Transition to turbulence in oscillating flows

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International Masters in Turbulence (M2)

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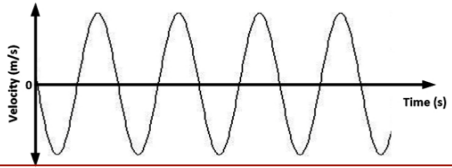
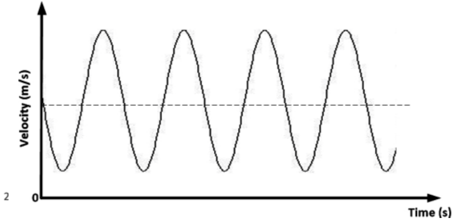


Pure oscillating flow



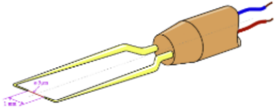
Pulsatile flow

Transition to turbulence in oscillating flow

Sub acoustic region

Acoustic Region

Mechanical probes (Hot wire anemometry)



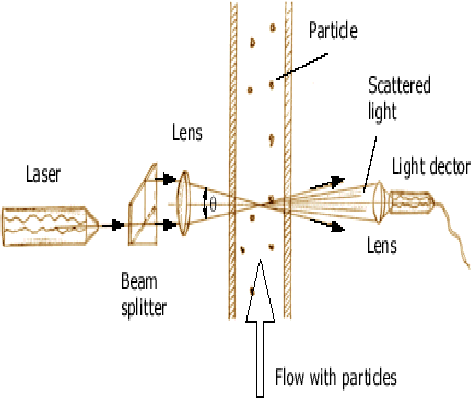
Acoustic frequencies :

$\delta_\nu = 0.5\text{mm for } f = 20\text{Hz}$

$\delta_\nu = 0.02\text{mm for } f = 20\text{kHz}$

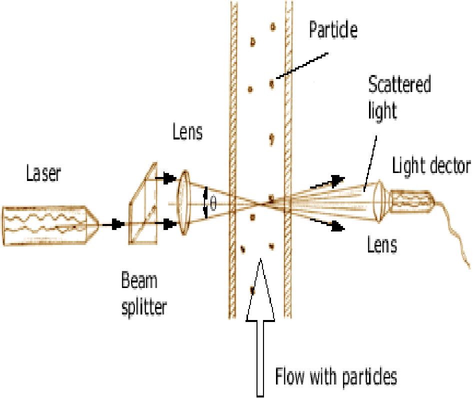
Objective

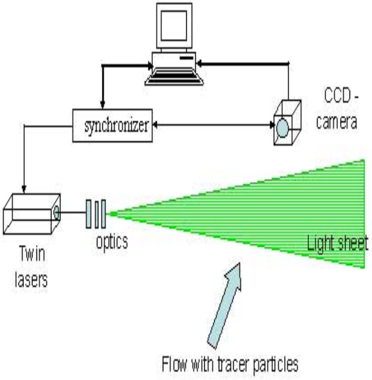
- Compare two different optical measurement techniques
  1. LDA
  2. PIV
- Focused on near wall region at high frequencies



1. Depicted from wiki

Optical Measurement Methods

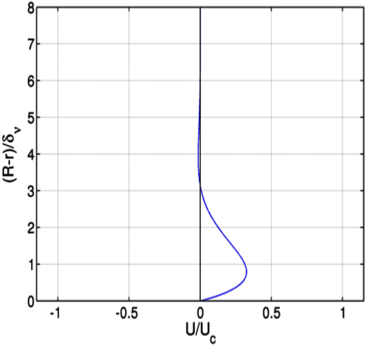




[1]

1. Depicted from wiki

Oscillatory boundary later



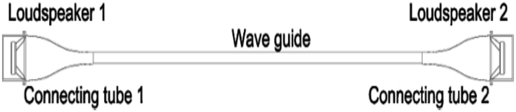
Oscillatory boundary layer thickness is given by

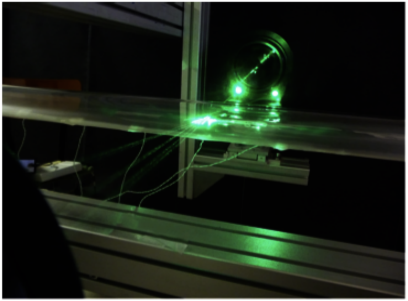
$\delta_v = \sqrt{2\nu/\omega}$

$\omega = 2\pi f$

a

a. Reyt et al





LDV Measurements

f = 25 Hz

Axial velocity along radius

Radial dependence of axial component

$\delta_\nu = 0.435\mathrm{mm}$

$Re_{\delta_\nu} = 64$ to 474 [a]

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a. Reyt et all

Sine wave of frequency that propagates along x axis in cylindrical wave guide of radius R

$$u_{ac}(x, r, t) = Ae^{i\omega(t-x/c)}\left(1 - \frac{J_0(r\sqrt{-i\omega/\nu})}{J_0(R\sqrt{-i\omega/\nu})}\right) \tag{1}$$

Acoustic boundary layer

Sine wave of frequency that propagates along x axis in cylindrical wave guide of radius R

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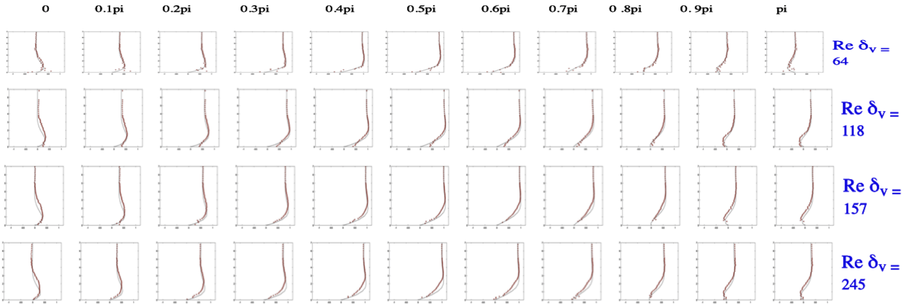
Acoustic boundary layer

Acoustic velocity profile at different phases along acoustic period

⋆ Experimental data - Theoretical data



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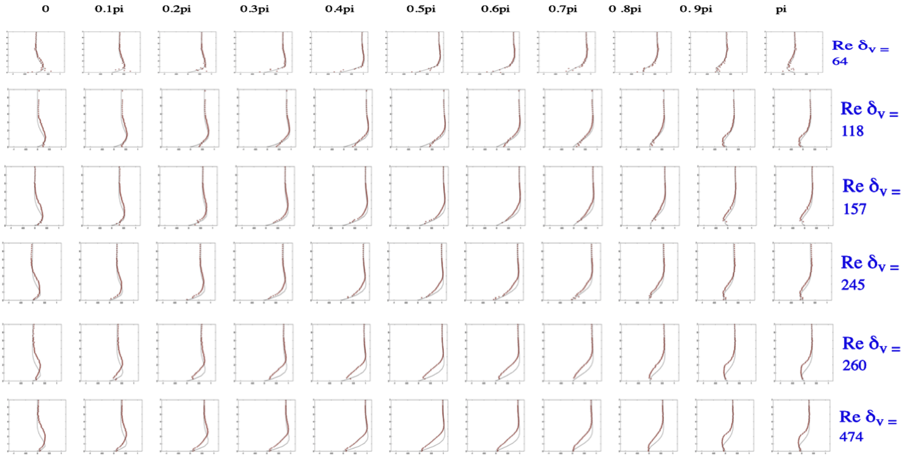
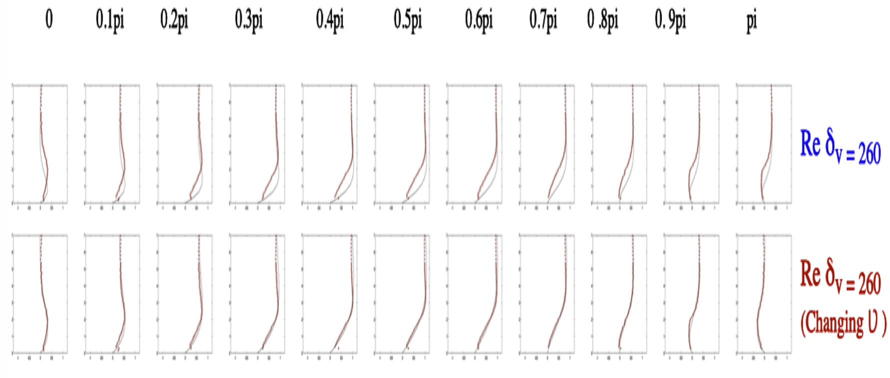


Acoustic boundary layer

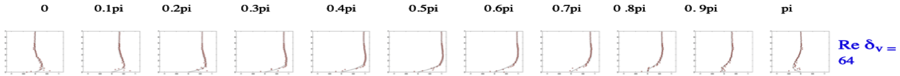
Acoustic velocity profile at different phases along acoustic period for Re_{δ_ν} = 260 $\star$ Experimental data - Theoretical data



Acoustic boundary layer

Acoustic velocity profile at different phases along acoustic period after changing the value of ν

$\star$ Experimental data - Theoretical data



Acoustic velocity profile at different phases along acoustic period after changing the value of ν

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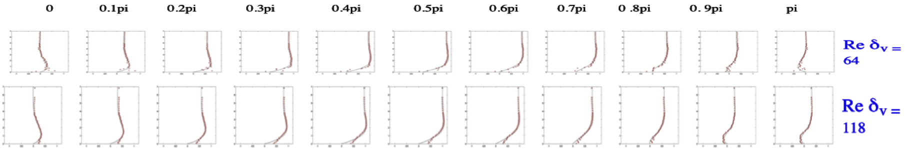

Acoustic boundary layer

Acoustic velocity profile at different phases along acoustic period after changing the value of ν

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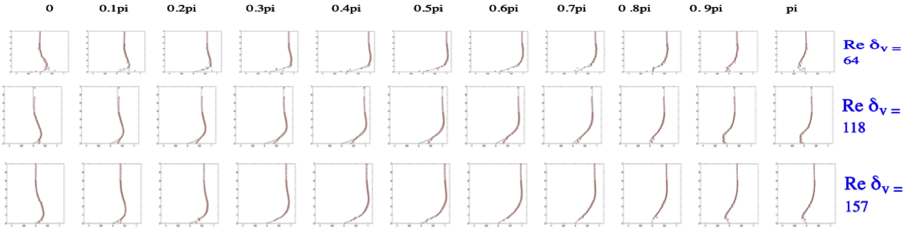

Acoustic boundary layer

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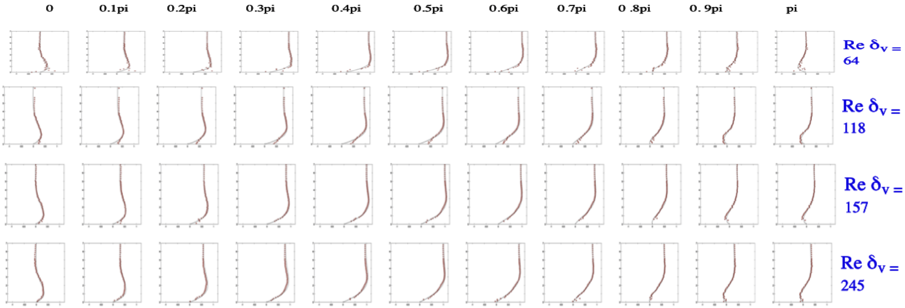
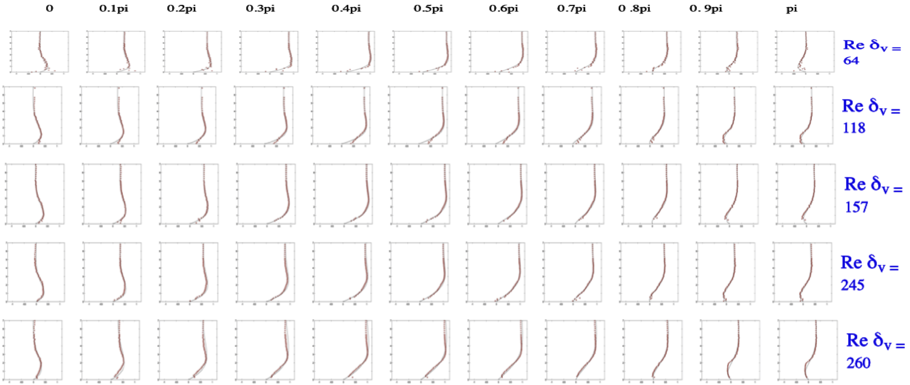


Acoustic velocity profile at different phases along acoustic period after changing the value of ν

$\star$ Experimental data - Theoretical data



Acoustic velocity profile at different phases along acoustic period after changing the value of ν

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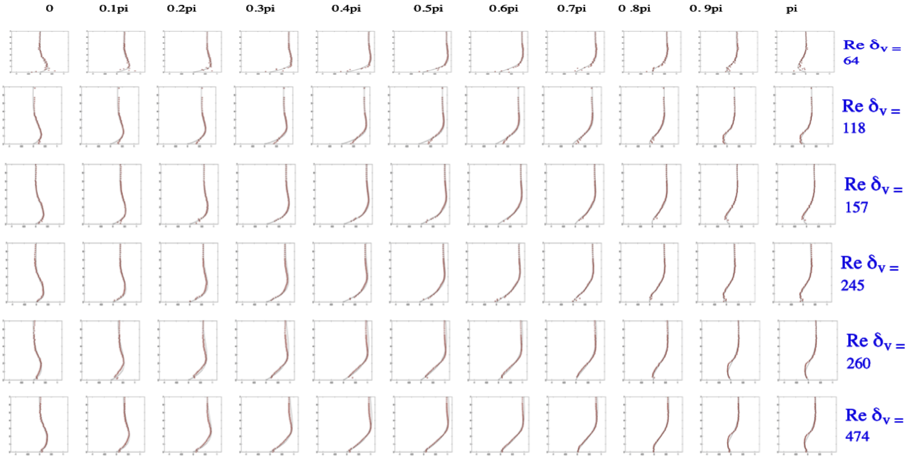
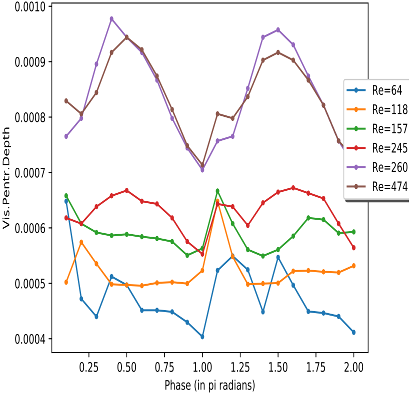


Stokes boundary layer

With an increase in Re_{δ_ν} we noticed the effective increase in boundary layer thickness.



Transition around $Re_{\delta_\nu} = 250$

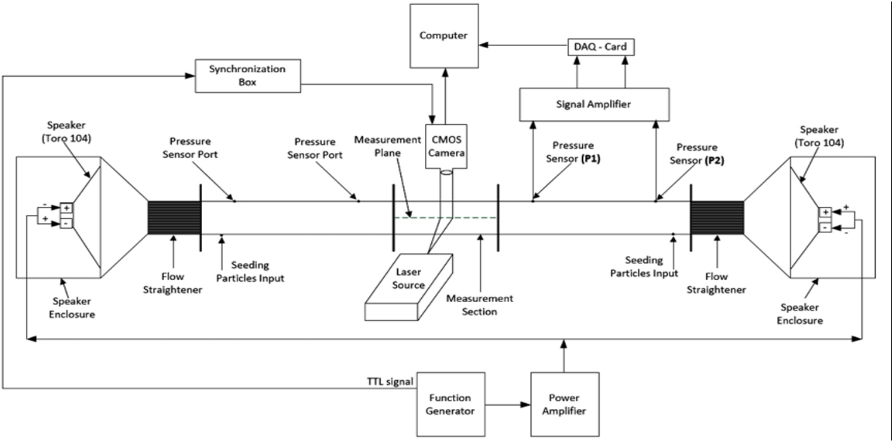
$\delta_\nu = 0.435\mathrm{mm}$

$Re_{\delta_\nu} = 64$ to 474

Experimental setup (PIV)

f_s = 25 Hz

$Re_{\delta_\nu} = 205$ to 466



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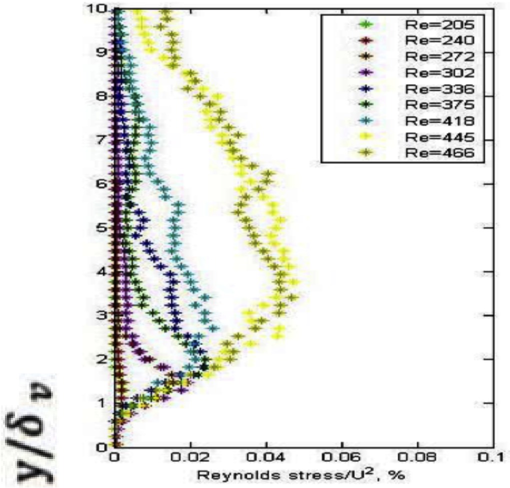
2. Ramadan et all

Distribution of normalized Reynolds stress



Flat up to Re 240

Sudden change at Re 272

At Re 418 flow ~ fully turbulent

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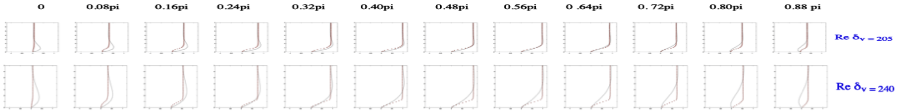
3. Ramadan et all

Velocity profiles

Acoustic velocity profile at different phases along acoustic period

⋆ Experimental data - Theoretical data



Acoustic velocity profile at different phases along acoustic period

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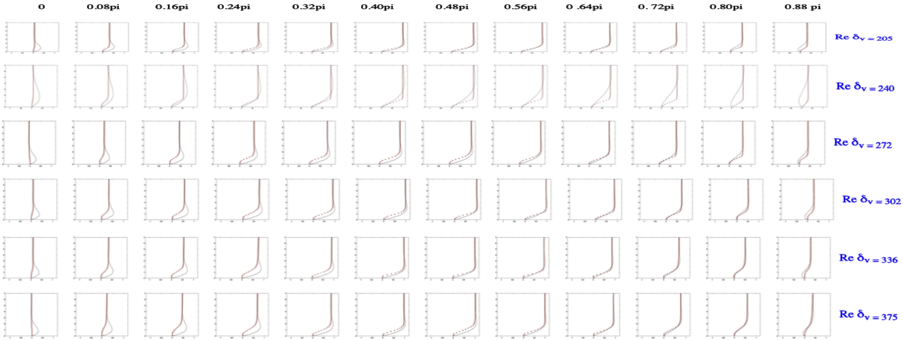

Acoustic velocity profile at different phases along acoustic period

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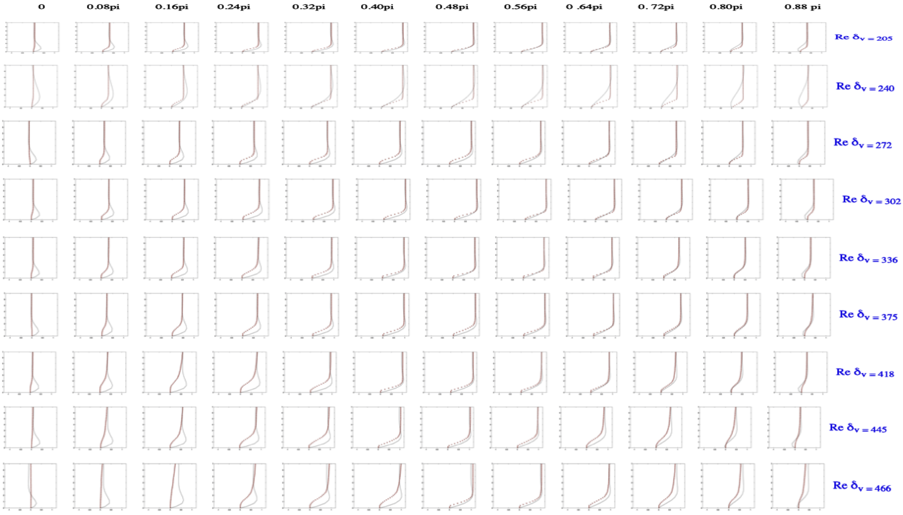
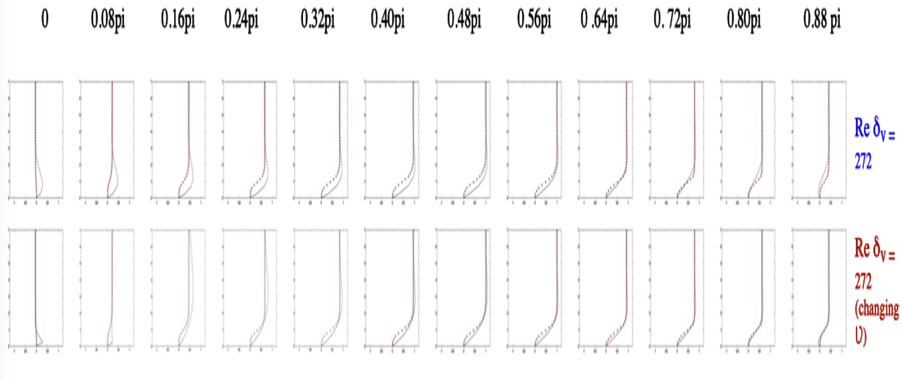
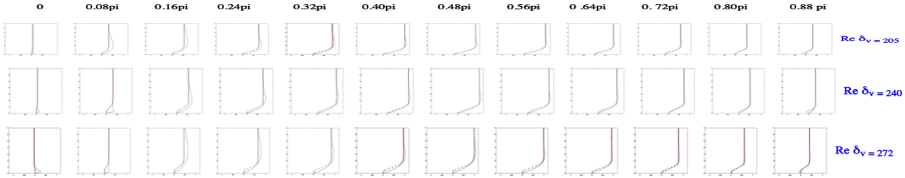


Acoustic velocity profile at different phases along acoustic period for Re_{δ_ν} = 272 $\star$ Experimental data - Theoretical data



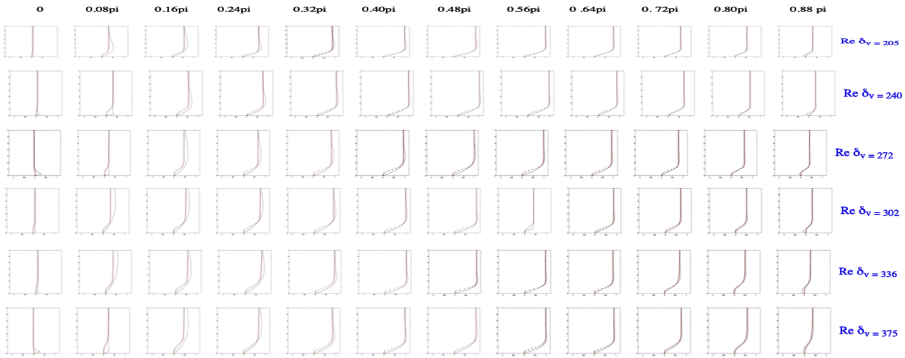
Velocity profiles

Acoustic velocity profile at different phases along acoustic period after changing the value of ν $\star$ Experimental data - Theoretical data



Velocity profiles

Acoustic velocity profile at different phases along acoustic period after changing the value of ν $\star$ Experimental data - Theoretical data



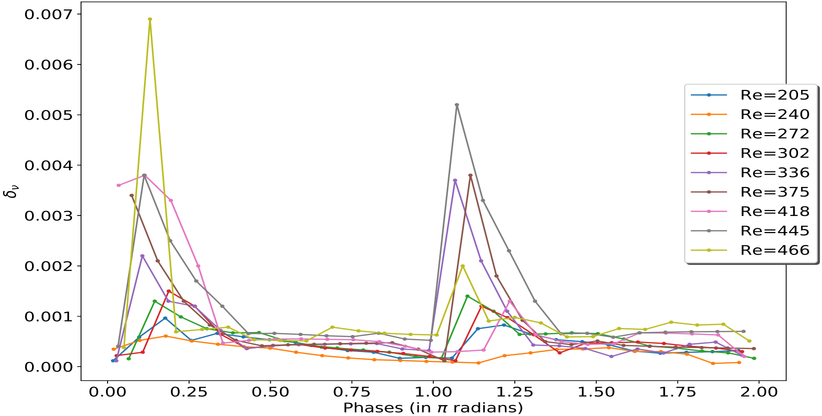
Velocity profiles

Acoustic velocity profile at different phases along acoustic period after changing the value of ν $\star$ Experimental data - Theoretical data

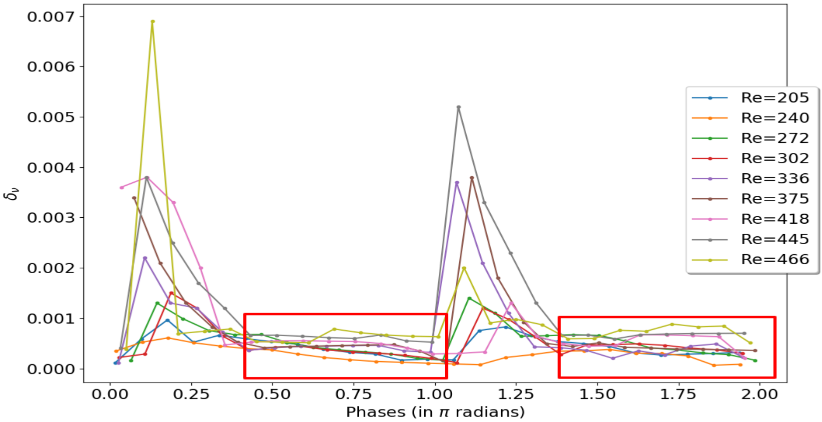
Results and discussions

Presence of spikes

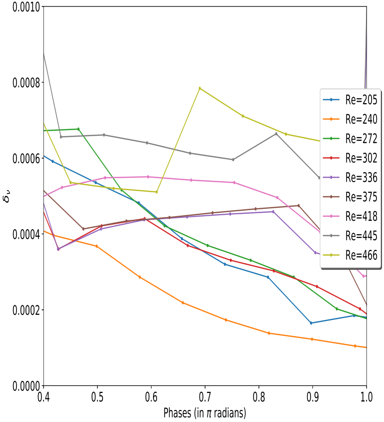
Mean velocity around zero in regions of high accelerations

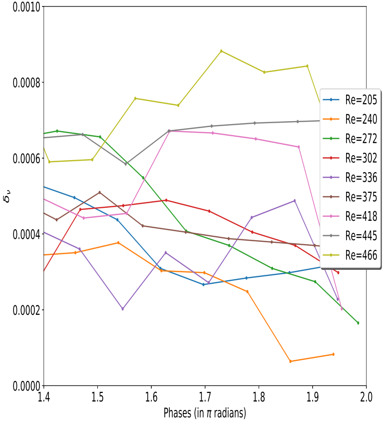


Results and discussions



Didn't observe any coherent result





Comparison

Compared two quite similar cases using different optical methods

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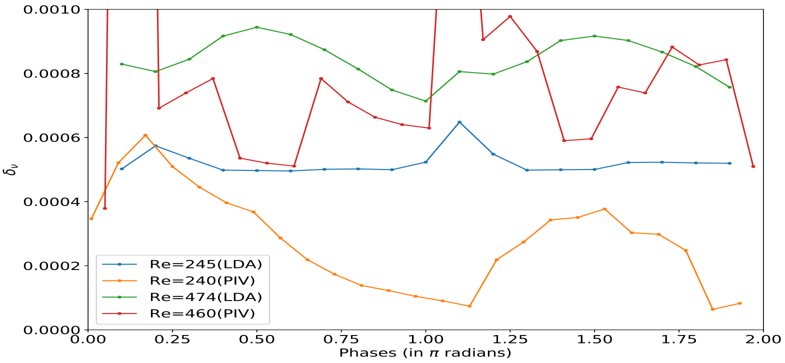

Comparison

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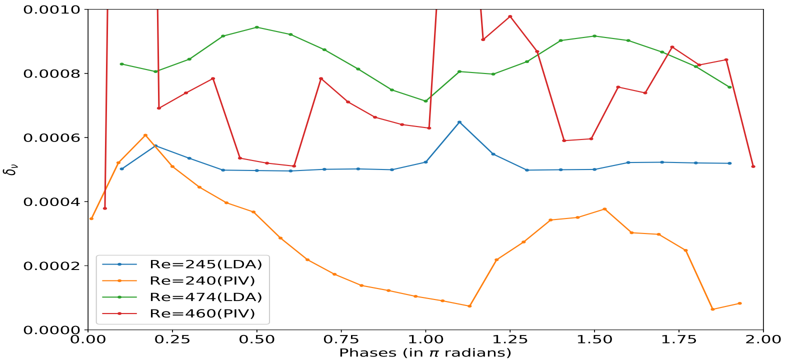

Conclusion and future work

- Compare two different optical measurement techniques
  1. LDA
  2. PIV
- Followed the methodology used in LDA methods
- Quantitatively the results seems similar for both the set of data but qualitatively the results are not comparable.
- Could be tried to get turbulent quantity out of LDA data
  1. Perform averaging over time, and we calculate S.D for these time slots
  2. It may represent turbulent intensity