XV workshop on Resistive Plate Chambers and Related Detectors (RPC2020)
Roma, 10 - 14 February 2020.

# Performance of the BIS78 RPC detectors: a new concept of electronics and detector integration for high-rate and fast timing large size RPCs

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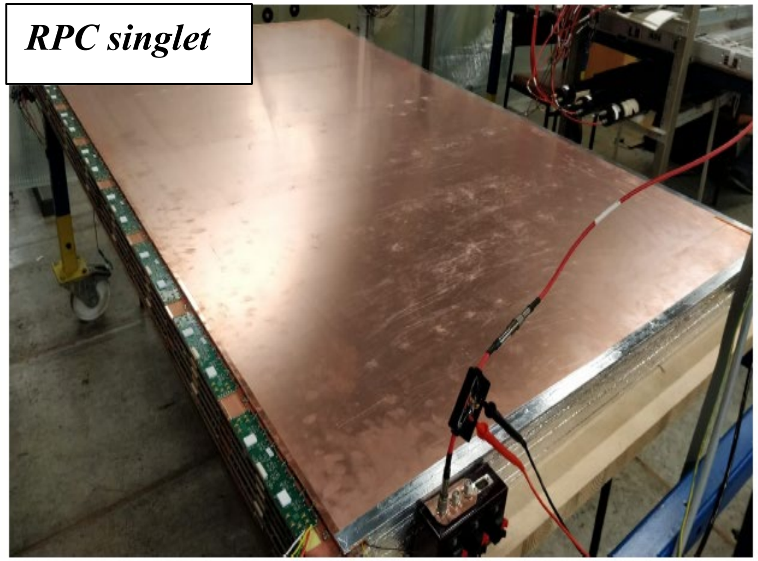
# Summary

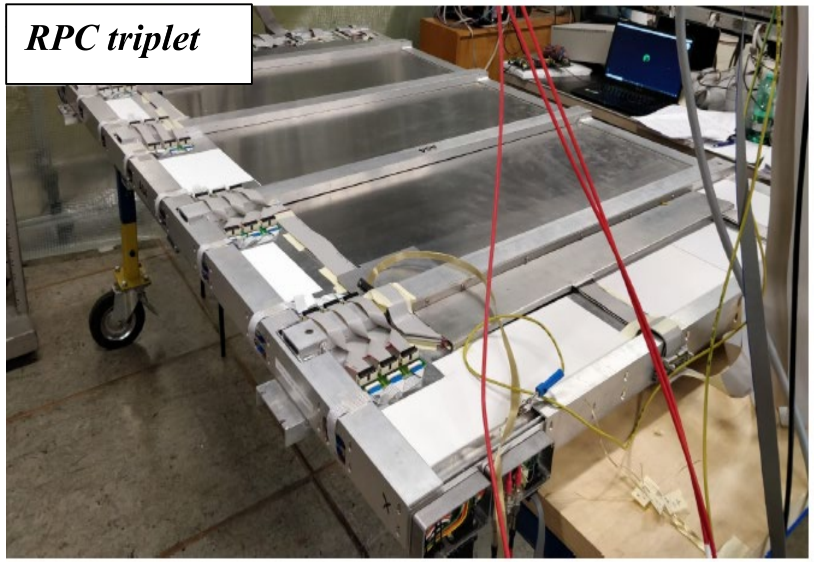
- *BIS78 ATLAS RPCs*
- *Front-electronics*
- *BIS78 RPCs performance*
- *System performance in high-radiation environment*

# BIS78 RPC production modules

***RPC singlet***

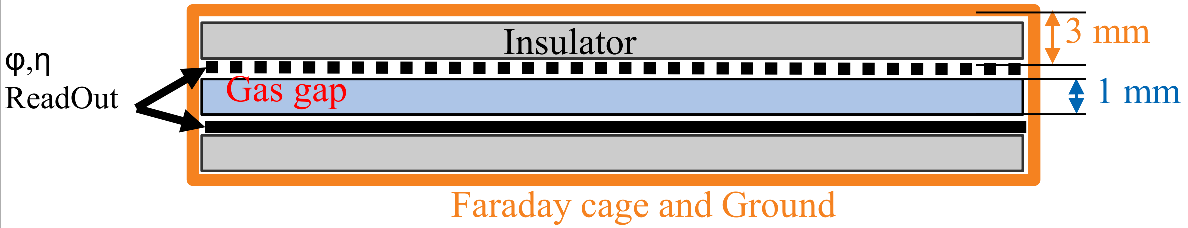


***RPC triplet***



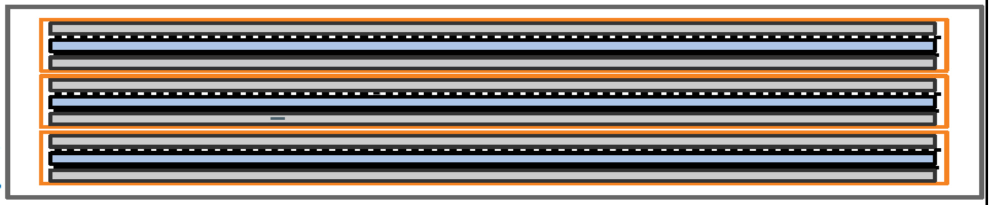
| | ATLAS New generation RPC |
|---|---|
| Detector | Mono gas gap |
| Gas Gap width | 1 mm |
| Electrode Thickness | 1.2 mm |
| Gas Mixture | 95% TFE, 4.7% i-$C_4H_{10}$, 0.3% $SF_6$ |
| Time Resolution | 0.4 ns |
| Space Resolution | 1 mm |

***RPC singlet layout***




***RPC triplet layout***

- 3 independent singlets
- 3 x 64 φ FE chs
- 3 x 16/40 η FE chs



# RPC rate capability upgrade

The **RPC rate capability** is mainly limited by the current that can be driven by the high resistivity electrodes.

$$V_{gas} = V_a - R \cdot I$$

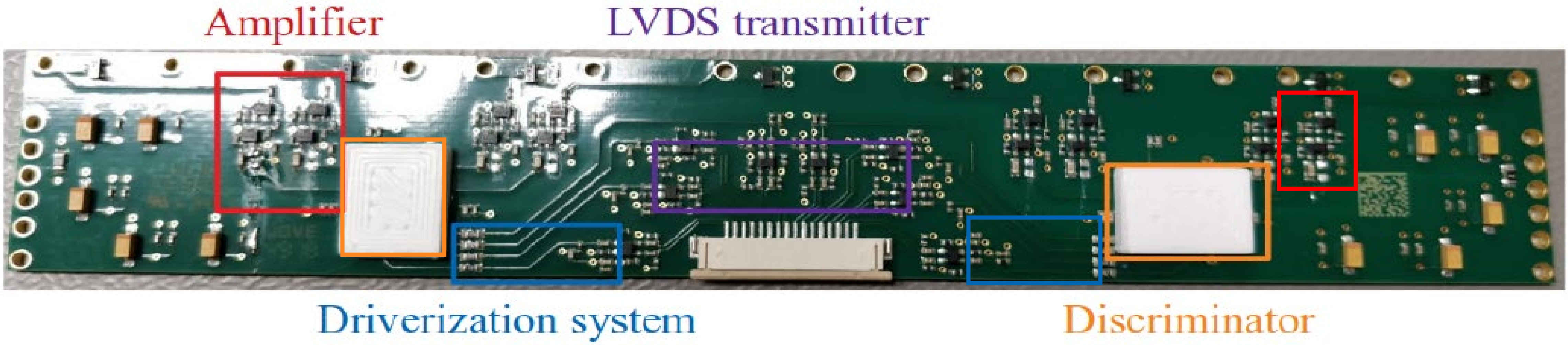
$$V_{gas} = V_a - \rho \cdot \frac{d}{S} \cdot \langle Q \rangle \cdot S \cdot \Phi_{particles} = V_a - \rho \cdot d \cdot \langle Q \rangle \cdot \Phi_{particles}$$

**Reduce the average charge per count Q:**
This method is the only one that permits to increase the rate capability while operating the detector at fixed current.
**No further ageing test required**

$\langle Q \rangle$ reduction requirements:

- Very sensitive FE electronics with an excellent signal to noise ratio
- High suppression of the noise induced inside the detector by the electronics and by external sources
- Very careful optimization of the chamber structure as a Faraday cage.

# New Front-End electronics




**Amplifier parameters**
- Silicon standard components
- Gain: 0.2-0.4 mV/fC
- Power consumption: 3-5 V 1–2 mA
- Band-width: 100 MHz

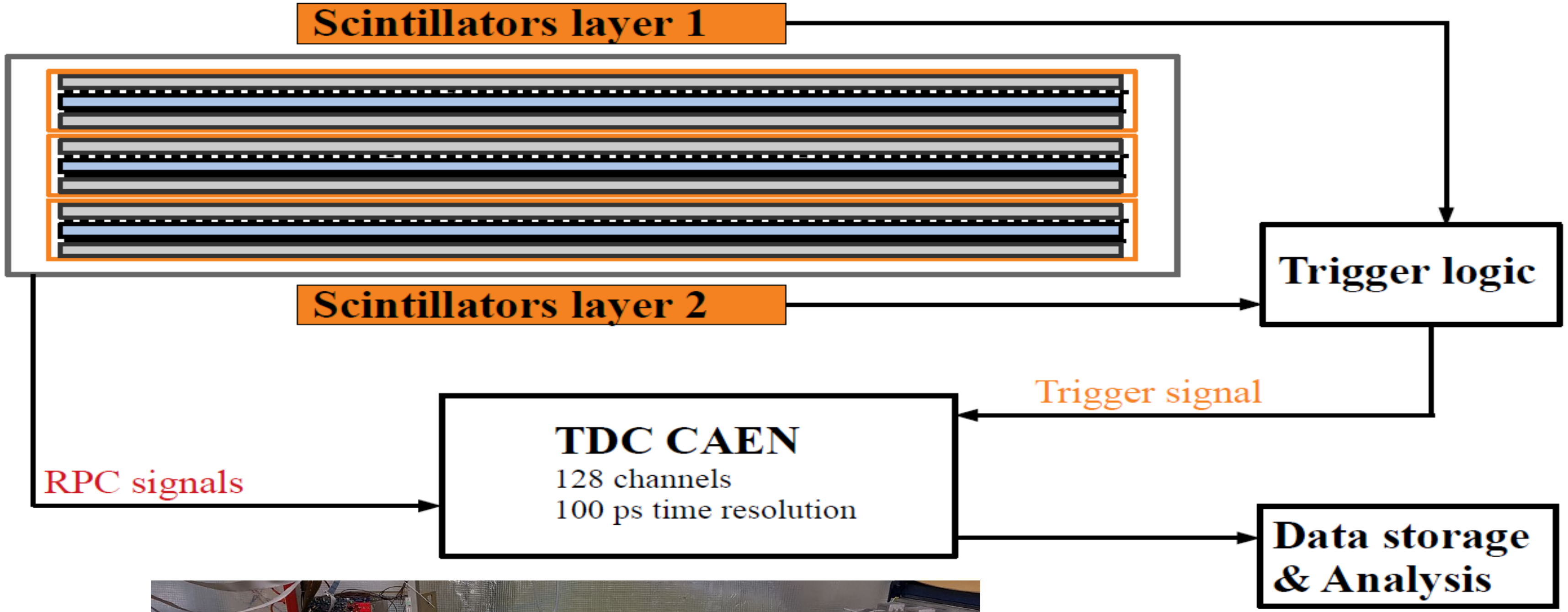
**Discriminator parameters**
- SiGe full custom
- Power consumption: 2-3 V 4-5 mA
- Threshold: 0.5 mV
- Band-width: 100 MHz

1. Minimum Threshold of 0.3 mV
2. Detectable signal of *1-2 fC*

Reduction of factor 5-10 in the charge produced inside the gas gap → **Rate capability up to some kHz/cm²**

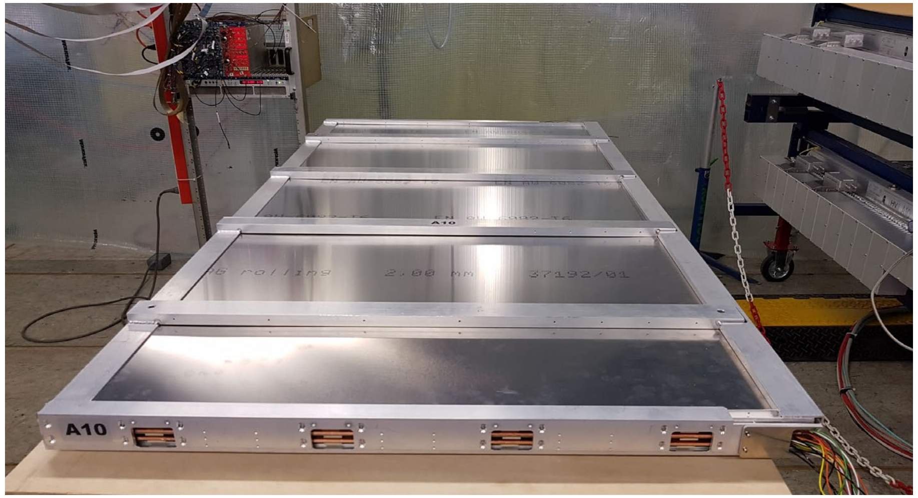
Time-over-threshold measurement achievable directly within the Front-End

# BIS78 Cosmic Ray performance test




**Performance tests:**

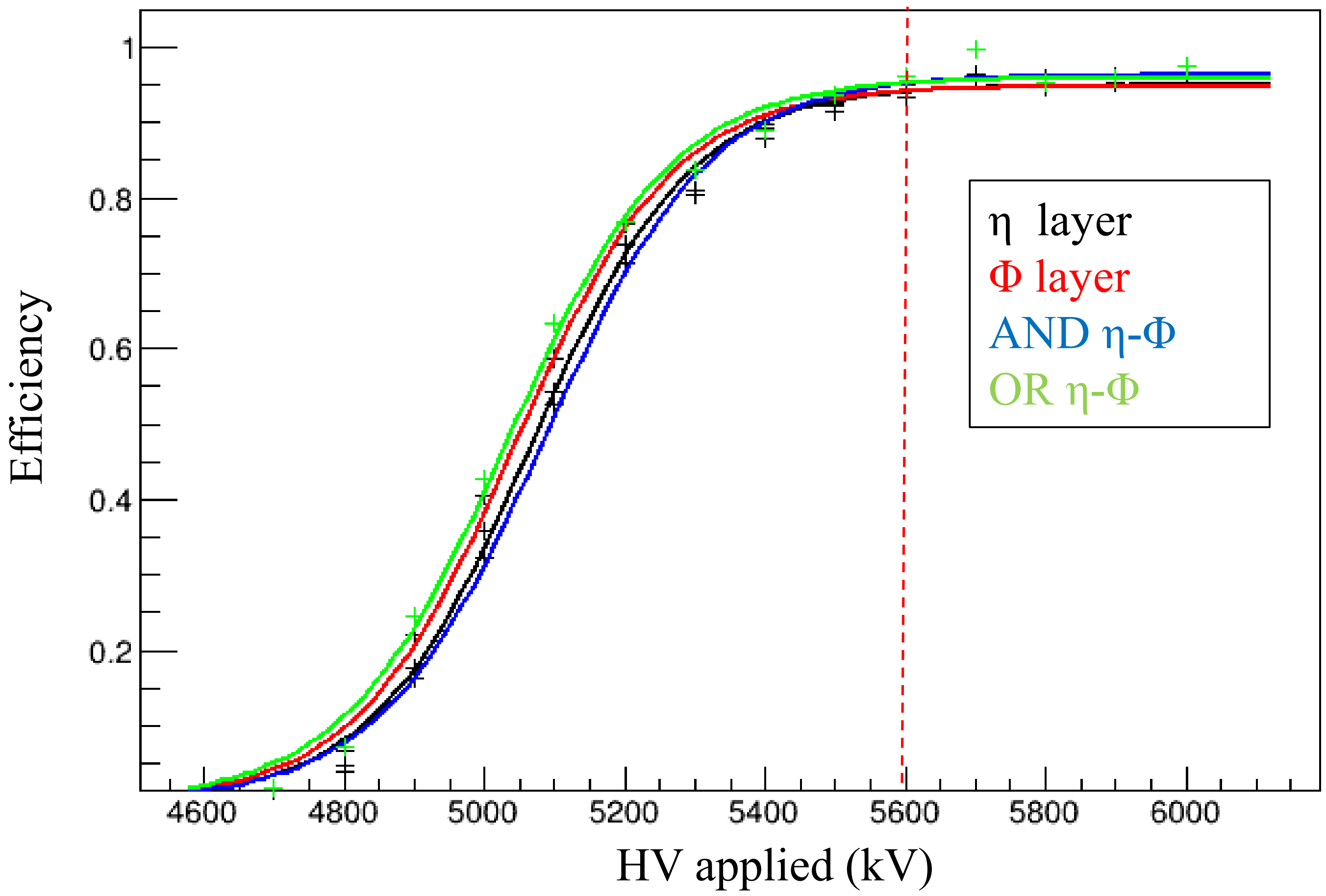
- Efficiency curve
- Cluster size
- Channels noise
- Output Width distribution
- Time Resolution




- 2 layers of scintillators (20 cm x 60 cm) as main trigger coincidence + 1 chamber at fixed HV as confirmation reference
- 100 ns coincidence window
- 3 singlets 200 cm x 110 cm

# BIS78 RPCs performance – Efficiency

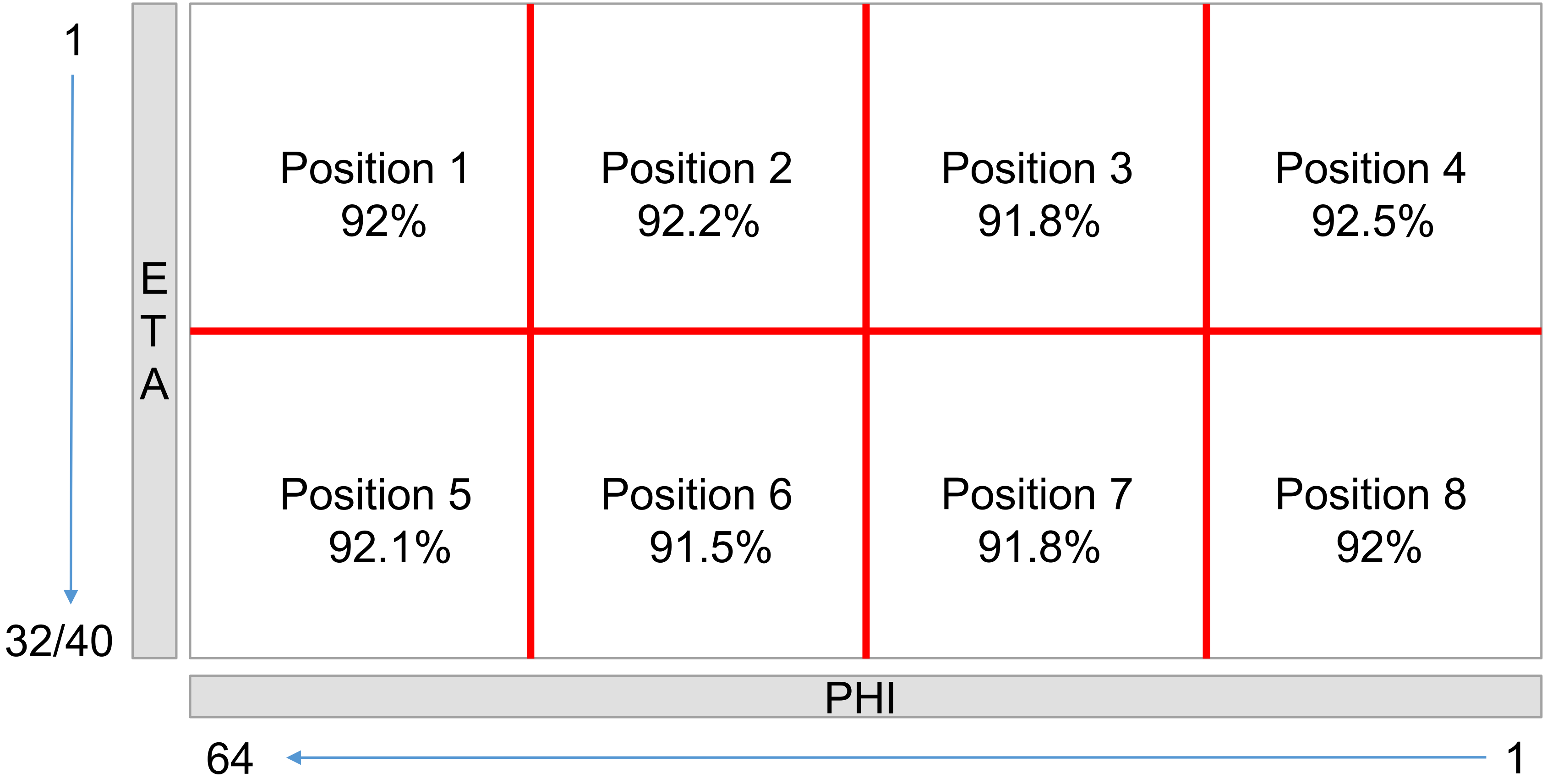
Efficiency curve all over the singlet surface




- 95% of efficiency at 5,6kV for each singlet

Efficiency curve shows the expected behaviour with the desired efficiency level

# BIS78 RPCs performance – Efficiency




Efficiency at the knee point (5.5 kV)
For each position tested
For a better resolution on a possible efficiency variation

The efficiency shows an homogeneous behaviour all over the singlet surface within the statistical fluctuation (±0.5%)

# BIS78 RPCs performance – Cluster Size

Chamber top view

η Readout (1 → 40)

| | | | |
|---|---|---|---|
| Cluster Size η / φ Position 1 1.26 / 1.45 | Cluster Size η / φ Position 2 1.27 / 1.46 | Cluster Size η / φ Position 3 1.28 / 1.43 | Cluster Size η / φ Position 4 1.24 / 1.58 |
| Cluster Size η / φ Position 5 1.25 / 1.33 | Cluster Size η / φ Position 6 1.18 / 1.37 | Cluster Size η / φ Position 7 1.21 / 1.4 | Cluster Size η / φ Position 8 1.24 / 1.28 |

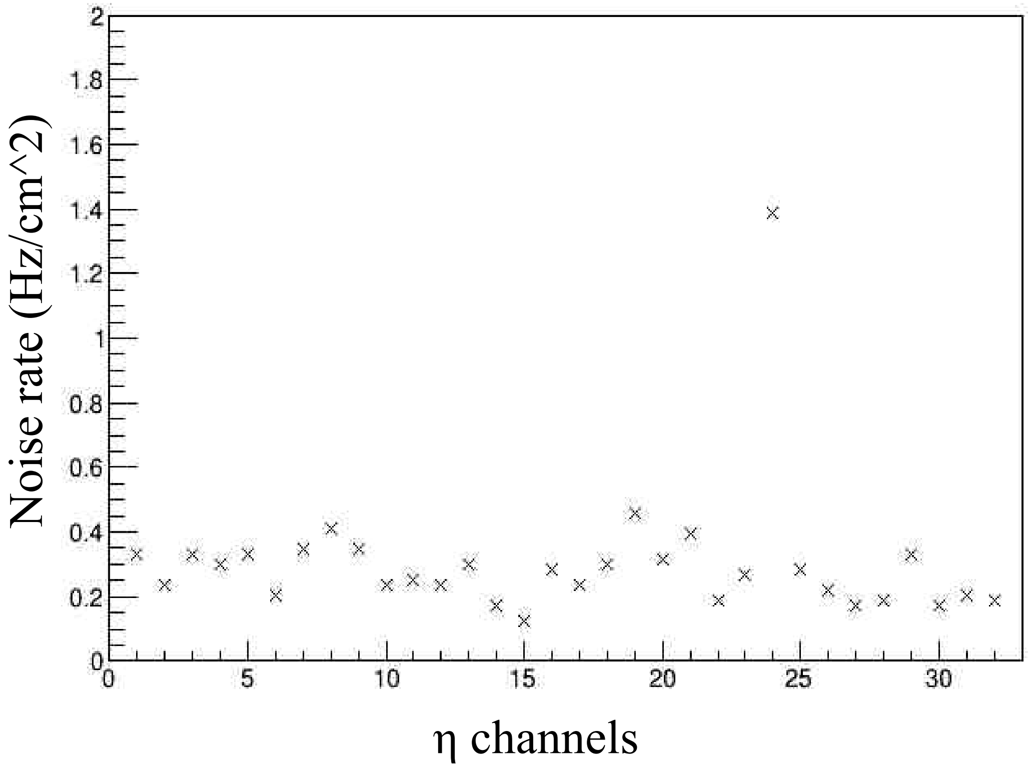
φ Readout (64 ← 1)

Cluster size at the knee point (5.5 kV)
For each position tested

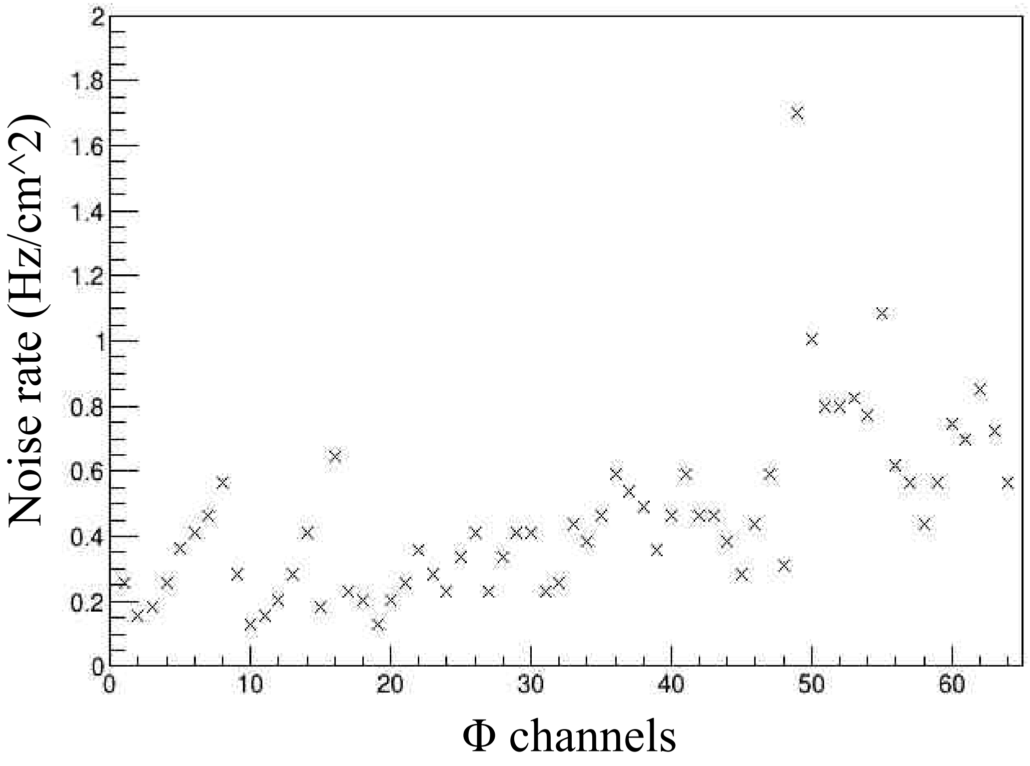
Showing the expected CS for a physical induction without crosstalk or self-induced noise effects

# BIS78 RPCs performance – Noise

Noise rate map of the η layer




Noise rate map of the Φ layer



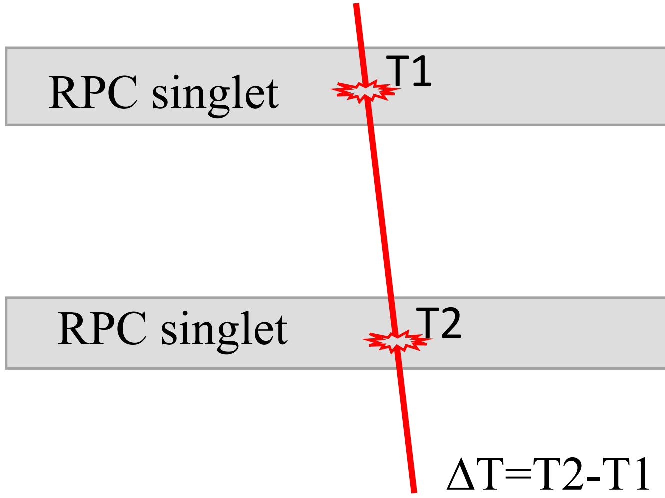

Channel noise of:

- η layer 0.1-0.5 Hz/cm²
- Φ layer 0.4-0.8 Hz/cm²

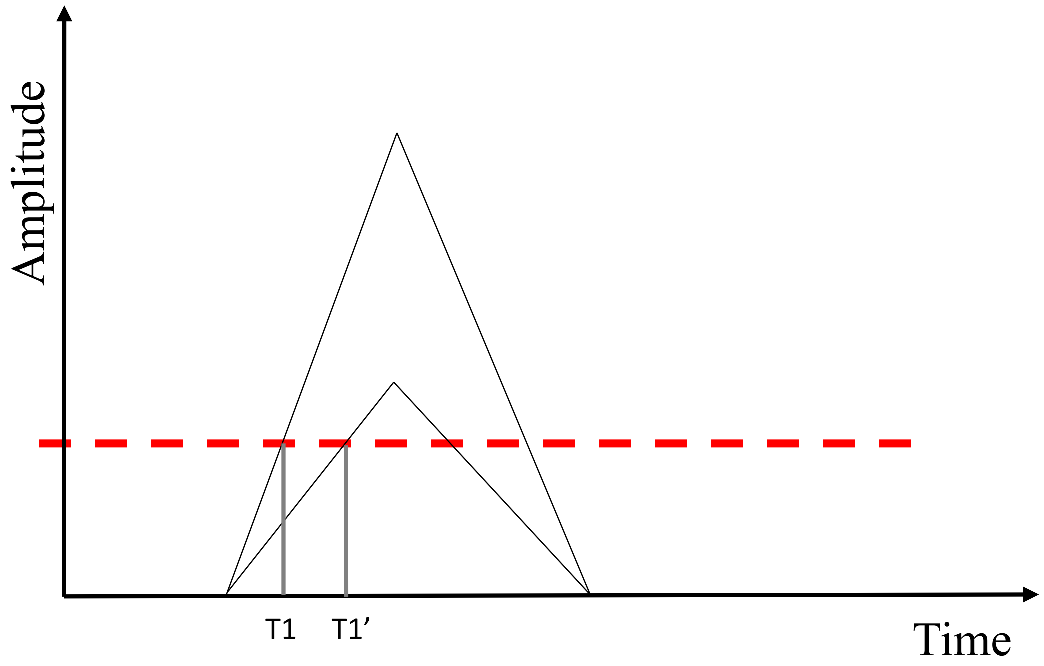
Obtained at HV=5.6 kV

# BIS78 RPCs performance – Time Of Flight and Time Walk

Time of Flight method for Time resolution calculation




Time resolution calculated as the sigma of the gaussian fit over the distribution of the difference between the arrival time of the signals of the 2 singlets (ΔT)

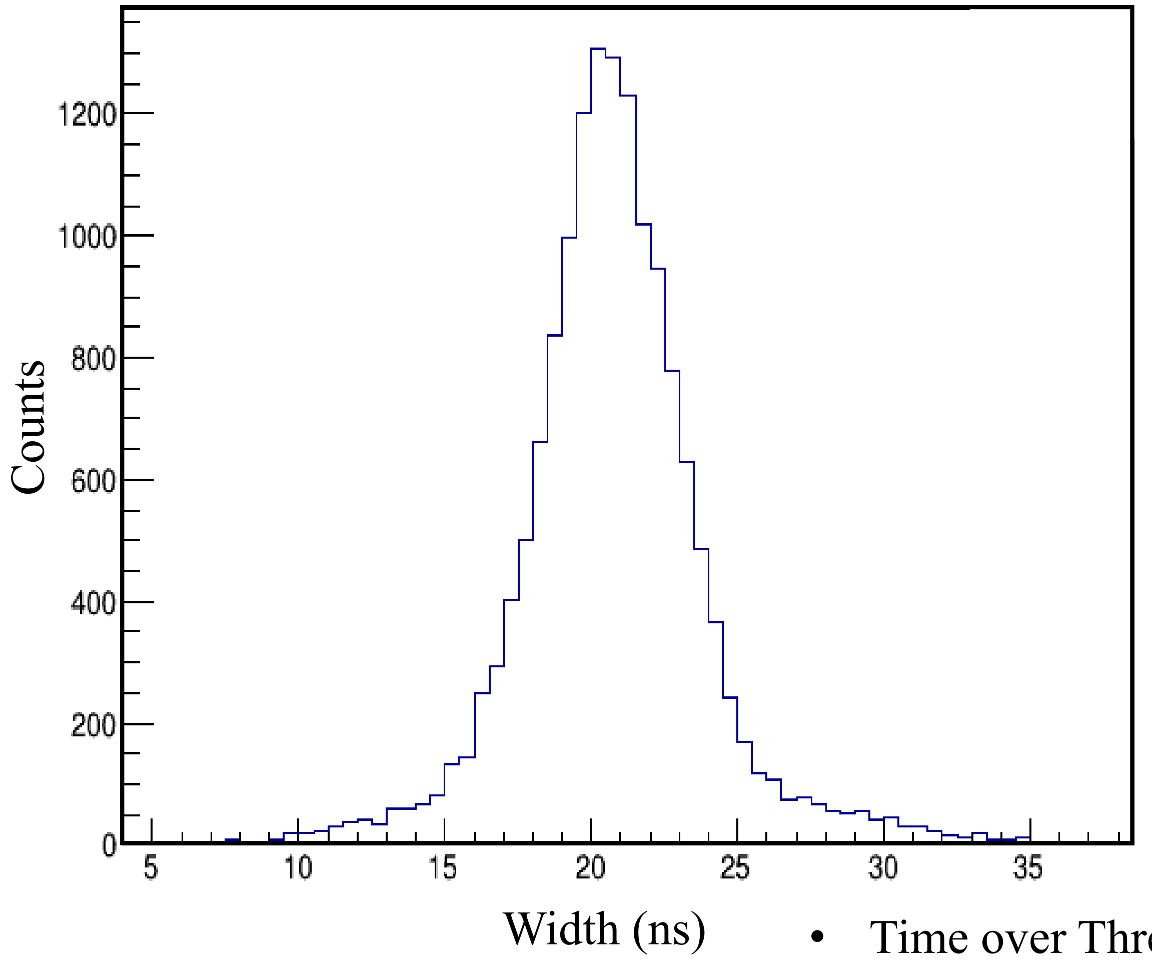



Time walk effect can be corrected by using the function F(Amplitude), which correlate the time when the signal passes the threshold and its amplitude

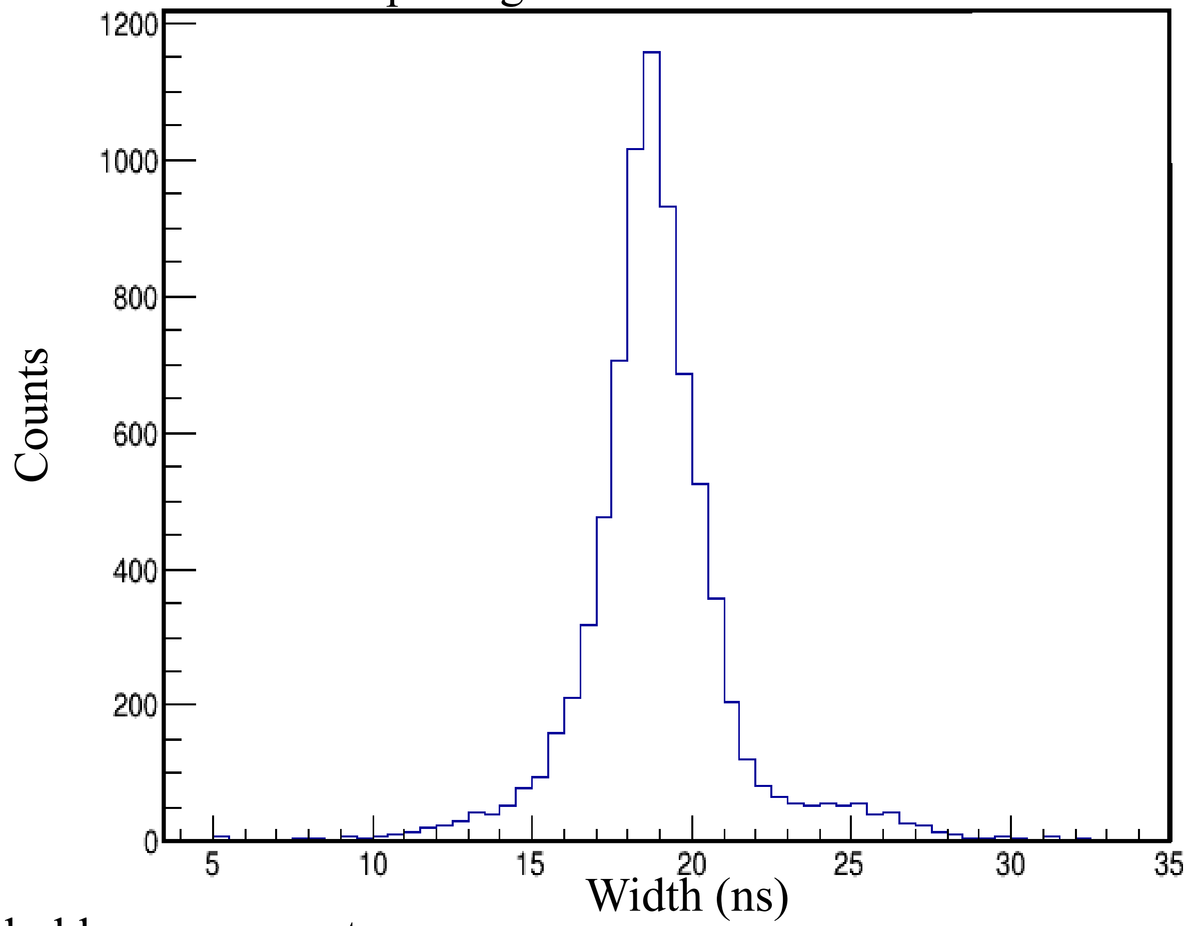
# BIS78 RPCs performance – Time Over Threshold

Obtained by taking the width of the first signal of each cluster at HV=5.6 kV

η Output Signal Width distribution



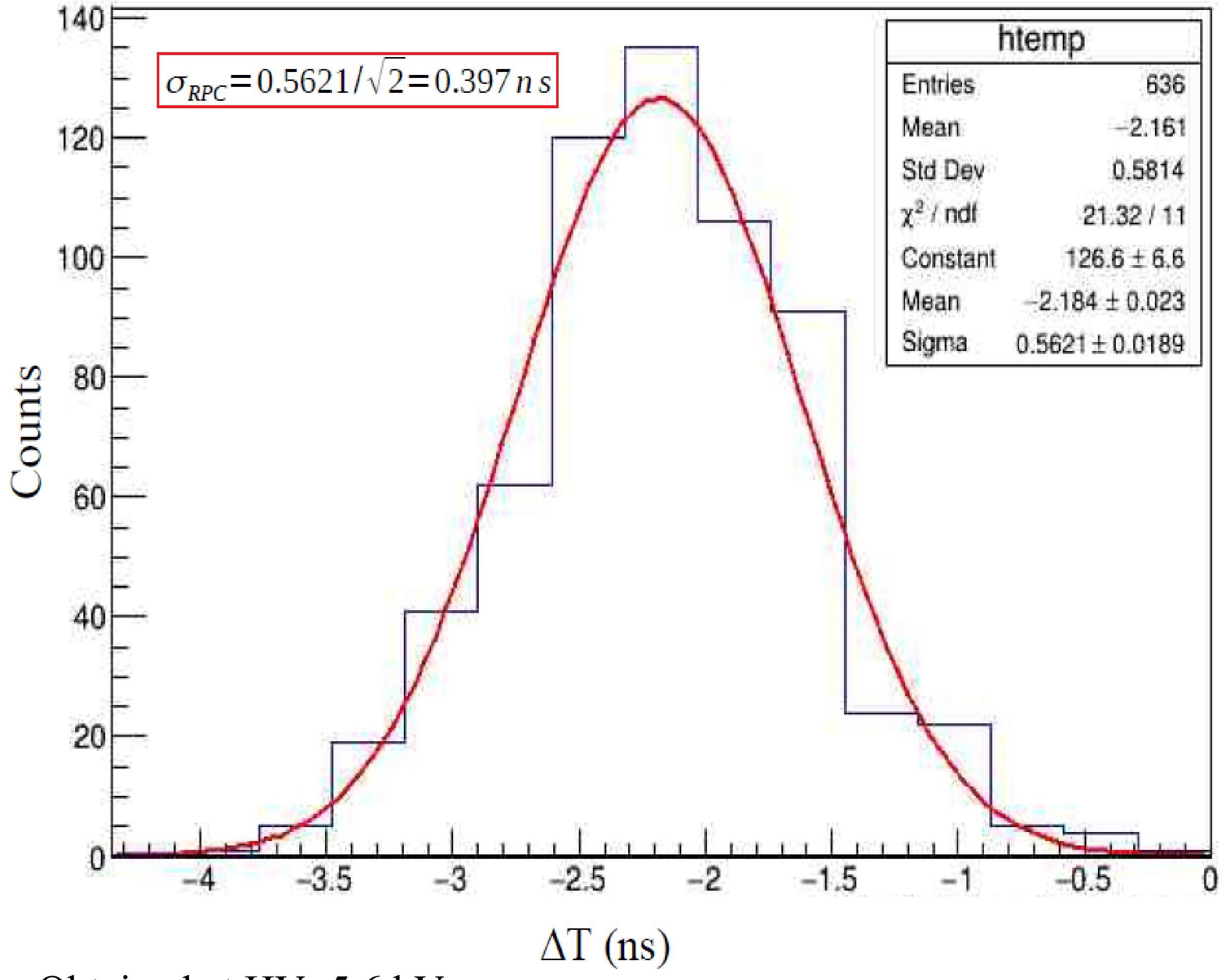

Φ Output Signal Width distribution



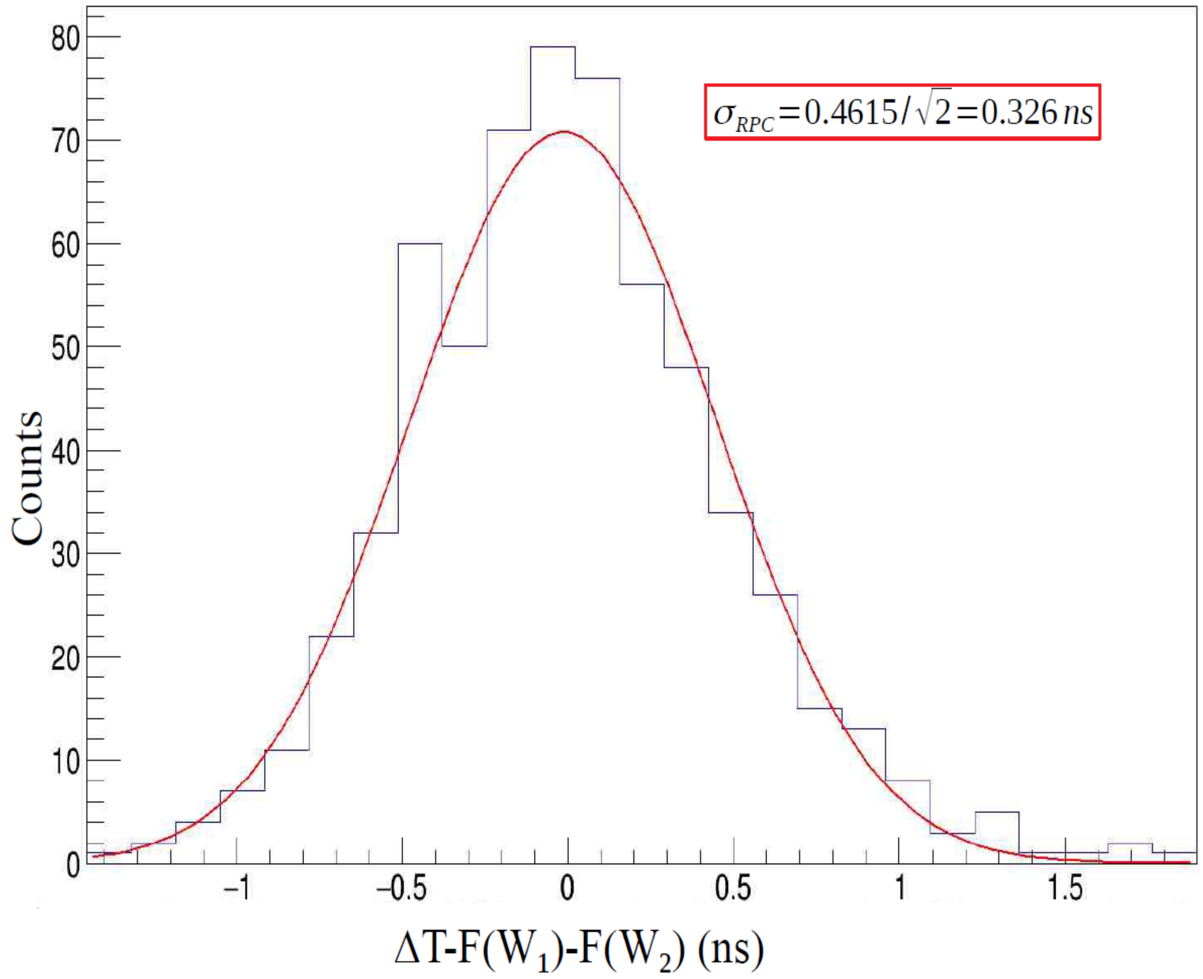

- Time over Threshold measurement
- Time walk correction for the time resolution

# BIS78 RPCs performance – Time resolution

Raw time resolution without correction

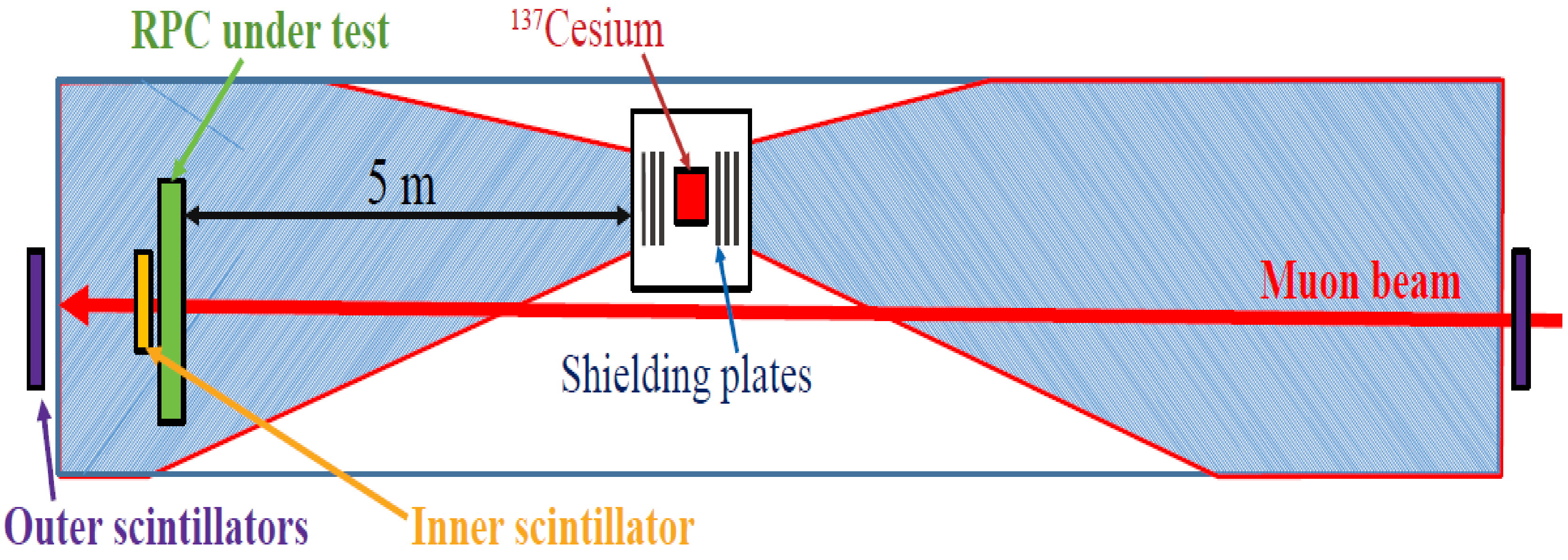


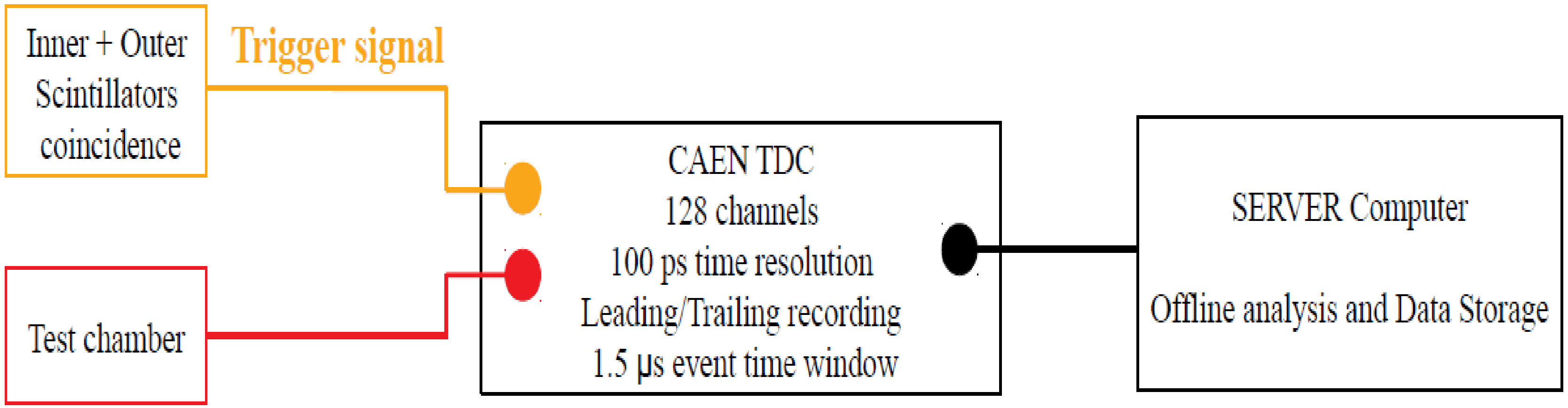

Time resolution with time walk correction




Obtained at HV=5.6 kV

# BIS78 RPCs performance – Test beam setup




Measurements performed:

1. FE Thresholds estimation
2. Rate capability

Different FE settings have been used:

- conservative threshold (BIS78)
- Performing threshold (lowest)

# BIS78 RPCs performance – FE thresholds & rate capability

$$I = \langle Q \rangle(\text{pC}) \times C_{photons}\,(\text{Counts/s})$$

⇩

Considering an average charge per count $\langle Q \rangle$ produced inside the gas of ~ 2pC

⇩

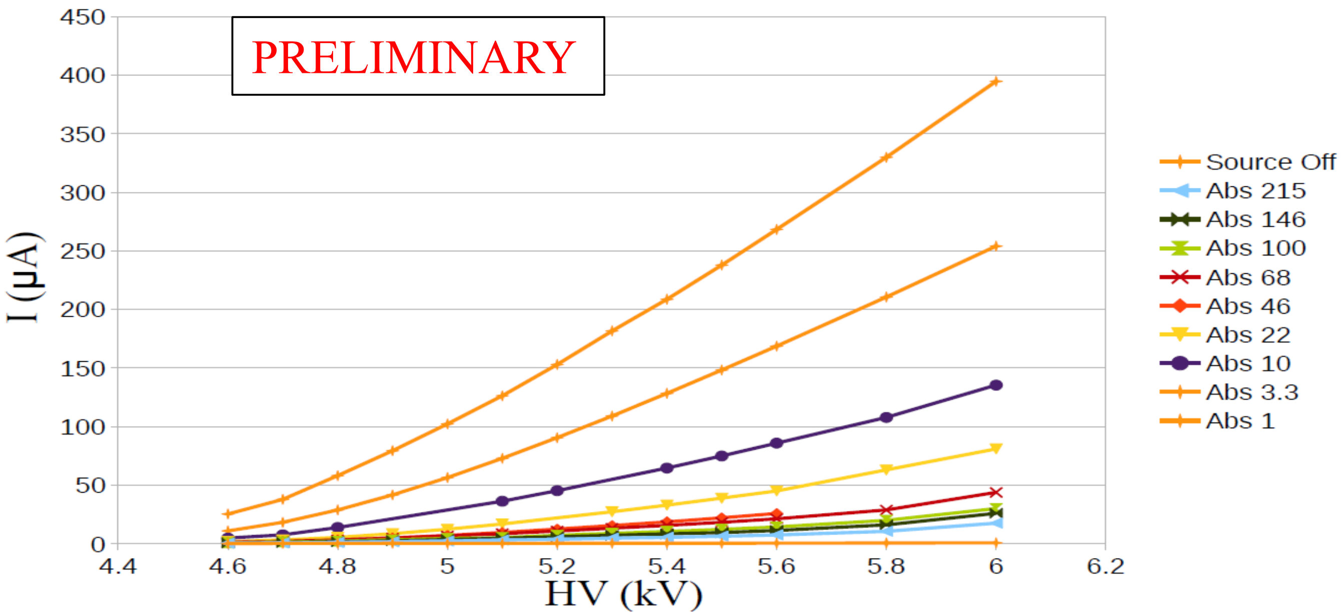
Estimation of the rate of converted photons inside the gas ( $Rate_E$ )

⇩

Checking the actual rate of converted photons measured by the FE ( $Rate_M$ )

⇩

$$Threshold = 2\,\text{pC} * \frac{Rate_E}{Rate_M}$$




| Expected rate of converted photons inside the detector | | |
|---|---|---|
| Absorption factor | Current ($\mu A$) | Expected rate ($Hz/cm^2$) |
| 215 | 7.5 | 208.3 |
| 146 | 11.3 | 313 |
| 100 | 14.4 | 400 |
| 68 | 21.3 | 591.6 |
| 46 | 25.8 | 716 |
| 22 | 45.1 | 1253 |
| 10 | 77.1 | 2141 |
| 3.3 | 210.5 | 5847.2 |
| 1 | 329.9 | 9163.2 |

# BIS78 RPCs performance – FE thresholds

PRELIMINARY

$I = \langle Q \rangle$(pC) $\times\ C_{photons}$ (Counts/s)

⇩

Considering an average charge per count $\langle Q \rangle$ produced inside the gas of ~ 2pC

⇩

Estimation of the rate of converted photons inside the gas ( $Rate_E$ )

⇩

Checking the actual rate of converted photons measured by the FE ( $Rate_M$ )

⇩

$$Threshold = 2\,\mathrm{pC} * \frac{Rate_E}{Rate_M}$$

**Conservative Threshold**

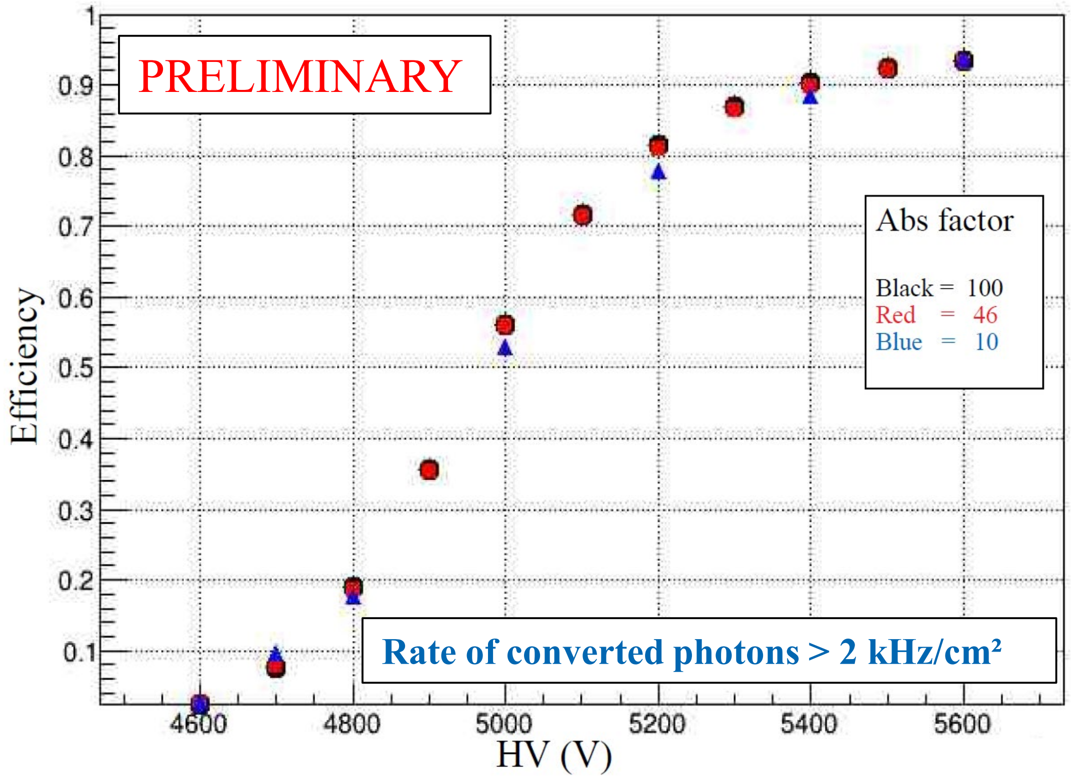
Front-End threshold on the average charge per count produced inside the detector estimated to be **5±1 pC**

**Performing Threshold**

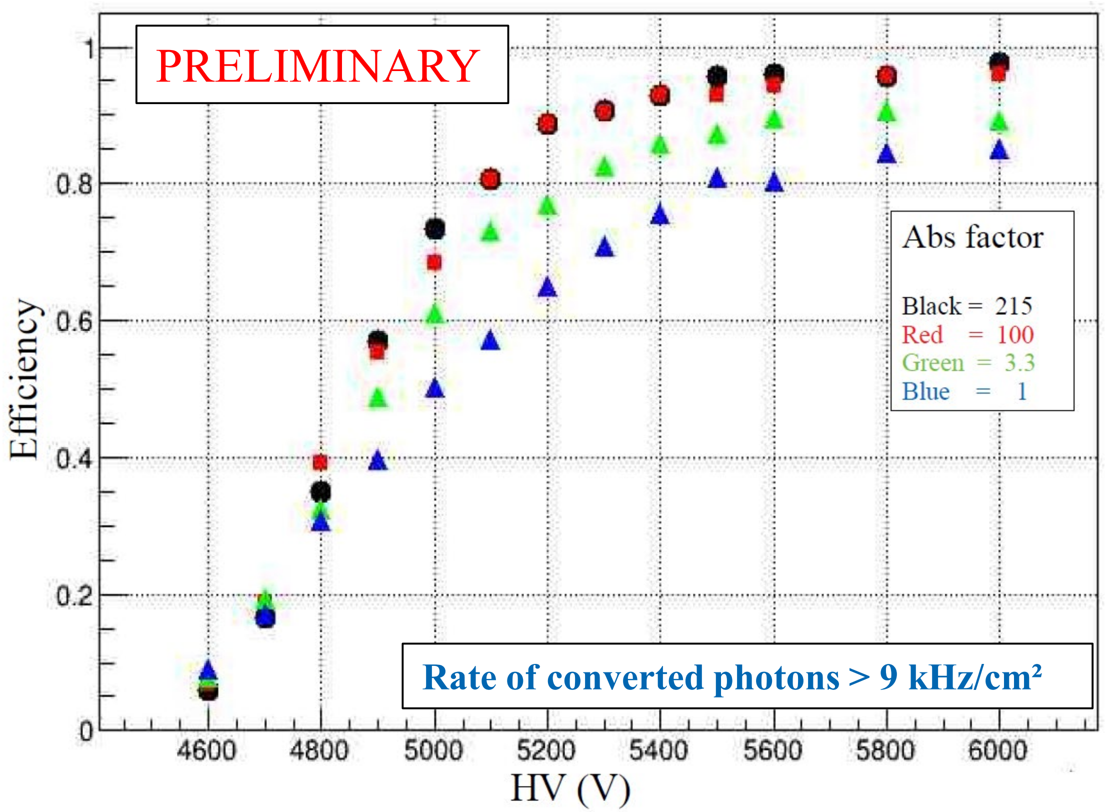
Front-End threshold on the average charge per count produced inside the detector estimated to be **3±1 pC**

# BIS78 RPCs performance – Rate capability

Conservative Threshold




Performing Threshold



# Conclusion

The new generation of RPC detector equipped with the newly developed Front-End electronics achieved the following:

**1. High performance along with huge uniformity**

**2. Raw time resolution of 400 ps and 330 ps considering the time walk correction**

***3. Rate capability > 9* kHz/cm²**

# Thank you !