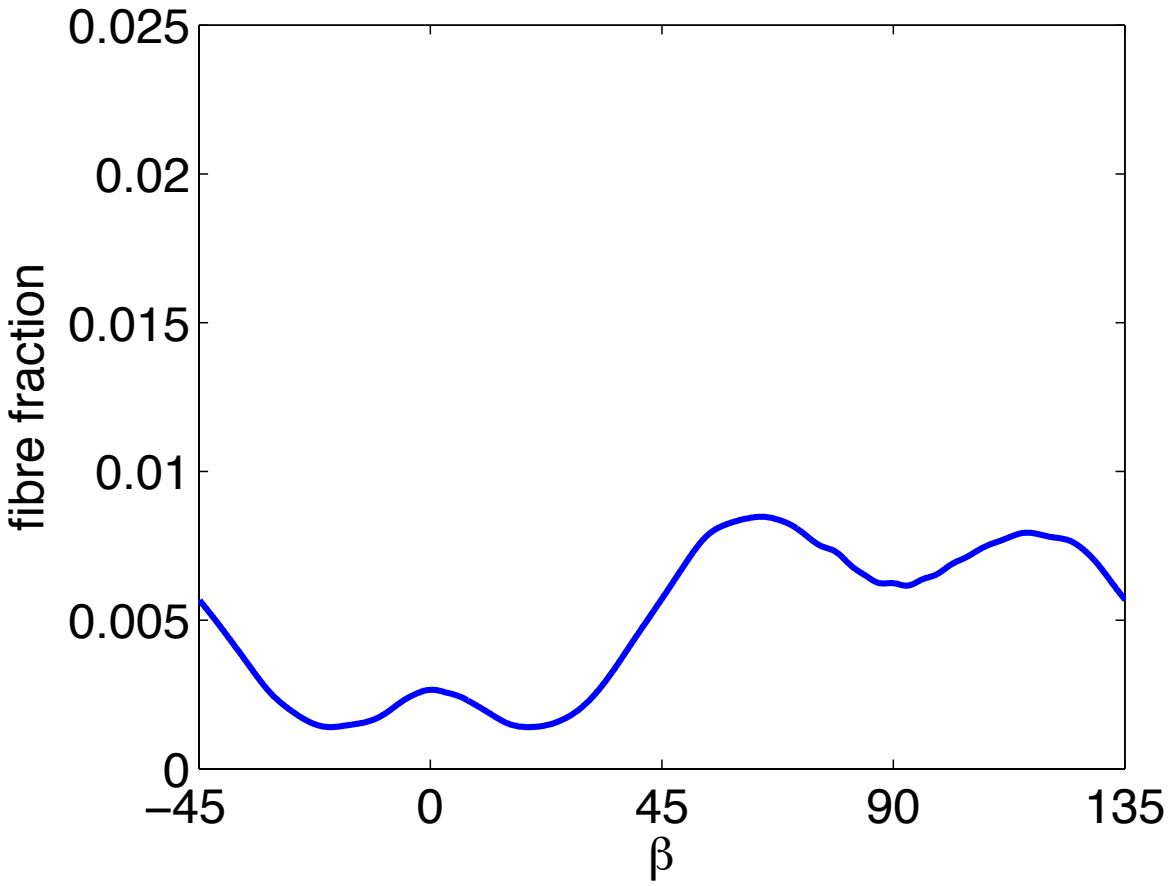


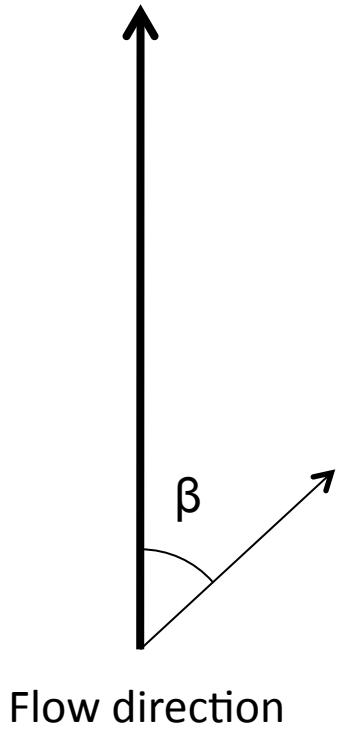
Fibre orientation



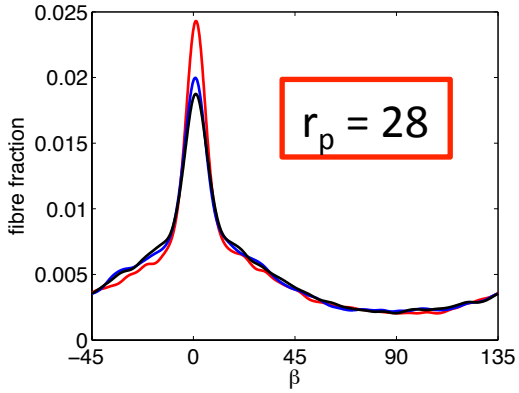


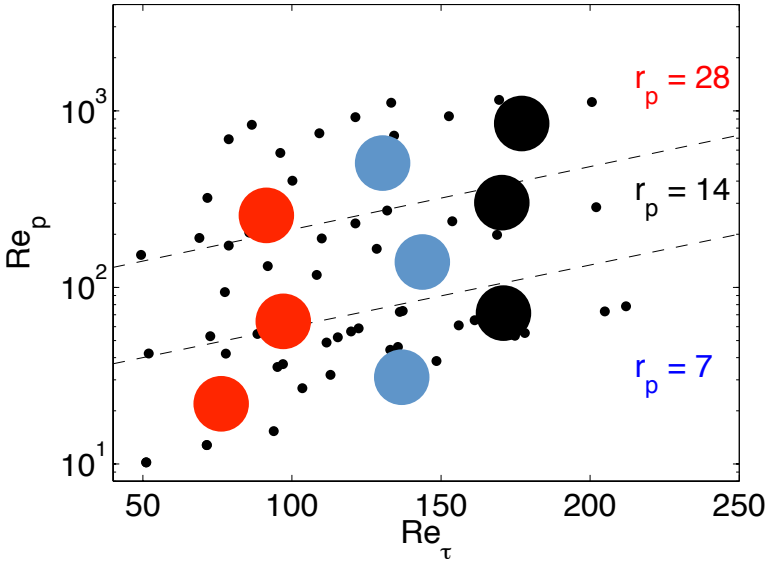
Fibre orientation distribution

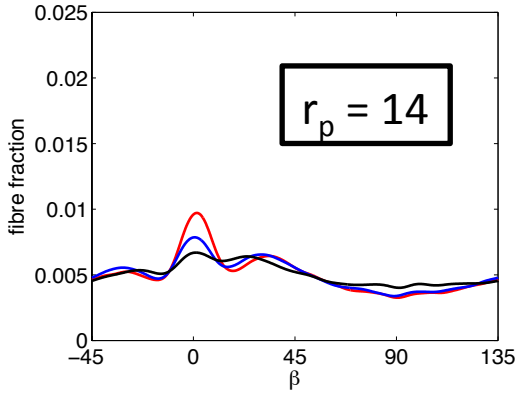


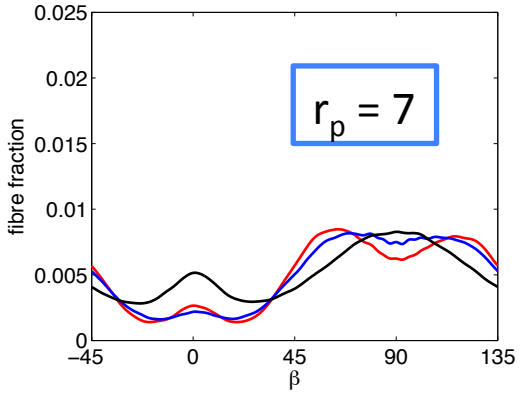


Fibre orientation



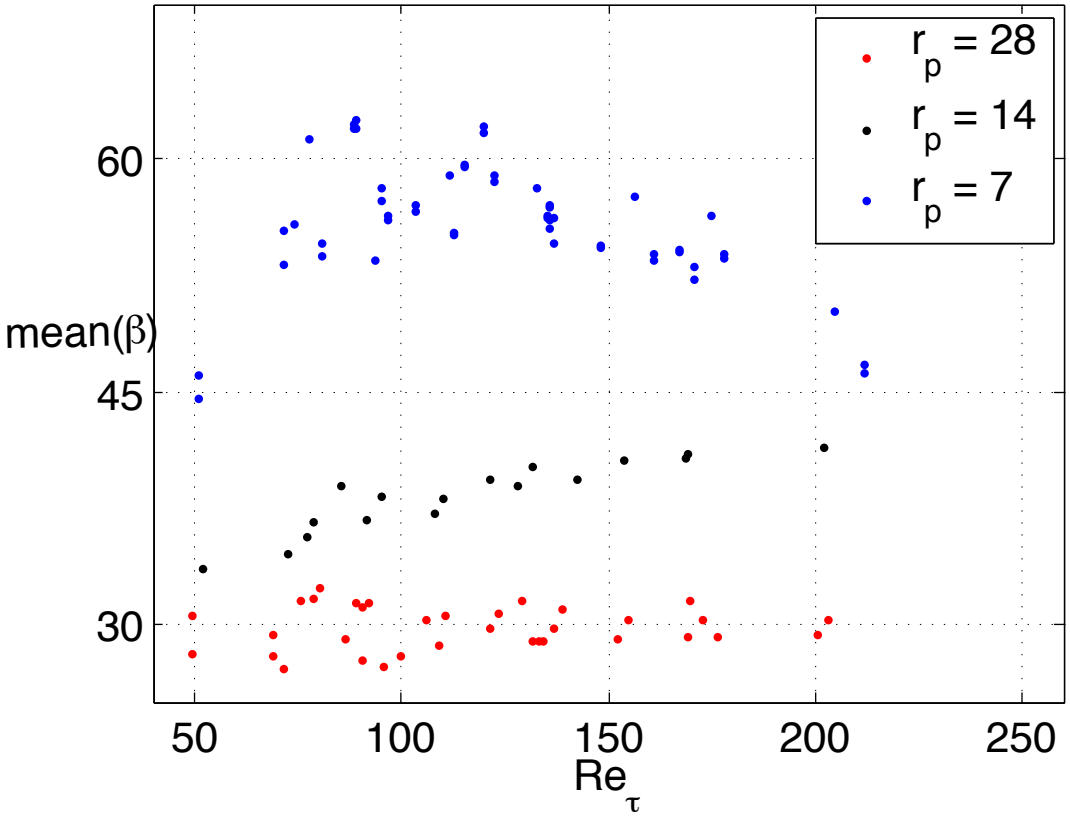






- Fibre orientation depends heavily on fibre length.

Mean fibre orientation

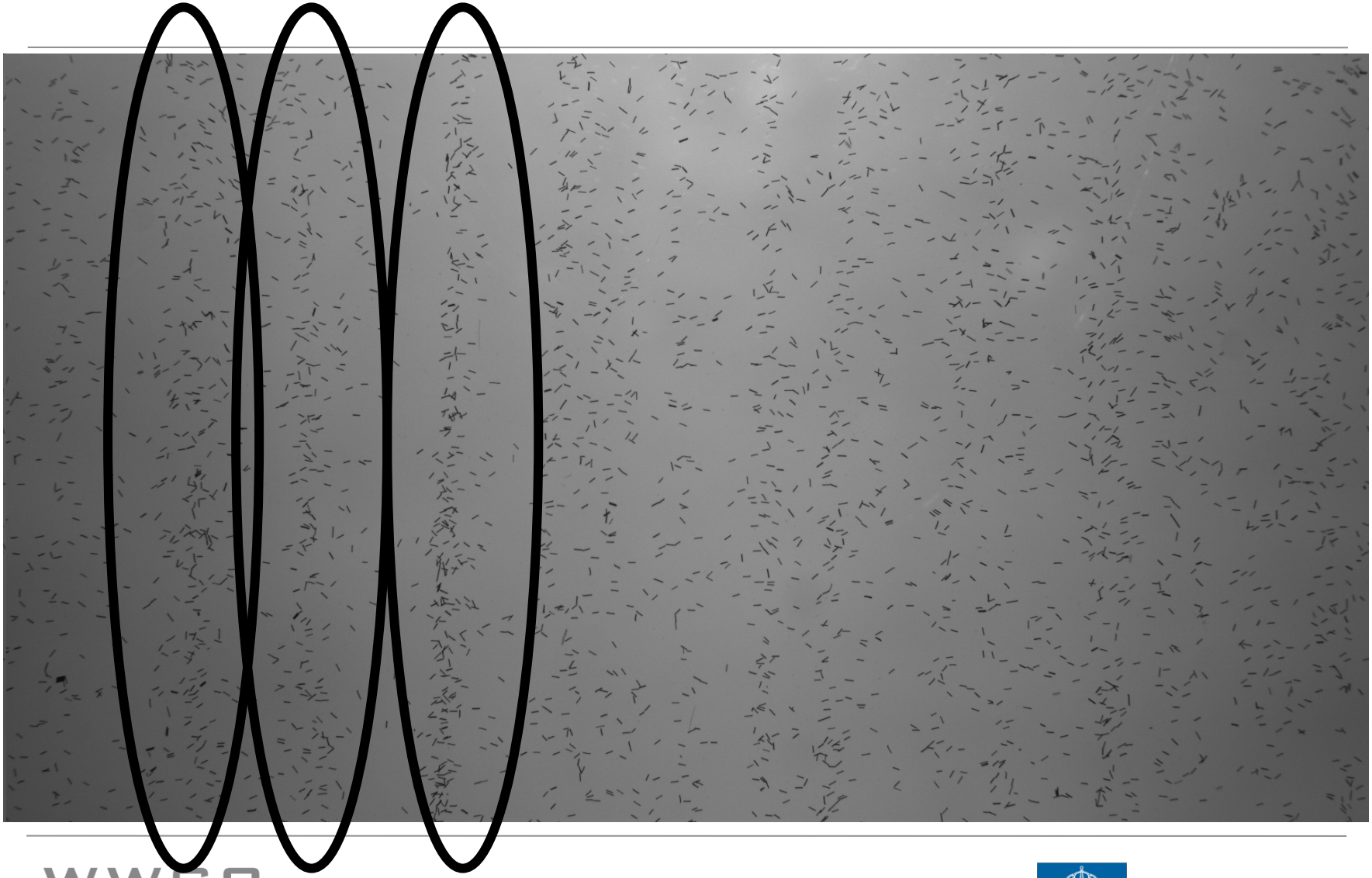


- Fibre orientation depends on Re_τ and drifts toward 45°.

Mean fibre orientation

- Competing effects:
  - Solid body rotation
  - Sedimentation
  - Wall contact
  - Turbulence

Streaks



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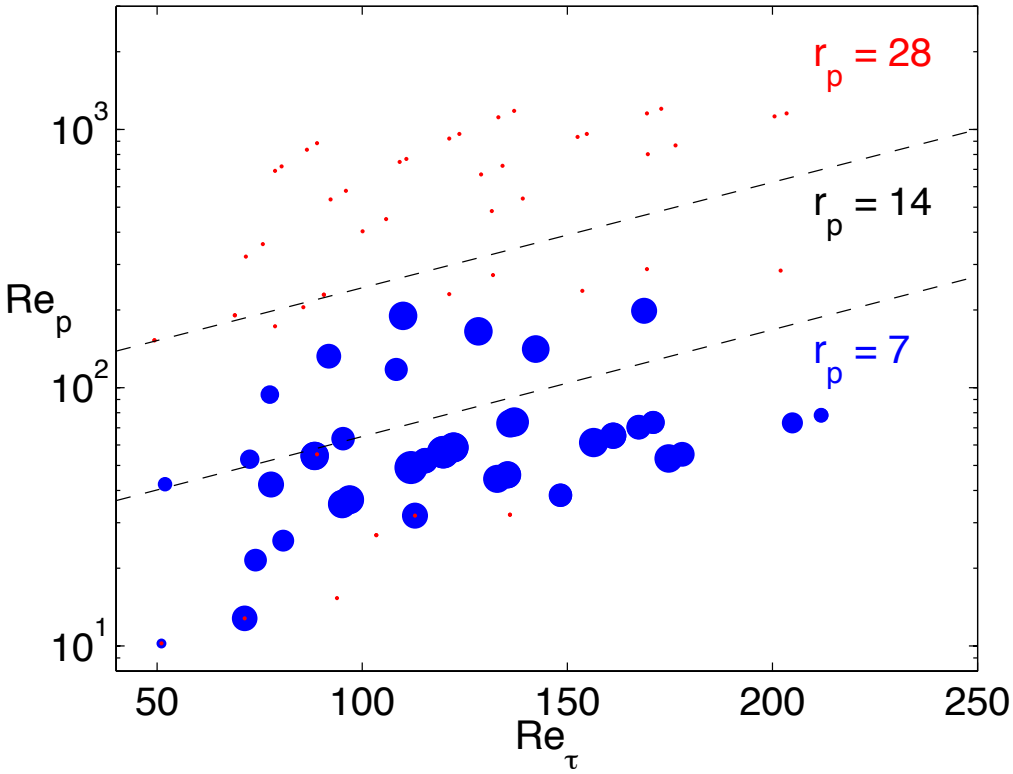
Streakiness



- The result indicate that the streakiness has a maximum with respect to Re_τ.

Scaling of streak width

- Streak width of low speed streaks in turbulent boundary layer scales with l^+.

Friction velocity:

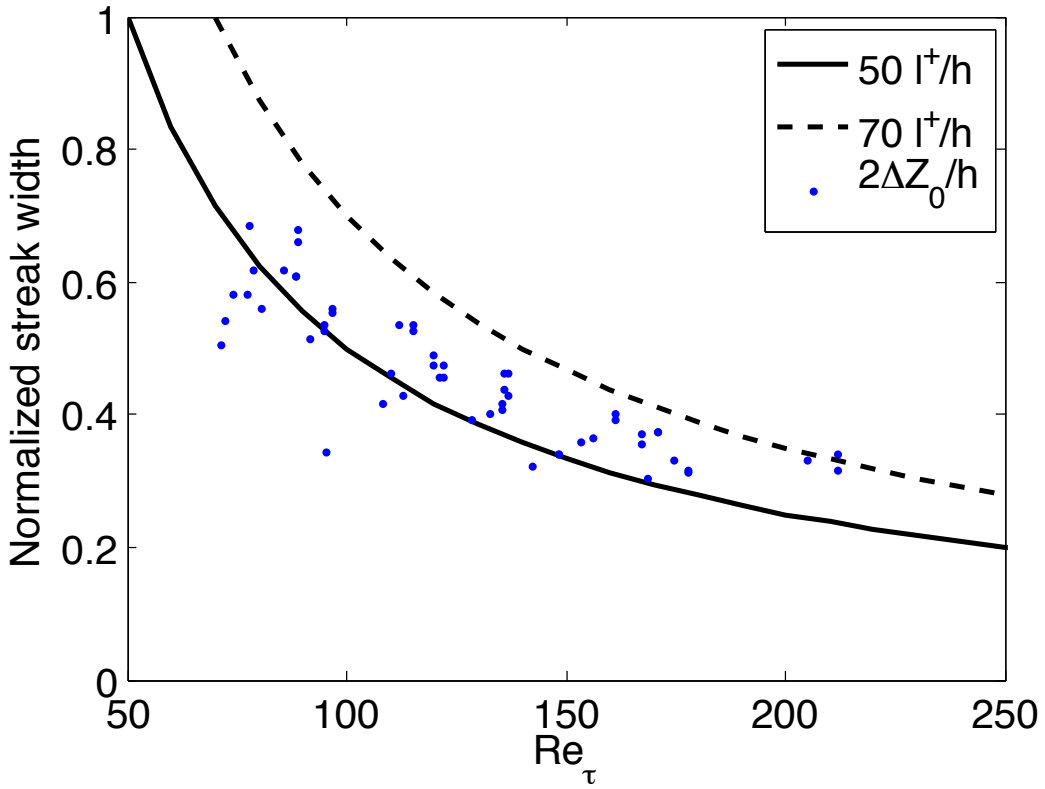
$$u_\tau = \sqrt{\frac{\tau_{wall}}{\rho}}$$

Viscous length scale:

$$l^+ = \frac{\nu}{u_\tau}$$

Streak width

Normalized streak width = $\frac{2\Delta Z_0}{h}$



- The width of the streaks is of the same order as the turbulent low velocity structures near the wall.

Conclusions

- Fibres near a wall in a turbulent flow have been studied experimentally.
- Fibre orientation highly dependent on fibre length.
- The result indicate that the streakiness has a maximum with respect to Re_τ.
- The width of the streaks is of the same order as the turbulent low velocity structures near the wall.

Thank you!

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