The air-cooling system for the IDEA Vertex Detector at FCC-ee: thermal performance and vibrational effects

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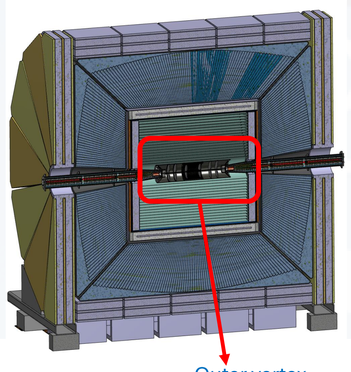
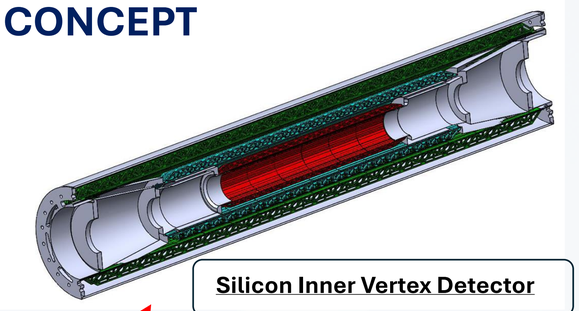
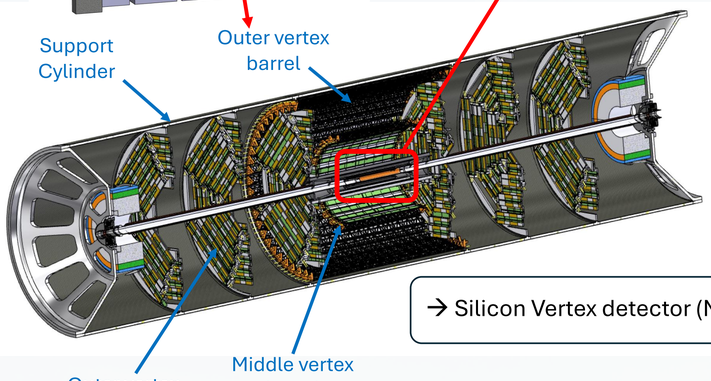
THE IDEA DETECTOR CONCEPT



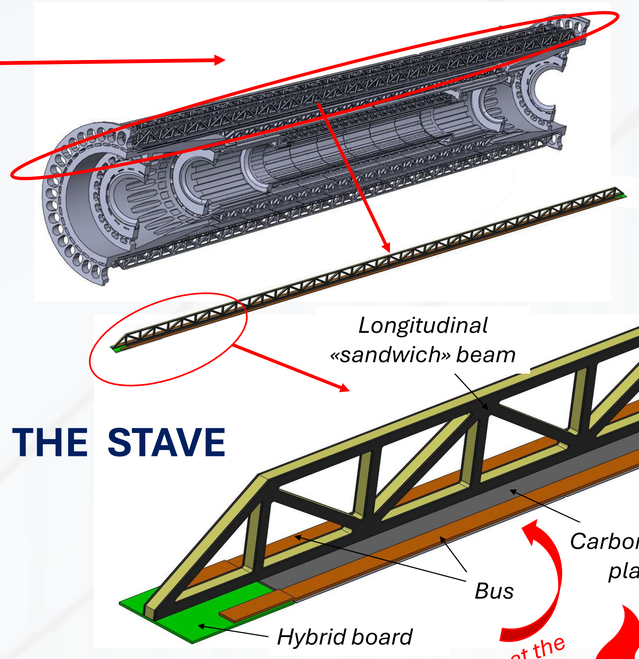


Silicon Inner Vertex Detector

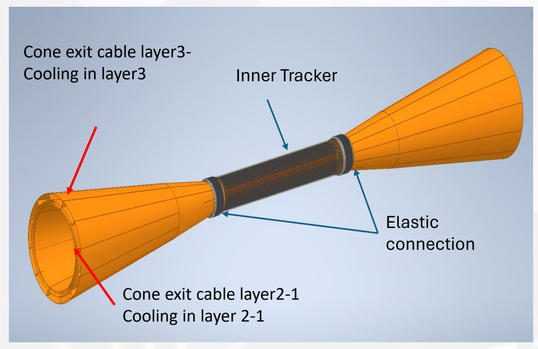


→ Silicon Vertex detector (MAPS)

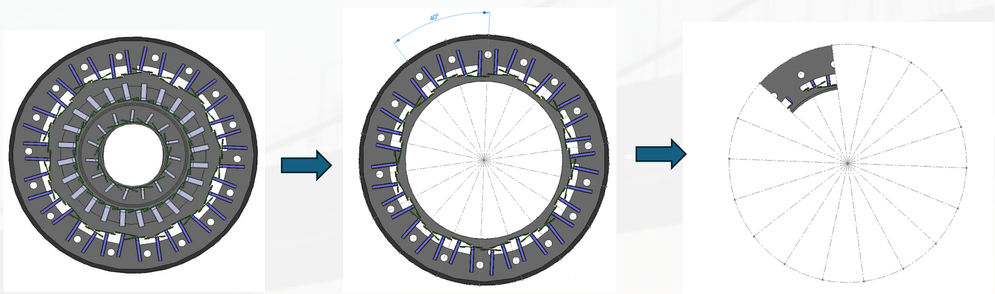
THE STAVE



AIR COOLING CONCEPT



EVALUATING THERMAL PERFORMANCE



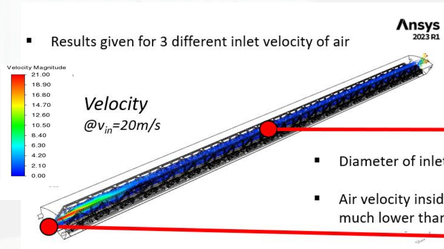
Starting from the full geometry

Removing layer 1 and 2

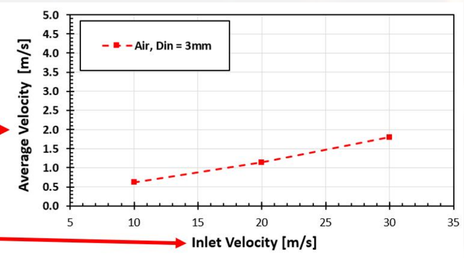
Focus on one sector of Layer 3 (40° circular symmetry)

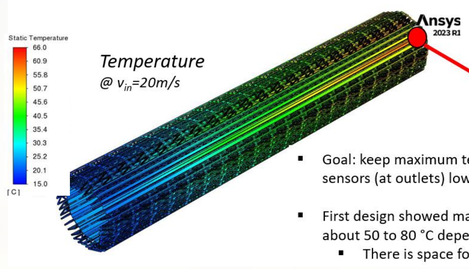
ANALYSIS OF RESULTS

- Results given for 3 different inlet velocity of air

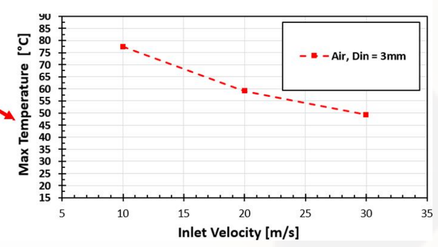


- Diameter of inlet holes D_{in} = 3mm
- Air velocity inside the cylinder much lower than inlets.



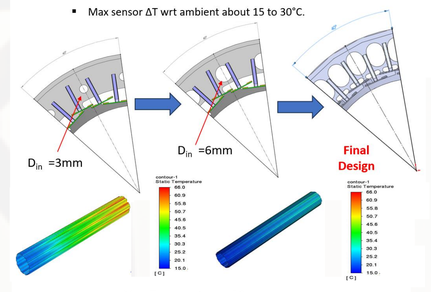


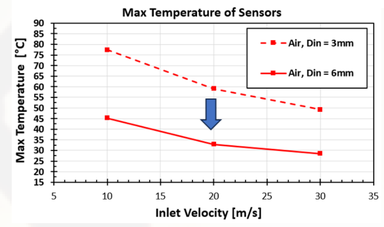
- Goal: keep maximum temperature of sensors (at outlets) low.
- First design showed max temperature about 50 to 80 °C depending on air flow.
  - There is space for optimizations!



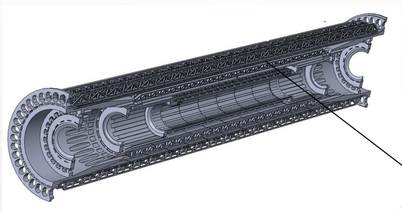
DESIGN OPTIMIZATION

- Increase the diameter for inlets holes.
  - Mass flow rate increase as well (for same v_{in}).
  - Max sensor ΔT wrt ambient about 15 to 30°C.





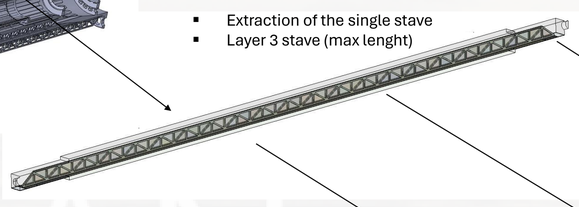
A MULTIPHYSICS MODEL FOR THE EVALUATION OF MECHANICAL STRESS



CAD Model

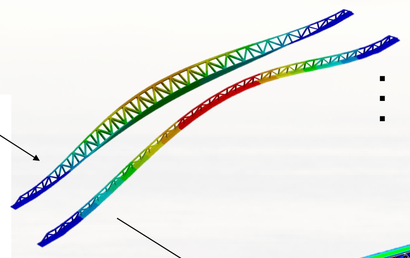
Geometry simplification

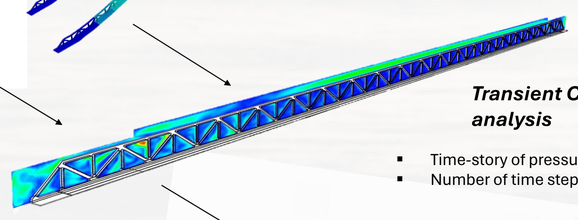
- Extraction of the single stave
- Layer 3 stave (max lenght)



Modal analysis

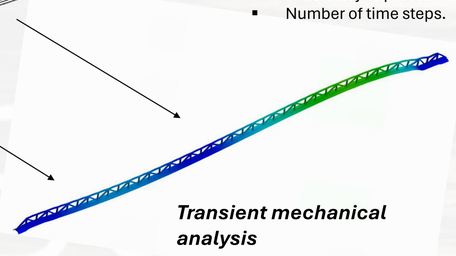
- Participation factors.
- Natural frequencies.
- Duration of time step.





Transient CFD analysis

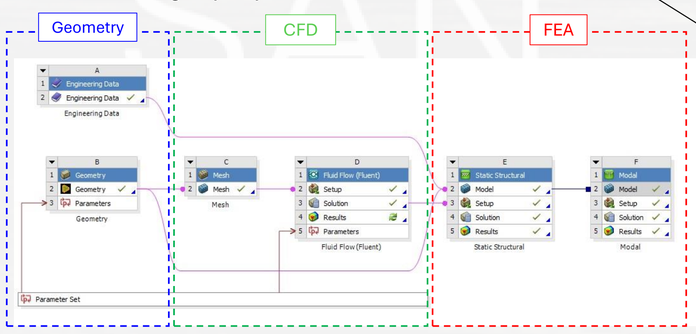
- Time-story of pressure load.
- Number of time steps.



Transient mechanical analysis

- Dynamic displacement

- Flow of data managed by Ansys Workbech

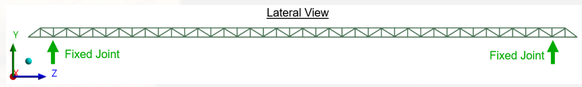


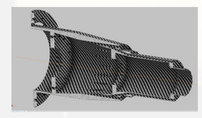
MODAL ANALYSIS

Natural frequencies are used to define the time step:

$$\Delta t < \frac{1}{f_{max} \cdot 10}$$

Support cone (anchoring of each stave) not deforming with time.



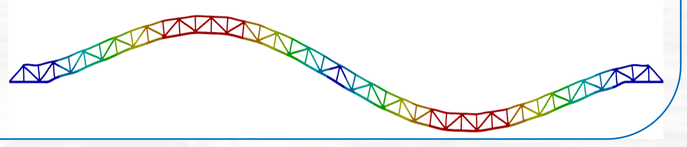


Results

Mode	Frequency [Hz]
1	118.8

Mode	Frequency [Hz]
2	147.1

Mode	Frequency [Hz]
4	292.1

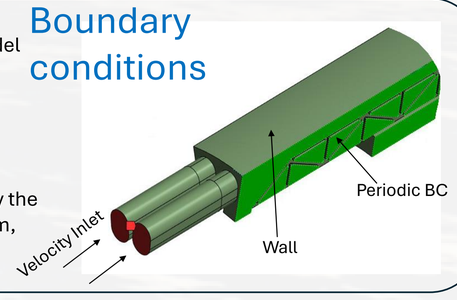


Mode	Frequency [Hz]
5	394.4

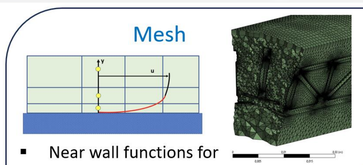
CFD TRANSIENT ANALYSIS

- Re > 4'000 – Turbulent flow
- Viscous model: Large Eddy Simulation (LES) Model
- Average velocity at inlet: V_{in_avg} = 10 m/s
- Turbulence generator at inlet (superimpose 10% turbulence).
  - ➢ Spectral Synthesizer Algorithm
- Time step = 6.8e-4 s
- N° of time steps (Total simulated time) defined by the time a flow particle takes to cross the entire beam, given the RMS velocity of the flow along the axis.
- NOTE: this involve long calculation time!

Boundary conditions

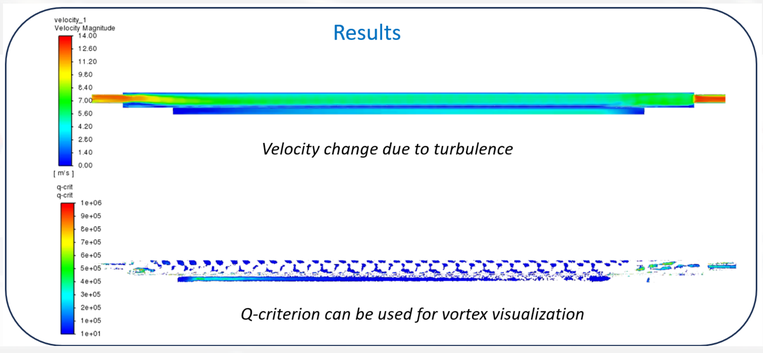


Mesh



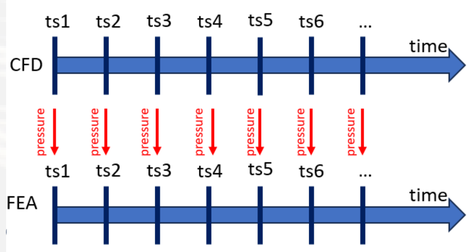
- Near wall functions for viscous sublayer
- Most challenging part of the simulation.
- Is very important to have good inflation at boundary layers.

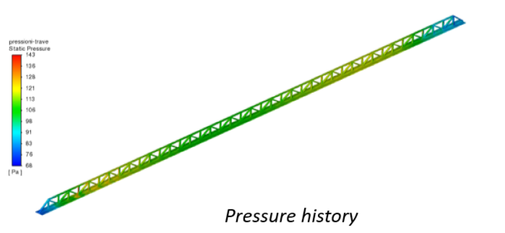
Results



MECHANICAL TRANSIENT ANALYSIS

- Same constrains and materials used for Modal analysis.
- Pressure history is imported from CFD as external load on all the boundary surfaces of the beam.
- Set time step (ts) for FEA simulations the same as for CFD (pressure load is updated each time step).





Pressure history

Maximum displacement magnitude ≈ 1.5 μm @ v_{in} = 10m/s

Y displacement of a point in the middle