Status of the Electronics and Mechanics for the new large SDHCAL prototype

Mary-Cruz Fouz (CIEMAT)
for the SDHCAL group

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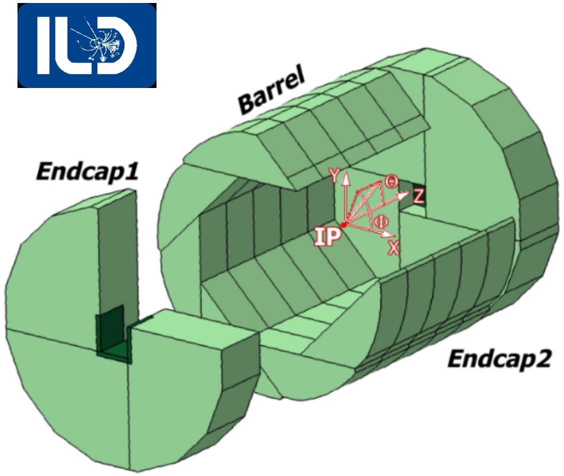
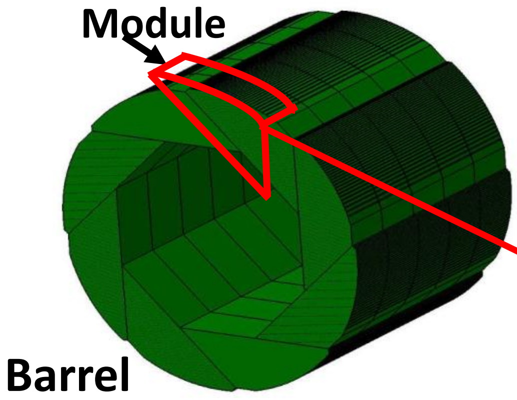
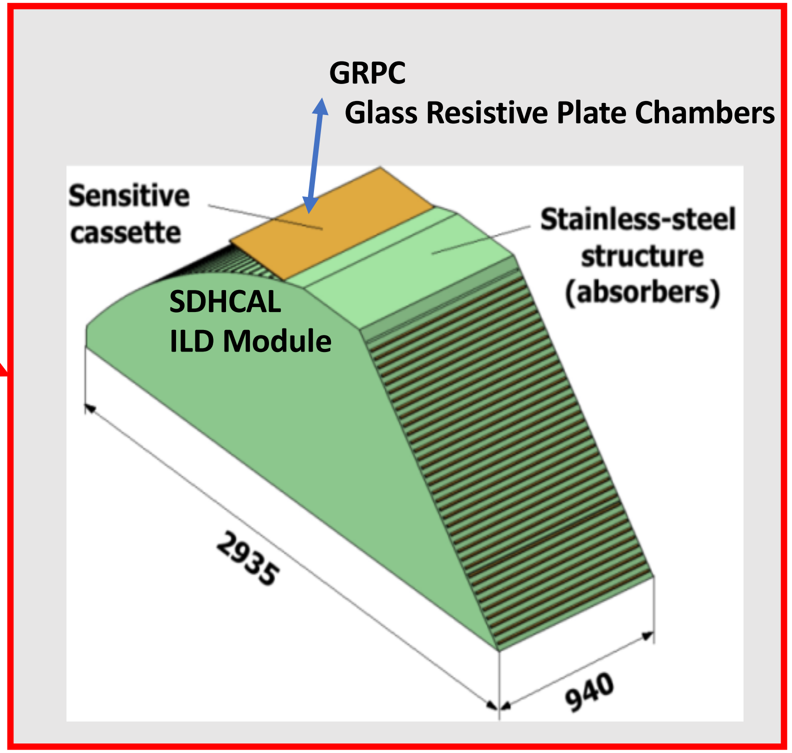
Introduction: The new SDHCAL prototype







The ~1m3 prototype built in the past was based of layers of plates absorbers of ~1m2.

To enlarge them to the maximum size (~3x1m2) expected at ILD, implies new challenges for the detector, embedded electronics and mechanics

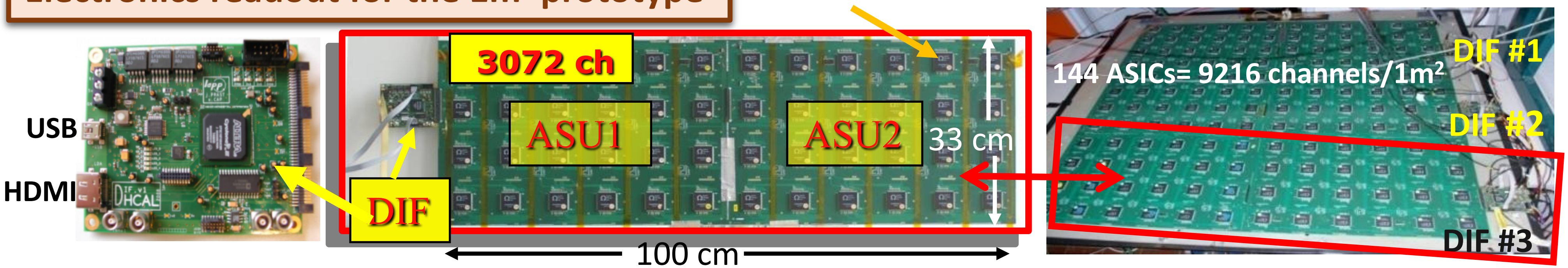
The goal

To build a ***new prototype*** ***with a mechanical structure of 4 plates of ~1x3m²*** (assembled with similar procedures to the final one) where inserting large ***RPCs equipped with a new improved electronics.***

Status of electronics (DIF)

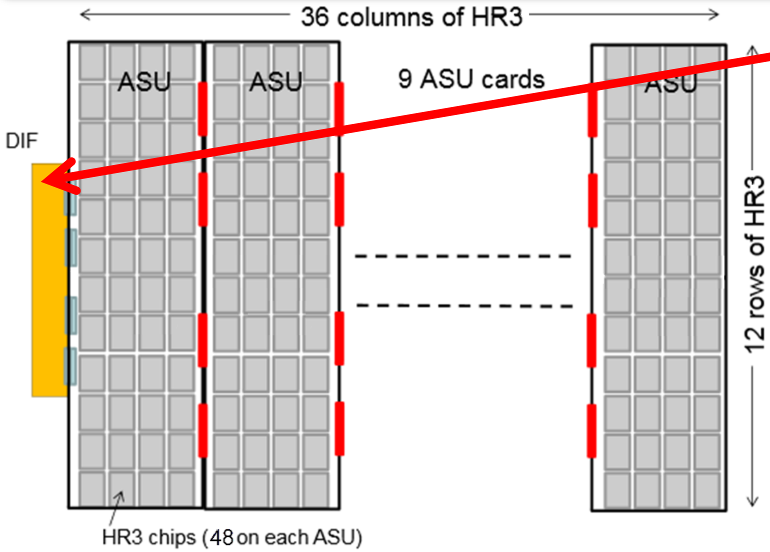
New electronics: ASIC,PCB,DIF

Electronics readout for the 1m³ prototype



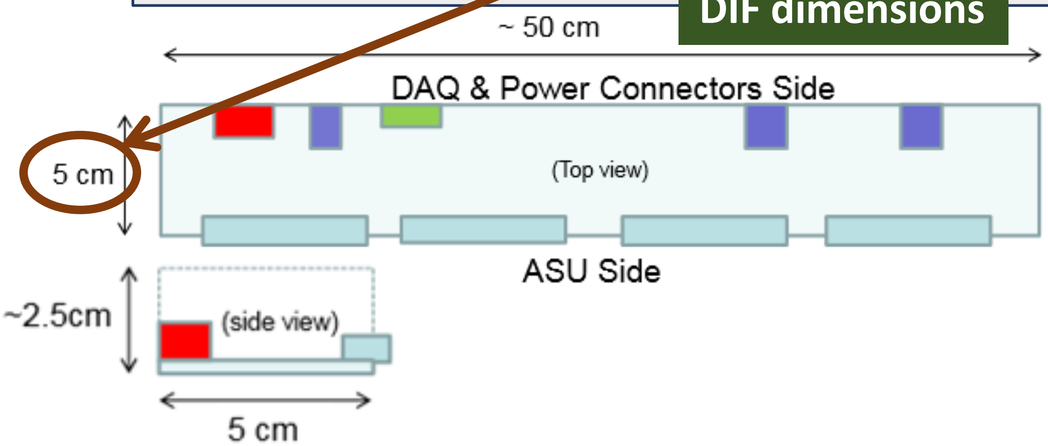
1 DIF for 2 ASU (Active Sensor Unit.- PCB+ASICs) ➔ **3 DIFs for ONE 1m2 GRPC detector**

Electronics readout for the final detector

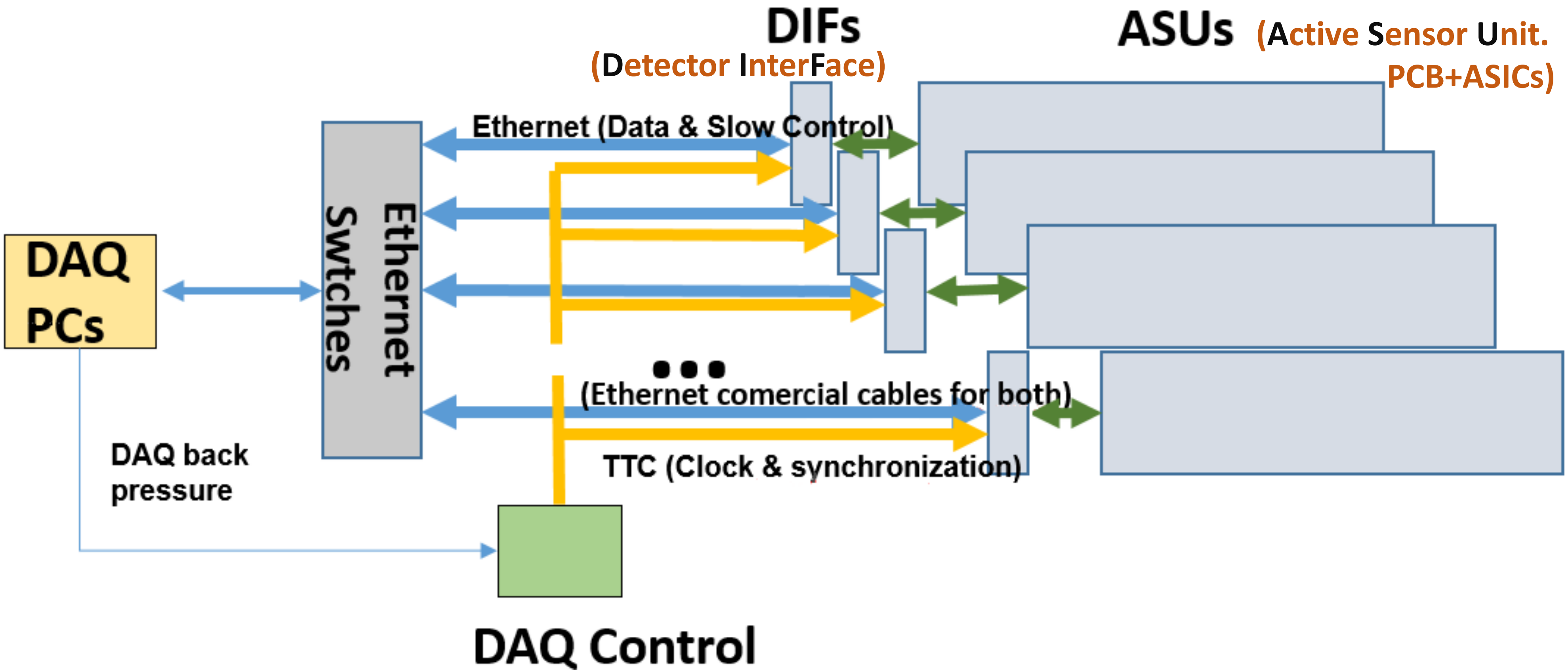


Only **1 DIF per GRPC (any dimension)** with small dimensions to fit in the **small** space available at the final detector

DIF dimensions



SDHCAL DAQ architecture



A ***central PC*** **collects data** from all the ***ASUs*** (containing de ***ASIC chips***) through an ***Ethernet switch*** acting in such a way **as data concentrator** and **generates the required commands for *ASU* and *DIF* configuration generating at the same time synchronization signal** required for a correct data acquisition process.

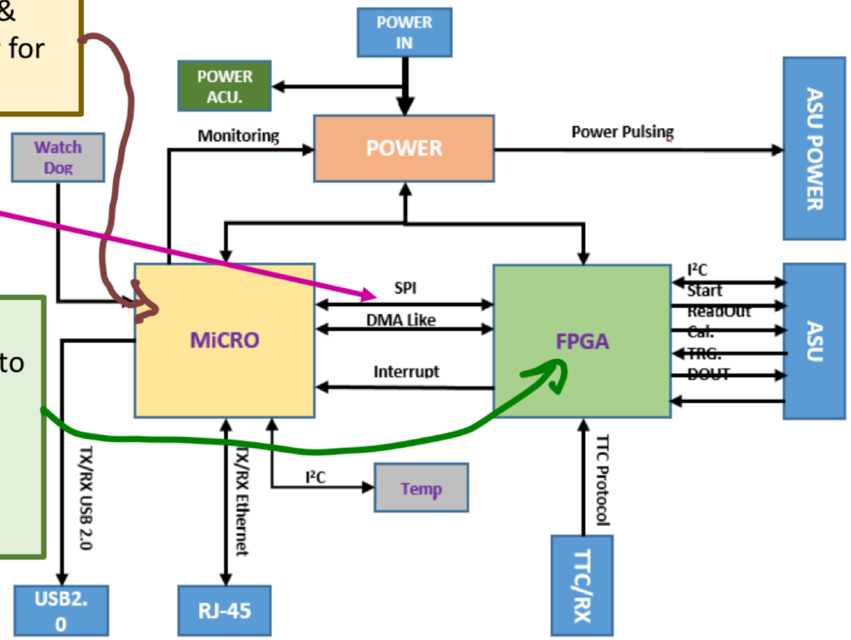
Calorimetry for detectors at future colliders.
ILD SDHCAL prototype - Electronics

DIF (Detector InterFace) sends DAQ commands (config, clock, trigger) to front-end and transfer their signal data to DAQ. It controls also the ASIC power pulsing

The microprocessor
- ➔ In charge of the DAQ communication &
- ➔ Implements the command interpreter for Ethernet and USB2.0 commands

A SPI (Serial Peripheral Interface) link allows to communicate the microprocessor with a FPGA

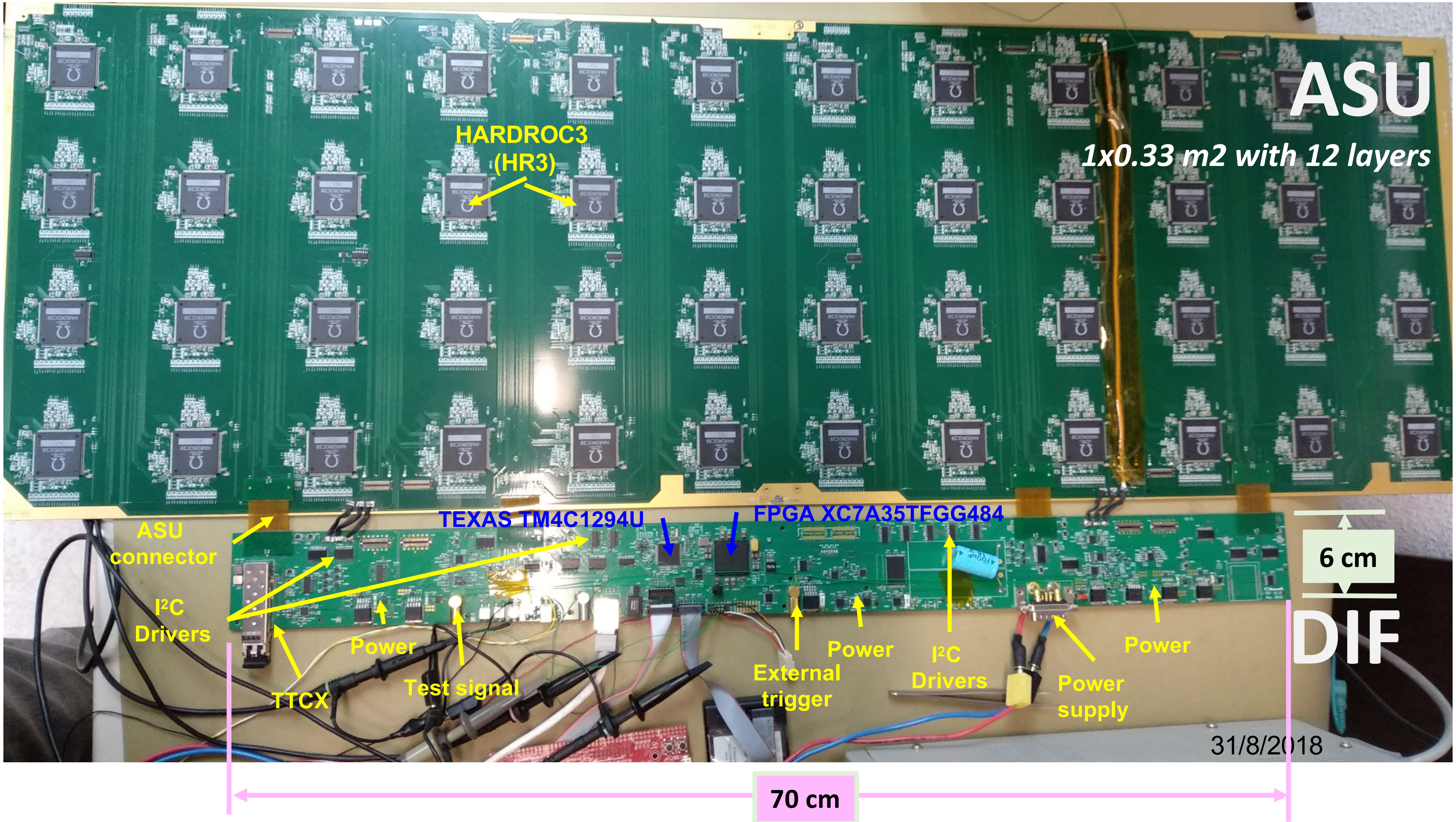
The FPGA
- ➔ Implements the required I2C links to perform the ASU slow control
- ➔ Implements the HR3 sequence during data acquisition
- ➔ Is in charge to generate the DAQ.



Once the data are acquired are transfer back to the microprocessor through a parallel link and back to the DAQ.

- Only **one DIF per plane** (instead of **three**)
- DIF handle up to **432 HR3 chips** (vs **48 HR2** in previous DIF)
- **Clock and synchronization** by **TTC** (already used in LHC)
- **93W Peak power supply** with super-capacitors (vs **8.6 W** in previous DIF)
- Spare I/O connectors to the FPGA (i.e. for GBT links)
- Upgrade **USB 1.1** to **USB 2.0**

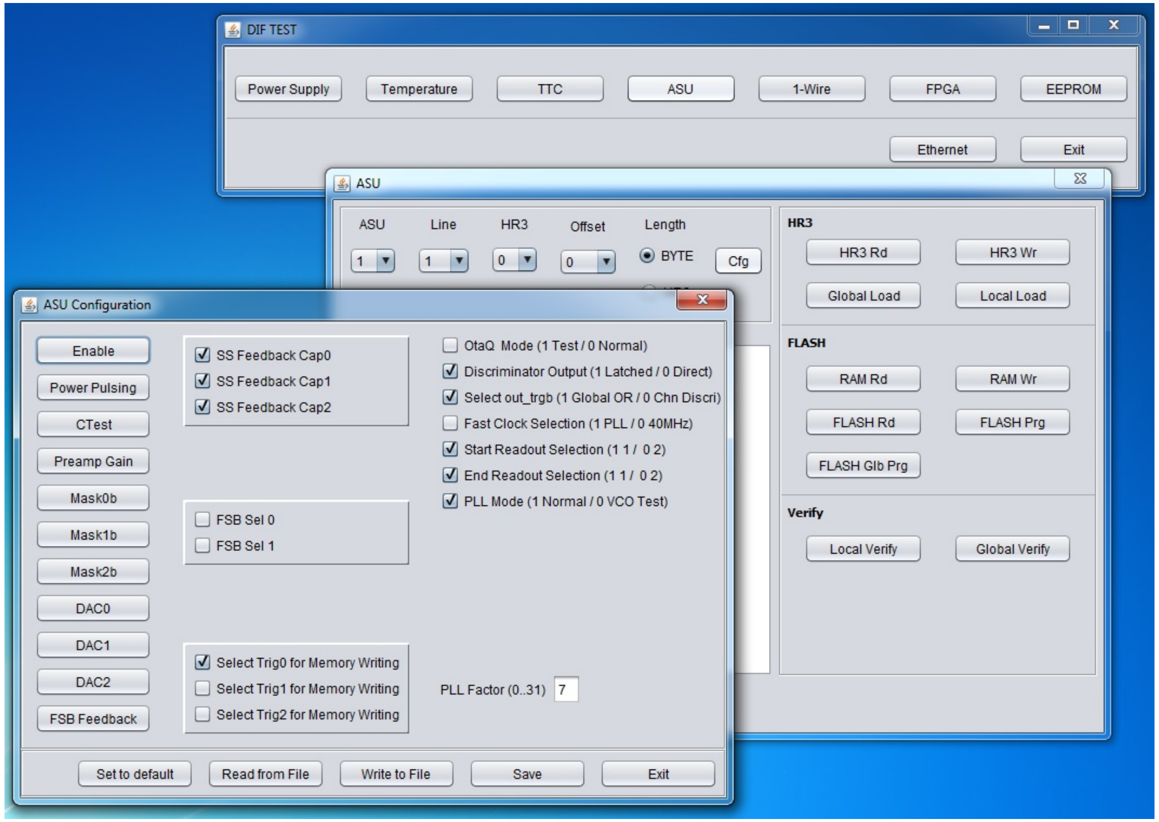
DIF + ASU under tests



Java Aplication

- **A Java application** has been designed to **test the different functionalities** of the **DIF and ASU** boards.

  - The application **communicates with DIF using the Ethernet link**.
  - The user can **read and write the registers of the different ICs** (power supply, temperature, TTC) **and those implemented registers using the microcontroller and FPGA**. On the other hand, it is possible to **read and write the registers of the HARDROC and 1wire chips.**



All the functionalities of both boards can be tested using this application

- **Another Java application** has been developed to allow the **remote programming** of the **FPGA memory**
  Other allowed actions are: blank checking, erasing, etc.

DIF Status

Documentation:	Schematics and Layout	√
Fabrication & Assembly:	**4 DIFs** fully assembled and operational	√
Firmware development:	**Micro-processor**	
	• Ethernet communication	√
	• FPGA communication	√
	• Data acquisition	√
	FPGA	
	• I^2C	√
	• Synchronization	√
	• Power Pulsing	X
	• Data acquisition	√
Functional tests:		
	• Power	√
	• FPGA	√
	• Micro-Processor	√
	• TTC Synchronization / commands	√ / X
	• Power Pulsing	X
	• Old slow control test with ASU	√
	• I2C slow control test with ASU	Ongoing
	• Data acquisition test with ASU	X

DIF Remaining tests

ASU board → most of these tests requires one ASU. A new design (100 x 33 cm) is being used. **This board is being tested and debugging in parallel with the DIF.**

- **Power Pulsing (PP) mode** → PP will be tested using one ASU and simulating powering ON the ASICs during the beam and powering OFF the rest of the time.
- **I²C communication** → it ***doesn't work with the new ASU*** but it works ***using a different HARDROC3 (HR3) board*** provided by IN2P3 (Lyon). So, **we are looking into the problem**.
- **Data acquisition** → it will be tested the data transmission from HR3 to the DIF and sending data to the DAQ using Ethernet.
- **TTC commands** in the synchronization part.

Status of the Mechanical structure absorber

Calorimetry for detectors at future colliders.
ILD SDHCAL prototype (AIDA2020) – Mechanics

NEW PROTOTYPE

Plates ~3x1 m², 15 mm thick
Spacers ~13 mm thick
(needed to create the space between absorber plates to insert the GRPCs GRPC+ cassette box=11mm):

Surface **planarity < 1mm** ,
Thickness tolerance **50µm**

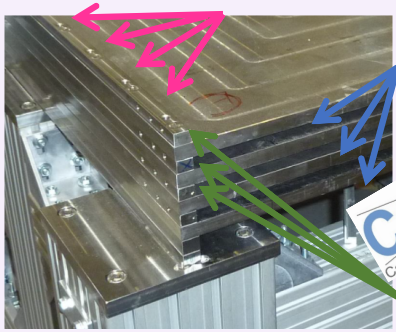
Material: Inox AISI 304 Inox
(stainless steel – non magnetic)

Assembly: Electron Beam welding (EBW)

~1m3 CALICE PROTOTYPE

Plates ~1x1 m², 15 mm thick

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

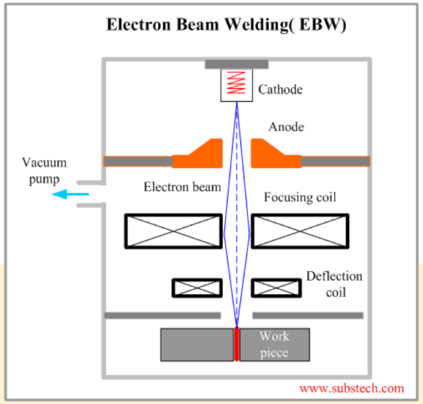


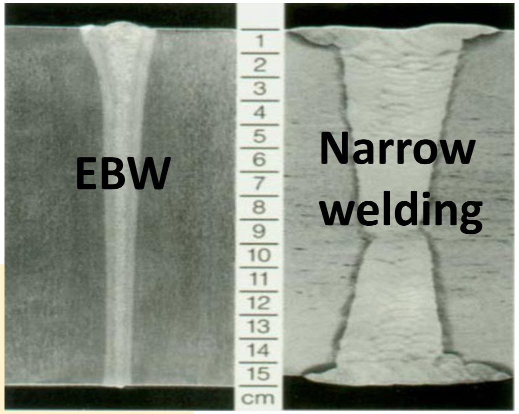
Detail after assembly the **first 4 absorber plates of the 1.3m³ prototype**

Assembly: Bolts

Larger (heavier) structure
- ➔ Bigger bolts, **larger dead spaces**, option: Welding

Standard Welding
- ➔ Heating introduces **deformations**





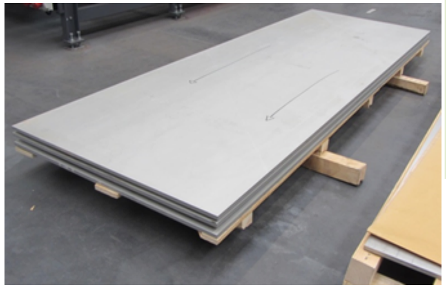
Electron Beam welding (EBW)
- ➔ Very **narrow**, but needs **vacuum conditions**

Plates need to be **very flat** for reducing the extra tolerance space for the GRPC insertion

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/*

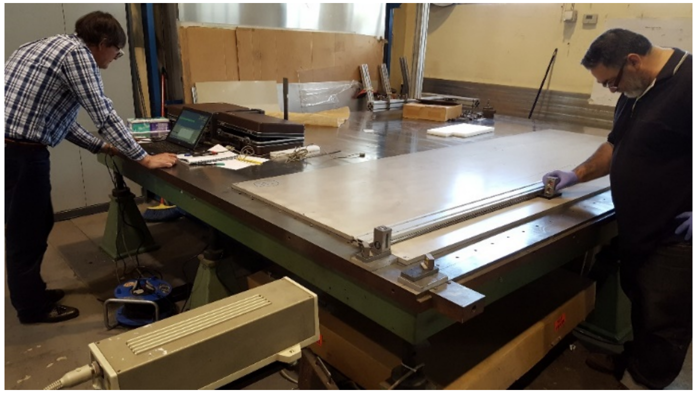


5 Plates available
Initial planarity between 1 and 3mm
Final planarity inside the required tolerances

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

(µm)	Plate D		Plate E	
	Side 1 up	Side 2 up	Side 1 up	Side 2 up
Average	458,7	546,1	610,2	521,9



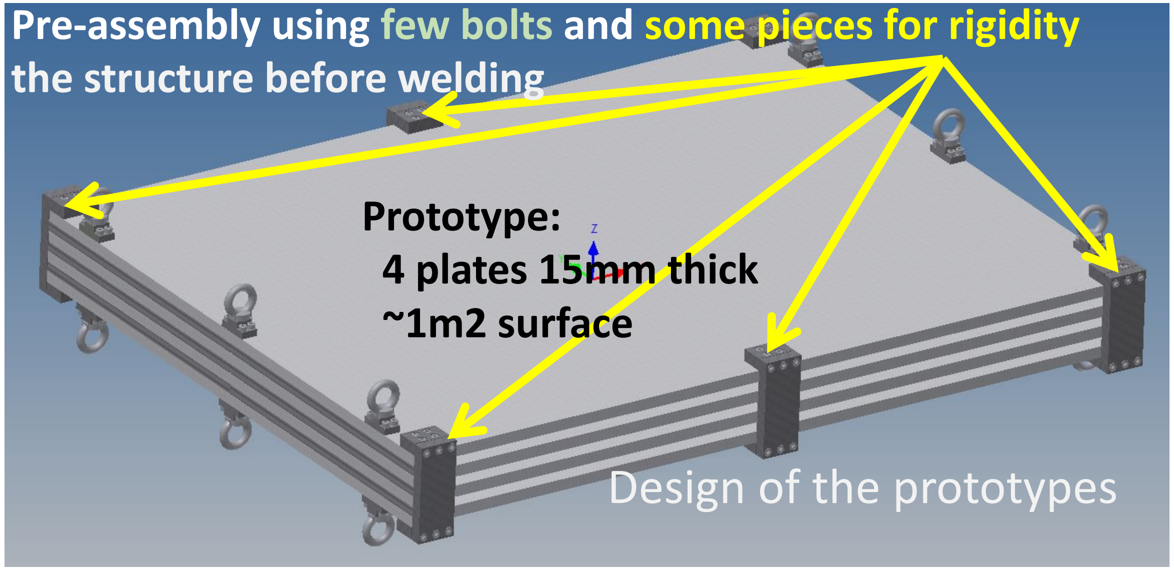
Measurements using **laser interferometer.**
Over a flat table (0.1mm planarity)

Thickness

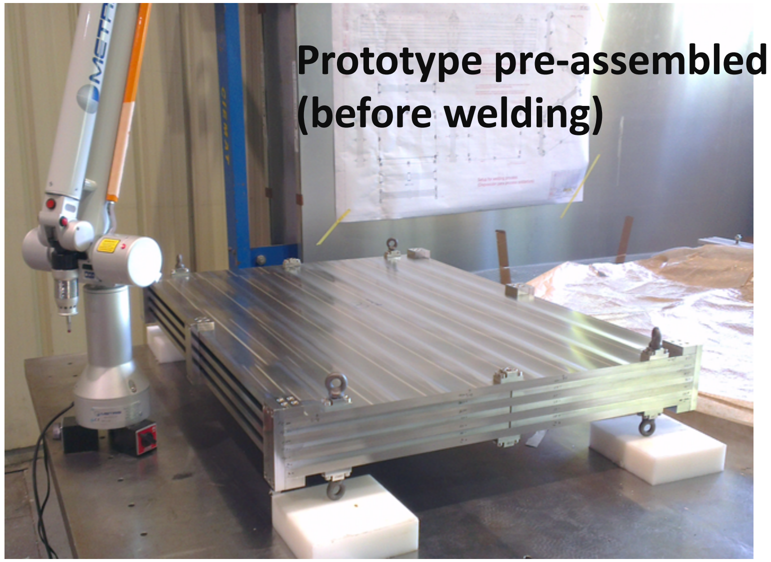
Plate	A	B	C	D	E
Average (mm)	15,324	15,233	15,334	15,225	15,322
max (mm)	15,324	15,292	15,348	15,270	15,325
min (mm)	15,323	15,173	15,320	15,179	15,318
Δ (mm)	0,001	0,119	0,028	0,091	0,007

Tests with smaller prototypes and special pieces

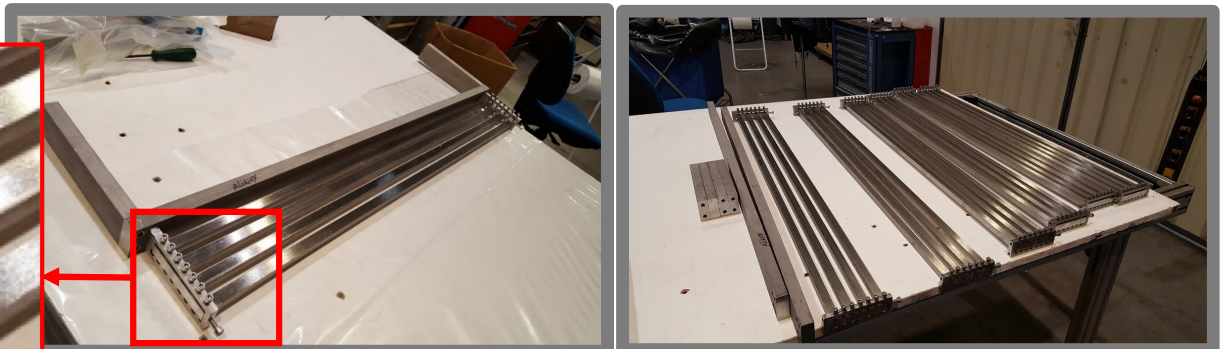
In order to optimize the procedure before welding the bigger prototype **4 smaller prototypes** of different sizes (4 plates 0.8x1m2, 4 plates 0.4x1m2) and **several special pieces** has been welded with ***different welding sequences and machine parameters***.



Design of the prototypes



Prototype pre-assembled (before welding)

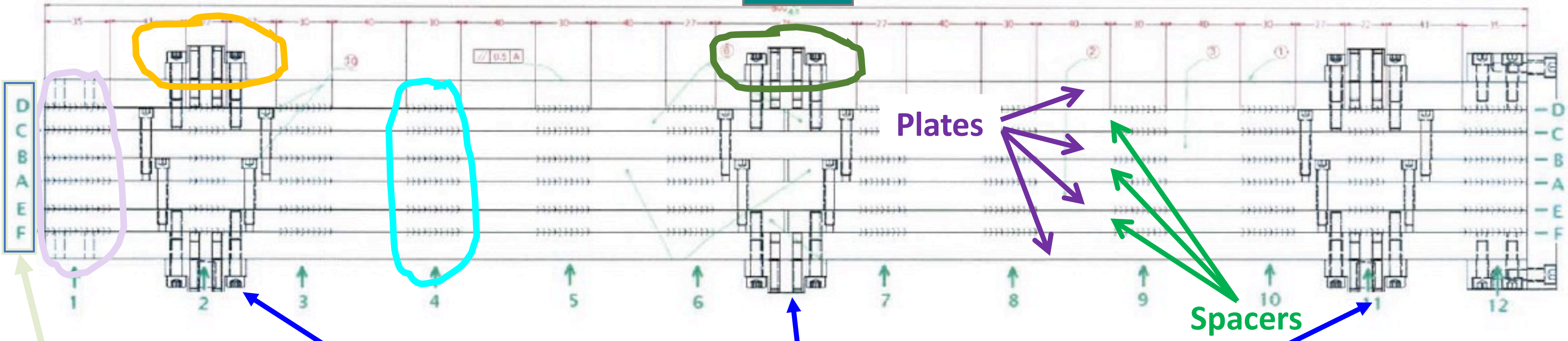


Special pieces used for helping on optimizing the welding procedure

They allow to make several **cheaper tests**, **changing the sequences and depth of welding** in order to find the procedure producing the **lowest deformation.**

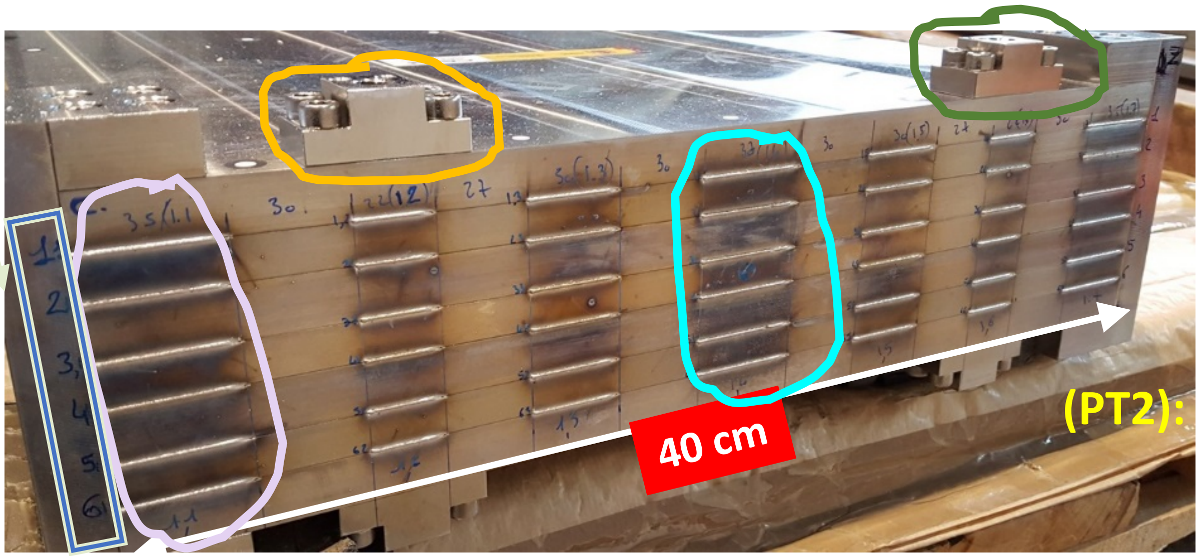
Mechanical Structure: Welding procedure

80 cm



Some bolts are needed to fix the plates together before welding

D➔1
C➔2
B➔3
A➔4
E➔5
F➔6



The welding is performed in a certain order not sequential, “jumping” in between the different welding point positions (horizontally and vertically).

The order of welding has an influence on the final deformations

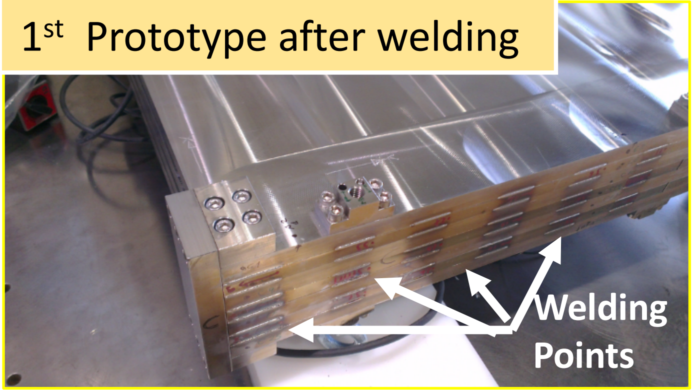
Firsts small prototypes

➔ **First small prototype:** 4 plates 1x1 m2

After comparing the measurements before and after welding deformations found (~1mm) bigger than expected in X-axis. O.K in Y-axis

➔ **Probably due to the welding sequence used**

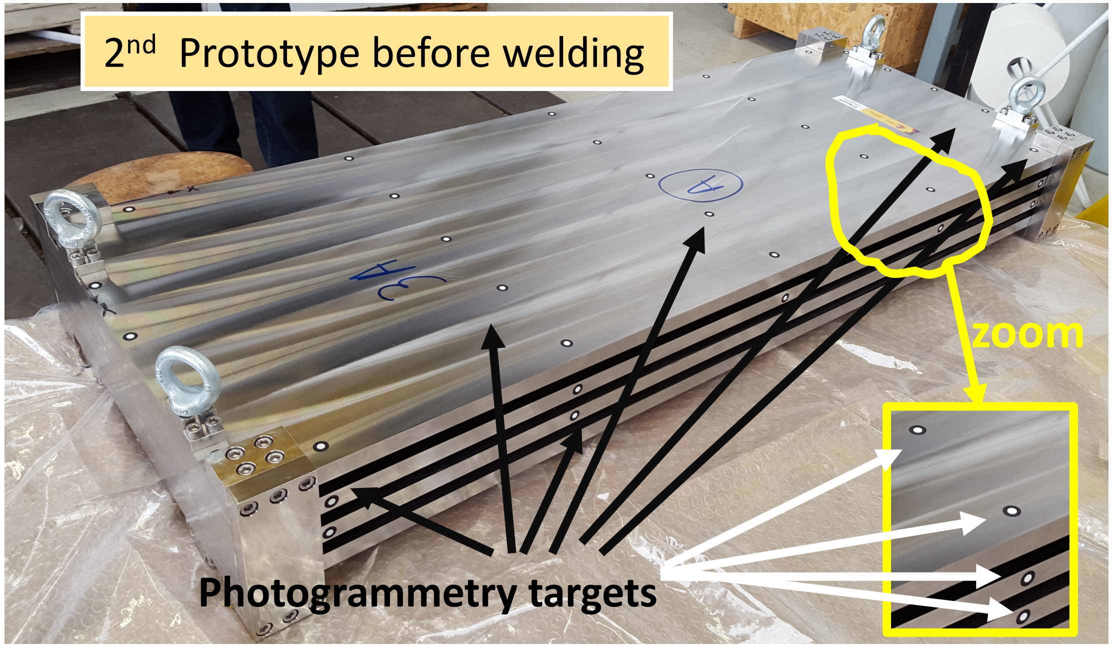
1st Prototype after welding

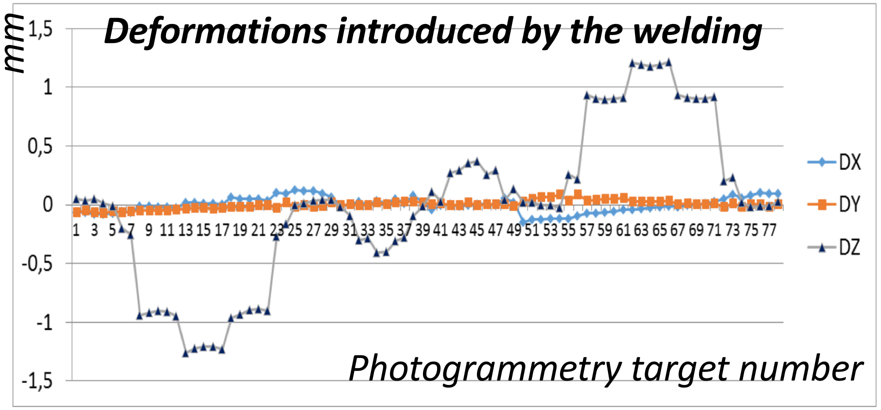


➔ **Second small prototype:** 4 plates 1x0.5 m2

Welding performed **changing a bit the welding sequence** with respect to the previous prototype

2nd Prototype before welding



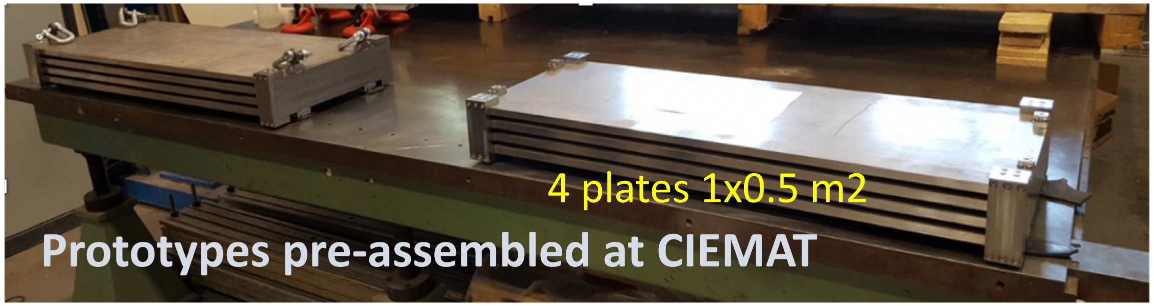


The deformation in X is still a bit large.

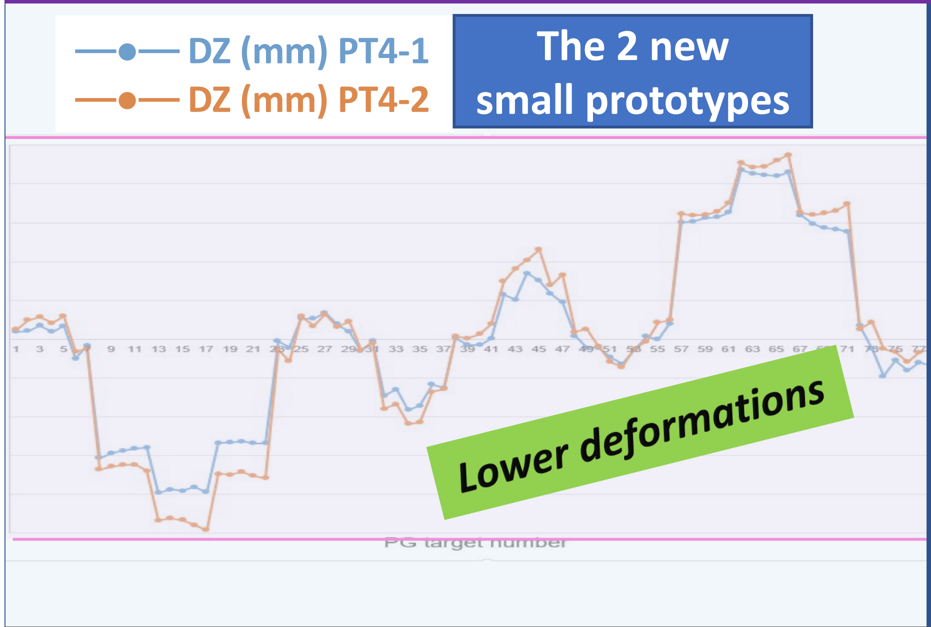
Several tests with the special pieces should help on improving the procedure to decrease the deformation

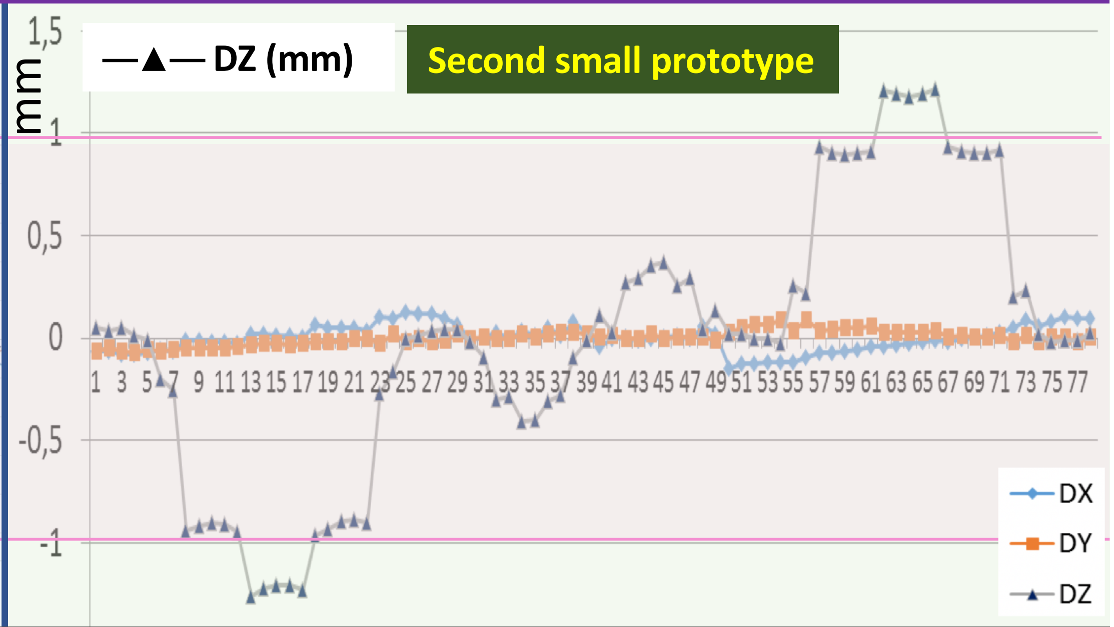
Last small prototypes

Two new small prototypes have been welded following the new welding procedures and 10mm penetration (previously 5mm)



Deformation induced by welding → Position After EBW – Pre-assembled vs Photogrammetry target number

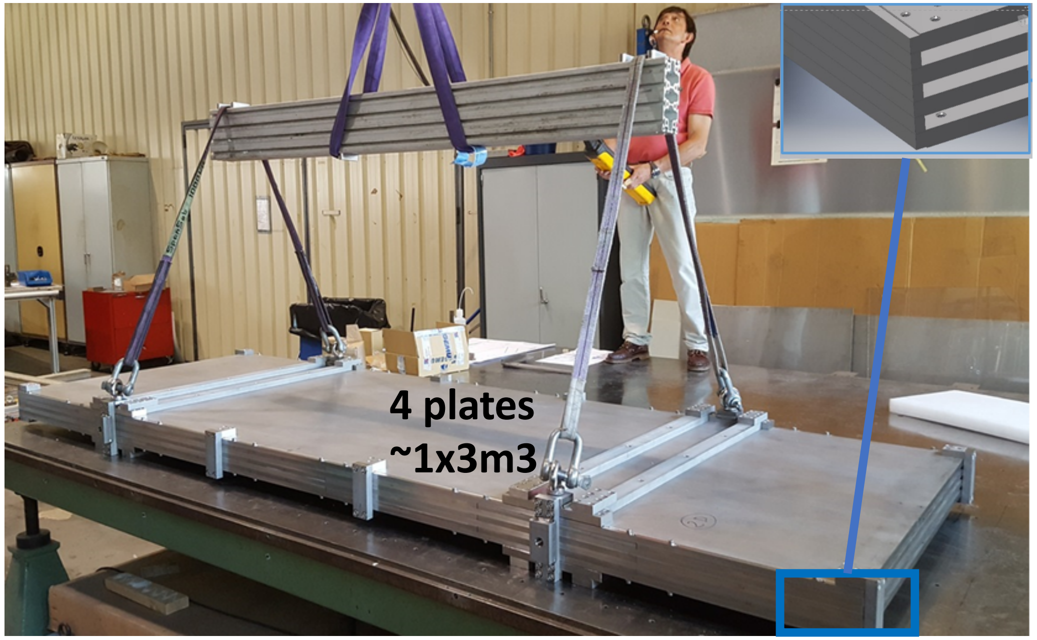


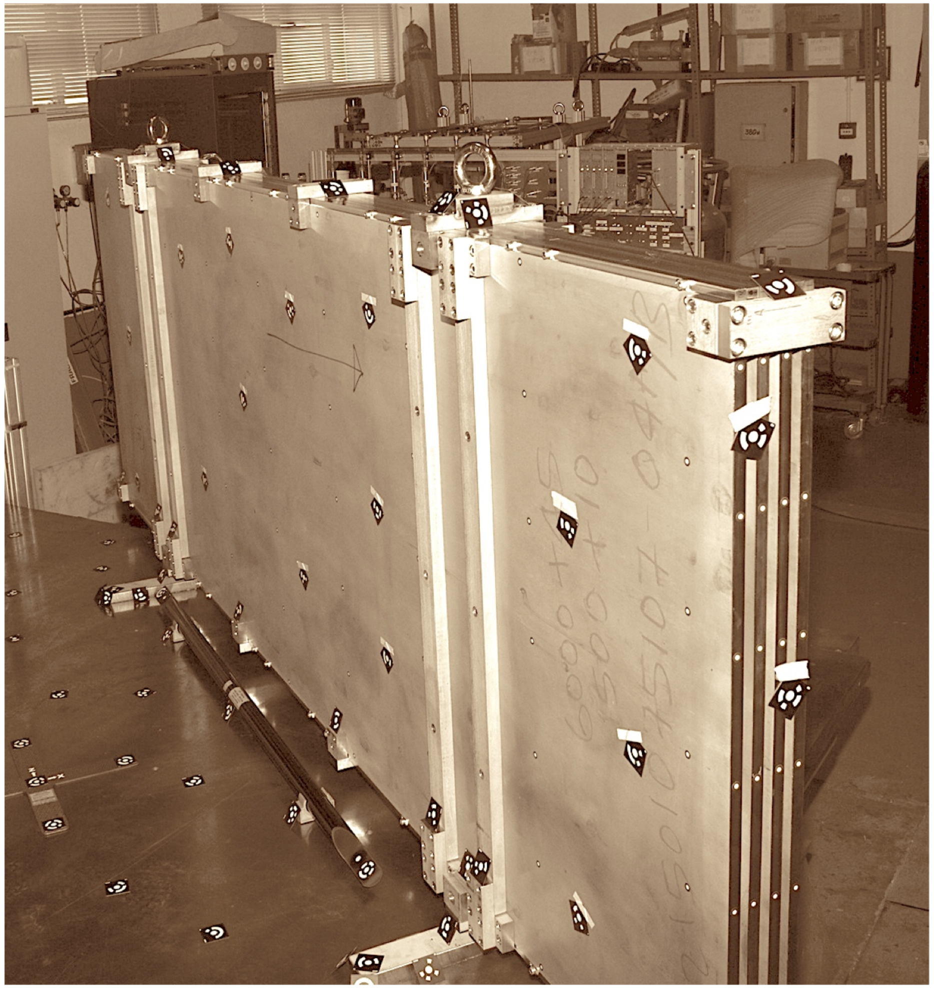


Even using a double penetration (10 vs 5 mm) which will make bigger deformation (but more robust) the **deformations are lower for new prototypes** (using optimized machine parameters and welding sequence)

Pre-assembling of the mechanical absorber structure prototype

Structure pre-assembled and prepared for photogrammetry measurement at CIEMAT





TACK Welding sequence (Secuencia del punteado de la soldadura):

1.- Side A, Tack welding, penetration 2 mm: *4.18, 3.18, 3.1, 4.1, 4.9, 3.9, 3.5, 4.5, 4.13, 3.13. (Rotation 180º around Y axis)*

2.- Side A, Tack welding, penetration 2 mm: *4.35, 3.35, 3.27, 4.27, 4.23, 3.23, 3.31, 4.31.*

3.- Side B, Tack welding, penetration 2 mm: *4.18, 3.18, 3.1, 4.1, 4.9, 3.9, 3.5, 4.5, 4.13, 3.13. (Rotation 180º around Y axis)*

4.- Side B, Tack welding, penetration 2 mm: *4.35, 3.35, 3.27, 4.27, 4.23, 3.23, 3.31, 4.31, 6.18, 1.18, 1.35, 6.35, 6.27, 1.27, 1.31,6.31, 6.23, 1.23. (Rotation 180º around Y axis)*

5.- Side B, Tack welding, penetration 2 mm: *6.1, 1.1, 1.9, 6.9, 6.5, 1.5, 1.13, 6.13.*

6.- Side A, Tack welding, penetration 2 mm: *6.18, 1.18, 1.35, 6.35, 6.27, 1.27, 1.31,6.31, 6.23, 1.23. (Rotation 180º around Y axis)*

7.- Side A, Tack welding, penetration 2 mm: *6.1, 1.1, 1.9, 6.9, 6.5, 1.5, 1.13, 6.13, 5.18, 2.18, 2.1, 5.1, 5.9, 2.9, 2.5, 5.5, 5.13, 2.13. (Rotation 180º around Y axis)*

8.- Side A, Tack welding, penetration 2 mm: *5.35, 2.35, 2.27, 5.27, 5.31, 2.31, 2.23, 5.23.*

9.- Side B, Tack welding, penetration 2 mm: *5.18, 2.18, 2.1, 5.1, 5.9, 2.9, 2.5, 5.5, 5.13, 2.13. (Rotation 180º around Y axis)*

10.- Side B, Tack welding, penetration 2 mm: *5.35, 2.35, 2.27, 5.27, 5.31, 2.31, 2.23, 5.23. (Rotation 180º around Y axis)*

(REMOVE lateral reinforcements on SIDE A & B)

Final welding sequence defined after all the tests and verifications using smaller prototype and specific pieces

Welding sequence (Secuencia de la soldadura):

11.- Side B, Welding, penetration 10 mm: *4.17, 3.17, 3.2, 4.2, 4.10, 3.10, 3.4, 4.4, 4.14, 3.14, 3.12, 4.12, 4.6, 3.6, 3.3, 4.3, 4.16, 3.16, 3.11, 4.11, 4.7, 3.7, 3.8, 4.8, 4.15, 3.15, 3.18, 4.18, 4.1, 3.1, 3.9, 4.9, 4.5, 3.5, 3.13, 4.13. (Rotation 180º around Y axis)*

12.- Side B, Welding, penetration 10 mm: *4.19, 3.19, 3.34, 4.34, 4.26, 3.26, 3.32, 4.32, 4.22, 3.22, 3.24, 4.24, 4.30, 3.30, 3.33, 4.33, 4.20, 3.20, 3.25, 4.25, 4.29, 3.29, 3.28, 4.28, 4.21, 3.21, 3.35, 4.35, 4.27, 3.27, 3.31, 4.31, 4.23, 3.23.*

13.- Side A, Welding, penetration 10 mm: *4.17, 3.17, 3.2, 4.2, 4.10, 3.10, 3.4, 4.4, 4.14, 3.14, 3.12, 4.12, 4.6, 3.6, 3.3, 4.3, 4.16, 3.16, 3.11, 4.11, 4.7, 3.7, 3.8, 4.8, 4.15, 3.15, 3.18, 4.18, 4.1, 3.1, 3.9, 4.9, 4.5, 3.5, 3.13, 4.13. (Rotation 180º around Y axis)*

14.- Side A, Welding, penetration 10 mm: *4.19, 3.19, 3.34, 4.34, 4.26, 3.26, 3.32, 4.32, 4.22, 3.22, 3.24, 4.24, 4.30, 3.30, 3.33, 4.33, 4.20, 3.20, 3.25, 4.25, 4.29, 3.29, 3.28, 4.28, 4.21, 3.21, 3.35, 4.35, 4.27, 3.27, 3.31, 4.31, 4.23, 3.23, 6.19, 1.19, 1.34, 6.34, 6.26, 1.26, 1.32, 6.32, 6.22, 1.22, 1.24, 6.24, 6.30, 1.30, 1.33, 6.33, 6.20, 1.20, 1.25, 6.25, 6.29, 1.29, 1.28, 6.28, 6.21, 1.21, 1.35, 6.35, 6.27, 1.27, 1.31, 6.31, 6.23, 1.23. (Rotation 180º around Y axis)*

15.- Side A, Welding, penetration 10 mm: *6.17, 1.17, 1.2, 6.2, 6.10, 1.10, 1.4, 6.4, 6.14, 1.14, 1.12, 6.12, 6.6, 1.6, 1.3, 6.3, 6.16, 1.16, 1.11, 6.11, 6.7, 1.7, 1.8, 6.8, 6.15, 1.15, 1.18, 6.18, 6.1, 1.1, 1.9, 6.9, 6.5, 1.5, 1.13, 6.13.*

16.- Side B, Welding, penetration 10 mm: *6.19, 1.19, 1.34, 6.34, 6.26, 1.26, 1.32, 6.32, 6.22, 1.22, 1.24, 6.24, 6.30, 1.30, 1.33, 6.33, 6.20, 1.20, 1.25, 6.25, 6.29, 1.29, 1.28, 6.28, 6.21, 1.21, 1.35, 6.35, 6.27, 1.27, 1.31, 6.31, 6.23, 1.23. (Rotation 180º around Y axis)*

17.- Side B, Welding, penetration 10 mm: *6.17, 1.17, 1.2, 6.2, 6.10, 1.10, 1.4, 6.4, 6.14, 1.14, 1.12, 6.12, 6.6, 1.6, 1.3, 6.3, 6.16, 1.16, 1.11, 6.11, 6.7, 1.7, 1.8, 6.8, 6.15, 1.15, 1.18, 6.18, 6.1, 1.1, 1.9, 6.9, 6.5, 1.5, 1.13, 6.13, 5.17, 2.17, 2.2, 5.2, 5.10, 2.10, 2.4, 5.4, 5.14, 2.14, 2.12, 5.12, 5.6, 2.6, 2.3, 5.3, 5.16, 2.16, 2.11, 5.11, 5.7, 2.7, 2.8, 5.8, 5.15, 2.15, 2.18, 5.18, 5.1, 2.1, 2.9, 5.9, 5.5, 2.5, 2.13, 5.13. (Rotation 180º around Y axis)*

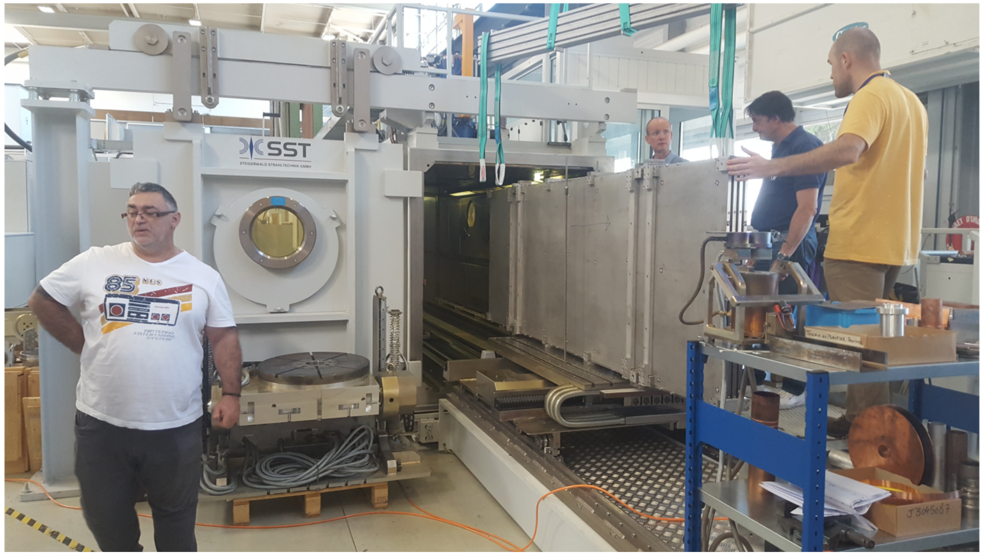
18.- Side B, Welding, penetration 10 mm: *5.19, 2.19, 2.34, 5.34, 5.26, 2.26, 2.32, 5.32, 5.22, 2.22, 2.24, 5.24, 5.30, 2.30, 2.33, 5.33, 5.20, 2.20, 2.25, 5.25, 5.29, 2.29, 2.28, 5.28, 5.21, 2.21, 2.35, 5.35, 5.27, 2.27, 2.31, 5.31, 5.23, 2.23.*

19.- Side A, Welding, penetration 10 mm: *5.17, 2.17, 2.2, 5.2, 5.10, 2.10, 2.4, 5.4, 5.14, 2.14, 2.12, 5.12, 5.6, 2.6, 2.3, 5.3, 5.16, 2.16, 2.11, 5.11, 5.7, 2.7, 2.8, 5.8, 5.15, 2.15, 2.18, 5.18, 5.1, 2.1, 2.9, 5.9, 5.5, 2.5, 2.13, 5.13. (Rotation 180º around Y axis)*

20.- Side A, [illegible] *2.32, 5.32, 5.22, 2.22, 2.24, 5.24, 5.30, 2.30, 2.33, 5.33, 5.20, 2.20, 2.25, 5.25, 5.29, 2.29, 2.28, 5.28, 5.21, 2.21, 2.35, 5.35, 5.27, 2.27, 2.31, 5.31, 5.23, 2.23.*

EBW Sequence

Electron Beam Welding of the Demonstrator

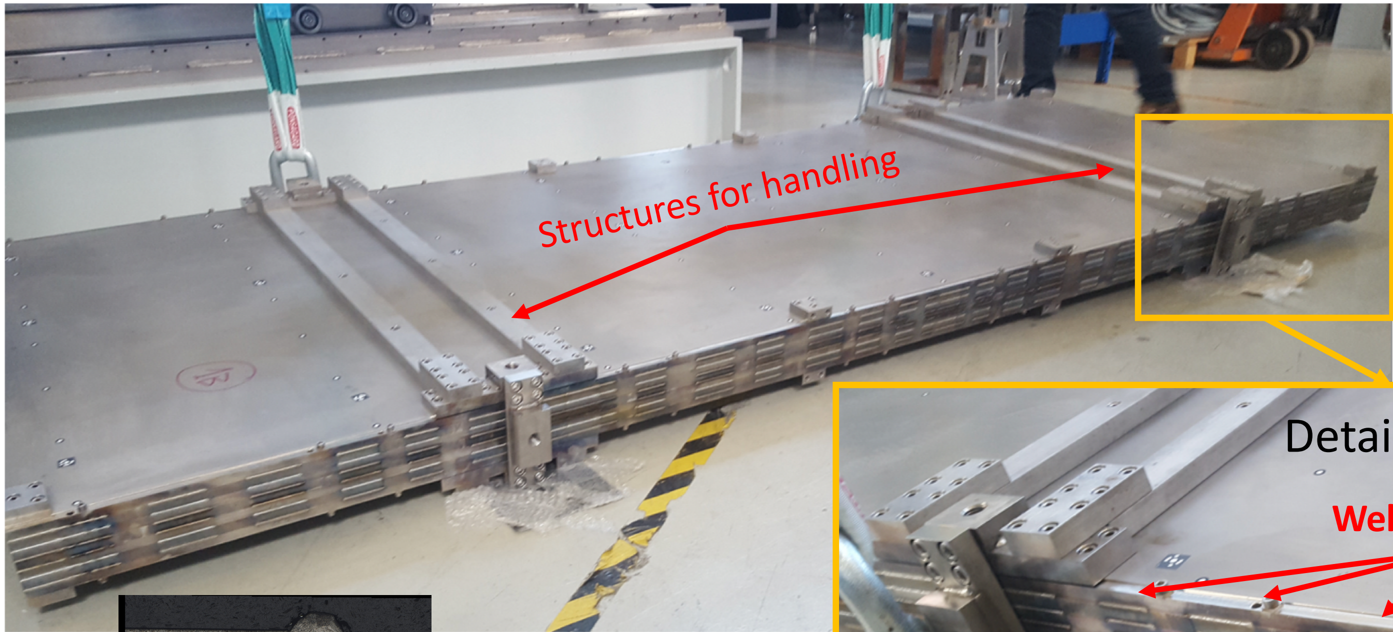


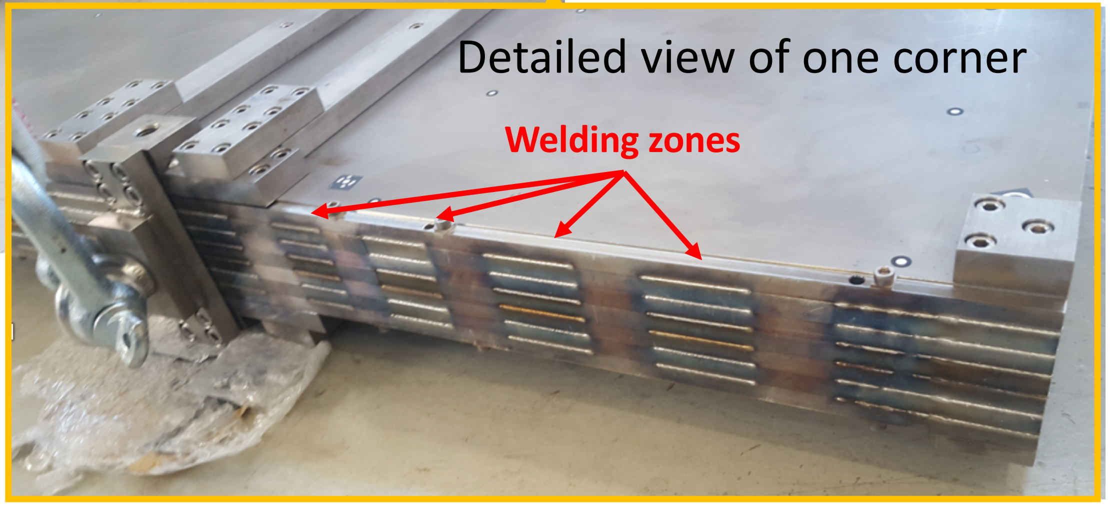
Introduction of the pre-assembled absorber structure inside the EBW machine at CERN

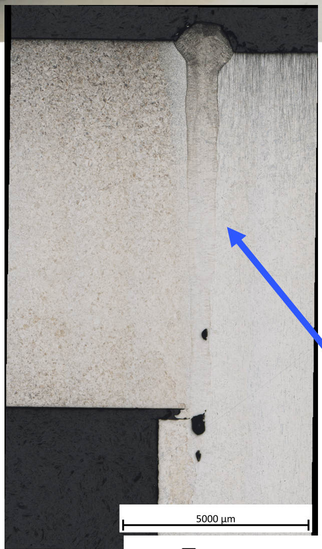
Participation of the CIEMAT mechanical engineer (E.Calvo) and two CIEMAT technicians (J.García, C.Puras) for helping the CERN people.

The procedure needs to **rotate** and place the structure in **several positions** inside the EBW machine to allow the welding cover both sides and the full 3m length.

Demonstrator after welding







5mm

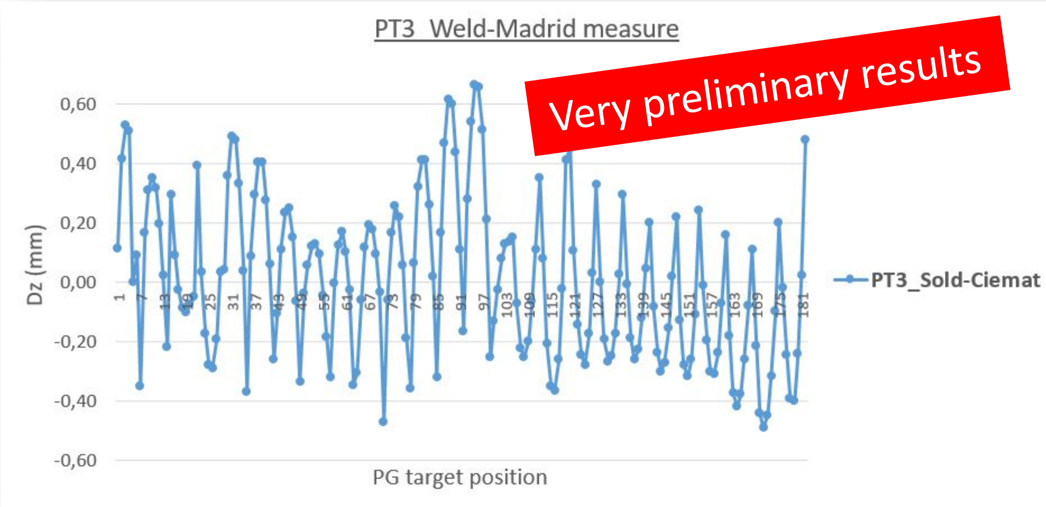
Detail of welding
(transversal cut zoomed)

Insertion tests

We have inserted an empty cassette (smaller length ~1m but same thickness) to check the future insertion of the new larger GRPCs.

Final results on deformations

- The results from the photogrammetry done at CERN are not yet available (should be in some days)
- The structure has came back to CIEMAT and some measurements have been performed



Data are being analyzed now but the **preliminary results** are **very promising, showing deformations smaller than for the small prototypes.** The results need also the crosscheck with the measurements done at CERN.

The structure of the final deformation should still better understood


THAT'S ALL FOLKS
BUT STAY TUNED!!
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