Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

Tip-to-tail SLAC: Calorimeter test run

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Muon g-2 Computing Review

Nov 07, 2016

Content

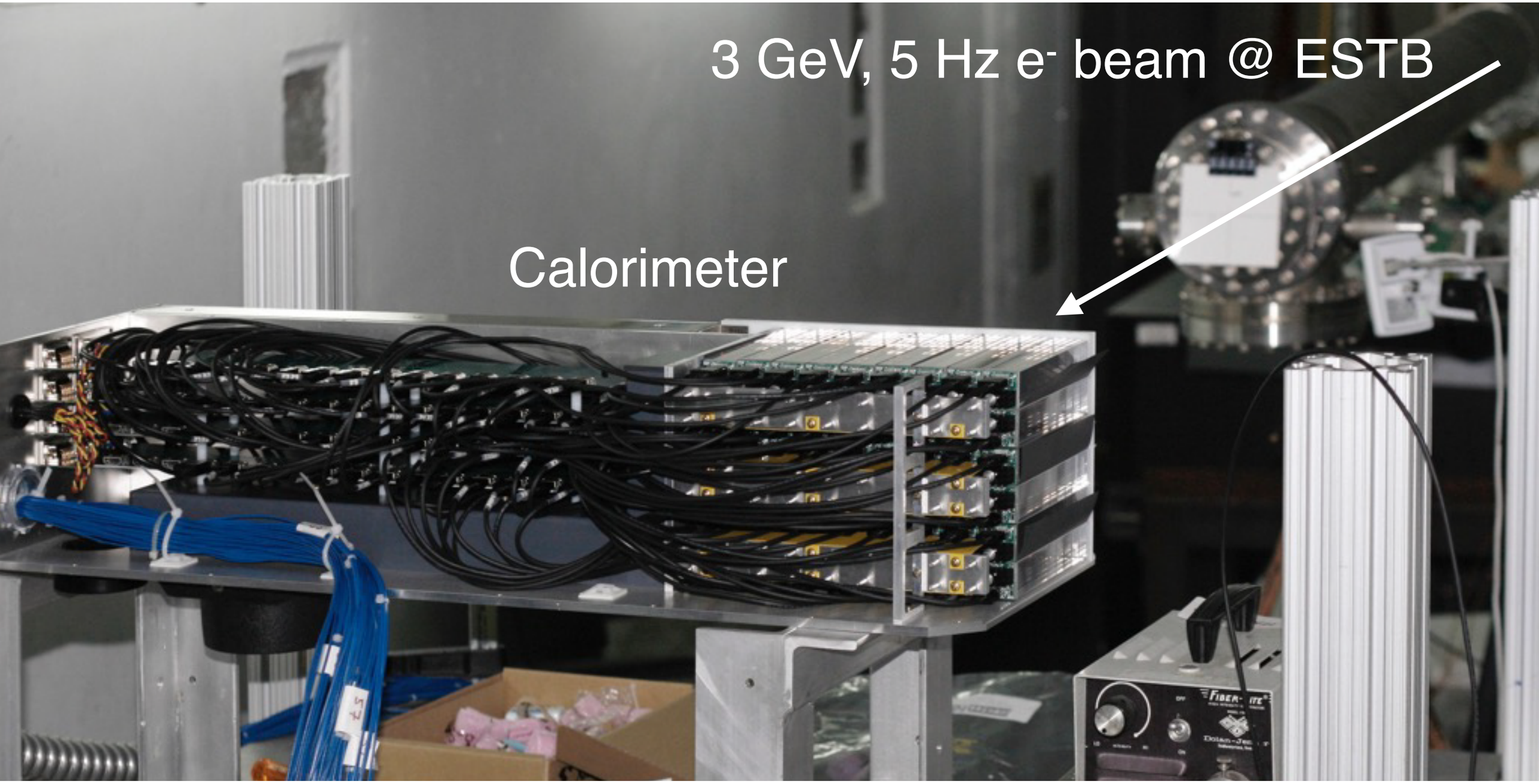
- Motivation
- Overview of SLAC calorimeter test run
- Offline computing framework
- User friendly tools
- Summary

Motivation

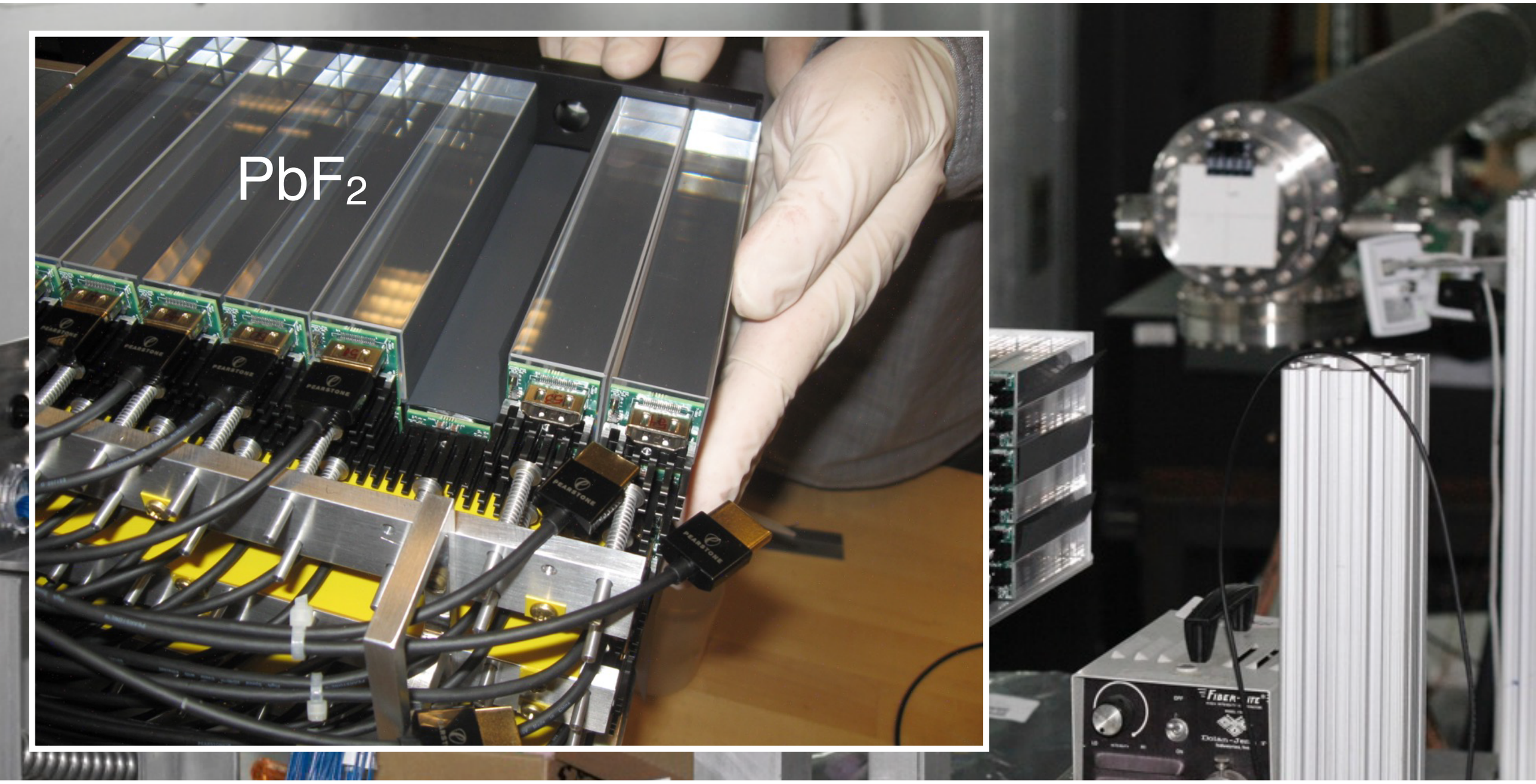
- End-to-end test of the calorimetry system
  - Lead Fluoride (PbF_2) Cherenkov calorimeter
  - Laser-based calibration and monitoring system
  - Custom 800 MSPS fast digitizer
  - FC7 trigger and clock distribution system
  - DAQ (frontend and backend)
  - ***art*-based offline computing framework**

- Characterization of the calorimetry system
  - Energy and timing resolution of the calorimeter
  - Stability of the energy scale
  - etc

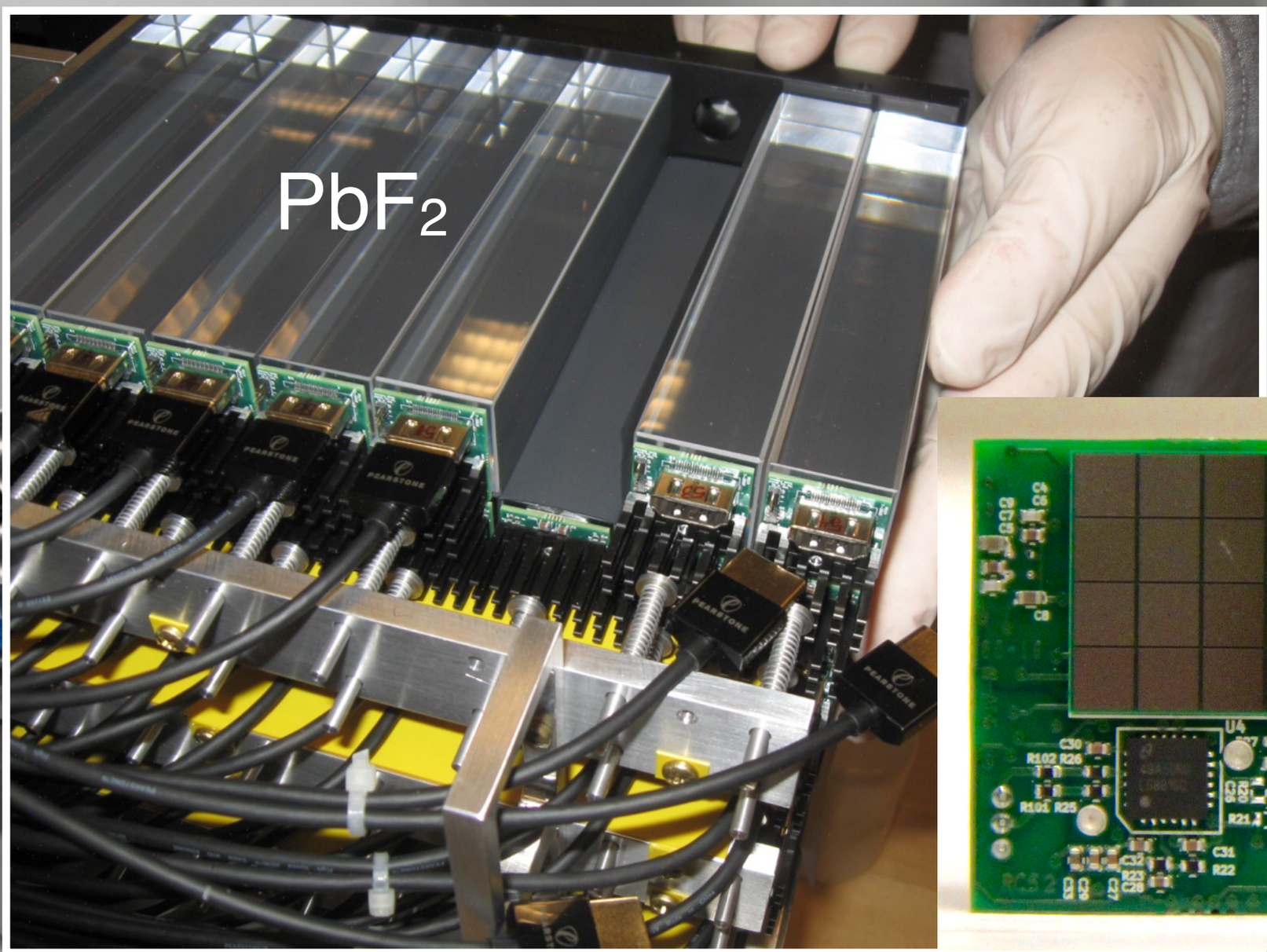
SLAC End Station A

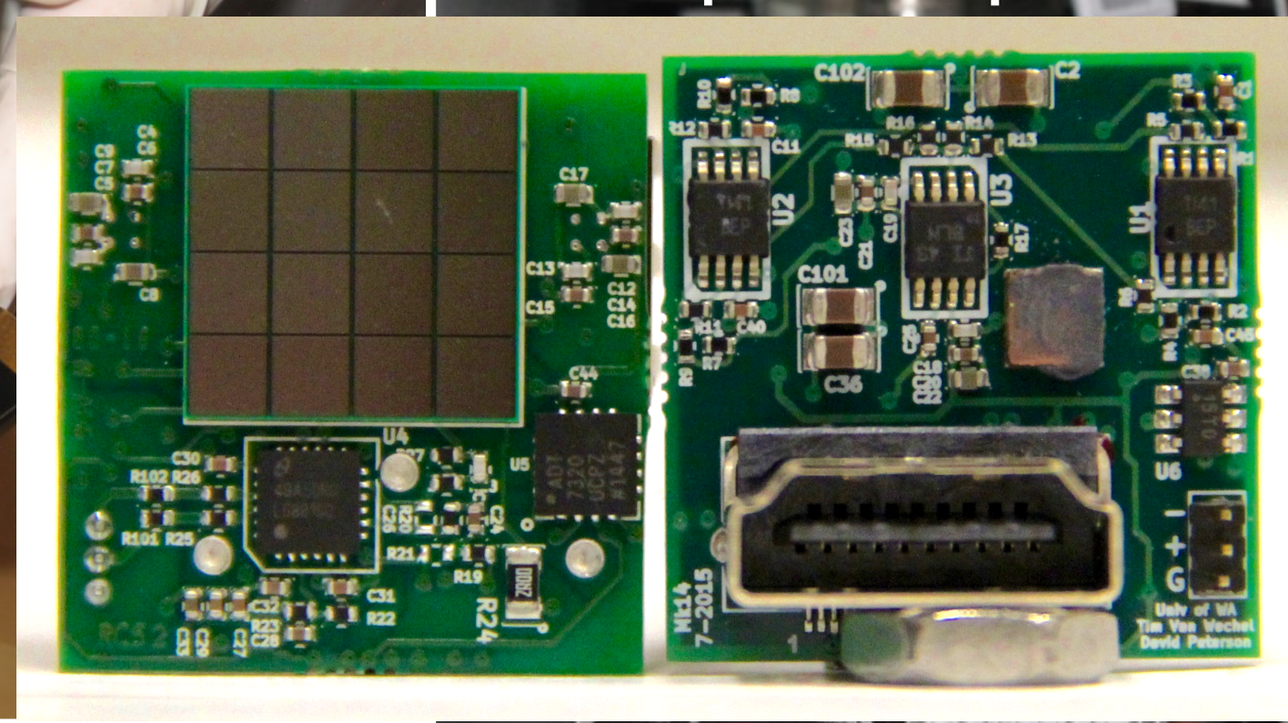


Calorimeter (PbF_2 + SiPM)

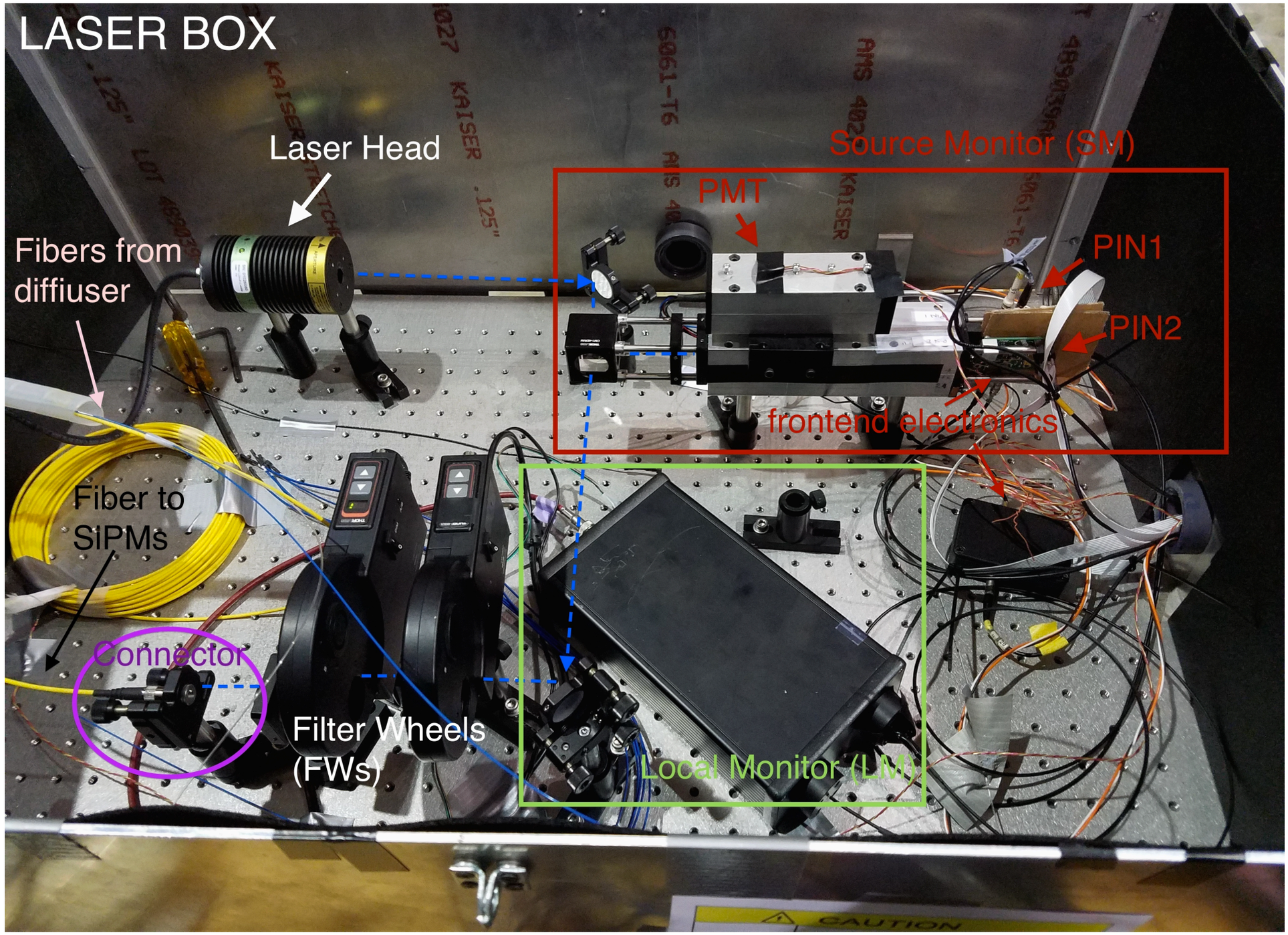


Calorimeter (PbF_2 + SiPM)

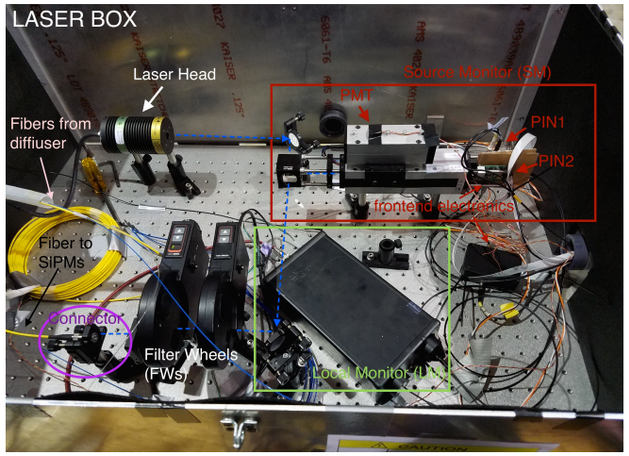


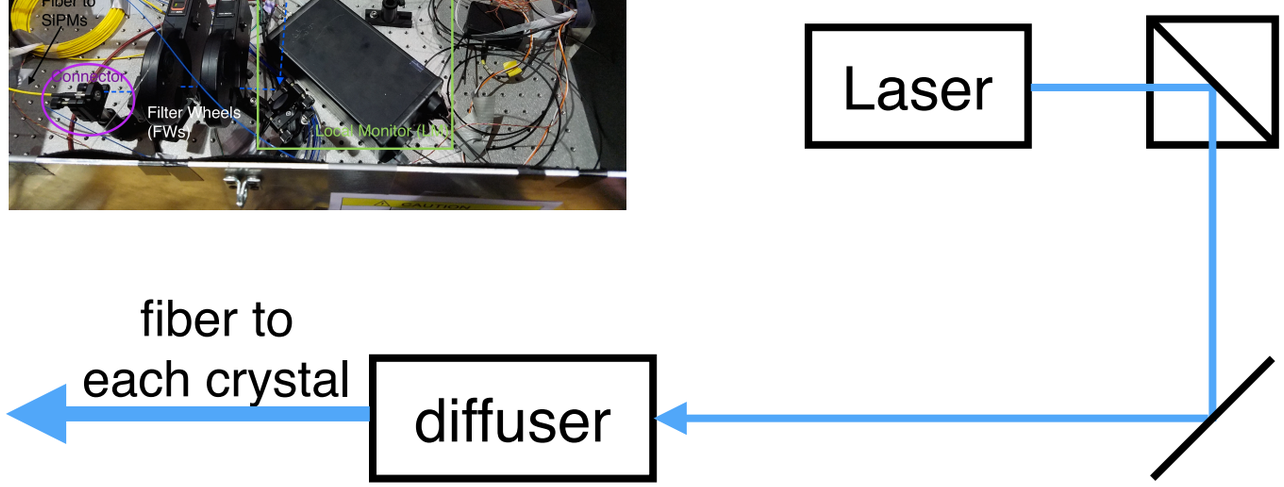


Laser calibration and monitoring system



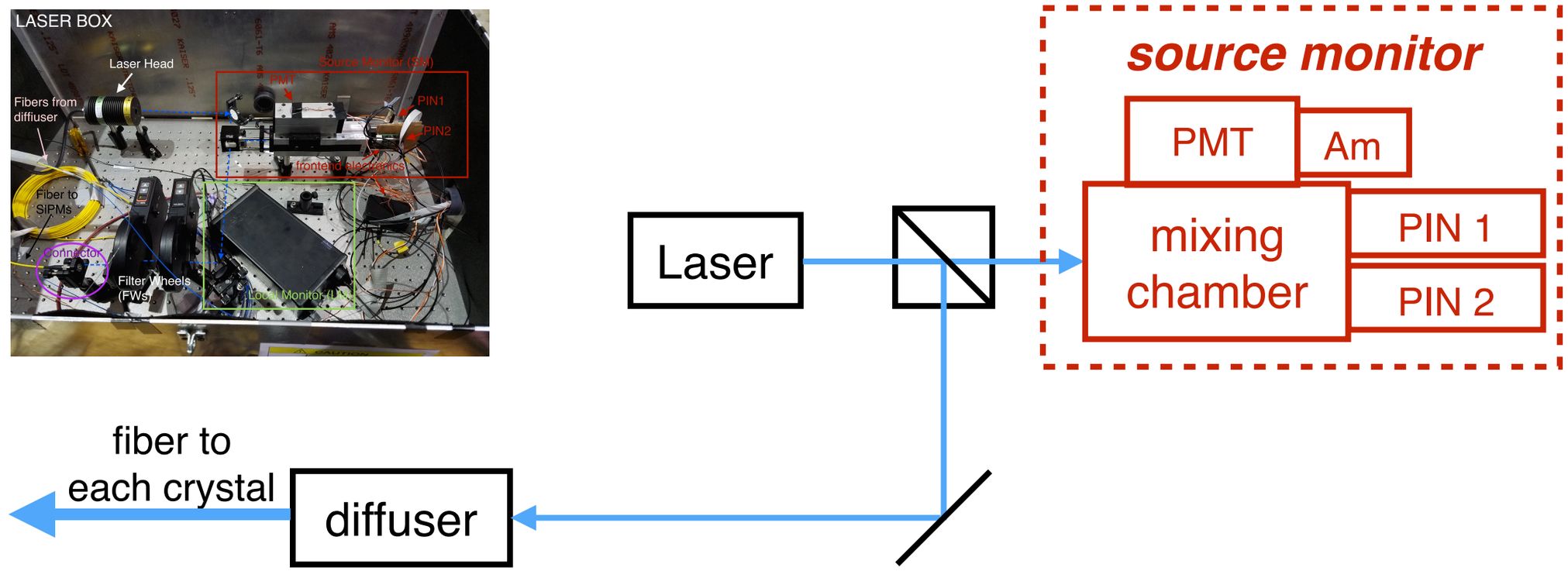
Laser calibration and monitoring system





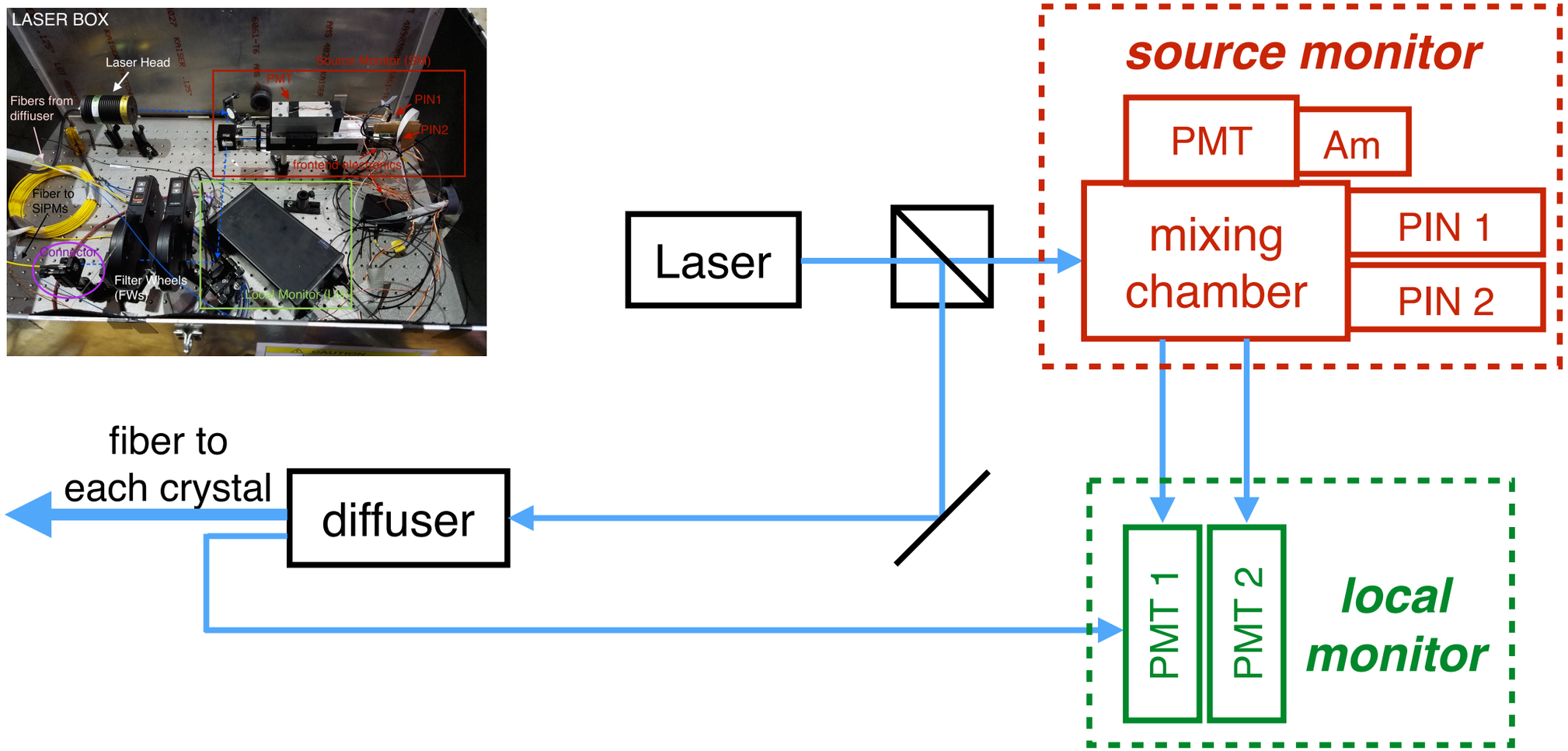
- SiPM gain monitoring - high stability 405 nm PicoQuant laser

Laser calibration and monitoring system



- SiPM gain monitoring - high stability 405 nm PicoQuant laser
- Laser intensity monitoring - Source monitor (PINs & PMT)

Laser calibration and monitoring system



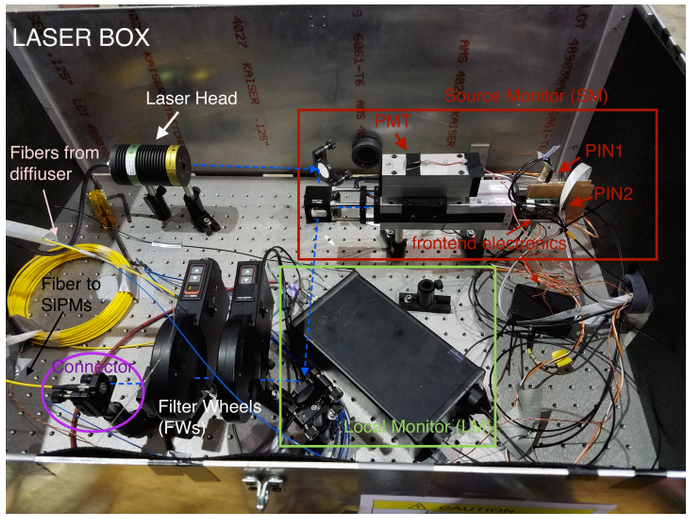
- SiPM gain monitoring - high stability 405 nm PicoQuant laser
- Laser intensity monitoring - Source monitor (PINs & PMT)
- Laser light distribution chain monitoring - Local monitor (PMTs)
- Target SiPM gain stability ~ 10^{-4}/hour in TDR

End-to-end system

Signal digitization

Trigger clock distribution system (TCDS)

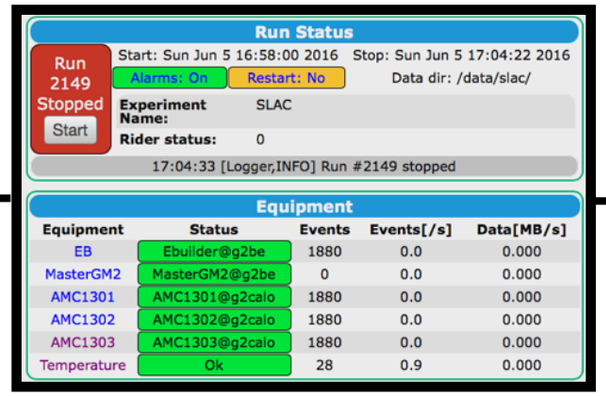
calorimeter



laser calibration and monitor

Frontend: mCPU + GPU processing

online data quality monitor



Data storage

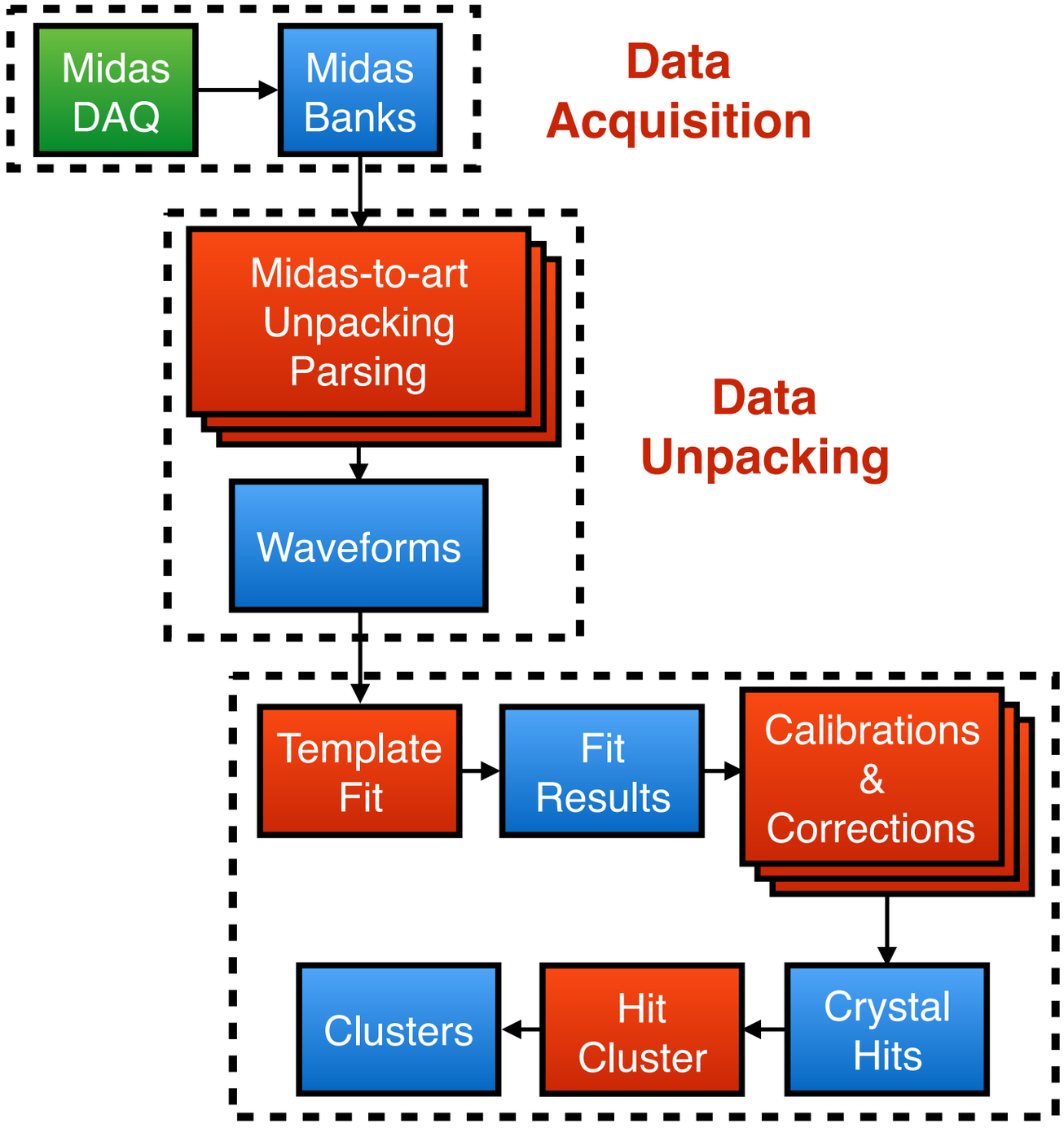
analysis machine

offline processing

Backend: MIDAS event builder

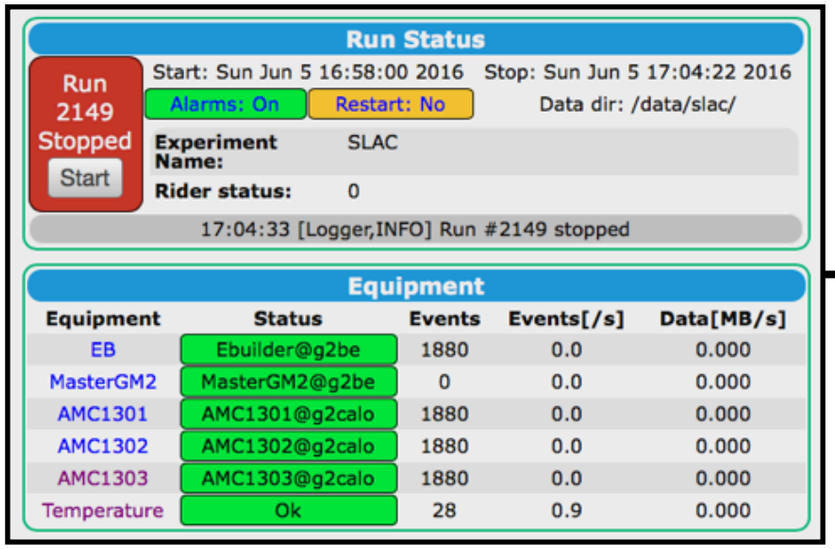
Fermilab

Offline framework (Pre-SLAC)



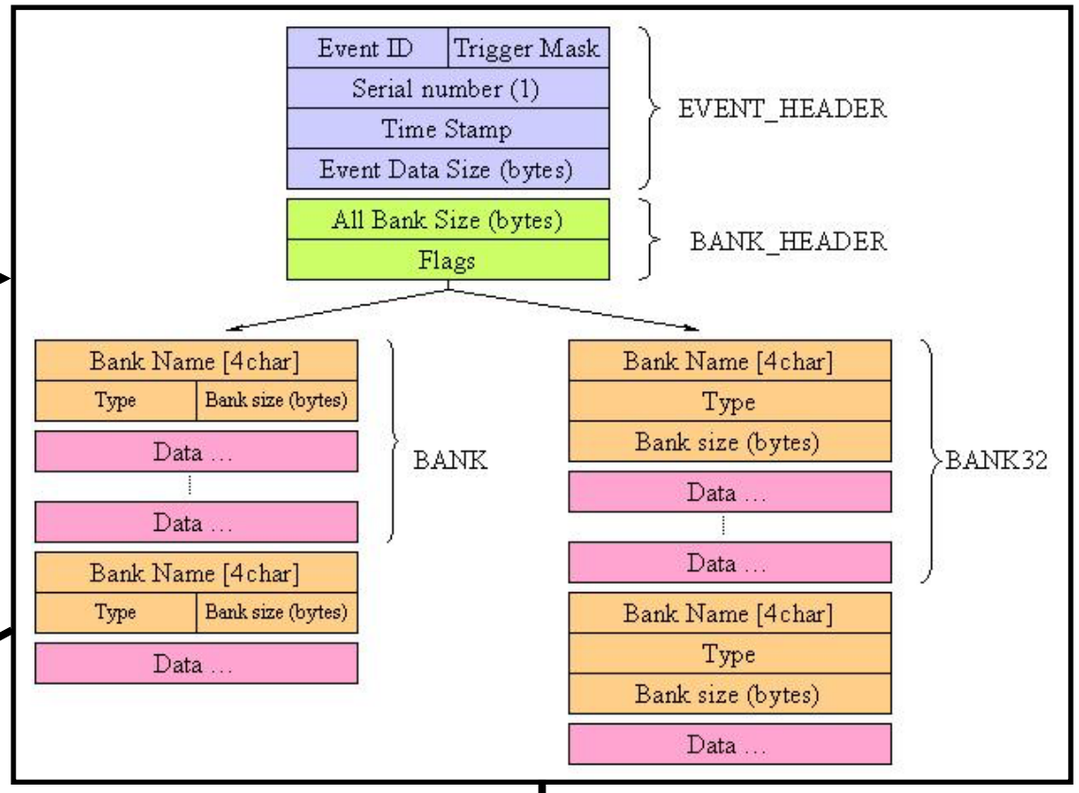
Tested using Geant4 simulated data and DAQ simulator

MIDAS-to-art



output MIDAS file

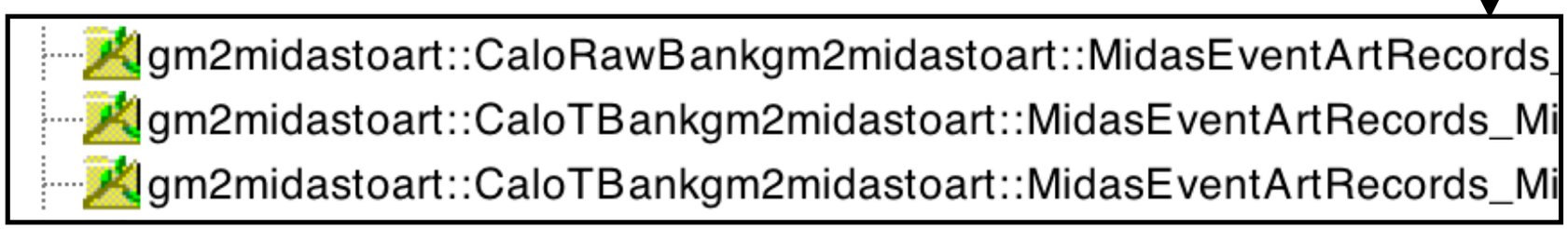
MIDAS Event Structure




```
Bank:CT01 Length: 322204(I*1)/80551(I*4)/161102(Type)
   1-> 30024     2    71    54   196     0 14149     0
   9->    42     0  1801  1805  1799  1801  1794  1807
  17->  1804  1802  1794  1775  1158  -119  -599   -39
  25->   933  1609  1805  1767  1705  1719  1769  1819
  33->  1858  1879  1894  1900  1882  1874  1851  1850
  41->  1840  1844  1847  1869  1886  1905  1902  1899
  49->  1880  1864  1832  1820  1746  1763  1756  1755
  57->  1741  1754  1753  1603   620  -284  -239   514
```

dumped data

MIDAS-to-art



stored as TBranches in ROOT

Data unpacking and parsing

```
Bank:CT01 Length: 322204(I*1)/80551(I*4)/161102(Type)
   1-> 30024     2    71    54   196     0 14149     0
   9->    42     0  1801  1805  1799  1801  1794  1807
  17->  1804  1802  1794  1775  1158  -119  -599   -39
  25->   933  1609  1805  1767  1705  1719  1769  1819
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  41->  1840  1844  1847  1869  1886  1905  1902  1899
  49->  1880  1864  1832  1820  1746  1763  1756  1755
  57->  1741  1754  1753  1603   620  -284  -239   514
```
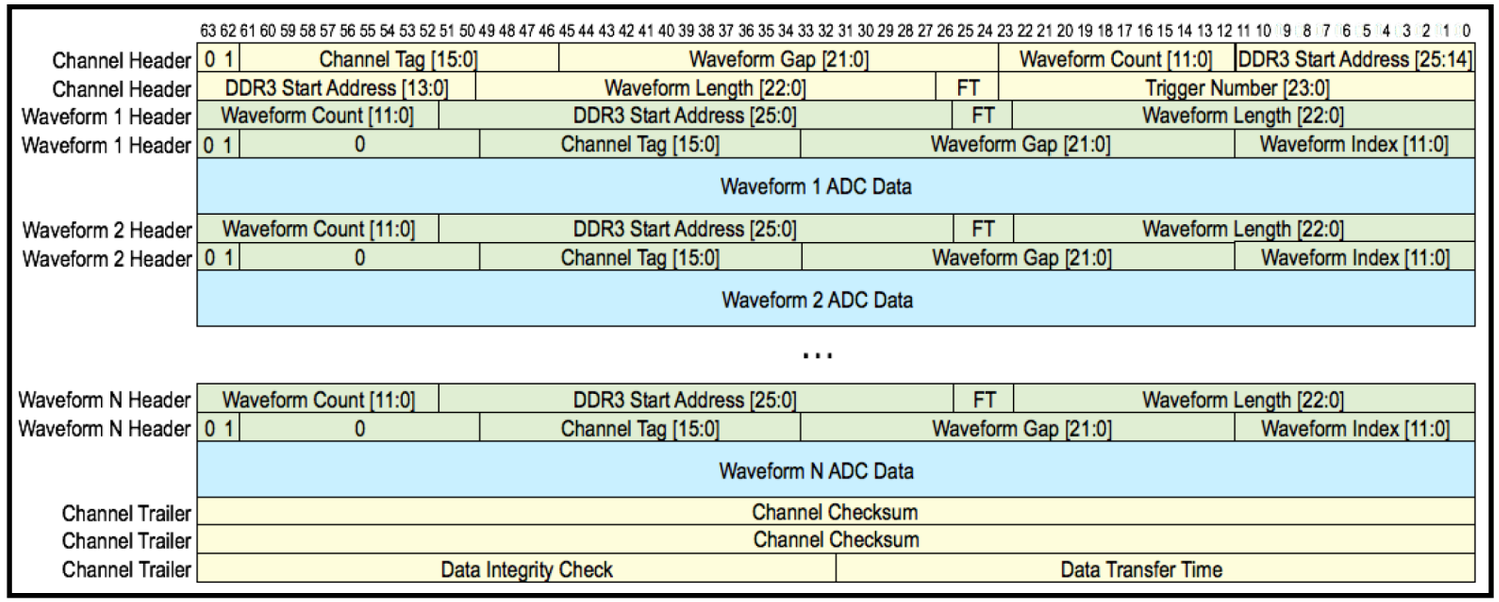

Simple data format

(GPU pre-processed data, DAQ timing data)



Raw digitizer data

gm2parser classes

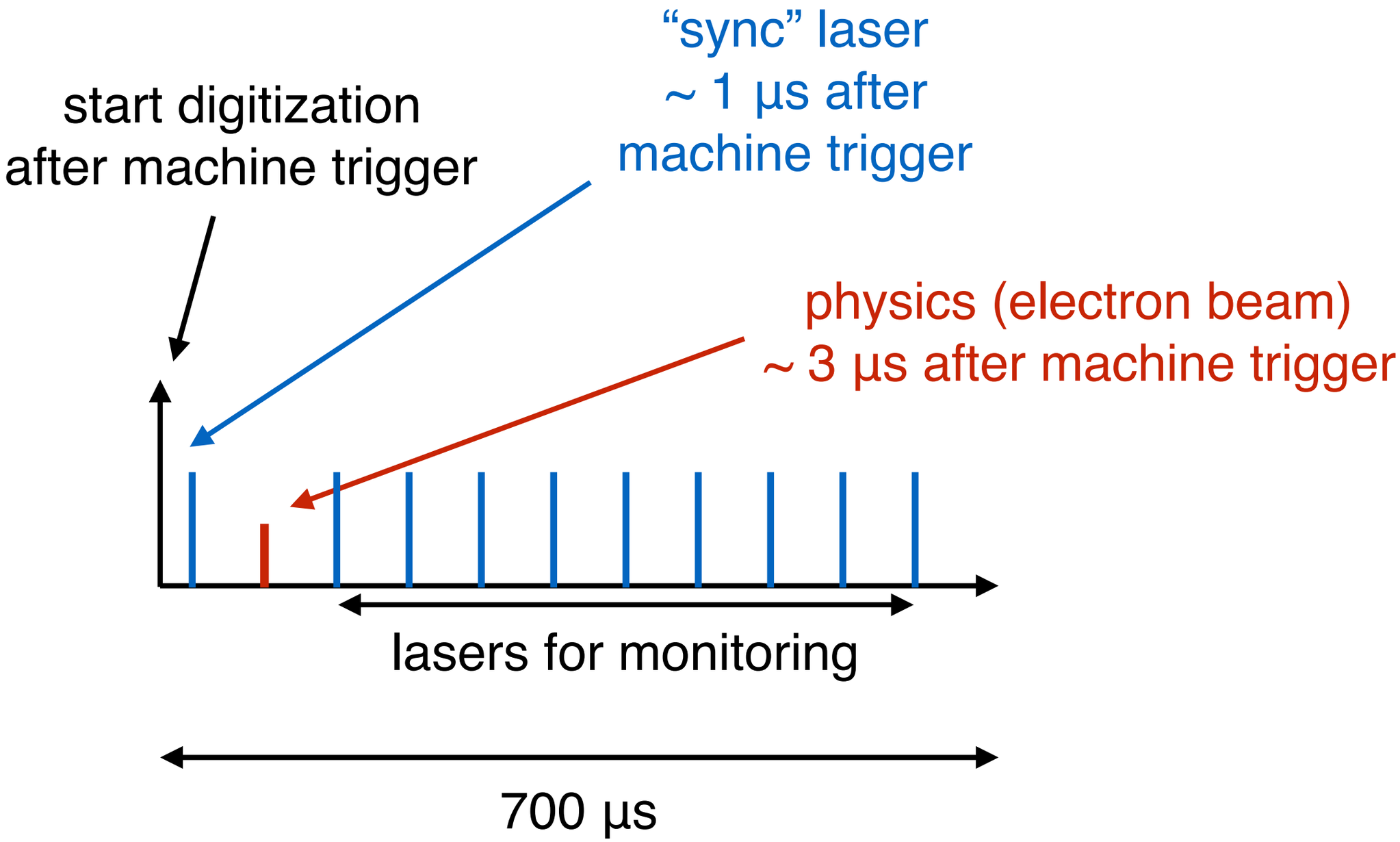
```
gm2parser::FedRider fedRiderCH;
fedRiderCH.AddRider(channelData);

if(verboseLevel_> 1){
    std::cout<<"\t\t---> Entering Channel #"<<fedRiderCH.ChannelTag()<<std::endl;
    std::cout<<"\t\tFillType: "<<fedRiderCH.FillType()<<std::endl;
    std::cout<<"\t\tWaveformGap: "<<fedRiderCH.WaveformGap()<<std::endl;
    std::cout<<"\t\tWaveformCount: "<<fedRiderCH.WaveformCount()<<std::endl;
    std::cout<<"\t\tWaveformLength: "<<fedRiderCH.WaveformLength()<<std::endl;
    std::cout<<"\t\tTrigNum: "<<fedRiderCH.TrigNum()<<std::endl;
    std::cout<<"\t\tDataIntCheck: "<<fedRiderCH.DataIntCheck()<<std::endl;
}
```

Waveforms (chopped)

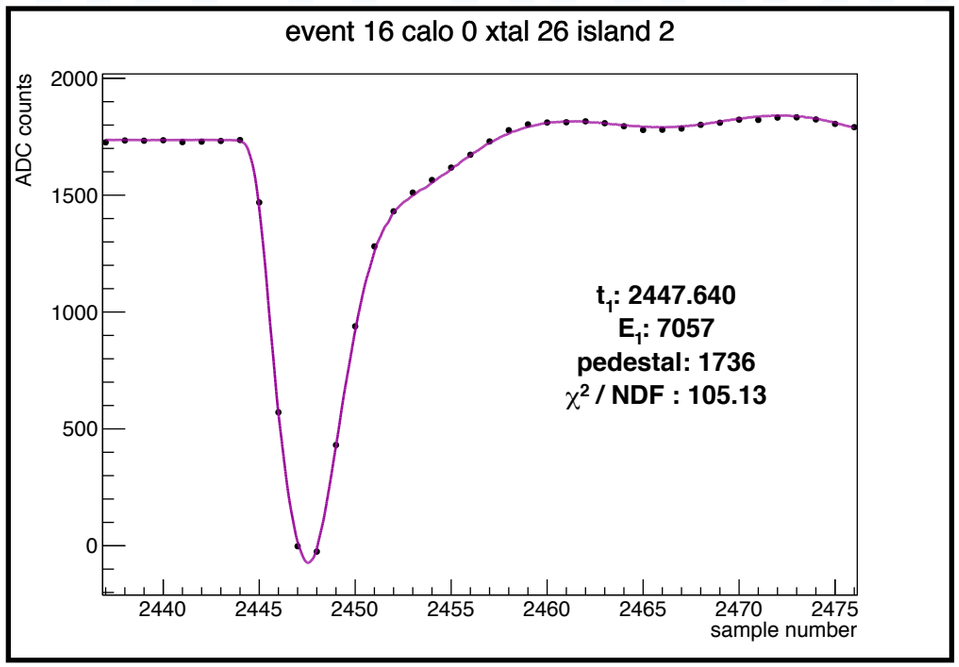
Headers

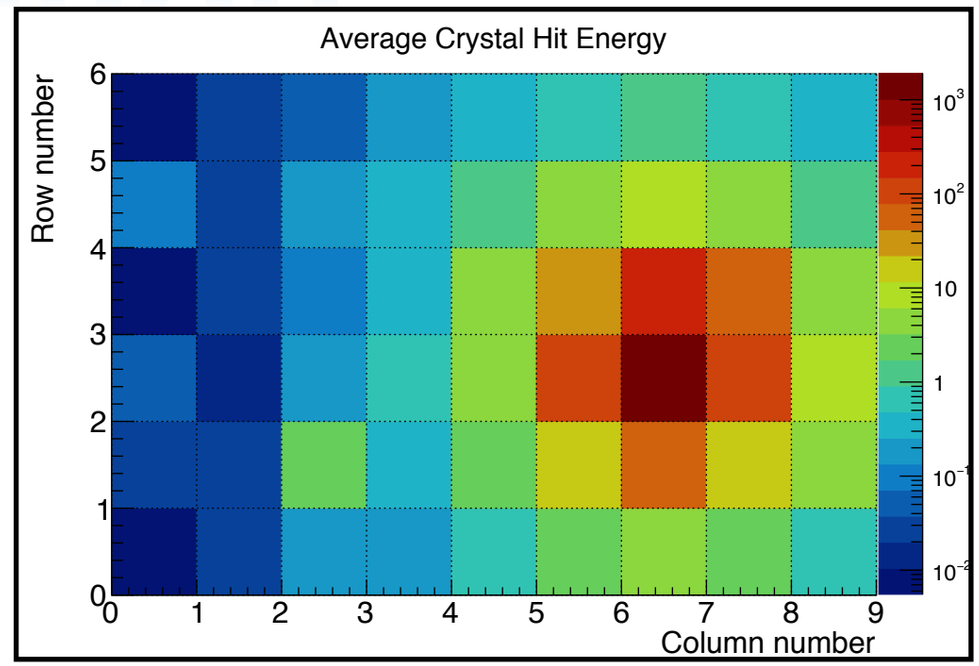
Waveforms (raw)

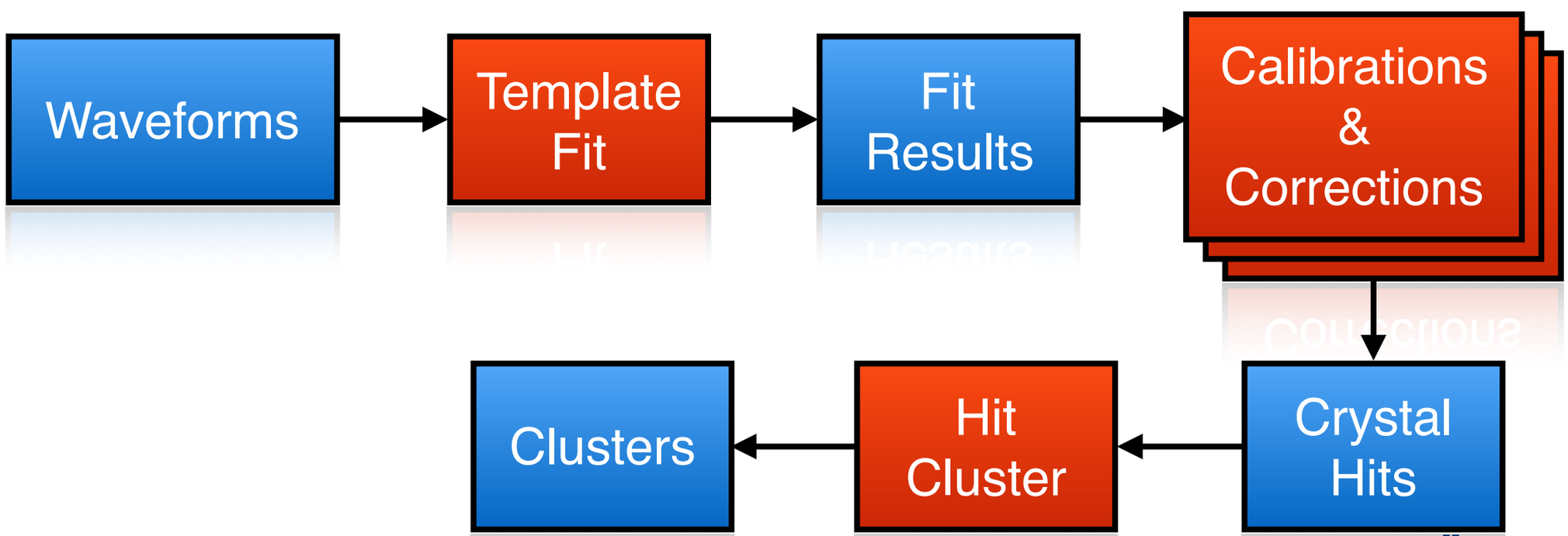
Fill event topology



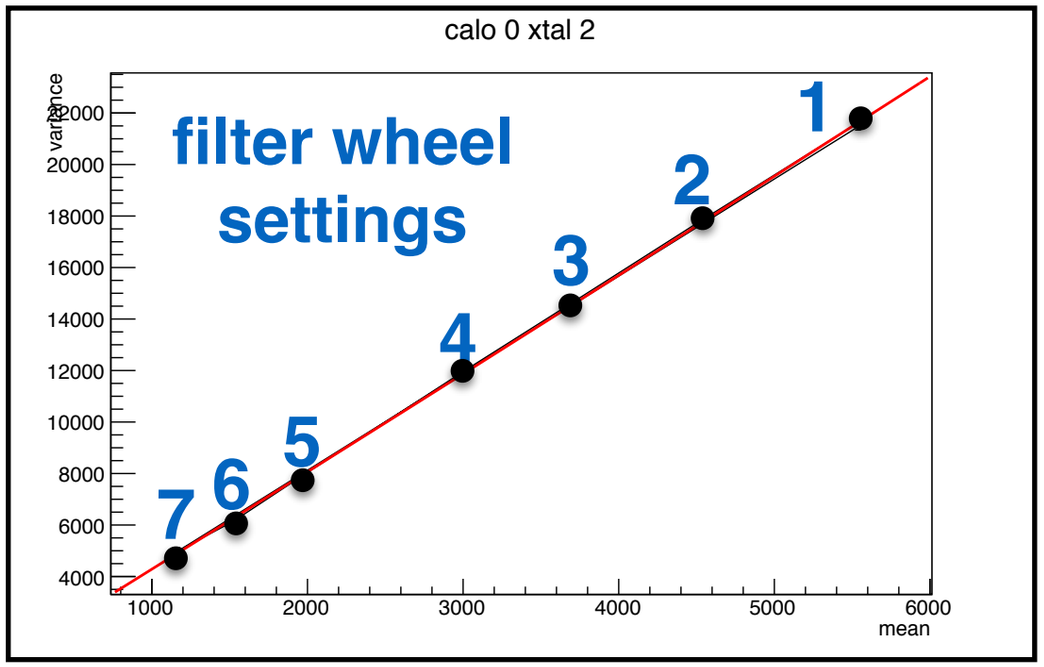
Data reconstruction



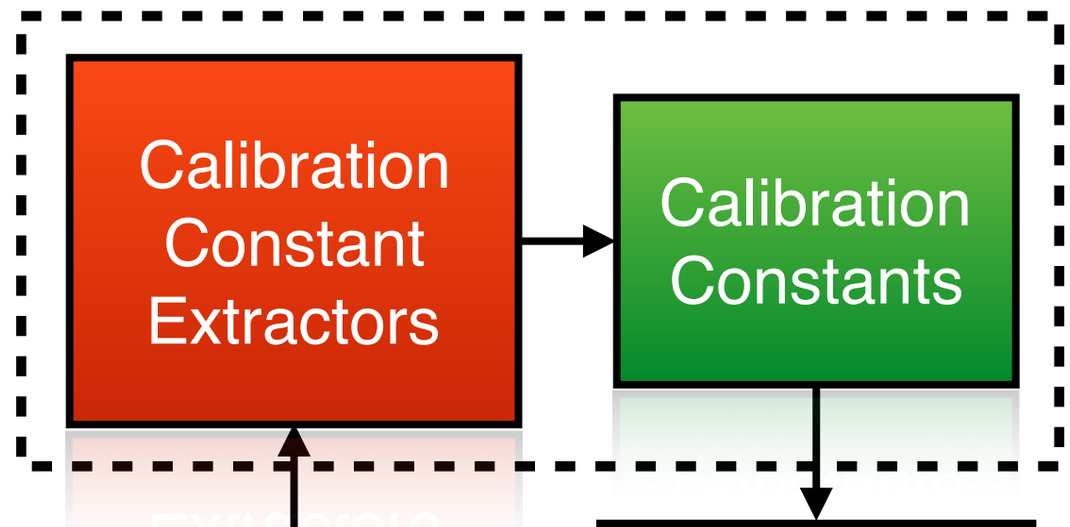


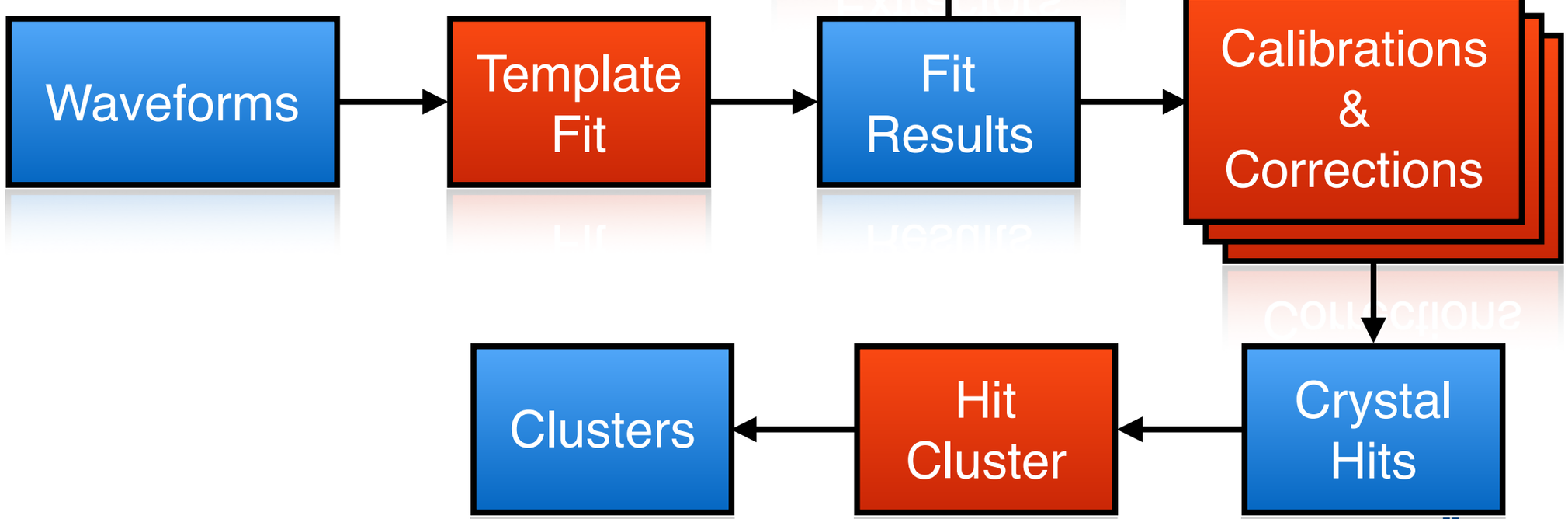


Energy calibration



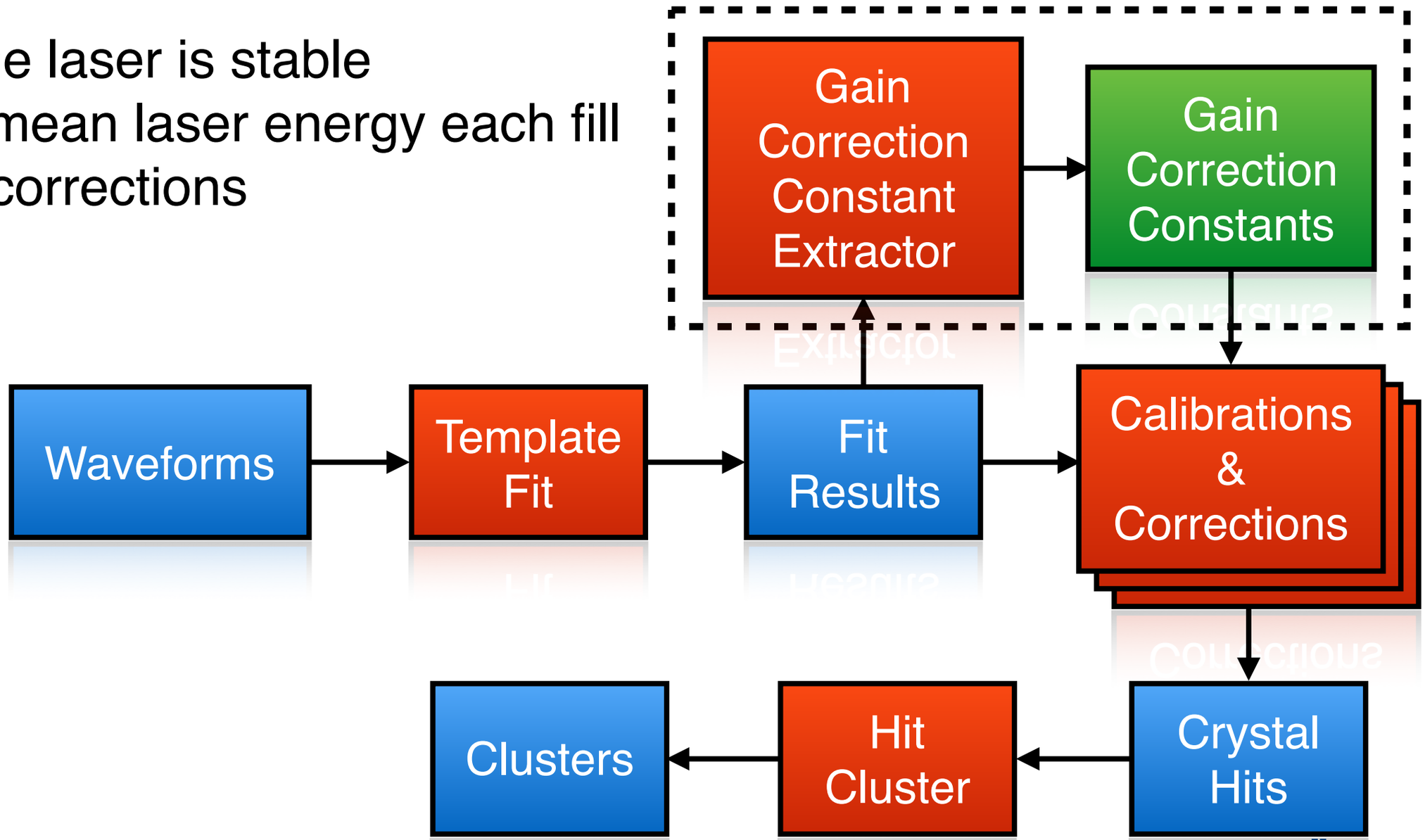
Developed in python, now incorporated into art.





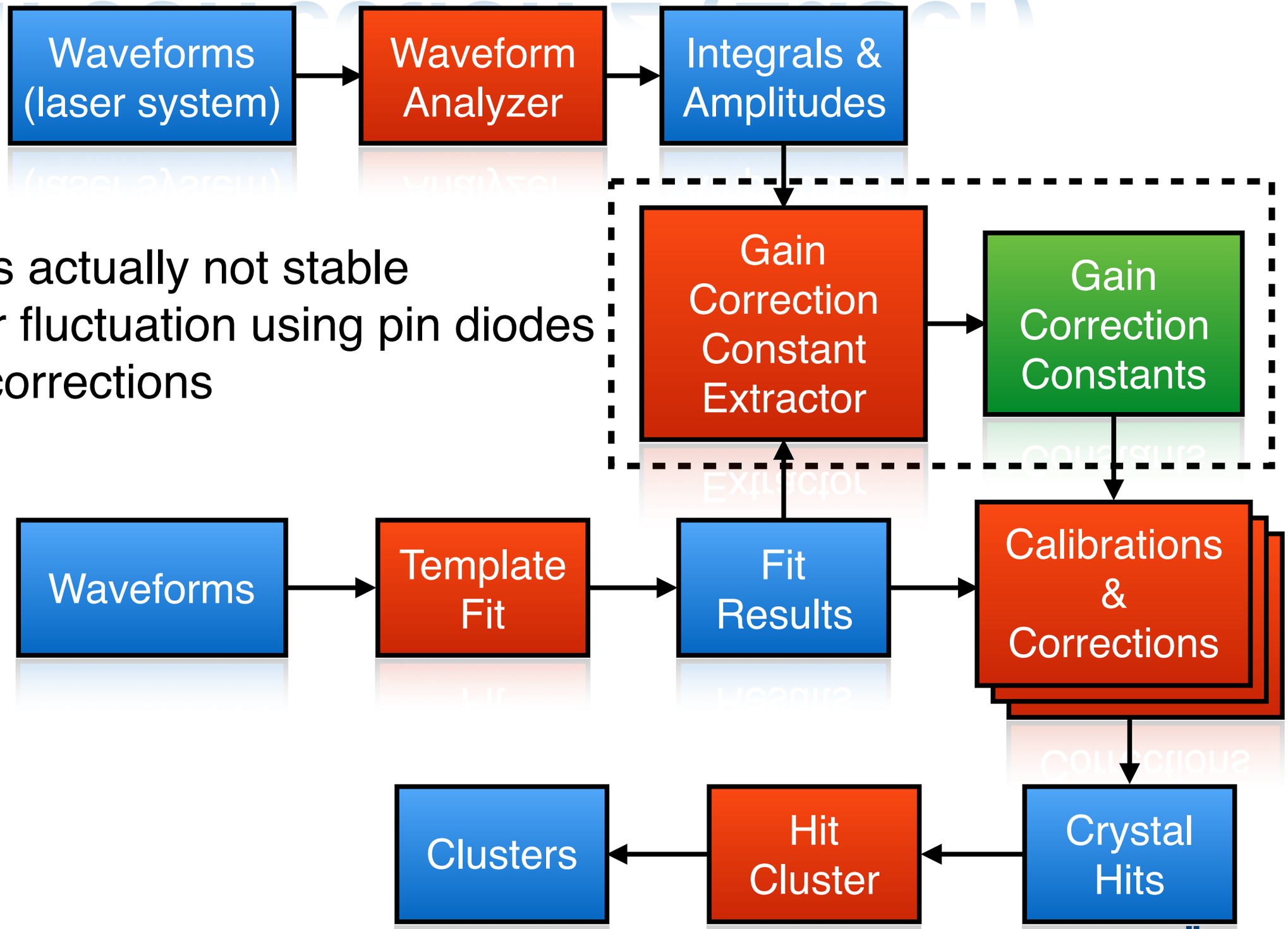
Gain correction 1 (SiPM)

- Assume laser is stable
- Track mean laser energy each fill
- Apply corrections



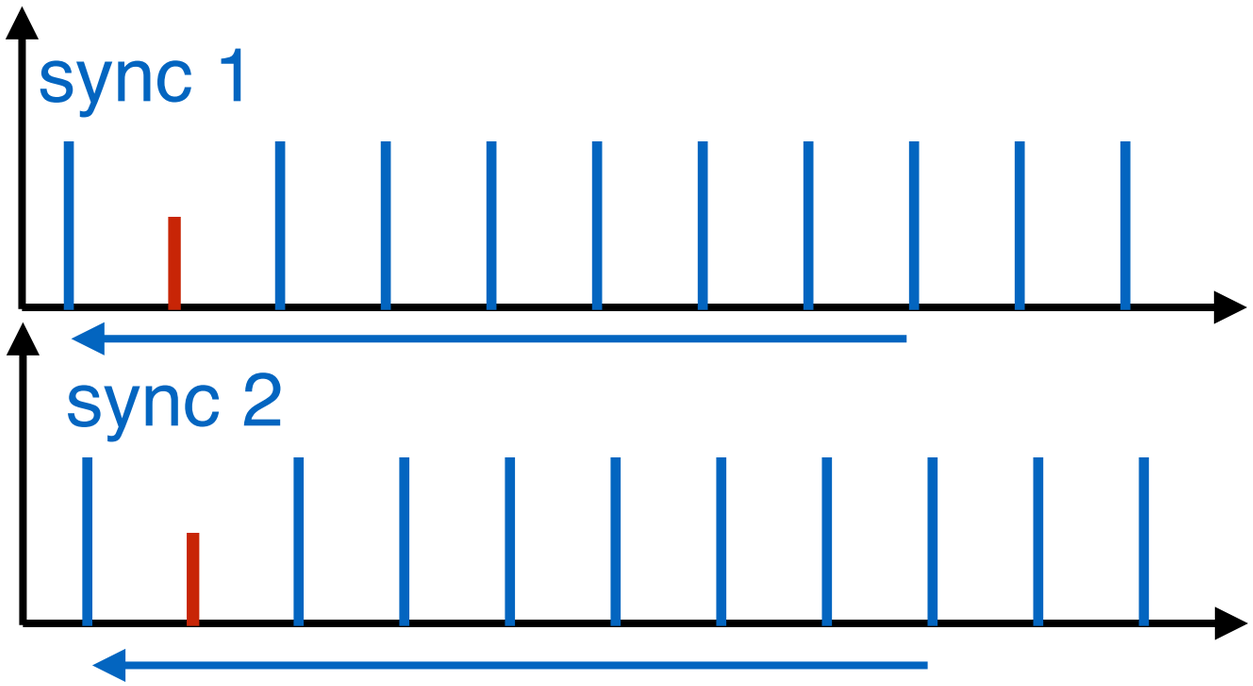
Gain correction 2 (Laser)

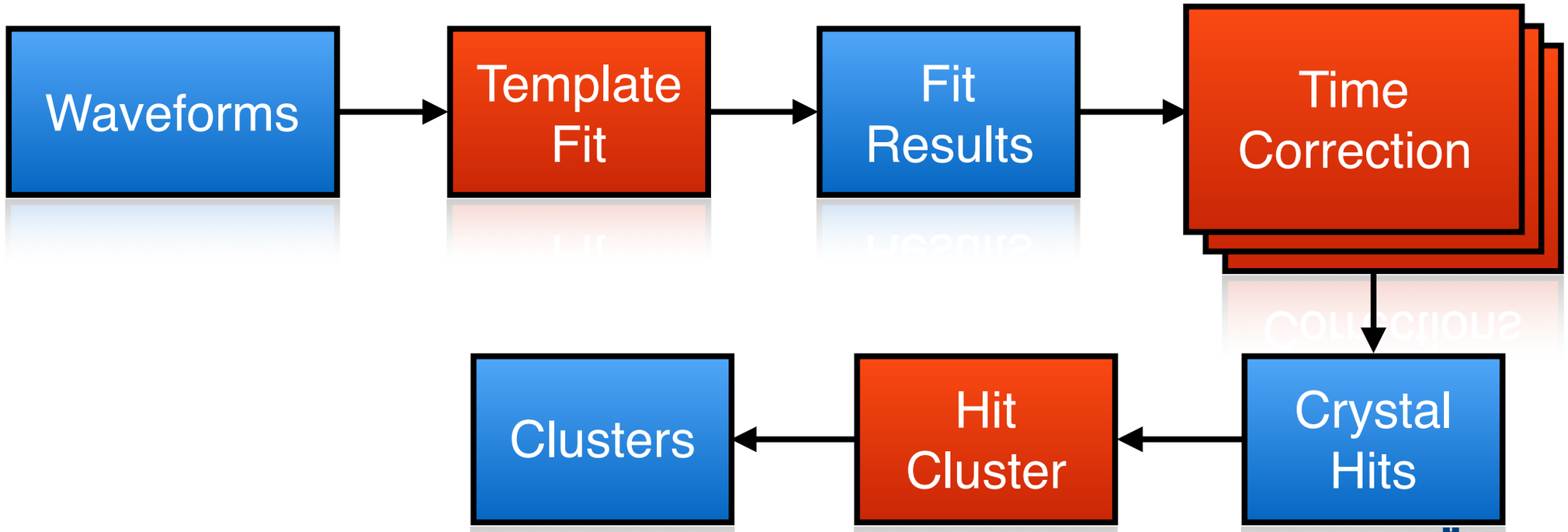
- Laser is actually not stable
- Monitor fluctuation using pin diodes
- Apply corrections



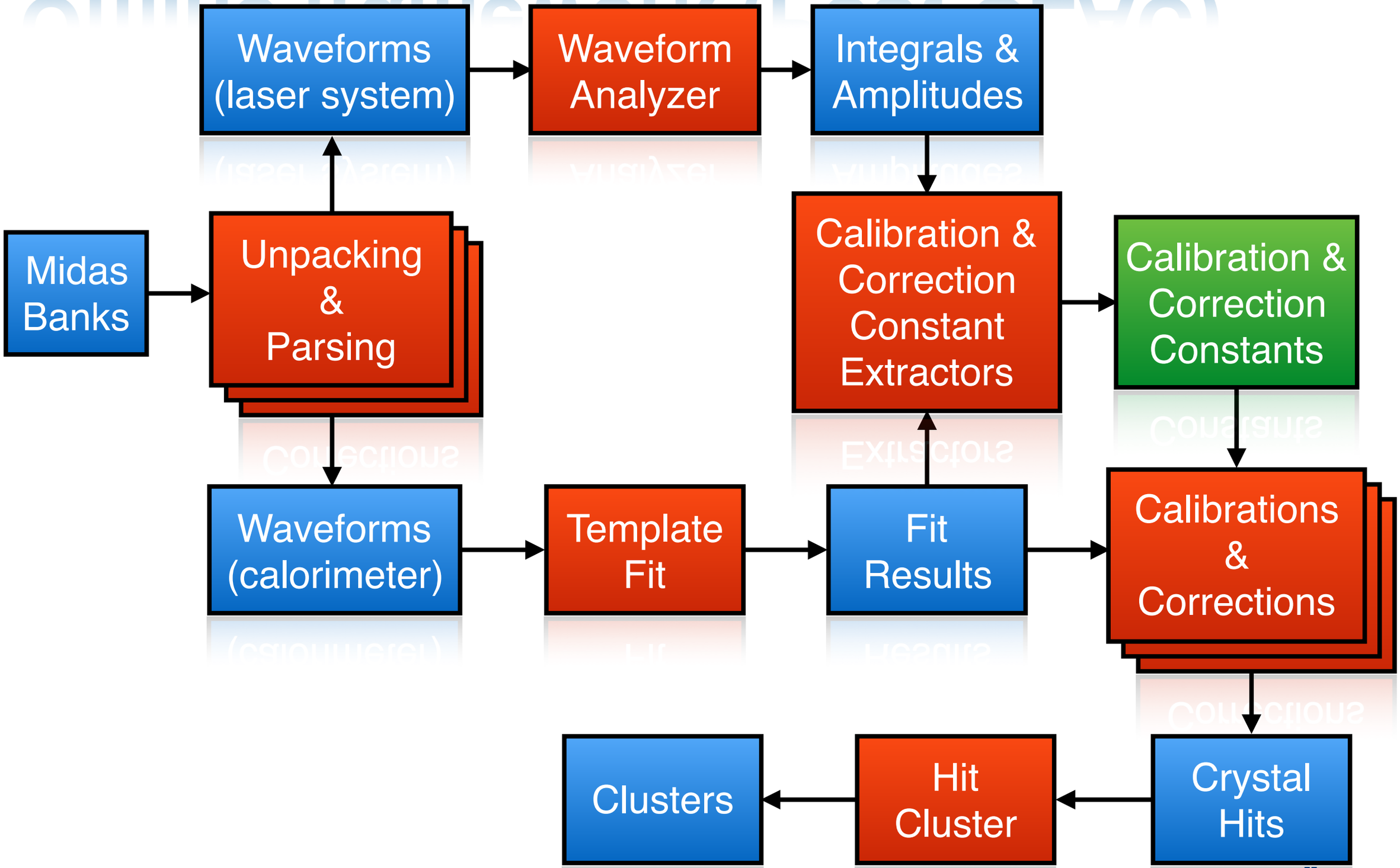
Time correction

- The digitized waveforms are not time aligned
- Laser sync pulses are configured to arrive after the “begin-of-fill”
- Align time in each channel to this pulse on per-fill basis

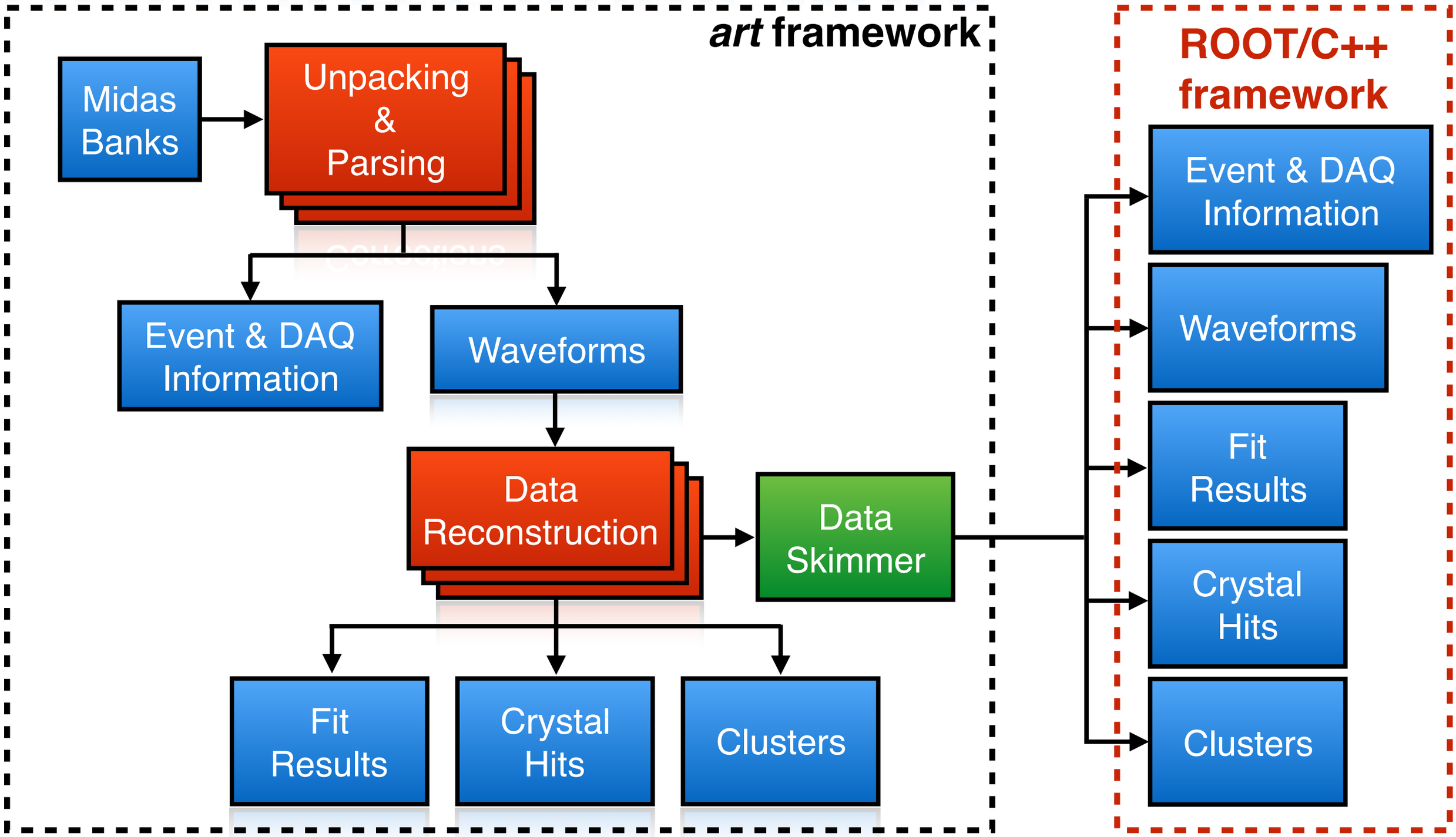




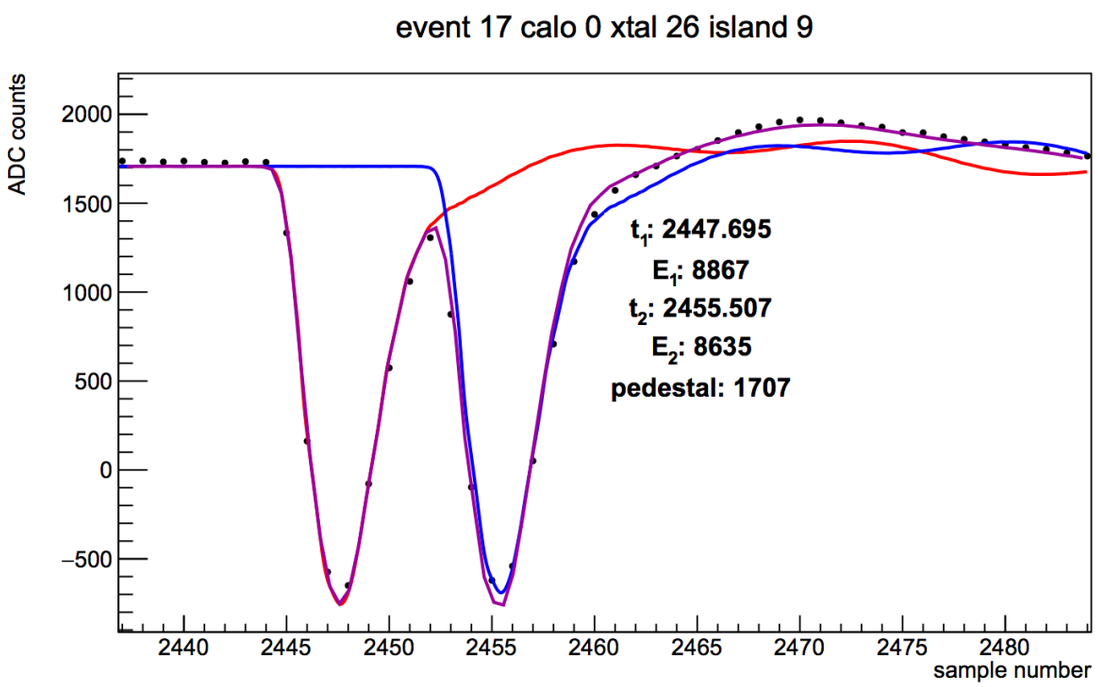
Offline framework (Post-SLAC)



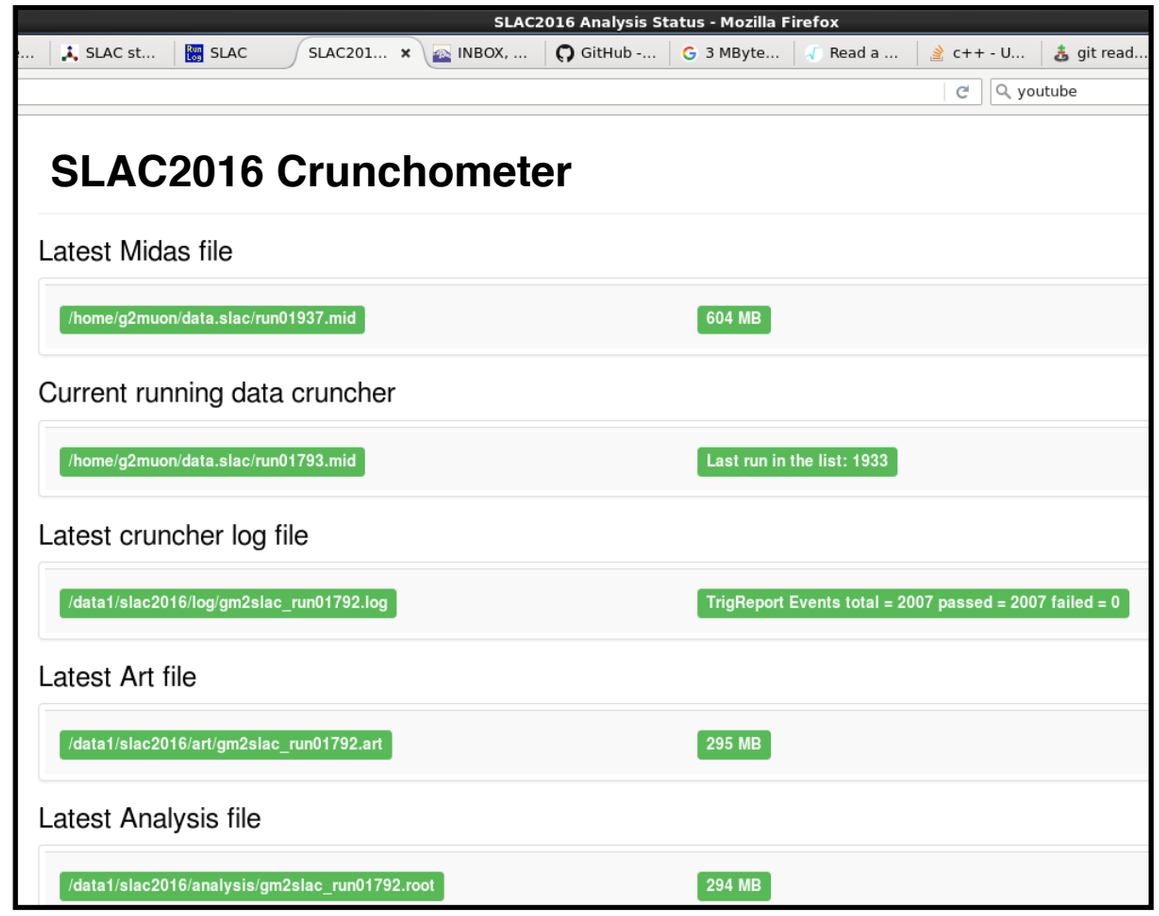
ROOT/C++ framework



Event display & Data processing monitor

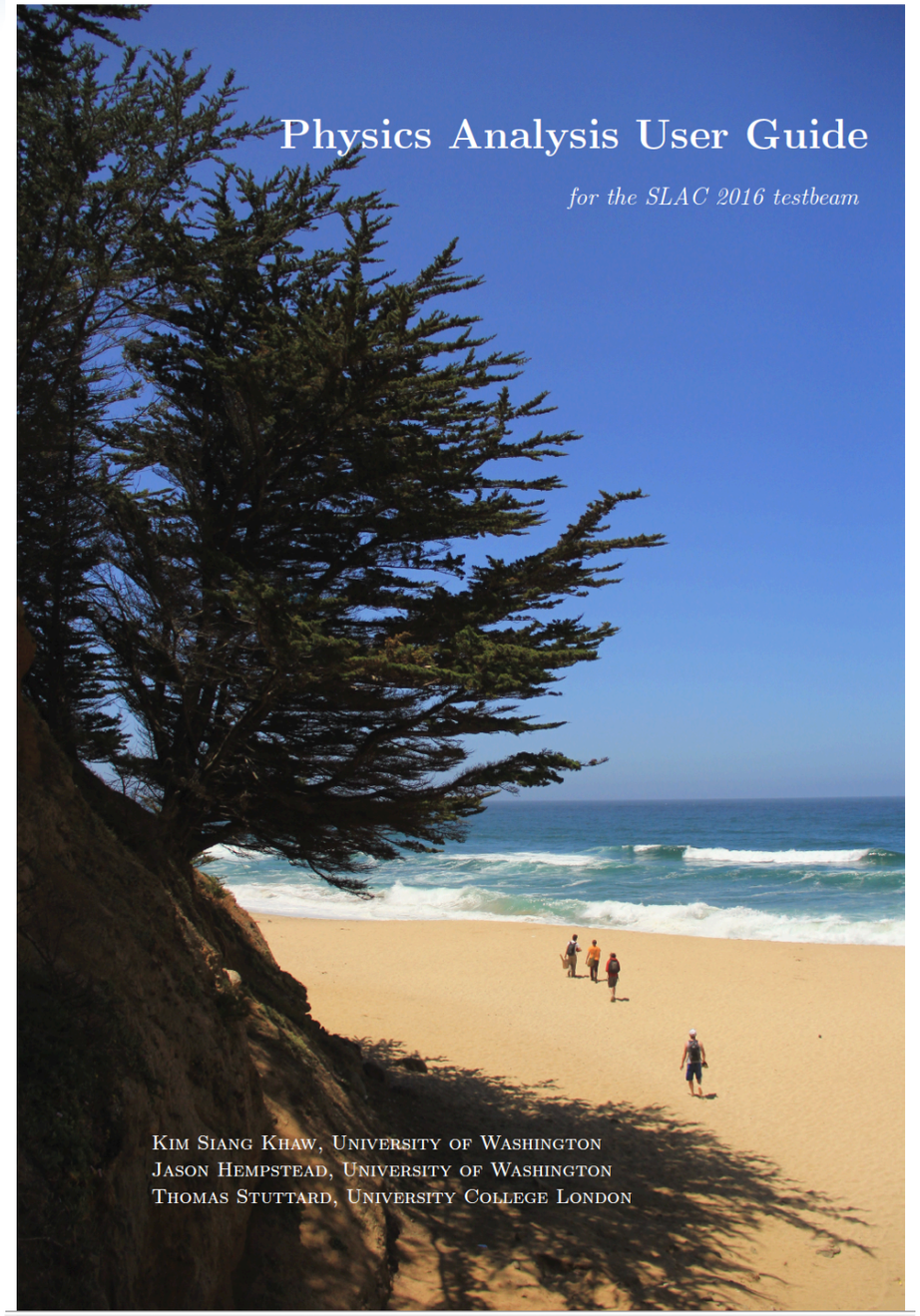


- Simple C++ program using ROOT library
- take root file as input, can plot the waveform and the fit results at the same time
- extremely helpful for DAQ/ detector debugging



- Monitoring current MIDAS DAQ file
- Monitoring current file being processed by offline machine

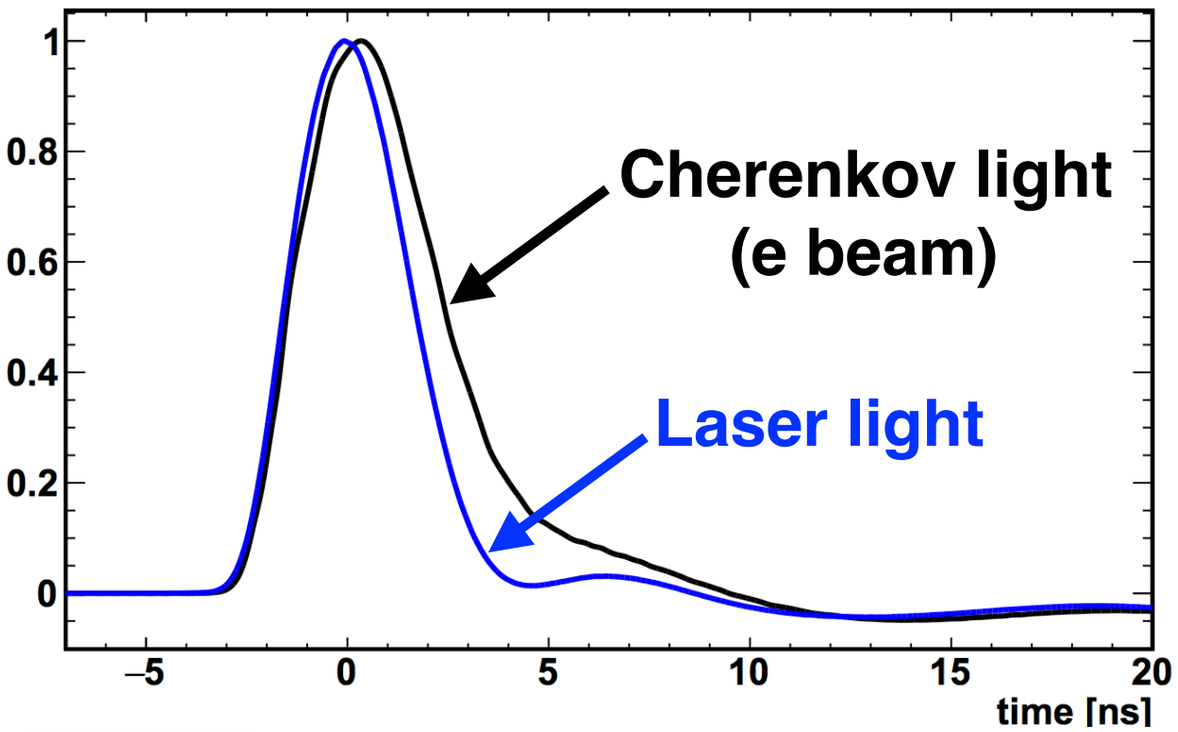
Analysis User Guide



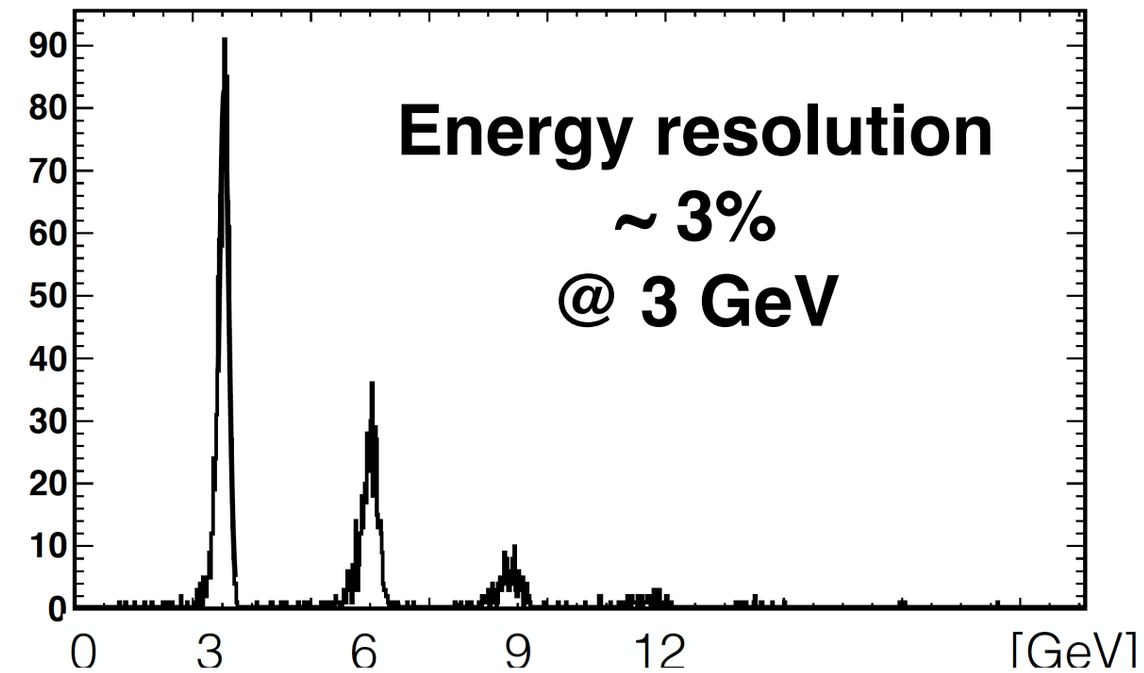
- Similar to Muon g-2 computing manual but focus on physics analysis and SLAC specific info
- A good starting point for future analysis guide
- Also documented the measurement program to aid the analysis

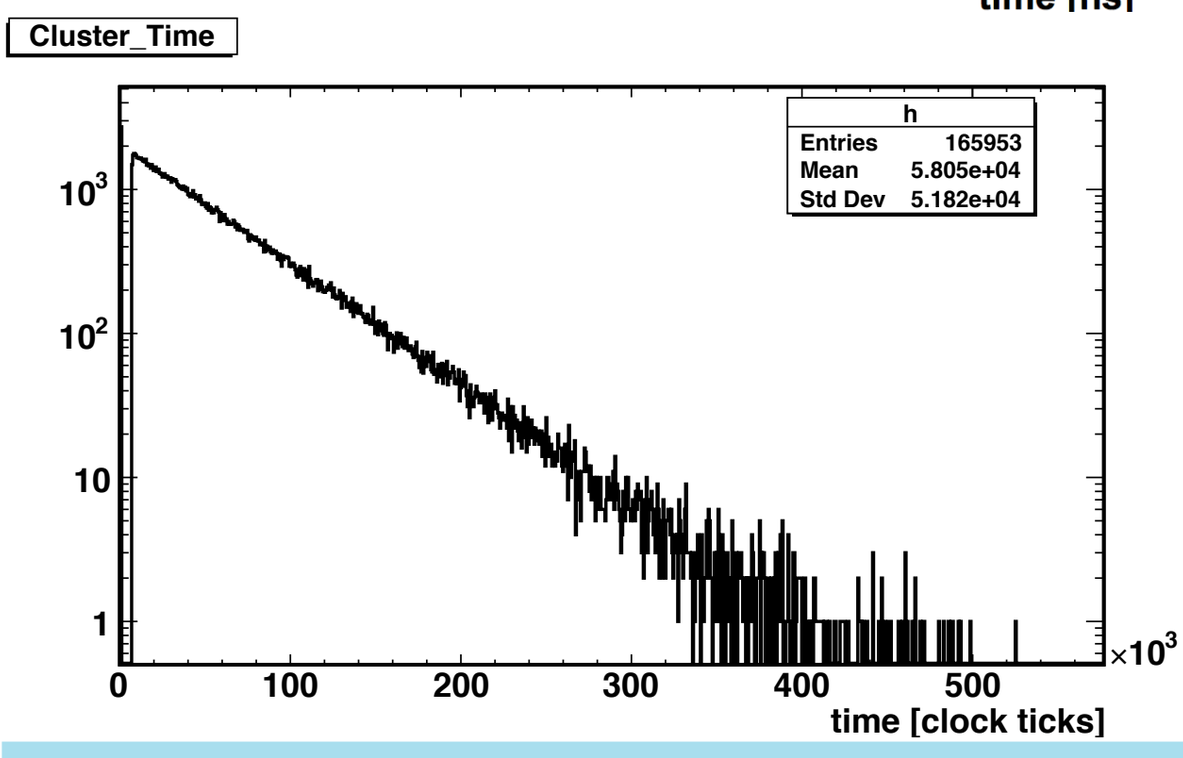
https://github.com/kimsiang/SLAC2016/tree/master/AnalysisManual

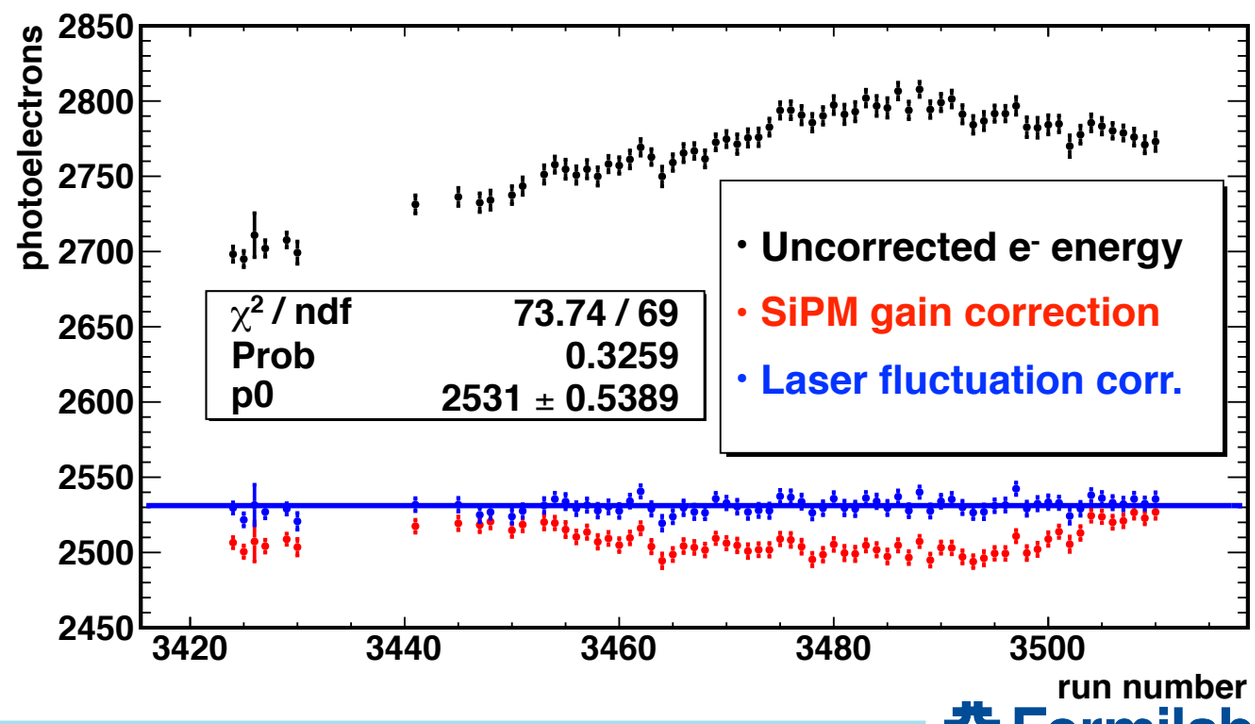
Preliminary results



Poisson comb of hit energies







Production

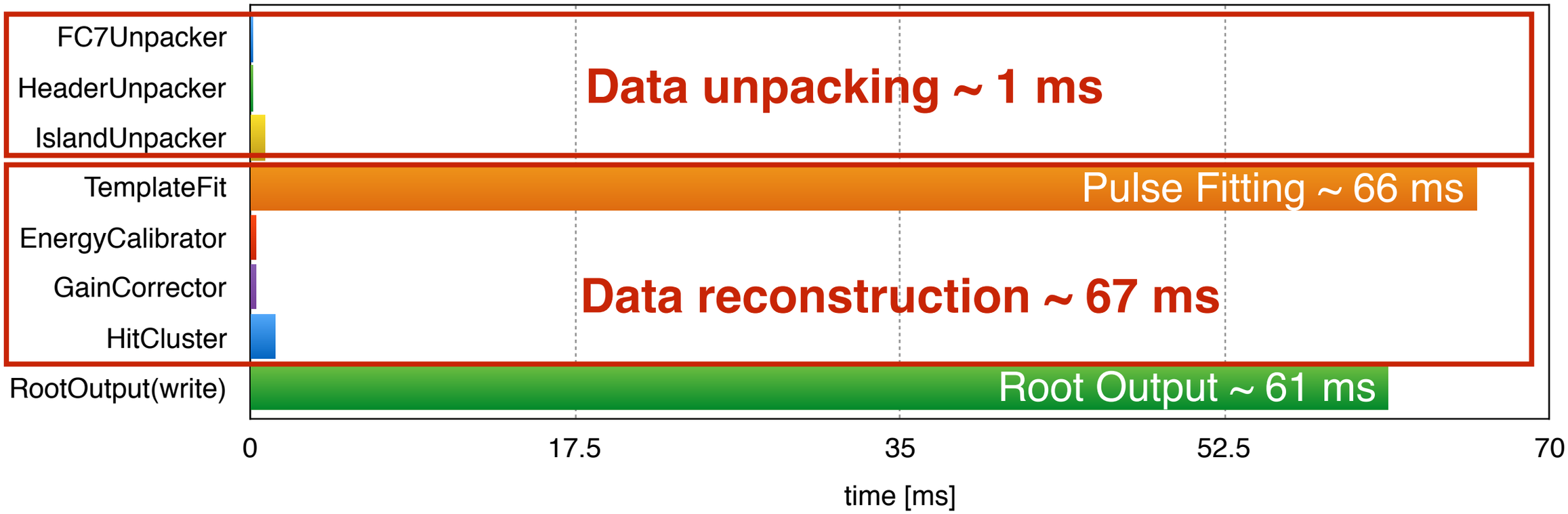
- Dataset collected at SLAC is great for practicing the production routine
- Since the offline processing rate was close to the DAQ rate (12 Hz), 4 weeks of test beam ~ 4 weeks of processing on single-core
- We used Fermi FTS to transfer the raw MIDAS file to dCache tape-backed area
- Initially we used jobsub only to reprocess all the files
- Then we used jobsub + SAM + ifdh to reprocess a subset of the files (tested all the Fermilab supported services we will use for the experiment)
- All the reprocessed files are stored in the dCache persistent area

Summary

- We had a successful end-to-end test run of the calorimetry system at SLAC in summer 2016
- The offline framework worked reasonably well and provided many valuable feedbacks to the calorimetry system
- We have developed several user friendly tools to aid the data analysis (ROOT/C++ framework, event display, data processing monitor, analysis user guide)
- We have tested the full production chain (FTS, jobsub, SAM, ifdh)
- Analysis is still ongoing, results expected ~ 3 months from now
- Based on our experience at SLAC, we are working towards a fast turnaround physics analysis framework (nearline analysis) utilizing CPU multithreading (and possibly GPU processing)

Backup

Timing test (as of this review)



TimeTracker printout (sec)	Min	Avg	Max	Median	RMS	nEvts
Full event	0.0606531	0.0689881	0.501452	0.063798	0.0435458	100
unpackerPath:fc7Unpacker:FC7Unpacker	7.604e-05	0.000102685	0.00109262	9.0768e-05	0.000100388	100
unpackerPath:headerUnpacker:HeaderUnpacker	8.3824e-05	0.000107083	0.000941674	8.80715e-05	8.62767e-05	100
unpackerPath:islandUnpacker:OnlineIslandUnpacker	0.000642255	0.000724877	0.00135163	0.000711773	7.16665e-05	100
unpackerPath:islandFitter:TemplateFit	0.0579027	0.0661387	0.494832	0.0609873	0.0431672	100
unpackerPath:energyCalibrator:EnergyCalibrator	0.000242105	0.000267431	0.000674476	0.000253493	4.61028e-05	100
unpackerPath:gainCorrector:GainCorrector	0.000232165	0.000259864	0.000460291	0.000242228	3.48295e-05	100
unpackerPath:hitCluster:HitCluster	0.00115472	0.00130267	0.00187135	0.00128985	8.2678e-05	100
unpackerPath:TriggerResults:TriggerResultInserter	1.3608e-05	1.48846e-05	3.0534e-05	1.41715e-05	2.91178e-06	100
end_path:outfile:RootOutput	2.015e-06	2.57126e-06	1.4517e-05	2.267e-06	1.51856e-06	100
end_path:outfile:RootOutput(write)	0.0597246	0.0613416	0.0658187	0.0611854	0.0011628	100

Current processing time (single-core)

* SSD/HDD = 0.7

Conditions	Offline processing [ms]	*RootOutput [ms]
1 calorimeter	69	42/61
24 calorimeters	1656	1008/1464
50% less pulses (Muon g-2)	**828**	504/732
Total	**1332/1560 ms**	

- 0.75/0.6 Hz (if we write out everything)
- 1.2 Hz (if we skip the root file output)
- write speed ~ 10 MB/s (SSD, c.f. gm2 simulation ~ 40 MB/s)

Q: How do we go from 1 Hz towards 12 Hz?