Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

Final development and testing of the DAQ system for the ICARUS experiment

Federico Roccati
Supervisor: Wesley Ketchum

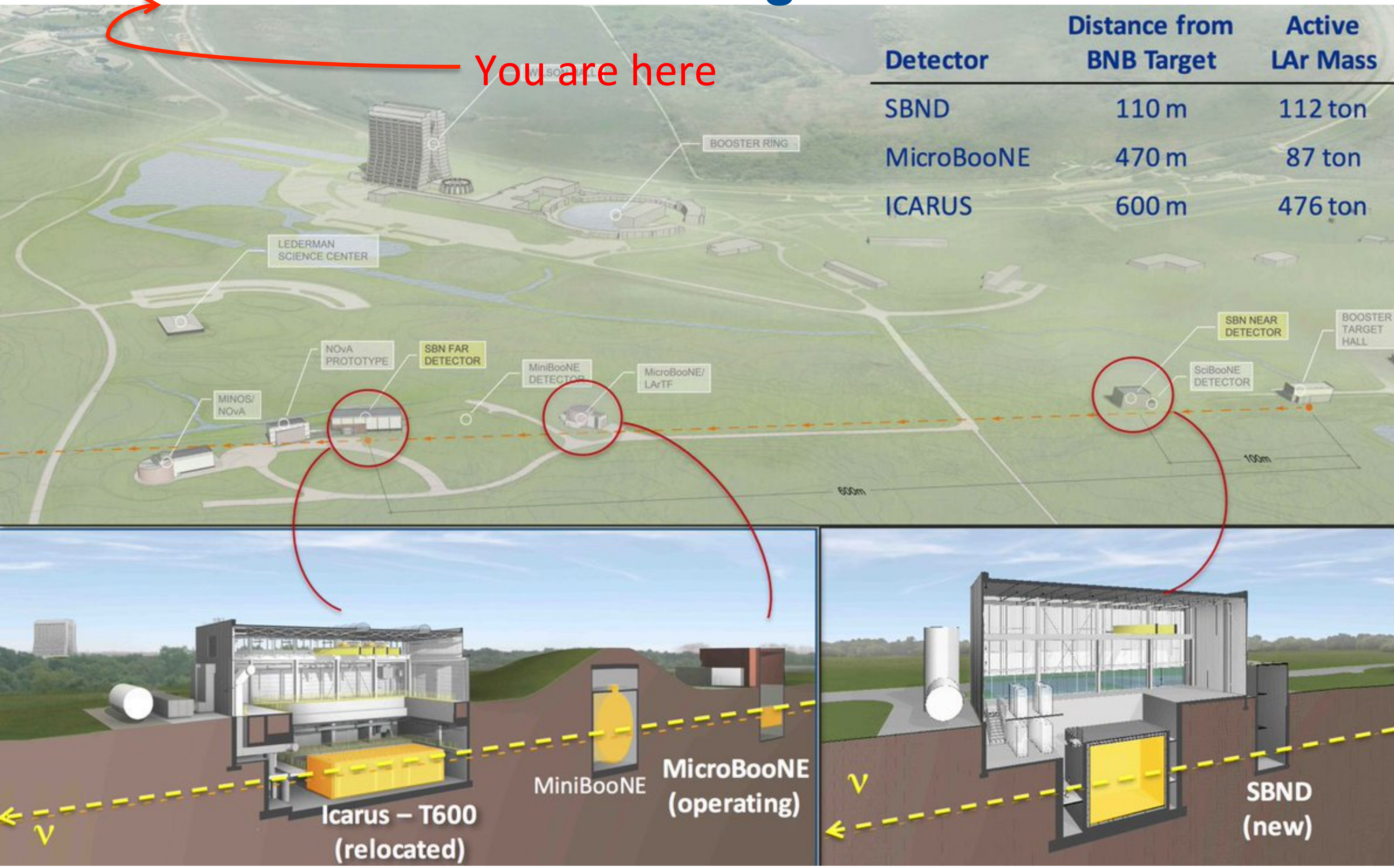
Final Presentation

September 27th, 2017

Short-Baseline Neutrino Program

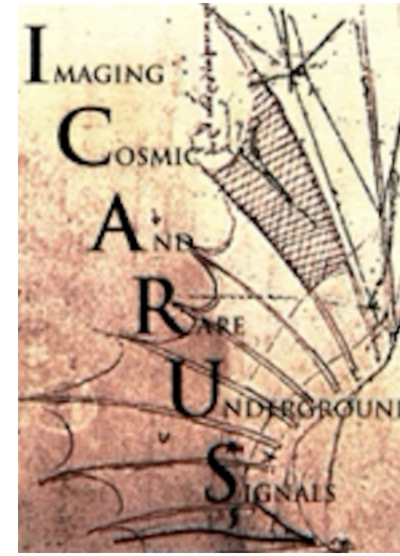
- Searches for ν_e appearance and ν_μ disappearance in the Booster Neutrino Beam (BNB)
- Motivation(s):
  - followup on the MiniBooNE low energy excess,
  - explore the phase space of short-baseline neutrino oscillations,
  - precision measurement of neutrino-argon interactions,
  - further develop the Liquid Argon Time Projection Chamber (LArTPC) technology.
- Setup:
  - BNB (muon neutrino beam)
  - Three detectors: Near Detector, MicroBooNE and **ICARUS**

Short-Baseline Neutrino Program

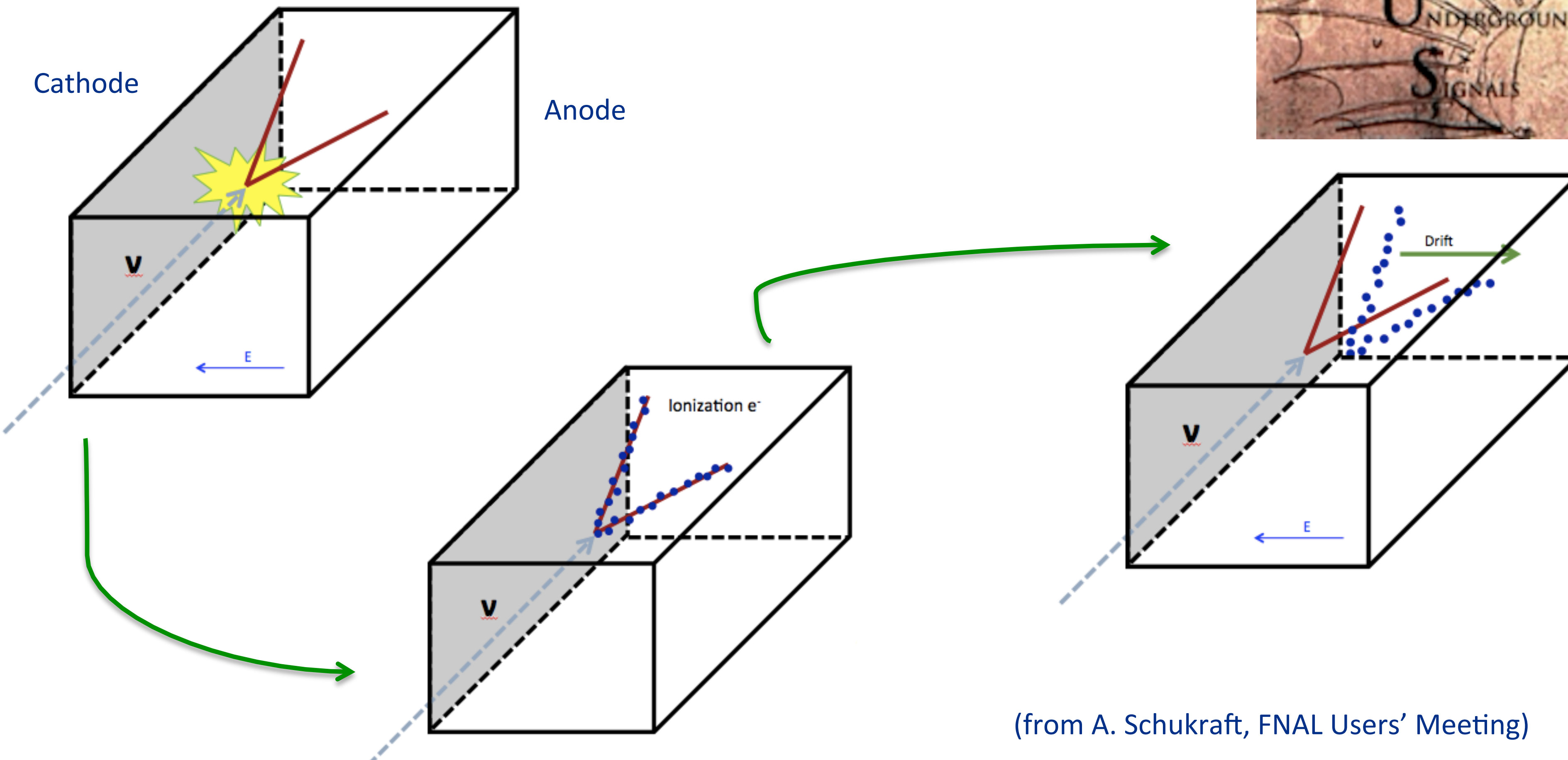


Detector	Distance from BNB Target	Active LAr Mass
SBND	110 m	112 ton
MicroBooNE	470 m	87 ton
ICARUS	600 m	476 ton

ICARUS detector



- 600 tons Lar-TPC
- Working principle:



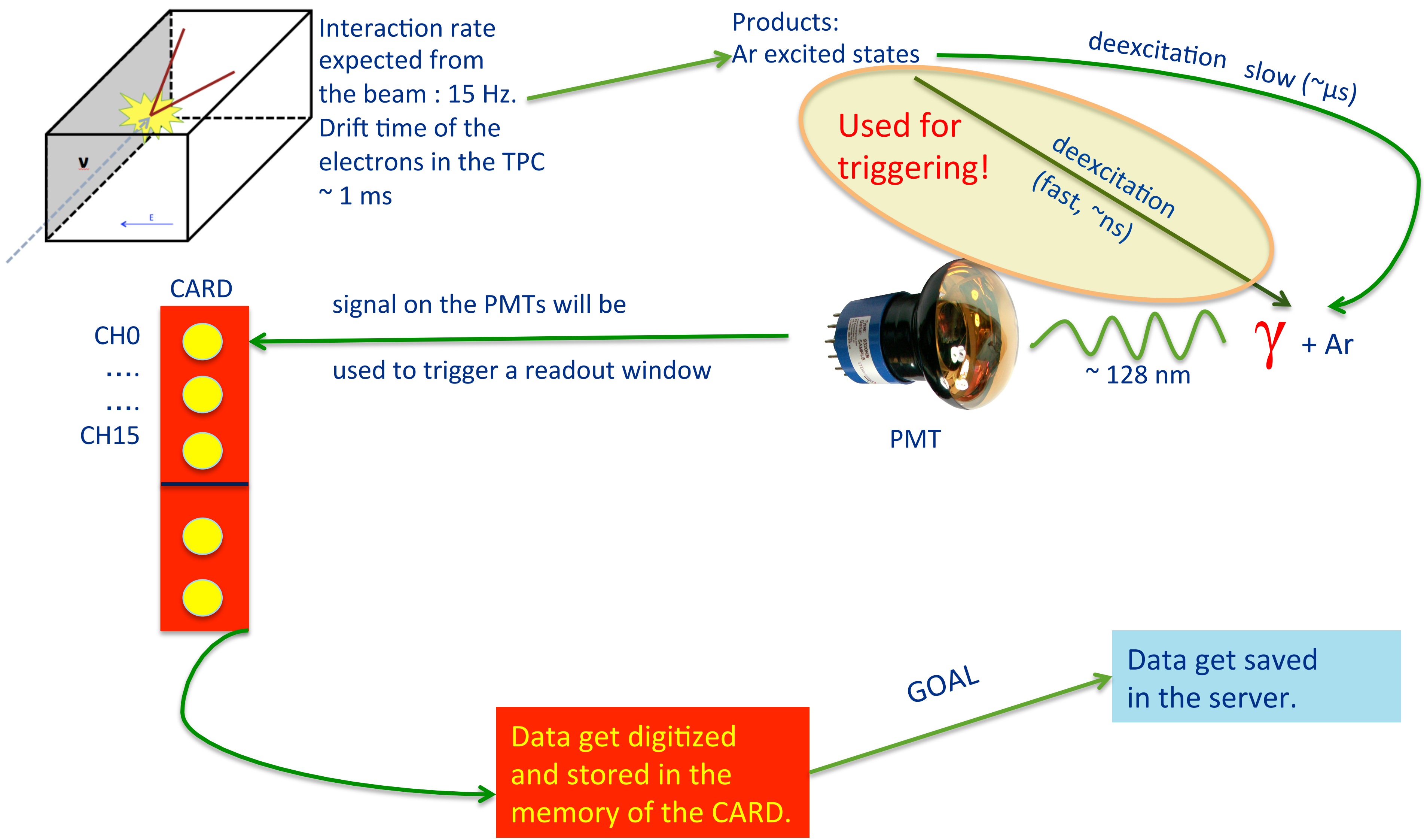
(from A. Schukraft, FNAL Users' Meeting)

Outline of the talk

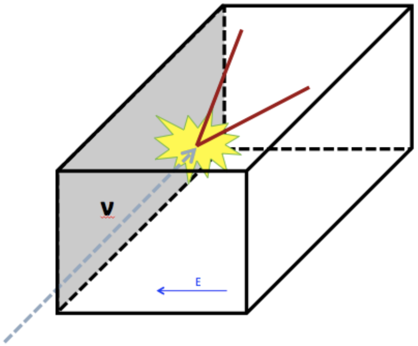
1. Data acquisition from the light readout system of the ICARUS experiment (summary)

2. Study of the timing of the DAQ system (new)

1. Light production in the detector volume



1. Light production in the detector volume



Interaction rate expected from the beam : 15 Hz.
Drift time of the electrons in the TPC ~ 1 ms

Products:
Ar excited states

deexcitation slow (~μs)

Used for triggering!

deexcitation (fast, ~ns)

γ + Ar

~ 128 nm

PMT

signal on the PMTs will be used to trigger a readout window

CARD

CH0
....
....
CH15

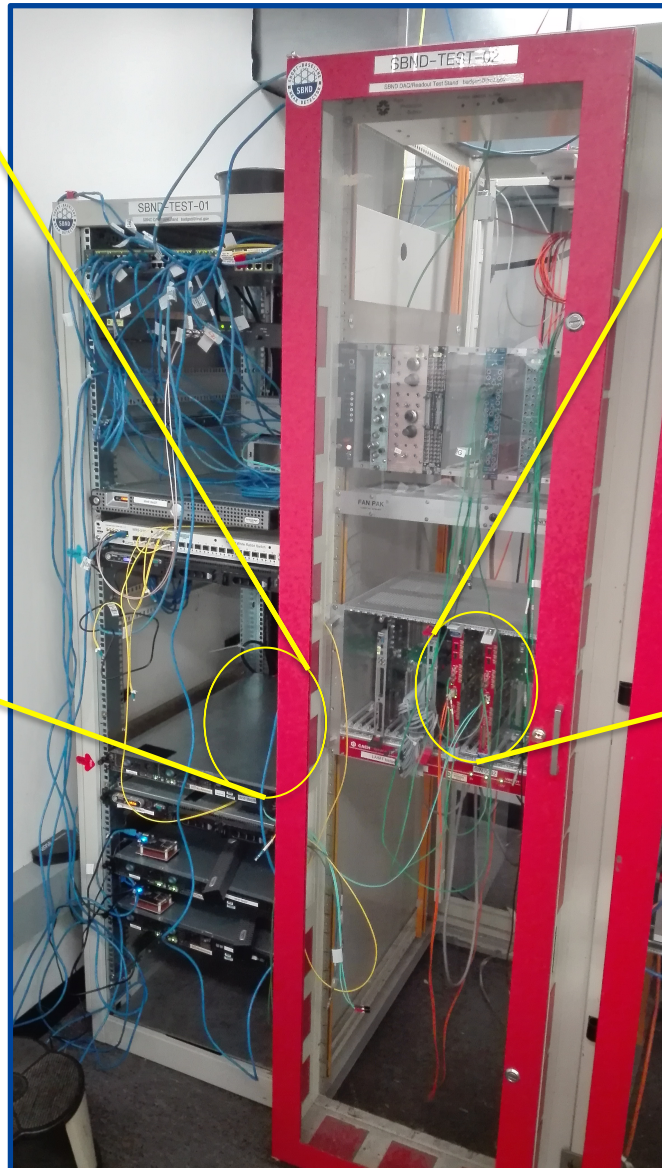
Me

Data get digitized and stored in the memory of the CARD.

GOAL

Data get saved in the server.

1. The test stand



sbnd-daq28 server (back)

CAEN V1730 16-channel waveform digitizer

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1. Operation mode throughout the measurements

- Acquisition window (following the BNB rate) into the S-IN channel: 15 Hz logic pulse with 2ms width (drift time of the electrons from the interaction point + some buffer to round up)

- Readout window into the TRG-IN to mimic the PMTs causing a trigger at 5 kHz

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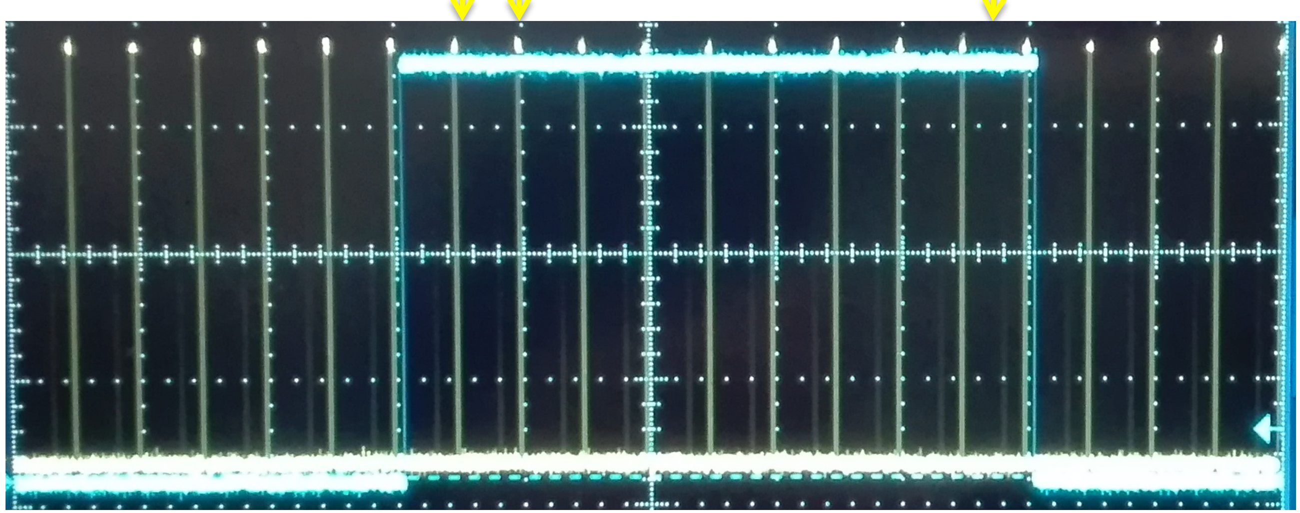
1. DAQ structure: goal

Goal (reminder): cast all these PMT events in one single TPC event

…



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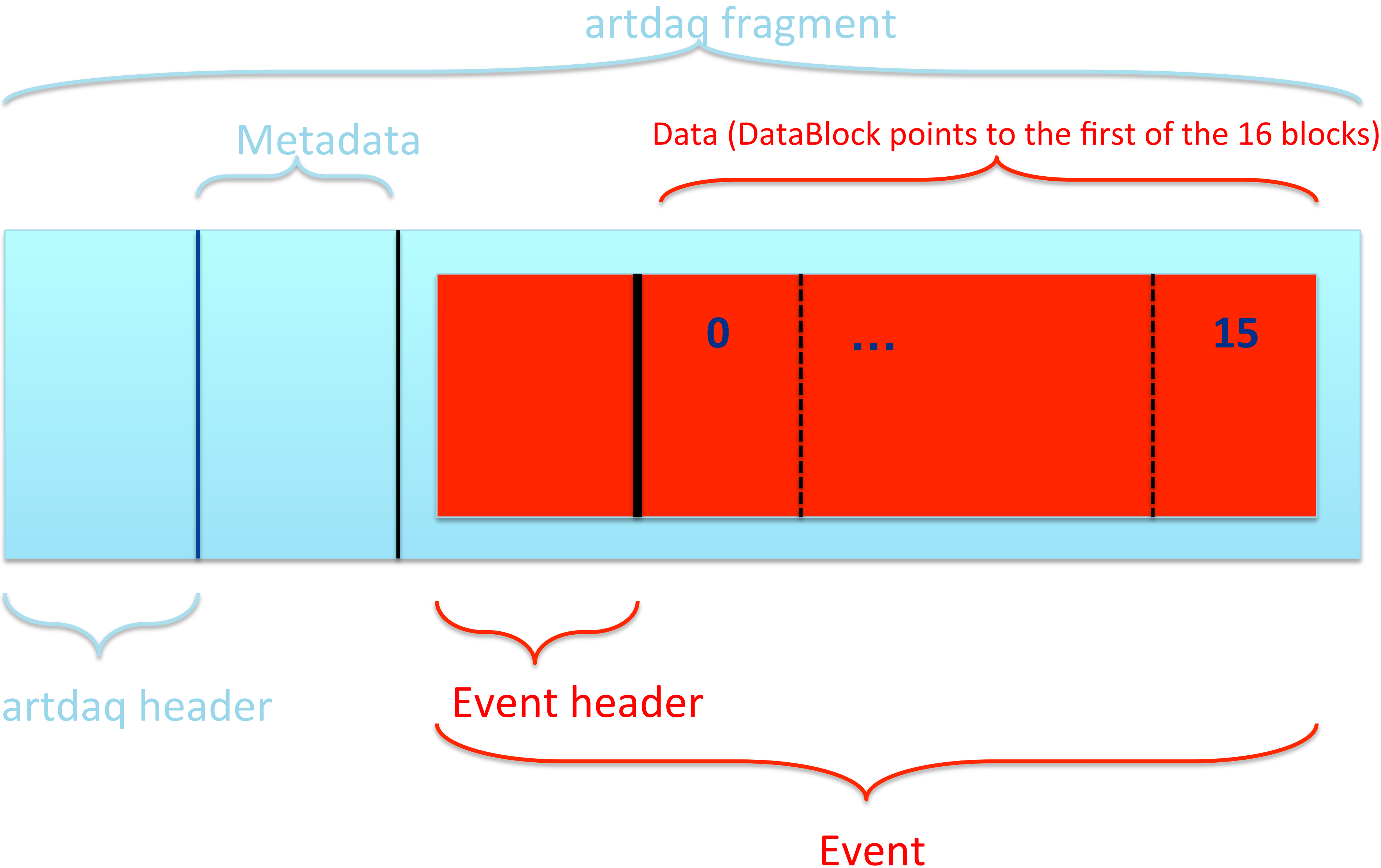
1. DAQ structure: data structure



1. DAQ structure: pseudocode

```
start_acquisition{
   set prev_eventcounter to 0
[…]
}
[…]
getNext_{
   Software/Hardware Trigger
   ReadData from the card

   if(there is no data) { return }
   Get number of PMT events (i.e. readout windows) in the amount of data read
   Create Metadata
   for(each PMT event){
      get its event counter from the header (it starts from 0)
      if(there are still readout windows to read){
         increment eventsize
         set prev_eventcounter to current eventcounter
         }
         else{
         create the fragment with the read data
         set prev_eventcounter to 0

   }
return
}
```

Outline of the talk

1. Data acquisition from the light readout system of the ICARUS experiment (summary)
   -> DONE!

2. Study of the timing of the DAQ system (new)

2. Goals

- Understand the timing of the DAQ
- Latency time, getNext time, time to read data
- The beam from the BNB is expected to be at 15Hz, so every 66 ms -> the DAQ code needs to be faster!

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- Note: All the measurements were conducted using a recordLength of 2000 (which means a readout time of 4 μs, considering that the sampling is at 2 ns/sample).
  This is done because it is enough to readout the slower component of the light produced after an interaction in the detector

2. Times of interest

- ReadData_NO_data = time from the start of getNext to the moment it knows there is no data to read
- ReadData time = time spent in the CAEN_DGTZ_ReadData function
- getNext time = time from the start of getNext to the first return statement

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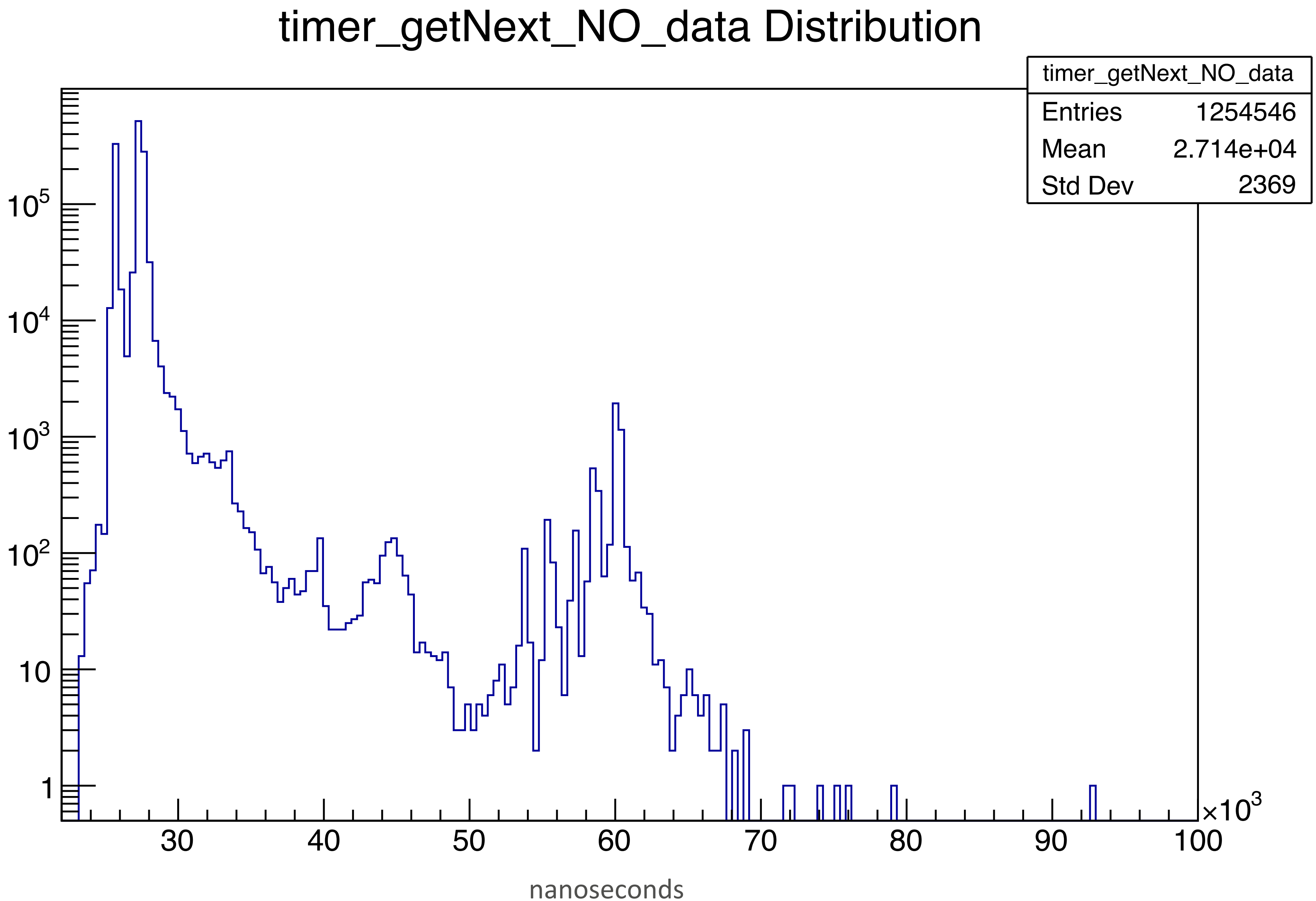
- getNext time = time from the start of getNext to the first return statement

-> why? Because when there is no data we don't want the DAQ to wait for long.
Everything should be dominated by the ReadData function (which is given)

2. Pseudocode (again, but with a different flavor..)

```
getNext call{
Start_getNext
Trigger
        start_ReadData
        CAENReadData call
        end_ReadData
                If(there is no data){
                        ReadData_NO_data = end_ReadData -  start_ReadData
                        time_getNext =       ReadData_NO_data
                        return}
        end_ReadData
        ReadData = end_ReadData - start_ReadData
        GetNumEvents
        Create Metadata
        Create fragment
        time_getNext = ReadData (+ time to write ReadData time in a file) + time_GetNumEvents +
                                        time_CreateMetadata + time_CreateFrag
        return}
```

2. Plots – NO data



2. Conclusion (when there's no data to read)

- At most they are ~100 µs -> OK!

- The DAQ code is fast enough

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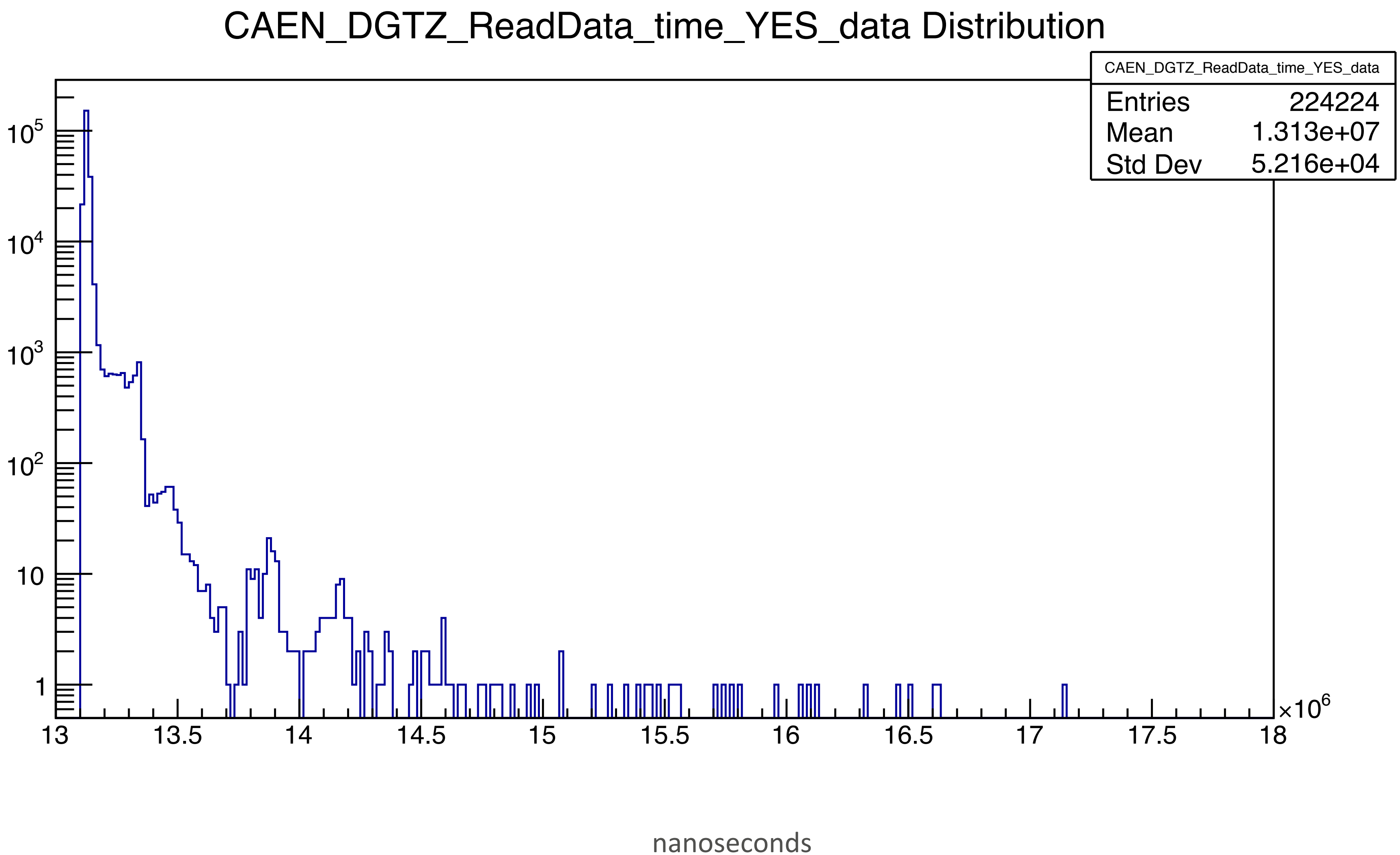
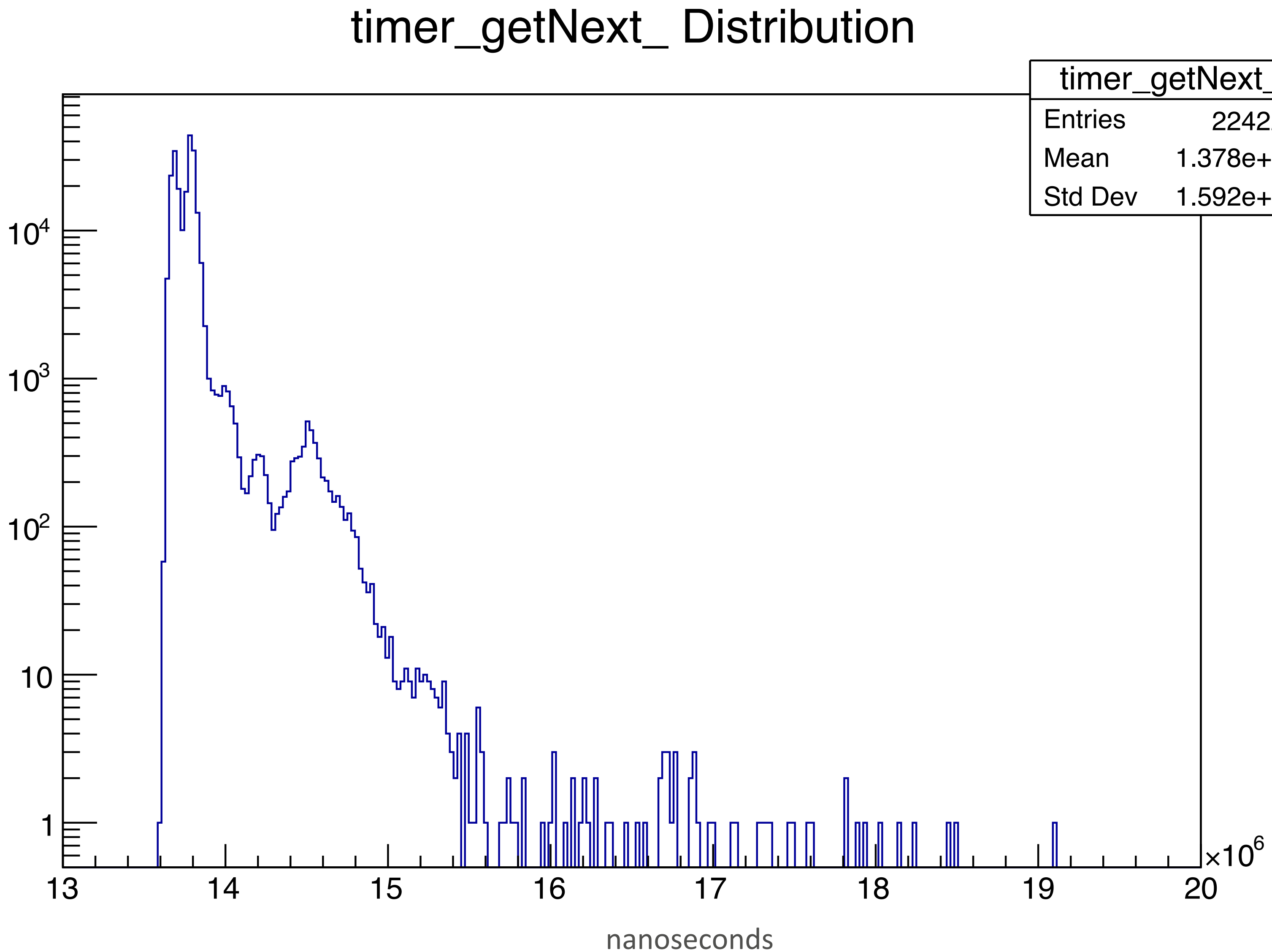
A DAQ:

2. Plots – YES data



2. Plots – YES data



2. Conclusion (when there’s data to read)

- Both ReadData time and getNext_ time increase by 3 orders of magnitude
- At most they are ~19 ms -> OK!

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- Both ReadData time and getNext_ time increase by 3 orders of magnitude
- At most they are ~19 ms -> OK! (can we do better?)

2. Future steps

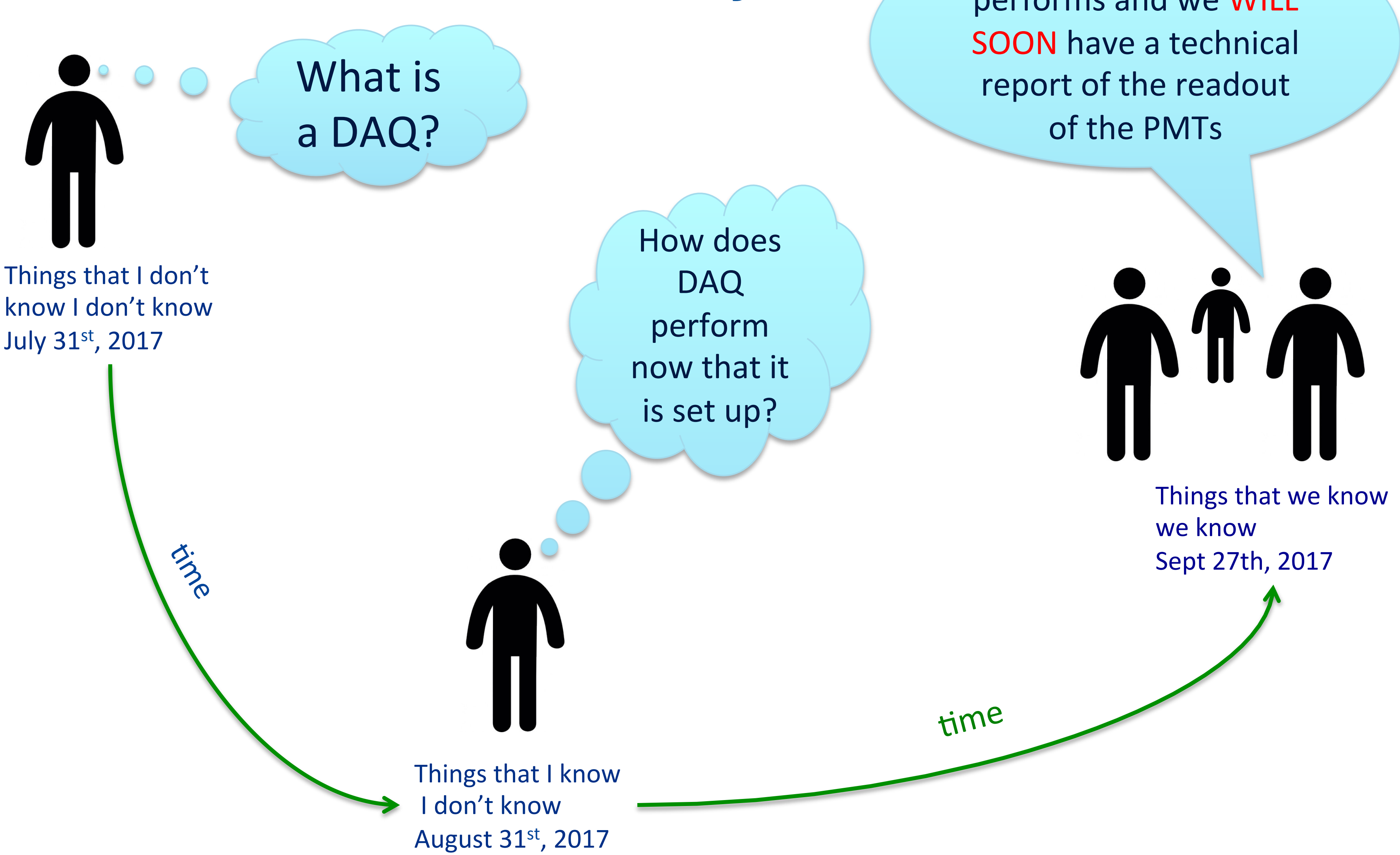
- 19 ms in the getNext_ function is not perfect
  -> we can surely improve what is done outside of the ReadData function

- For instance, avoid useless copy of data

- How does the timing change when we readout more signal, i.e. increase the recordLength?

- Computing the total bandwidth

As we were told the first day...



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Grazie
Thank you
Danke
Dziękuję
Ačiū
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1 26.09.17 Federico Roccati I MidTerm Presentation, FNAL