WP 13.2.1
Establishing new resistive materials for high rate RPCs

P. Fonte

LIP

WP 13.2.1

DESCRIPTION

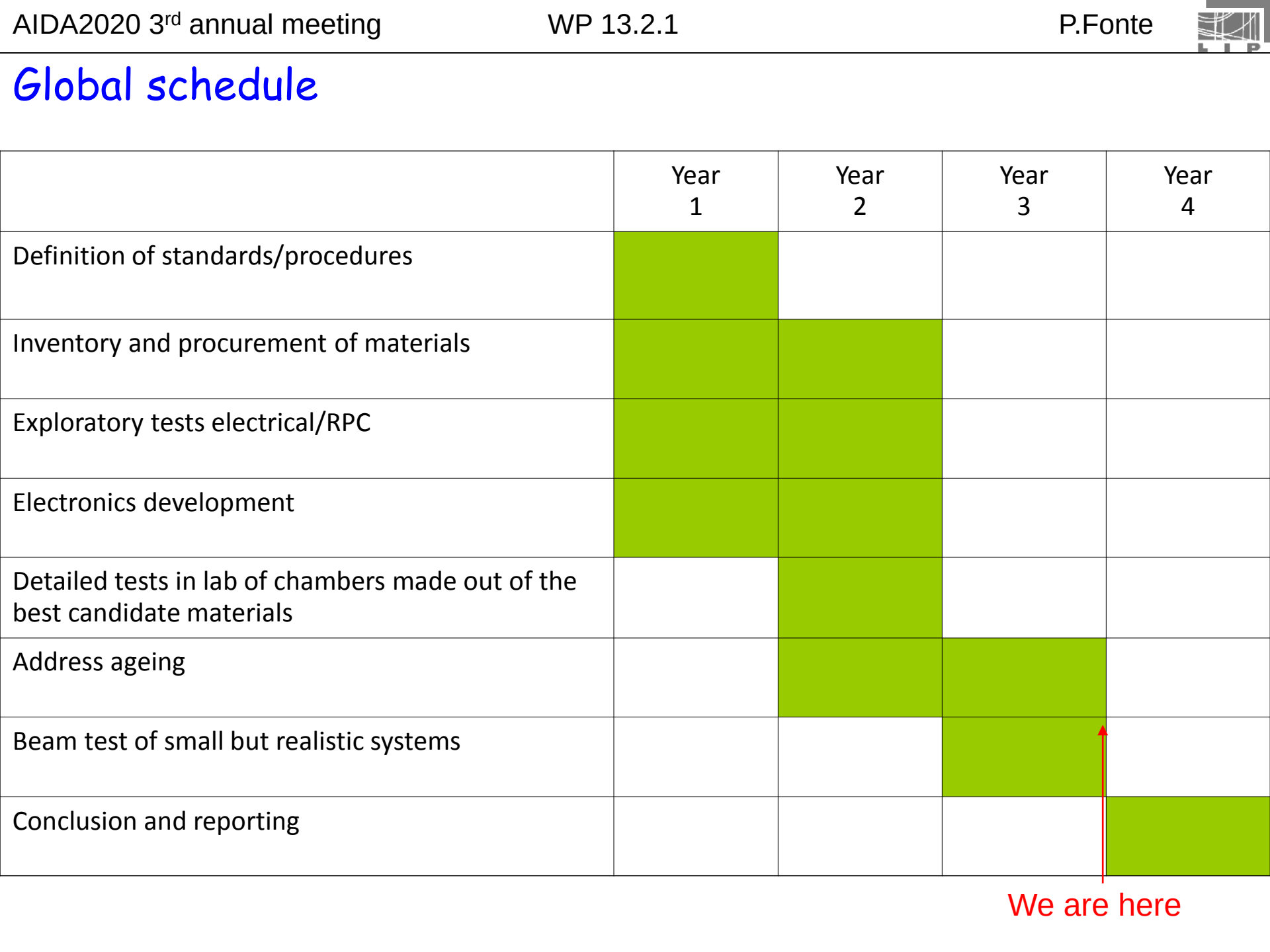
•A list of low resistivity materials like HPL, Glass, Ceramics and new plastics is established;
•Their resistivity (bulk, surface) and homogeneity are studied;
•Their ageing properties due to large integrated doses are also determined;
•The materials are qualified by determining the rate response and ageing properties of RPCs (single and multi-gap) by exposing these materials to intense sources/beams

DELIVERABLES

“Validation of new resistive materials for high rate RPCs through the study of the rate and ageing properties of small RPC prototypes (single and multi-gap-detectors) exposed to intense sources/beams.” [M36]

Global schedule

	Year 1	Year 2	Year 3	Year 4
Definition of standards/procedures				
Inventory and procurement of materials				
Exploratory tests electrical/RPC				
Electronics development				
Detailed tests in lab of chambers made out of the best candidate materials				
Address ageing				
Beam test of small but realistic systems				
Conclusion and reporting				



Materials considered

Beam-tested

- low ρ PVdF+C (plate 400x300x2 mm^3 produced by injection by the Lyon group)
- KREFINE™ (large plate bought, cut and distributed to the participants)
- Phosphate glass (kindly provided by Tsinghua University)
- Thin (0.4mm) soda-lime glass for reference

Not tested because of too small size

- Pestov glass (obtained from GSI stock)
- Ceramics (developed by HZDR - Helmholtz-Zentrum Dresden-Rossendorf)

Procedures

Besides traditional beam-testing, all chambers were tested at several stages by argon-discharge, allowing to measure the resistance of the electrode in-chamber and infer the resistivity, while monitoring the stability of the material and the presence of strong surface anomalies (examples ahead).

PVdF + carbon nanoparticles

PVdF is a thermoplastic material and has similar chemical and mechanical characteristics as PEEK, but could be melt at a lower temperature (180 °C for PVdF and around 400 °C in the PEEK case) which facilitates its production.

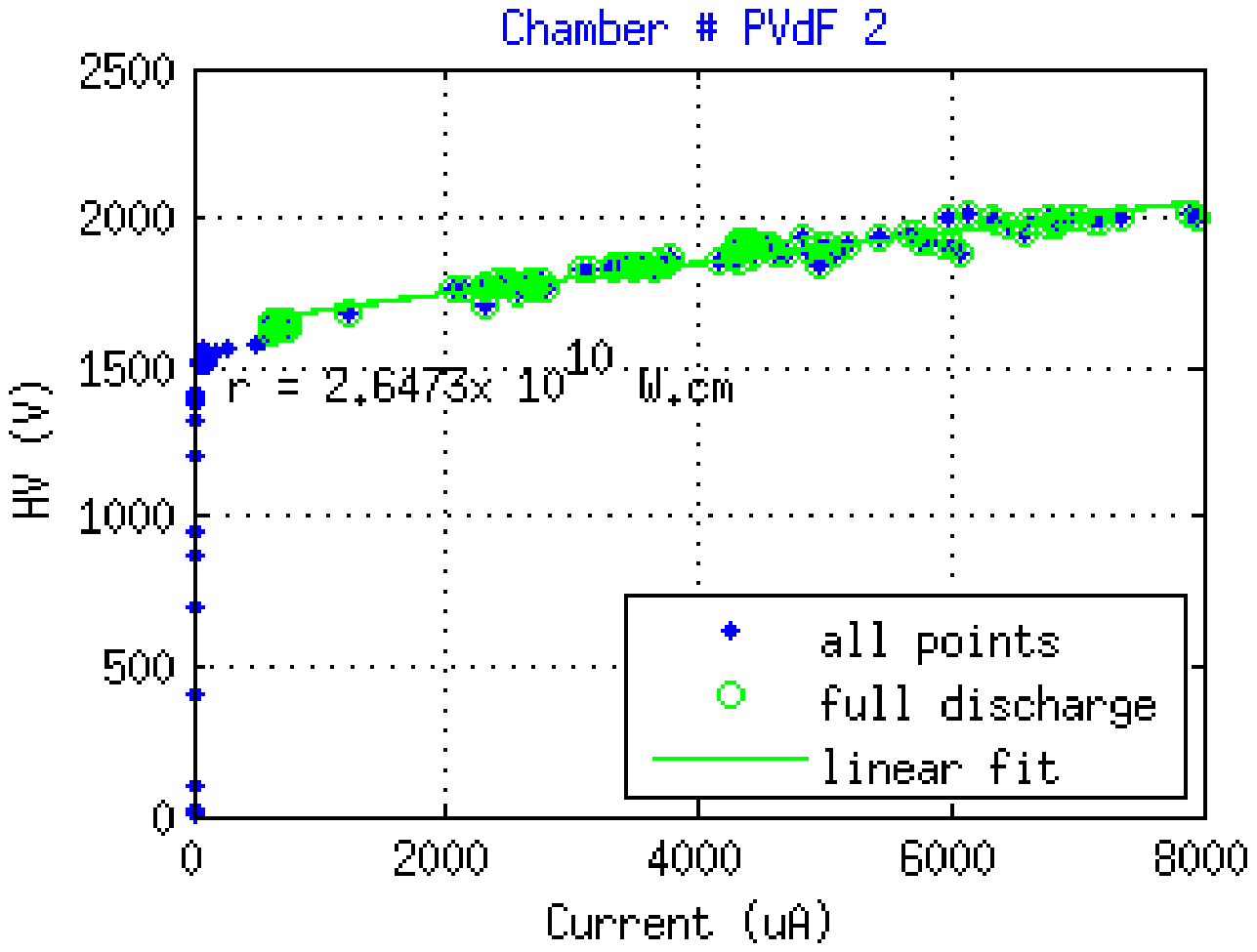
Several loadings (6 to 8%) were tested. Plates of 30 cm × 40 cm of 2 and 3 mm were produced by injection process at the IPC company in France.

Plates with the black-carbon 6% loading were found to have a bulk resistivity of 10^{12} Ω·cm. Several RPC detectors were produced and successfully tested. Efficiency reaching 96% were measured.

The plates with higher loading (8%) reach lower resistivity values (a few 10^{10} Ω·cm).

PVdF + carbon nanoparticles

Example of argon test of a PVdF-C chamber



The resistive electrode was composed by two 2.5mm thick plates glued together

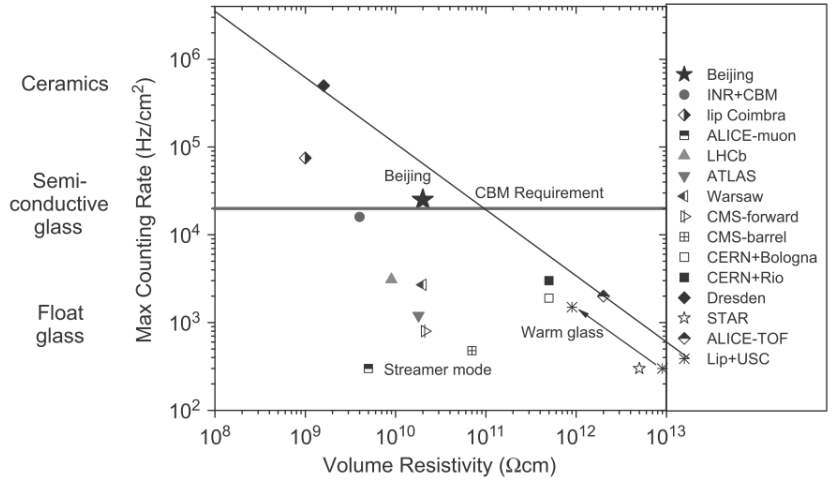
Phosphate glass

Phosphate glass is produced by Tsinghua University for high-rate RPC applications

Table 1
Specifications of low-resistivity glass.

[Yi Wang et al., 2012]

	Specifications
Maximum dimension	50 cm × 50 cm
Bulk resistivity	$\sim 10^{10}\ \Omega$ cm
Standard thickness	0.7–1.5 mm
Thickness uniformity	20 μm
Roughness	< 10 nm
Dielectric constant	10
DC measurement	Very stable



g. 1. Timing RPC world map.

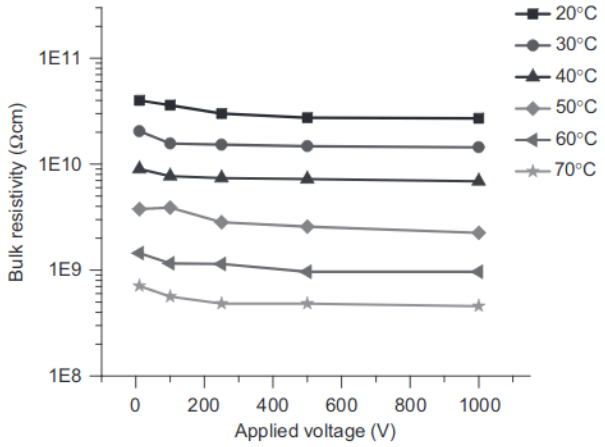


Fig. 1. Bulk resistivity of the newly developed low-resistive silicate glass as a function of applied voltage at various temperatures.

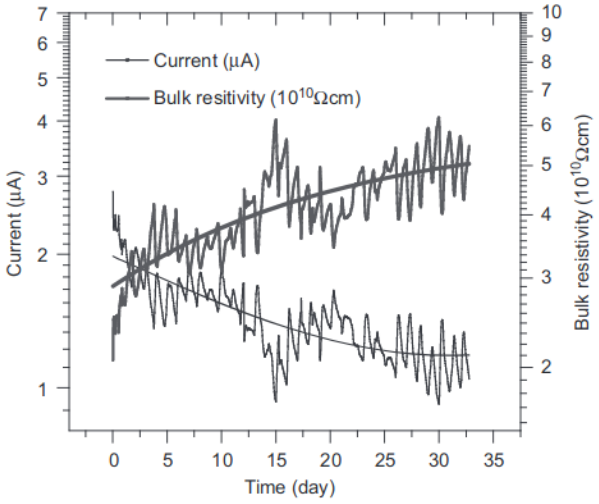


Fig. 2. Long term stability test of the low-resistive silicate glass for 34 days: current (lower line) and bulk resistivity (upper line) as a function of time at 28 °C, for an applied voltage of 1 kV. The total transported charge across the material was 1 C/cm².

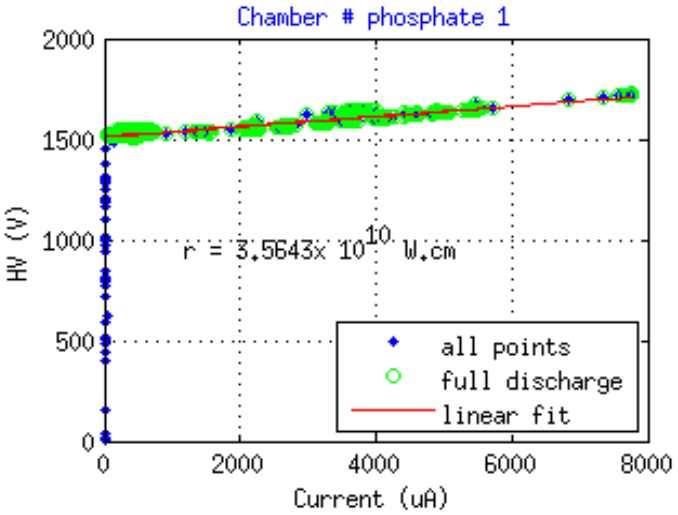
resistivity and good mechanical characteristics [17,18], of which semi-conductive glass is a promising candidate. The rate capability of MRPCs is largely determined by the bulk resistivity of

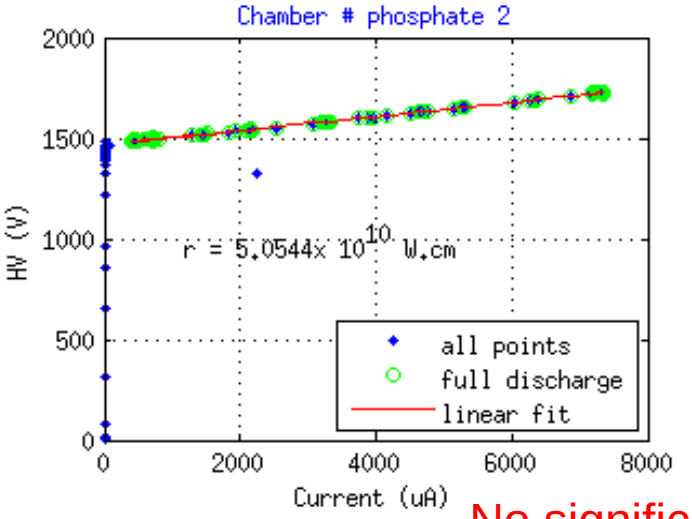
[Jingbo Wang et al., 2010]

Phosphate glass

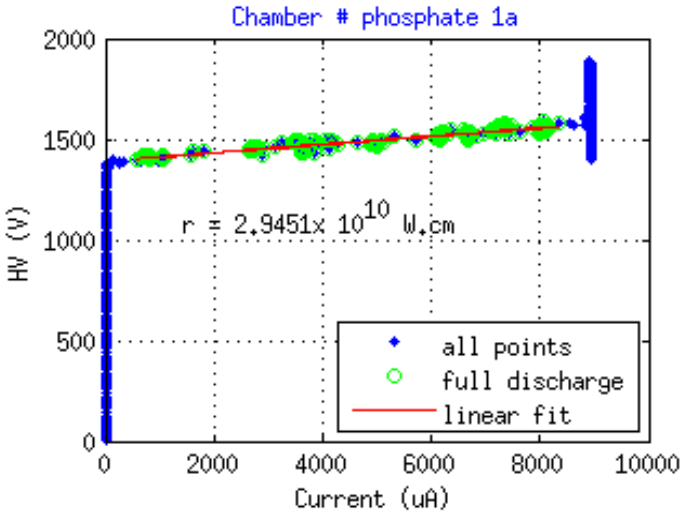
Argon tests of the phosphate glass chambers

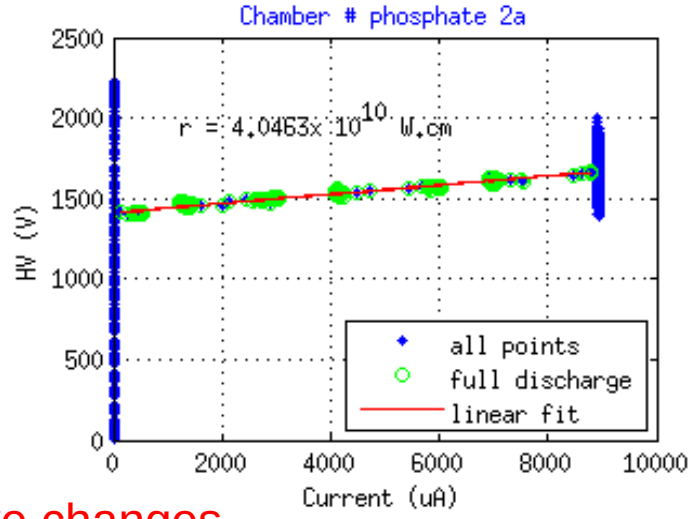
pre-beam





post-beam



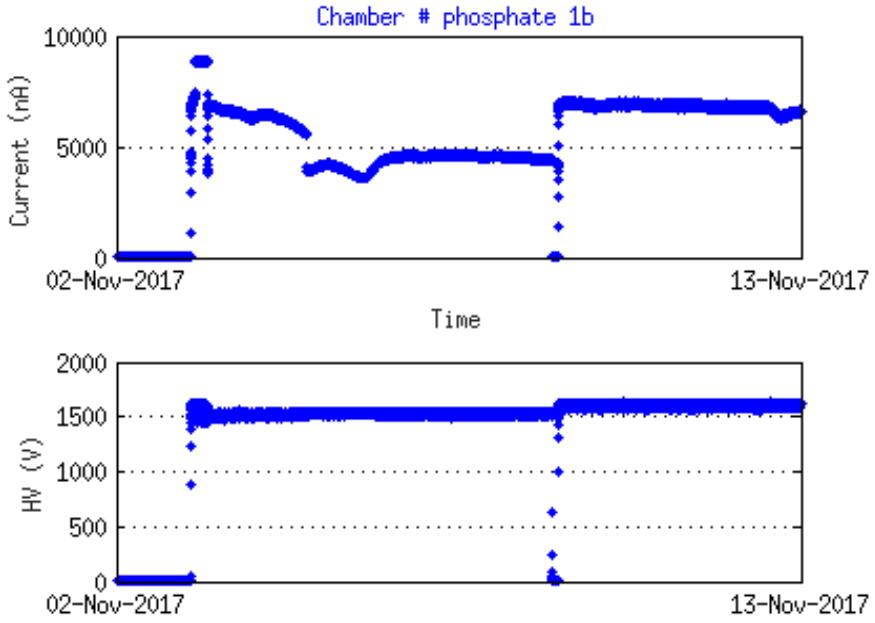


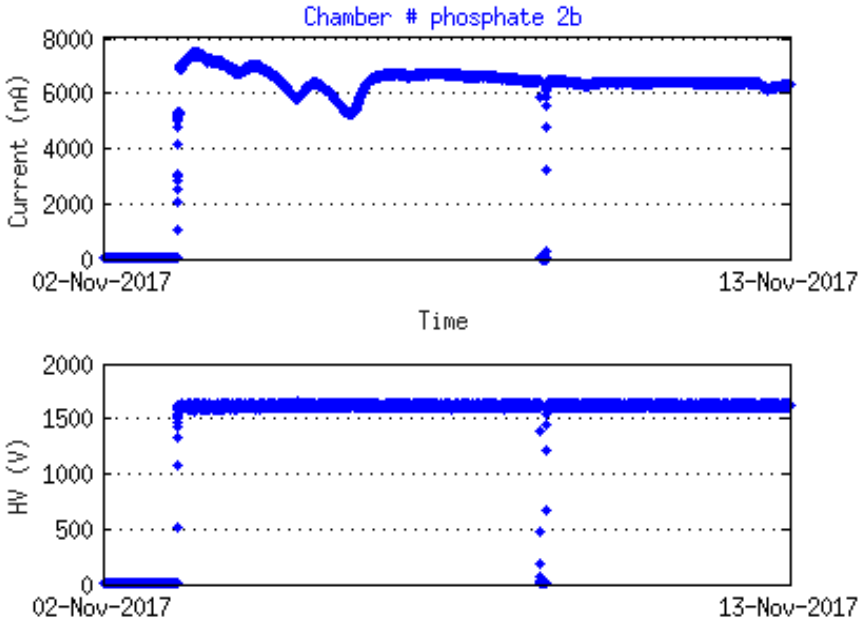
No significative changes

The resistive electrode was composed by a single 0.7 mm thick plate

Phosphate glass

Long term argon test to evaluate resistivity stability





The material shows an essentially stable conductivity over time, suggesting a minor ionic contribution to its conductivity.

KREFINE

:: Krefine

Carbon Technology for the New Generation

Krefine provides a variety of Electro-Static Dissipative (ESD) control materials, Injection molded parts, rods & sheets, and machined parts. The surface resistance is easily controlled at the specific levels required for ESD control materials by the use of Krefine's special carbon technology. Kureha Extron will recommend the best polymer type to meet a customer's requirements when the specifics of the end use application are provided such as: ESD range, desired heat or chemical resistance, mechanical properties, etc. Krefine® products can also be tailor made to meet specific ESD values for your end-use needs.

KREFINE PRODUCTS & CONTACTS

Kureha America
info@kureha.com
420 Lexington Ave - Ste 2510
New York, NY 10170
212-867-7040

Grade	EKH-SS07	EKH-SS09	EKH-SS11	EKH-SS12
Base Polymer	PEEK			
Surface Resistance	1.0E+06~9.9E+08 ohms	1.0E+08~9.9E+10 ohms	1.0E+10~9.9E+12 ohms	1.0E+11~9.9E+12 ohms
Typical Applications	Hard Disk Drive	Wafer Handling	Burn-in & Test Sockets	Burn-in & Test Sockets

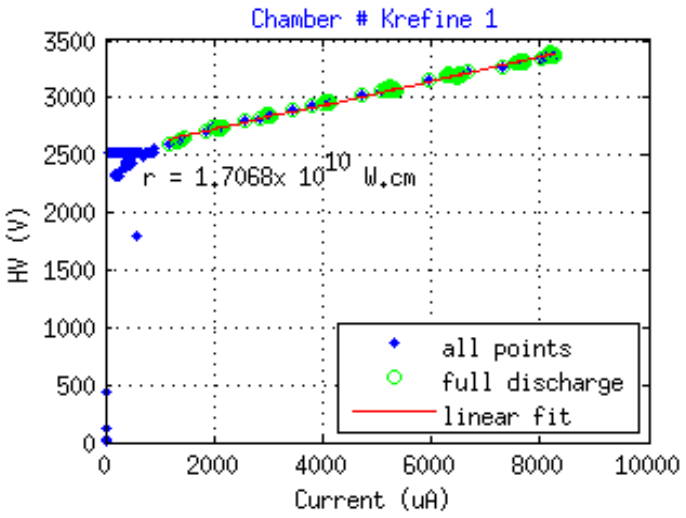
Grade	EIH-SS11	CDH-SS08
Base Polymer	PEI	PPS
Surface Resistance	1.0E+09~9.9E+12 ohms	1.0E+07~9.9E+09 ohms
Typical Applications	Burn-in & Test Sockets	Hard Disk Drive, Wafer Handling

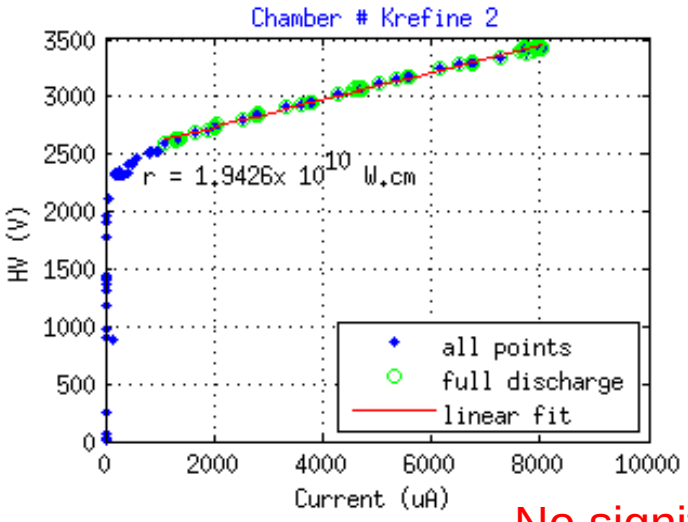
An interesting range of resistivies
Quite expensive (~3k€/m^2)

KREFINE

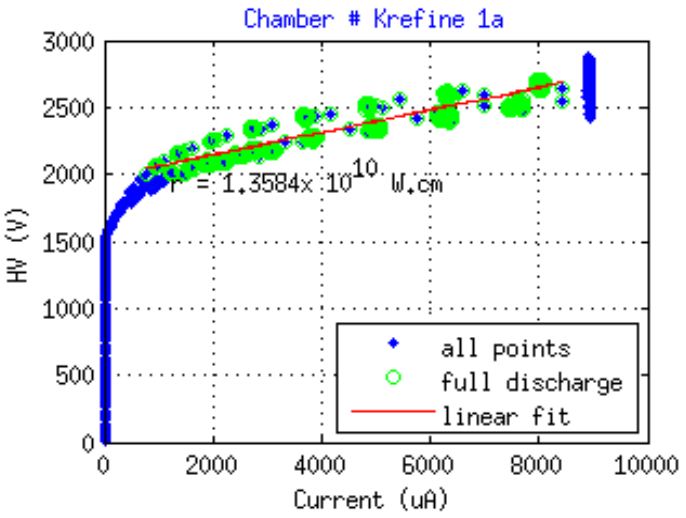
Argon tests of the KREFINE chambers

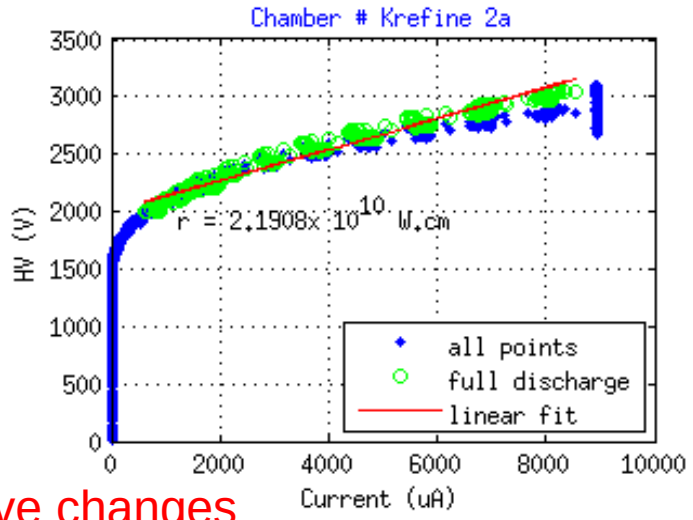
pre-beam





post-beam



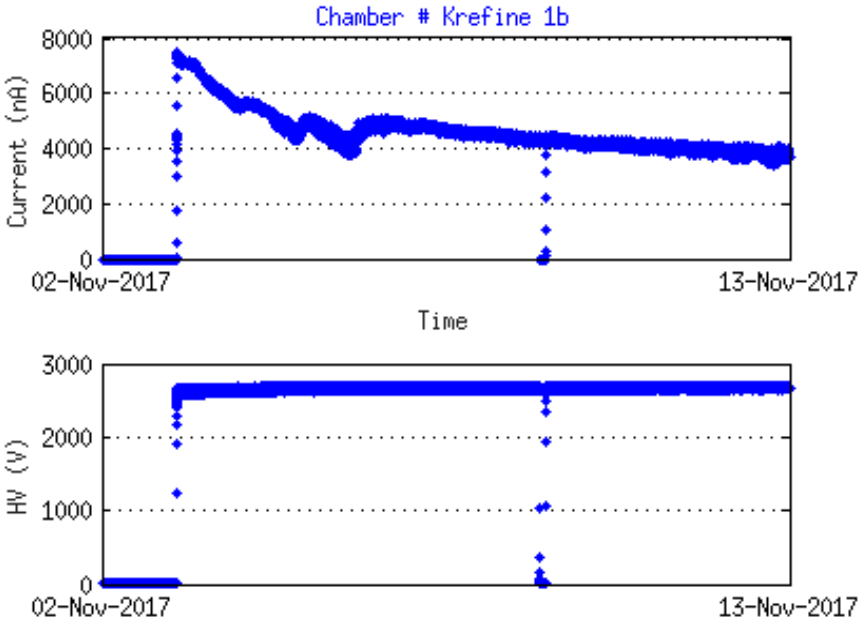


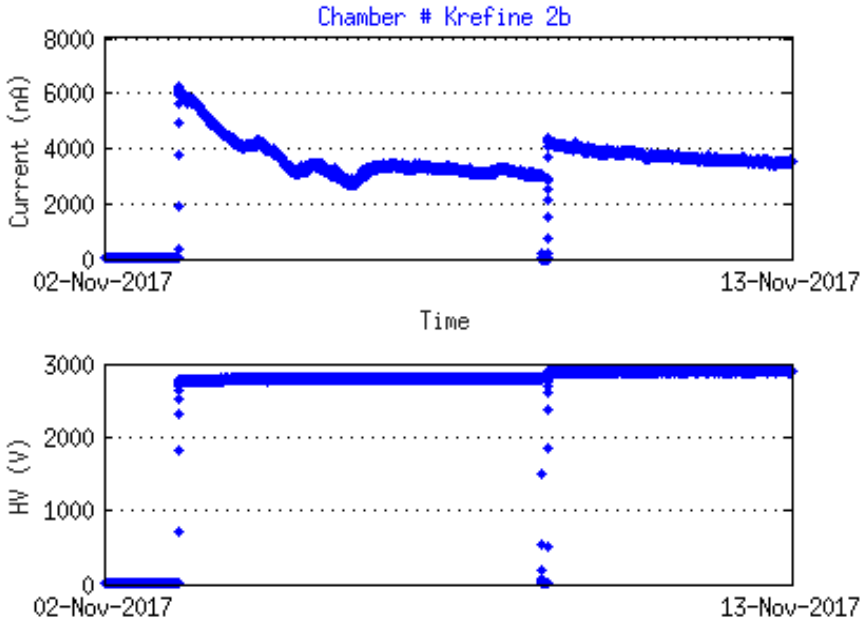
No significative changes

The resistive electrode was composed by two 3 mm thick plates

KREFINE

Long term argon test to evaluate resistivity stability





The material shows a conductivity that decreases at a progressively lower rate over time, suggesting a mixed ionic and electronic conductivity.

Nevertheless, the electronic part seems to assure a usable long-term conductivity within a factor 2 of its short-term value.

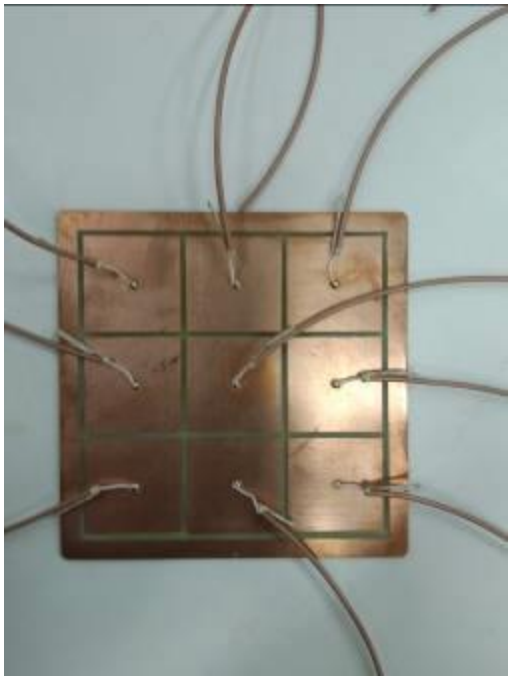
Beam test - hardware

All chambers of identical construction:
1 mm gas gap
1 stainless steel cathode
1 resistive anode
Painted HV layer
No internal spacers

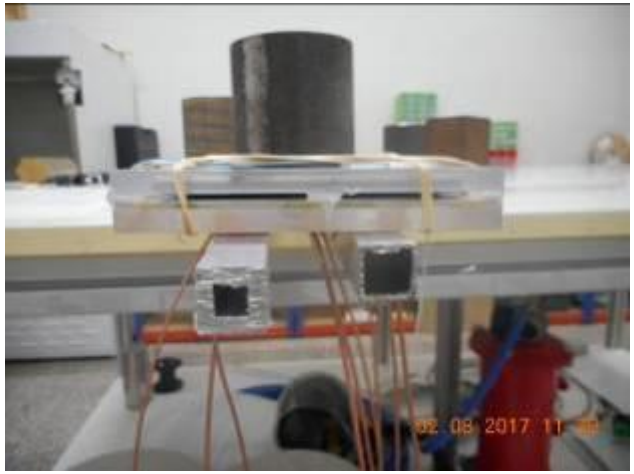
Resistive anode
(PVdF in this case)

Stainless steel cathode
(100 cm^2)

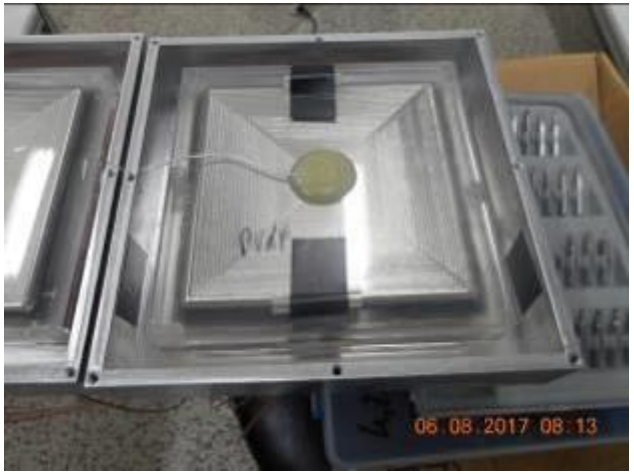
9 readout pads



Spacerless construction



Shielding box



Beam test - hardware

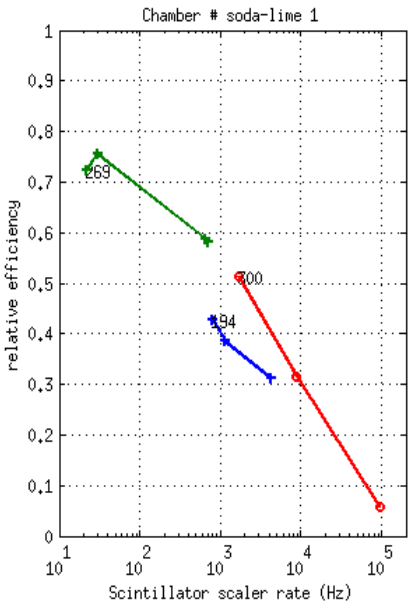
Inner view

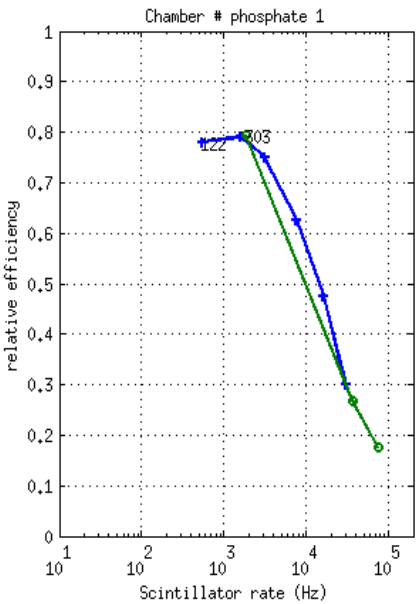
Outer view w/out shielding

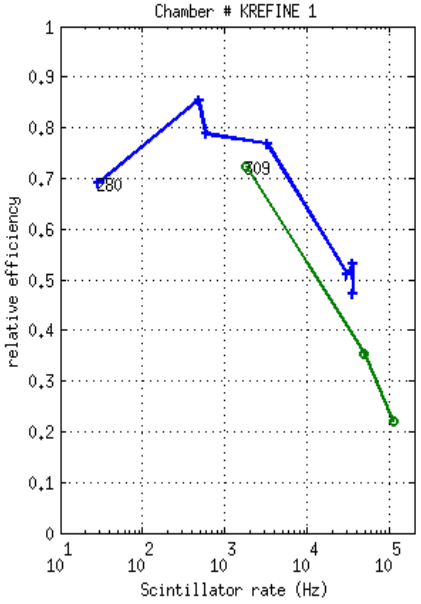
Beam line view

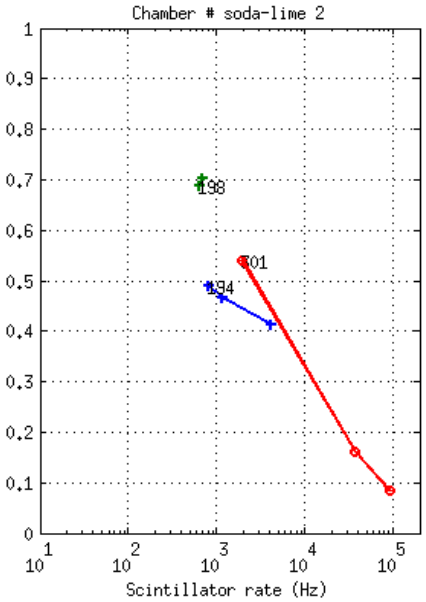
Both charge and time could be read on each pad (not at same time)

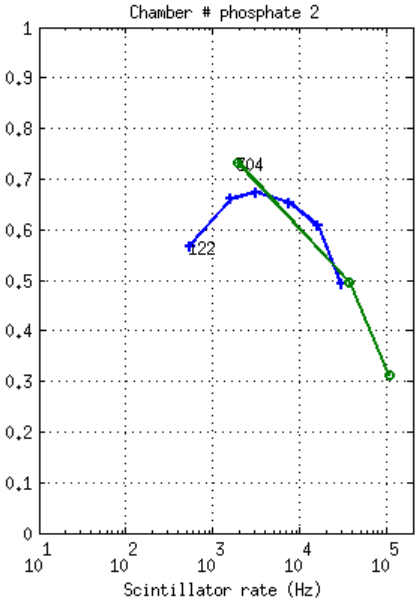
Beam test – relative rate capability

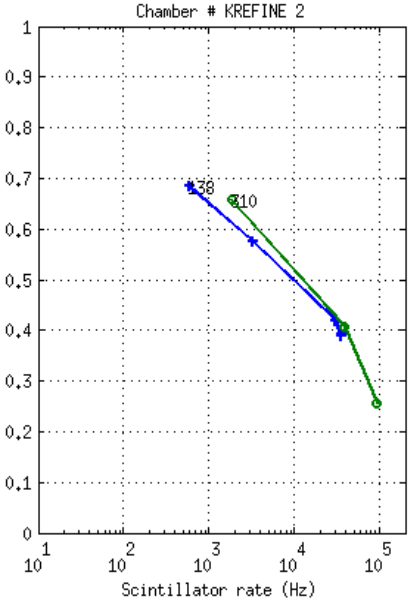












As expected, phosphate glass and KREFINE allow at least two orders of magnitude larger rate capability than thin soda-lime glass

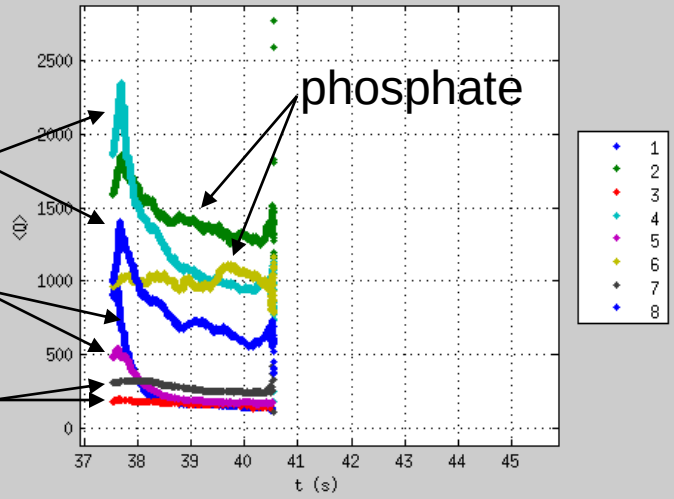
Beam test – relative rate capability

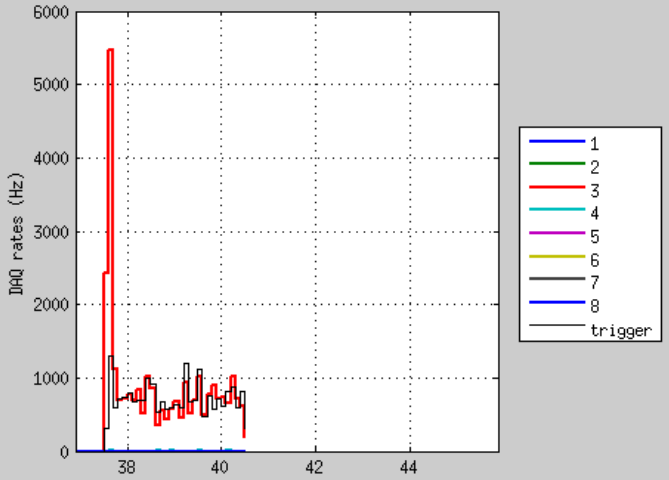
Single spill @ intense beam

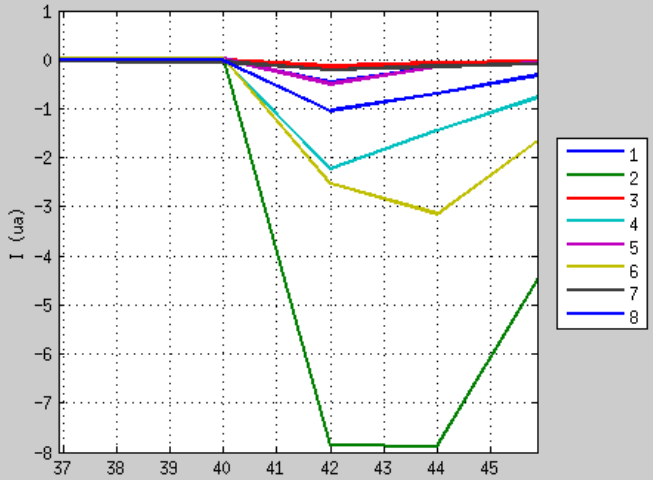
KREFINE

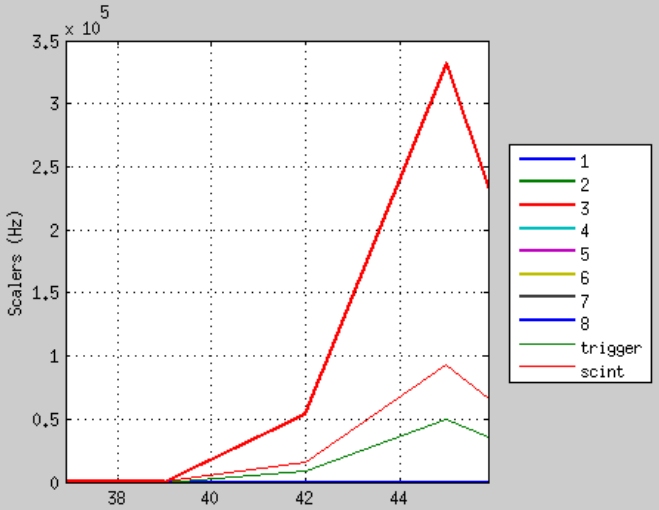
soda-lime

PVdF



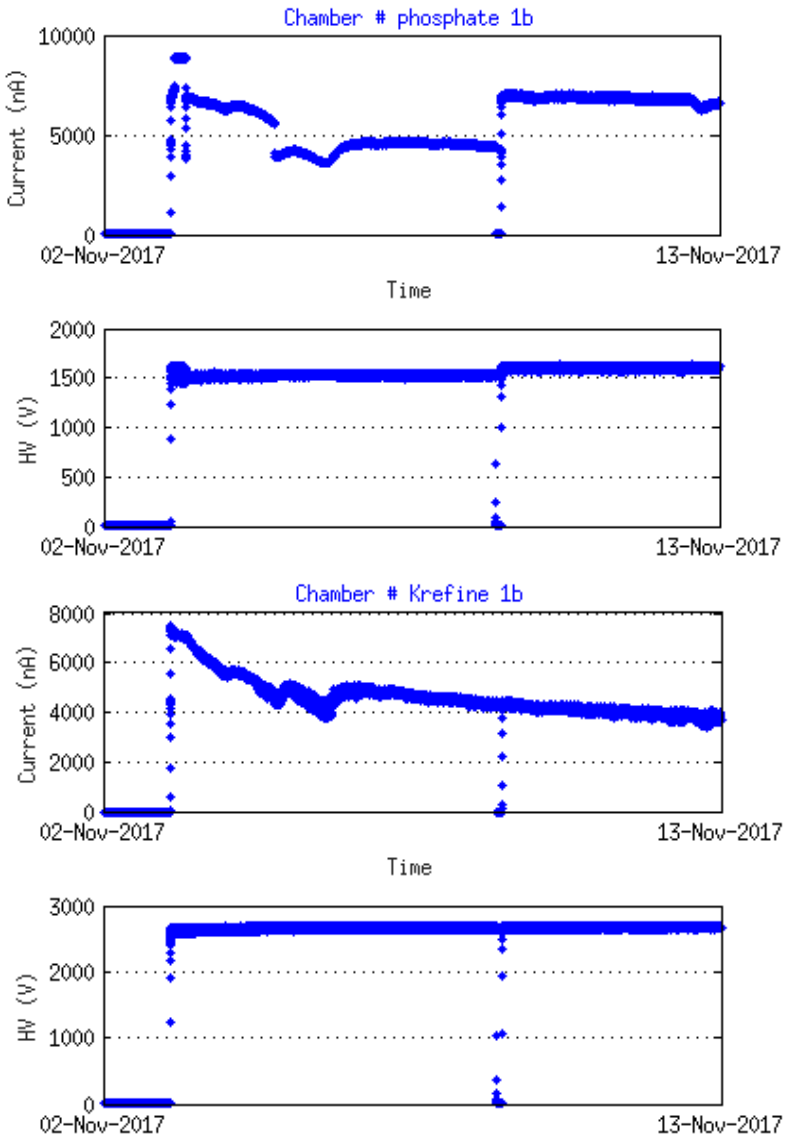


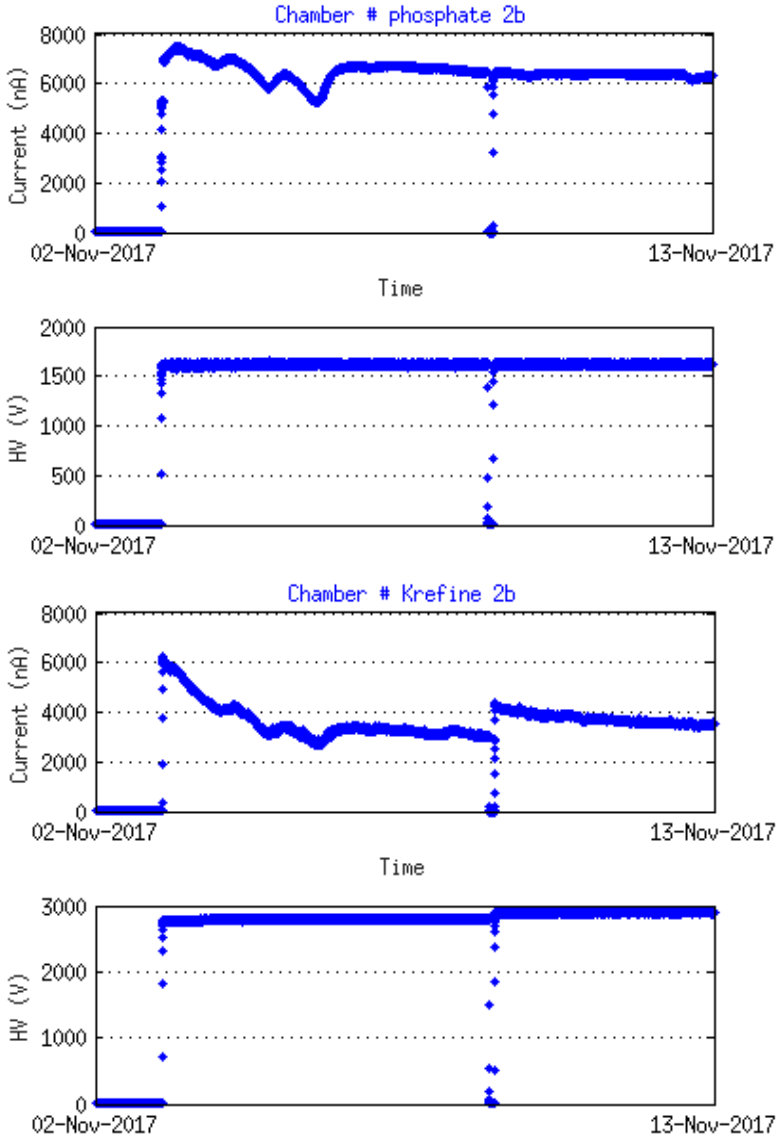




Aging – resistivity

Long term argon-discharge test to evaluate resistivity stability

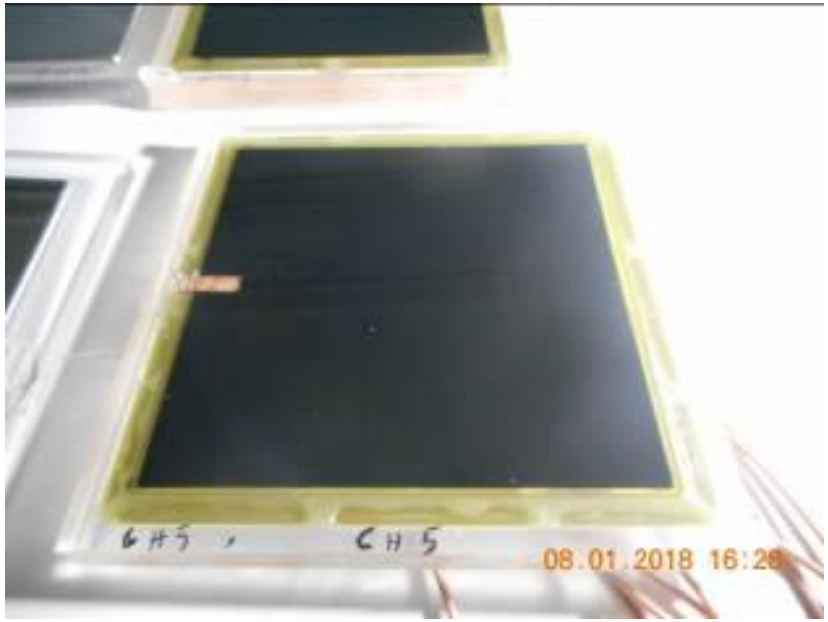


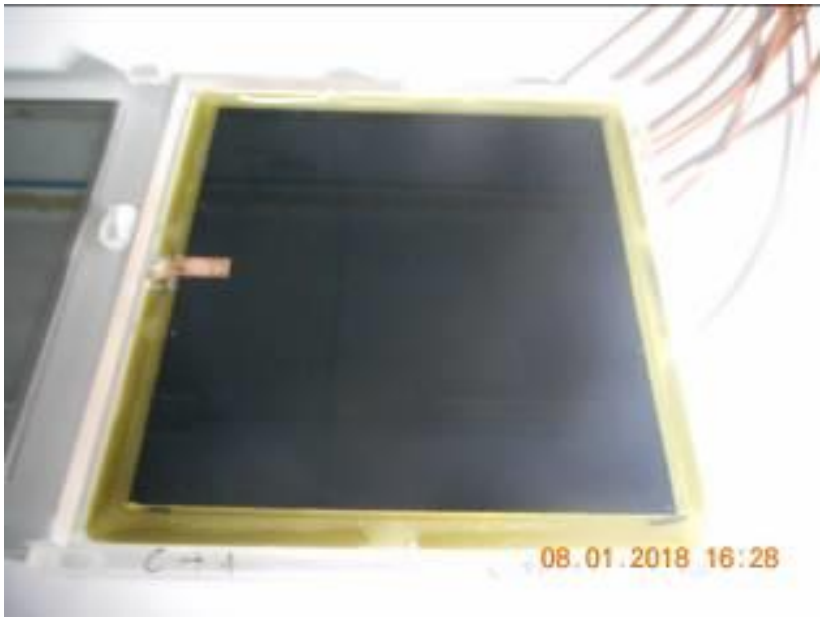


Small or tolerable effects

Aging – soda-lime

Post-beam examination





No alterations

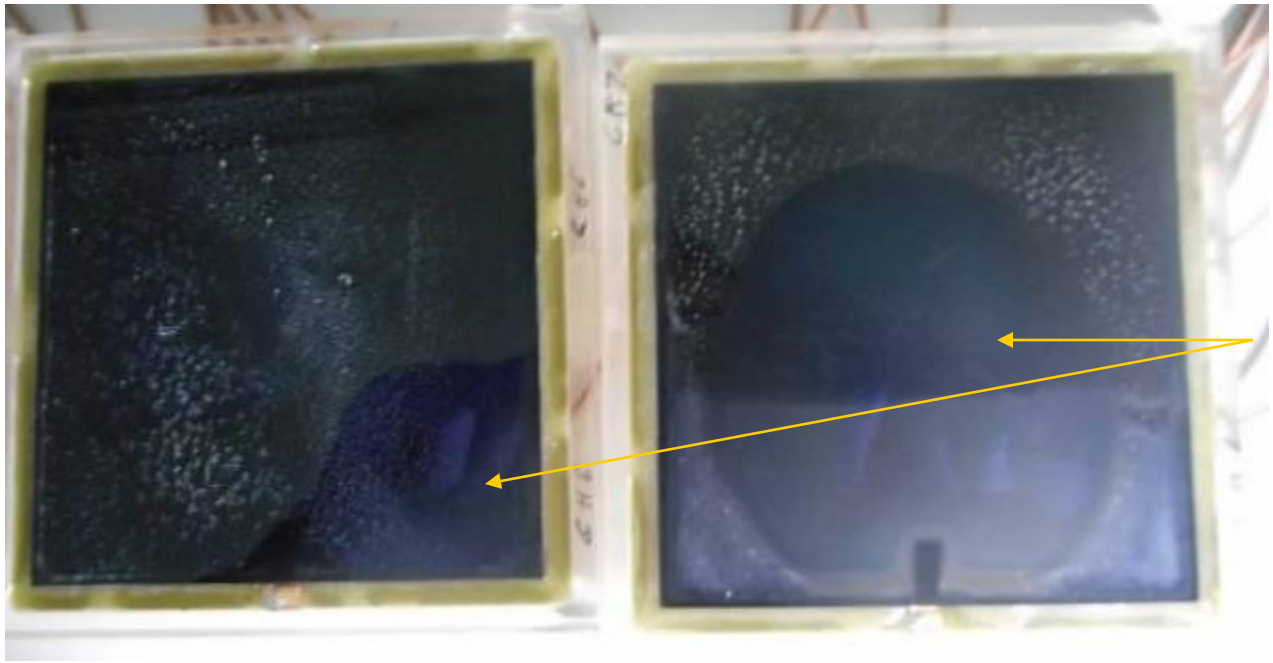
Aging – PVdF

Post-beam examination

No alterations

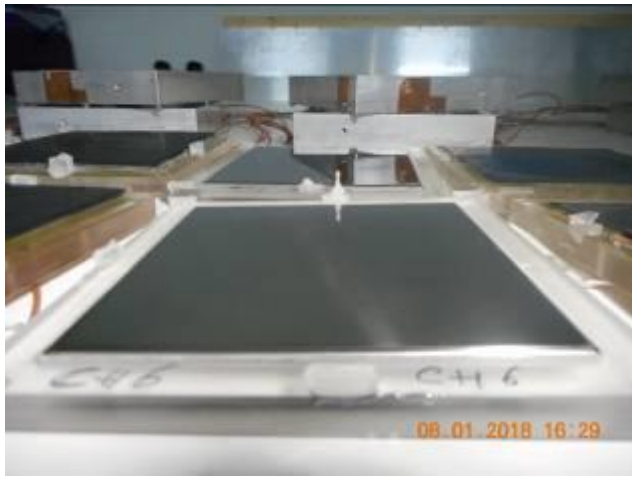
Aging – Phosphate

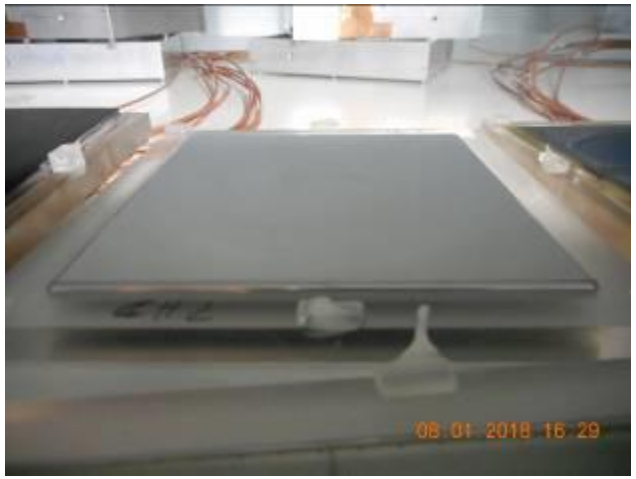
Post-beam examination



Clean regions!
Maybe by the argon discharge.

This deposit could be wiped clean with alcool.



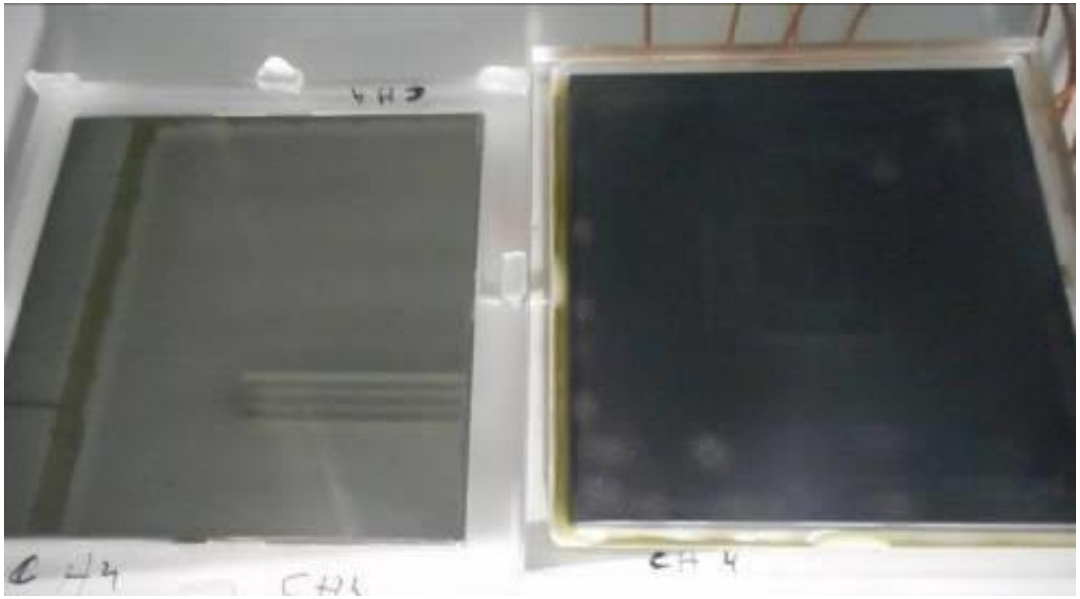


Clear cathodes

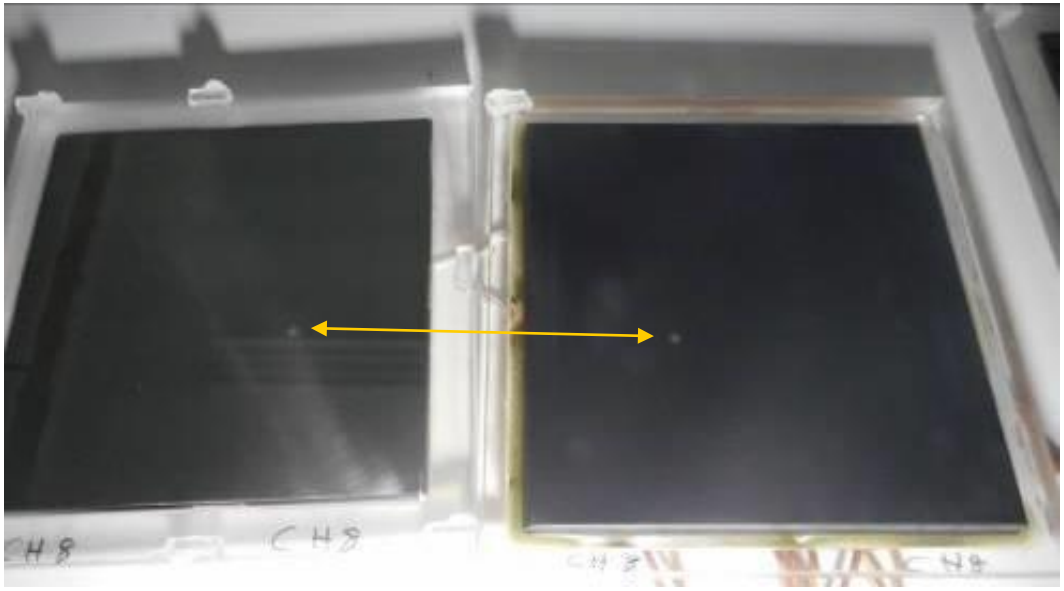
Alterations visible on the glass, but not on the SS. **Both chambers worked normally.**

Aging – KREFINE

Post-beam examination



Some stains.
Looks like erosion.



Little hole + transfer of material to the cathode

Stains on the plastic, some transferred to the SS. **Both chambers worked normally.**

Conclusion

- Three different new resistive materials for high rate RPCs were identified or developed and extensively tested.
- Eight RPCs were made, two of each kind of new material, plus two made out of standard soda-lime glass, for reference. In these chambers the cathodes were made out of stainless-steel plates and there were no internal spacers, to isolate as possible the materials' behavior from the constructive details.
- The resistivity of the materials was measured in the chambers themselves by the argon-discharge method, both before and after irradiation.
- A beam test was performed on the set of eight chambers, confirming their different rate capability.
- After-beam observations revealed that the resistivity of the materials was not changed, but that some signs of surface alterations were visible on some of the materials. **Despite such alterations the chambers continued to operate normally.**
- Future work should include similar tests with the resistive electrodes also performing as cathodes and longer irradiations.