

# R&D progress on resistive DLC

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On behalf of the Resistive DLC Collaboration



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# Outline

- **Short summary of small samples made by Hauzer**
- **Adhesion test of the new DLC + Cu foils**
- **R&D on large area DLC coating**

# Advantages of the Hauzer device(Compared with Teer)

- **Able to heating the substrate up to 450°C;**  
**(Effective way to increase the adhesion between DLC & substrate)**
- **Provide very powerful plasma source etching(PSE);**  
**(Effective way to increase the adhesion between DLC & substrate)**
- **Maximum sample size up to 1.4m × 0.65m;**  
**(Make the production for large size samples possible)**
- **Vacuum degree can be controlled by computer;**  
**(Better for resistivity control)**
- **Shutters for target protecting are available and can be controlled by computer;**  
**(Allow multi-coating in one batch)**

# First time to use Hauzer for the production

- Teer is not able to coat large area samples, so we try to use Hauzer for the production ;
- We coated DLC, Metal doping DLC, DLC+Cu using the Hauzer;



Different kind of drums;



Round for soft substrates



Square for hard substrates



# Measurement tools

**HIOKI**

SUPER MEGOHM METER  
SM7110, SM7120

NEW

300 Times Better Noise Resistance

Min. 6.4 ms Measurement Speed

Max. 2000 V Output

Max.  $2 \times 10^{19} \Omega$  Display

Min. 0.1 fA Resolution

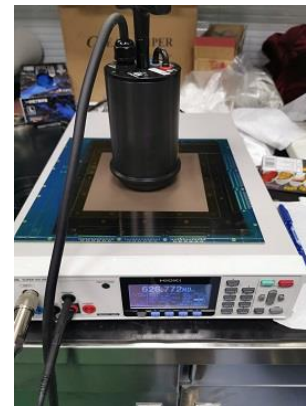
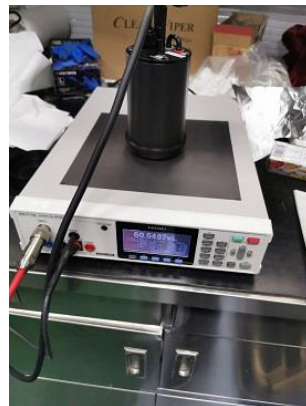


SUPER MEGOHM METER  
**SM7120**

Flexible, Multipurpose Design  
Electrometer  
Picoammeter  
IR Meter

CE

Max. 1000 V Output  
SM7110



- HIOKI SM7110 and 7120 are used for the resistivity measurement of most samples;
- The small tools are used to measure very small samples, or the samples with very low resistivity;
- Resistivity value measured by these two kind of tools have a factor of (1.3~1.4)

# Resistive DLC made by Hauzer

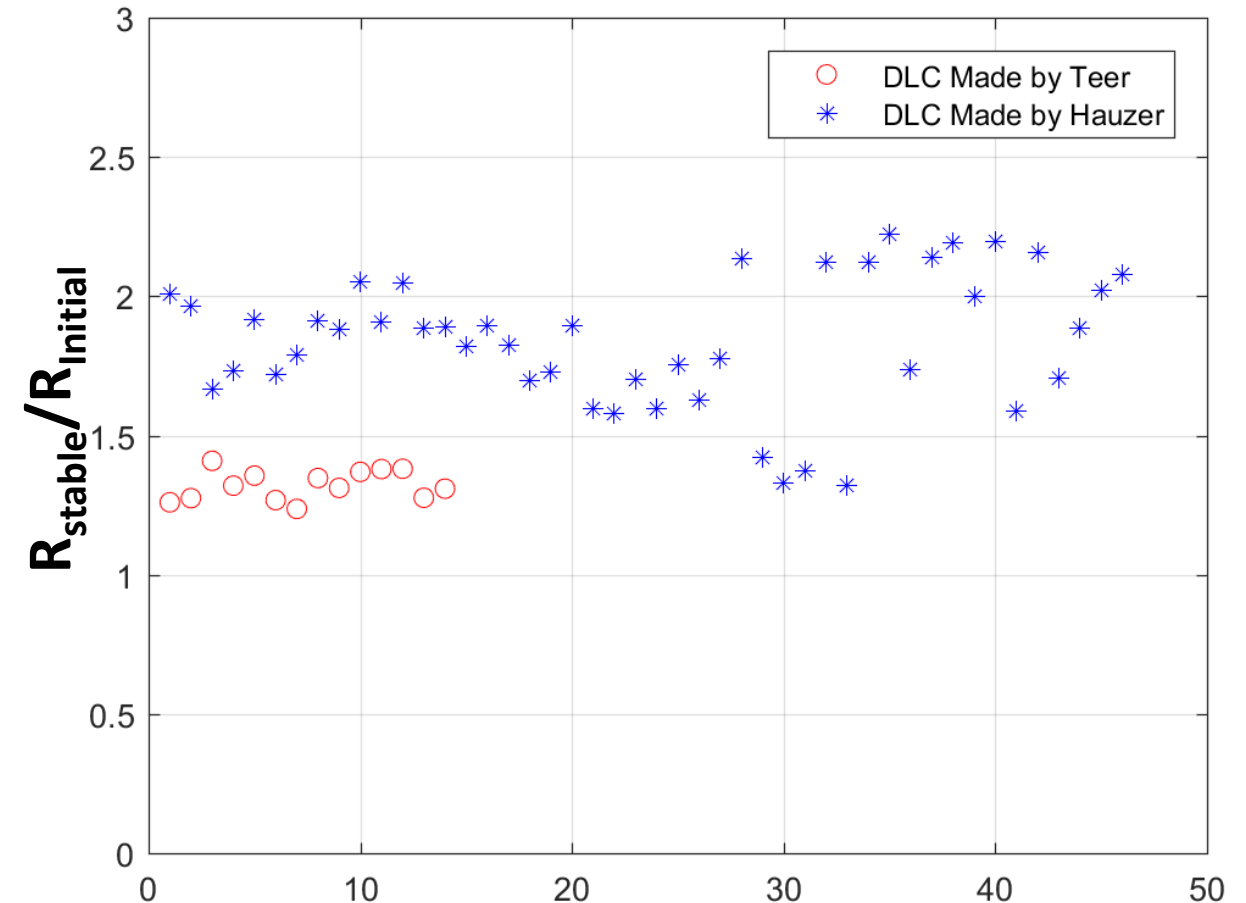
## Rules are similar with Teer

- Better vacuum will get lower resistivity;
- Higher temperature will get lower resistivity;
- Resistivity increases in air then become stable;
- Hydrogen doping can greatly increase the resistivity;

## Different performances

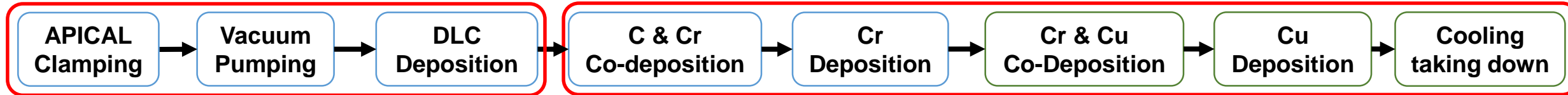
- **Much long passivation time in air;**  
DLC made by Teer is about 3~4 days;  
DLC made by Hauzer is about 10~14days;
- **Resistivity increasing in air is much larger;**  
DLC made by Teer is about 30%~40%;  
DLC made by Hauzer is about 40%~120%;

## Resistivity increasing in air

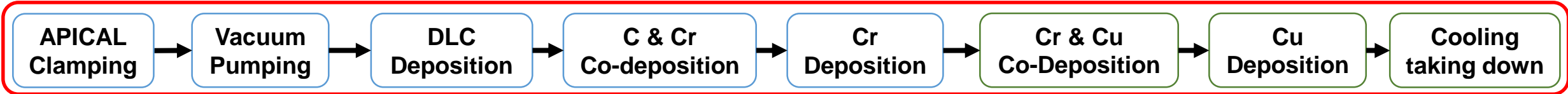


# Preparing DLC + Cu with advanced technique

## Flow chart of the DLC + Cu with “C & Cr co-deposition” Layer



## Flow chart of the DLC + Cu by “One-batch” method



### C & Cr co-deposition

C: 2kW → 0kW, Cr: 0kW → 1.5kW, For 1min

### Cr deposition

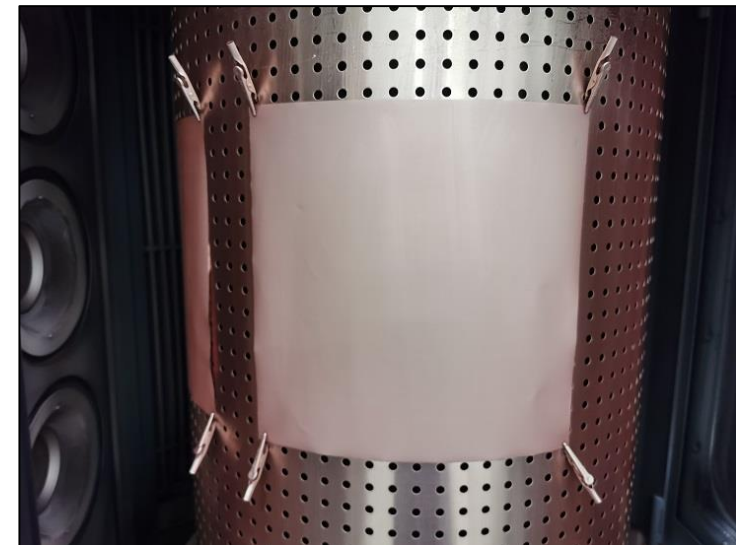
Cr: 1.5kW → 3kW immediately, then keep 3kW for 1min

### Cr & Cu co-deposition

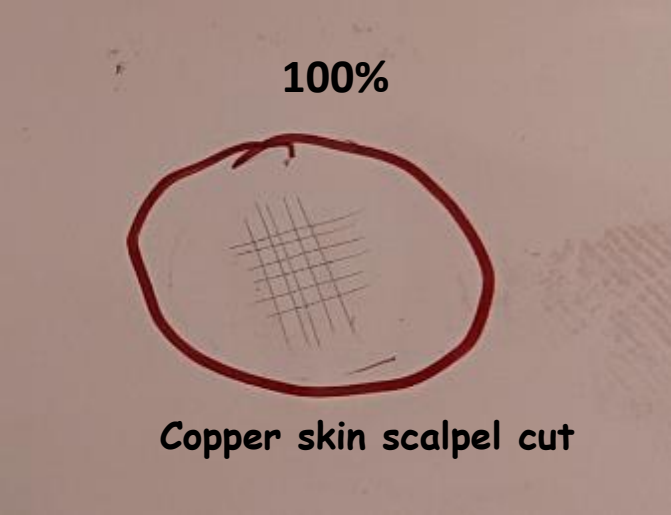
Cr: 3kW → 0kW, Cu: 0kW → 1.3kW, For 0.5min

### Cu deposition

Cu: 1.3kW → 4kW immediately, then keep 4kW for 97.5min



# Adhesion Test

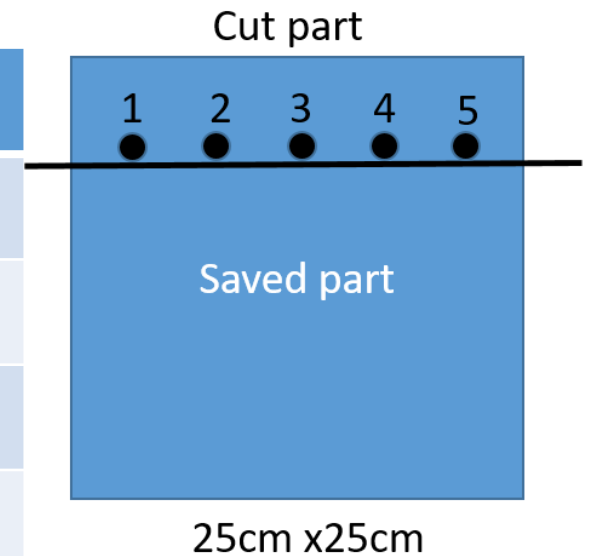




# Adhesion test 1

## DLC+Cu with C & Cr co-deposition layer

Batch No.	Adhesion1	Adhesion 2	Adhesion 3	Adhesion 4	Adhesion 5
H2020-06-21-4	0	0	0	0	0
H2020-06-23-9	0	0	0	0	0
T2020-06-19-1	0	0	0	0	0
T2020-06-17-2	0	0	0	0	0

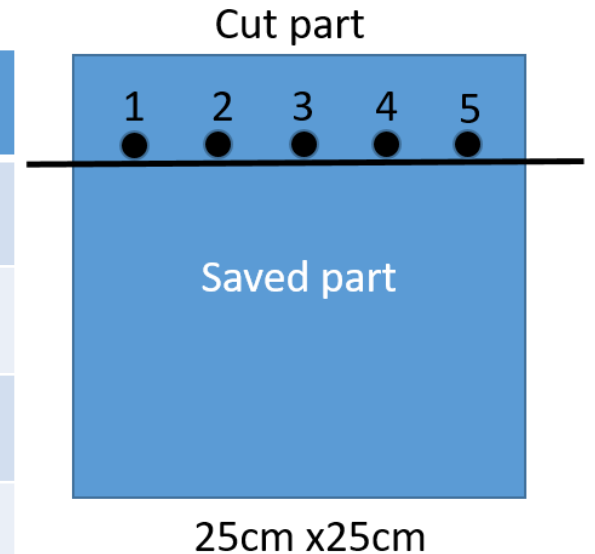


- Adhesion is very bad, this maybe caused by the missing of the plasma source etching(PSE) process;

# Adhesion test 2

## DLC + Cu Made by “One-Batch” method

Batch No.	Adhesion1	Adhesion 2	Adhesion 3	Adhesion 4	Adhesion 5
H2020-06-28-3	100	100	100	100	100
H2020-06-28-3	100	100	100	100	100
H2020-06-28-4	100	100	100	100	100
H2020-06-28-4	100	30	30	60	60



- “One-Batch” method shows very good adhesion;
- The 4<sup>th</sup> sample is not perfect, the possible reason is the surface is not clean and the PSE process is missing;

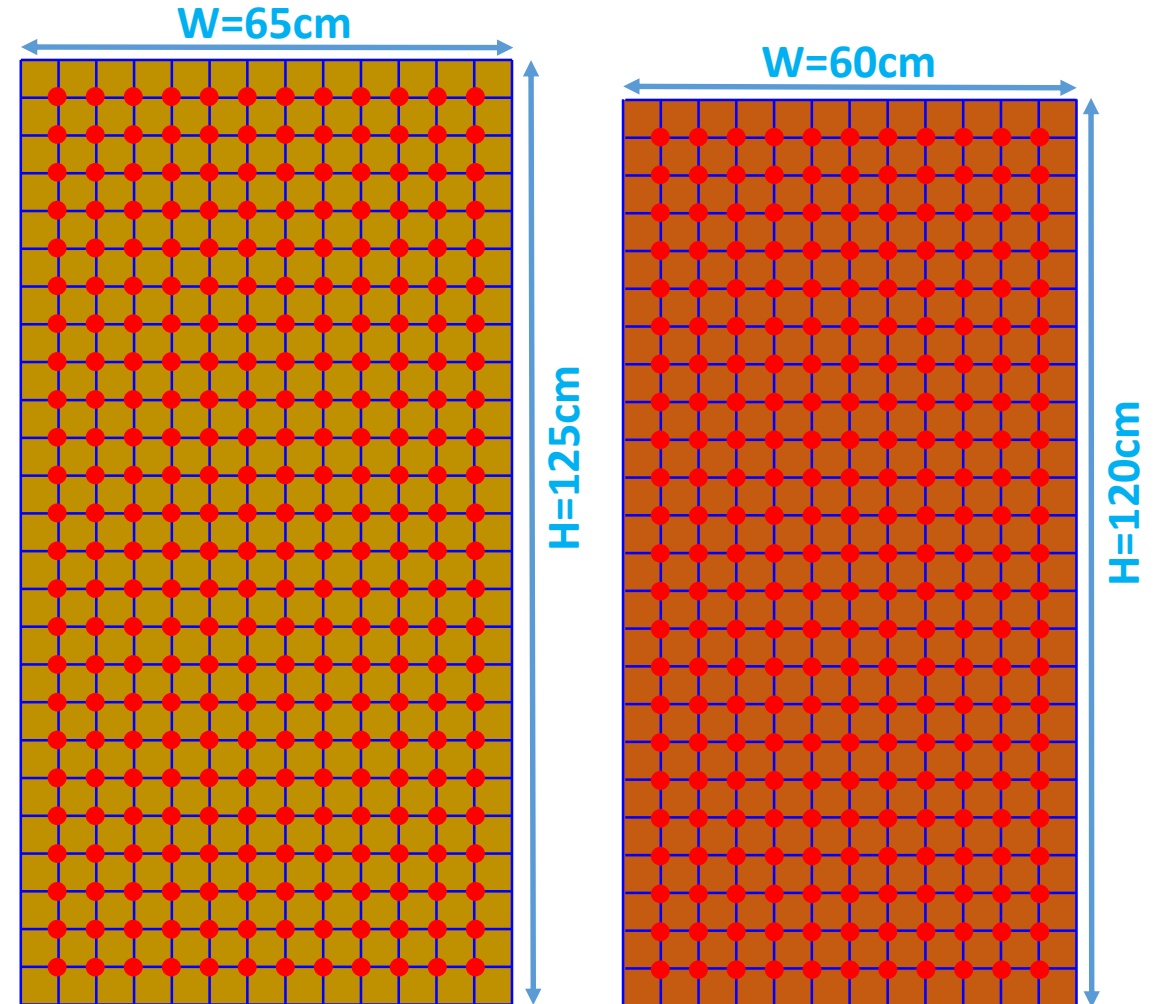
# Coating for Large area samples(PCB and APICAL)



# Resistivity measurement for large area samples



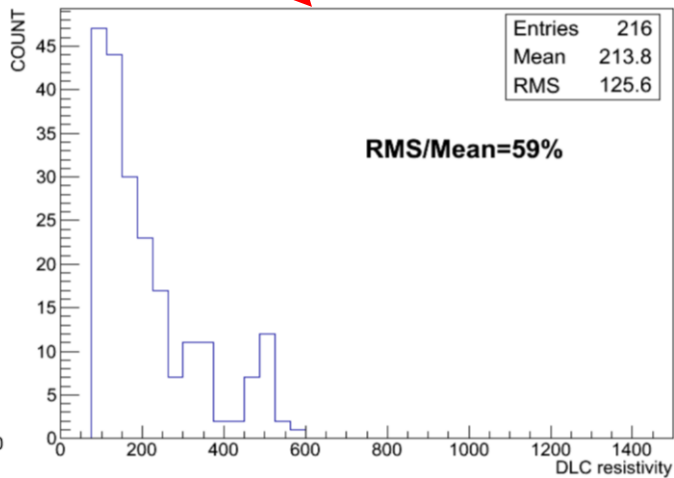
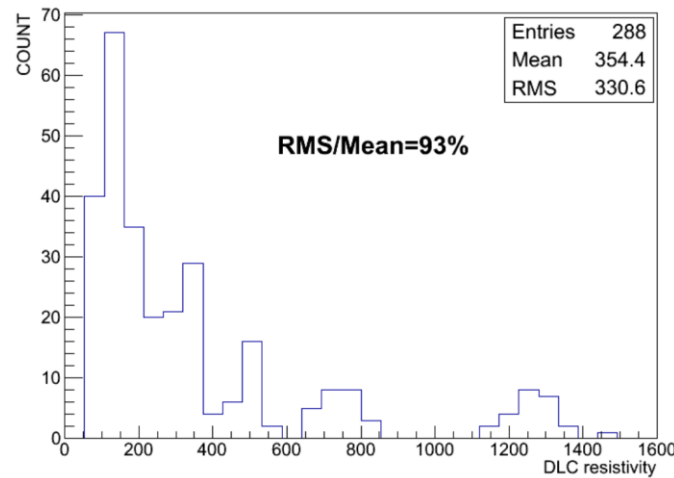
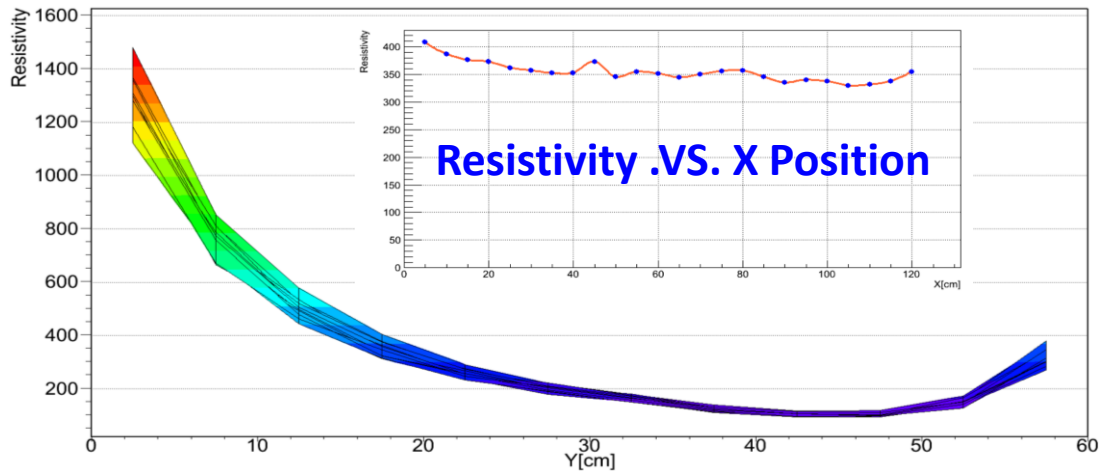
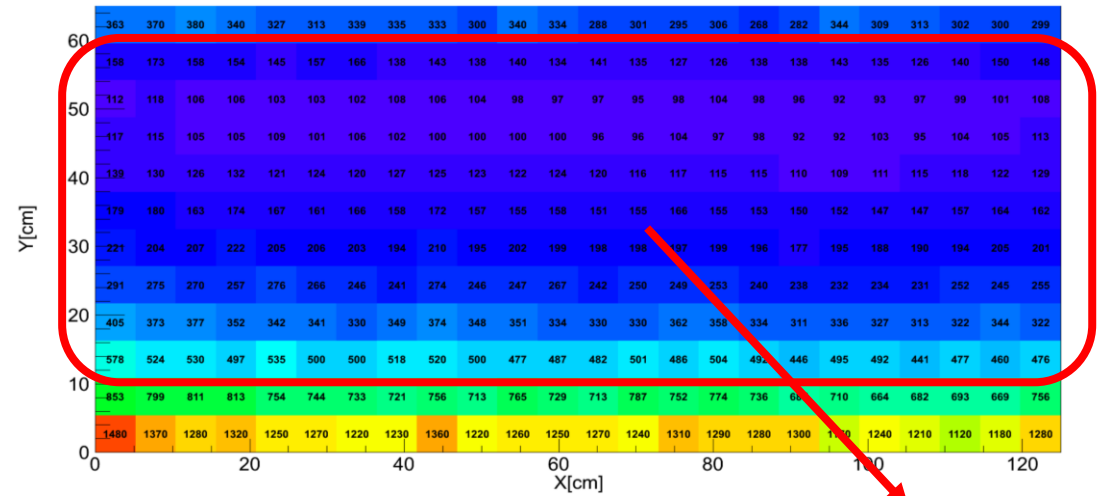
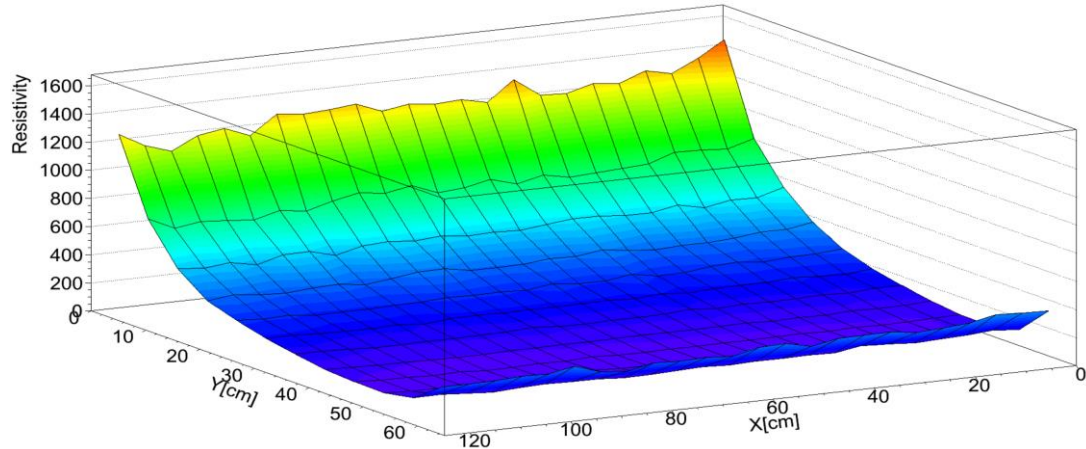
PCB:  $24 \times 12$  points  
APICAL:  $23 \times 11$  points



● Measurement Position



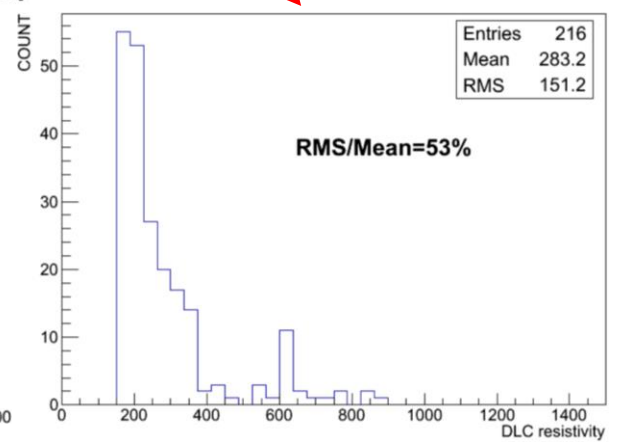
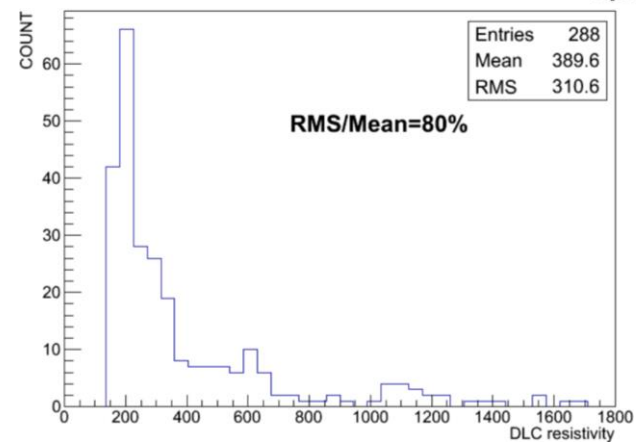
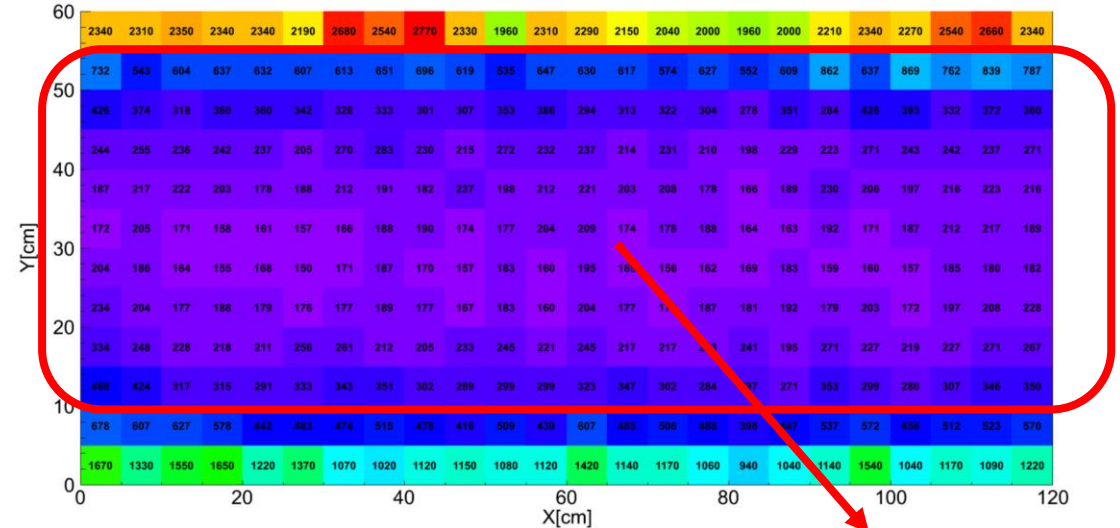
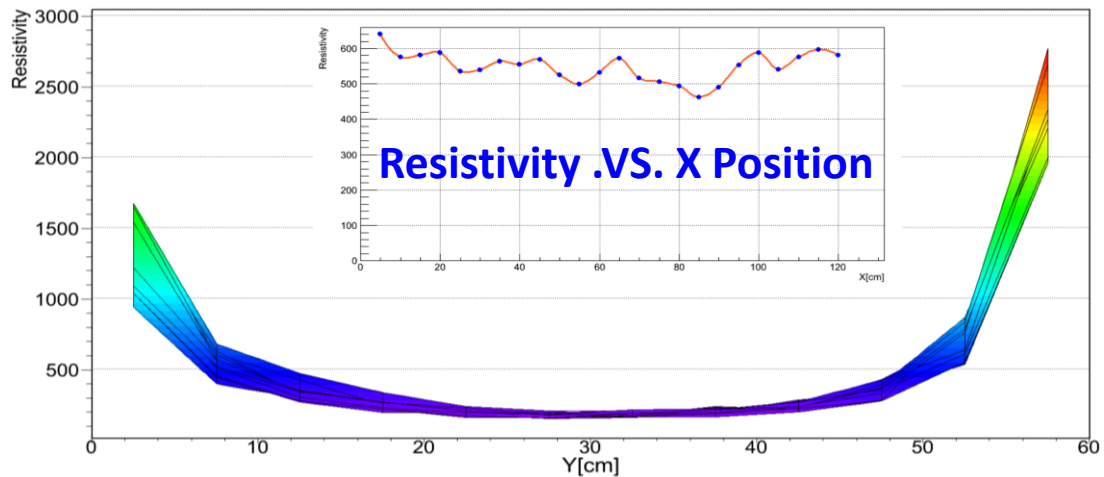
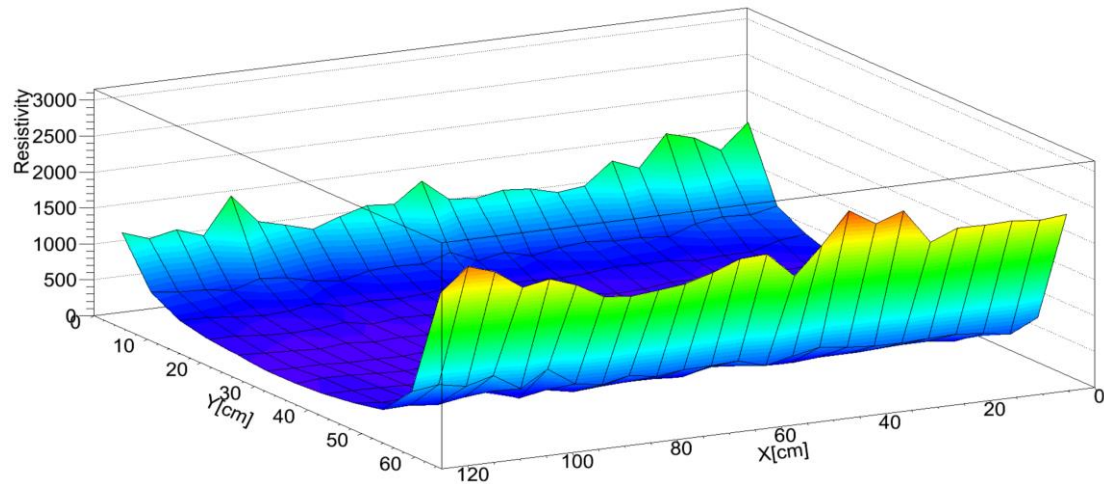
# Resistivity uniformity of a-C:H on 125cm×65cm PCB



➤ The resistivity significantly decreasing when the height is increasing, this caused by the  $C_2H_2$  gas flow;

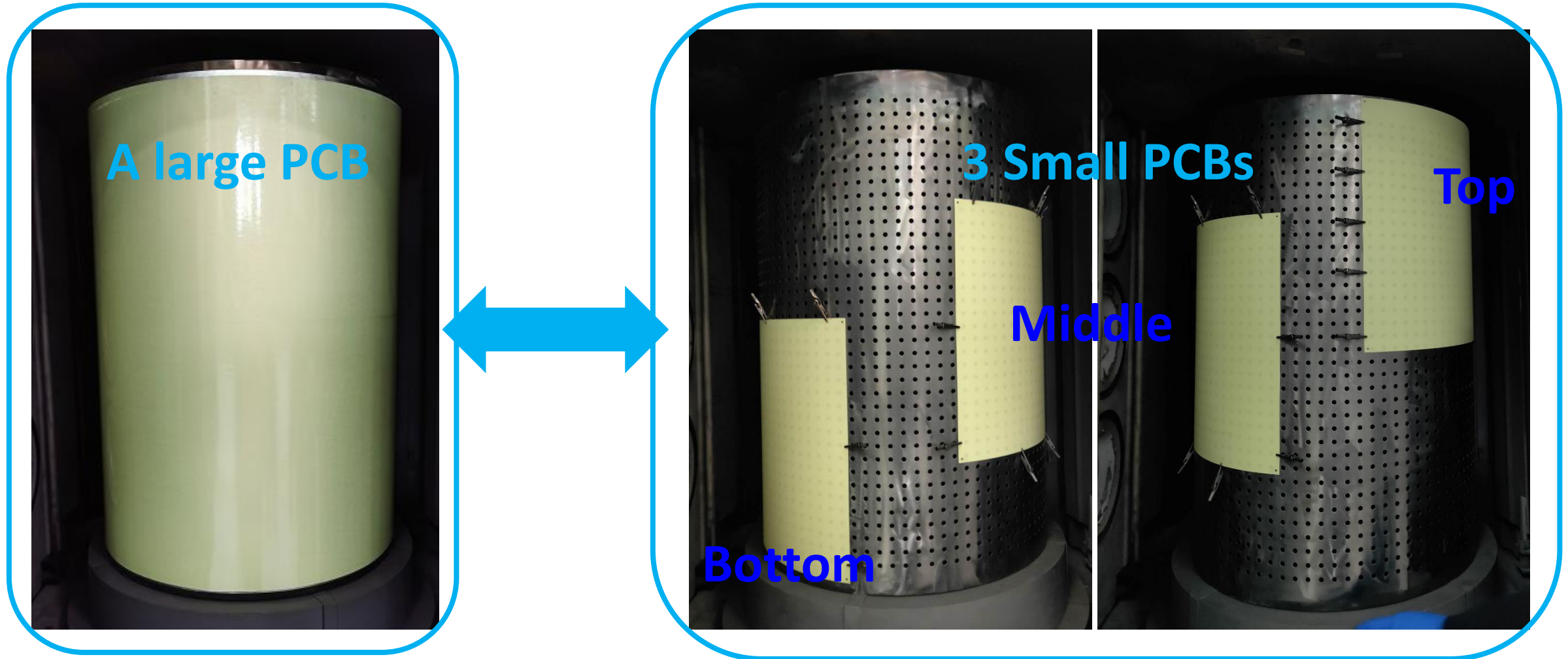


# Resistivity uniformity of a-C on 125cm×65cm PCB



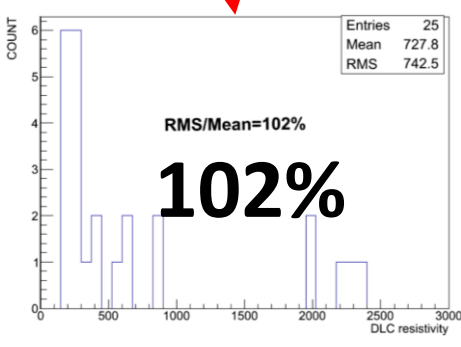
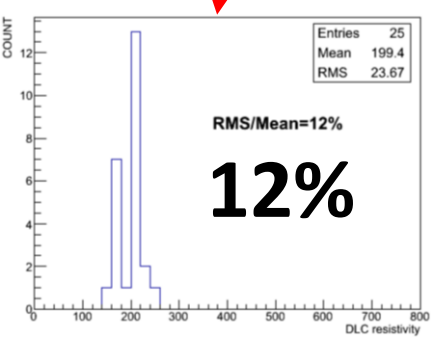
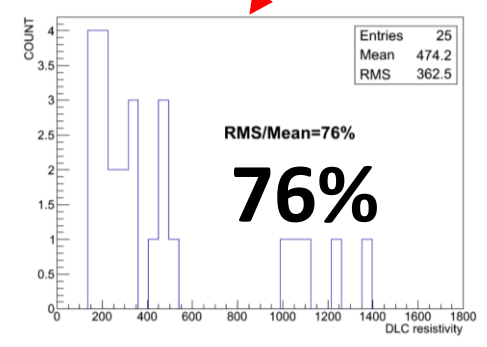
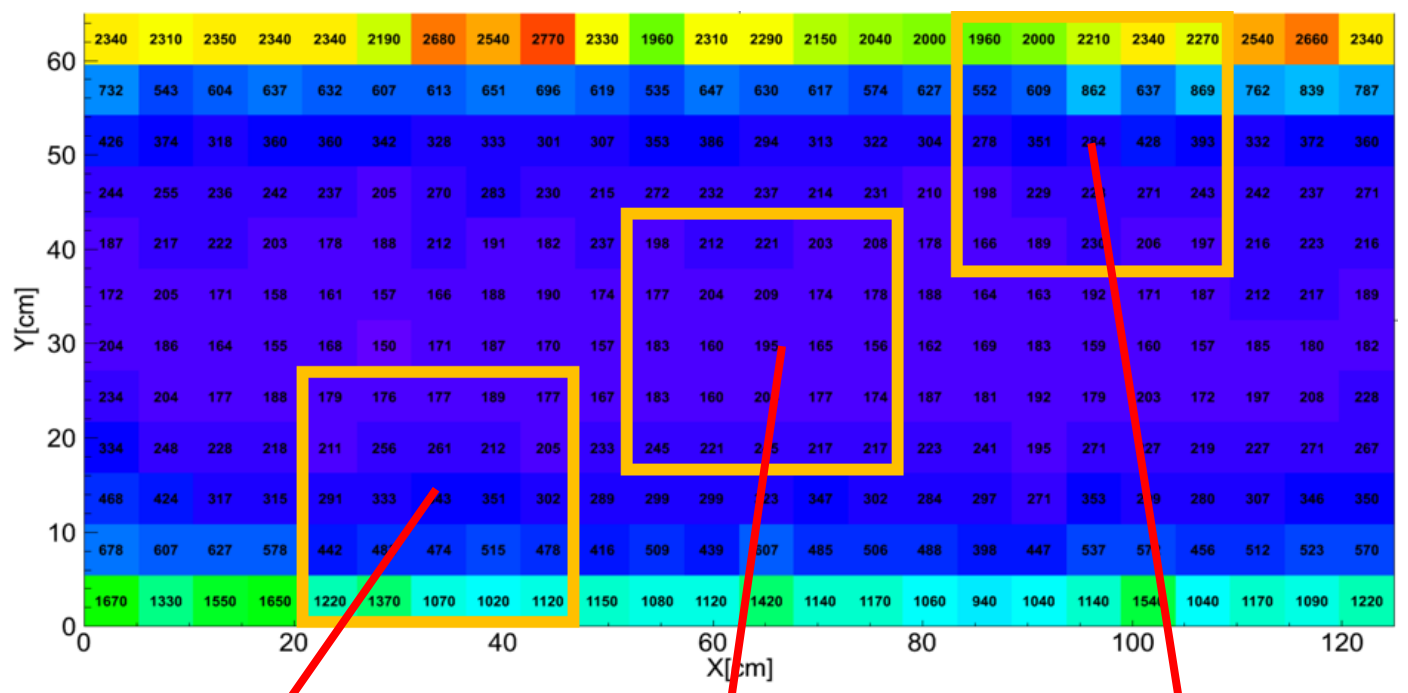
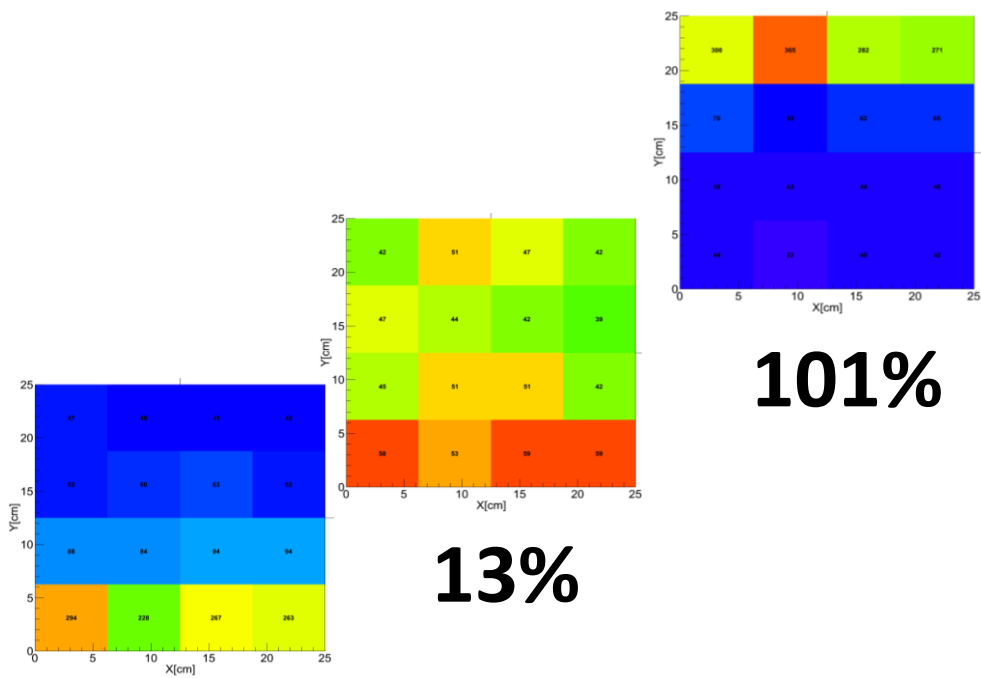
➤ The variation of the resistivity is reasonable now;

# Test of edge effect



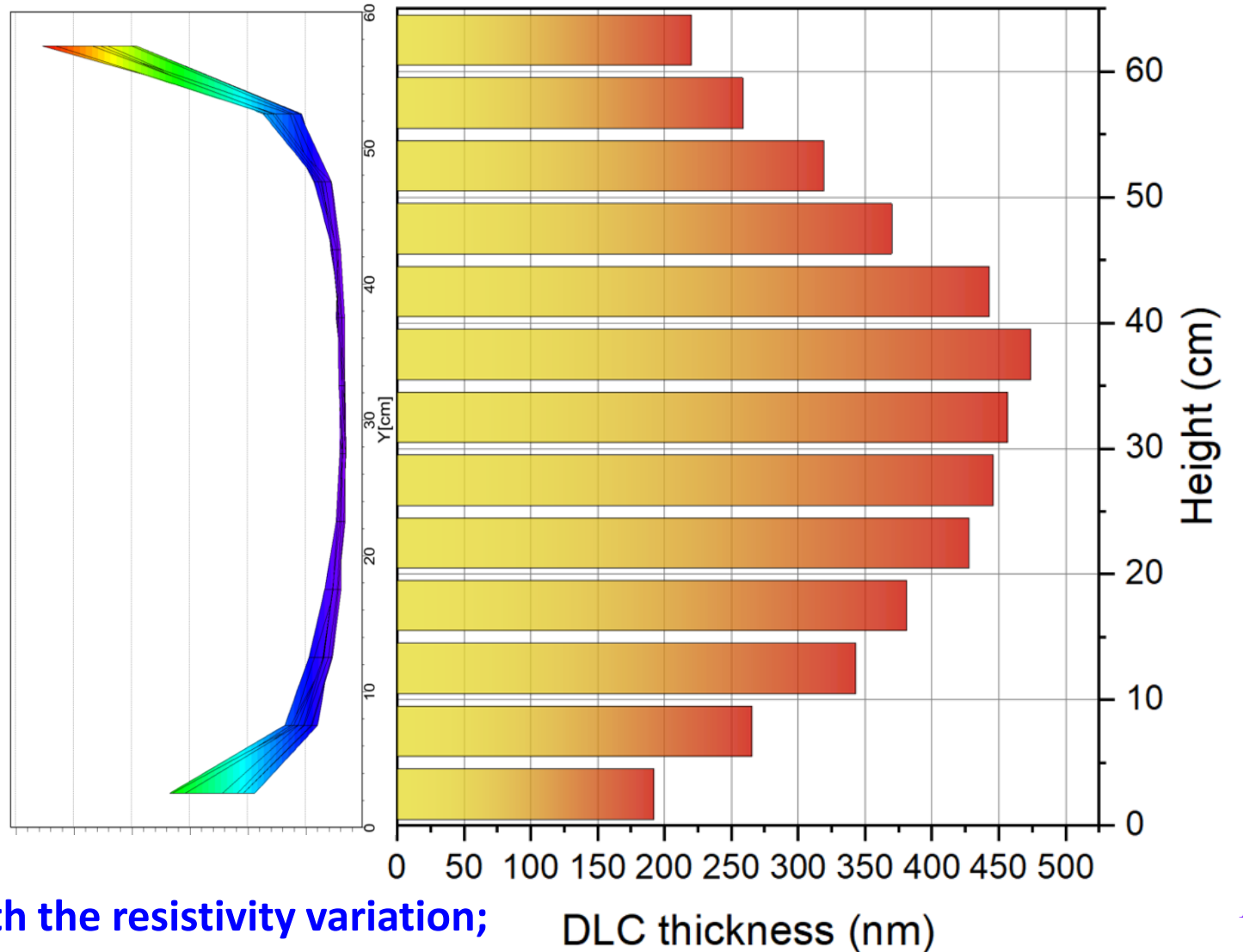
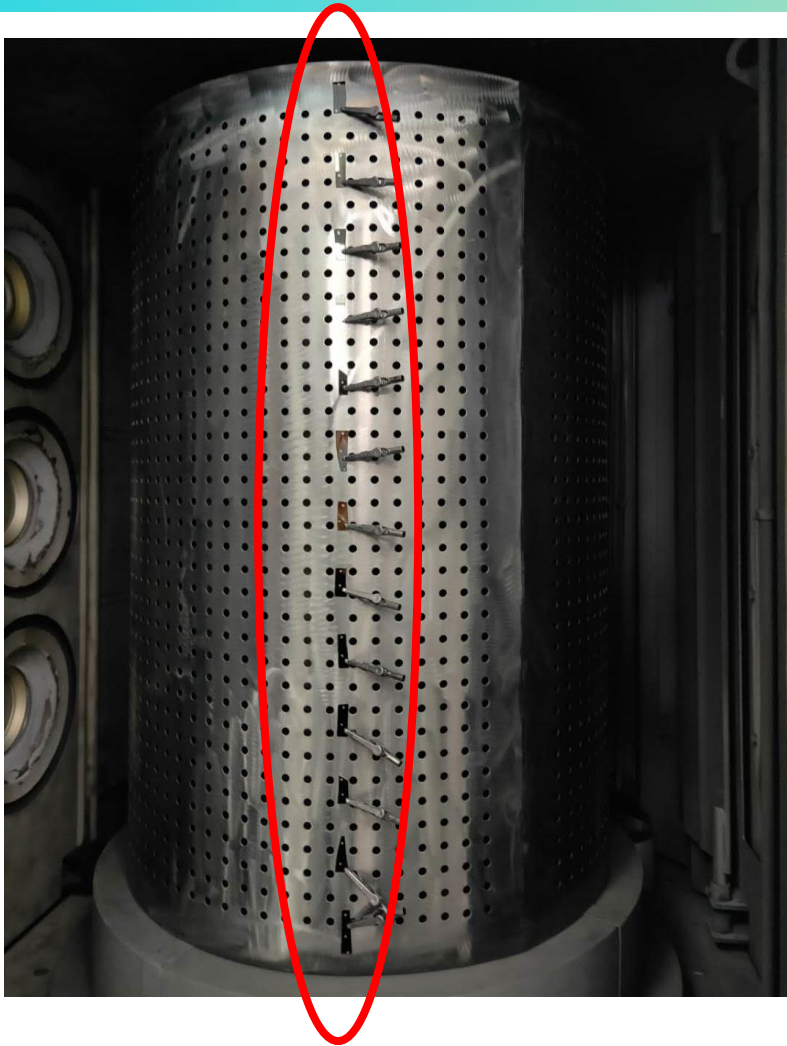
➤ To make sure it is not the edge effect caused the large resistivity on Top & Bottom;

# Uniformity Comparing



- The large area PCB and the 3 small PCBs are coated in the same condition, but due to the different gas release, the absolute value is quite different;
- The uniformities are quite consistent;

# Calibration of Thickness .VS. Height

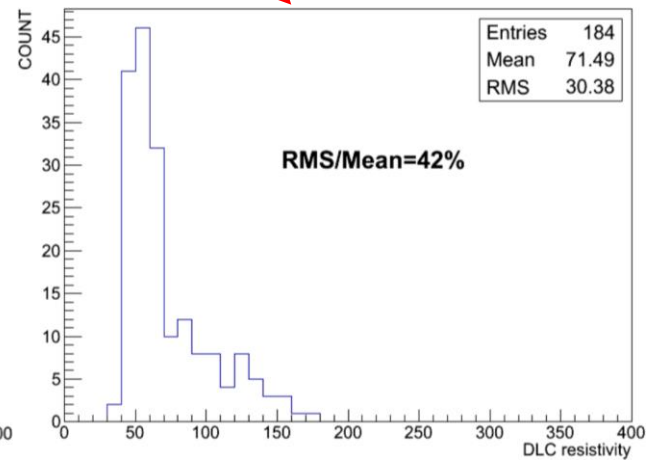
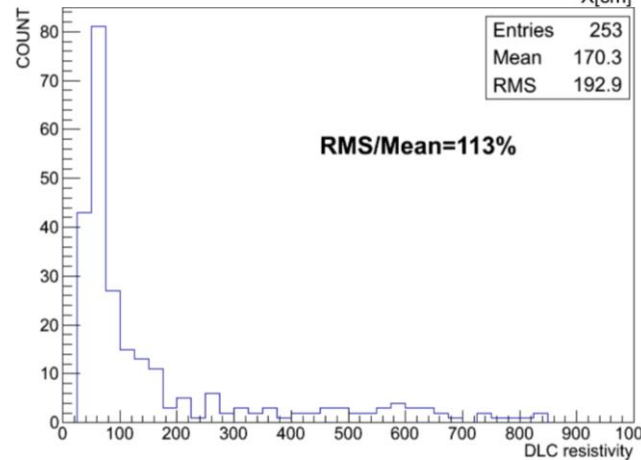
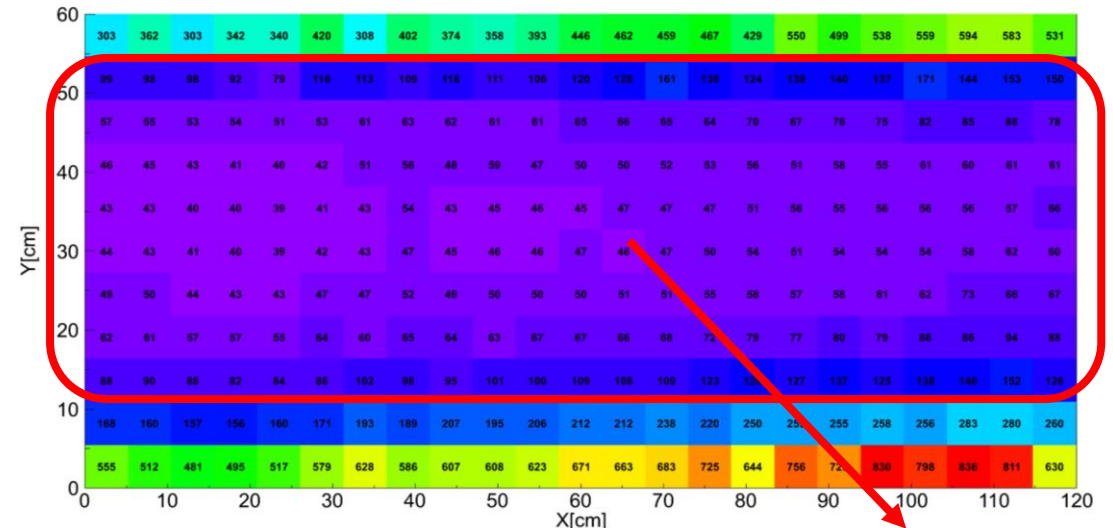
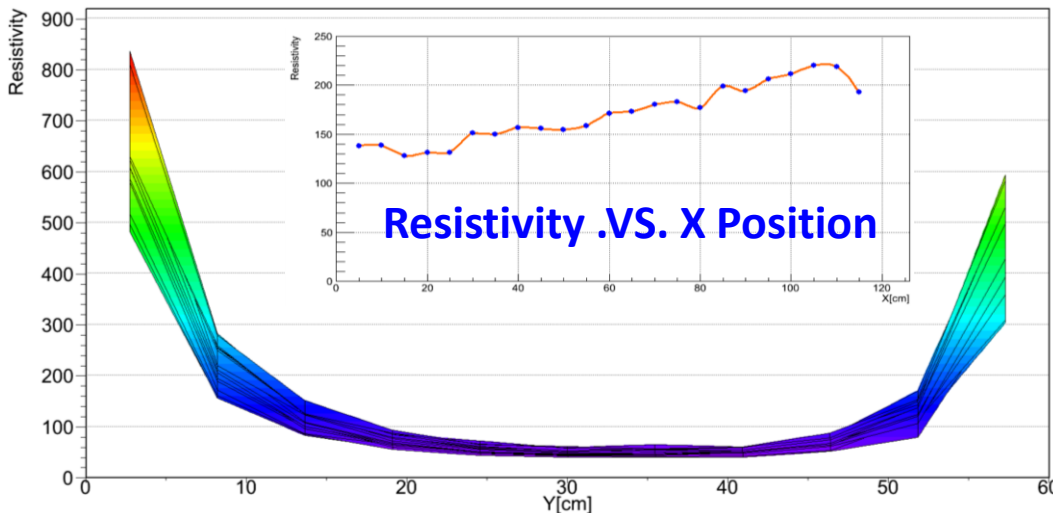
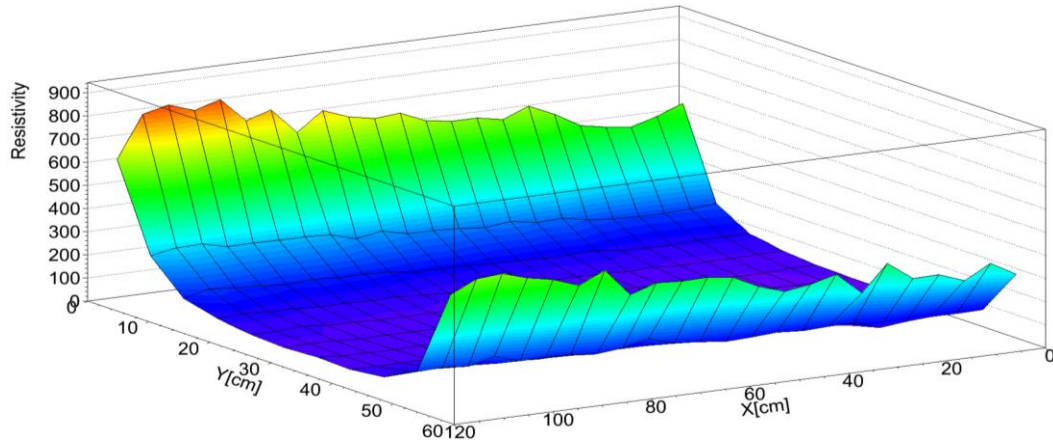


➤ The thickness variation is consistent with the resistivity variation;

DLC thickness (nm)



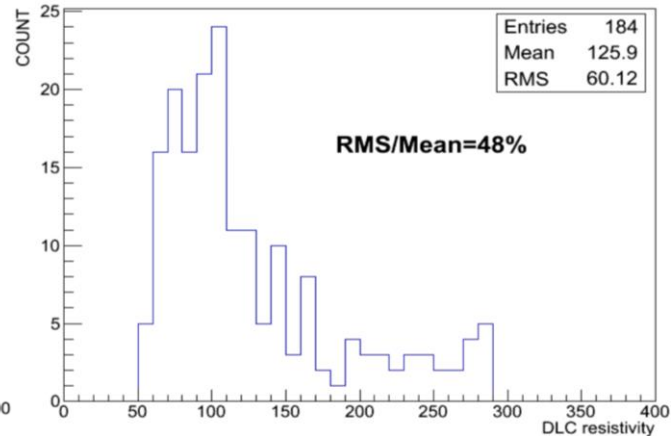
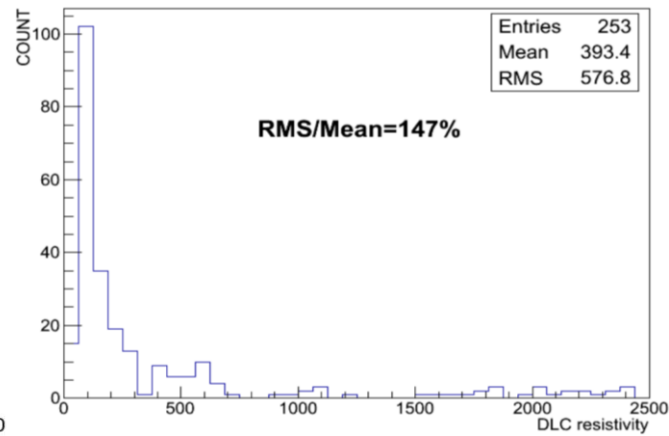
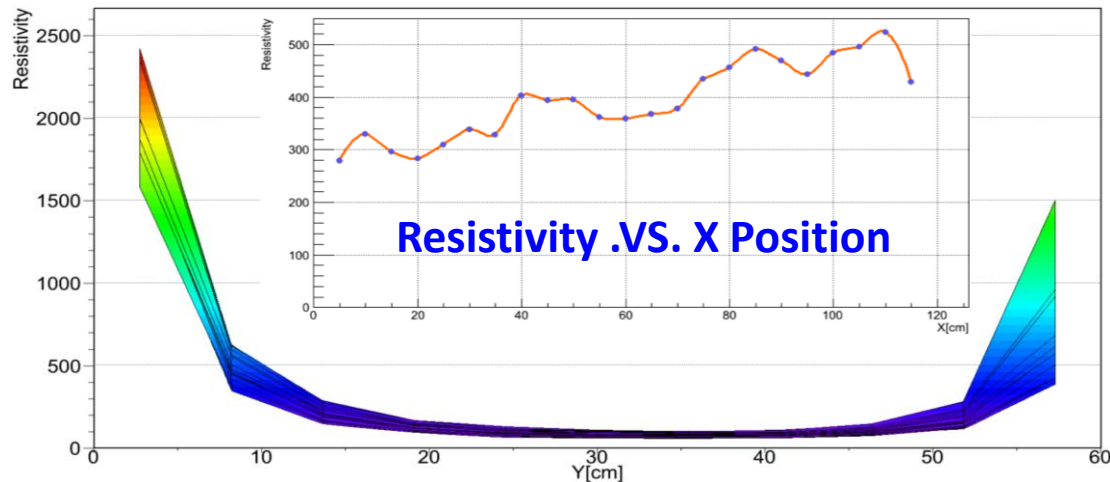
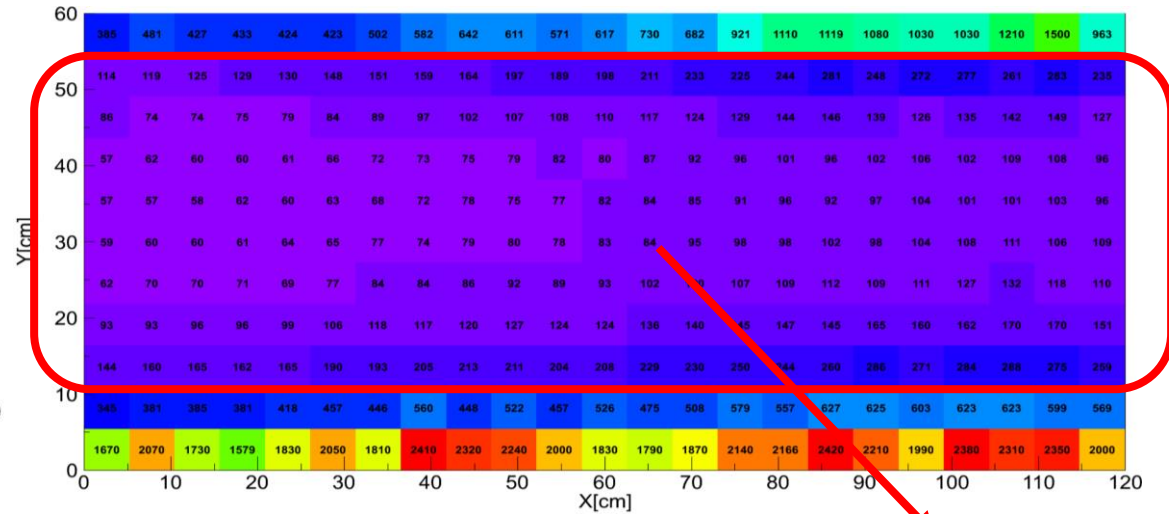
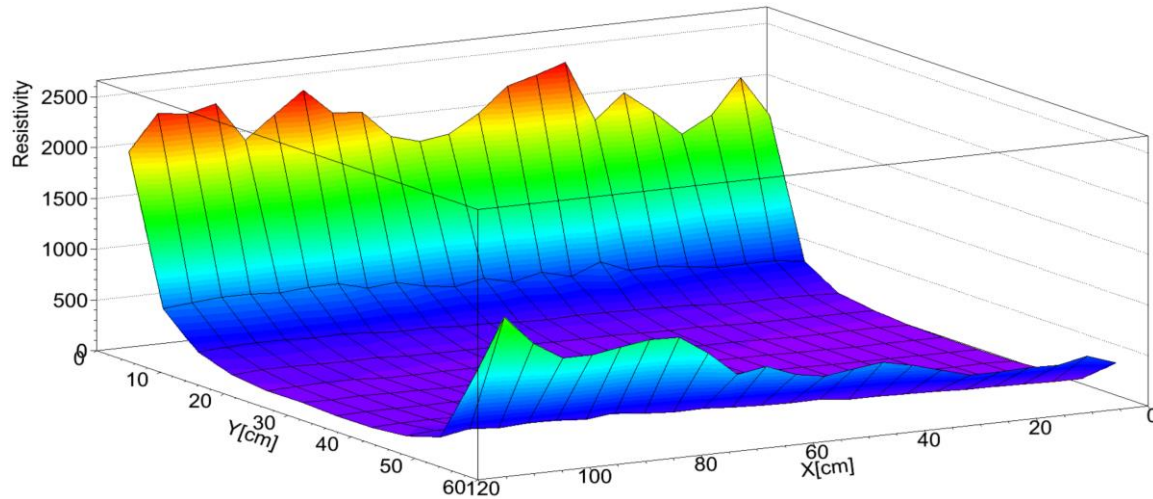
# Resistivity uniformity of APICAL1



- The drum horizontally moved, this caused the center of the drum deviated the rotating axis;
- The distance between the target and one end of the foil are shorter than the other end of the foil;

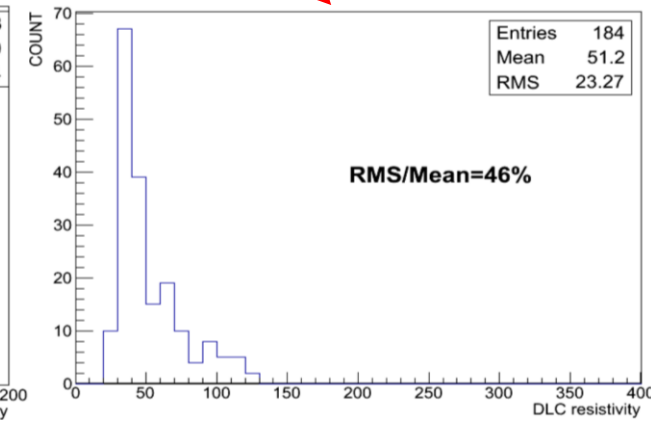
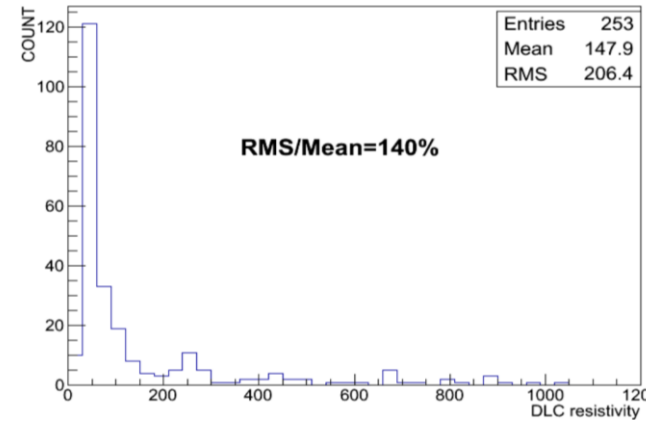
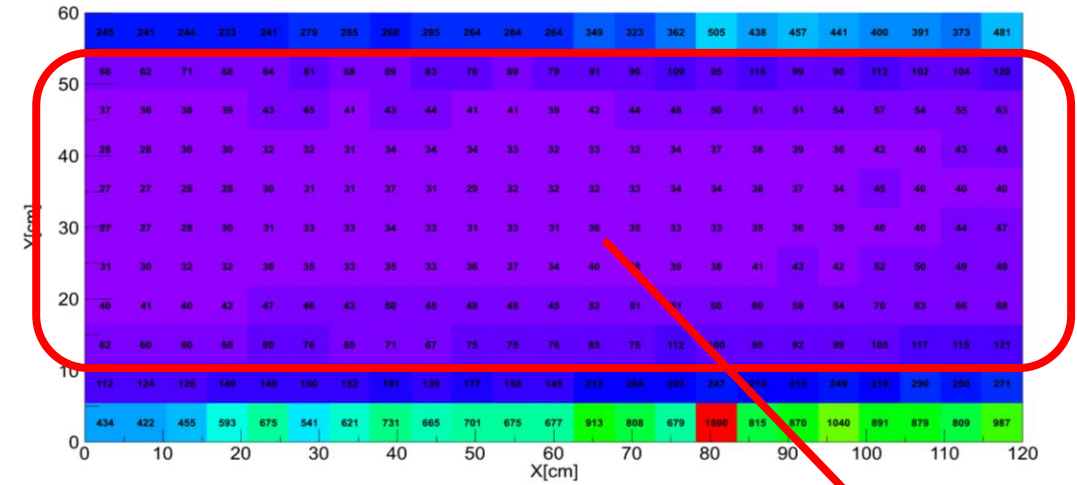
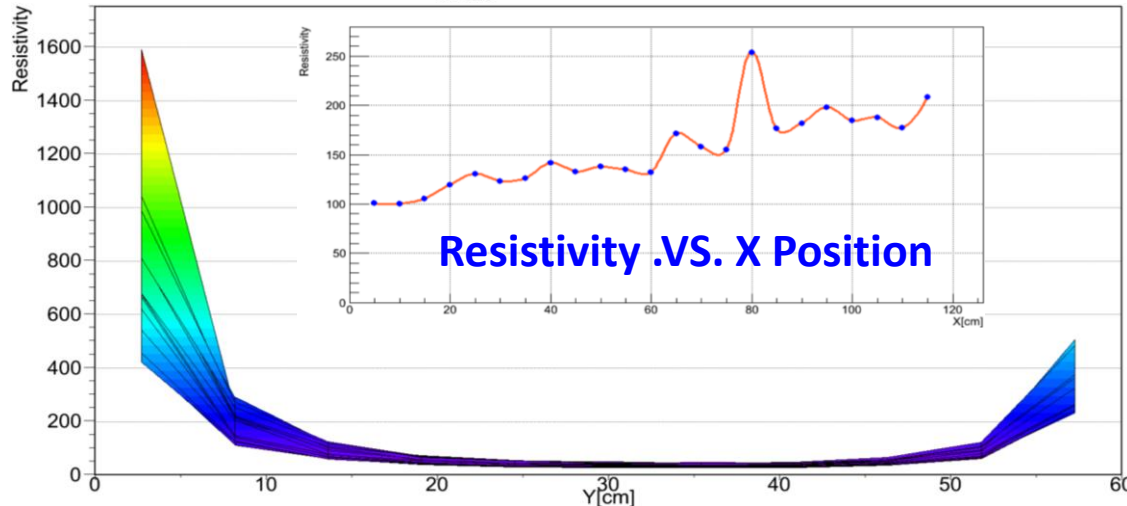
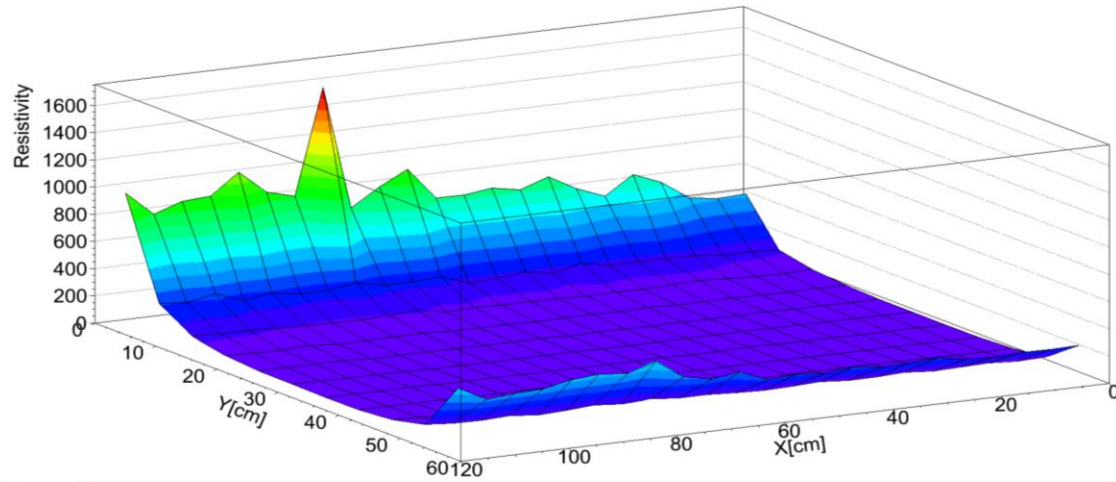


# Resistivity uniformity of APICAL2



➤ Same reason caused the resistivity increases when the X position increase;

# Resistivity uniformity of APICAL3



➤ Same reason caused the resistivity increases when the X position increase;

# Summary and next work

## Resistivity of DLC made by Hauzer shows different behavior

- Resistivity increasing caused by passivation is quite different, we need more samples and test;
- Resistivity decreasing caused by heating should also be systematically tested;

## We need more R&D on Adhesion

- “C & Cr” co-deposition layer should work, we will try to add a PSE step before “C & Cr” coating to see if it can improve the adhesion
- “One-Batch” is a potential method to improve the adhesion, we will continue work on this to understand how to make the resistivity controllable;

## R&D on Large area coating

- Maximum size of DLC samples is up to 1.4m × 0.65m;
- For a-C, we have much better uniformity;
- Try to find the thickness which can provide the best uniformity;
- We will try to coat large area DLC + Cu samples next time;