PIV Measurement and CFD Modeling of Flow Field through Pleated Filters

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Outline

- Introduction
- Objectives
- Experimental methods and numerical model
- Results and discussion

Introduction

- Filters are pleated to have larger surface area in a confined space (capture more particles)

- Airflow passing through plated filters is affected by the pleat geometry (pleat density, pleat shape, and pleat height), filter properties (porosity and fiber size), and face velocity
  (Chen et al., 1995, Fabbro et al., 2002, Rebai et al., 2010)

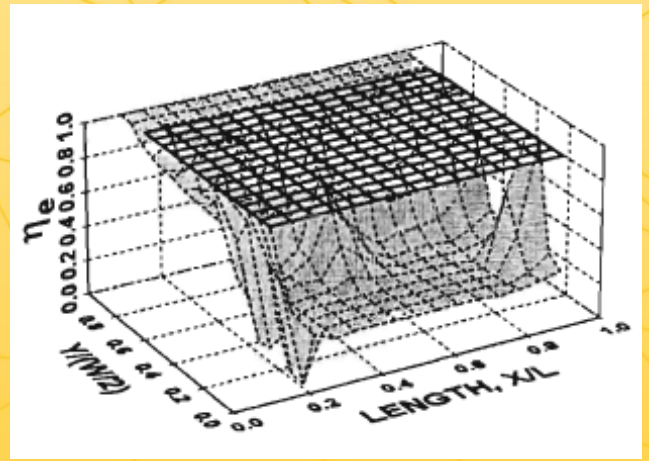
- Abovementioned factors are directly connected to the filter performance (**Pressure drop** and **collection efficiency**)
  (Fotovati et al., 2012)

- Most studies have focused on **Pressure drop** measurement
- **Validation method** is needed for CFD models

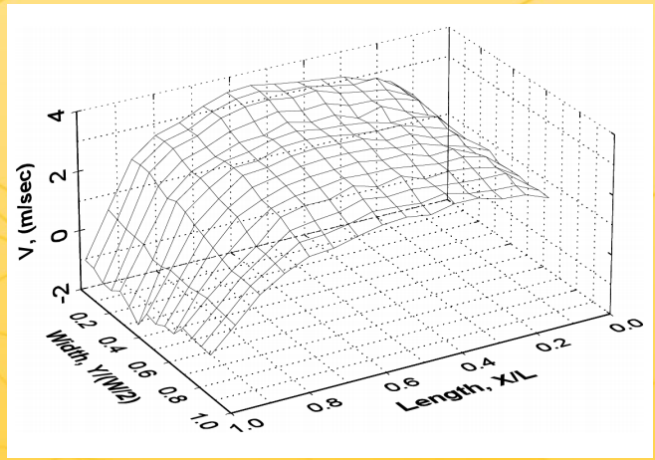
Chen et al. (1995). Aerosol Science and Technology, 23.4: 579-590.
Fabbro et al. (2002). Filtration & separation, 39.1: 34-40.
Rebaï et al. (2010). Chemical Engineering Science, 65.9: 2835-2846.

Effect of airflow on filtration efficiency

- Chambers *et al*. (2001) investigated the upstream velocity distribution of pleated filters
  - Filtration efficiency is affected by nonuniform flow approaching the pleated filter
  - Captured particles can be spatially inhomogeneous



Chambers et al. (2001)

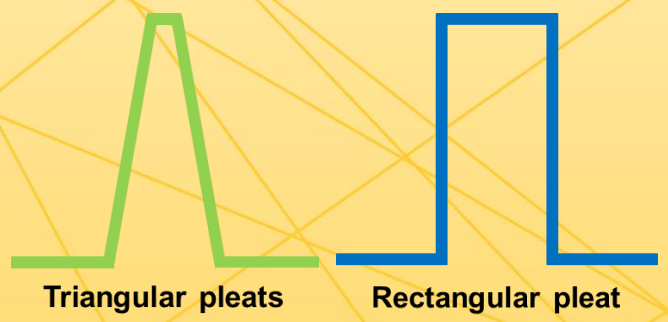


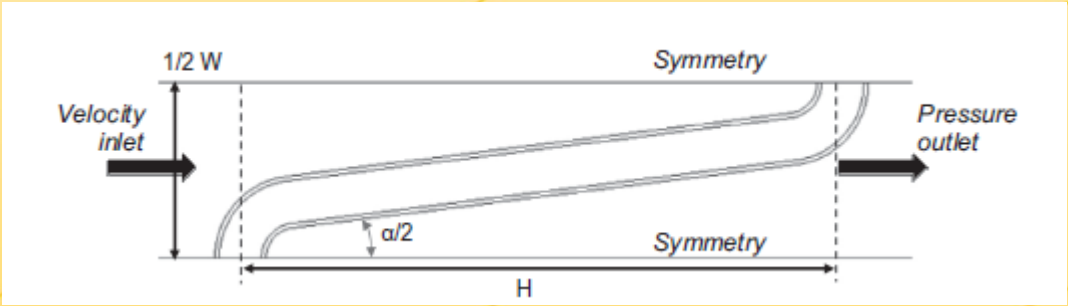
Al-Sarkhi and Chambers (2004)

Chambers et al. (2001). Particulate Science and Technology, 19.1: 1-21.
Al-Sarkhi and Chambers (2004). Particulate science and technology, 22.3: 235-252

Validation of CFD models

- Many studies model pleated filter with one pleat





Theron et al. (2017)

- **Need a method to measure the airflow patterns of pleated filters representing entire flow domain**

Theron et al. (2017). *Separation and Purification Technology*, 182: 69-77.

Available measurement methods

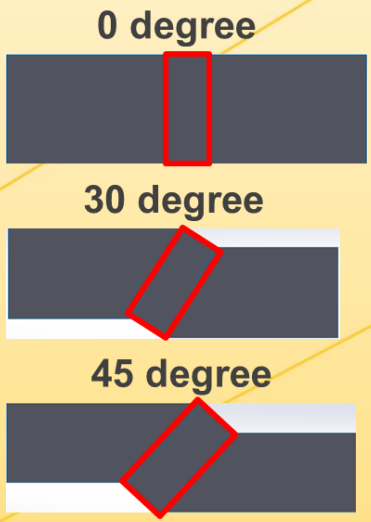
- **Laser Doppler anemometer**
  - Single point measurement
  - Non-intrusive
- **Hot wire anemometer**
  - Single point measurement
  - Intrusive
  - Contamination
- **Particle image velocimetry**
  - 2D spatial velocity fields (relatively large area of interest)
  - Non-intrusive

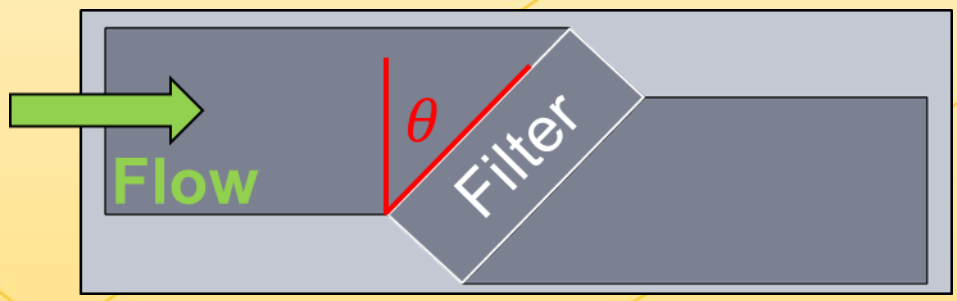
Objectives

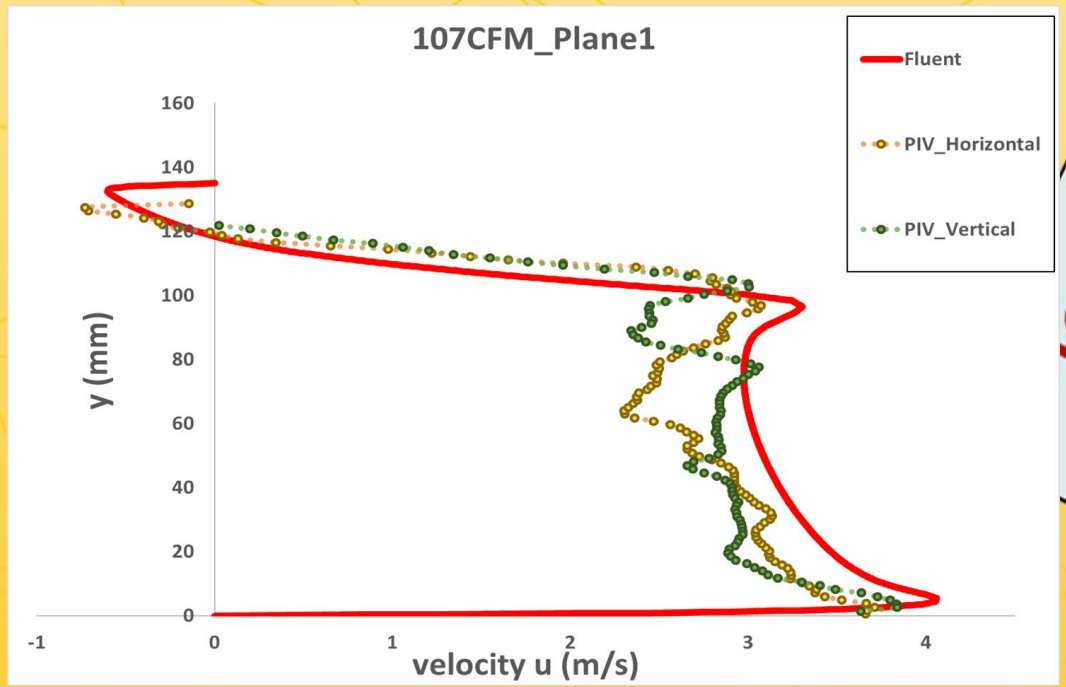
- To develop a validation method for the computational fluid dynamics (CFD) modeling

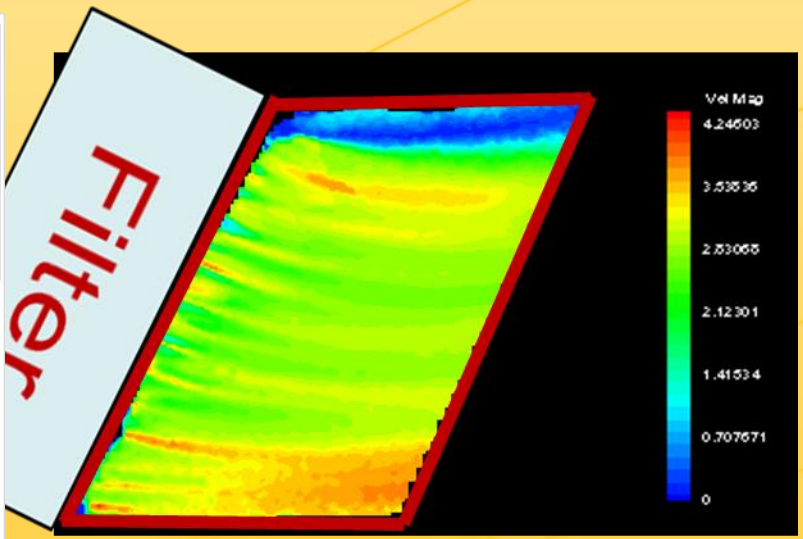
- To conduct systematic studies of airflow patterns through pleated filters with different pleat geometries

Previous CFR meeting



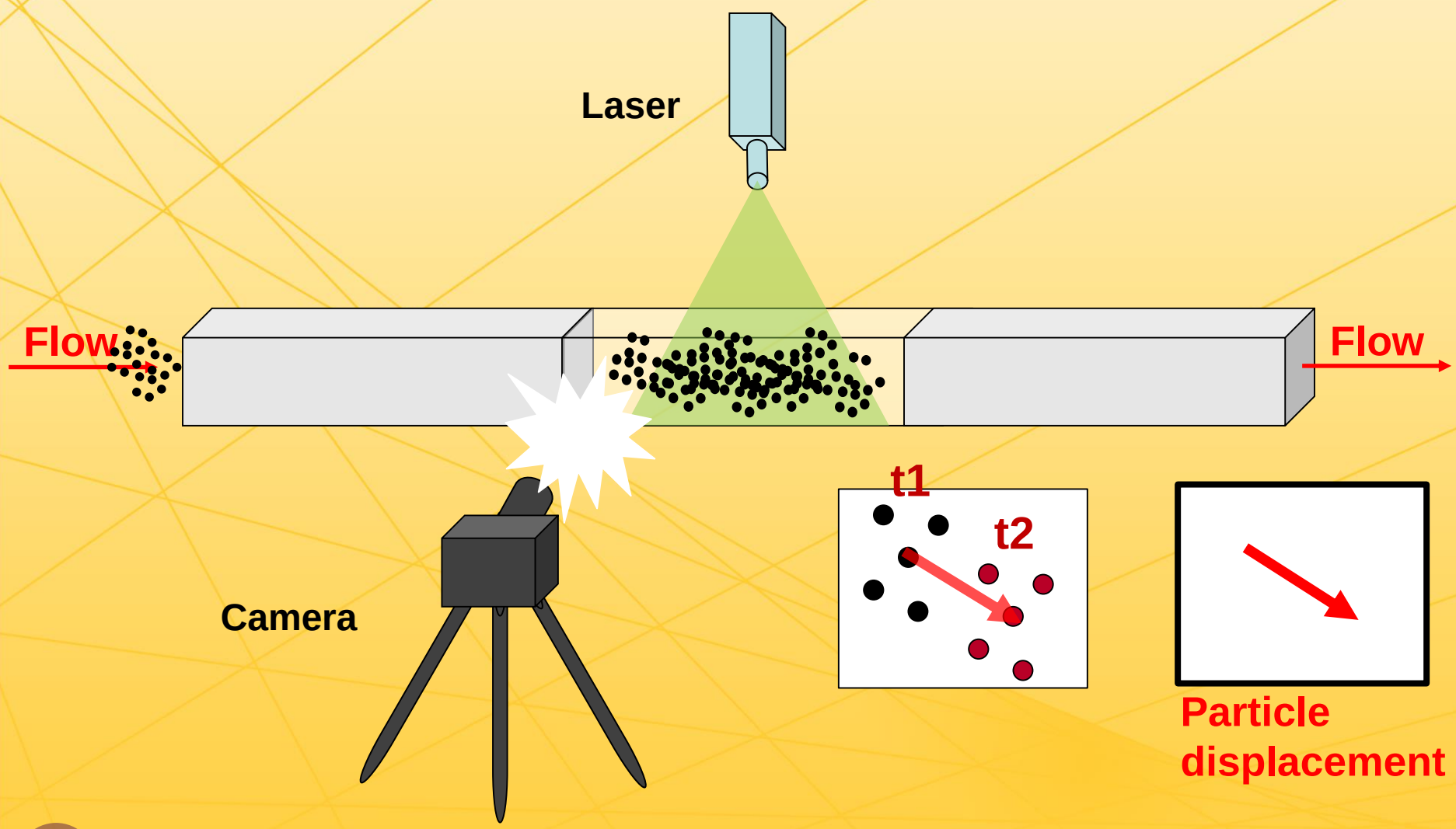






PIV experiment

Particle Image Velocimetry (PIV)



an optical imaging technique to measure fluid velocity vectors at many points in a flow field simultaneously

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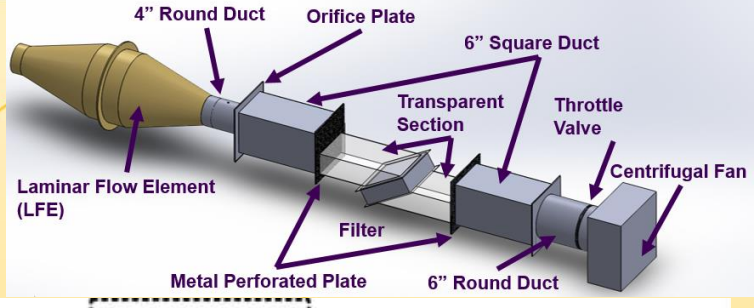
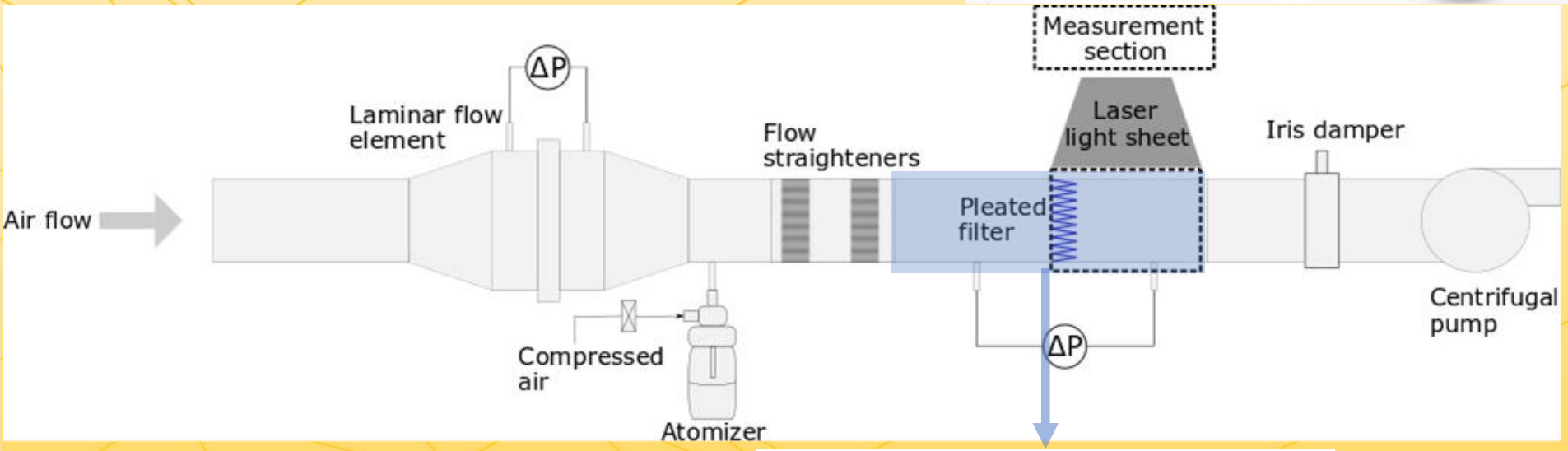
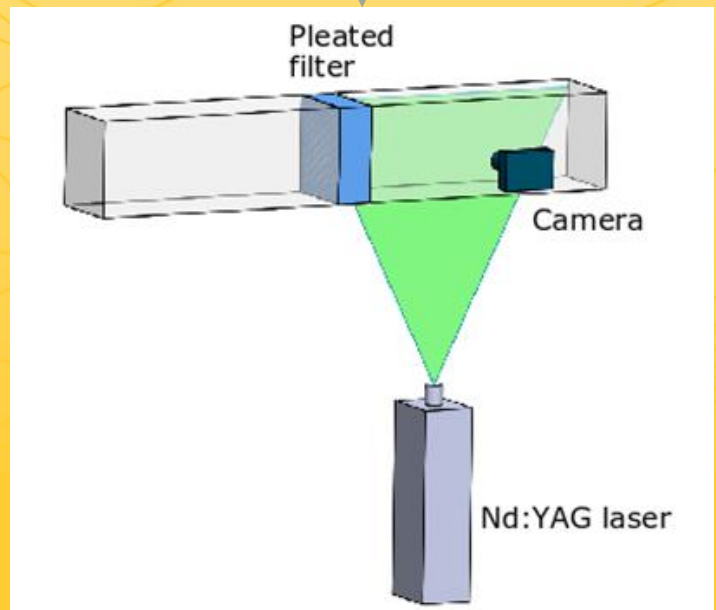
Experimental setup

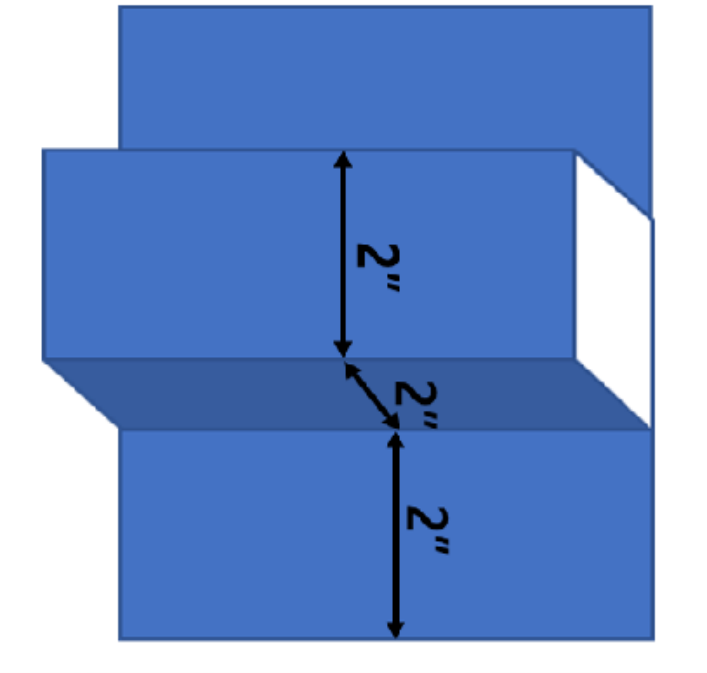




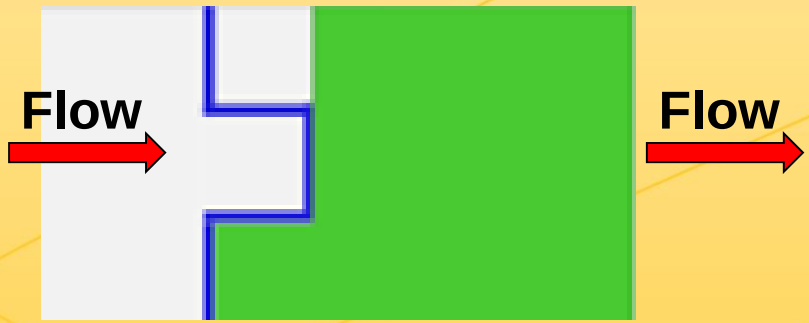
Rectangular pleated filter



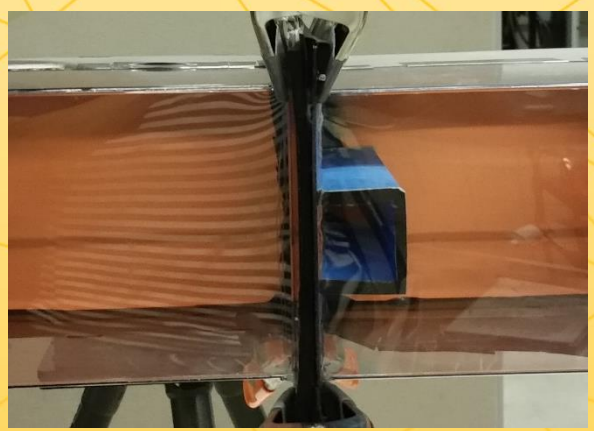
Filter geometry



Rectangular pleated filter

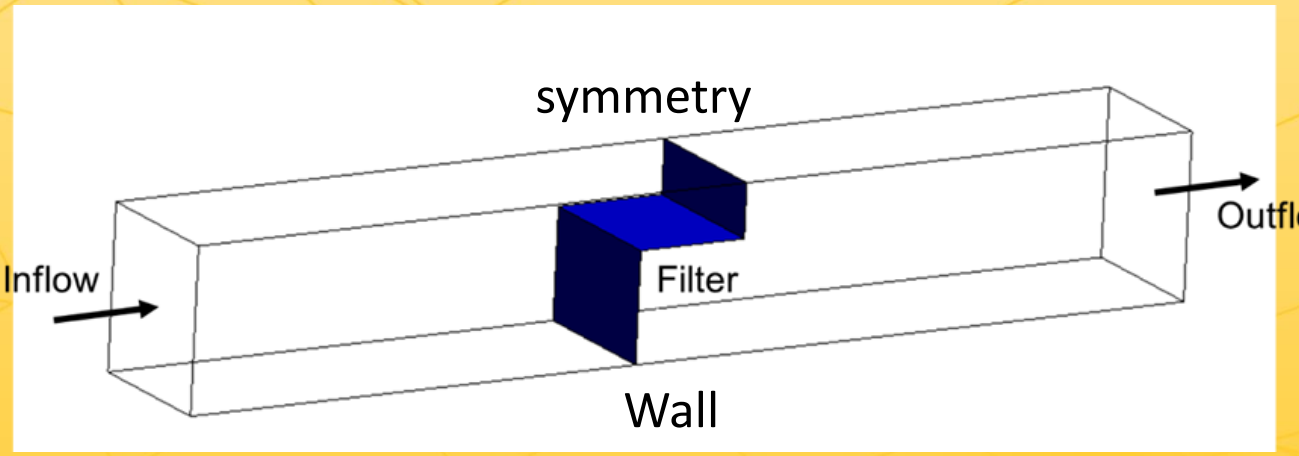


Examples of pleated filters



CFD simulation

- **Fluent version: 16**
- **Physics model: DES (Detached Eddy Simulation)**
- **Boundary conditions**



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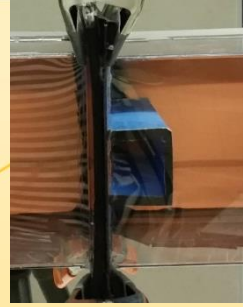
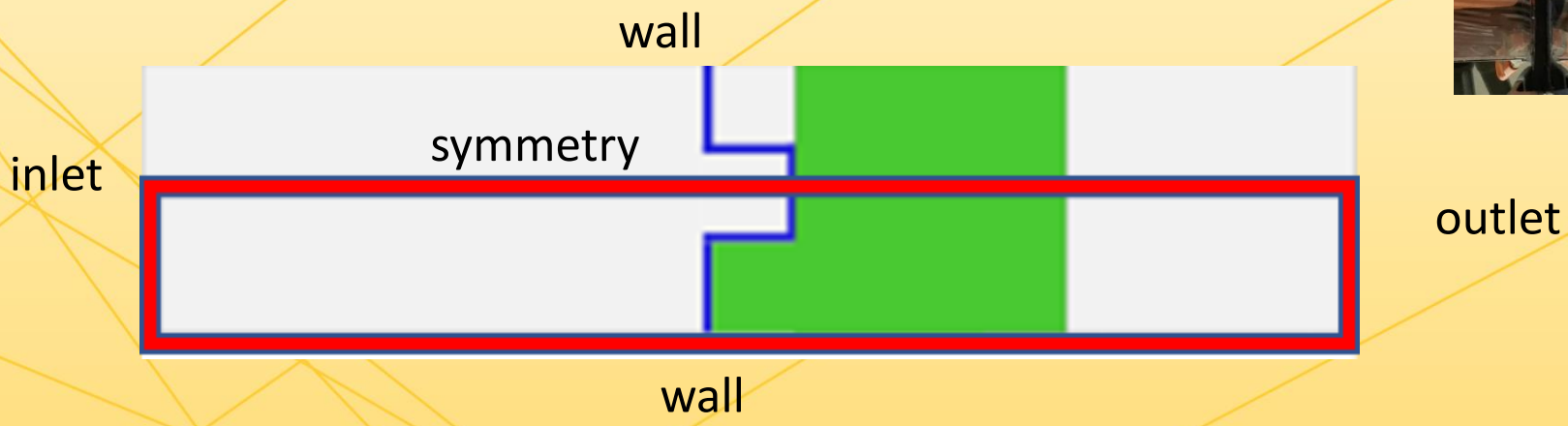
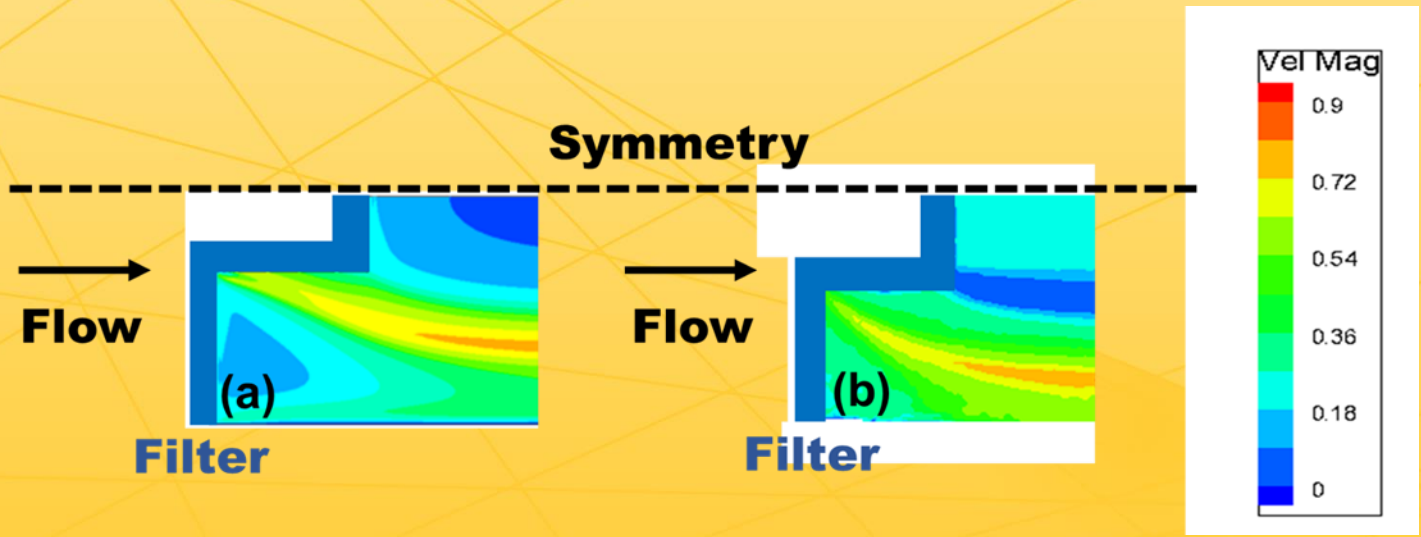
PIV vs CFD (Contour plots)



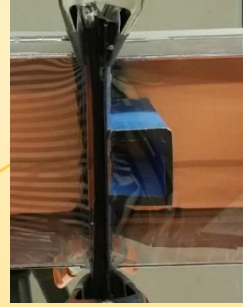


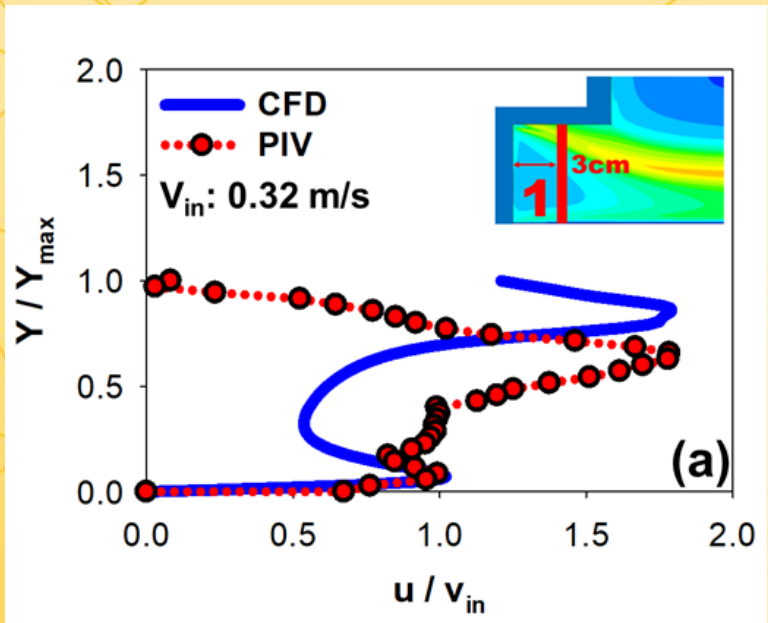


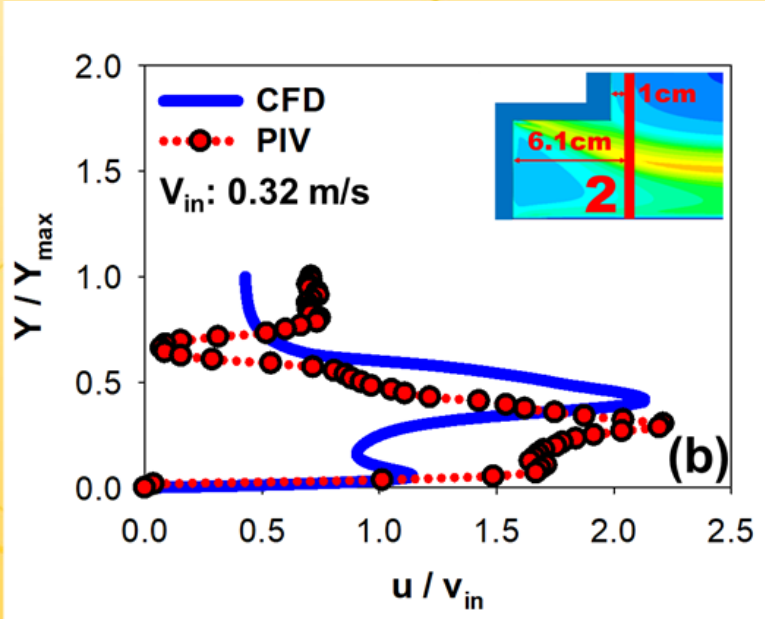
(a) CFD **(b) PIV**

Time-averaged contour plots at the inlet velocity of 0.32 m/s

PIV vs CFD (velocity distribution)





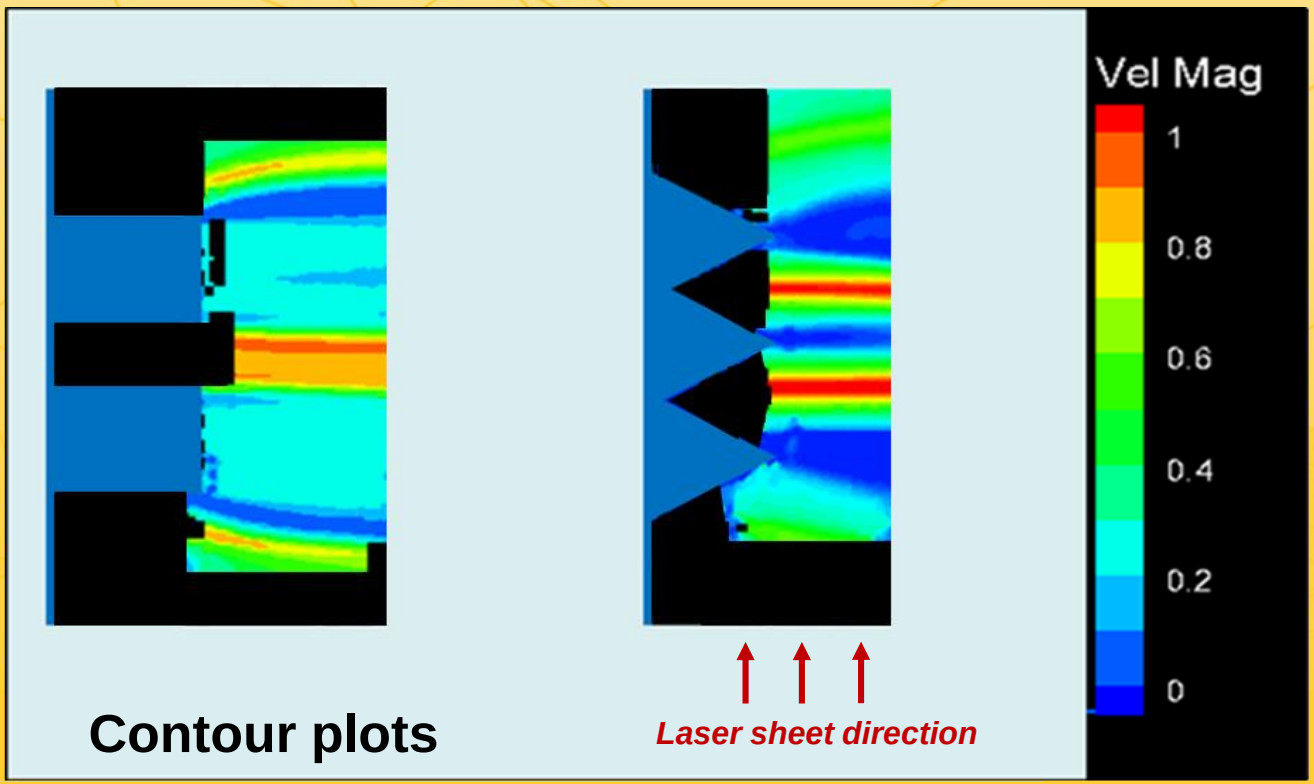


(a) at x = 3 cm

(b) at x = 6.1 cm

Normalized streamwise velocity distribution along the y-axis

Contour plots (Preliminary tests)



Next plan

- Improve the quality of flow profiles
- Measure flow profiles between pleats (upstream & downstream)

Summary and future works

- A test method is developed to study the airflow patterns downstream of pleated filters

- Air flow patterns through pleated filters will be studied with different pleat geometry, filter properties, and flow rates