

Plans & prototyping for  
data acquisition and real-time processing.

Rare Pion Decay Workshop

Oct. 6-8, 2022

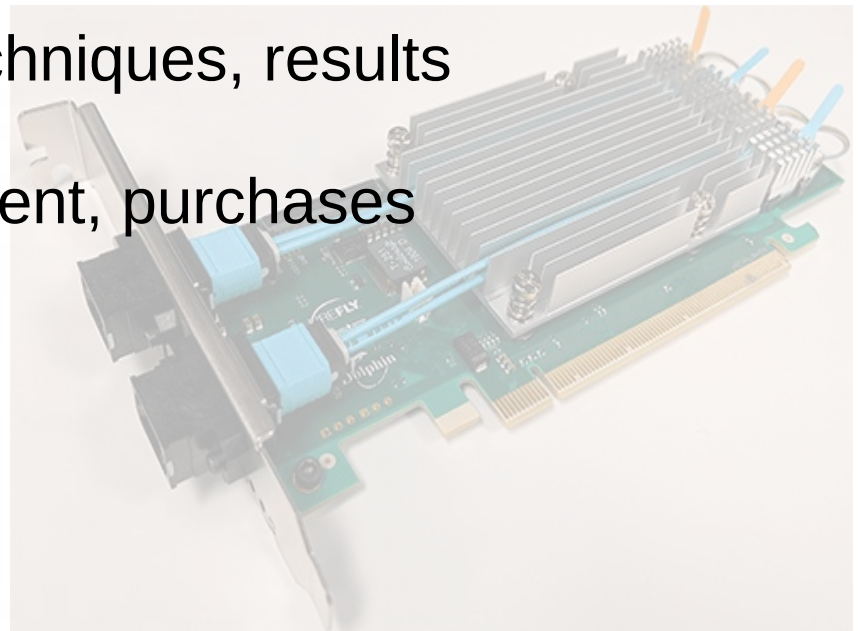


Tim Gorringer, [tim.gorringer@uky.edu](mailto:tim.gorringer@uky.edu)

# Outline

- challenges, rates, compression, ...
- proposed hardware & software
- prototyping test-stand & activities

- compression techniques, results
- future development, purchases



# DAQ requirements

DAQ will provide 3.5 GB/s readout of ATAR, calorimeter, tracker and other detector sub-systems over PCI-e

DAQ will provide real-time processing for event building and > 10-fold compression for data storage on PSI's Petabyte archive

DAQ will provide run control / configuration over PCI-e / IPbus for operations w/ full record of config. metadata

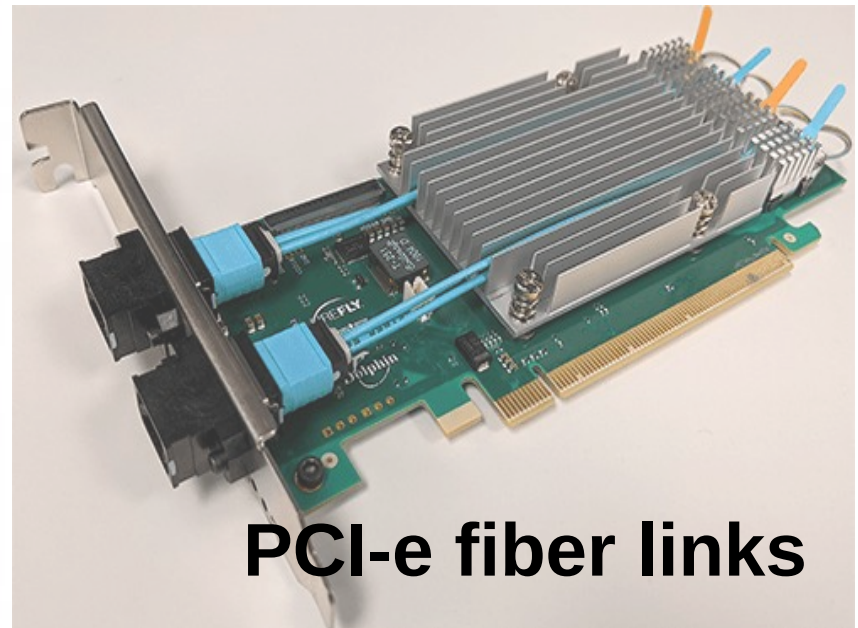
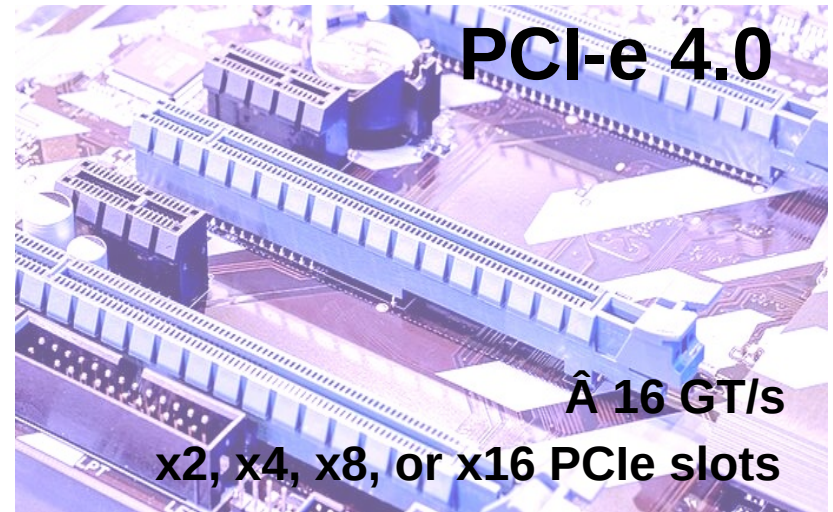
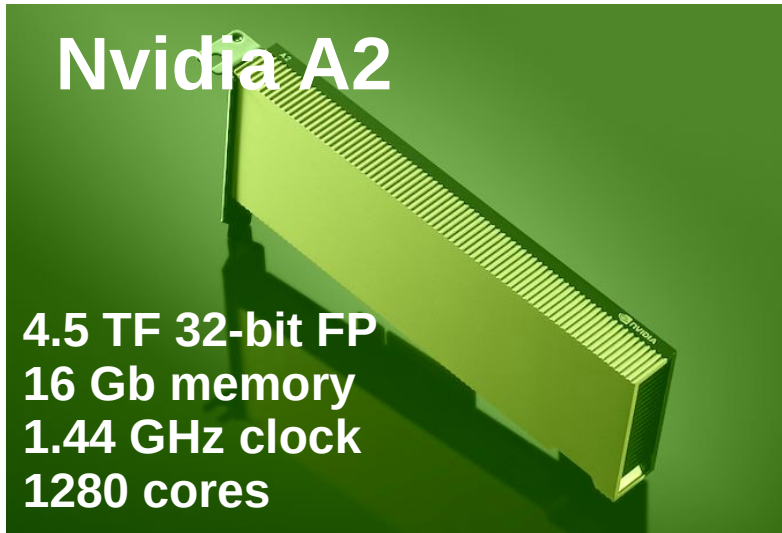
## Trigger, data rates

arXiv:2203.01981

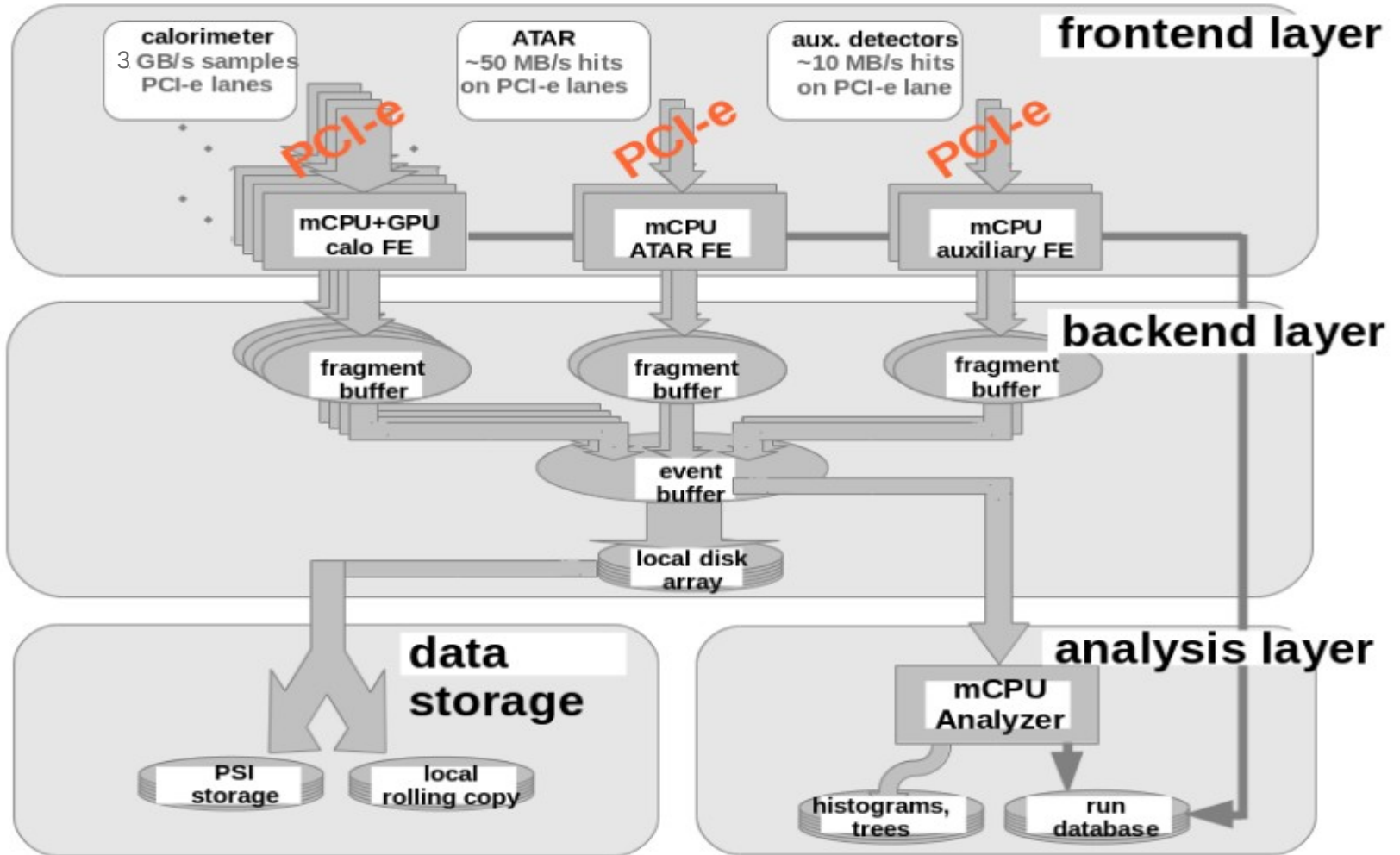
triggers	prescale	range	rate	CALO			ATAR digitizer			ATAR high thres	
				TR(ns)	(kHz)	$\Delta T$ (ns)	chan	MB/s	$\Delta T$ (ns)	chan	MB/s
PI	1000	-300,700	0.3	200	1000	120	30	66	2.4	20	0.012
CaloH	1	-300,700	0.1	200	1000	40	30	66	0.8	20	0.004
TRACK	50	-300,700	3.4	200	1000	1360	30	66	27	20	0.014
PROMPT	1	2,32	5	200	1000	2000	30	66	40	20	0.2

# Data acquisition / real-time processing technologies

- leverage commercial technologies



# Parallel, layered CPU / GPU network



Schematic showing frontend layer for data readout / compression, backend layer for event assembly / data storage, and the analysis layer for online monitoring

# MIDAS data acquisition framework

The screenshot displays the MIDAS data acquisition framework interface. On the left is a sidebar menu with options: Status, Transition, ODB, Messages, Chat, Alarms, Programs, Buffers, MSCB, Sequencer, Config, Help, ChanMap, Straw Tracker Settings, WFD5, CollimatorControl, FiberHarpControl, Laser, StrawTrackerPower, AMC13ThreadMonitor, CaloSCThreadMonitor, and TCAOSCThreadMonitor. The main content area is titled 'GM5' and shows 'Alarms: None' and the date '3 Oct 2022, 12:04:10 GMT-4'. The 'Run Status' section indicates the system is 'Running' (Run 54206) with a start time of 'Wed Sep 21 08:51:24 2022' and a running time of '290h12m46s'. It includes 'Stop' and 'Pause' buttons, 'Alarms: On' and 'Restart: On' indicators, and a 'Data dir: /dataSSD1/gm2' field. Below this is an 'Equipment' table with columns for Equipment, Status, Events, Events[/s], and Data[MB/s].

Equipment +	Status	Events	Events[/s]	Data[MB/s]
EB	Ebuilder@g2be1.fnal.gov	25.373M	12.0	0.001
MasterGM2	MasterGM2@g2be1-priv	25.373M	28.6	0.003
AMC1300	AMC1300@g2aux-priv	25.373M	28.0	0.038
AMC1301	Disabled	4.026M	0.0	0.000
AMC1302	Disabled	4.026M	0.0	0.000
AMC1303	Disabled	4.026M	0.0	0.000
AMC1304	Disabled	4.026M	0.0	0.000
AMC1305	Disabled	4.026M	0.0	0.000
AMC1306	Disabled	4.026M	0.0	0.000
AMC1307	Disabled	4.026M	0.0	0.000
AMC1308	Disabled	4.026M	0.0	0.000

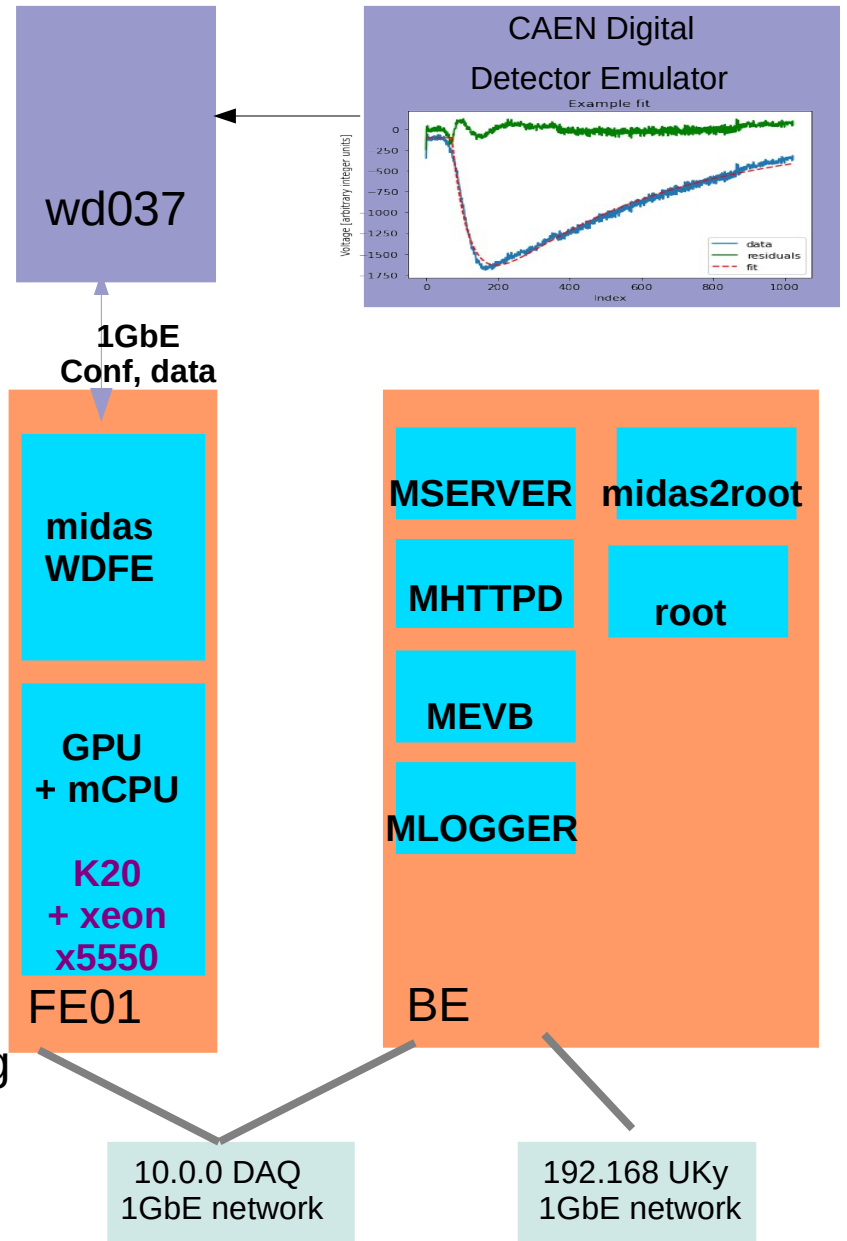
package of modules for run control, expt.. configuration, data readout, event building, data storage, slow control, alarm systems,

# Uky test-stand



*development activities include*

- pci-e communication prototyping
- lossless / lossy compression prototyping
- system component rate testing



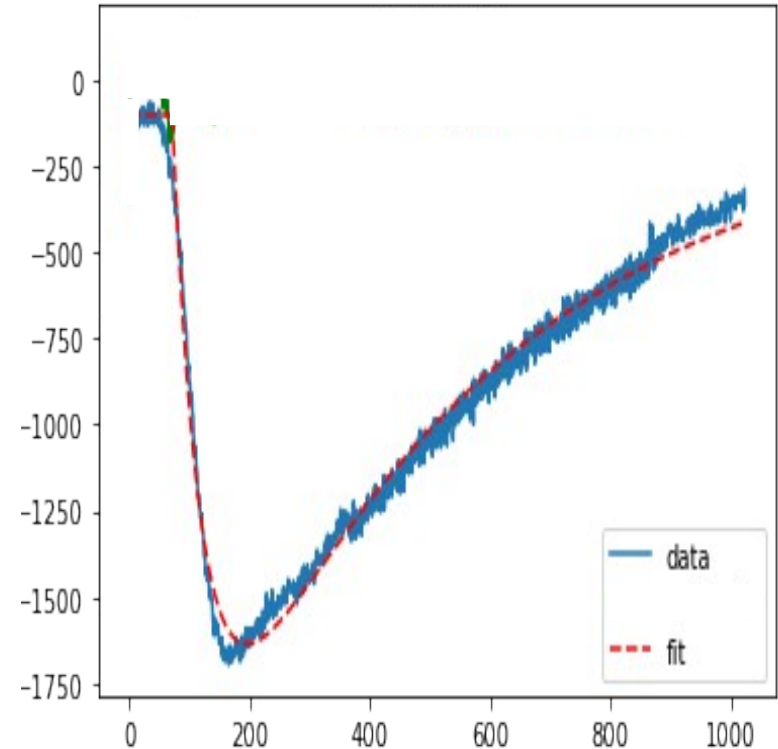
# Data compression

## Signal conditioning

- zero suppression,  $\delta_i = y_i - P$
- delta encoding,  $\delta_i = y_i - y_{i-1}$
- linear fit,  $\chi^2 = \sum (A T(t_i - t_0) - P)^2$
- digital filtering,  $y'_i = b_0 y_i + b_1 y_{i-1} + \dots$

## Lossless compression

- Huffman encoding - assign variable-length codes to input words w/ codebook
- Golomb encoding - assign variable-length codes to input words w/ quotient + remainder



## Bibliography of real-time compression in particle, nuclear, medical

“High-Performance Lossless Compression Algorithm for Digitized Analog Signals”, D Mathews, C Crawford,

“TPC data compression”, J Berger, Nuclear Instruments and Methods in Physics Research A 489 (2002) 406–421

“Data Compression in the NEXT-100 Data Acquisition System” R. Bosch et al, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9318325/>

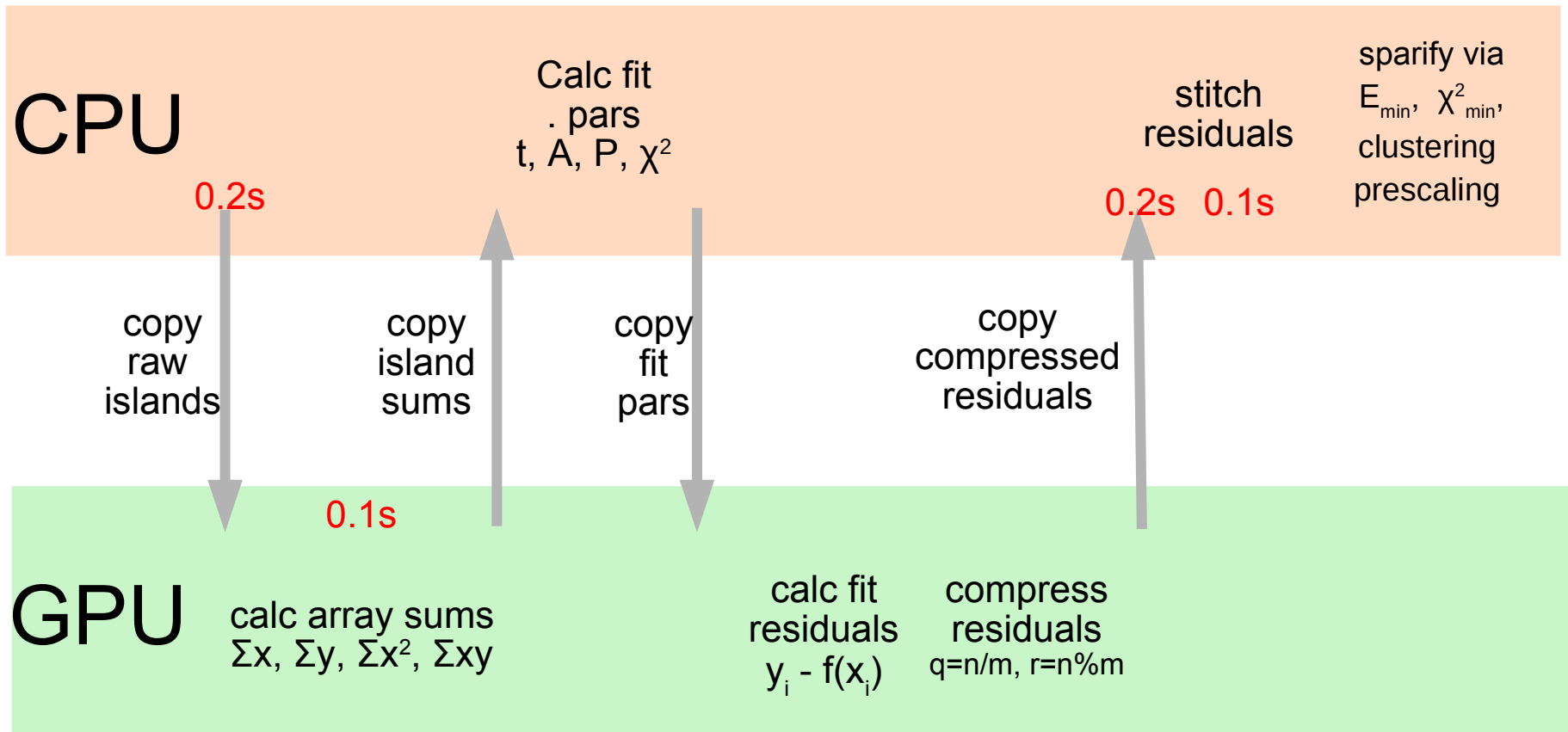
“Potential of fast delta encoding for higher compression ratio”, H. Tan et al, 2020 IEEE International Conference on Cluster Computing

“Data compression in zero suppressed high energy physics data”, H Beker, M. Schindler,

“Lossy and lossless data compression of data from high energy physics experiments”, C Patauner, CERN-thesis 2011-211.pdf

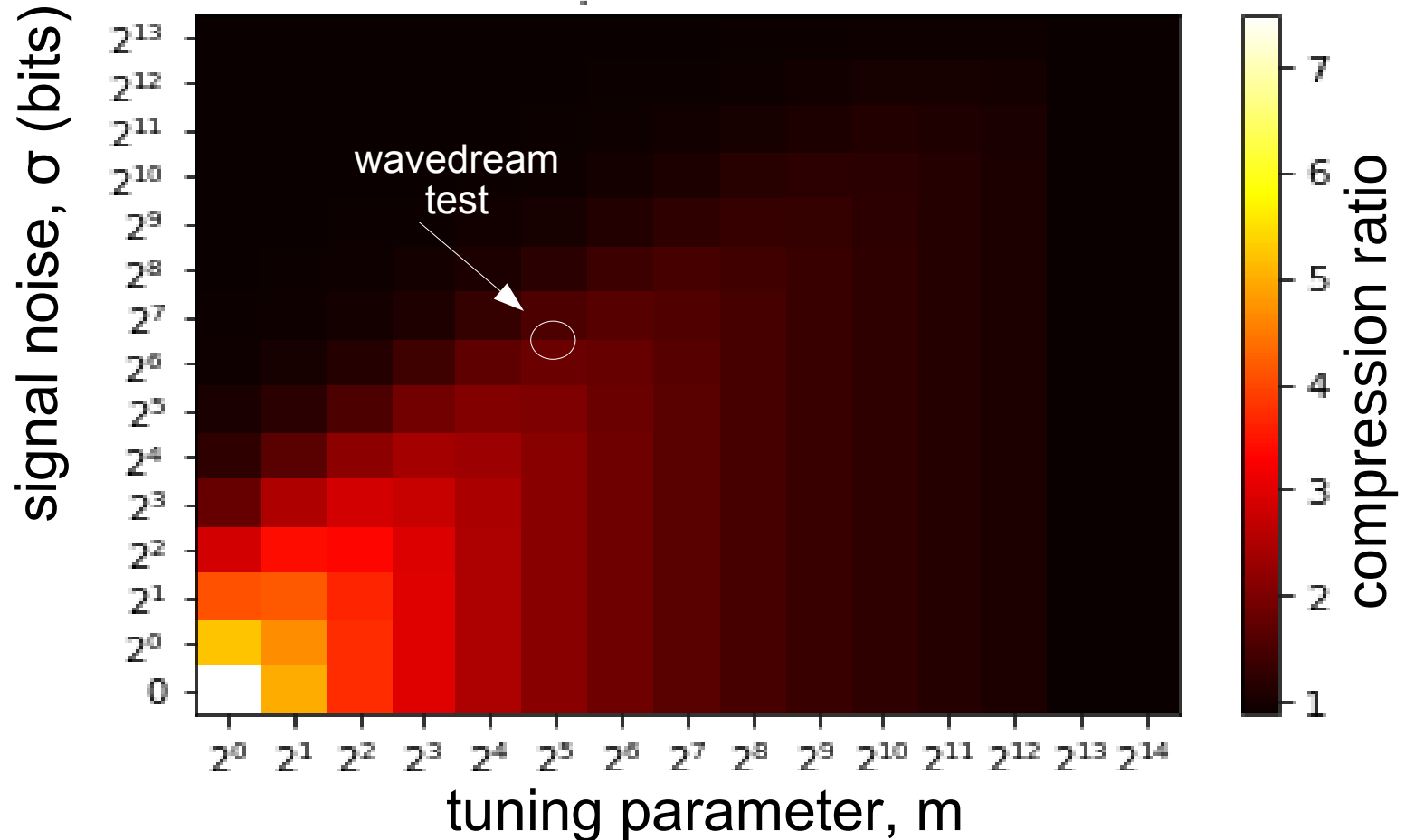


# GPU / CPU compression scheme



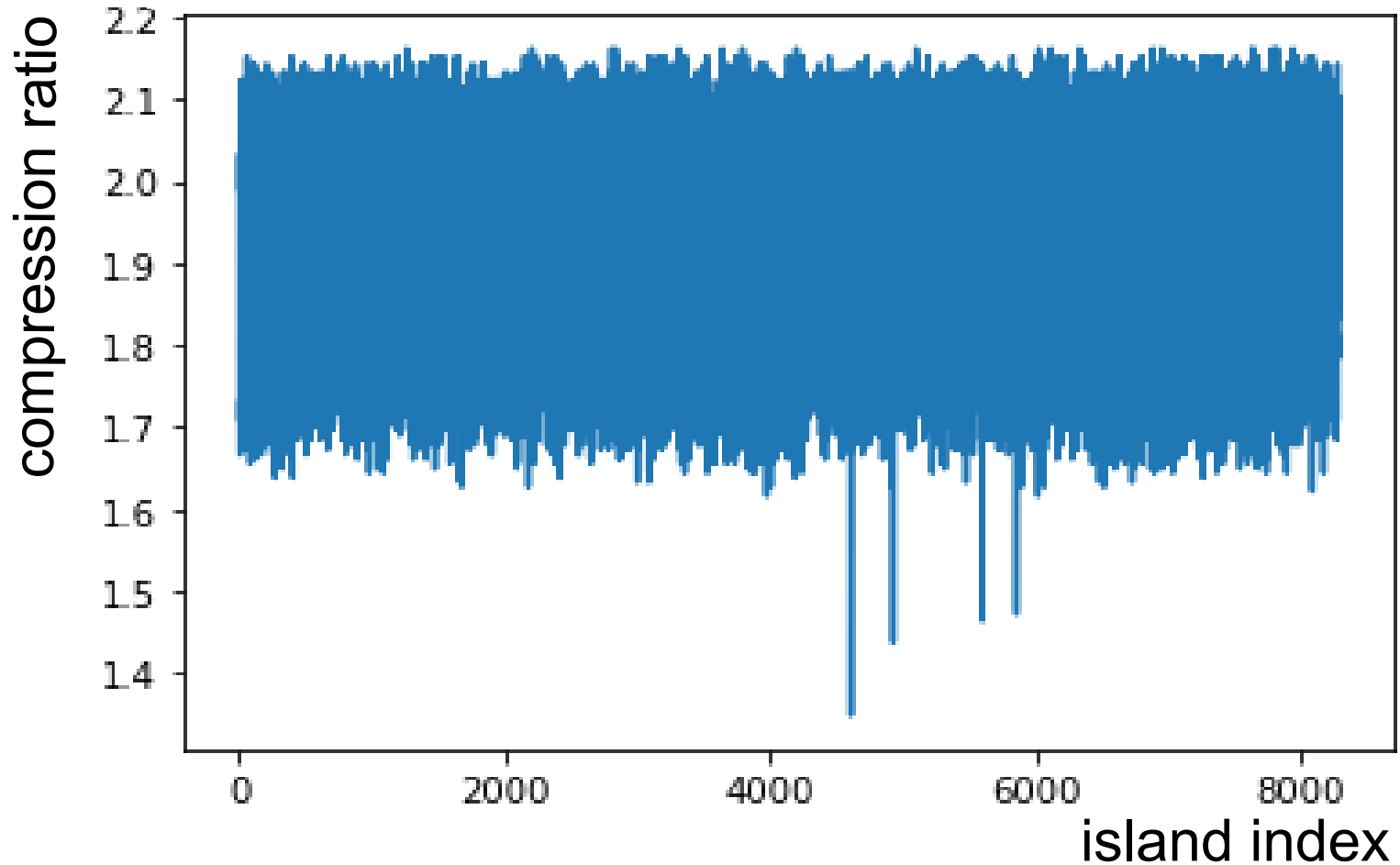
# Golomb compression ratio of linear fit residuals

assigns variable-length codes to input words using quotient + remainder of division by  $m$

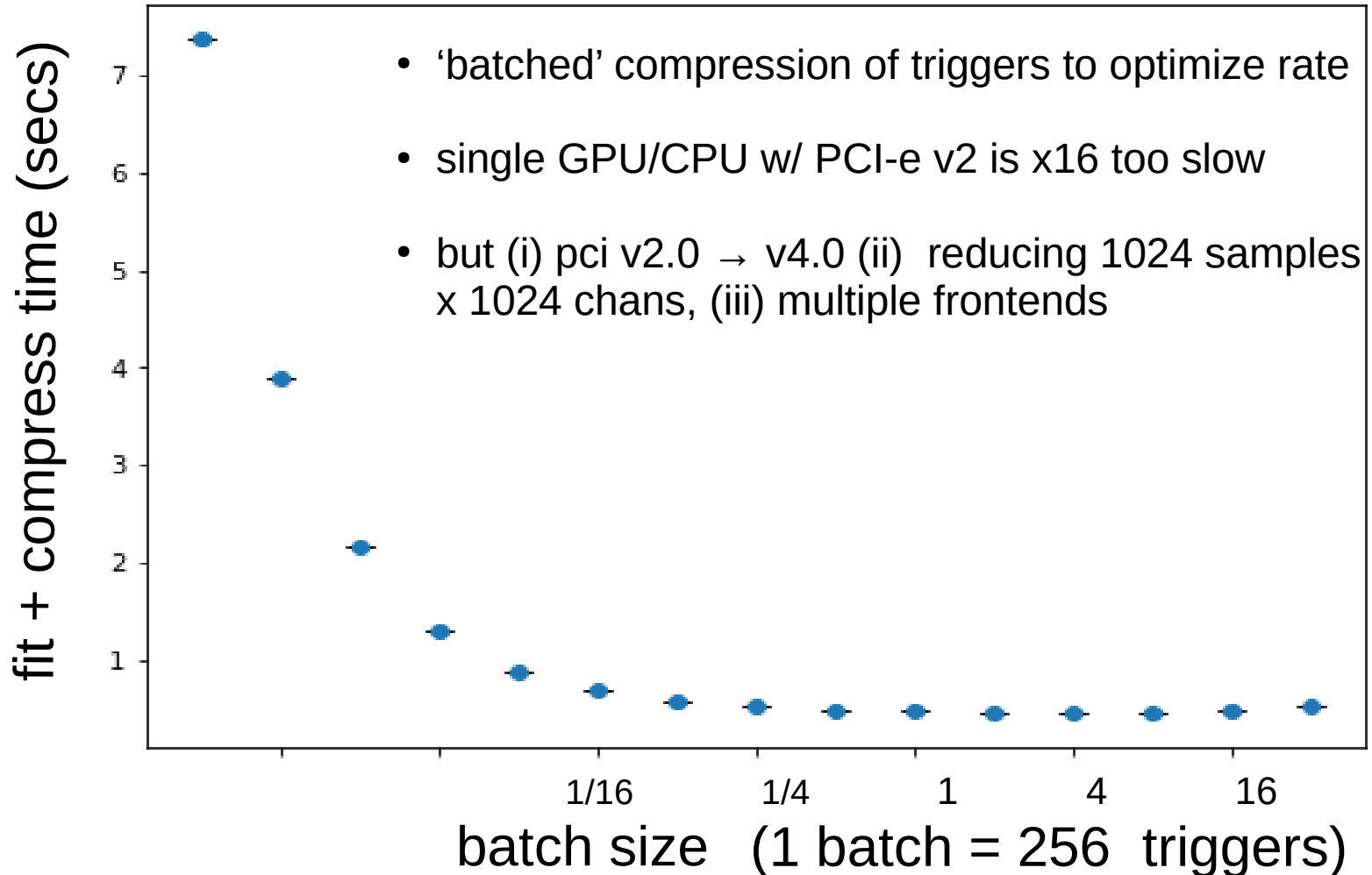


\* tunable parameter  $M$  divides words into quotient (unary coded), remainder (binary coded)

# Golomb compression of linear fit residuals of wavedeam data



# fit + compression timing



# Summary

- established UKy test stand
- UKy graduate student joined daq development
- started compression studies
- planning purchase of pci-e over fiber + GPU/CPUs

