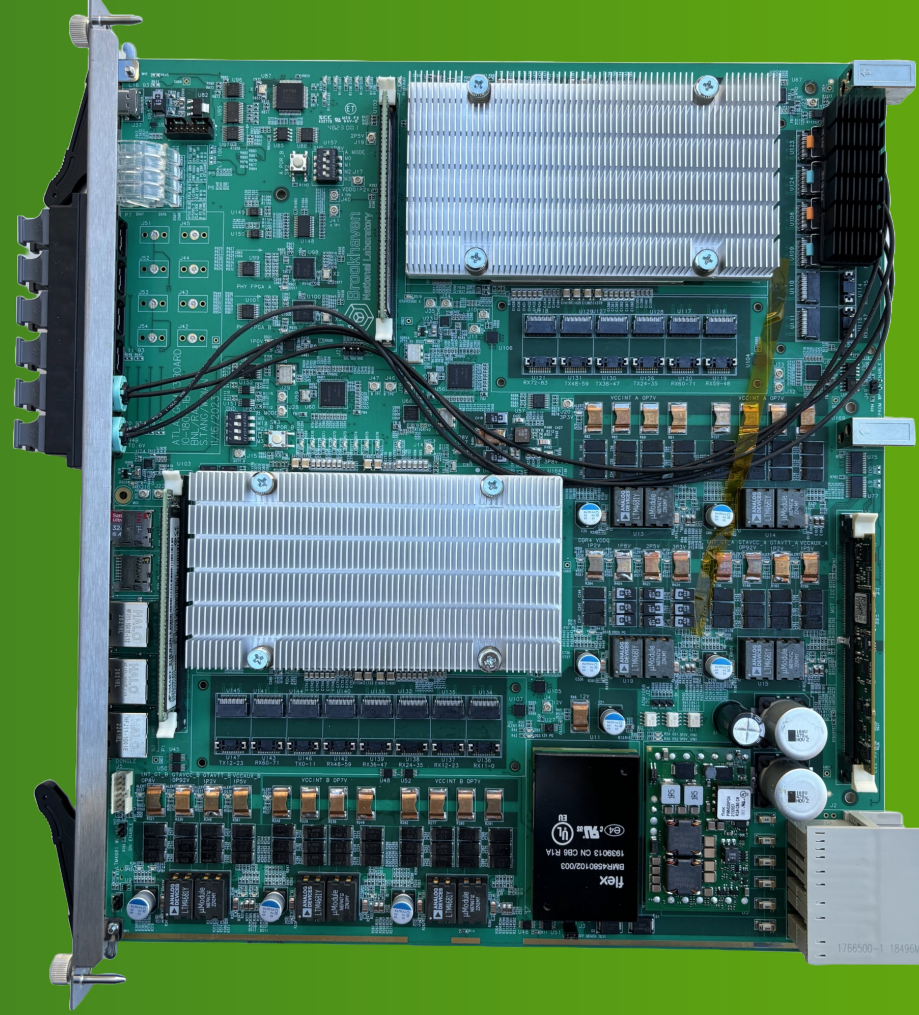
Integration Testing of the Global Common Modules for the ATLAS Global Trigger

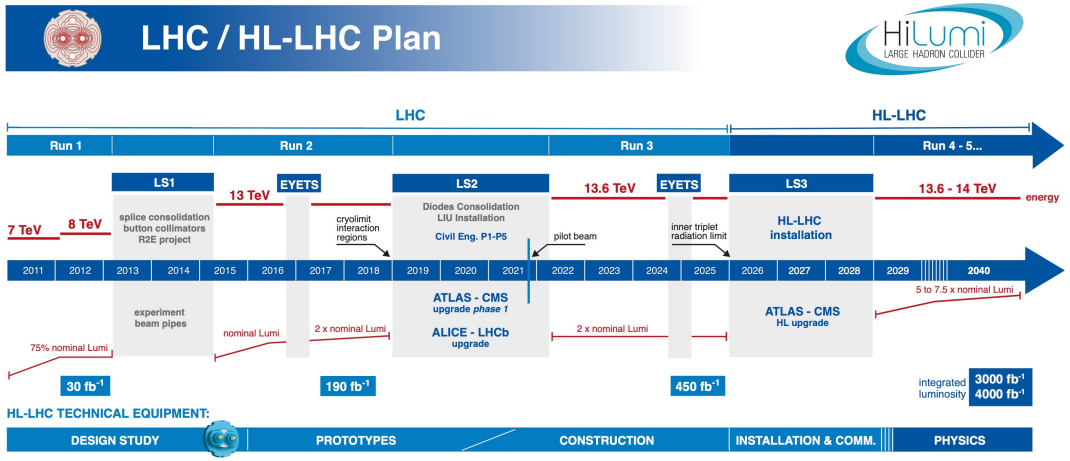


Tim Mathew, UO
Michael Begel, Shaochun Tang, Eric Buschmann,
Marcos Silva-Oliveira

US LUA Annual Meeting
Dec 18th, 2024

Brookhaven National Laboratory
U.S. DEPARTMENT OF ENERGY
UNIVERSITY OF OREGON
ATLAS EXPERIMENT

High Luminosity LHC



- ~10x the integrated luminosity
- 140-200 interactions per bunch crossing at 40 MHz

Necessitates upgrades to ATLAS

Physics Goals

Di-Higgs

Long-Lived Particles

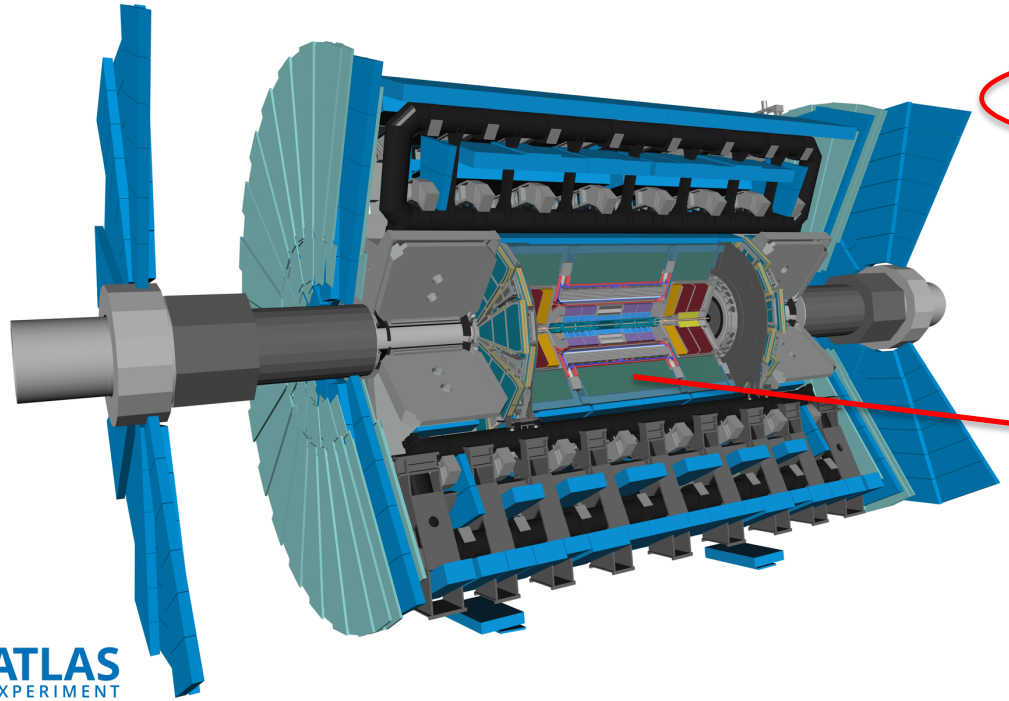
Dark Sectors

Many More!

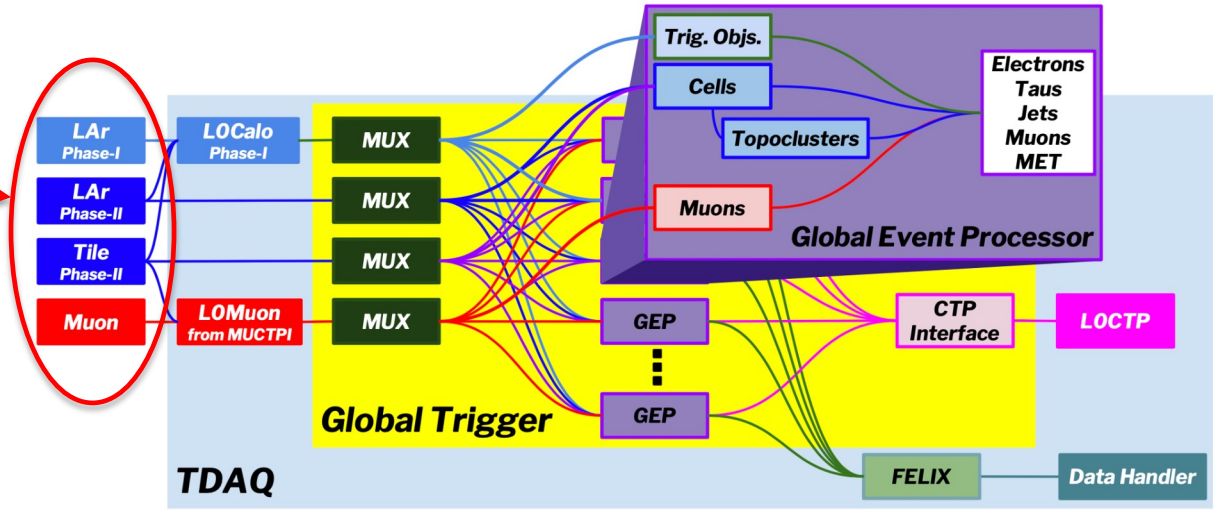
High Luminosity LHC: TDAQ Upgrades

ATLAS Trigger and Data Acquisition system (TDAQ)

Global Trigger: Offline-like capability for L0 Triggers

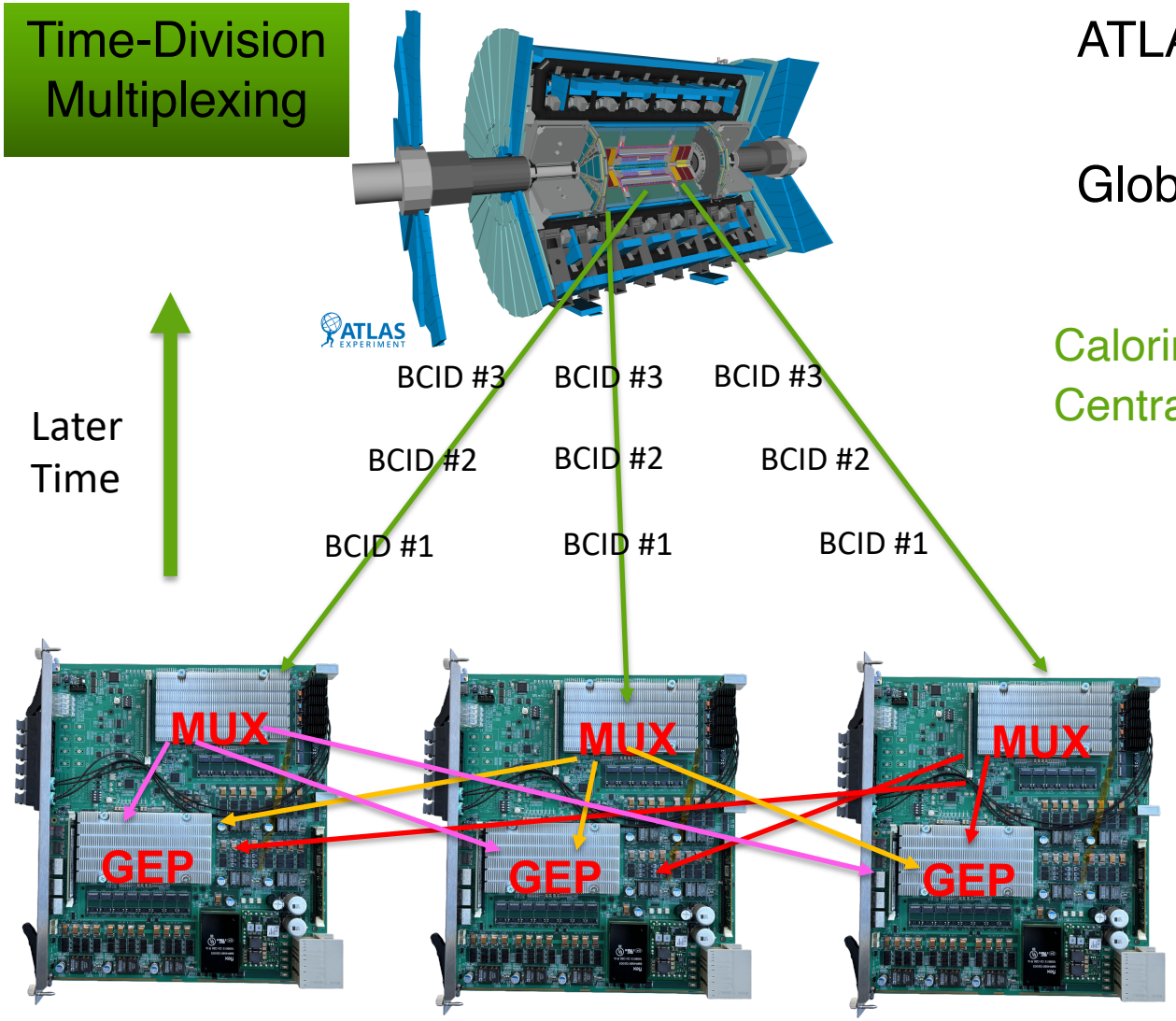


Calorimeter cells → Multiplexers → Global Event Processors → Central Trigger Processor



High Luminosity LHC: TDAQ Upgrades

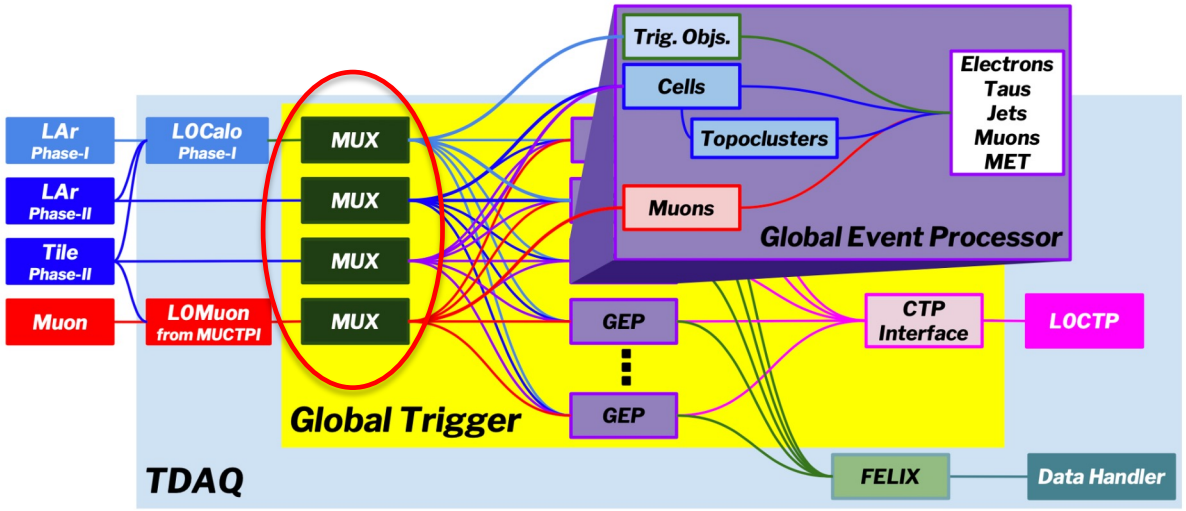
Time-Division Multiplexing



ATLAS Trigger and Data Acquisition system (TDAQ)

Global Trigger: Offline-like capability for L0 Triggers

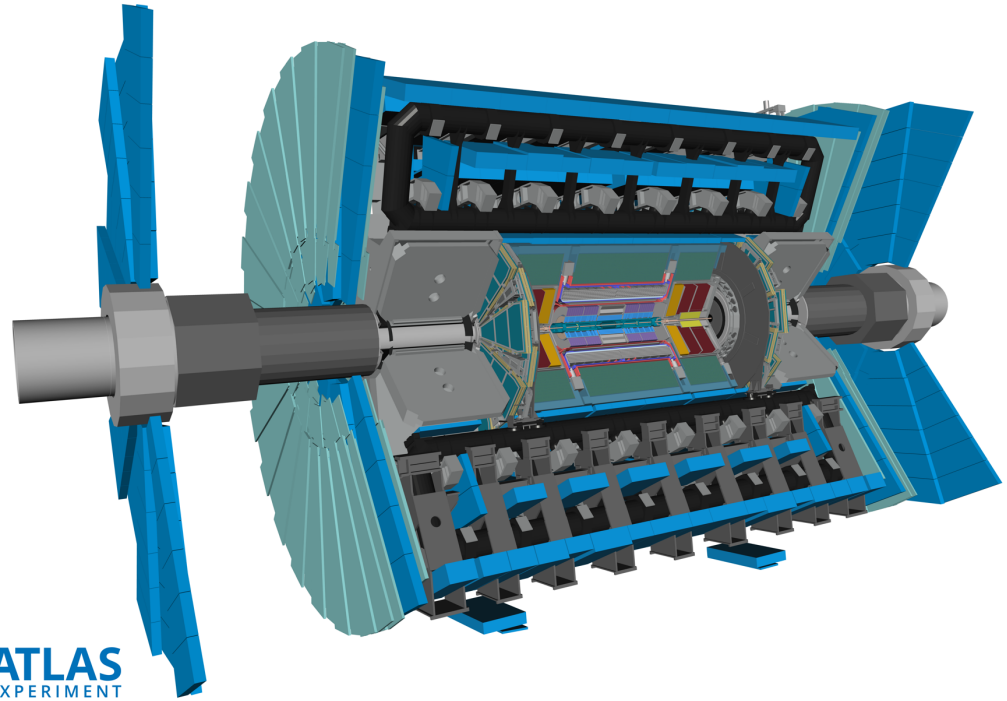
Calorimeter cells → Multiplexers → Global Event Processors → Central Trigger Processor



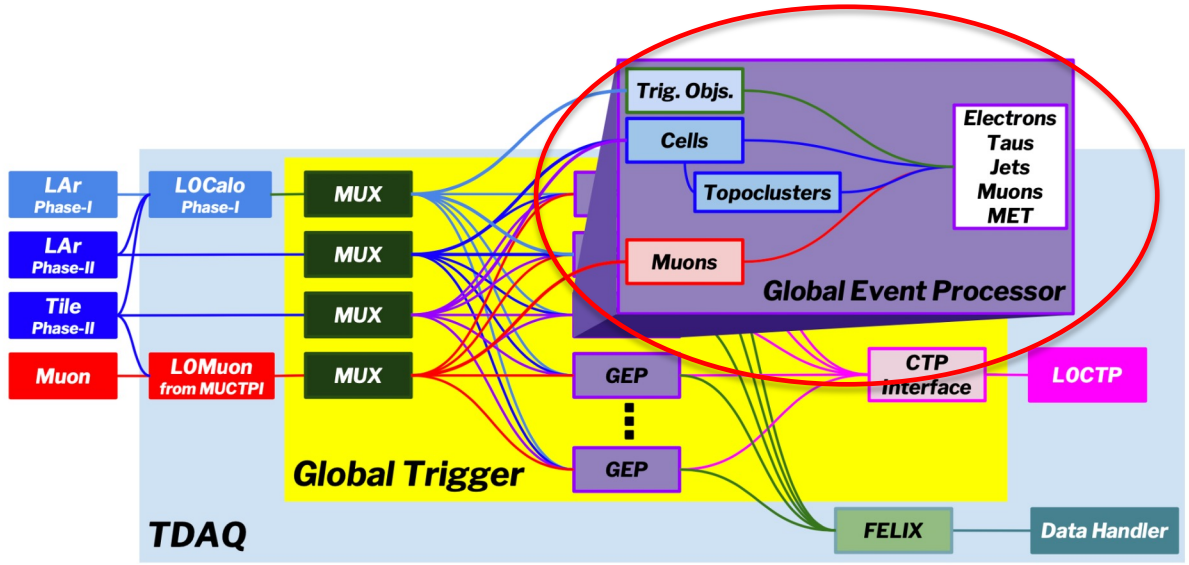
High Luminosity LHC: TDAQ Upgrades

ATLAS Trigger and Data Acquisition system (TDAQ)

Global Trigger: Offline-like capability for L0 Triggers



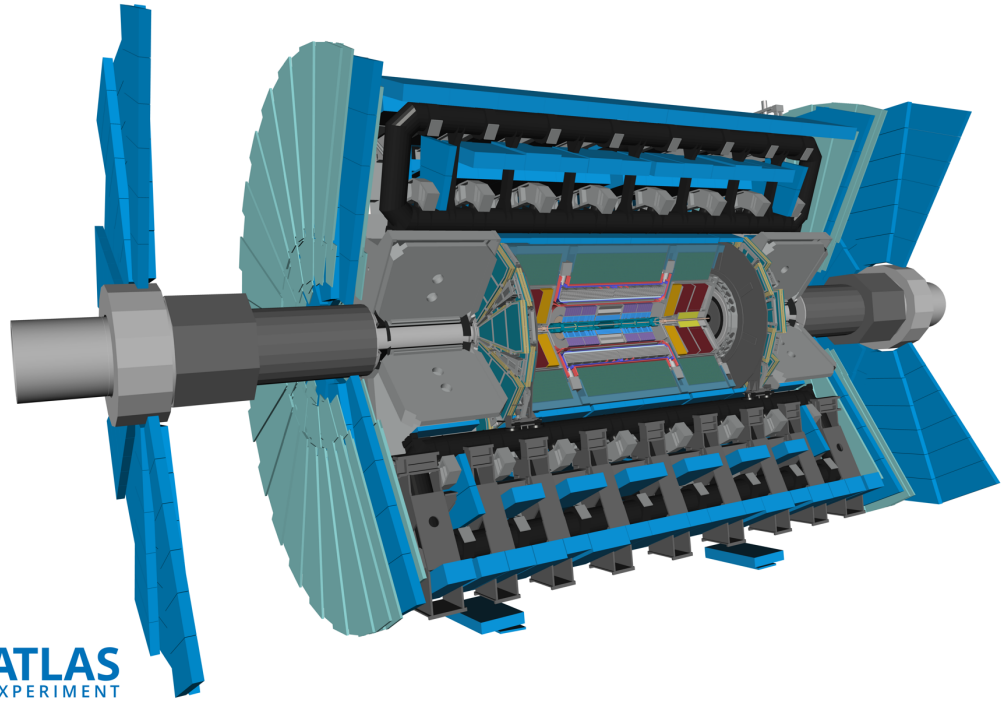
Calorimeter cells → Multiplexers → Global Event Processors → Central Trigger Processor



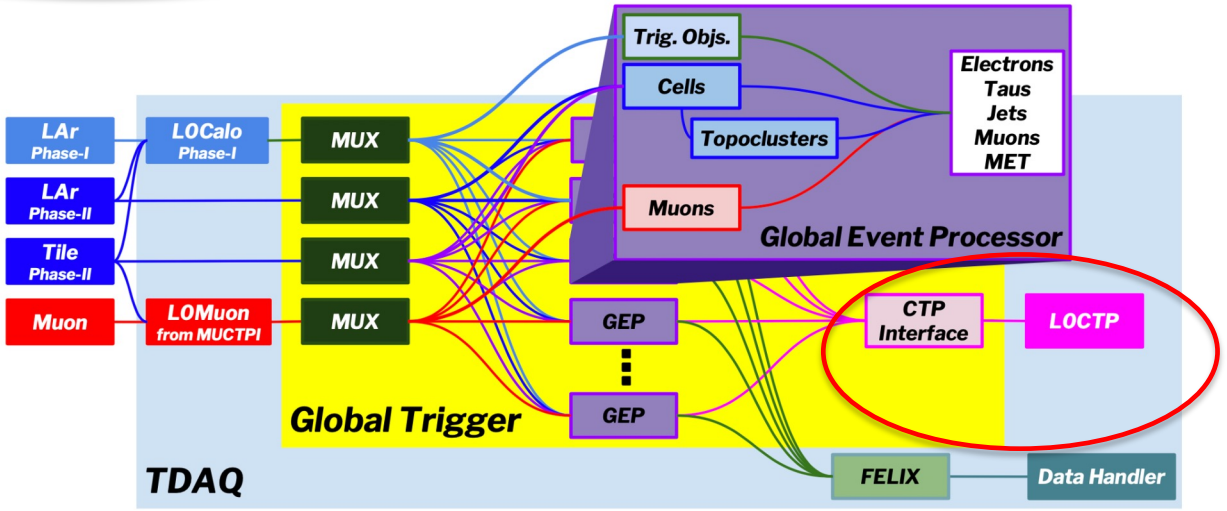
High Luminosity LHC: TDAQ Upgrades

ATLAS Trigger and Data Acquisition system (TDAQ)

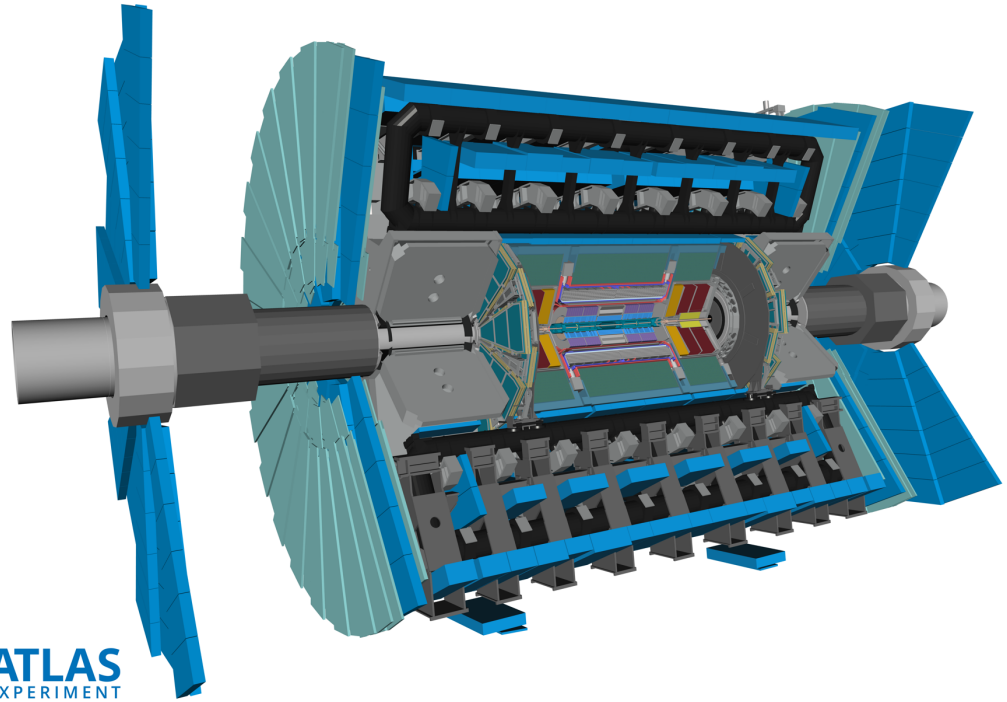
Global Trigger: Offline-like capability for L0 Triggers



Calorimeter cells → Multiplexers → Global Event Processors → Central Trigger Processor



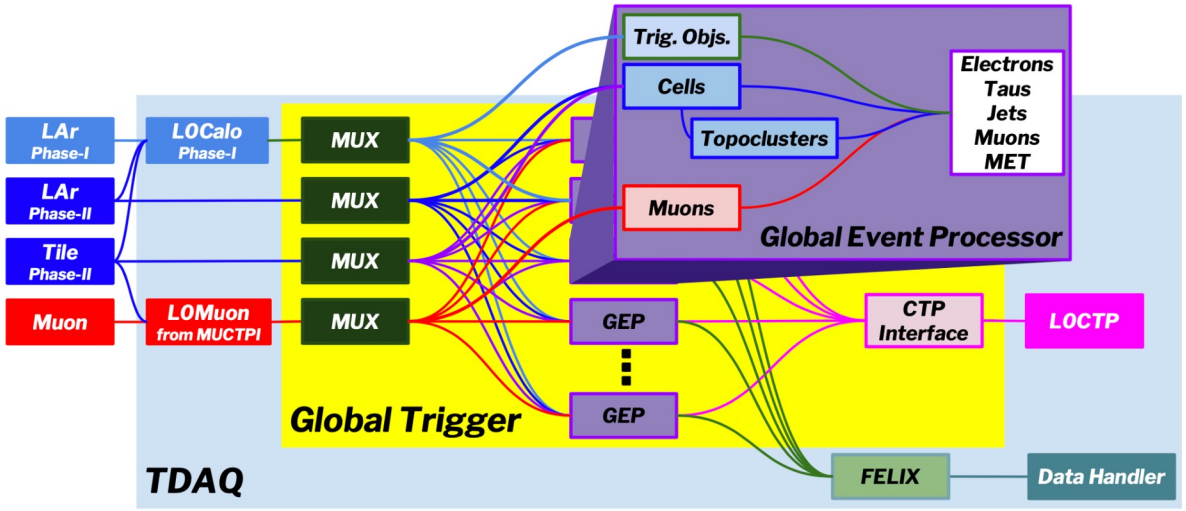
High Luminosity LHC: TDAQ Upgrades



ATLAS Trigger and Data Acquisition system (TDAQ)

Global Trigger: Offline-like capability for L0 Triggers

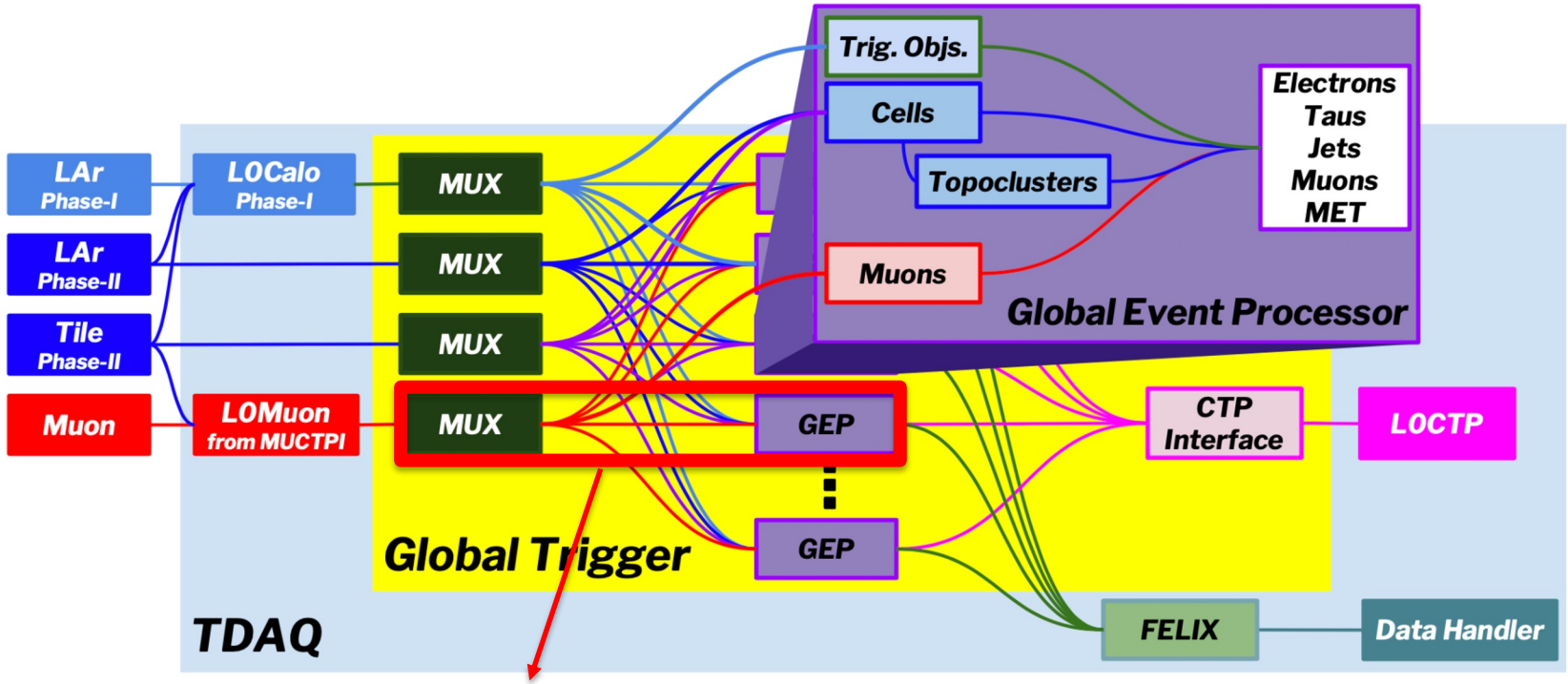
Calorimeter cells → Multiplexers → Global Event Processors → Central Trigger Processor



~4 μs effective time to process an event

Critical that this system works!

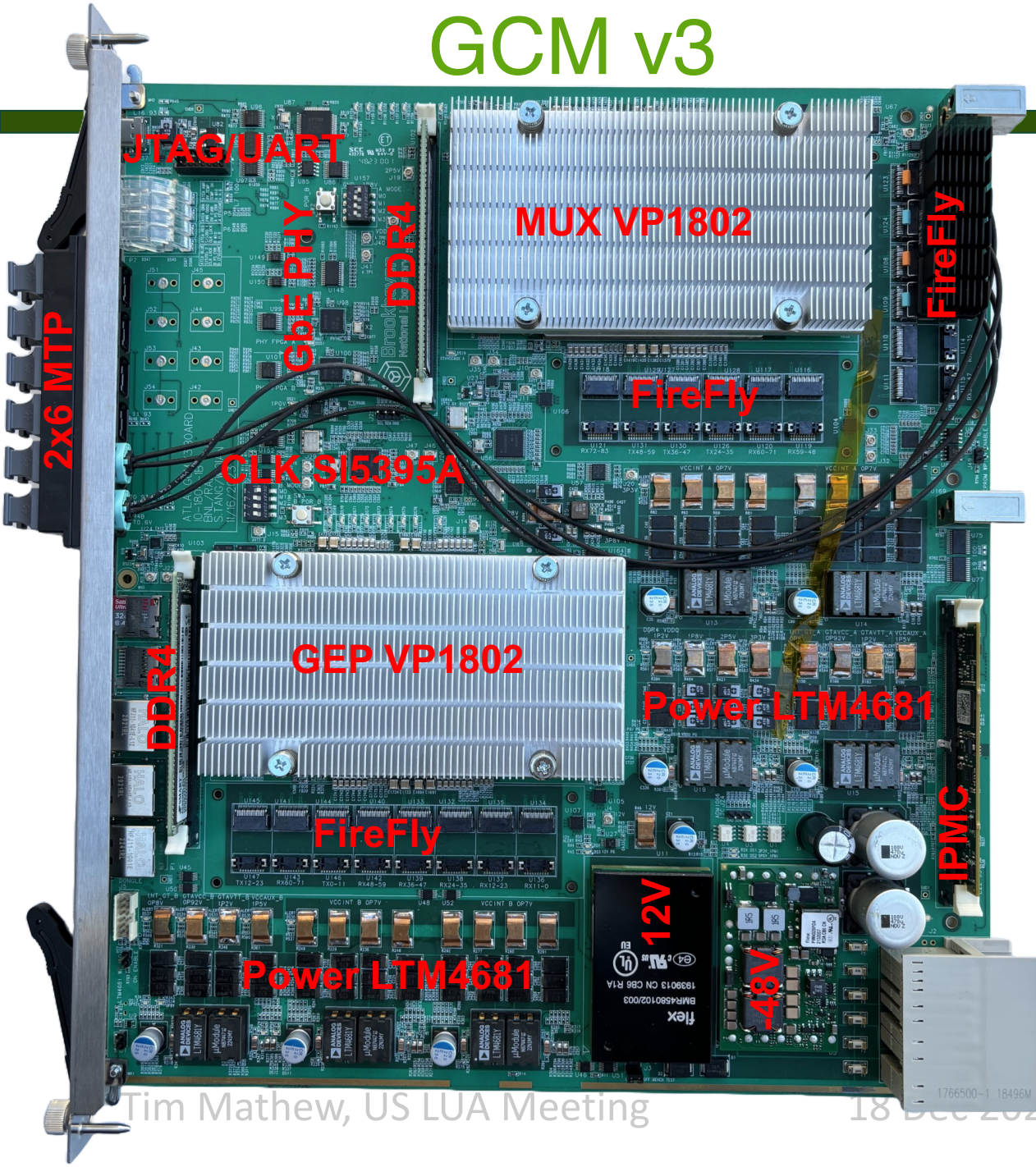
Global Trigger: Global Common Module (GCM)



GCM: Common hardware platform for the Global Trigger FPGAs

- USA15 → power and cooling constraints
- ~60 GCM's with 2 FPGA's each
- Current version designed and tested at BNL

GCM v3



- 2 SD slots
- Petalinux, Almalinux9
- 20 Firefly Modules 25 Gb/s
- 2 16GB DDR4
- 3 GbE: MUX, GEP, IPMC
- USB-C

Testing of the GCM's

Currently in progress

Production Testing

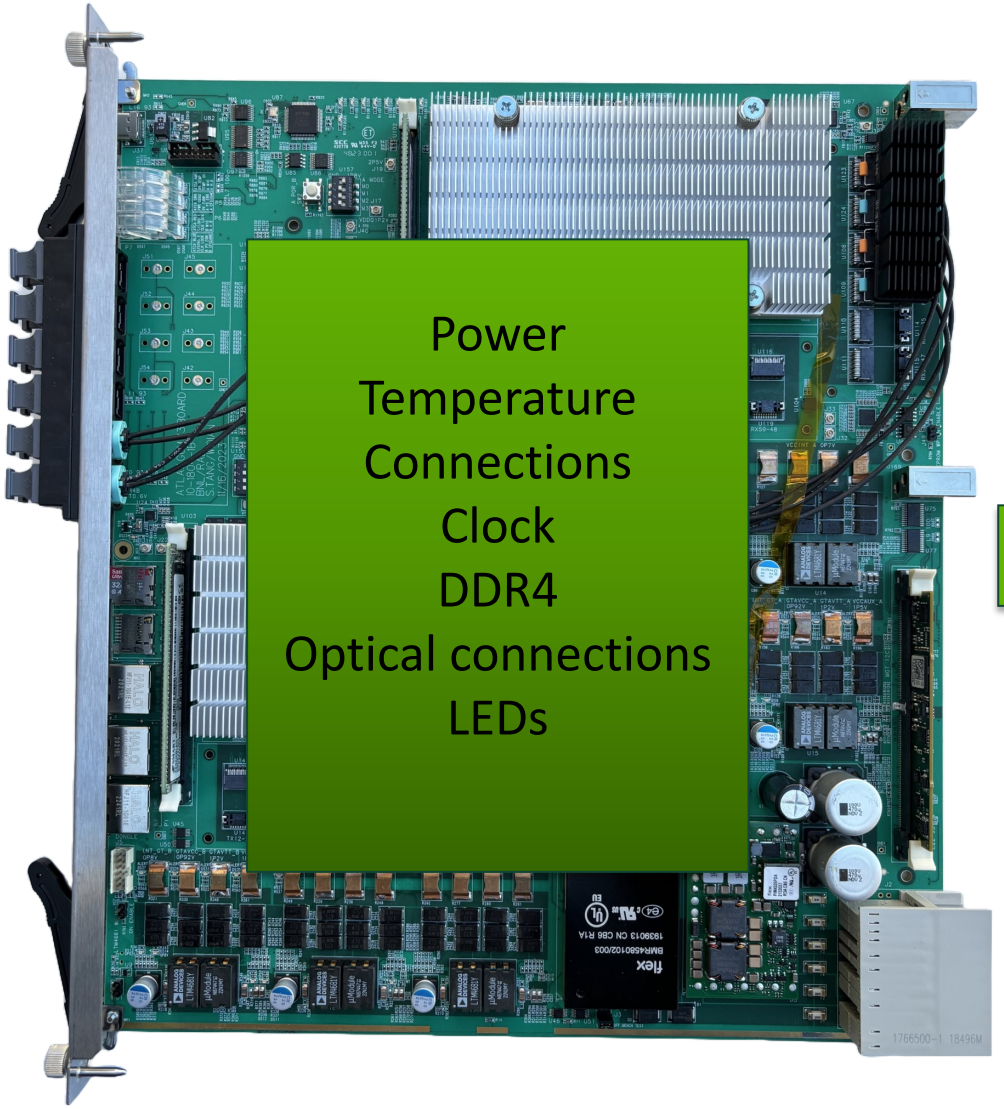
- ~60 GCM's to fabricate
- Hardware needs to be tested and cleared for use

In Preparation

Integration Testing

- Inter-GCM communication
- Sending data across GCM's through MUX

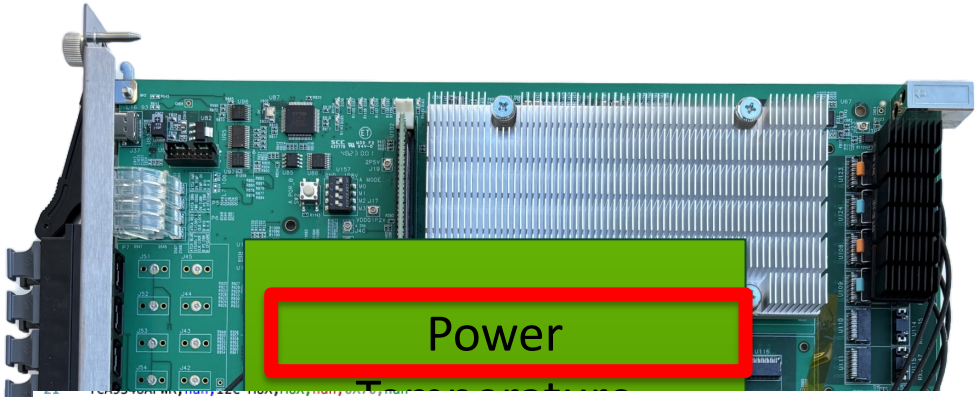
Production Testing



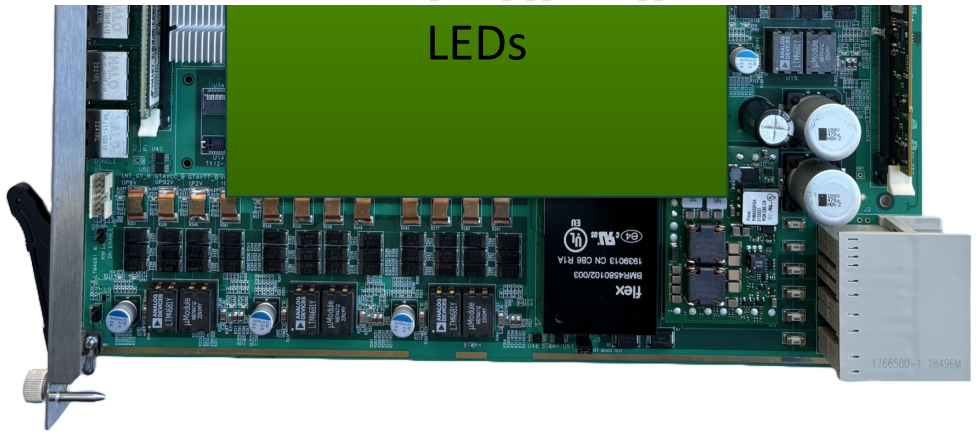
Reliable testing package loaded in Linux to run at startup

- Simple
- Limited dependencies
- Modular
- Clear communication and direction for production facility

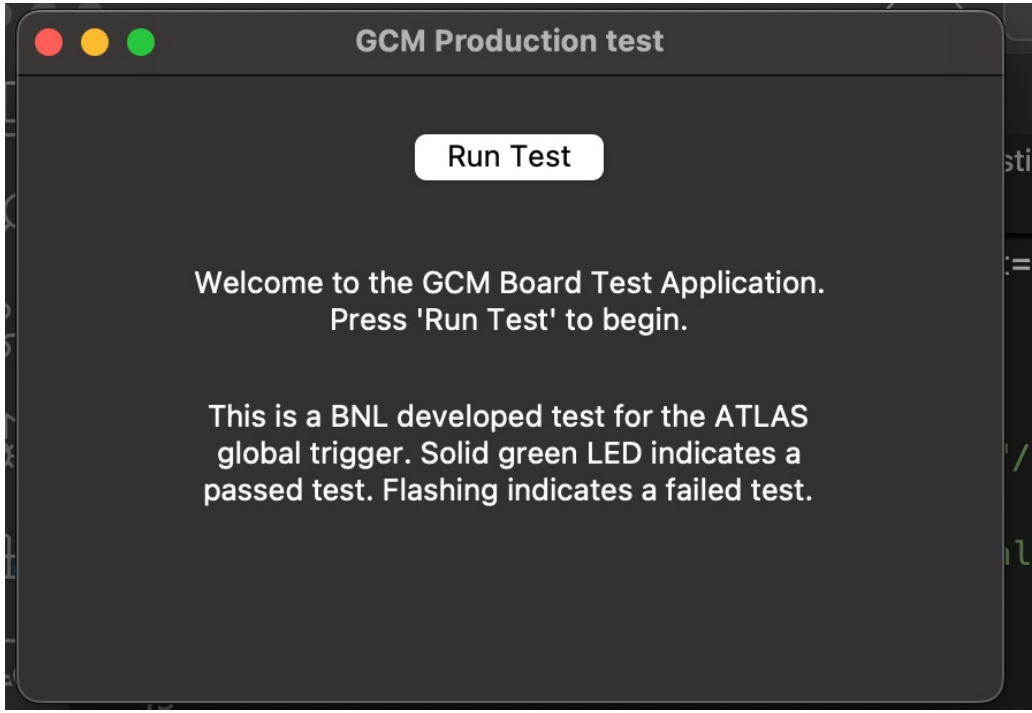
Production Testing



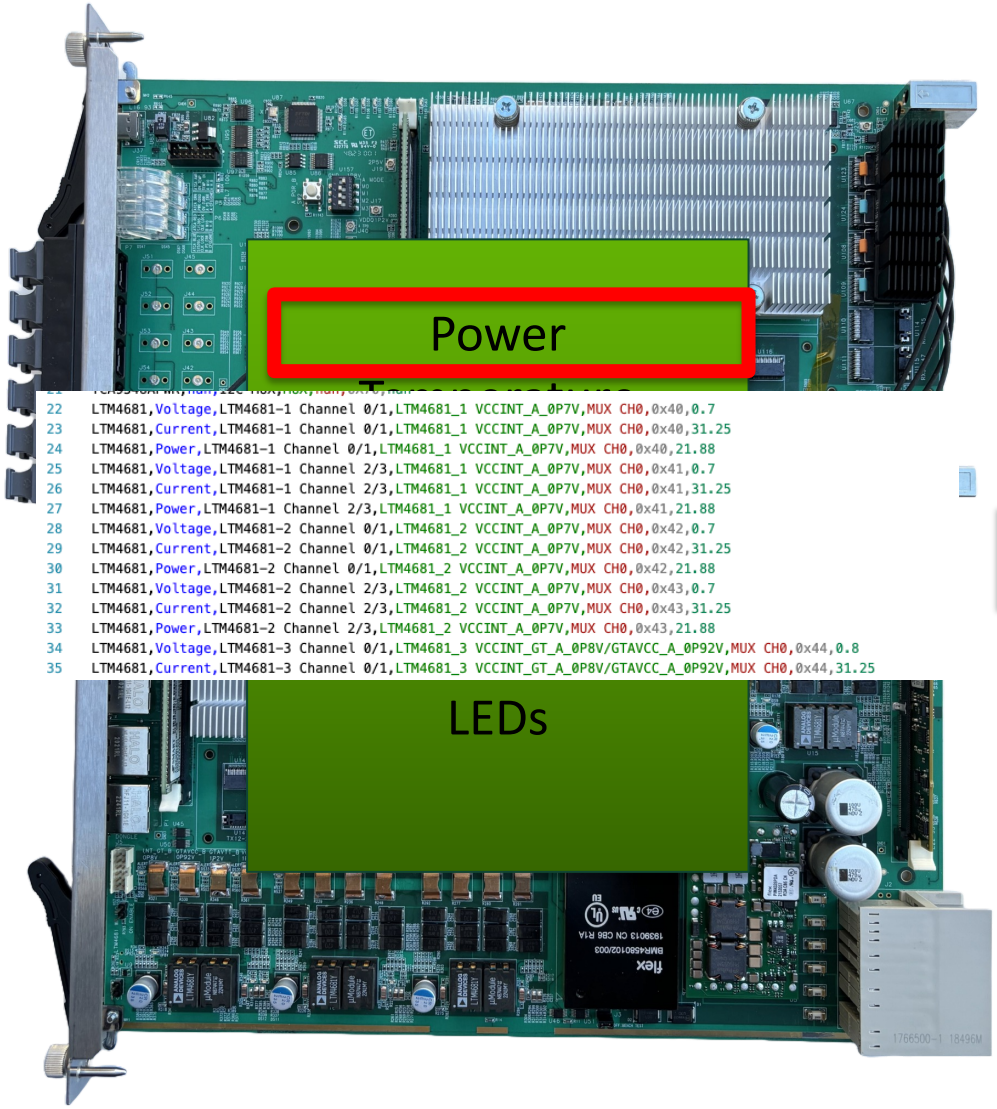

```
LTM4681,Voltage,LTM4681-1 Channel 0/1,LTM4681_1 VCCINT_A_0P7V,MUX CH0,0x40,0.7
LTM4681,Current,LTM4681-1 Channel 0/1,LTM4681_1 VCCINT_A_0P7V,MUX CH0,0x40,31.25
LTM4681,Power,LTM4681-1 Channel 0/1,LTM4681_1 VCCINT_A_0P7V,MUX CH0,0x40,21.88
LTM4681,Voltage,LTM4681-1 Channel 2/3,LTM4681_1 VCCINT_A_0P7V,MUX CH0,0x41,0.7
LTM4681,Current,LTM4681-1 Channel 2/3,LTM4681_1 VCCINT_A_0P7V,MUX CH0,0x41,31.25
LTM4681,Power,LTM4681-1 Channel 2/3,LTM4681_1 VCCINT_A_0P7V,MUX CH0,0x41,21.88
LTM4681,Voltage,LTM4681-2 Channel 0/1,LTM4681_2 VCCINT_A_0P7V,MUX CH0,0x42,0.7
LTM4681,Current,LTM4681-2 Channel 0/1,LTM4681_2 VCCINT_A_0P7V,MUX CH0,0x42,31.25
LTM4681,Power,LTM4681-2 Channel 0/1,LTM4681_2 VCCINT_A_0P7V,MUX CH0,0x42,21.88
LTM4681,Voltage,LTM4681-2 Channel 2/3,LTM4681_2 VCCINT_A_0P7V,MUX CH0,0x43,0.7
LTM4681,Current,LTM4681-2 Channel 2/3,LTM4681_2 VCCINT_A_0P7V,MUX CH0,0x43,31.25
LTM4681,Power,LTM4681-2 Channel 2/3,LTM4681_2 VCCINT_A_0P7V,MUX CH0,0x43,21.88
LTM4681,Voltage,LTM4681-3 Channel 0/1,LTM4681_3 VCCINT_GT_A_0P8V/GTAVCC_A_0P92V,MUX CH0,0x44,0.8
LTM4681,Current,LTM4681-3 Channel 0/1,LTM4681_3 VCCINT_GT_A_0P8V/GTAVCC_A_0P92V,MUX CH0,0x44,31.25
```



Working version of package with complete control of the board!



Production Testing



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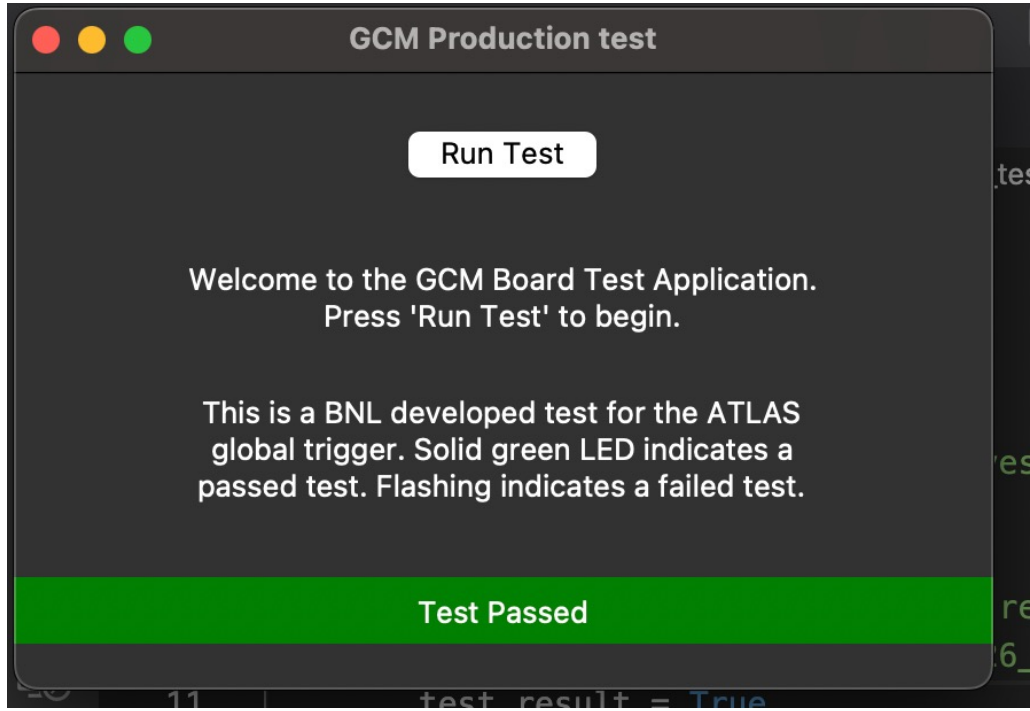
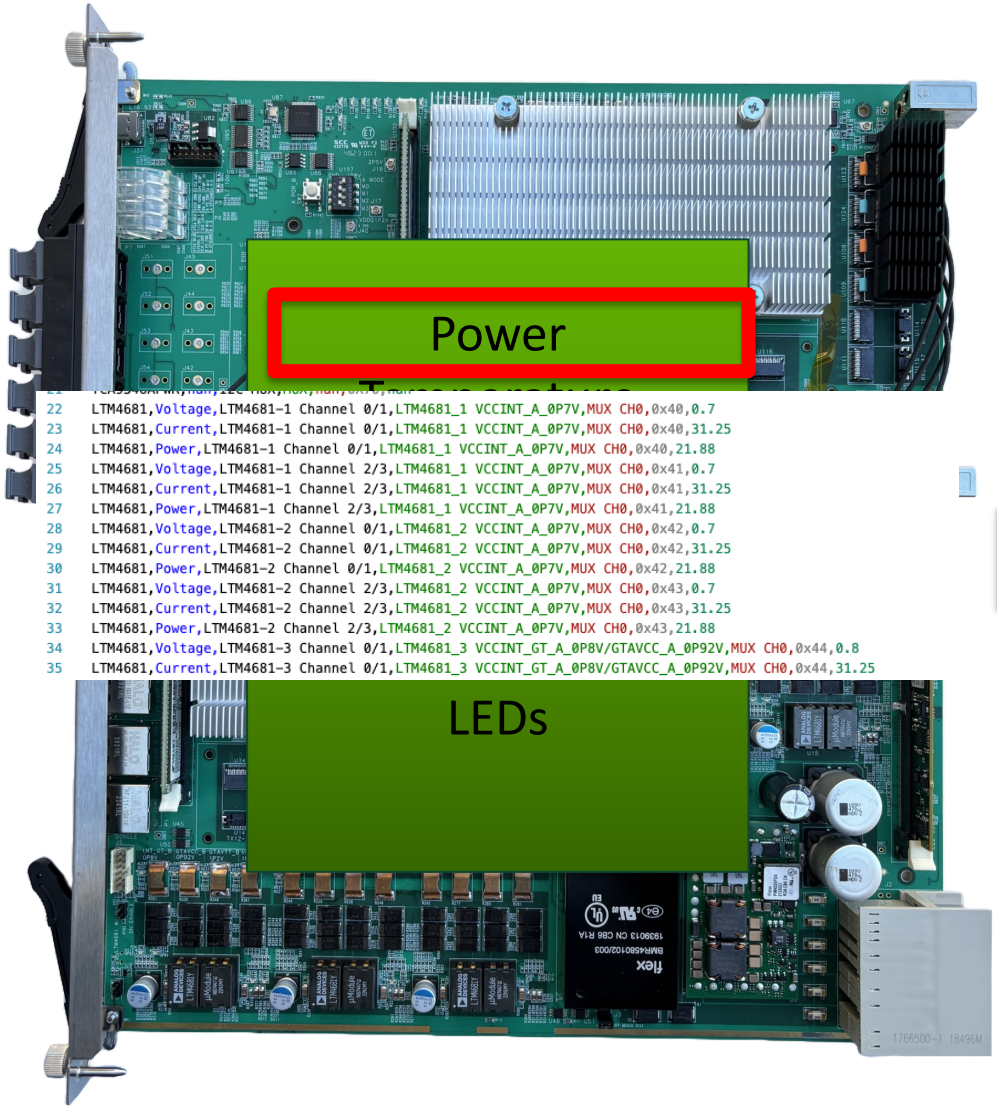
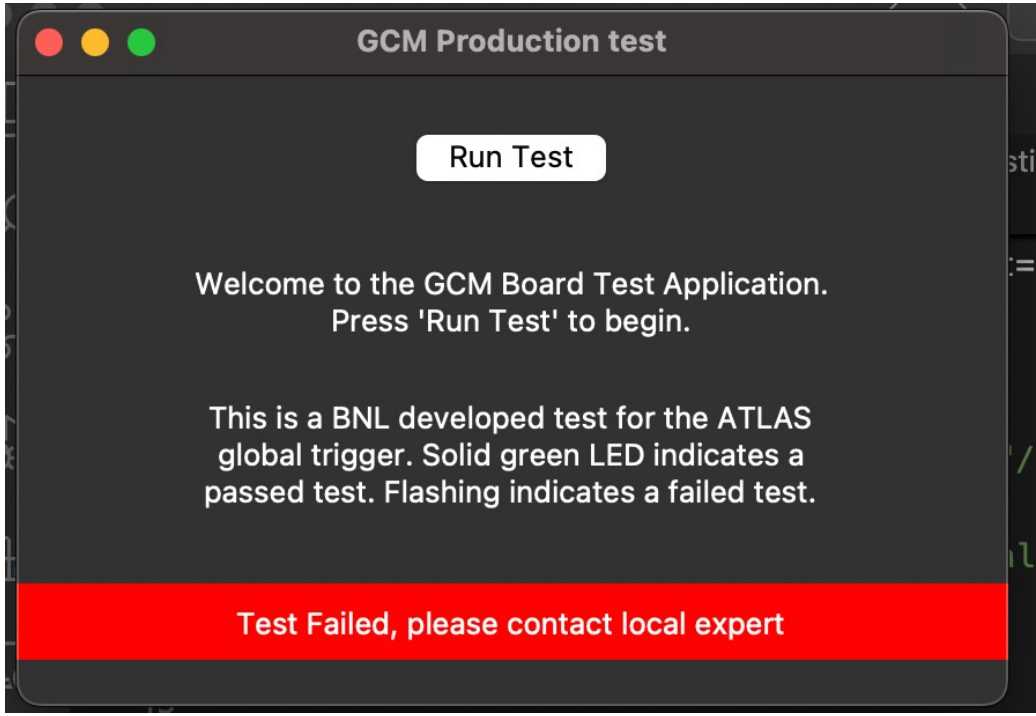


Board passed testing

Production Testing

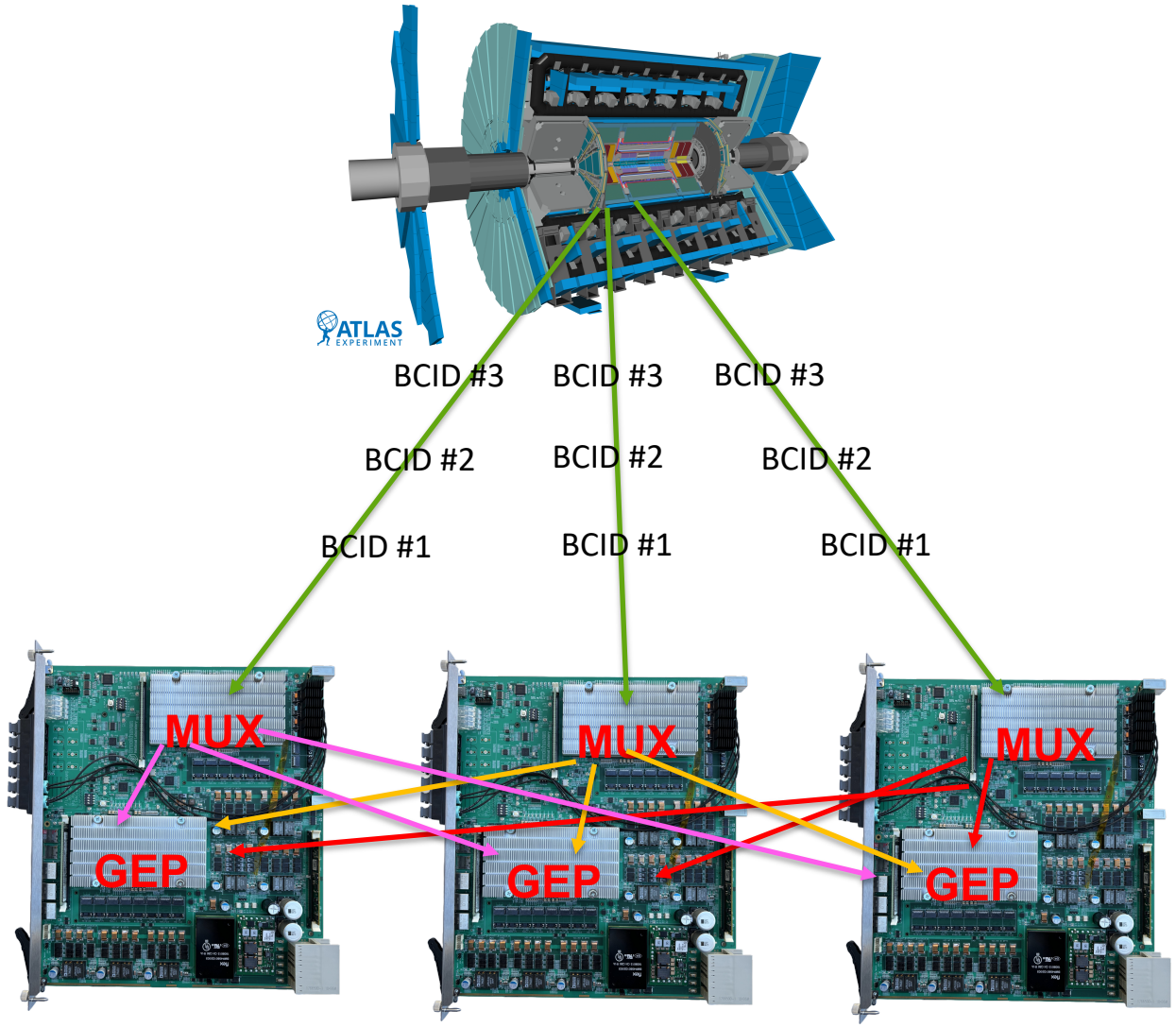


Working version of package with complete control of the board!



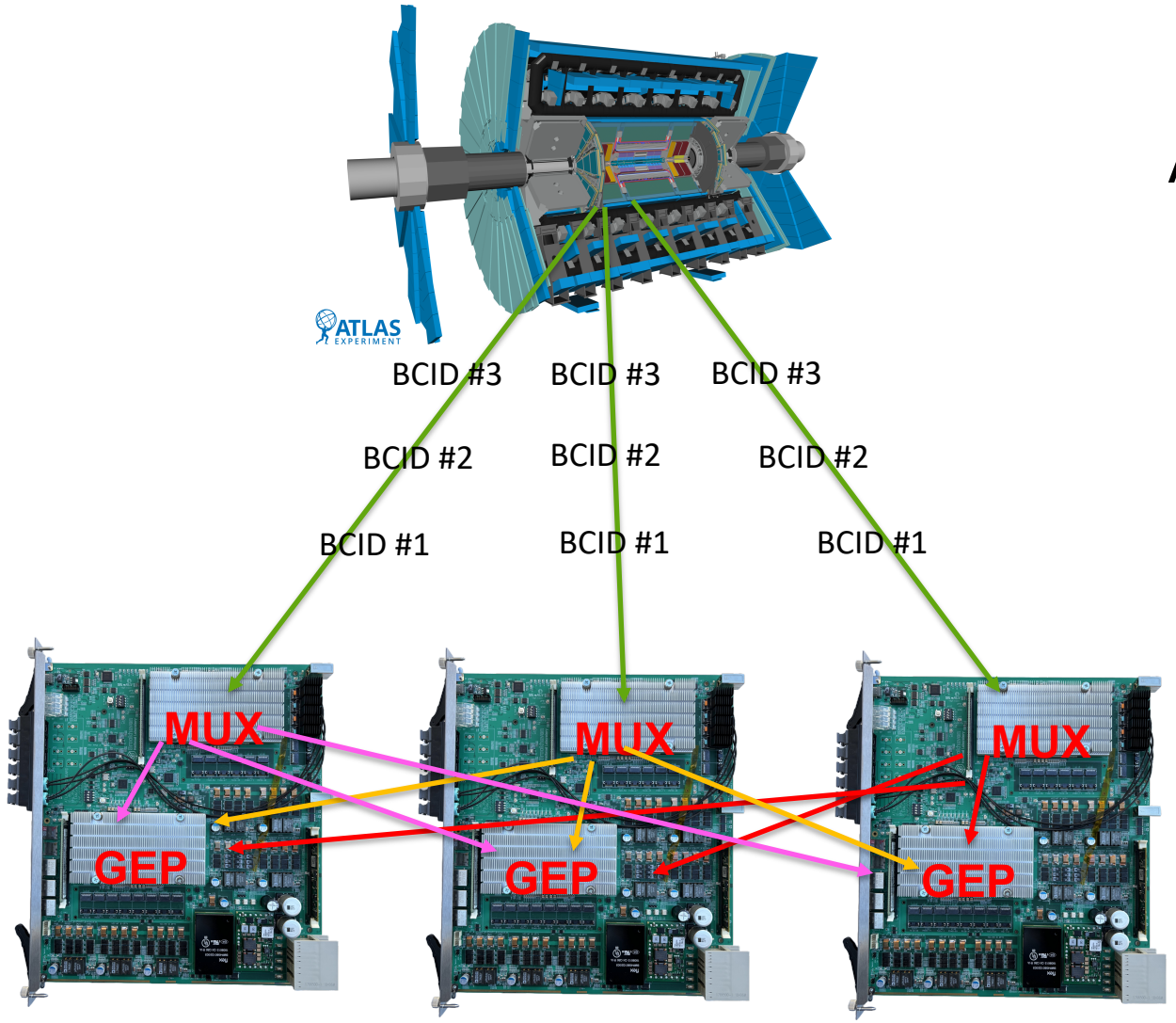
Board failed testing

Integration testing: slice test preparations

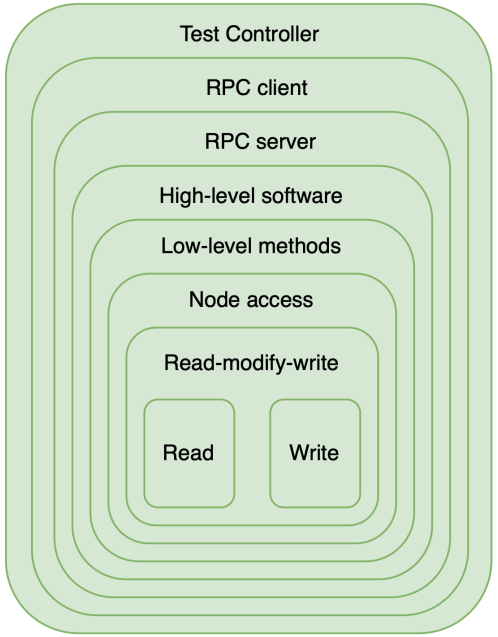


Demonstrate time multiplexing

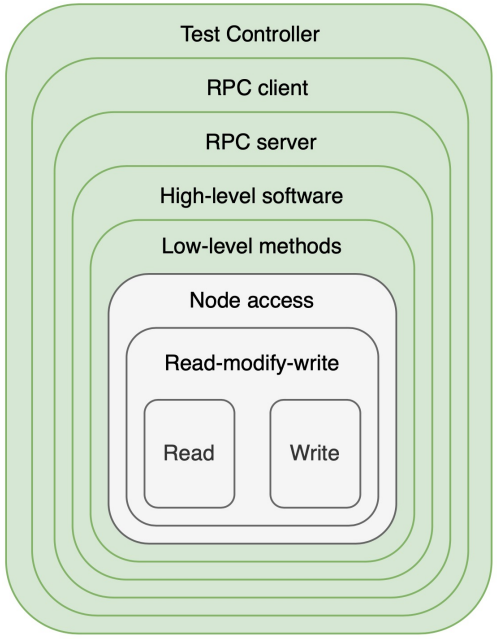
Integration testing: slice test preparations



Accessing and controlling MUX and GEP: Read/write latency testing



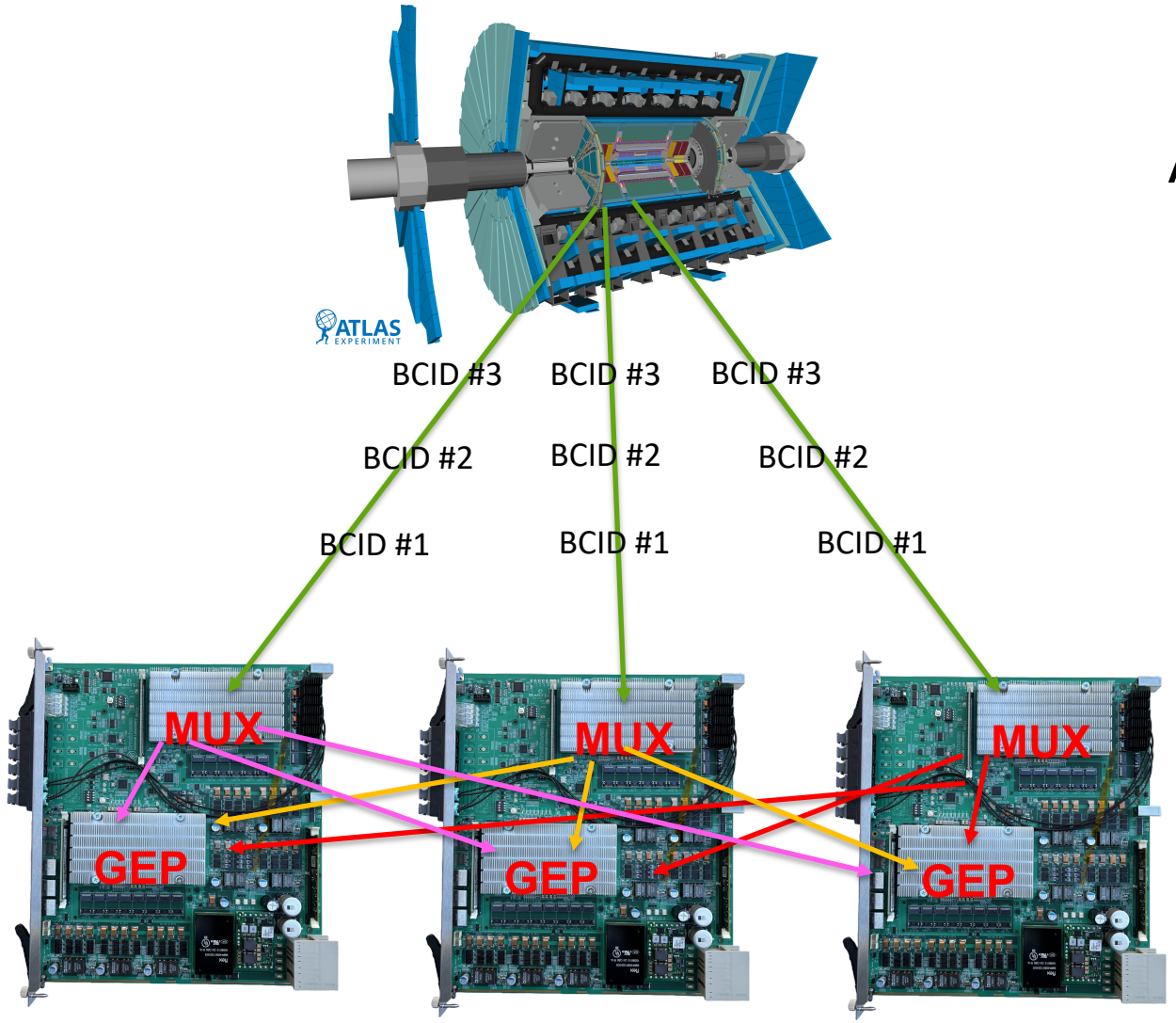
8-Layer software system



Enhanced 8-Layer software system

Python C/C++

Integration testing: slice test preparations



Accessing and controlling MUX and GEP:
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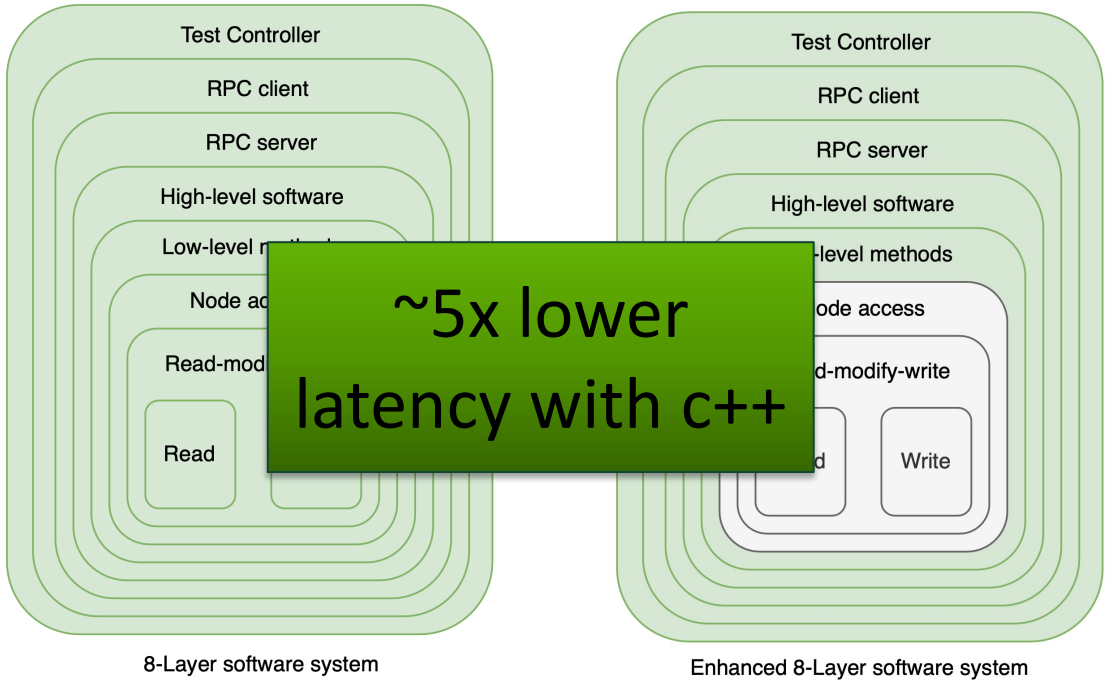
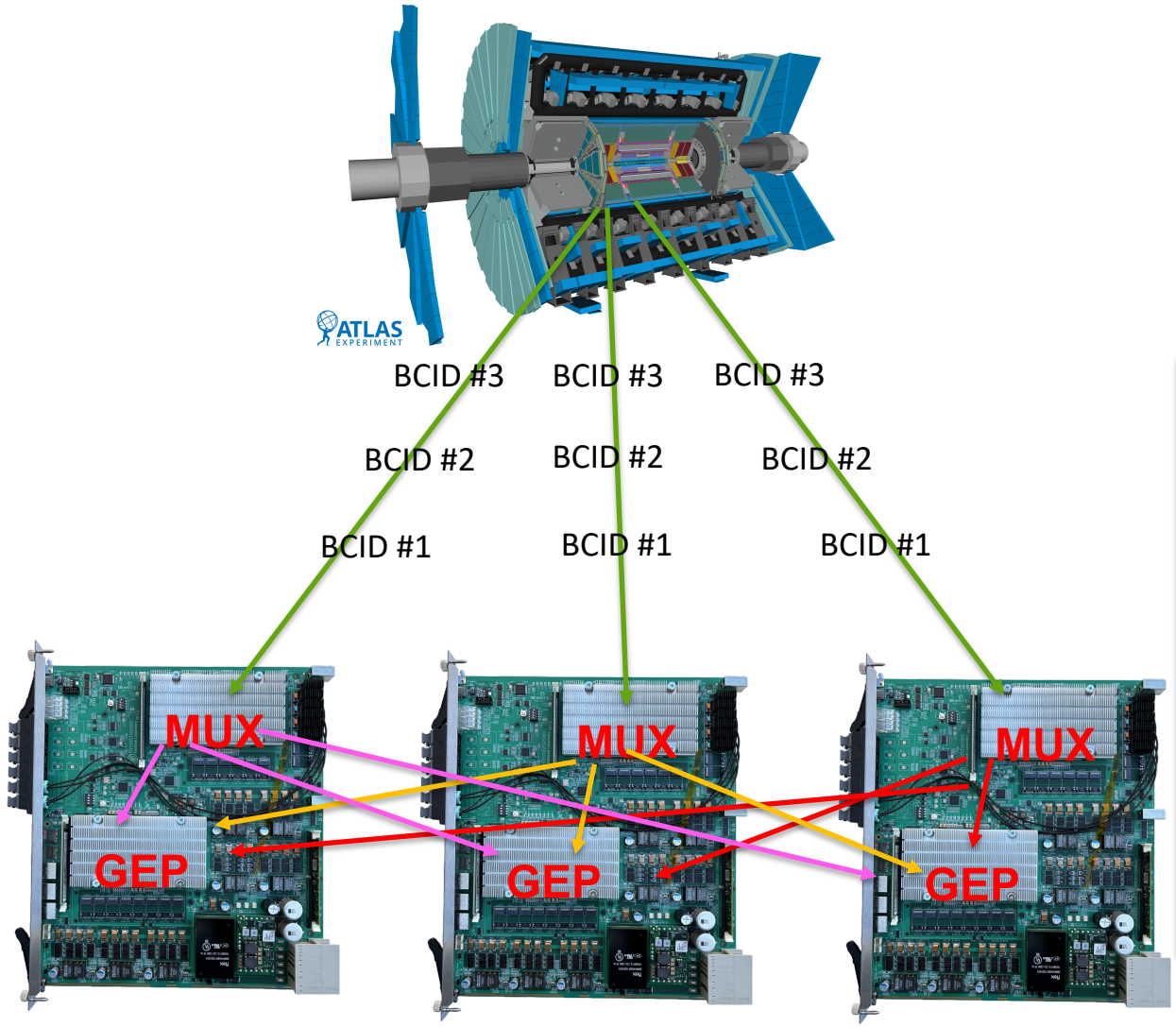
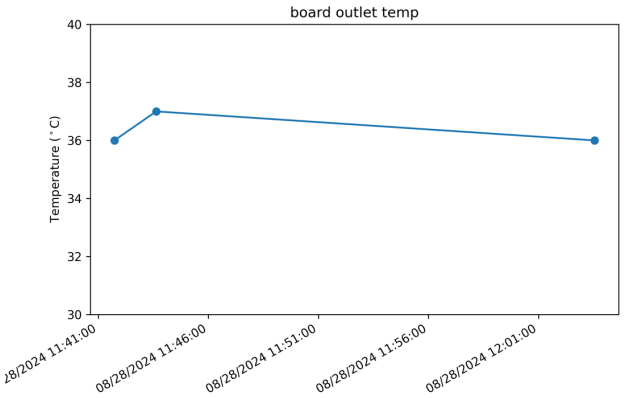


Integration testing: slice test preparations



Slow Controls/Monitoring

Power
Temperature
Connections
Clock
DDR4
Optical connections
LEDs



Summary and Next Steps

To take full advantage of HL-LHC potential, need optimized trigger.

Global Trigger system is critical to ATLAS physics goals!

- GCM v3 hardware is fully functional
- We can access and control the board (hardware and firmware)
- Full production test is ready
- Slice test in the coming year

Work at BNL is super fun!

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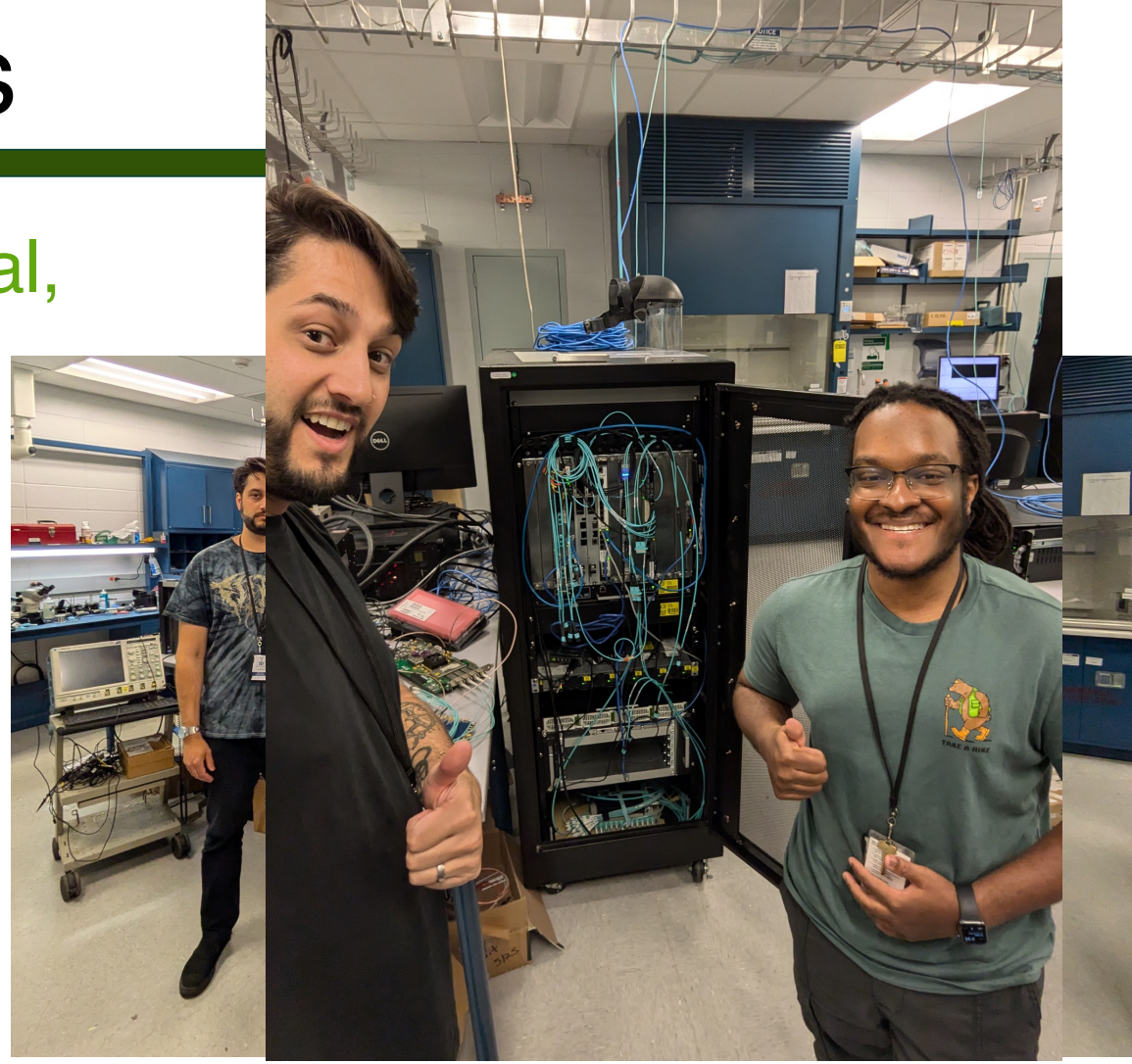
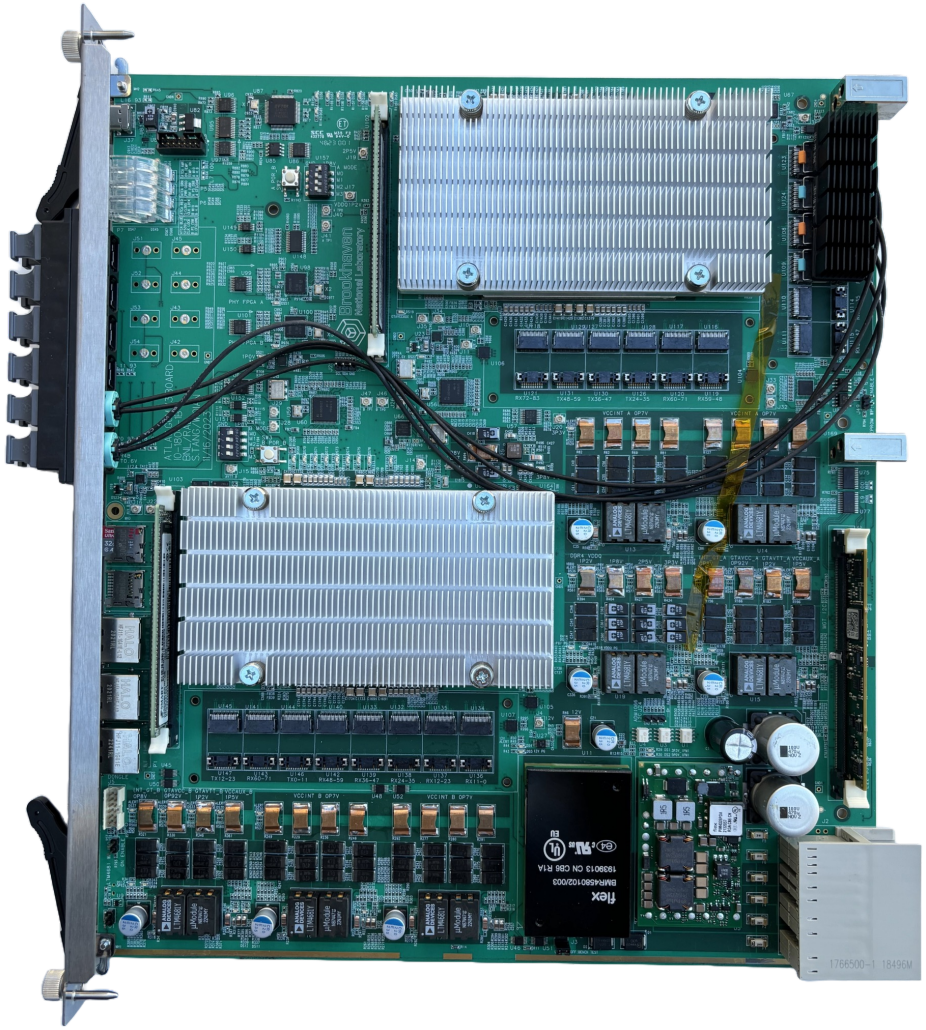


Work at BNL is super fun!

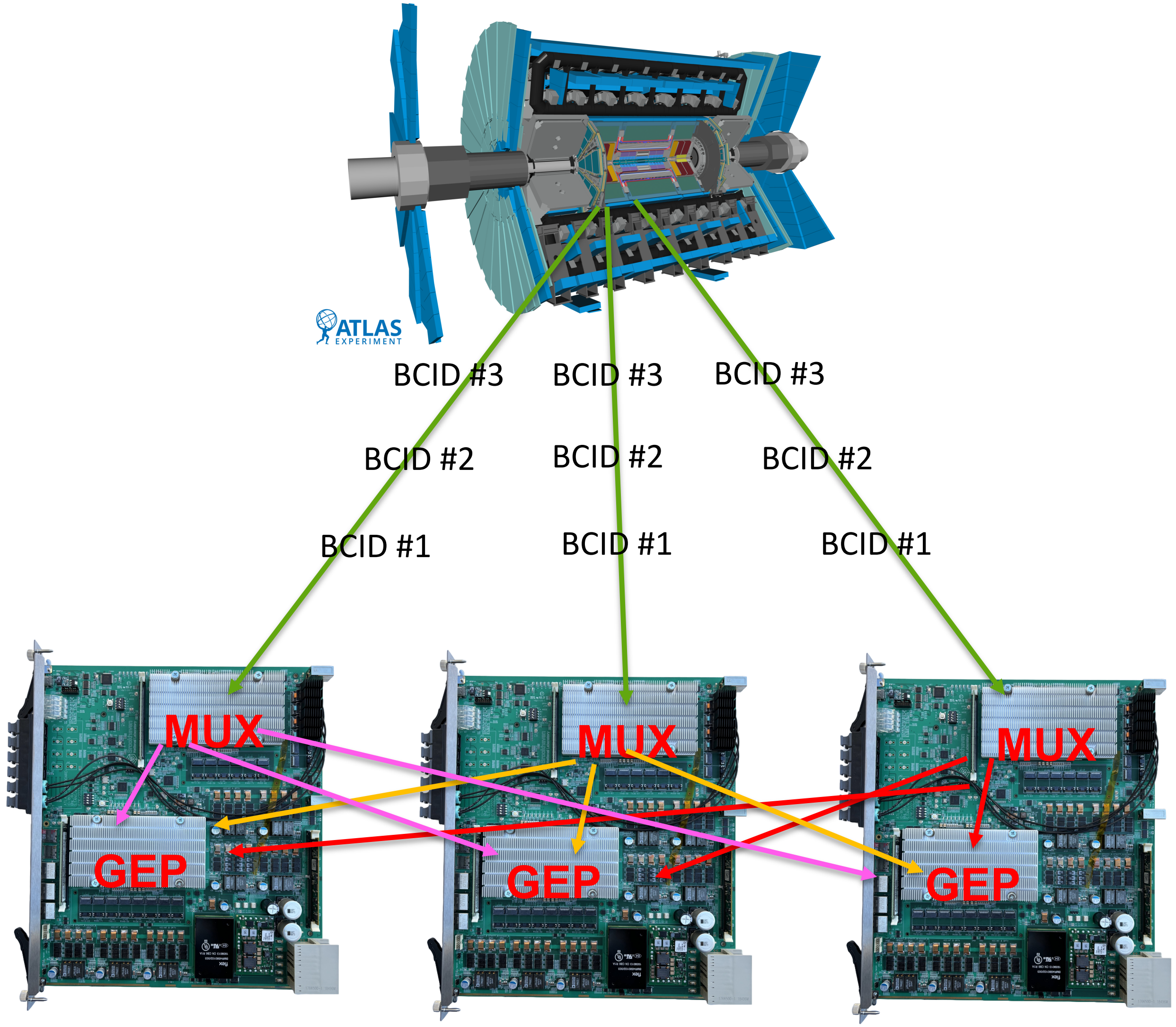
Thanks!

Questions?

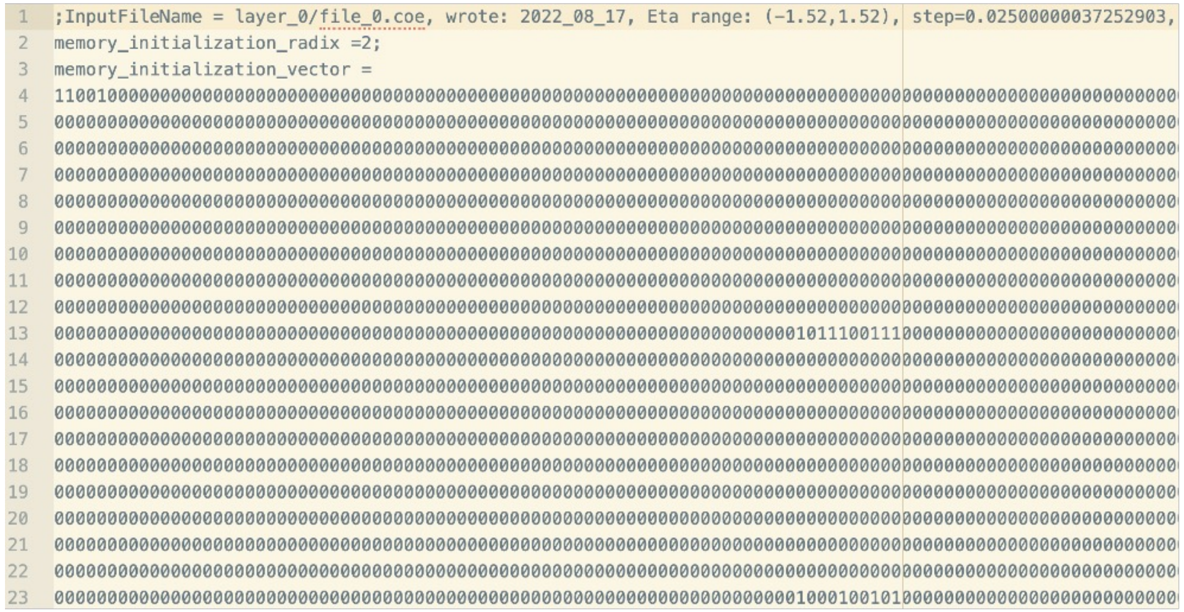


Backup

Integration testing: slice test preparations



Test Vectors



```
;InputFileName = layer_0/file_0.coe, wrote: 2022_08_17, Eta range: (-1.52,1.52), step=0.02500000037252903,
memory_initialization_radix =2;
memory_initialization_vector =
11001000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000010111001110000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
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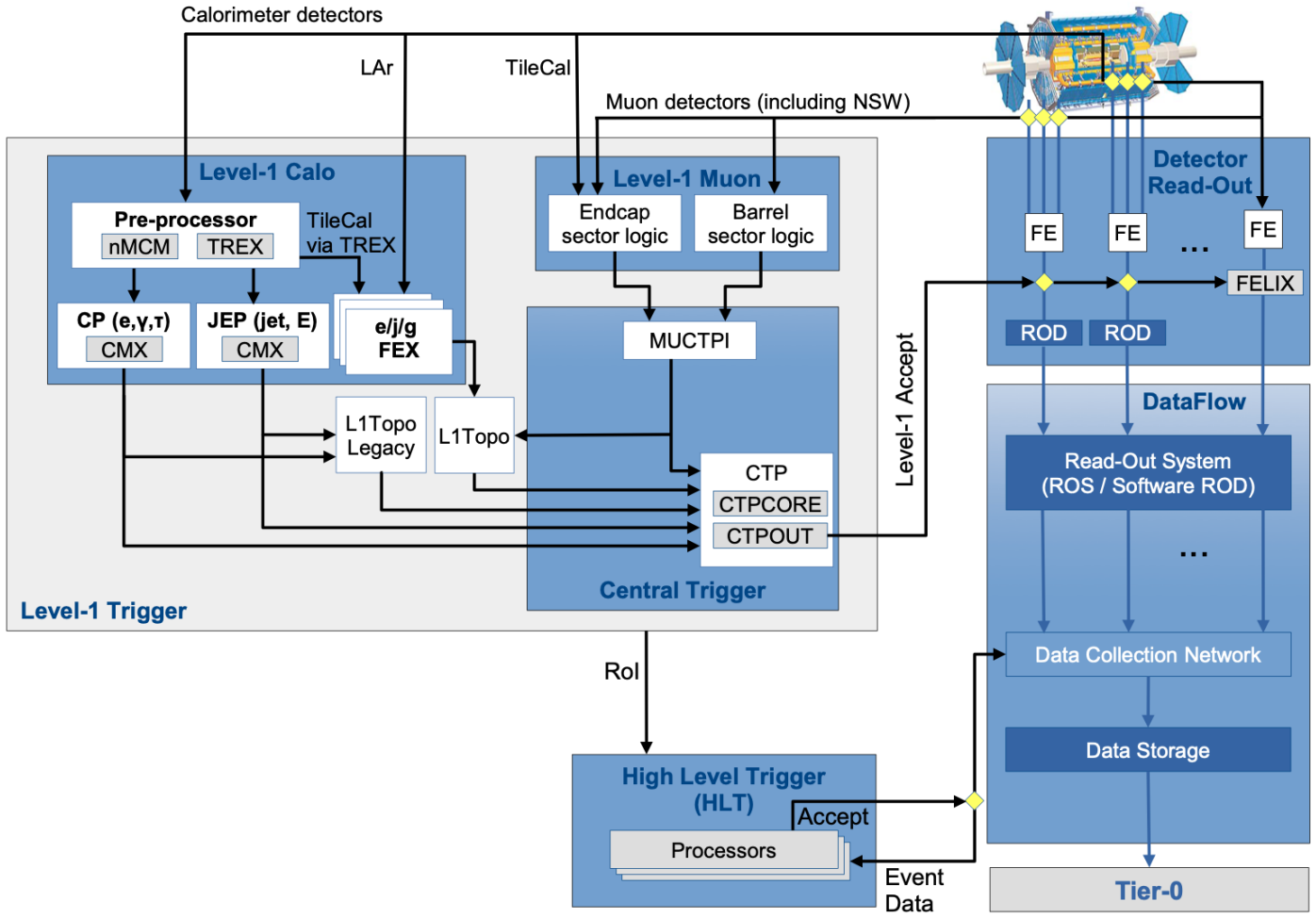
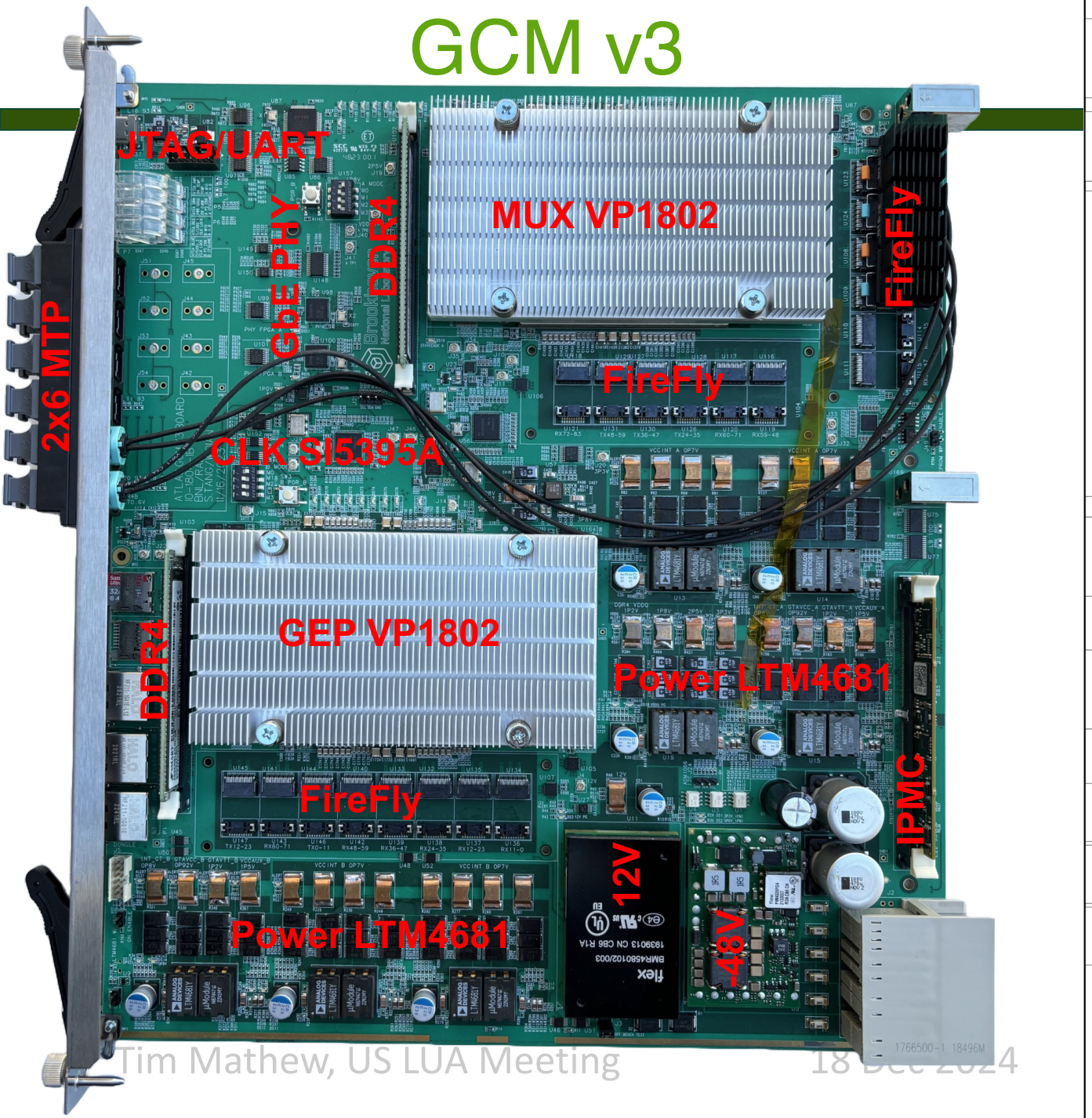

Calorimeter detectors
LAr
TileCal
Muon detectors (including NSW)
Level-1 Calo
Pre-processor
nMCM
TREX
TileCal via TREX
CP (e,γ,τ)
CMX
JEP (jet, E)
CMX
e/j/g FEX
L1Topo Legacy
L1Topo
Level-1 Muon
Endcap sector logic
Barrel sector logic
MUCTPI
CTP
CTPCORE
CTPOUT
Central Trigger
Level-1 Trigger
Level-1 Accept
Detector Read-Out
FE
FE
FE
FELIX
ROD
ROD
DataFlow
Read-Out System (ROS / Software ROD)
Data Collection Network
Data Storage
Tier-0
RoI
High Level Trigger (HLT)
Processors
Accept
Event Data

GCM v3


JTAG/UART
GbE PHY
DDR4
MUX VP1802
FireFly
2x6 MTP
FireFly
CLK SI5395A
DDR4
GEP VP1802
Power LTM4681
FireFly
IPMC
12V
48V
Power LTM4681

USB-C JTAG/ UARTs
LEDs
FIBER INPUTs 12 MTP24
PHY
PHY
SI5395A
SI5395A
Micro-SD
Micro-SD
RJ45
RJ45
RJ45
PS 16GBDDR4 DIMM
PS 16GBDDR4 DIMM
GPIO
GPIO
MUX XCVP1802-1LSEVSVA5601
SLR0 SLR2 SLR1 SLR3
GEP XCVP1802-1LSEVSVA5601
SLR0 SLR2 SLR1 SLR3
XPIO 700-702
XPIO 703-705
XPIO 706-712
GTYP 102-106
GTM 109-111
GTM 112
GTM 115-116
GTM 117-118
GTM 121
GTM 122-124
GTM 222-224
GTM 219-221
GTYP 200
GTYP 201
GTM 202-203
GTM 204-206
GTM 207-209
GTM 210-212
GTM 213-215
GTM 216-218
ECUO-25G FireFly TX 12
ECUO-25G FireFly RX 12
LTM4638
LTM4681
LTM4681
LTM4681
LTM4681
LTM4681
LTM4681
LTM4681
LTM4681
2 x 470uF Capacitors
IPMC
600W DC/DC (12V) BMR458221002
540W PIM(48V/54V) PIM4328PLA
ZONE1
GCM V3