Andrea Serafini

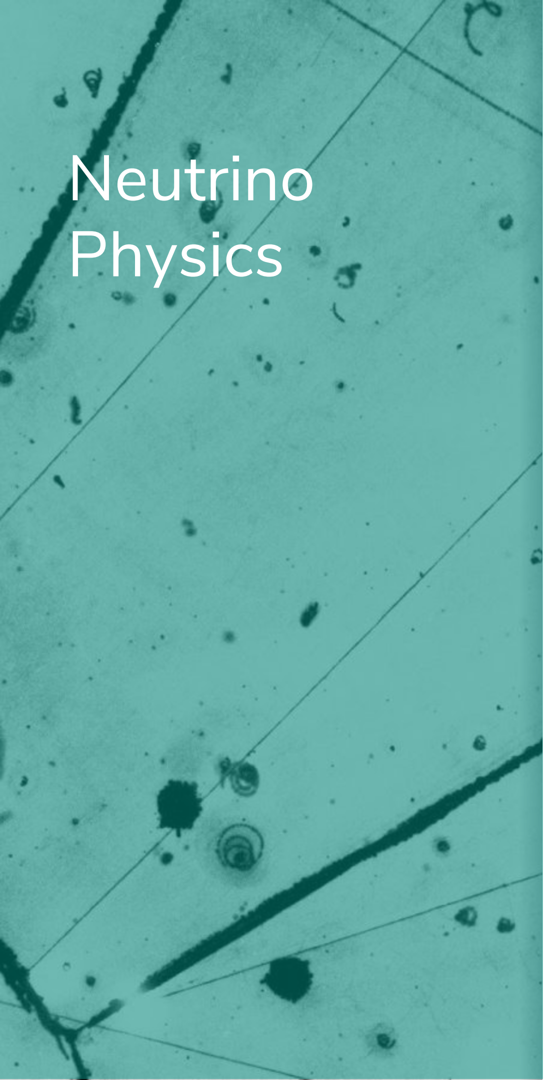
PRELIMINARY STUDY FOR LArTPC SYSTEMATIC ERRORS

1.

NEUTRINO PHYSICS

Let's start with a brief recap on neutrinos

Neutrino Physics

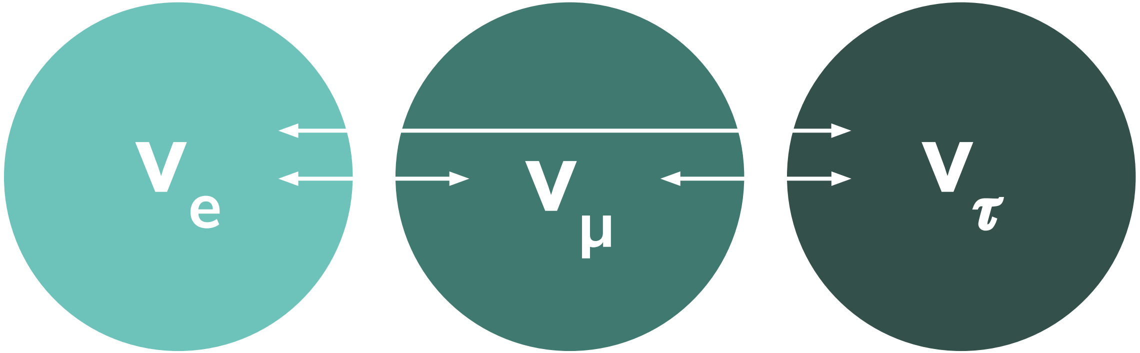


Neutrinos were introduced in Standard Model:

- Massless;
- Electrically neutral;
- Weakly interacting.

$| \nu_{mass} \rangle = \sum_i U_i \, | \nu_{flavour} \rangle$ where U is the PMNS matrix.

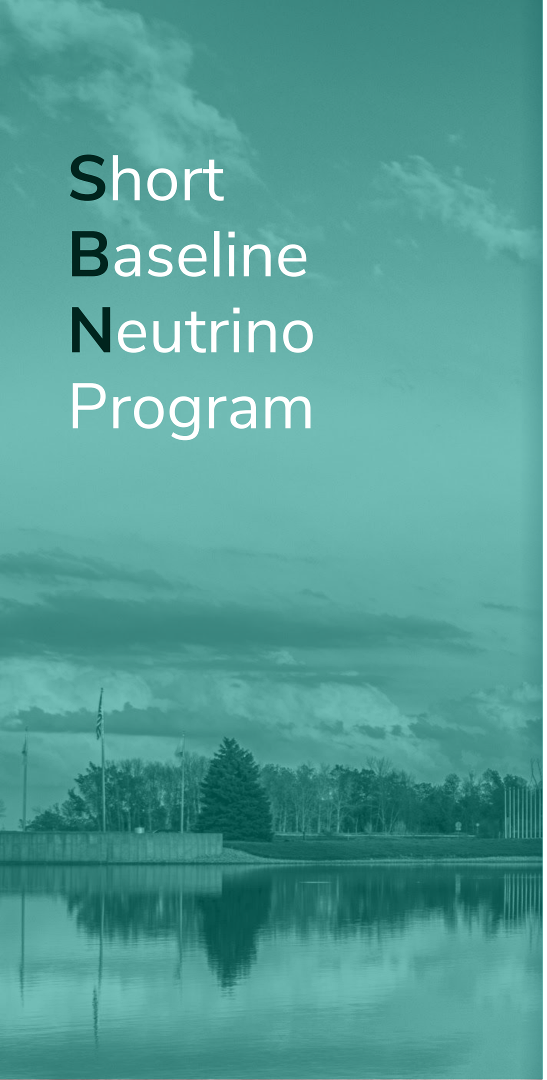
$P_{\alpha \to \beta} \sim \sin^2 (\Delta m^2 \cdot L/4E)$



2.

SBN PROGRAM

A brief introduction on the SBN collaboration



Short Baseline Neutrino Program

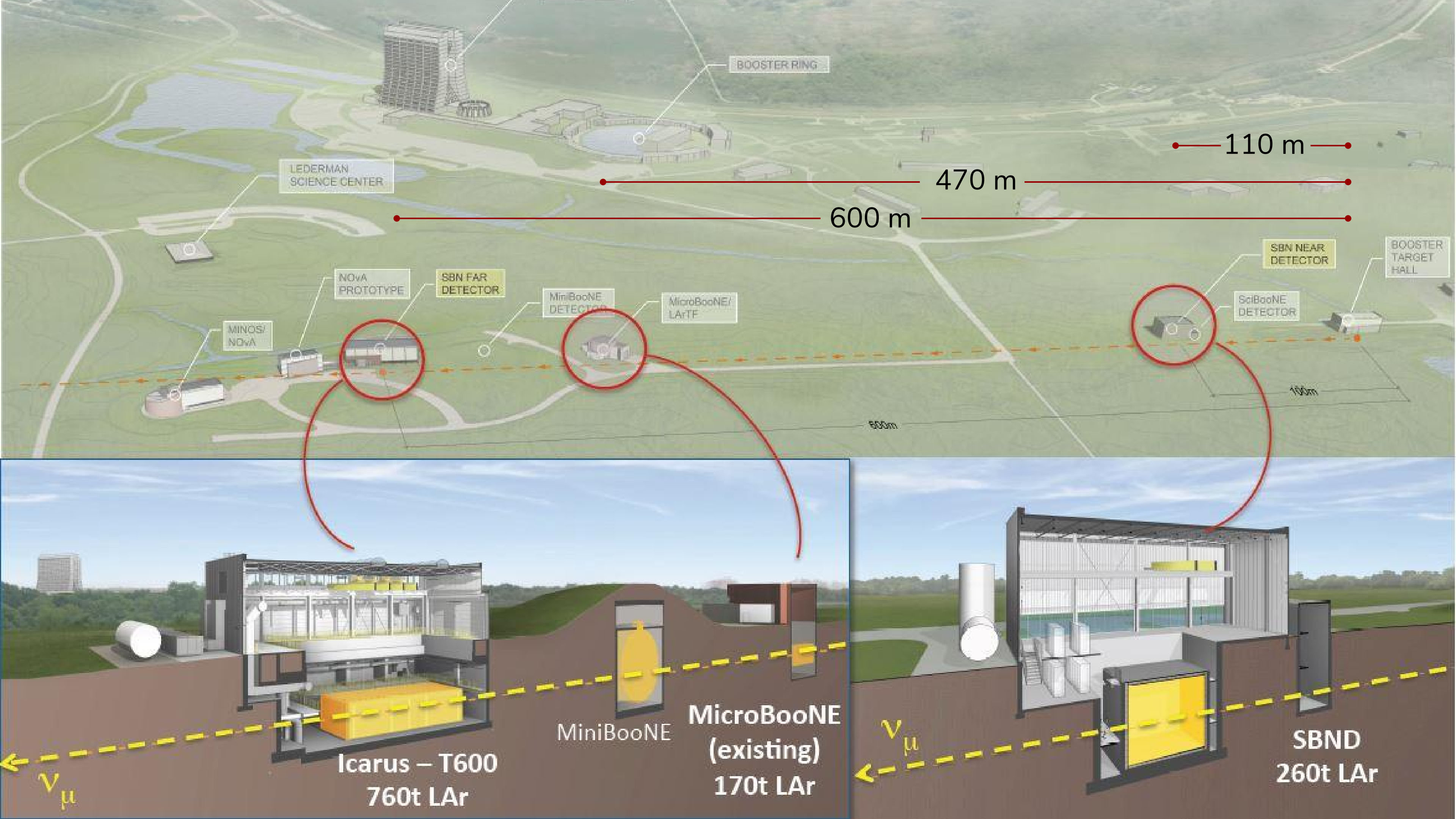
Anomalies in LSND and MiniBooNE suggest the possible existence of a 4th “sterile” neutrino. [1]

The SBN program aims at detecting non-standard ν oscillations by measuring ν_μ disappearances and ν_e appearances on short baseline. For ν_e appearance recognizing ν_e CC is crucial.

SBN program main physics goals are:

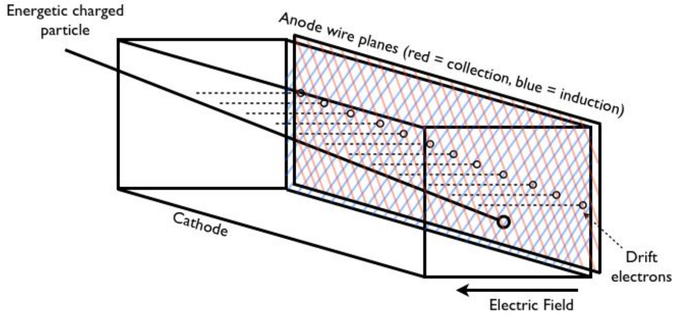
- Explain LSND and MiniBooNE anomalies;
  - Find their sources;
  - Confirm or rule out the existence of a sterile ν;
- Measure low-energy ν-Ar cross section;
- Help the development of the DUNE experiment.

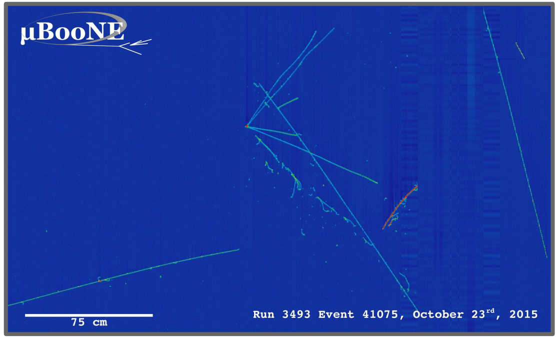
[1] LSND: Phys.Rev. D64 (2001) 112007 - MiniBooNE: Phys.Rev.Lett. 110 (2013) 161801



BOOSTER RING
LEDERMAN SCIENCE CENTER
110 m
470 m
600 m
SBN NEAR DETECTOR
BOOSTER TARGET HALL
SciBooNE DETECTOR
NOvA PROTOTYPE
SBN FAR DETECTOR
MiniBooNE DETECTOR
MicroBooNE/ LArTF
MINOS/ NOvA
ν_μ
Icarus – T600
760t LAr
MiniBooNE
MicroBooNE
(existing)
170t LAr
ν_μ
SBND
260t LAr

LArTPC Detectors





- Incoming charged particles ionise Argon
- An electric field guides electron through one or more induction plane towards a collection plane made of wires
- Wire and time coordinates of signals in each plane give the 2D trajectory
- A 3D trajectory is reconstructed matching all 2D projections

Neutrino Interactions

The way to identify ν_e appearances is to detect CC events, **identifying electrons** in the final state (discriminating them from NC π^0).

Electrons in liquid Argon usually **shower**, producing an electromagnetic cascade. $\pi^0 \to 2\gamma$ produced in NC neutrino interactions can produce similar signatures.

e^- can be distinguished from π^0 using:

- **Separation** of the shower from **vertex** of interaction;
- **Invariant mass**;
- Ionization in the first segment of shower (**1 MIP or 2 MIPs**).

⇒ A good understanding of **topology** and **calorimetry** is crucial to identify and analyse neutrino interactions.

Challenges

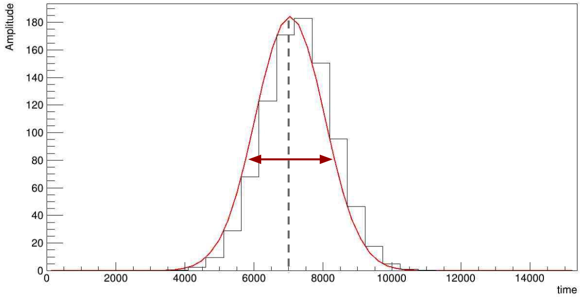
SBN Program: 3 detectors, same technology, different configuration

Same technology, different configurations:

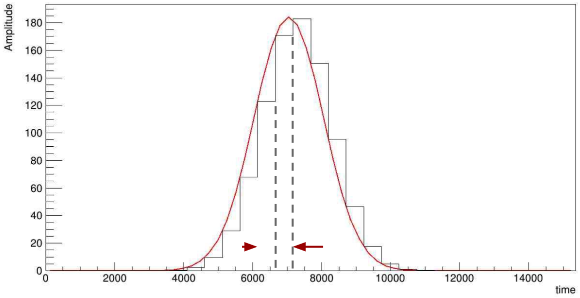
- Wires orientation;
- Electric field;
- Drift velocity;
- Liquid Argon purity;
- Light collection system & CRT;
- TPC readout electronics.

In particular for the readout electronics:

- **Preamp outside** the detector for ICARUS vs. **inside** for MicroBooNE/SBND.
- Detectors have different **shapers** (i.e. circuits that take signals from the detector, return amplified gaussian-like ones). **Shaping time** (time constant of the shaper) parametrize the differences among amplifiers.
- **Sampling** frequency of the digitizer is slightly different for the detectors.



Shaping time



Sampling time

3.
SIMULATION

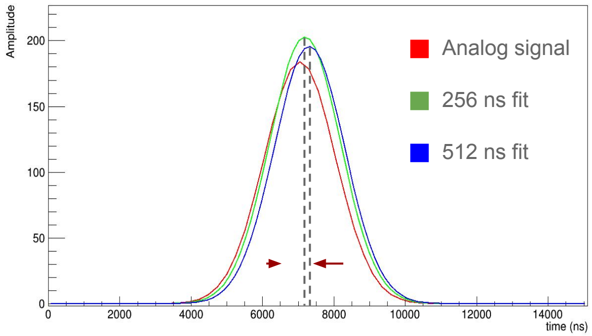
A simulation on sampling and shaping

Simulation

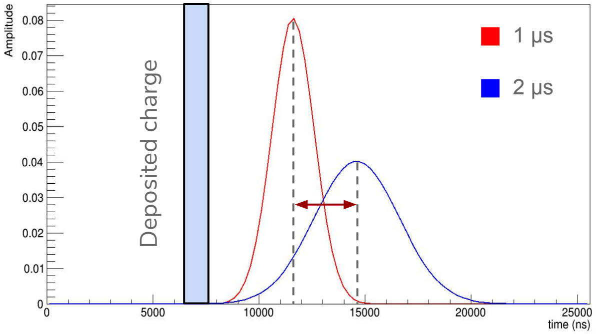
SAMPLING

Starting from a random gaussian signal, two **different samplings** are performed.

The output signal is then reconstructed using **gaussian fits.**



SHAPING

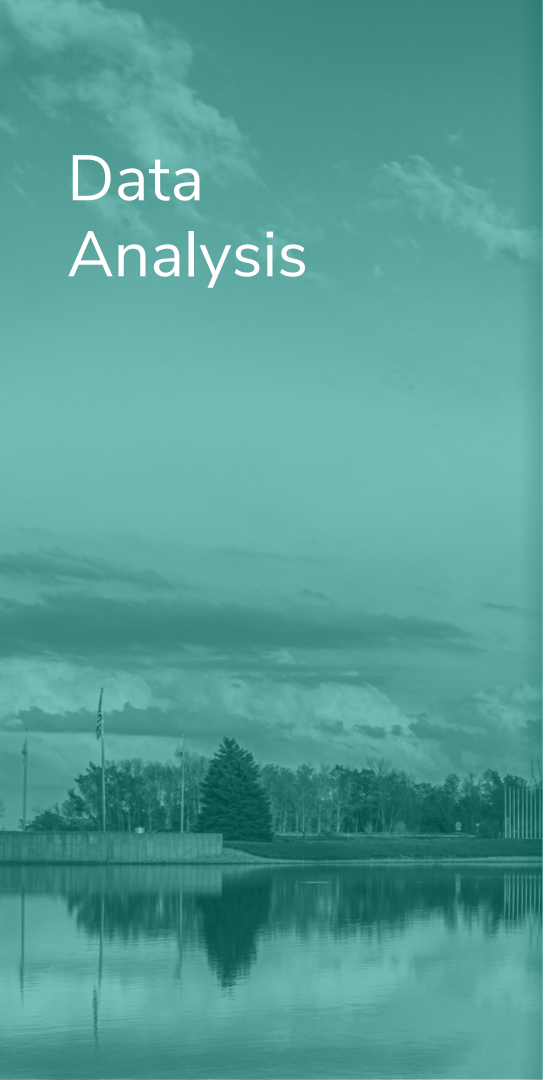


Given a **random** amount of **charge** deposited in time, two gaussian signals with **different shaping** times are generated.

The signal is then **sampled** and **reconstructed**

4.
DATA ANALYSIS

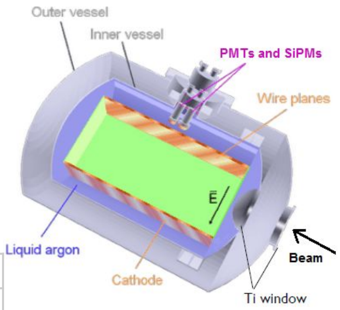
Data analysis and comparison with simulation results.



Data Analysis

To study the impact of electronics on data, an analysis on **topology** and **calorimetry** has been performed using **real data**.

Real data were taken from LArIAT experiment, because of its small volume (0.24 tons[2]) and negligible electrical noise.



		GAIN				
		0 (4.7mV/fC)	1 (14mV/fC)	2 (7.8mV/fC)	3 (25mV/fC)	
SHAPING TIME	0 (1.0 mics)	2691	225	202	336	3454
	1 (3.0 mics)	241	271	265	289	1066
	2 (0.5 mics)	226	1428	2004	278	3936
	3 (2.0 mics)	324	2151	839	839642	842956
		3482	4075	3310	840545	

For the sampling study, **750 tracks** have been selected at 256ns. The corresponding 512ns data set was obtained by software. A study **event per event** was possible.

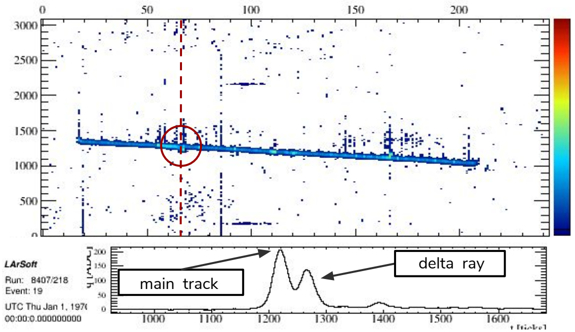
For the shaping study **30 tracks** at 1.0μs and 2.0μs have been chosen, both at 256ns. Therefore a **statistical study** was necessary.

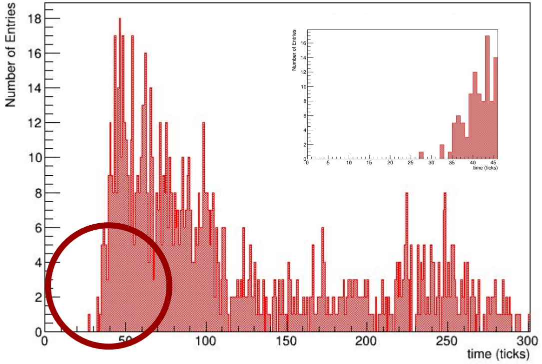
[2] LArIAT: Liquid Argon In A Testbeam: arXiv:1406.5560v3

Time Resolution
(sampling)

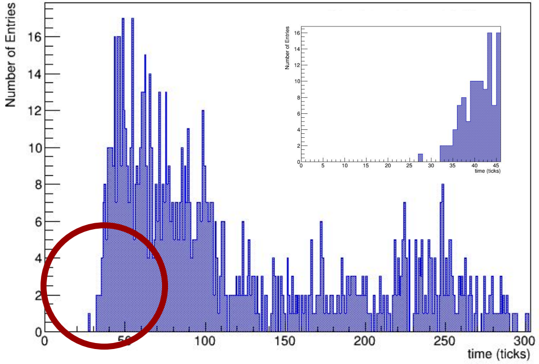
Time resolution is investigated by measuring the **minimum time difference** between hits in the same wire.

For sampling time **210 delta rays** have been analyzed.





256 ns sampling time



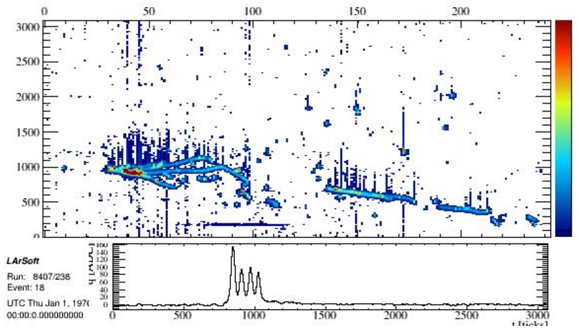
512 ns sampling time

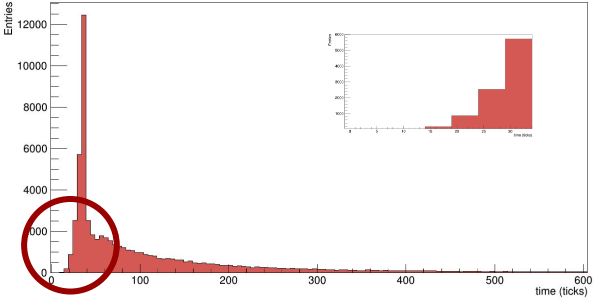
No visible difference

Time Resolution
(shaping)

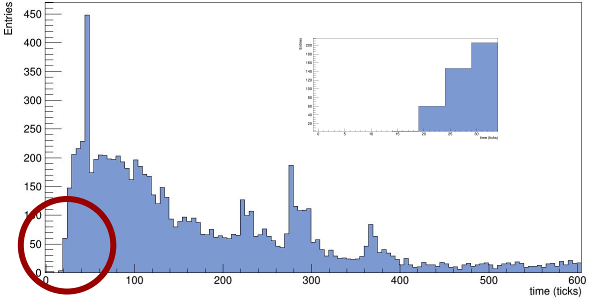
Time resolution is investigated by measuring the **minimum time difference** between hits in the same wire.

For sampling time **680 events** have been analyzed.





1μs shaping time



2μs shaping time

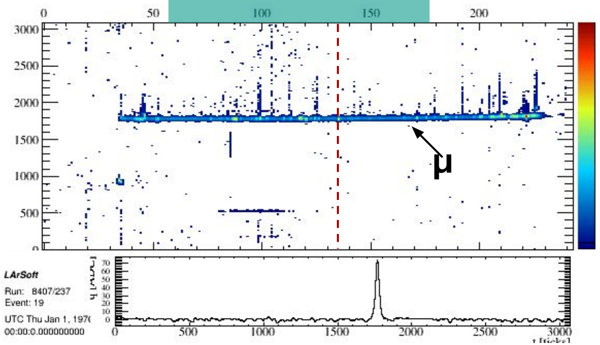
No visible difference

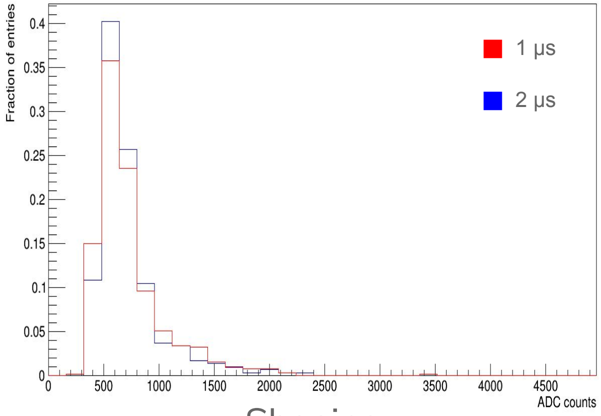
Calorimetry

Calorimetry is investigated by measuring the **total area under each hit**, which is proportional to the collected charge.

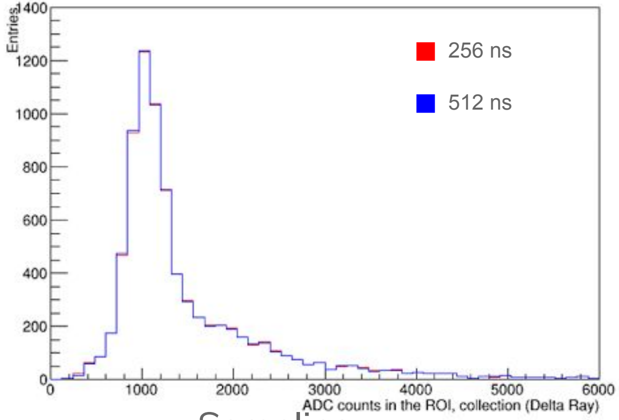
290 single tracks for sampling time and **30 single tracks** for shaping time have been analyzed.

Single track





Shaping



Sampling

No visible difference

SUMMARY

- **Topology** and **calorimetry not affected** by sampling and shaping parameters!*
- During the analysis lots of issues with analysis software (**LArSoft**) have been found

⇒ This will **help** software **development**.

Things I learned:

- **Neutrino** events **topology**;
- Basic concepts on **readout electronics**;
- **LArTPC** principles of operation.

Things I liked:

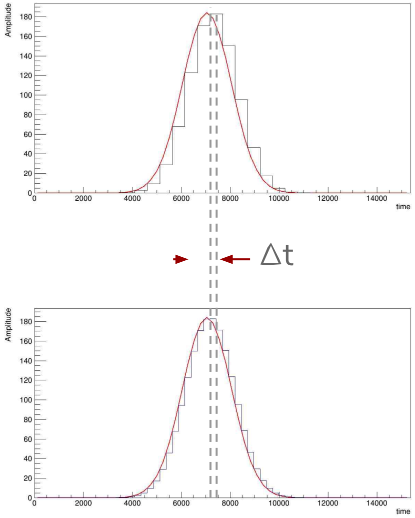
- **Neutrino physics**: neutrinos are one of the most mysterious topics of modern physics. Studies on them are, to say the least, intriguing.

Many thanks to **Raquel**, **Angela** and all the LArIAT people, who followed me in these months

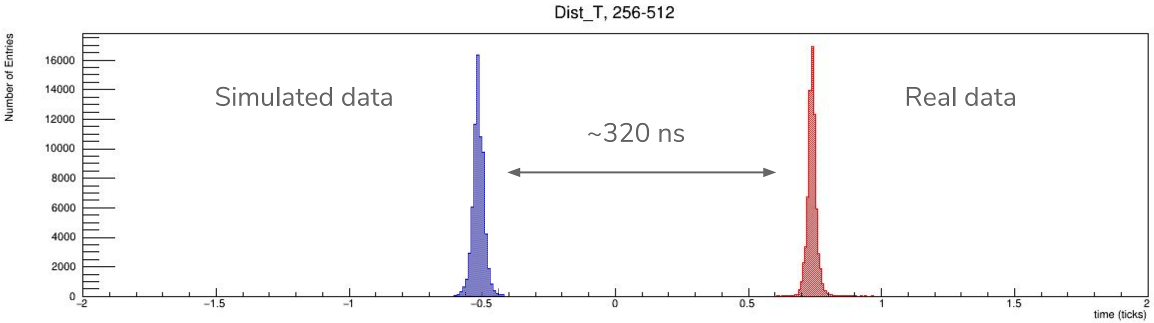
Thanks for your attention!

Peak Time
(sampling)

A new **“matching” algorithm** had to be developed, in order to associate each hit with the corresponding one for the other sampling time.



No significative difference has been found in real data(Δt < 256ns).

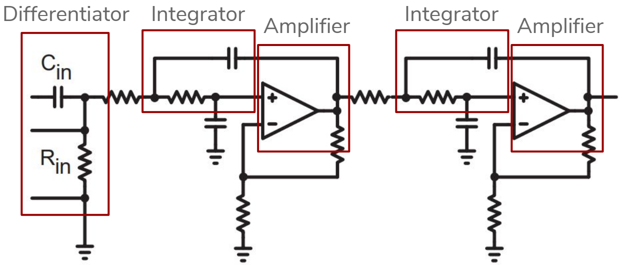


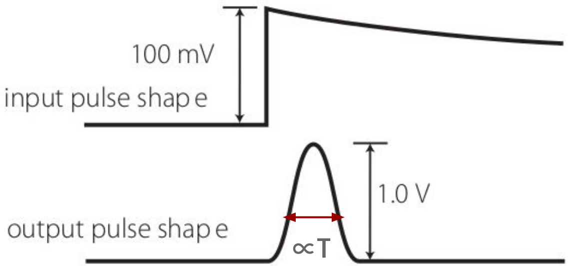
Shaping Time

The shaper takes the signal coming from the detector, **returning** an amplified and **gaussian**-like **signal**.

When integrating the signal over a certain period of time, most of the **white noise cancels out**.

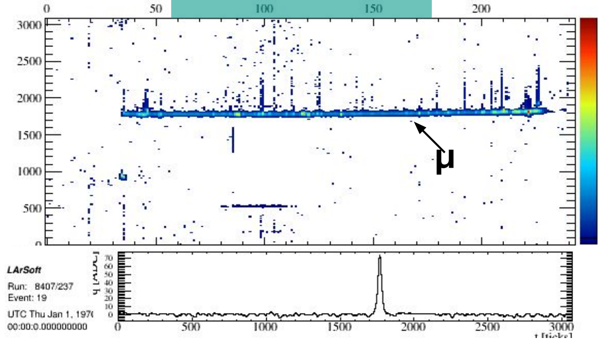
The time constant of the circuit is the shaping time.



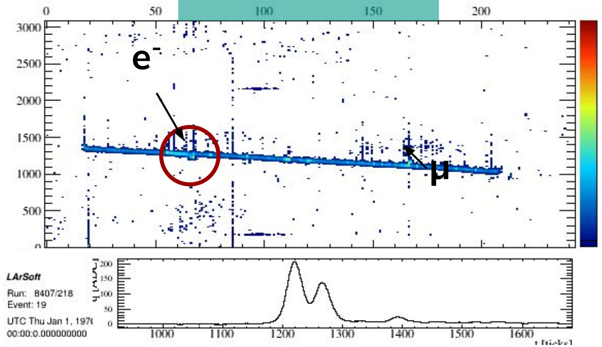


Events

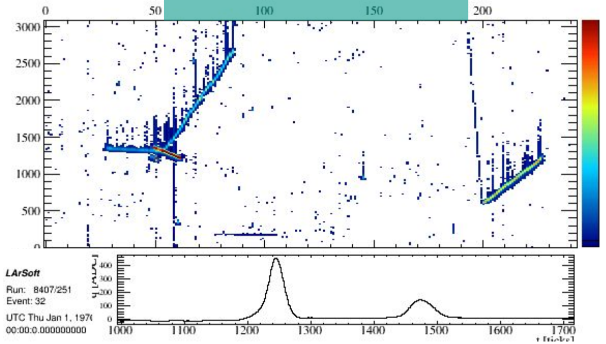
Single track



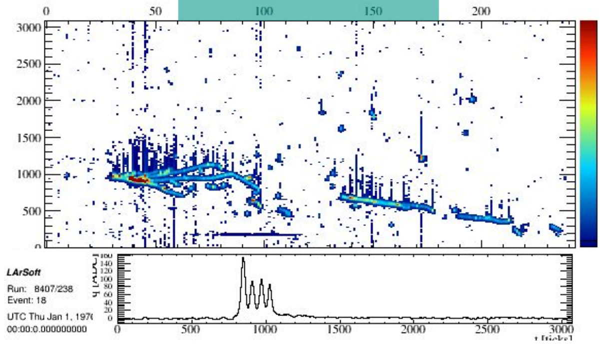
Delta ray



Multiple track



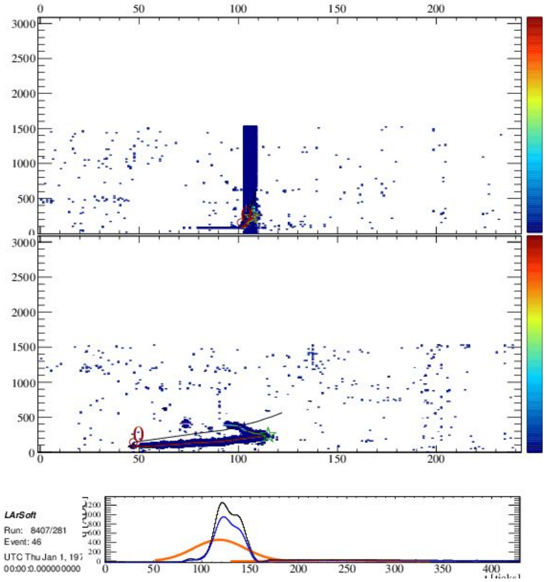
Shower

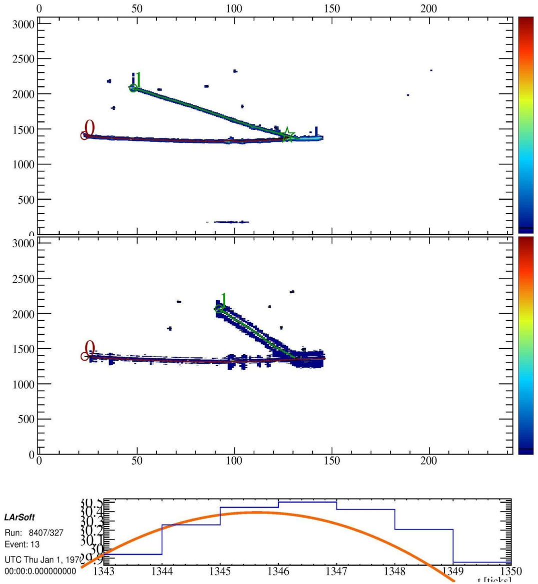


Problems

During this study it turned out that all differences were not due to different physical behaviour under different sampling times, but to problems with the fitting algorithm.

A global study on the data showed that this problem does affect both sampling times, confirming that sampling time seems not to affect the identification of hits.





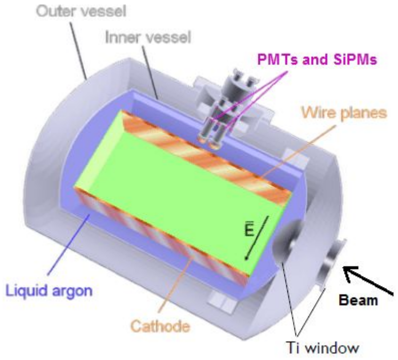
LArIAT

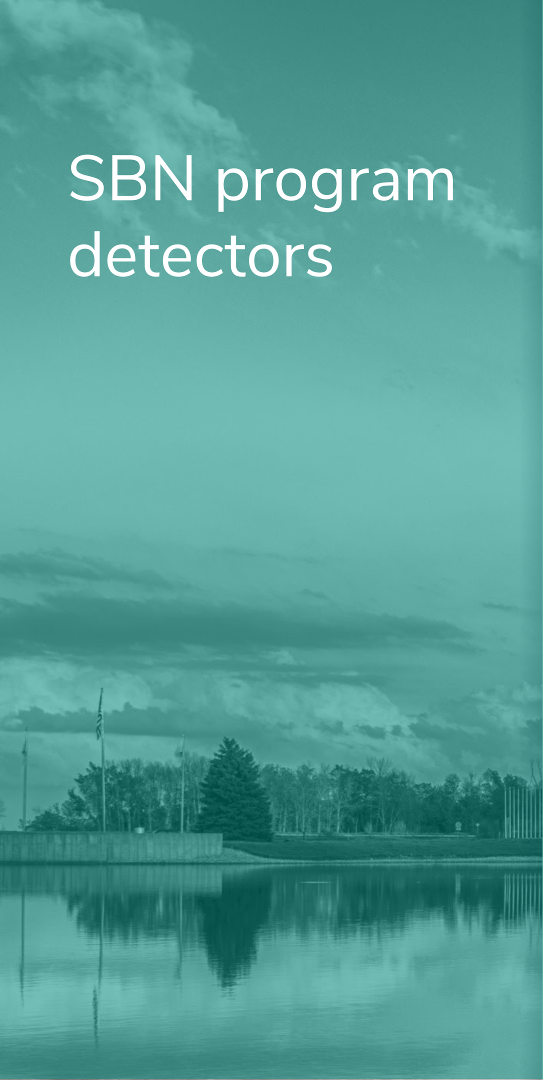
Background for neutrino experiments is **difficult to simulate**

The SBN collaboration chose to study **real data** from LArIAT.

LArIAT shares all the readout electronics with MicroBooNE and it is easier to study because of its **small volume**.

Electronic noise is **negligible** for LArIAT data, allowing to focus exclusively on electronics.





SBN program detectors

ICARUS T600

ICARUS is the farthest detector of the program.

It is composed by two semi-independent cryostats, holding 2 liquid argon time projection chambers each.

It is located at a distance of 600 meters from the neutrino source, where the sterile neutrino oscillation should be maximum.

It is the largest of the three detectors, with 500 tons of liquid argon in the active volumes.

ICARUS arrived from CERN on July 26 and is now under installation.

MicroBooNE

MicroBooNE is the central detector of the three.

Placed at a distance of 470 meters from the source it consists of a liquid argon time projection chamber, with 80 tons of liquid argon in the active volume.

It is located in the exact same place where MiniBooNE took place, in order to try to explain its anomalies.

The cryostat was filled in 2015 and the detector is currently operating; this data will produce neutrino cross section measurements, useful for future experiments, such as DUNE and the SBN program.

Short-Baseline Near Detector

SBND will be a 112 ton active volume liquid argon time projection chamber to be located only 110 m from the neutrino source.

The detector is currently in the design phase.

SBND will record over a million neutrino interactions per year. By providing such a high statistics measurement of the **un-oscillated** content of the booster neutrino beam, SBND is a critical element in performing searches for neutrino oscillations.

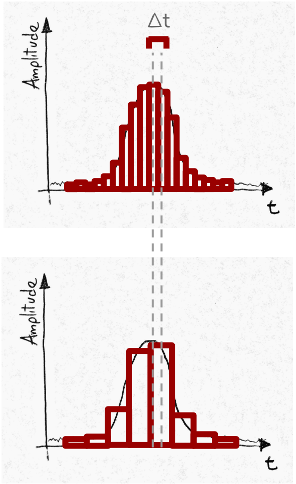
Peak Time

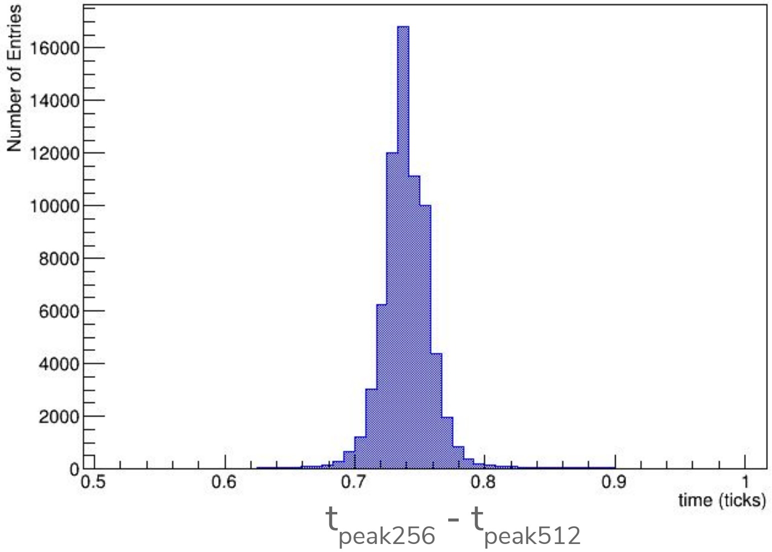
We proceeded studying how the sampling time could affect the identification of the peak time.

In order to do this we compared hit by hit two sets of data for through-going clean muon tracks.

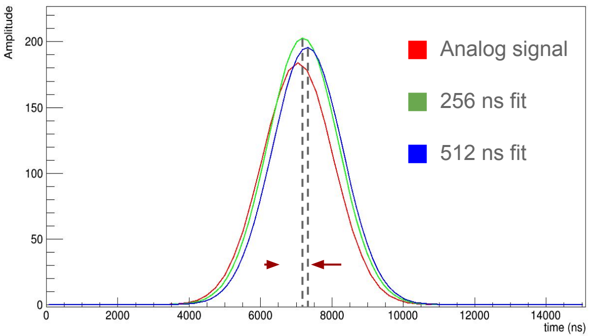
A new “matching” algorithm had to be developed, in order to associate each hit with the corresponding one for the other sampling time.

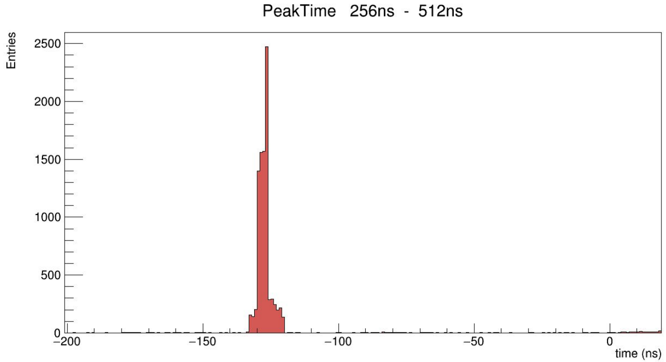
No significative difference has been found ($\Delta t < 256\text{ns}$).

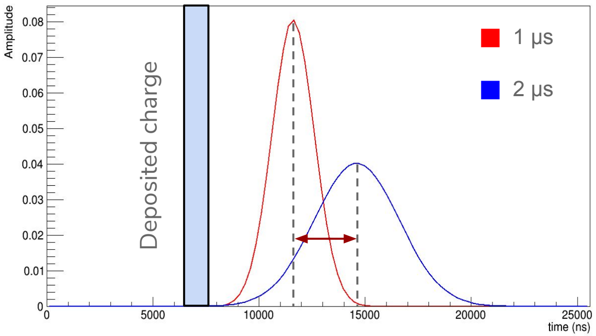


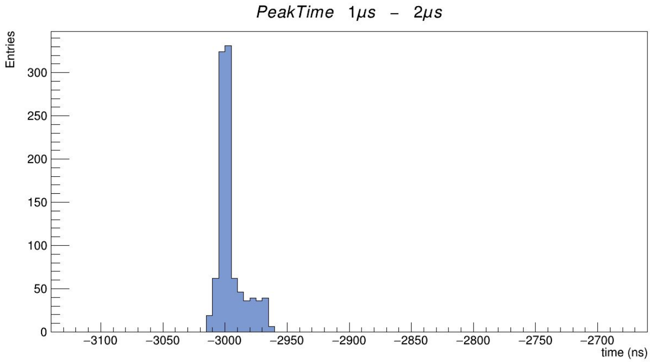


Simulation


Amplitude
time (ns)
Analog signal
256 ns fit
512 ns fit


PeakTime 256ns - 512ns
Entries
time (ns)


Amplitude
time (ns)
Deposited charge
1 μs
2 μs


PeakTime 1μs – 2μs
Entries
time (ns)

Peak Time

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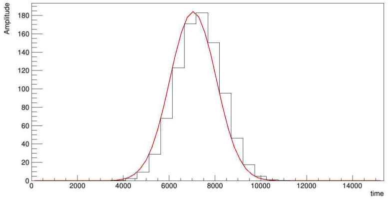
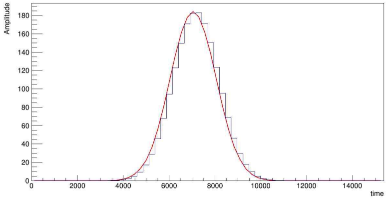
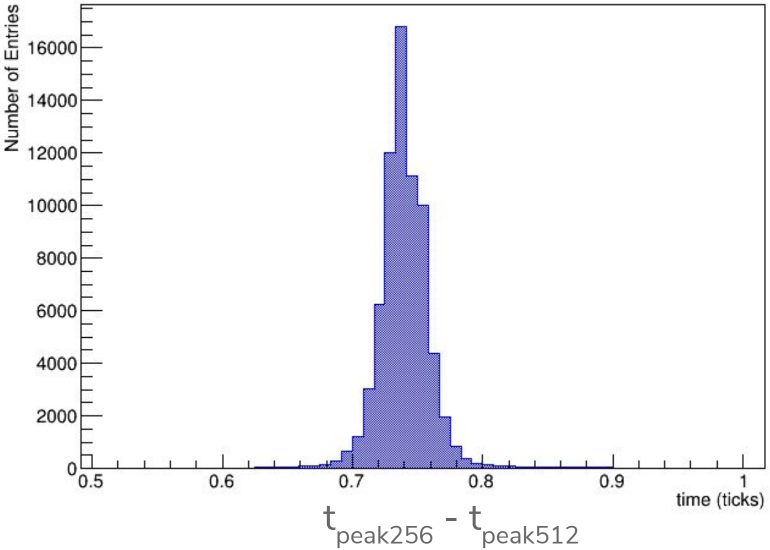
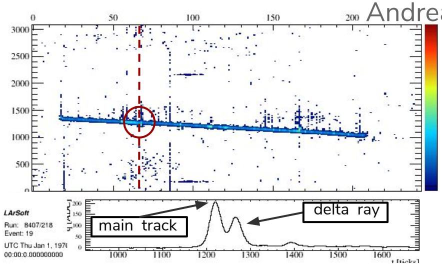






Time Resolution

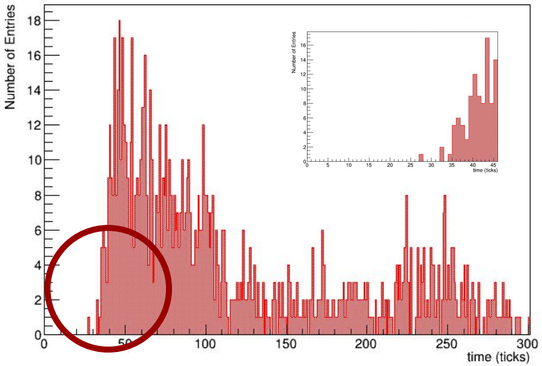
Delta ray events have been analyzed in order to understand the minimum discernable time distance between peaks.



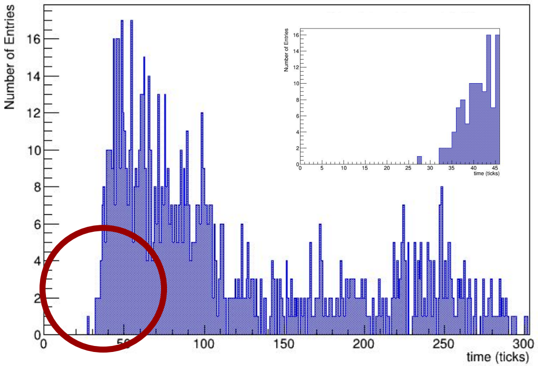
Although the behavior seems to be the same for both sampling times, plots differ for a small fraction of events.

A critical study of differences could lead to important knowledge on the behaviour of different electronics.

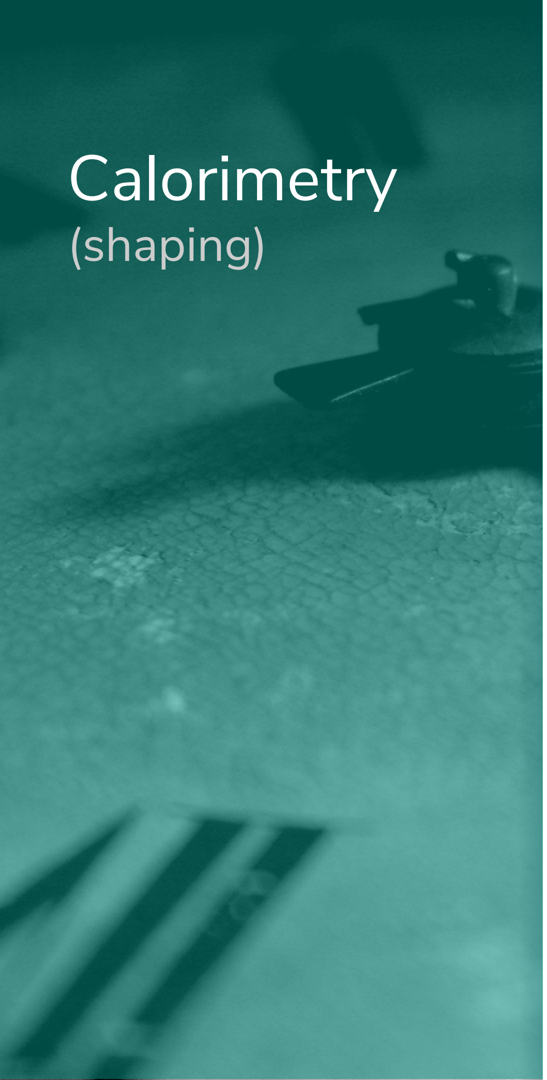
A event by event study was done in order to understand these differences.



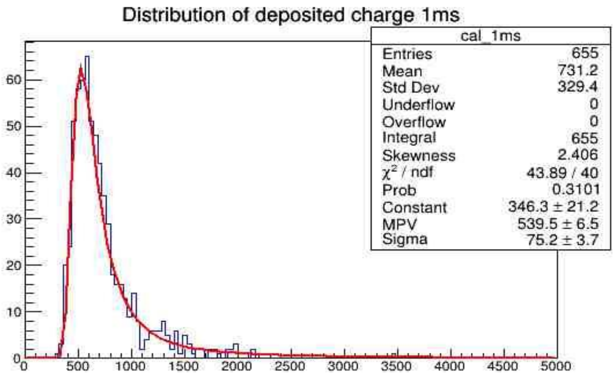
256 ns sampling time

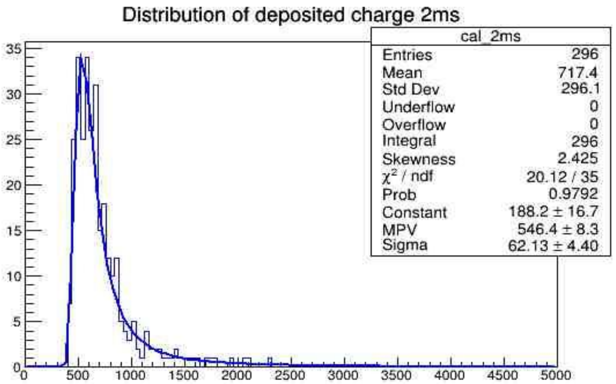


512 ns sampling time



Calorimetry
(shaping)





Fitted Deposited Charge
(normalized by hits)