RPC with Gallium Arsenide electrodes, a solution for medium sized high-rate detectors

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DETECTOR DESCRIPTION

✓High Rate RPC

$$V_{gas} = V_{gen} - \rho d \bar{Q} \phi$$

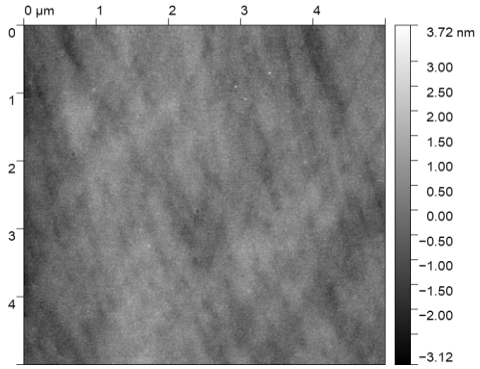
State of the art: $\bar{Q} \sim 6\ pC$; $Q_{th} \sim 2 - 4\ fC$; **d=1.25 mm;** $\rho \sim 10^{10}\ \Omega\ cm$;

-> ϕ ~7 kHz/cm²

ϕ ~1 MHz/cm²

The HPL electrodes guarantee stable operation up to a total integrated charge of 0.3 C/cm² **--> Effective rate capability significantly limited by the experiment lifetime and background radiation**

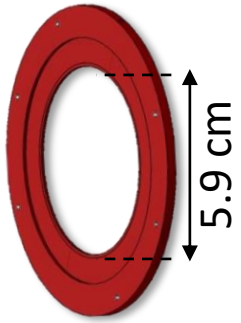
Material	Semi Insulating undoped GaAs
Thickness	$640 - 643; \mu m$
Diameter	$3''$
Resistivity	$1.4 \times 10^8\ \Omega cm$
Surface treatment	both polished
Growth method	VGF
Orientation	$(100) \pm 0.01°$
Mobility	$5300\ cm^2/Vs$



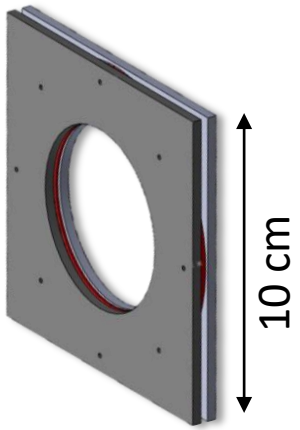
A new material immune to the ageing effect should improve the effective rate capability of a factor ten, just with $10^{10}\ \Omega cm$ resistivity

Thanks to Prof. M. Lucci for the GaAs metallization

Wafers spacer 1 mm

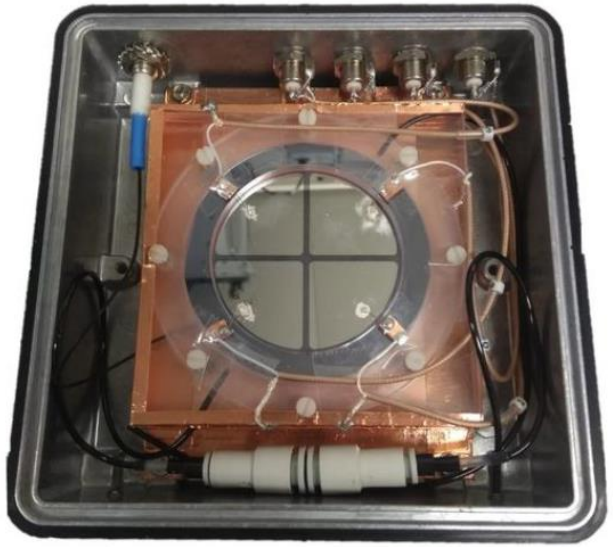


Wafers holder



Voltage supply	3–5 Volt
Sensitivity	2–4 mV/fC
Noise (independent from detector)	4000 e^- RMS
Input impedance	100–50 Ohm
B.W.	10–100 MHz
Power consumption	10 mW/ch
Rise time $\delta(t)$ input	300–600 ps
Radiation hardness	1 Mrad, 10^{13} n cm^{-2}

Gas inlet ø 2 mm -> ø 0.6 mm



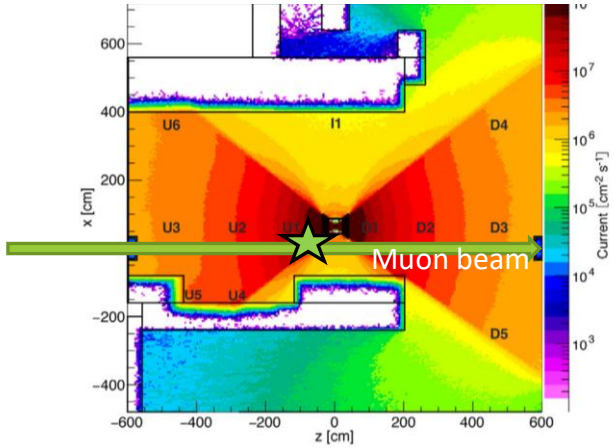
Wafers sputtering holder

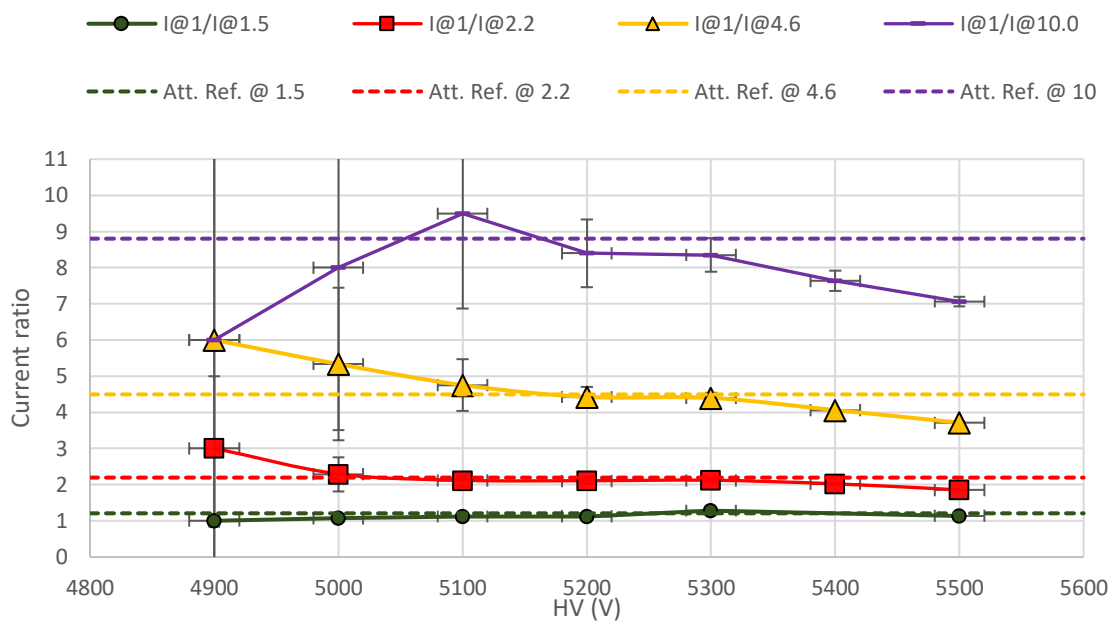
[R. Cardarelli et al, "Performance of RPCs and diamond detectors using a new very fast low noise preamplifier"]

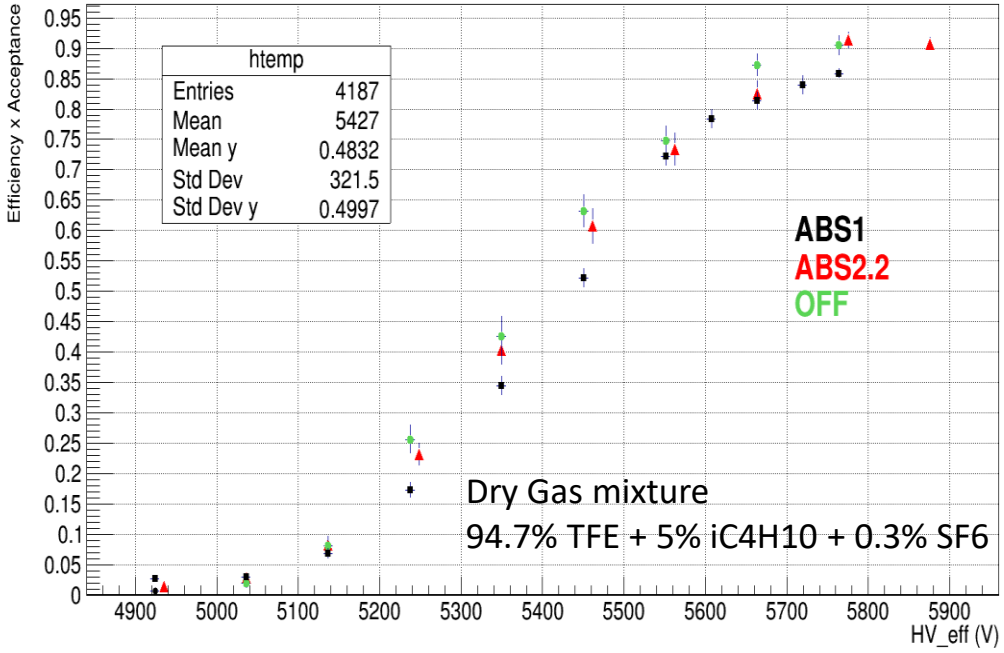
HIGH-RATE TESTS

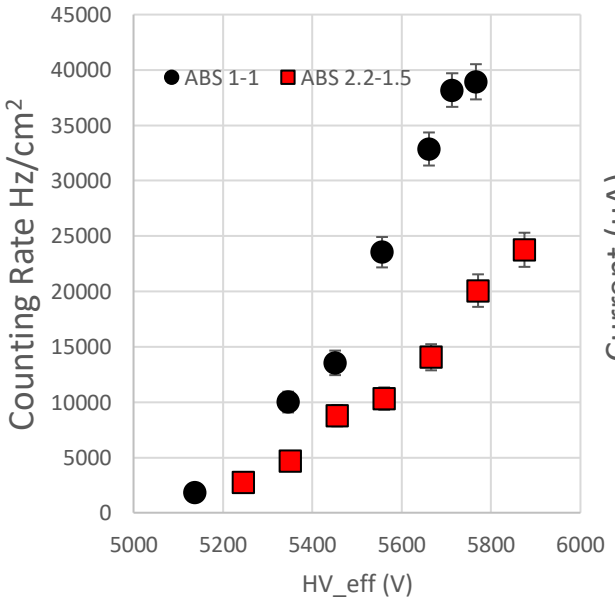
The rate capability was measured at GIF ++ at CERN. The detector efficiency response is constant up to the maximum observable flow at the Facility.
The maximum counting rate measured is 39 kHz/cm$_2$, a value consistent with the photon current if we consider a photon conversion efficiency approximately 1-2‰

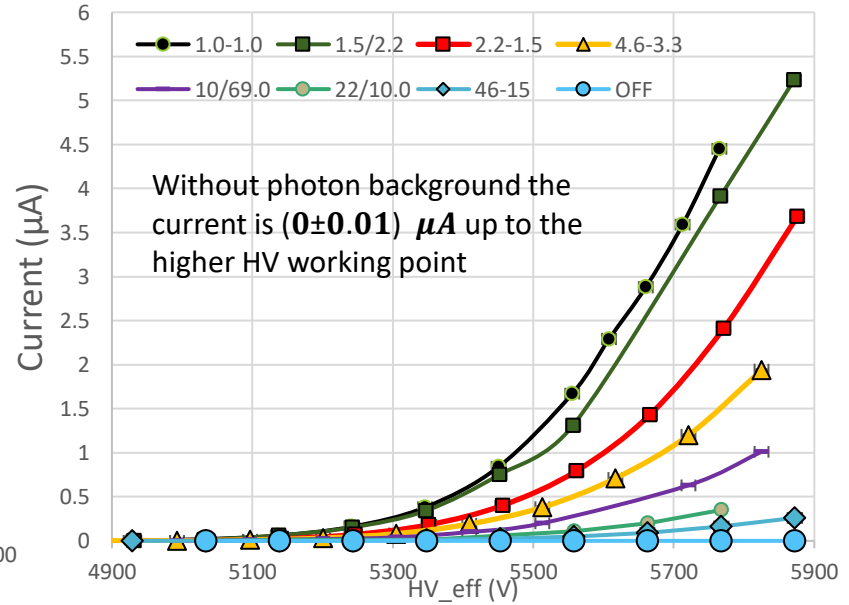
The measured attenuation of the source is consistent with the reference values





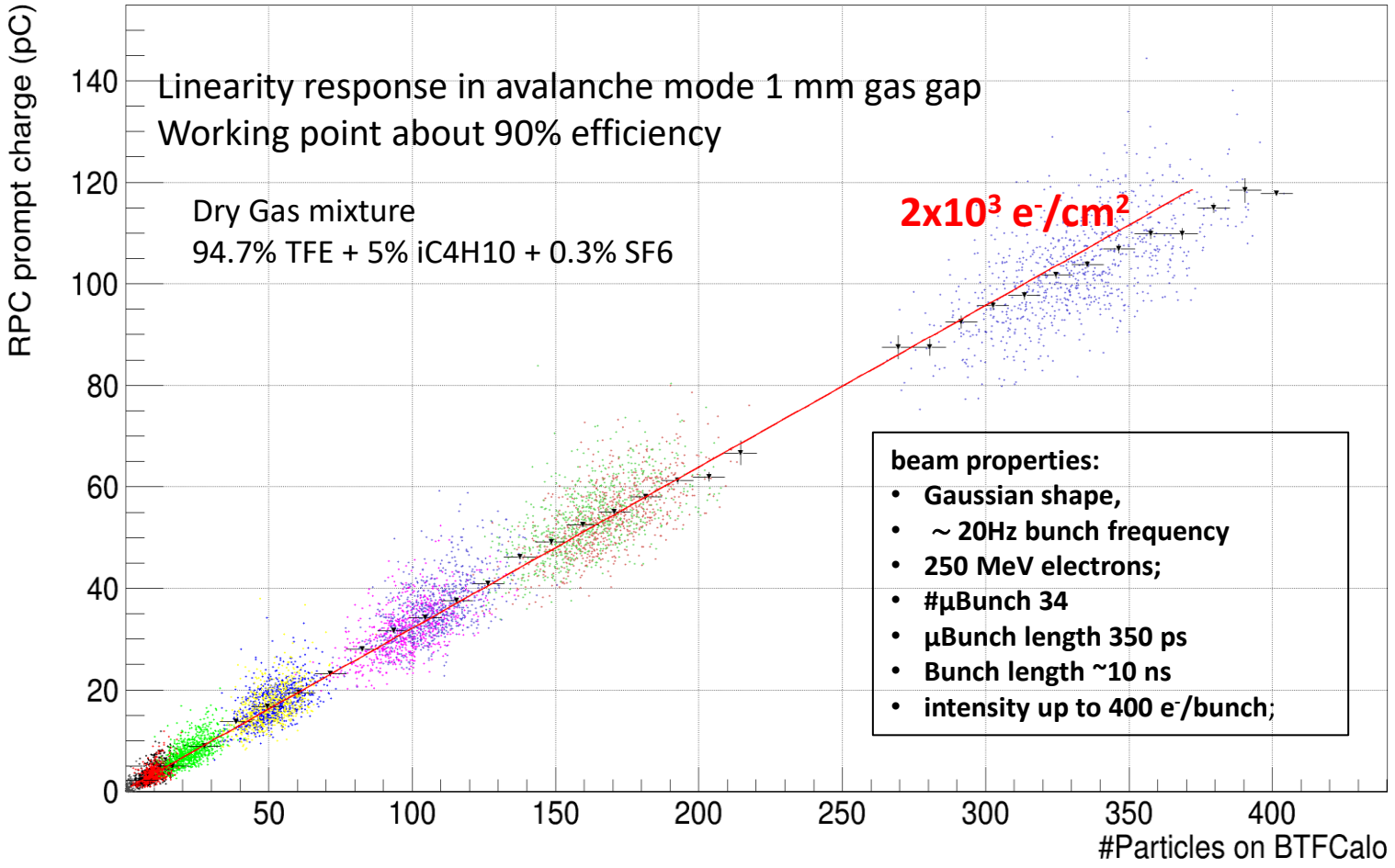






BUNCHED PARTICLES RESPONSE:

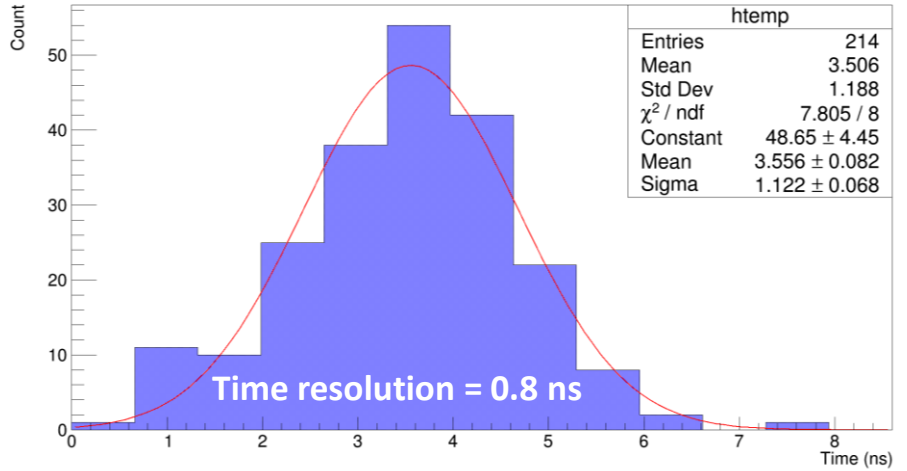
LINEARITY AND TIME RESOLUTION



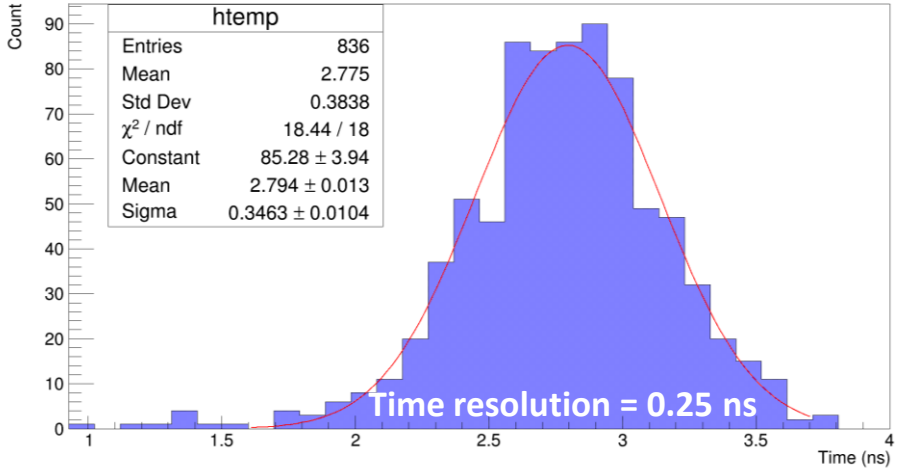
Time resolution with bunched particles improves as

$$\frac{1}{\sqrt{synchronous\ particles}}$$

1 e⁻/bunch



~300 e⁻/bunch (10 e⁻/µbunch)



[B. Buonomo, G. Mazzitelli and P. Valente "Performance and Upgrade of the DAFNE Beam Test Facility (BTF)"]

[A. Rocchi et al "Linearity and rate capability measurements of RPC with semi-insulating crystalline electrodes operating in avalanche mode"]

Conclusions

- The functionality of the detector has been extensively demonstrated: thanks to the **high sensitivity of the FE electronics** and to the **surface quality of the new GaAs wafers** the detector is stable up to full efficiency.
- The detector **performance is constant up to the maximum photon flux available at the GIF ++** facility, and the maximum counting rate **measured** is **39 kHz / cm^2** (**about 1-2 ‰ photon efficiency**).
- **Negligible random counting rate, negligible dark current**

Open question:

- What changes in the physics of the detector when passing from an amorphous electrode to a semiconductive crystal?
- What role does electron mobility play?
- Does the resistivity of the electrode change with irradiation?
- What is the maximum rate capability of the detector?
- What is the aging damage of the detector?

Costs

3-inch Undoped GaAs wafer about 100 $/pz, 6-inch Undoped GaAs wafer about 200 $/pz.

Electrode sputtering?