DE LA RECHERCHE À L'INDUSTRIE

ERAM Detector

ERAM module

HA-TPC

CHARACTERIZATION OF RESISTIVE MICROMEGAS DETECTORS FOR THE HORIZONTAL TIME PROJECTION CHAMBERS IN THE UPGRADE OF T2K

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On behalf of the ND280/HA-TPC collaboration

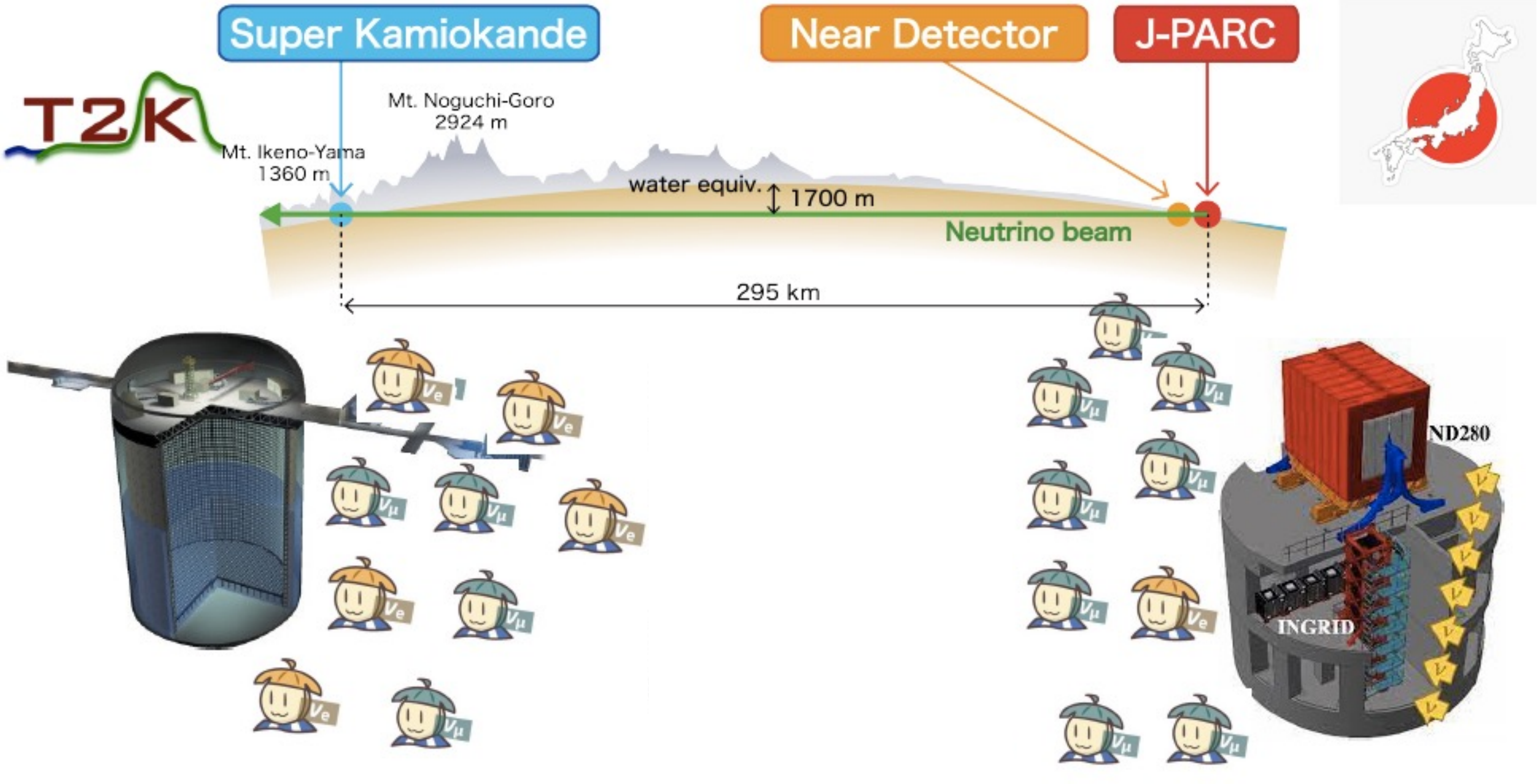
February 28th 2023

RD51 Mini-Week (WG1)

OUTLINE

1. T2K near detector upgrade (ND280) using resistive Micromegas for HA-TPC.
2. DLC resistivity measurements
3. Modelling of charge spreading with resistive Micromegas.
4. Resistive Micromegas performance using X-ray data.
5. Conclusion

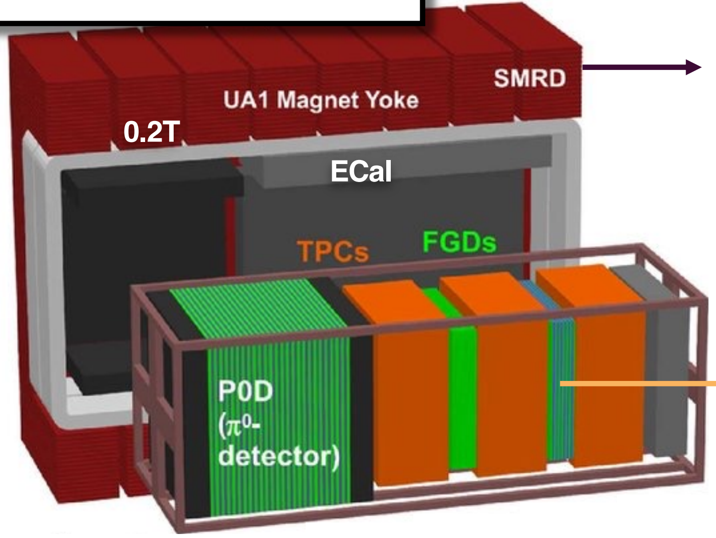
The T2K experiment: Tokai to Kamioka

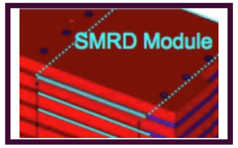


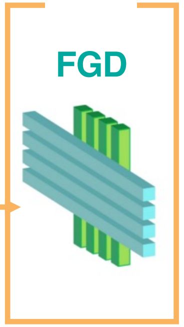
Neutrino cartoons by Yuki Akimoto

NEAR DETECTOR : ND280

Current ND280





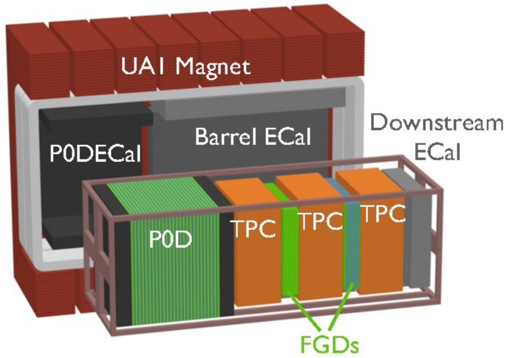


ND280 measures beam spectrum and flavor composition before the oscillations

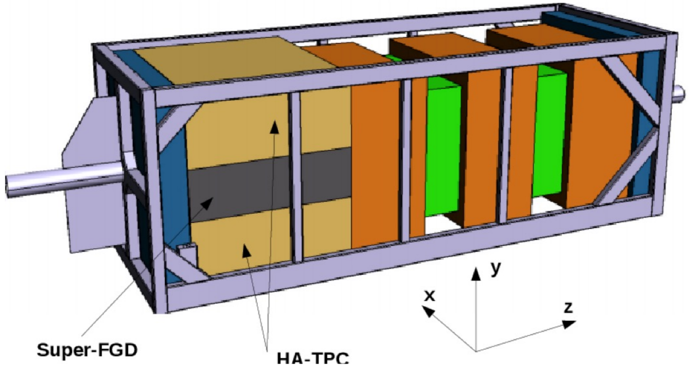
- Detector installed inside the **UA1/NOMAD magnet (0.2 T)**
- **A detector optimized to measure π^0 (P0D)**
- **An electromagnetic calorimeter to distinguish tracks from showers**
- A tracker system composed by:
  - **2 Fine Grained Detectors (target for ν interactions).**
    FGD1 is pure scintillator,
    FGD2 has water layers interleaved with scintillator
  - **3 vertical Time Projection Chambers: reconstruct momentum and charge of particles, PID based on measurement of ionization**

The vertical TPCs were using bulk MicroMegas.
→ **It was a success story (fast and effective production, good performances and longevity >10years).**

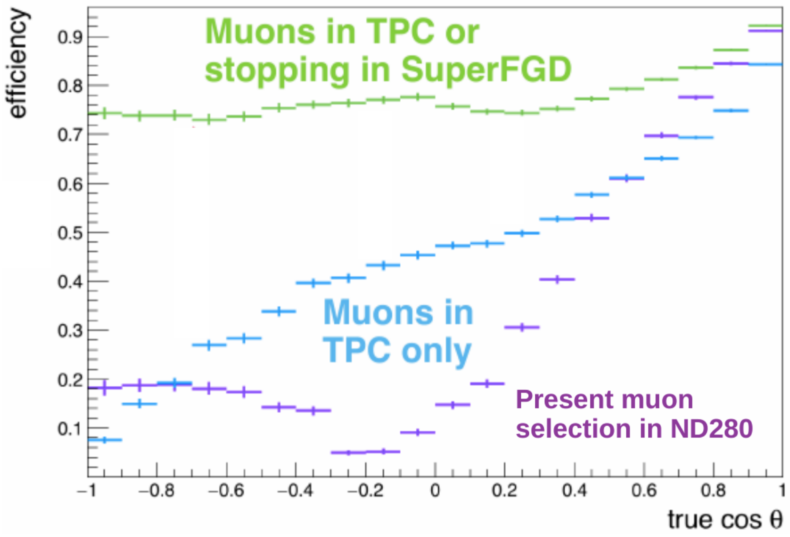
Now



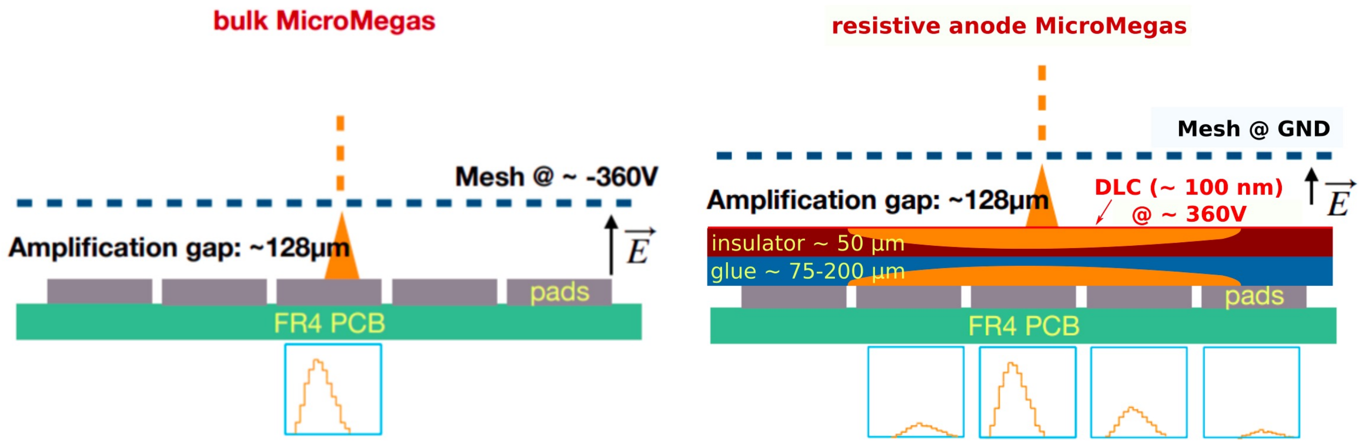
After Upgrade



- **The HA-TPC should have at least the same performance of the 'old' vertical TPCs**
  - Average 700µm space resolution (and possibly even better)
  - 7-8% energy loss resolution for MIP
  - Stability and longevity (>10 years)



- **New horizontal TPC**
  - Better angular acceptance
  - Similar spatial resolution with larger pad size
- **Super FGD**
  - Lower thresholds for particles stopping
  - Capability of measuring neutrons

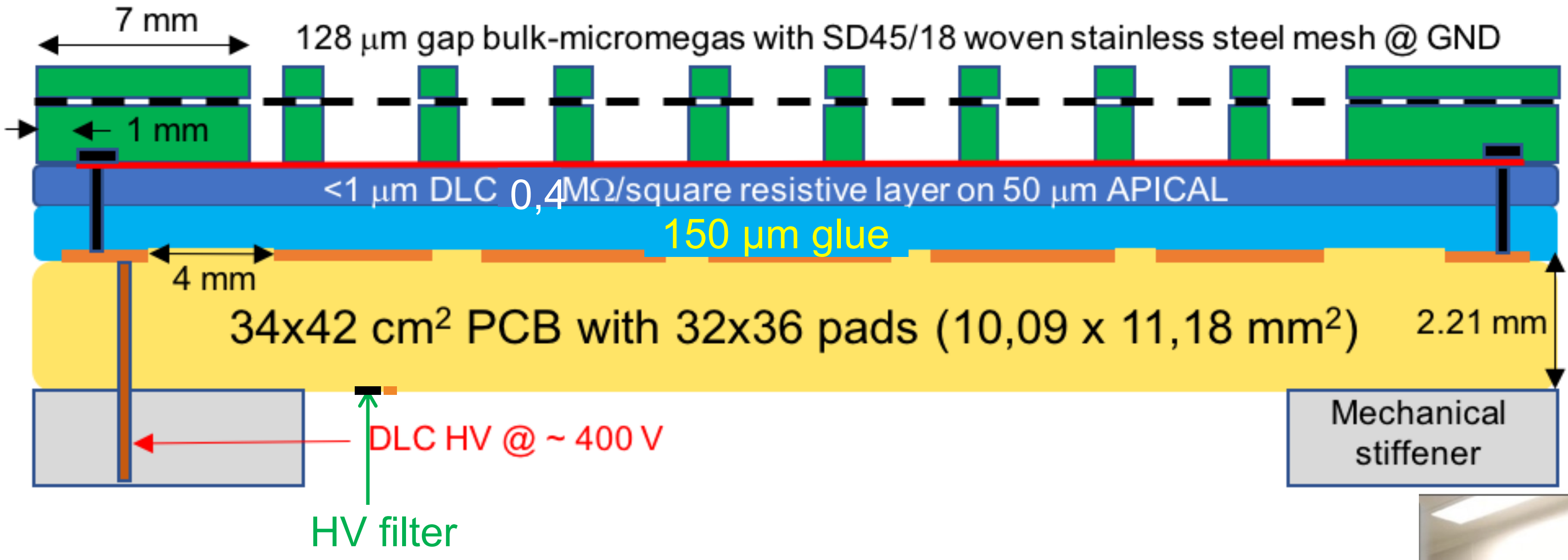


Resistive MicroMegas detectors achieved thanks to the addition of a resistive layer Diamond Like Carbon (DLC)

- Charge sharing between pads → More precise position reconstruction
- Better resolution with lower number of pads.
- Reduced risk of sparks → No need for protection circuit on readout electronics
- Allows to put mesh at ground for better E-field uniformity.
- Smaller RC → Larger charge spreading (better spatial resolution)

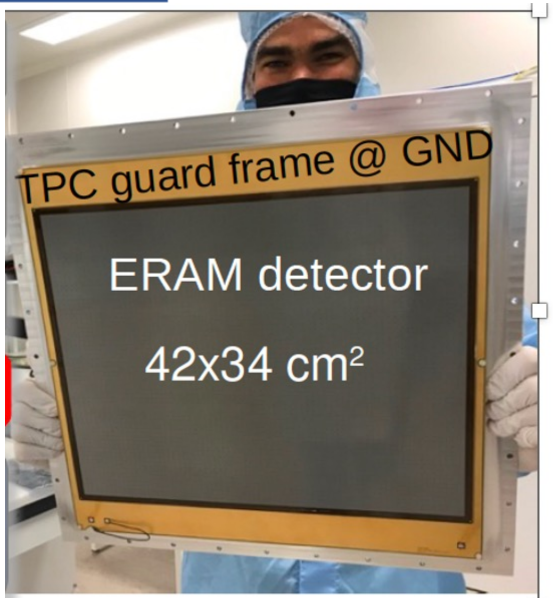
$$\rho(r,t) = \frac{RC}{4\pi t} e^{\frac{-r^2 RC}{4t}} \qquad \sigma_t = \sqrt{\frac{2t}{RC}}.$$

R = Surface resistivity
C = Capacitance / unit area

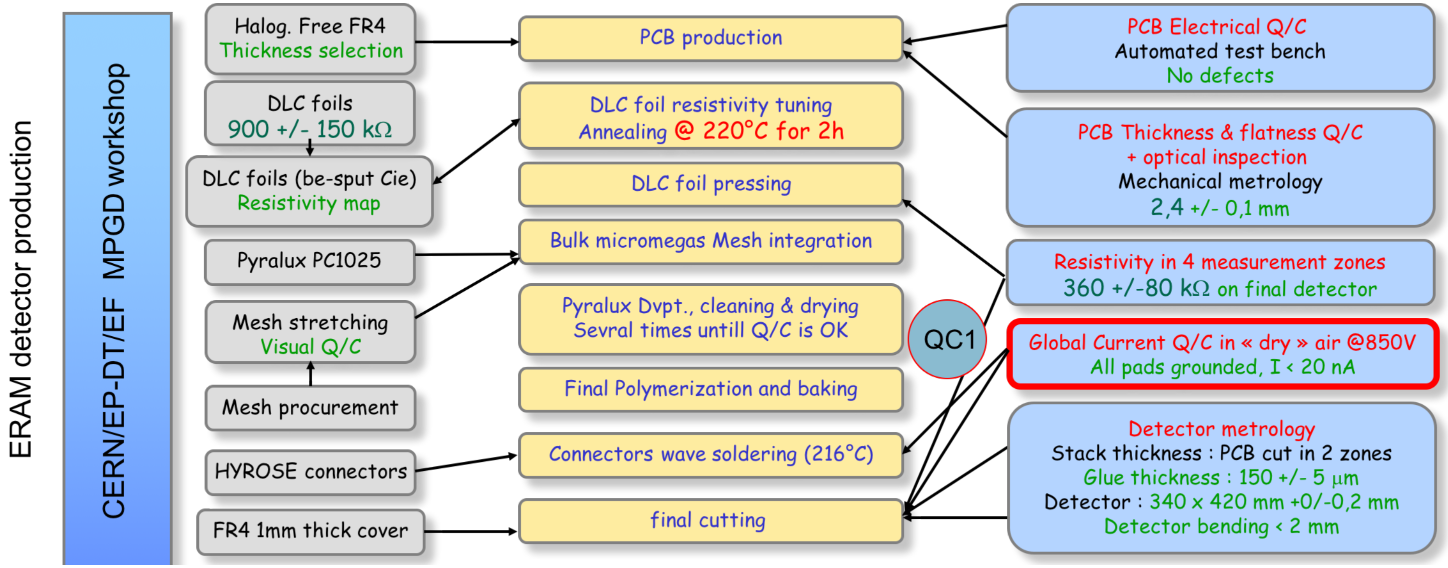


Production version of the ERAM (Encapsulated Resistive Anode Micromegas) detector

- Readout PCB: HA-TPC
- 36 × 32 pads
- 11,18 × 10,09 cm² pads
- ~400 kΩ/❑ (after annealing in air at 220°C, ~ 1MΩ/❑ before)
- 150 μm of glue
- HV filter directly on the PCB using a switchable common ground



ERAM production & QA/QC



- **The DLC production is done in Japan (Be-Sputter company)**

- **The whole production is done by the EP/DT: the PCB workshop (Rui and al.)**
  - Allows a close following of the production and good responsiveness
    - DLC foils procurement and stability, design evolution, improvement of production

- The ERAM detector configuration and the manufacturing processes are stabilized and validated. The production is launched. 21/32 final detectors were produced.

Summary of ERAM development

D. Attié et al. NIM A984, (2020), 163286. doi:10.1016/j.nima.2019.163286
D. Attié et al. NIM A1025, (2022), 1661109. doi:10.1016/j.nima.2019.166109

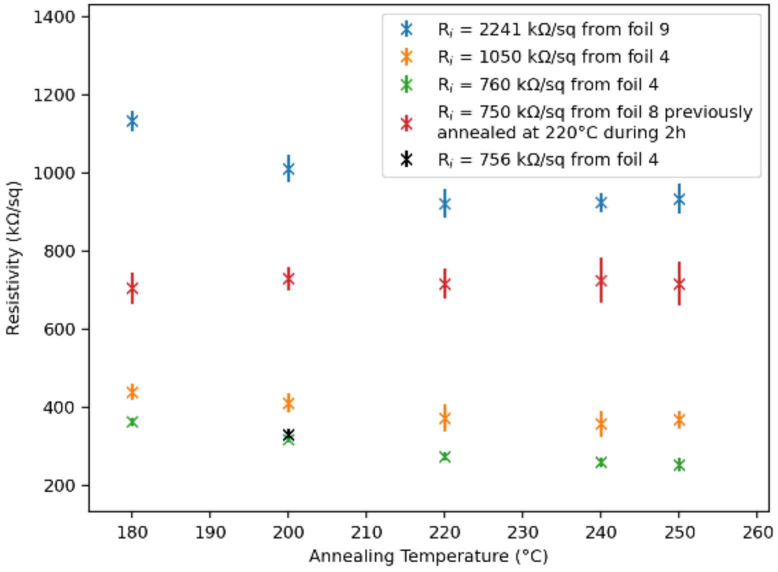
2018 — 2019 — 2020 — Nov. 12 PRR — Pre-series To series production — 2021

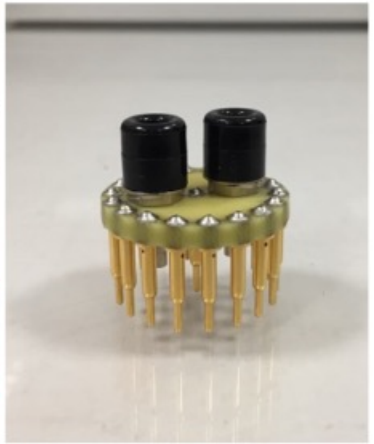
CERN/T9 test beam — DESY test beam — ERAM-01 @ DESY 2021, ½ TPC @ CERN/T10 sept. 2022

	2018 MM0-DLC#	2019 MM1-DLC1 & 2	2020 ERAM-P1 & P2	Production ERAM-xx (ERAM-01-28)
Readout PCB	Original T2K-TPC	HA-TPC V1 + ARC FEE	HA-TPC V2 + final FEE V1	HA-TPC V2 + final FEE V2
Size	34 × 36 cm²	34 × 42 cm²	34 × 42 cm²	34 × 42 cm²
Pads	48 × 36 cm²	32 × 36 cm²	32 × 36 cm²	32 × 36 cm²
Pad size	6,85 × 9,65 mm²	10,09 × 11,18 mm²	10,09 × 11,18 mm²	10,09 × 11,18 mm²
Number of pads	1728	1152	1152	1152
DLC resistivity (MΩ/sq.)	~2,5 (original foil) Not meas.on detector	0,32-0,44 (batch#P1 foils) 0,2-0,27 (meas. on detector)	0,28-0,40 (batch#P1 foils) 0,15-0,22 (meas. on detector)	**~1 (foils) / ~0.28-0,4 (det.)** Top TPC: 1-1.5 (foils) **After baking : ~0,4-0,55**
RC_{design} [ns/mm²] RC_{data} [ns/mm²]	~400	60<RC<80 X-ray scan to process	24<RC<35	**55<RC<78** **102<RC<145 (this talk)**
Insulation layer	200 µm glue + 50 µm APICAL	75 µm glue + 50 µm APICAL	200 µm glue + 50 µm APICAL	150 µm glue + 50 µm APICAL
σ (mm) For 200 ns peaking t For 412 ns peaking t	~1,6 ~2,3	~3,8 ~5,4	~5,8 ~8,3	~3,9 ~5,6
dE/dX (measured 1 det.) Extrapol. to 2 detectors	9 to 9.5% (e- & p) <7%	9 to 9.5 % (e-) with 0.2T <7%	Energy resolution @5.9 keV ~20% FWHM	8.5 to 10 % (e-) with 0.2T <7%
Spatial resolution (µm) Beam (Horizontal tracks) cosmics	300 (0T)	MM1-DLC1 200 (0 or 0.2T, 200/400 ns t_p) 700 (MM1-DLC2, @370V)	300-350 (ERAM-Px @370V)	@ DESY 07/ 21 200-800 µm (ERAM-01) / horizontal – 45° tracks (412ns)

DLC RESISTIVITY MEASUREMENT

- DLC ensures charge spreading over several pads thus a better spatial resolution
- DLC production is insured by Be-Sputter Company in Japan
- There was no common way to measure resistivity: two probes designed “Ochi” & “CERN”
  - Used “CERN” after tests insuring reproducible results





- Identify evolution of resistivity during detector production
- DLC resistivity evolves as function of temperature: @220 degrees → /2.3
  - Decided to bake DLC before mounting to stabilize it
  - **→ Works! No change of resistivity during process**

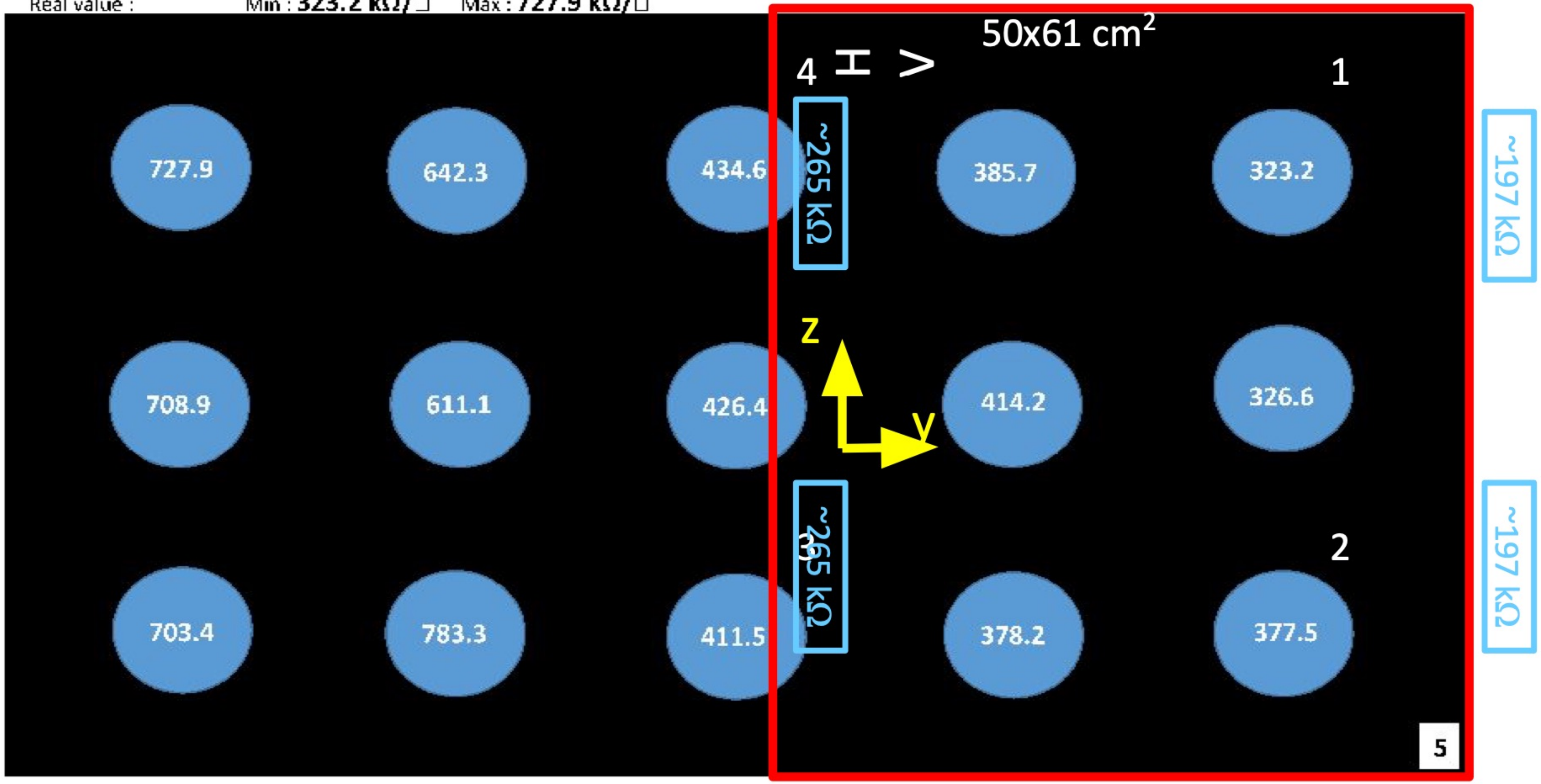
- We order DLC to reach a final resistivity of 400k but received batches of ~200 kΩ/☐ & ~400 kΩ/☐
- Production of one ~200 kΩ/☐ detector for testing
  - R&D shows that charge spreading could be adapted with:
    - Glue thickness
  - BUT higher risk of sparks! Reliability issues?

Theoretical value **500 kΩ/□**

Part of DLC foil #5 used for MM1-DLC2

Foil size : 100x61cm

Real value : Min : **323.2 kΩ/□** Max : **727.9 kΩ/□**

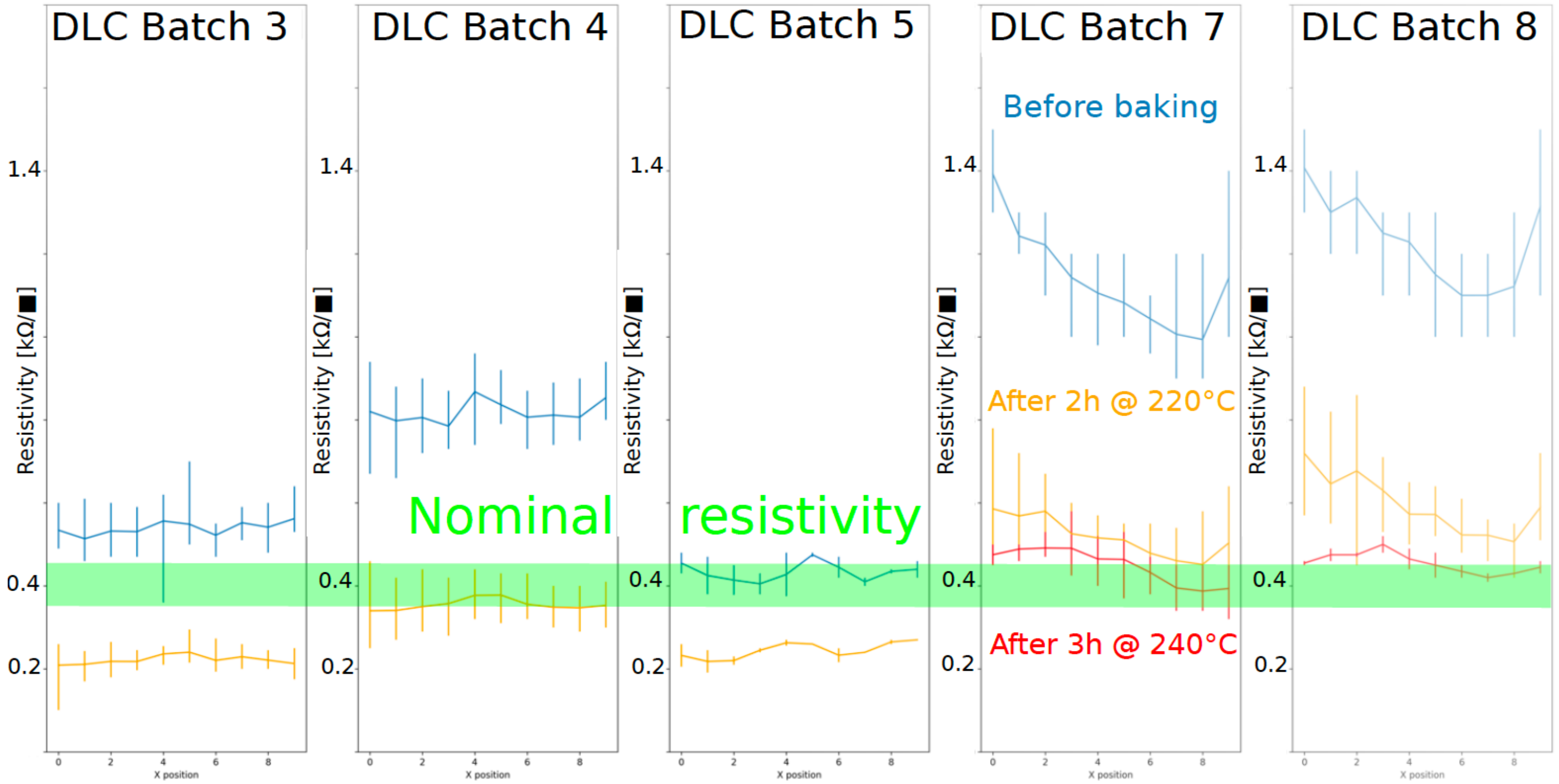


R=197 KΩ
RC = 49 ns/mm²

R=265 KΩ
RC = 67 ns/mm²

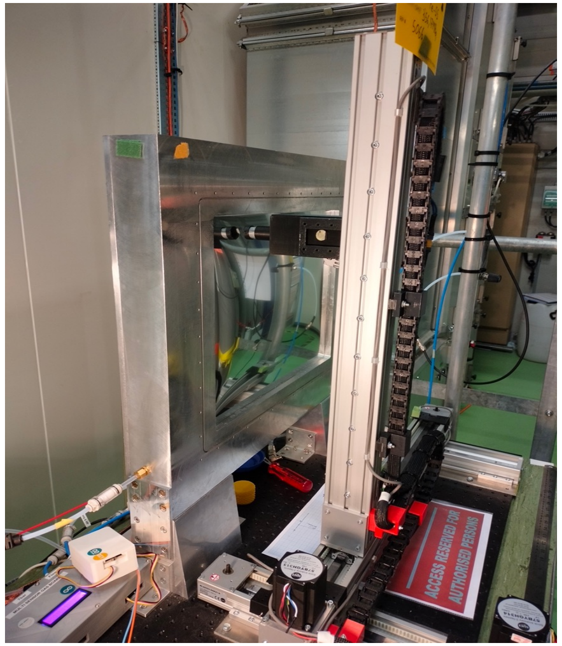
In blue : measured value outside detector area once detector is finished

DLC FOIL SELECTION FOR ERAMs

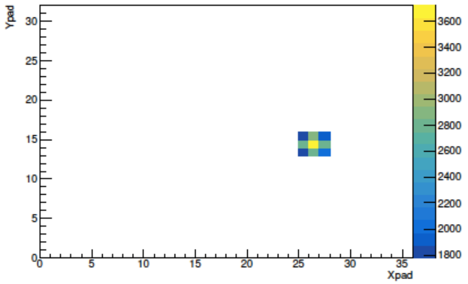


- A batch = 7 DLC foils (0,6x1,2 m^2)
- **Batch 4** with nominal resistivity ⇒ 9 final detectors
- **Batch 3 and 5** with half nominal resistivity ⇒ Prototypes
- **Bacthes 7 and 8** needed 2 bakings to provide nominal resistivity ⇒ ~ 8 final detectors
- 21/32 final detectors produced

ERAM Tests Using X-ray data

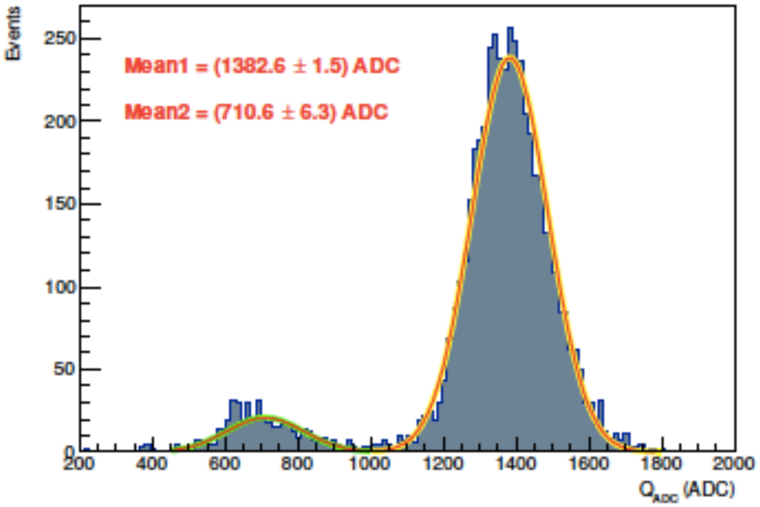


X-ray test bench at CERN



- Each pad(1152) of an ERAM placed inside an X-ray chamber is scanned using a robot holding an ^{55}Fe X-ray source.
- Charge is deposited in targeted pad and its neighboring pads (due to charge spreading), from electron avalanche caused by an X-ray photon.
- ^{55}Fe spectrum can be reconstructed using all events in one pad → Summing all waveforms in each event and taking amplitude max of summed waveform
- Gain is obtained for a pad by fitting its ^{55}Fe spectrum. Resolution of 10% is obtained.

Example of a ^{55}Fe spectrum



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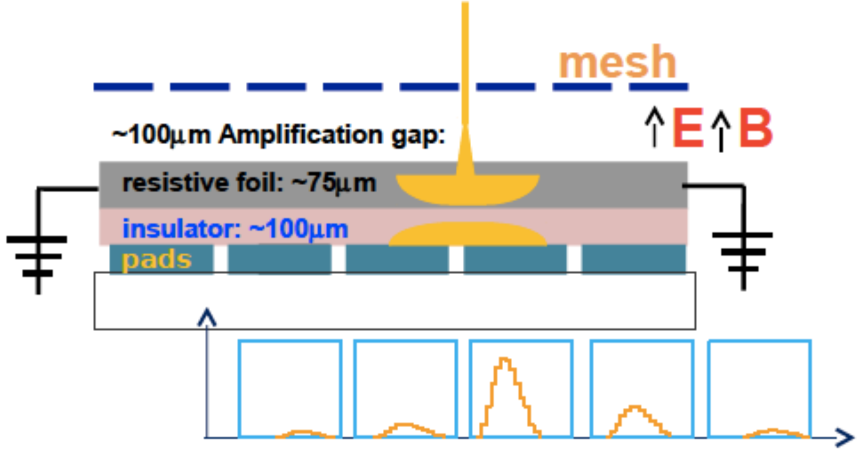
MODELLING THE CHARGE DISPERSION PHENOMENA

- Continuous RC network, defined by material properties and geometry, shares evenly the charge among several pads.
- Obeys Telegraph equation:

$$\frac{\partial \rho}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 \rho}{\partial r^2} + \frac{1}{r}\frac{\partial \rho}{\partial r}\right]$$

$$\Rightarrow \rho(r,t) = \frac{RC}{2t} e^{\frac{-r^2 RC}{4t}}$$



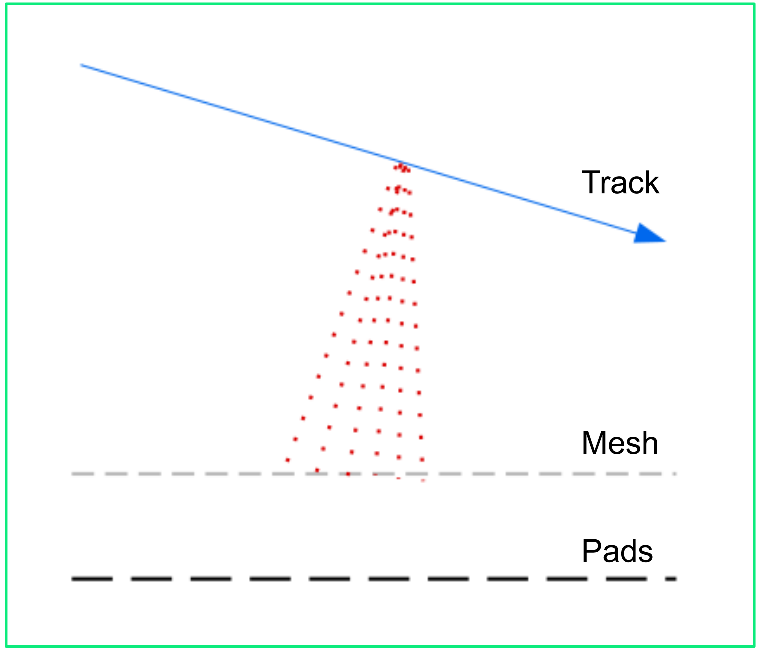
- The anode charge density is time dependent and sampled by readout pads.

Pad size 1.1x1. cm^2

References : M.S. Dixit et.al., NIM A518, 721 (2004) , M.S. Dixit & A. Rankin, NIM A566, 281 (2006)

Transverse diffusion

$$T(x) = \frac{1}{\sigma_x \sqrt{2\pi}} \exp(\frac{-x^2}{2\sigma_x^2})$$



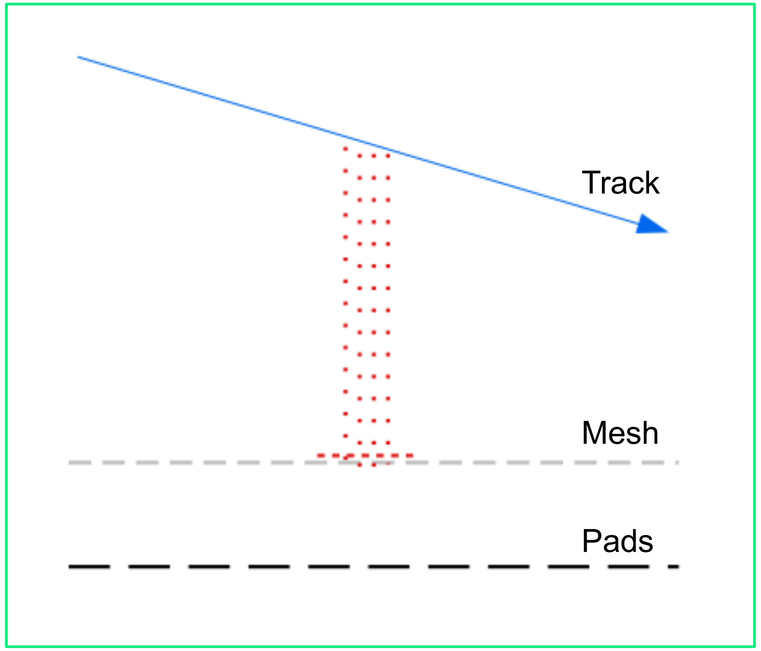
Modelling the Charge Dispersion phenomena

Transverse diffusion

$$T(x) = \frac{1}{\sigma_x\sqrt{2\pi}} \exp\left(\frac{-x^2}{2\sigma_x^2}\right)$$

Longitudinal diffusion

$$L(t) = \frac{1}{\sigma_t\sqrt{2\pi}} \exp\left(\frac{-t^2}{2\sigma_t^2}\right)$$



Modelling the Charge Dispersion phenomena

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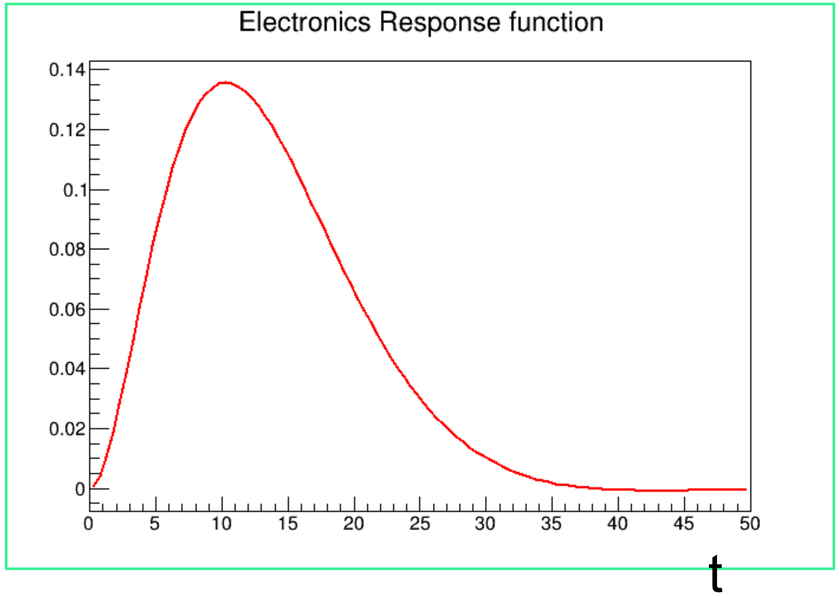
$$T(x) = \frac{1}{\sigma_x \sqrt{2\pi}} \exp(\frac{-x^2}{2\sigma_x^2})$$

Longitudinal diffusion

$$L(t) = \frac{1}{\sigma_t \sqrt{2\pi}} \exp(\frac{-t^2}{2\sigma_t^2})$$

<u>Electronics Response</u>

R(t)



Modelling the Charge Dispersion phenomena

Transverse diffusion

$$T(x) = \frac{1}{\sigma_x \sqrt{2\pi}} \exp(\frac{-x^2}{2\sigma_x^2})$$

Longitudinal diffusion

$$L(t) = \frac{1}{\sigma_t \sqrt{2\pi}} \exp(\frac{-t^2}{2\sigma_t^2})$$

$Q = \int \rho(r)\, dr$

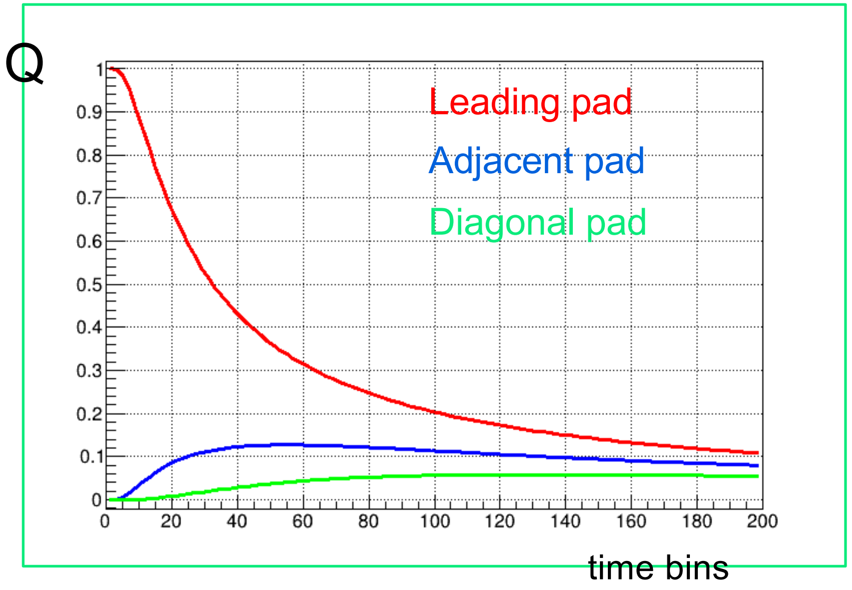
Electronics Response

R(t)

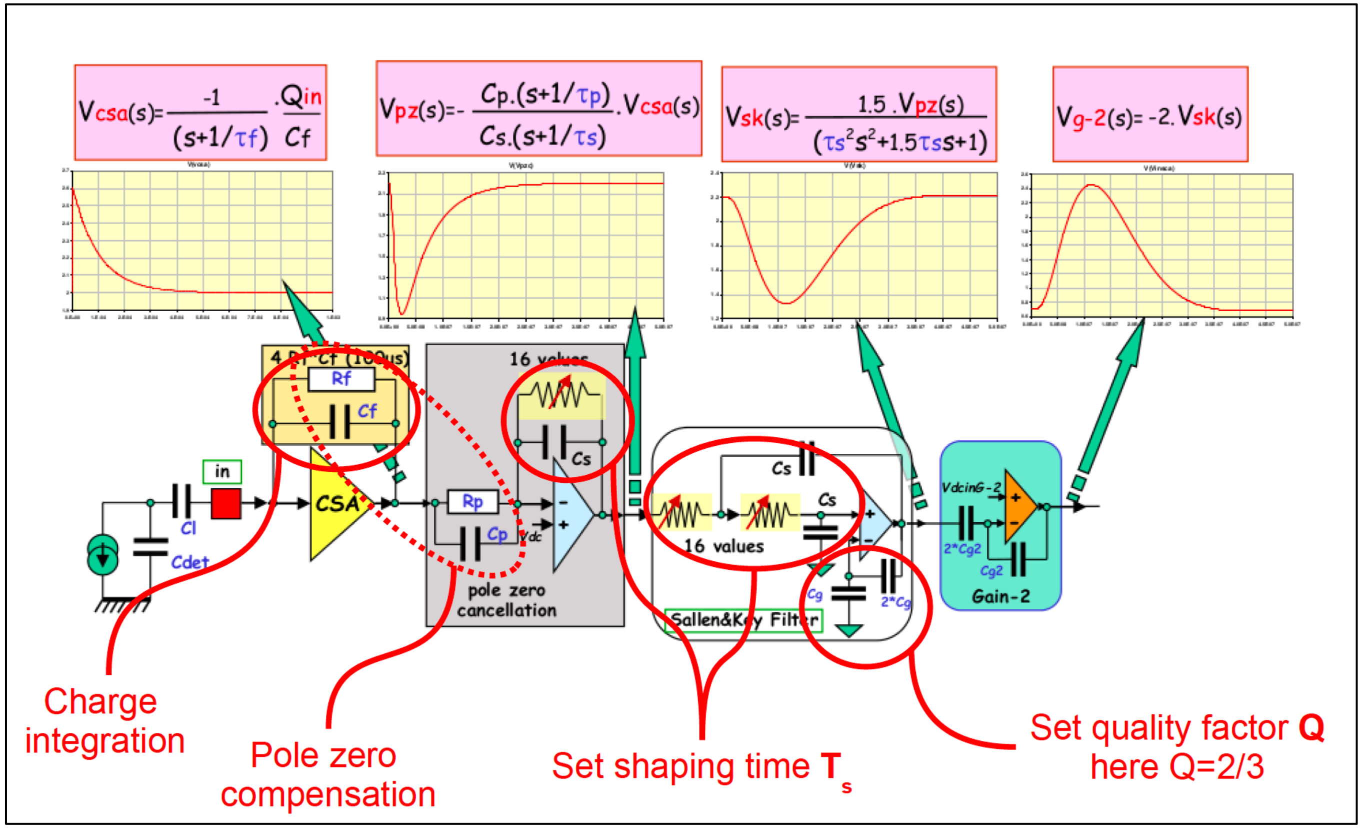
Resistive foil + glue

$$\rho(x,y,t) = \left(\frac{1}{\sigma_t \sqrt{\pi t h}}\right)^2 \exp\left(\frac{-(x^2+y^2)}{4th}\right)$$

$$h = 1/RC$$



AFTER chip



Transfer function $\frac{V_0}{I_s} = \left[-\frac{1}{C_f}\frac{1}{w_f+s}\right]\left[-\frac{C_p}{C_s}\frac{w_p+s}{w_s+s}\right]\left[Q w_s^2 \frac{1}{s^2+\frac{1}{Q}w_s s+w_s^2}\right]$

with $T_f = w_f^{-1} = R_f C_f$, $T_p = w_p^{-1} = R_p C_p$ and $T_s = w_s^{-1} = R_s C_s$

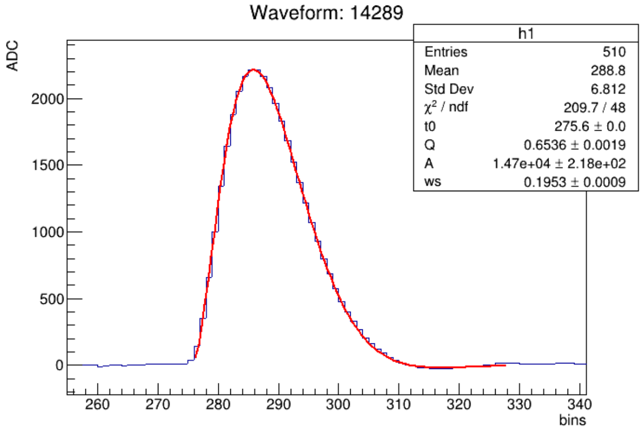
Response to a Dirac pulse for perfect pole zero compensation

$$V_o(t) \propto e^{-w_s t} + e^{-\frac{w_s t}{2Q}}\left(\sqrt{\frac{2Q-1}{2Q+1}}\sin\left(\frac{w_s t}{2}\sqrt{4-\frac{1}{Q^2}}\right) - \cos\left(\frac{w_s t}{2}\sqrt{4-\frac{1}{Q^2}}\right)\right)$$

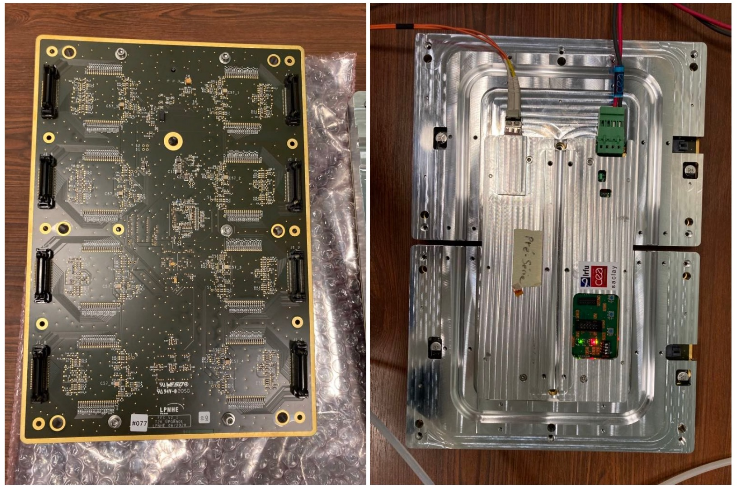
but a normalization factor depend on 2 parameters: T_s and Q

Electronics response function

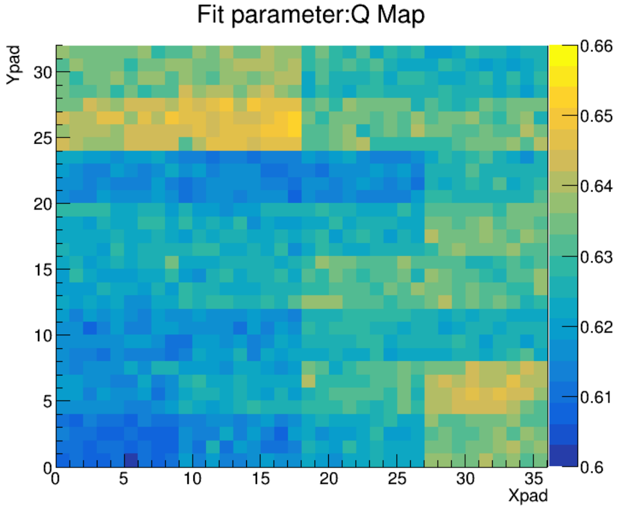
- Each channel of an Electronics card is injected with multiple pulses of different amplitudes.
- Resulting output signals(response of Electronic cards) are fitted with the Electronics response function.



$$R(t) = A\left[e^{-w_s t} + e^{\frac{-w_s t}{2Q}}\left(\sqrt{\frac{2Q-1}{2Q+1}}\sin\left(\frac{w_s t}{2}\sqrt{4-\frac{1}{Q^2}}\right) - \cos\left(\frac{w_s t}{2}\sqrt{4-\frac{1}{Q^2}}\right)\right)\right]$$



- ➢ Parameterized by two main variables related to shape of a signal waveform: **Q** and $\mathbf{w_s}$.
- ➢ Variation in these fit parameters over all the pads was studied to determine if they can be set as constants.



- Q = 0.6368
- w_s = 0.1951

} **fixed (412ns peaking time)**

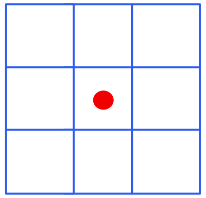
Samira Hassani

Charge diffusion function:

$$Q_{pad}(t) = \frac{Q_{norm}}{4}\left[erf\left(\frac{x_H - x_0}{\sigma(t)\sqrt{2}}\right) - erf\left(\frac{x_L - x_0}{\sigma(t)\sqrt{2}}\right)\right]\left[erf\left(\frac{y_H - y_0}{\sigma(t)\sqrt{2}}\right) - erf\left(\frac{y_L - y_0}{\sigma(t)\sqrt{2}}\right)\right]$$

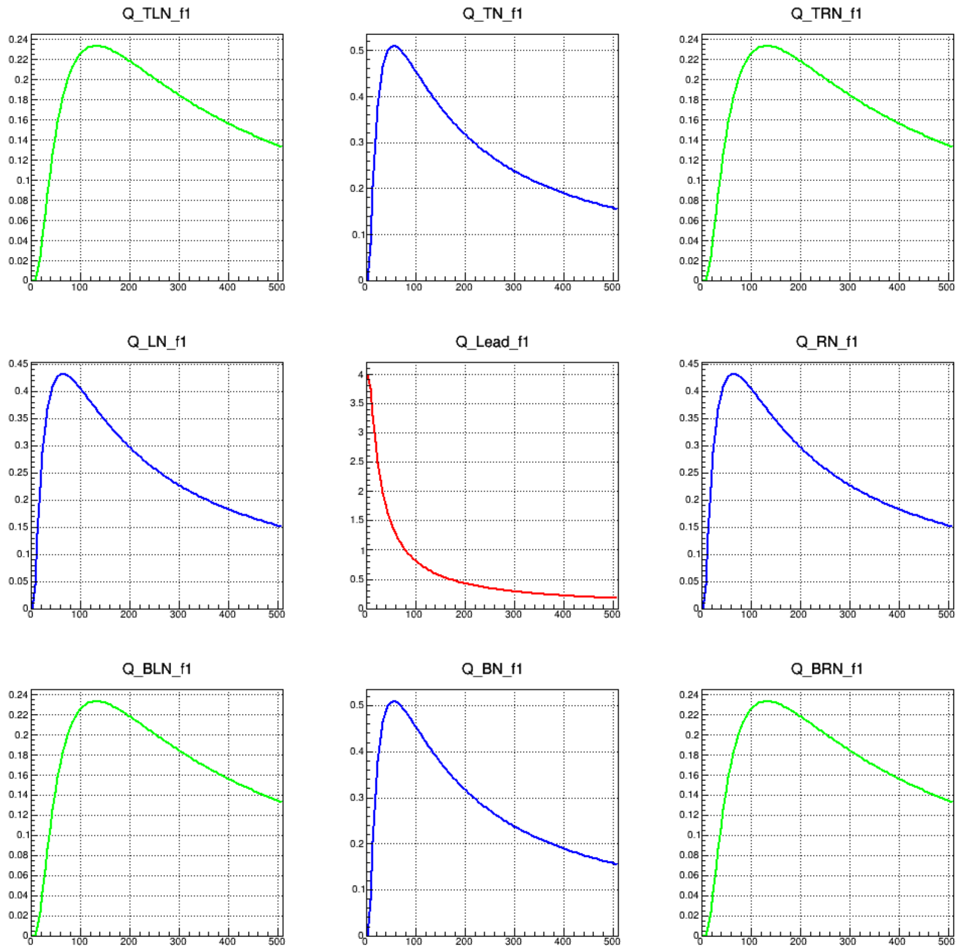
$$\sigma(t) = \sqrt{\frac{2t}{RC} + \omega^2}$$

- Obtained from Telegraph equation for charge diffusion.
- **Integrating charge density function over area of 1 readout pad.**
- **Parameterized by 5 variables:**
  - x_0 } Initial charge position
  - y_0 }
  - t_0 : Time of charge deposition in leading pad
  - RC : Describes charge spreading
  - Q_{norm} : Total charge deposited in an event



RC = 60 ns/mm^2
Q_{norm} = 4 units

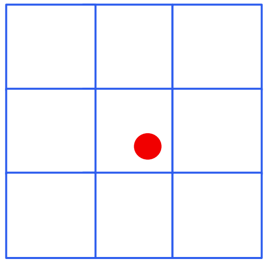
x_H, x_L: Upper and lower bound of a pad in x-direction
y_H, y_L: Upper and lower bound of a pad in y-direction



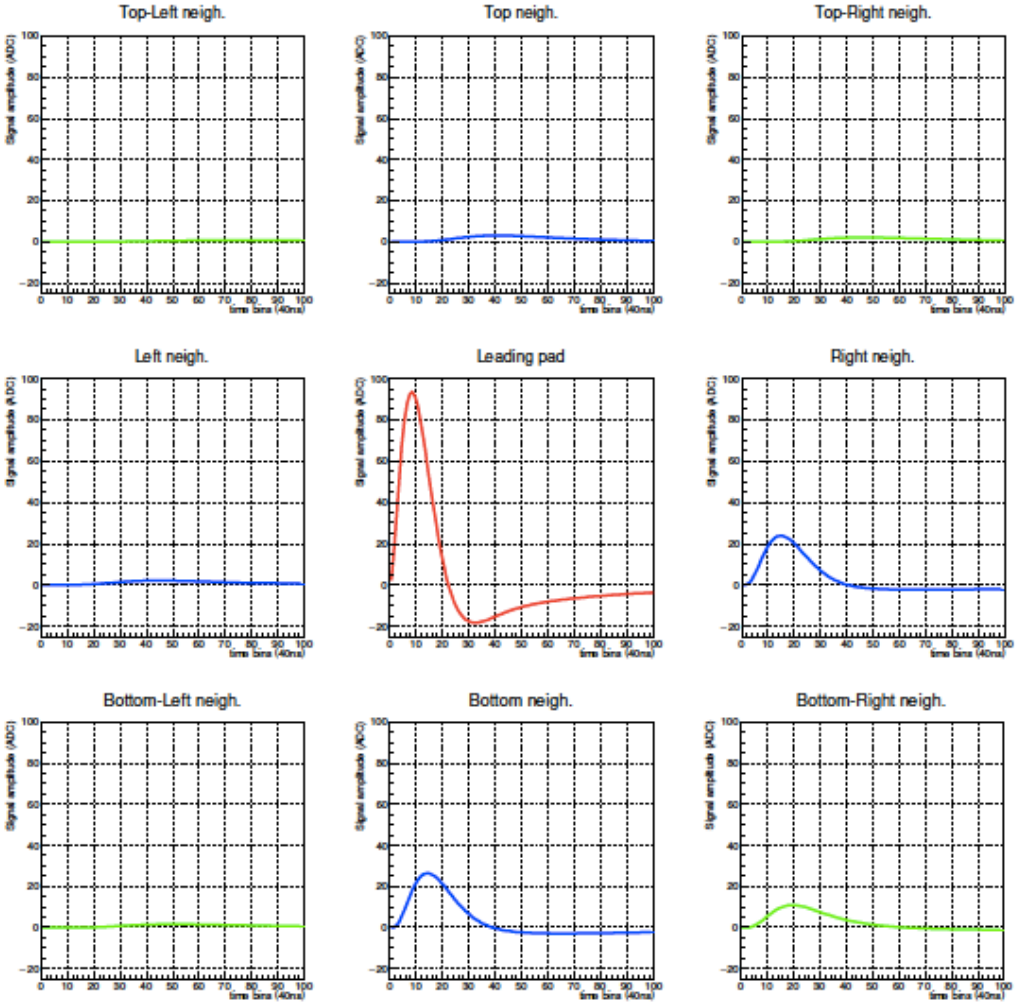
SIGNAL MODEL

- Convolution of charge diffusion function with derivative of electronics response function.

$$S(t) = Q(t) * \frac{dR}{dt}$$



RC = 60 ns/mm^2
Q_{norm} = 4 units



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RC MEASUREMENTS USING X-RAY DATA

Examples of RC extraction from Simultaneous fit

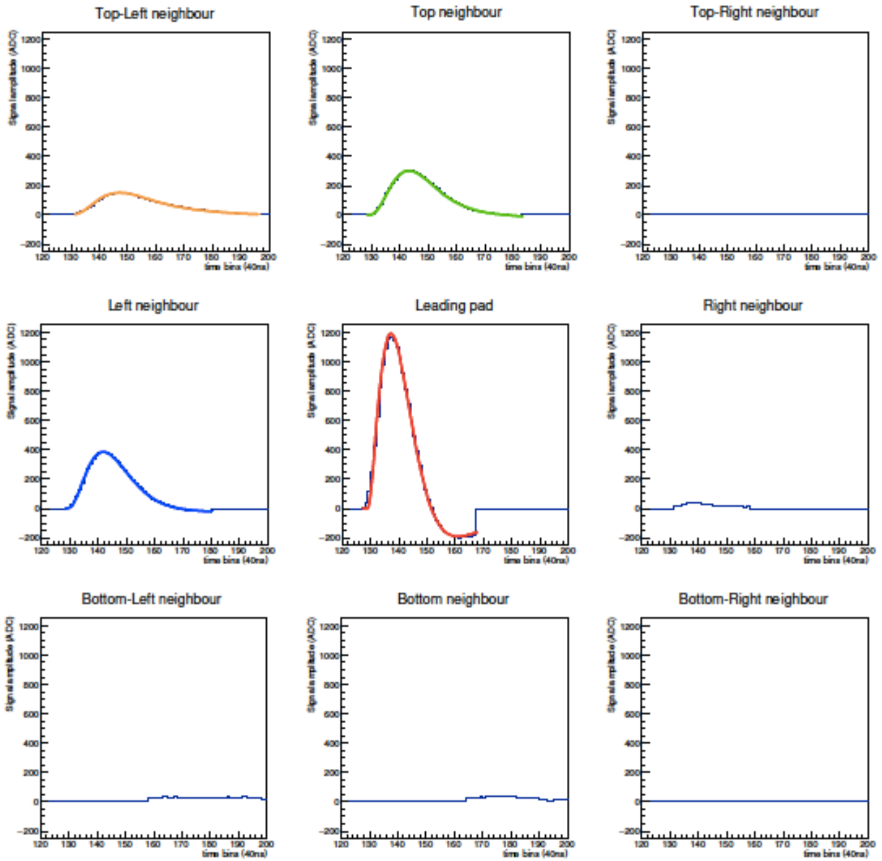


Figure 18: An example of a simultaneous fit of four waveforms of an X-ray generated event. <u>Fit results:</u> RC = (146.6 ± 1.6) ns/mm^2, Q_{norm} = (1788.4 ± 9.8) ADC, (x_0, y_0) = (-0.442 cm, 0.352 cm)(w.r.t center of leading pad), χ^2/Ndf = 1.08

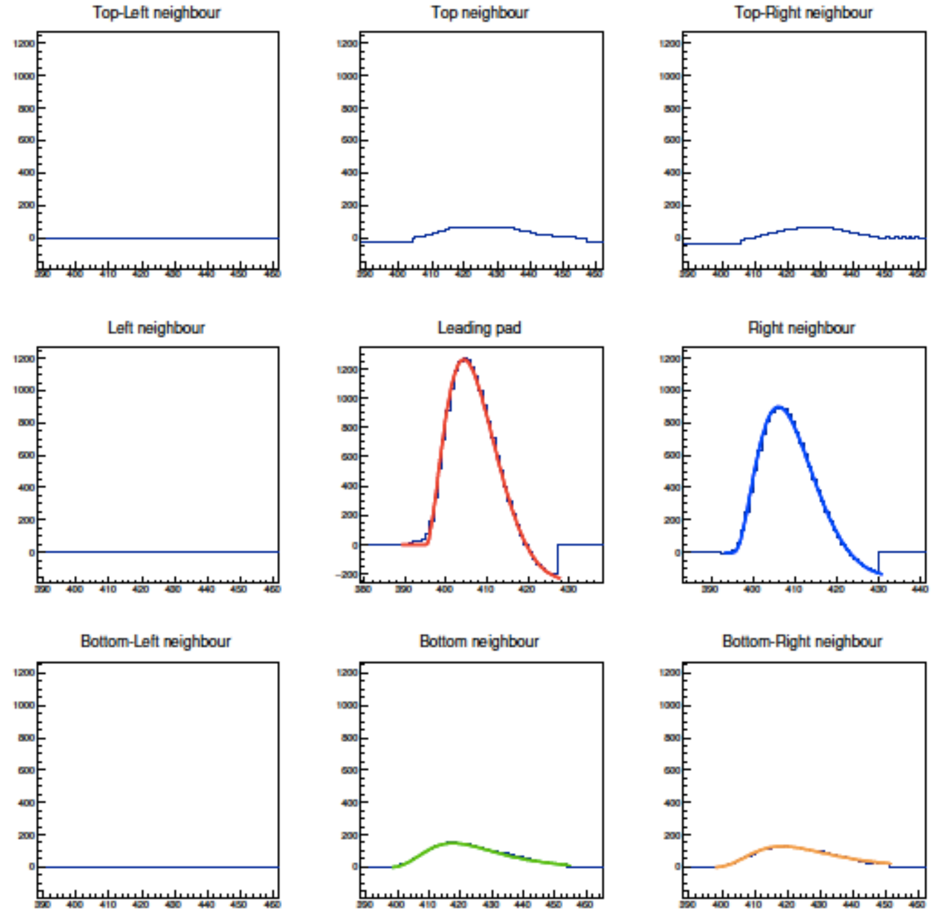
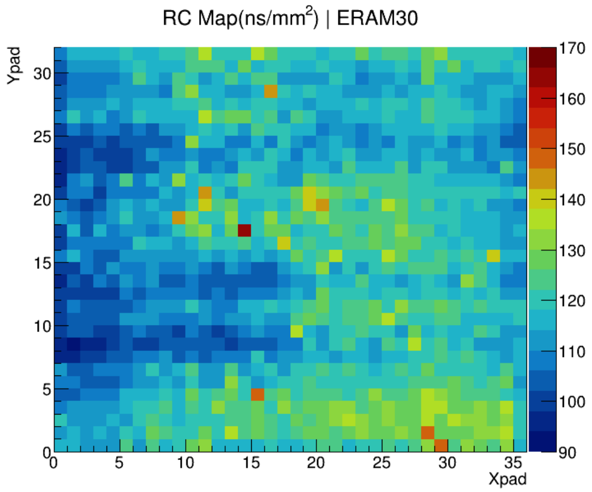


Figure 23: Second example of a simultaneous fit of 4 waveforms of an X-ray generated event. <u>Fit results:</u> RC = (100.5 ± 1.1) ns/mm^2, Q_{norm} = (2218.4 ± 11.5) ADC, (x_0, y_0) = (0.523 cm, -0.108 cm)(w.r.t center of leading pad), χ^2/Ndf = 1.48

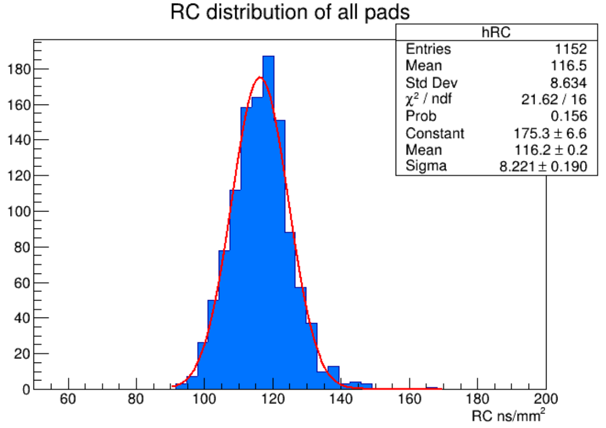
RC extraction from Simultaneous fit

RC map of ERAM30

RC distribution of ERAM30

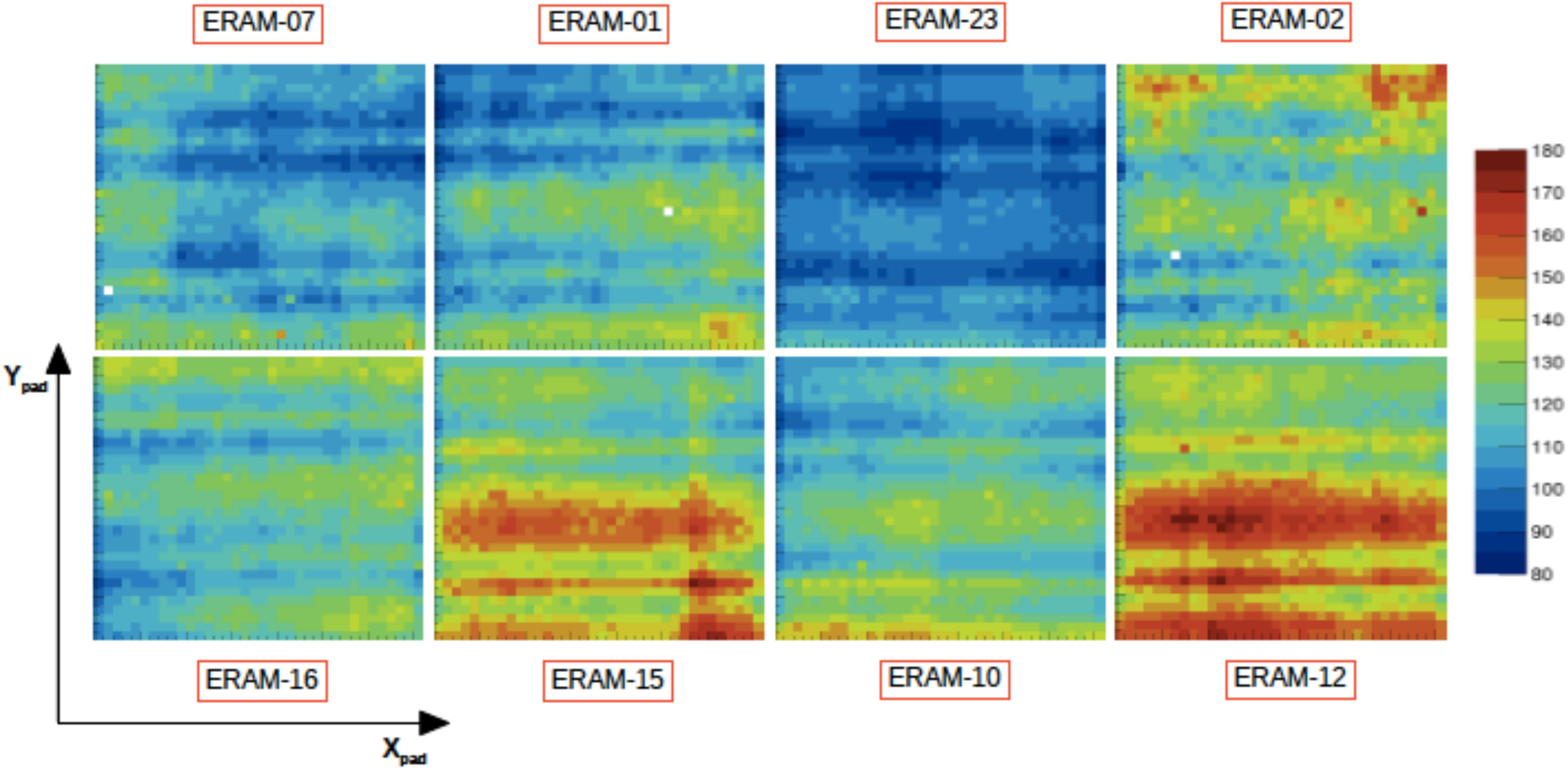


RC_{mean} = 116.2 ns/mm^2



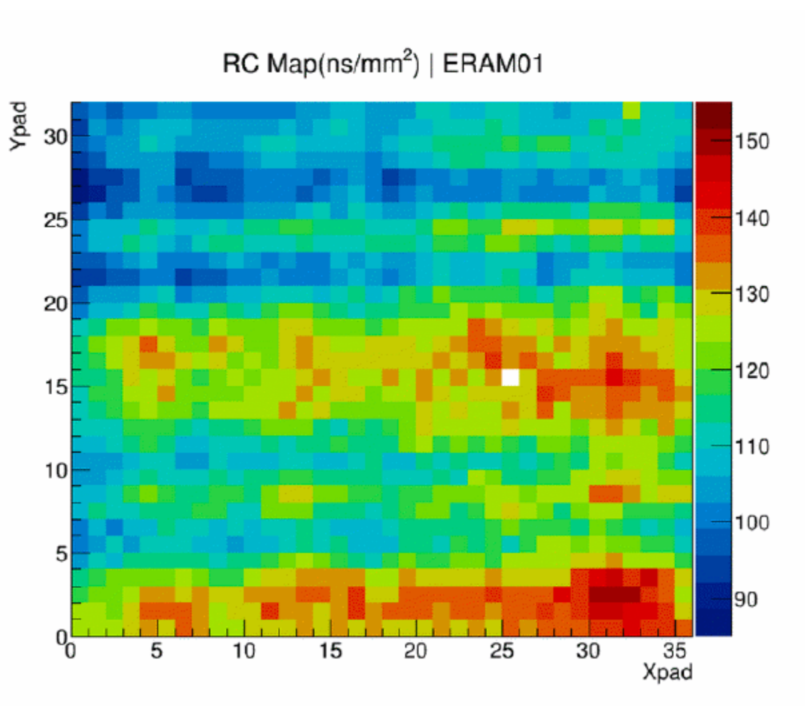
- Results from simultaneous fit of events from all pads.
- RC uniformity in horizontal direction.

RC MAPS OF DIFFERENT ERAMS

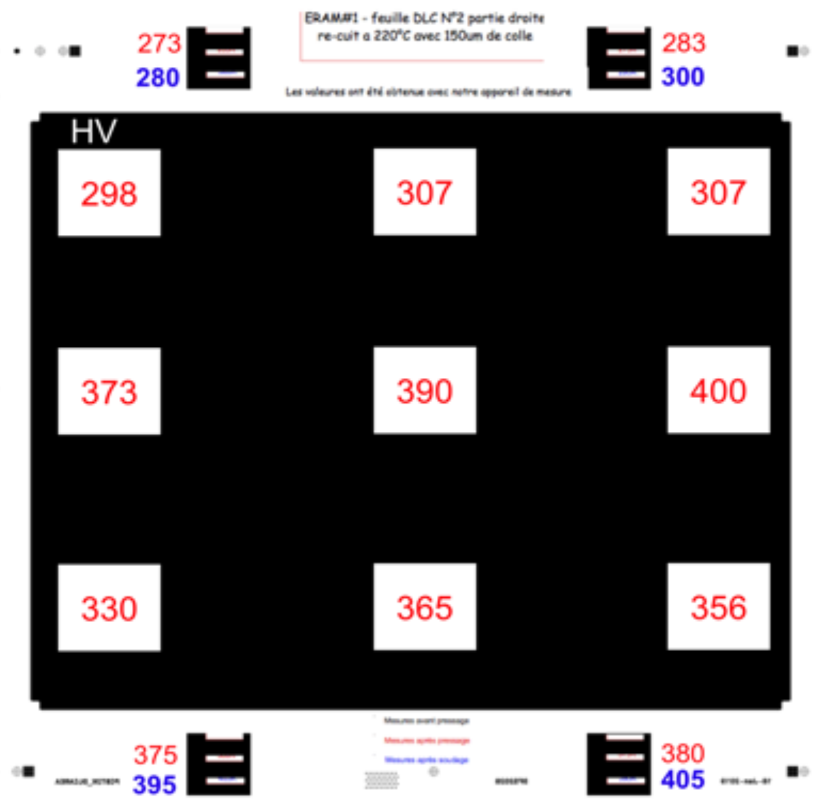


DO WE UNDERSTAND RC MAP STRUCTURE ?

ERAM-01: RC map from fit



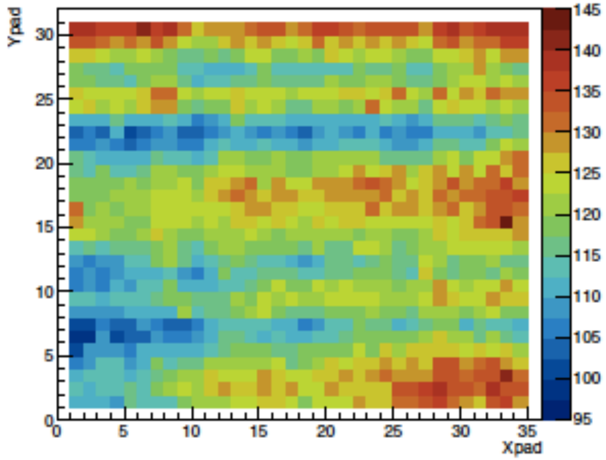
ERAM-01: Resistivity Measurements



RC map structure seems to be correlated to the resistivity (R) measurements.

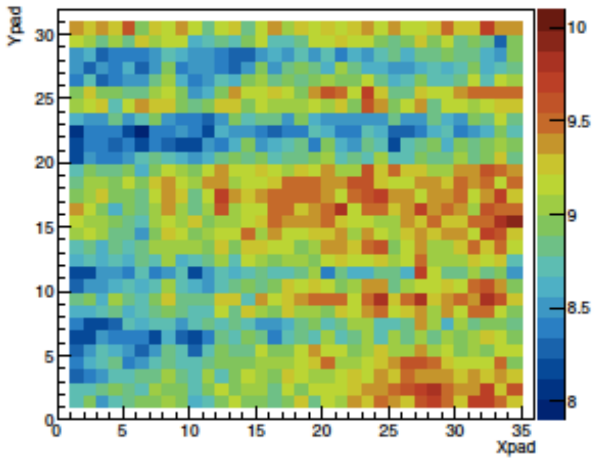
DO WE UNDERSTAND RC MAP STRUCTURE ?
RECONSTRUCTING BASIC-LEVEL VARIABLES

RC map from fit



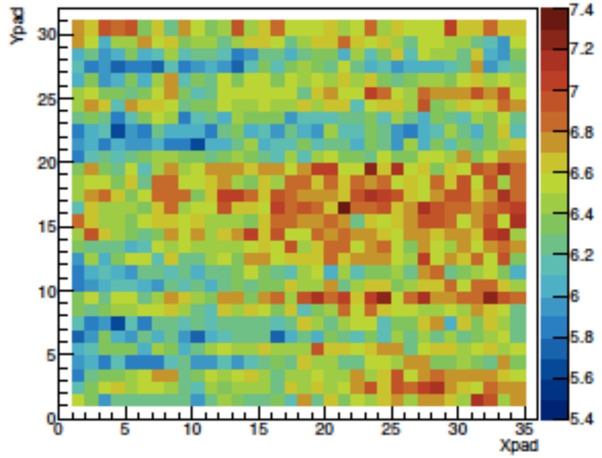
(a)

Basic level variable (var2) map

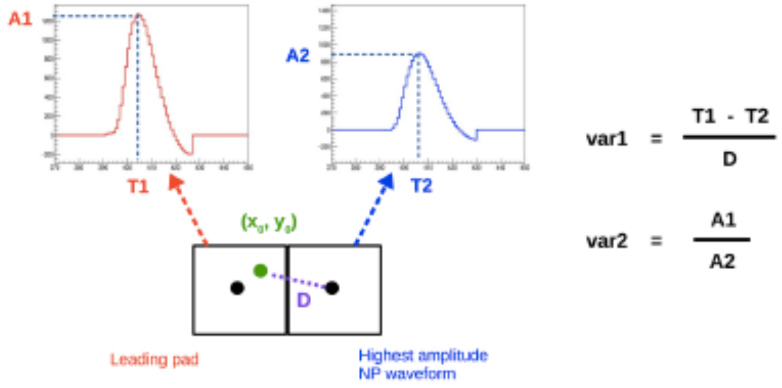


(b)

Amplitude Ratio (var2) map



(c)



(d)

Do We Understand RC Value?
RC Calculation from First Principle

Plane capacitance

$$C = \frac{\varepsilon_0 \times \varepsilon_r \times S}{d}$$

$$R \times \left(\frac{C}{S}\right) = \frac{\varepsilon_0 \times \varepsilon_r}{d}$$

- Vaccum permitivity $\varepsilon_0 = 8.854\times10^{-12}$ Fm^{-1}
- Relative permitivity ε_r [APICAL]~3.3 and ε_r [glue] ~4.8
- d = 150 (glue) + 50 (Apical) = 200 μm
- R = 280-405 kΩ /☐

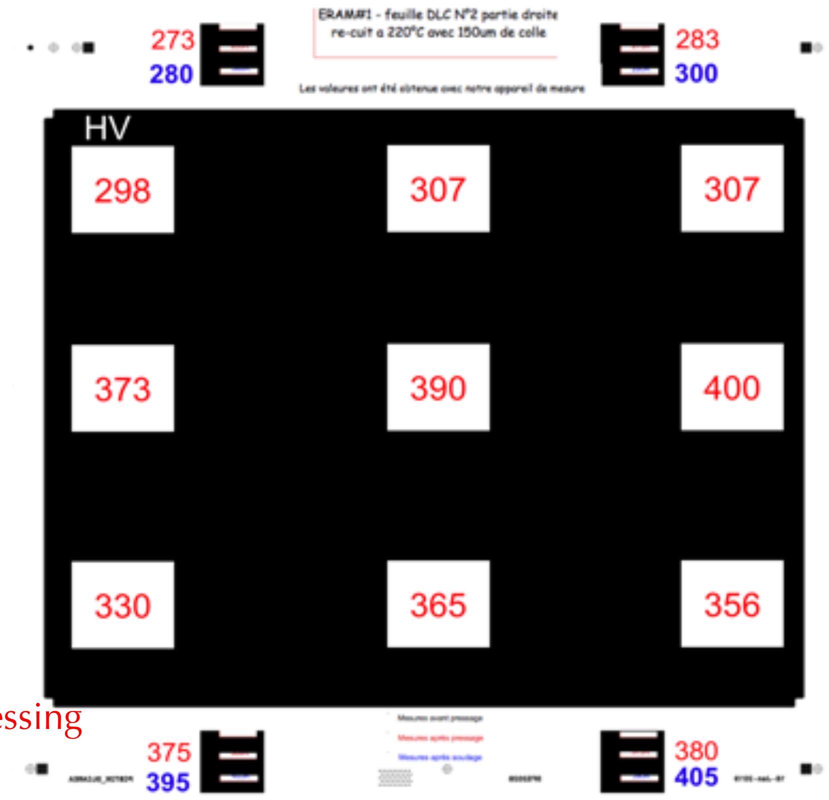
R = 280 kΩ/☐
RC = 53 ns/mm^2

R = 405kΩ/☐
RC = 77 ns/ mm^2

RC from fit is ~2 times higher than the RC from simple calculation ?!

- **Uncertainties on RC calculation:**
  - How well do we measure R?
  - Do we know precisely the distance d ?
  - Is ε_r value precise or approximate?

ERAM-01: R Measurements



ERAM-01 R (kW) after DLC pressing

ERAM-01 R (kW) finished

RC Mean Value for different ERAMs

$R_{std.}$ = 400 kΩ/□

$d_{std.}$ = 150 µm

ERAM	Mean RC (ns/mm^2)
01	114.9 ± 0.4
02	124.2 ± 0.5
03	116.4 ± 0.3
07	111.3 ± 0.3
10	119.9 ± 0.3
12	144.2 ± 0.6
15	134.9 ± 0.5
16	119.3 ± 0.3
18	68.98 ± 0.15
23	100.2 ± 0.2
26	115.3 ± 0.2
29	102.0 ± 0.2
30	112 ± 0.3

ERAM 18:

- 200 kΩ/□
- 150 µm

($R_{std.}/2$ ⟹ $(RC)_{std.}/2$)

ERAMs 23–30:

- 200 kΩ/□
- 75 µm

($R_{std.}/2$, $d_{std.}/2$ ⟹ $(RC)_{std.}$)

DE LA RECHERCHE À L'INDUSTRIE

GAIN MEASUREMENTS USING X-RAY DATA

www.cea.fr

Charge density:

$$\rho_{0D}(r,t)=\frac{Q_{primary}G}{2\pi}\frac{1}{\sigma^2(t)}e^{-\frac{r^2}{2\sigma^2(t)}}$$

Charge on a pad:

$$Q_{pad}(t)=\boxed{\frac{Q_{primary}G}{4}}\left[\operatorname{erf}\left(\frac{x_H-X_0}{\sigma(t)\sqrt{2}}\right)-\operatorname{erf}\left(\frac{x_L-X_0}{\sigma(t)\sqrt{2}}\right)\right]\left[\operatorname{erf}\left(\frac{y_H-Y_0}{\sigma(t)\sqrt{2}}\right)-\operatorname{erf}\left(\frac{y_L-Y_0}{\sigma(t)\sqrt{2}}\right)\right]$$

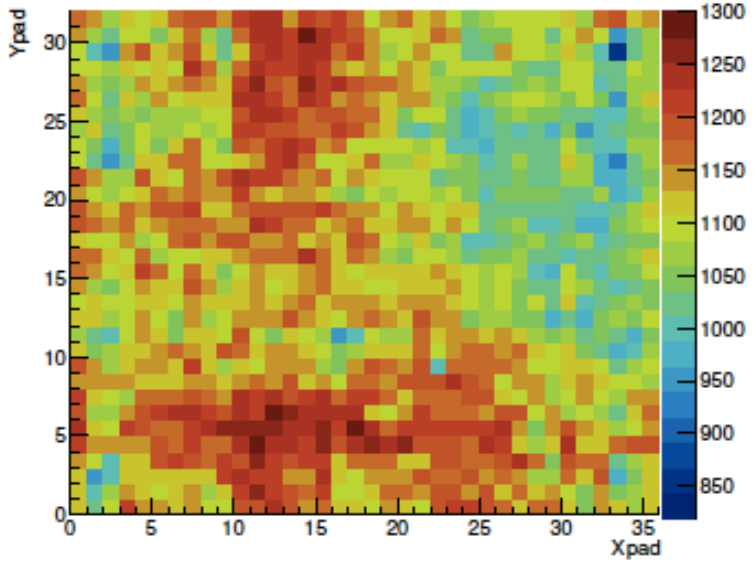
Electronics response: (upto ADC) Dirac impulse response

$$ADC_{Dirac}(t)=\boxed{\frac{4096}{120\,fC}\frac{F(t)}{F^{Max}}}\text{ with } F(t)=e^{-w_s t}+e^{-\frac{w_s t}{2Q}}\left(\sqrt{\frac{2Q-1}{2Q+1}}\sin\left(\frac{w_s t}{2}\sqrt{4-\frac{1}{Q^2}}\right)-\cos\left(\frac{w_s t}{2}\sqrt{4-\frac{1}{Q^2}}\right)\right)$$

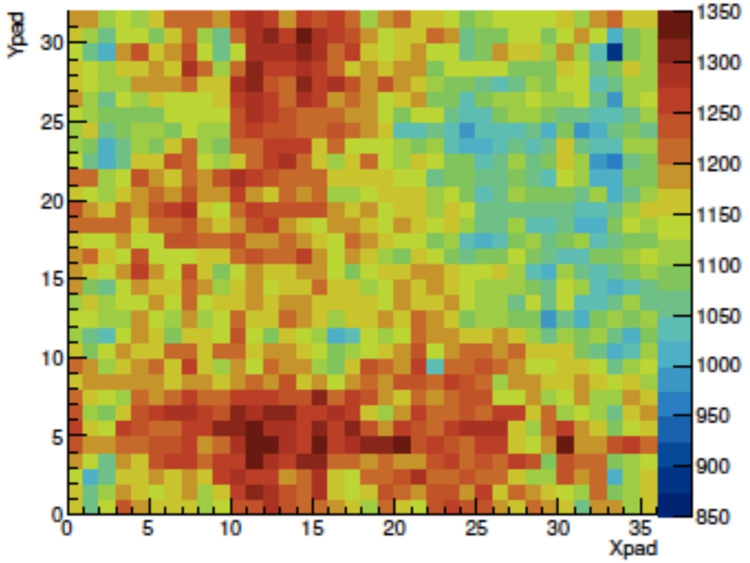
- Implementing the correspondence : **120 fC** ⟷ **4096** counts.
- Dirac current pulse carrying 120 fC → ADC(t) impulse response with a maximum amplitude of 4096 counts.

COMPARISON OF GAIN FROM TWO METHODS

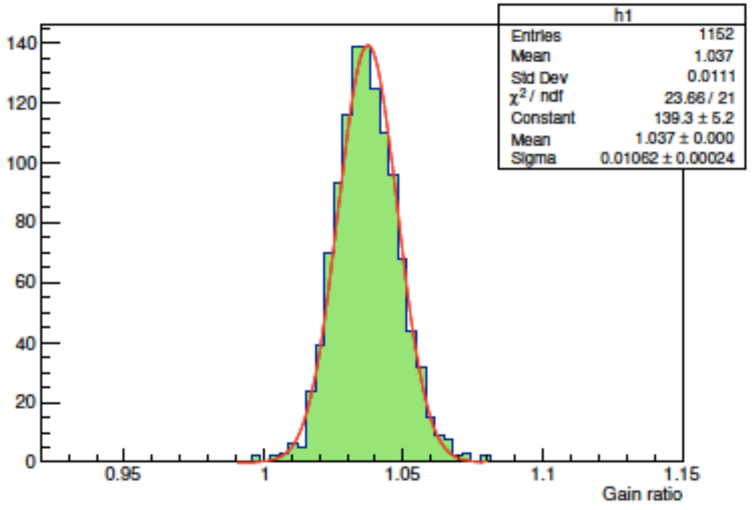
Gain map from simultaneous fit method



Gain map from ^{55}Fe spectrum



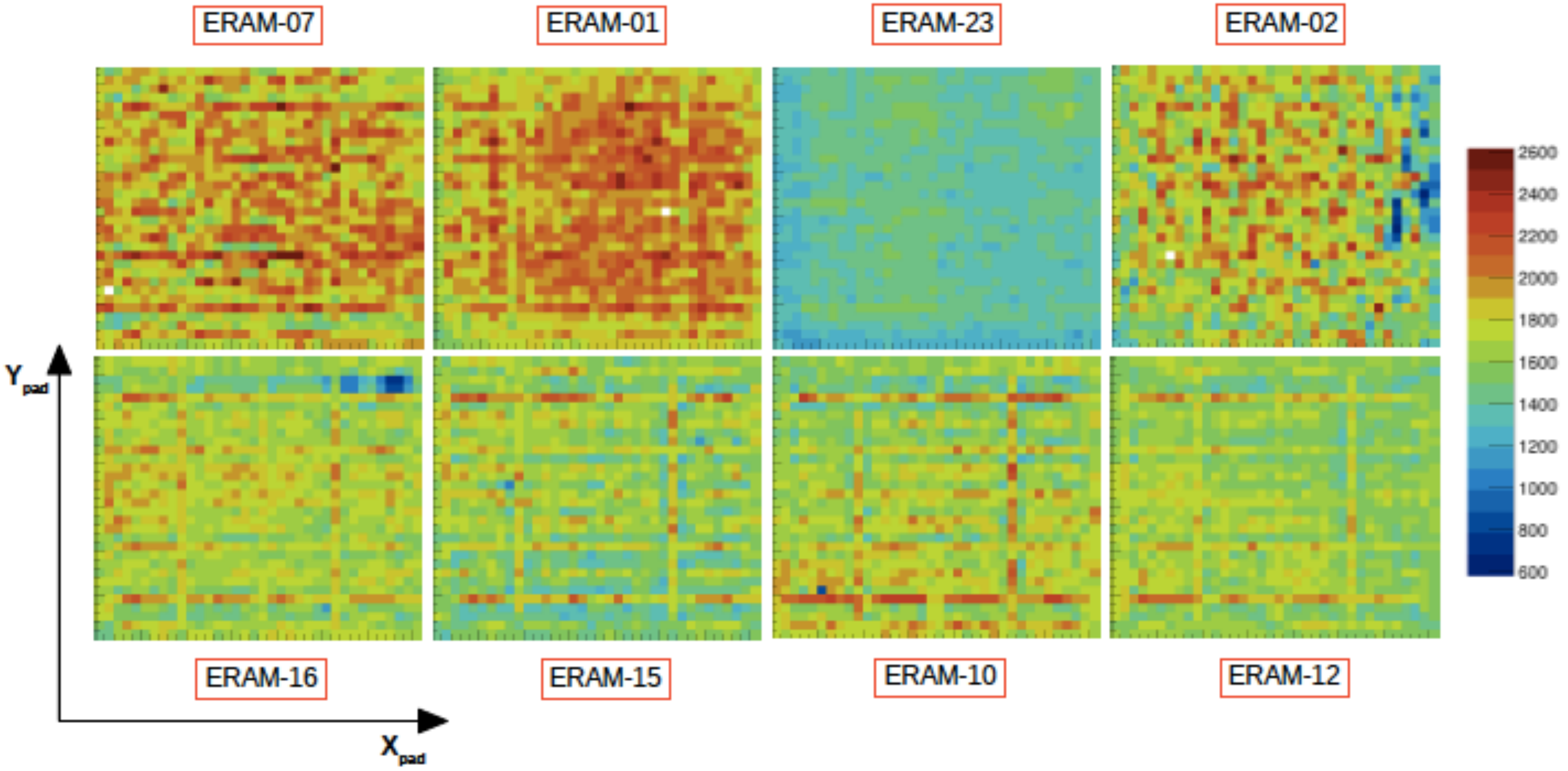
Ratio of Gain(of each pad) obtained from 2 different methods



$Ratio_{mean}$ = 1.04

- Very high similarity in Gain maps obtained from 2 different methods (^{55}Fe spectrum can be re-constructed from simultaneous fit using Q_{norm}) .
- **Gain results serve as validation for Electronics Response function, and robustness of entire model.**

Gain maps of diffrent ERAMs

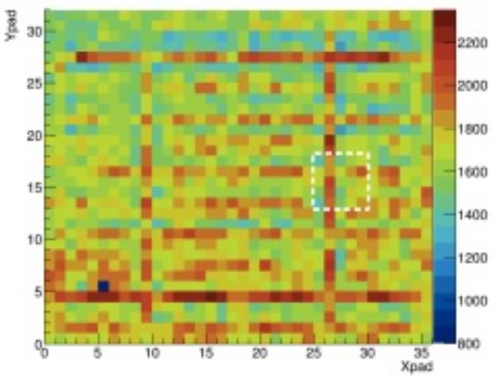


Various PCB designs visible due to mechanics ribs, not since ERAM-23

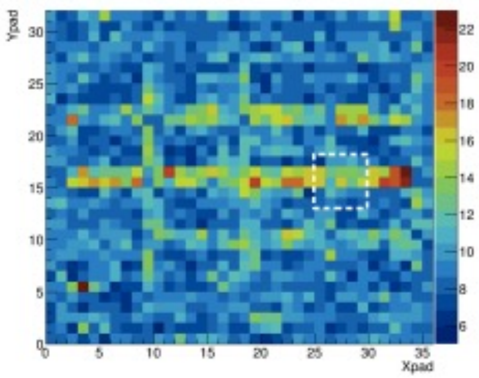
LARGER GAIN AND RESOLUTION ON SEVERAL DETECTORS

- For some modules, we have seen larger gain and energy resolution where the aluminum stiffener is glued (up to 20% corresponding to 1-2 µm of gap variation).
- This is due to local extra thickness of copper & soldermask on the backside of the PCB which affect the micromegas amplification gap after DLC foil & stiffener gluing under pressure
  →**solved with modified PCB**

Gain map



Resolution map



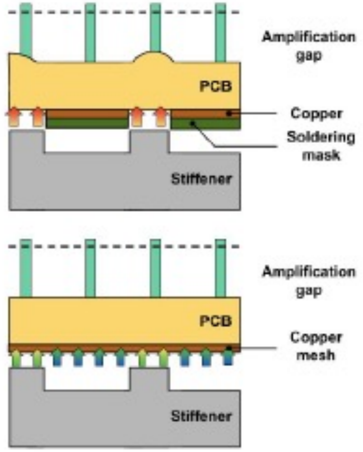
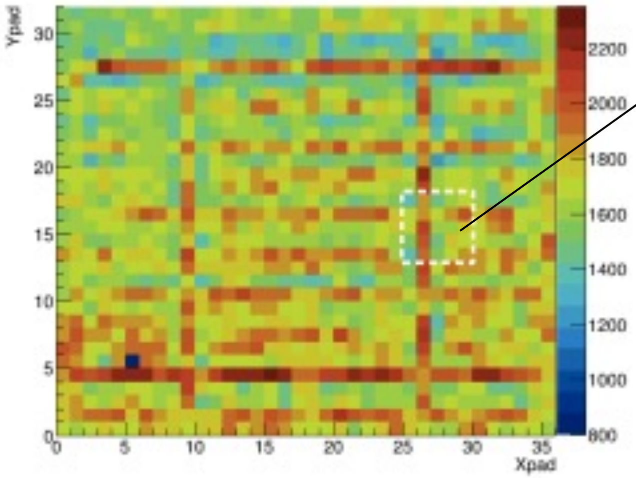
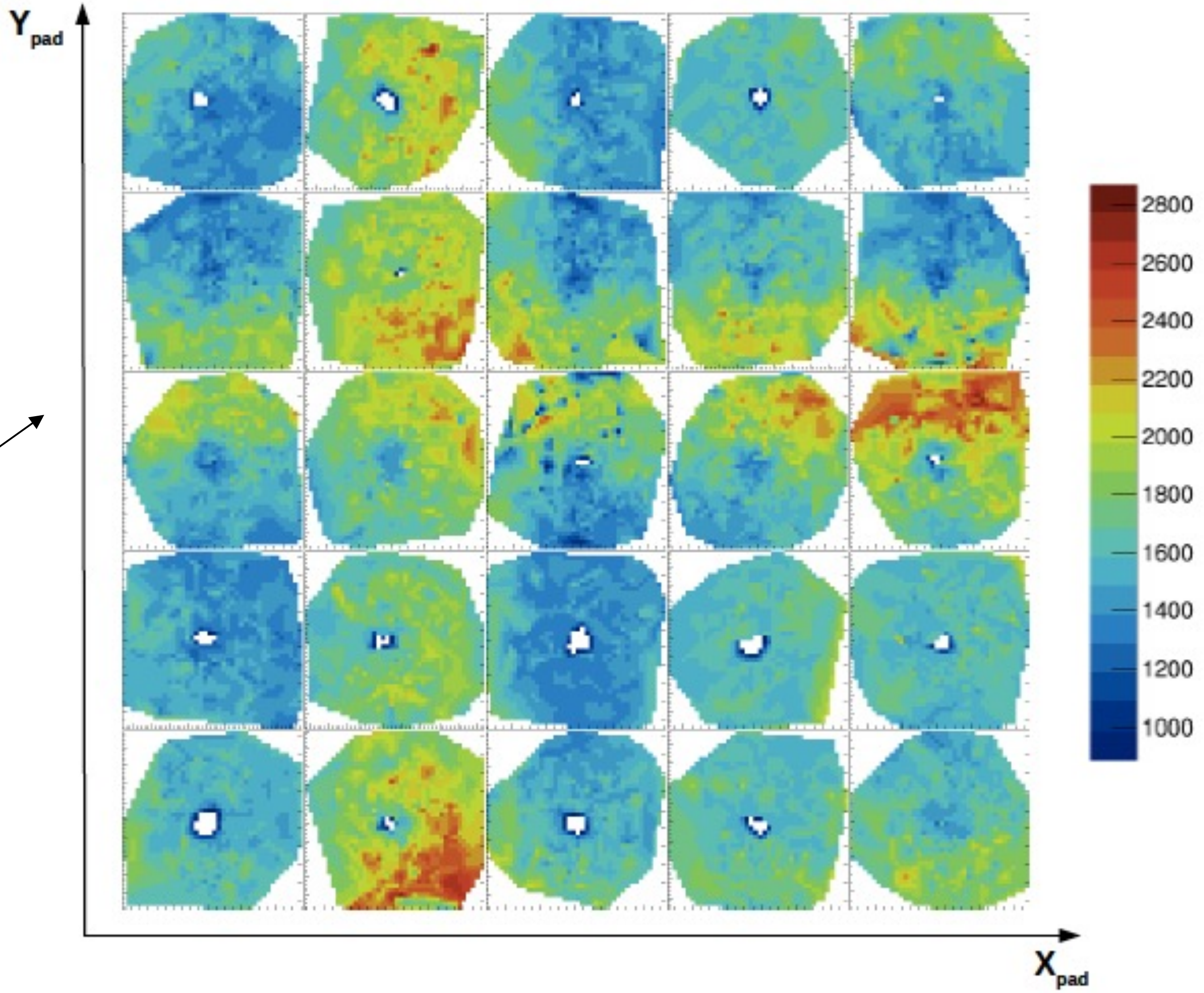


Figure 32: Schematic view of the assembly of the detector on its mechanics resulting in the non-uniformities observed on the 2D gain and energy resolution maps. The arrows represents the mechanical constraints applied which are evenly distributed when the soldermask is removed and replaced by the copper mesh.

Gain Variation Within a Pad

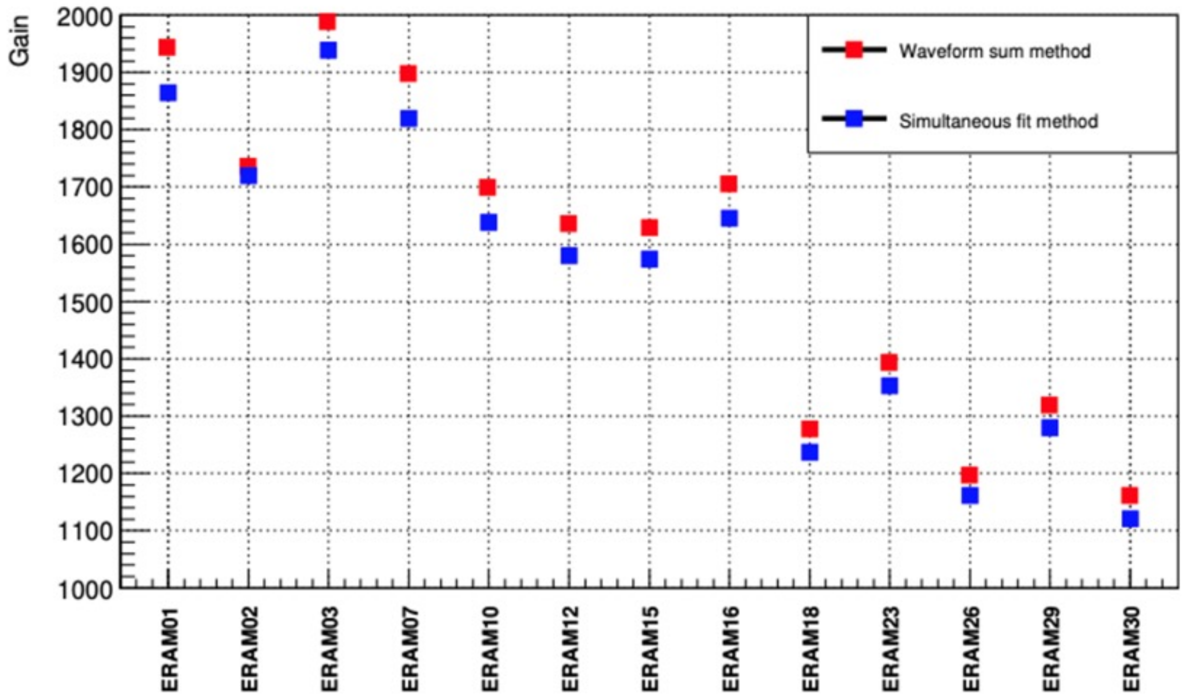


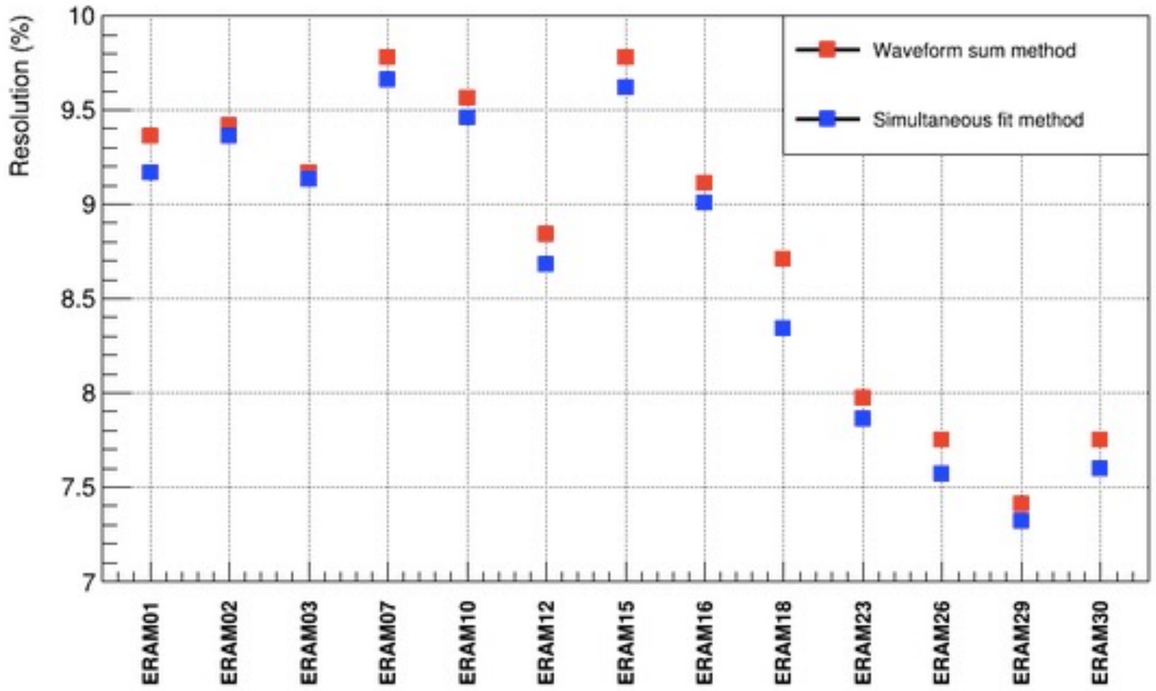


ABSOLUTE GAIN AND RESOLUTION OF ERAMS ANALYZED

Summary of Gain vs #ERAM

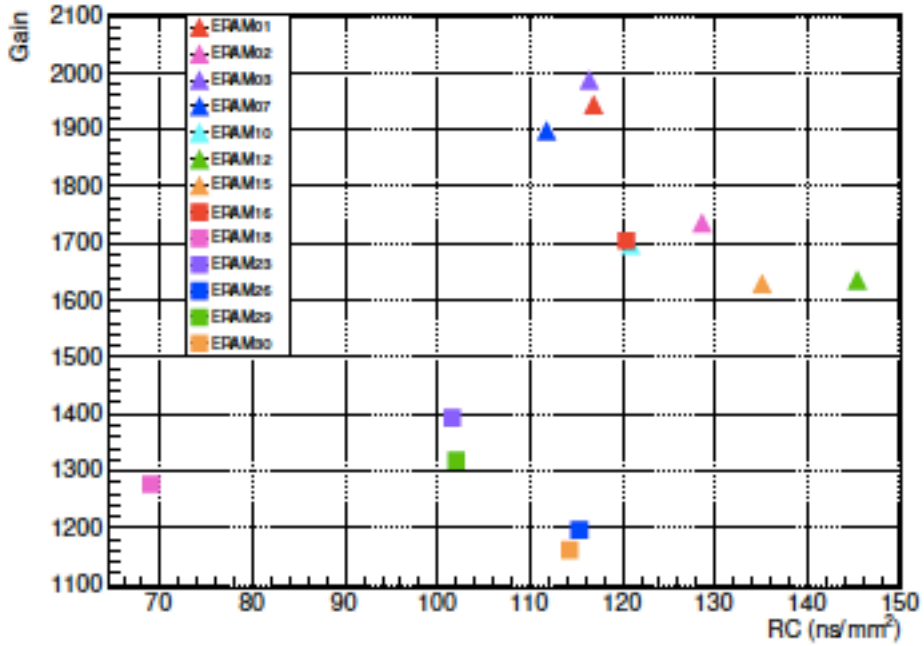
Summary of Resolution vs #ERAM

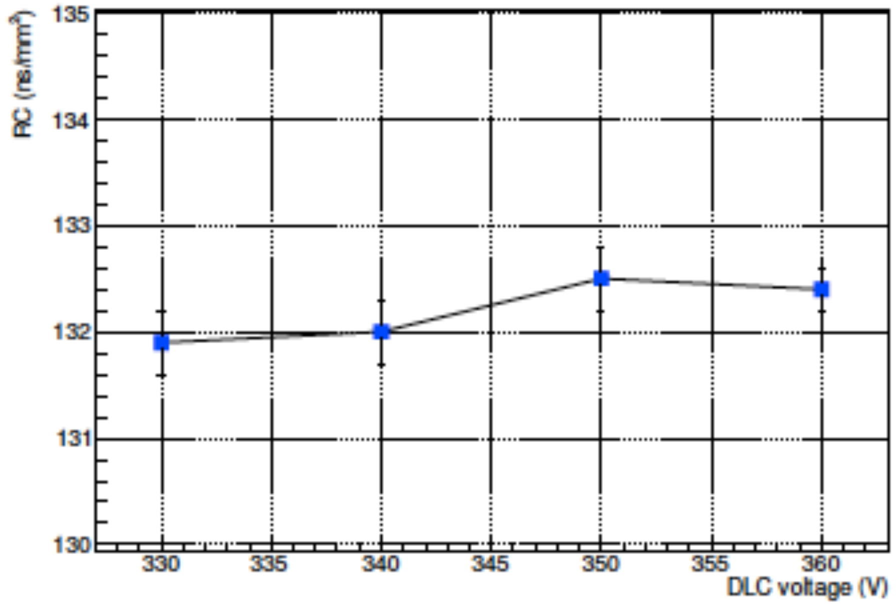




- Absolute gain of ERAM detectors changes with design → under investigation
- The gain difference between the two methods for different ERAMs is less than 4%. This systematic difference is due to the electronics effect in the simultaneous fit.

DEPENDENCE OF MEAN RC ON MEAN GAIN





- There is no apparent correlation between mean RC and mean gain.
- This observation is confirmed by the fact that RC doesn't change with DLC voltage.

CONCLUSION

- ND280 upgrade will employ resistive Micromegas for the read-out of HA-TPC, which works on the principle of charge spreading.
- **The ERAM technology is complex and delicate to produce. The expertise and excellent partnership with the CERN/PCB workshop enabled a high yield (~80%) of high quality production of 21 ERAMs up to now.**
- Charge spreading model is obtained from convolution of charge diffusion function and derivative electronics response function. The model is able to successfully fit waveforms from X-ray data.
  - RC and Gain can be simultaneously extracted from X-ray data.
- A test beam was conducted at CERN to characterize 8 ERAM modules inside a field cage mockup.
  - dEdx and spatial resolution for horizontal tracks is also within ND280 upgrade requirements.
- The installations of the bottom and top high-angle TPCs in the T2K/ND280 near detector are planned for June and October 2023 respectively.
- A paper summarizing the results presented here (and more) will be submitted to NIM next week.

DE LA RECHERCHE À L'INDUSTRIE

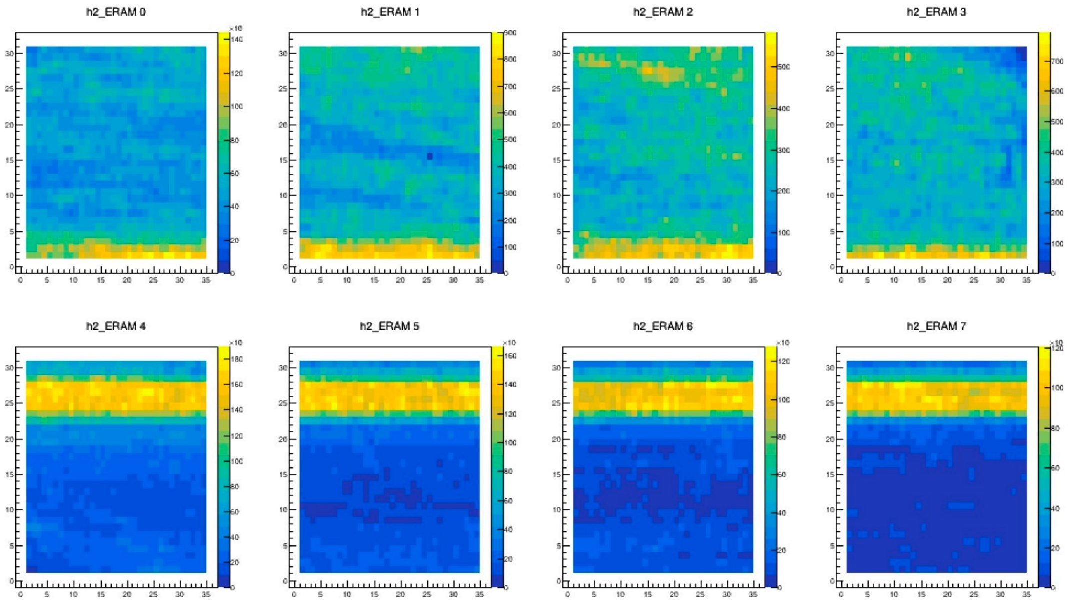
RESULTS FROM TEST BEAM
- SPATIAL RESOLUTION
- DEDX

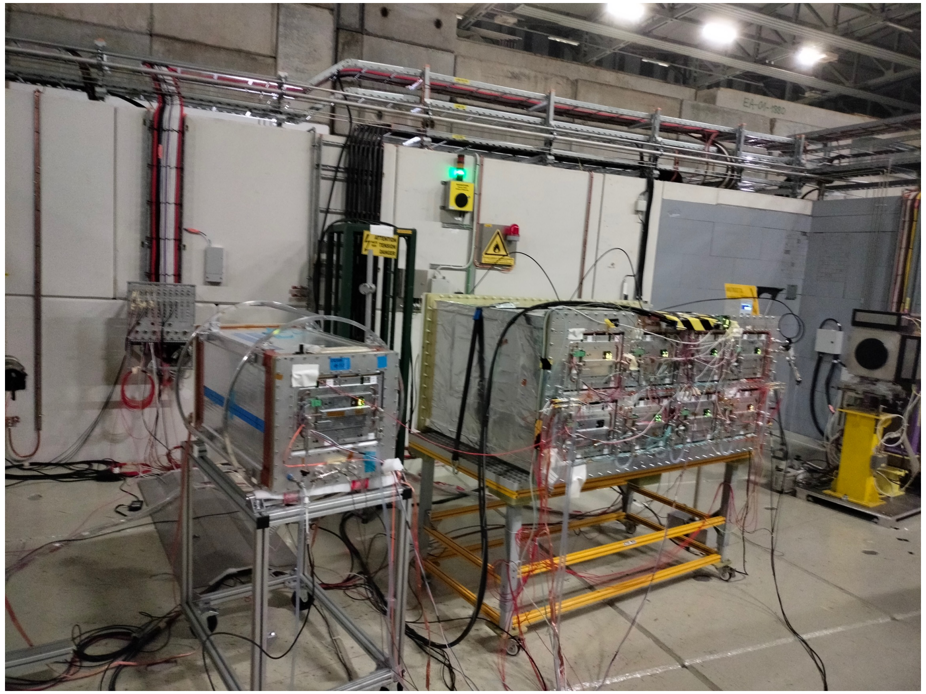
TEST BEAM AT CERN

- Commissioning with beam and characterization of final 8 ERAM detectors and electronics using Field Cage mockup.

<u>Mockup Data analysis</u>:

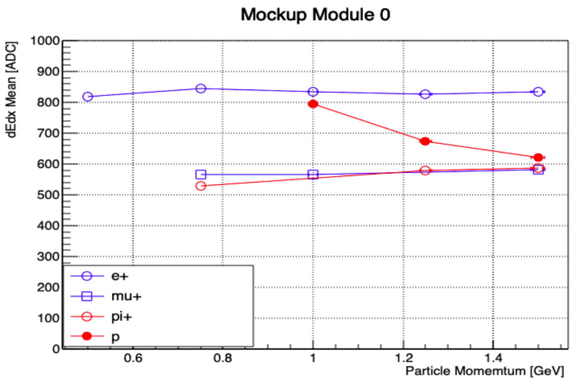
- Track dE/dx resolution & PID study:
  e, proton, muon, pion (momentum range 0.5 –1.5GeV.
- Track spatial resolution (No B field):
  scan along 5 drift distances and 3 Y-positions.



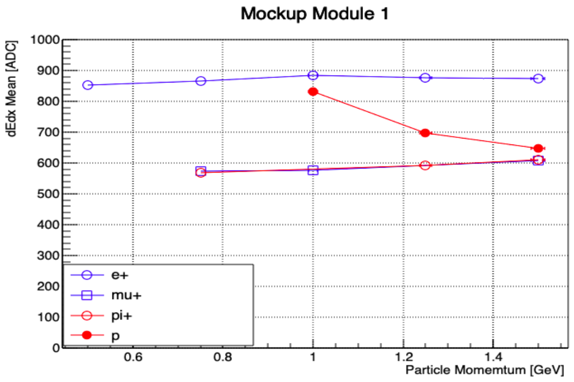


DEDX MEAN

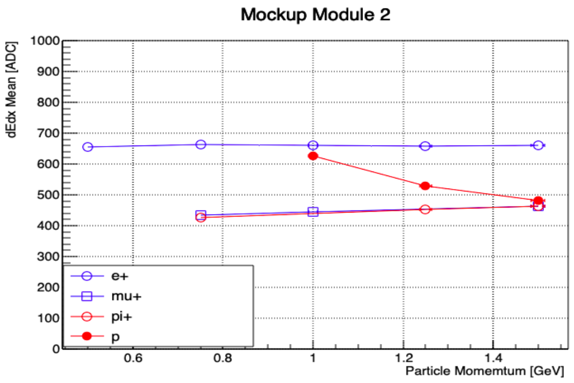
ERAM-07



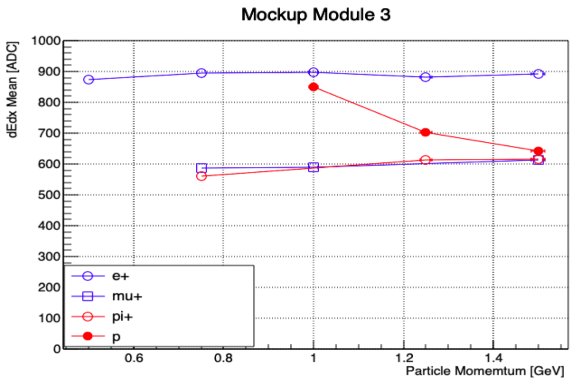
ERAM-01



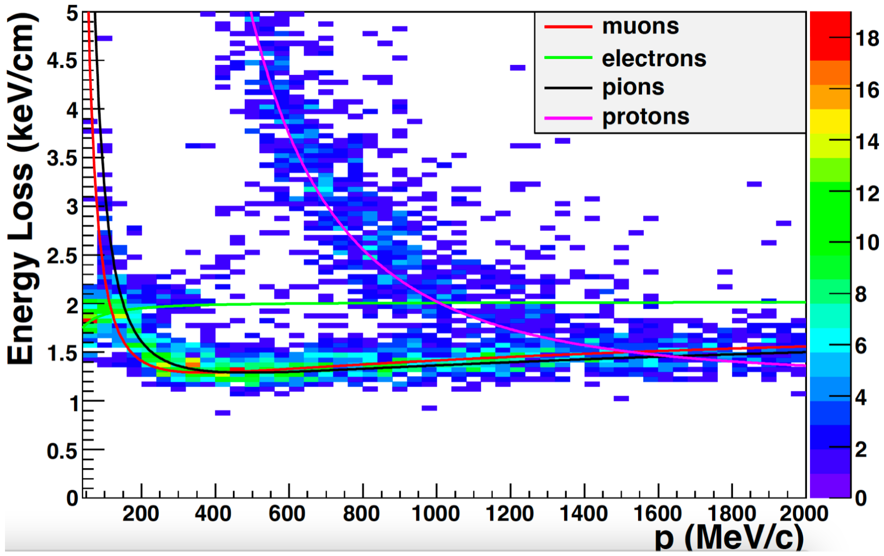
ERAM-23



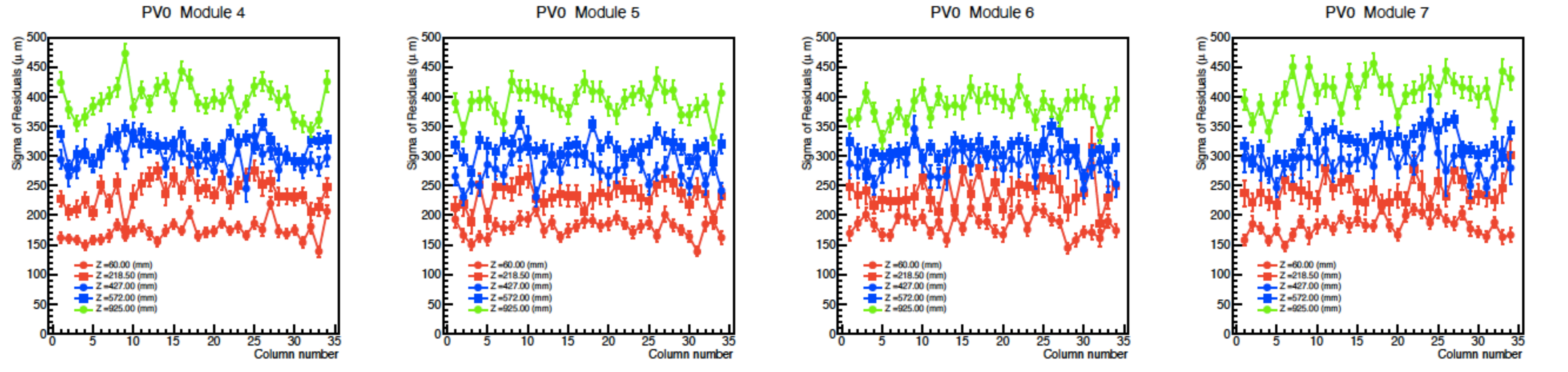
ERAM-02



- The mean dEdx for different ERAMs, particle and momentum are nicely following the simulation.
- ERAM-23 has small mean E_{loss} compared to the others
  →Should correct for the gain.
- dEdx resolution (10%) is within ND280 upgrade requirements

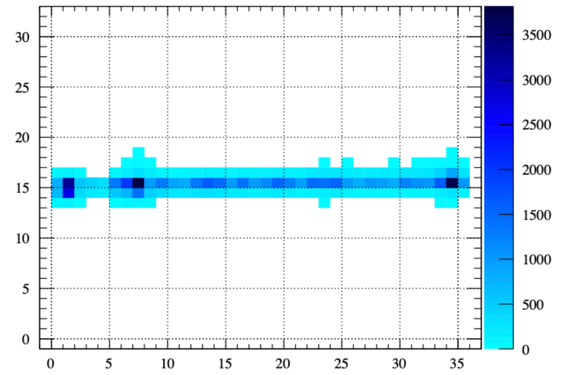


Resolution VS Column number

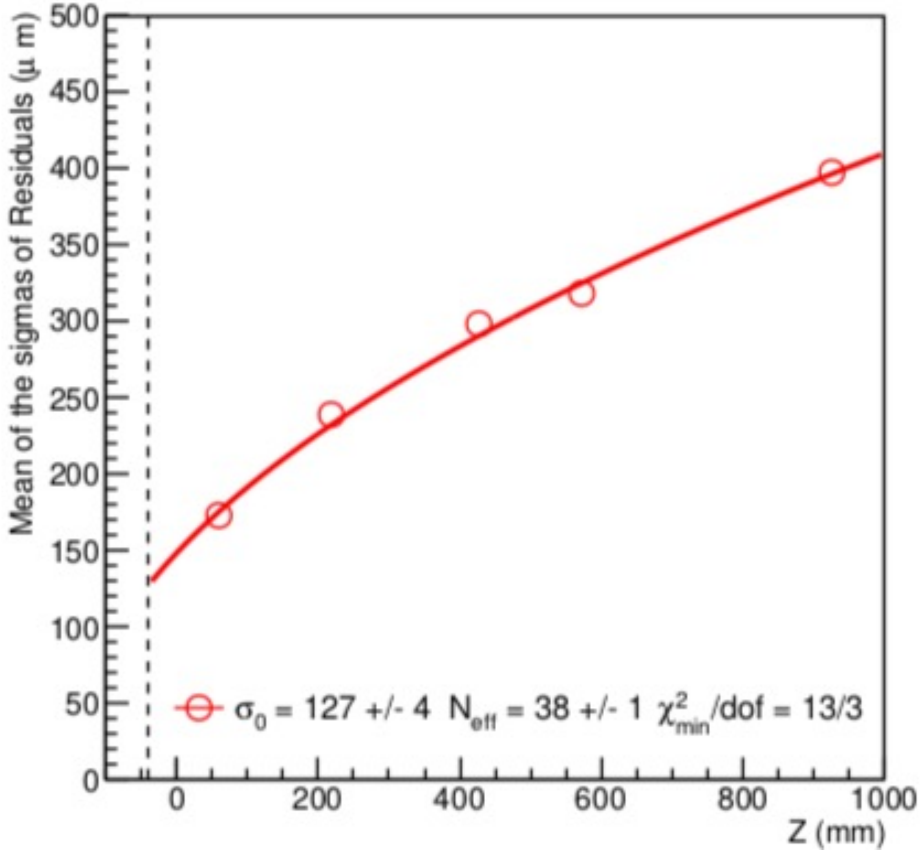


- The spatial resolution as a standard deviation of the difference between the reconstructed position in a given cluster (obtained using Pad Response Function) and a global track fit

- Spatial resolution for horizontal tracks is within ND280 upgrade requirements



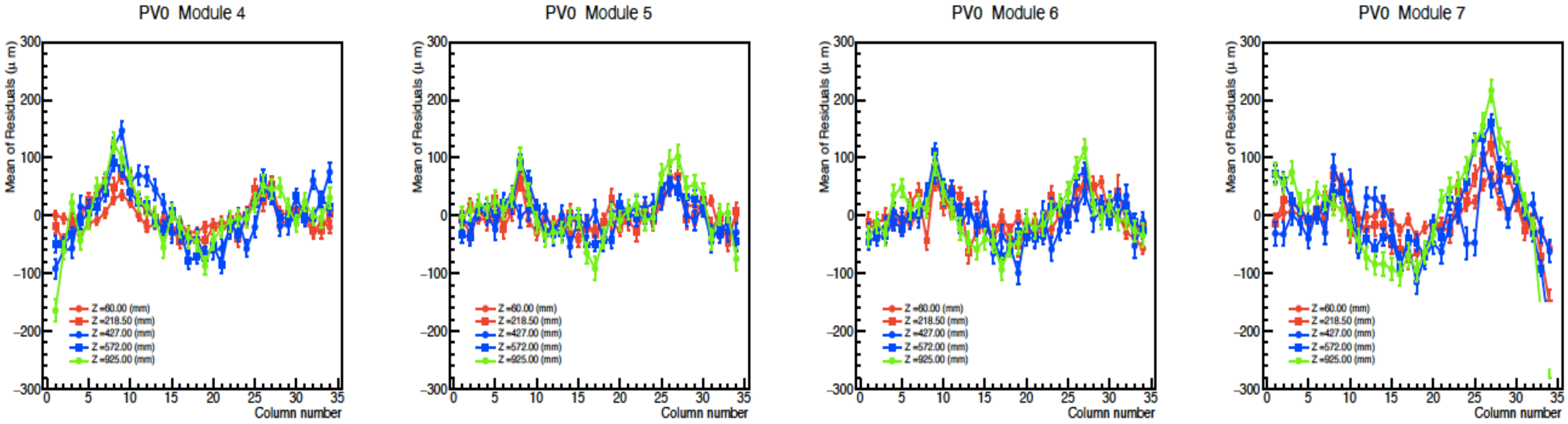
SPATIAL RESOLUTION VS Z VALUES



- Spatial resolution for horizontal tracks is within ND280 upgrade requirements

BIAS VS Z SCAN

Bias VS Column Number



- The bias is defined as the mean value of the residuals between the reconstructed position in a given cluster (obtained using Pad Response Function) and a global track fit.
- The bias are intrinsic to the device and not an artifact of the analysis method (we cross-checked the results with different methods)
- On going work to study the effect of non uniformity of pad responses, misalignment of the pads, RC non-uniformity,… using Monte Carlo

DE LA RECHERCHE À L'INDUSTRIE

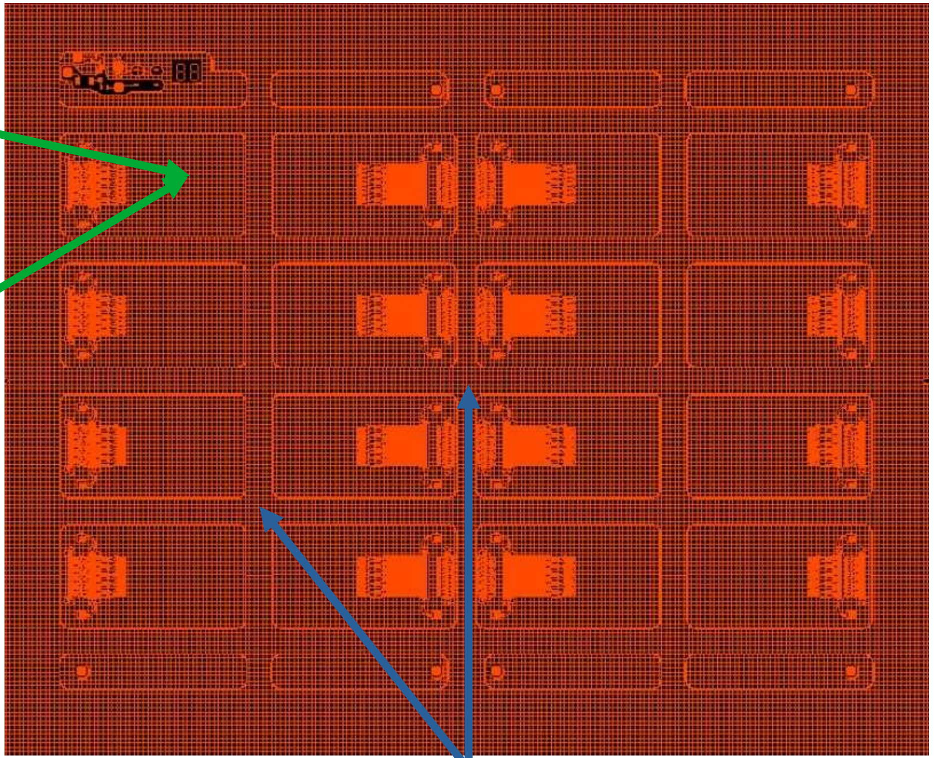
BACKUP

ERAM PCB Modifications

- Stiffener gluing procedure was first suspect but no clear correlation found after several tests (change of gluing process)
- Assumption that non uniformity of PCB backside affects DLC side flatness and therefore amplification gap by a few microns after pressing DLC
- **→ PCB modification!**

- ERAM up to 16
  - Those areas are also covered with green soldermask
- ERAM09-16
  - PCB produced by ELTOS Cie following industry IPC standard
  - Copper & soldermask is probably thicker than @ CERN
- ERAM17-24
  - Soldermask was removed
- ERAM23
  - Replaced copper pad by a copper mesh
  - **→More uniform PCB**
  - **→ More uniform Gain**

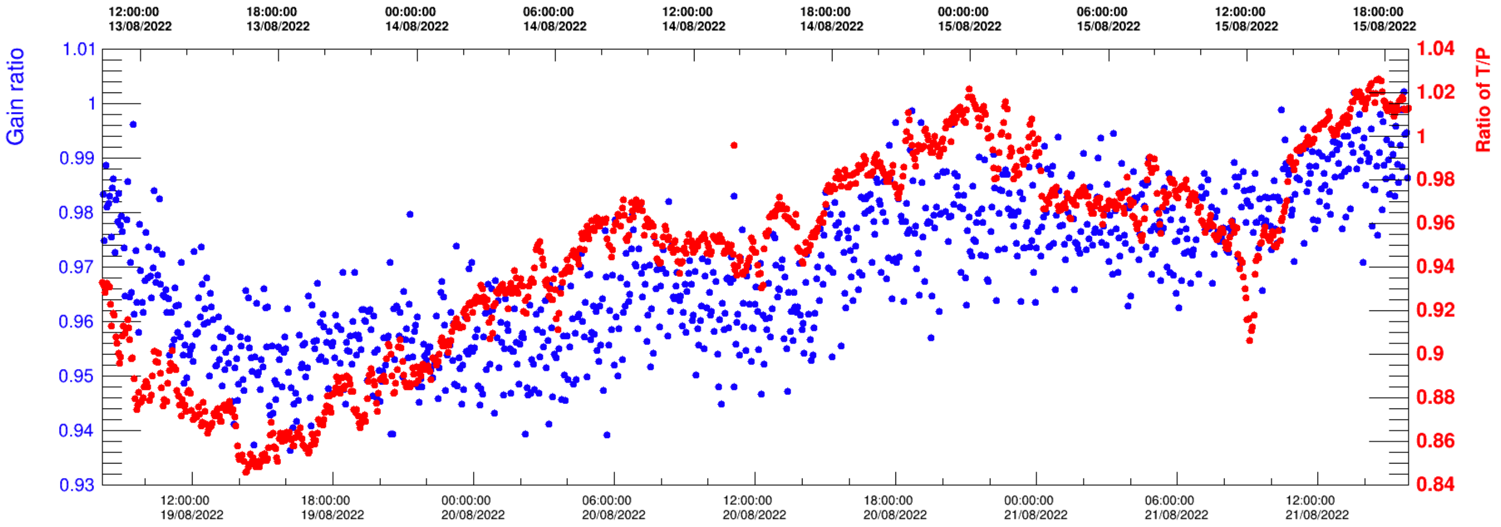
ERAM top layer up to ERAM-23

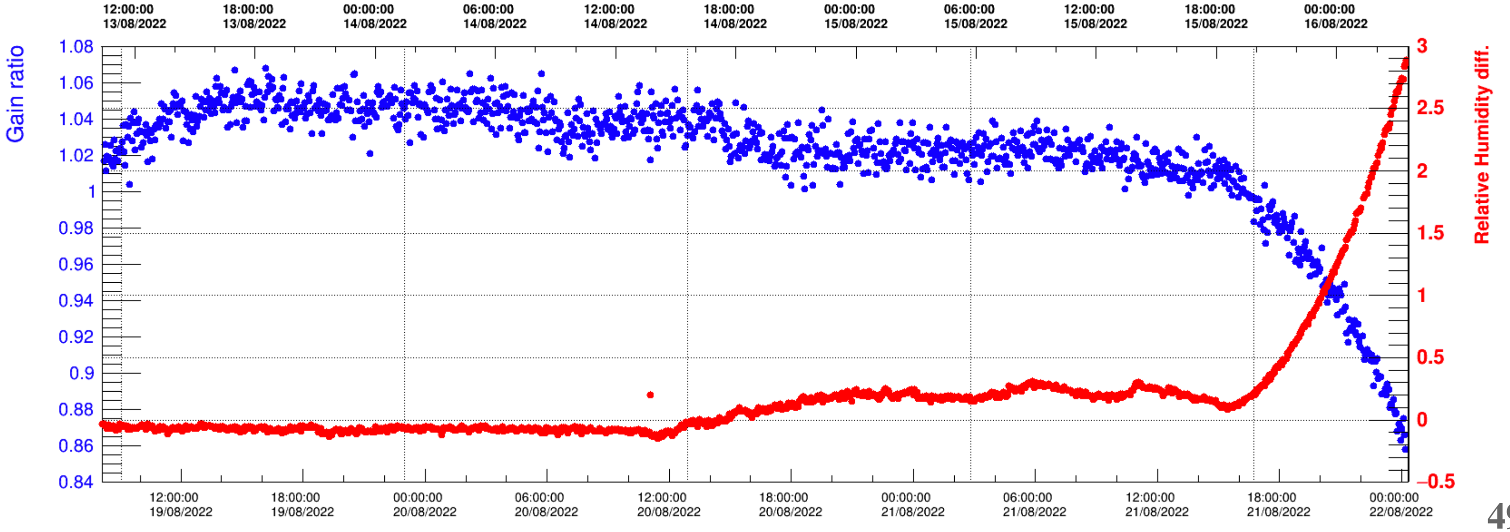


Stiffener is glued on the PCB TOP layer where copper mesh is

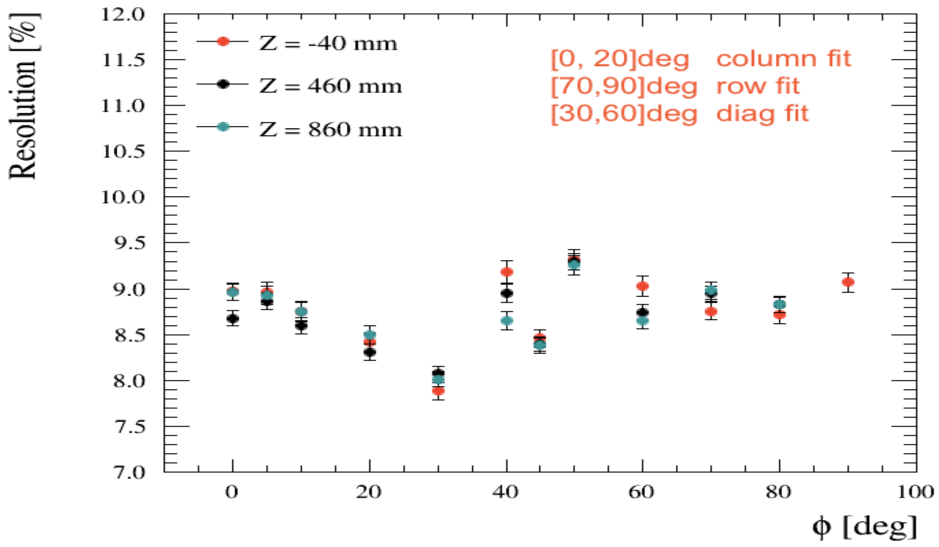
ENVIRONMENTAL EFFECTS ON GAIN

- Effect of following environmental conditions,recorded during an X-ray test bench shift, on gain is studied:
    - **Gas temperature**
    - **Chamber pressure**
    - **Relative gas humidity**
- An ERAM was scanned twice at two different instances.
- Ratio of Gain of each pad from both the instances was compared with the ratio of environmental conditions recorded during those pad-scans.
- Gain maps to be corrected in case of significant changes in environmental conditions.

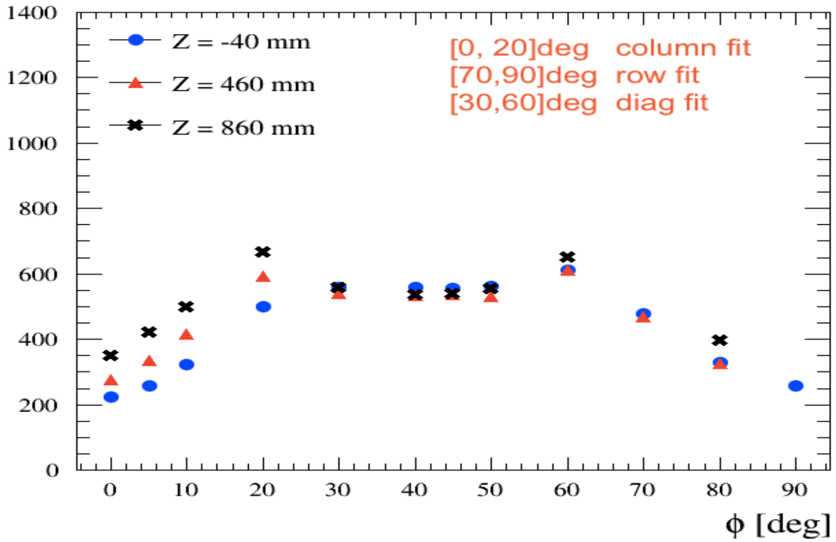




dEdx Resolution

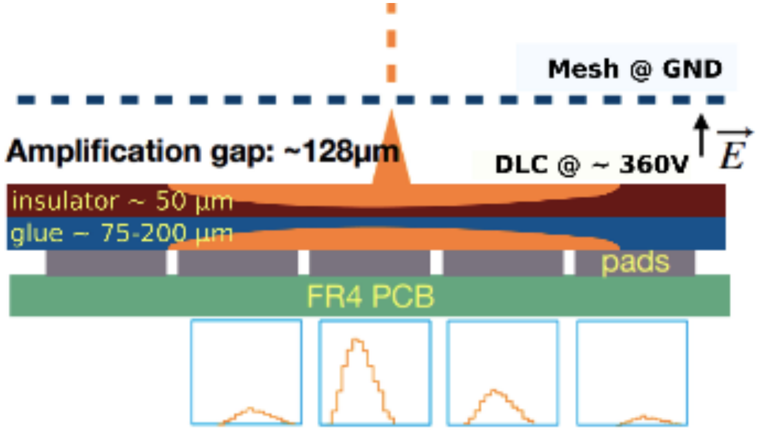


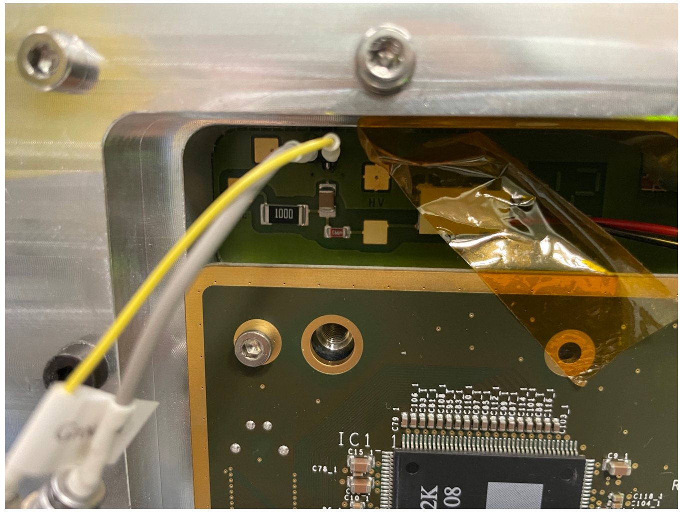
Spatial Resolution



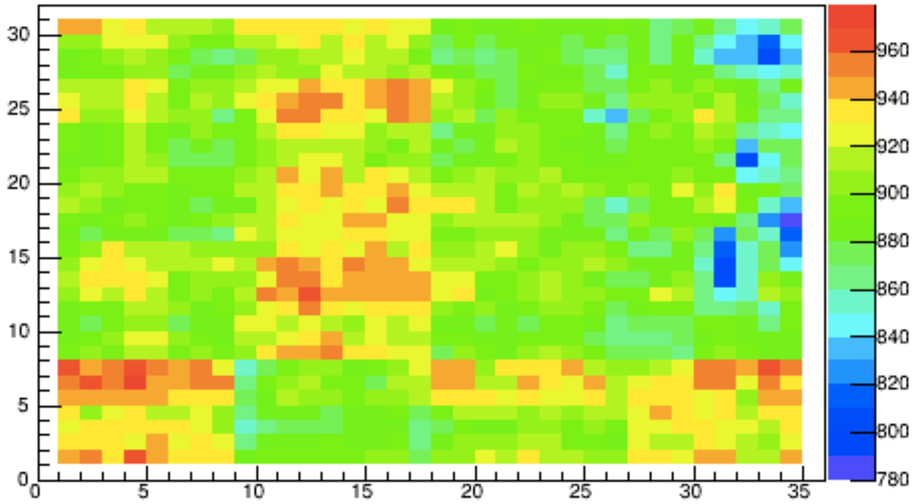
- dE/dx resolution is between 7.5 % and 9.5% (almost no dependency on drift distance)
- Spatial resolution for small inclination is worse for higher z due to transverse and longitudinal diffusion.
- Resolution significantly degrades for inclined tracks. The obtained results: σ varies between 0.2 mm and 0.7 mm wrt ϕ

MESH PULSING





ERAM-02: Amplitude map



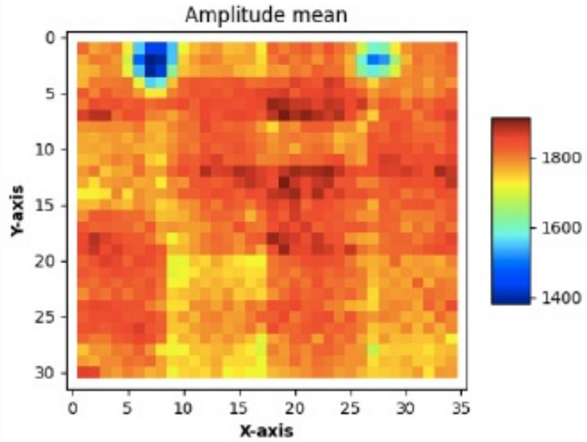
- The aim of this test is to try to separate the detector gain and the electronics response, DLC, glue (RC) effects.

- Principle : we inject a signal in the mesh. If the electronics response and the RC is uniform, we should observe a signal of the same amplitude at the same time in all the pads.

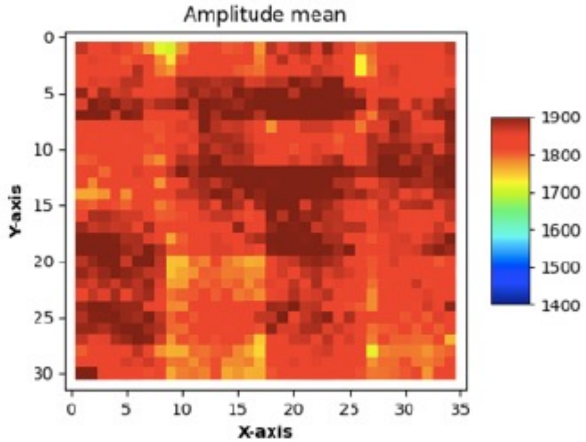
MESH PULSING PROCEDURE

- In case of issues we observed a lower amplitude region
  - Find defects on three detectors due to **Pyralux pillars not well fixed on DLC due to dust during pressing**
  - **Solution: Bake with weight on mesh to refix the pillars.** This has the advantage of avoiding possible dead zone due to the glue

Before



After



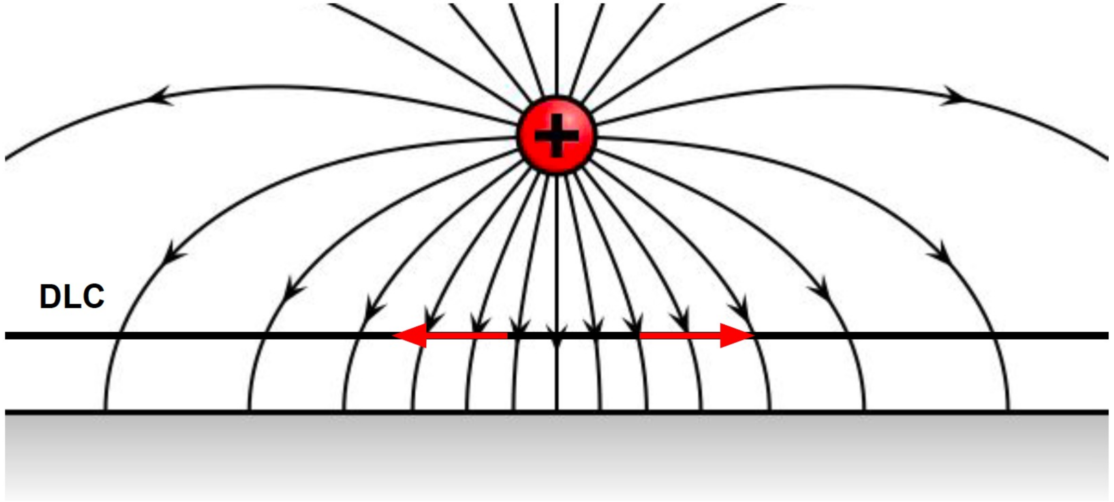
Mesh pulsing is performed before and after gluing stiffener.

- **The first scan** allows to spot low gain region: blue will have a 2 times lower gain with X-ray
- Criteria to accept a detector is: uniformity of 15%
- **The second scan** allows us to check if the gluing process change the response.

Shepherd dog effect

L. Scomparin, G.Collazuol

Ion field on DLC greatly affects long distance charge spread



- **The ions limit the spread of the charge.**
- The RC value is a factor 2.7 greater than the one obtained without considering the ion contribution (from toy study).