Supernova Data-Compression in MicroBooNE

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October 19th 2015

Outline

The MicroBooNE experiment

Continuous data-stream and the need for compression

The MicroBooNE data-compression scheme

Performance studies

Note: I will focus on the Monte-Carlo studies which I have been performing, but there is a lot of work on the development and firmware-implementation of this data-compression scheme performed by the rest of the Nevis electronics team.

The MicroBooNE Experiment

MicroBooNE is a 170 ton LAr TPC neutrino experiment which sits on the Booster beam at Fermilab.

MicroBooNE aims to:

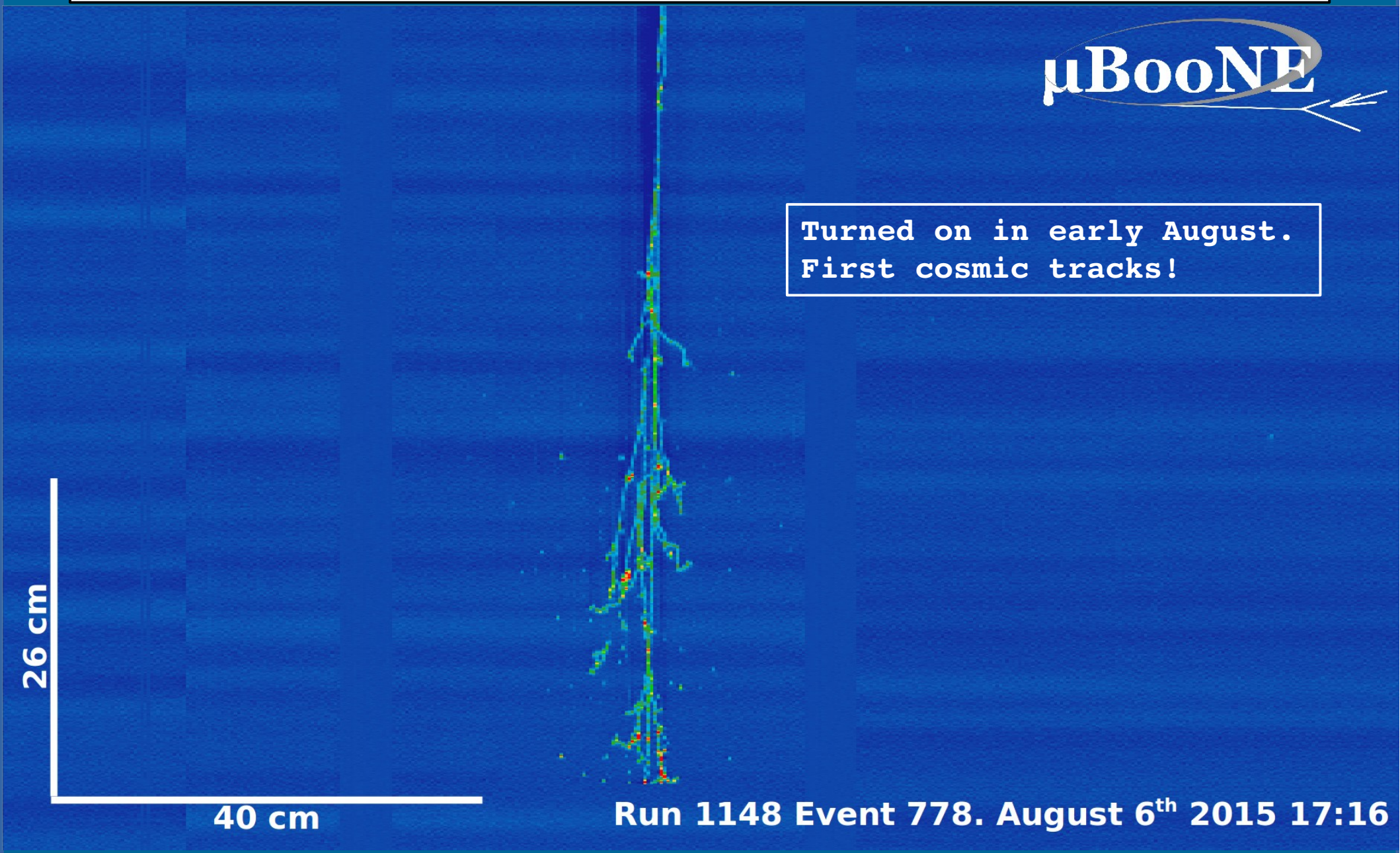
- investigate the MiniBooNE Low Energy Excess.

- perform ν-Ar cross-section measurements in the 1 GeV region.

- LAr neutrino detector technology R&D.

+ many more physics topics, including supernova neutrinos.

The MicroBooNE Experiment



MicroBooNE vs. DUNE

Continuous Data Stream

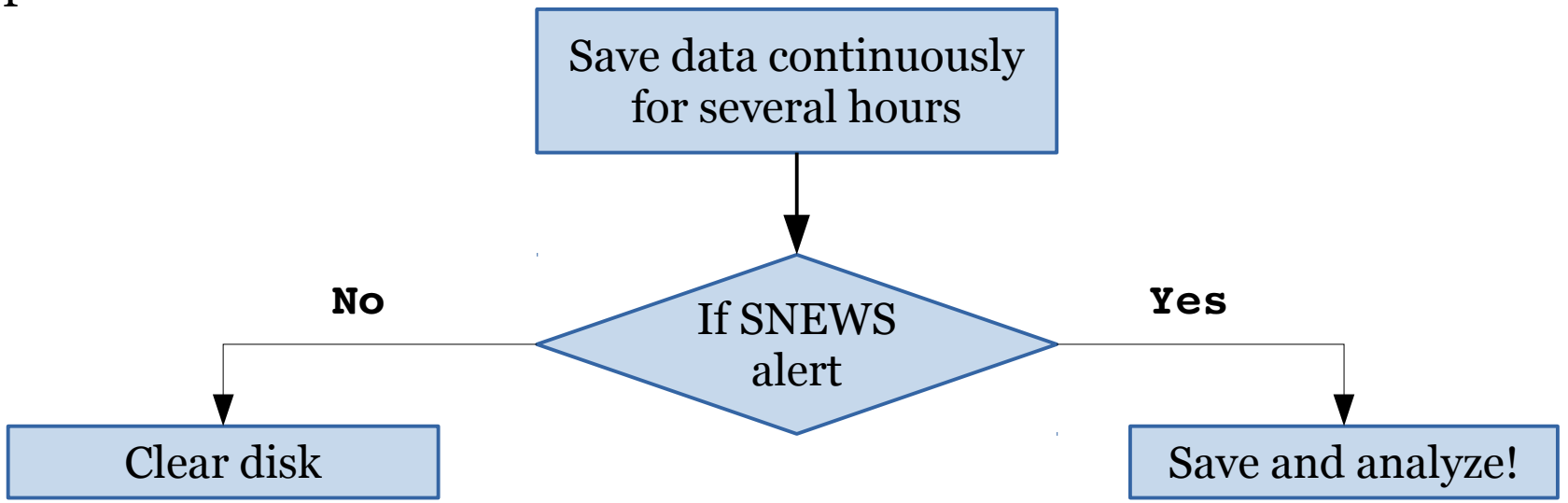
MicroBooNE is sensitive to supernova neutrinos...

...but we don't have a supernova trigger.

We expect to see O(10) neutrino interactions (10s of MeV) in a O(10 sec) time-span. Hard to trigger on with a surface detector.

Instead, we rely on the SuperNova Early Warning System (SNEWS), a trigger from larger experiments mostly used by telescopes around the world.

The plan:



Continuous Data Stream

What does it mean to save data continuously?

The MicroBooNE TPC Data:

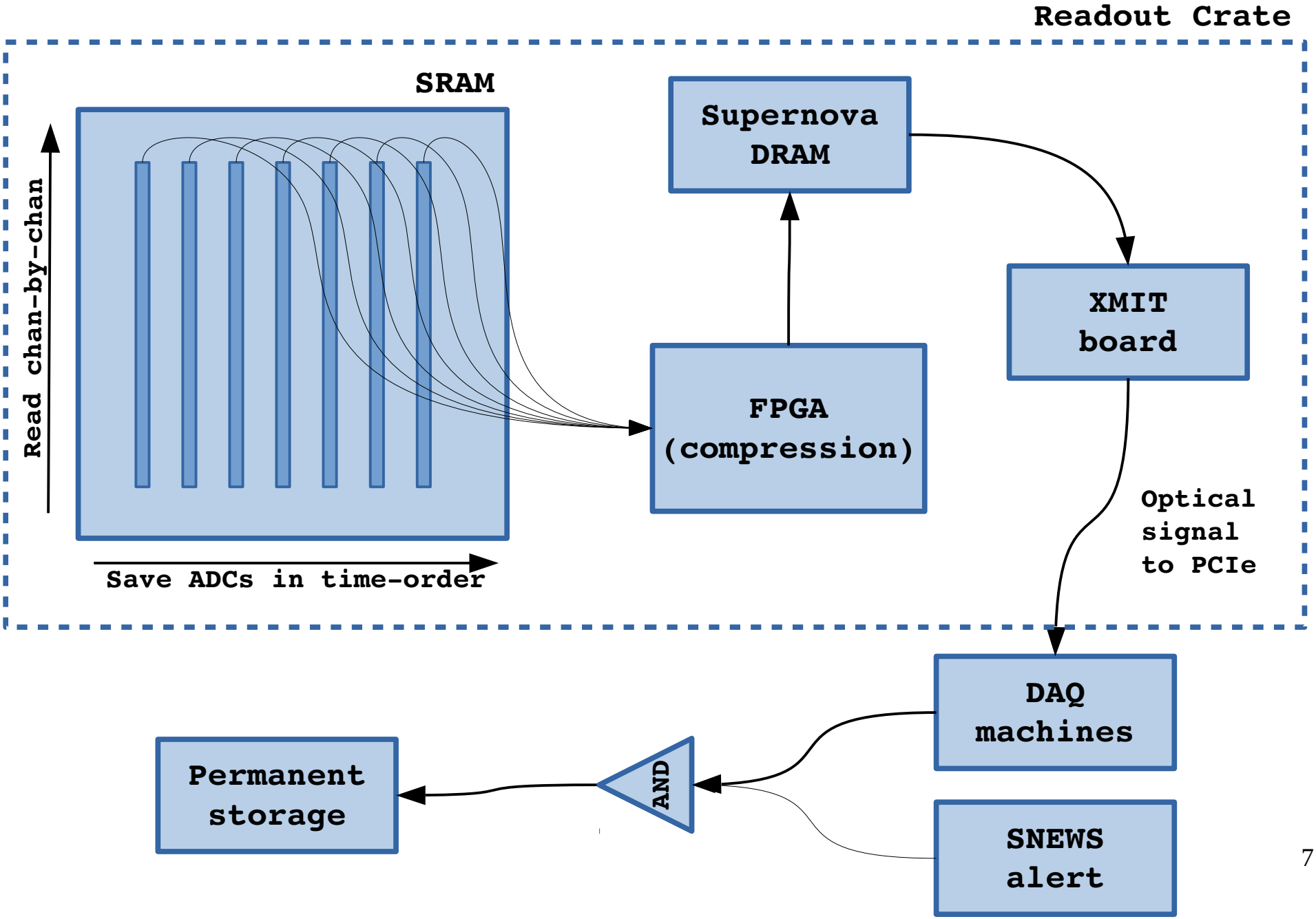
8256 wires on 3 planes
2 Bytes per sample @ 2 MHz sampling
→ 33 GB/sec.

Limited bandwidth → we need a compression factor of x80

How do we plan on achieving this?

Huffman compression is not enough.
→ use a lossy compression scheme

Continuous Data Stream



Continuous Data Stream - Physics Constraints

MicroBooNE's compression-scheme needs to efficiently save data associated with charge deposited by interactions from supernova neutrinos.

Supernova neutrino interactions in MicroBooNE: $\nu_e + {}^{40}\mathrm{Ar} \rightarrow e^- + {}^{40}\mathrm{K}^*$

Produce 10s of MeV e- and 1-3 MeV de-exitation photons.

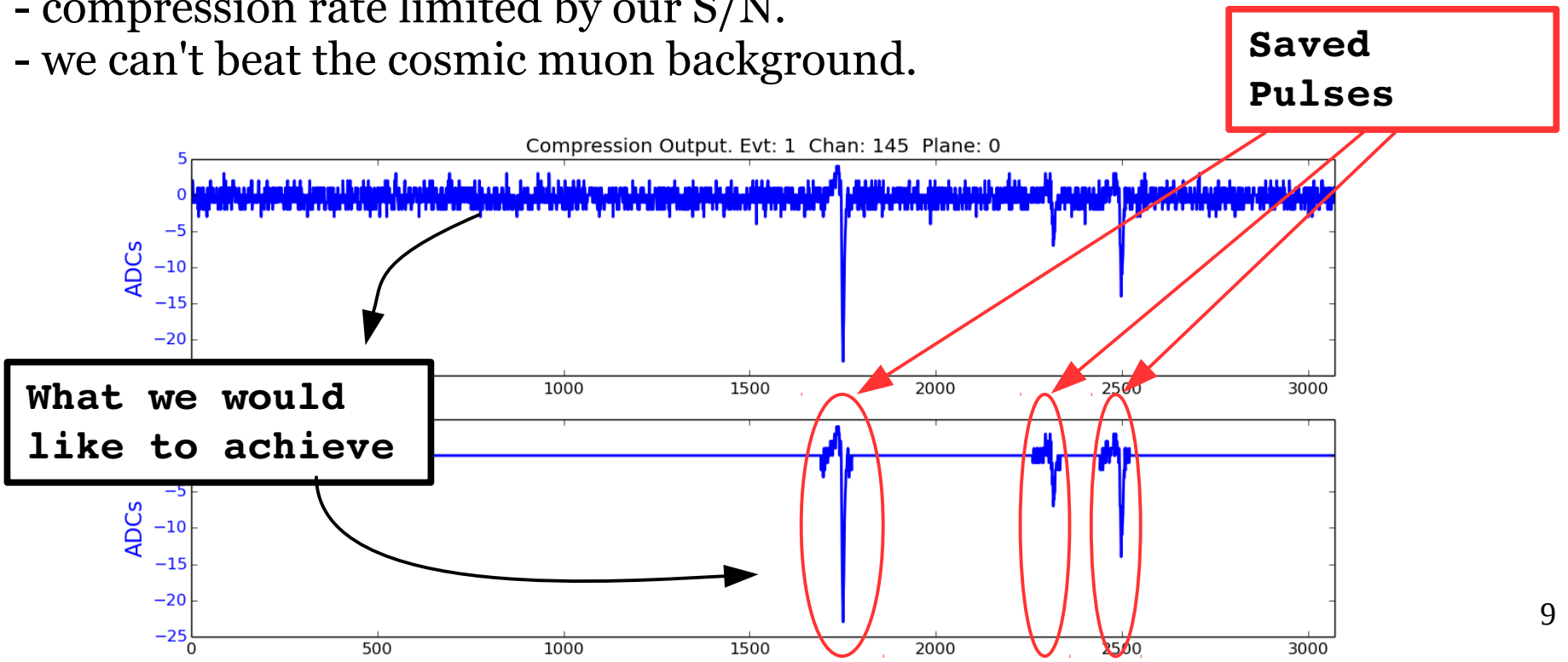
This means saving pulses from O(1-10 MeV) particles.

MicroBooNE Data-Compression Scheme

The goal is to limit the data-flow.

Do this by saving only a subset of the TPC data:
- remove quiet/noise regions of waveforms
- save pulses caused by drifting charge in TPC

General rules:
- compression rate limited by our S/N.
- we can't beat the cosmic muon background.

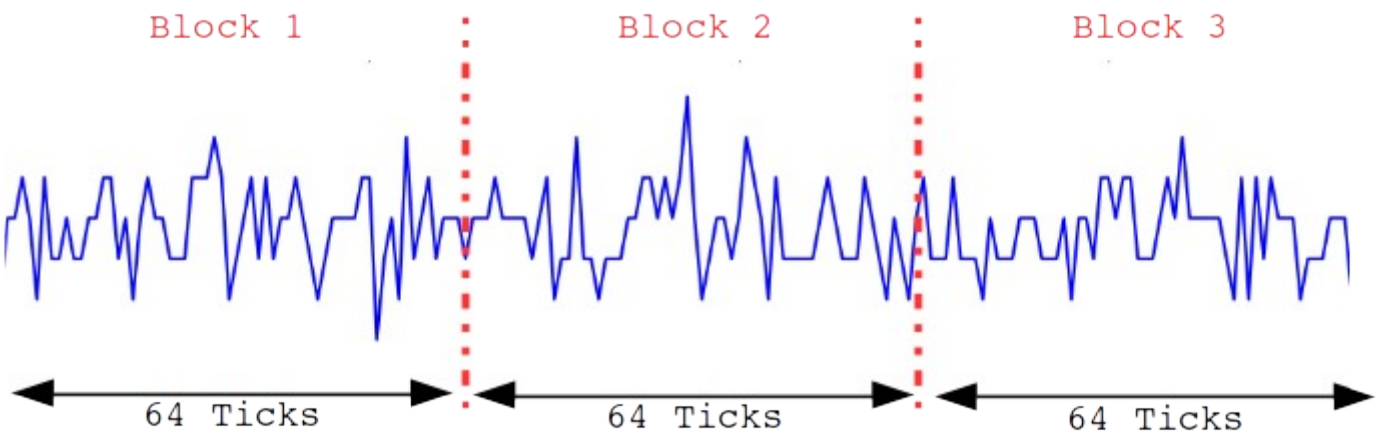


MicroBooNE Data-Compression Scheme

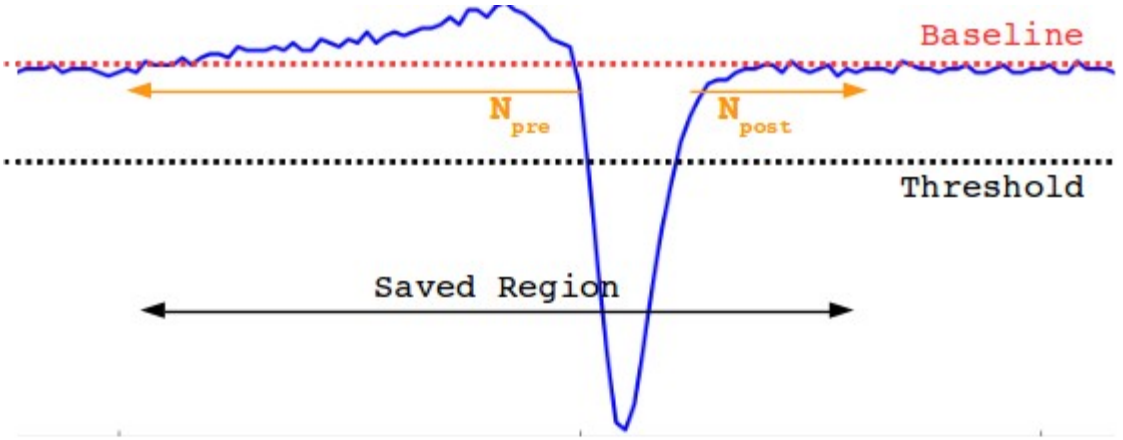
Possible envisioned compression scheme:

Step 1) search for baseline in stable region.

Rolling baseline updated based on baseline and variance stability



Step 2) save pulse if above/below a baseline-subtracted threshold.



Channel-by-channel settable parameters and thresholds.

...Scheme details evolving

Monte-Carlo Performance Studies

Regardless of how one chooses to compress the data, it is important to study the effects of any data-suppression scheme.

Questions to address:

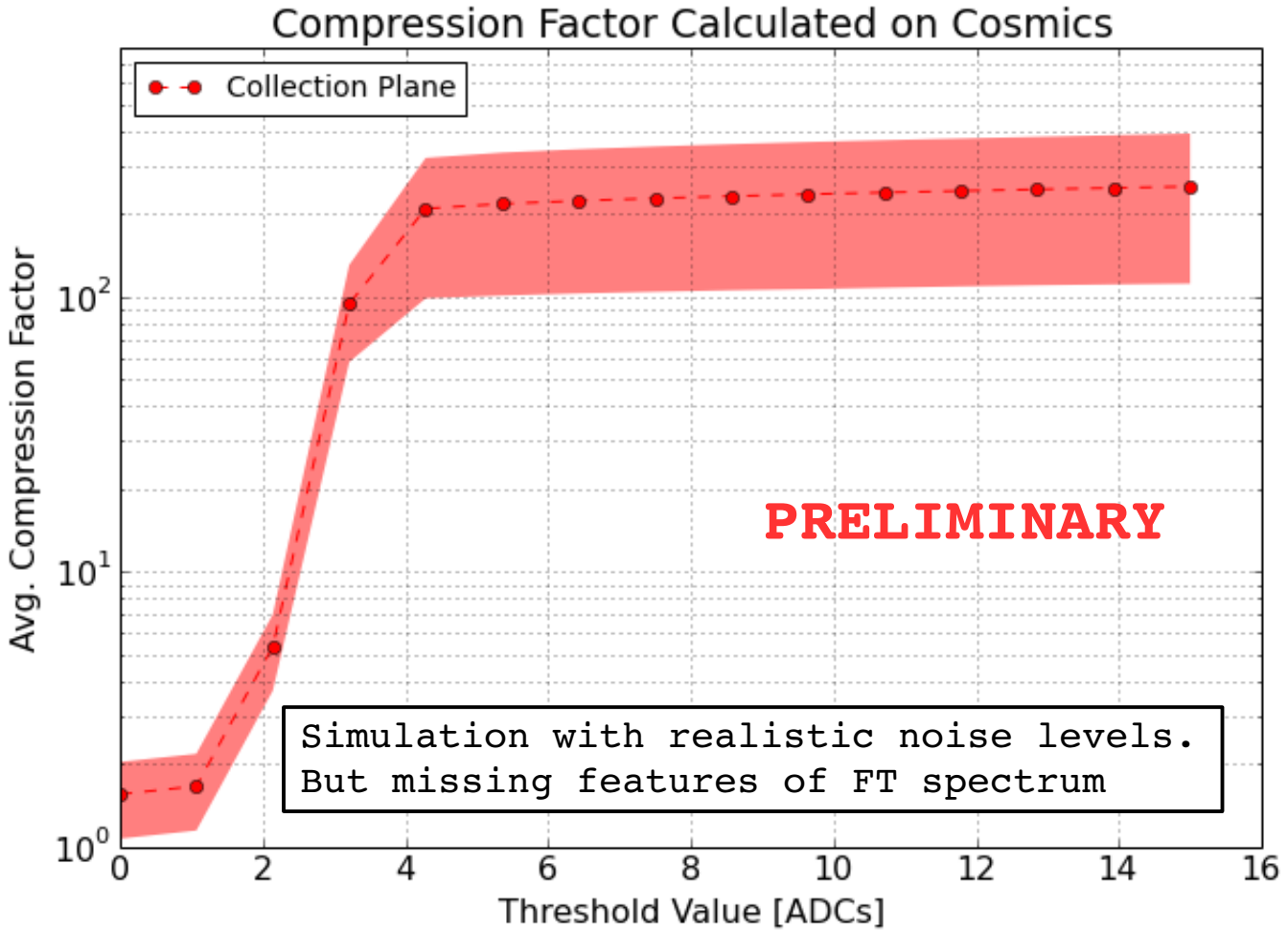
- What compression factor is achieved?

- What are the inefficiencies?

- How much / what information is lost?

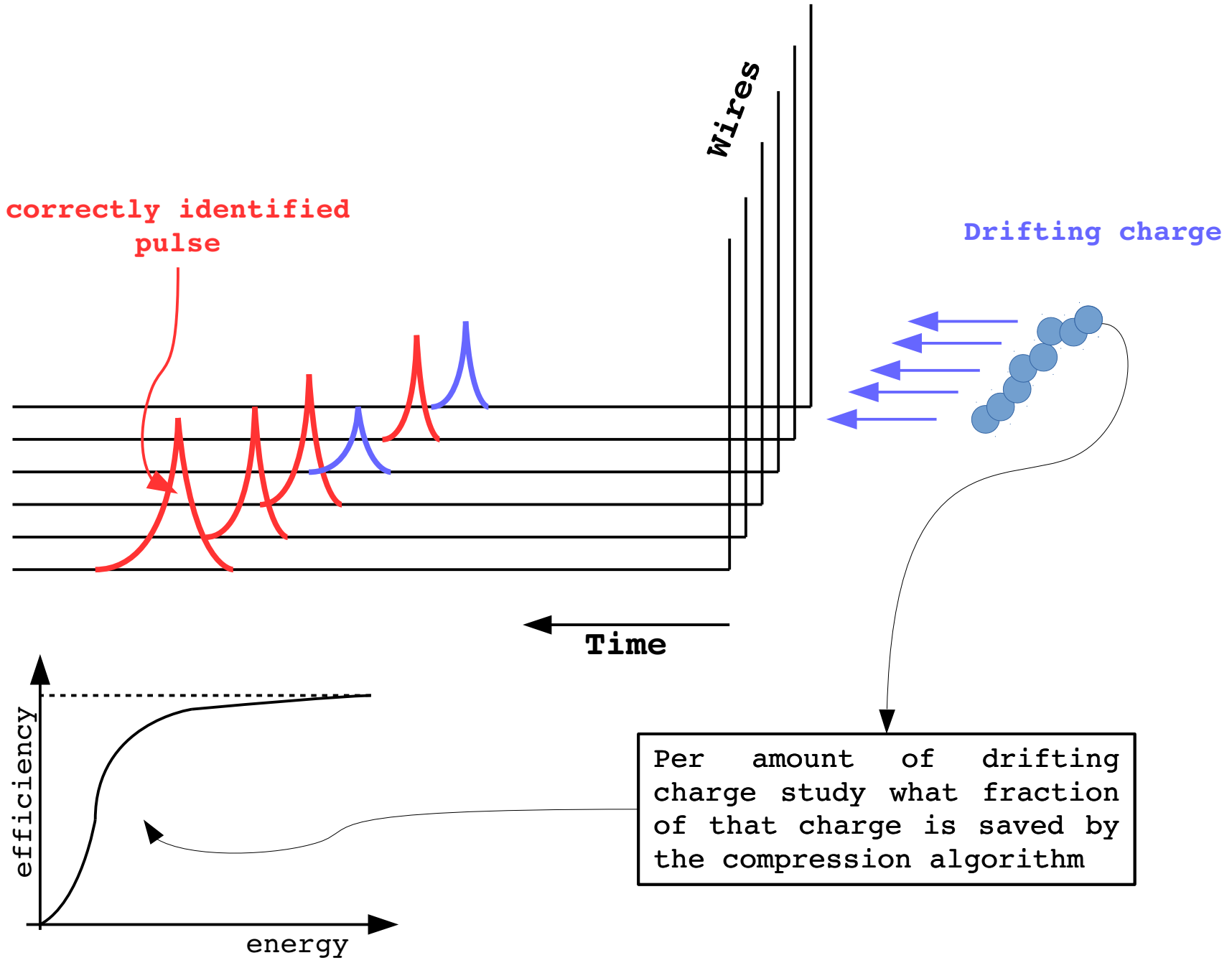
- Energy dependence?

Monte-Carlo Performance Studies

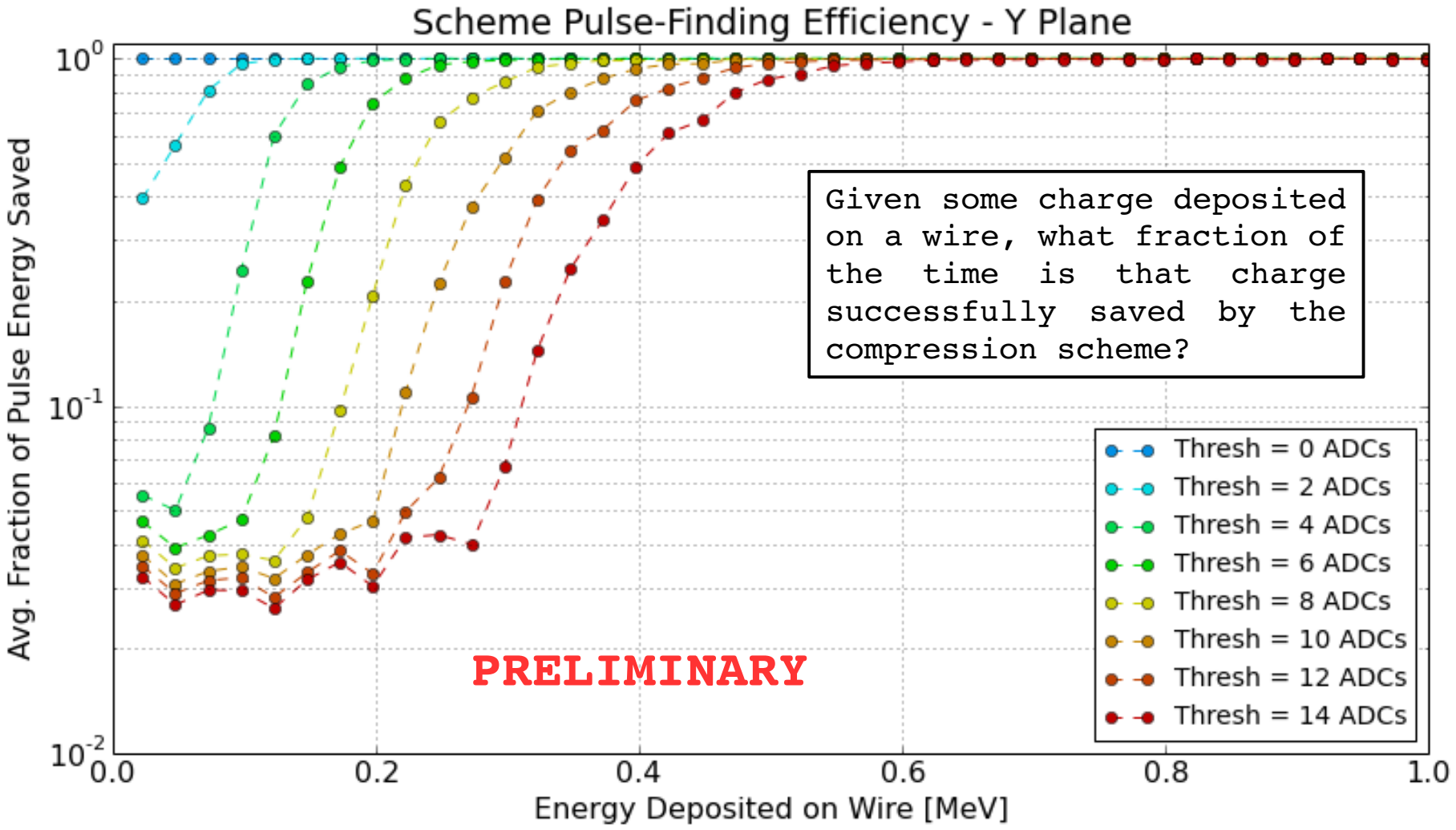


One can study the compression factor achieved as a function of the thresholds used in the scheme.
Compression Factor = outgoing/incoming data-size

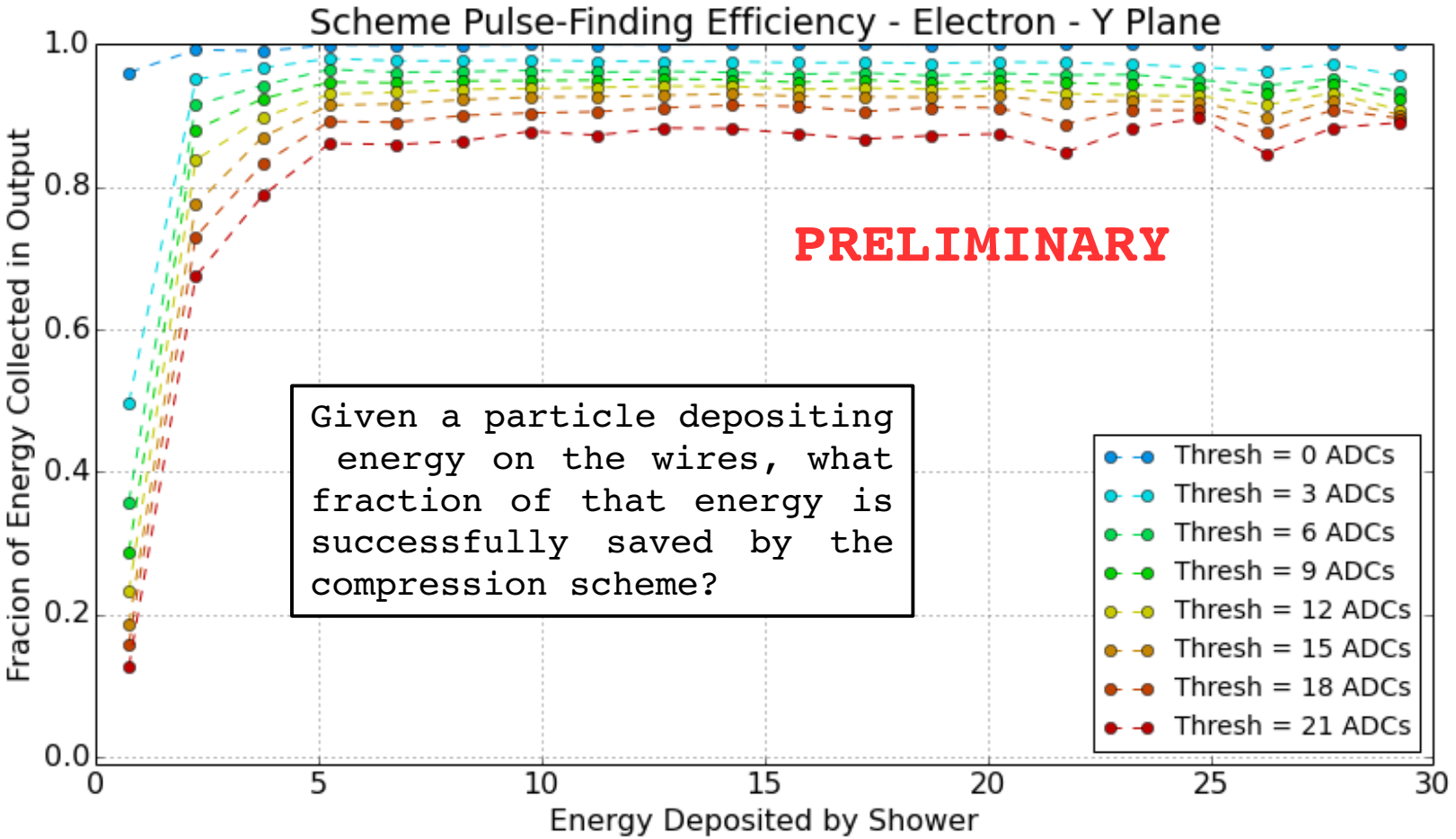
Monte-Carlo Performance Studies

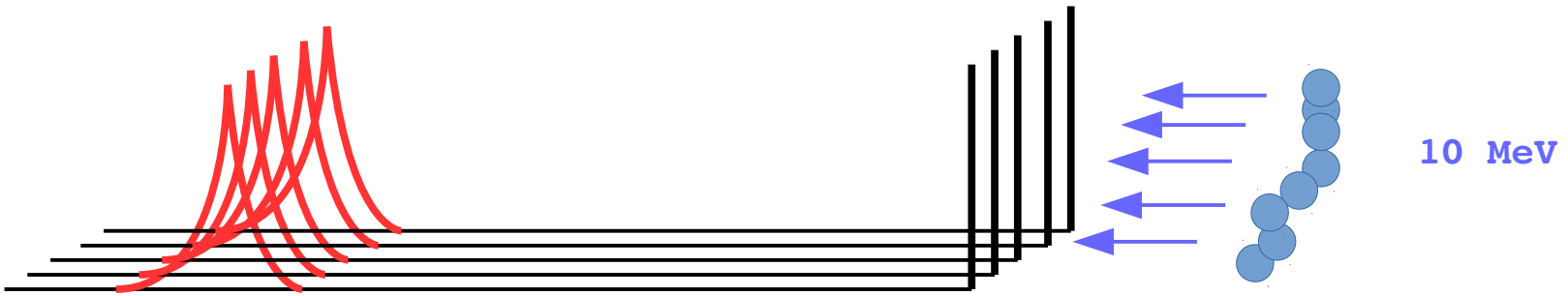


Pulse-finding efficiency for charge on single wire



Pulse-finding efficiency for charge from single particle

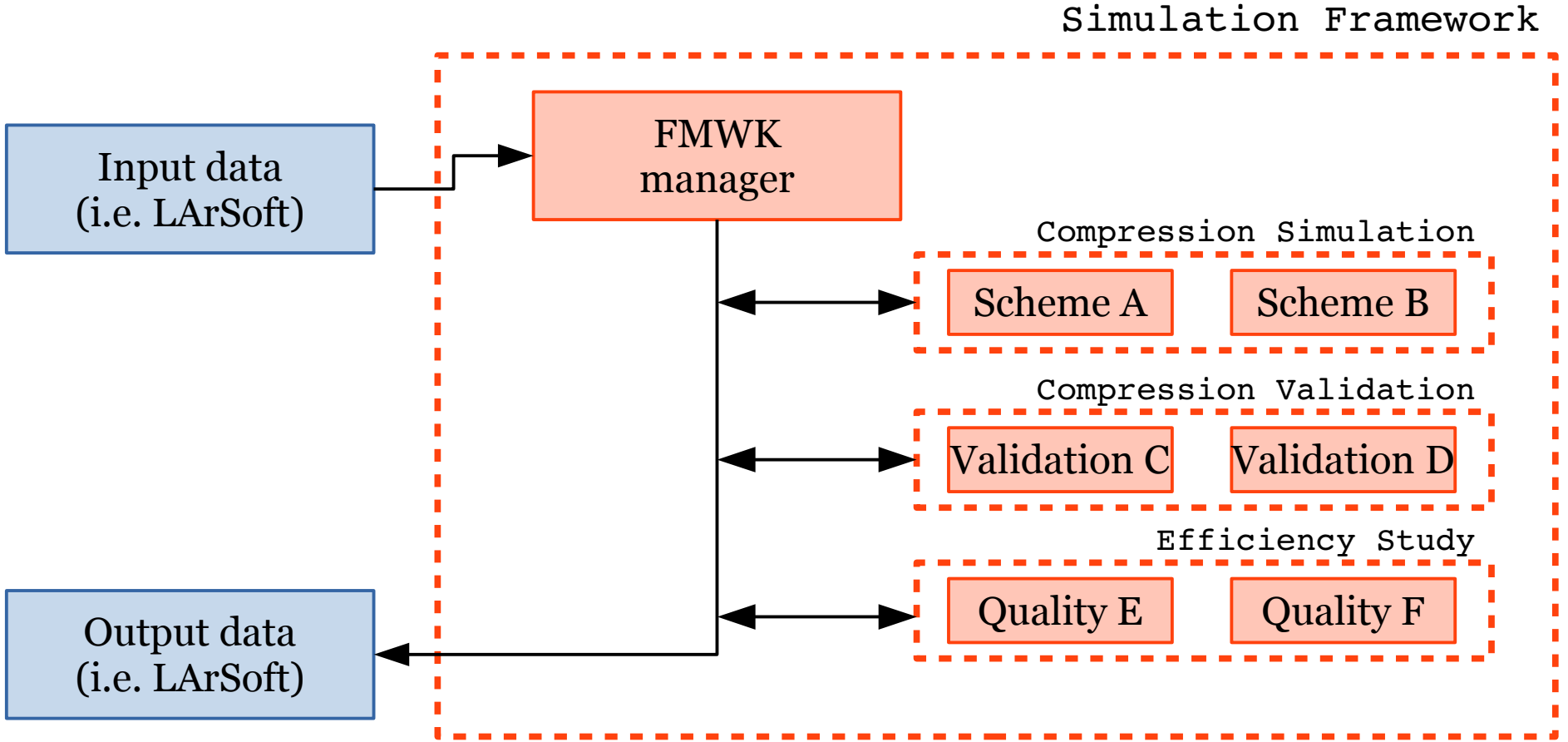




Simulation Framework

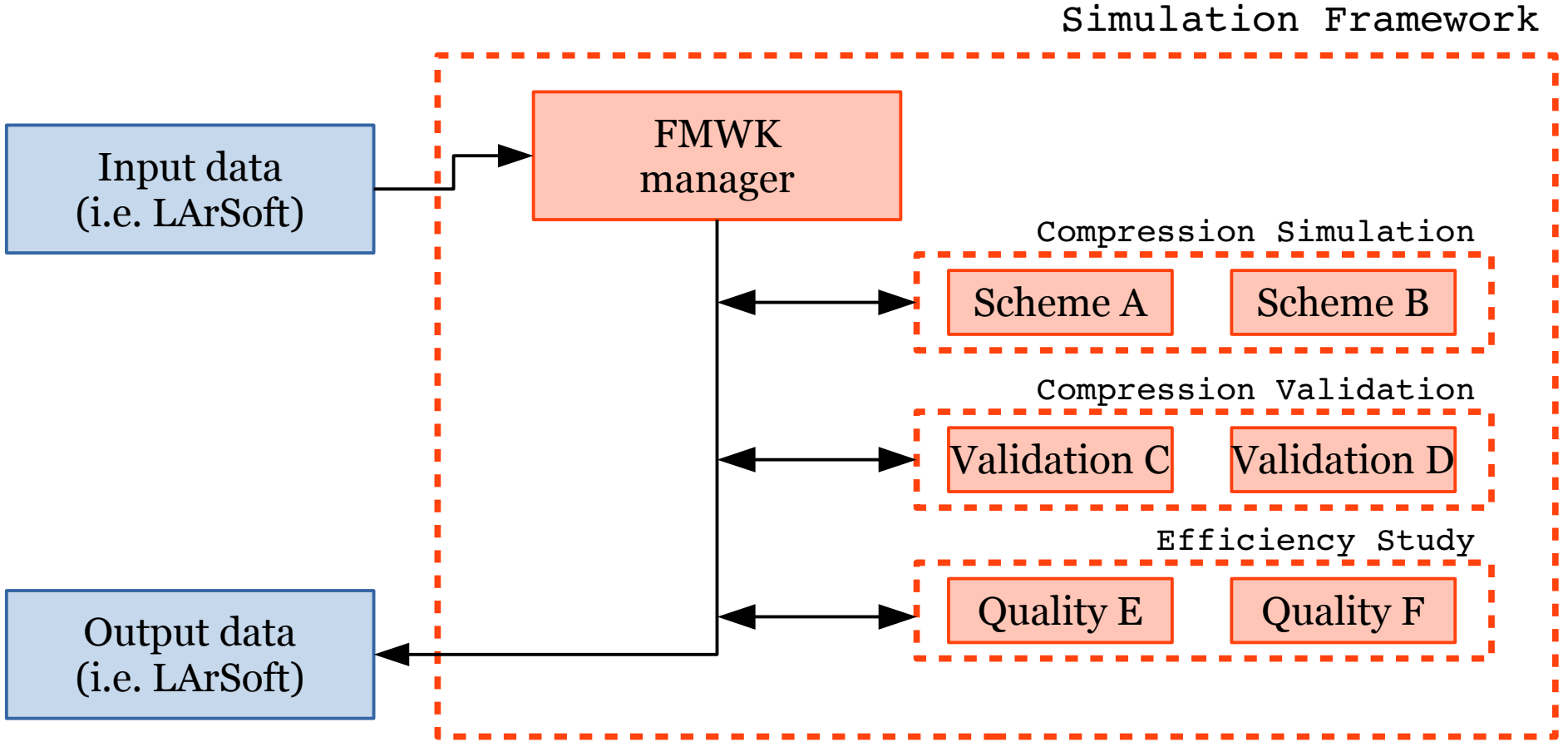
A simulation tool for a data-compression scheme needs to:

- be able to evaluate different compression schemes
- evaluate/validate the scheme's decision making logic
- evaluate the scheme's performance and efficiency



Simulation Framework

Framework is dependent on C++/ROOT.
Designed so that it can be easily interfaced with other tools (i.e. LArSoft)



Conclusions

MicroBooNE is a LArTPC currently operating in the Booster Neutrino Beamline.

MicroBooNE has a dedicated data-stream for a supernova neutrino search.

This data-stream is subject to a lossy compression, to reduce data-rates.

The validation and evaluation of possible data-compression schemes is a necessary step in order to understand:

- compression scheme performance
- efficiencies and physics impact

Do this in a flexible and re-usable framework.

Backup

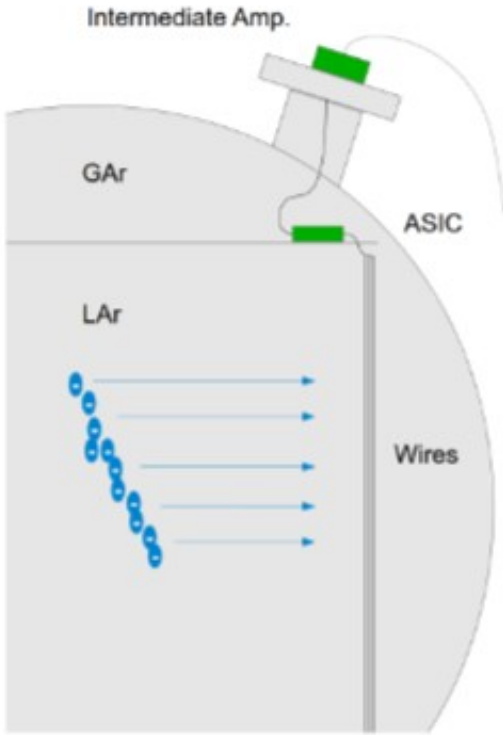
TPC Readout Electronics

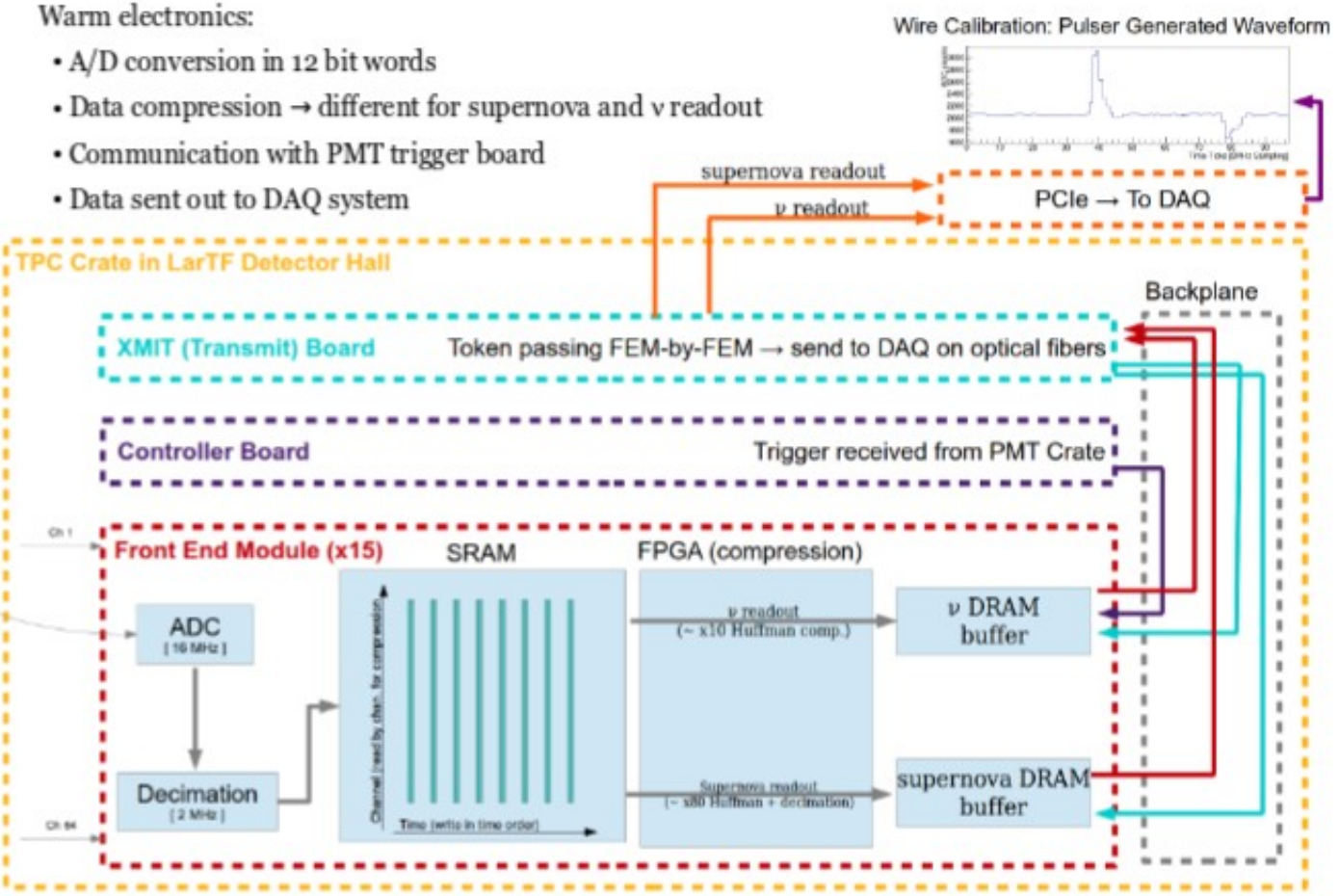
Cold electronics:

- Signal amplification and shaping
- Low temp. and short cables → noise reduced by factor of ~3
- Calibration tools to pulse wires

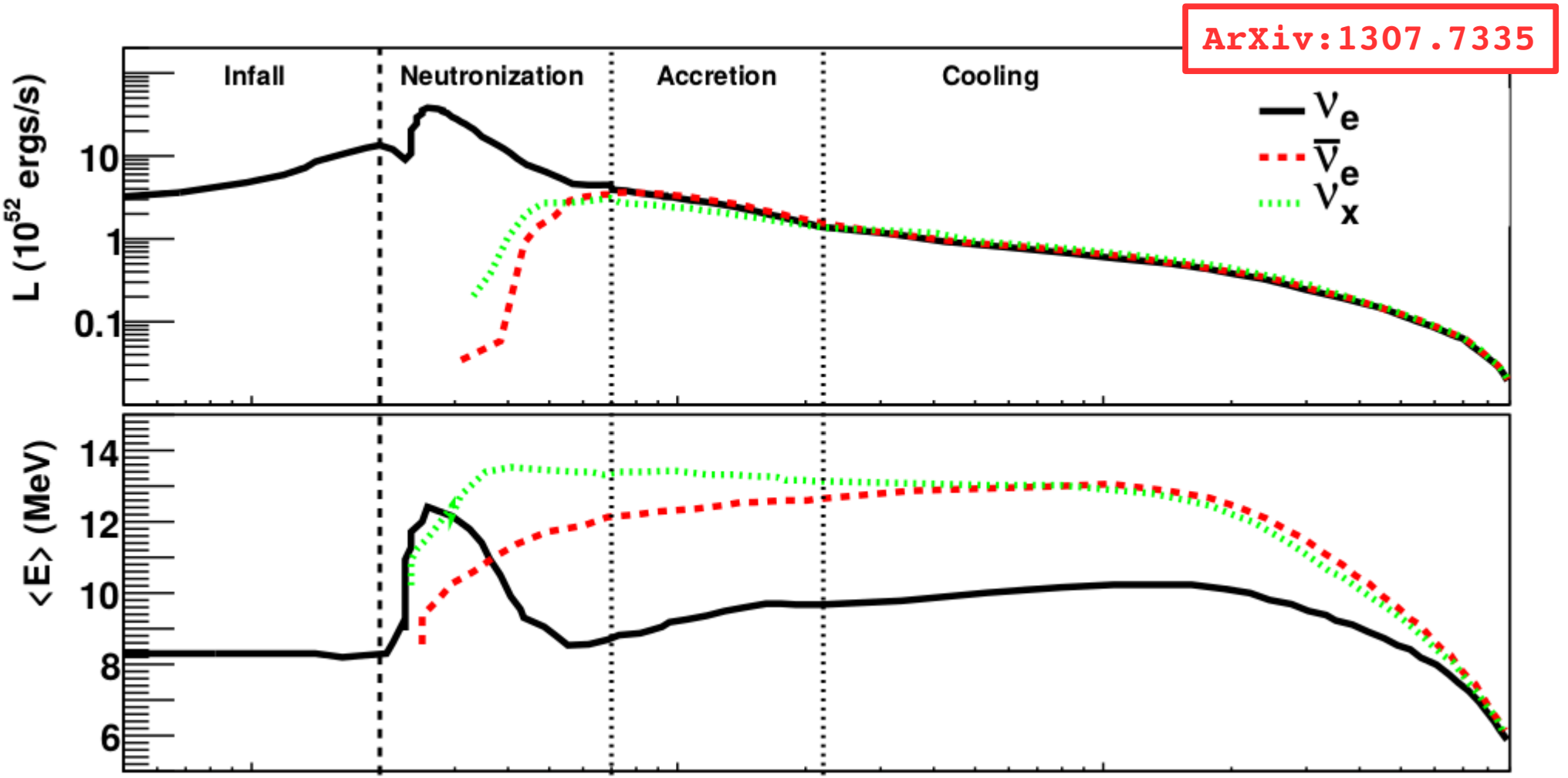
Warm electronics:

- A/D conversion in 12 bit words
- Data compression → different for supernova and ν readout
- Communication with PMT trigger board
- Data sent out to DAQ system



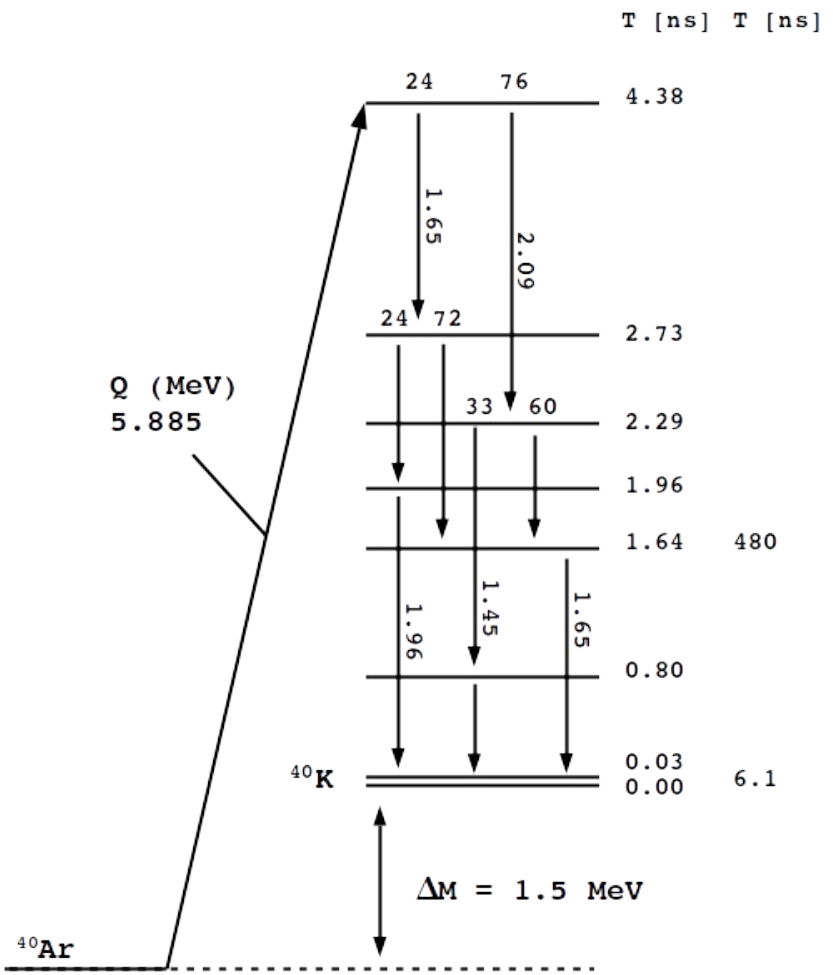


Supernova Neutrino Flux



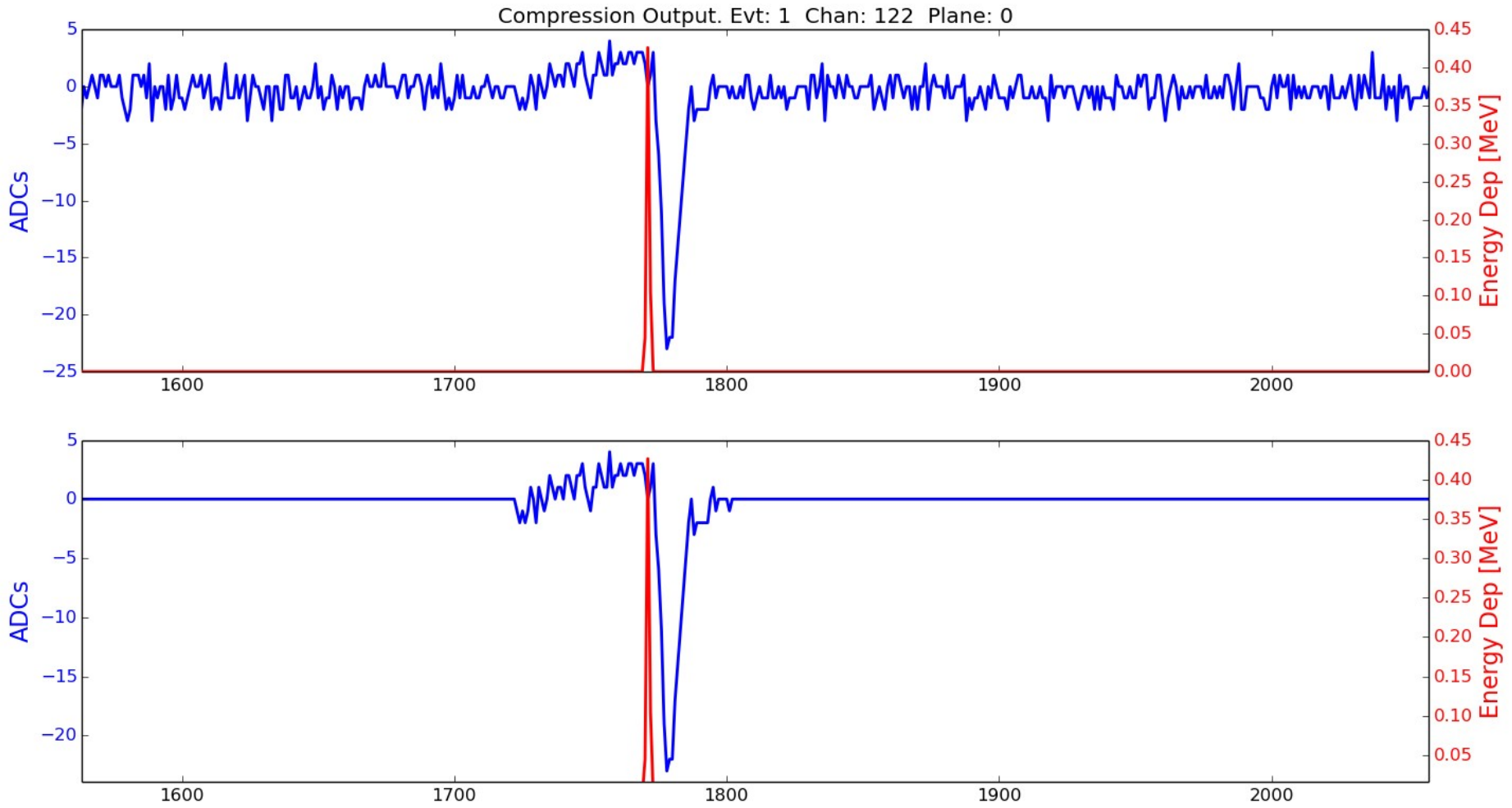
time-dependent luminosity and mean energy by flavor

Supernova de-excitation photons



$^{40}K^{*}$ decay spectrum [Raghavan Model]

MC efficiency estimation



Searching for deposited charge