
Summary of LArPix ADC Saturation Energy Correlation Studies using July 2024 2x2 Beam Data

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THE UNIVERSITY OF
CHICAGO



DEEP UNDERGROUND
NEUTRINO EXPERIMENT



LArPix ADC Saturation Basics

- ADC saturation occurs when the charge collected **exceeds the dynamic range** of the ADC for a given pixel
 - 8-bit ADCs (“saturation dataword” is **255**)
 - Dynamic range is configurable through reference voltages and gain

Findings from Module Data

- As far as I know, only a subset of **Module 0 data** was evaluated
 - Details in [this presentation](#)
- Module 0 studies indicated **very low levels of ADC saturation**
 - Most “saturation packets” removed using a **sync noise cut** (now implemented natively in flow)
 - Sync noise cut implemented manually in these studies at 1 ms from sync packet timestamp (later Module data used 100 ms cut, and 2x2 uses 10 us)
 - In these studies, **8 ADC saturation packets out of all events in 24 files** (**not full data set)

2x2 Data Samples Used

- **Data:** All files** in the following subdirectories of the v5 reflowed charge data available [here](#)
 - july8_2024/nominal_hv/packet-0*.hdf5
 - july10_2024/nominal_hv/packet-0*.hdf5
- **Data** were further filtered to **require an external trigger with io_group == 5** (i.e. a beam trigger)

Initial 2x2 LArPix ADC Saturation Studies

- In 2x2 beam data, **~1.7% events** record at least one “ADC saturation packet”
 - For **events with ADC saturation and at least 100 hits**, **<2% of hits** in the event originate from ADC saturated packets
 - While there is overlap between ADC saturation and hot pixel triggering (HPT), statistics here **do not include packets from pixels exhibiting coincident ADC saturation + HPT**
- For full details, see [2x2 Charge Readout Low-Level Data Features note](#)

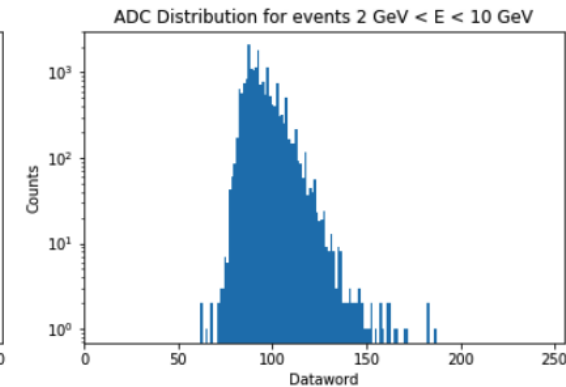
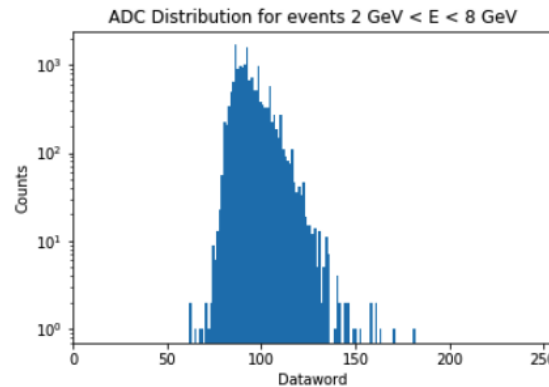
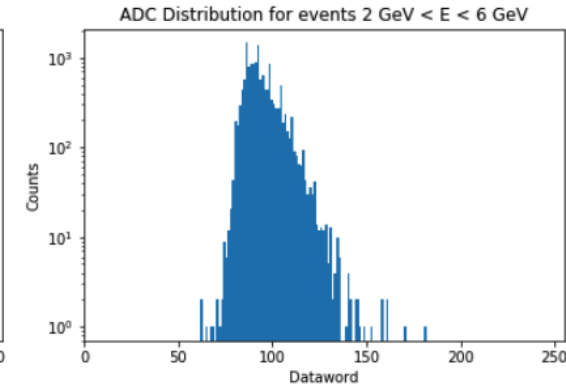
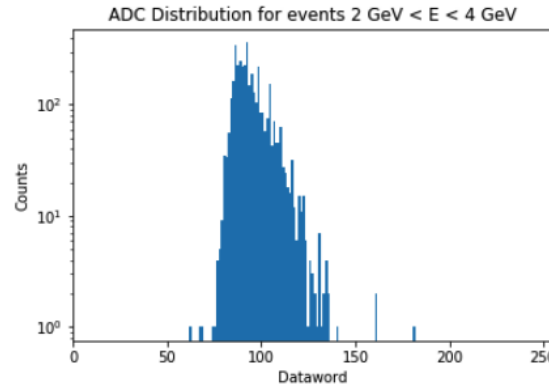
Follow-Up Study Motivation

- **Why is there significantly more ADC saturation in 2x2, especially when dynamic range in Module 0 was more limited?**
- **Is there a correlation between event energy and ADC saturation?**

Follow-Up Study Motivation

- Why
- dyna
- Is th

- Previous approach starts from saturated hits
- By looking at the ADC distribution for energies of interest (subsets of 2-10 GeV), we can see if we expect saturation
- No counts above 190: consistent with no saturation for any energy window

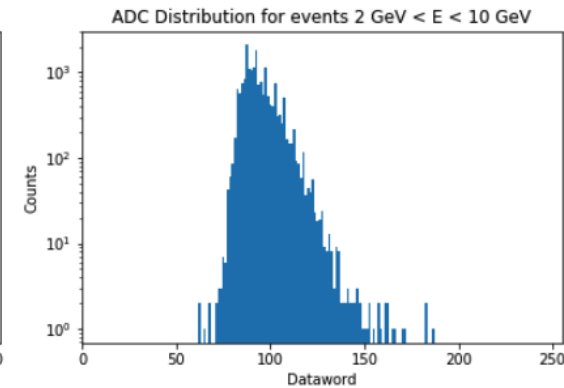
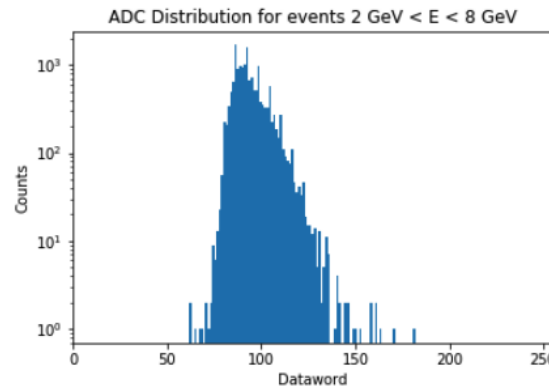
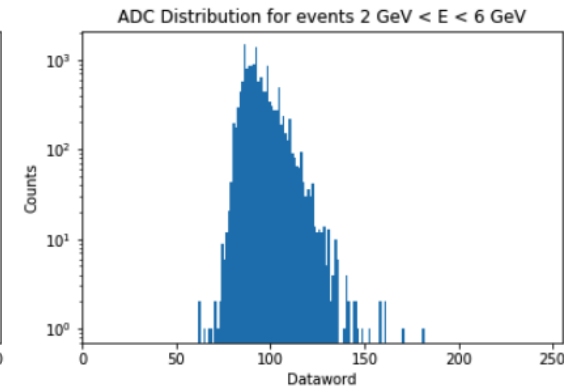
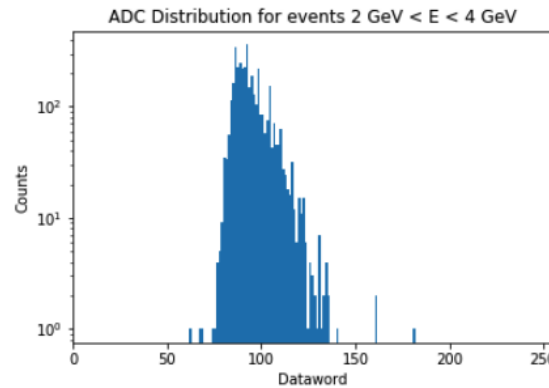


Why when
on?

Follow-Up Study Motivation

Goal: Recreate plots similar to these plots for 2x2 beam data

- Why dynamic range?
- Is there saturation?
- Previous approach starts from saturated hits
- By looking at the ADC distribution for energies of interest (subsets of 2-10 GeV), we can see if we expect saturation
- No counts above 190: consistent with no saturation for any energy window



Why when
on?

Preface to Plots

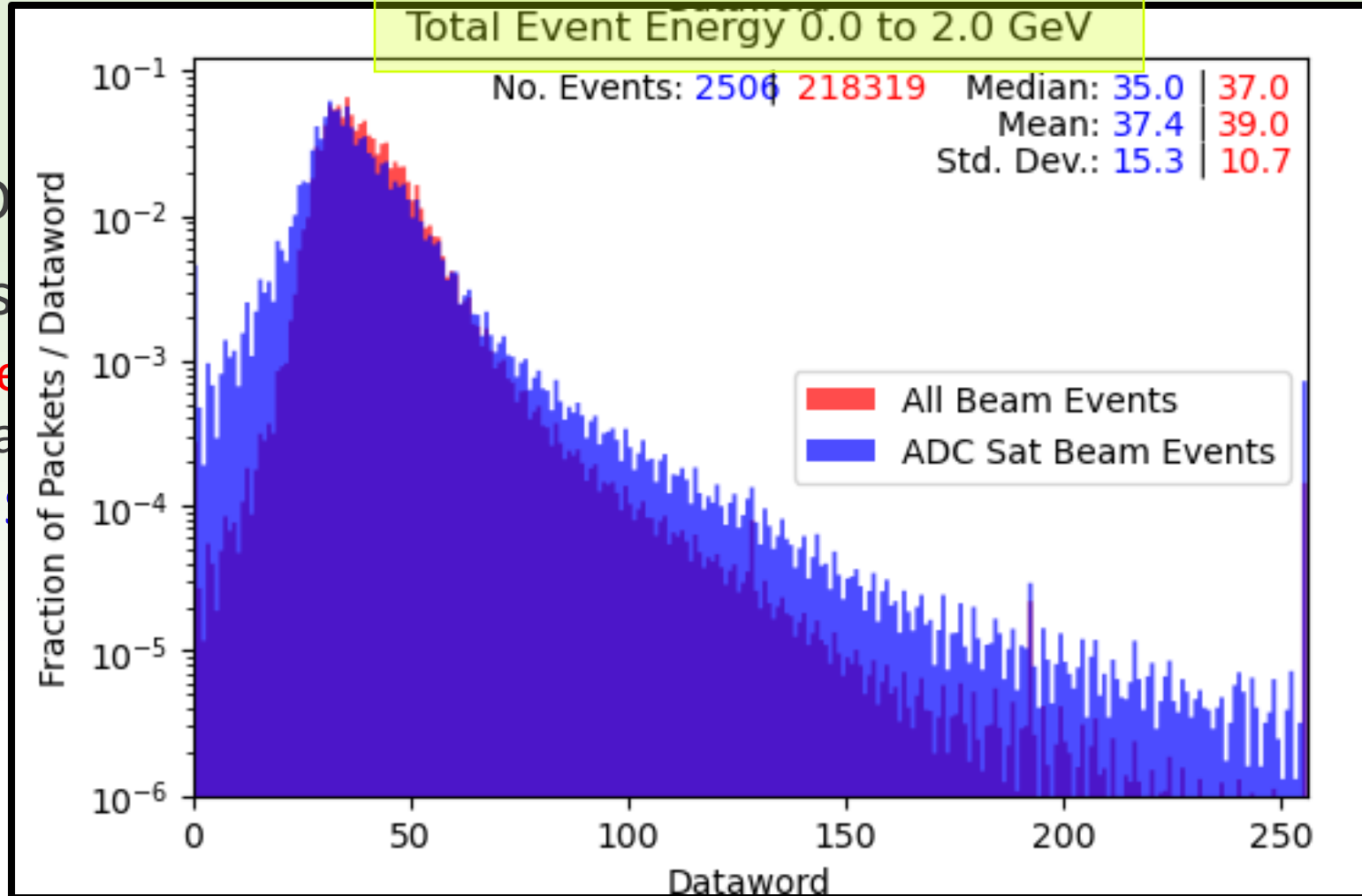
- **Caveat:** Binning 2x2 beam data by energy is currently flawed due to bias from ADC droop issue
- Samples used:
 - “All beam events” = All beam events (including those with saturation packets)
 - “ADC Sat Beam Events” = All beam events with at least one non-HPT associated saturation packet

Preface to Plots

Energy Bin

Total Event Energy 0.0 to 2.0 GeV

- **Caveat:** from AD
- Samples
 - “All beam saturation packets”
 - “ADC saturation packets”



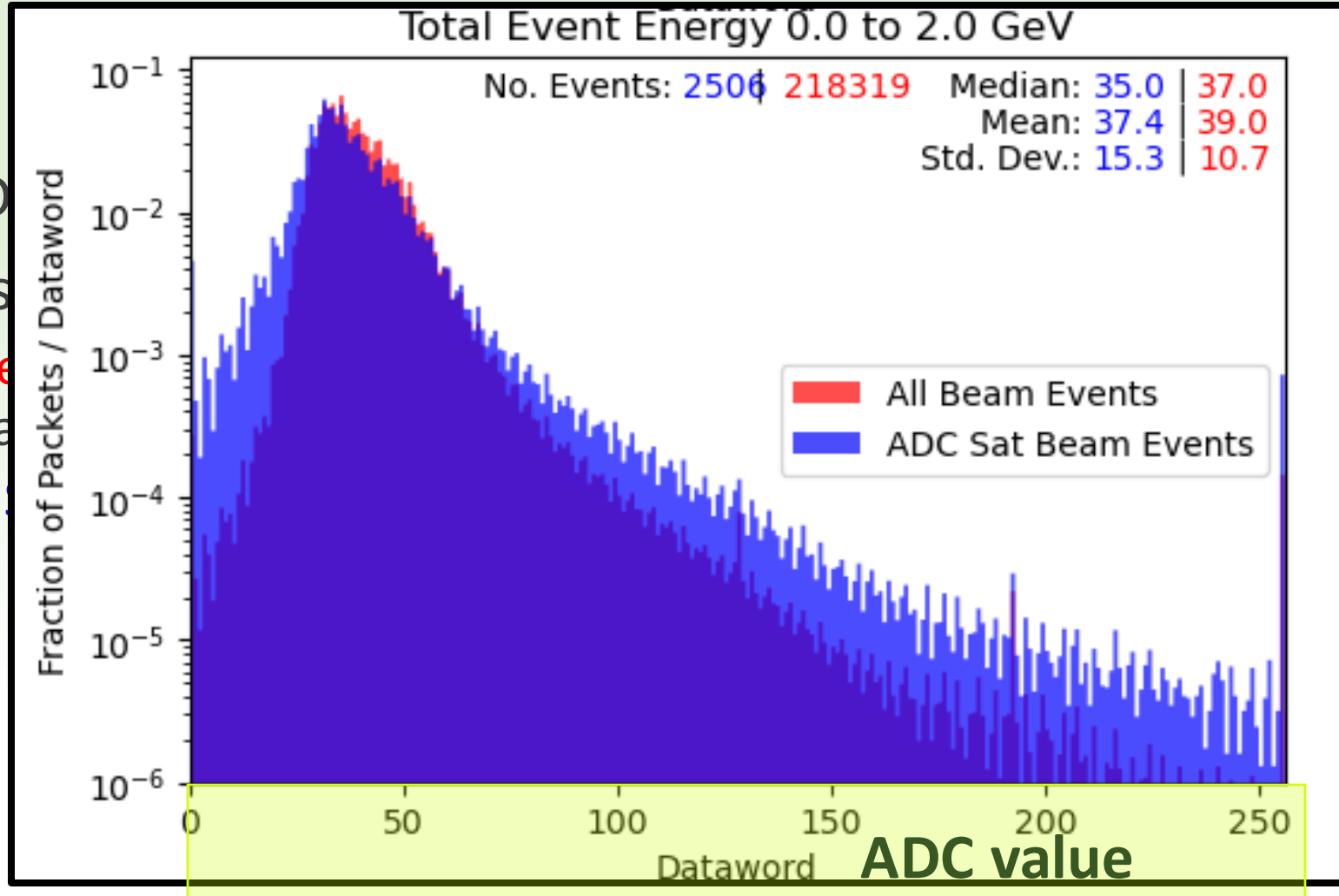
due to bias

sociated

turation packets)

Preface to Plots

- **Caveat:** from AD
- Samples
 - “All beam
 - saturat
 - “ADC



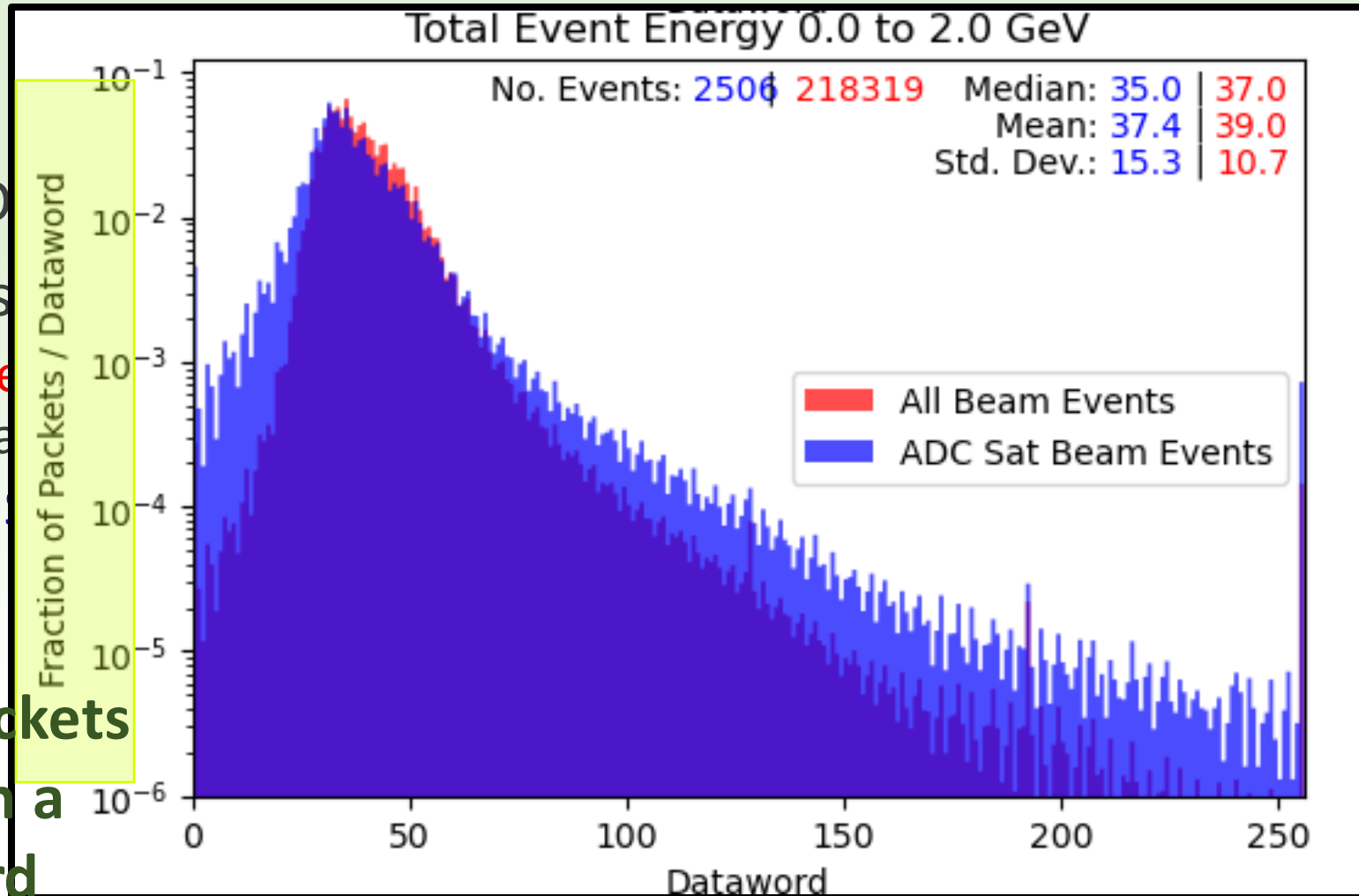
due to bias

sociated

turation packets)

Preface to Plots

- **Caveat:**
from AD
- Samples
 - “All beam
 - “ADC



**Fraction of packets
in sample with a
given dataword**

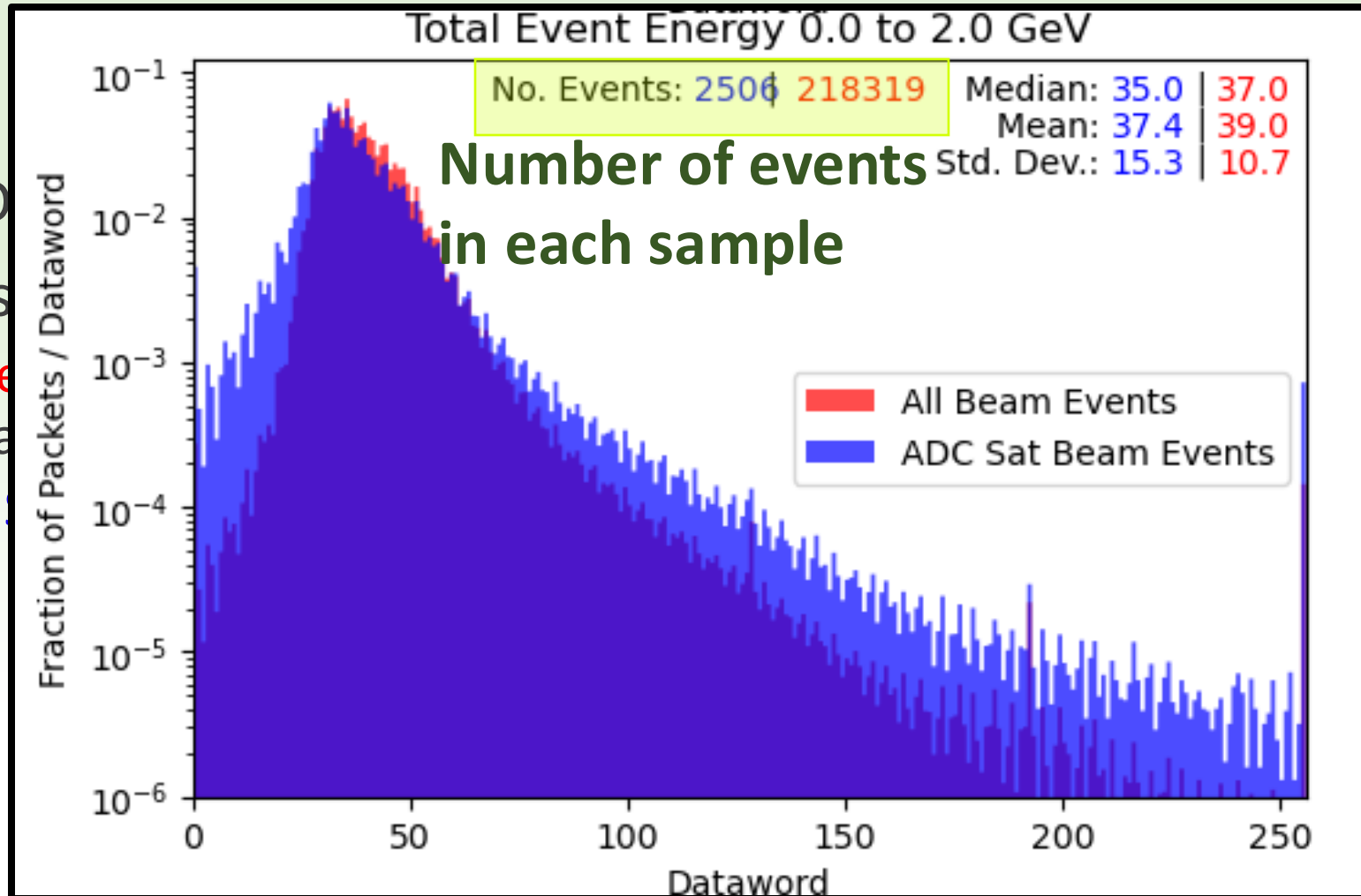
due to bias

associated

(saturation packets)

Preface to Plots

- **Caveat:** from AD
- Samples
 - “All be
 - satur
 - “ADC



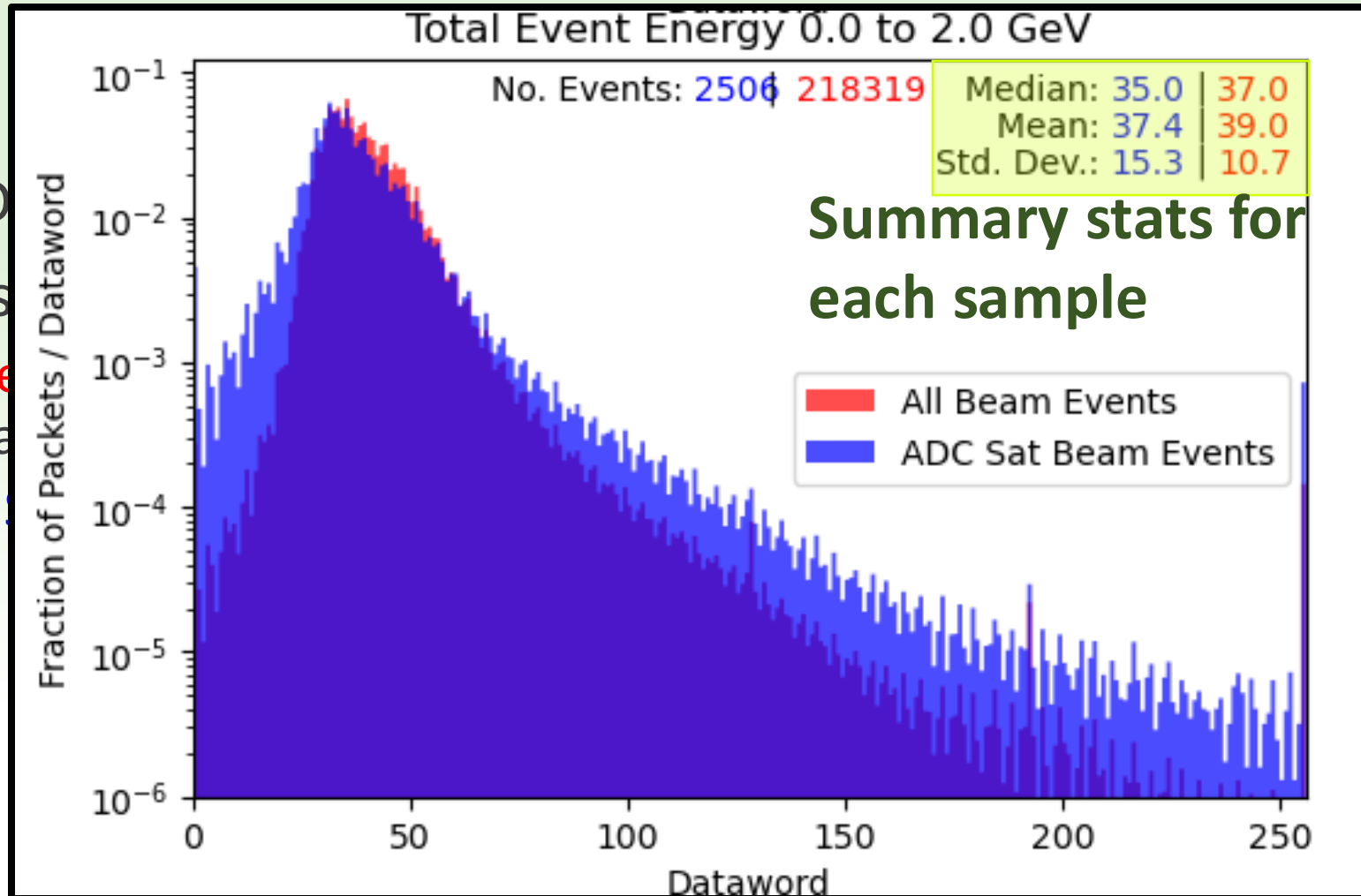
due to bias

sociated

turation packets)

Preface to Plots

- **Caveat:** from ADC saturation
- Samples
 - “All beam events” (red)
 - “ADC saturation packets” (blue)

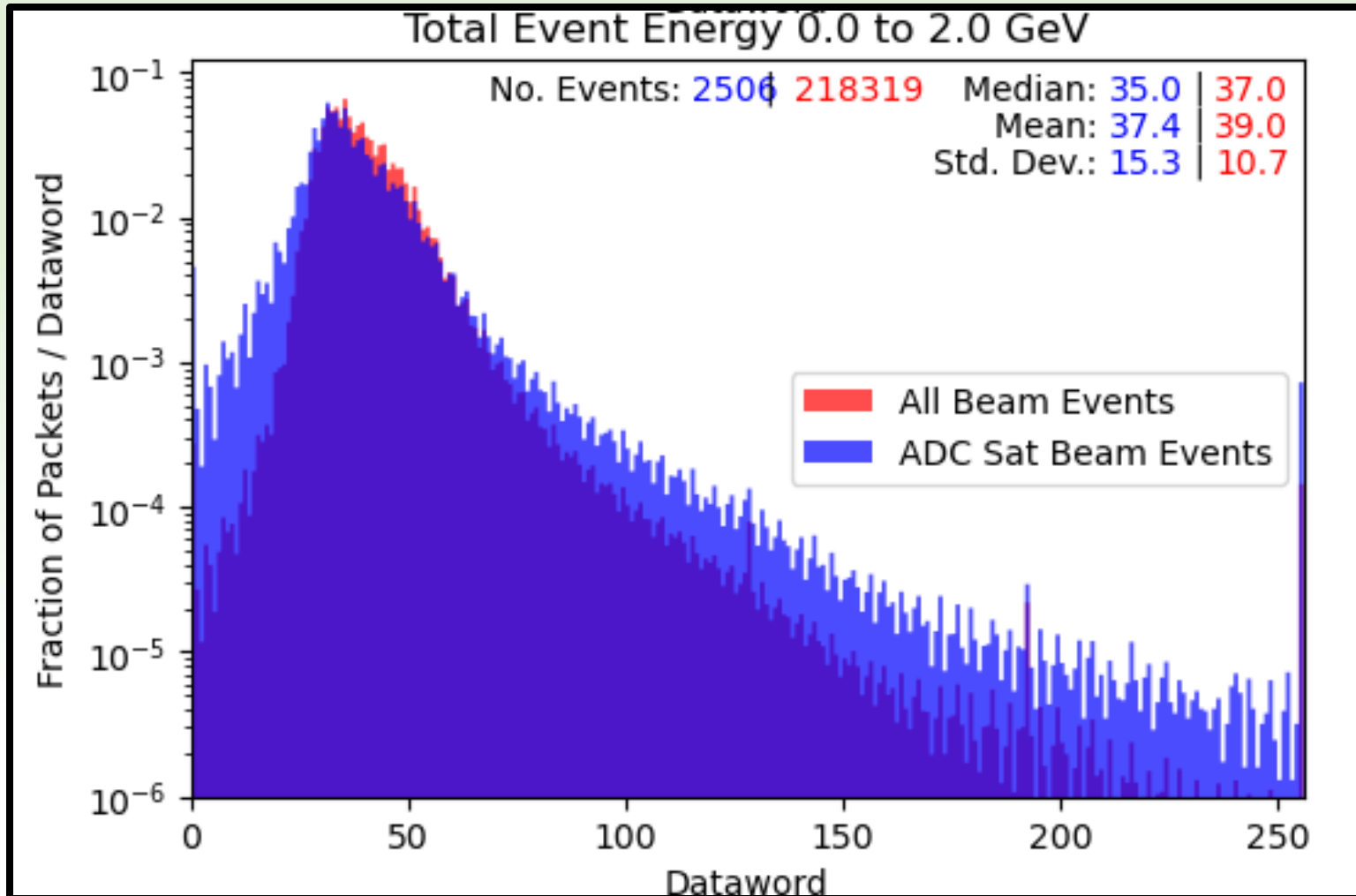


due to bias

associated

(saturation packets)

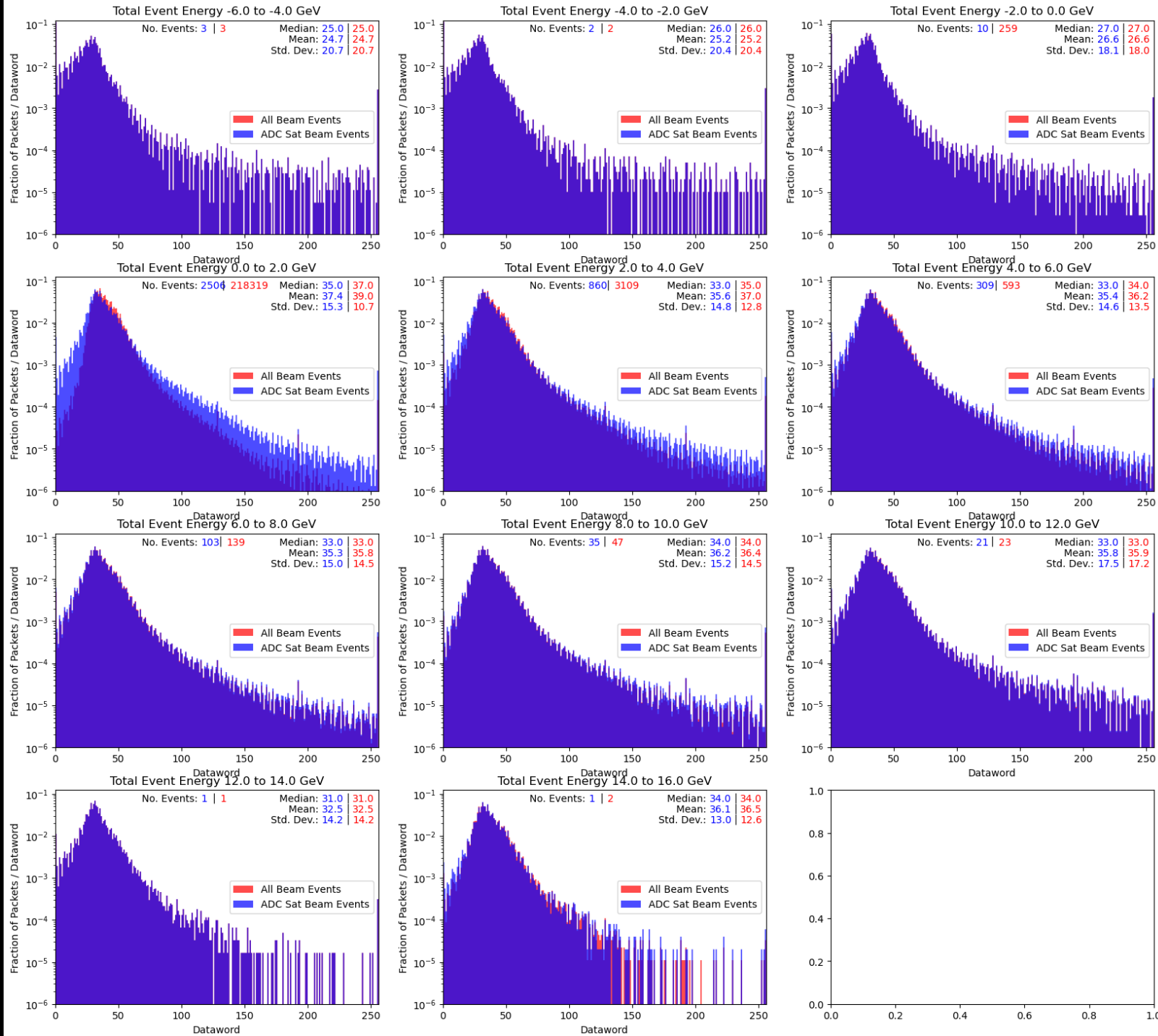
Single Plot (Most Events)



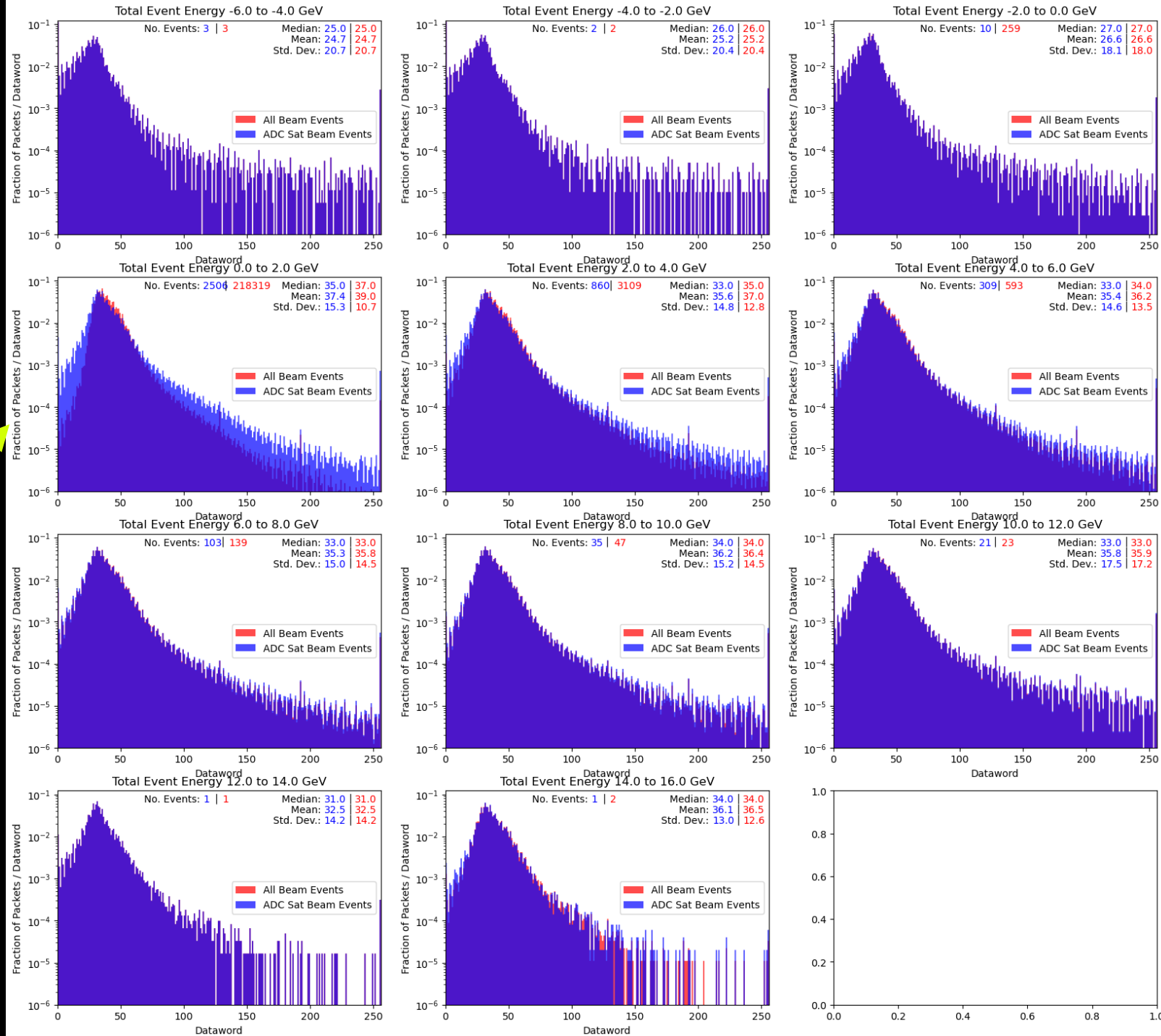
- All events sample is narrower than ADC sat sample
- Also, the ADC sat sample is approximately 1% the size of the all events sample

Plots for All Bins!

Plots



Plots

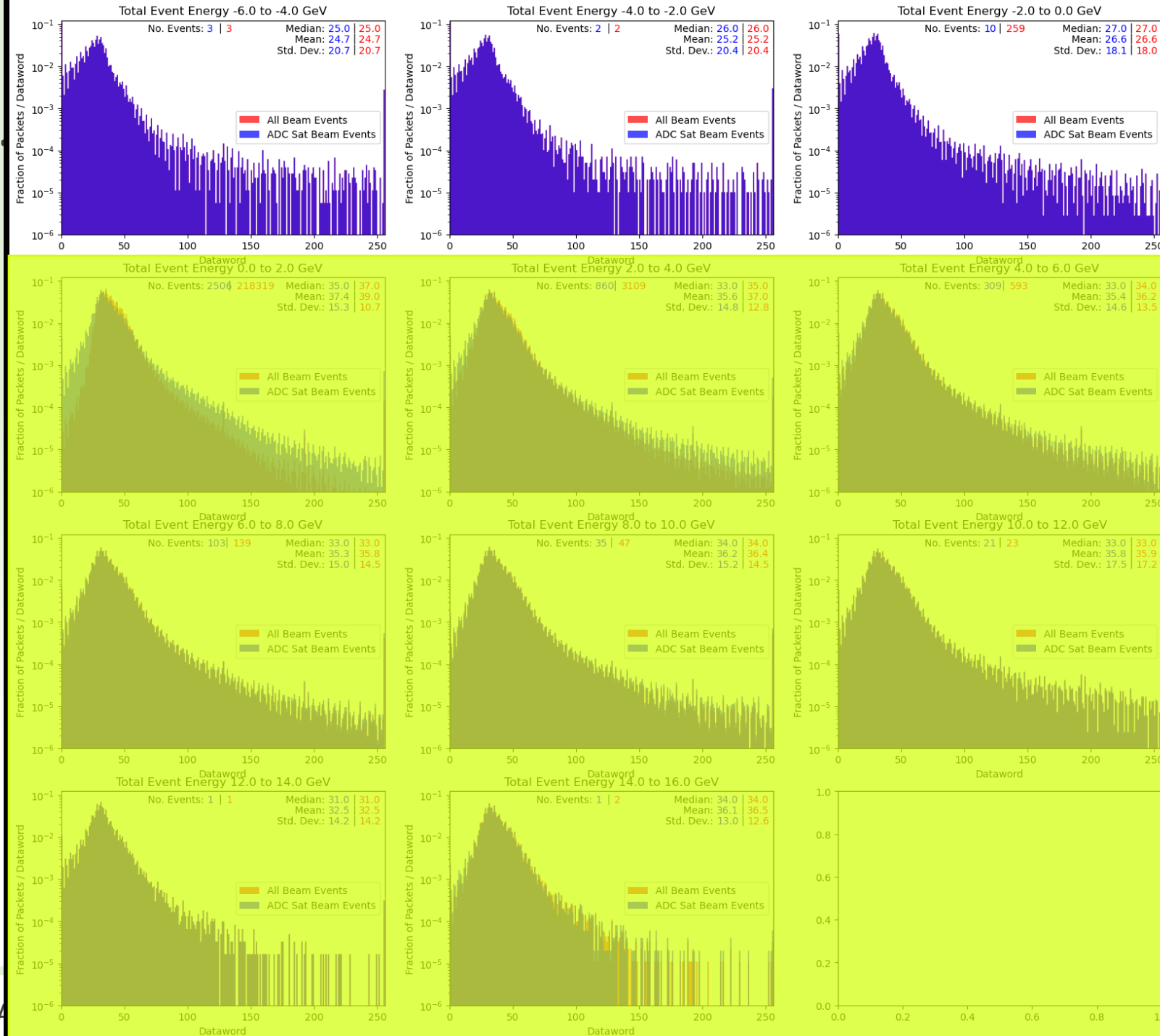


Bin from previous slides

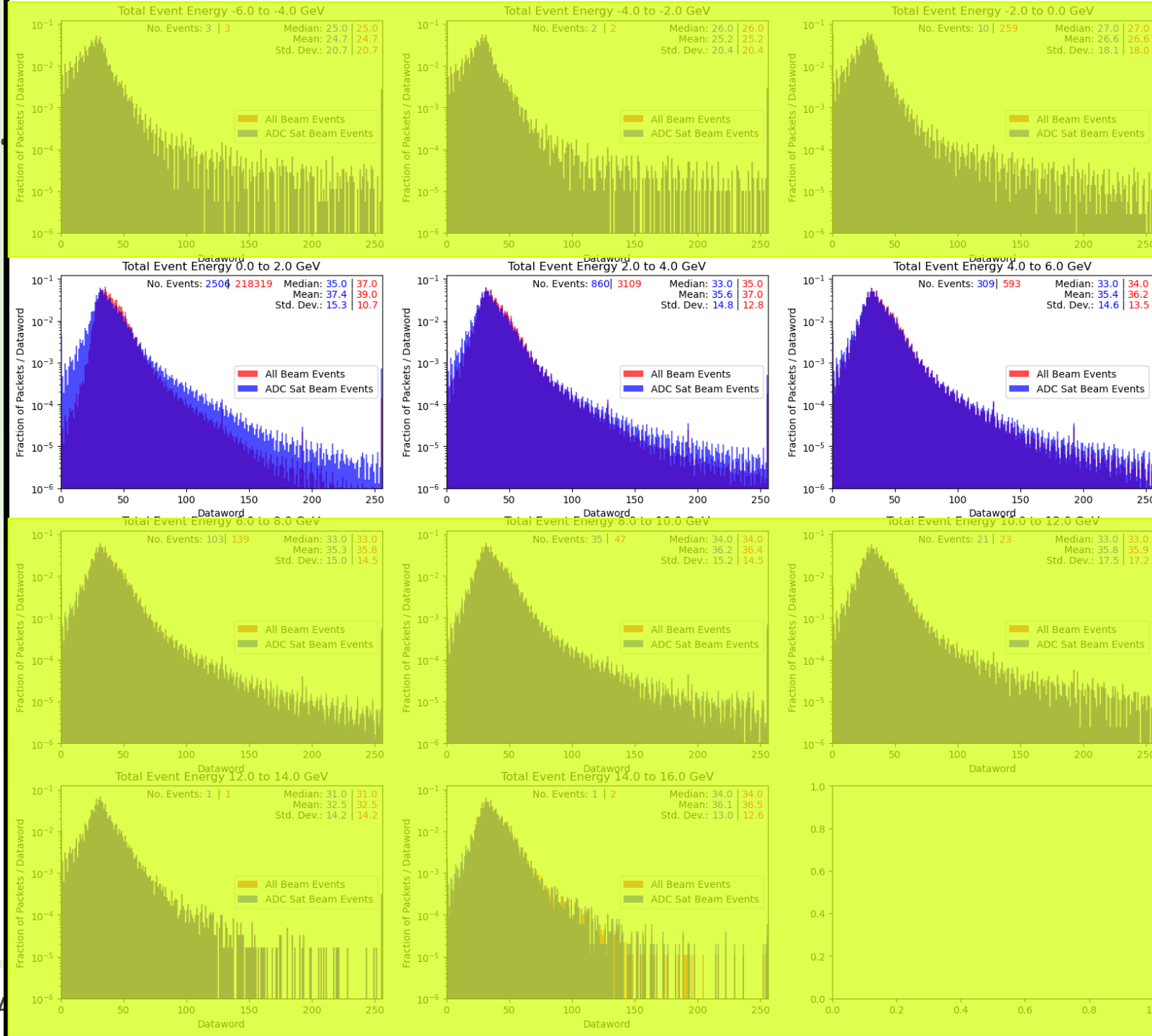


Plots

Negative Energy Bins



Plots

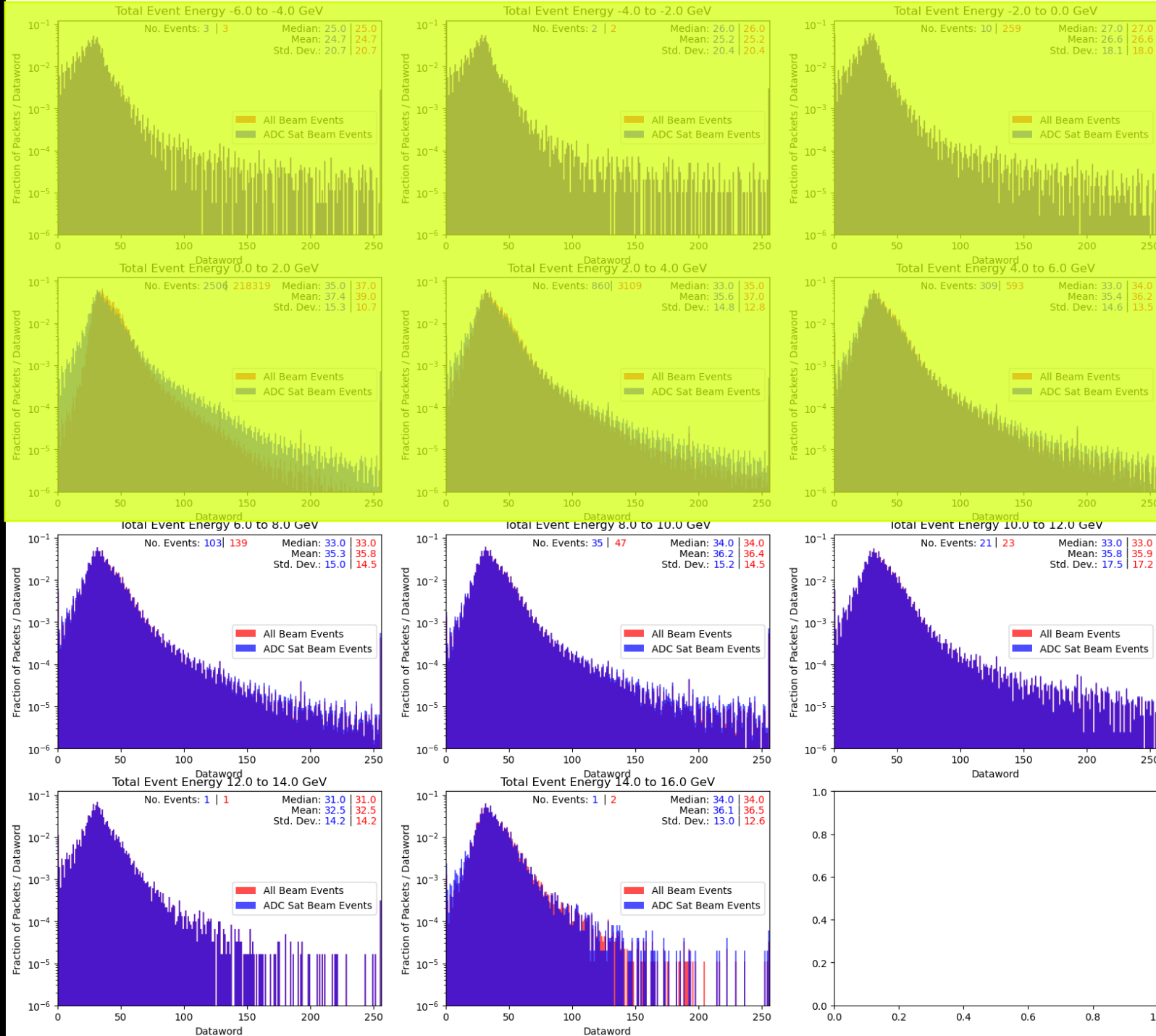


Higher fraction of ADC sat event hits at higher and lower datawords



Plots

Larger fractions of **All Event** samples in these bins are also in **ADC sat** sample



Very similar distributions for **ADC Sat** and **All Event** samples



Takeaways: 2x2 Event Energy/ADC Sat Study

- **Higher fraction of higher energy events** have some ADC saturation packets (**vs. lower energy events**)
- However, hard to make definitive statements given that event energy in 2x2 is uncalibrated
- **Also, back to Module 0 findings – why is what we see in 2x2 so different?**

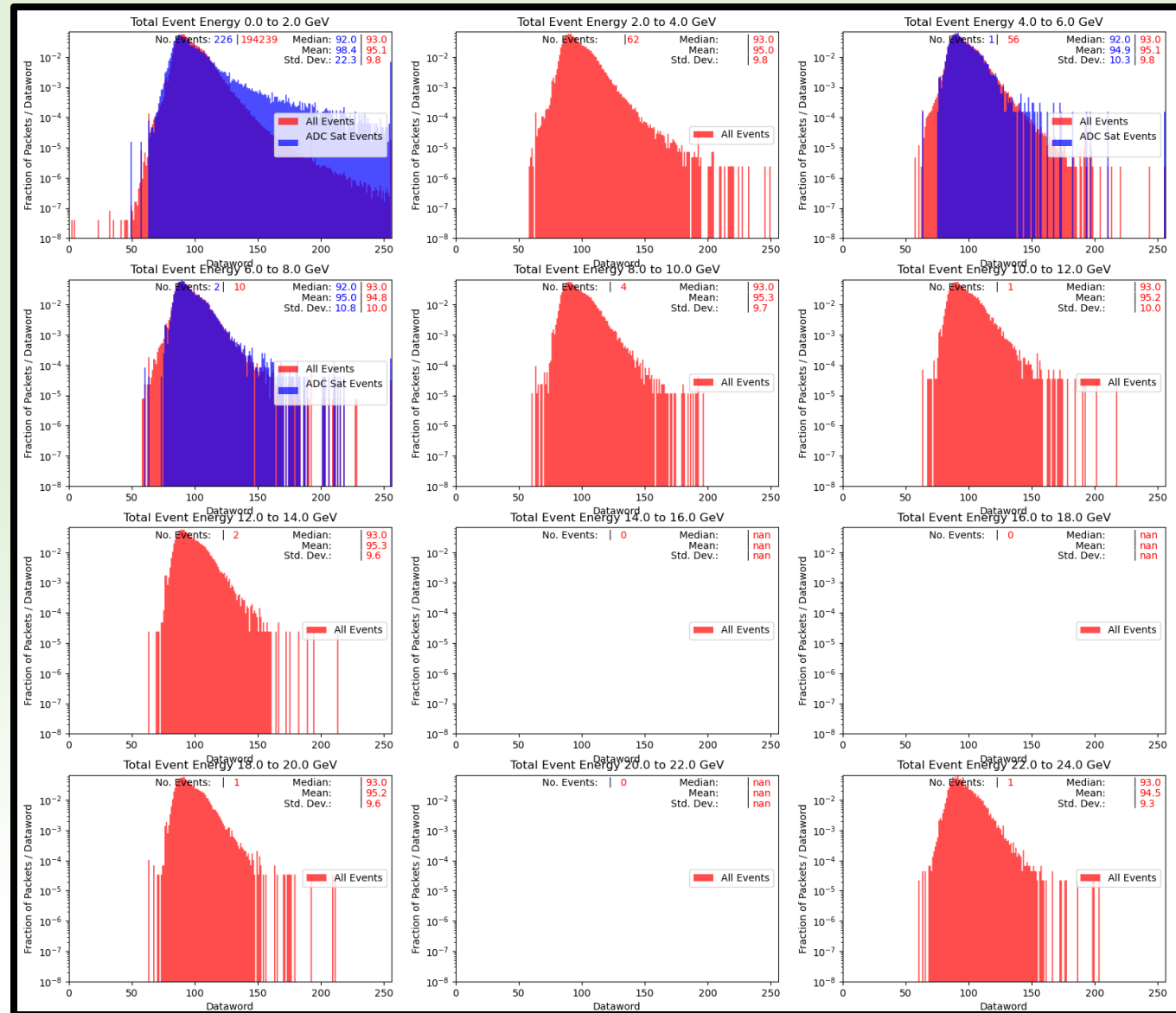
Back to Module 0

- Spoke with Roberto Mandujano to learn about these initial studies
- Studies were likely carried out before production current version of Module 0 data files on NERSC, but we identified these files as the likely 24 files he studied
- **I carried out my studies on six of these files (too big to use more):**
 - **Directory:**
/global/cfs/cdirs/dune/www/data/Module0/merged/prod3/output/combined/mod0-run1-medm-256/reco/
 - **Files:** datalog_2021_04_09_15_08_48_CEST.h5 , datalog_2021_04_09_17_00_20_CEST.h5 , datalog_2021_04_09_12_15_31_CEST.h5 , datalog_2021_04_09_11_35_28_CEST.h5, datalog_2021_04_09_13_48_43_CEST.h5 , datalog_2021_04_09_11_55_30_CEST.h5

Initial Findings

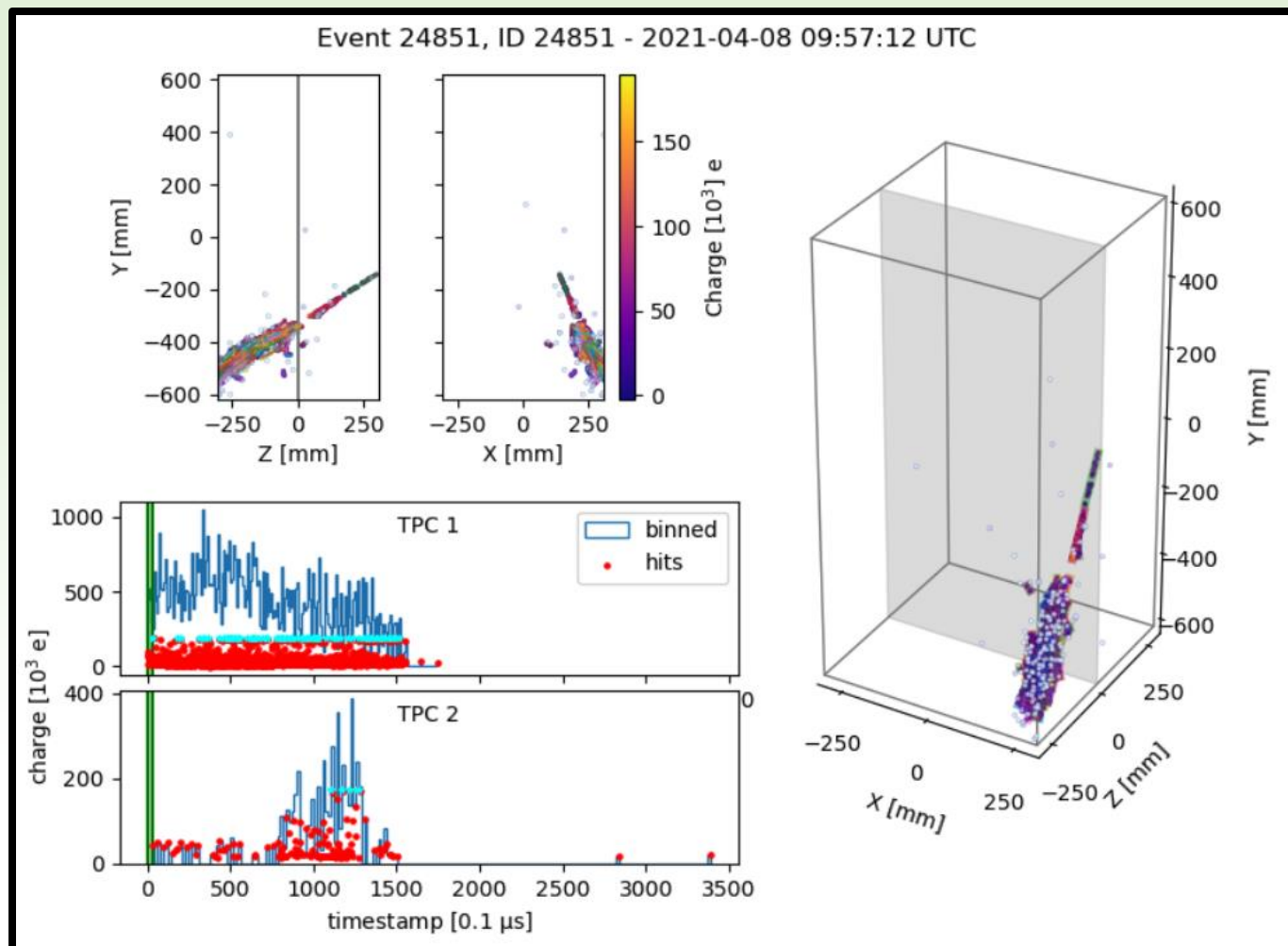
- In those six files, I found that 3431/1599601 events had at least one ADC saturation packet (0.21%)
- While this is not a significant fraction overall, it is significantly more than were identified in the initial Module 0 ADC saturation studies

Energy Plots*



*Full 6-file sample plots didn't finish rendering, so this is for only 1 Module 0 file

Example (**event not in reported sample)



Summary

- Low levels of ADC saturation in 2x2 beam data
- Some initial indication of a correlation between higher event energy and likelihood of having at least one ADC saturation packet
- Previous reports of virtually no ADC saturation in single module runs are potentially misleading

Backup