RPC physic and performance v.s. low threshold

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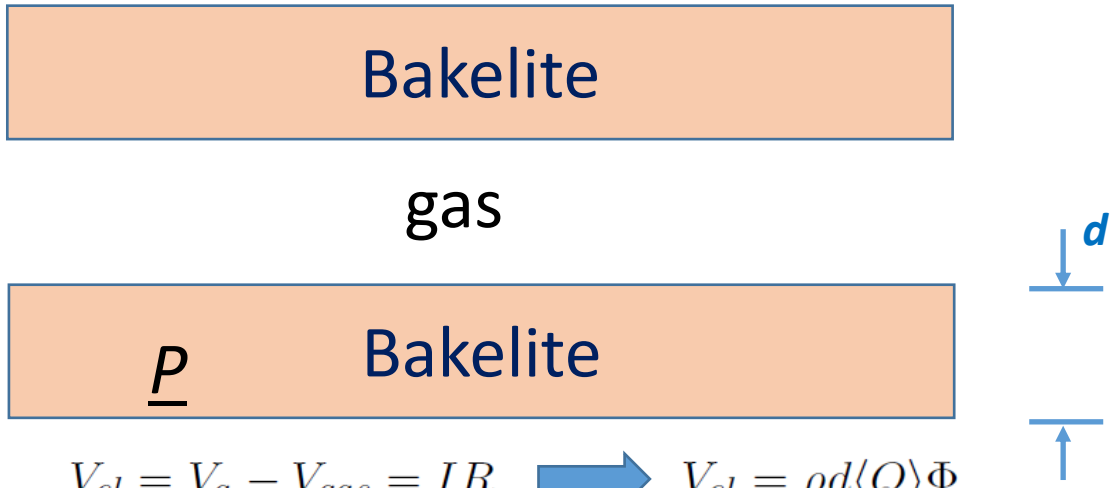
Introduction

- New high-energy experiments in accelerator machines require particle detectors to have high counting capabilities, high time resolution and high spatial resolution. These requests have a major impact on the design of gas detectors and on the electronic front end
- Increasing the counting capacity implies moving the amplification from the gas to the electronics which must have high gains and very low noise
- Increasing the time resolution requires very rapid multiplication processes in the gas, very intense electric fields, fast electronics and the measurement of the signal Amplitude for the correction of the rising time

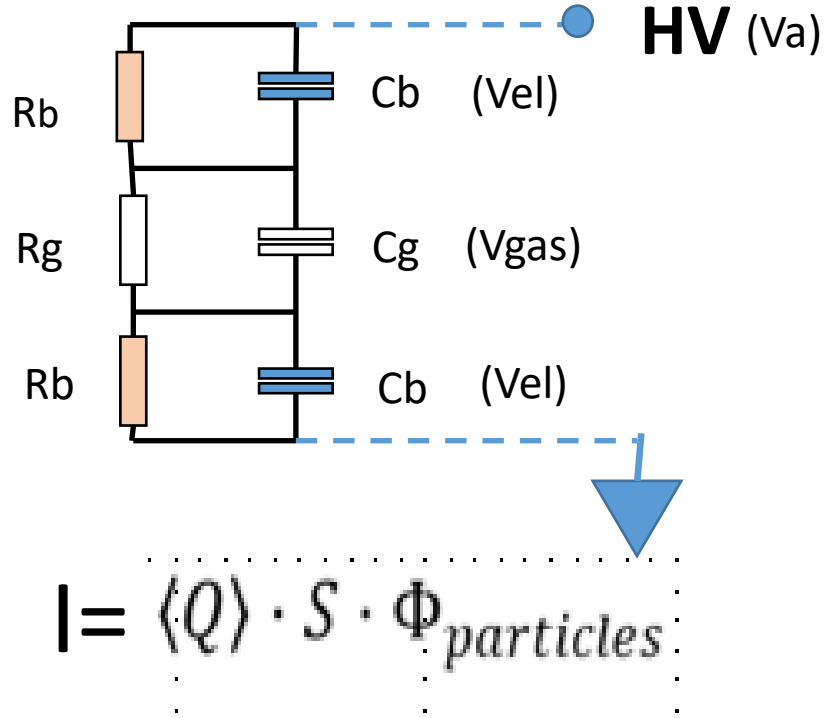
Drop voltage in the Bakelite and gas average current



$$V_{el} = V_a - V_{gas} = IR \Rightarrow V_{el} = \rho d \langle Q \rangle \Phi$$

$$V_{gas} = V_a - \rho \cdot \frac{d}{S} \cdot \langle Q \rangle \cdot S \cdot \Phi_{particles} = V_a - \rho \cdot d \cdot \langle Q \rangle \cdot \Phi_{particles}$$

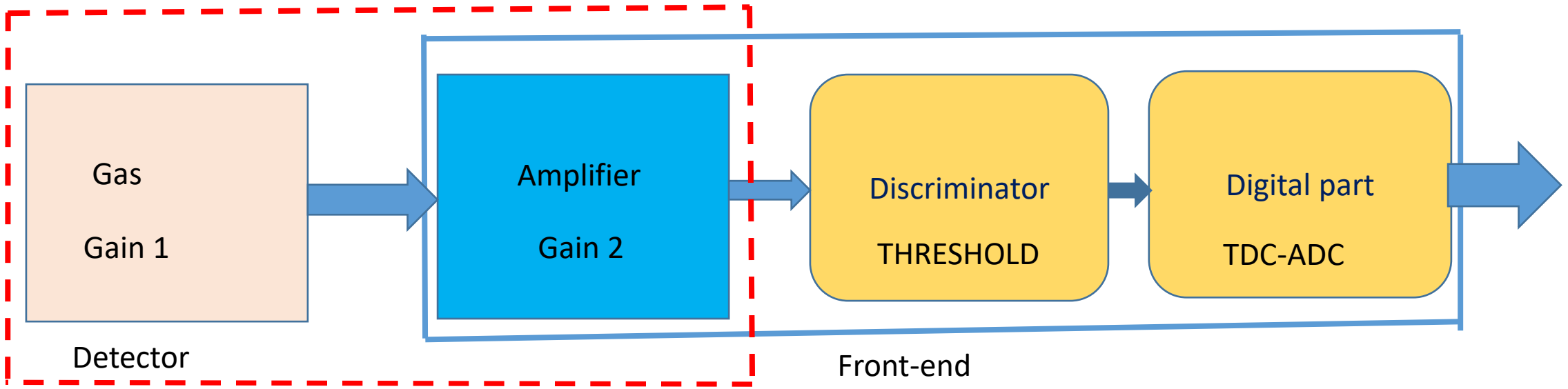
$$RateCapability = \frac{\Phi}{V_{el}} = \frac{1}{\rho d \langle Q \rangle}$$



$$I = \langle Q \rangle \cdot S \cdot \Phi_{particles}$$

Diagram of Front-end

- Basic concept to move the gas gain to the amplifier gain to degrease ‹Q›



Gas and amplifier gain v.s. RPC working mode

Gain gas	**RPC working mode**	Ga**in amplifier**
• High gain	Streamer	low gain
• Medium gain	saturation avalanche	medium
• Low gain	avalanche	high

Increase amplifier gain decrease the average charge in the gas and increase the RPC rate-capability

Minimum possible threshold

Once induced and self-induced noises have been eliminated, the number of spurious signals produced by the discriminator are:

- $V_{th}=n\sigma$ $F = P(n\sigma)*BW$
- **F** frequency of false pulses discriminator from noise
- **P(nσ)** probability of having a higher tension (n * sigma noise)
- **BW** passband amplifier

Problem to transfer the gain to the amplifier

- Amplifier parameter:

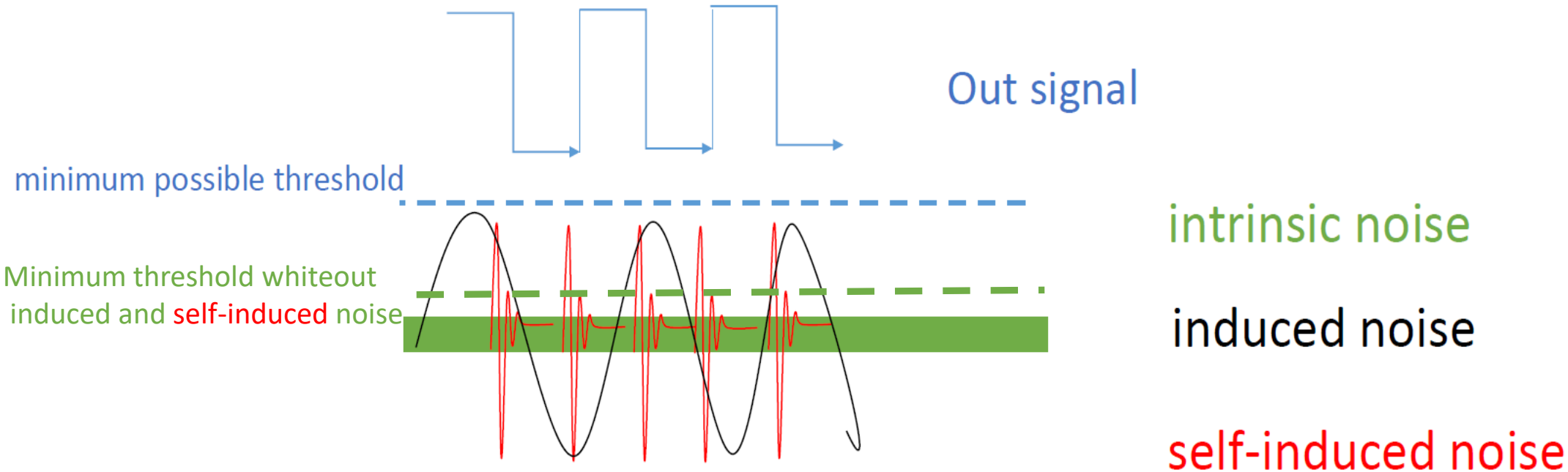
1) Amplification
2) Dynamic
3) Noise

The limit to transfer the gas gain to the amplifier gain is the noise of the amplifier.

- We have tree type of noise :

1) Intrinsic noise (like thermal, 1/f, shot ……)
2) Induced noise (Very large in big dimension)
3) Self induced noise (Low Impedance)

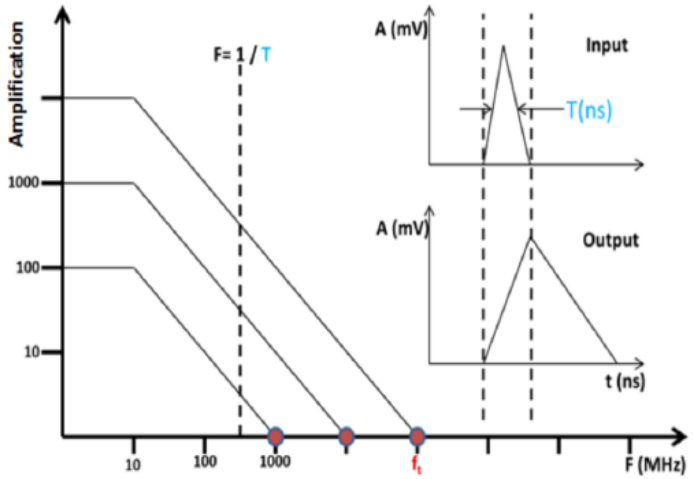
Forms of the different types of noise



The noise

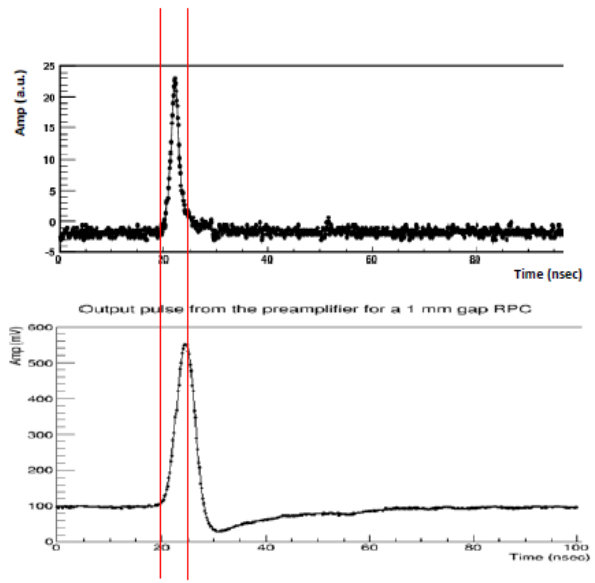
- The intrinsic noise is characteristic of the transistor and the circuit diagram
- The **inducted noise** can be reduced by the Faraday cage
- The **self induced noise** can be reduced by integrating front-end electronics and the detector
- The **intrinsic noise** is the ultimate parameter limiting the low threshold operation in RPCs and gaseous detectors in general

Strategy for the new front-end (SiGe)

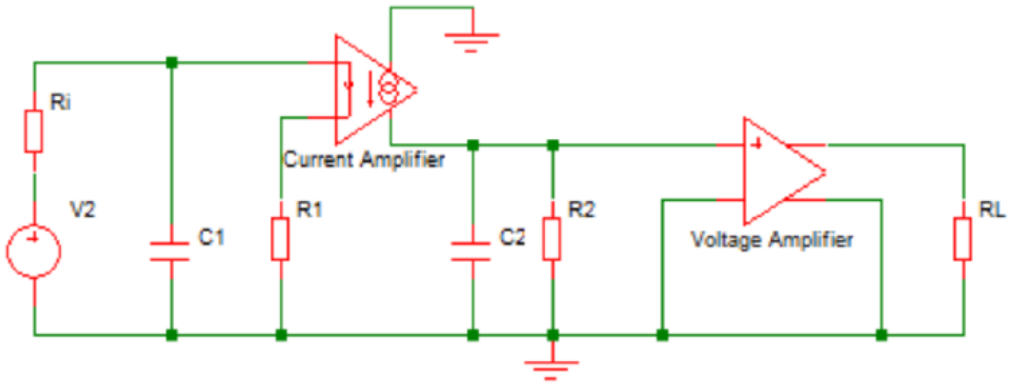


Working strategy

Actual result for the RPC signal



The block diagram of the preamplifier



0,2-0,4

The same scheme can be used for both Silicon and SiGe technology for a comparison.

Silicon technology

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}

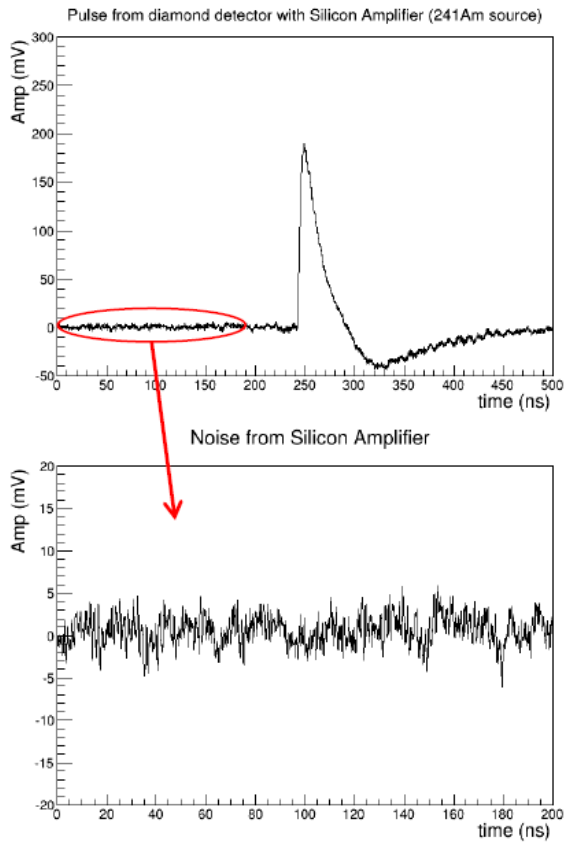
SiGe technology

Voltage supply	2–3 Volt
Sensitivity	2–6 mV/fC
Noise (independent from detector)	200 e^- RMS
Input impedance	50–200 Ohm
B.W.	30–100 MHz
Power consumption	2 mW/ch
Rise time $\delta(t)$ input	100–300 ps
Radiation hardness [4]	50 Mrad, 10^{15} n cm^{-2}

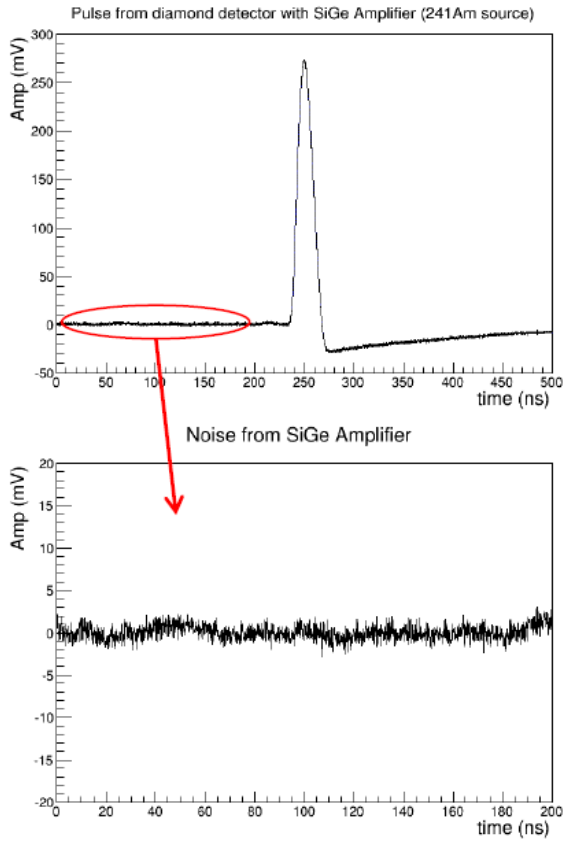
Signal and noise from SiGe Amplifier and Silicon Amplifier

Pulses recorded from a 500 micron diamond sensor irradiated by ^{241}Am source.

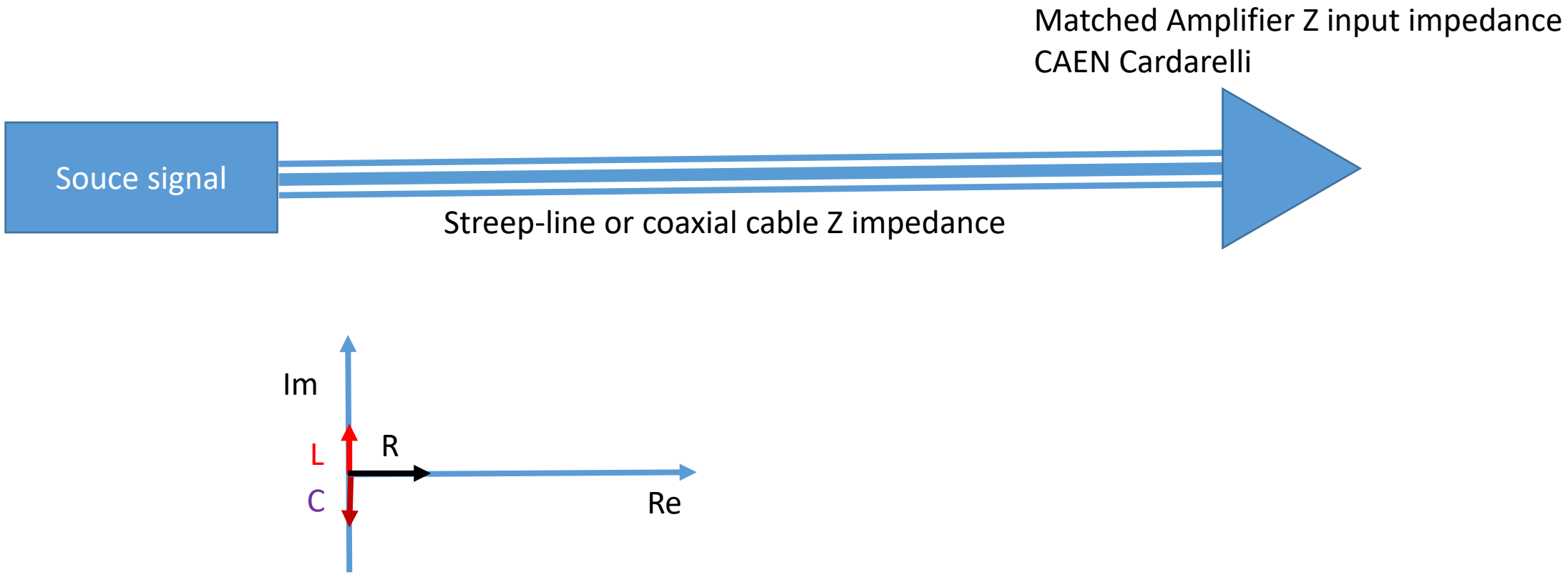
Silicon amplifier



SiGe amplifier



Neutralization capacitance of pick-up



Actual threshold in ATLAS RPC

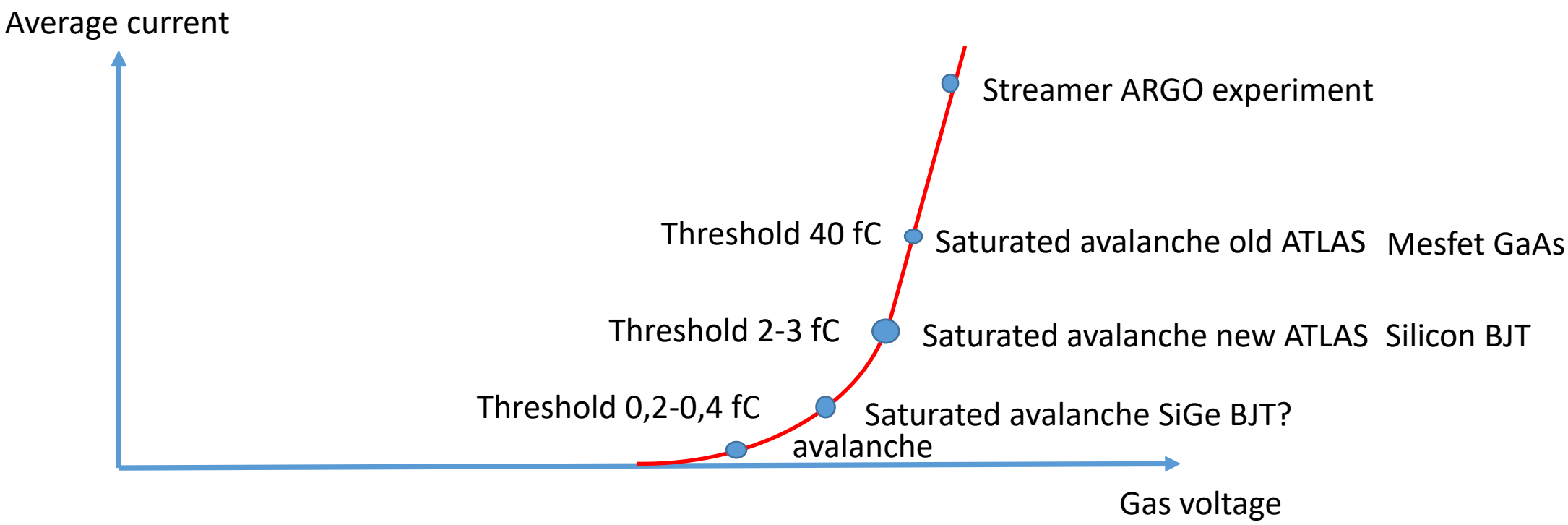
- For the amplifier we have chosen BJT silicon transistors in trans-impedance diagram, the performances are:

	Silicon BJT		SiGe BJT
		working in progress collaboration with Ginevra University	
Amplification	10-100		
BW	100MHz		
Intrinsic noise	**4000 e- RMS**	Next	**100-200 e- RMS**
Power	1mW		
Input impedance	50-100 ohm		

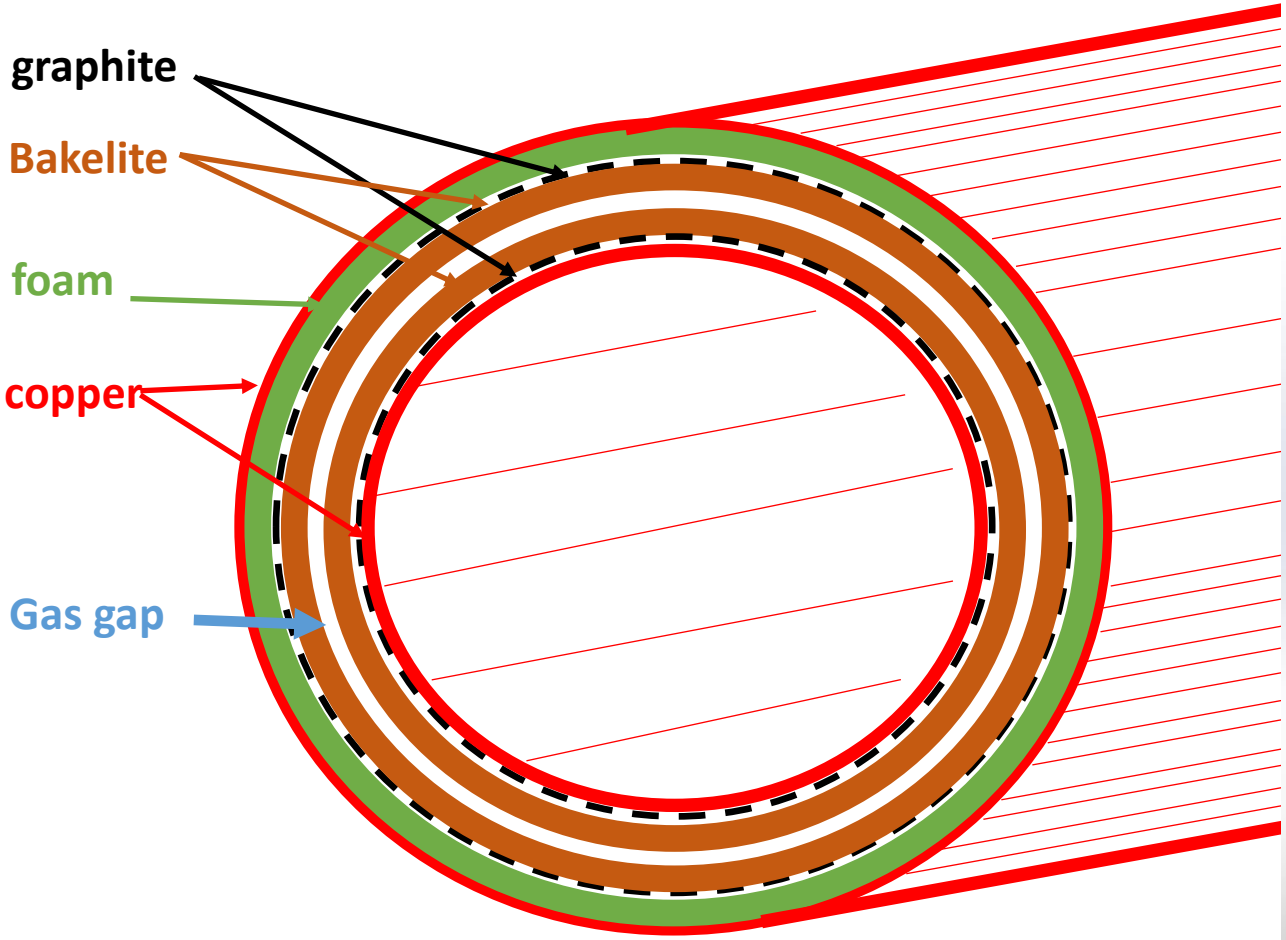
Performance obtained with our discriminator (L. Pizzimento's Ph.D. thesis)

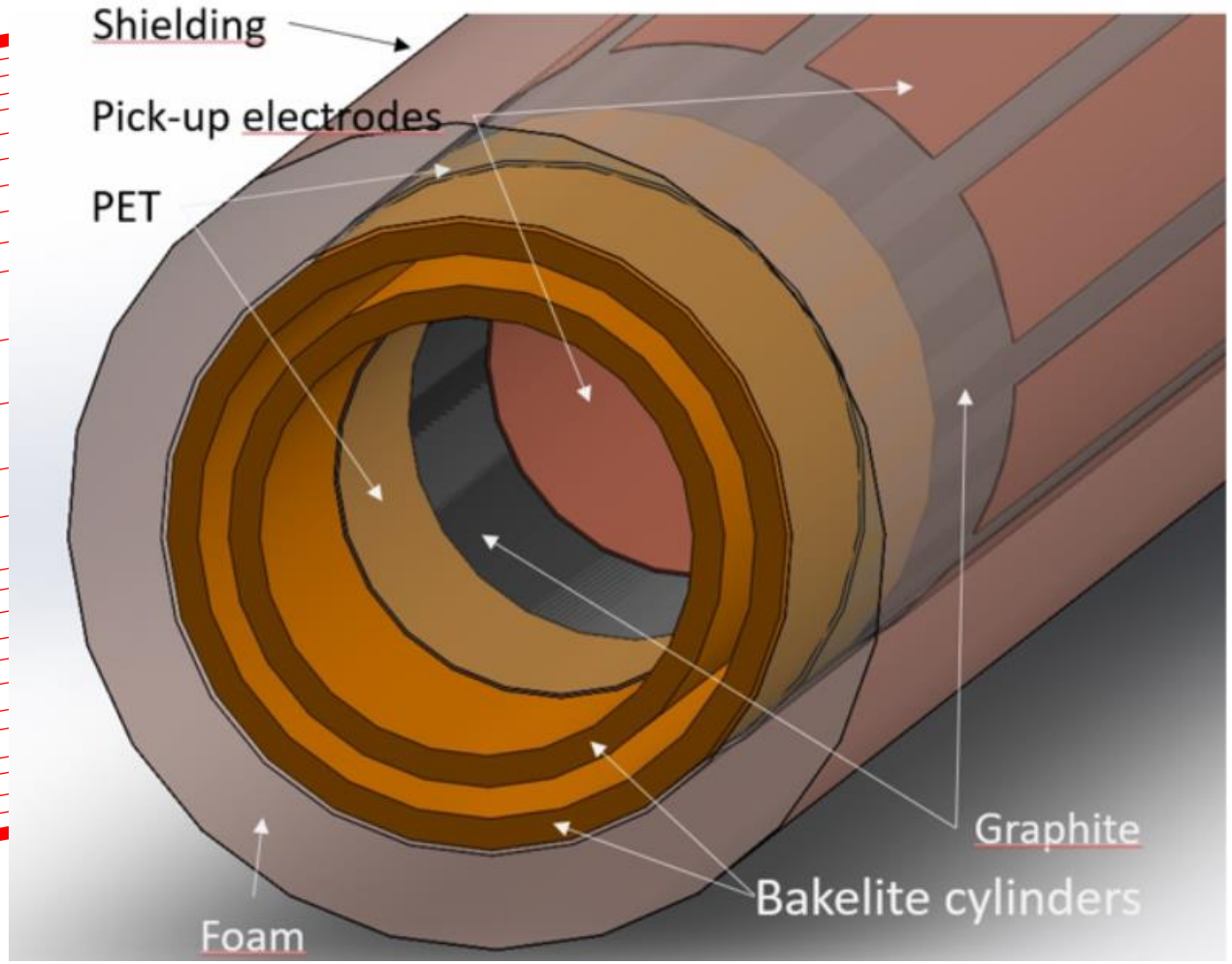
The threshold is	**1-2 fC**	Next	**0.1-0.2 fC**

RPC average current for different threshold

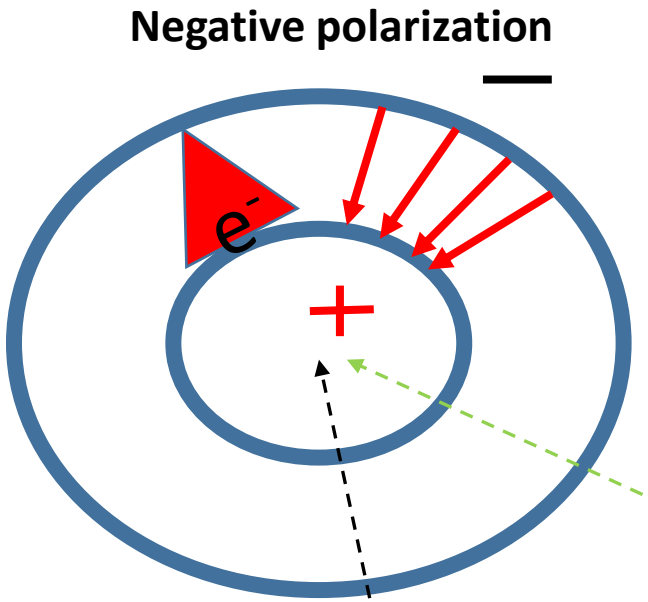


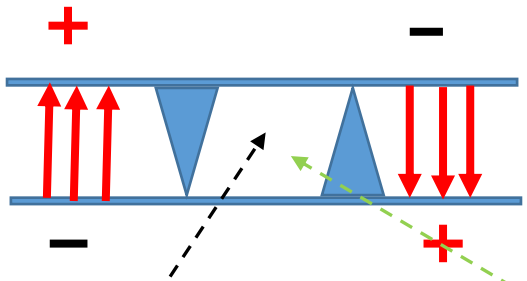
RCC structure

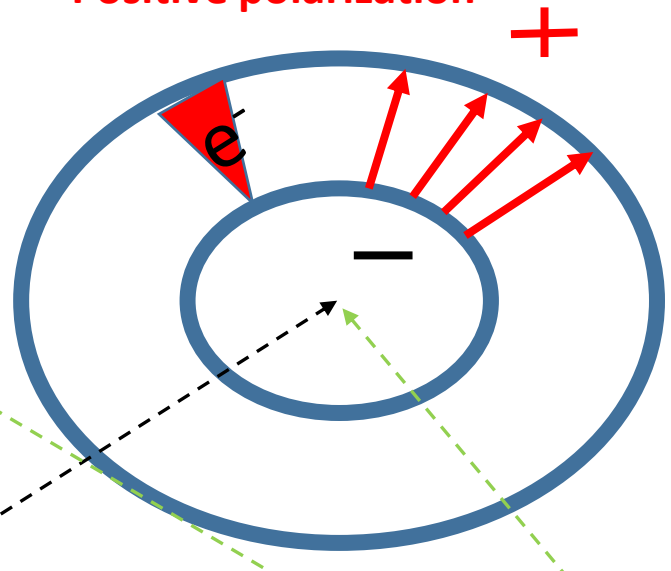


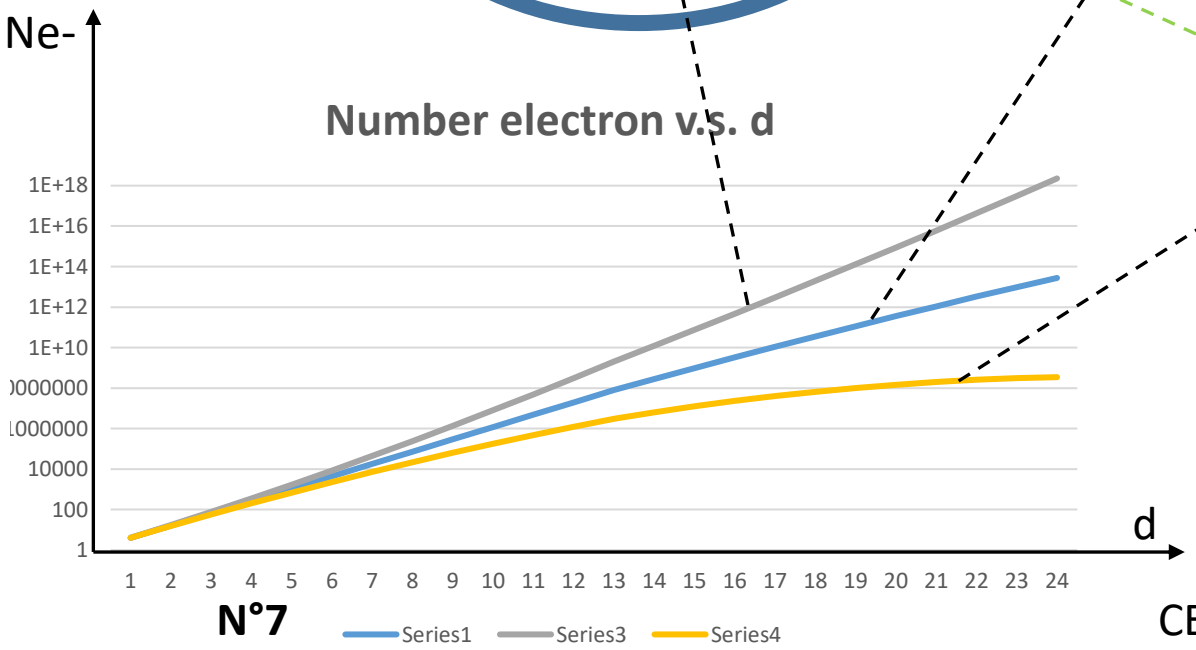


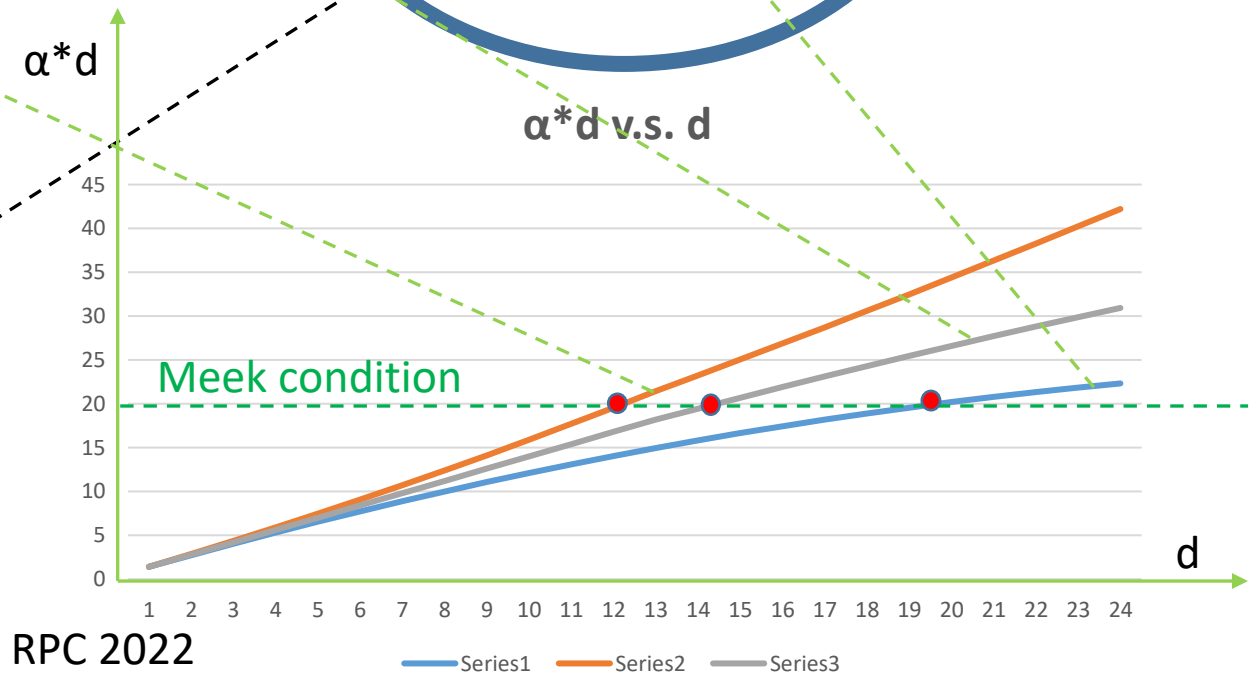
Electrons valence evolution RCC and RPC











Conclusions

- In future high energy and luminosity colliders the application of gas detectors requires a very low threshold obtained by moving the gas amplification to the electronics.
- SiGe bjt technology amplifiers show very low noise and are therefore very interesting.