Summary of Parallel II

The Building Blocks of Future Detectors

Matt Wetstein
Iowa State University

NNN 2017

Oct 28, 2017

Many Exciting New Tools and Approaches

Sensors | Readout Electronics | Trigger and DAQ | Reconstruction

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Jose Crespo Anadon
LAr Electronics and DAQ

Matthew Malek
Development of LAPPDs

Andy Blake
LAr Reconstruction

Carlos Maximiliano Mollo
IceCube and KM3Net DOM/ Electronics

Frederico Nova
GPUs in modern detectors

Yugi Takeuchi
Superconducting Tunnel Junction Detectors

Ryan Murphy
Deep CNNs in NOvA

Helen O'Keeffe
Hyper-K Detector Elements

Sensors: PMTs for Hyper-K

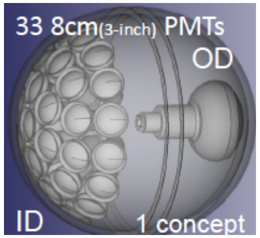


Photo Multipliers (PMTs)


Super-K PMT

Used in SK for 20 years

High QE Photocathode →

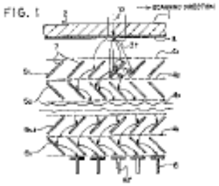

HQE SK PMT

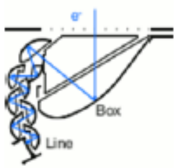
Under Viability Test

Dynode Improvement →


50cm HQE Box&Line PMT

Under Viability test


Venetian Blind



Box-and-Line Dynode

Hybrid Photo Detectors (HPDs)


20 cm HPD

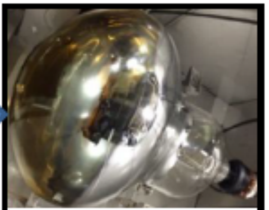
Under Viability Test

Larger Aperture →


50cm HQE HPD w/ 5mm ϕ AD

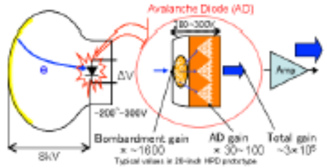
Already Developed.
Low Collection Efficiency

Larger Avalance Diode →


50cm HQE HPD w/ 20mm ϕ AD

Under Development

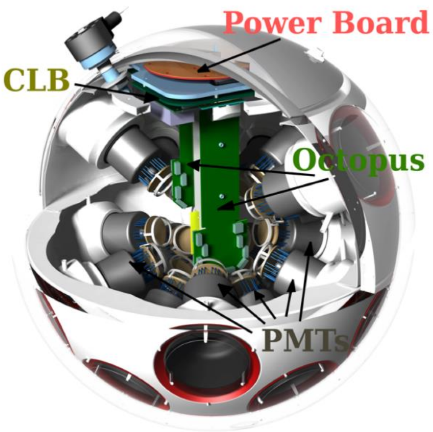
Avalance Photo diode



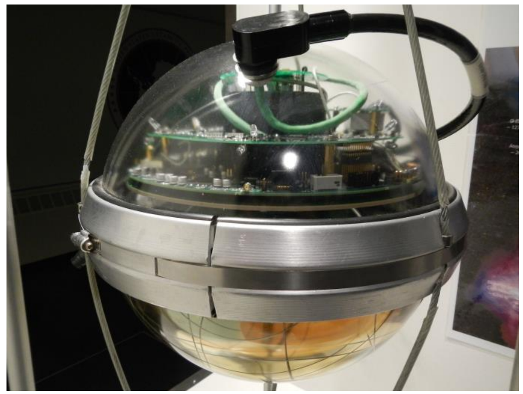
see Helen O'Keeffe

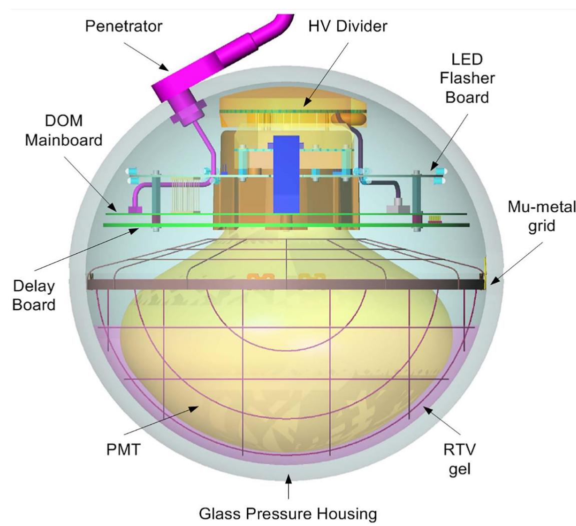
Sensors: DOMs (Digital Optical Modules)

KM3NeT



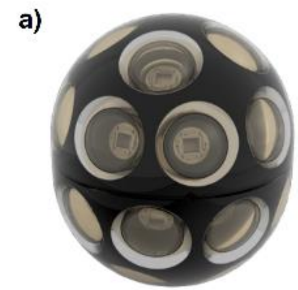
IceCube (Gen 1)

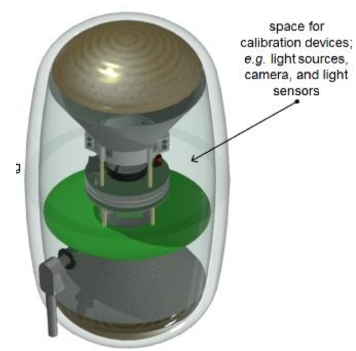


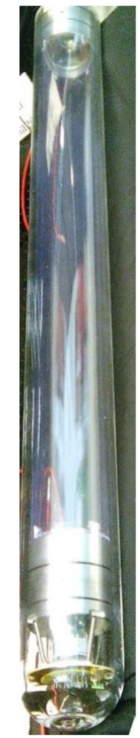


IceCube (next-Gen)

mDOM





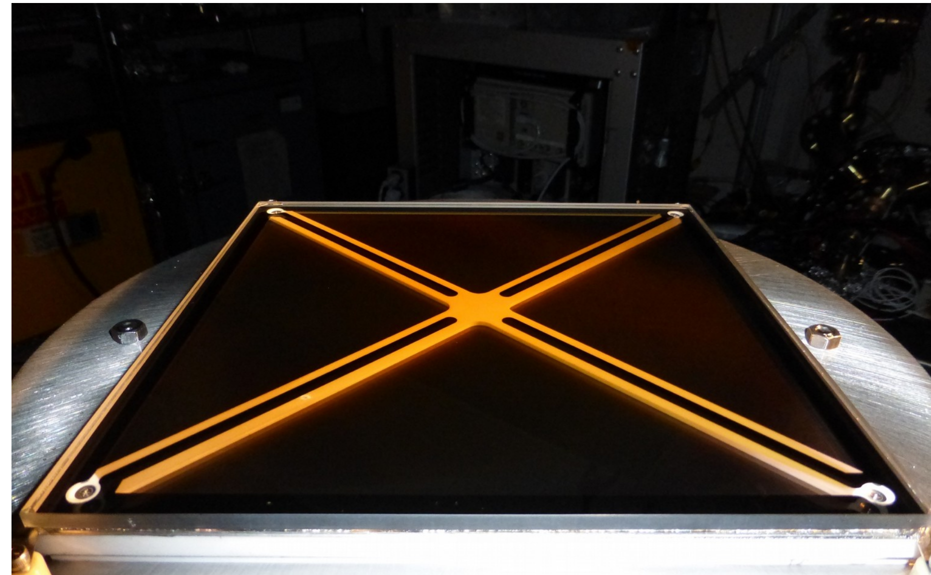


see Carlos Maximiliano Mollo

Sensors: LAPPDs

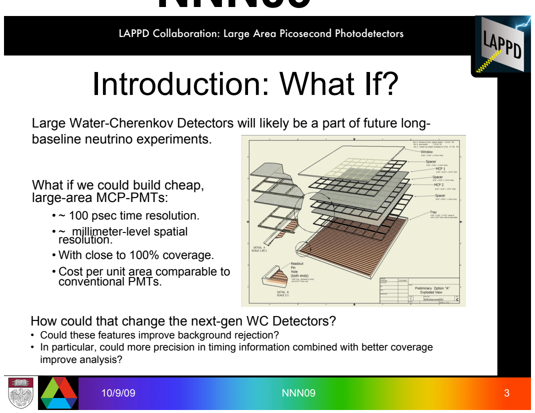
Large Area Picosecond Photodetectors:

- <100 psec time resolution
- <cm spatial resolution
- >10^6 gains
- >20% QE
- 20 cm x 20 cm



- LAPPDs are being commercialized by Incom, Inc. 4-5 working tiles now exist with more on the way.

NNN09



LAPPD Collaboration: Large Area Picosecond Photodetectors

Introduction: What If?

Large Water-Cherenkov Detectors will likely be a part of future long-baseline neutrino experiments.

What if we could build cheap, large-area MCP-PMTs:

- ~ 100 psec time resolution.
- ~ millimeter-level spatial resolution.
- With close to 100% coverage.
- Cost per unit area comparable to conventional PMTs.

How could that change the next-gen WC Detectors?

- Could these features improve background rejection?
- In particular, could more precision in timing information combined with better coverage improve analysis?

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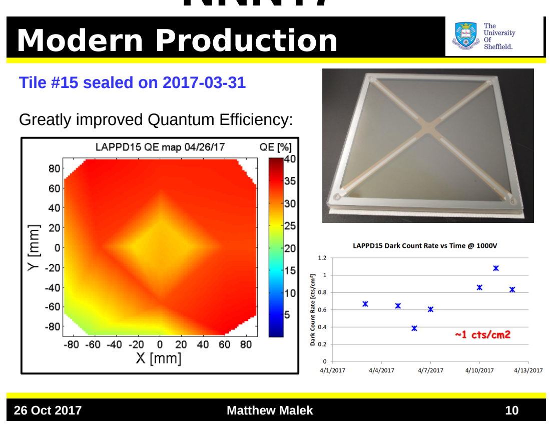


Modern Production

Tile #15 sealed on 2017-03-31

Greatly improved Quantum Efficiency:

26 Oct 2017 Matthew Malek 10

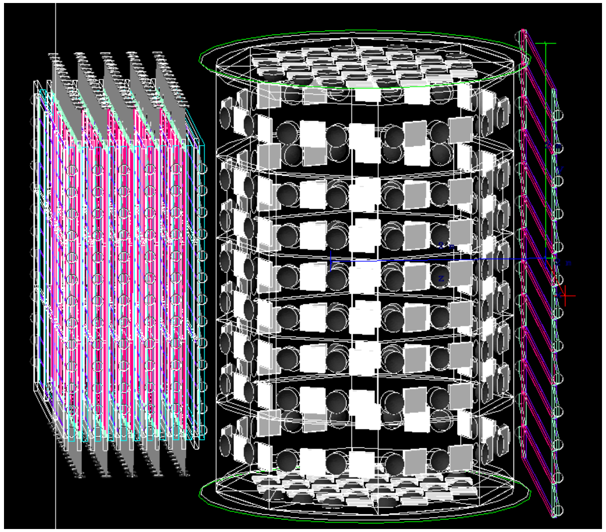
- Incom is working to finalize the process and expand production.
- Existing LAPPDs prototypes have been extensively tested both by Incom and prospective early adopters.

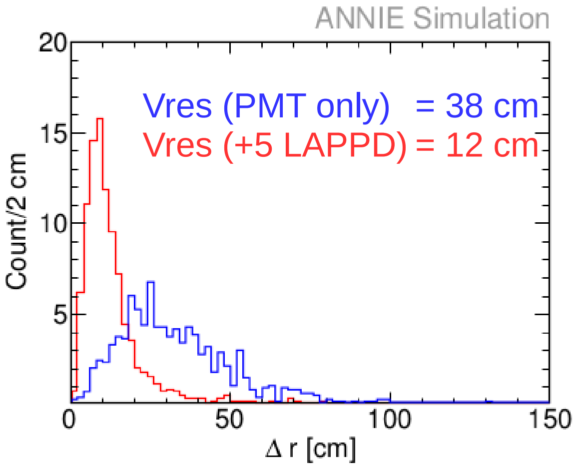
see Matthew Malek

Sensors: LAPPDs: Applications in ANNIE and Beyond

- ANNIE (Accelerator Neutrino Neutron Experiment)
    - studies neutrino-nucleus interactions
    - will be a first major HEP test of LAPPDs in a physics context
    - developing the various systems needed to deploy arrays of LAPPDs

- As production volume scales and markets grow, this will be a promising technology for future neutrino experiments.





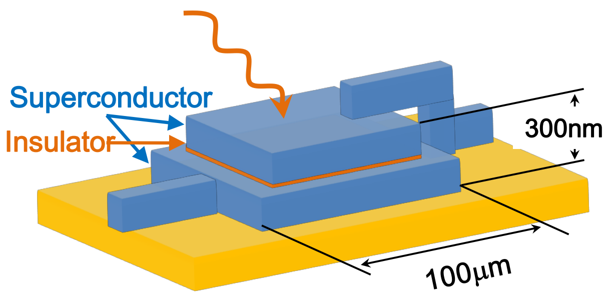
see Matthew Malek

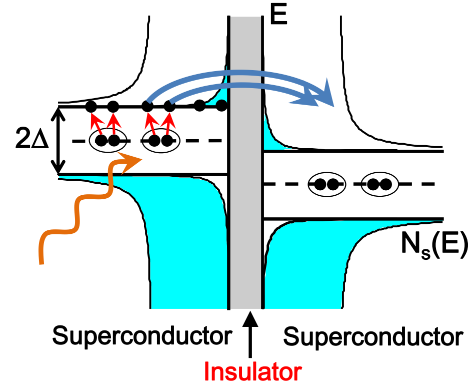
Sensors: Superconducting Tunnel Junction Detectors I

Superconducting Tunnel Junction (STJ) Detector

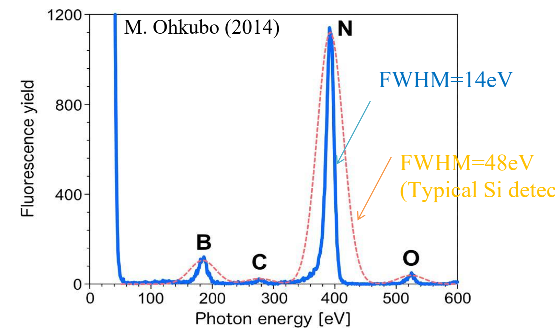
Superconductor / Insulator /Superconductor

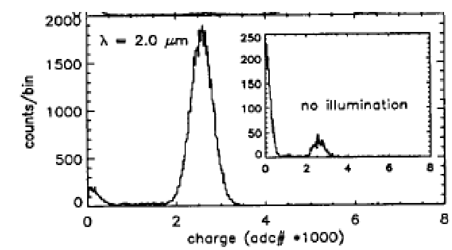
Josephson junction device





Δ: Superconducting gap energy





P. Verhoeve et. al 1997

- A constant bias voltage ($|V|<2\Delta/e$) is applied across the junction.
- An energy absorbed in the superconductor breaks Cooper pairs and creates tunneling current of quasi-particles proportional to the deposited energy.

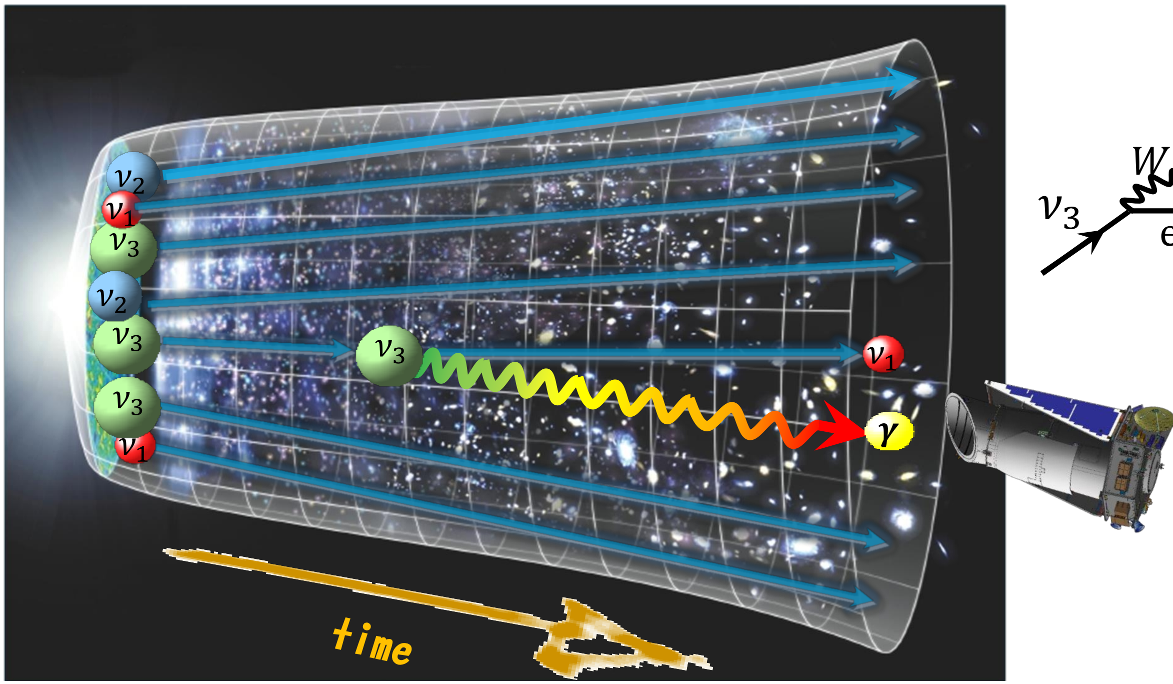
see Yugi Takeuchi

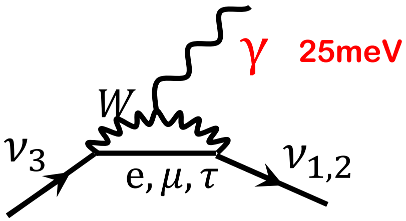
Sensors: Superconducting Tunnel Junction Detectors II

COBAND (COsmic BAckground Neutrino Decay)

Search for Neutrino decay in Cosmic background neutrino

➔To be observed as far infrared photons of $\lambda \sim 50\mu m$ (E~ 25meV)





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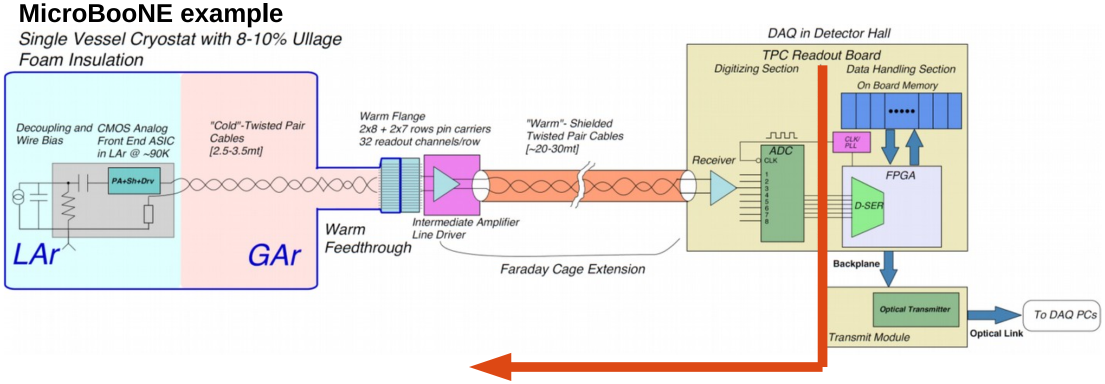
see Yugi Takeuchi

Readout Electronics: Liquid Argon

- A variety of different designs, particularly with respect to where the various levels of readout electronics are located (ie cold and warm)
- Many design challenges involved in LAr electronics
- Current and near-term efforts (MicroBooNE, ICARUS, proto-DUNE, SBND) are critical to defining future efforts like DUNE

	Warm PA + Sh	Cold PA + Sh (inaccessible)	Cold PA + Sh (accessible)
Warm ADC	ICARUS	MicroBooNE	ProtoDUNE-DP
Cold ADC		SBND, ProtoDUNE-SP	

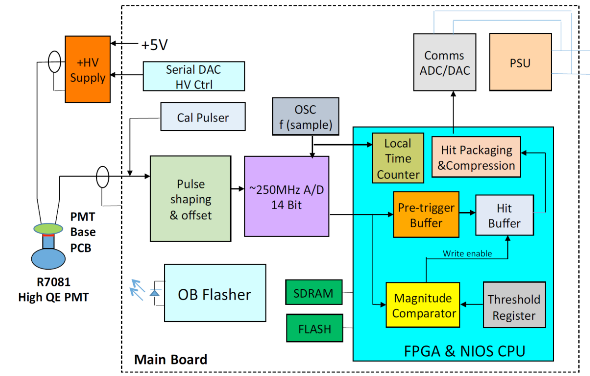
MicroBooNE example

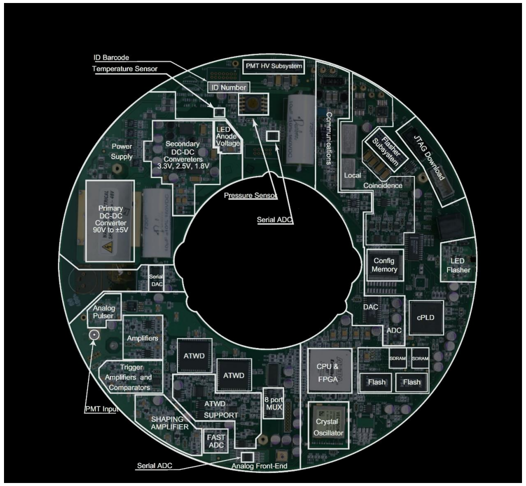


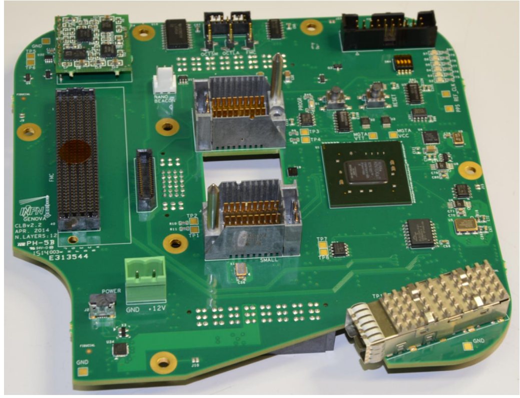
see Jose Crespo Anadon

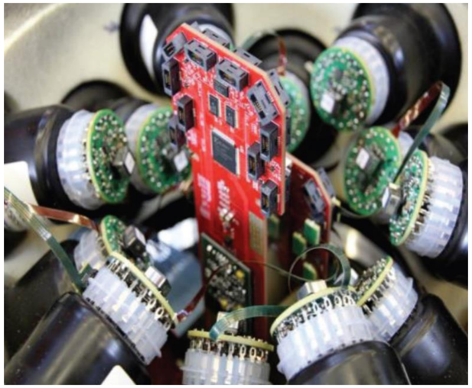
Readout Electronics: IceCube/KM3Net

- Digitization performed close to the PMT - a useful approach to many future experiments
- HV is also made inside the DOMs
- IceCube and KM3Net have developed sophisticated techniques for synchronization and trigger over vast distributive systems.
- Both use waveform sampling electronics



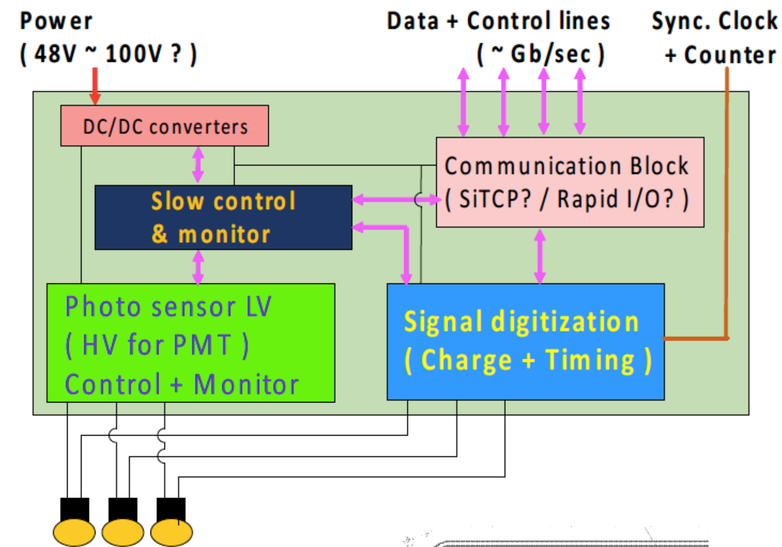




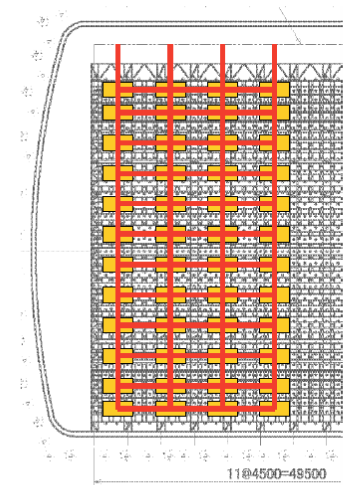


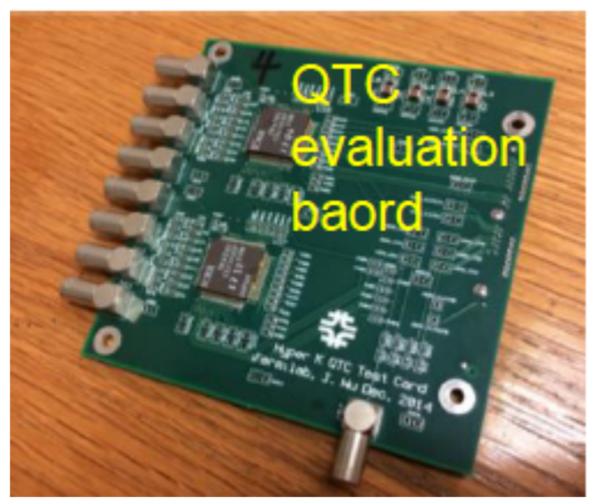
see Carlos Maximiliano Mollo

Readout Electronics: Hyper-K



- Hyper-K is also moving towards digitization at the PMT
- Considering multiple options:
    - SuperK-like TDC
    - flash ADCs
    - Switched Capacitor Array readout

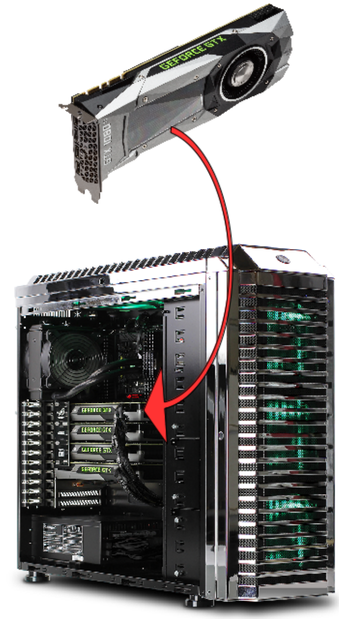


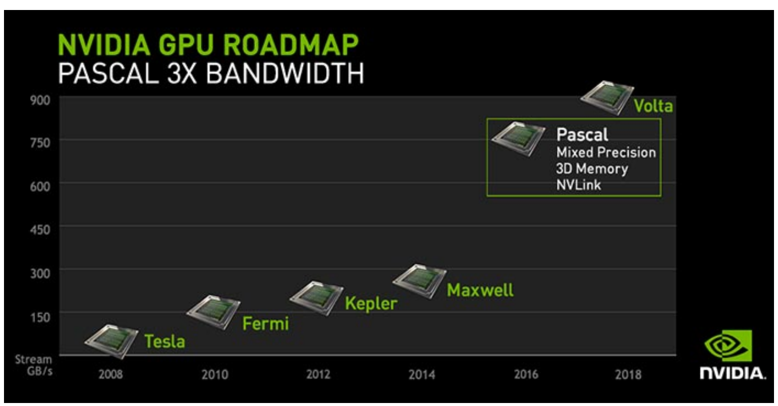


see Helen O’Keeffe

Data Acquisition and Triggering: GPUs I

- Highly parallelized computation
- Easy to program (even for physicists!)
- Enables very fast, pattern-based decision making
- Makes it very promising for developing more sophisticated triggering systems
- Also a powerful tool for offline analysis (MC and reconstruction

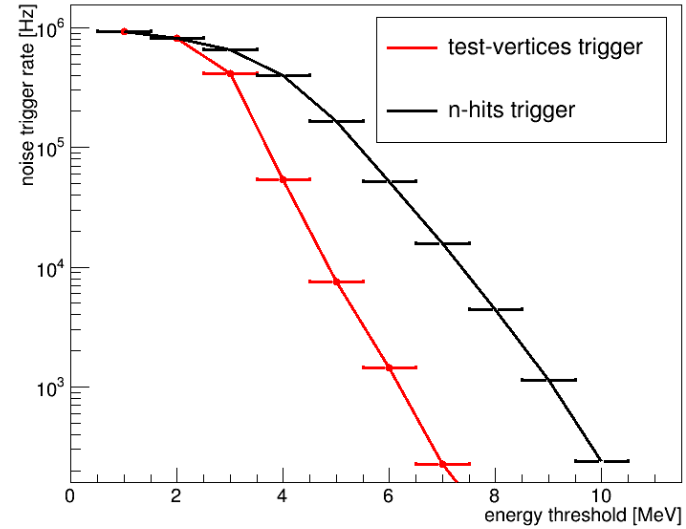


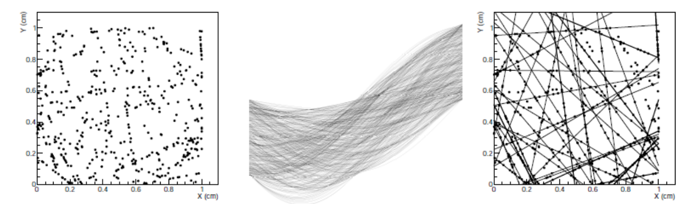


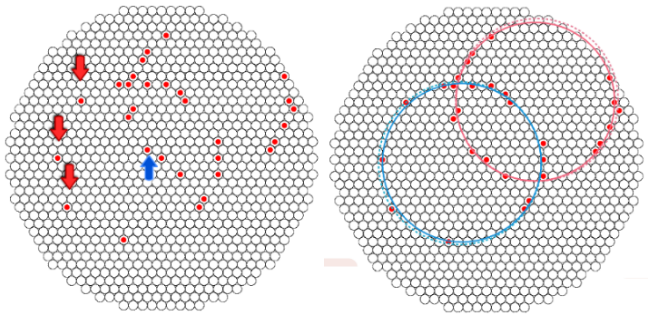
see Frederico Nova

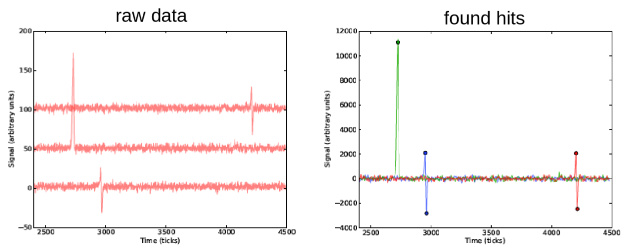
Data Acquisition and Triggering: GPUs II

- GPU-based techniques have been applied to a number of physics concepts:
    - LHC, E61, Hyper-K, DUNE
- Also for a number of algorithmic approachesL
    - Hough Transforms, ring matching pulse finding, vertex fitting







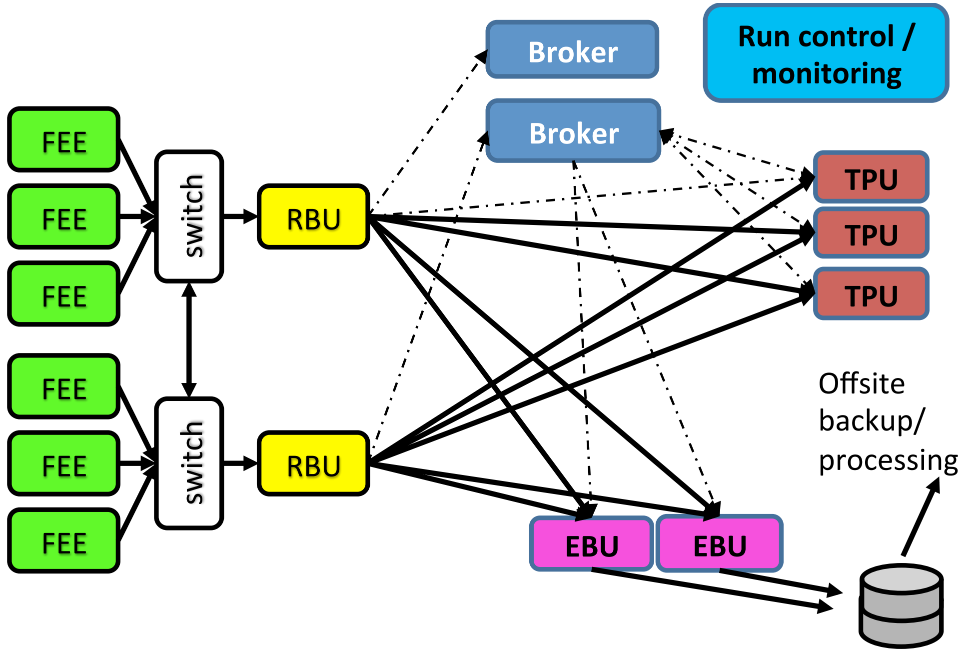


see Frederico Nova

Data Acquisition and Triggering: Hyper-K

Uses the custom-designed, highly modular ToolDAQ Framework

Developing a flexible trigger system, including the possibility of GPU/neural net-based pattern recognition

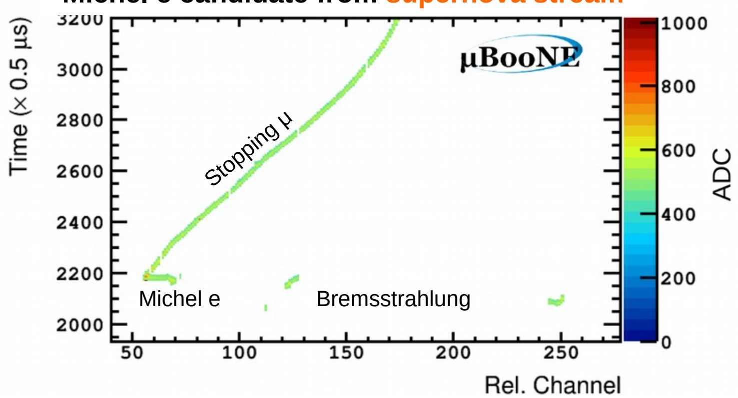


see Helen O'Keeffe

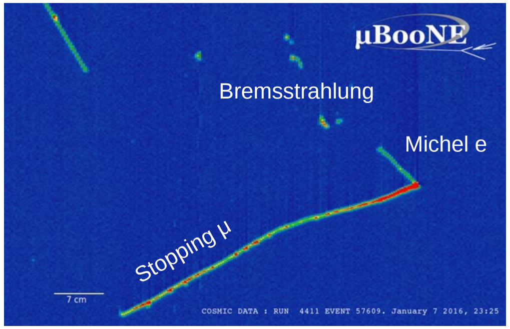
Backend Data Acquisition and Triggering: LAr

- Multiple back-end electronics options are being explored, from custom systems to industry standards. Multiple designs: FPGA vs CPU-centric (and others)
- Triggering in current LAr-TPCs largely PMT-based. TPC-based triggers might be necessary for DUNE
- Supernovae: Surface detectors cannot self trigger - rely on continuous recording and loopback. Considerable data-throughput issues.
- FNAL ArtDAQ system to be used in the long run

Michel e candidate from supernova stream



Michel e candidate from trigger stream



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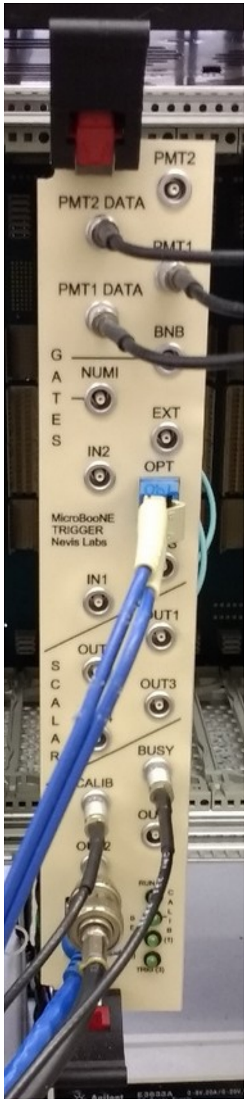
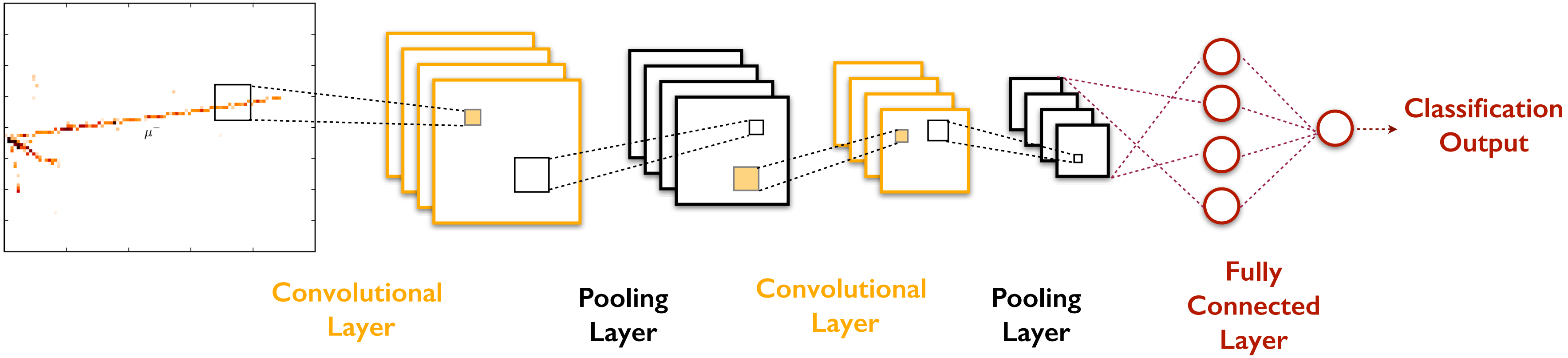


Jose Crespo Anadon

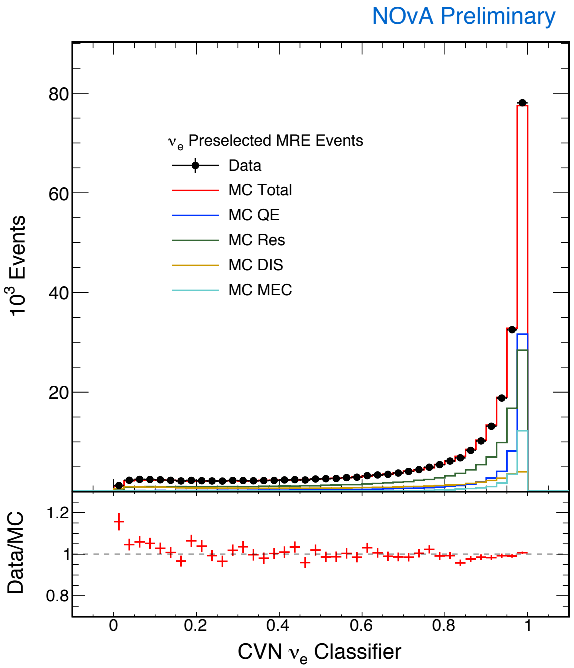
Reconstruction: Convolutional Neural Networks I

- Machine learning is at the cutting edge of event reconstruction: multi-layered neural nets are highly capable of pattern matching.
- The NOvA experiment has done ground-breaking work to develop its CVN (convolutional visual network) system - a first in HEP

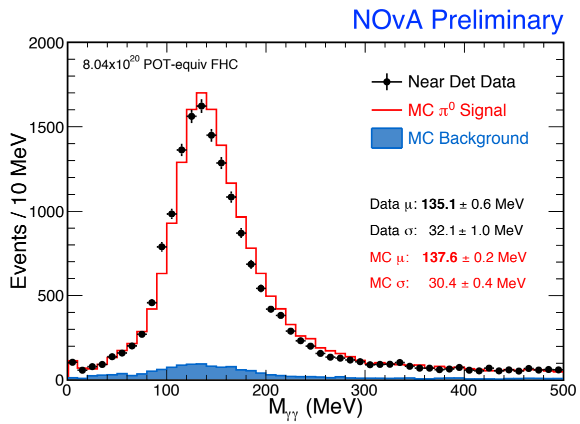


Ryan Murphy

Reconstruction: Convolutional Neural Networks II



- Initial use of CVN was in event identification
- NOvA is now pushing towards more granular, prong-based reconstruction
- Much work is also going into testing these algorithms and comparing with more conventional approaches

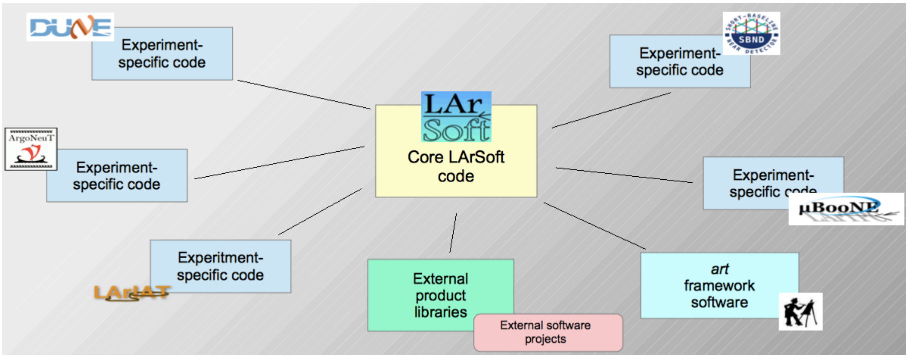


New Method with Prong CVN

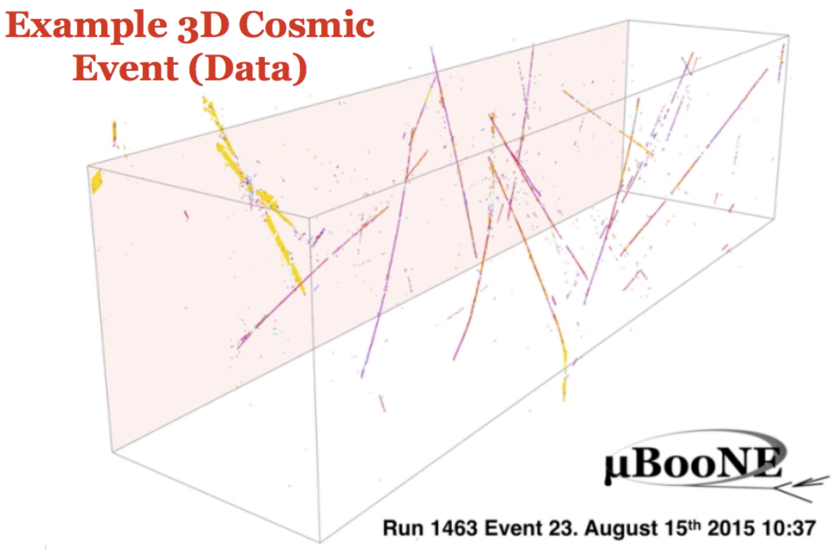
see Ryan Murphy

Reconstruction: LAr I

- LAr-TPCs produce a lot detail
- A wide variety of reconstruction tools have been developed, taking different approaches to the problem.
- Many of these techniques are fairly mature and data-tested
- Great progress towards fully automated reconstruction

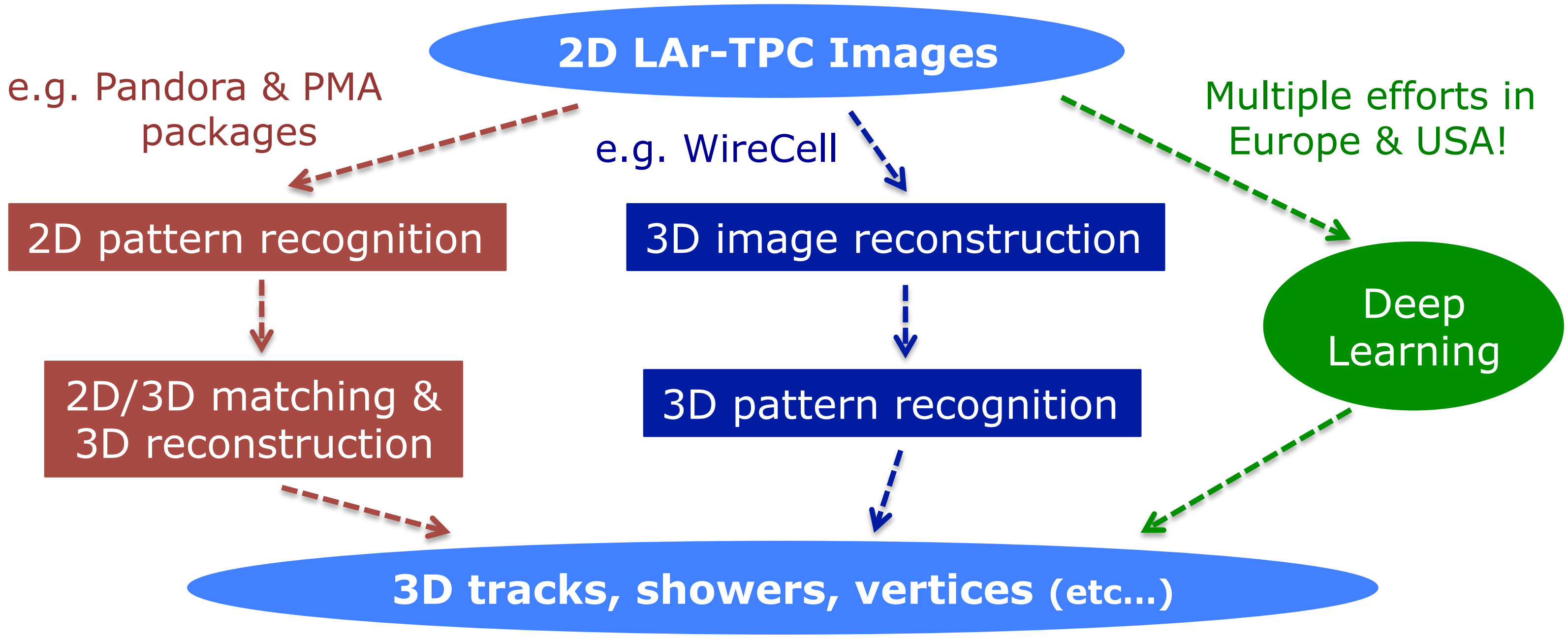


LArSoft: Common analysis framework among all major LAr efforts



see Andy Blake

Reconstruction: LAr II

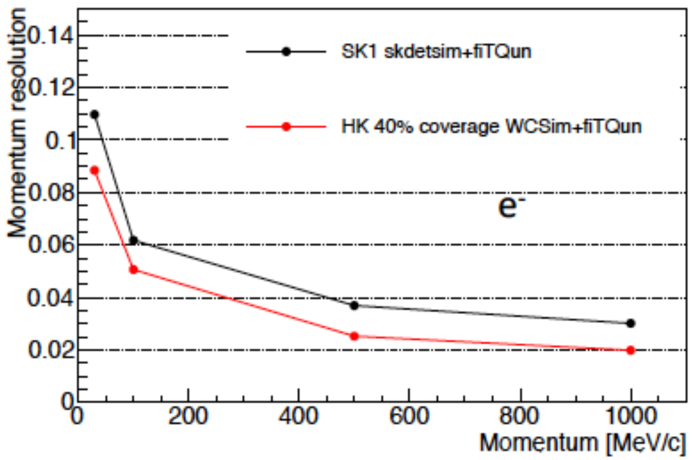


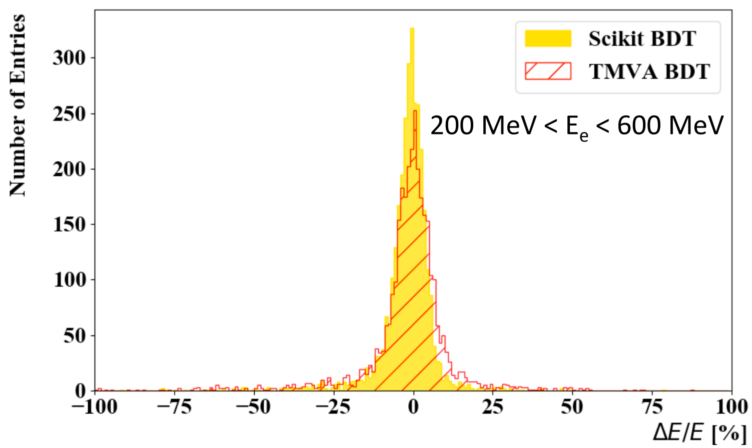
Andy Blake

Reconstruction: Hyper-K

The Hyper-K Collaboration is continuing adapt and perfect a number of cutting edge tools developed for Super-K/T2k:

- FiTQun (detailed pattern-based fitting)
- Bonsai (low energy reconstruction)





Work is also underway to develop advanced, deep-learning techniques

see Helen O'Keeffe

Conclusions

- There have been many new and exciting developments in sensor and readout technology in recent years
- These have great promise to enhance both planned future detectors and to pave the way for novel new experimental contexts
- Please check out the slides from Parallel Session II and talk to the speakers!
- Thank you to the speakers and to the conference organizers

Helen O'Keeffe