ADC simulation tools

ProtoDUNE
Simulation and Reconstruction

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Introduction

I have been looking at ADC test data taken at BNL

- For the P1 ADC version we will use in protoDUNE

- Performance is far from ideal but much better than 35t

- See following slides and talks at DUNE cold electronics and others

Like to include realistic ADC in DUNE simulation

- I am working on tool to provide this
  - Input: input voltage, channel #, time/event
  - Output: ADC count/bin (i.e. in range 0 – 4095)
- Main subject of this talk
- I would like this tool to usable in other contexts
  - Other experiments: SBND, …
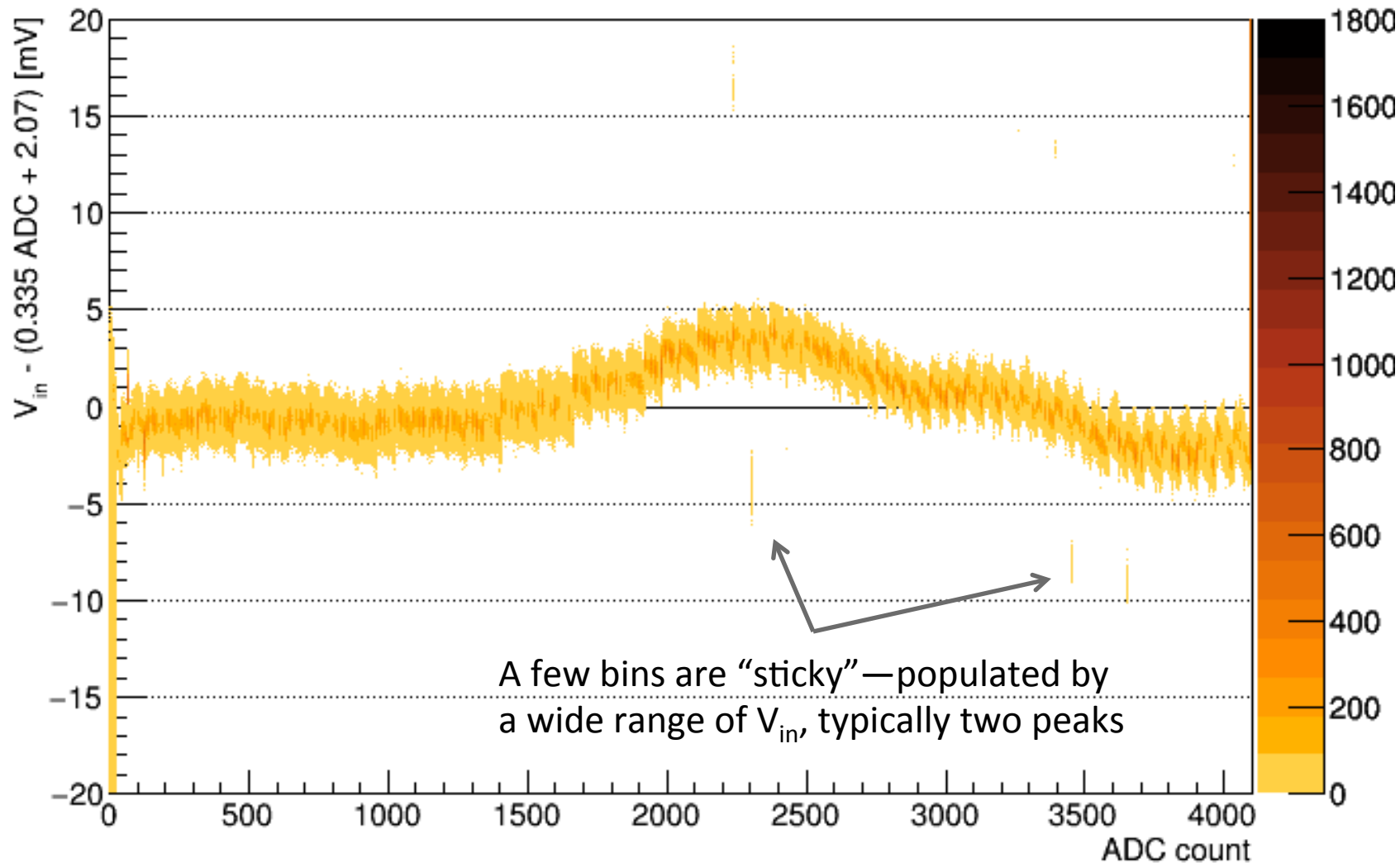 - Outside art framework: Root macros, standalone quick simulations
- Details follow

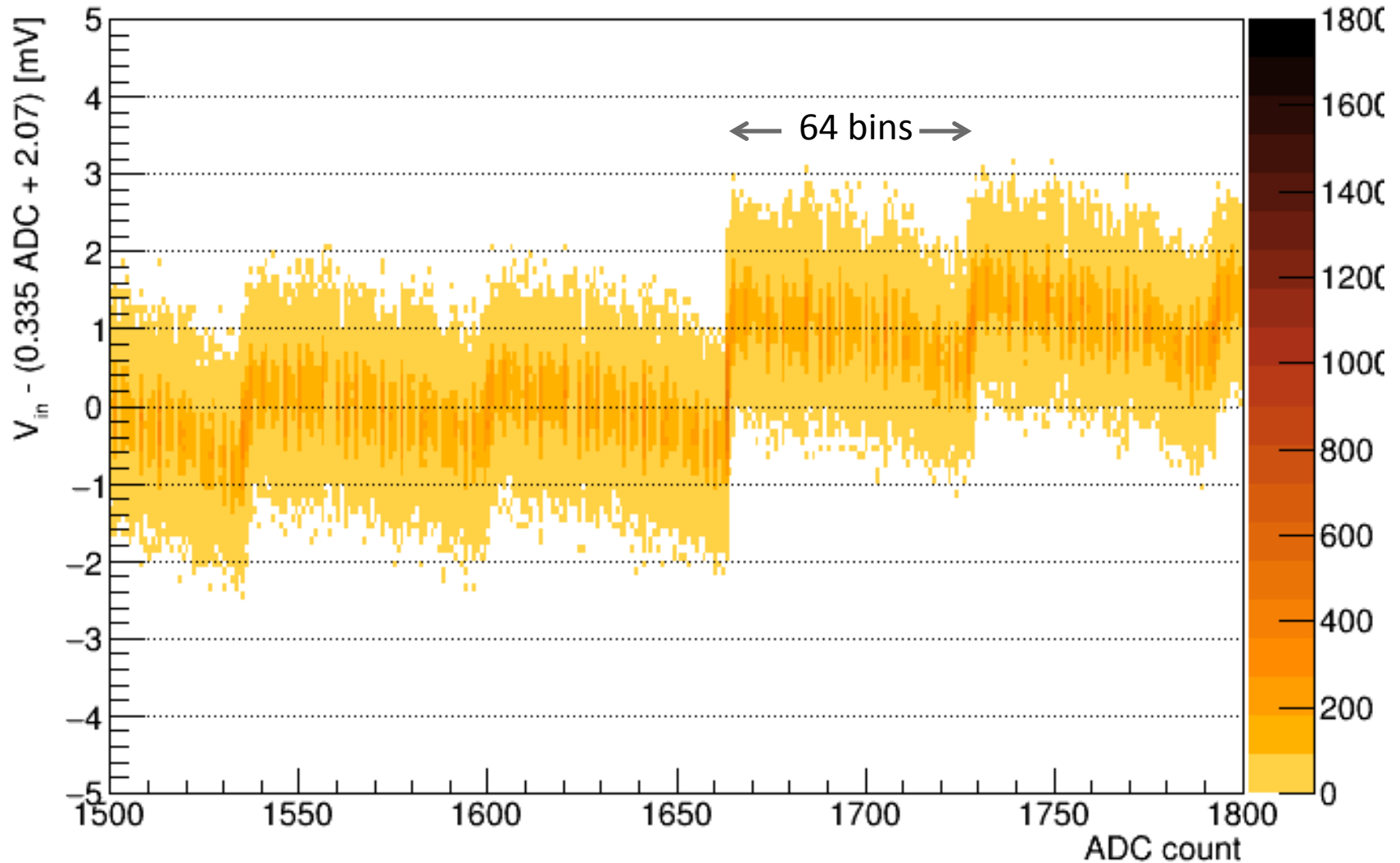# Example P1 inverse response

201703a_D04 channel 7

Cannot trust low ADC bins.
Especially below 64.
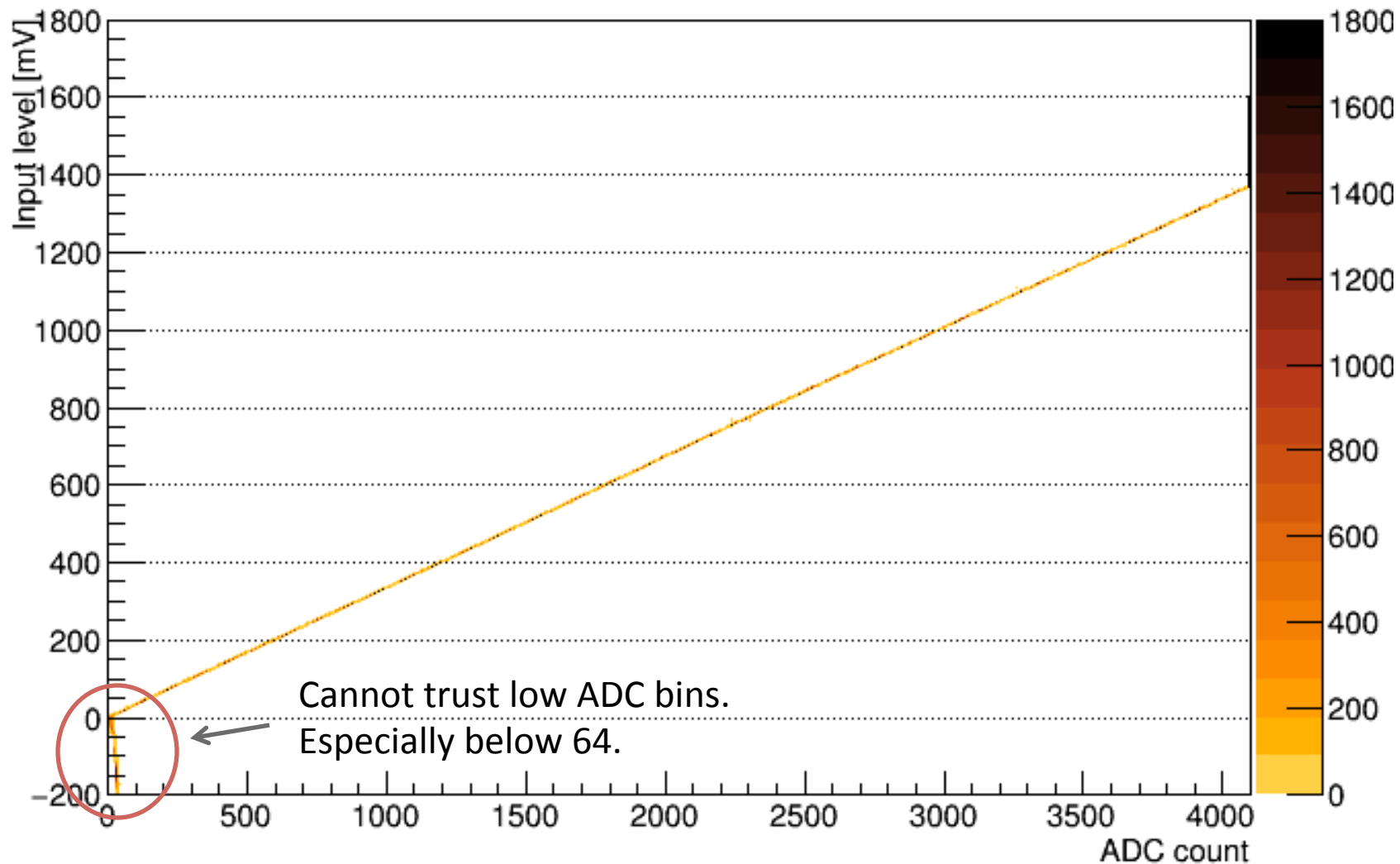
Example P1 linear fit residual

201703a_D04 channel 7

A few bins are "sticky"—populated by a wide range of V_{in}, typically two peaks
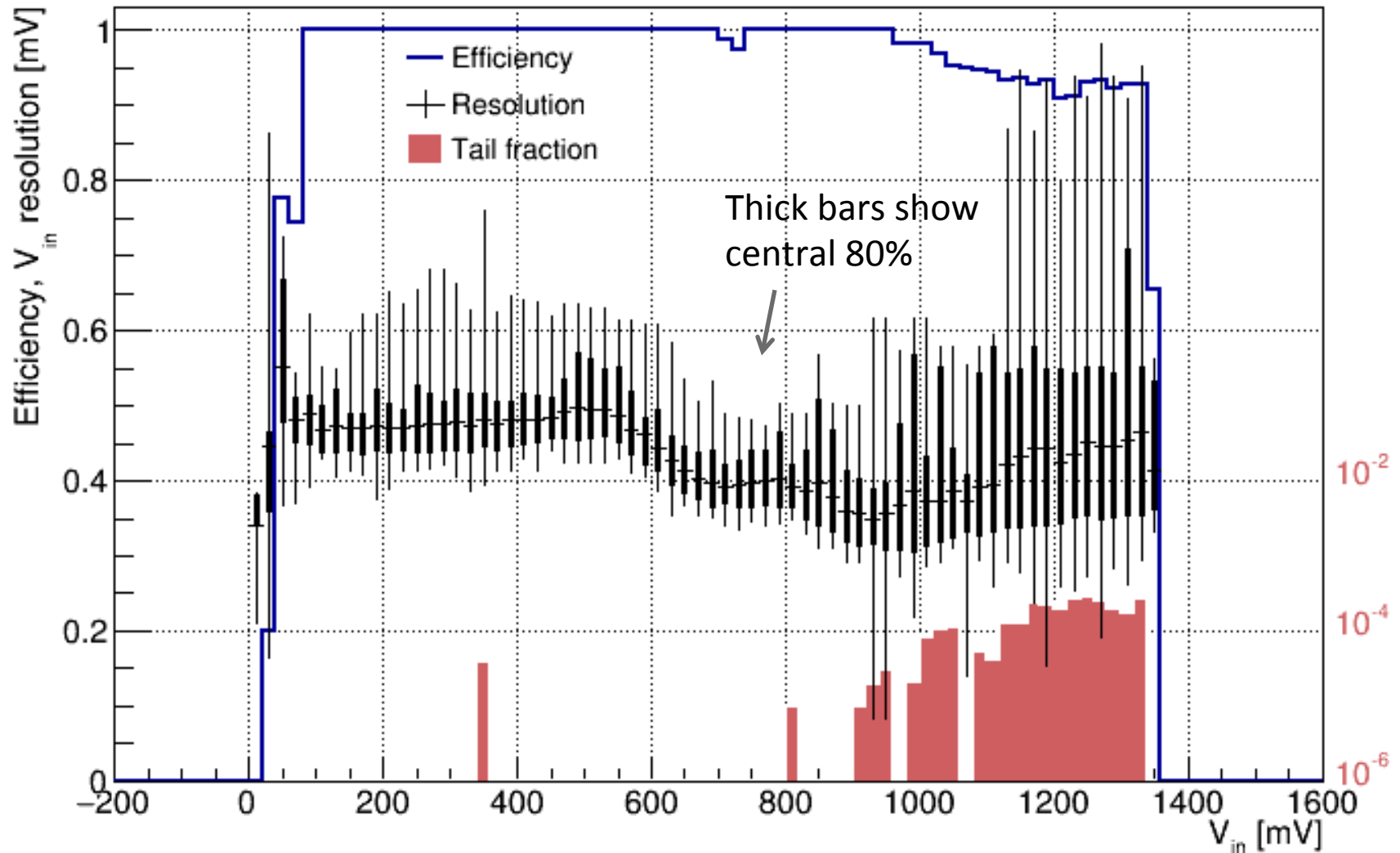
Example P1 linear fit residual zoomed

201703a_D04 channel 7

Example P1 performance summary plot

201703a_D20 channel 10 actual performance for RMS < 1 mV

Software structure 1

Requirements

- Support multiple simulation strategies
  - Ideal ADC
  - Any one of the tested ADC chips
  - Detector mapping to many ADC chips
  - And more (e.g. dual ADC ideas)
- ADC simulators should be easily usable by all interested parties
  - Both inside and outside art event-processing framework
- Easily-shared, named configurations
  - E.g. "adcsim_mar2015_D05" run in two places will give the same results
- Minimal compile and linker dependencies
  - Should be easy to plug in a different ADC simulations

Software structure 2

Adopted solution

- ADC simulators are constructed as art class tools
  - See https://cdcvs.fnal.gov/redmine/projects/art/wiki/Guide_to_writing_and_using_tools
- ADC simulator has a base interface AdcSimulator
  - Clients access simulators via this interface
  - See dunetpc/dune/DuneInterface/AdcSimulator.h
    - Hope to move this into larsoft soon
    - In dedicated package so clients need not depend on any of rest of larsoft
- Concrete simulators inherit from this base
  - Include art CPP macro to register tool
  - Provide ctor from FCL for configuration
- Tool manager allows clients to access tool configurations
  - By interface type (e.g. AdcSimulator) and name (e.g. adcsim_ideal)
  - FCL configuration file maps names to configuration
  - Configuration includes the name of concrete type and all parameters required by the ctor for that type
  - See dunetpc/ArtSupport/DuneToolManager.h
    - Hope to replace/supplement this with art or larsoft tool manager

ADC simulation tools

Plan the following concrete ADC simulators

- Ideal ADC simulation
  - Already implemented—see following slides
  - See IdealAdcSimulator in dunetpc/dune/DetSim/Tool
    - Expect to move this to dedicated larsoft package
- Simulation based on results from test stand measurements
  - For any one ADC chip measurements
  - Data provide an ADC count pdf for any input voltage
  - Simulator would randomly select from the pdf
    - Begin without time correlations
- Many-chip simulator
  - Passes call to single-chip simulator based on channel map
- Easy for others to provide additional implementations

DUNE detector simulation

DUNE DetSim is already modified to use the AdcSimulator

- Tool is accessed in the SimWireDUNE module
  - Used for DUNE 35t, protoDUNE, FD, …
  - Probably could/should be renamed and moved to larsoft for use by other experiments
- Previously ideal ADC simulation was embedded in the module
- Now module looks for and uses an AdcSimulator
  - Tool name is a FCL parameter for the module
  - If blank, old simulation is used with (lots of) warning messages

ADC gain

- At present, the signal-shaping service (SSS) converts collected charge to floating ADC counts
  - So ADC simulator must have a gain of one
- I would prefer to have SSS convert charge to ADC input voltage
  - And let ADC simulator convert voltage to ADC count
  - If no objection, I will make this change

Validation

Following slides compare old and new ADC simulation

- Old is the code embedded in SimWireDUNE module
- New is the updated module using IdealAdcSimulator (adcsim_ideal)
- Results show for three planes in one event
- All for the 35t standard simulation of a single muon
- No visible differences

Direct check

- I also compared the old and new values for 10 events in the code and saw no differences
- For both 35t and FD126 geometries
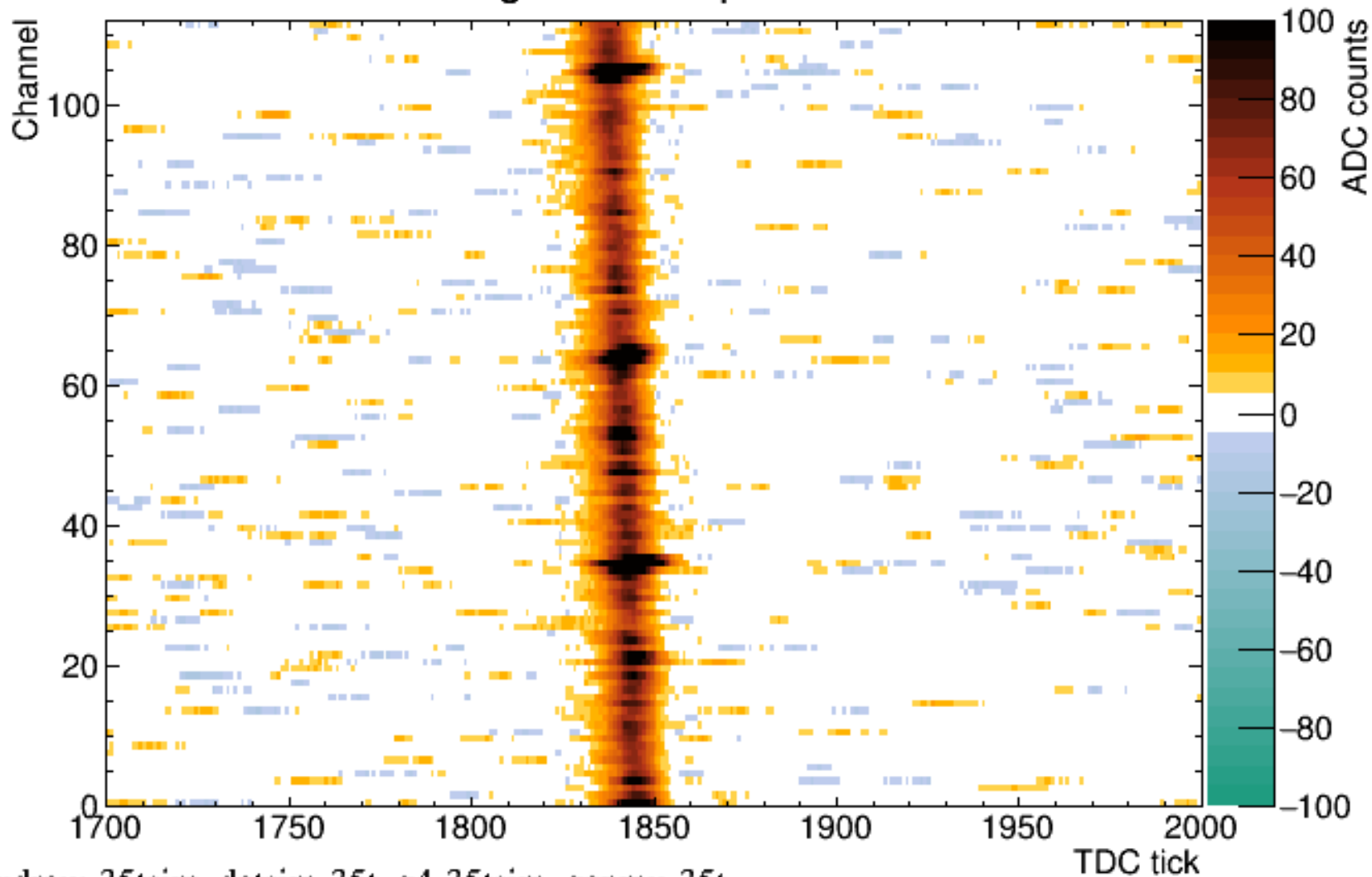
Old simulation: 2z2

Raw signals for apa2z2 event 1
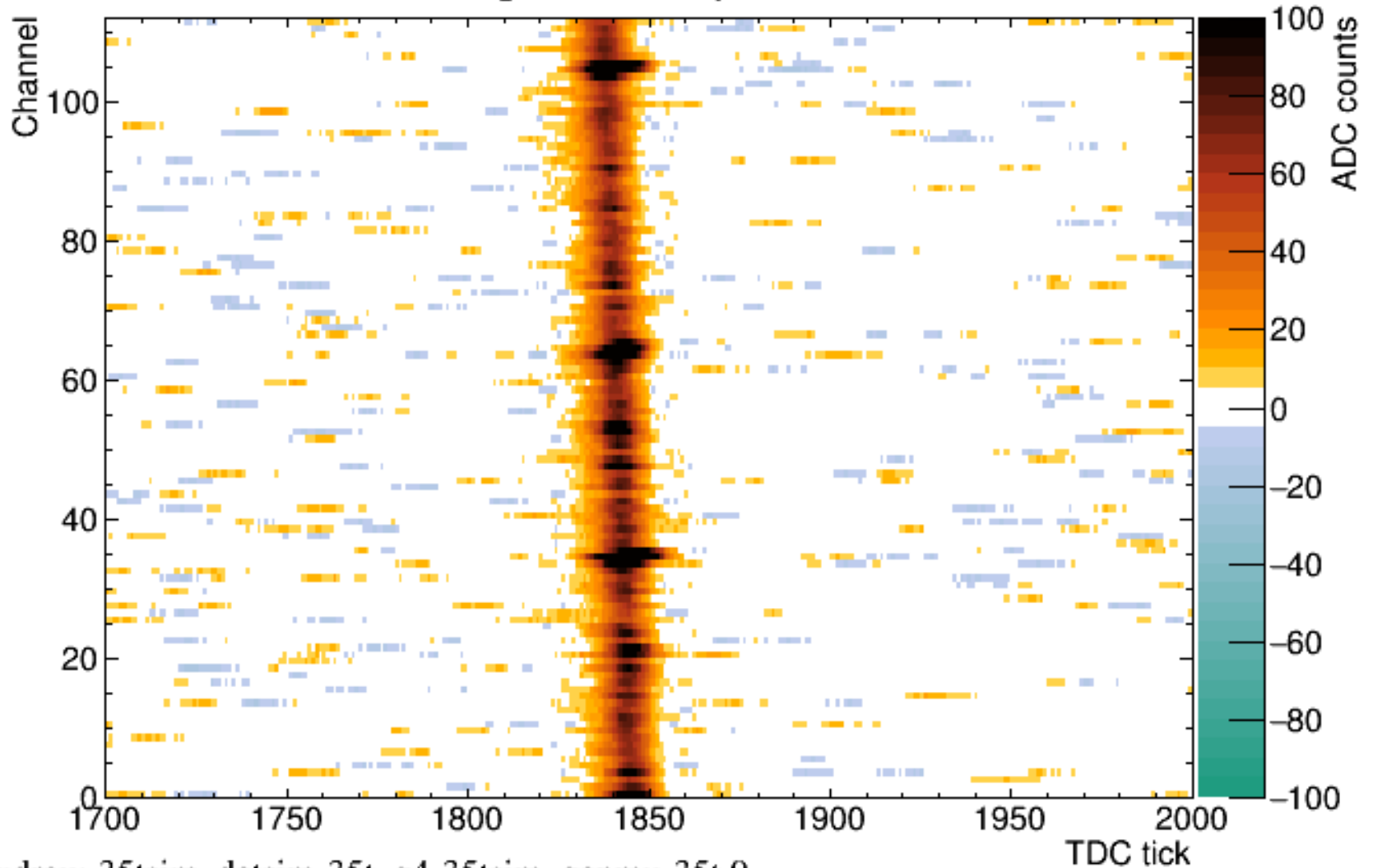
dxdraw-35tsim_detsim-35t_g4-35tsim_genmu-35t.0
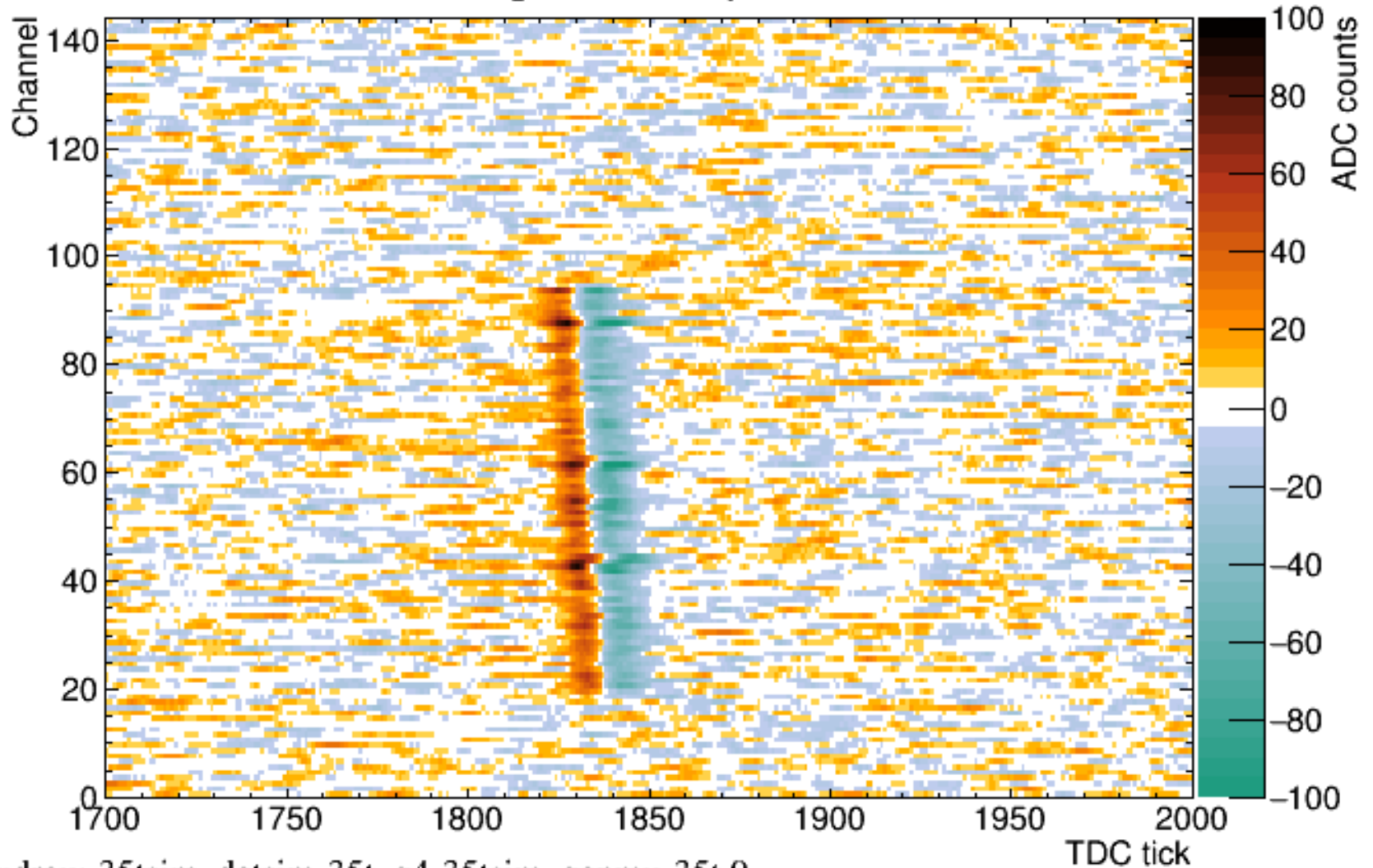
New simulation: 2z2

Raw signals for apa2z2 event 1

dxdraw-35tsim_detsim-35t_g4-35tsim_genmu-35t
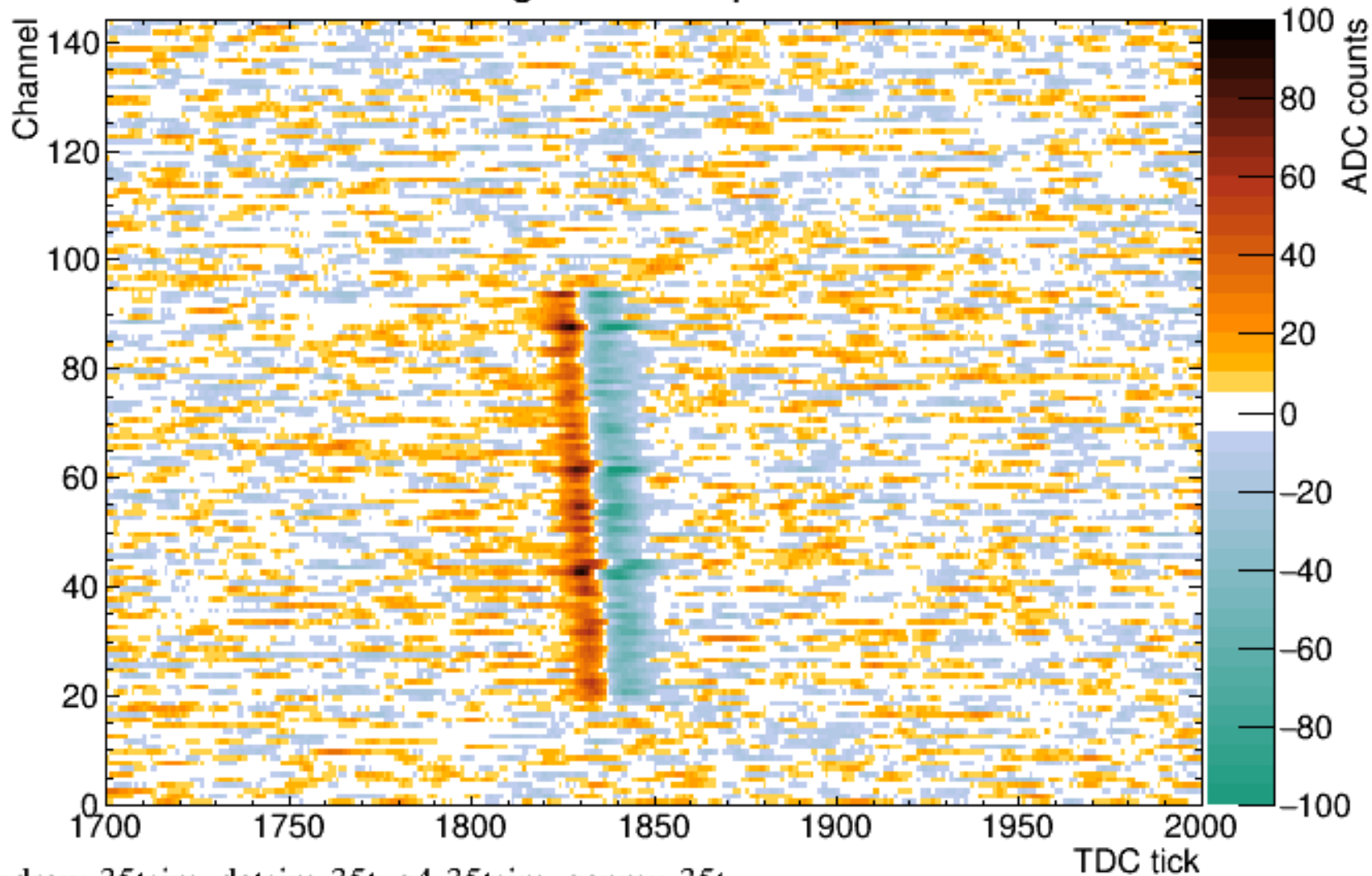
Old simulation: 2u

Raw signals for apa2u event 1

dxdraw-35tsim_detsim-35t_g4-35tsim_genmu-35t.0
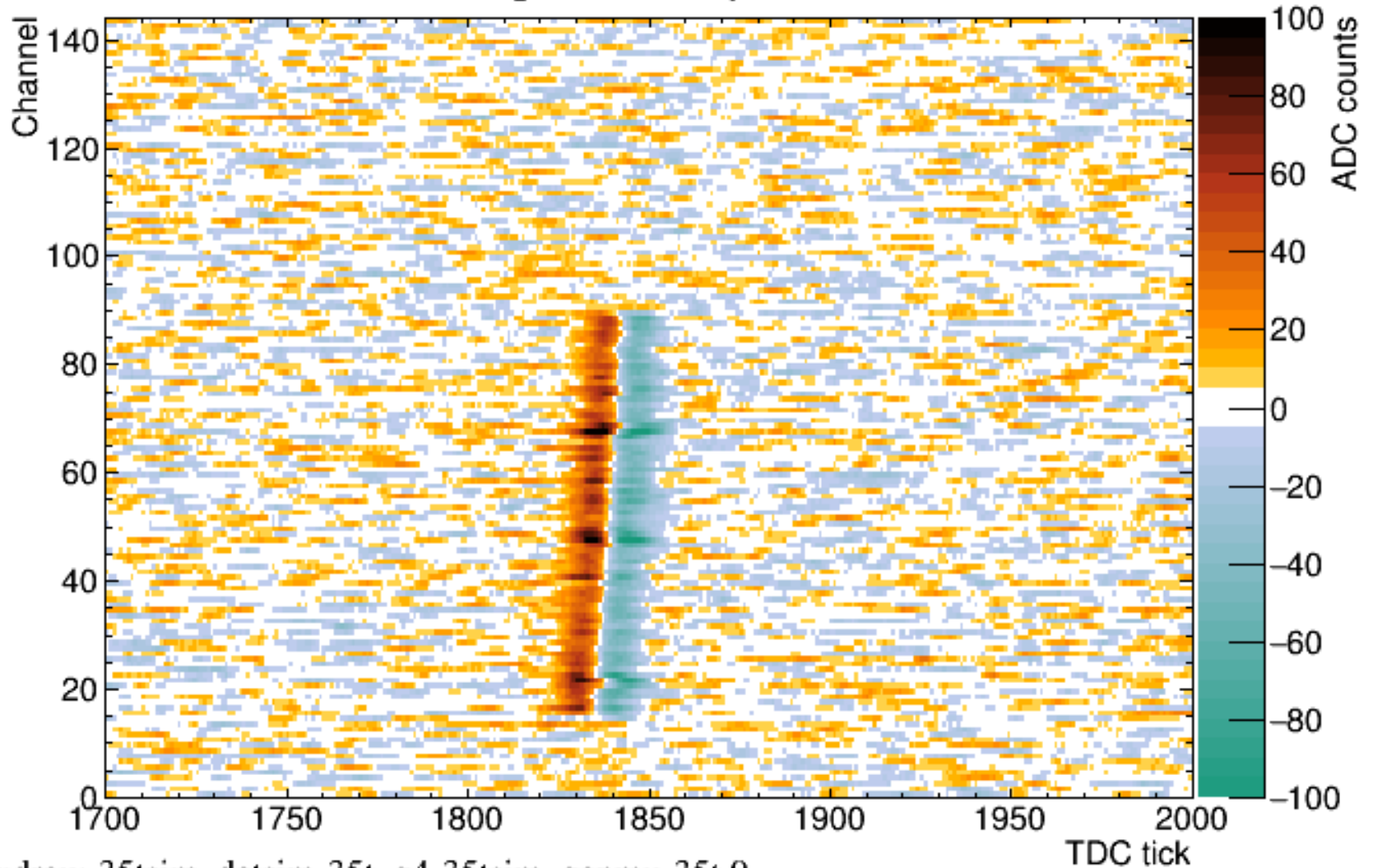
New simulation: 2u

Raw signals for apa2u event 1

dxdraw-35tsim_detsim-35t_g4-35tsim_genmu-35t
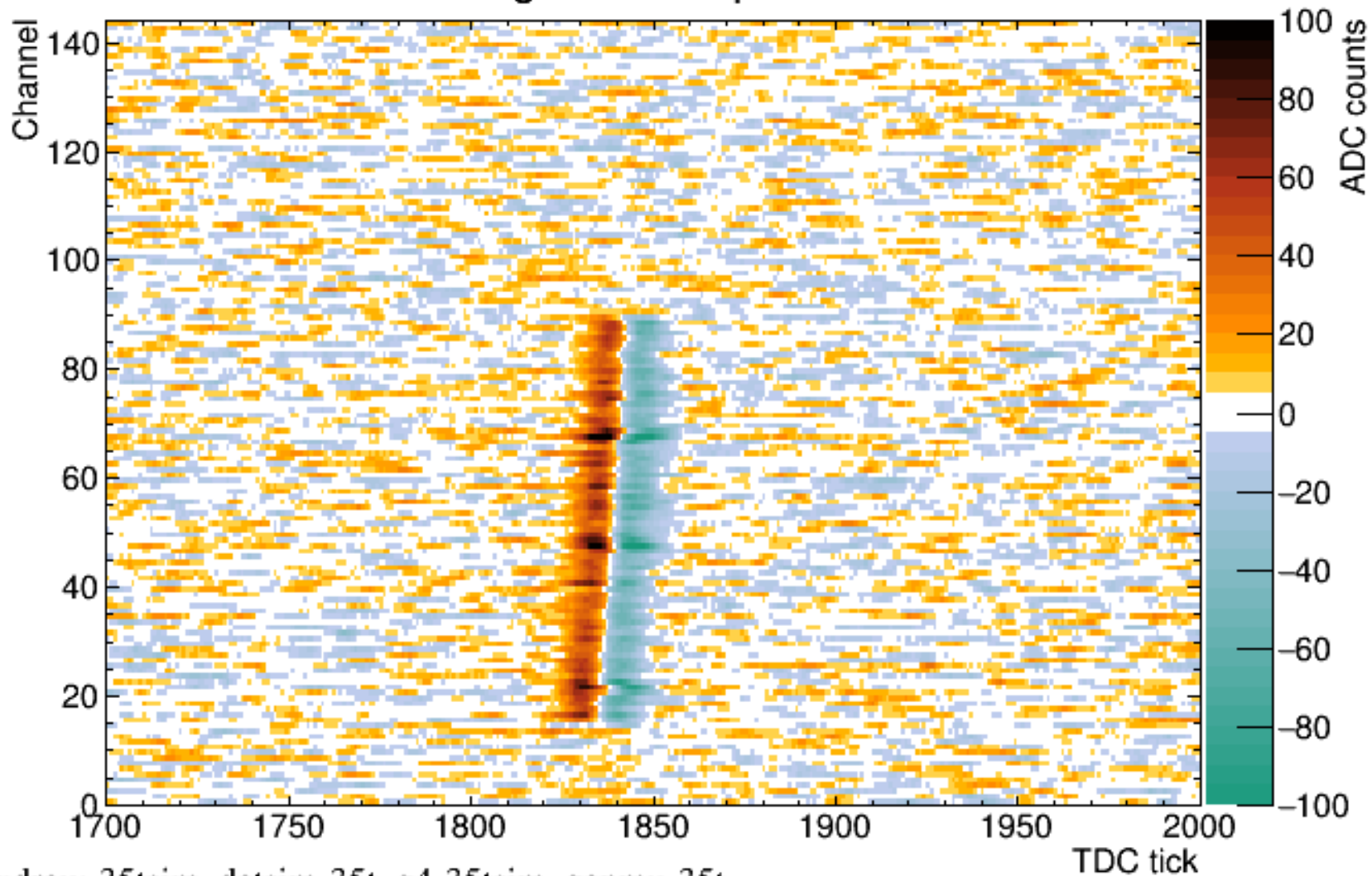
Old simulation: 2v

Raw signals for apa2v event 1

dxdraw-35tsim_detsim-35t_g4-35tsim_genmu-35t.0

New simulation: 2v

Raw signals for apa2v event 1

dxdraw-35tsim_detsim-35t_g4-35tsim_genmu-35t

Summary/Conclusions

ADC simulation tools are being developed

- Ideal ADC simulator is available now
- P1 simulator based on test stand measurements coming soon
  - Resolution 4-5X worse than ideal
    - 0.5 mV instead of 0.1 mV
  - Approximately 1% of ADC bins are sticky
    - True input voltage may be far from the calibrated value
    - Far means much more than the nominal resolution
- Plan to add tool that selects between multiple chips

ADC simulator follows new tool pattern

- Define interface for each type of tool
- Provide one or more implementation of the interface as art class tools
- Define named tool configurations in FCL
- Client uses tool manager to find named tool configurations
  - Typically name is a FCL parameter of the tool client