sRPC: an RPC based on resistive MPGD technology

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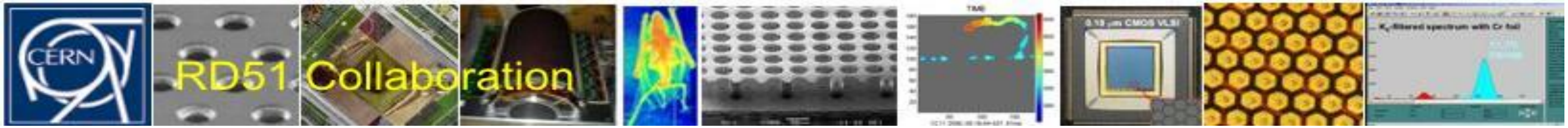
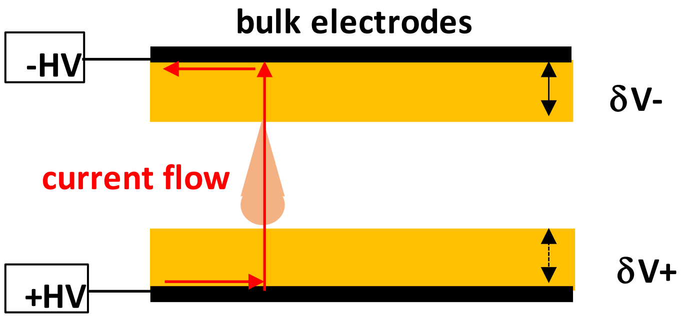


sRPC vs RPC

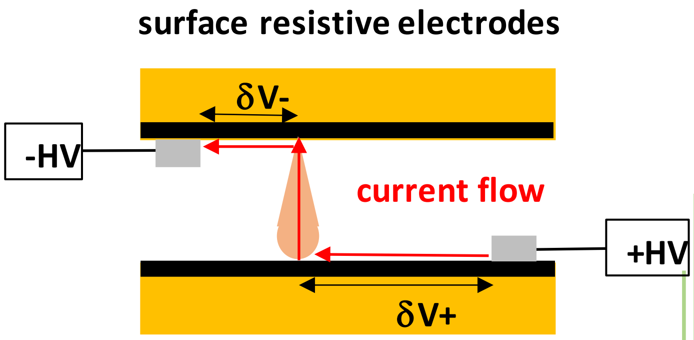
Classical RPCs

- **bulk resistivity electrodes** (bakelite, float-glass …)
- **recovery time** proportional to **volume resistivity** and **electrode thickness (ρ_b, ε_r, d, g)**
- **low volume resistivity and thin electrodes,** together with the **reduction of the gas gain** (⊕ *high gain low noise pre-amp*) is the standard **recipe to increase the detector rate capability**



sRPC

- **surface resistivity electrodes** manufactured with industrial sputtering techniques of **Diamond-like-carbon (DLC) on flexible supports**
- the technology allows to realize large electrodes with a **DLC surface resistivity** in a **very wide range, 0.001 ÷ 10 GΩ/□**
- **high density current evacuation schemes**, similar to those used for **resistive MPGD** (μ-RWELL, MM), can be implemented **to improve the rate capability** of the detector



Brevetto-Italia N. 102020000002359 (submitted to INFN 10 Sept 2019 - registered at the Ufficio Brevetti 6 Feb 2020)
INFN – "ELETTRODO PIANO A RESISTIVITÀ SUPERFICIALE MODULABILE E RIVELATORI BASATI SU DI ESSO."

Diamond Like Carbon

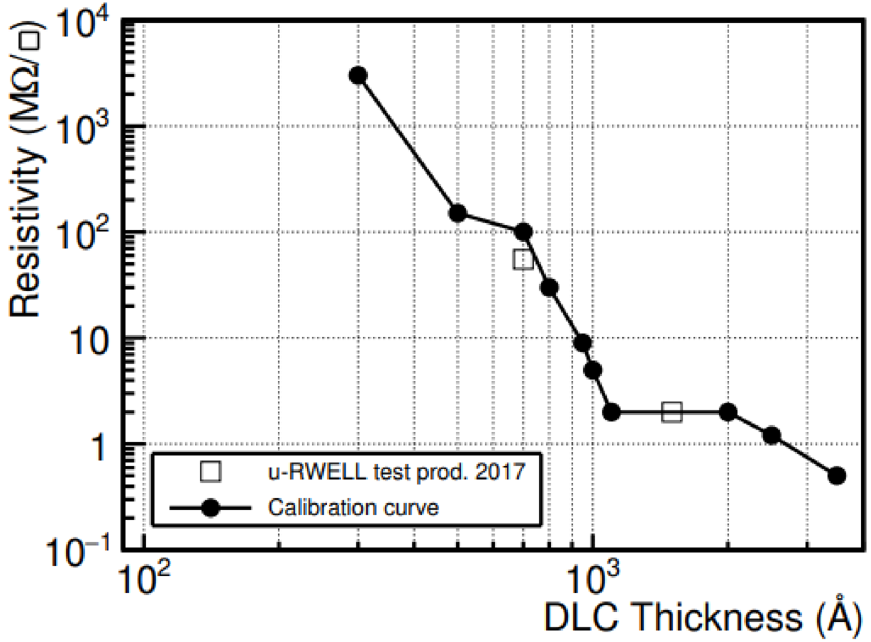
The **DLC sputtering technology** is used in many **industrial applications** (mechanics, automotive and medical industry) that require **surface hardening and reduced abrasive wear.**

The **DLC is a class of carbon material** that contains both the **diamond** as well as **the graphite structure** in different fractions, depending on sputtering parameters.

The **DLC film (typically 0.1 μm thick) is deposited** by sputtering **graphite** on one side of a **large Apical® foil.** The resistivity depends on the DLC thickness and gas atmosphere used in the process.

The production of **DLC Apical®** foils for our detectors (**μ-RWELL, MicroMegas, sRPC**) has been done by the **Be-Sputter Co., Ltd. in Japan (size ~1.2x0.6 m²).**

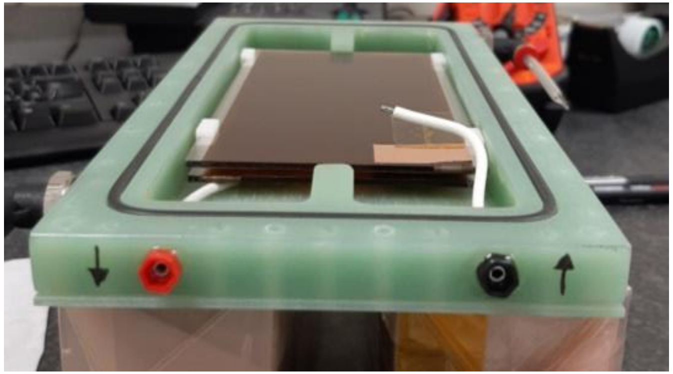
In the near future a **DLC machine, co-funded by CERN and INFN,** will enter in operation at the **CERN MPT- Workshop (size ~2x0.6 m²).**



Prototype layout (I)

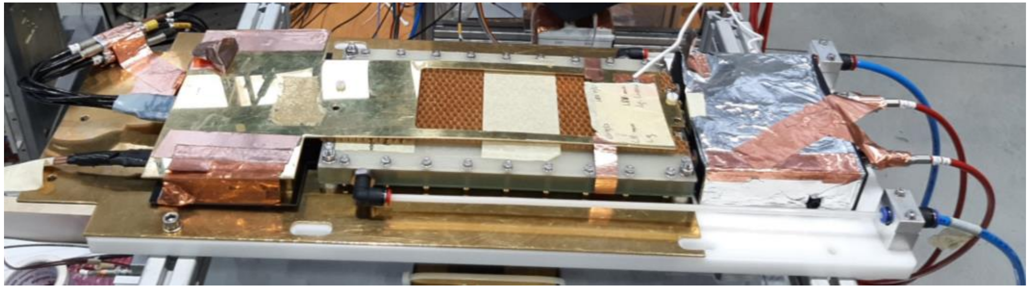
- The **baseline** version of the detector is built with **patterned DLC electrodes** sputtered on **Apical®** foil then **glued** on **float-glass substrates**
- The **glass support** is used because its **excellent planarity and very smooth surface** (*use of standard PCB in future not excluded*)
- The **2 mm gas gap** between the two electrodes is ensured by **E-shaped spacers made of Delrin,** ensuring a good gap uniformity
- The **electrodes stack** is inserted in a **FR4 box** that acts as **gas volume container**

glass 140x78 mm^2 - DLC 120x64 mm^2



Prototype layout (II)

- The **HV** to **DLC electrodes (baseline version)** is supplied through a **dot-like connection** realized on **DLC tails** bent on the **external side of the glass** support
- **External strip-patterned** boards are used to pick-up the **induced signals**
- The **readout** is based on the **six-channels VTX pre-amplifier** with analog output, **10mV/fC sensitivity**
- Detectors have been operated with the **$C_2H_2F_4$/iso-C_4H_{10}/SF_6 = 93.5/5/1.5** gas mixture

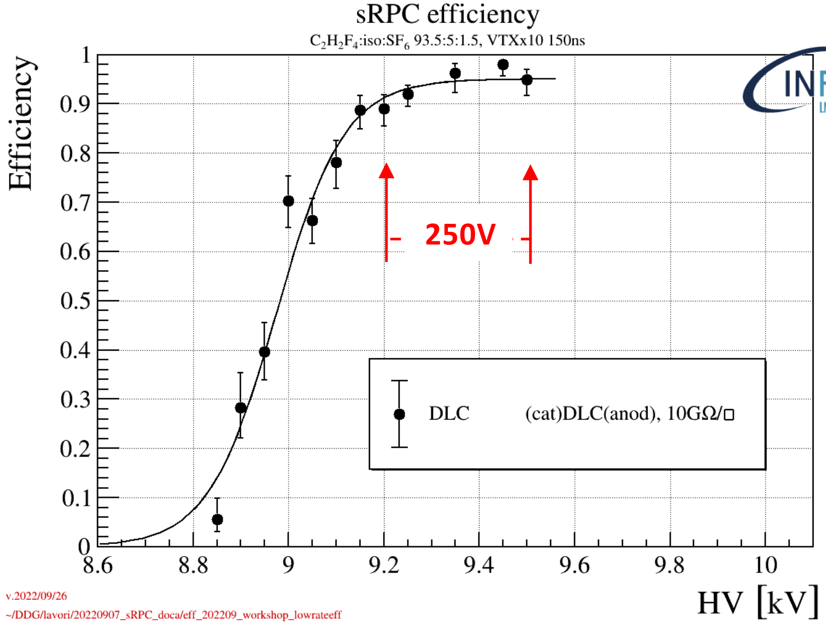


The cathode puzzle (I)

The **efficiency plateau** is **not** as **large** as the one obtained with standard RPC(*) with bulk resistivity electrodes (≥ 1kV).

Instability correlated **with a constant current drawn** has been observed **over a certain HV threshold.**

Since the **DLC has a work function of few eV**[1] and exhibits a **non-negligible sensitivity to UV-photons**[2], **secondary electron emission due to photon-feedback and/or field emission**[3] may occur at the **cathode surface.**



(*) RPCs with cathode electrode made of float-glass (*that don't exhibit secondary electron emission*) exhibit plateau larger than 1kV.

[1]A. Valentini, RD51-NOTE-2020-006.
[2] Kordas, et al., 15th Vienna Conference on Instrumentation, Feb. 18-22, 2019.
[3] S.A. Korff, Electron and Nuclear Counters, D. Van Nostrand Company -Inc, Fourth Avenue, New York, USA, 1955.

The cathode puzzle (II)

A **possible solution** of this problem is the production of a **thin barrier on the cathode surface** in order to **suppress the electron extraction from DLC.**

Several **passivation coatings of the DLC cathode** surface have been tested, among these the **Licron** led to **positive results** by significantly **improving the stability** of the detector.

In order to do not affect the correct behavior of the electrode, the **passivation film** should have a **surface resistivity comparable with the DLC one.**

$\rho_{DLC} \sim \mathbf{10^8 \div 10^9\ \Omega/\square}$

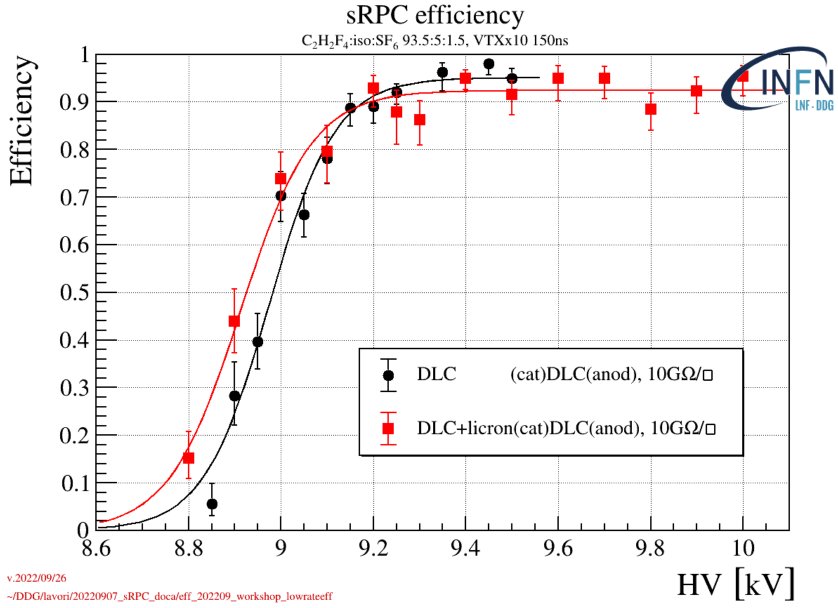
$\rho_{film} \sim \rho_{DLC}$

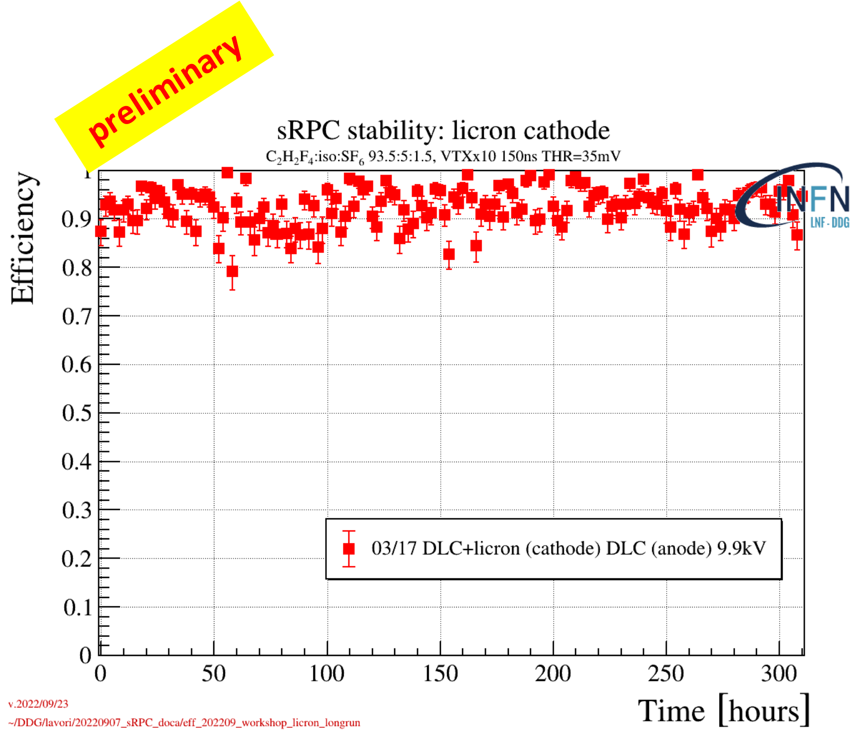
Features / Benefits

- Rugged static dissipative coating
- Surface Resistivity of 10^6 To 10^9 ohms
- Operating temperature range up to 302°F (155°C)
- Humidity independent
- Superior adhesion to variety of surfaces: glass, plastic, etc.
- Coverage - 1 gallon @ 1 mil wet film will cover ~1600 sq. ft., @ 2 mil ~800 sq. ft.
- Non-ozone depleting

At the moment the **cathode passivation is done manually**. Looking for **SBU technology.**

The cathode puzzle (III)



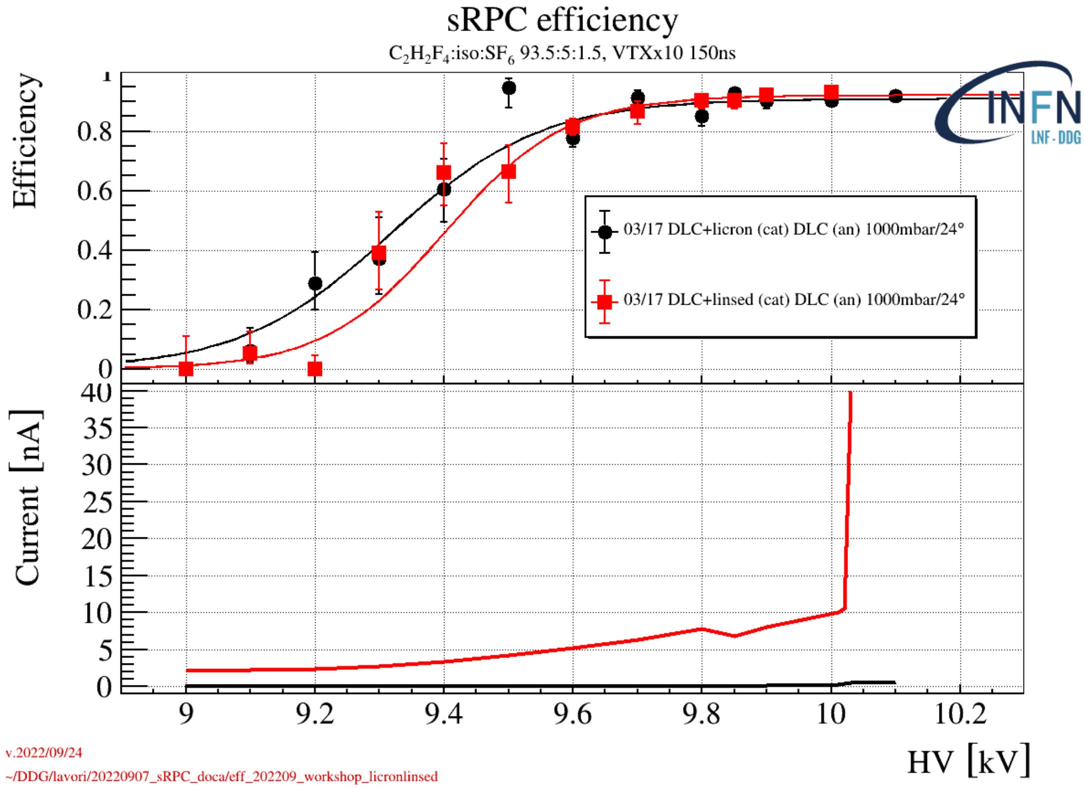


Detectors with **Licron cathode passivation** show an **efficiency plateau of the order (or larger than) of 1 kV,** while a **long-term test** to verify the **detector stability** is in progress.

Linsed-oil vs Licron (dot-like HV connection)

Main **differences** between **linsed-oil** and **Licron:**

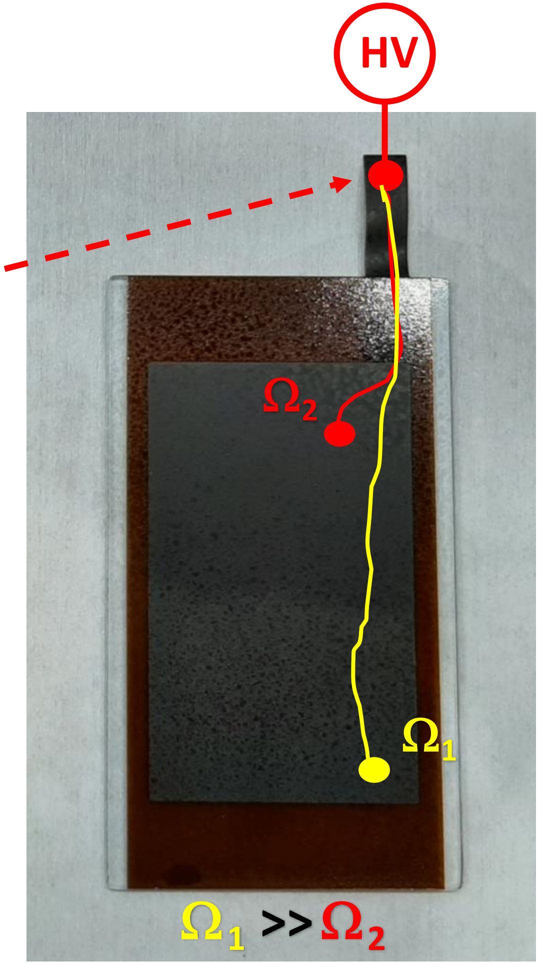
- $\rho_{\text{linsed-oil}} >> \rho_{\text{Licron}}$
- **Licron is easier to apply/engineering**
- Detectors with DLC cathode passivated with **linsed-oil** show **dark current** and **breakdown at high voltage**



LR (baseline) layout limitation

A **drawback** of the **surface resistivity electrode** with **single dot-like current evacuation scheme** is that, beside the **reduced capability to stand high particle fluxes,** the **detector response is not uniform** over its surface.

This is more evident as the **size of the detector increases**. This effect is correlated to the **average resistance (Ω)** faced by the charge/current produced in the avalanche that **depends on the distance between** the **particle incidence position** and the **current evacuation point** on the electrode.

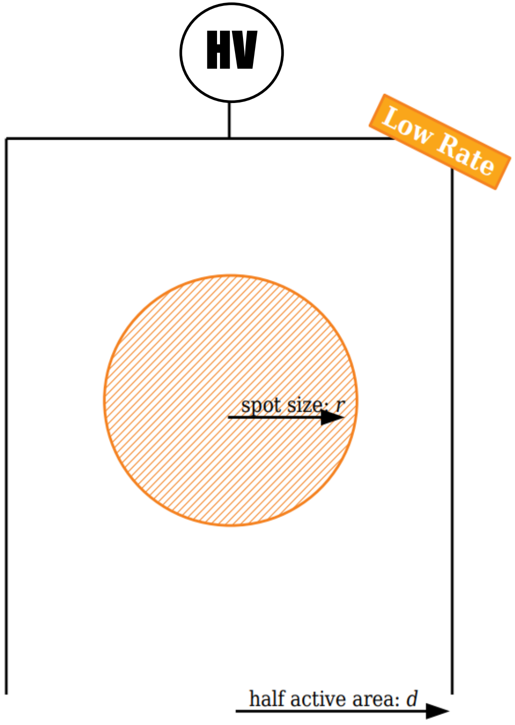


LR vs HR layout (I)

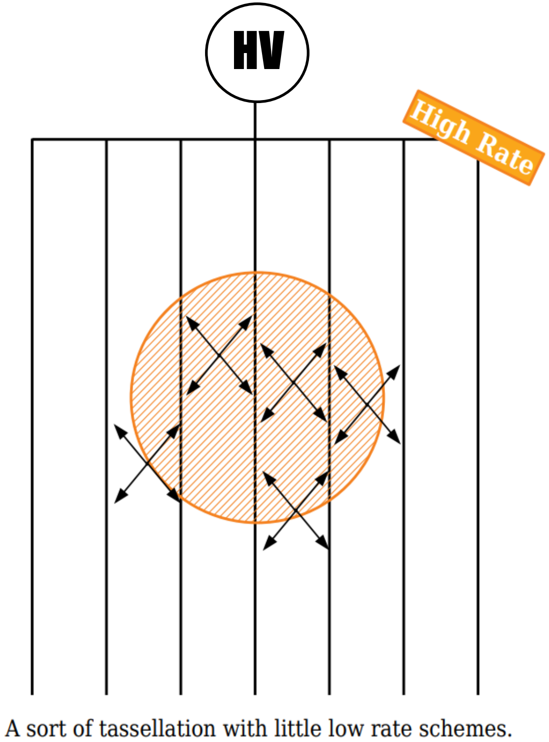
Exploiting our **experience done with the R&D of the μ-RWELL**, the solution could be the implementation of a **"dense" conductive network** on the **resistive electrode.**

In this way the **average path of the current towards the evacuation connection is reduced** thus **improving the rate capability** of the detector, while increasing the **detector response uniformity.**

The **performance** of such a **HR layout** depends on the **DLC resistivity** as well as the **pitch of the conductive network.**



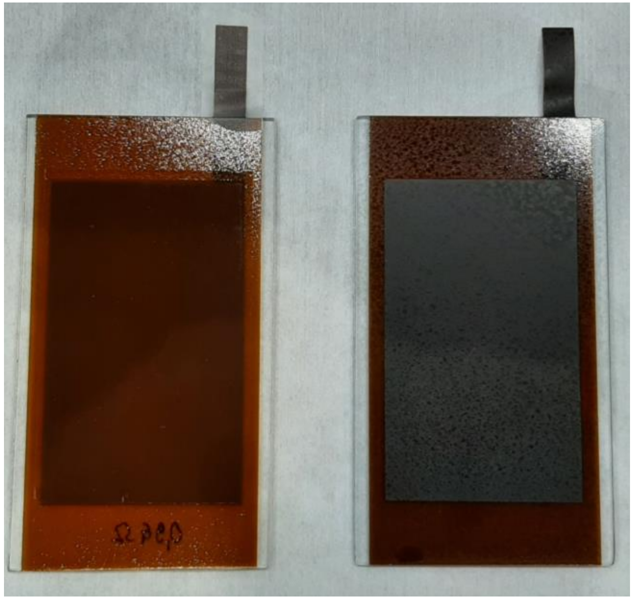
LR layout

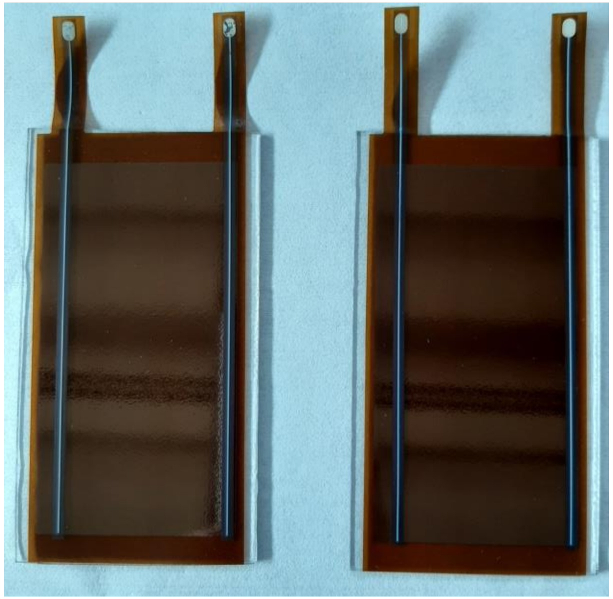


HR layout

LR vs HR layout (II)

High-rate: same structure **as Low-rate electrode ⊕ conductive grid** acting as a **fast current evacuation** scheme

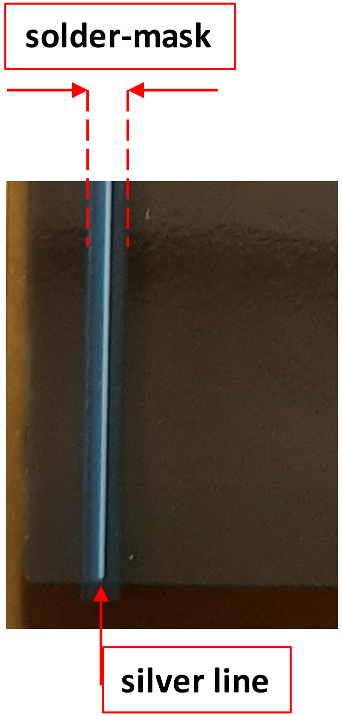


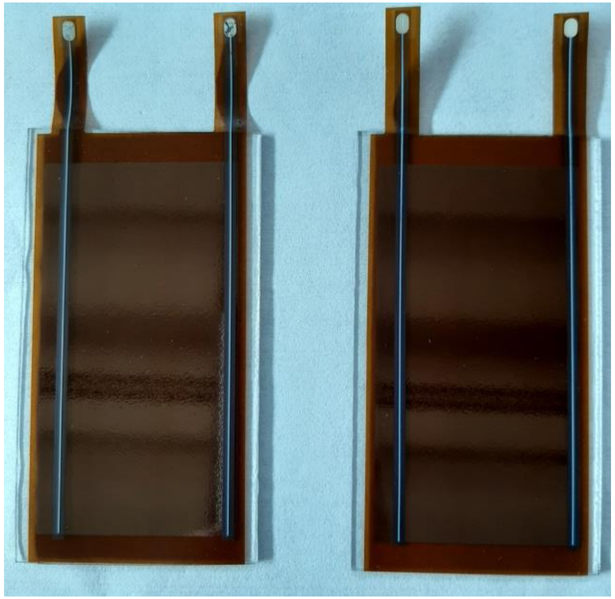


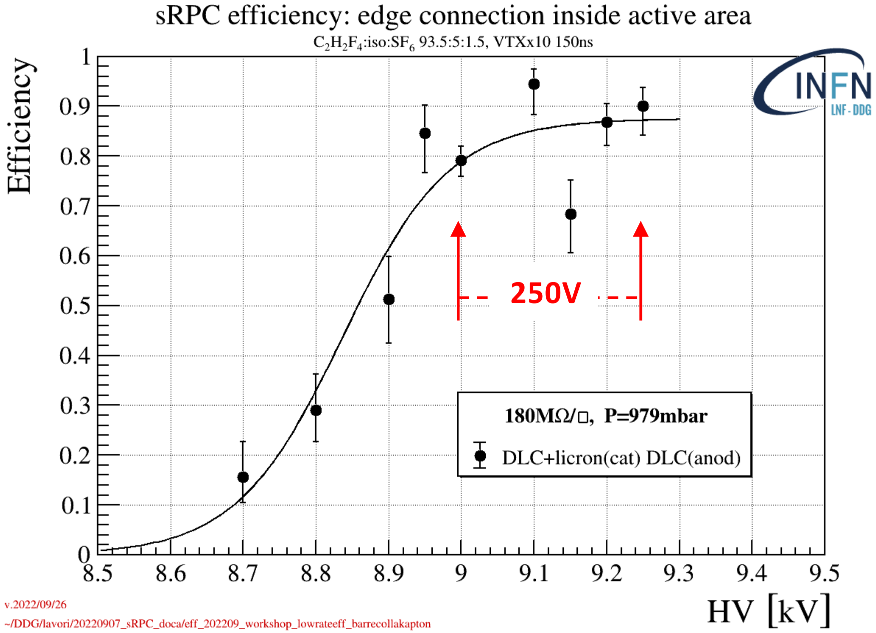
Low-rate: DLC sputtered **on Apical® foil** then **glued** on **2 mm thick float glass**

The **conductive grid** is realized by **0.3 mm wide silver screen-printed lines.** A **5 mm wide solder-mask** strip deposited **on the silver lines** ensures the **insulation. Width** and **thickness** of the **solder-mask** still **to be optimized.**

High-rate layout (I)



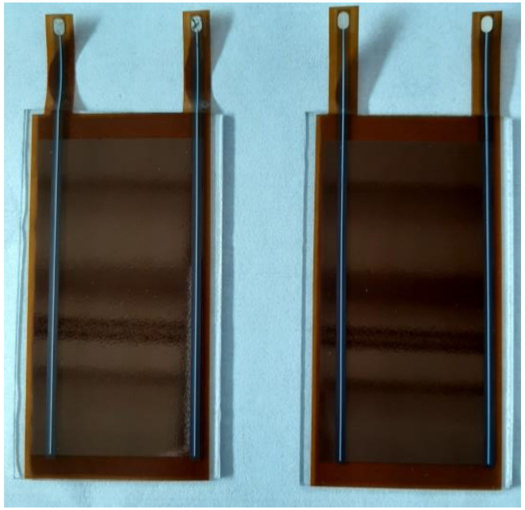




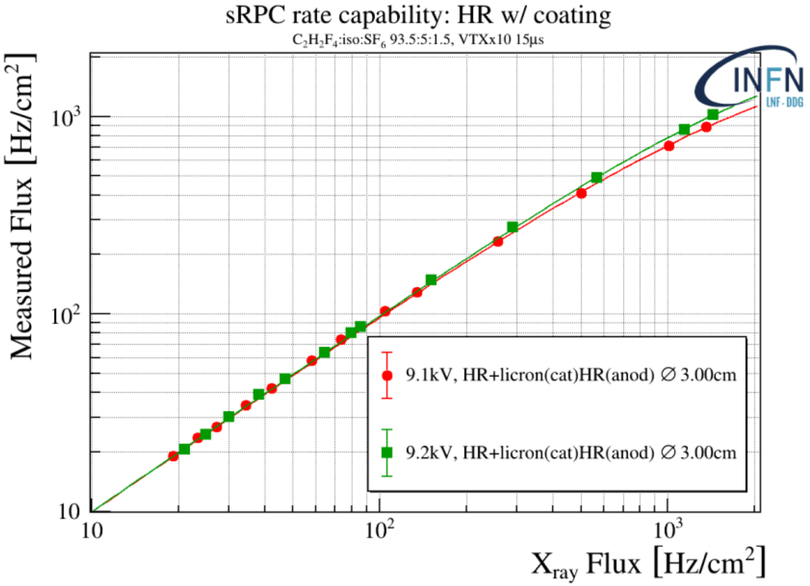
The implementation of **conductive lines** on the DLC, even though protected with **solder-mask**, seems to introduce an **instability at higher voltage,** sensibly **reducing the plateau width wrt the baseline** version.
The problem is still to be solved, discussion about solder-mask characteristics is in progress.

High-rate layout: preliminary rate capability

A preliminary measurement of the **rate capability** *(defined as the radiation flux corresponding to an efficiency drop of 20%)* of the **high-rate layout** has been performed by irradiating the detector with **a 5.9 keV X-ray gun** with a **spot size comparable with the pitch of the conductive grid** realized on the **DLC** (ρ_{DLC}~200 MΩ/□).



Layout still to be optimized (resistivity, grid-pitch, insulation …)



Rate capability of ~**1 kHz/cm² with X-ray,** corresponding to ~ **3 kHz/cm² m.i.p.**

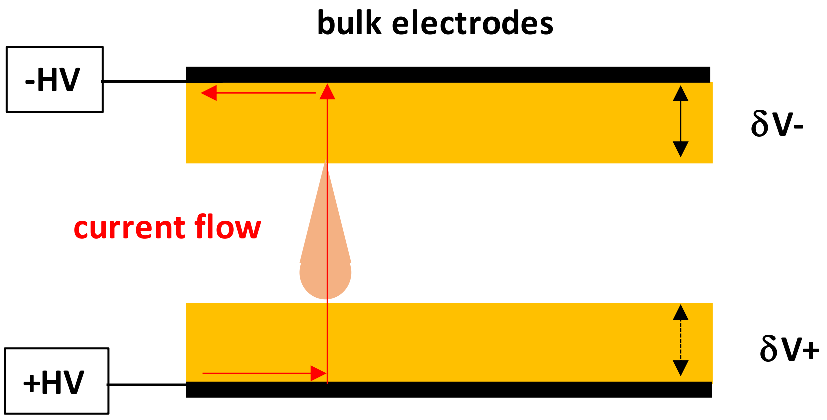
Summary

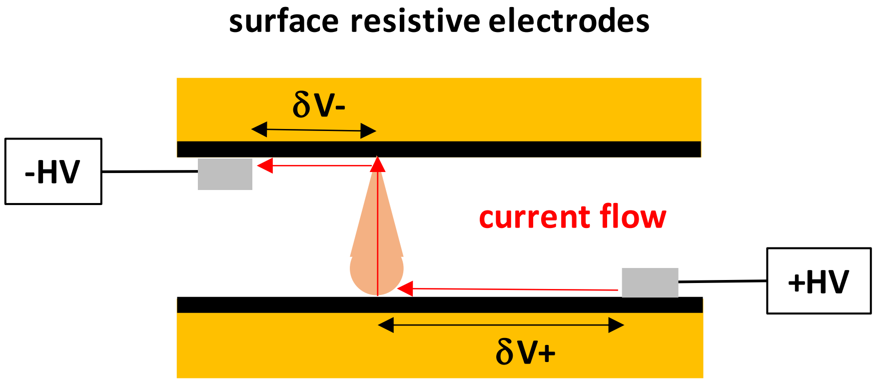
By exploiting the technology based on the **industrial DLC sputtering procedure** developed for **resistive MPGDs** we realized **electrodes** with **different surface resistivity** for a **new promising RPC concept**

- The **baseline version** of the detector (*dot-like HV connection* ⊕ *cathode passivation with Licron*) exhibits **high stability (ΔV ≥ 1kV)** and **good performance** in terms of **efficiency (~95%)** and **time resolution (~1 ns)**
- The **High-rate** version based on **current evacuation** schemes realized **with conductive grids** shows **some instability,** while a **rate capability** of **~3kHz/cm^2** with **m.i.p,** has been measured
- Detector **stability** (*grid insulation and geometry …*) and **optimization** studies in terms of **DLC resistivity, grid-pitch** (…) are the **priorities** for the near future
- **Engineering** studies, replacing glass support with **standard PCB** (SBU tech.)
- **The DLC** sputtering process is a **scalable technology** allowing to realize **large area electrodes at low cost:** the **CERN-INFN DLC** sputtering facility allows the manufacturing of ~**2x0.5 m DLC foils**

SPARE SLIDES

Bulk-RPC vs Surface-RPC





$$\tau = f(\rho_b, \varepsilon_r, d, g)$$

$$\tau = f(\rho_S, p, \dots)$$

DLC-DLC vs DLC-float_glass layout

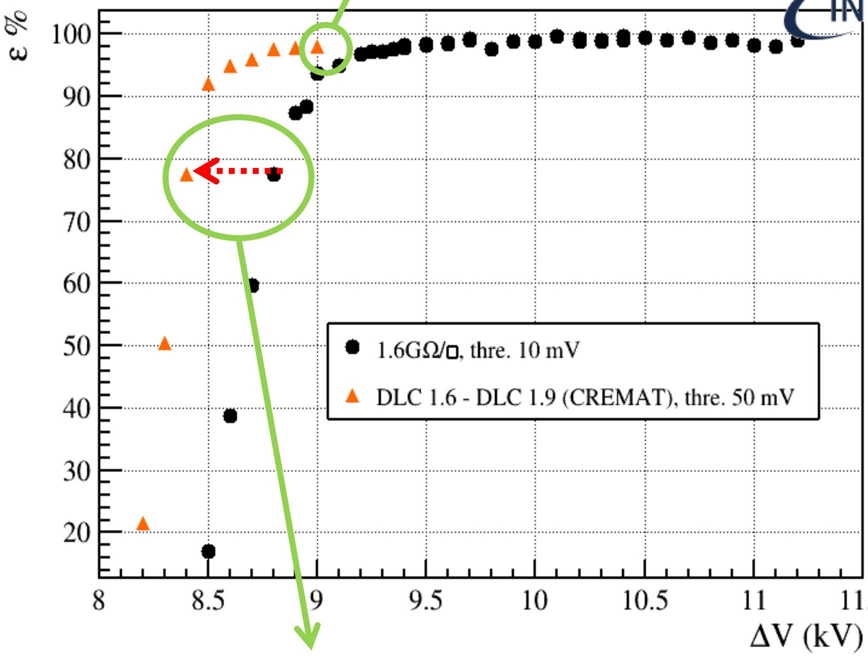
Symmetrical

- **DLC (anode) – DLC (cathode)** electrodes shows **instability at high voltage**
- possible **photon-feedback or/and field emission effects** on the **DLC surface** of the cathode
- with more sensitive electronics **few hundreds of Volts of stable operation can be found**

Hybrid

- **DLC (anode) – float glass (cathode)** electrodes shows high stability (plateau larger than to 2 kV)
- **Float-glass cathode** does **not** suffer of **photon-feedback or field emission effects**
- **not a solution for high-rate** because limited by the relatively **high resistivity of the float-glass**

onset of the **DLC-cathode instability**



CREMAT 110 fee lowering the operating point

Time resolution