UNIVERSITY OF MINNESOTA
Driven to Discover℠

Data Driven Triggers for the NOvA Experiment

On behalf of NOvA

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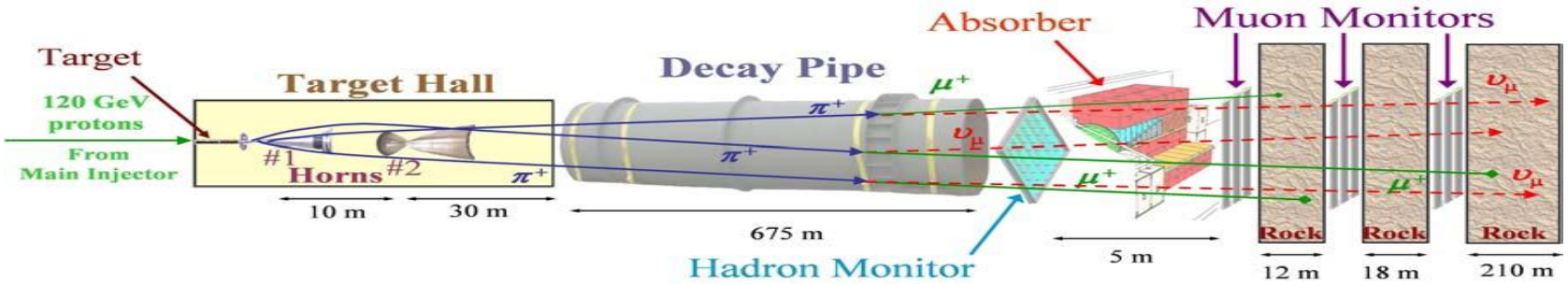
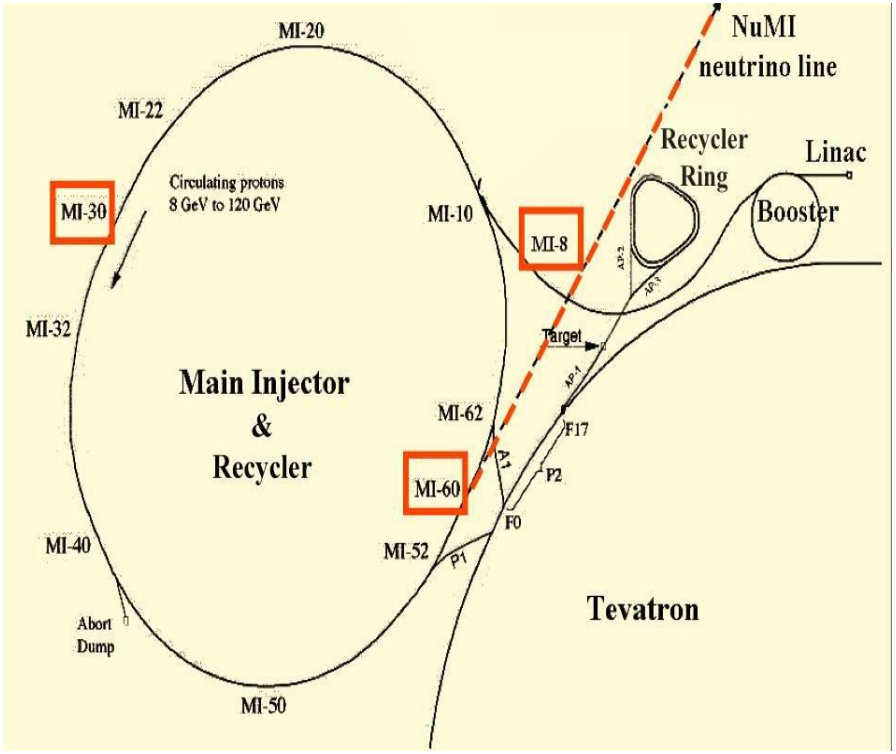
APS DPF Meeting – 08/15/2013

Introduction to NOvA

- **Neutrino Oscillation Experiment**
  - $P(\nu_\mu \rightarrow \nu_e)$
  - $P(\nu_\mu \rightarrow \nu_\mu)$
  - **As well as anti-neutrino channels**
- **Physics Goals**
  - **Precision measurement of θ_{23} and $|\Delta m^2_{32}|$**
  - **Measure θ_{13}**
  - **Resolve mass hierarchy**
  - **Constrain δ_{CP}**

The Accelerator



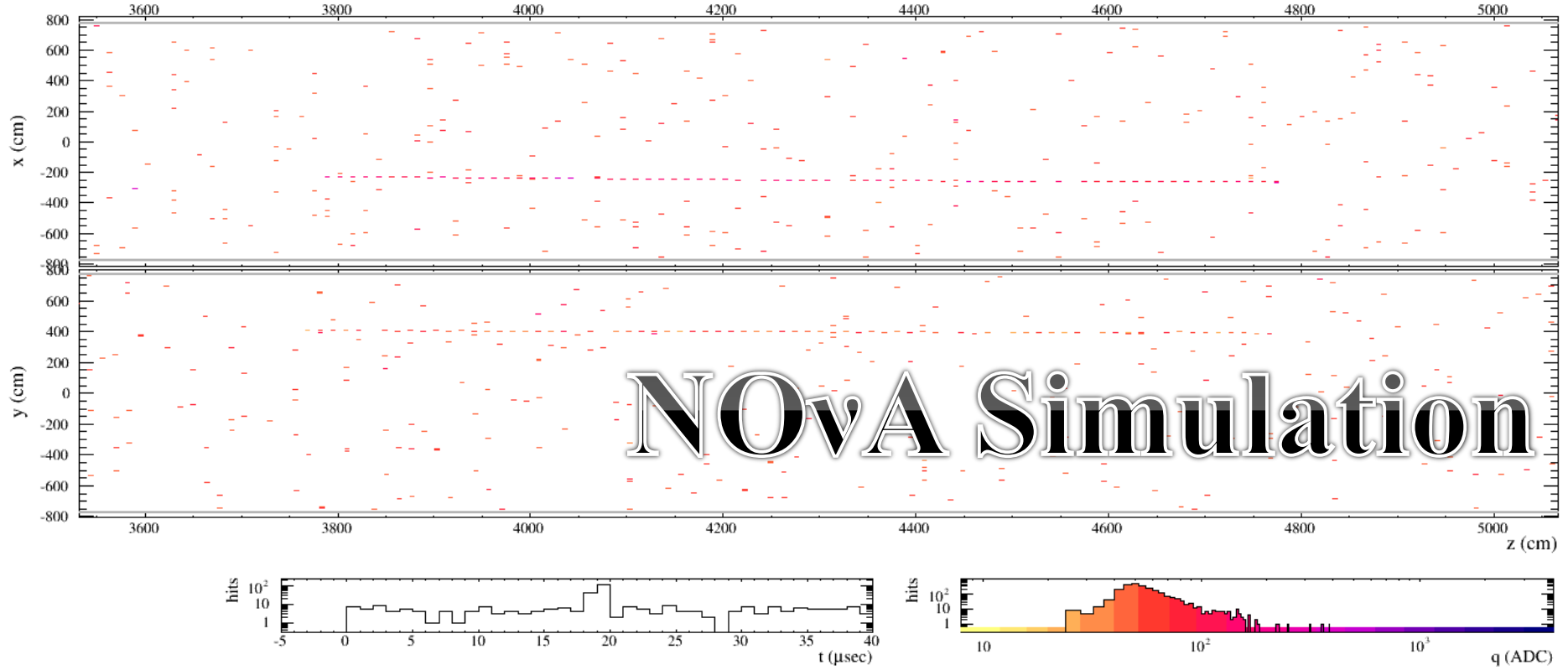


- **NuMI Beamline**
  - **Graphite target**
  - **Magnetic focusing horns**
  - **10 μs beam spill every 1.3 s**
  - $\pi^+ \rightarrow \mu^+ + \nu_\mu$
  - **700 kW capable beam**

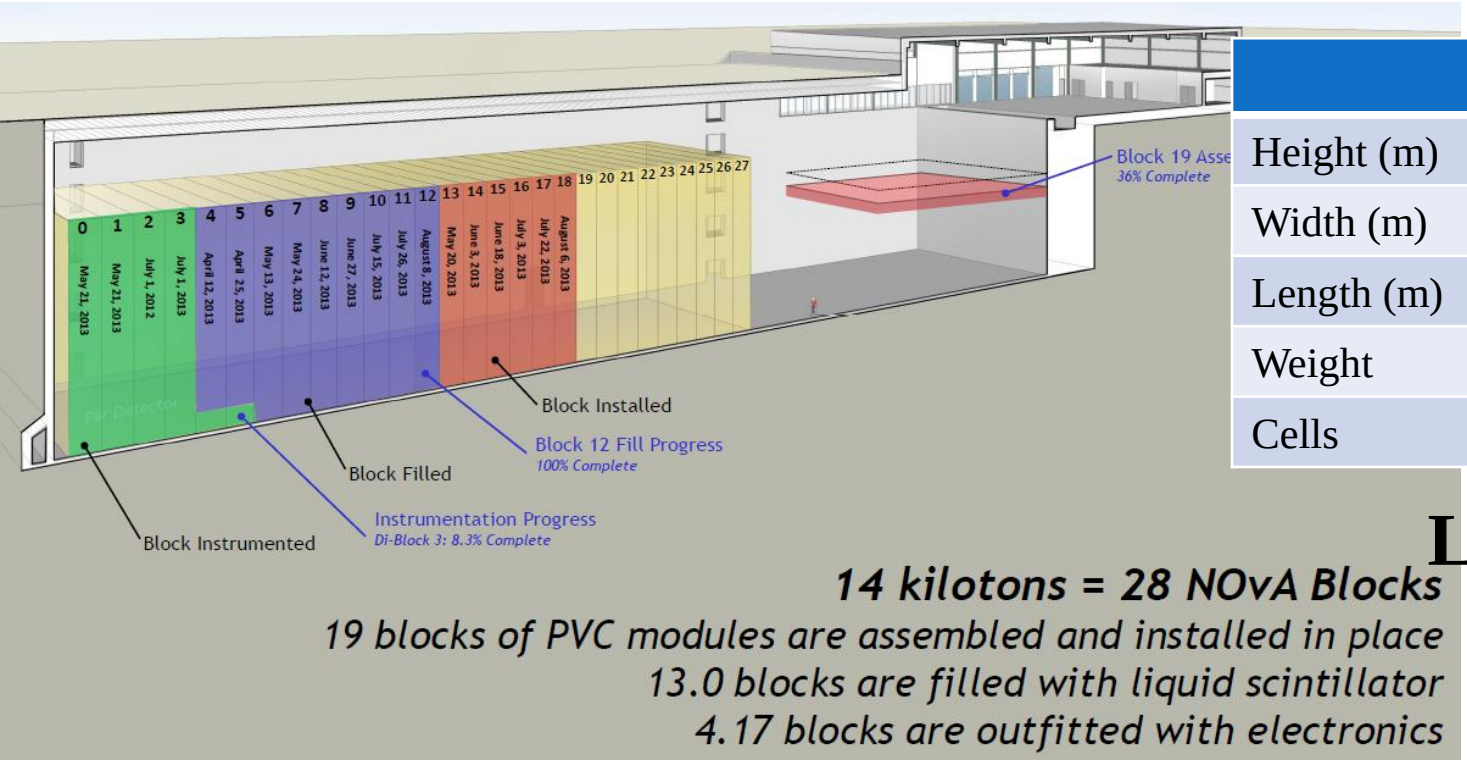
Data Driven Triggers (DDTs)

- **Aid beam related analyses**
  - **~600 beam neutrino events at Far Detector per year**
  - **Every single one is precious**
- **Crucial for non beam related physics**
  - **Magnetic Monopoles**
  - **Supernovae**
- **Enhance calibration and alignment samples**

Rare Topologies



The Detector



	FarDet	NearDet
Height (m)	15.6	4.2
Width (m)	15.6	4.2
Length (m)	63	14.3
Weight	14 kt	260 tons
Cells	344,064	20,256

- **Mostly active**
- **Staggered planes**
- **Construction underway**

Large detector

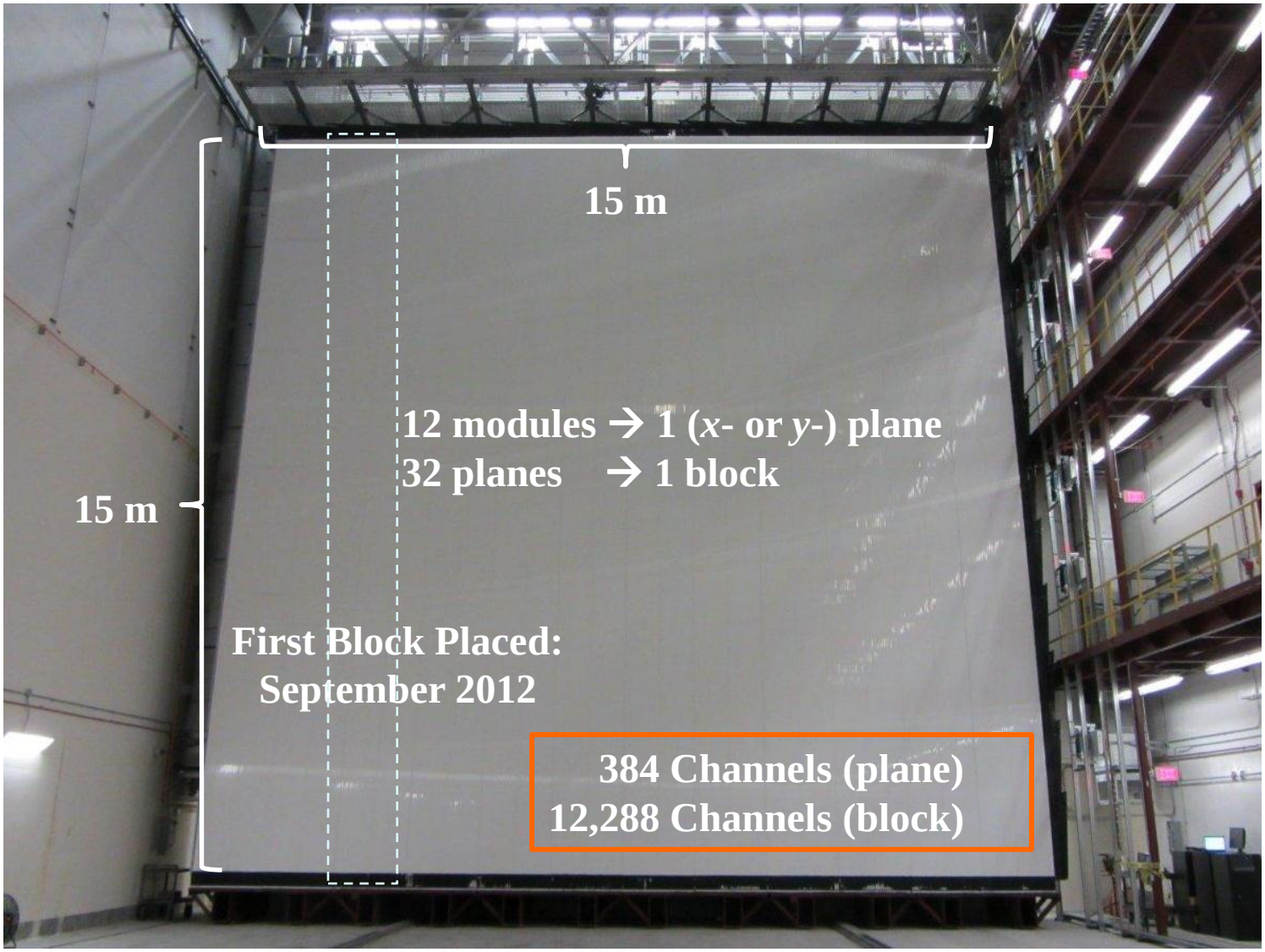
- **Supernovae**
  - **DDT**

Large surface area

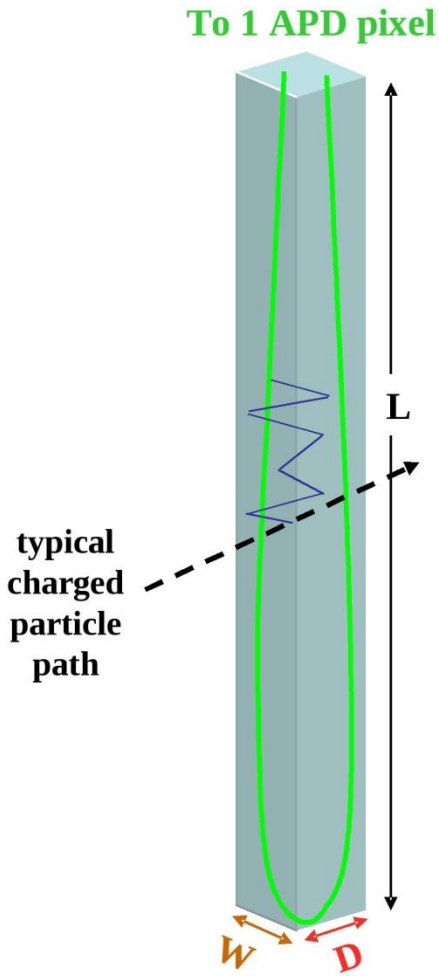
- **Magnetic Monopoles**
  - **DDT**

Far Detector

Far Detector Face

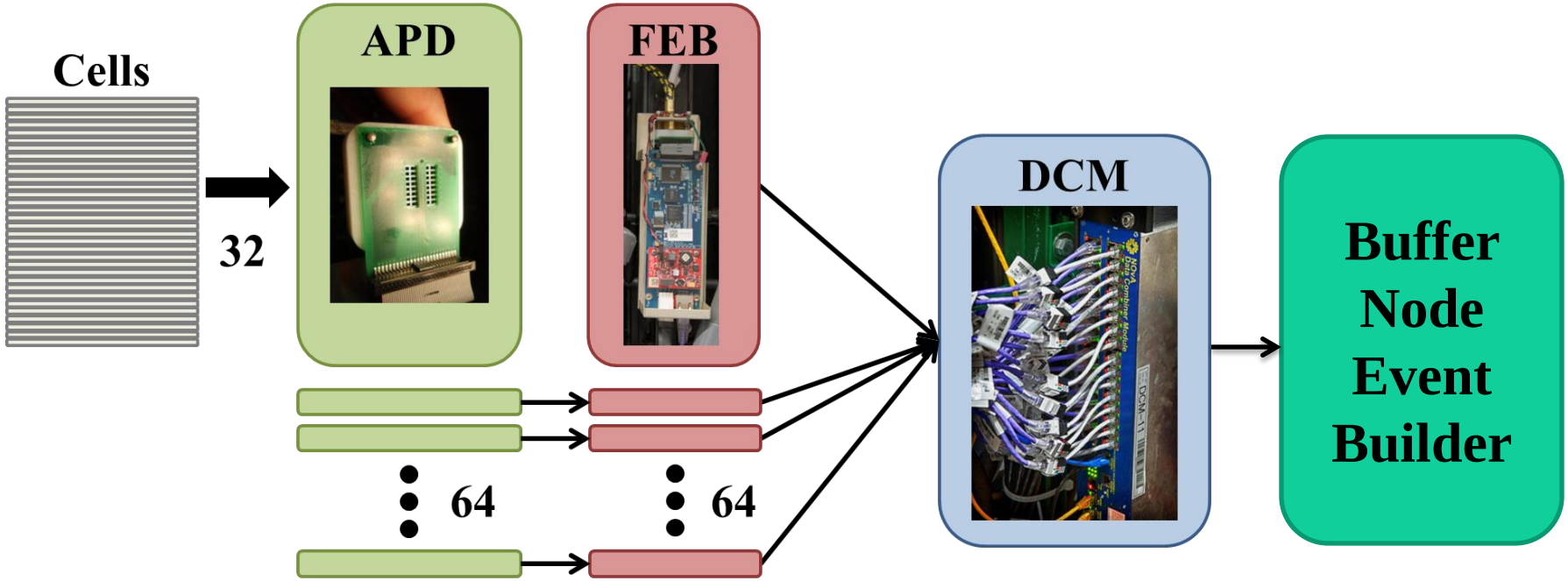


The Cells



- 32 cells per module
- Scintillation light travels to Avalanche Photo Diode (APD) via Wavelength Shifting Fiber
- Data at this stage
  - Pulse height
    - Analog to Digital Conversion (ADC) counts
  - Time stamp
  - Cell ID

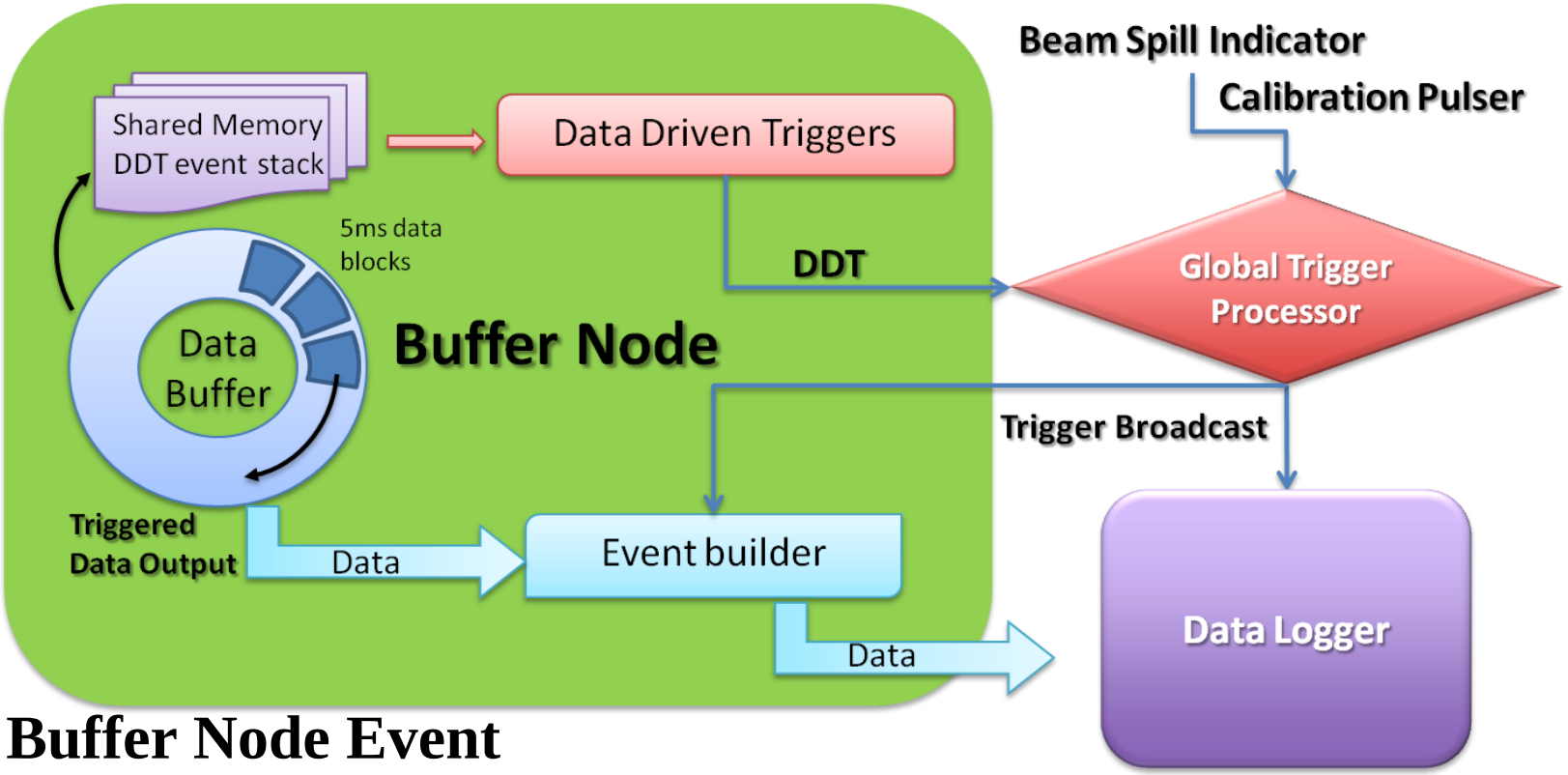
The Readout



- APD reports photo electrons
- Front End Board decides what's a hit

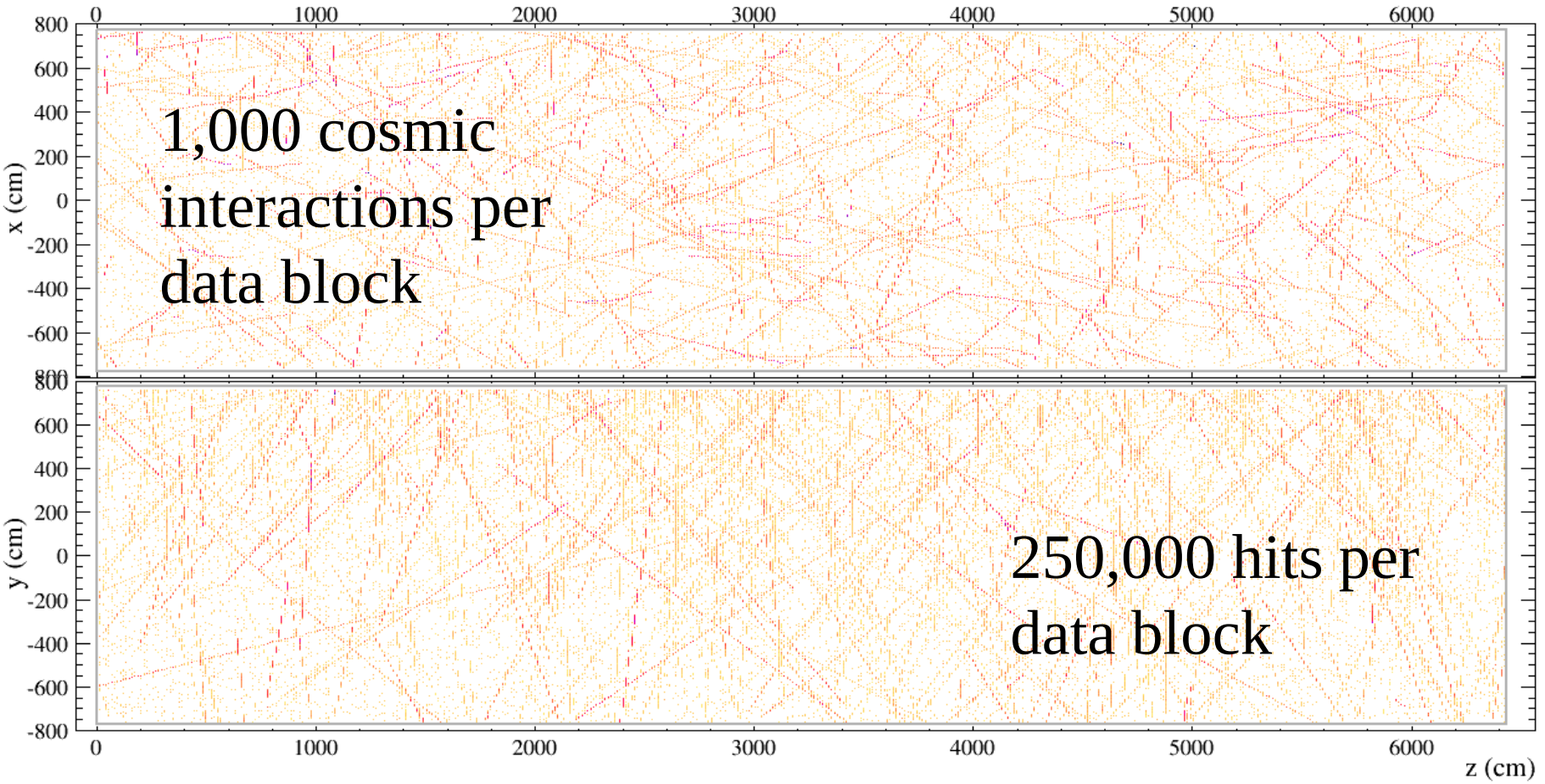
- Data Concentrator Module
  - Collects discretized data
    - Micro- and Millislices

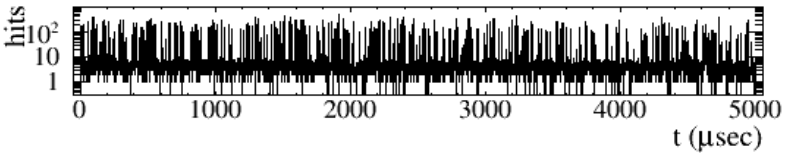
Data Buffering

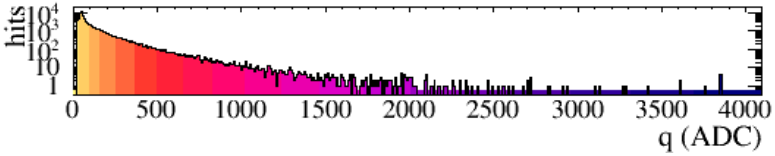


- **Buffer Node Event Builders**
  - **Assembles millislices into milliblock**
    - **Snapshot of the detector**
- **Global Trigger**
  - **Manages trigger messaging**

Far Detector Simulation



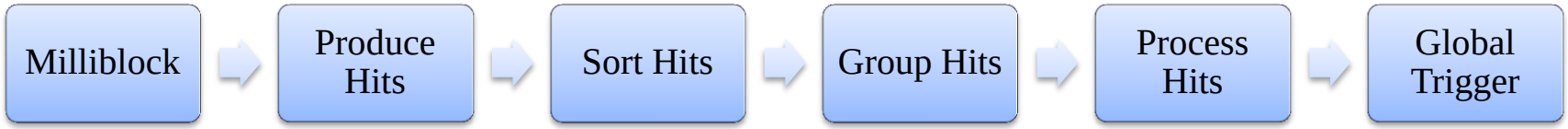




Data Rates

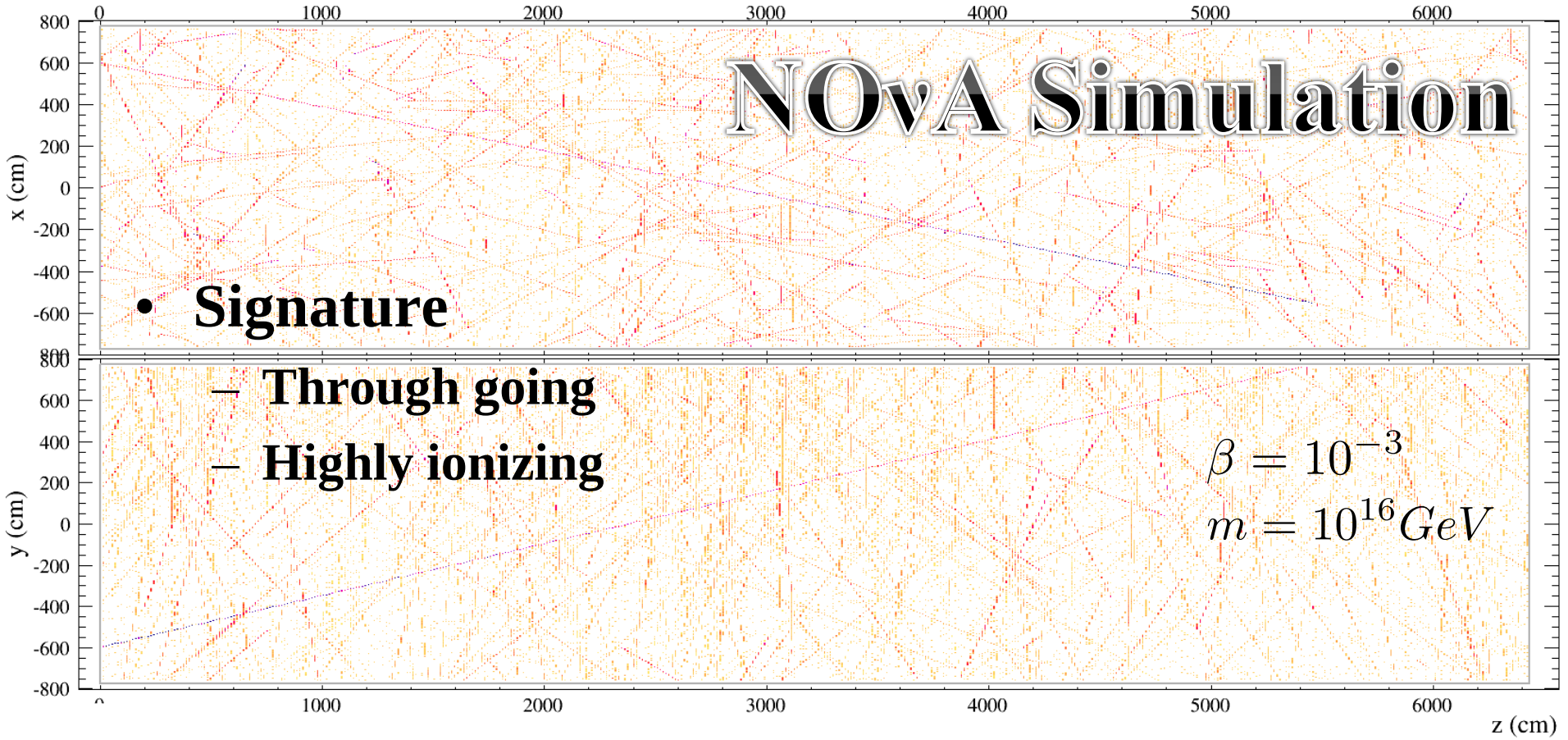
- **No dead time**
  - **~600 MB/s to write all to disc**
- **200 kHz Cosmic rate**
- **0.8 Hz Beam neutrino rate**
  - **600 interactions per year**
  - **20 μHz**
- **DDT sieve needed**
- **Can save**
  - **~10% of live time to disc**
    - **~2 PB/yr**
  - **Bandwidth limited**
- **Planned upgrades to increase bandwidth**

DDT in Action



- **Produce list of hits**
- **Sort the list**
  - **Time**
  - **Detector region**
- **Group hits within list**
- **Process grouped hits**
  - **Tracking**
  - **Clustering**
- **Trigger**
  - **Send message to Global Trigger**
  - **Forwarded to Buffer Nodes**

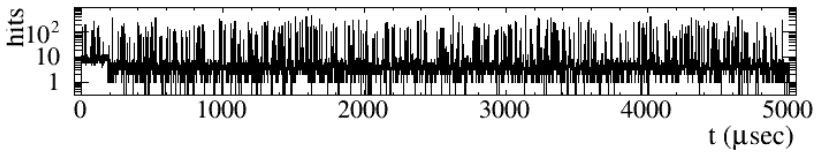
Magnetic Monopoles

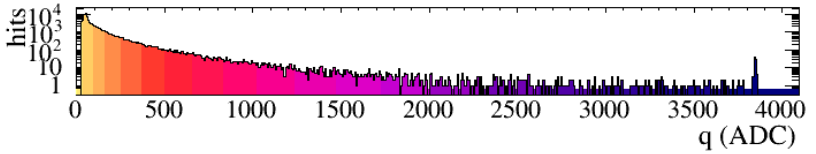


- **Signature**
  - **Through going**
  - **Highly ionizing**

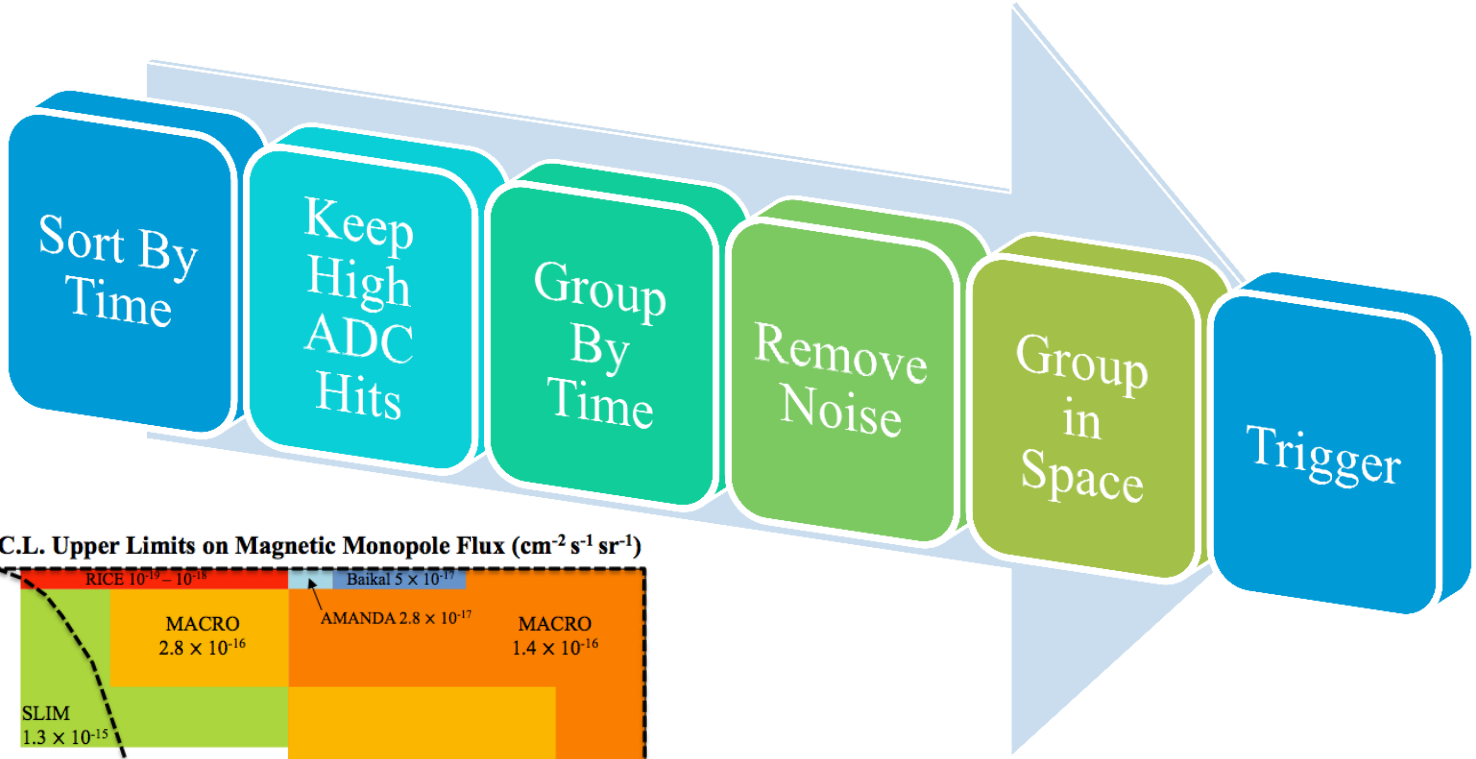
$\beta = 10^{-3}$

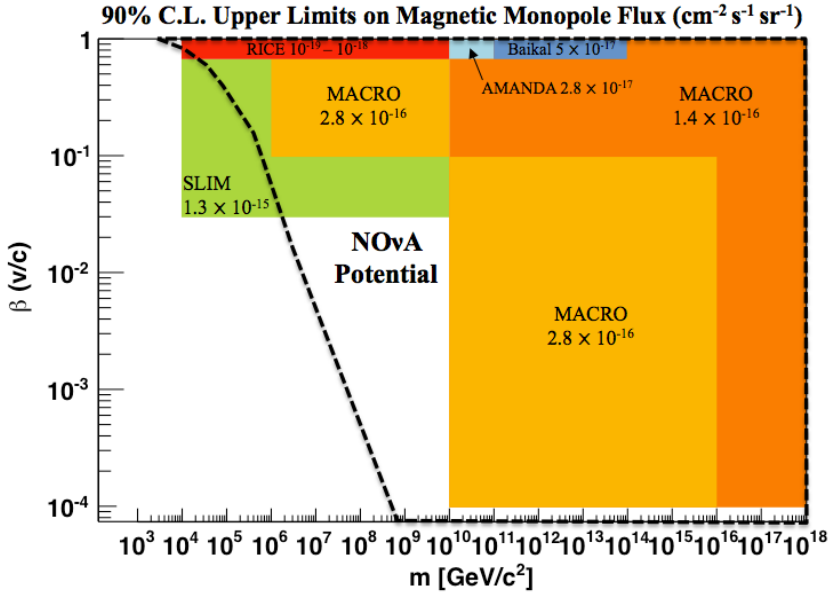
$m = 10^{16} GeV$





Fast Monopoles in NOvA





Trigger on

- Min/Max position of grouped hits
- ADC Threshold

Supernova Trigger Challenges

- **Energy Spectrum**
  - **~5k neutrinos > 10 MeV**
- **Provide time profile**
- **Framework**
  - **5 ms windows aren't long enough**
  - **Global noise level**
- **Under active development**

Class	Channel	GKVM	Livermore
Inverse Beta Decay			
	IBD	3185	5355
ν_e CC on Carbon			
	ν_e (^{12}C)	134	50
	$\bar{\nu_e}$ (^{12}C)	131	195
Elastic Scattering			
	ν_e	72	125
	$\bar{\nu}_e$	31	55
	ν_μ	12	22
	$\bar{\nu}_\mu$	10	18
	ν_τ	12	22
	$\bar{\nu}_\tau$	10	18
	Total	3464	5811

Class	Channel	GKVM	Livermore
Neutral Current on Carbon			
	ν_e (^{12}C)	61	30
	$\bar{\nu}_e$ (^{12}C)	64	96
	ν_μ (^{12}C)	61	223
	$\bar{\nu}_\mu$ (^{12}C)	61	223
	ν_τ (^{12}C)	61	223
	$\bar{\nu}_\tau$ (^{12}C)	61	223
	Total	371	1020

Conclusions

- **Successes**
  - **Data framework developed**
  - **Trigger messages sent and received**
  - **Fast magnetic monopole trigger implemented**
- **Future Work**
  - **Need studies of trigger rate and efficiency**
  - **Need monitoring tools**
  - **Implementing more triggers**
    - **Contained muons**
    - **Supernova trigger**
    - **Upward going tracks**

Thanks!

The DDT Group:

Gavin Davies, Martin Frank, Craig Group, Alec Habig, William Henderson, Adam Moren, Andrew Norman, Yuri Oksuzian, Brian Rebel, Louise Suter, Matthew Tamsett, Zukai Wang

Special Thanks to:

Martin Frank, Andrew Norman, Zukai Wang, and The ARTists

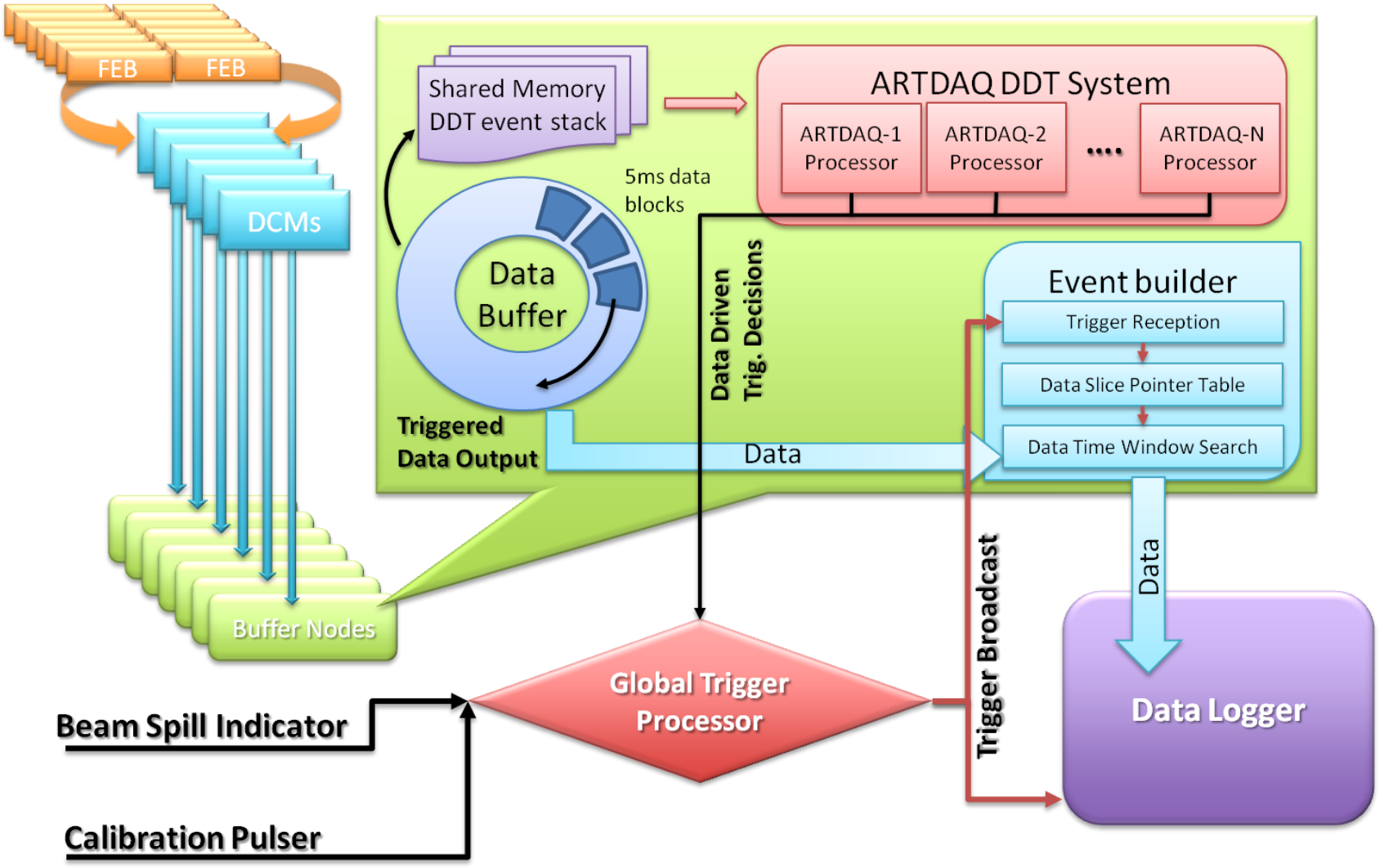
Data Concentration

- **Front End Board**
  - **Digitizes signal from one APD**
  - **2 MHz sampling**
  - **Assigns timing information**
    - **32 bit word gives unique stamp within 67 second window with 64 MHz clock**
  - **Produces one nanoslice per hit**
- **Data Concentrator Module**
  - **Reads out 64 FEBs**
  - **Assigns another 24 bits of timing information**
    - **Rolls over every ~36 years**
  - **Produces 50 μs (microslice) activity window of detector region from individual nanoslices**
  - **Collects microslices into 5ms microslice for transfer**

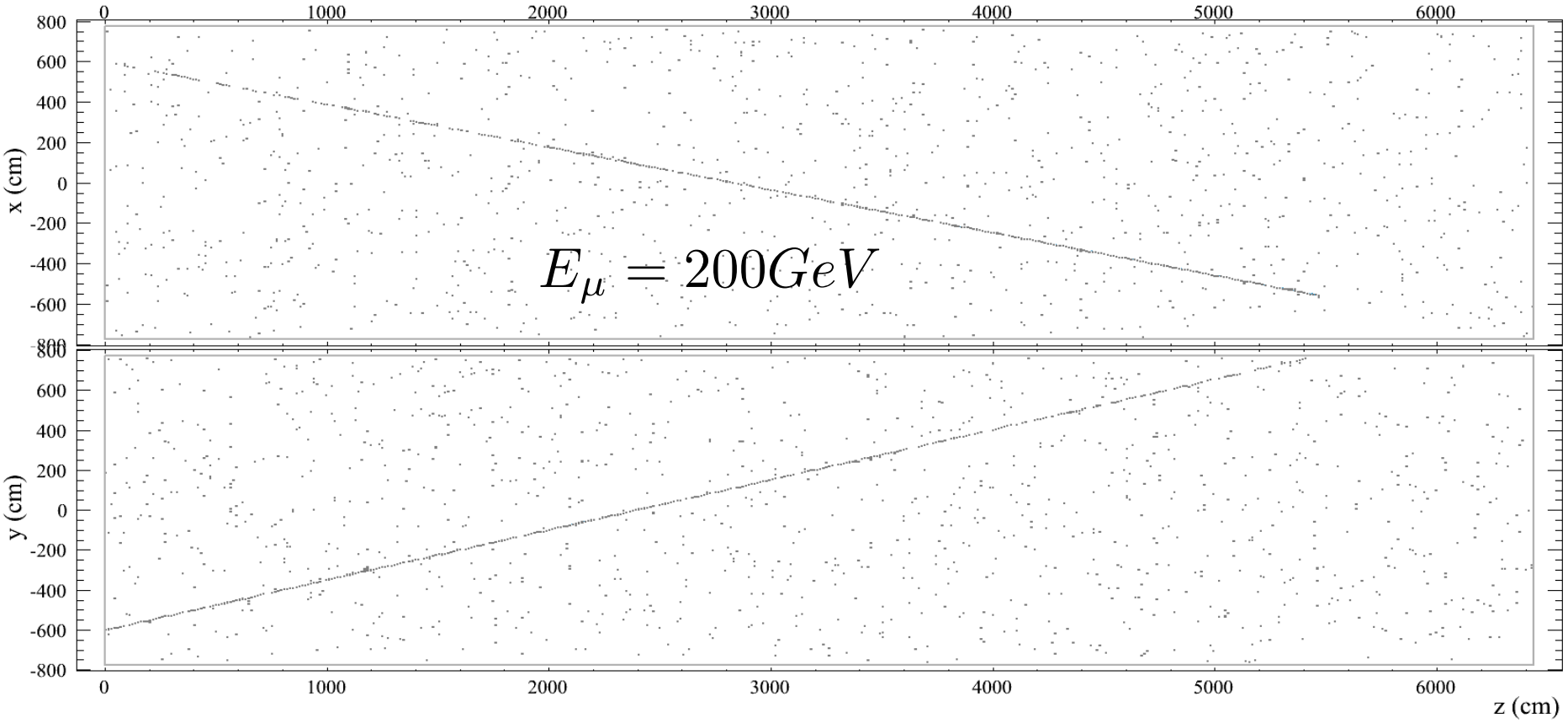
Global Trigger

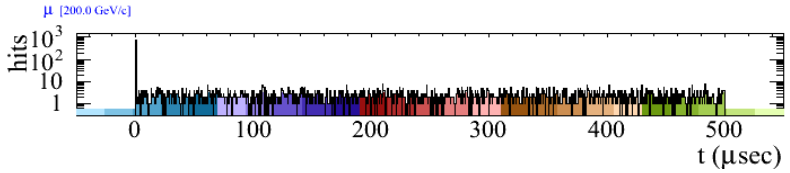
- **Process**
  - **Listening for trigger messages**
    - **Calibration Pulser**
    - **Beam Spill Indicator**
    - **DDT**
  - **Broadcast to Buffer Farm to send appropriate microslices to Data Logger**
  - **Data Logger appends data to correct trigger stream**
- **DDS Messaging**
  - **Data Distribution Service**
  - **Publishers and Subscribers**
    - **Mailboxes**
  - **How NOvA's DAQ functions**

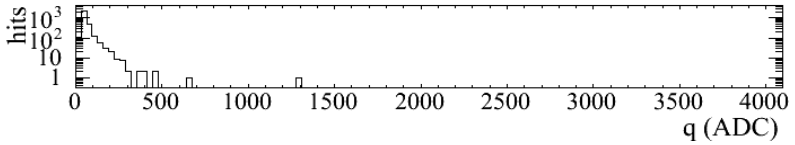
DAQ Summary


FEB
FEB
DCMs
Buffer Nodes
Shared Memory
DDT event stack
5ms data
blocks
Data
Buffer
Triggered
Data Output
ARTDAQ DDT System
ARTDAQ-1
Processor
ARTDAQ-2
Processor
....
ARTDAQ-N
Processor
Data Driven
Trig. Decisions
Event builder
Trigger Reception
Data Slice Pointer Table
Data Time Window Search
Data
Trigger Broadcast
Data
Data Logger
Global Trigger
Processor
Beam Spill Indicator
Calibration Pulser

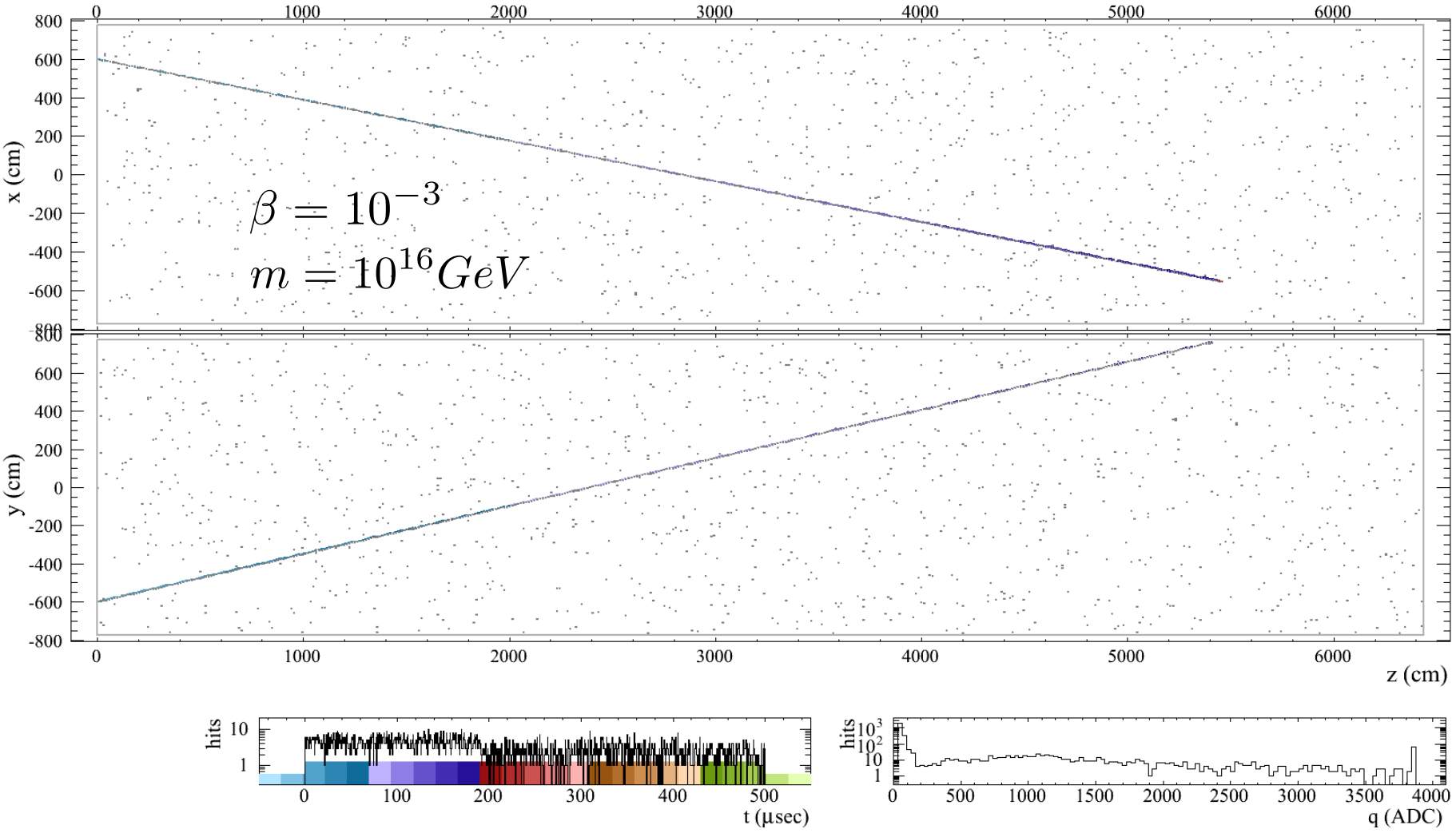
High Energy Muon







Magnetic Monopole



High Energy Muon vs Monopole