14.5 Mechanical and thermal tools for innovative calorimeters

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Task 1: Precision mechanics for calorimeter structures ***(CIEMAT)***

Task 2: Infrastructure to evaluate thermal properties of calorimeter structures

2.1 Cooling system to test thermal modelling of large CF (carbon fiber) structures *(LPSC)*
2.2 Cooling system for low power calorimeter readout electronics *(DESY)*

Institute	Contact person	Contact person e-mail	Activities	EU Funding
CIEMAT	Mary-Cruz FOUZ	mcruz.fouz@ciemat.es	Task1	Beneficiary
CNRS-LPSC Grenoble	Denis GRONDIN	grondin@lpsc.in2p3.fr	Task2	Beneficiary
DESY	Felix SEFKOW	Felix.Sefkow@desy.de	Task2	Beneficiary
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14.5 Mechanical and thermal tools for innovative calorimeters

Task 1: Precision mechanics for calorimeter structures ***(CIEMAT)***

Introduction

Mechanical (absorber) structure of **sampling calorimeters** must be **robust** and **compact** with **as less as possible dead spaces** (lateral and longitudinally)

It can be built by assembling together **absorber plates and spacers** that guarantee the space needed to insert the active detectors.

Good accuracy of plate planarity (~1mm) and spacer thickness (~50µm) allow reducing tolerances needed for the safe insertion (and eventual extraction) of the detectors.
➔ minimize the dead spaces and reduce the radial size view (important when located inside a coil)

The assembly of **absorber plates and spacers** can be done using:

➔ **Bolts**

Big bolts are needed to support the big weight of the structure

➔ biggest lateral size of the spacer

➔ **Increase lateral dead zones between prototype modules**

➔ **Welding**

➔ Allows to **decrease the lateral size of the spacer** ➔ **Less dead zone**

➔ Could introduce **deformations**

Different possible welding methods can be considered
The most precise

Electron beam welding:
The **best** but it **needs vacuum conditions** and not clear how affordable it is for big modules

Planned activities

WP14.5-Task 1	Precision mechanics for calorimeter structures (CIEMAT)

Goal

To investigate the suitability of the electron beam welding technology for very precise absorber mechanical structures for highly compact imaging calorimeters

Deliverable : **D14.7 (Month 42)**

To design and build a mechanical absorber structure with ~5 long plates using beam welding

The deliverable will be **based** in the **SDHCAL design for the ILD @ ILC**

Deliverable characteristics

Plate dimensions:

15mm thickness

~1m x ~2.5m

(limited by the CERN beam welding machine)

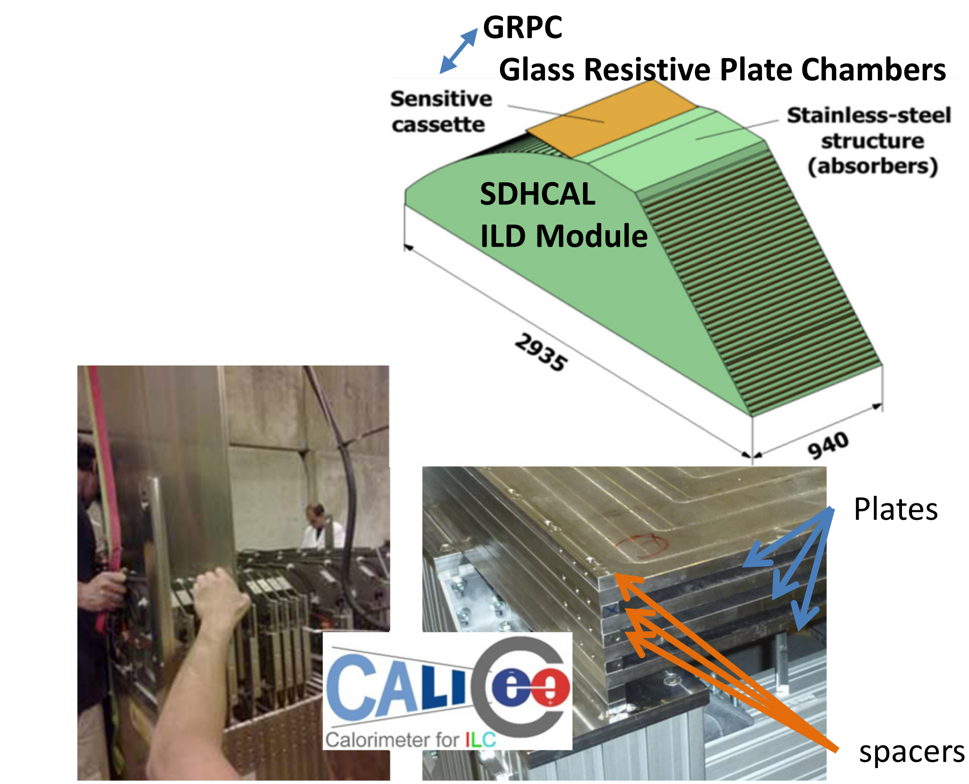
Spacers thickness:

~13mm

(GRPC+ cassette box=11mm, developed by IN2P3-Lyon)

Material:

Inox AISI 304 (stainless steel – non magnetic)



Vertical insertion of GRPCs in the ~1m3 SDHCAL mechanical structure built using bolts

Working plan

1) **Design** of the **structure** and associated **handling tools**

2) **Construction**

2.0 Construction of **handling tools**
2.1 The structure will be **pre-assembled** using smaller bolts (to fix the position of the plates) **at CIEMAT**
2.2 **Verification** of the **dimensions**
2.3 **Electron beam welding at CERN**
2.2 **Verification** of the **dimensions at CIEMAT** to check the **deformations**
➔ **Report of results**

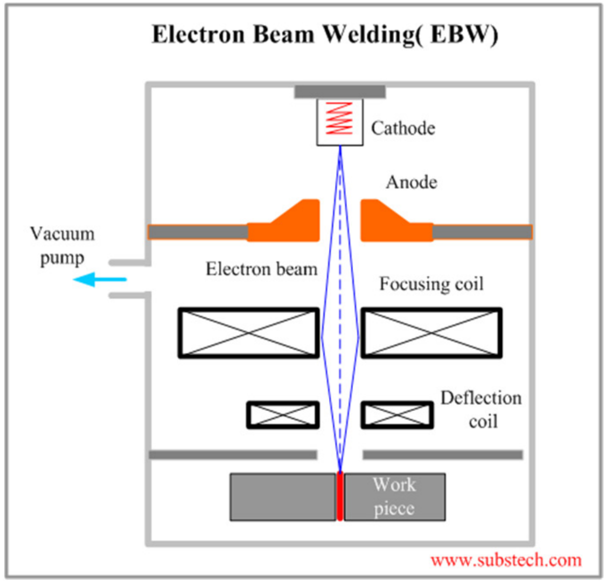
Before the assembly of the final big structure tests on smaller ones are planed following a similar planning as described before

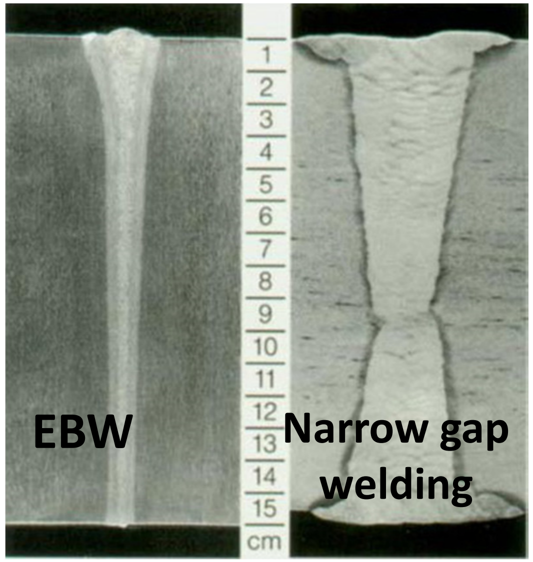
Tests are ongoing and some results are already available.

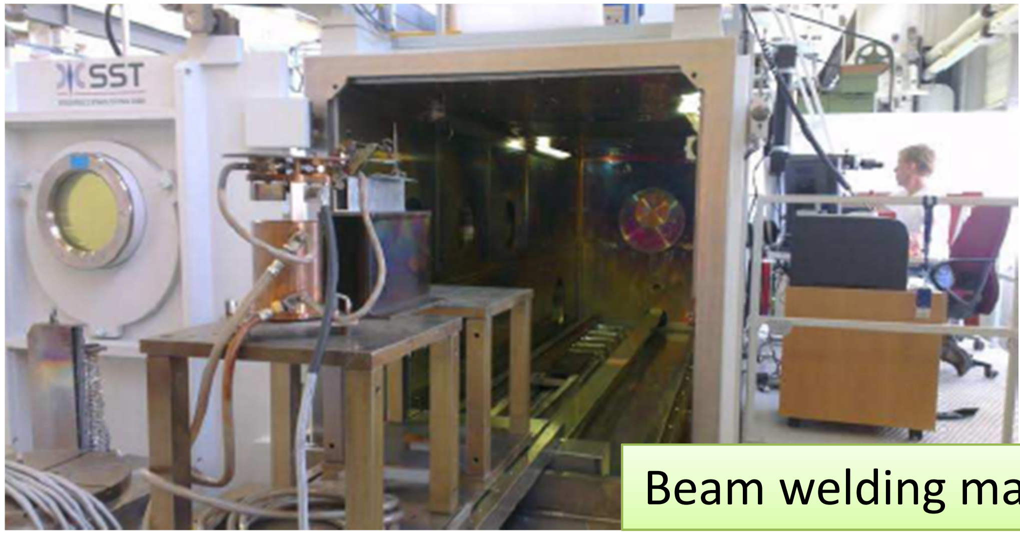
Actual background & available equipment
Electron beam welding

Collimate electron beam
➔ Very **narrow welding**
➔ **Less deformations**

Vacuum conditions needed

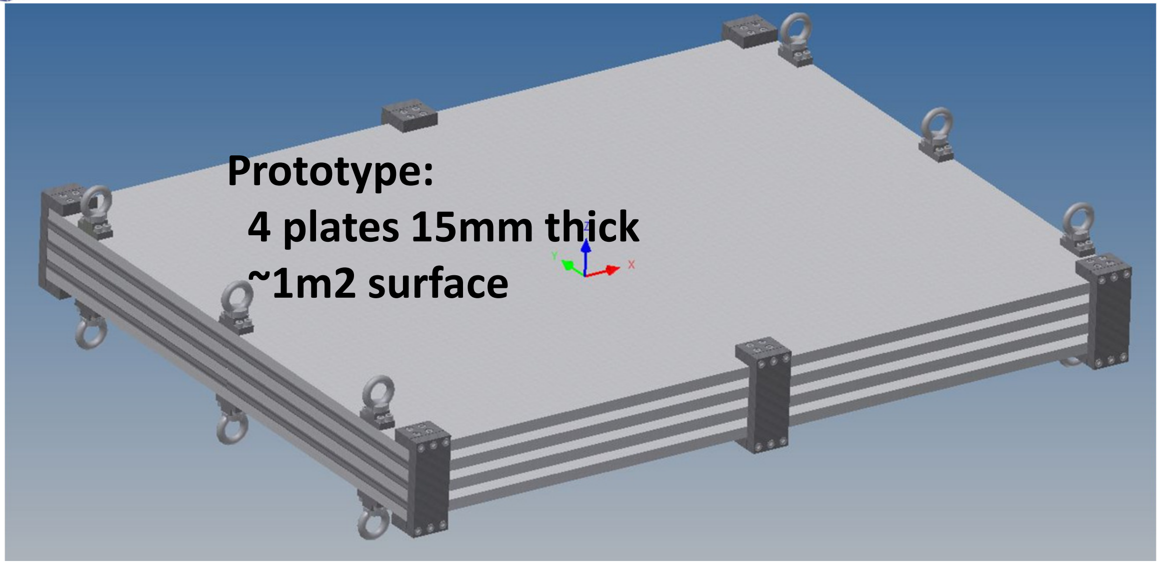


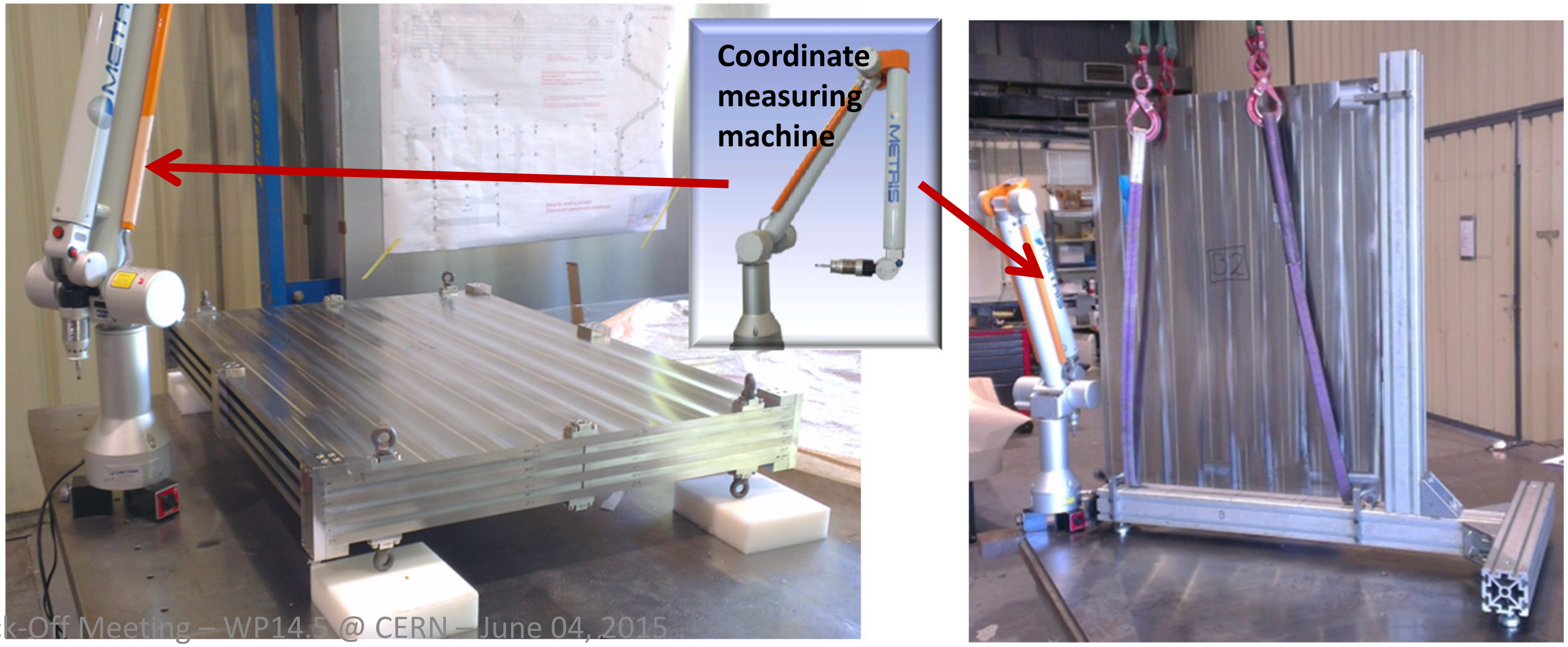




Beam welding machine @ CERN

Actual background & available equipment
~1m^2 Prototype assembly & verification @ CIEMAT





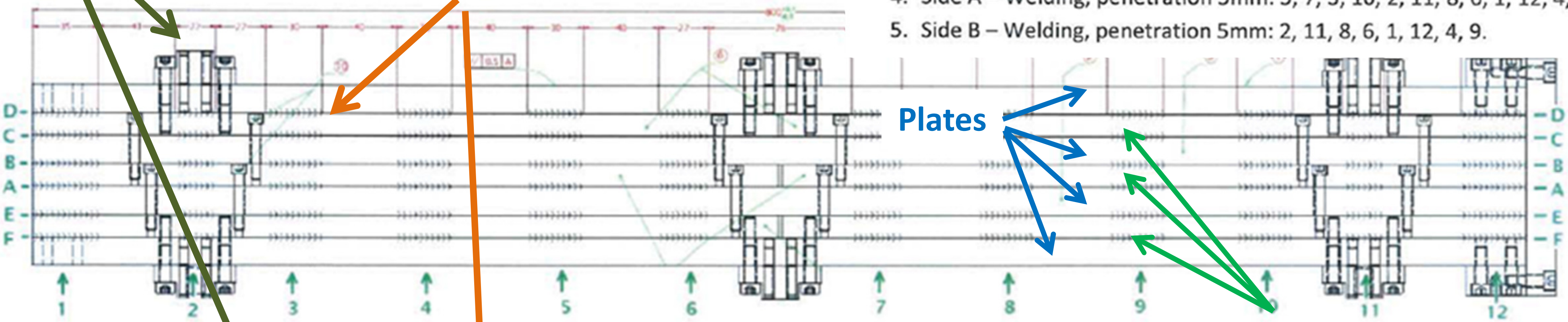
1m^2 Prototype welding @ CERN

The welding sequence has been the following:

1. Side A – Tack welding, penetration 2mm: 6, 1, 12, 4, 9.
2. Side B – Tack welding, penetration 2mm: 6, 1, 12, 4, 9.
3. Side B – Welding, penetration 5mm: 5, 7, 3, 10.
4. Side A – Welding, penetration 5mm: 5, 7, 3, 10, 2, 11, 8, 6, 1, 12, 4, 9.
5. Side B – Welding, penetration 5mm: 2, 11, 8, 6, 1, 12, 4, 9.

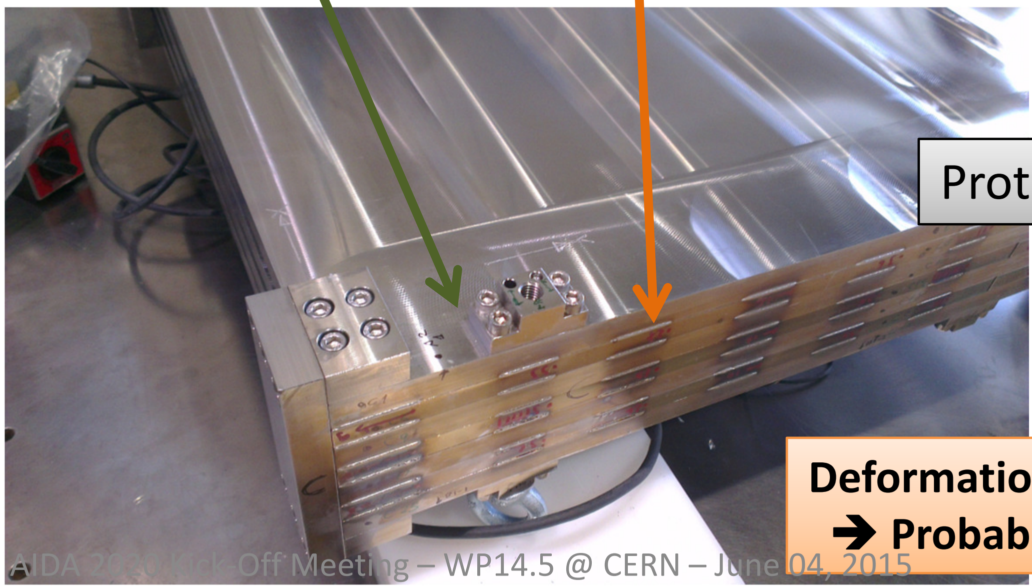
Bolts to fix the plates and spacers for further welding

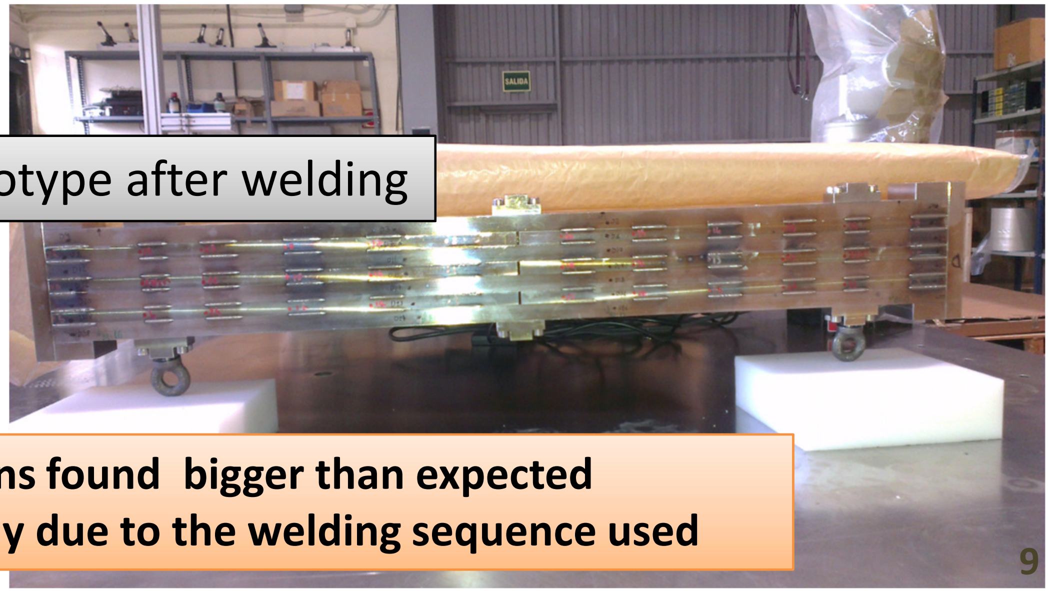
Welding points



Plates

Spacers





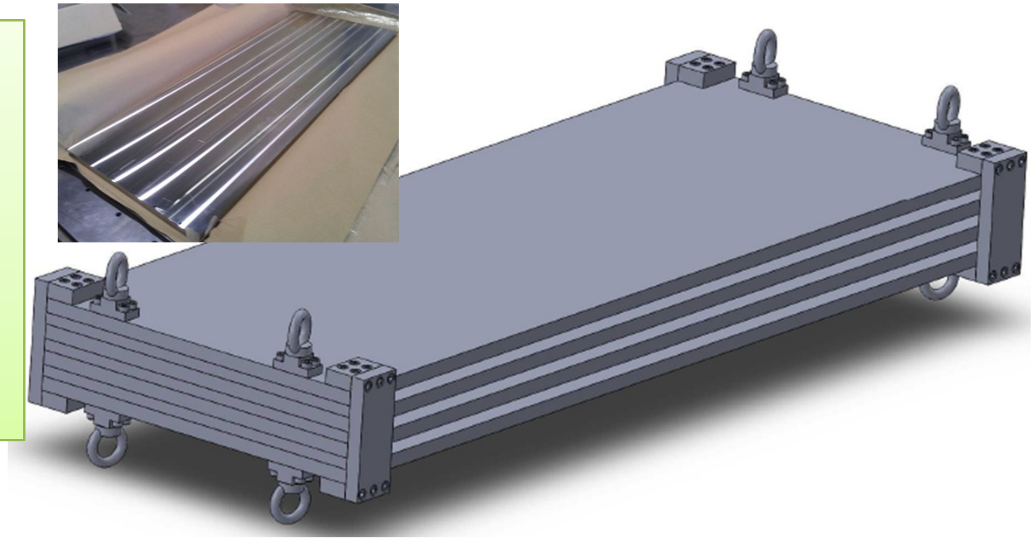
Prototype after welding

Deformations found bigger than expected
➔ Probably due to the welding sequence used

Towards the final demonstrator

Two new smaller prototypes ~1000x400 mm2 to be built and welded to optimize the procedure before assembly the final one

1.- Using a more symmetric welding sequence
2.- Using a more symmetric welding sequence and changing parameters to reduce energy



Final design of the final prototype & handling tools

Production of big plates

Investigating the possibility of roller leveling to achieve the required flatness. It could be difficult to obtain the required flatness for only few plates at reasonable cost. But, in this case we will increase a bit the tolerances in the gaps for the detectors using thicker spacers

But the welding test will be still valid, since we can see anyway the level of the deformations introduced by the welding that are independent of the flatness of plates and thickness

At the moment we don't see major problems on producing a demonstrator

14.5 Mechanical and thermal tools for innovative calorimeters

Task 2: Infrastructure to evaluate thermal properties of calorimeter structures

2.1 Cooling system to test thermal modelling of large CF (carbon fiber) structures *(LPSC)*
2.2 Cooling system for low power calorimeter readout electronics *(DESY)*

Planned activities

WP14.5-Task 2	Infrastructure to evaluate thermal properties of calorimeter structures

2.1 Cooling system to test thermal modelling of large CF (carbon fiber) structures *(LPSC)*
2.2 Cooling system for low power calorimeter readout electronics *(DESY)*

Goals

- Thermal modelling and test on different types of local heat exchangers.
- Develop and test a Global cooling True scale leak less loop for ECAL (13m,10m,9m) (based on previous developments for SiW ECAL prototypes) *(LPSC)*
- Develop a cooling system for the EUDET mechanical structure (the ILD stack), a first version based on overpressure and the final one a leak less system to be used in test beam and evaluate its scalability for a large detector *(DESY)*

Milestones

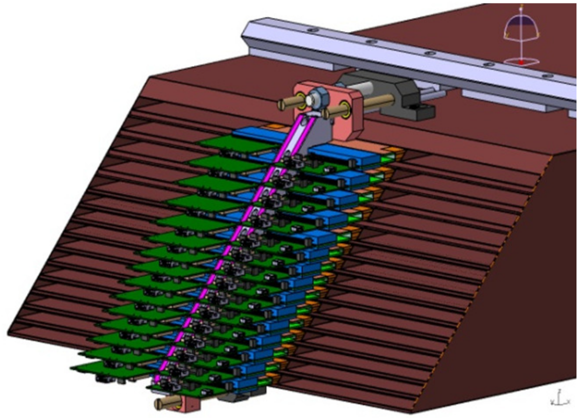
MS31 (Month 18) **: Specification** and **Design** of leak-less water cooling systems
- for tungsten / carbon-fibre structures
- for hadron calorimeter structures

Deliverables

D14.8 (Month 36) **: - Leak-less Systems, prototype tests, demonstration and performance**
-Thermal **model**

ECAL / INTRODUCTION

Thermal properties of tungsten and carbon fibre based absorber elements drive the cooling concepts of ultra-granular SiW ECAL. It will feature 10 to 15 layers of double sided integrated detector elements (SLABs) in a Tunsgten-Carbon Fiber (W-CF) support.



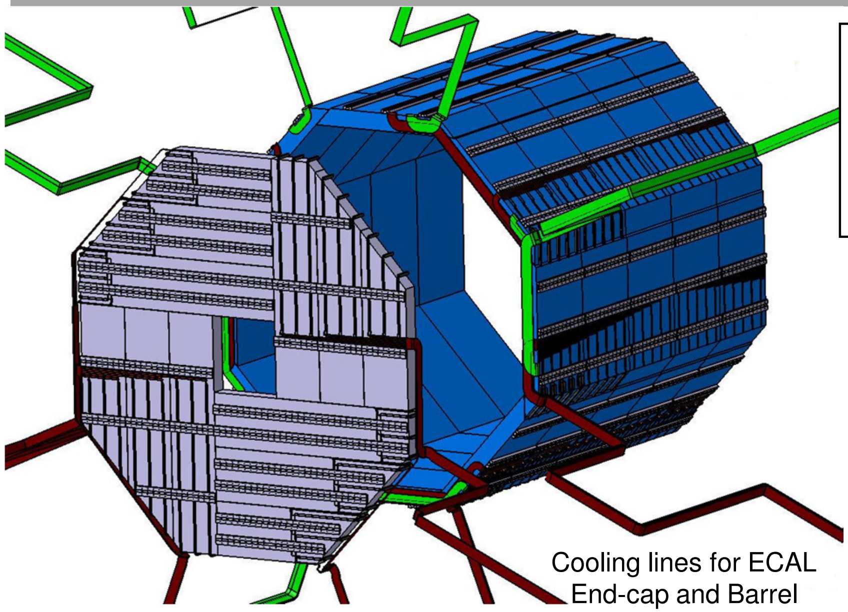
WP14.5-Task 2 / ECAL

Cooling: leak-less water system

Build a large **leak less cooling loop** to confront thermal simulations with measurements

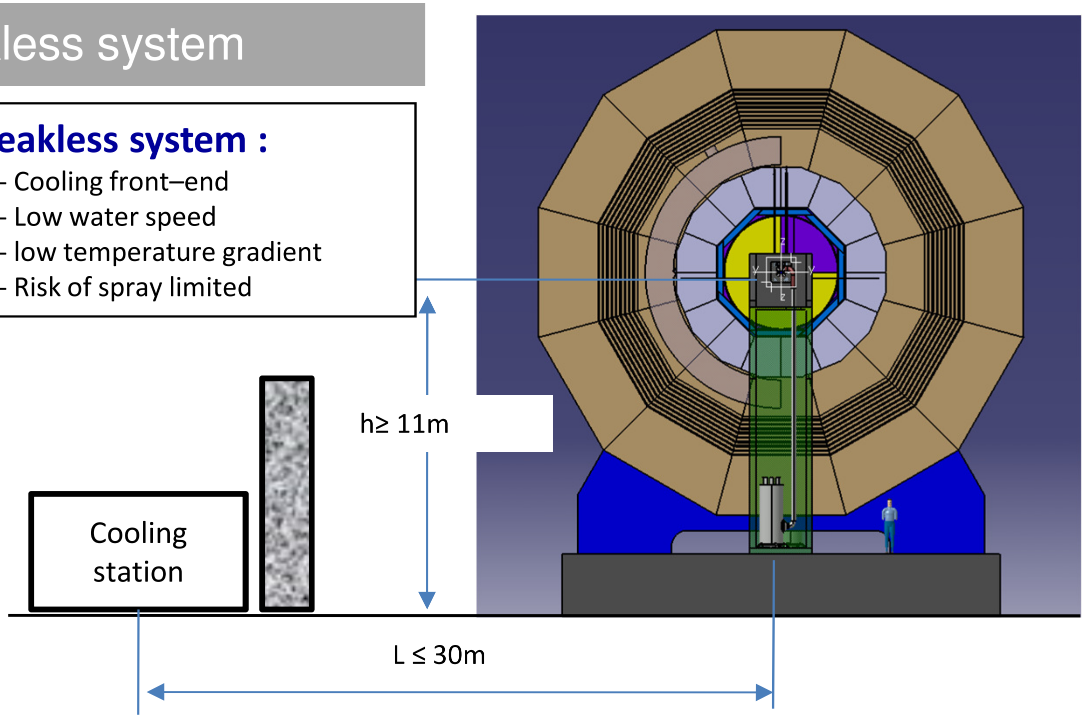
1 : Design - Thermal transfer inside the modules
2 : Local cooling / Connection on module
3 : Global cooling / large leak-less loop on 3 levels

ECAL General Cooling Integration - Leakless system



Cooling lines for ECAL End-cap and Barrel

Leakless system :
- Cooling front–end
- Low water speed
- low temperature gradient
- Risk of spray limited



ECAL: Actual background

AIDA 2020

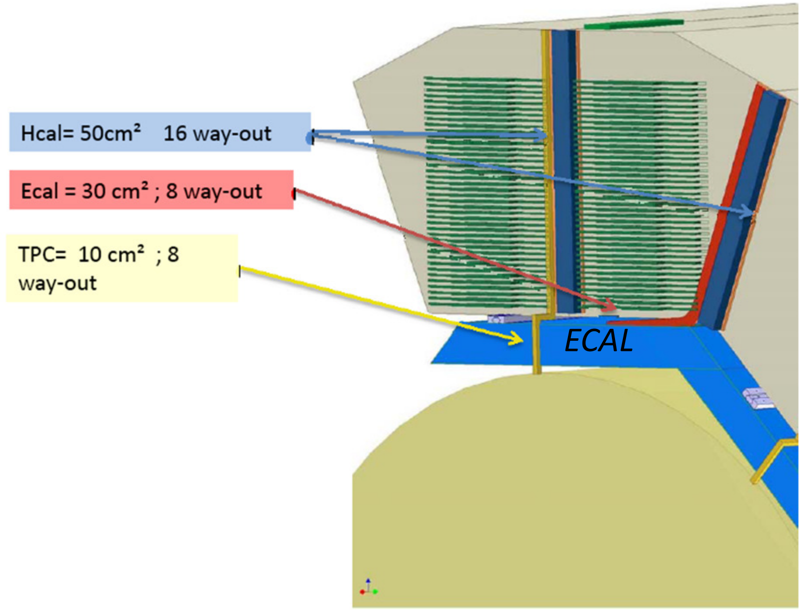
CALICE Calorimeter for ILC

LPSC Grenoble

Study from the power source to the global cooling

MS31 (Month 18) **: Specification** and **Design** of leak-less water cooling system for tungsten / carbon-fibre structures

1 : Design - Thermal transfer inside the modules
2 : Local cooling / Connection on module - heat exchanger
3 : Global cooling / - hydraulic network head loss
- design of cooling station
- large leak-less loop on 3 levels

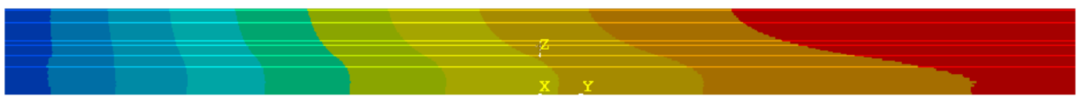


Thermal flux inside a column of 1 module

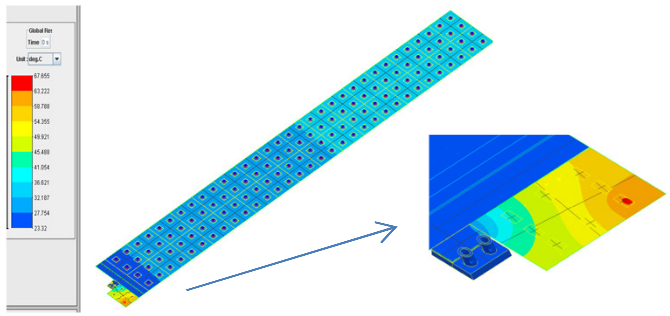
Power on PCB = 0,205 W (barrel) / 0,356 W (End-cap)
Boundary condition T = 23 °C

Results
Barrel : (1.5m) Max T < 25,5 °C ΔT = 2,2°C

End Cap : (2.5m) Max T = 29 °C ΔT = 6°C



Power : 30*0,356 = 10,68 W



Thermal simulation and test on Slab

General distribution foreseen:
- Water circulation @ sub atmospheric pressure
- Water temperature input: 18°c
- Water temperature output: 23°c
- Maximal power per column: 150 W
- Pipes diameter : 13 mm

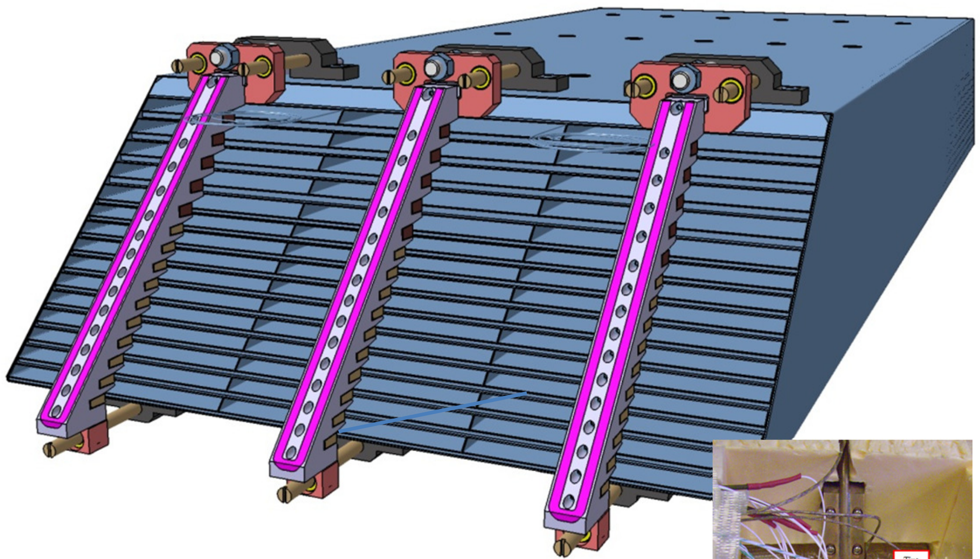
ECAL: available equipment

Design & thermal tests of heat exchanger

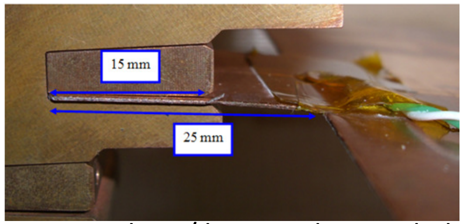
Full scale leak-less loop demonstrator

D14.8 (Month 36) **: - Leak-less Systems, prototype tests, demonstration and performance**
-Thermal **model**

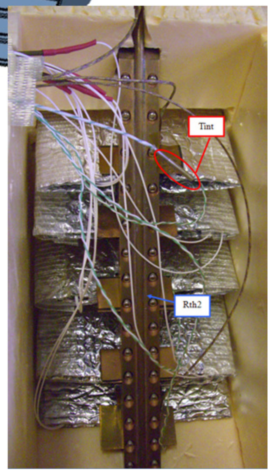
- Design & build Water heat exchanger near detector
- Thermal tests & simulations / power variations (limit of pulsing)
- Full scale leakless loop Integration (3 loops 9-10 & 13m <1 atm)
- Cooling station assembly and testing + network



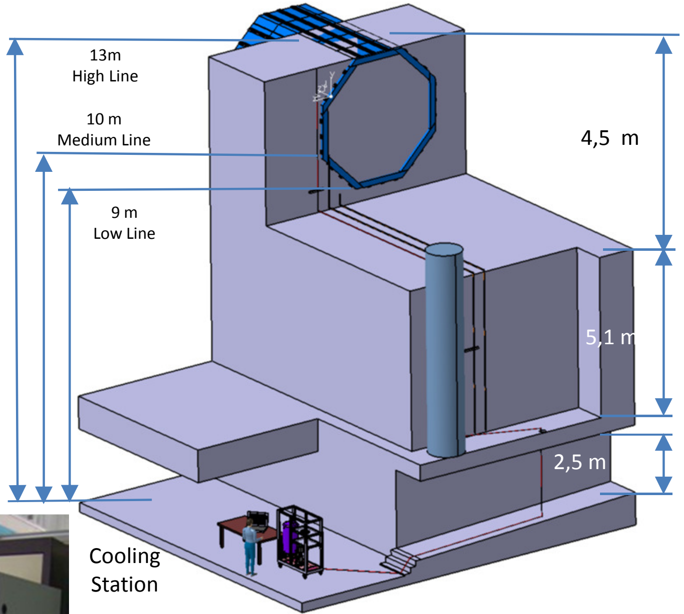
EUDET adaptation of Water heat exchanger



Copper plate / heat exchanger link



Cooling station on going

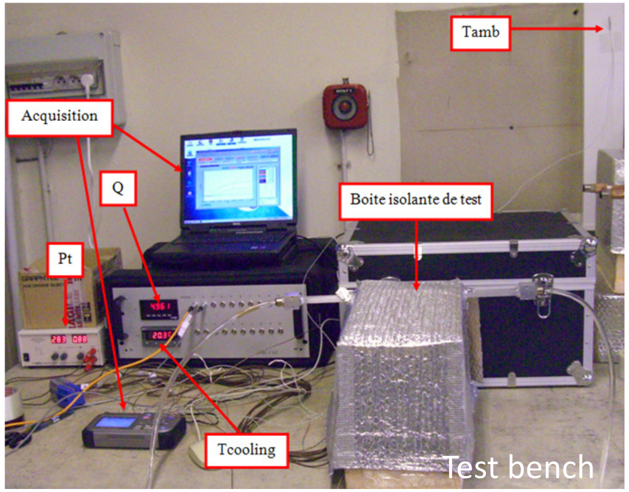


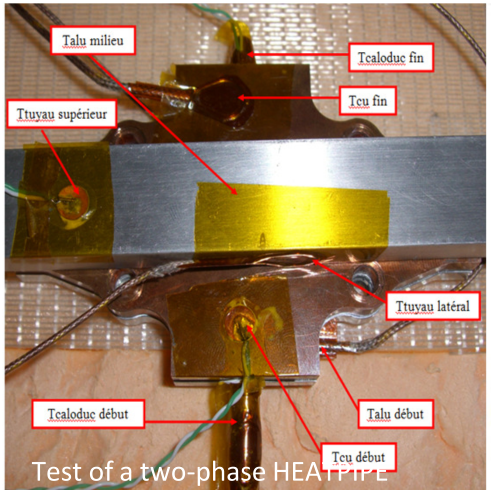
LPSC cooling test area with a drop of 13 m

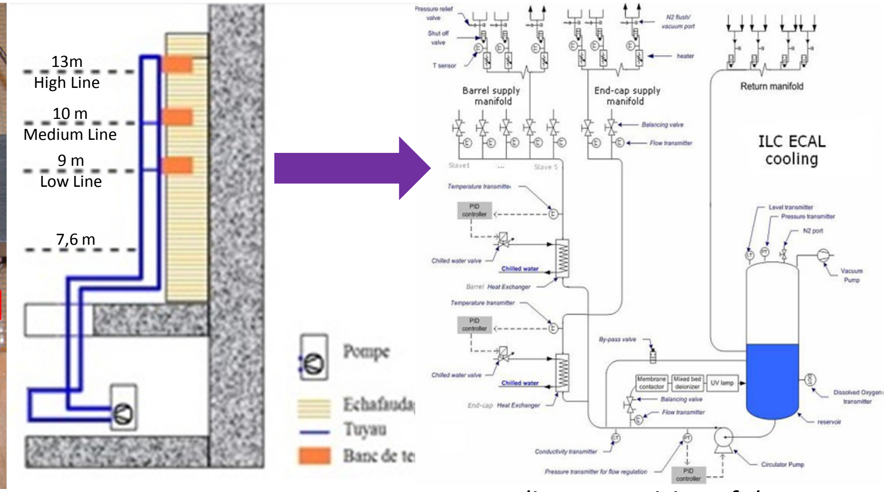
Validation of leakless system (<1atm)

ECAL / Towards a large leak-less network

Thermal tests and validation of thermal model







cooling supervision of the representative process

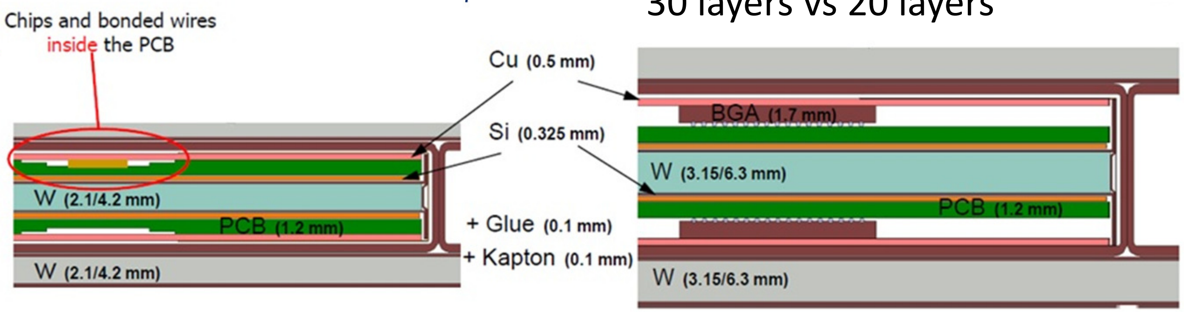
Impact of foreseen evolutions on cooling design

Due to geometry reduction & 30 layers vs 20 layers…

- Electronics in development => uncertainty on final power (4.5 KW to 30 KW)
- Update models and tests / re-adaptation of the full leak less loop
- *SLAB constitution (material distribution)*
- *Power location (Front end or SLAB) & Power variation*
- Update of water heat exchanger / BGA

But for now it's not the baseline

30 layers vs 20 layers



Starting from the baseline

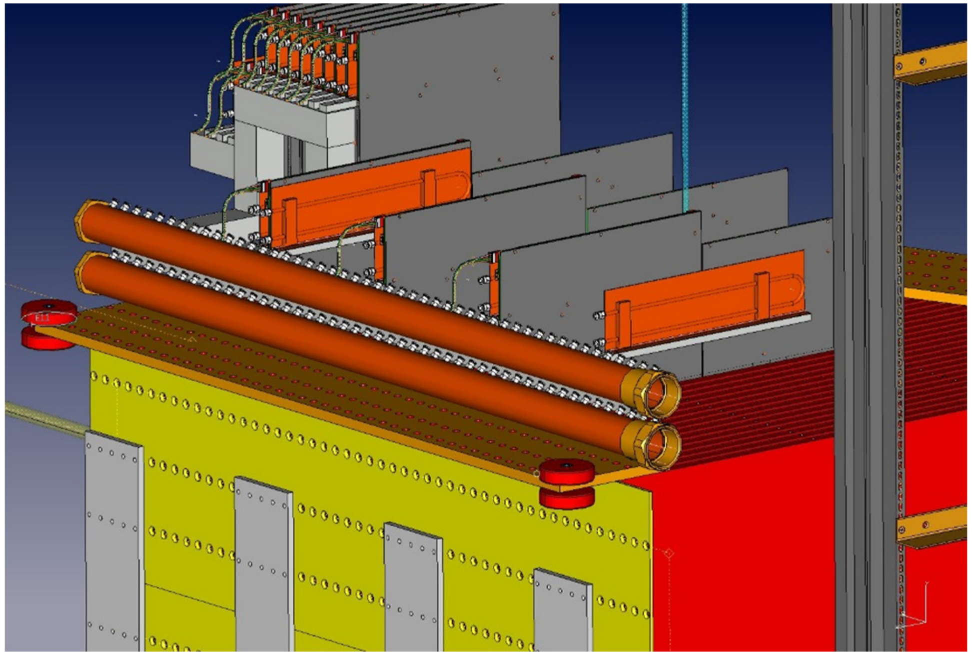
At the moment we don't see major problems on producing a demonstrator

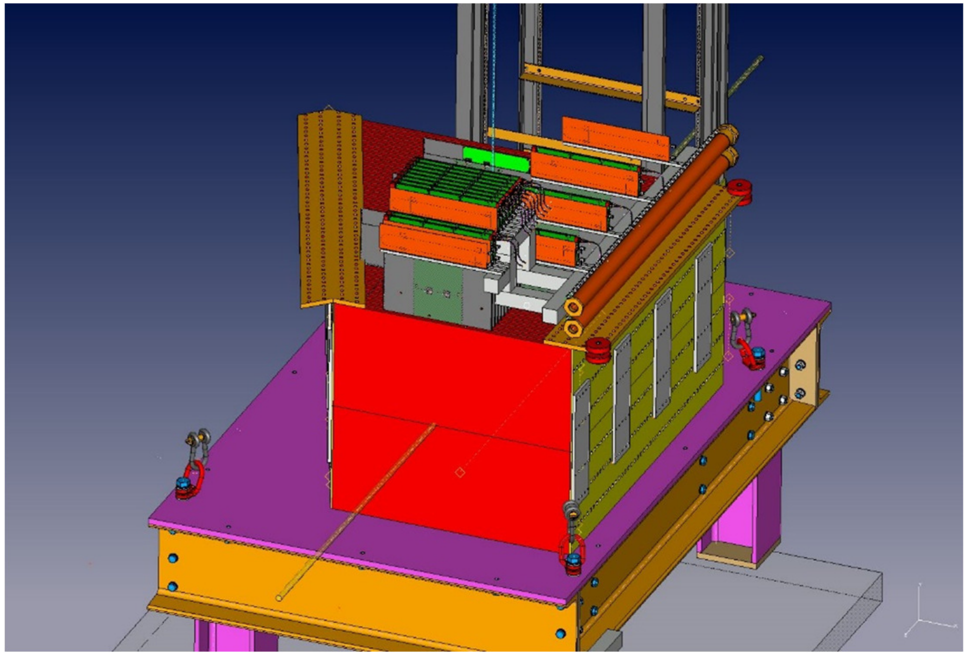
AHCAL: existing cooling

- existing: cooling pre-prototype designed for testbeam
- EUDET steel absorber stack has final HCAL design
- but cassettes for active layers adapted to testbeam needs

➔ design of cooling plates different from final HCAL design

➔ thermal coupling differs from final HCAL design

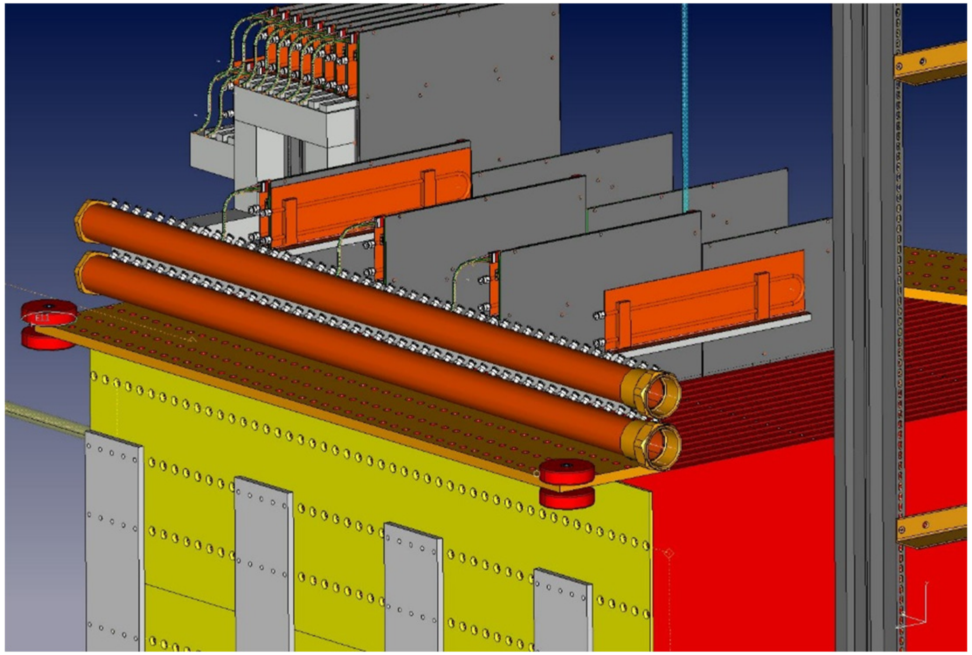




AHCAL: existing cooling

- existing testbeam system based on overpressure

➔ use to study needed cooling power and best thermal contact from electronics to cooling plate



AHCAL: new prototype cooling

- prototype for final leak-less system
- heat exchanger and chiller existing
- main task: design and production of cooling plates and pipes