Preliminary studies on RPCs for SWGO

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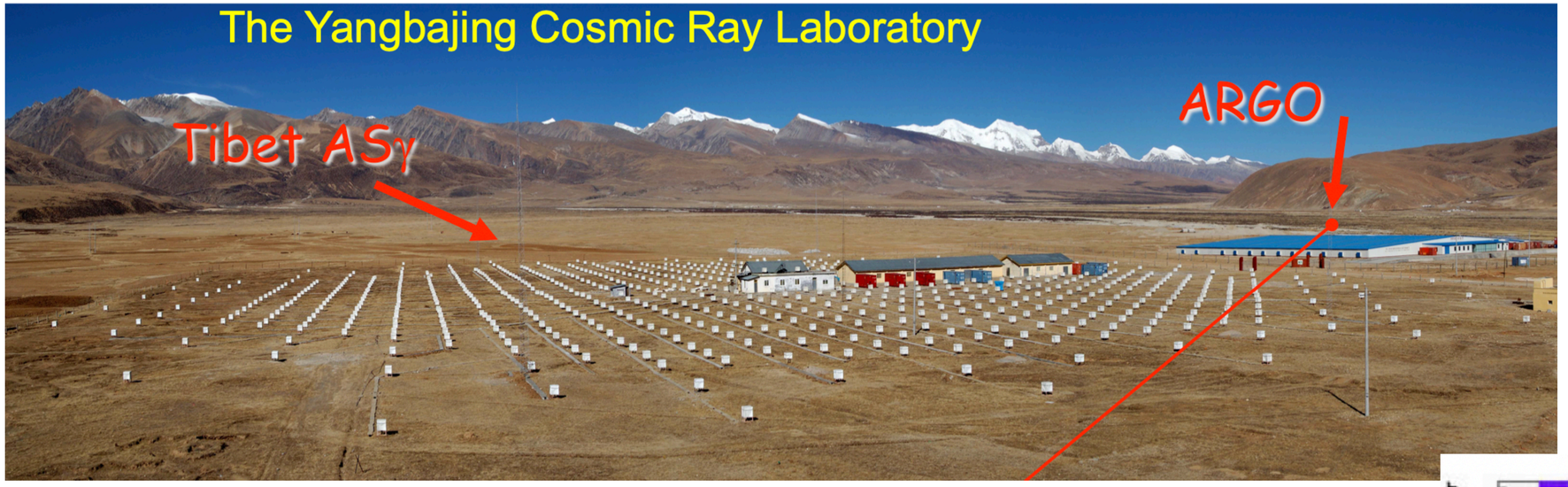
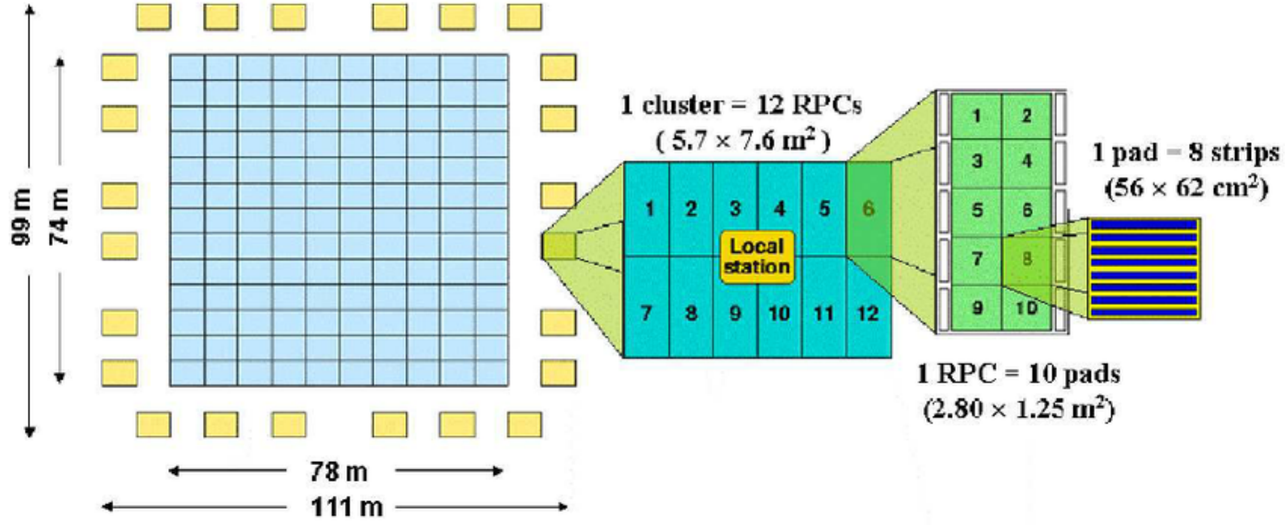
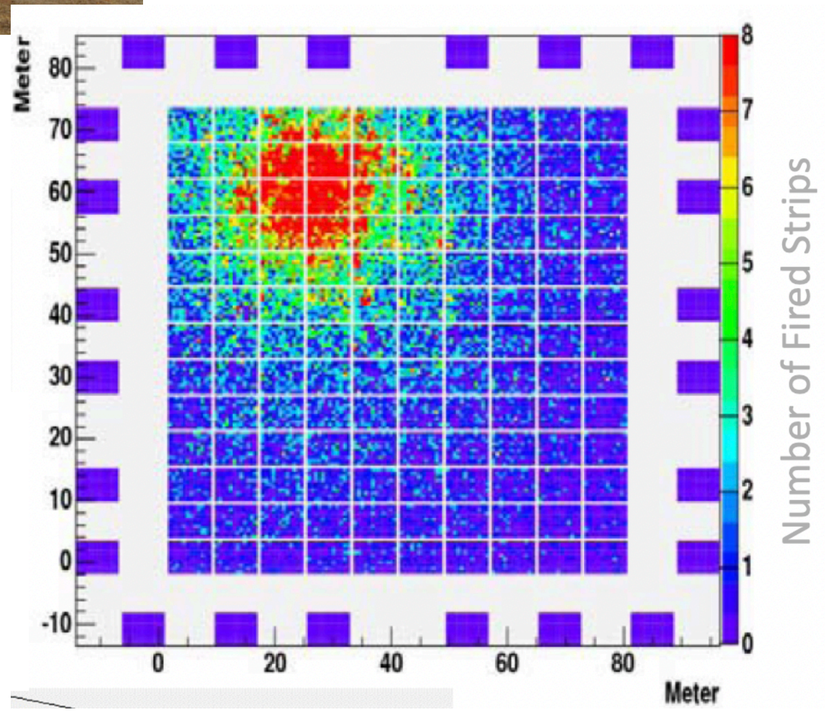
B) **INFN LNF**
C) **Università Tor Vergata**

RPCs for Cosmic Ray Physics



Data taking with Very low maintenance:
2007 -2012
Angular resolution **0.5° at 1 TeV** (shower front projection with time measurement)
Energy Range: **100 GeV - 10 PeV**
5600 m² of active area + **1100 m²** guard ring





R&D for an RPC project for SWGO

In the framework of PNRR CTAplus, Working Package 1520, INAF

INFN will support the construction and test of an hybrid RPC + Water-Cerenkov of about 100-200 m2

Rome TorVergata group lead the RPC construction project starting from the Argo experience

Timeline for the project:

- Tenders closed by the end of 2023:
  1) Front-End Read-Out per RPC production
  2) HPL electrodes production for RPC
  3) HV, LV e Read Out systems
  4) **Full assembled RPCs production-> N° 32 RPC total area 73 m^2**

  Note: 1 Cluster of Argo 50 m^2 produced physics results (Astroparticle Physics 17 (2002) 151–165)
- Test station preparation before April 2024
- RPC Production and test: main fraction before end of 2024
- Site definition for final test end of 2024
- Installation and operations in 2025
- **Application for SWGO if approved by the Collaboration**

Man Power:

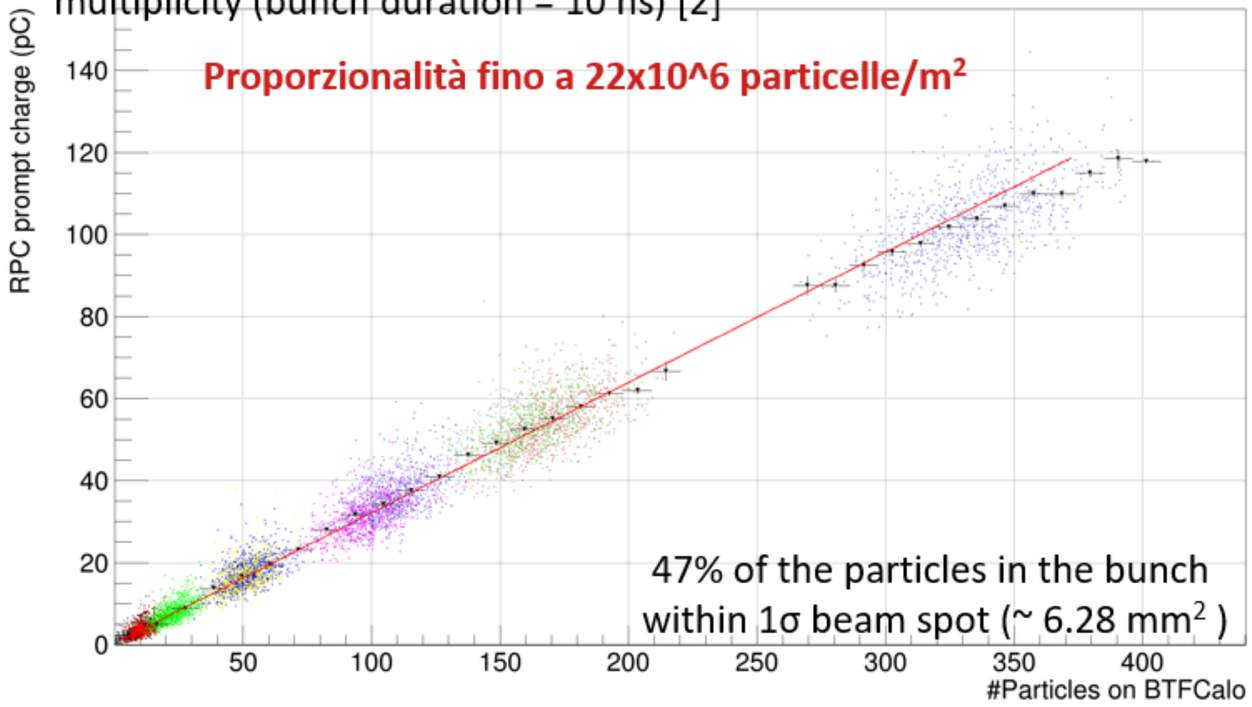
Rome 2 TorVergata INFN: 1.5 FTE for 2024

LNF INFN: interest with the plan to create a small group for middle 2024 (1.5 FTE)

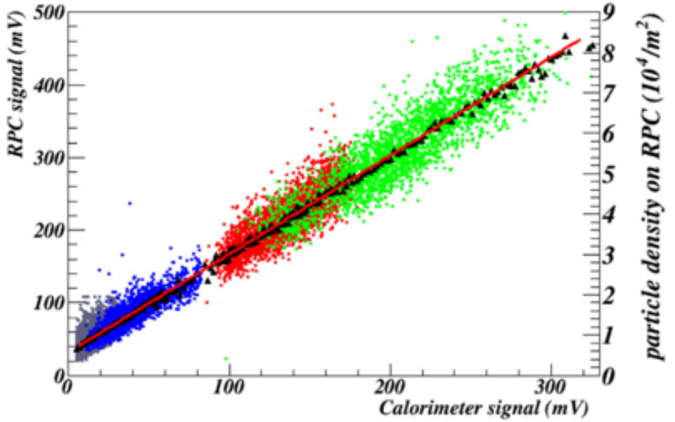
Main differences with Argo:
1) RPC operated in avalanche mode -> Advanced Linearity

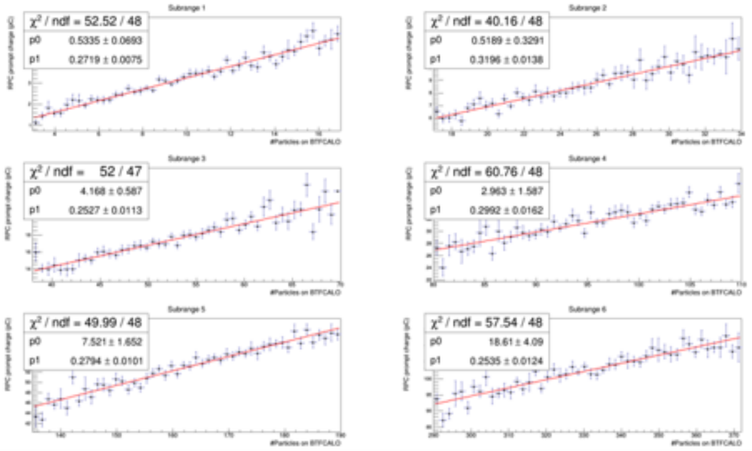
Analog calorimetry with RPC
operated in saturated avalanche regime

RPC (1 mm gas gap thickness) electronic signal charge vs beam bunch multiplicity (bunch duration = 10 ns) [2]



Streamer regime response [1]



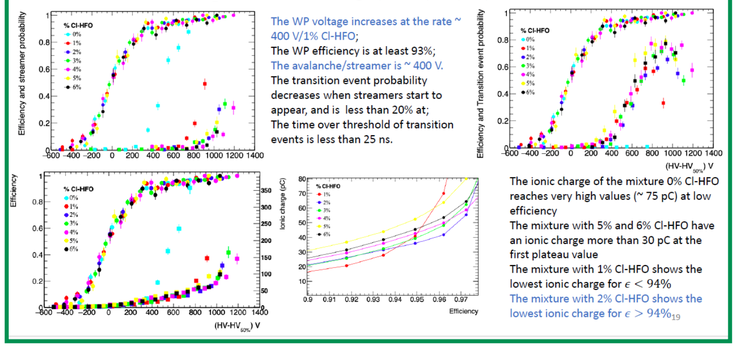


R. Bartoli et al. *Intrinsic linearity of bakelite Resistive Plate Chambers operated in streamer mode*. NIM Section A, 2019.
A. Rocchi, R. Cardarelli, B. Liberti et al. *JINST* 15 (2020) 12, C12004. 10.1088/1748-0221/15/12/C12004

Main differences with Argo:
2) Gas in closed loop -> Ecogas Mixture and Eco Compatibility

- Gas mixtures tested: HFO/CO2/i-C4H10/HFO-Cl

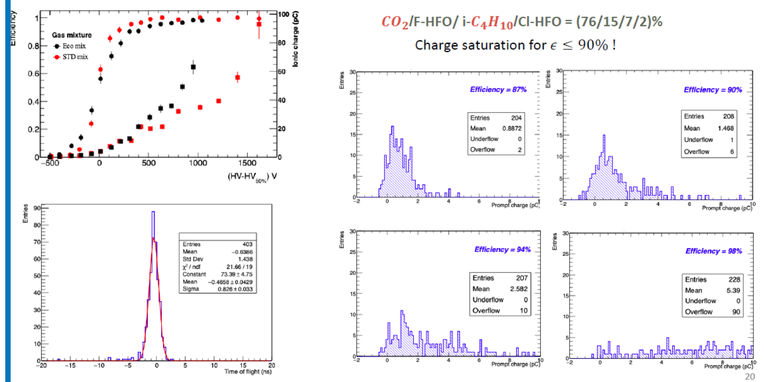
HFO/i-C_4H_{10} at a fixed ratio of (15/7) %+
variable ratio of CO_2/ Cl-HFO in the range (78/72) %/(0-6) %



The WP voltage increases at the rate ~ 400 V/1% Cl-HFO;
The WP efficiency is at least 93%;
The avalanche/streamer is ~ 400 V.
The transition event probability decreases when streamers start to appear, and is less than 20% at;
The time over threshold of transition events is less than 25 ns.

The ionic charge of the mixture 0% Cl-HFO reaches very high values (~ 75 pC) at low efficiency
The mixture with 5% and 6% Cl-HFO have an ionic charge more than 30 pC at the first plateau value
The mixture with 1% Cl-HFO shows the lowest ionic charge for $\epsilon < 94\%$
The mixture with 2% Cl-HFO shows the lowest ionic charge for $\epsilon > 94\%_{19}$

- HFO-Cl Best operating performance mixture



CO_2/F-HFO/ i-C_4H_{10}/Cl-HFO = (76/15/7/2)%

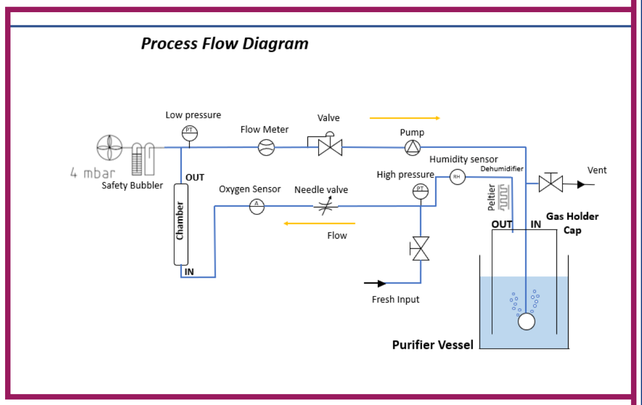
Charge saturation for $\epsilon \leq 90\%$!

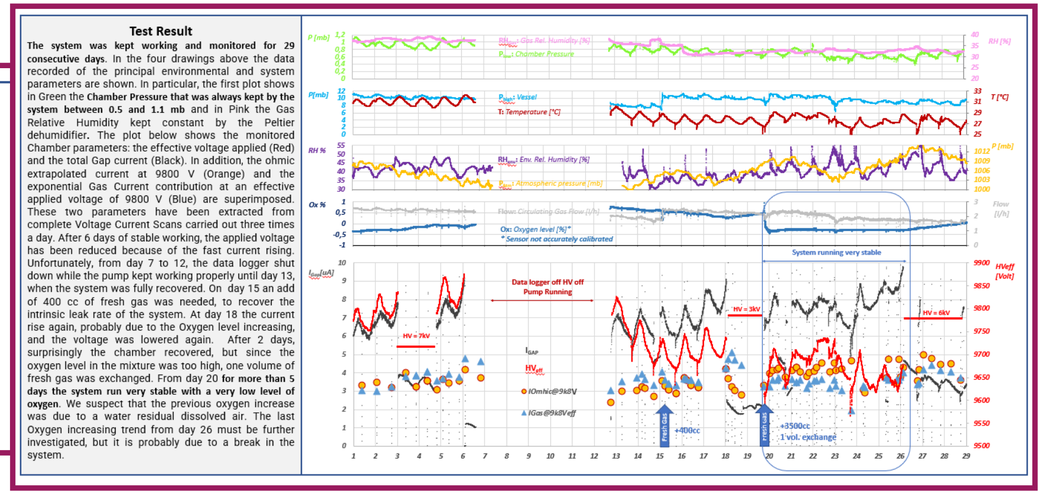
20

Search for EcoGas Mixture started in 2014, HFO and CO2 based mixtures

Search for SF6 substitute, HFCl and other possible candidates

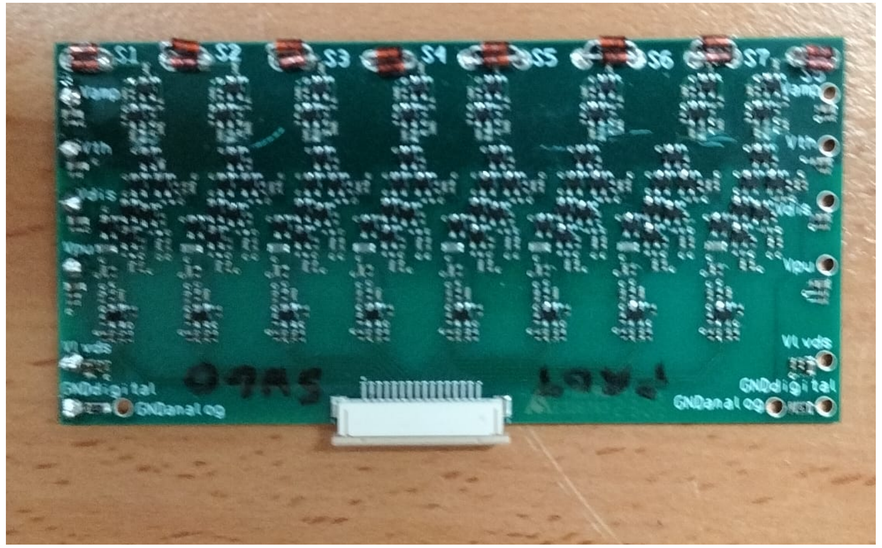
Low cost Closed Loop/ Recirculation System under study





Main differences with Argo:
3) Improved electronics with lower threshold

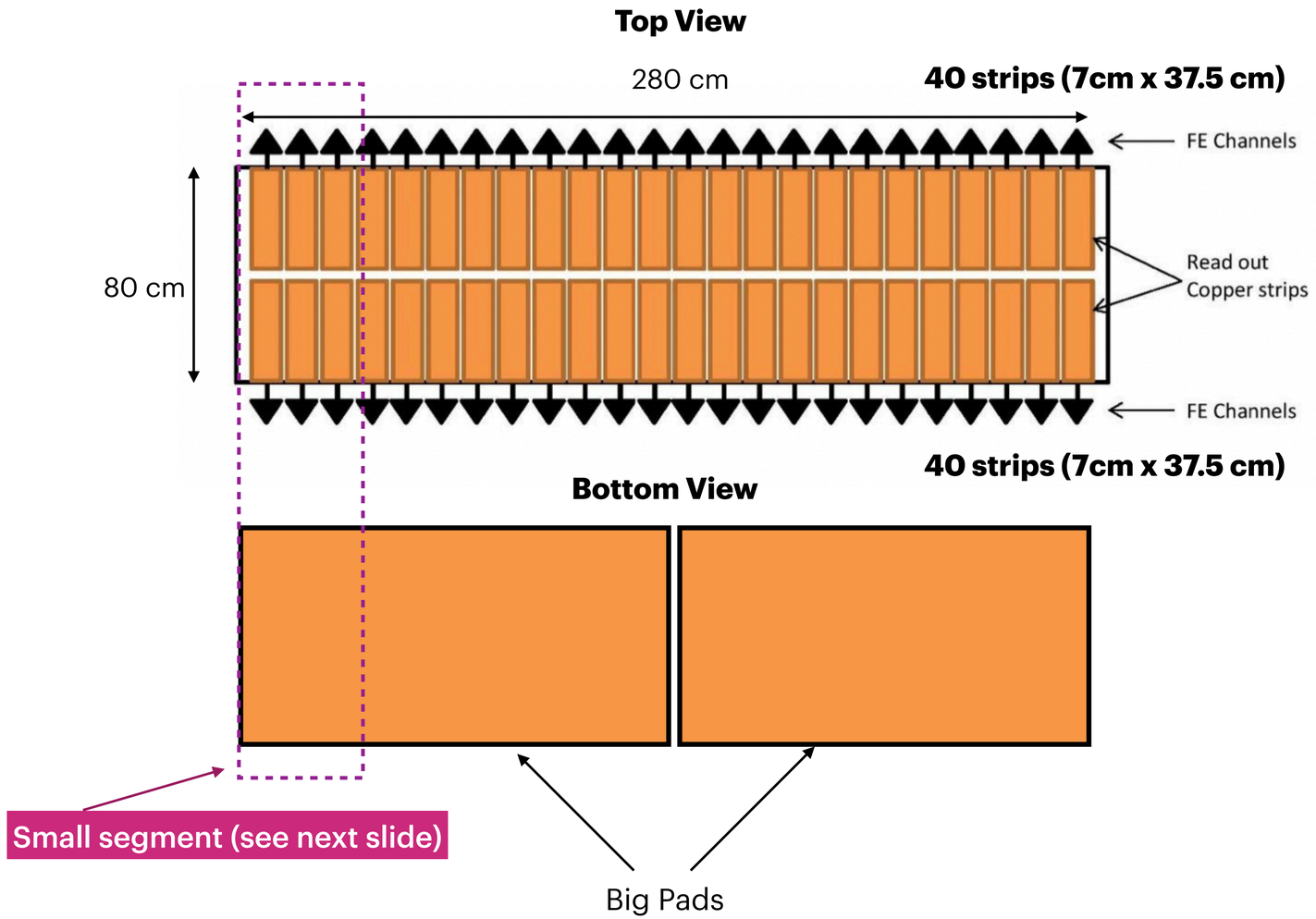
- New Front-End adequate to avalanche-mode
- Discrete components version of a Full Custom circuit (dedicated to ATLAS activity)
- 1 Board 8 channels, LVDS Outputs



Work in progress

R&D for an RPC project for SWGO

- **RPC chamber deisgn**

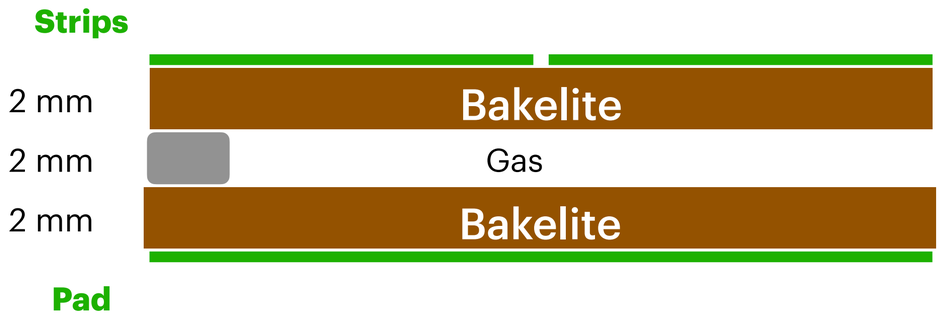


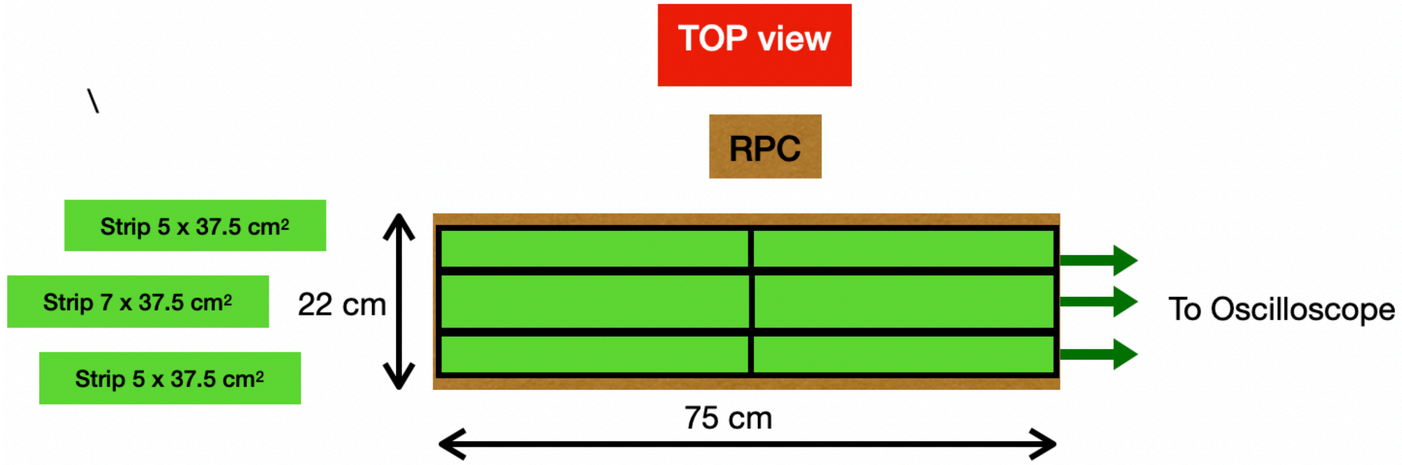
Goal of R&D

- Evaluate performance (efficiency and time resolution) with large strips
- Optimization of Front-end readout
- Mechanical layout evaluation

Tor Vergata test: small segment (6 strips) RPC layout

2 mm gap RPC Not in scale

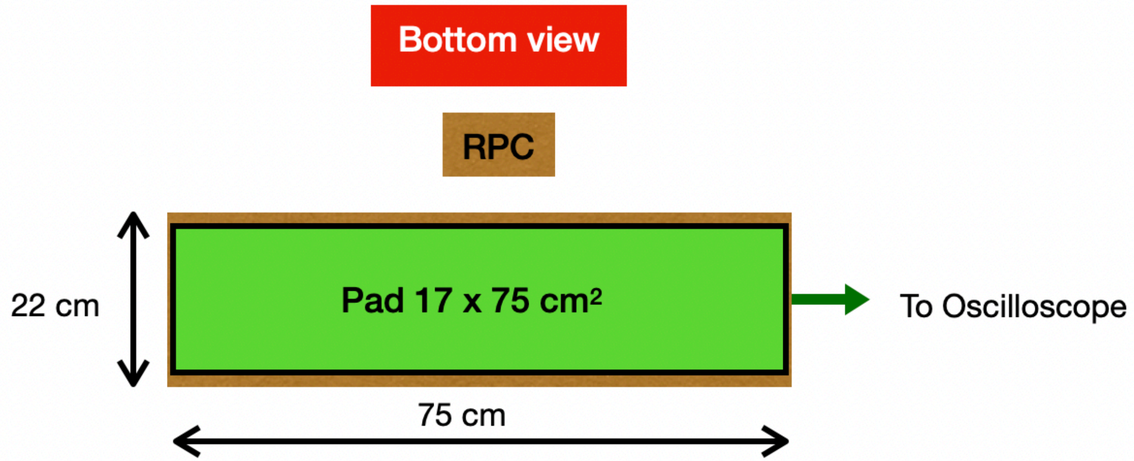




Detector:

Single Gap RPC: 2 mm gas gap

Gas mixture: $C_2H_2F_4$ - C_4H_{10} - SF_6 (95.2% - 4.5% - 0.3%)



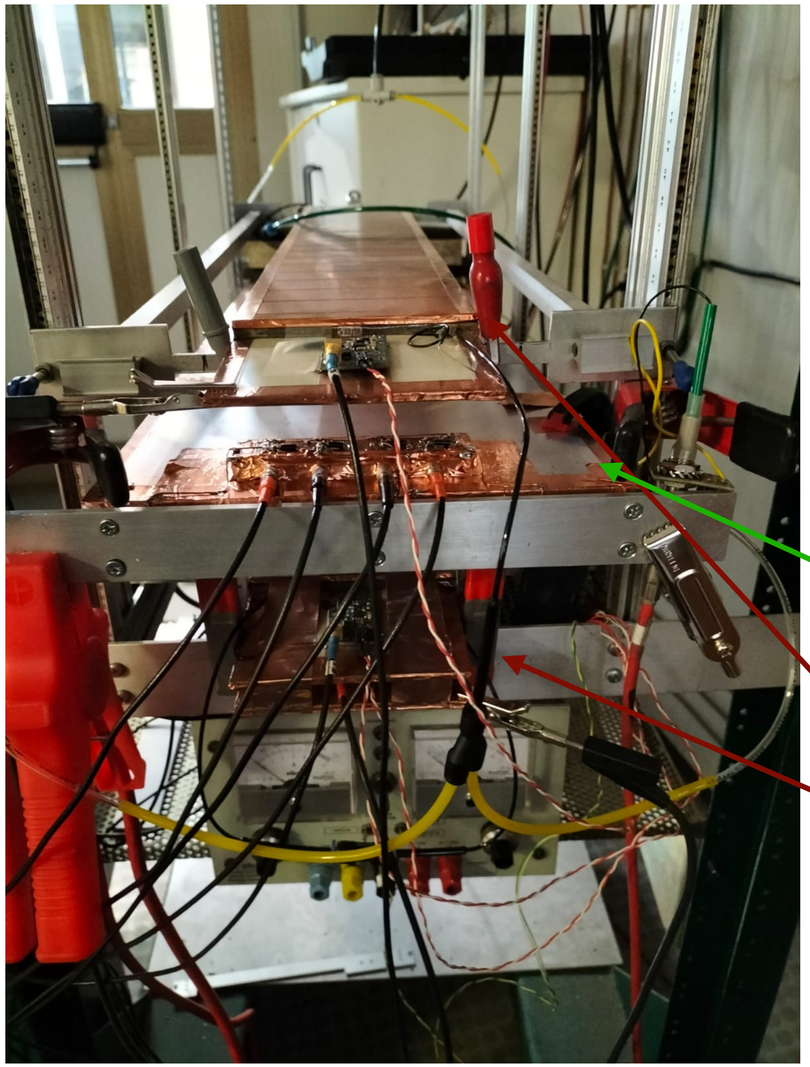
Readout:

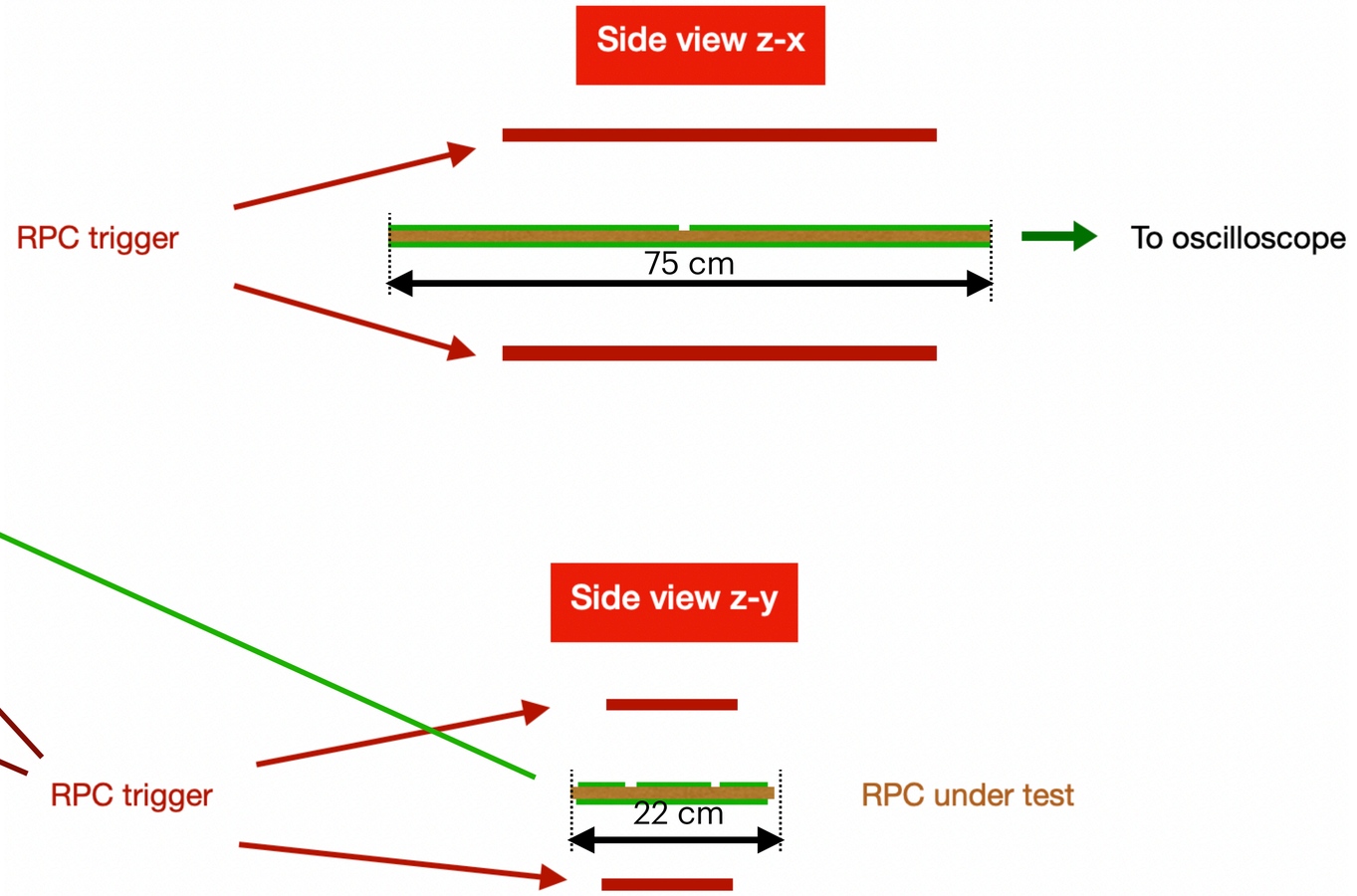
3 strips to oscilloscope from one side

3 strips to front end electronic from the other side (still not used)

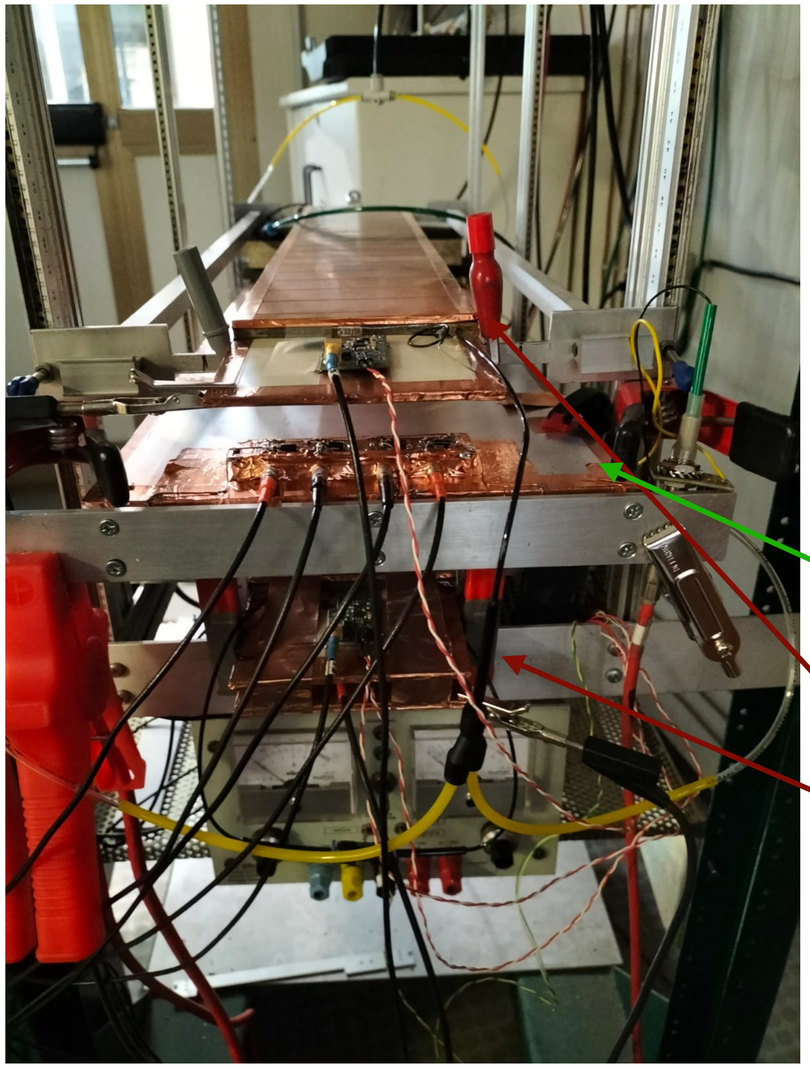
1 bigger pad to oscilloscope

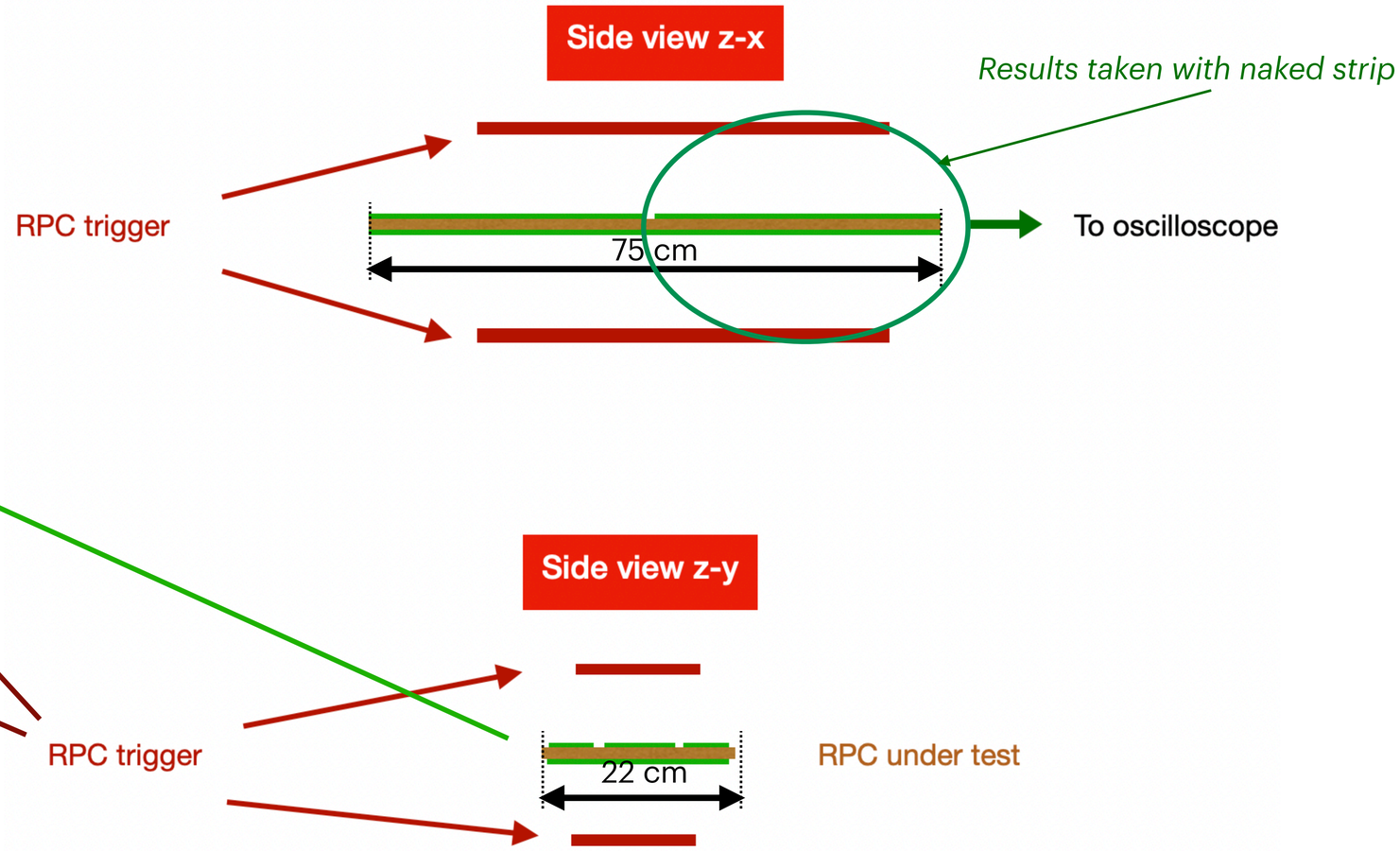
System layout



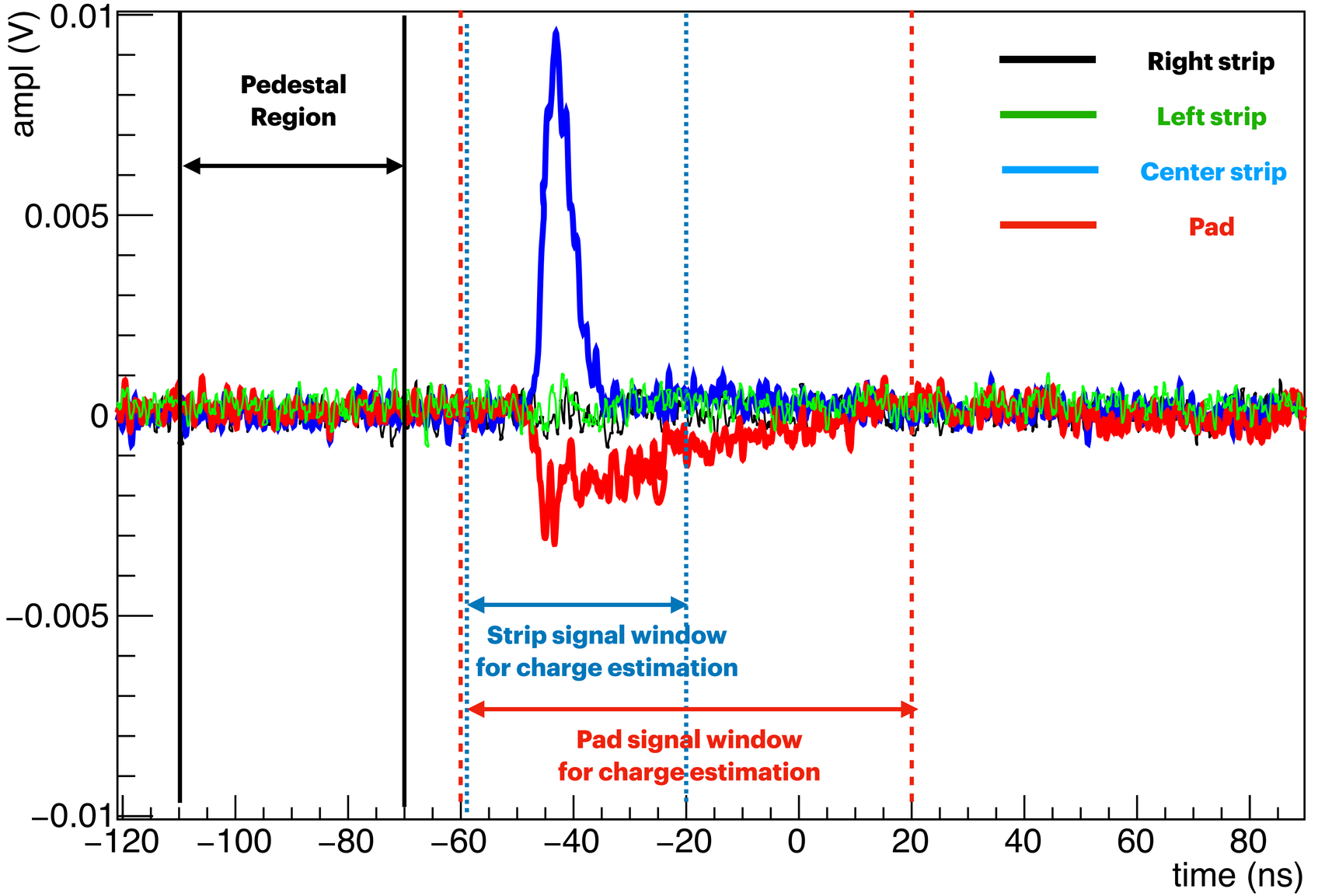


System layout



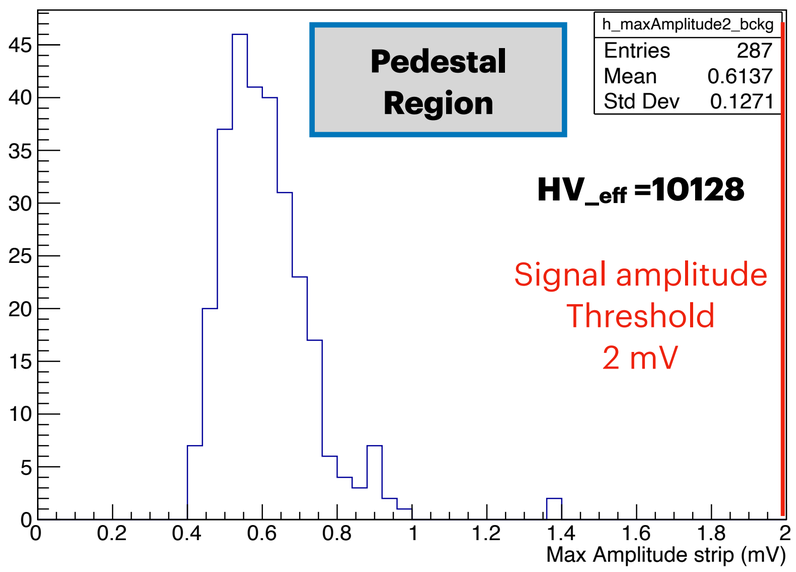


Typical signal waveform

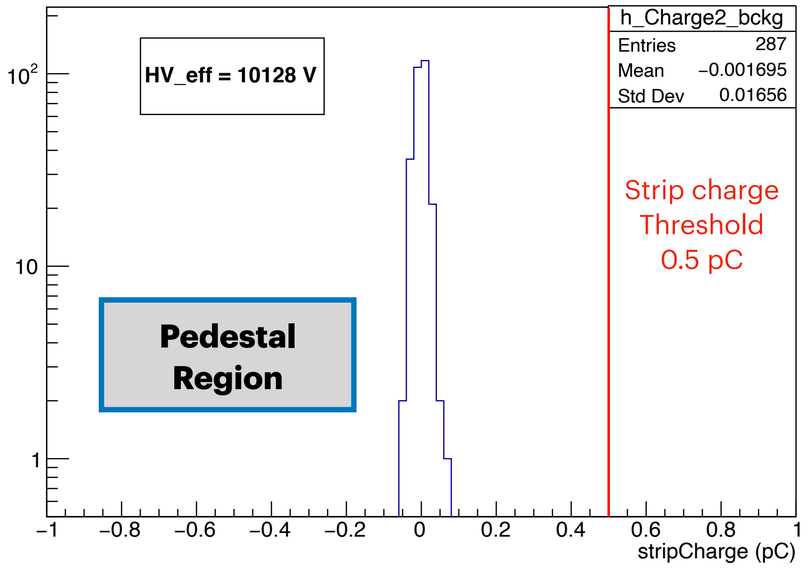


Efficient Event selection

Max amplitude middle strip in background region (ch2)



Integrated Charge middle strip in background region (ch2)

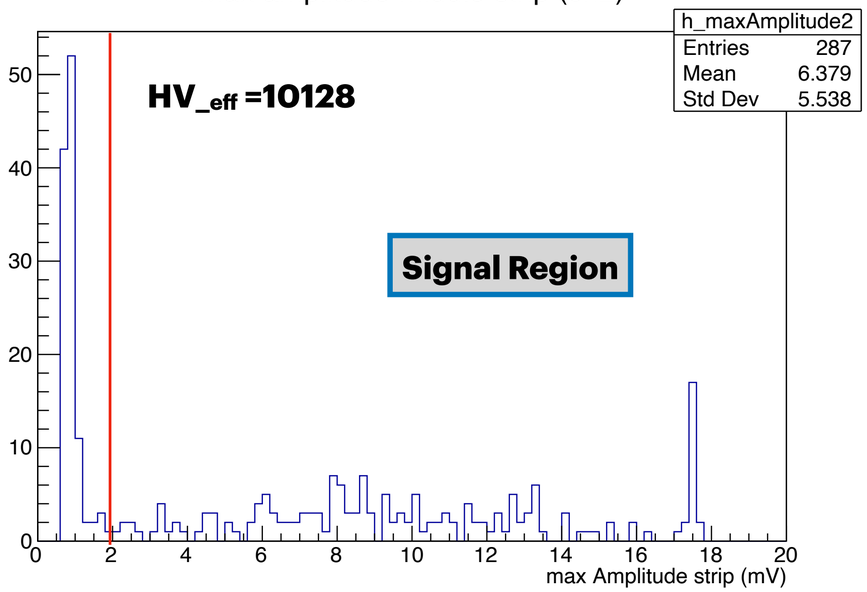


RPC efficient if:
Peak amplitude middle strip > 2 mV
Middle strip integrated charge > 0.5 pC

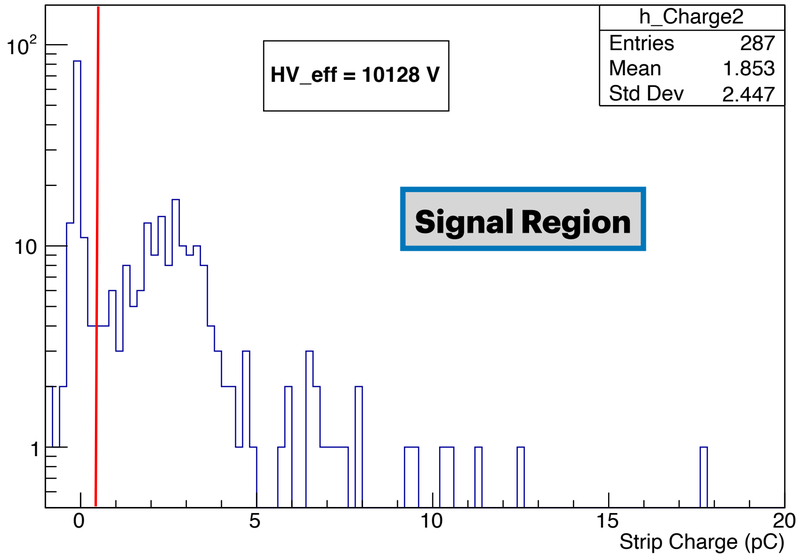
Pedestal Region

HV normalized at
P_0 = 1010 mbar
T_0 = 20°

Max amplitude middle strip (ch2)

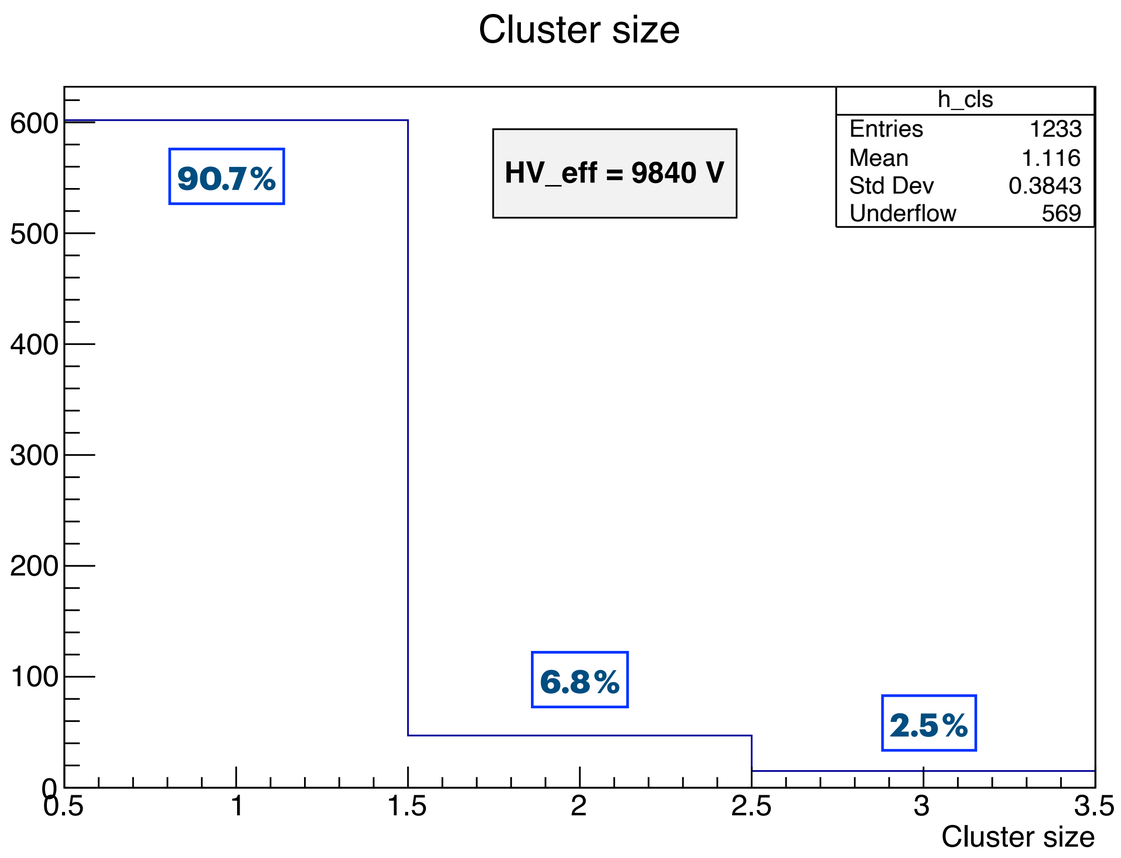


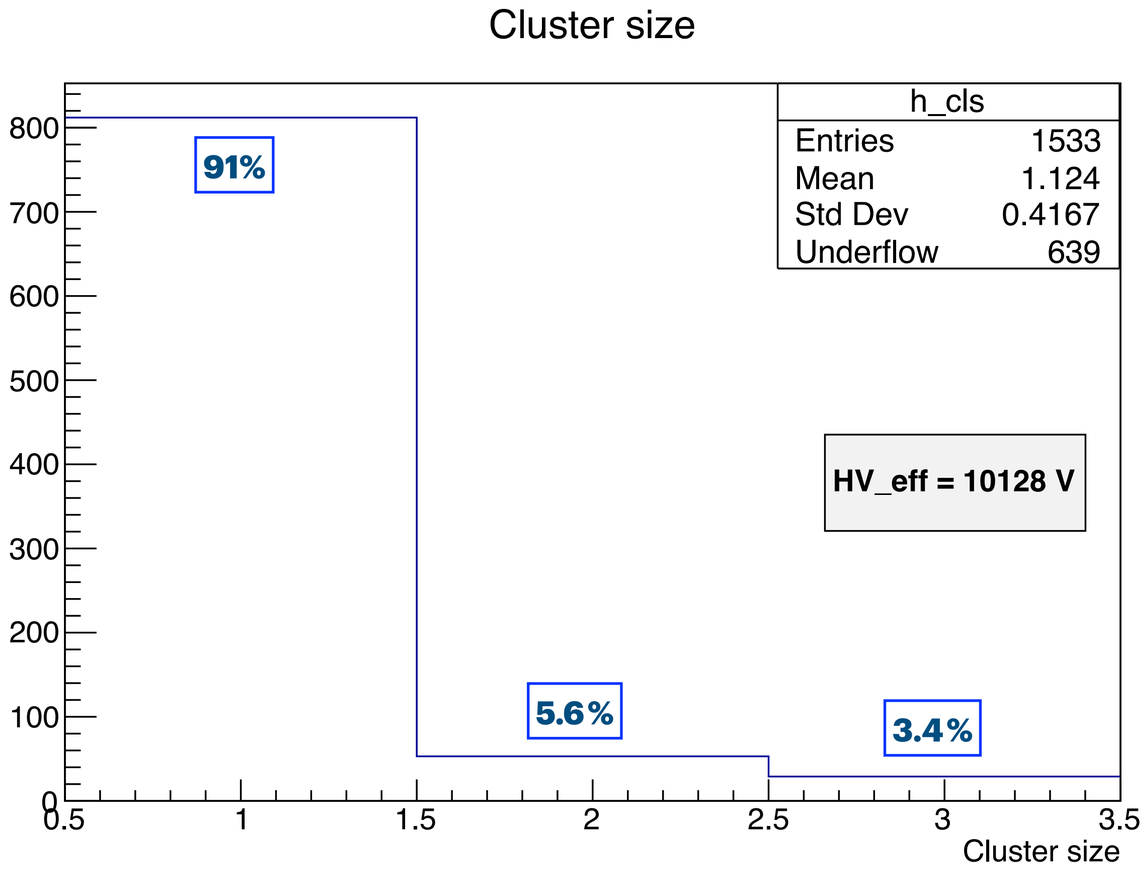
Integrated Charge middle strip (ch2)



Signal Region

Cluster size





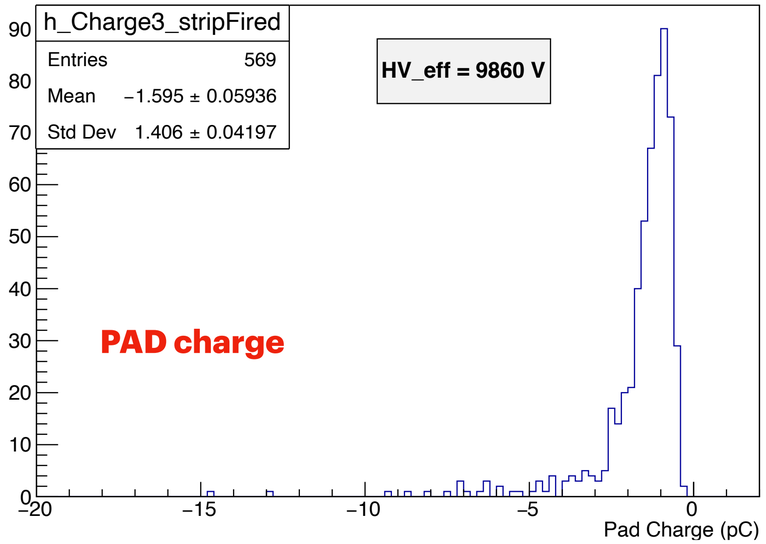
HV normalized at
P_0 = 1010 mbar
T_0 = 20°

Integrated charge HV_{eff} = 9860 V

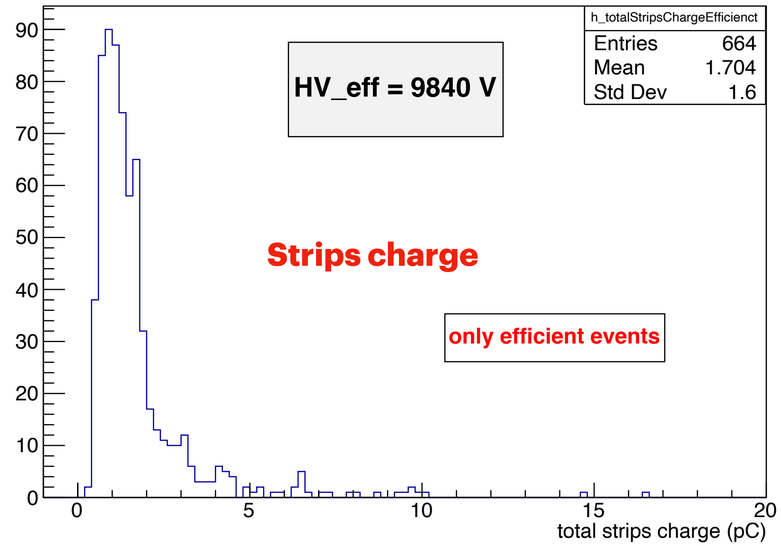
HV normalized at
P_0 = 1010 mbar
T_0 = 20°

Strip fired

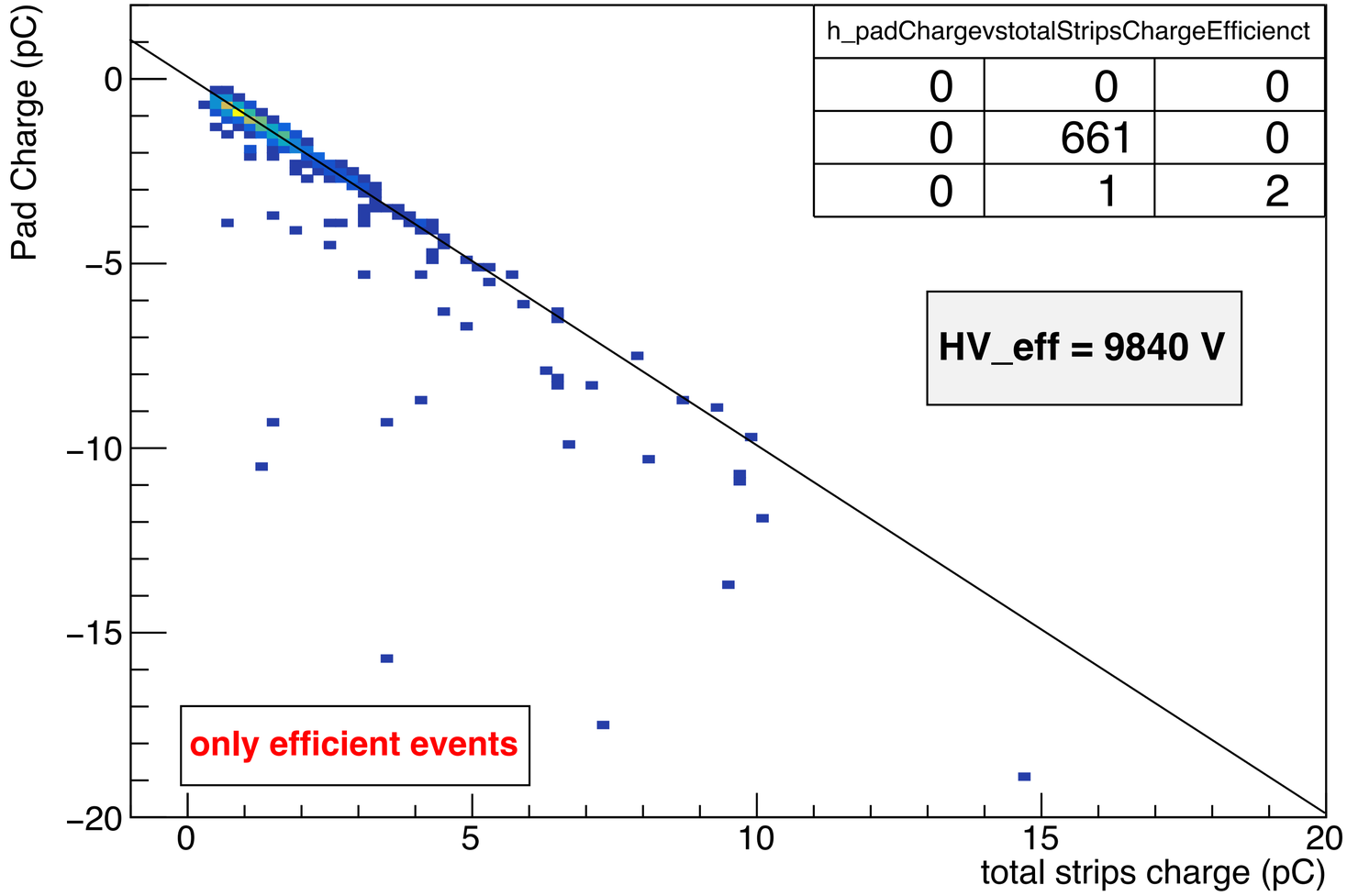
Integrated Charge pad (ch3) strip Fired



total strips charge for efficient events

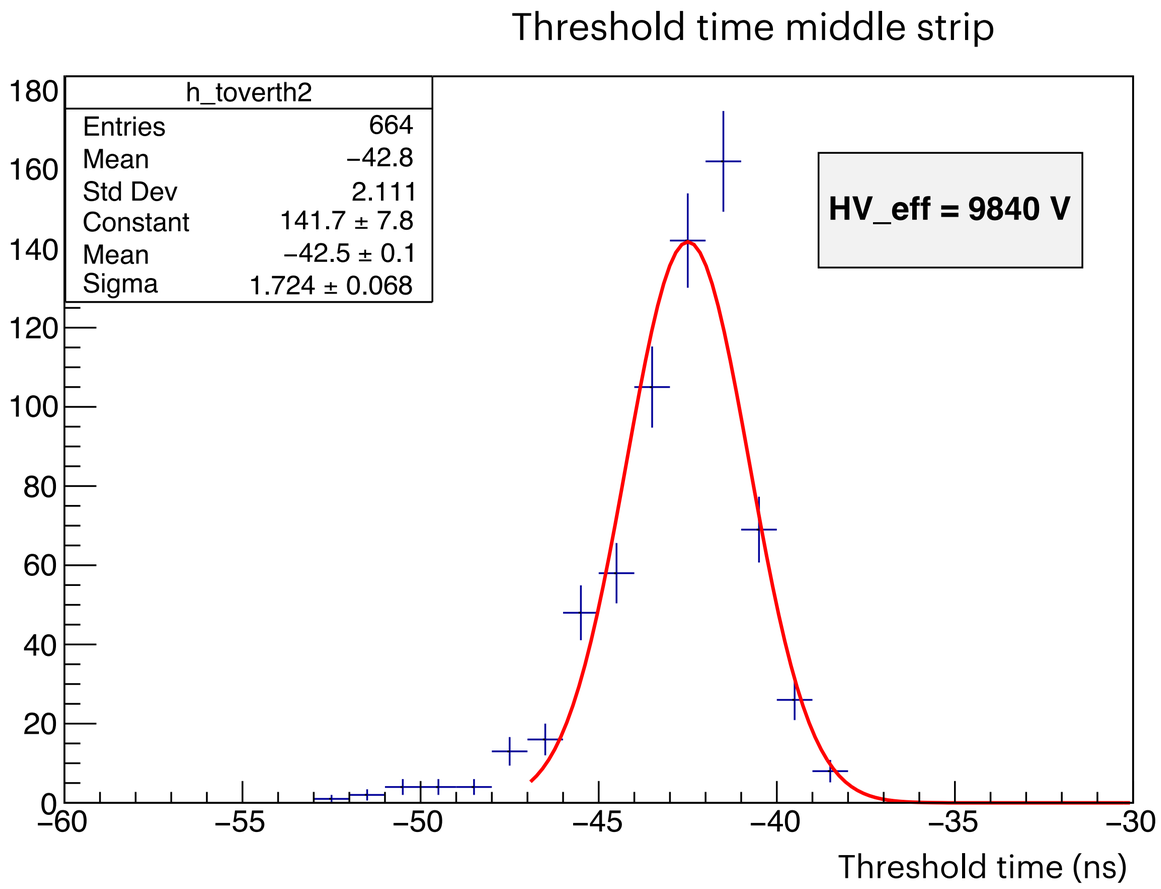


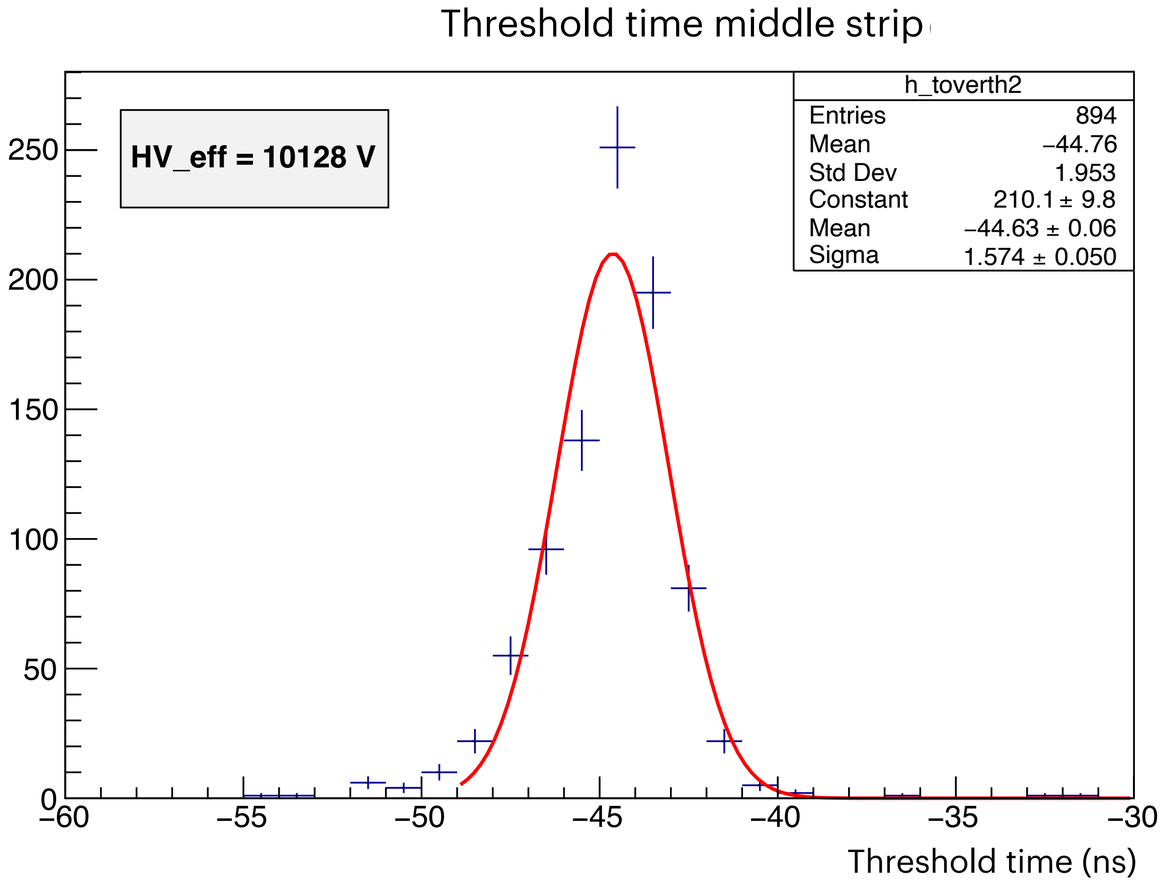
Integrated Charge pad (ch3) vs total strips (ch2+ch1+ch4)



Total strip charge left+middle+right

Time resolution

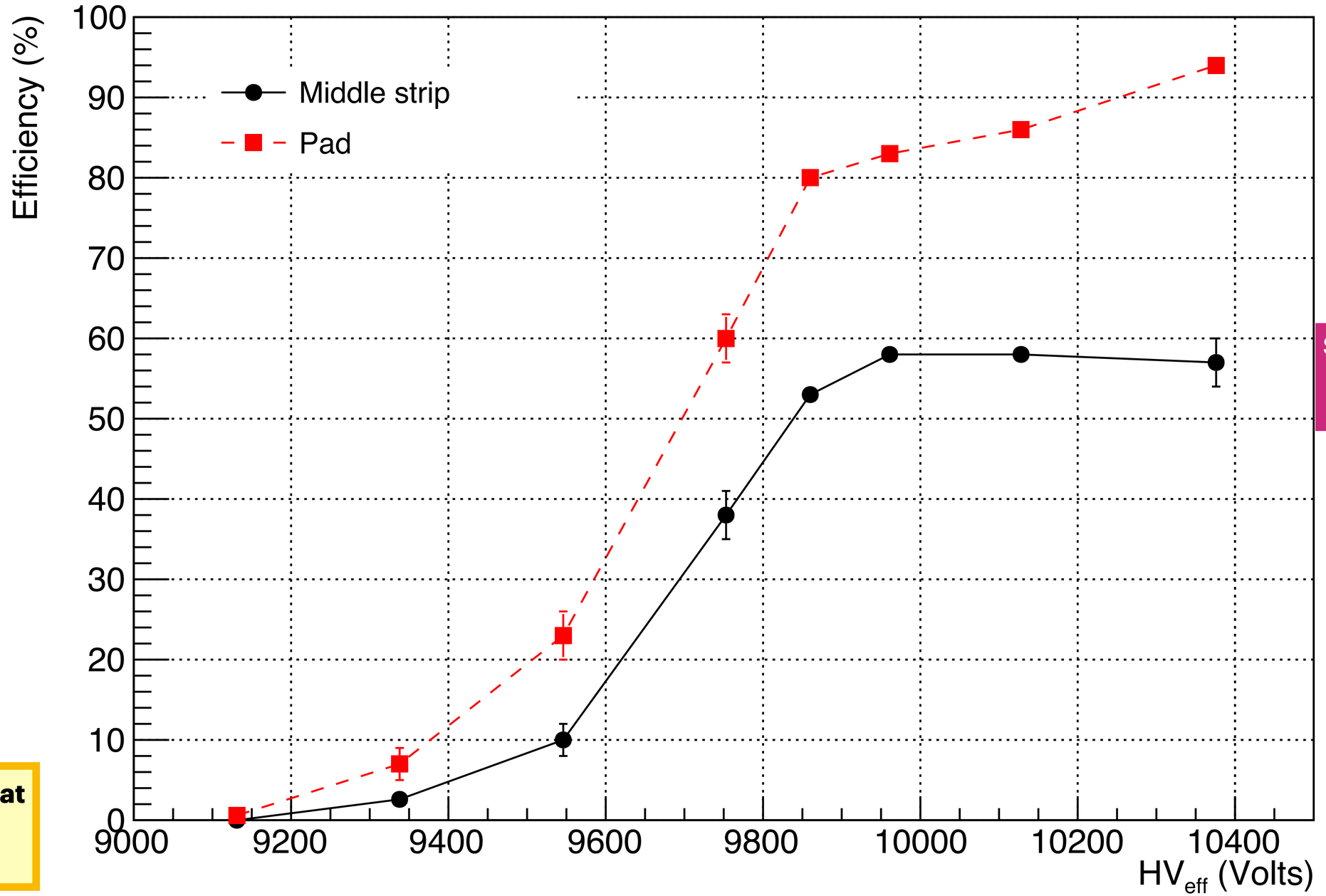




Contribution of trigger not subtracted **but negligible**

HV normalized at
P_0 = 1010 mbar
T_0 = 20º

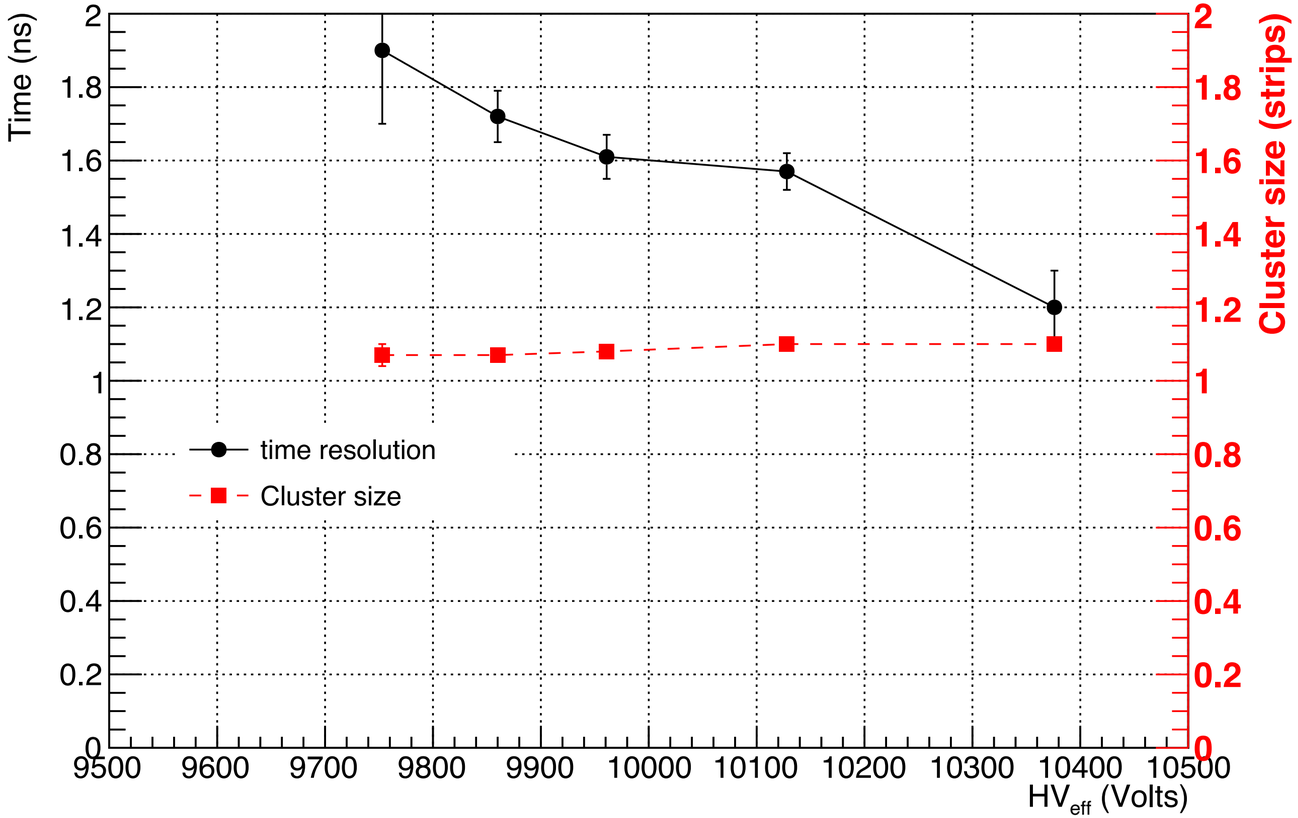
Efficiency scan

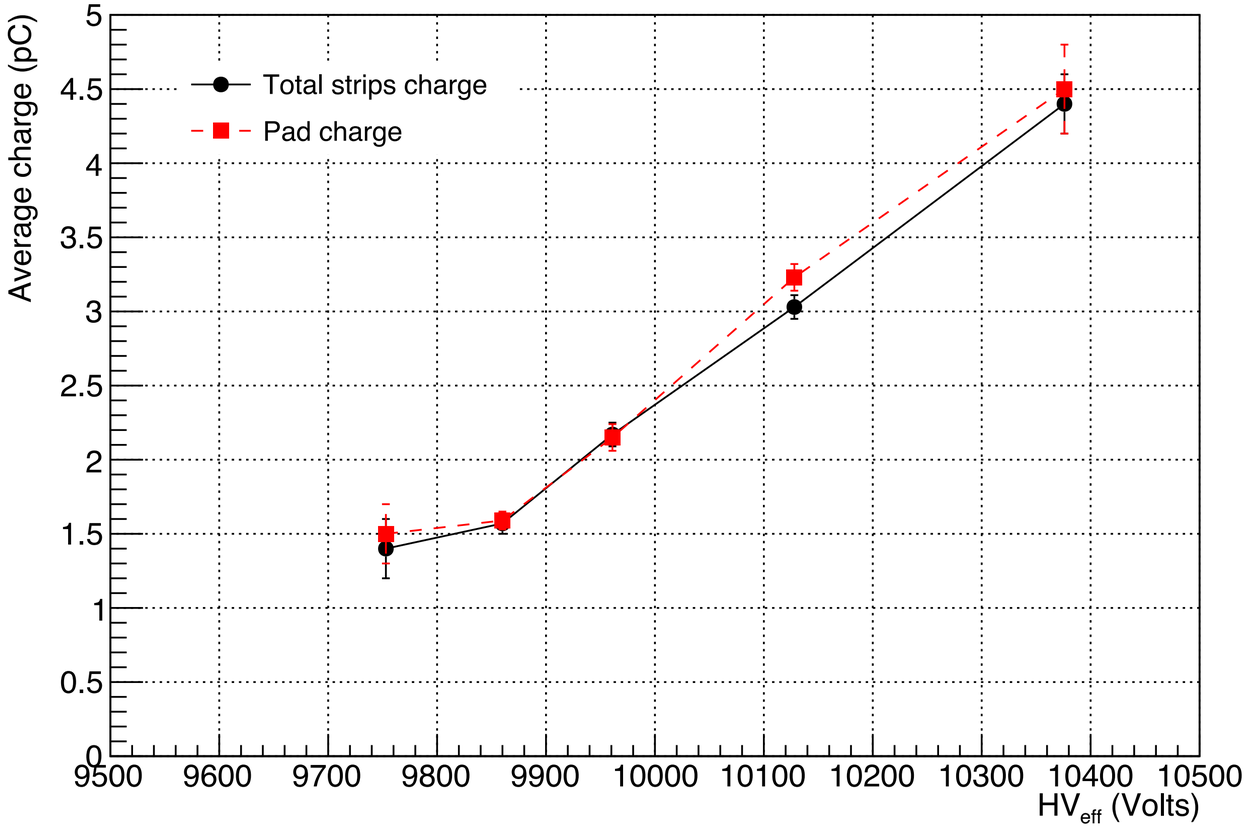


HV normalized at
P_0 = 1010 mbar
T_0 = 20°

Strip geometrical acceptance About 60%

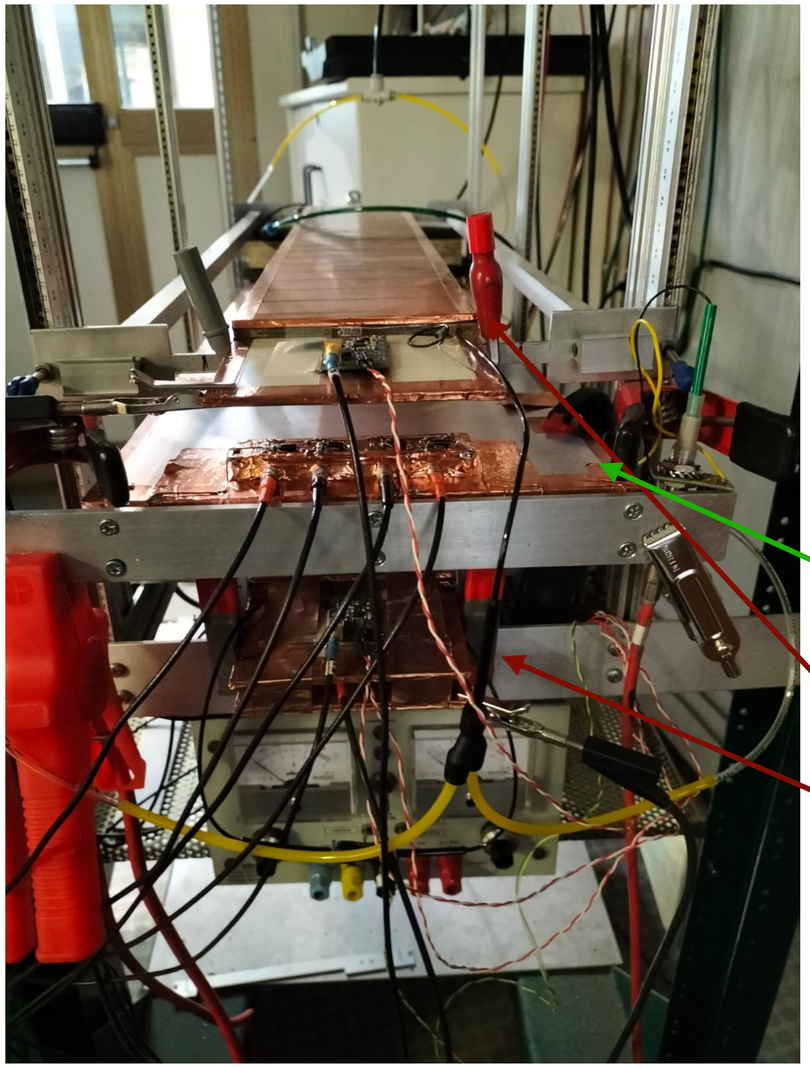
Time resolution, cls, charge scan

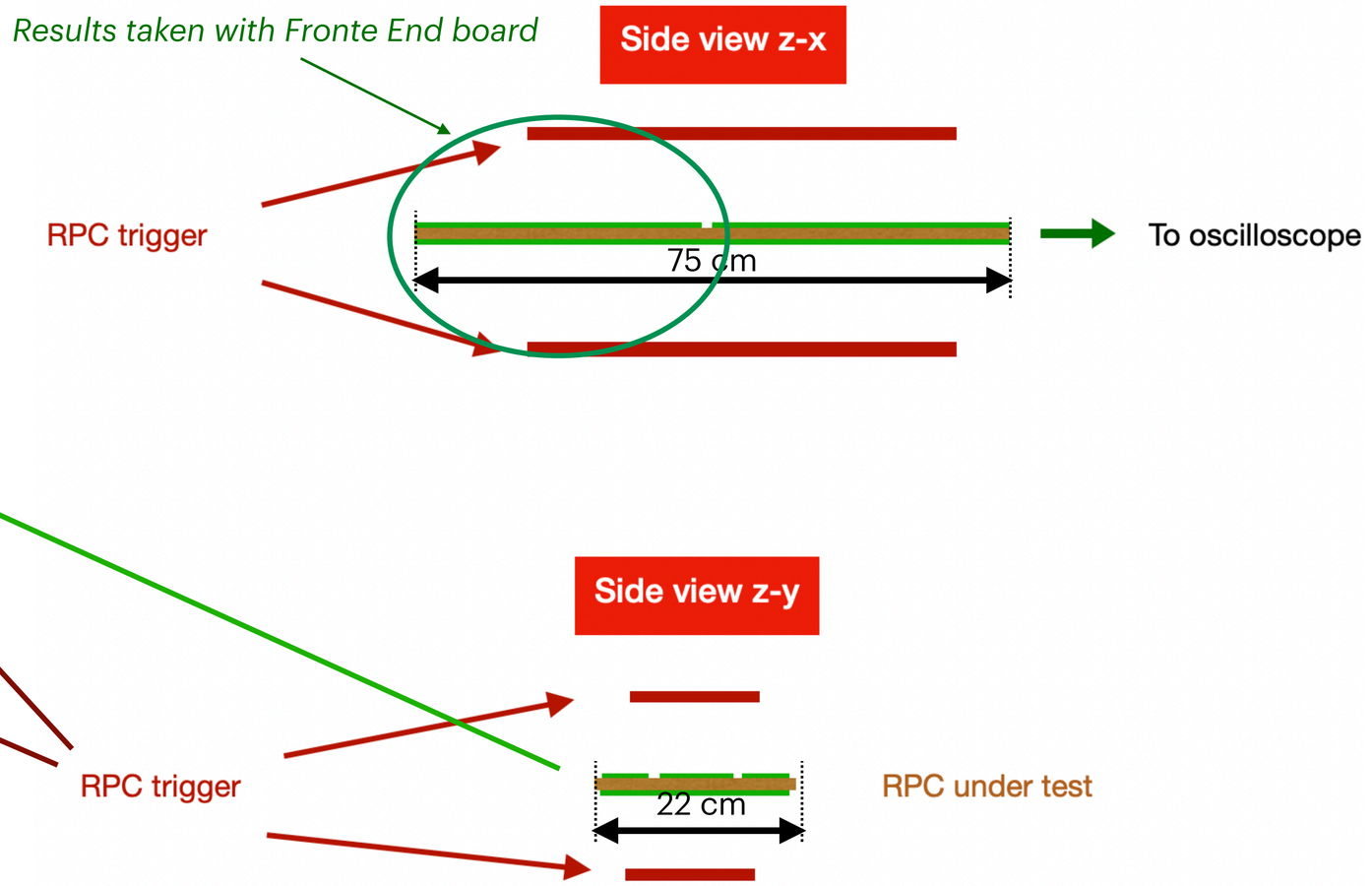




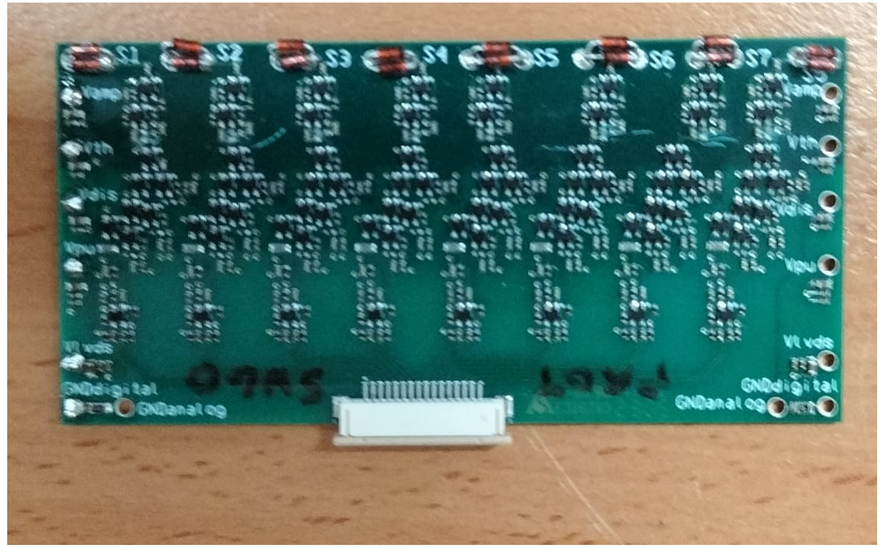
HV normalized at
P_0 = 1010 mbar
T_0 = 20°

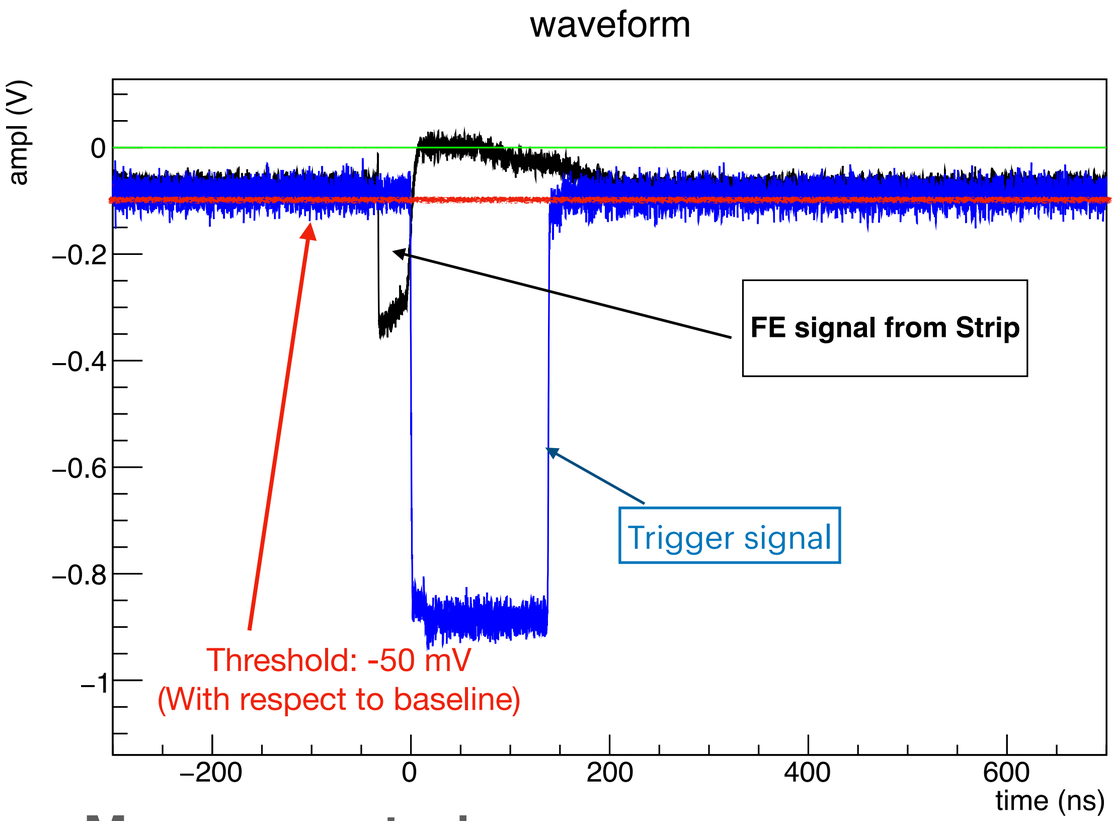
System layout for Front end stdies

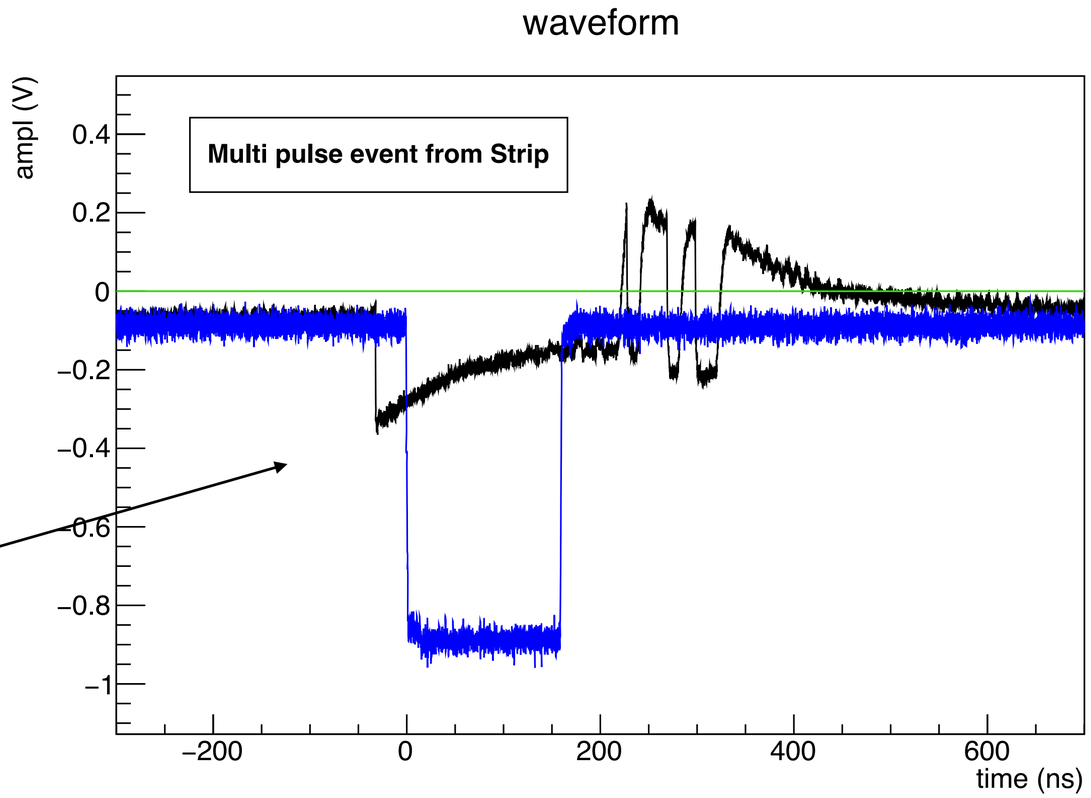




Test of Front End Board *Developed by R. Cardarelli (TorVergata)*



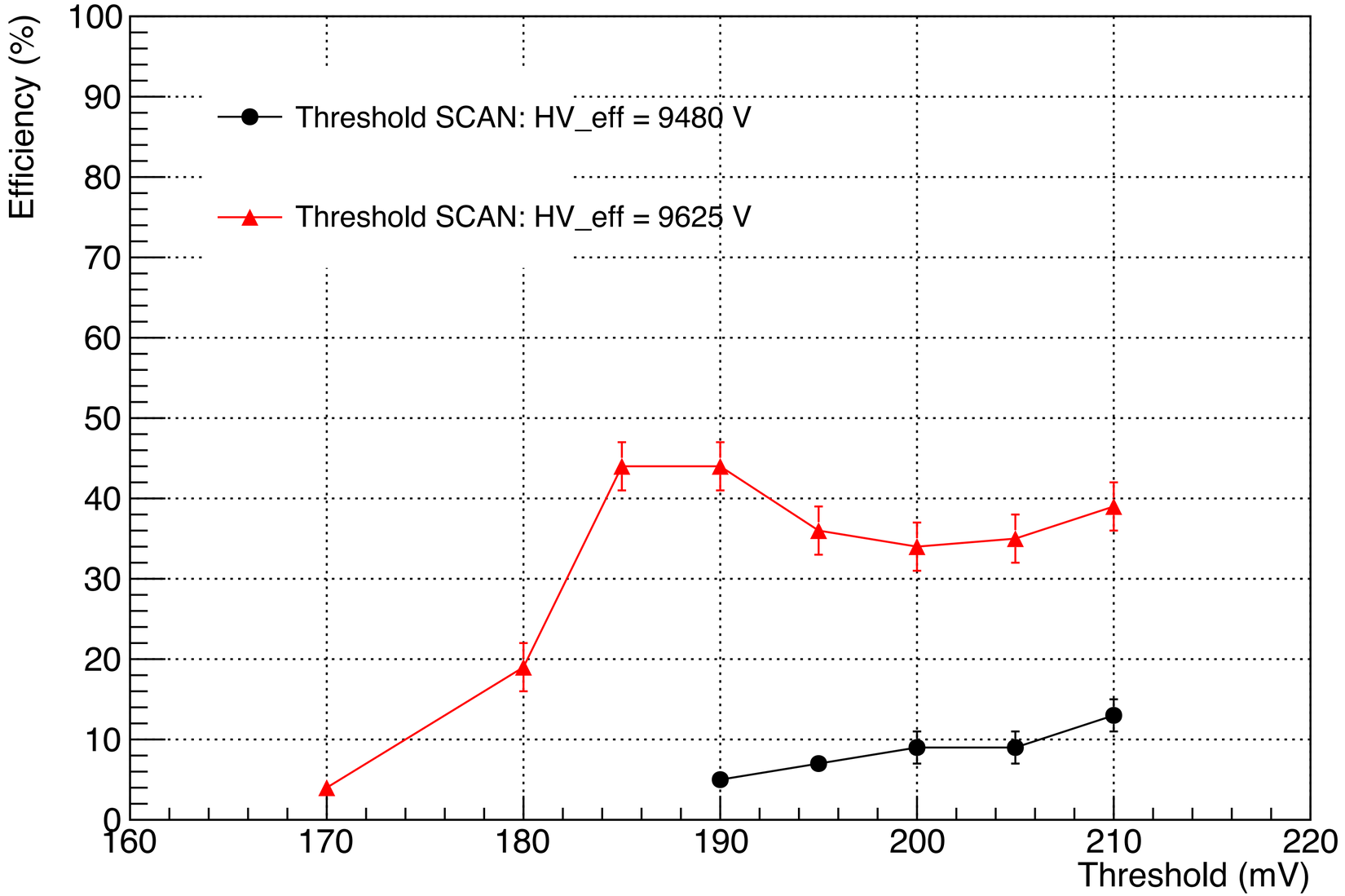




Measurements done:

- Efficiencies
- Fraction of multi pulses
- Threshold (- 50 mV) time distribution

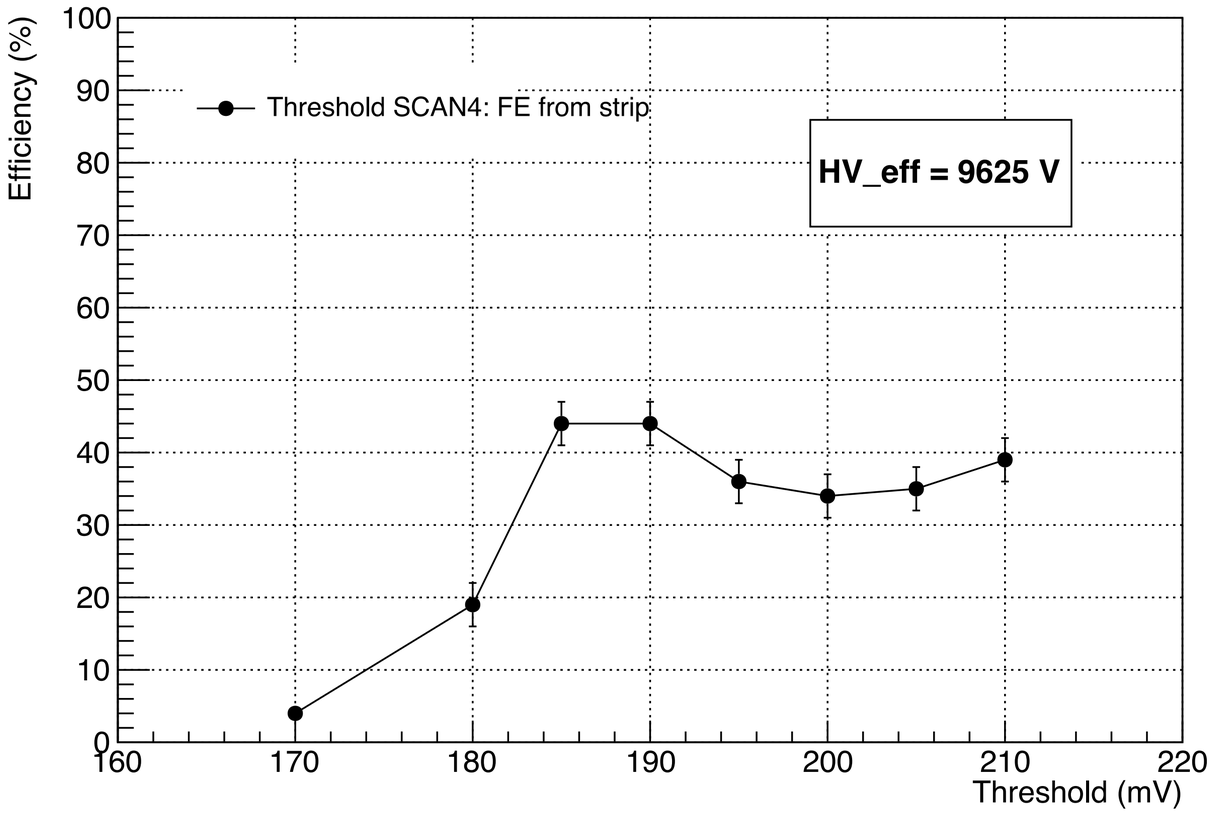
Threshold scan @9300 kV (9480 effective) vs 9500 kV (9625 effective)

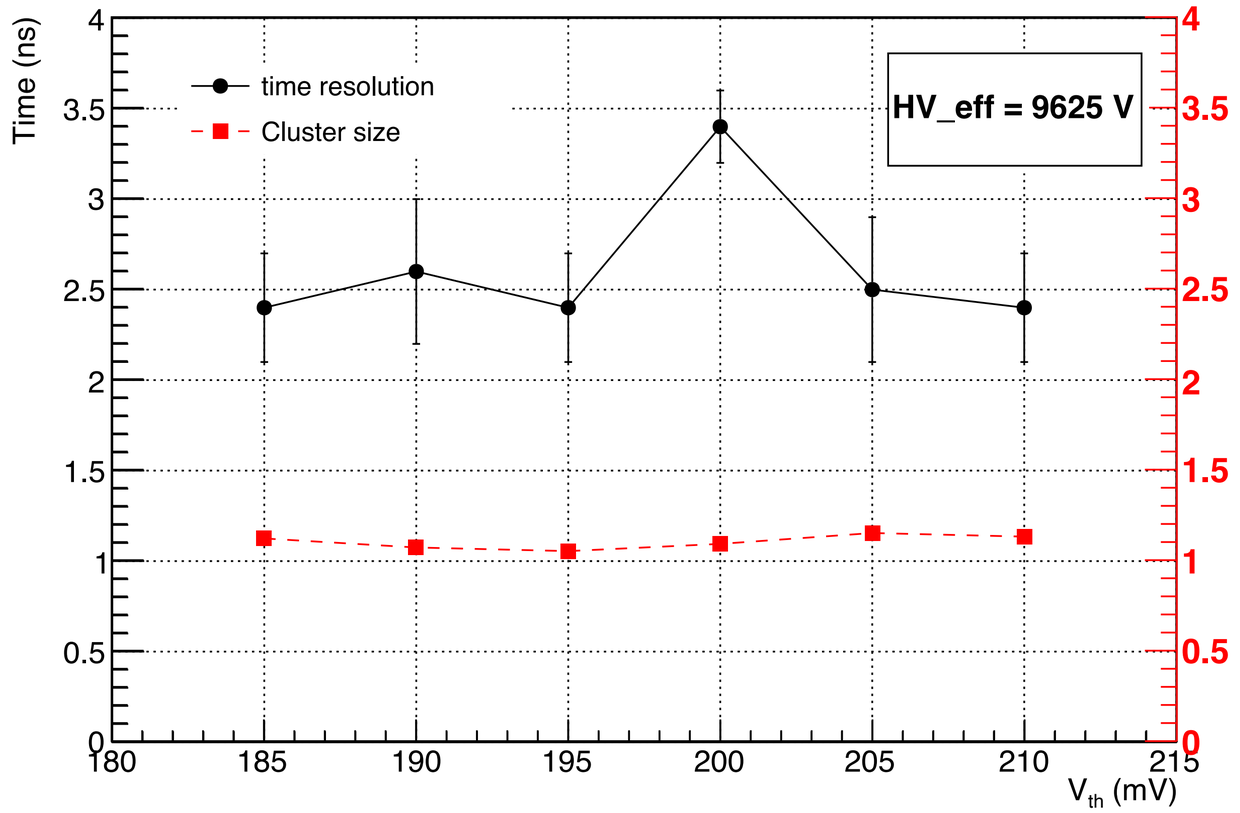


Characterization of front end board started

- Noise under control (1%-2% of noisy events)
- Threshold studies ongoing

Threshold scan @ HV = 9500 kV (9625 effective)





Characterization of front end board started

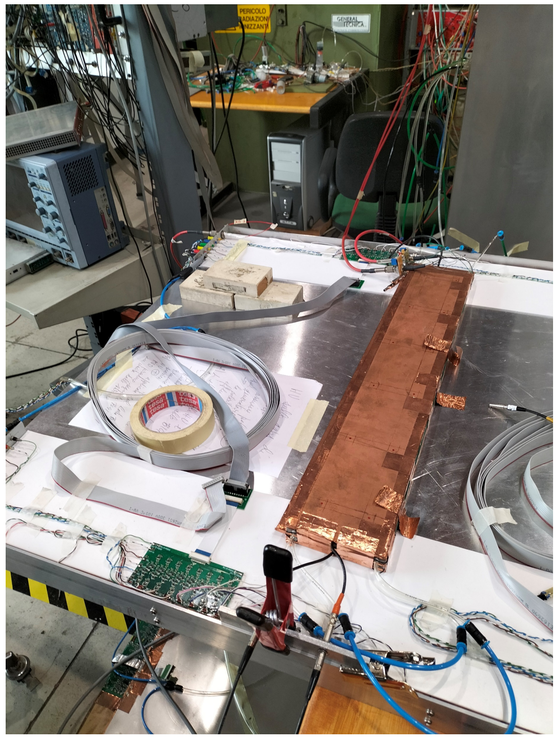
- Efficiency sable after 185 mV
- Cluster size and time resolution almost stable

NOTE:
Chamber operated at lower efficiency

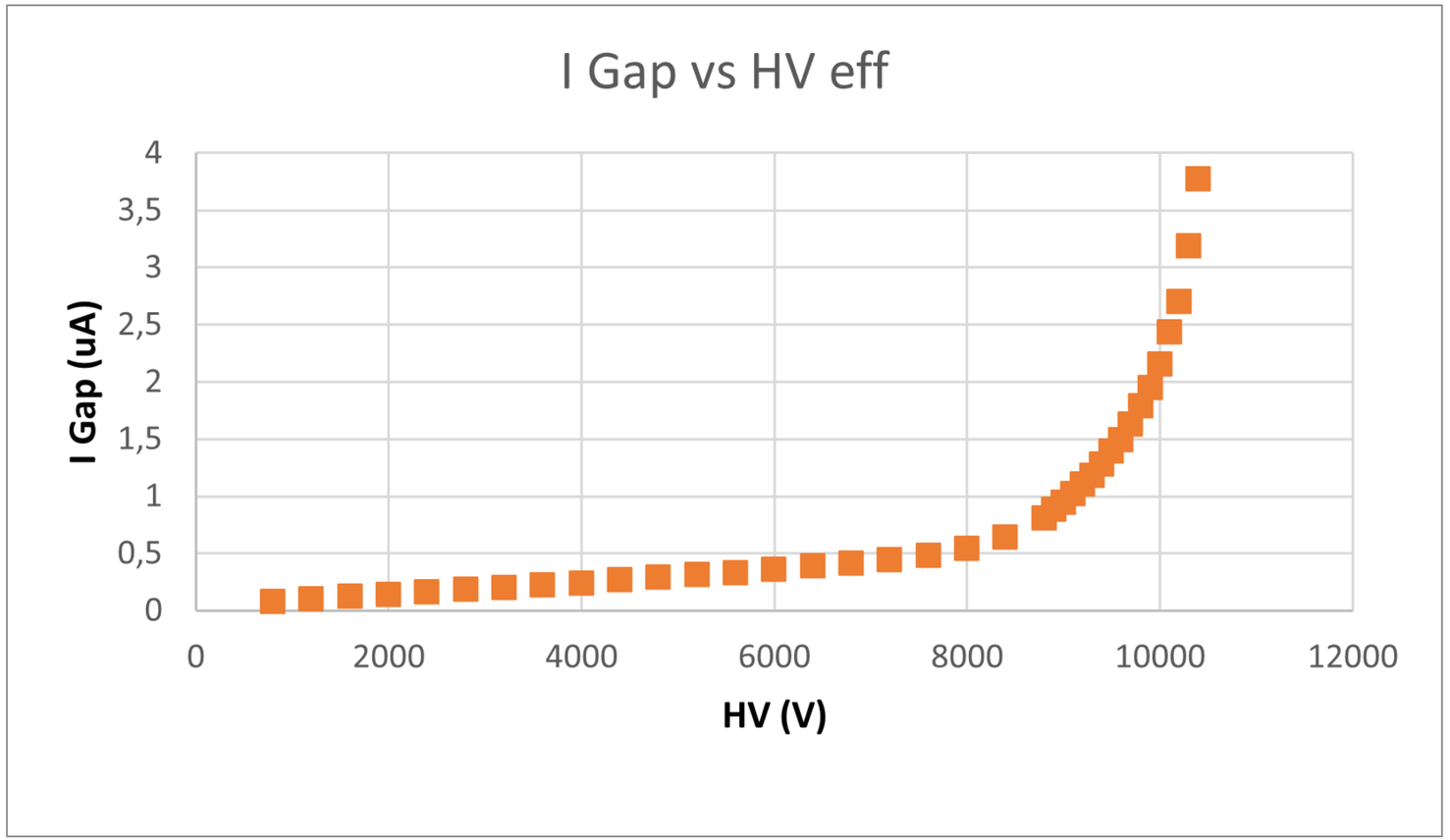
Tor Vergata test Real Size Prototype (RP):

Just Arrived….

We are working!!!



Current-Voltage Characterization

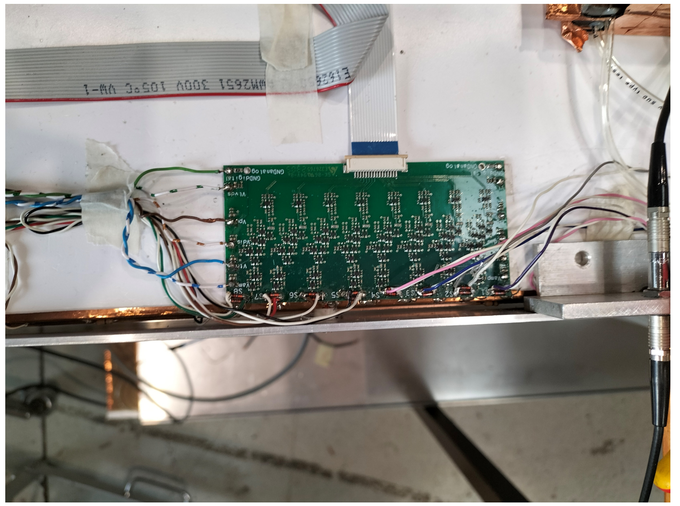


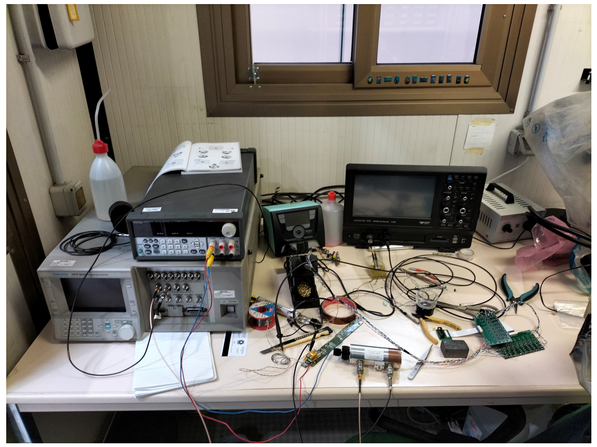
- The Gap current is first QC for the gap
- @ WP (10,0 kV) Igap=2 uA
Current density = 0,009 uA/m^2

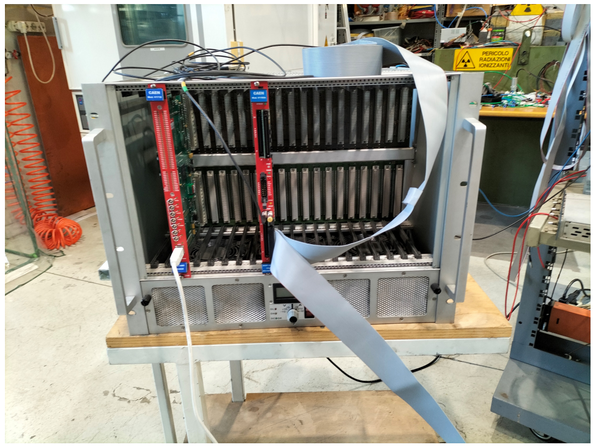
Tor Vergata test Real Size Prototype (RP):

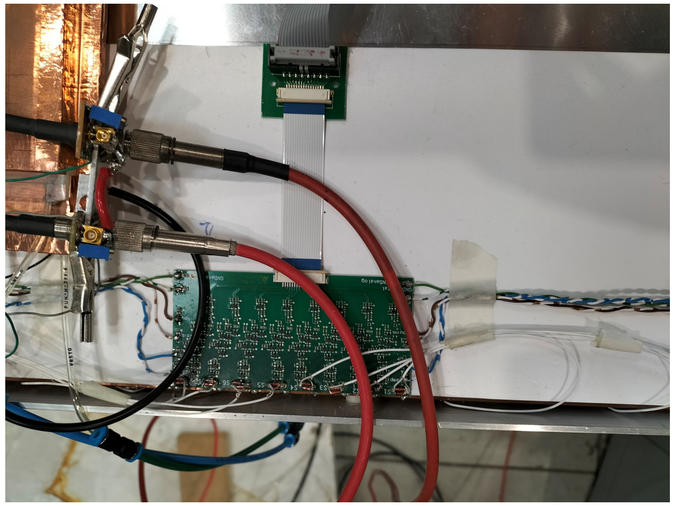
1) Two different cabling, for matching strip size with FE pitch
2) Two RPC (One strip equivalent active area) Trigger
3) VME-TDC based acquisition of LVDS signal

First Results before the end of the year









Conclusions

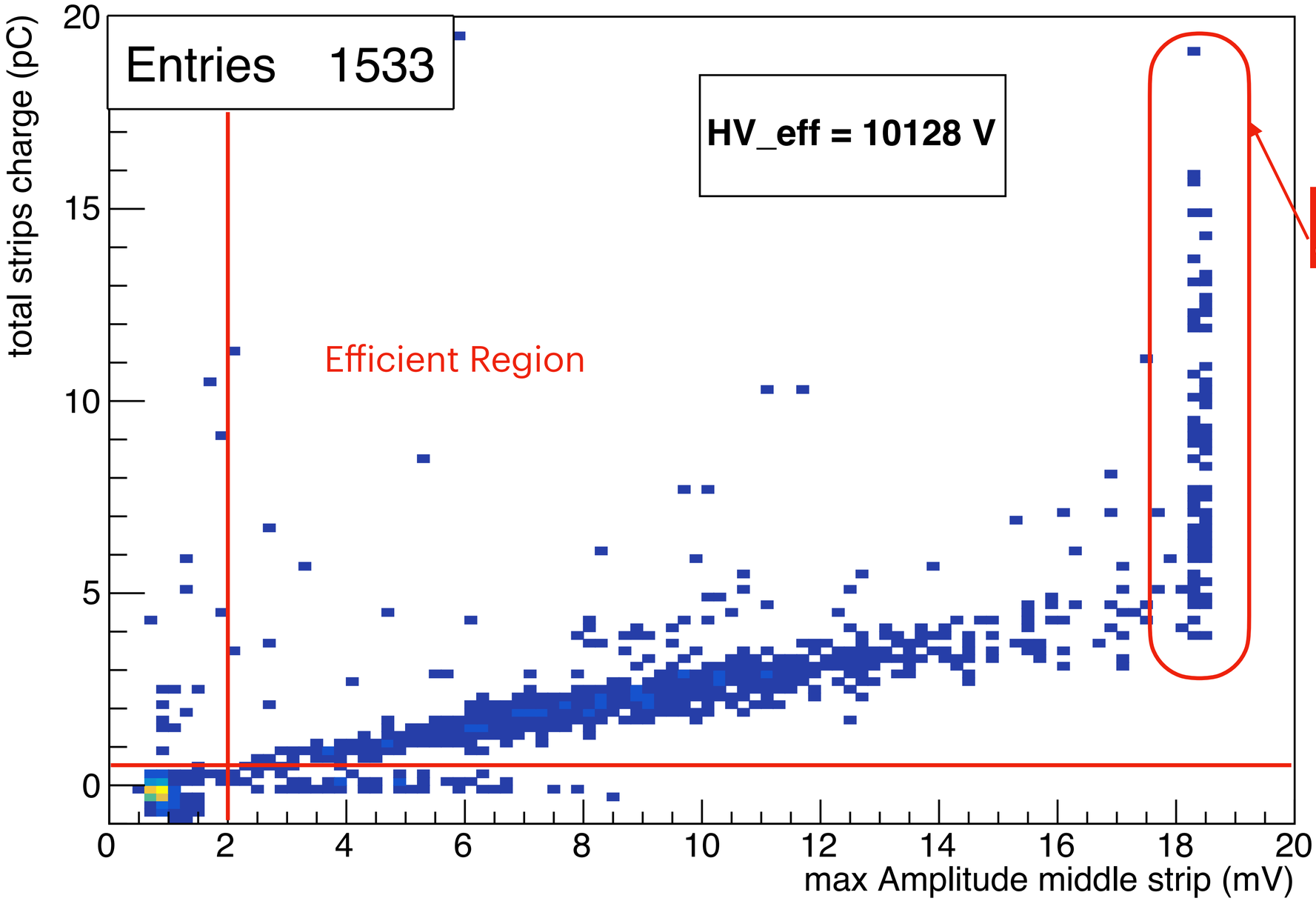
- **First tests with small RPC segment in the SWGO configuration started few months ago**
  - Single gap 2 mm
  - Strip size 7 cm
  - Pad readout
- **Performance verified and in agreement with expected results with standard gas mixture**
  - Efficiency (driven from geometrical acceptance)
  - Strip charge (between 2 and 3 pC @ WP)
  - cluster size (average value = 1.1)
  - time resolution (better than 1.6 ns @ WP)
- **Performance of front end board started**
- **Study of cabling and layout for real size chamber operations**
- **Next steps:**

  Characterization of Front End Board

  Start measurements on real size chamber

Backup

total strips Charge vs max amplitude middle strip



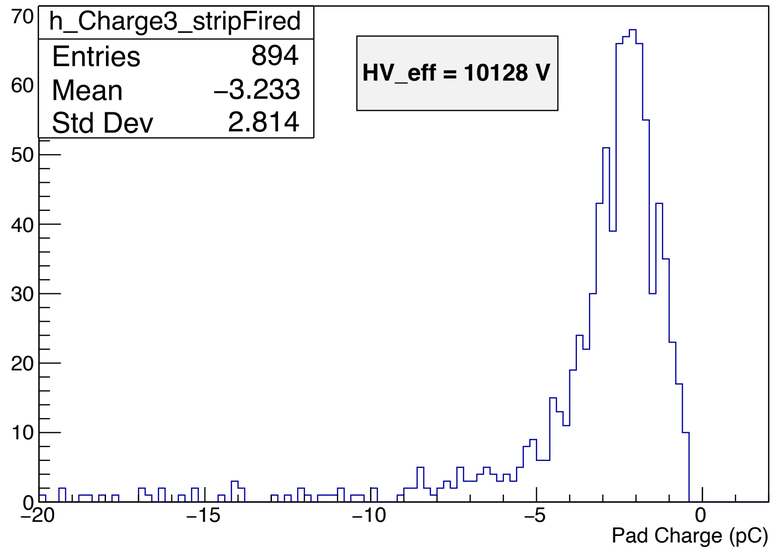
Saturation of oscilloscope channel

HV normalized at
P_0 = 1010 mbar
T_0 = 20°

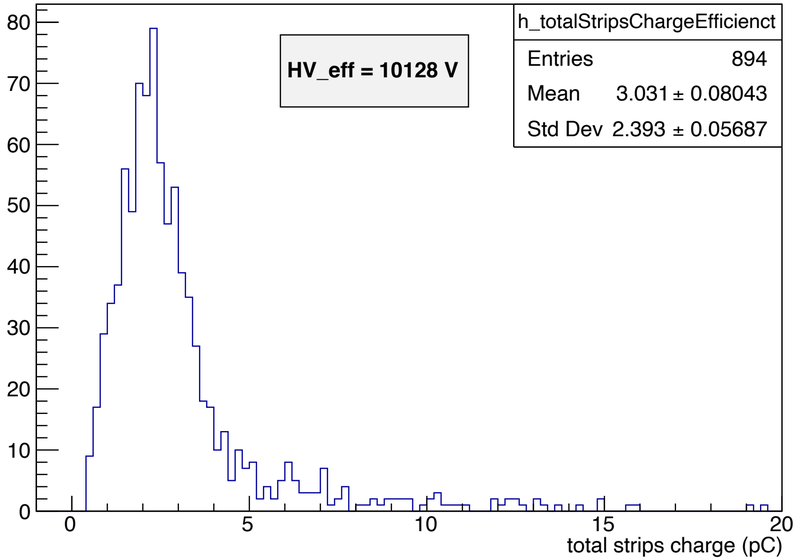
Integrated charge HV_{eff} = 10128 V

HV normalized at
P_0 = 1010 mbar
T_0 = 20°

Integrated Charge pad (ch3) strip Fired

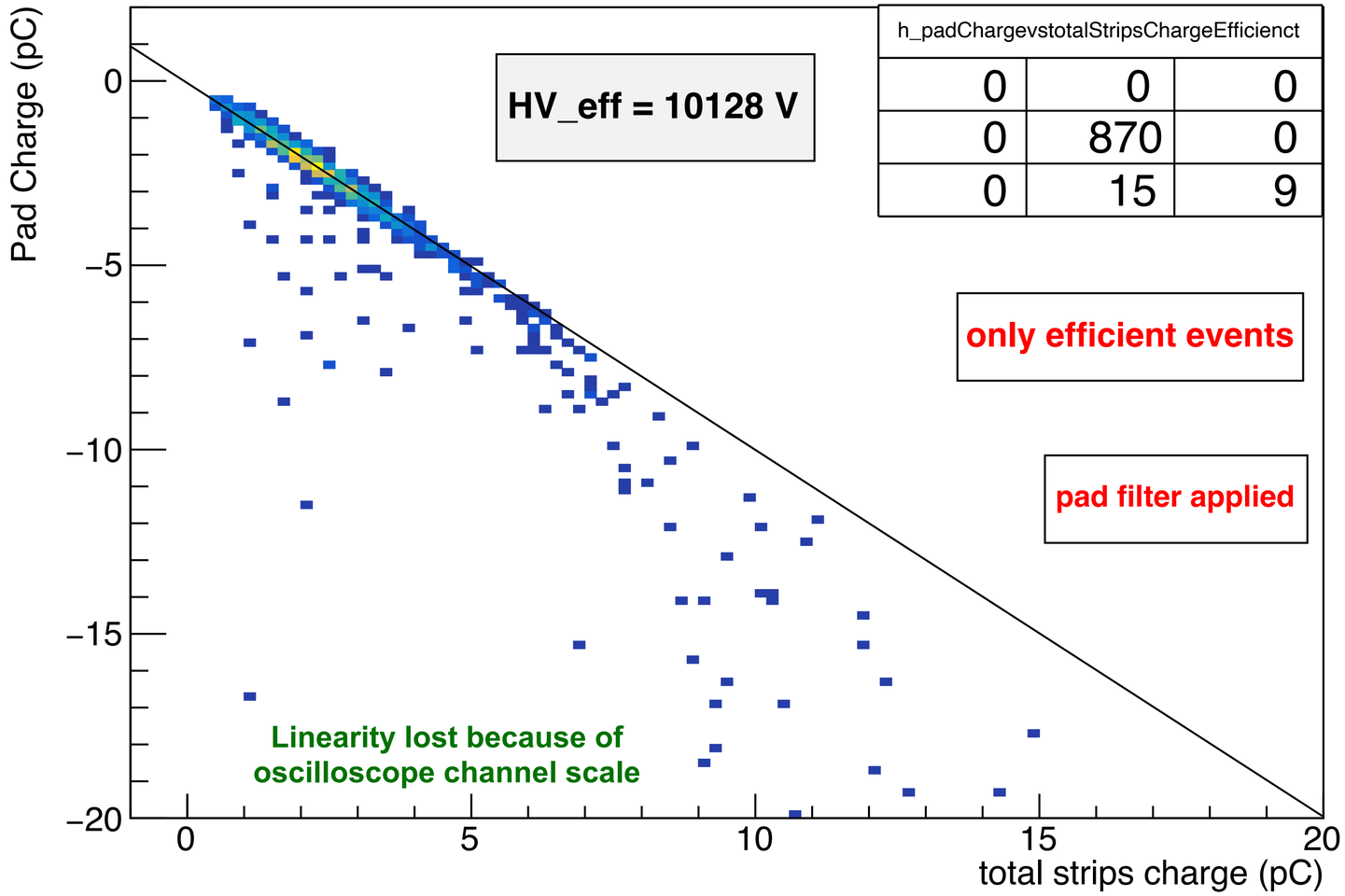


total strips charge for efficient events



Strip fired

Integrated Charge pad (ch3) vs total strips (ch2+ch1+ch4)



Total strip charge left+middle+right