XIV Workshop on Resistive Plate Chambers and related detectors
Puerto Vallarta, Jalisco State, MEXICO

Università di Roma Tor Vergata

INFN

DEVELOPMENT OF GASEOUS PARTICLE DETECTORS BASED ON SEMI-CONDUCTIVE PLATE ELECTRODES

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ON BEHALF OF TOR VERGATA ATLAS GROUP

RPC EVOLUTION

(Avalanche regime)

Standard Bakelite Electrode + Phase0 FE

- $\rho \cong 10^{10}\Omega \cdot cm$
- $d = 1.8mm$
- $\epsilon_r \cong 5-8$
- $Gap = 2mm$
- $FE\ Noise \cong 10000\ e^-$

Thin Bakelite Electrode + new FE

- $\rho \cong 10^{10}\Omega \cdot cm$
- $d = 1.2mm$
- $\epsilon_r \cong 5-8$
- Gap= 1mm
- $FE\ Noise \cong 1000\ e^-$

Semi-Insulating Electrode SI-GaAs + new FE

- $\rho \cong 6.4 \times 10^{7}\Omega \cdot cm$
- $d = 0.4mm$
- $\epsilon_r \cong 12$
- Gap =1mm
- $FE\ Noise \cong 1000\ e^-$

Timeline

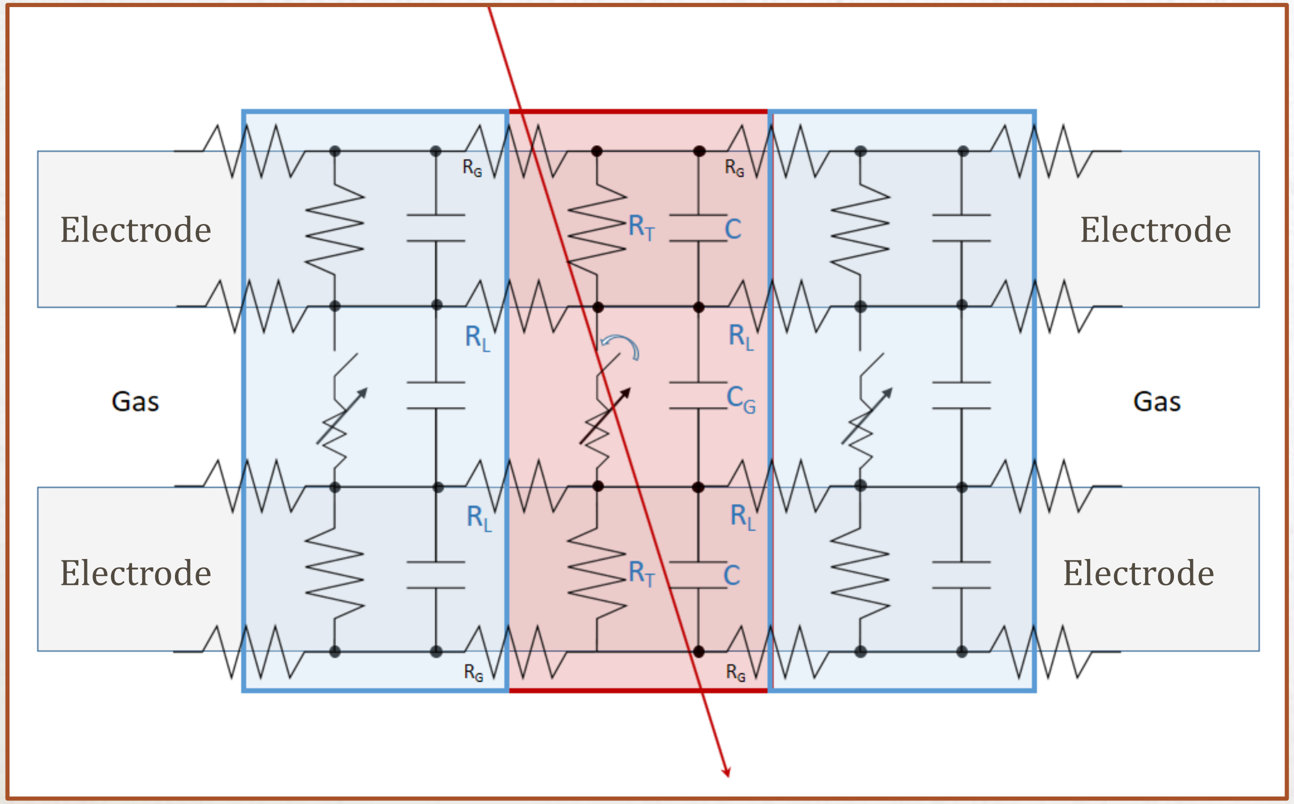
2010 | 2018 | ?

Intrinsic Rate Capability

1kHz/cm^2 | 10kHz/cm^2 | MHz/cm^2 ?

LUMPED ELEMENT MODEL

- $C_G = Gas\ capacitance$
- $C\ \ = Electrode\ capacitance$
- $R_L = Electrode\ longitudinal\ resistance$
- $R_L = Electrode\ trasversal\ resistance$
- $R_G = Graphite\ resistance$



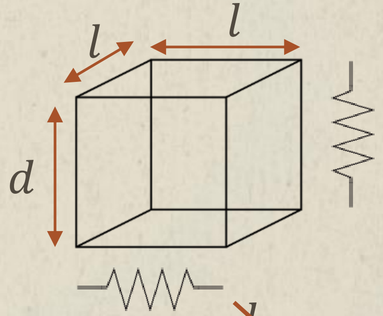
Unit Cell

Discharge

$$V_{Drop} = 2\,\rho\, d < Q > \phi_{eff}$$

Recharge

$$\tau \cong \rho\epsilon_0\left(\epsilon_r + 2\frac{d}{g}\right)$$



$$R_T = \rho \cdot \frac{d}{l^2}$$

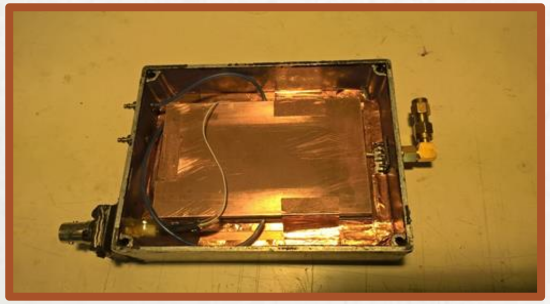
$$R_L = \rho \cdot \frac{\cancel{l}}{d \cdot \cancel{l}}$$

- **Lowering ρ** → decrease V_{Drop} and τ
- **Lowering d** → $R_L \gg R_T$ → reduced Unit Cell

(<u>Increased Rate Capability</u>)

Prototype 1

- **HV Electrode:** SI-GaAs ($\rho = 7 \cdot 10^7$ Ω·cm; 400μm)
- **Ground Electrode:** SI-GaAs ($\rho = 7 \cdot 10^7$ Ω·cm; 400μm)
- **Gas-gap:** 1mm
- **Gas**: 95%TFE/4.5%iC_4H_{10}/0.5%SF6

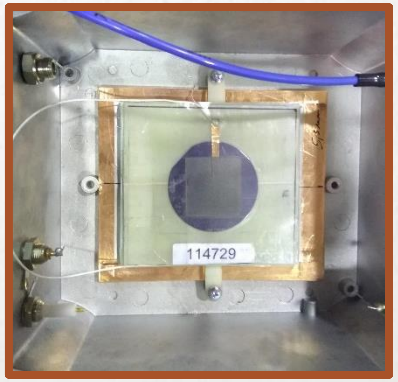


Prototype 2

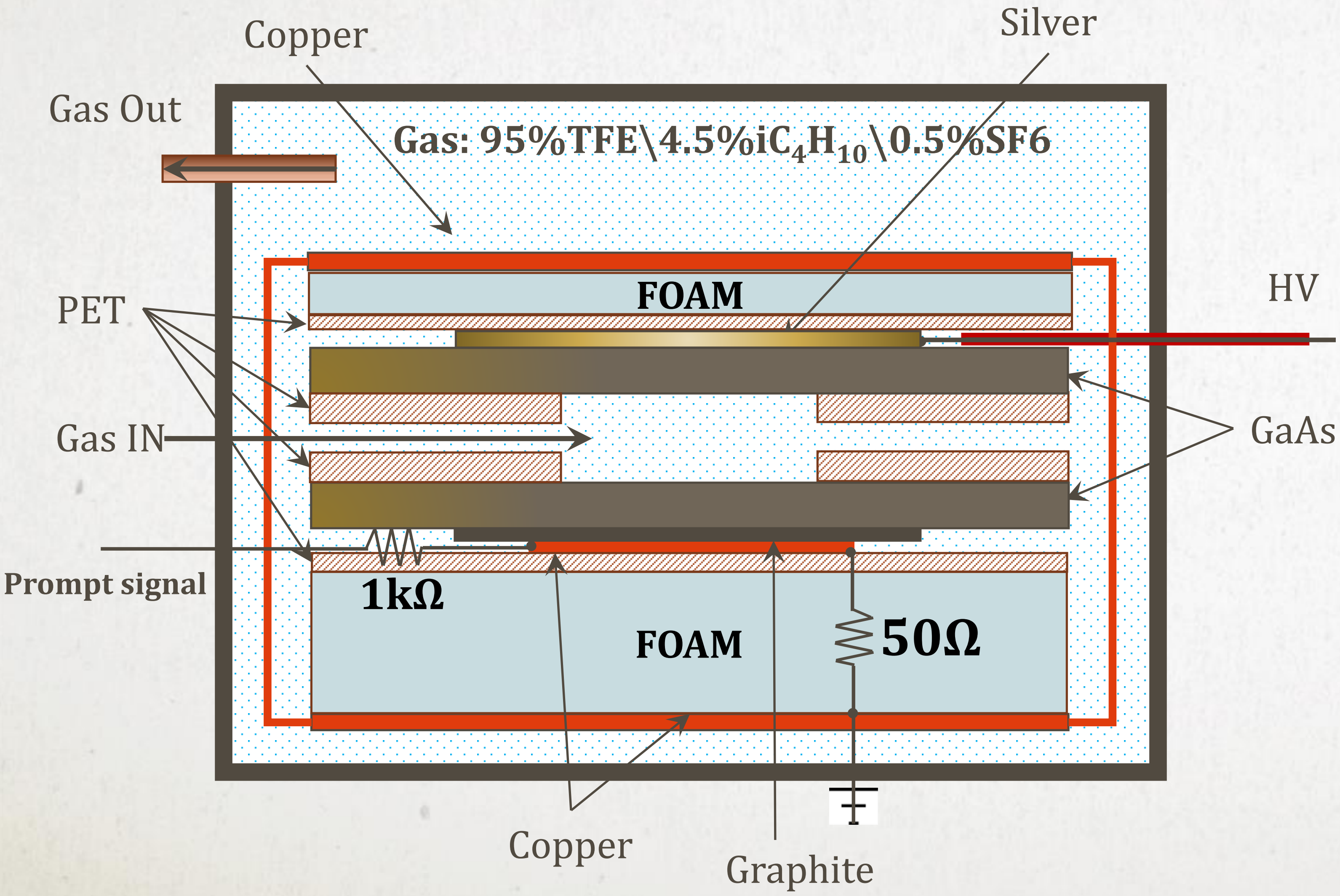
- **HV Electrode:** SI-GaAs ($\rho = 6{,}4 \cdot 10^7$ Ω·cm; 400μm)
- **Ground Electrode:** Silicon ($\rho = 10^4$ Ω·cm; 400μm)
- **Gas-gap:** 1.5mm
- **Gas:** 40%iC_4H_{10}/60%Ar

Prototype 3

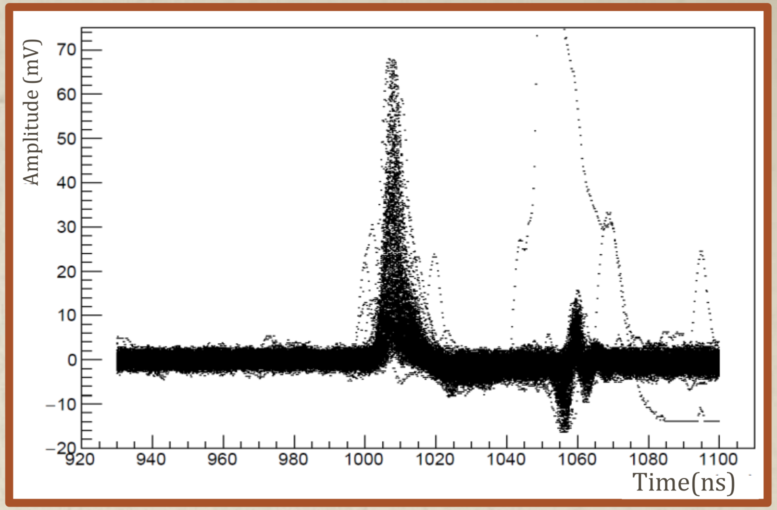
- **HV Electrode:** SI-GaAs ($\rho = 5.7 \cdot 10^7$ Ω·cm; 400μm)
- **Ground Electrode:** SI-GaAs ($\rho = 5.7 \cdot 10^7$ Ω·cm; 400μm)
- **Gas-gap:** 1.3mm
- **Gas**: 95%TFE/4.5%iC_4H_{10}/0.5%SF6



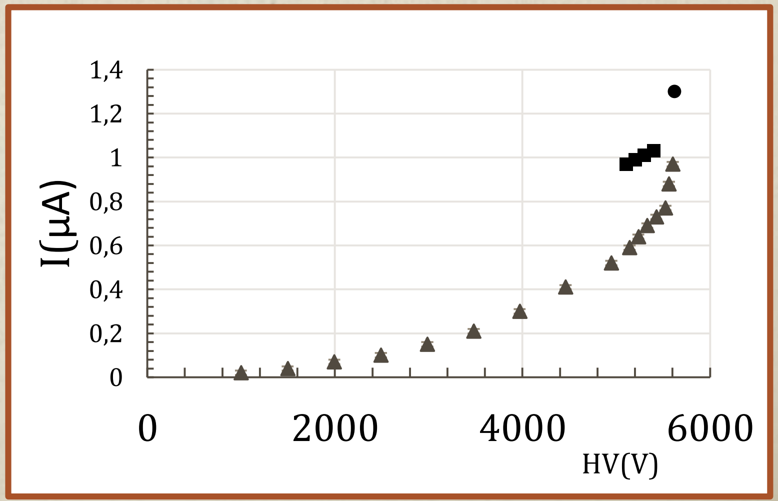
PROTOTYPE 1
(Semi-Insulating GaAs)



Prototype 1 Pulses



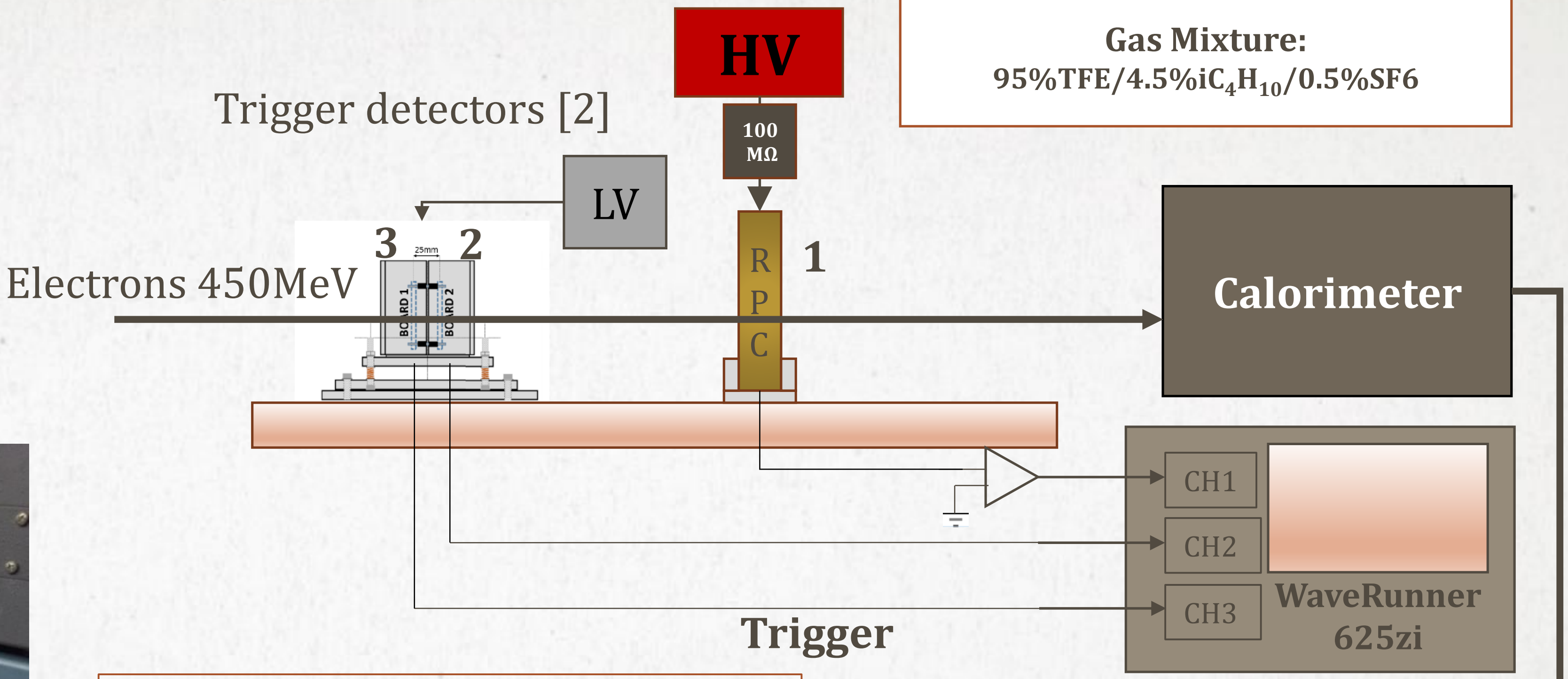
Prototype 1 shows instability during tests

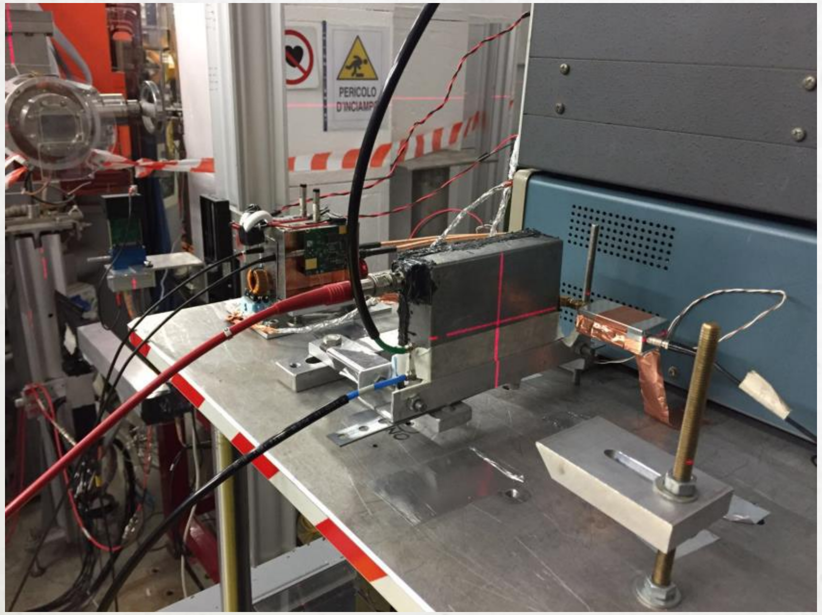


Experimental Set-Up (BTF-LNF[1])

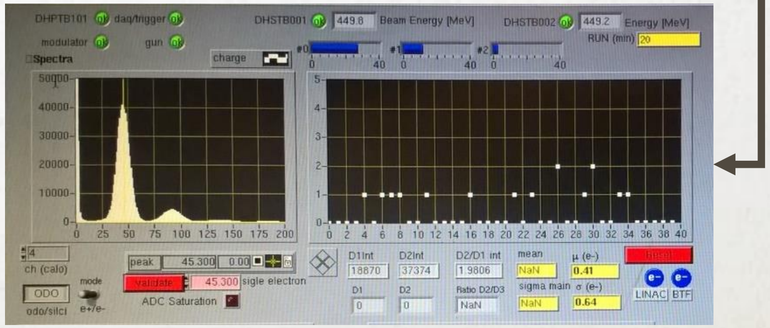
Gas Mixture:
95%TFE/4.5%iC_4H_{10}/0.5%SF6

Beam specs:
Energy = 450 MeV;
Bunch Rate = 50Hz;
Mean Multiplicity = 0.3;





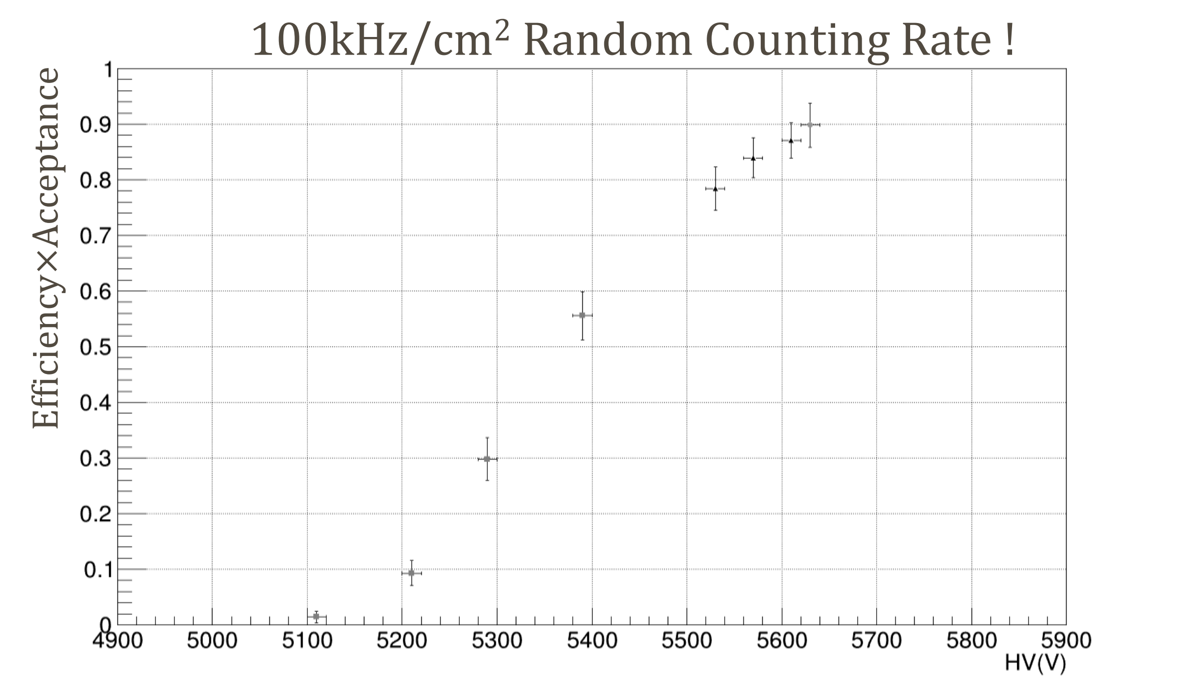
FE features:
Low Voltage = 4V;
Sensitivity = 2-4 mV/fC;
Bandwidth = 10-100MHz
Input impedance= 100-50Ω
1000 noise electrons



[1]http://www.lnf.infn.it/acceleratori/btf/
[2] BENOIT M. ET AL., *Jinst*, **10.1088/1748-0221/11/03/P03011** (IOP for SISSA Medialab) 9/2016.

RESULTS
EFFICIENCY – TIME RESOLUTION

- 1mm gas gap
- **Efficiency = triple/double**
- **Threshold=5*RMS background (~7mV)**
- **2%** Random count probability in **30ns** time window

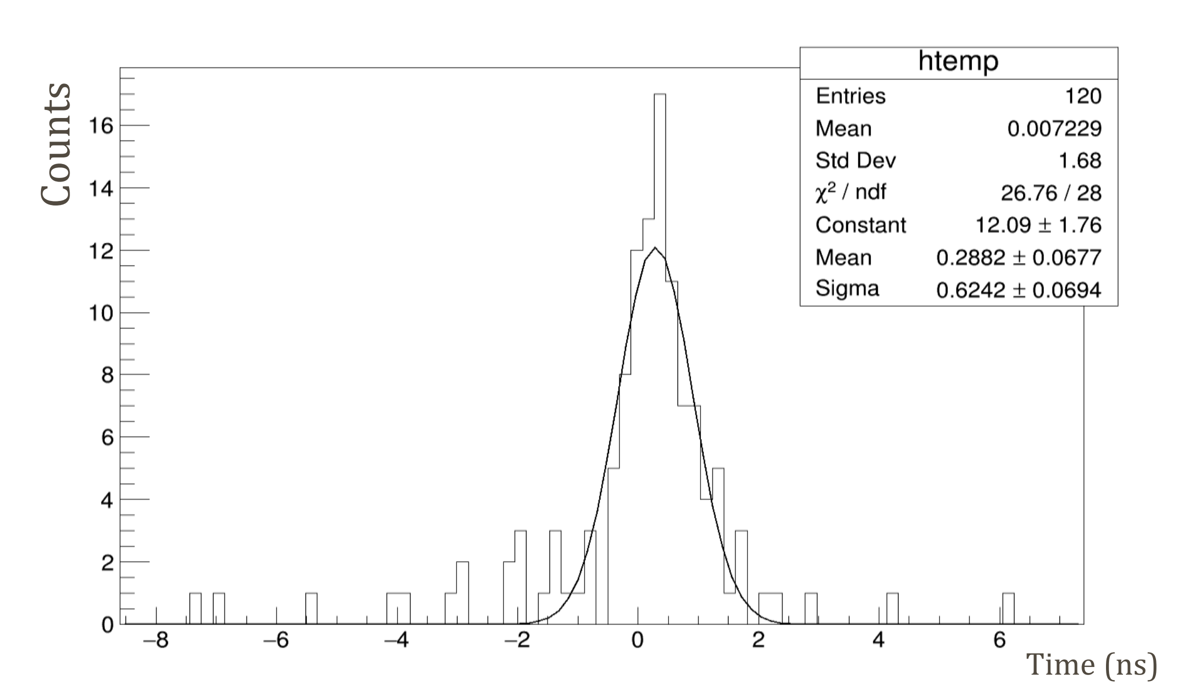


- HV=5627V
- Time walk correction

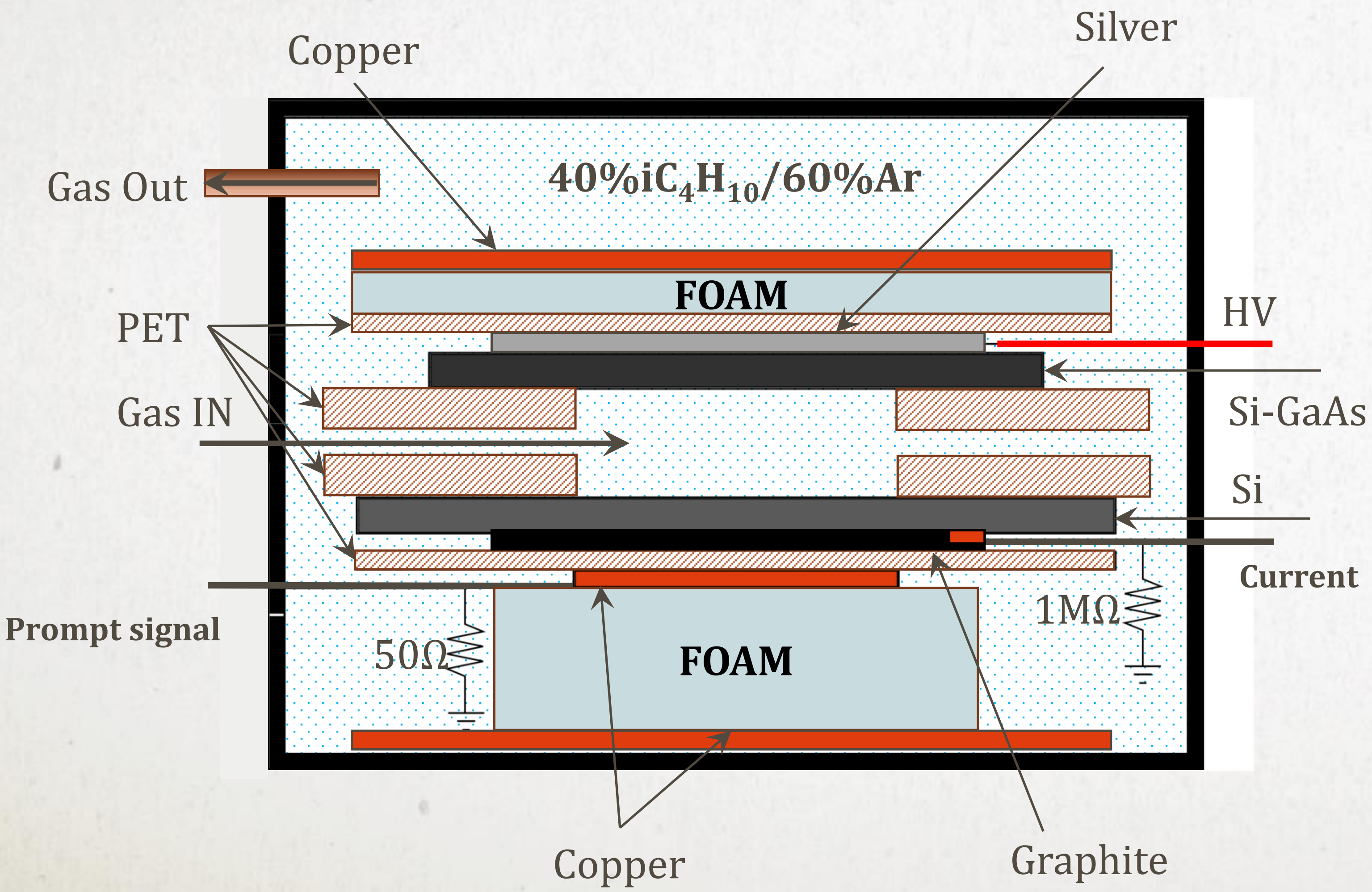
$\sigma_{trig} = 180ps$

$\sigma_{RPC}^2 = \sigma^2 - \sigma_{trig}^2$

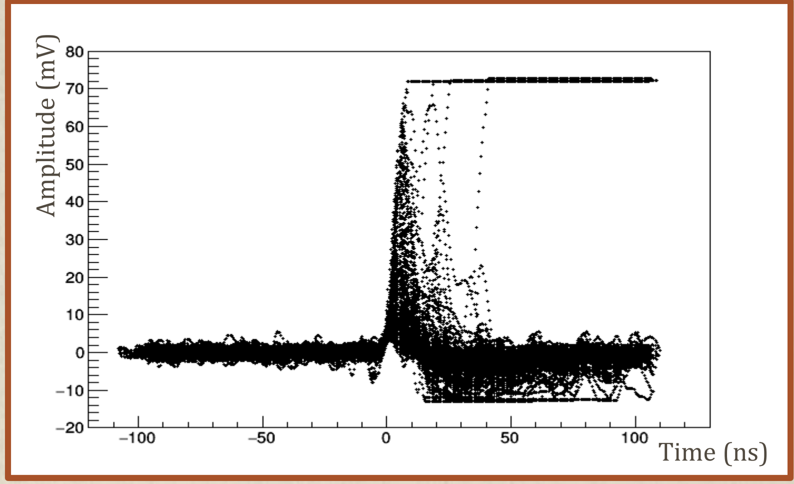
$\sigma_{RPC} = 590ps$



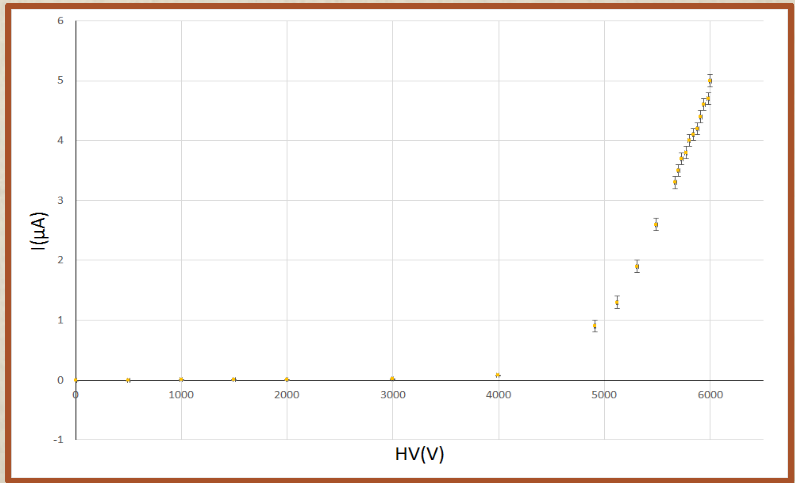
PROTOTYPE 2
(Semi-Insulating GaAs/Silicon)



Prototype 2 Pulses



Prototype 2 shows stability only with Argon/Isobutane mixture



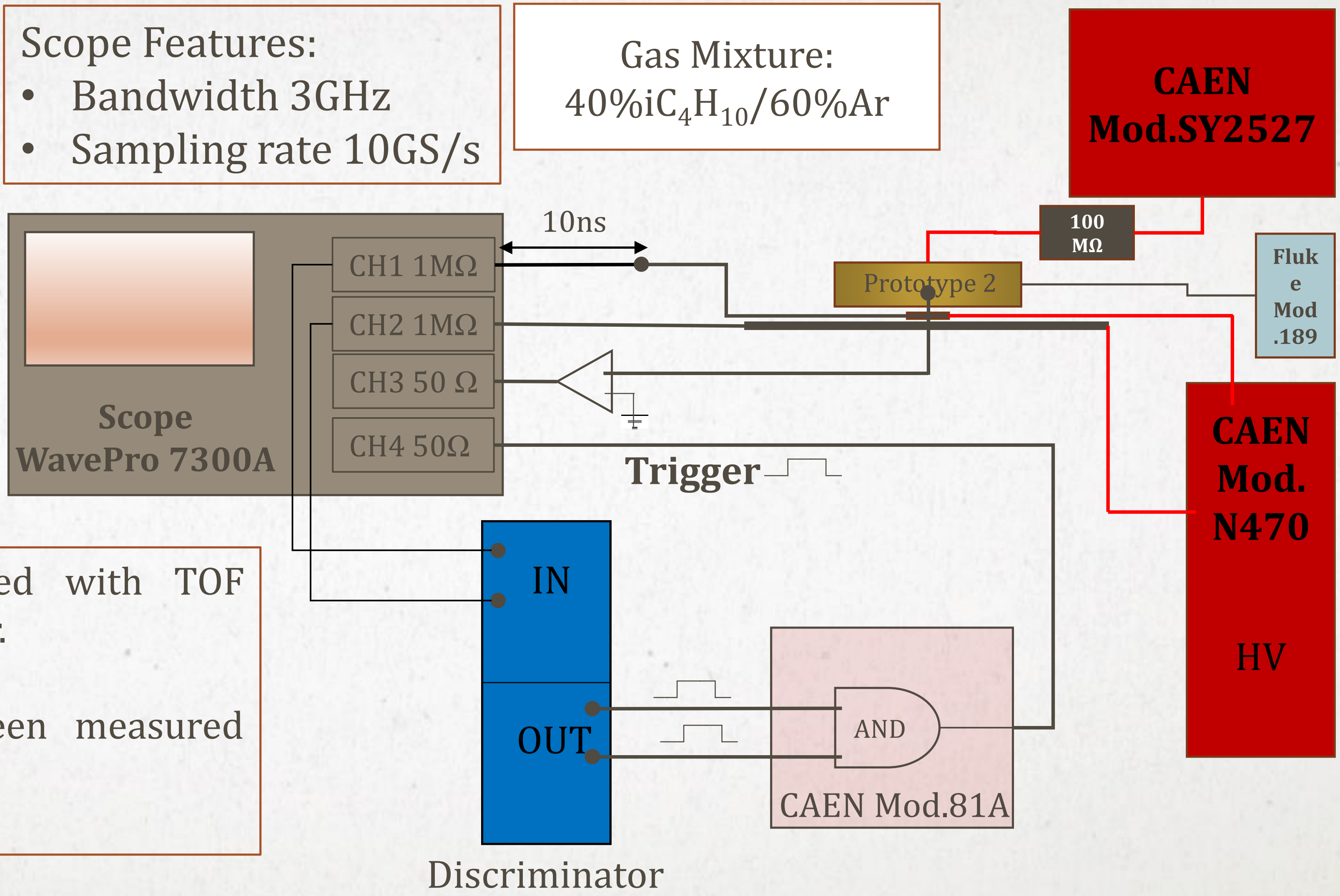
Experimental Set-Up (INFN ROMA2)

Scope Features:
- Bandwidth 3GHz
- Sampling rate 10GS/s

Gas Mixture:
$40\%iC_4H_{10}/60\%Ar$

Prototype 2 characterization was carried out exploiting **atmospheric muons**.

Two scintillators have been used as trigger reference.



Time resolution has been measured with TOF technique, with respect to a scintillator.

The trigger time resolution has been measured during the test resulting in 456ps.

RESULTS
EFFICIENCY – TIME RESOLUTION

- 1.5mm gas gap
- **Efficiency=triple/double**
- **Threshold=5*RMS background (~7mV)**

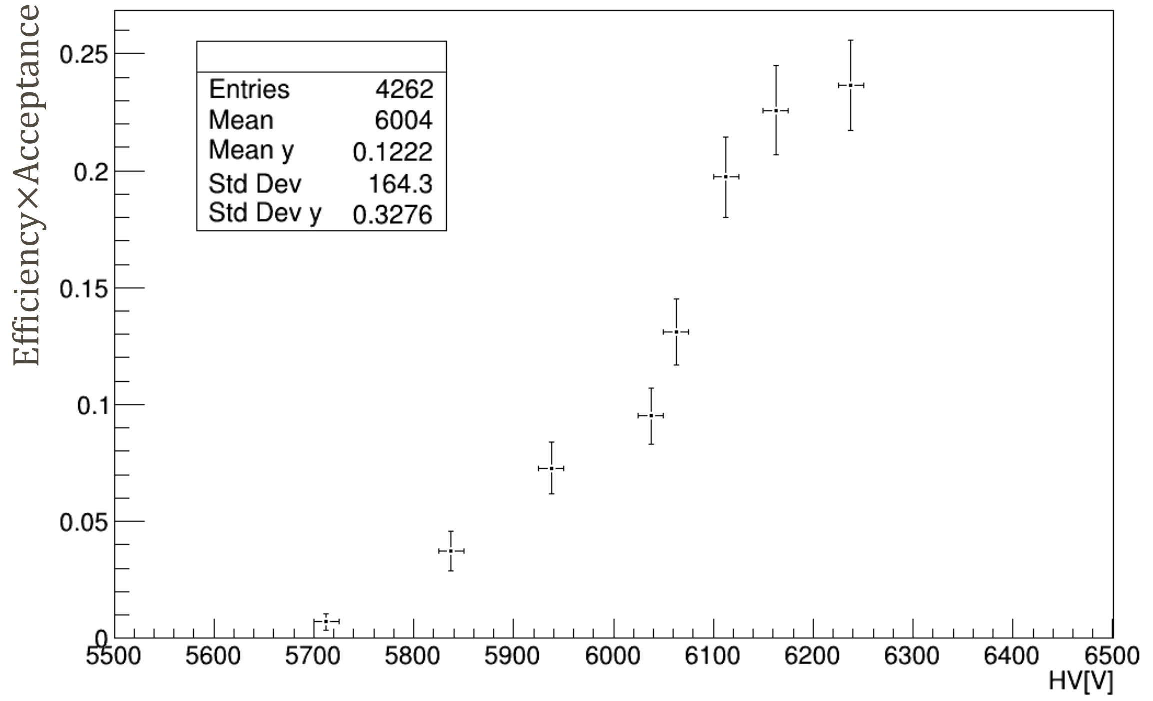
- HV = 6190V
- Time walk correction

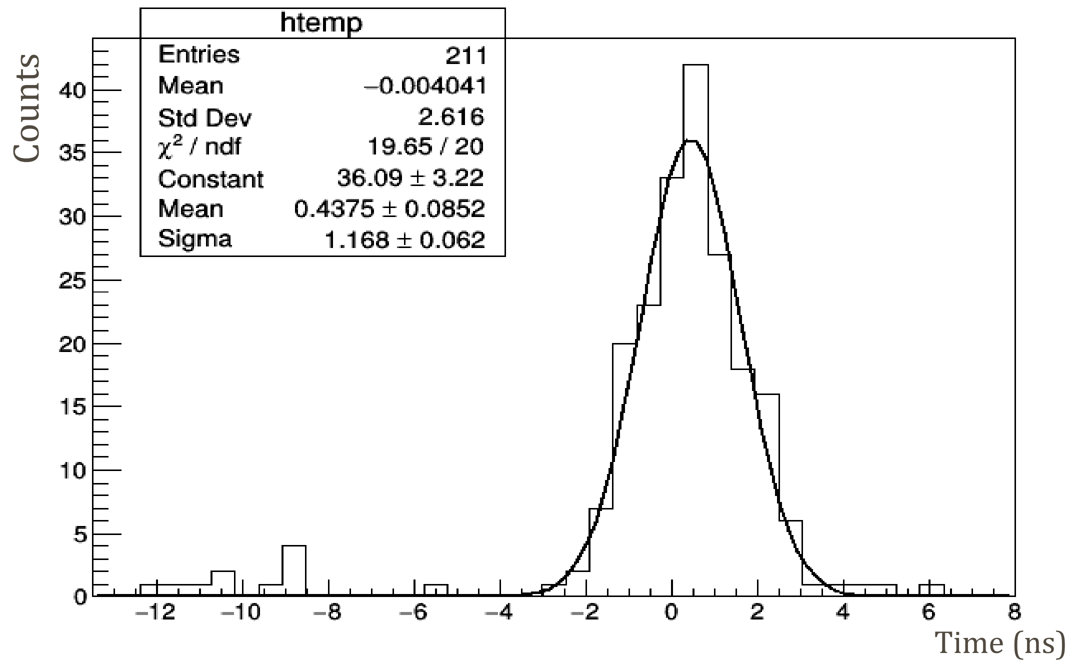
$\sigma_{RPC}^2 = \sigma^2 - \sigma_{scint}^2$

$\sigma_{scint} = 456ps$

$\sigma_{RPC} = 1.1ns$

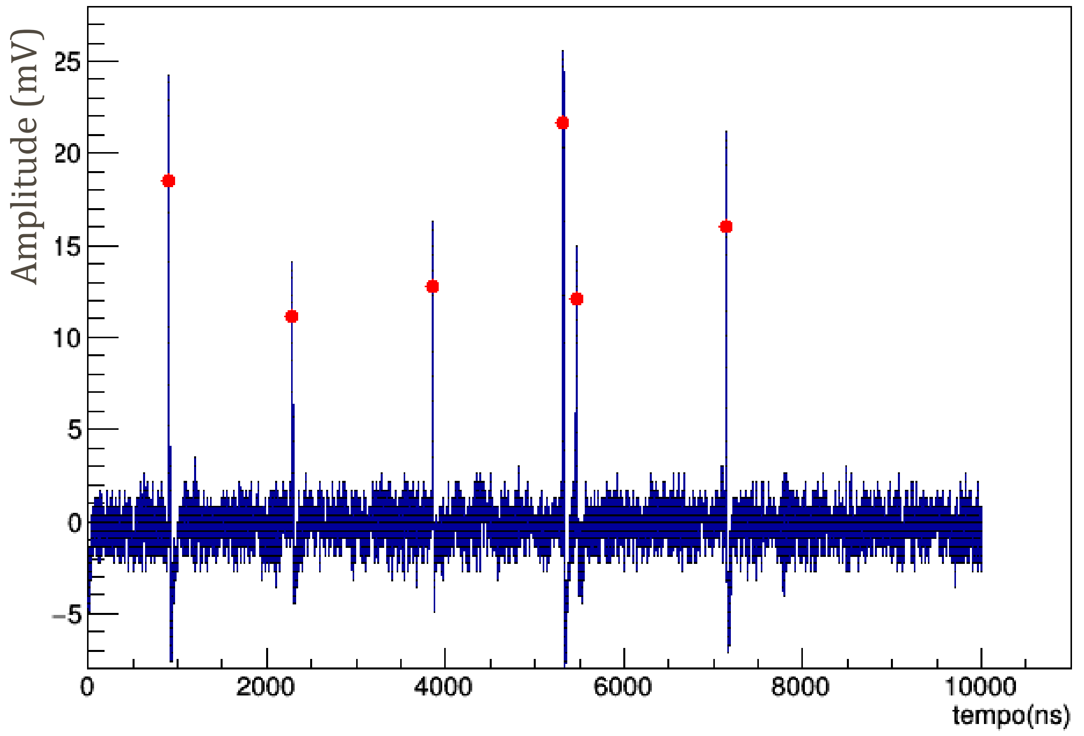
More than 30kHz/cm² Random Counting Rate

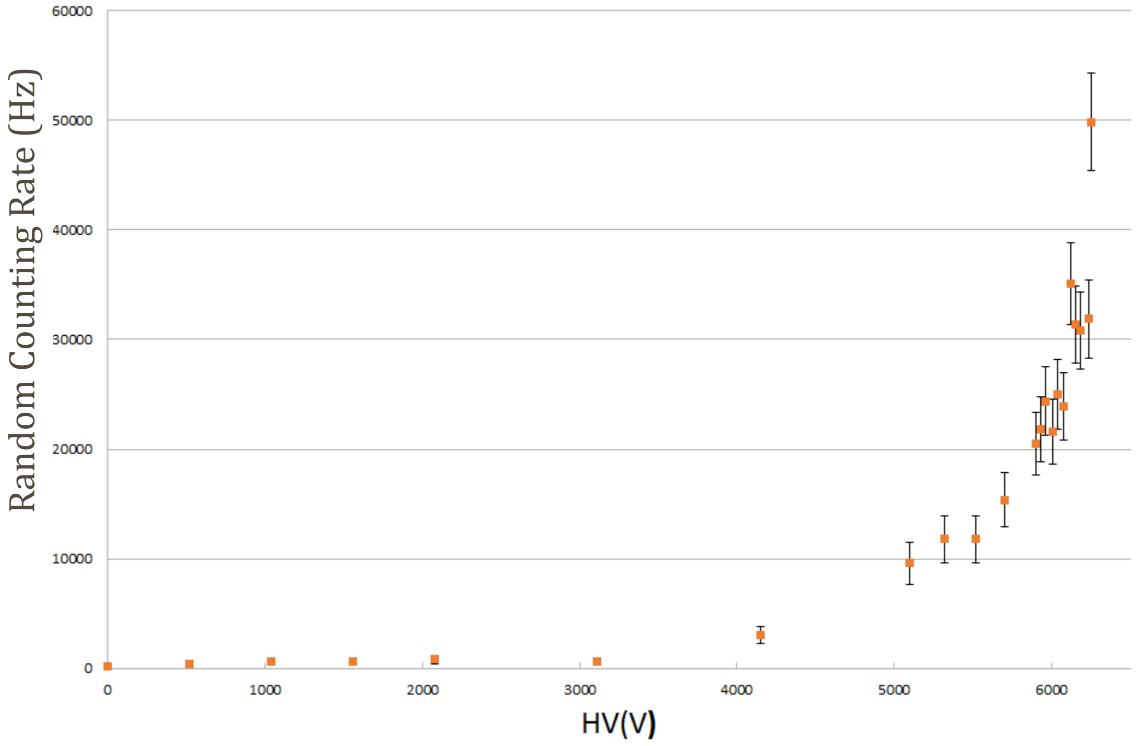




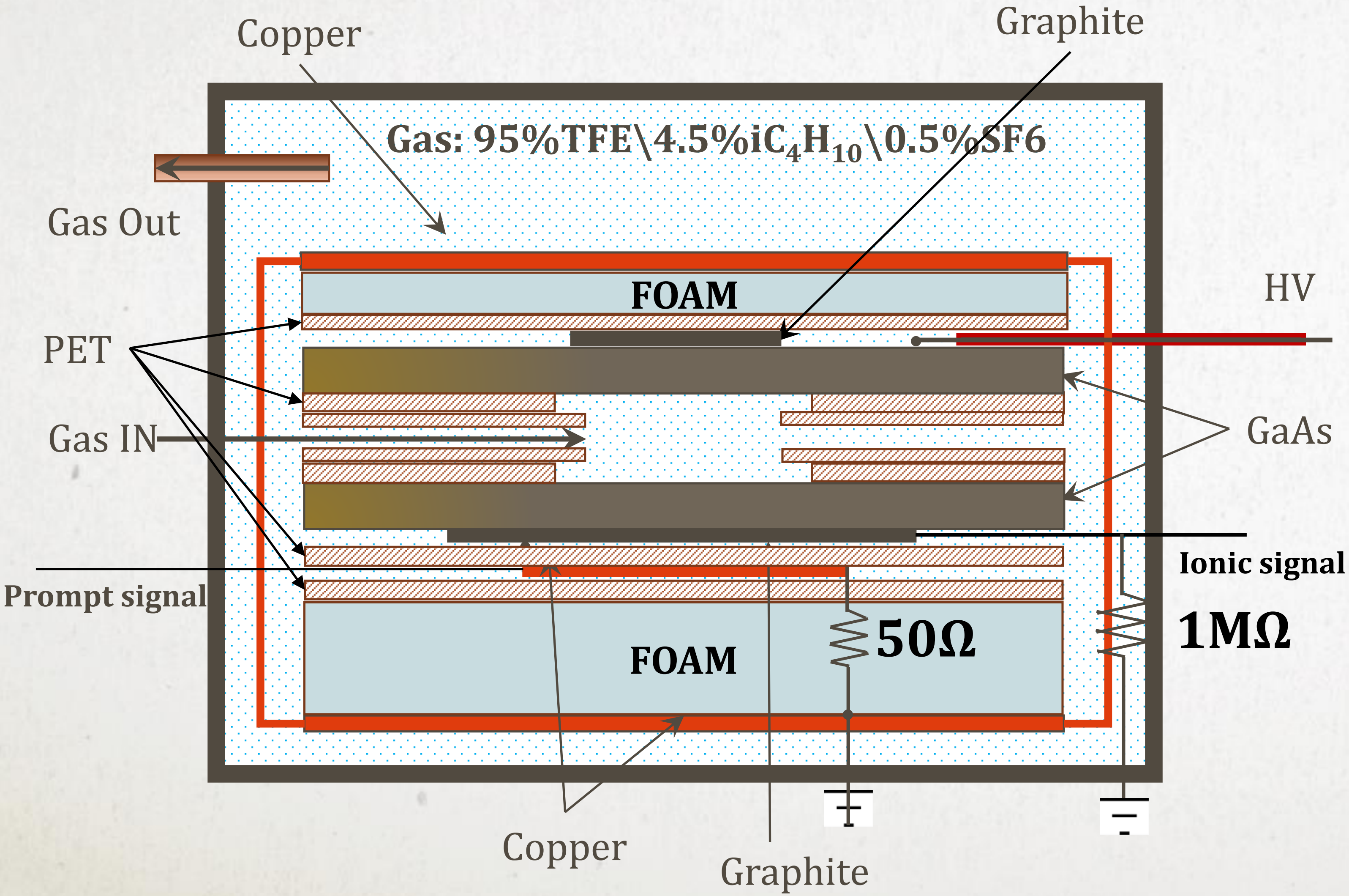
RESULTS
RANDOM COUNTING RATE

Random counting rate has been measured acquiring waveforms in a 10μs time window and discriminating signals over the same threshold used in efficiency measure.

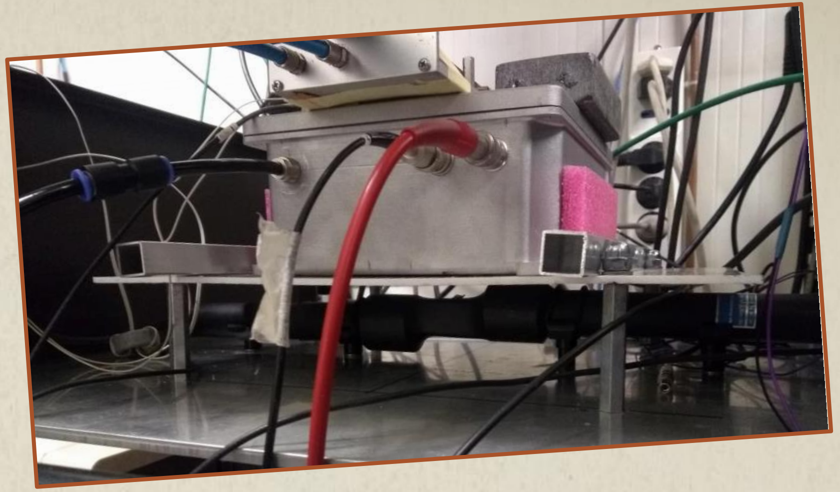




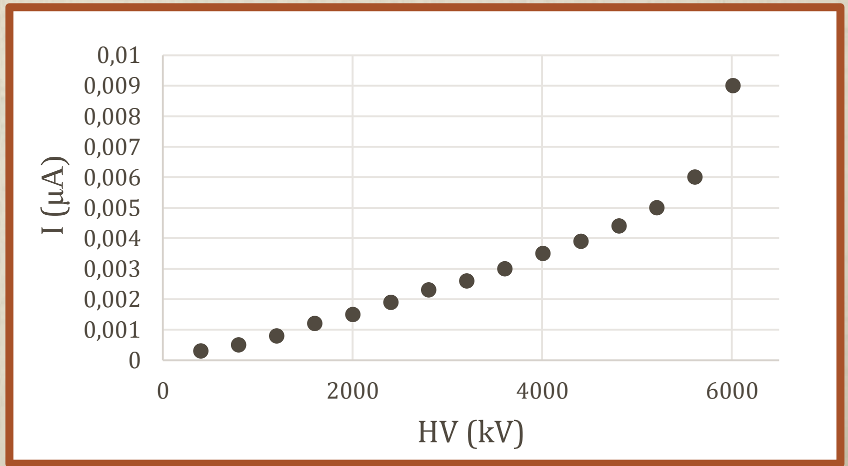
PROTOTYPE 3 (Semi-Insulating GaAs)



Prototype 3 Set-Up



Prototype 3 shows impressive stability with standard mixture

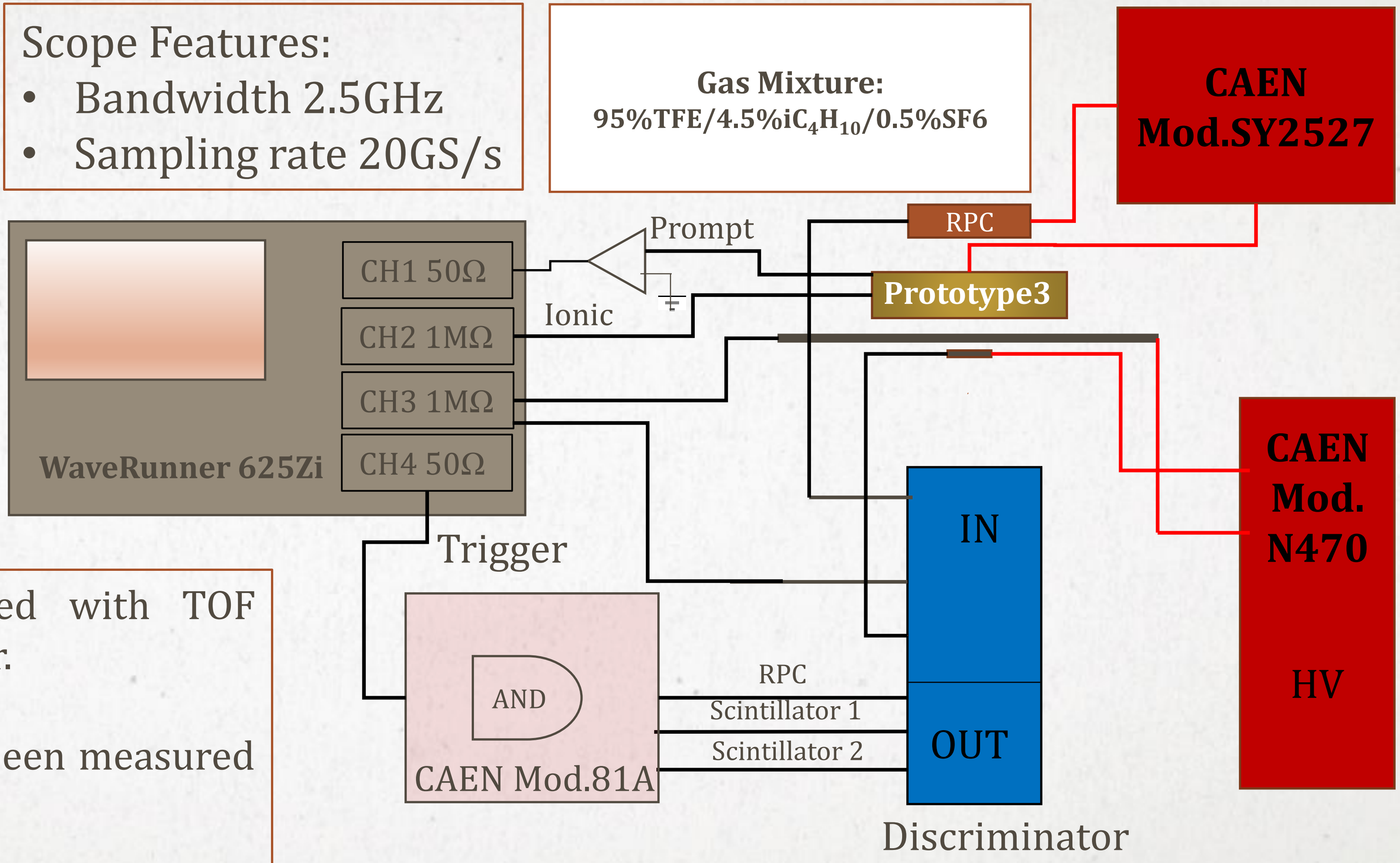


Experimental Set-Up (INFN ROMA2)

Prototype 3 characterization was carried out exploiting **atmospheric muons**.

Two scintillators and one RPC have been used as trigger reference.

Scope Features:
- Bandwidth 2.5GHz
- Sampling rate 20GS/s

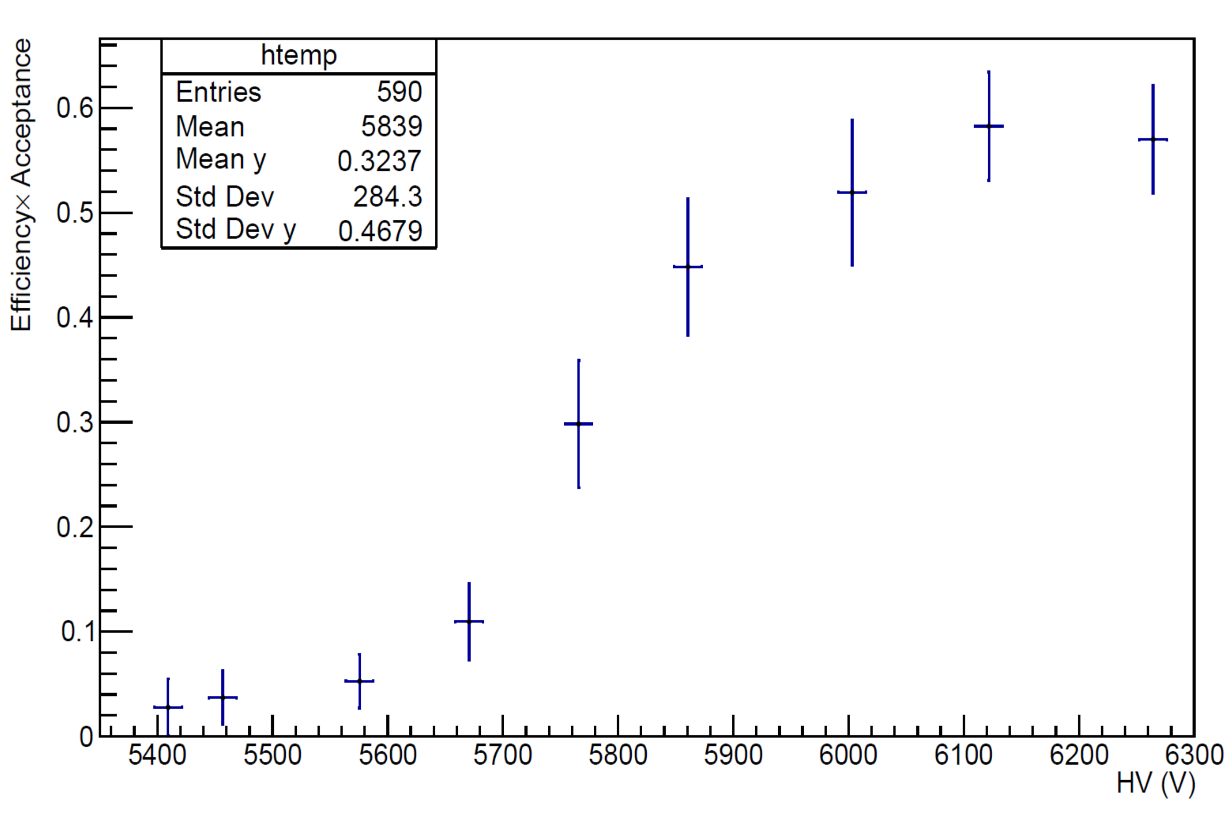


Time resolution has been measured with TOF technique, with respect to a scintillator.

The scintillators time resolution has been measured during the test resulting in 267ps.

RESULTS
EFFICIENCY – TIME RESOLUTION

- 1.3mm gas gap
- **Efficiency=quadruple/triple**
- **Threshold=5*RMS background (~25mV)**

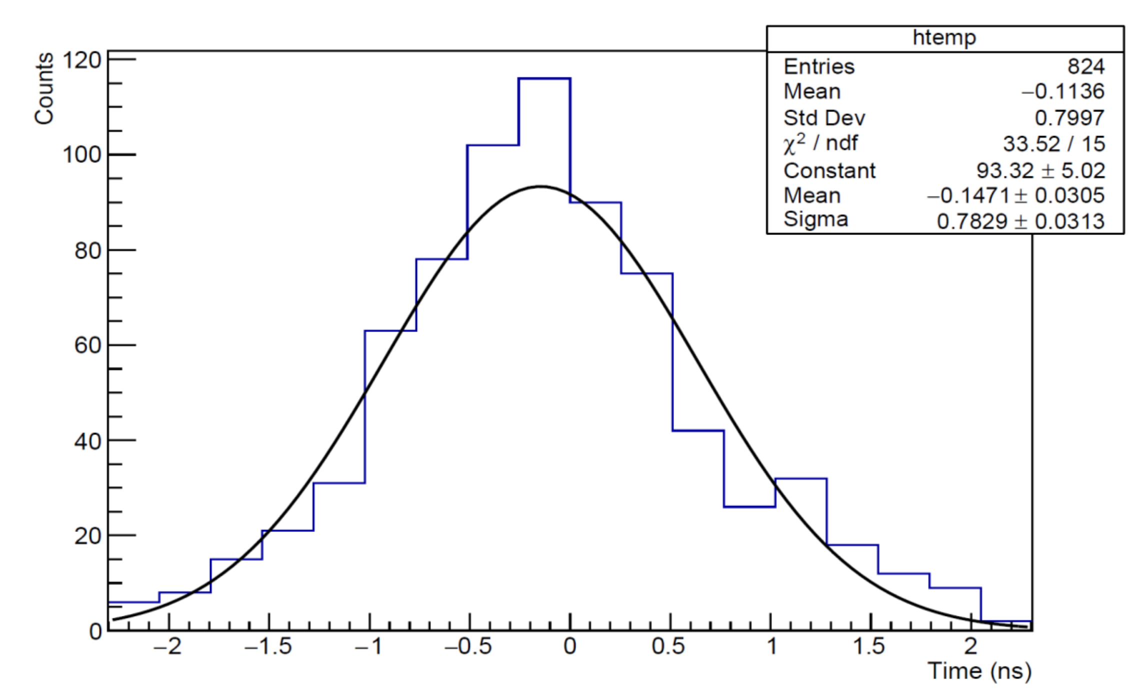


- HV = 6130V
- Time walk correction

$\sigma_{RPC}^2 = \sigma^2 - \sigma_{scint}^2$

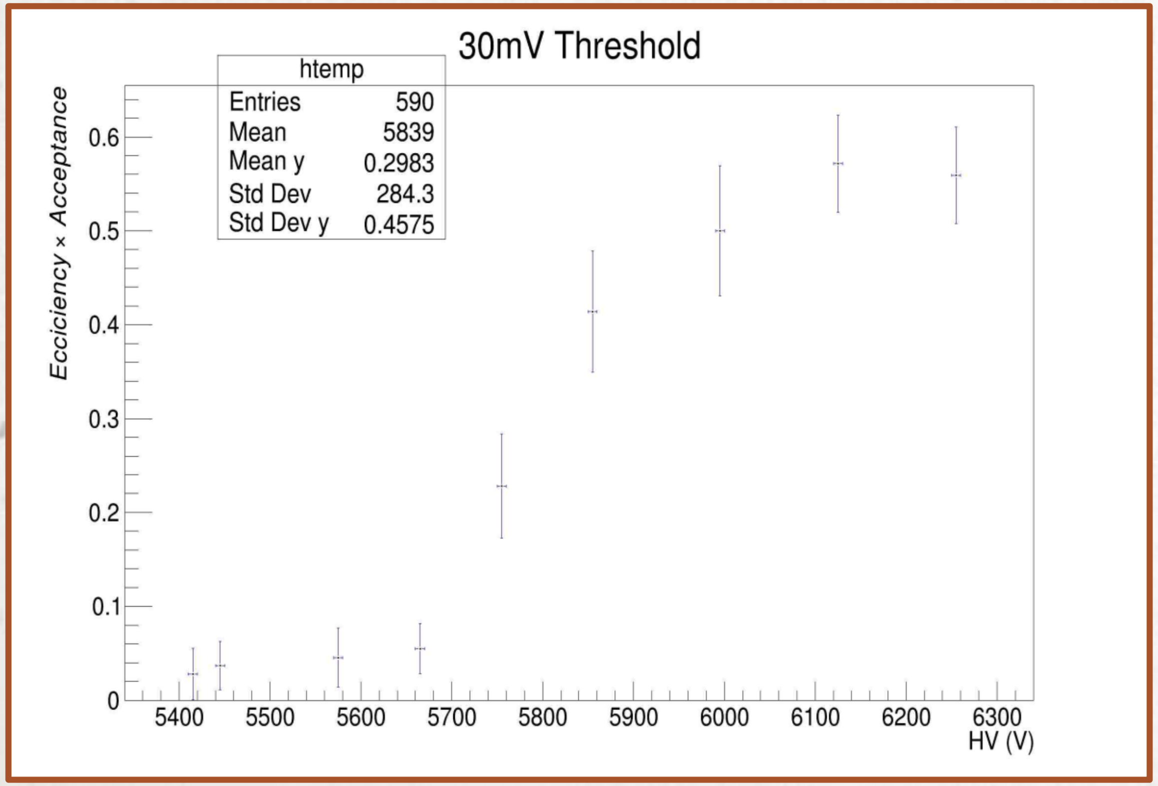
$\sigma_{scint} = 267ps$

$\sigma_{RPC} = 736ps$

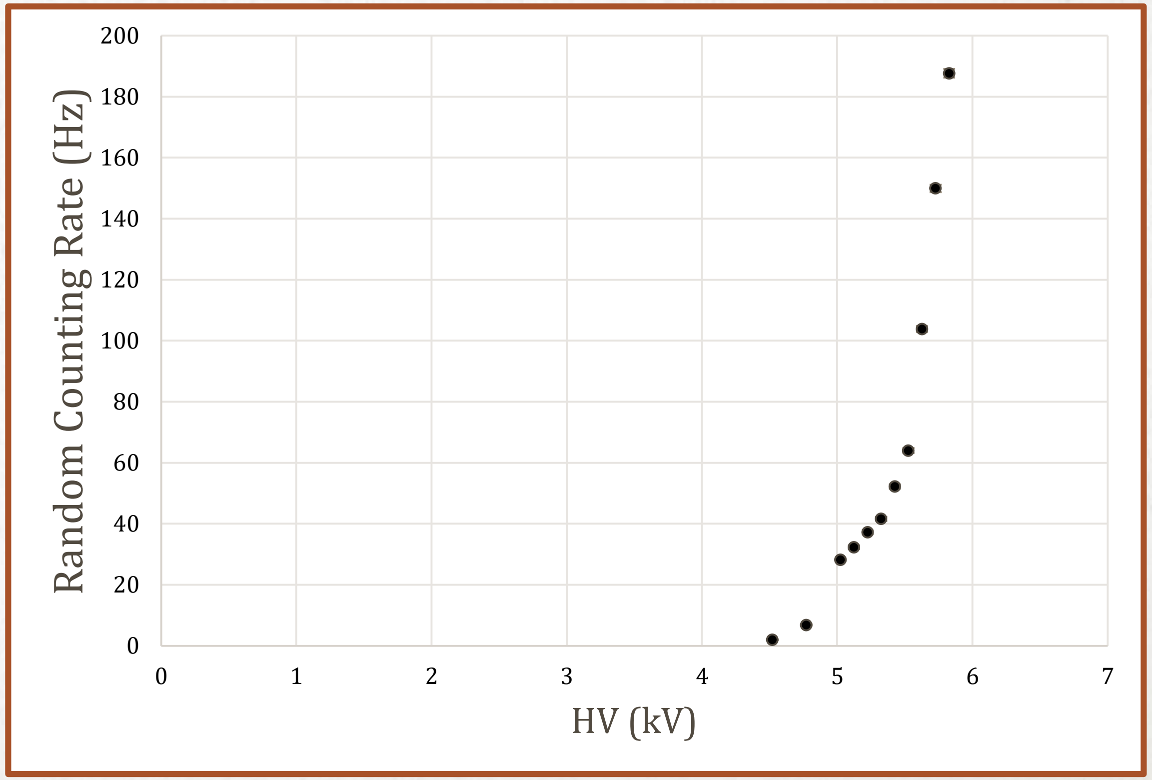


RESULTS
RANDOM COUNTING RATE

Random Counting Rate has been measured discriminating signals with 30mV threshold

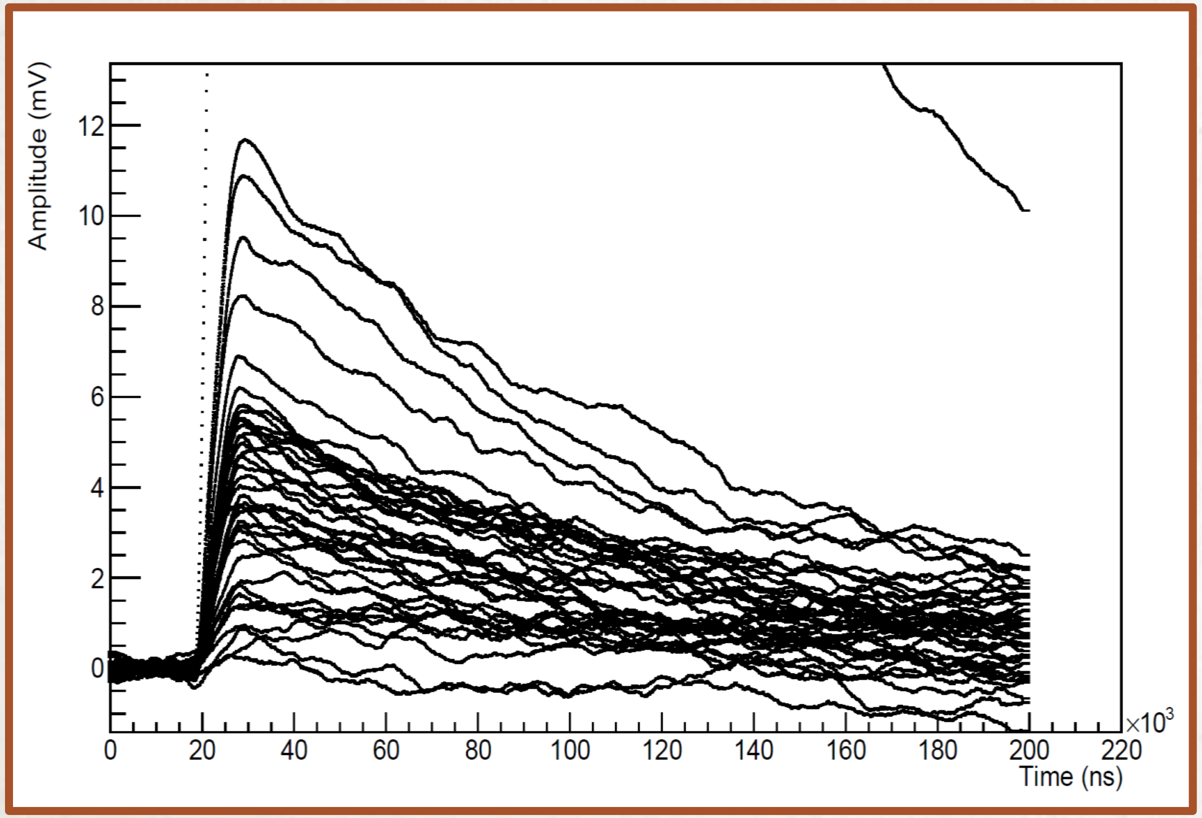


4cm^2 Surface

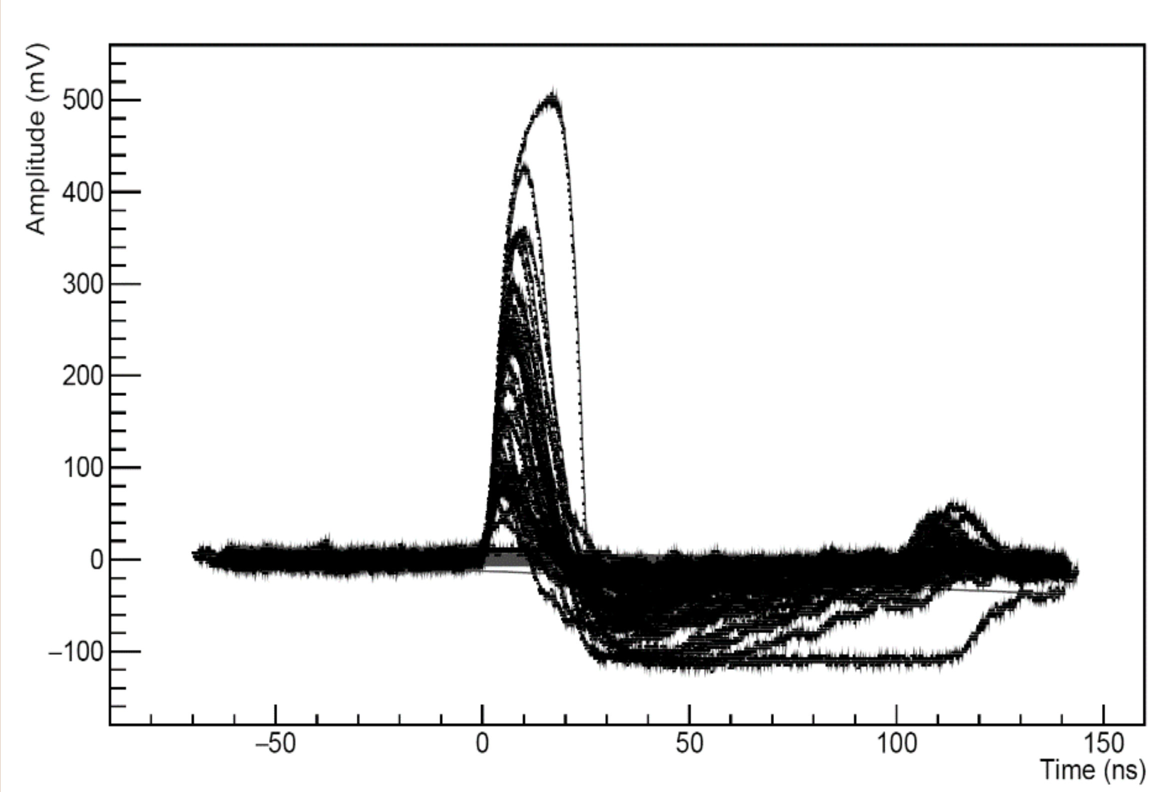


Prompt and Ionic signals

Ionic signals
200μs waveforms without random pulses



Prompt signals (Charge amplifier shaping)



Conclusions

All prototypes give good results in term of efficiency knee and time resolution.

Prototype 1 test, on electron beam, proves that detector can reach at least 90% efficiency despite 100kHz/cm^2 random counting rate (lower limit for Rate Capability)

Prototype 2 test prove that similar results can be reached substituting ground electrode with one of lower resistivity

Prototype 3 test prove that random counting rate can be drastically reduced improving build quality

Stability and low noise reached in prototype 3 allow to conduct careful studies on ionic/prompt ratio in addition to process dynamics and Rate Capability