Calorimetry: Time Resolution τ_{RES}, Estimation

Understanding LED Data Channel by Channel

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LED Sample – Motivation

Time Resolution

This is one of the critical performance parameters for the detector determination of the time for events reconstruction/recognition – design, - event reconstruction, and -final physics results.

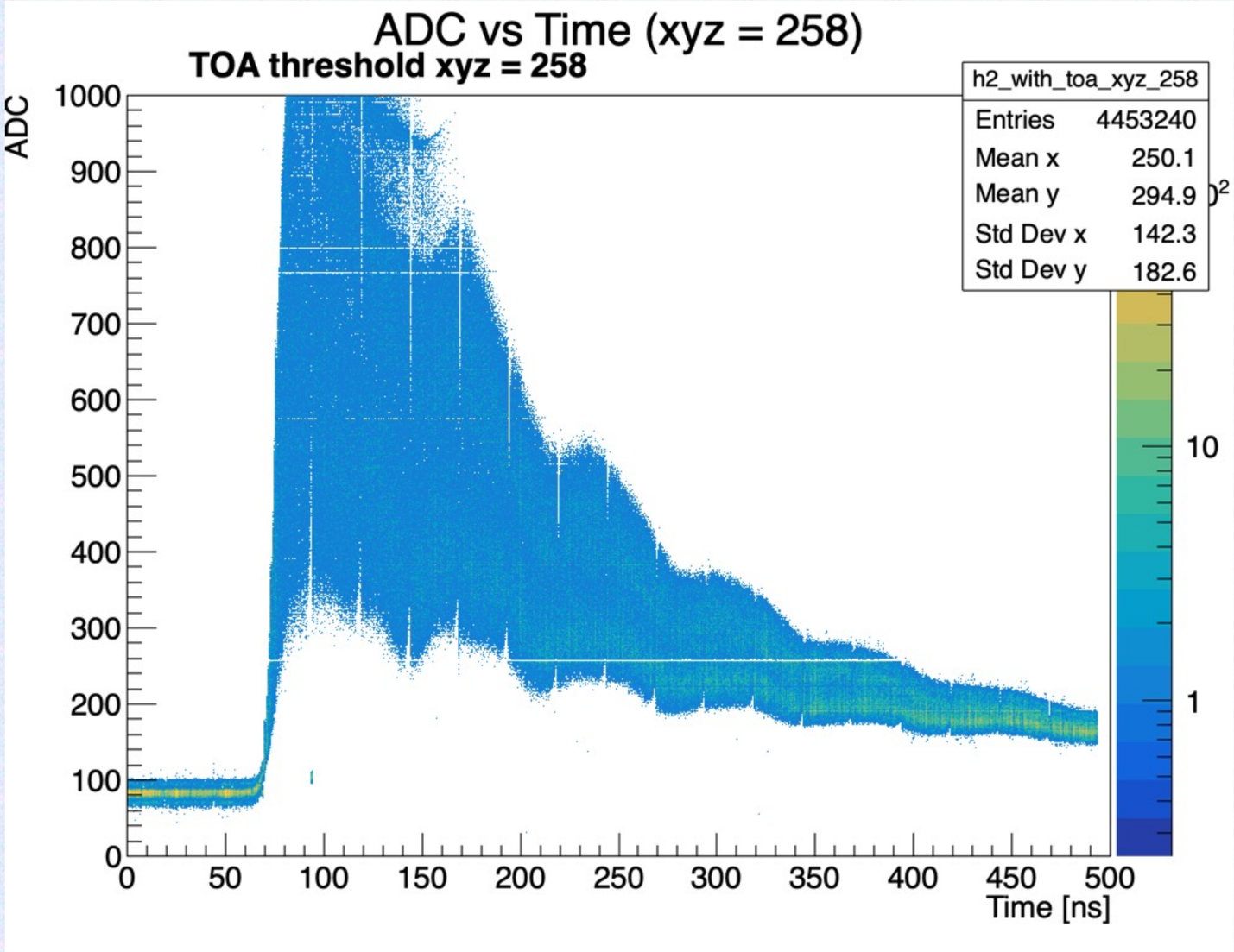
BHCal

- Background/noise suppression
- TOF particle identification
- Energy and position reconstruction
- Trigger Performance – precise timing

Goal:

- Improves PID in the Calorimeter, reducing hadronic contamination and electronic noise.

LED Sample – Waveform

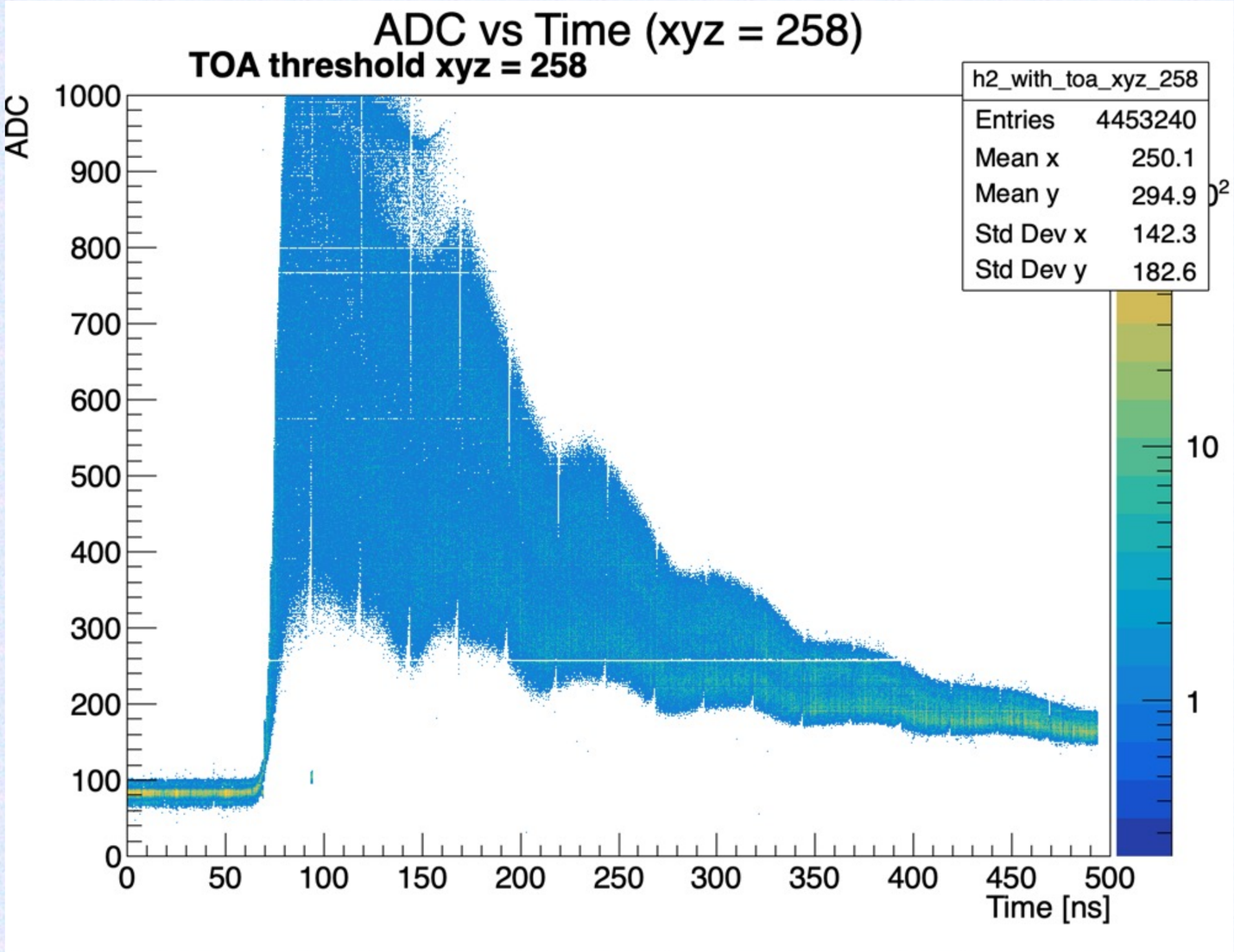


Pedestal (0–80 ns):
Stable electronics baseline (~100 ADC)
Fast Rise (80–110 ns):
Sharp increase due to LED light arrival
Pulse Peak (~100–140 ns):
High ADC (up to ~1000)
Driven by LED intensity + detector gain

Exponential Decay:
Signal decreases as electronics shaping dissipates charge

Confirms proper LED triggering
Good timing alignment
Full pulse captured within sampling window

LED Effect – Waveform Ringing



What is Ringing?

Oscillatory structures after the main pulse

Appears as ripples / ridges in ADC vs time

Where It Appears:

~150 ns → 350 ns region

Visible as periodic intensity bands

Characteristics in Data: Non-smooth decay

Repeating enhancements in ADC

Time-structured oscillations

Impact: Can affect timing extraction

Influences pulse integration

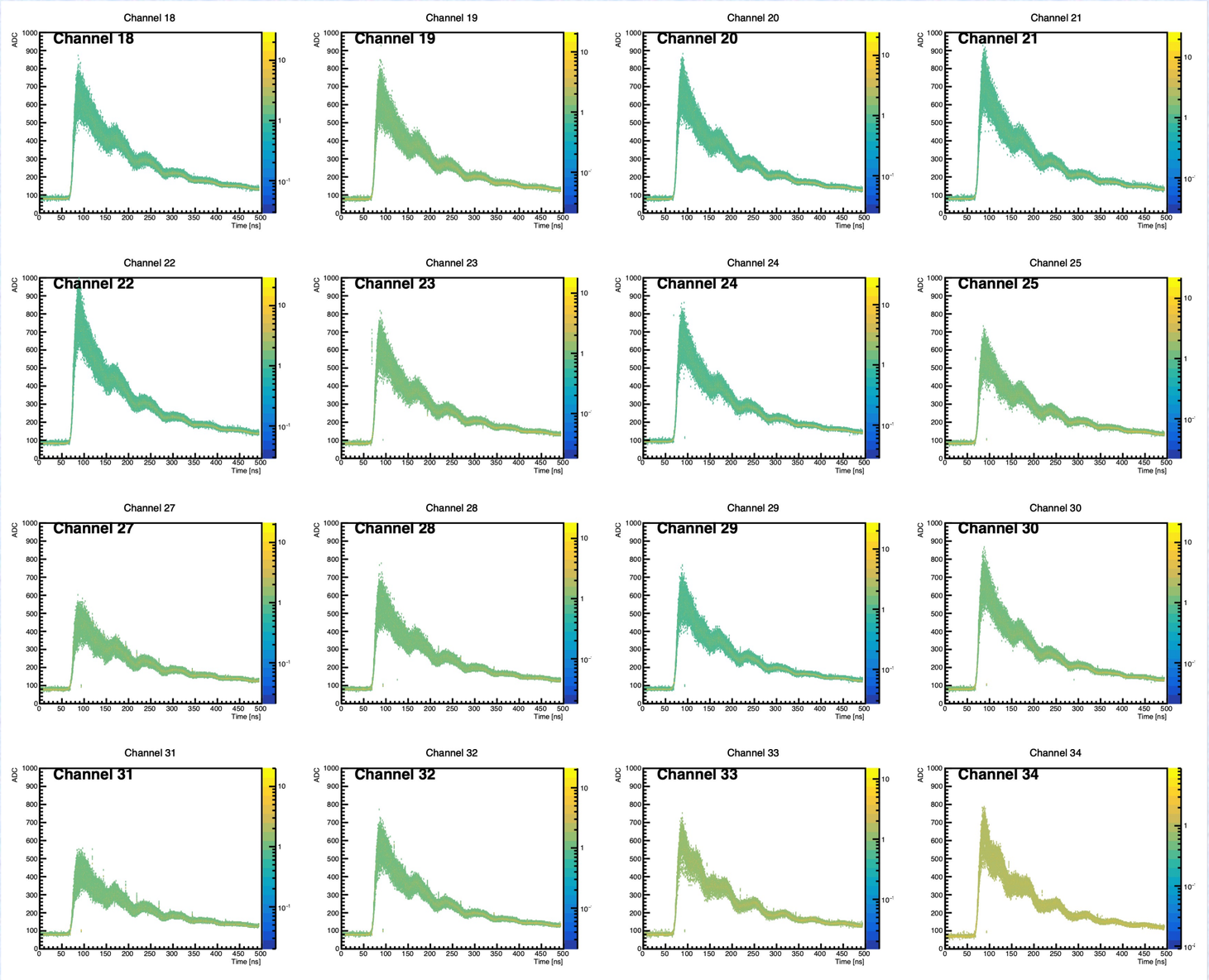
Important for calibration studies

LED Sample – Channel by Channel

Why Channel by Channel?

In detector and electronics analysis (like this LED timing study). A look at each channel helps reveal:

- Hidden problems with the hardware in order to understand and correct the timing shift, gain variation, baseline shift, and noise differences.
- Outliers related to bad channel
- Calibration issues



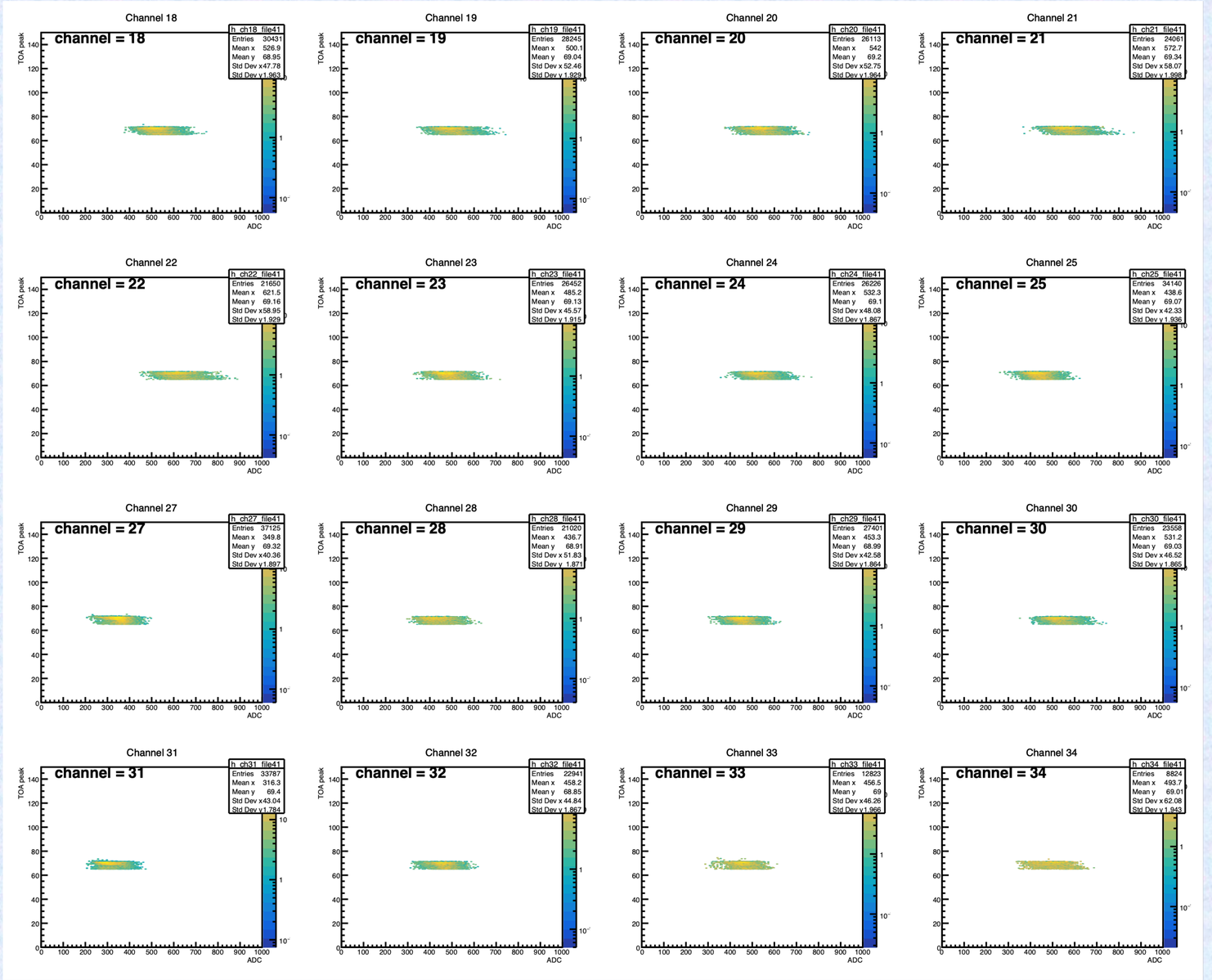
NB: 1-7, 9-16, 35-43, and 45-52 and not connected while 8, 17, 26, 35, 44, 53, 62, and 71 are skipped

LED Sample – ADC_vs_TOA 2D Diagnostic Plots

Each point represents **One event ADC value** at the **Time of arrival**.

It shows how signal amplitude and timing are correlated, allowing to evaluate timing resolution, detect time-walk effects, validate pulse fits, and diagnose detector or electronics/hardware problems.

The **pulse timing stability**



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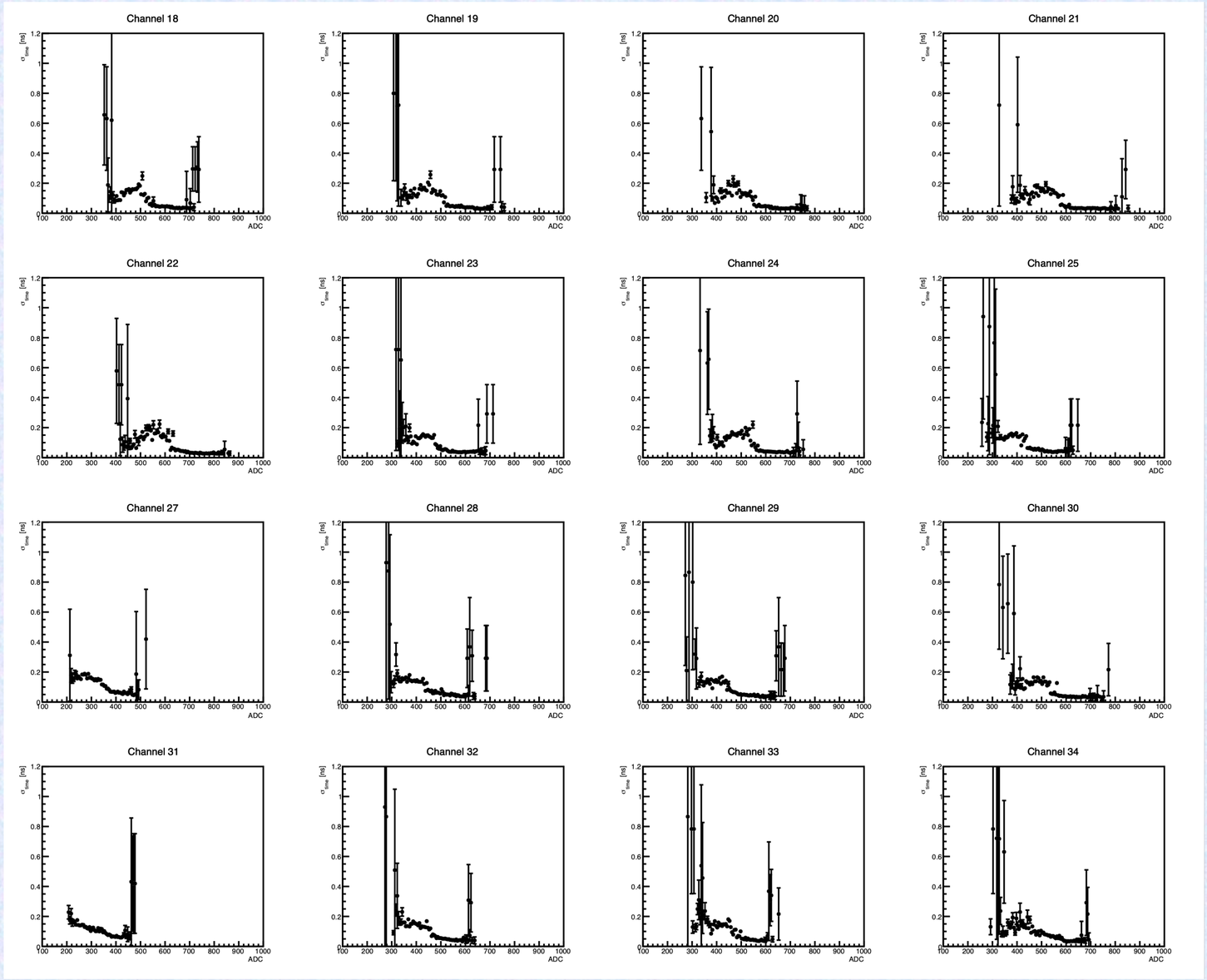
LED Sample – Channel by Channel τ_{RES}



This timing resolution simply means the spread of the measured arrival times for LED signals for each channel.

Timing precision improves when the signal is larger.

The bumps which sometimes appear could indicate:

- saturation
- pulse-shape distortion

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LED Sample – Channel by Channel τ_{RES}

Zooming into the channel 21

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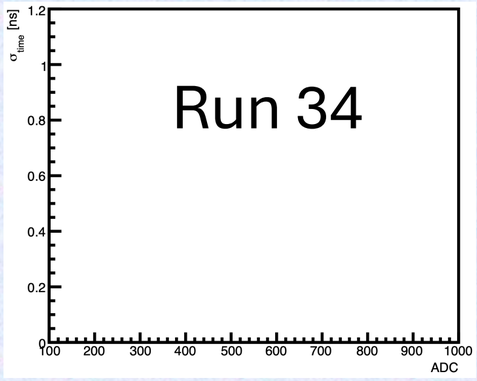
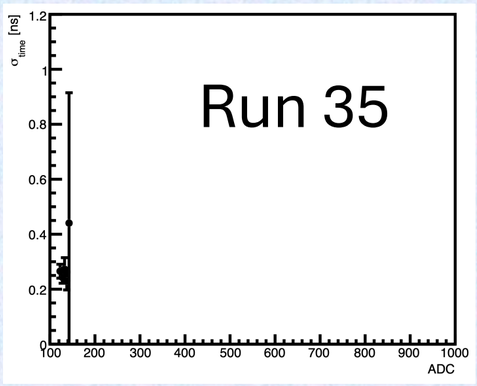
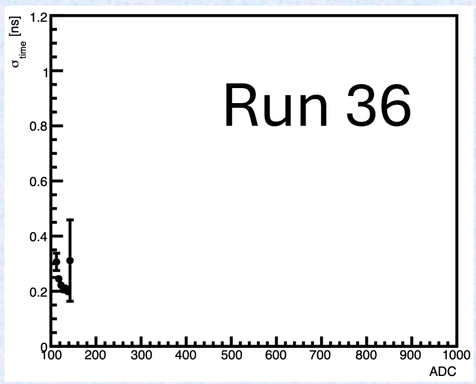
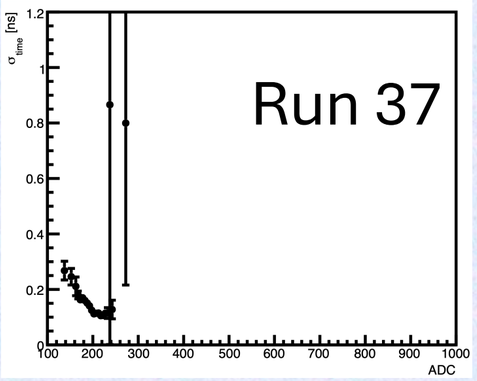
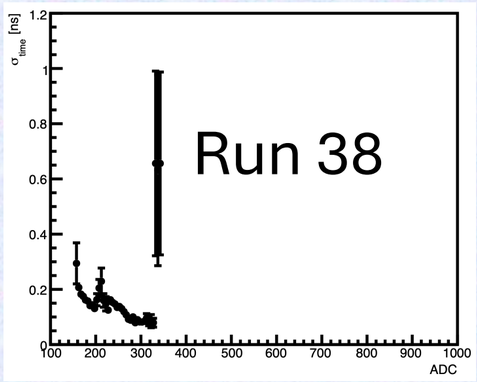
LED Sample – Channel by Channel

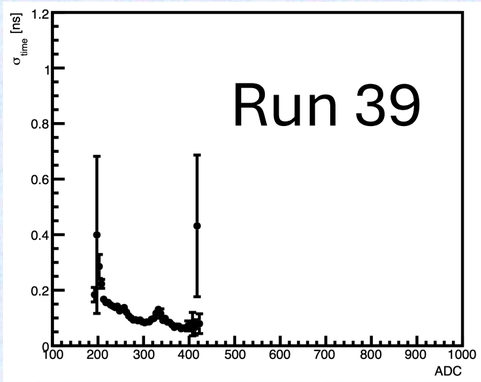


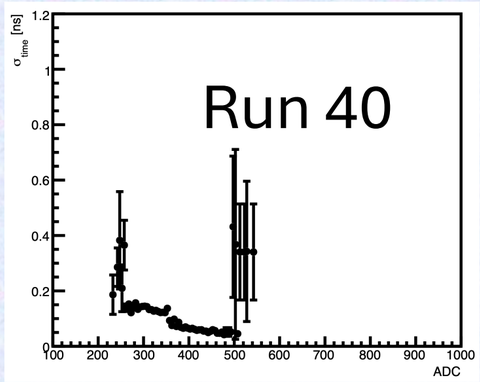


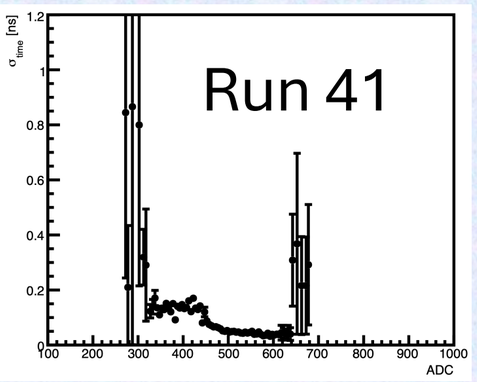


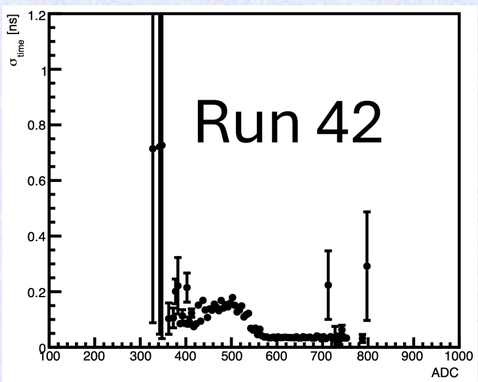


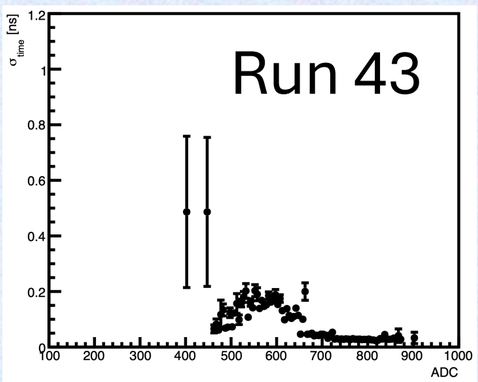


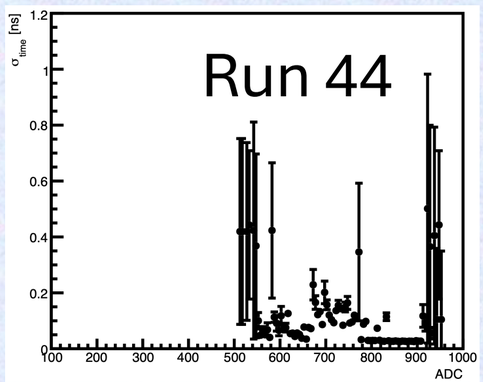


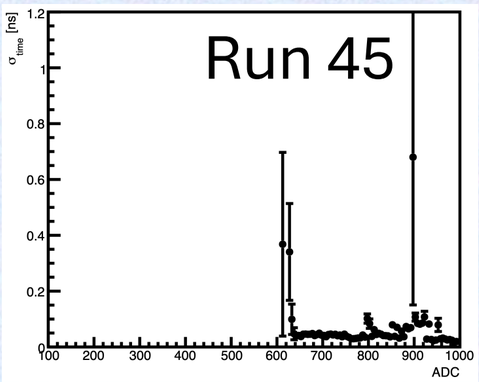




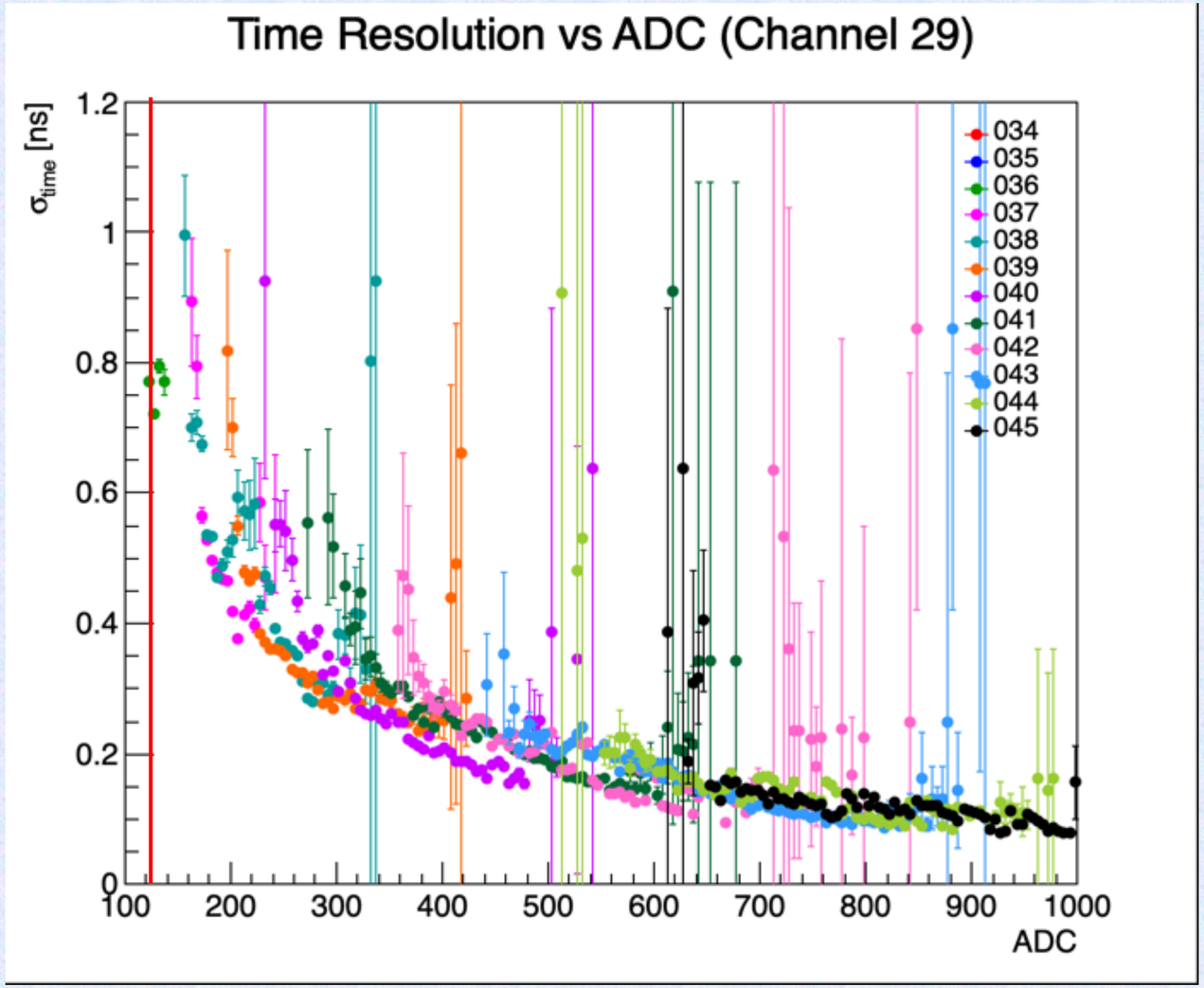


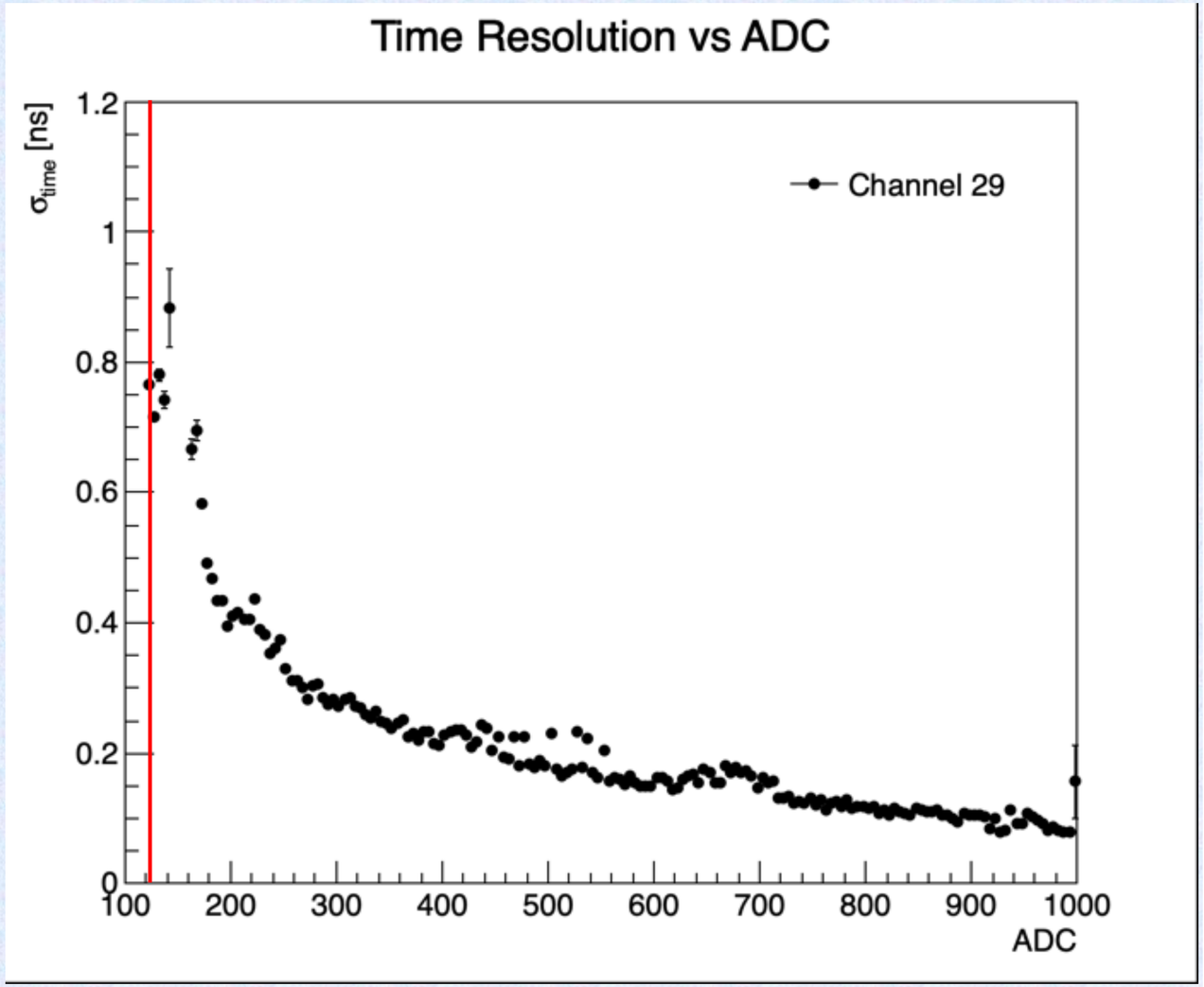






LED Sample – Channel by Channel τ_{RES}





Individual files - Each color corresponds to a different run/file.

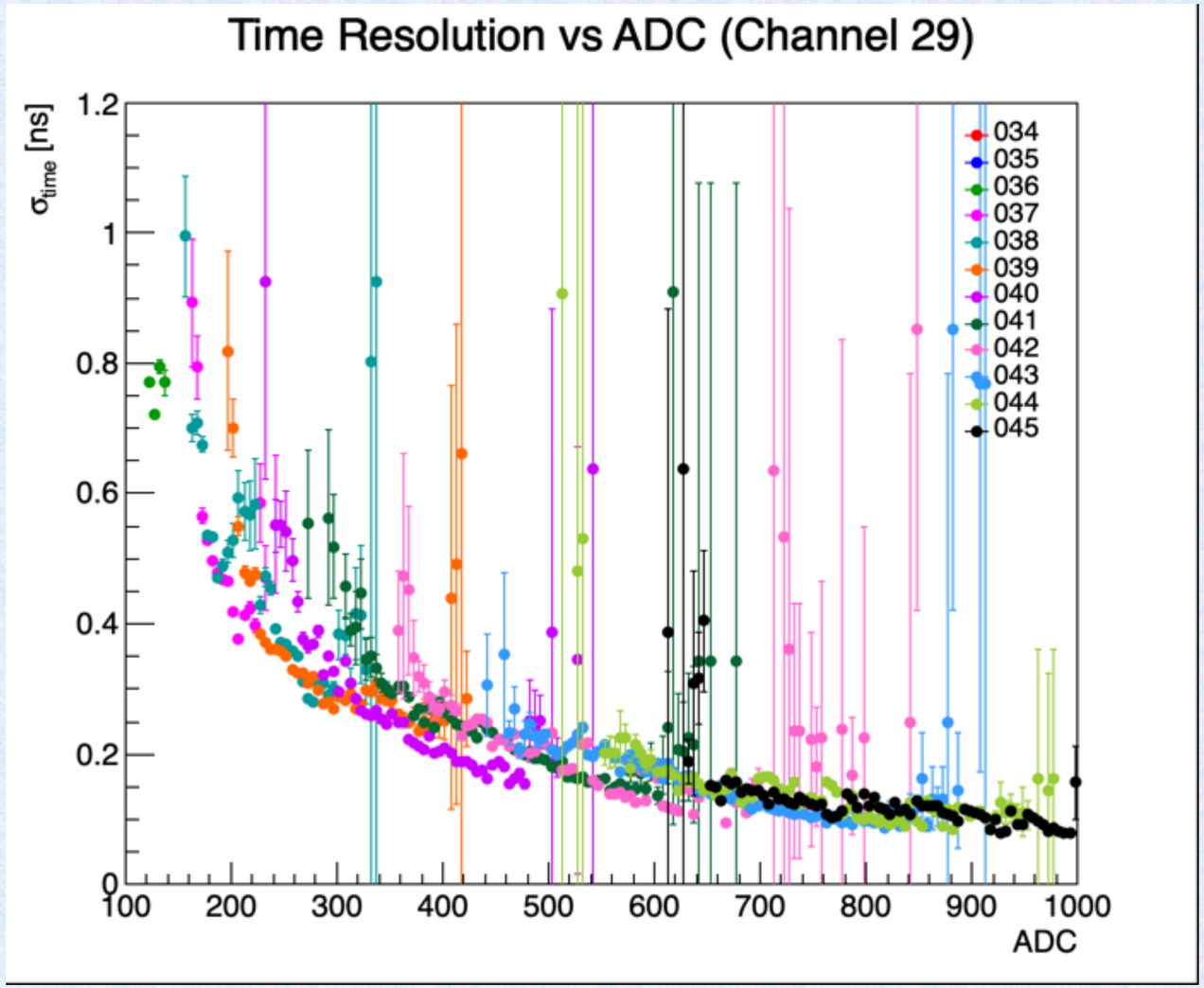
Combined result - The right plot shows all runs together into a single averaged behavior.

LED Sample – Channel by Channel τ_{RES}

This figure emphasizes stability (mostly overlapping color plots) of timing measurement across different runs (files) for different channels. So, the electronics are stable across runs.

Points with huge vertical errors are due to either **low statistics in that ADC bin** or **broad timing distribution**.

ADC Region	Timing Resolution (ns)
100-200	~0.7-0.9
200-400	~0.3-0.4
400-600	~0.2
600-1000	~0.08-0.12



LED Sample – Next Step/Summary

Next Step

- Fine-tune with MIP dynamics
- Calibrate the channels

Summary

- This study verifies run-by-run consistency
- Each channel gives better resolution with large signal