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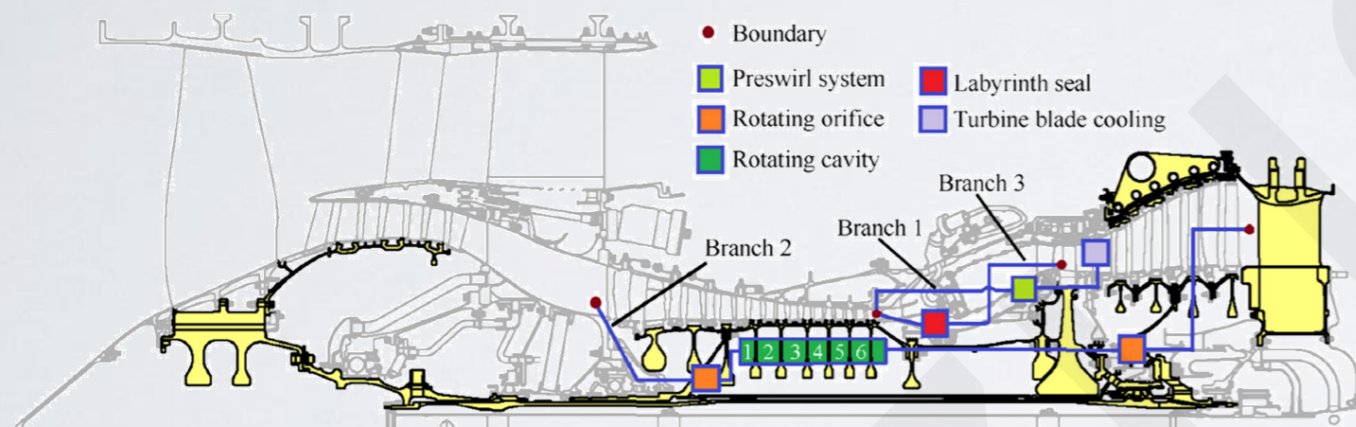
Investigation of flow characteristics in a rotor-stator cavity under crossflow using wall-modelled large-eddy simulation

Key words:

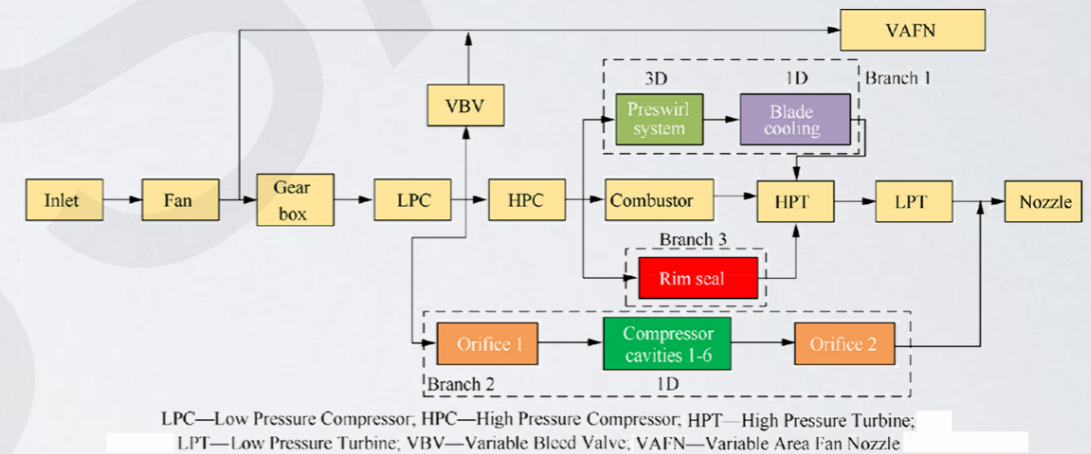
Wall-modeled large-eddy simulation (WMLES);
Rotor-stator cavity; Flow instability

What is this project for?

Secondary air system in CFM 56 engine



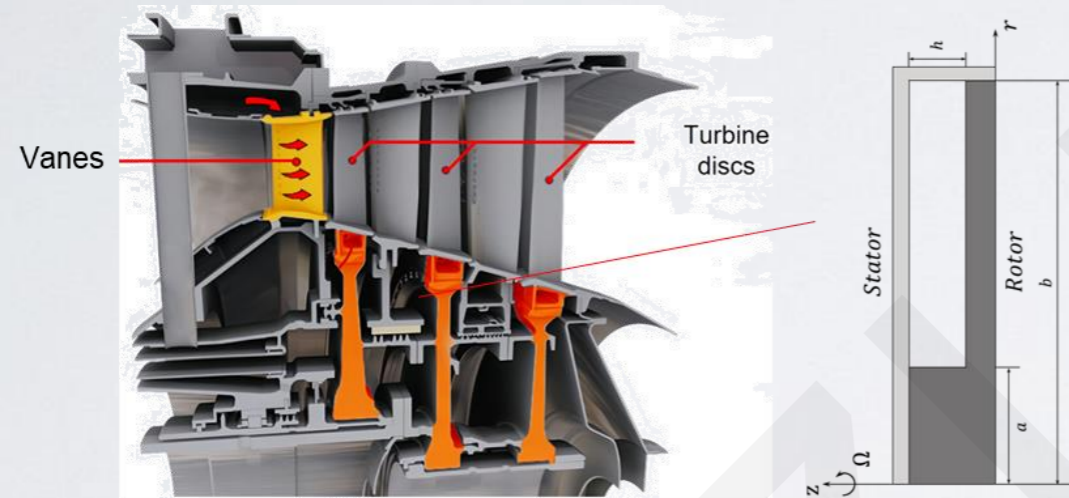
Reduced-order modelling: flow network



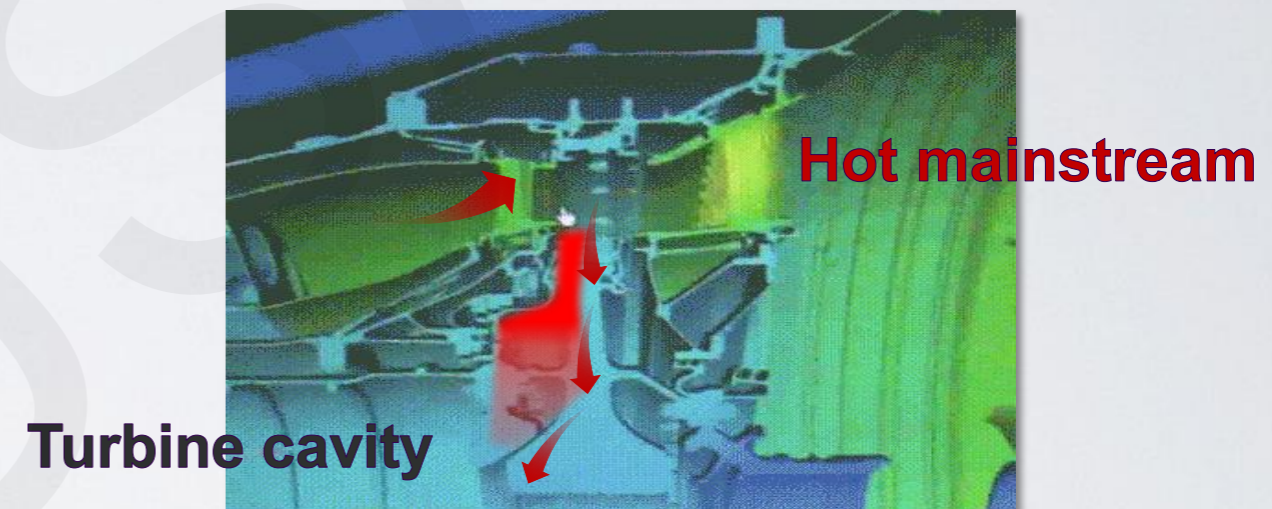
- **Secondary air system** plays a vital role in modern gas turbines.
Dissipating extra heat, delivering cooling air, rim sealing, maintaining loading on bearings, isolating oil system.....
- **Reduced-order fluid network approach** is widely adopted in secondary air system designing process
Empirical correlations, reduced-order modelling, reliable experimental database,
- **Cavities** are important components in the system.
Enclosed rotating cavity, rotor-stator cavity with radial outflow/inflow/axial throughflow,

What is the research aim?

Turbine rotor-stator cavity



Hot gas ingestion



- **Turbine cavity** is a typical type of **rotor-stator cavity**

External hot gas ingestion, superimposed radial sealing flow, flow instability, inertia effects.....

- **Hot gas ingestion** severely affects the operation of the jet engine

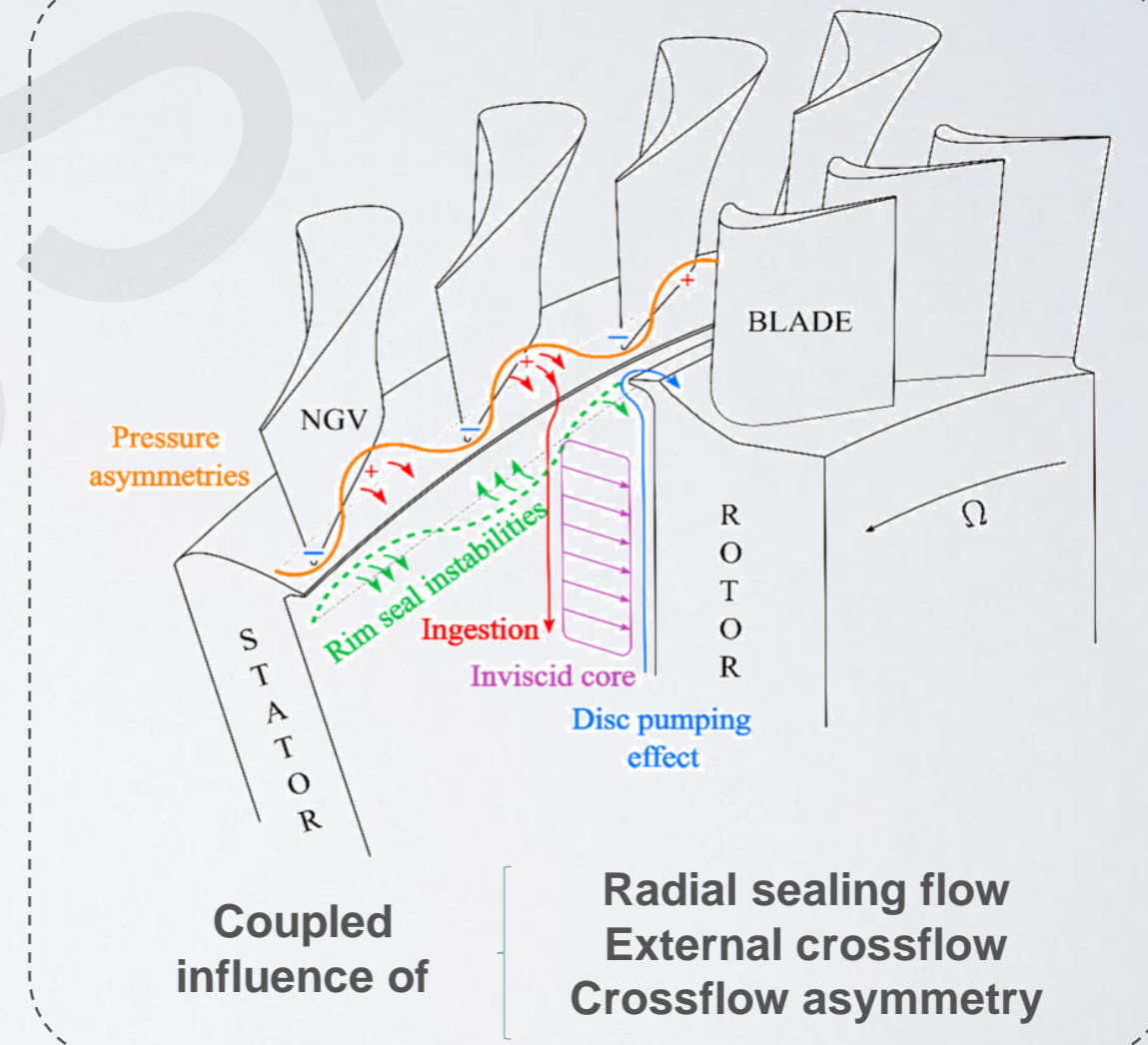
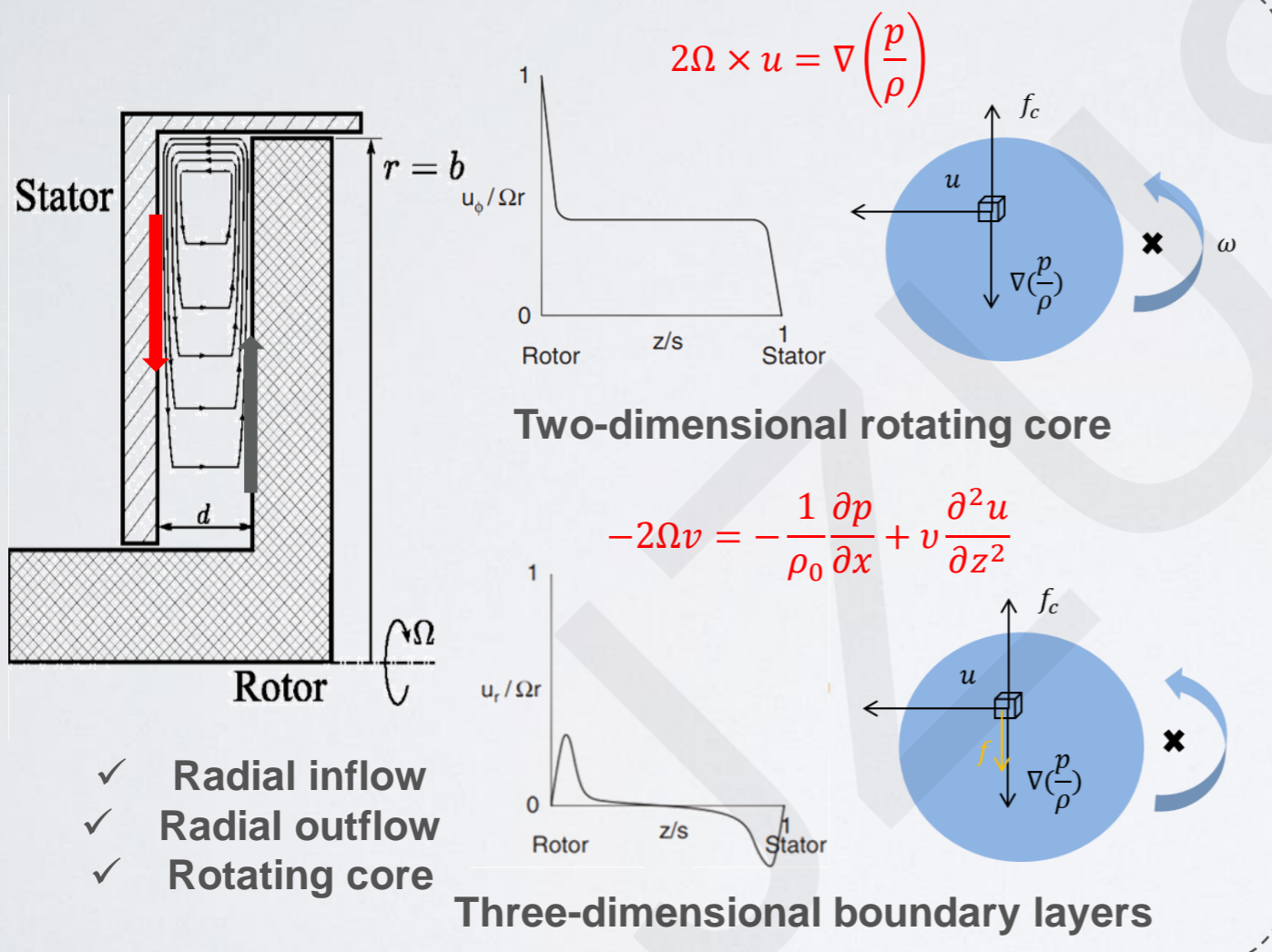
Inevitable rotor-stator gaps to accommodate relative motions, hot gas ingestion, purge air supplied to seal the rim and cool the plate

- **Research aims: complex flow characteristics** and reduced-order modelling of the **turbine cavity**

What challenges are faced?

Basic flow in rotor-stator cavity

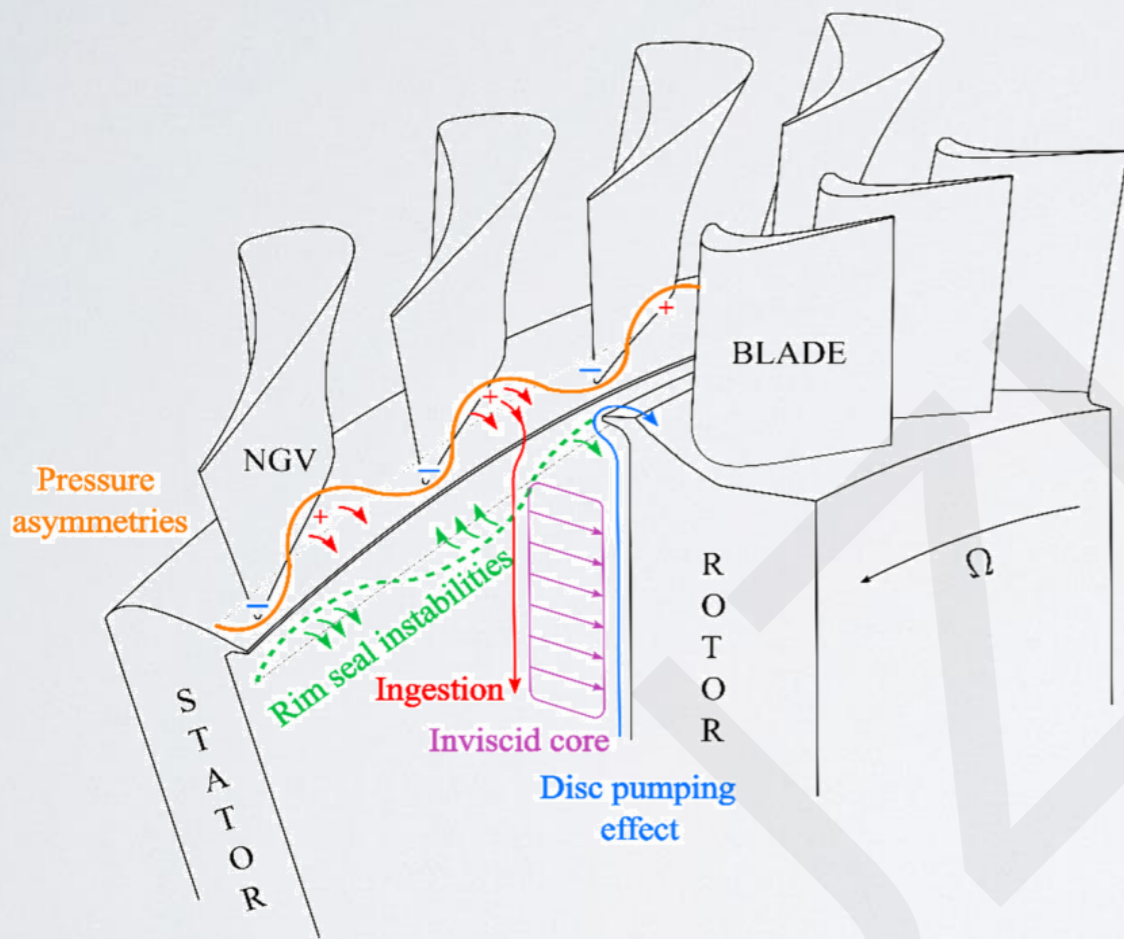
Complex coupled flow in turbine cavity



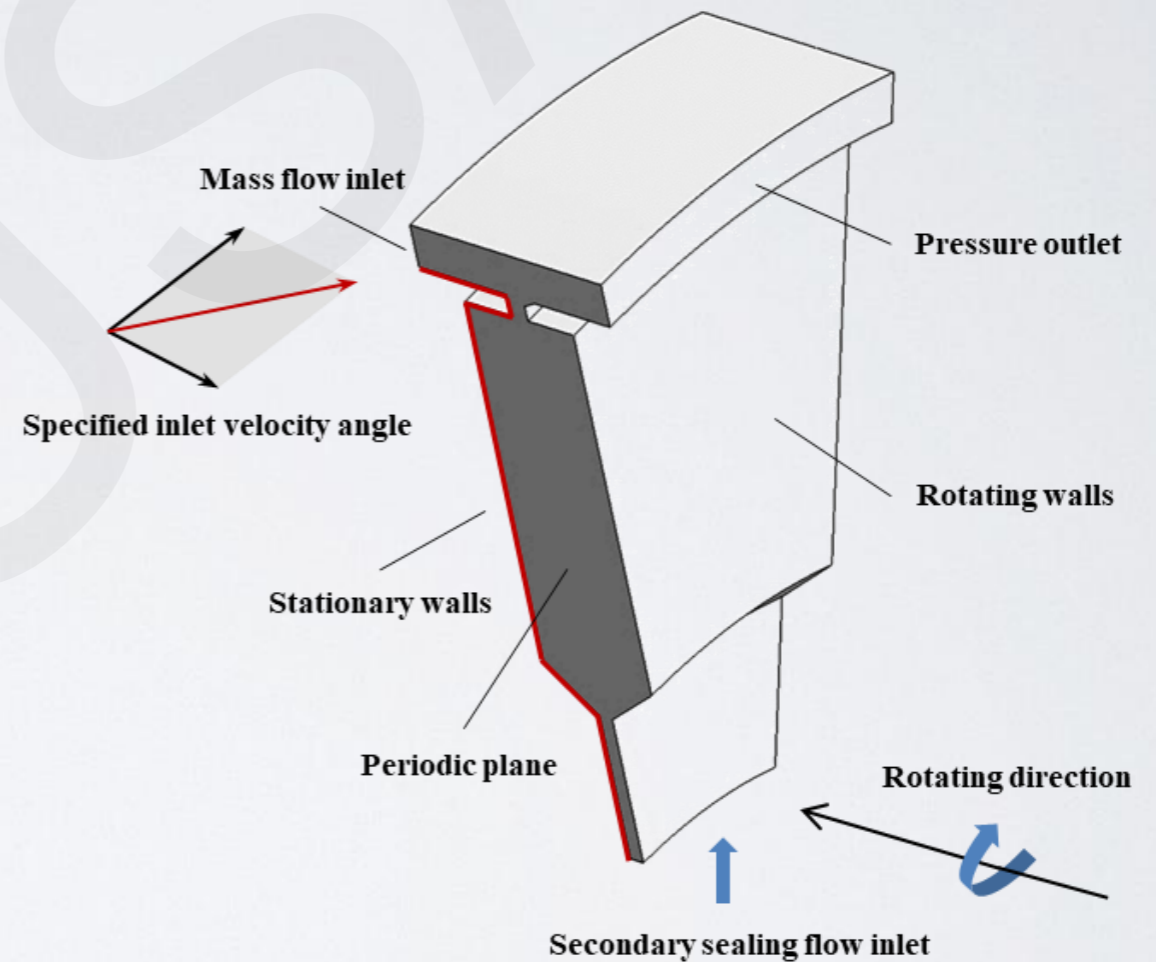
Solution to the challenge

Coupled turbine mainstream flow and cavity

De-couple the pre-swirl effect of the turbine guide

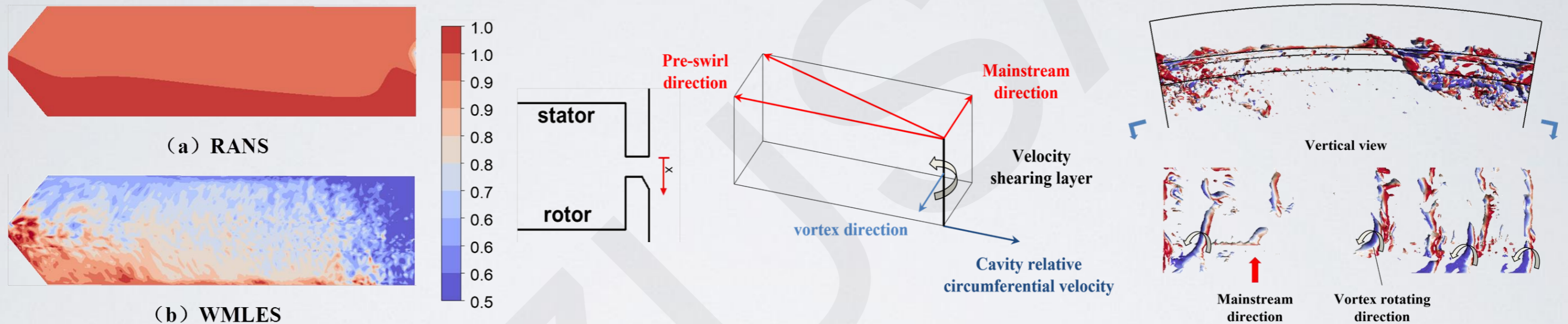


- ✓ Sealing flow
- ✓ External crossflow
- ✓ Crossflow asymmetry



- ✓ Sealing flow
- ✓ External crossflow
- Crossflow asymmetry

Importance of Kelvin-Helmholtz instability in the ingestion

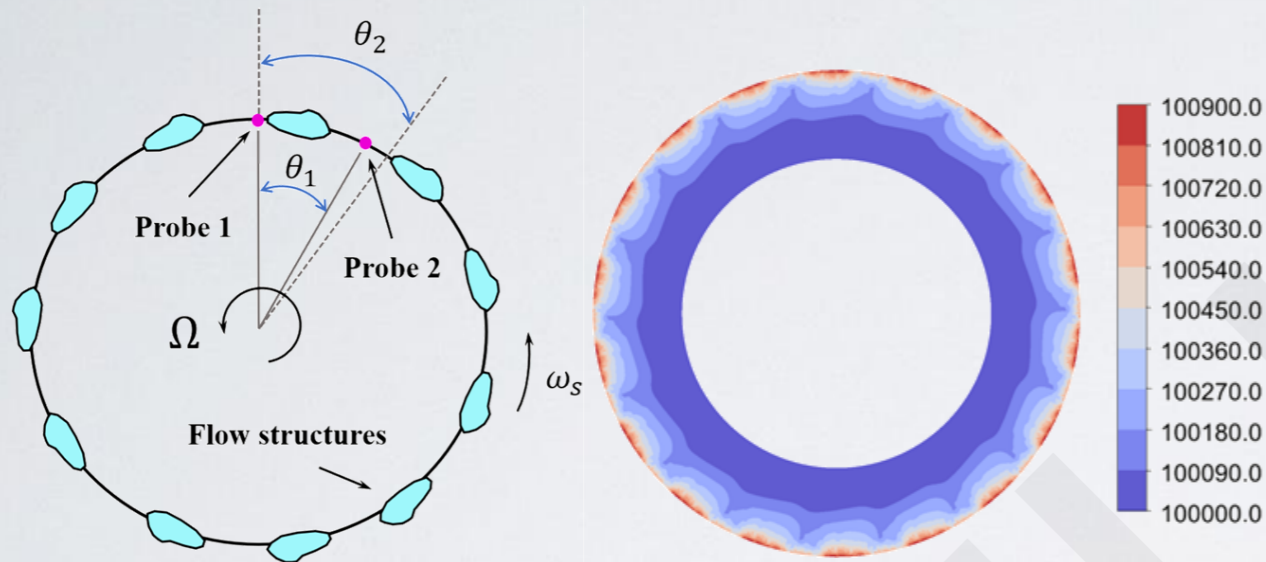


Sealing flow concentration in the cavity

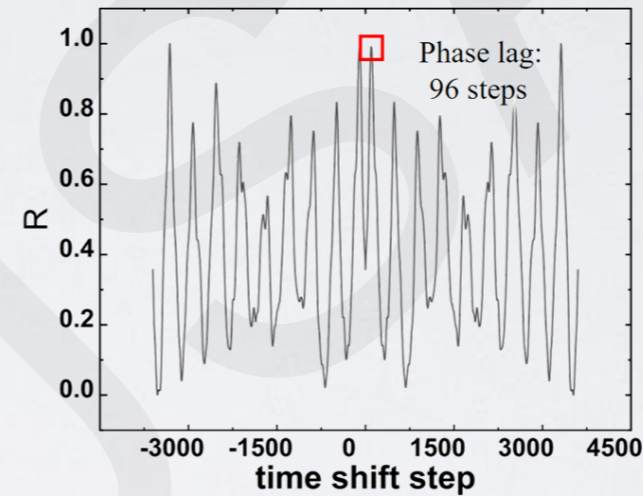
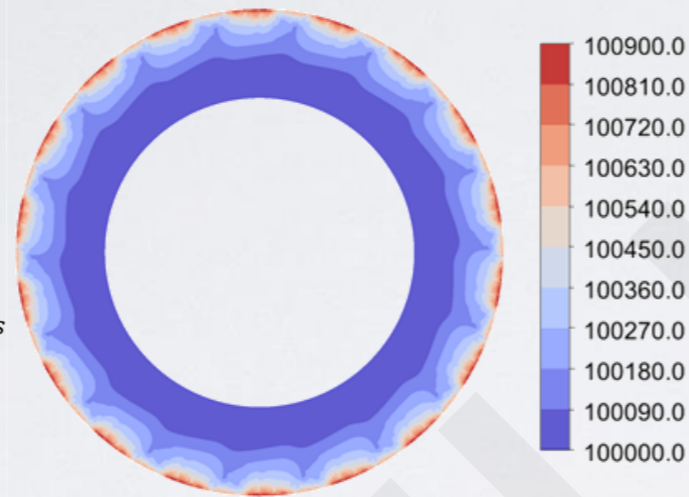
Velocity shearing and K-H vortex observed in the cavity rim region

- *External ingress is drastically underestimated by the RANS approach;*
- *Velocity shearing is observed at the cavity rim due to the guidance of the turbine vane blade;*
 - *K-H instability is induced by the velocity shearing;*
- *Radial inward and outward flow induced by the K-H instability influenced the ingress process.*

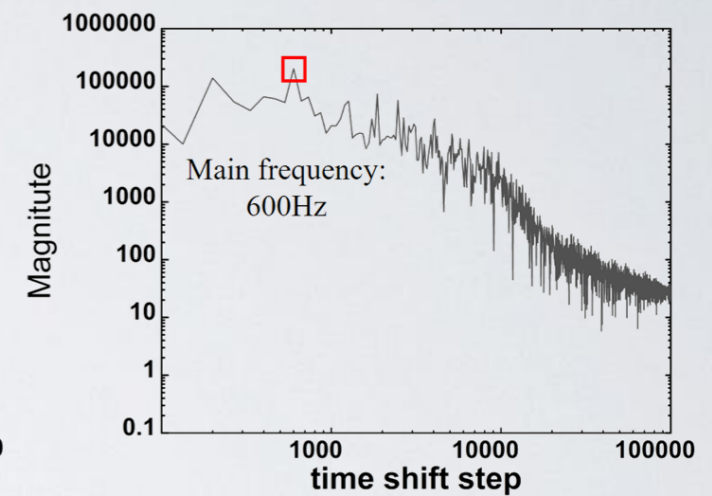
Large scale flow structures inside the cavity



Large-scale flow structures observed in the cavity



Determination of the speed and number of the flow structures



- *Large scale flow structures* are observed in the cavity;
- The *number and speed* of the flow structure lobes can be determined using **phase lag** and **main frequency** of the **pressure oscillations**;
- The **phase lag** between two adjacent structures can be determined **by cross-correlation**, and the **main frequency** of the pressure oscillation is determined by **FFT**.