A comparitive investigation of MRI and UVP measurement of fibre suspension flow

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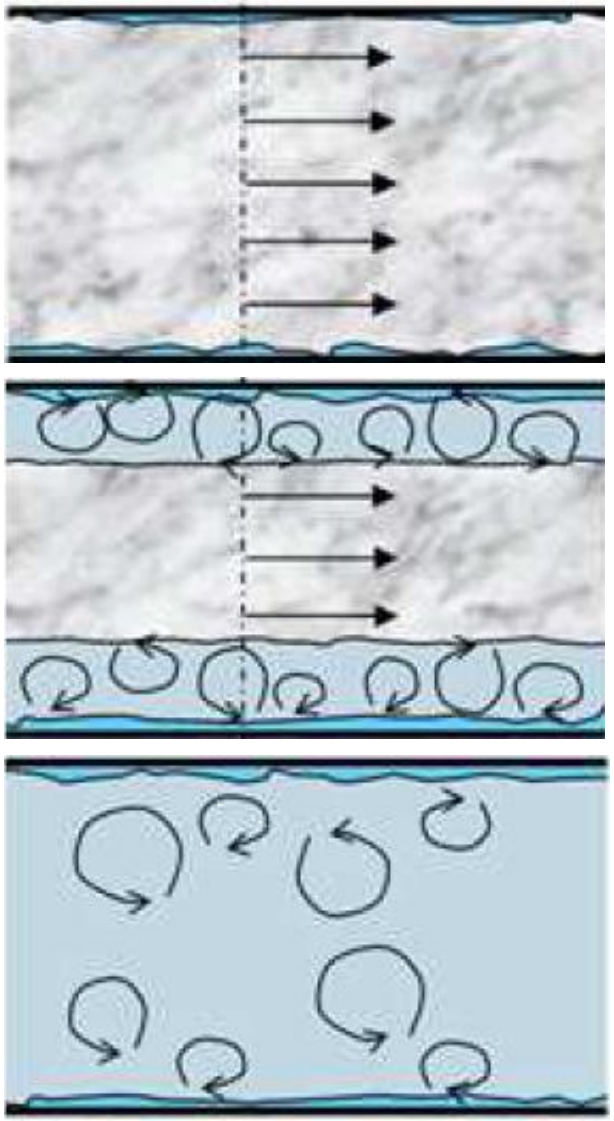
Fibre Suspension Flows

- Basic flow regimes in papermaking
  1. Plug:
     - Interconnected fibre network
     - Thin water layer near walls
  2. Mixed
     - Unstable wall layer
     - Turbulent Annulus
     - Plug begins to break up
  3. Turbulent
     - Flow is fully turbulent
     - Plug is fluidized and breaks apart

- Highly dependant on concentration, stock contents, and flow speed



Literature & Current Knowledge

- Sedimentation
- Fluidized bed reactors.
- Near wall slip velocity (suspension – wall)
- Pressure driven flows?

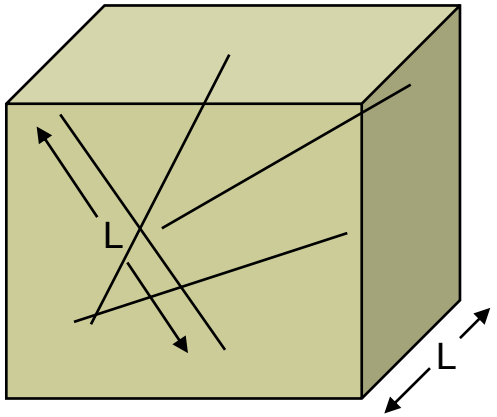
Concentration Regimes

- Fibre type: Rayon
- Average fiber length, L = 2 mm
- Average fiber diameter, d = 60 µm
- Fiber aspect ratio, r = L/d = 33

$$nL^3 \leq 1 \qquad \textbf{\textit{Dilute}}$$

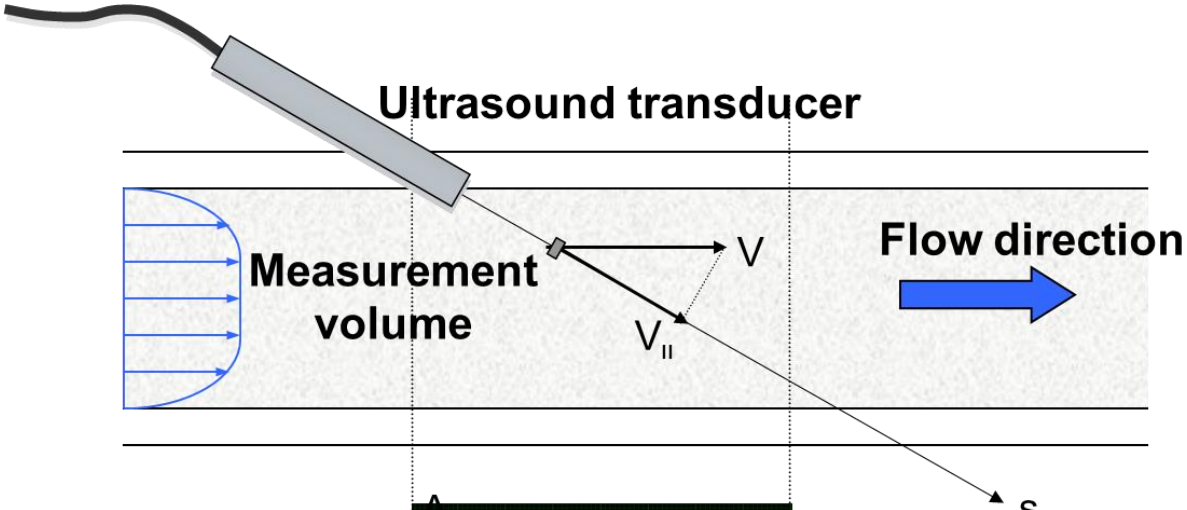
$$1 \leq nL^3 \leq r \qquad \textbf{\textit{Semi-dilute}}$$

$$nL^3 \geq r \qquad \textbf{\textit{Concentrated}}$$

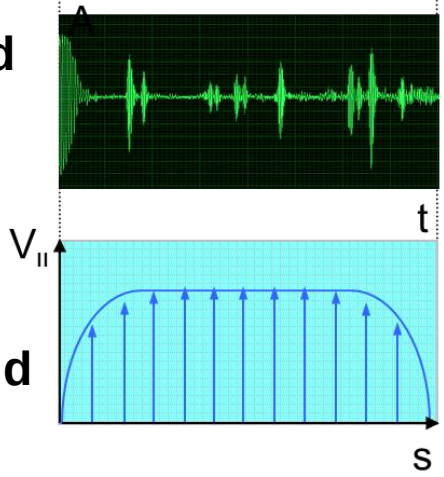


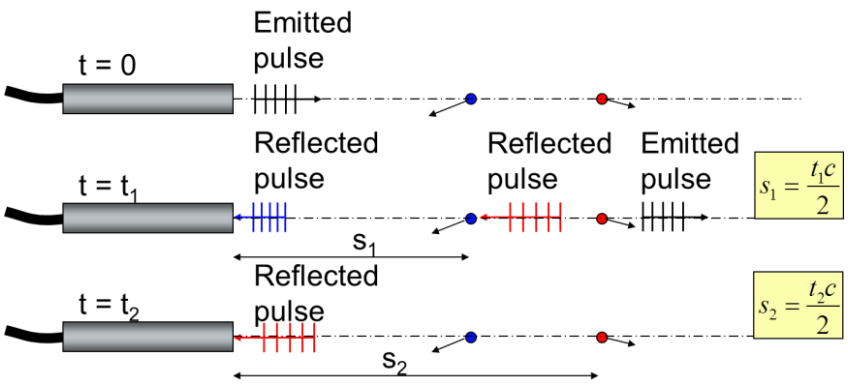
$nL^3 = 4$

Particle Velocity Measurement: Ultrasonic Velocimetry Profiling (UVP)



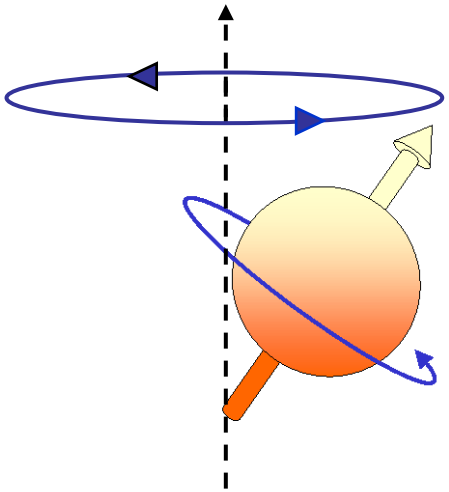
Ultrasound echo generated by reflecting sounds wave off particles in the flow

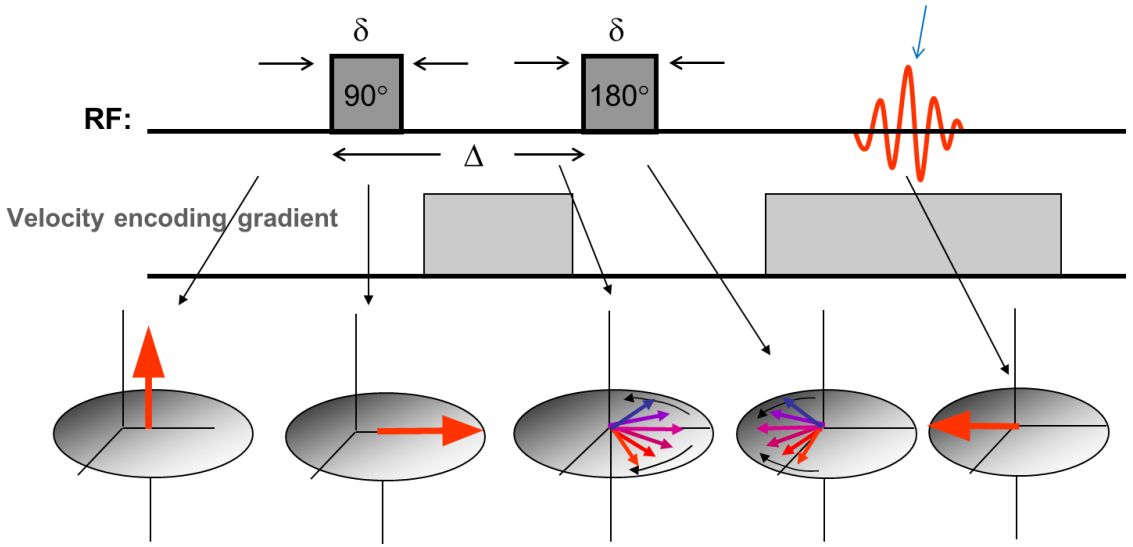


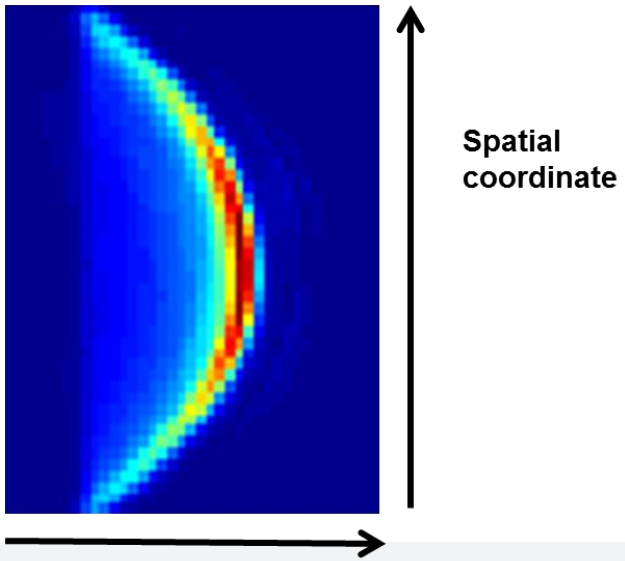


Doppler effect allows estimation of the mean and fluctuating/turubulent velocity profile

Water Velocity: Magnetic Resonance Imaging (MRI)



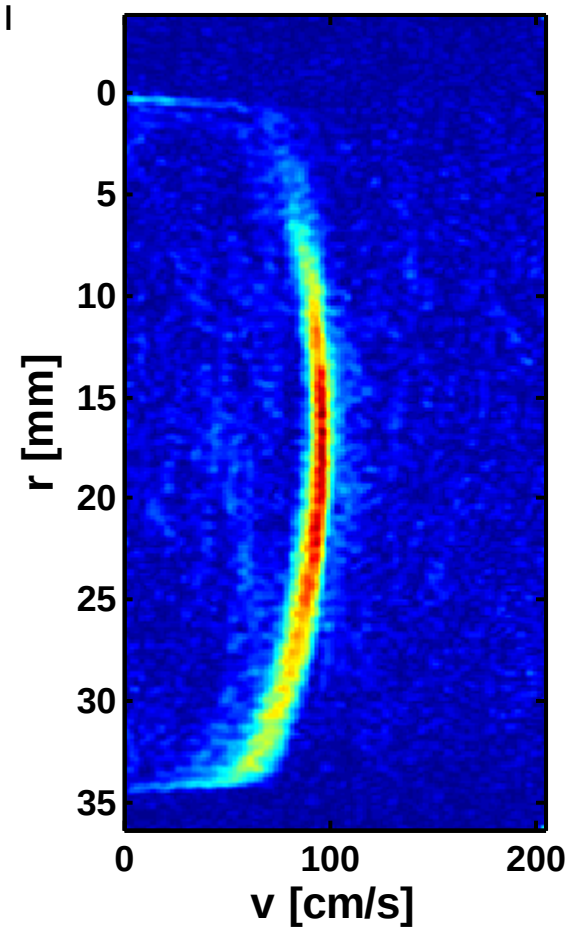




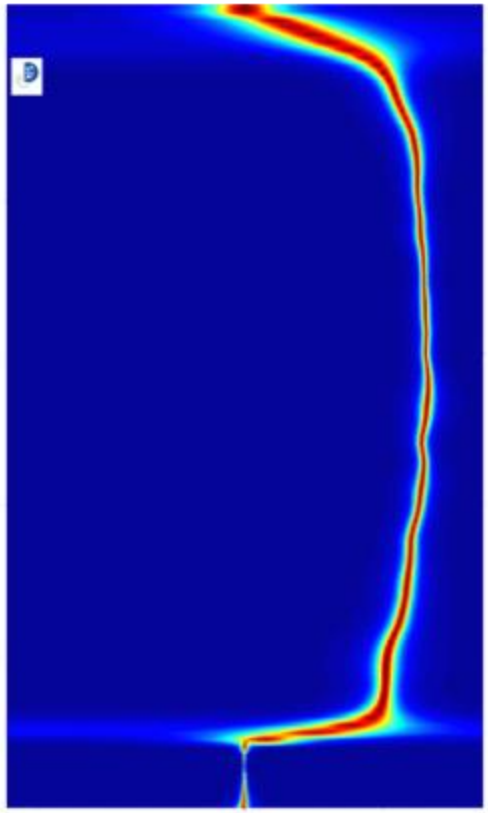
H^1 is excited by application of a m-field. A 'signal' is obtained through manipulation of the magnetization.

Comparison of Flow Images

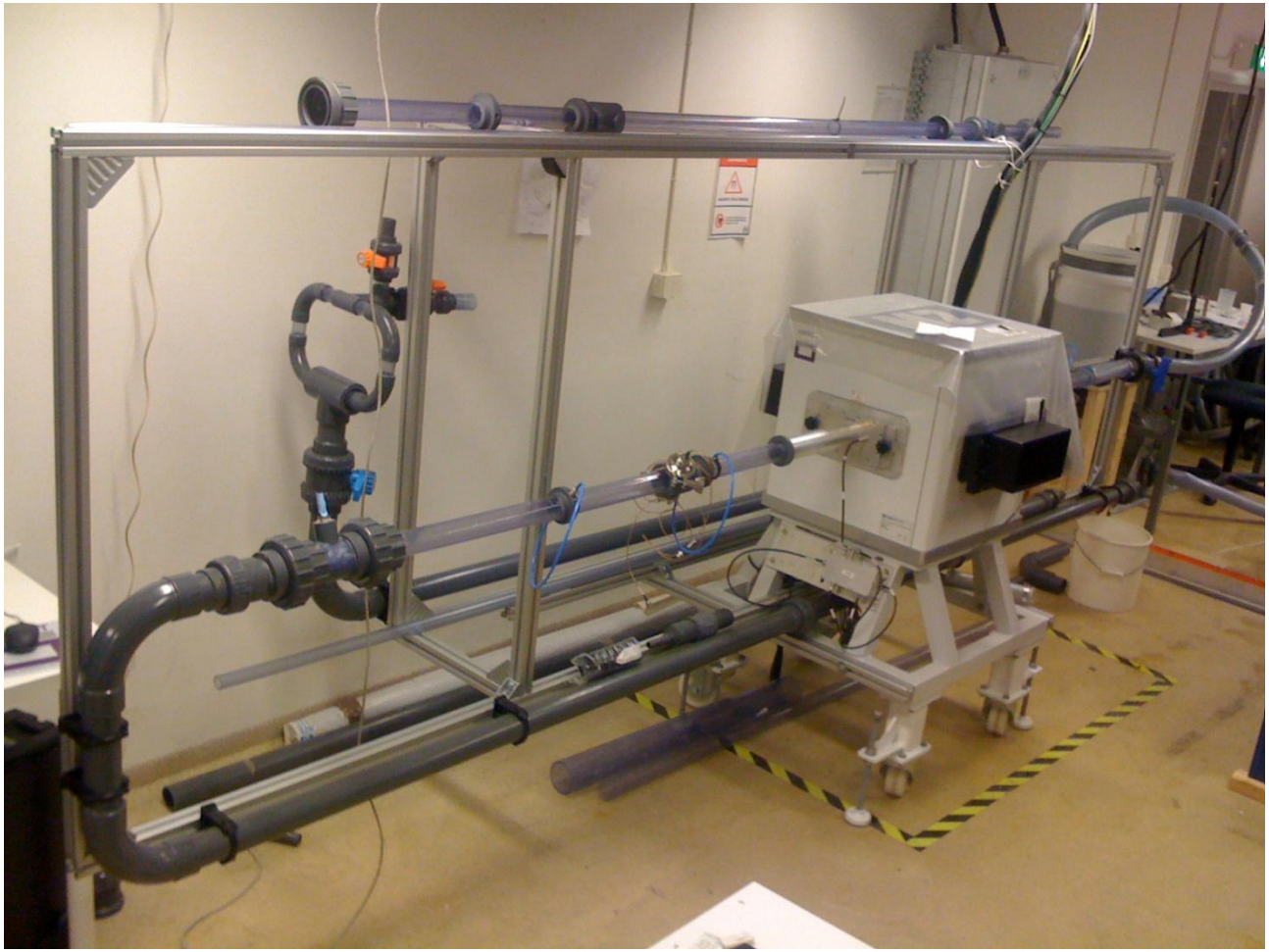
MRI



UVP



The Orignal Flow Loop



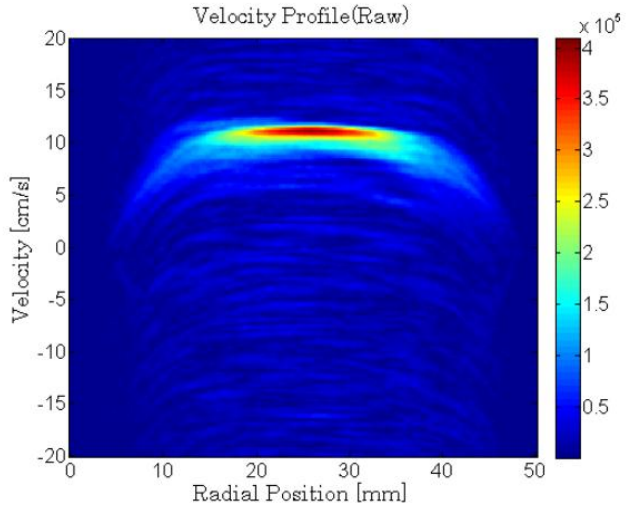
The Rebuilt Flow Loop

Previous results and mistakes……

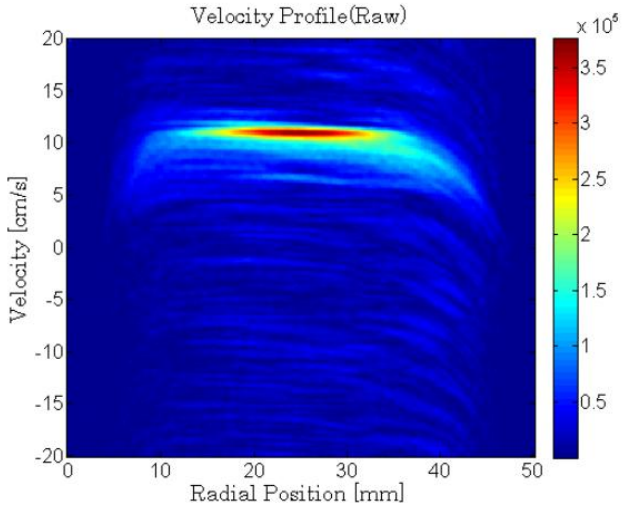
But still rather interesting

MRI measurements

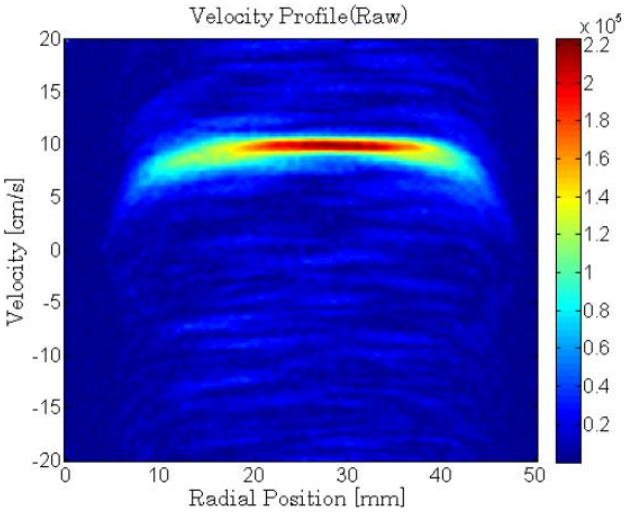
Horizontal Slice

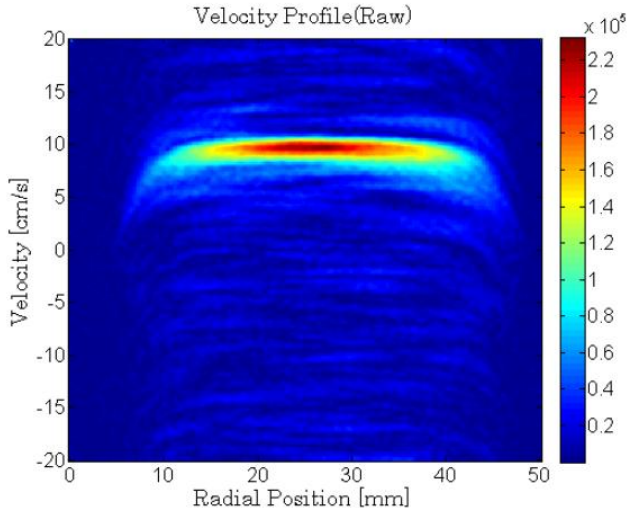


Vertical Slice



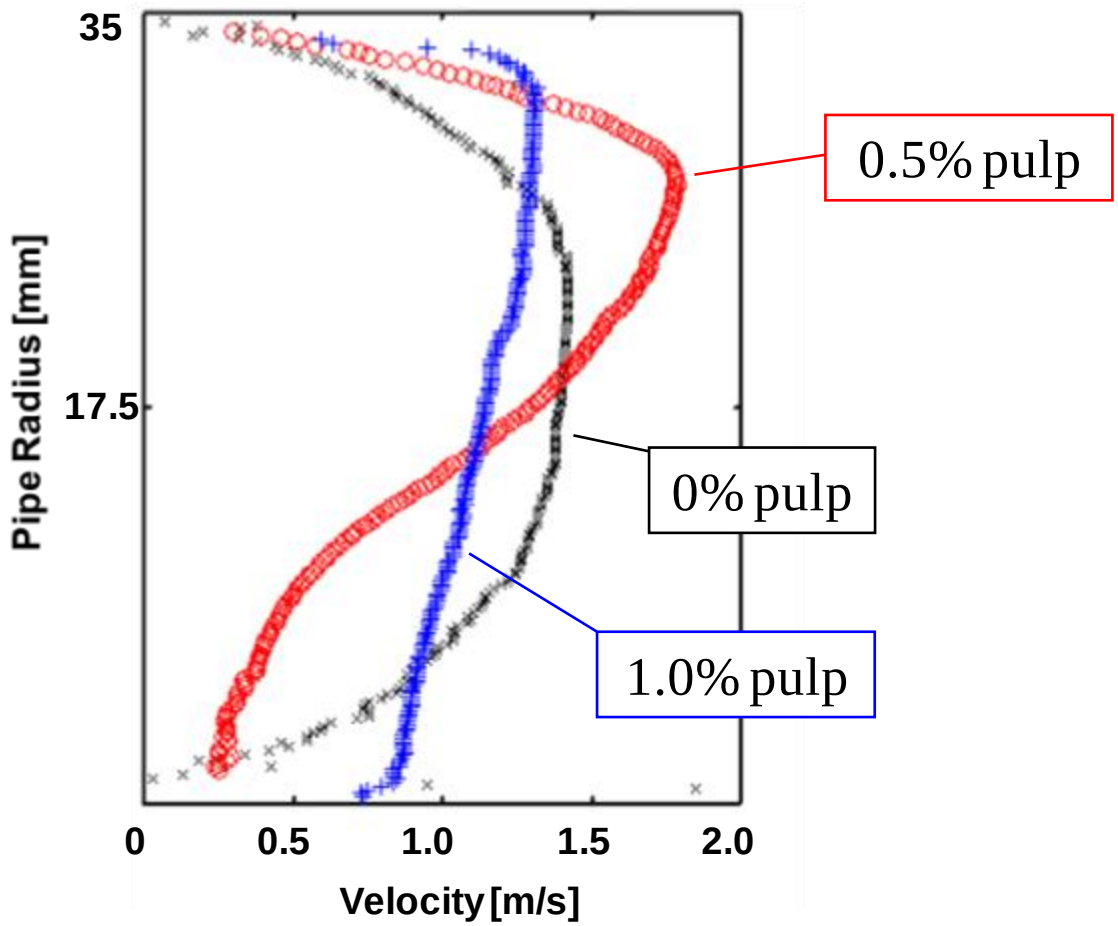
Velocity profile with 90° elbow



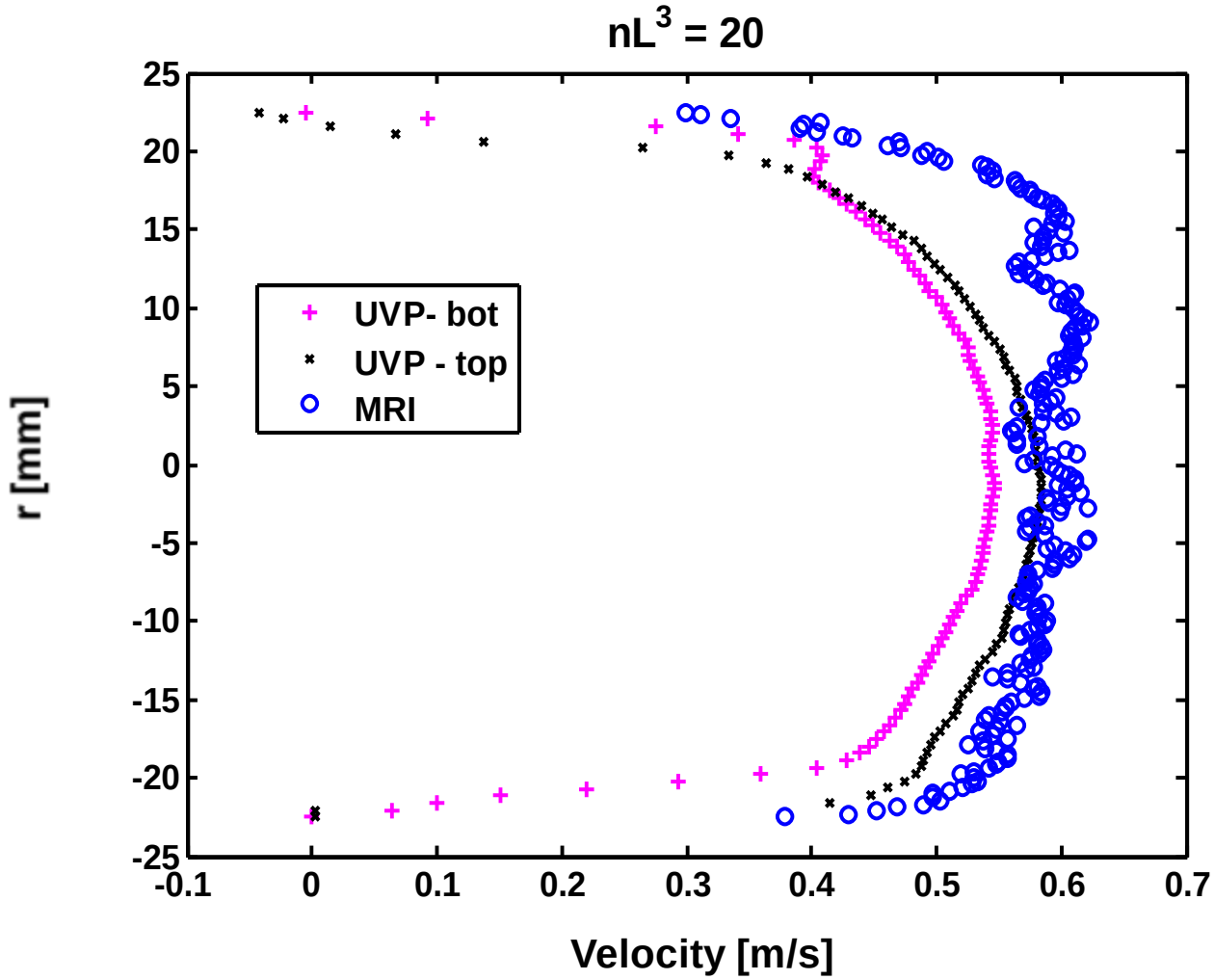


Velocity profiles with flow splitter

Effect of Elbow on Flow with Pulp Fibres



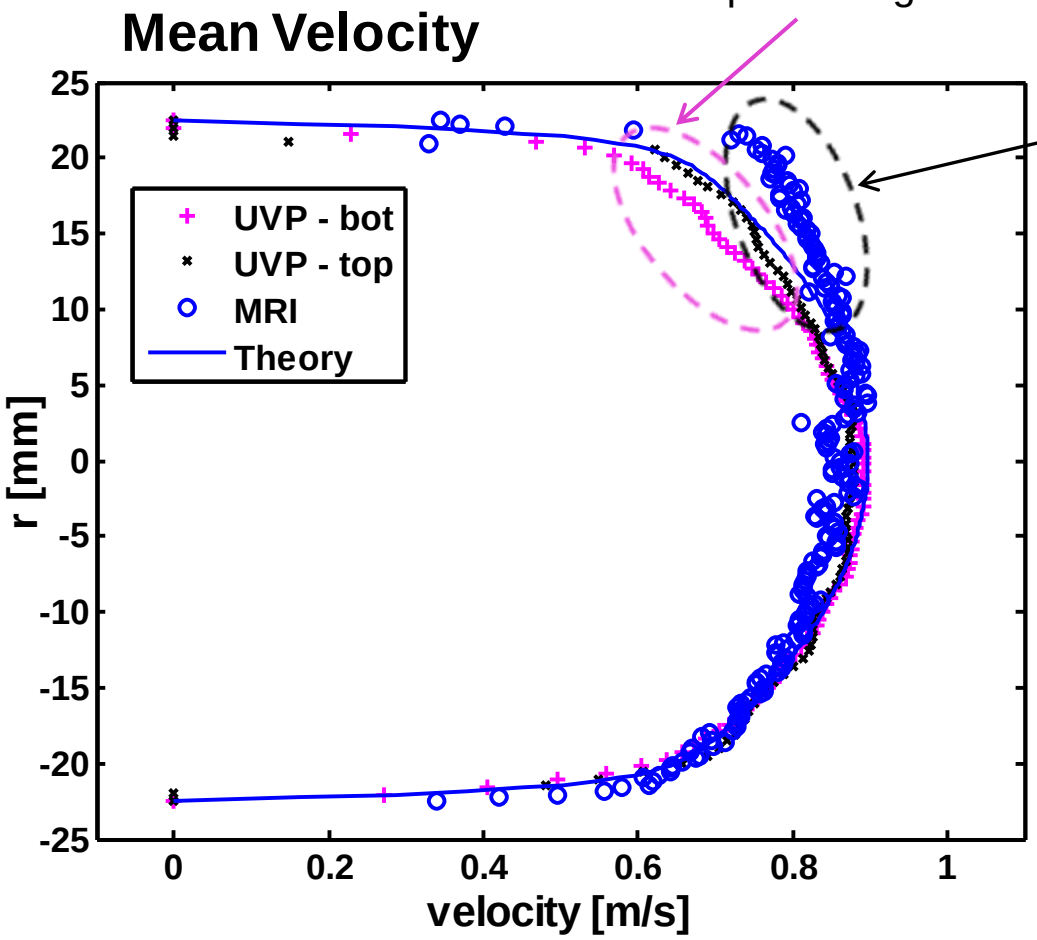
$nL^3 = 20$, v ~ 0.55 m/s



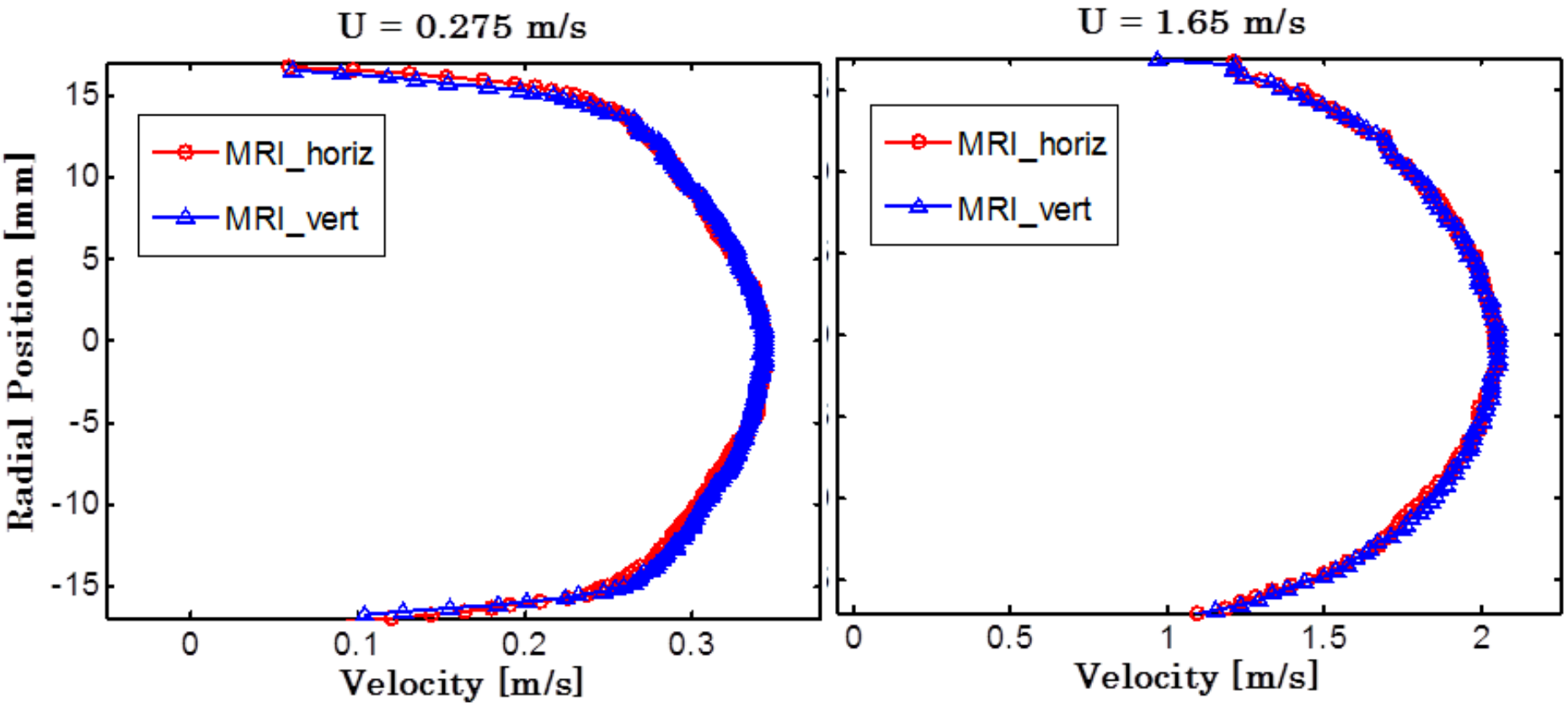
Comparison – Dilute Suspension

UVP bottom probe under-estimate due to incorrect probe angle

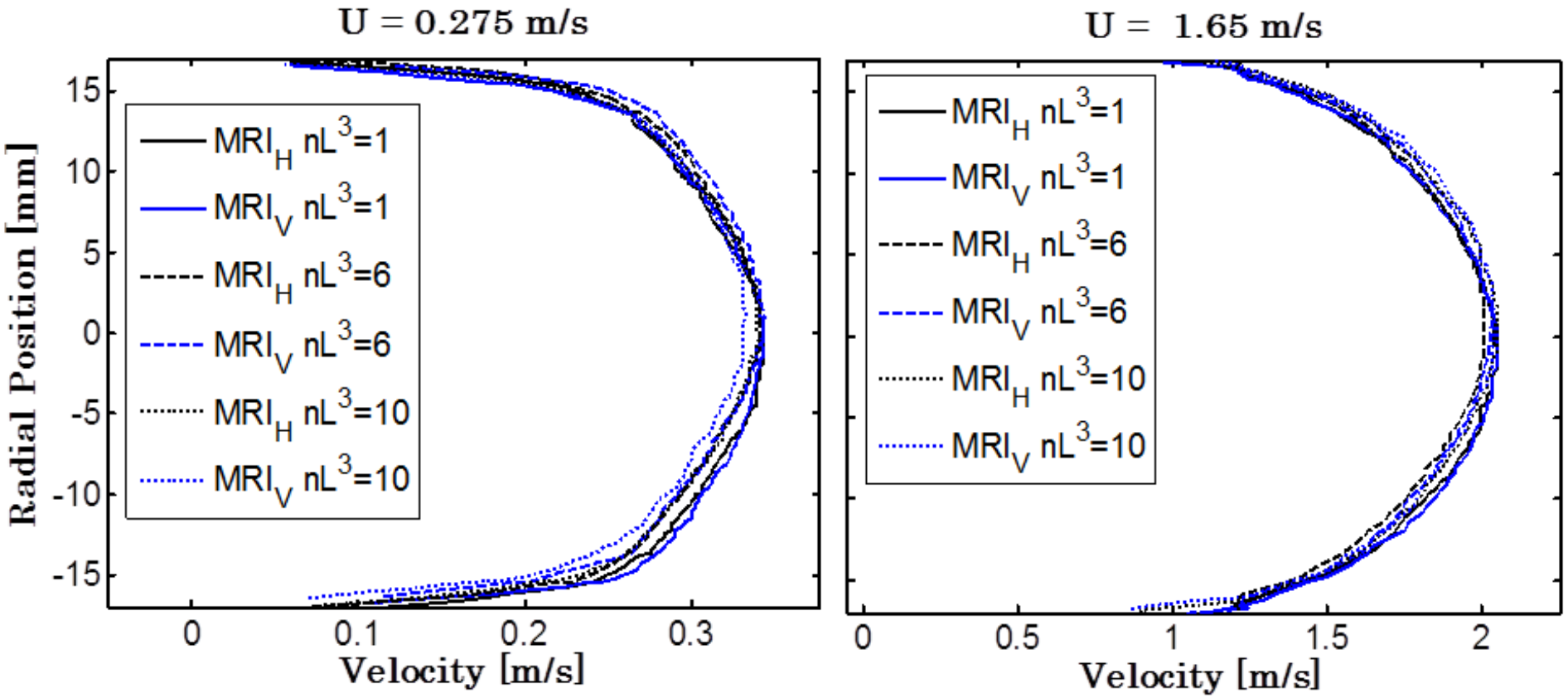
MRI Over-estimate due to asymmetry



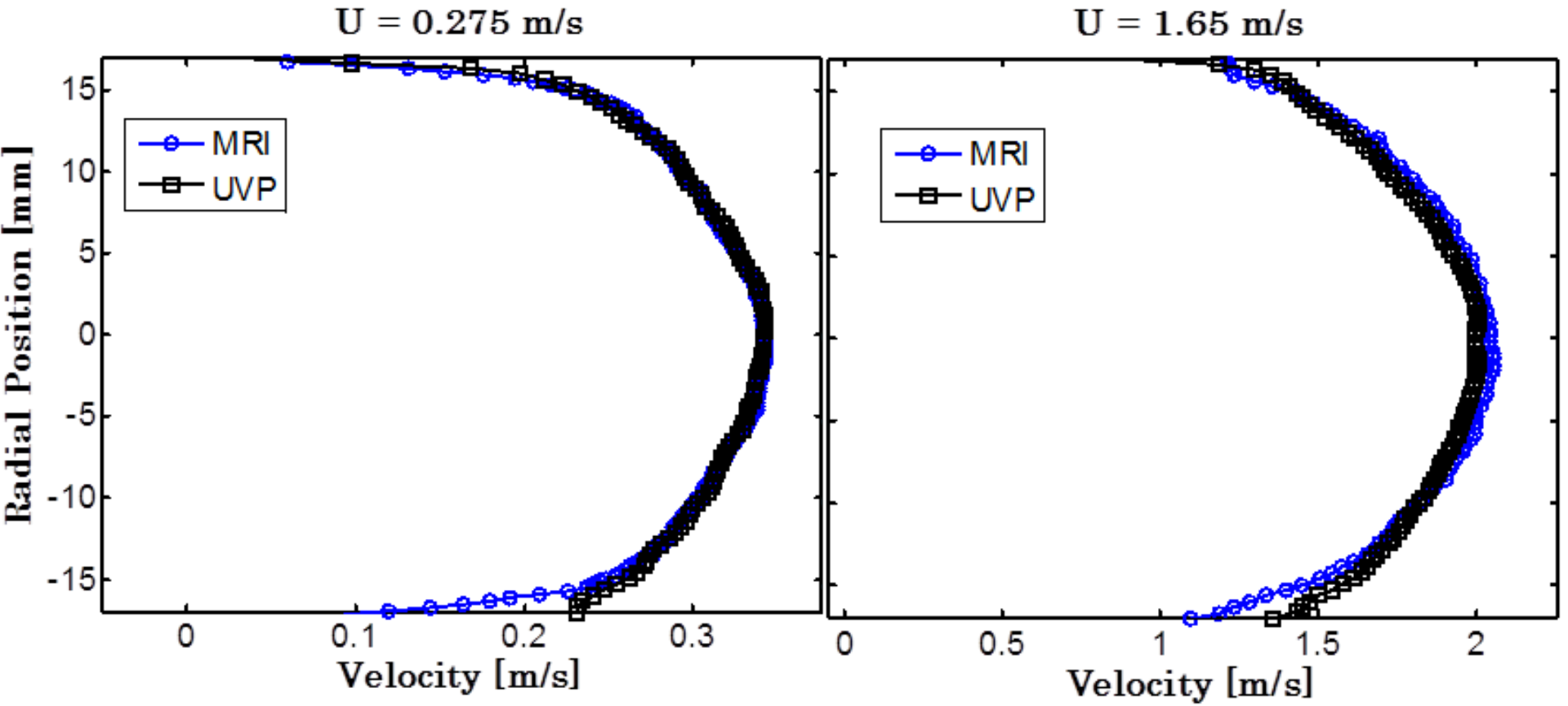
New Results – Flow symmetry



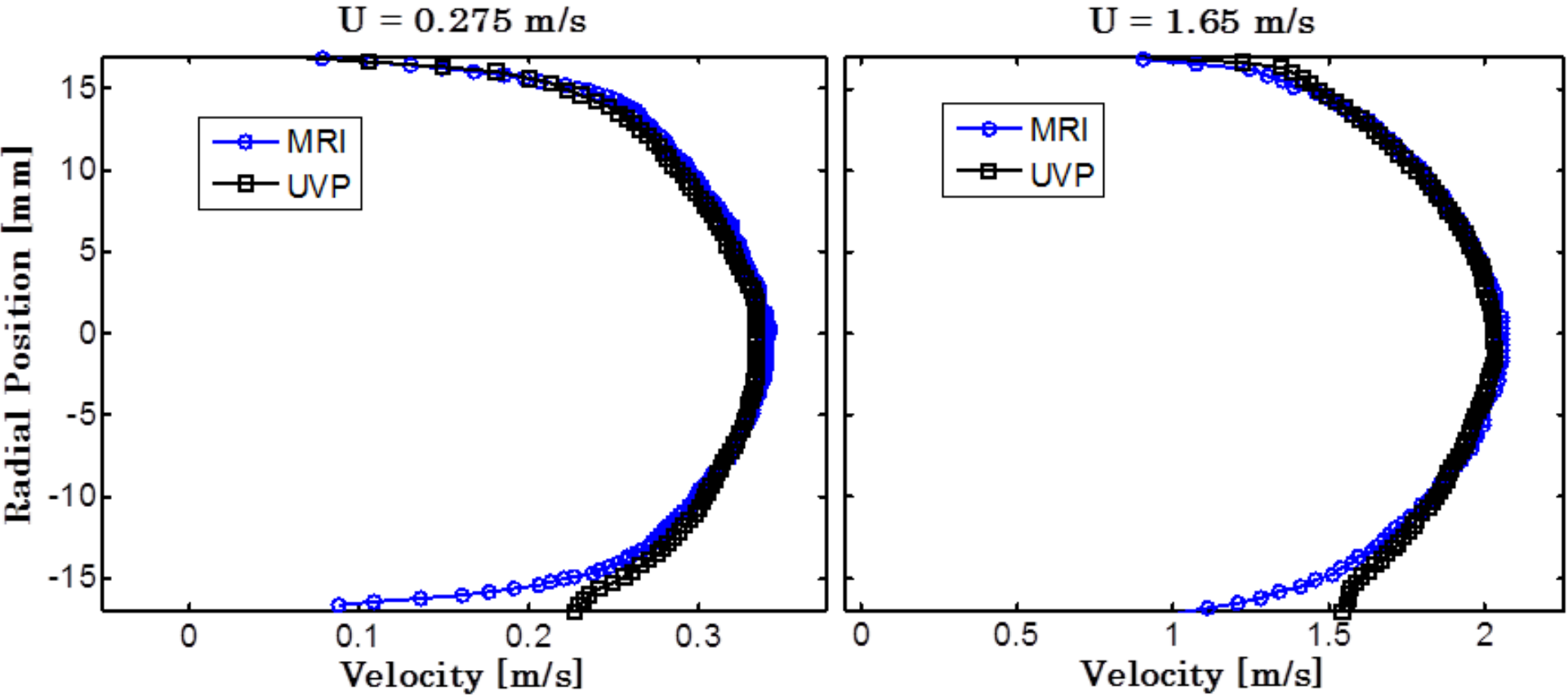
Effect of fibres on water velocity



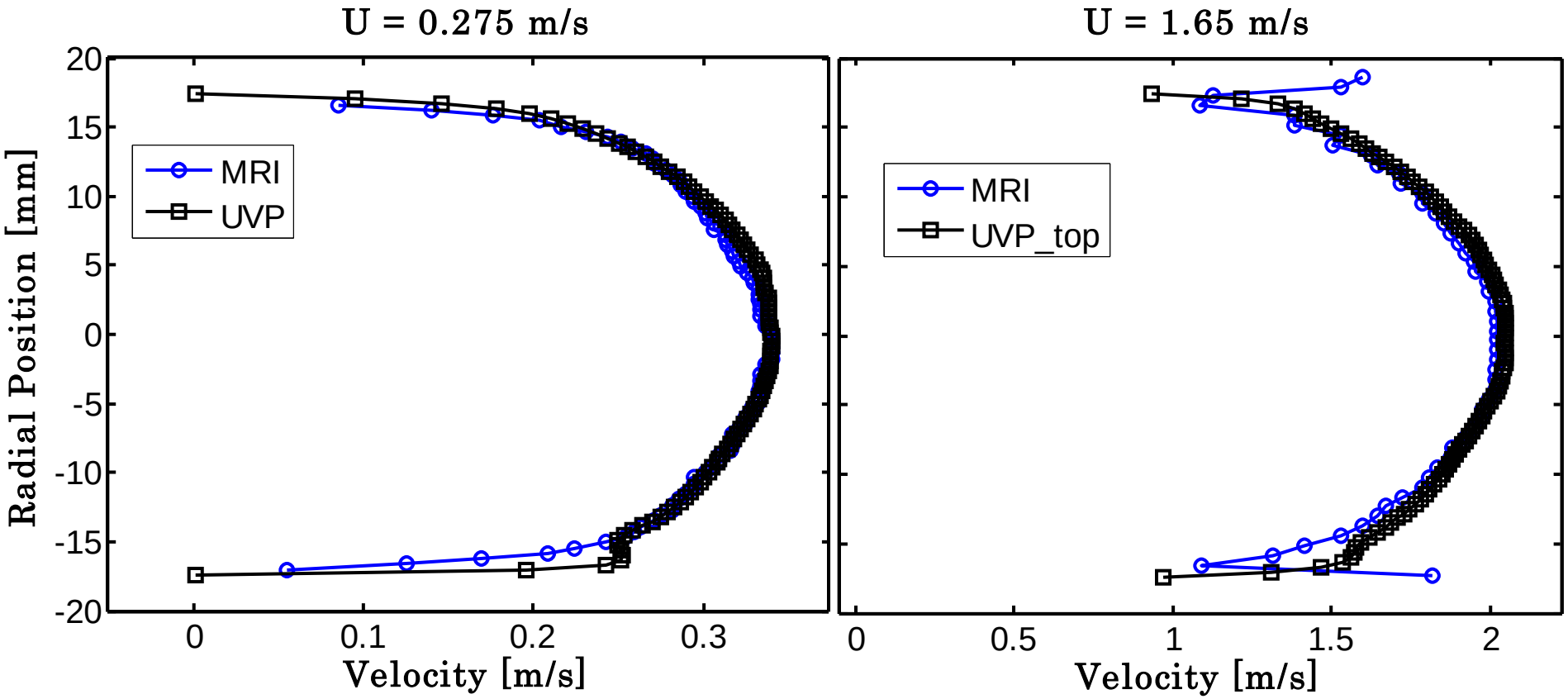
nL3 = 1


U = 0.275 m/s
U = 1.65 m/s
MRI
UVP
MRI
UVP
Radial Position [mm]
15
10
5
0
-5
-10
-15
0
0.1
0.2
0.3
0
0.5
1
1.5
2
Velocity [m/s]
Velocity [m/s]

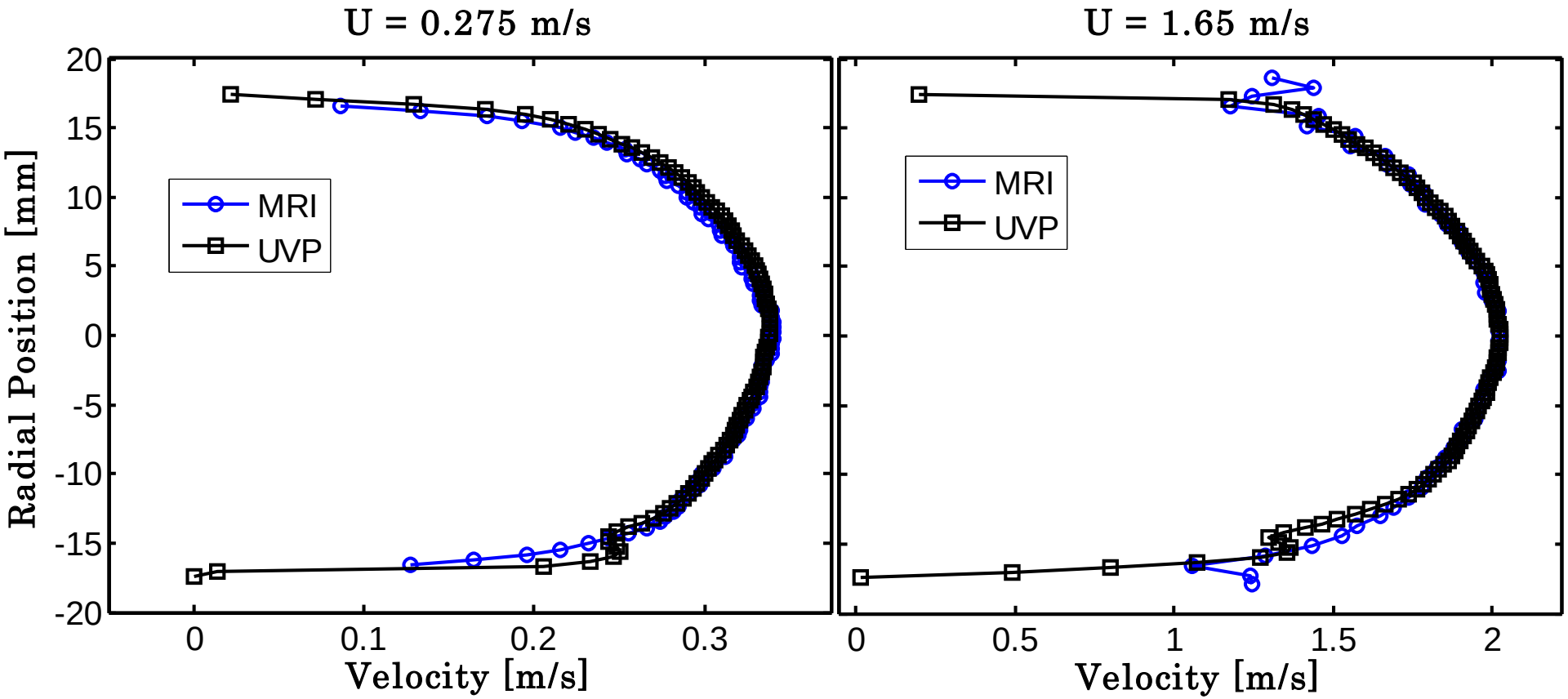
nL3 = 10


U = 0.275 m/s
U = 1.65 m/s
MRI
UVP
MRI
UVP
Radial Position [mm]
15
10
5
0
-5
-10
-15
0
0.1
0.2
0.3
0
0.5
1
1.5
2
Velocity [m/s]
Velocity [m/s]

nL3 = 13


U = 0.275 m/s
U = 1.65 m/s
Radial Position [mm]
Velocity [m/s]
Velocity [m/s]
MRI
UVP
MRI
UVP_top
20
15
10
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
0
0.5
1
1.5
2

nL3 = 16


U = 0.275 m/s
U = 1.65 m/s
Radial Position [mm]
20
15
10
5
0
-5
-10
-15
-20
MRI
UVP
0
0.1
0.2
0.3
0.5
1
1.5
2
Velocity [m/s]

Conclusions / Questions

- Q. Does the flow asymmetry lead to a slip velocity?
- Q. Does a slip velocity exist in pressure driven flow and what are the conditions for this to occur?
- Q. What is causing the MRI measurements to degrade near the walls at high flow / high concentration?
- C. MRI and UVP agree extremely well with each other -> reliable measurement techniques (WG1 goal is/has been to prove this)
- C. Fibre velocity = fluid velocity in the fibre/concentration/velocity ranges studied here

Thank you!