CFD Simulations of LHC Experiments

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Abstract

CERN is the European Organization for Nuclear Research, the world's largest particle physics laboratory and the birthplace of the World Wide Web. Its primary objective is to provide the scientific community with facilities to study the sub-nuclear particles and forces of matter. Most of the activities at CERN are currently directed towards building a new particle accelerator and collider, the Large Hadron Collider (LHC) and the detector experiments for it. Construction of these experiments requires an extraordinary engineering effort and the CFD Team of TS/CV/DC Section has been asked to develop numerical simulations of thermal-fluid related problems, particularly during the development, design and construction phases of the LHC experiments. The poster focus on studies performed for the experiments currently being built to run on the collider, for example, a 2D transient simulation of the thermal behaviour of ATLAS cavern and a 3D steady-state natural convection study of the ALICE Muon magnet.

1. CFD Applications at CERN

AT CERN, a parallel commercial CFD code is used to provide assistance to the LHC machine and detectors during the prototype, design and installation phases of their components. Most investigations involve prediction of velocity and temperature fields in natural convection environments. Since May 2005, the CFD Team at CERN can rely on the high performance of a dual, Intel Itanium®, 64 bits processor cluster named Openlab (www.cern.ch/openlab) to produce compute-intensive computational fluid dynamics simulations. Availability of the Openlab cluster increased up to eight times the performance of the CFD simulations, reducing the delivery time and increasing the accuracy of the studies.

2. ALICE L3 Magnet

https://edms.cern.ch/document/692019/1
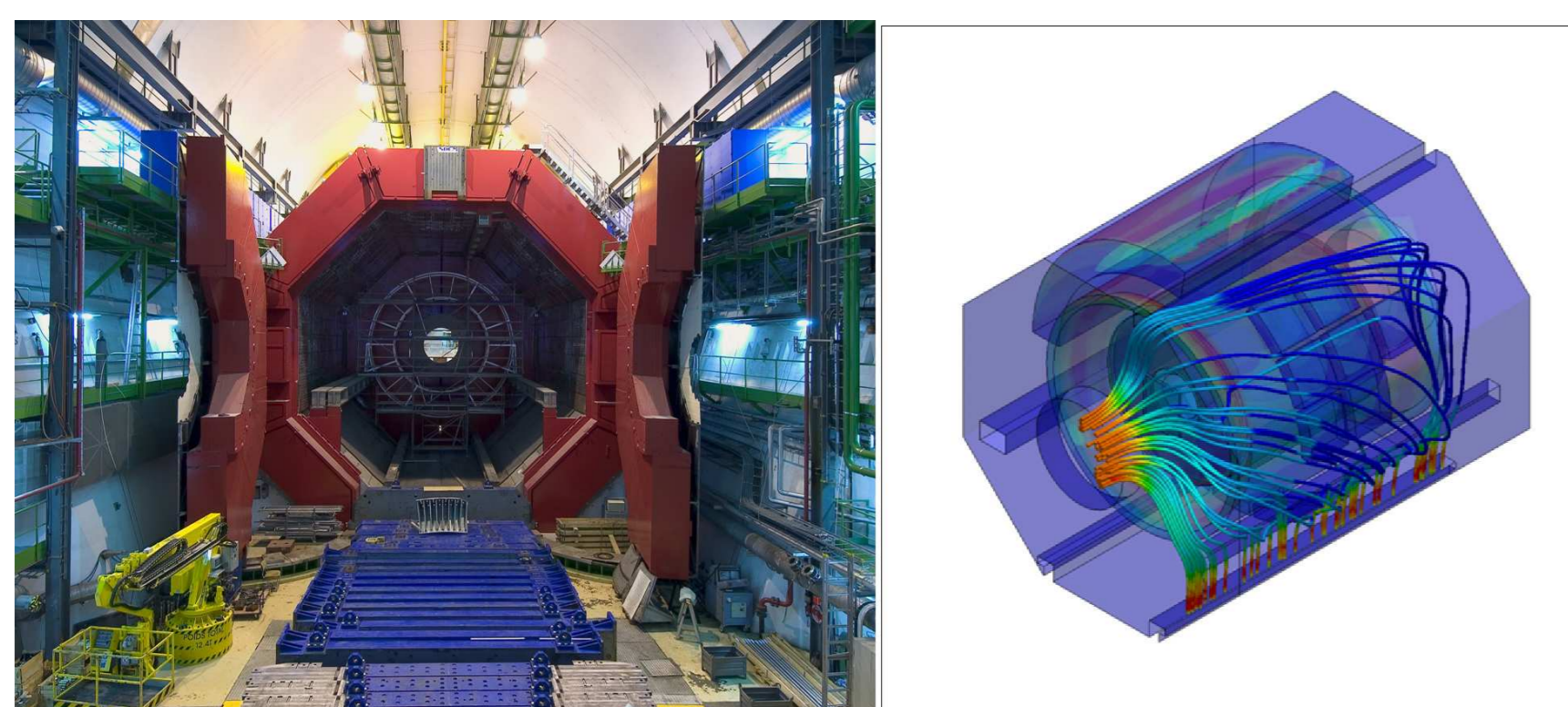
Problem: The L3 magnet is a large volume enclosing a number of heat dissipating devices. To achieve optimal particle measurements, the air temperature inside the magnet must be uniform and within a specified limit.

Objective: To optimise the flow and temperature fields of the air inside the L3 magnet in order to improve mixing and obtain uniform temperature conditions.

CFD Model: 3D, transient, $k - \epsilon$ model, no solid parts included, buoyancy effect, heat sources, ~500.000 trimmed cells.

Results: Revealed presence of hotspots; provided an understanding of the flow distribution indicating that tuning of the ventilation system was necessary; through a number of parametric studies it was possible to find the best ventilation configuration capable not only of improving mixing but also of achieving more uniform temperature conditions.

Calculation Time: Each casestudy required ~12 hours of CPU time on 6 Openlab cluster machines.

3. CNGS Horn

https://edms.cern.ch/document/492210/4

Problem: Particle energy deposition on the horn system and its shielding will heat up these structures so that a dedicated ventilation system has been designed.

Objective: To evaluate the performance of the designed ventilation system to cool down the horn system and determine the temperature map of the horn and its close environment.

CFD Model: 3D, transient, $k - \epsilon$ model, buoyancy effect, heat sources, ~1.000.000 tetrahedral cells.

Results: The proposed ventilation system was found to be inefficient so that a number of modifications were introduced and the cooling process improved.

Calculation Time: Each casestudy required ~3 days of CPU time on 6 Openlab cluster machines.

4. ALICE Dipole Magnet

https://edms.cern.ch/document/692478/1
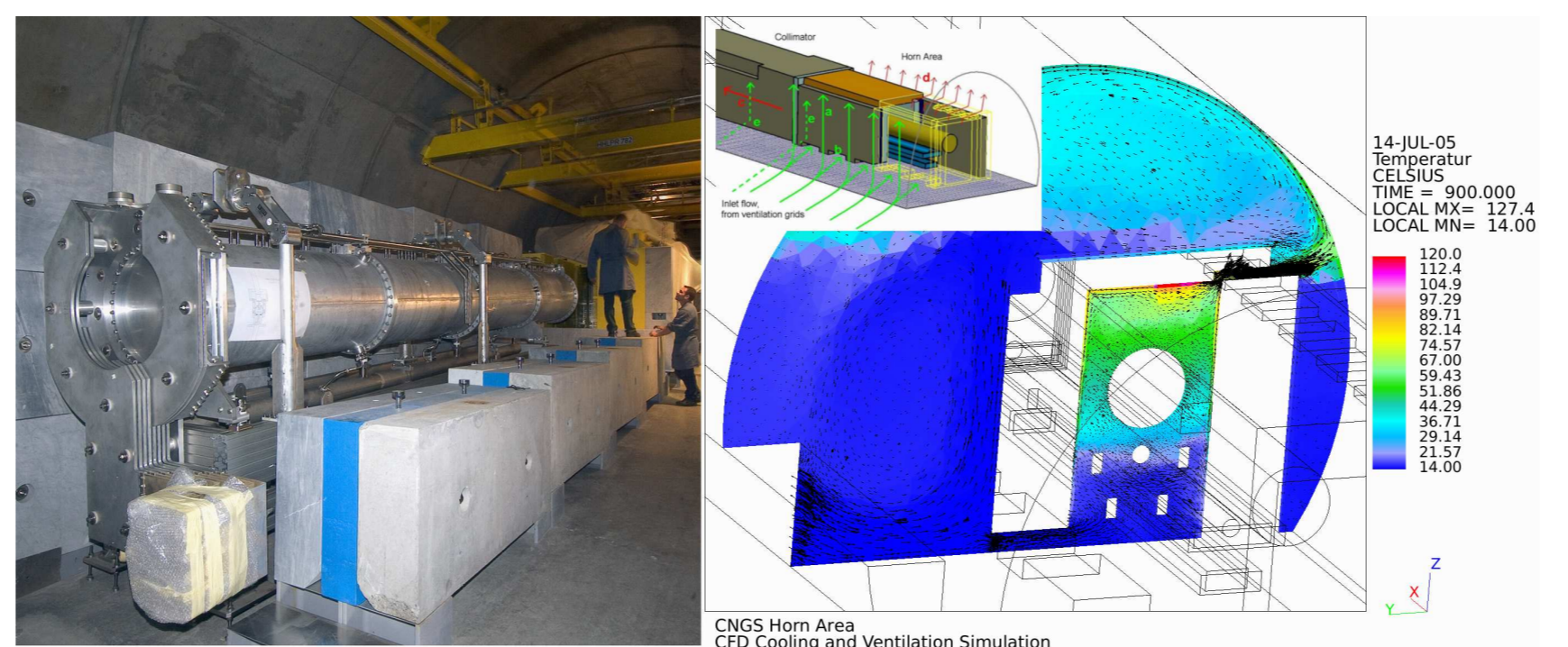
Problem: Dipole magnet dissipates heat by Joule effect which is not totally removed by the dedicated water cooling system currently in place. For optimal working conditions of its enclosed components, temperature within the magnet cannot exceed a specified limit.

Objective: To evaluate the overall heat loss from the coils, yoke, supports to air and the temperature field around the magnet.

CFD Model: 3D, steady-state, $k - \epsilon$ model, half geometry including solid parts, buoyancy driven flow, radiation effect, ~700.000 tetrahedral cells

Results: Demonstrated that the dedicated water cooling system in place is adequately designed since temperature inside the magnet is well within the acceptable operational levels so that no extra insulation was required for the coils.

Calculation Time: Each casestudy required ~7 days of CPU time on 6 Openlab cluster machines.
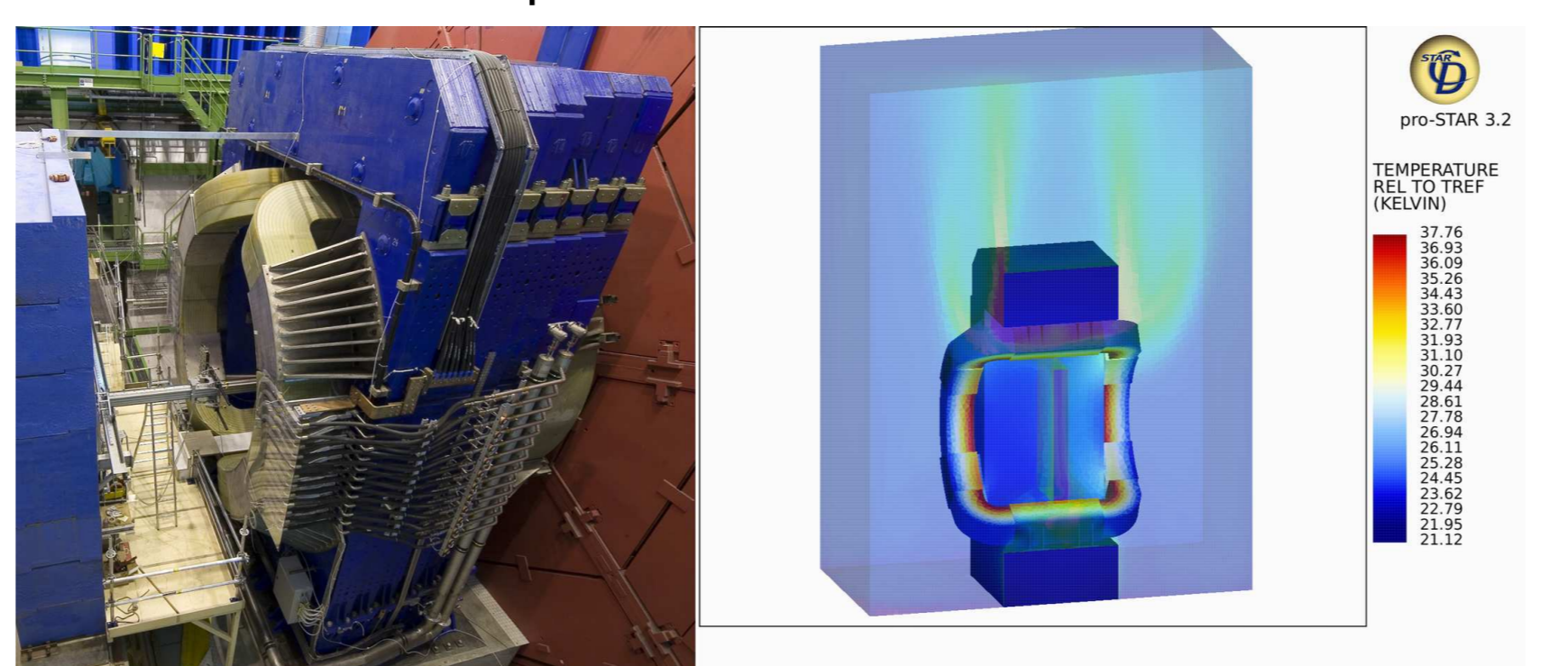
5. ATLAS Muon Chambers and Cavern

https://edms.cern.ch/document/592555/2

Problem: For optimal operational conditions of the detecting chambers, the temperature and velocity gradients must be minimised in regions around the detector which are packed with electronic equipment dissipating heat to the surrounding environment.

Objective: To find temperature and flow distributions around the detector.

CFD Model: 2D, transient, $k - \epsilon$ model, convection as main heat transfer mode, buoyancy effect, heat sources, cavern ventilation system taken into account, ~250.000 non-uniform hexahedral cells.

Results: Showed stratification of temperatures around the detector and location of hotspots, particularly in the topmost chambers. As a consequence thermal screens will be placed in these regions to reduce the maximum temperature spots.

Calculation Time: Overall study required ~7 days of CPU time on 8 Openlab cluster machines.

6. LHCb PS VFE Board

https://edms.cern.ch/document/685527/1
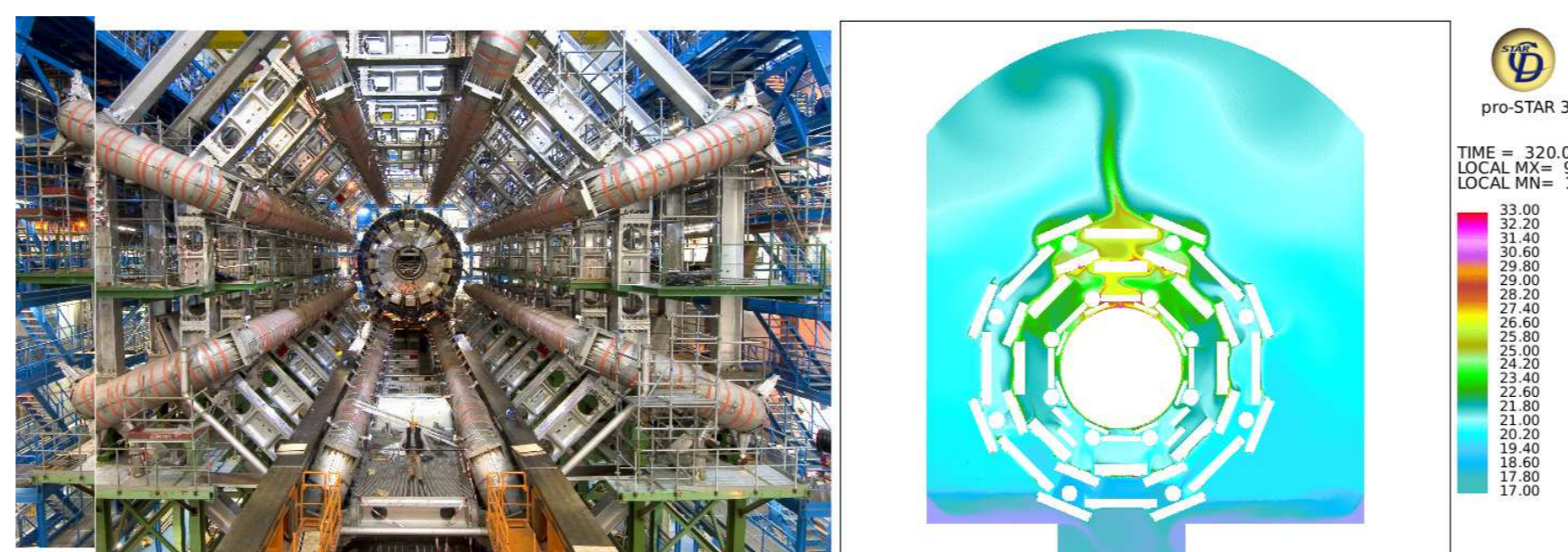
Problem: The PS VFE board is a small electronic, heat dissipating device mounted in the LHCb experiment. Because of construction and material properties constraints, the PS VFE board requires a dedicated cooling system to maintain maximum temperatures within a specified limit.

Objective: To study the thermal behaviour of the board when cooled down by two different systems, one using air and the other water as the cooling fluid.

CFD Model: 3D, transient, $k - \epsilon$ model, solid parts included, heat sources, ~500000 non-uniform hexahedral cells.

Results: The air cooling solution was found to be more expensive and less effective than the water cooling system.

Calculation Time: Each casestudy required ~6 hours of CPU time on 6 Openlab cluster machines.

7. GLOBE

https://edms.cern.ch/document/624346/1
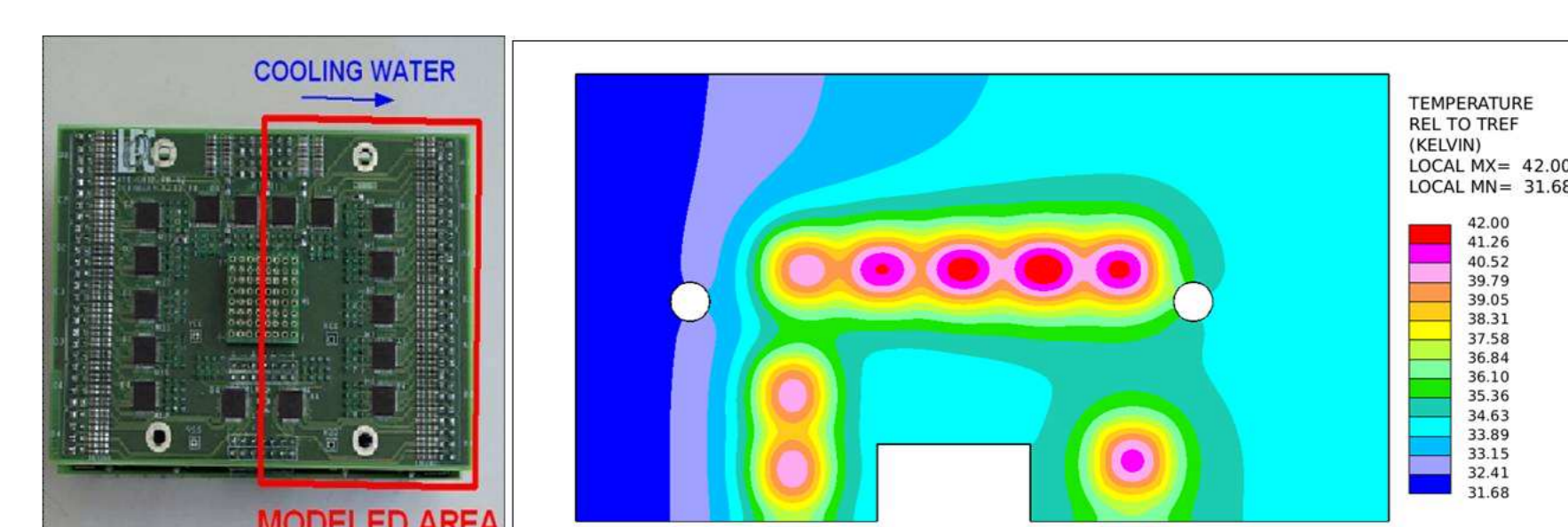
Problem: In view of issuing the necessary authorisation term for usage of the Globe of Science and Innovation as CERN's exhibition centre, the building needs to comply with established fire safety regulations in what concerns the placement of window openings at the dome to aid smoke and heat evacuation.

Objective: To evaluate the effectiveness of current emergency strategies to control heat and smoke spread in the event of a fire in the building.

CFD Model: 3D, transient, $k - \epsilon$ model, only first floor hall considered, buoyancy effect, heat source, ~500.000 tetrahedral cells.

Results: Indicated temperature stratification at the dome as a consequence of a fire development in the hall. Placement of hatches at the top region of the dome was found to provide improved evacuation of the hot gases accumulated.

Calculation Time: Each casestudy required ~7 days of CPU time on 4 Openlab cluster machines.
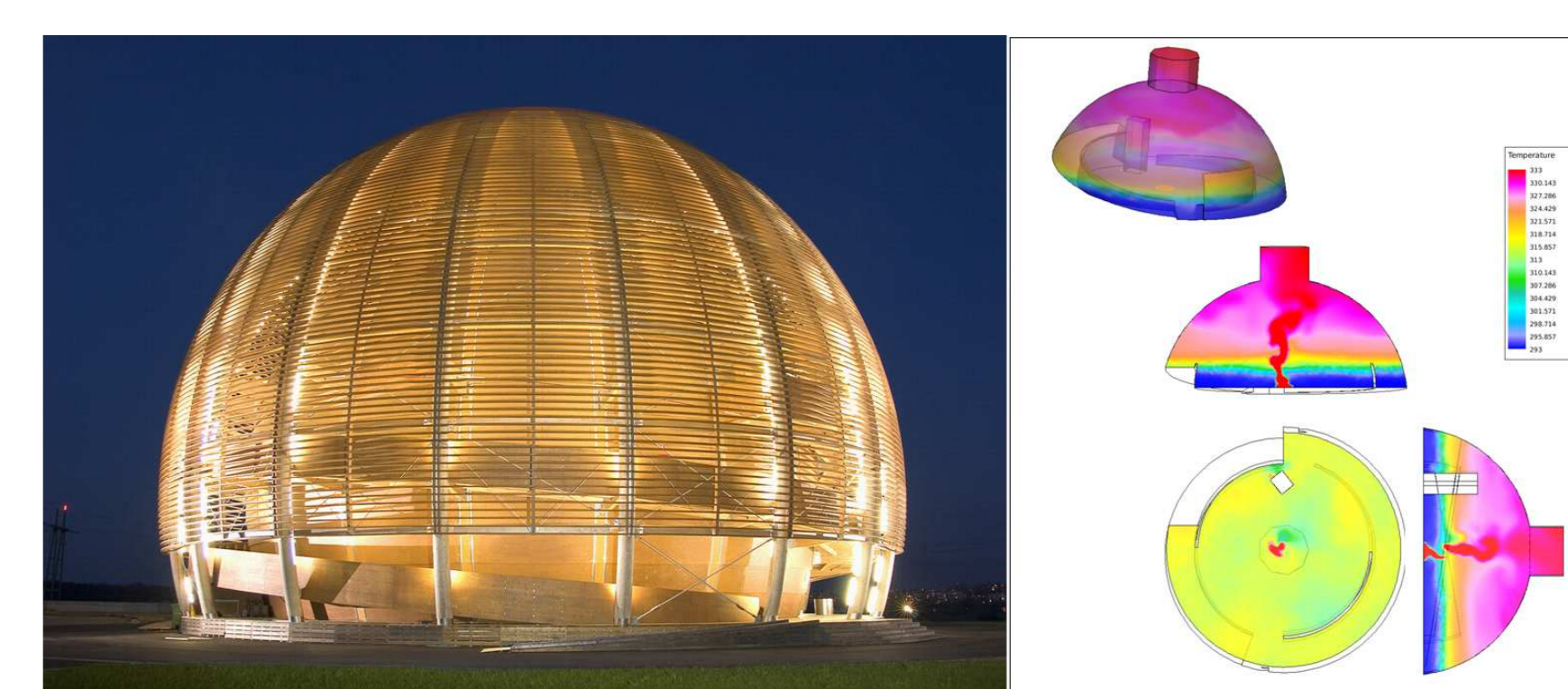
8. CFD Team

THE CFD Team is part of the Detector Cooling (DC) Section of the Cooling and Ventilation (CV) Group in the Technical Support (TS) Department at CERN. Our mission is to provide engineers, physicists and scientists working on all CERN units, with flow and thermal analysis using CFD tools and methods to solve fluid flow and heat transfer related problems.

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