

DE LA RECHERCHE À L'INDUSTRIE



# THERMAL MANAGEMENT SOLUTIONS WITHIN THE MECHANICAL ENGINEERING DESIGN



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*On behalf of: IRFU/SIS/LCAP*

*LCAP: The Mechanical Design Office*

[www.cea.fr](http://www.cea.fr)



*Double Chooz ALICE Edelweiss HESS Herschel CMS*

*Detecting radiations from the Universe*

- Thermal management is considered early on in the mechanical design:
  - Evaluation of the heat sources (drafting phase)
  - Integration of the adequate *cooling* solution if necessary consistent with the system specification
  - Consideration of the heat transfer on sensitive components such as electronics
  
- The solution for heat evacuation depends on:
  - The heat source and the adequate cooling strategy:
    - Radiation, « warm » or cryogenic cooling, convection (gaseous or liquid, natural or forced), ...
  - The environment: volume for integration, critical areas & access
  - Cost and reliability
  
- The thermal study is conducted:
  - Primarily with numerical tools & multi-physics simulations (ANSYS, CASTEM, OPENFOAM, SATURNE, SYRTHES...)
  - Experimentally: prototyping, tests on system components, characterization of relevant properties...

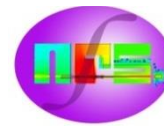


- *Ongoing thermal studies within the IRFU's mechanical design office:*

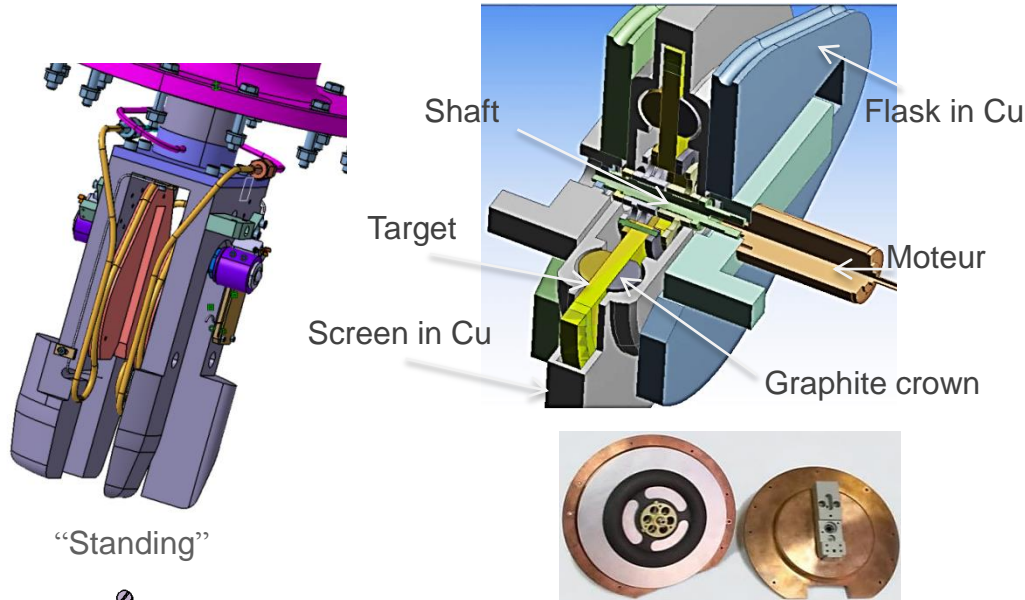
- NFS: Neutron For Science in SPIRAL2 experiments
- CTA: Camera for the large Cherenkov Telescope Array
- ESS: The Radio Frequency Quadrupole in European Spallation Source experiments
- S3BD: The Super Separator Spectrometer Beam Dump in SPIRAL2 experiments

- *Developments & Perspectives within the Lab:*

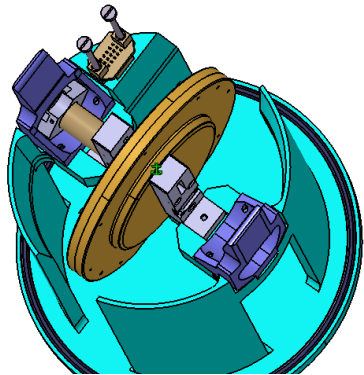
- Introduction of new software: Tests and Benchmarking
- R&D and Academic Collaborations:
  - MISSMEHT (MicroSurface Structuring in Minichannels for Enhanced Heat Transfer)



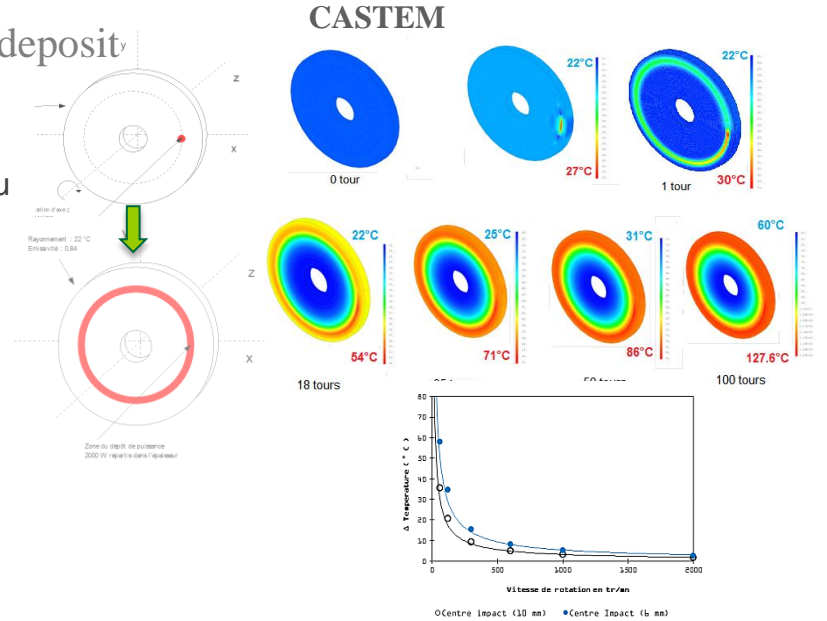
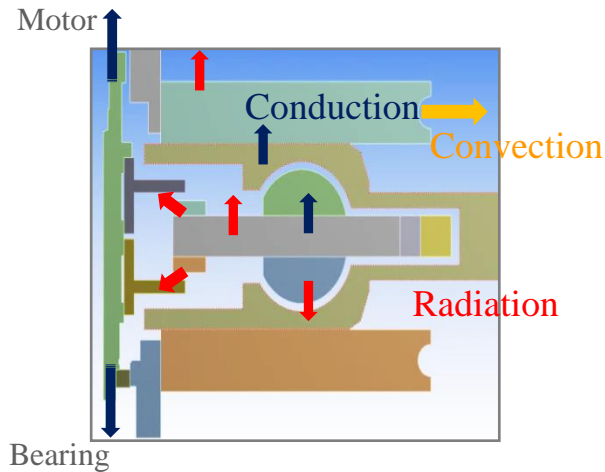
- Design of a converter system withstanding 2kW heat deposit



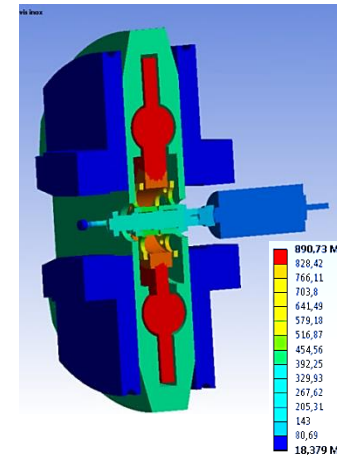
“Standing”



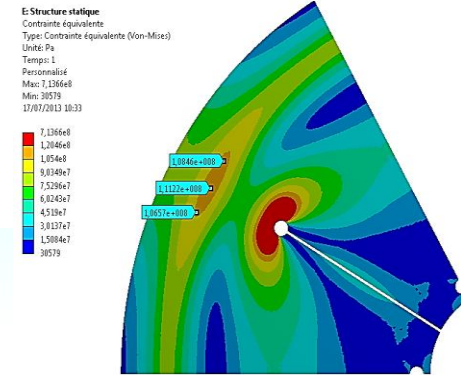
“Exchangeable”



Target Rotation velocity vs. Temp gradient

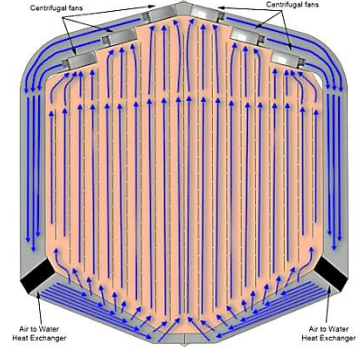
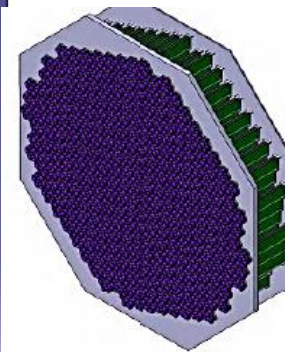
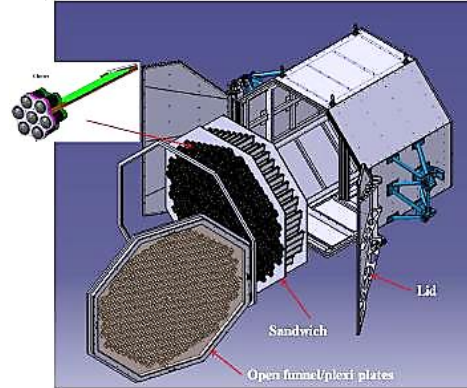
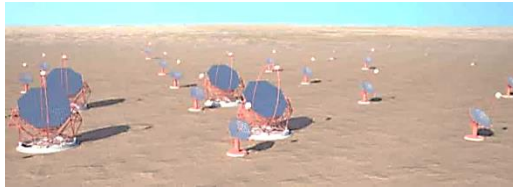


Assembly temp. field



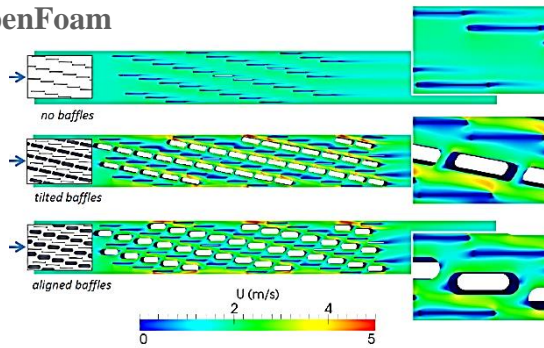
Optimization of the thermal stresses on target

- Optimization of the cooled air circulation within the camera to control the overall temperature gradient  $< 8^{\circ}\text{C}$  (a total 4kW heat deposit from )

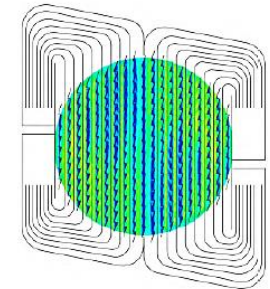
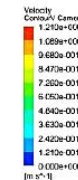
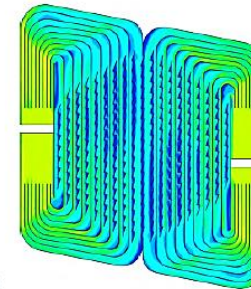


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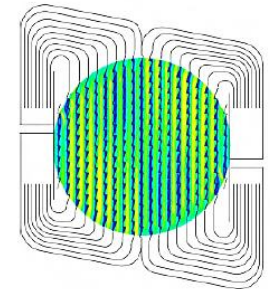
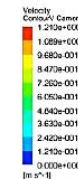
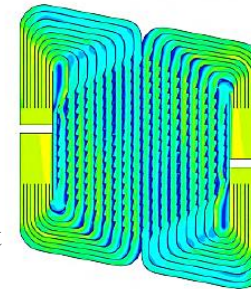
OpenFoam



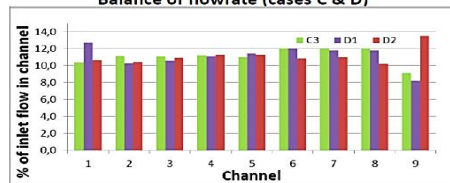
model D1



model D2



Balance of flowrate (cases C & D)

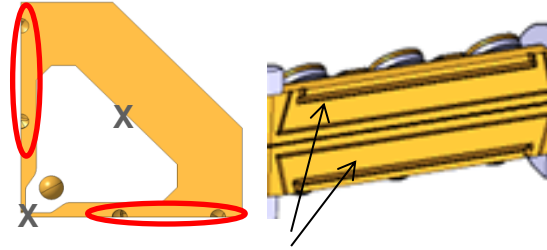


Air circulation through the different «channels»: Validation with experimental data

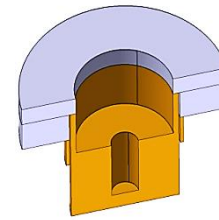
- Geometrical deformation of the internal cavity  $\sim 10\mu\text{m}$  for a heat input of 50kW



4,8m RFQ with 5 sections



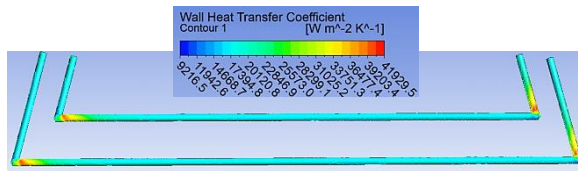
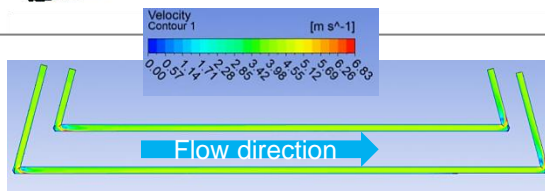
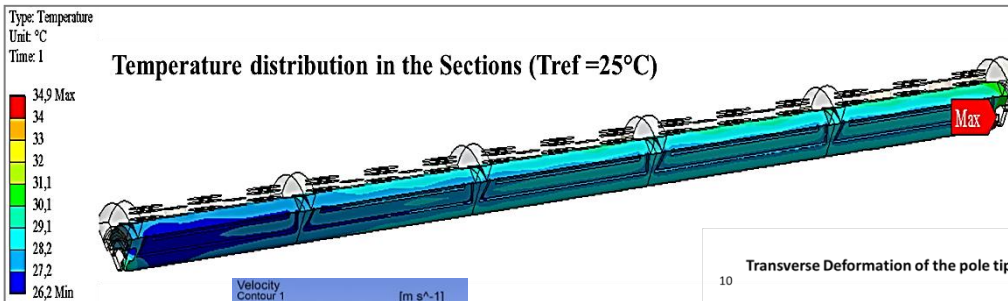
Body and vane channels



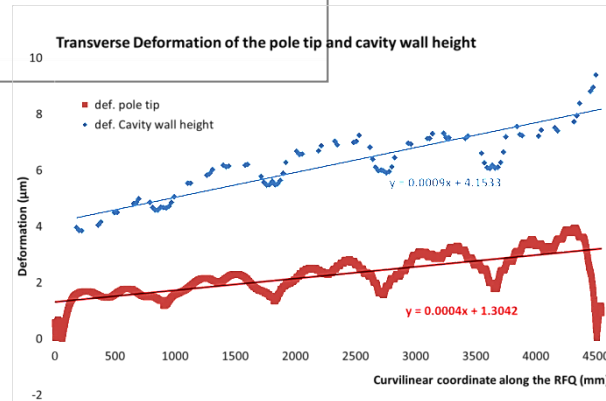
Piston



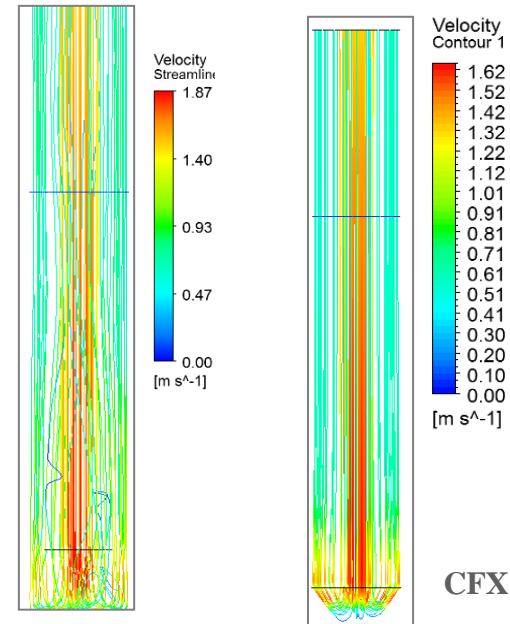
## HFSS-ANSYS: 3D simulations



Heat transfer Coeff.

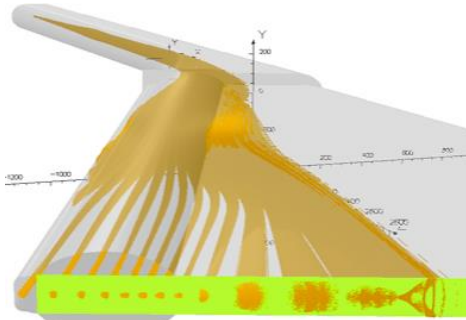


Vane and cavity deformation

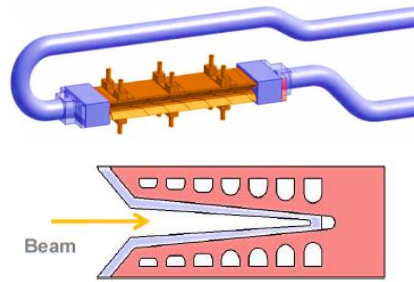


Optimisation of coaxial tubes

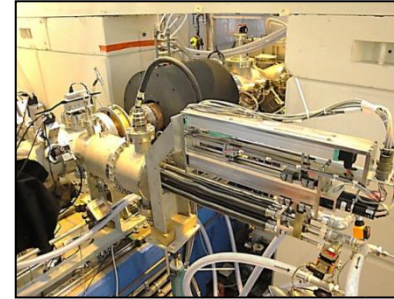
- Design components of a 10mm width stopping a 1kW heat deposit equivalent to a peak of 5kW/cm<sup>2</sup>  
<=> preserving the integrity of the fingers for 20years!



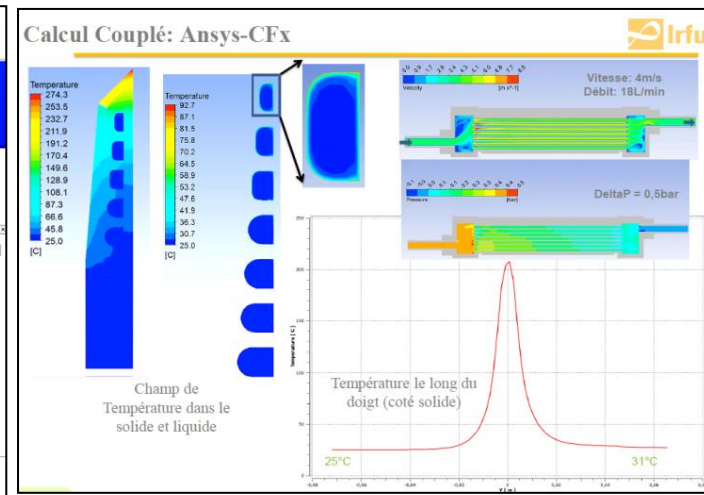
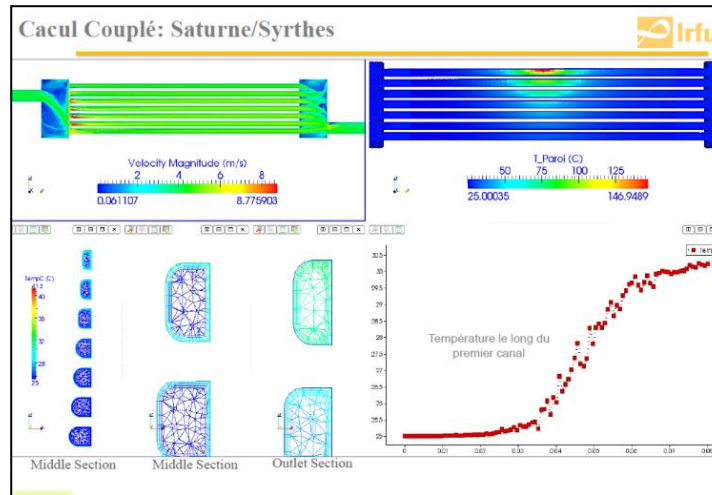
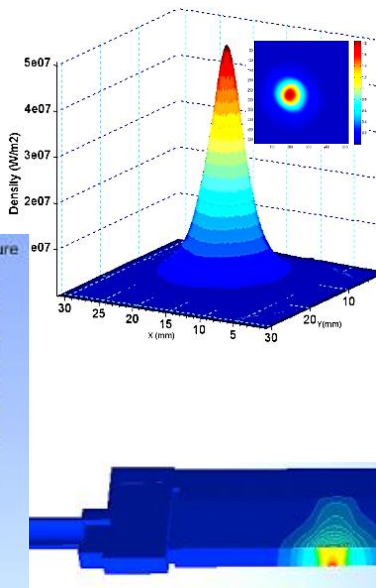
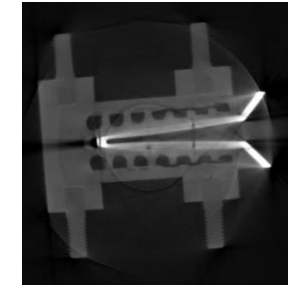
Beam dynamics in S3



Mini-channels cooling technology

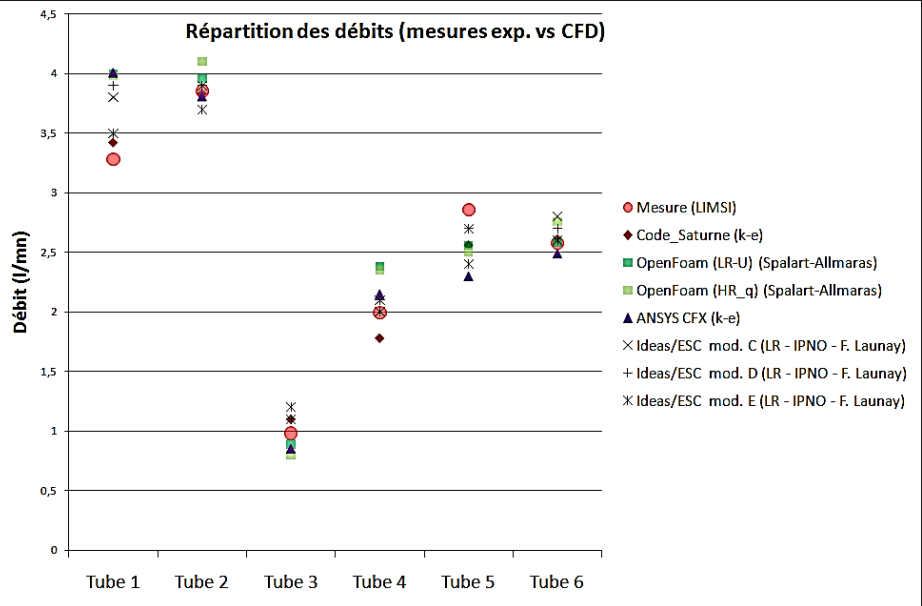
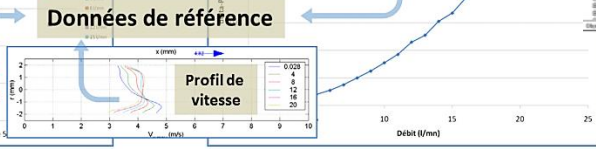
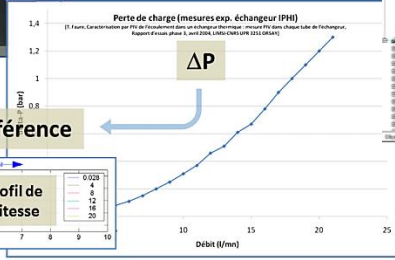
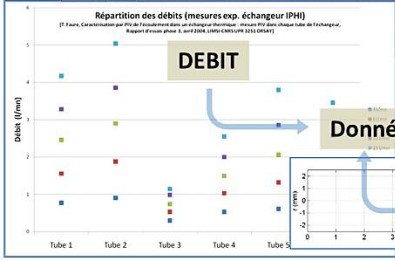
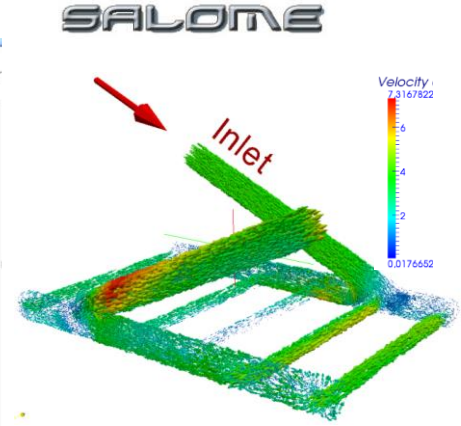
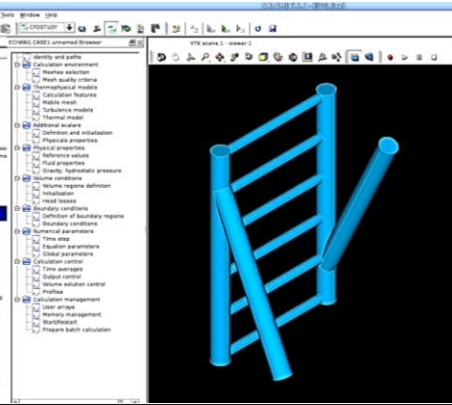
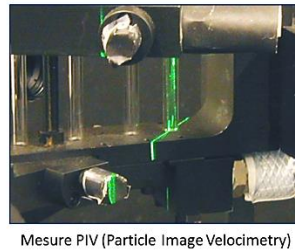
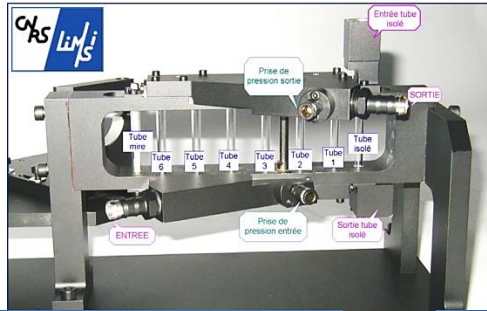


Prototyping and testing on SILHI@ IPHI (SACM)



Optimization of channels disposition & definition of the operating conditions (CHT)

→ Comparative Analysis for various CFD Solvers (CFX, code\_Saturne et OpenFoam)



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OpenFOAM

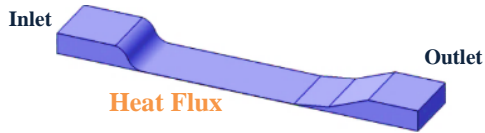




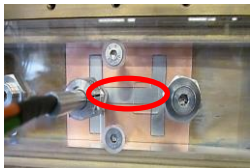
## LNCMI/LEGI



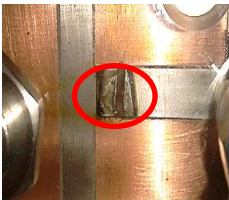
Experimental test bench



Mini-channel (2D)



©P. Sinistro 2014  
LNCMI

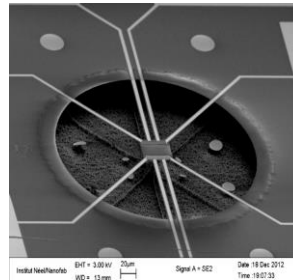
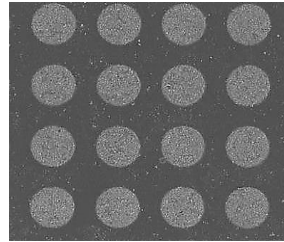


Heating up to  $1\text{ kW/cm}^2$  possible

Experimental testing  
& Instrumentation

1/19/2015

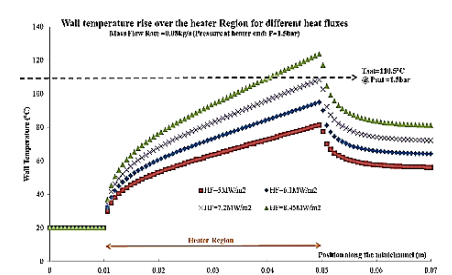
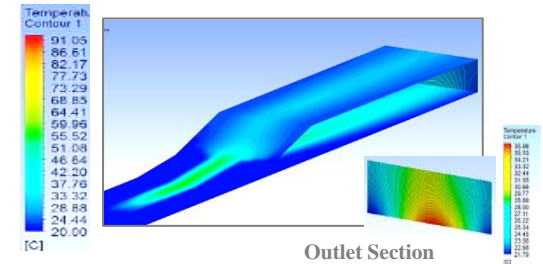
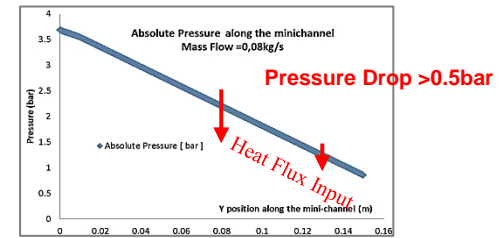
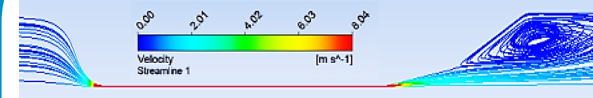
## LEGI/Néel



Micro-surface structuring

Acoustic Detection  
testing for Nucleate  
Boiling (IRFM)

## CEA/LEGI



Numerical Development  
Code\_Neptune / TRIO\_U

- Illustration of various levels of advanced studies applied to the thermal management in systems:
  - Similar approaches found in other disciplines:
    - Vibration (Euclid)
    - Multi-scale approaches (CoCascope & NSW)
  - Introduction of various numerical platforms and methods:
    - Optimize the licenses' pool
    - Ensure the reactivity and the flexibility
    - Homogenize procedures: HFSS-ANSYS, WPMAG (DEMO)
    - Stem collaborations and partnerships: CEA-DEN, CEA-IRFM, CNRS-LEGI
  - Strong experimental feedback is part of the numerical development:
    - Prototyping & Destructive and Non-Destructive testing
    - Planning of commissioning phases and project feedback
  - Fostering further research activities:
    - Anticipate the scientific and technological needs for IRFU's projects
    - Promote hosting PhD candidates, publishing & patents