μRWELL simulation + FEE upgrade

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Status

μRWELL simulation done

TIGER simulation done

White noise implementation

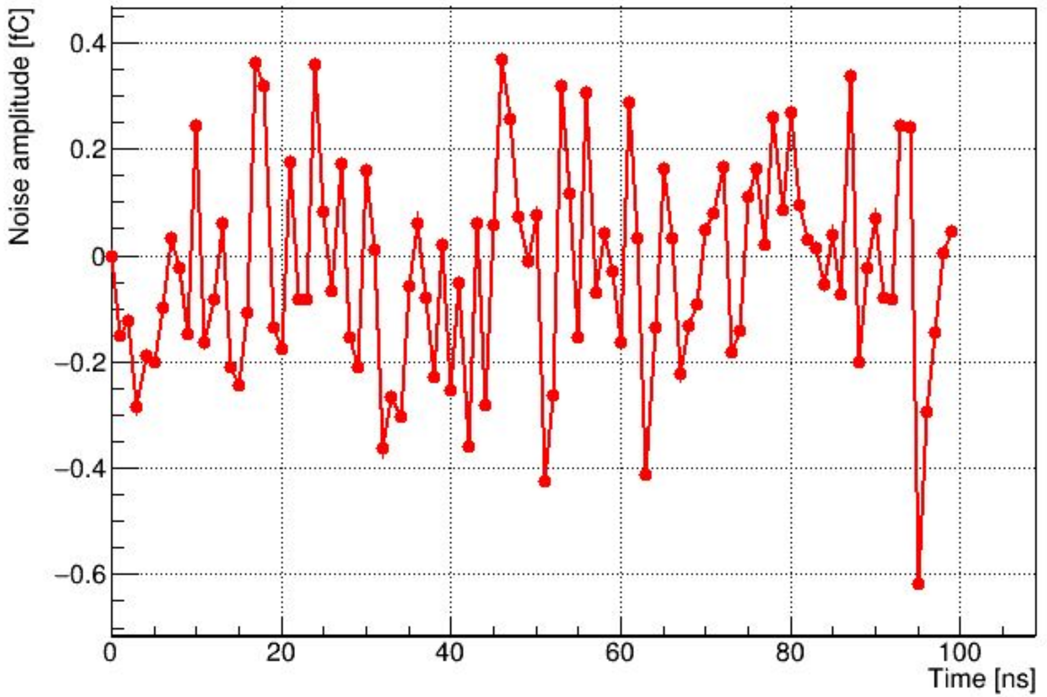
```
const int max_freq = 1e6;
float white_noise(int itime){
   float output=0;
   for(int ifreq=1;ifreq<max_freq;ifreq*=10){
      output+=r->Gaus()*max_amplitude*sin(itime*ifreq);
   }
   return output;
}
```

itime = 1 ns bin

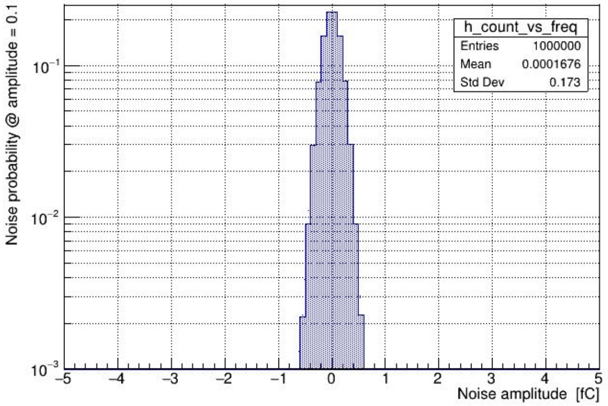
For each frequency [1,10,100,1000,10000,10000] a sinusoidal function with the same amplitude is considered.

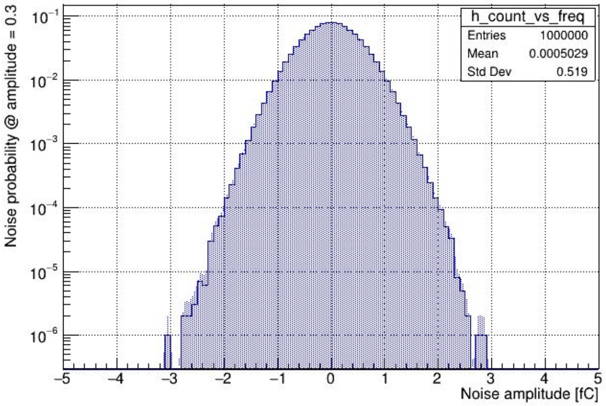
White noise = flat amplitude vs frequency

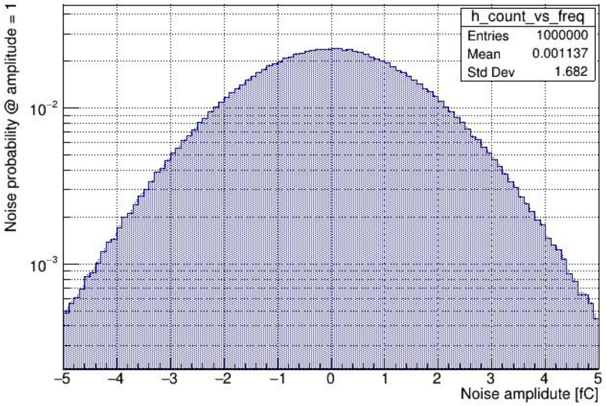
Simulation time ~ 1e7 time bin -> 10s



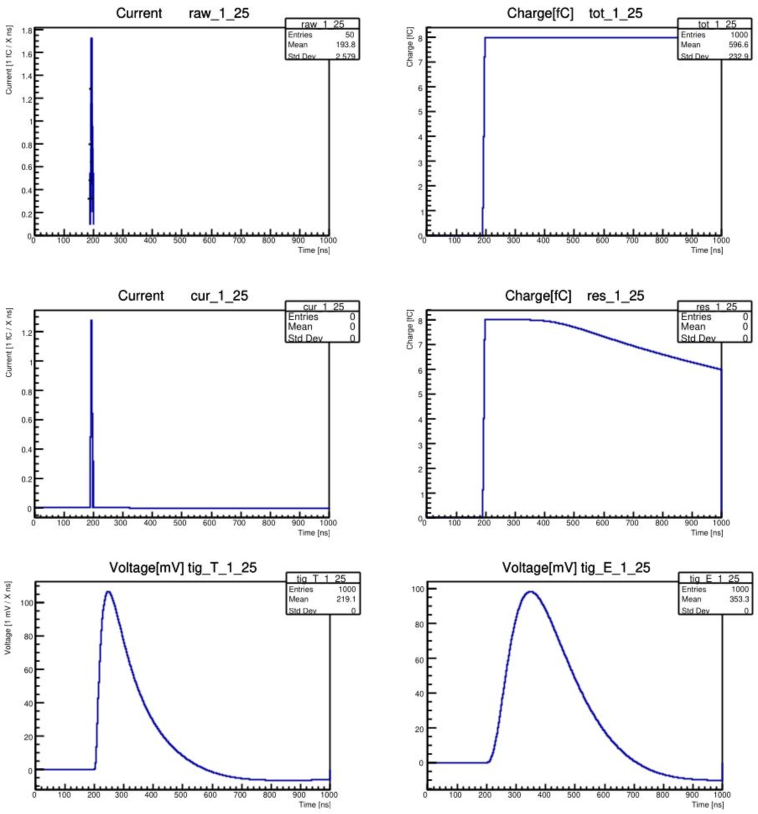
White noise implementation



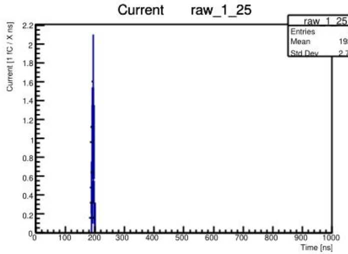


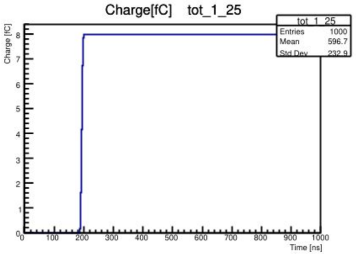


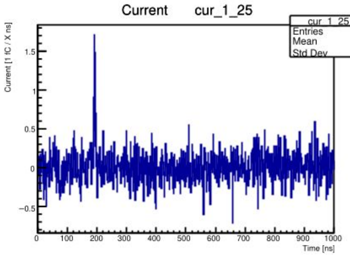
White noise implementation - no noise

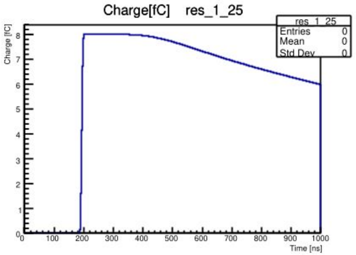


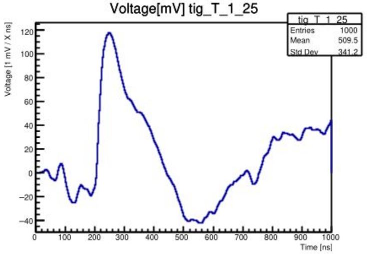
White noise implementation - amplitude 0.1

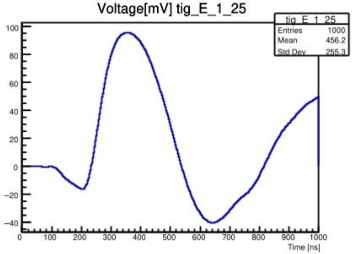




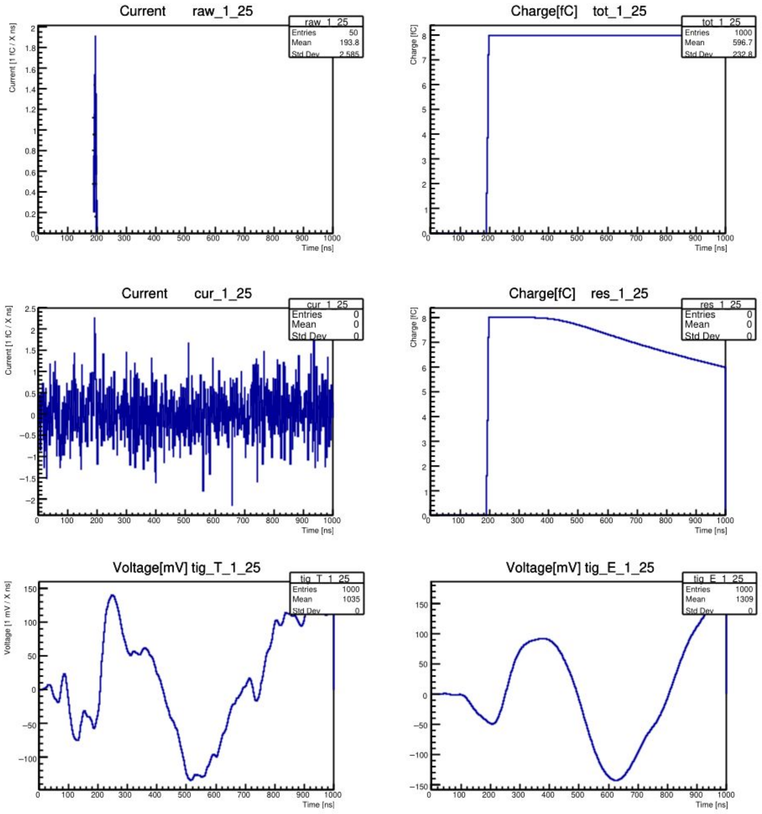




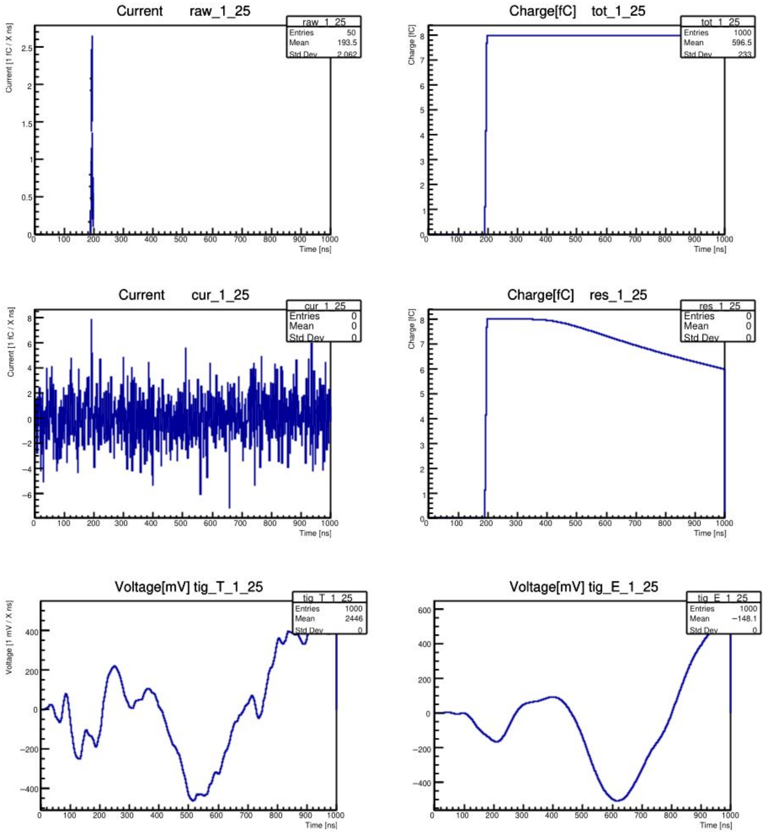




White noise implementation - amplitude 0.3

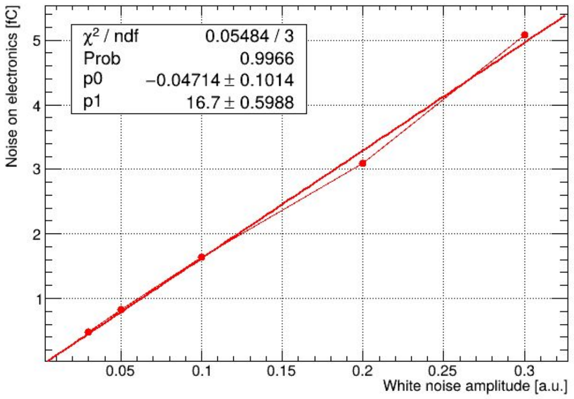


White noise implementation - amplitude 1

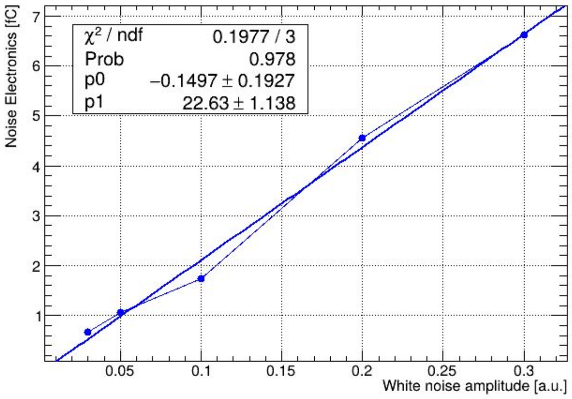


Noise calibration in PARSIFAL

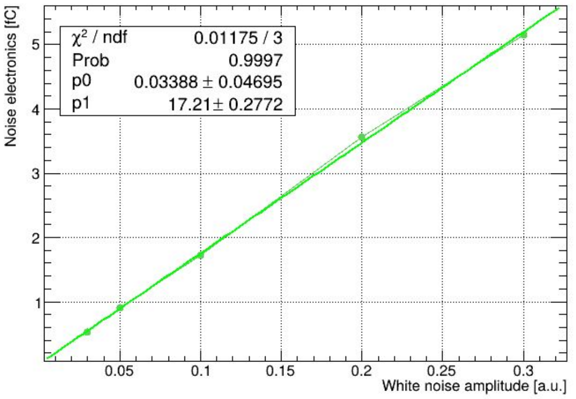
APV



TIGER
E-branch



TIGER
T-branch



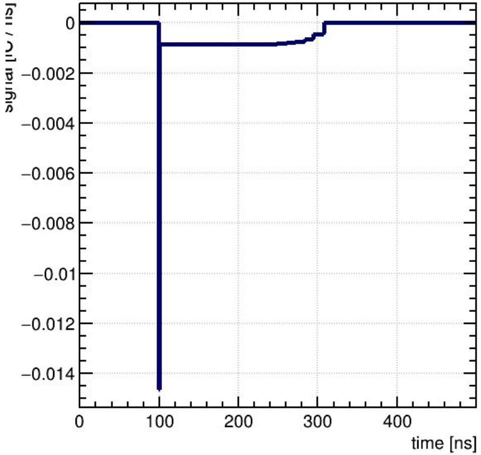
Given the same white noise amplitude, the noise collected on the E-branch of the TIGER is the larger.

In general, the longer is the shaping time, the larger is the noise amplitude.

Single electron/ion induction

Ground model for the induction is to inject a pulse of 1ns and 1.6e-4fC once the electron reach the readout plane of the µRWELL.

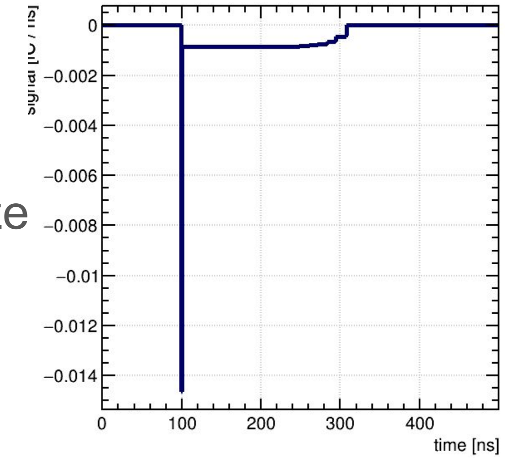
To improve the reliability of the induction, the ion tails needs to be considered. A simulation of 1 e- and 1 Ar+ drift along +60µm and -60µm together the relative induction of a plane is reported.



Single electron/ion induction

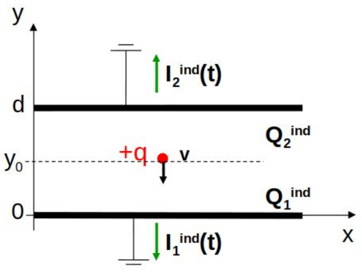
electron+ion peak amplitude = -0.01463 fC/ns
after 1ns the bump goes down to the ion tail

ion tail amplitude = -0.00085 fC/ns
ion tail duration = 140ns @ fix value + 70 ns to go ze



time bin size | ratio e+I / I
1ns | 0.058 (1   bin)
0.1ns | 0.060 (10 bin)

The induced current depends on the ionization place



$$y(t) = y_0 - vt \qquad \frac{dy(t)}{dt} = -v \qquad 0 < t < \frac{y_0}{v}$$

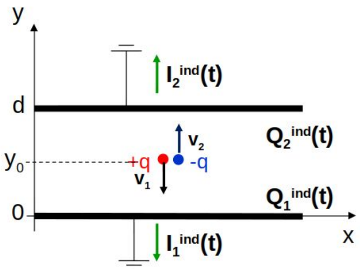
$$I_1(t) = -\frac{q}{V_w} E_1(y(t)) \frac{dy}{dt} = q\frac{v}{d}$$

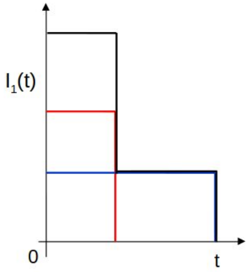
$$I_2(t) = -\frac{q}{V_w} E_2(y(t)) \frac{dy}{dt} = -q\frac{v}{d}$$

$$I_1(t) + I_2(t) = 0$$

Total induced charge on electrode 1

$$Q_{1tot}^{ind} = \int_0^{y_0/v} I_1(t)dt = \frac{q}{V_w}\left[\psi_1(0) - \psi_1(y_0)\right] = q\frac{y_0}{d}$$





Two charges +q, -q moving from y_0 to the electrodes with velocities v_1 and v_2, arriving at the electrodes at times t_1 and t_2

$$t_1 = \frac{y_0}{v_1} \qquad t_2 = \frac{d - y_0}{v_2}$$

Induced currents

$$I_1(t) = q\frac{v_1}{d}\Theta(t_1 - t) + q\frac{v_2}{d}\Theta(t_2 - t) \qquad I_2(t) = -I_1(t)$$

$$I_2(t) = -I_1(t)$$

Total induced charges

$$\begin{aligned} Q_{1tot}^{ind} &= \int_0^{\infty} I_1(t)dt \\ &= \frac{q}{V_w}\left[\psi_1(0) - \psi_1(y_0)\right] - \frac{q}{V_w}\left[\psi_1(d) - \psi_1(y_0)\right] \\ &= q \end{aligned}$$

In all physics processes, pairs of charges with opposite sign are produced at the same position, which results in the fact that the total induced charge is equal to the charge that has arrived at the electrode, once ALL charges have arrived at the electrodes.

If you wait enough time, the total charge is Q, where Q=Ne*gain.

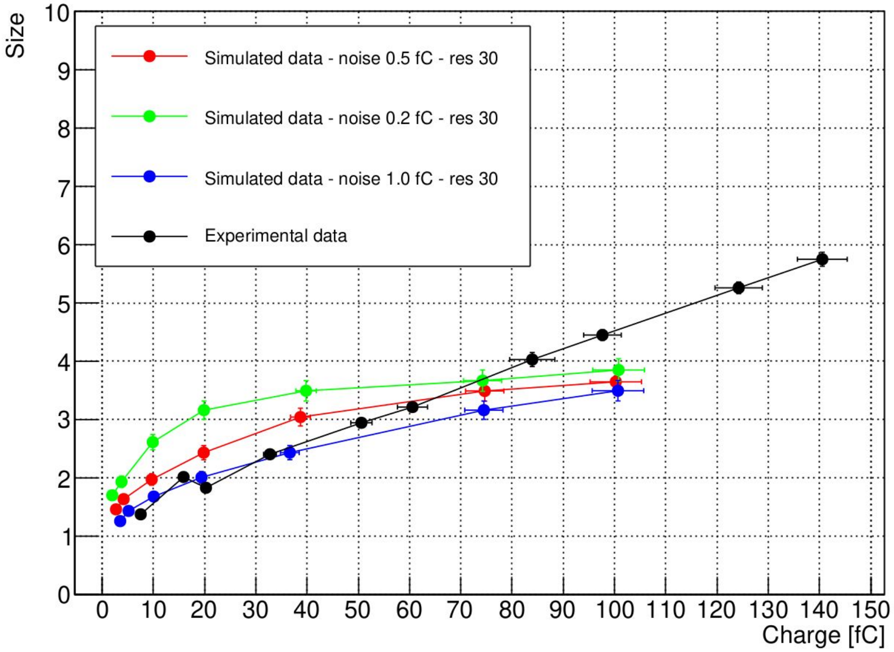
The fast (electron) and slow (ion) contribution is not 50-50. A precise number can be extracted from the weighting field evaluation. On RPC this fraction is 5:95 while on MicroMegas is 15:85.

We can assume a Micromegas-like signal induction.

Noise scan

Exp. data from TB 2021 and resistivity 80MOhm/square

Noise impact on the low-charge regime with an impact on the cluster size.



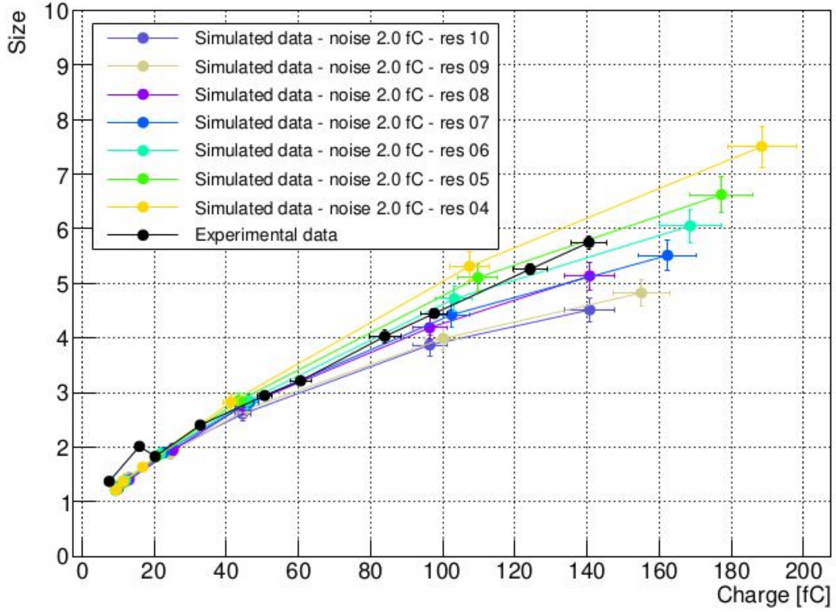
Gain scan in exp and sim

Exp. data from TB 2021 and resistivity 80MOhm/square

Resistivity simulation a là Dixit + GF formula.

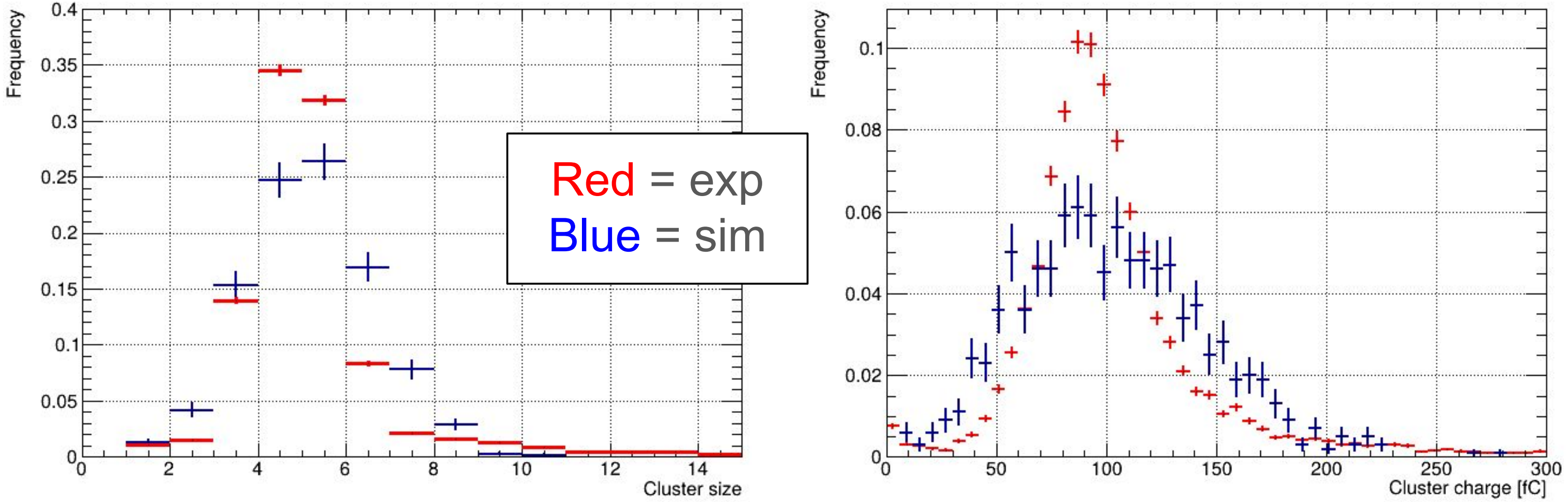
Tuning ongoing on sigma_0 and tau parameters.

$$
\begin{aligned}
Q(t) &= \int_{x_1}^{x_2} \rho(x,t)\mathrm{d}x \\
&= \frac{q}{\sqrt{2\pi}\left[\sigma_0\left(1+\frac{t-t_0}{\tau}\right)\right]} \int_{x_1}^{x_2} \exp\left[-\frac{(x-x_0)^2}{2\sigma_0^2\left(1+\frac{t-t_0}{\tau}\right)^2}\right] \Theta\left(t-t_0\right)\mathrm{d}x \\
&= \frac{q}{2}\left[\operatorname{erf}\left(\frac{x_2-x_0}{\sqrt{2}\sigma_0\left(1+\frac{t-t_0}{\tau}\right)}\right) - \operatorname{erf}\left(\frac{x_1-x_0}{\sqrt{2}\sigma_0\left(1+\frac{t-t_0}{\tau}\right)}\right)\right]\Theta\left(t-t_0\right)
\end{aligned}
$$



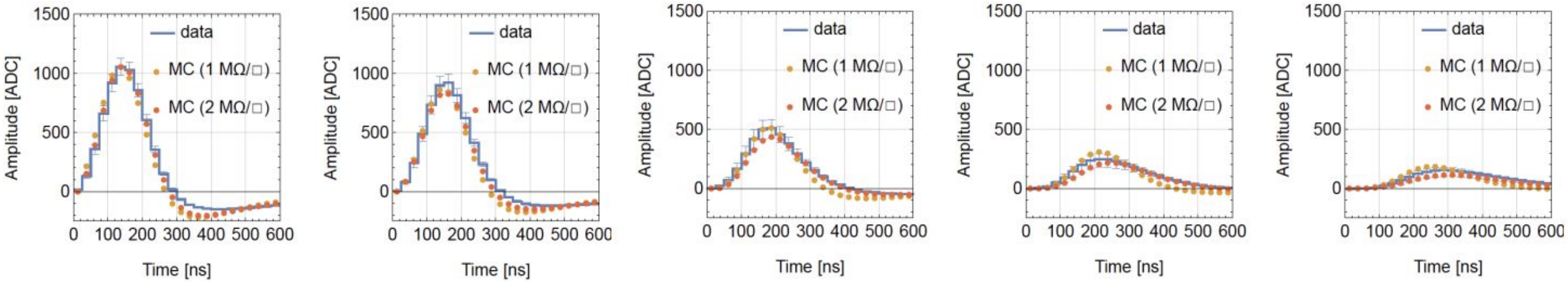
Gain scan in exp and sim

There is a resistivity value that matches the experimental data but looking into the details of the run, we found some discrepancies.



Next step 1

1. Tune sigma_0 parameter to match the cluster charge distribution
2. Check the time distribution of the single event to complete the tuning on APV



3. Use the resistivity value from APV gain scan and check the matching with TIGER gain scan

Next step 2

4. Validate the gain scan for APV and TIGER and performance measurement
   a. efficiency
   b. resolution

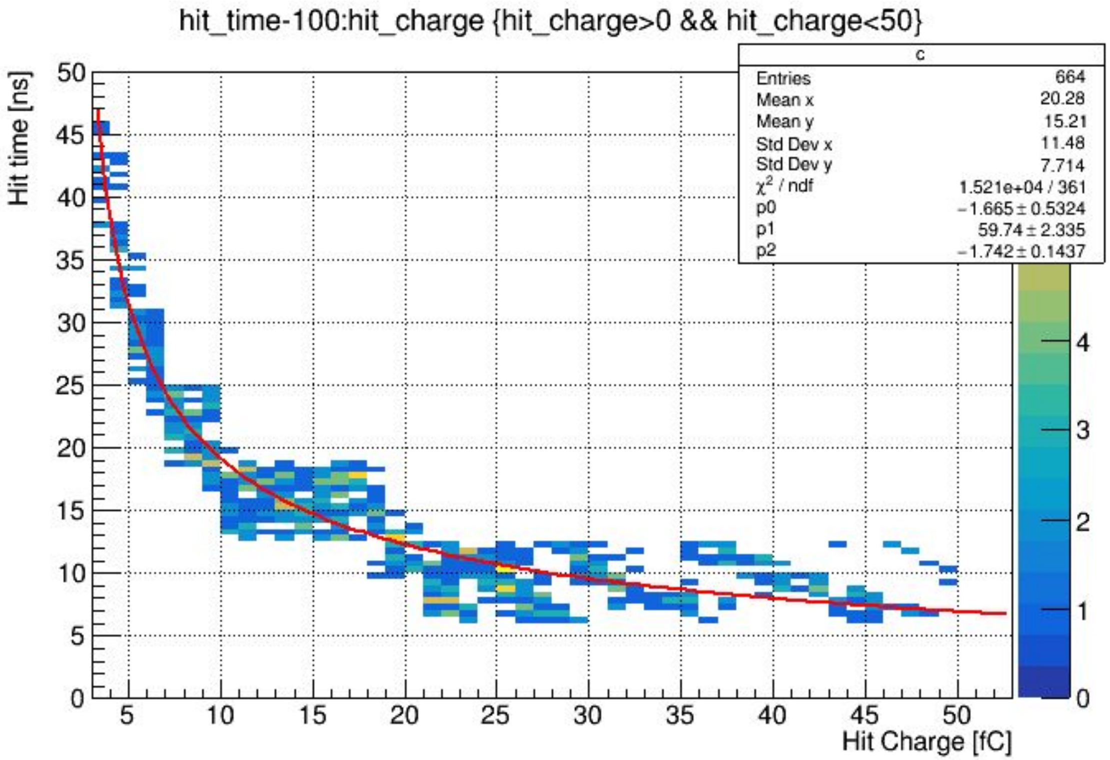
5. Validate the resistivity scan

6. Validate the drift scan (to test different drift velocity)
   a. charge collection

Next step 3

7. Scan in shaping time (Tpeak) and electron drift velocity
    a. noise
    b. charge collected
    c. time-walk
    d. performance
8. Charge dynamic range
    a. saturation
    b. charge collected
    c. performance
9. Cancellazione di polo zero
10. Multi-sampling (APV)
11. Misure tempo con doppia soglia
    a. time-walk measurements
12. Binning diverso dai 6.25 ns

μRWELL+TIGER: timewalk studies



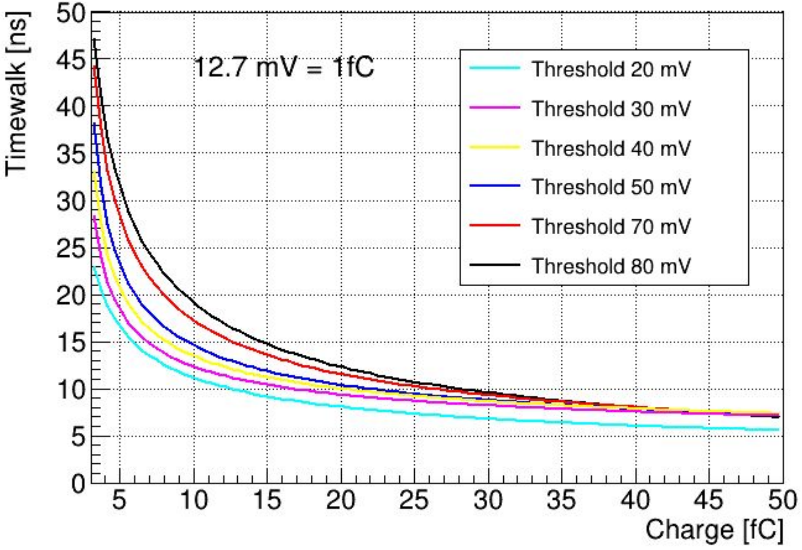
Simulation of a single electron ionization at fixed time and different gains.

The fitting line describe the time shift due to the time-walk.

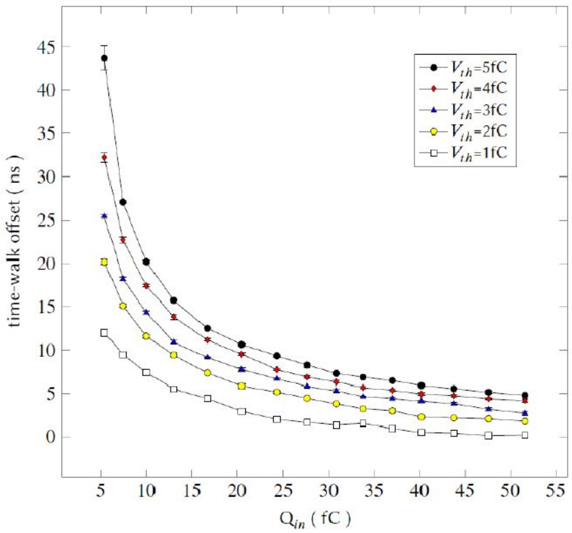
Threshold used: 80-80

µRWELL+TIGER: timewalk studies

SIM



DATA



Compatible results have been obtained.