RD51 October 2019

CERN MPT

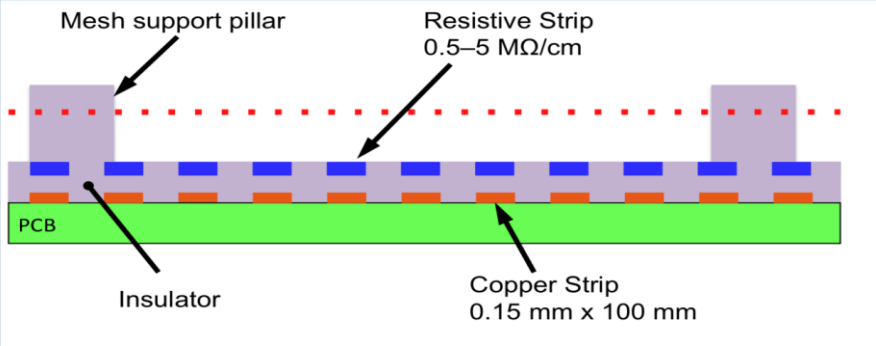
resistive protections

outline

- MPGD Resistive protections with resistive paste 100K/sqr
- Single DLC application
- Embedded DLC application
- 2 DLC foils application

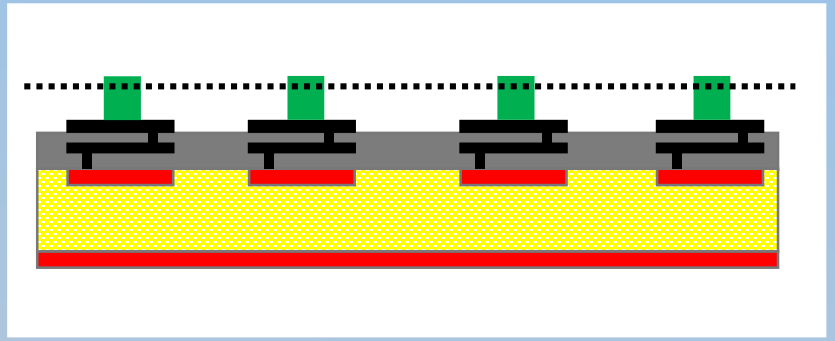
Spark protection with resistive paste

Medium rate Micromegas detectors

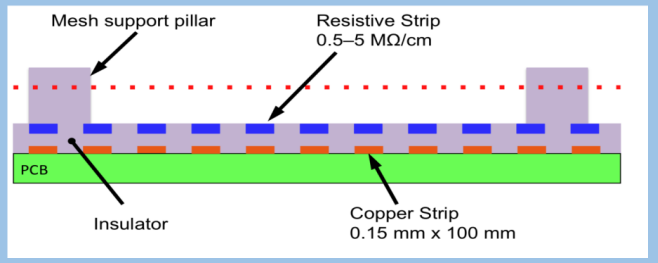


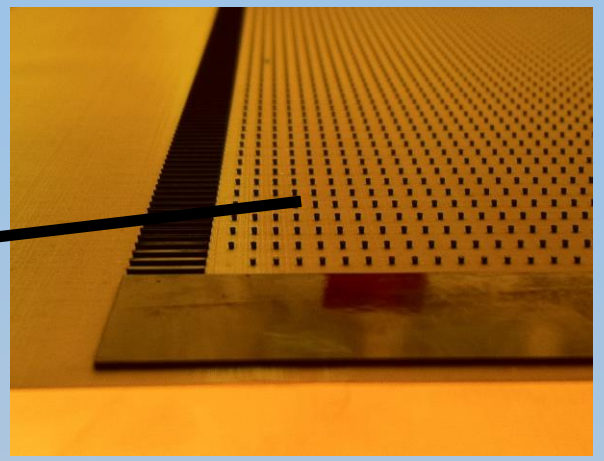
- Single layer resistive paste screen printed

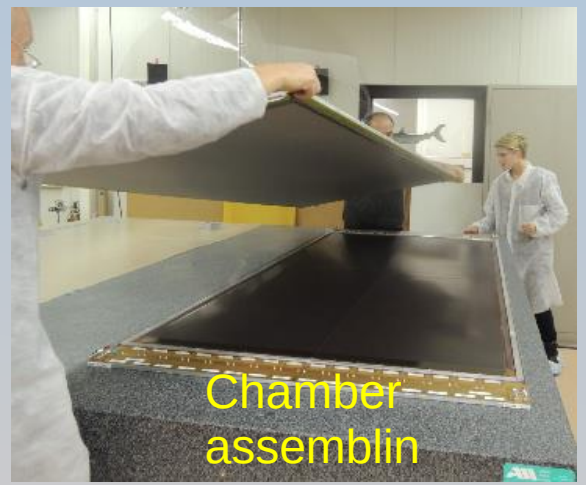
High rate Micromegas detectors



- Resistive paste Embedded resistor

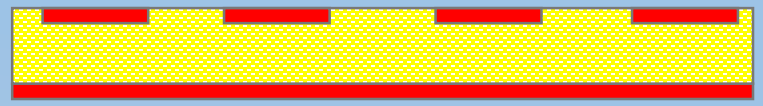




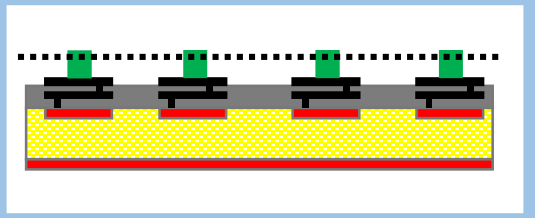


Final chamber
Ready to be tested
2000 m2 for Atlas NSW

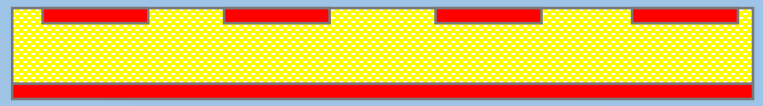
Embedded resistor made with resistive paste: high rate detectors



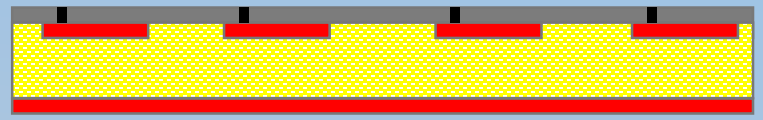
PCB



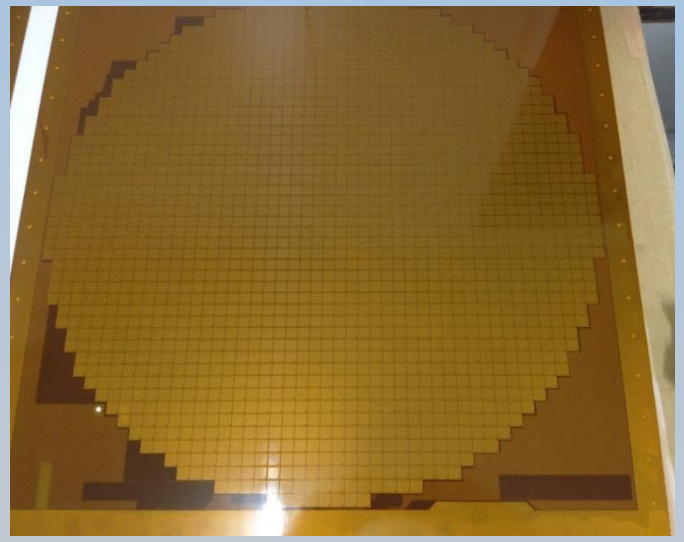
Embedded resistor made with Screen printed paste: high rate detectors



PCB

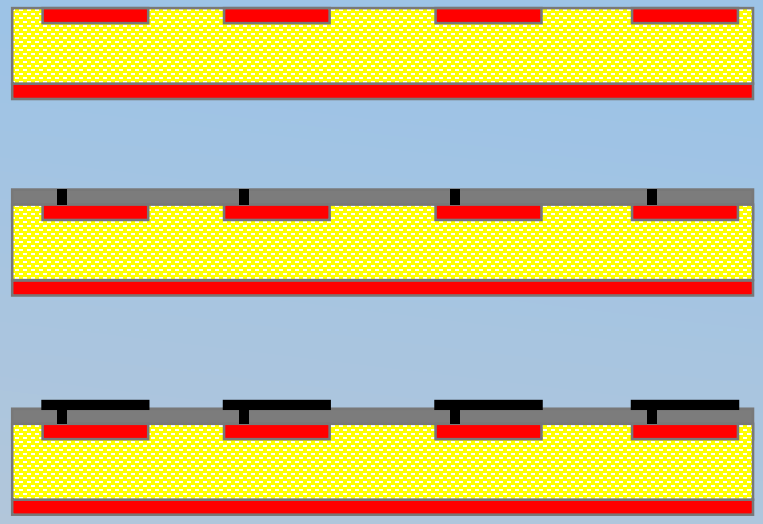


12um Kapton gluing + drilling + silver via fill



Coverlay deposited with an isostatic press

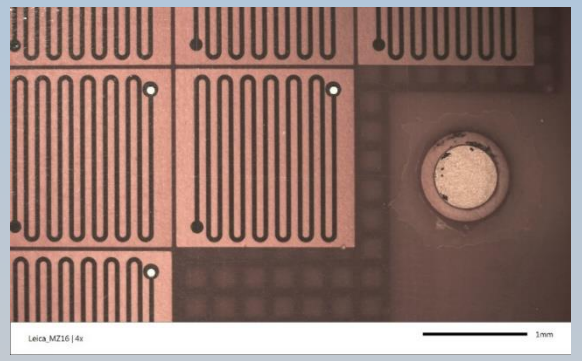
Embedded resistor made with Screen printed paste: high rate detectors



PCB

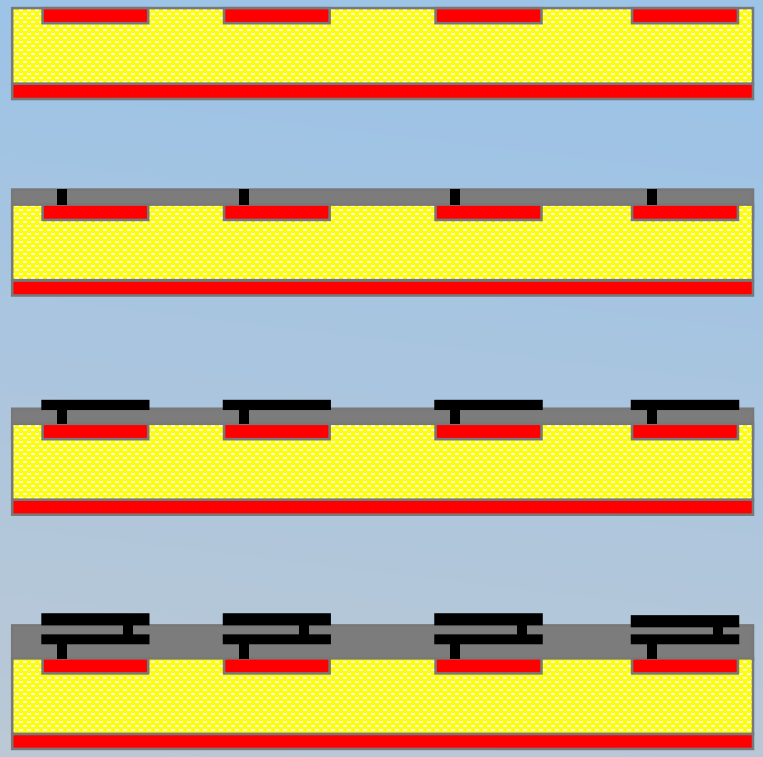
12um Kapton gluing + drilling + via fill

embedded resistor with resistive paste



Shapes defined by photolitographic processes

Embedded resistor made with Screen printed paste: high rate detectors

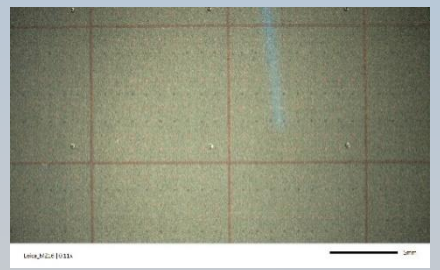


PCB

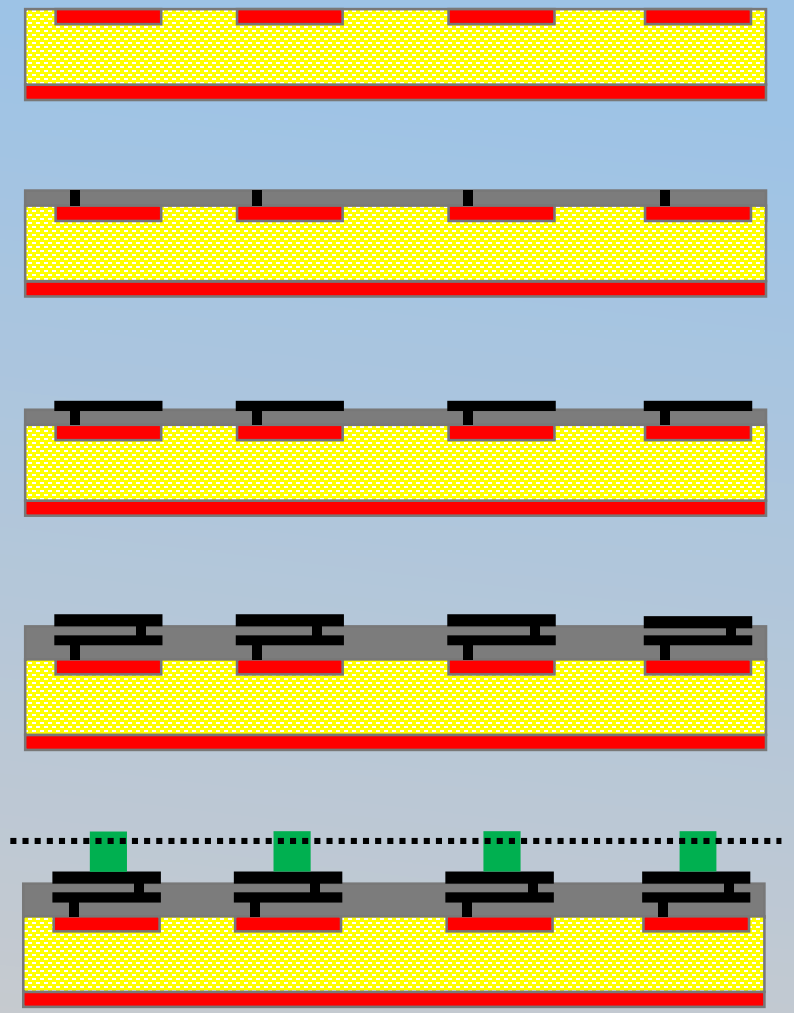
12um Kapton gluing + drilling + via fill

embedded resistor screen printed

12um Kapton gluing + via fill
+ top resistive printing



Embedded resistor made with Screen printed paste: high rate detectors



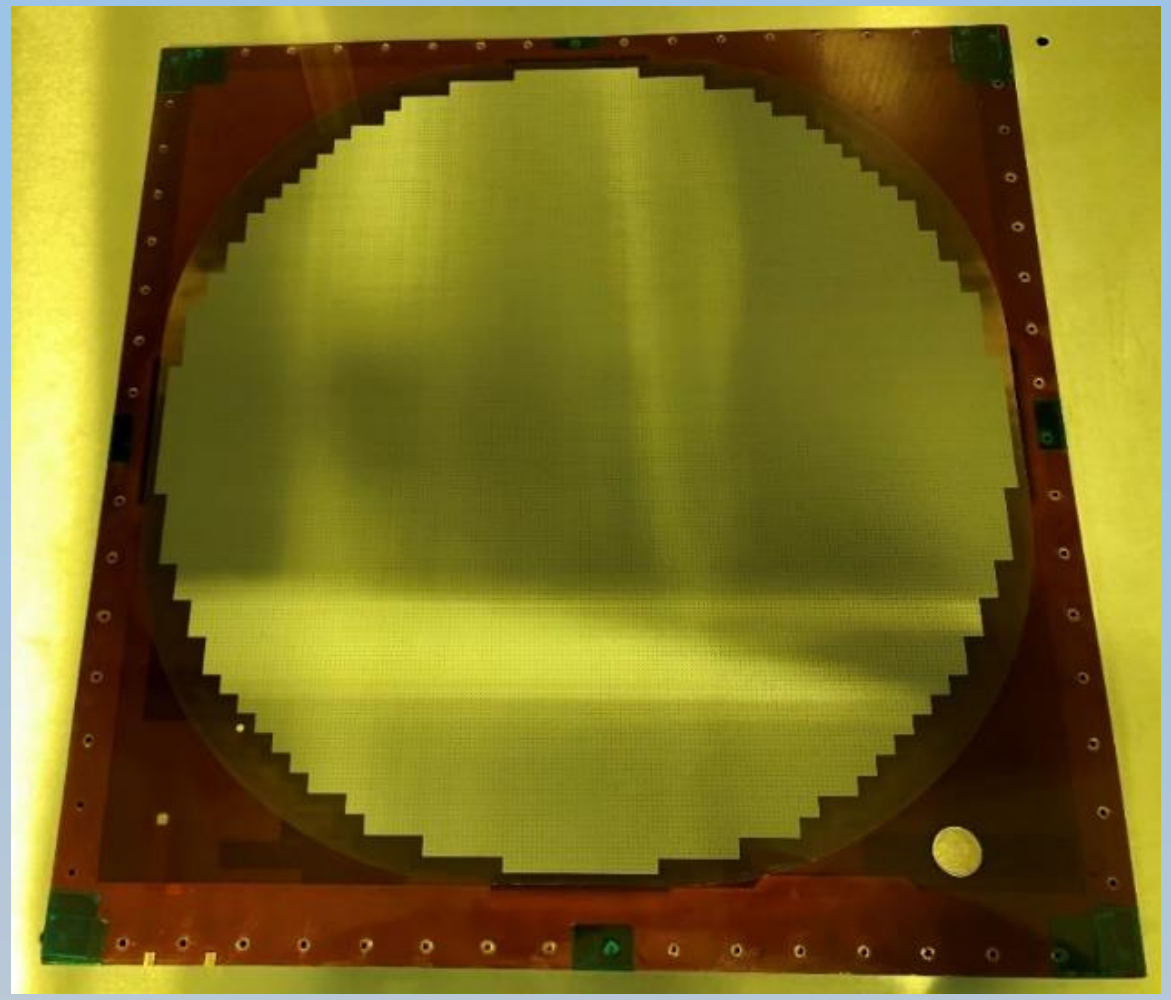
PCB

12um Kapton gluing + drilling + via fill

embedded resistor screen printed

12um Kapton gluing + via fill
+ top resistive printing

Bulk deposition



ILC DHCAL

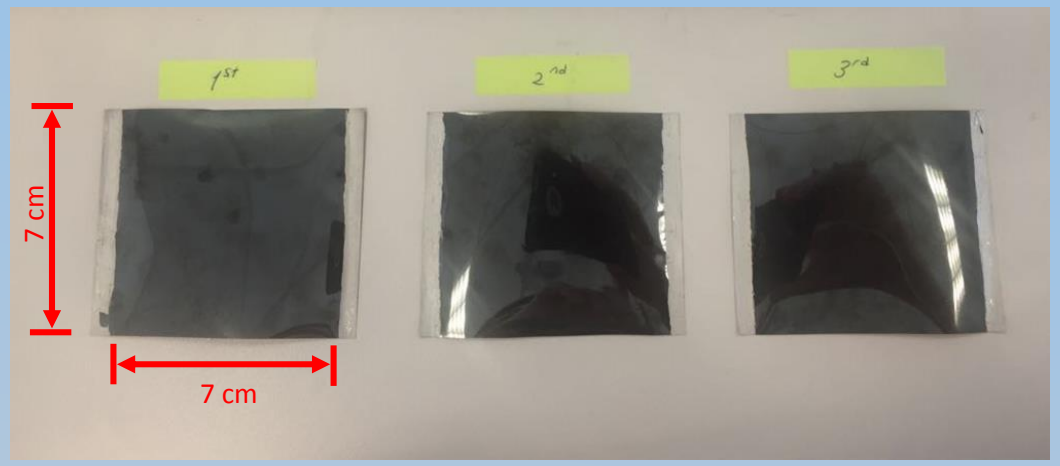
Size 540x530mm – 8 layers PCB – 1.6mm
Active area 480x480mm
Mesh 45/18 - Gap 128um
Rate of 10Mhz/mm2 have been reached

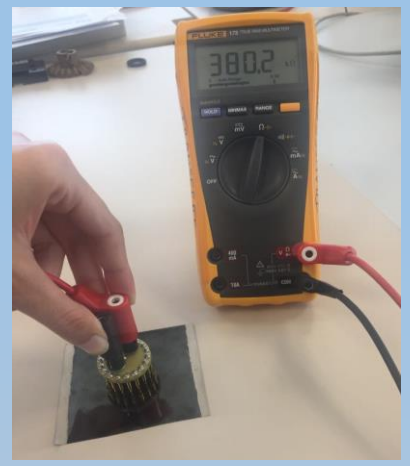
2017 Introduction of DLC

GEM base material
Cu 5um/0.01umCr/50umApical/0.01umCr/5um Cu

Adding DLC on one side
Cu/Cr/Polyimide/DLC

CALIBRATION of CUSTOM-MADE PROBE

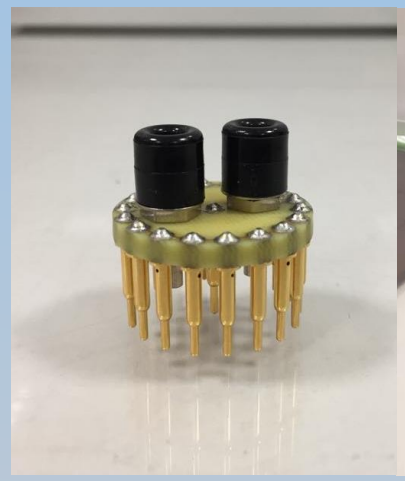




DLC Film	Surface Resistivity (kΩ/□)	Surface Resistance From The Probe (kΩ)	Coefficient Factor	Error (%)
1	359	345	1.041	4
2	386	364	1.060	6
3	403	380	1.061	5

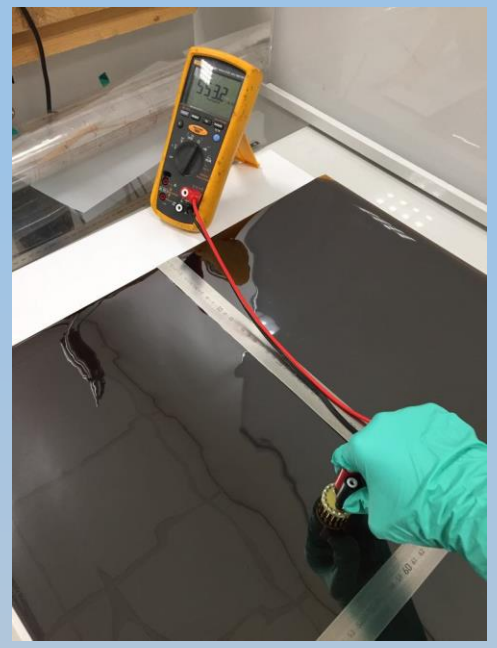
- 7cm x 7cm square of DLC coated films are cut and painted with silver to make a connection between two edges of the film in order to measure the surface resistivity per square.
- Later, the probe is placed onto the surface of the DLC film and the resistance measurement is taken by using the multimeter.
- From the both measurement results, given in the table, the probe could be calibrated to coefficient factor at 1.06 and the error percentage is decreased up to 4 %. Since the coefficient factor is close to 1, the value measured from the probe can be considered as the surface resistivity of the film.
- The probe does not have limitations on the resistivity range, it depends on the used multimeter.

EXPERIMENTAL SETUP



- As it was mentioned in the previous slide, custom-made probe and multimeter are used for the measurement.

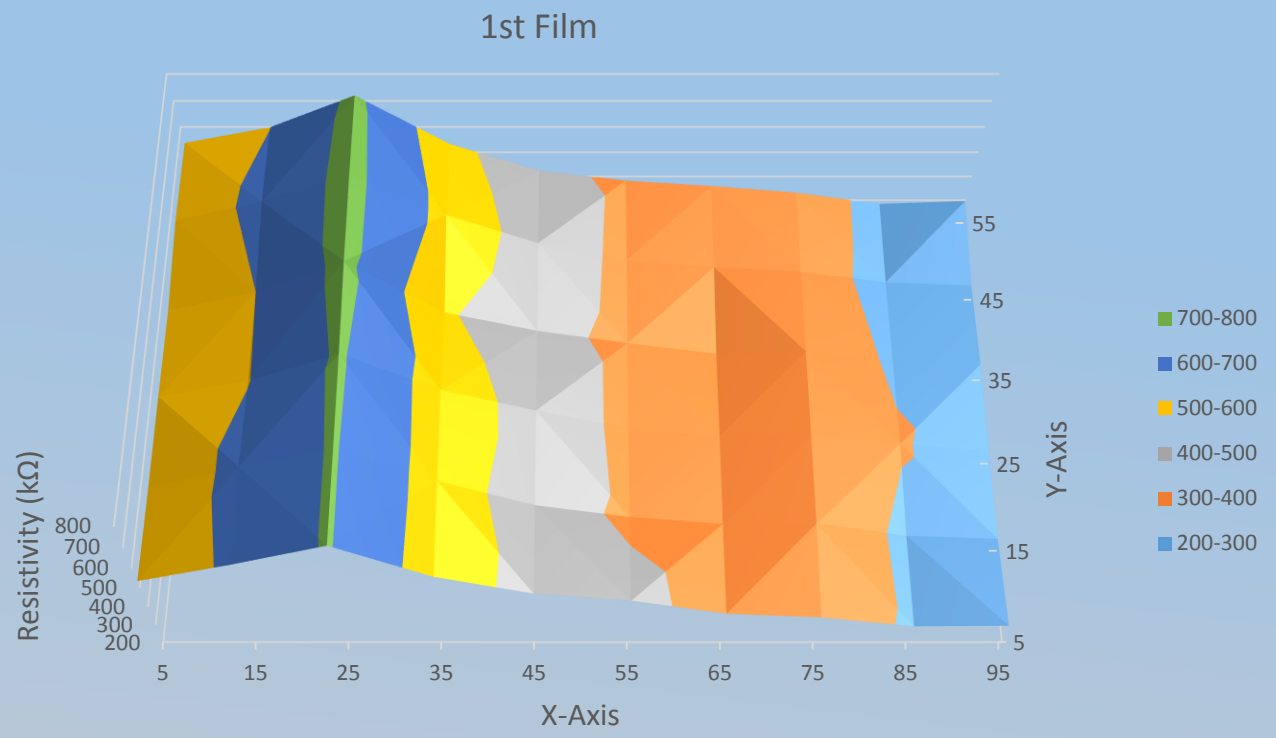
- Two rulers were adjusted to take surface resistivity measurement from 10cm x 10cm squares. The bottom-left corner of the film was assigned as origin point. 1m x 0.6m foils



- By measuring the center of the squares, the film is scanned and results are transferred to Excel for 3D graph.

RESULTS

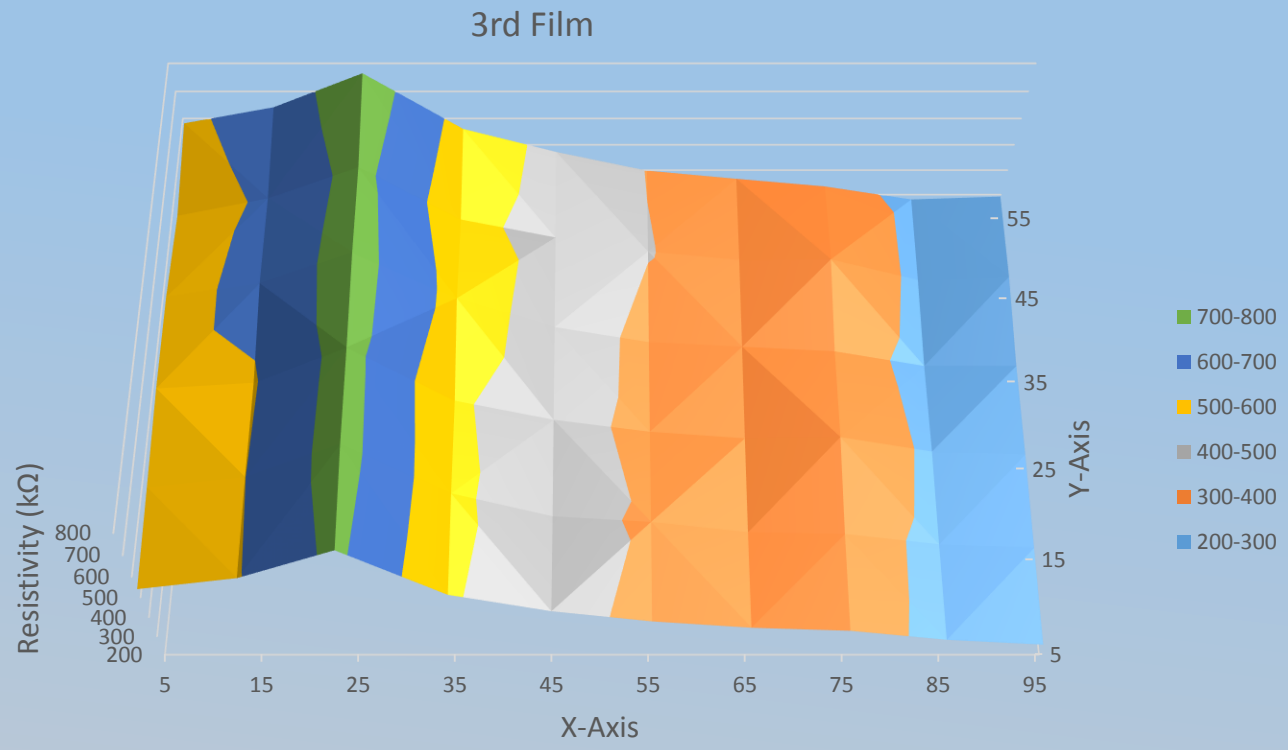
1st Film	5	15	25	35	45	55	65	75	85	95
5	532	615	708	554	467	430	360	339	290	293
15	526	625	708	559	442	384	348	350	286	270
25	525	597	712	556	462	377	342	346	305	270
35	520	600	726	512	431	376	327	338	293	278
45	546	623	728	570	453	380	349	328	282	267
55	537	599	721	532	425	383	360	332	283	296



- The measured minimum and maximum resistivity values are 267 - 728 kΩ.
- On the left side of the thin film, the resistivity increases to the right. However, after reaching the highest surface resistivity area the surface resistivity starts to decrease.

RESULTS

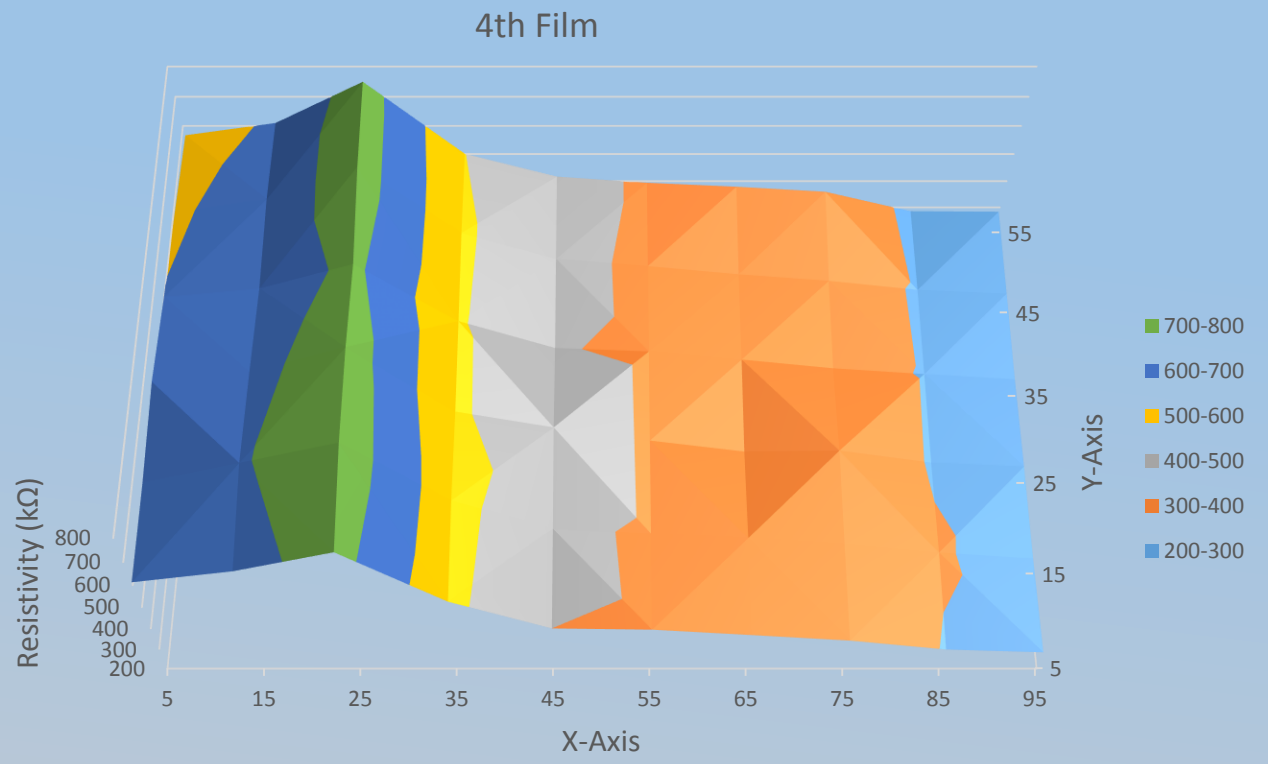
3rd Film	5	15	25	35	45	55	65	75	85	95
5	540	593	723	512	430	378	345	329	281	255
15	554	599	742	526	419	392	342	333	282	264
25	569	593	738	516	432	378	348	354	287	273
35	570	625	745	565	445	380	360	340	275	275
45	547	615	733	532	460	403	368	370	283	296
55	582	642	765	561	472	398	365	334	280	292



- The measured minimum and maximum resistivity values are 255 - 765 kΩ.
- On the left side of the thin film, the resistivity increases to the right. However, after reaching the highest surface resistivity area the surface resistivity starts to decrease.

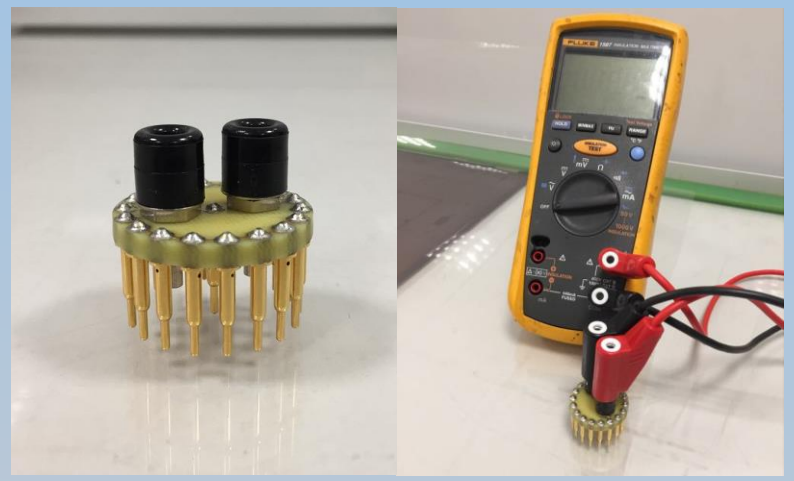
RESULTS

4th Film	5	15	25	35	45	55	65	75	85	95
5	612	660	741	525	400	394	368	341	297	283
15	613	690	769	536	414	392	372	344	305	277
25	629	665	759	511	446	391	344	348	296	279
35	603	634	723	510	404	390	357	321	297	275
45	589	638	752	516	417	389	357	331	295	280
55	567	610	750	501	417	394	379	360	285	283

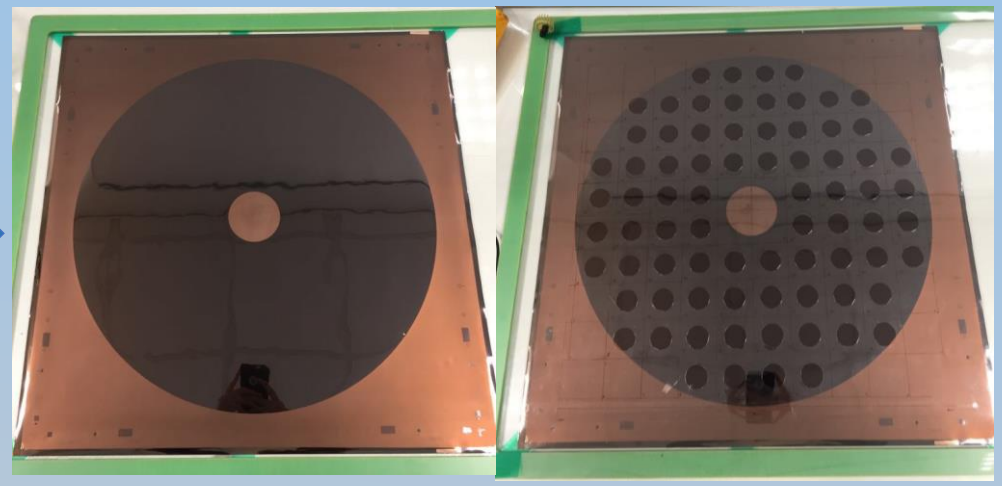


- The measured minimum and maximum resistivity values are 275 - 769 kΩ.
- On the left side of the thin film, the resistivity increases to the right. However, after reaching the highest surface resistivity area the surface resistivity starts to decrease.

EXPERIMENTAL SETUP



- As it was mentioned in the previous slide, custom-made probe and multimeter are used for the measurement.



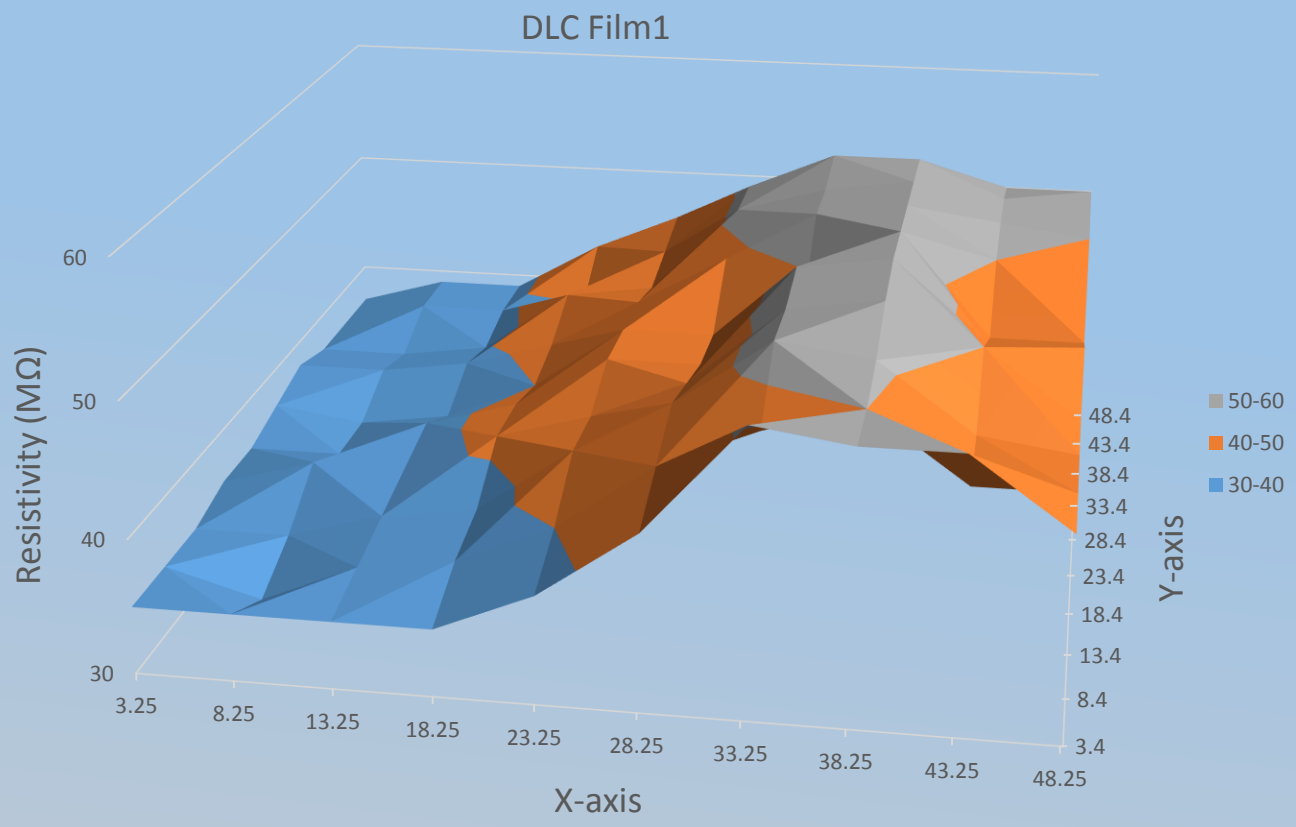
- The square template, which has the same side length with the diameter of the DLC coating, was divided into 5cm x 5cm squares and was opened a hole in order to make the measurement from the center of the square.
- Later, it was placed onto the DLC coated film and adjusted to origin point.

- By measuring the center of the holes, the film is scanned and results are transferred to Excel for 3D graph.

RESULTS

- ✓ The area in the middle of the template and squares, which are not in the circle coating area, were assigned approximate resistivity values according to measurement in the adjacent squares in order to create a mesh in Excel for 3D graph. This was applied to all three DLC films.

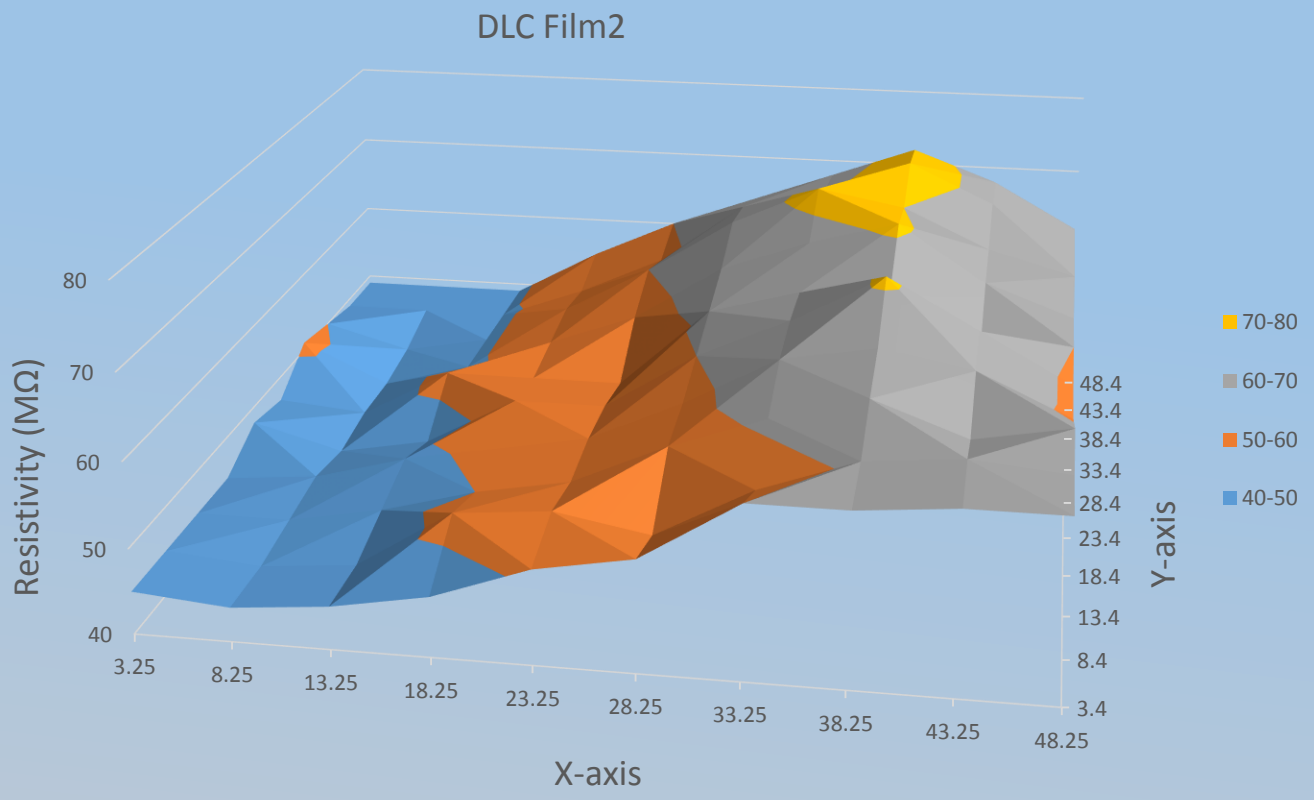
DLC1	3.25	8.25	13.25	18.25	23.25	28.25	33.25	38.25	43.25	48.25
3.4	35	35	35	35	38	43	51	50	50	45
8.4	35	33	36	37	40	45	48	50	45	45
13.4	35	35	37	38	43	47	52	51	46	45
18.4	36	38	38	41	43	46	52	53	50	45
23.4	36	36	39	41	45	45	53	54	48	48
28.4	37	36	37	40	45	45	49	54	46	46
33.4	38	38	39	41	45	49	53	54	50	48
38.4	37	37	38	43	44	51	53	54	51	50
43.4	37	39	39	40	45	51	54	54	51	50
48.4	37	39	39	43	46	49	52	51	50	50



- ➢ The measured minimum and maximum resistivity values are 35 - 54 MΩ.
- ➢ The resistivity increases from left to right part of the thin film.

RESULTS

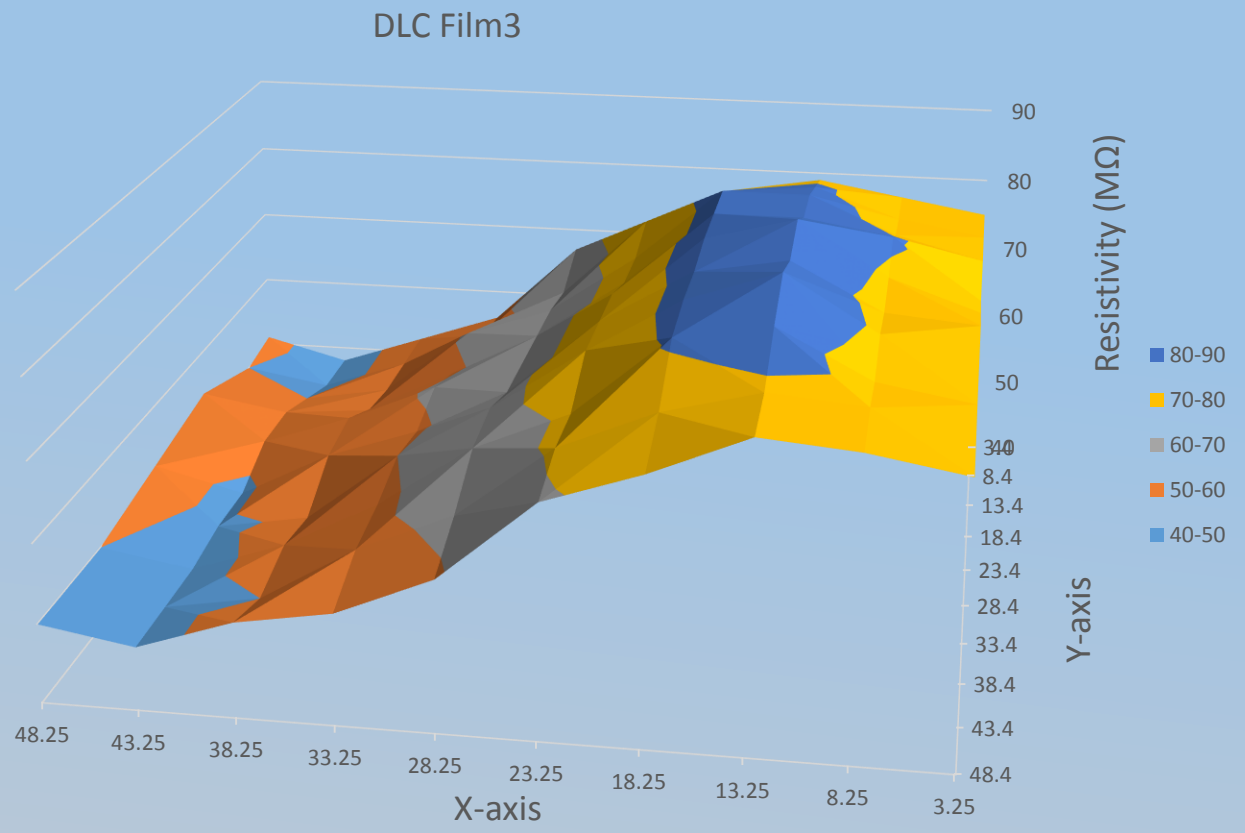
DLC2	3.25	8.25	13.25	18.25	23.25	28.25	33.25	38.25	43.25	48.25
3.4	45	44	45	47	51	53	60	60	61	61
8.4	45	44	45	52	53	51	57	61	62	61
13.4	45	45	47	50	52	57	61	64	60	62
18.4	45	46	49	51	53	58	64	66	64	59
23.4	48	45	47	53	53	60	65	71	65	59
28.4	47	46	52	52	52	62	65	67	60	60
33.4	51	46	49	53	57	64	68	71	64	60
38.4	50	47	49	54	60	67	72	70	65	62
43.4	49	49	49	53	58	66	69	73	68	62
48.4	49	49	49	55	60	64	68	72	68	62



- The measured minimum and maximum resistivity values are 44 - 73 MΩ.
- The resistivity increases from left to right part of the thin film.

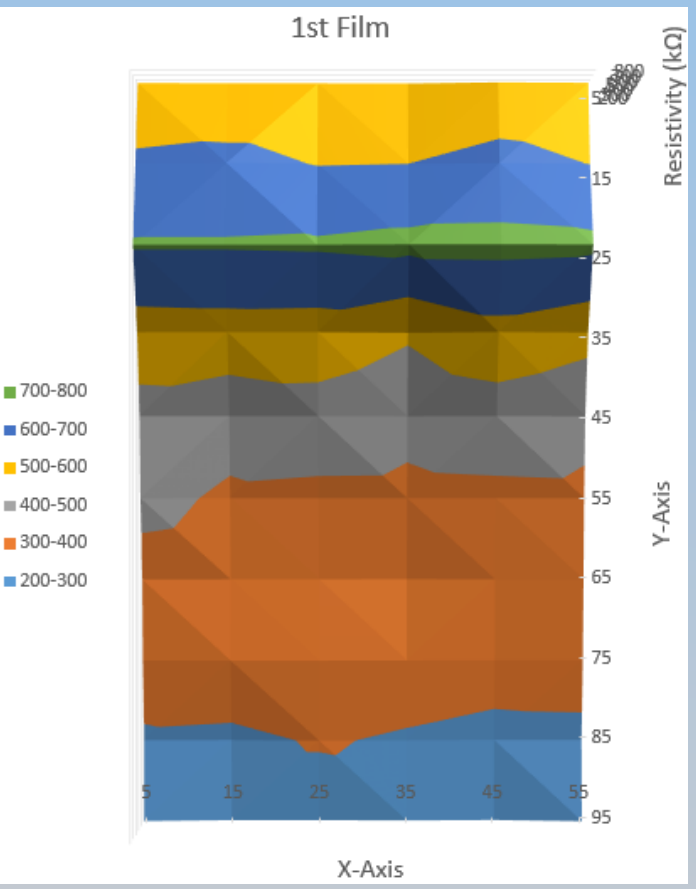
RESULTS

DLC3	3.25	8.25	13.25	18.25	23.25	28.25	33.25	38.25	43.25	48.25
3.4	75	77	79	77	69	67	56	52	48	51
8.4	75	77	81	80	75	64	57	52	48	50
13.4	75	78	83	83	73	65	61	52	50	52
18.4	73	81	83	83	73	65	59	53	52	54
23.4	75	79	86	83	75	65	61	56	52	53
28.4	77	78	84	82	75	65	59	55	49	52
33.4	76	79	86	82	75	67	60	51	49	51
38.4	75	77	83	81	71	66	58	52	48	50
43.4	75	78	79	76	71	62	57	50	48	50
48.4	75	77	78	73	69	59	54	52	48	50

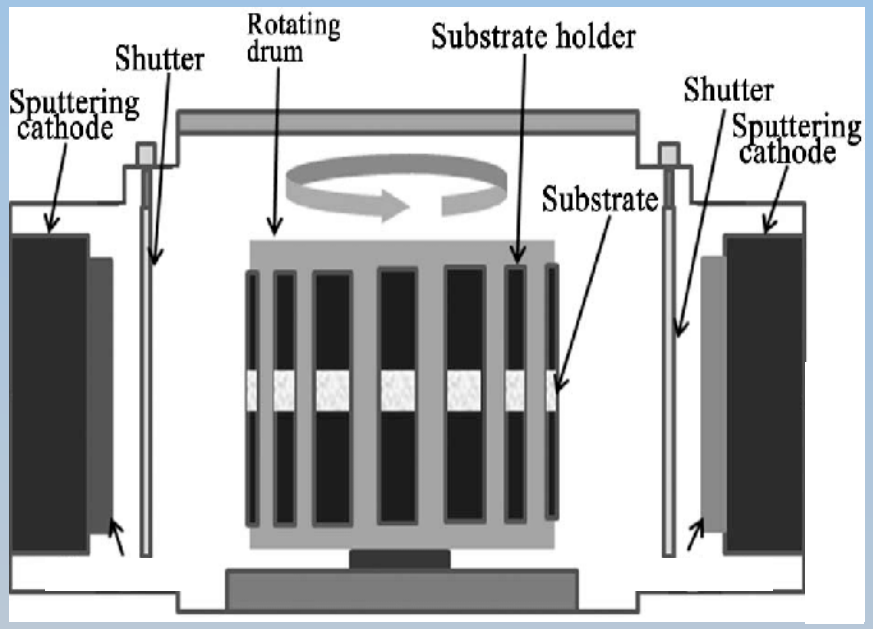


- The measured minimum and maximum resistivity values are 48 - 86 MΩ.
- The resistivity increases from left to right part of the thin film.

Discussion



*Rotation of the film 90° to the right from the origin is assumed as the coating direction.



Typical Schematic representation of magnetron sputtering mechanism.

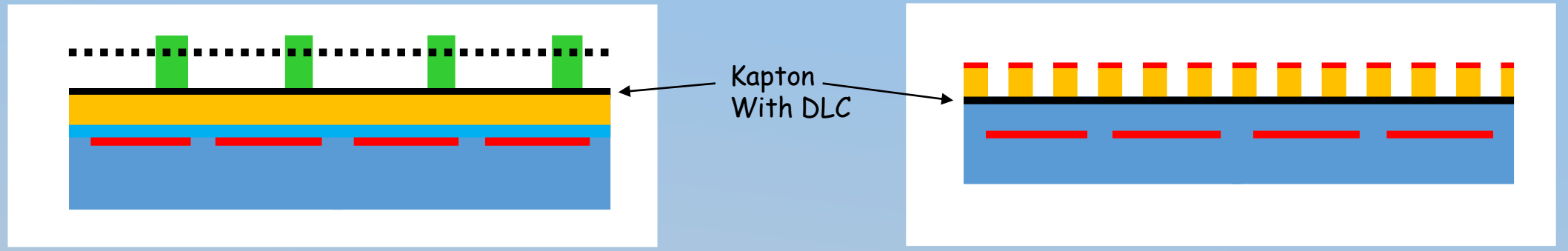
→Surface resistivity could be measured by using the custom-made probe.

→There are may be few explanations for the non uniform DLC layer;

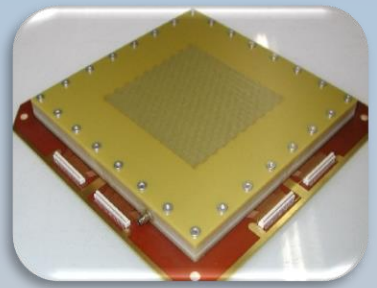
-Graphite target not placed parallel to the substrate,

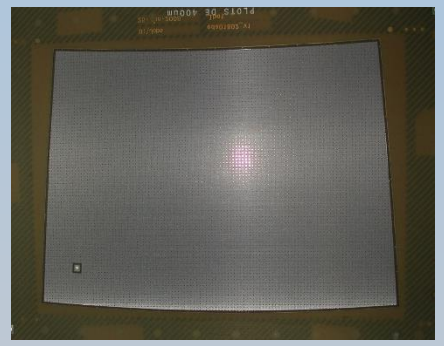
-In case of target split in many small ones, the current density may be different in every one.

DLC applied to Micromegas and uRwell



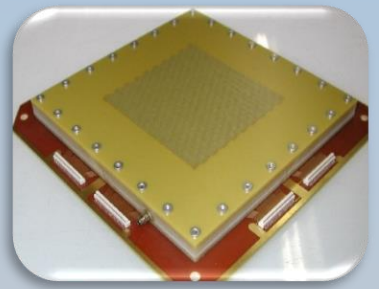
- Single Diamond like carbon (DLC) layer



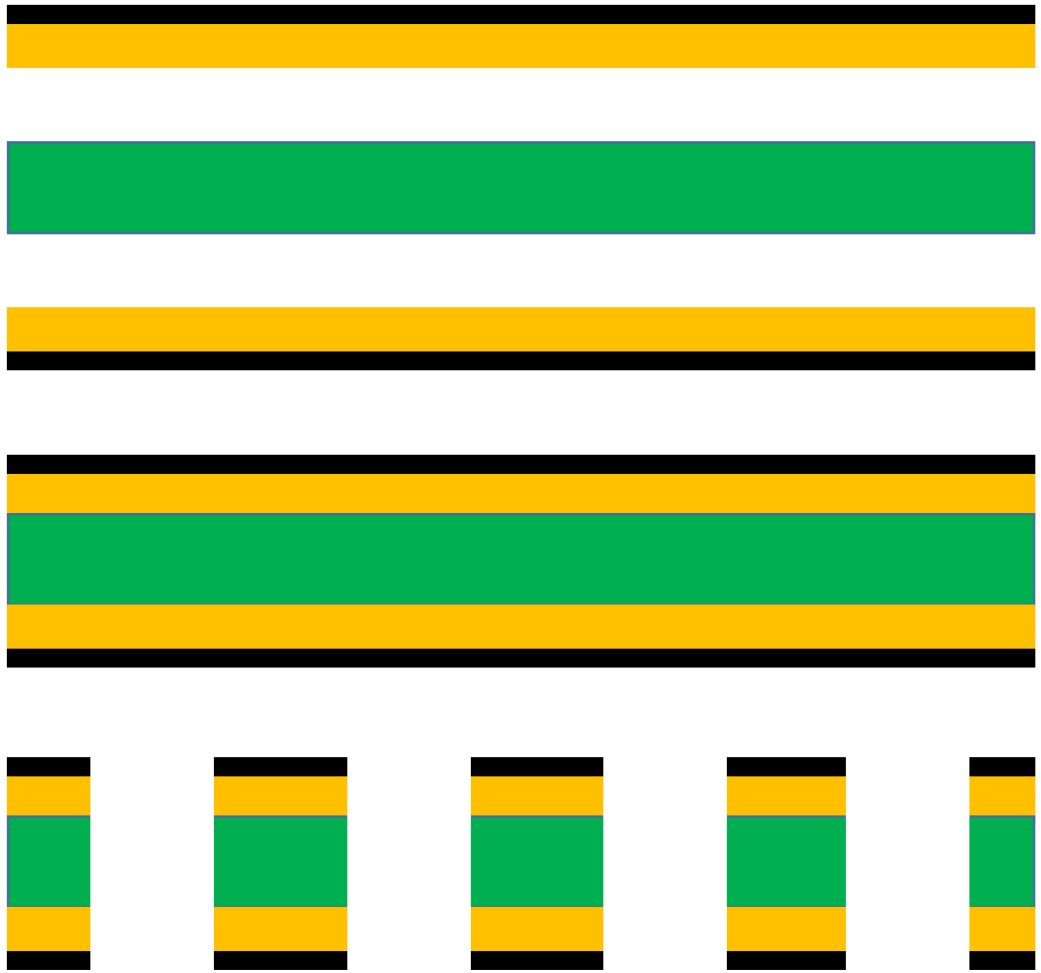


-ILC TPC 15cm x 30cm
-Many evaluation detectors 10cm x 10cm
-T2K upgrade detectors production in progress
32 detectors 40cm x 40cm

-Only evaluation detectors 10cm x 10cm



Resistive THGEM

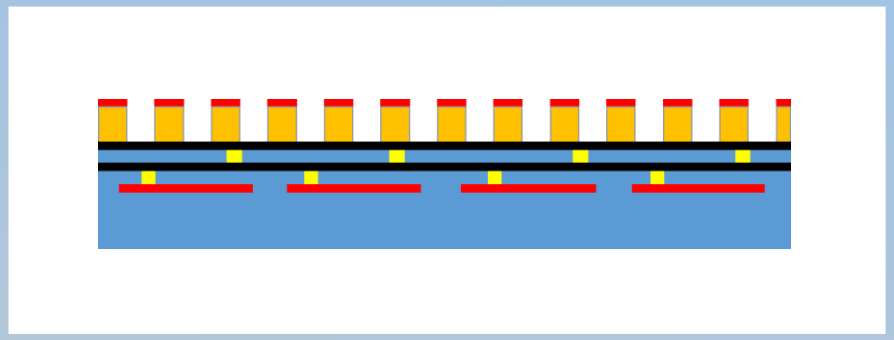


2018 Cu on DLC

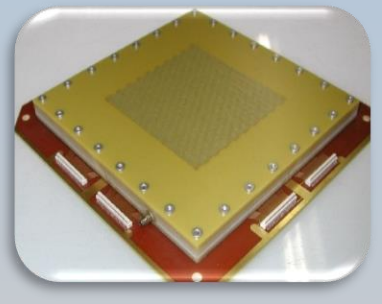
- Cu/Cr/Polyimide/DLC/Cr/Cu

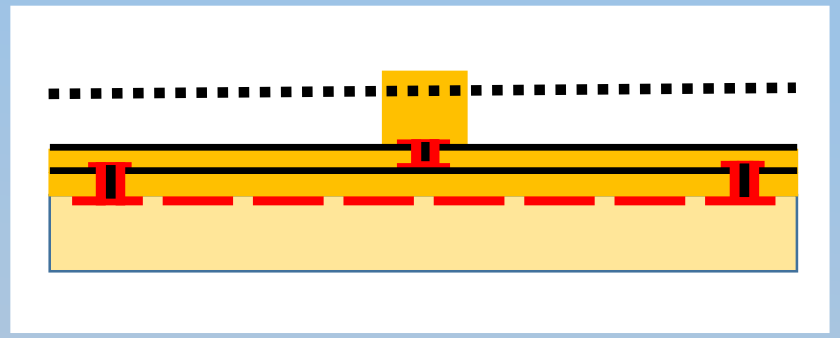
Embedded DLC protection in MicroMegas and uRwell

High rate detectors

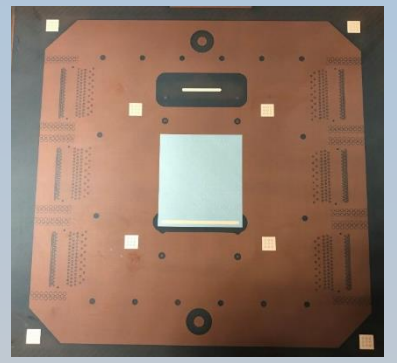


-Only evaluation detectors 10cm x 10cm active area
PAD read out 1cm x 1cm and X/Y





-Only evaluation detectors 4cm x 4cm
Pixels 3mm x 1mm



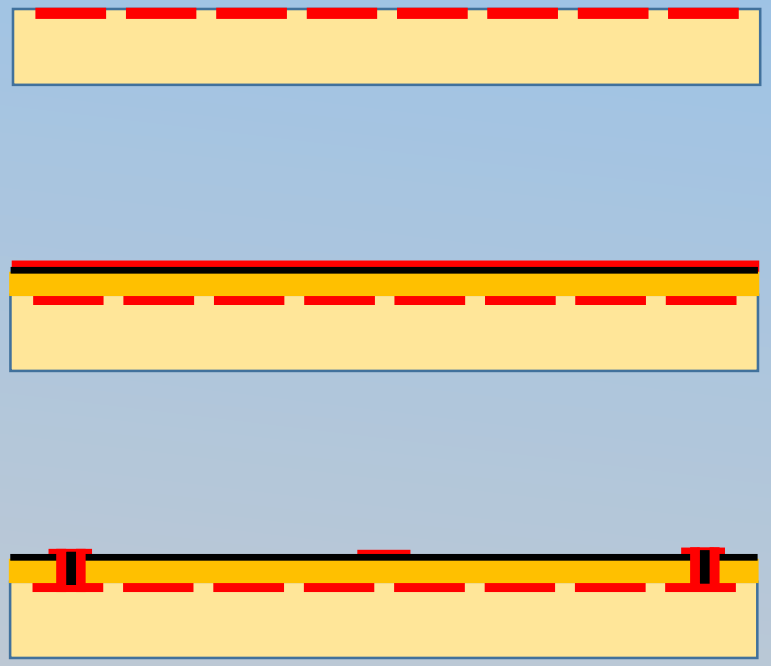
Embedded DLC layer : high rate detectors
"Sequential Built Up" technique

Base PCB

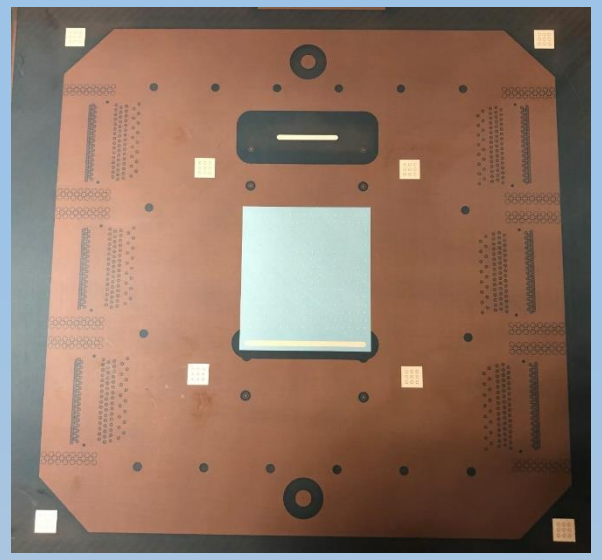
Embedded DLC layer : high rate detectors

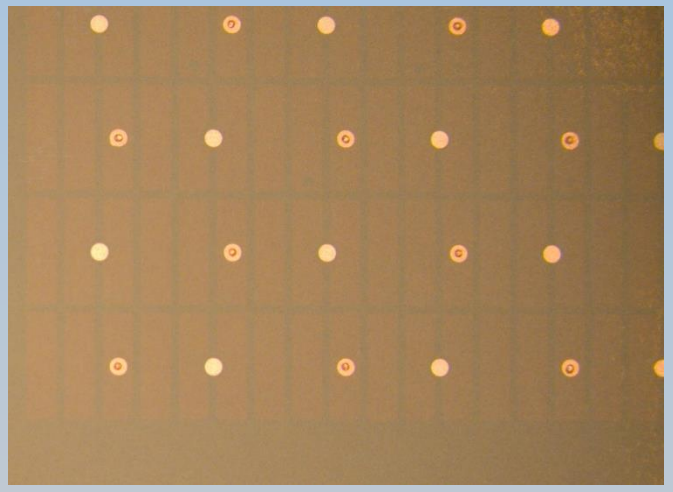
PI/DLC/Cu foil gluing

Embedded DLC layer : high rate detectors

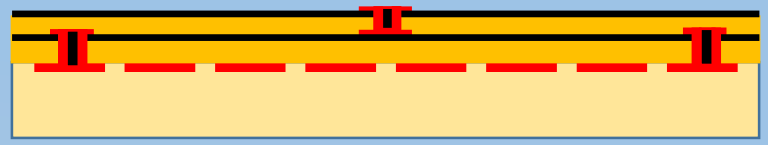


Micro via drilling + Cu plating + Cu patterning +DLC patterning

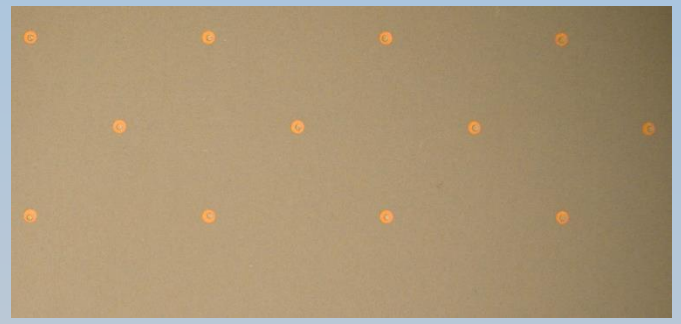




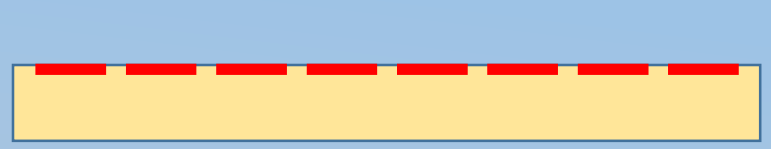
Embedded DLC layer : high rate detectors

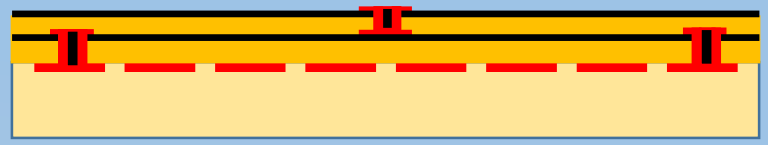


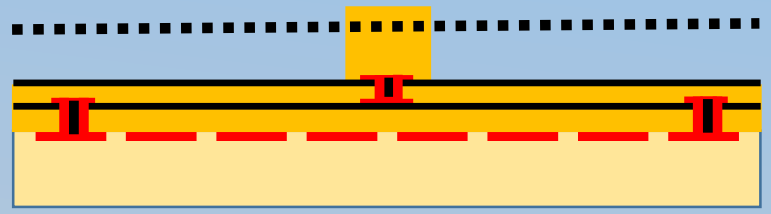
New PI/DLC/Cu gluing
+ microvia drilling
+ Cu Plating
+ Cu Patterning
+ DLC patterning



Embedded DLC layer : high rate detectors

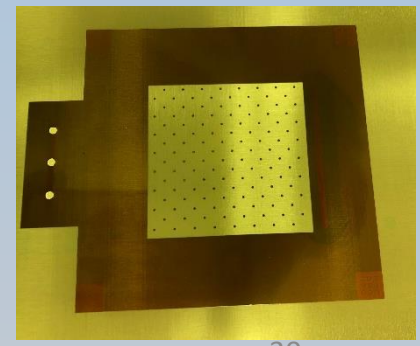






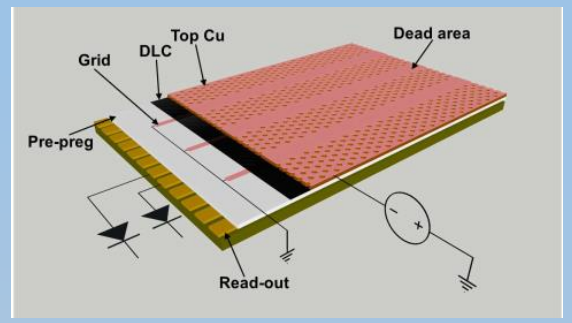
Bulk creation on top of the structure

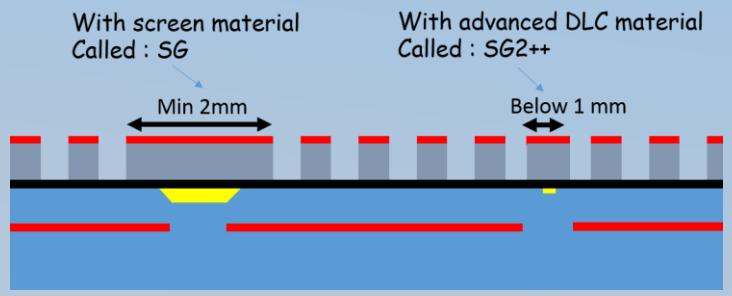
-Pillars hiding the Microvias
-Better energy resolution



High rate uRwells

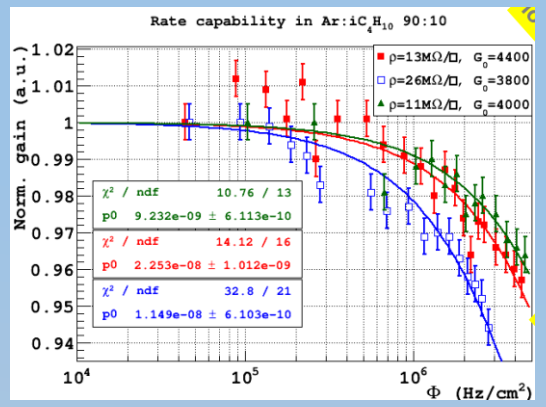
SRL + Silver Grid: called "SG"

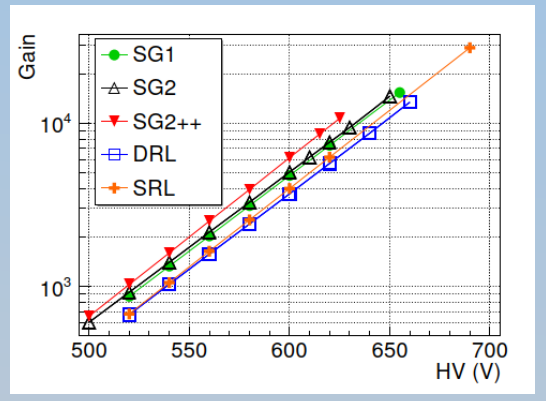


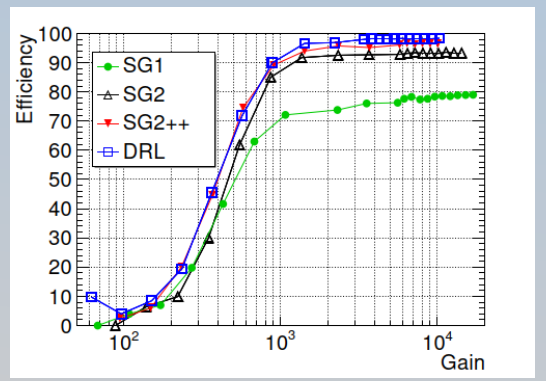


-High rate
-Flexible
-Low mass

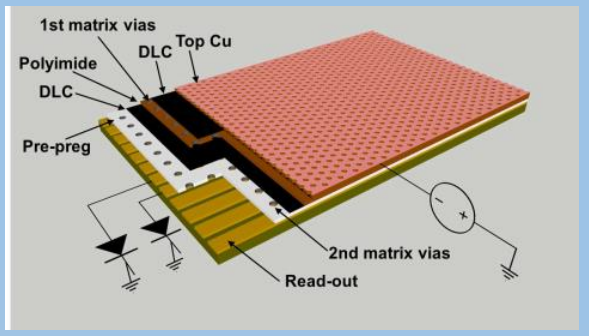
-Alignment accuracy defining DOCA problematic with large detectors

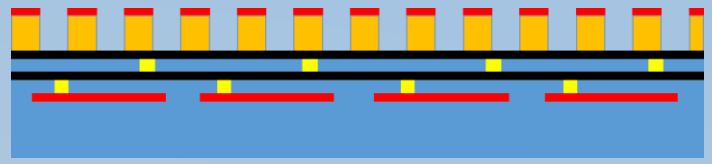






Double res layer : called "DRL"

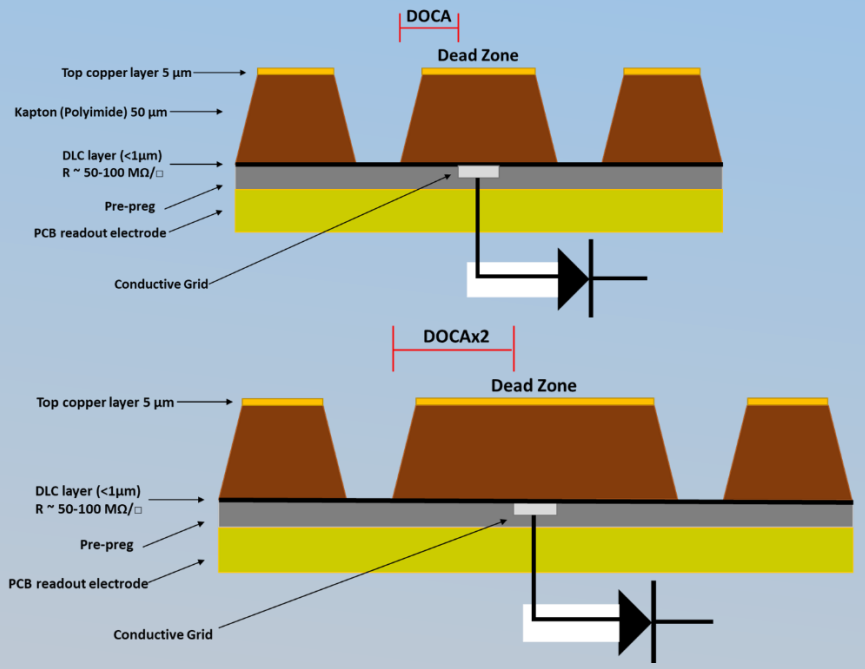


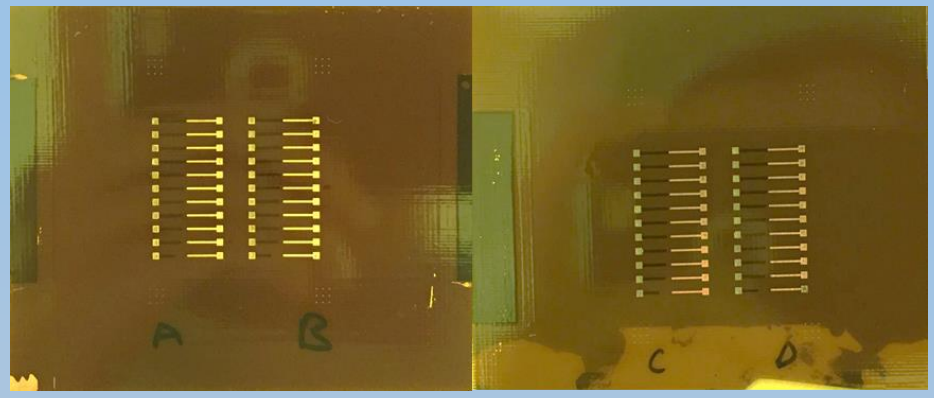


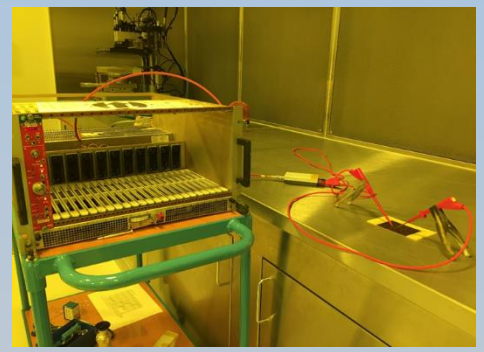
-Highest rate in theory
-Flexible
-Low mass

-More steps of production

-DOCA distance varies on the samples
(Distance Of Closest Approach)
-between 1.0-0.1 mm
-DLC 60M
-11 samples per row



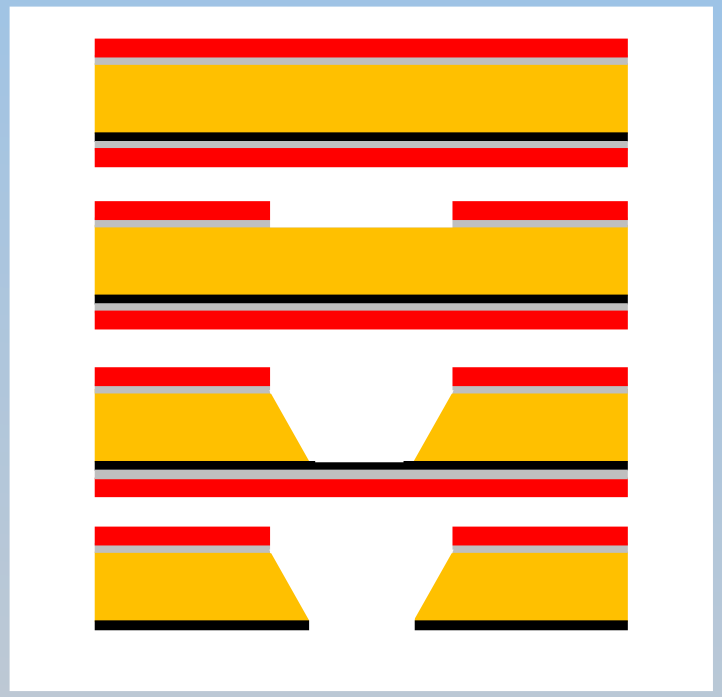




Discussion on DOCA

- First surprise : the voltage to reach instabilities (up to 800V in air)
  - We were expecting 650V/670V for a 50um gap
- After 30 sec with a limitation to 30nA we can already observe a voltage drop
  - It stabilize at voltages between 550V to 650V
  - An average current of 30nA per hole means 15mA for a 10cm x 10cm detector
  - This current is too high and not realistic.
  - We need to repeat the test with lower currents.
- We aren't able to define how many "low energy sparks" are created.
  - We would like to study the current peaks with a fast oscilloscope
- No real difference from the different DOCA with 60M DLC

Single DLC Resistive GEM

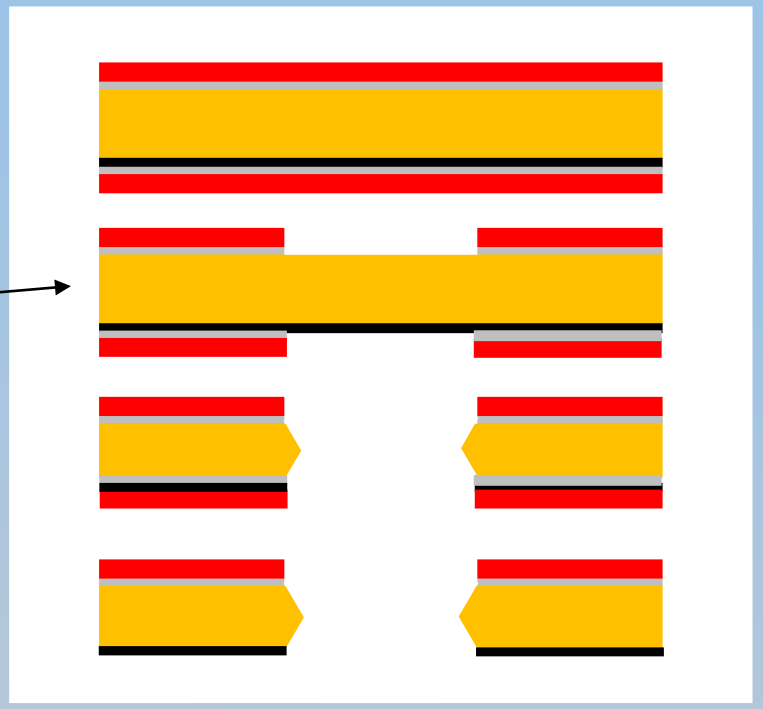


Base material:
Cu/Cr/Polyimide/DLC/Cr/Cu

Copper/Cr patterning
+ sand blasting

Kapton etching

Copper/Cr stripping



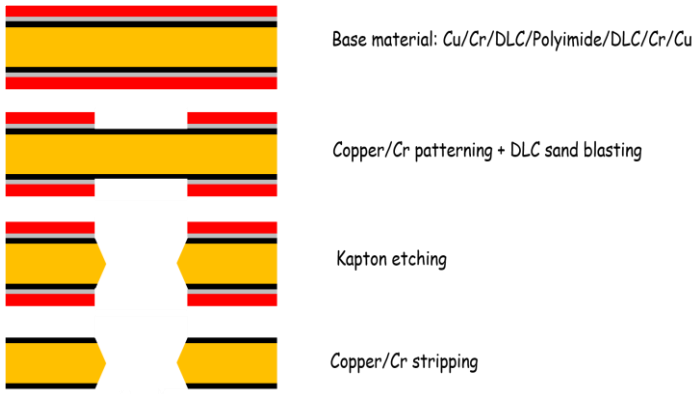
"on behalf of GDD, MPT and USTC"

2019 Cu and DLC both sides:

- Cu/Cr/DLC/Polyimide/DLC/Cr/Cu

Devices not yet existing

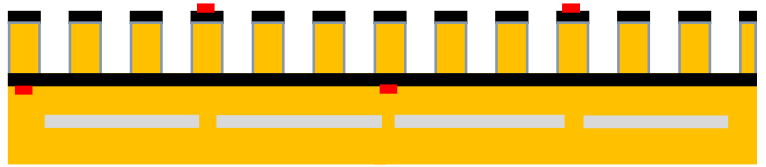
Full DLC GEM



Full DLC uRwell and AL pick up lines

Low mass detector, medium rate version

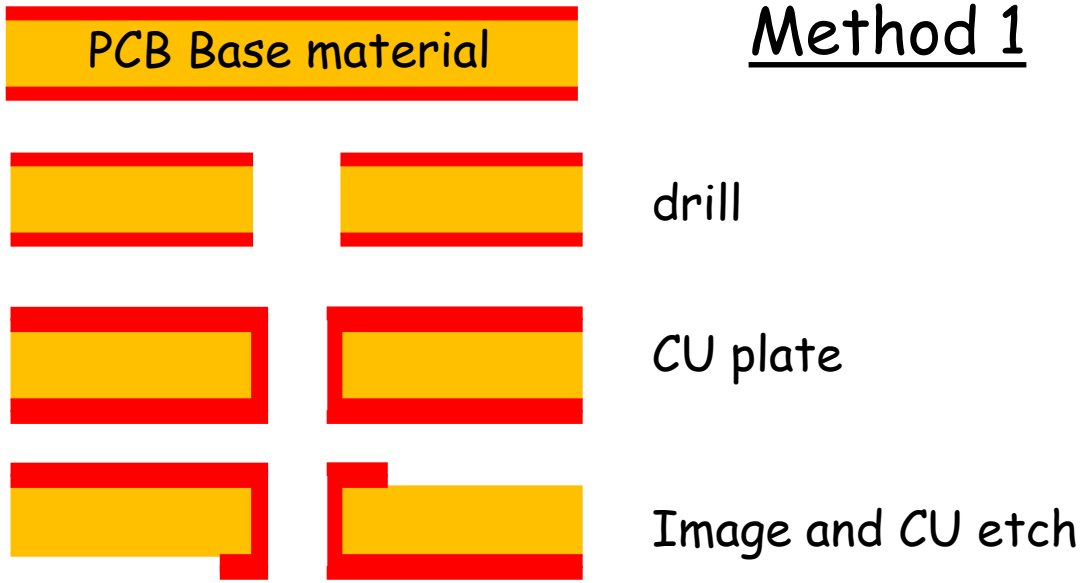
Low mass detector, high rate version



- We are still suffering from a low adhesion of Cr on DLC

Just for fun
Here are 2 methods to produce
a plated through hole

Method 1

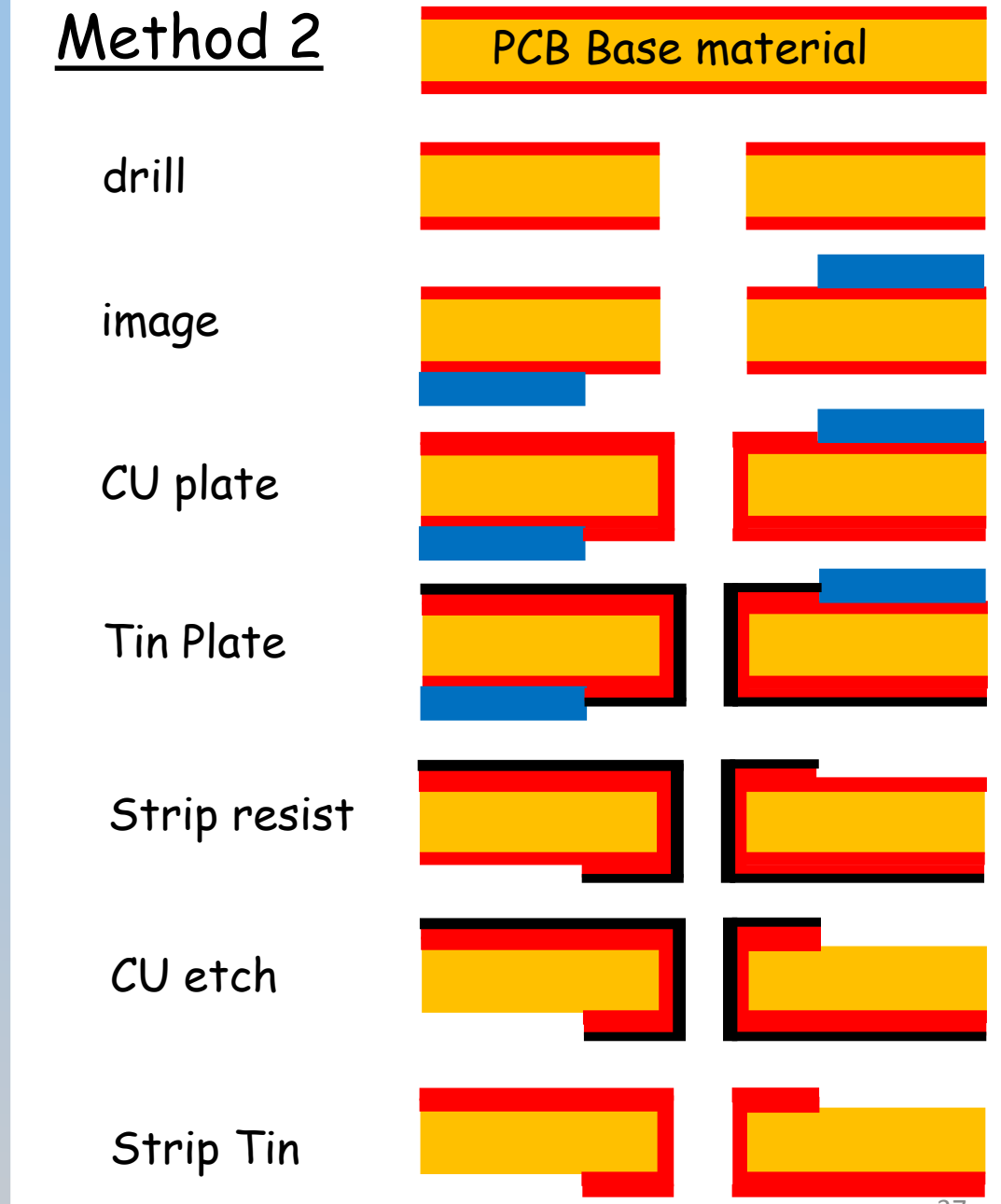


Simple but
Lower yield

Complex but
Cheaper

The best processes are not always the simplest ones !

Method 2



Conclusion

- We master now the embedded resistive paste process in large size
- The production of single DLC schemes are also stabilized
- The SBU process needs some improvements
- The 2 DLC foils shows interesting possibilities but we still need to improve base material for perfect structures