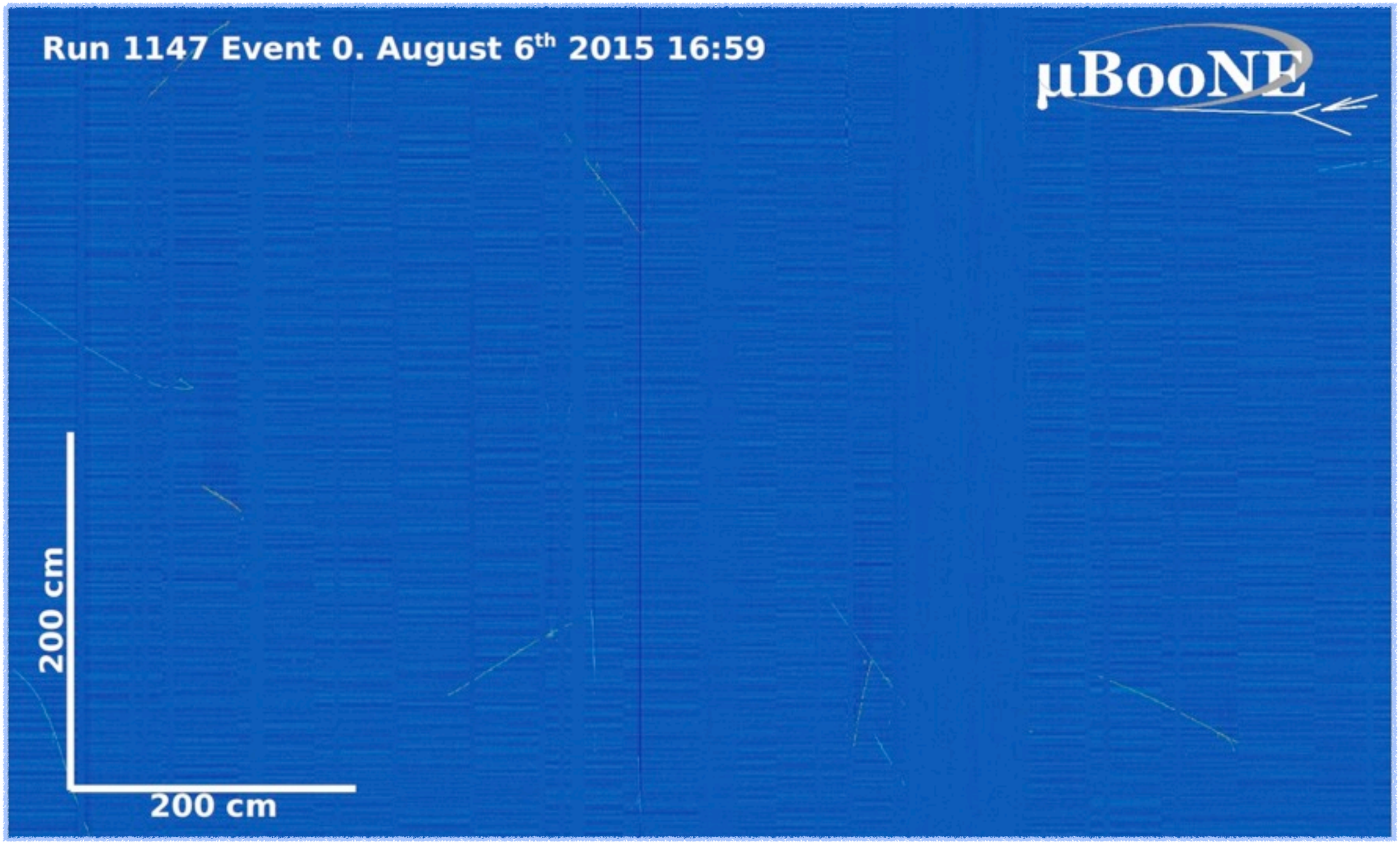
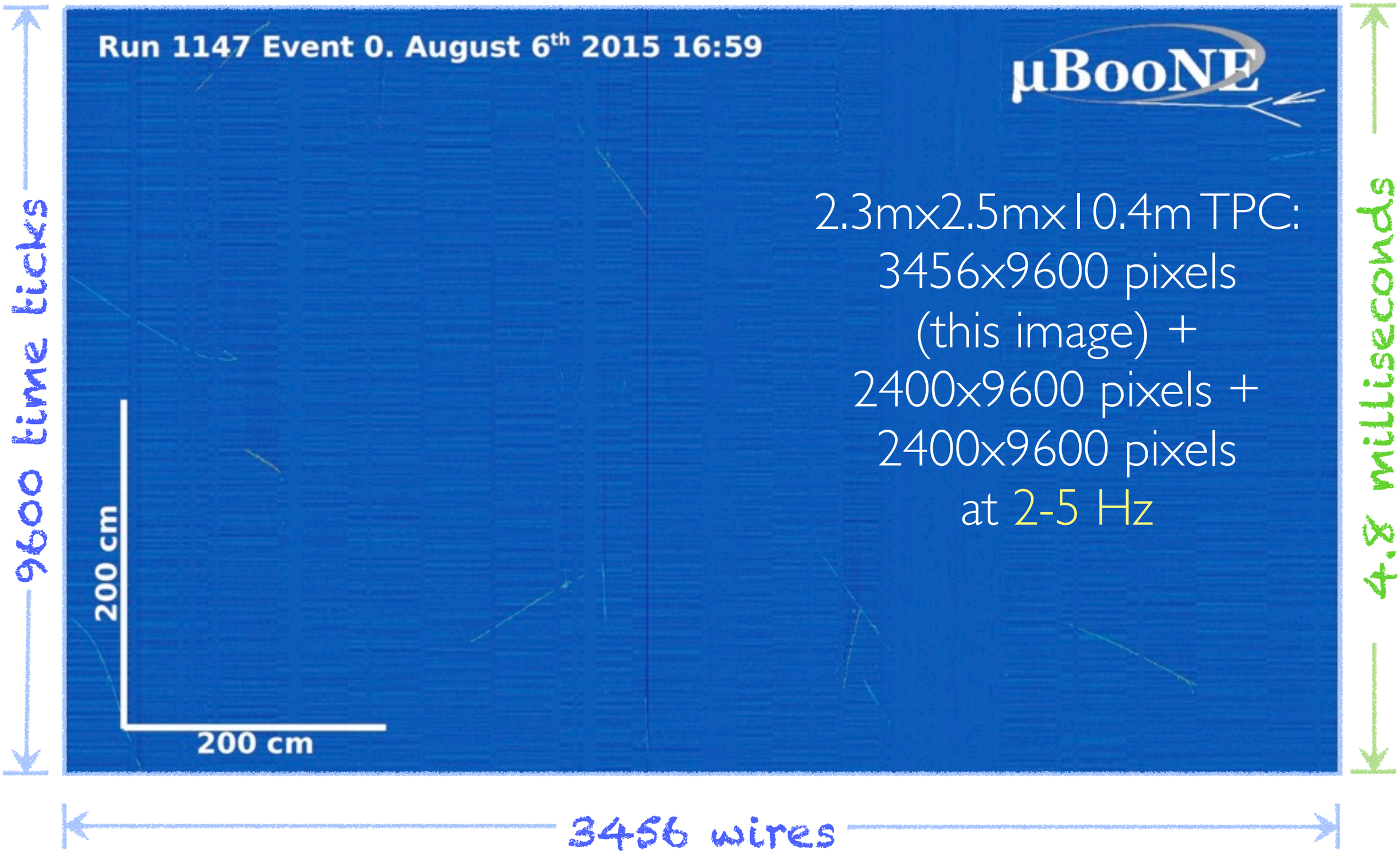
# Triggering and Charge Readout of Liquid Argon TPC from MeV to multi-GeV

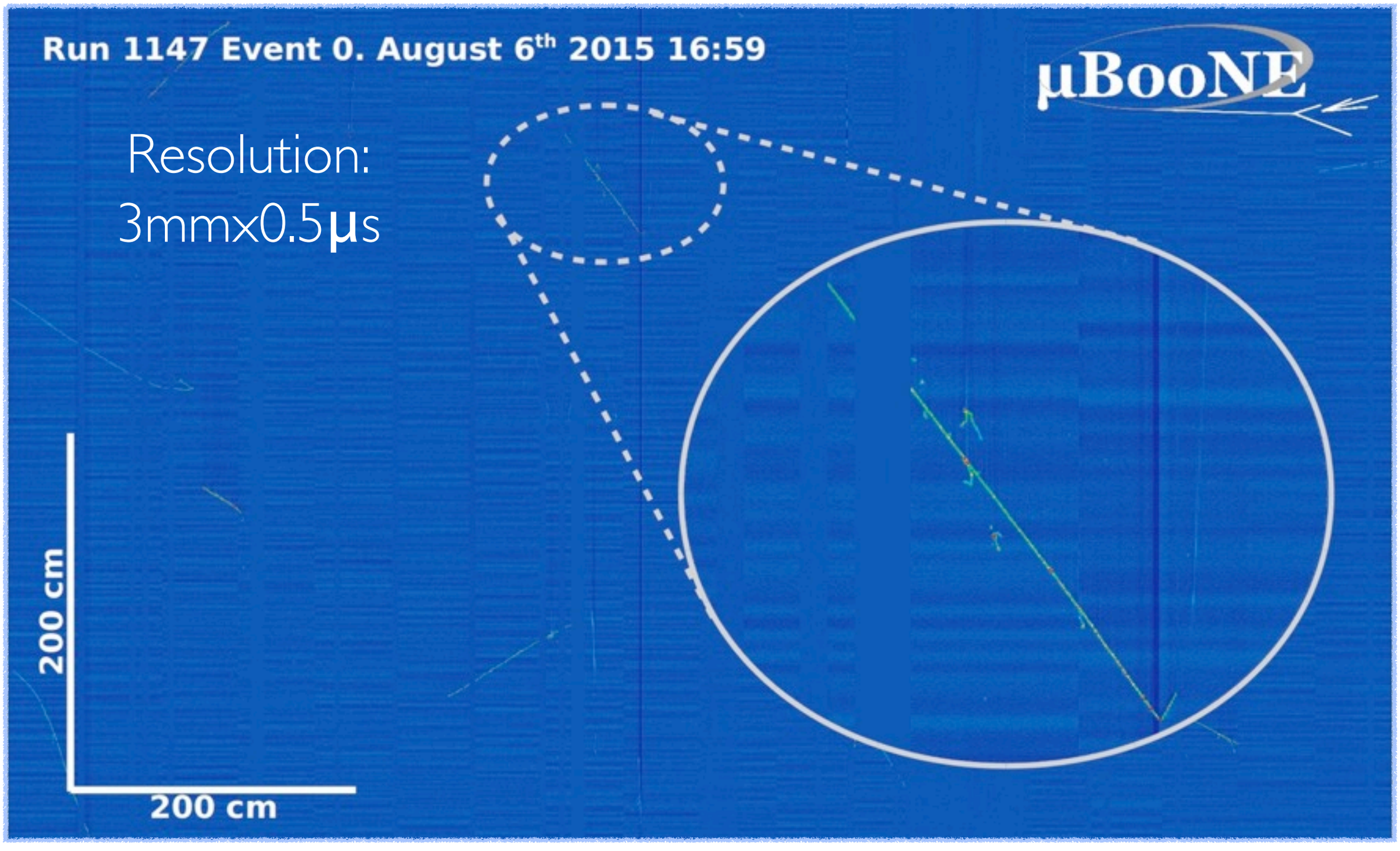
Yun-Tse Tsai (SLAC)

NNN15; October 28th, 2015


Run 1147 Event 0. August 6th 2015 16:59
μBooNE
200 cm
200 cm


10.4 m
Run 1147 Event 0. August 6th 2015 16:59
µBooNE
2.3mx2.5mx10.4m TPC:
3456x9600 pixels
(this image) +
2400x9600 pixels +
2400x9600 pixels
at 2-5 Hz
200 cm
200 cm
9600 time ticks
4.8 milliseconds
3456 wires

10.4 m




9600 time ticks

4.8 milliseconds

3456 wires

# Large LArTPC

| Parameter | best-fit ($\pm 1\sigma$) | $3\sigma$ |
|---|---|---|
| $\Delta m^2_{21}$ $[10^{-5}\mathrm{eV}^2]$ | $7.54^{+0.26}_{-0.22}$ | 6.99 – 8.18 |
| $\lvert\Delta m^2\rvert$ $[10^{-3}\mathrm{eV}^2]$ | $2.43\pm0.06$ $(2.38\pm0.06)$ | 2.23 – 2.41 (2.19 – 2.56) |
| $\sin^2\theta_{12}$ | $0.308\pm0.017$ | 0.259 – 0.359 |
| $\sin^2\theta_{23}$ | $0.437^{+0.033}_{-0.023}$ $(0.455^{+0.039}_{-0.031})$ | 0.374 – 0.628 (0.380 – 0.641) |
| $\sin^2\theta_{13}$ | $0.0234^{+0.0020}_{-0.0019}$ $(0.0240^{+0.0019}_{-0.0022})$ | 0.0176 – 0.0295 (0.0178 – 0.0298) |

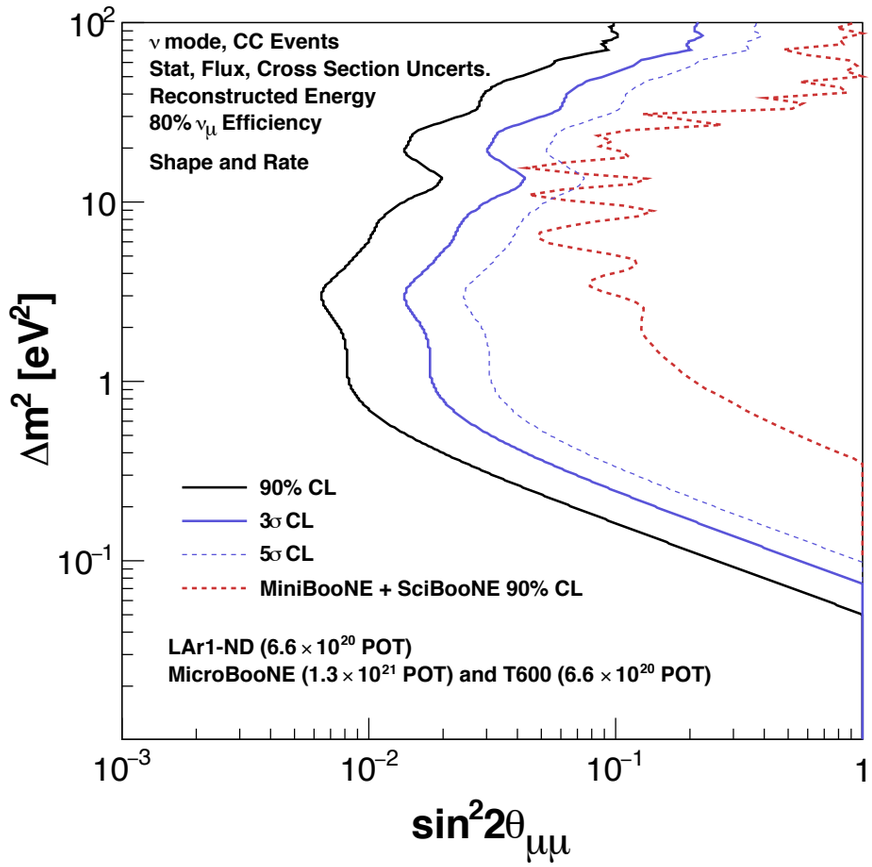
PDG

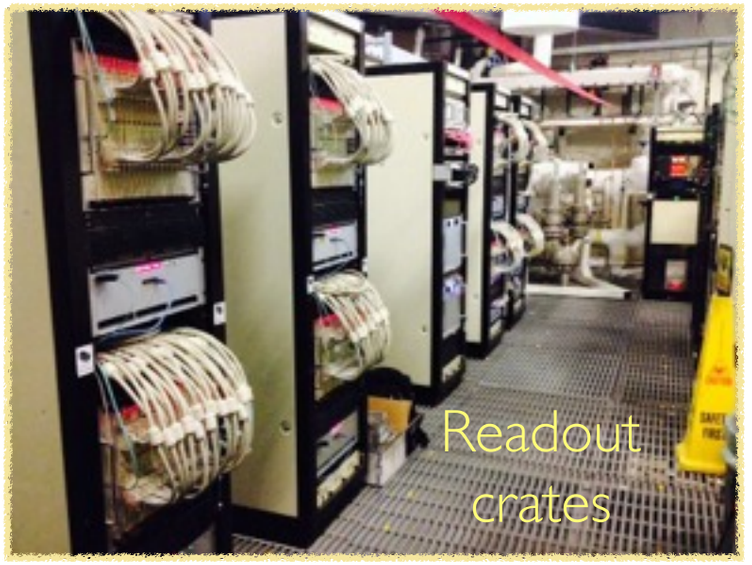

This talk: MicroBooNE ⇒ DUNE

| Requirement | | Physics Goal |
|---|---|---|
| High resolution | Detailed event topology | Neutrino oscillation, cross sections, etc. |
| | Excellent calorimetry | Supernova neutrino detection, proton decays, etc. |
| Large scale | More statistics for rare interactions | |

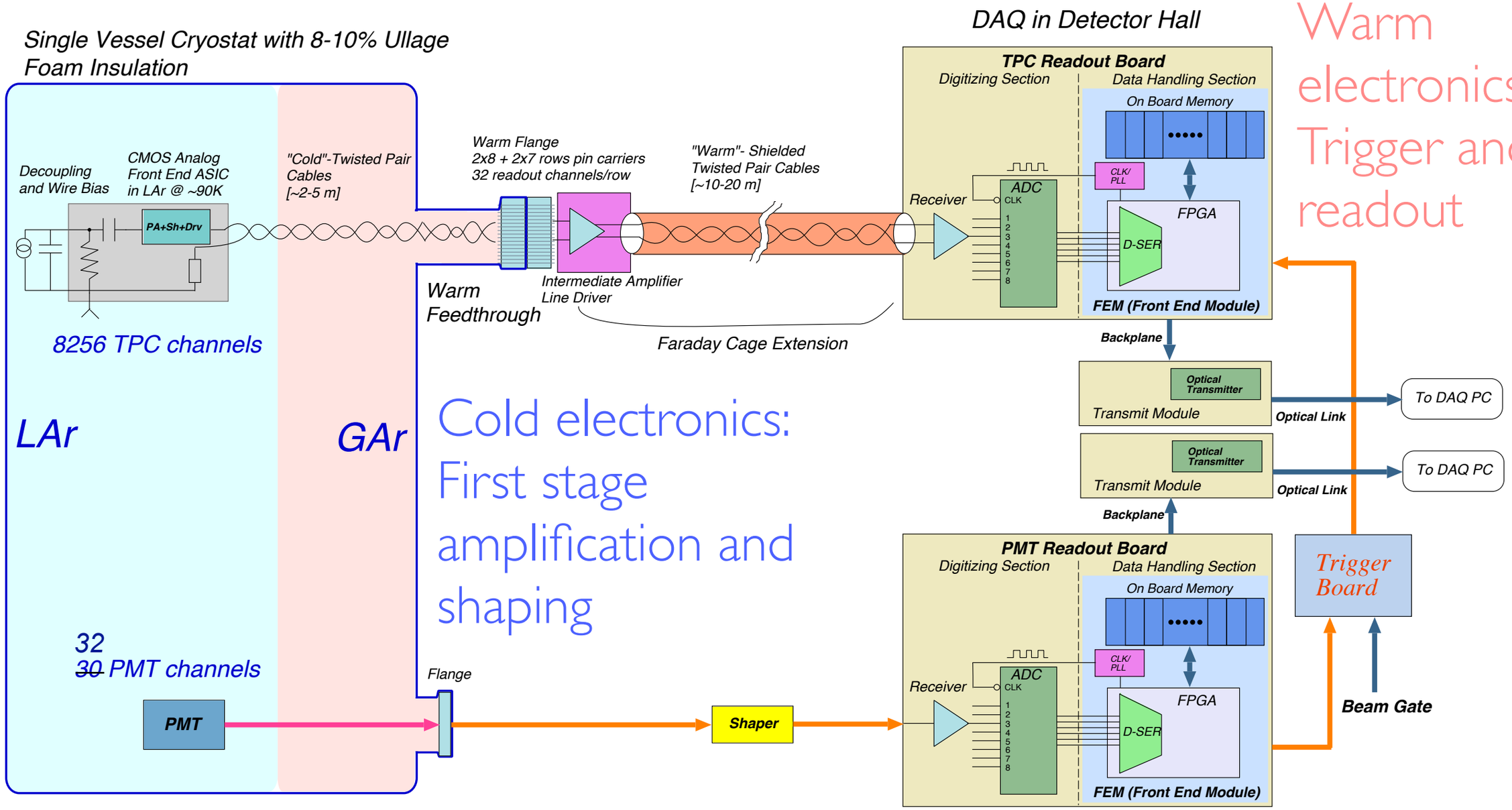
# MicroBooNE

- 1st large LArTPC in the US
- Physics objectives
  - MiniBooNE low energy excess; sterile **ν**s?
  - **ν**-Ar cross sections
  - LArTPC R&D
- **ν** source: Booster neutrino beam
- 1 TPC: 2.3mx2.5mx10.4m
- LAr: 89 tons (active)
- Charge readout: 8192 wires at 2MHz (0.5**μ**s)



# MicroBooNE Readout



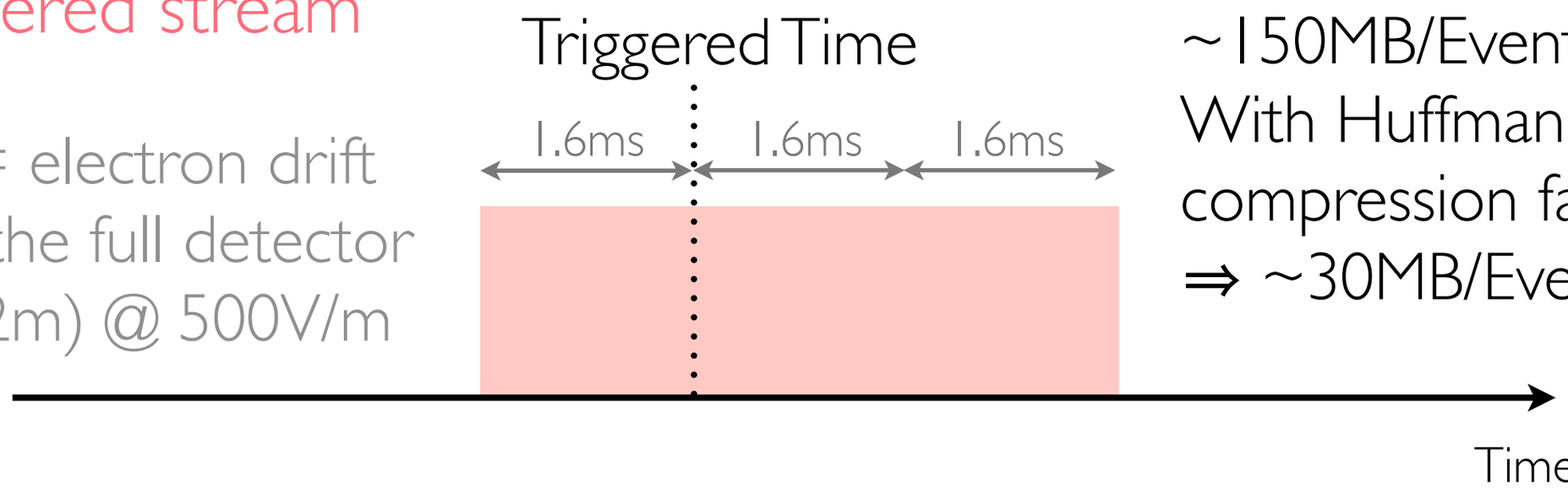

Warm electronics: Trigger and readout

Cold electronics: First stage amplification and shaping

# Readout Streams

1. Triggered stream

1.6ms = electron drift time for the full detector length (2m) @ 500V/m




~150MB/Event
With Huffman compression factor ~5
⇒ ~30MB/Event

2. Continuous stream (commissioning)

~50MB/1.6ms
With Huffman compression factor ~5
⇒ ~30GB/s

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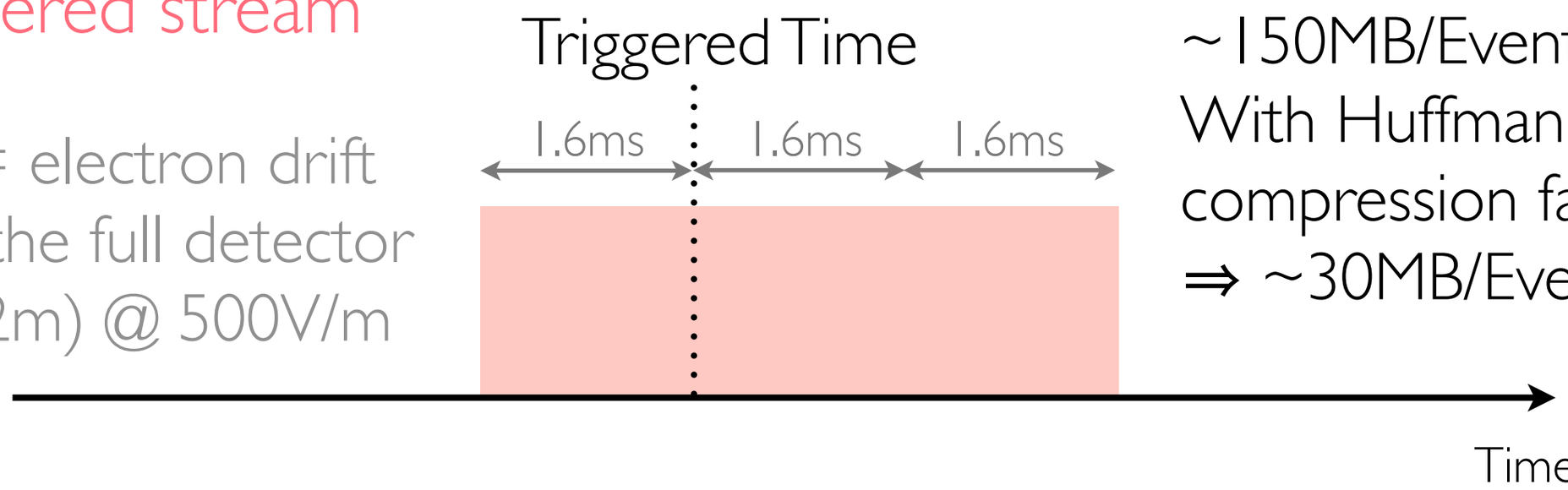


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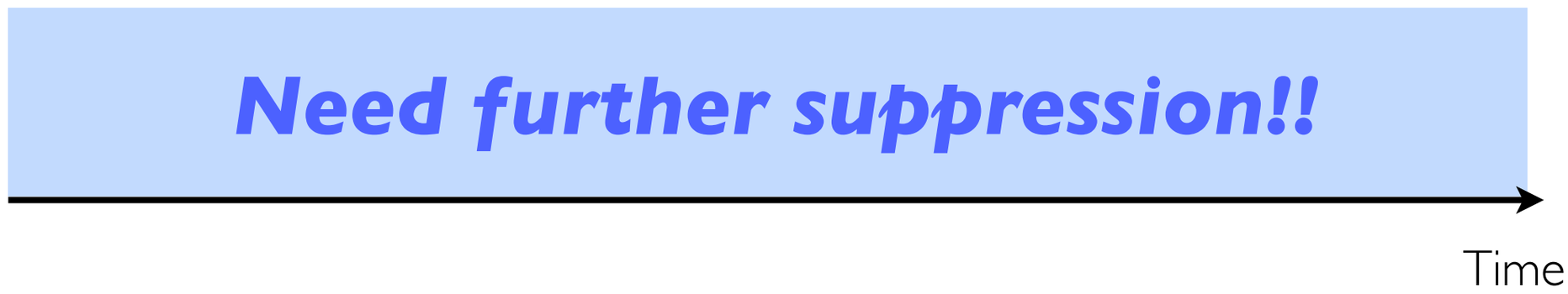
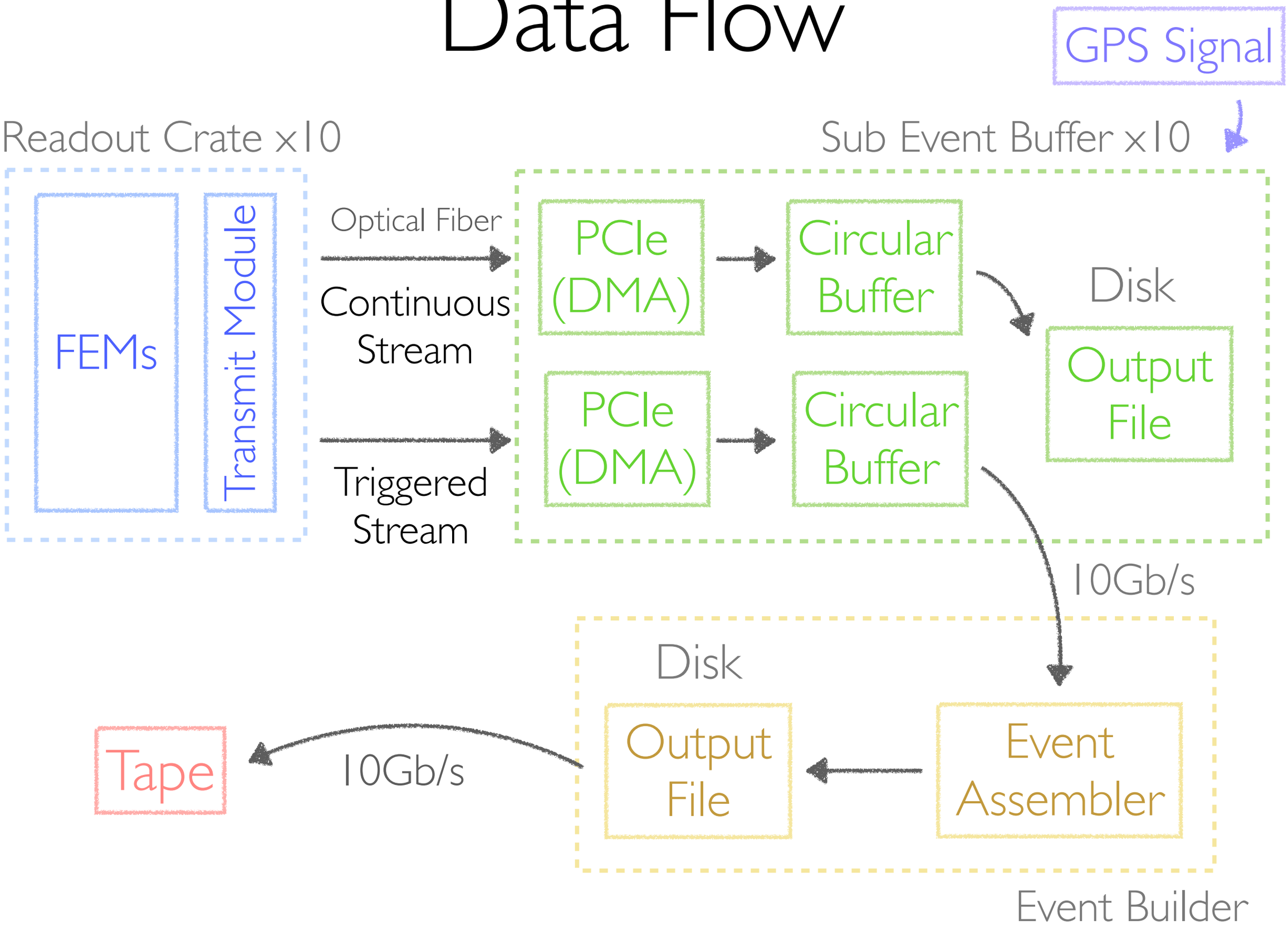
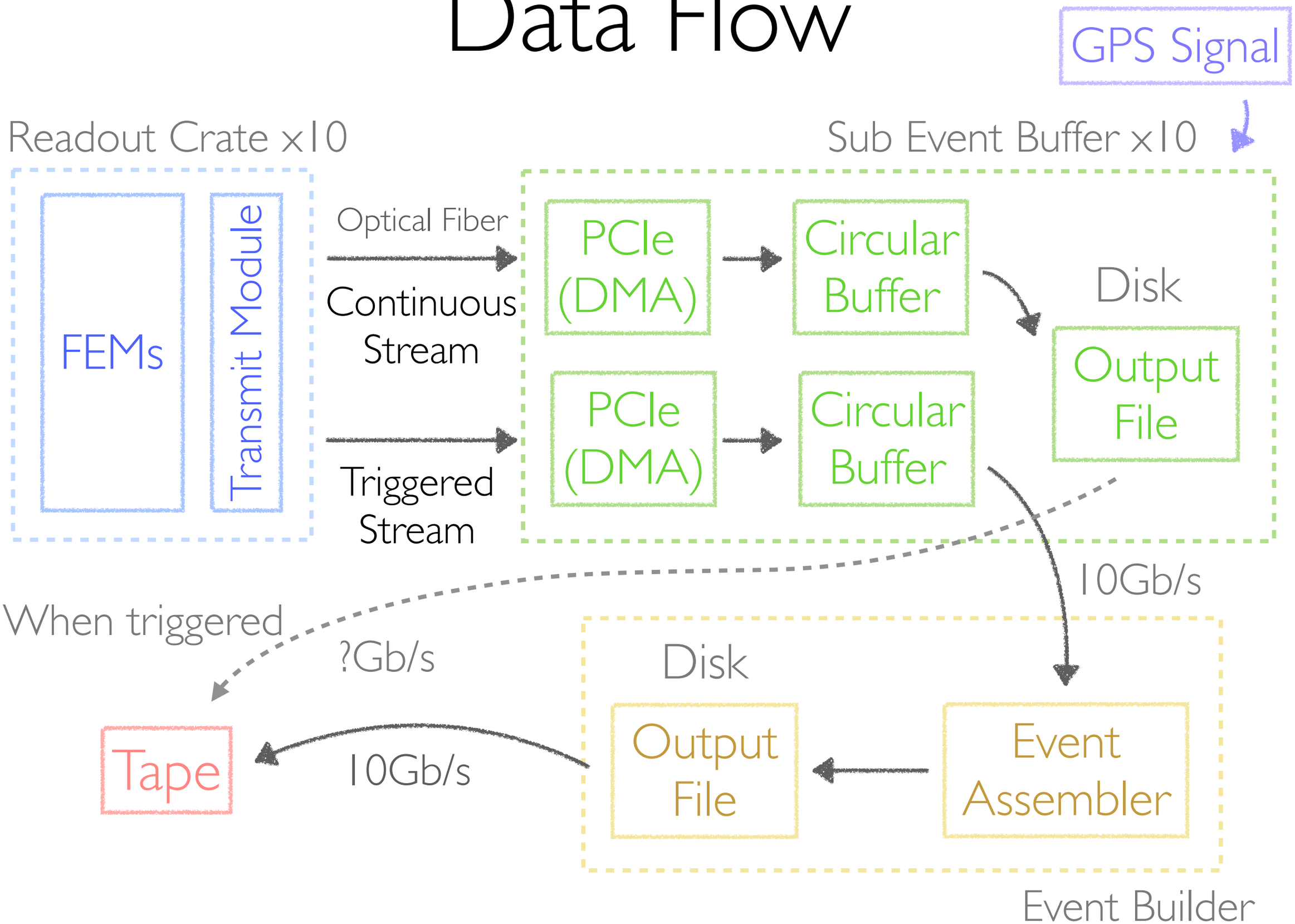


# Data Flow


GPS Signal
Readout Crate x10
Sub Event Buffer x10
FEMs
Transmit Module
Optical Fiber
Continuous Stream
Triggered Stream
PCIe (DMA)
Circular Buffer
PCIe (DMA)
Circular Buffer
Disk
Output File
10Gb/s
Disk
Output File
Event Assembler
Tape
10Gb/s
Event Builder

# Data Flow


GPS Signal
Readout Crate x10
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FEMs
Transmit Module
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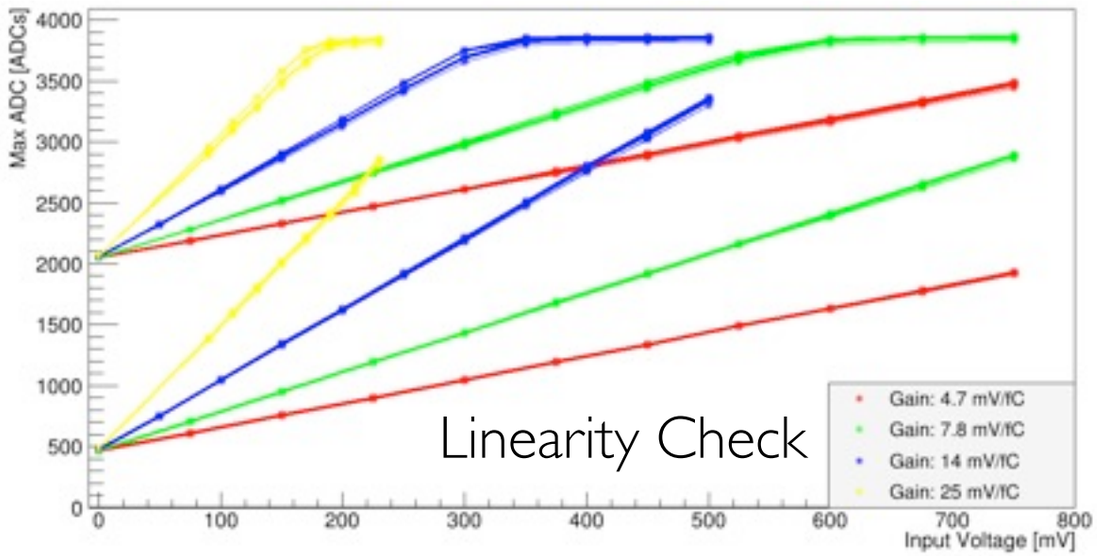
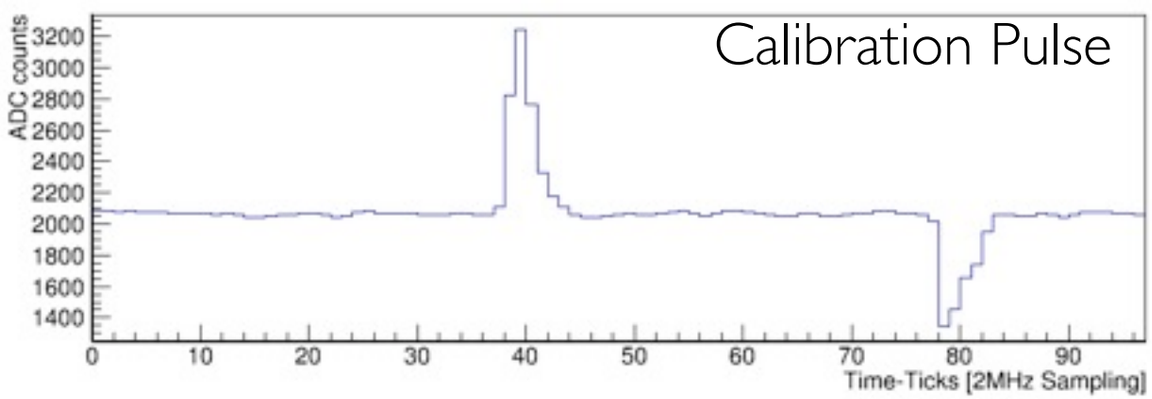
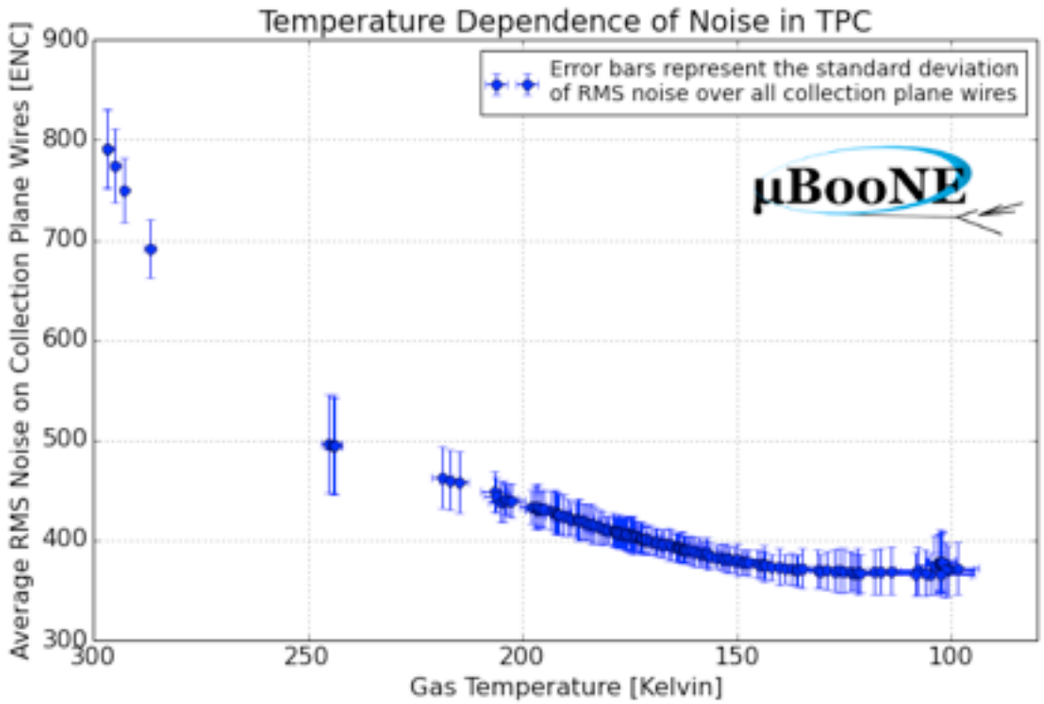
PCIe (DMA)
Circular Buffer
PCIe (DMA)
Circular Buffer
Disk
Output File
10Gb/s
When triggered
?Gb/s
Tape
10Gb/s
Disk
Output File
Event Assembler
Event Builder

# TPC Readout Calibration

- Inject pulses with known charges and check
  - linearity w.r.t. the gain settings
  - cross-talk
  - rise-time
- Measure the baseline
- Measure the noise level



# DAQ Status

- Started taking beam data at 4:02pm CDT, October 15th 2015
- Beam trigger rate at 5Hz for 8 days
- Readout and DAQ running stably
  - Averaged uptime 98% (1st event - last event)
    - 7 hours for a run; 3-4 minutes for run transition

| | Shift 2015-10-27 00:00 to 08:00 | Shift 2015-10-27 08:00 to 16:00 | Shift 2015-10-27 16:00 to 00:00 |
|---|---|---|---|
| Cumulative Run Length | 477 min. | 469 min. | 437 min. |
| UpTime Fraction | 99.42% | 97.83% | 98.42% |

# Triggering

- MicroBooNE triggers
  - External: beam alert, strobe, paddle, and laser
  - Self trigger: PMT (commissioning)
  - SNEWS (SuperNova Early Warning System)

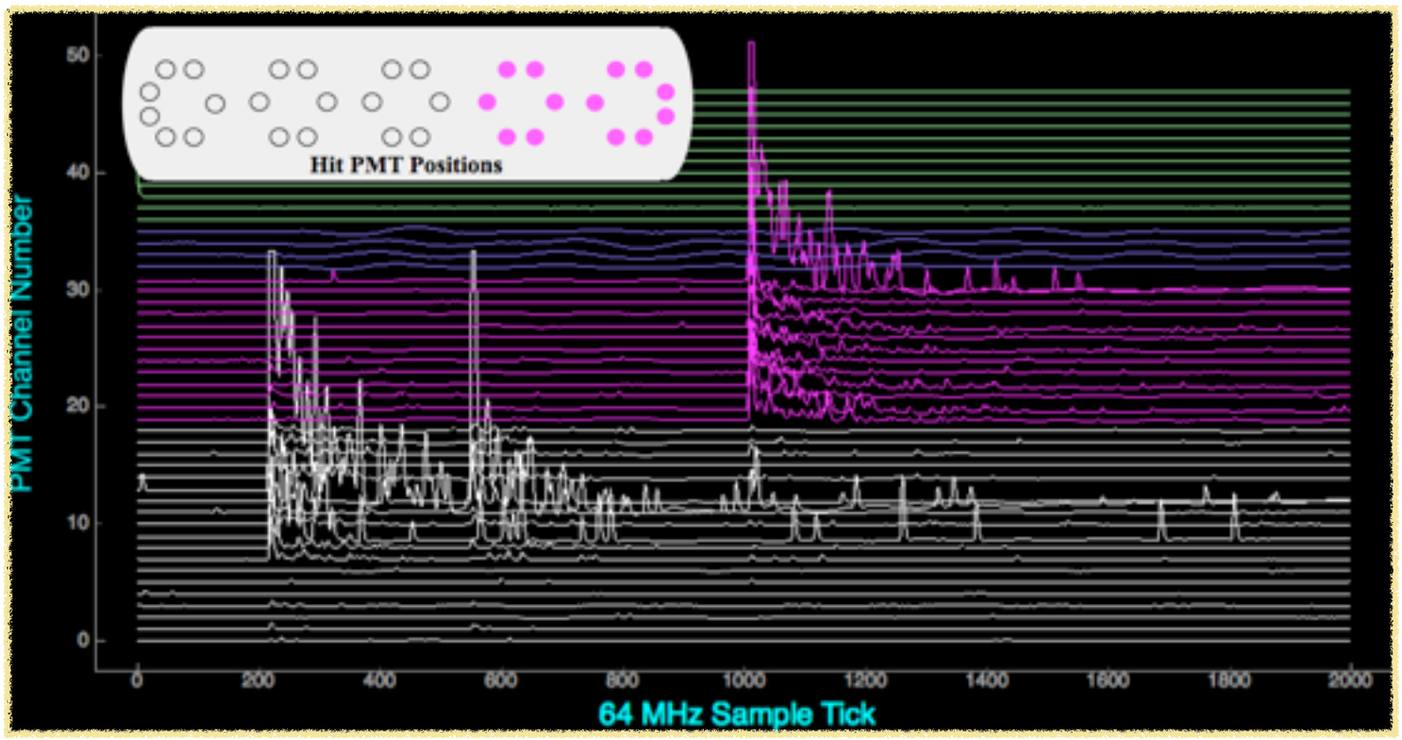
- Using only the beam alert trigger, we will have 500 TB (4PB) of raw (processed) data after 90 days with 2Hz of event rate
  ⇒ Self triggering is needed!

- Proposed self triggers in future experiments (e.g. DUNE):
  TPC, SiPM (photon detector), and TPC+SiPM

# PMT Trigger

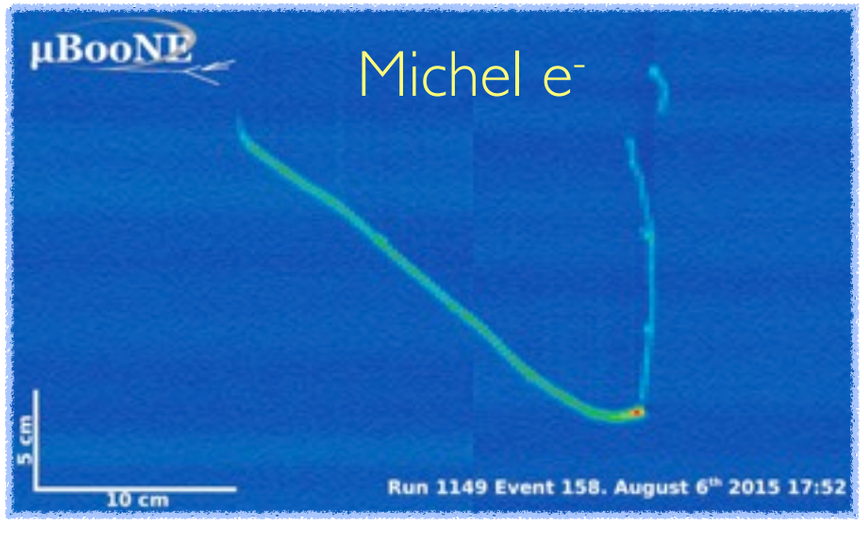
- Fast component of the scintillation light in LAr: 6ns
- Fast readout (compared to TPC): 64MHz
- Criteria on the multiplicity of PMT with light signals, and the sum over the collected light

Example of light collection readout: the light from cosmic rays has significant amplitudes in the waveforms, and, the signified PMTs are localized



# Trigger Efficiency Study

- MicroBooNE is measuring self PMT trigger efficiency with data (efficiency w.r.t. reconstructed variable)
  - Prescaled beam alert triggered events
    - use optical reconstructed variables
  - Paddle triggered events (cosmic rays)
  - Events from above containing Michel electrons:
    - explore low energy regime
    - capable of using TPC reconstructed variables



# Supernova Neutrino Trigger

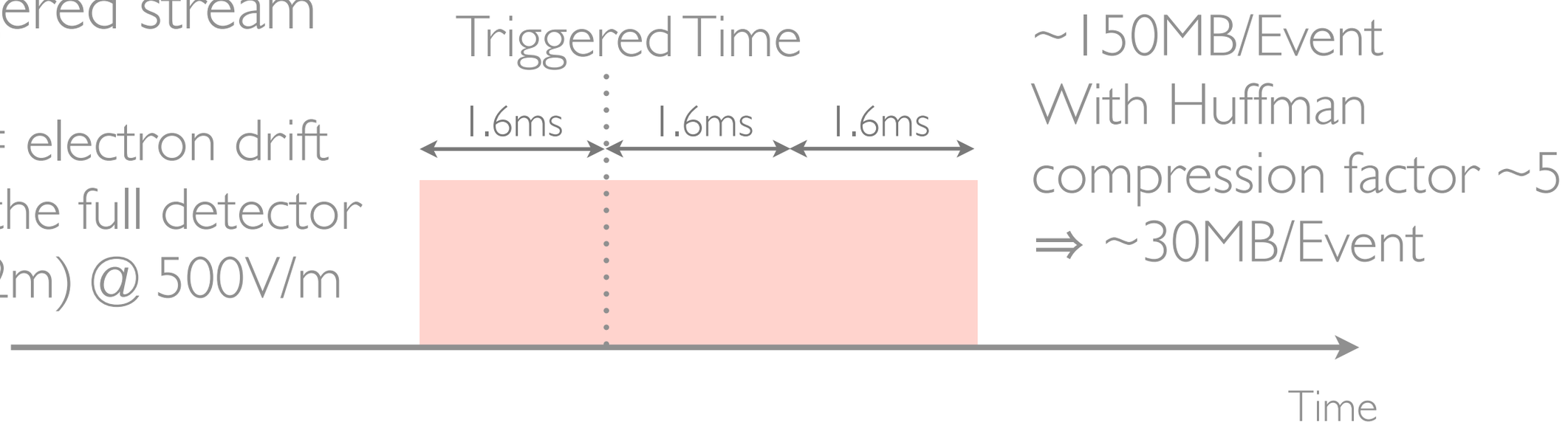

- MicroBooNE is not sensitive to self triggering on supernova neutrinos owing to its size and background events (surface location)
- Continuous stream keeps writing to disk
- SNEWS: sends out xml messages and emails when signals from several detectors coincide
- When received SNEWS, start transferring data files from disk to tape

- Self triggering R&D: Plan to explore PMT triggers for non-beam physics: SN **ν**s, proton decays, etc.

# Continuous Stream

1. Triggered stream

1.6ms = electron drift time for the full detector length (2m) @ 500V/m




~150MB/Event
With Huffman compression factor ~5
⇒ ~30MB/Event

2. Continuous stream (commissioning)

~50MB/1.6ms
With Huffman compression factor ~5
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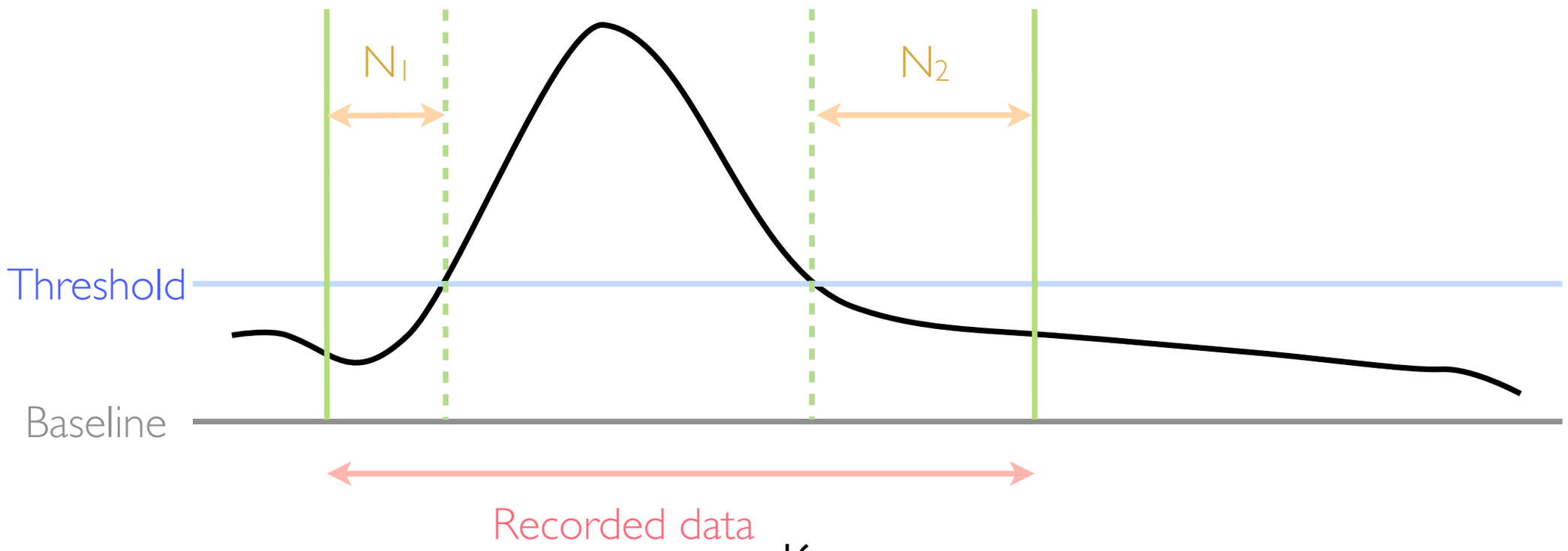
***Need further suppression!!***

Time

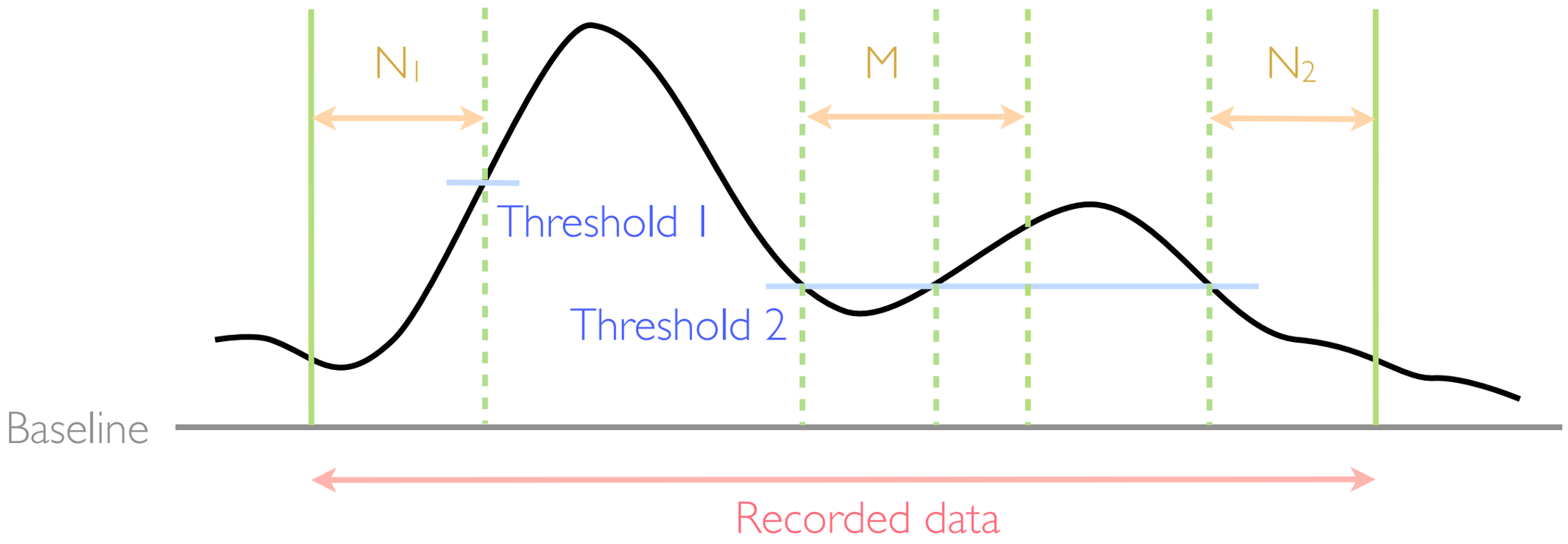
# Data Suppression

- MicroBooNE and 35 ton prototype of DUNE both have ongoing development on zero suppression algorithms
  - MicroBooNE aims to reach a suppression factor of 50-100
  - Current MicroBooNE suppression scheme



# Zero Suppression

- Current status
  - started studying simulation of supernova neutrinos and minimizing signal loss in suppression algorithms
  - dealing with noise and waveform feature: e.g. average samples to determine whether to pass the threshold
- Suppression scheme for 35ton; able to handle pile-ups

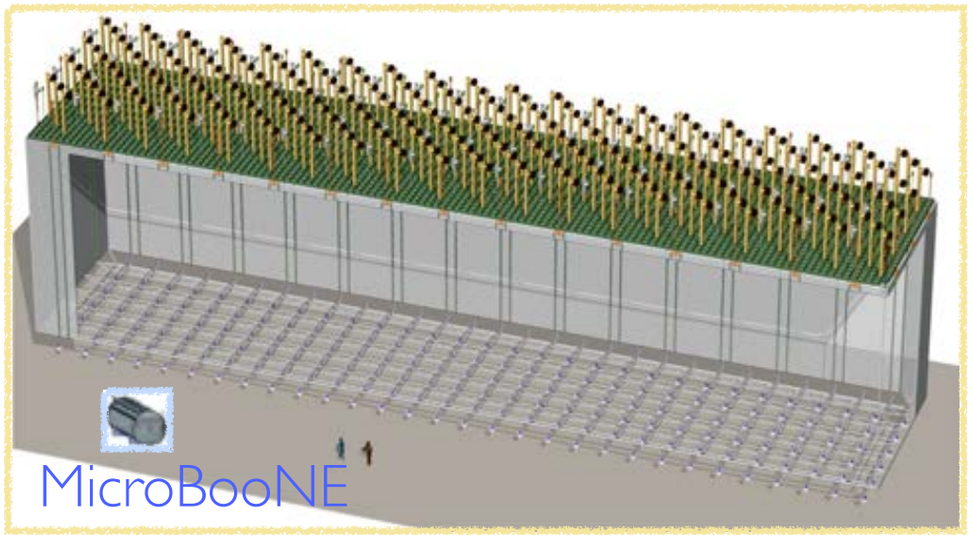


# Avenue Towards DUNE

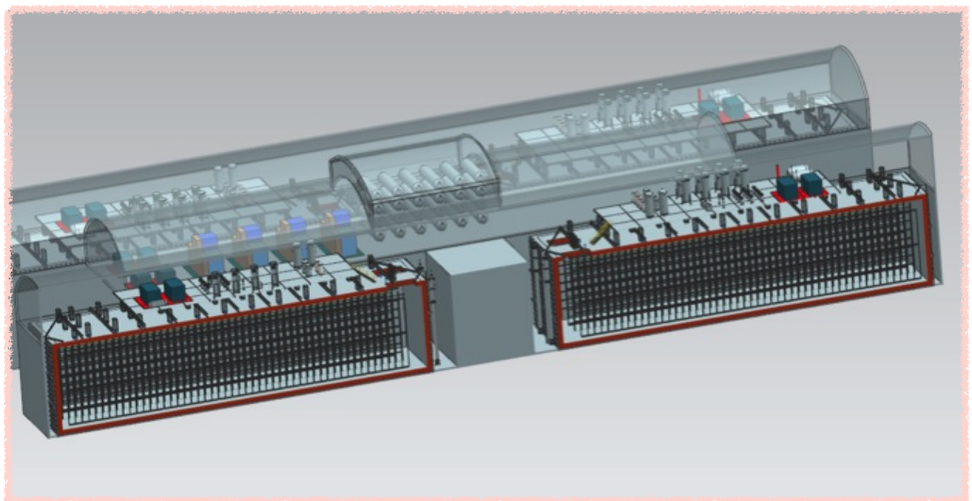
# DUNE Far Detector DAQ

- One of the physics goals: Supernova neutrino measurement
  - self triggering in low energy regime required
- Aim to save non-zero-suppressed data for all interesting regions in interesting events
  - trigger decision made after readout

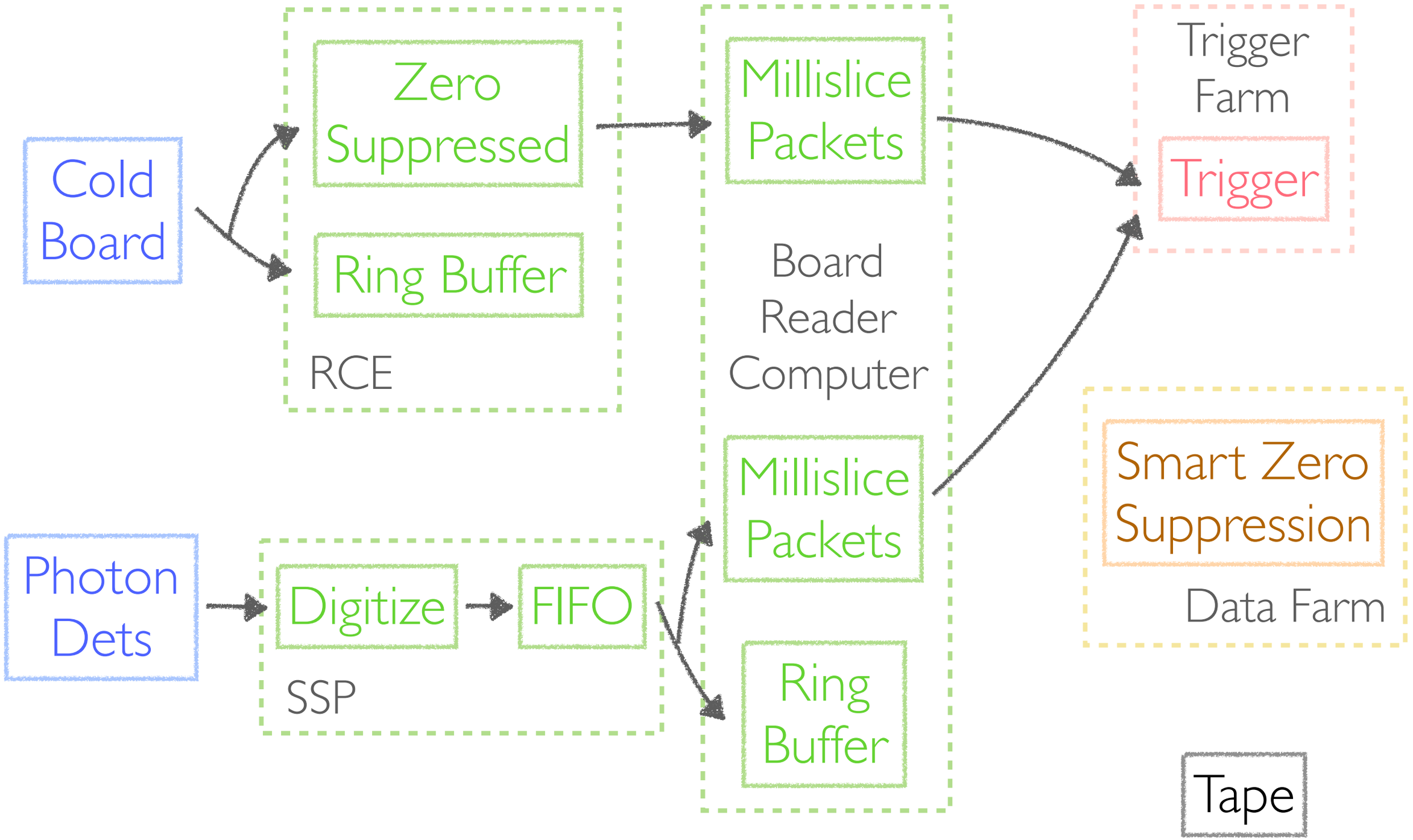
DUNE reference design (10kt)




Ultimately have 4x10kt LAr



# Readout-DAQ Plan



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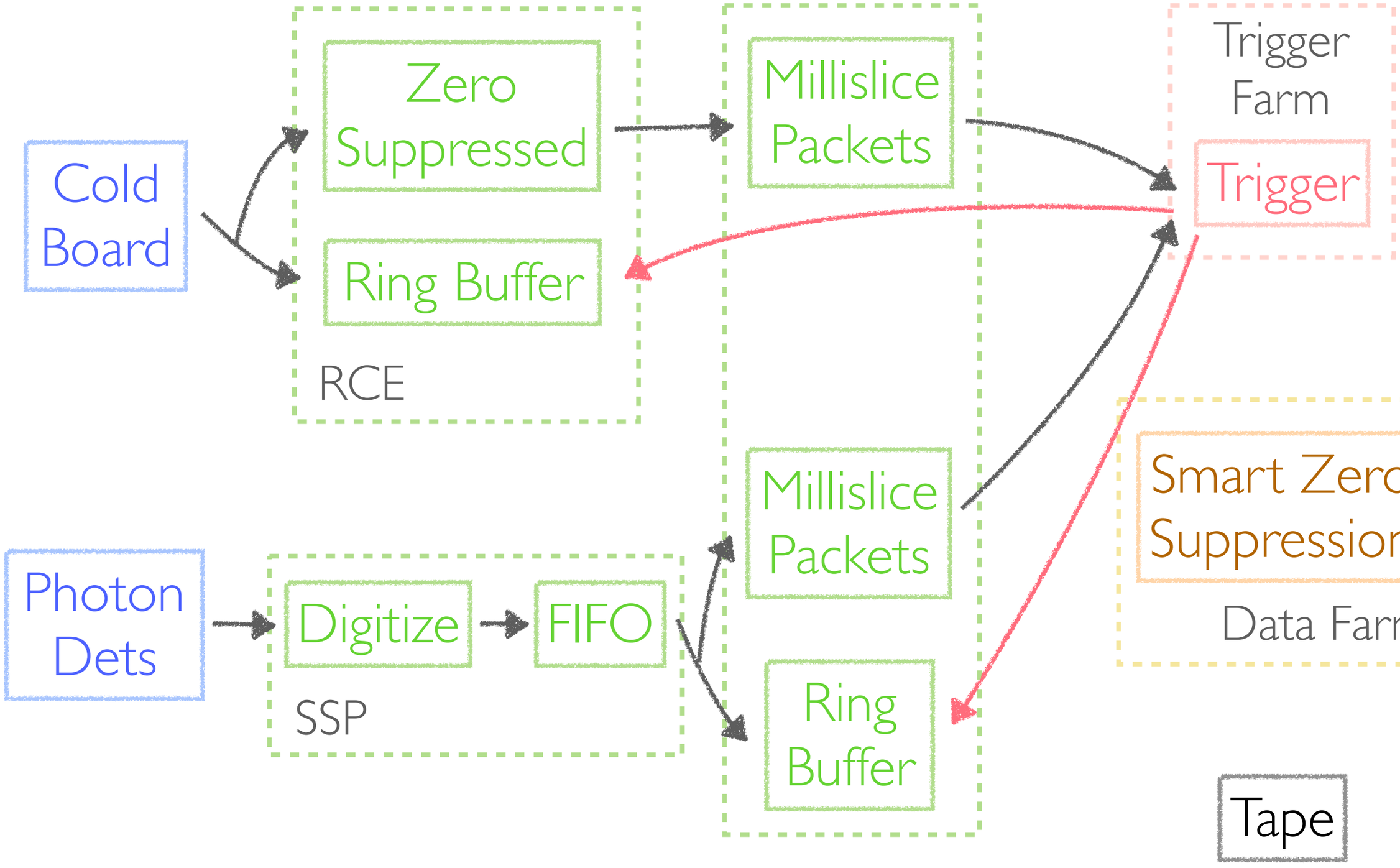

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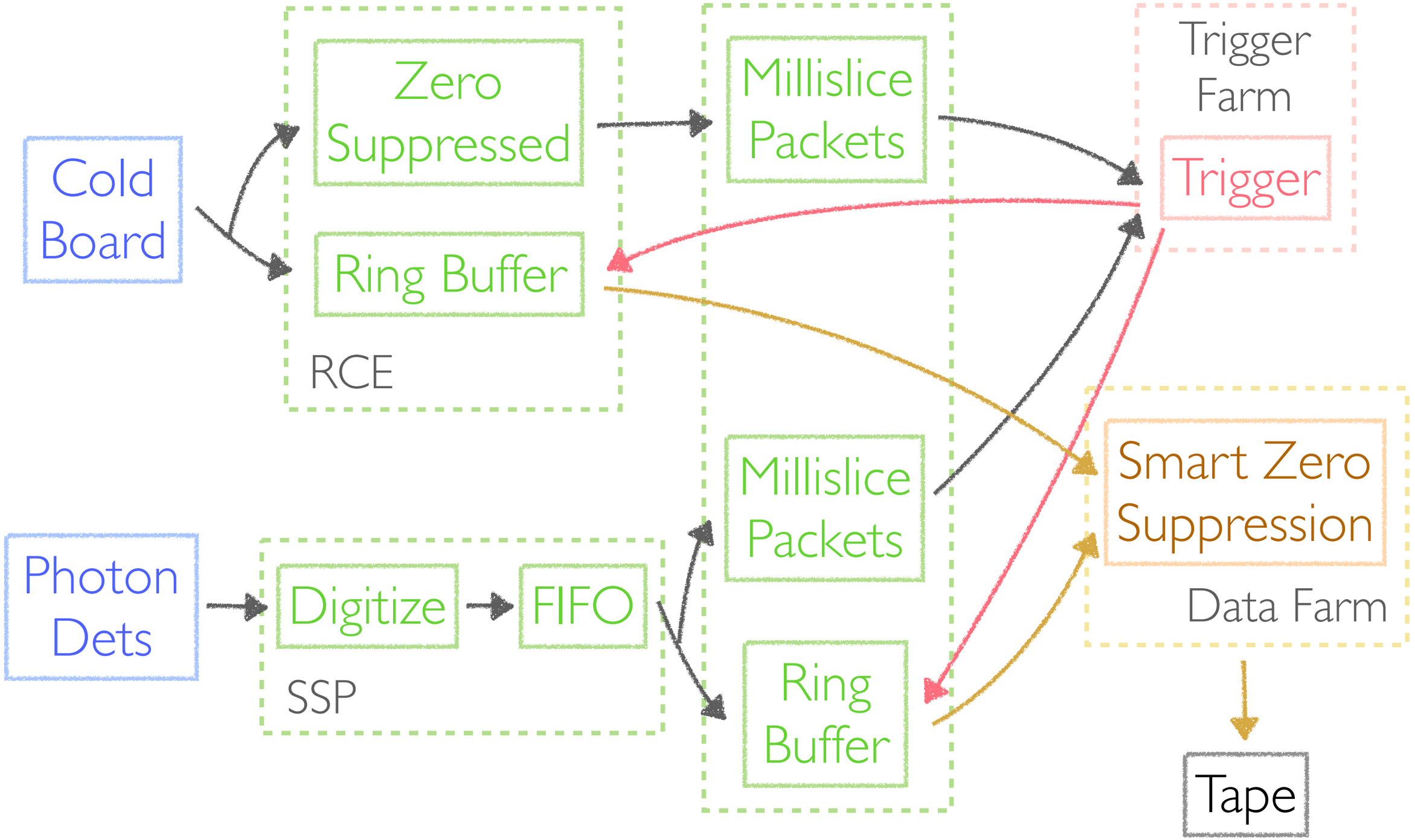
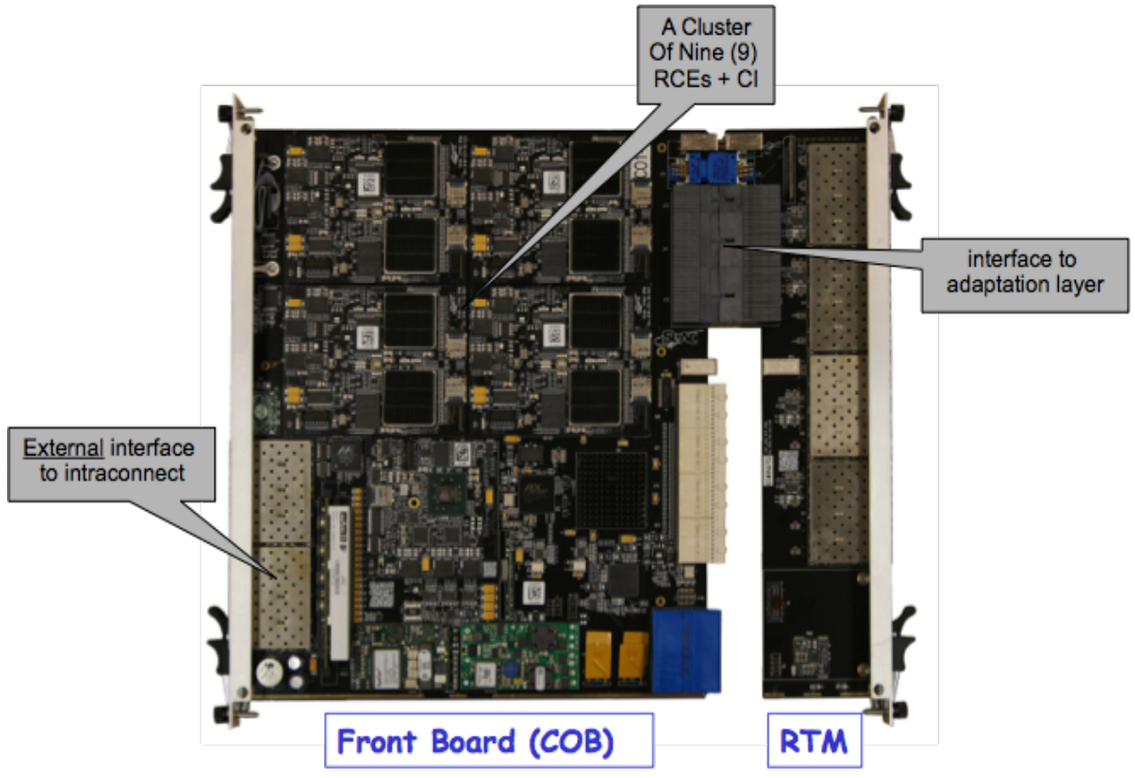


# TPC Trigger and RCE

- Plan to have both TPC and SiPM triggers
  - may rely on TPC trigger for low energy objects
- TPC trigger
  - needs data buffering and smart algorithms
- RCE allows
  - sophisticated algorithms
  - currently 1GB of RAM; plan on 8-16GB(?)
- Reconfigurable Cluster Element (RCE)
  - powerful FPGA
  - generic hardware used in multiple experiments



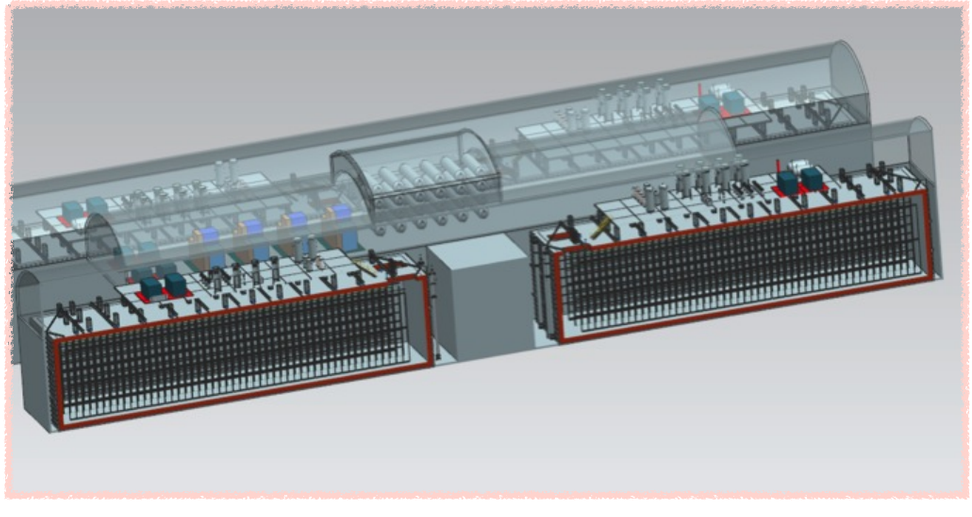
# Summary

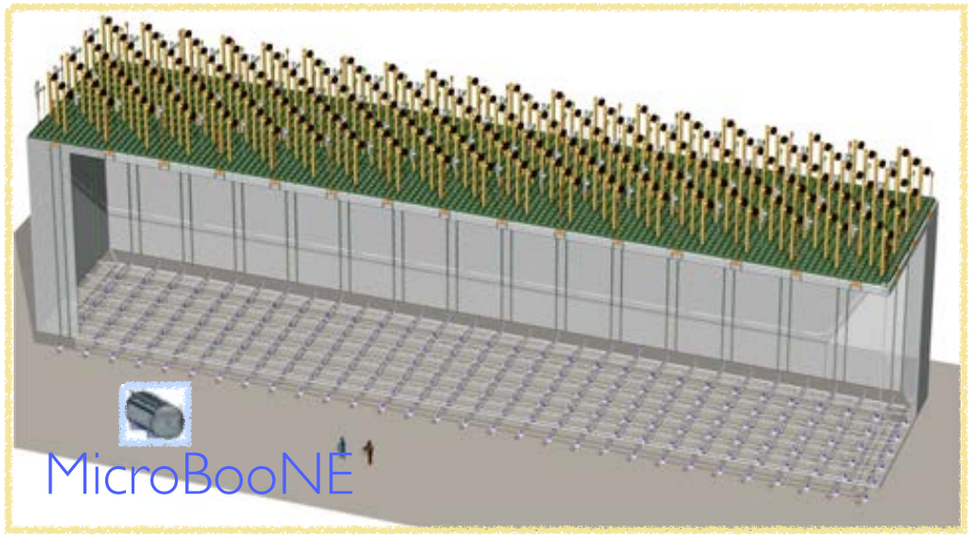
- MicroBooNE DAQ is running stably!
  - triggered stream; taking data at 5Hz
  - 98% of DAQ uptime during neutrino beam uptime
  - currently studying the efficiency of self PMT trigger
  - zero-suppressed continuous stream is under commissioning
- DUNE DAQ is designed to retain all interesting non-zero-suppressed data for non-beam physics
  - 35 ton prototype is testing the design with RCEs and will take data in next few months
- Stay tuned!

# Backup

# DUNE Far Detector DAQ

- One of the primary physics goals:
  Supernova neutrino measurement
- Plan to have DAQ in each cavern loosely-coupled to the others
  - minimize the chances that SB bursts when all DAQ systems are down
- Likely have single stream
  - smart data suppression is required

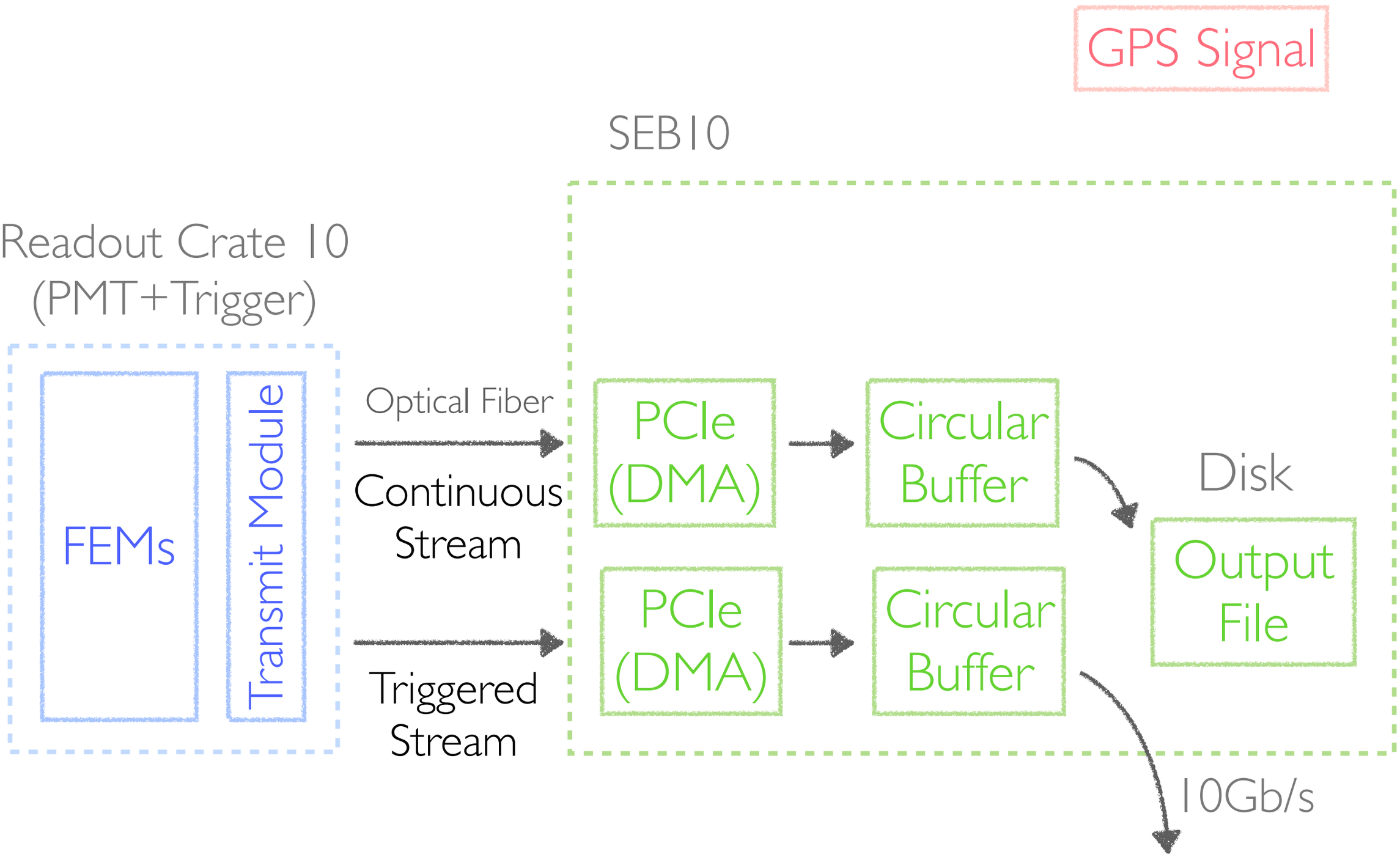




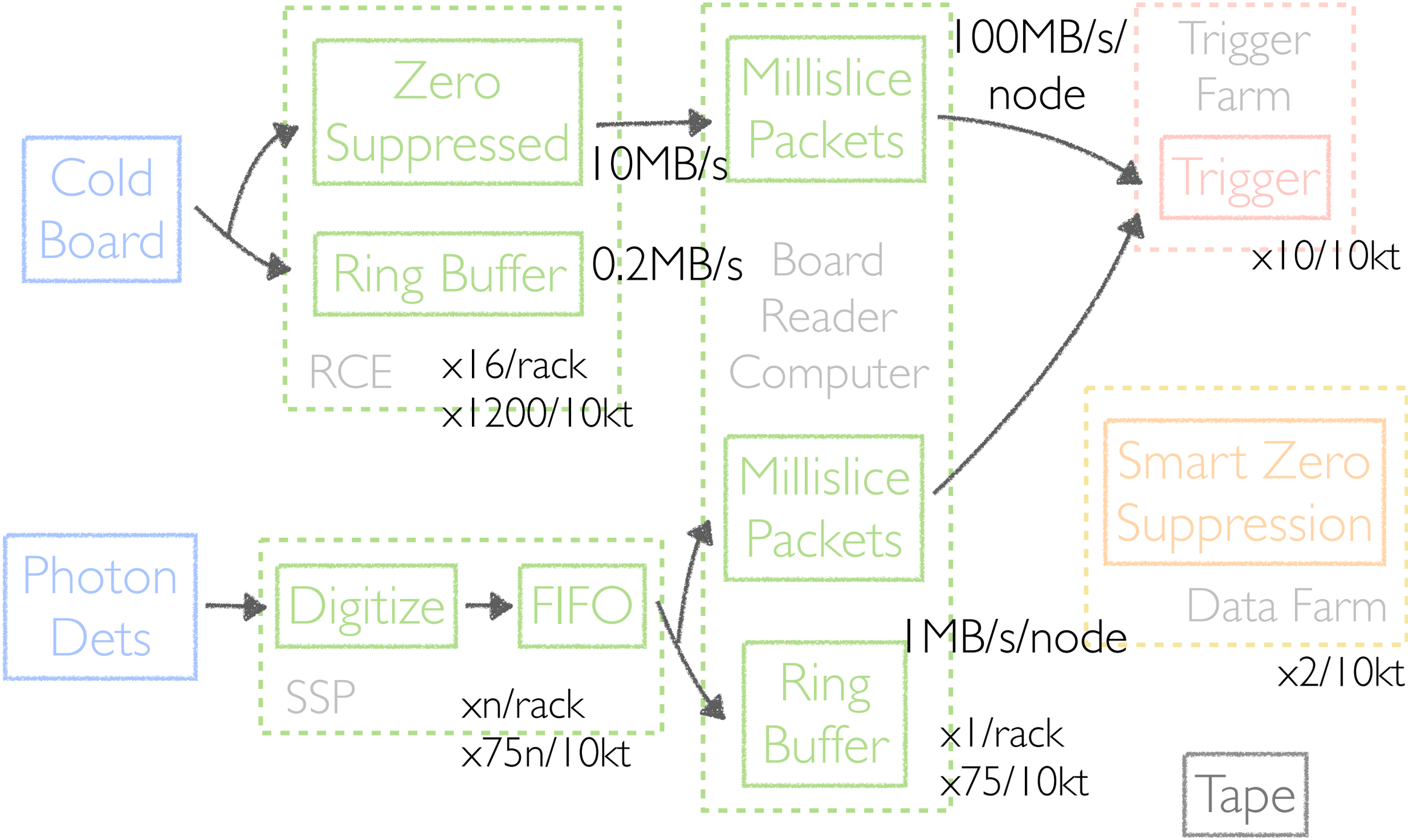


xO(30)x$R_T$x4
$R_T$: Ratio of readout window

# GPS Time Stamp



# Data Amount Estimate



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