

Making the Donut in the Water – Vortex Ring

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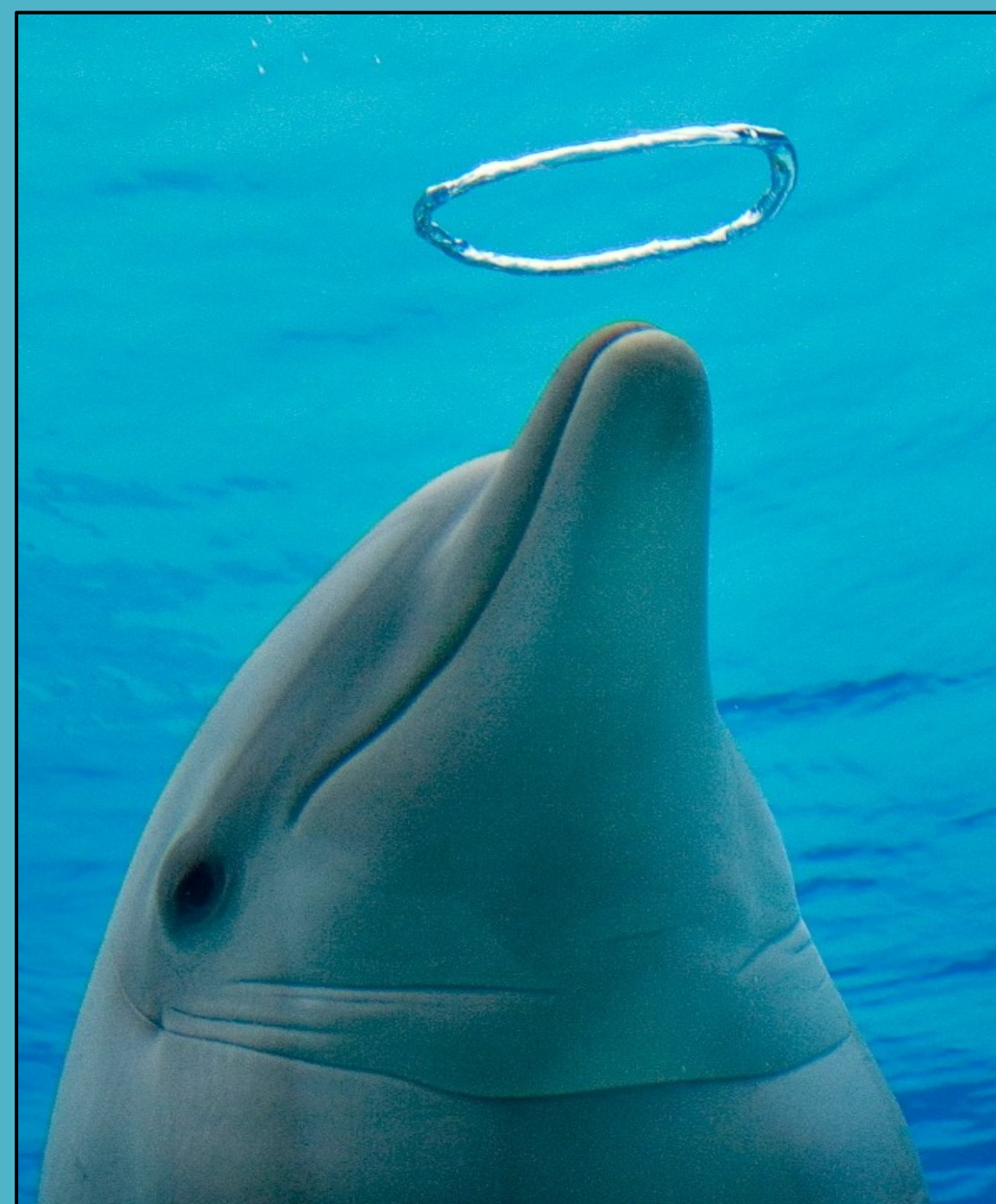
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A vortex ring is a toroidal volume of vorticity fluid moving in a steady medium and shown in the “donut” shape. They are composed of vortices arranged annularly. We are interested in how these special “donuts” are formed. Therefore, we want to know their physical properties, like its flow field, vorticity distribution and variation of the vortex ring.

Motivation

We could observe the vortex rings in the biosphere. For example, dolphins would spit out a vortex ring for . We also could see them in the volcanos’ eruption. The most famous example is the smoke generated with a distinctive ring structure by Mount Etna.

We are curious about how a vortex ring is formed. Therefore, we study the characteristics of the vortex ring such as the flow fields around the vortex ring, the evolution of the vortex ring, and the vorticity distribution.



Dolphins playing the vortex ring [2]

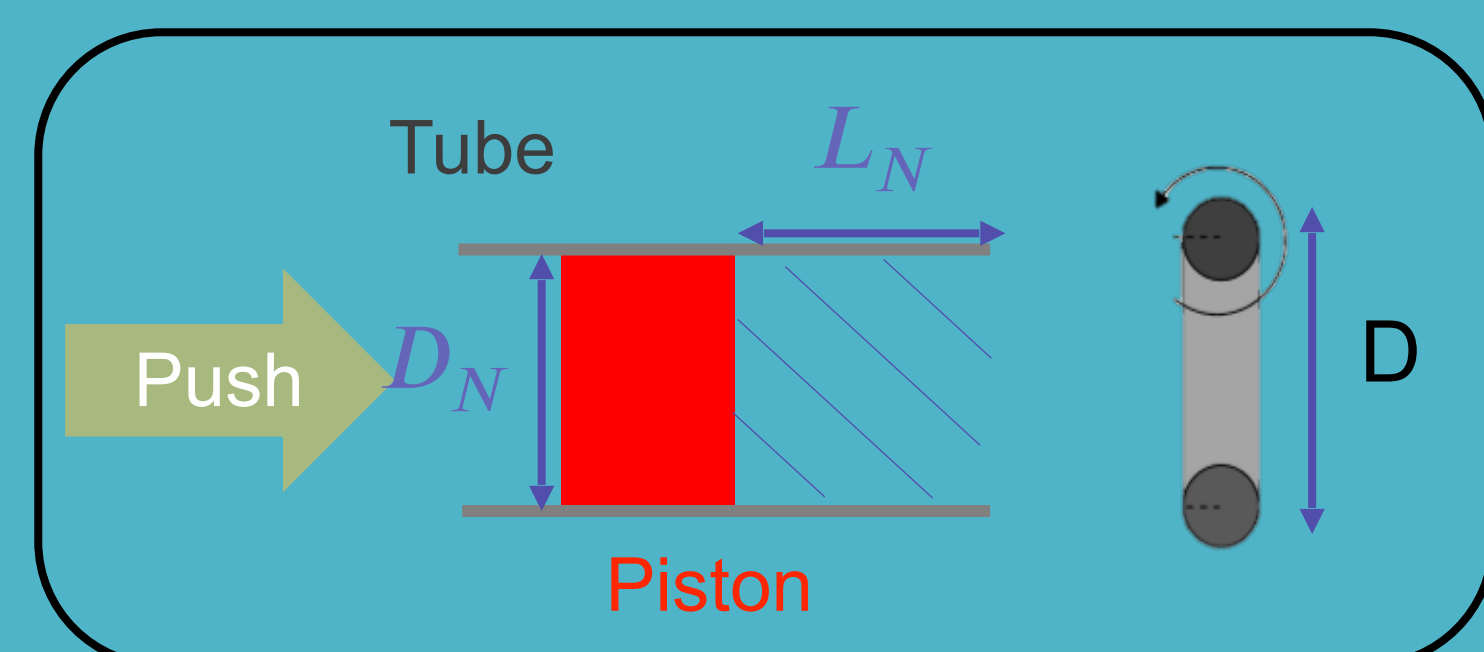


Mount Etna [3]

Experimental Goals

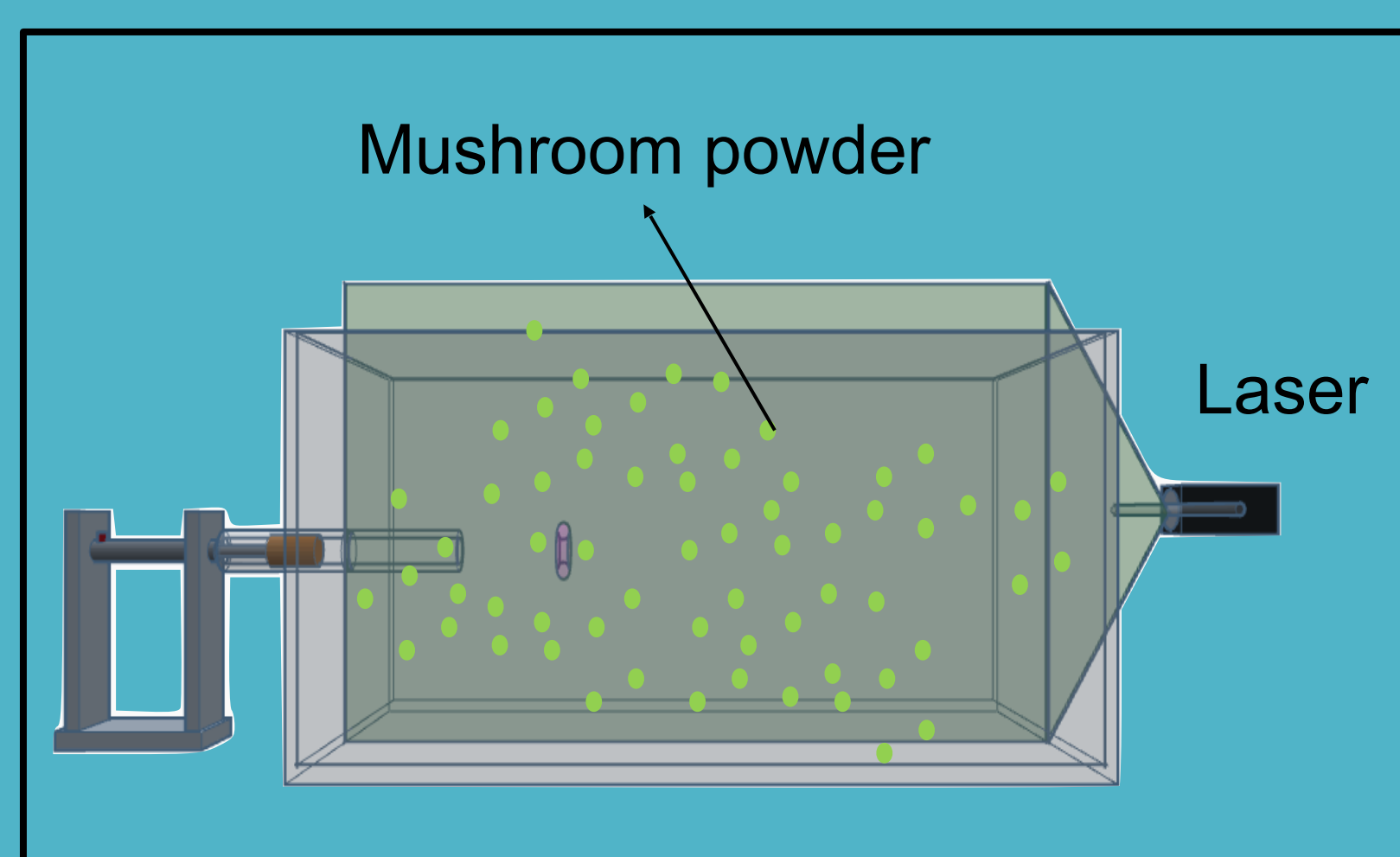
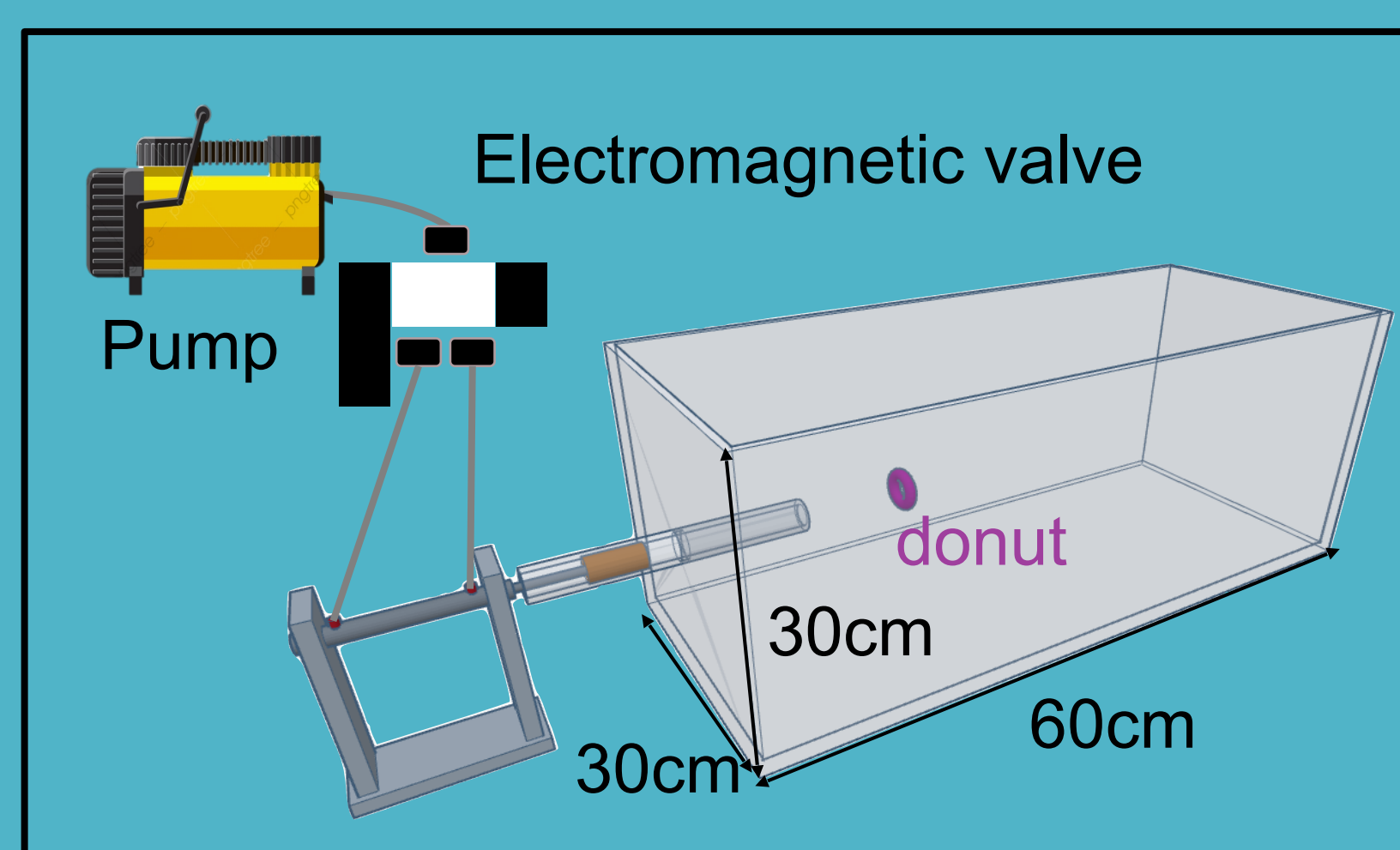
- Find the relation between stroke ratio ($\frac{L_N}{D_N}$) and D.
- Observe the vorticity and velocity of fluid.
- Measure the spatial evolution of vortex ring.
 - Vortex ring’s size
 - Vortex ring’s speed

Experimental Setup



Setup 1:
Measure the **diameter & velocity**

Setup 2:
Measure the **vorticity distribution**



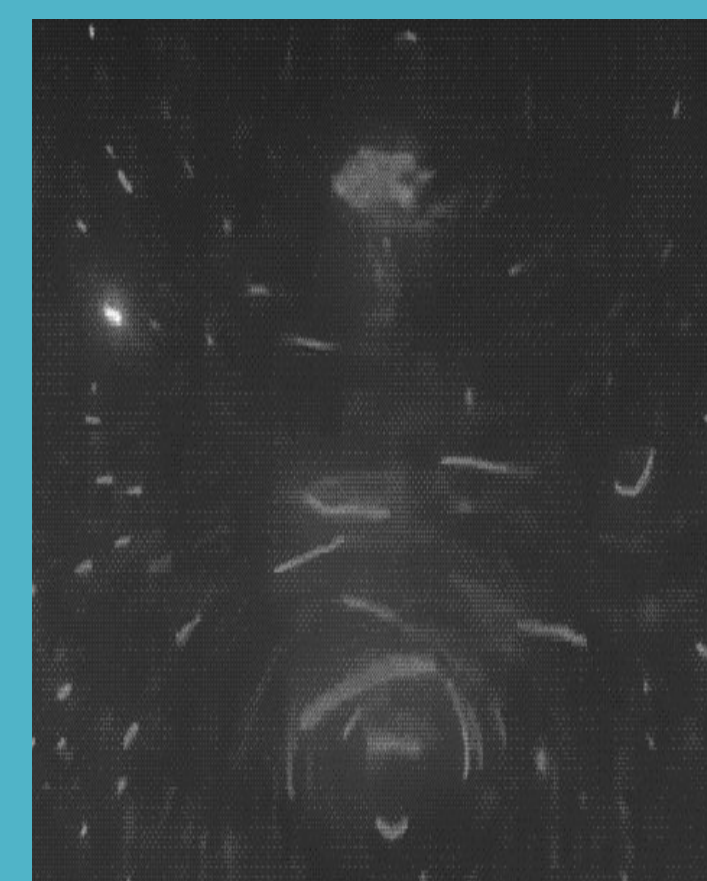
Theory

- The vortex ring propagates along the direction of the normal ring plane (\hat{n}).
- Fluid field at its outer edge is dragging against its traveling direction to maintain the vortex.
- The vortex ring is an axisymmetric object.
- The vortices do not destroy each other.

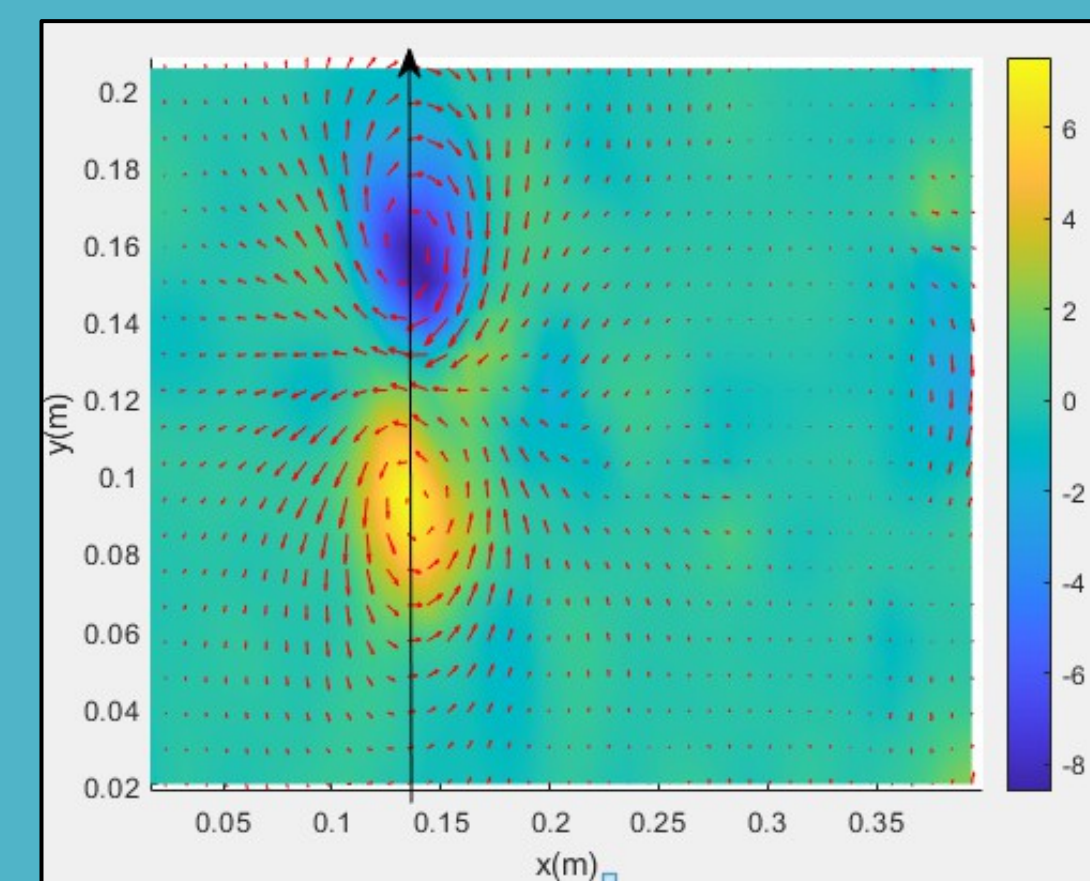
r_0 : Ring Diameter
 σ : Vortex Core Radius
 ω : Vorticity

Vortex ring [4]

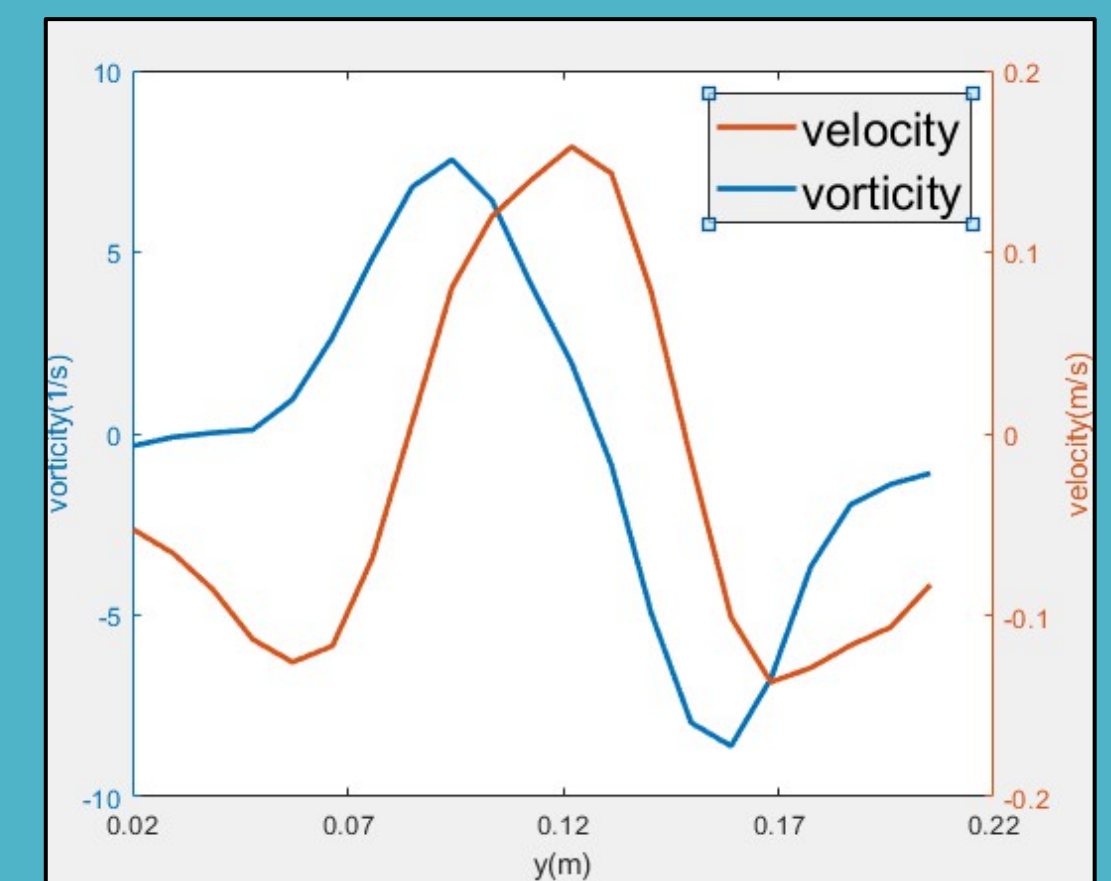
Results



Real image



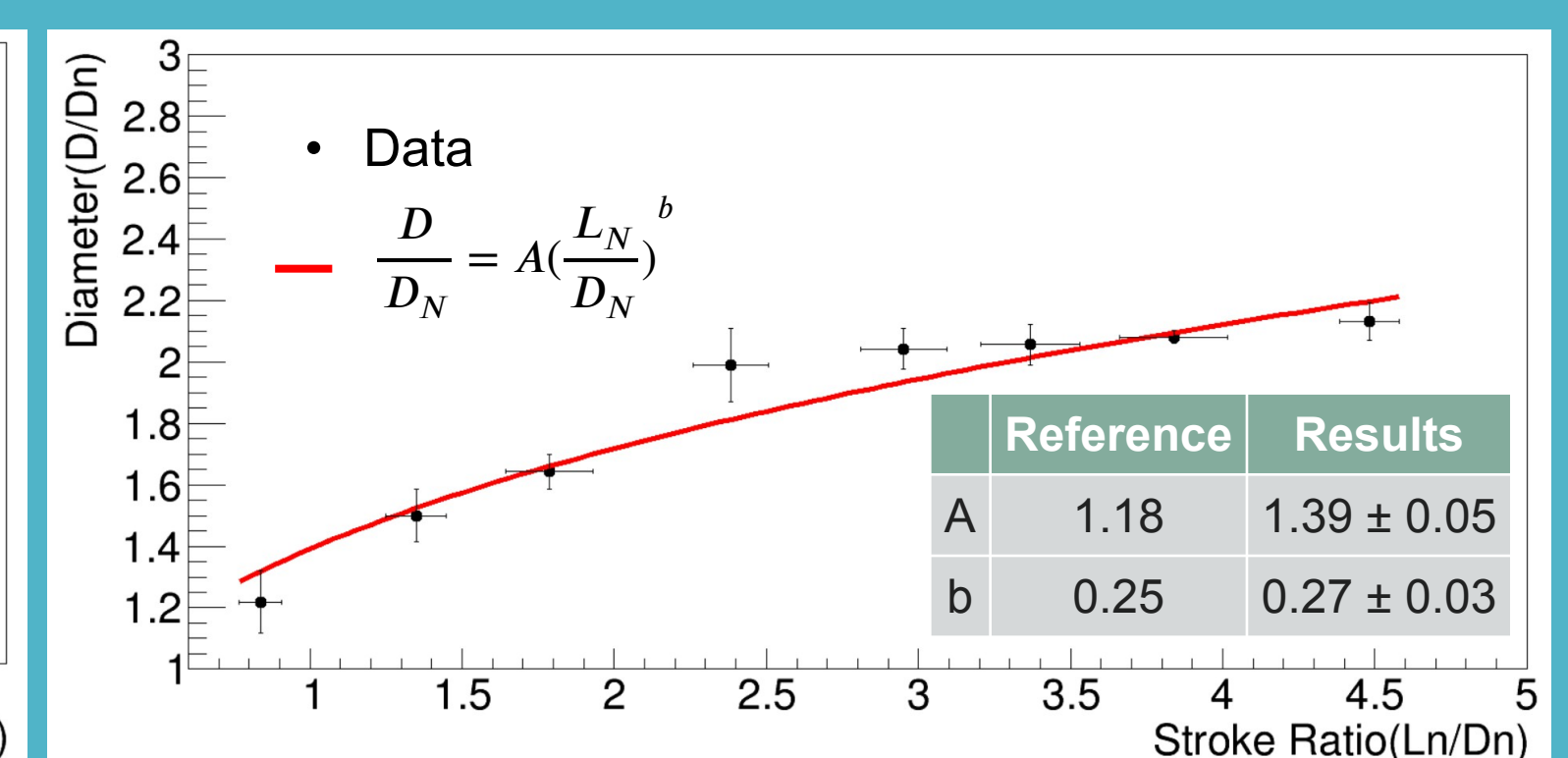
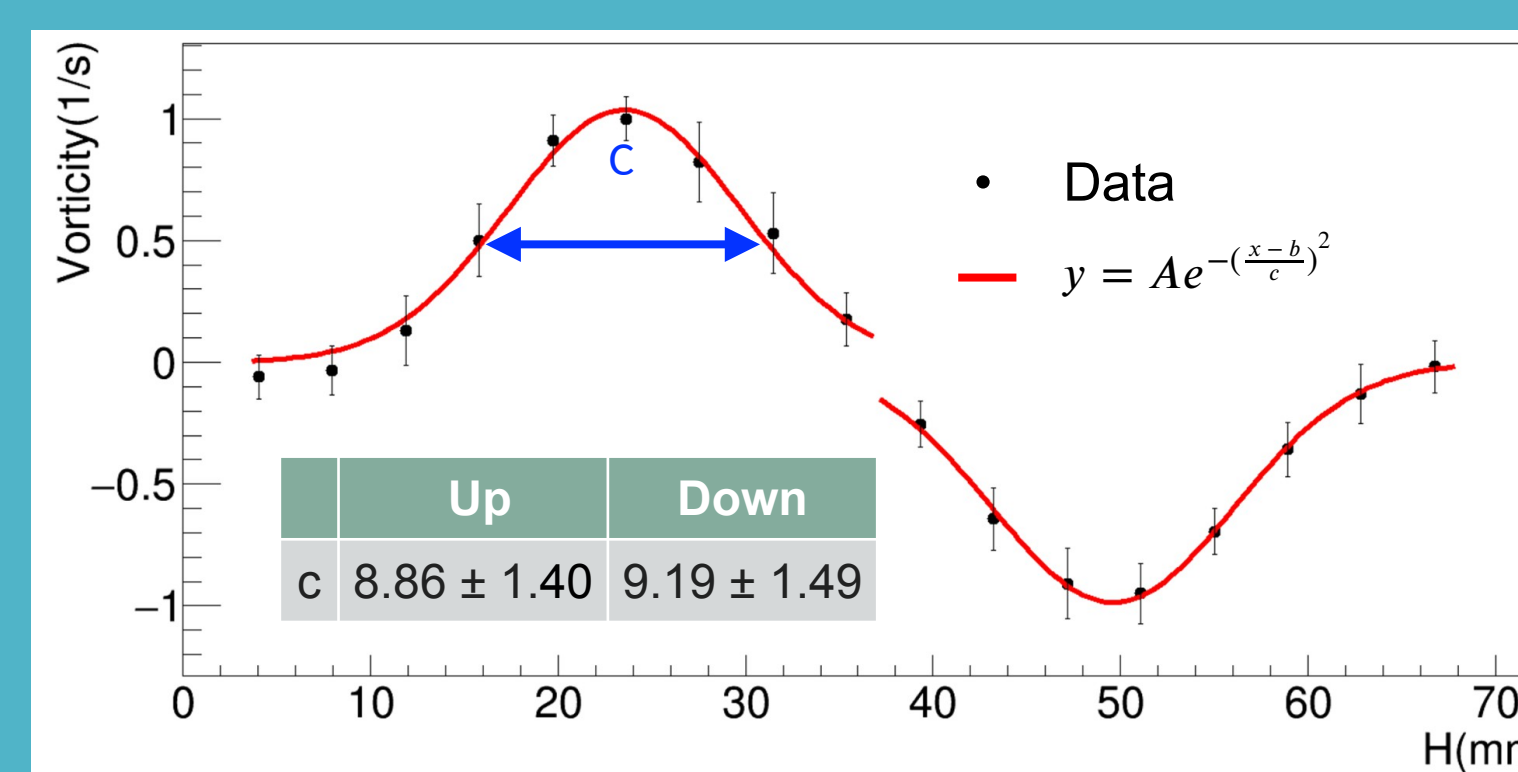
PIV analysis



Vorticity & velocity along the line

The flow fields around the vortex ring

- The top and bottom vortices rotate in the opposite direction.
- The center of the vortex ring has the highest velocity.

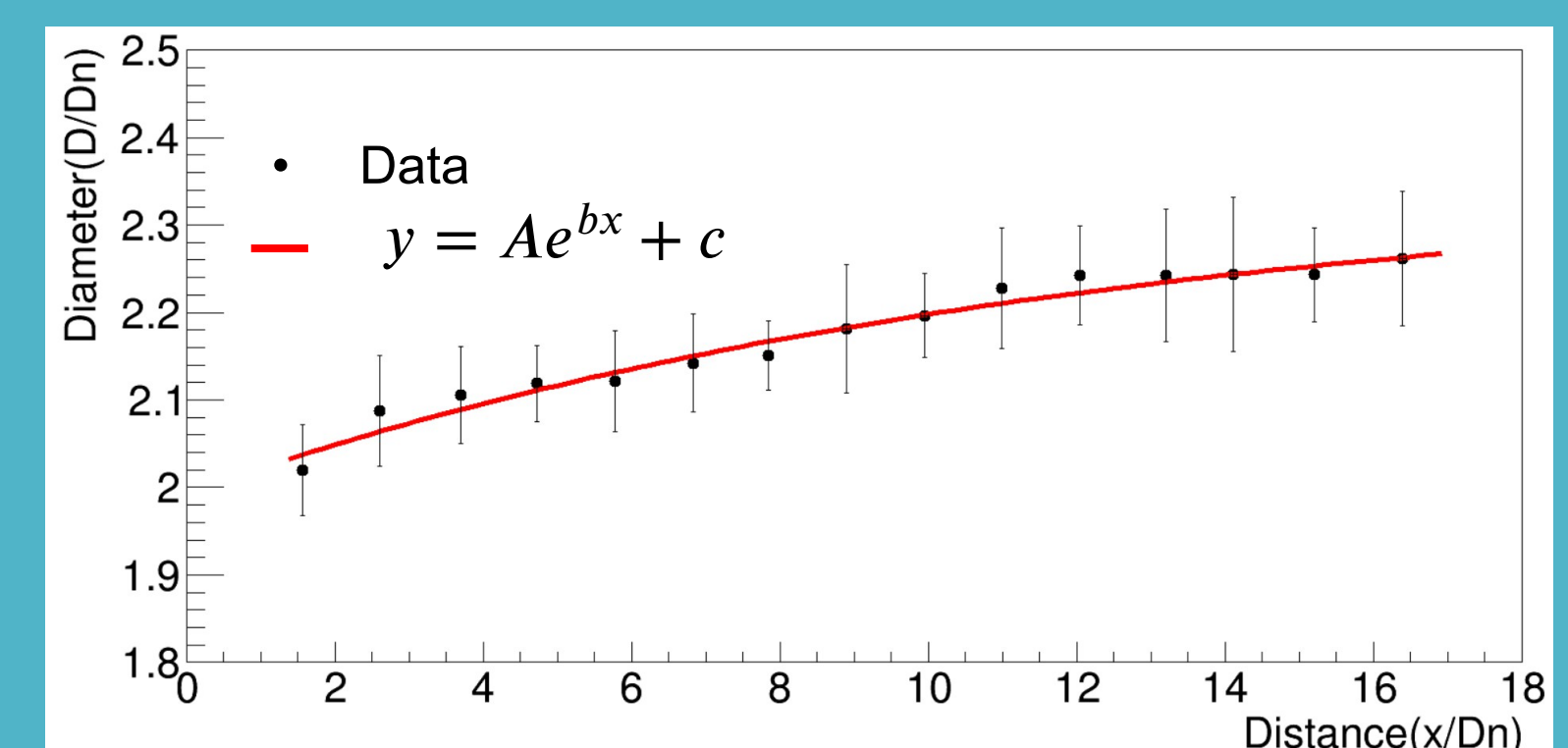
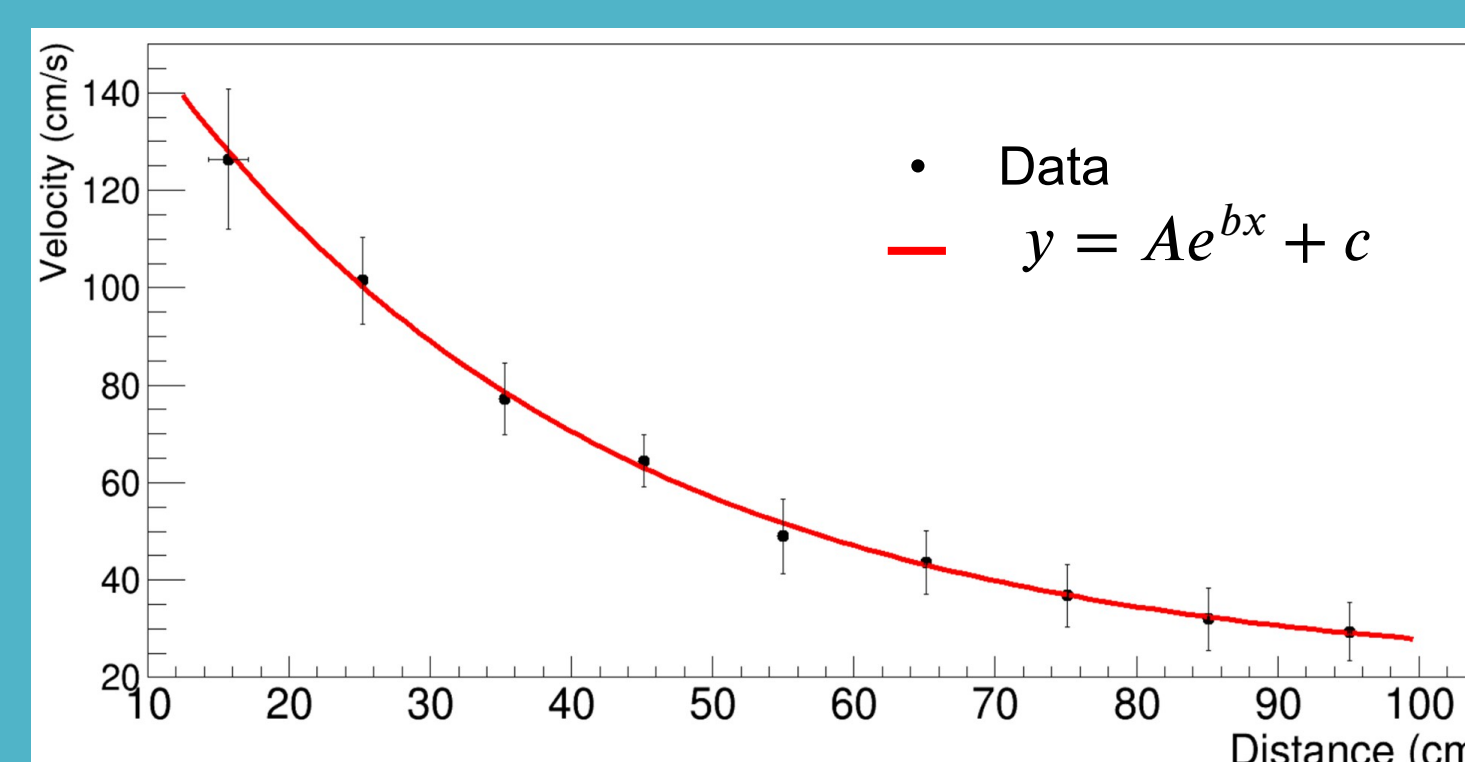


Radial vorticity

- It can be described a Gaussian function.
- The widths of the up and down are similar.

Diameter vs Stroke ratio

The initial diameter of the vortex ring depends on the stroke ratio.

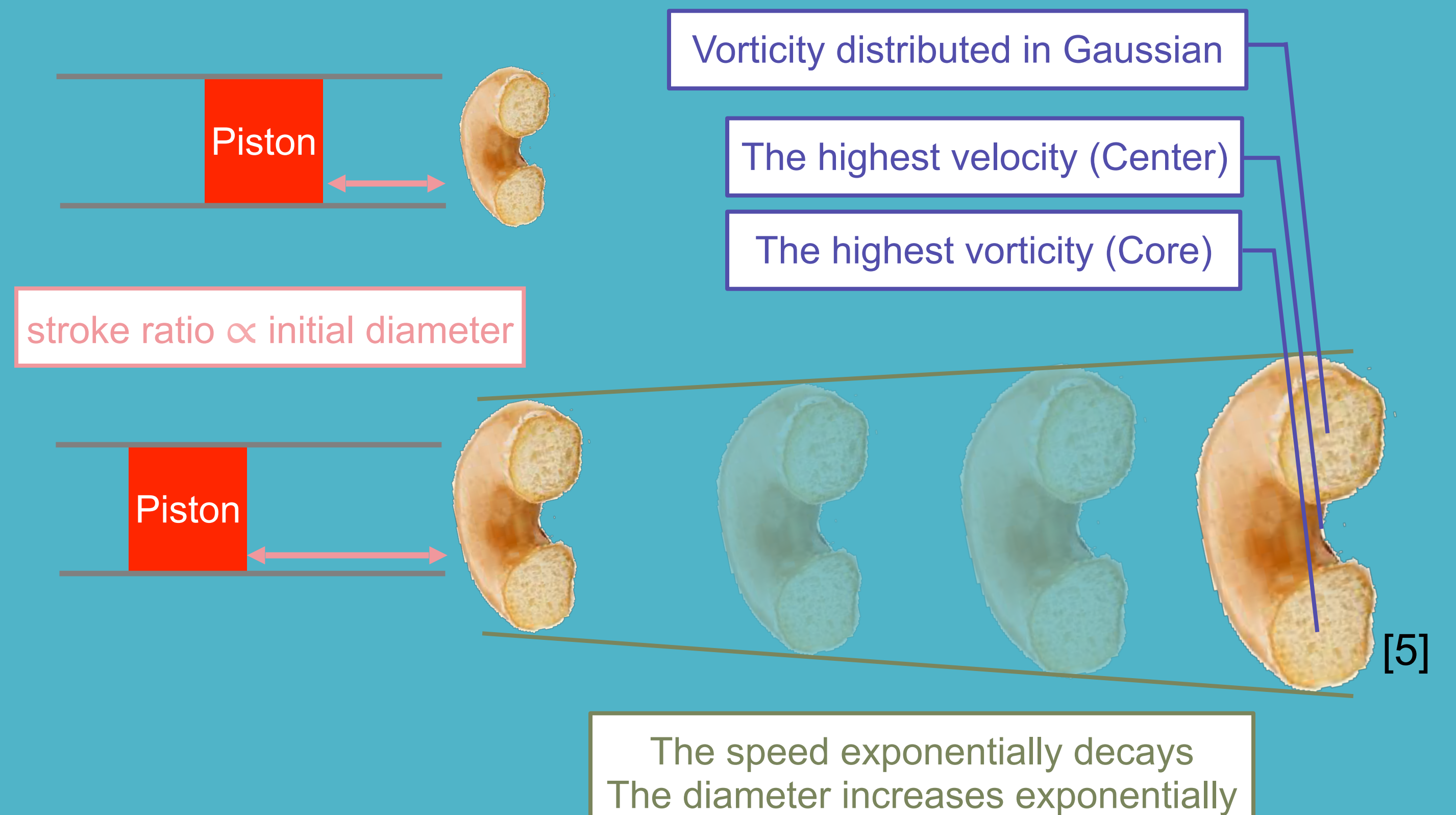


Velocity vs Traveling Distance

The speed shows the exponential decay as propagating.

The diameter increases exponentially when it travels further.

Conclusions



References

- [1] Deepak Adhikari(2009). Some experimental studies on vortex ring formation and interaction.
- [2] <https://reurl.cc/R4mb4G>
- [3] <https://reurl.cc/exAm6m>
- [4] <https://reurl.cc/AqYR8p>
- [5] <https://reurl.cc/pdAxZx>

