ECT Status Update:
Production and Test of the ETA Redesign for the Enevlope Changes

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Jan 16th 2026 – MPGD DSC ECT meeting

Outline

- Production of the engineering test article (ETA)
- Preparation of the test beam
- Preliminary results of the TB data analysis
- Redesign: study of the acceptance

ETA Production

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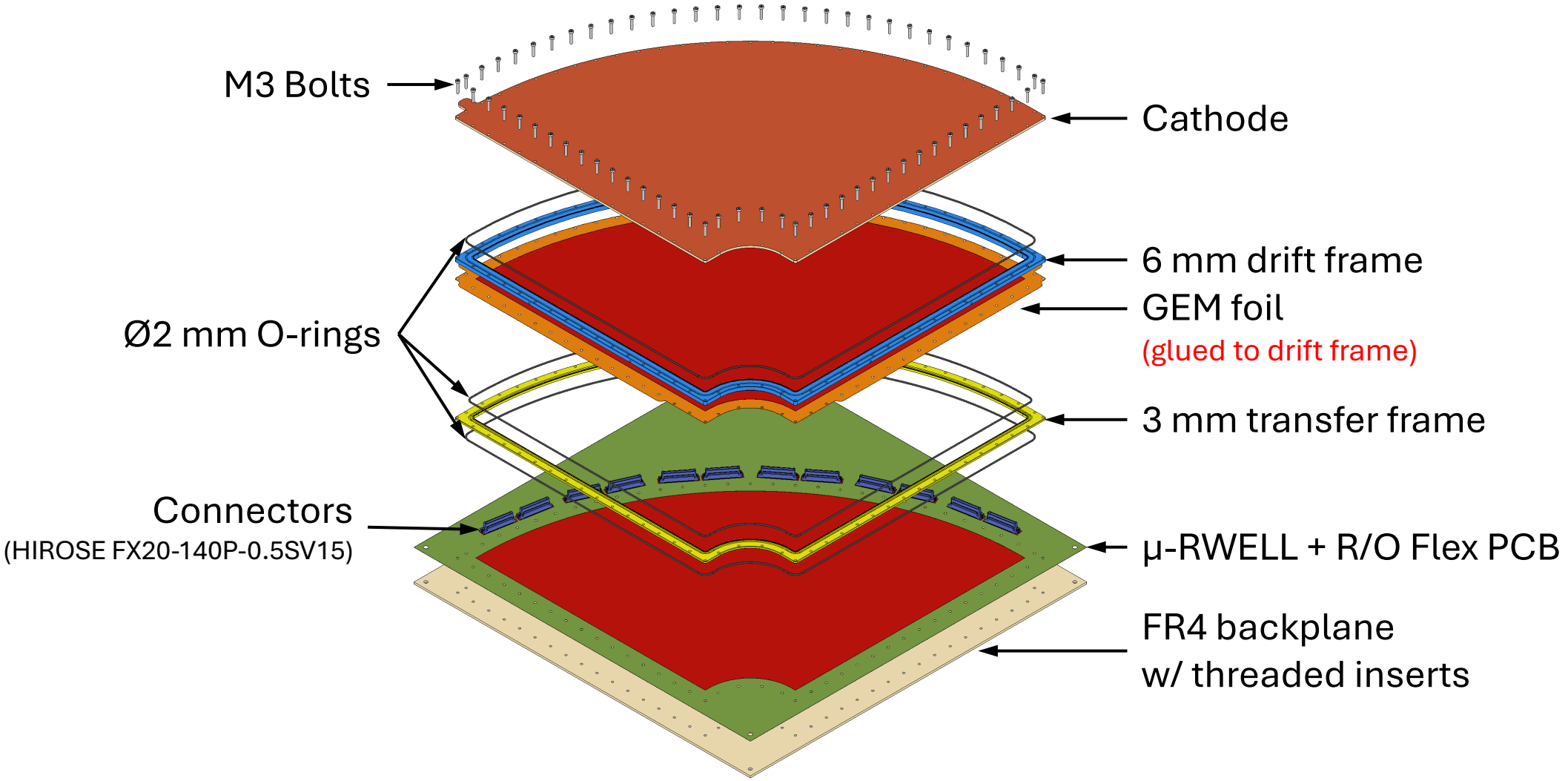
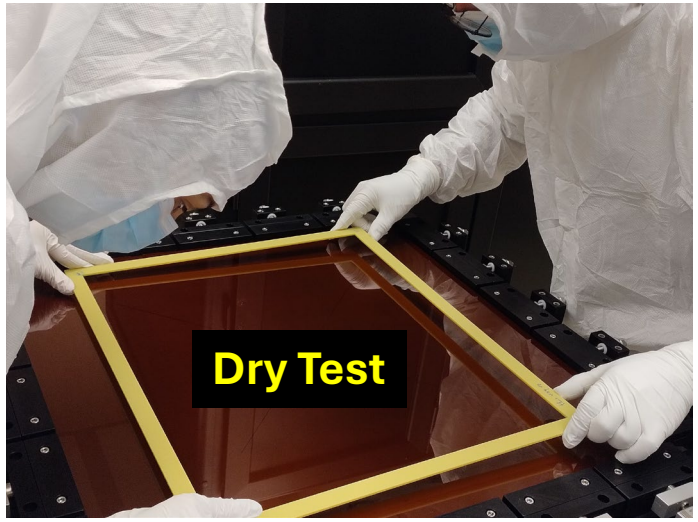
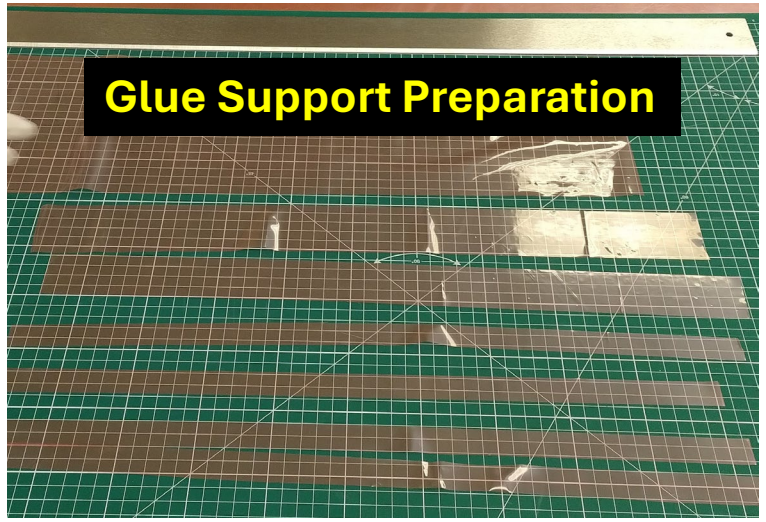
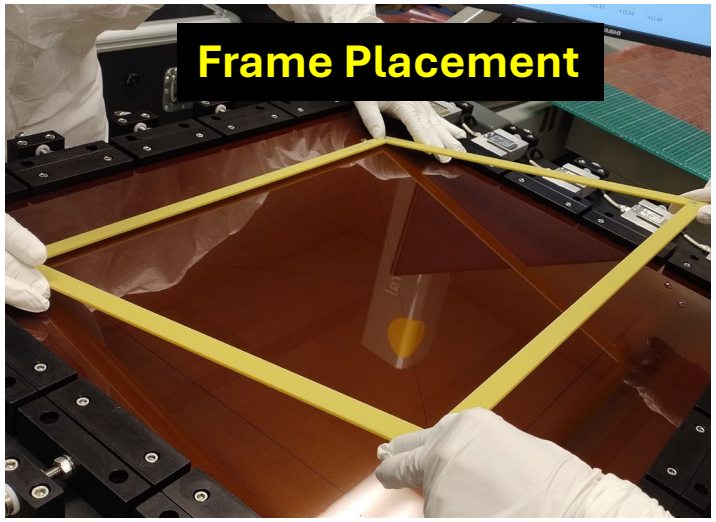
ETA Main Components and Assembly

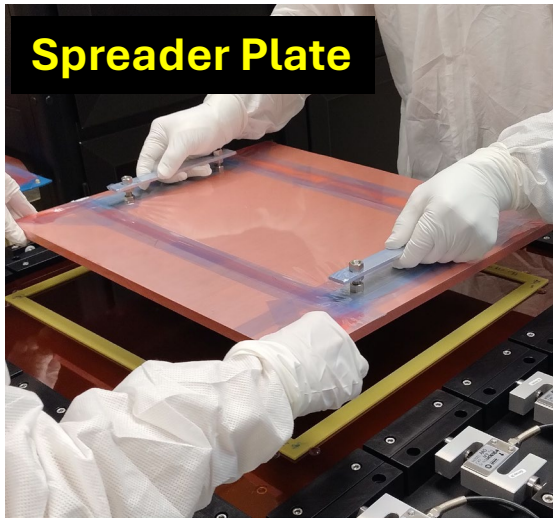


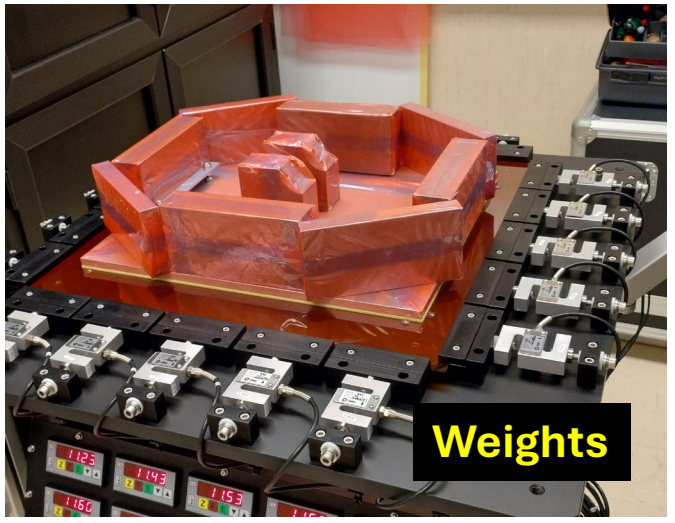
Gluing Tests and Glue Transfer Technique











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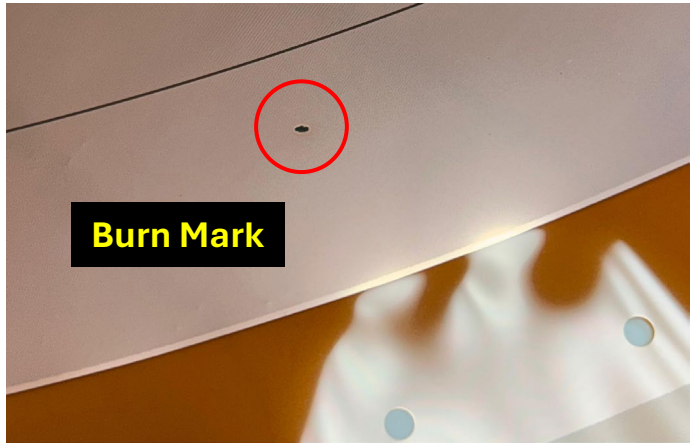
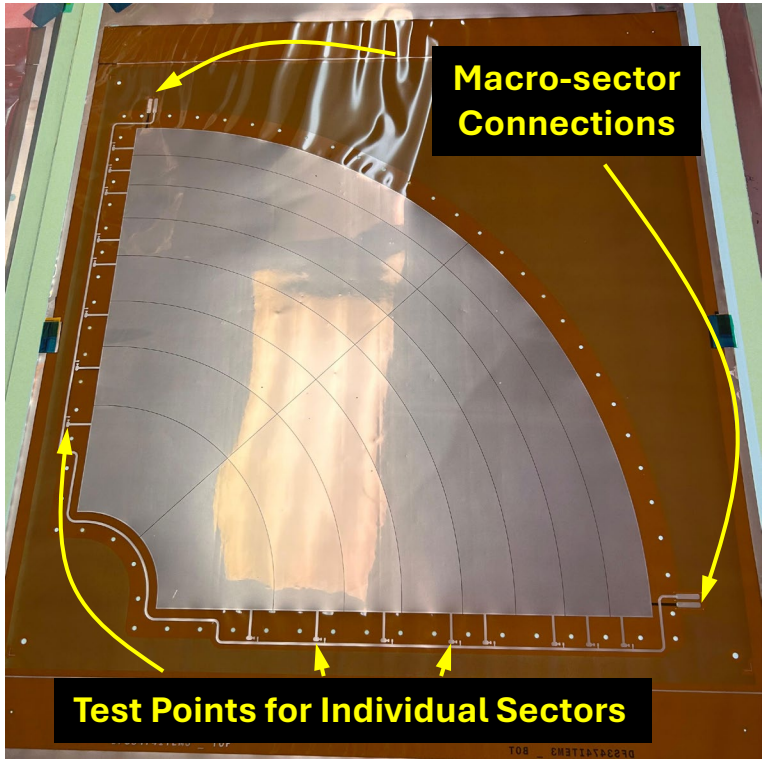
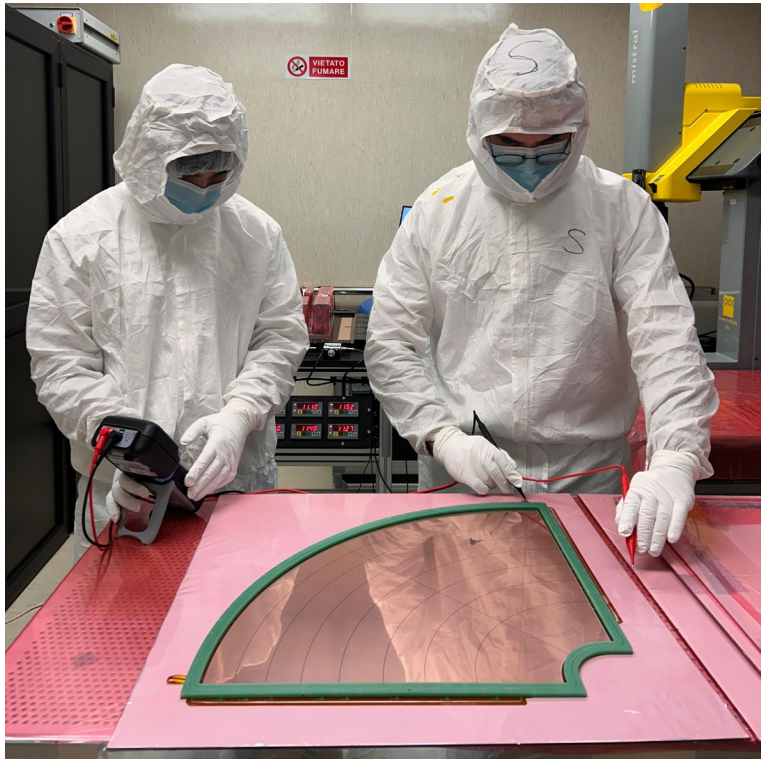
Quality Control of the GEM Foils



- Optical inspection
- Capacitance measurement
- Resistance measurement
- ~~Insulation test up to 500V (Requires N2 enclosure)~~



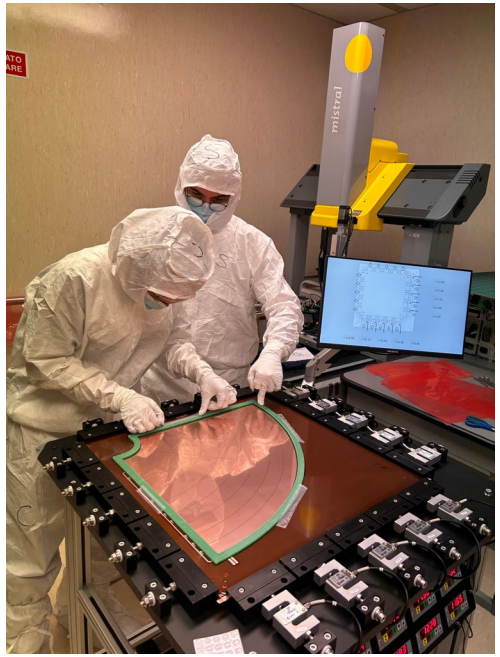


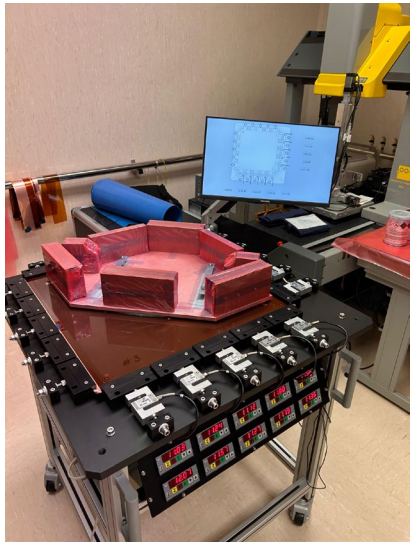
Performed on arrival and after the gluing, before shipping the foils back to CERN

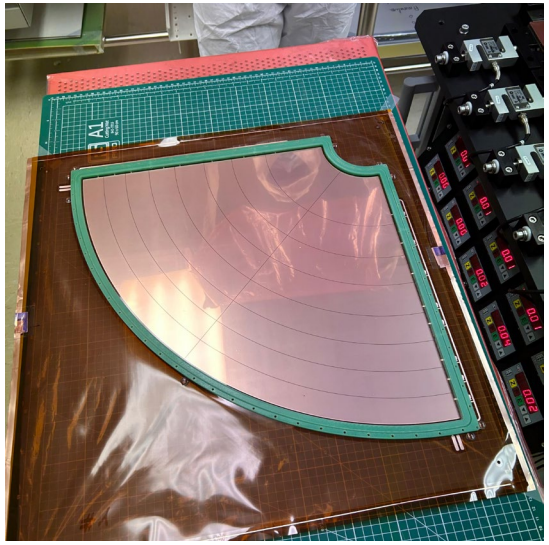
One sector already shorted on arrival, **no new sectors were damaged in the operations**

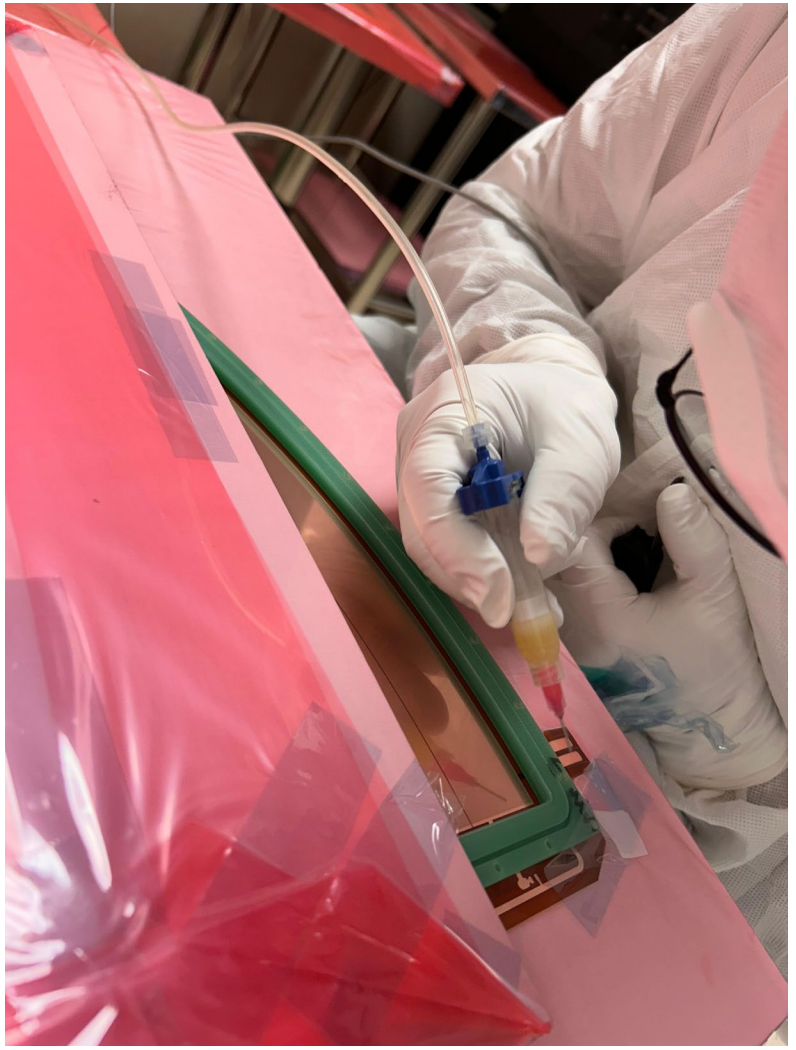
The gluing procedure is "clean"

GEM Gluing









Araldite AY103 epoxy deposited in a 3 mm wide strip

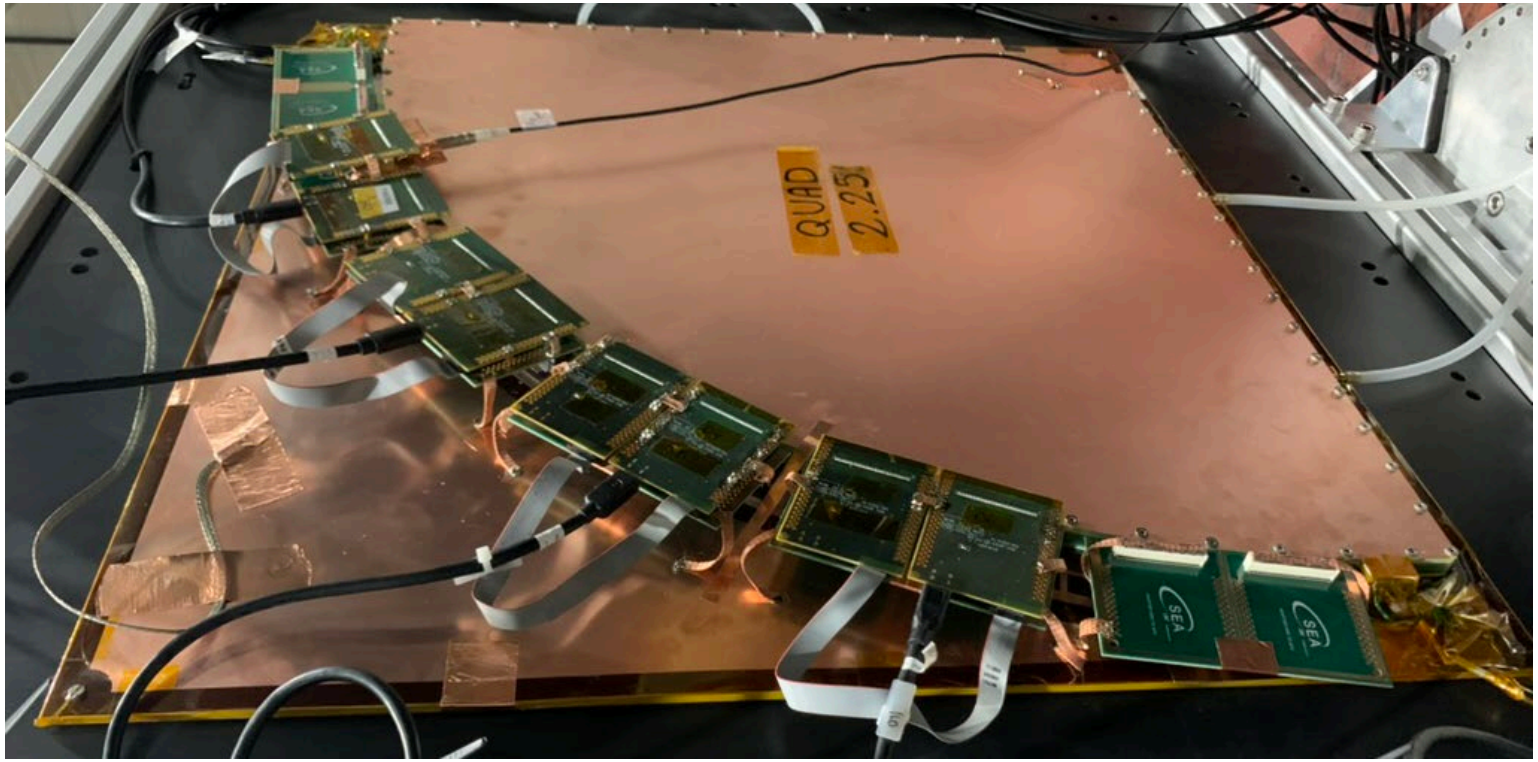
GOOD for mechanical stability, no overflow, no holes occluded

BAD for gas tightness, internal sealing with Araldite 2011 required

4 GEMs Glued in total (2x ETA Quadrants, 2x CS prototypes)

The technique is serviceable, there is room for improvement

ETA Assembly and First Conditioning



μ-RWELL + R/O PCB Manufactured at CERN MPT Workshop

Final assembly and first detector **conditioning** also performed **at CERN**

Nr. 2 ECT ETAs ready for the second week of the test beam **(1 w/ grids and 1 w/o)**

Test Beam Preparation

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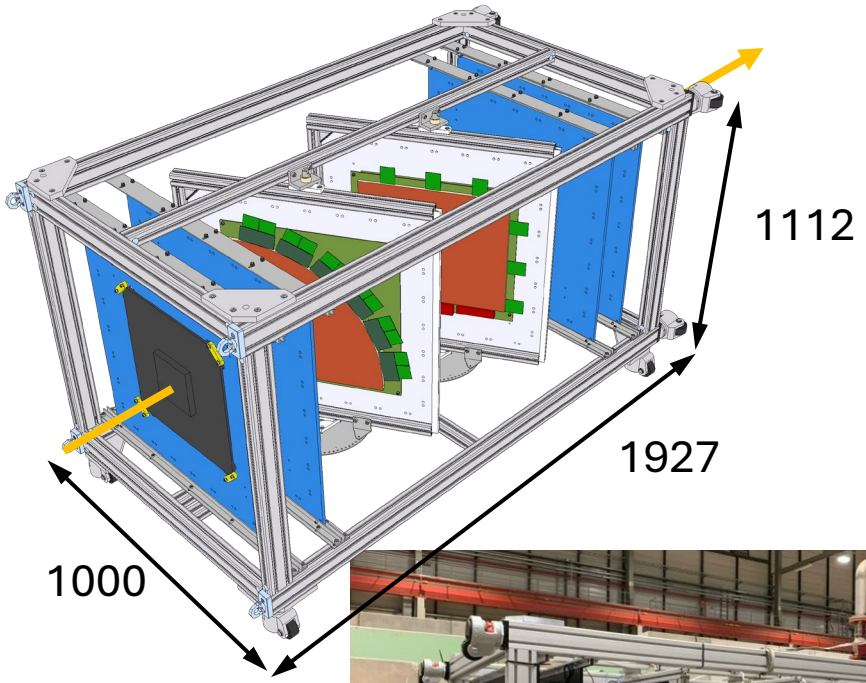
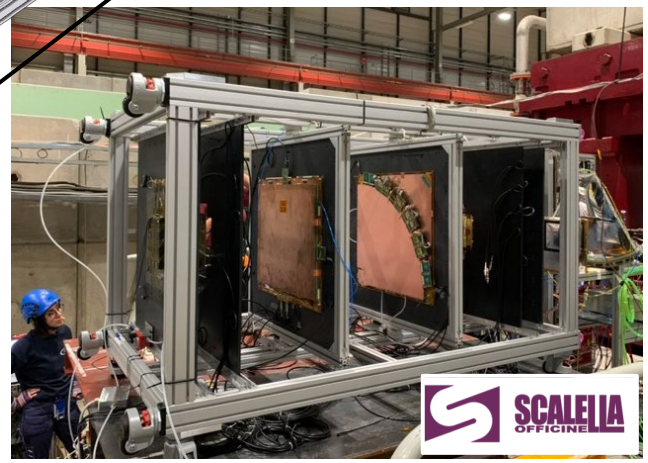
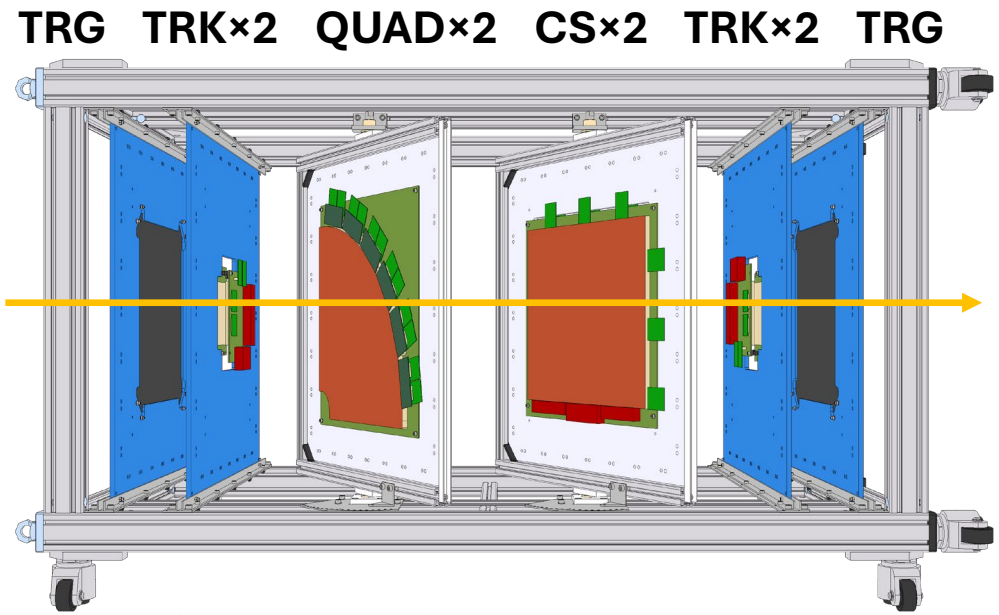
Setup and Detector Arrangement



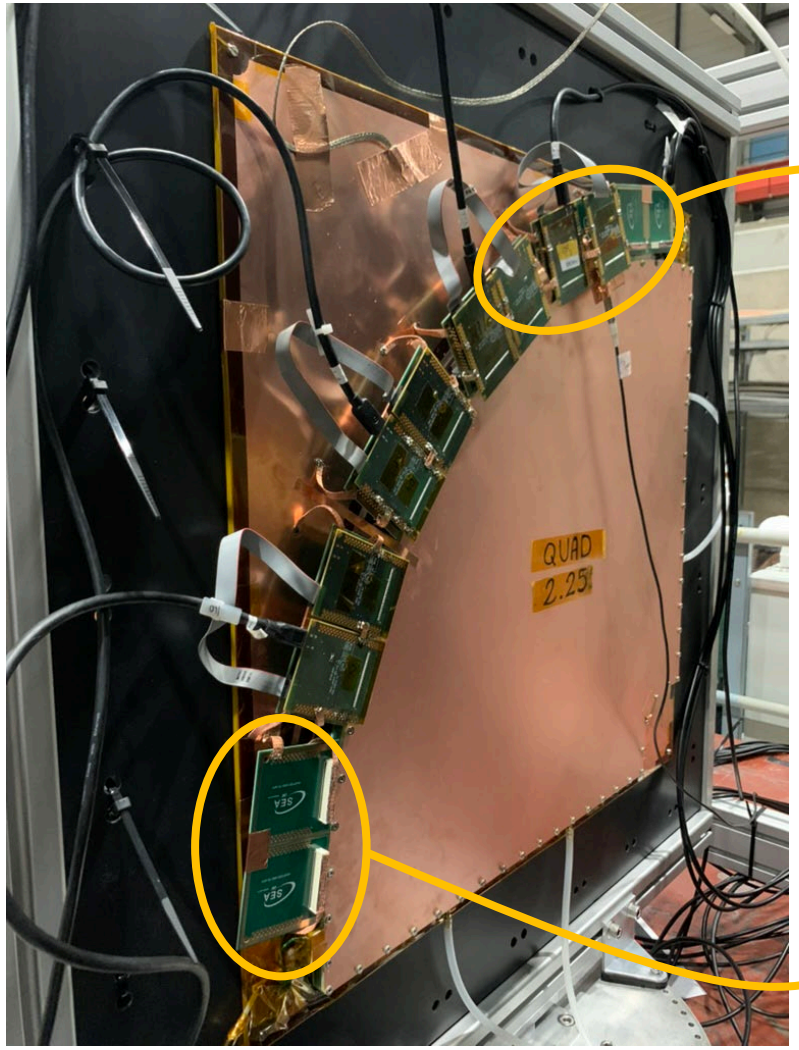




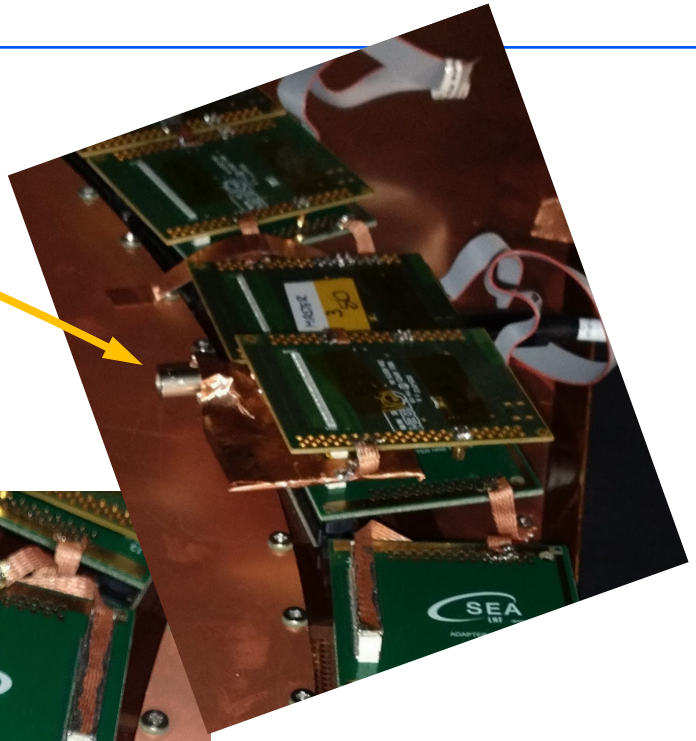
DET	Pitch (μm)	Active Area	Readout	Capacitive Sharing
TRK	400	10x10 cm^2	2D XY	No
QUAD	600	R = 45 cm	2D XY	No
CS	1200	46x40 cm^2	2D XY	3 Layers (300μm)
TRG	NA	15x15 cm^2	SiPM	NA

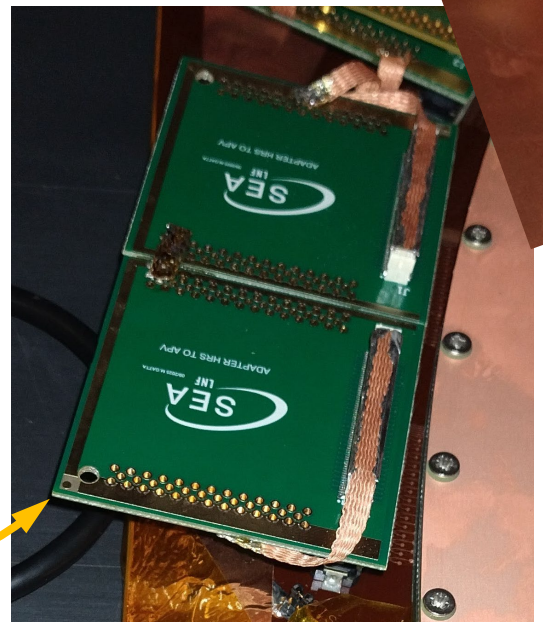
All MPGDs operating with Ar:CO_2:CF_4 (45:15:40)

DAQ



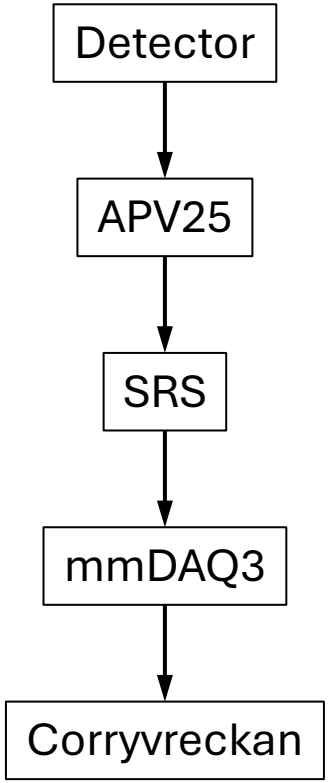
Trigger Signal
Injection Board



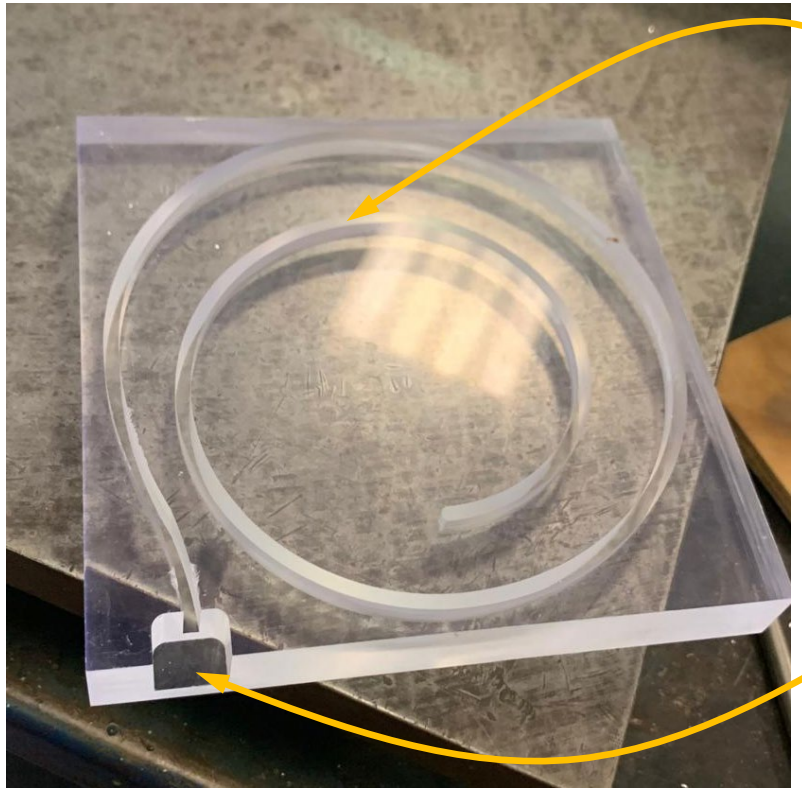


HIROSE to Panasonic
Transition Board

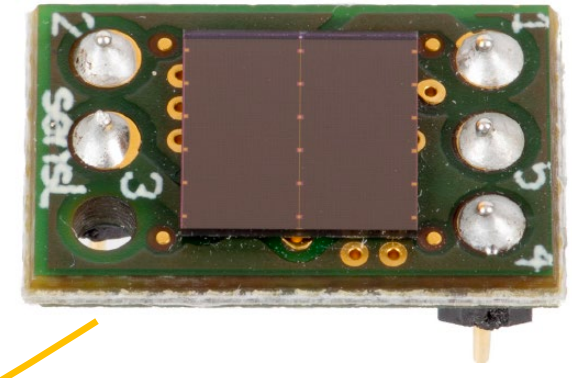
Data Pipeline



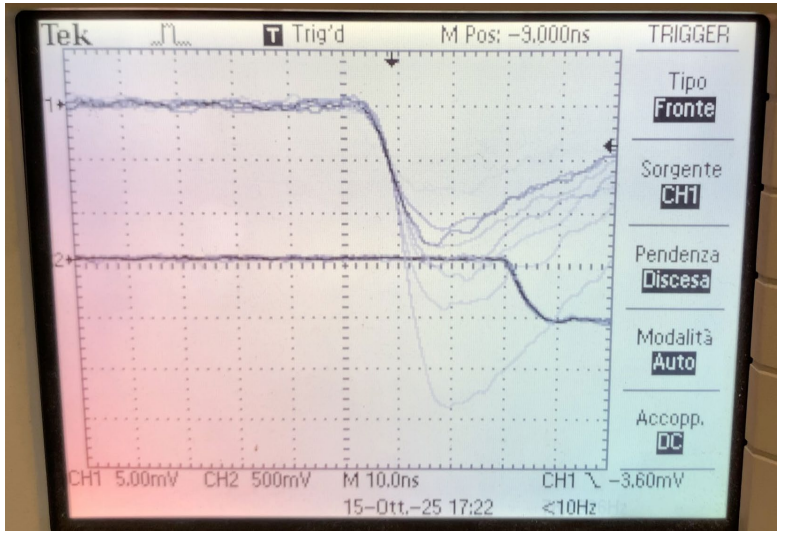
Trigger



×9 Ø1 mm wavelength shifter fibers
Bundled and embedded in the groove



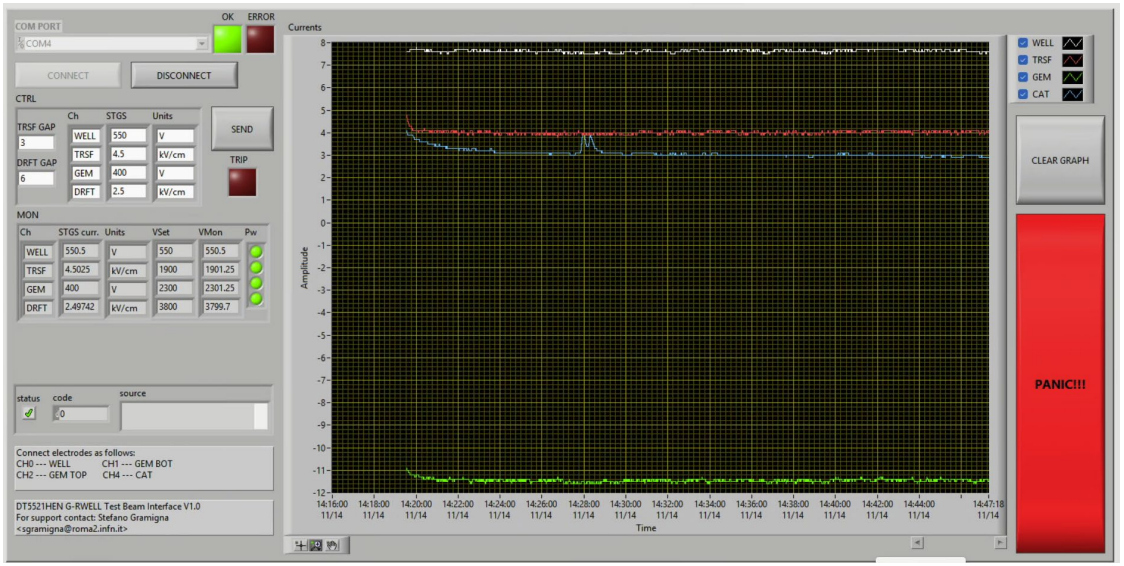
Onsemi J-Series 30020
3x3 mm^2 SiPM Area

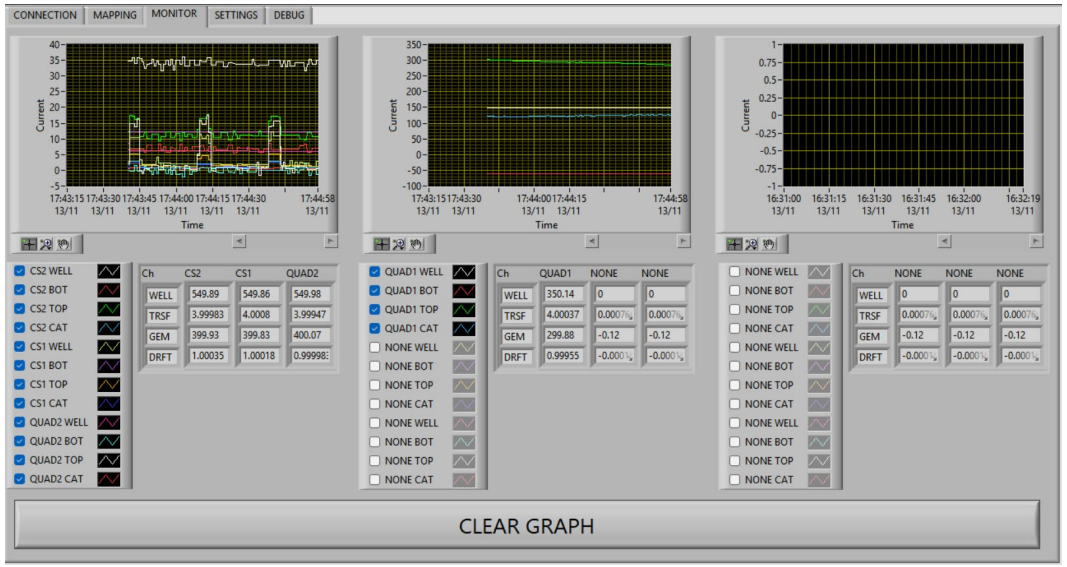


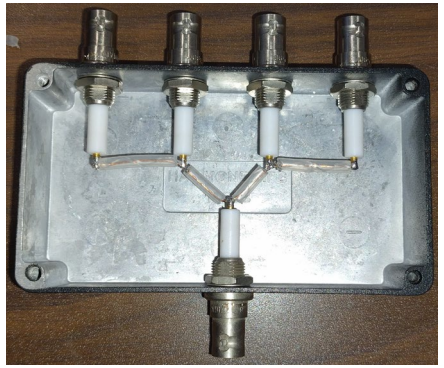
Non-amplified signal output
from cosmic rays

Also provides a time reference ($\mathbf{t_0}$) to selected APVs for µTPC reconstruction

HV Slow Control and Current Monitor







Trackers powered in **parallel**

1 HV Channel per type of electrode

Same electrodes of different detectors grouped together

4 HV channels in total

DUT's electrodes powered **individually**

1 HV Channel per electrode per detector

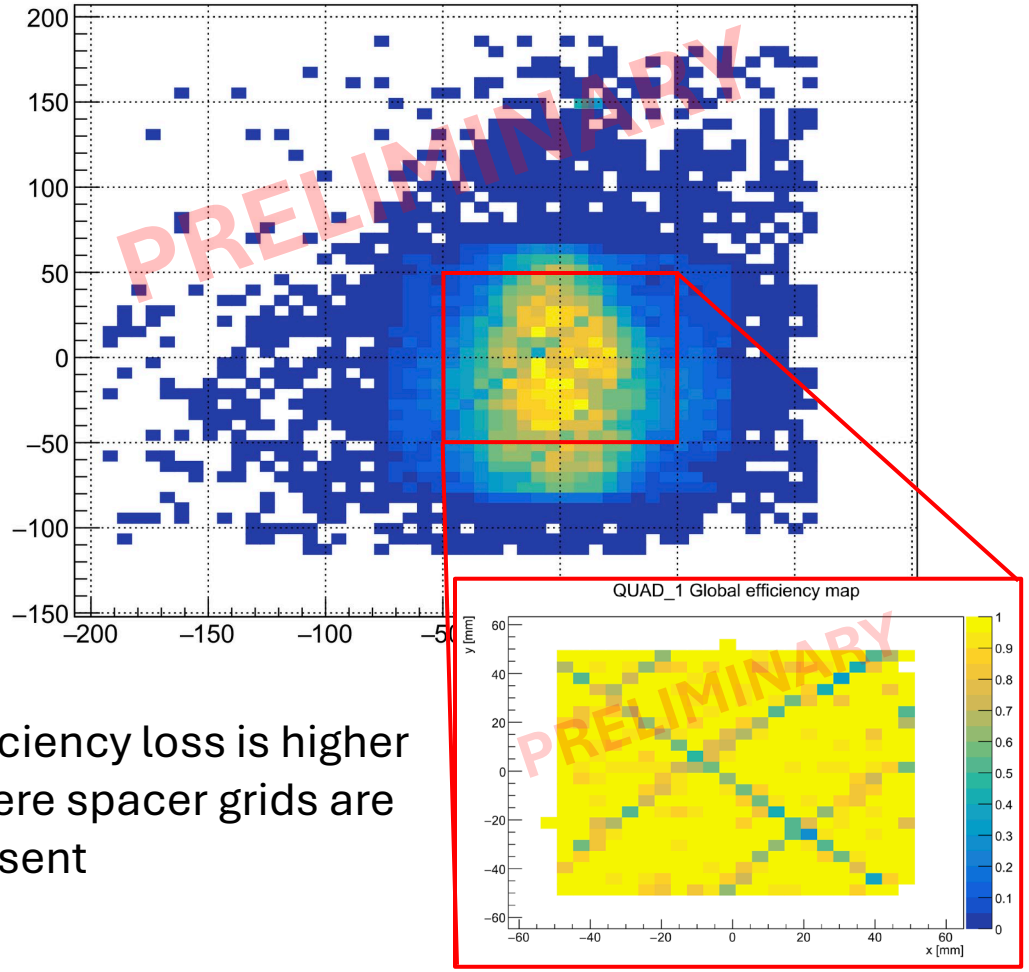
16 HV channels in total

Finer diagnostics and HV regulation

Preliminary Results

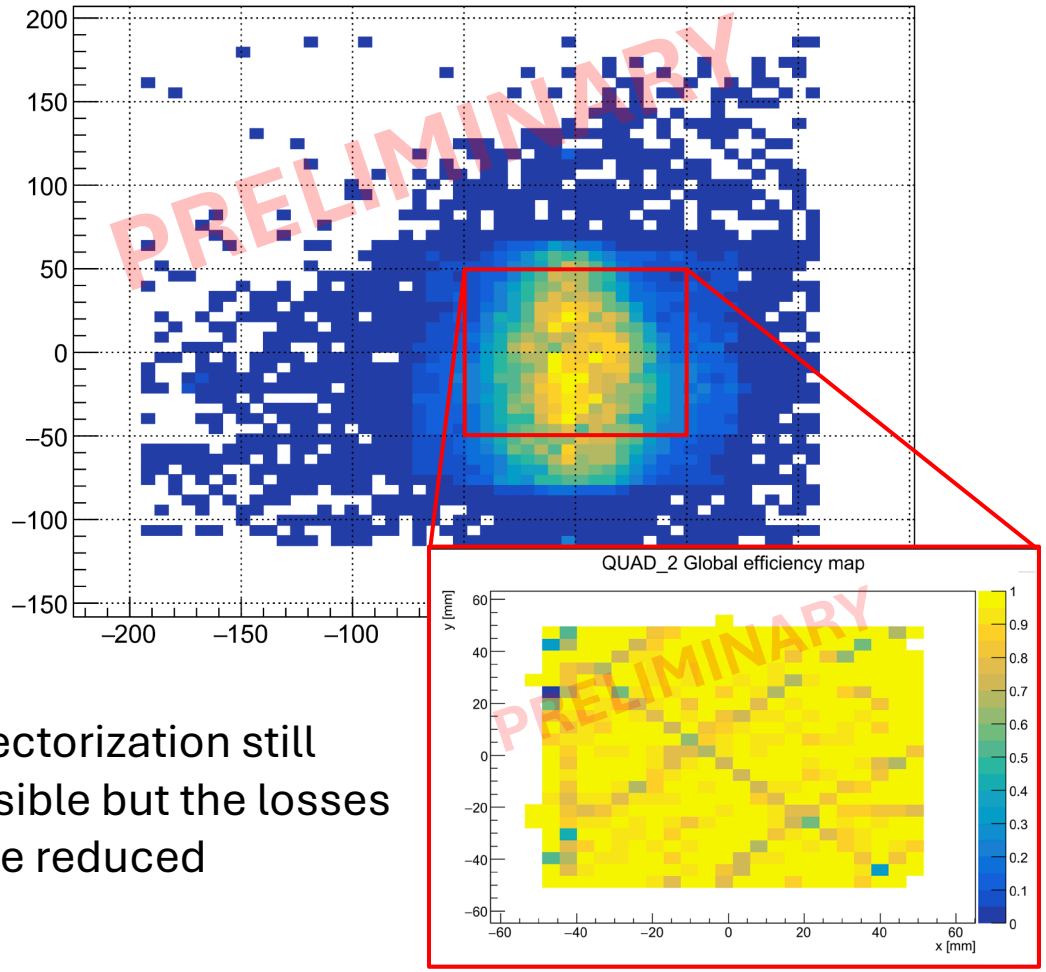
Position and Efficiency Maps

Highest charge cluster position QUAD1 (w/ grids)



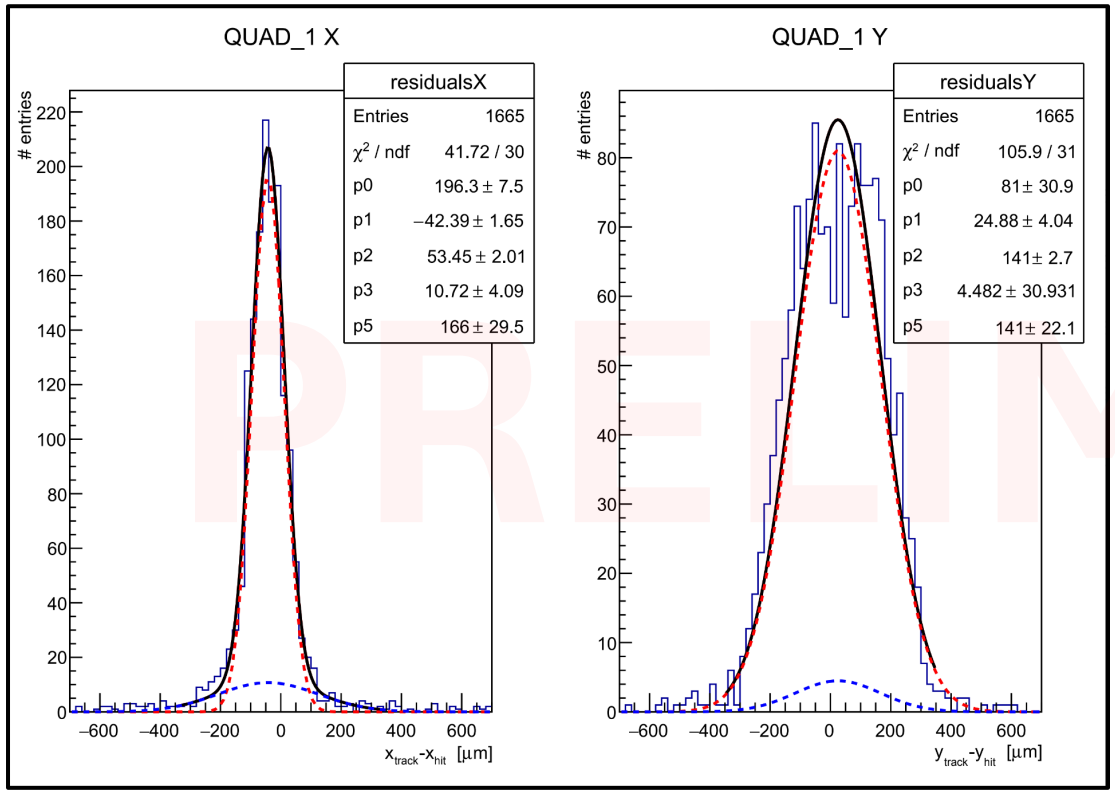
Efficiency loss is higher where spacer grids are present

Highest charge cluster position QUAD2 (w/o grids)



Sectorization still visible but the losses are reduced

Residuals Distributions



$\sigma_{x\,eff} = 80\mu m$

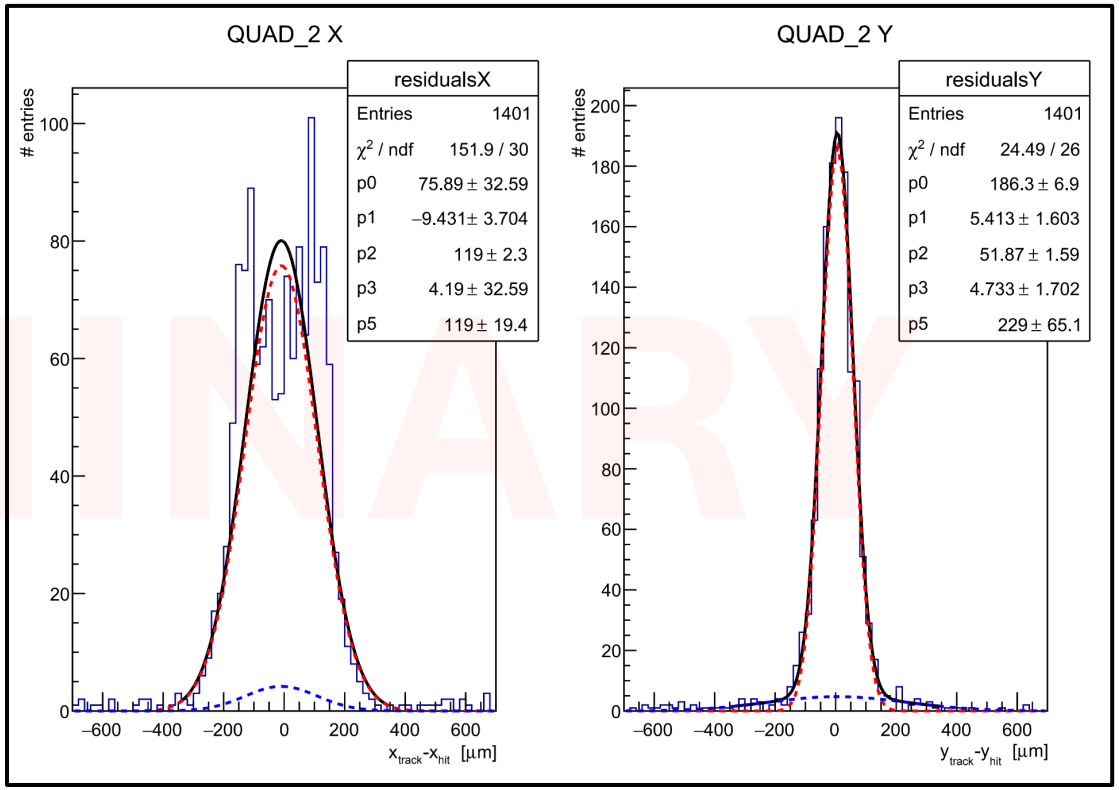
Lower view

520 μm strips width

$\sigma_{y\,eff} = 141\mu m$

Upper view

90 μm strip width



$\sigma_{x\,eff} = 120\ \mu m$

Upper view

90 μm strip width

$\sigma_{y\,eff} = 88\ \mu m$

Lower view

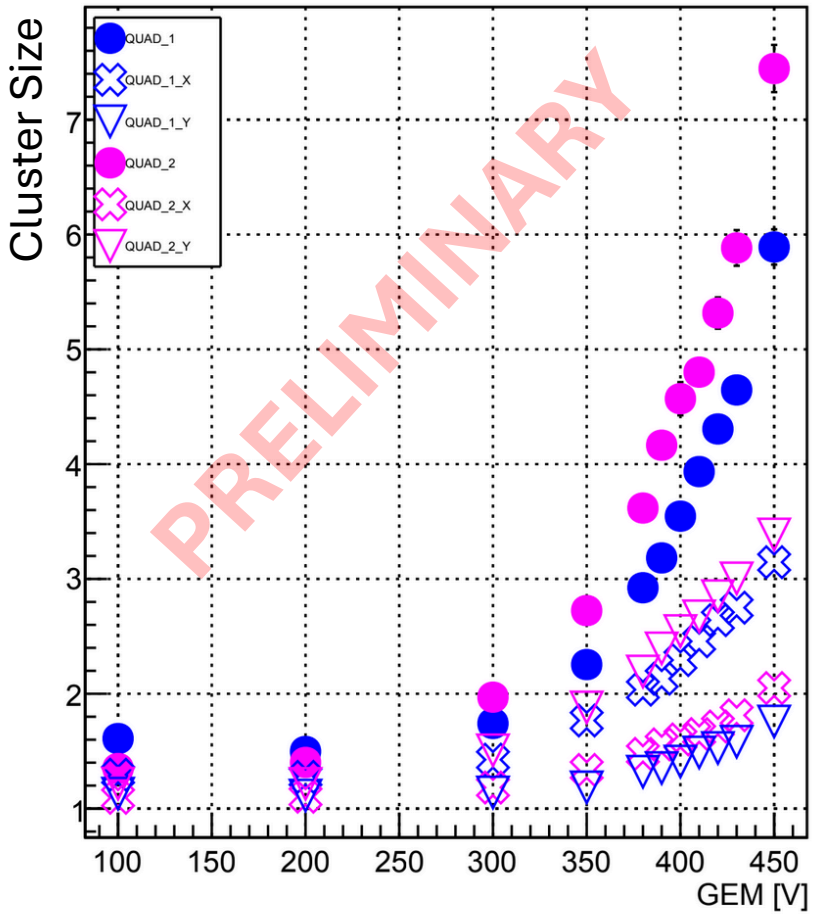
520 μm strip width

The two quadrants are rotated by 90 degrees with respect to each other, hence the X-Y exchange

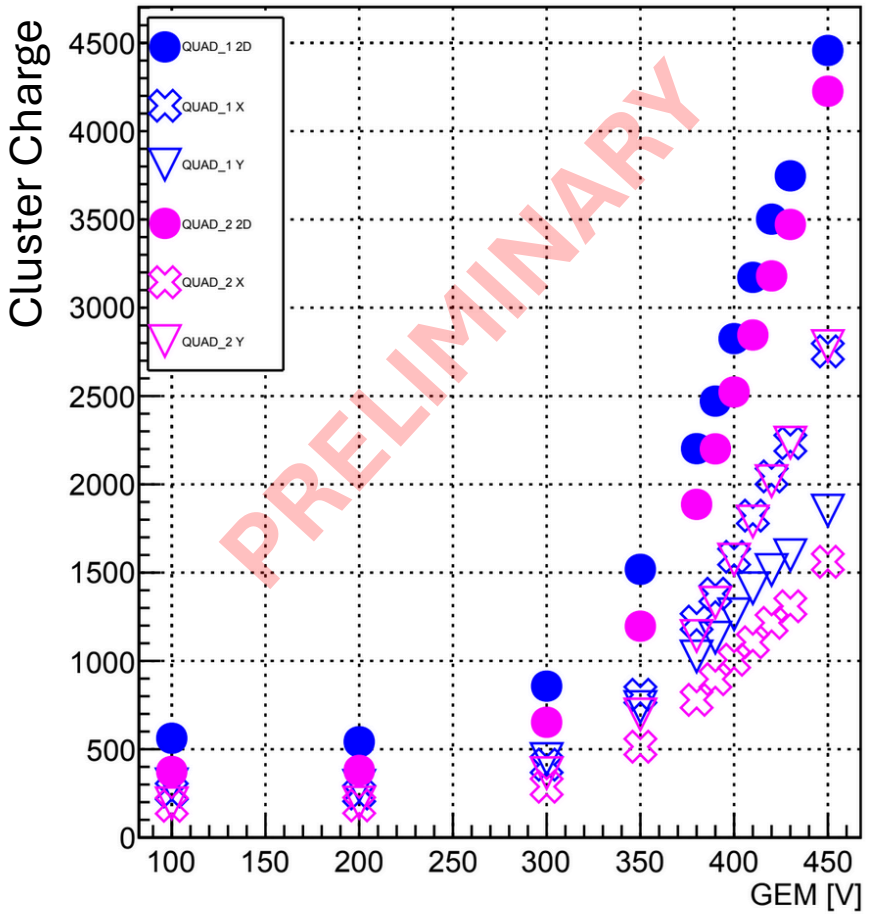
PRELIMINARY

Size and Charge of the Signal Clusters

Cluster Size VS GEM Voltage *



Cluster Charge VS GEM Voltage *



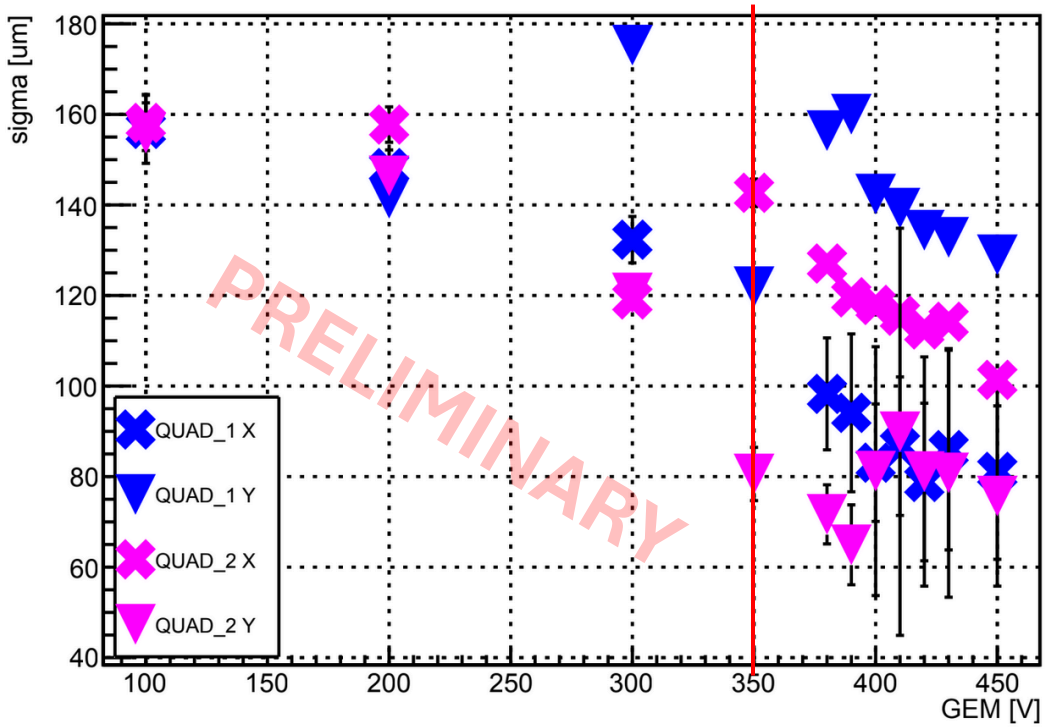
- QUAD1
- QUAD2

Charge sharing visibly skewed in favor of the wider strips of the lower view

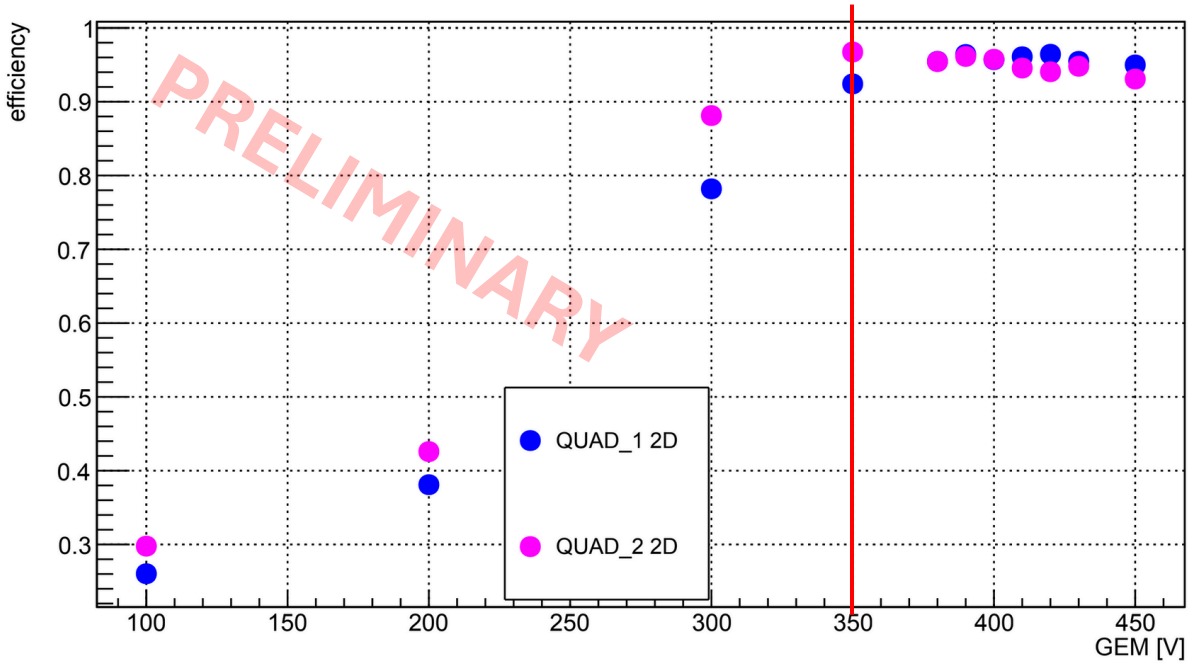
* WELL = 550 V
TRSF = 4.5 kV/cm
DRFT = 2.5 kV/cm

First Resolution and Efficiency Estimates

Residuals' σ VS GEM Voltage *



2D Efficiency [1x1 cm^2] VS GEM Voltage *



Preliminary performance satisfy requirements @ HV GEM = 350V

Generous leeway for safe detector operation and optimization

* WELL = 550 V
TRSF = 4.5 kV/cm
DRFT = 2.5 kV/cm

Conclusions

- Two **size 1 ETAs** for the ECT **produced and tested successfully**
- **GEM stretching** technique **well consolidated**
- **Gluing** procedure serviceable but **could be improved**
- **Many new ancillary systems** were **deployed** for the test beam
- The **preliminary results** from the analysis are encouraging:
  - **Spacer grids** do **not** seem **necessary** at the tested dimensions
  - **Charge sharing** between the two views is **not even**, needs optimizing
  - **First estimates for resolution and efficiency fully within requirements**
  - **Large operability range** available for further optimization

ECT Redesign: Acceptance Study

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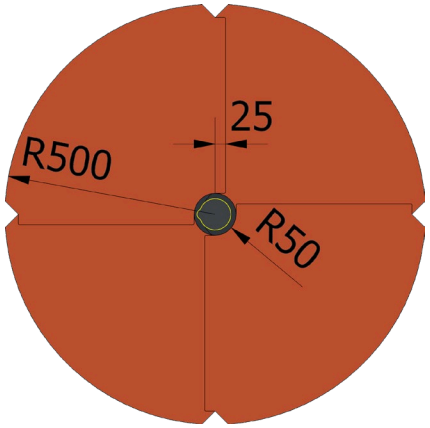
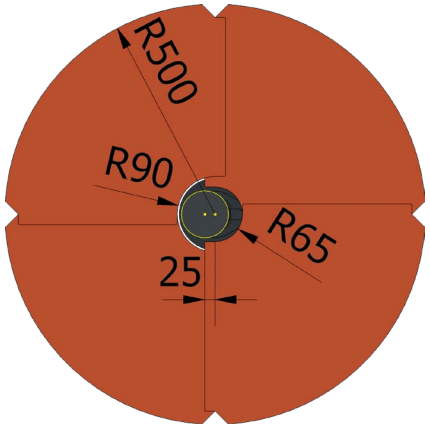
Purpose of the Study



LEPTON SIDE



HADRON SIDE

Before the envelope change, active area coverage near the beam pipe was maximized using **3 different module layouts**

Changes to the disks' location along the beam direction **might render this optimization** of the modules' geometry **unnecessary**

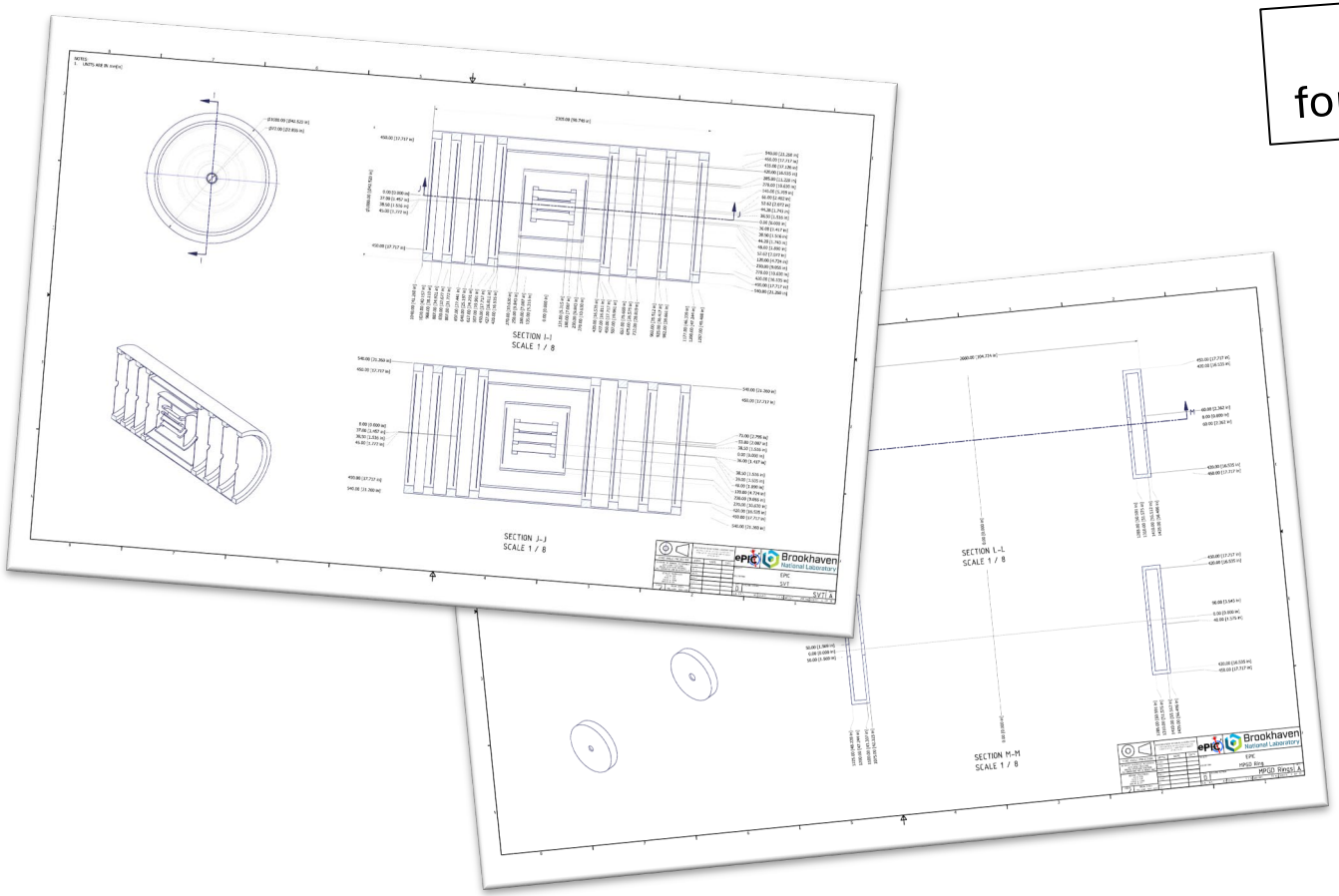
Project recommended a reassessment, taking **SVT coverage** along η into account

Falling **back to 2 or even 1 module layouts** could greatly **simplify design and serial production**

Sources and References

The design of the SVT maximizes angular coverage **for each individual layer**, arranging sensors as close as possible to the edges of the envelope (5 mm from beam pipe)

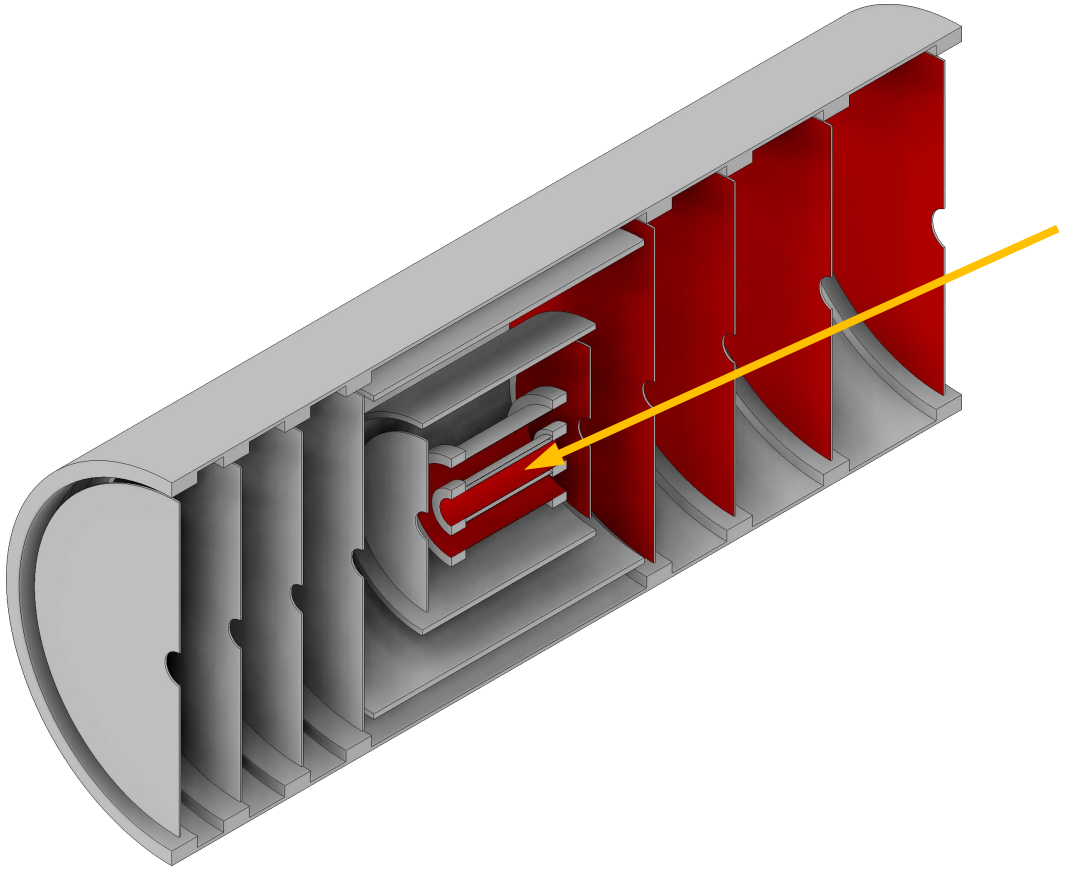
Many thanks to Ben and Ernst
for their helpful explanations on the matter



Envelope drawings released on **09/22/2025** were adopted as reference for all coming geometric considerations

Simplification of the Problem: SVT Layers

The **sensitive surface** of each SVT layer is assumed **as large as the surface of the relevant envelope volumes facing the IP**



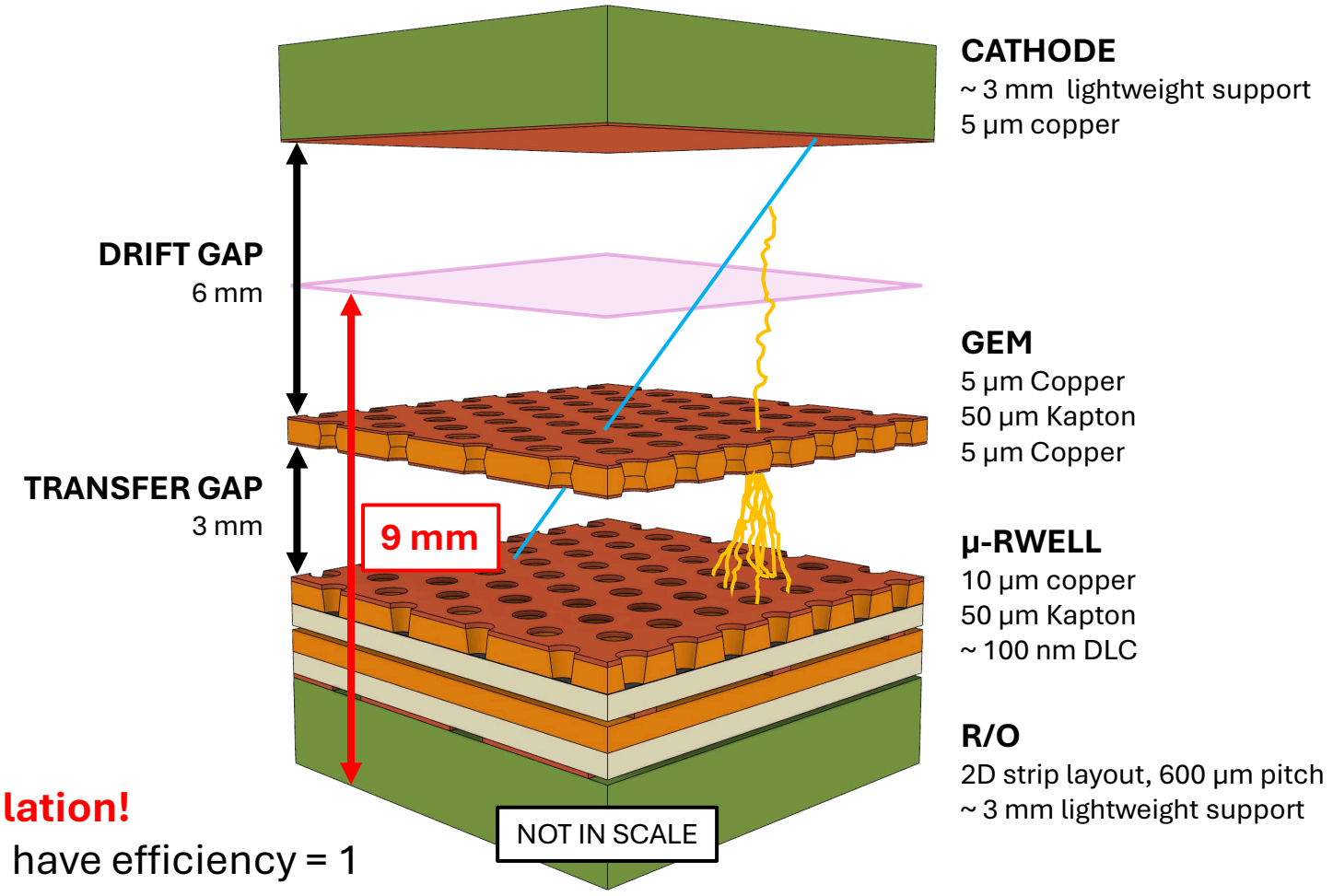
Only the first SVT barrel layer was included in the study

SVT barrel layers affect a region of **little to no interest for** the optimization of the **ECT modules' central cavity**

Simplification of the Problem: ECT Layers

ECT sensitive surfaces account for **manufacturing constraints:**

- **Z:** Sensitive surfaces are offset 10 mm from the envelope outer surfaces (9 mm detector stack + 1 mm mechanical interfaces)
- **R_{in}:** Inner radius is offset by 20 mm (15 mm support frame + 5 mm assembly clearance)
- **R_{out}:** Outer radius is offset by 50 mm to leave space for FEBs and services

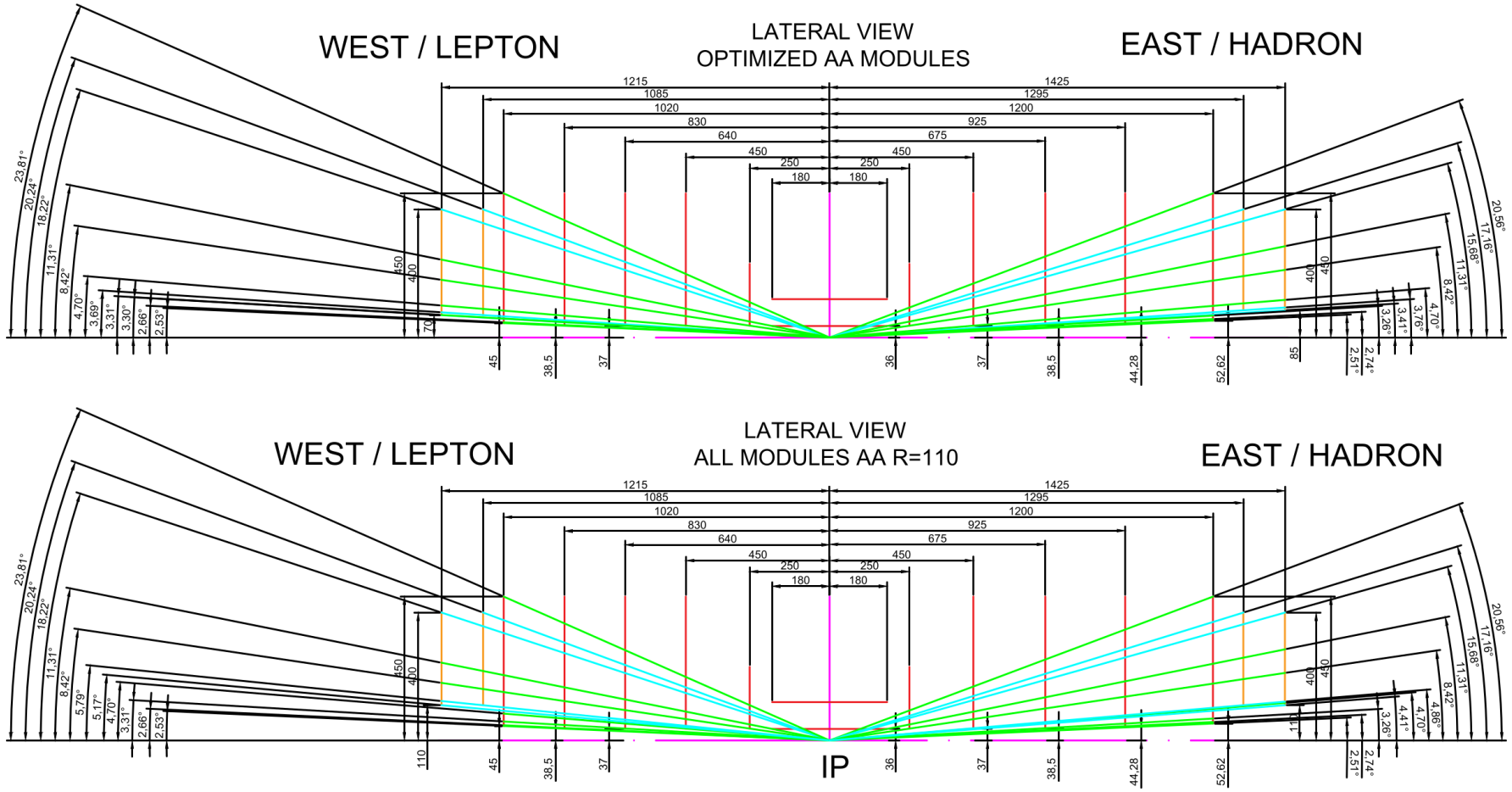


DISCLAIMER: This study is not a simulation!

All sensitive surfaces are considered to have efficiency = 1

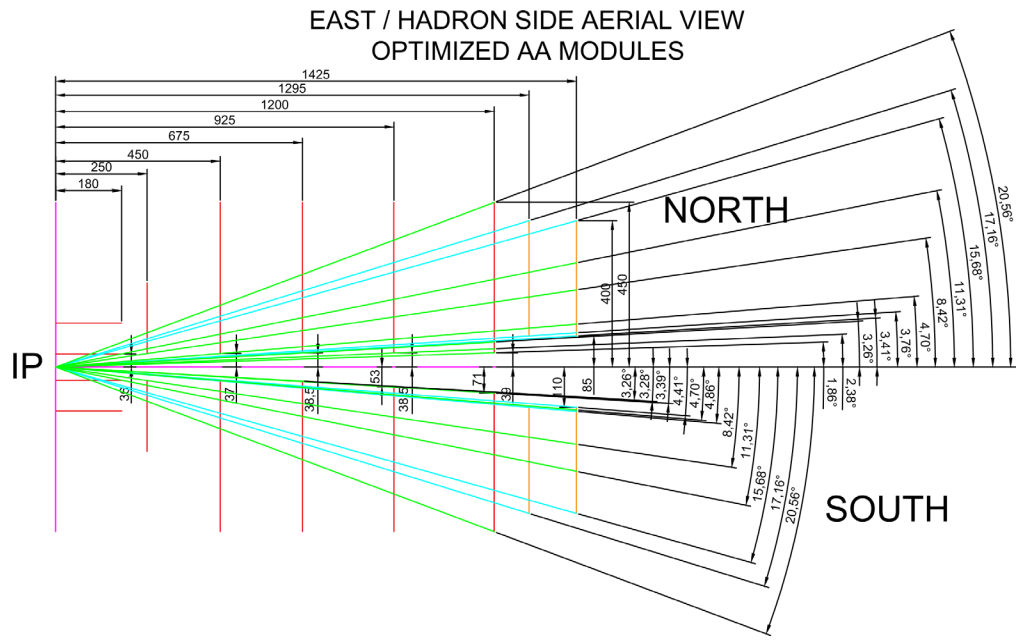
If a track crosses them, then it generates a hit in the detector

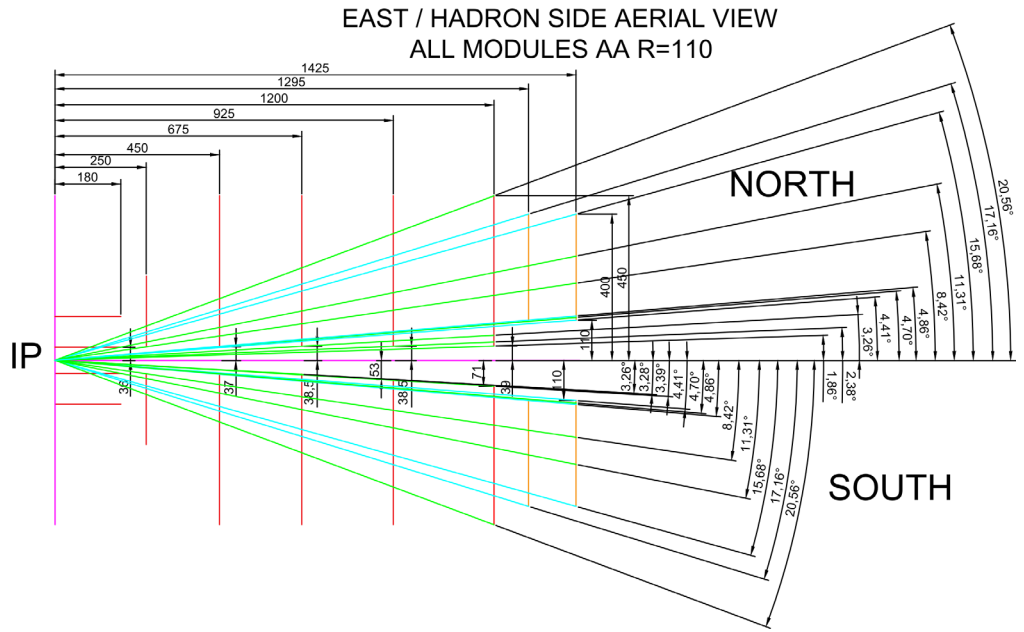
Coverage Determination: Lateral View



The **lepton side is axially symmetric, lateral and aerial view match**

Coverage Determination: Aerial View



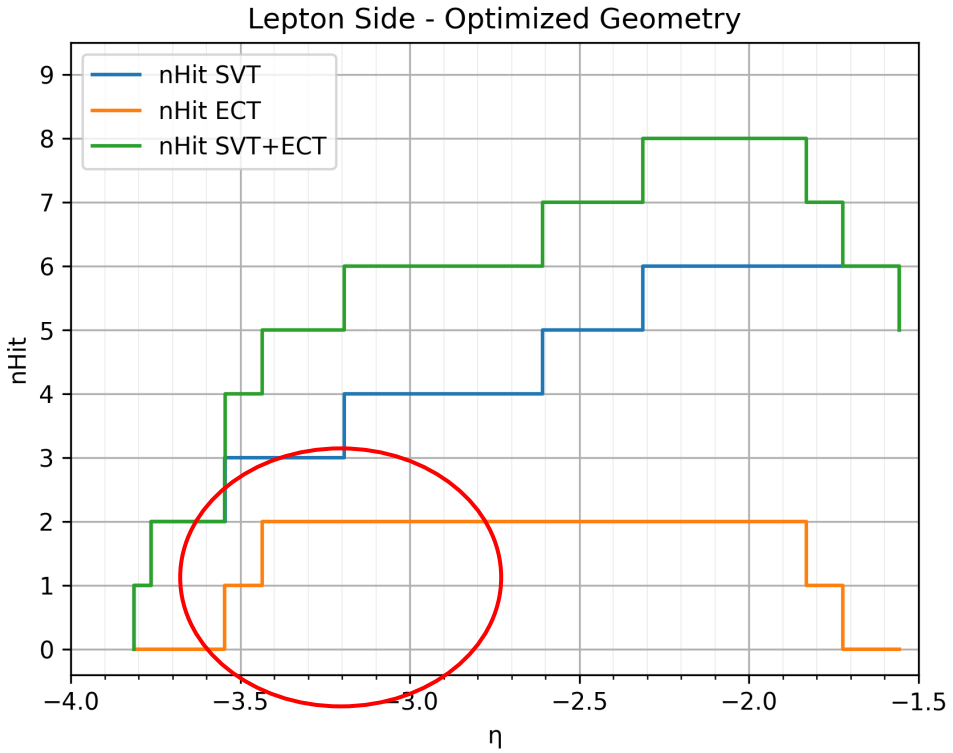


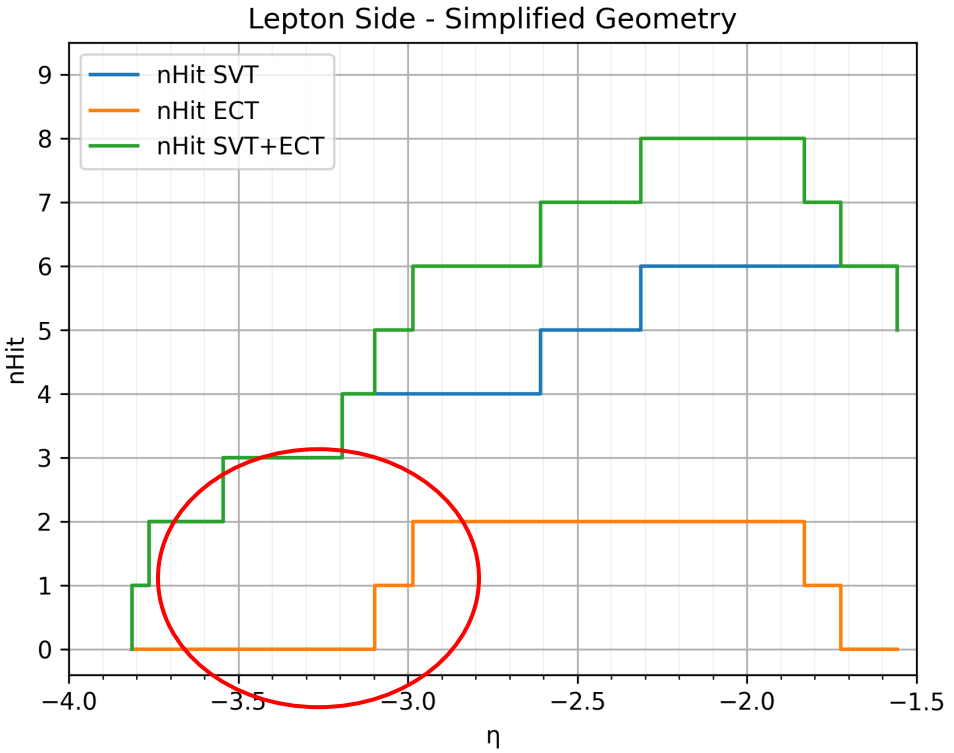
The **hadron side adapts to the beam pipe asymmetry**, the **north and south sides are studied separately**

The wider cavity of the **south side determines the simplified design** (R_{in} = 110)

Impact on Tracking Information

Lepton Side (Lateral View = Aerial View)

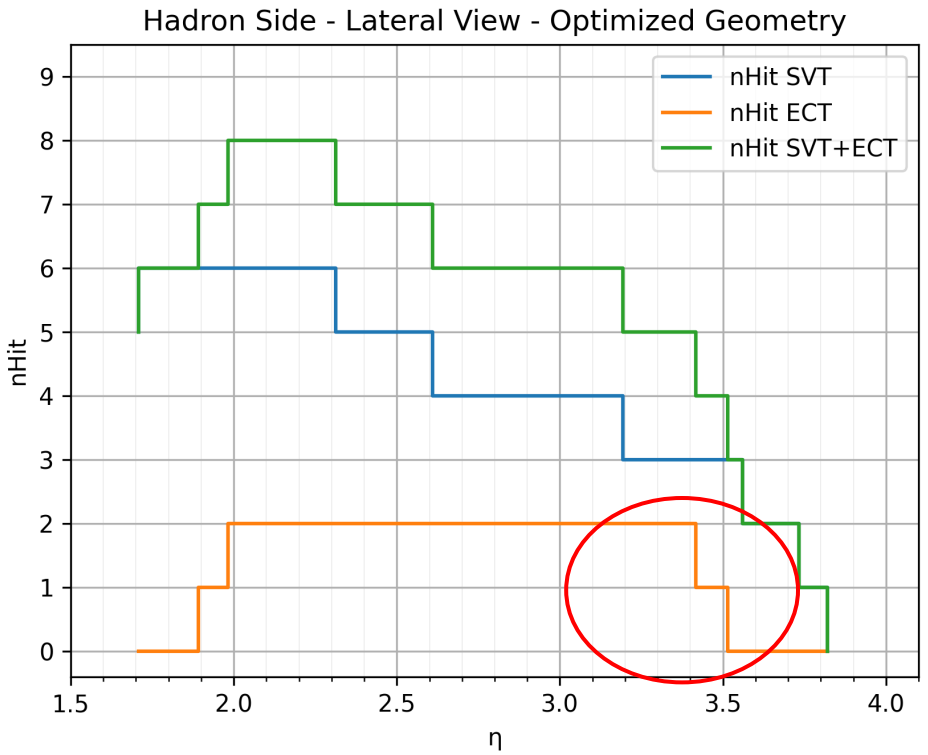


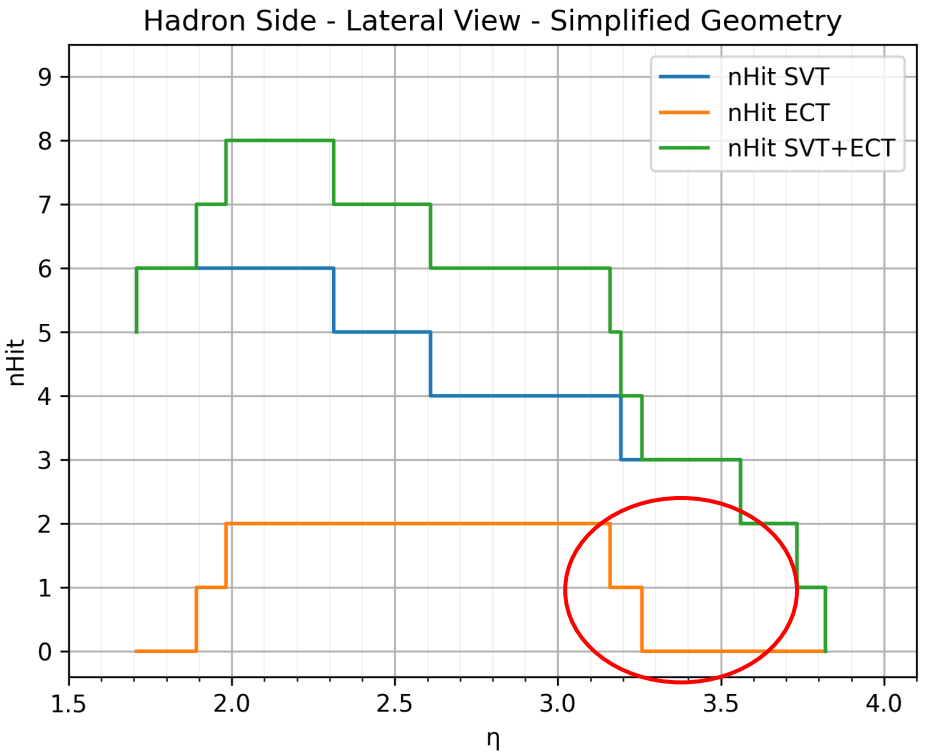


Number of sensitive surface crossings are counted for every η interval

Impact on Tracking Information

Hadron Side Lateral View

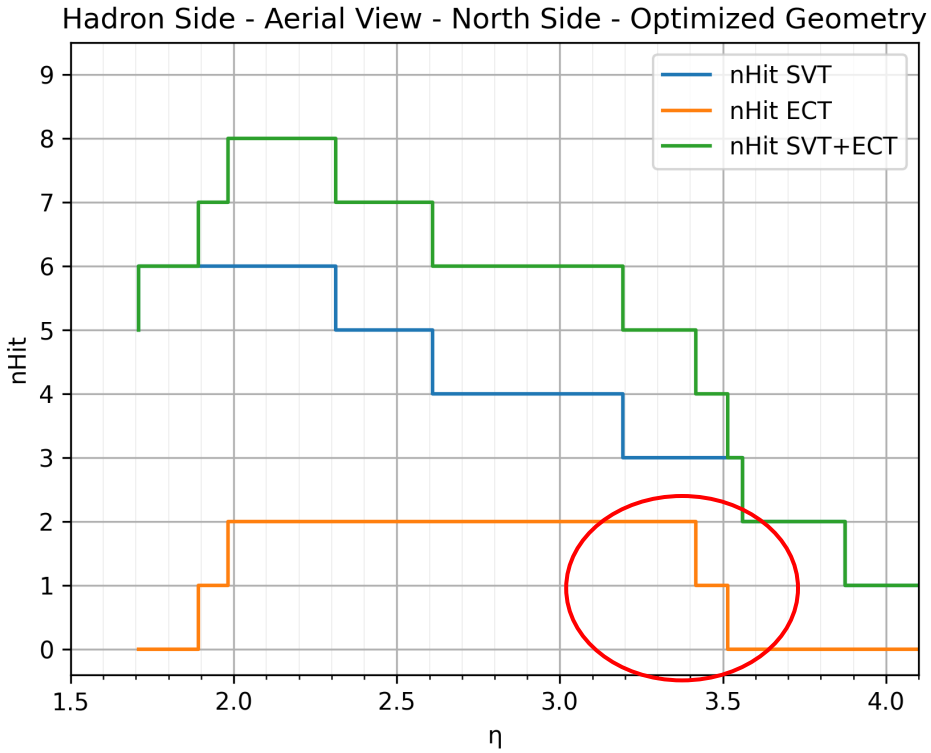


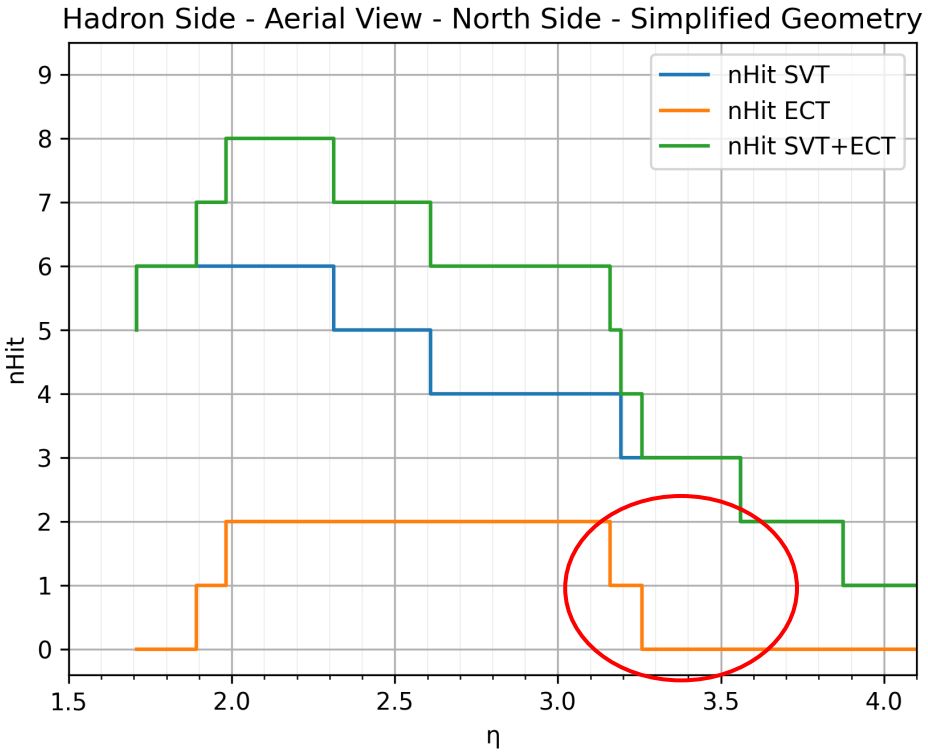


Number of sensitive surface crossings are counted for every η interval

Impact on Tracking Information

Hadron Side Aerial View North Side

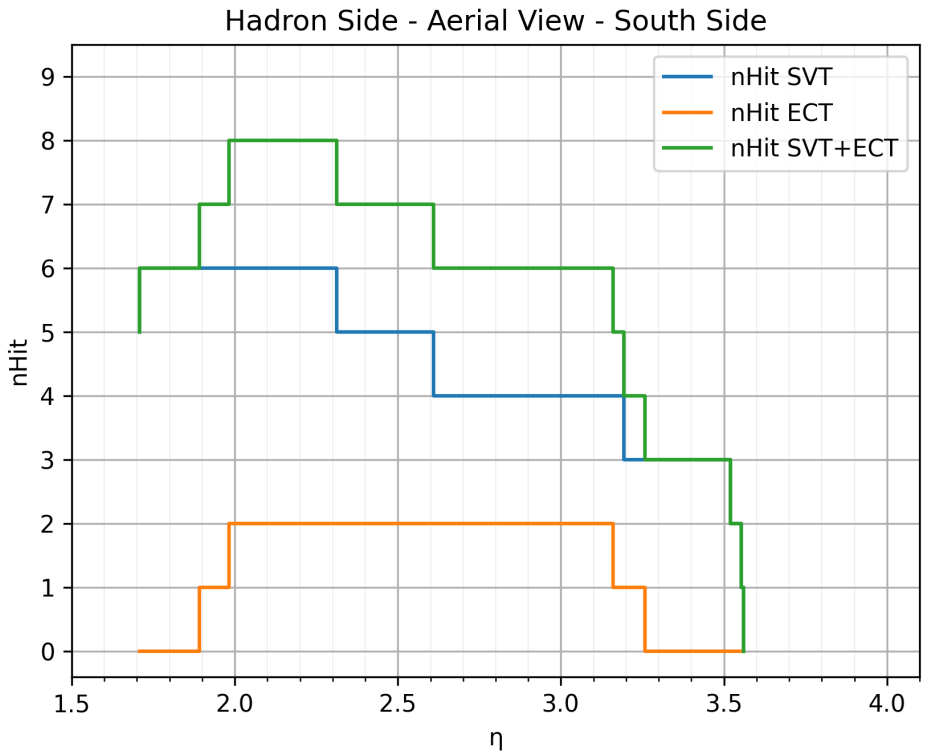




Number of sensitive surface crossings are counted for every η interval

Impact on Tracking Information

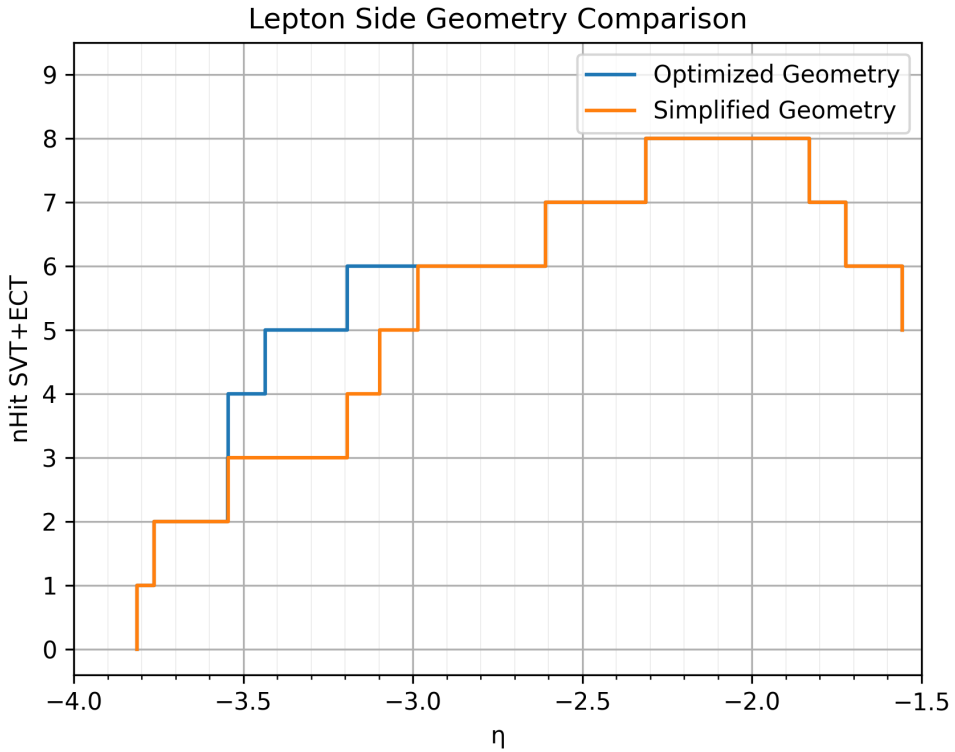
Hadron Side Aerial View South Side



Number of sensitive surface crossings are counted for every η interval

Impact on Tracking Information

Comparison – Lepton Side

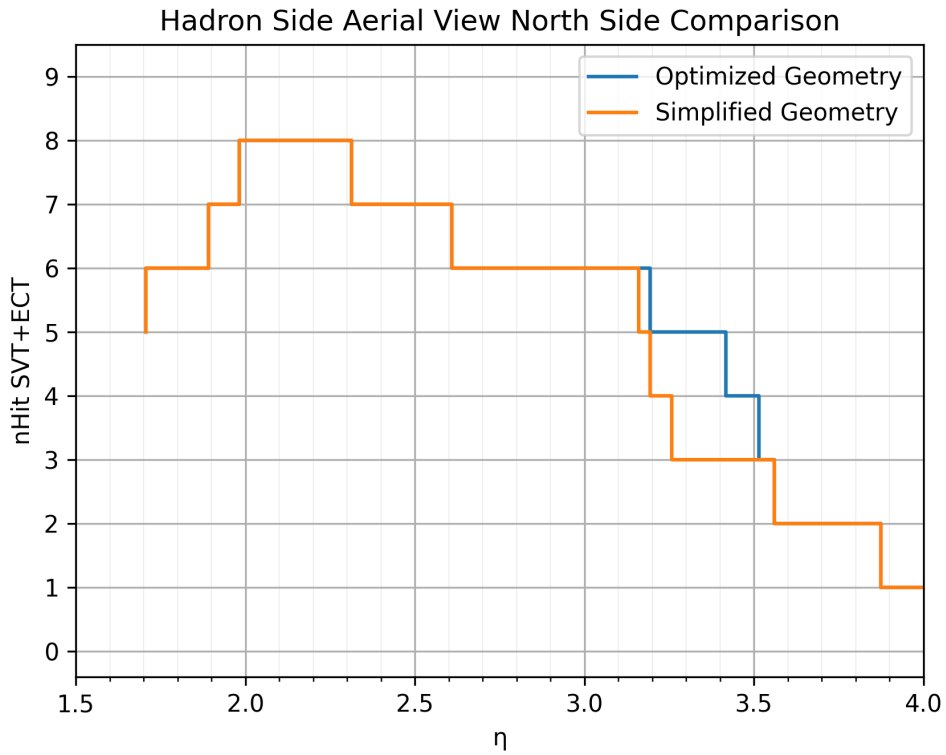


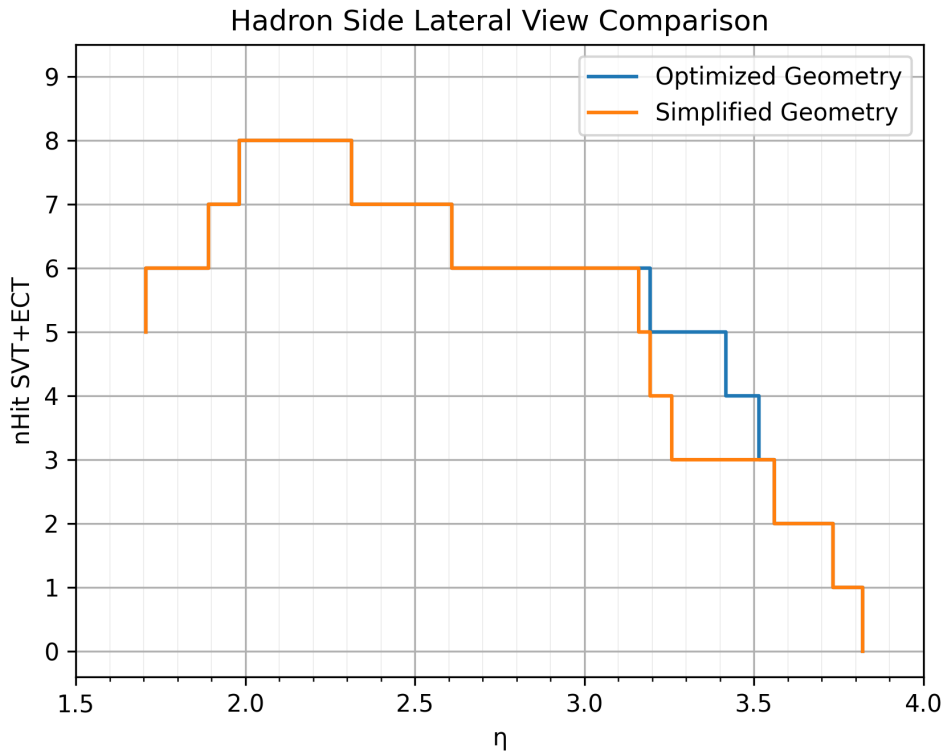
Loss of tracking information concentrates in -3.5 < η < 3.0

Sufficient tracking information from SVT available in the same region (nHit > 2)

Impact on Tracking Information

Comparison – Hadron Side





Loss of tracking information concentrates in **3.2 > η > 3.5**

Sufficient tracking information from SVT available in the same region (nHit > 2)

Conclusion

Enough hits (>2) are **independently provided by the SVT** disks in the region |η|>3, affected by central cavity optimization

Two extra points from ECT might improve or help conserve tracking performance at **-3.5 < η < 3.0 and 3.2 > η > 3.5**

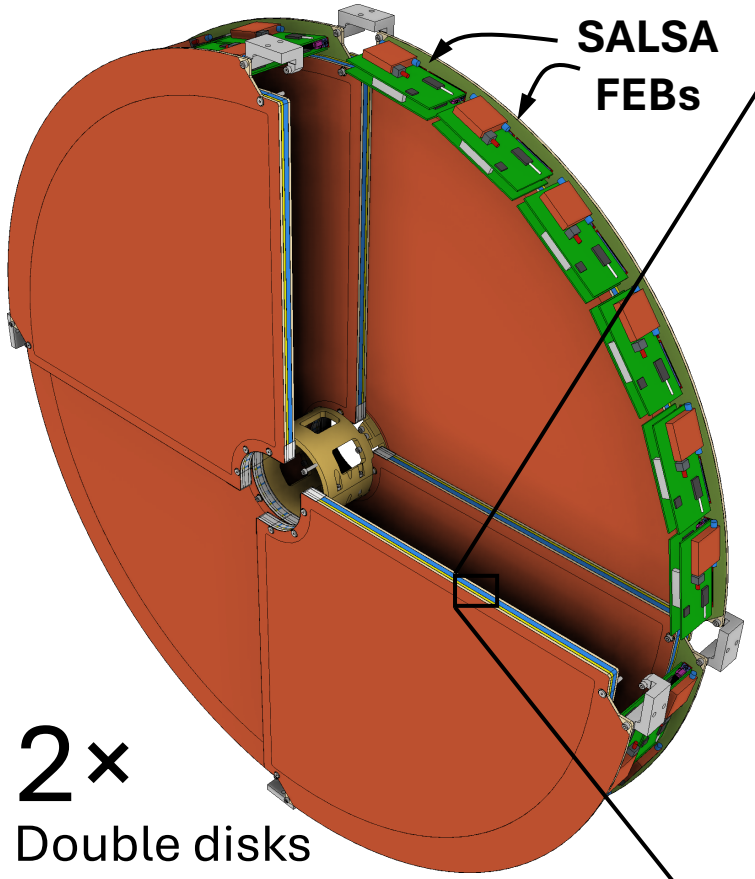
Unless disproven by finer simulations, optimization of the disks' central cavity seems to still be worth the additional workload

~~Thanks for your attention!~~

Off to the CAD for a quick showcase of the redesign

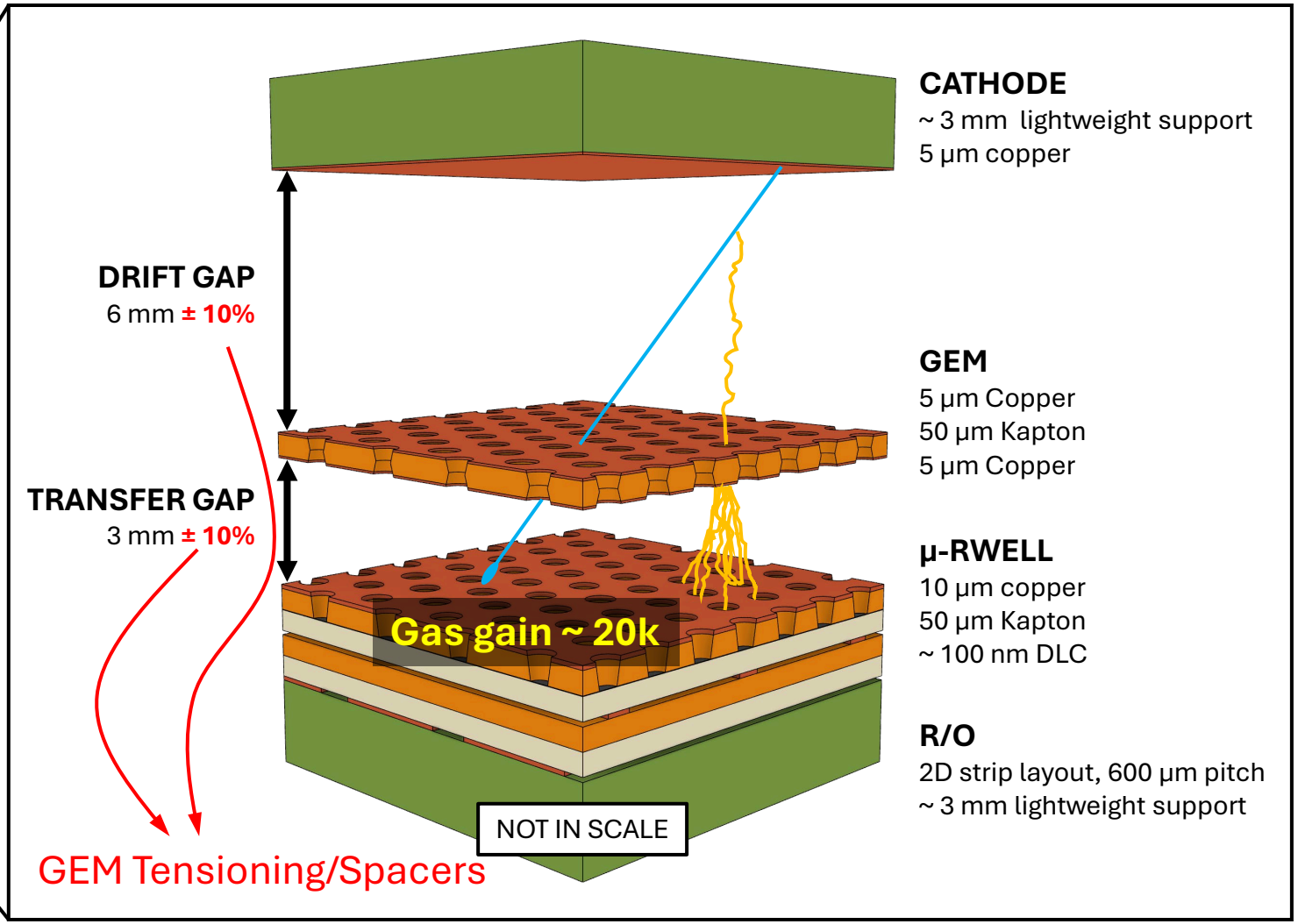
Backup slides

Recap: ECT and G-RWELL Technology



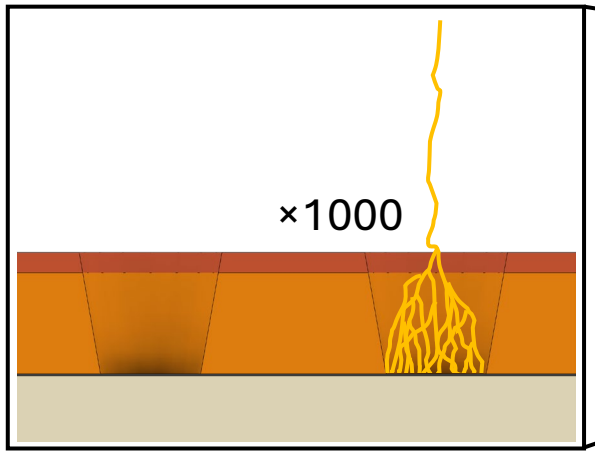
2×
Double disks

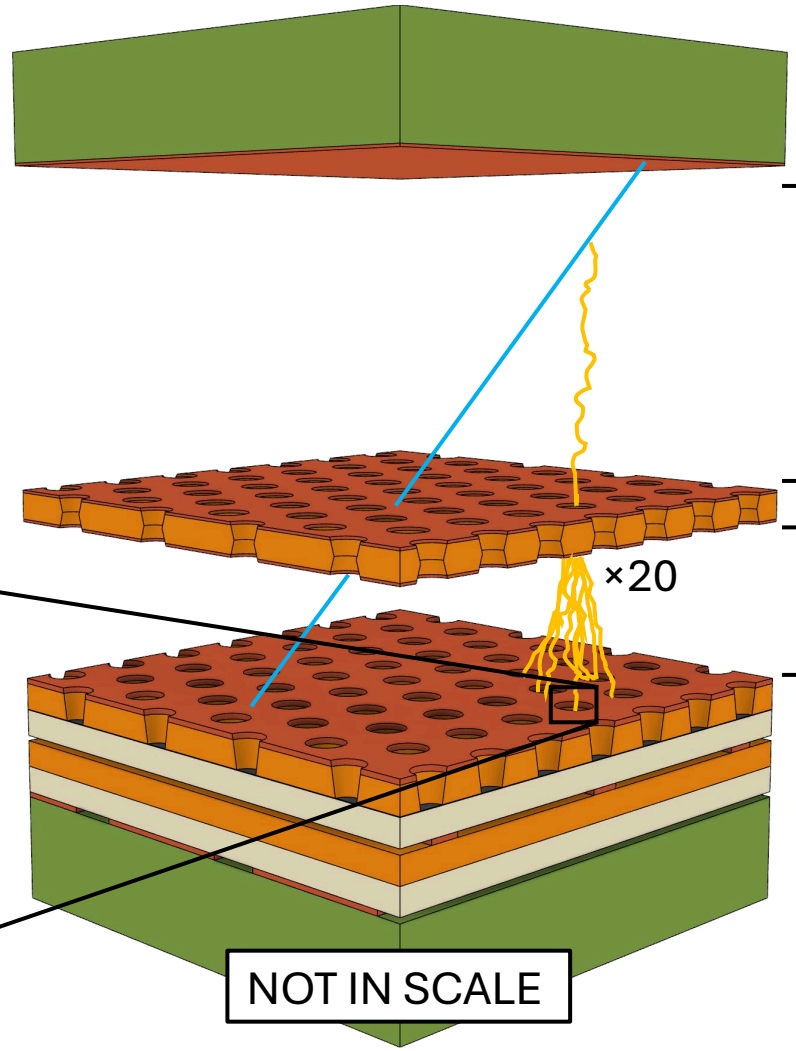
16 Modules total



G-RWELL Technology

ECT Performance Requirements	
Spatial resolution	≤ 150 μm
Time resolution	≤ 20 ns
Single layer efficiency	≥ 97%
Material budget (per layer)	≤ 1% X_0





CATHODE
~ 3 mm lightweight support
5 μm copper

DRIFT
6 mm

GEM
5 μm Copper
50 μm Kapton
5 μm Copper

TRANSFER
3 mm → 2 mm in the future?

μ-RWELL
10 μm copper
50 μm Kapton
~ 100 nm DLC

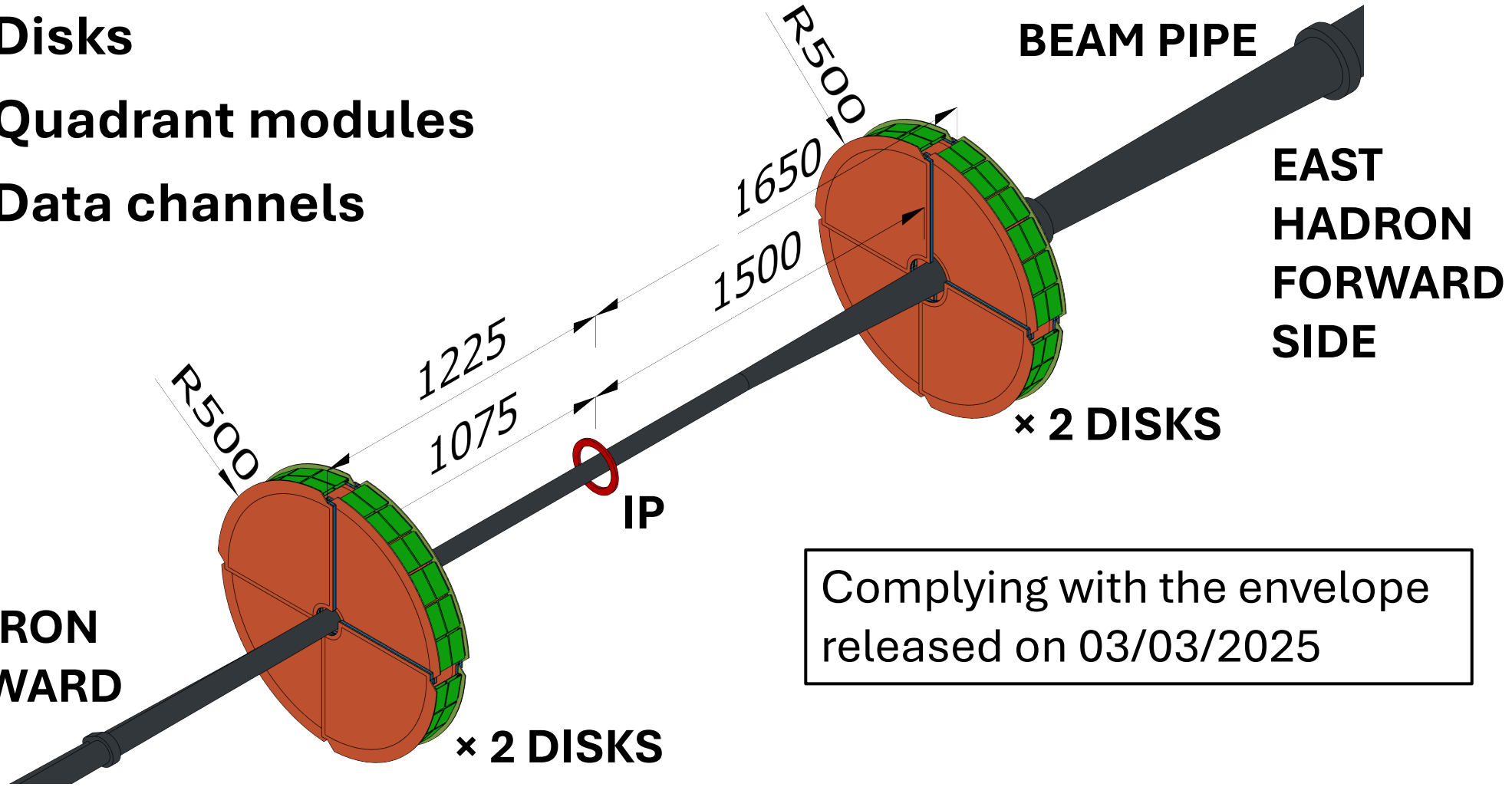
R/O
2D strip layout, 600 μm pitch
~ 3 mm lightweight support

ECT Overview

4 Disks

16 Quadrant modules

24576 Data channels



Complying with the envelope released on 03/03/2025

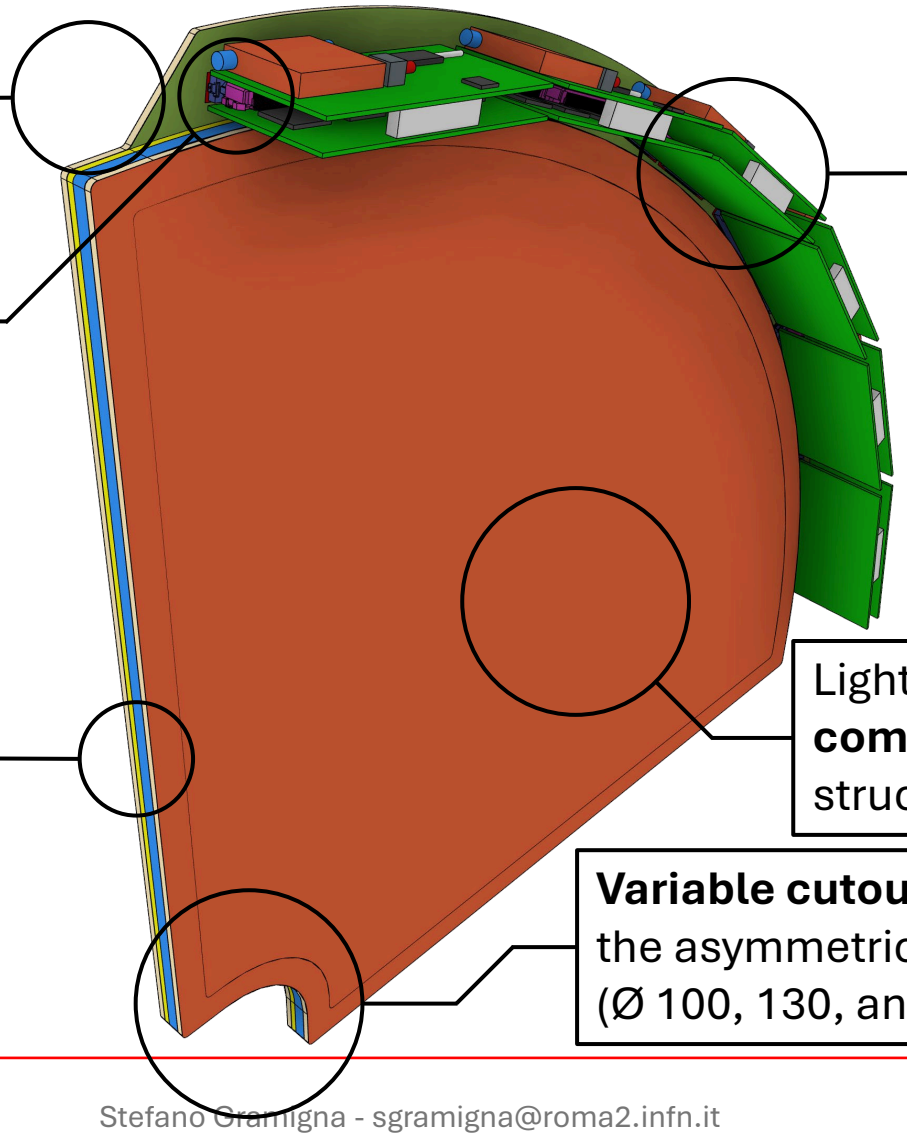
Quadrant Concept

Cutouts for services
At 0°, 90°, 180°, and 270°

4x **SALSA** ASICs per FEB

2x **Hirose FX20-140P** Connectors per FEB

Fiber-reinforced epoxy frames define the gas gap and reinforce the outer support panels



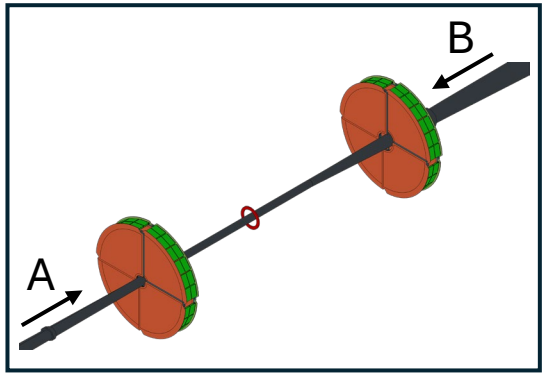
6 **FEBs** per quadrant located in the service rim

Lightweight **sandwich-structured composites** for anodes/cathodes' structural supports

Variable cutout to cope with the asymmetric beam pipe (Ø 100, 130, and 180)

Stefano Gramigna - sgramigna@roma2.infn.it

Arrangement of the Quadrants



3 quadrant designs overall:

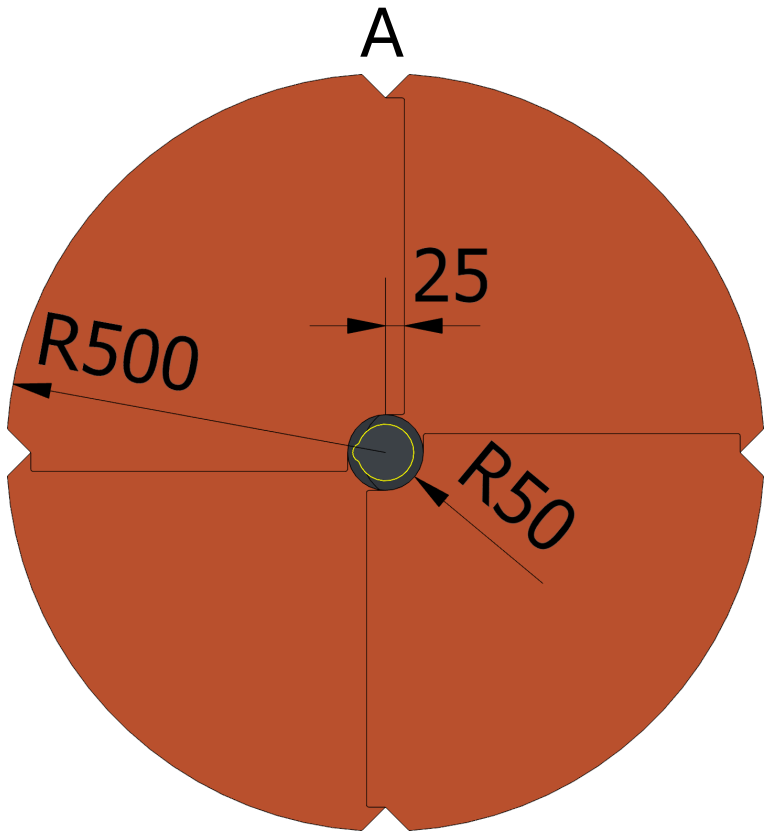
Electron side

1 design → 8 quadrants

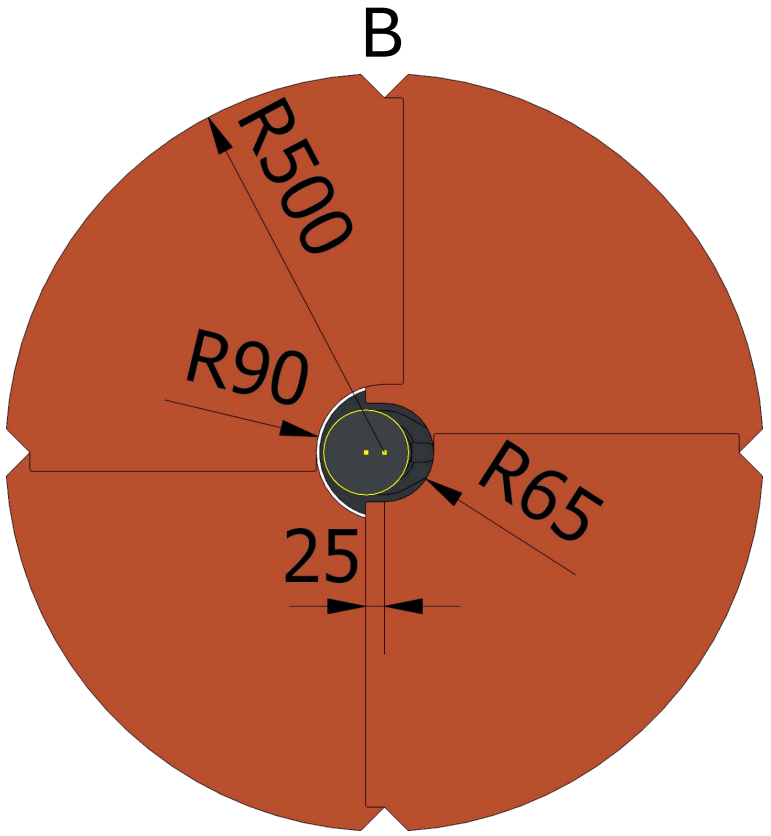
Hadron side

2 designs → 4 + 4 quadrants

Quadrants **overlap** to achieve total azimuthal coverage*



WEST/ELECTRON/BACKWARD SIDE

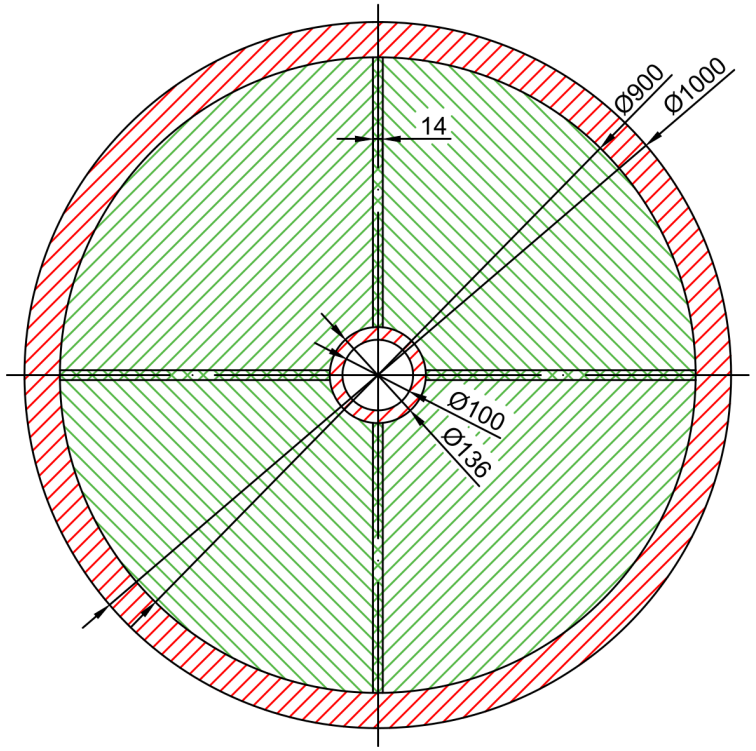


EAST/HADRON/FORWARD SIDE

*Further details and AA coverage in the backup

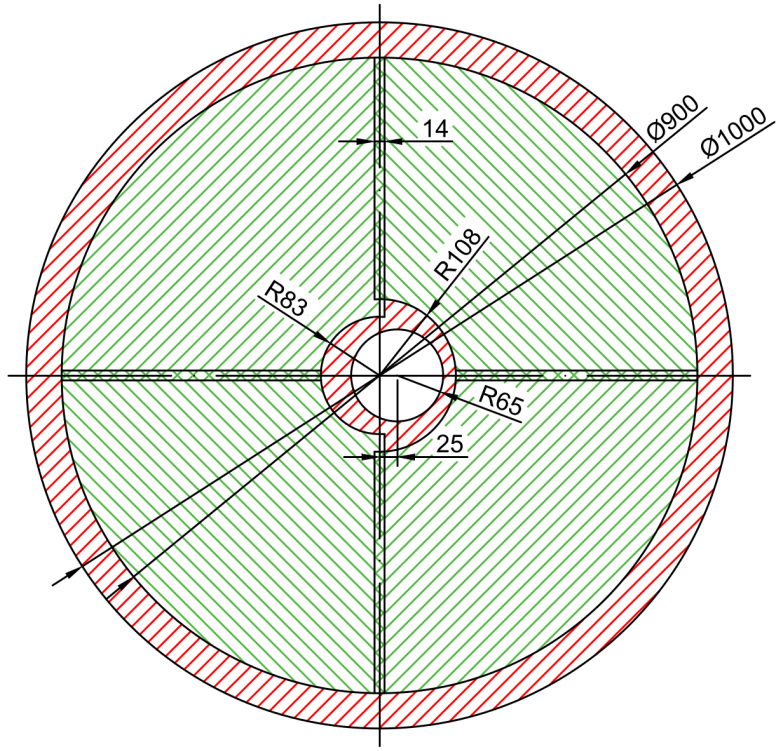
Active Area Coverage

WEST/ELECTRON/BACKWARD SIDE



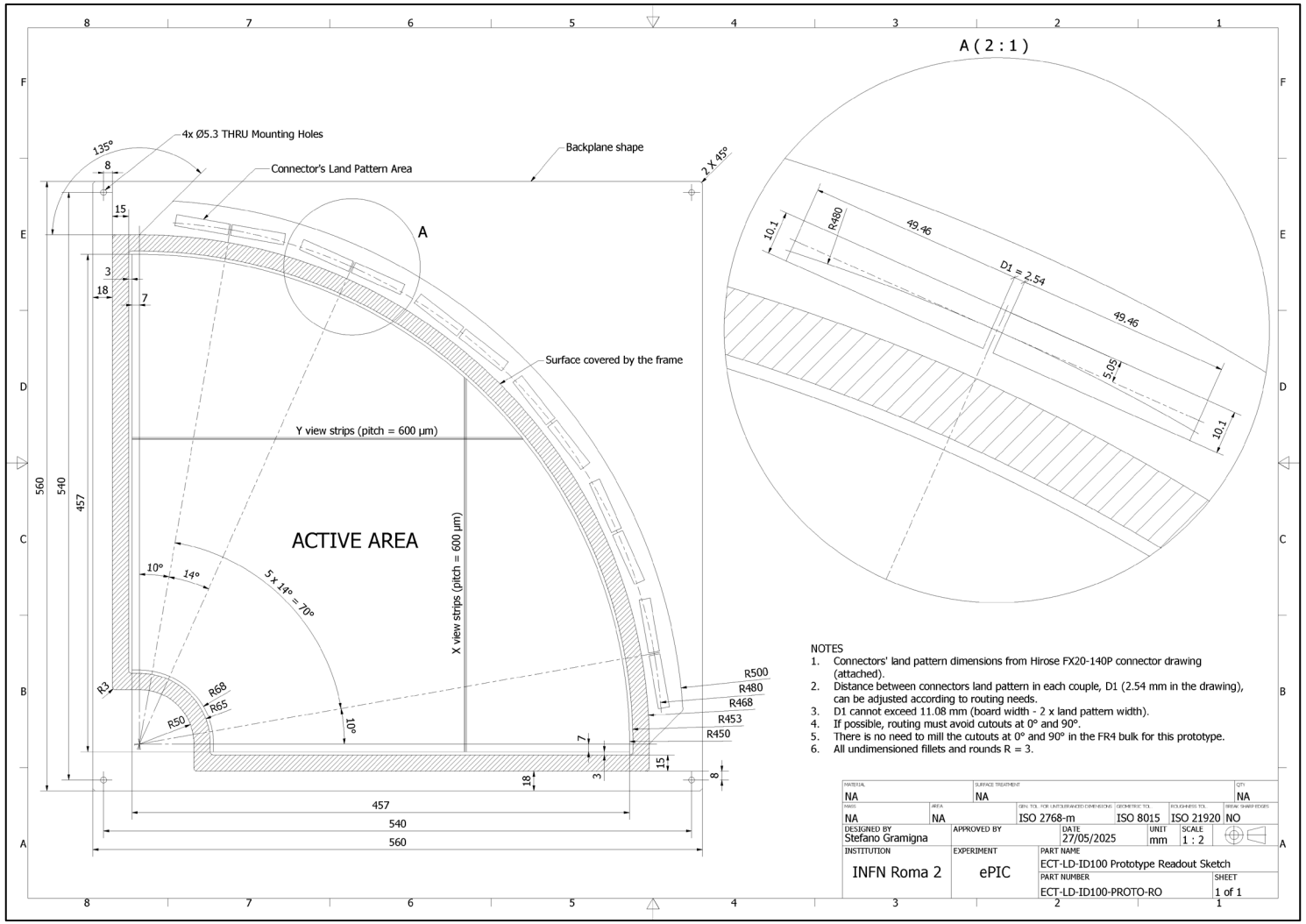
79,95% envelope coverage
-1,72 > η > -3,46

EAST/HADRON/FORWARD SIDE

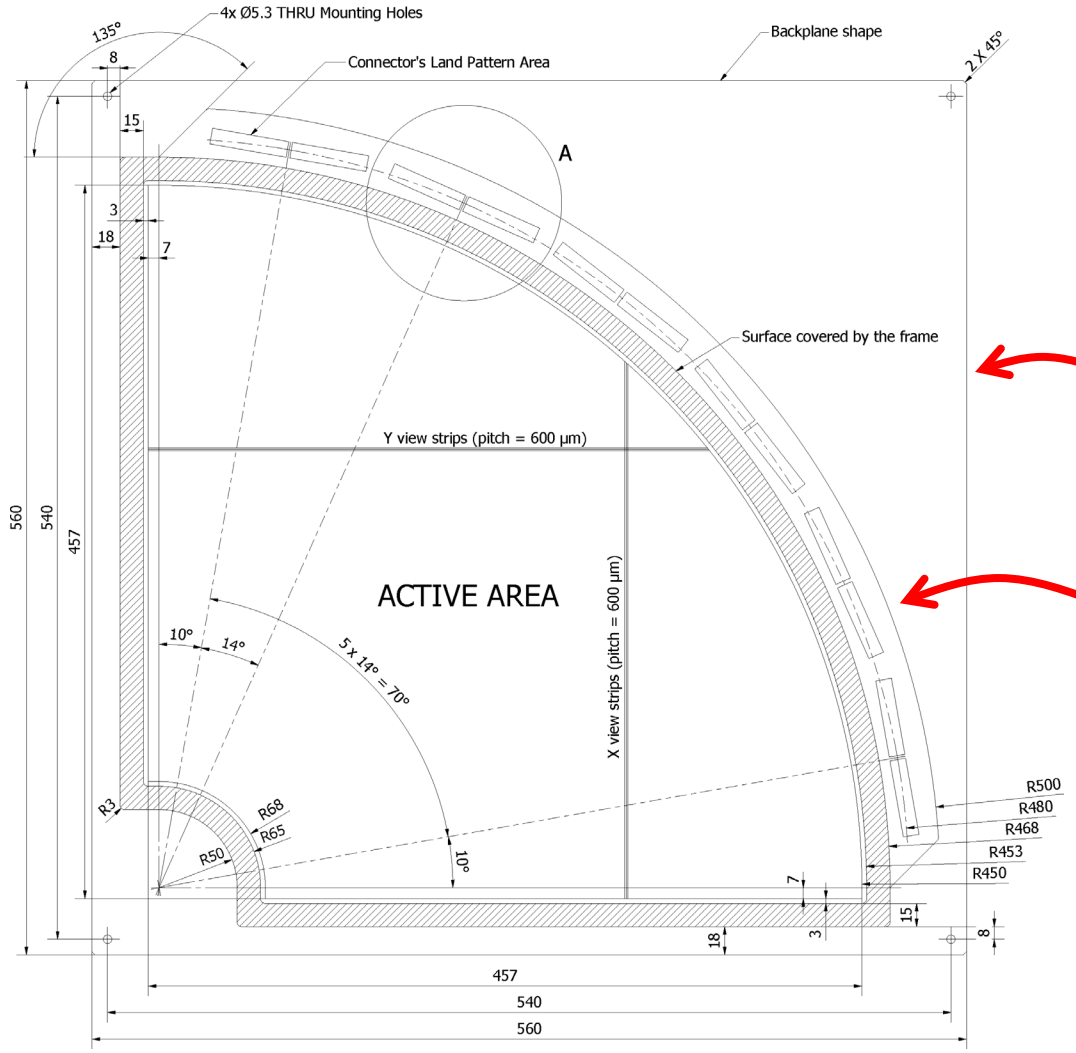


78,62% envelope coverage
2,01 < η < 3,59/3,33

Complete ETA R/O Sketch



R/O Sketch, Our Input for CERN



Defined ETA PCB shape and mounting interfaces

Convenient form factor for testing, routing/services still constrained by ECT final shape

Towards a Final Design

@ Quadrant level

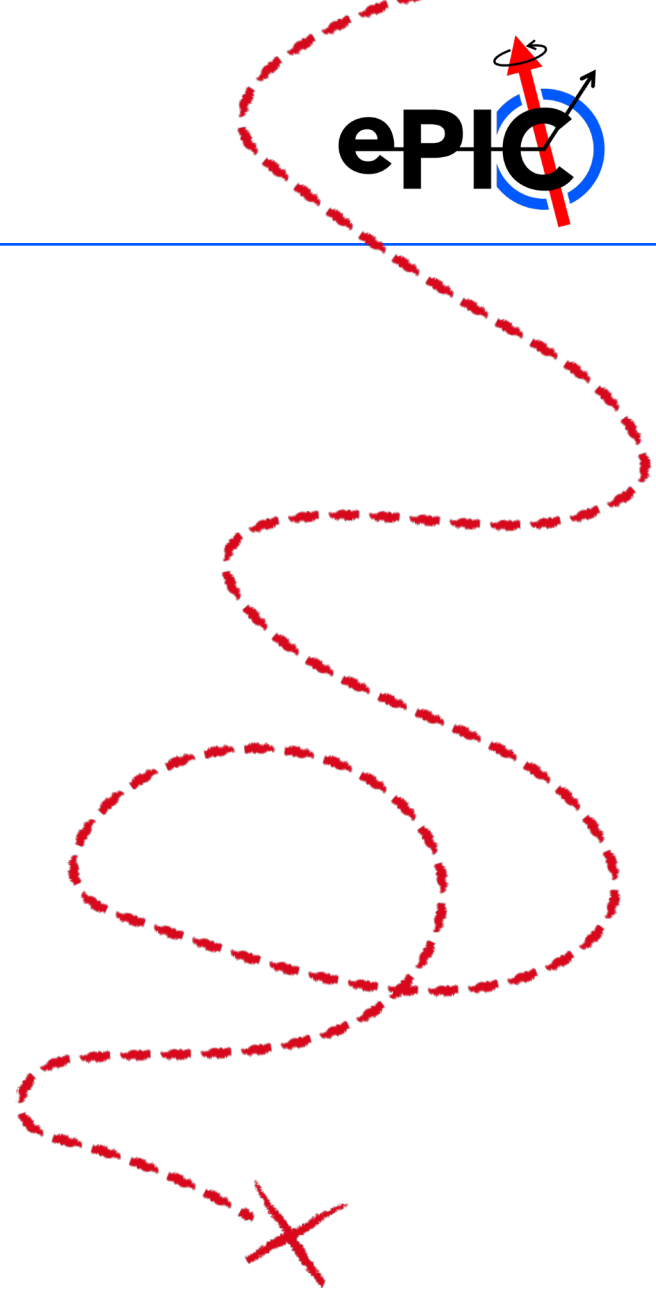
- Finalize frames/spacers design — Ongoing
- Implement gas inlets/outlets + distribution
- Define assembly procedure and jig interfaces
- HV connectors/filter integration
- Implement interconnection interfaces
- FEB integration → FEB supports

@ Disk level

- Interconnection/support structures — Coming next
- Thermal shielding for BP bakeout — Coming next
- Integration within PST
- Installation procedure → mechanical aids
- Mechanical alignment

@ System level

- Service routing
- Cable supports/cabling schematics



Ongoing and Future R&D Plans

Detector R&D

Engineering Test Article

Objectives:

- Validate **scalability of G-RWELL** technology
- Practice **operation** of a large area detector
- Advance towards **final AA and routing scheme**

Features:

- **Reliable** mechanics
  - FR4 supports for anodes and cathodes
  - Wider, sturdier frames if necessary
- **Recoverable** design:
  - O-ring and screw closure or hybrid solution
  - Glue reservoirs for eventual sealing
- **Semi-final routing** with Hirose connectors
- **Convenient** mounting points and form factor

Mechanics R&D

Mechanical mock-up(s)

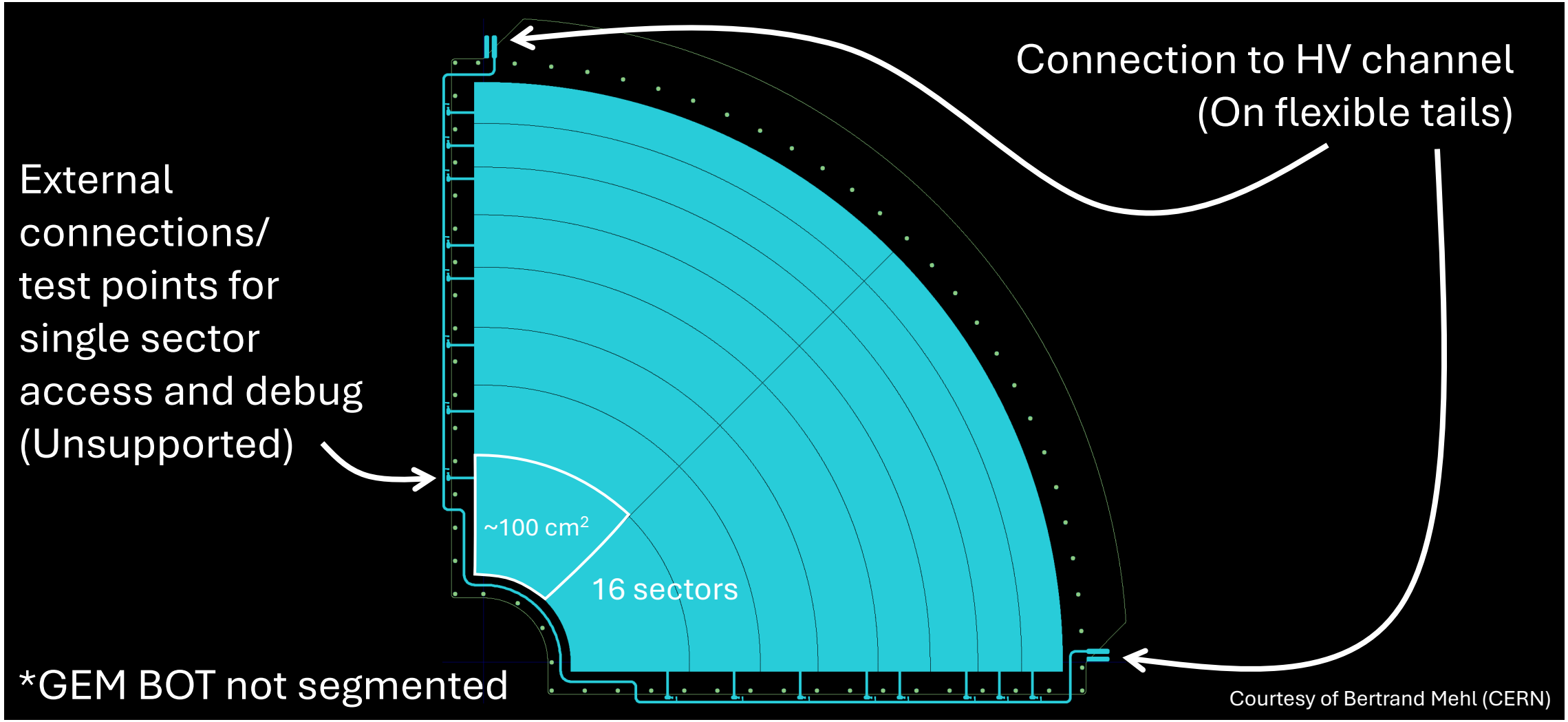
Objectives:

- Study **lightweight** mechanical solutions
  - Sandwich-structured composites
- Study **gas tightness** solutions
  - Full epoxy sealing or hybrid solutions
- Study **gas distribution** solutions*
- Study **Vibration resistance** and resonance studies*
- Practice **production techniques**
- Finalize **construction tooling**

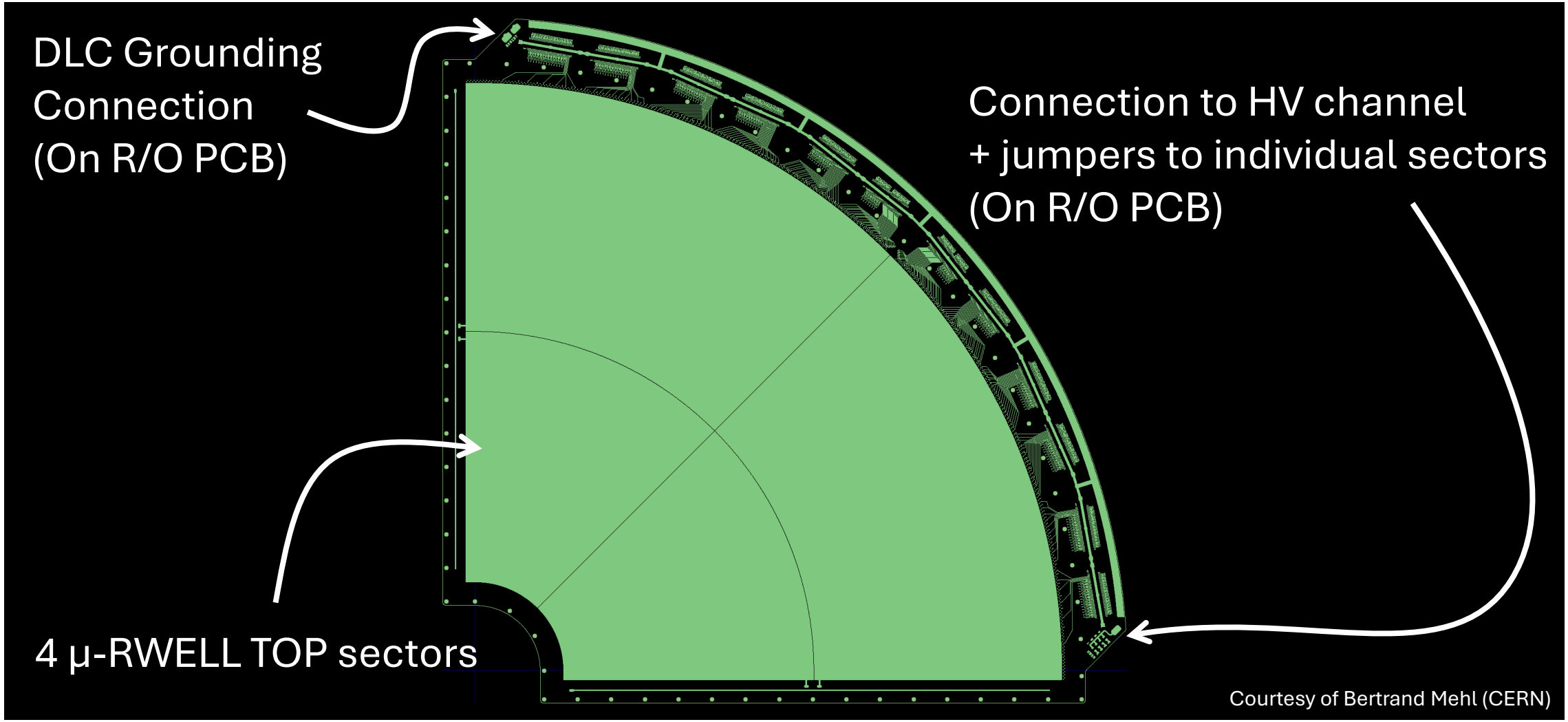
Mechanics R&D is now also being conducted on existing large area prototypes -Lumi upgrade

* unplanned but possible

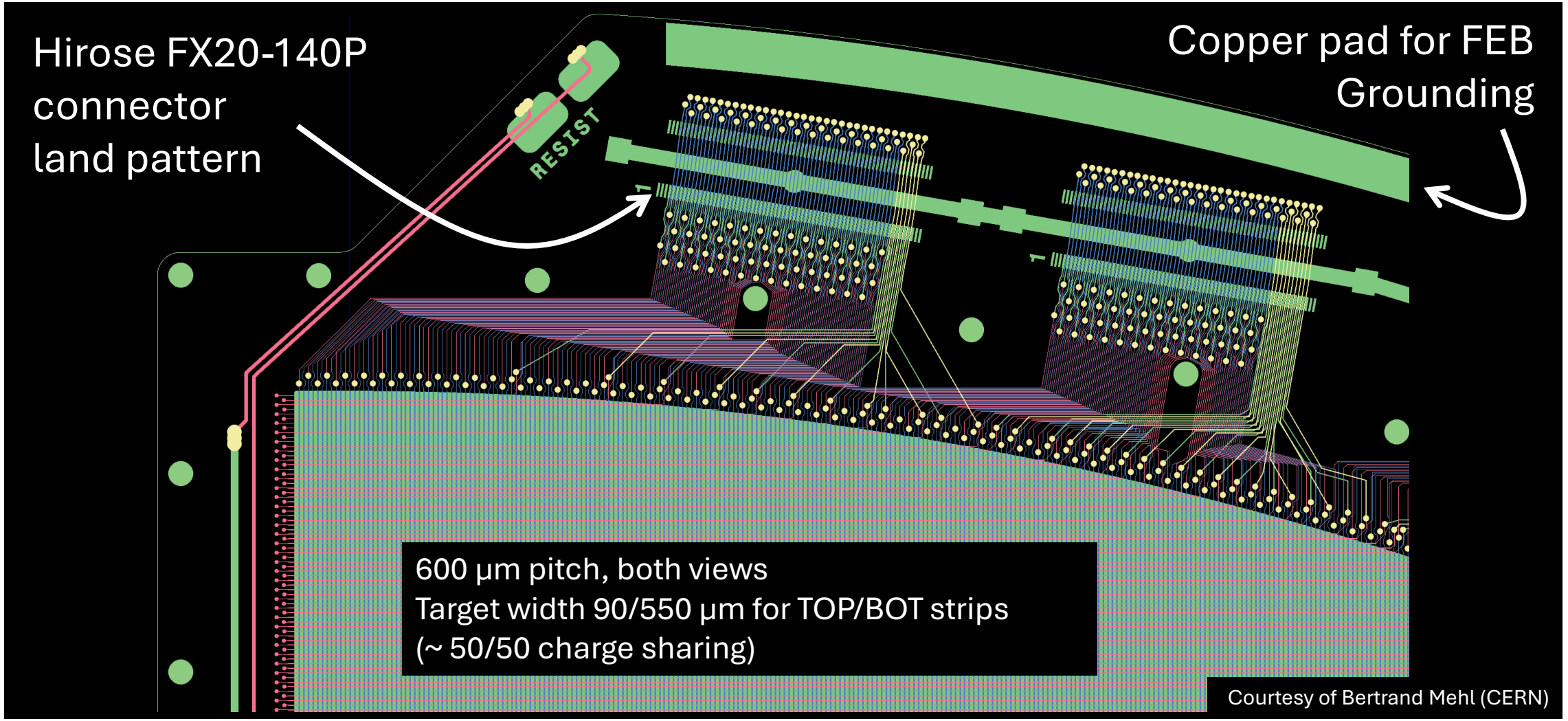
GEM Sectorization



μ-RWELL Sectorization



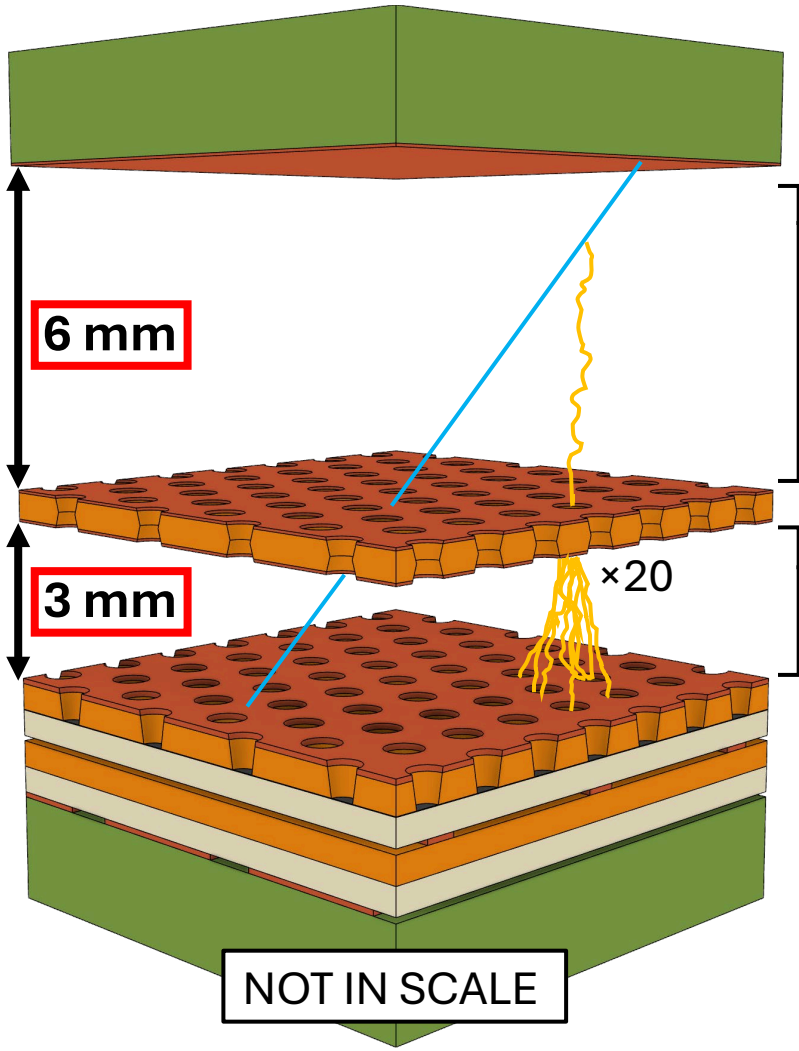
Strip Routing Detail



GEM Deflection in Large Area Detectors

TARGET: Drift and Transfer Gap within **10%** of nominal dimensions

- The GEM is glued to the frames
- Tension is applied to the foil before gluing to counteract deflection
- Spacer grids can be introduced to support the foil
- The spacers should not touch the μ-RWELL



CATHODE
~ 3 mm lightweight support
5 μm copper

DRIFT
6 mm

GEM
5 μm Copper
50 μm Kapton
5 μm Copper

TRANSFER
3 mm → 2 mm in the future?

μ-RWELL
10 μm copper
50 μm Kapton
~ 100 nm DLC

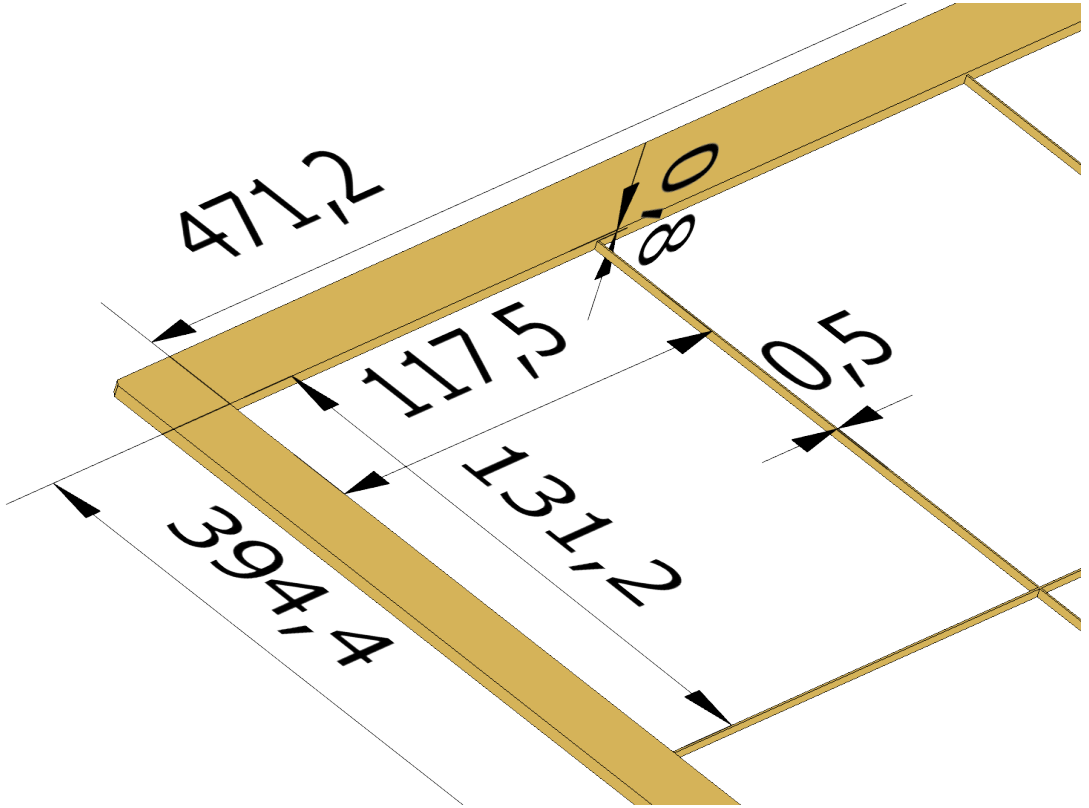
R/O
2D strip layout, 600 μm pitch
~ 3 mm lightweight support

Spacer Grid Materials and Dimensioning

All mechanical studies are now being conducted on the existing ~400x460 AA prototypes (ECT AA = 457x457)

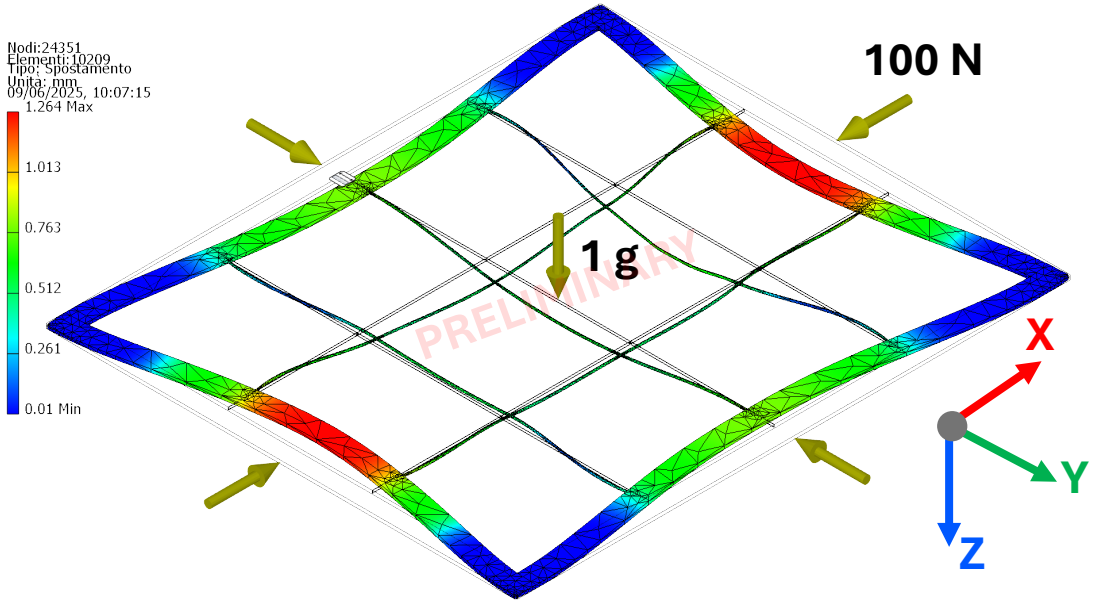
PEEK was the initial candidate for frame production, now **switched to Permaglas ME730** (Durostone EPM 203)

The new material **requires PU coating** to avoid particle dispersion (Nuvovern LW)

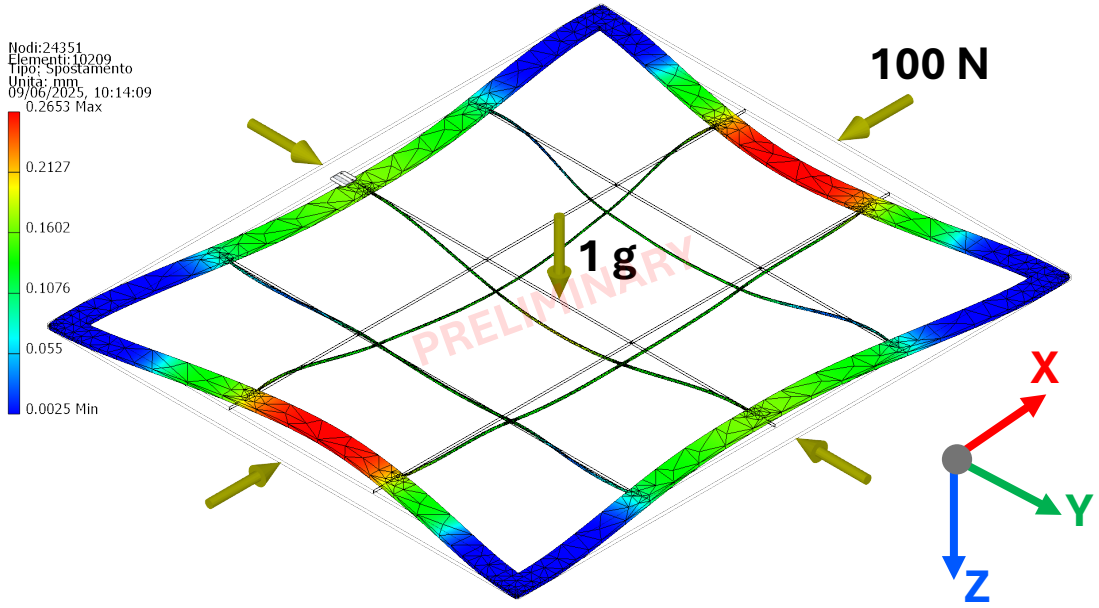


FEA Results

PEEK



PERMAGLAS



	PEEK	PERMAGLAS
ΔX max	1,242	0,2614
ΔY max	0,9426	0,1981
ΔZ max	0,6683	0,2121

Frames with and without spacers already in production @ CERN

The gluing tests will inform the design of the ECT's frames and spacers

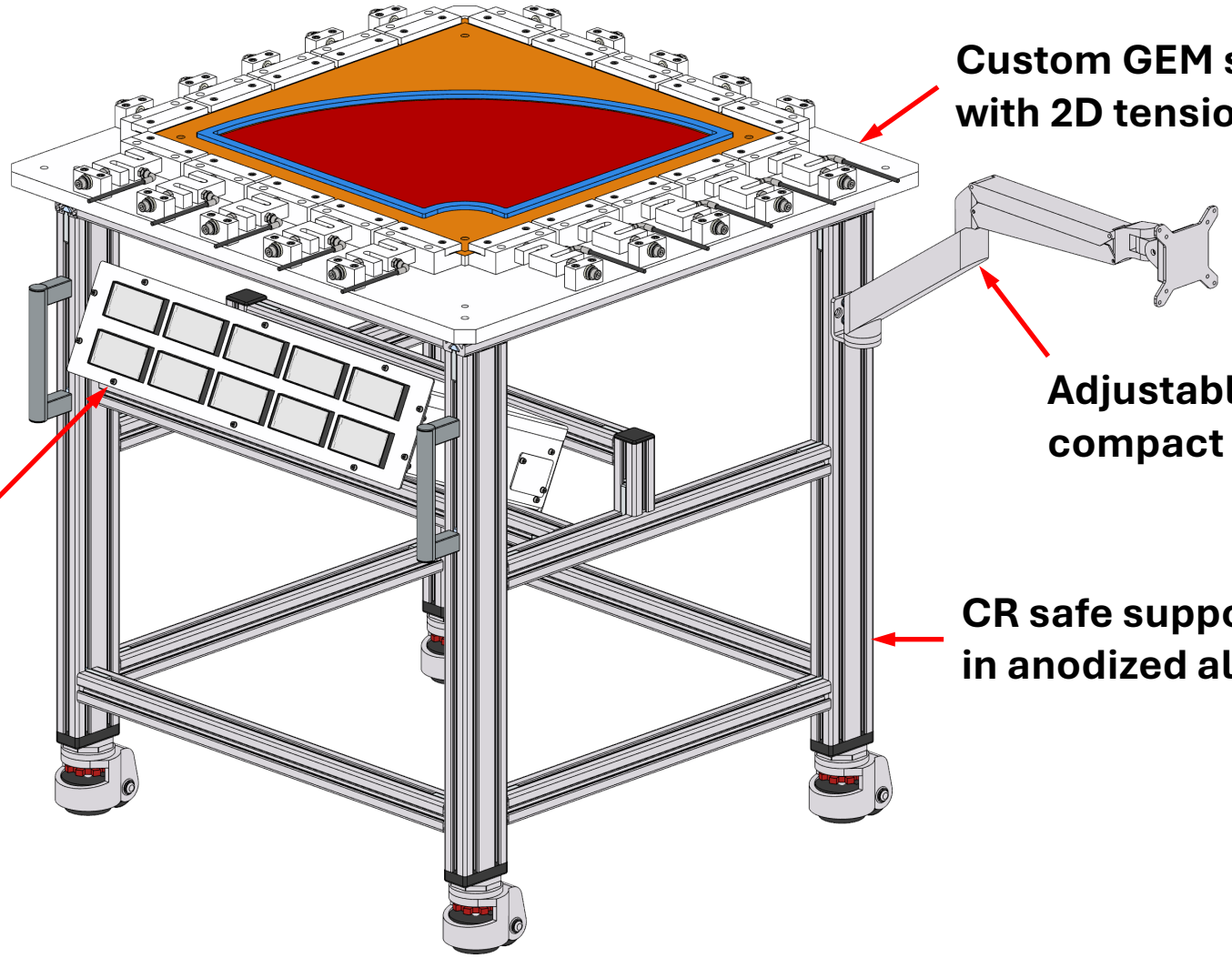
Summary of Tested Configurations (PEEK)

Variant	dz	dt	Rods in X	Rods in Y	Mesh size	Max deformation
Baseline	0.2	0.5	3	2	117.43 x 131.13	0.48
Baseline	0.5	0.5	3	2	117.43 x 131.13	0.60
Baseline	1.0	0.5	3	2	117.43 x 131.13	0.93
Thick rods	0.5	1.0	4	3	117.05 x 130.80	0.57
Thin rods	0.5	0.3	4	3	117.58 x 131.25	0.61
Fine mesh	0.2	0.5	4	3	93.84 x 98.20	0.49
Fine mesh	0.5	0.5	4	3	93.84 x 98.20	0.61
Fine mesh	1.0	0.5	4	3	93.84 x 98.20	0.95
Slab	0.2	NA	NA	NA	NA	0.25

The grid either touches the PCB or it is ineffective in containing GEM displacement

GEM Stretching and Gluing Station Pt. 1

Dimensions:
850x850x920



Custom GEM stretching + gluing table with 2D tension measurement

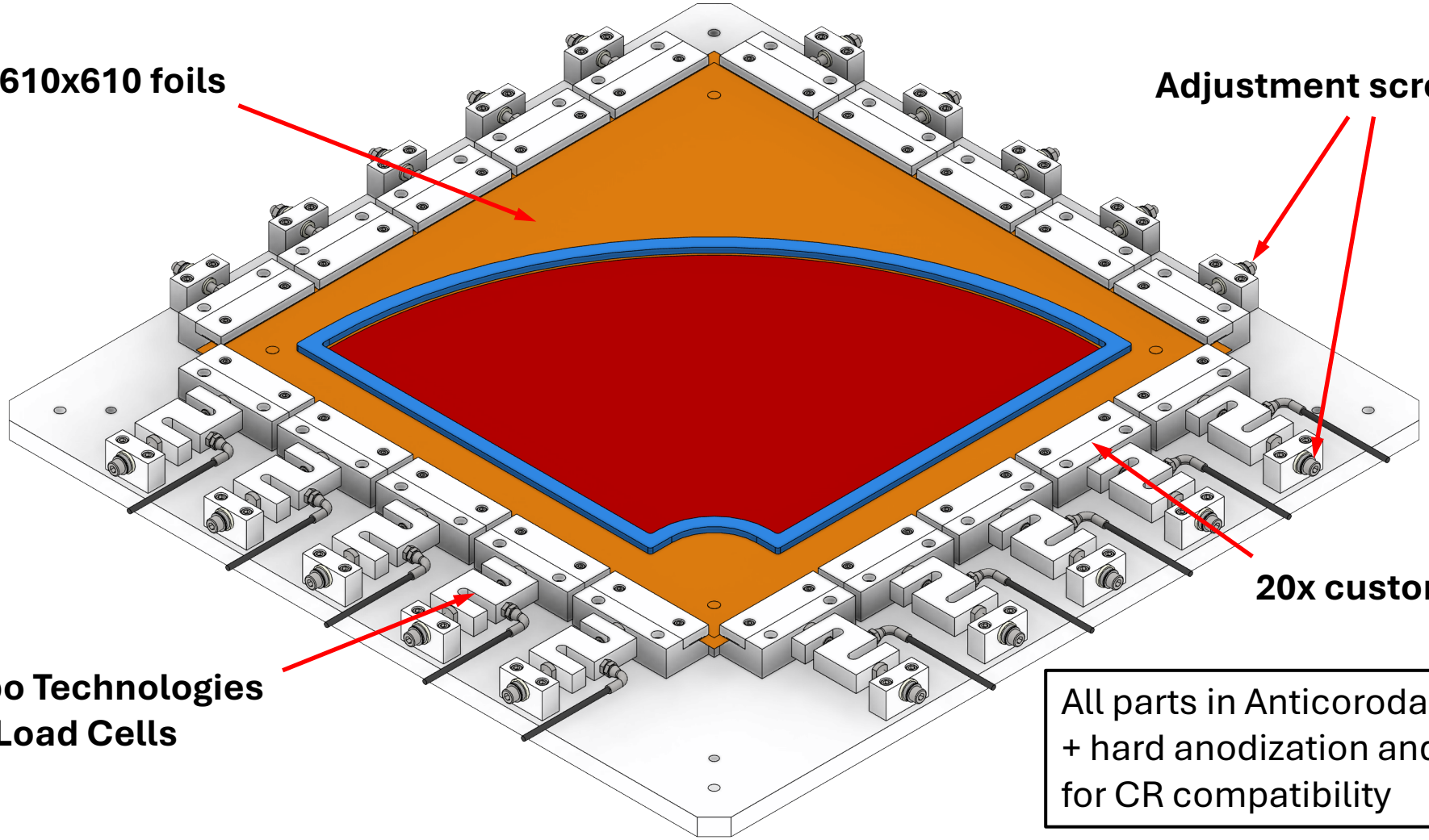
Adjustable monitor arm for compact operator interface

Custom module for load cell R/O

CR safe support structure in anodized aluminum

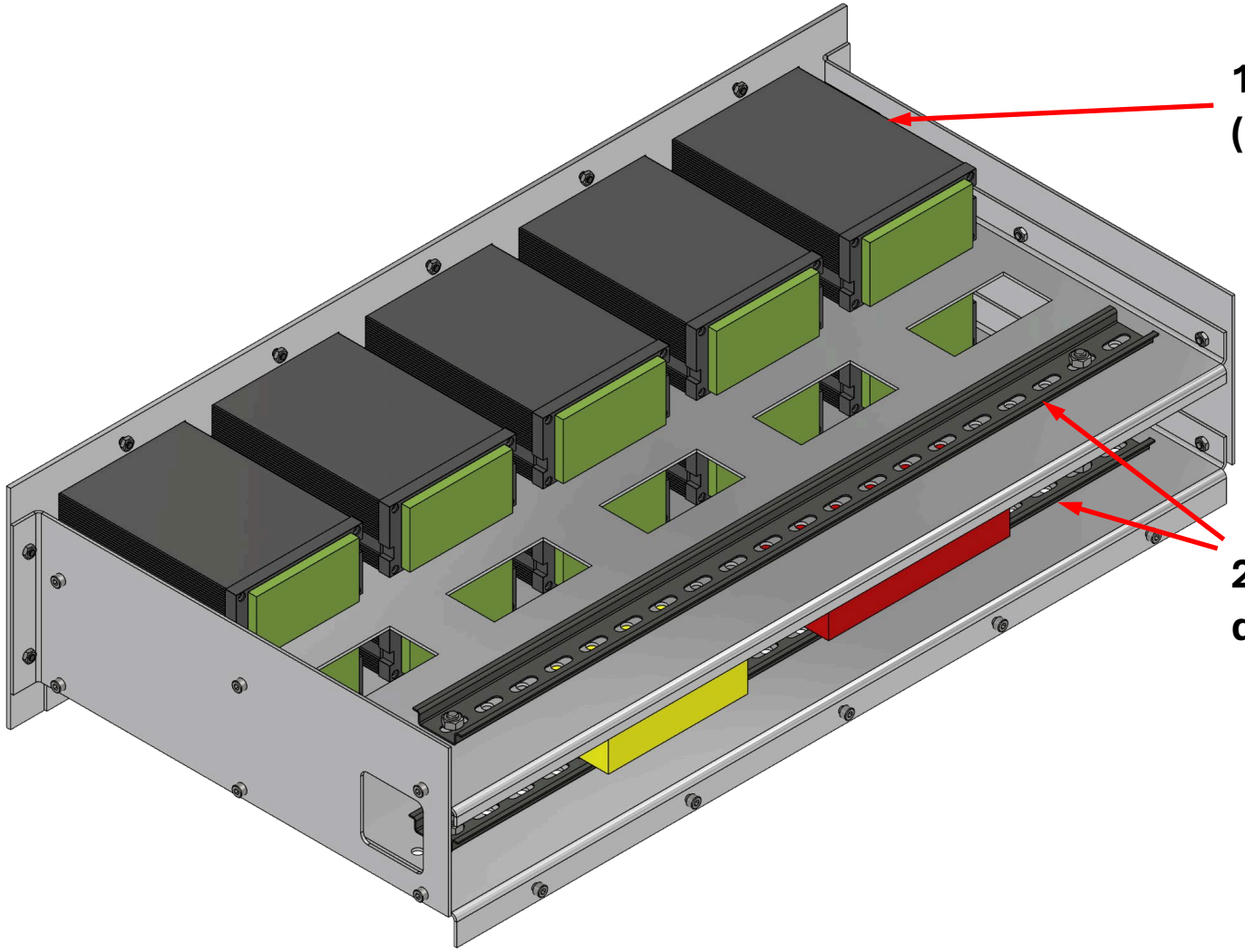
Stefano Gramigna - sgramigna@roma2.infn.it

GEM Stretching and Gluing Station Pt. 2



All parts in Anticorodal 6082
+ hard anodization and sealing
for CR compatibility

GEM Stretching and Gluing Station Pt. 3

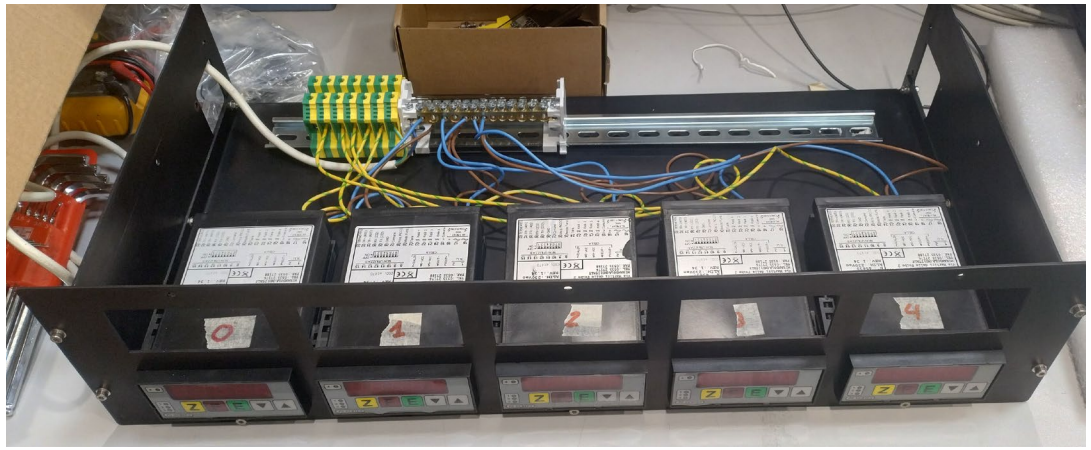


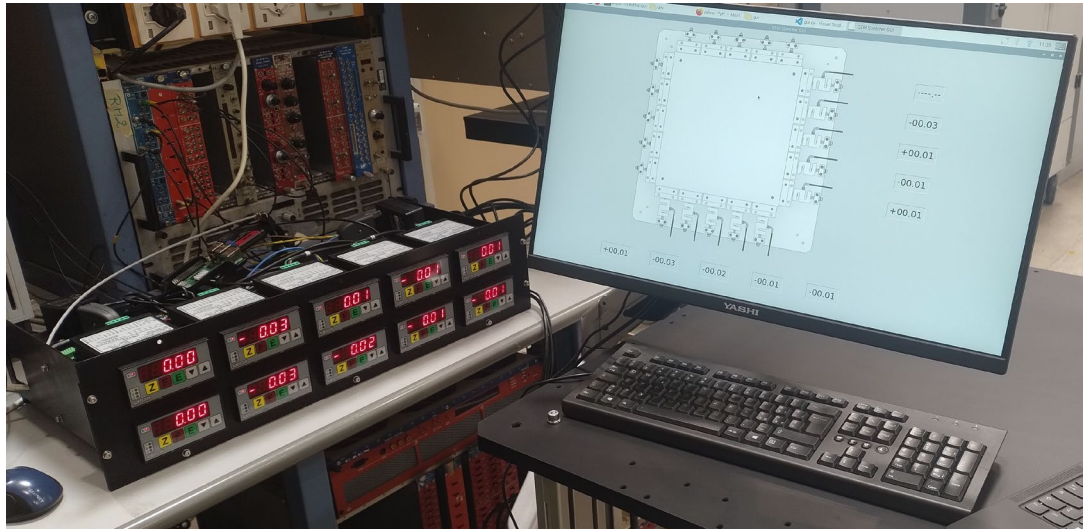
10x Picotronik PS30 digital indicators (load cell R/O and serial communication)

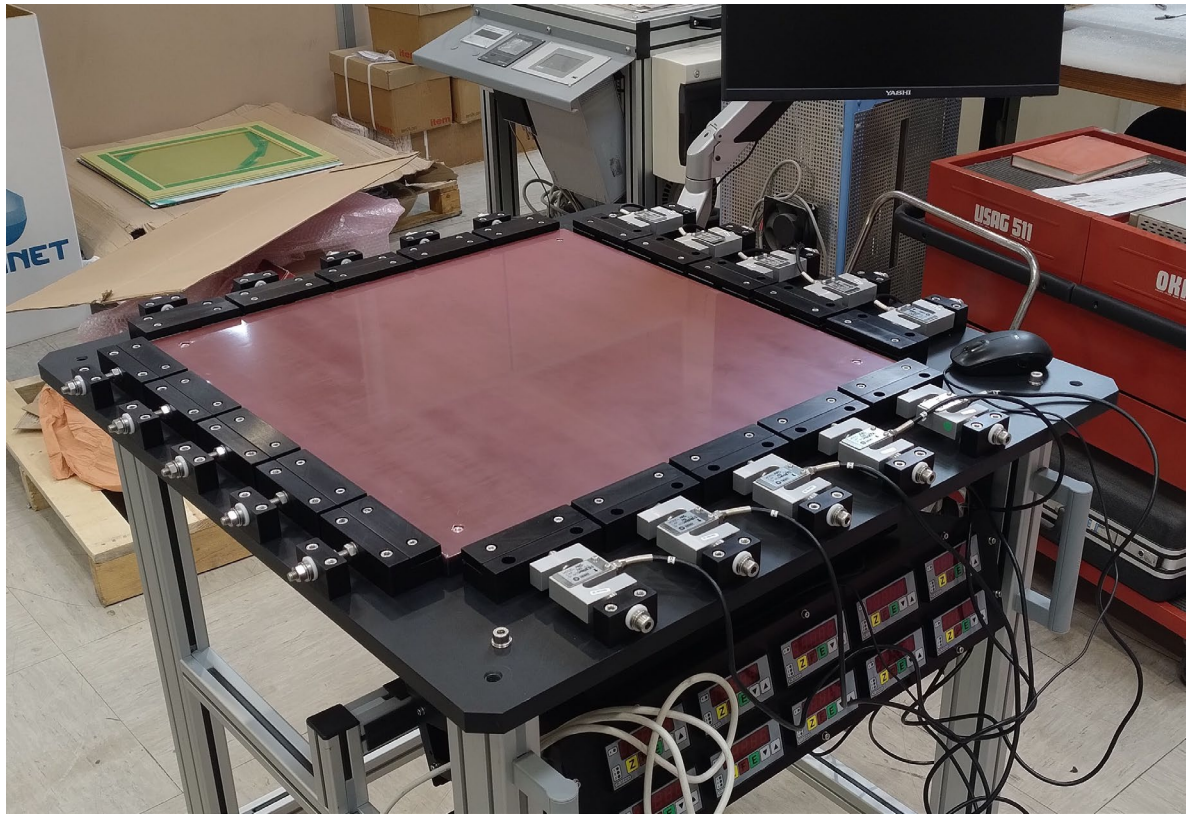
2x DIN rails for Power and GND distribution + room for feature expansion

All box parts in Peraluman 5083 + hard anodization and sealing for CR compatibility

GEM Stretcher Assembly

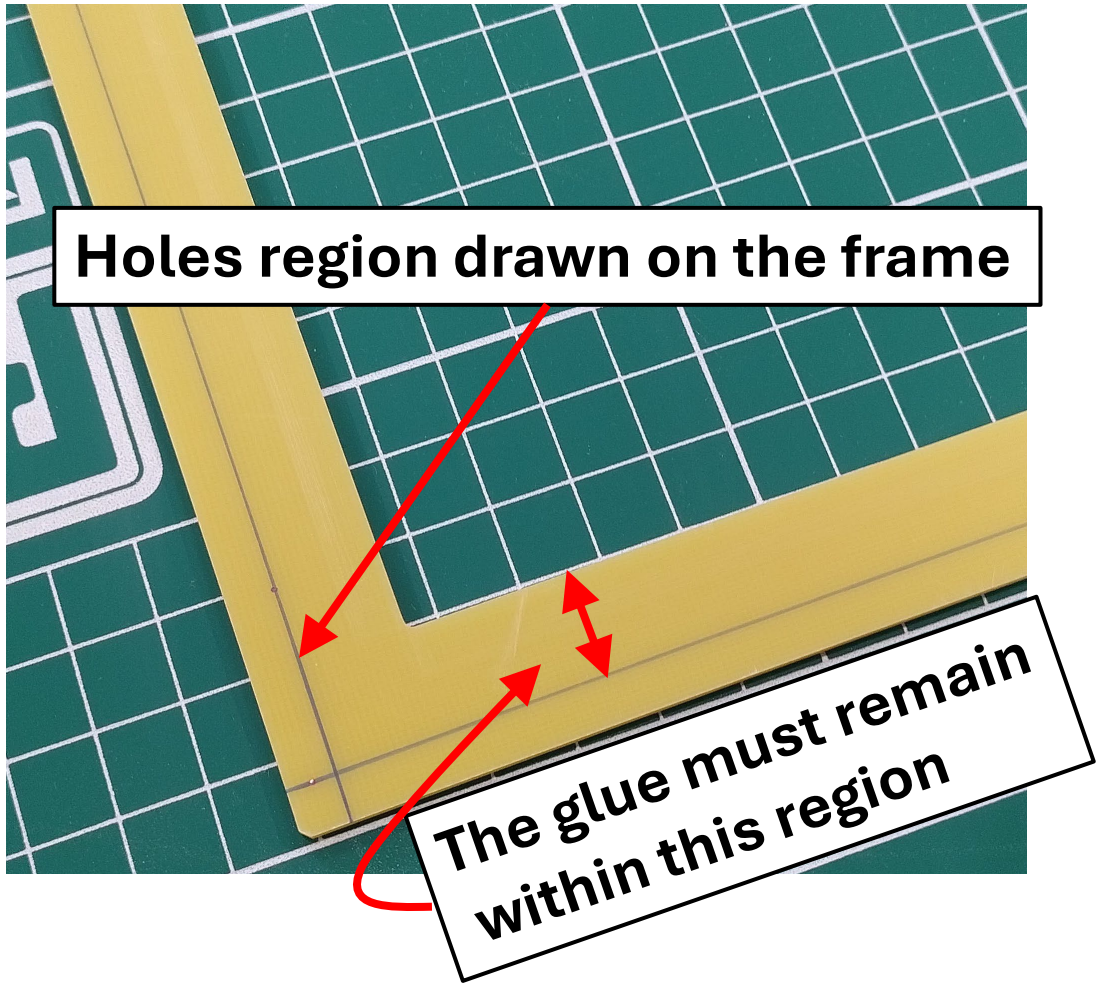






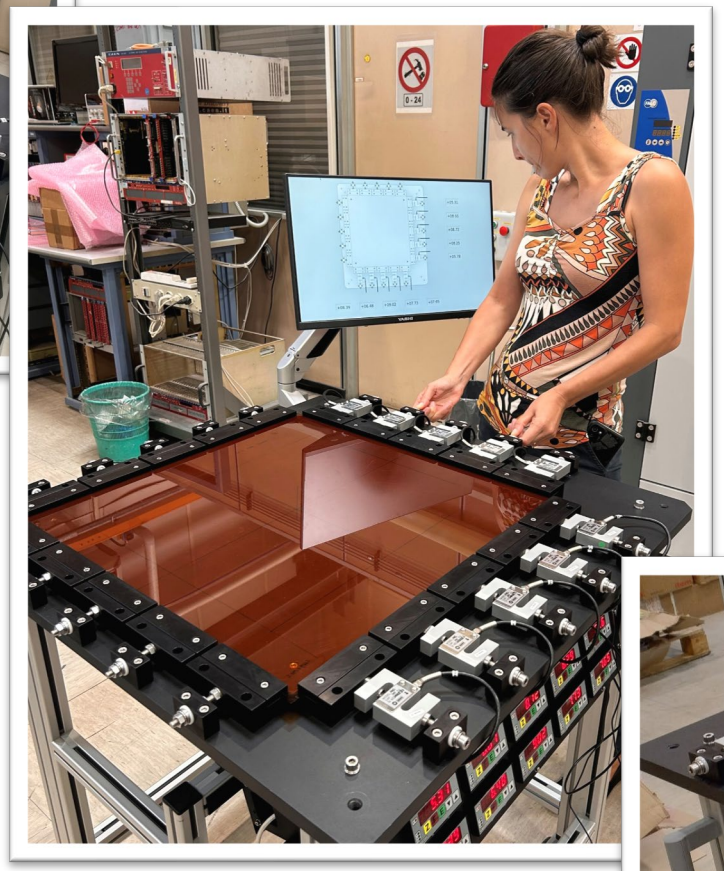
AMCO
ATTREZZATURE MECCANICHE E AUTOMAZIONE

Sample preparation



Stretching

BEFORE

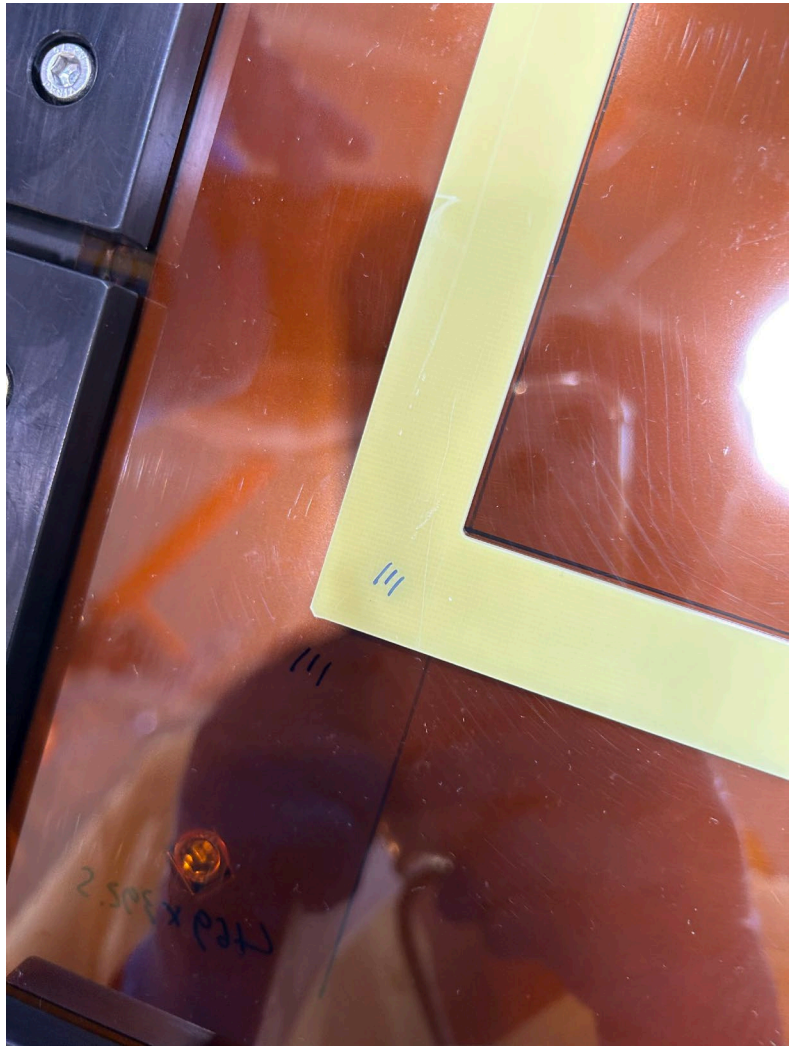


12 kg initial tension to have
10 kg after curing

AFTER

Stefano Gramigna - sgramigna@roma2.infn.it

Dry Test

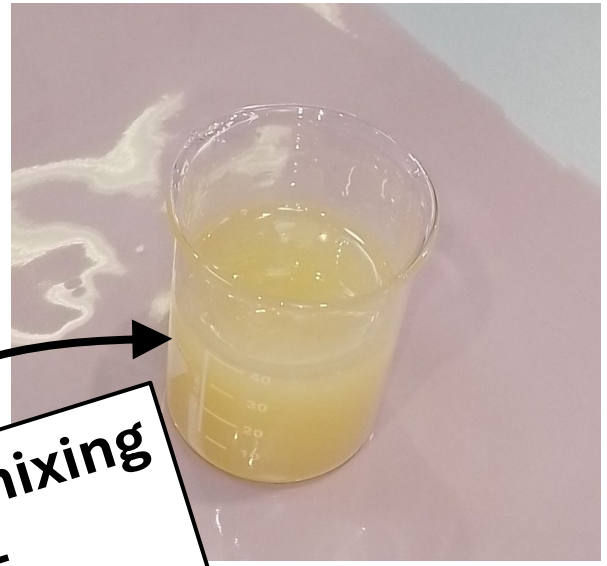


- Place frame onto foil
- Center the active area
- Tape in place

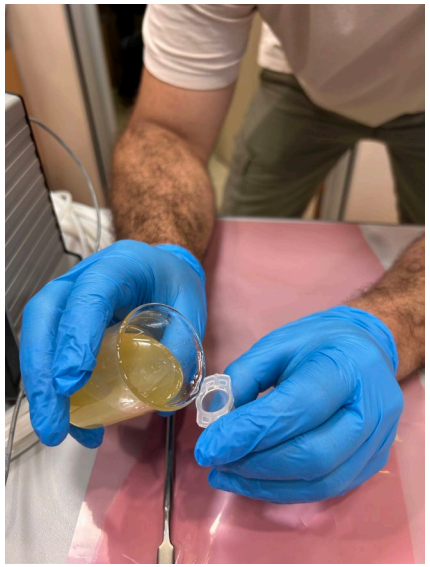
- Mark corners and edges
- Place reference silicone pads

Stefano Gramigna - sgramigna@roma2.infn.it

Glue Preparation



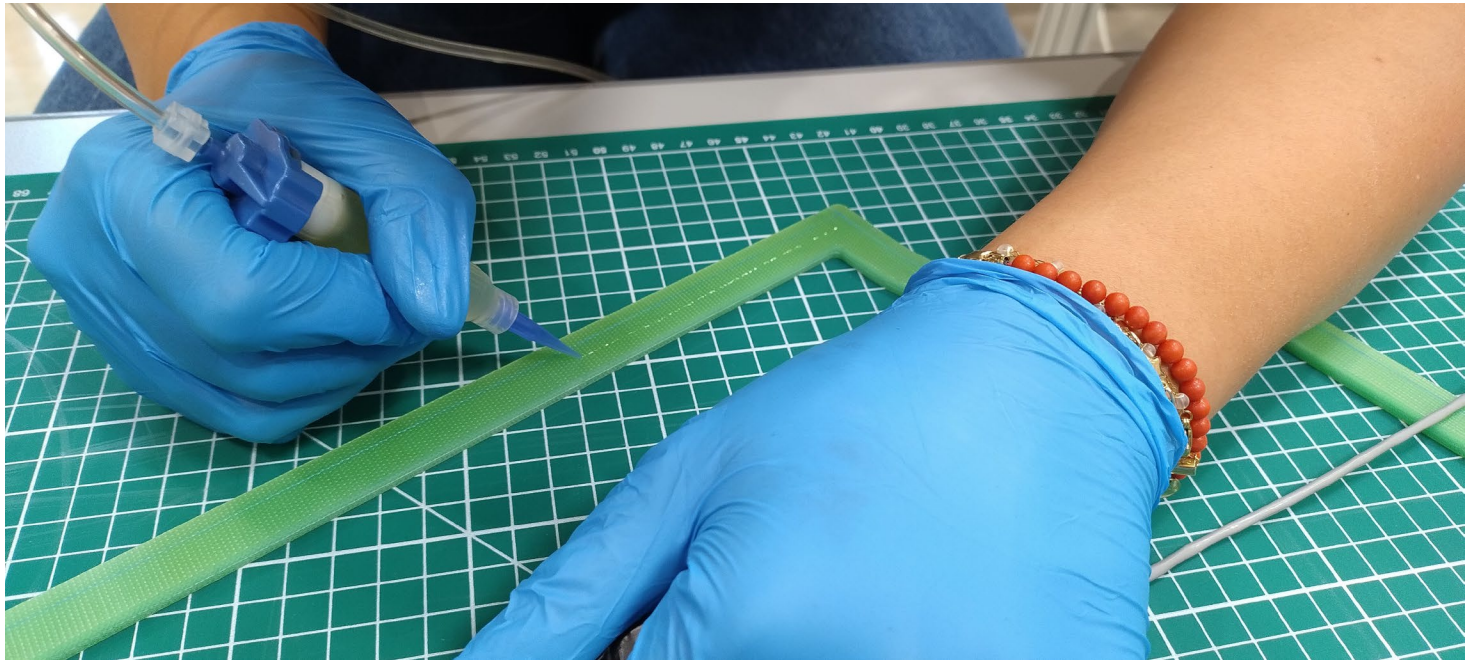
After mixing
+
20’ rest



Araldite AY 103-1 + Hardener HY 991 - 100:40 (mass ratio)

1. Slowly mix with a spatula
2. Rest for 20’
3. Break bubbles with spatula
4. Pour into the syringe

Glue Deposition, Line Method

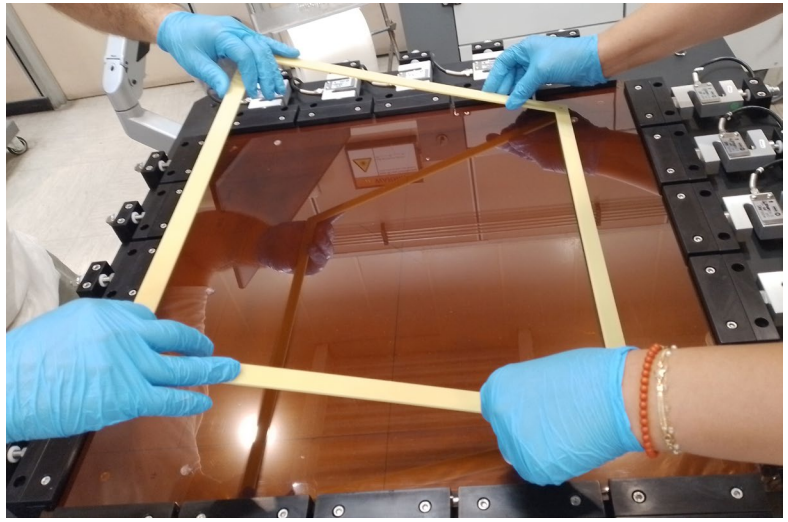


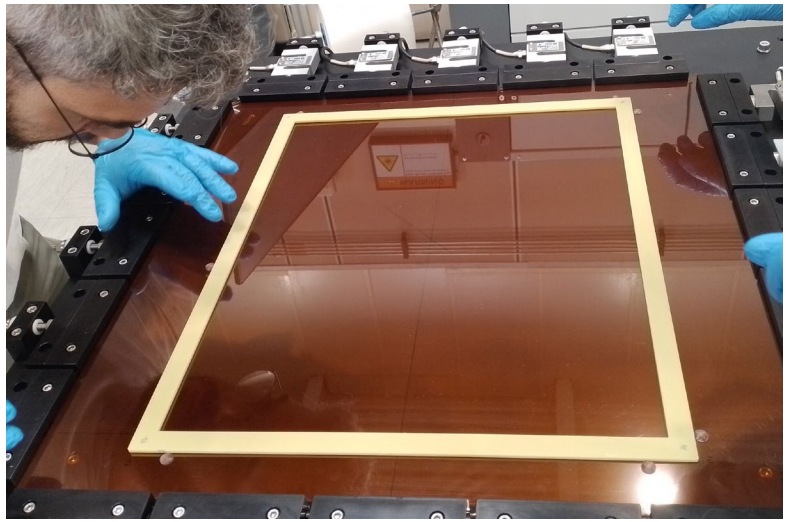
The glue is deposited in a thin line in the middle of the allowed region

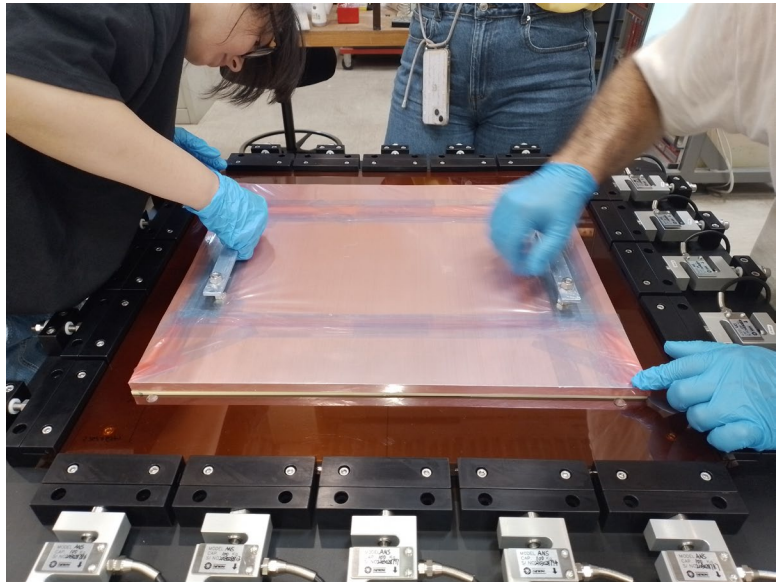
Needle gauges from 14 (1.6 mm) to 25 (0.254 mm) tested

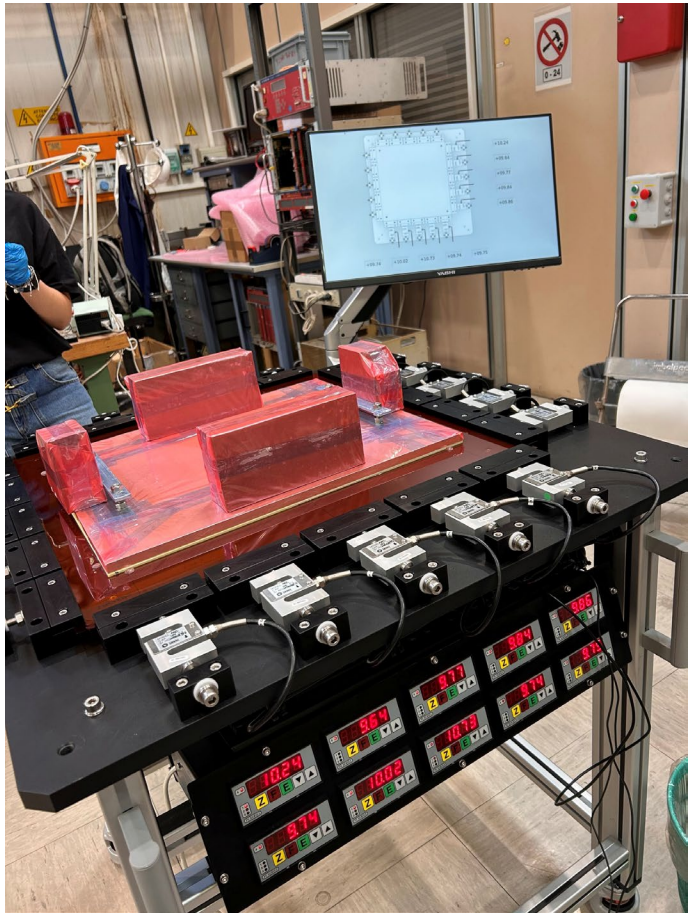
Various pressures and dispensing times tested

Frame Placement

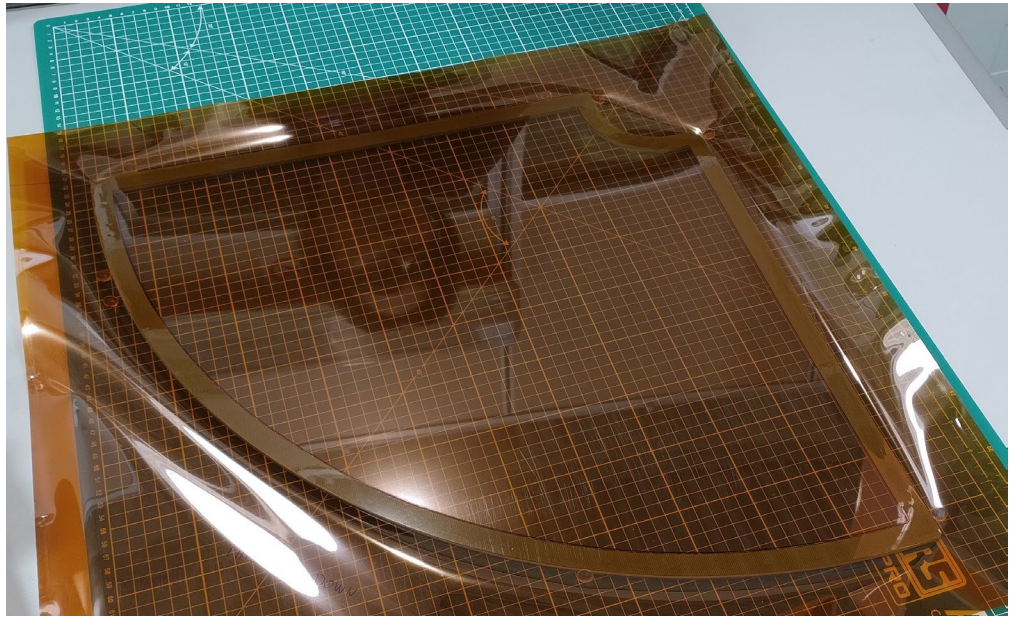


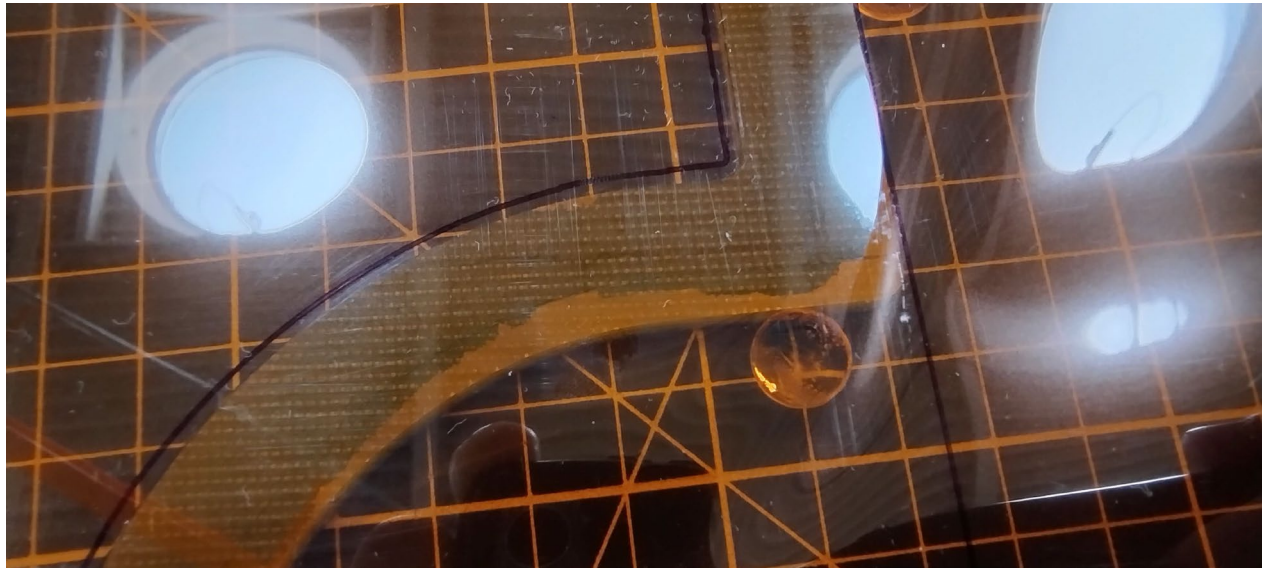


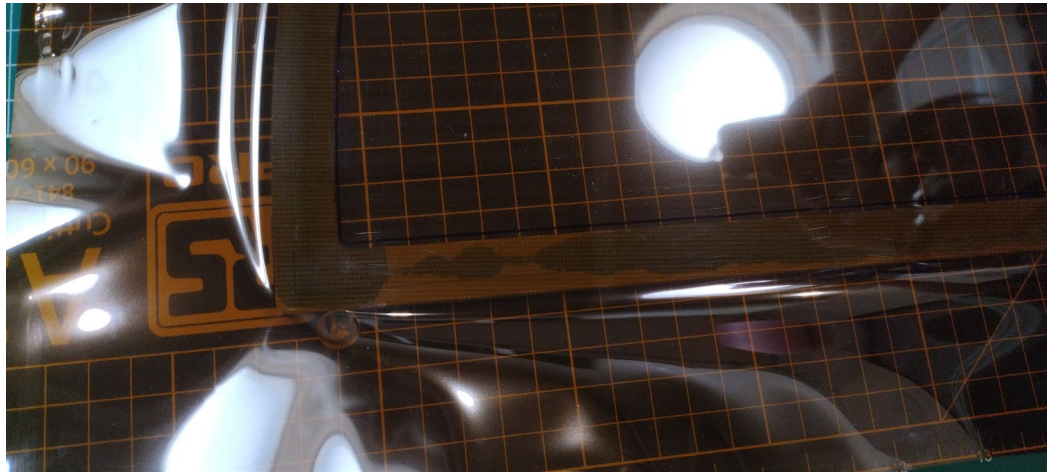




Test Results





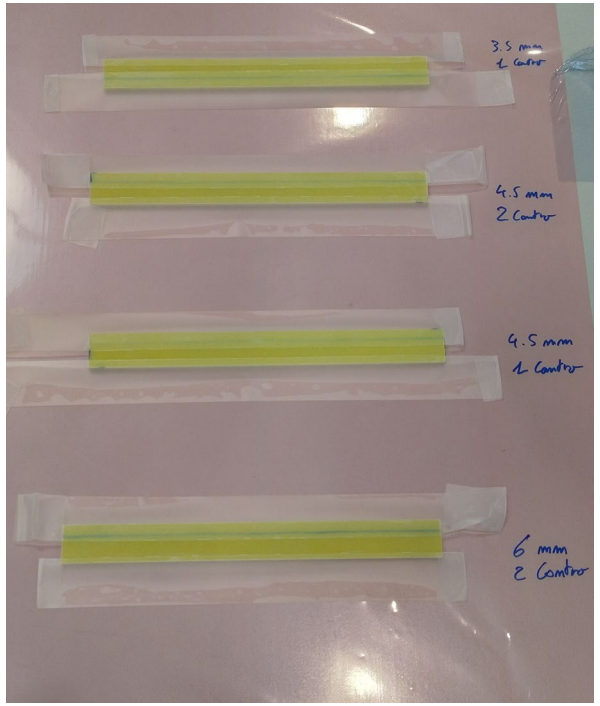


Stretching results are **satisfactory**

Tension is retained within the frame for both geometries, frame deformation within acceptable range

Glue deposition unsatisfactory on all samples, excessive overflow may require a change of technique

Glue Deposition, Transfer Method

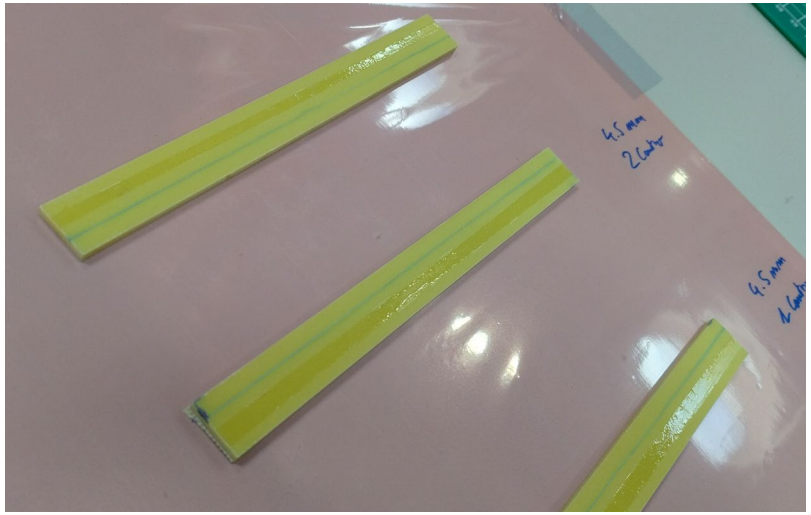


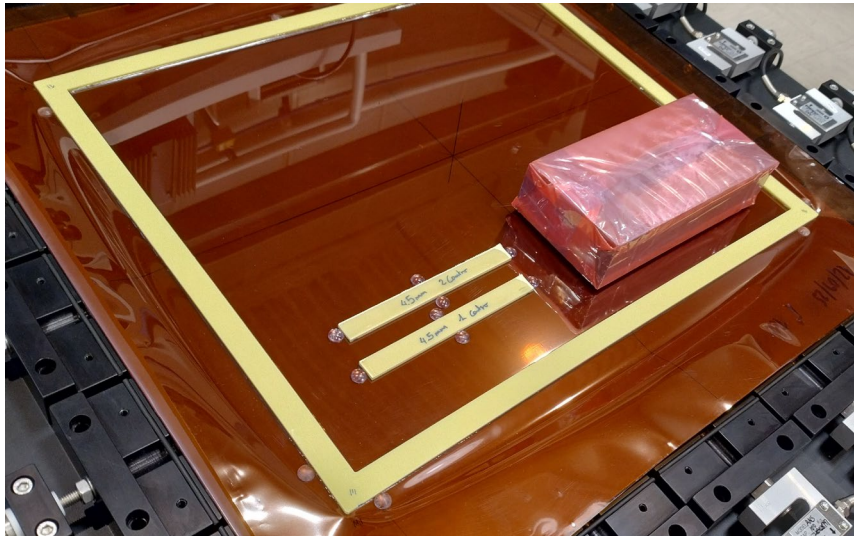
Glue Transfer Technique

Glue is spread on the working surface with a roller and then transferred onto the samples using Nylon film strips

Glue is removed one or more times (also using Nylon strips) to reduce the thickness of the glue layer

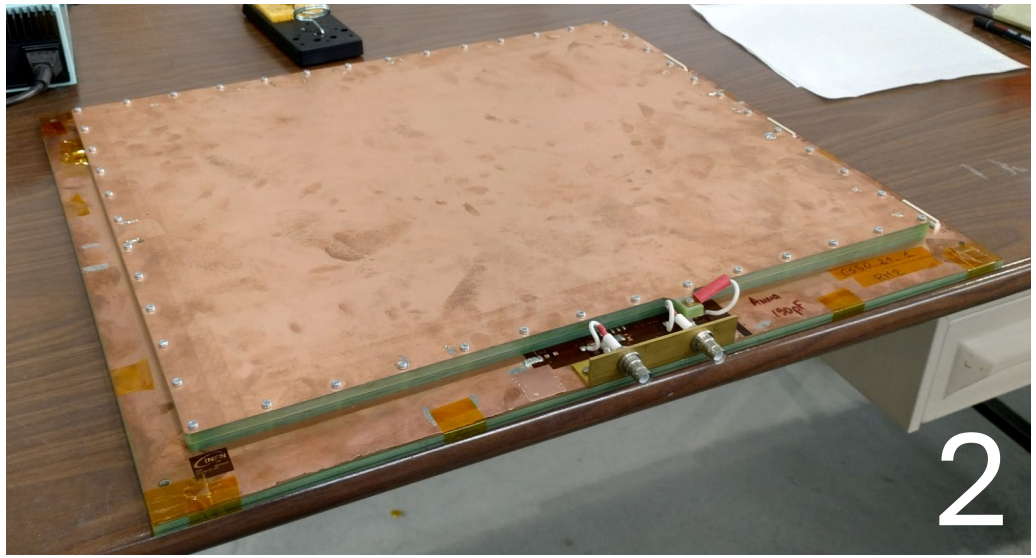
Downward force is applied during the curing period with lead weights



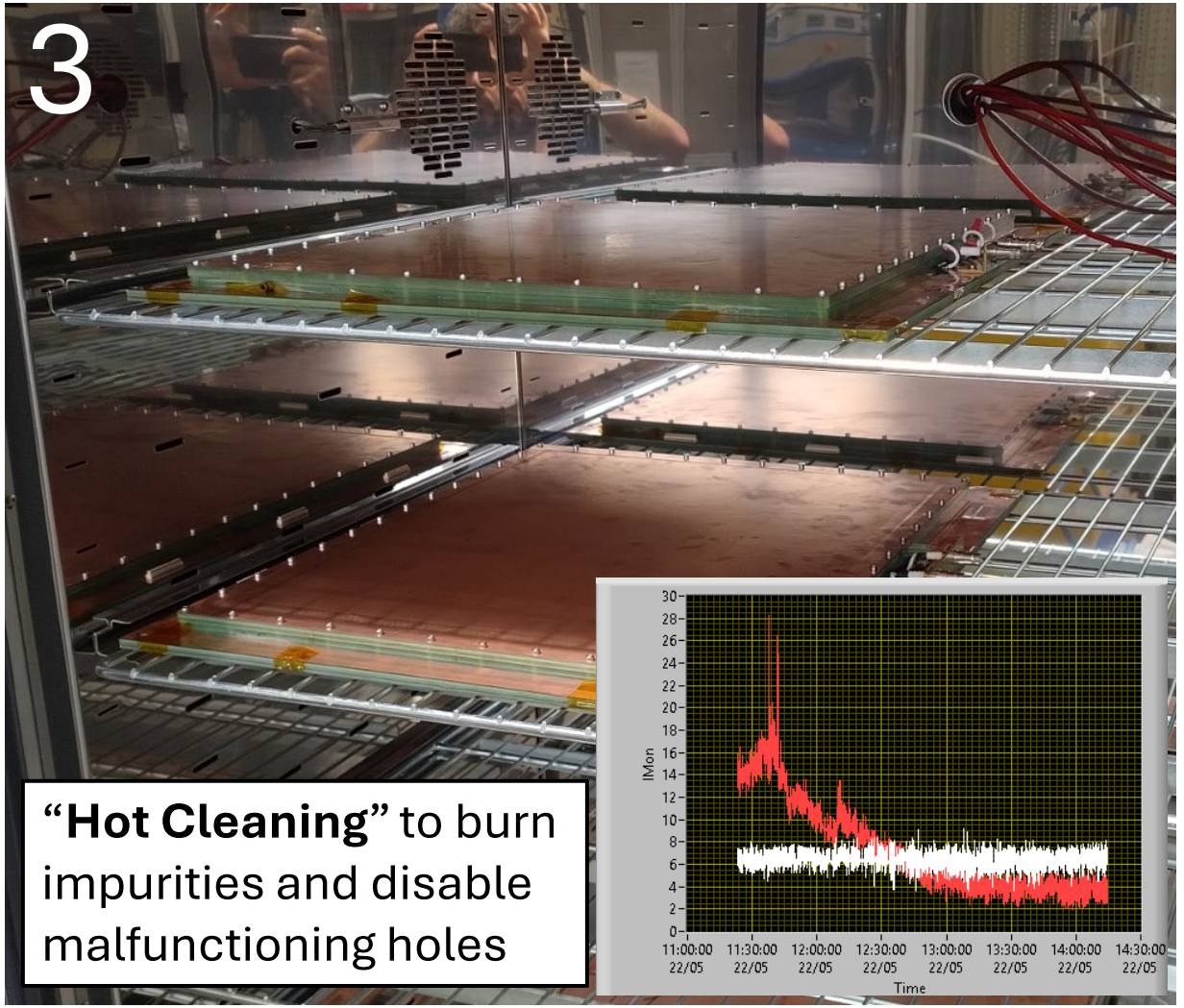


Detector Commissioning Pt.1

1 **Assembly** will be conducted @CERN → Easy access to a cleaning facility if the μ-RWELL is contaminated during assembly



“**Dressing**” of the detector
(Installation of filters and connectors)



“**Hot Cleaning**” to burn impurities and disable malfunctioning holes

Detector Commissioning Pt. 2

4) Detector Power-on in X-ray flux

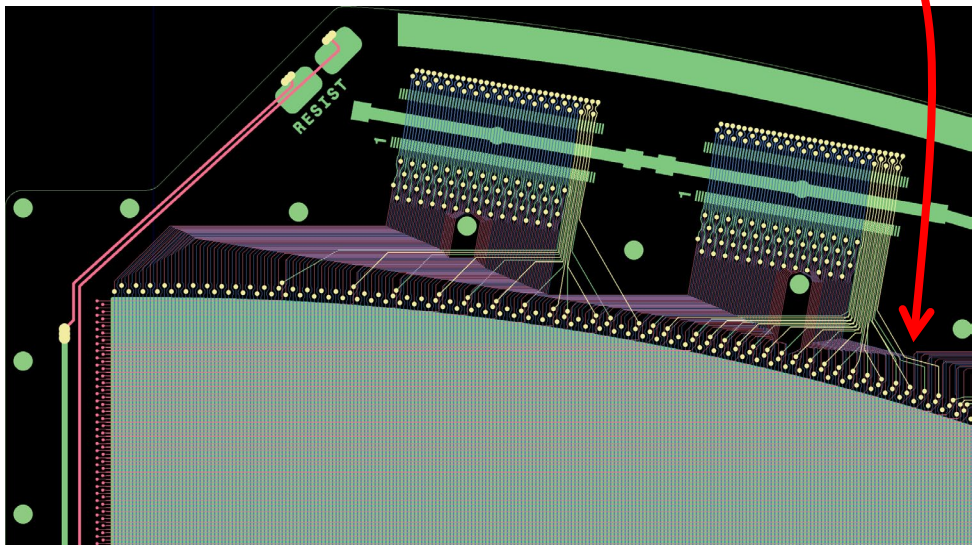
→ High rate stability

5) Detector Characterization (Gain Measurement)

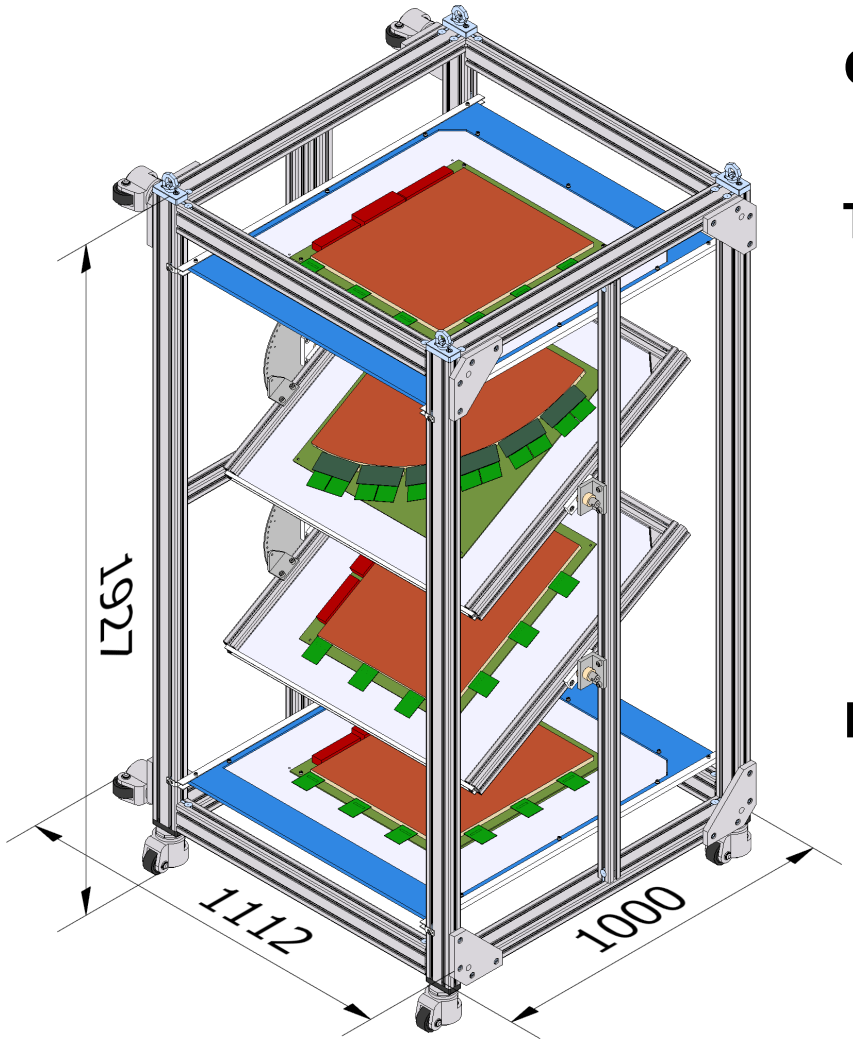
→ Determination of operating parameters

6) Search for pathological channels (requires software mapping)

→ R/O production QA



A Cosmic Ray/Test Beam station



Convertible

- For horizontal and vertical operation

Transportable

- For short distances on paved floor
  → **wheeled**
- By forklift and crane for experimental area deployment
  → **Rigid frame, anchor points, longerons and clearance when horizontal**
- By truck over long distances
  → **vibration resistant**

Expandable

- For reuse as more detectors are produced