WG1 Satellite session on practical use of resistive coatings

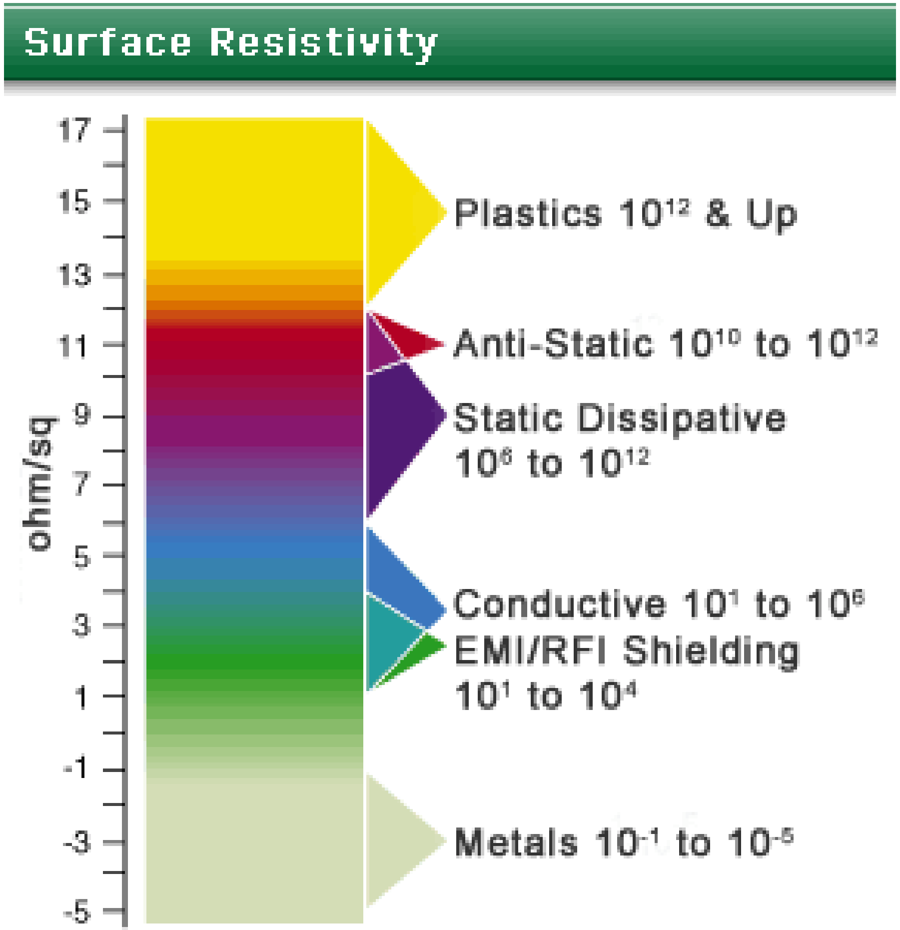
P. Colas

Use of resistive coatings for:
-Spreading the charge to improve resolution while limiting the number of electronic readout channels
-Stabilizing RPCs
-Stabilizing Micromegas detectors (spark suppression)
-Protecting integrated circuits

Numerous techniques tried since a decade or more :

Characterization of coverlays : measurement of surface resistivity, bulk resistivity and thru-resistivity

Terminilogy



-A Resistor is define by:

-Value Ohms
-Precision %
-TCR ppm/Deg C
-max power W or W/m2
-breakdown voltage V

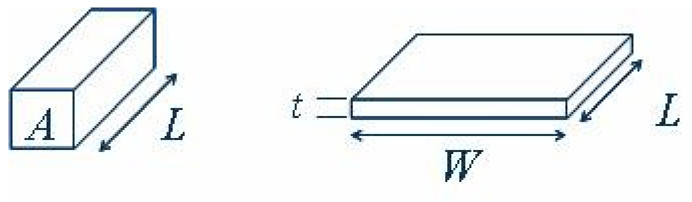
-Resistivity in Ohm*m

-Sheet resistance or surface resistivity in Ohm/sqr

-TCR: Temperature coefficient of the resistor

-Cermet: is a composite material composed of ceramic (cer) and metallic (met) materials.

Rs: Sheet resistance Ω/sq



$$R = \rho \frac{L}{A} = \rho \frac{L}{Wt}$$

$$R = \frac{\rho}{t} \frac{L}{W} = R_s \frac{L}{W}$$

Polymer resistive pastes

www.electrapolymers.com

Product	Surface resistance
ED7500 - 1Ω	1Ω□$^{-1}$
ED7500 - 10Ω	10Ω□$^{-1}$
ED7500 - 100Ω	100Ω□-^{1}
ED7500 - 1kΩ	1kΩ□$^{-1}$
ED7500 - 10kΩ	10kΩ□$^{-1}$
ED7500 - 100kΩ	100kΩ□$^{-1}$
ED7500 - 1MΩ	1MΩ□$^{-1}$

TECHNICAL DATA SHEET
ELECTRA^{Ω}D'OR
ED7500 SERIES

PASTES for FIXED RESISTORS and
POTENTIOMETERS on RIGID CIRCUIT BOARDS

Curing:

ED7500 may be cured in a convection oven or by using IR radiation.

Typical Cure Schedules are:	Convection oven:	30 mins at 150 - 200°C
	IR tunnel oven	6 mins at 200°C

1 Mohms/Sqr seems to be the limit for these polymers

Polymer Resistive foils

The miracles of science™

Constructions

100XC10E7 is our standard offering for anti-static applications. It is a one mil film with a nominal surface resistivity of 5 mega ohm/sq. Two grades are available as described in **Table 2**. Custom constructions are also available, and can be produced in thickness from 1 to 5 mil, and with surface resistances from 90 to 10^8 ohms/sq.

Table 2
Electrical Properties of Kapton® 100XC10E7 and 100XC10E5 Polyimide Film

Property	Typical Value	Test Method
Film Type 100XC10E7		
Surface Resistivity Aim, mega ohm/sq.	5	ETS 870 electrometer at 100V
Resistivity Range, avg, mega ohm/sq.	.5-50	
Film Type 100XC10E5		
Surface Resistivity Aim, mega ohm/sq.	5	ETS 870 electrometer at 100V
Resistivity Range, mega ohm/sq.	0.1-1000	

Spraying glass

Constraints on resistive paint

Surface resistivity in the range of 1 – 5 MΩ/□
Easily applicable
Resistivity **not** dependent on humidity (very important!!!)

Paint

Used commercial spray (LICRON) in the past, but new product not useful
Identified some 2-component 'artist paint' ⟶ satisfies constraints
Paint needs to be mixed appropriately and sprayed (with spraying gun)

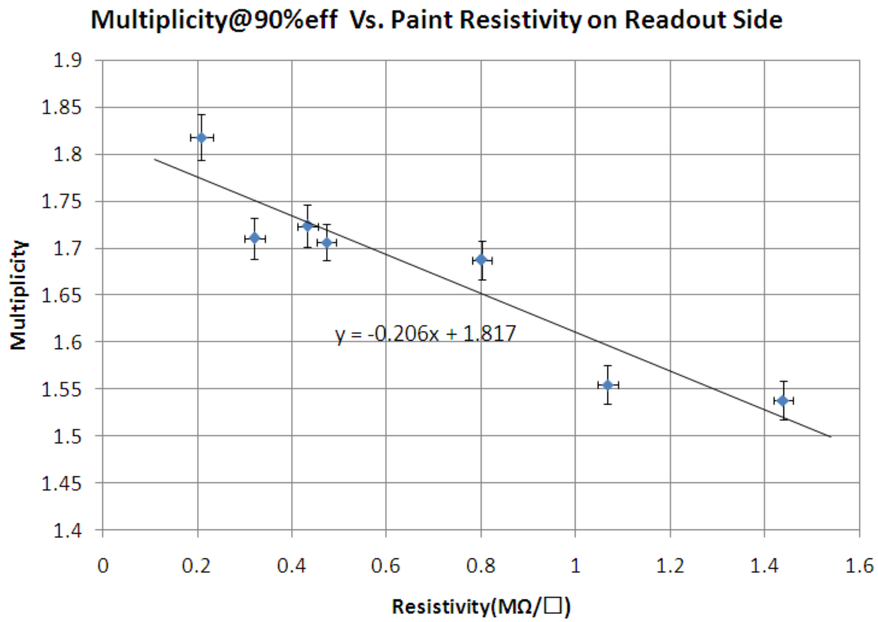
Spraying booth

Built large booth to exhaust (non-toxic) fumes
Movement of spraying gun controlled with step motors (~ 2minutes/plate)

Spraying procedure

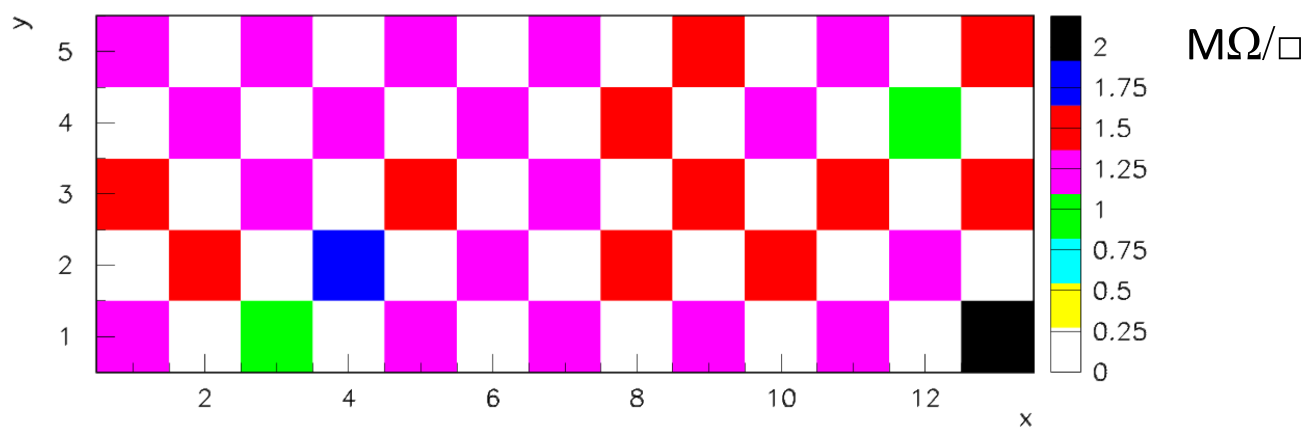
Significant preparation needed: cleaning of glass, masking off rims, mixing paint, cleaning tools
1-botton operation
Could spray up to 8 plates in one day

Results



Uniformity obtained by adjusting

- Speeds
- Distance to glass plate
- Order of spraying
- Air flow in booth



Resistive coating – summary of products tested

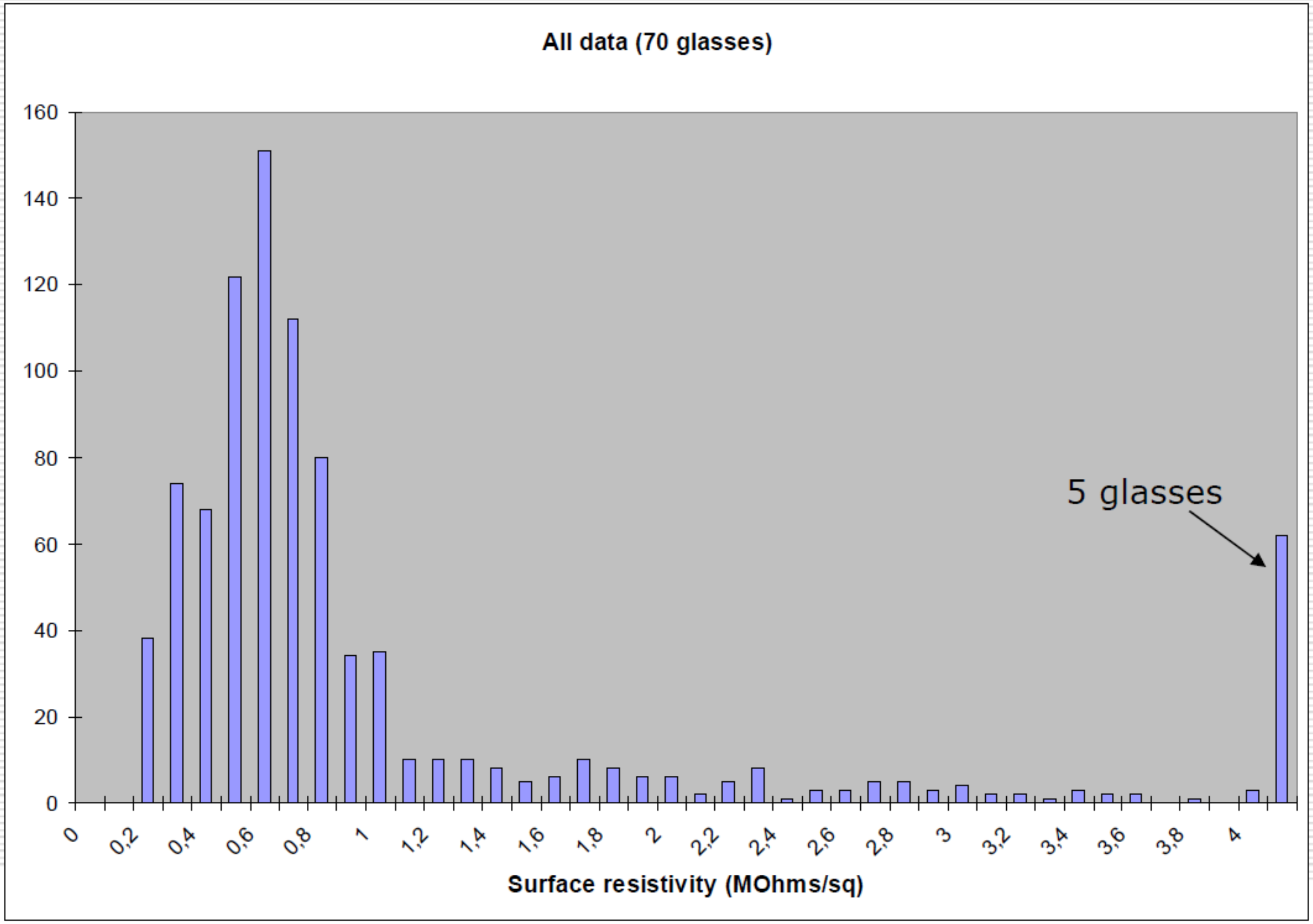
	Licron	Statguard	Colloidal Graphite type I	Colloidal Graphite type II
Surface resistivity (MΩ/□)	~20	1-10	~0.5	Depends on mix ratio; choose ~0.7
Best application method	Spray	Brush	Silk screen printing	Silk screen printing
Cost, EUR / kg	130	40	670*	240*
Delivery time (weeks)	3	<1	6	6

*Estimate 20m² (10 chambers) / kg using silk screen printing technique

Licron: fragile coating, problems with HV connections over time
Statguard: long time constant for stable resistivity (~2 weeks), poor homogeneity

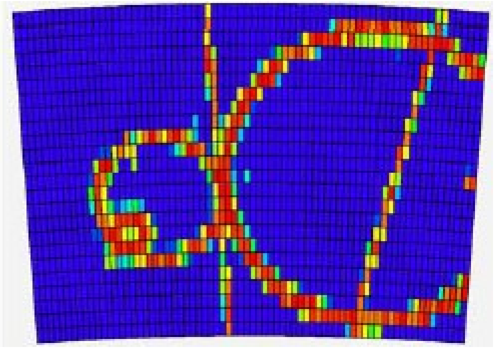
Baseline for technological prototype is colloidal graphite type II

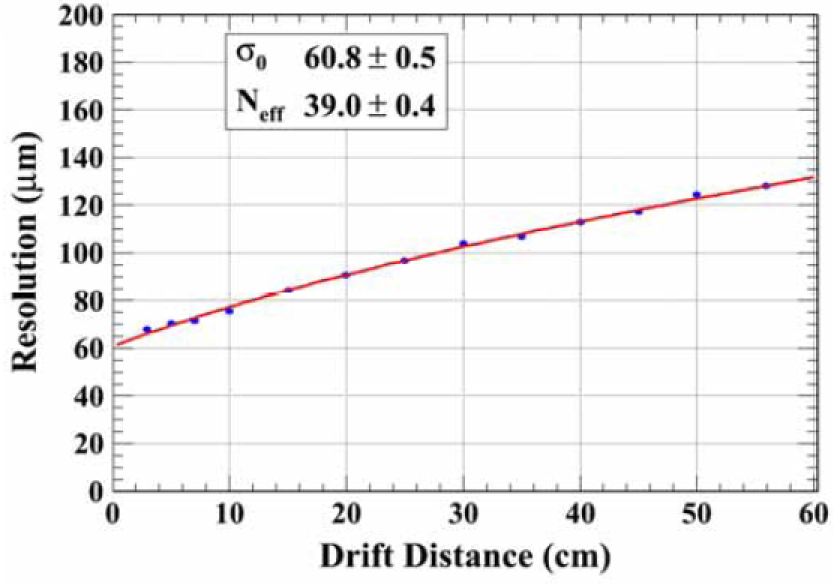
Data for all 35 chambers built so far



ILC-TPC : charge spreading

Resistive bulk
Micromegas

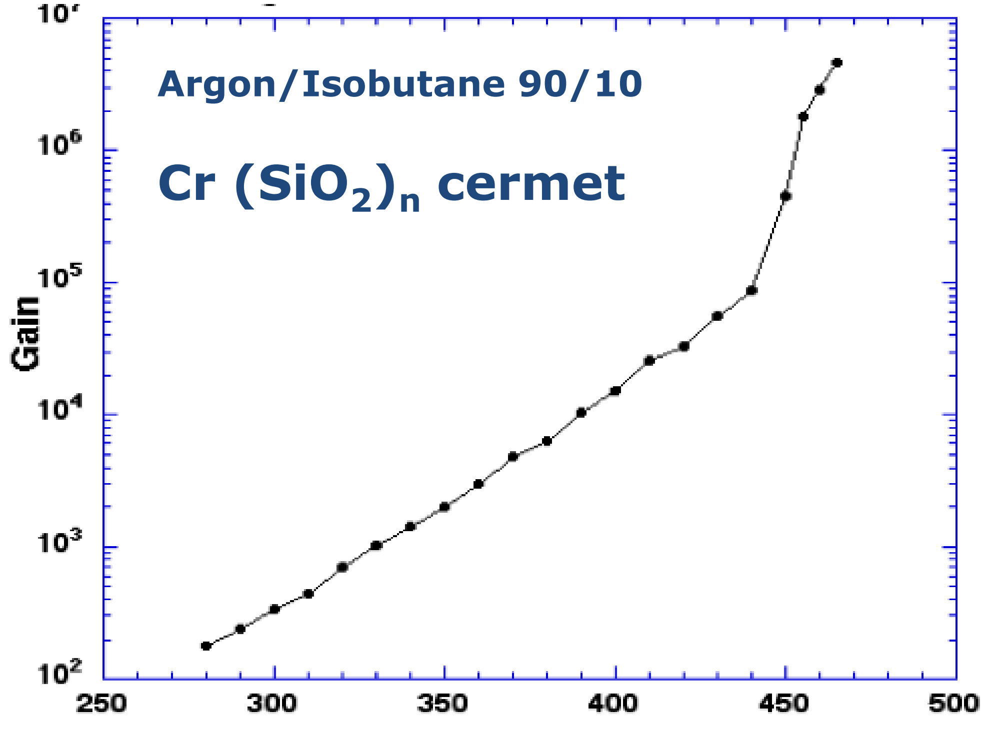




Continuous RC circuit spreads the charge -> resolution improvement

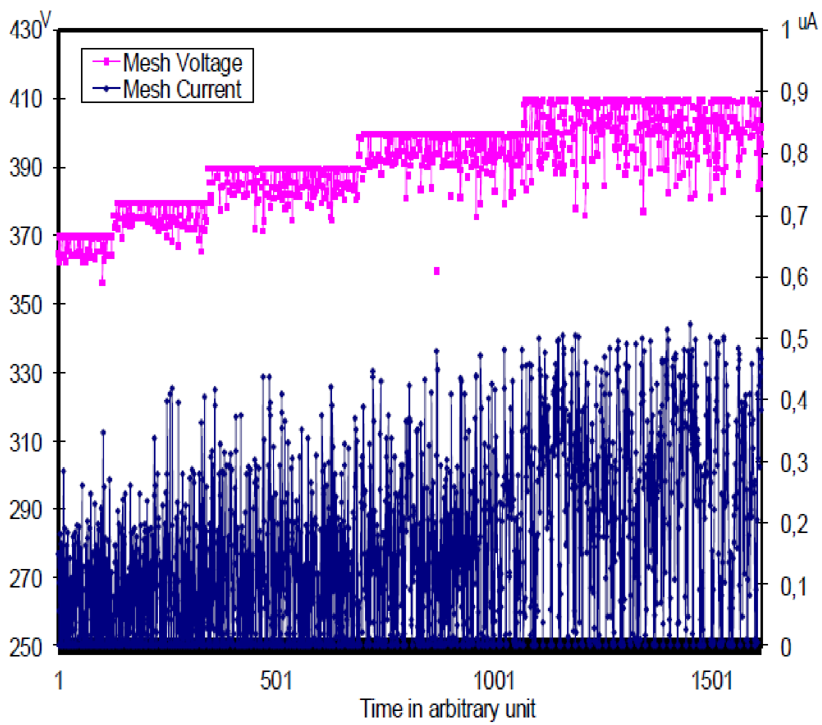
60 μ resolution at 0 drift with 3 mm pads !

Also the resistive foil stabilizes Micromegas: no more breakdown, stable current

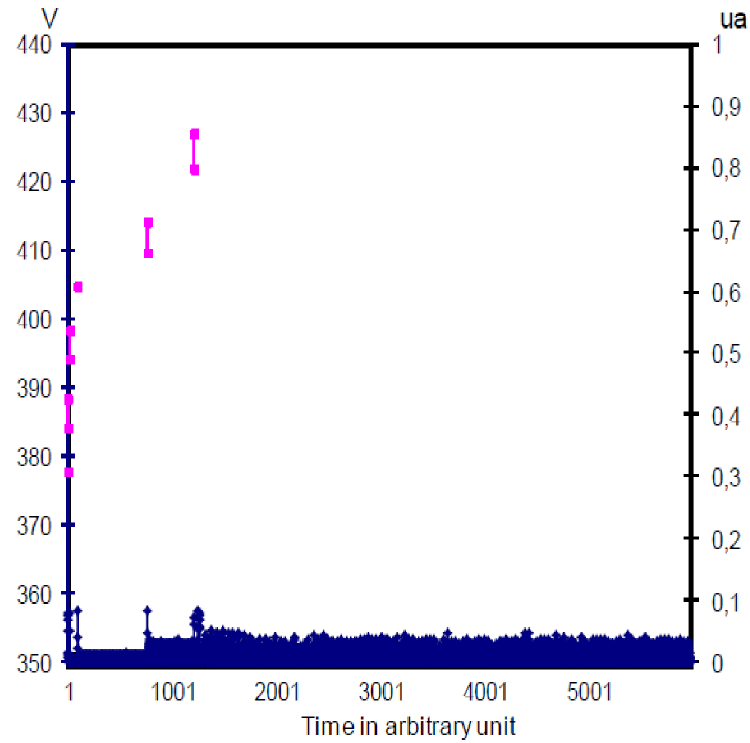


P.C., M. Dixit, I. Giomataris
2005 LC workshop, Stanford

Standard Micromegas

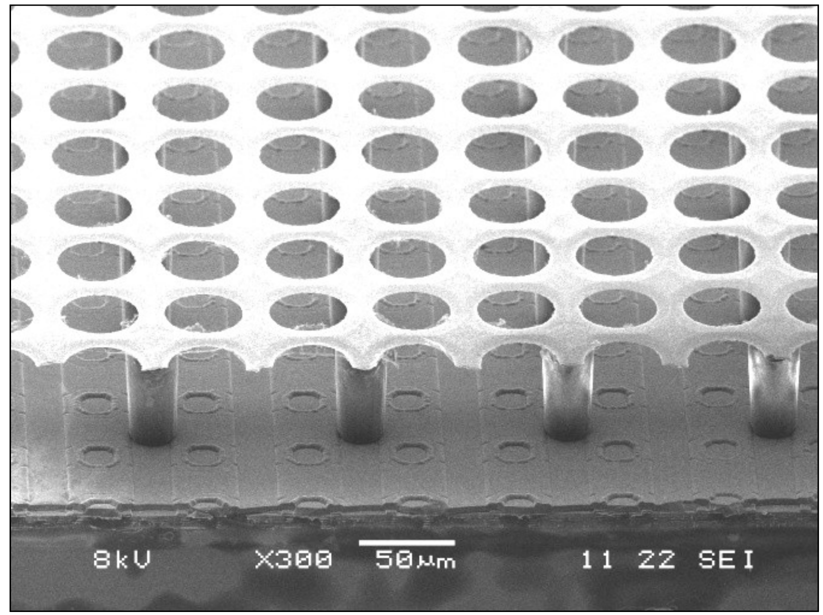


Resistive Micromegas



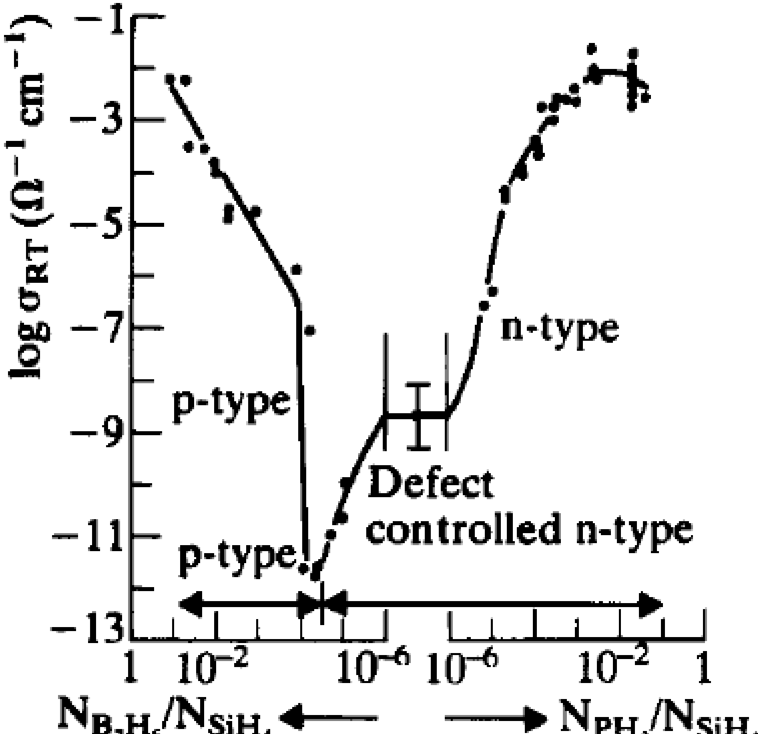
MAMMA beam test, 15 kHz hadron beam, October 2009

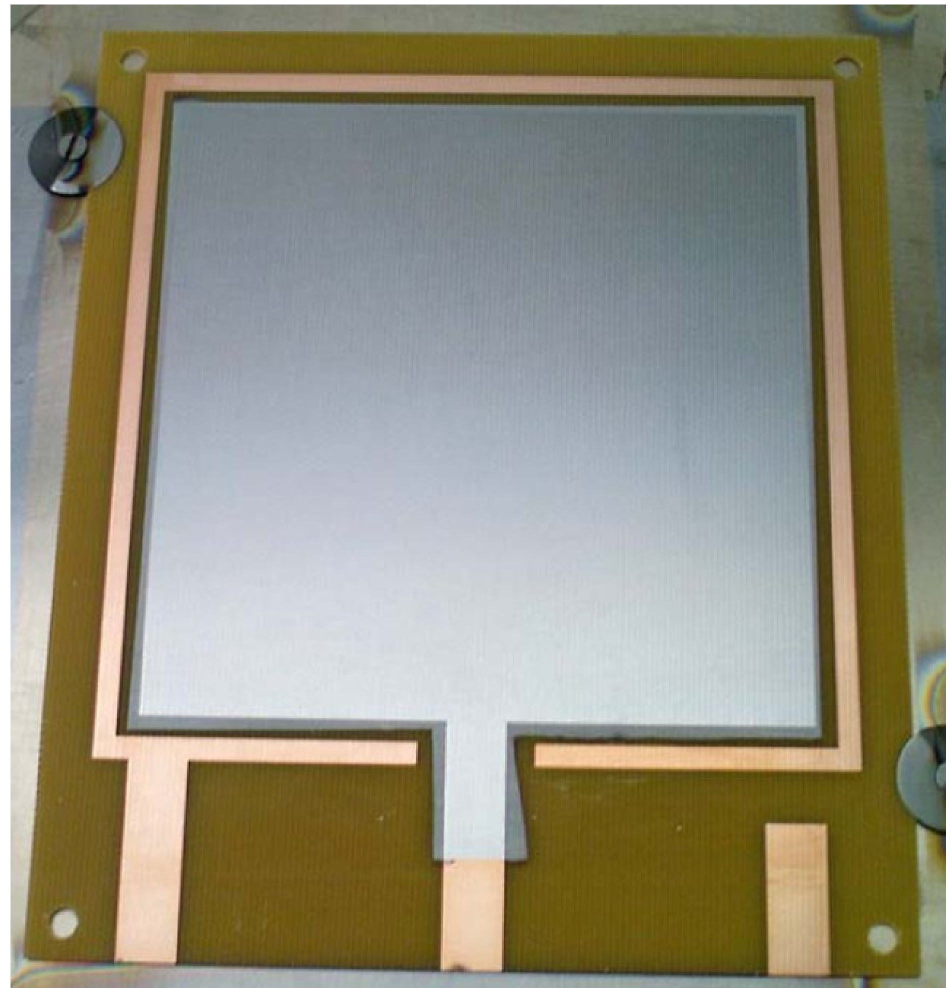
Resistive deposits also protect TimePix Chips from sparks
(10 microns of aSi:H, 4-7 microns of Si_xN_y (H. VdGraaf, N. Wyrsch)



Deposition of thin layers (10 µ thick) of a-SiH (10^{13} Ω.cm)
Neuchatel, N. Wyrsch

Possibility to add a doped layer on top



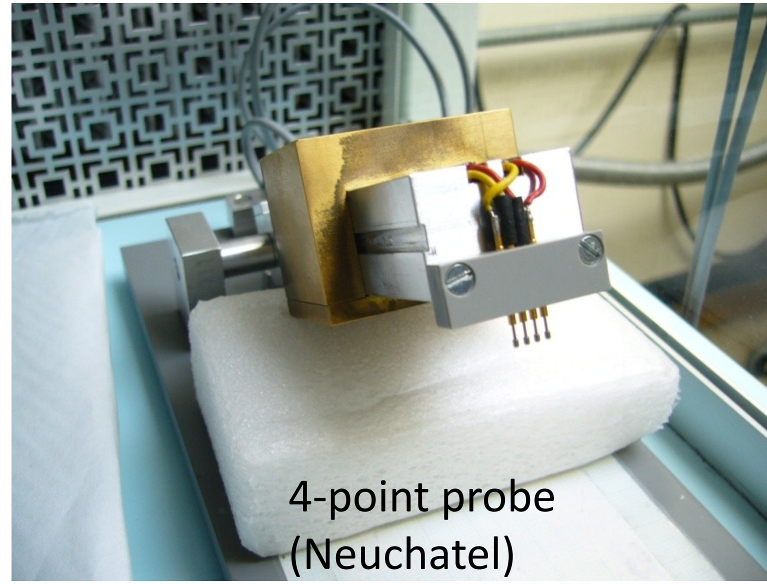


We used several techniques to measure resistivities.

-May depend on voltage, pressure of the contact,…

-Often see discrepancies, inhomogeneities, unstabilities

-Thru-resistivity sometimes inconsistent with surface resistivity



4-point probe (Neuchatel)

Circular probe

Conducting tape, insulating substrate

lxL resistive sample = L/l ’squares’

Measure resistance, divide by number of squares

Diagnostic tools : thermal image of the prototype with a high-resistivity layer and a lower-resistivity layer on top (N. Wyrsch, EPFL, Neuchatel)

Hot spots due to leakage current

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Type of coating	PROs	CONs
Cermet (Sheldal; M. Dixit et al.)	Tunable resistivity, homogeneous Stable once laminated	Fragile / scratchable
Carbon-Loaded polyimide (Dupont; M. Dixit et al.)	Accurate thickness (25 μ) Large surfaces easy	
Thin layer deposition (H. VdGraaf, N. Wyrsch, EPFL)	Limited to few micron thickness	Limited to small surfaces (10x10cm2). Very clean substrate needed.
Sprays (G. Mikenberg, Tel Aviv, J. Répond, I.Laktineh)	Large surfaces. Needs tuning	10-20% homogeneity
paints	Can be patterned. Large surfaces.	inhomogeneous