

Digital Data Acquisition for Nuclear Physics

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- SkuTek DAQ has the following qualities
 - [High resolution](#) appropriate for any detector, including HPGe.
 - [High throughput](#) pipelined DSP firmware.
 - [Real time energy](#) windows.
 - [Real time trigger](#).
 - [Time & Trigger Control Link](#) (DGS/GRETINA TTCL): trigger, time stamp, sampling clock.
 - [White Rabbit](#) clock input (under development).
 - [Board control and monitoring with Embedded Linux](#).
 - [Interface with EPICS](#), embedded web page, Jupyter, or SSH + Command Line.
 - [Event streaming](#), either 1G or 10G, in parallel from each digitizer.
 - [End-to-end data](#) streaming and management, from the digitizers [to NERSC](#).
 - Up to 100G with hardware acceleration with commercial FPGA boards.

Component Boards of SkuTek Large Scale DAQ

Digitizer with 32 channels

Logic & Trigger Module Serving 320 Channels

Gigabit
Ethernet
LVDS link

32 Inputs

Analog out
NIM I/O



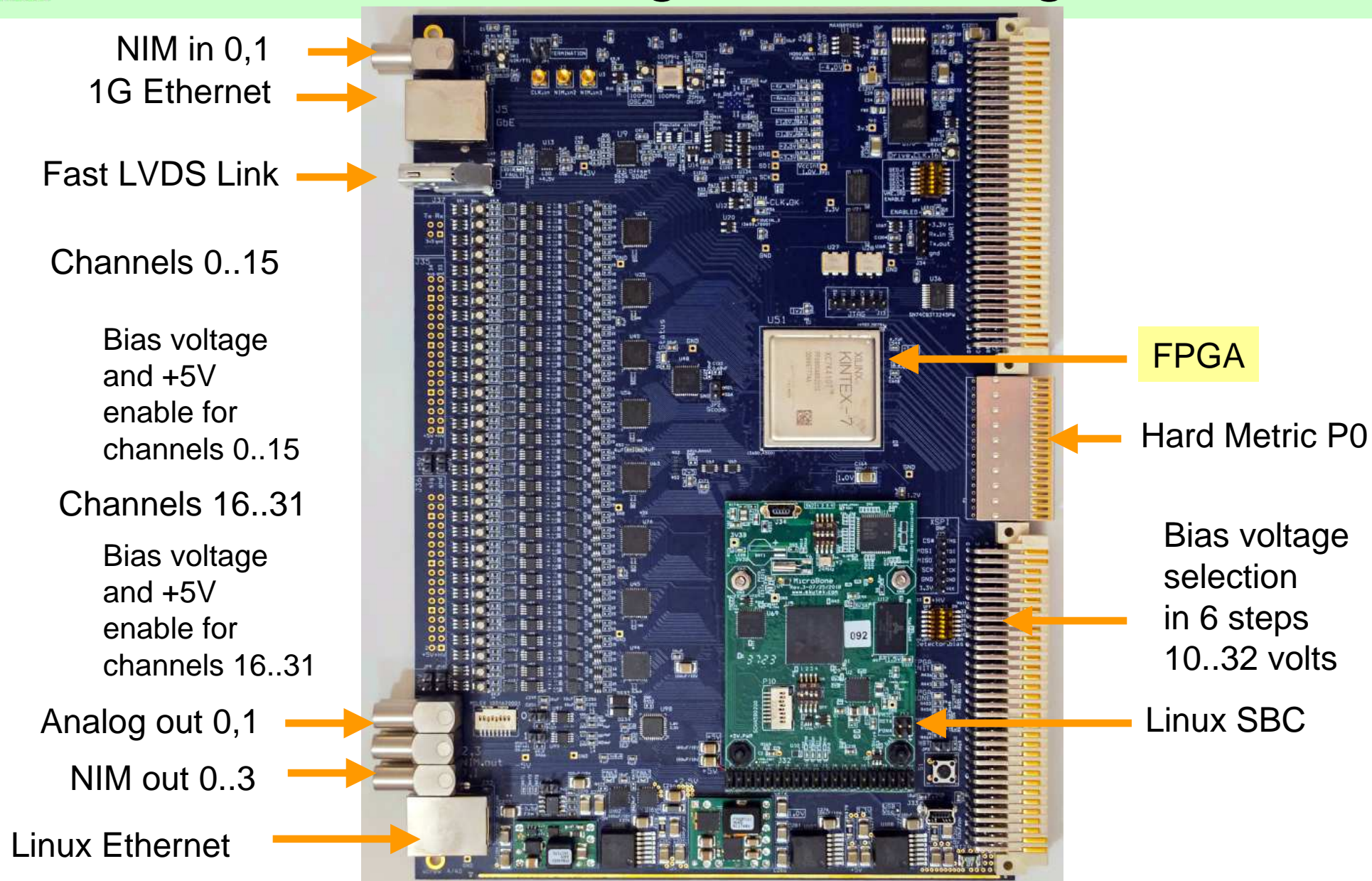
Gigabit
Ethernet

Fast
LVDS
links

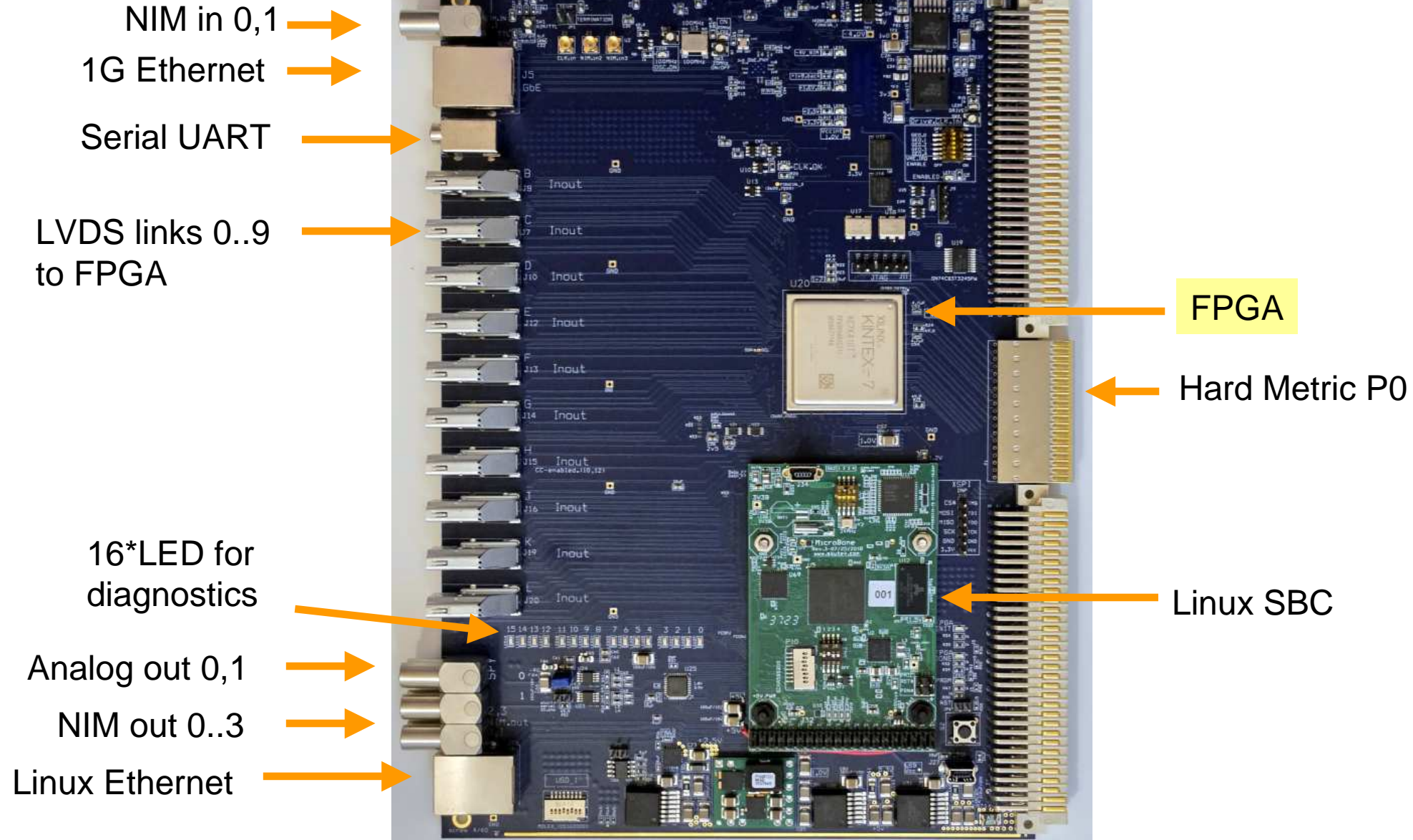
Analog out
NIM I/O



32-Channel Digitizer for Large Scale DAQ



Logic & Trigger for Large Scale DAQ



Event Streaming With 10G Optical Ethernet.

32-Channel Digitizer

Rear Transition Module (RTM)

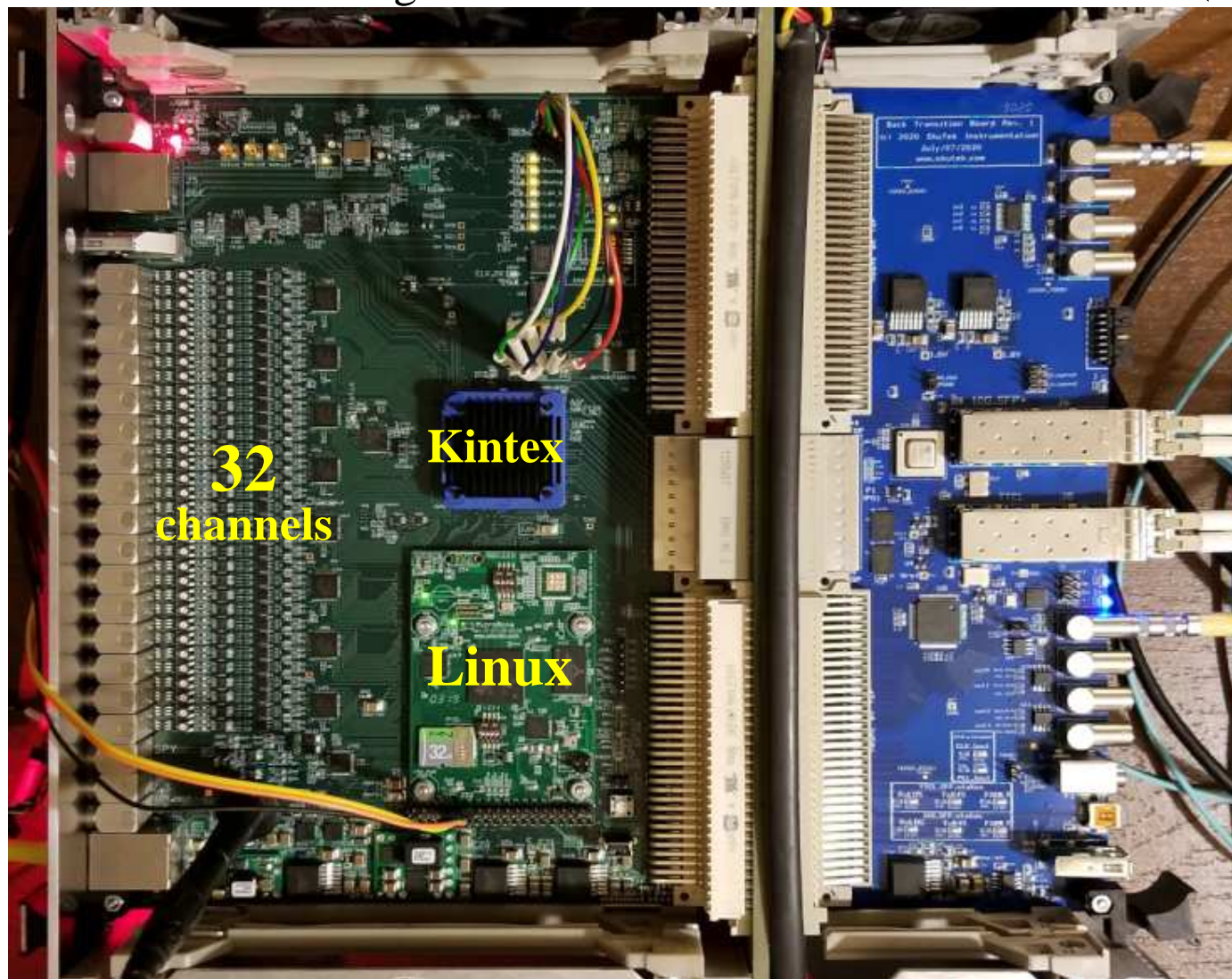
1 GbE (FPGA)

LVDS link

32 Analog
inputs

2 Analog
outputs

1 GbE (Linux)



4 * NIM in

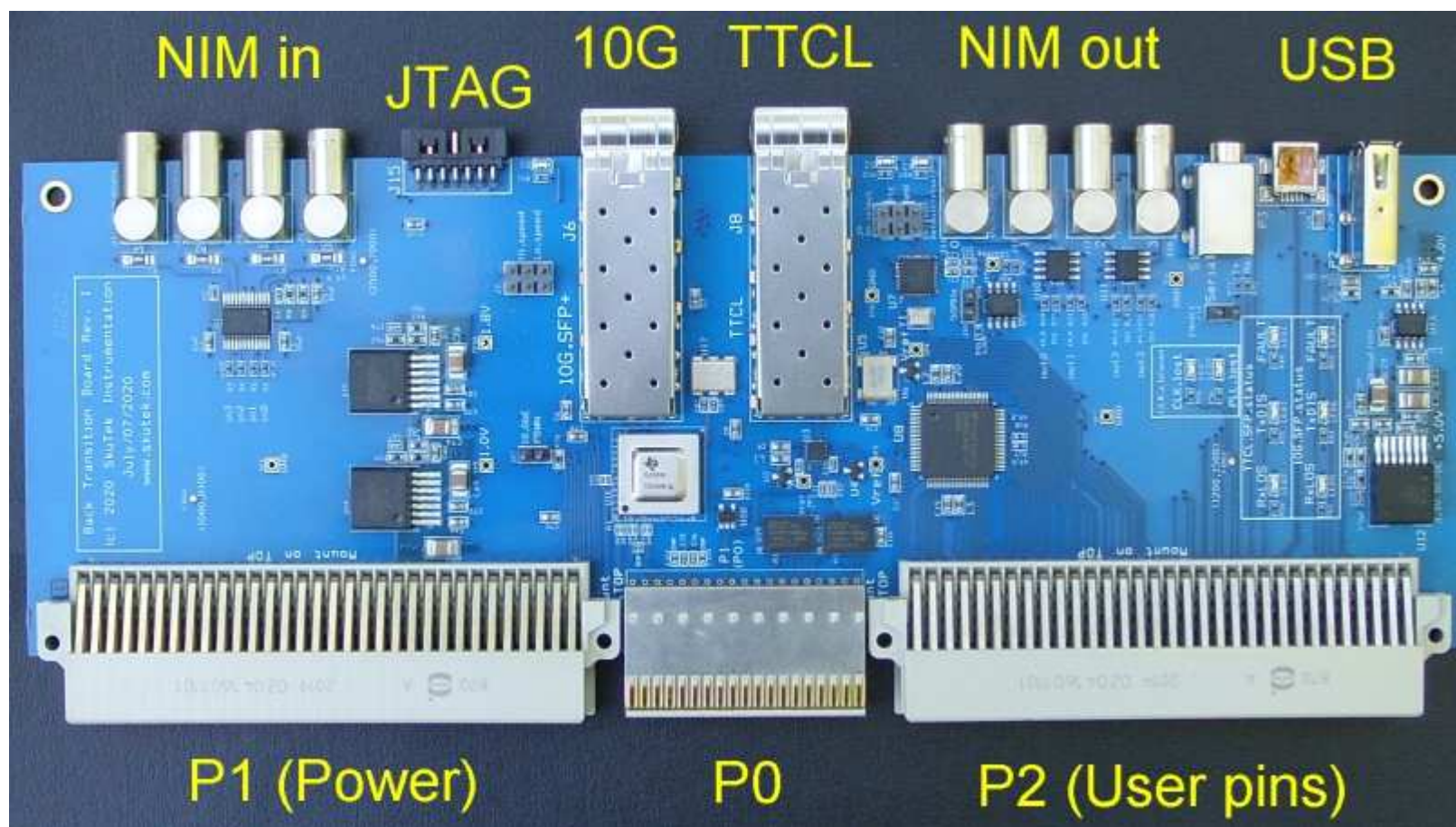
10 G Ethernet
Optical TTCL
**Compatible with
GRETA**

4 * NIM out

Serial UART
(Linux)

High Speed Rear Transition Module (RTM)

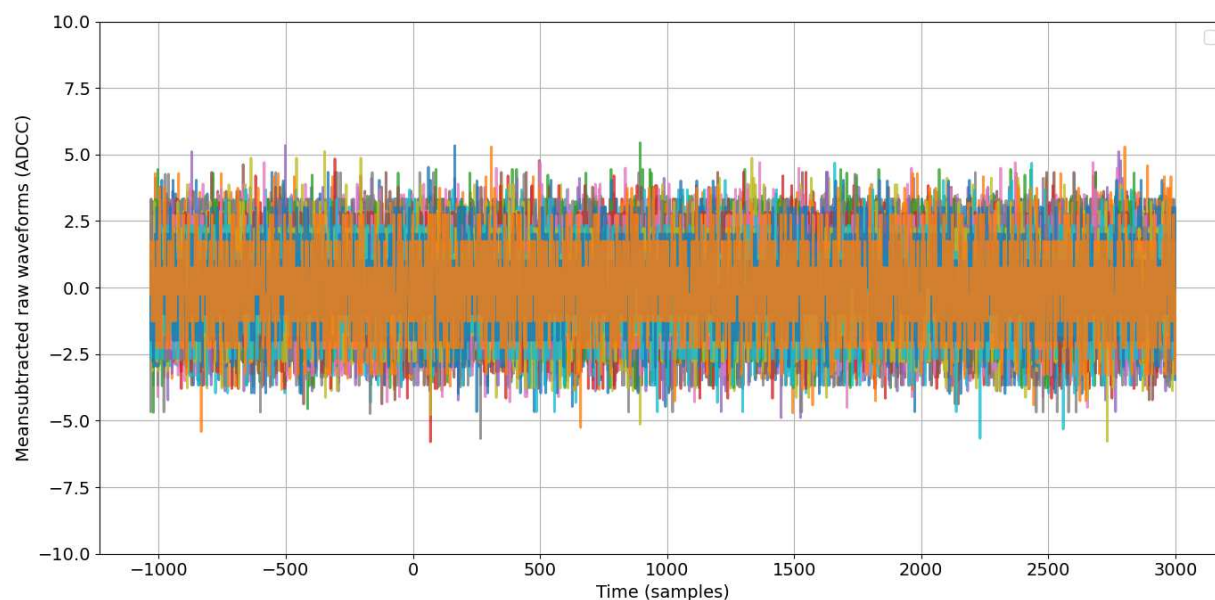
- RTM provides system integration with Nuclear Physics framework.
- High speed 10G data streaming with GRETA-compatible binary format.
- White Rabbit support is under development.



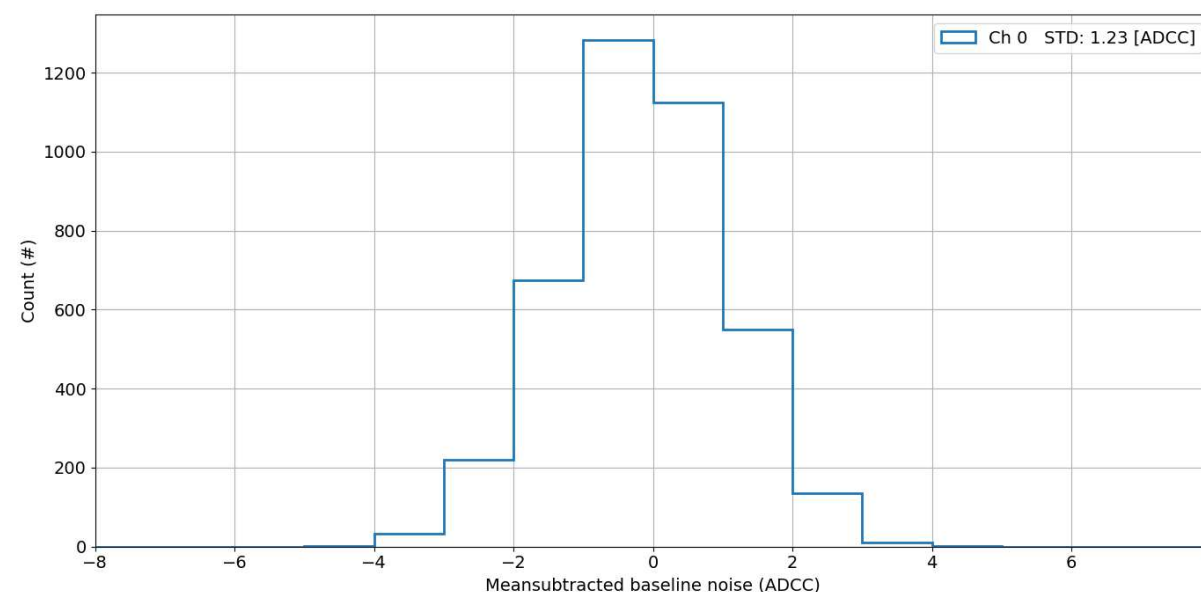
Analog to Digital: Very Low Noise

- Signal range = 2 volts, digitized with 14 bits @ 100 MSPS.
- $1 \text{ LSB} = 2 \text{ V} / 16\text{k} = 122 \mu\text{V}$

Noise waveforms from 32 channels



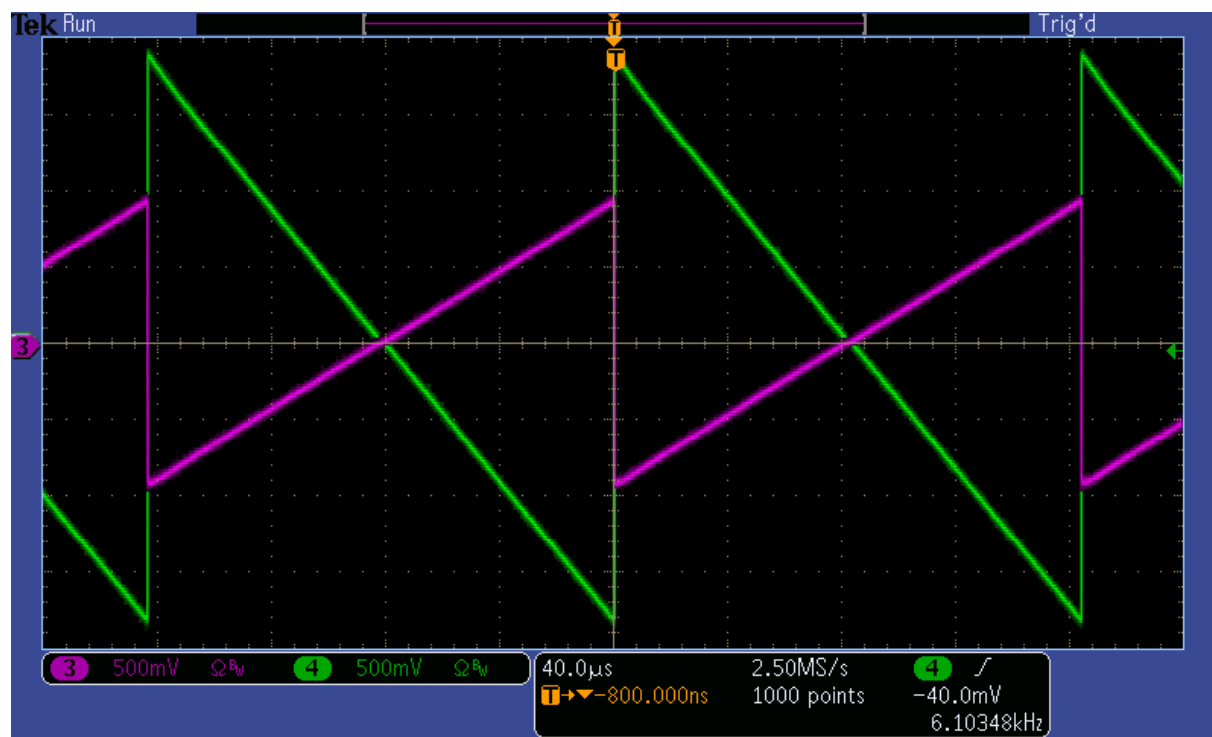
Noise RMS = 1.23 LSB = 150 μV



Digital to Analog: Very High Convenience

- Signal range = 2 volts, synthesized with 14 bits @ 100 MSPS. (“Inverse digitization”.)
- Any signal can be synthesized and examined with a scope: any input, any internal trigger, multiplicity, energy sum, etc.
- Logic Module can synthesize any input from any slave digitizer, **while the input stays connected.**

Two analog reconstruction channels, 14 bits @ 100 MSPS



- In this figure, two SPY channels are outputting two internally generated sawtooth signals.
- SPY outputs were connected to a Tek scope.

Recording your data

Each 32-Channel Digitizer can stream data at 10G

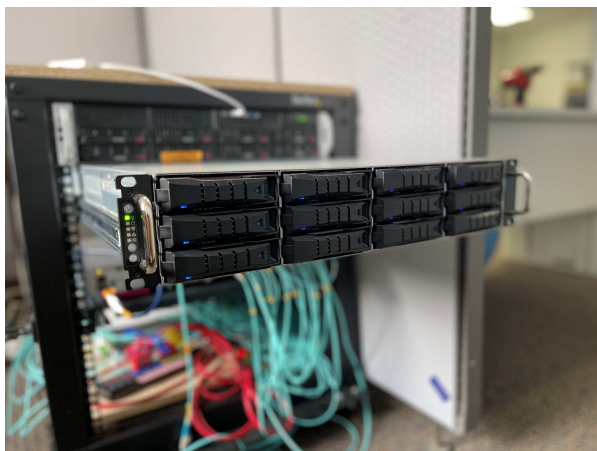
1 Digitizer = 10G = 1.2GB/s ~ **140K waveforms per second**

4 Digitizers = 40G = 5GB/s ~ **700K waveforms per second**

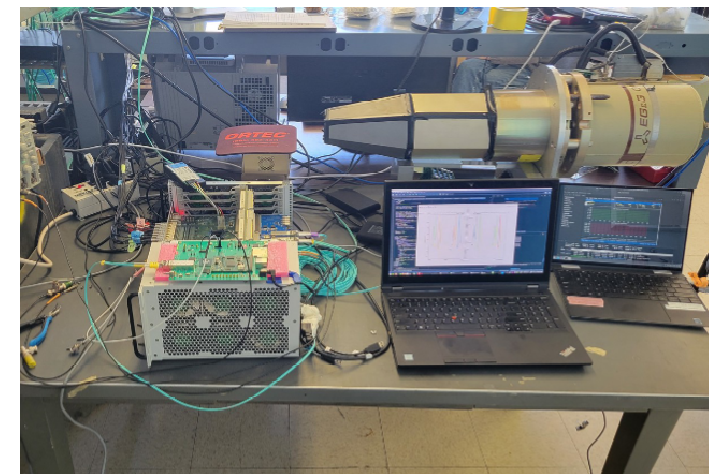
10 Digitizers = 100G = 12GB/s ~ **1.4M waveforms per second**

**Assuming 4096 Samples per waveform*

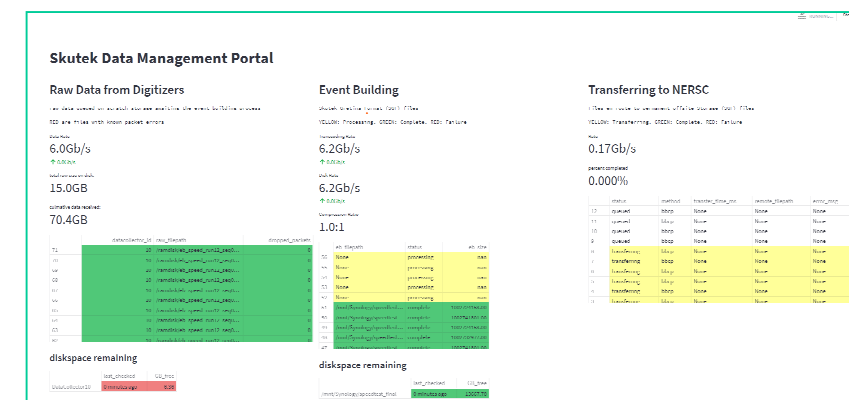
Our Data Management Solutions will receive the streams and transfer your data to NERSC or another supercomputing center



Data Collector servers receive event streams and convert them to files



10G Data Collection Demonstration at ANL



A Web-based Interface will let you monitor your data as it's collected, processed, and transferred to NERSC

- Resolution of our digitizers was **equivalent** to LBNL digitizers with HPGe Gammasphere detectors.
- **Fast readout** using 1G or 10G Ethernet links directly from the digitizers.
- Setup and **monitoring** using the on-board **Linux**, separate from the fast readout.
- **Device control** with EPICS, Jupyter, embedded web pages, or Command Line.

Integration with High Volume Data Management:

- Digitizers will primarily serve as massive data sources. High volume data offloading will be crucial. We will utilize Data Collector Computers developed under Data Management grant DE-SC0021502. Under this grant we are developing data transfer rates up to 100 gigabits per second (GBPS) all the way up to NERSC.
- Even higher rates will be provided with ESNET (*Efficient High-Performance Data Transfer Over ESnet for Massive-Scale Data Analytics*, DE-SC0024797, with Jeff Maggio serving as the PI). We envision data transfer rates approaching 400 GBPS.
- **Ready to serve your experiments!**

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