# The effect of heat release on the recirculation zone structure in bluff body stabilised turbulent premixed swirling flames

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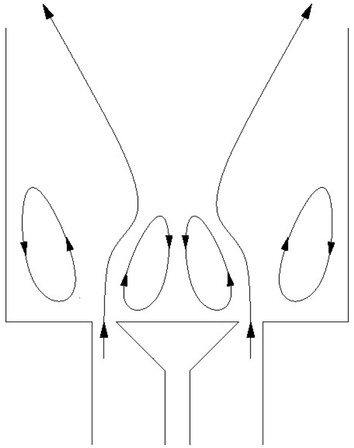
# Stabilising a flame

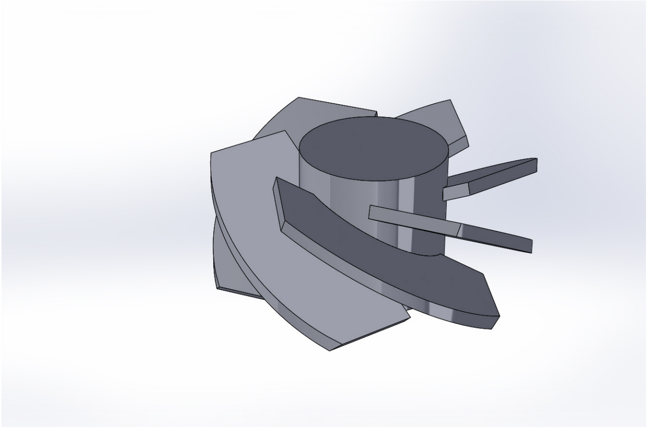
Bluff Bodies:

- A central recirculation zone (CRZ) with a pair of counter rotating vortices
- Created from the transfer of momentum from the flow to the bluff body.
- Creates favourable conditions for the flame to stabilise

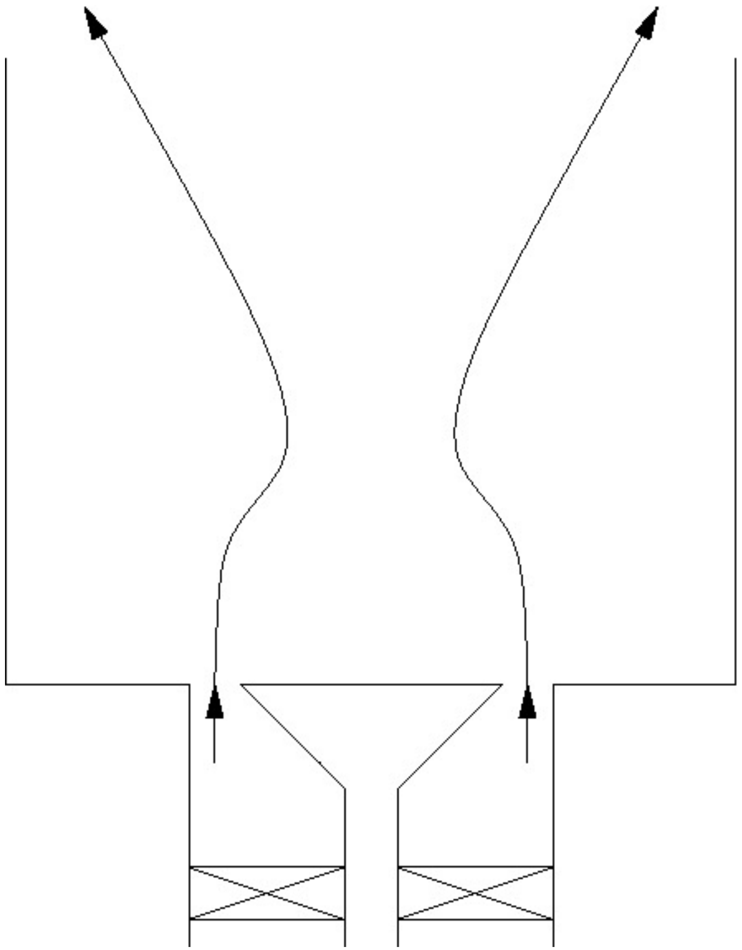


Swirl:

- Axial momentum is unable to overcome the adverse pressure gradient by the expanding flow
- A vortex breakdown bubble (VBB) is created in which hot products are recirculated.
- Similar to a bluff body wake, this helps in stabilising flames.



# Flow in isothermal swirling flow behind a bluff body



1. Sheen et al. (1996), AIAA J., 34(3)

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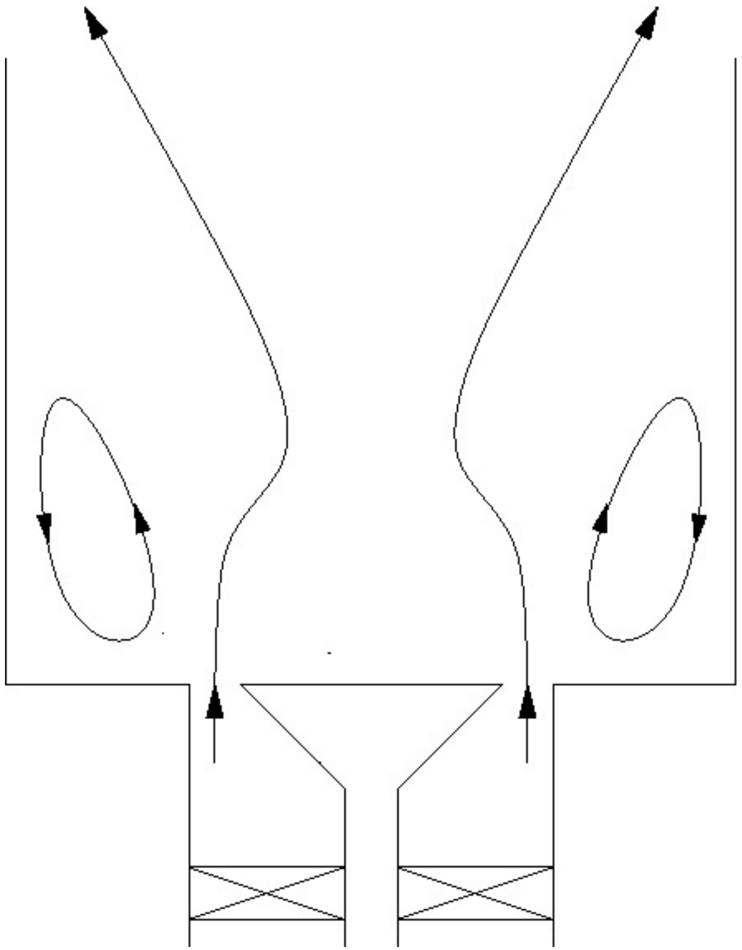



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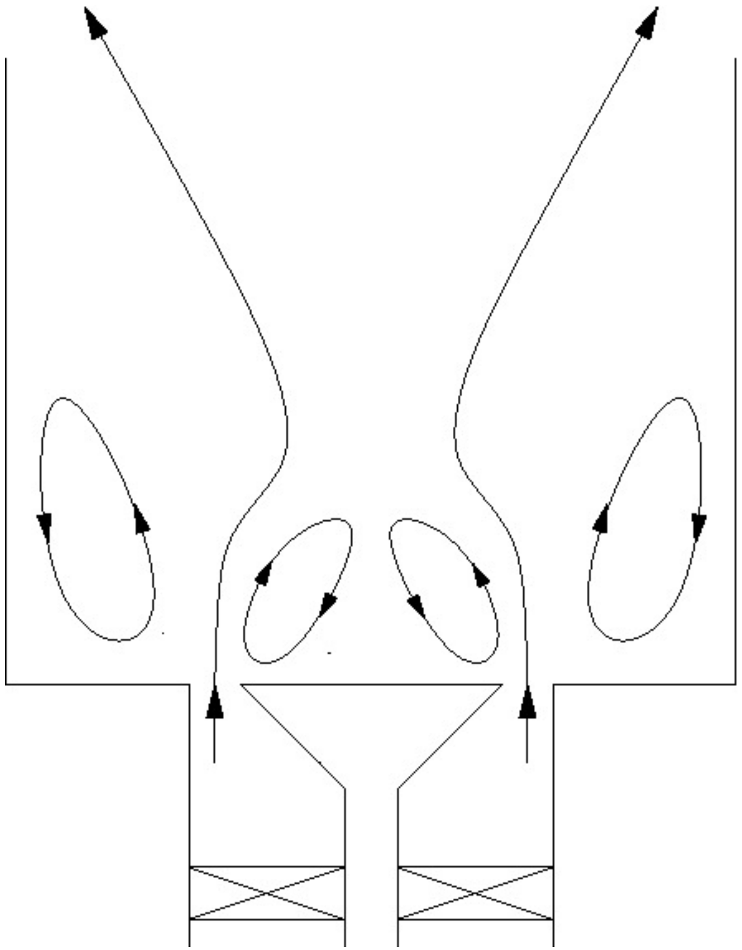

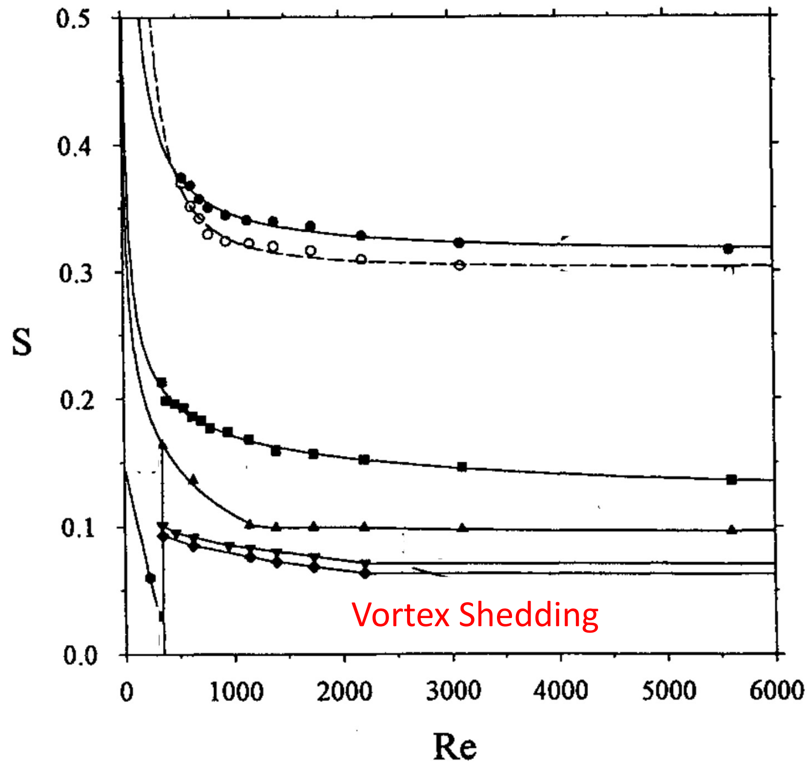




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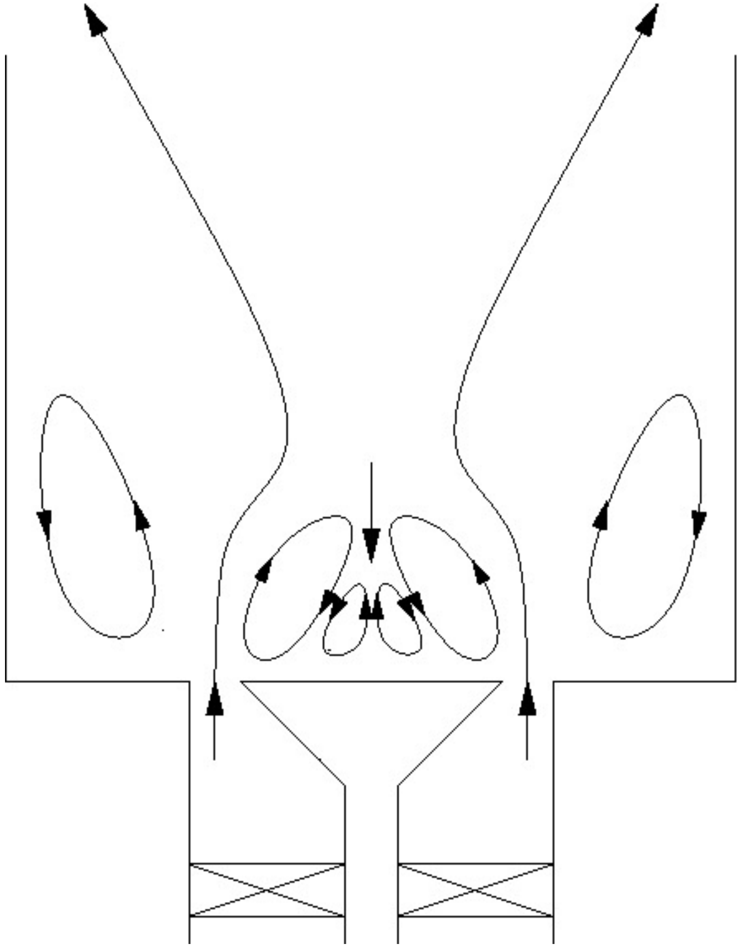

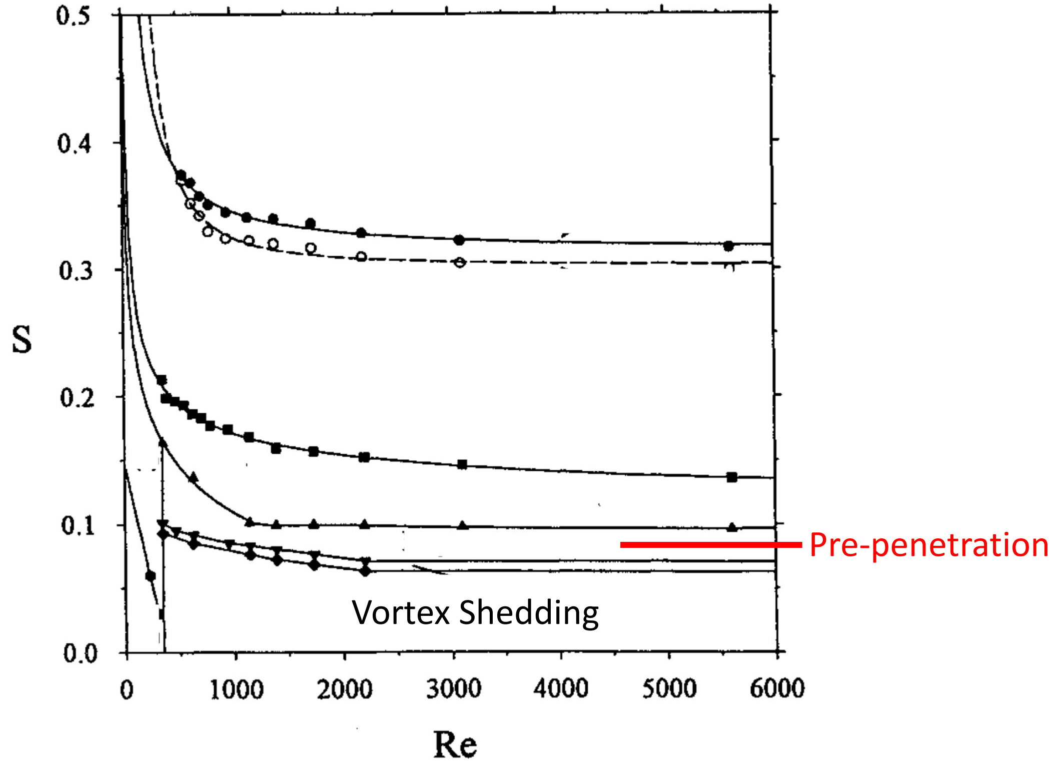


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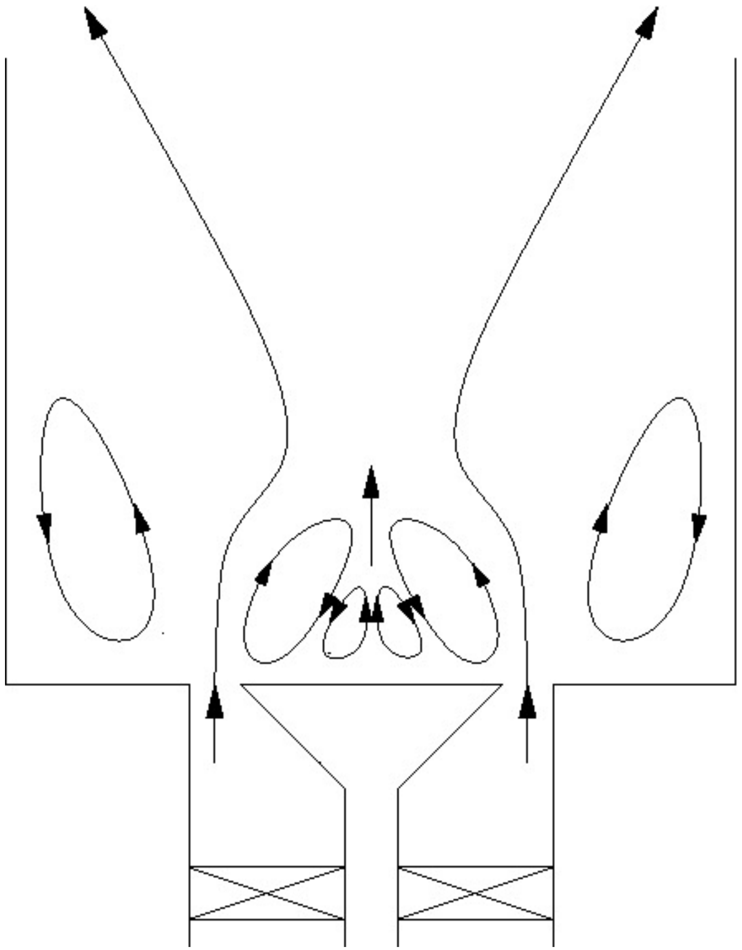

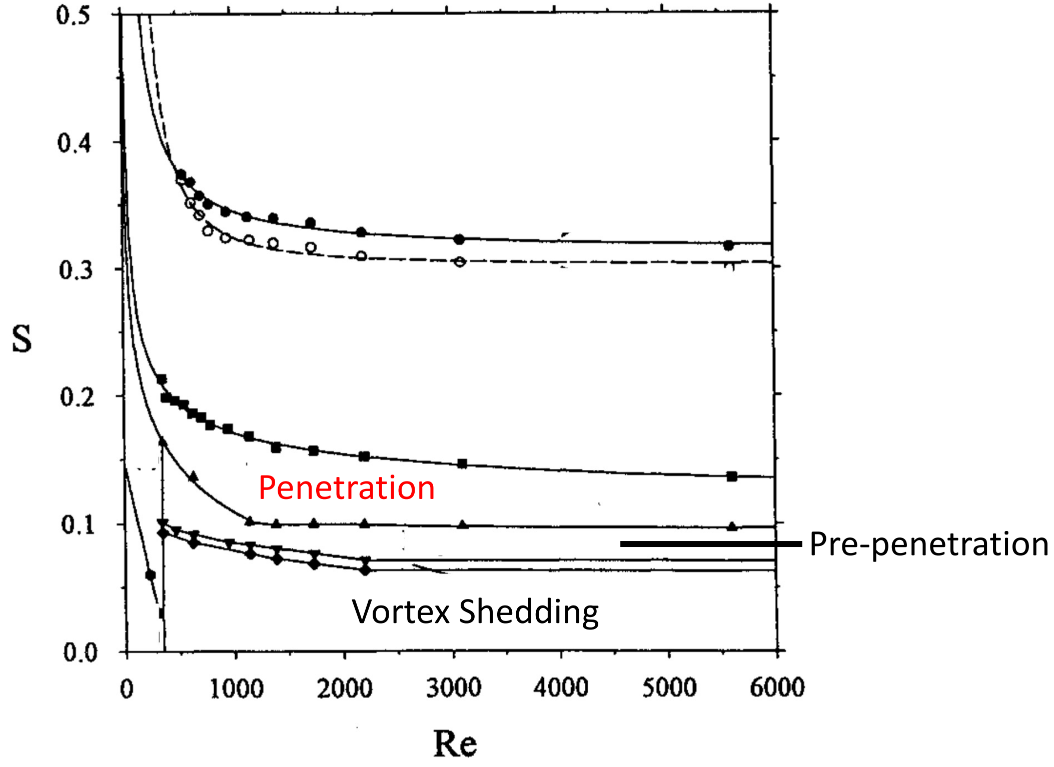


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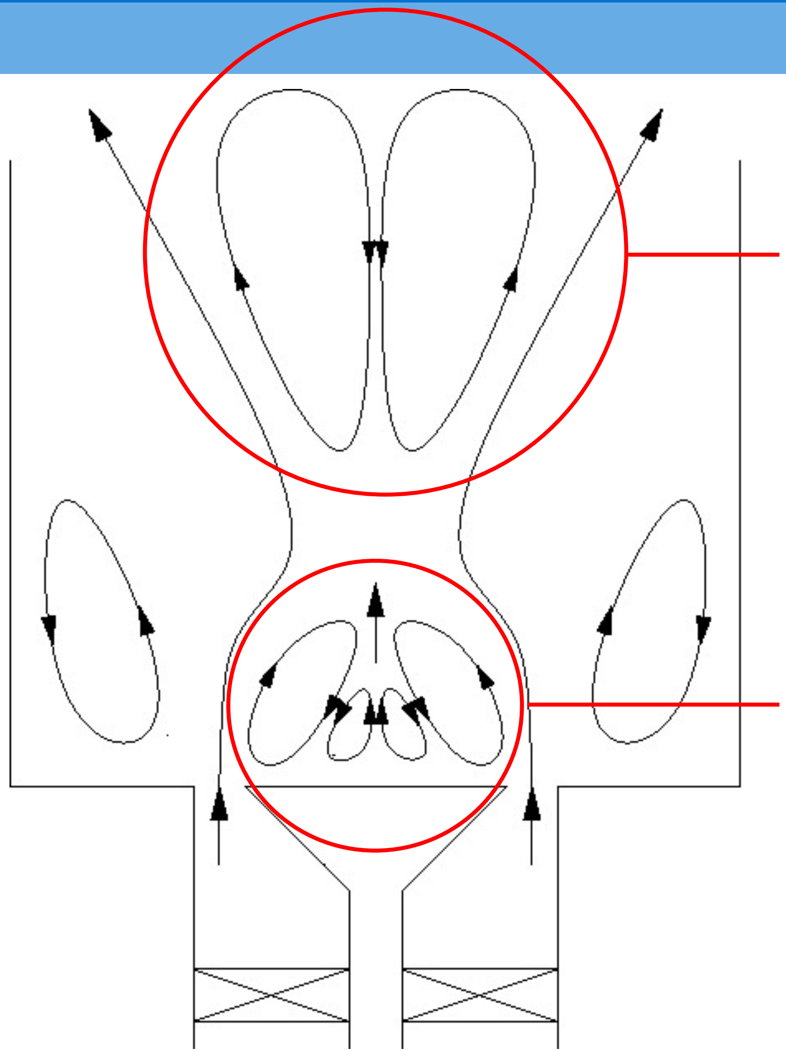


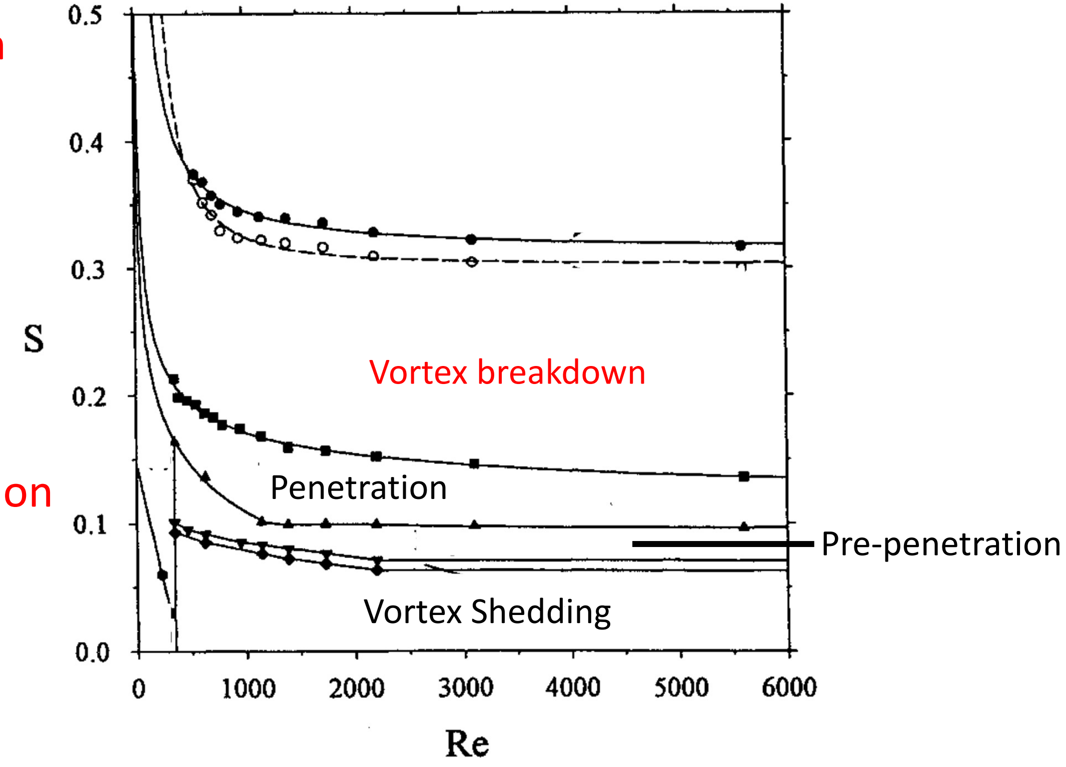


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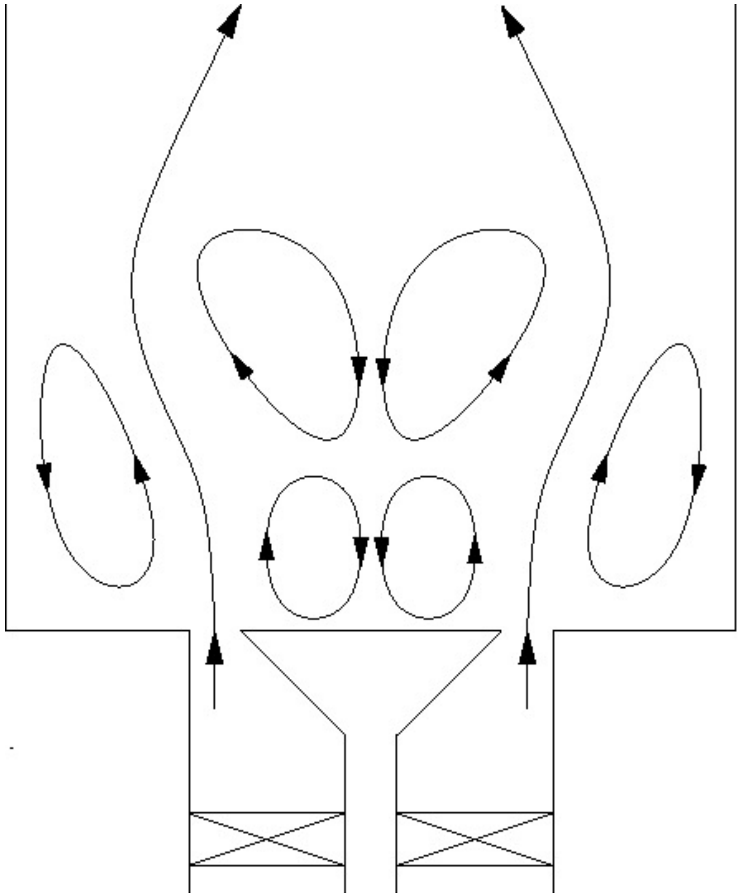
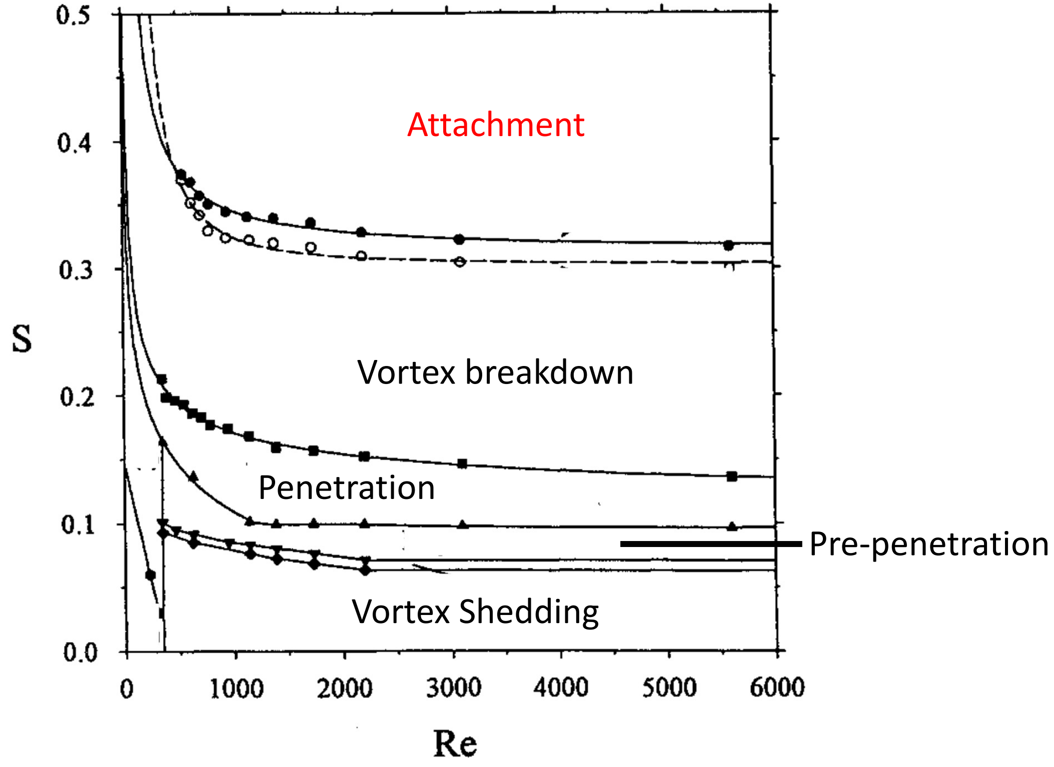
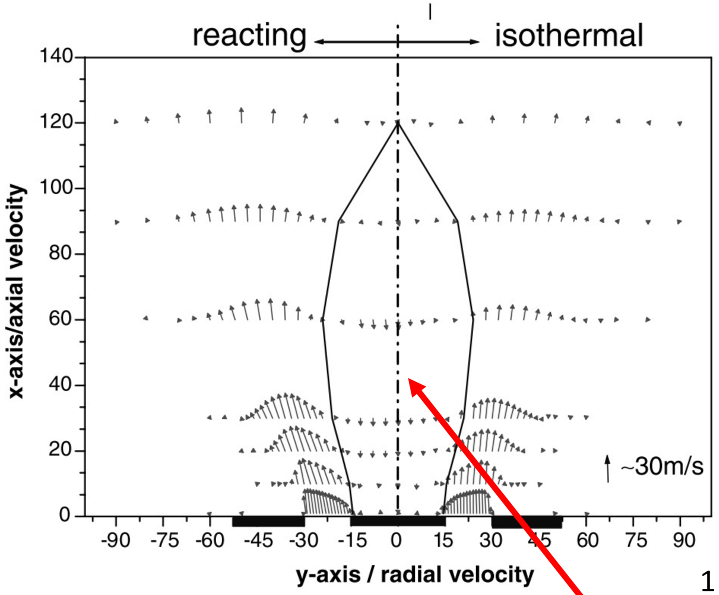







1. Sheen et al. (1996), AIAA J., 34(3)

# Flow in reacting swirling flow behind a bluff body

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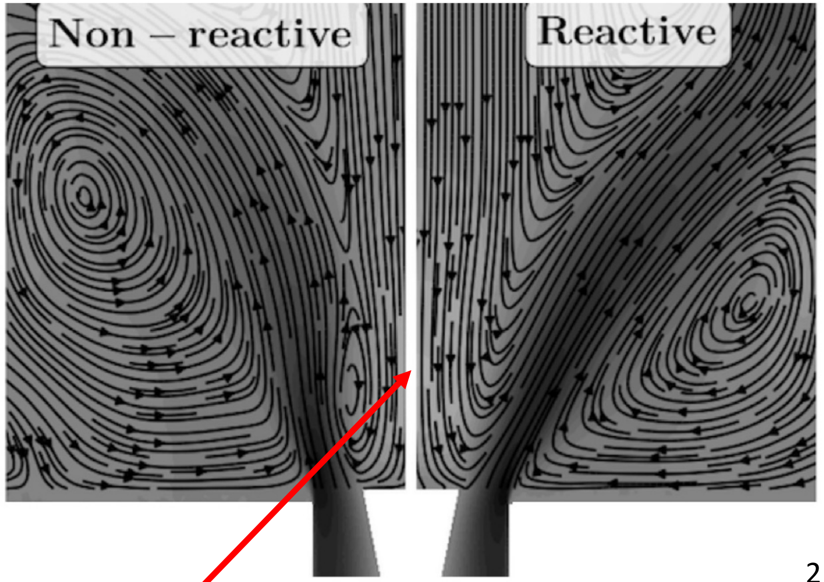


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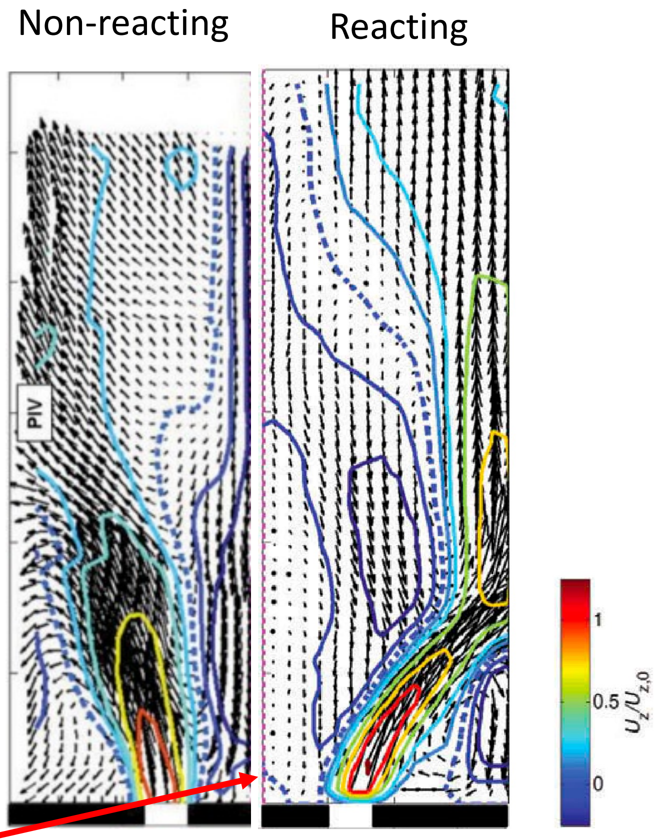



3

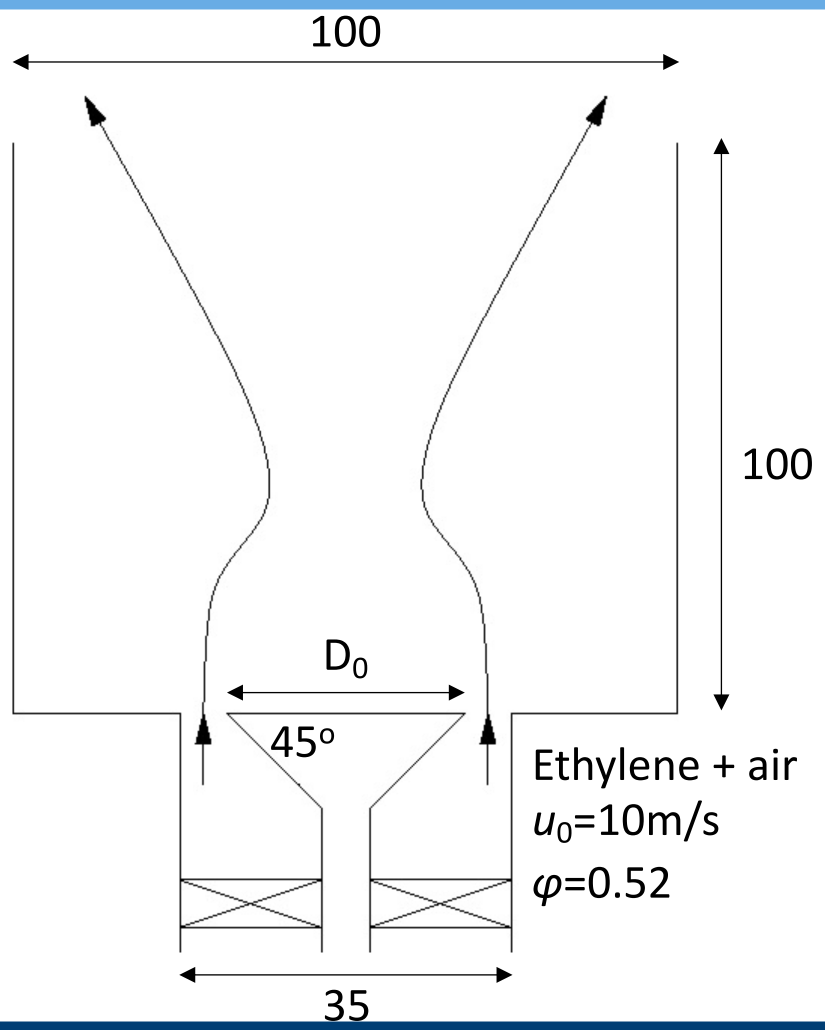
Negative Axial Velocity in the entire CRZ
for both non-reacting and reacting

Stagnation Point in reacting flow



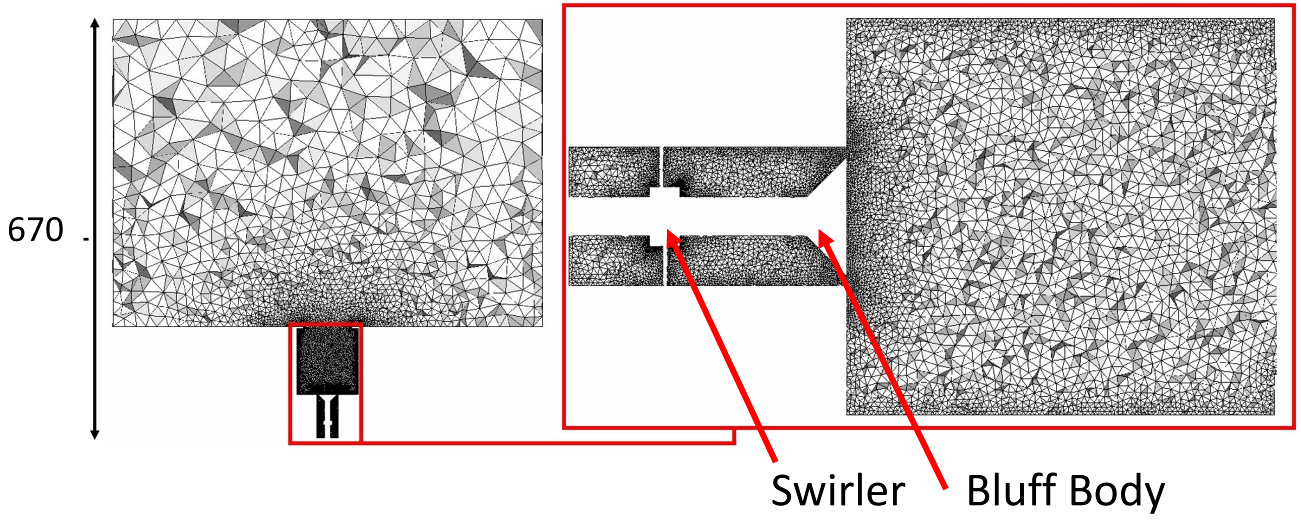
1. Schneider et al. (2005), Flow Turbul. Combust., 74(1)
2. Dupuy et al. (2020), Combust. Flame. , 217
3. Chterev et al. (2014), Combut. Sci. Technol., 186(8)

# Geometry Description




| Case | Swirler Angle (°) | $D_0$ (mm) | Blockage Ratio | S | LES/Exp. |
|---|---|---|---|---|---|
| S45-BB30 | 45 | 30 | 0.73 | 0.30 | Yes/Yes |
| S45-BB25-1 | 45 | 25 | 0.51 | 0.44 | Yes/Yes |
| S45-BB25-2 | 45 | 25 | 0.51 | 0.58 | Yes/No |
| S30-BB25 | 30 | 25 | 0.51 | 0.32 | Yes/No |
| S60-BB25 | 60 | 25 | 0.51 | 0.80 | Yes/No |
| S60-BB30 | 60 | 30 | 0.73 | 0.42 | Yes/No |

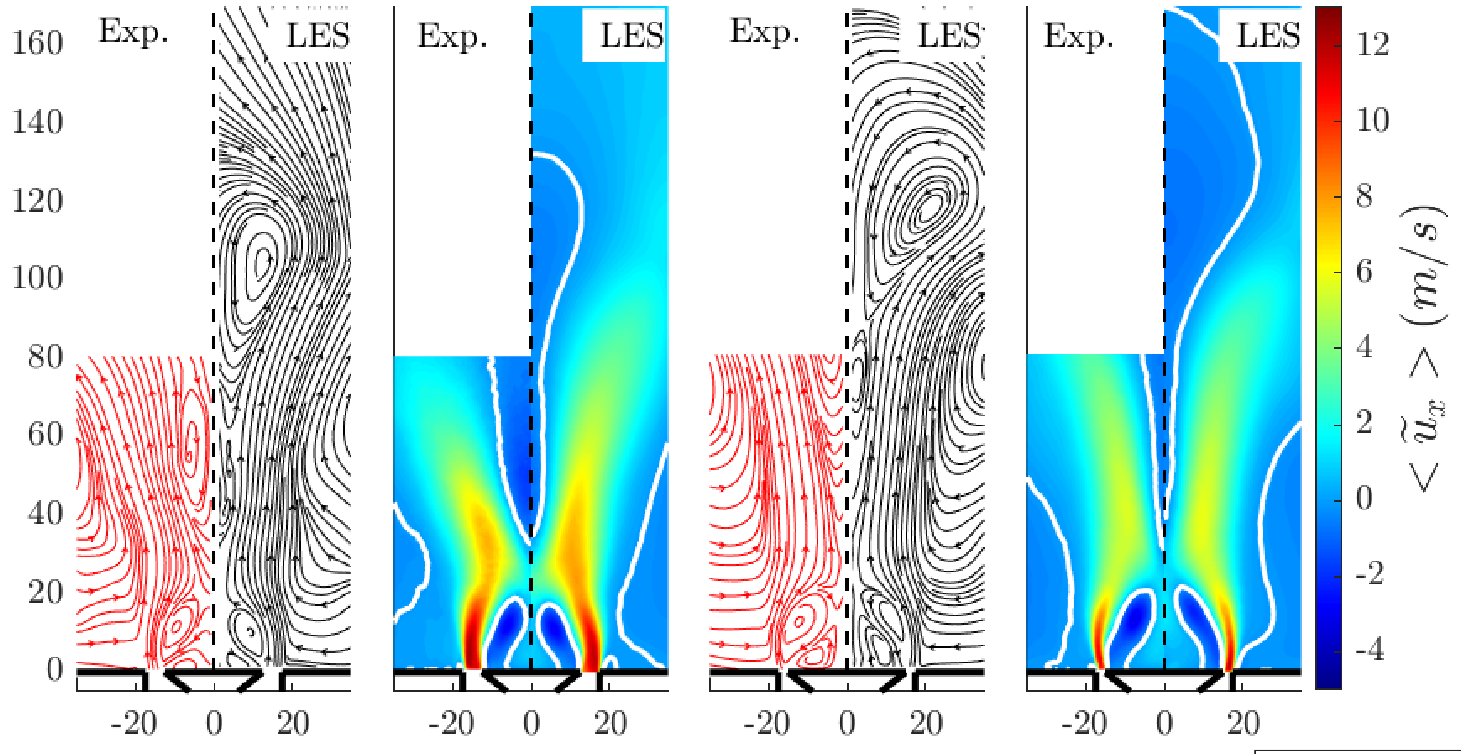
# Effect of blockage and swirl

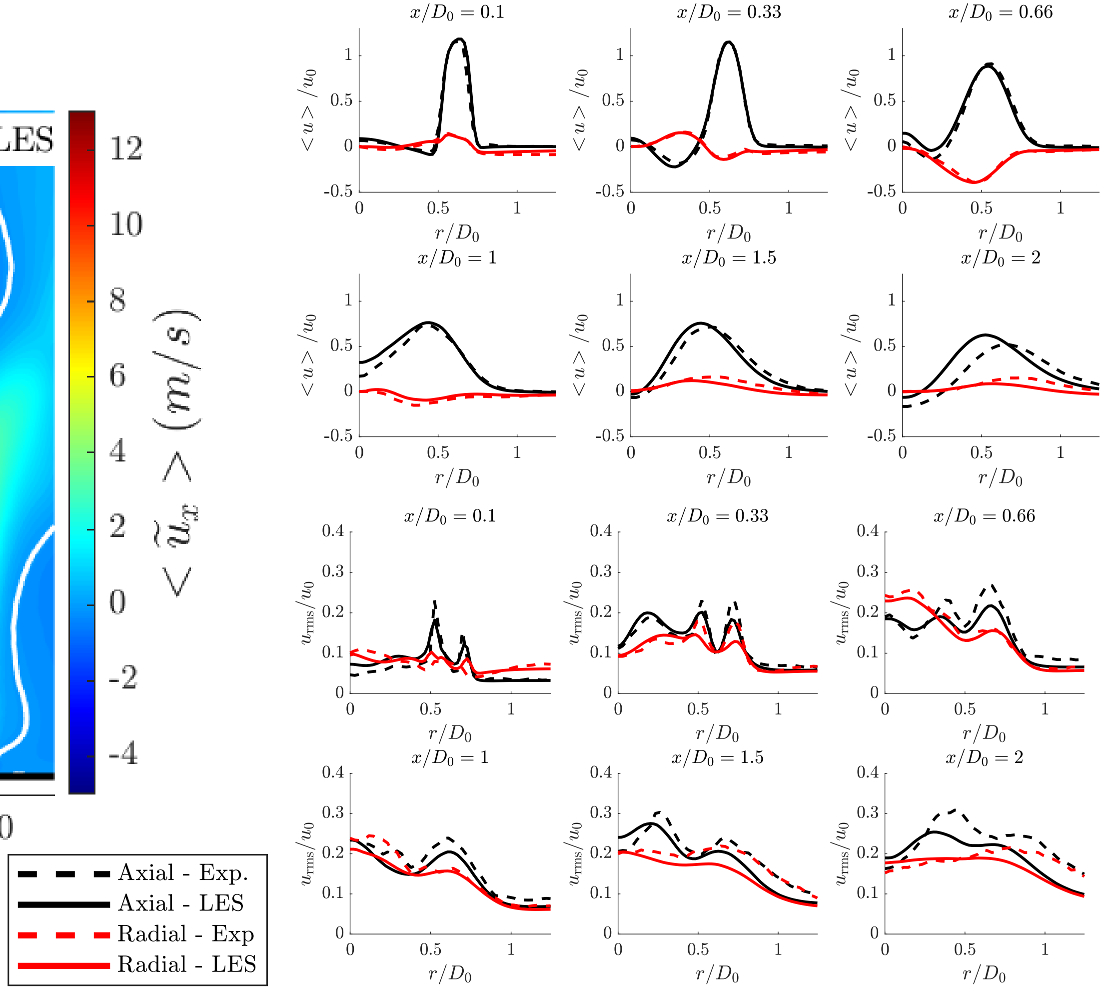



- Dynamic Smagorinsky Model for subgrid turbulence
- Cambridge FlaRe model for combustion
- 2.5-2.9 million tetrahedral cells
- Extended domain as the VBB extends outside the confined region of the combustor and the outlet conditions are unambiguous
- Second order numerical schemes for spatial derivatives and first order time scheme
- Statistics are obtained for at least 10 flow through times
- Computation cost is roughly 80 CUs for each non reacting simulation and 150 CUs for reacting.

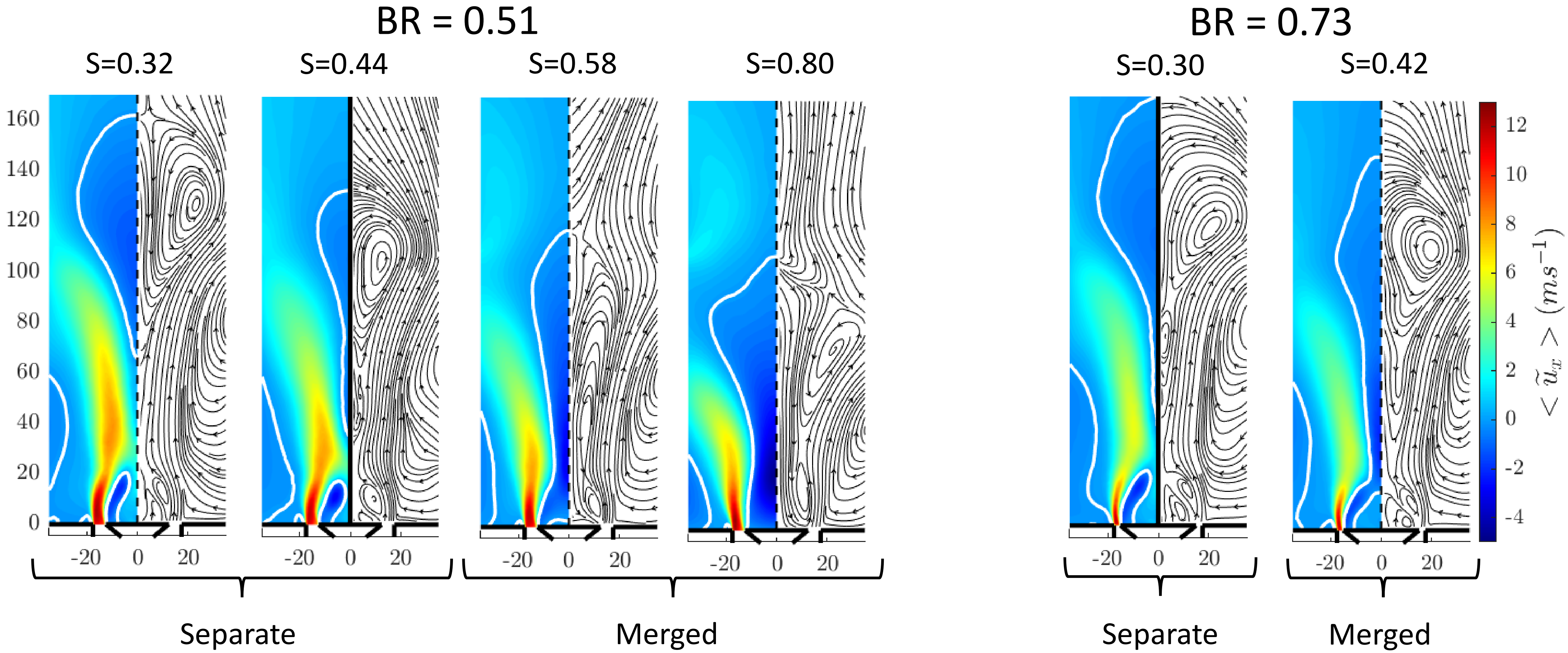
# Non-Reacting Flow

S=0.44 BR=0.51 S=0.30 BR=0.73

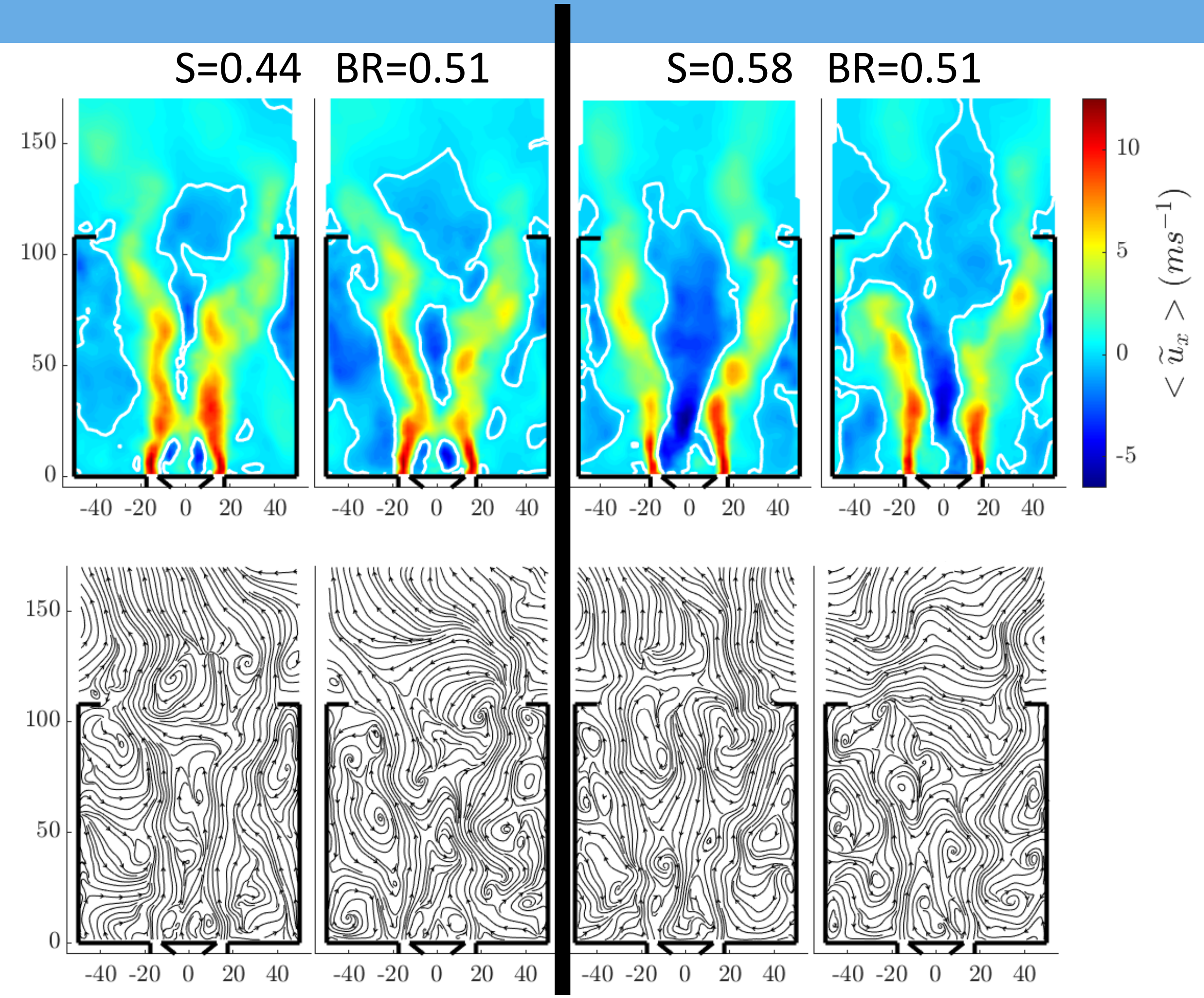


# Non-Reacting Flow



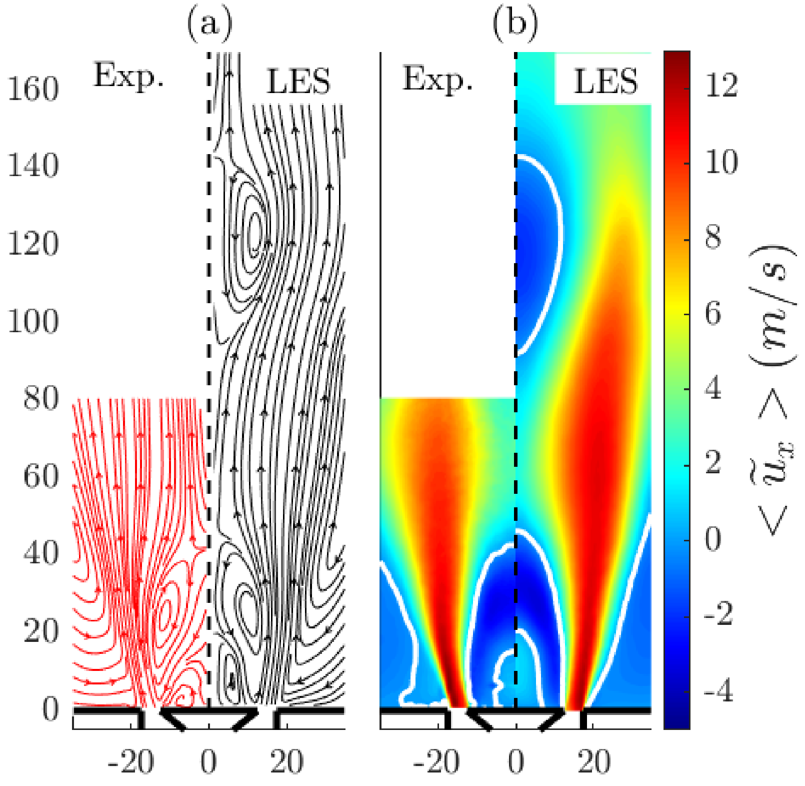
# Instantaneous CRZ structure

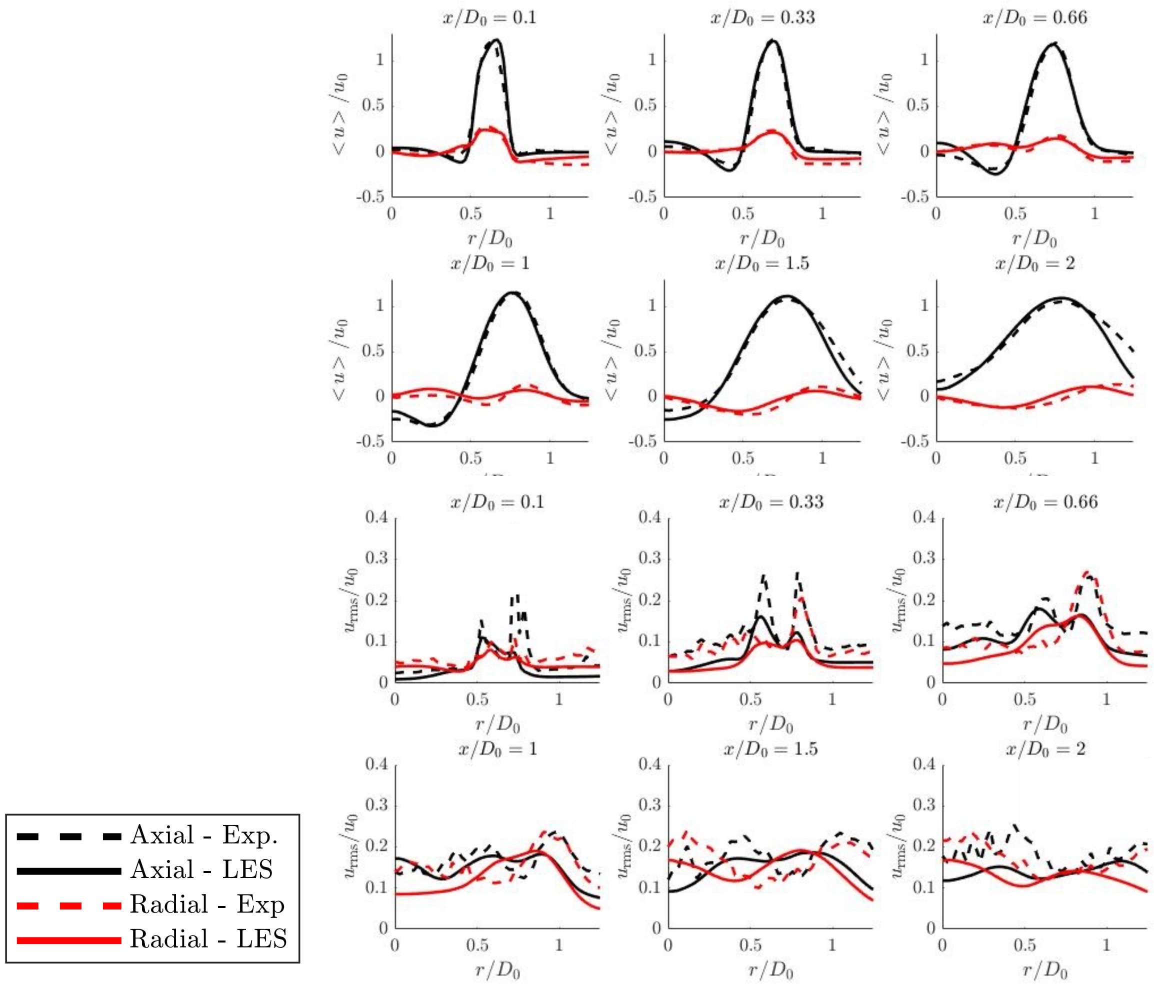



- In separated cases the shape of the VBB in instantaneous contours is very different to the in the mean ones.
- Vortices move around a large area and don’t have a fixed location.
- The structure of the CRZ appears to be more similar to that in the mean fields.
- Once the VBB and CRZ merge, the merged CRZ structure also changes significantly over time.

# Reacting Flow

BR=0.51 S=0.44

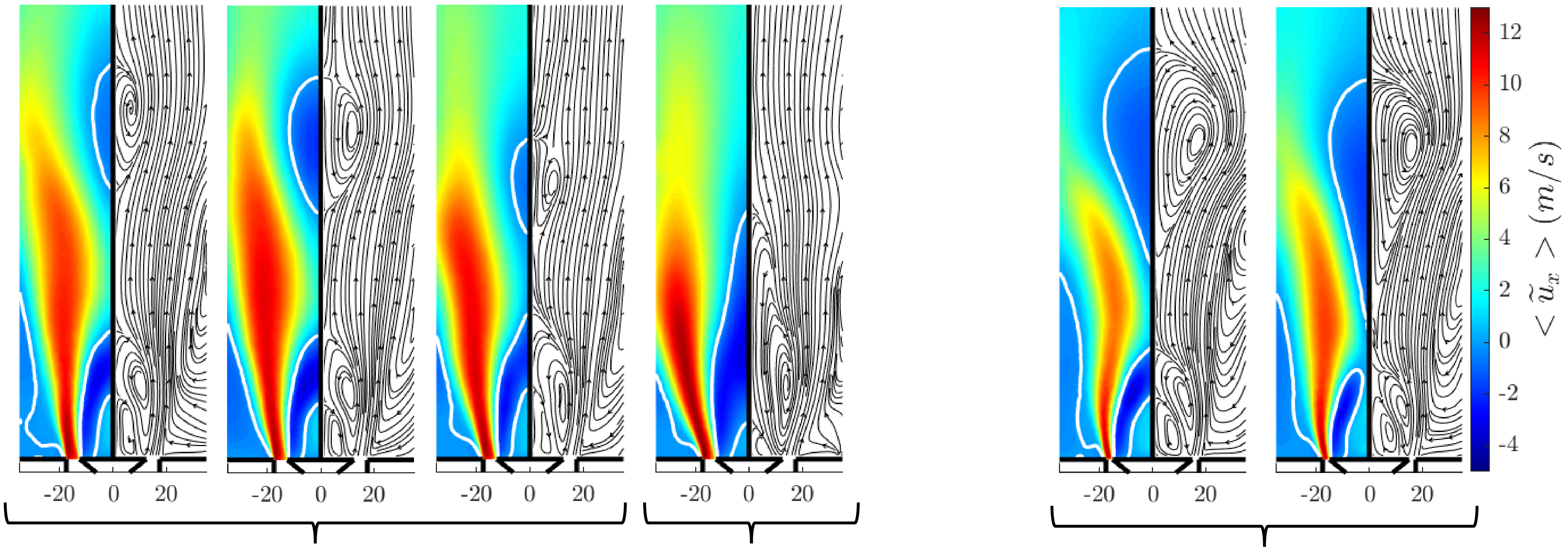


# Reacting Flow

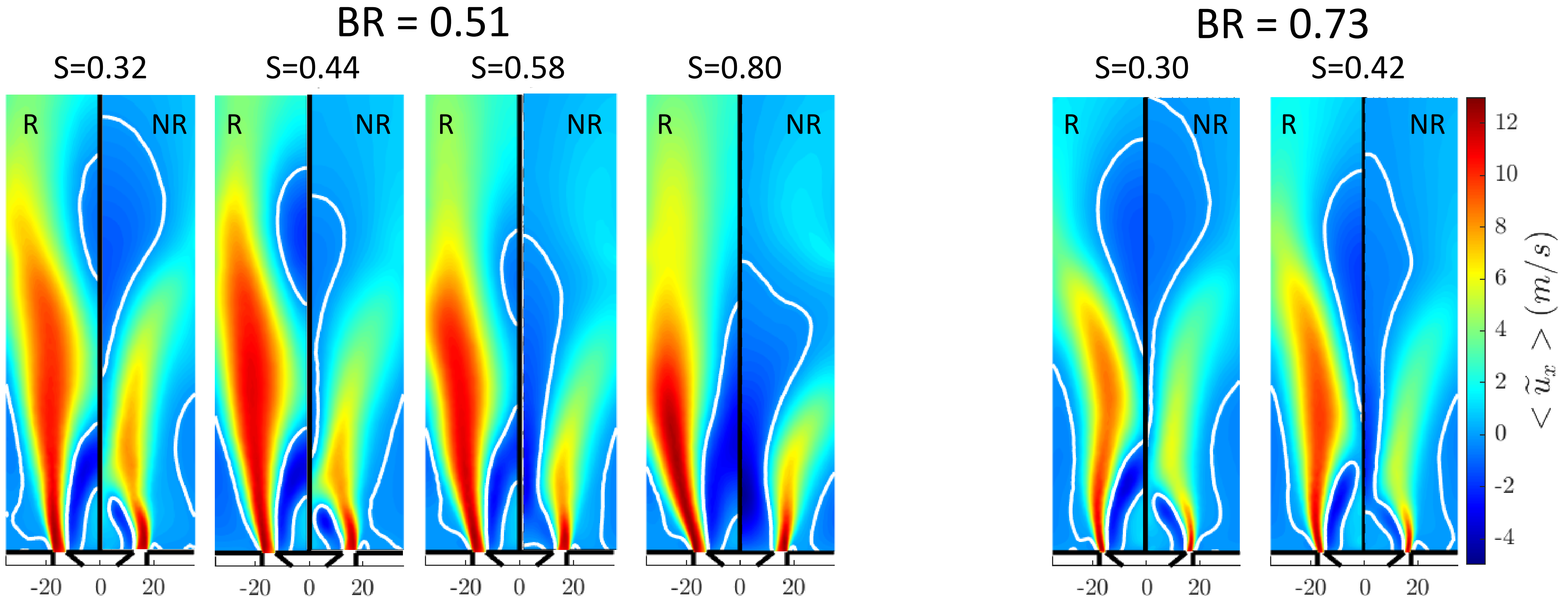
BR = 0.51 BR = 0.73

S=0.32 S=0.44 S=0.58 S=0.80 S=0.30 S=0.42




Separate Merged Separate

# Reacting Flow



# Conclusions

## Non-reacting

- Increasing the swirl number moves the VBB close to the CRZ until they merge altering their structure. A critical number $S_c$ exists when the merging occurs
- Increasing the blockage ratio moves the VBB closer to the CRZ without changing their structures. $S_c$ is a function of the blockage ratio.
- The instantaneous features of the VBB are significantly different than its mean features.
- The instantaneous features of the CRZ in separated cases do not change significantly over time.
- When the VBB and CRZ have merged the entire structure becomes unsteady.

## Reacting

- Heat Release is altering the flow characteristics.
- If the swirl number is close to $S_c$ , the flow structure can change.
- If it is lower than $S_c$, the VBB is moved downstream.
- This happens due to swirl number changes in the axial direction and dilatation
- Changes in swirl number and blockage ratio affect the position of the VBB in the same way as in non-reacting flow.
- In separated cases, the inner vortices in the CRZ do now have enough momentum to penetrate the outer vortices.

# Questions?

# Thank you