Helium-based gas mixtures : status of the analysis review

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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

New dataset added to the analysis!

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

ANALYSIS OUTPUT:

- Efficiency
- Cluster multiplicity
- Streamer fraction
- X/Y residuals (new)

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

Updates!

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

All chambers with He mixtures data

Status summary

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

New!

+ investigation on hits outside chamber (@+-140cm)

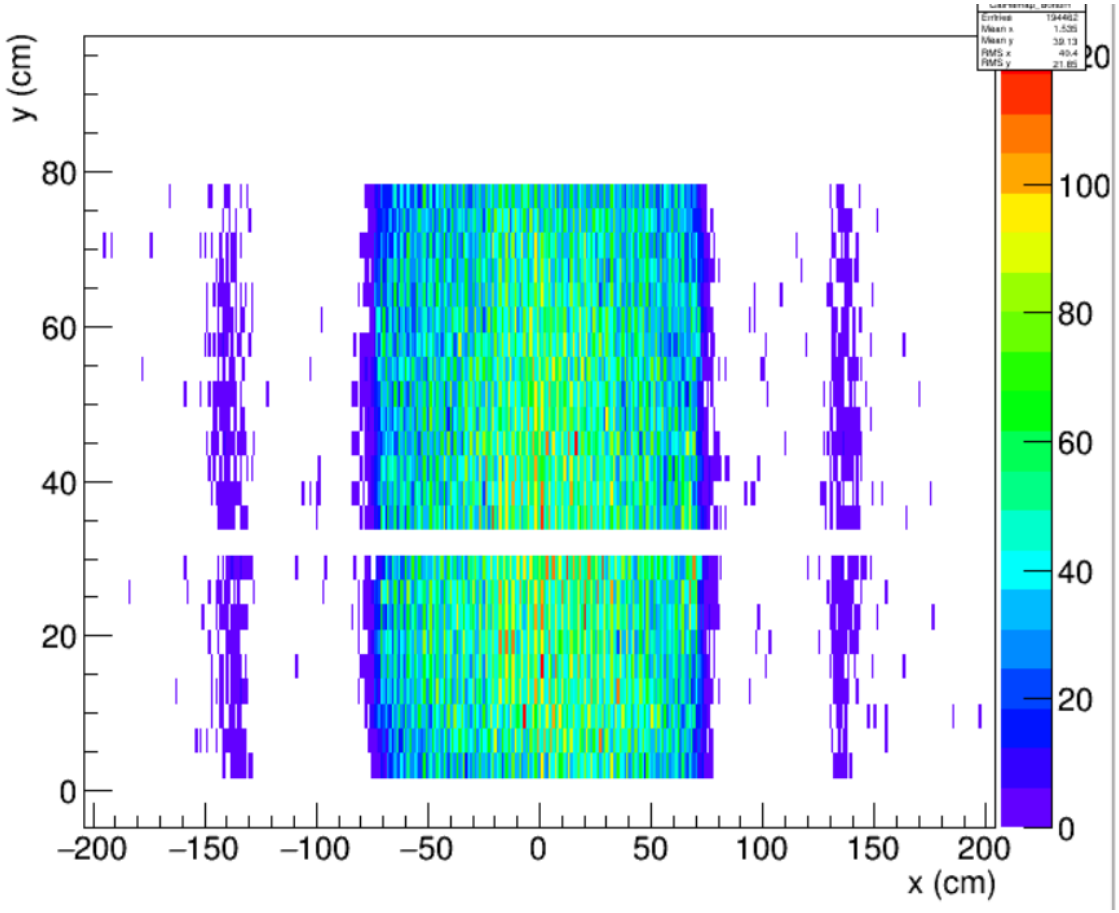
Investigation on hits outside chamber

Hits outside chamber edges

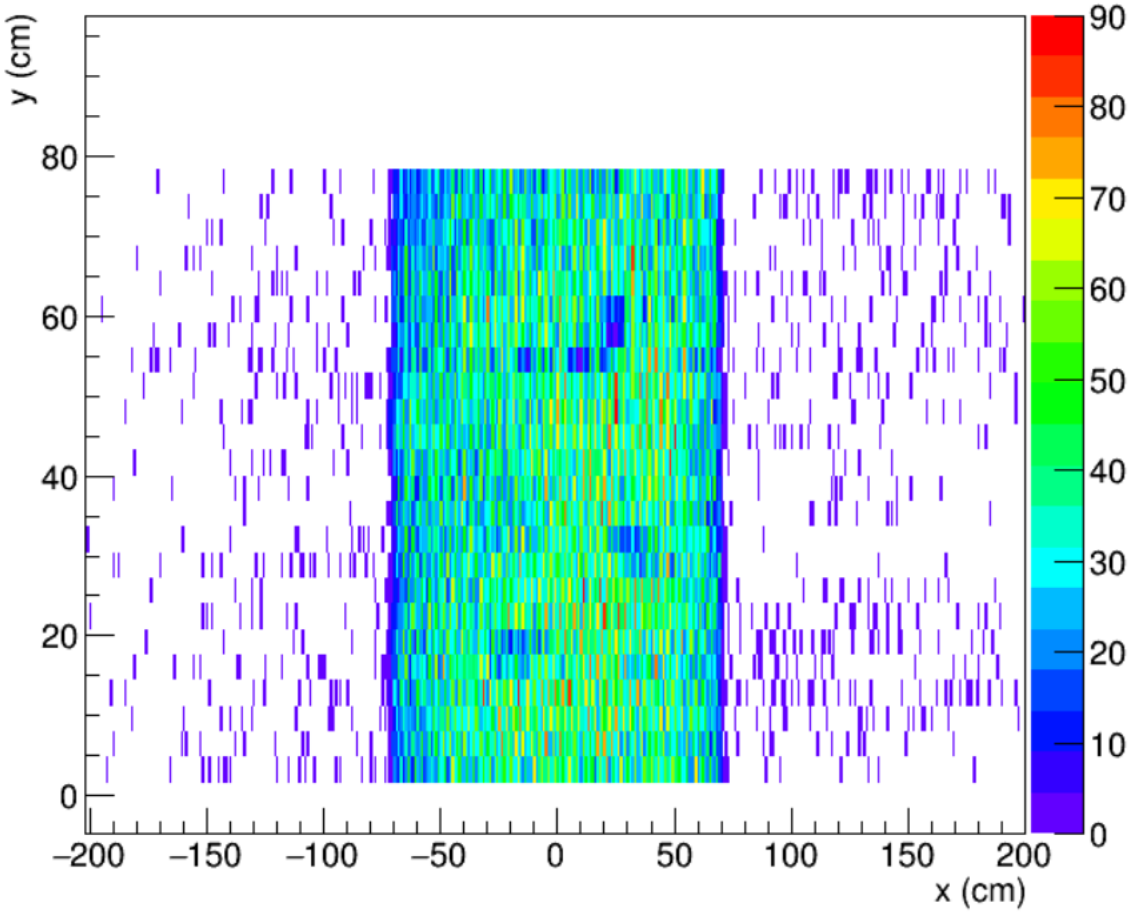
Extreme Energy Events
Science inside Schools

Already shown

PISA-01 Bottom camber, 50-50



PISA-01 Middle camber, std

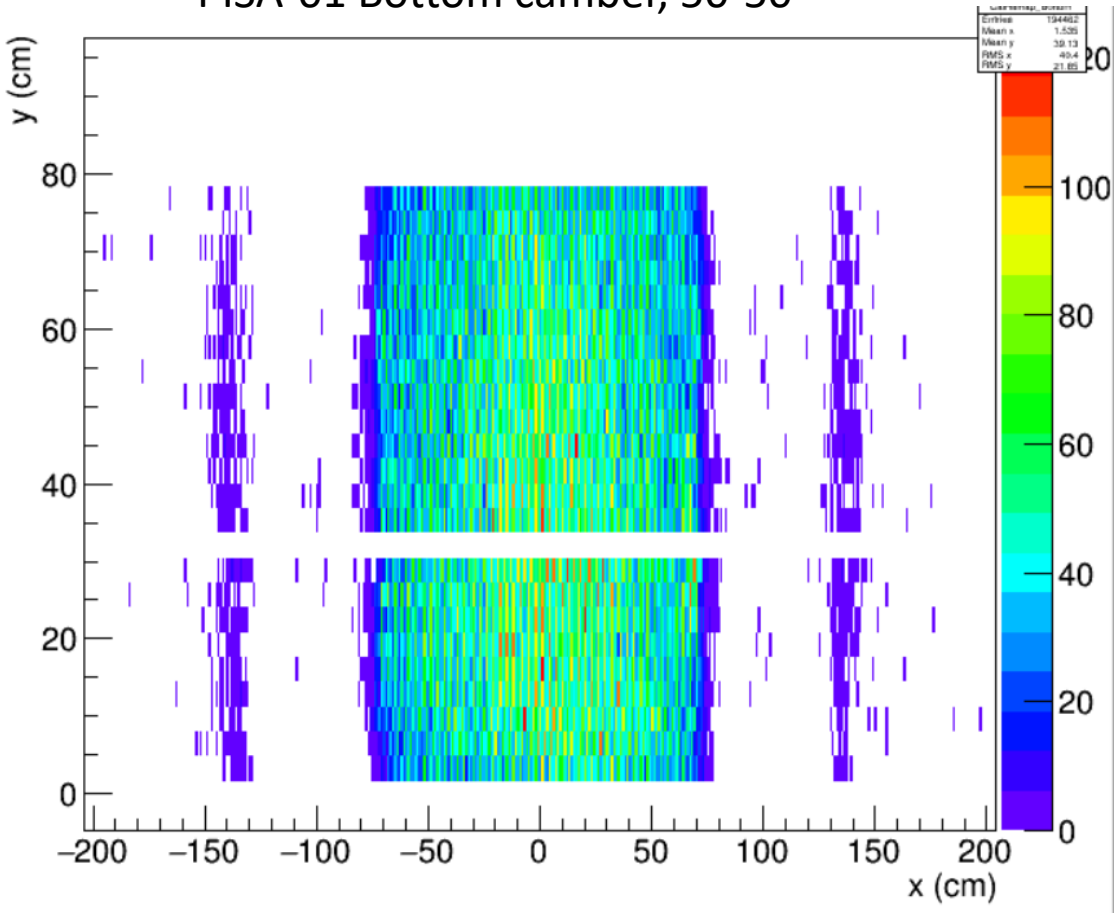


In test chamber, hits reconstructed outside active region of the chamber are accumulated in a well-defined area.
Reason still not clear. The peaks are at +-140cm Reflections on patch FE cards??

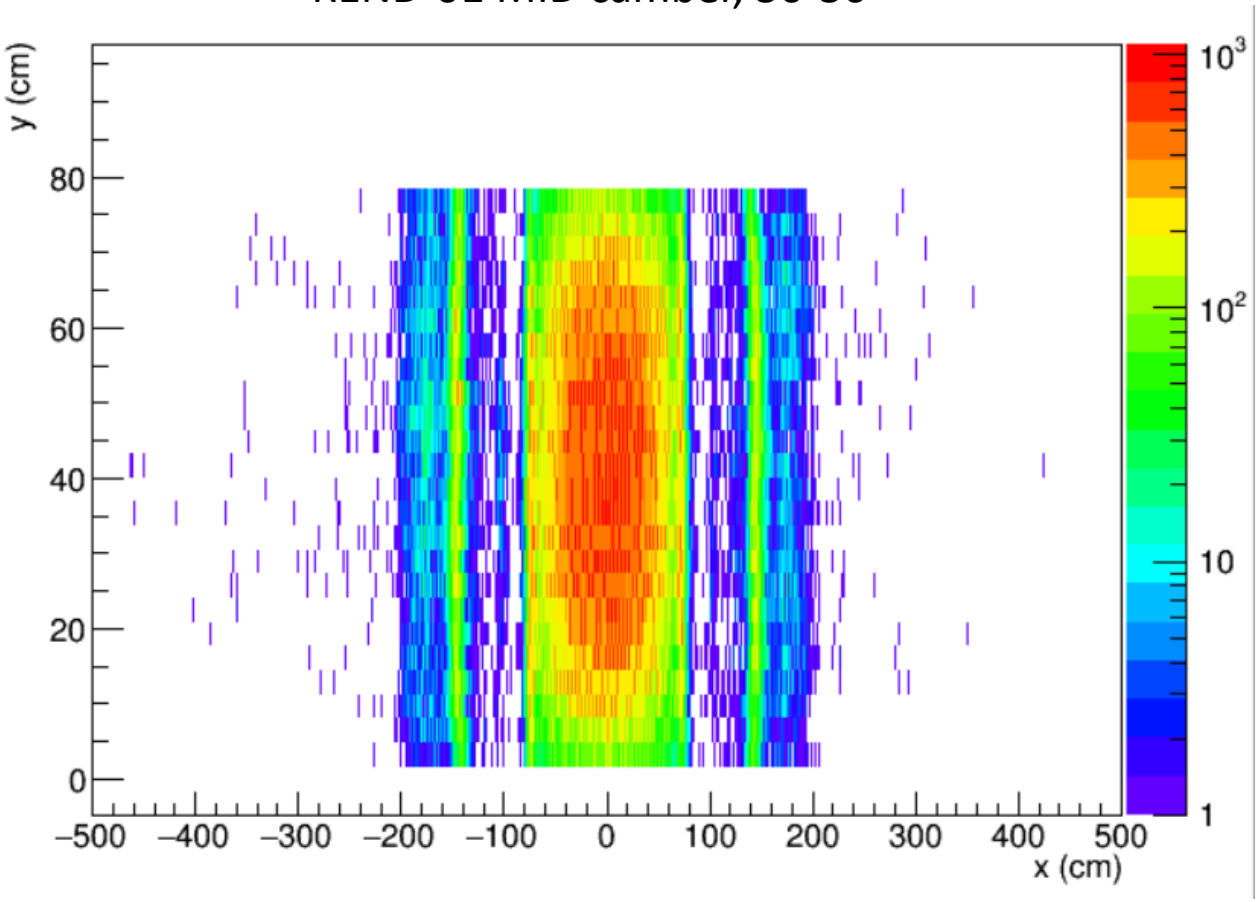
Hits outside chamber edges

Already shown

PISA-01 Bottom camber, 50-50



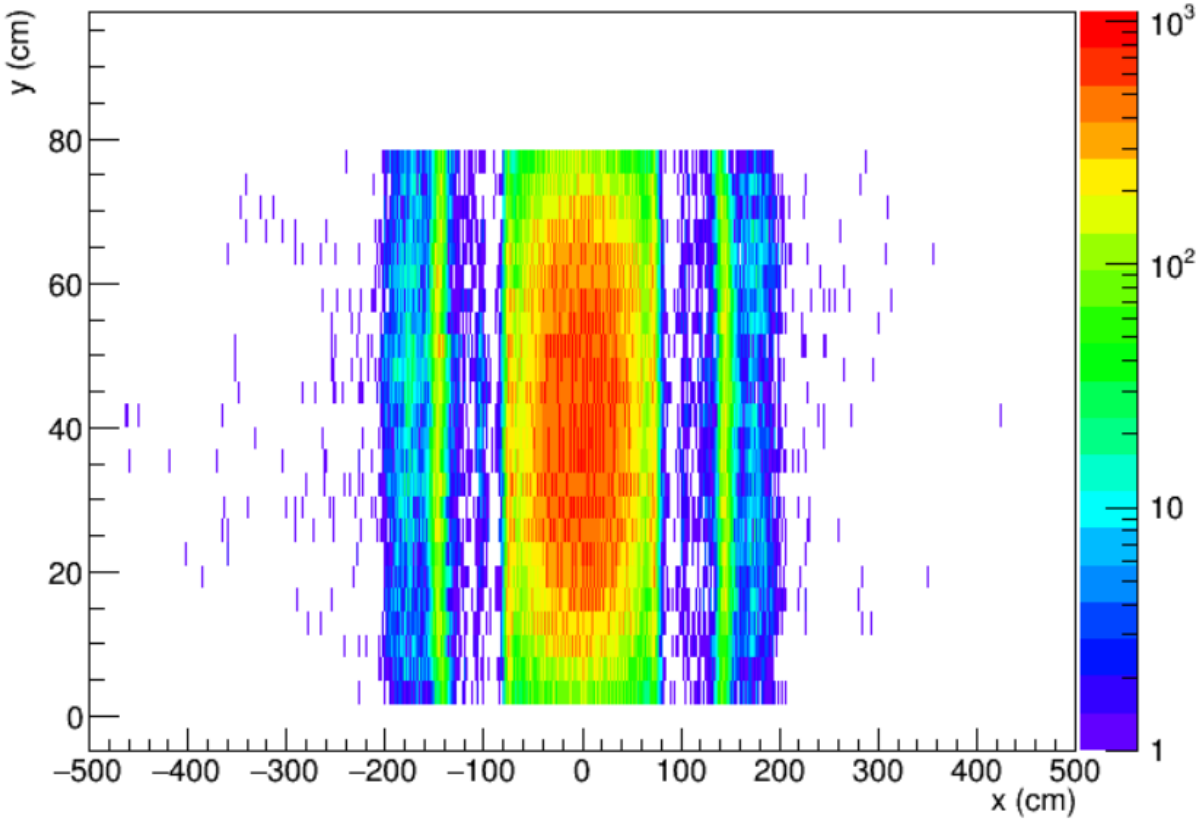
REND-01 MID camber, 50-50



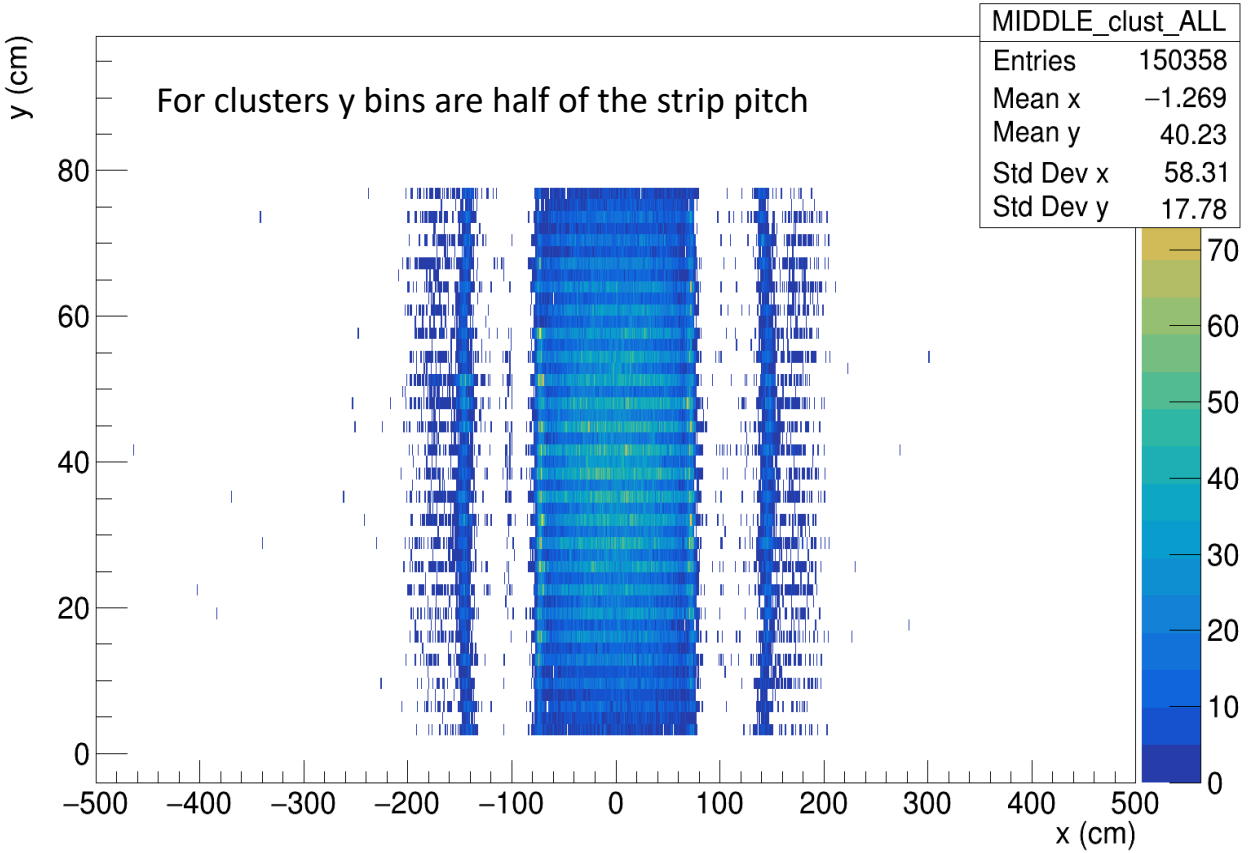
In test chamber, hits reconstructed outside active region of the chamber are accumulated in a well-defined area.
Reason still not clear. The peaks are at +-140cm Reflections on patch FE cards??

Clusters outside chamber edges

REND-01 MID camber, 50-50 - HITS



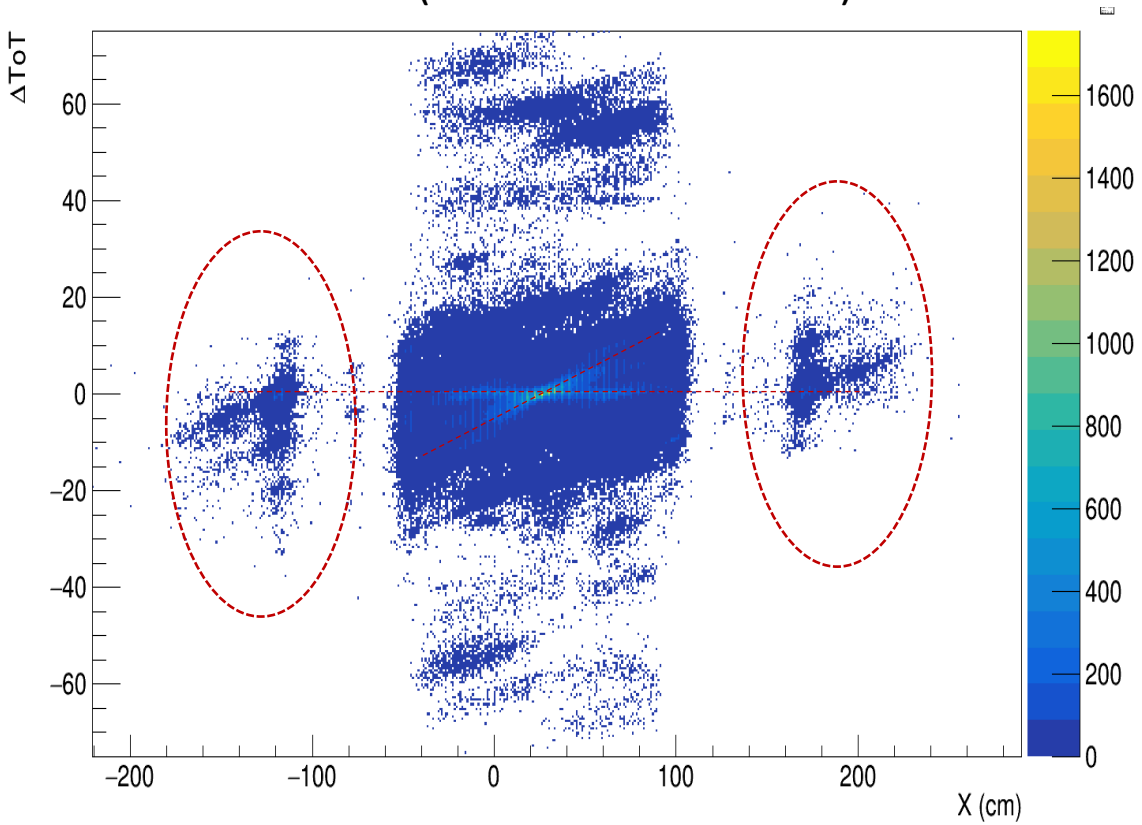
REND-01 MID camber, 50-50 - CLUSTERS



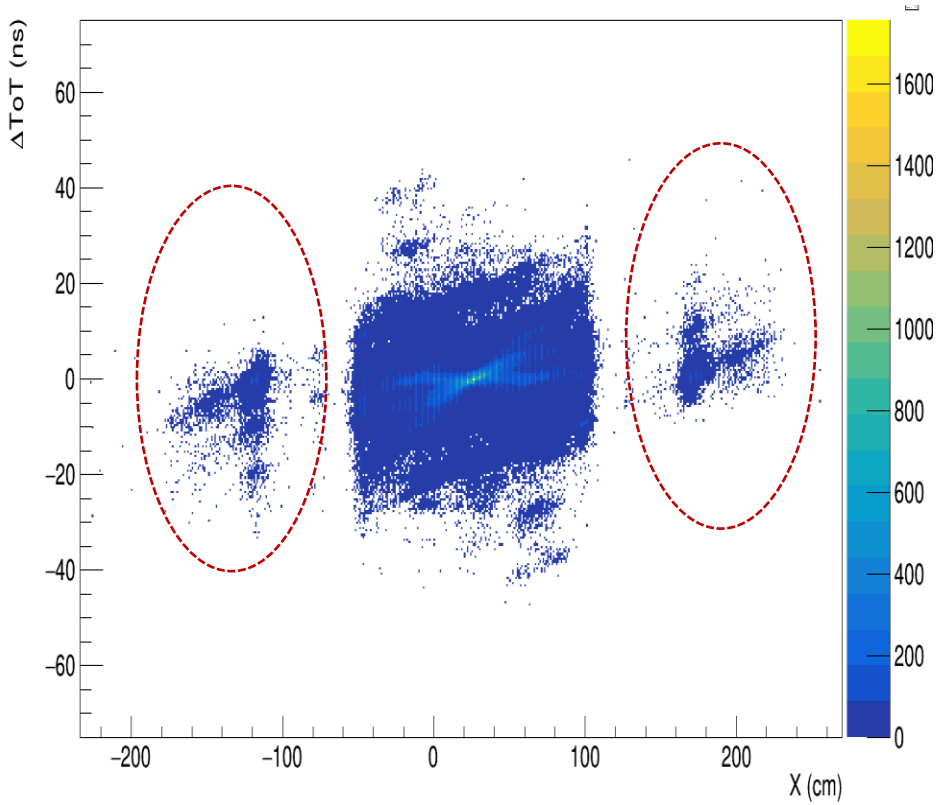
Same effect visible in the Cluster distribution

Correlation X-DeltaToT

REND-01 MID camber, 50-50
All hits (at least one valid ToT)



REND-01 MID camber, 50-50
hits with valid ToT on both sides



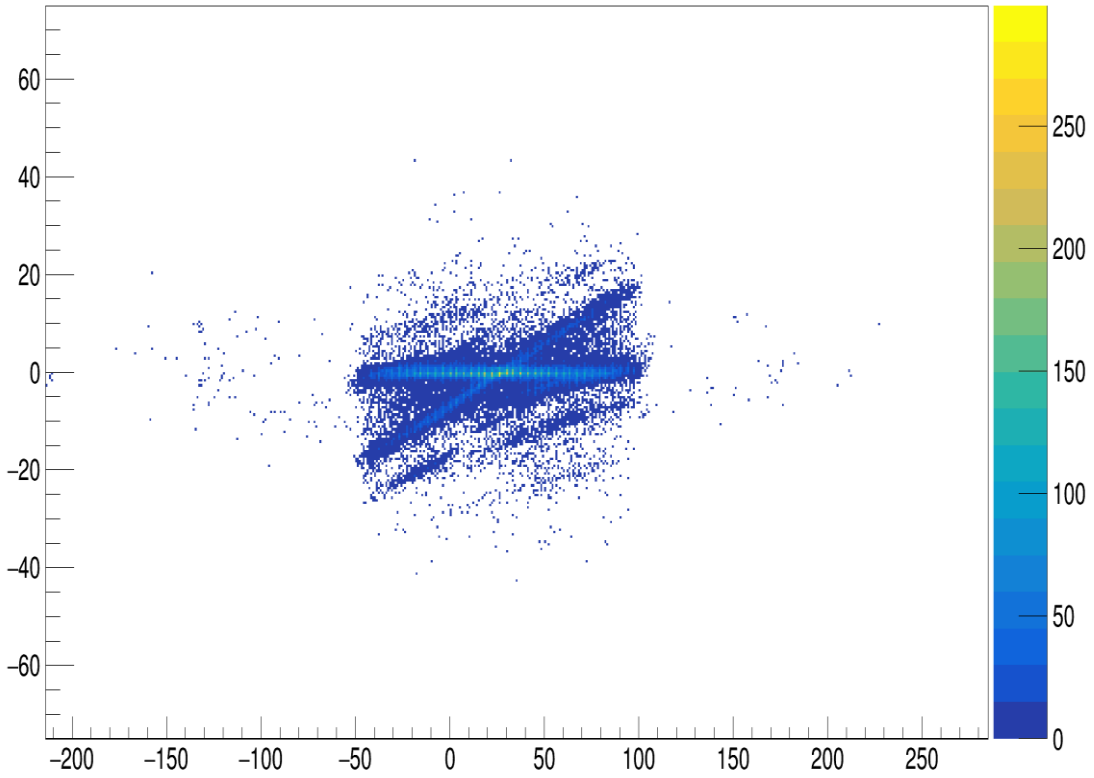
We can detect two population (at least!) in the central region:

- uncorrelated to X position
- Linearly correlated with X postion

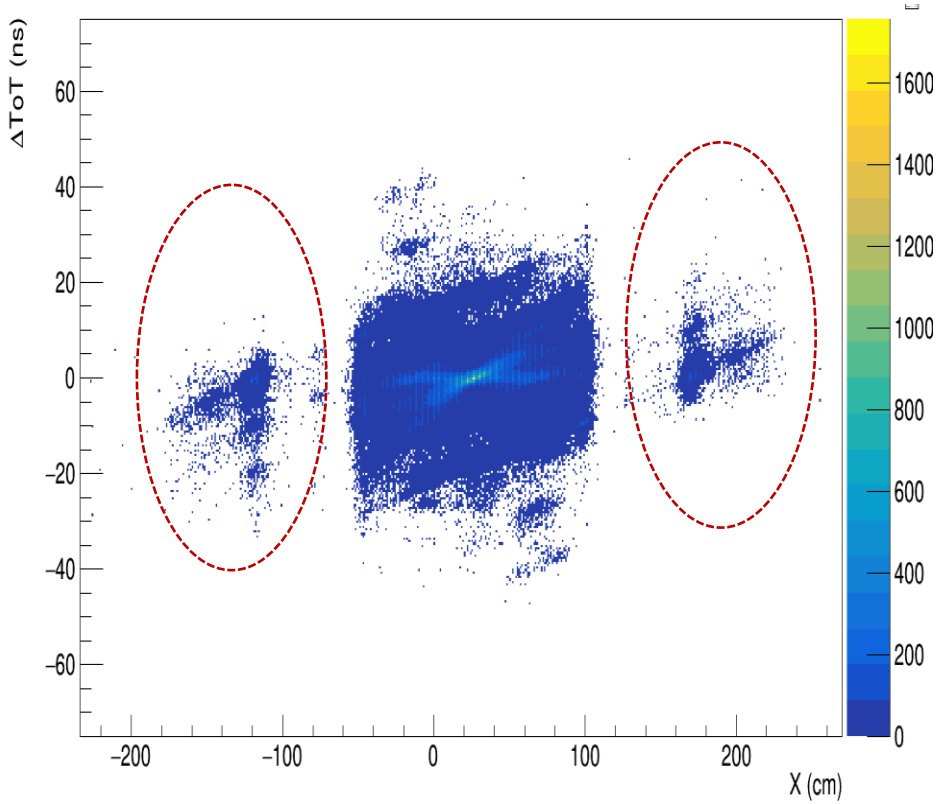
Hit peaks outside borders seems to be part of the uncorrelated population

Correlation X-DeltaToT

REND-01 MID camber, Std
hits with valid ToT on both sides



REND-01 MID camber, 50-50
hits with valid ToT on both sides



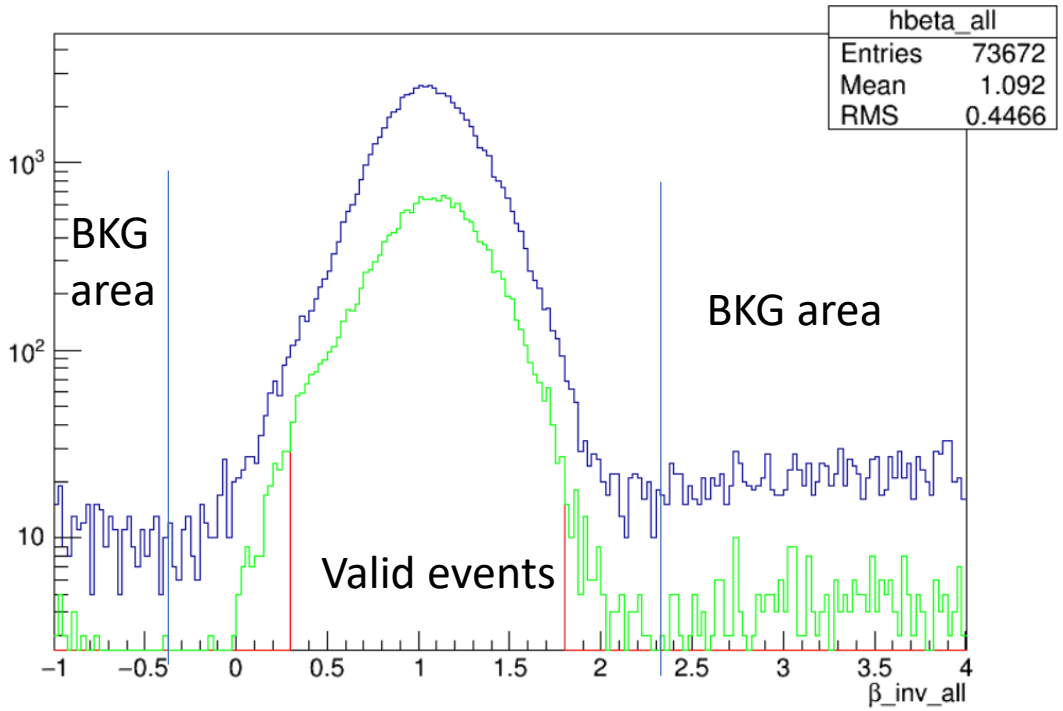
In the central region of the plot a similar beahviour is found with std mixtures. Further investigation ongoing…

Hit peaks outside borders seems to be part of the uncorrelated population

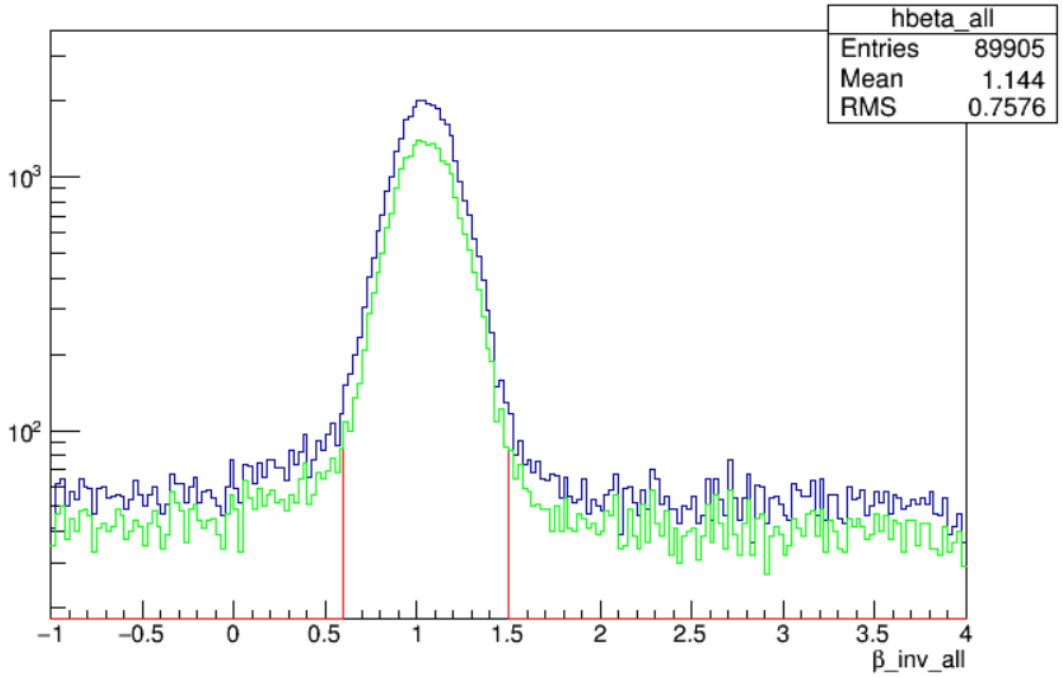
Update on efficiency and other parameters

Efficiency

PISA-01



REND-01



- All events with only one hit in triggering chambers
- After fiducial cut
- INV beta cut

- Wider distribution for PISA-01: top and middle chamber known to be not very good
- Non negligible background for REND-01

Corrections

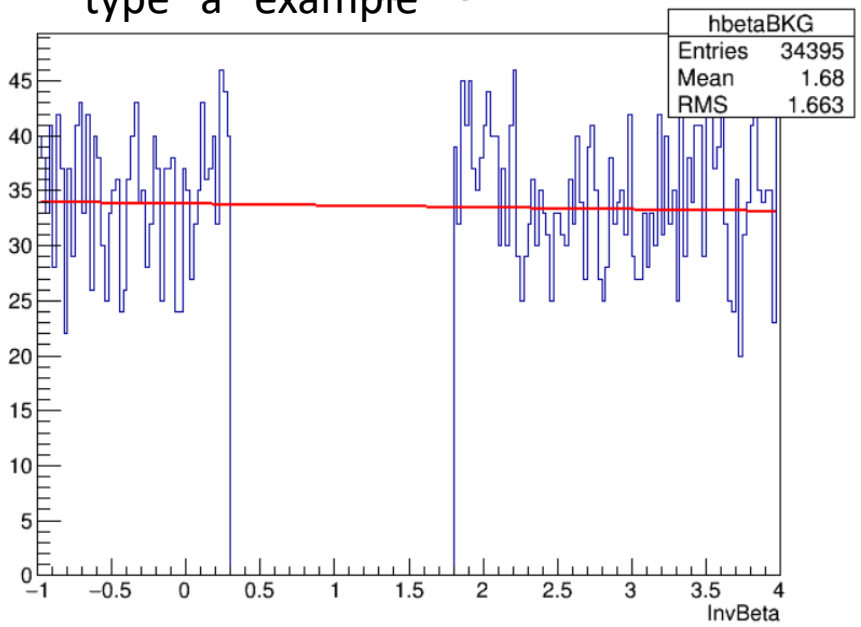
3 typologies of corrections considered:

a. selected event was generated by noise in triggering chambers, considered inefficient -> false negative
b. selected event was generated by noise in triggering chambers, matched in test chamber-> triple noise coincidence (considered negligible)
c. selected event is a real particle, matched in test chamber by a noise hit -> false positive

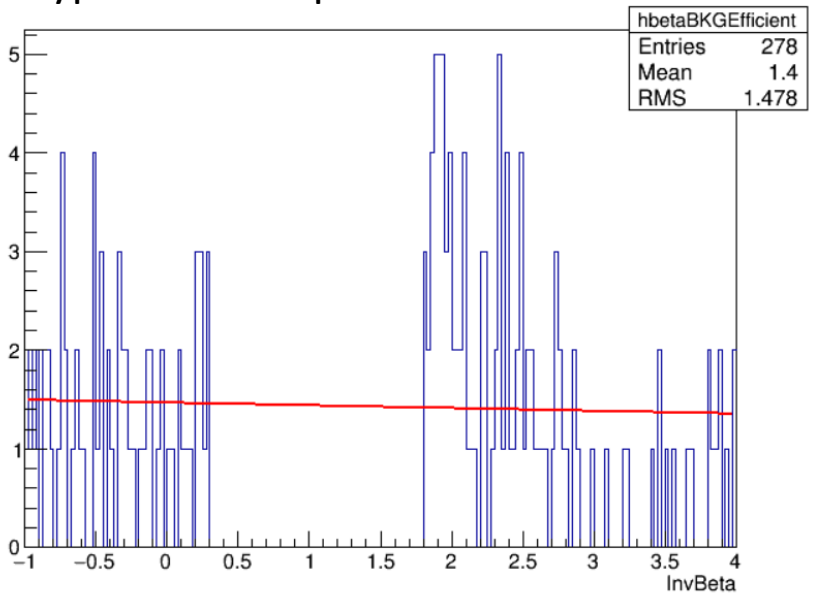
Correction can be performed by estimating the number of event for each category and modifying the numerator/denominator for the efficiency

a -> reduction of the denominator
b -> reduction of both numerator and denominator
c ->reduction of numerator

type “a” example



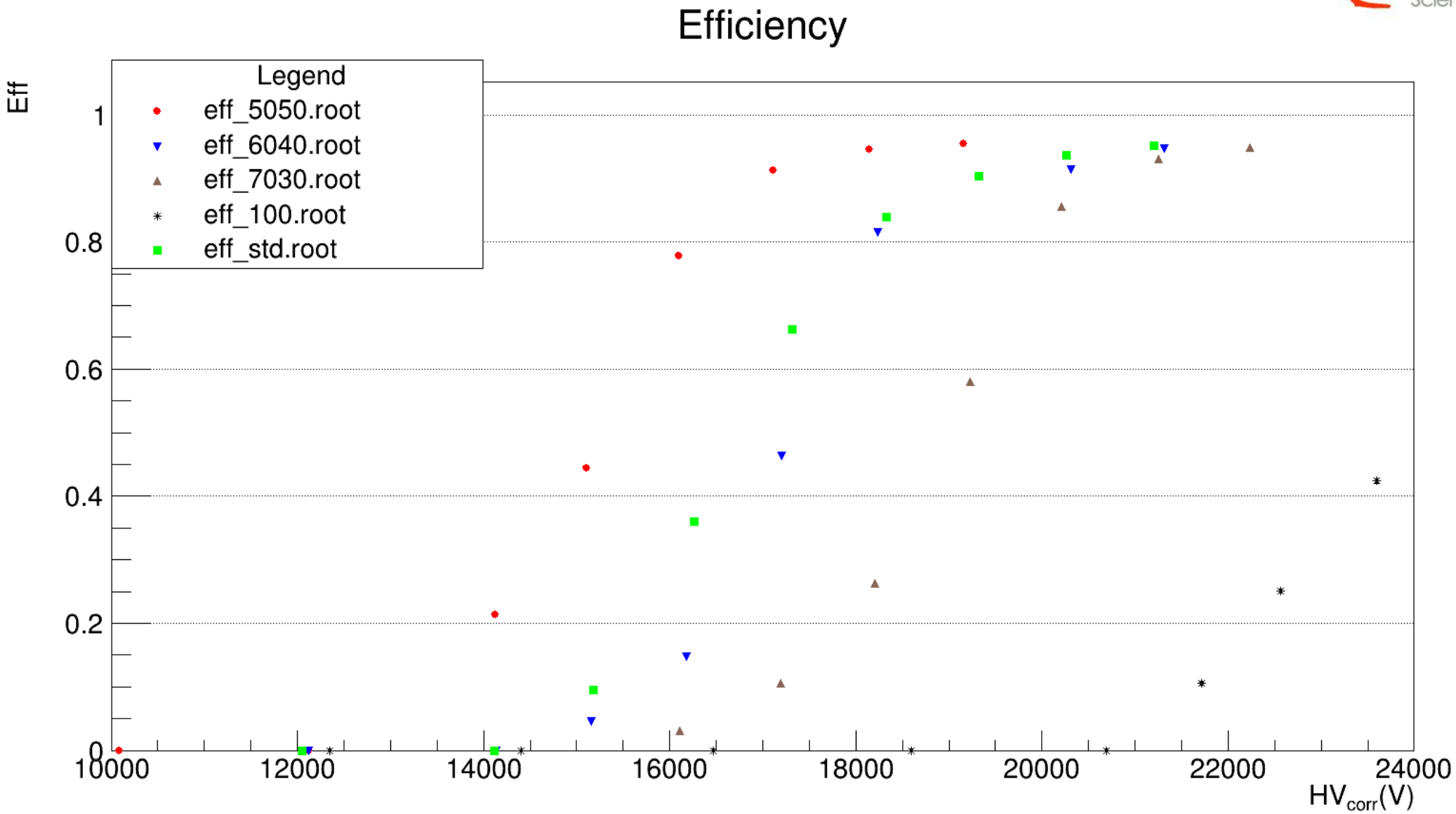
type “b” example



The corrections are computed by fitting the invbeta distribution in the BKG region and integrating the fitting function in the signal region.

- For REND-01 a positive relative correction of ~6% is found
- Type b correction are usually negligible

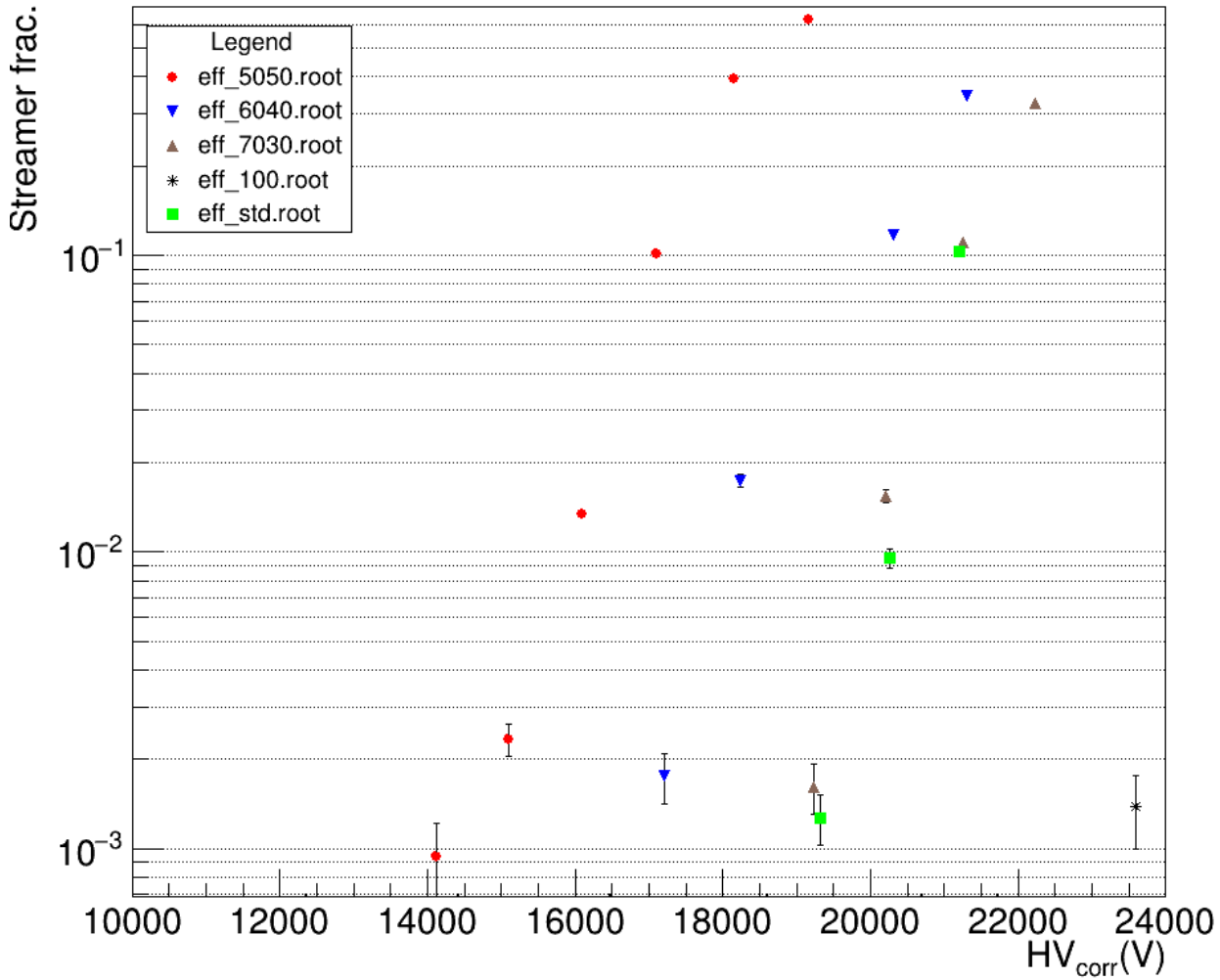
Efficiency


Efficiency
Legend
eff_5050.root
eff_6040.root
eff_7030.root
eff_100.root
eff_std.root
Eff
1
0.8
0.6
0.4
0.2
0
10000
12000
14000
16000
18000
20000
22000
24000
HV_corr(V)

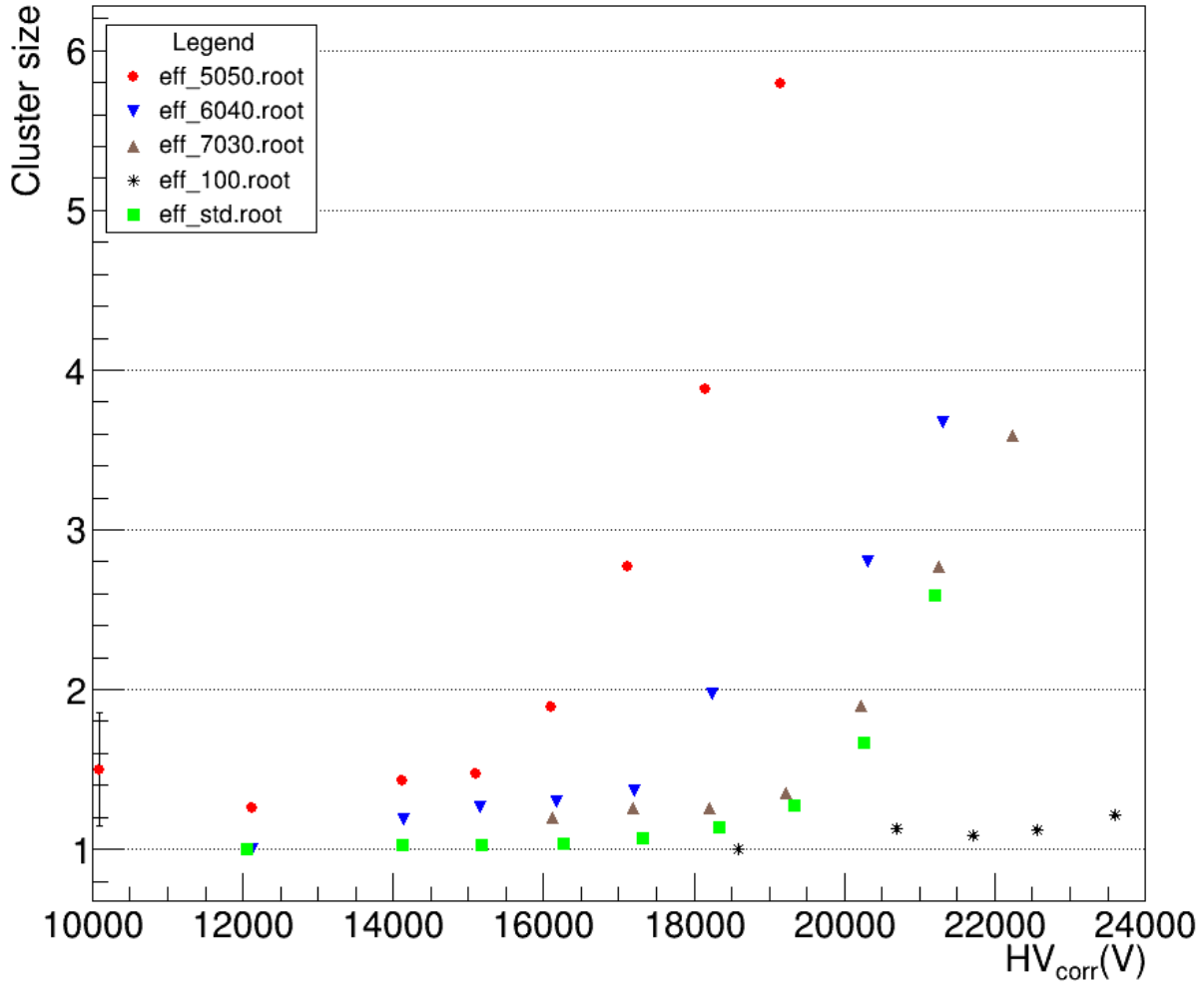
Efficiency

Extreme Energy Events
Science inside Schools

Streamer fraction

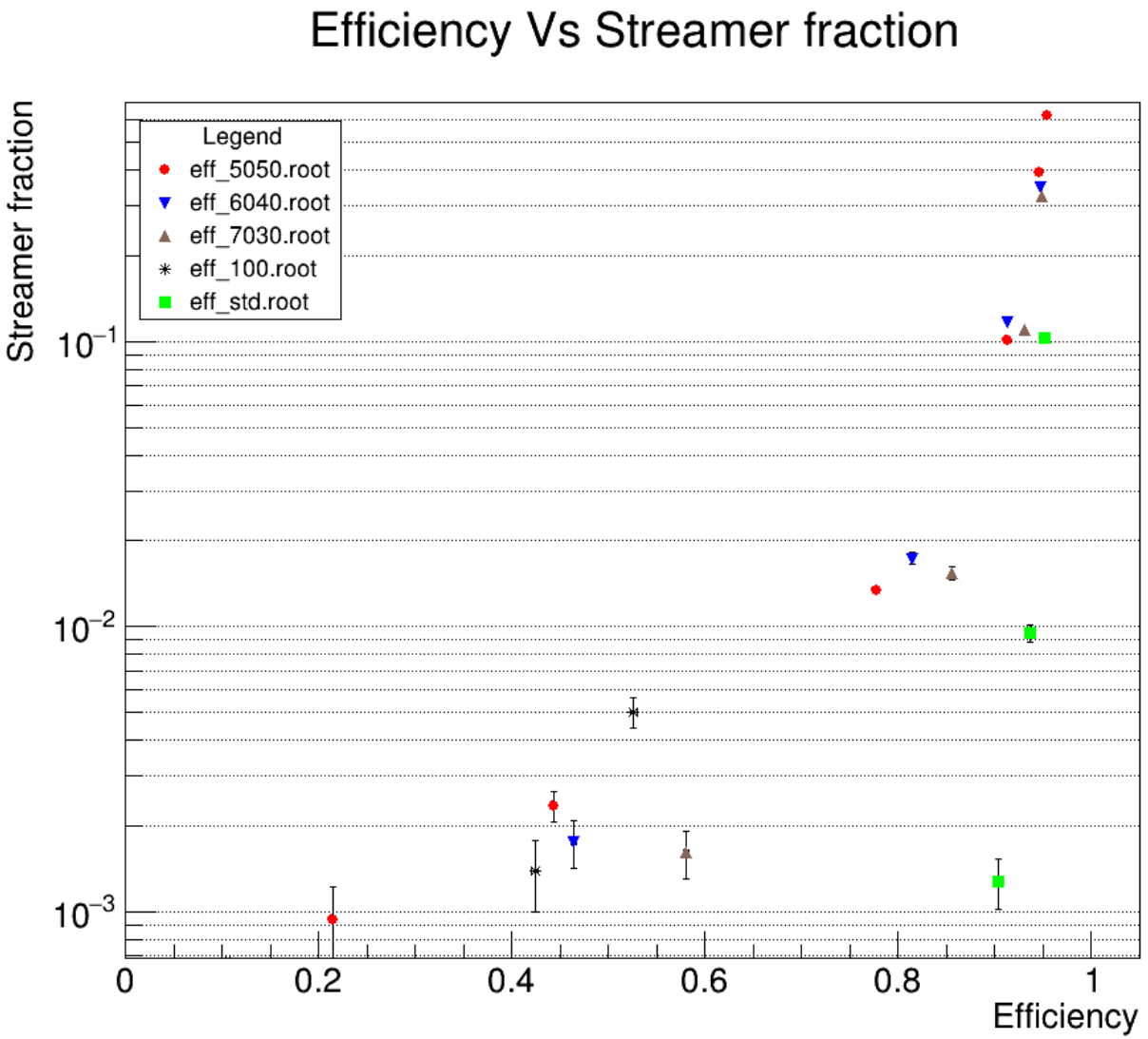


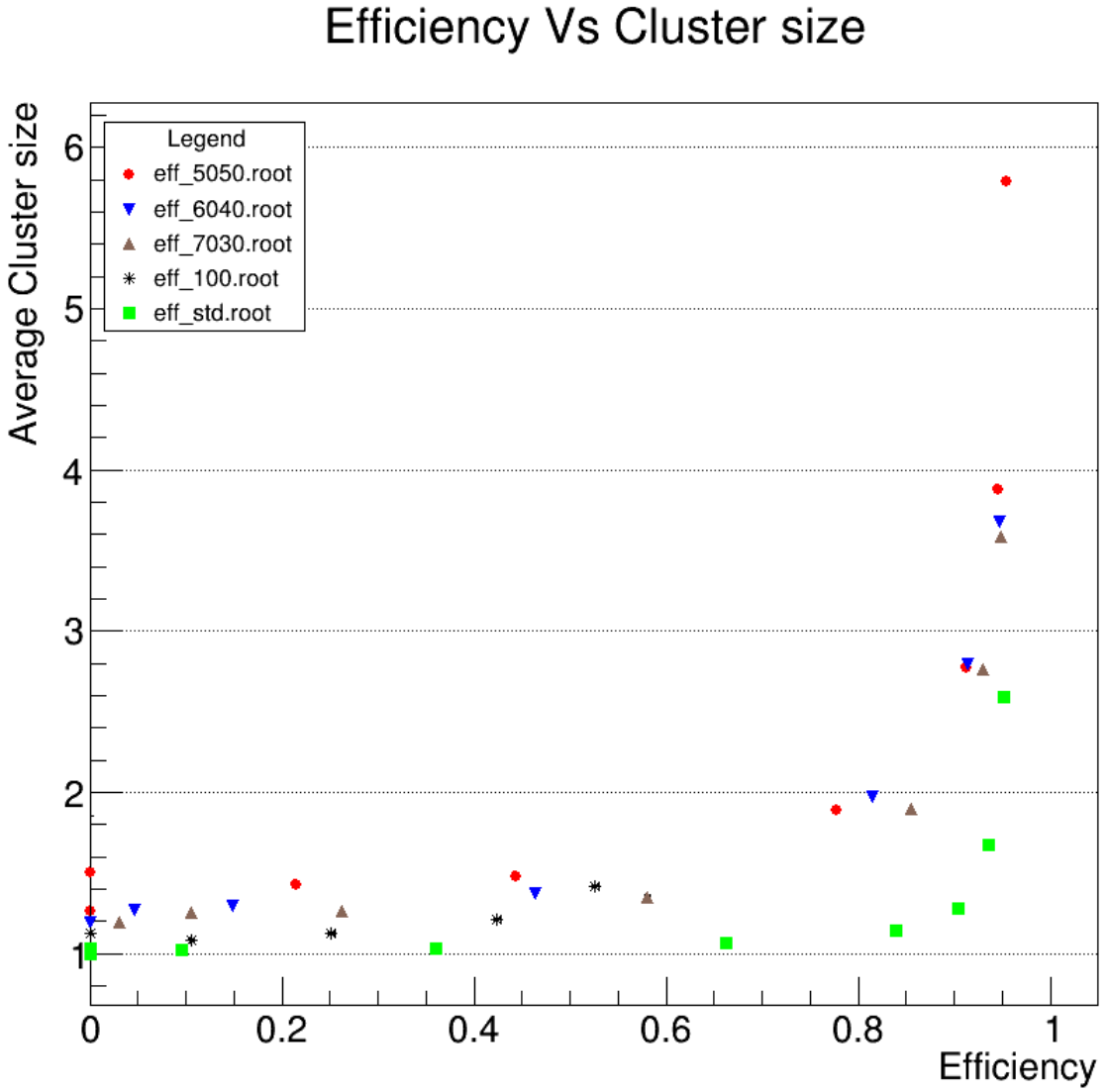
Cluster size



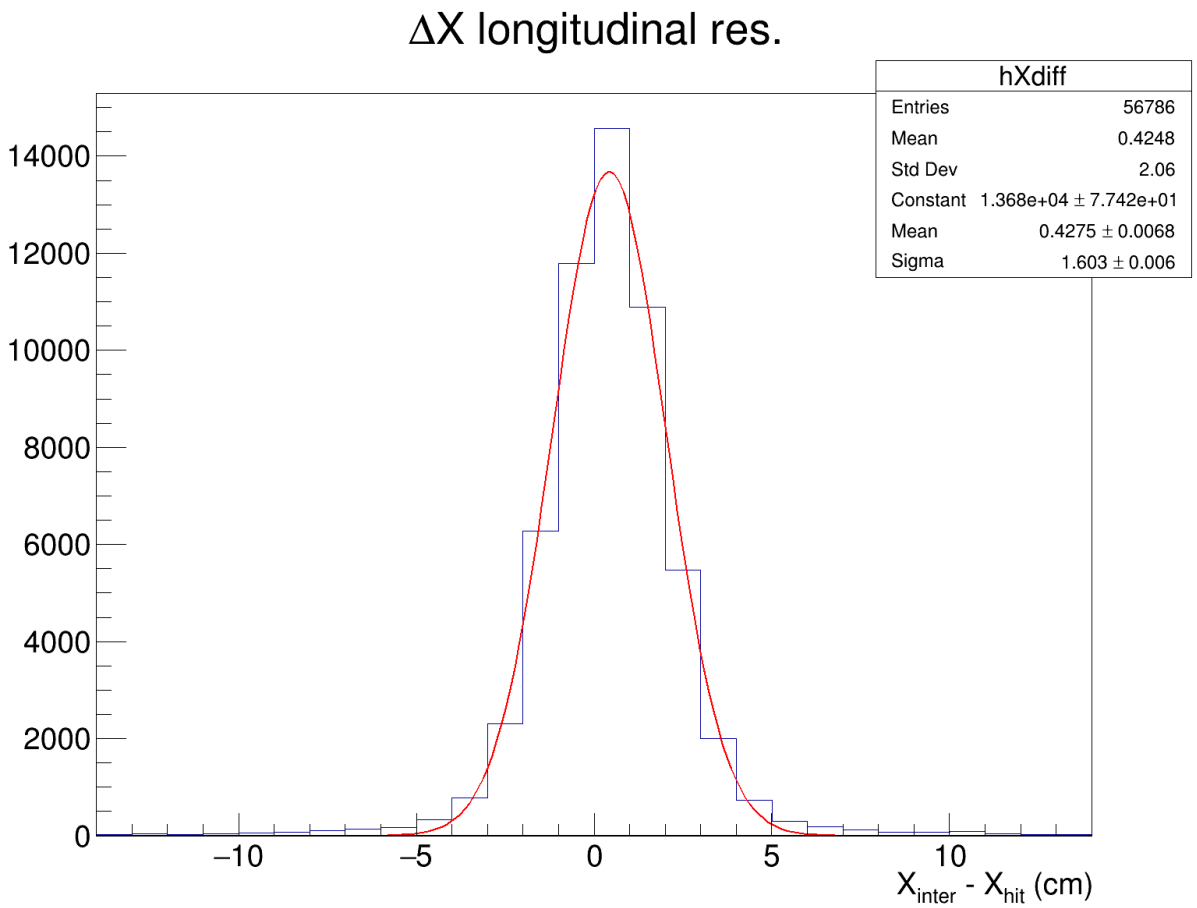
Efficiency

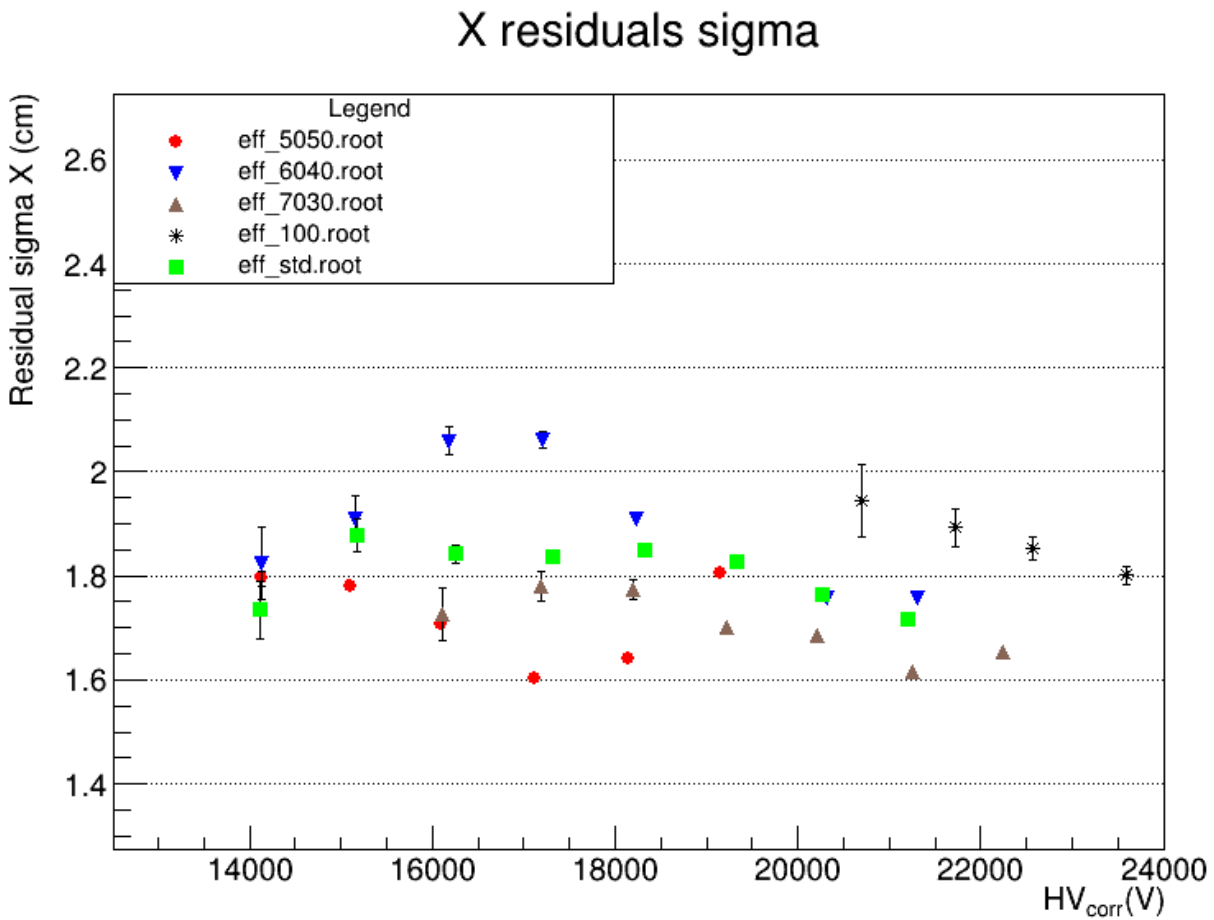
Extreme Energy Events
Science inside Schools





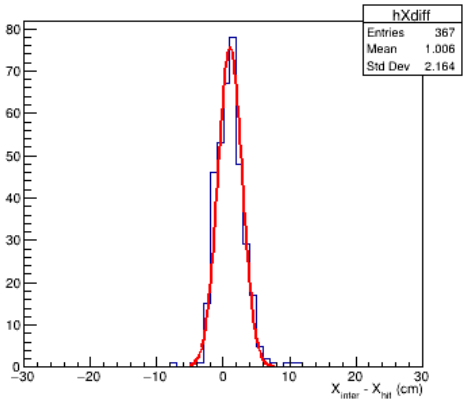
X Residuals

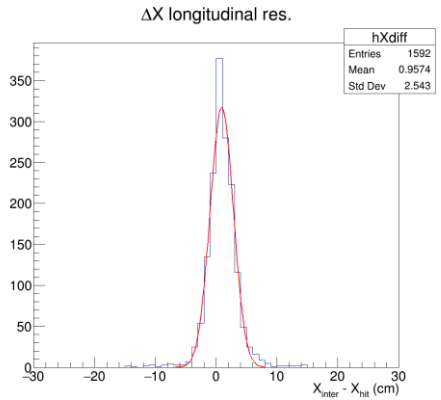


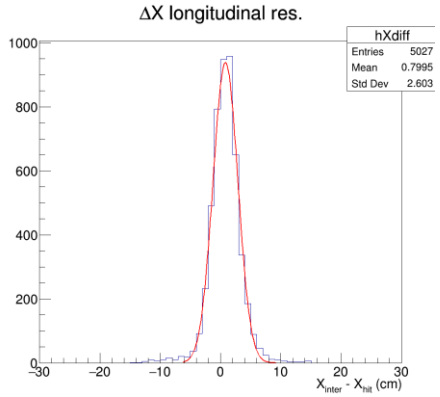


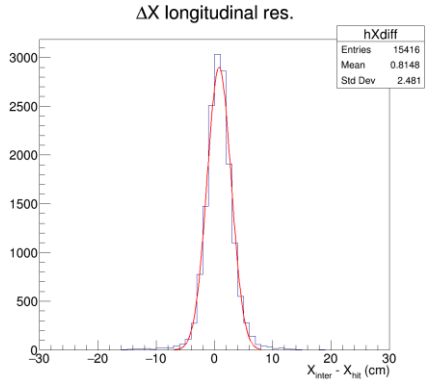
Remark: X postion is computed as a non-weighted average of all the hits of the cluster

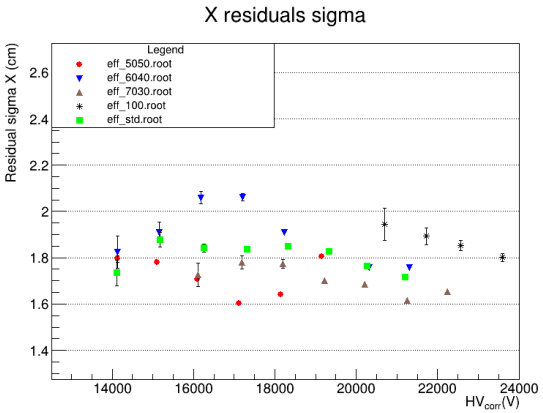
X Residuals – All 60/40 histos

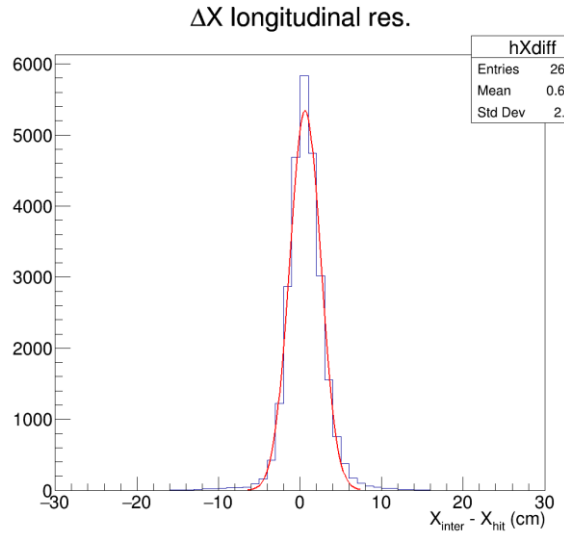


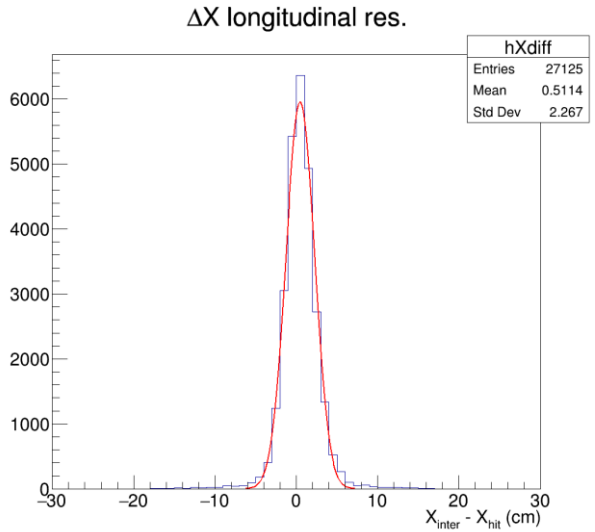


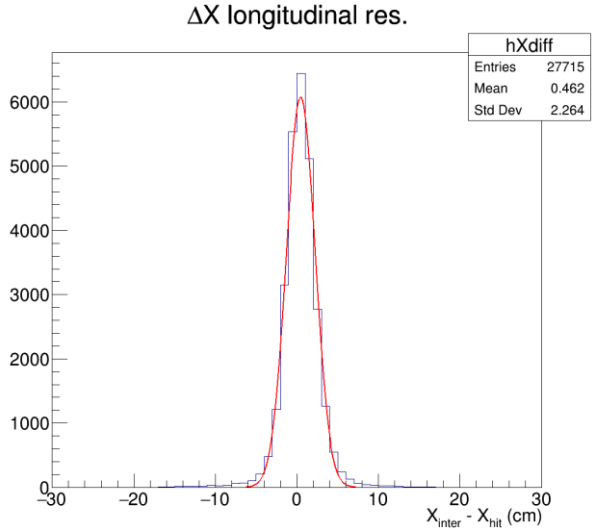








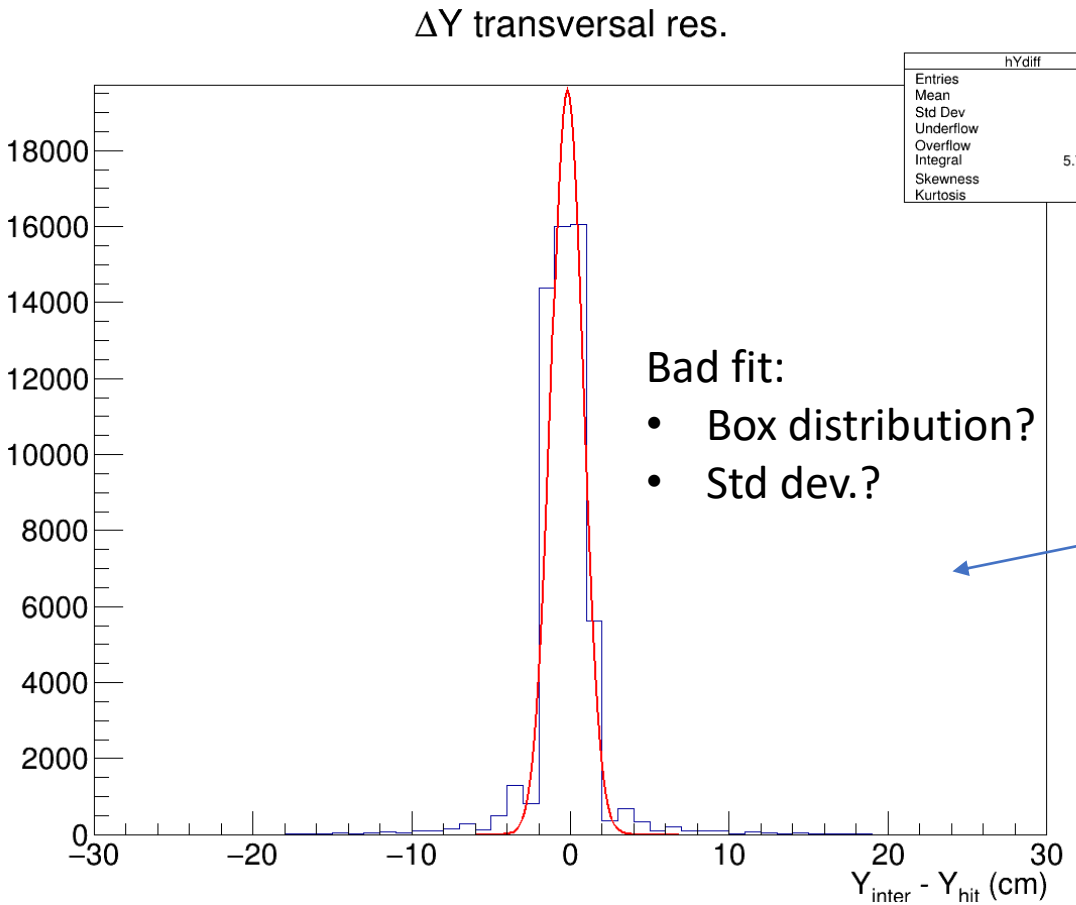




- Double gaussian?
- If yes, how to justify?

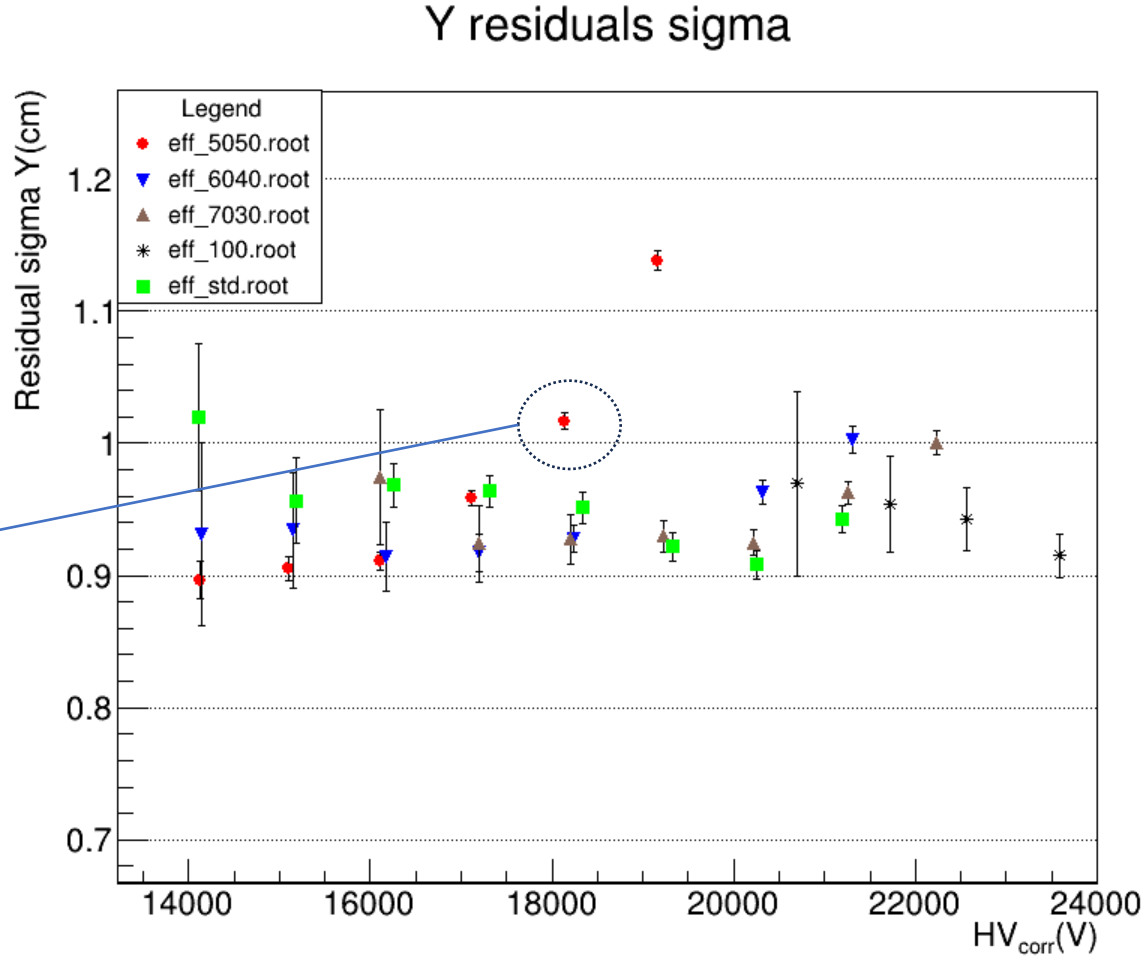
Y Residuals

Similar shape for all measurements



Bad fit:

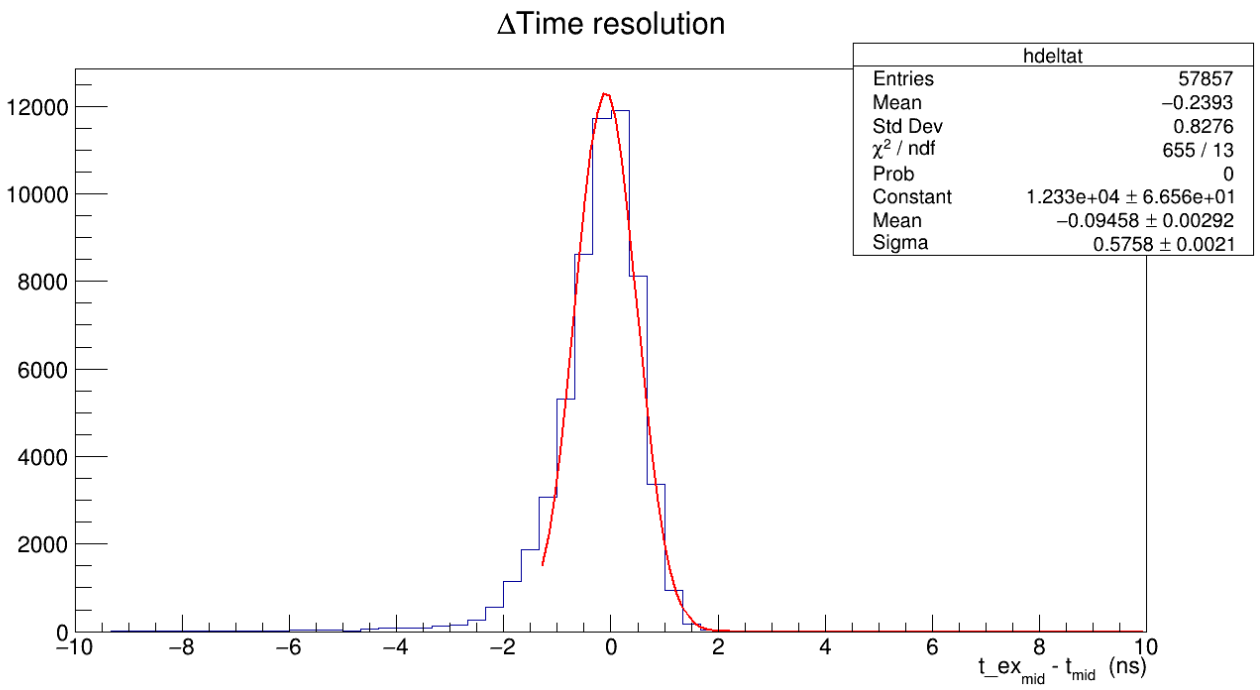
- Box distribution?
- Std dev.?



Remark: y coordinate «suffer» of discretization

Preliminary Timing Studies

T Residuals – naïve approach

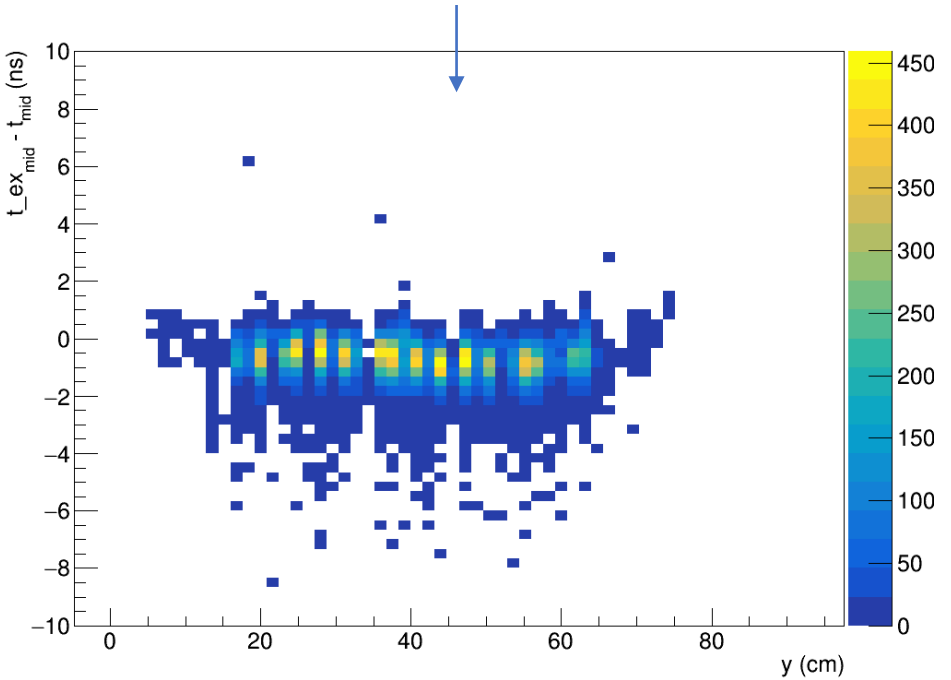


50/50 mixtures, 18kV (high efficiency)

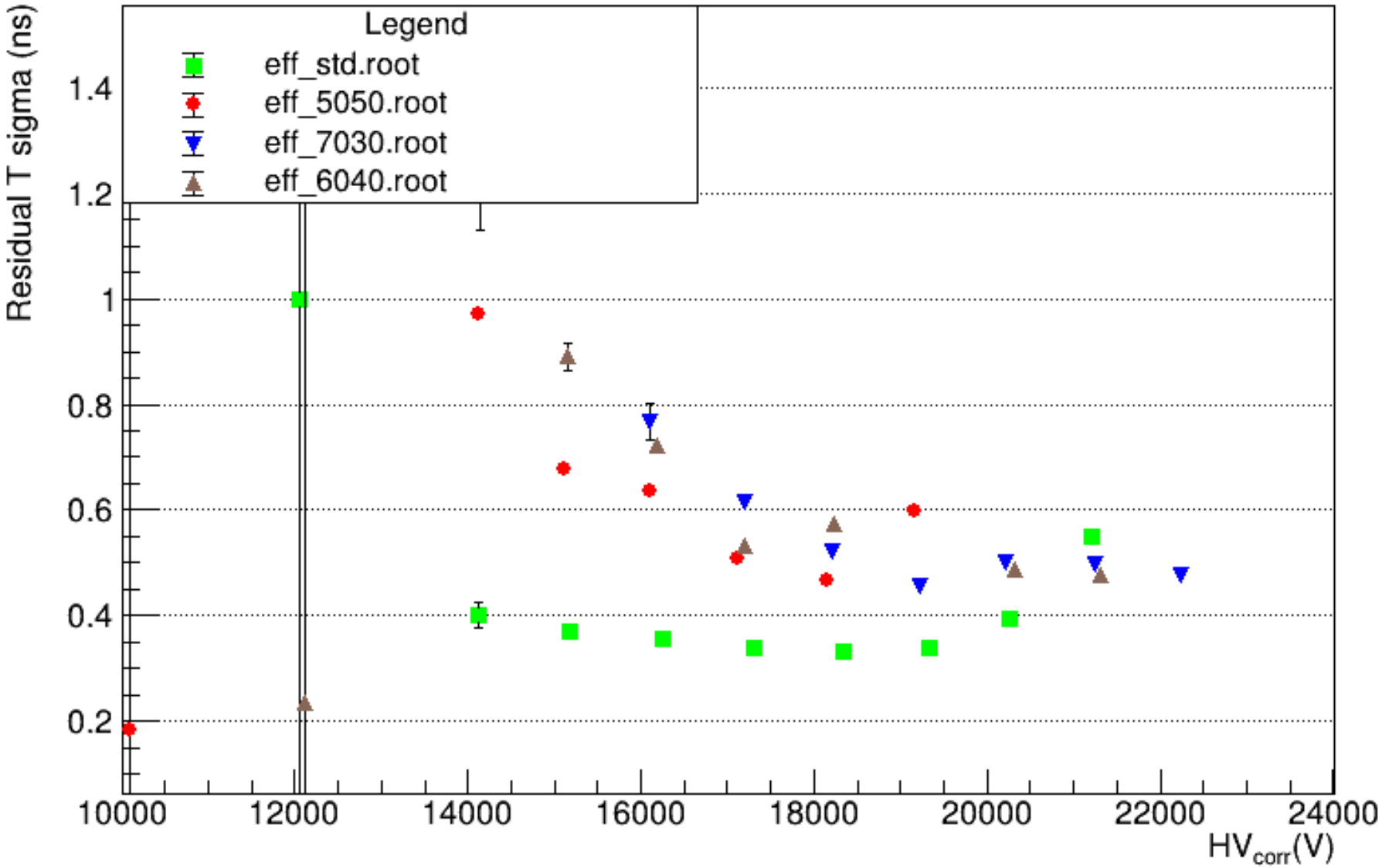
Residuals with Sigma~575 ps

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

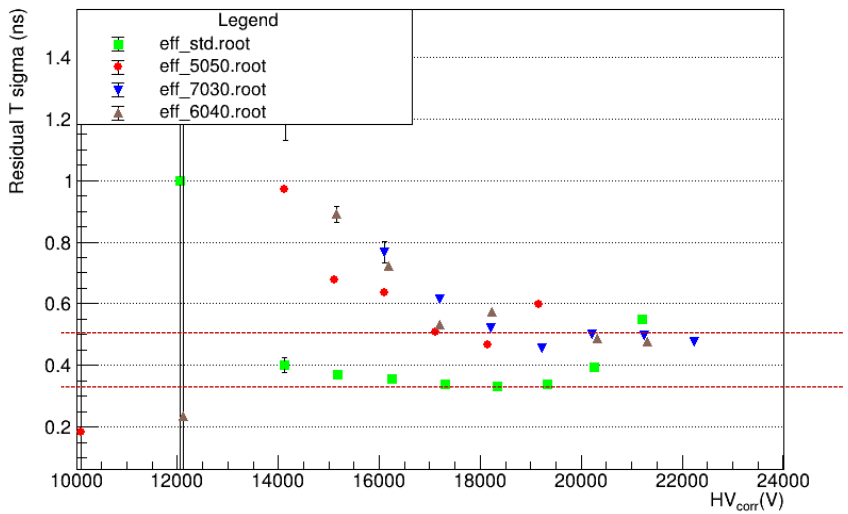
- T calibration only at the hit level (see old presentations) -> not enough precision, ~1ns

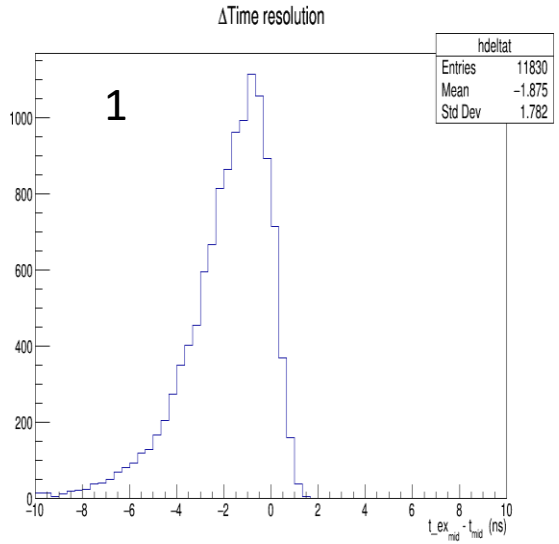


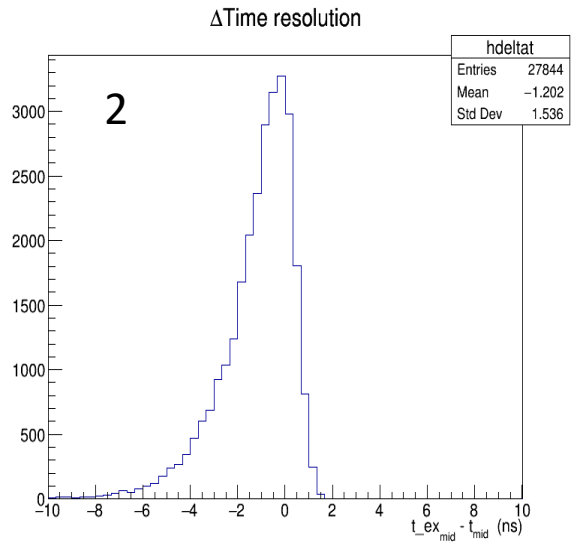
T Residuals – naïve approach

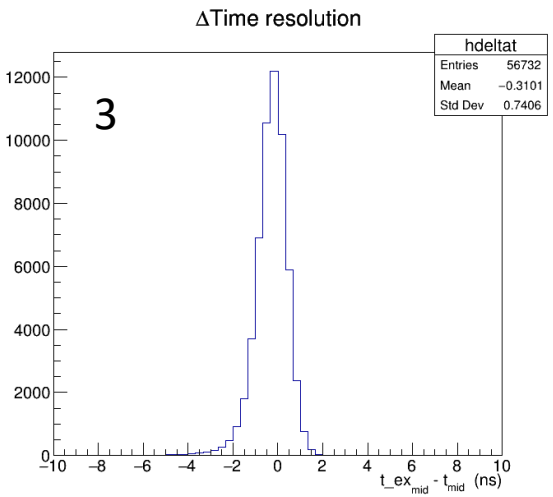


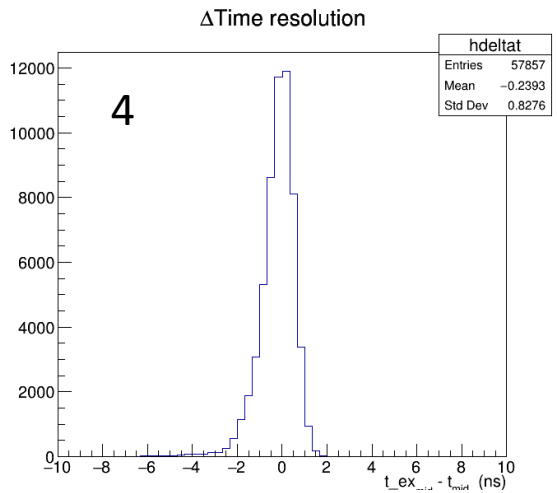
T Residuals – naïve approach

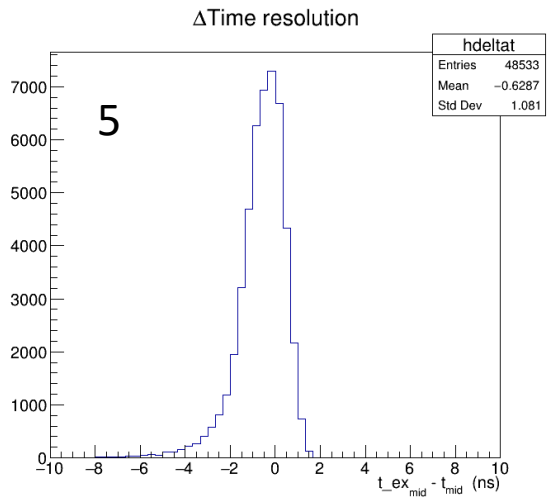


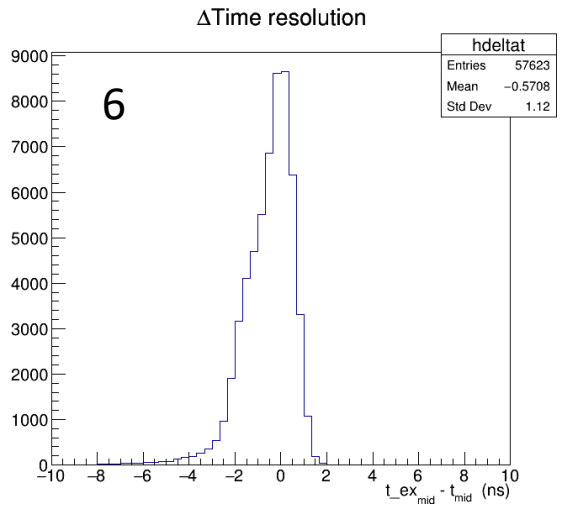










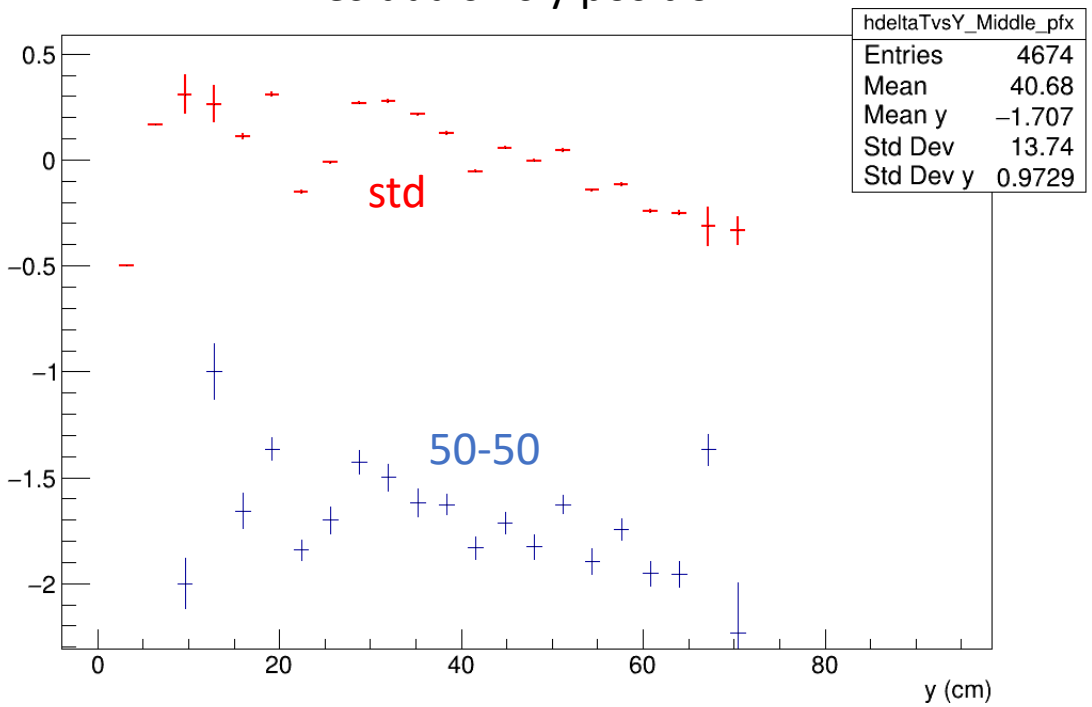


T Residuals – strategy

Strategy for better time computation, after several test:

- Compute the cluster time as the time of the hit with larger ToT -> 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

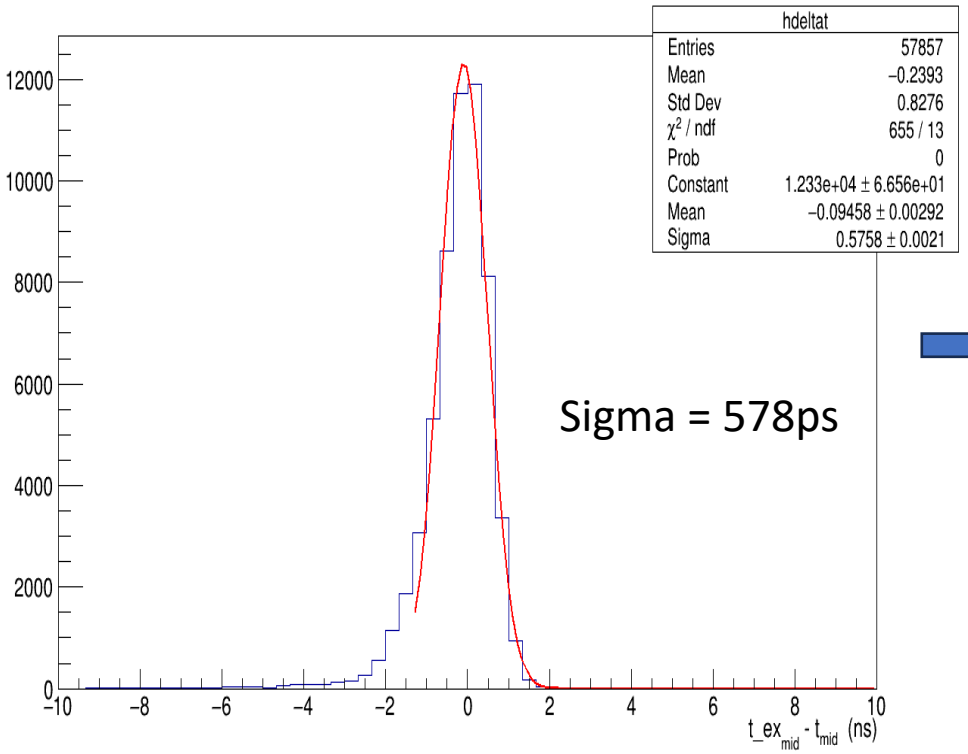


The same calibration has been used for all mixtures/HV extrapolated from the std mixture.

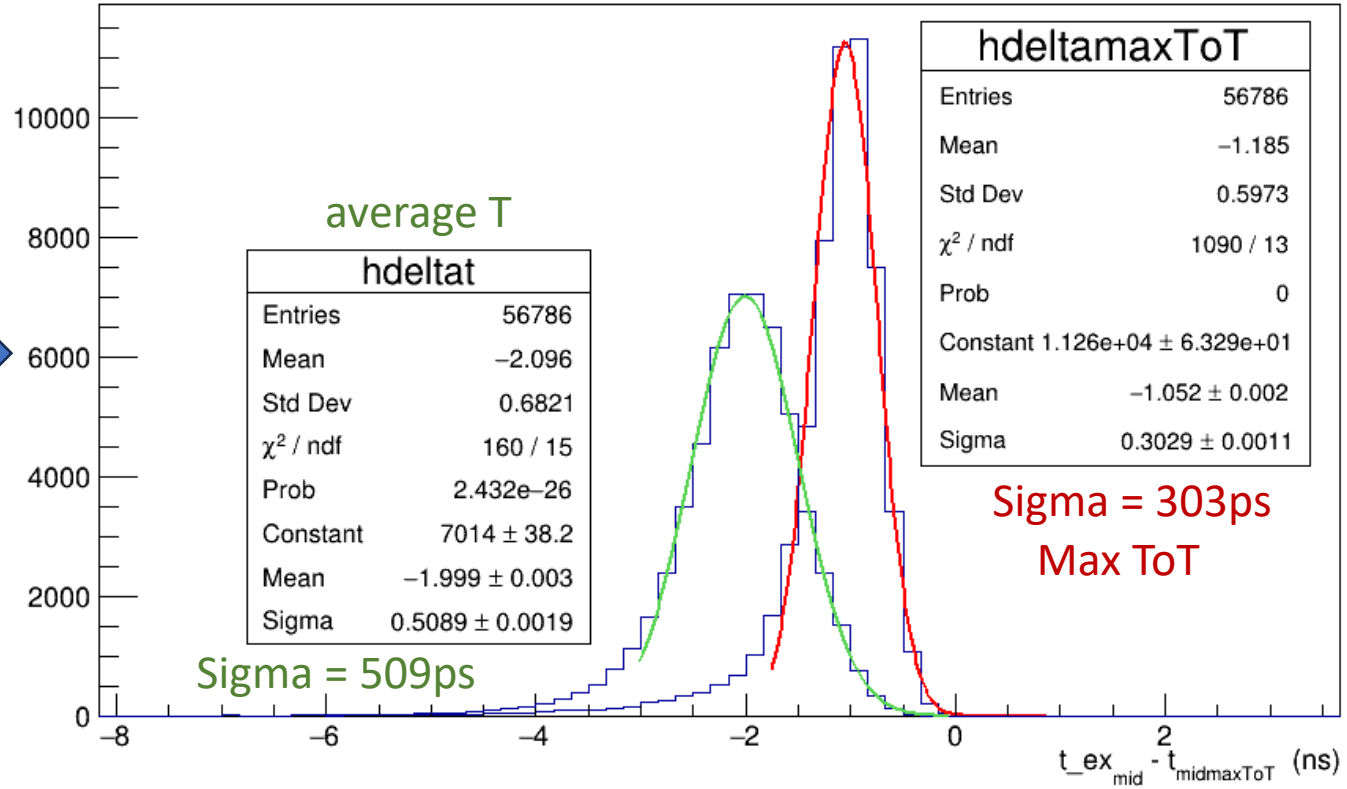
Can be refirned by doing a different calibration for each mixture

Calibration effect

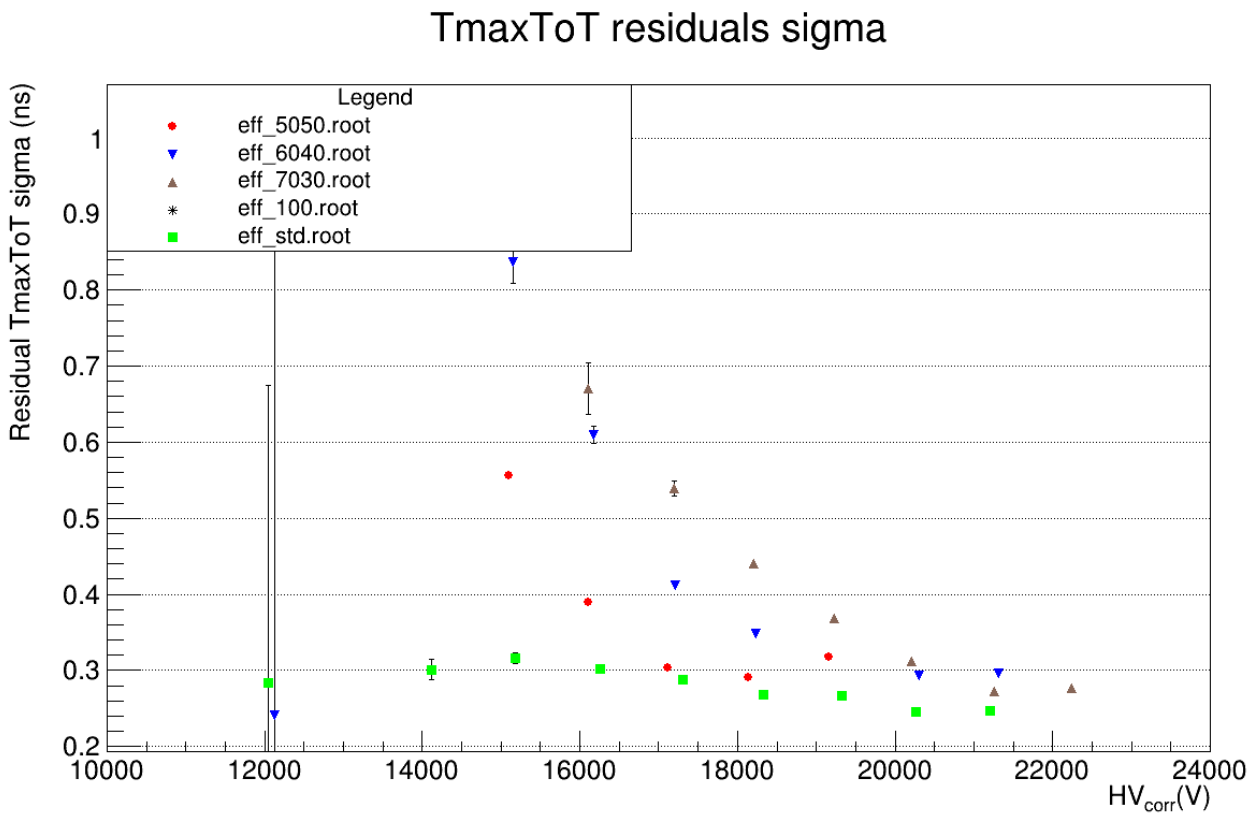
No calib, average T



Strip calibration

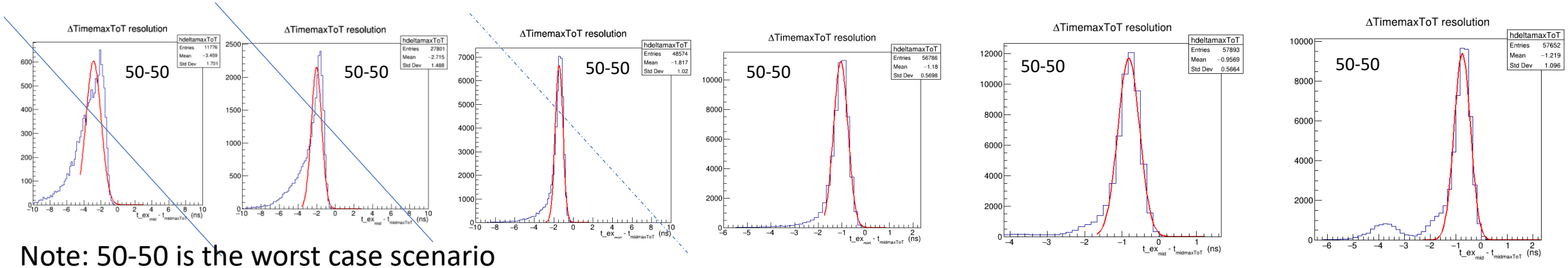


Calibration effect



Few remarks:

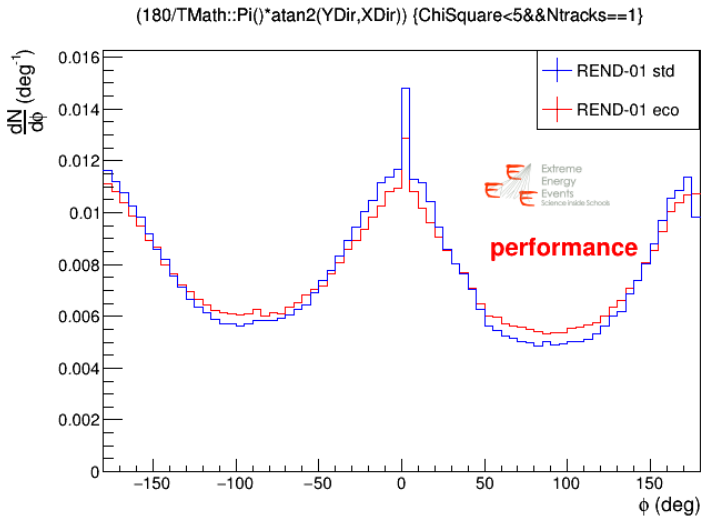
- This procedure is really different from what is currently implemented
- It is focused on the minimization of the middle chamber only. Quite «ad hoc» implementation.
- Still at large bias time precision degrade, in particular with large fractions of Helium. This is due to a residual corelation between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



Note: 50-50 is the worst case scenario

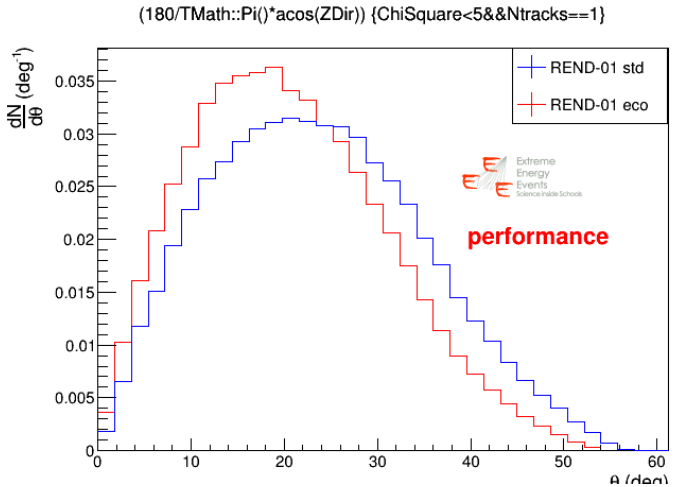
DQM distributions and stability

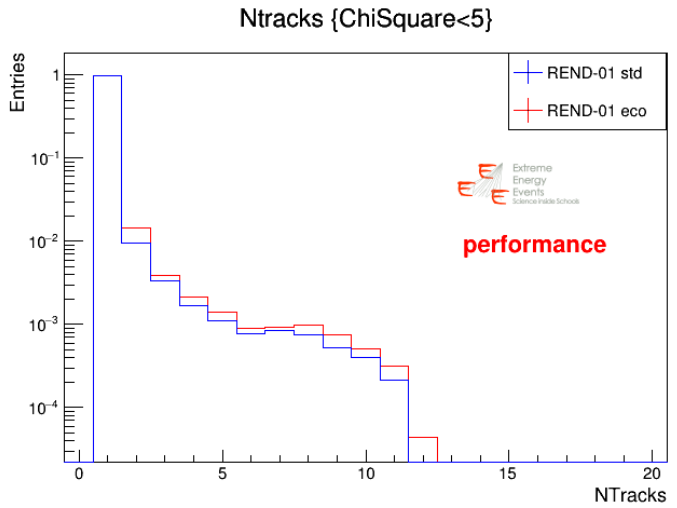
DQM distributions



Needs clear explanation of the differences:

- Theta distribution completely changed. Different interdistance?
- Phi Distribution less asimmetric (linked to theta?)
- Higher track multiplicity -> likely an artifact induced by the larger cluster size



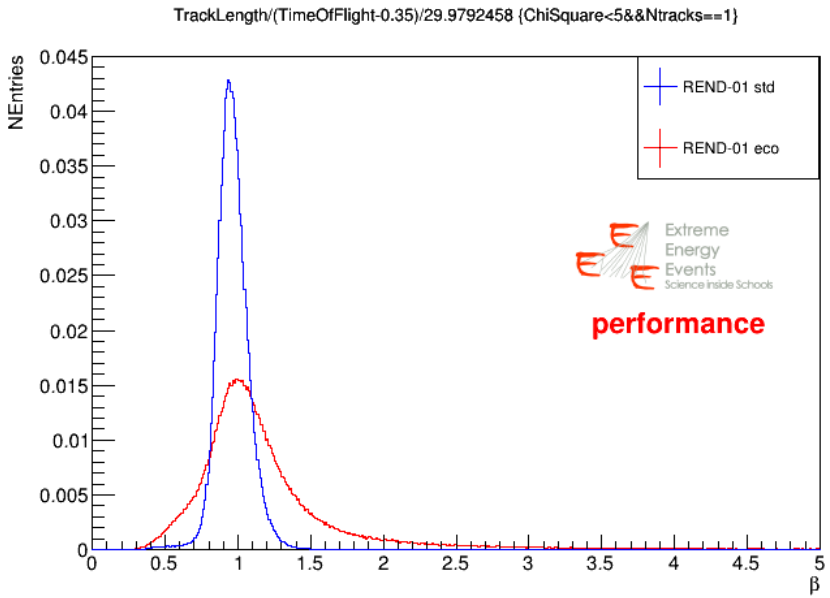


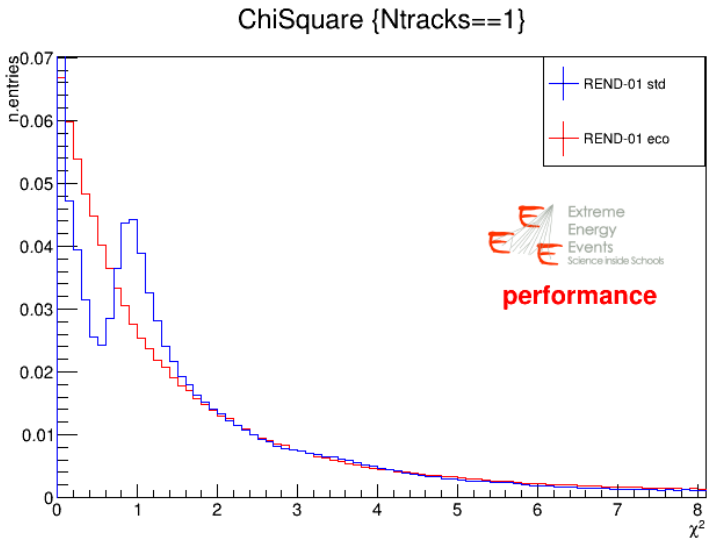
Plots generated with all three chamber fluxed with new mixture 60-40.

Could be worth adding PISA-01 (or others)?

Thanks to C.Ripoli for the plots!

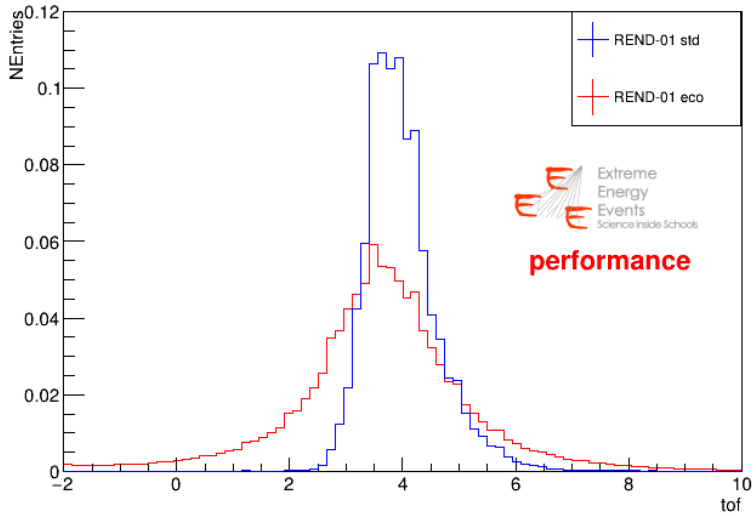
DQM distributions





Needs clear explanation of the differences:

- Tot/beta linked to the uncorrected timing
- Why double peak in std X^2 distribution?



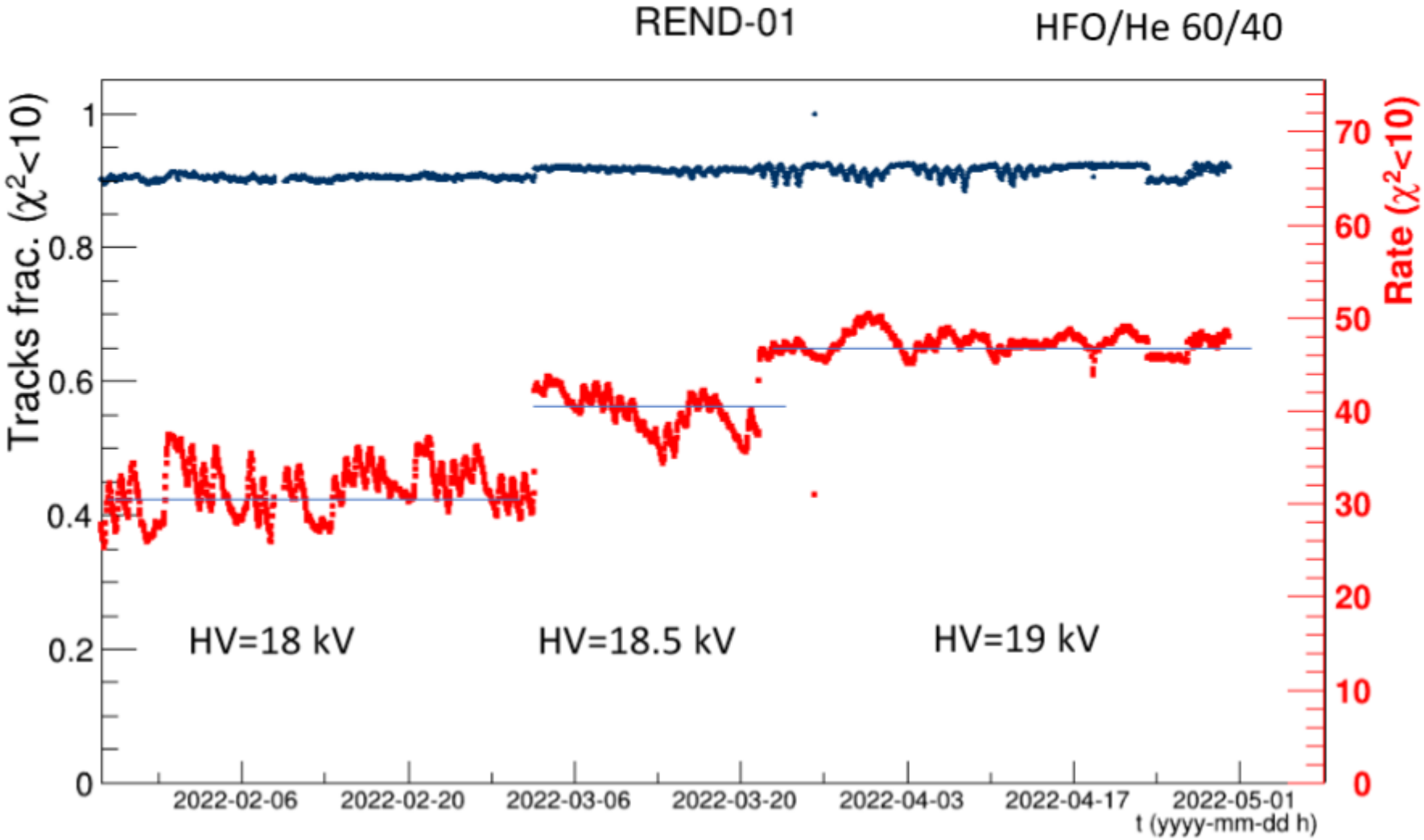
Plots generated with all three chamber fluxed with new mixture 60-40.

Could be worth adding PISA-01 (or others)?

Thanks to C.Ripoli for the plots!

Stability plot 1

Apologize for the low resolution

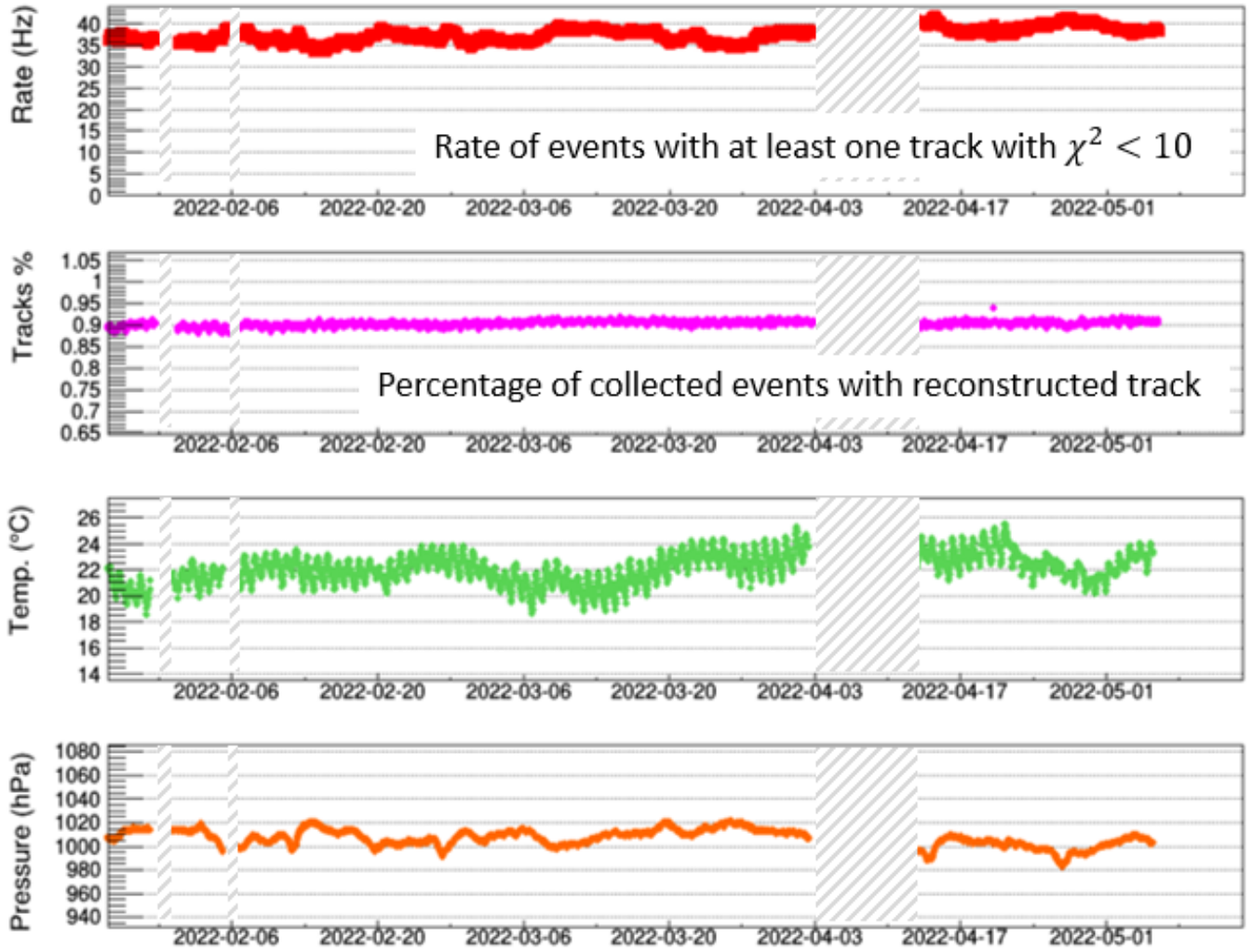


Plot generated with all three chamber fluxed with new mixture 60-40.

Stability plot 2

Apologize for the low resolution

Data from PISA-01 – 50/50 mixture



Plot generated with all three chamber fluxed with new mixture 60-40.

Conclusion

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- A first estimation of all parameters for REND-01 station has been done

- Few aspects need further investigation, especially in the time domain
- Some aspect of the DQM plots needs to be clarified

backup

Analysis steps

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☑ 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)

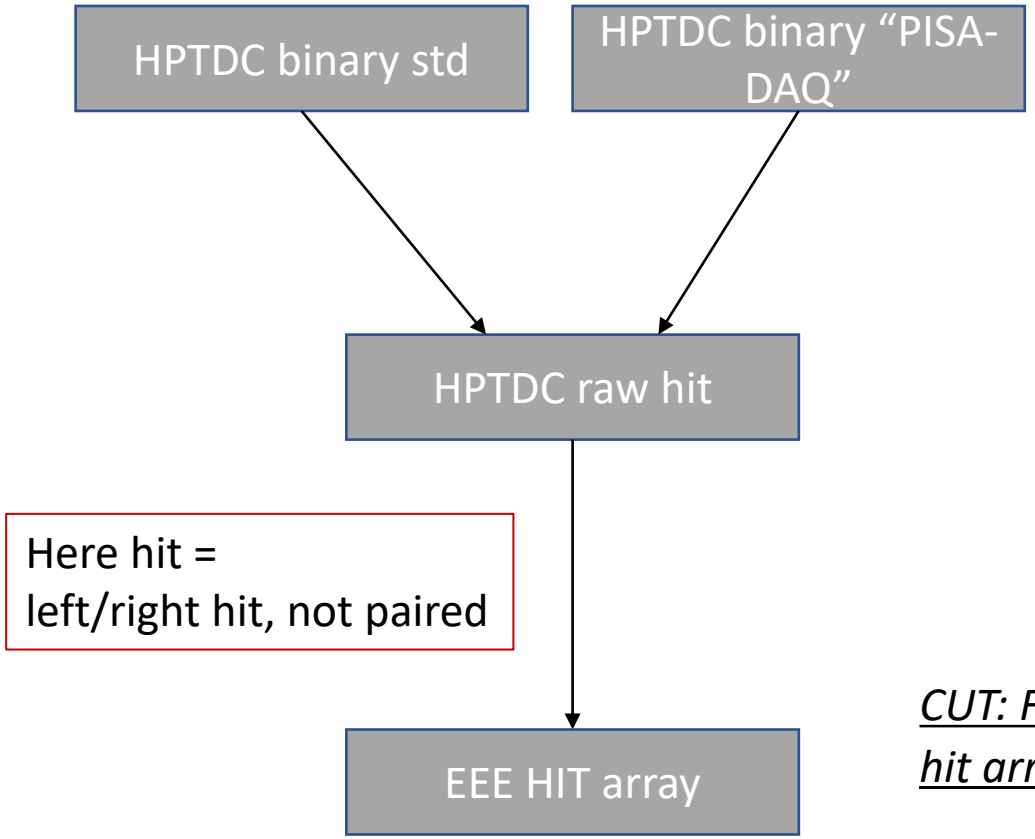
☑ Validation on a larger set of runs (at present I’m using a PISA run with 50/50 mixture @ eff. plateau, worst condition in terms of reconstruction).

☑ 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

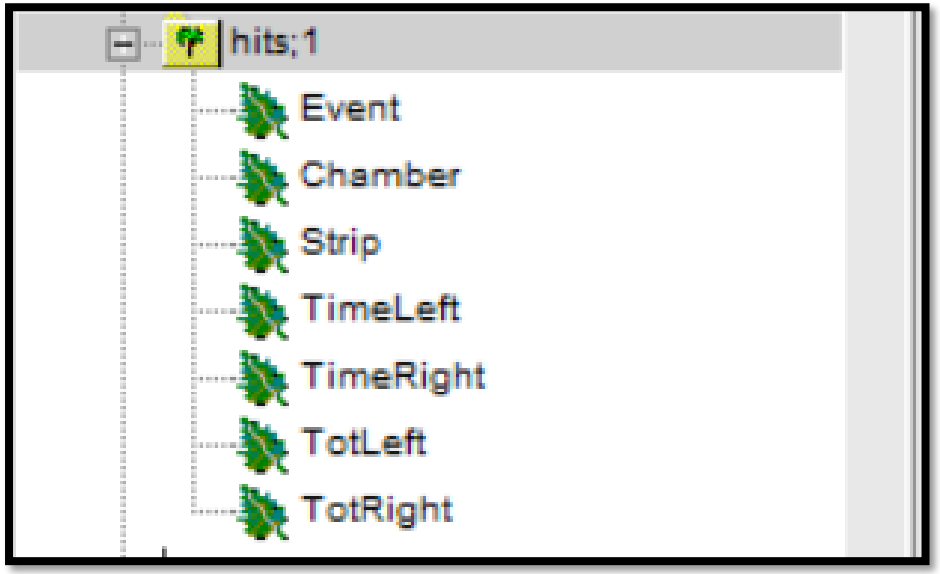
Code review: CNAF

EEE HIT array → EEE Debug tree

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

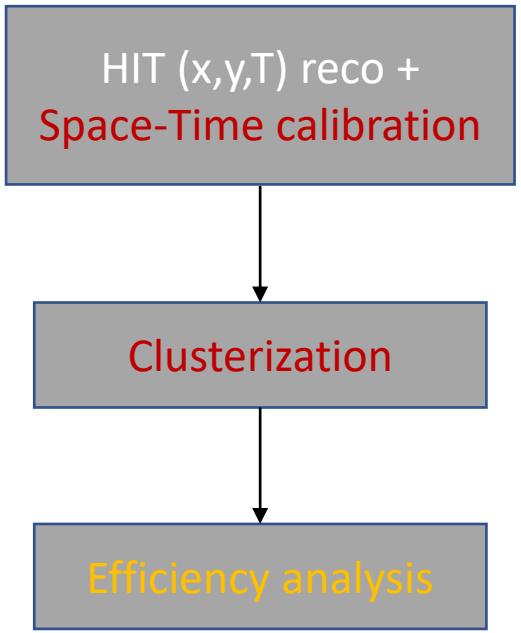
DST file content



- 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

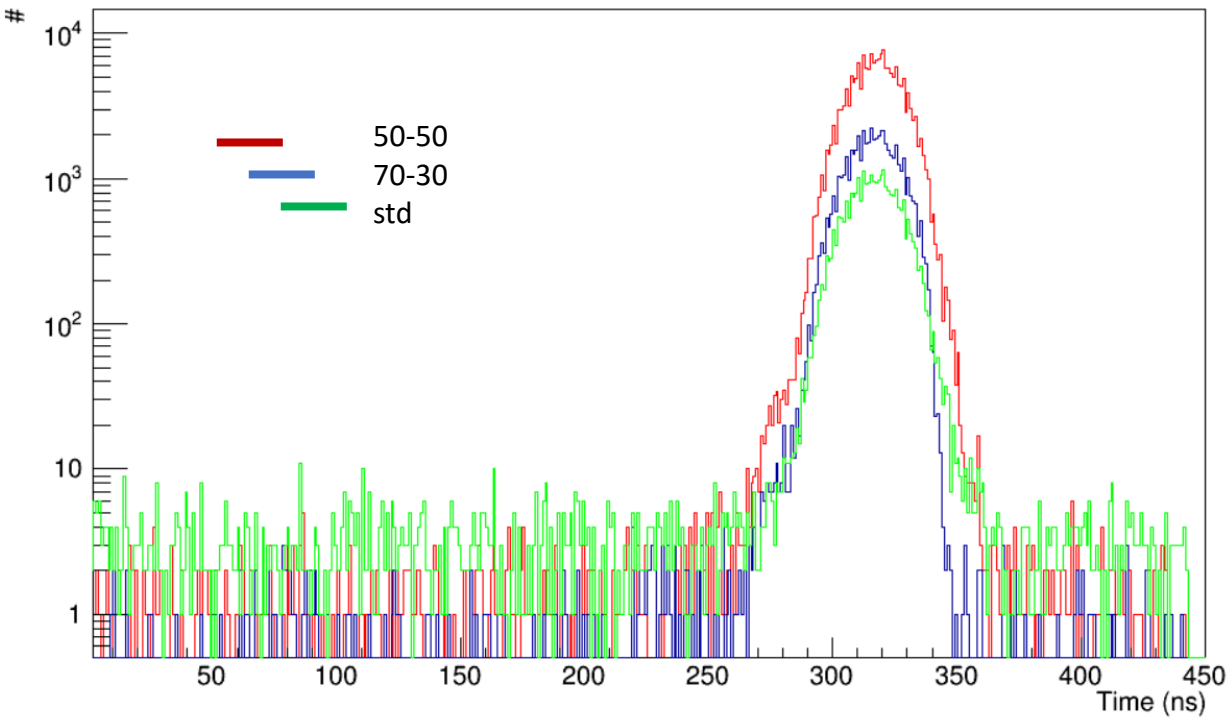
Details are given here

Analysis workflow –T Limit selection

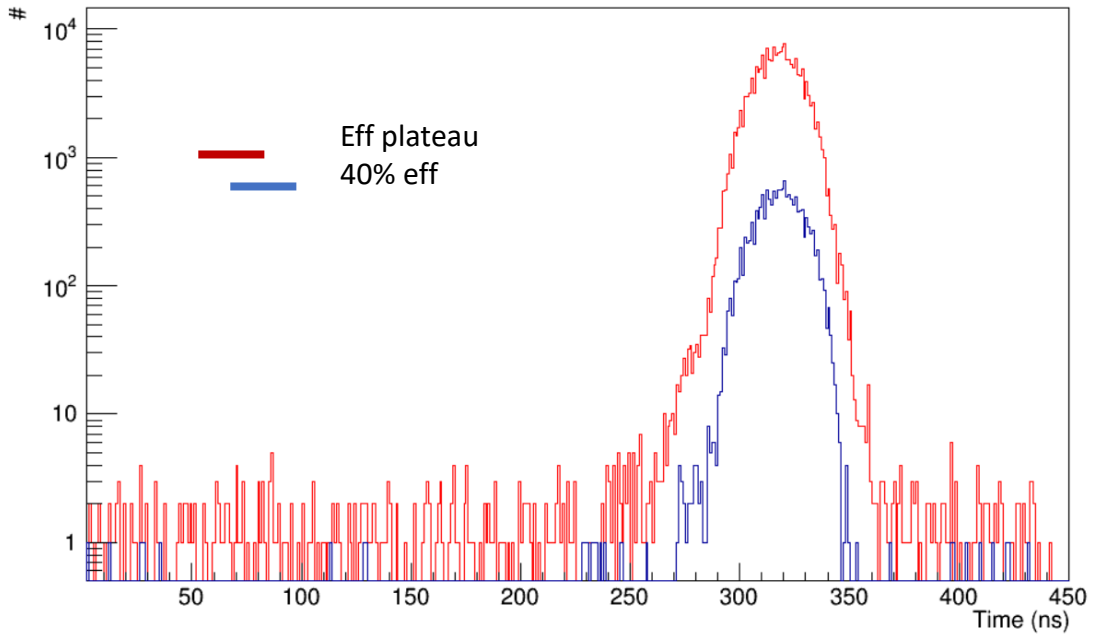
For each mixture, a “pilot” run is selected, with a voltage of the chamber under test in the plateau region. Plateau is known from the previous analysis on the dataset.

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

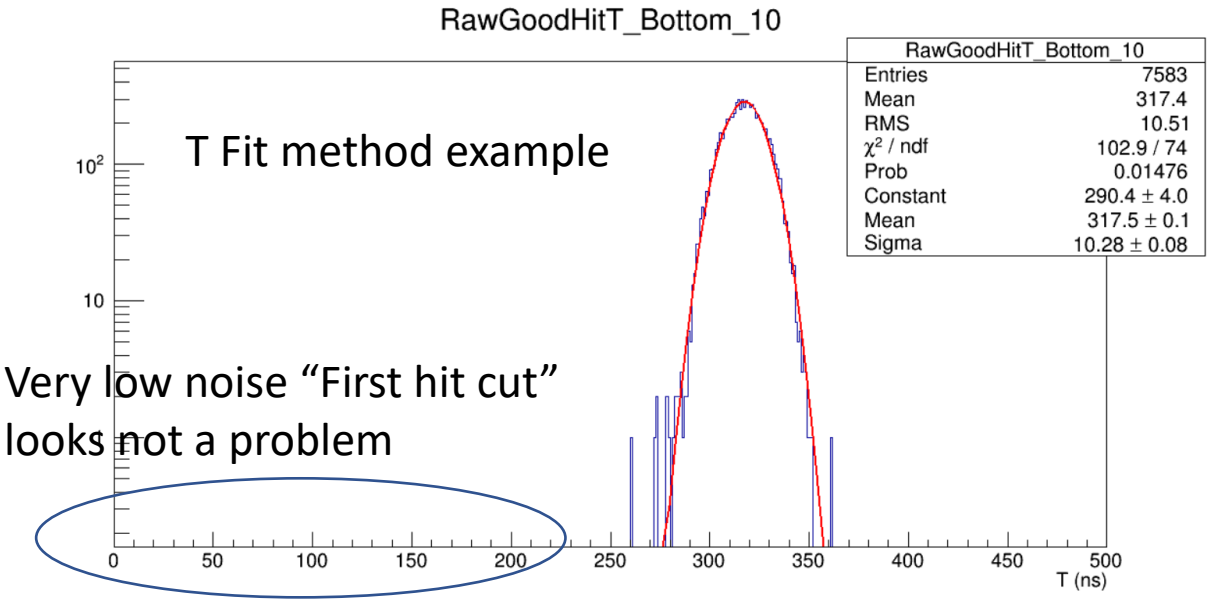
The calibration performs a simultaneous calibration of space and time.
It also calibrate the average middle time to be centered w.r.t. the outer chambers.

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

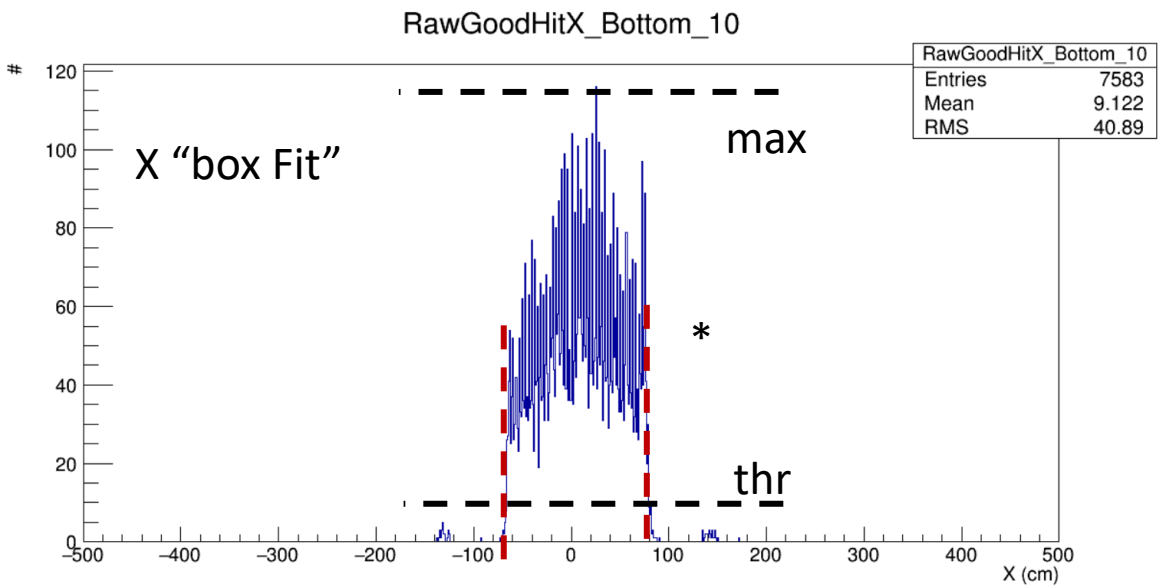
2. For each chamber:
- Average hit T distribution

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)



Very low noise "First hit cut"
looks not a problem



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

Calibration

Extreme Energy Events
Science inside Schools

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 <<
        }

    }
```

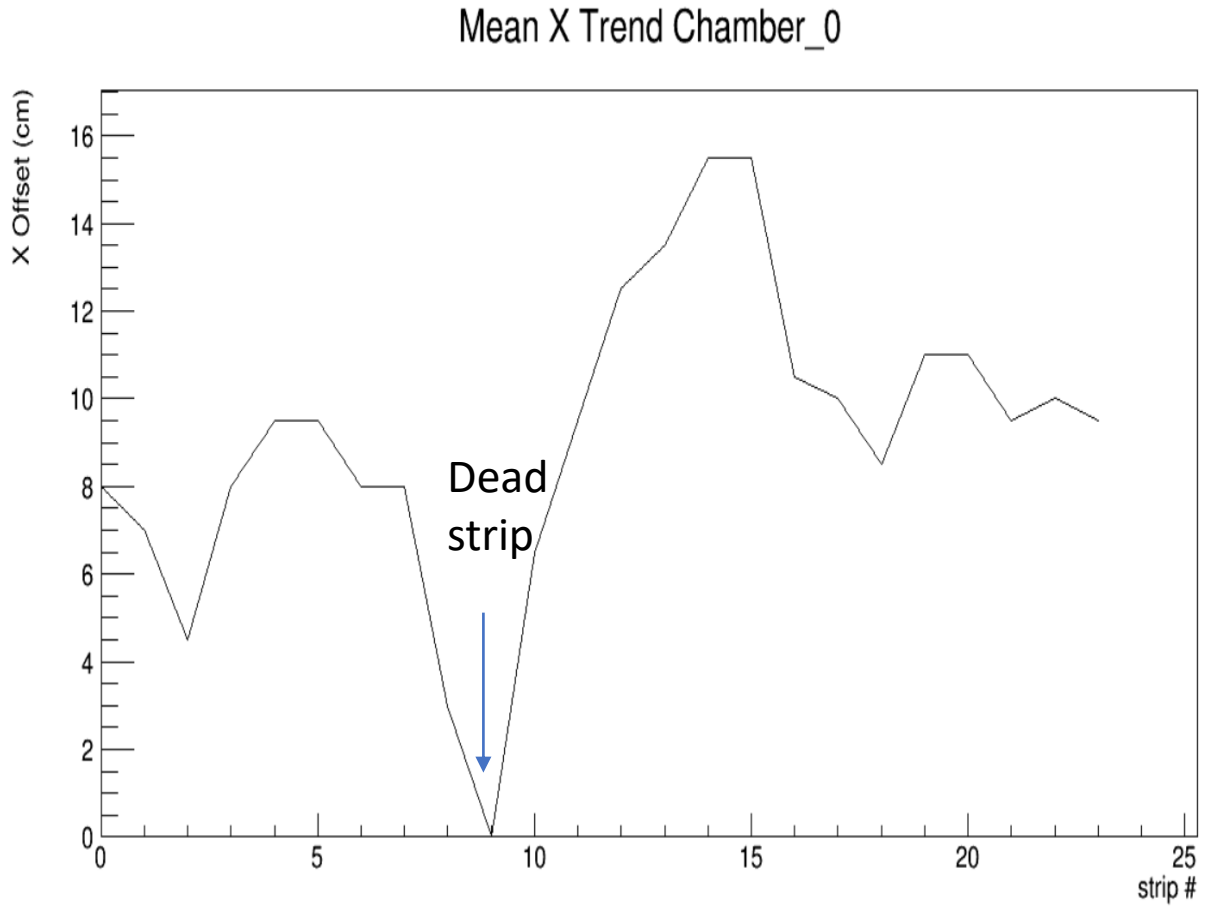
Average chamber correction

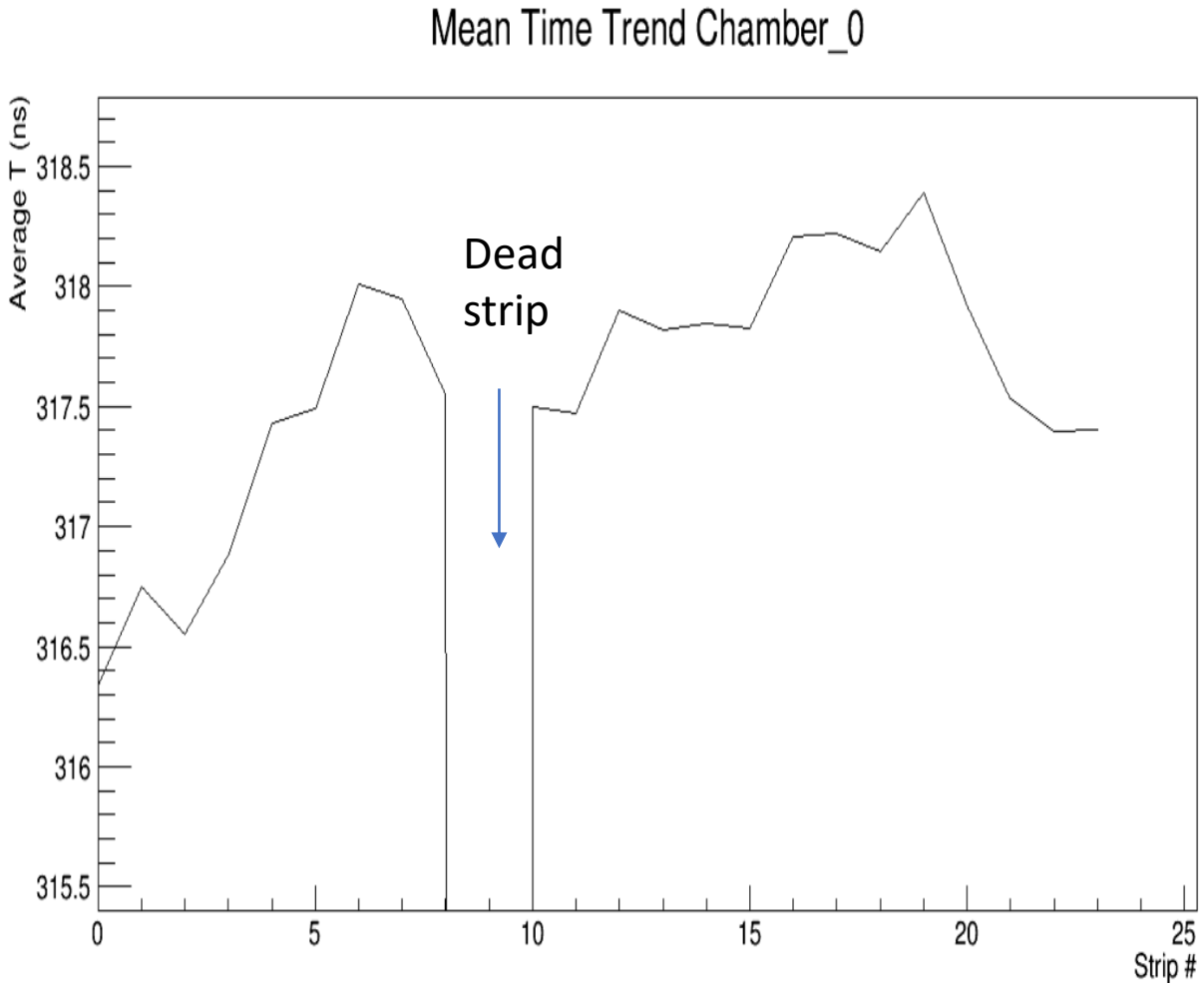
Time calibration

Space calibration

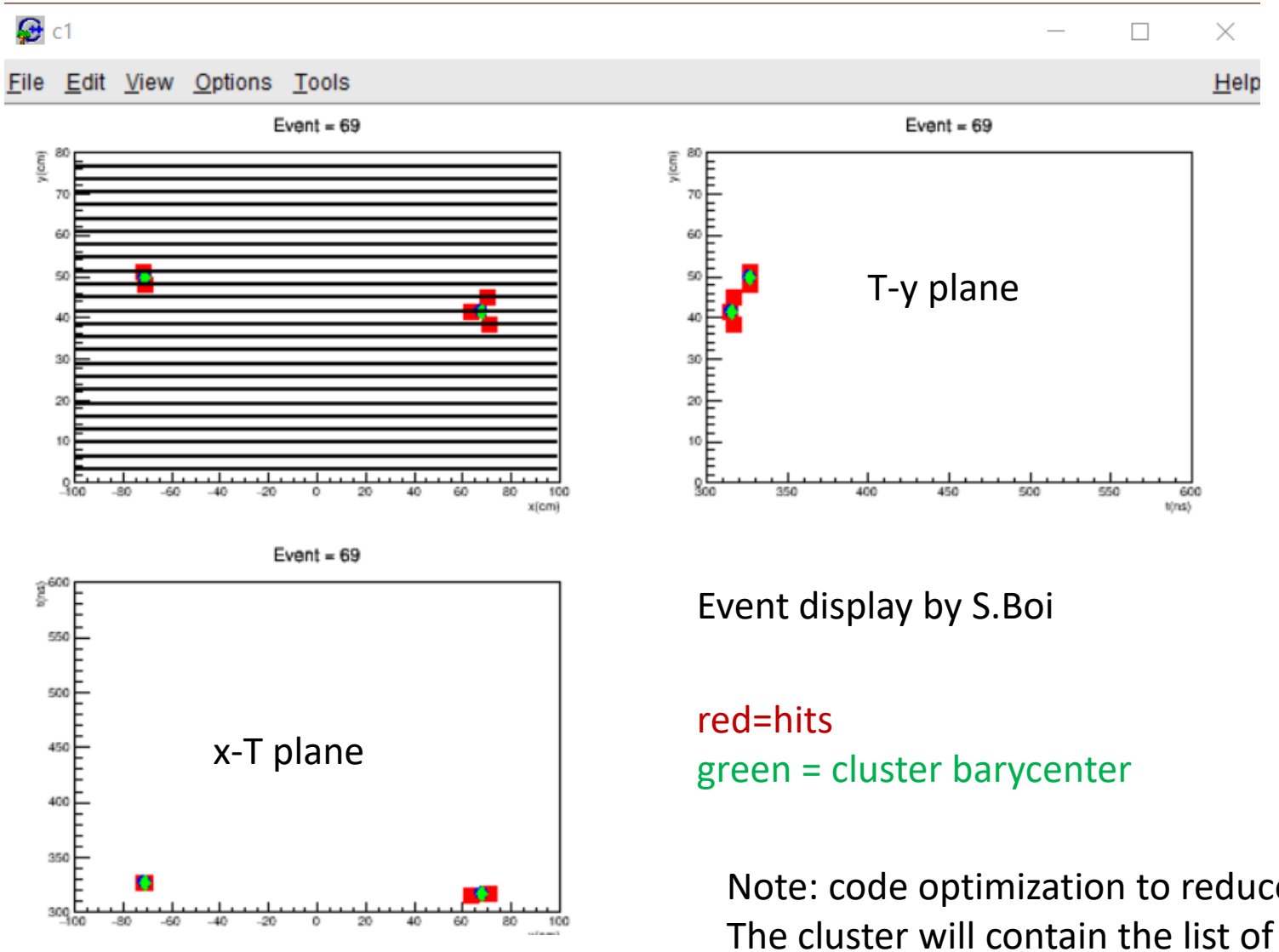
Calibration can be saved/retrieved

Raw data offset





Clusters



Event display by S.Boi

red=hits

green = cluster barycenter

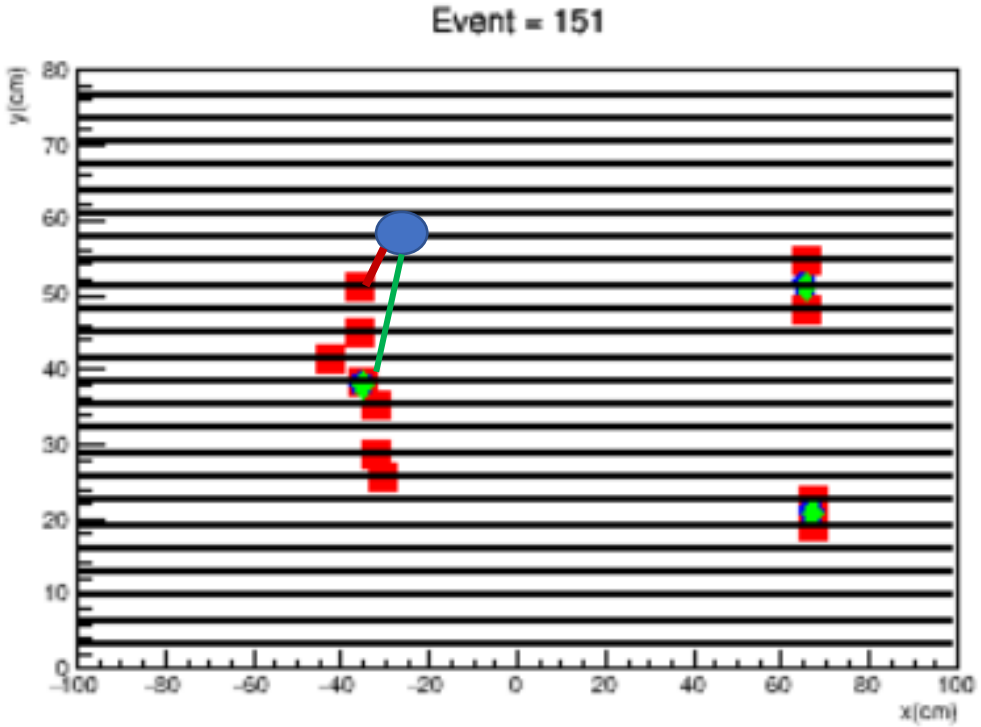
The algorithm in short:

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

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.

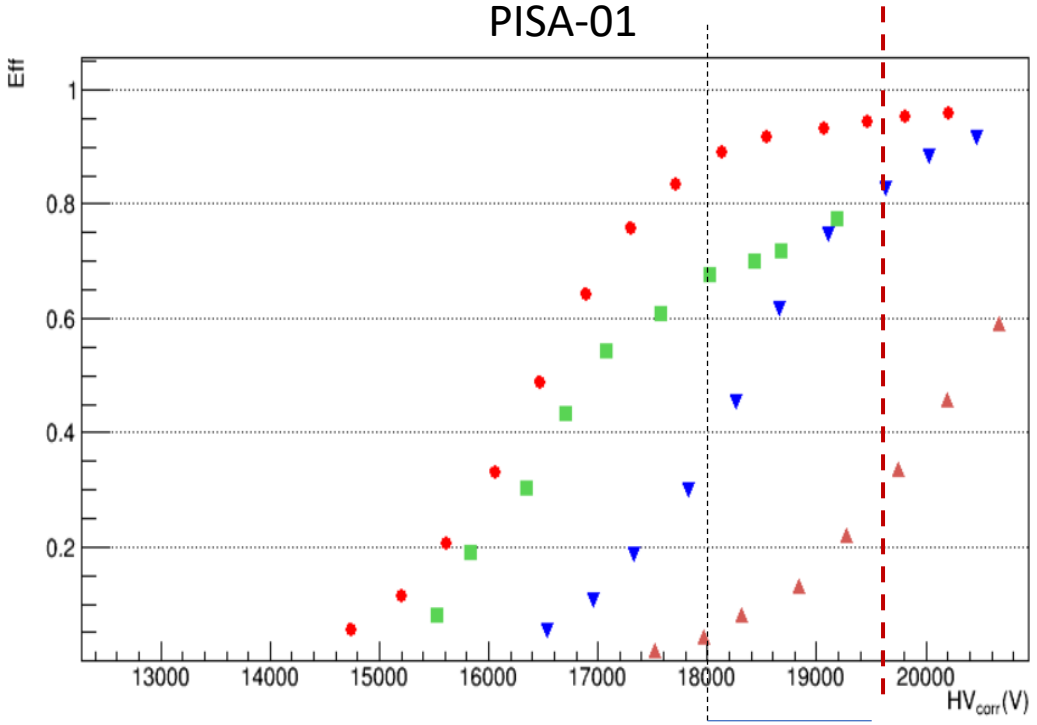
Selection cut on the triggered events (some tuning still needed):

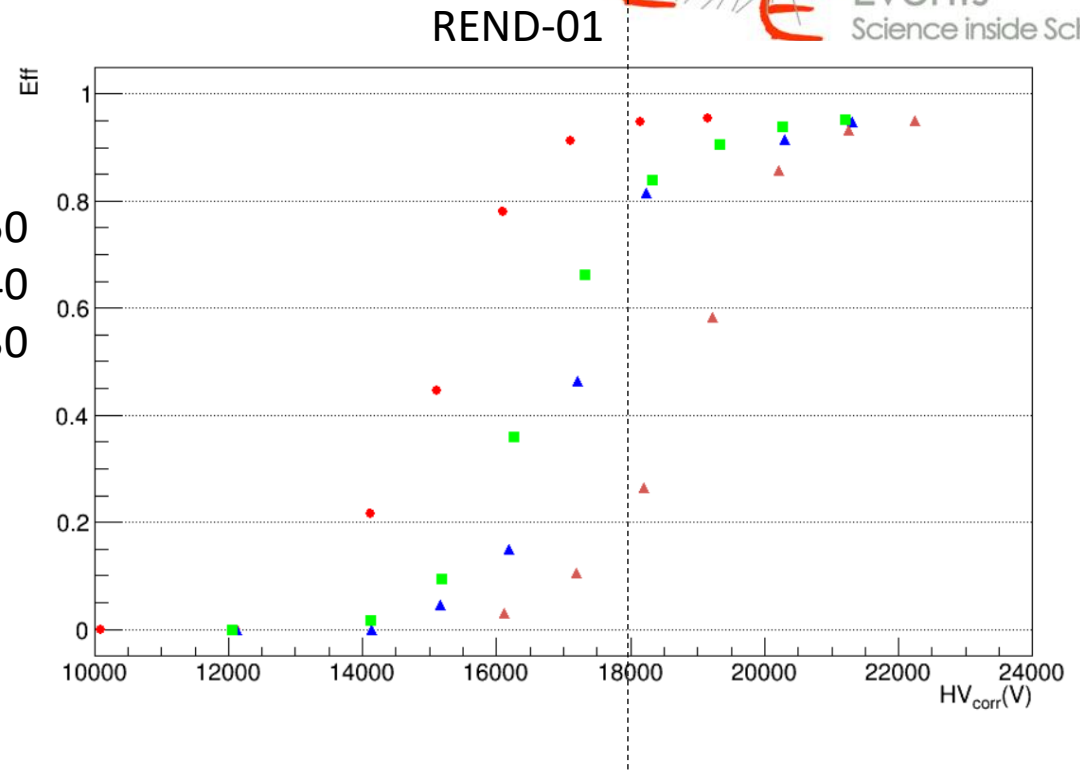
- Extrapolated hit within test chamber acceptance (5<y<75 cm, -60<x<60 xm)
- zdir > 0.9 (DISABLED)
- particle inverse beta within correct window (see next slide)

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

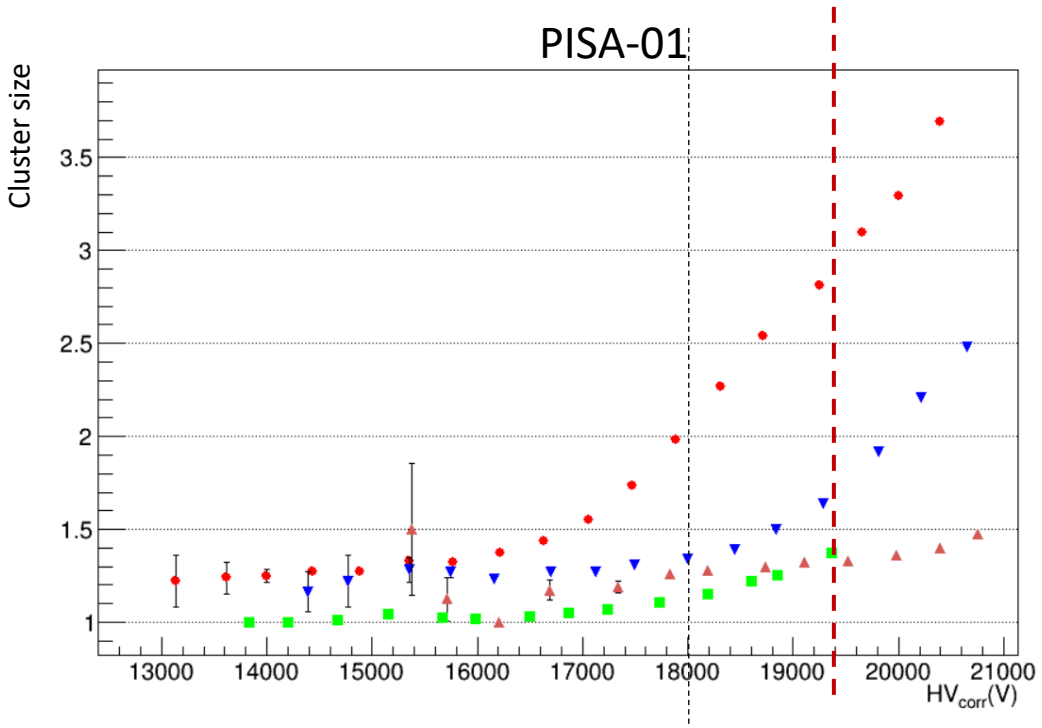


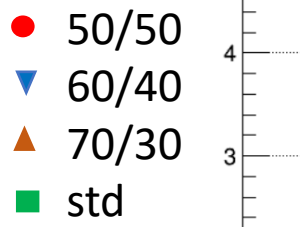


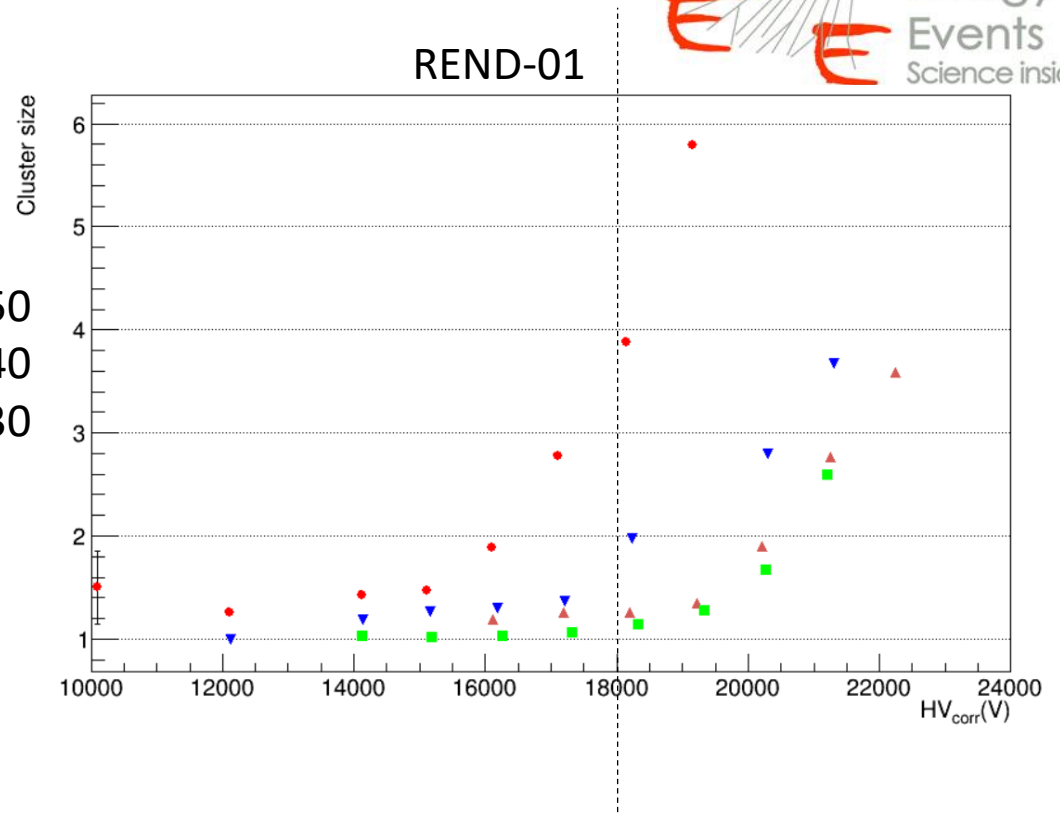
- Weird behavior of PISA-01 “std” mixture
- Curves looks shifted by ~1.5kV -> potentially due to HV readout offset, chamber differences

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

Cluster size



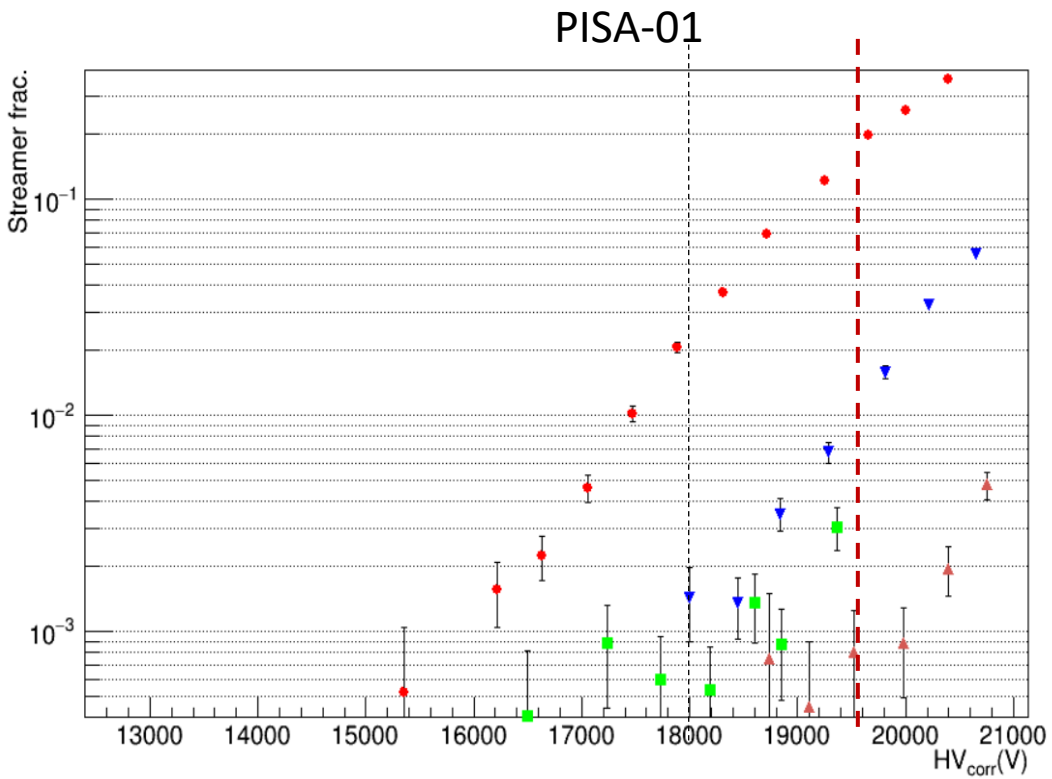




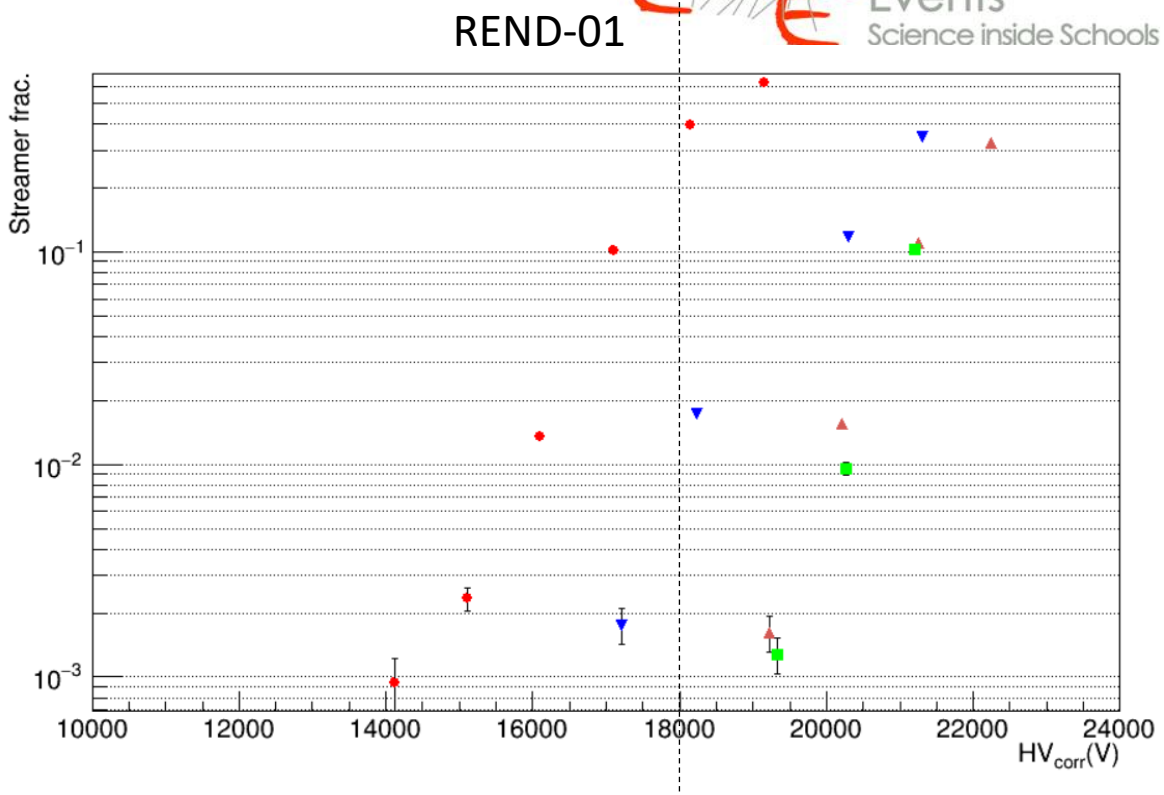
Def: Cluster size is the number of hits forming the cluster closer to the extrapolated point in the test chamber.
The uncertainty is the RMS of the cluster size distribution divided the square root of the number of entries in the histogram

Same behavior between the two station, apart for the HV “offset”

Streamer fraction



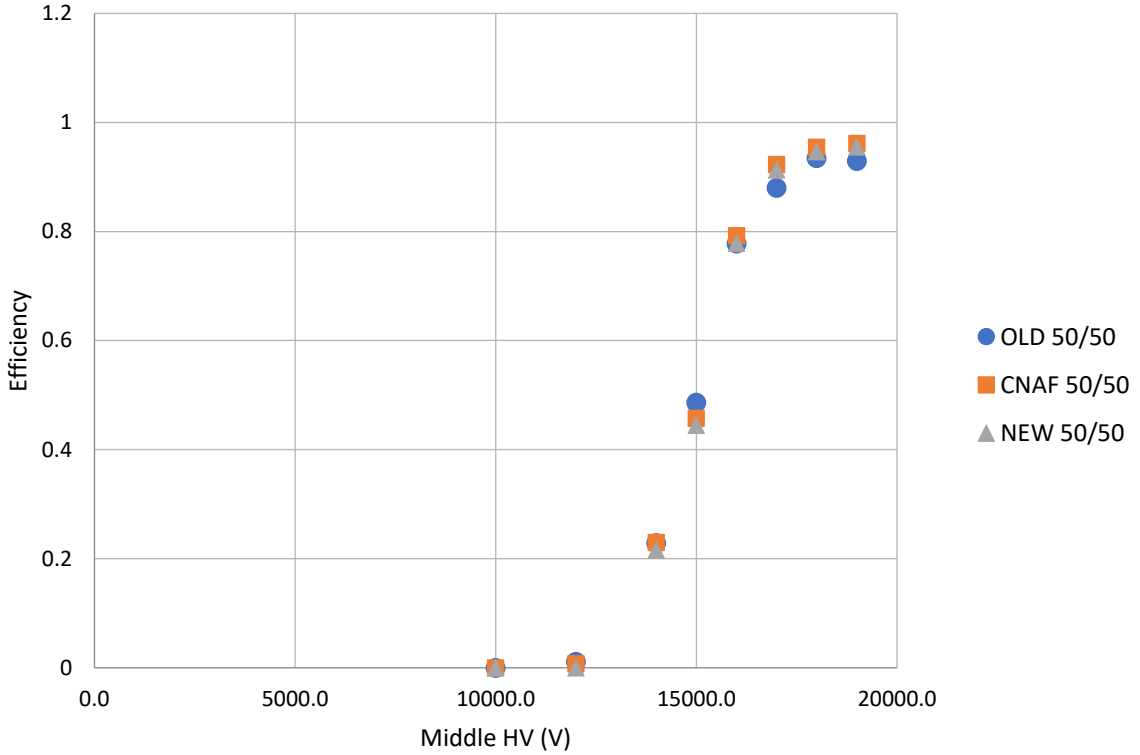
50/50
60/40
70/30
std

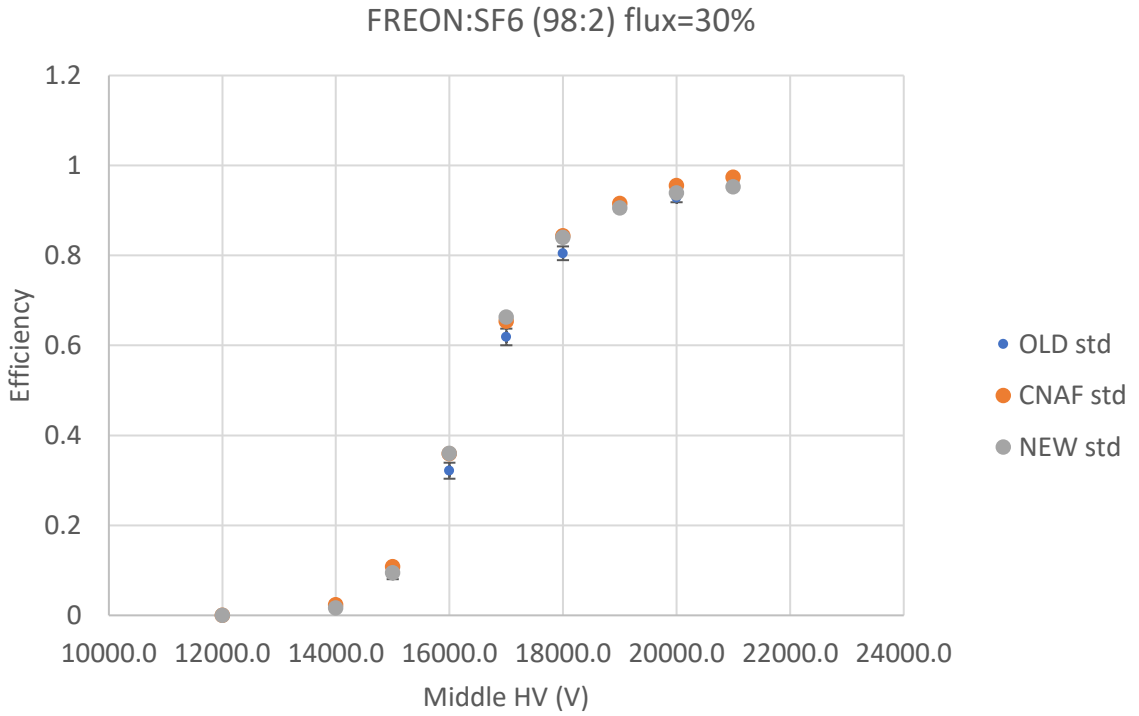


Def: Streamer fraction is the fraction of efficient events where the cluster size in the test chamber was > 3
Same behavior between the two station, apart for the HV “offset”

- 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

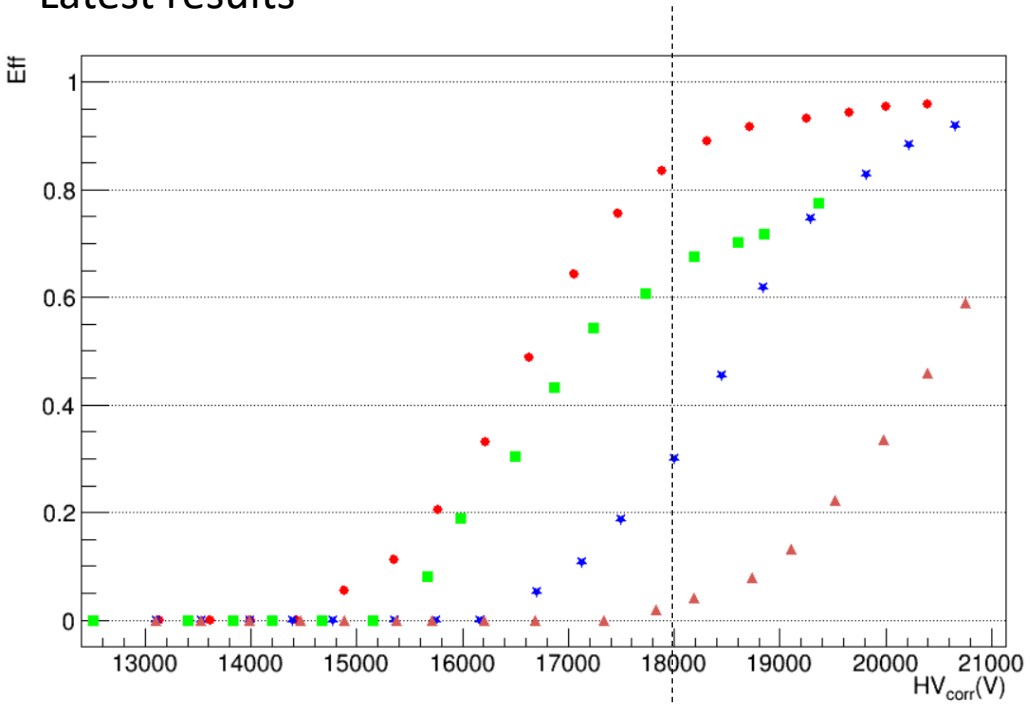




Comparison of analysis results of REND-01 data are consistent between CNAF, present analysis and old studies

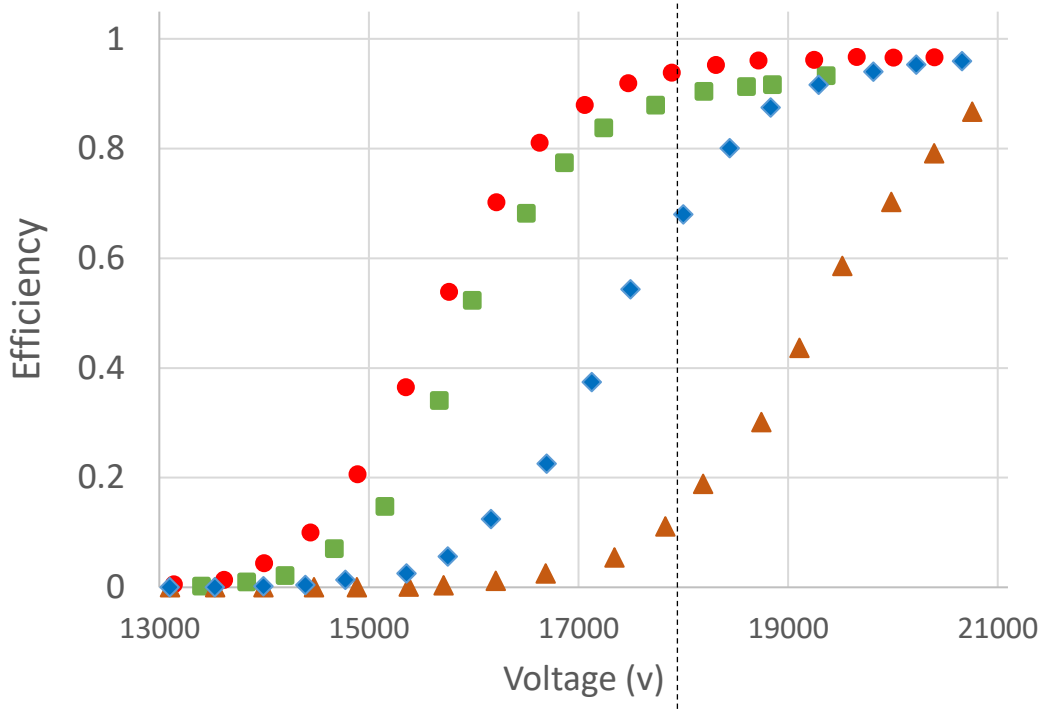
PISA-01: CNAF comparison

Latest results



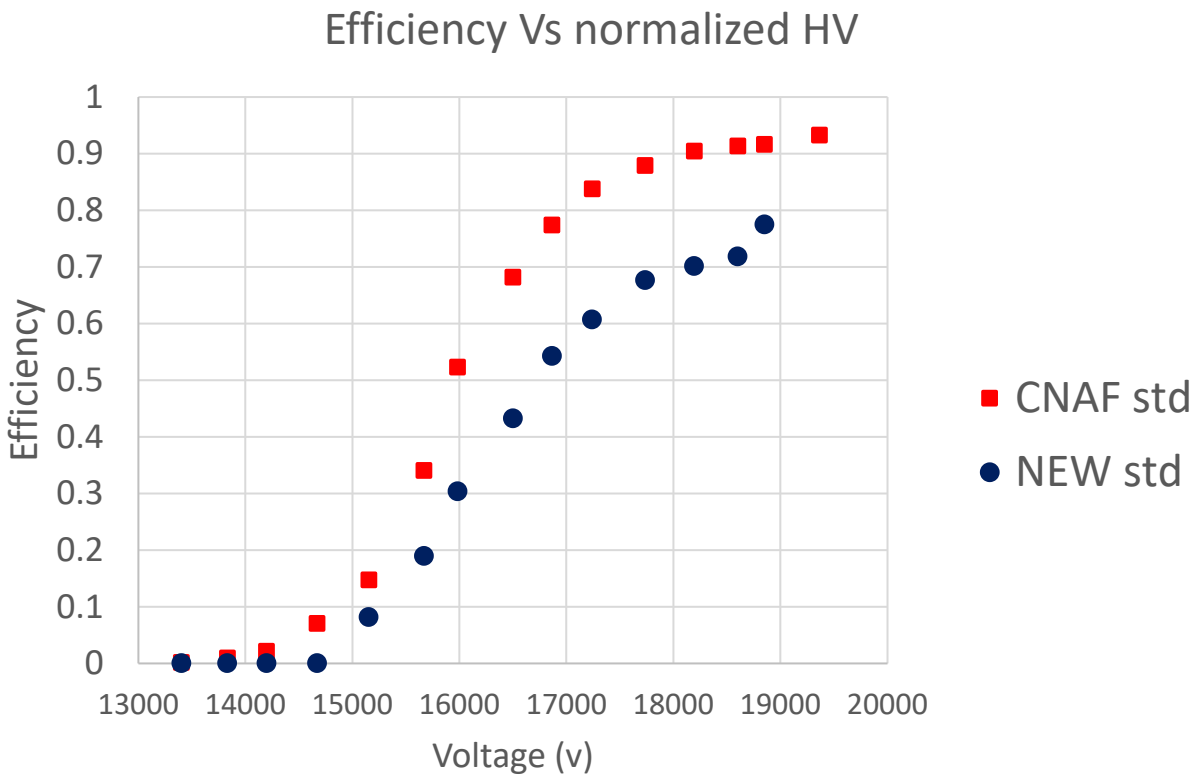
50/50
60/40
70/30
std

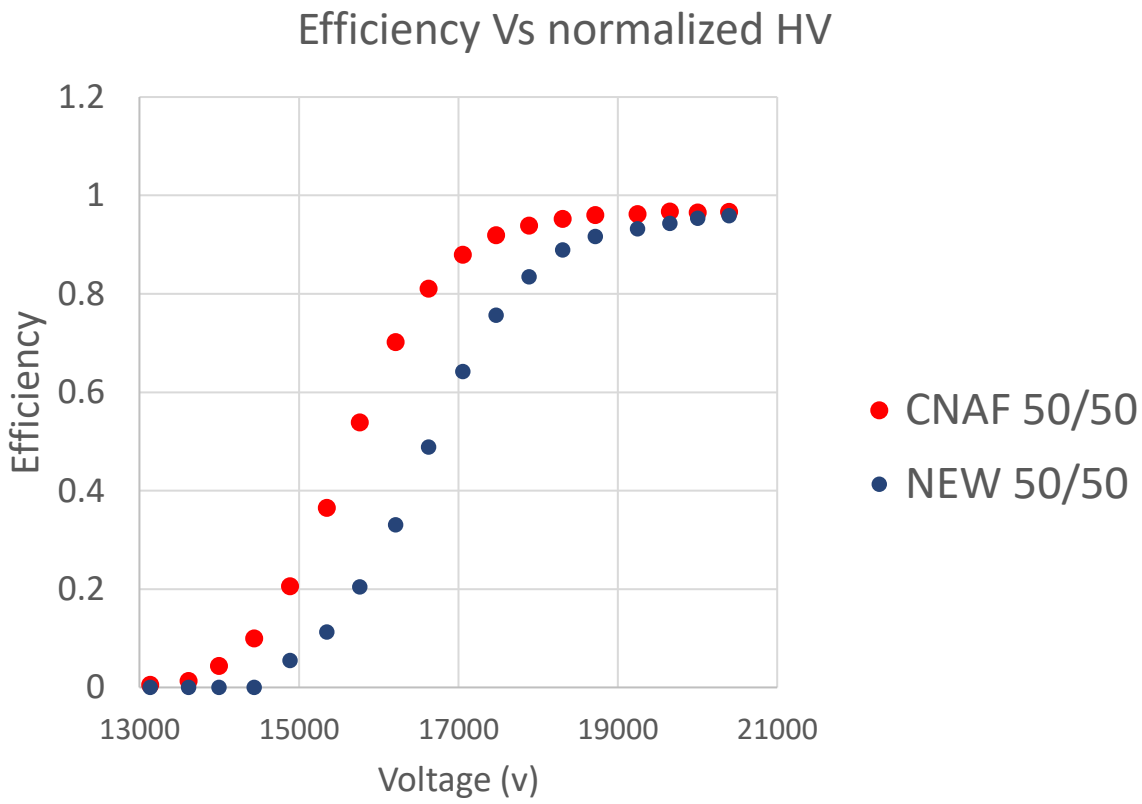
CNAF



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