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

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**Jan 26th, 2026 – I3 meeting**

# Outline

- Production and test of the ETA
  - Production
  - Preliminary results of the TB data analysis
- ECT Redesign
  - Acceptance Studies
  - Preview of the new model

# Production and Test of the ETA


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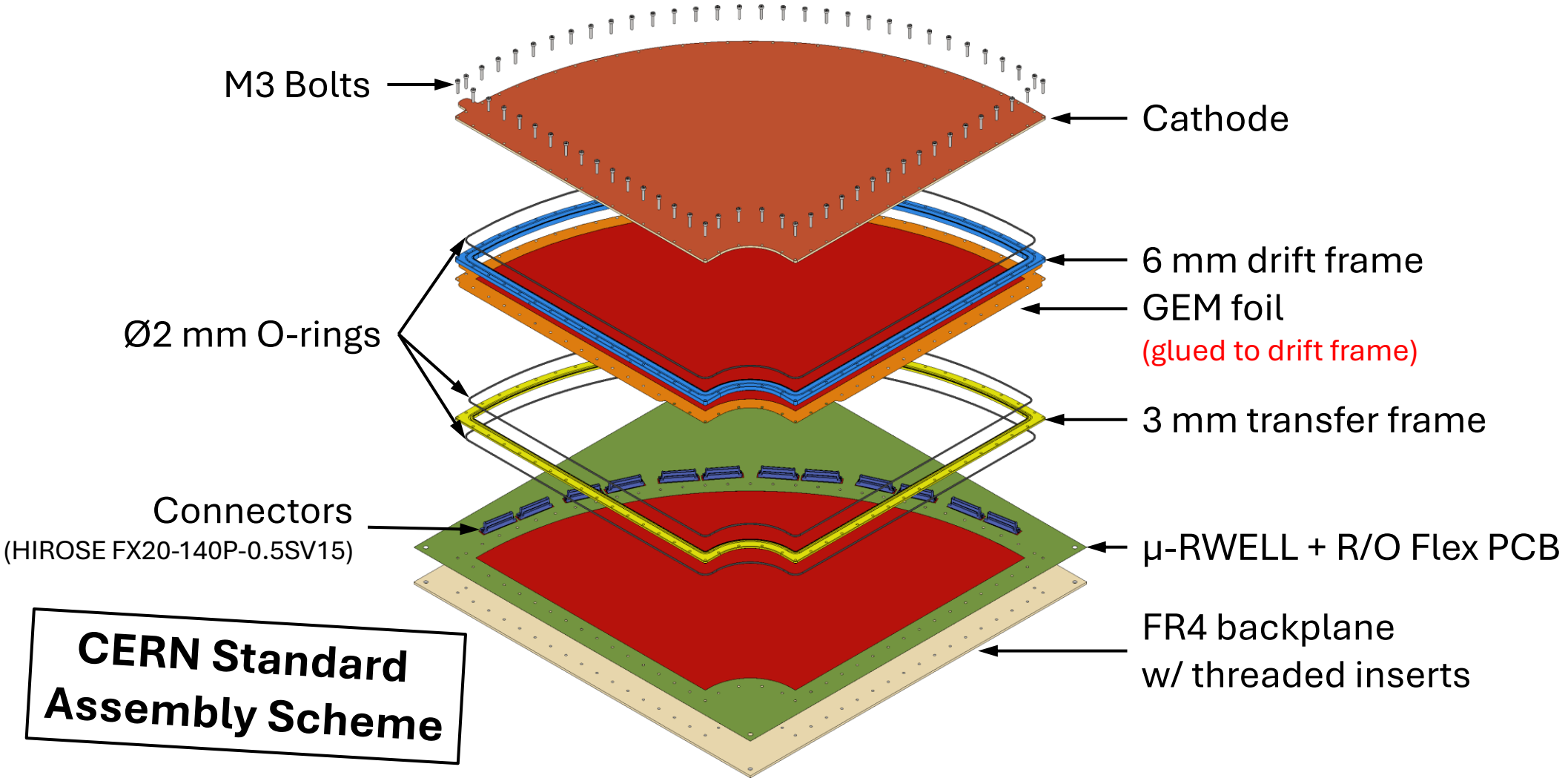
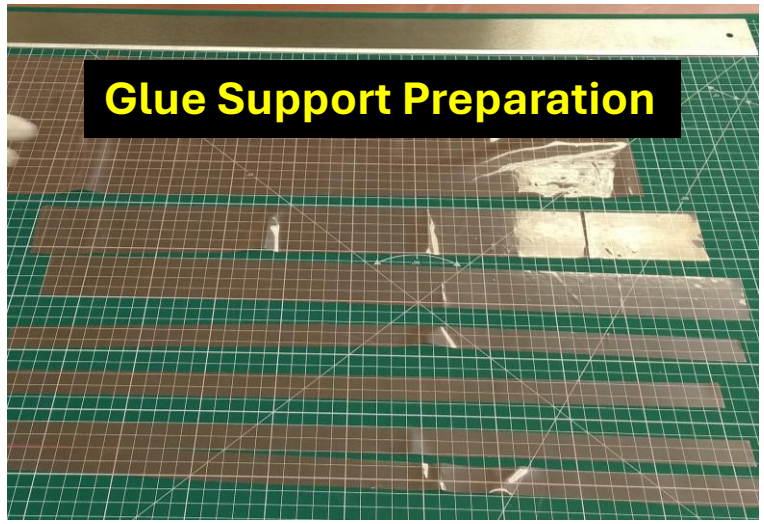
# ETA Main Components and Assembly

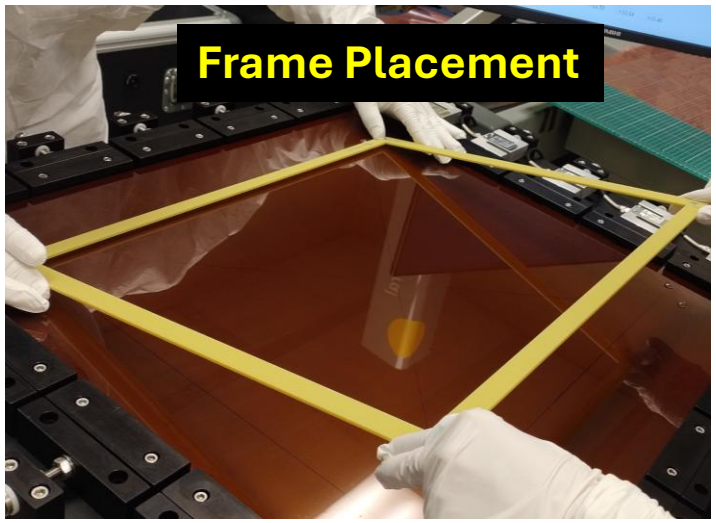


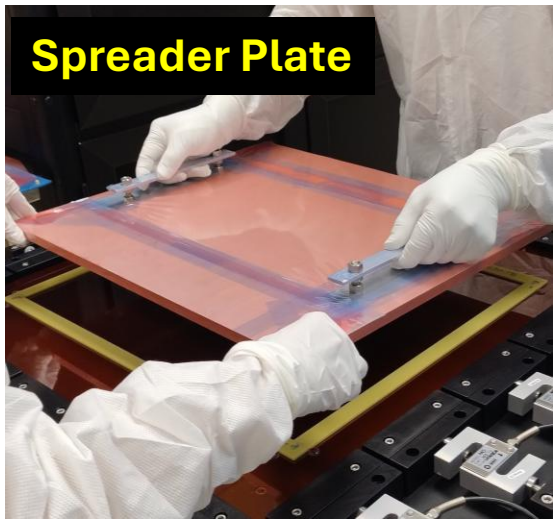
# Gluing Tests and Glue Transfer Technique

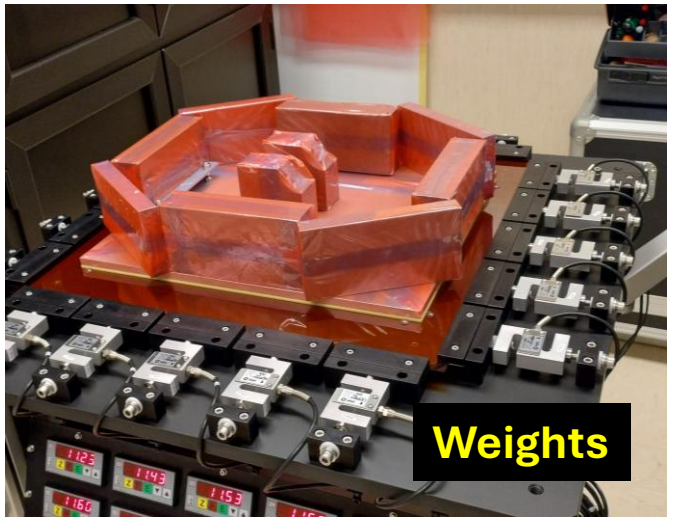








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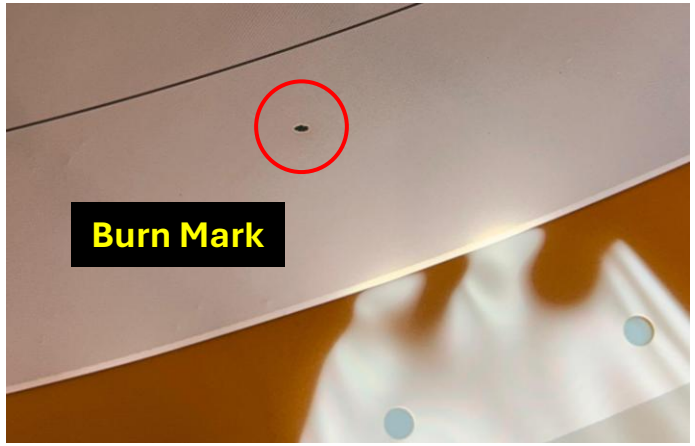
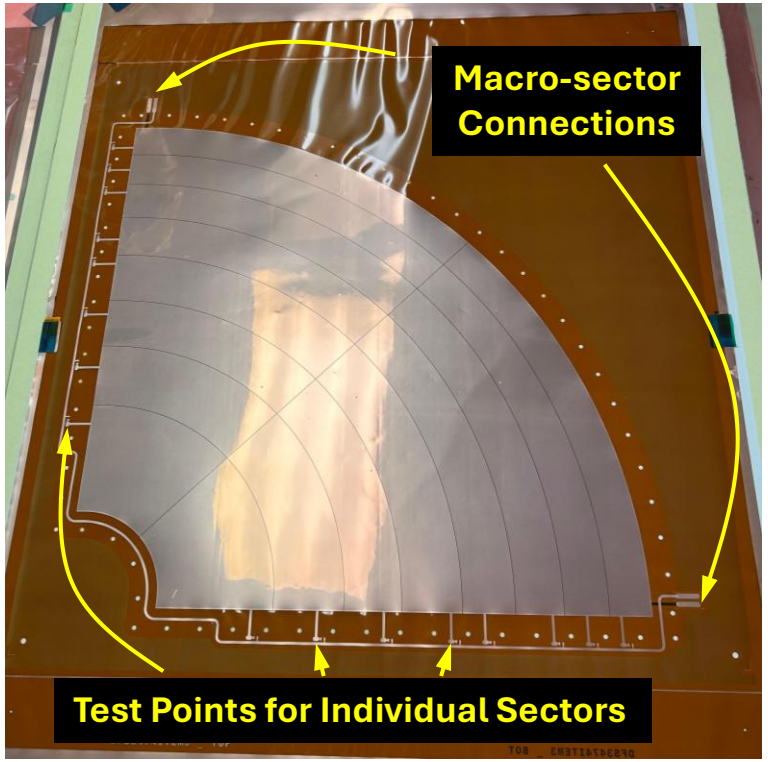
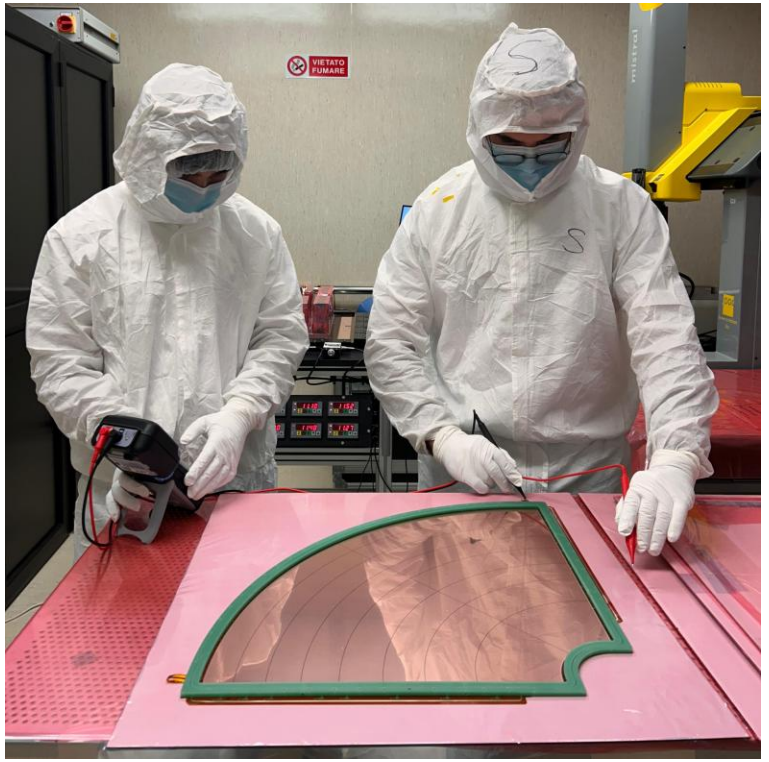
# Quality Control of the GEM Foils




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



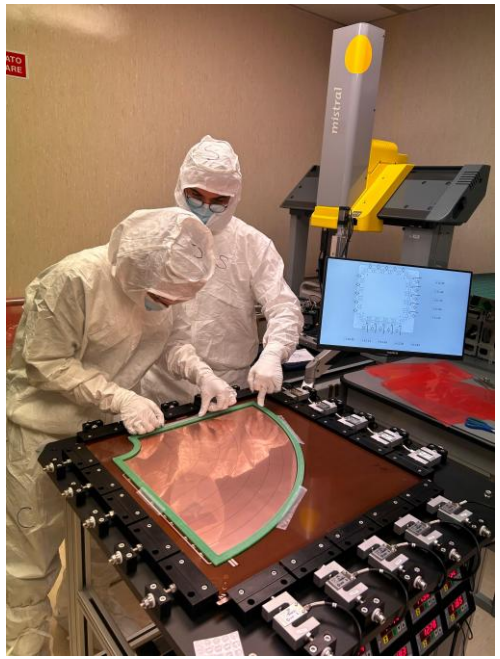



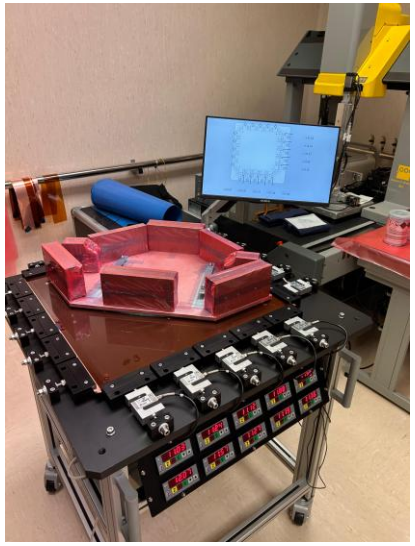
Performed on arrival and after the gluing, before shipping the foils back to CERN

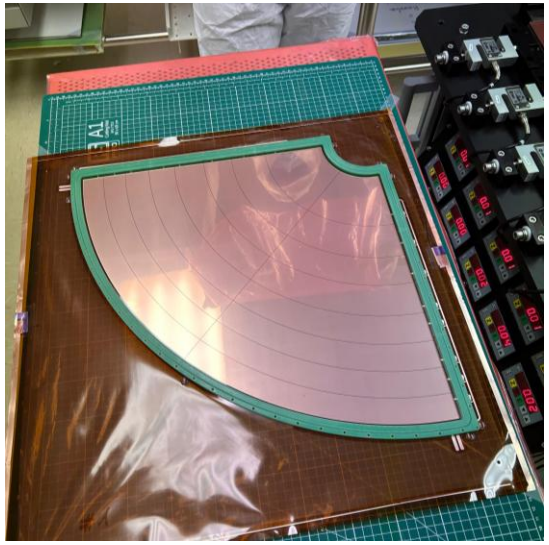
One sector already shorted on arrival, **no new sectors were damaged in the operations**

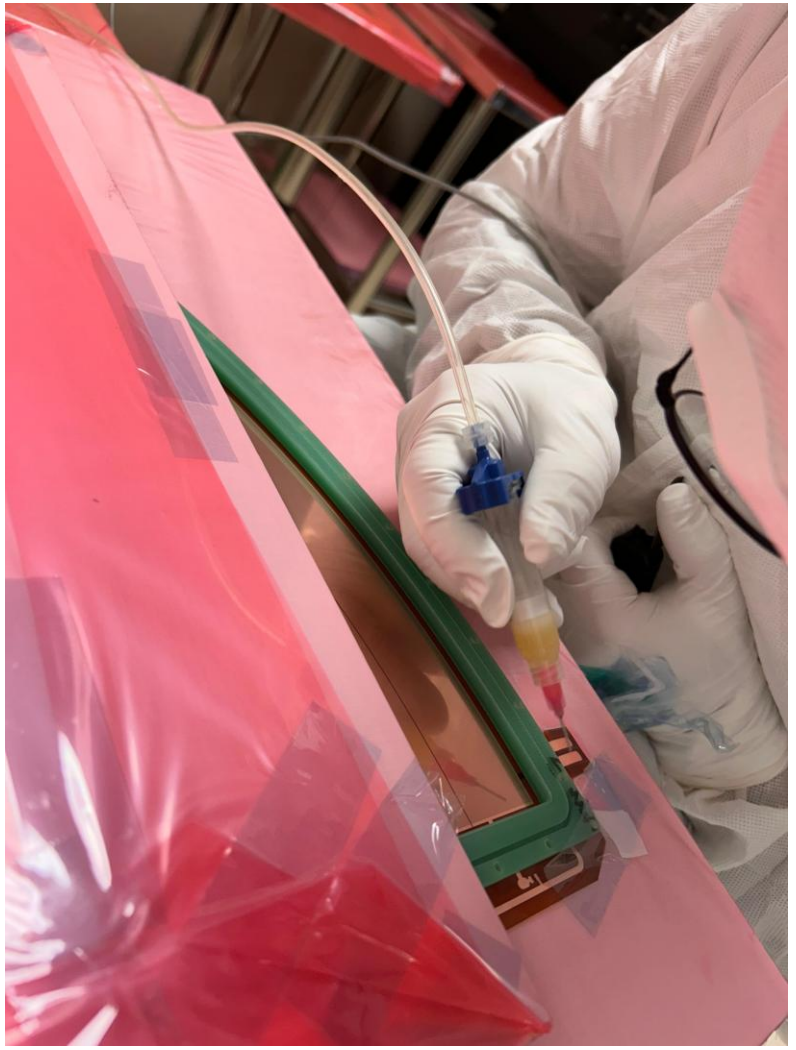
**The gluing procedure is "clean"**

# GEM Gluing







Araldite AY103 epoxy deposited in a 3 mm wide strip

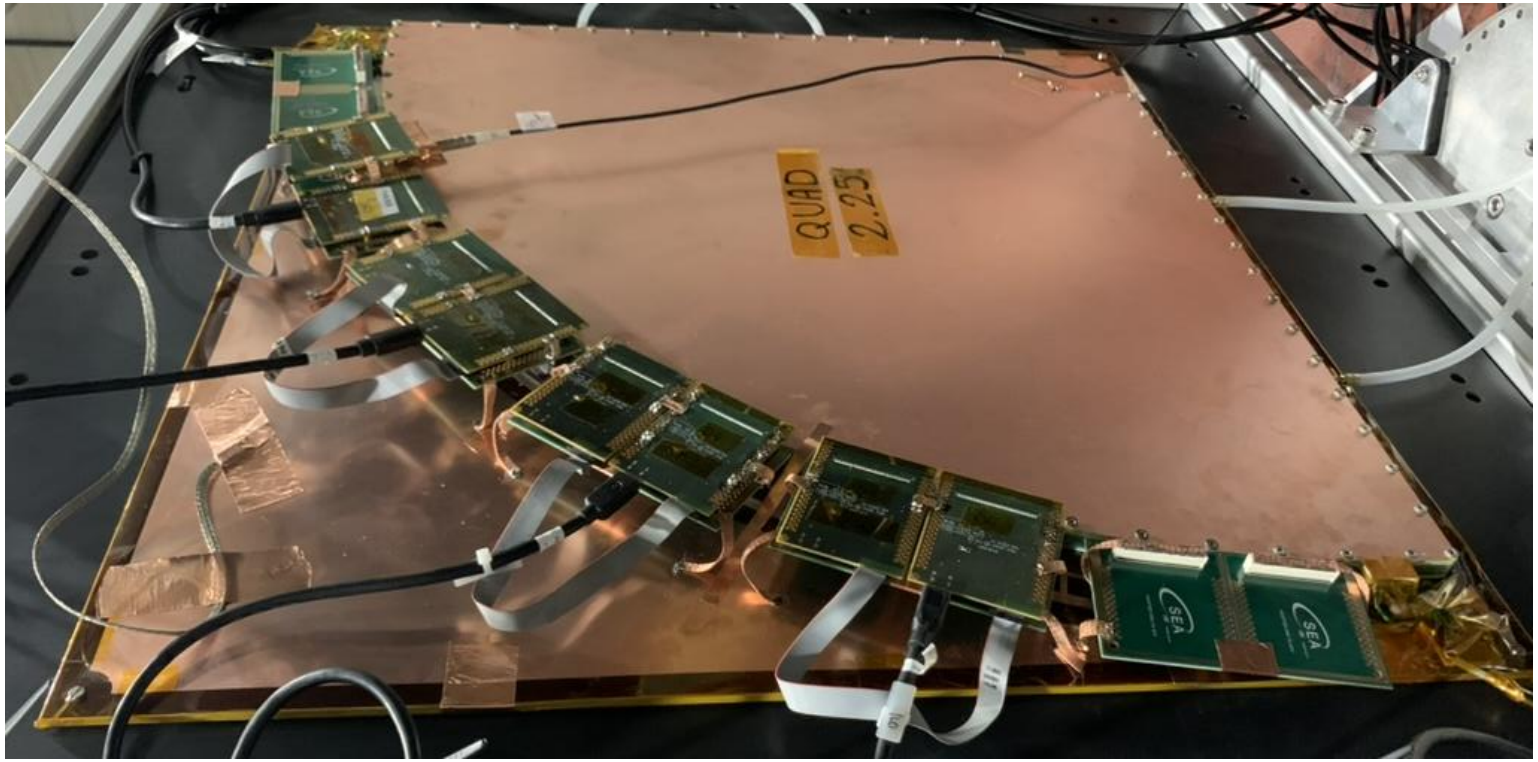
**GOOD** for mechanical stability, no overflow, no holes occluded

**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)**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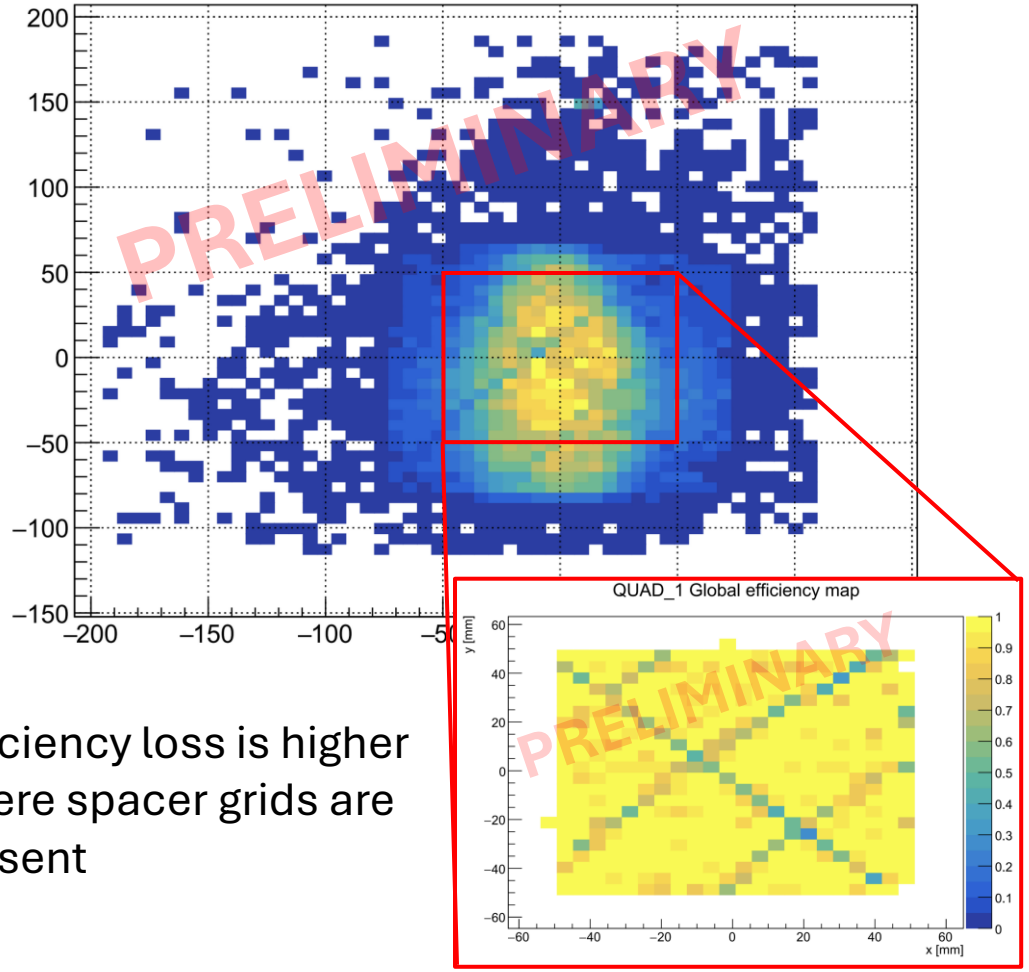
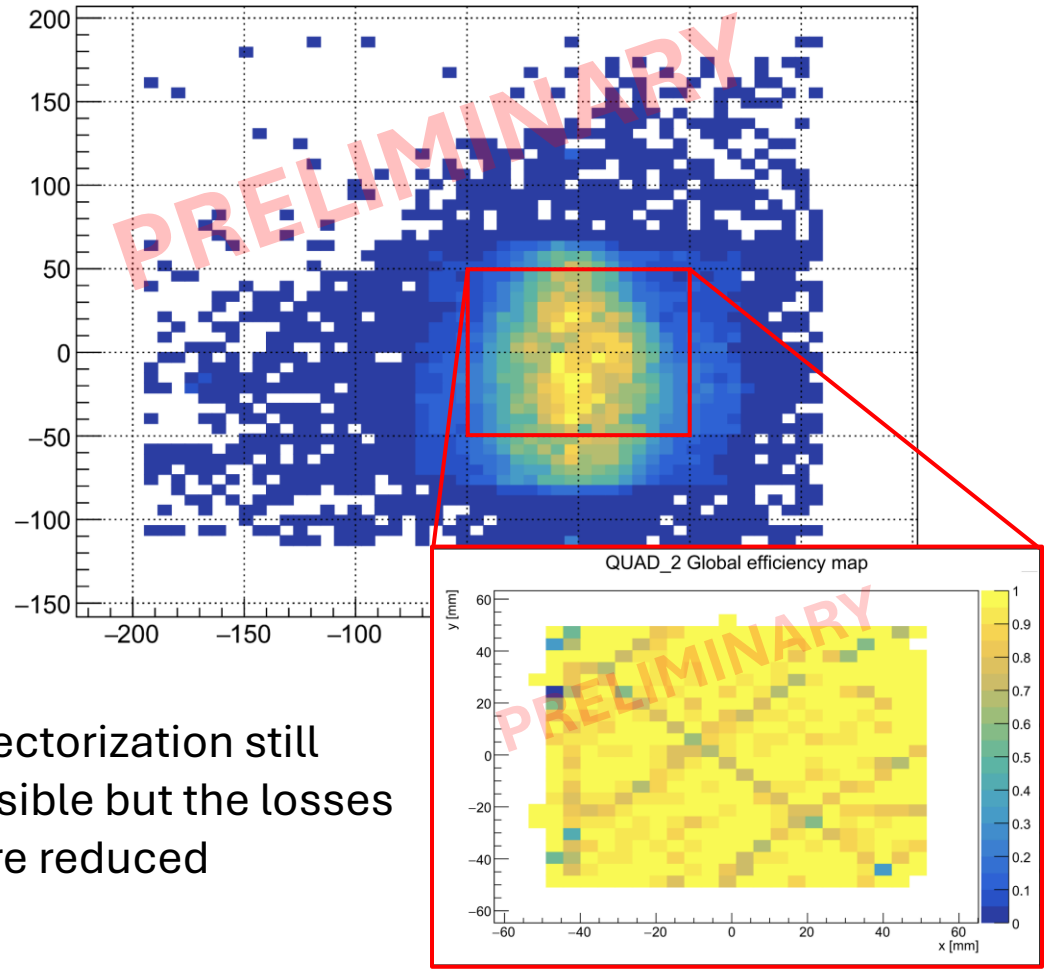
# Preliminary Results: Position and Efficiency Maps

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

# Section Summary

- Two **size 1 ETAs produced and tested successfully**
- **GEM stretching** technique **well consolidated**
- **Gluing** procedure serviceable but **could be improved**
- **Spacer grids** may **not** be **necessary** at the tested dimensions

# ECT Redesign for the Envelope Changes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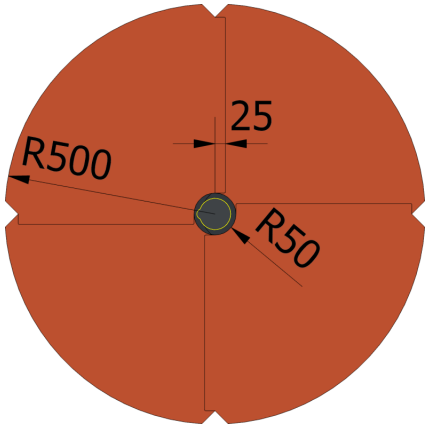
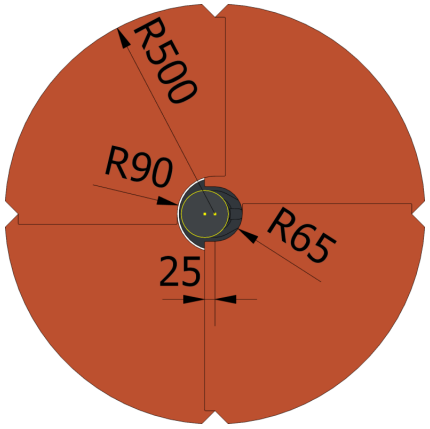
# Purpose of the Acceptance Study




**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**

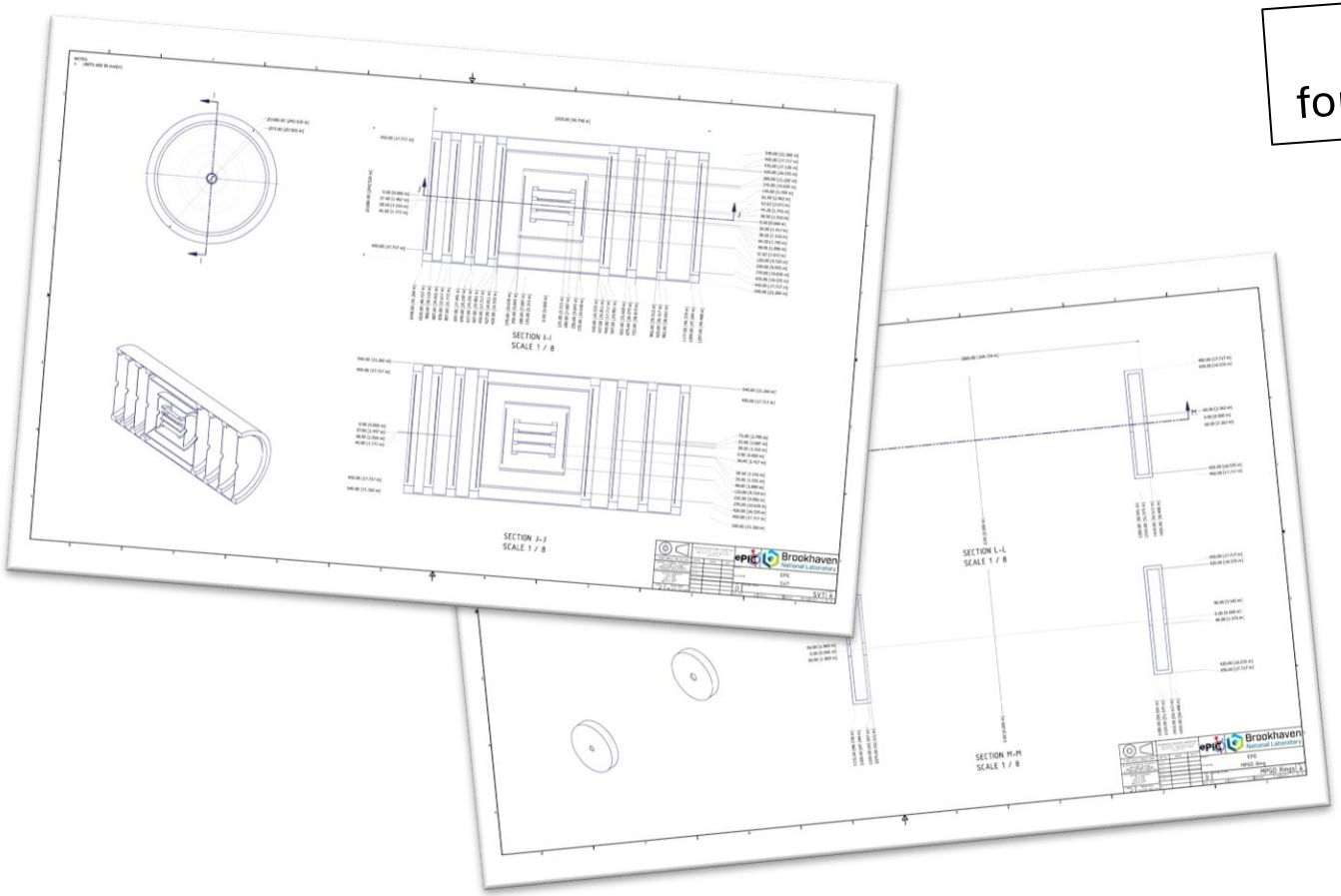
**Project recommended a reassessment,** taking **SVT coverage** along η into account

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)

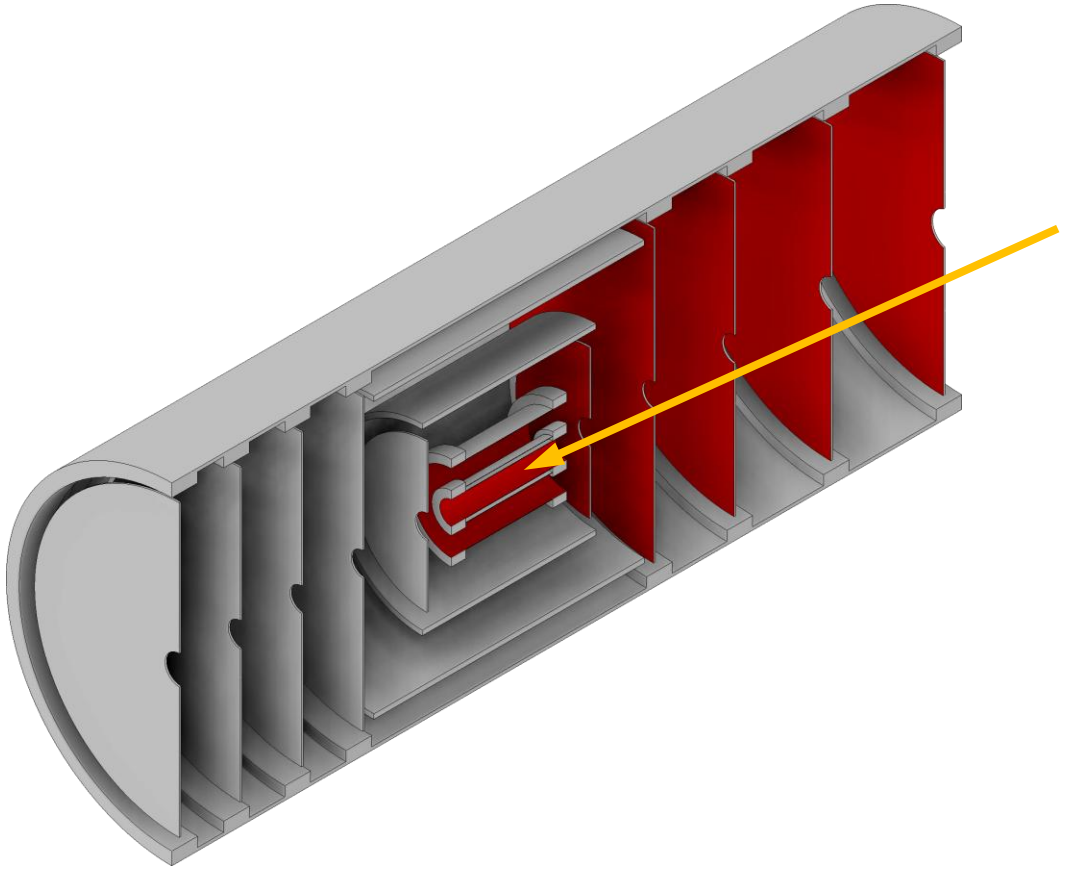
**Many thanks to Ben and Ernst**
for their helpful explanations on the matter




**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**



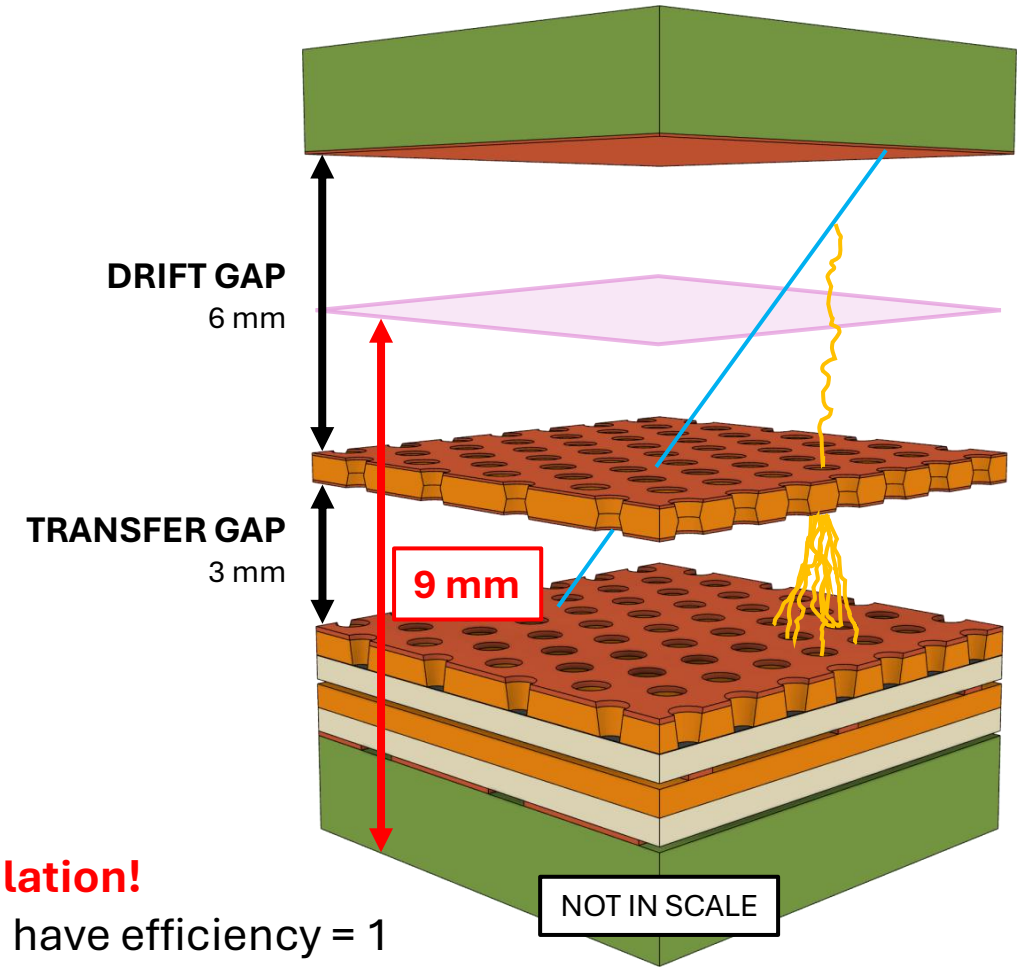
**Only the first SVT barrel layer was included** in the study

**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

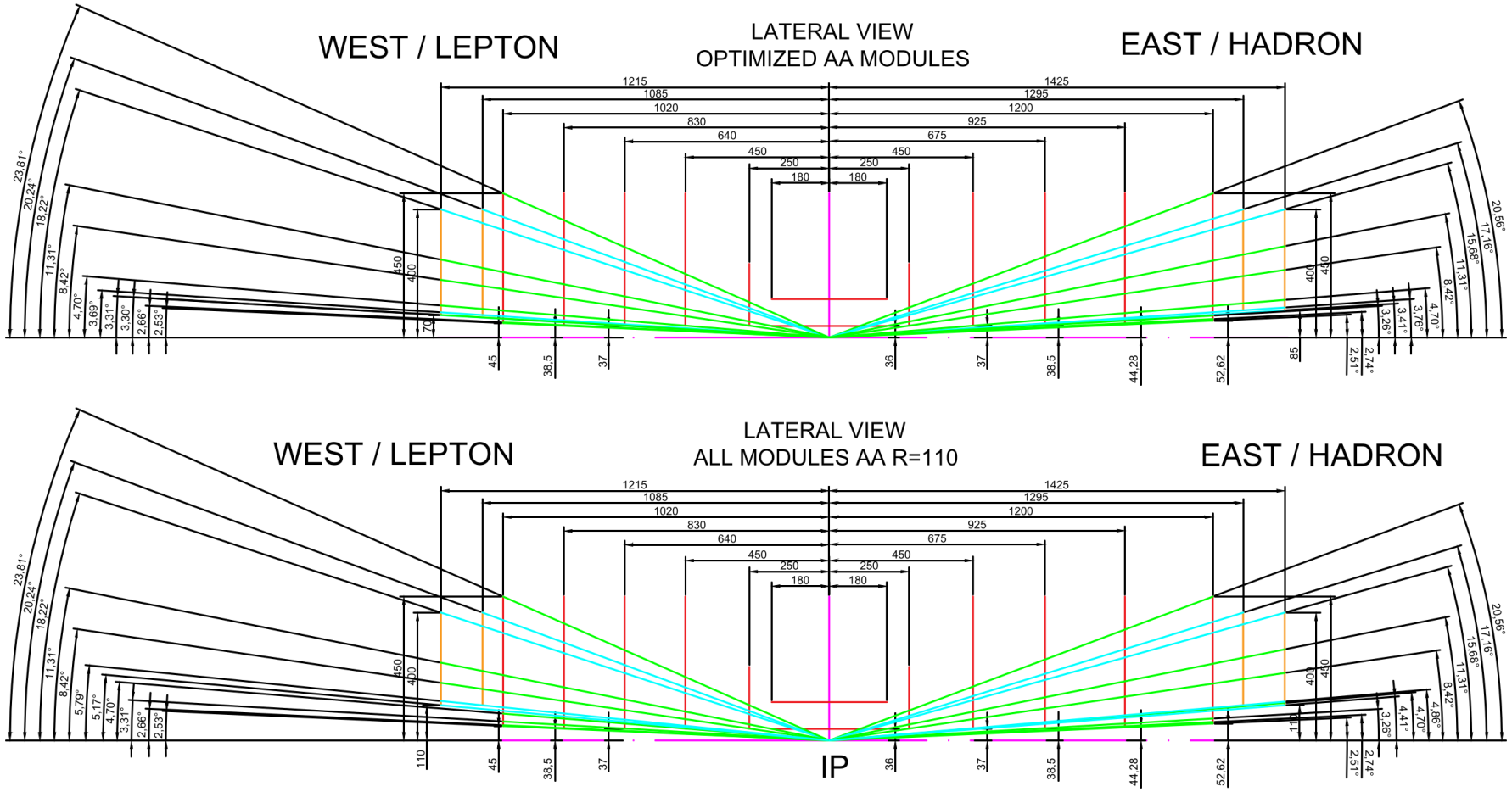



**DISCLAIMER: This study is not a simulation!**

All sensitive surfaces are considered to have efficiency = 1

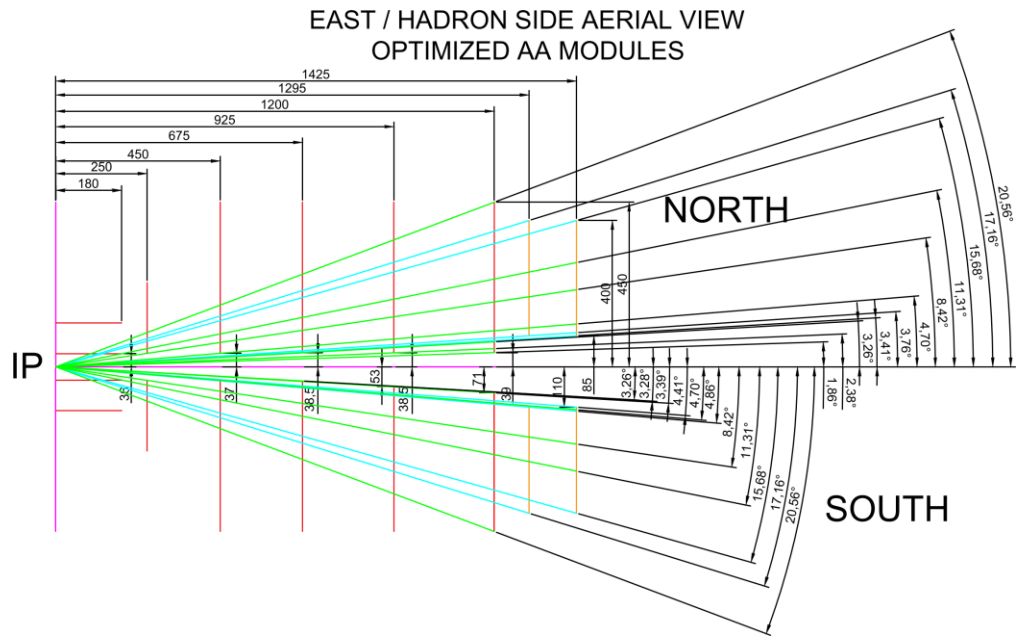
If a track crosses them, then it generates a hit in the detector

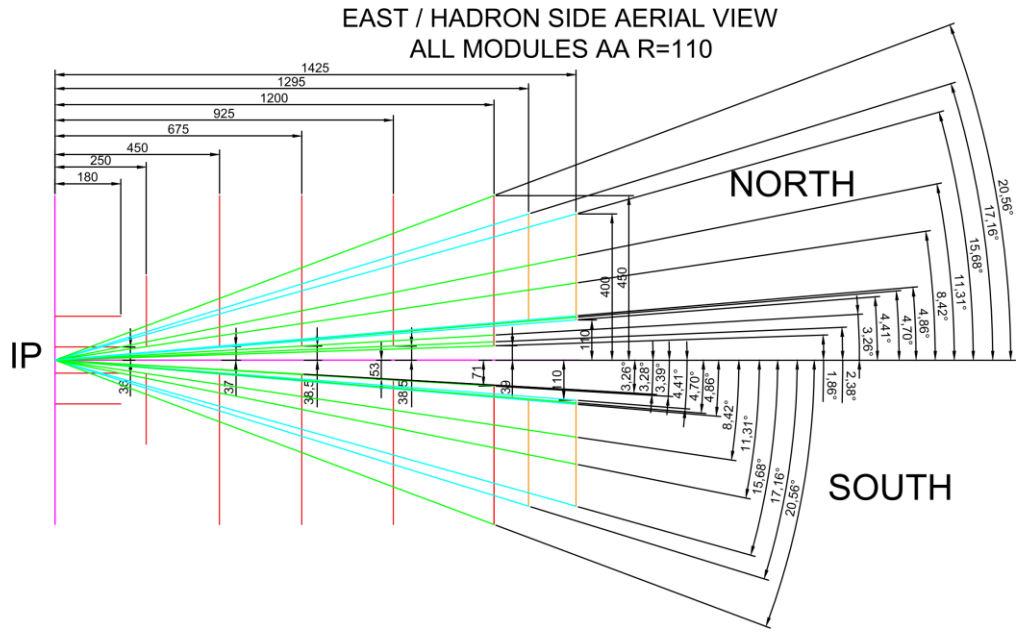
# Coverage Determination: Lateral View




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

# Coverage Determination: Aerial View



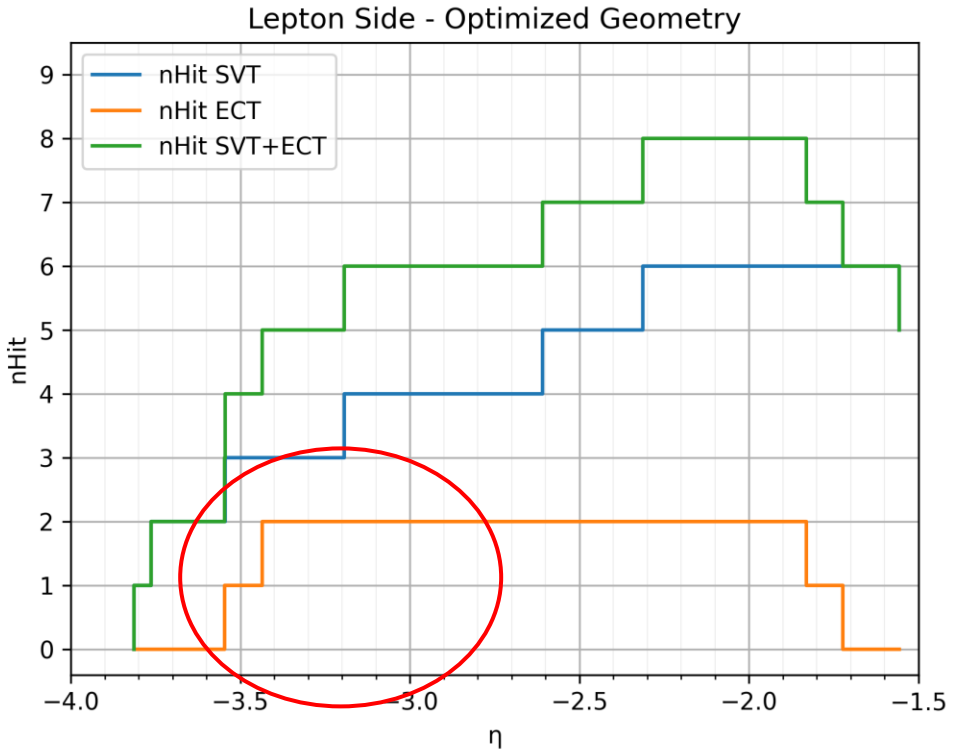



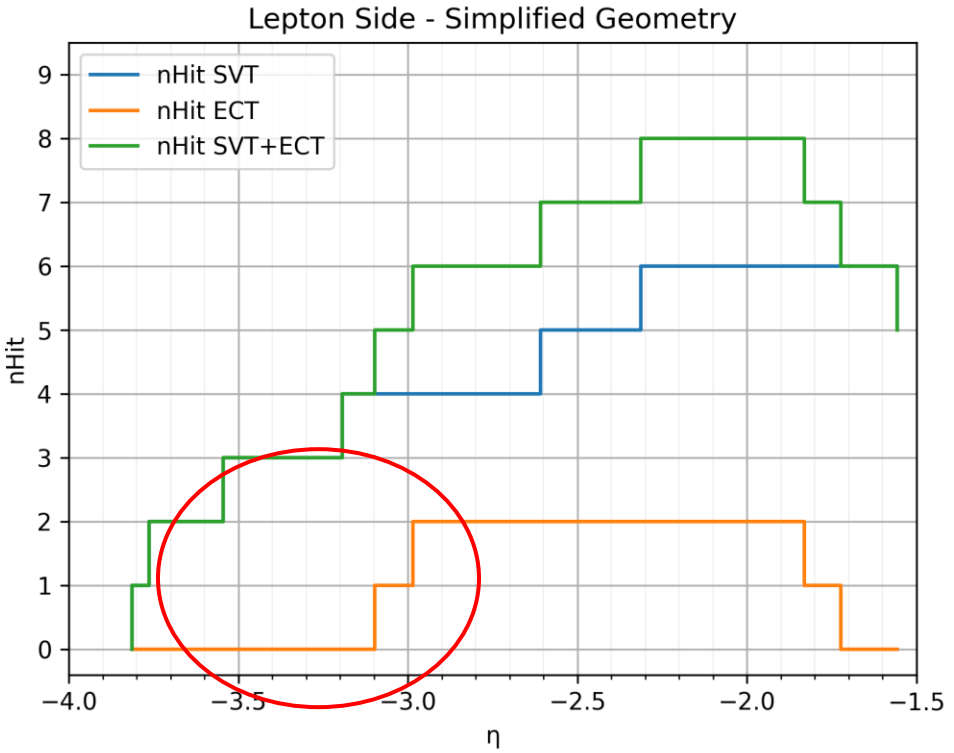

The **hadron side adapts to the beam pipe asymmetry**, the **north and south sides are studied separately**

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

# Impact on Tracking Information

**Lepton Side (Lateral View = Aerial View)**

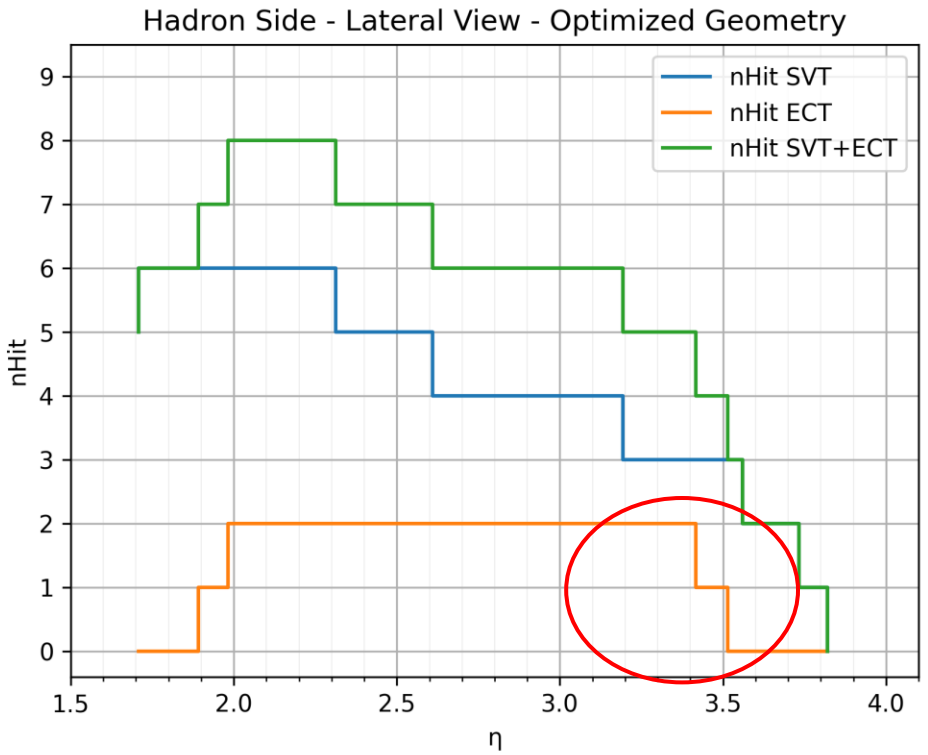


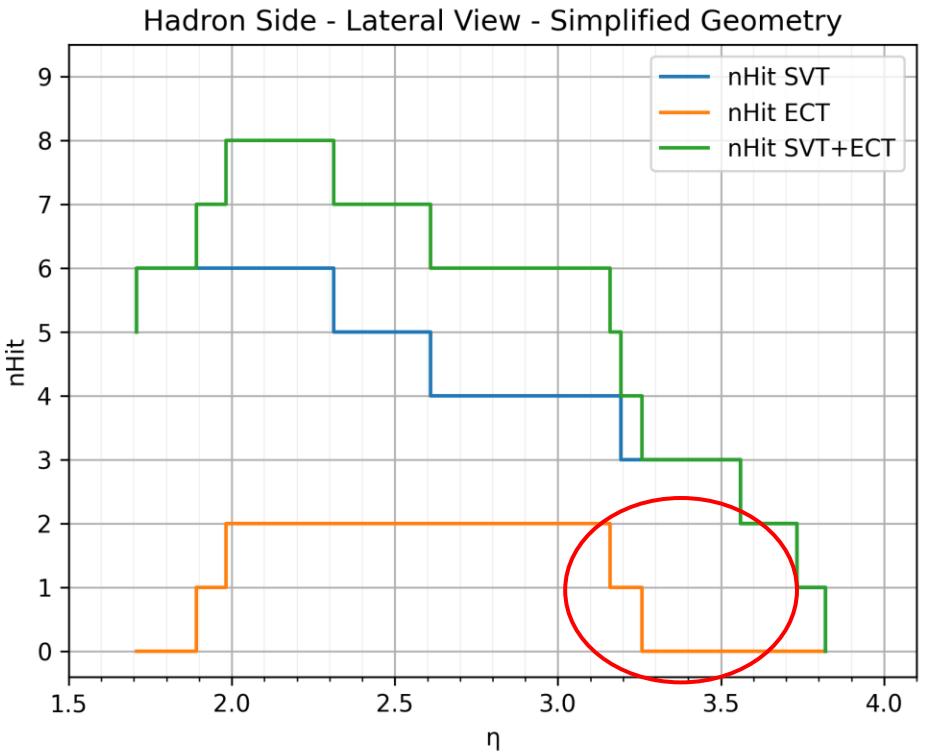




Number of sensitive surface crossings are counted for every η interval

# Impact on Tracking Information

## Hadron Side Lateral View

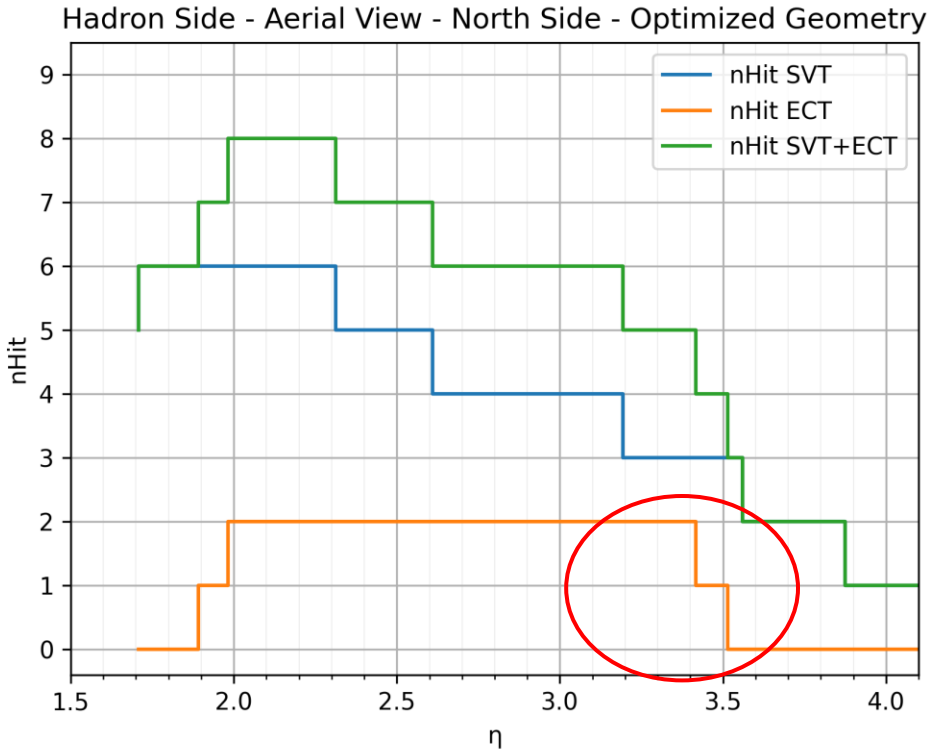


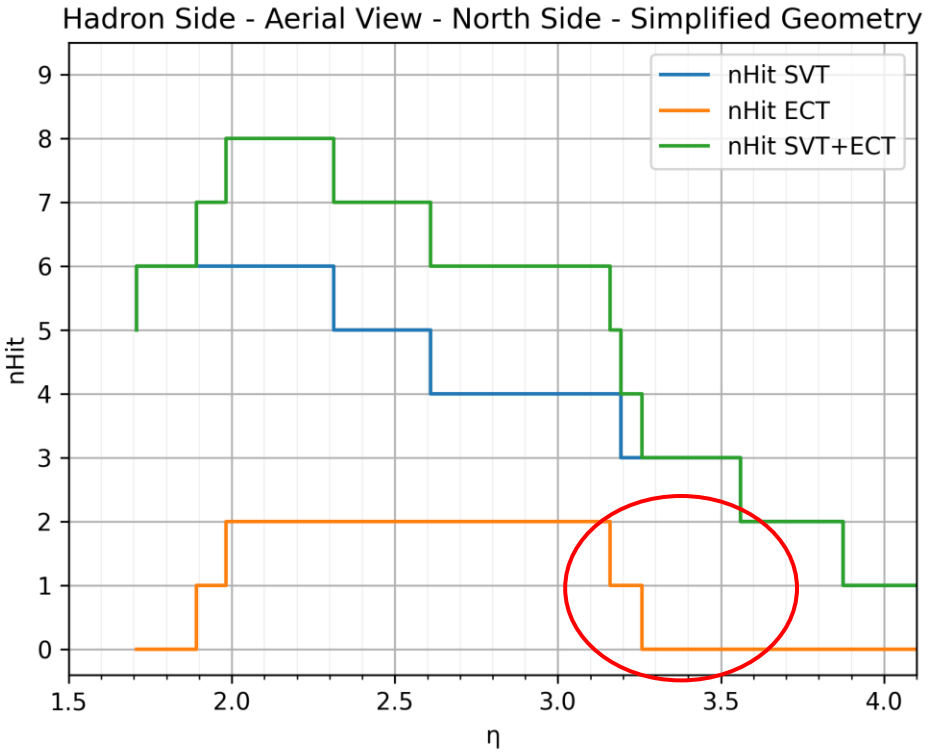




Number of sensitive surface crossings are counted for every η interval

# Impact on Tracking Information

## Hadron Side Aerial View North Side

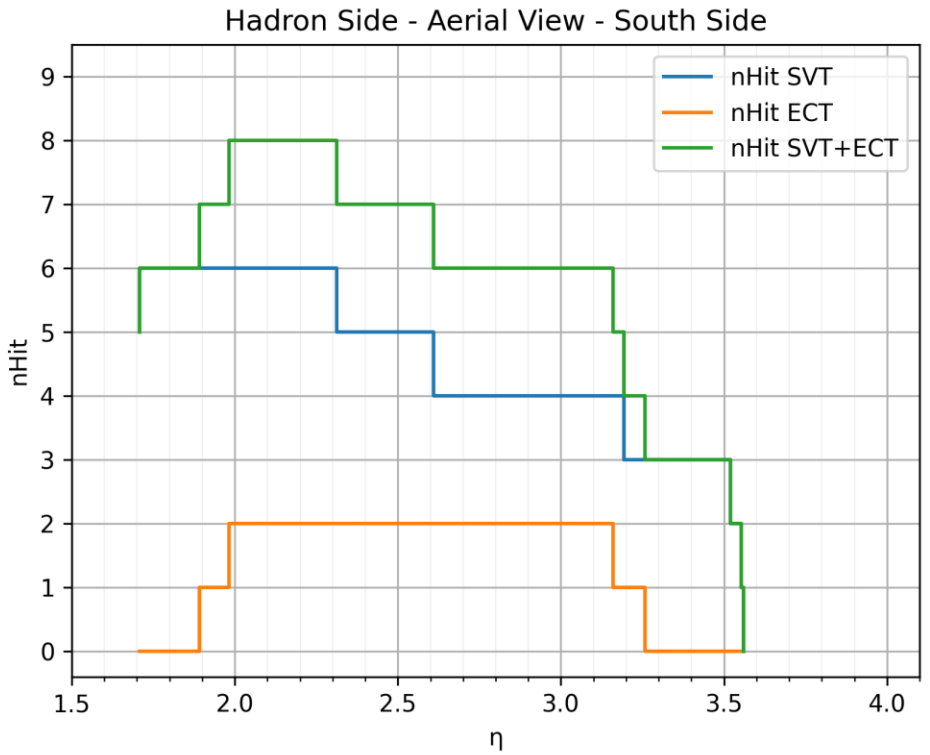



Number of sensitive surface crossings are counted for every η interval

# Impact on Tracking Information

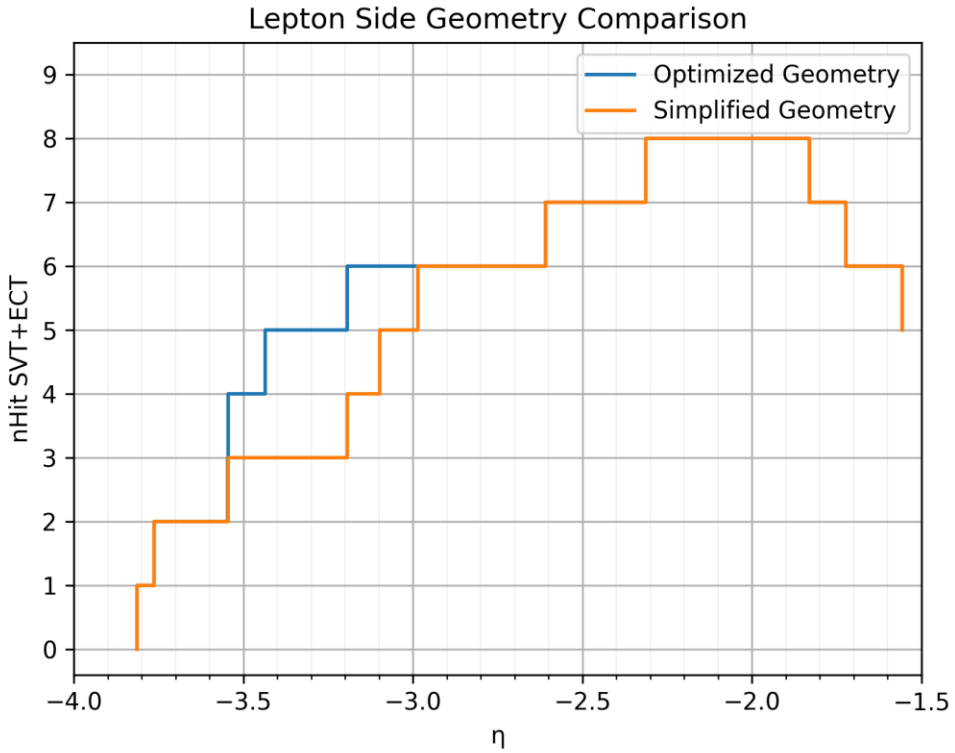
## Hadron Side Aerial View South Side




Number of sensitive surface crossings are counted for every η interval

# Impact on Tracking Information

## Comparison – Lepton Side

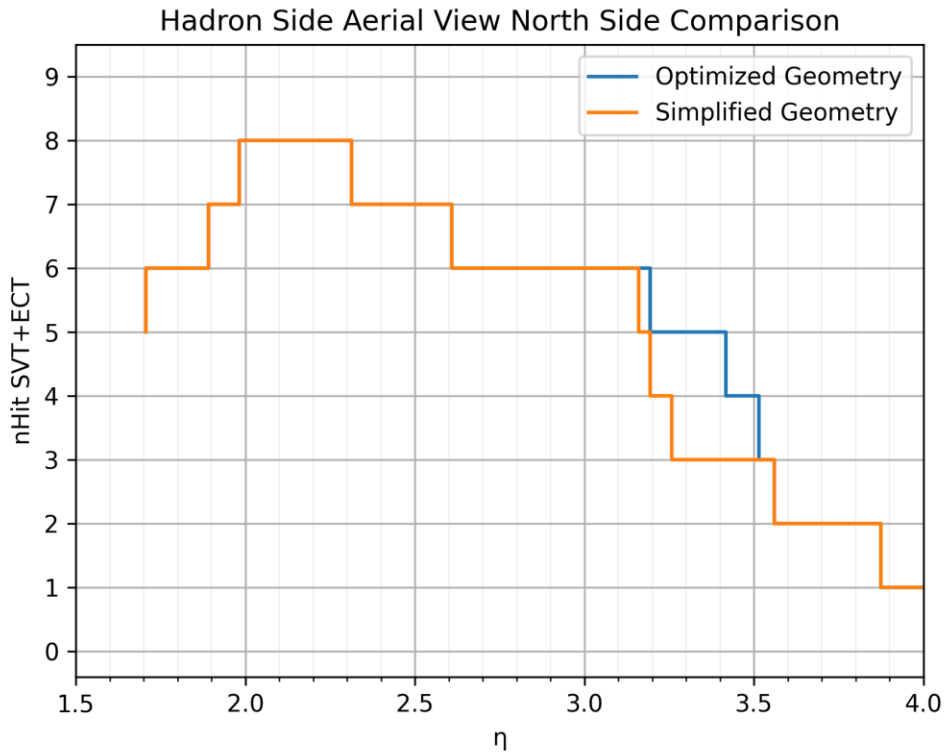


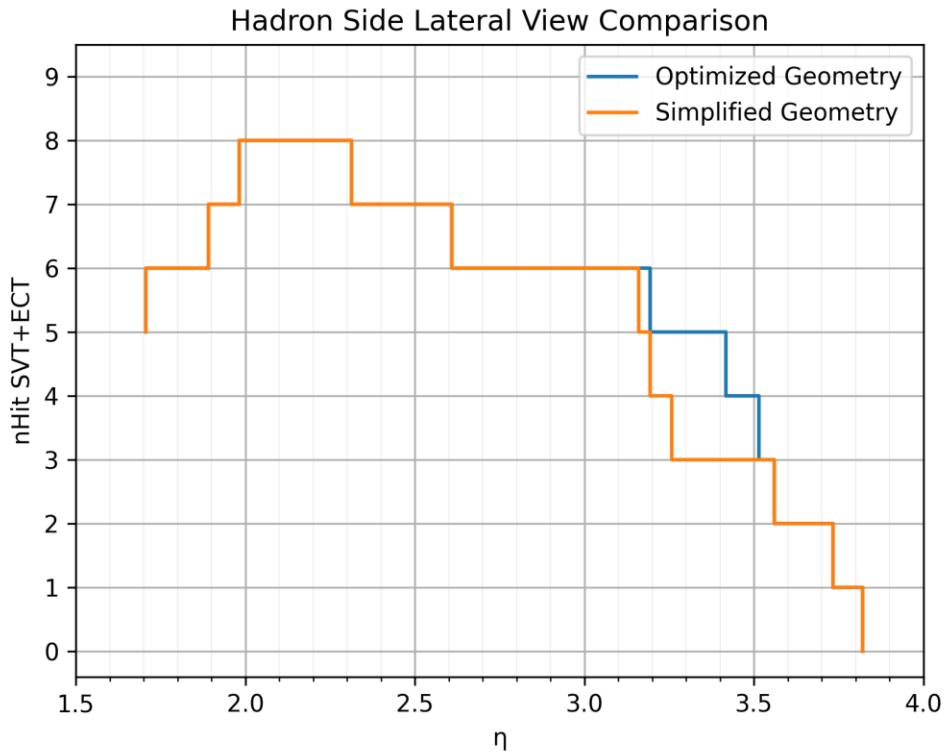

**Loss of tracking information concentrates in -3.5 < η < 3.0**

**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)

# Section Summary

**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**

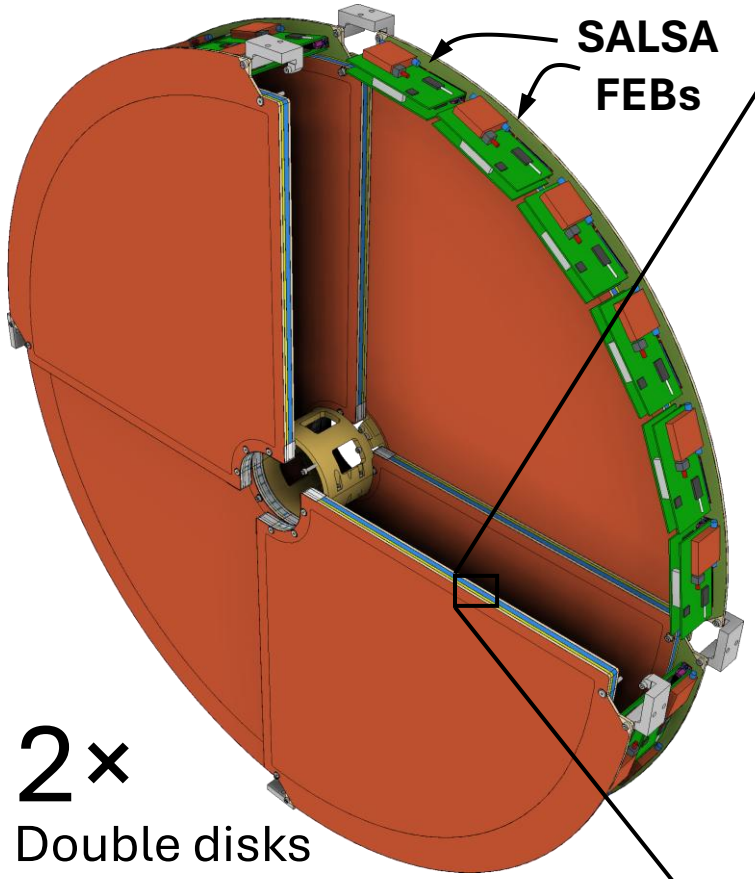
Unless disproven by finer simulations, **optimization of the disks' central cavity still seems to be worth the additional workload**

~~Thanks for your attention!~~

Off to the CAD for a quick showcase of the redesign

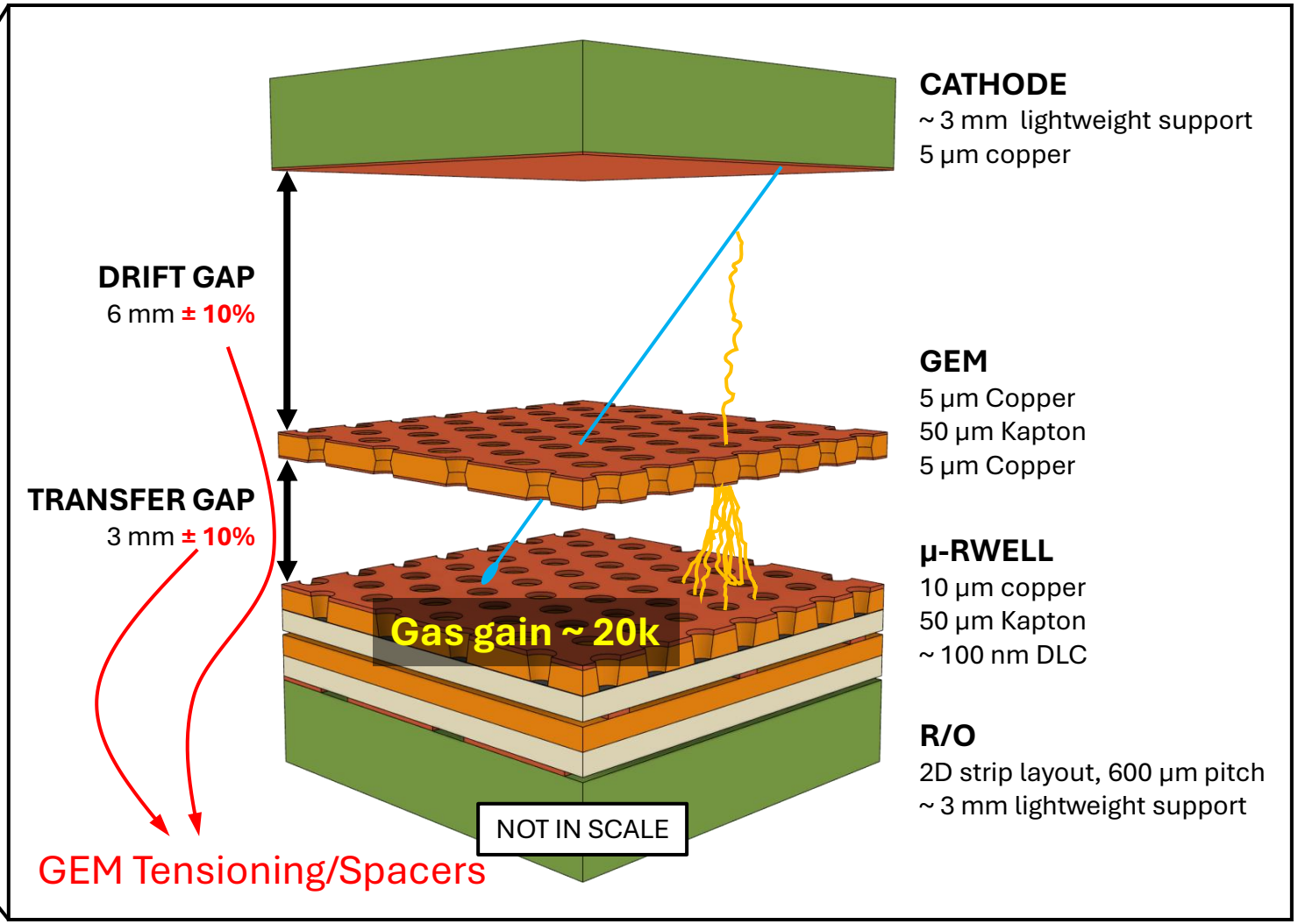
# Backup slides

# Recap: ECT and G-RWELL Technology



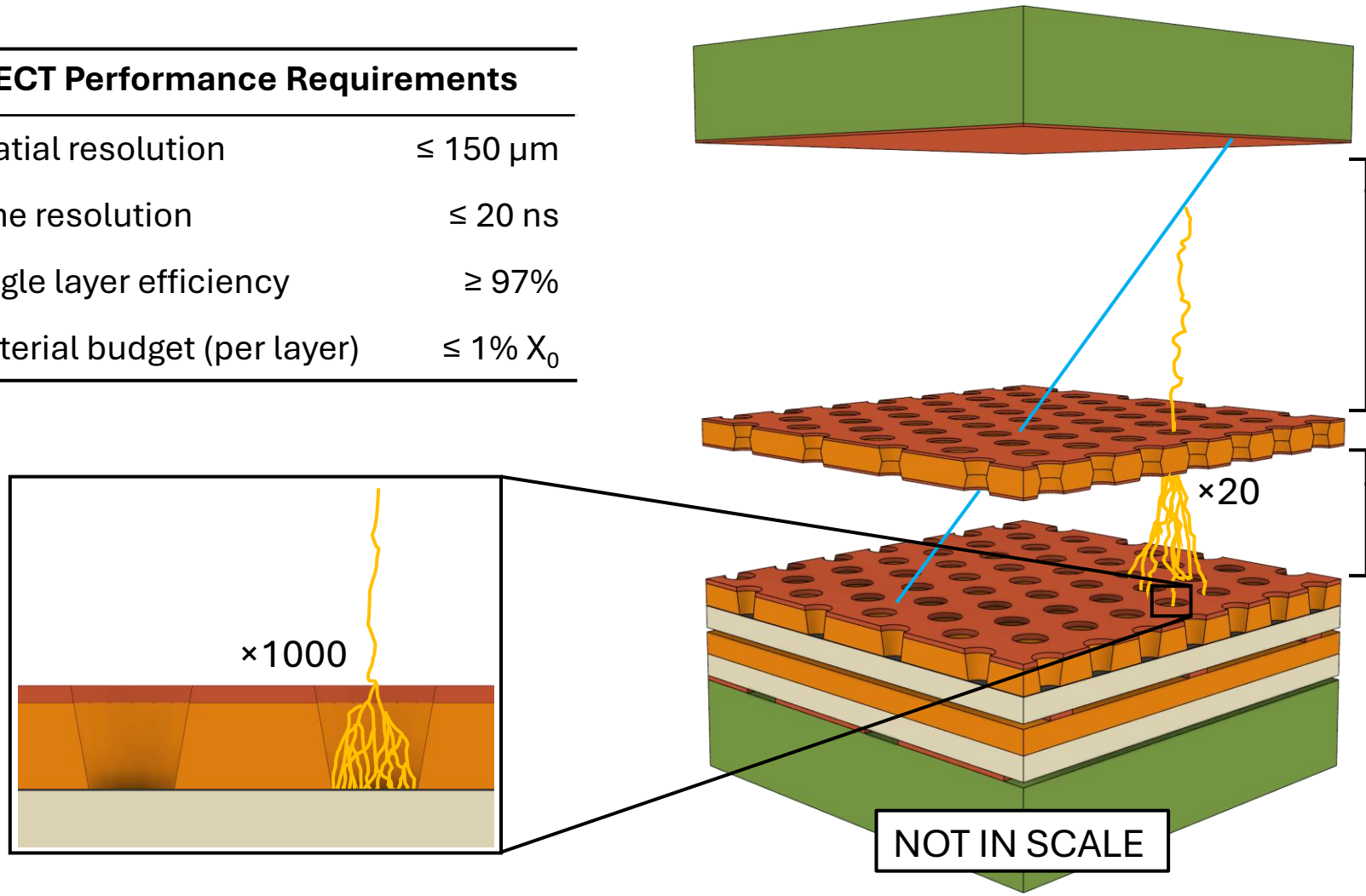

2×
Double disks

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

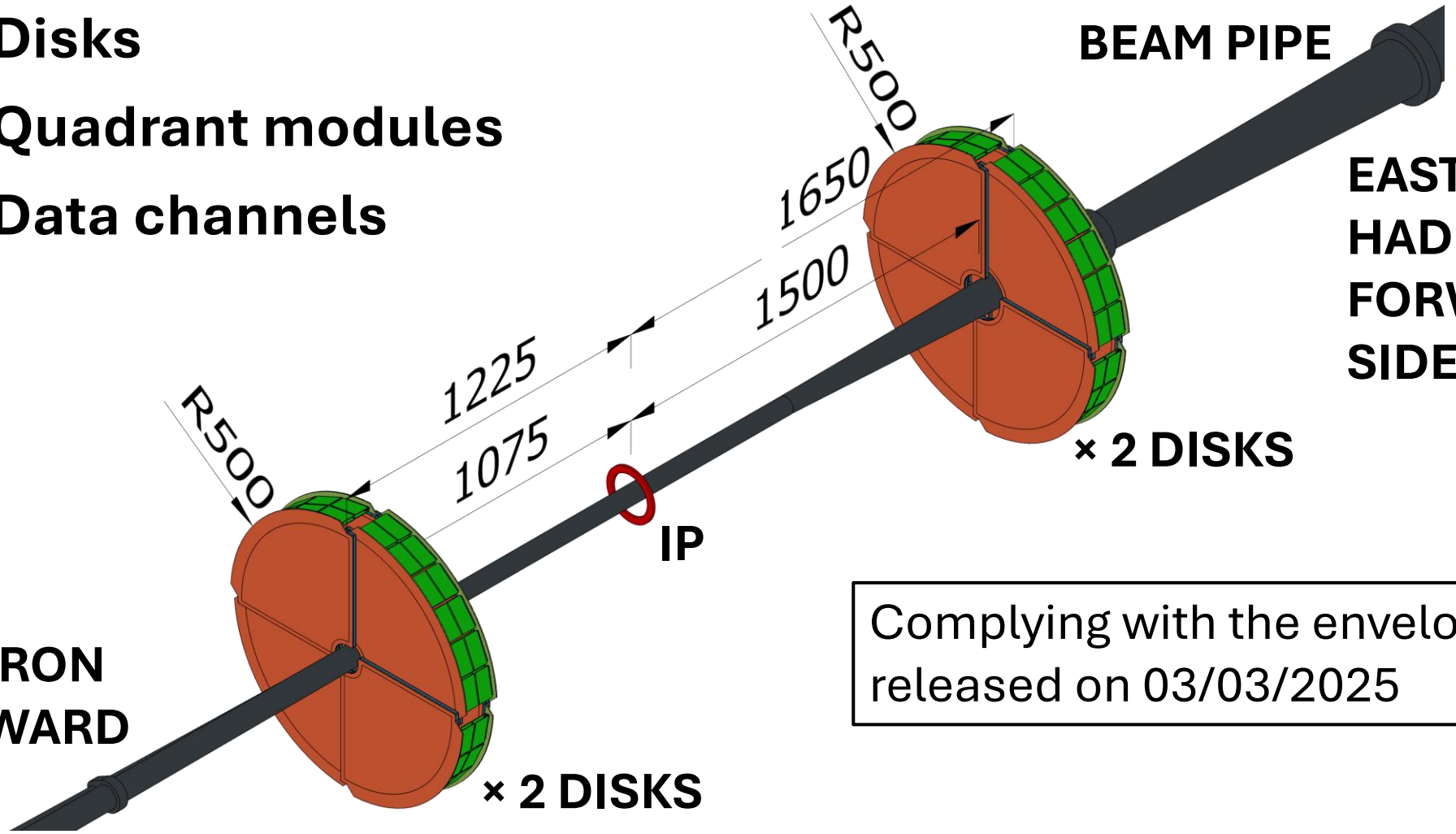
**R/O**
2D strip layout, 600 μm pitch
~ 3 mm lightweight support

# ECT Overview

**4 Disks**

**16 Quadrant modules**

**24576 Data channels**



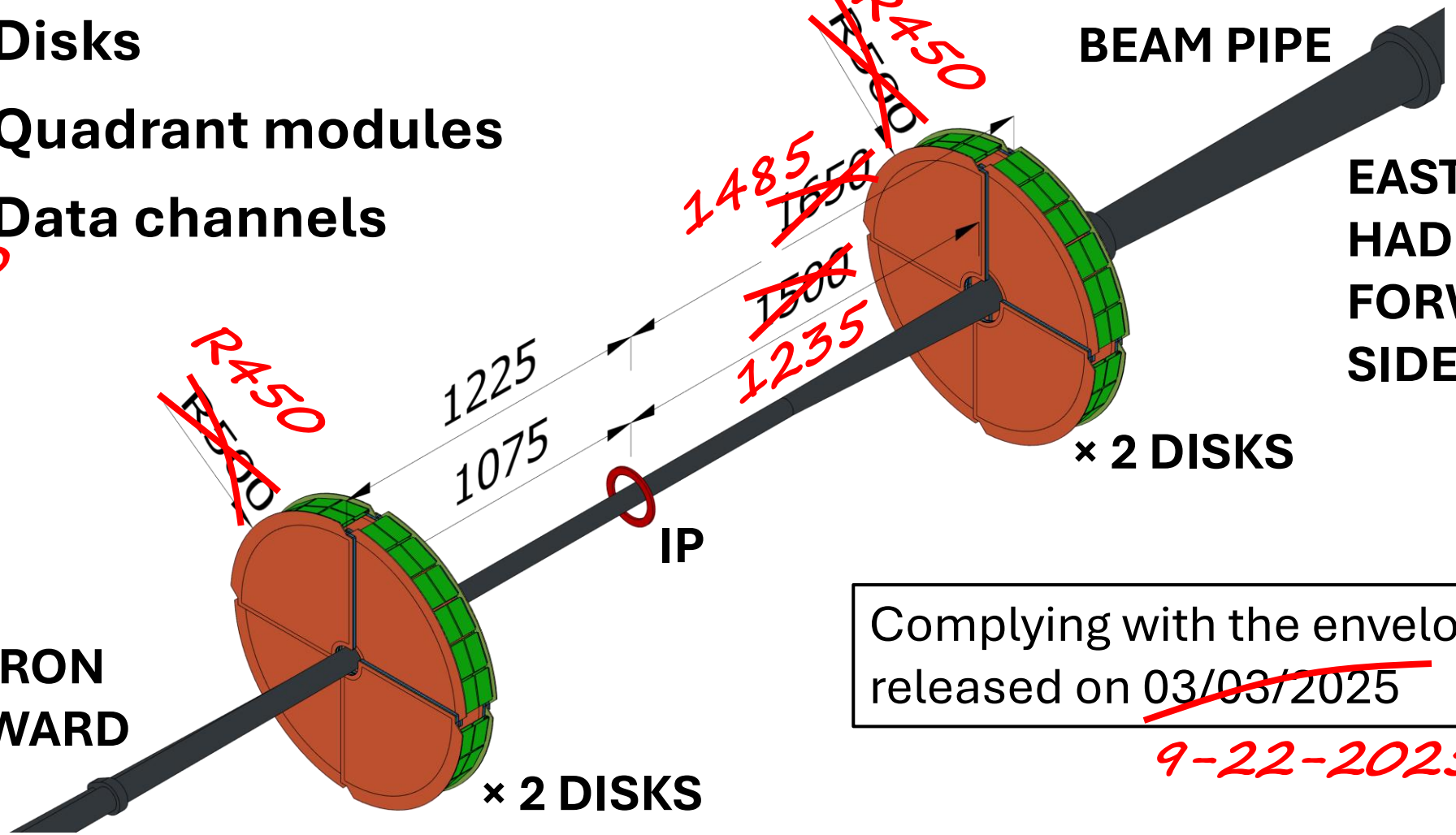

Complying with the envelope released on 03/03/2025

# ECT Overview: Envelope Changes

**4 Disks**

**16 Quadrant modules**

**~~24576~~ 20480 Data channels**




Complying with the envelope released on ~~03/03/2025~~ 9-22-2025

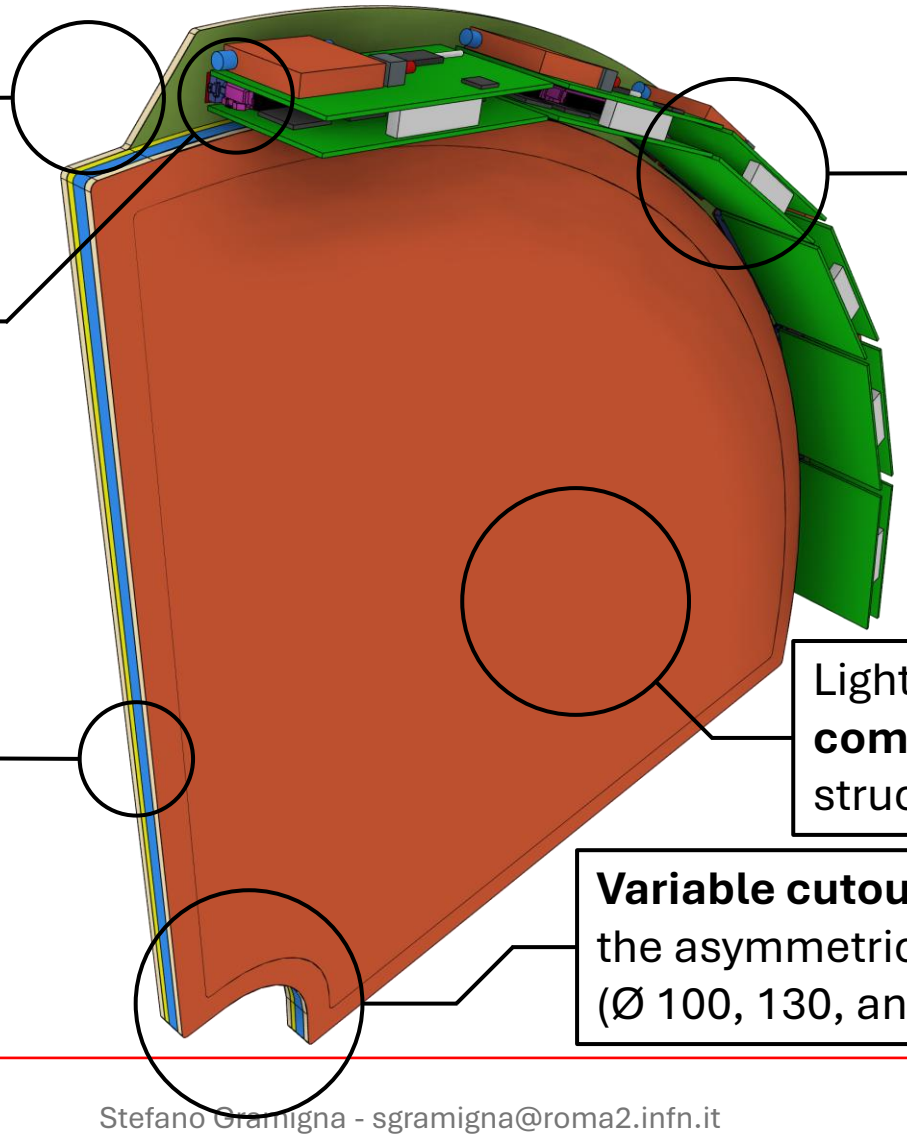
# Quadrant Concept

**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)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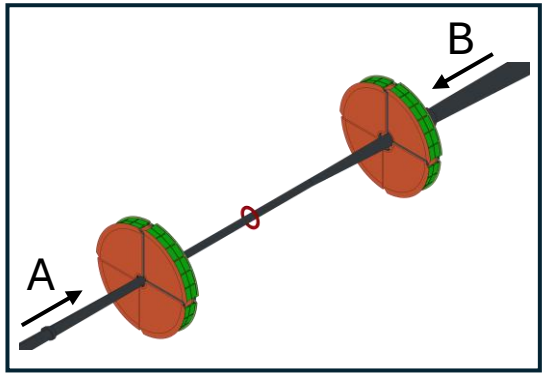
# Arrangement of the Quadrants




**3 quadrant designs overall:**

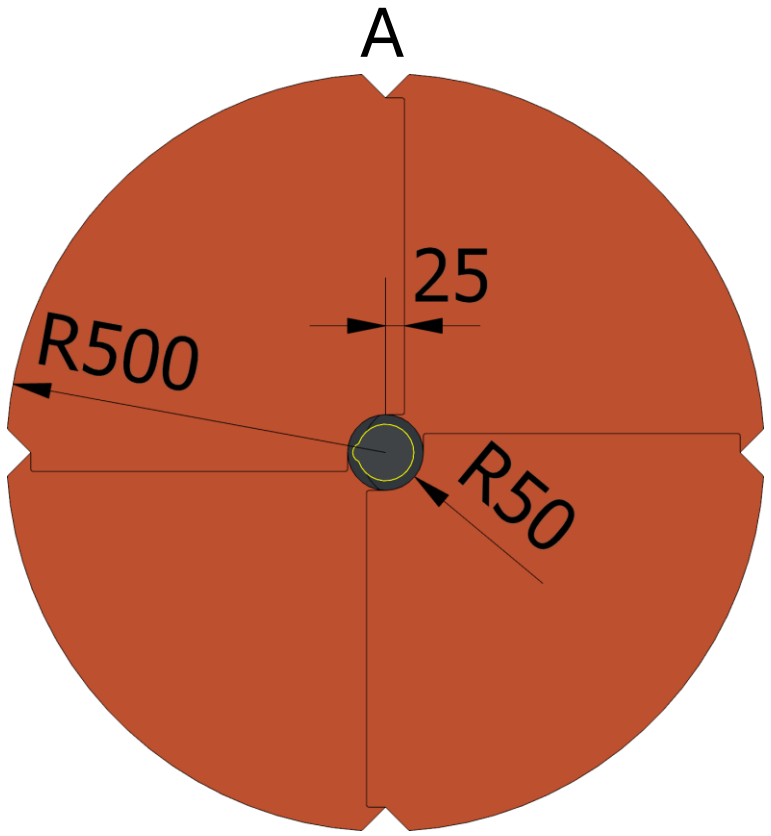
Electron side

1 design → 8 quadrants

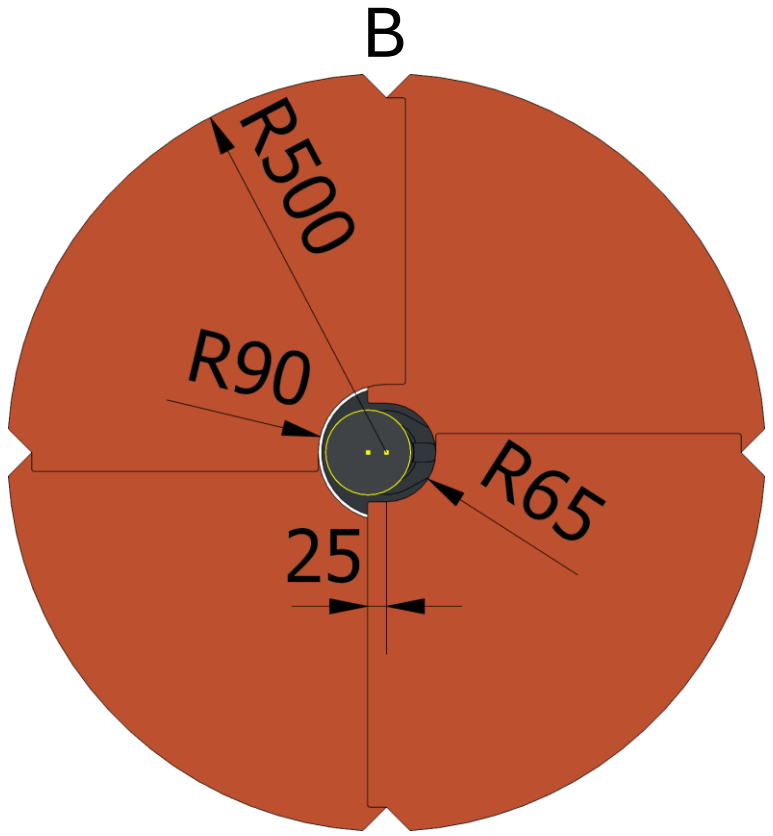
Hadron side

2 designs → 4 + 4 quadrants

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




**WEST/ELECTRON/BACKWARD SIDE**

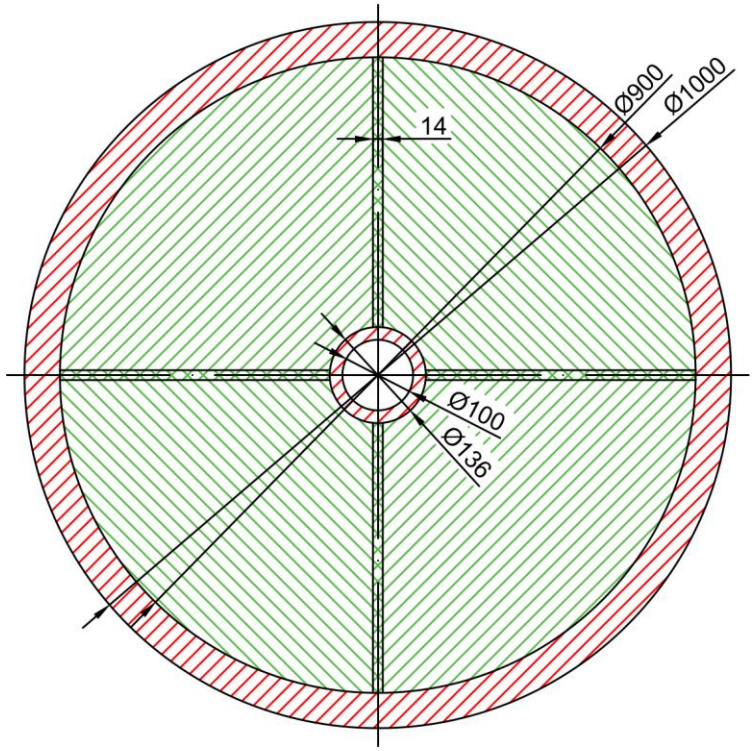



**EAST/HADRON/FORWARD SIDE**

*Further details and AA coverage in the backup

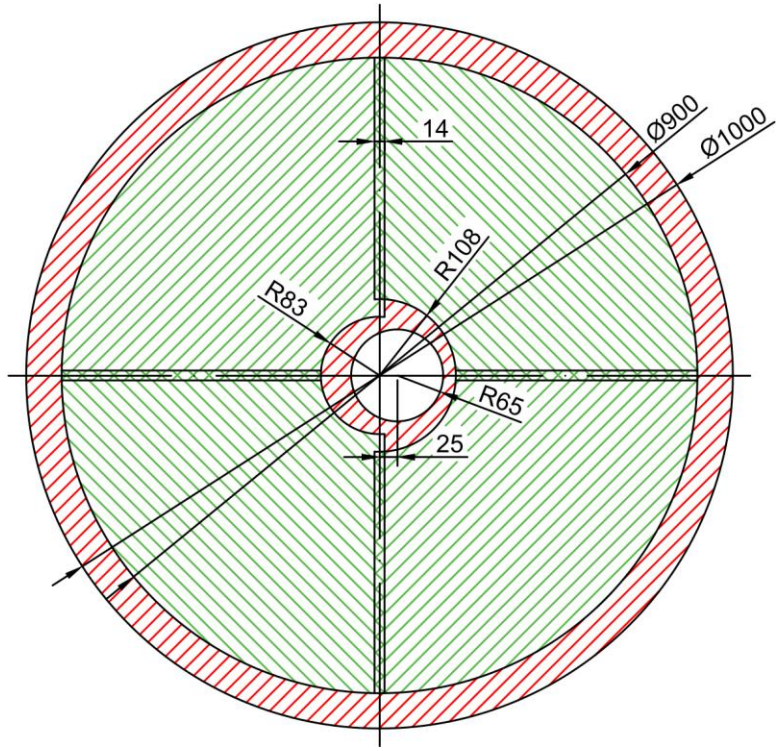
# Active Area Coverage

WEST/ELECTRON/BACKWARD SIDE



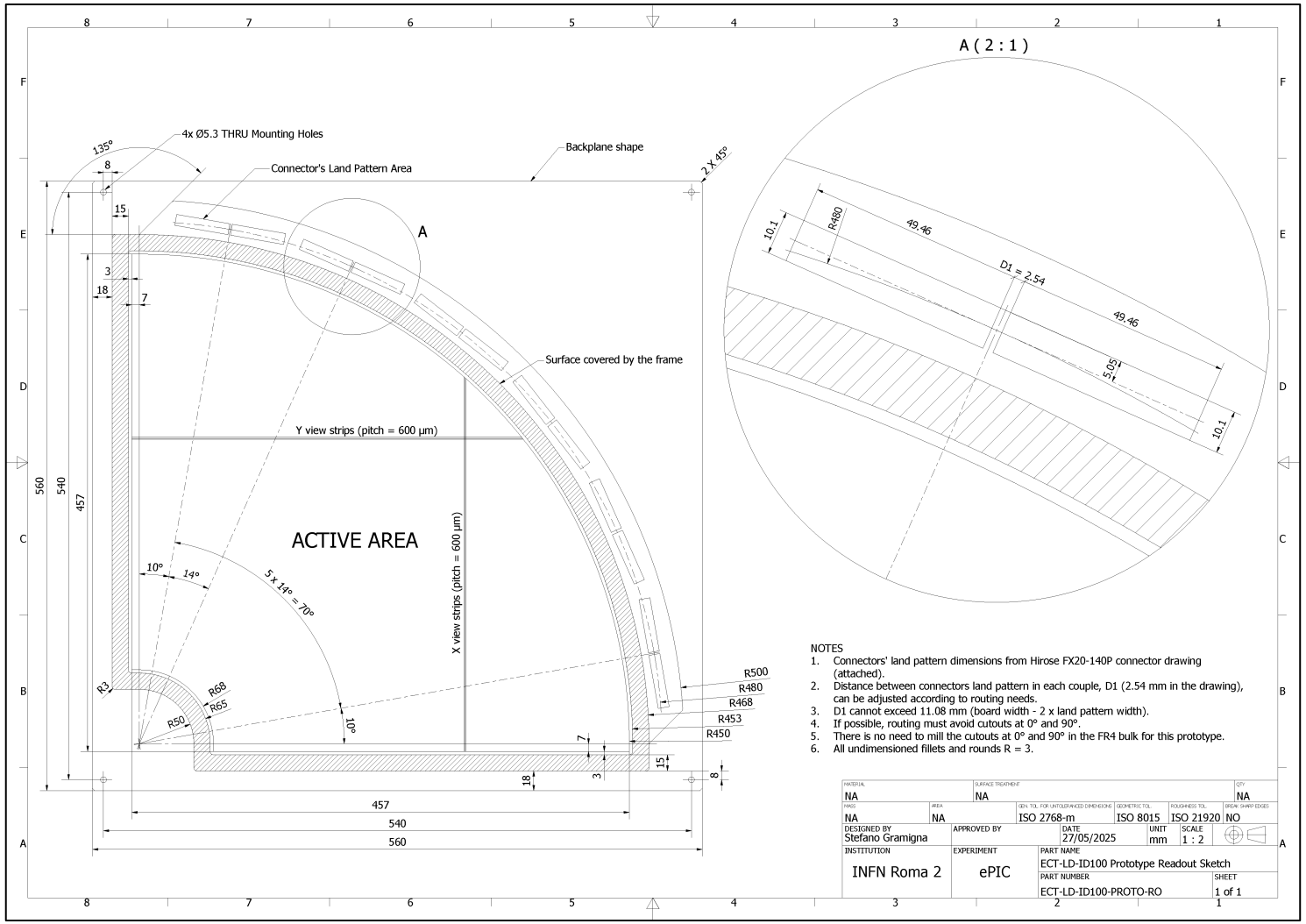

**79,95% envelope coverage**
**-1,72 > η > -3,46**

EAST/HADRON/FORWARD SIDE

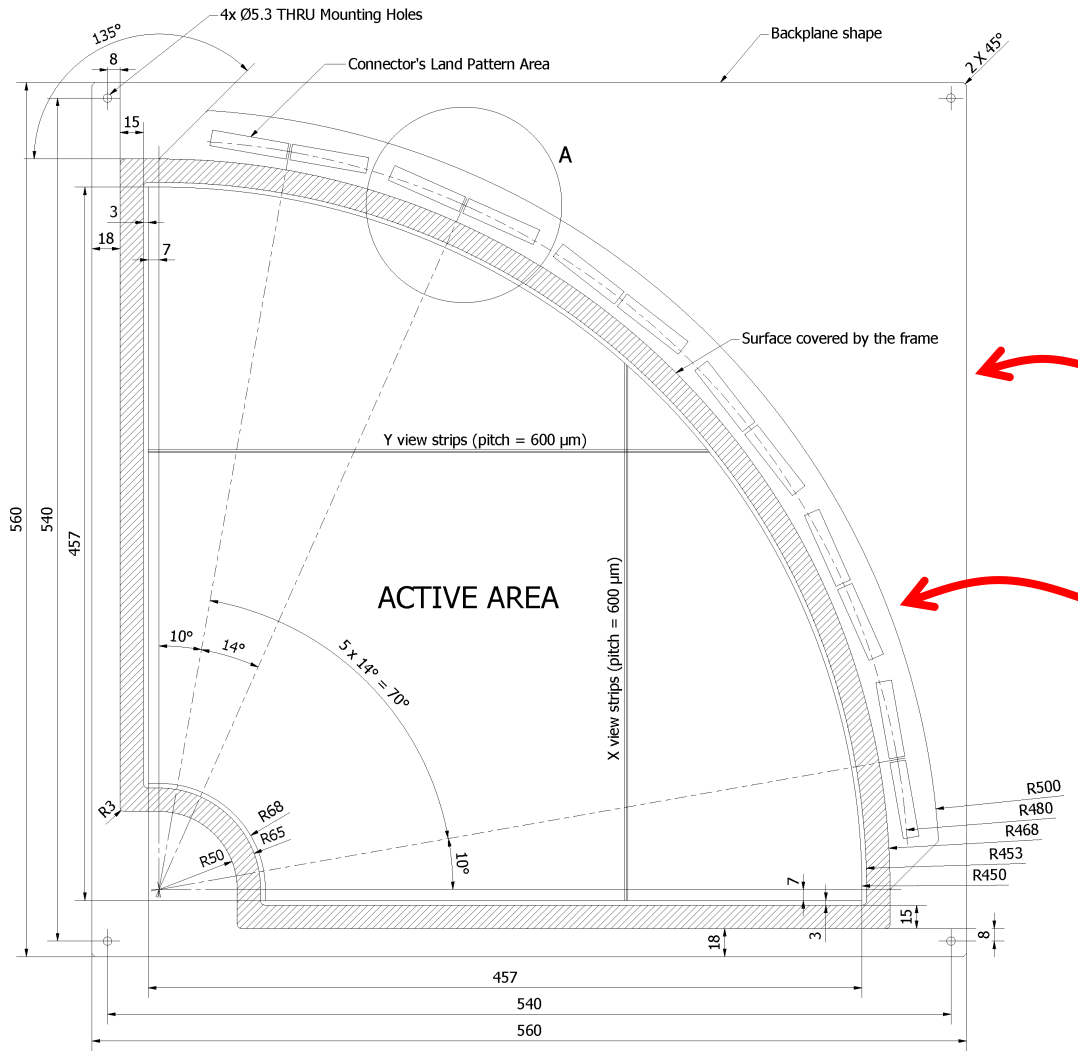



**78,62% envelope coverage**
**2,01 < η < 3,59/3,33**

# Complete ETA R/O Sketch



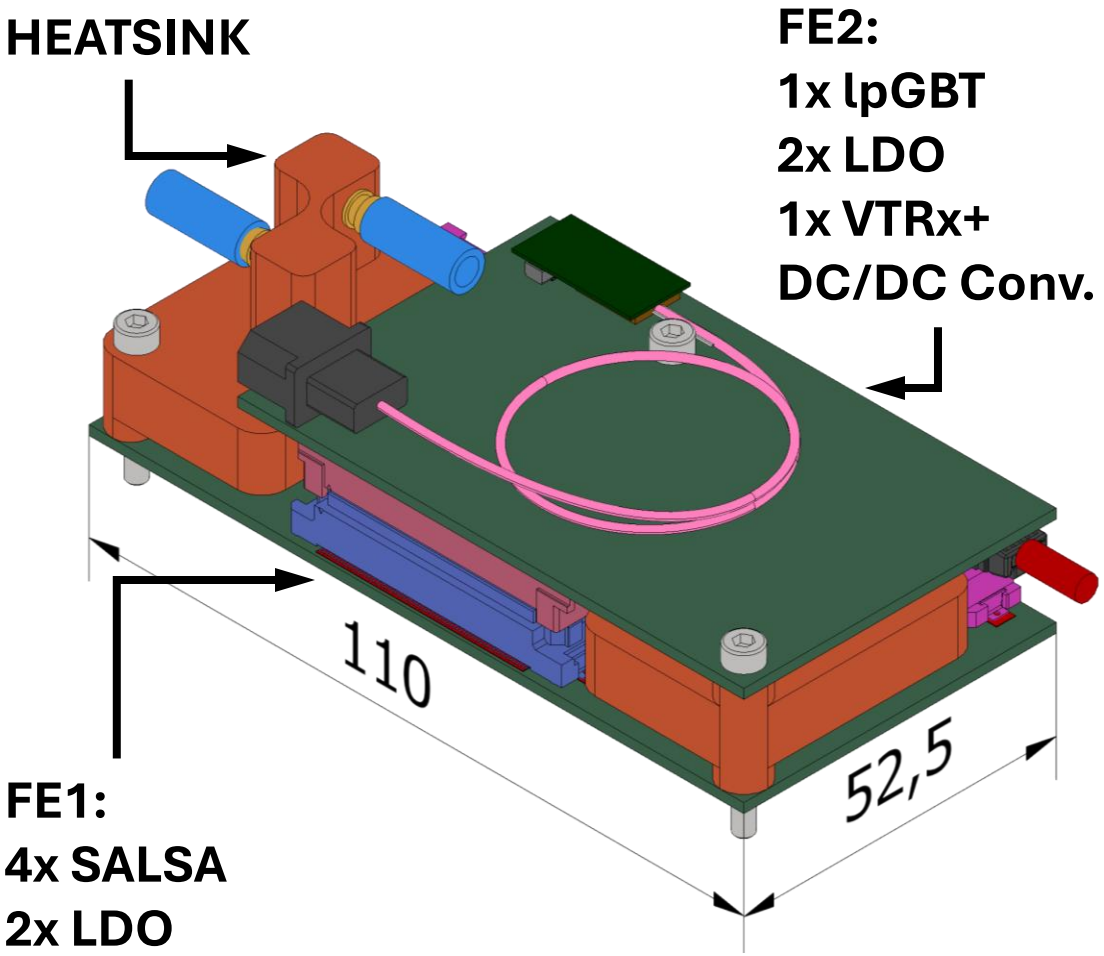
# R/O Sketch, Our Input for CERN

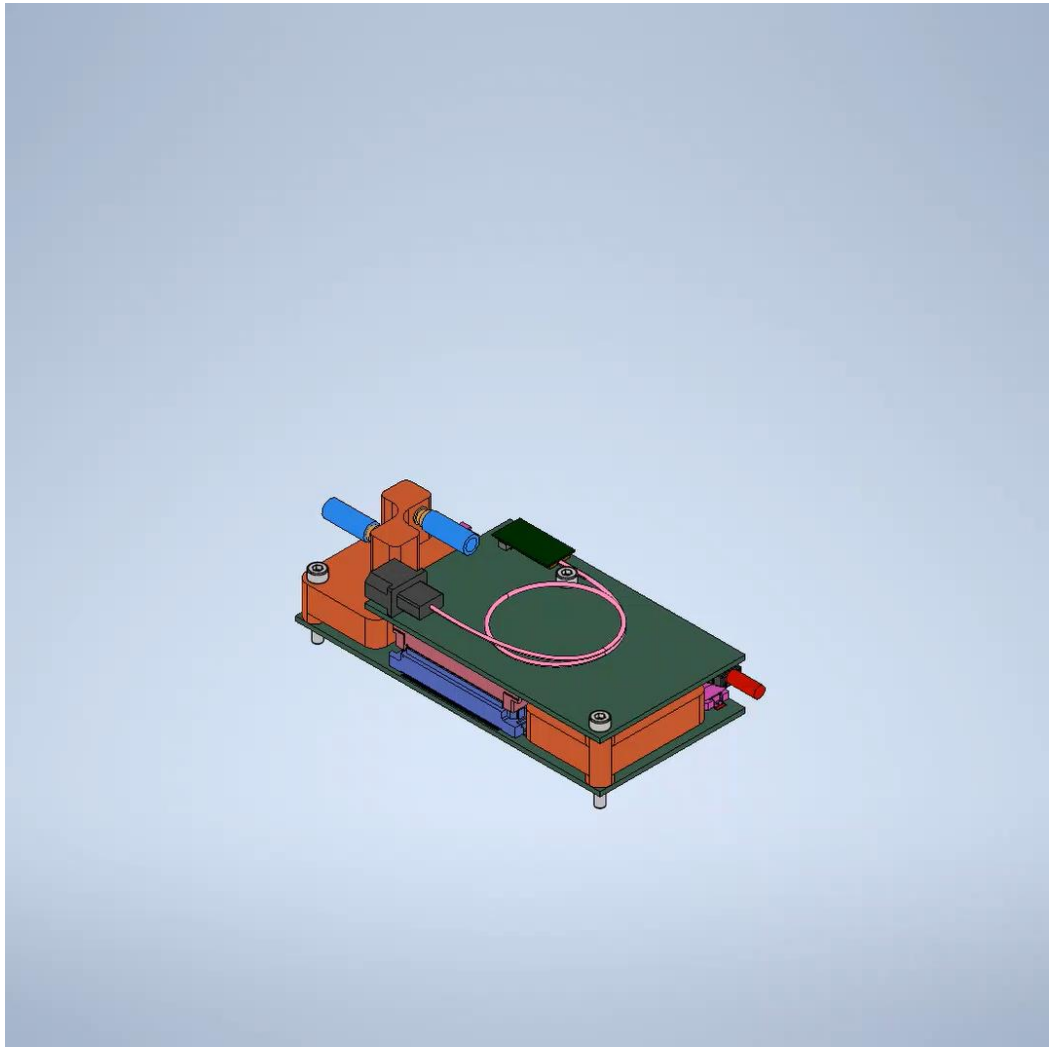



Defined ETA PCB shape and mounting interfaces

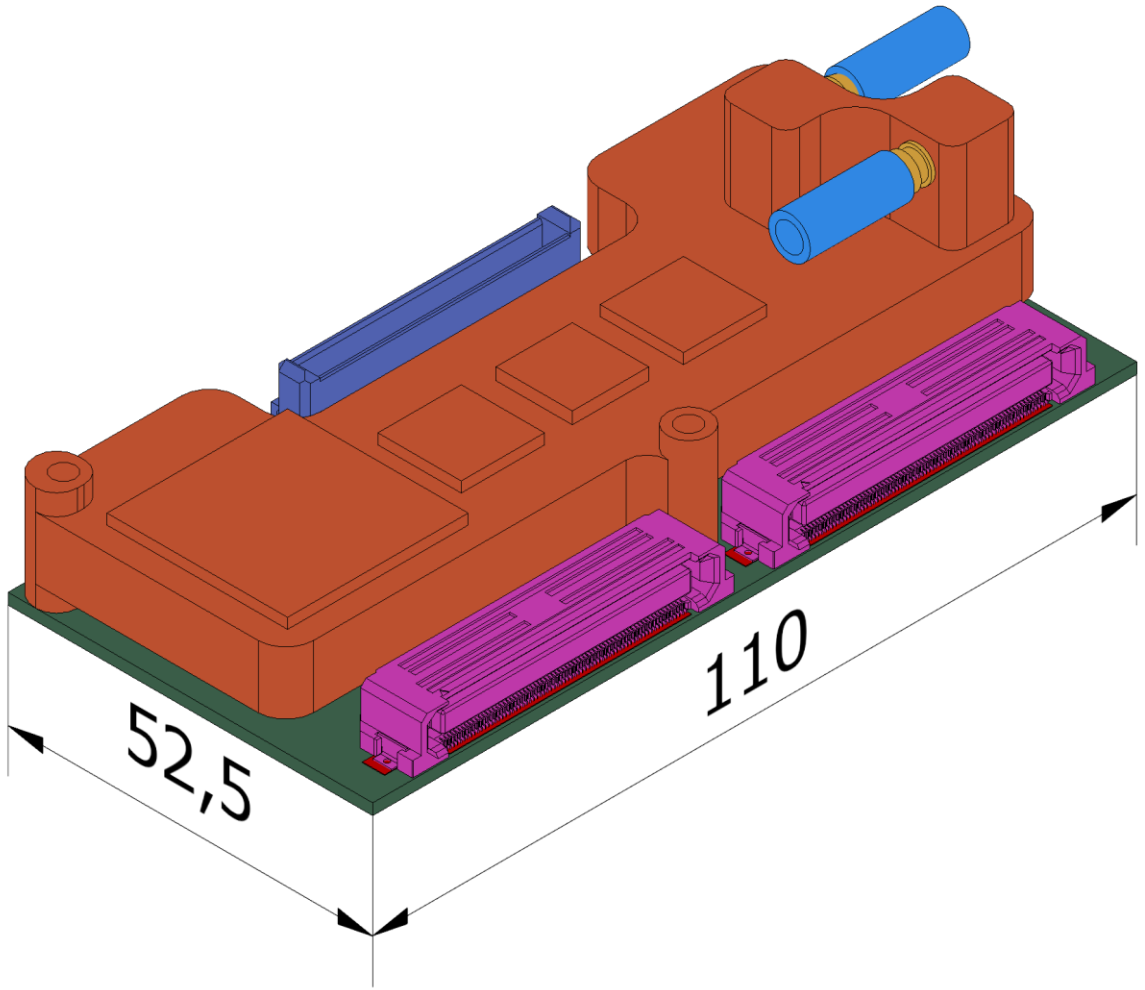
Convenient form factor for testing, routing/services still constrained by ECT final shape

# New FEB Model



# Cooling Strategy

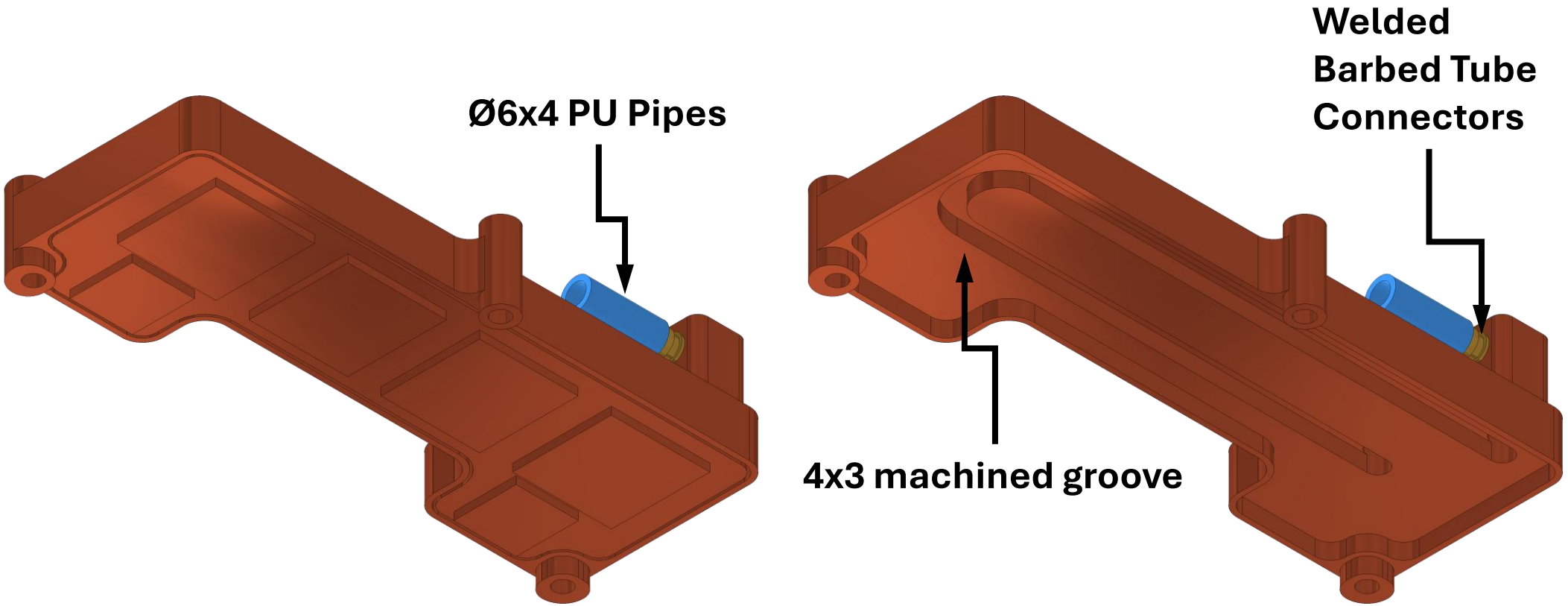



All 5 **heatsinks** in a module **connected in series** with pipes running close to the outer rim

No. **2 Ø6x4 PU pipe per module** as inlet/outlet for the cooling chain

All major heat sources are mounted on the top/bottom face of FE1/FE2 to face the heatsink

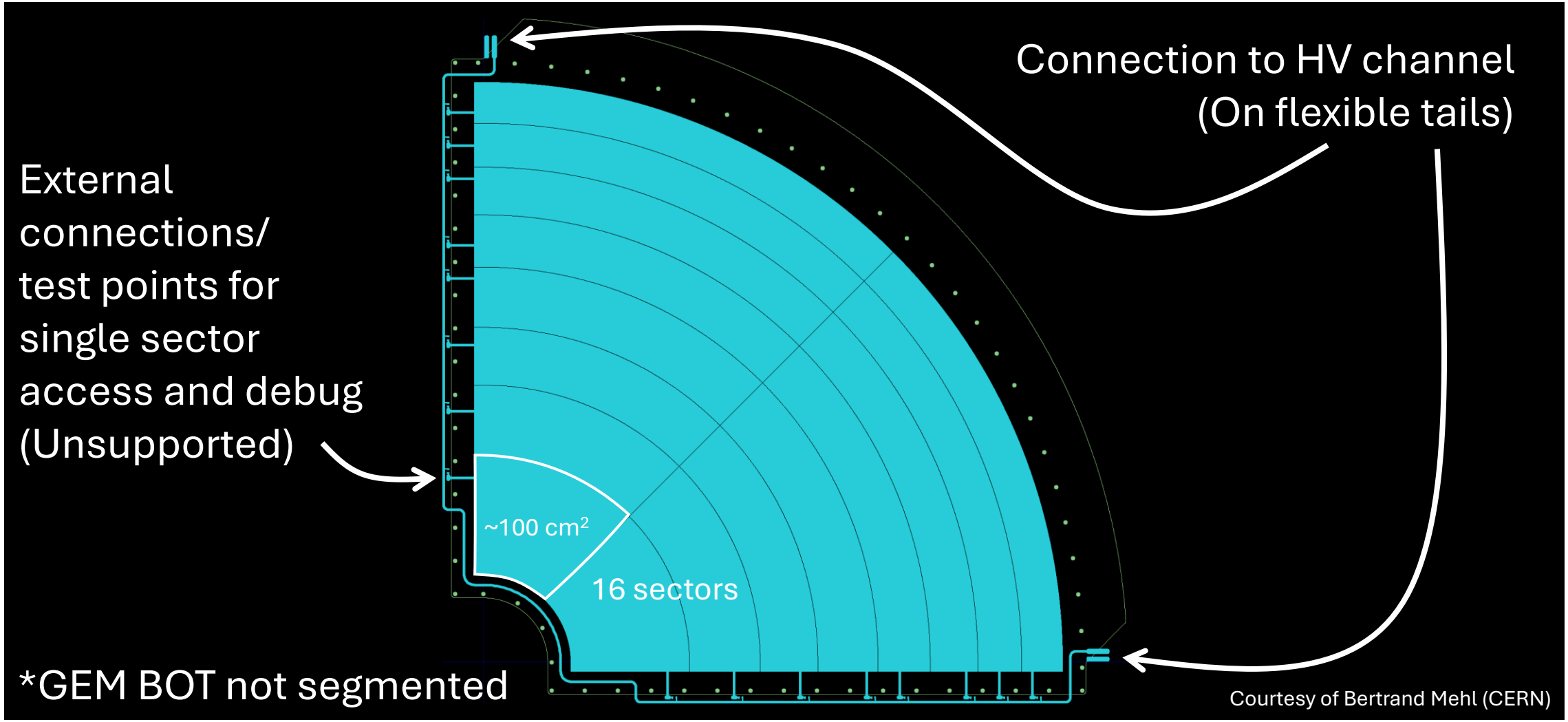
# Heatsink



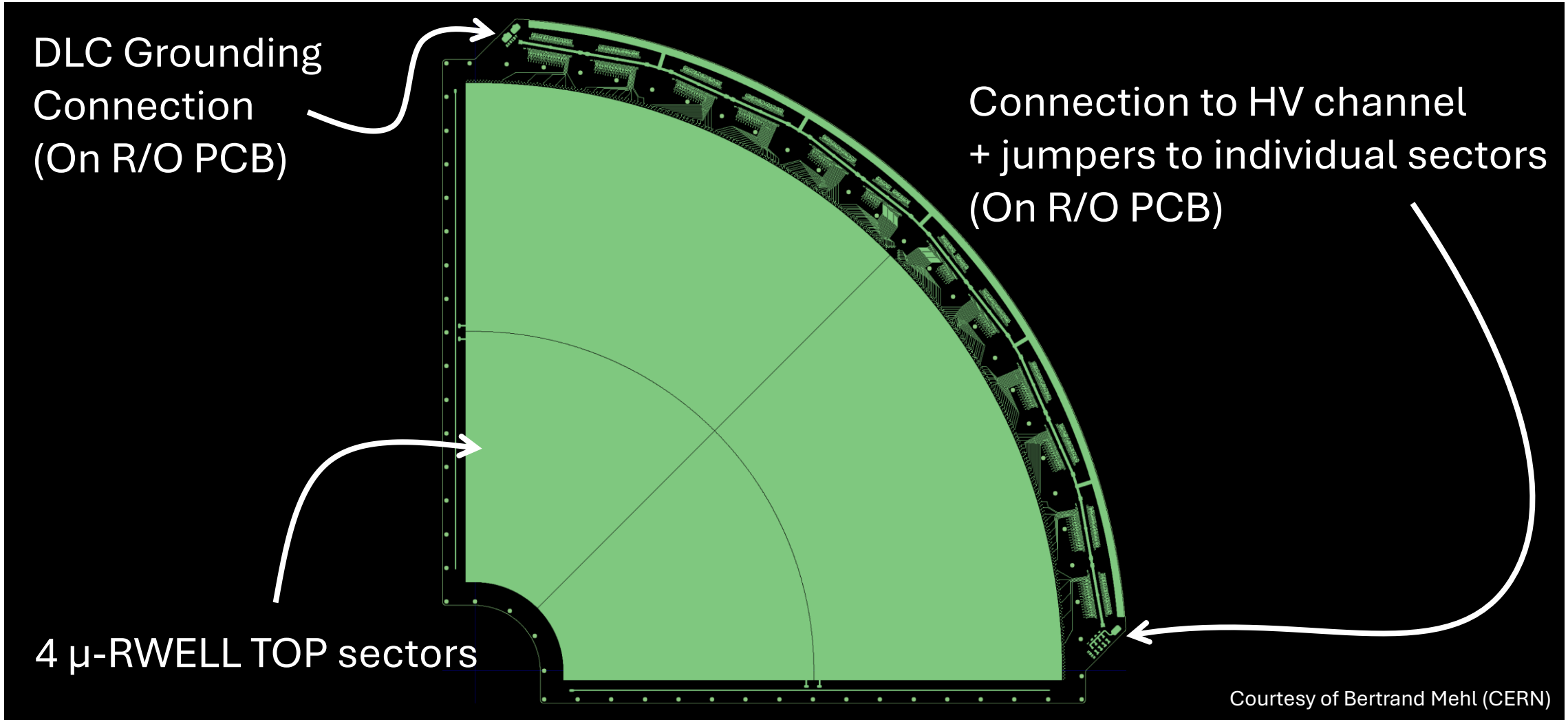

**Preliminary** proposal, no simulation has been run yet

Quite **bulky and difficult to manufacture** → We will be working on **alternative cooling solutions**

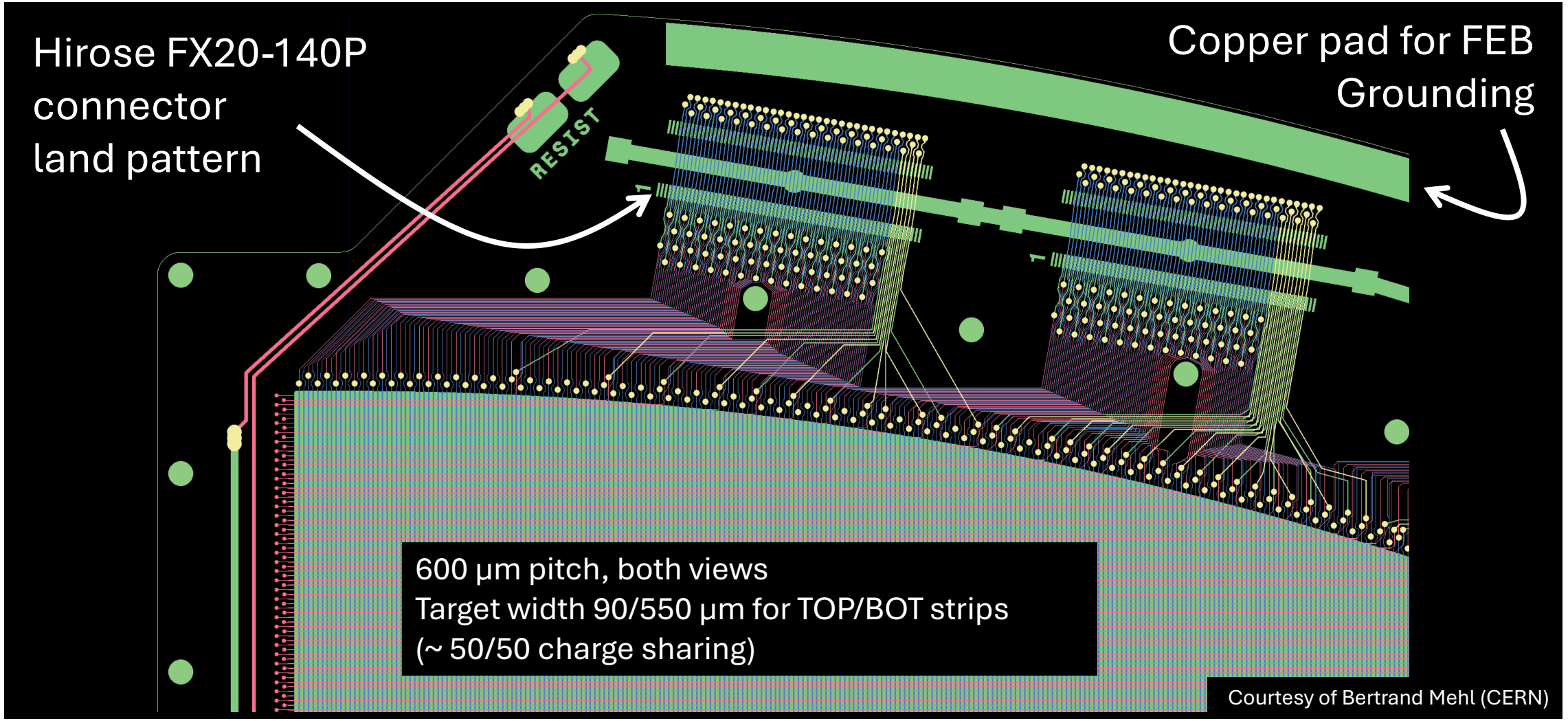
# GEM Sectorization



# μ-RWELL Sectorization



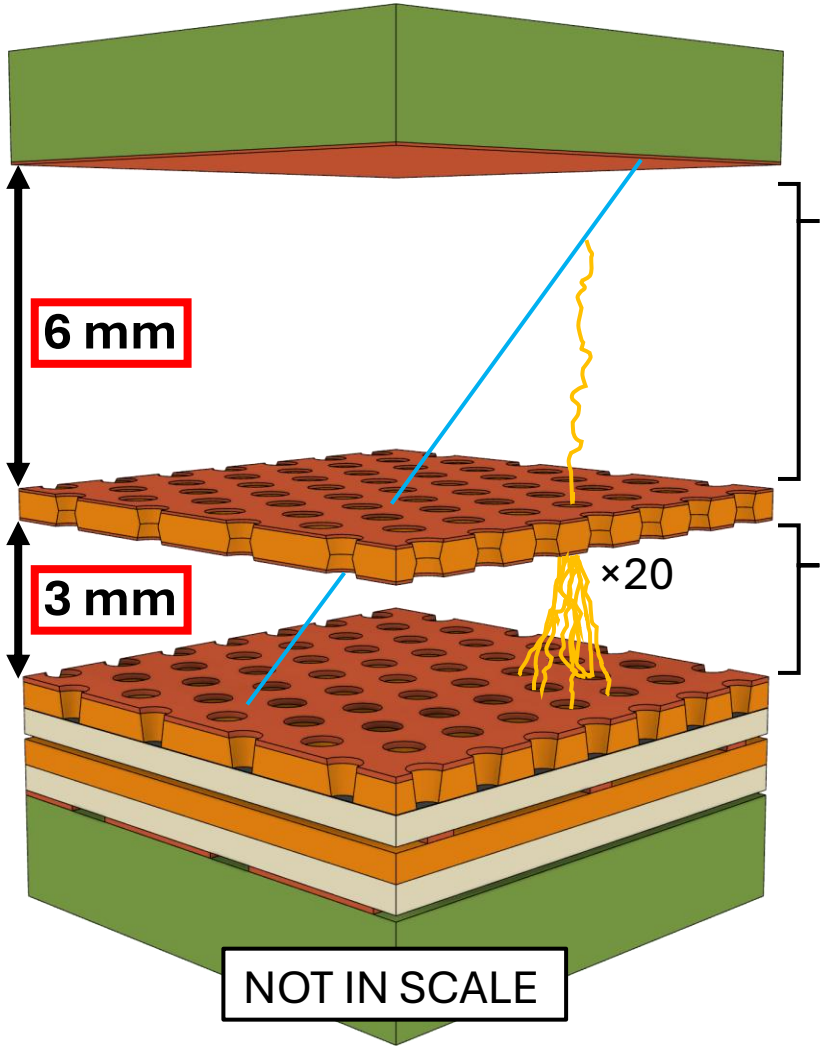
# Strip Routing Detail



# 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

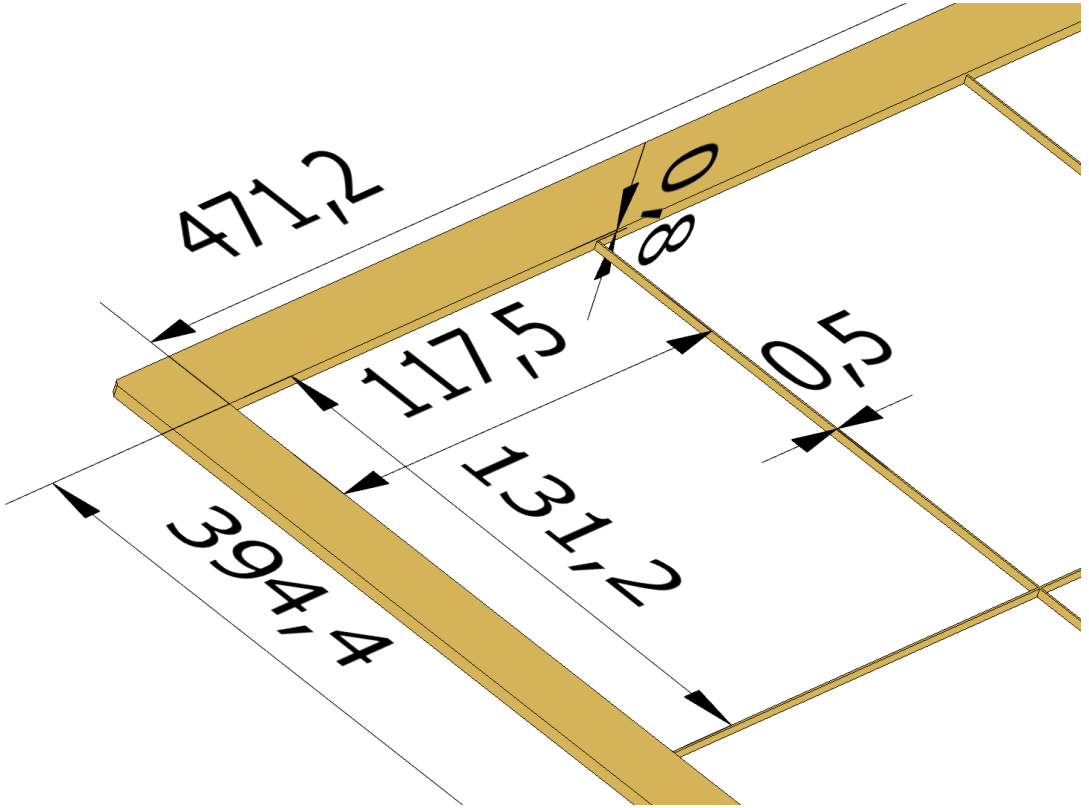
**R/O**
2D strip layout, 600 μm pitch
~ 3 mm lightweight support

# Spacer Grid Materials and Dimensioning

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

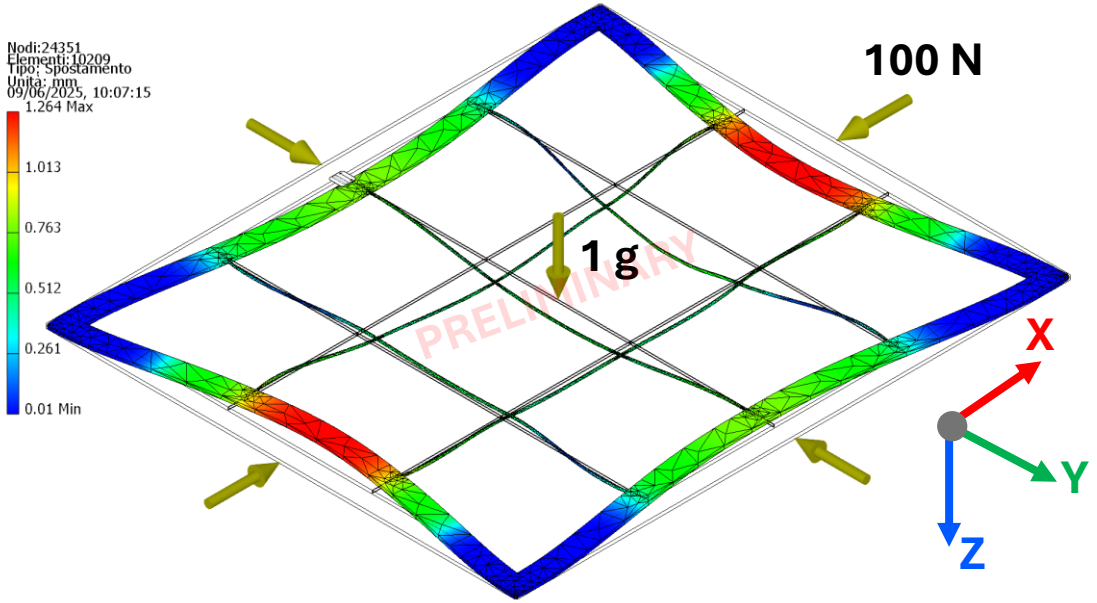
PEEK was the initial candidate for frame production, now **switched to Permaglas ME730** (Durostone EPM 203)

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

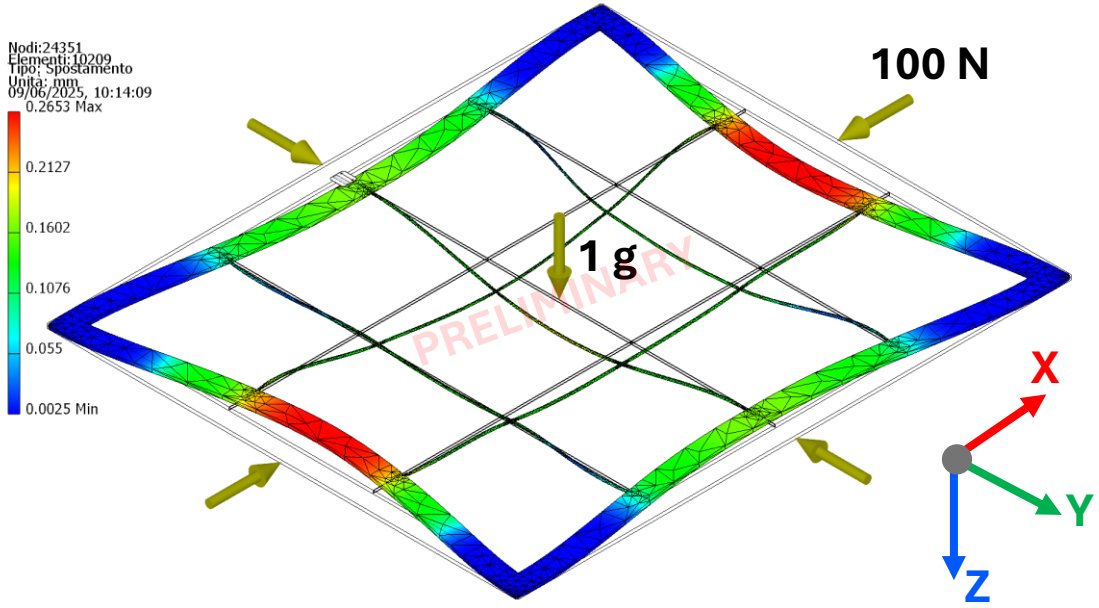


# FEA Results

## 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**

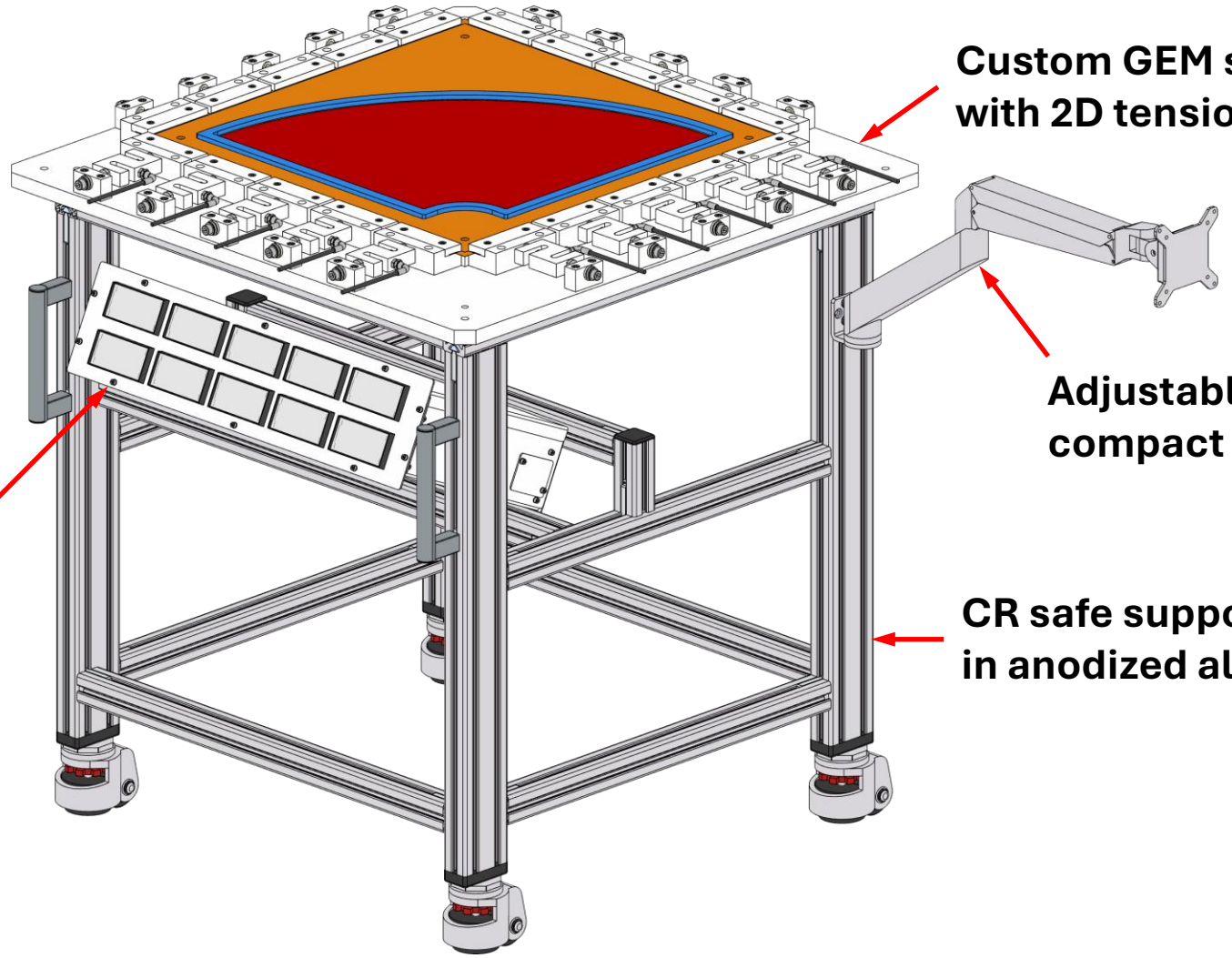
# Summary of Tested Configurations (PEEK)

| 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**

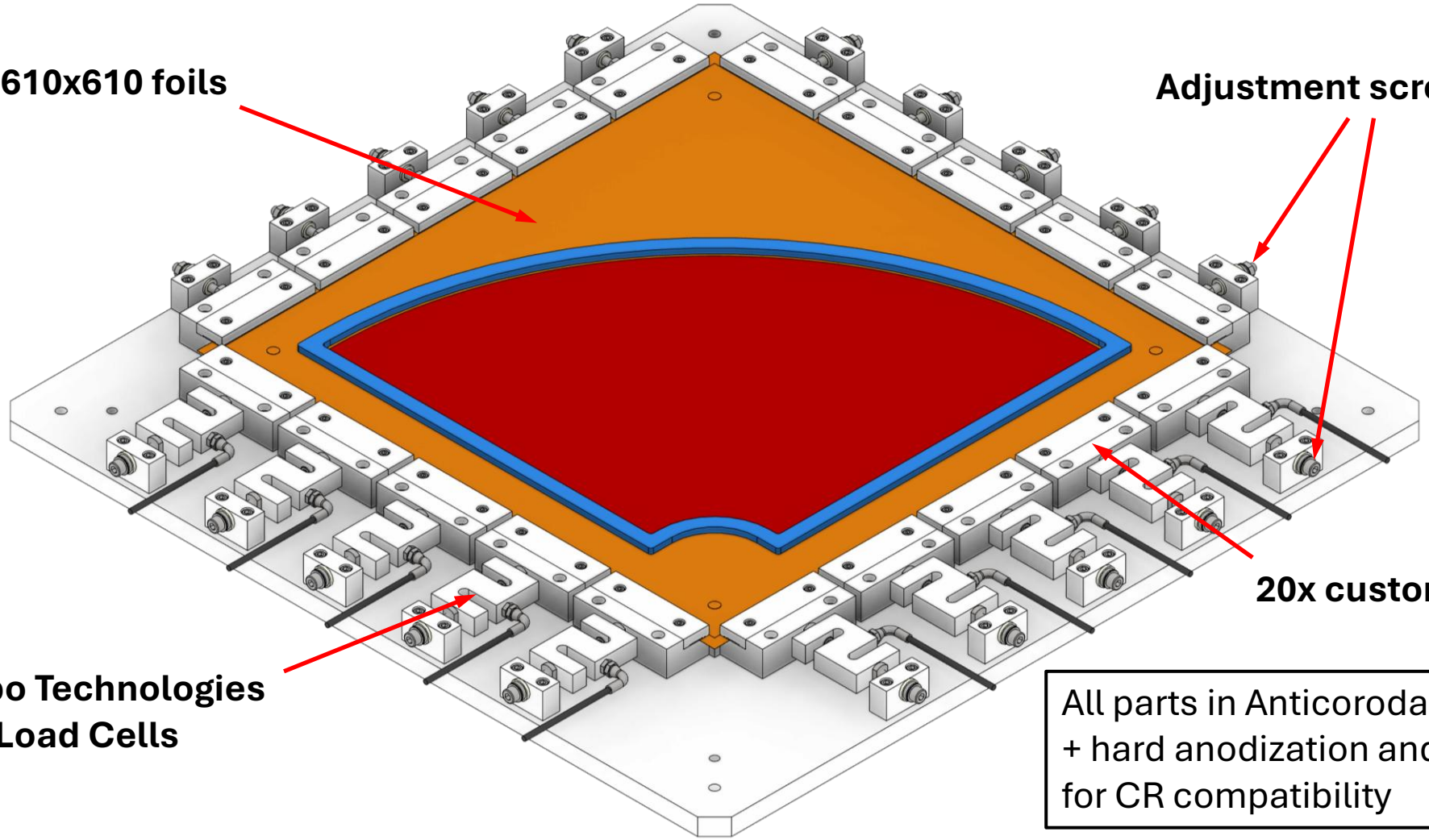
**Adjustable monitor arm for compact operator interface**

**Custom module for load cell R/O**

**CR safe support structure in anodized aluminum**

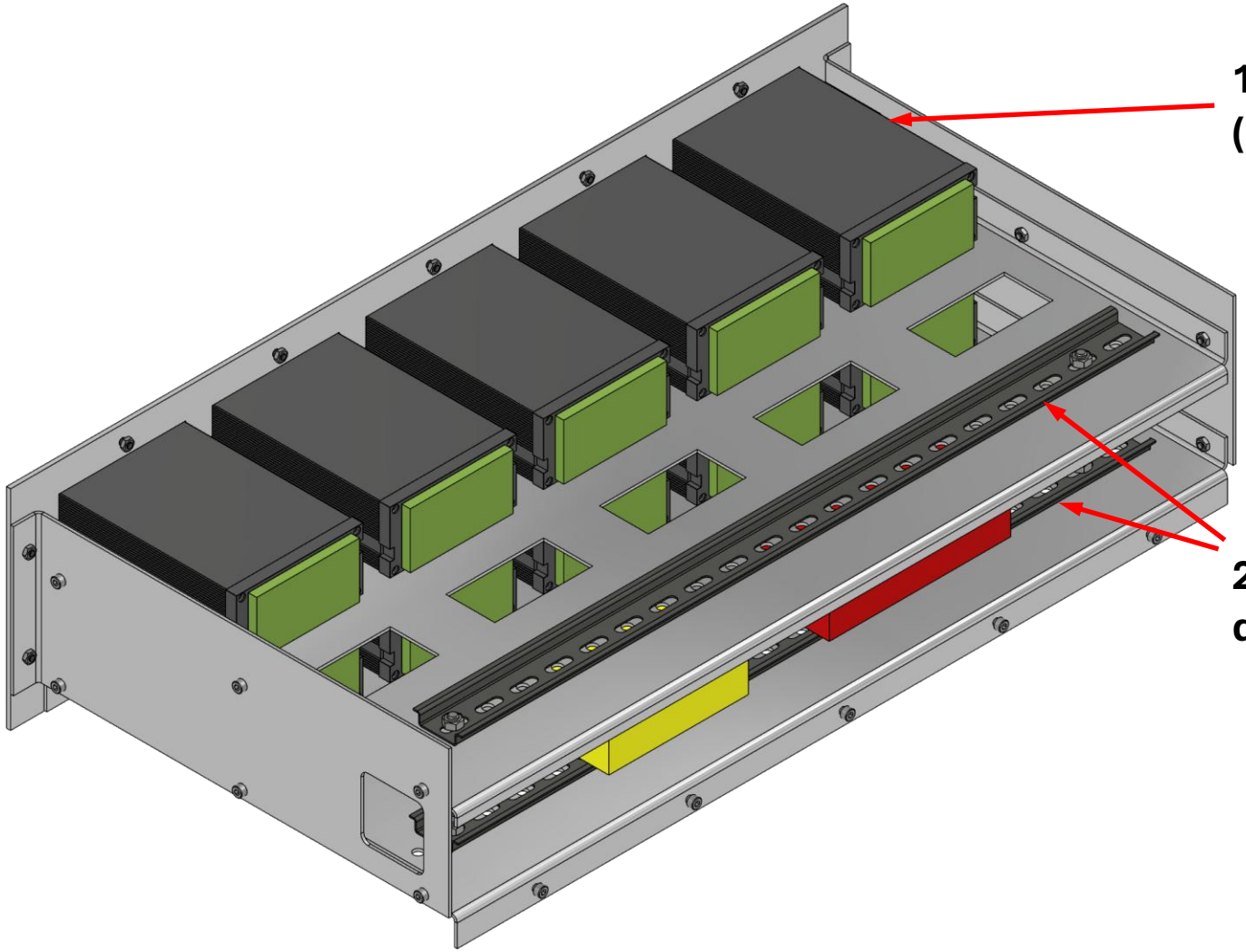

Stefano Gramigna - sgramigna@roma2.infn.it

# 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

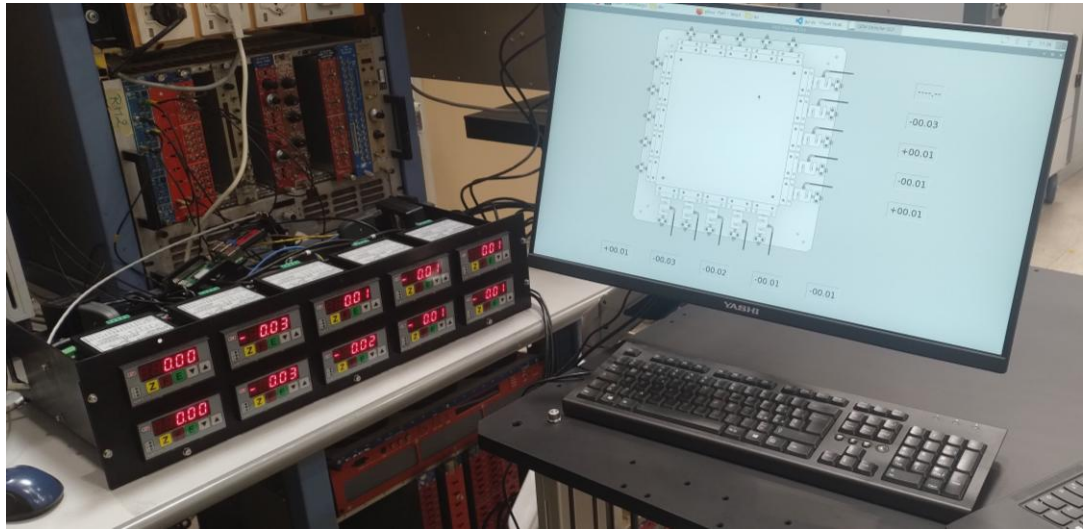


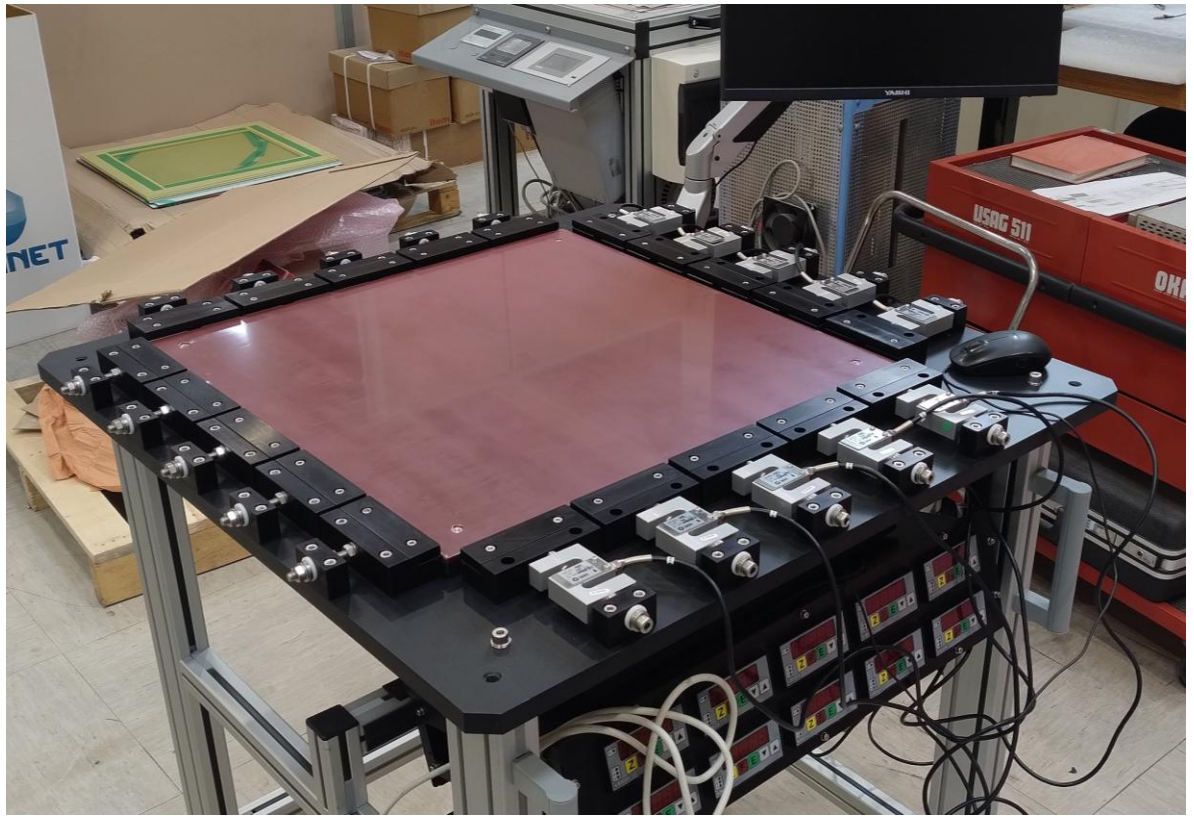
**10x Picotronik PS30 digital indicators (load cell R/O and serial communication)**

**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

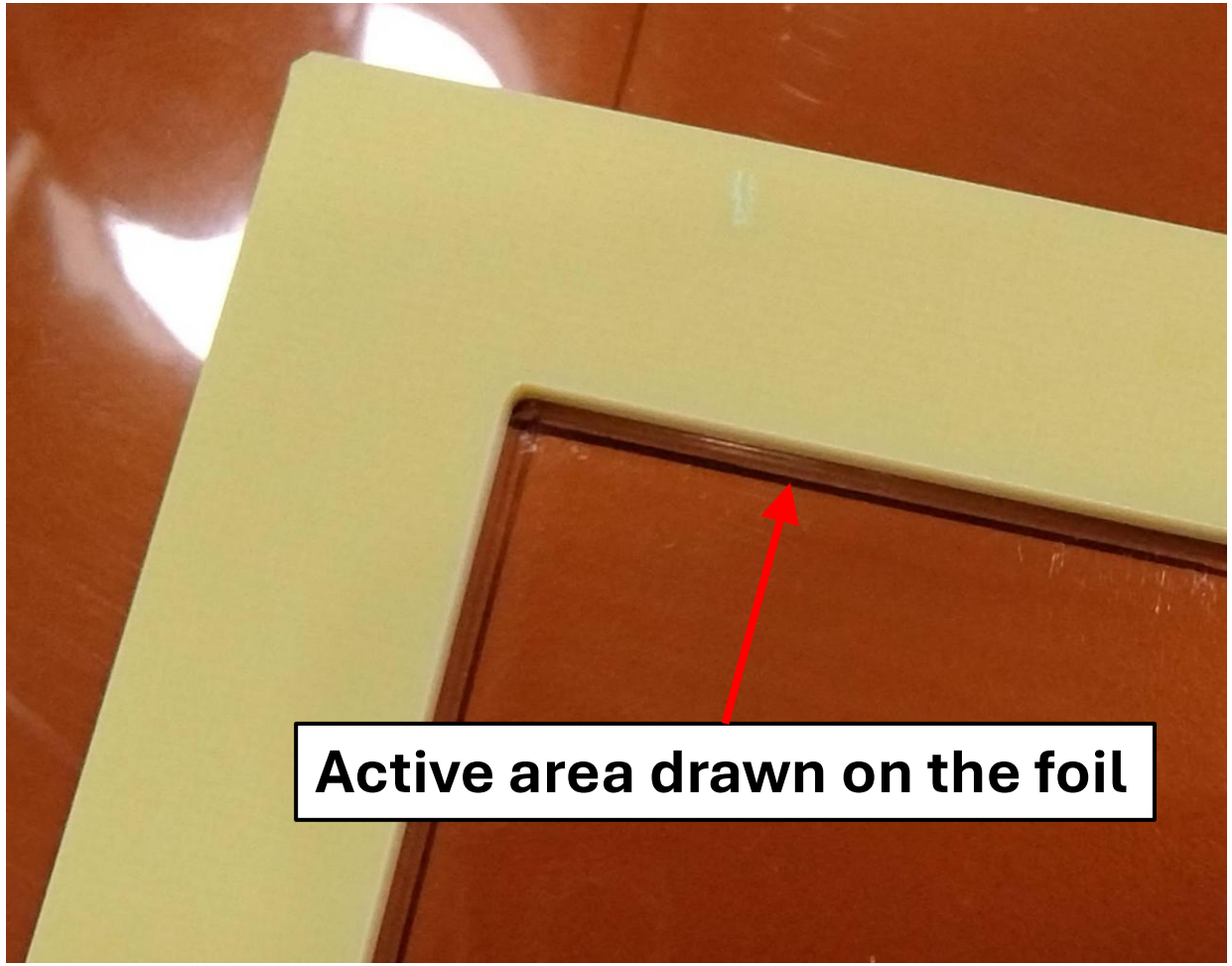
# GEM Stretcher Assembly

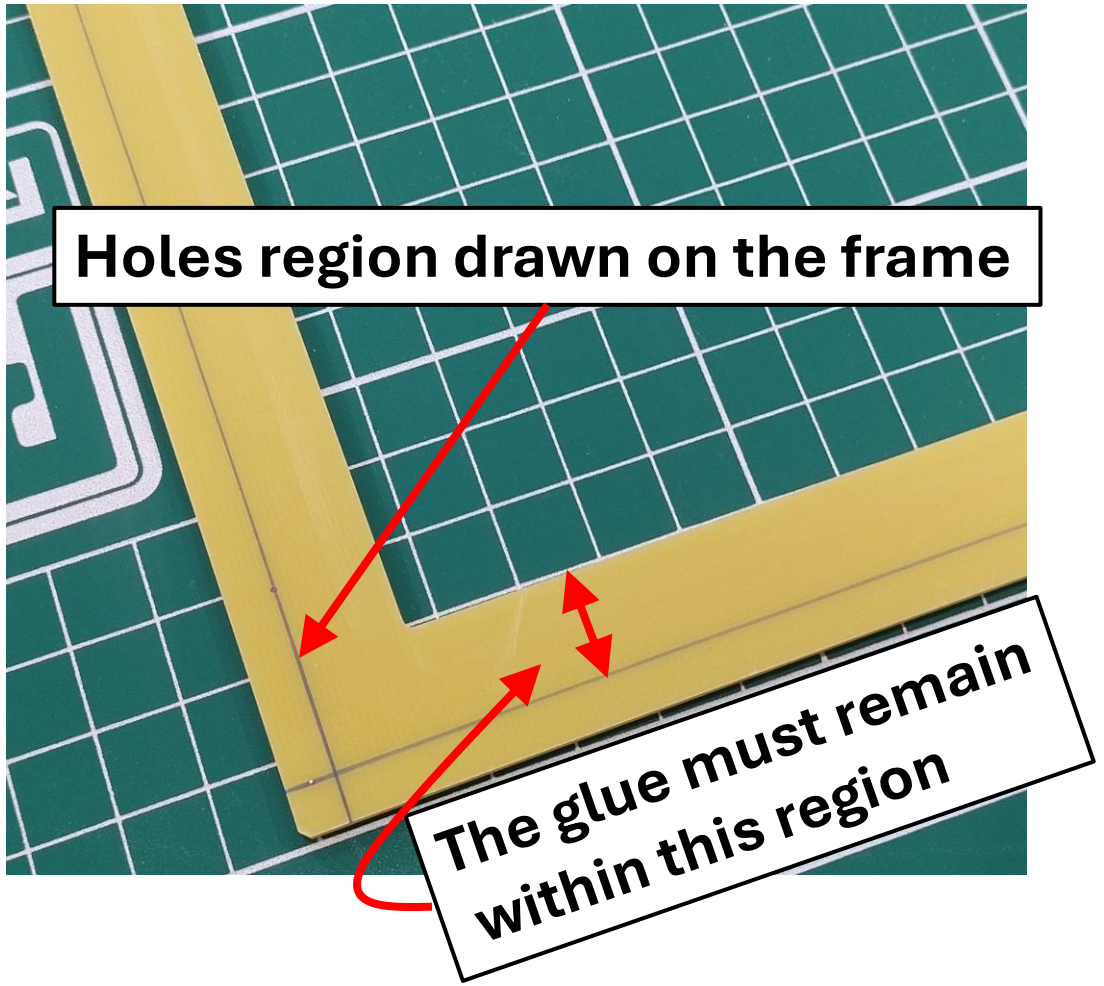




AMCO
ATTREZZATURE MECCANICHE E AUTOMAZIONE

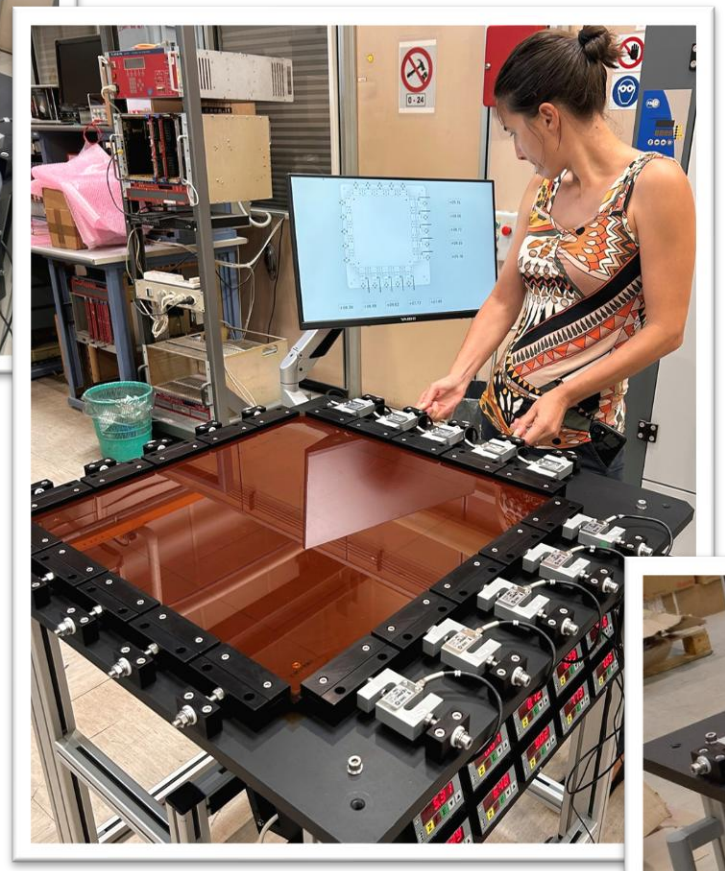
# Sample preparation



# Stretching

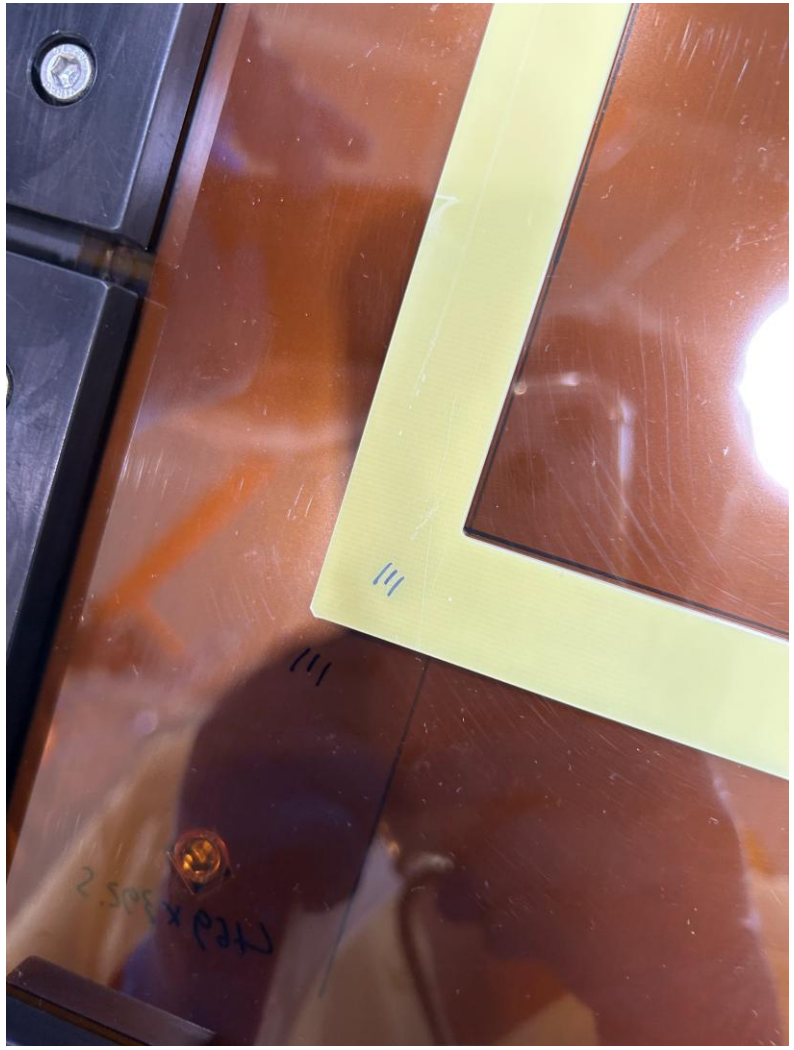

**BEFORE**



12 kg initial tension to have
10 kg after curing

**AFTER**

# Dry Test



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

- Mark corners and edges
- Place reference silicone pads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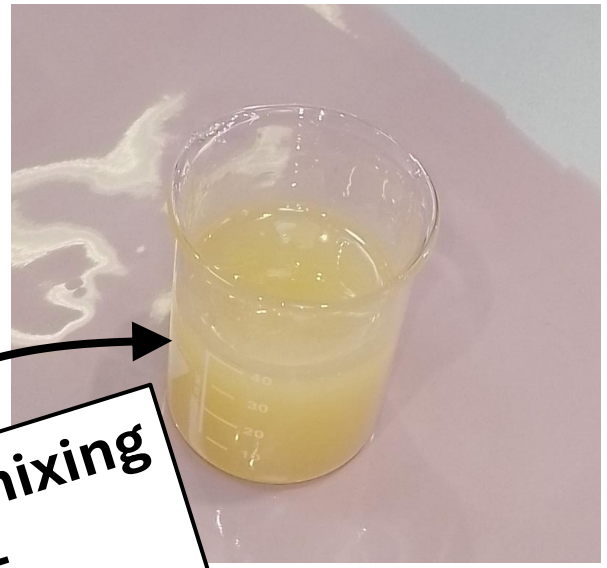
# Glue Preparation

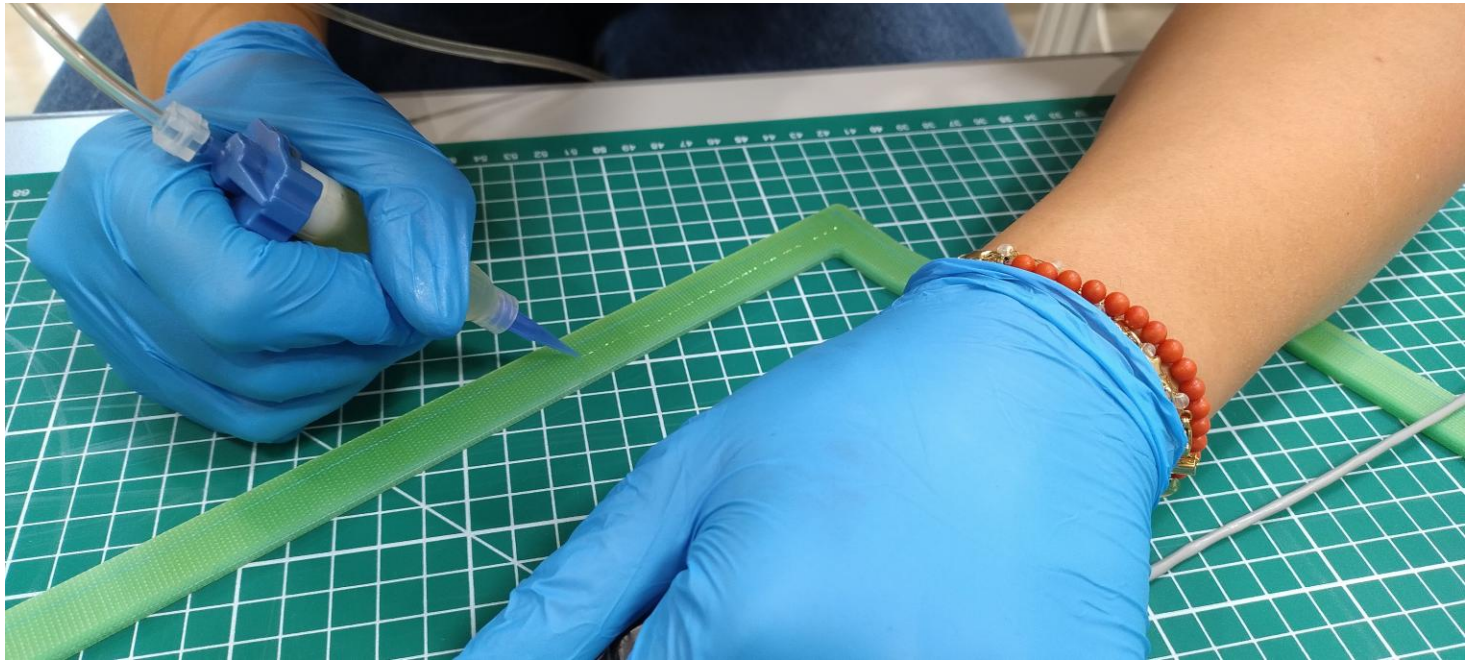



After mixing
+
20’ rest

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

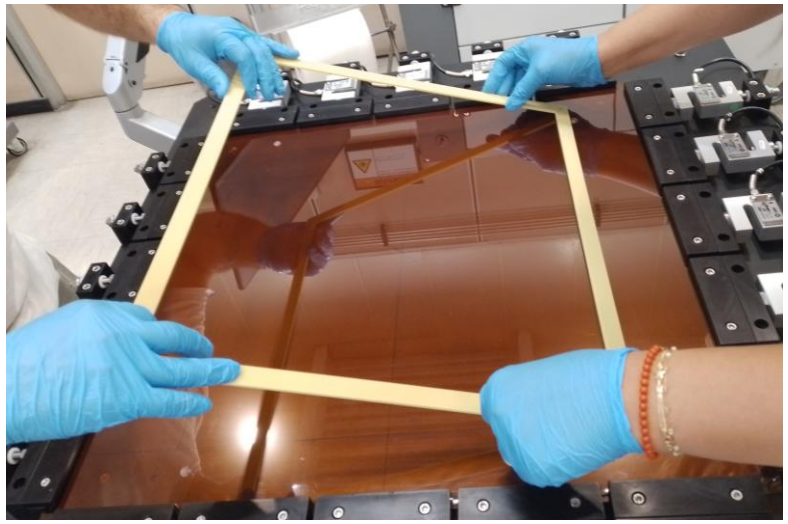


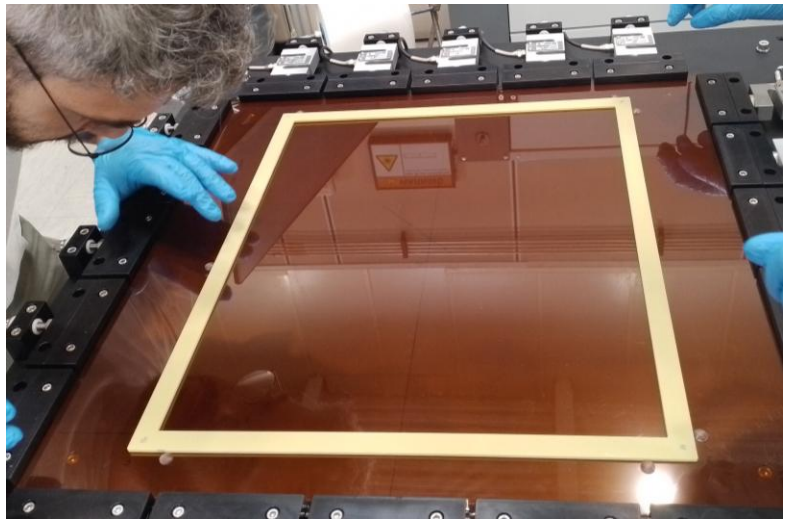
The glue is deposited in a thin line in the middle of the allowed region

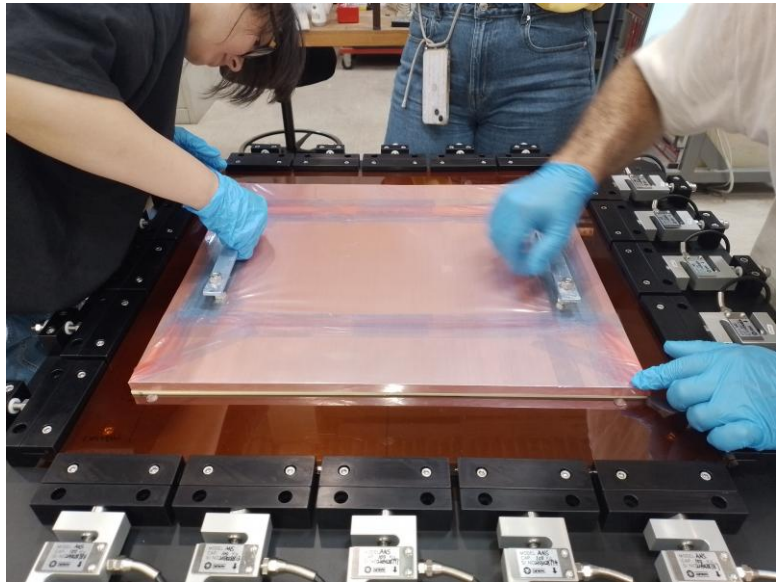
Needle gauges from 14 (1.6 mm) to 25 (0.254 mm) tested

Various pressures and dispensing times tested

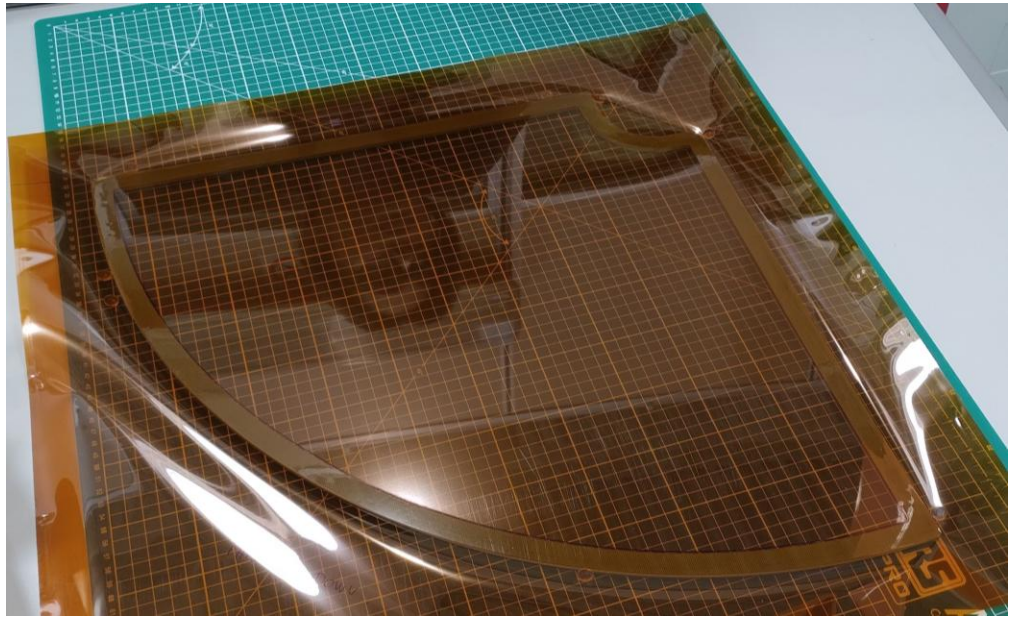
# Frame Placement

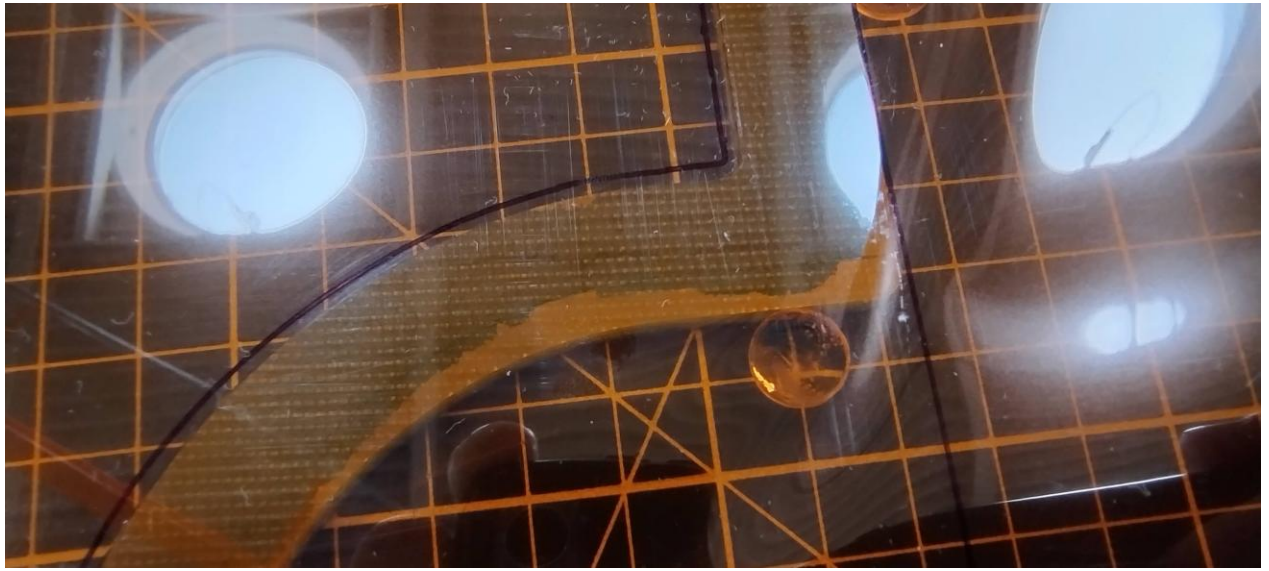


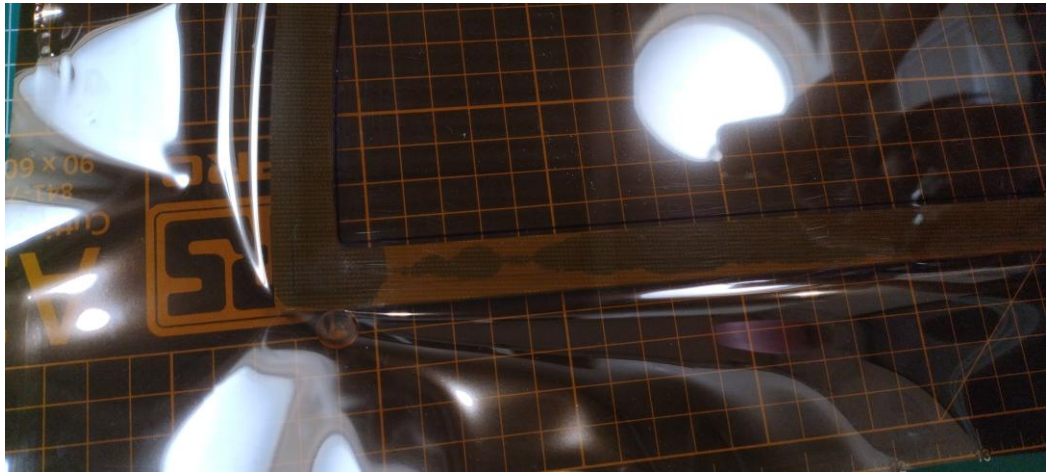




# Test Results





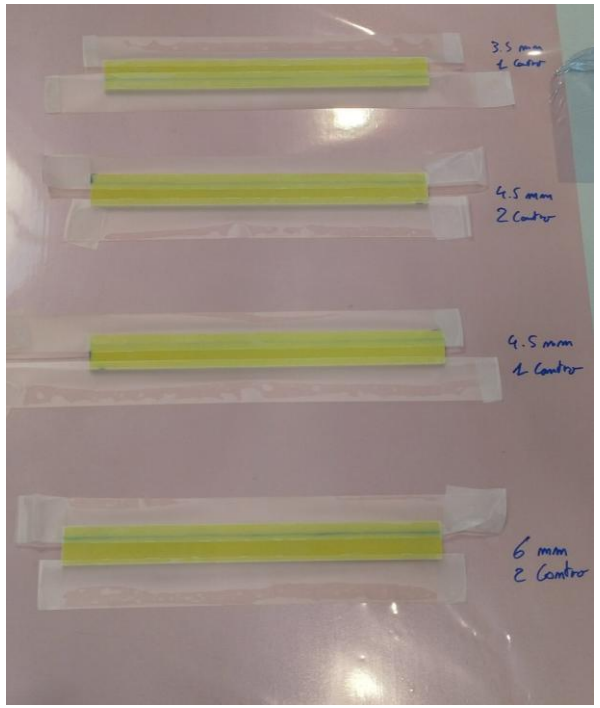


**Stretching** results are **satisfactory**

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

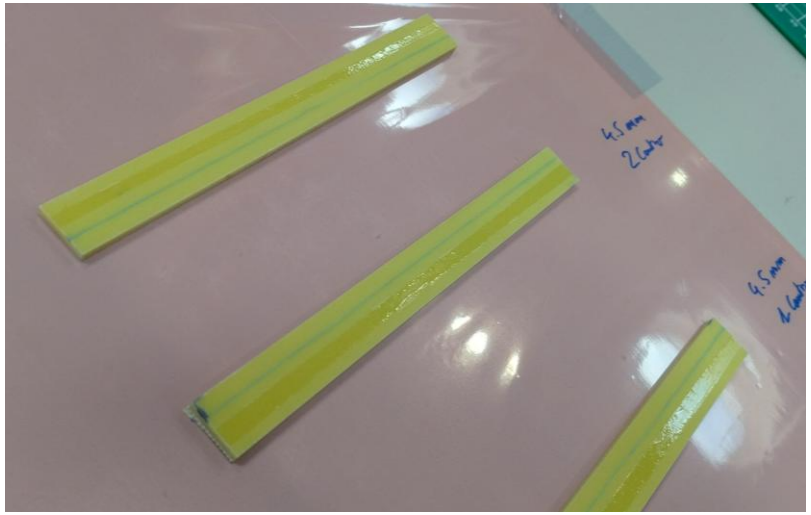


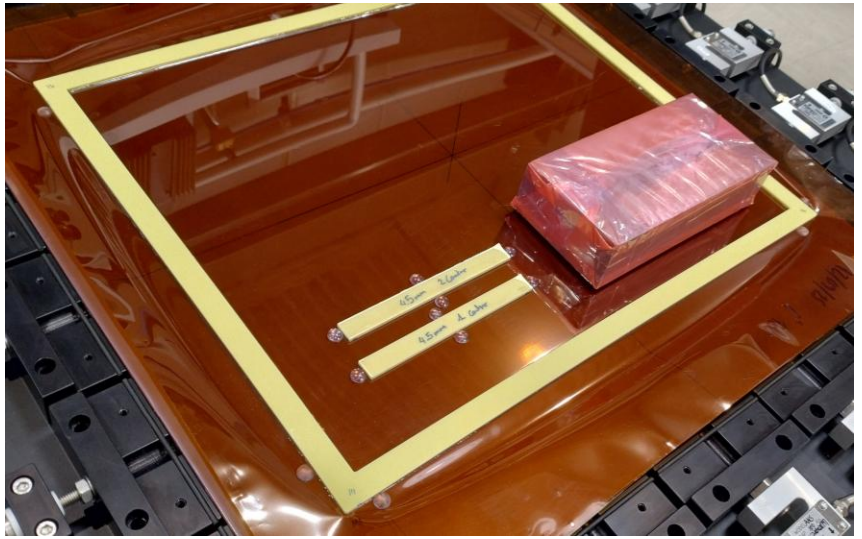

**Glue Transfer Technique**

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

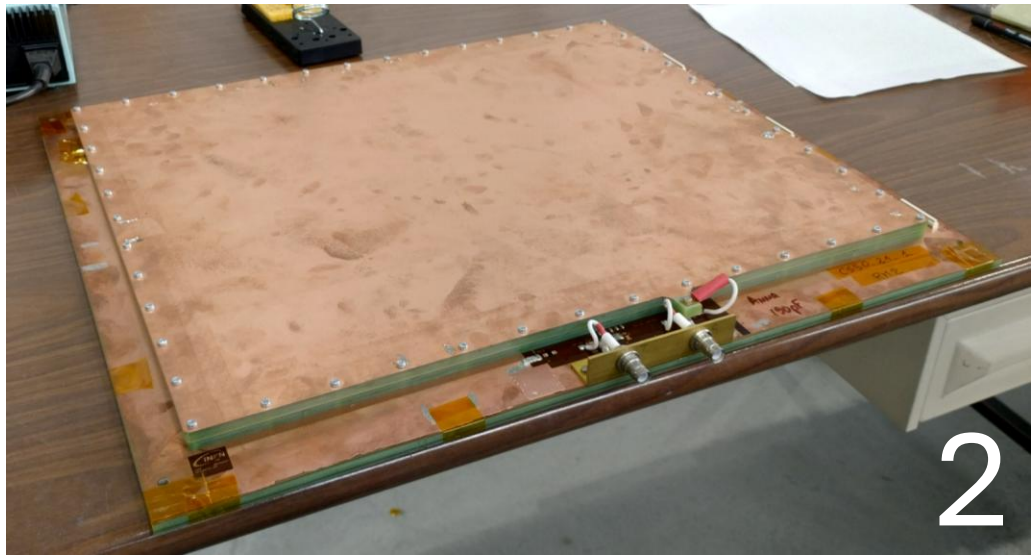
Downward force is applied during the curing period with lead weights



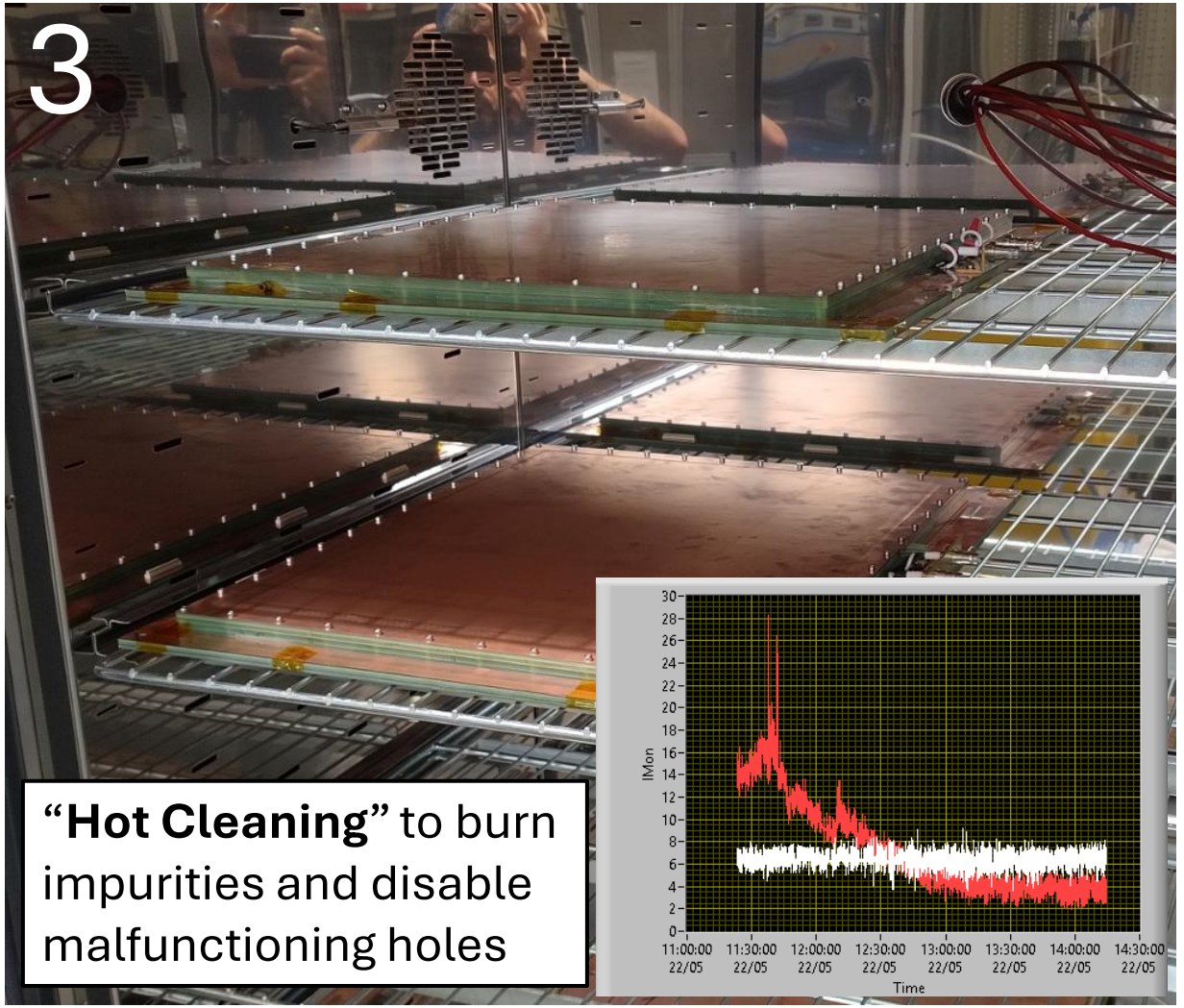



# Detector Commissioning Pt.1

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

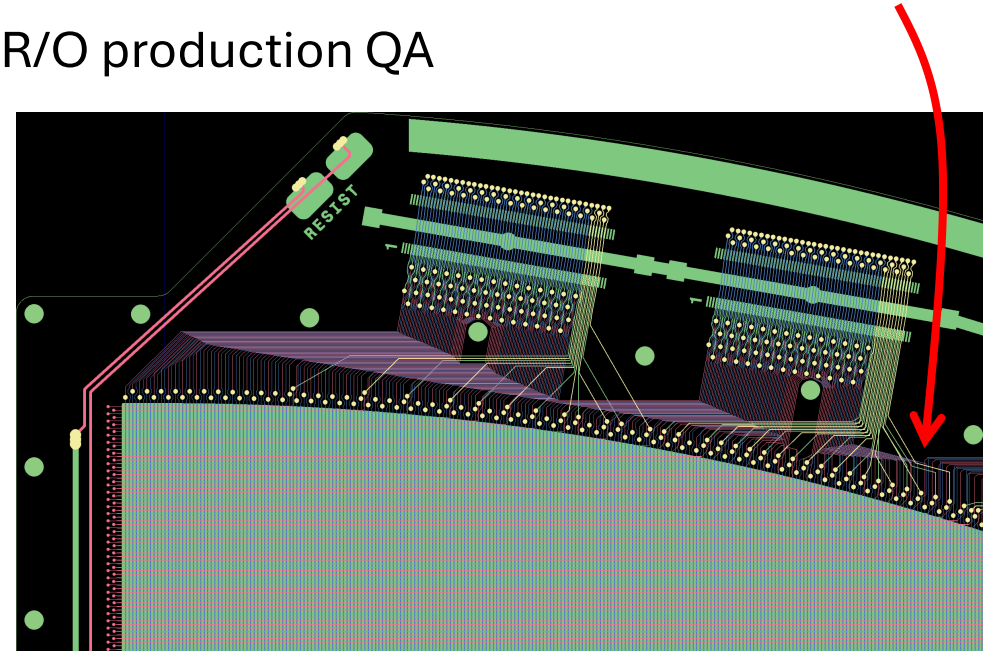
→ High rate stability

5) Detector Characterization (Gain Measurement)

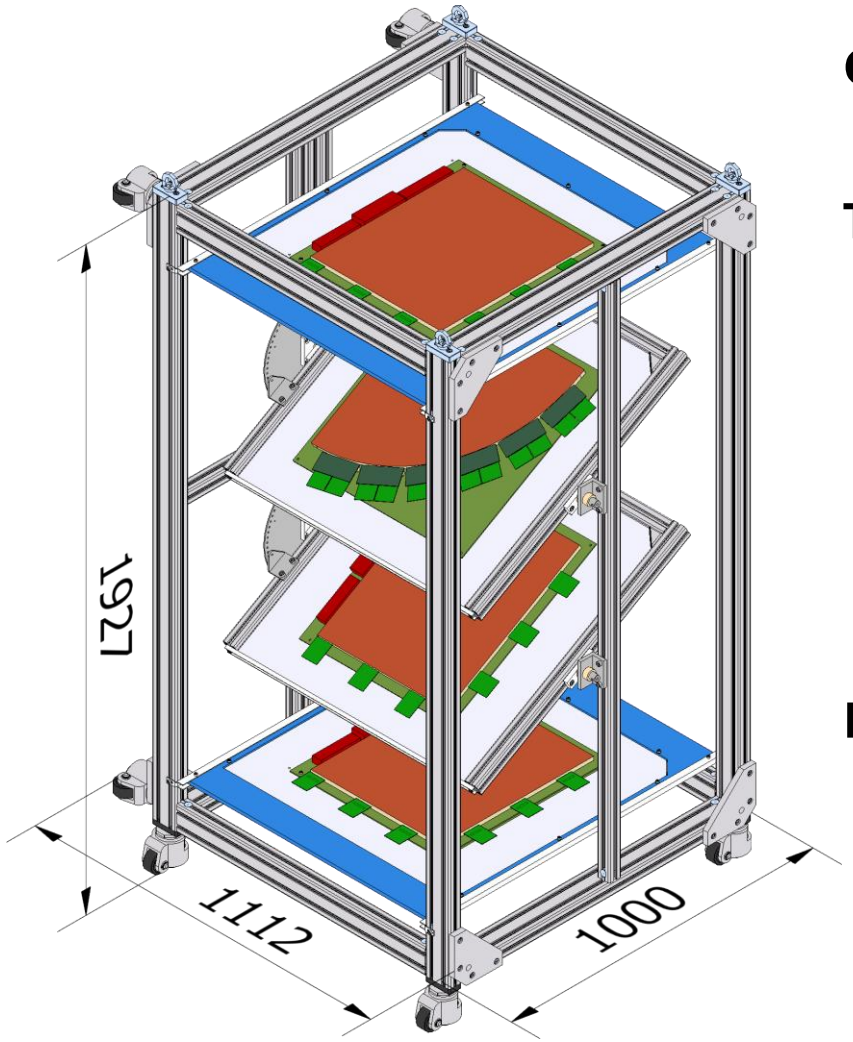
→ Determination of operating parameters

6) Search for pathological channels (requires software mapping)

→ R/O production QA



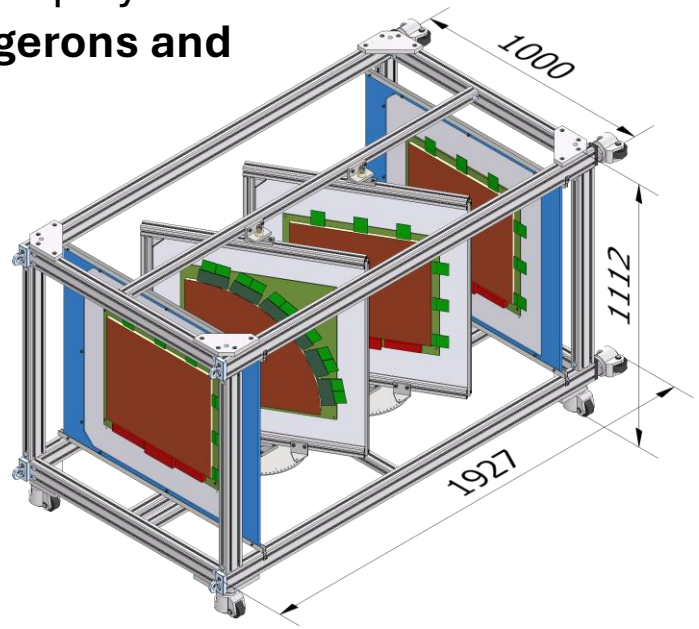

# A Cosmic Ray/Test Beam station



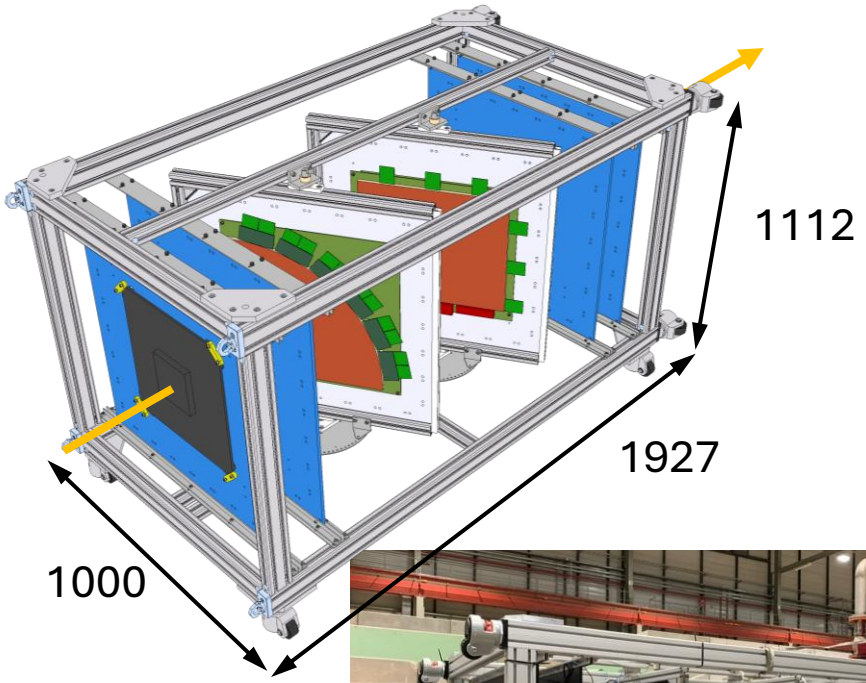

**Convertible**
- For horizontal and vertical operation

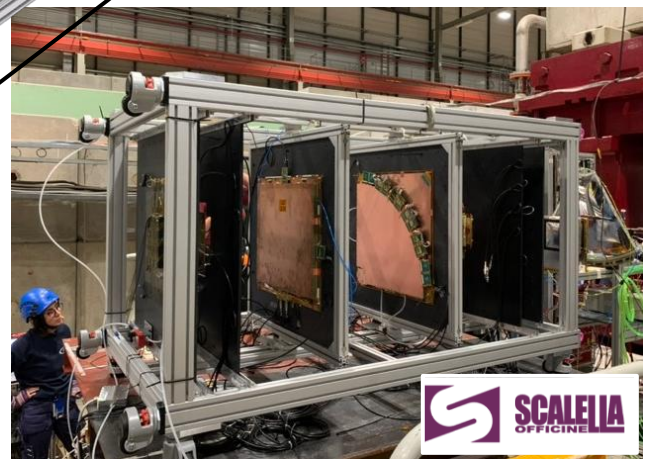
**Transportable**
- For short distances on paved floor
  → **wheeled**
- By forklift and crane for experimental area deployment
  → **Rigid frame, anchor points, longerons and clearance when horizontal**
- By truck over long distances
  → **vibration resistant**

**Expandable**
- For reuse as more detectors are produced

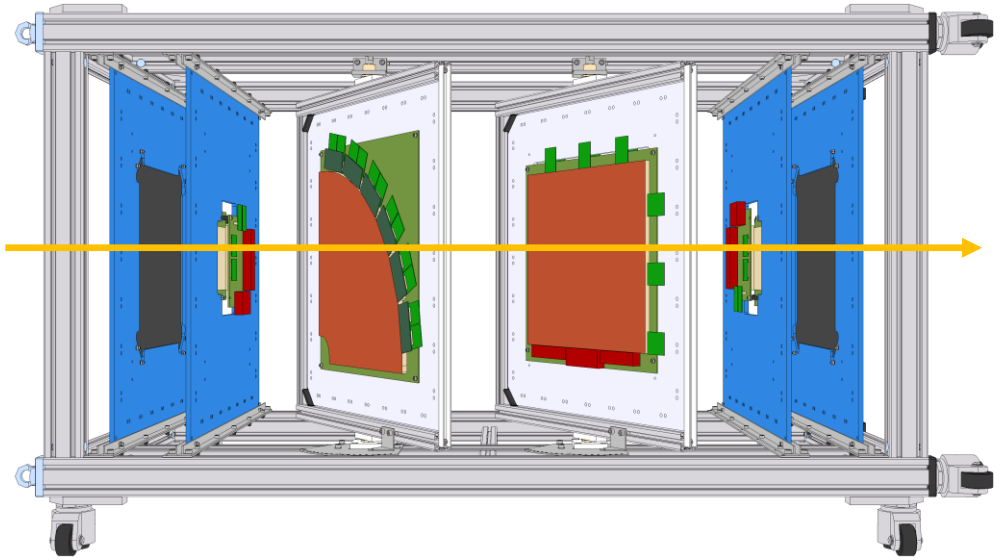


# Setup and Detector Arrangement



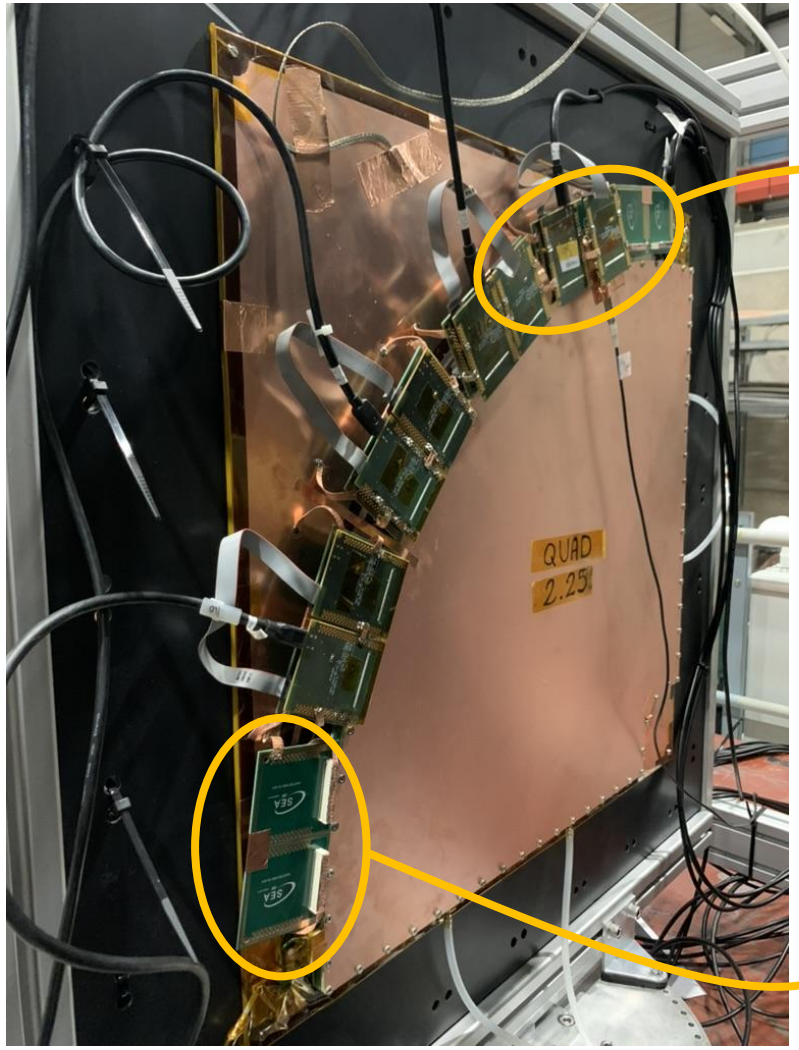

TRG TRK×2 QUAD×2 CS×2 TRK×2 TRG



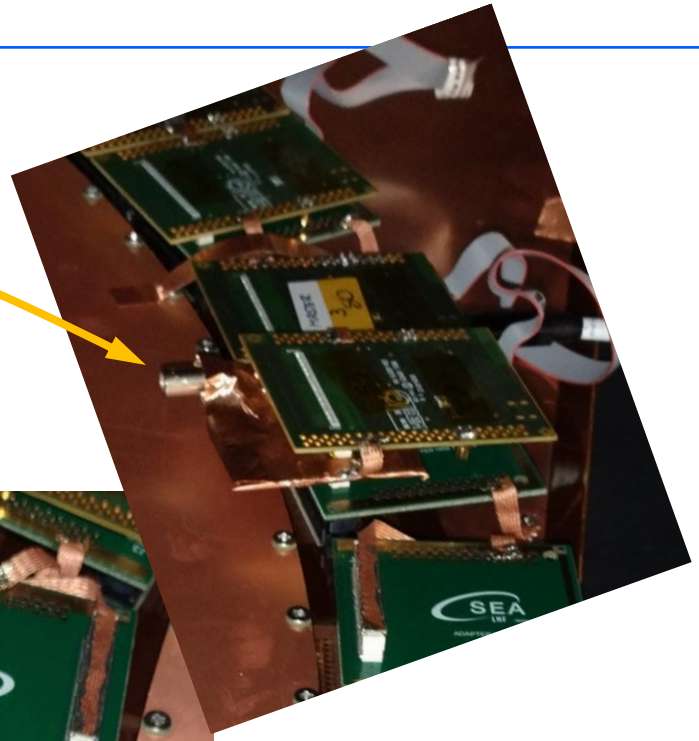
| DET | Pitch (μm) | Active Area | Readout | Capacitive Sharing |
|---|---|---|---|---|
| **TRK** | 400 | 10x10 $cm^2$ | 2D XY | No |
| **QUAD** | 600 | R = 45 cm | 2D XY | No |
| **CS** | 1200 | 46x40 $cm^2$ | 2D XY | 3 Layers (300μm) |
| **TRG** | NA | 15x15 $cm^2$ | SiPM | NA |

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

# DAQ



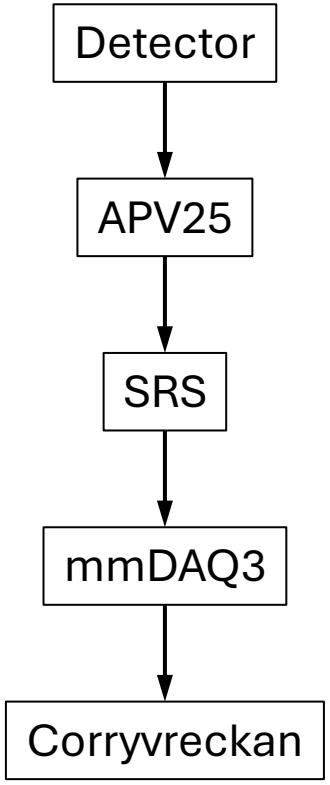

Trigger Signal
Injection Board



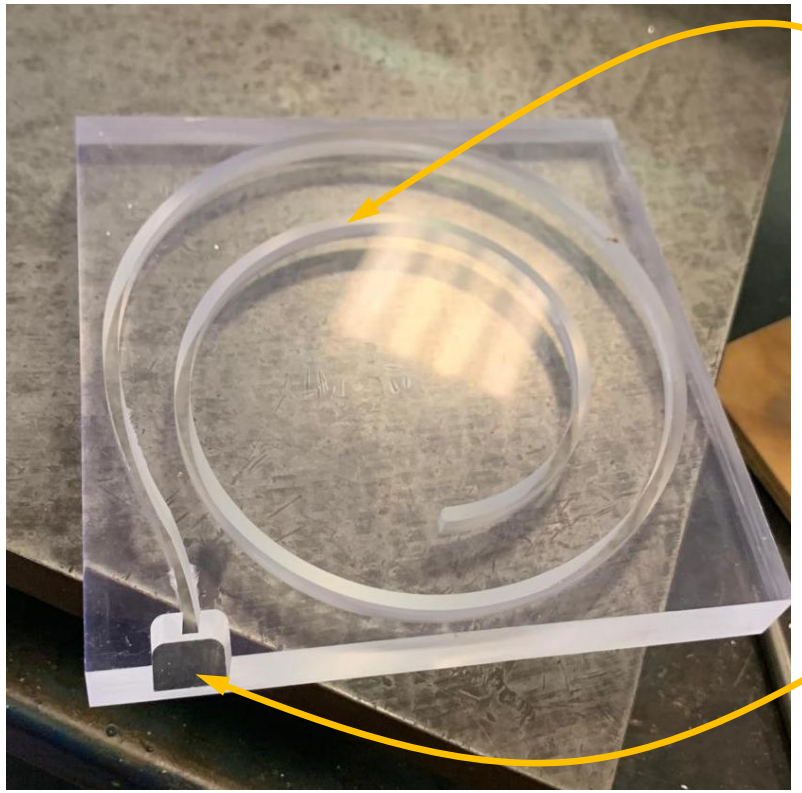


HIROSE to Panasonic
Transition Board

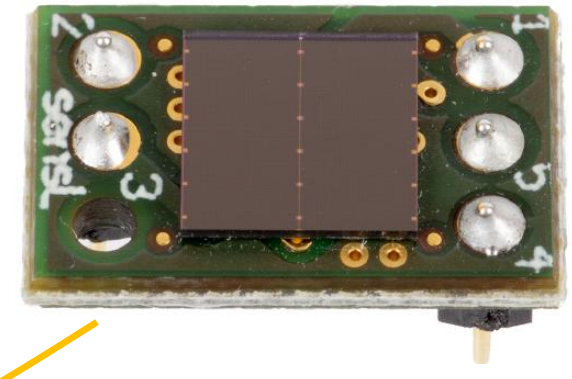
**Data Pipeline**



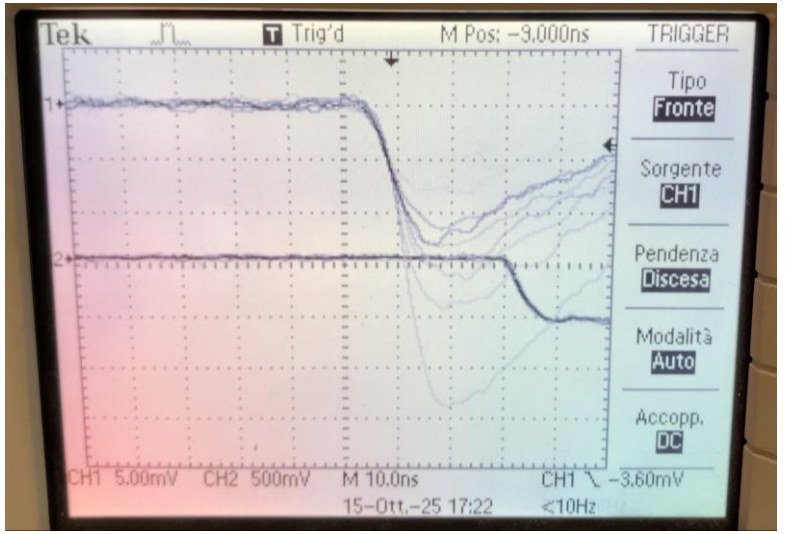
# Trigger



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



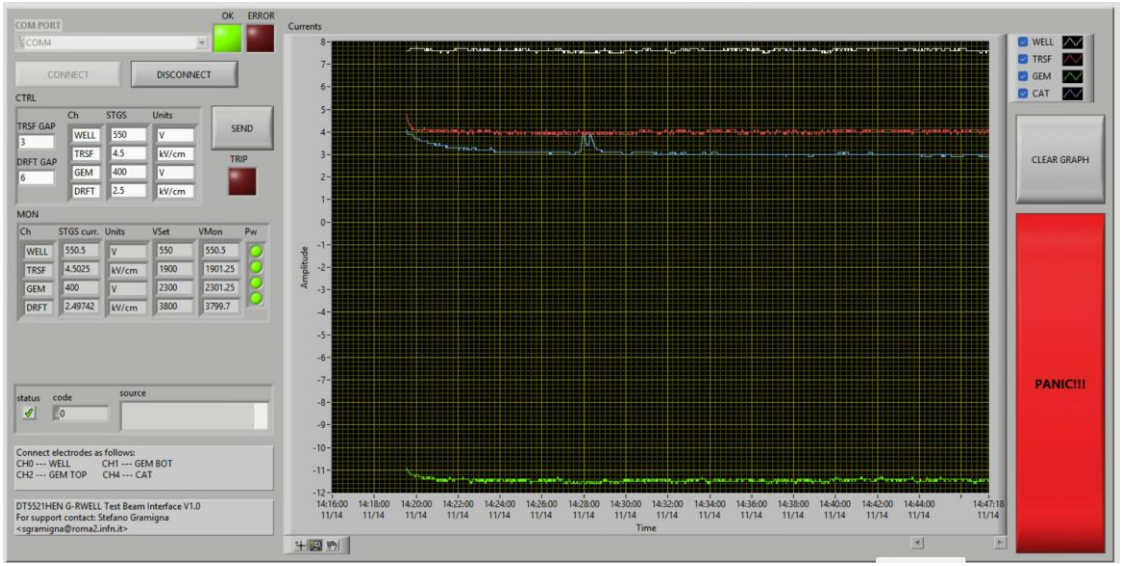
Onsemi J-Series 30020
3x3 $mm^2$ SiPM Area

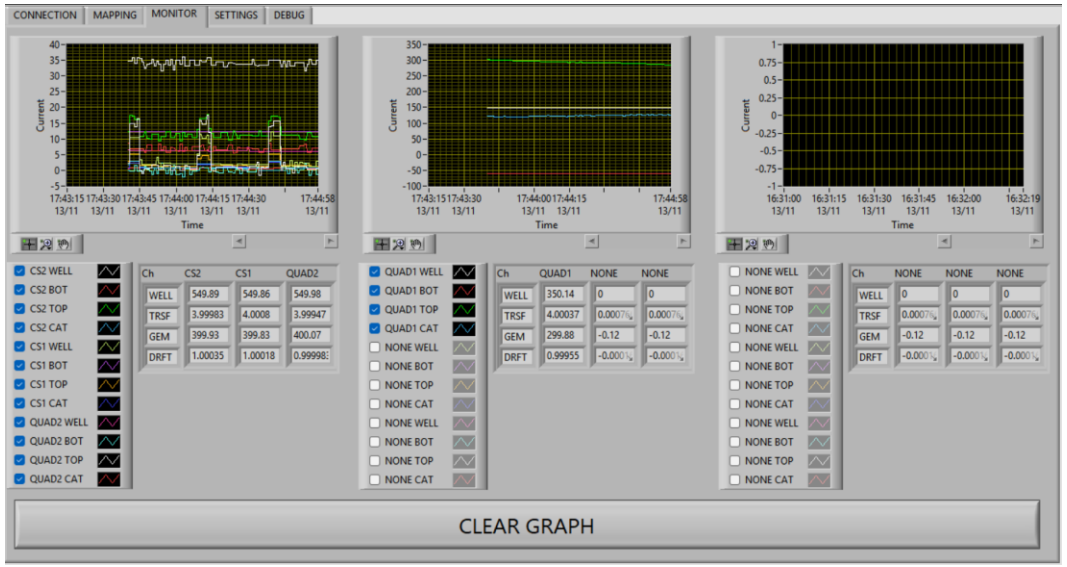


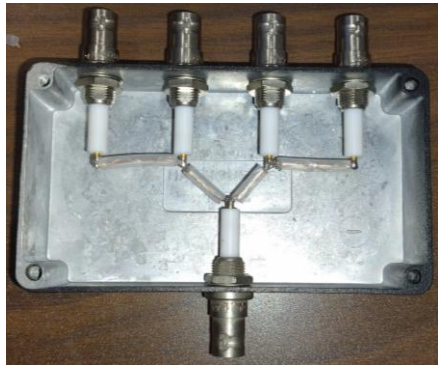

Non-amplified signal output
from cosmic rays

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

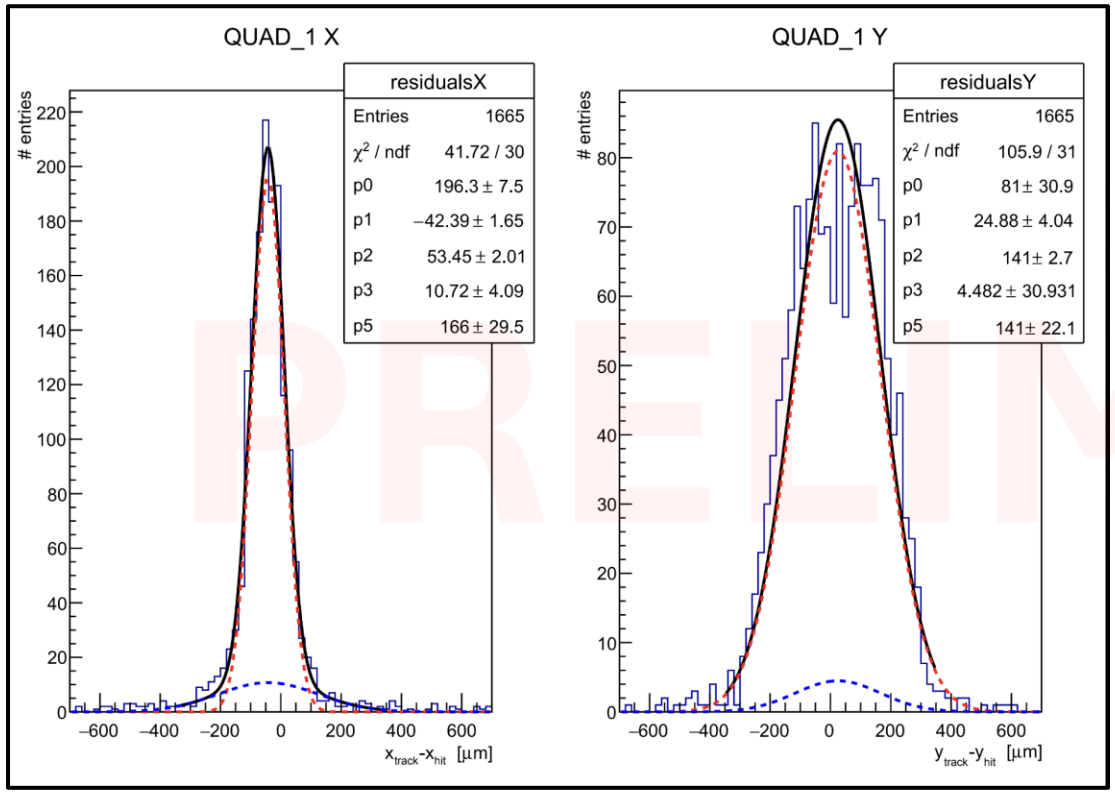
**DUT's** electrodes powered **individually**

1 HV Channel per electrode per detector

16 HV channels in total

Finer diagnostics and HV regulation

# Residuals Distributions




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

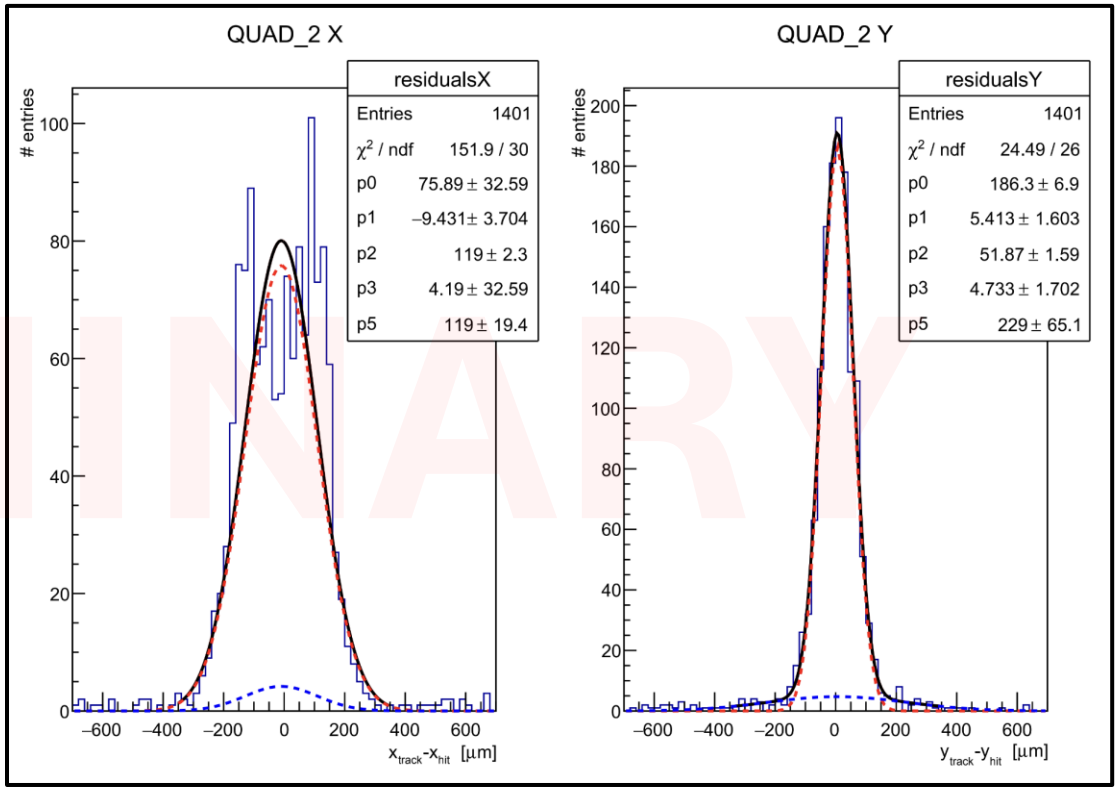
Lower view

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

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

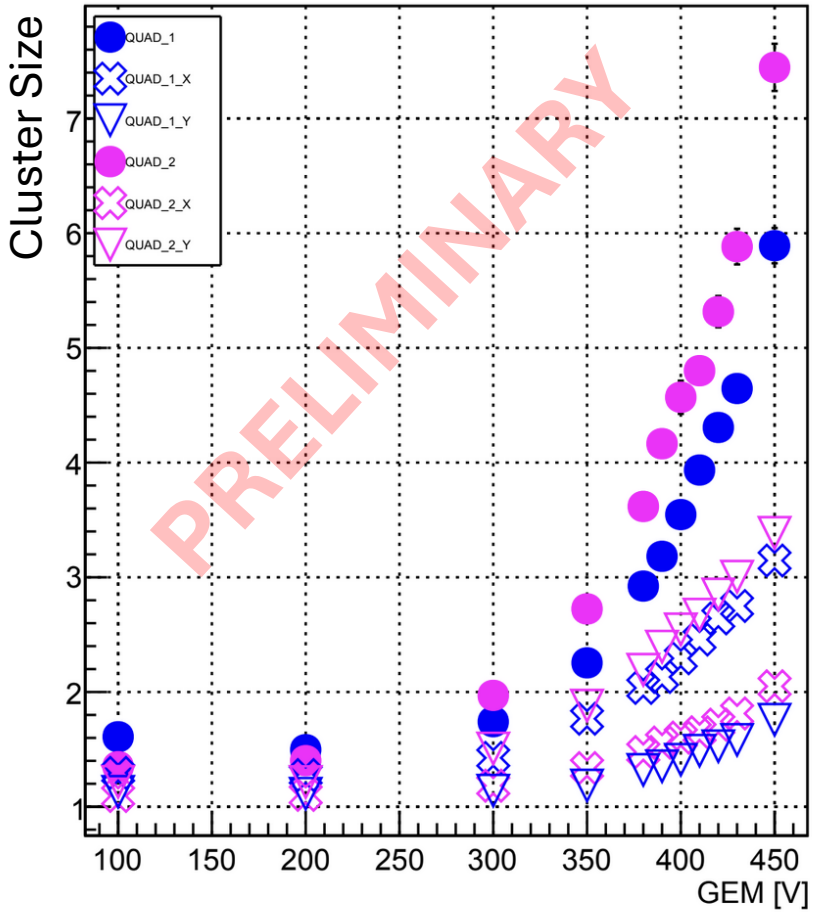
Lower view

520 μm strip width

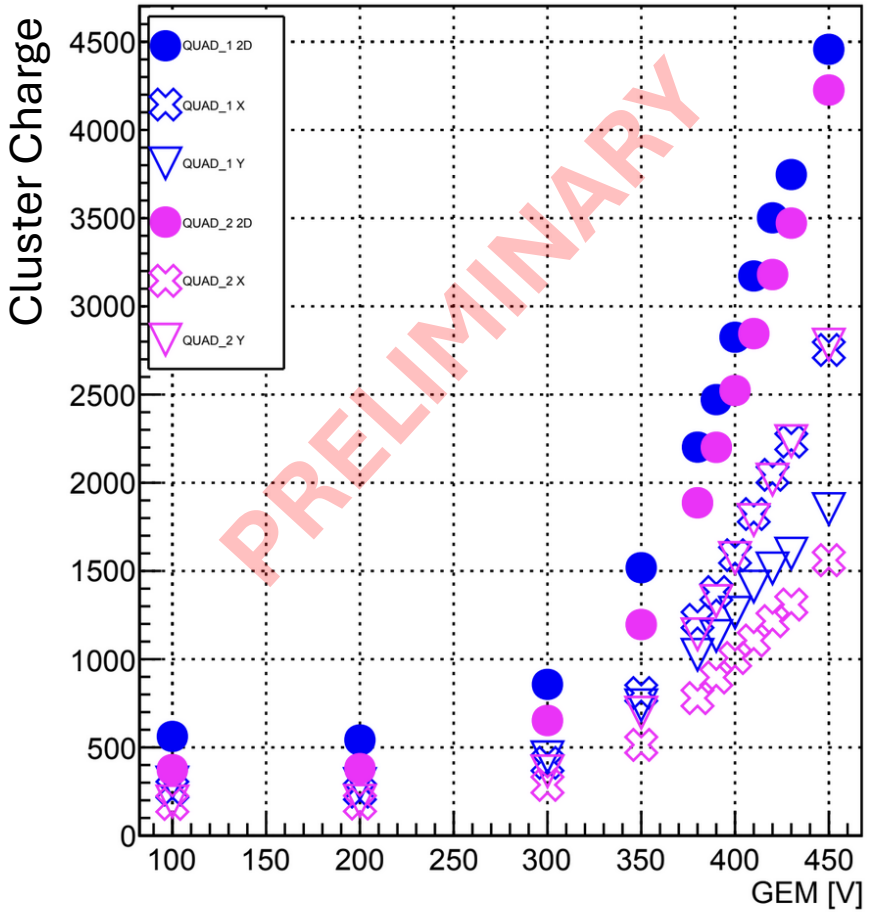
The two quadrants are rotated by 90 degrees with respect to each other, hence the X-Y exchange

# Size and Charge of the Signal Clusters

**Cluster Size VS GEM Voltage ***




**Cluster Charge VS GEM Voltage ***



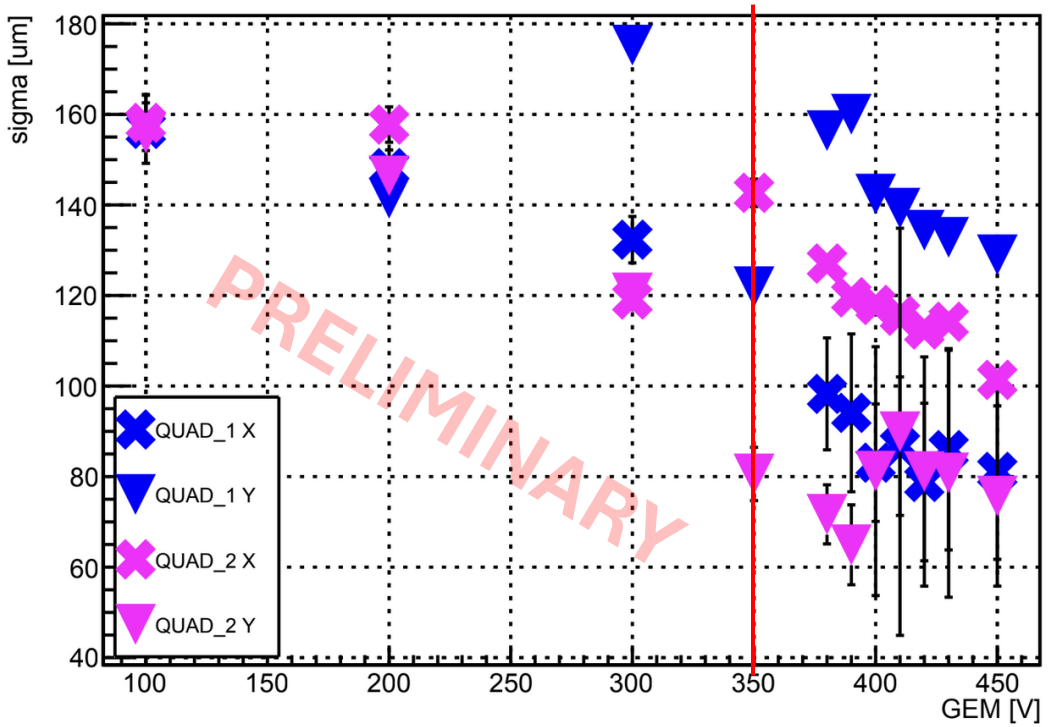

- QUAD1
- QUAD2

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

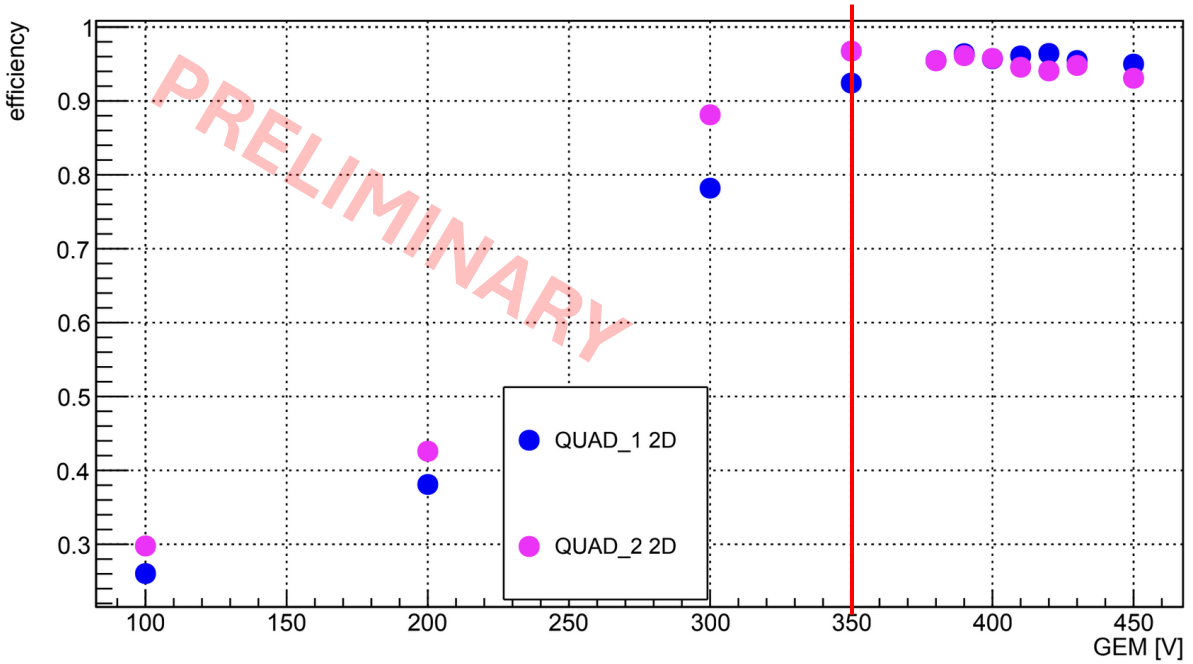
* WELL = 550 V
TRSF = 4.5 kV/cm
DRFT = 2.5 kV/cm

# 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