Resistive MPGDs

Screen printed resistors versus DLC

Rui De Oliveira

workshop on the upgrade of T2K March 20-21

- MM Projects @ CERN and MPGD R&D
- Medium rates detectors
- High rate detectors
- Screen printed resistor Spark study
- conclusion

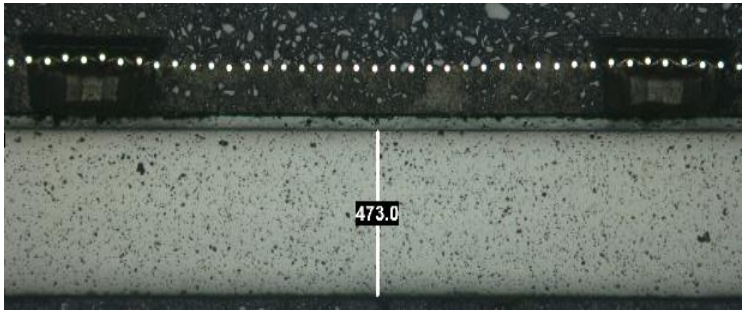
Resistive MPGD projects at CERN

•Production of MM	**resistor family**
•ATLAS NSW	screen printed
•CLAS 12	screen printed
•Mcube	screen printed
•Gbar	screen printed
•LSBB	DLC
•BL4S	gap filling
•STD detectors 10 x 10 1D	screen printed
•STD detectors 10 x 10 2D	gap filling
•R&D Micromegas	
•ATLAS resistive Kapton Micromegas Muon large pitch	resistive Kapton
•ATLAS High rate screen printed Embedded resistors BULK	screen printed
•High rate DLC Embedded BULK Micromegas detector	DLC
•Embedded front end electronics in read-out boards	Screen printed
•Micromegas pS resistif	Screen printed
•Transparent Micromegas detectors	ITO
•R&D other resistive structures	
•CMS FTM multiple resistive well detectors	DLC
•CMS u-Rwell high rate Muon detectors	DLC
•LHCB u-Rwell high rate Muon detectors	DLC
•Low cost sticky Piggy back u-Rwell	DLC

BULK or Standard ?

"bulk" Micromegas

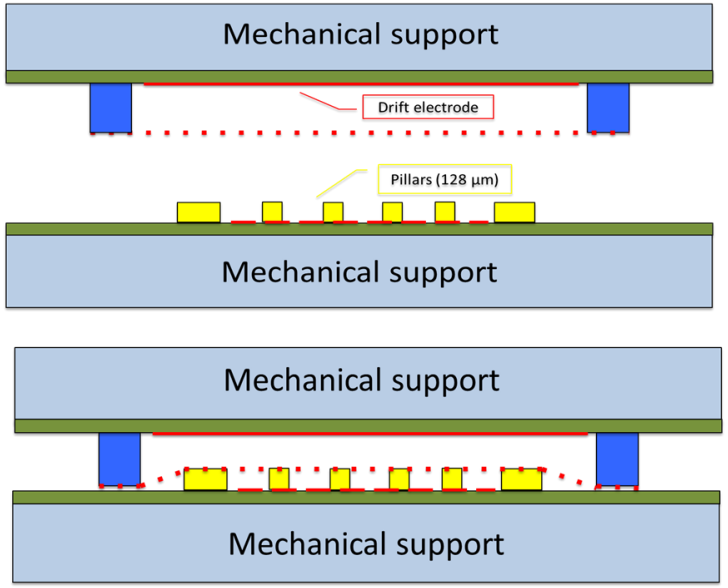
Mesh embedded in pillars



- Production in clean room is mandatory to avoid dust trapping
- We are now at CERN artificially Limiting the size to 550mm x 550mm active area for optimum yield
- Self supporting , limited dead zones
- Cylindrical detectors

"Standard" Micromegas

Mesh separated from pillars



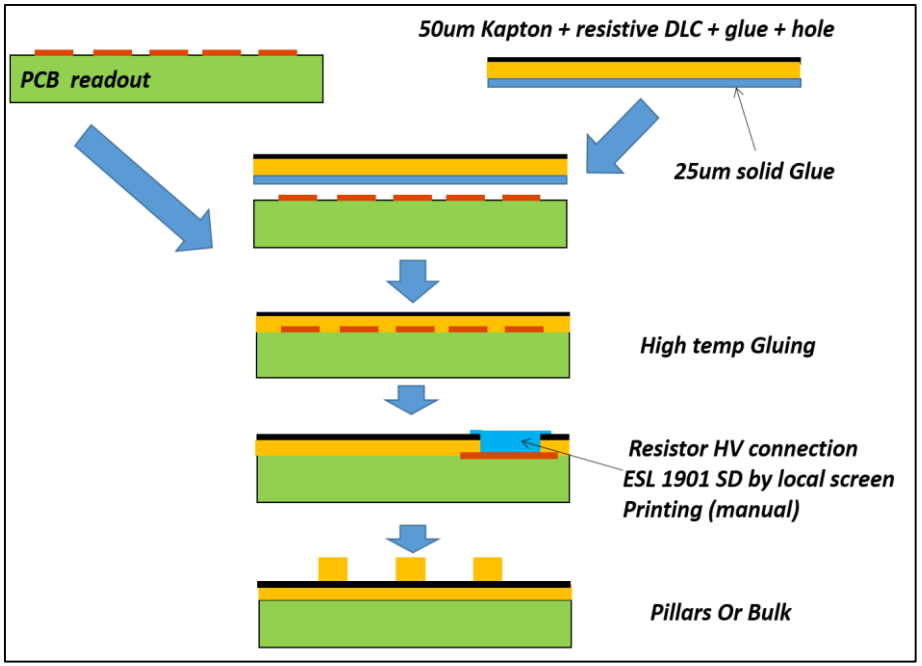
- Need strong mechanical supports
- Planarity to be controlled! (to guarantee amplification gap constant)

- Large sizes (~ 2m) (ATLAS)
- easy to open and clean
- Lower cost for mass production

- Medium rate detectors
  0 to 100khz/cm2

Resistor scheme in Micromegas detectors for medium rates

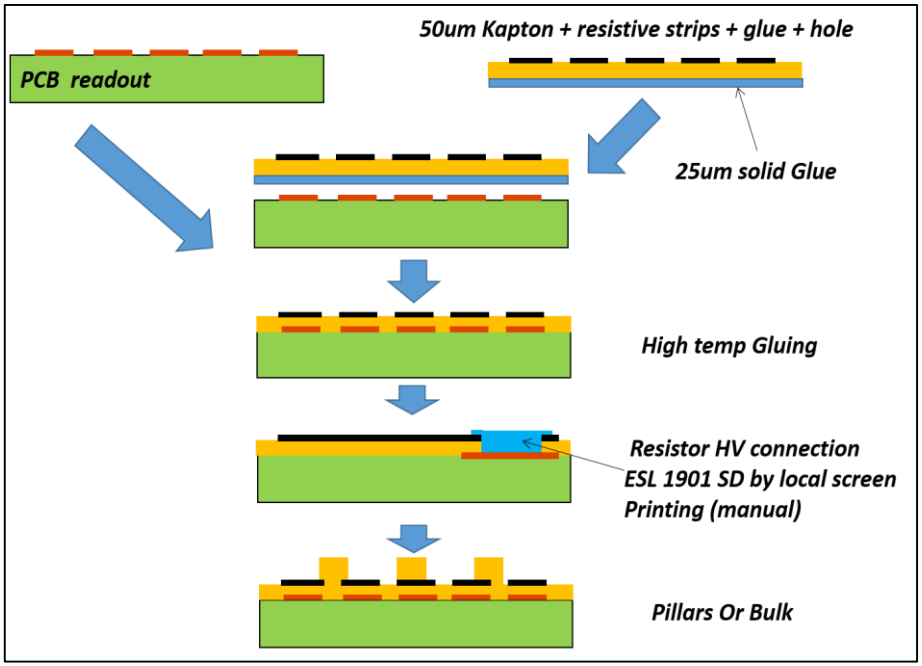
DLC



- Single source today
- DLC size limited now to 1.2m x 0.6m max

- No tooling
- less charging up due to inter-pads dielectric
- 1Mohms/square up to 1Gohms/square
- Clusters are equal in X/Y read-out

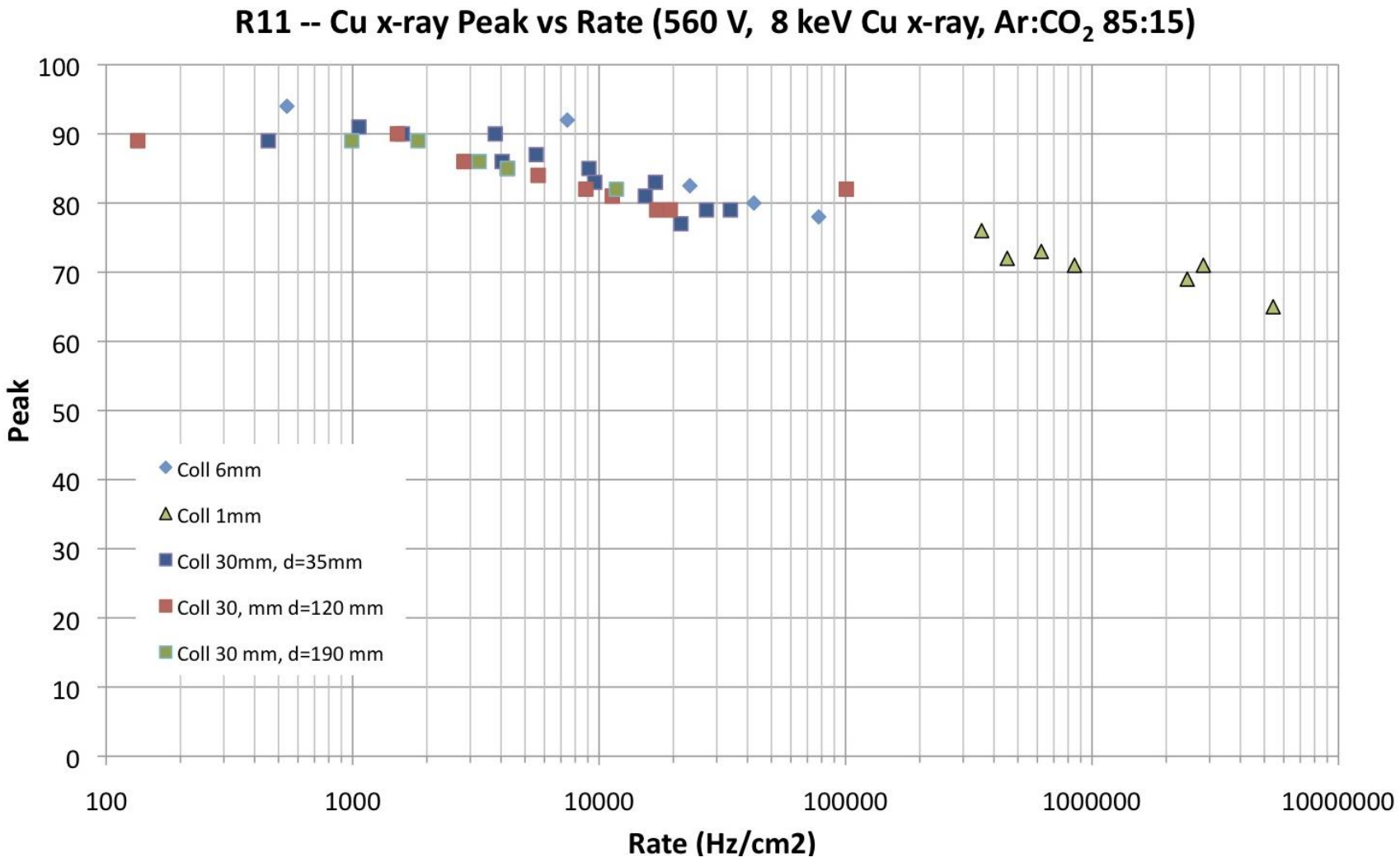
Screen printing



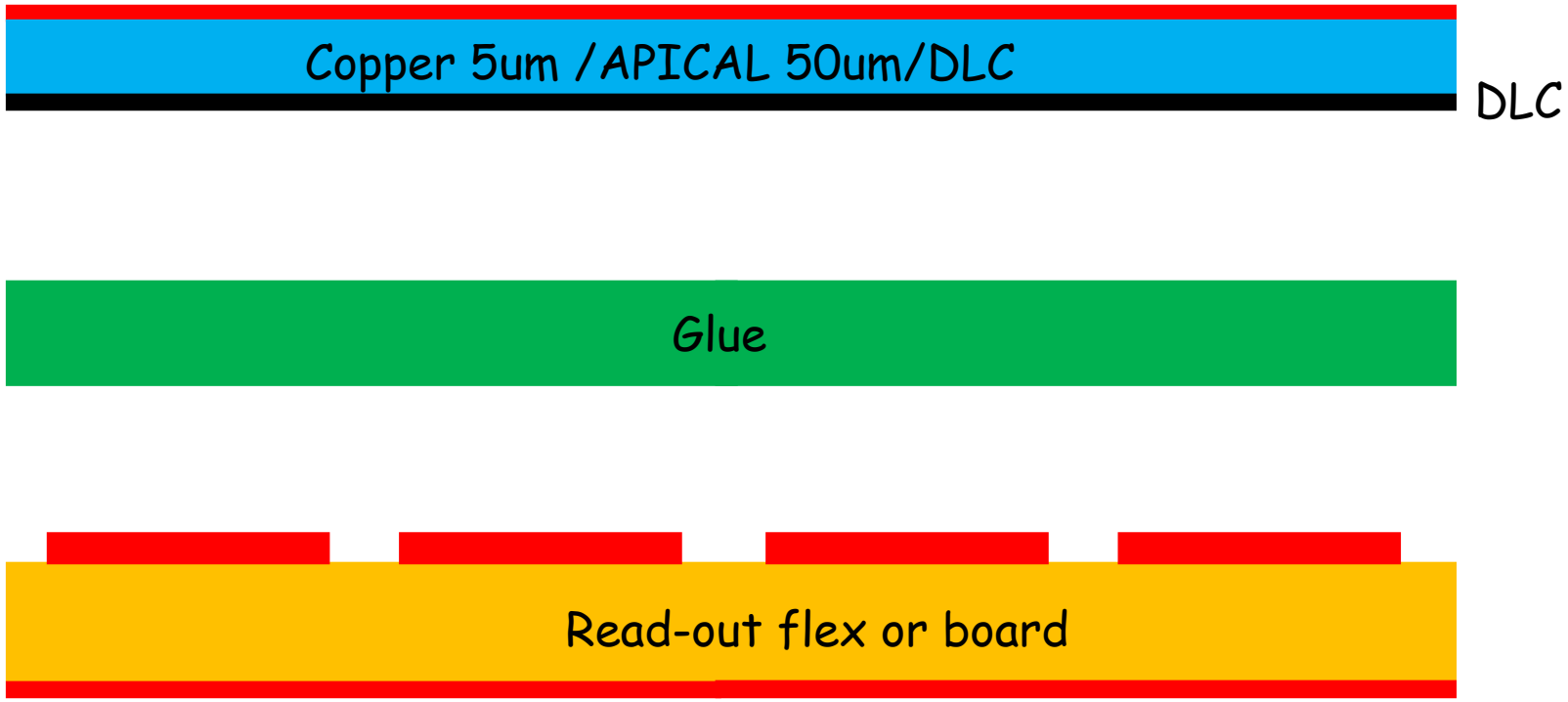
- Need tooling for screen printing
- Need alignment
- 1K ohms /square up to 100Kohms/square
- Different clusters in X/Y read-out

- Low cost in large volume
- Routine Screen printing up to 2m x 0.5m
- Many suppliers are existing

R11-rate performance



u-Rwell for medium rate



u-Rwell medium rate

Vacuum Press gluing

u-Rwell medium rate

Top copper pattern + APICAL etch
Detector ready

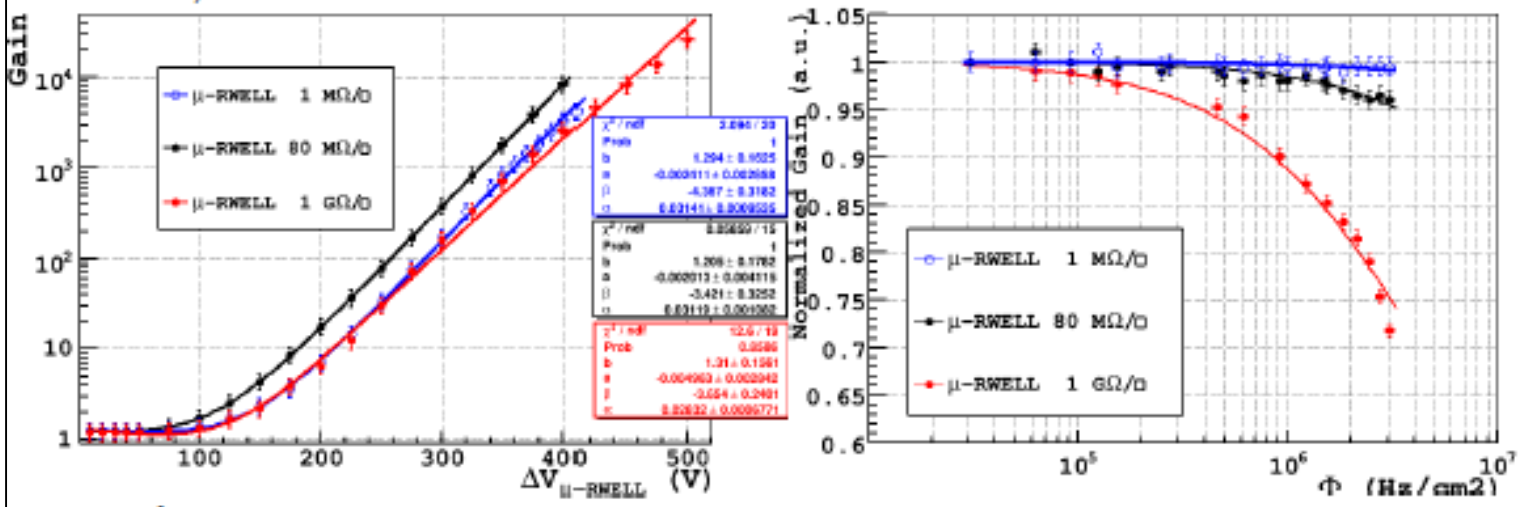
Flexible or rigid detector
Radio pure materials possible
thickness of 0.2mm possible

Max size today : 1.2m x 0.55m
Real limit 1.6mx 0.55m
Cheapest MPGD detector

μ-RWELL: other prototypes

X-ray tube, Ar:iC_4H_{10} 90:10

2,5 mm Diameter Collimator



Fit Results:

Resistivity declared by the deliverer: **1 GΩ/□**; from fit **ρ_S= 883.8 ± 176.7 MΩ/□**

Resistivity declared by the deliverer: **80 MΩ/□**; from fit **ρ_S= 79.3 ± 15.8 MΩ/□**

Resistivity declared by the deliverer: **1 MΩ/□**; from fit **ρ_S= 11.7 ± 2.3 MΩ/□**

14

Giovanni Bencivenni and all 2016

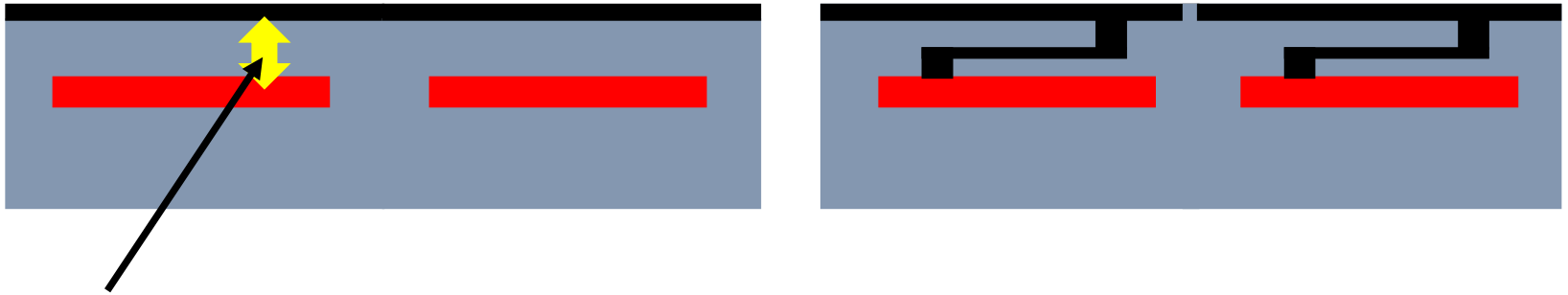
- High rate detectors

From 100Khz to "100Mhz/cm2"

Embedded resistors are mandatory for High rate applications

- The embedded resistor evacuates locally the charges
- We can define the embedded resistor max spark power and its breakdown voltage by design

Surface resistor → 2 layers



-The thickness above the pad should be limited in both structures
-Around 50 to 75um on the produced prototypes

MM Production steps

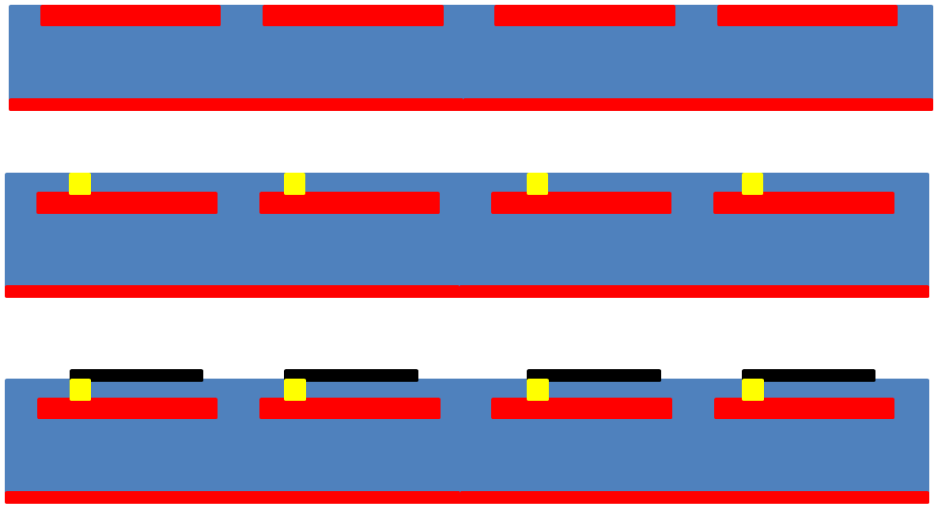
Bare PCB

MM Production steps

Bare PCB

Coverlay gluing + via fill

MM Production steps

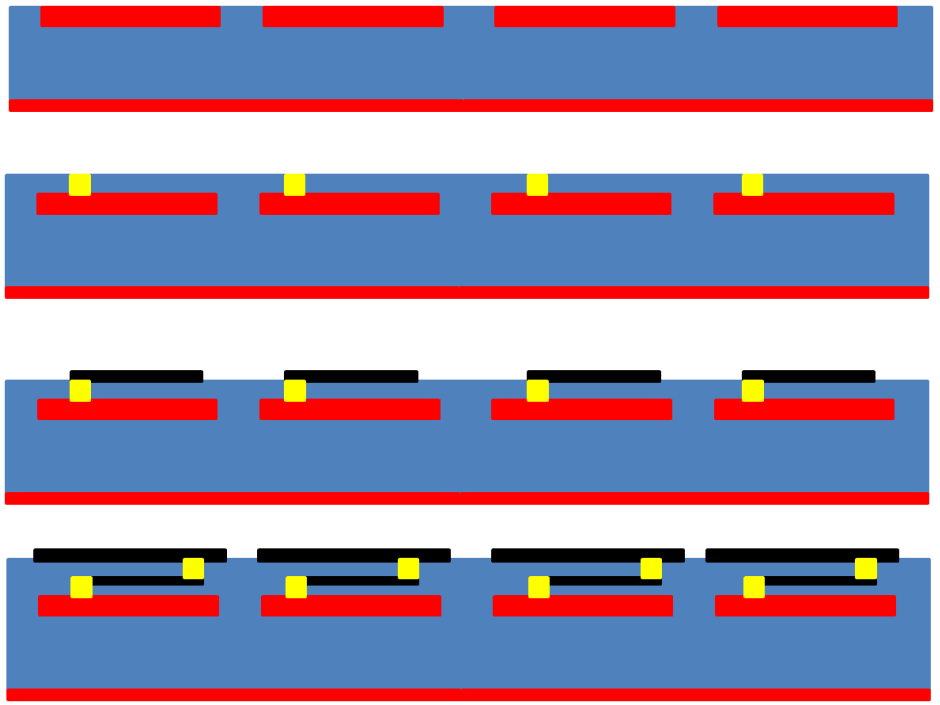


Bare PCB

Coverlay gluing + via fill

Inner resistor printing

MM Production steps



Bare PCB

Coverlay gluing + via fill

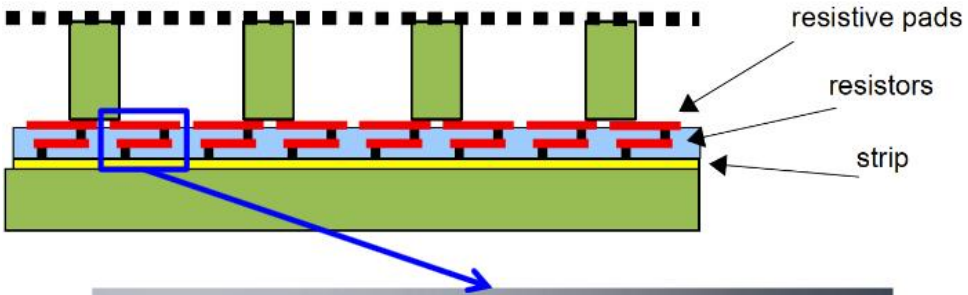
Inner resistor printing

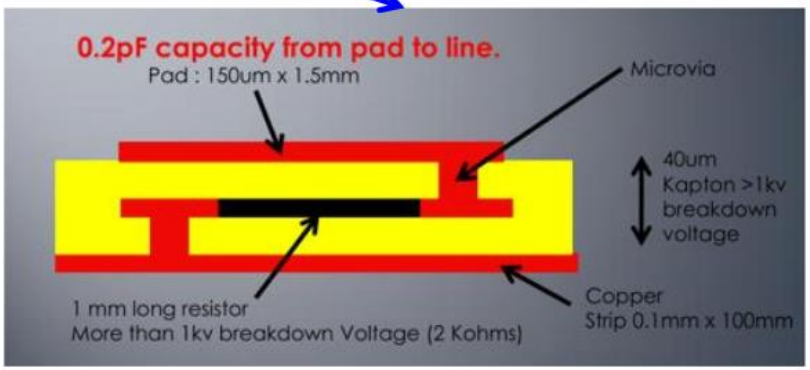
Coverlay gluing + via fill
+top resistive layer print

Ready for BULK process

MM with embedded resistors : High rate

- Quick rise of the resistive pads' potential
- Limitation of the discharge amplitude
- Compatible with a pixelized readout

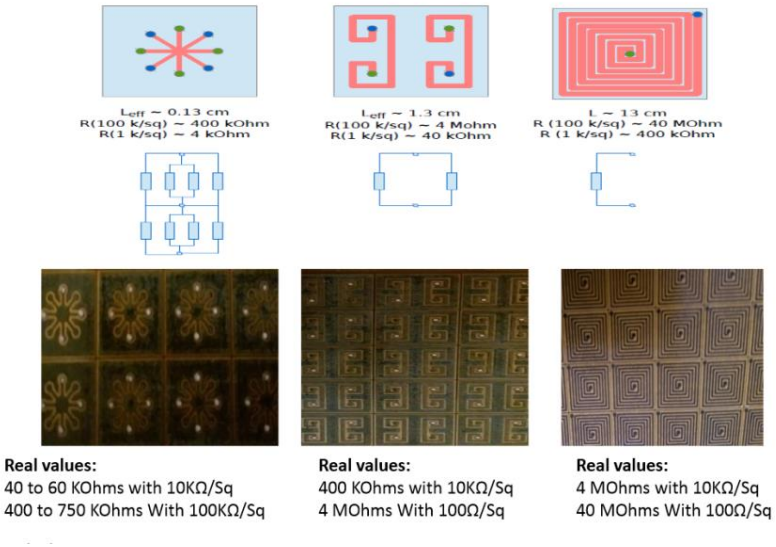




Design by Rui de Oliveira et al.

Shapes and values

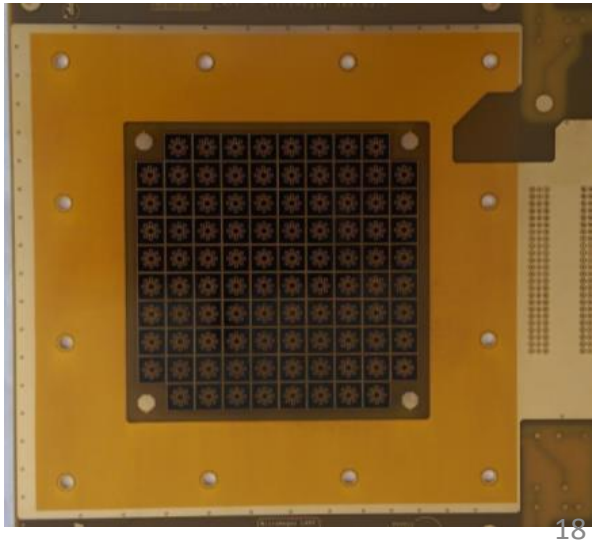
Mr Chefdeville R1 Detectors for the LAPP



Real values:
40 to 60 KOhms with 10KΩ/Sq
400 to 750 KOhms With 100KΩ/Sq

Real values:
400 KOhms with 10KΩ/Sq
4 MOhms With 100Ω/Sq

Real values:
4 MOhms with 10KΩ/Sq
40 MOhms With 100Ω/Sq

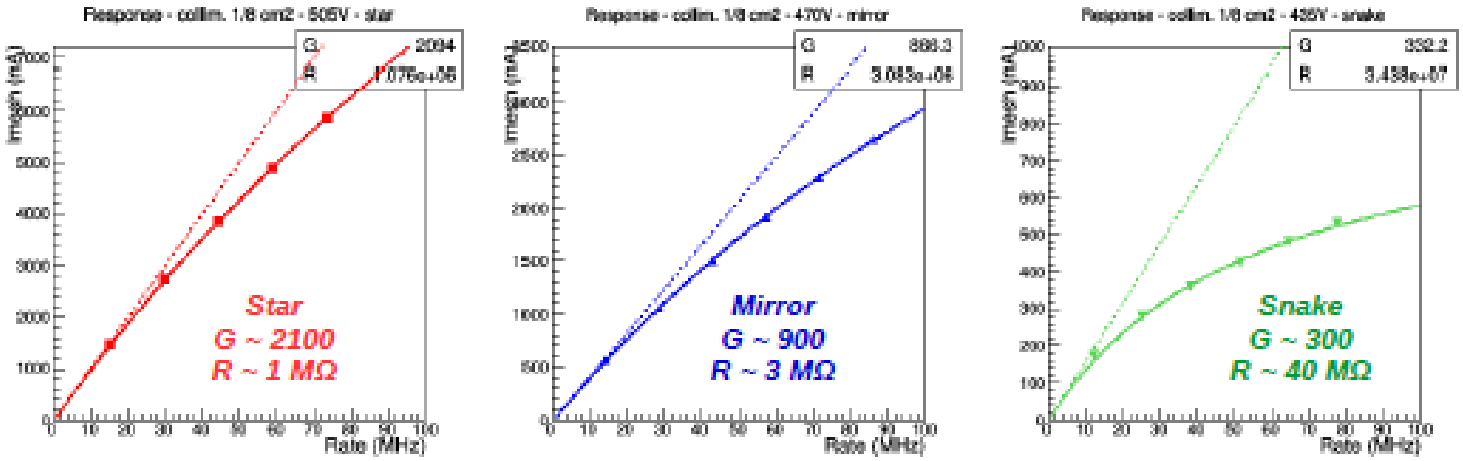


Rate capability

Here : linearity deviations less than 1 % at G = 4200, for 8 keV Xrays & 1 MHz/mm2
Can be extrapolated to other running conditions (better for MIPs, worse for showers)
Anyway, 1 MHz/mm2 remains impressive.

Response curves (current I VS rate f) are described by : $I(f) \sim Q_0.f / (1+B.R.Q_0.f)$
[B] = 1/V, slope of gain curve ; $Q_0 = q_e.N_p.G_0$, primary charge * G(dV=0)

→ (G_0,R) are fitted to the data.
Useful for characterisation.



Max Chefdeville and all Lapp dec 2015

u-Rwell Process for high rate

DLC1

Base material , DLC (100 Mohms/square)

u-Rwell Process for high rate

Glue DLC2 (100M) layer (pre drilled) on DLC1(100M)
via filling with silver paste (yellow)

Screen printed resistors above 10K/square are not behaving correctly in this multilayer configuration

u-Rwell Process for high rate

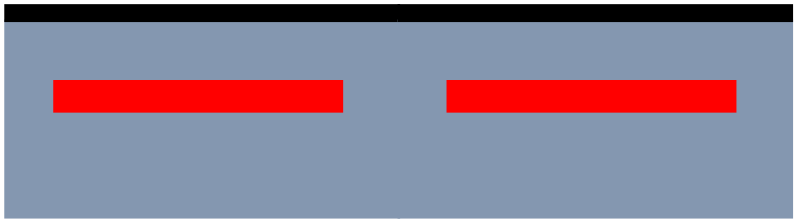
Glue a flex read-out circuit (Strip or pad) pre drilled (green) on DLC2
via filling with silver paste (yellow)

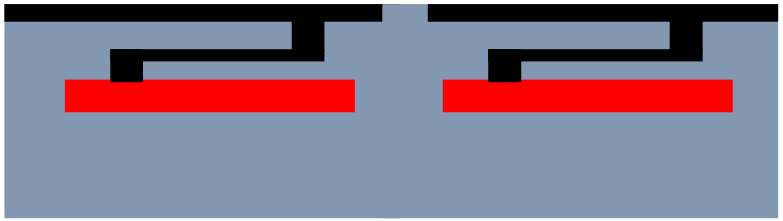
u-Rwell Process for high rate

Top layer patterning
APICAL etching

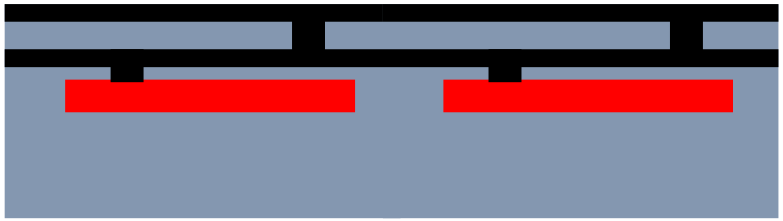
- MM Resistive BULK with DLC?

Medium rates
Single layer protection
Screen printed or DLC





High rates
Digital read-out
2 layers screen printed



High rates
Analog read-out
2 layers DLC (R&D in progress)

Screen printing Vs DLC

Screen printing

- 10K to 100 K/square
- need a pattern
- X/Y clusters are different
- Medium cost
- no sharing
- Energy resolution
  - Similar to metallic MM
- Spark energy
  - 10^3 reduction / metallic MM

DLC

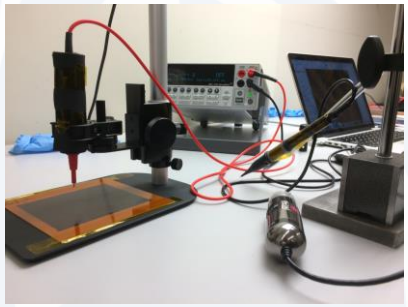
- 1M to 1G/square
- No pattern
- X/Y similar cluster
- Cheaper in low volumes
- Controlled sharing
- Energy resolution
  - Better than metallic MM (TBC)
- Spark energy
  - More than 10^3 reduction

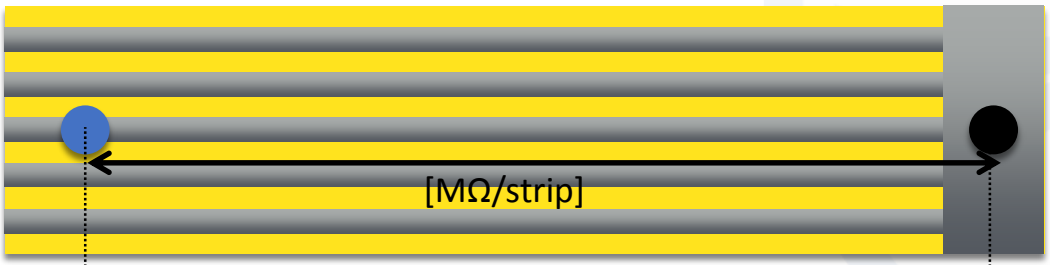
- Screen printed resistor Spark study

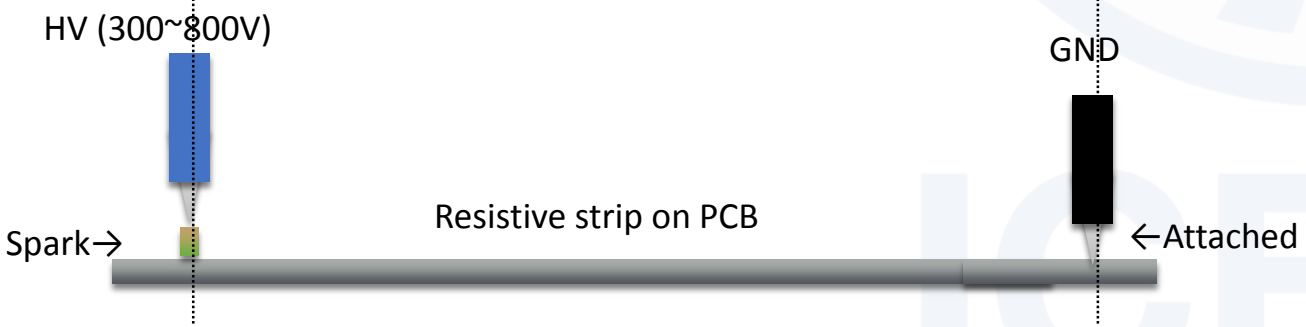
SEM observation of resistive strips after Spark discharge

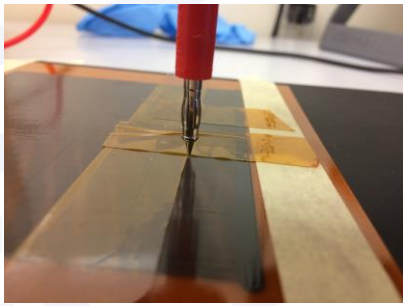
Masahiro Yamatani, Tatsuya Masubuchi
ICEPP, University of Tokyo

- Keithley for voltage adding (300,500,800 V)
- 2 probes connected to Resistive strips
  - → One is attached on HV line side
  - → Other one is on the strips (floating for spark)
- Optional current limit (10uA, 100uA, …)



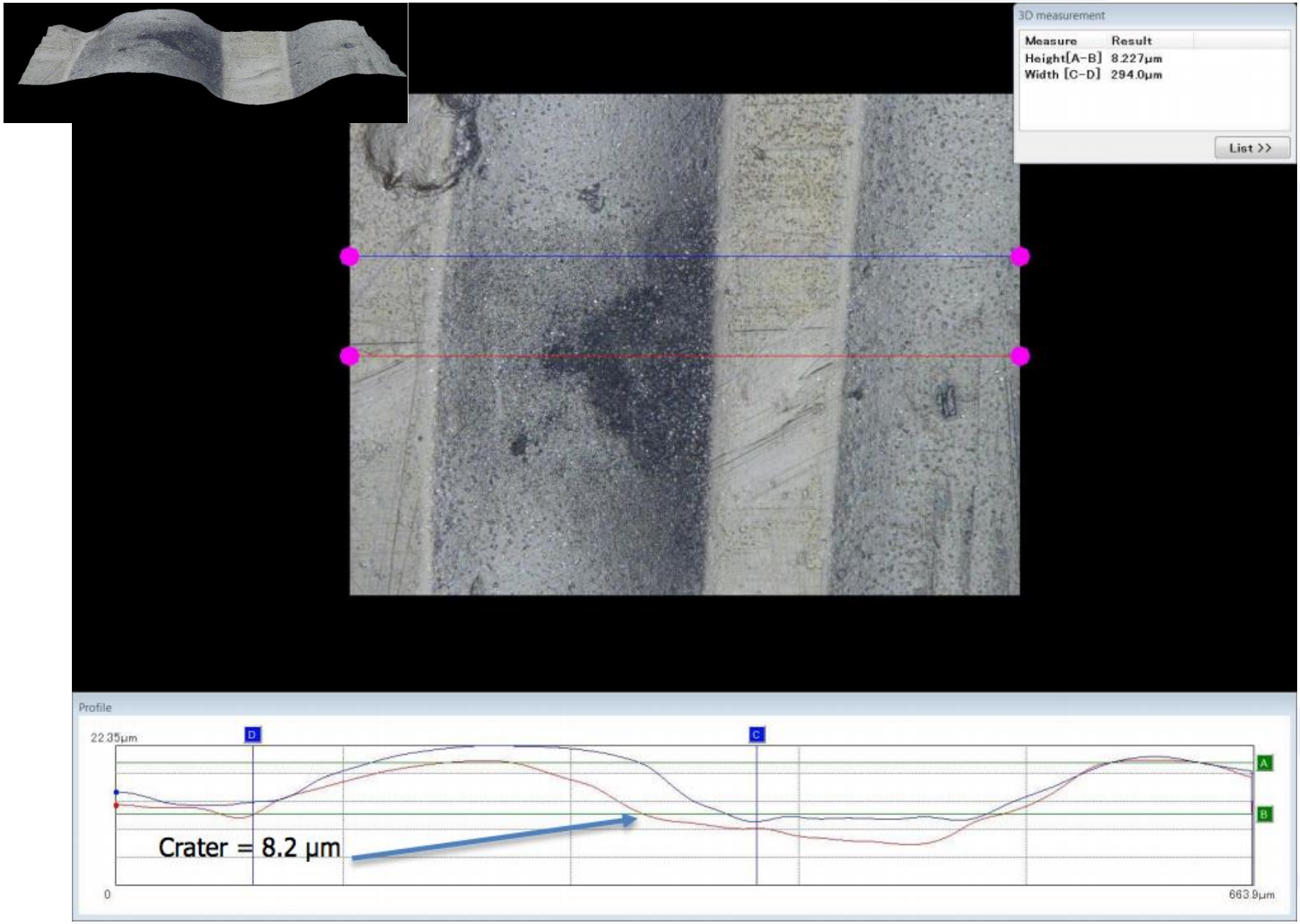




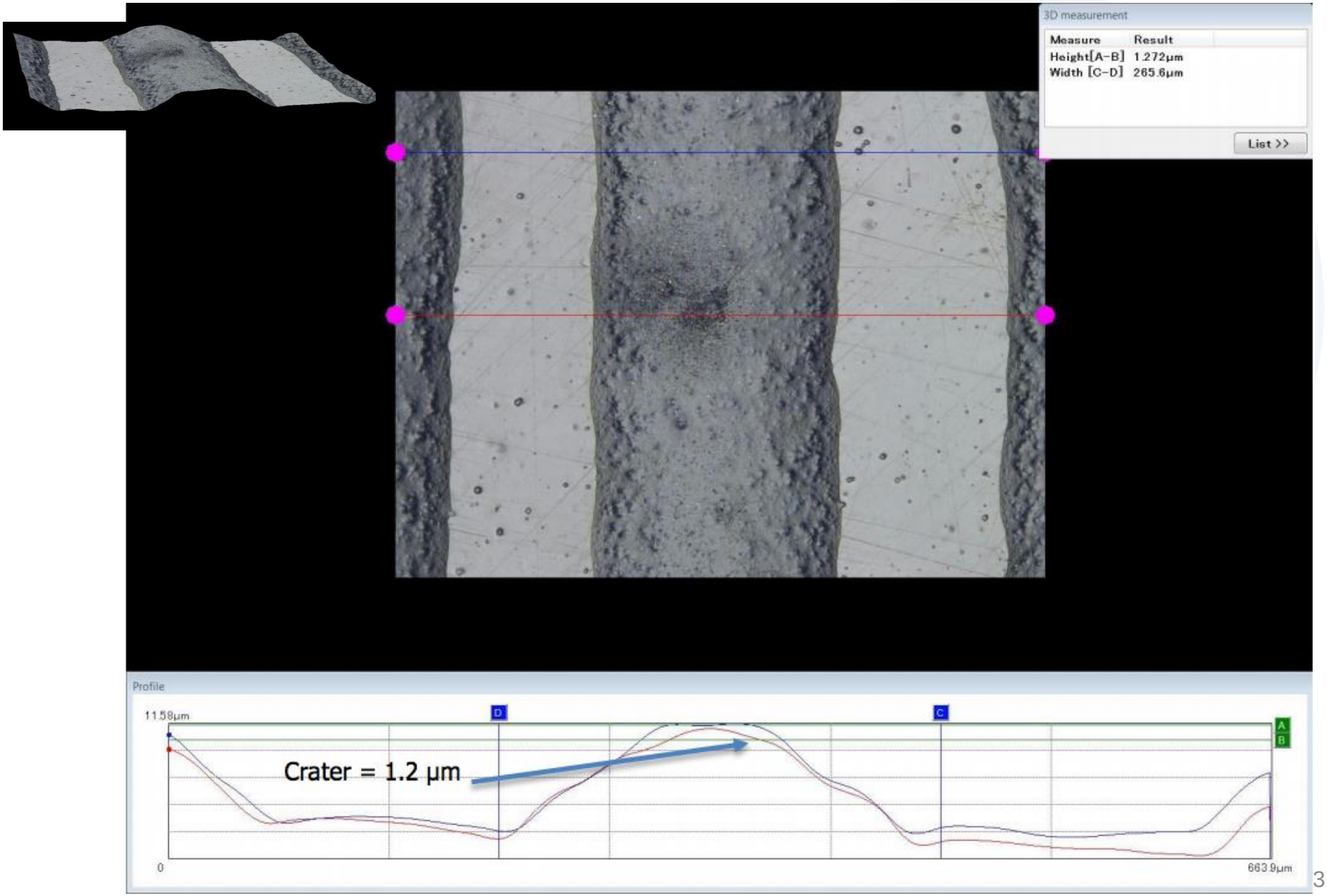


- **Checked resistivity/strip vs surface status by SEM**

Point : 5 Voltage : 300 V Resistance : 4.41 MΩ Current limit : 10 μA



Point : 8 Voltage : 300 V Resistance : 4.41 MΩ Current limit : 10 μA



Point : 2 Voltage : 900 V Resistance : 4.41 MΩ Current limit : 10 µA

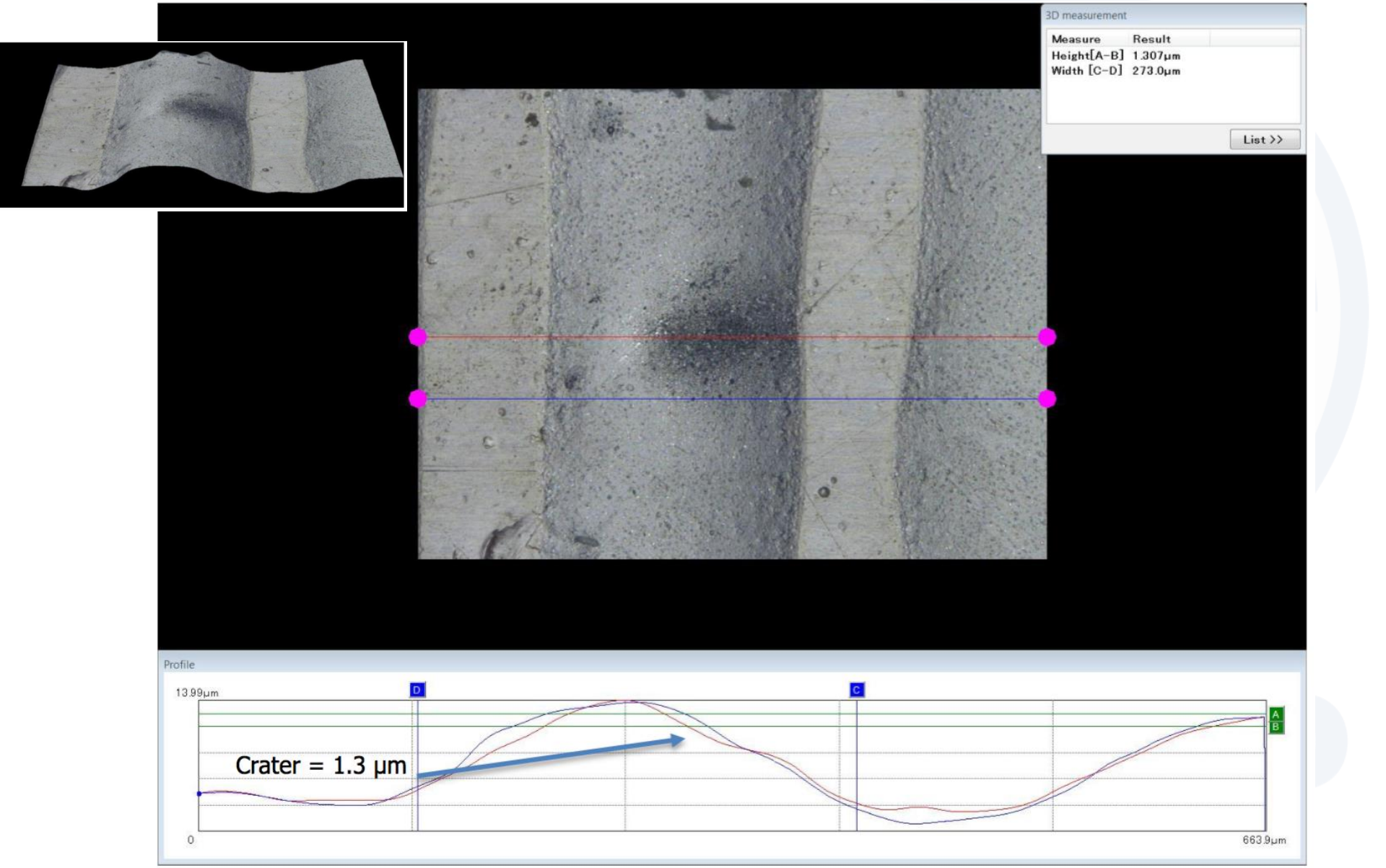


Table 5 – 3D profile of the spark discharge crater.

Point : 4 Voltage : 500 V Resistance : 1.3 MΩ Current limit : 10 µA

Table 7 – 3D profile of the spark discharge crater.

Point : 9 Voltage : 900 V Resistance : 0.9 MΩ Current limit : 100 µA

Table 13 – 3D profile of the spark discharge crater.

Point : 12 Voltage : 500 V Resistance : 1.2 MΩ Current limit : 100 µA

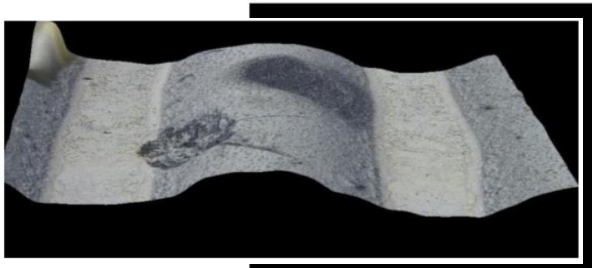


Table 20 – 3D profile of the spark discharge crater.

- Conclusion

Bulk technology

-600mm x 600mm →metal or single resistive

-10cm x 10cm → double resistive high rate

STD Micromegas

-2m x 500mm→ metal or single resistive

u-Rwell

-1.3m x 0.5m → single resistive

-10cm x 10cm → double resistive high rate