Readout Electronics for the Time Projection Chamber in the μBooNE Experiment

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The μBooNE Experiment

μBooNE: 170 Ton Liquid Argon Time Projection Chamber neutrino detector

- On Booster Neutrino Beamline at FermiLab (~ 1 GeV neutrinos)
- R&D - Investigate miniBooNE "low-energy excess" - Cross Sections
- Potential to observe neutrino events from a supernova within our galaxy
- TPC will give us morphology of neutrino interactions
- Signal from TPC and PMTs → powerful and exciting detector!

- TPC data will be read out in two modes: "neutrino" and "supernova":
  - neutrino: trigger on beam events
  - Supernova: record data continuously and wait for alert
    → Recording all data requires lossy data compression

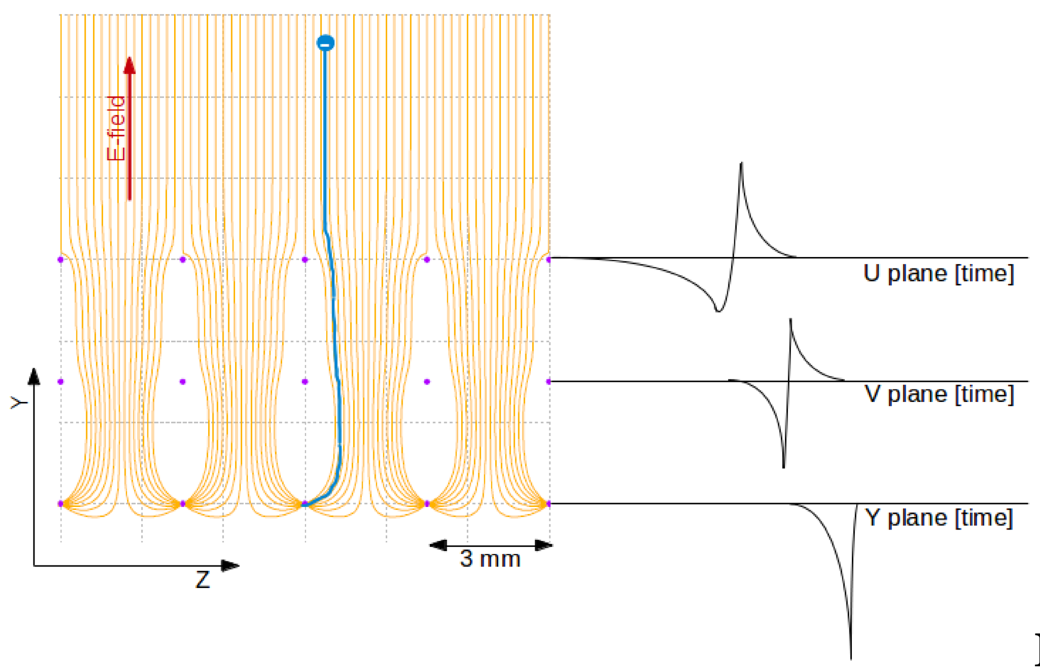
How μBooNE's TPC Works

Ionization electrons drift in 500 V/cm field towards three wire-planes.

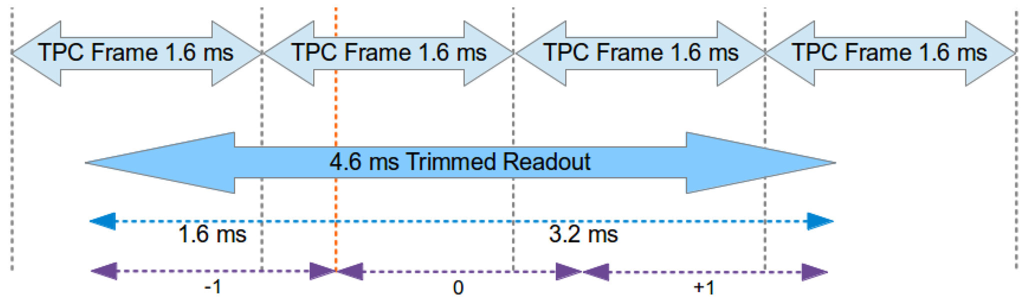
Induced current on wires gives us signal:

- Digitize at 2 MHz
- Three planes + PMTs → 3D track reconstruction
- Total of 8256 wires. Wire separation is 3 mm.
- Amount of charge deposited → calorimetric reconstruction & particle ID

Concept Behind μBooNE's Time Projection Chamber



- Two "induction" planes
- One "collection" plane
- Drift speed at 500 V/cm: ~ 1.6 mm/μs



Data in **frames**:

- 3200 2 MHz samples
- 1.6 ms → time for e⁻ to drift across detector.

Two readout modes:

- Supernova (continuous)
- ν (beam events)

"**ν**" readout mode:

- Store data when a trigger is received from the PMT Crate
  → For more, see poster by David Kaleko at Neutrino14
- Many triggers: Beams, PMTs, Calibration, Laser

1/2500 Beam spills with ν-event. Require beam + PMT trigger → 1/20

Data Rates:

4.8 ms x 2 MHz samples x 2 bytes/sample x 8256 wires.

BNB (10Hz) → ~ 1.5 GB/s. BNB+PMT trigger → ~ 12 MB/s. Huffman → ~ 1.2 MB/s

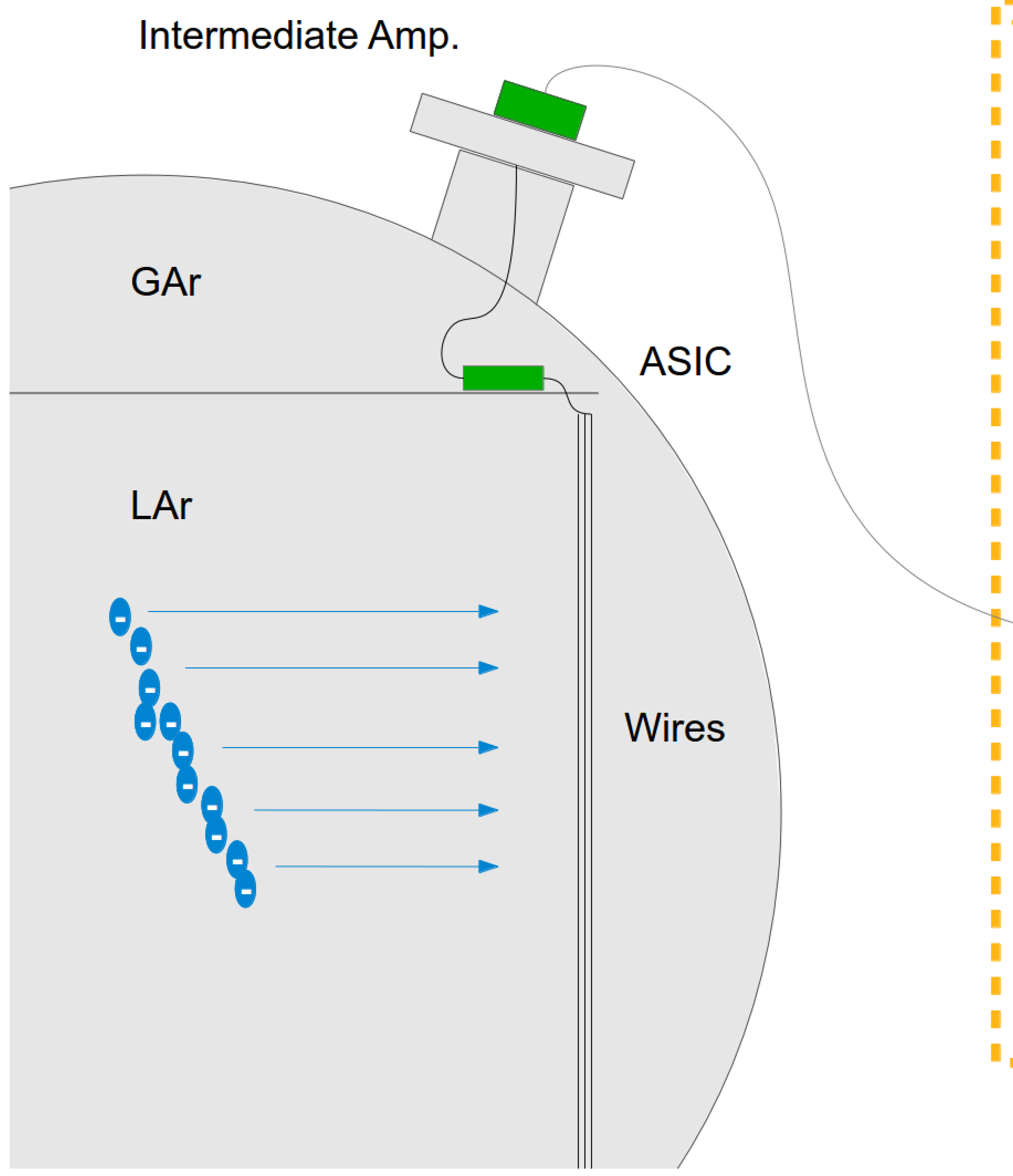
μBooNE's Time Projection Chamber Readout Chain

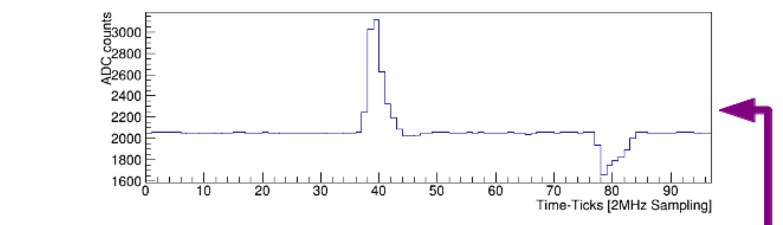
Cold electronics:

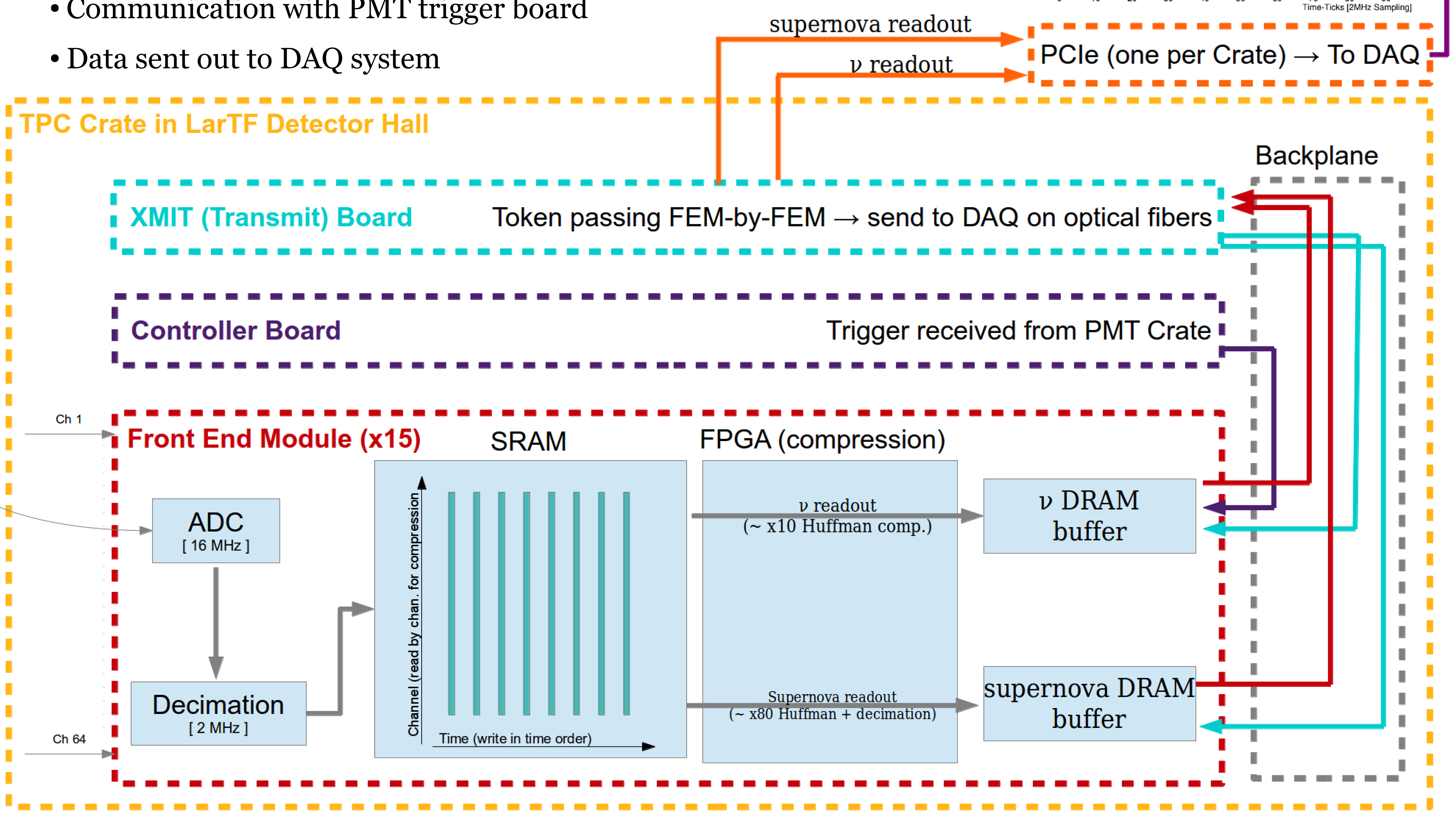
- Signal amplification and shaping
- Low temp. and short cables → noise reduced by factor of ~3
- Calibration tools to pulse wires

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 Readout and Data Compression

- μBooNE will be sensitive to supernova neutrino events
  Channel: $\nu_e + {}^{40}\mathrm{Ar} \rightarrow e^- + {}^{40}\mathrm{K}^*$
- Expect ~ 10s of events for a supernova within our galaxy.
- Hard to trigger on → Instead wait for SuperNova Early Warning System (SNEWS)

Need to:

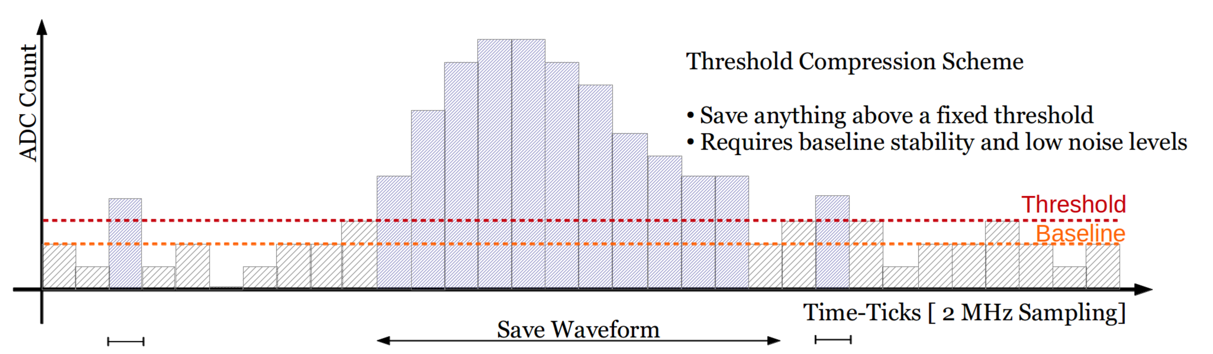
- Record data continuously
- Hold on to it for ~ 1 hour

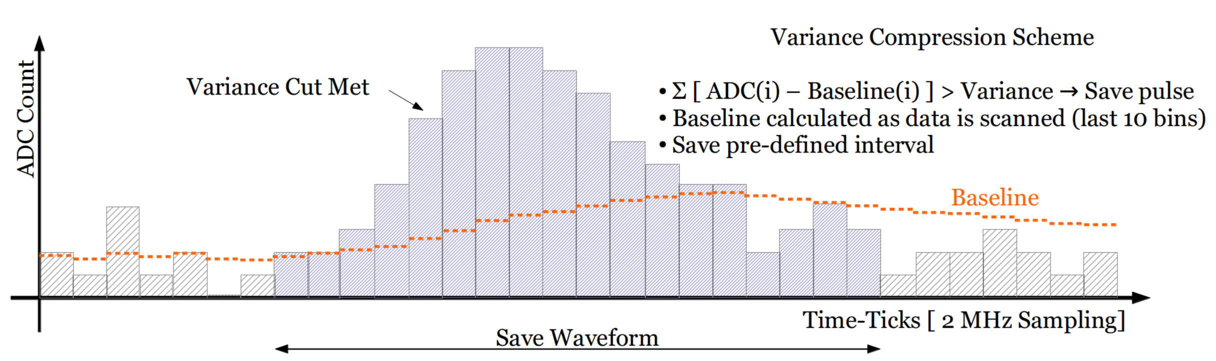
- How much Data?
  Sample @ 2 MHz x 2 bytes/data-word x 8256 wires → 33 GB/sec
- Must compress by ~ x80 to be within experiment's data-writing limits

- Compression "on the fly" → must be fast!
- Leave out quiet regions & save interesting pulses
- Interested in 10s of MeV electron tracks from supernova

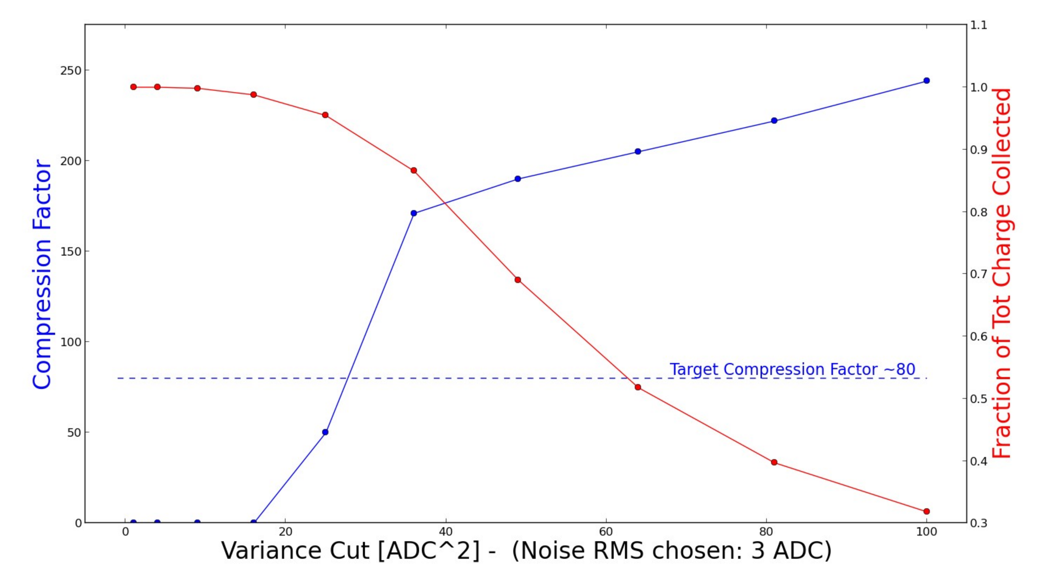
Compression Scheme will depend on:

- Baseline stability + Noise levels + Signal Shape
  → Optimize based on Detector





Study of Variance Scheme on Simulated Events



Compression Factor: Tot Data / Saved Data

- Calculated from cosmics (rate ~ 5 KHz)

Fraction of Charge Collected

- Looked at simulated 10 MeV e⁻

Trade-off → find balance