Summary viewpoint focus by technology

Academia meets Industry: RPC and TGC
Vienna University of Technology
March 25th 2014
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Industrial availability of materials

- Such large area detectors demand large amounts of qualified materials to be found in the industry
- Resistive electrodes
  - require a material of good mechanical properties with resistivity around 10^10 - 10^12 Ohm cm.   There is (there was) no industrial material qualified with this resistivity
  - We tried therefore to qualify ourselves two industrial materials with resistivity approximately in the correct range: phenolic high Pressure Laminates and Glass
  - It took a long work to adapt the standard production to our specific needs
  - Thanks to the joint effort of research and industry the production of phenolic laminates and glass plates with the required resistivity it is now possible

Industrial availability of materials: the working gas

- The working gas
  - A suitable RPC gas has good quenching properties ie good UV photon absorption and is somewhat electronegative
  - Moreover it has also to fulfill other requirements concerning the safety and the environment preservation: non flammability (in most cases); low environment impact
  - good gas candidates were found fin the refrigeration industry
- Therefore the RPC gas evolution closely followed the refrigeration gases evolution. A few examples
  - CF_3Br was widely used, some time ago, both in the refrigeration and as a RPC gas component. Its industrial production was strongly limited, by the Kyoto convention, for its environment impact
  - $C_2H_2F_4$ substituted the previous one. More gentle environment impact: one halogen instead of two, some hydrogen not replaced by fluorine. GWP about 1500
  - The Tetrafluoropropene molecule, with structure CH_2=$CFCF_3$ and GWP=4, Is the new gas industrially produced to replace $C_2H_2F_4$
- This new gas, which is presently under test, is characterized by a double Carbon bond, C=C, that is an unprecedented feature for the RPC gas

Introduction

- Single PCB's can be purchased with dimensions of $1.28 X 3.00 m^2$ that are flat to within $50 \mu m$, except at the edges.
- Using usual PCB print methods are not very reproducible to the precision one needs.
- One needs VERY PRECISE external references, in order to align each plane with the design accuracy.
- CNC machining provides the necessary accuracy.
- Combined the 2 technologies.

Development of low resistivity glass

Components:

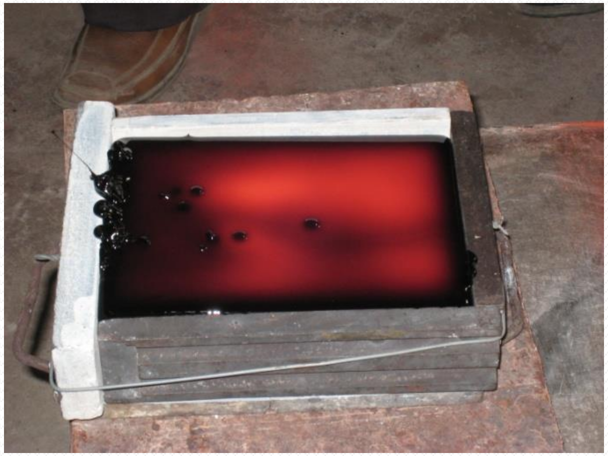
$SiO2$, Fe_2O_3 , Na_2O ,AL_2O_3 ,…

Glass resistivity: ~10^{10} Ωcm

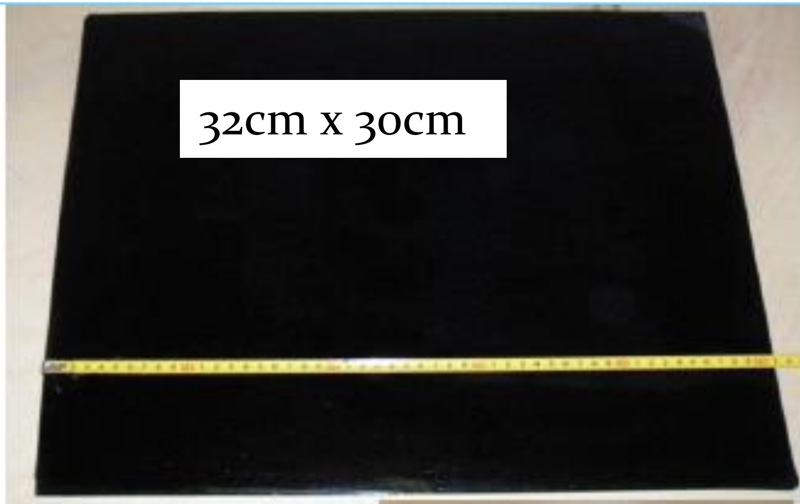
Process:

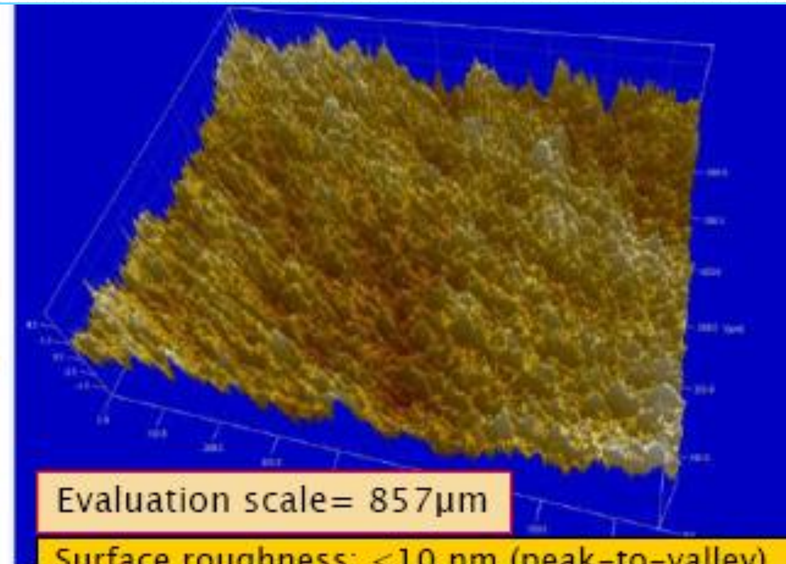
Melting → Cooling → Cutting → Polishing

- Different compositions and related production procedures have been studied, yielding a tunable bulk resistivity in the range of 10^{10}–10^{11} Ωcm.
- In the mass production, in order to produce reliable glasses with high quality, surface measurement has been taken as a key part of the quality control.
- This glass shows a large stability against electrical stress.

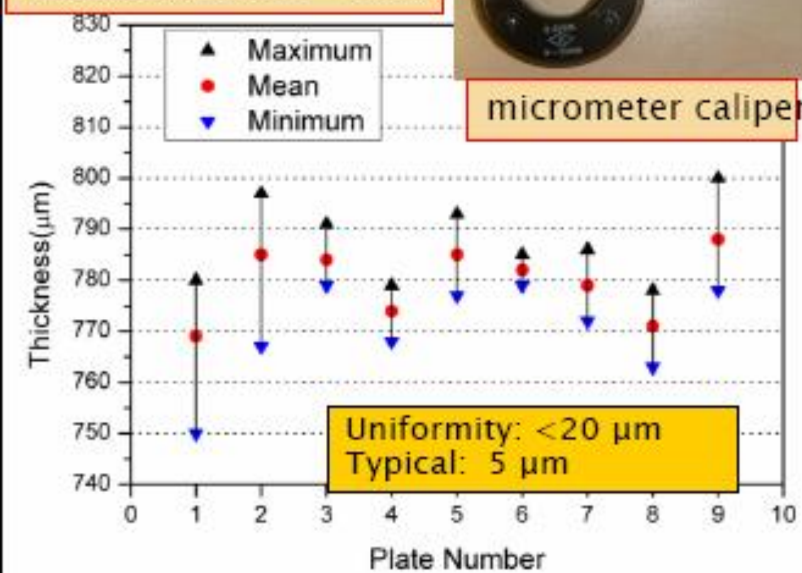


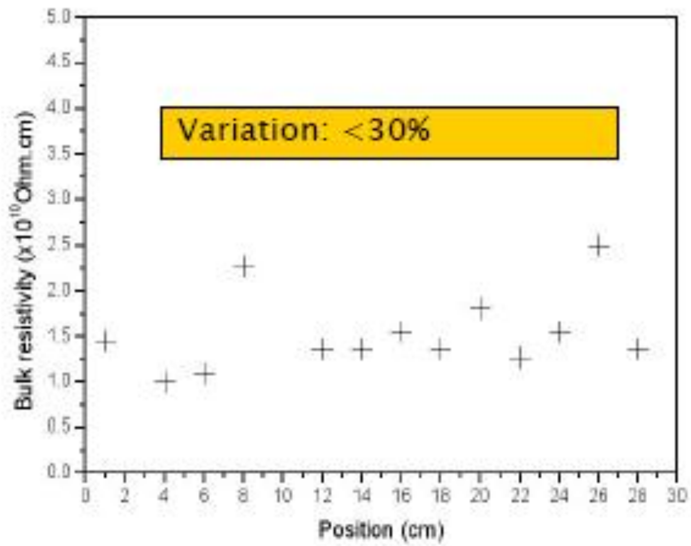
Development of low resistivity glass





Thickness distribution
(Evaluation scale= 30cm)





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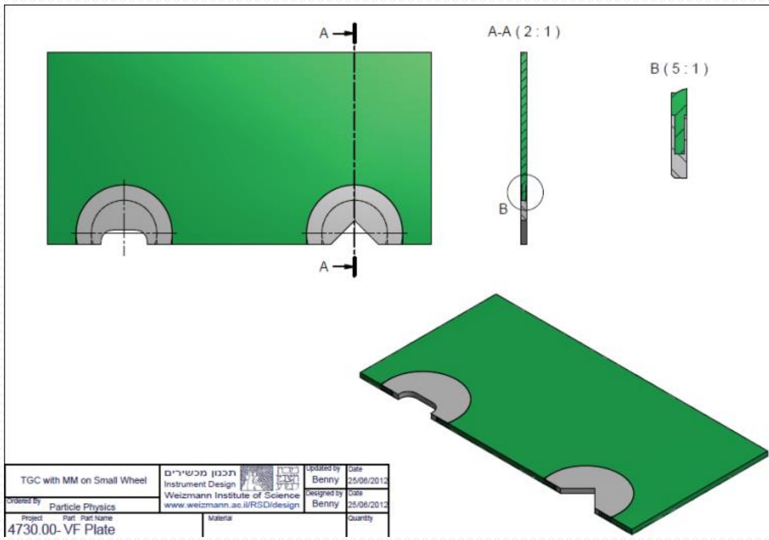
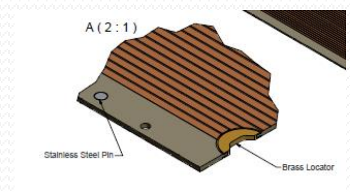
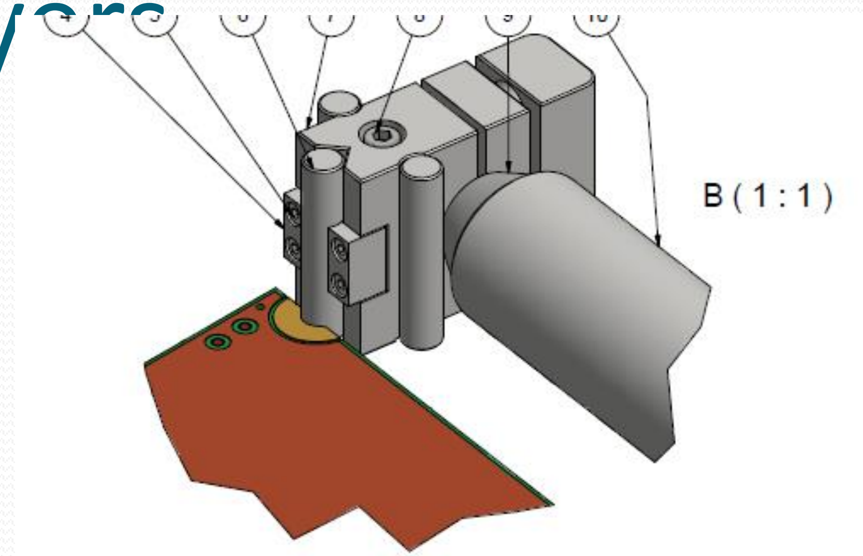
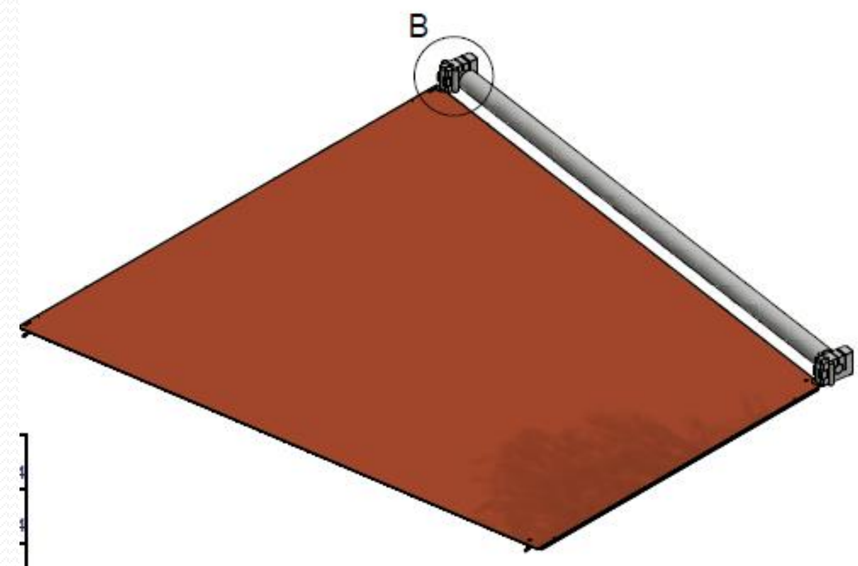




- Use the inserts that are machined together with the strips to get the precision

Use a precision jig to transfer the precision across layers



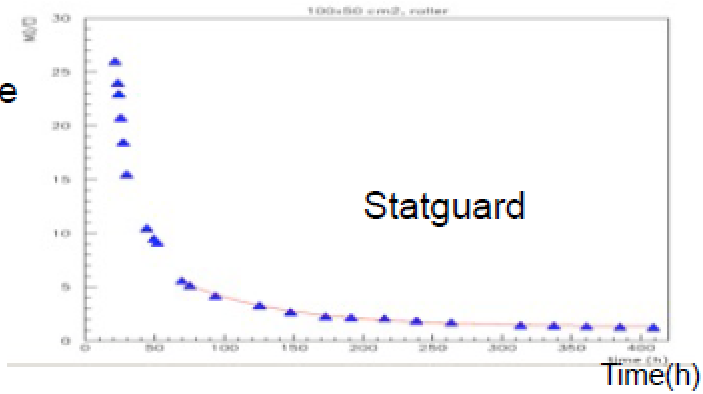


Resistive coating study

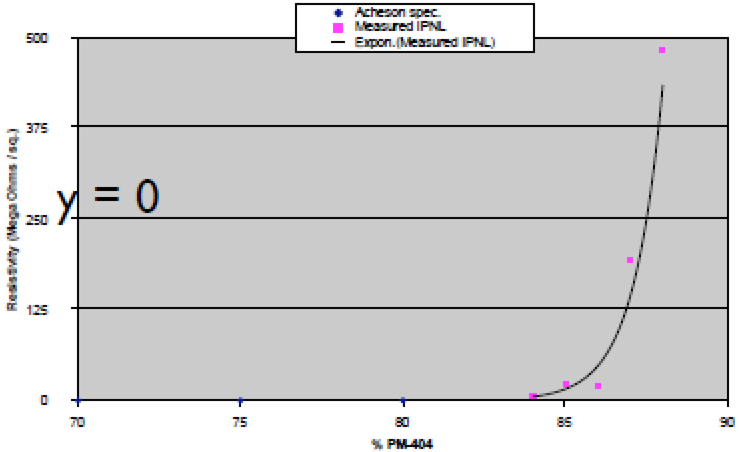
Licron and Statguard are more appropriate for low pad multiplicity. However :

Licron : Loss of HV connection over time (1-2 months)

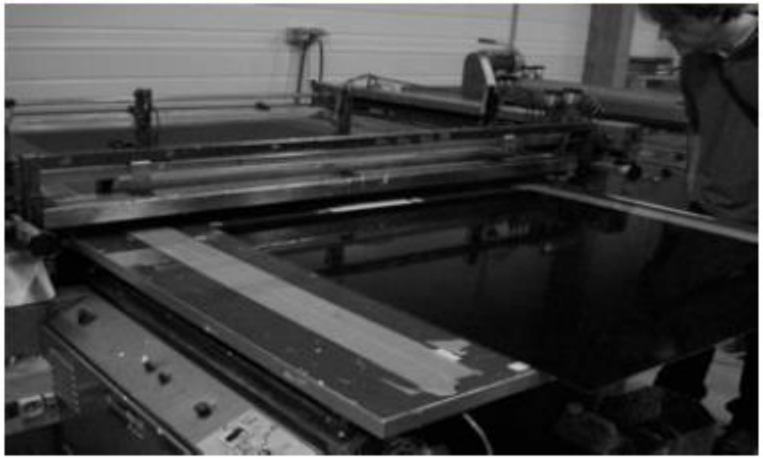
Statguard : long time constant for stable resistivity (2 weeks), poor homogeneity



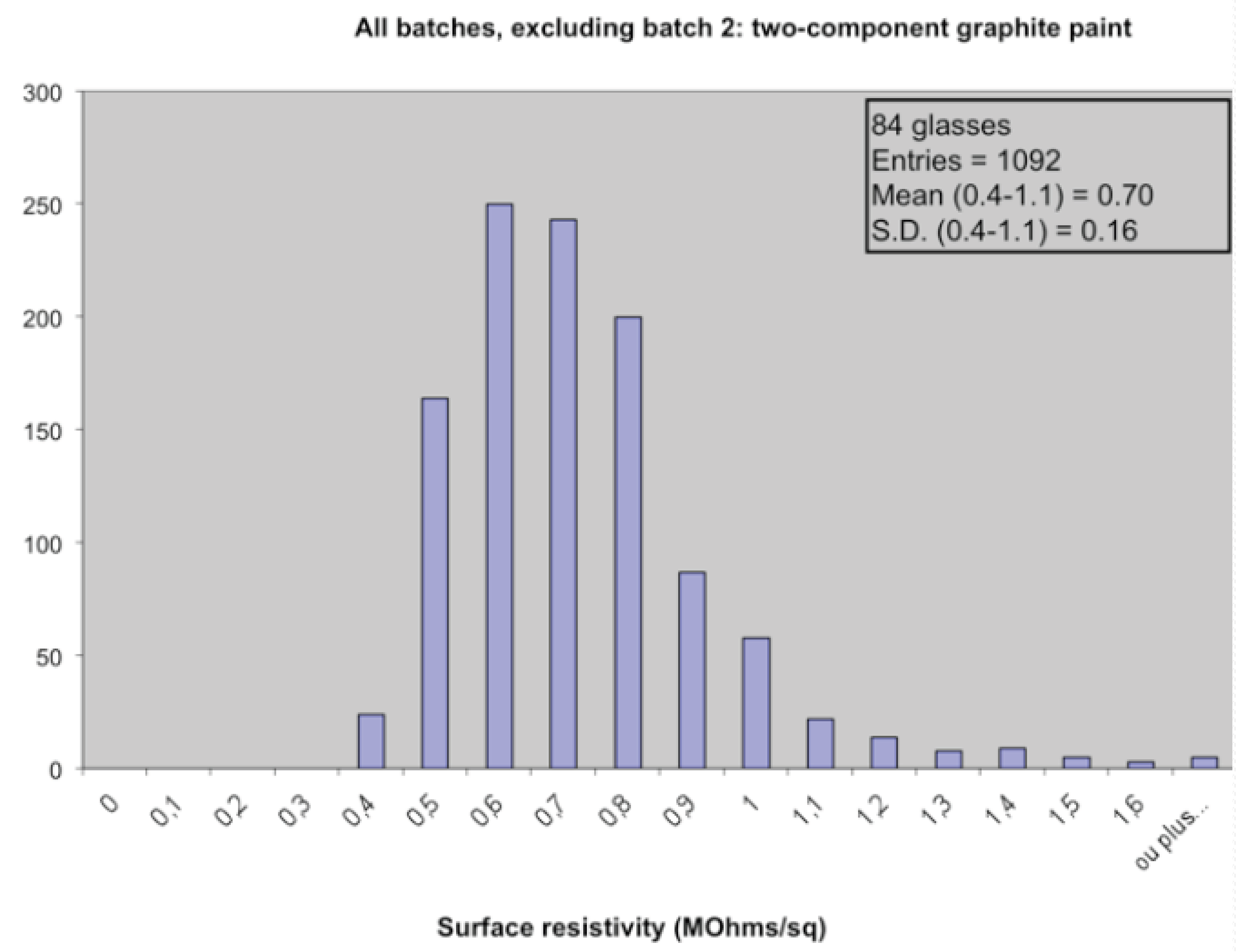
The colloidal graphite of type II is less expensive and allows to choose the needed resistivity even if this is a delicate operation



Measured resistivity as a function of the mix ratio

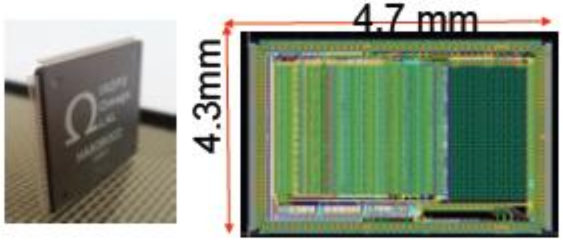


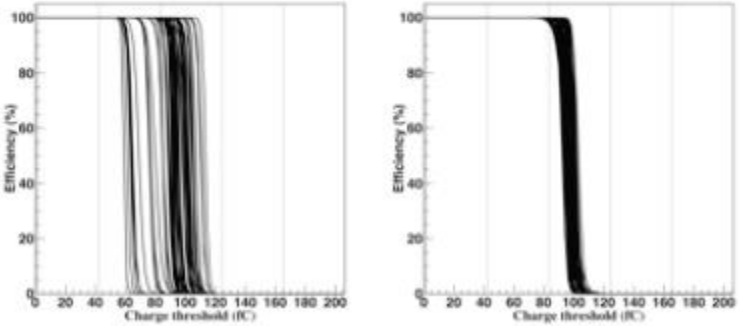
Silk-screen print method provides very good uniformity

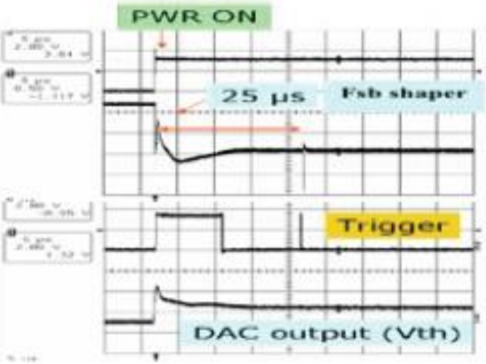

All batches, excluding batch 2: two-component graphite paint
84 glasses
Entries = 1092
Mean (0.4-1.1) = 0.70
S.D. (0.4-1.1) = 0.16
300
250
200
150
100
50
0
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
1,1
1,2
1,3
1,4
1,5
1,6
ou plus...
Surface resistivity (MOhms/sq)

Electronics readout development

ASIC: HARDROC
64 channels, trigger less mode, memory depth: 127 events
2-bit readout : 3 thresholds
Dynamic range: 10 fC-15 pC
Gain correction → uniformity
Power-pulsed → reduced power consumption







Printed Circuit Boards (PCB) were designed to reduce the x-talk with 8-layer structure and buried vias.
Tiny connectors were used to connect the PCB two by two (the 24X2 ASIC are daisy-chained).
DAQ board (DIF) was developed to transmit fast commands and data to/from ASICs.

Moving the amplification from the gas to the Front End electronics

A_{FE} (Amplification of the Front End electronics)

A_{FE} X A_{gas} = k   where k is the discriminator threshold

A_{FE} streamer – We assume it is 1 for streamers

A_{FE} high saturation = Q_{el} streamer / Q_{el} high saturation $\cong$ 100

A_{FE} low saturation = Q_{el} Stramer / Q_{el} low saturation $\cong$ 1000

Signal/Noise requirements

- threshold $\cong 0.1 \cdot Q_{el}$ and V_{th} at 5σ over the front-end noise

$$\text{Noise of the front end} = Q_{el} \cdot 0.1 \cdot 0.2$$

For streamer $N \cong 10^{-10} \cdot 0.1 \cdot 0.2 = 2 \cdot 10^{-13} = 5 \cdot 10^{6}\ e^{-}\ \text{rms}$

For high saturation $N \cong 2 \cdot 10^{-12} \cdot 0.1 \cdot 0.2 = 2 \cdot 10^{4}\ e^{-}\ \text{rms}$

For low saturation $N \cong 2\ 10^{-13} \cdot 0.1 \cdot 0.2 = 2 \cdot 10^{3}\ e^{-}\ \text{rms}$

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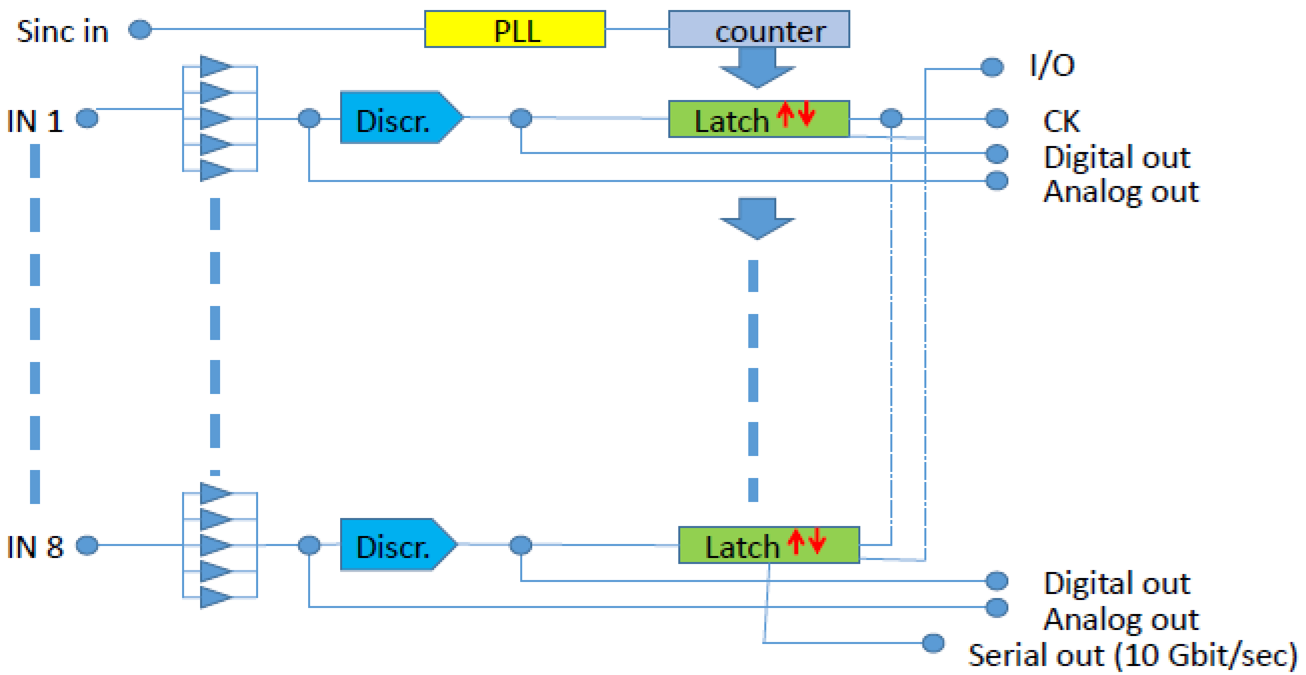
For low saturation $N \cong 2\ 10^{-13} \cdot 0.1 \cdot 0.2 = 2 \cdot 10^{3}$ e^{-} rms

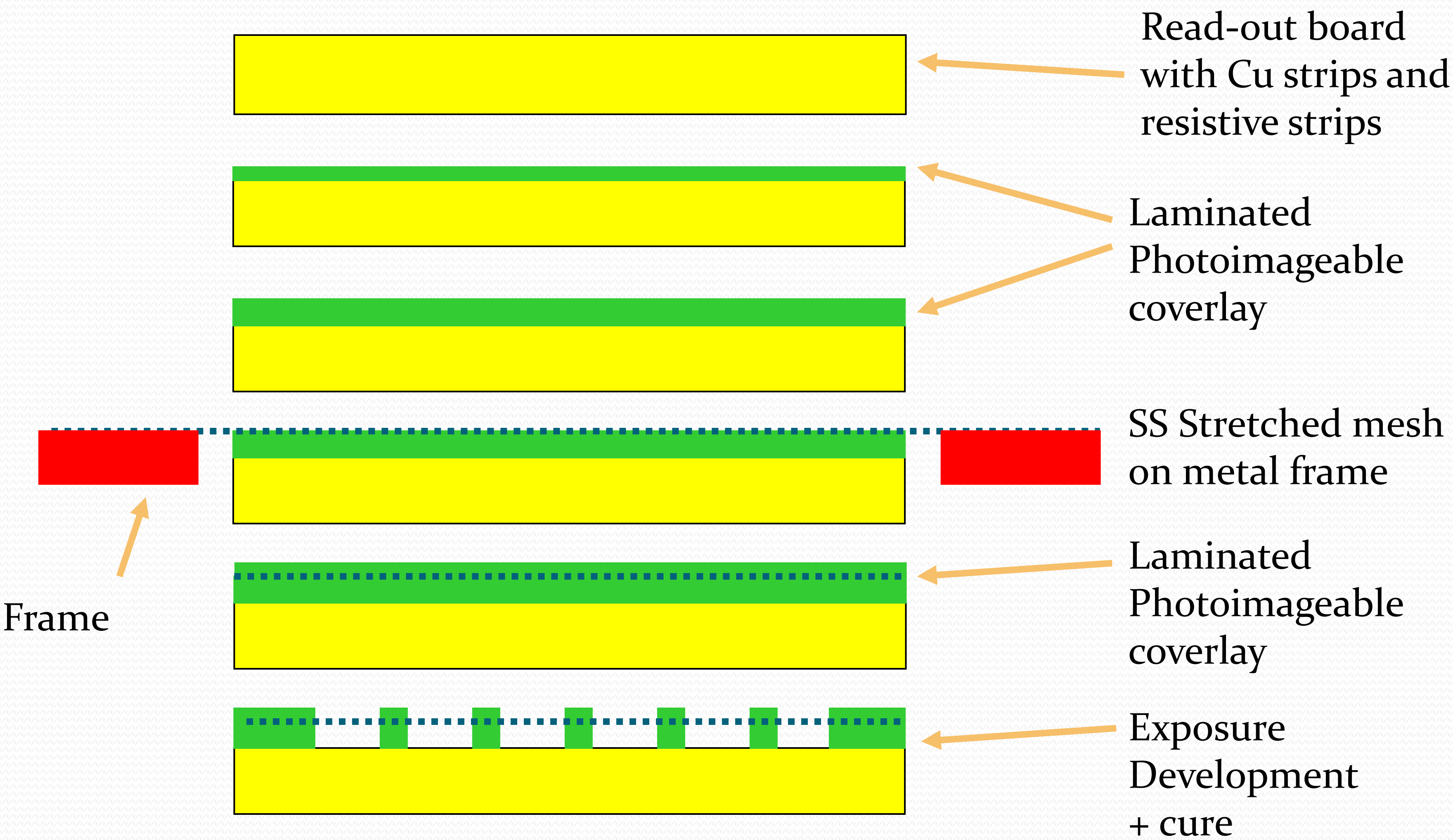
SiGe requirements for the full custom chip

- Presently this transistor is designed for microwave applications ($> 2\ GHz$). → Optimization of the transistor for low frequency applications ($\sim 100\ MHz$).
- Sinusoidal signal. → Pulse signal.
- $^1/_f$ noise. → As low as possible.

Block diagram and performance of a new full custom front-end chip



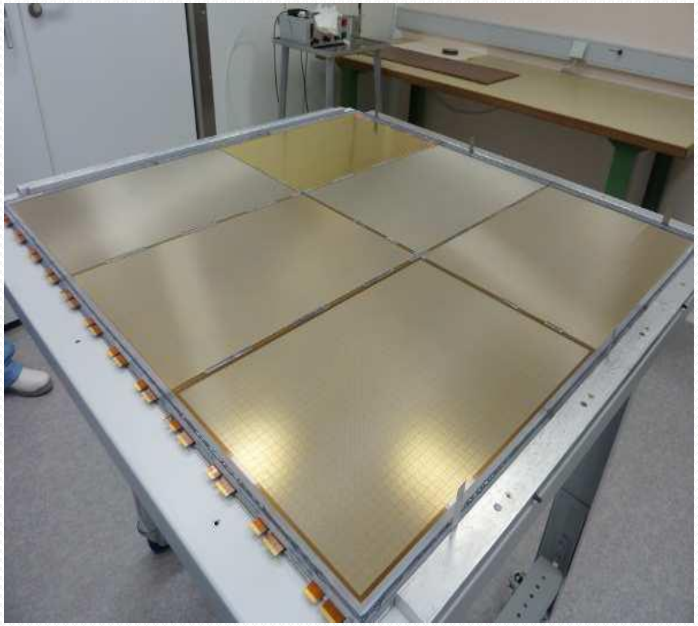
BULK Micromegas production steps



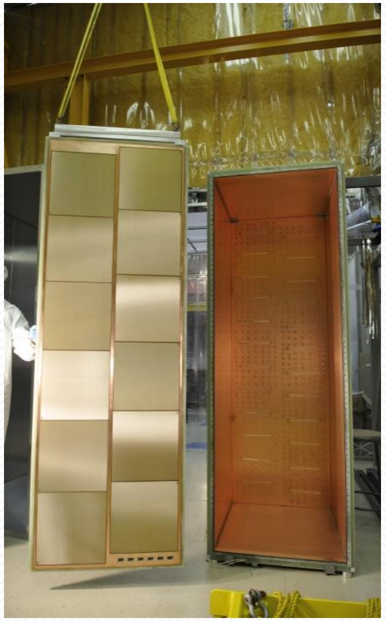
BULK Micromegas examples

<u>BULK Technology</u>
DUPONT PC 1025 coverlay
BOPP Meshes

<u>Largest size produced:</u>
1.5m x 0.6m
Limited by equipment



ILC DHCAL



T2K

Requirements from the CR physics

- An adequate circuit for the analog read out

Conclusions

- A strong Academia-Industry connection/collaboration will be the key element to create a number convincing scientific an industrial projects in the next future
- Several ideas for applications to the scientific projects to be developed in a few years are already there
- These projects will be possible only with a considerable industrial investment
- BUT…any investment implies the assumption of a risk that can be minimized but not reduced to zero.
- How this risk is balanced inside the proposed collaboration? → My answer: the scientists risk there time and credit; the industry risks some money