14.5 Mechanical and thermal tools for innovative calorimeters

Task 1	**Precision mechanics for calorimeter structures**
Task 2	Infrastructure to evaluate thermal properties of calorimeter structures

Enrique Calvo Alamillo (CIEMAT)

AIDA-2020 Second Annual Meeting

WP14 meeting. Paris, 05/04/2017

Planned activities

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

Goal

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

Deliverable : **D14.7 (Month 42) ➡ (End of 2018)**
To design and build a mechanical absorber structure with 4 long plates using EBW

The deliverable will be **based** in the **SDHCAL design for the ILD @ ILC** **(Sampling Calorimeter made of Stainless steel + GRPC-Glass Resistive Plate Chambers)**

DELIVERABLE CHARACTERISTICS

Plates ~3x1 m², 15 mm thick (Roller leveled)
Slot for the casette ~12 mm thick
(needed to create the space between absorber plates to insert the GRPCs):

Surface **planarity < 1mm** ,
Lateral thickness tolerance **+-100µm**

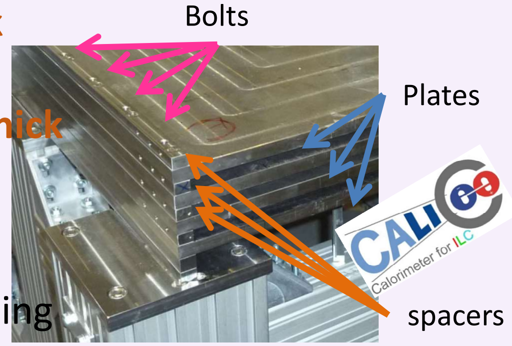
Material: Inox AISI 304
(stainless steel – non magnetic)

Assembly: Electron Beam welding (EBW)

~1m3 CALICE PROTOTYPE

Plates ~1x1 m², 15 mm thick (Machined)
Slot for the casette ~13 mm thick

Plates assembled together by using an intermediate **spacer** insuring the place for introducing the detectors



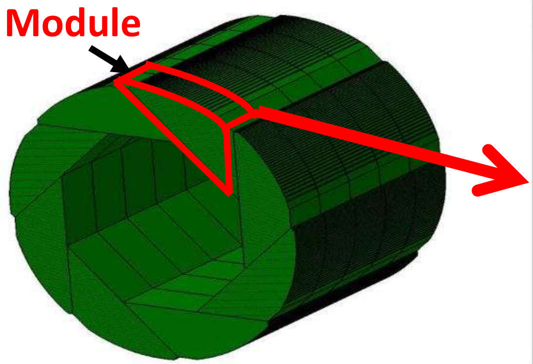
Detail after assembly the **first 4 absorber plates of the 1.3m³ prototype**

Assembly M8 Bolts

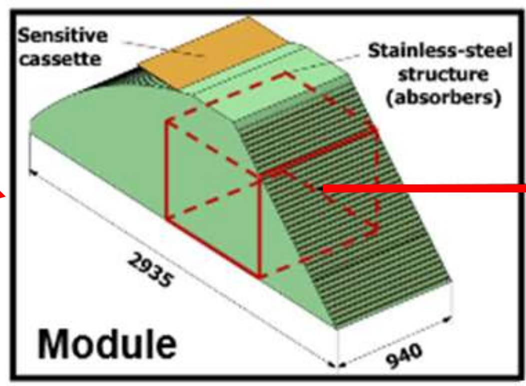
Semi-Digital Hadronic Calorimeter (SDHCAL)-ILD prototypes

The structure will be focused to the SDHCAL-GRPC, proposed for **ILD of ILC**.
Sensor detectors are made of **GRPC** (**G**lass **R**esistive **P**late **C**hambers) and placed in **self-supporting mechanical** structure to serve as absorber as well.

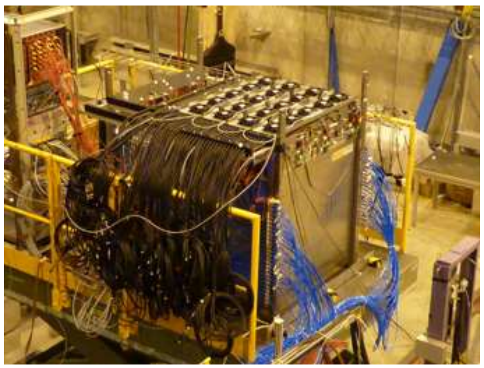
SDHCAL ILD barrel



SDHCAL ILD module



SDHCAL 1.3m^3 prototype



Absorber: Stainless Steel
Active Medium: GRPC
SemiDigital readout. **1cm^2 pads**

Electronics embeded in the detector

HIGH GRANULARITY CALORIMETER

ILD SDHCAL

Plates & GRPCs:
up to **~3x1 m^2**
Absorber assembly
Welding?
(To minimize dead space)

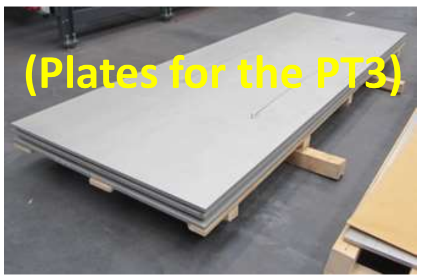
~1.3m3 SDHCAL prototype

Plates & GRPCs :
~1x1 m^2
Absorber assembly:
Bolted

Plates production & Quality Control

The best standard plates in the market have a larger planarity **(~several mm)** than the required one **(<1mm)**

Planarity achieved using roller leveling at ARKU Baden-Baden (Germany) *www.arku.de/*



5 Plates (~3x1 m2) available at CIEMAT
Initial planarity between 1 and 3mm
(8 smaller (~0.4x1 m2) plates for previous test)
Final planarity inside the required tolerances

Measurements using **laser interferometer.**
Over a flat table (~0.1mm planarity)

Planarity

Planarity (µm)	Plate A		Plate B		Plate C	
	Side 1 up	Side 2 up	Side 1 up	Side 2 up	Side 1 up	Side 2 up
Average	469,3	852,6	511,6	596,3	983,4	1038,0

Plate D		Plate E	
Side 1 up	Side 2 up	Side 1 up	Side 2 up
458,7	546,1	610,2	521,9

Thickness

Thickness (mm)	Plate A	Plate B	Plate C	Plate D	Plate E
average	15,256	15,259	15,282	15,247	15,279
max.	15,352	15,340	15,348	15,342	15,350
min.	15,157	15,161	15,216	15,147	15,201
Δ	0,195	0,179	0,132	0,195	0,149

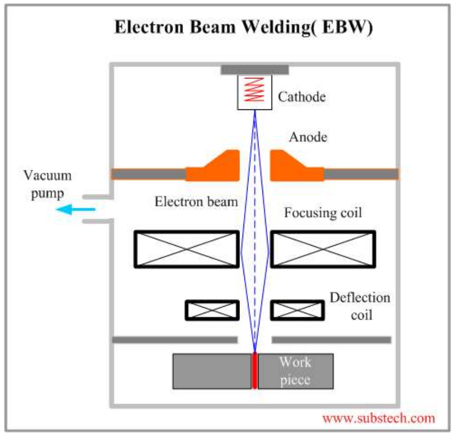
Mechanical Structure: Welding procedure

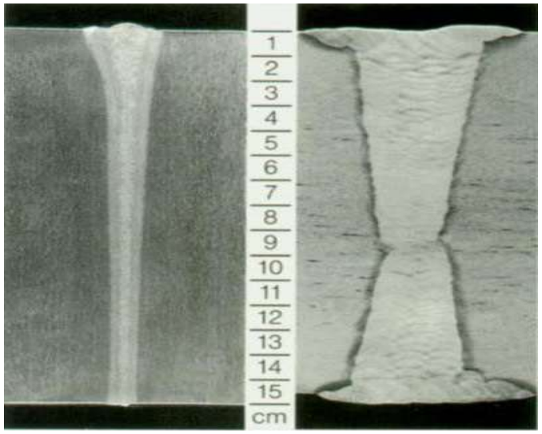
Improvement on the present system is being made by using **Electron Beam Welding (EBW) at CERN** rather tan bolts to reduce the lateral dead space.

Collimate electron beam

→ Very **narrow welding** → **Less deformations**

Vacuum conditions needed

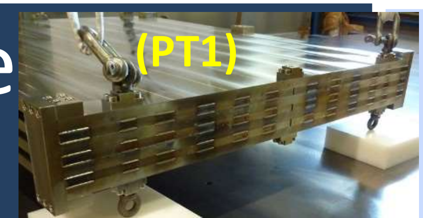




EBW Machine @ CERN

~0.4x1 m^2 (4 slots) welded prototype

Assembly of the Structure
Previous Welding tests

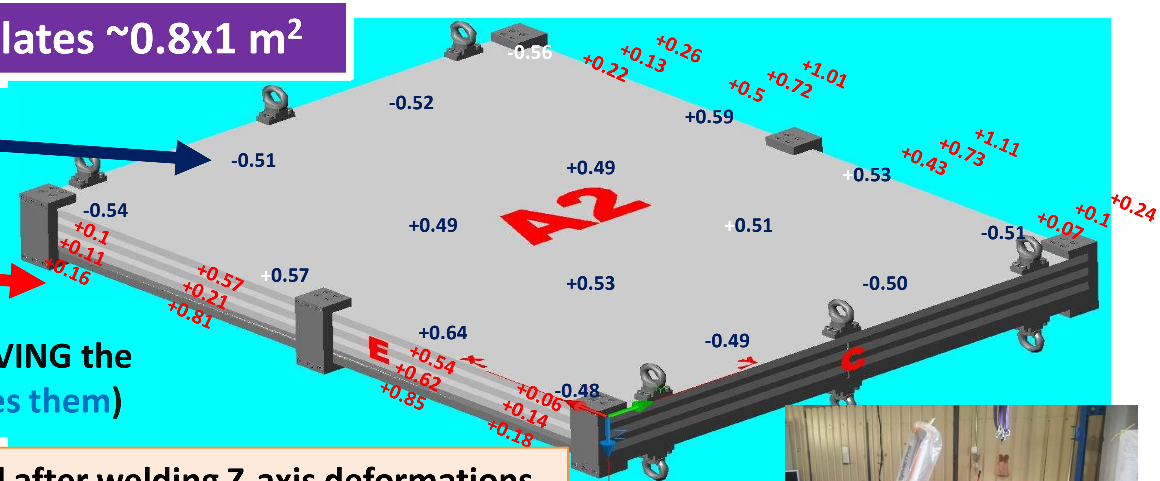


First small prototype (PT1): 4 plates ~0.8x1 m^2

Differences with respect to the initial status of the ***plate in Z.***

Differences with respect to the initial status of the ***distance between plates***

Measurements have been done AFTER REMOVING the PIECES used FOR RIDIGITY (the picture includes them)

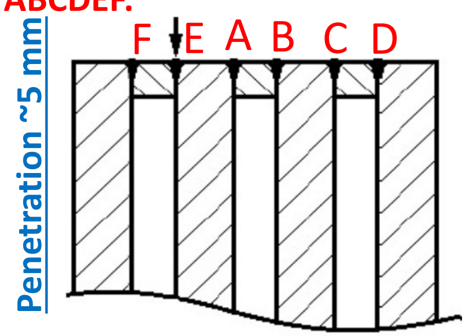


After comparing the measurements before and after welding Z-axis deformations found (~1mm the external plates) in X-direction. O.K in Y-direction (this is positive for the 3 m long prototype).

Deformations not symmetric Z-direction → Probably due to the not symmetry welding sequence used??

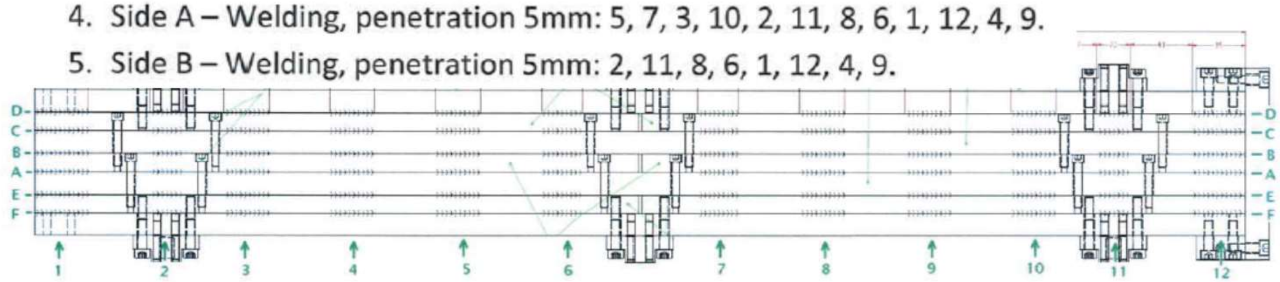
Coordinate 3D measuring machine

Welding has been performed column by column following the same row order ABCDEF.



The welding sequence has been the following:

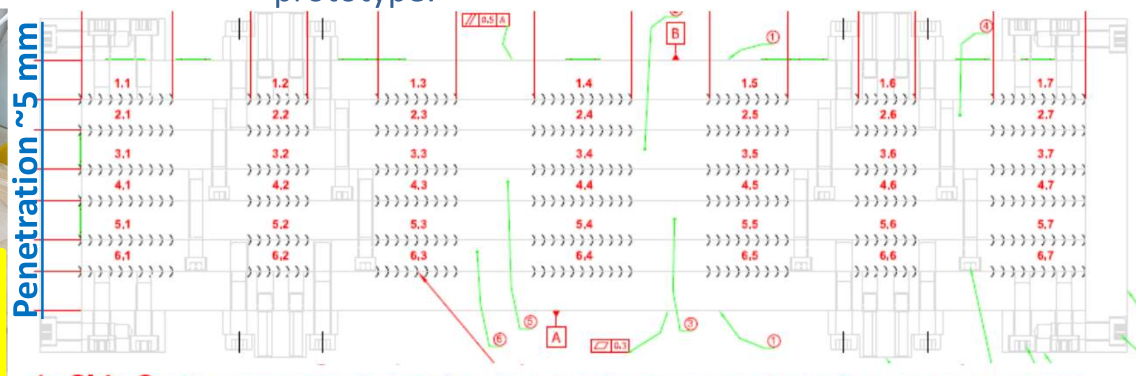
1. Side A – Tack welding, penetration 2mm: 6, 1, 12, 4, 9.
2. Side B – Tack welding, penetration 2mm: 6, 1, 12, 4, 9.
3. Side B – Welding, penetration 5mm: 5, 7, 3, 10.
4. Side A – Welding, penetration 5mm: 5, 7, 3, 10, 2, 11, 8, 6, 1, 12, 4, 9.
5. Side B – Welding, penetration 5mm: 2, 11, 8, 6, 1, 12,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



Assembly of the Structure
Previous Welding tests

Second small prototype (PT2): 4 plates 0.4x1 m²

Welding performed **changing a bit the welding sequence and machine parameters** with respect to the first prototype:



1.- Side C, Tack welding, penetration 2 mm: 3.4, 4.4, 4.1, 3.1, 3.7, 4.7, 2.4, 5.4, 5.1, 2.1, 2.7, 5.7, 1.4, 6.4, 6.1, 1.1, 1.7, 6.7.

2.- Side D, Tack welding, penetration 2 mm: 3.4, 4.4, 4.1, 3.1, 3.7, 4.7, 2.4, 5.4, 5.1, 2.1, 2.7, 5.7, 1.4, 6.4, 6.1, 1.1, 1.7, 6.7.

3.- Side D, Welding, penetration 5 mm: 3.3, 4.3, 4.5, 3.5, 3.6, 4.6, 4.2, 3.2, 2.3, 5.3, 5.5, 2.5, 2.6, 5.6, 5.2, 2.2, 1.3, 6.3, 6.5, 1.5, 1.6, 6.6, 6.2, 1.2.

4.- Side C, Welding, penetration 5 mm: 3.3, 4.3, 4.5, 3.5, 3.6, 4.6, 4.2, 3.2, 2.3, 5.3, 5.5, 2.5, 2.6, 5.6, 5.2, 2.2, 1.3, 6.3, 6.5, 1.5, 1.6, 6.6, 6.2, 1.2, 3.4, 4.4, 4.1, 3.1, 3.7, 4.7, 2.4, 5.4, 5.1, 2.1, 2.7, 5.7, 1.4, 6.4, 6.1, 1.1, 1.7, 6.7.

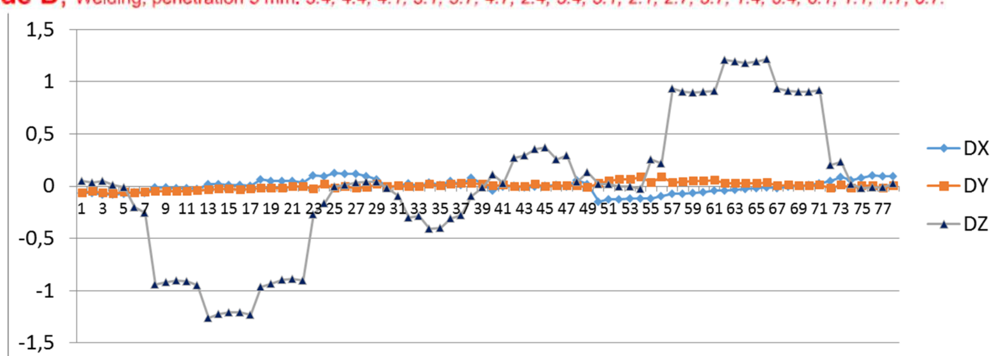
5.- Side D, Welding, penetration 5 mm: 3.4, 4.4, 4.1, 3.1, 3.7, 4.7, 2.4, 5.4, 5.1, 2.1, 2.7, 5.7, 1.4, 6.4, 6.1, 1.1, 1.7, 6.7.

After comparing the measurements before and after welding Z-axis deformations found (~1mm the external plates) in X-direction.

O.K for Y-direction (this is positive for the 3 m long prototype).

Now the Z-direction deformations is symmetric.

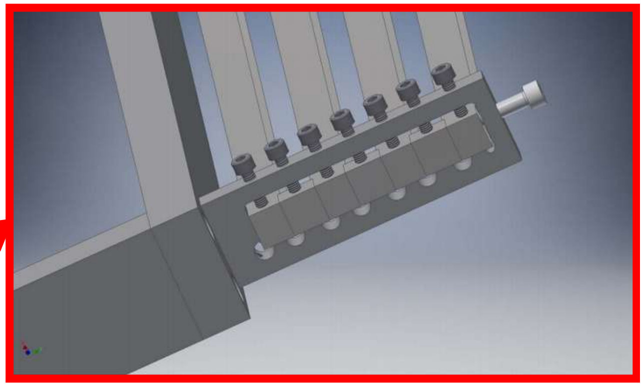
➔ Similar deformation results.



Assembly of the Structure
Next Welding tests

Before to weld the next prototypes with 10 mm penetration (greater strength), some tests using **smaller pieces** are foreseen to evaluate "qualitatively" the best way for performing the final welding sequence.

This should allow to make several **fast & cheaper tests**, **changing the sequence & machine parameter of welding** in order to find the procedure producing the **lowest deformation**.

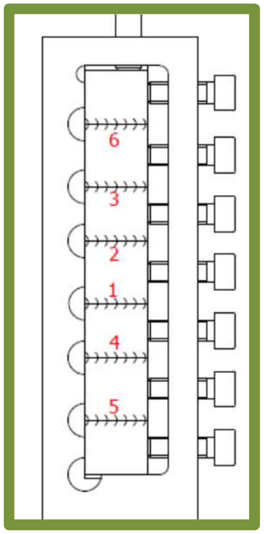


Pieces produced at CIEMAT and waiting at CERN after the photogrammetry for the EBW during April.

Penetration ~10 mm

Assembly of the Structure
Next Welding tests

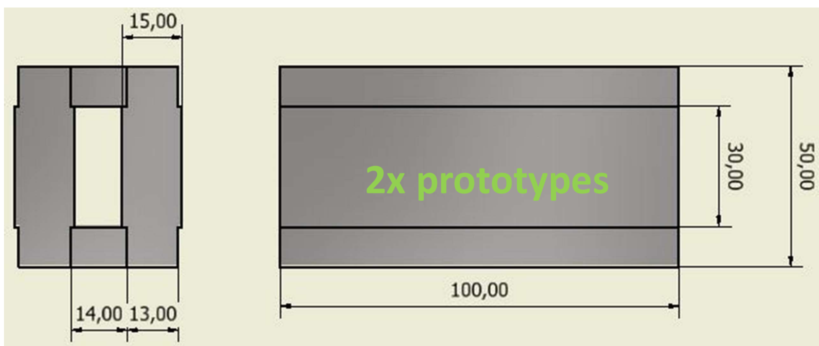
Welding sequence for the *"qualitatively"* smaller tests:
Three different option to try with.

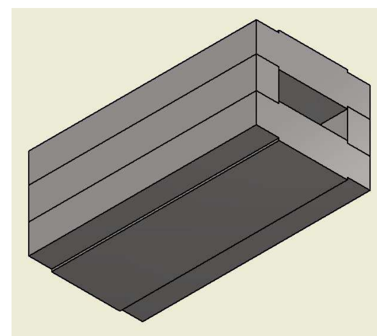


Penetration ~10 mm

Welding Secuence (Secuencia de Soldadura)						
Step (Paso)	test A-B_1	test A-B_2	test A-B_3	test C-D_1	test C-D_2	test C-D_3
1er. (2 mm depth)	1, 2 (side A)	1, 2 (side A)	5, 6 (side A)	1, 2 (side C)	1, 2 (side C)	5, 6 (side C)
2nd. (2 mm depth)	1, 2 (side B)	1, 2 (B)	5, 6 (B)	1, 2 (D)	1, 2 (D)	5, 6 (D)
3rd. (2 mm depth)	3, 4 (side B)	6, 5 (B)	3, 4 (B)	3, 4 (D)	6, 5 (D)	3, 4 (D)
4th. (2 mm depth)	3, 4 (A)	6, 5 (A)	3, 4 (A)	3, 4 (C)	6, 5 (C)	3, 4 (C)
5th. (2 mm depth)	5, 6 (A)	4, 3 (A)	1, 2 (A)	5, 6 (C)	4, 3 (C)	1, 2 (C)
6th. (2 mm depth)	5, 6 (B)	4, 3 (B)	1, 2 (B)	5, 6 (D)	4, 3 (D)	1, 2 (D)
7th. (10 mm depth)	1, 2 (B)	1, 2 (B)	5, 6 (B)	1, 2 (D)	1, 2 (D)	5, 6 (D)
8th. (10 mm depth)	1, 2 (A)	1, 2 (A)	5, 6 (A)	1, 2 (C)	1, 2 (C)	5, 6 (C)
9th. (10 mm depth)	3, 4 (A)	6, 5 (A)	3, 4 (A)	3, 4 (C)	6, 5 (C)	3, 4 (C)
10th. (10 mm depth)	3, 4 (B)	6, 5 (B)	3, 4 (B)	3, 4 (D)	6, 5 (D)	3, 4 (D)
11th. (10 mm depth)	5, 6 (B)	4, 3 (B)	1, 2 (B)	5, 6 (D)	4, 3 (D)	1, 2 (D)
12th. (10 mm depth)	5, 6 (A)	4, 3 (A)	1, 2 (A)	5, 6 (C)	4, 3 (C)	1, 2 (C)

➔ **At the same time, will be tested two very small prototypes to fix the *machine parameters.***





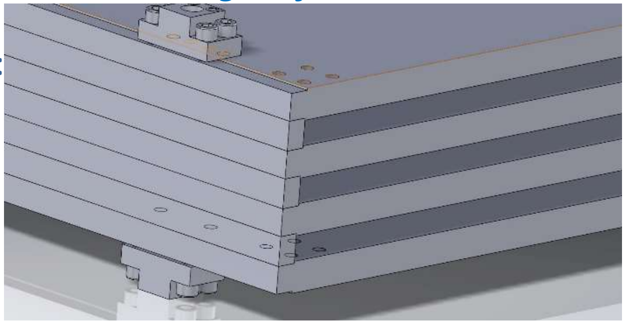
Once the procedure is optimized two identically prototypes (plates ~0.4x1 m^2) will be welded with those parameter to validate the procedure.

Assembly of the Structure
Next Welding tests

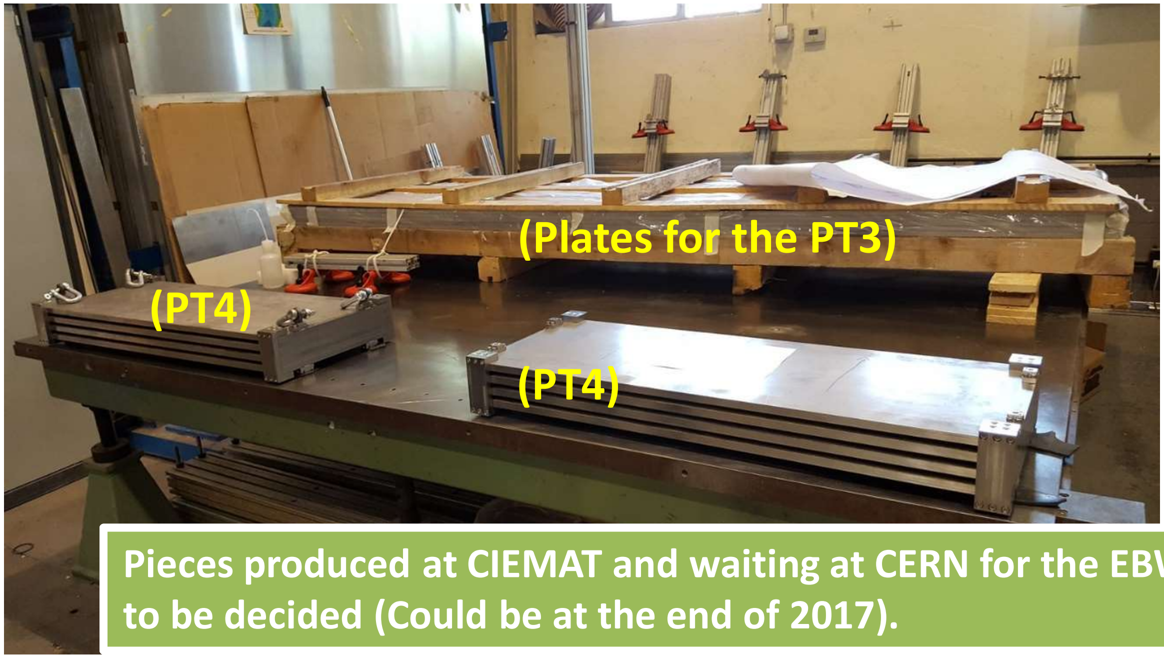
Two identical small prototypes (PT4): 2x (4 plates 0.4x1 m^2)

Complete Penetration ~10 mm

Greater strength of the structure.



Welding will be performed **in functions of the results of the previous welding tests:**



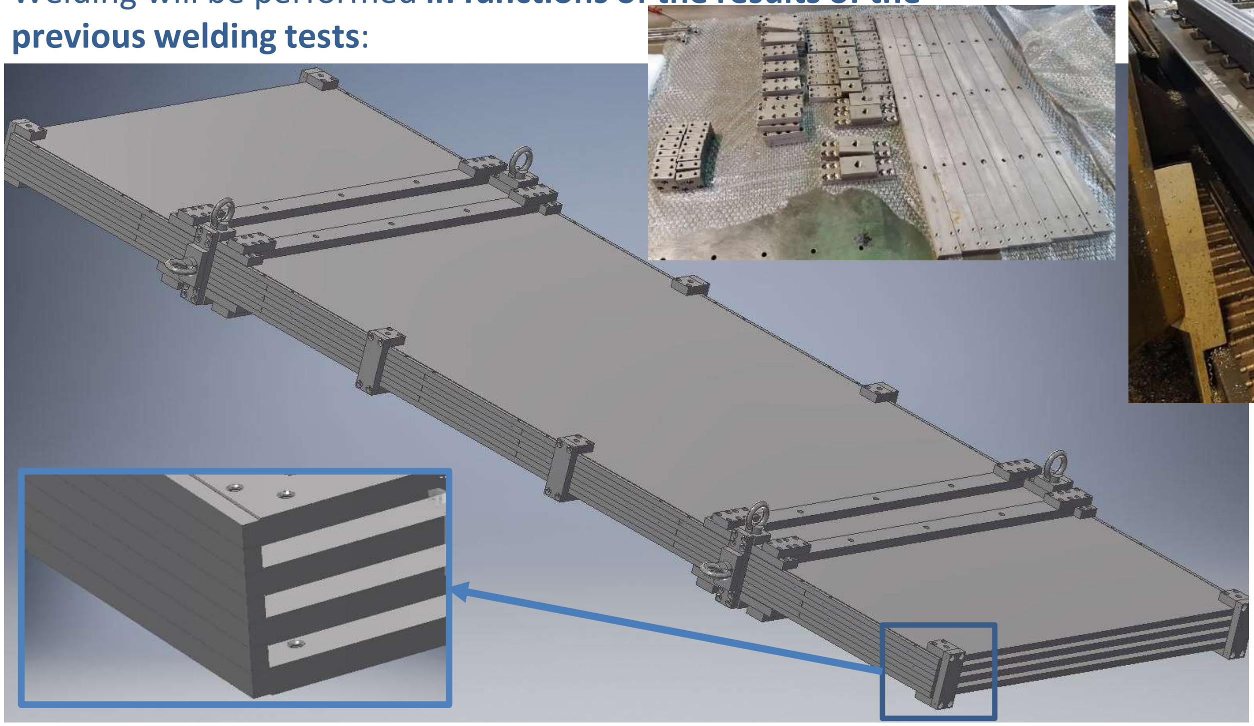
Pieces produced at CIEMAT and waiting at CERN for the EBW. The date needs to be decided (Could be at the end of 2017).

Once validated the procedure, will be welded the big demonstrator (plates ~3mx1m)

Assembly of the Structure
Next Welding tests

Sampling calorimeter prototype (PT3): 4 plates 3x1 m²

Welding will be performed **in functions of the results of the previous welding tests**:



Complete Penetration ~10 mm

Greater strength of the structure.

Pieces for the demonstrator produced and waiting for the preliminary measures and assembly at Ciemat (April to June 2017).

Next actions & Status of the final absorber structure

Next prototypes

Small pieces for tests and the last 2 small prototypes (PT4) → Done
Start of tests with small pieces during April
(Lasts small prototypes will be welded after defined the best welding parameters with the small pieces)

Final demonstrator

- **Big Plates (~3x1m^2) with planarity <1mm → Done**
- **Big Plates Handling and machine tool → Done**
- **Auxiliary pieces for fixing rigidity → Done**
- **Spacers → Done**
- **Small machining on 3x1m2 plates needed for fixations and assembly → Done**
- **Verification of the plates and spacers →April 17**
- **Demonstrator assembly and preliminary measures at Ciemat → May-June 17**
- **Transport to CERN, Photogrammetry before EBW → to be decided with CERN (End of 17)**
- **EBW & photogrammetry after EBW → to be decided with CERN (beginning 2018)**

Additional tests that could be implemented with the previous prototypes

Could be welded both *PT4* to create a bigger one prototype (8 plates prototype (*PT5*)).
Could be welded *PT2 & PT1* (8 plates prototype (*PT6*)).
Could be welded those previous prototypes (*PT5 & PT6*) to create a 16 plates prototype (*PT7*).

Conclusions

At present the **project advances well** according to the schedule steps needed for arriving to have the demonstrator on time

No special problems are envisaged

(The **goal** is to **show the capabilities of this welding method**, in the project no claim was written about the expected performance going to be achieved)

Topics:

We have created infrastructure and tools to follow with this task in the future.

We are developed technological procedures that can be translate to the companies during the fabrication of the final modules phase:

- We developed a procedure with the world leader on Roller levelers technology (ARKU), to minimize the planarity for 3 m x 1m x 15 mm Stainless Steel plates. They can supply us the European companies with the necessary machines to carry out this task.
- We are developing, in cooperation with CERN, the procedure to weld by EBW technology some of the biggest prototype expected for the future hadron calorimeter. CERN people know several European companies with the necessary machines to carry out this task.