The Well (micro-WELL) Electron Multiplier with the DLC anode – a key element of the robust and fast 2D-position sensitive MPGD

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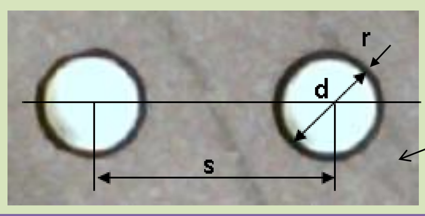
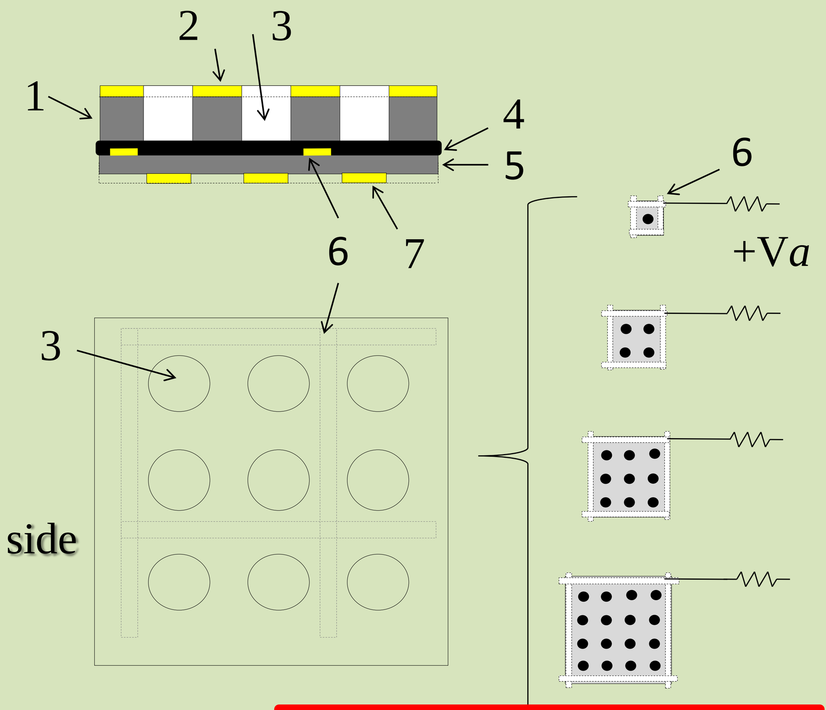
Design details



s=500 μm, d=200 μm, r~15 μm
Thickness 500 μm (FR4)

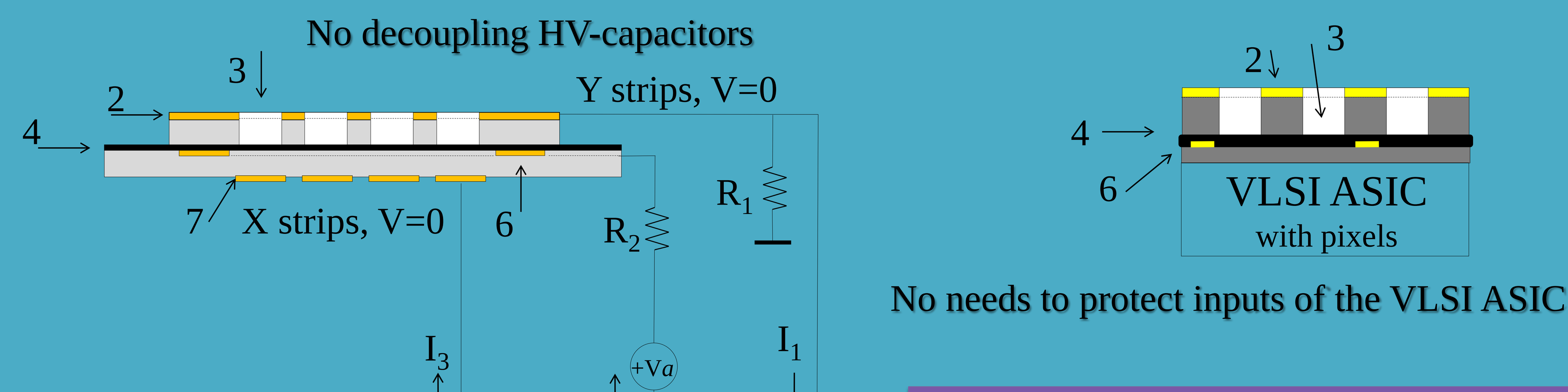


1 Dielectric substrate with Copper on one side
2 1-st electrode (cathode)
3 Well-like hole
4 DLC layer (anode)
5 Dielectric substrate with Copper on one or both sides
6 2-nd electrode (Copper mesh)
7 3-rd electrode (strip/pixel readout)

Configurations for mesh surrounding 1 hole, 4=2×2, 9=3×3 and 16=4×4 holes

2D Readout Schemas

XY-strip readout — **Pixel readout**



No needs to protect inputs of the VLSI ASIC

2 1-st electrode (cathode,Y-strips)
4 DLC layer (anode)
6 2-nd electrode (Copper mesh)
7 3-rd electrode (X-strips or pads/pixels)

Achievements:
Low material budget X/X0 ~ 0.1% [1, 2]
Rate capability ~ 10^7 Hz/cm² [3, 4]
Spatial resolution σ_{XY}~70 μm [5]

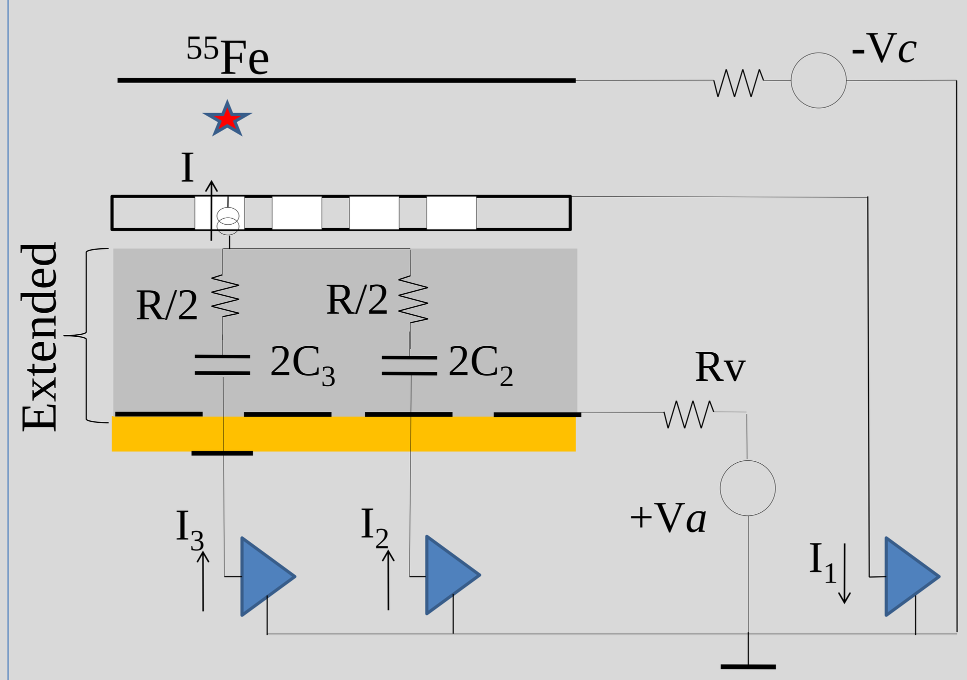
Fundamental Requirements to Robust Operation

- Choice of resistive material for the anode is crucial for discharge-free operation, robustness against discharges and for the rate capability.
- Charge produced by an avalanche process in the well-like holes bombards resistive anode.
- Electro-thermal breakdown in the resistive layer occurs at high gas gain above 10^4. The breakdown is very complicated and influenced by many factors.
- Our goal is to check a robustness of the WELL (μ-WELL) Electron Multiplier with the thin DLC film.

The WELL (μ-WELL) Electron Multiplier – Operational Principles

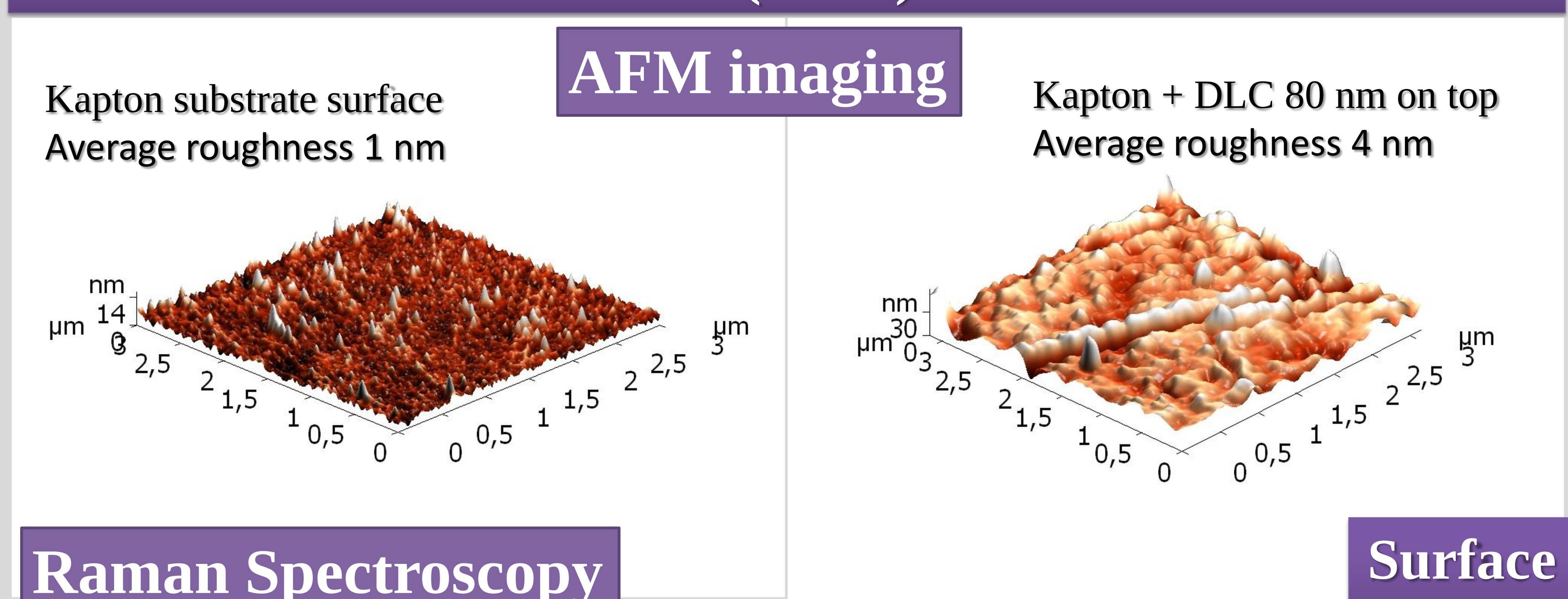
- The WELL (micro-WELL) detector operates without induction gap combining GEM/THGEM and RPC concepts.
- Gas mixture used in the test is Ar/CO2 (90/10) at 1 bar pressure and room temperature.
- In contrast to GEM/THGEM the capacitance per unit of area between the 1-st and 2-nd electrodes is separated by large R and reduced significantly.
- As shown (*right*), the DLC film as RC-system is considered as R and C connected in series, where R is the surface resistance and C is the "local" capacitance normalized to one hole: C_2 from the top of DLC to the 2-nd electrode,
C_3 from the top of DLC to the 3-rd electrode.
- Arrows show how the current flow, $I_1 \approx I$ and $I_1 = I_2 + I_3$.

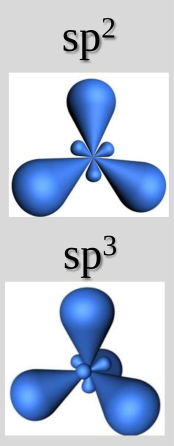
Detector assembled for test



Diamond-Like-Carbon (DLC) film characterization

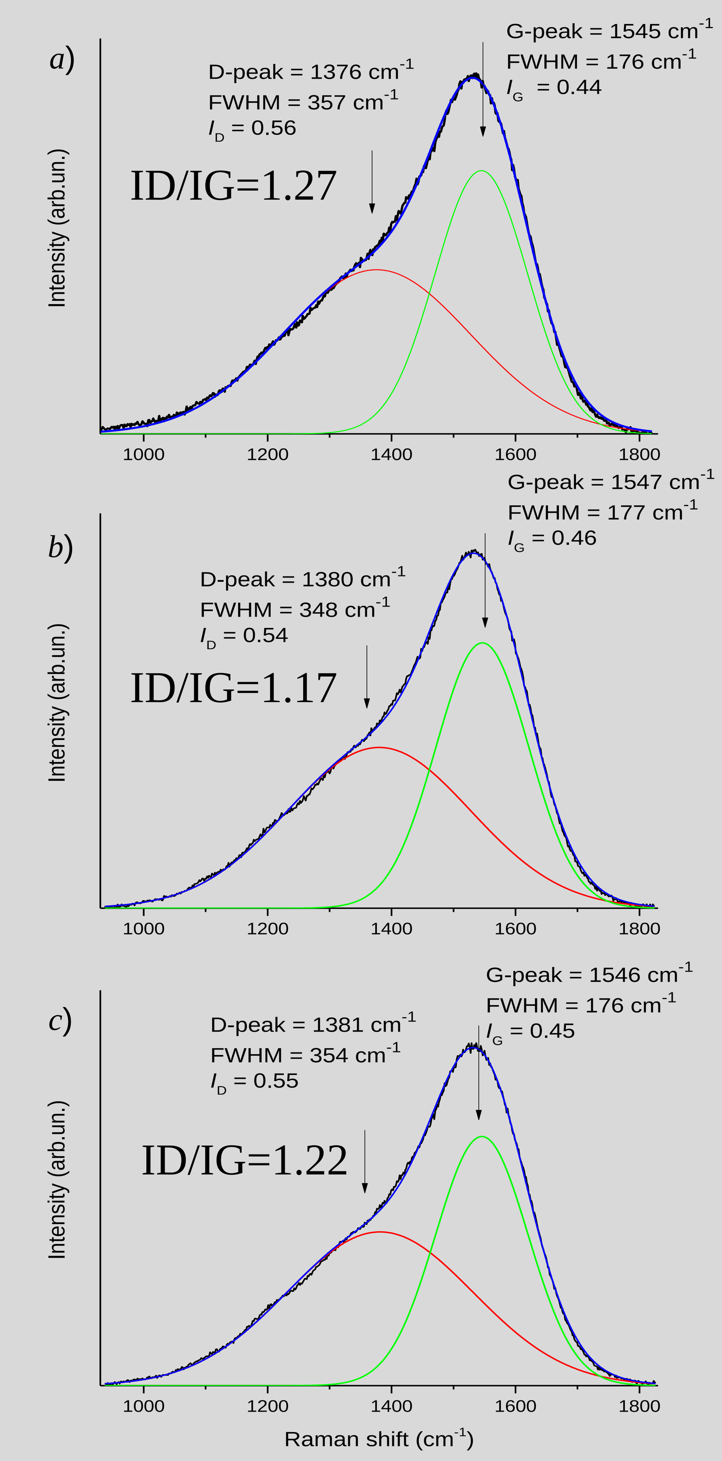
AFM imaging



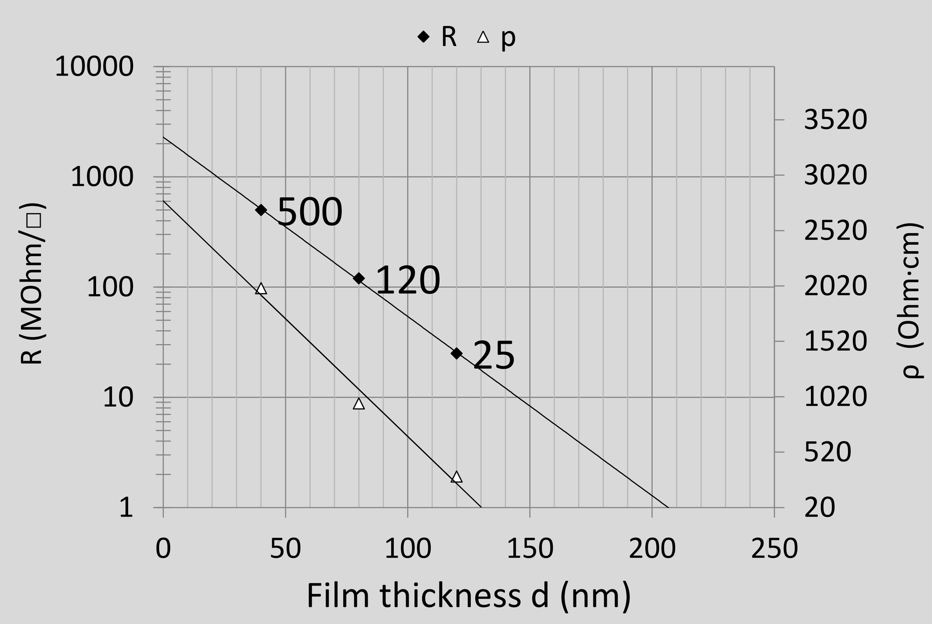


Raman Spectroscopy

- DLC structure can be estimated from spectra of light scattering deconvoluted into two Gaussians around 1540-1570 cm^{-1} (G-peak) and around 1370-1390 cm^{-1} (D-peak).
- The ratio of the peaks indicated with arrows, ID/IG, gives the most important information of sp3 (Diamond-like) and sp2 (Graphite-like) bonds content in DLC films.
- Information about quality but not about quantity.
- The smaller the D-peak, the better DLC film quality in the respect of diamond-like performances.
- As shown below the ratio sp3/sp2 ≈ 50% in our samples of films, prepared for the experiment with thickness of 120 nm for three configurations of mesh surrounding 1 hole (*a*), 4=2×2 (*b*) and 9=3×3 (*c*) holes on the anode substrate.

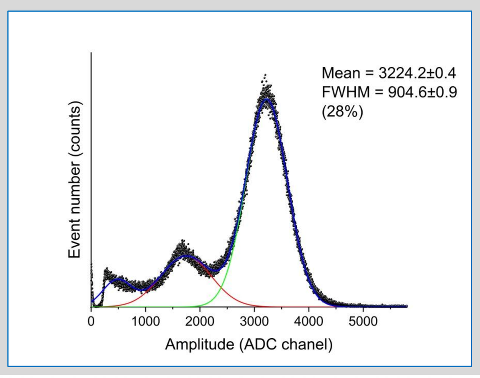


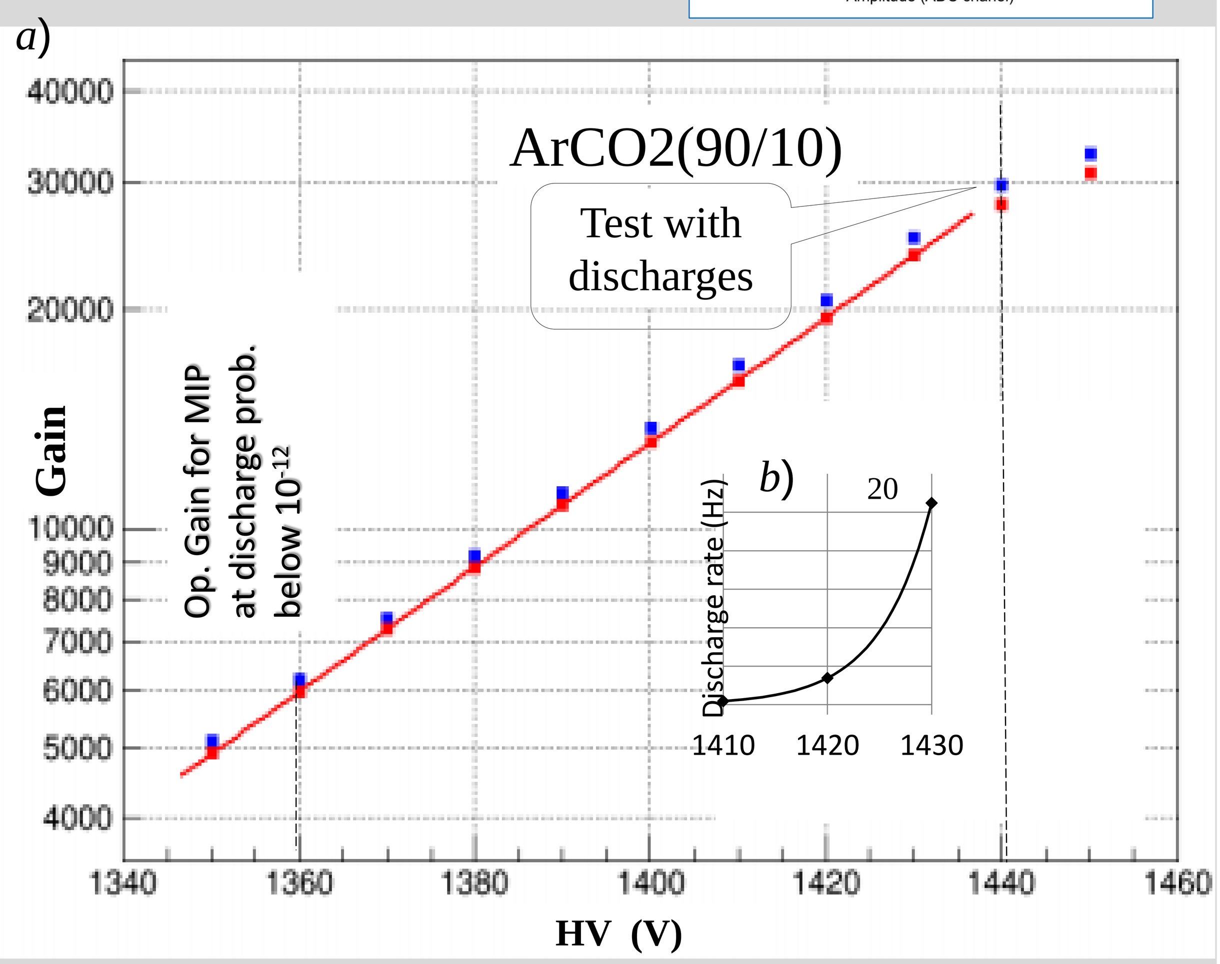
Surface resistance R (MOhm/□) and bulk resistivity ρ (Ohm·cm)



Gas Gain and Discharge Rate vs HV

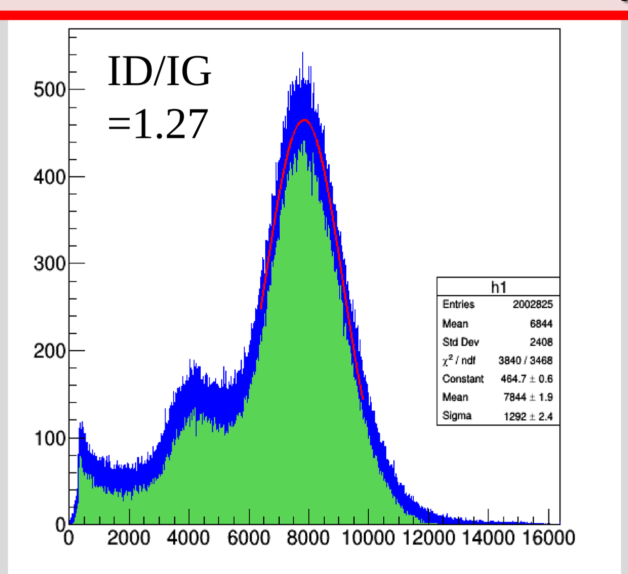
- Amplitude spectrum from ^{55}Fe (peak 5,9 keV and 3 keV escape) with resolution 28% was measured at gas gain 30,000 (*right*).
- Gain (*a*) and discharge rate (*b*) *vs* voltage. Measured relations allow to estimate the discharge probability at operational gain for MIP of 5000 to be about 10^{-12}.

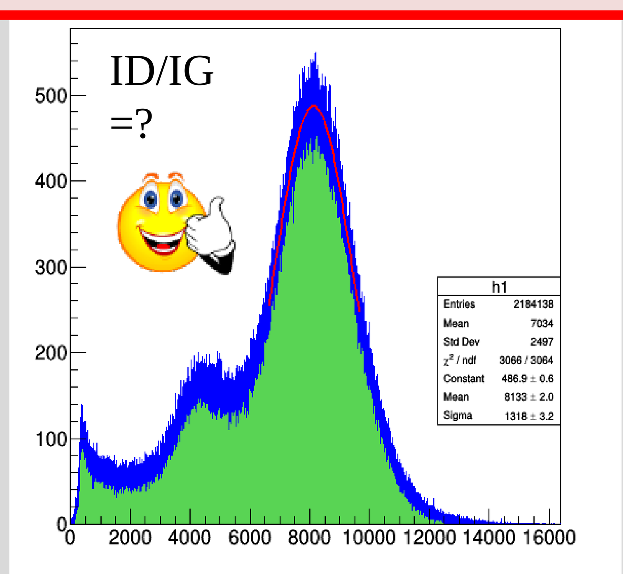




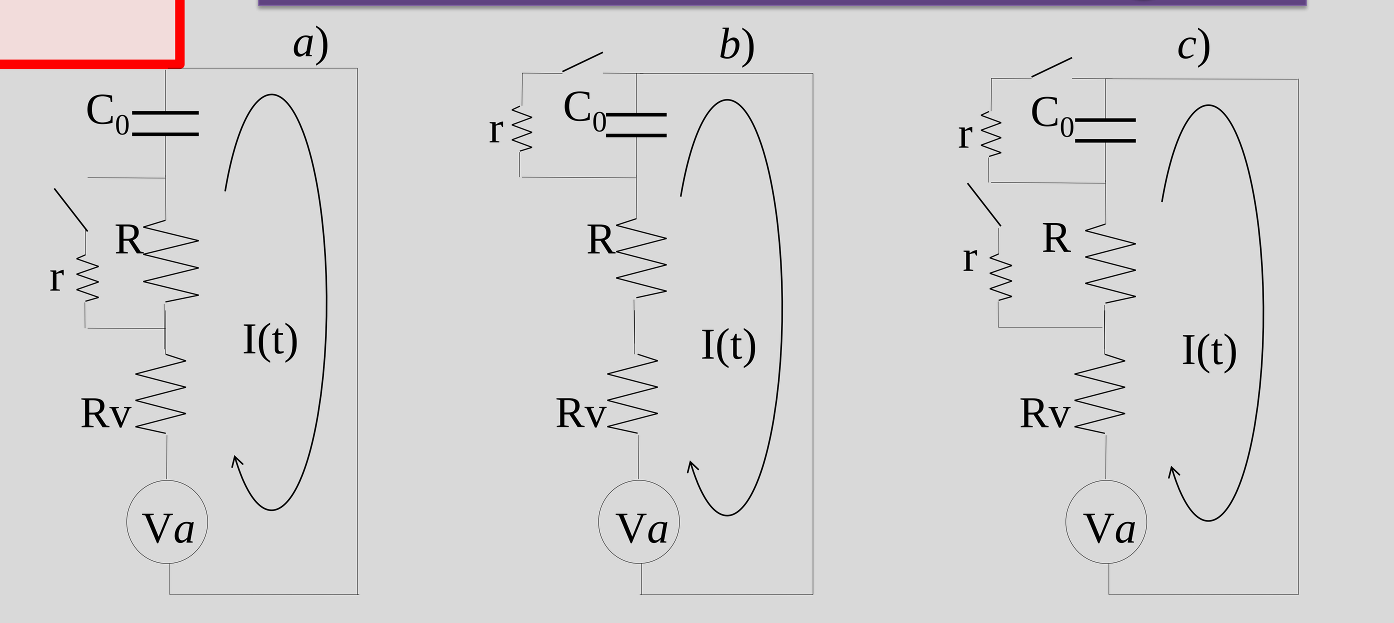
Test for Robustness Against Discharges

- The WELL-detector for the test has been prepared with the DLC anode at thickness of 120 nm and with the Copper mesh surrounding 1 hole.
- Two amplitude spectra from X-ray source ^{55}Fe are compared at the end of the test.
- First one (*left spectrum*) accumulated at the beginning of the test at switching on HV at the gas gain about 30,000 and discharge rate in a range of 10-30 Hz (micro-Amps).
- Second one (*right spectrum*) was accumulated (similar statistics) after one day of continuous operation with same conditions - the number of discharges during the day was estimated as approximately ~0.5 millions.
- Three scenario at discharges are presented below: *a*) discharge in the DLC - large resistance R becomes small r; *b*) discharge in the hole in gas – capacitor becomes r; *c*) discharge in both media simultaneously.
- In cases *a*) and *b*) current I(t) in a range of nano-Amps; in case *c*) I(t) ≈Va/Rv – micro-Amps.
- One can conclude that no difference in the shape of two spectra.
- No visible damages was found on the electrodes.
- The detector continues to work correctly.





Three Scenario at Discharges



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