

TRD2D Production Prototype Instance 0 & 1

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48th Collaboration Meeting
14th September 2026
Warsaw

TRD2D production prototyping

Chamber construction and production steps

Assembly

Assembly tools meant to provide reproducible, **high precision** geometry for **minimal man-power costs**.

Electrodes winding

Devices for producing wire electrodes within **achievable limits** of precision requirements.

Electrodes installation

Devices for measuring, calibrating, aligning and QA of the electrodes wires wrt the chamber frame.

Pad Plane (PP)

Read-out pads, connectors to FEE and gas sealing procedures

Components

Supporting structure of the chamber [FR4 ledges] and of the PP [Honeycomb (HC)], gas adapters, etc.

Entrance Window (EW)

FR4 structure reinforced with C ledges, kapton(Al) pre-stretched electrode.

Anode (A) assembly

Structure holding the PP and anode electrode.

Cathode (C) assembly

Structure holding the EW and cathode electrode.

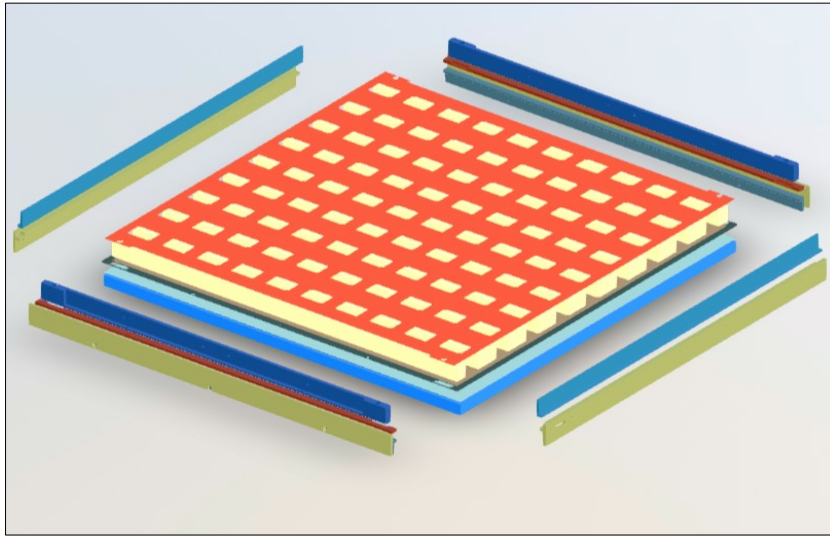
Chamber assembly

Combine anode and cathode assemblies assuring gas and HV connectivity without gas leaks and dark currents.

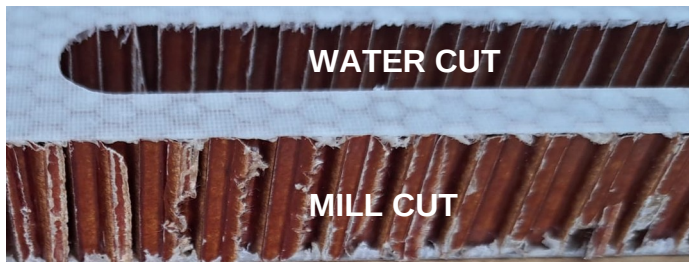
QA

Gas, HV, [uniformity, gain, packaging, etc.]

Ledges & HC plates



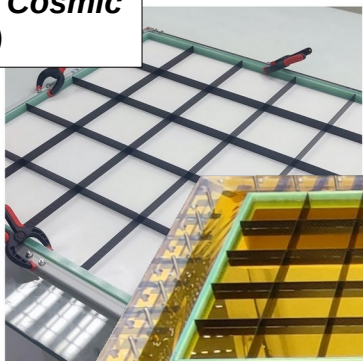
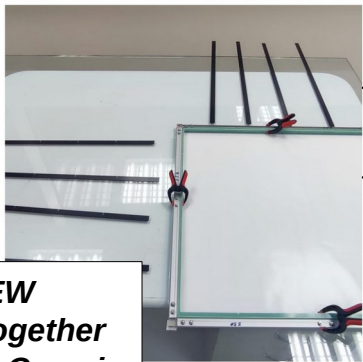
- components for 2 chambers (+ 2 entrance window frames) were realized by our external collaborators **ProPlastic** ([Laura](#))
- HC processing improved (CR group)
- the gas inlet / outlet ledge  was adapted to the SERTO gas connection of the TRD gas system ([Daniel B. & Laura](#)) see S7.



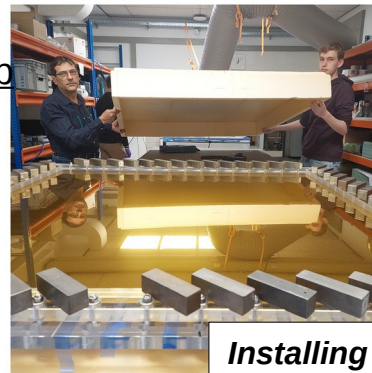
Entrance window



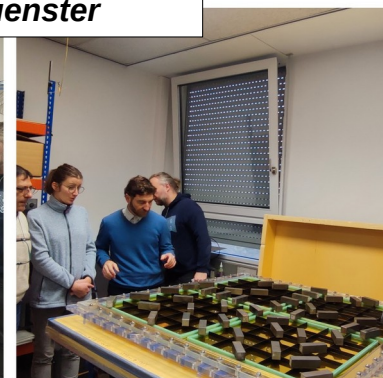
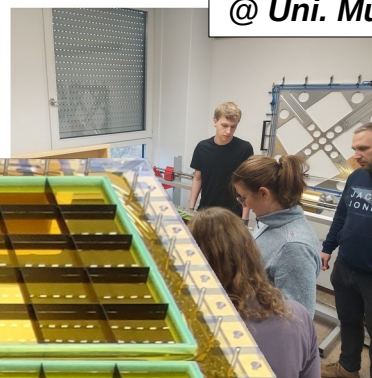
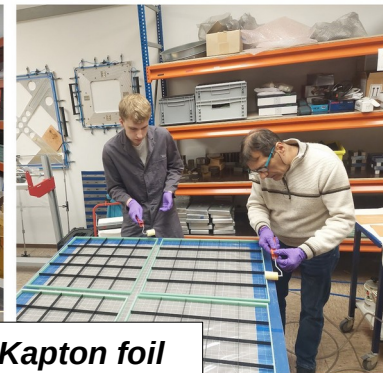
Construction of the EW frame in Bucharest together with colleagues from Cosmic Rays group (IFIN-HH)



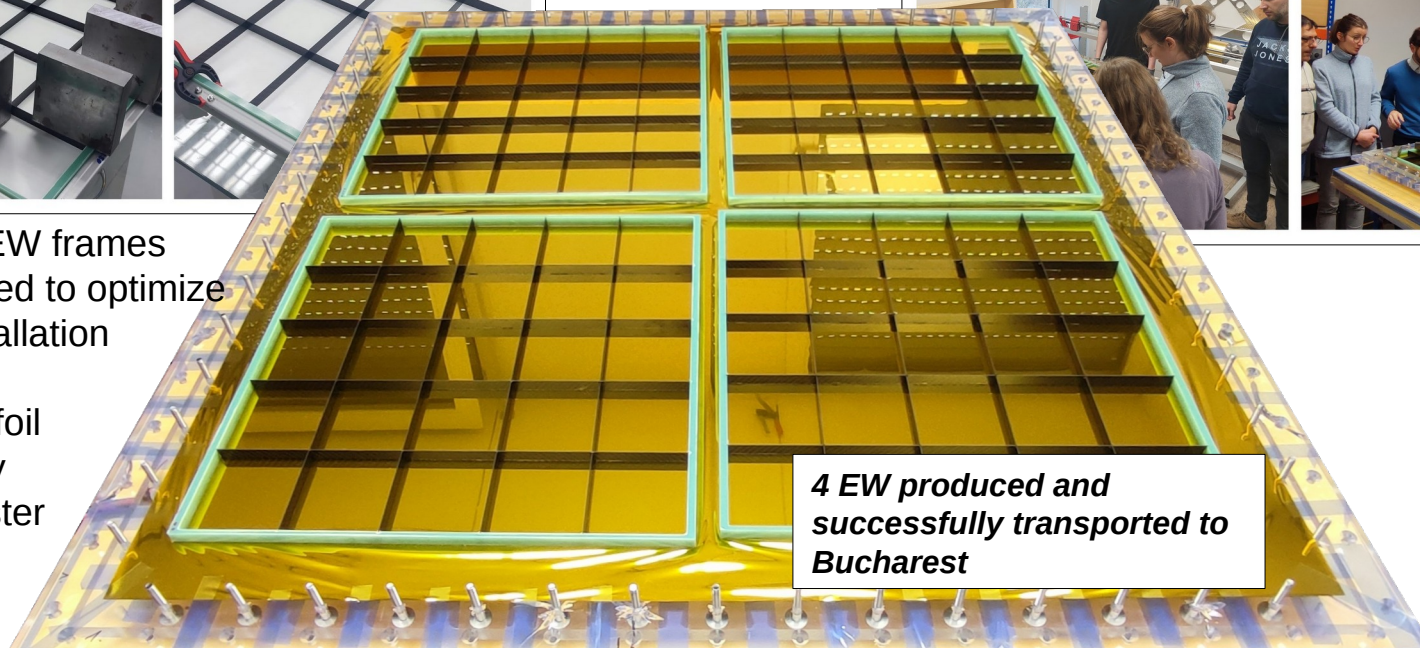
Uni. Muenster :
Henning, Laura, Philipp
IFIN-HH :
Laura, Marian, Alex



Installing Kapton foil @ Uni. Muenster

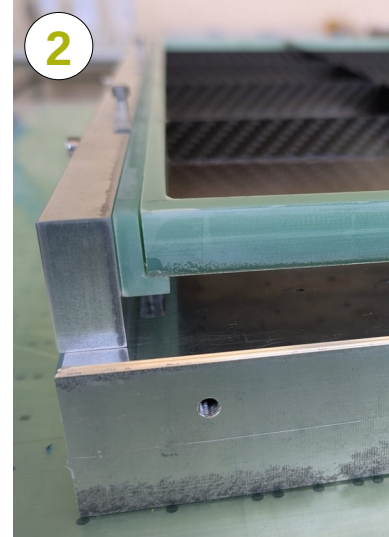
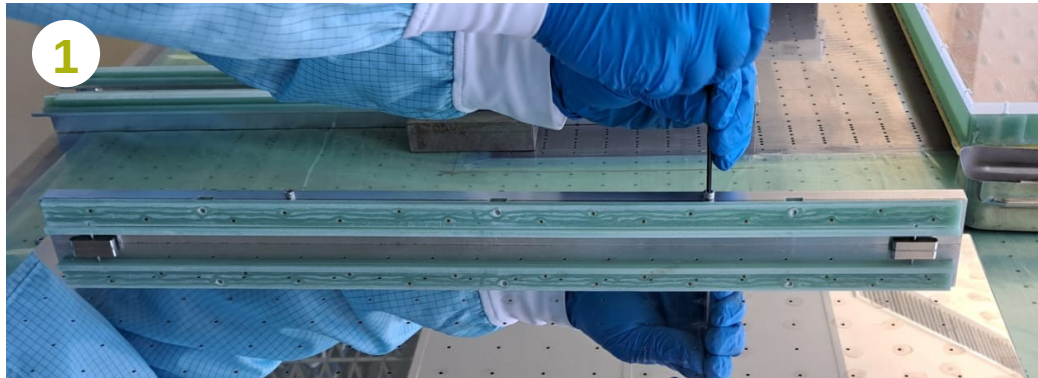


*) 2 **extra** EW frames were realized to optimize the foil installation procedure
**) Kapton foil provided by Uni. Muenster



4 EW produced and successfully transported to Bucharest

Cathode Assembly construction



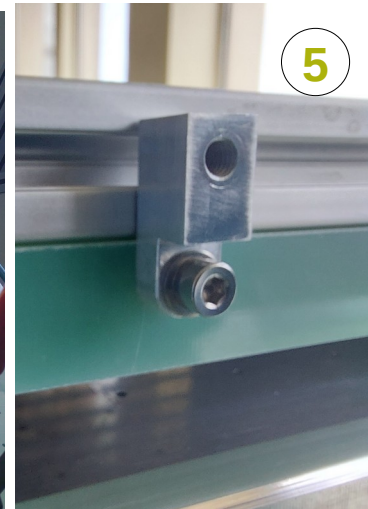
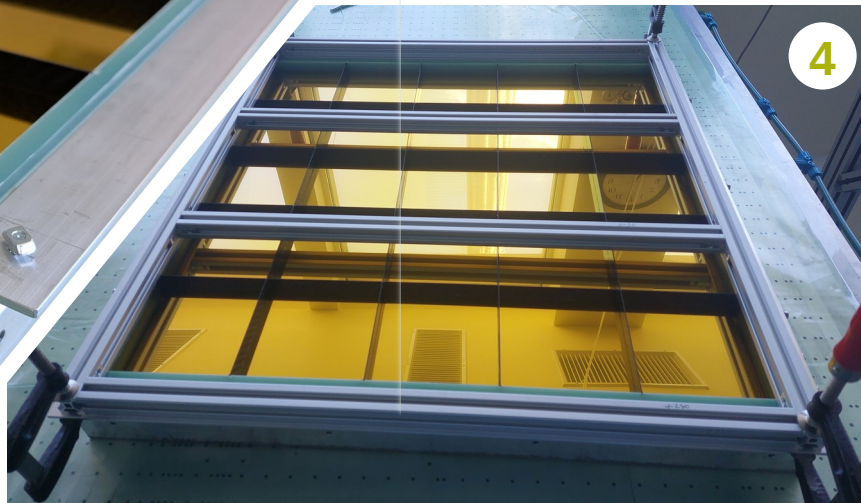
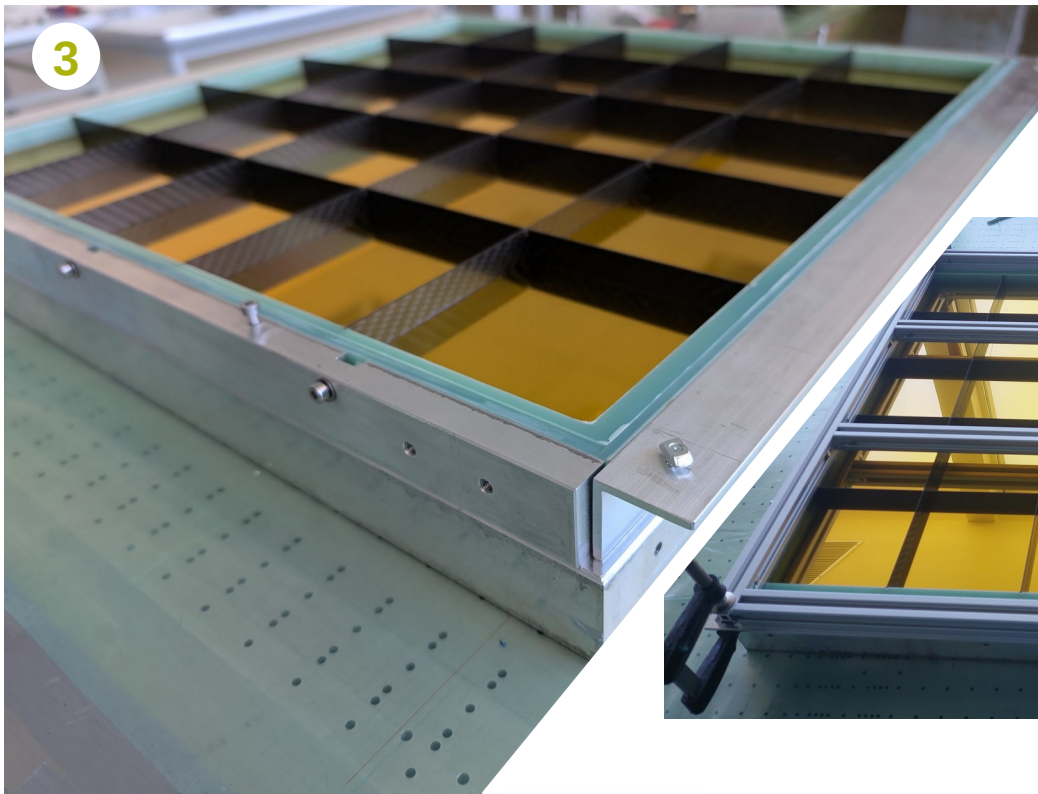
1. Installing ledges on the assembly table

2. Installing entrance window

3. Closing the cathode assembly

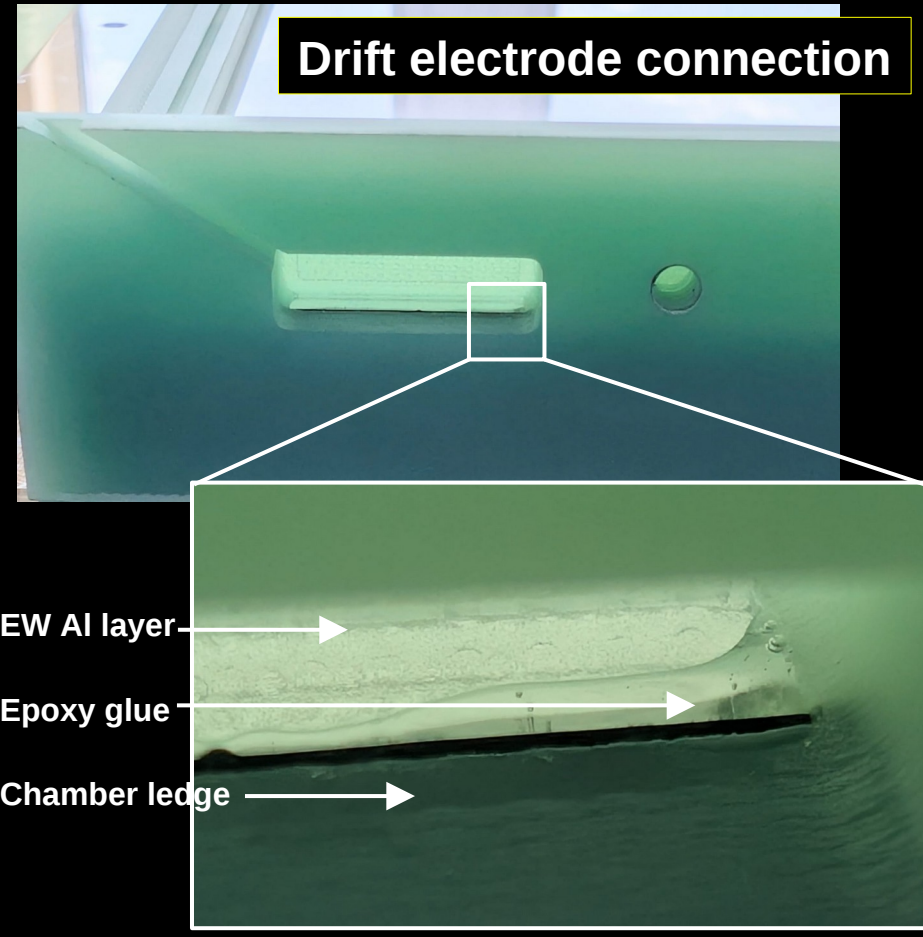
4. Reinforcing the cathode assembly

5. Reinforcing the cathode assembly (detail)



Cathode Assembly gas sealing

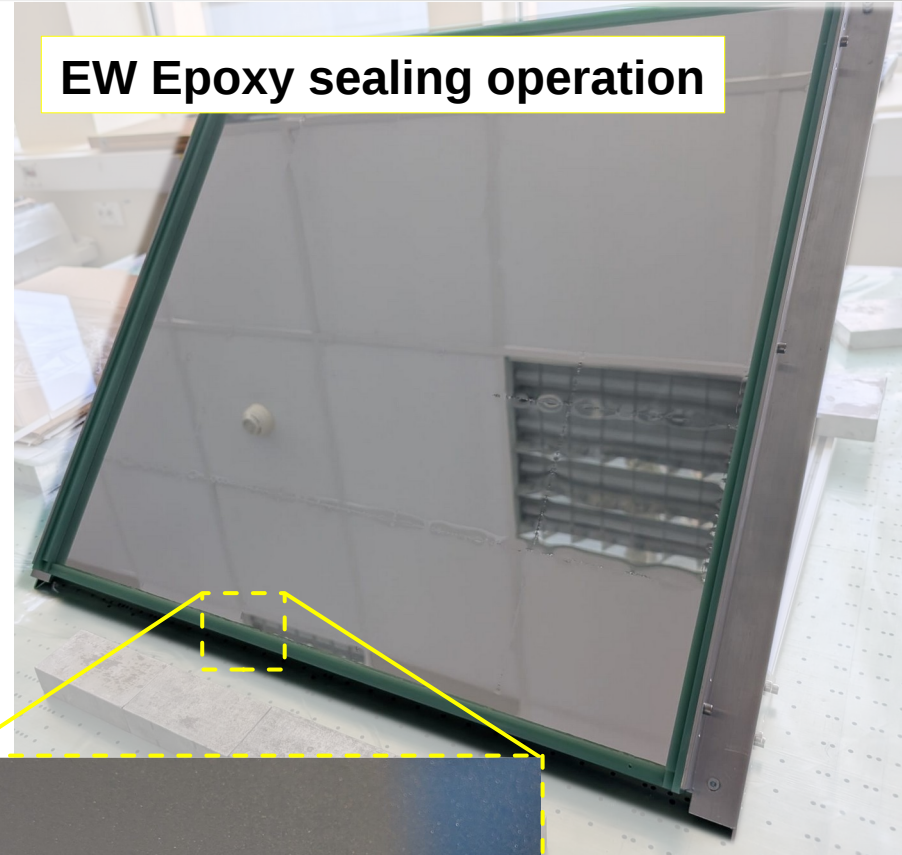
Drift electrode connection



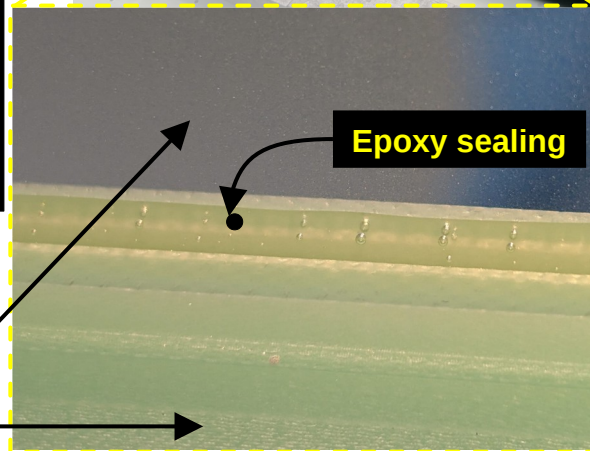
Connection to the **HV** is performed **outside** of the gas volume to avoid gas leaks.

The **cathode assembly** is gas sealed on the interior at the boundary between the kapton(Al) foil and the ledge

EW Epoxy sealing operation



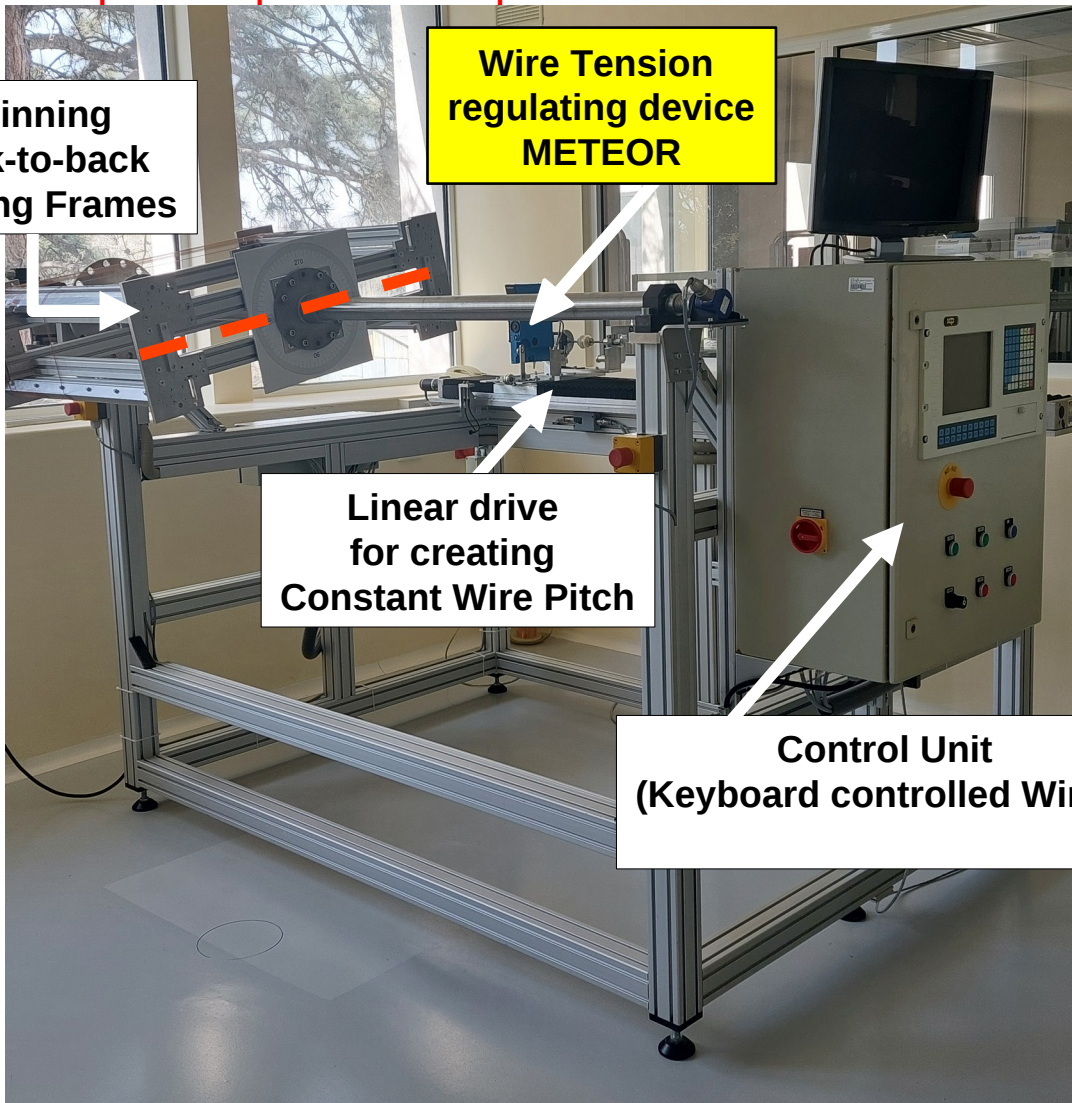
Epoxy sealing



Gas sealing the 4 edges of the EW is a long process (**1day/edge**) but can be shortened if realized in a parallel production.

ELECTRODES winding

Device for wire winding inherited from **ALICE TRD** construction.
No updates planned or possible similar to those done by Uni. Frankfurt.

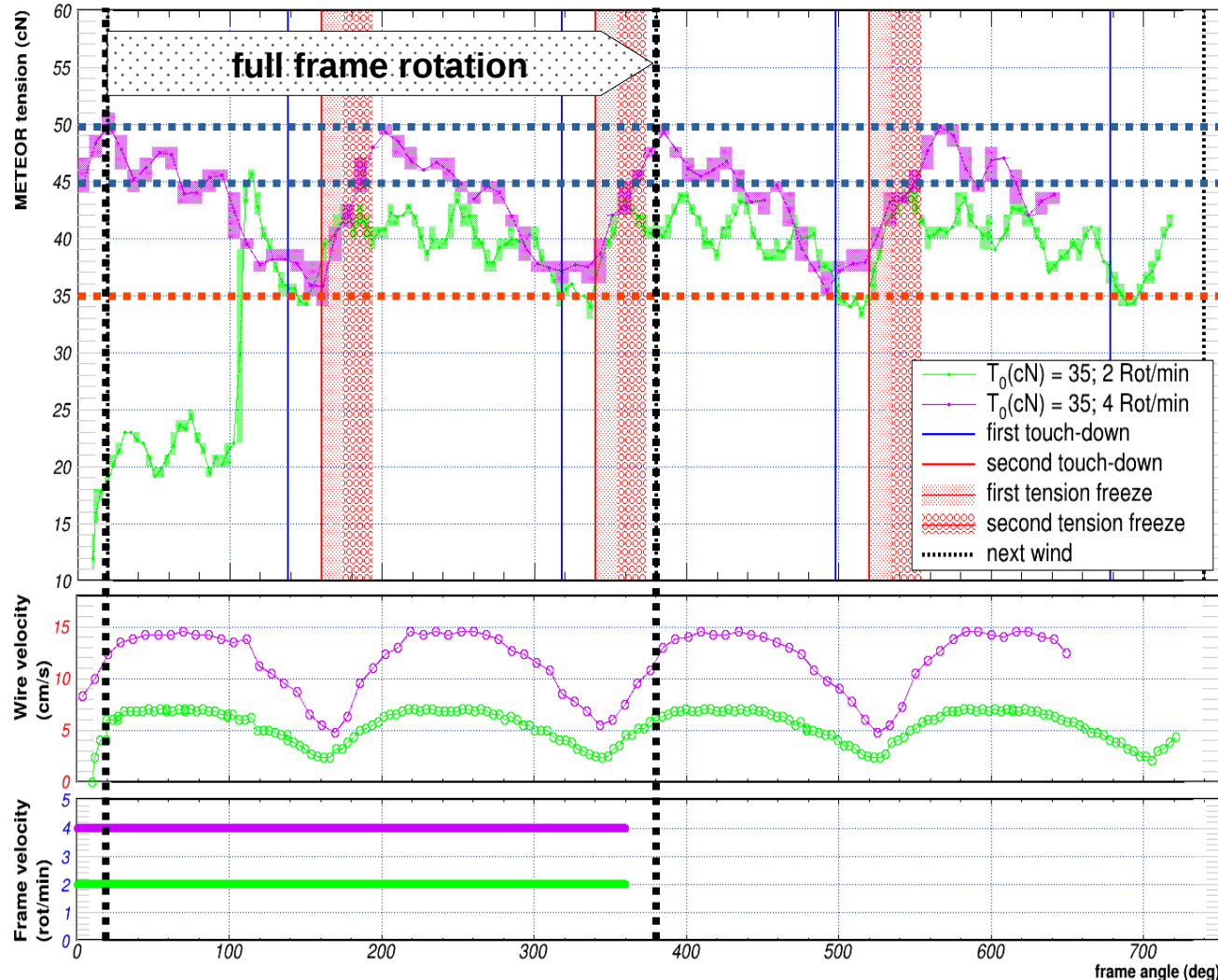


Project request (anode)

- WRe3 20 μ m Luma wires
- Nominal wire tension **50 cN**
- Elasticity limit **52 cN**
- Never enter plastic deformation
 - dynamically during winding process
 - statically on the support

SW/CFG update

HW update

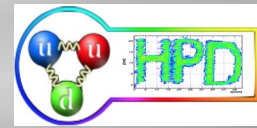


replacing the breaking wheel was simple but it took **4 months** of bureaucratic negotiations

replacing the **constant angular** velocity of the frame *winding mode* with the **constant linear** velocity of the wire is producing a flat profile of the wire tension **during winding**. Further device configurations for **in-depth QA** data.



ELECTRODES winding



From the QA data collected from the METEOR we can build a **detailed report on each wire**. Unfortunately the momentary value of wire tension is not recorded but the **linear velocity** is and it is **used as proxy**.

Results for the winding of the cathode for PP0.

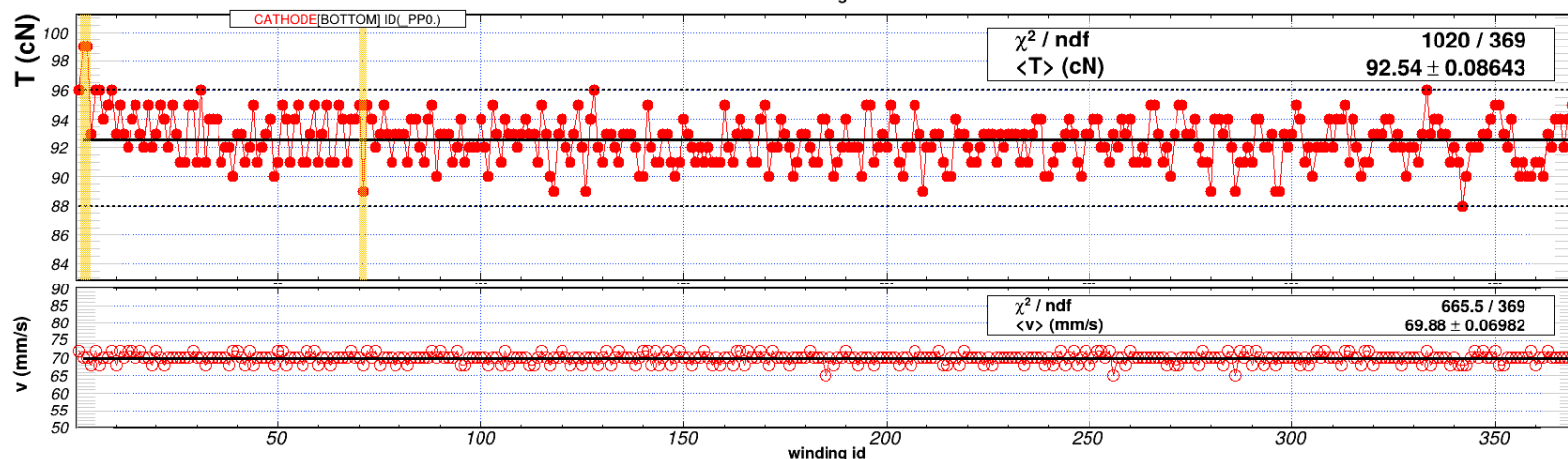
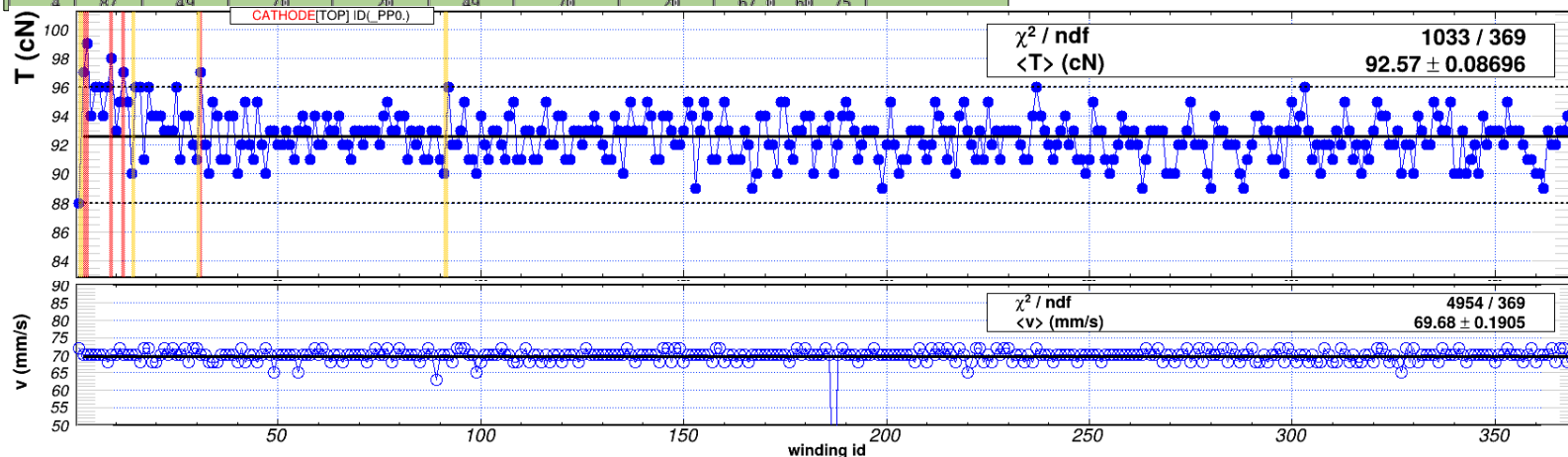
The limit of full-range precision of $\pm 2\text{cN}$ was not reached.

The production limit was set to $\pm 4\text{cN}$

4/7/26 A2.report

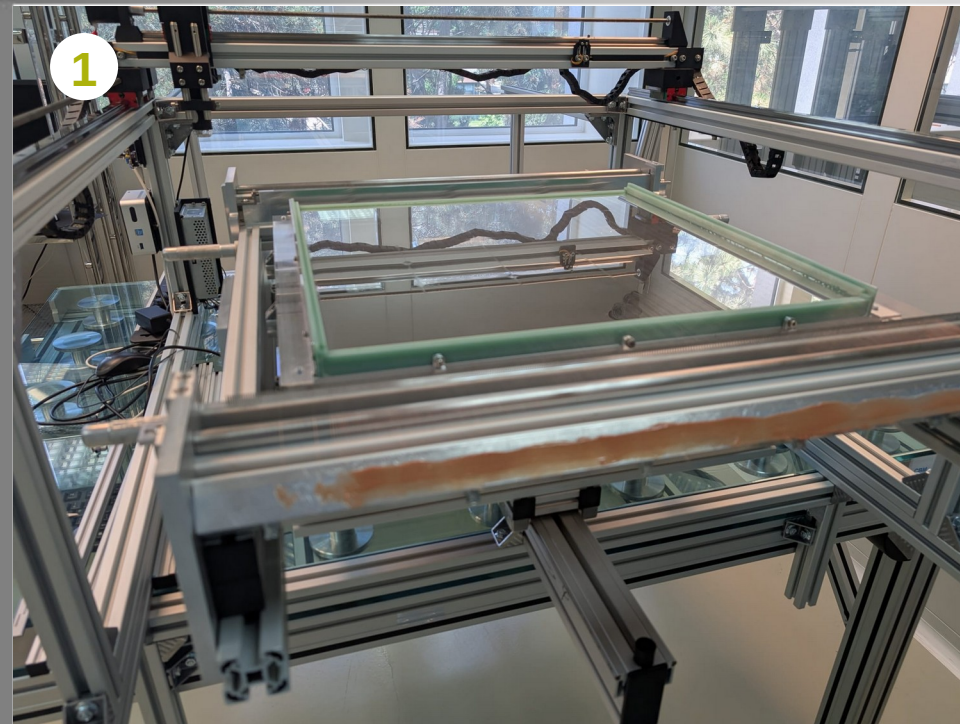
```
Info in <qawinding>: FILE NAMING CONVENTION : DONE.
Info in <qawinding>: Suspect LOCAL Winding. No. 8 on the "BOTTOM" frame has tension 2(cN) from neighbor.
Info in <qawinding>: Suspect LOCAL Winding. No. 8 on the "TOP" frame has tension 2(cN) from neighbor.
Info in <qawinding>: Suspect LOCAL Winding. No. 9 on the "TOP" frame has tension 2(cN) from neighbor.
Info in <qawinding>: LOG FILE INTEGRITY : DONE.
Info in <qawinding>: GLOBAL WINDING : DONE.
```

Wire	Stat	Tb(cN)	vb(mm/s)	time(s)	Tu(cN)	vu(mm/s)	time(s)	<v>	vm	vM
1	87	49	68	20	49	70	20	66.8	58	75
2	87	49	72	21	49	70	20	66.6	55	75
3	85	48	68	20	50	65	20	66.1	5	75
4	87	49	70	20	49	70	20	67.0	60	75



Cathode Assembly

cathode electrode installation

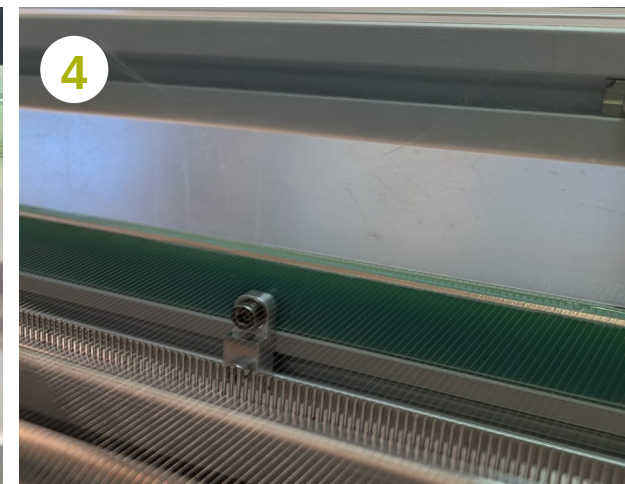


1.The device for aligning the cathode assembly to the winding frame holding the electrode.

2.Putting the chamber and the cathode electrode in contact with micron precision to conserve wire tension

3.Gluing the CuBe wires to the chamber ledge along the specially designed groove.

4.Preparing for electric soldering. A special shield is installed on the device to avoid contamination with rosin (flux).



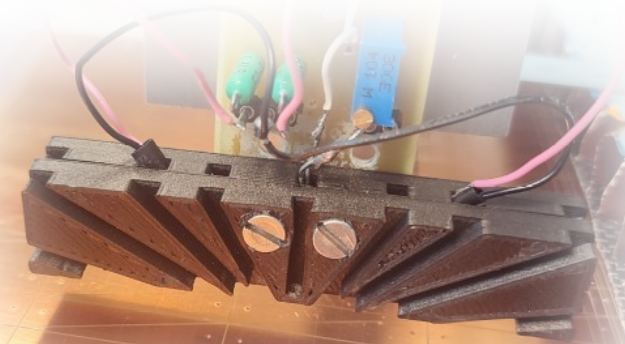
Wire Tension Device [WTD] positioning & tension

Device for wire QA inherited from **ALICE TRD** construction. Frequencies of the TRD2D wires a factor 2 above ALICE. Different background for anode measurement (Au/Au). No updates planned or possible similar to those done by Uni. Frankfurt.

Linear drive
for measuring the
Wire Pitch

Wire Imaging Device
WTD
(LabView)

Control Unit
(Mouse controlled
Win98)



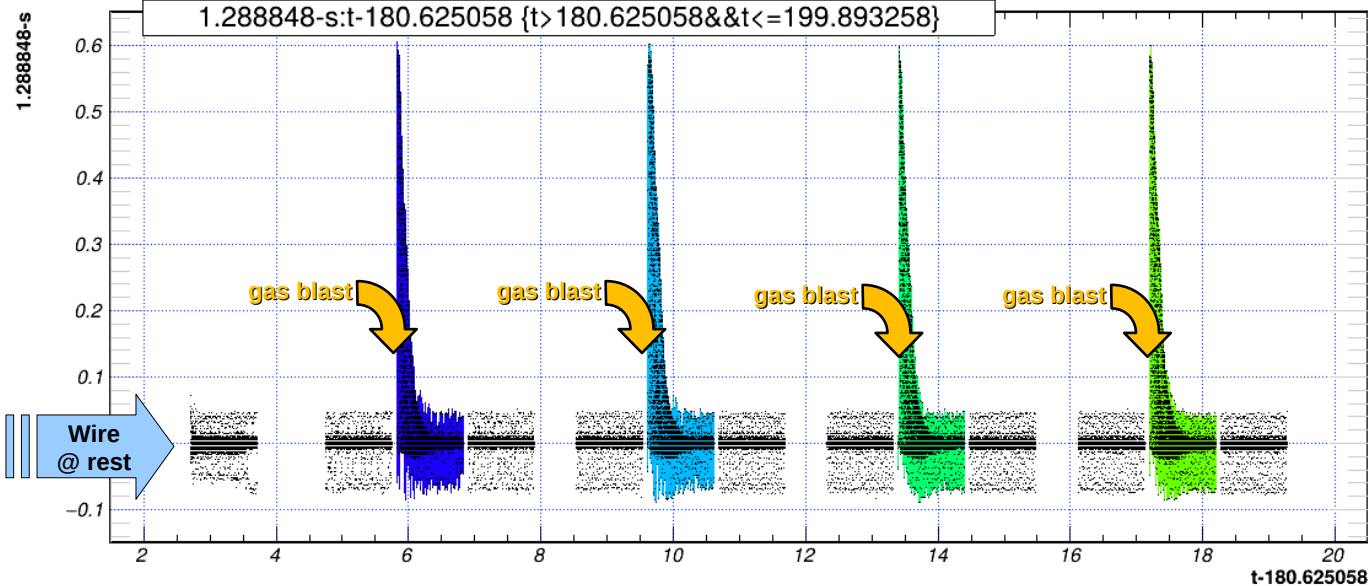
In parallel a new device was developed (together with Uni Muenster) based on **CAN-BUS** communication. It was developed up to the ADC integration.



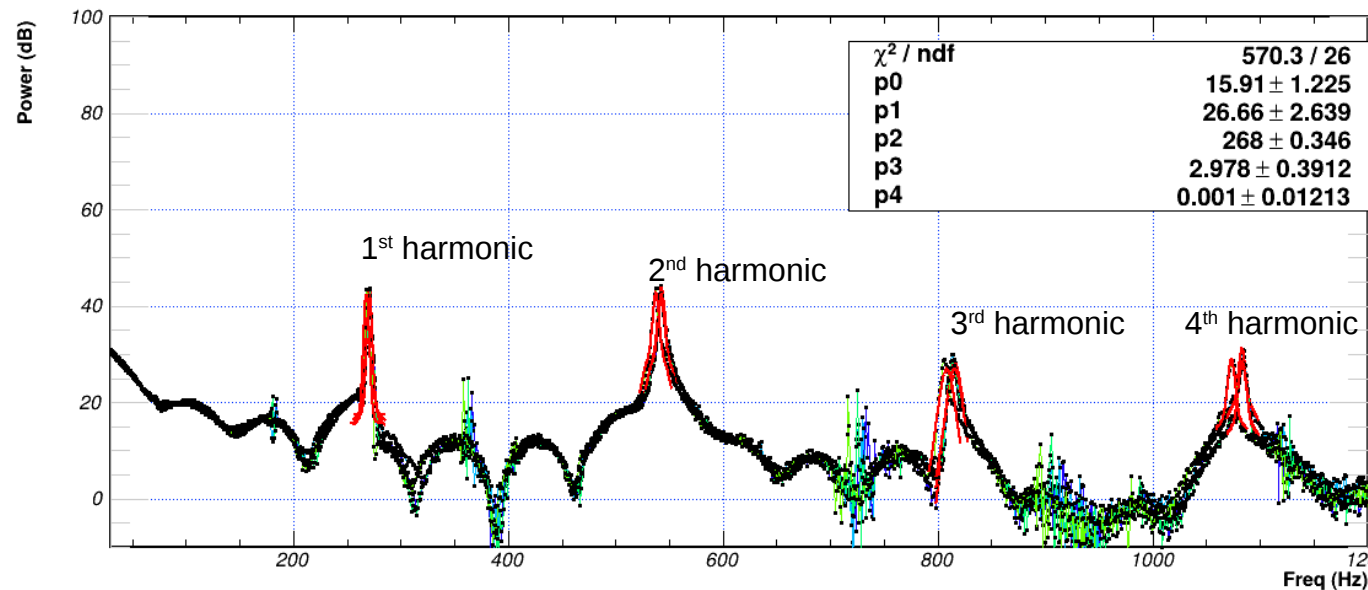
In parallel the obsolete analysis and configuration of the old WTD device was ported to **offline** keeping the LabView based DAQ.



Wire Tension Device [WTD] positioning & tension



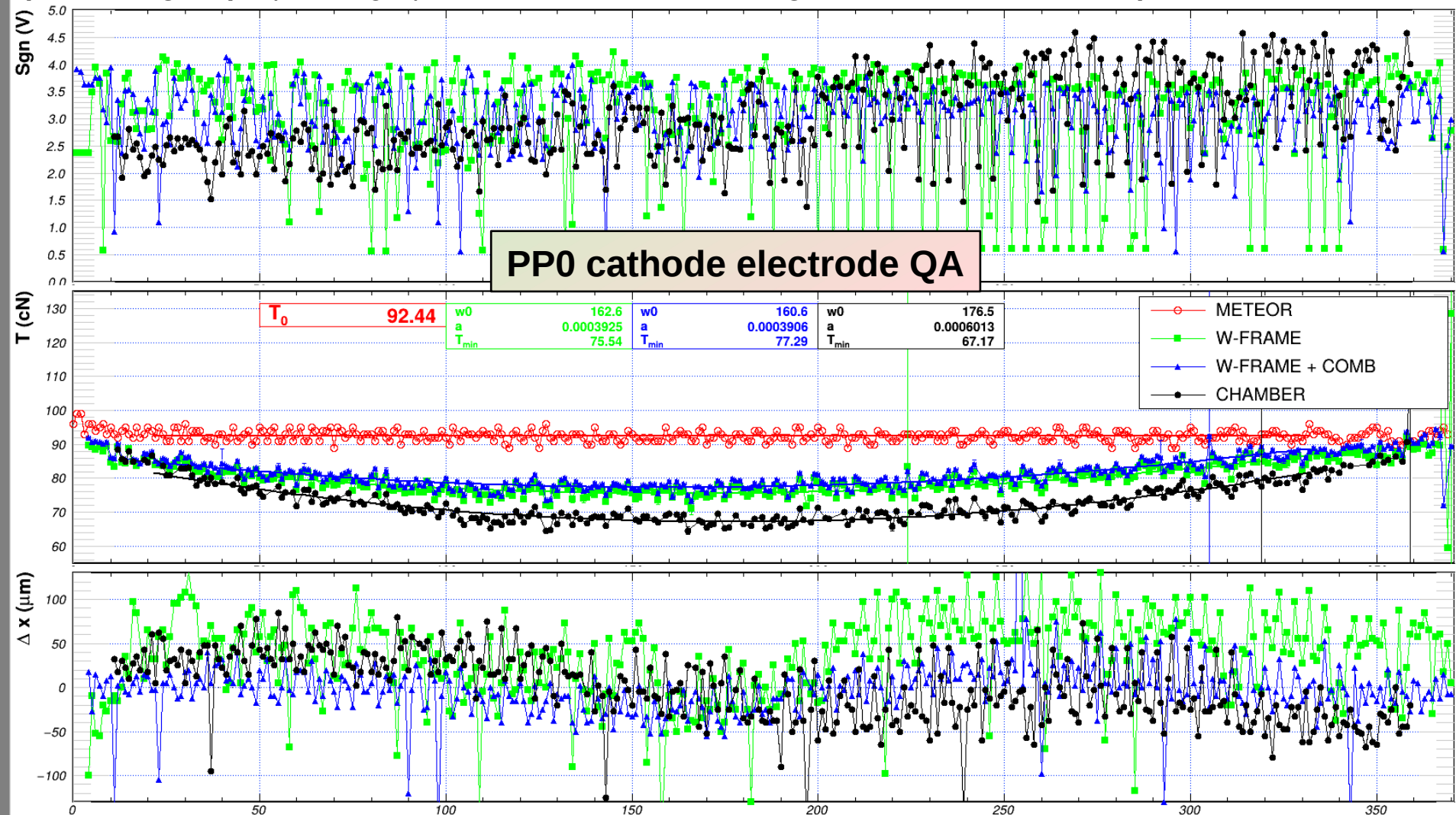
For each wire detected the full wave form is exported. Several blasts are issued which provide statistical accuracy.



For each oscillation Fourier analysis is performed. First 4 harmonic oscillations are registered. **Filtering of noisy oscillation and statistical accuracy.**

Wire Tension Device [WTD] positioning & tension

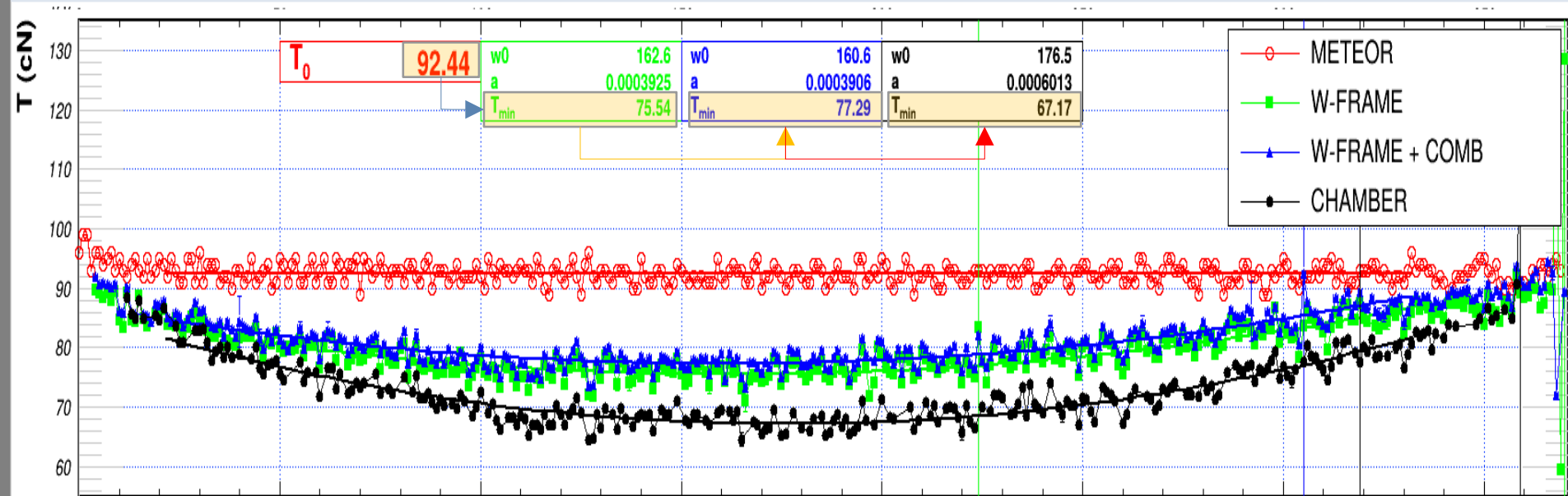
In the end we produce a full QA plot of the winding process for **each individual wire** and for **each of the 4 processing steps** (challenges) wrt. 3 observables: **static signal**, **tension** and **relative position**.



Wire Tension Device [WTD] positioning & tension

CATHODE ELECTRODE (CuBe 75 μ m, 1.5mm pitch)

Wire tension distribution; Mechanical deformations of auxiliary devices and chamber.



METEOR Value of tension reported by **winding regulator** on the moment of **touch-down** on the winding frame.

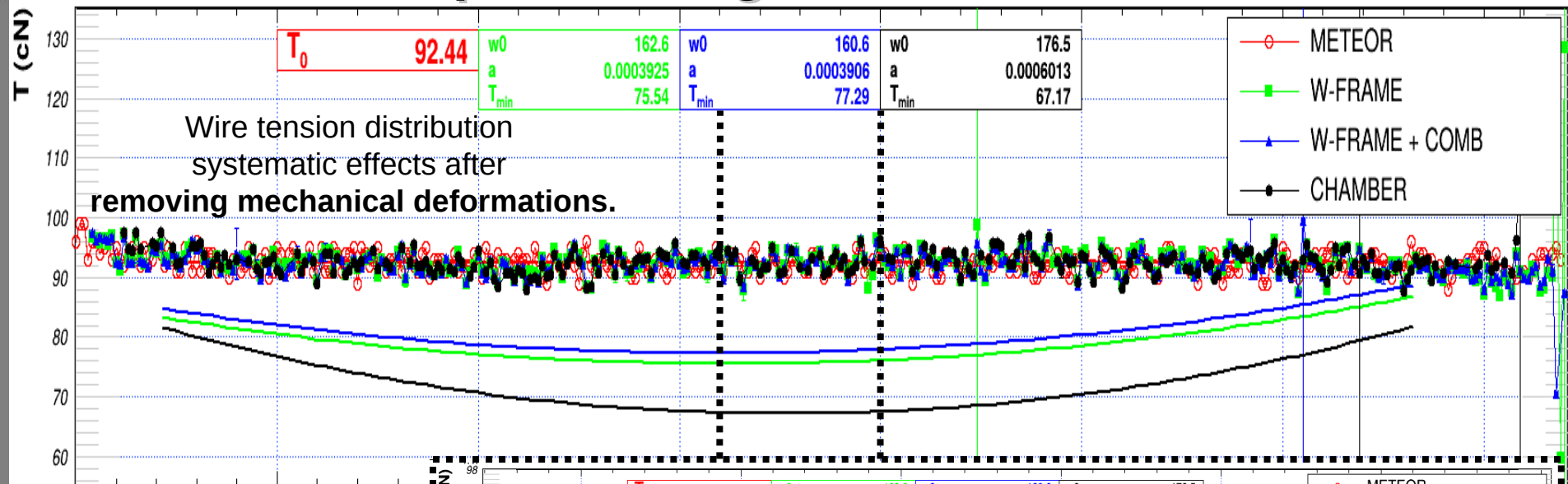
W-FRAME Value of tension reconstructed offline from **WTD measurements** on **half frame**. The maximum drop in wire tension is **17 cN** (in the middle of the frame) due to its deformation.

W-FRAME + COMB Two calibrated wire combs (GSI) are applied on both ends of the electrodes to regulate wire pitch (1.5mm). An average of **2cN** are added to the wire tension due to extra stretching.

CHAMBER Final value of cathode wire mechanical tension on chamber. The further drop of **10cN** is due to chamber deformation.

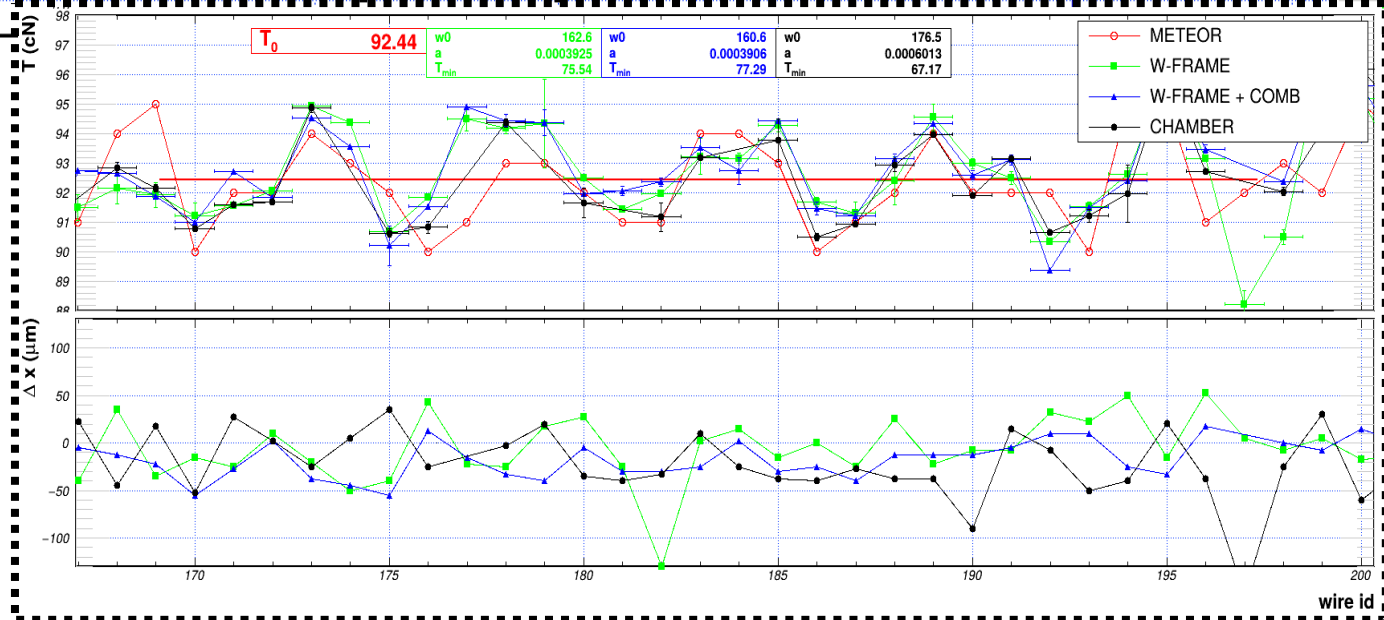
*The production steps (of the cathode electrode) add **systematic effects** and **resolution drops** to the winding performance. Let's investigate some correlations ...*

Wire Tension Device [WTD] positioning & tension

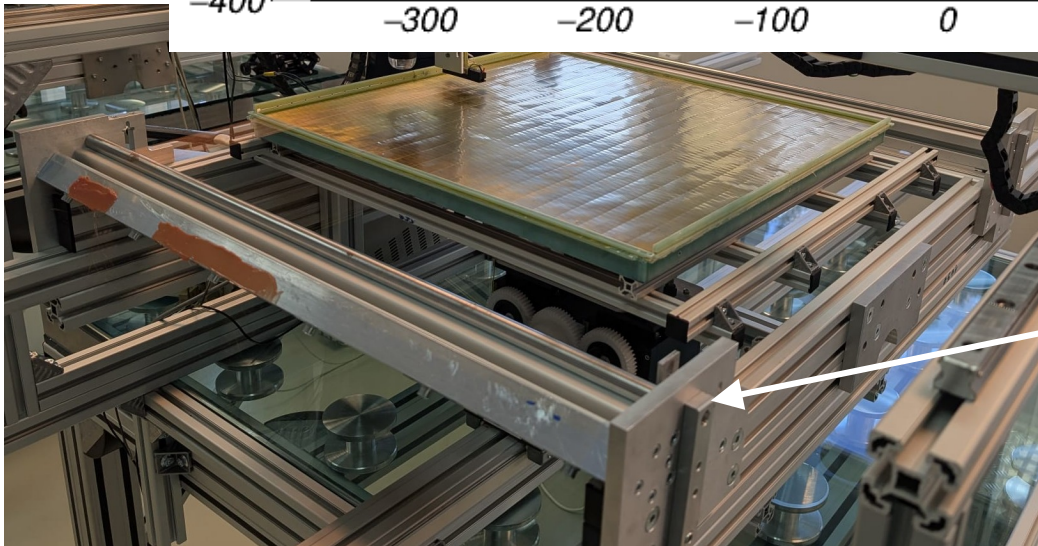
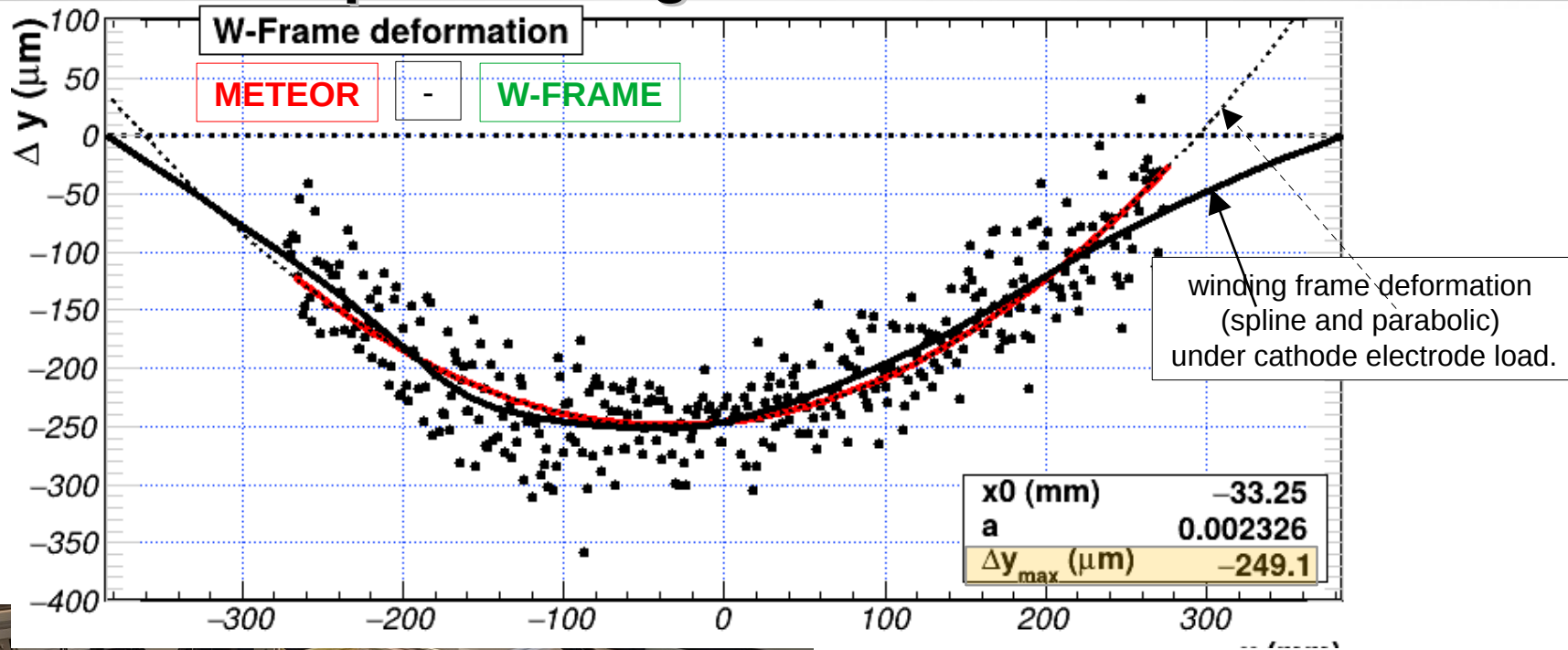


Periodic systematic effects of $\pm 2\text{cN}$ are generated by the winding machine. **Local effects** in wire tension are harder to calibrate/monitor than **global effects** (mechanical deformations). Fixing such issues **beyond production scope**.

Wire-by-wire production history under control.

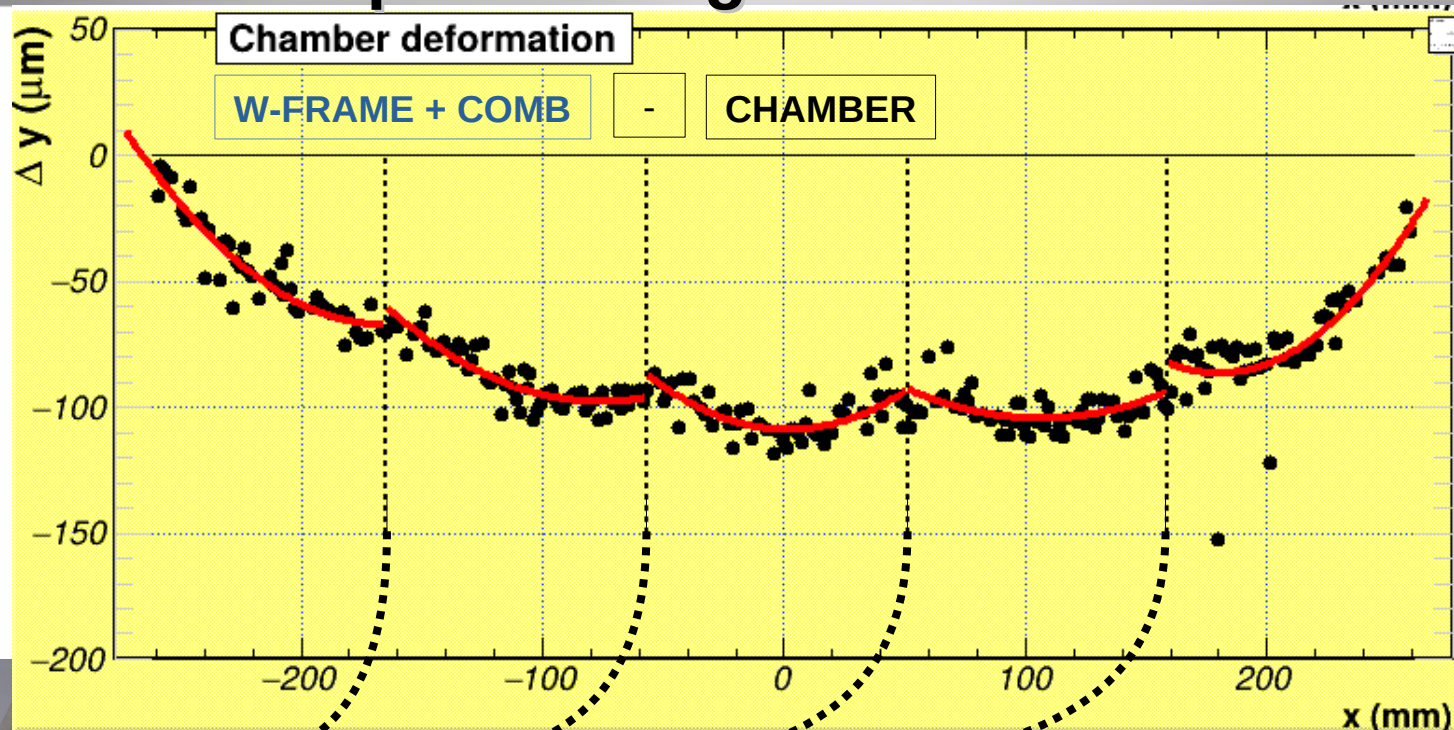


Wire Tension Device [WTD] positioning & tension



The **winding frame** is a **17kg** Al-profile support of, **770 x 800 mm²** for installing electrodes. It is optimized for TRD2D size. A deformation of **<150μm** per edge when **37kg** of uniform load is applied is realistic (*)

Wire Tension Device [WTD] positioning & tension

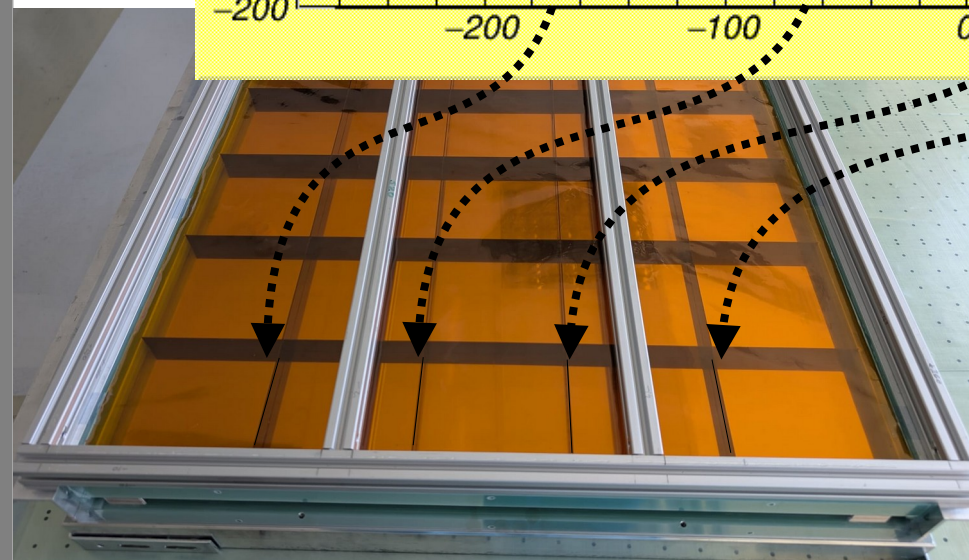


The **cathode assembly + scaffold** deformation:

- Global of $\sim 50\mu\text{m}$ / edge
- Local of $\sim 5\mu\text{m}/\text{edge}$ (C-C ledge)

Good QA of Wire-Wire identification and Tension estimation facilitate such subtle observations.

Smooth variation of cathode tension over the chamber are no problem for detector operation.



Wire Tension Device [WTD] positioning & tension

METEOR

-

W-FRAME

=

DEFORMATION

One can estimate the **dispersion of wire mechanical tension measurements** around the simple **parabolic model** and derive the resolution of each method for [CuBe, 75 μ m]:

→ resolution WTD $\sigma_T(\text{cN}) < 0.65$

→ resolution METEOR $\sigma_T(\text{cN}) < 2.20$

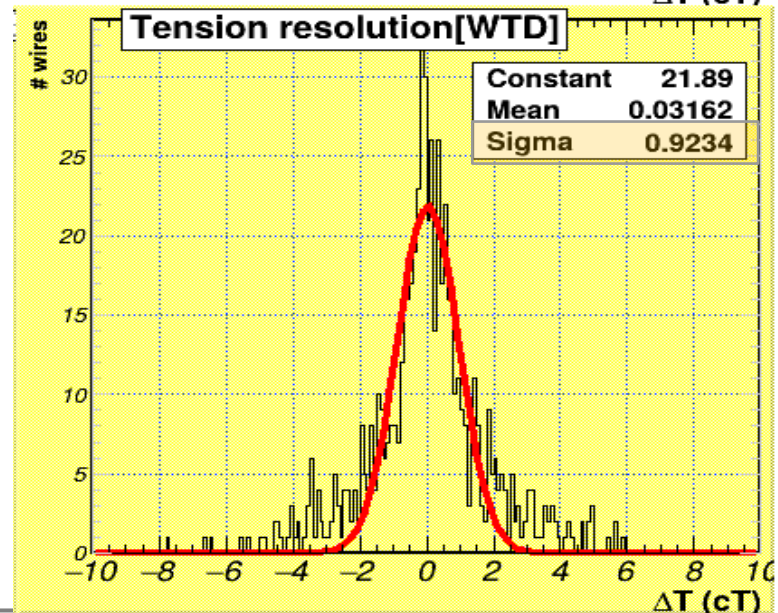
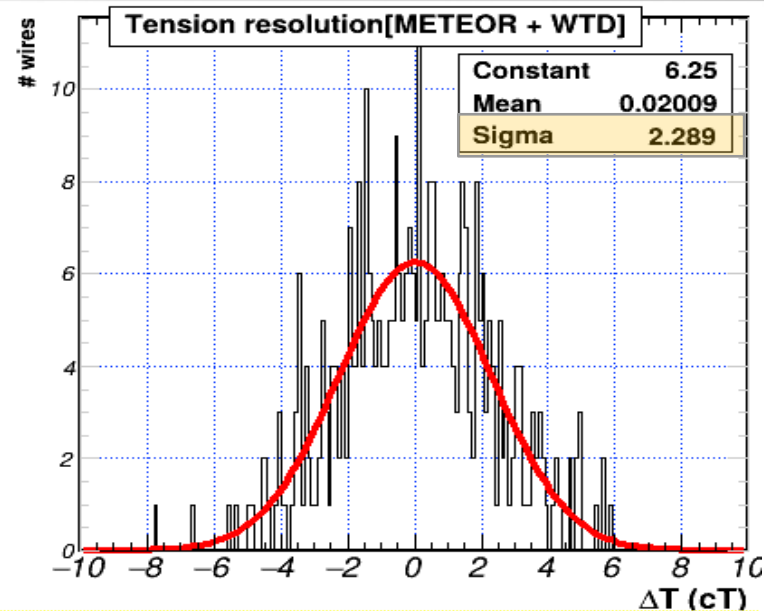
W-FRAME + COMB

-

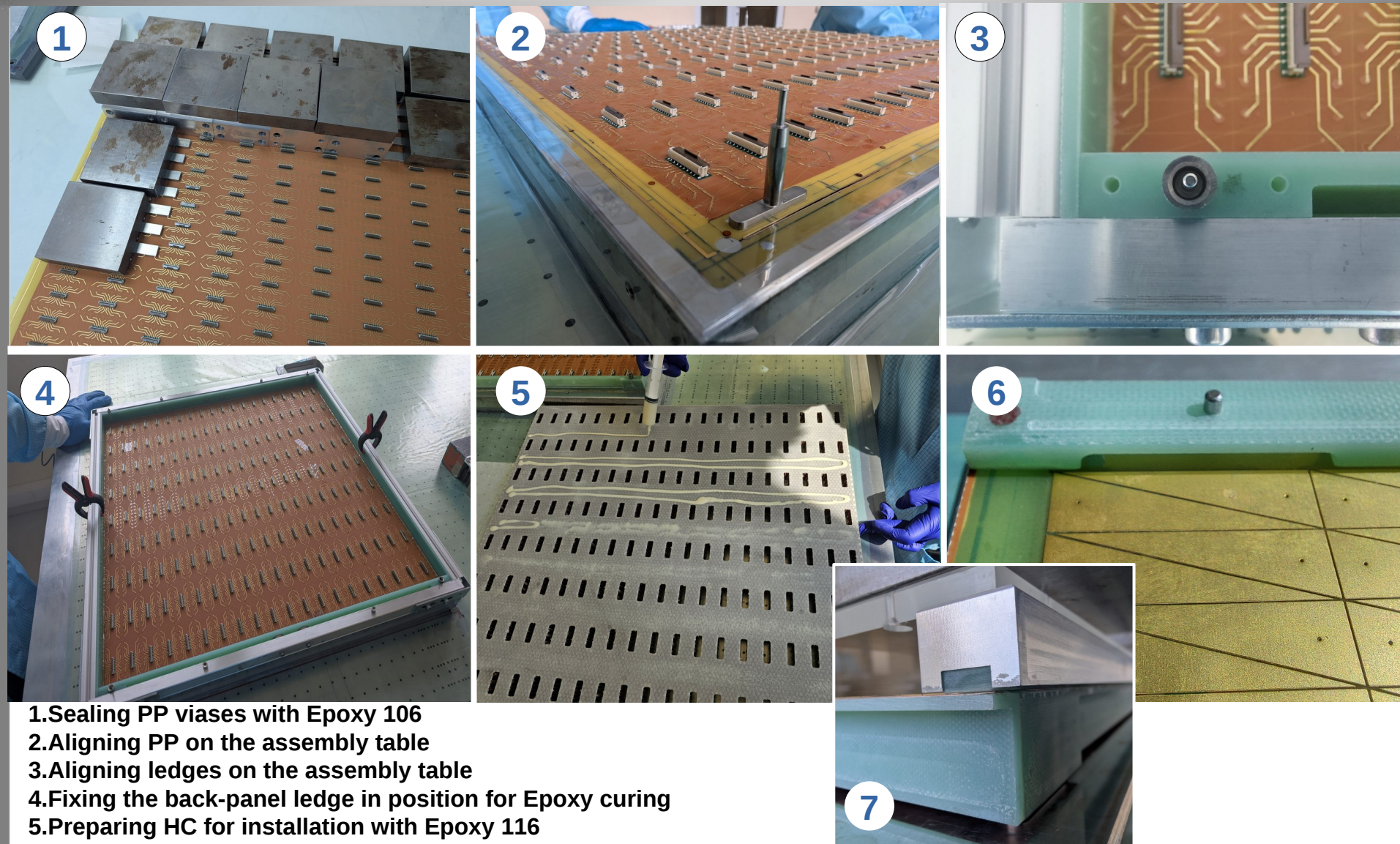
CHAMBER

=

DEFORMATION



Anode Assembly construction



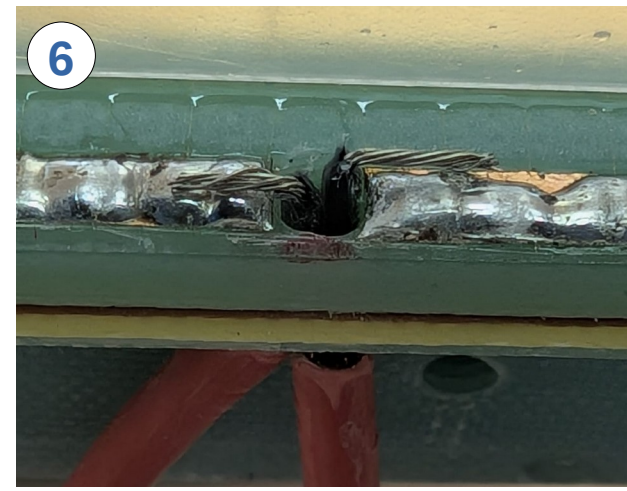
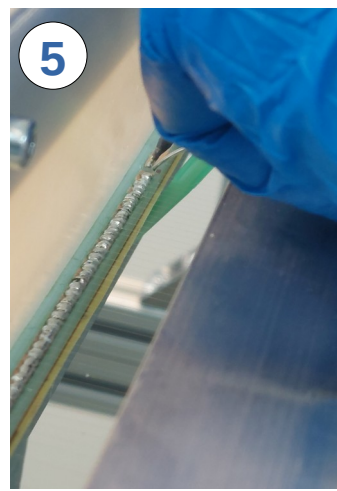
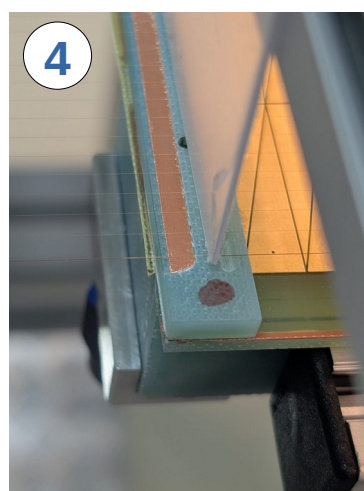
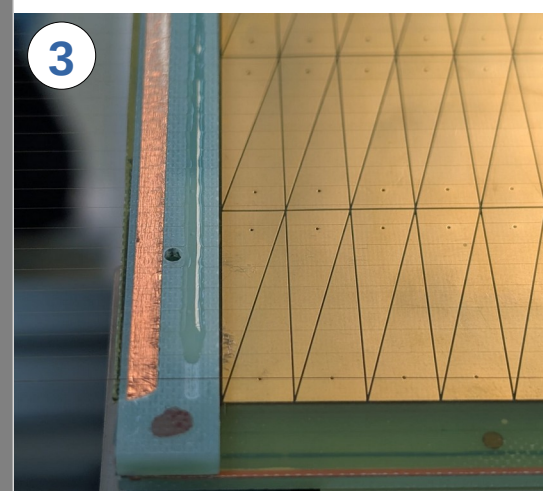
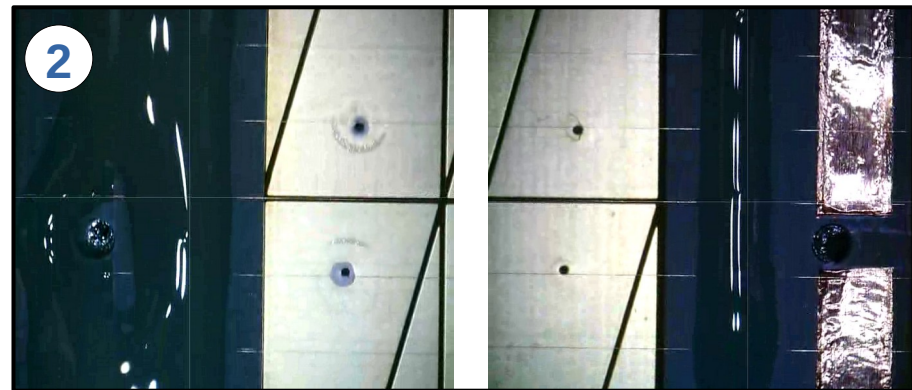
1. Sealing PP vias with Epoxy 106
2. Aligning PP on the assembly table
3. Aligning ledges on the assembly table
4. Fixing the back-panel ledge in position for Epoxy curing
5. Preparing HC for installation with Epoxy 116
6. Installing ledges to support the anode electrode.
7. Fixing the ledge in position for curing

Anode (A) Assembly

anode electrode installation



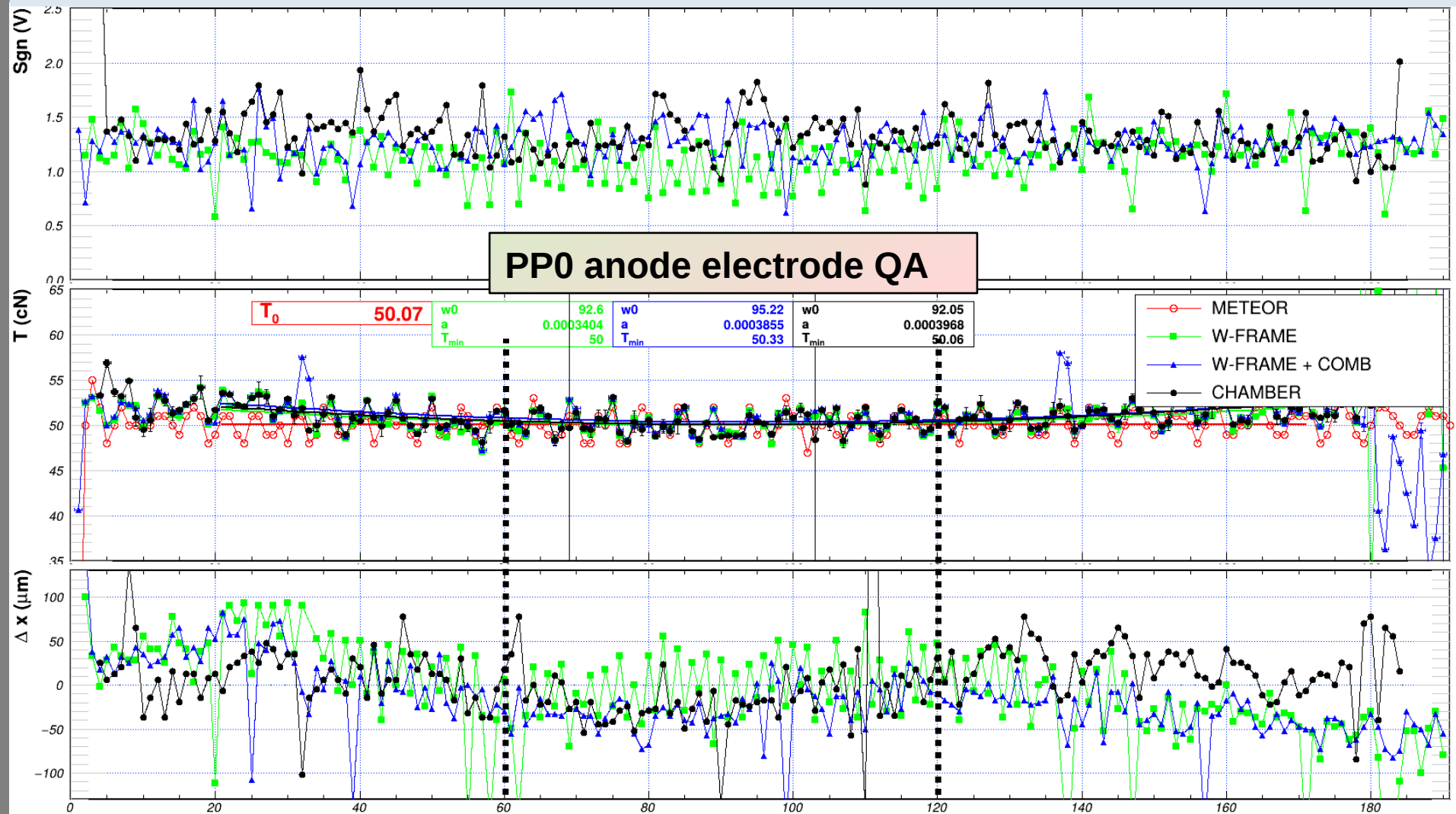
1. Assembly A alignment to the winding frame holding the electrode.
2. Aligning the central A wire to the PP, left and right
3. Gluing the A wires to the chamber ledge along the special groove.
4. Installing the special shield to protect chamber from soldering rosin (flux).
5. Soldering wire-by wire
6. Inserting HV cables (2 x 2) for soldering and sealing



Wire Tension Device [WTD] positioning & tension

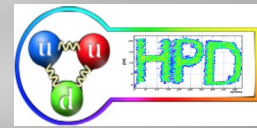
ANODE ELECTRODE (WRe3 20 μ m, 3.0mm pitch)

Wire tension distribution;



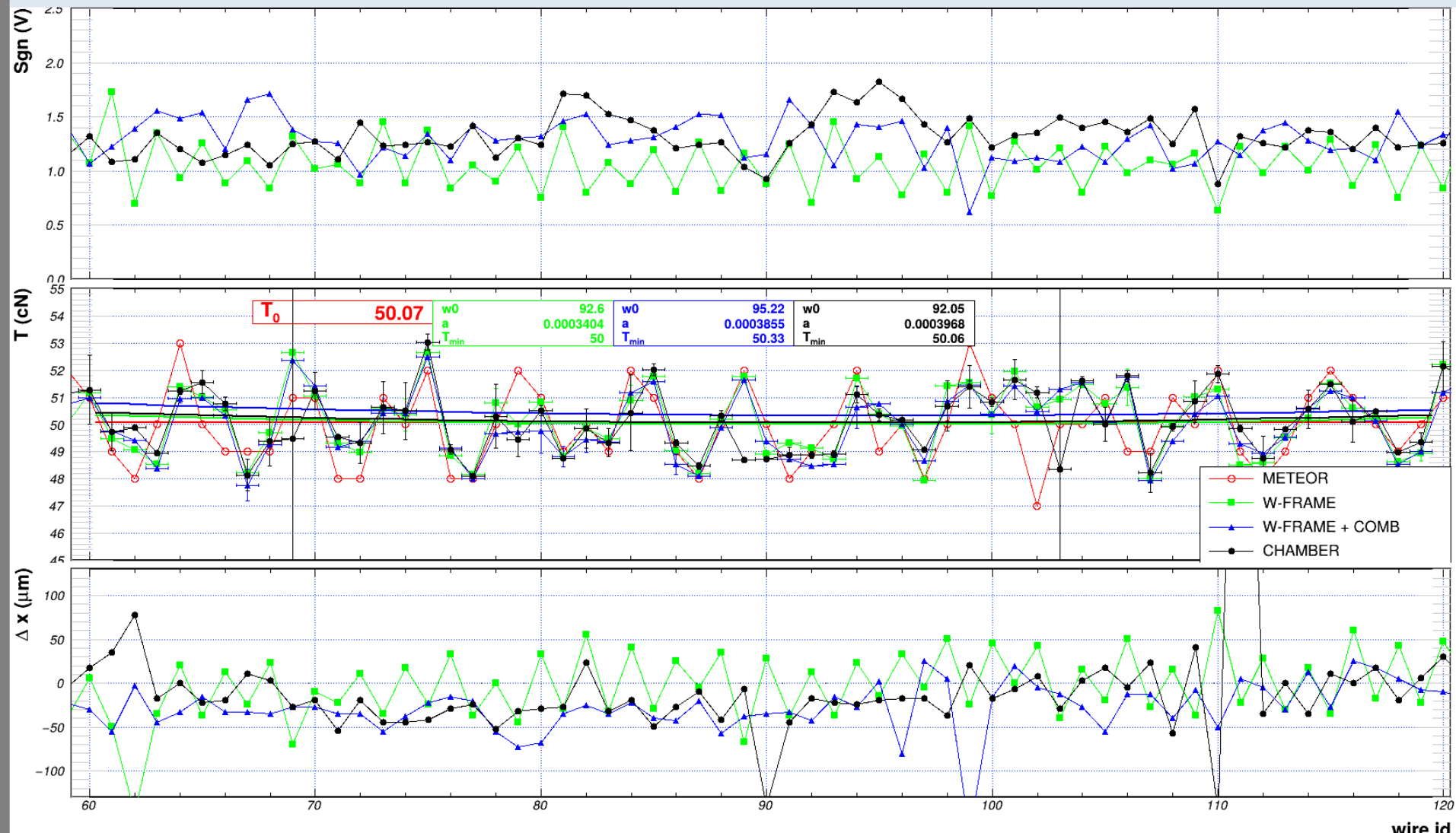


Wire Tension Device [WTD] positioning & tension



ANODE ELECTRODE (WRe3 20 μ m, 3.0mm pitch)

Wire tension distribution;

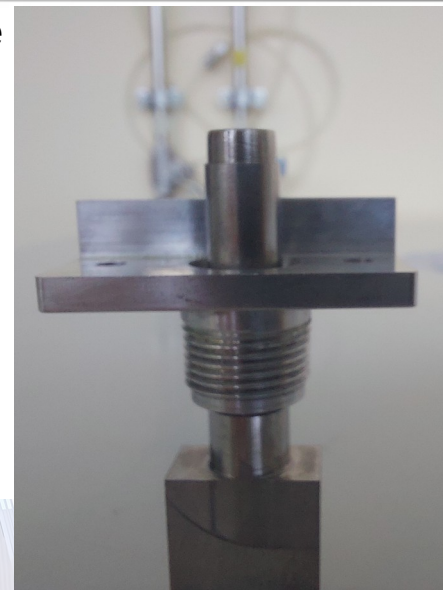


wire id

Gas adapter

design, technology and realization

Pre-assembly of the gas adapter and SERTO gas sleeve.



Standard interface with outside world.
(SERTO M14)

- Customized adapter
- SERTO stiffener sleeve
- Gas sealing epoxy
- TRD2D ledge
- Screw

FLOW PROFILE INTERFACE

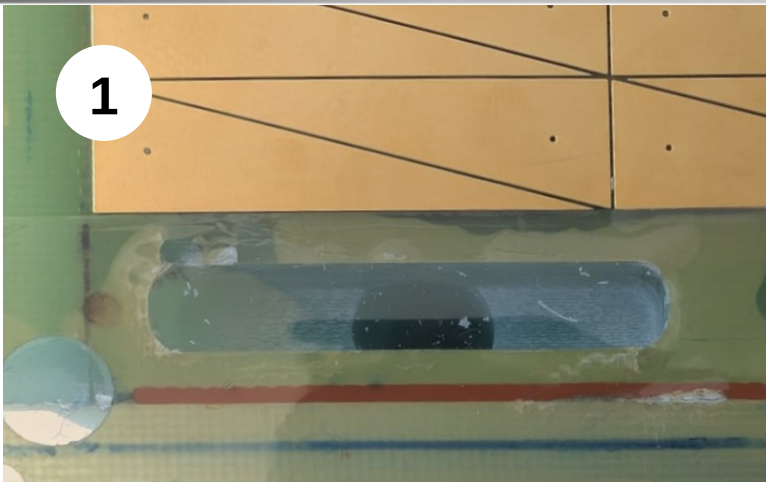
Specific interface with TRD2D chamber

Installing the gas-adapter on the TRD2D chamber

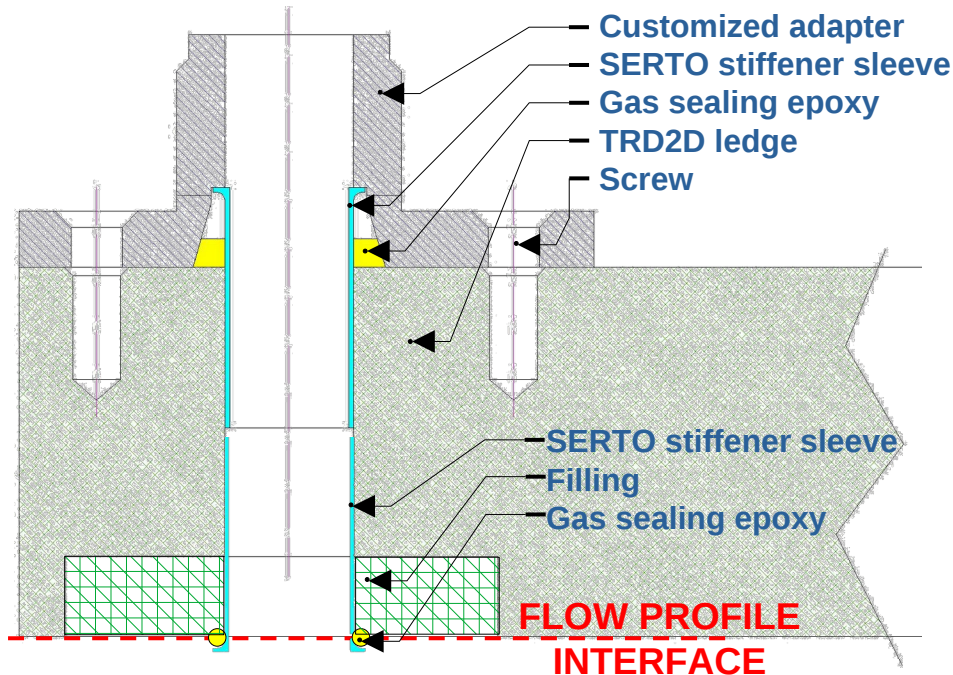
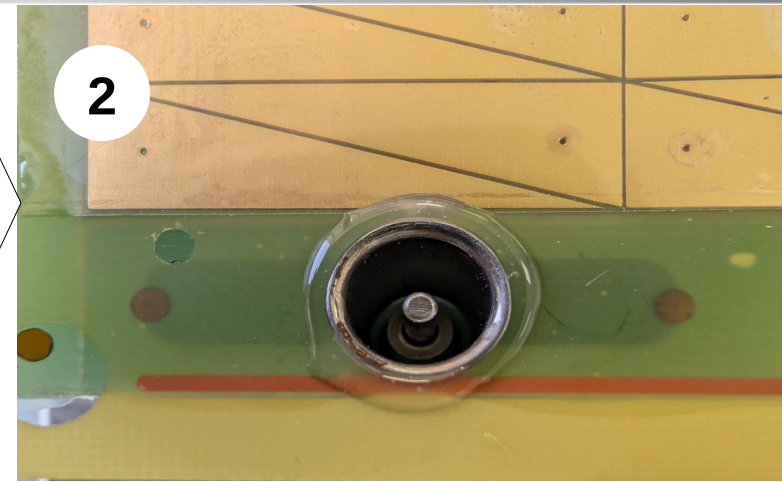


Gas adapter

updated design and realization



Updated
interface
for gas
inlet



After assembling PP0 we **observed a large gas leak**. A possible source was identified in

1

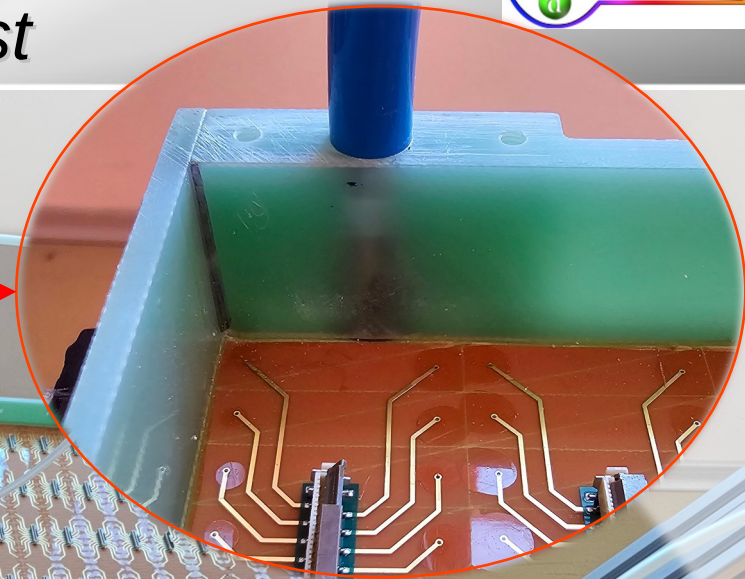
A **mock-up** of a TRD2D chamber using the **new design** was used to run a **dedicated test** of gas leakage using a temporary gas sealing solution.
→ see next slide

Gas adapter *realization and test*

Gas leakage test done on partially assembled TRD2D chamber. The two assemblies are sealed with liquid latex.

In the zoom insert one can see the sealings of:

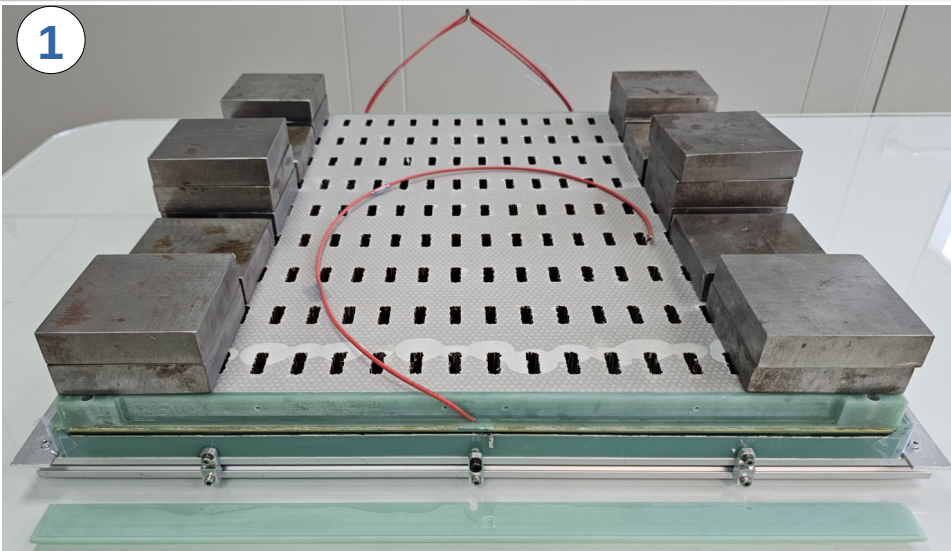
- chamber-ledge to pad-plane
- pad-plane viases



- Leaks at chamber-ledge to pad-plane boundary not observed !
- Vias leaks observed but curable by proper HC mounting.
- A fully build chamber was impossible to mock-up – gas leaks on the edges impossible to cure.

Chamber assembly

1



1.Connecting the A and C assemblies. The closure ledge is added to mark its position.

2.Preparing the closure ledge. Glue and spacers are arranged such that the gas sealing and mechanical integrity are optimized.

3.Gas sealing of the HV cathode entry on the finalized A assembly .

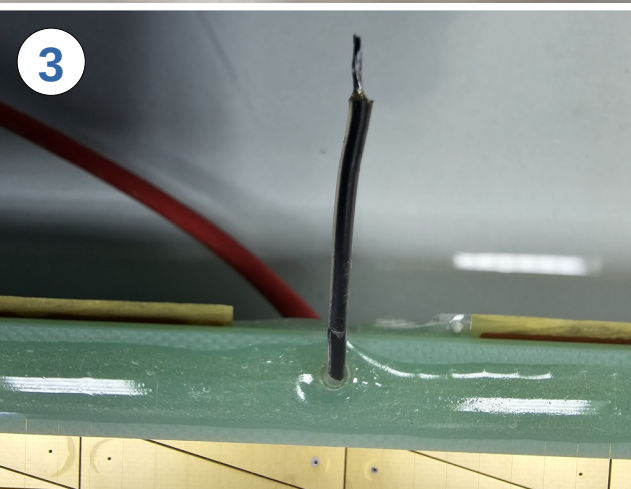
4.Soldering HV to the cathode electrode

5.Installing the closure ledge on the chamber and a detail of the corner gluing

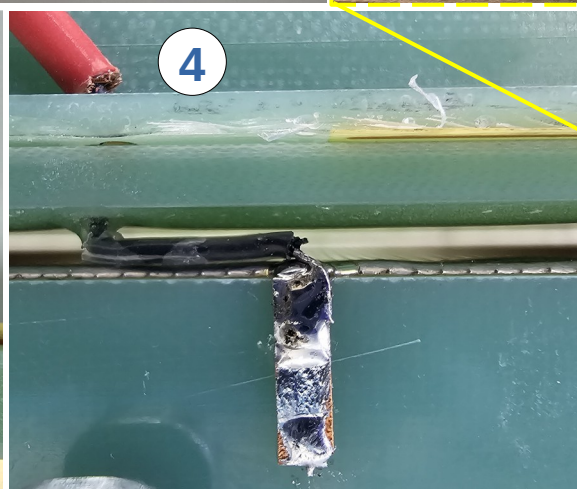
2



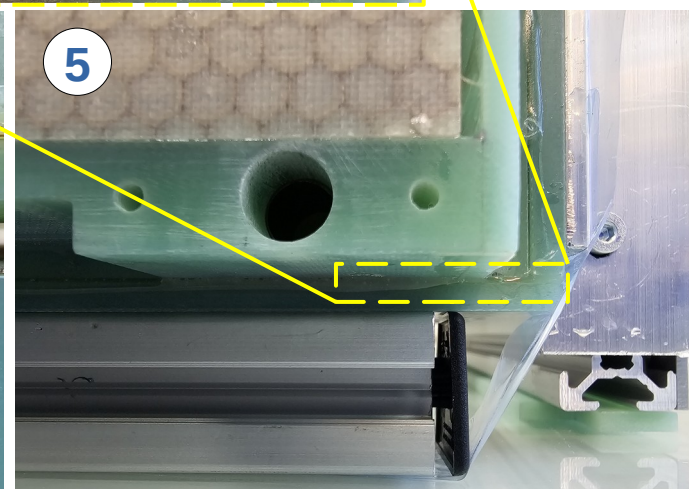
3



4



5



Anode Wire Tension

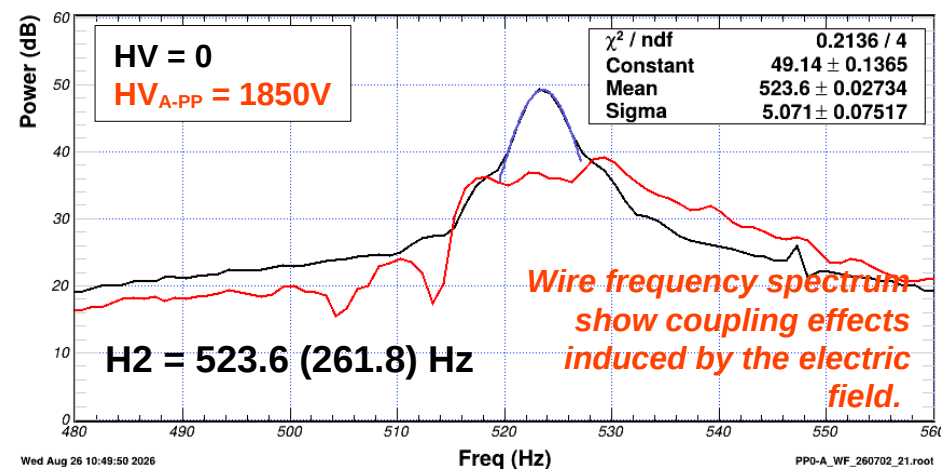
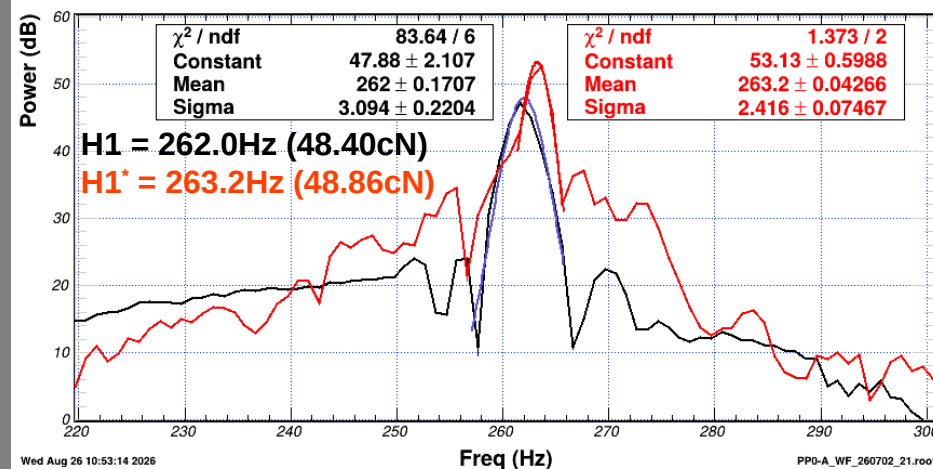
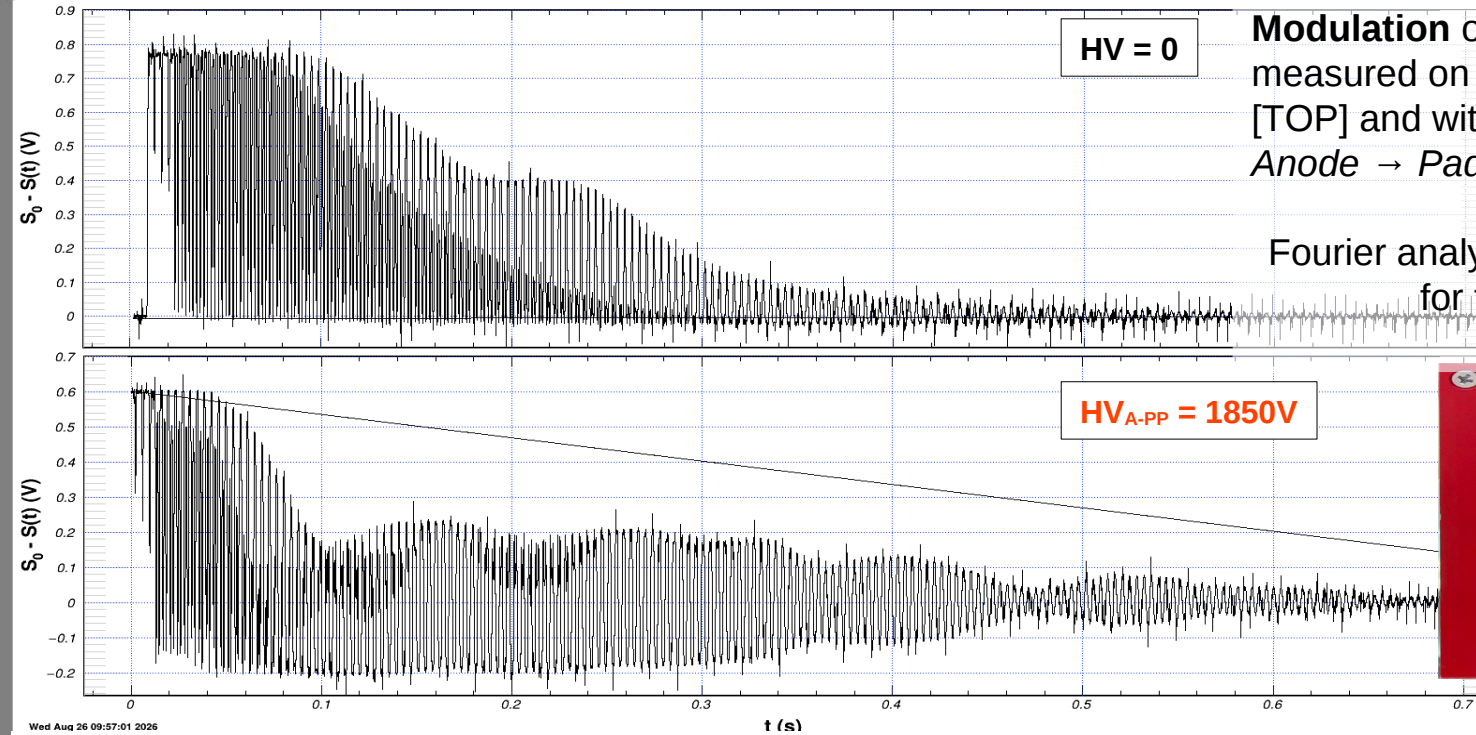
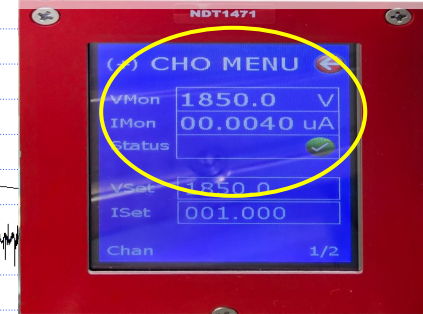
HV ON/OFF (Open atmosphere)

HV = 0

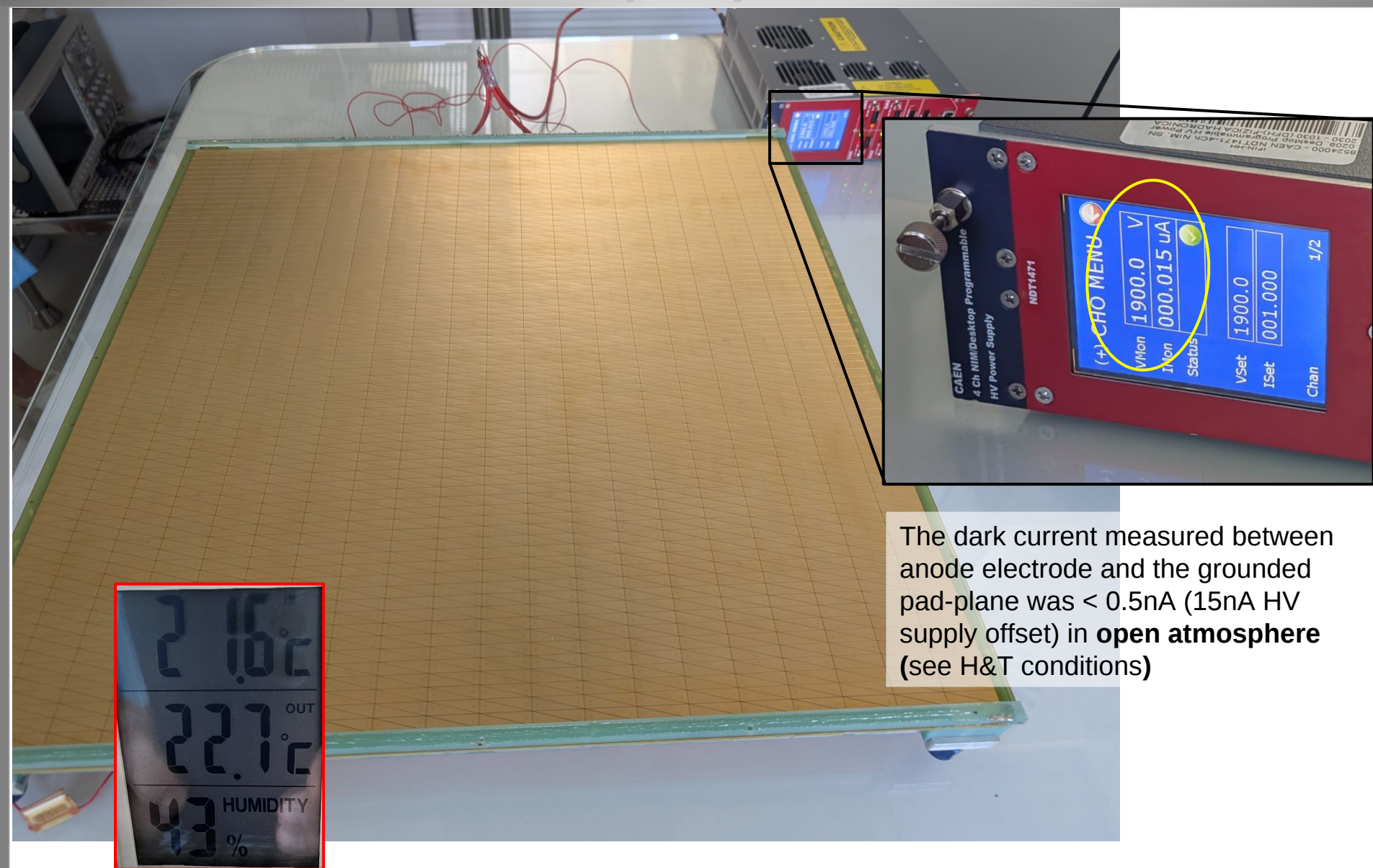
Modulation of oscillation amplitude measured on **the same** wire without [TOP] and with [BOTTOM] electric field
Anode → Pad-Plane.

Fourier analysis of the two oscillations for the first and second order harmonics.

HV_{A-PP} = 1850V

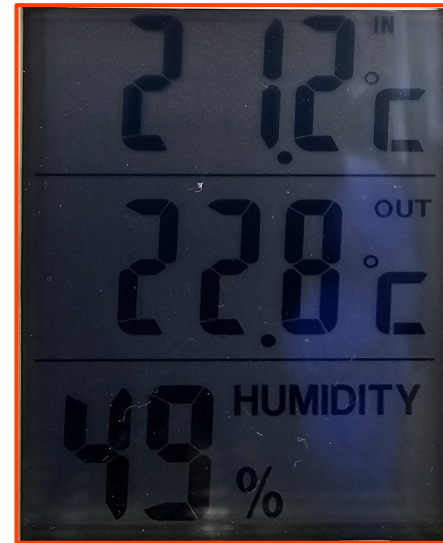


HV tests anode - pad-plane



HV tests anode - cathode

PP0



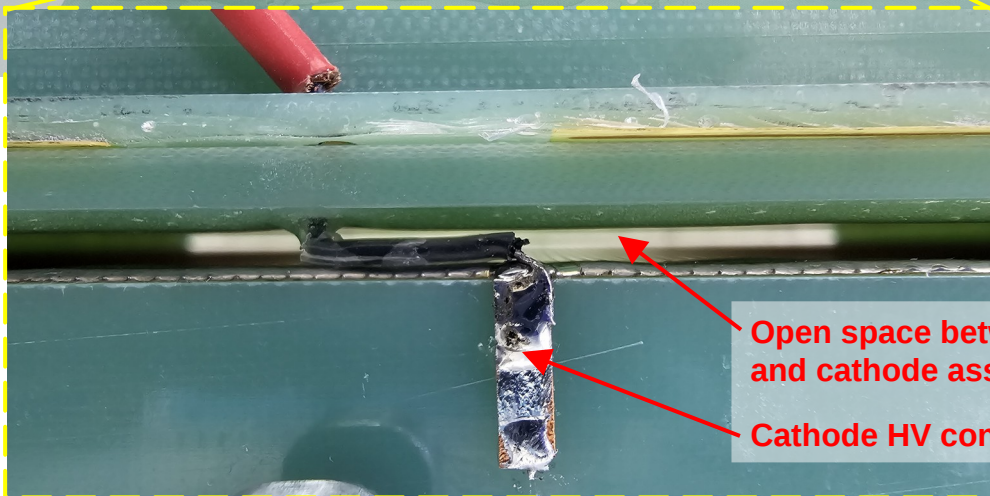
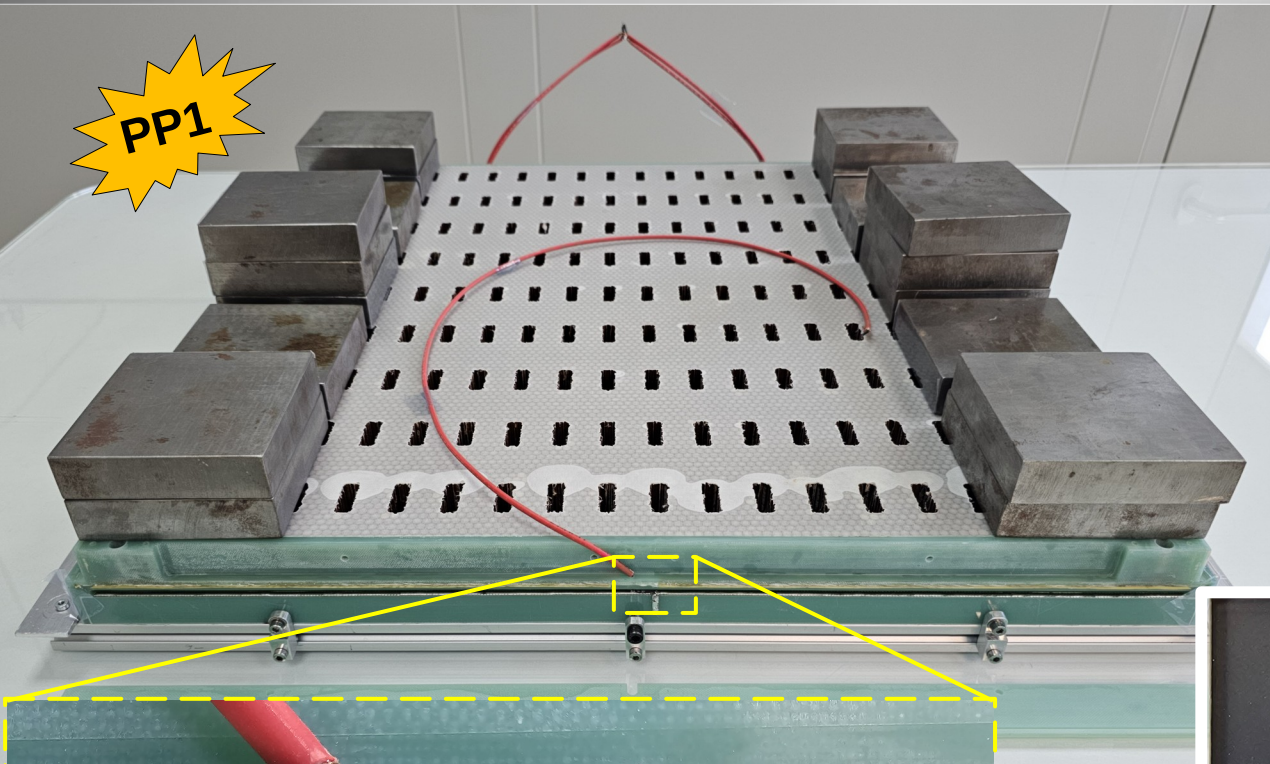
- Chamber (*partially*) flushed with N₂
- pad-plane and drift electrodes **floating**
- air humidity **H ≈ 50%**

- a max of **$U_{AC}=2.1kV$** were tested on the chamber with dark currents
 $I_{DC} < 100pA$

Confirming design of the chamber in 2 independent parts (anode + cathode) from HV point of view.

HV tests anode - cathode

PP1



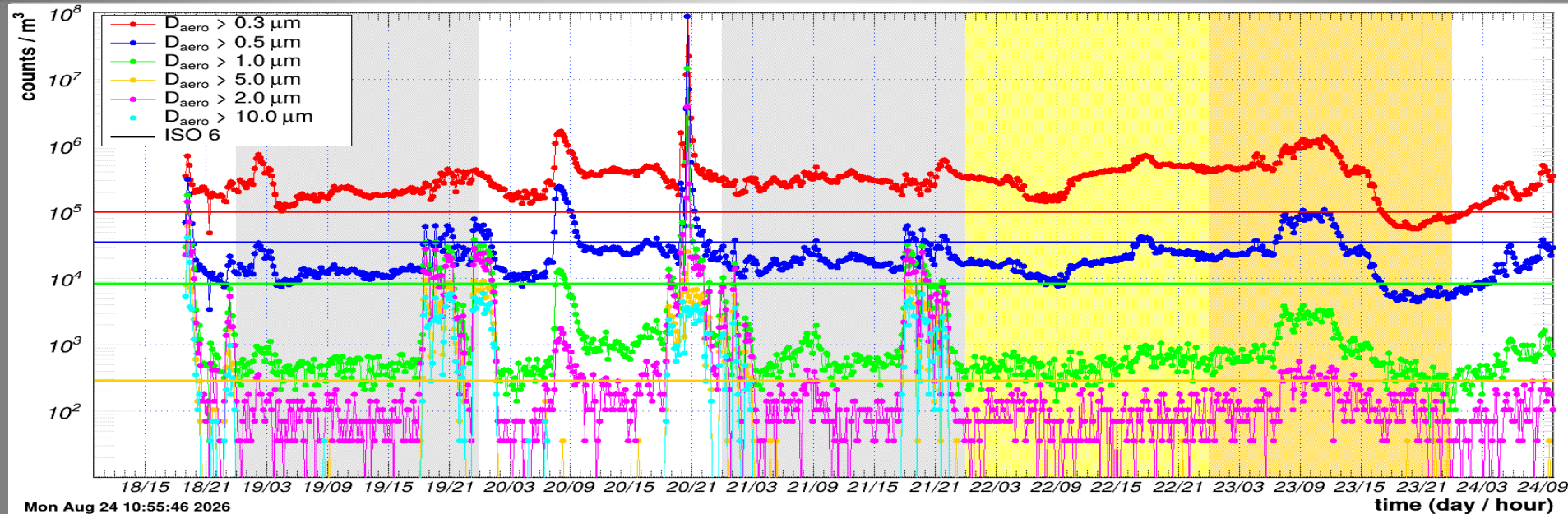
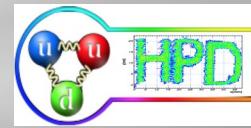
Open space between anode and cathode assemblies

Cathode HV connection





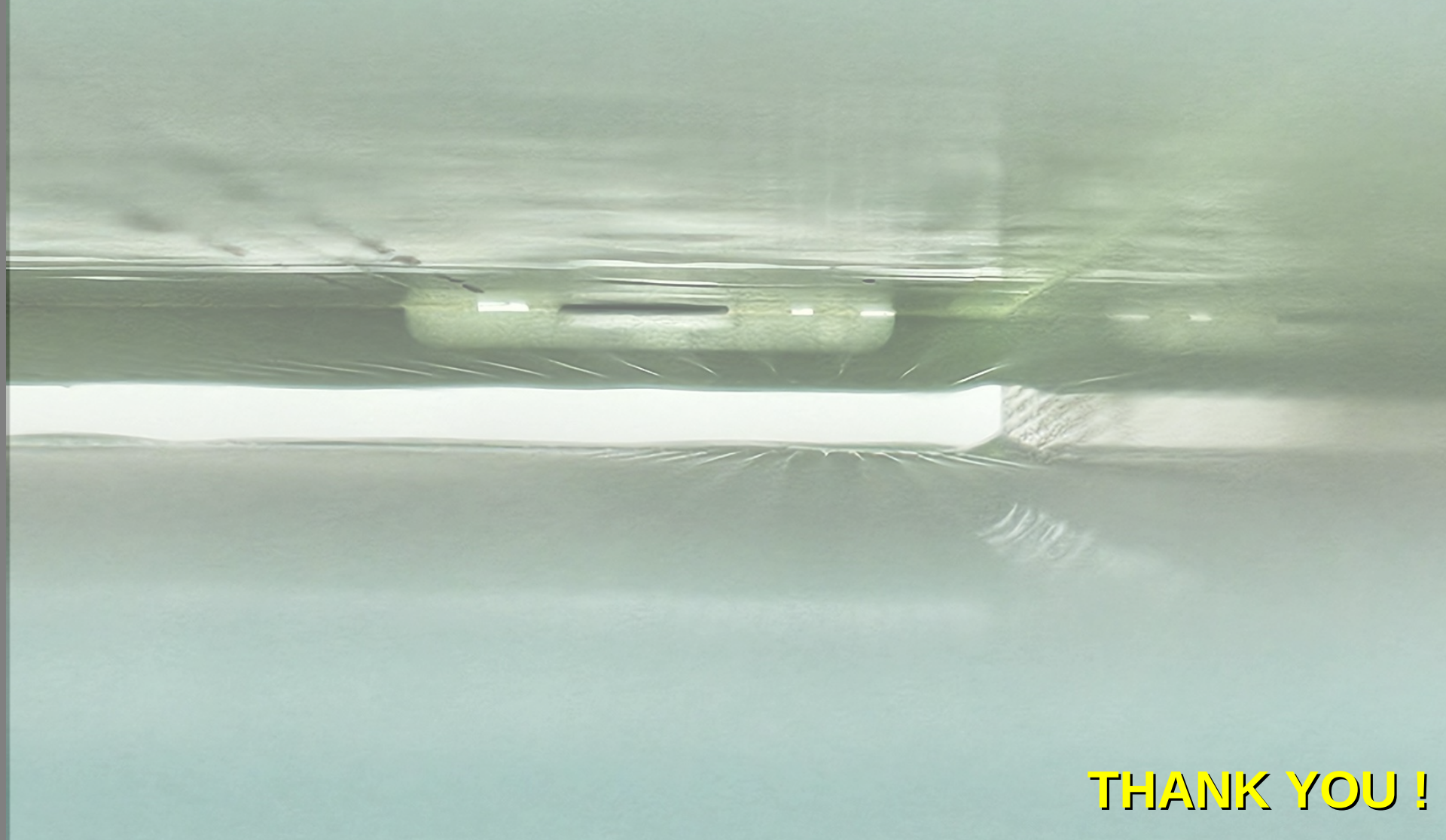
Environment monitoring electrodes installation



Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday
Cathode winding	Cathode W-Frame Cathode W-Comb	Cathode Chmb Anode winding	Anode W-Frame Anode Comb			Anode Chmb

Conclusions

View of the internal geometry of the TRD2D chamber centered on its custom gas inlet. Electrodes are also visible in the image .



THANK YOU !