

Single Crystal Test Beam Study for Electromagnetic Calorimetry

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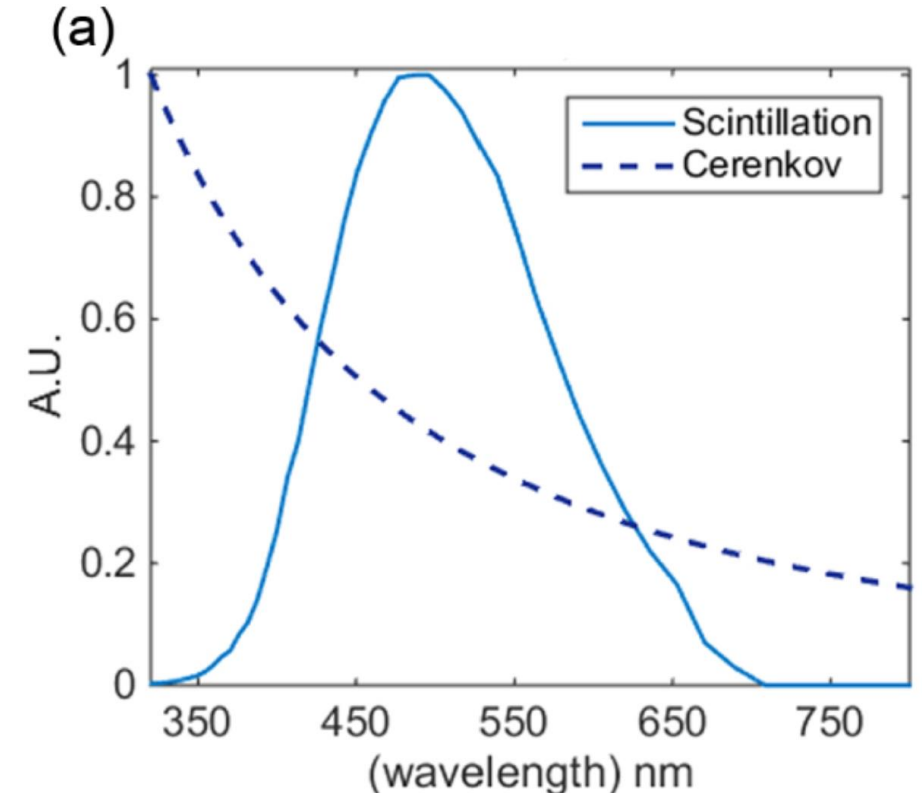
27 June 2024

Background

Scintillation vs Cherenkov radiation

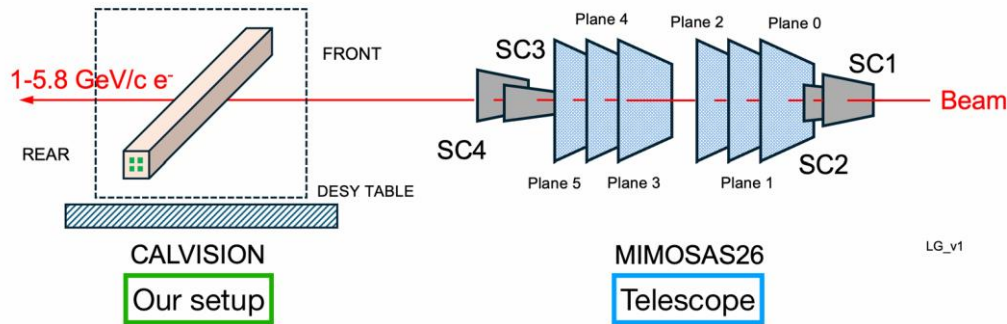
- Large shower fraction fluctuations in EM and hadronic calorimetry
 - poor energy resolution
- Dual-Readout Calorimetry:
 - Simultaneous scintillation and Cherenkov measurements
 - better energy resolution!

Scintillation Radiation	Cherenkov radiation
<ul style="list-style-type: none">• Photons emitted due to relaxation of excited particles• Isotropic: propagates in all directions• Time delay in emission	<ul style="list-style-type: none">• Photons emitted due to relativistic particles with $v > c$ polarizing the medium• Directional• Instantaneous



Emilie Roncali et al 2019 Biomed. Phys. Eng. Express 5 035033

April 2024 Test Beam Setup at DESY



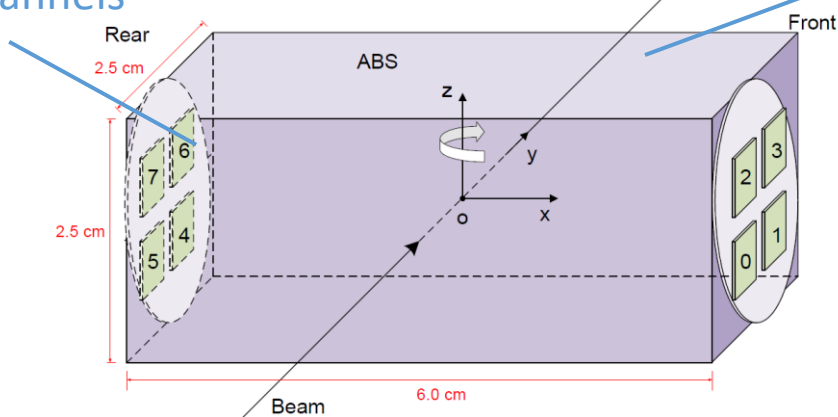
PWO: Lead Tungstate

- Produces scintillation and Cherenkov radiation
- Used to study scintillation and Cherenkov separation
- Filter in the rear

PbF2: Lead Fluoride

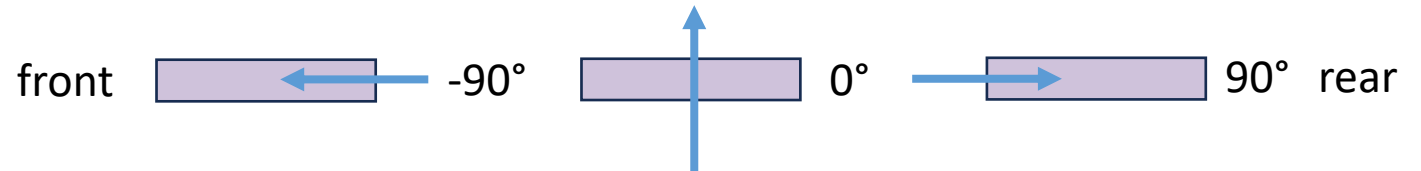
- Produces only Cherenkov radiation
- Used as a reference to study Cherenkov properties
- No Filters

8 channels

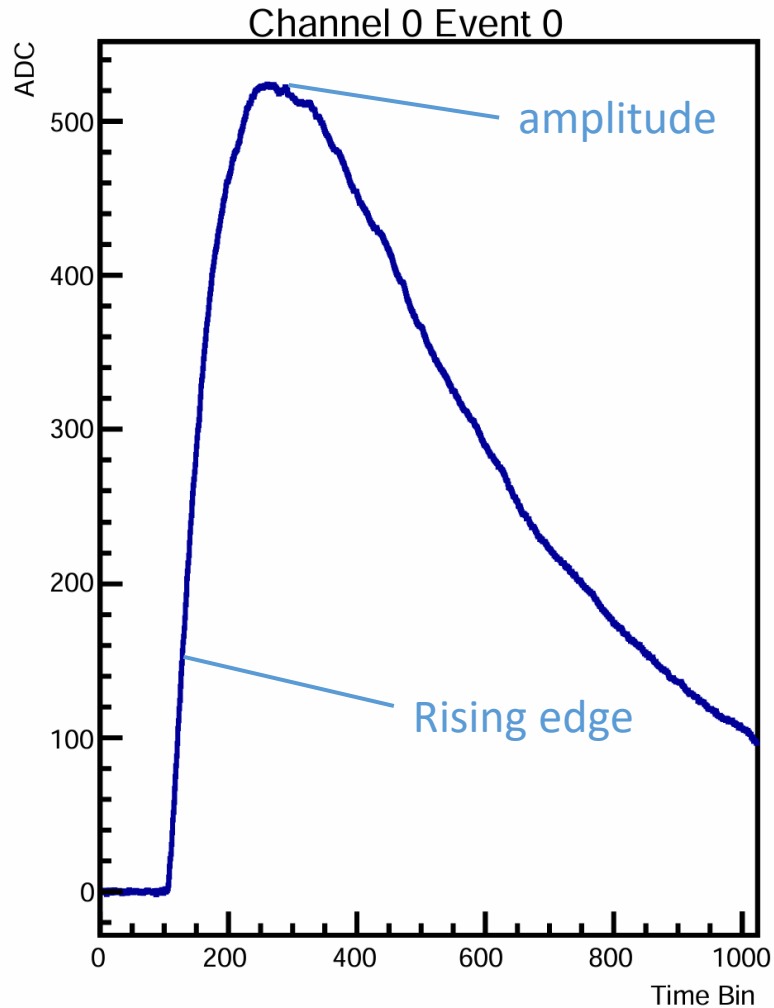


2 GeV electron beam

Not shown: optical coupling, filter, SiPM, amplifier, and other electronics



Questions to be studied



- How does the amplitude, rising edge, and the shape of the waveform change with different crystals and setups?
- Are our observations consistent with theory and simulations?
- Where are the anomalies in the data and how can we explain them?
- What are the faults in the setup and how can they be improved?

PWO

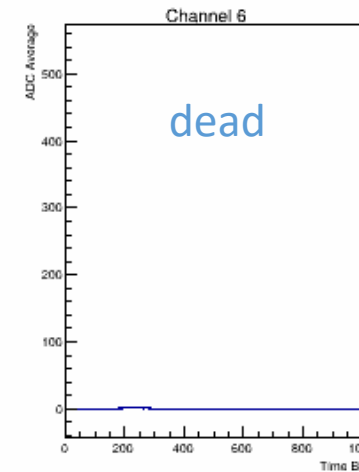
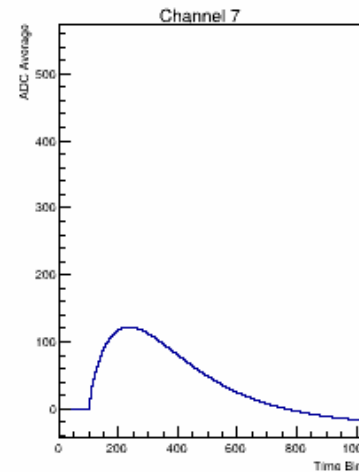
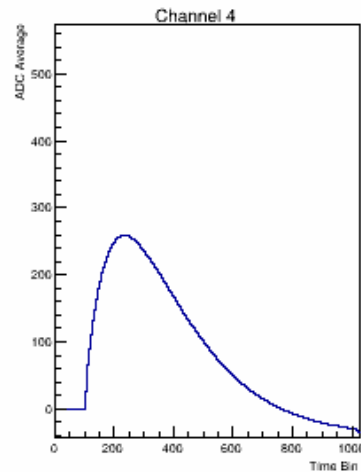
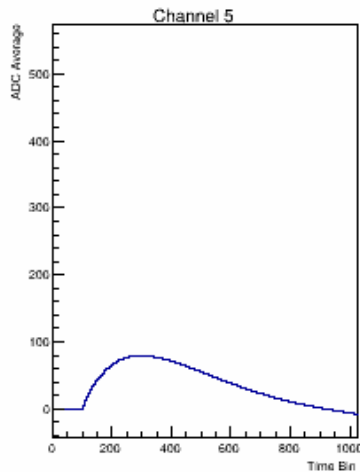
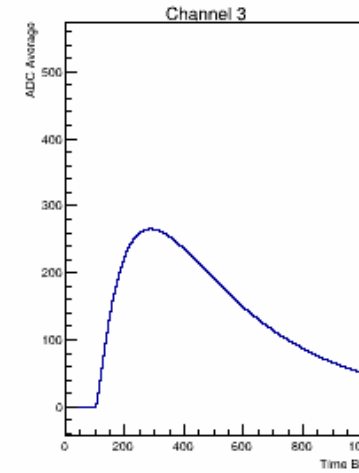
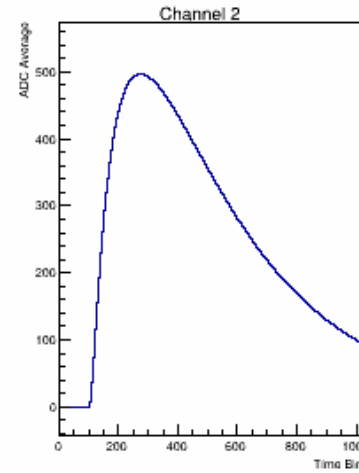
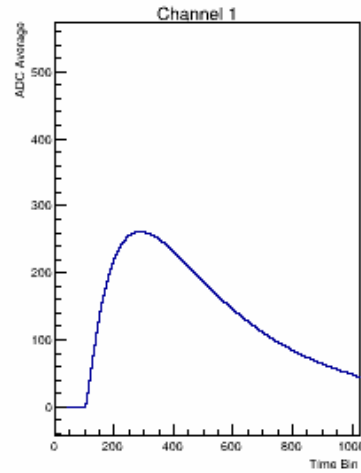
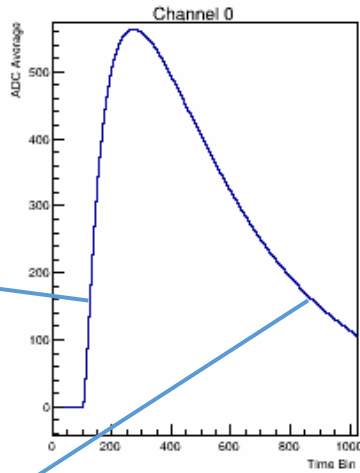
70 degrees

Averaged Waveforms

Expect similar responses, but what could be the cause of the nonuniformity?

Slow rising edge due to time delay of scintillation radiation

Exponential decay due to discharge of SiPM

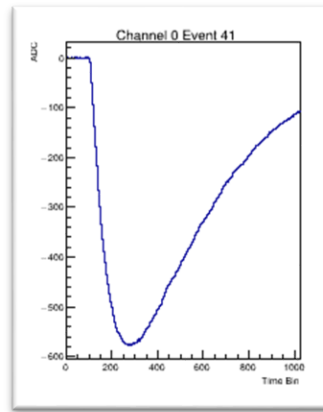


Back channels have filter → smaller but more Cherenkov signal

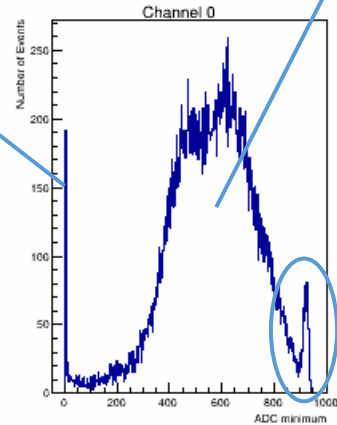
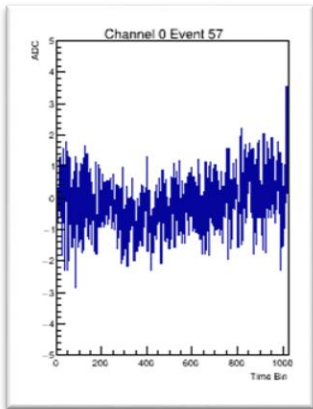
Noise events removed from data

Waveform Peak Distribution

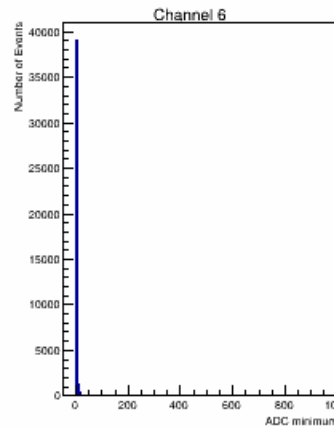
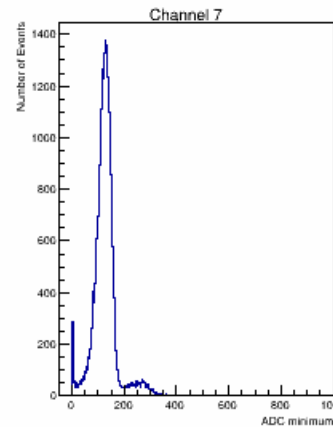
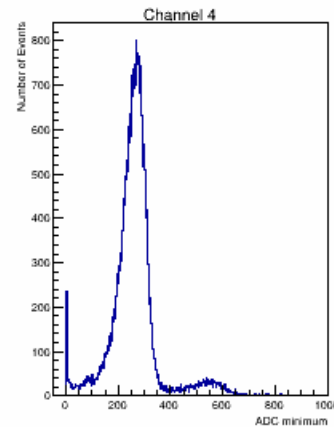
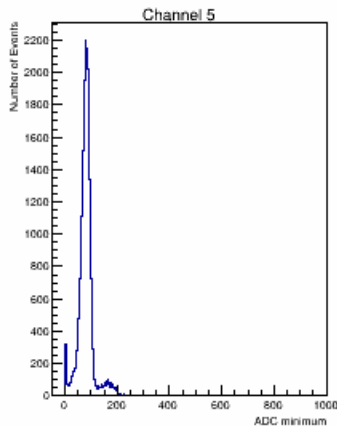
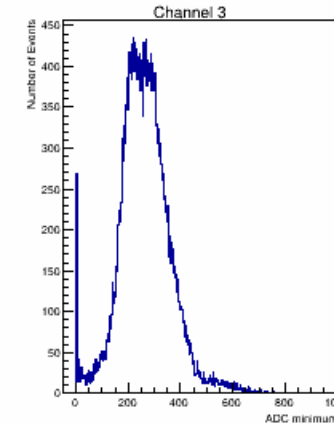
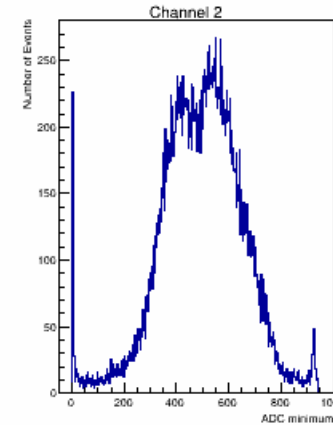
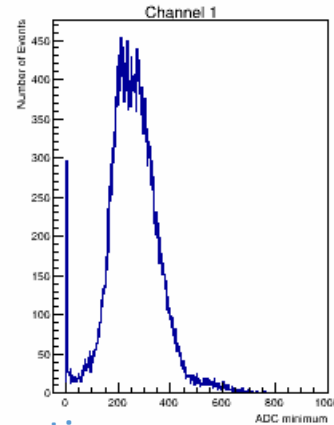
Real signal



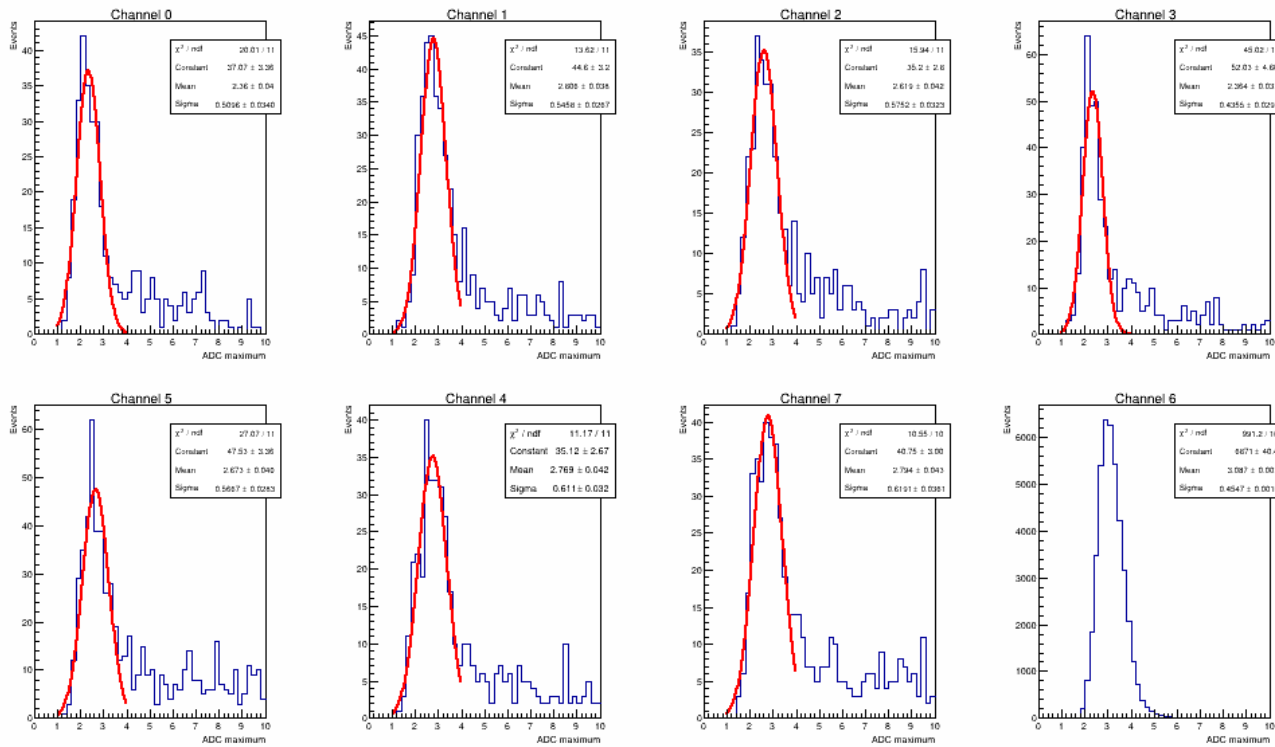
Noise signal



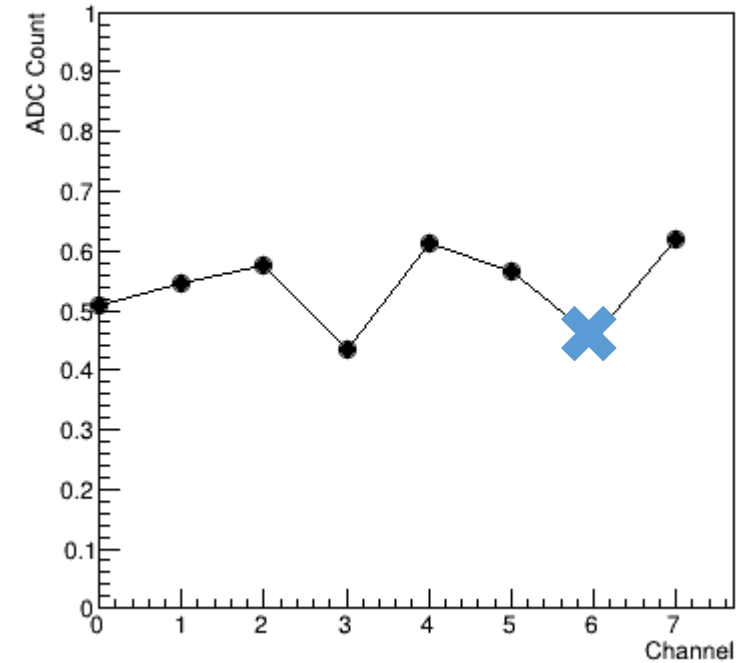
saturation



Is the noise stable?



Sigma of Gaussian Fit on Noise Fluctuations



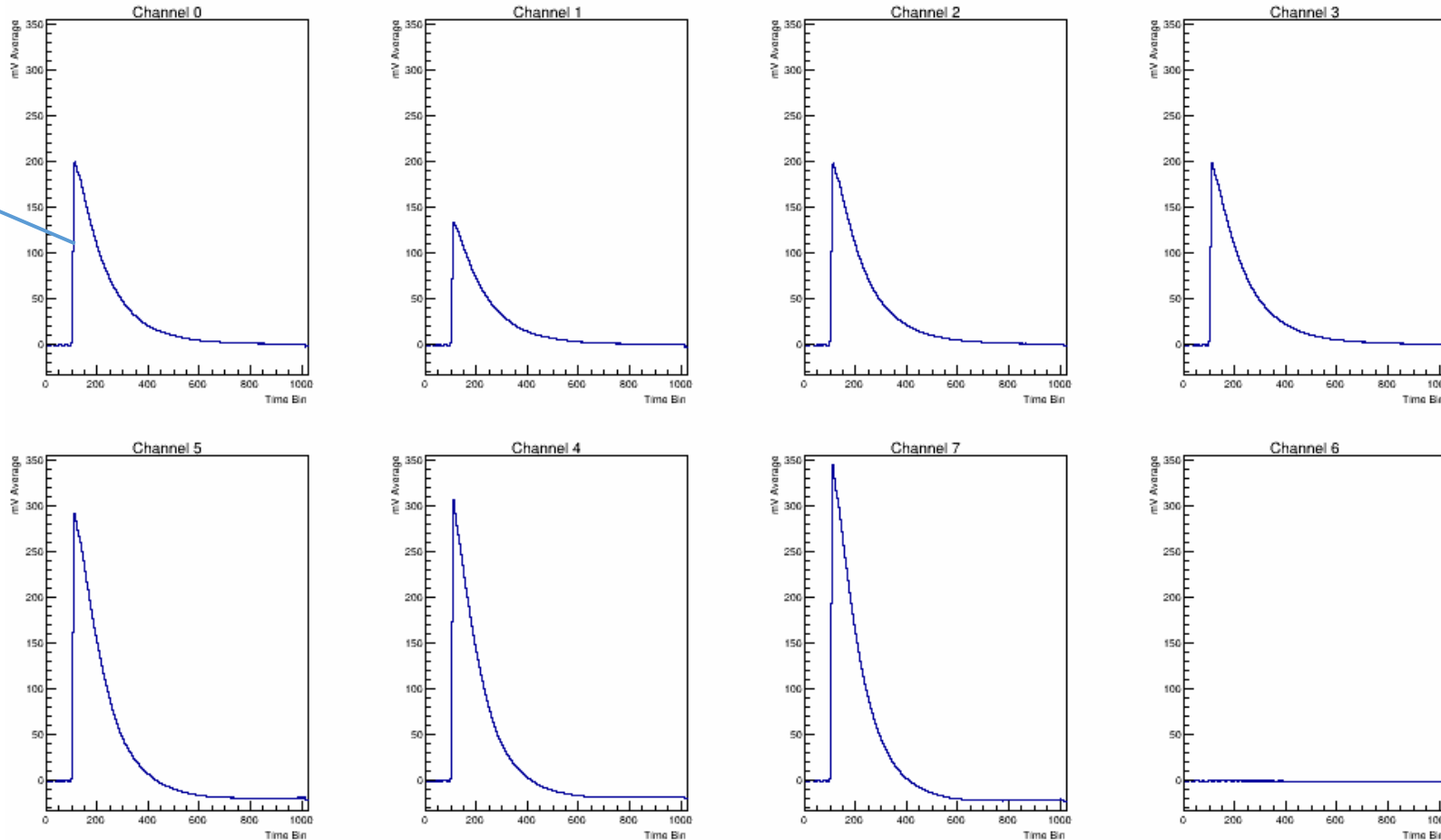
- Yes! Noise is stable and below 1 ADC Count
- Sufficient resolving power
- Independent of crystal, angle, and filter

PbF₂

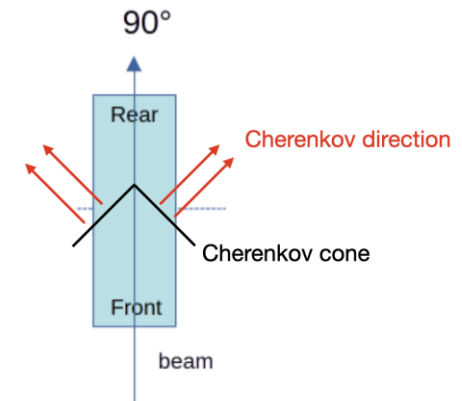
Only Cherenkov radiation is produced

Averaged Waveforms: 90 degrees

Instantaneous radiation \rightarrow steep rising edge

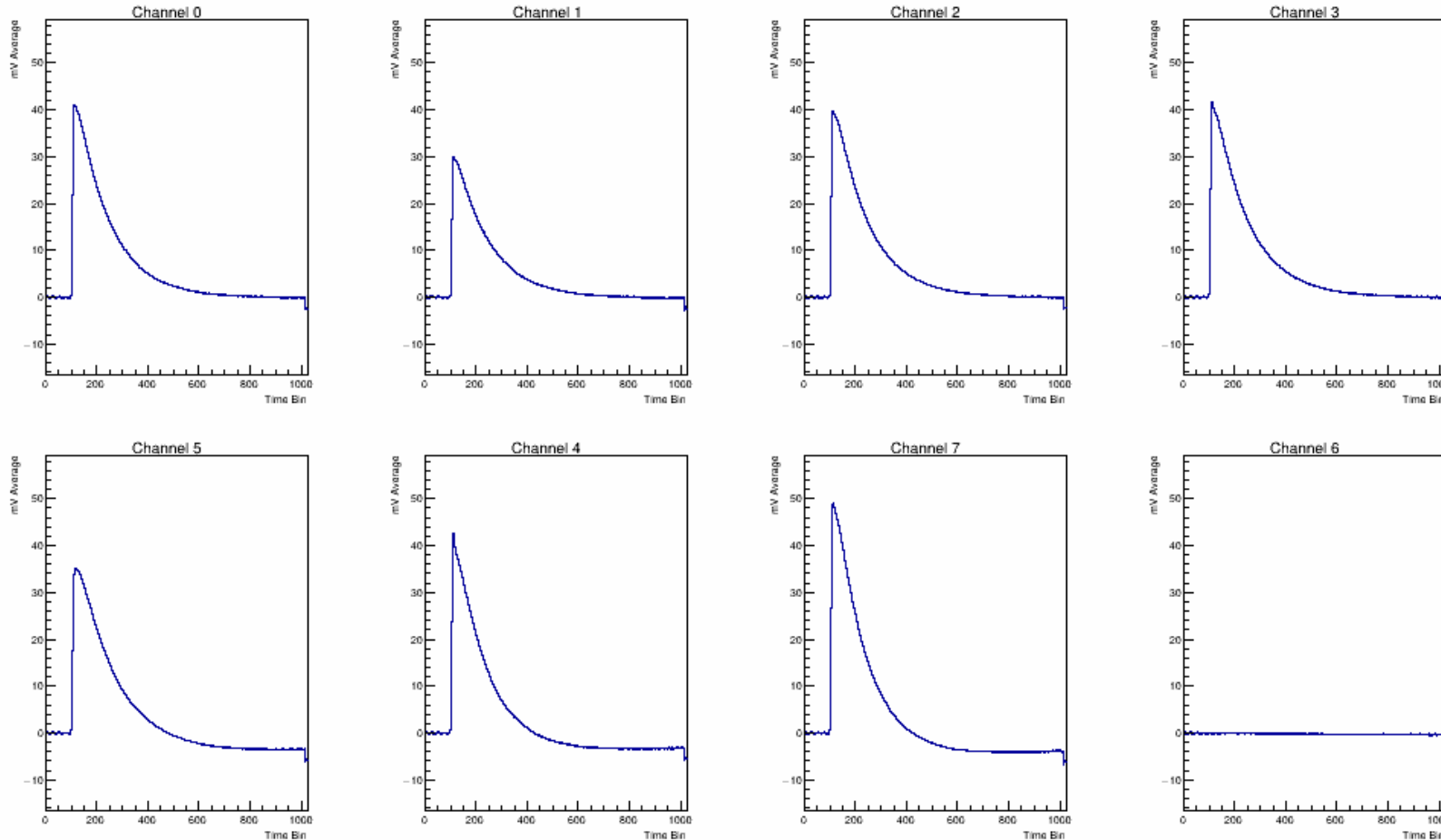
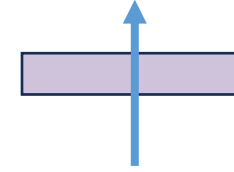


When beam is parallel to the crystal, greater signals are expected in the back channels due to directionality of Cherenkov radiation



Noise events removed from data

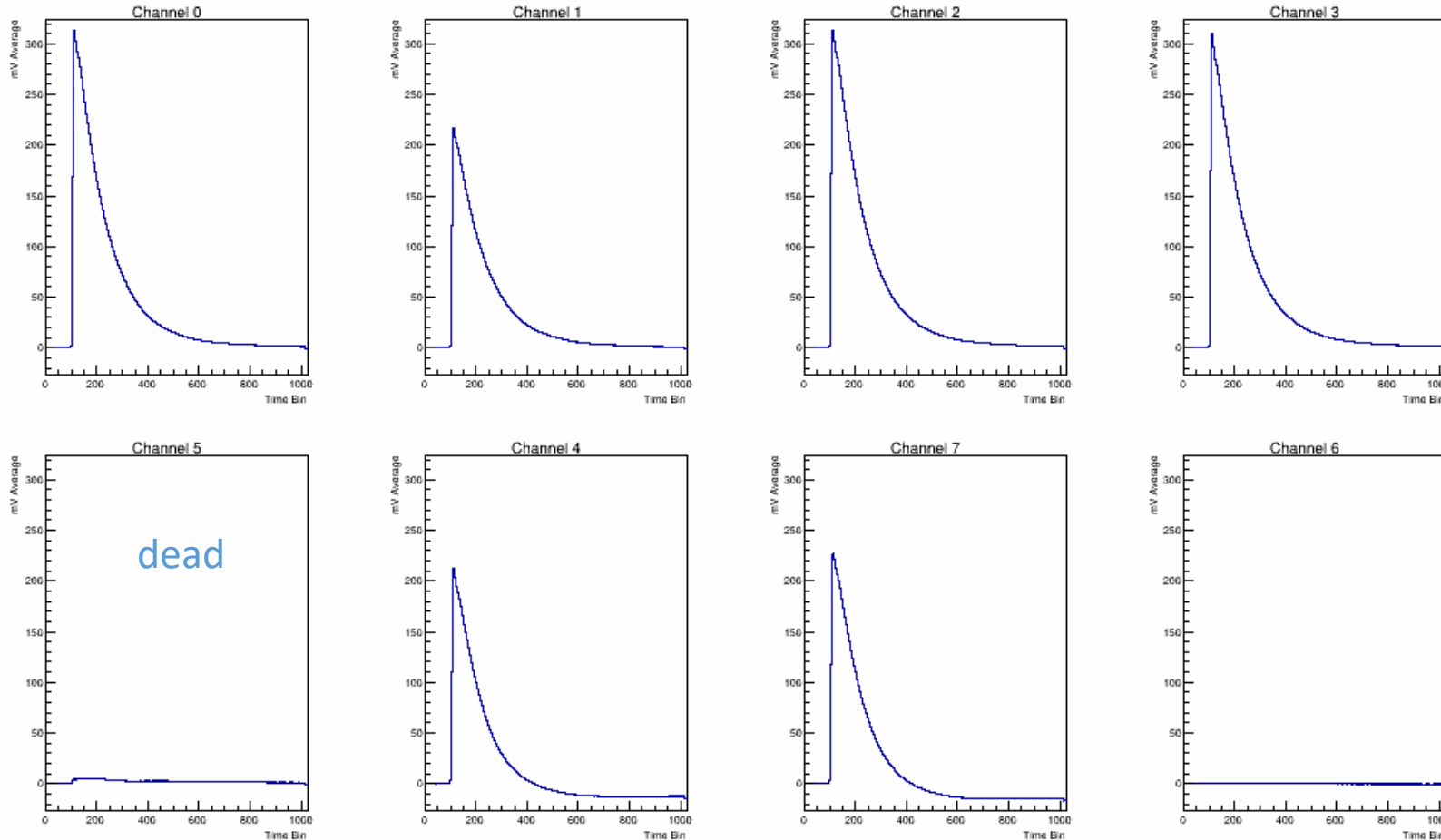
Averaged Waveforms: 0 degrees



When beam is perpendicular to the crystal, signals should be comparable between two ends

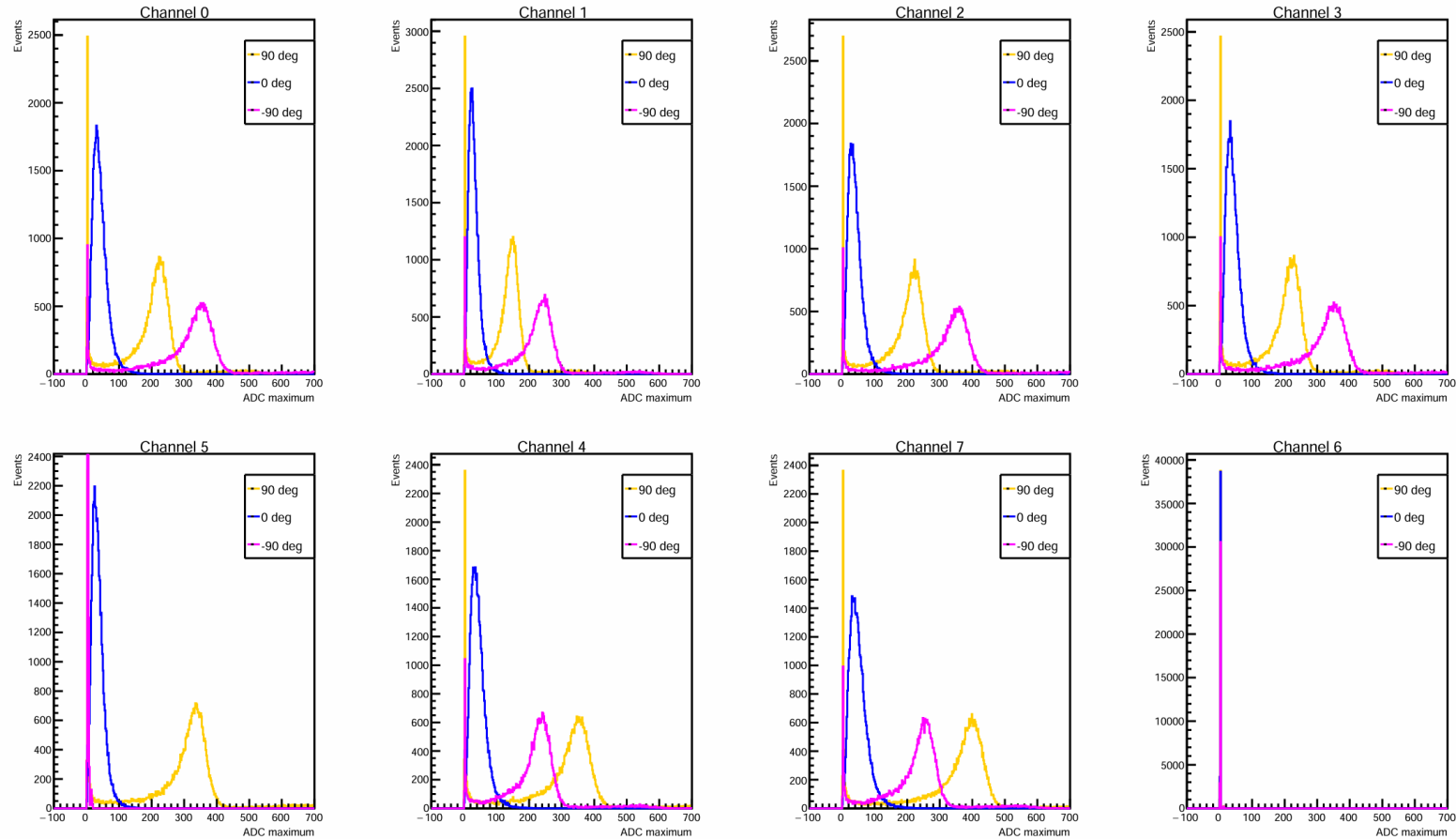
Noise events removed from data

Averaged Waveforms: -90 degrees



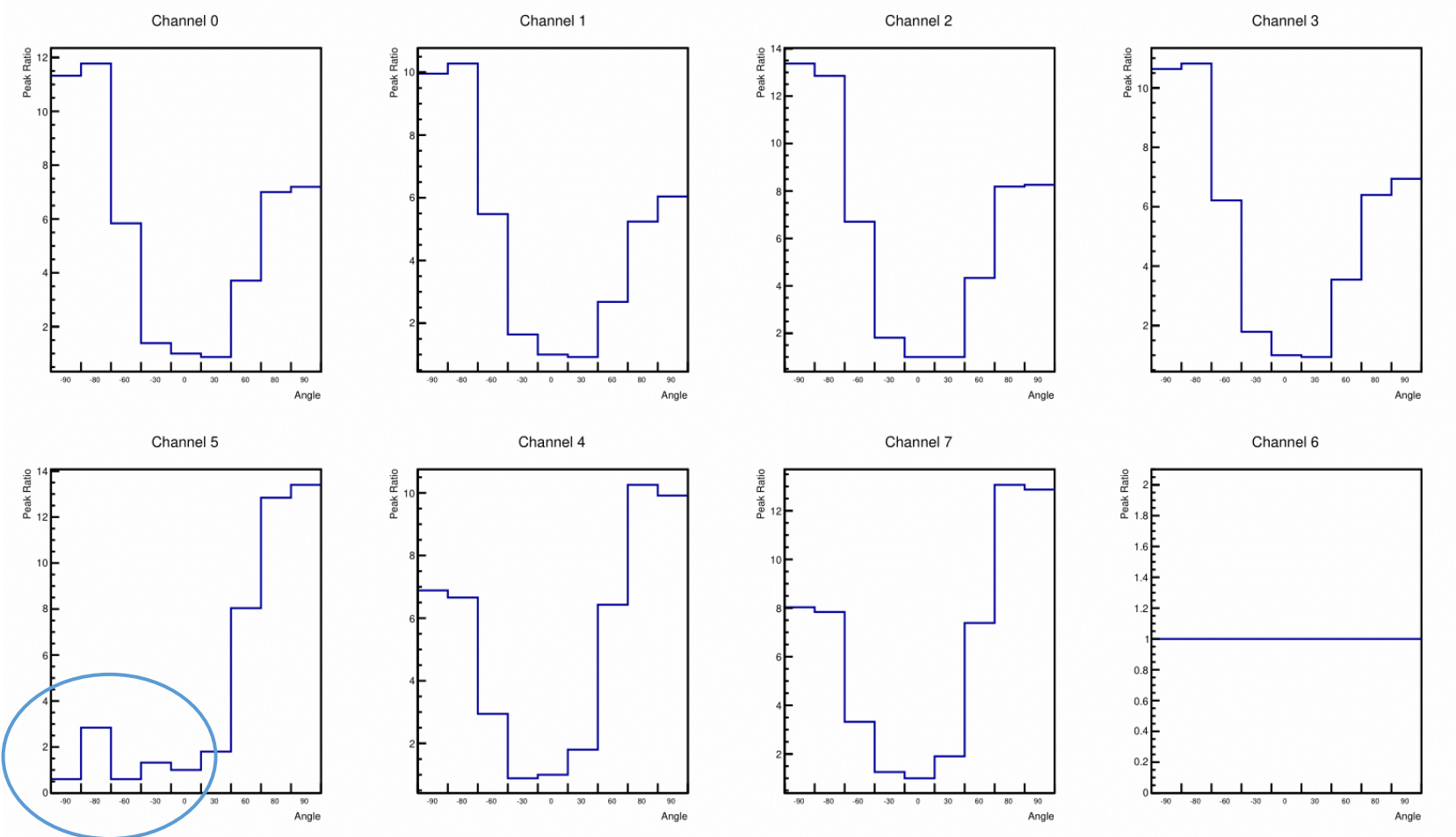
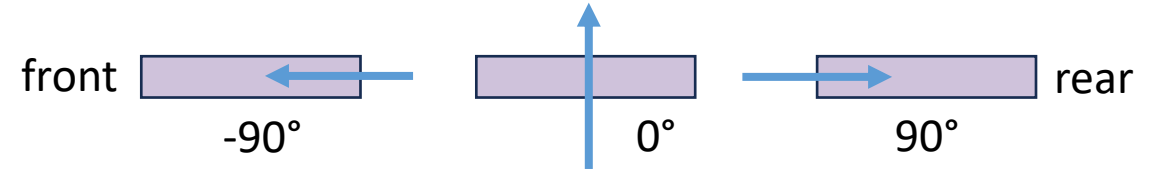
Noise events removed from data

Waveform Peak Distribution for 0, 90, -90 deg



0 degrees follows the expected Landau distribution. +/-90 deg does not.

Angle Dependence Study



Channel 5 is dead for negative angles

Next steps

- Continue with waveform analysis on other runs and compare
- Look into telescoping system to track the test beam
- July Test Beam

Pictures from the past month!

