CLAS12 Software

G.Gavalian (Jefferson Lab)

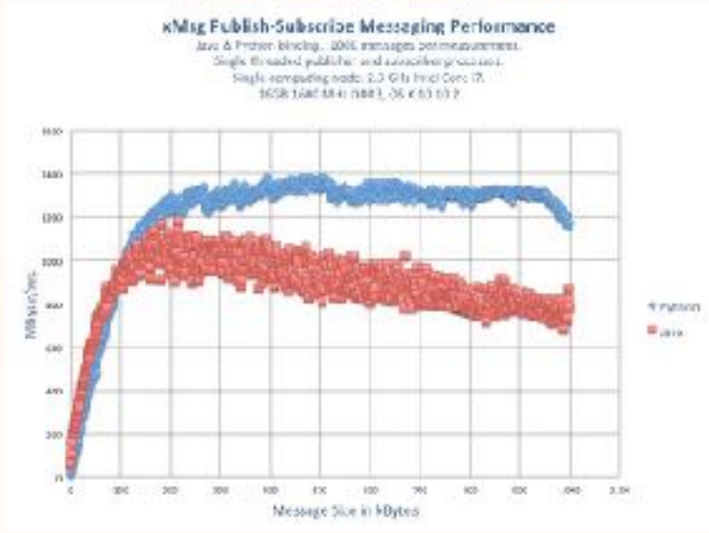
Outline

- CLAS12 reconstruction
- CLARA services
- Performance
- Raw data compression
- Summary

Reconstruction (CLARA 4.3)

- **xMsg CLARA service bus**
  - ✓ general purpose public subscribe MPI
  - ✓ utilizes zeroMQ socket libraries
- **Sockets that carry messages across various transports**
  - ✓ In-process
  - ✓ Inter-process
  - ✓ TCP
  - ✓ Multicast

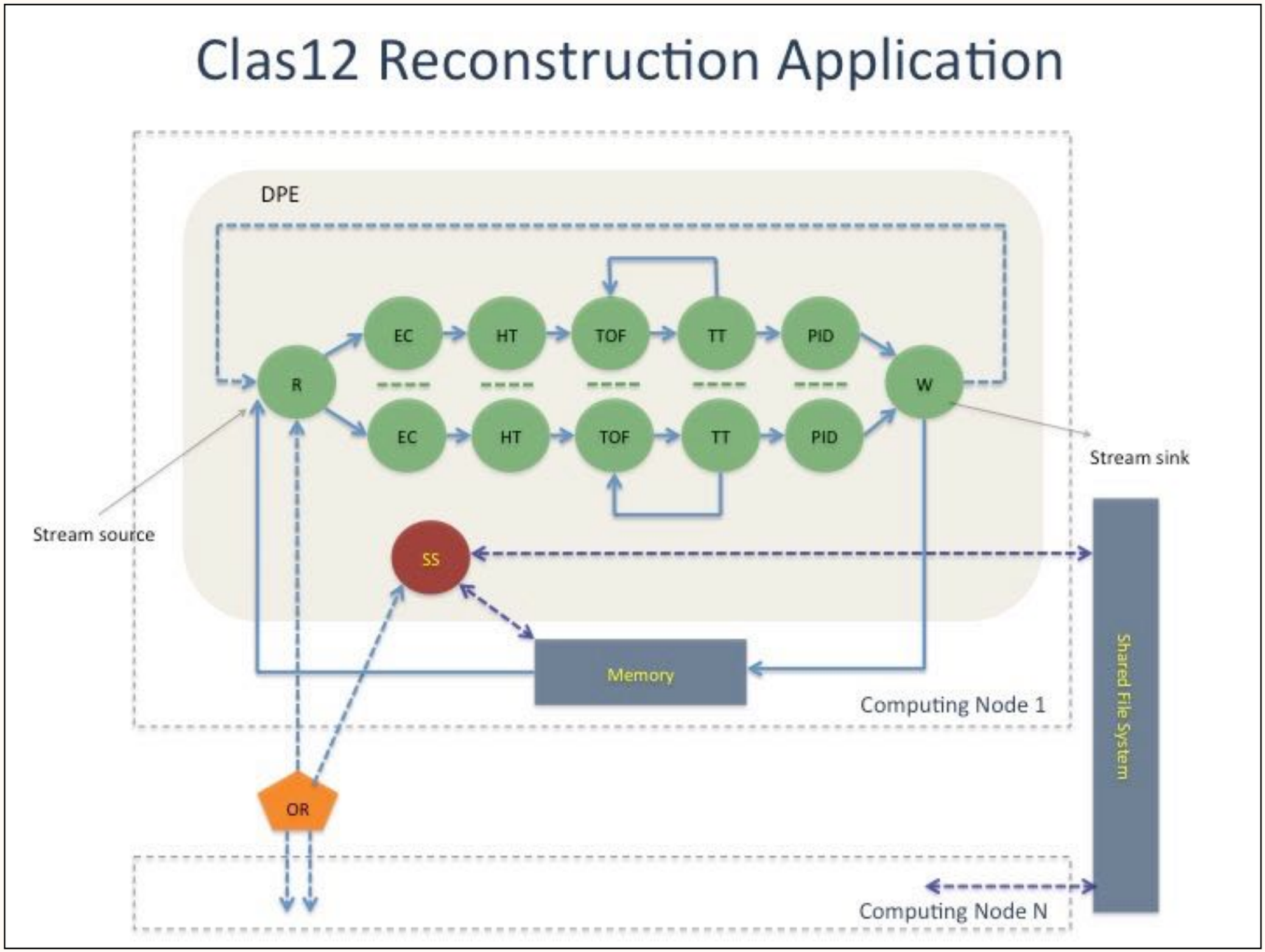
- **Sockets can be connected N-to-N with patterns**
  - ✓ Fan-out
  - ✓ Pub-sub
  - ✓ Task distribution
  - ✓ Request-reply
- **Java, C++, Python bindings**



Key Features

1. micro-services architecture of data analytics
2. network distributed workflow organization
2. decoupling between service engine programmer and the framework
3. presents auto-scaling, i.e.multi-threading and multi-processing
4. makes efficient use of multi-core architectures systems as well as commercial cloud resources.

CLAS12 Reconstruction Application



CLARA Performance

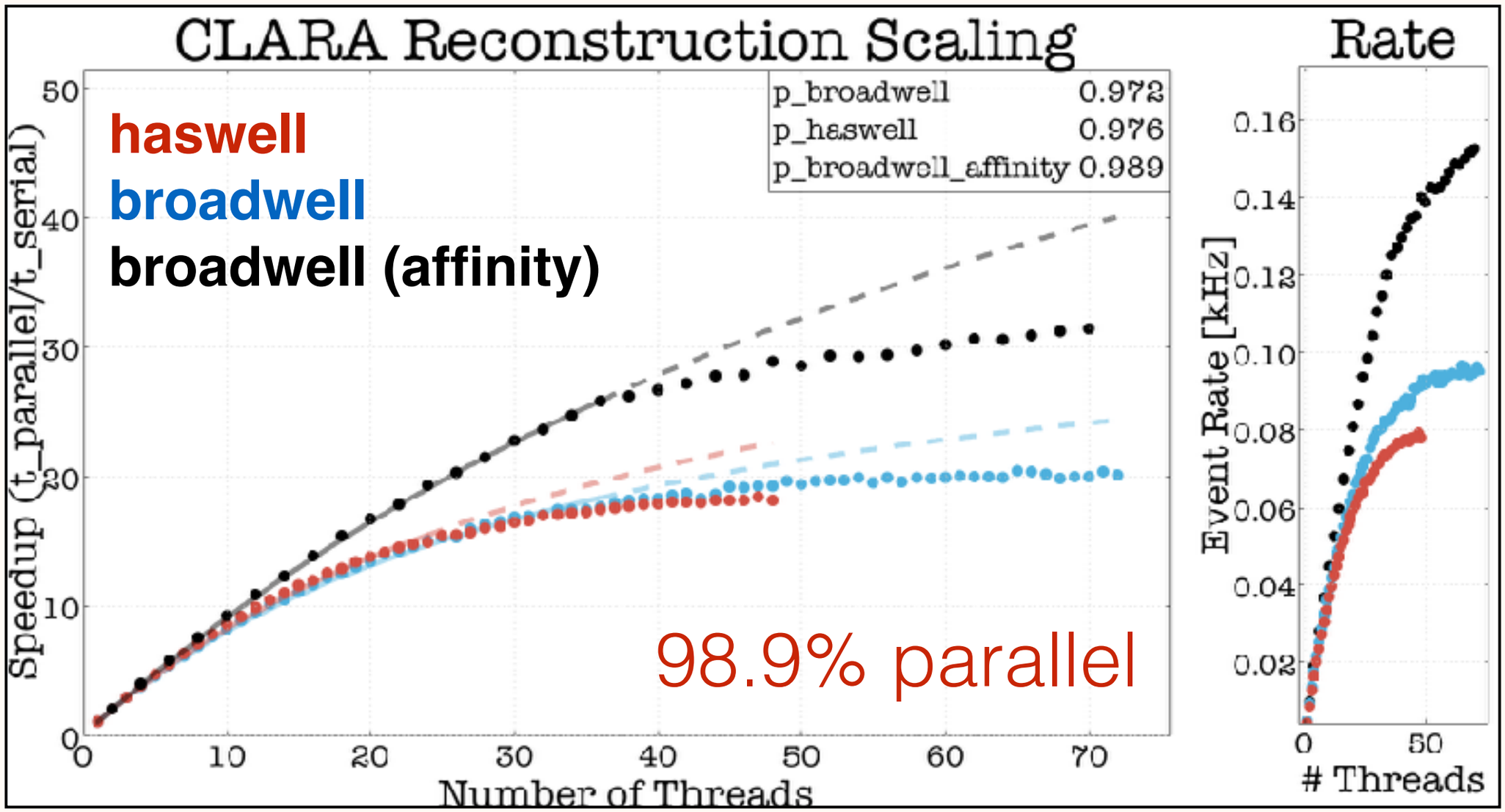
Amdahl's law

gives the theoretical speedup in latency of the execution of a task at fixed workload that can be expected of a system whose resources are improved.

$$S_{\text{latency}}(s) = \frac{1}{(1-p) + \frac{p}{s}}$$

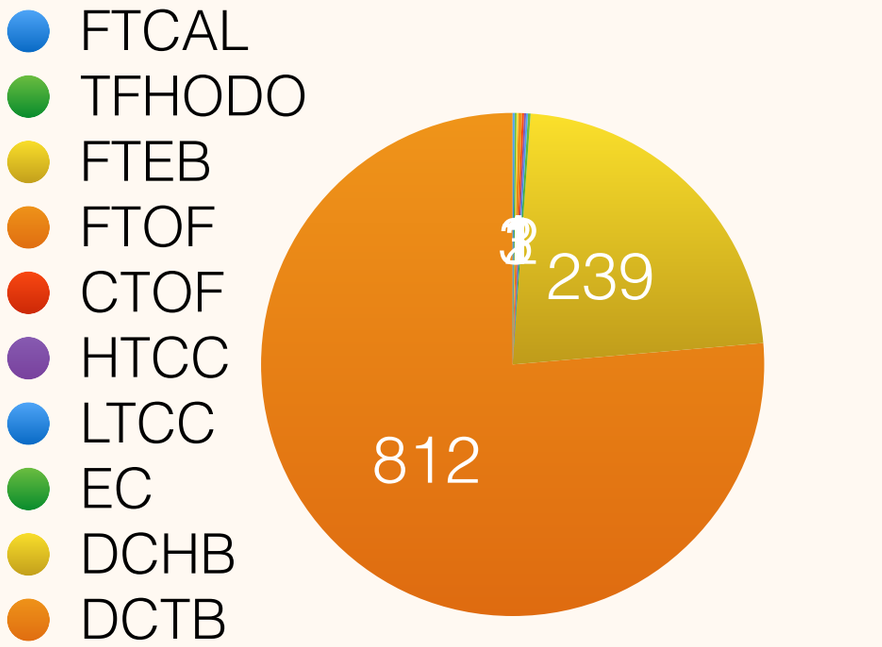
p - is the percentage of the execution time of the whole task concerning the part that benefits from the improvement of the resources of the system before the improvement.

s - is the speedup in latency of the execution of the part of the task that benefits from the improvement of the resources of the system



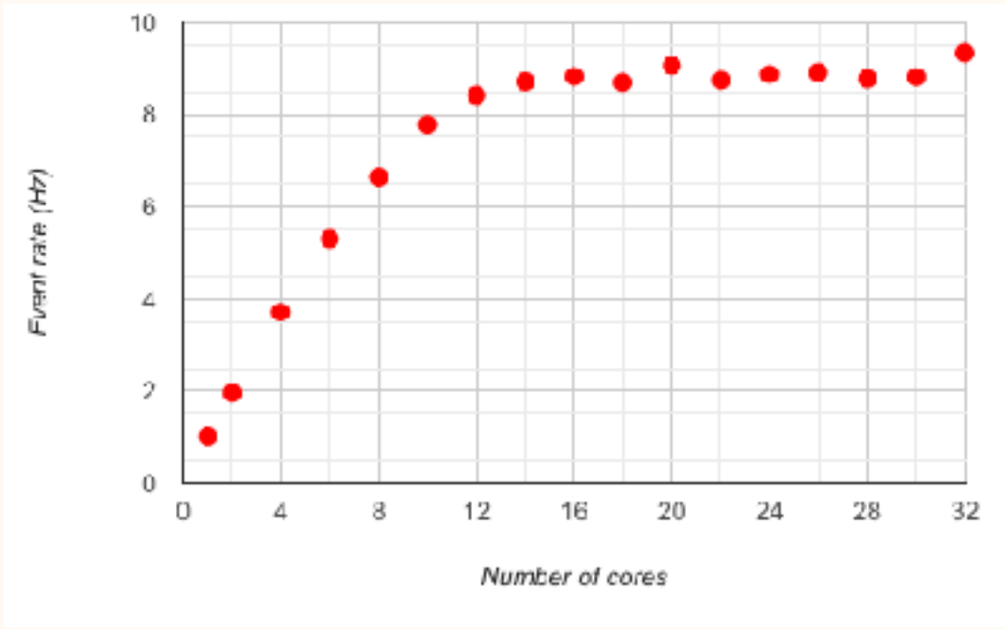
Software Status at KPP

- **KPP preparation:**
  - ✓ Hit based tracking was changed to KF (for better vertex reconstruction)
  - ✓ Time based tracking code improvements (better resolutions)
- **Performance Hit:**
  - ✓ Object creation and destruction (especially inside loops)
  - ✓ Magnetic filed swimming (ATAN, COS and SIN slow)
  - ✓ Magnetic filed tri-linear interpolation (fetches neighbors at each request)



1.2 sec/event

Reconstruction Rate ~**10 Hz**

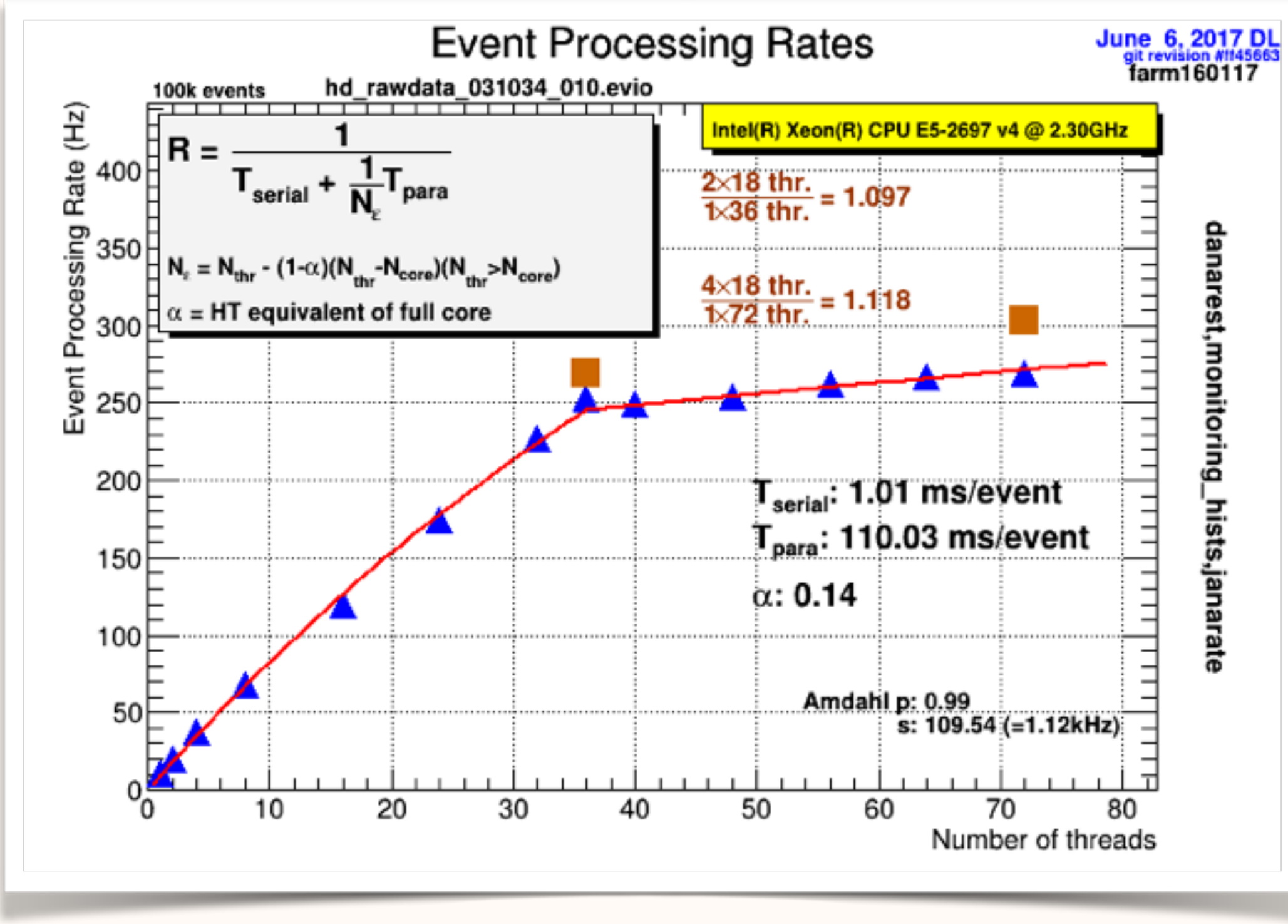



What
Do I Do
Now

Back To Drawing Board

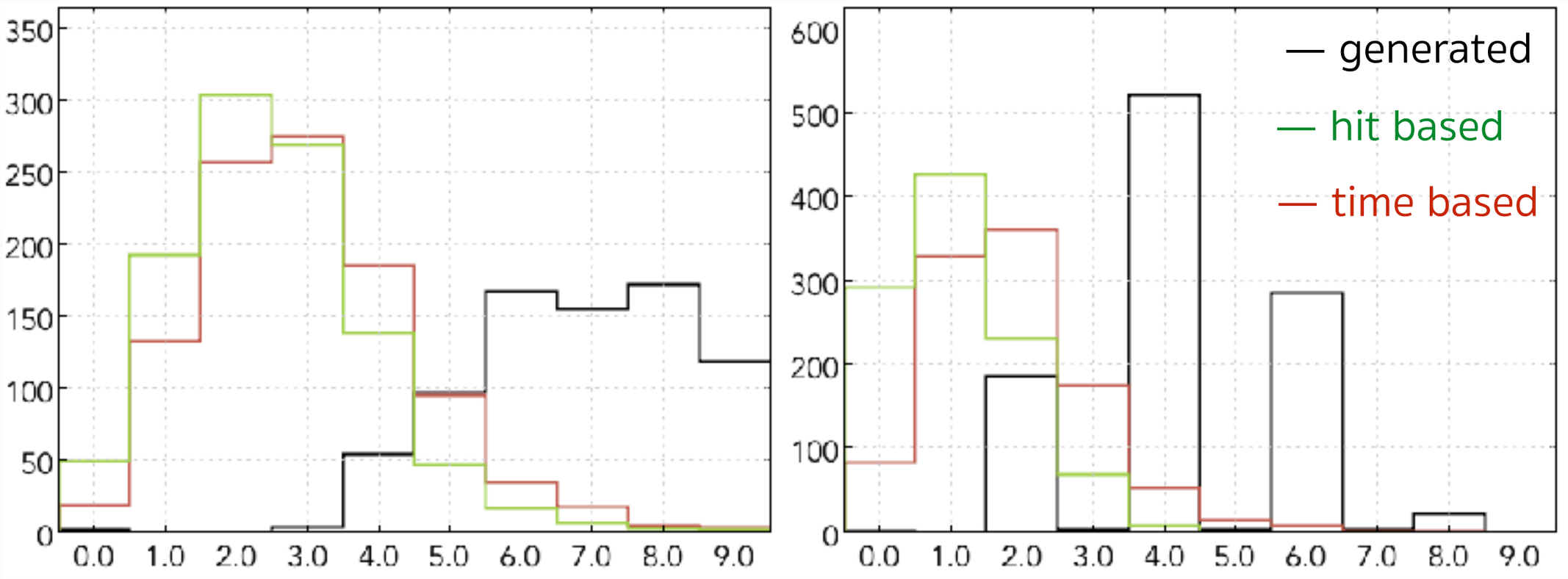
- **Magnetic Field Package Improvements (performance improvement 3-4x)**
  - ✓ Added Apache Fast Math as an option for trigonometry calculations
  - ✓ Implemented faster (less accurate 10e-5) gaming trigonometry
  - ✓ Introduced magnetic probe with neighbor cell caching
- **Tracking Code Improvements (performance improvements 10-14x):**
  - ✓ Modified code to reuse arrays inside the KF loops
  - ✓ Removed unnecessary object creation
  - ✓ Changed the magnetic field transport step size
- **Future Improvements (performance improvements TBD)**
  - ✓ Matrix inversion library improvements (or reimplementation)
  - ✓ Clean other parts of the code from unnecessary object creations
  - ✓ Try using object pools for storing track hits and clusters
  - ✓ Implement Ranga-Kutta adaptive step size for swimming
  - ✓ Use non-virtual (inline) functions where speed is relevant
  - ✓ Resolve some thread contention issues

HALL-D Reconstruction Rates



SIDIS events with electron polar angle between 10 and 35 deg

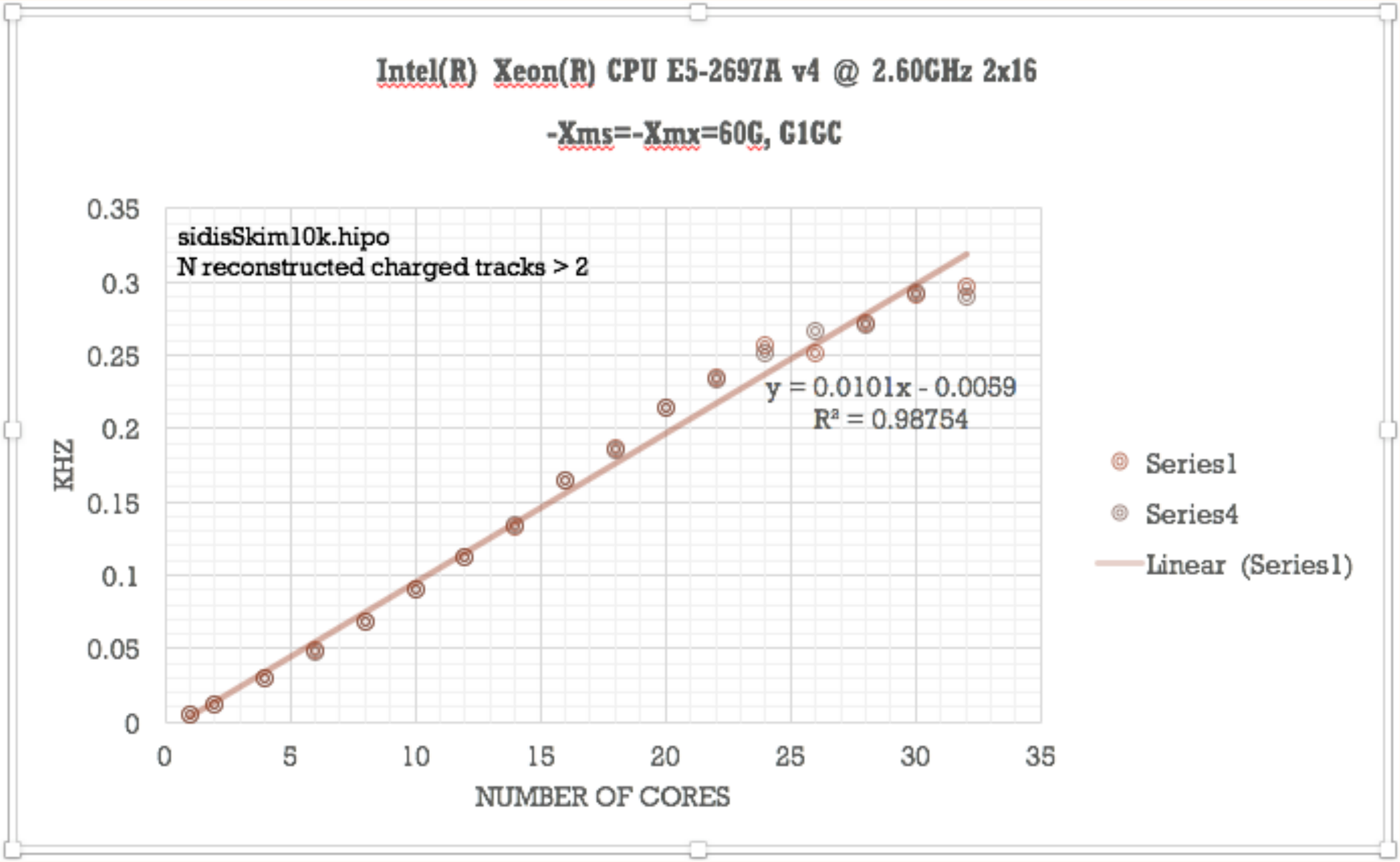
Track Multiplicity



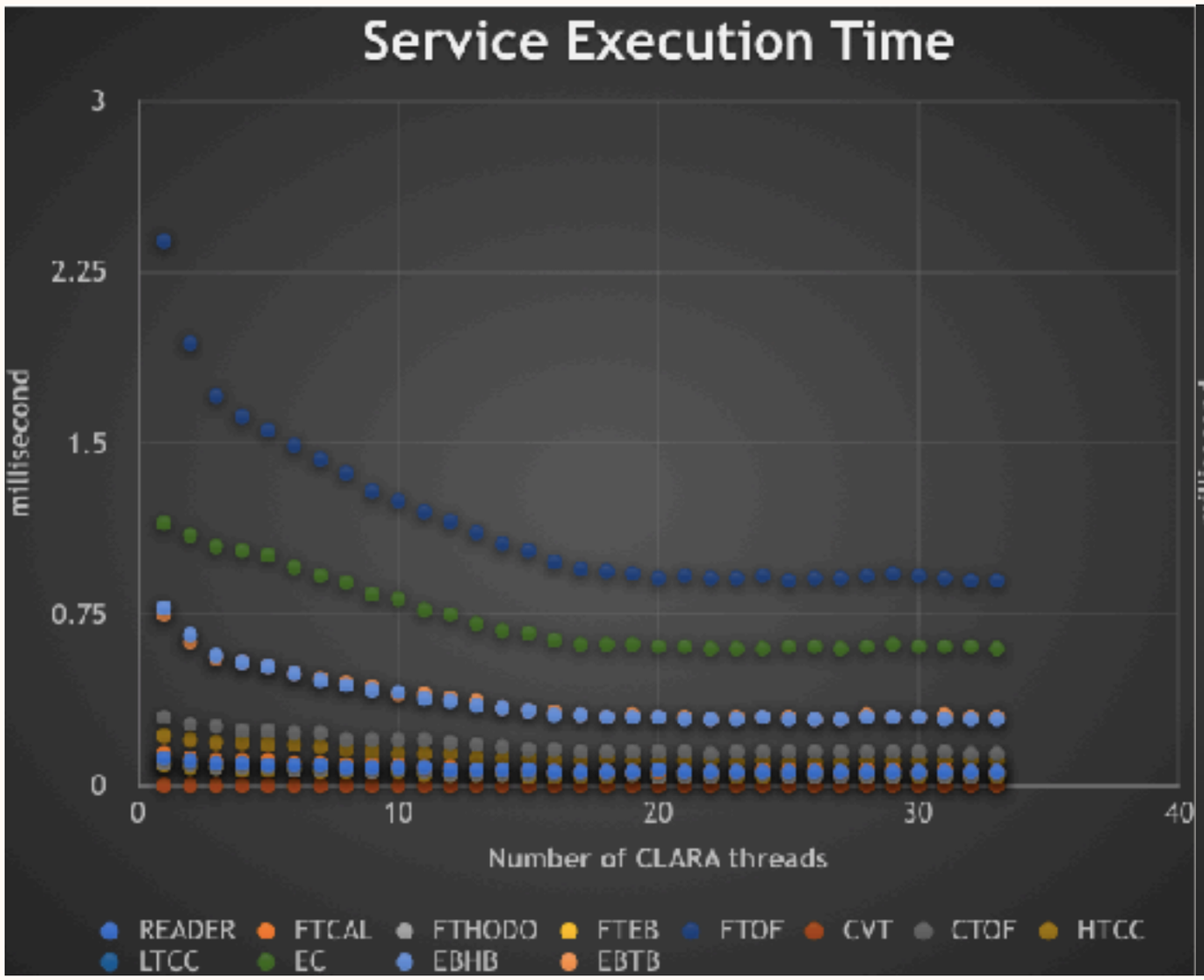
All Particles

Charged Tracks

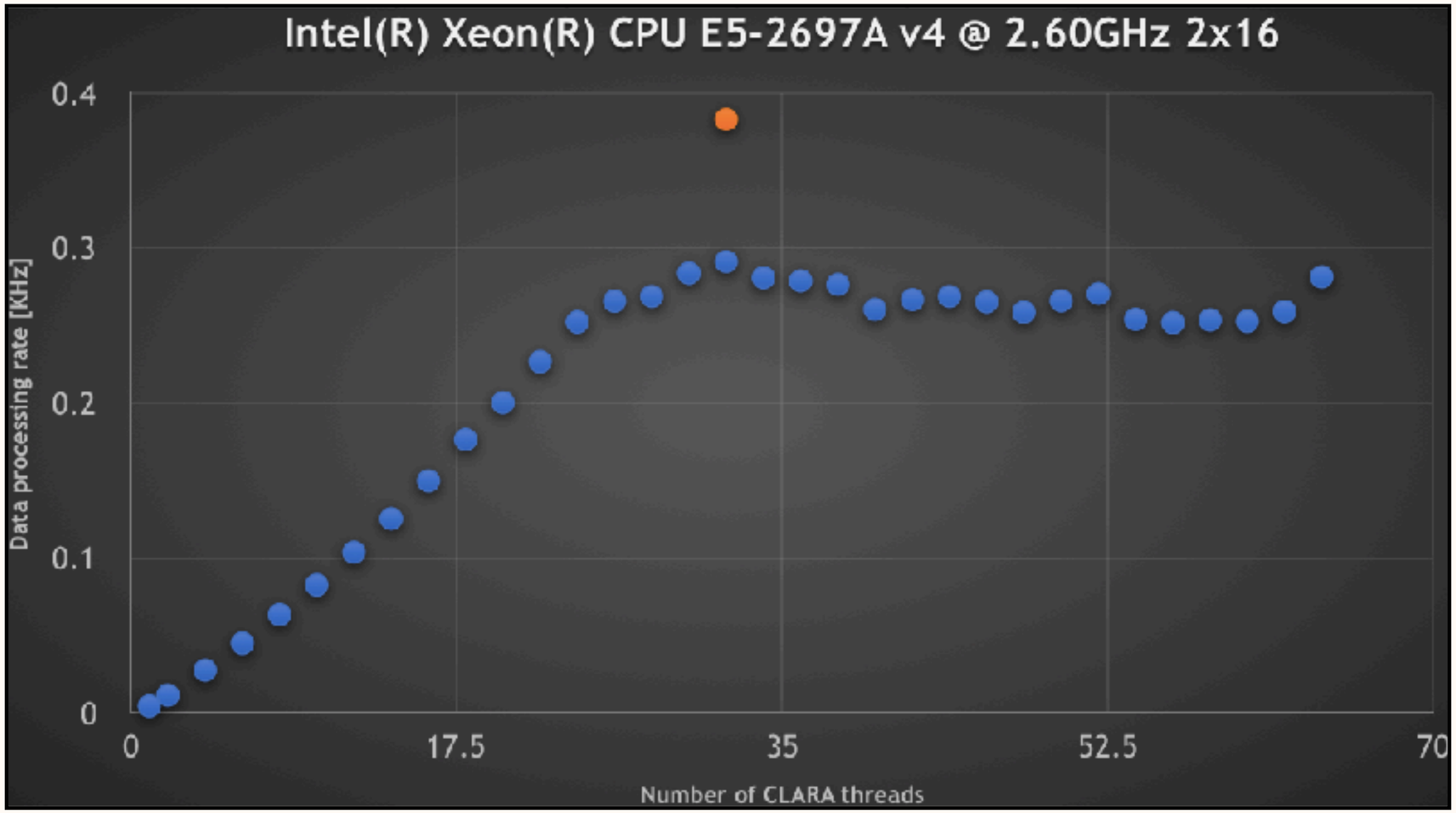
HALL-B reconstruction status



Thread contention



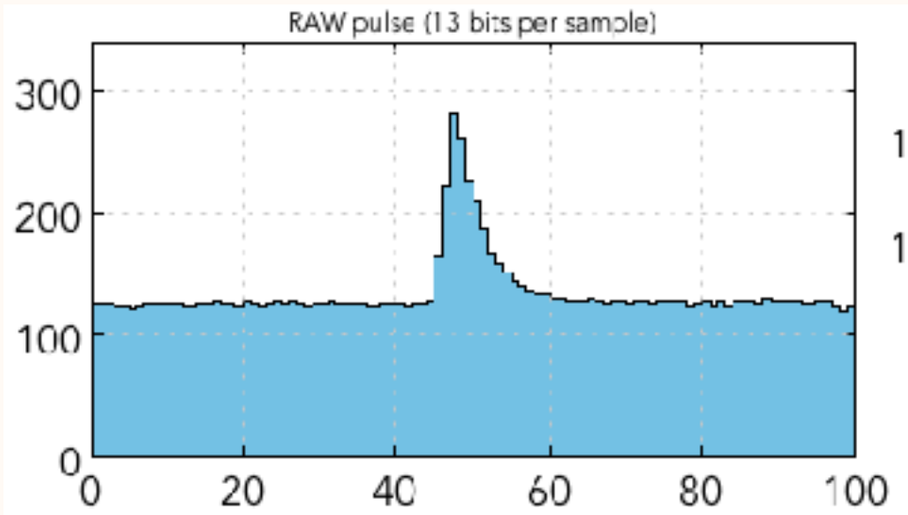
Future Development



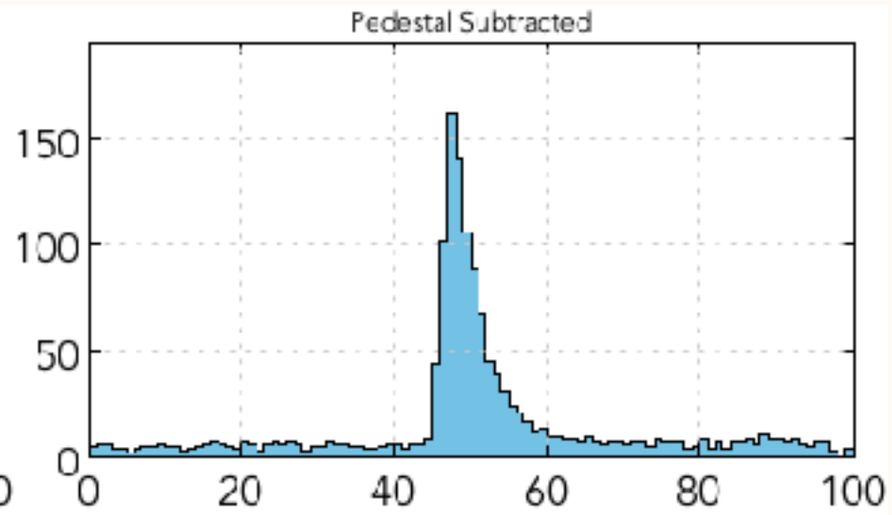
- With Thread affinity (2 JVMs on 32 core), reconstruction rate is **385 Hz**
- Resolving issues with thread contention can scale this to **500 Hz** per node
- Online farm with **10-15** nodes will be able to run online reconstruction

Data Compression

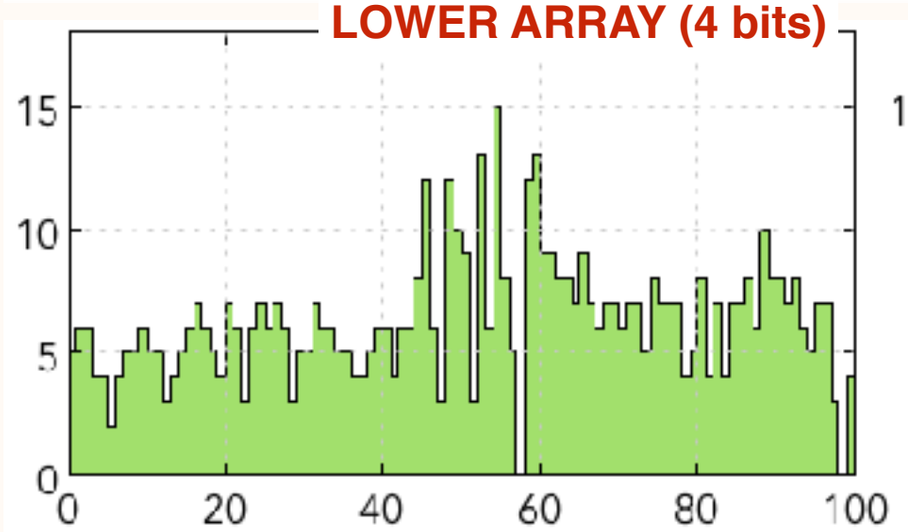
RAW PULSE (200 Bytes)



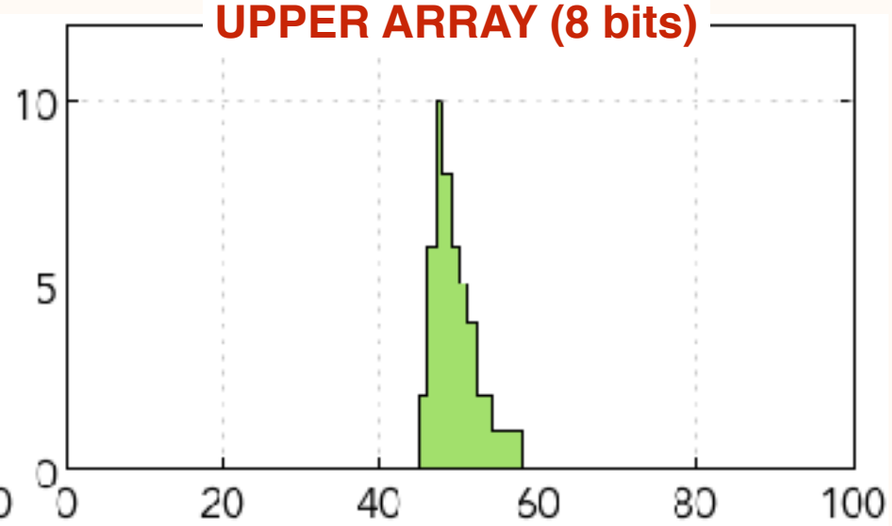
PEDESTAL SUBTRACTED



LOWER ARRAY (4 bits)



UPPER ARRAY (8 bits)



- **Pulse bit packing**
  - ✓ separating lower 4 bits and upper 8 bits of the pulse
  - ✓ encode lower 4 bits into 50 byte array (or 25 bit for lossy)
  - ✓ append non-zero elements of the upper 8 bit array to the pulse
  - ✓ further compression (LZ4) reduces data size even further

CLAS NOTE 2017-007

Method	File Size	Ratio
Raw	1.87 MB	1.00
Raw (LZ4)	0.81 MB	0.43
Raw (GZIP)	0.71 MB	0.37
Bit Packed	0.63 MB	0.34
Bit Packed (LZ4)	0.55 MB	0.29
Bit Packed (GZIP)	0.48 MB	0.26
Bit Packed Lossy	0.39 MB	0.21
Bit Packed Lossy (LZ4)	0.30 MB	0.16
Bit Packed Lossy (GZIP)	0.27 MB	0.14

- **Bit packing efficiency**
  - ✓ lossless packing provides data compression **~1/3** (**~1/5** with compression)
  - ✓ lossy packing provides compression ratio of **~1/5** (**~1/7** with compression)
  - ✓ lossy packing for average sized pulse introduces a loss of **~0.2%-0.6%** of total integral
  - ✓ storing only surrounding area of the pulse (not all 100 bins) reduces data **~1/14**
  - ✓ mode 7 stores data in **12 bytes**, lossless partial waveform **16 bytes** (**38-42** bytes for lossy)

Summary

- Significant improvements to the code were done (mainly tracking) to improve reconstruction performance.
- Reconstruction was tested on new Haswell nodes with 2 track event sample and 300 Hz reconstruction rate was achieved.
- Scaling curve shows that all services work well (without thread contention)
- Further work is needed to improve performance (500 Hz possibly)

- Pulse bit packing algorithm was developed to reduce event size while writing full FADC pulses. Significant reduction in size up to 7 times.
- Possible to take data in RAW pulse mode (at least some times).
- Partial waveform bit packing will increase by ~25% (over mode 7)