High-Fidelity PIV of a Naturally Grown High Reynolds Number Turbulent Boundary Layer

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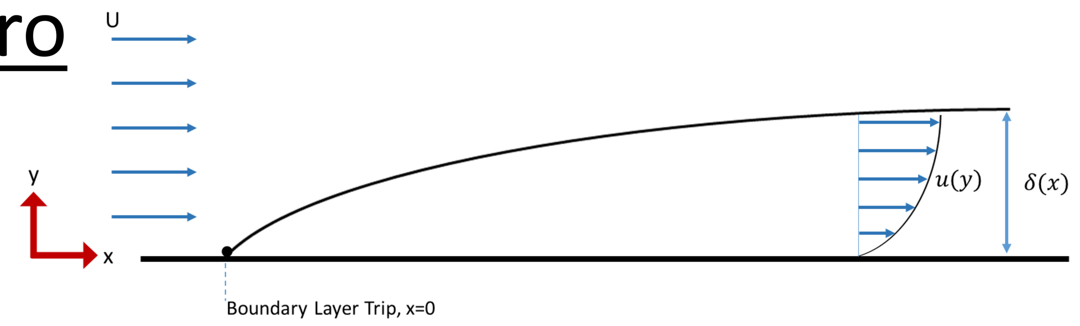
Intro



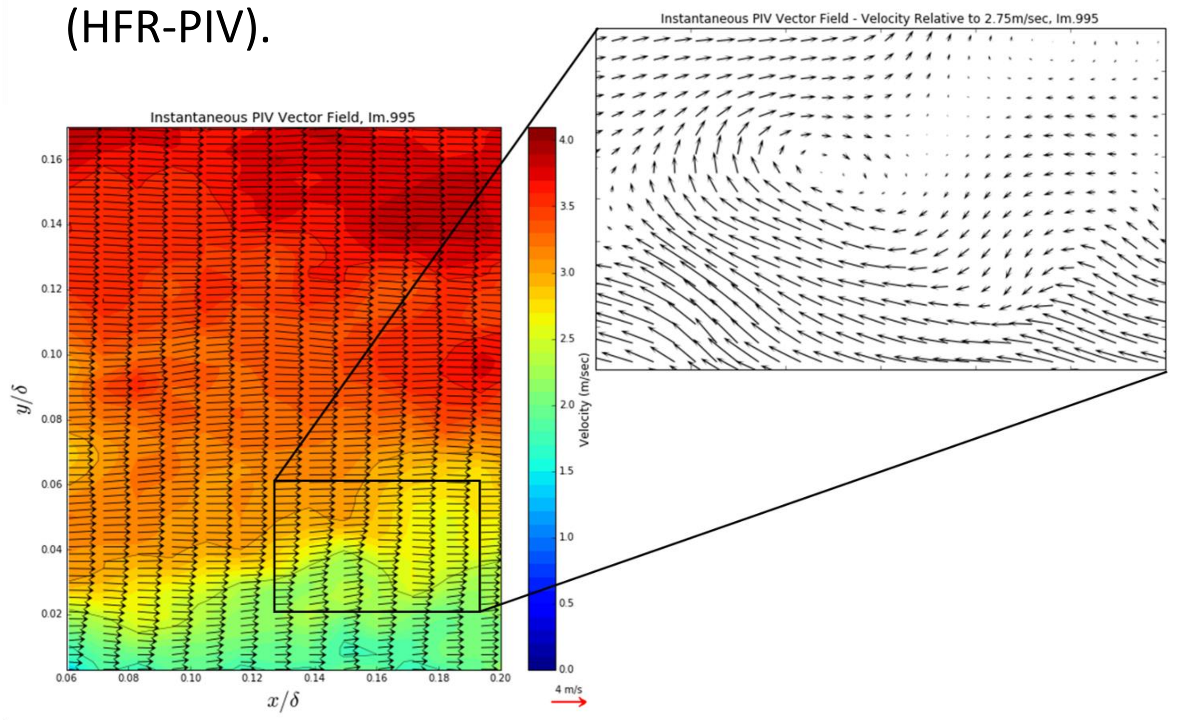
High-fidelity measurements acquired at high Reynolds number are important towards the development of high accuracy physics based models of the turbulent boundary layer. These models can then be utilized to improve the design and performance of engineering systems in turbulent environments. This poster describes particle image velocimetry (PIV) measurements acquired in the Flow Physics Facility (FPF) at the University of New Hampshire.

Background and Motivation

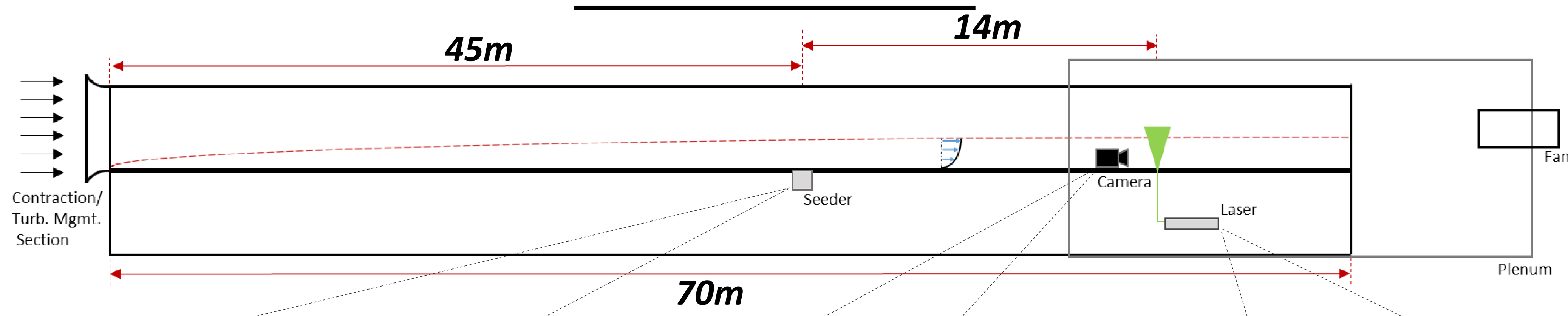
The Flow Physics Facility (FPF) at the University of New Hampshire is a large scale open circuit wind tunnel. It has a working cross section of *2.8m x 6m* and a development length of *72m*.

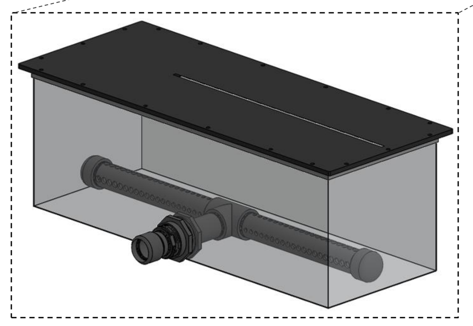
The tunnel is powered by two *2.6m* diameter *400hp* fans, with a speed range of 3m/sec -> *14.5m/sec*. The tunnel utilizes a 'big and slow' approach to grow boundary layers up to δ*=1m* in the rear of the tunnel. The tunnel flow dynamics have been previously validated by Vincenti *et al.* (2013).

This work targets the detection of uniform momentum zones and fissures within the inertial layer of a high Reynolds number boundary layer using high frame rate particle image velocimetry (HFR-PIV).



Data Collection



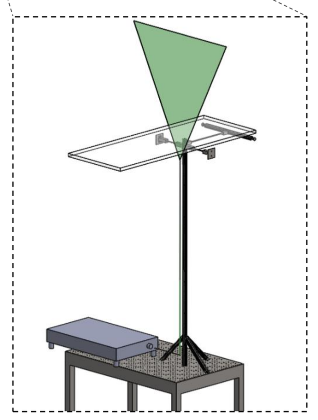


Seeding Mechanism

- *6mm* slot at *60º*
- *1m* slot length
- Inlet manifold to disperse fog
- $1-5\mu m$ particles

High Speed Camera

- *200mm* lens
- *4.5:1* magnification
- ~1y⁺ / pixel
- FOV: 0.1δ x $.01\delta$



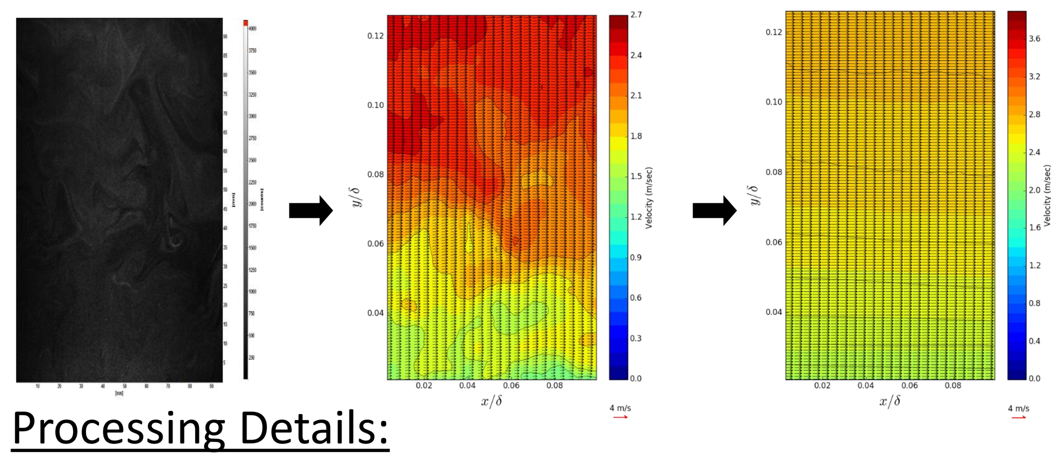
Laser / Optics Train

- Spherical focusing lens
- Cylindrical sheet optics
- Adjustable laser position

Experimental Parameters

- Rep Rate: 1Khz
- Downstream position: *59m*
- U_∞ = *4 m/sec*
- Re_{δ^+} = 6915
- 10,000 images captured
- Varied wall normal position: *17mm – 357mm*

Vector Processing

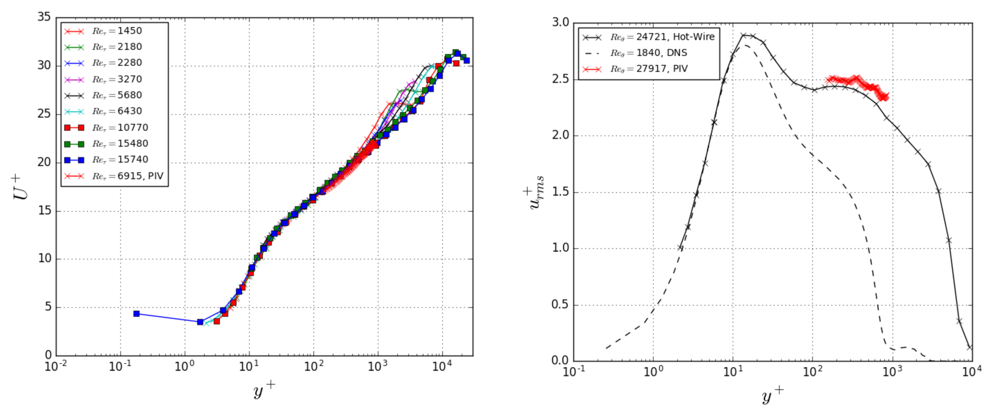


Processing Details:

- Pre-processing: count inversion + normalization
- Processing: multi-pass with decreasing interrogation area
- Post-processing: STD filter to remove spurious images and vectors

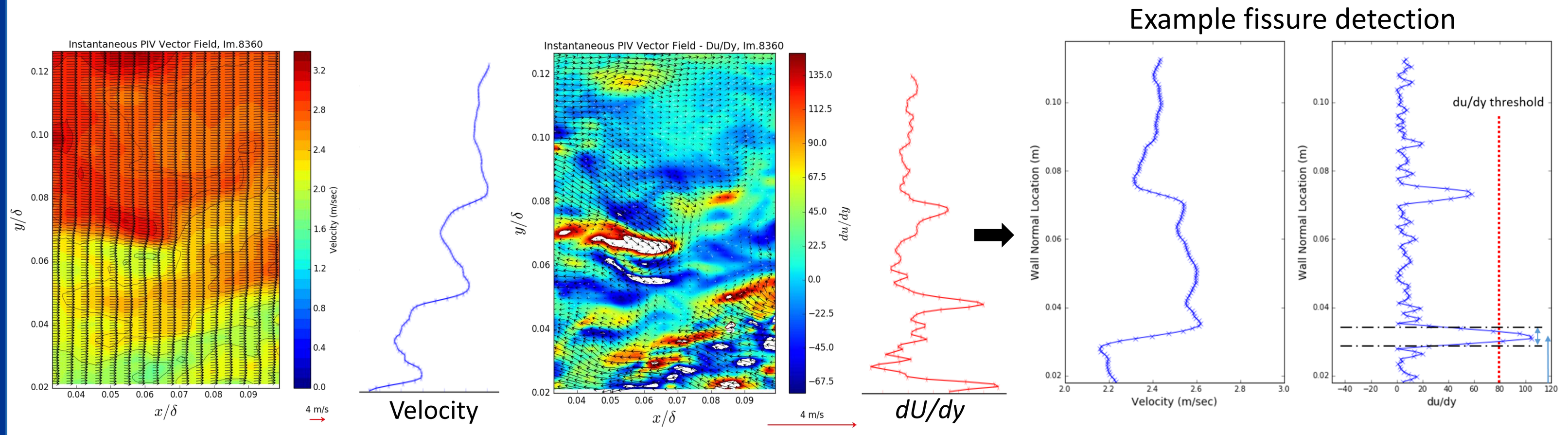
Data Validation

Experimental data collected is plotted against experimental datasets taken using hotwire anemometry and DNS datasets.



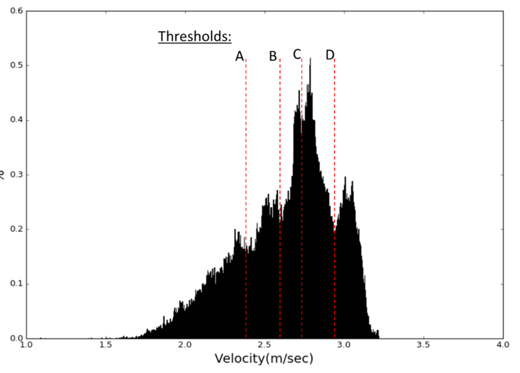
Structures – (UMZ/Fissure)

Instantaneous images of the velocity field are examined for internal structures such as uniform momentum zones and vortical fissures. This is achieved by computing dU/dy and comparing the location of spikes in this term with specific contours of velocity.

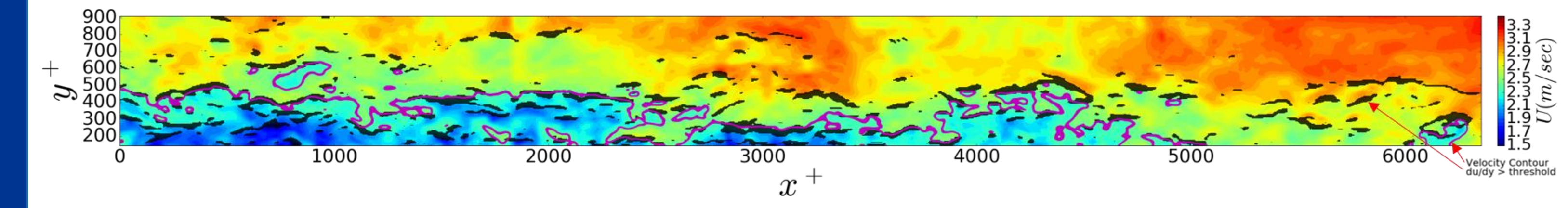


A histogram of velocity is shown below to understand how to discretize the stitched FOV into section of uniform momentum. This method has been utilized previously by de. Silva *et al*. (2017) to identify uniform momentum zones.

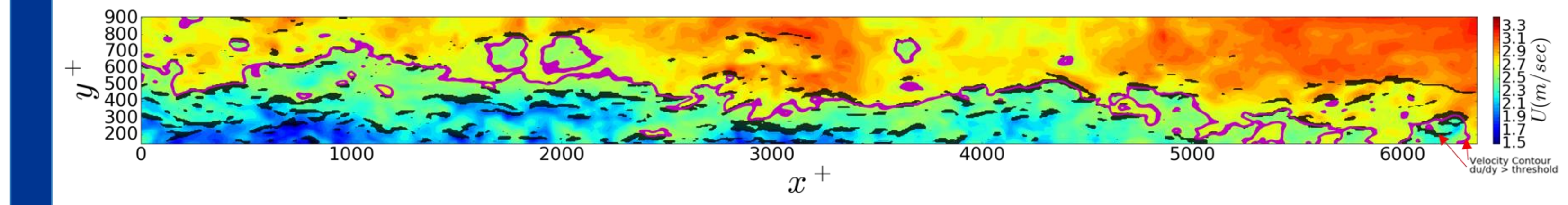
Threshold positions of A-D are determined by examining for valleys in the histogram.



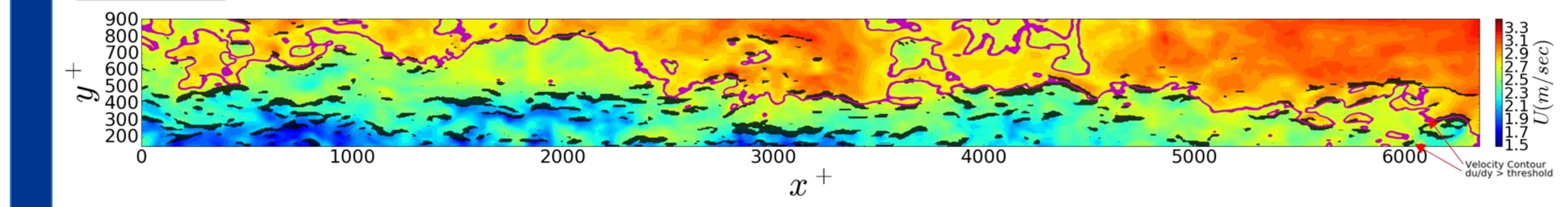
Threshold A



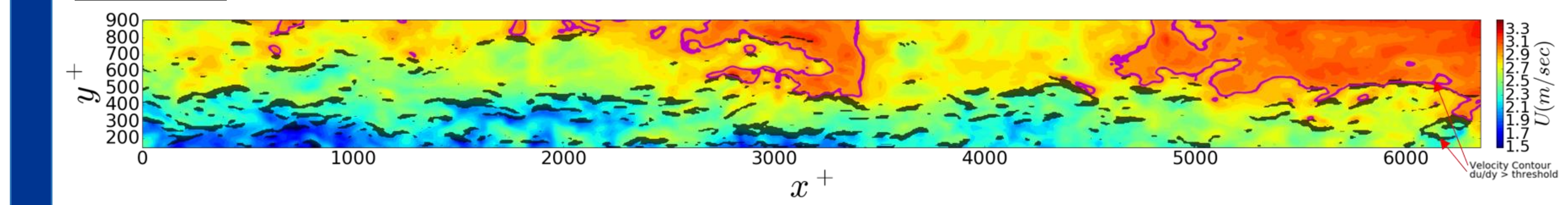
Threshold B



Threshold C



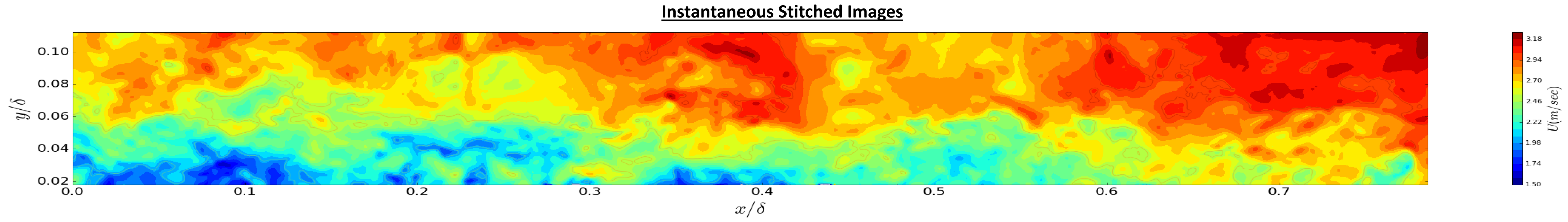
Threshold D



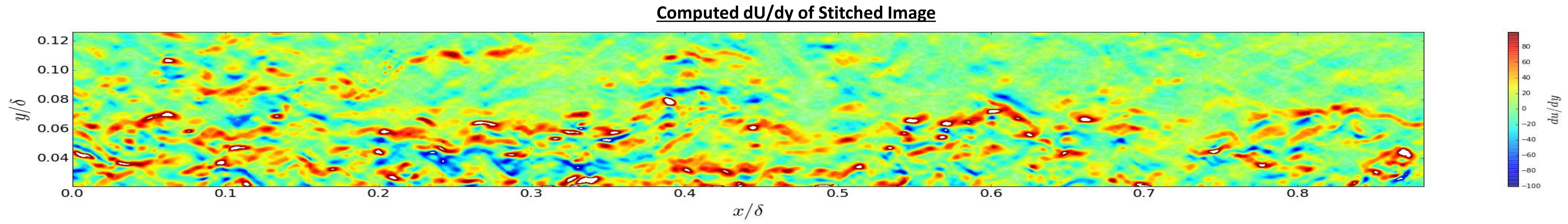
Temporal Stitching

Ten consecutive HFR-PIV images are stitched together using a least-square root-mean-square matching technique. The stitching allows evaluation of the spatial development of the boundary layer in the spirit of Taylor's frozen flow hypothesis.

Instantaneous Stitched Images



Computed dU/dy of Stitched Image



Conclusion

- HFR-PIV measurements of a turbulent boundary layer at high Reynolds number have been acquired in the FPF at UNH.
- To examine spatial development of the boundary layer a temporal stitching algorithm was developed utilizing Taylor's frozen flow hypothesis
- Uniform momentum zones (UMZ) were identified using the histogram method of de Silva. The interface between adjacent UMZ correlate well with regions of large dU/dy.

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