Capacitively induced wire plane diagnostic system

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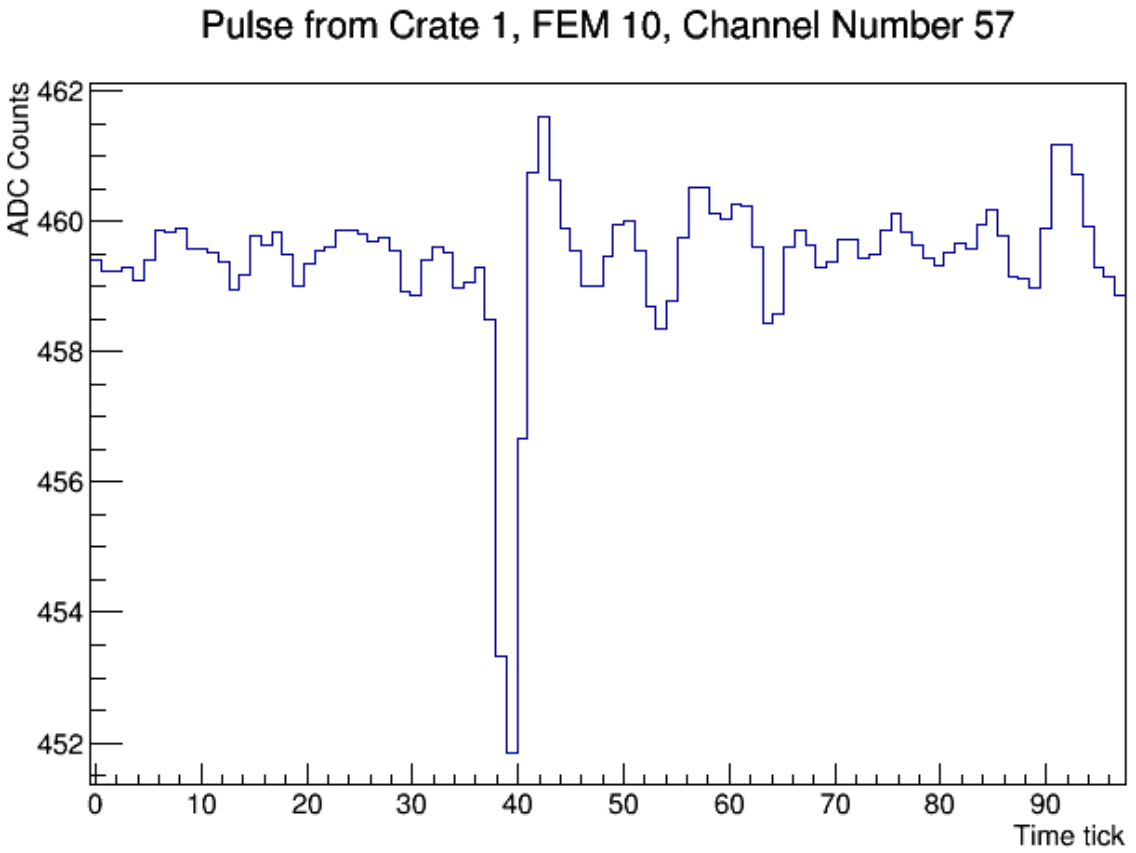
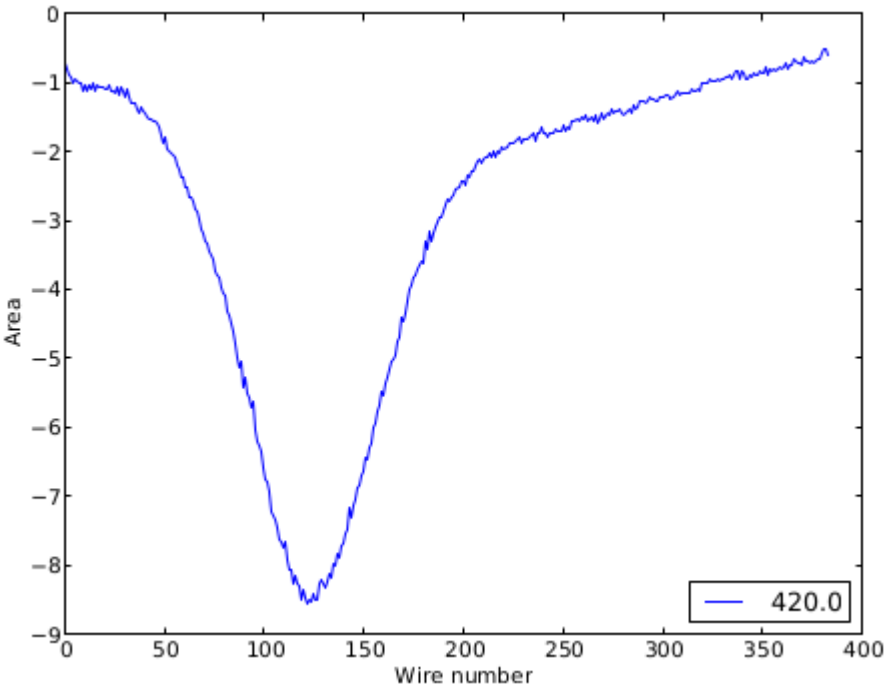
Previously...

- PMTs were shown to induce charge on the wire plane.



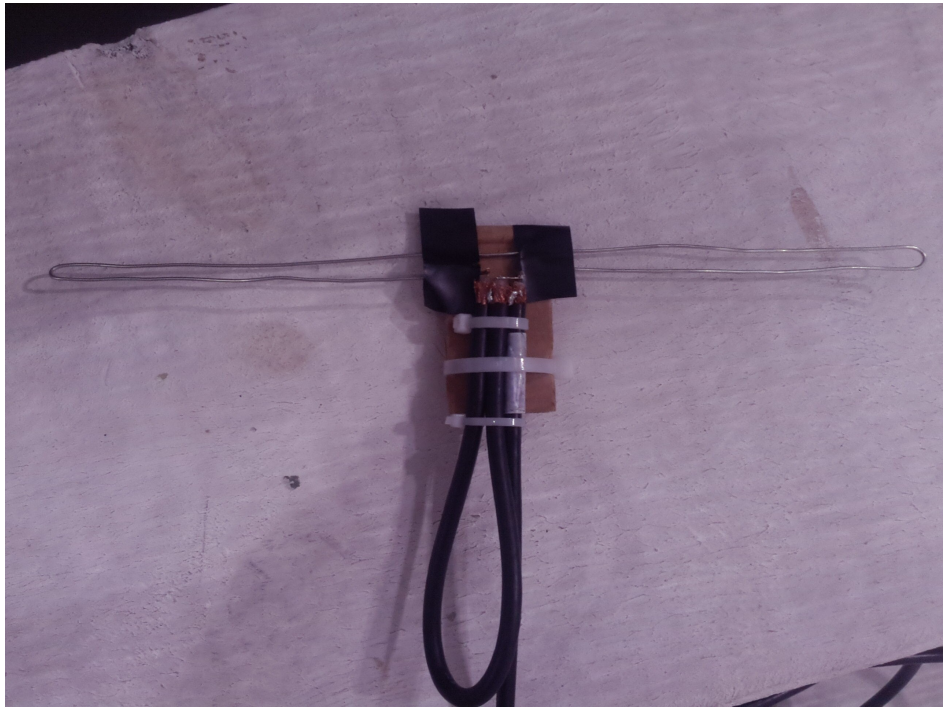


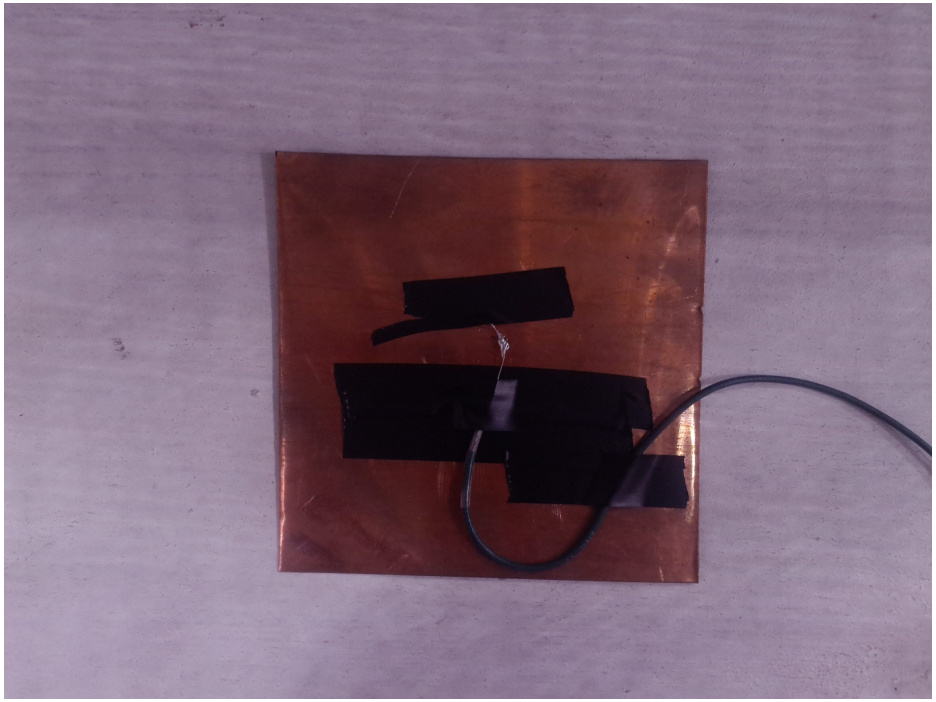
Motivation

- Effect could serve to diagnose broken wires.
- Currently there is no way to put charge directly on the wires.
- Charge injection system puts charge on the motherboards.
  - Can detect broken wires through crosstalk on adjacent channels.
    - Reliant on wires falling into each other.
  - Is there another diagnostic method?
- PMTs are world's most expensive antennas.
  - We should design a dedicated antenna based diagnostic system.

Design

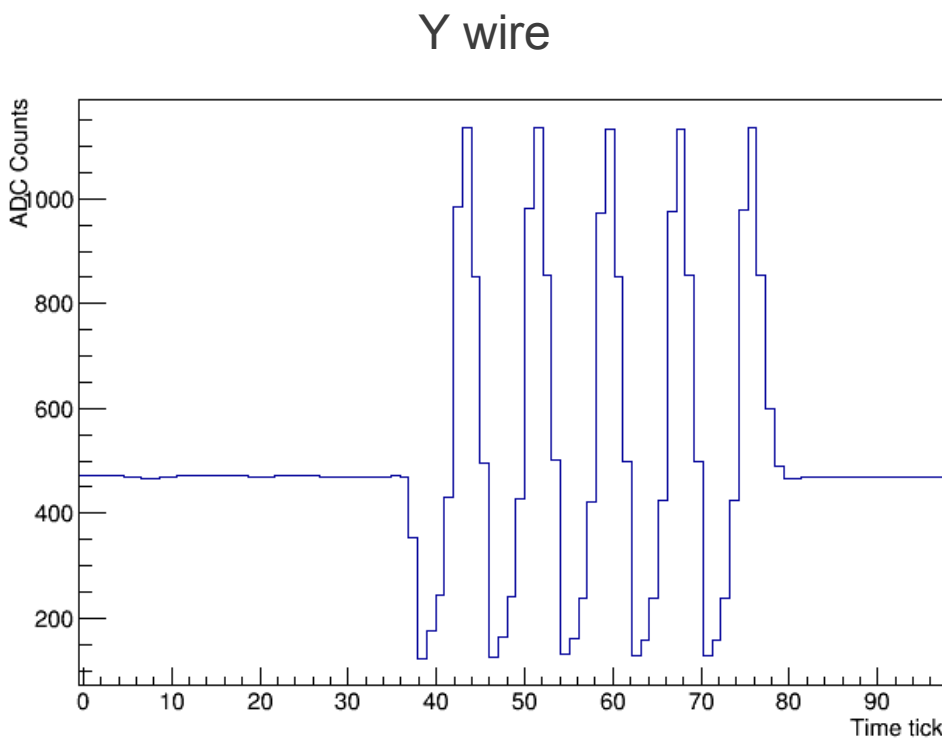
- Magnetic coupling to wire plane not possible.
  - Leaves capacitive and radiative.
- Left: 4:1 balun dipole. Right: Plate.

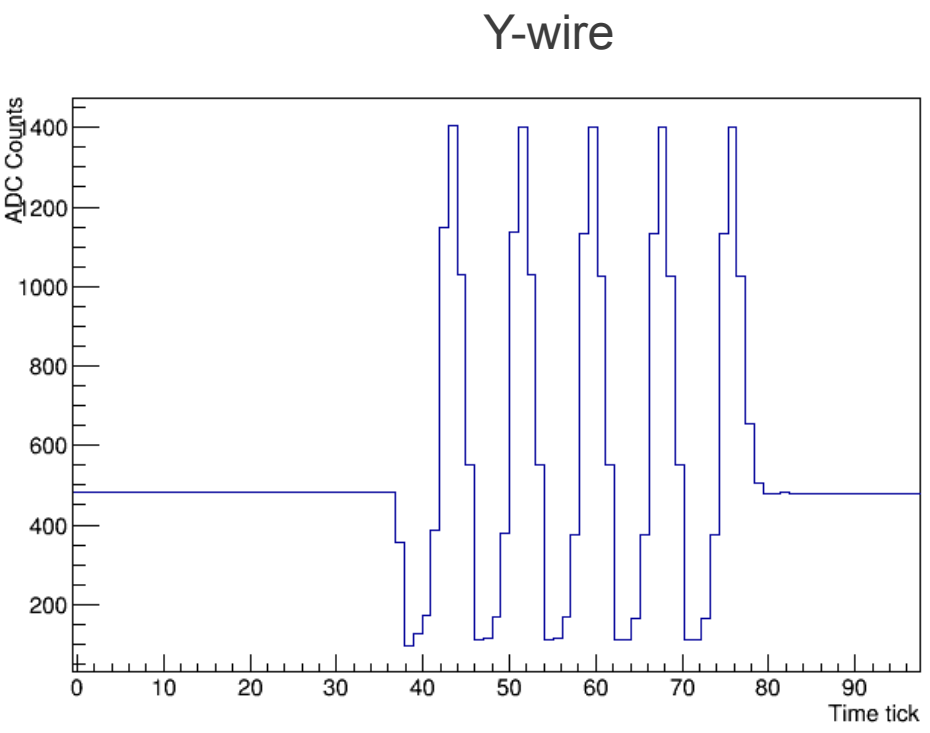




Design

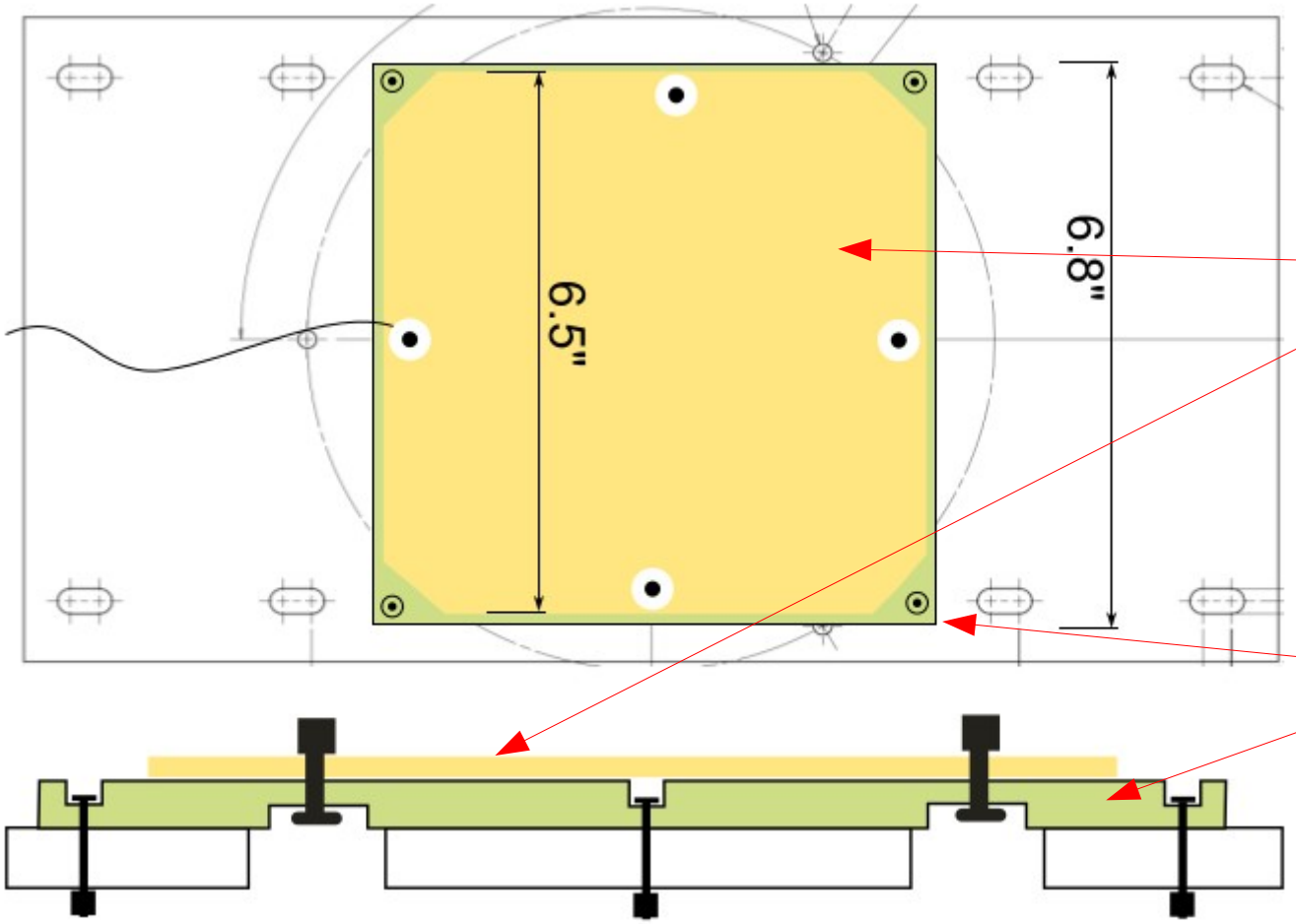
- Waveforms measured on the wire plane.
- Averaged over 10k events.
- Left: Dipole. Right: Plate.





Design

- Mounted on proven PMT back plate design.
- Insulated from grounded back plate by G10.



Stainless steel antenna plate

G10 insulator

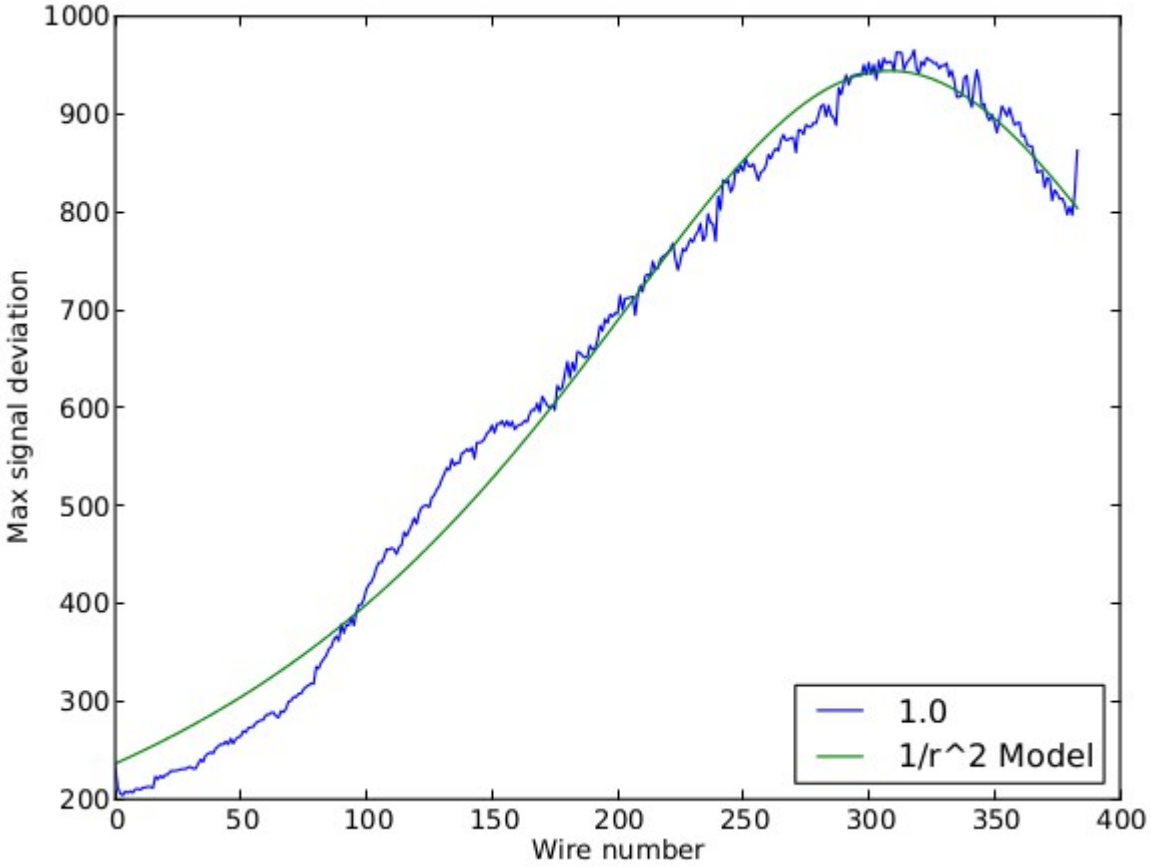
Design: Signal delivery

- PMT feed-through has 4 spare channels.
- These will be used to drive the antennae.
- Currently spare channels are coiled in the cryostat. Installing antennae will leave them secured in a known location.
- Driving signal will be provided by a standard programmable function generator, placed in the PMT rack.

Design: Placement

- Necessary to know range of antenna:
  - Fit to spatial distribution,

$$f(x) = \frac{A}{d^2 + (x-c)^2}$$

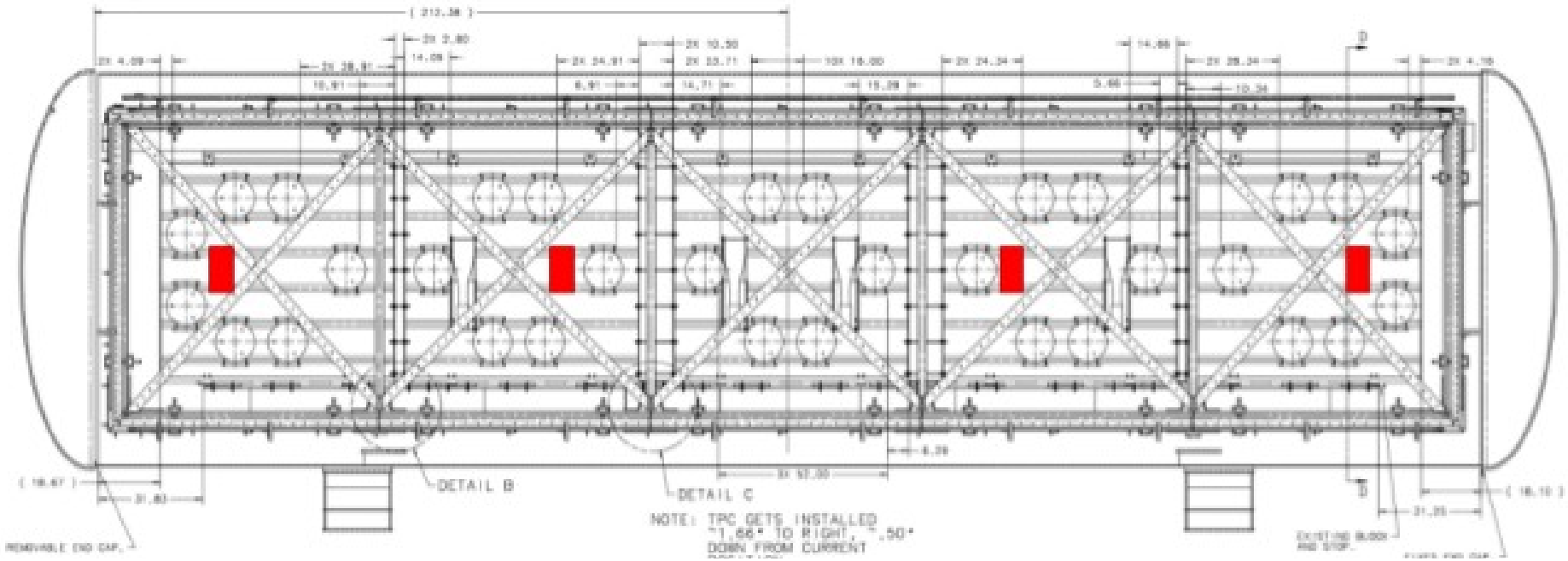


Best fit:
A = 3E7 ADCs
c = 308 wires
d = 178 wires = 21 in

Actual d = 20 in

Design: Placement

- Extrapolating fit gives signal of at least 24 ADC counts at x = 1100 wires.
- Y-plane has 3456 wires in total so two antennae can cover the entire plane.
- Remaining two are placed in corners to drive the corner wires in the U and V planes, which are shielded by the Y plane.



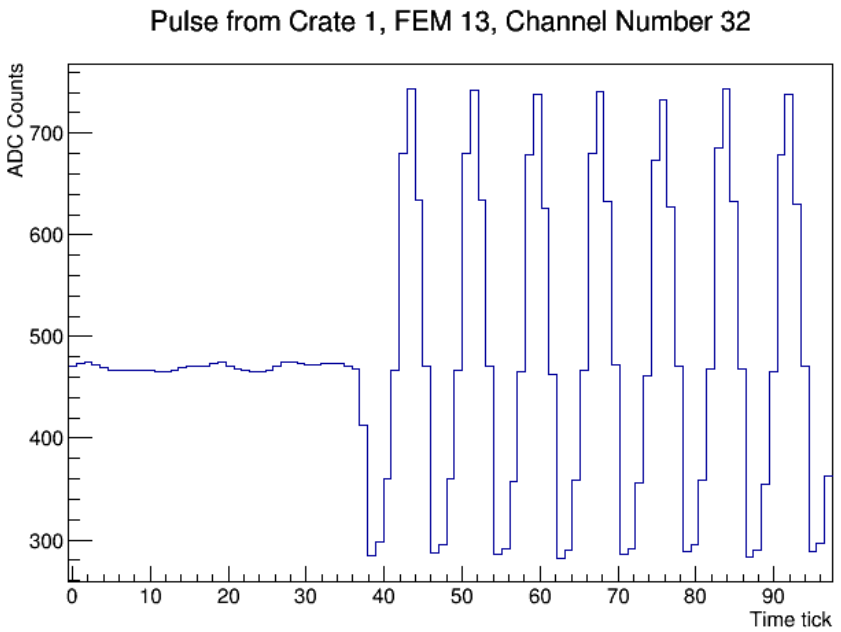
Risks: Mechanical

- Mechanical risks are largely mitigated by repurposing the proven PMT mounting system.

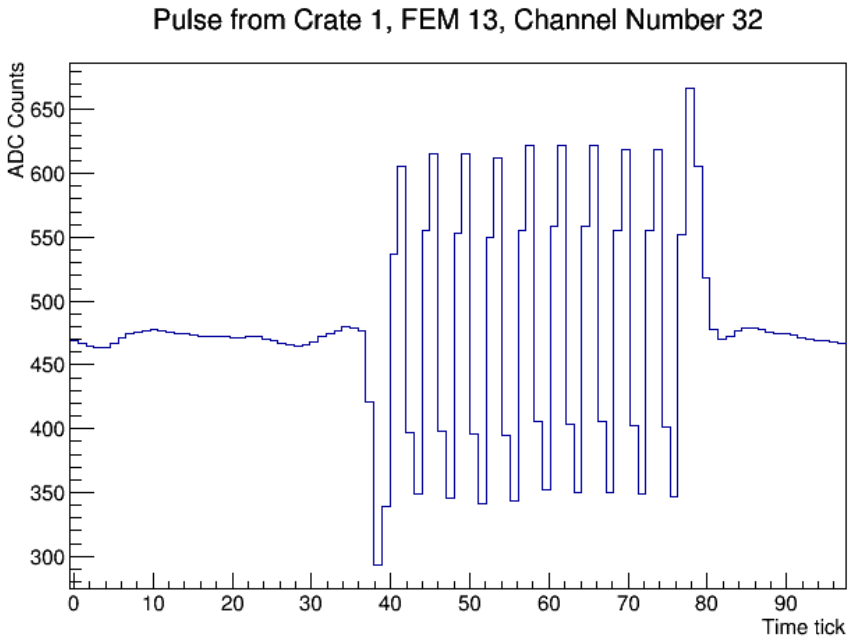
- Some risk of the RG316 signal cable breaking loose and leaving the antenna as a floating conductor.
  - No greater than posed by the PMTs.

Risks: EMI

- Antennae could act as a conduit for EMI into the cryostat.
- Mitigated by terminating the signal cables at the feed-through when not in use.
- Can calculate upper bound of expected noise:
  - First, note that integrating effect of readout electronics reduces amplitude of high frequency signals.



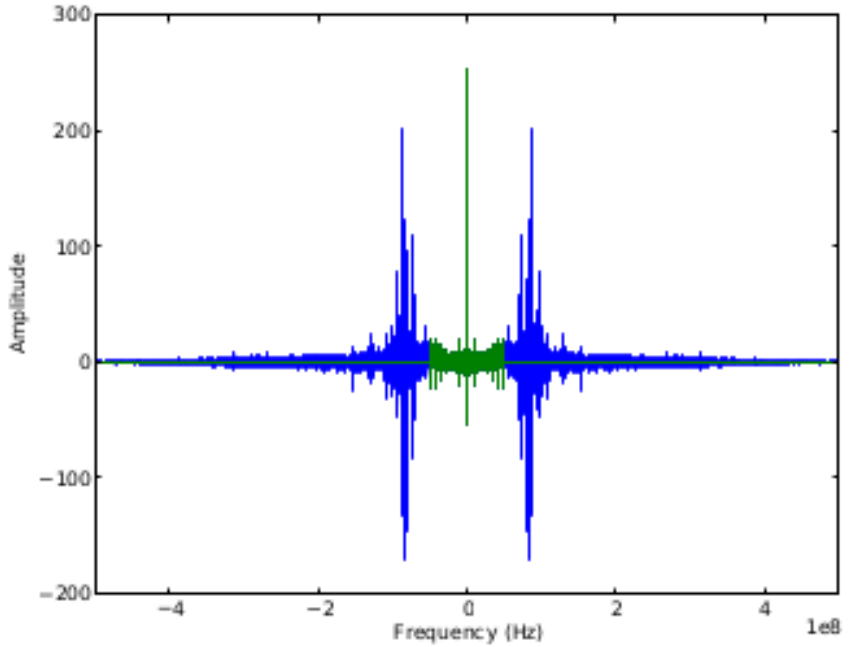
Y-wires, 4us period, 300 ADC amplitude



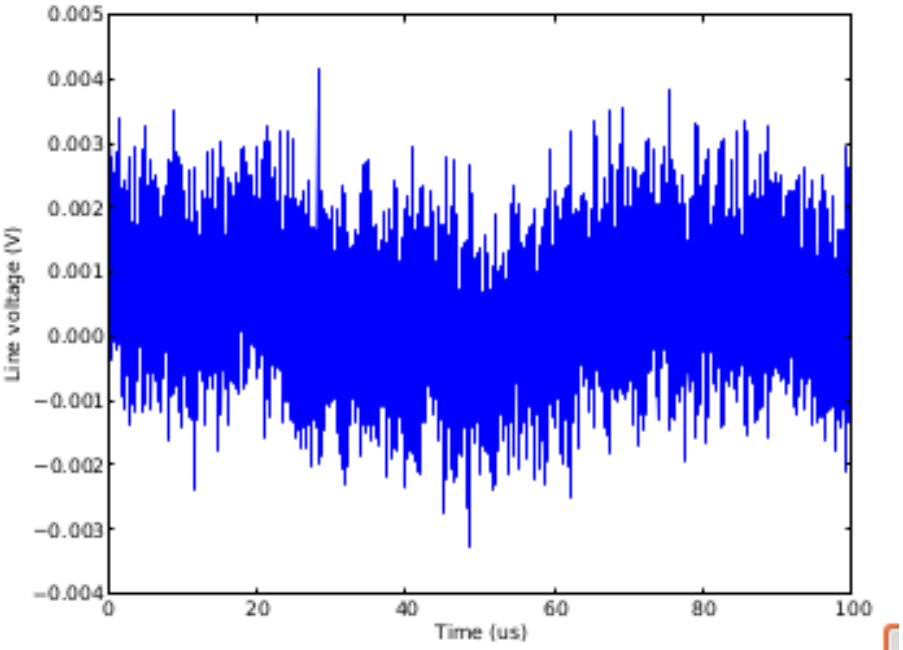
Y-wires, 2us period, 150 ADC amplitude

Risks: EMI

- Any signals which have period < 50ns should have negligible contribution.
- Noise spectrum was measured on a 3.7m terminated RG316 cable at DAB.
- High frequency components were filtered out.
- Noise with amplitude 3mV remains.
  - This corresponds to 4 ADC counts of noise on the wire plane.



Noise spectrum, blue was filtered out.



Remaining line noise after filtering.

Risks: Electrical

- The spare PMT channels are fitted with SHV connectors.
  - This presents a risk that HV is accidentally connected to an antenna.
- Labelling and painting the antenna plugs should minimise this risk.
- Ideally SHV to BNC connectors would be permanently affixed to the relevant channels on the feed-through.

Cathode?

- We are proposing to put small conductive plates in the cryostat.
  - But there is already a huge plate in the cryostat: The cathode.
- Can we induce a signal on the wire plane using the cathode? Maybe.
- Advantages:
  - No added mechanical or EMI risk.
  - U plane is more visible to the cathode.
- Disadvantages:
  - Much greater electrical safety risk. Is it possible to hook a signal generator up to the HV feed-through?
  - Y plane is less visible to the cathode.

What about the PMT shielding?

- A large cosmic might produce 1000 PEs on each PMT.
- From previous studies (DocDB-2757), this would result in a 10 ADC count signal induced on each Y-plane wire.
- A MIP might produce 100 ADC counts per wire.
- Thus, we expect an obscuration of at most 10%.
- Mechanical risks of modifying the TPB plates to hold shields considered not acceptable given this small effect.