Experience of running Icarus-T600 DAQ system @ LNGS and plans for next run @ FNAL

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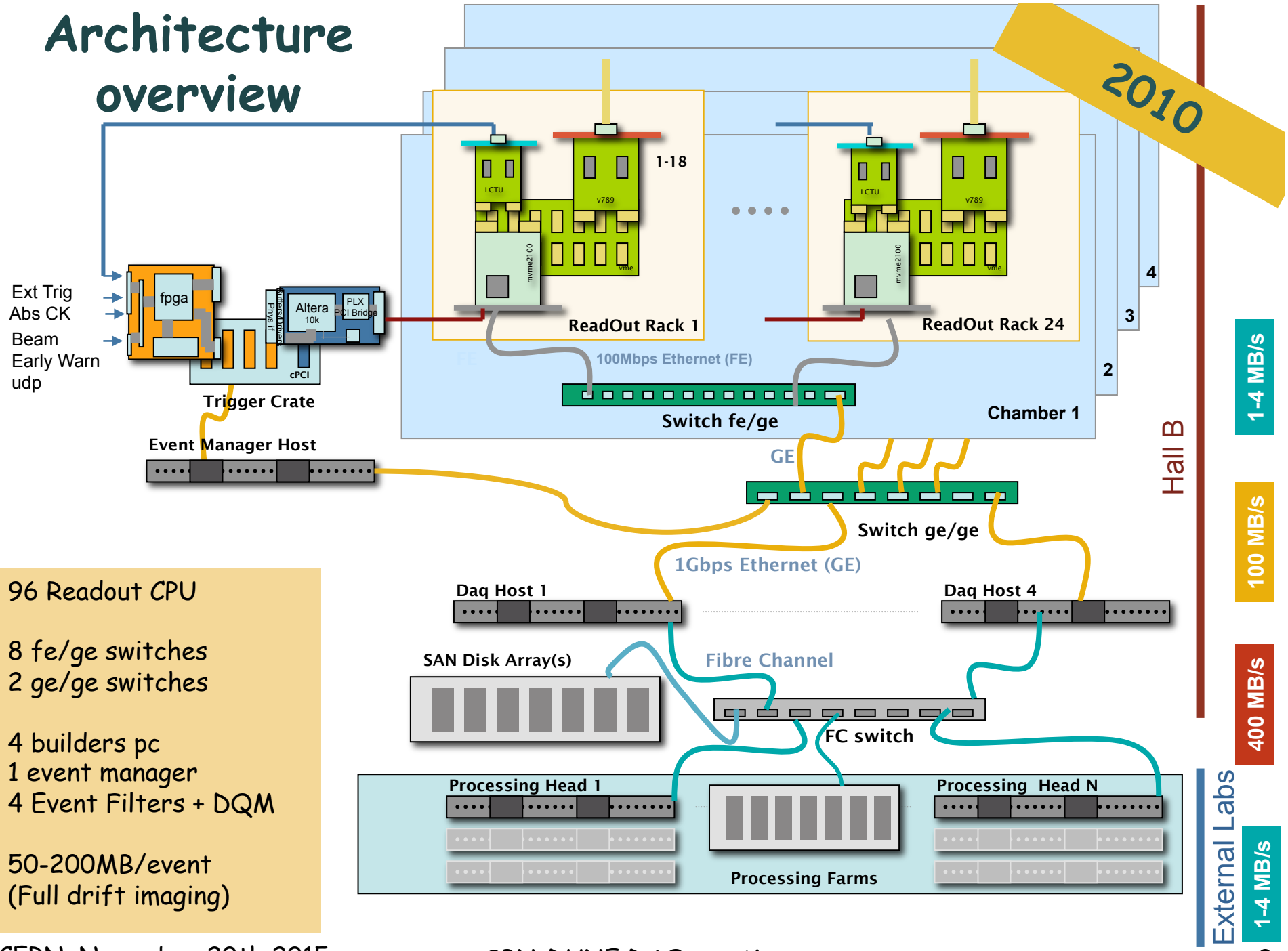
Architecture overview



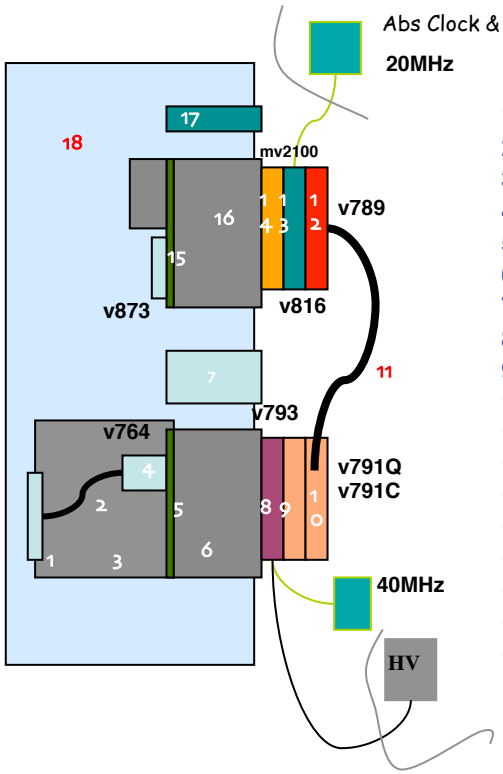
96 Readout CPU

8 fe/ge switches
2 ge/ge switches

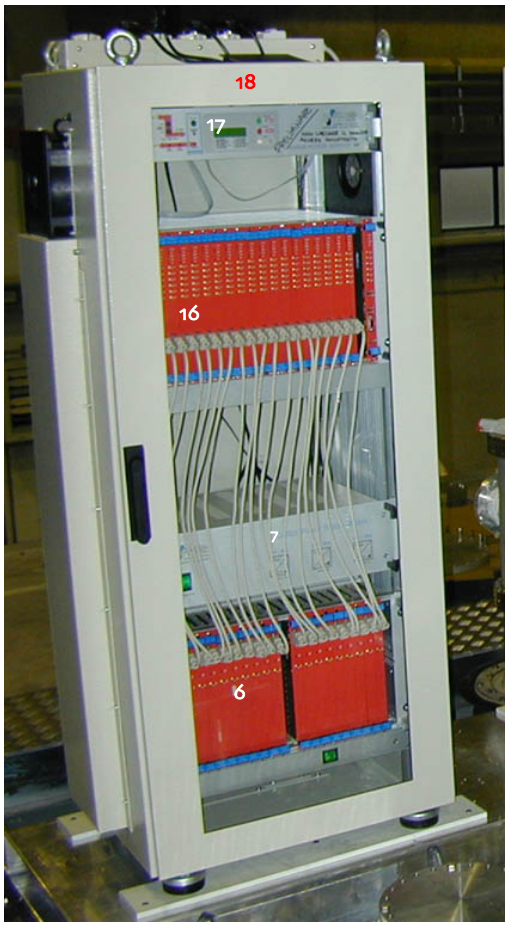
4 builders pc
1 event manager
4 Event Filters + DQM

50-200MB/event
(Full drift imaging)

Front-end electronics Rack



1 Flanges
2 Cables & Conn.
3 Screening Boxes
4 Decoupl. Boards
5 An. Backplanes
6 An. Crates
7 An. Power Supply
8 Slow Control Mod.
9 Charge An. Boards
10 Current An. Boards
11 Dig. Link Cables
12 Dig. Boards
13 Abs. Clock Trig. Mod.
14 Cpu
15 Dig. Backplane
16 Dig. Crate + P.S.
17 P.S. Fan Temp. Controller
18 Rack

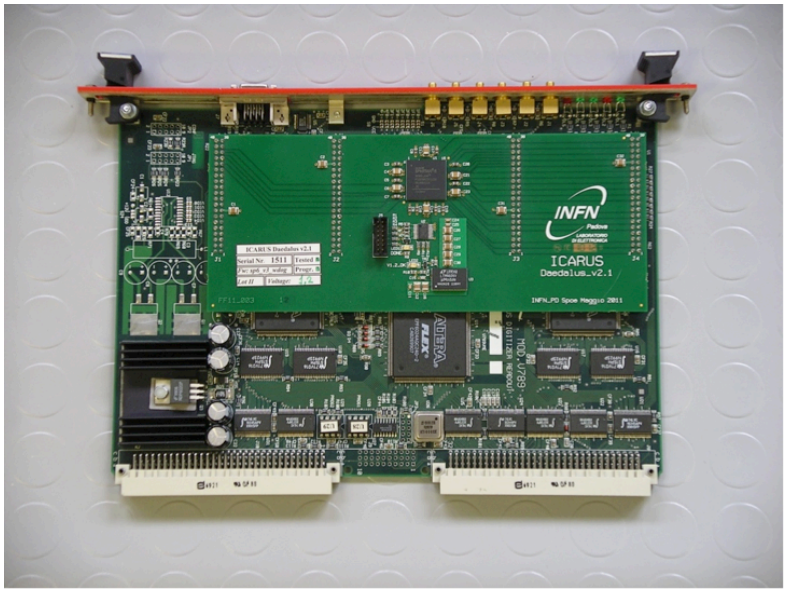


96 (+4 spares) units on the t600

Air tight structure (to reduce post installation servicing). Fan controlled air flow through the alu heat exchanger moderates internal temperature.
A custom unit allows remote probing and control of rack status via an I2C interface.

Operation principle of Front-End electronics

- Signals from TPC wires were continuously digitized at 2.5 MHz (1 t-sample = 400 ns).
- The digital board acted as a 32 channels, 10 bit wide, waveform recorder, storing data in multi-event circular buffers (MEBs).
- MEBs length was set to 4096 t-samples, corresponding to 1.6 full drift window (1.5 m) at the nominal electric field 500 V/cm.
  For each digital board 8 MEBs were available.
- An online lossless compression scheme was adopted to reduce the data volume.
  For each set of 4 consecutive wires, 4-bit differences of signal amplitude w.r.t. the previous t-sample are stored in the same 16-bit word. In case of "overflow" (difference > ± 7 ADC) the 4 differences are stored in 16-bit words.



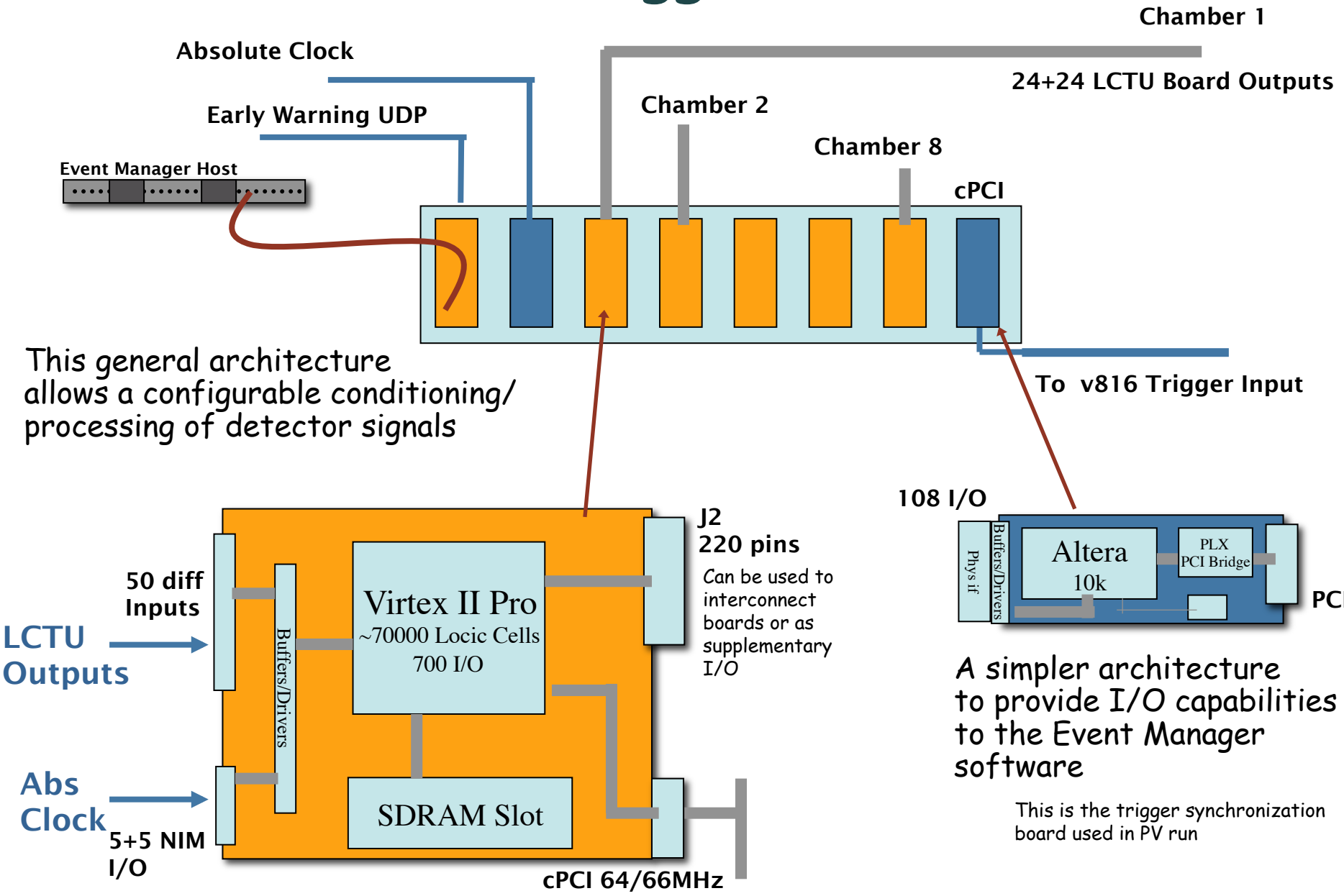
Raw data

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Overhead						10-bit raw data									

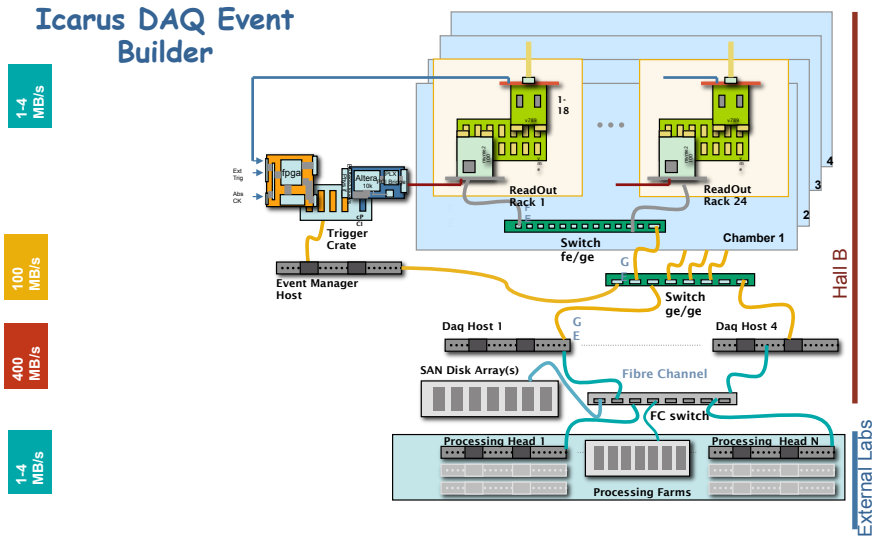
Compression scheme

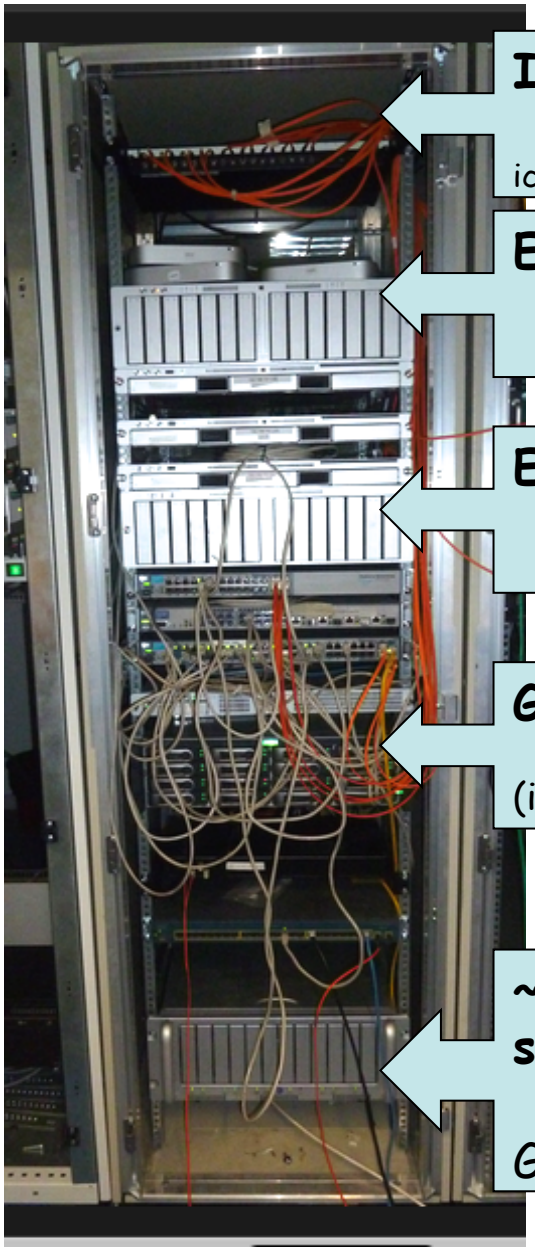
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
4-bit difference of channel N				4-bit difference of channel N+1				4-bit difference of channel N+2				4-bit difference of channel N+3			

The trigger crate



DAQ Rack





Icarus Private Net
up to external labs thorugh icab224 (icadaq2.lngs.infn.it)

Event Filter & DQM
icab229 to icab232

Event Builders
icab225 to icab228

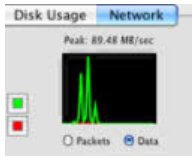
Gateway/DB Server
icab222 (icadaq1.lngs.infn.it)

~100TB of online storage
Data volume ~250 GB/day

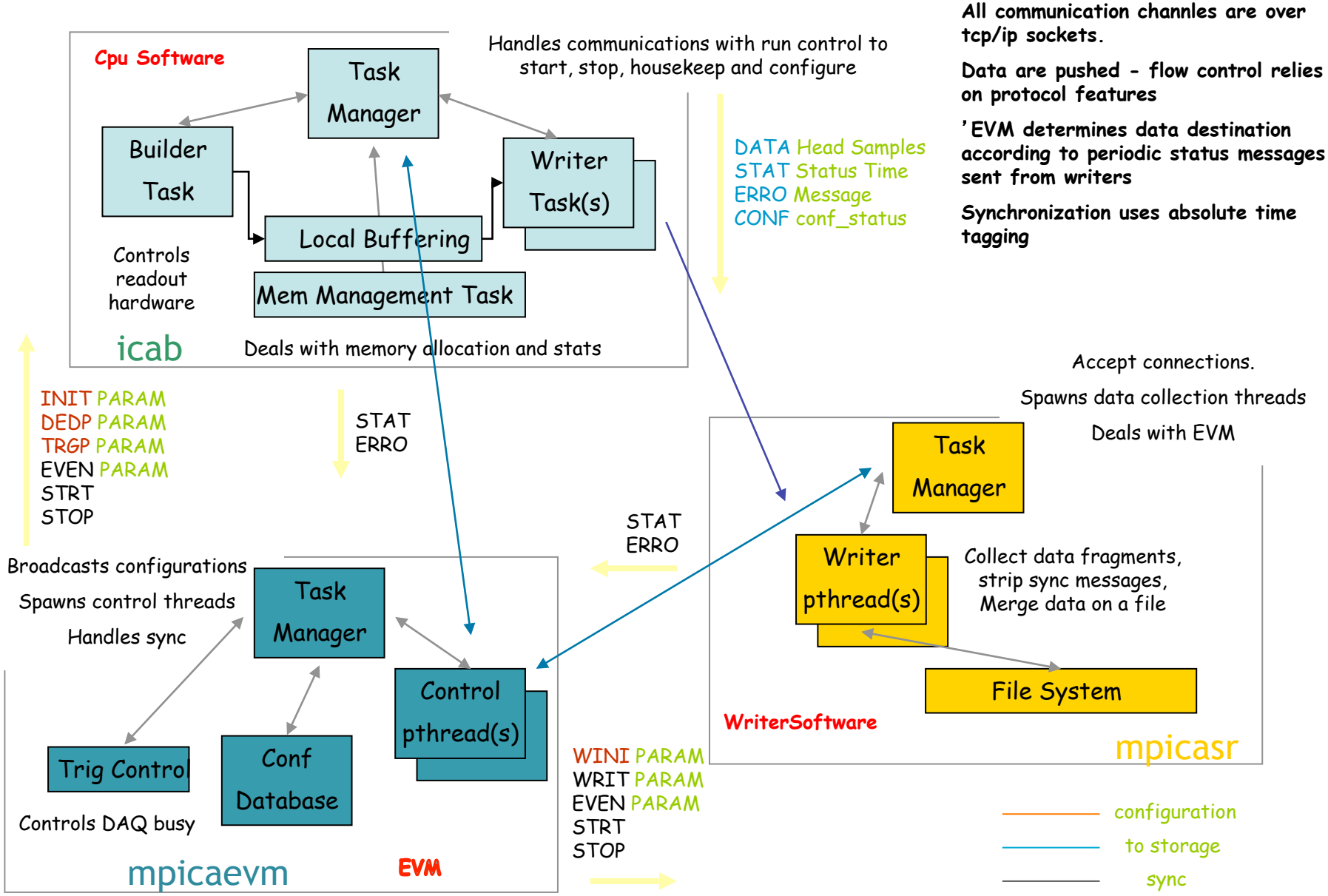
DAQ online storage over a XSAN (StoreNext)
a private FC connection with external labs to alllow external / offline world direct access

Trig<->Daq handshake
over a UDP link

80 MB/s per chamber
Bulding rate ~3 Hz for a 1.6ms drift full image when using 4 parallel builders and readout compression 4



T600 Software Builder Overview



All communication channles are over tcp/ip sockets.

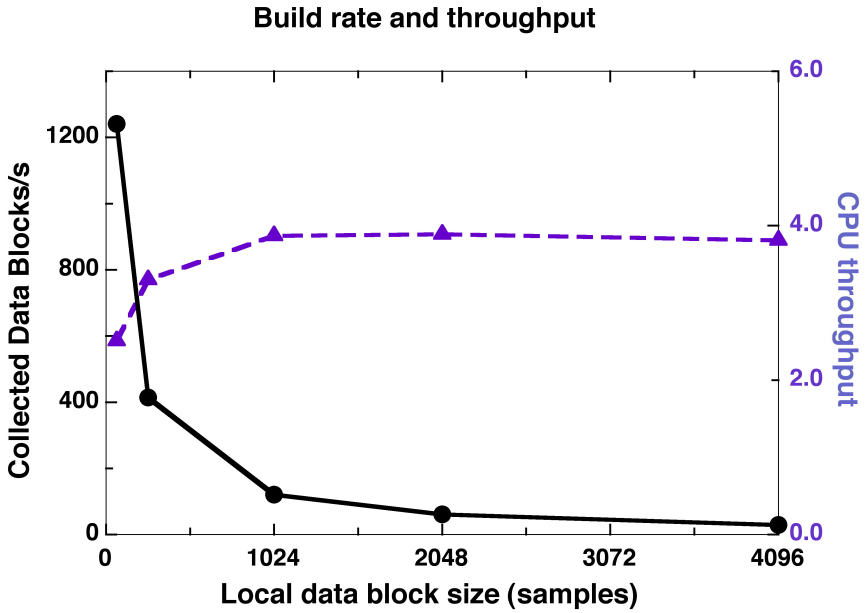
Data are pushed - flow control relies on protocol features

'EVM determines data destination according to periodic status messages sent from writers

Synchronization uses absolute time tagging

T600 Builder Performances

mvme2100



Evaluation of single crate throughput

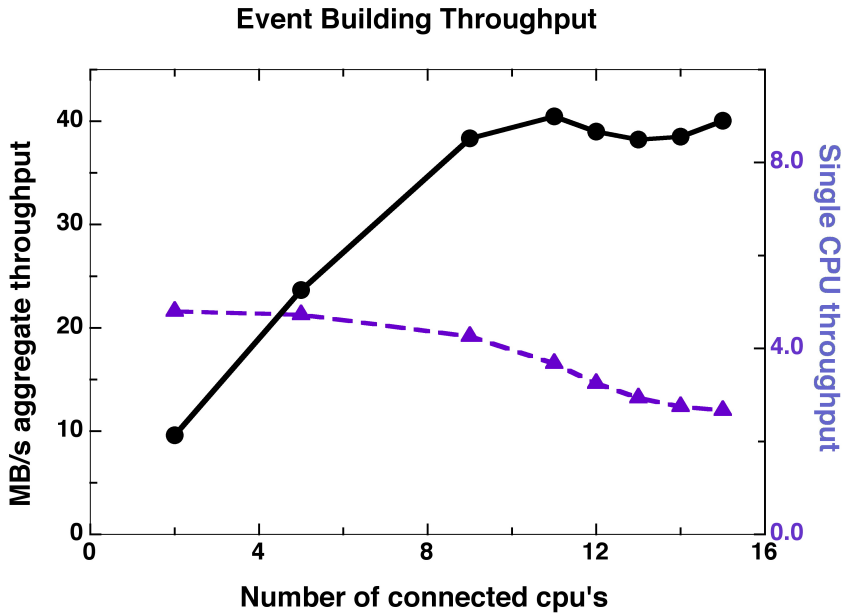
Daq builds from a single rack
Taken into account:
- Synchronization
- VME bus data I/O
- Network protocol overhead

Number of blocks/s satisfies requirements (~1Hz per wire)

Evaluation of aggregate throughput

Daq builds to a single receiver from cpu's running at max throughput
N network streams merged to a single (multithreaded) process (no disk writing)

Receiver saturation over 9 sources, max throughput enough for a whole chamber (24 crates)

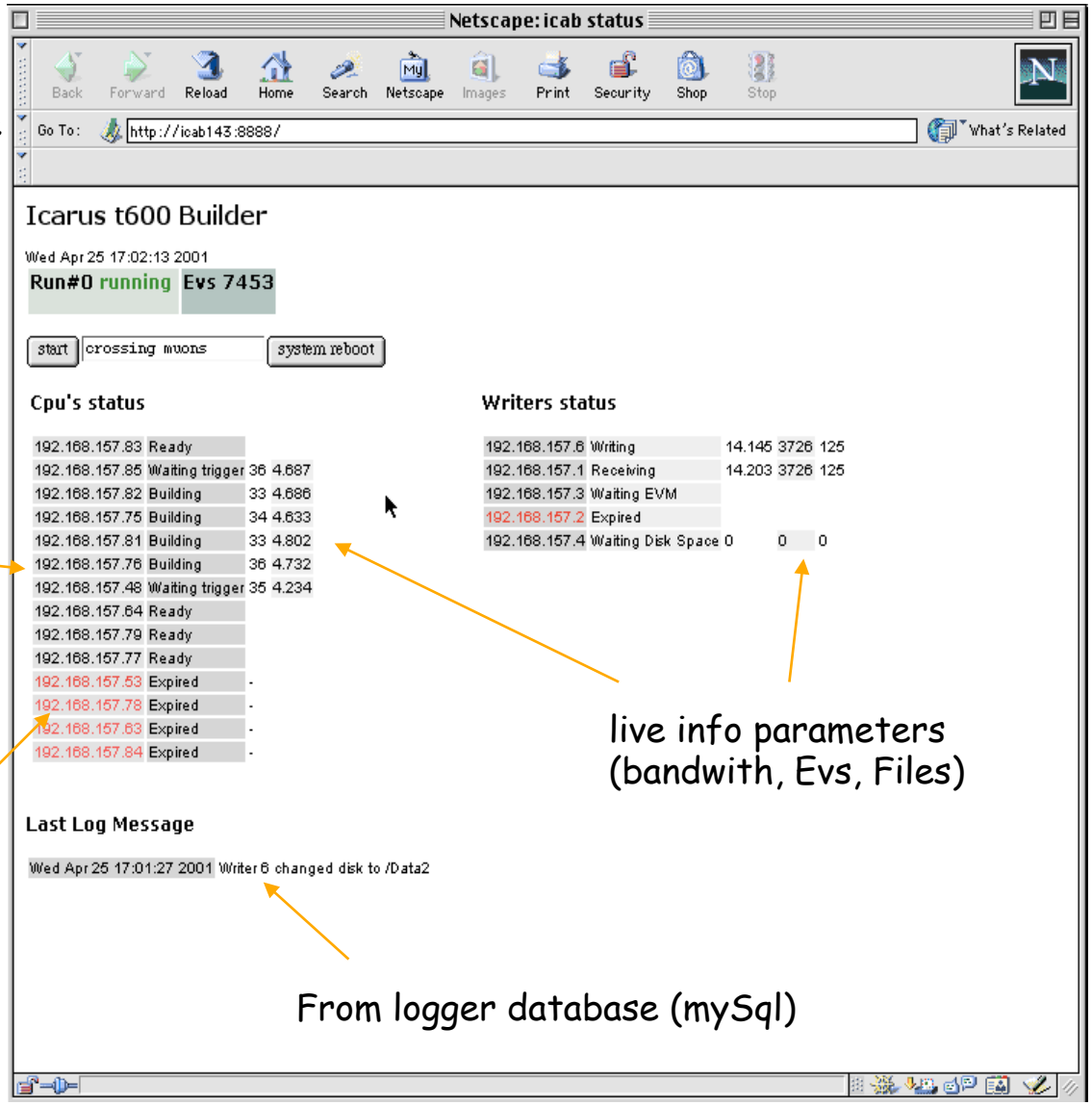


Daq web GUI

An EVM embedded minimal http server provides a view of the daq status and the basic commanding.

The list is built upon udp broadcasts
sent by each component:

```
Struct udppack
{
  long class;
  long status;
  char humanstatus[80];
  long prm[10];
}
```



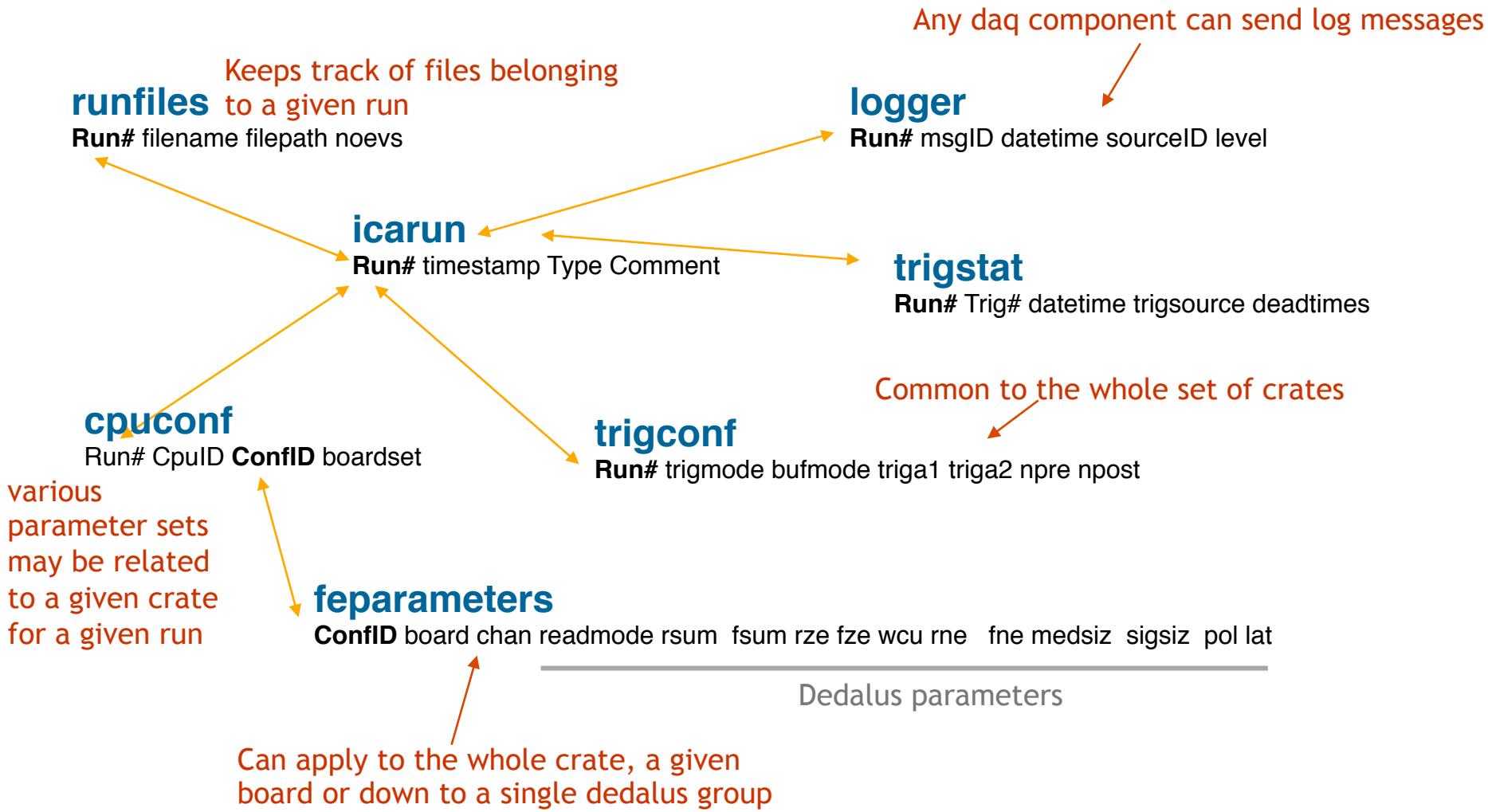
live info parameters
(bandwith, Evs, Files)

Item that don't send anymore

From logger database (mySql)

Database structure

Running on a mySql server, master/slave redundancy



Overview of data flow

"Online" farm

"Offline" farm

Trigger Manager

TPC Front-end

24 x 4 streams of TCP/IP packets

Event building

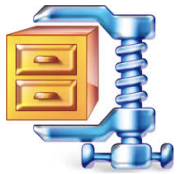
4 files

Data Quality Monitor

4 files

Empty events rejection

4 files



Data compression

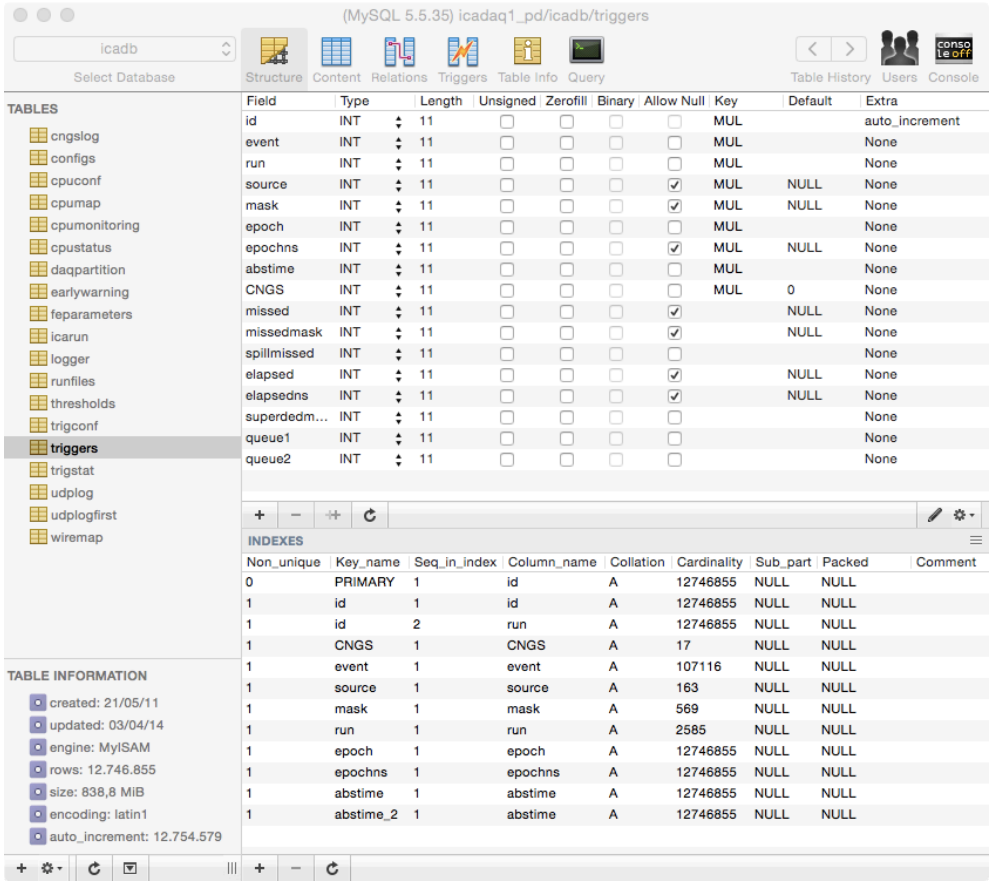
Data merging: offline storage

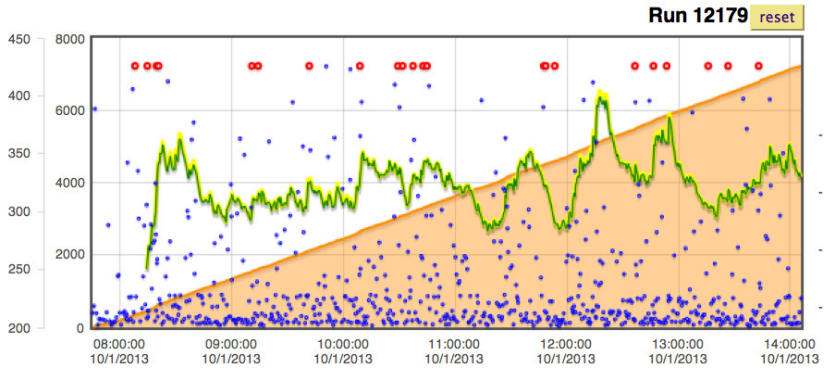
Permanent storage

DAQ monitoring and information logging

A dedicated database was devoted to log, for each event:

- trigger info (source and mask);
- timestamp;
- CNGS tag;
- trigger frequency;
- other info for DAQ monitoring (number of occupied buffer, dead time and building time).

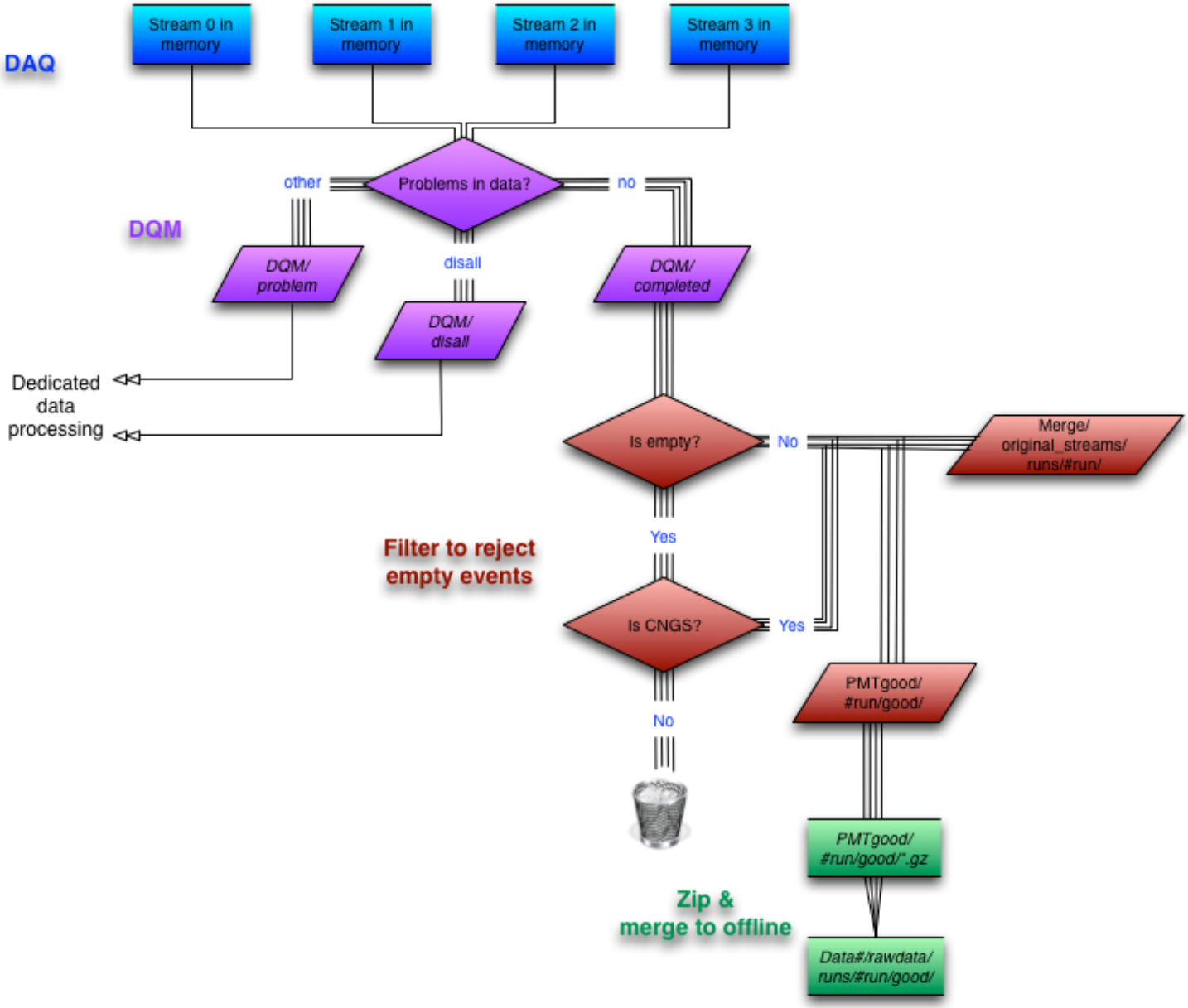




Run	Type	Start	Last event	Missed/Dead time PMT	Spill	CNGS	Event Count/Trigger rate (mHz) Total	East cr.	West cr.	2R ch.	2L ch.	1R ch.	1L ch.	PMT S1	PMT S2	Ded. S1	Ded. S2	Ded. atm.	Spill	Last file	Time info
12179	cosmic rays	2013-01-10 07:44:11	2013-01-10 14:06:07	54	0	0	7224	2717	1906	0	0	0	0	0	0	0	0	2650	0	/Data1/pmt/t600Run12179_07224_3.dat	Export
				1	1	0	315.6	118.7	83.3	0	0	0	0	0	0	0	0	115.8	0		
12178	cosmic rays	2013-01-09 19:08:48	2013-01-10 07:40:39	49	0	0	14017	5269	3673	0	0	0	0	0	0	0	0	5142	0	/Data1/pmt/t600Run12178_14017_3.dat	Export
				0.5	0.5	0	310.9	116.9	81.5	0	0	0	0	0	0	0	0	114	0		
12177	cosmic rays	2013-01-09 08:21:12	2013-01-09 19:05:12	29	0	0	12055	4349	3217	0	0	0	0	0	0	0	0	4555	0	/Data1/pmt/t600Run12177_12055_3.dat	Export
				0.5	0.5	0	312.2	112.6	83.3	0	0	0	0	0	0	0	0	118	0		
12176	cosmic rays	2013-01-09 07:37:33	2013-01-09 08:19:31	9	0	0	835	273	180	0	0	0	0	0	0	0	0	387	0	/Data1/pmt/t600Run12176_00835_0.dat	Export
				2.6	2.6	0	337.8	110.4	72.8	0	0	0	0	0	0	0	0	156.6	0		
12175	cosmic rays	2013-01-08 20:01:26	2013-01-09 07:20:07	36	0	0	11982	4519	3142	0	0	0	0	0	0	0	0	4381	0	/Data1/pmt/t600Run12175_11982_3.dat	Export
				0.6	0.6	0	294.4	111	77.2	0	0	0	0	0	0	0	0	107.6	0		

A webpage, continuously and automatically updated, was made available for shifter checks.

Flow chart of data files processing

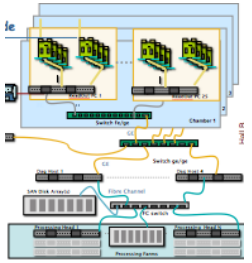


A quick look into possible future scenarios

An improved front-end electronics is being developed for ICARUS operations at FNAL, and DAQ must be changed accordingly.

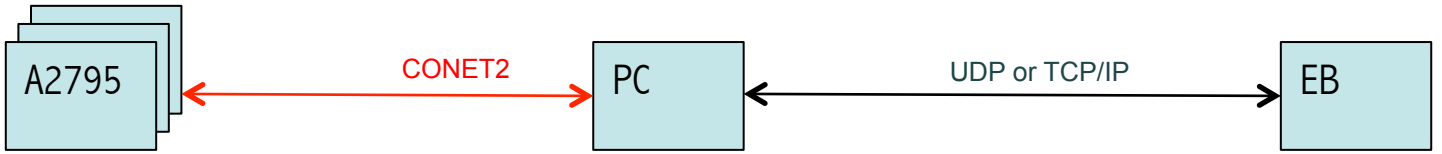
Legacy DAQ with ReadOut units upgrade

The A2795 Frant End electronics foresee a CONET 2 link. Legacy vme cpu's replaced by stock pc's equipped with Conet interface. DAQ system untouched.



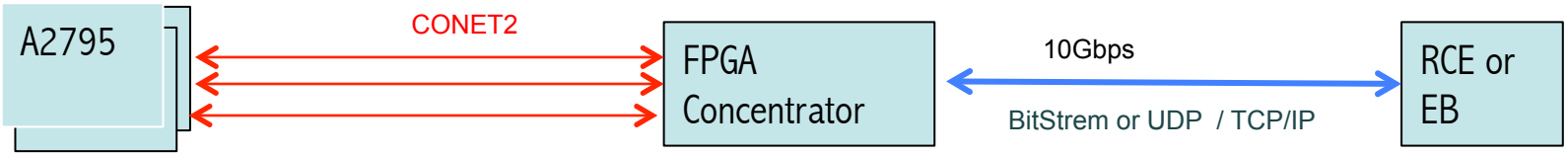
NewDAQ with ReadOut units integration

Legacy vme cpu's replaced by stock pc's equipped with Conet interface. Integration in a new DAQ as a network node in the event builder with appropriate behavior.



NewDAQ with FPGA based interface

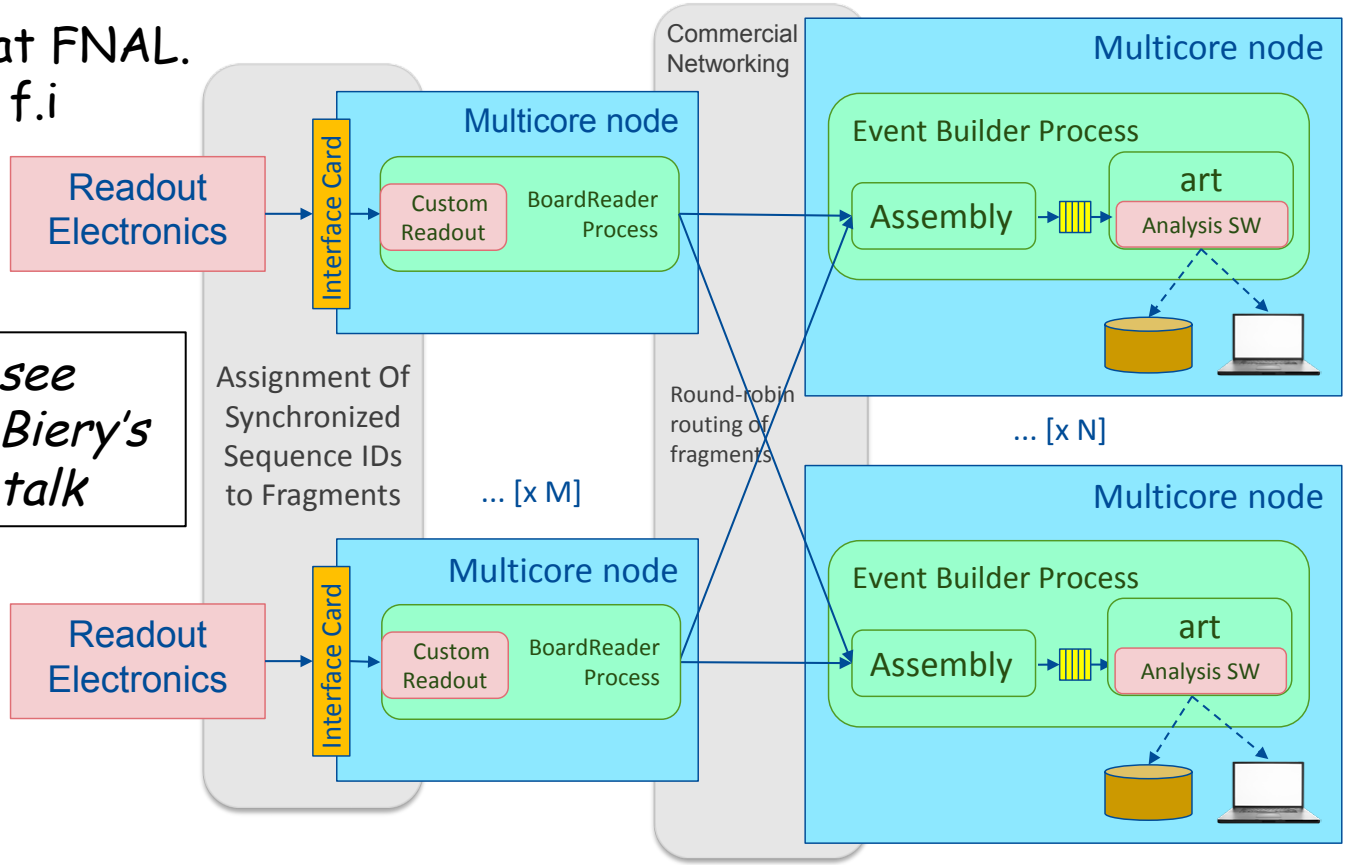
An FPGA based "interface" handles the A2795 CONET links, and concentrates them to a new DAQ directly on high speed serial links (with appropriate pipeline buffering and data formatting)



A possible software integration: ArtDAQ

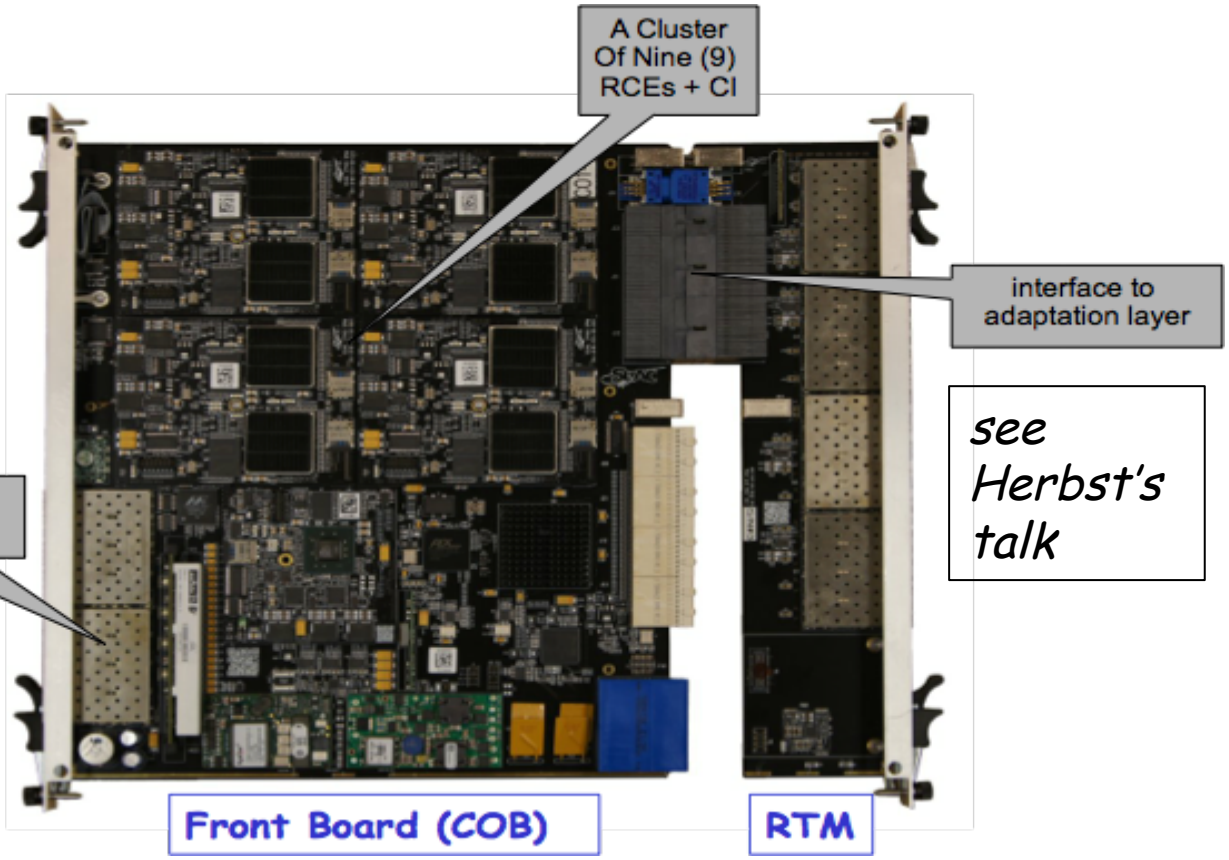
- A toolkit (*artdaq*) is available at FNAL to develop DAQ systems.
- It provides data transfer, event building, quality monitoring and writing of data to disk, in a customizable way in order to match specific experimental needs.
- Tiles of data coming from the detector at each trigger are uniquely identified by a sequence number, and are then routed all to the same event builder, where they are queued for processing with art reconstruction tools.
- It is broadly adopted at FNAL. However MicroBooNE, f.i a slightly different system, even if easily traslatable.
- Many issues, proved to be crucial in data taking at LNGS (database, trigger/ DAQ handshake, software trigger…) need to be developed, but there is good potentiality.

see Biery's talk



A possible hardware solution: RCEs

- AIR (Advanced Instrumentation for Research) group at SLAC develops has broad expertise in developing electronics and DAQ systems for HEP, Astronomy and Photon science.
- One existing example is a board hosting a customizable interface to the front-end electronics specific of the experiment, together with a general purpose part (Reconfigurable Cluster Element RCE) equipped with an FPGA to provide the link with DAQ.
- It is a cost effective solution mainly for a limited number of high-speed links. In order to apply it to ICARUS, a concentration effort should be spend upstream (f.i. at the level of the FPGA on the digital boards).
- A solution based on these devices is been used in DUNE-35t prototype in triggerless mode.



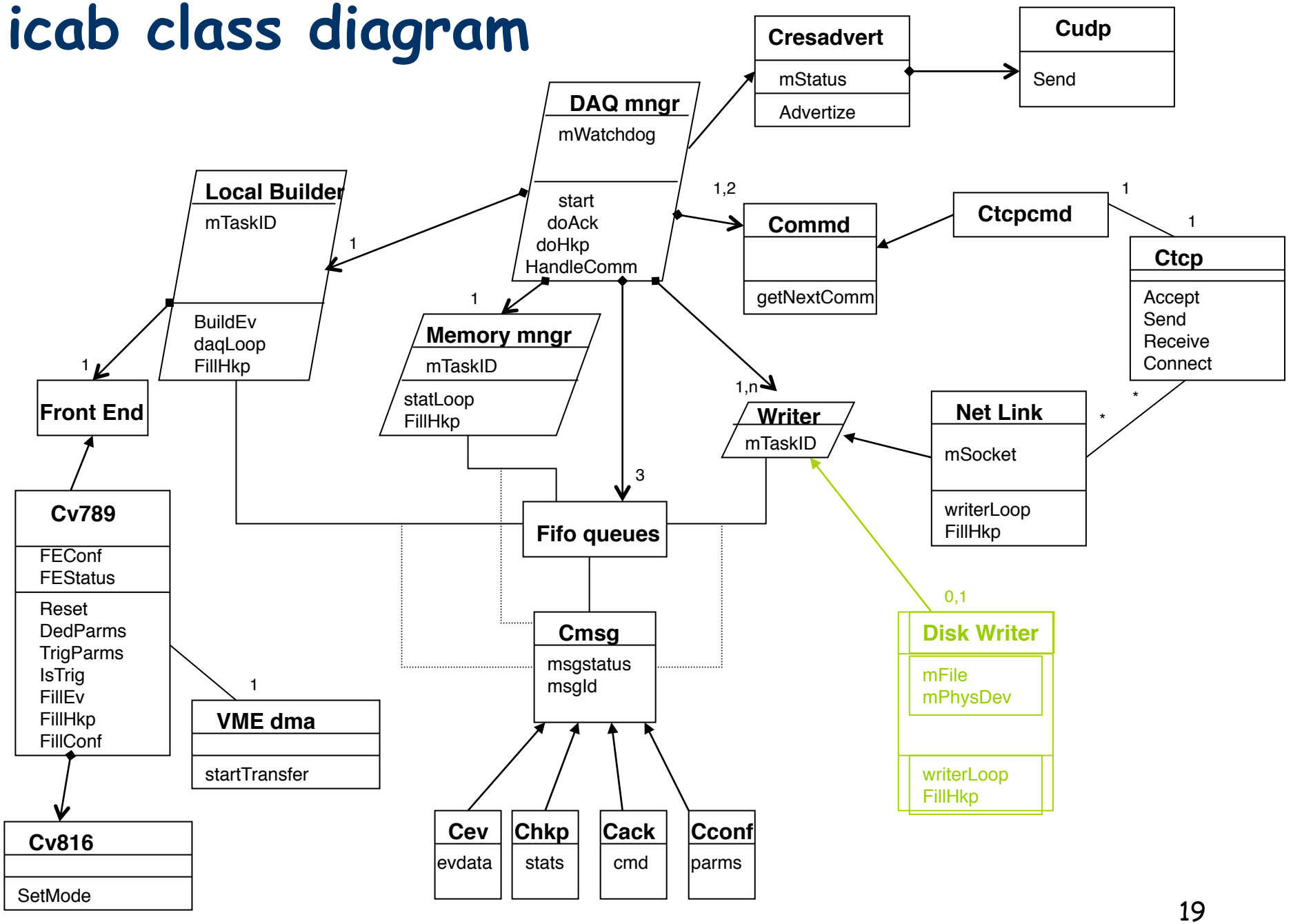
see Herbst's talk

Closeout and activity plans

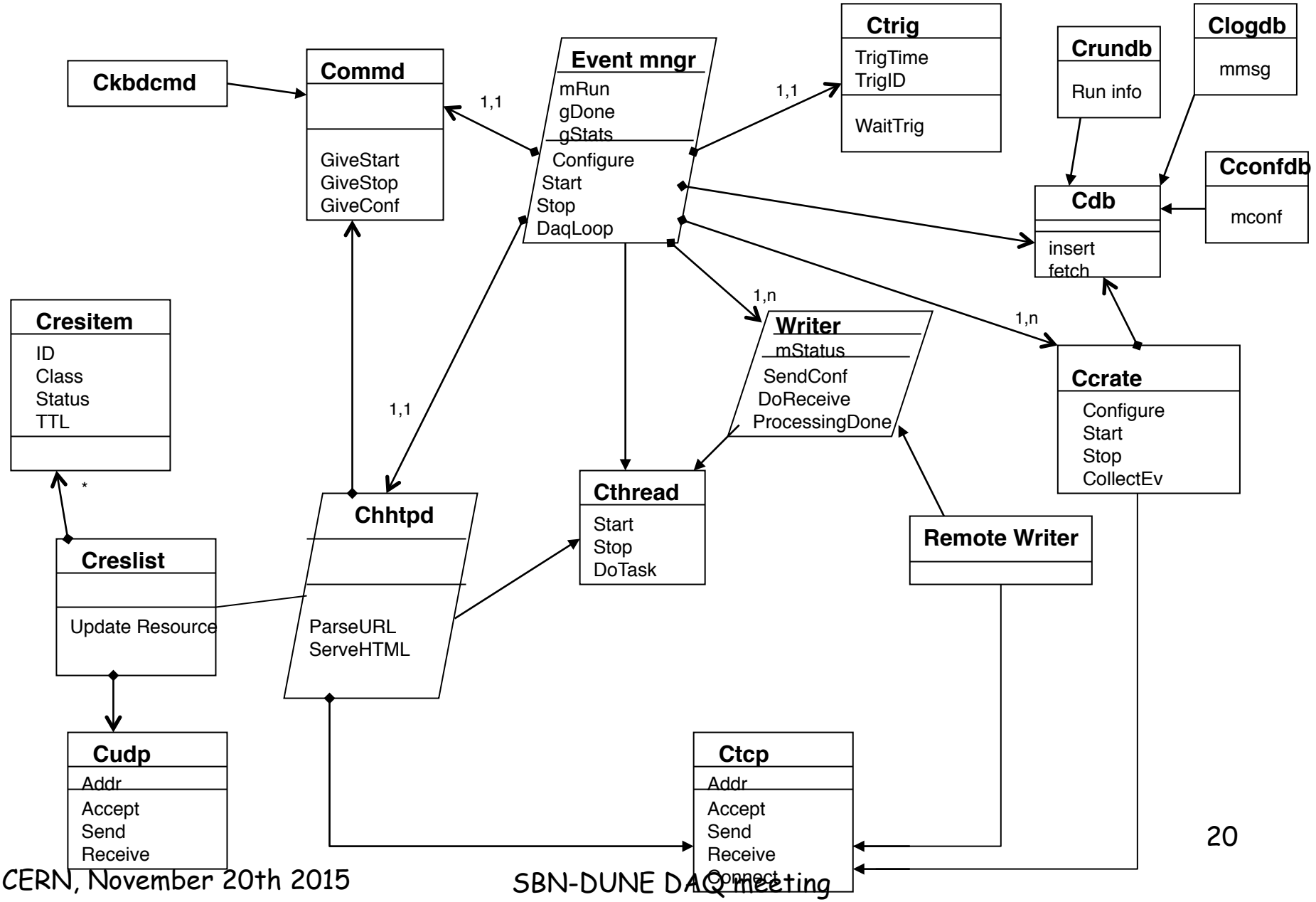
- The experience of data taking with ICARUS-T600 at LNGS is the baseline for designing the architecture of ICARUS DAQ for data taking @ FNAL in the framework of SBN Program.
- A crucial point to be discussed is the level at which integration between ICARUS DAQ and FNAL framework should occur.
- A few possible scenarios have been identified: evaluation of which the better solution is may depend on requirements, existing resources and manpower, having as a main goal to fit into a tight time schedule.
- An operative approach to help clarifying the situation is to setup a demo of a 1-by-1 system equipped with *artdaq* toolkit.
  This activity is already ongoing.
- In view of an integration, importance of customizable quality monitoring (to deal with data taking being able to promptly react even to originally unexpected problems) as well as trigger handling should not be neglected.
- Issue of data acquisition of the other sub-detector components, beyond the signals from TPC, should be taken into account as soon as possible.
  For instance the hardware RCE solution proposed by SLAC could fit the needs of the PMT system.

Backup

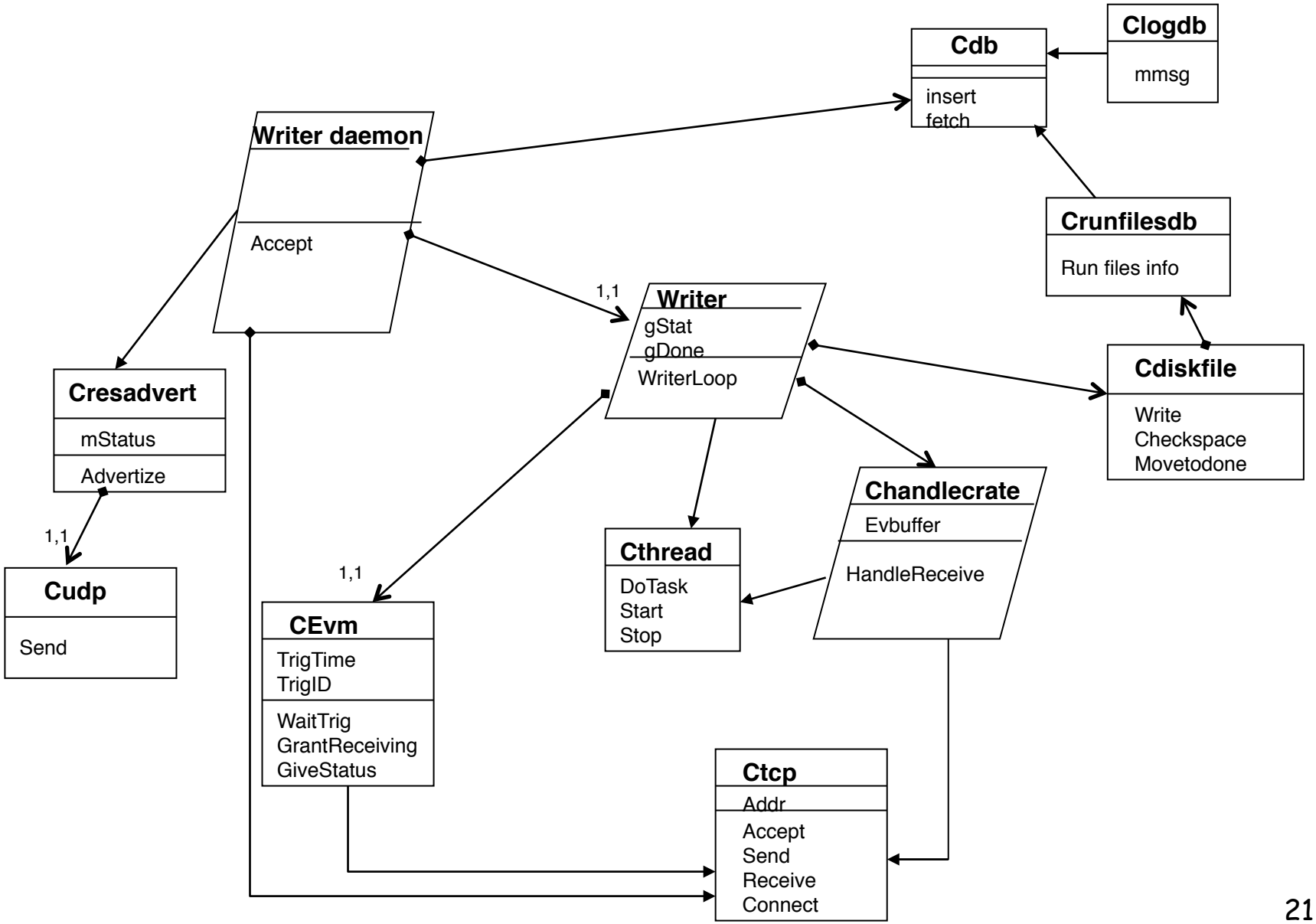
icab class diagram



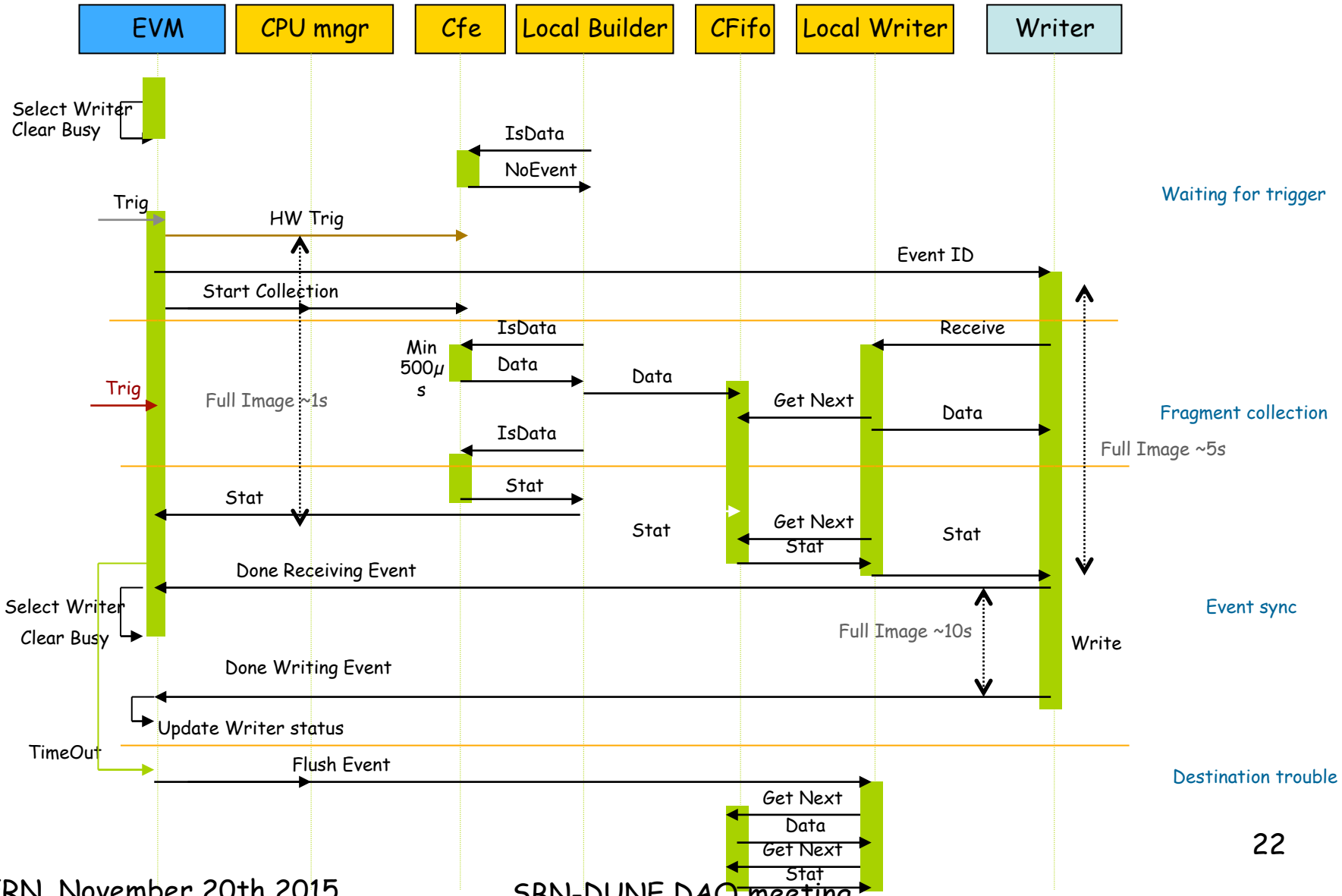
evm class diagram



writer class diagram



T600 Daq Loop Sequence Diagram



T600 writing task structure