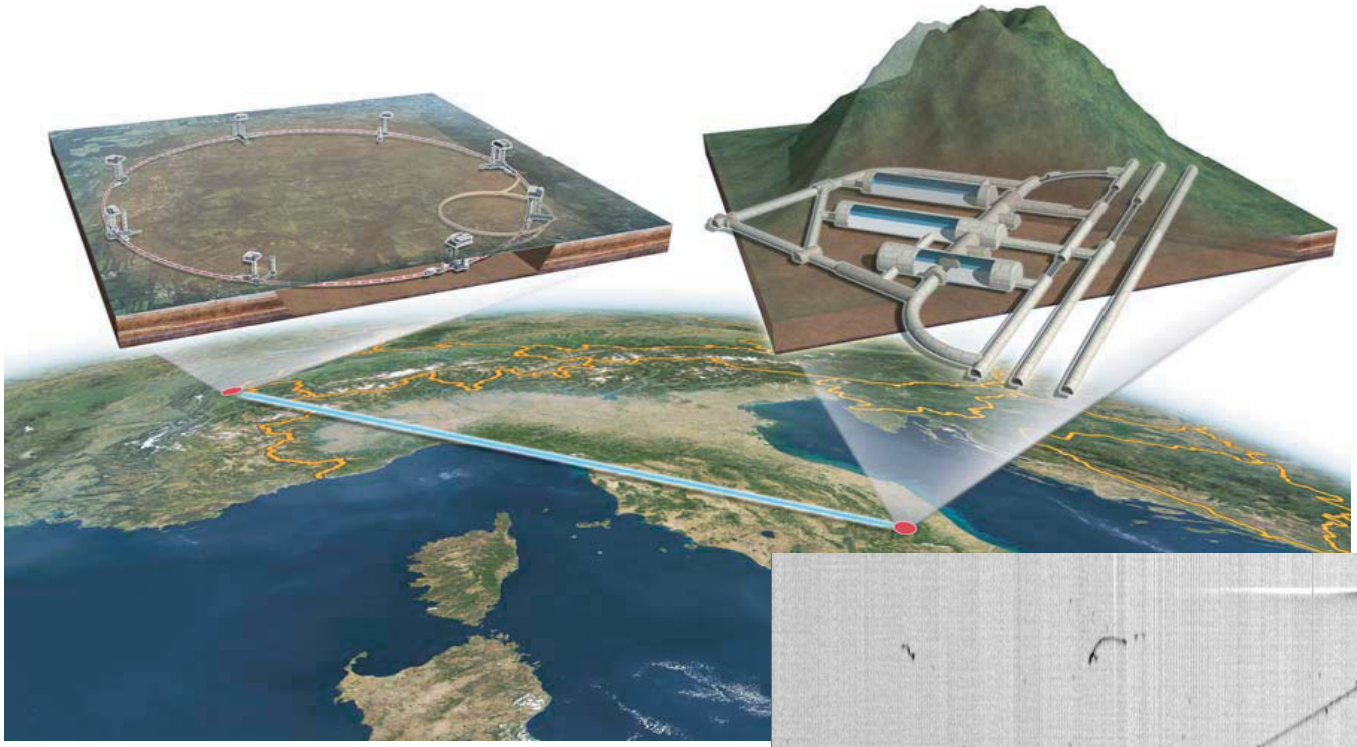
Measurement of LAr purity in ICARUS and status of the implementation for the new FNAL run



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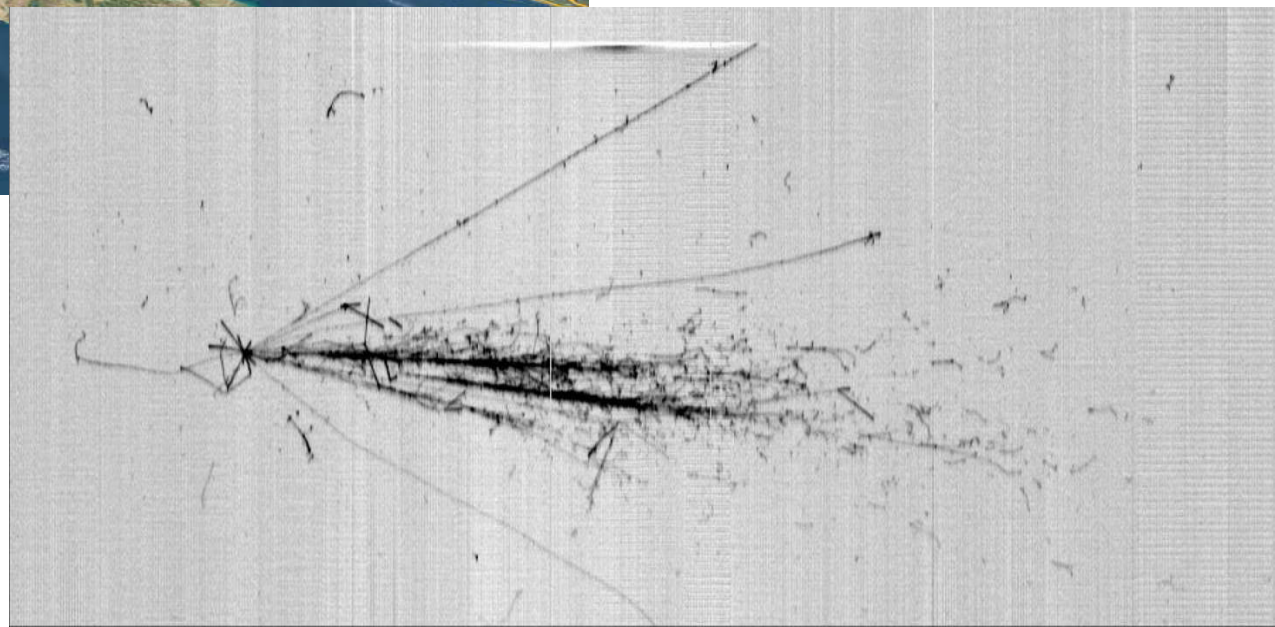


September 19, 2018

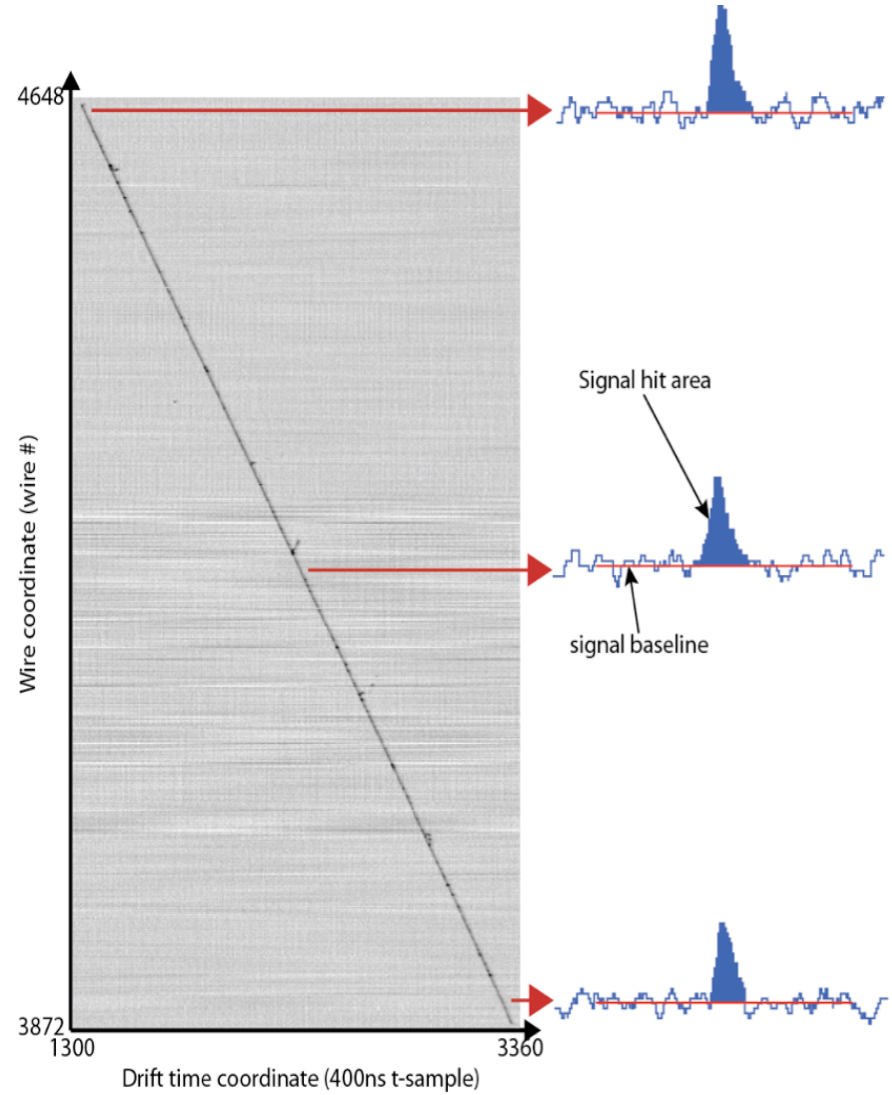
Purity measurement in ICARUS

- The measurement of the free electron lifetime τ_{ele} is a key feature both for a precise measurement of the deposited energy in the collected events and for the monitoring of the Liquid Argon condition in the TPCs;
- A fully automatic procedure to monitor online the attenuation $\lambda = 1/\tau_{ele}$ has been prepared for the Gran Sasso LNGS run starting from the experience cumulated in a small TPC in Legnaro (LNL);

- Outline of the talk:
  - Short description of the developed methods for the T600 data taking in Gran Sasso;
  - First step for the preparation of the method for the T600 run at FNAL;

Purity measurement in the T600@LNGS: method description

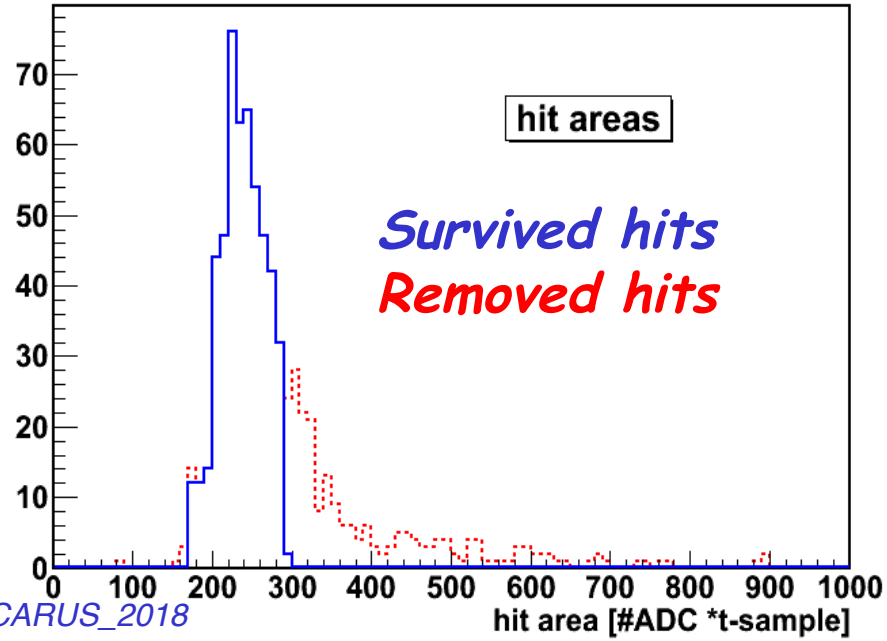
- An event-by-event method has been developed for the electron lifetime measurement during the LNGS run;

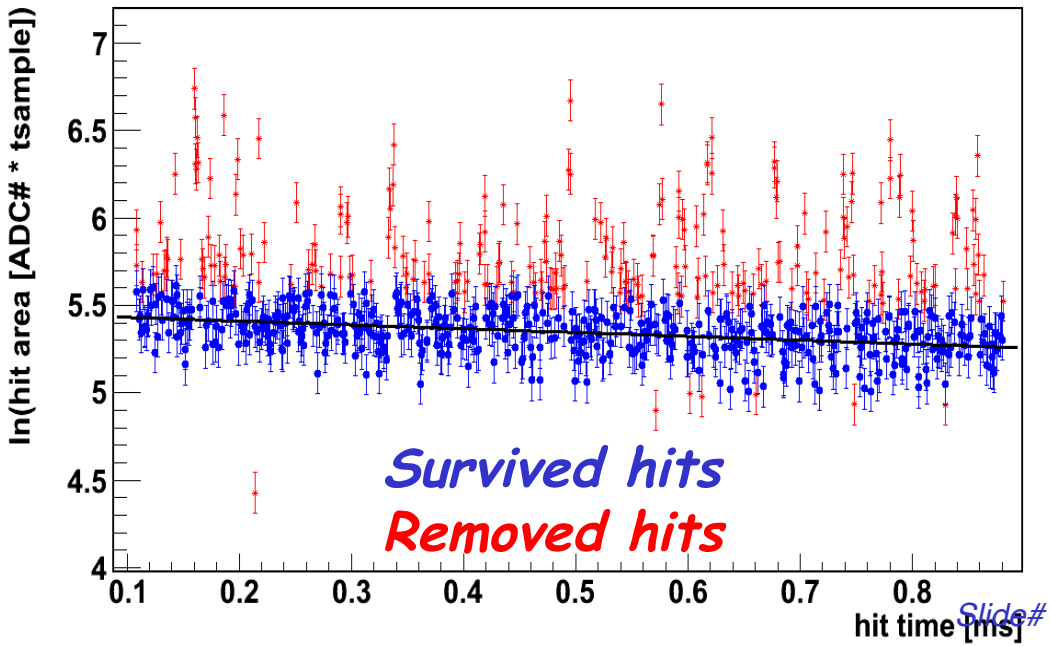


- Automatic selection of through-going cosmic-ray muons (only Collection view used, no 3D reconstruction needed);
- The event is "good for purity measurement" if the muon cluster occupies at least 100 wires and 1450 ticks (400 ns each) and if the track presents a reduced e.m. activity.
- Recursive rejection of hits at more than 3 mm distance from the track is applied: residual δ-rays along the track are removed;

Purity measurement in the T600@LNGS: method description -2

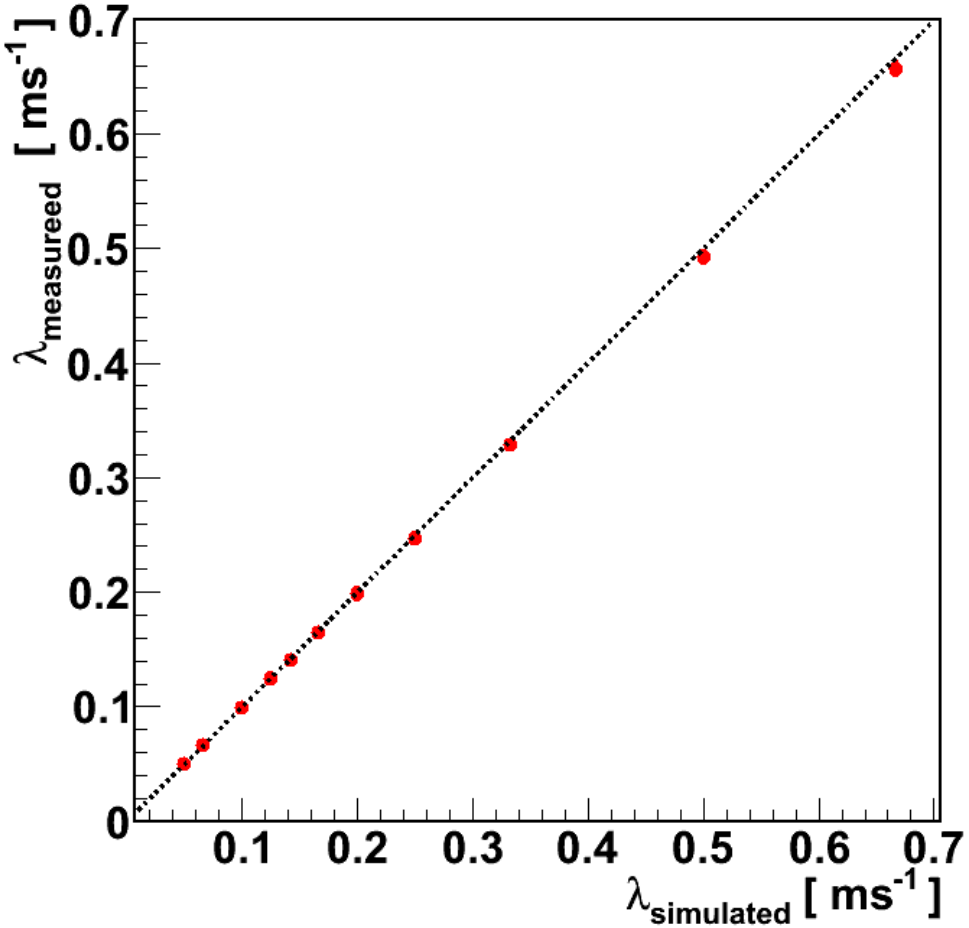
- $\lambda_{track} = 1/\tau_{ele}$ obtained by a fit of the charge attenuation along each selected tracks; a 2-step procedure has been prepared to reduce the fluctuations due to the asymmetric Landau tail of the dE/dx;
- In the second step the hit signals are corrected using the provisional λ' value obtained in the first step and using 100 tracks; a truncation method is applied to each track ➔ *signal distribution centered around the most probable dE/dx value*
- The final value of $\lambda = 1/\tau_{ele}$ estimated averaging on 100 tracks;





Purity measurement: test on MC events

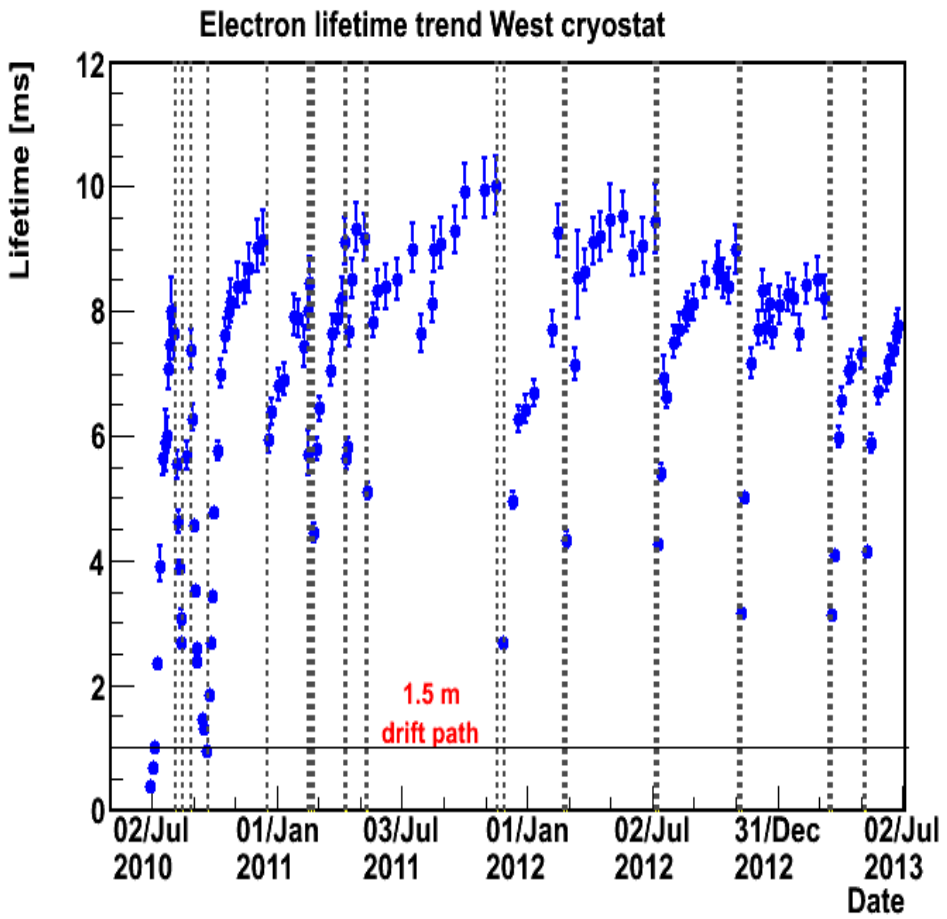
- The described method has been validated using a sample of 9000 simulated muon tracks with energy spectrum / angular distribution of cosmic rays as measured at LNGS

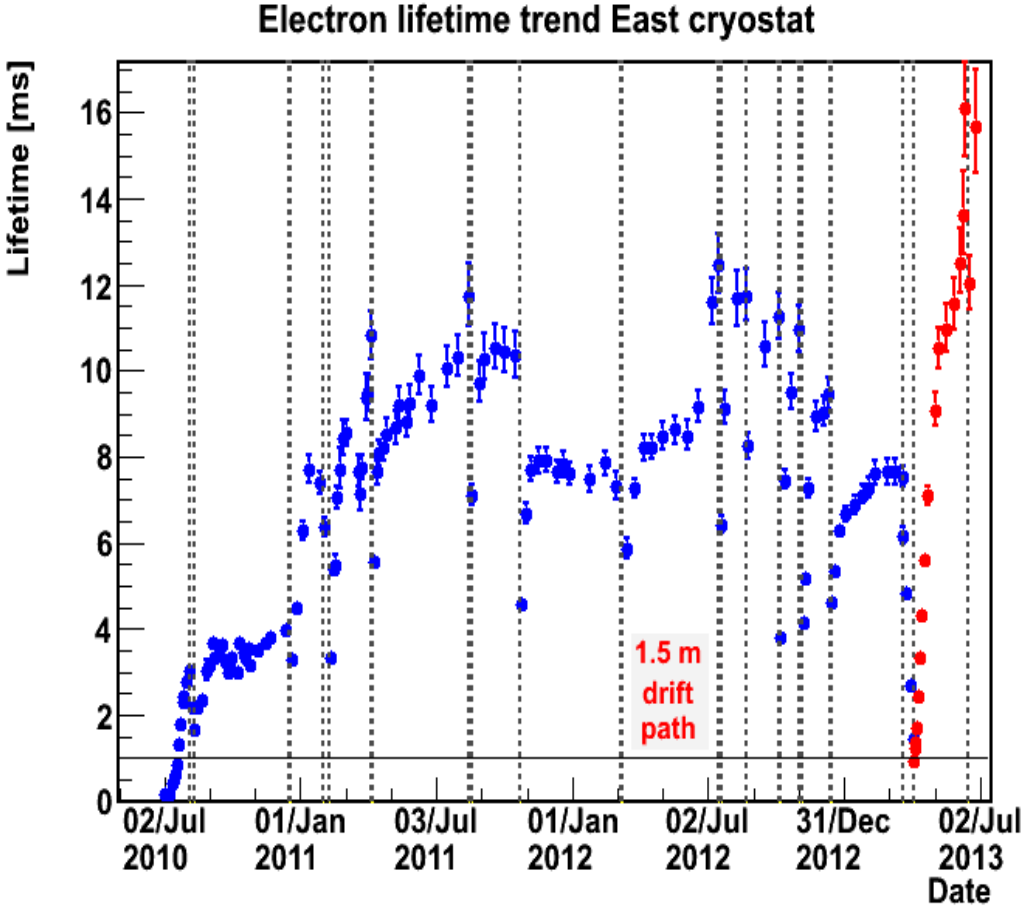


- Method tested for electron lifetime in the 1.5 - 20 ms range;
- <1 % underestimation for τ_{ele} > 3 ms ➔ maximum effect on the energy measurement < 0.3 %
- 1.5 % underestimation for τ_{ele} < 3 ms ➔maximum effect on the energy measurement ~ 1 %

Purity measurements during the LNGS data taking

- During the LNGS run, electron lifetime measured in the 2 cryostats applying the described method on selected runs, taking into account of the stops and restarts of the liquid recirculation system.





- Detailed description of the method in JINST 9 P12006 (2014), SBN-doc-2133-v1, SBN-doc-1678-v1

Purity measurement at FNAL: update needed - 1

- The procedure for the purity measurement at LNGS has been developed taking into account of:
  - the reduced collected number of cosmic muons (~ 3100 per day);
  - the high energy spectrum of the crossing muons ➔ small variation of the dE/dx along the track;
  - usually only one muon in a well defined drift region for each event.
- These conditions will not be verified during the data taking at FNAL:
  - in each event there are more than 10 muon tracks with no defined t_0 time;
  - ~ 15 % of the muons stop in the detector ➔ large variation of the dE/dx along the track to be combined with the fluctuations associated to the purity measurement.
- In addition during the FNAL run we will also have the CRT that can help in the identification of cosmic muons;

Purity measurement at FNAL: update needed - 2

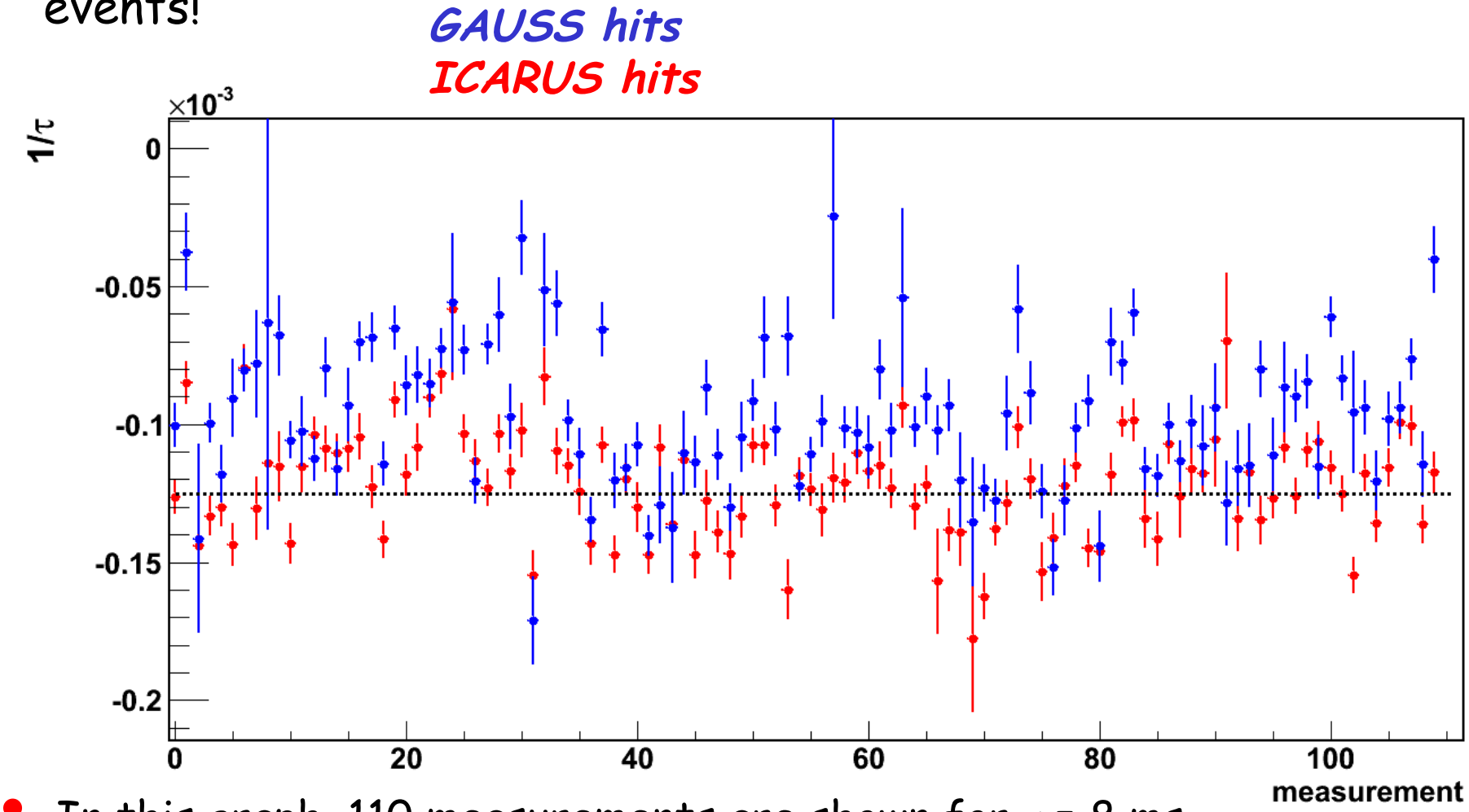
- The LNGS event-by-event method requires some important updates:
  - ✓ Application of the method to a full MC sample with the expected number of cosmic tracks in each event and with the energy spectrum expected at shallow depth;
  - ➢ Study of the effects of the different energy spectrum on the electron lifetime resolution;
  - ➢ Study of the space charge effect on the purity measurement;
  - ➢ Possible measurement of the uniformity of the electron lifetime over the full detector volume (improvement on the energy measurement).
- This method can be directly applied on the reconstructed clusters in collection views assuming that the cluster identification can provide a first separation of different physical activities in the events:
  - ✓ study of the cluster properties (number of wires/samples, average number of hits in a wire…) to automatically identify the muon tracks "good for purity measurements";

Purity measurement at FNAL: work in progress

- The code for the purity measurement has been fully "translated in LArSoft language" and is now working in a semi-automatic way;
- The code has been fully tested using a full simulation of cosmics with the expected time exposure and considering a 3 m concrete overburden
- The events has been reconstructed to identify hits and clusters (used code version v06_68);
- Simulation of the wire electronic noise based on the noise measurements obtained during the Gran Sasso run;
- The simulated events has been divided in groups of 100 "triggers" just to have a first evaluation: 110 groups analysed. The final electron lifetime is the average of the 110 measurements.
- Two different approaches used:
  - "icarus raw" hits
  - "gaussian" hits, identified after the signal deconvolution

Purity measurement at FNAL: work in progress - 2

- First results, obtained averaging over the tracks good for purity in 100 events!

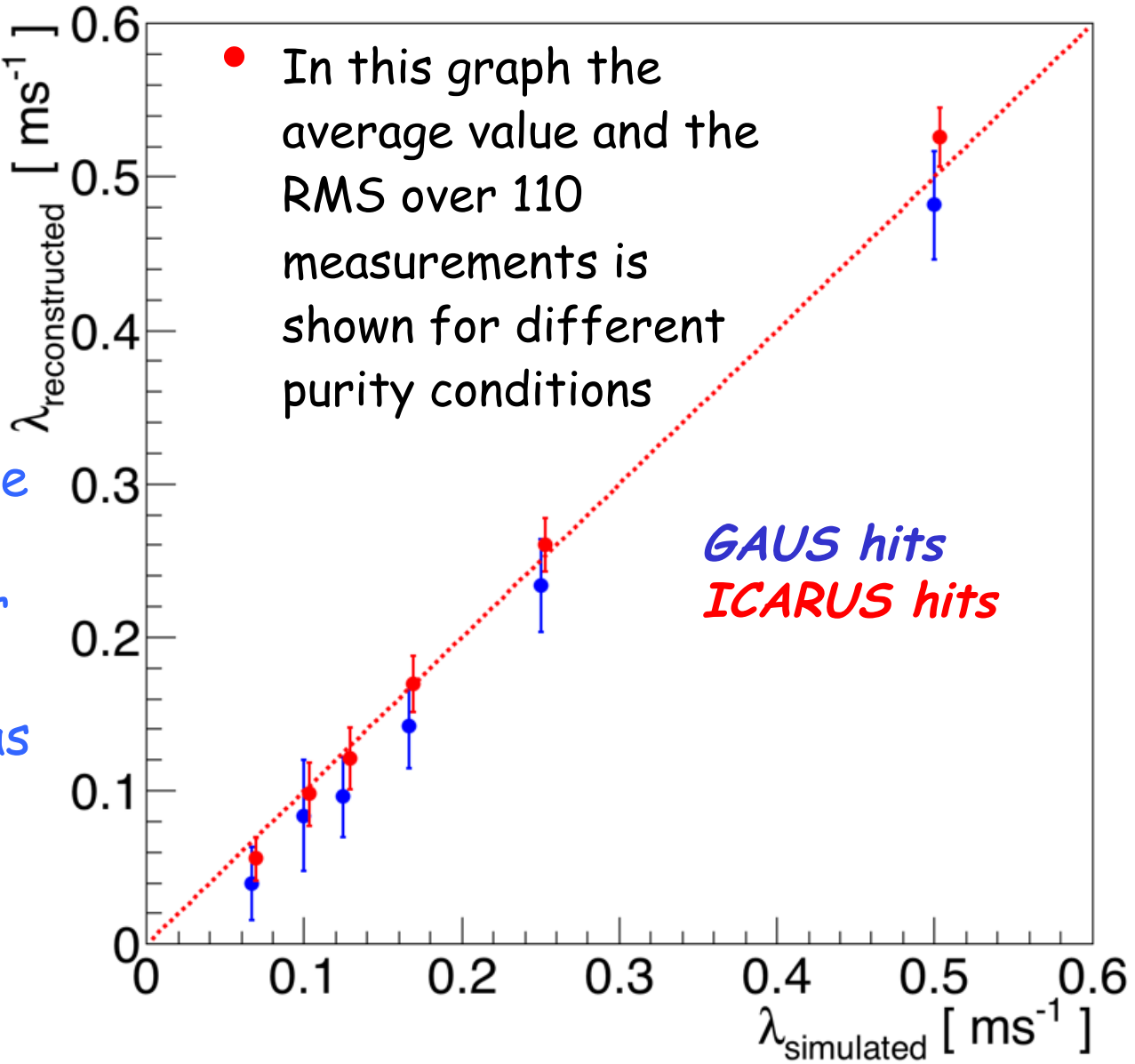


- In this graph, 110 measurements are shown for τ = 8 ms

  - On average 3.5 μ tracks per event "good for purity"

Purity measurement at FNAL: work in progress - 3

- On average 3.5 muon tracks per event selected as "good for purity"



Purity measurement at FNAL: next steps

- This first test shows that the method can provide an evaluation of the electron lifetime but a dedicated study to try to improve the precision of the final measurements for the "final" calibration is required:
  - Tuning of the selection criteria
  - Use of the 3D track reconstruction
  - Study of the selected tracks to identify possible improvements in the method
  - Study of the differences in the two cases ICARUS/Gaus hits
- This analysis has been performed with a very old reconstruction code version
  - A new full simulation of cosmic events with different values of the electron lifetime and reconstructed using the most recent version of the icaruscode is needed and it will be done as soon as possible;
- The use of additional information, for example from the CRT, should be also studied;

Analysis of the first events from MCC1

- This first cosmic rays events prepared in the MCC1 (1000 events with τ_{ele} = 9.7 ms) have been analysed using the same code and provide similar results.

- On average 3 muon tracks per event selected as "good for purity"