



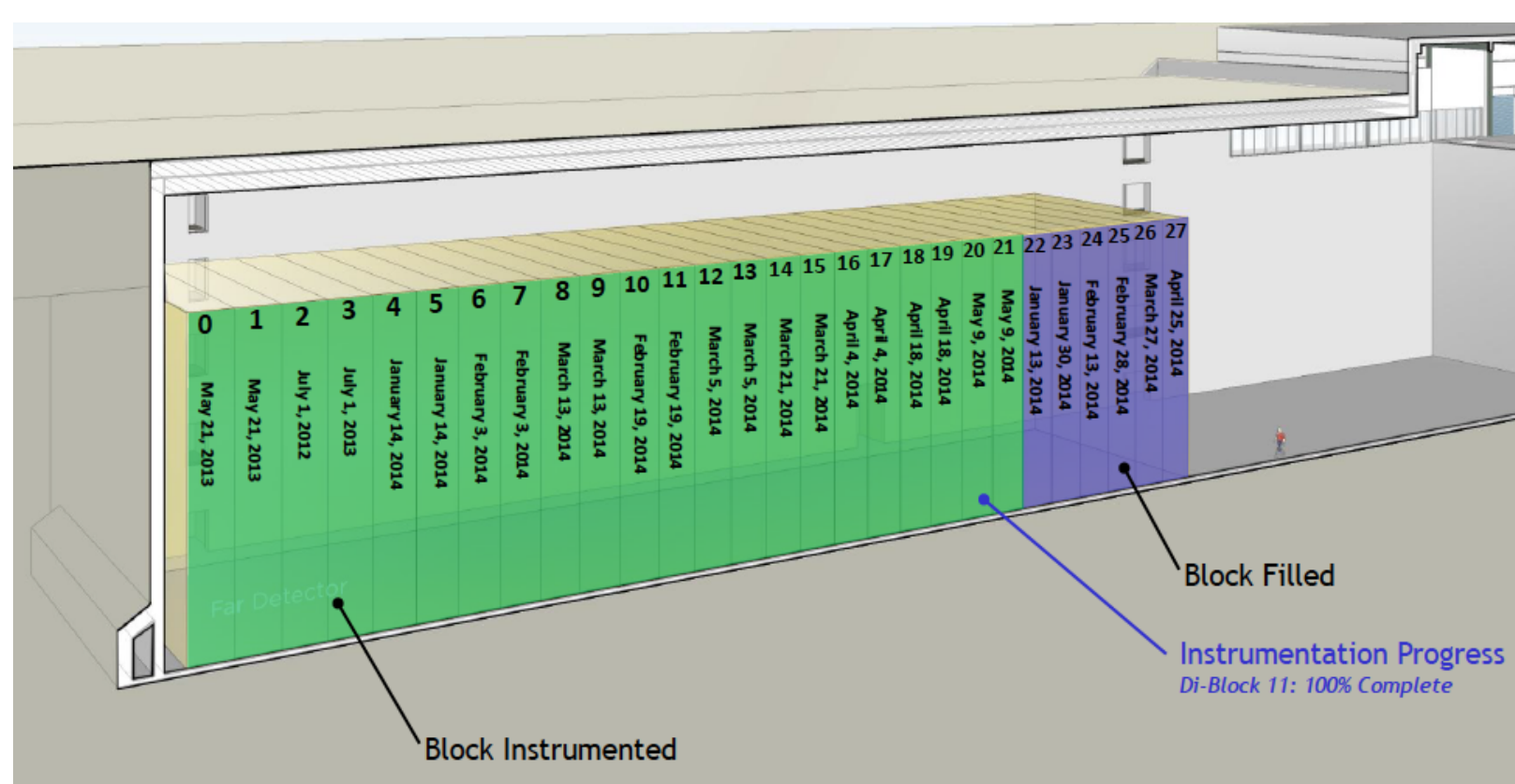
The NOvA data driven trigger

Matthew Tamsett for the NOvA collaboration

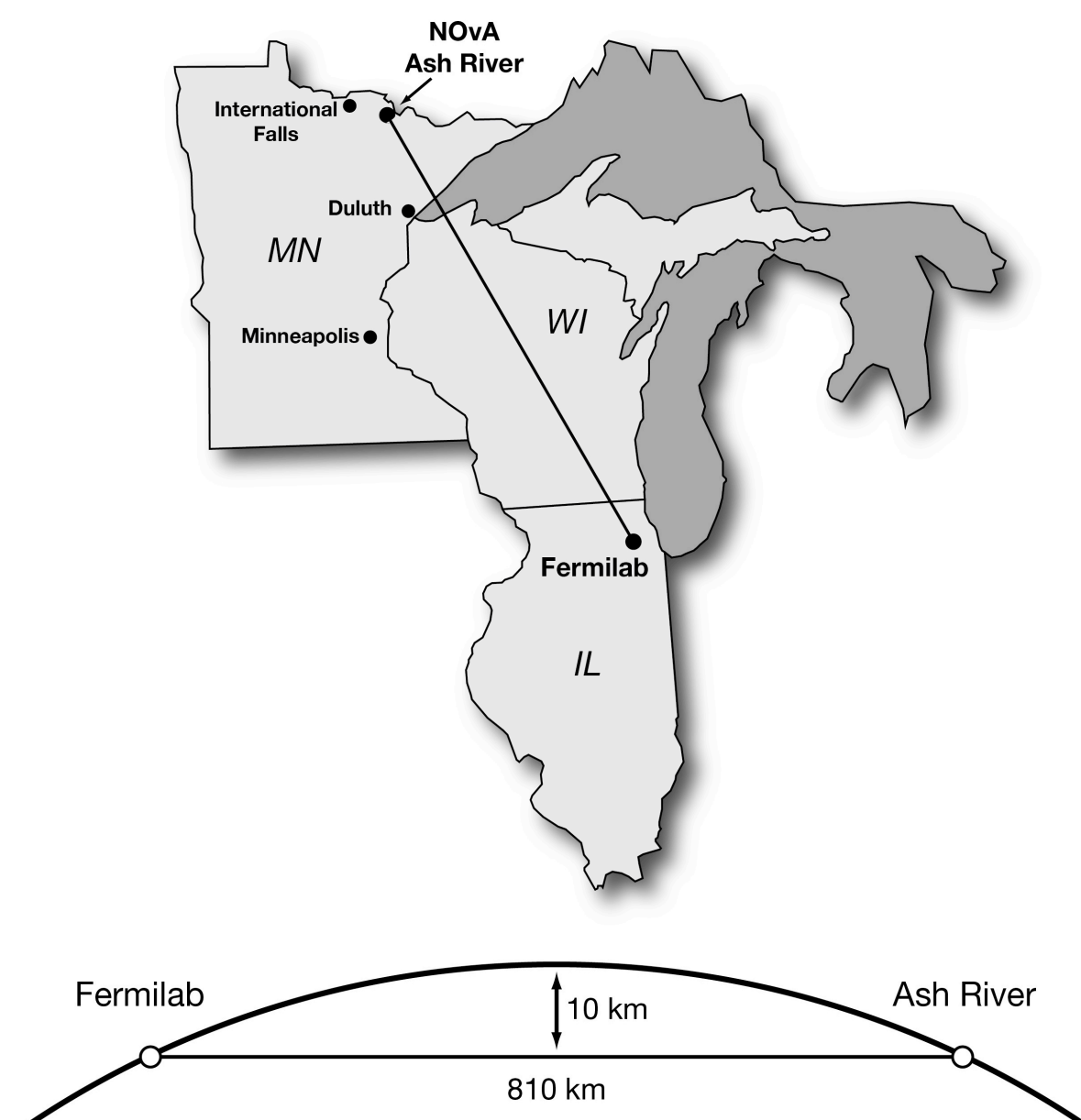


NOvA

NOvA is a second generation long-baseline neutrino oscillation experiment situated in the Fermilab NuMI beam line. NOvA consists of a 300-ton near detector and a 14-kiloton far detector (FD) separated by 810 km. It is designed to measure the ν_e and ν_μ content of the NuMI beam before and after oscillation with the aim of making high precision measurements of the neutrino mixing parameters and determining the neutrino mass hierarchy.



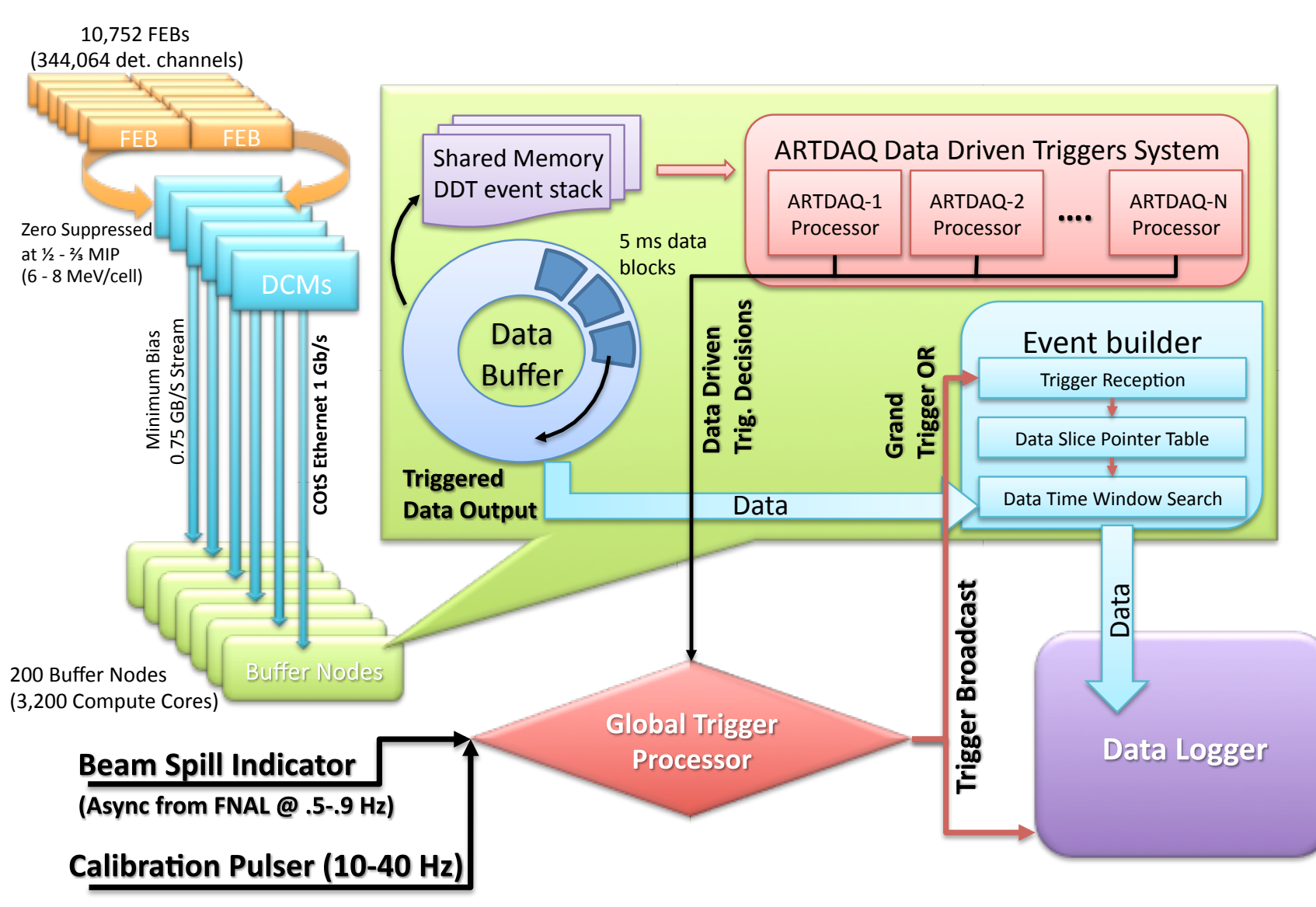
Far detector assembly status as of 12th May 2014.



The NOvA detectors are made up of alternating perpendicular planes of PVC extrusions each filled with liquid scintillator, read out by looped wavelength shifting fibres and instrumented with avalanche photo diodes.

Data acquisition

NOvA uses a novel data acquisition system based on a continuous deadtime-less readout of the front-end electronics, extended buffering of the data stream and asynchronous software triggering. In this system each of the detector cells (more than 340,000 at the FD) is constantly sampled and buffered for real time analysis by the “data-driven trigger” (DDT) system. The decision to record or discard time windows in the data streams can thus be based on complex event topologies.



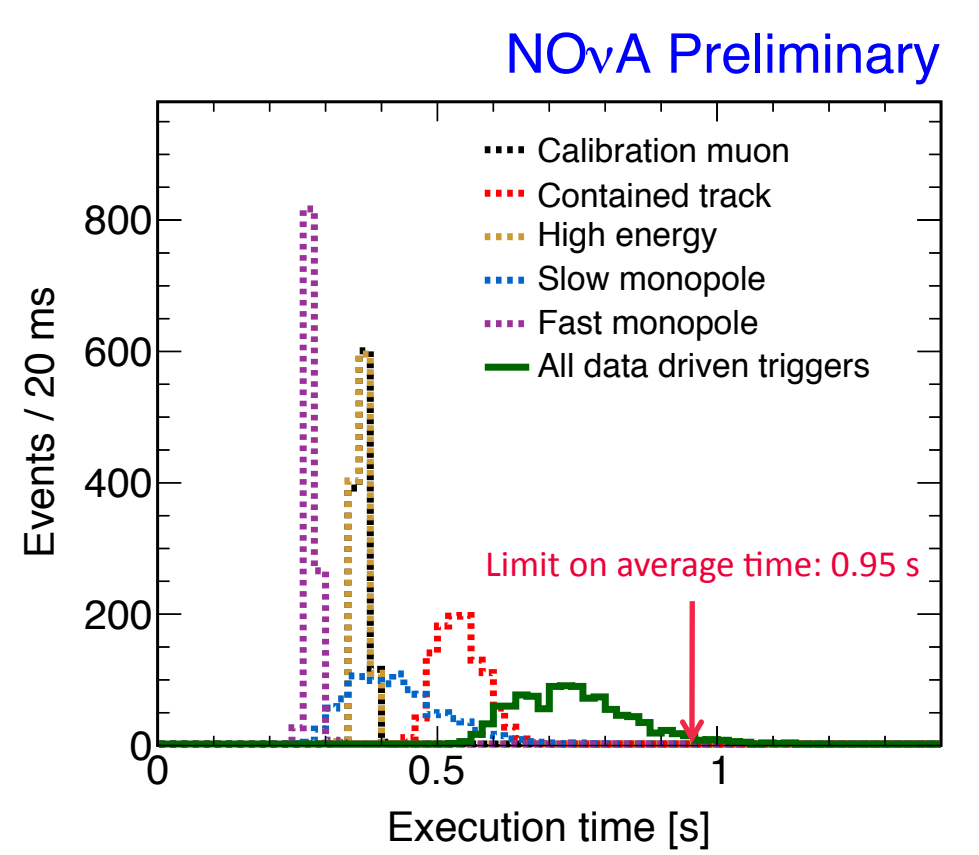
A schematic overview of the data acquisition system.

The system's highly asynchronous operation allows for the delayed extraction of data corresponding to a beam spill time window and also allows for the use of external input sources, such as the supernovae early warning system, to trigger data long after its initial collection.

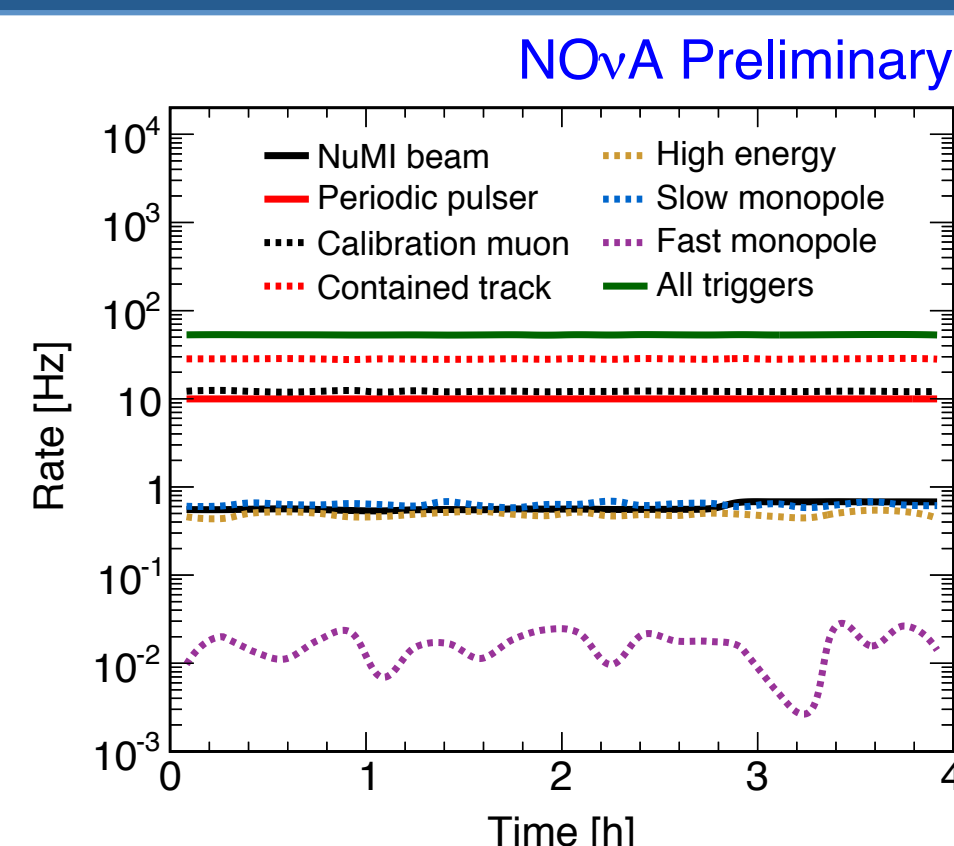
This flexibility allows NOvA to collect enhanced samples of important backgrounds, good calibration data and even to search for new exotic particles.

Data driven trigger

The DDT analyses all the data collected by the NOvA detectors in real time using hundred of parallel instances of highly optimised analysis software running within the ARTDAQ framework. It has been in operation continuously as part of both the prototype near detector and the FD for several months and has exhibited well understood, stable, rates as well as algorithm execution times that fit within the stringent criteria needed to operate in real time.



Execution time for various DDT algorithms.



The rates of all triggers.

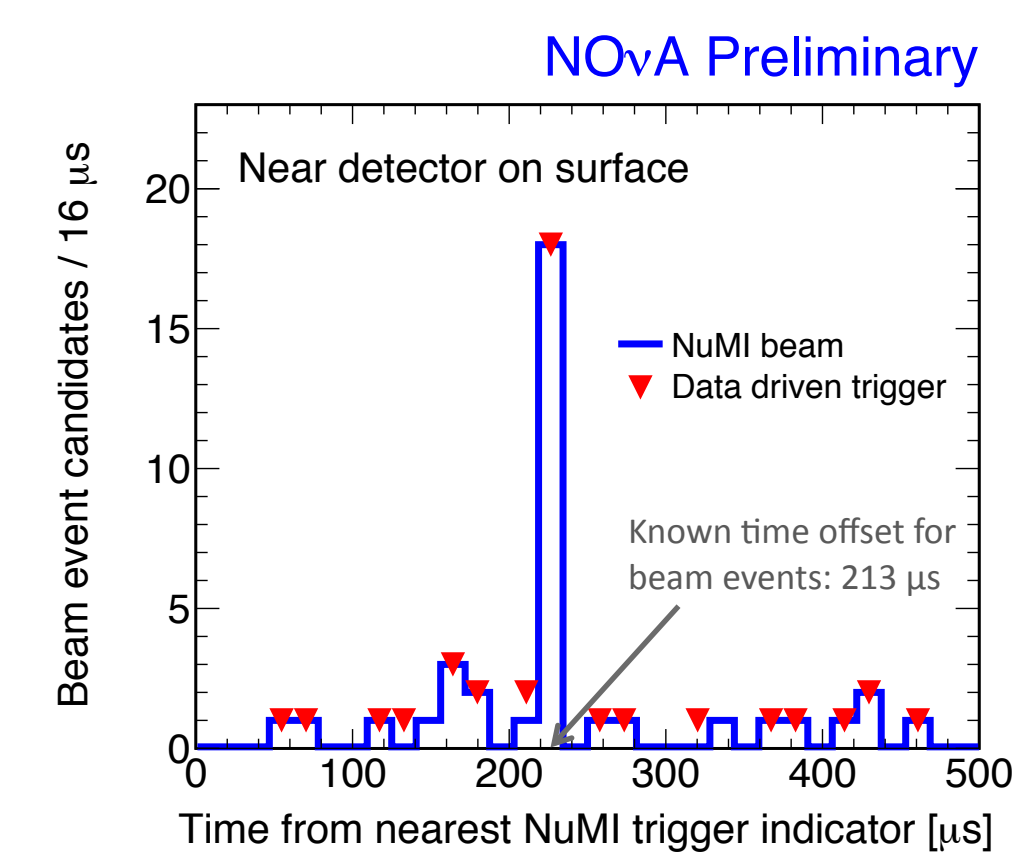
The current selection of triggers includes algorithms designed to identify muon tracks useful for calibration, contained tracks collinear with the beam line, high energy deposits, as well as both fast and slow monopoles. It is trivially extendable to support many more signatures.

The modular software design means common components are only executed once, making optimum use of the computing resources.

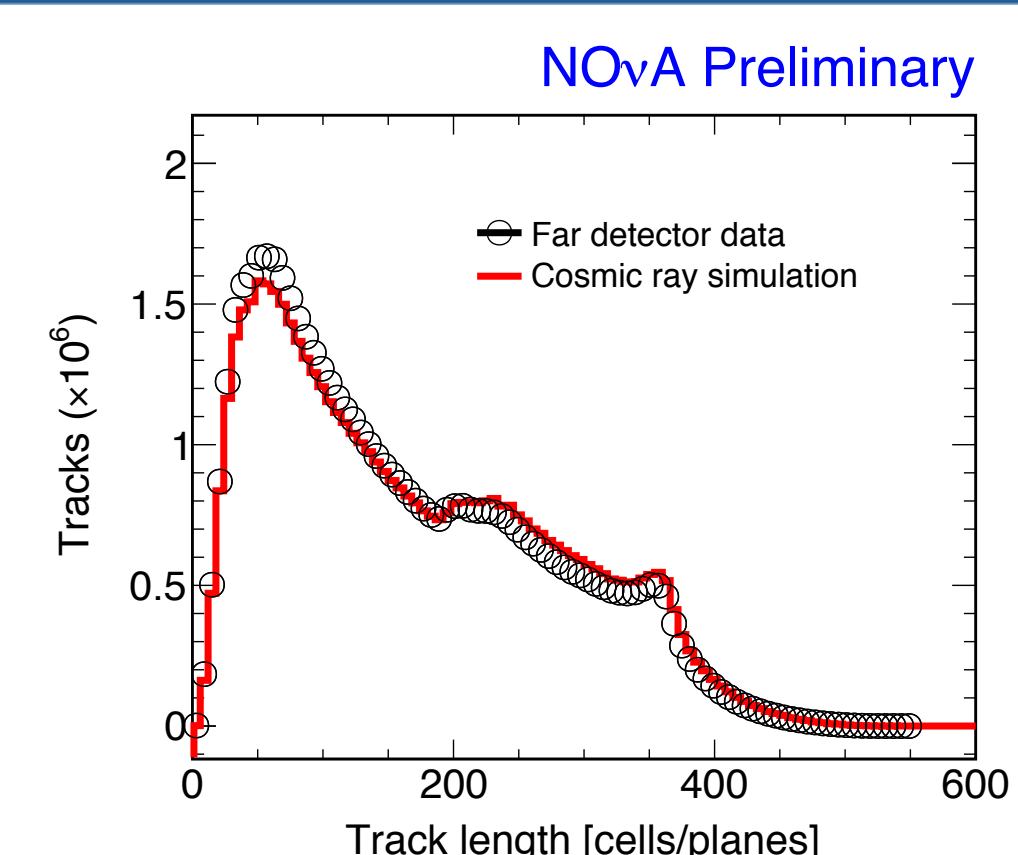
Real-time tracking

The ability to run pattern recognition & tracking algorithms on all data enables NOvA to quickly and efficiently identify useful event topologies.

Examples of such topologies that include tracks are: straight, muon-like tracks used in the calibration of the detector and contained tracks, collinear with the beam line, similar in topology to that expected from neutrino beam originated events.



Timing distribution for candidate beam events over a 32 hour period.



Track length as measured in FD data and Monte Carlo simulation.

The efficient identification of the signatures of neutrino beam-like tracks enables the monitoring of the beam spill timing peak to be performed independently of any external information.

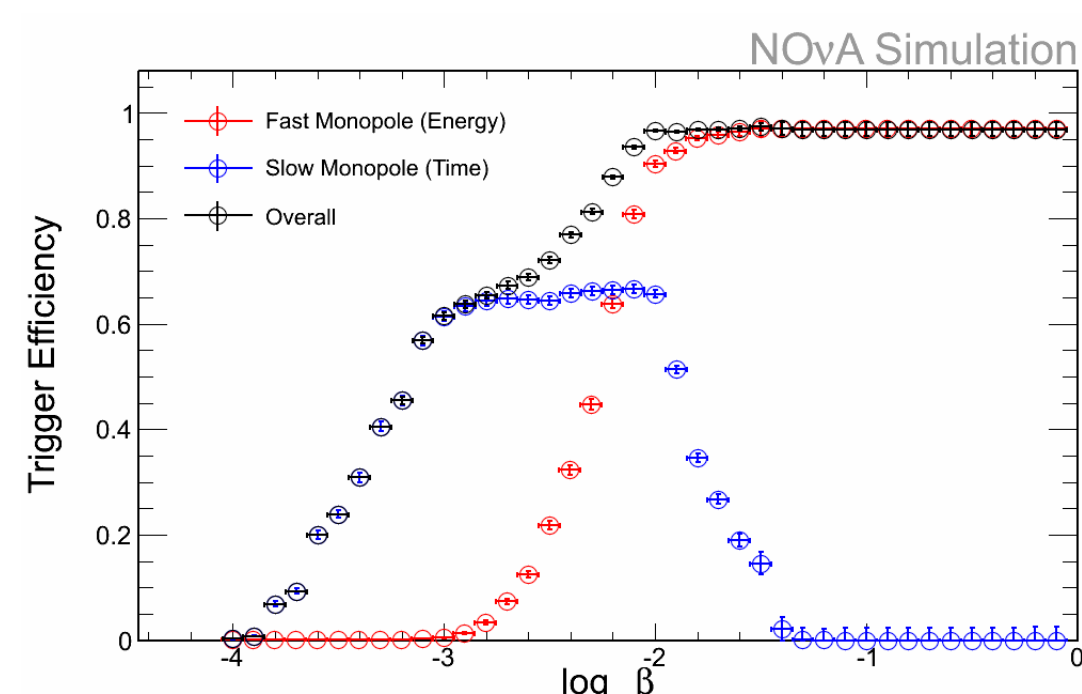
The figure to the right shows just such a peak as identified in 32 hours of near-detector prototype data. The DDT has no knowledge of the beam spill timing.

Exotica

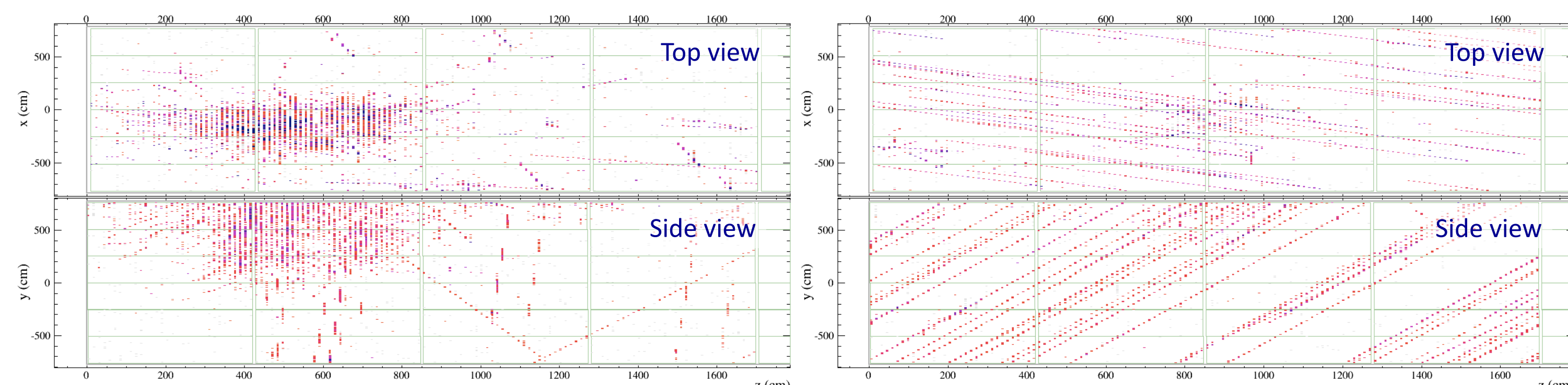
NOvA's above ground location and constantly live DDT combine to enable searches for rare and exotic phenomena. Such as hypothetical magnetic monopoles, the cores of high energy cosmic ray air showers, WIMP annihilation signatures, and even neutrinos from supernovae.

The flexibility of the system enables combinations of algorithms to be run simultaneously, each optimised for a different signature or phase space.

An example is illustrated above. Here two algorithms optimised for different classes of monopoles combine to provide efficient coverage of a wide region of phase space in a manner that keeps background rates under control.

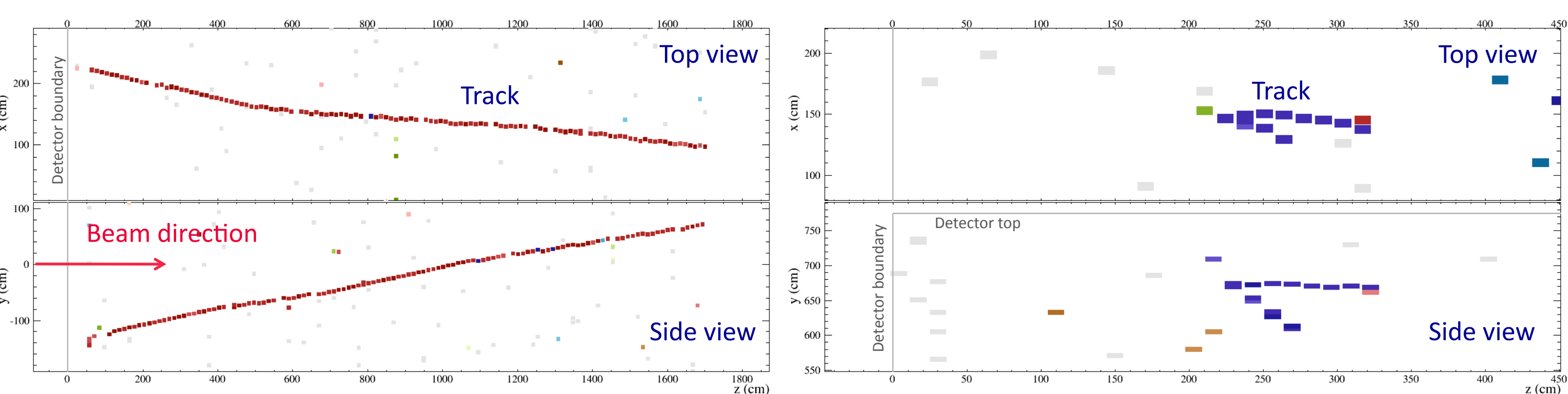


Simulated efficiency of two magnetic monopole DDTs.



An example of an interesting event identified by the DDT: a very high energy EM-like shower.

A large number of parallel muon-like tracks.

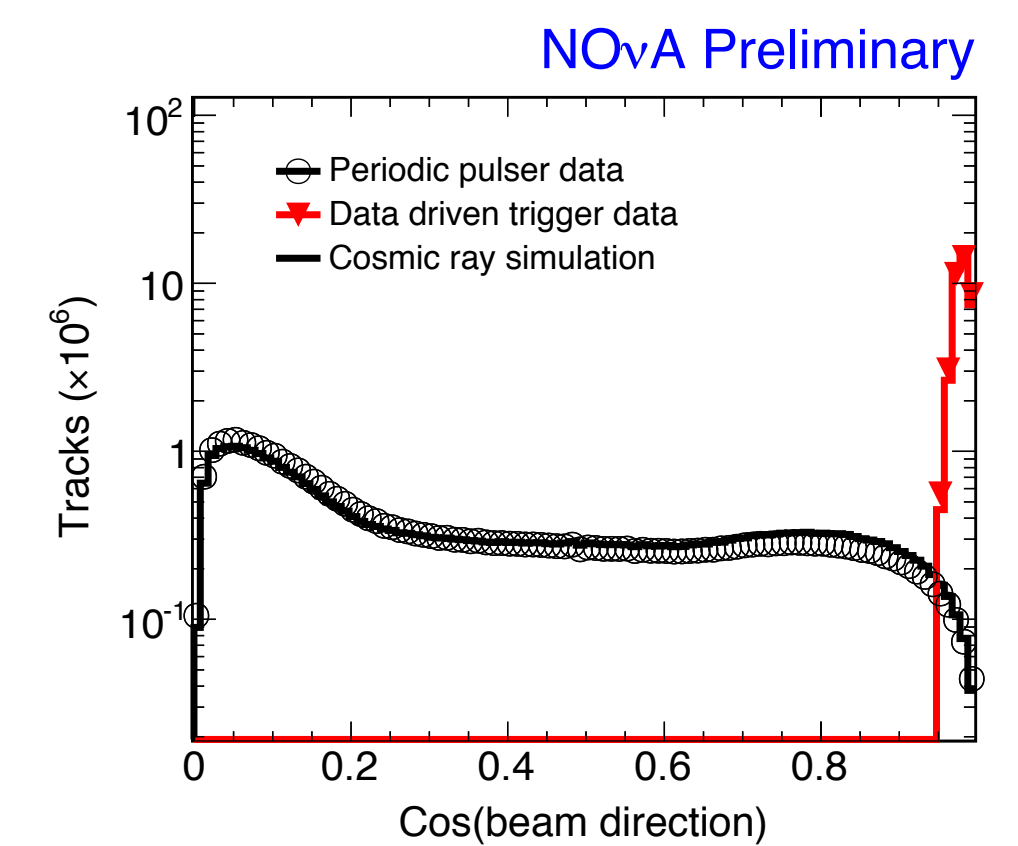


An event display of a track contained in the X (horizontal) & Y (vertical) dimensions, collinear with the beam direction, identified by the DDT in the 6-block FD.

A track contained in X, Y & Z.

This system also enables the collection of cosmic originated events that appear to mimic the signatures of the beam. An example being shown in the right-hand event display above.

By picking these events out from the entire live-stream rather than relying on periodic pulser or off-time beam windows, NOvA is able to enhance the statistics in this important region by several orders of magnitude. Moreover, by only recording the information pertaining to these events, it is able to do this in a way that significantly reduces the disk space requirements.



Cosine of the angle between tracks & the beam direction for tracks collected with the DDT & with the periodic pulser.

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