Cold Electronics Performance in MicroBooNE

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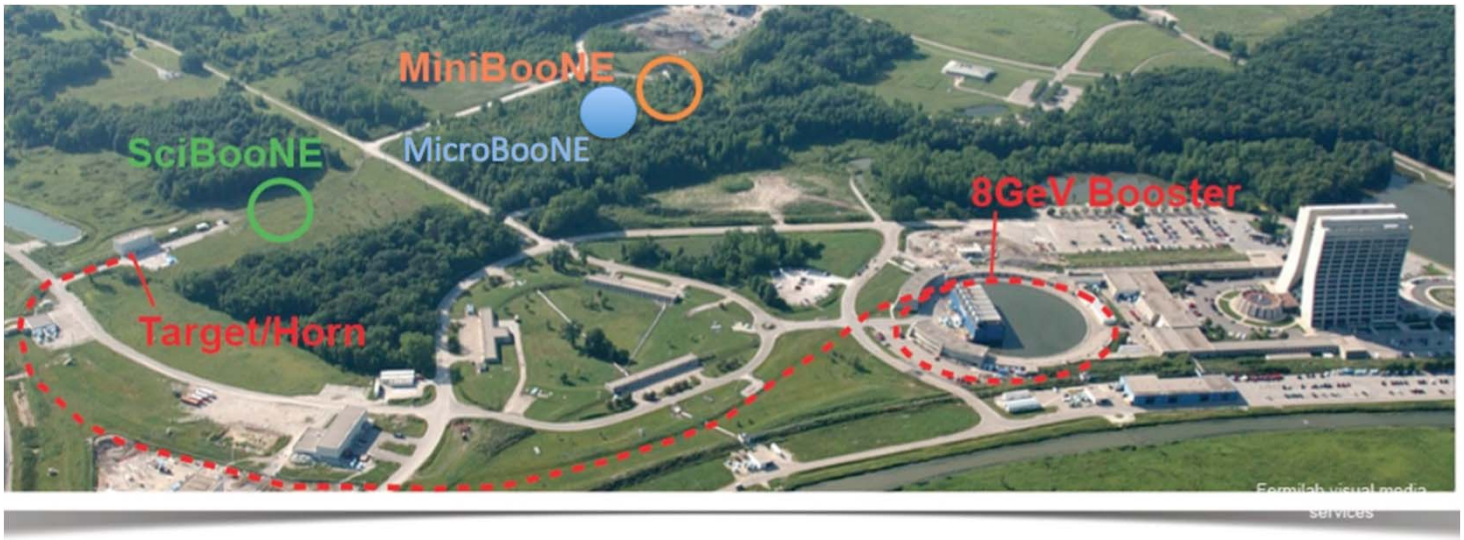
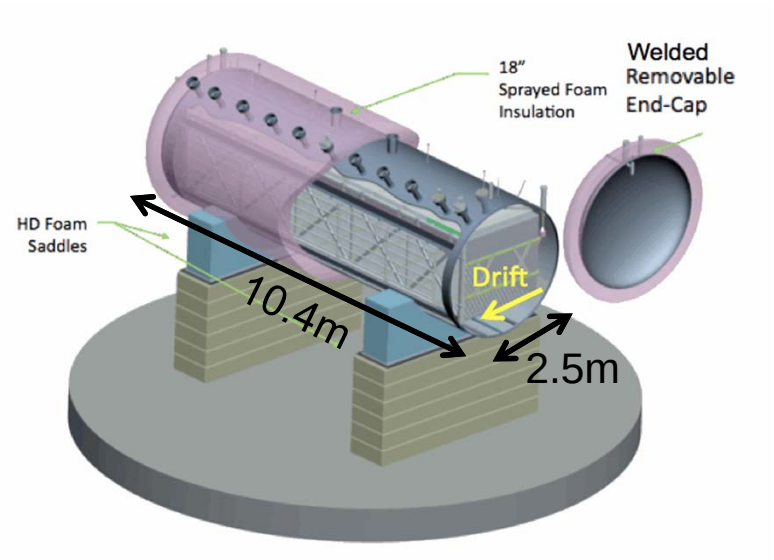
BNL

On behalf of MicroBooNE Collaboration

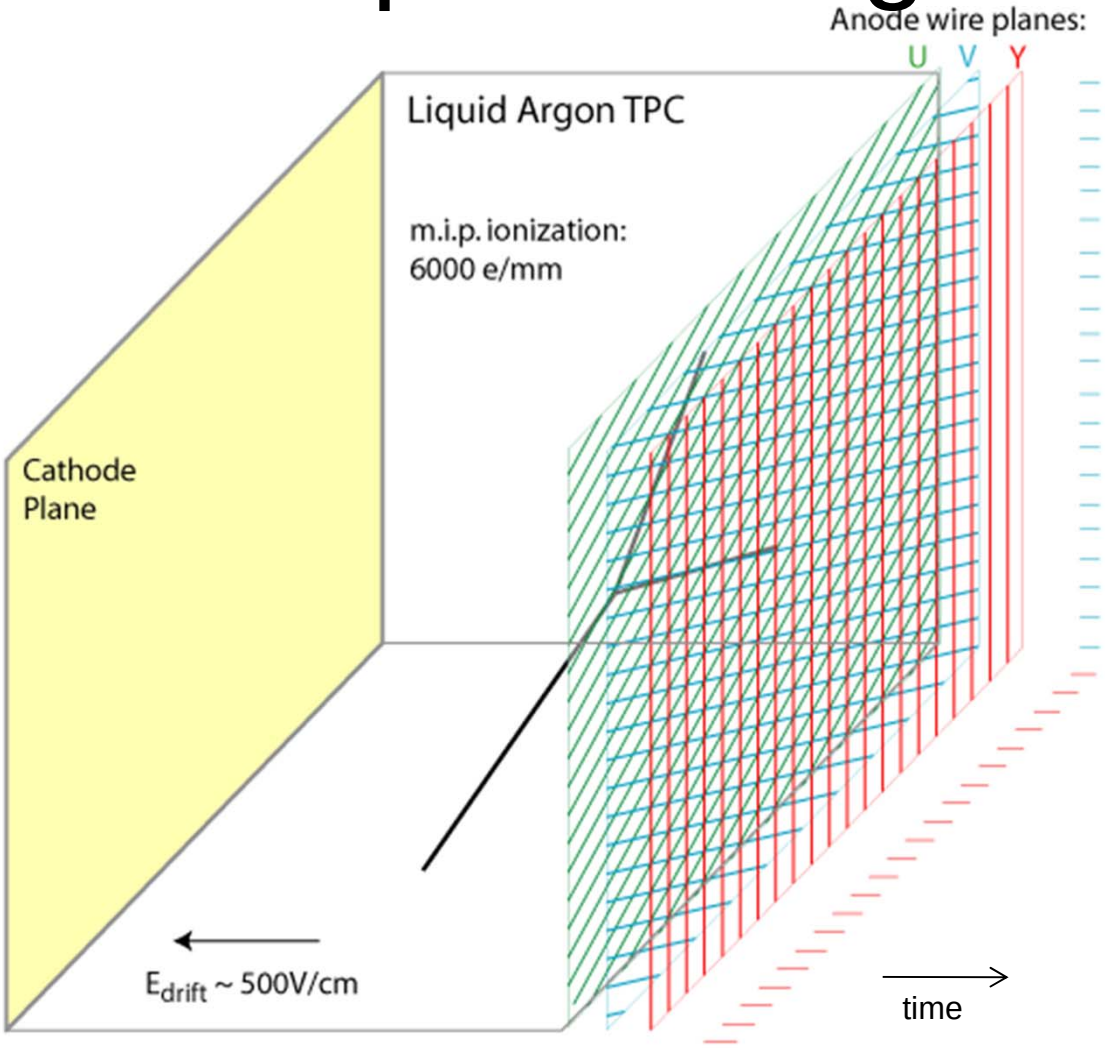
MicroBooNE





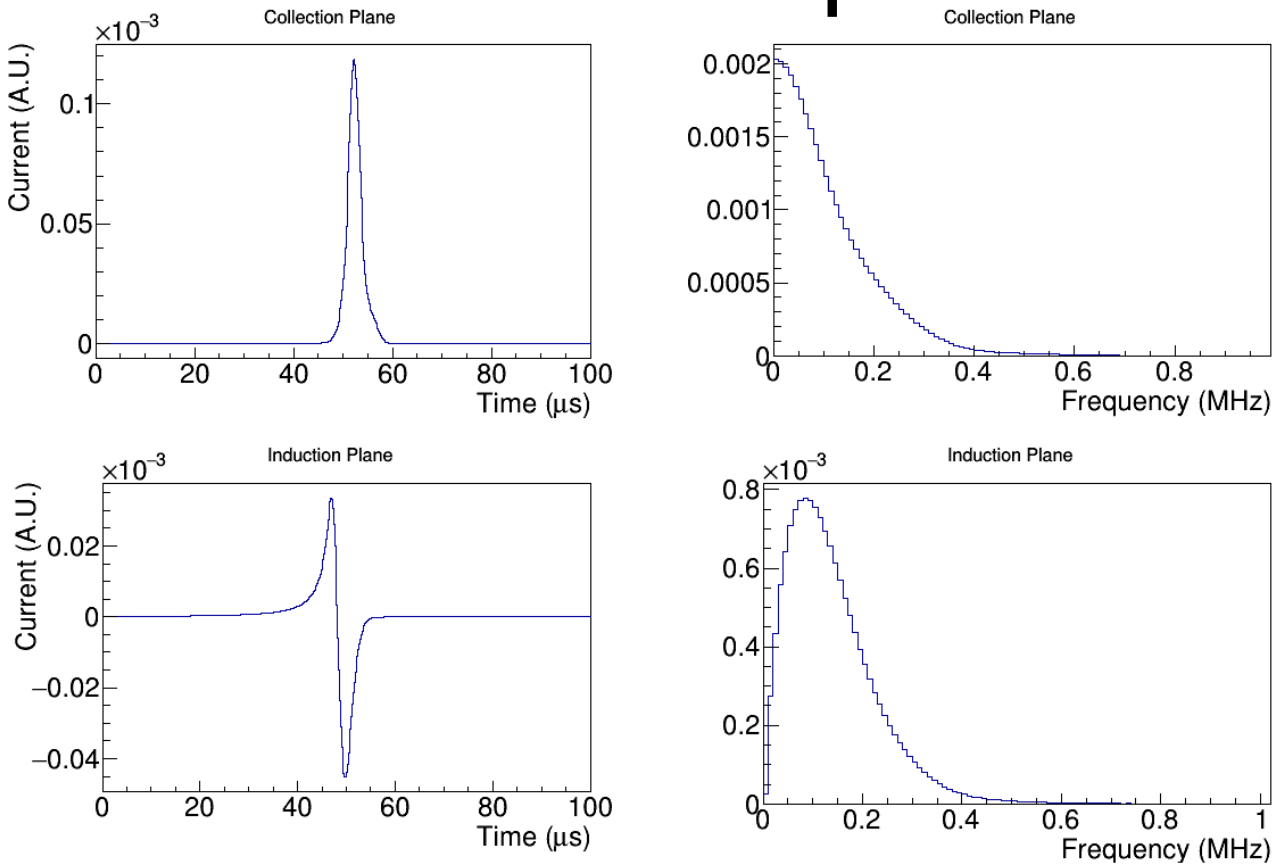
- 170 ton LAr TPC
  - *same beam & location as MiniBooNE*
  - *new detector technology*
- goals:
  - *MiniBooNE excess events*
  - *σ_ν measurements in argon*
  - *R&D for future LAr TPCs*

Principle of Single-Phase LArTPC



- LArTPC has mm scale position resolution
- Energy deposition and topology can be used to do PID

Collection vs. Induction Impulse Response

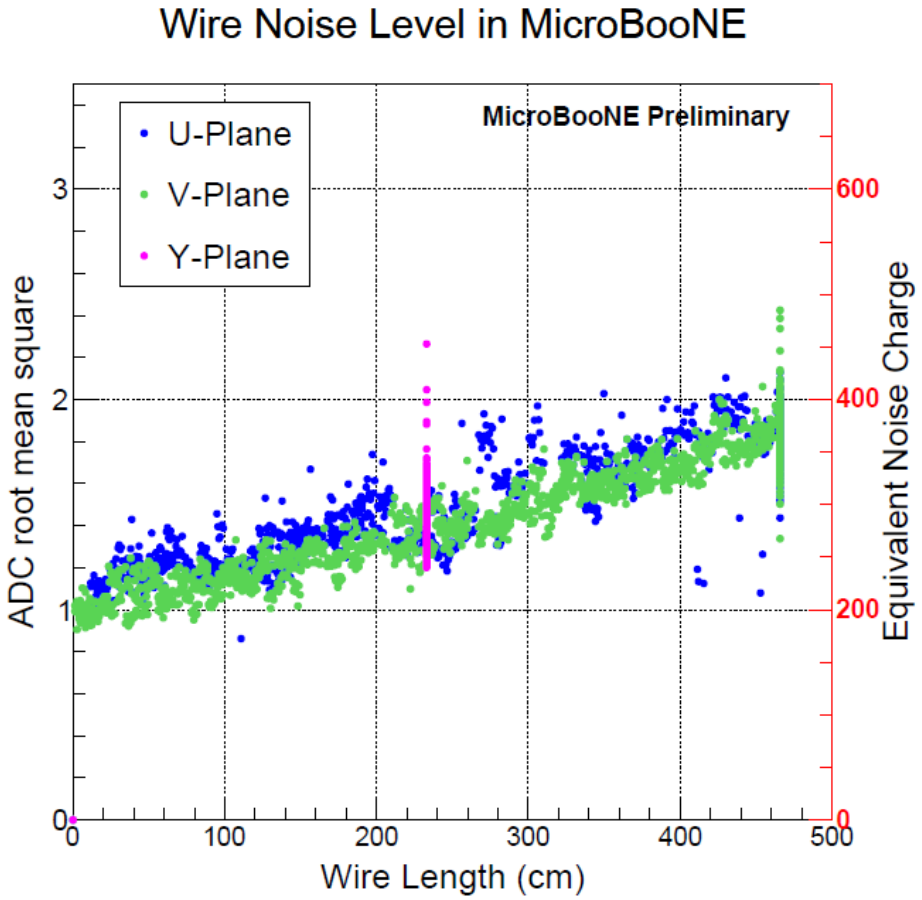


Impulse response is for a point ionization electron

- Impulse response of induction plane is smaller than that of collection plane
- Bipolar nature of induction plane signal lead to suppression at low frequency, reduced signal to noise ratio for long signals

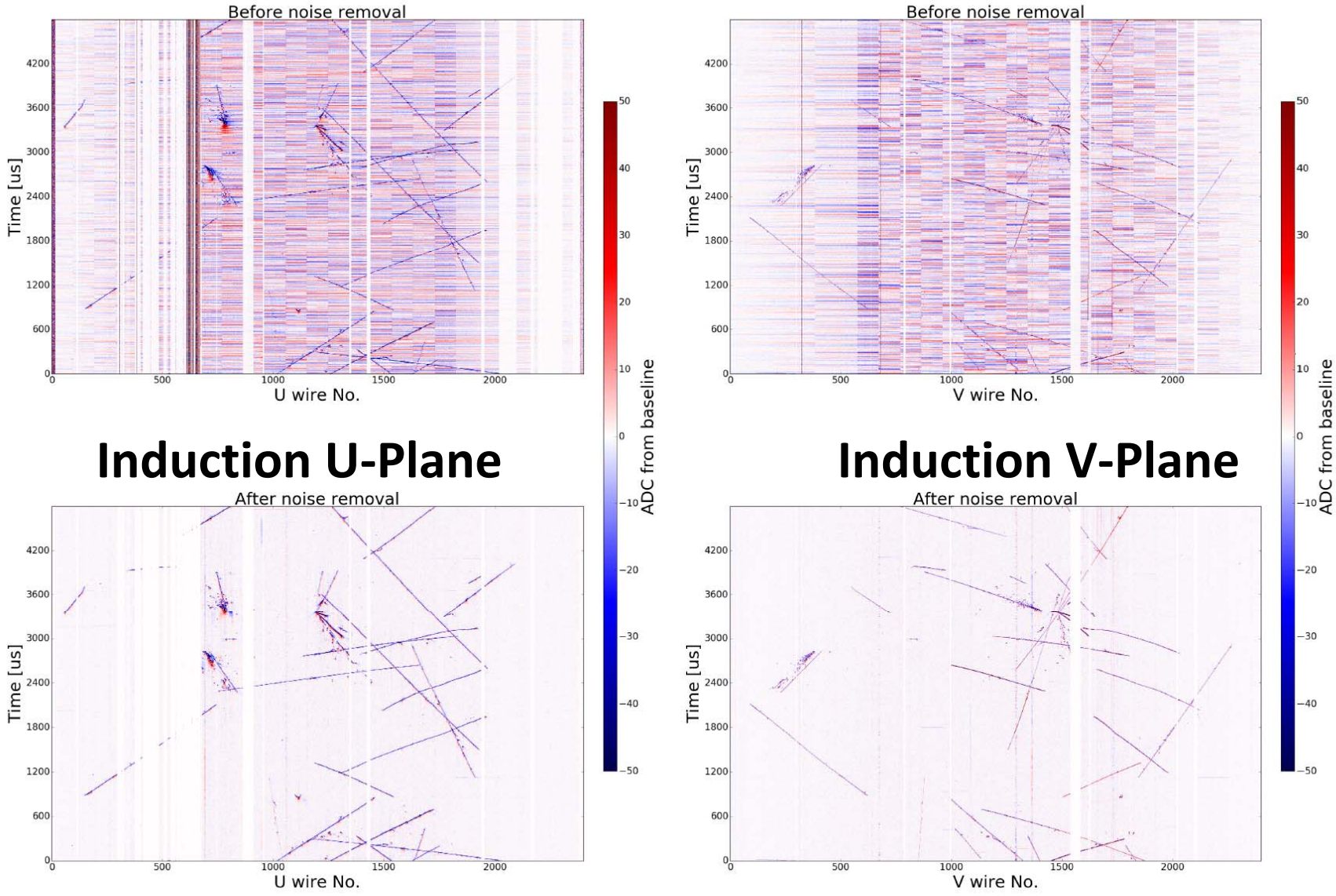
Enabling technology: Cold Electronics

- Placing the preamplifier inside LAr significantly reduced the electronics noise
  - 5-6 times comparing to past warm electronics (10:1 → 60:1 MIP peak-to-noise ratio in the collection)
  - Significantly improve the performance of induction wire plane



MicroBooNE Technote-1016: http://www-microboone.fnal.gov/publications/publicnotes/MICROBOONE-NOTE-1016-PUB.pdf

Before and After Excess Noise Filter



Excess noises are observed and have to be filtered

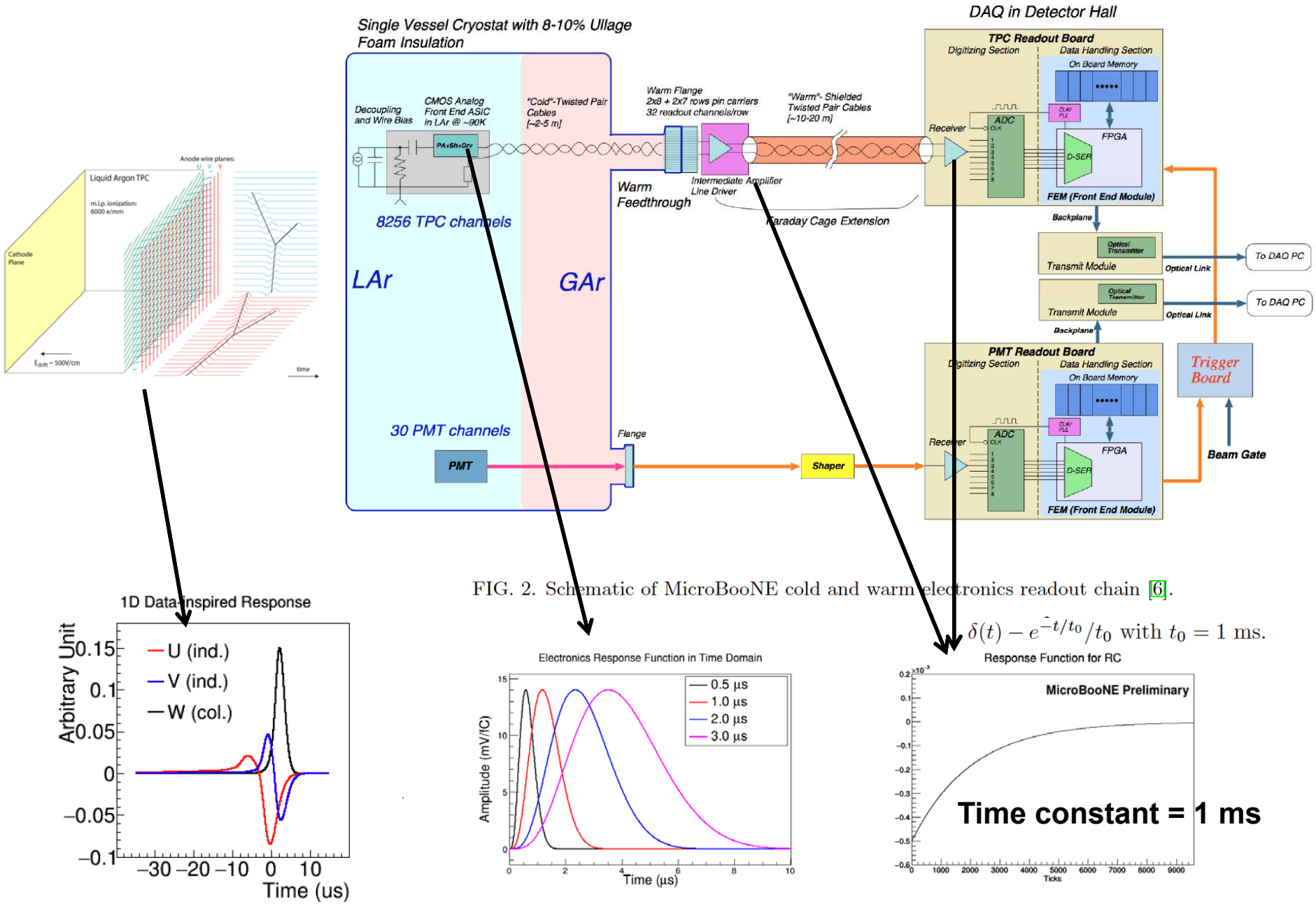


FIG. 2. Schematic of MicroBooNE cold and warm electronics readout chain [6].

$\delta(t) - e^{-t/t_0}/t_0$ with $t_0 = 1$ ms.

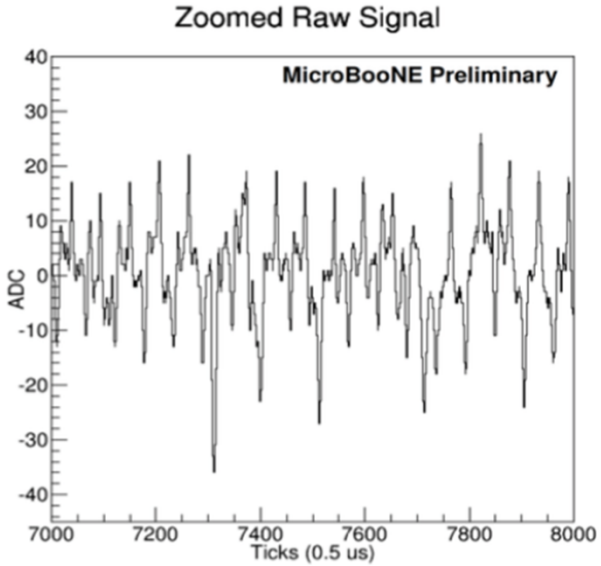
Time constant = 1 ms

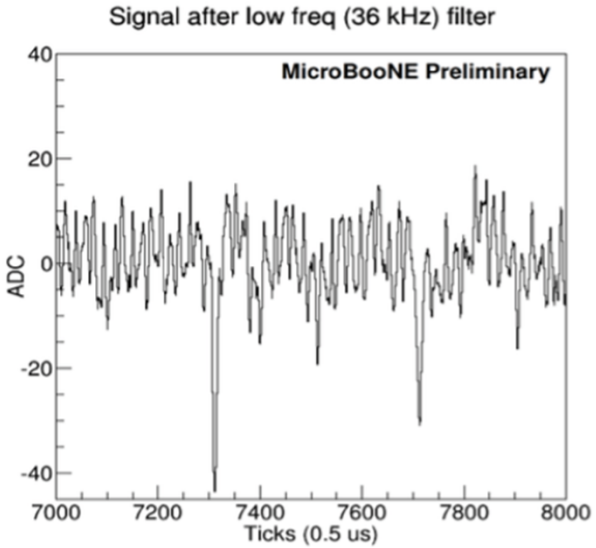
900 kHz ‘Burst’ Noise and HV Power Supply Noise

* The source of 900 kHz is most likely in the PMT HV and laser interlock system
  * More prominent in case of lower shaping time
  * More prevalent on the downstream side of the TPC

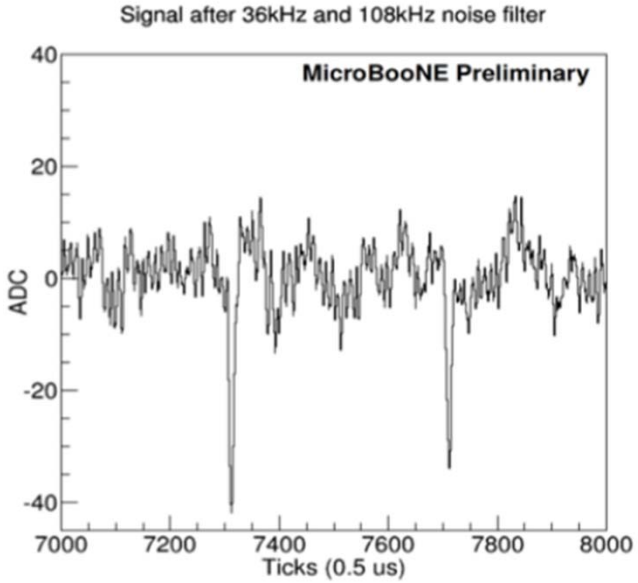
* Series of single frequency noise sources are observed, odd harmonics of 36kHz
  * Highest peak (36kHz) and second highest peak (108 kHz)
* V-plane is shielded by U-wires & Y-plane noise is further attenuated by V-wires
* Anode plane is very sensitive to even small potential changes at cathode (which is 2.5m away)
  * Some charge got induced (capacitively coupled) on anode wire plane resulting from potential variations in cathode
  * Largely removed by the filter installed on HV power supply

This harmonic noise filtered out directly in the frequency domain





Induction U-Plane Channel



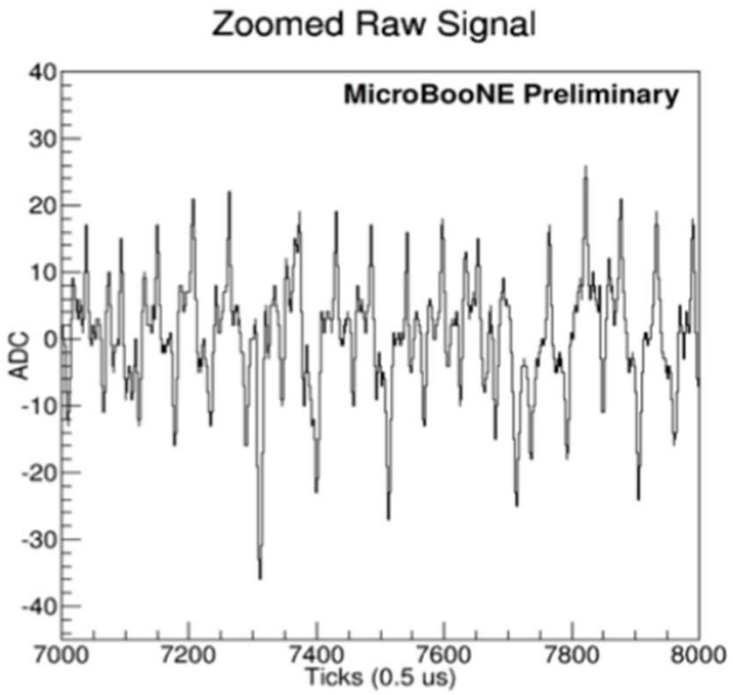
Low Frequency Noise from Voltage Regulator

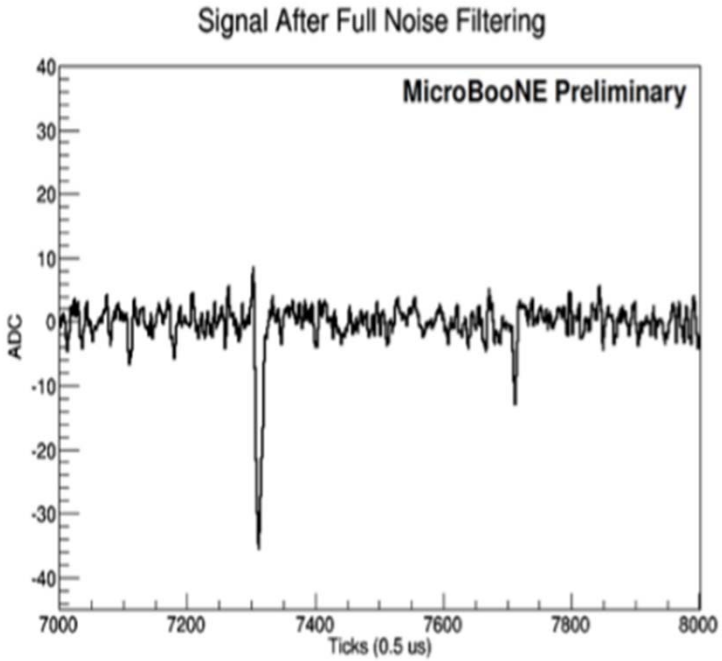
* Low frequency (10 - 30 kHz) coherent noise affecting groups of channels simultaneously
* High correlation between channels on Mother Board pairs (1 MB = 48U +48V + 96Y) on same service-board (SB) with low voltage regulator for ASICs
* Correlation is slightly higher between channels on 1MB as compared to 1SB

- Largely removed by the new service board upgrade

Regulator Noise Filtration

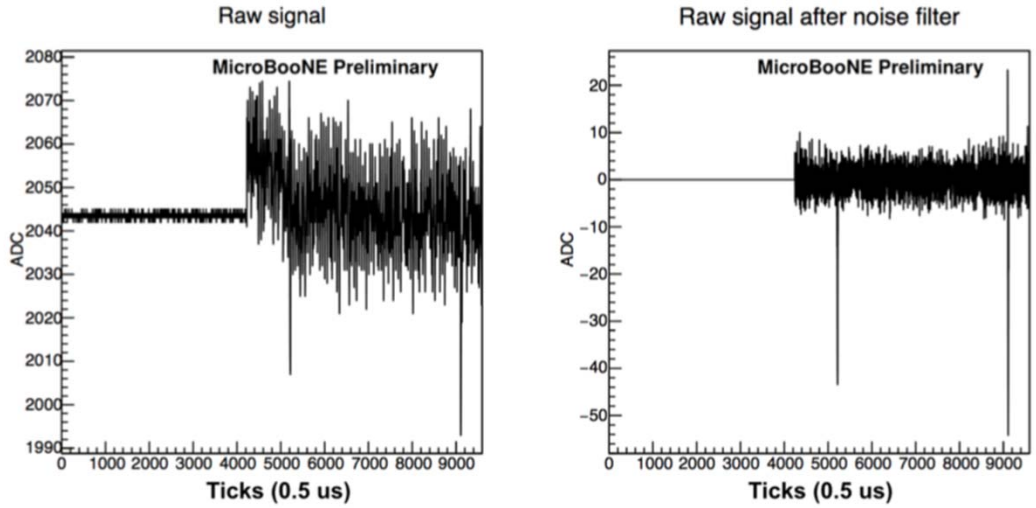
* Subtract coherent noise using median ADC value of set of 48 channels at MB level
  * Before subtraction, signal region is identified and removed from the waveform
* Noise level is reduced by a factor for 4-5 for the induction and 2-3 for the collection plane





Saturation of ASICs

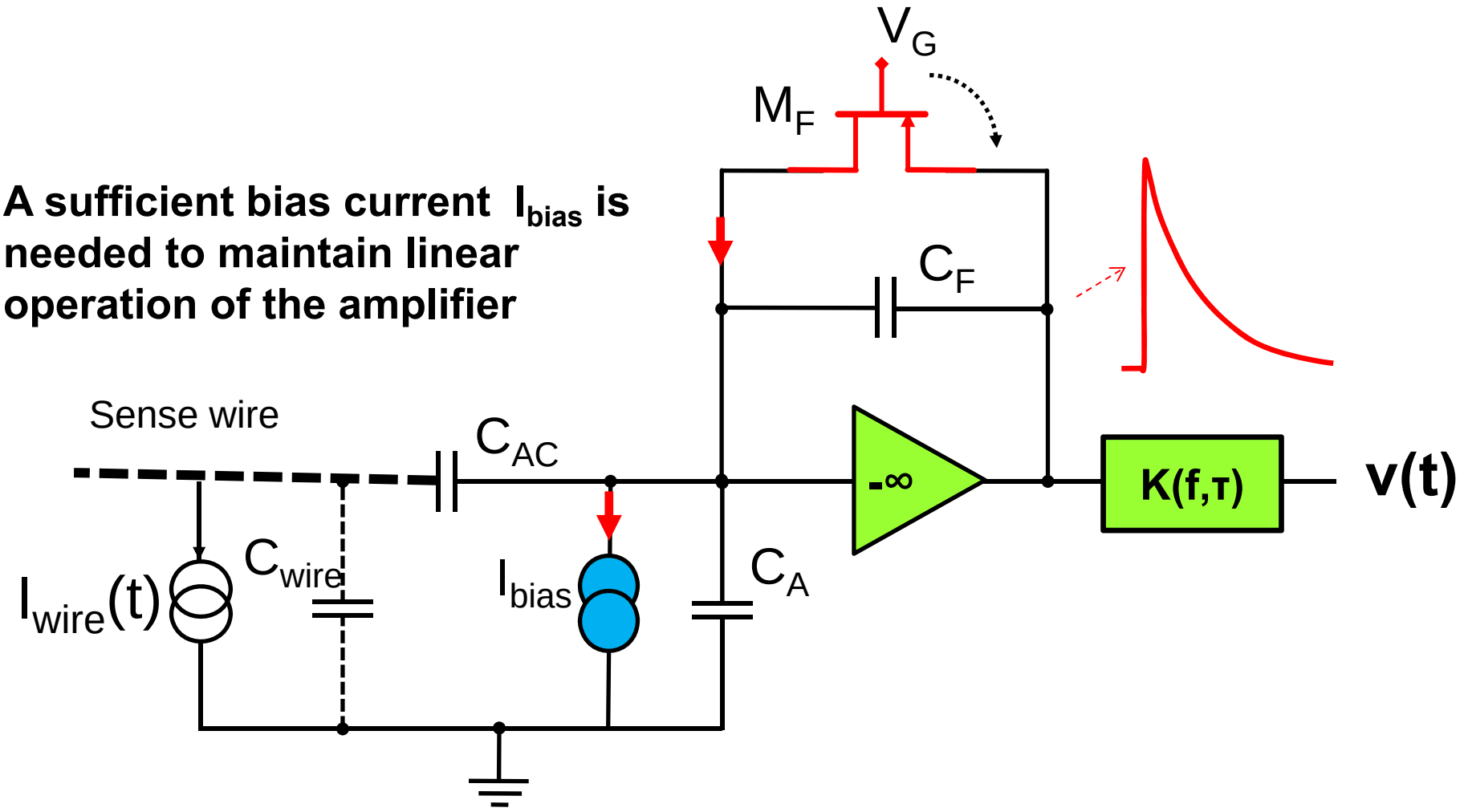
An example U-Plane raw waveform before and after filtering



* Intermittent dead regions (low RMS) on waveform when wire bias is ON
  * Origin is the wire motion inside LAr
* Largely reduced by changing ASIC bias current from 100 pA to 500 pA
* Easily identified in the waveform and can be filtered

Reset in AC-coupled front-end ASICs due to wire motion

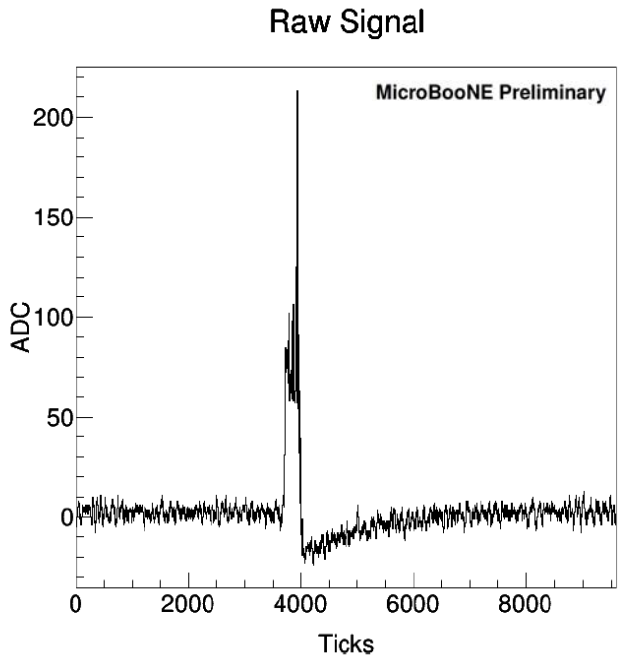
A sufficient bias current I_{bias} is needed to maintain linear operation of the amplifier

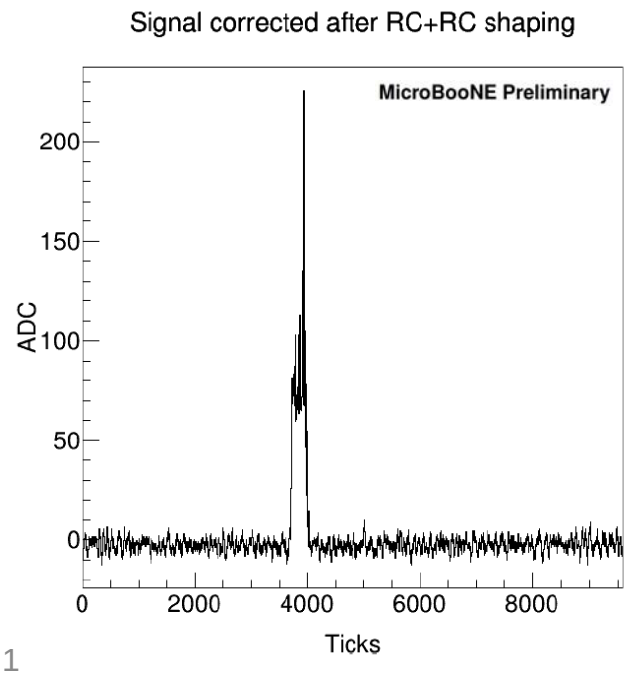


In LAr FE ASIC I_{bias} is programmable as 100pA or 500pA (default 500pA gives ~ 60e- noise). In the new version 1nA and 5nA will also be available.

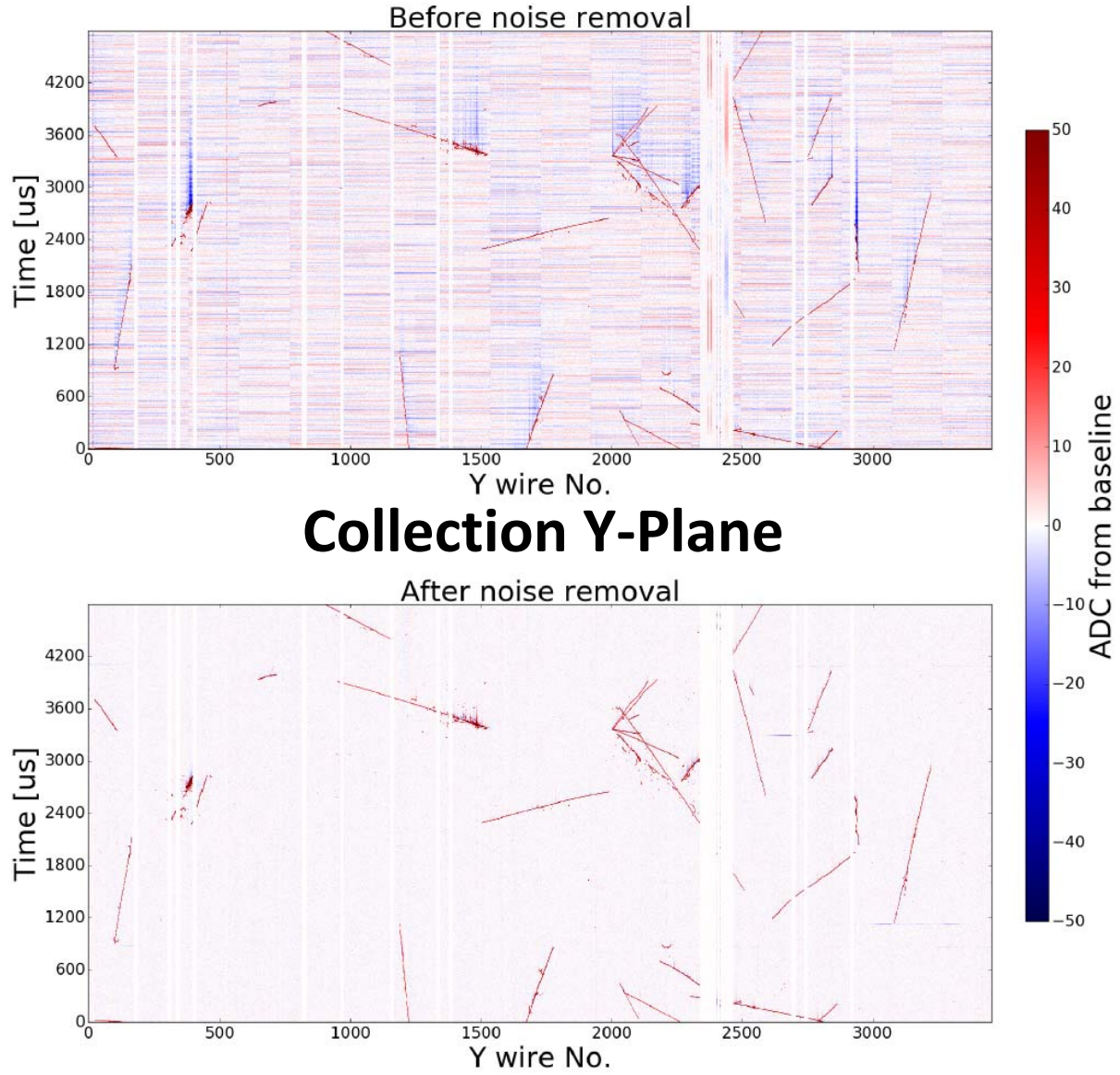
RC Filter Response

* There are two RC hardware filters in readout system with 1ms time constant
  - One in the intermediate amplifier
  - Second in the FADC
* This leads to the negative tail in the signal
* Corrected through deconvolution





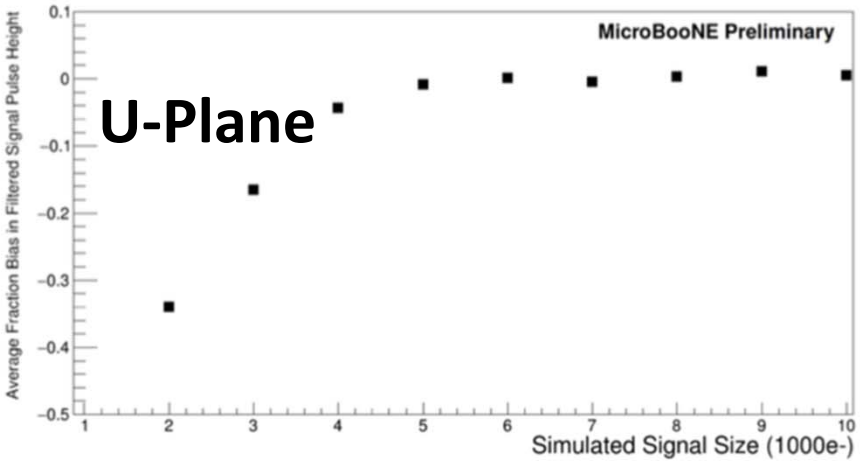
Event display

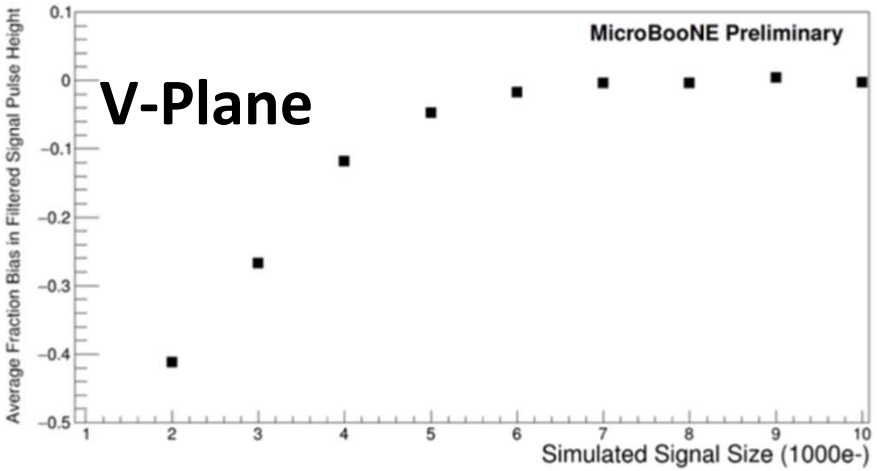


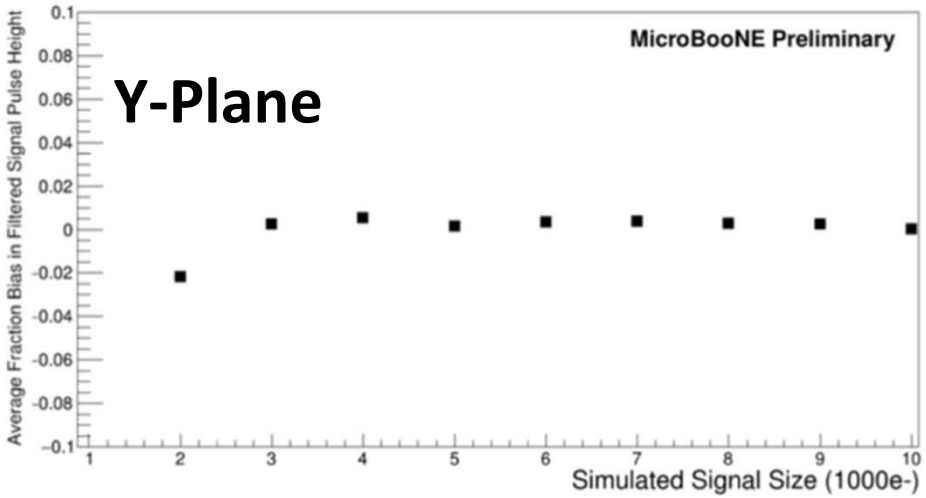
Collection Y-Plane

Impact of Excess Noise Filtering on Signal

* Among all the software filters, only the coherent noise removal (10-30 Hz due to regulator) can lead to reduction of signal for track traveling parallel to the wire plane
* Small impact (**MIP corresponds to 18 k electrons at 3 mm pitch**)







This will be reduced with new Service board upgrade!

Summary

- Pioneering cold electronics in MicroBooNE reach the expected performance
  - < 600 electron ENC leads to significant improvement in the induction plane signal performance
- Sources of excess noise are all identified and hardware fixes are in order
  - Software filter is developed to successfully remove excess noise with negligible impact on signal
- Stay tuned for new results from MicroBooNE