Performance of He-based mixtures: update

E.Bossini

Datasets

PISA:

50/50 : 22-23 Dic 2021
60/40: 7-8 Dic 2021
70/30: 6-7 Nov 2021
std: 13 Ott 2021

RENDE:
100/0: 10 Jul 2021
50/50 : 14 Oct 2021
60/40: 15 Oct 2021
70/30: 16 Oct 2021
std: 23 Dic 2021

Same dataset used for plots shown at previous conferences

- Std, 50-50, 60-40 and 70-30 mixtures studied on each telescope
- Triggering chambers with fixed HV and std mixture
- Bottom chamber (PISA) and middle chamber (REND-01) used as test chamber
- Chamber gaps : 300um
- Thr ~600mV

Data at different Thrs are available for both stations, but not used in the present analysis

What's new

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ANALYSIS OUTPUT:

- Efficiency
- Cluster multiplicity
- Streamer fraction
- X/Y residuals

Test chamber with He mixture, triggering chambers with std mixture
Dedicated reco.

- ~~Angular distribution, speed, TOF of the reconstructed tracks~~
- ~~Stability in time (rate, %reco,...)~~

~~All chambers with He mixtures data~~

~~All chambers with He mixtures data from Standard reconstruction. (~ready)~~

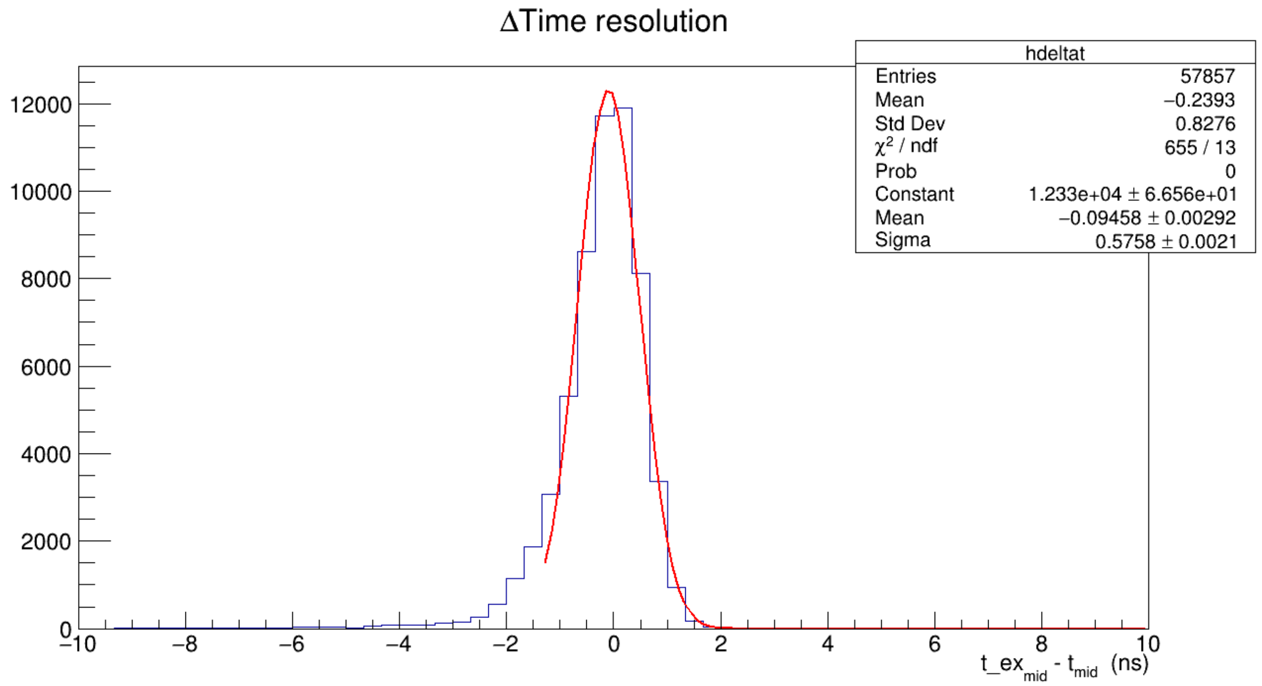
- Time resolution without TW correction?

Raw performance
Best time-tag for clusters
Position dependent-corrections

Updates!

Updated Timing Studies

T Residuals – naïve approach

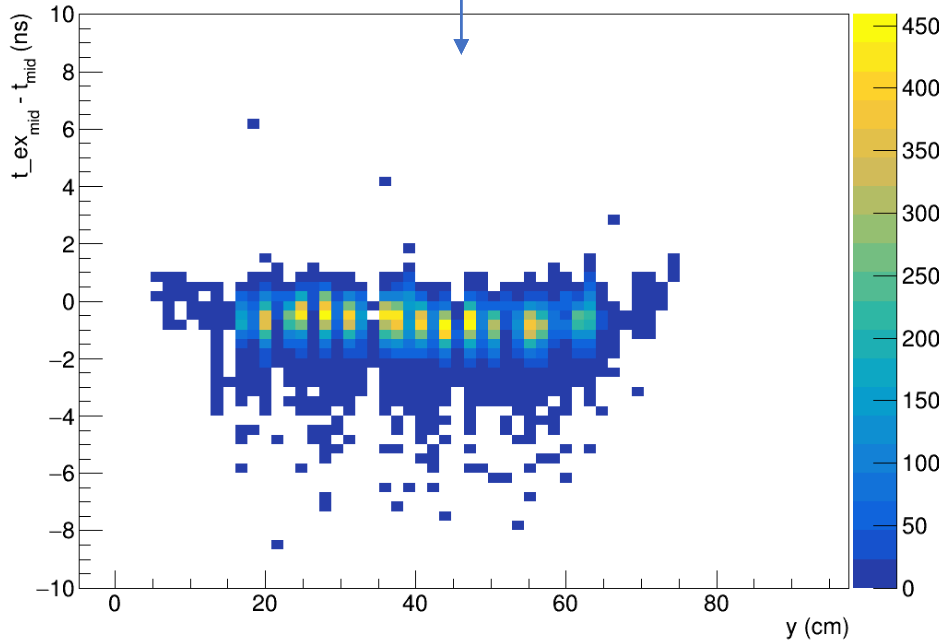


50/50 mixtures, 18kV (high efficiency)

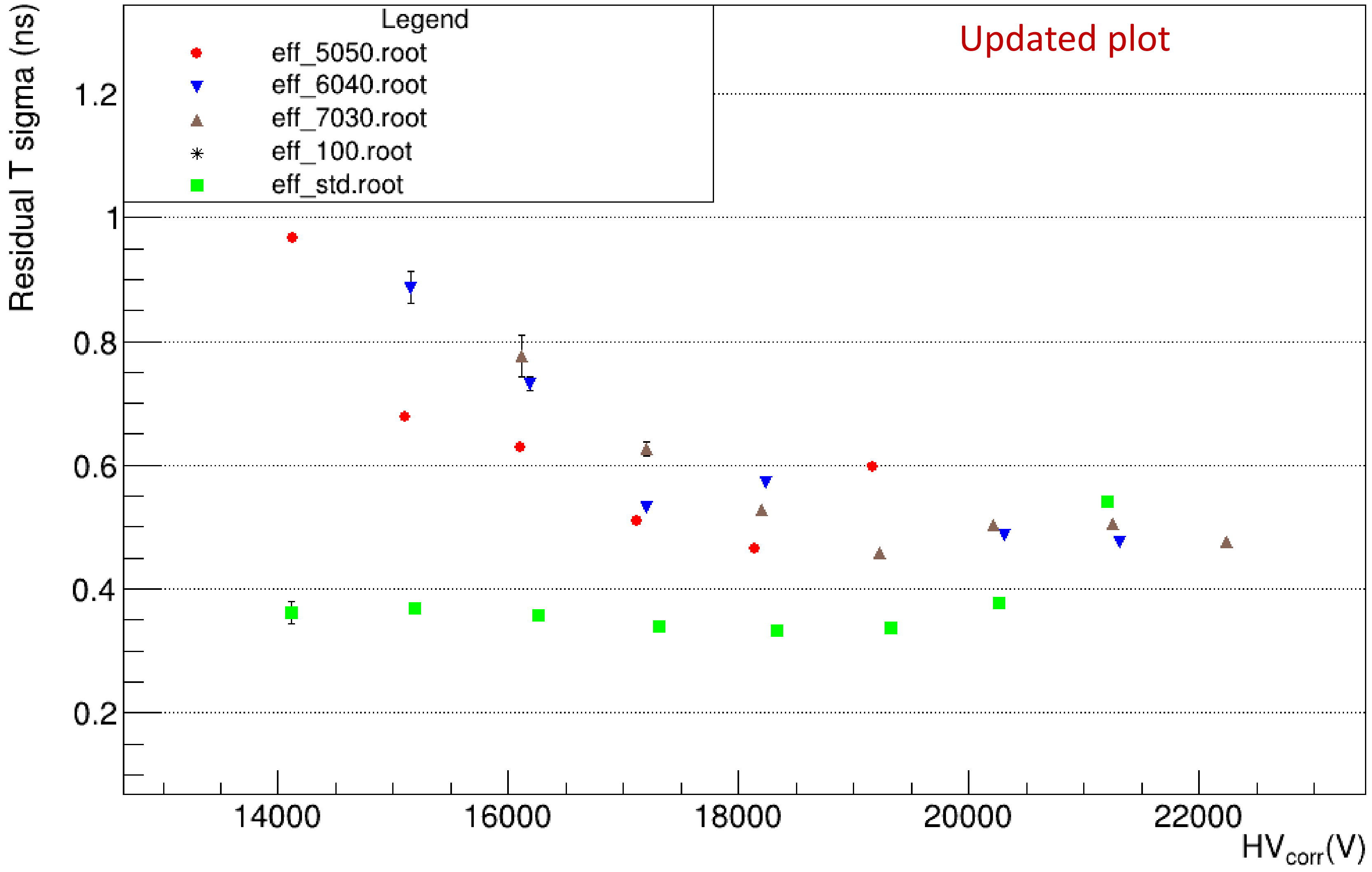
Residuals with Sigma~575 ps

- T of middle chamber computed as a non-weighted average of all hits in the matching cluster
- No ToT calibration

- T calibration only at the hit level (see old presentations) -> not enough precision, ~1ns

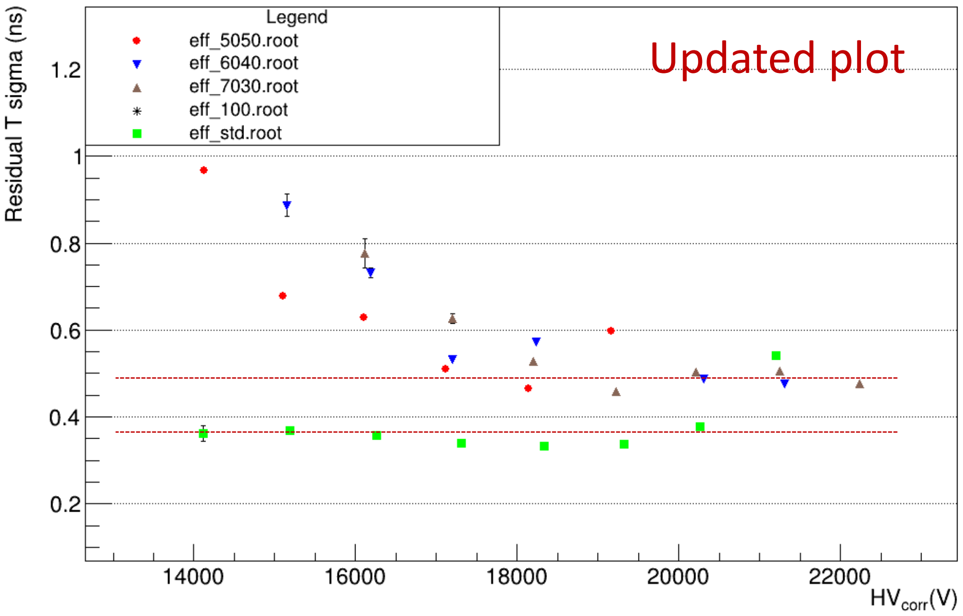


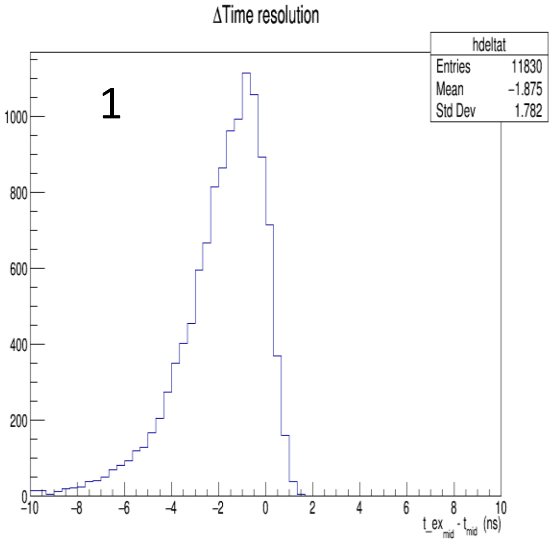
T Residuals – naïve approach

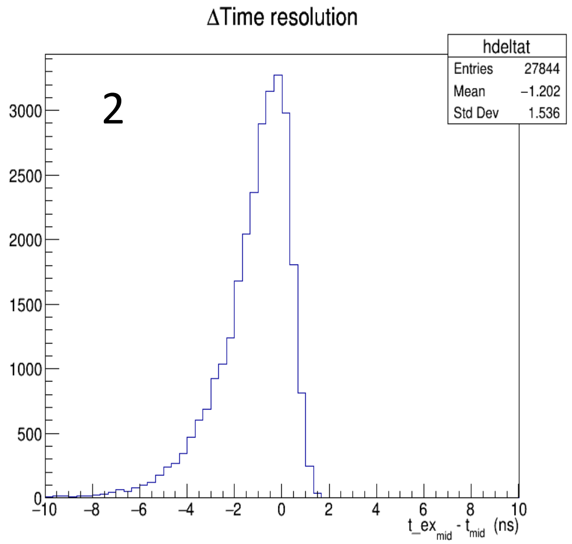


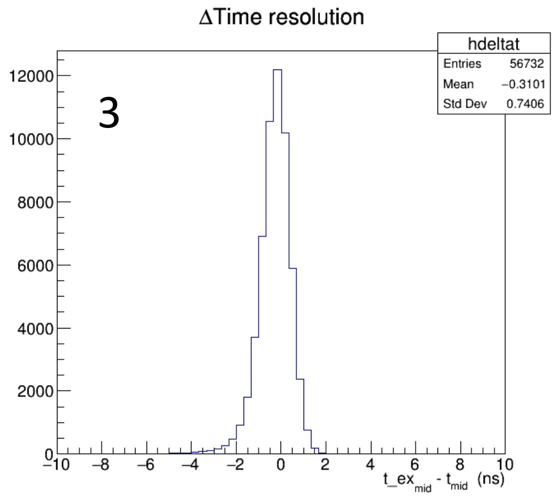
T Residuals – naïve approach

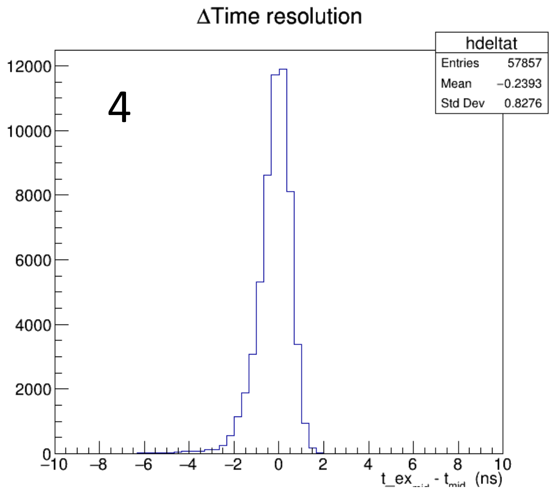
Updated plot

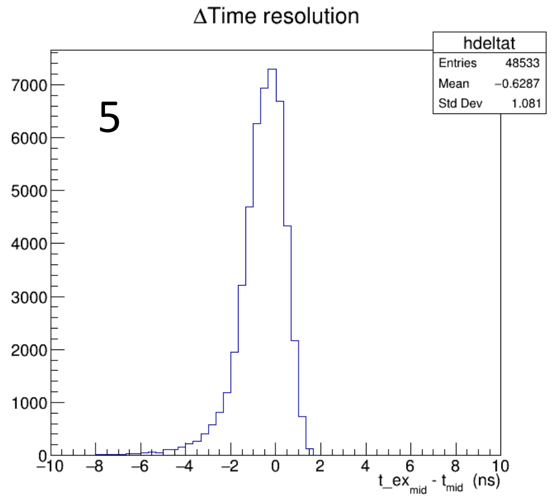


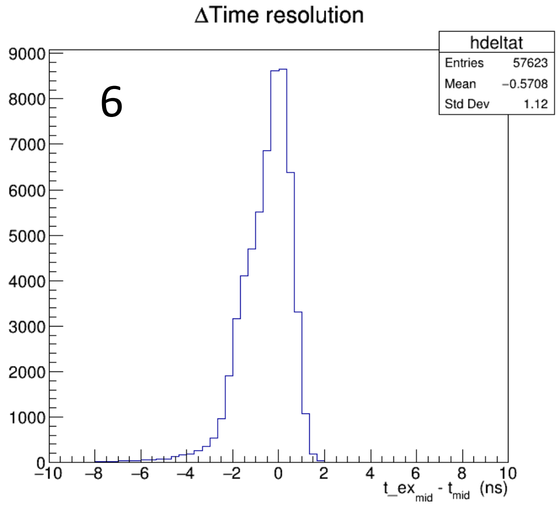










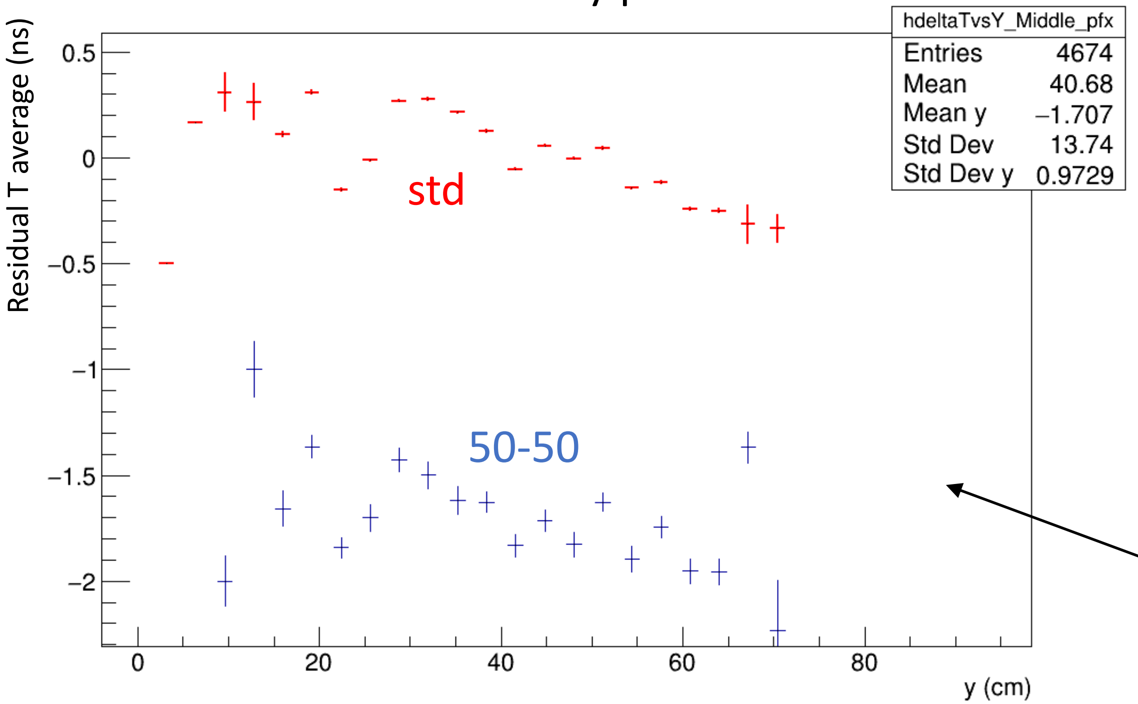


T Residuals – strategy

Strategy for better time computation, after several test:

- Compute the cluster time as the time of the hit with ~~larger ToT~~ minimum T -> cluster time determined by only one strip
- Remove the time calibration applied during the hit reconstruction
- Apply a «strip by strip» time calibration, based on the residual offset on each strip

T Residuals Vs y position



~~The same calibration has been used for all mixtures/HV extrapolated from the std mixture.~~

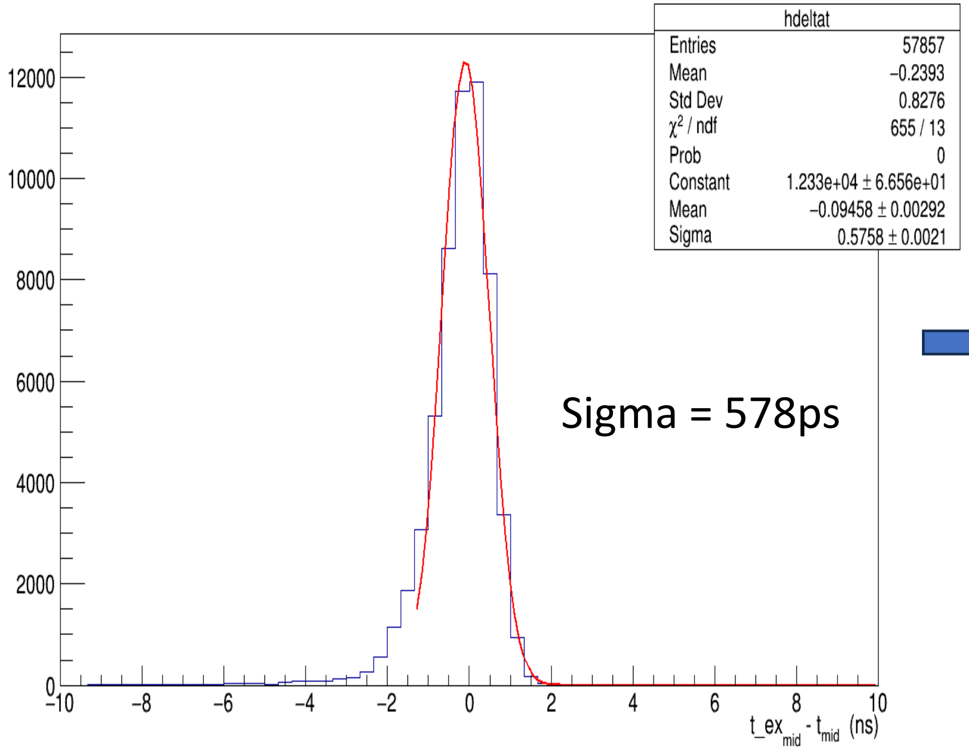
Can be refined by doing a different calibration for each mixture → DONE

Calibration procedure, <u>for each mixtures</u>:

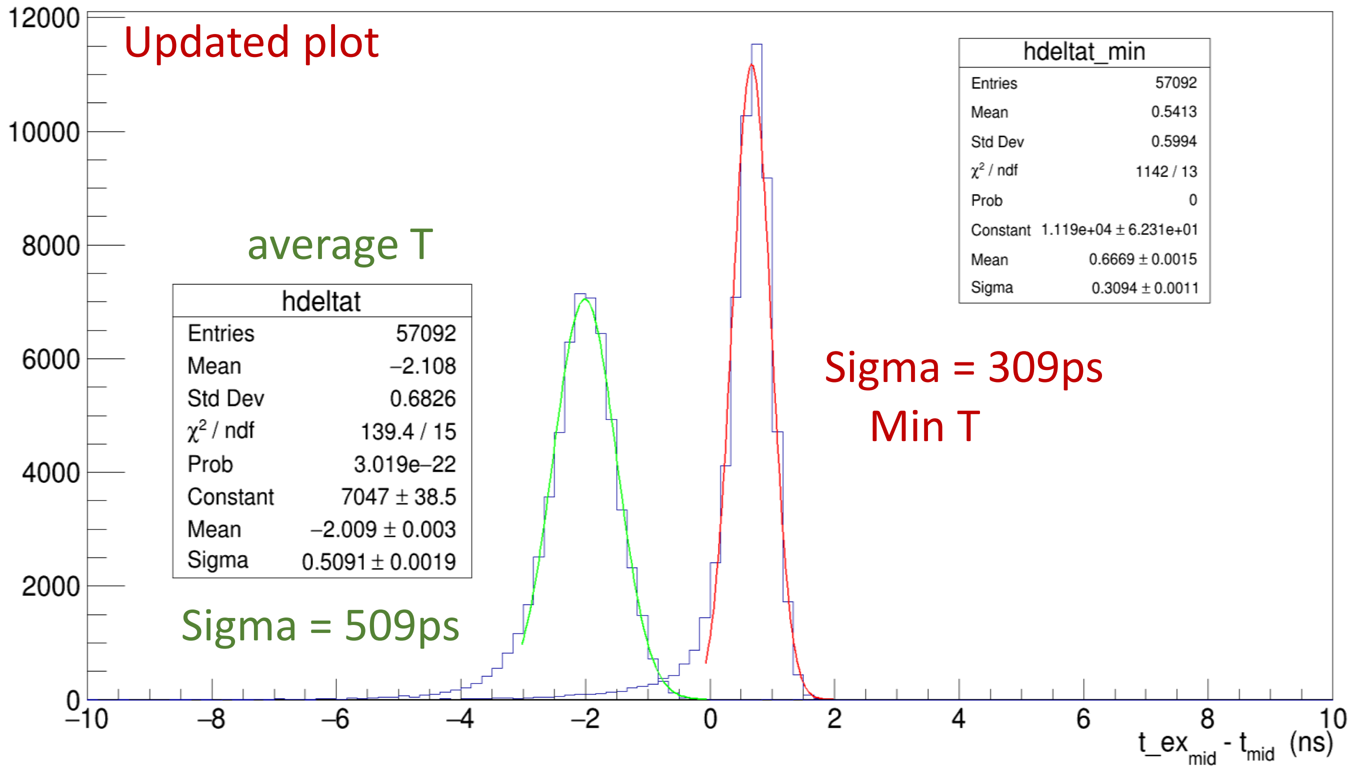
1. Perform the analysis selecting events with only 1 Hit in the test chamber, removing the cut on the fiducial area.
2. Compute the profiles of the the residual T distribution (Vs y)
3. Compute the strip-by-strip time calibration

Calibration effect

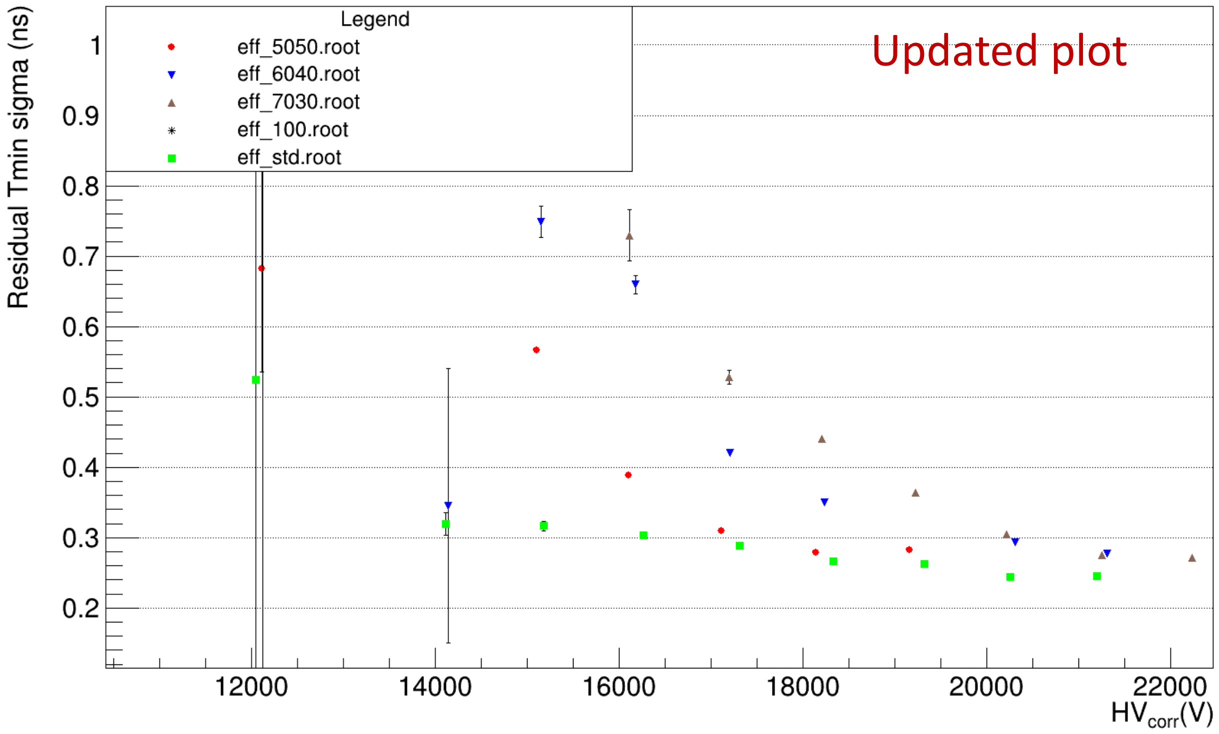
No calib, average T



Strip calibration



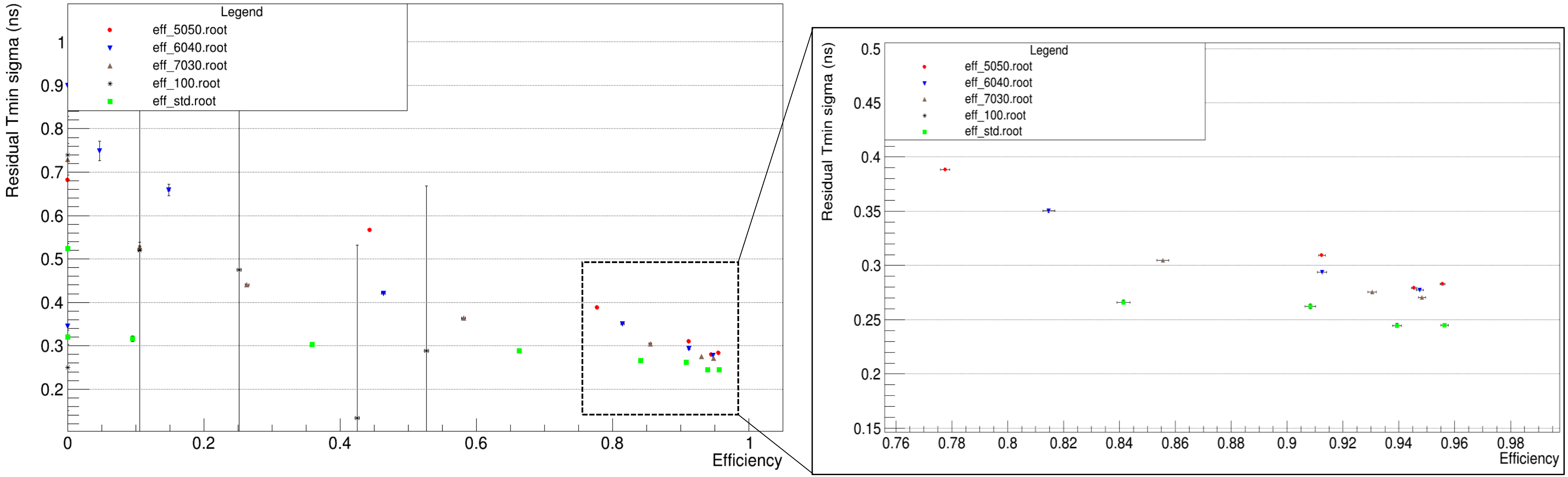
Calibration effect



Few remarks:

- This procedure is really different from what is currently implemented
- It is focused on the minimization of the middle chamber only. Quite «ad hoc» implementation.
- Still at large bias time precision degrade, in particular with large fractions of Helium. This is due to a residual correlation between the T residuals and the cluster size
- Not all distribution are gaussian. <u>We must define a criteria to exclude some of the points</u>

Calibration effect



Conclusion

- The study of several parameters for REND-01 station has been done

- Few details still to be improved, but we can proceed with the draft of the article backup

Analysis steps

☑ Review of efficiency code(s) :

- ➢ CNAF official reco code (from binary to "debug tree")
- ➢ Dedicated efficiency code by S.Boi.

2 main critical aspects :

- Efficiency, streamer fraction and cluster multiplicity are not obtained in a consistent way (different codes and/or different cuts). -> Difference in efficiency between CNAF eff. code and dedicated code (tuned for streamer % computation) ~10%
- Streamer are not <<1%, but of the order of 10% (50/50 mixture)

☑ Debug/improve actual code. Main changes:

- ➢ New clusterization algorithm
- ➢ New calibration procedure (simultaneous time/space calibration)
- ➢ New selection cuts

At present the code can extrapolate streamer and efficiency simultaneously. Difference in efficiency between CNAF eff. code and dedicated code below 2%

☑ Further optimization/automatization of the code, target discrepancy below 1% (Autom./optim. to be refined)

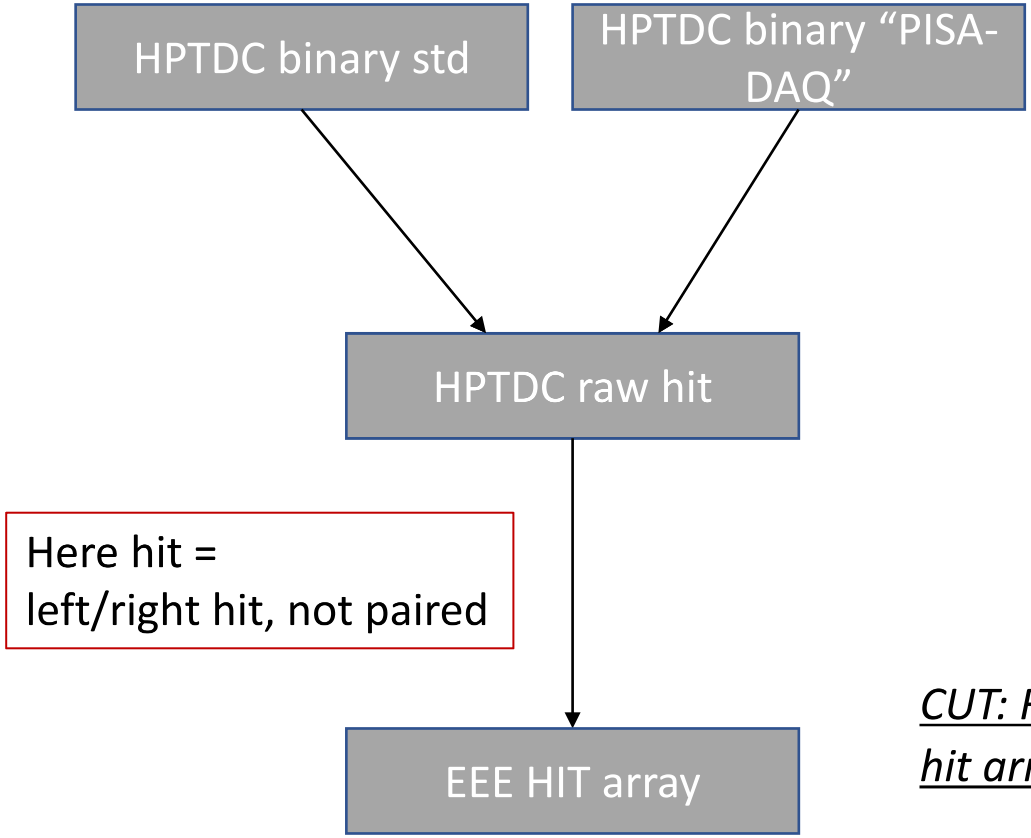
☑ Validation on a larger set of runs (at present I'm using a PISA run with 50/50 mixture @ eff. plateau, worst condition in terms of reconstruction).

☑ Recompute efficiency for the selected efficiency scans (2 telescopes, ~4 mixtures)

☑ Re-reco of PISA data after fix of DST producer -> New plots of parameter distributions (beta, Theta, ToF,...) -> C.Ripoli

Code review: CNAF

Several codes used for the efficiency analysis, I decided to base the analysis review on the code developed by S.Boi. It takes as input the DST files generated by the CNAF reconstruction code, using a low level TTRee.

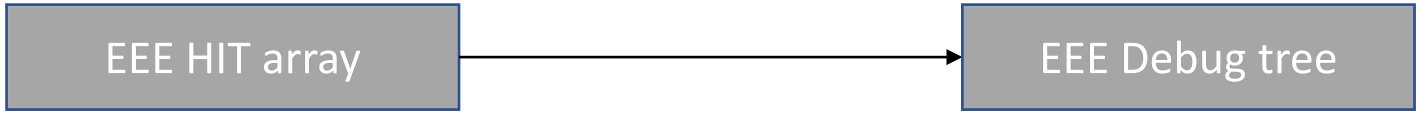


1. *multi-hit on the same channel possible*
2. *Trailing edges without prior leading edge are discarded*
3. *leading edges without a trailing edge are registered with TOT=0*

CUT: hit is discarded is the time of arrival is outside the limits taken by the configuration file «if (timeHit >= fCalib->GetTbLowLimitRight() && timeHit < fCalib->GetTbHighLimitRight())»

CUT: For each channel a maximum of 6 hit are passed to the hit array

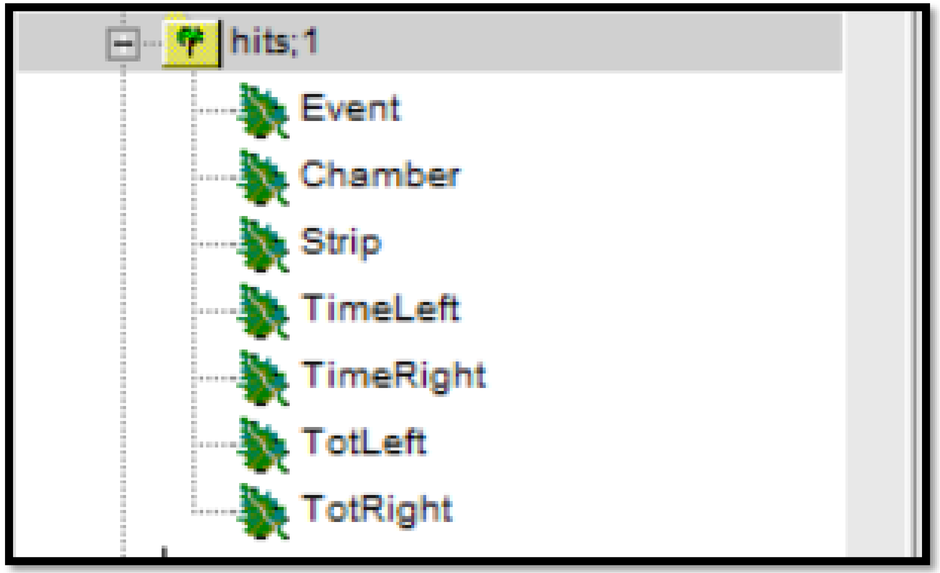
Code review: CNAF



Note: If a strip has no hit on one side, the time on that channel is set to 0 and the TOT=-1

CUT: ONLY the first hit per channel is transmitted, other are discarded

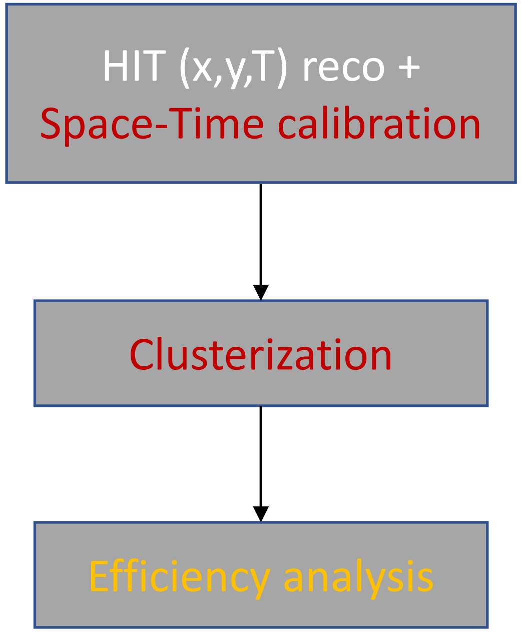
DST file content



- ❑ Data from "PISA" DAQ are reconstructed with hardcoded values:
  - ➢ of the geometry (in particular distance between chambers, wrongly set) -> RE-RECO DONE
  - ➢ of the architecture (NINO version, correctly set)

Code review: efficiency extraction

Workflow based on the workflow of S.Boi.



Keeping the same code infrastructure (well done and with an event display!), the following section were changed:

- New calibration procedure (simultaneous time/space calibration)
- New clusterization algorithm
- Upgraded selection cuts
- Minor fixes (not discussed here) and more control histograms

Details are given here

Analysis workflow –T Limit selection

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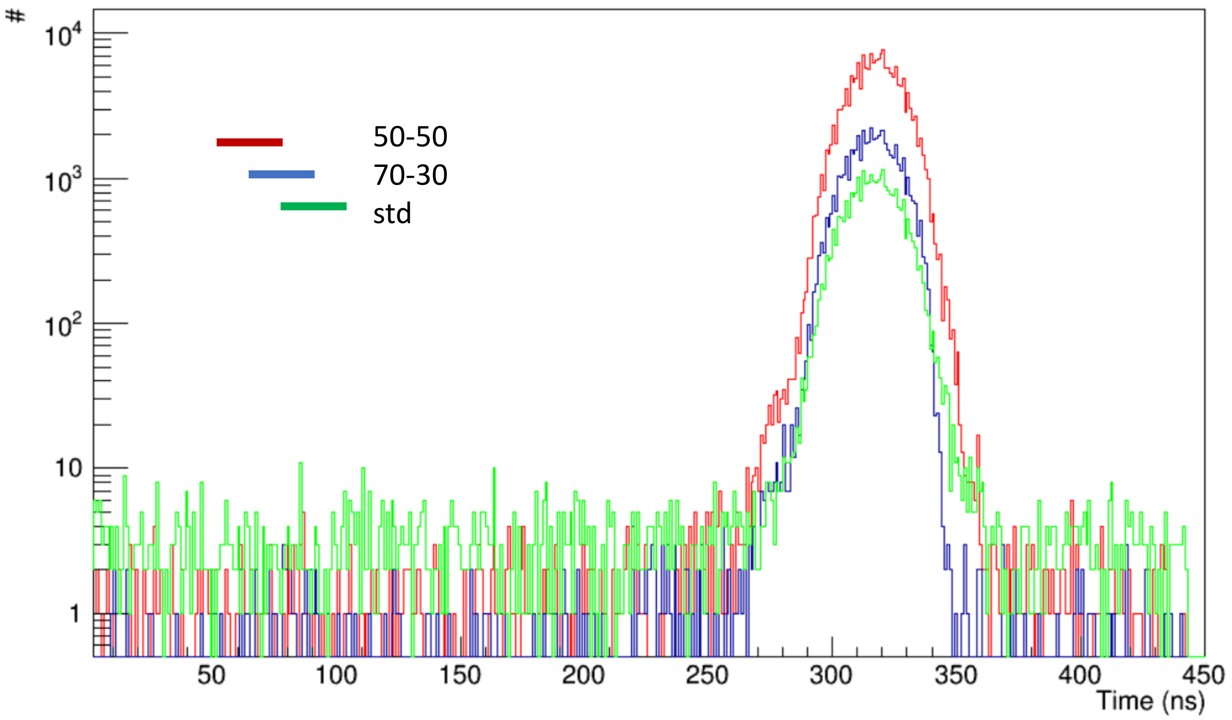
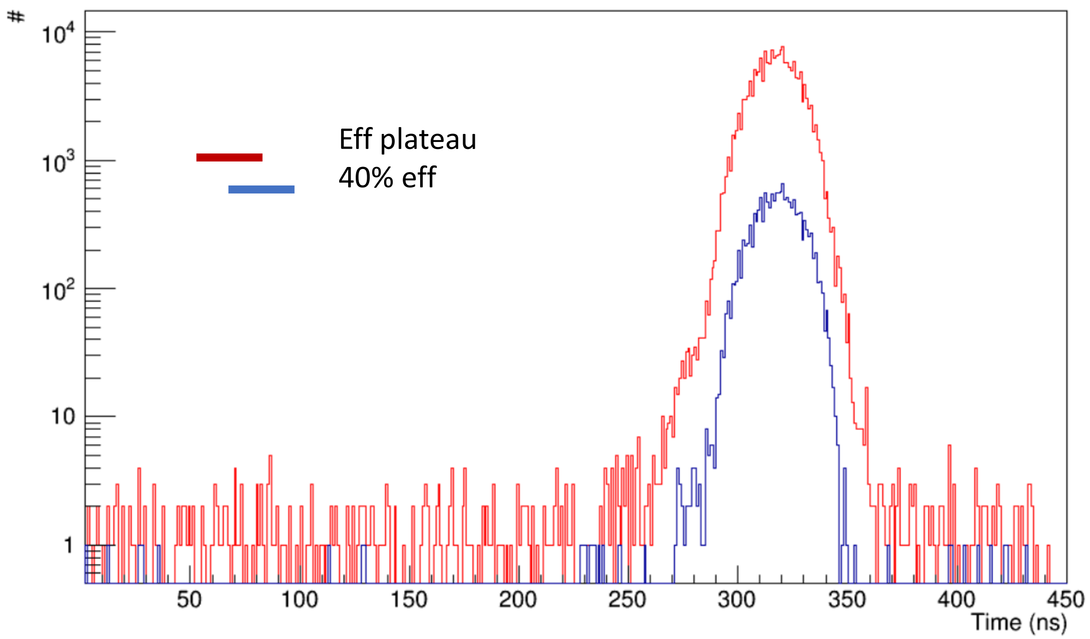
For each mixture, a “pilot” run is selected, with a voltage of the chamber under test in the plateau region. Plateau is known from the previous analysis on the dataset.

The pilot run is reconstructed without T-cuts at CNAF and the hits reconstructed with the analys workflow (1st stage).
The raw T distributions are then used to optimize the T-cut.
All runs with the same mixture are then reconstructed with the same cut.

PISA-01 Bottom camber



PISA-01 Bottom camber



T-cuts are quite stable w.r.t. different mixtures and HVs

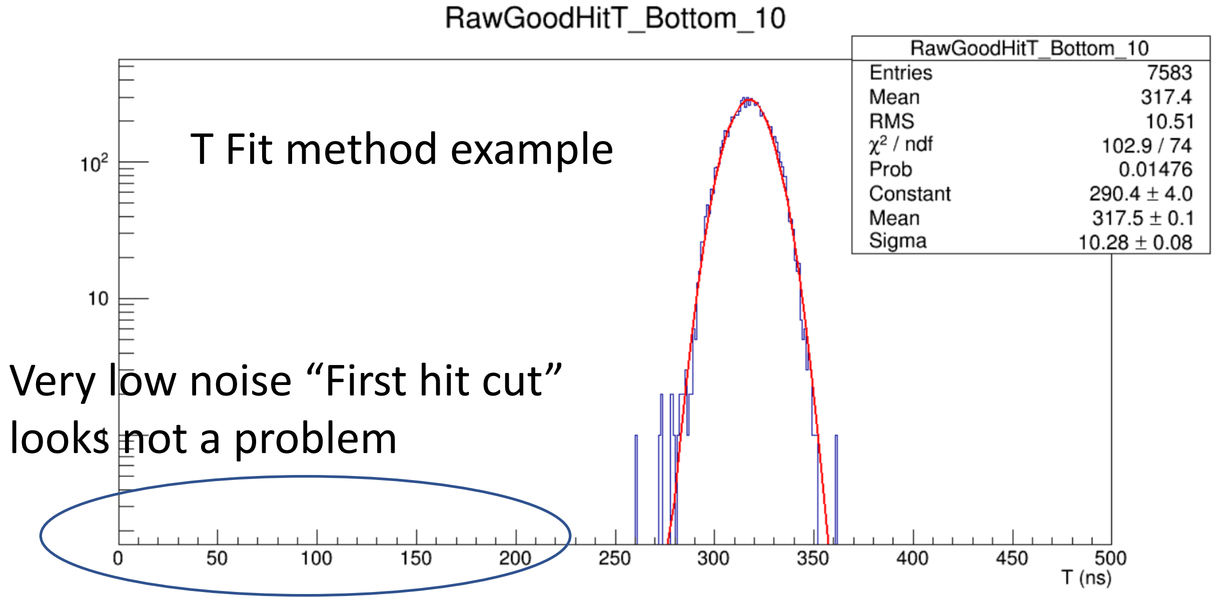
Calibration

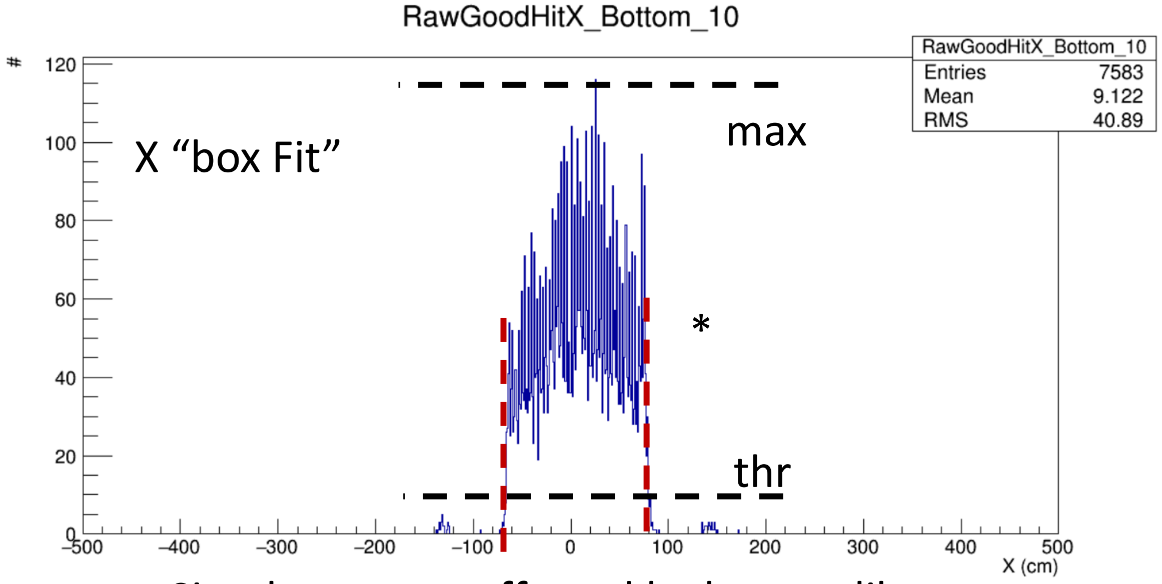
The calibration performs a simultaneous calibration of space and time.
It also calibrate the average middle time to be centered w.r.t. the outer chambers.

1. For each strip compute
   - average x coordinate
   - average hit T (Tl+Tr/2) distribution

2. For each chamber:
- Average hit T distribution

T distribution have large shape variation between telescopes and clk distribution system. The average T can be computed with two parametrized modes:
- Gaussian Fit
- “Box fit” (as for the x coordinate)





Simple average affected by large calib. error for non uniform hit distributions

Calibration

3. Space/ correction are independently applied

```
if(!external_calib)
{
    std::cout<<"Computing corrections..."<< std::endl;
    double delta_time,strip_offset, Avg_T_adjust[3],x_offset;

    Avg_T_adjust[0]=.0;
    Avg_T_adjust[1]= ch_time[1] - ((ch_time[2]+ch_time[0])/2);
    Avg_T_adjust[2] = .0;

    std::cout << "Mean hit time adjust for chamber 0: " << Avg_T_adjust[0] << std::endl;
    std::cout << "Mean hit time adjust for chamber 1: " << Avg_T_adjust[1] << std::endl;
    std::cout << "Mean hit time adjust for chamber 2: " << Avg_T_adjust[2] << std::endl;

    for (int chamb_idx = 0; chamb_idx < 3; chamb_idx++) //chambers loop
    {
        //adjust strip offset
        for (int str_idx=0;str_idx<24;str_idx++) // secondo loop sulle strip
        {
            //offset tra la media della strip e la media della camera
            if (MeanT_map[make_pair(chamb_idx,str_idx)]>0)
                delta_time=((ch_time[chamb_idx] - Avg_T_adjust[chamb_idx]) -MeanT_map[make_pair(chamb_idx,str_idx)]);  //ns
            else delta_time=0.0;
            Calib_map[make_pair(chamb_idx,str_idx)].first=delta_time;   //hit time = (Tleft+Tright)/2
            Calib_map[make_pair(chamb_idx,str_idx)].second=delta_time;

            //std::cout<<"strip "<<strIdx<<" time correction: "<< delta_time<<std::endl;
            //correzione spaziale


            x_offset = MeanX_map[make_pair(chamb_idx,str_idx)];
            std::cout<<"strip "<<str_idx<<" x cm offset: "<< x_offset<<std::endl;
            strip_offset=x_offset*2.0/EEEHit::SpeedOfPropagation; //mean ns strip offset
            //std::cout<<"strip "<<strIdx<<" y ps offset: "<< strip_ps_offset<<std::endl;

            Calib_map[make_pair(chamb_idx,str_idx)].first+=strip_offset/2.0;   //negative side
            Calib_map[make_pair(chamb_idx,str_idx)].second-=strip_offset/2.0;   //positive side
            std::cout << "Chamber " << Chamber_name[chamb_idx] << ", strip " << str_idx << " left:" << Calib_map[make_pair(chamb_idx,str_idx)].first << s
            std::cout << "Chamber " << Chamber_name[chamb_idx] << ", strip " << str_idx << " right:" << Calib_map[make_pair(chamb_idx,str_idx)].second <<
        }

    }
```

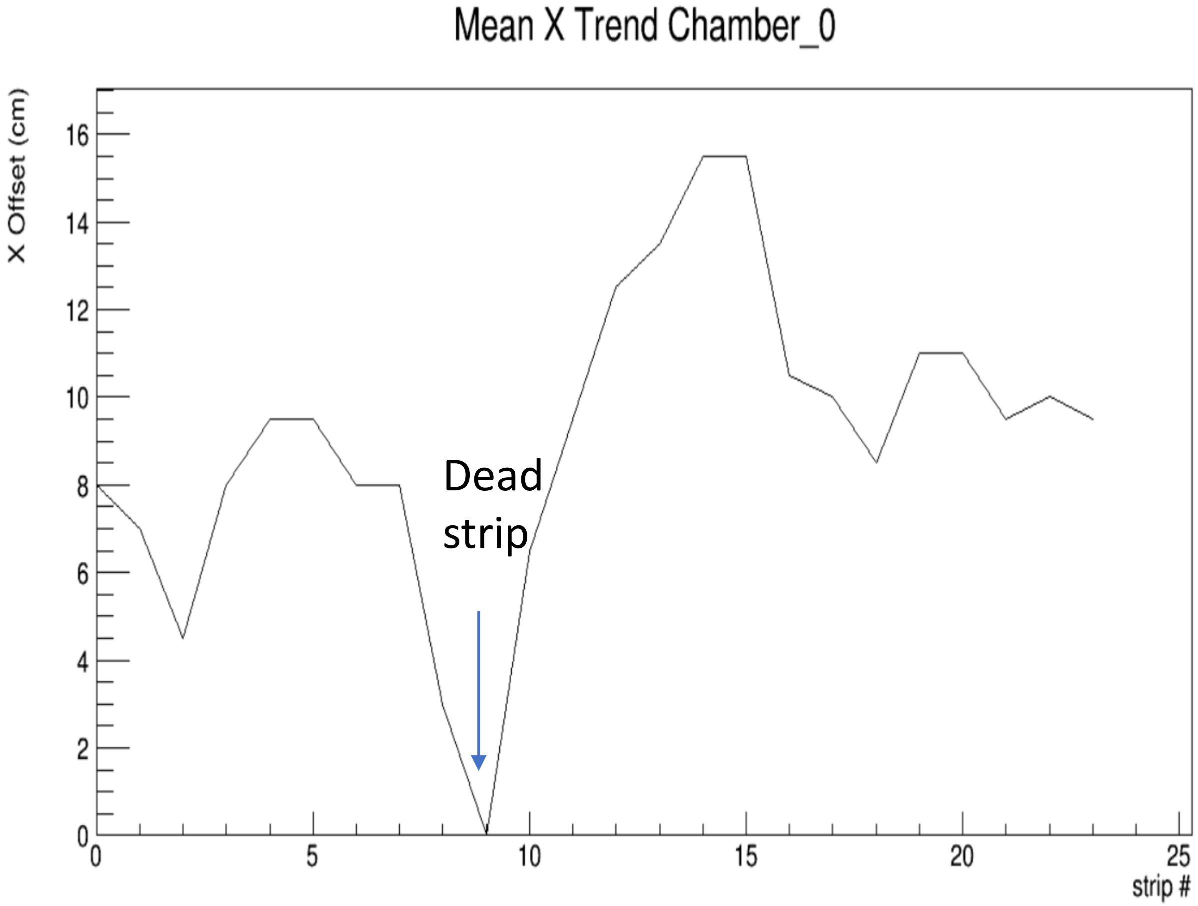
Average chamber correction

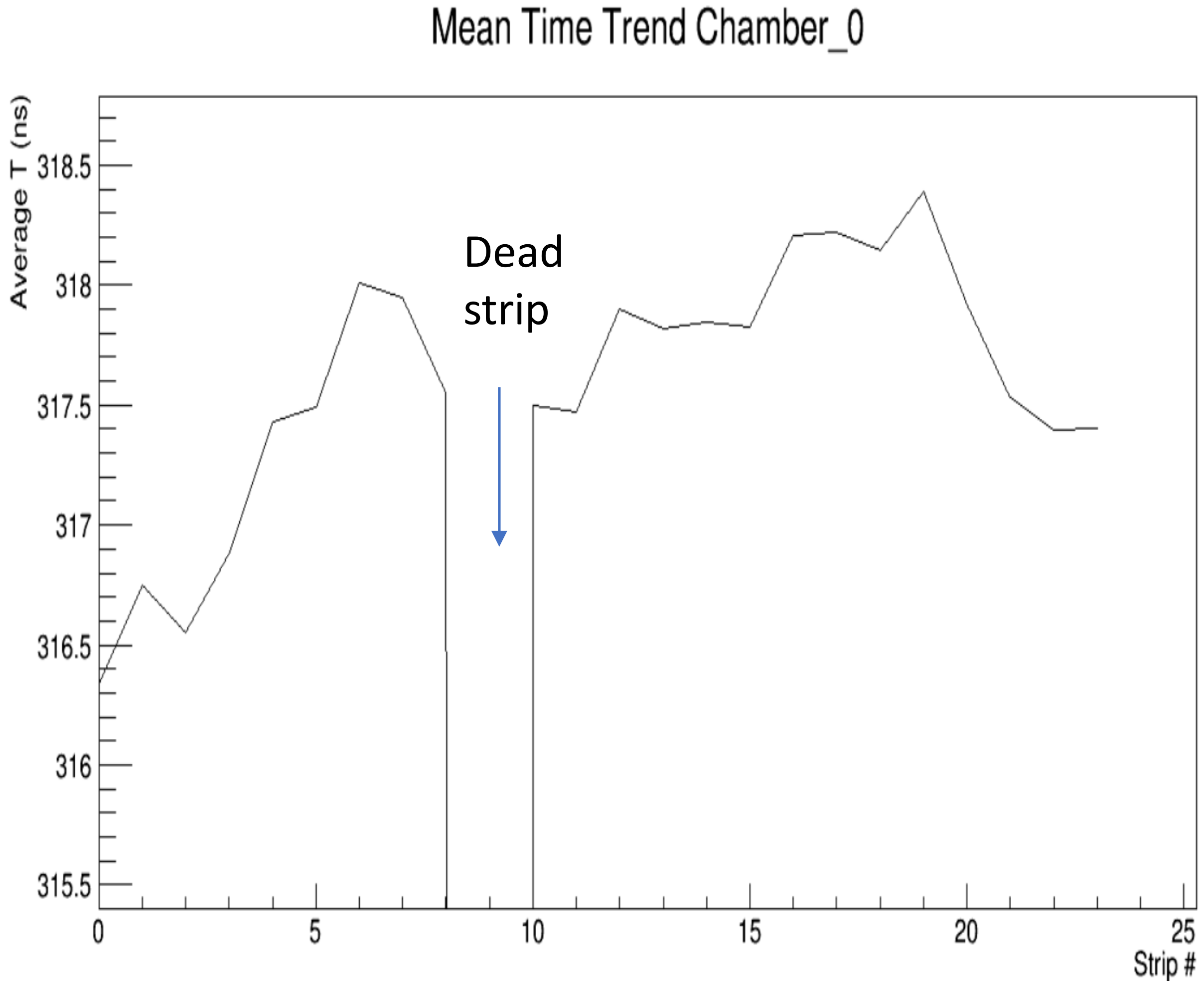
Time calibration

Space calibration

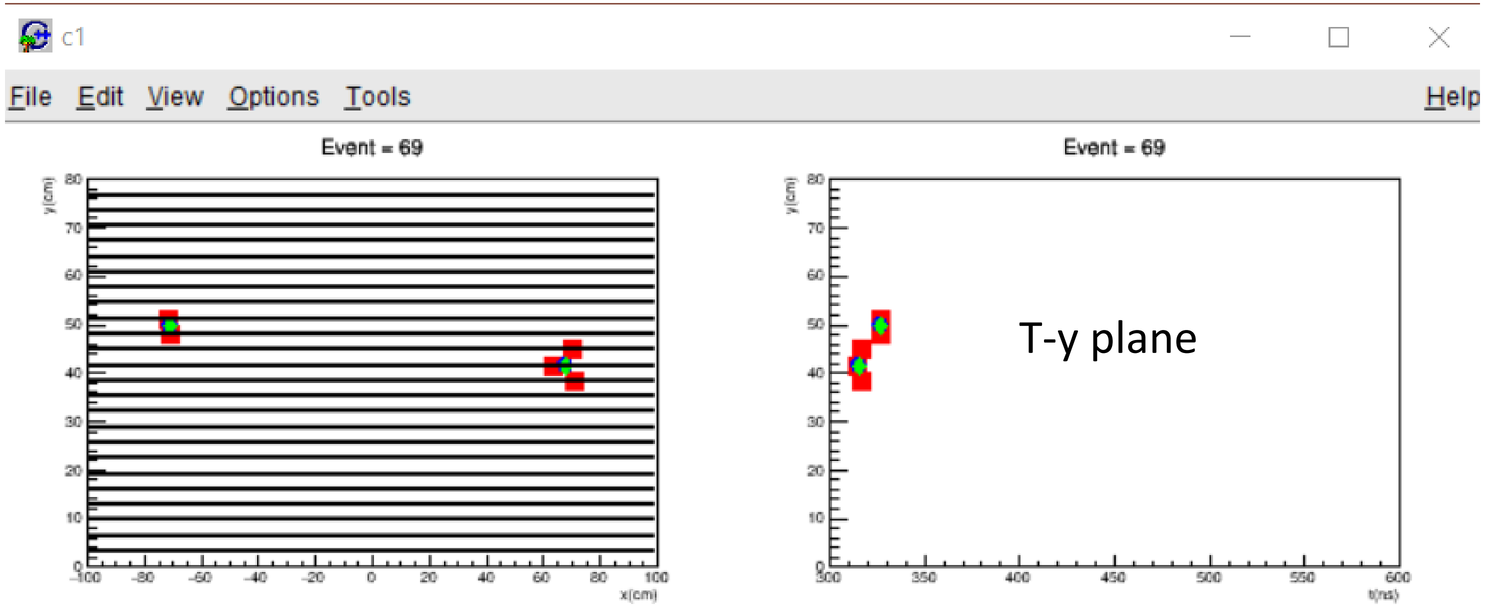
Calibration can be saved/retrieved

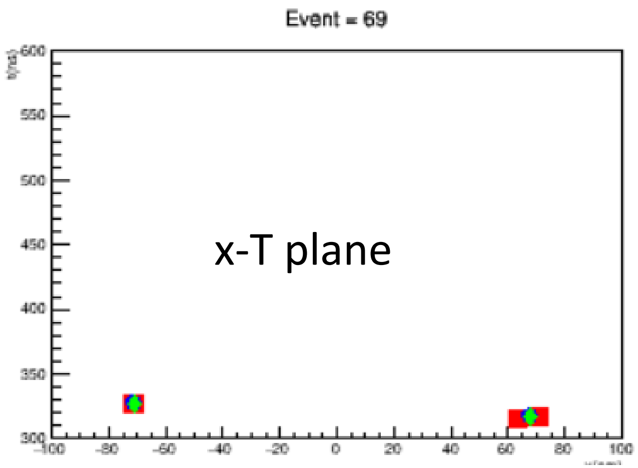
Raw data offset





Clusters





Event display by S.Boi

red=hits
green = cluster barycenter

The algorithm in short:

1. First hit is promoted to cluster and removed from hit array.
2. Scan over the hit array to find the first hit with XY distance below 10cm. Metrics: minimum distance between the hit and all the hits already part of the cluster
3. If some hit is added to cluster, remove it form the hit array and go back to point 2.
4. When no more hits can be added to the present cluster, compute cluster parameter (baricenter, T, average ToT)
5. if the hit array is not empty, create a new cluster with first hit and go back to point 2.

Note: code optimization to reduce clusterization step to few seconds (100K events)
The cluster will contain the list of hits -> useful in the last stage of the analysis

Efficiency

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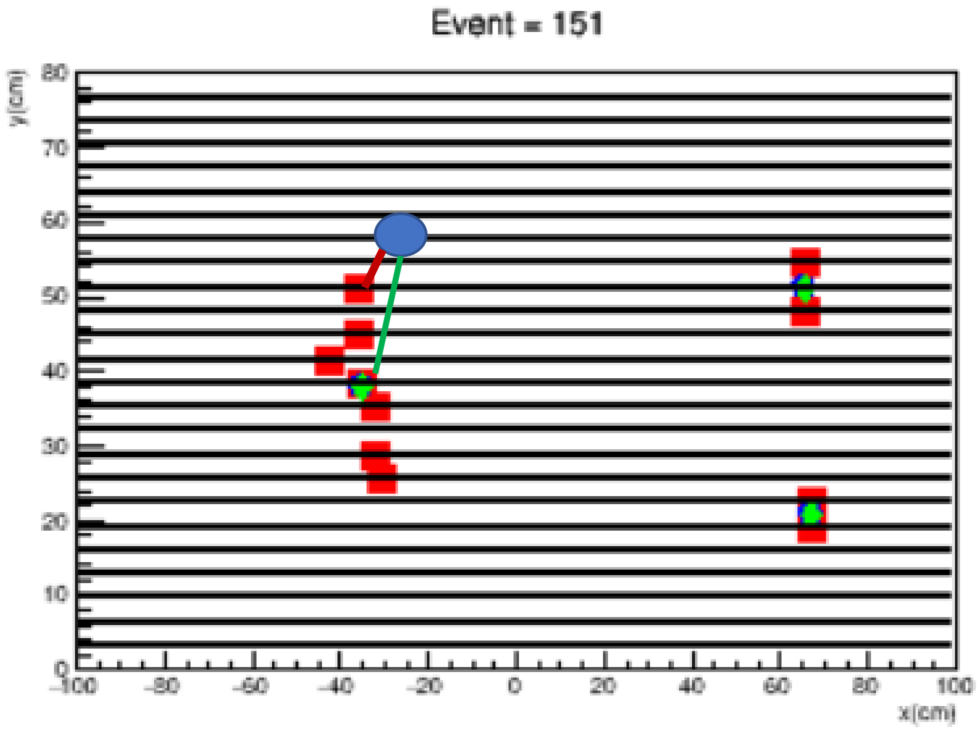
Event selection as in the past but new metrics to check the “distance” between a cluster and the projected hit



Old metrics: Distance to barycenter
New metrics: distance to closest hit of the cluster

Cluster multiplicity and streamer are computed from the multiplicity of best-matching cluster.

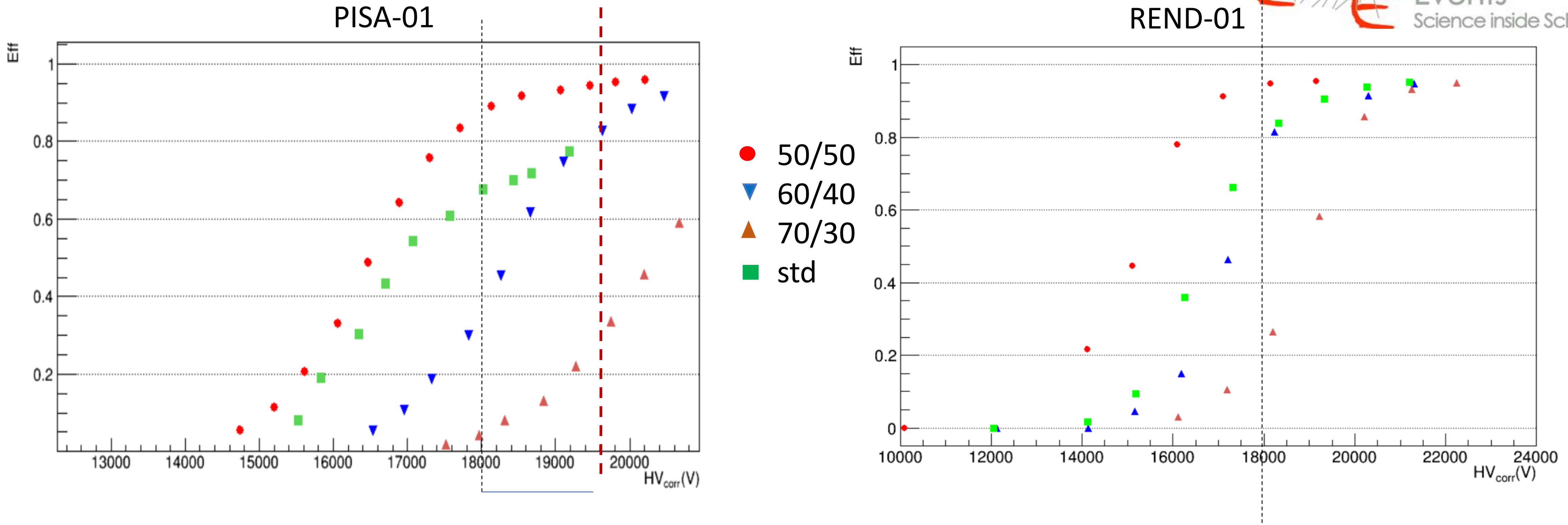
Selection cut on the triggered events (some tuning still needed):

- Extrapolated hit within test chamber acceptance (5<y<75 cm, -60<x<60 xm)
- zdir > 0.9 (DISABLED)
- particle inverse beta within correct window (see next slide)

Criteria for efficiency:

- distance between the extrapolated hit and the closest cluster below 15 cm
- Time difference between the extrapolated hit and the closest cluster below 10 ns

Efficiency



- Weird behavior of PISA-01 “std” mixture
- Curves looks shifted by ~1.5kV -> potentially due to HV readout offset, chamber differences

- Std” curve lies between 50/50 and 60/40 for both stations

Cluster size

Extreme Energy Events
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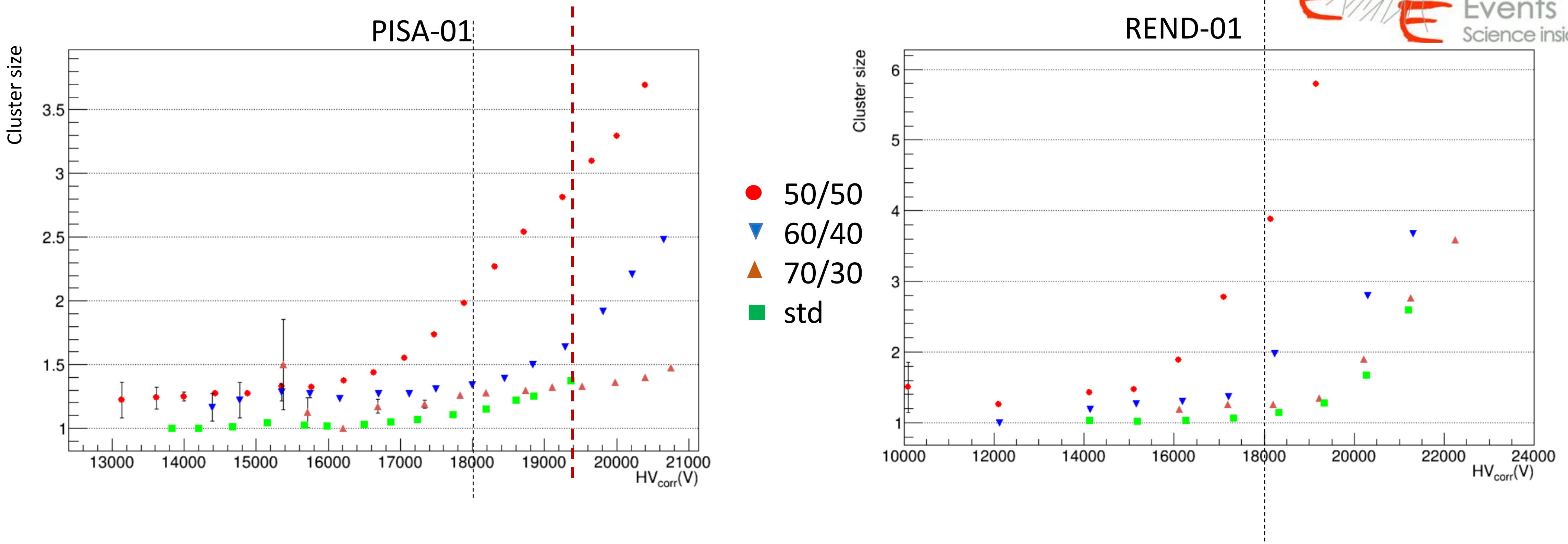
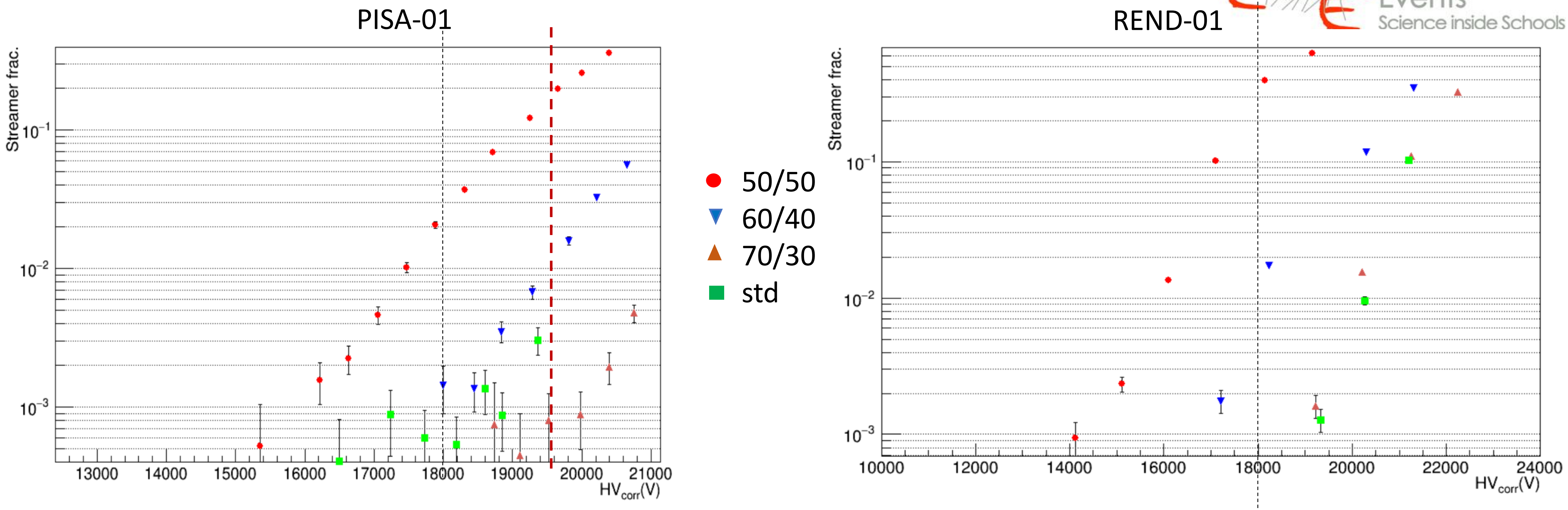


Def: Cluster size is the number of hits forming the cluster closer to the extrapolated point in the test chamber.
The uncertainty is the RMS of the cluster size distribution divided the square root of the number of entries in the histogram

Same behavior between the two station, apart for the HV "offset"

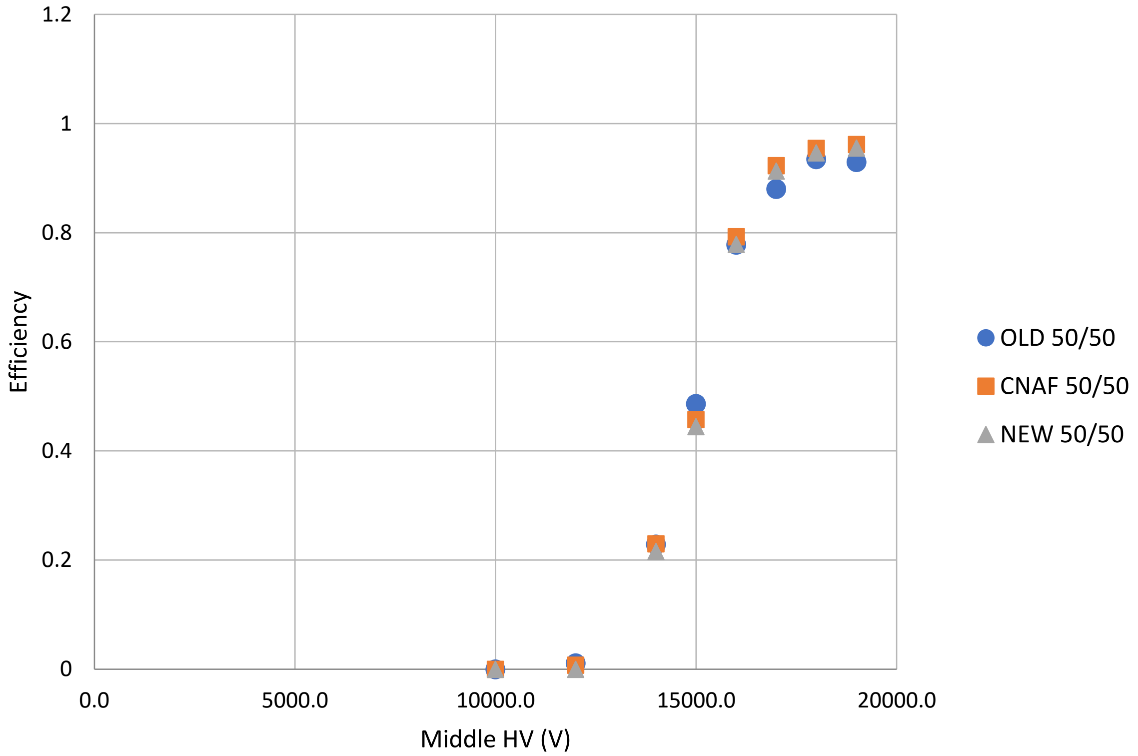
Streamer fraction

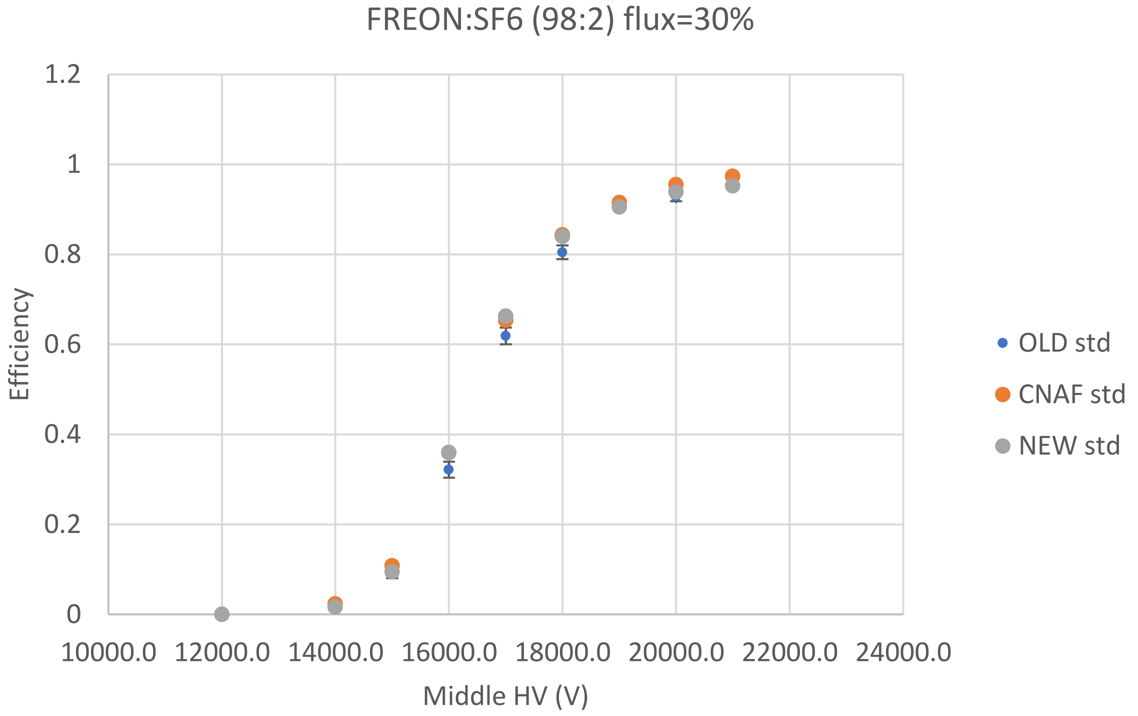


Def: Streamer fraction is the fraction of efficient events where the cluster size in the test chamber was > 3
Same behavior between the two station, apart for the HV "offset"

- Streamer fraction reach high values for both 60/40 and 50/50 mixtures (i.e., it is already ~1% @ 80% efficiency for 60/40 mixture)

REND-01: CNAF comparison

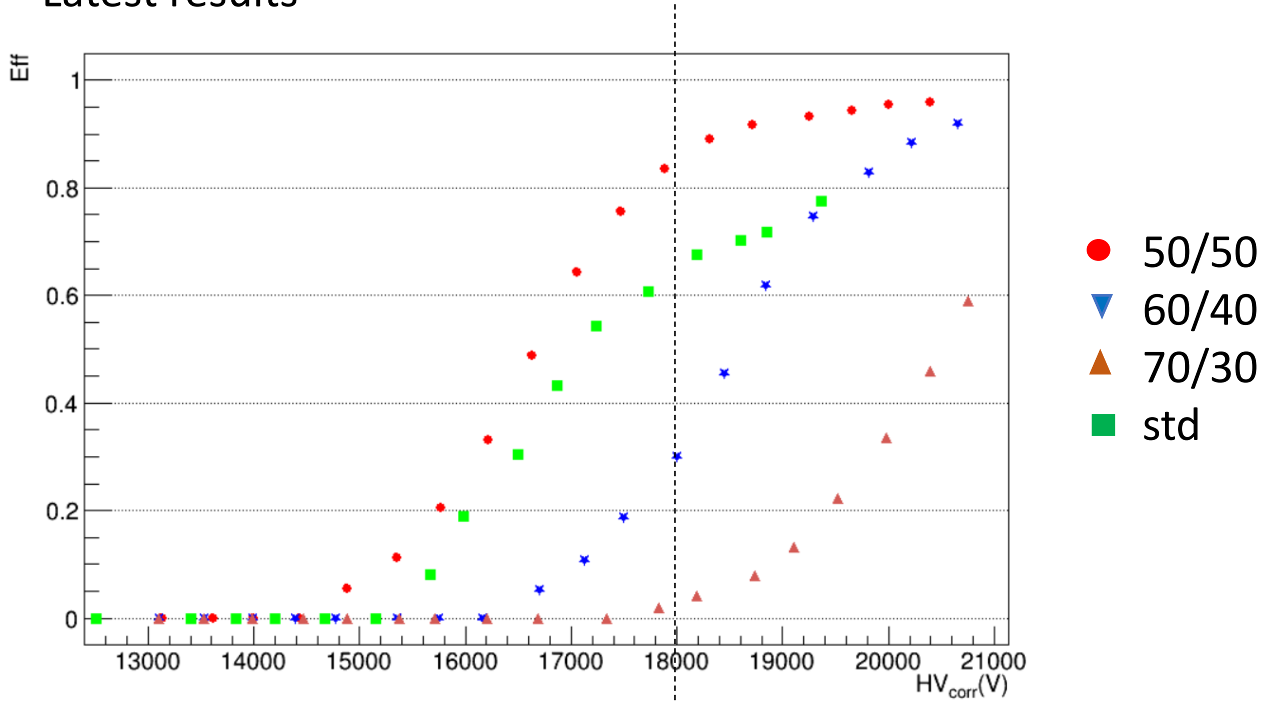




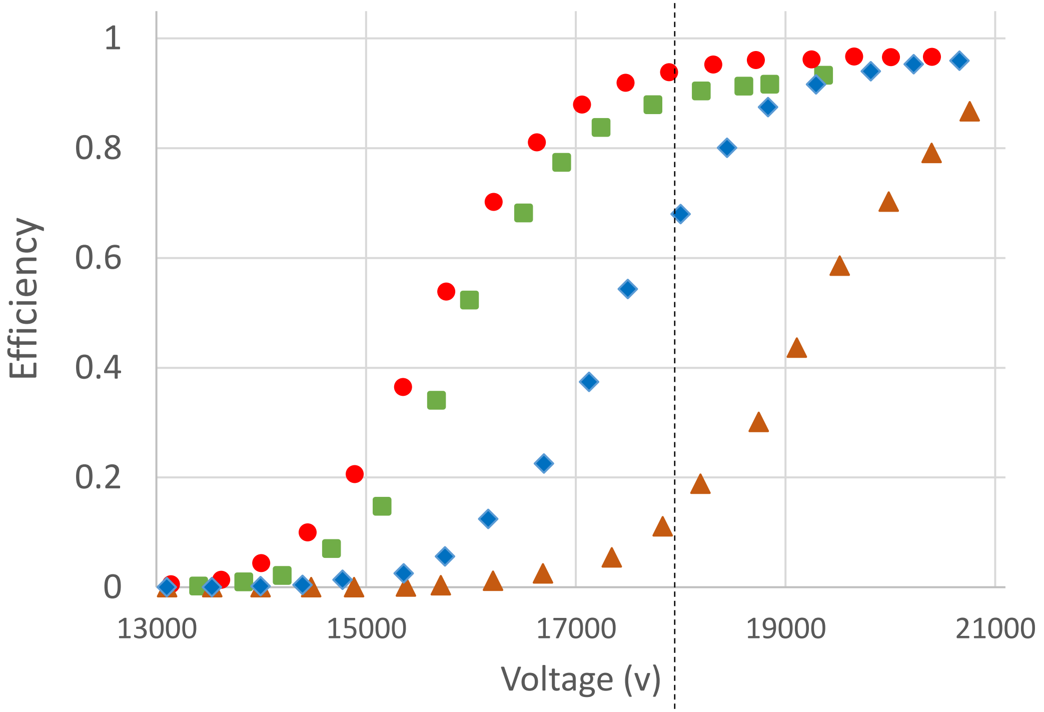
Comparison of analysis results of REND-01 data are consistent between CNAF, present analysis and old studies

PISA-01: CNAF comparison

Latest results

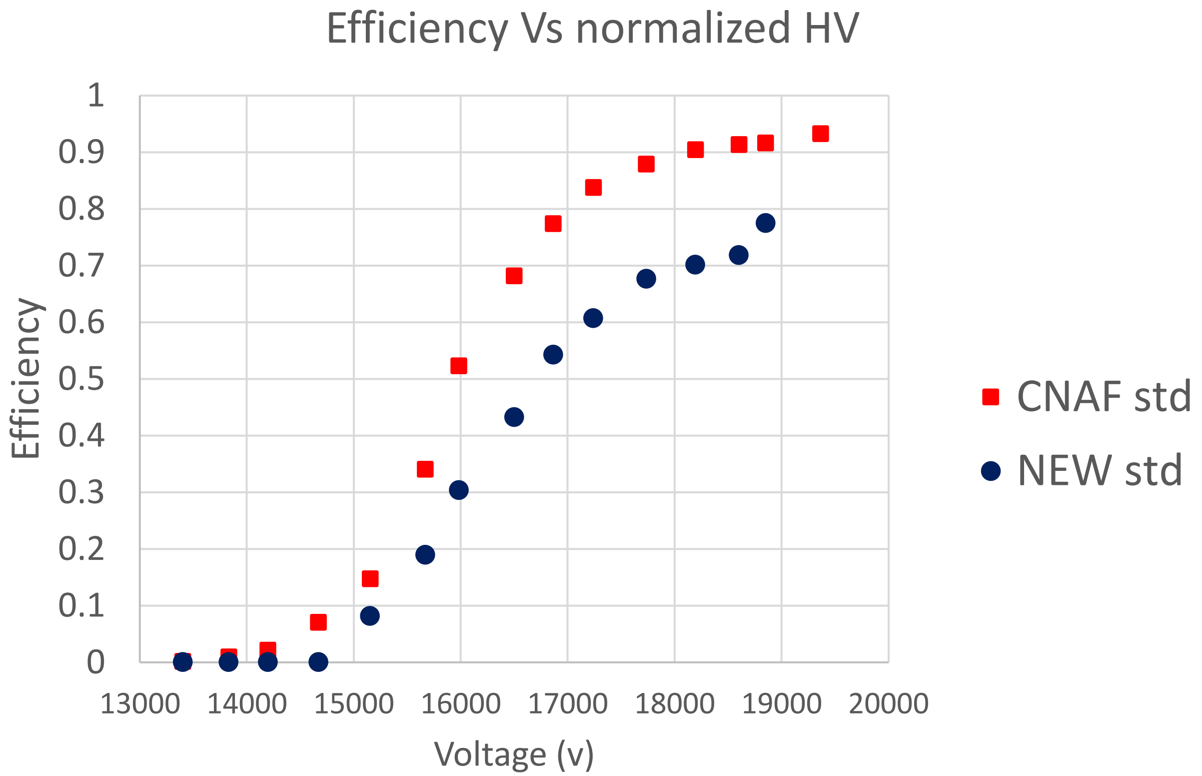


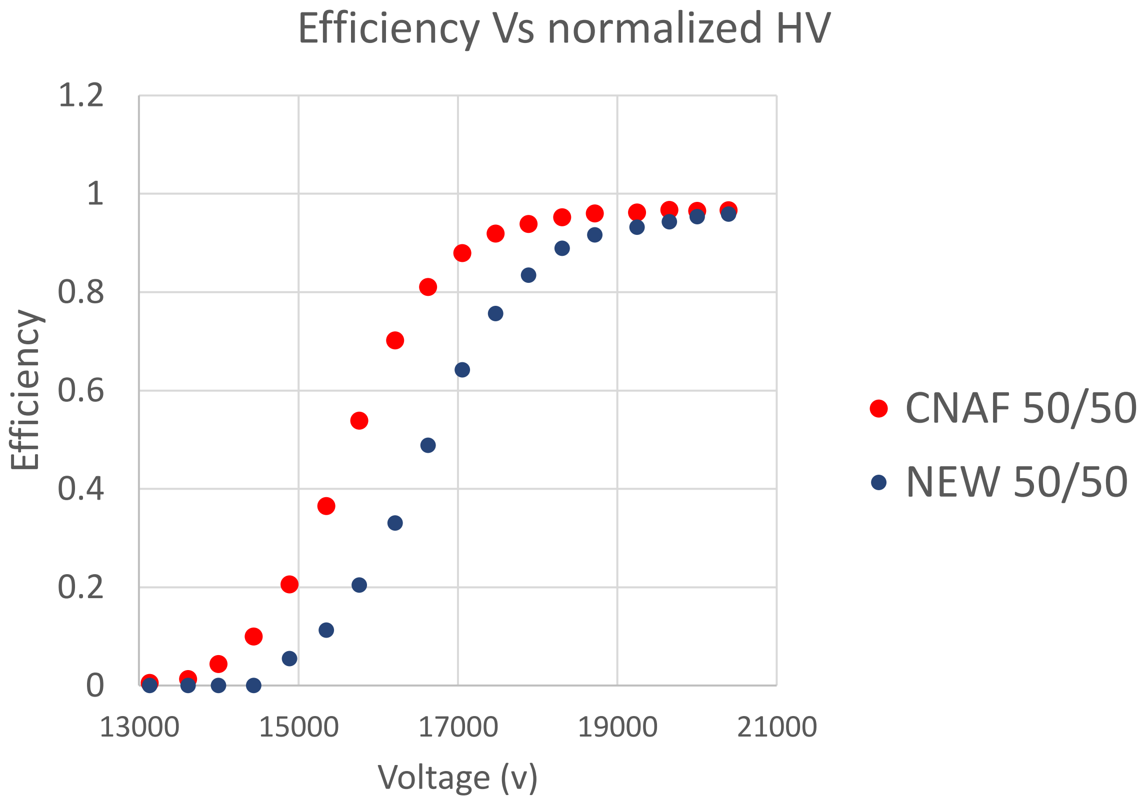
CNAF



Comparison of analysis results of PISA-01 data shows inconsistent results between CNAF and present analysis

PISA-01: CNAF comparison





Comparison of analysis results of PISA-01 data shows inconsistent results between CNAF and present analysis

This aspect requires further investigation, which is ongoing