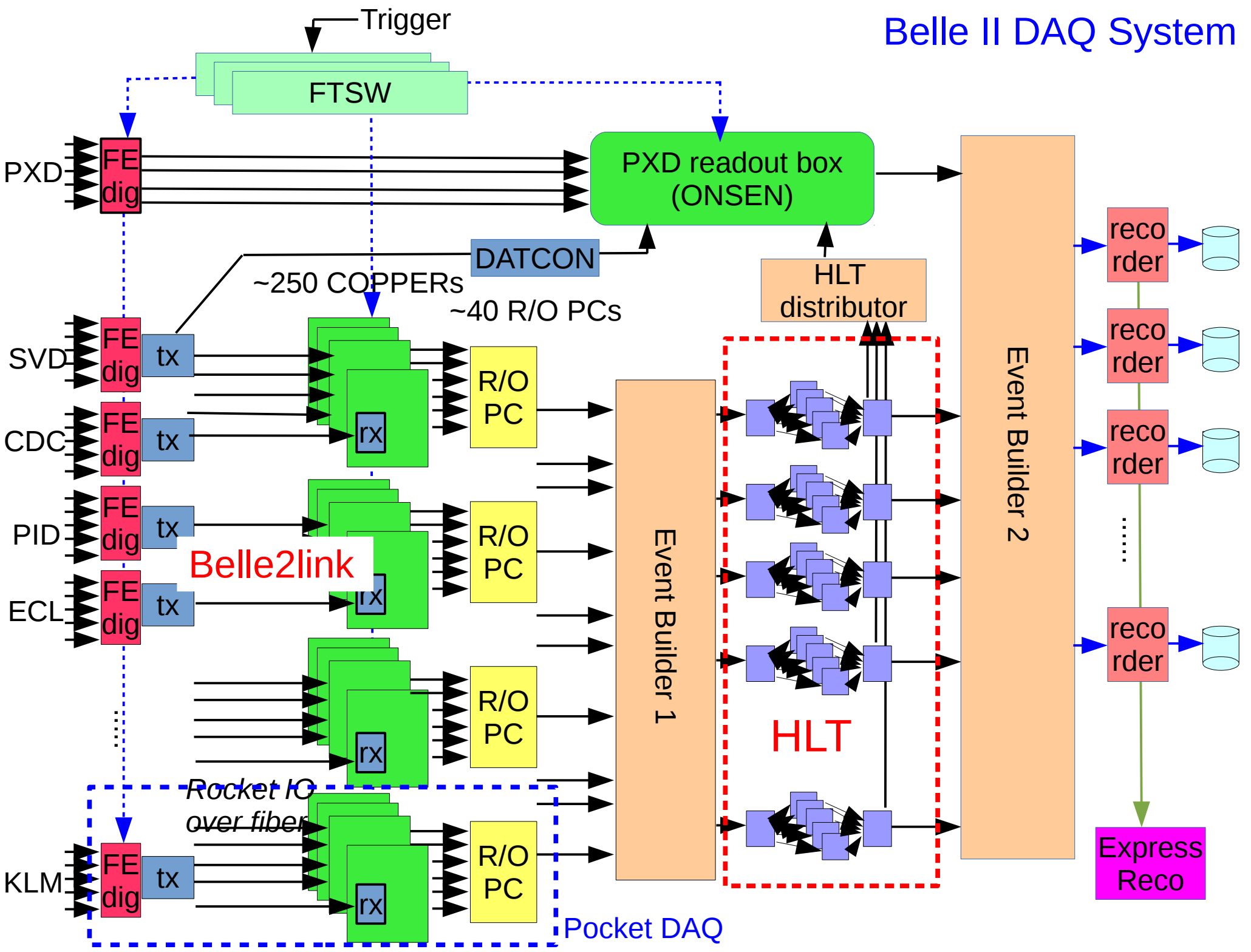
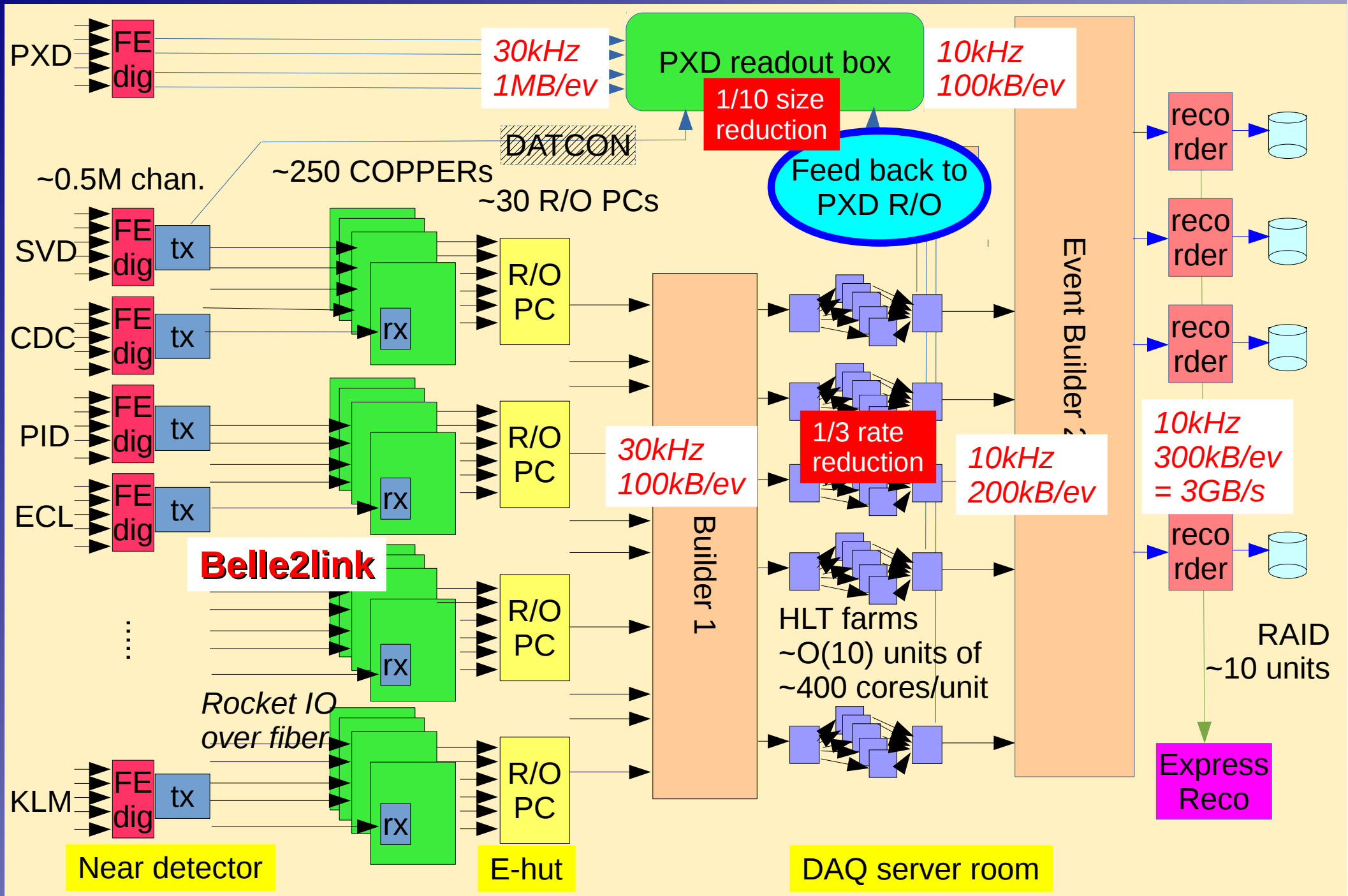
HLT Framework

R.Itoh, KEK


Belle II DAQ System
Trigger
FTSW
PXD
FE dig
PXD readout box (ONSEN)
DATCON
~250 COPPERs
~40 R/O PCs
HLT distributor
SVD
CDC
PID
ECL
KLM
tx
rx
R/O PC
Belle2link
Event Builder 1
Event Builder 2
HLT
reco rder
Express Reco
Rocket IO over fiber
Pocket DAQ

Data Flow in Belle II DAQ



1. Introduction

Functionality of Belle II HLT

0. Final conversion of raw data into ROOT objects (except PXD)

1. Perform real time “full reconstruction” of events with data from all detectors (except for PXD) and Trigger decision.
   * Tracking with SVD+CDC
   * ECL clustering + energy reconstruction
   * PID with TOP+ARICH
   * Physics event reconstruction using all info.
   * Physics trigger decision

2. Data quality monitoring by live histogram transfer

3. RoI feedback to PXD

Estimation of required HLT processing power in DAQ design

- The required processing power of Belle II HLT was estimated based on our experience with RFARM used in the previous Belle experiment.

- The RFARM was equipped with 140 equivalent cores (number scaled to be equivalent to Belle II HLT cores) and the full event reconstruction was performed using the same offline software and scripts.

- The RFARM had been processing the maximum luminosity of Belle = 2.0×10^{34} with an 80-90% average CPU consumption.

- The luminosity of SuperKEKB at t=0 was assumed to be 1/4 of the design luminosity = 2.0×10^{35}, which is 10 times of Belle's maximum luminosity. Therefore the required number of cores at t=0 is estimated to be 140 * 10 = 1400 cores.

- Our plan is to have 5 HLT units at t=0 where one unit is equipped with 320 cores, and we will have 1600 cores in total with 5 units. It should be enough for t=0, if we scale our experience at Belle.

- For the beyond to reach the design luminosity, we will add more HLT units gradually. We assume Moore's law in the addition expecting to have more number of cores in one unit. So the reduction in total number of units is in the design and we expect the full luminosity of 8×10^{35} can be processed with 10-15 HLT units with 1600*4 = 6400 cores.

HLT processing rate in the original design

- At the full luminosity of 8×10^{35}, the physics rate for BBbar and Continuum events is 4kHz while 2kHz for "low multiplicity(=$\tau\tau$,$\mu\mu$, etc.)" events.

- The expected average L1 trigger rate at the full luminosity is 20kHz (Note: 30kHz is the peak maximum), and it is supposed to be processed with 6400 cores. So the required processing rate per core is ~3Hz resulting in the required average processing time per core to be ~0.3 sec.

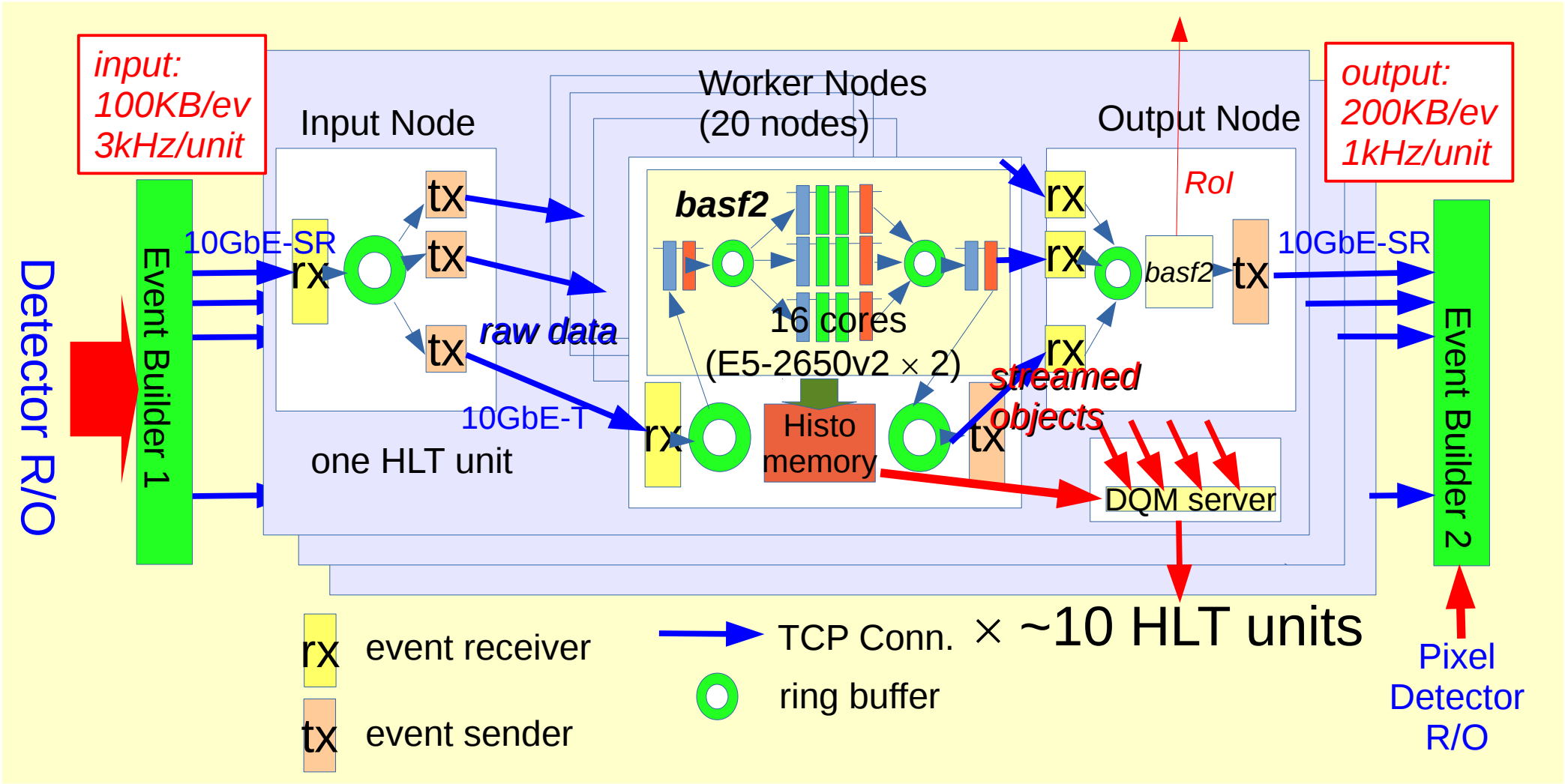
- The physics rate estimation shows, in the 3Hz rate, 20% are from BBbar and Continuum, 10% from "low multiplicity" events, and remaining 70% from other events including beam BGs and two photons.

- The processing time for "low multiplicity" and "other" events is expected to be significantly less than that for hadronic (=BBbar+Continuum) events.

- If we assume the processing time per core for one hadronic event (20%) to be 1.0 sec and 0.1 sec for "low multi" and other events (80%), the average processing time per event could be 0.28 sec, which satisfies 3Hz/core processing.

- The detail of the processing time is now being studied using the real Belle II software with the HLT configuration on the test bench. The results will be reported at next BPAC meeting.

Structure of Belle II High Level Trigger (HLT)



- 320 cores / unit (HLT1). Possible to have more cores/unit when adding more units. (following Moore's law.)
- Increase number of units gradually to keep up with the lum. improvement in accelerator.
- We need at least 6400 cores for the full luminosity, but could be more depending on the processing load of HLT reconstruction.

Trigger and Event Selection at HLT

- At the end of reconstruction chain, an event selection module is placed in basf2.

- The module summarizes the various reconstruction results and decides the event should be taken or not.

- The result of the decision is written to “HLTtag” object.

- A module to select objects to be sent to storage is placed right after the selection module.

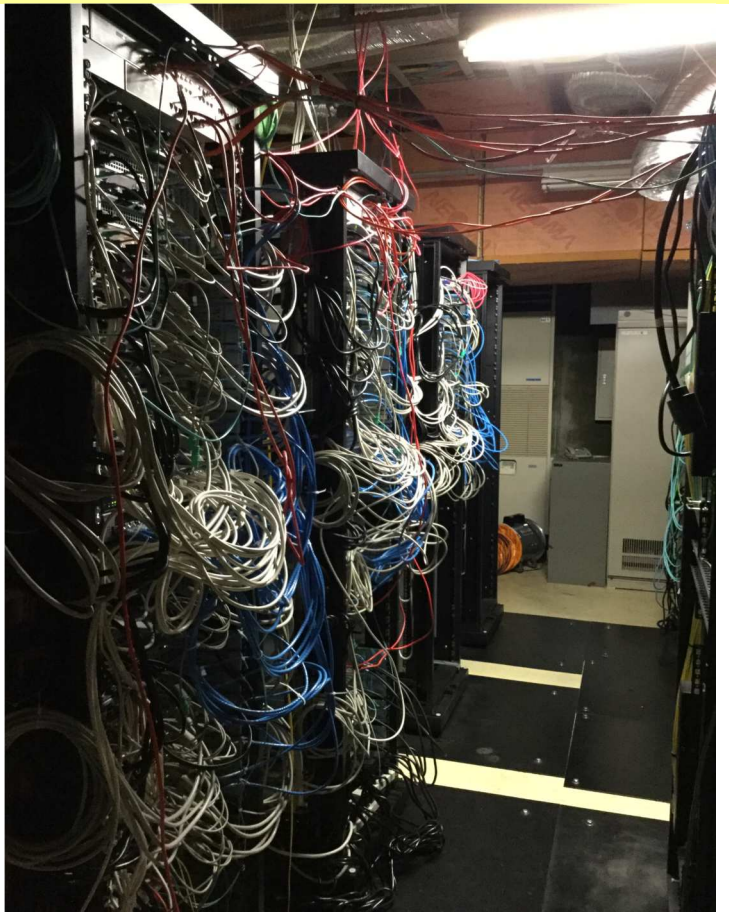
- The module erases the unnecessary objects from DataStore by looking at HLTtag. If the HLTtag says the event to be discarded, all rawdata objects (RawXXXs) are erased.

- However, at least, EventMetaData and trigger summary objects are left and sent to the storage even for the discarded event.

2. Hardware Status of HLT+Storage

- 5 units are now in operation.

- 2 units are being used for the GCRT, one unit is for the software development, and remaining two units will be used for the preparation of VXD readout in phase 2 run in September.



- We already have 1600 cores (out of 6400).
  <- capable to handle 1/4 of maximum luminosity.

3. Operation in CRT

C-H.Li

Cosmic ray reconstruction on HLT

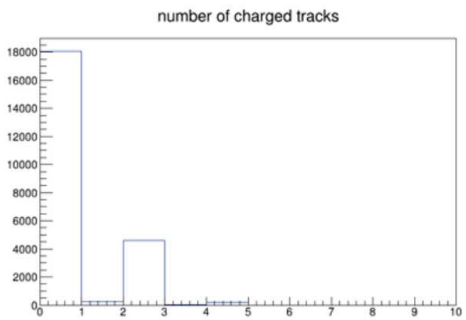
- Cosmic ray rec. is running on HLT with unit HLT01 during data taking
- Software version: commit 83ba2b9635d8a85(June 13)
- The reconstruction of all detectors are included

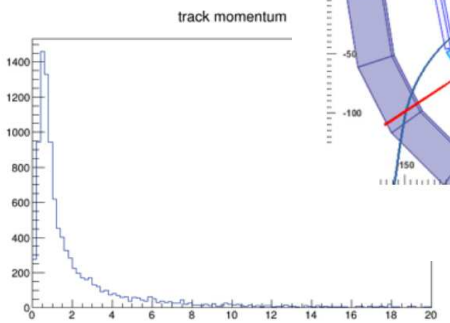
```
# track finding
add_cdc_cr_track_finding(crashsafe_path)
# track fitting
crashsafe_path.add_module('SetupGenfitExtrapolation', energyLossBrems=False,
noiseBrems=False)
# Time seed
crashsafe_path.add_module("PlaneTriggerTrackTimeEstimator",pdgCodeToUseForEstimation=13,
                    triggerPlanePosition=[0,0,0],triggerPlaneDirection=[0,1,0],
                    useFittedInformation=False)
# Initial track fitting
crashsafe_path.add_module("DAFRecoFitter", probCut=0.00001, pdgCodesToUseForFitting=13)
# Correct time seed
crashsafe_path.add_module("PlaneTriggerTrackTimeEstimator", pdgCodeToUseForEstimation=13,
                    triggerPlanePosition=[0,0,0], triggerPlaneDirection=[0,1,0],
                    useFittedInformation=True)
# Track fitting
crashsafe_path.add_module("DAFRecoFitter",pdgCodesToUseForFitting=13)
# Create Belle2 Tracks from the genfit Tracks
crashsafe_path.add_module('TrackCreator', defaultPDGCode=13,useClosestHitToIP=True)
# Add further reconstruction modules
add_posttracking_reconstruction(crashsafe_path, components=components, pruneTracks=True,
                                addClusterExpertModules=True, trigger_mode="all")
```

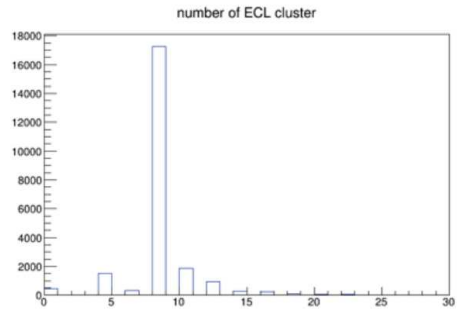
cdc tracking

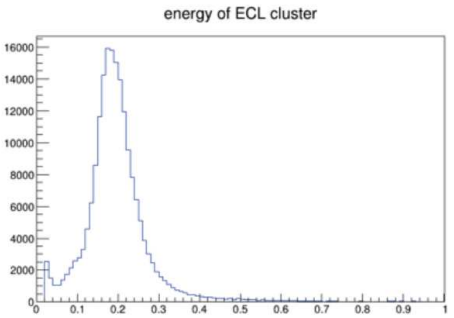
other detectors rec., same as physics rec

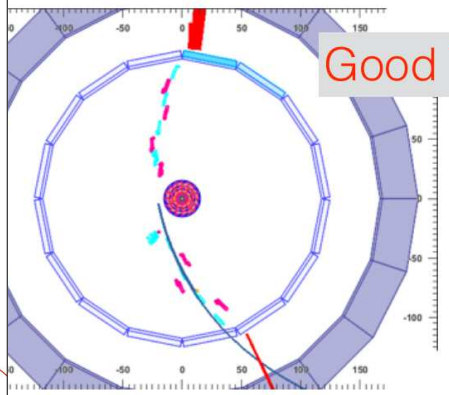
DQM of Cosmic ray on HLT

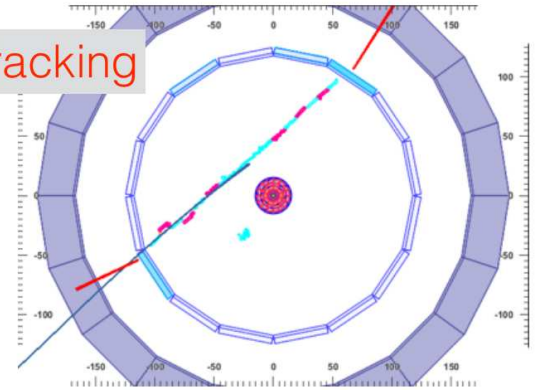


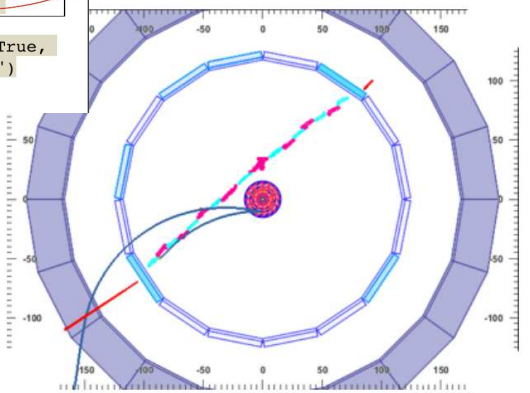


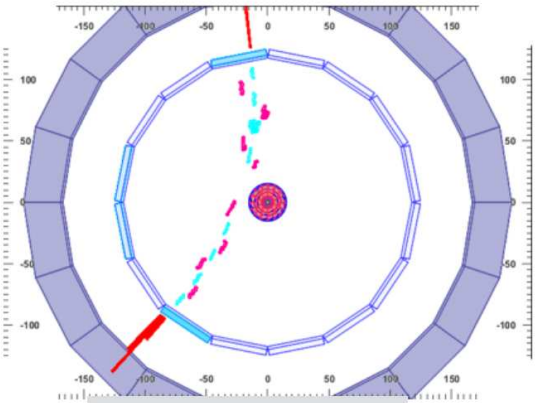






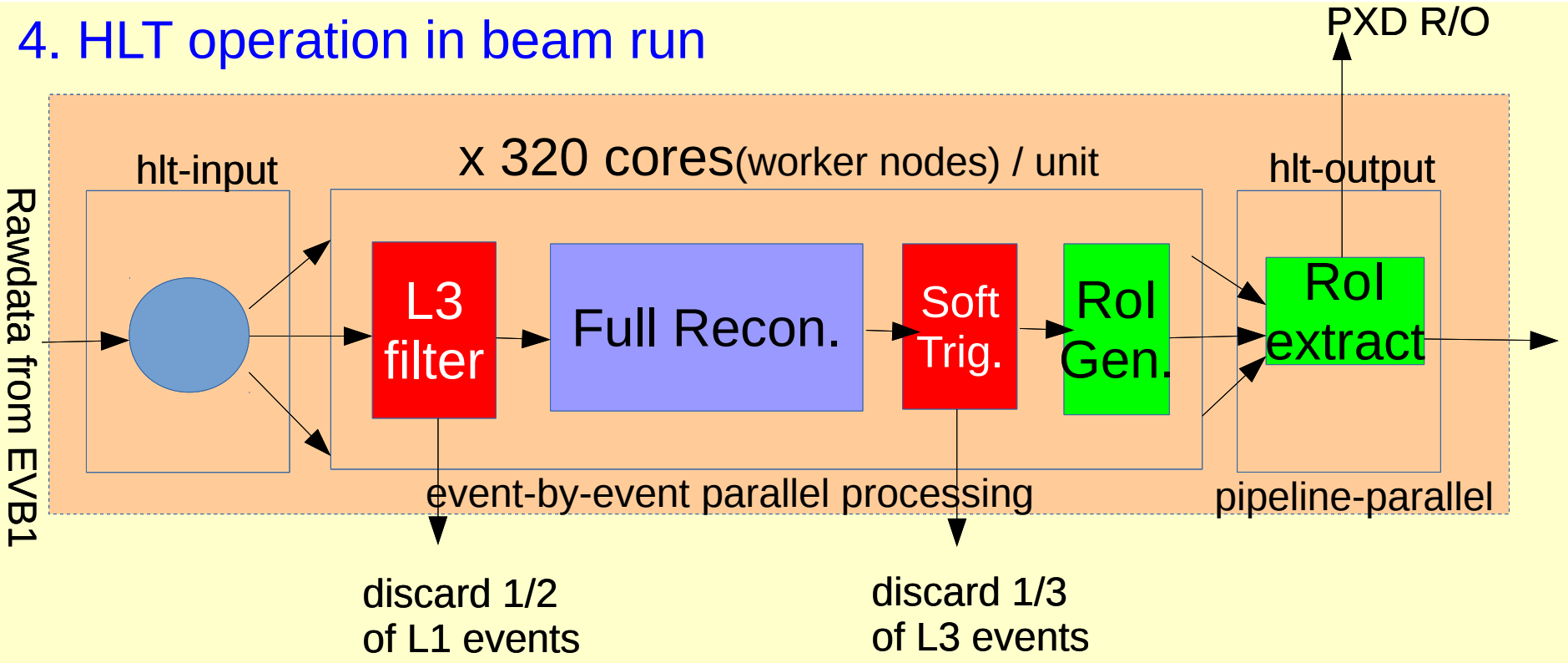






- HLT framework is fully working in CRT with the CDC tracking
- No crash up to now. Very stable.
- Further tuning of tracking code with up-to-date calib. const. is necessry.

4. HLT operation in beam run



- One unit processes
  * ~ 2-3 kHz L1 rate (of total of 30kHz) with event size <100kB
  * 1/2 rate reduction with “Level 3” filter
    - Based on fast CDC tracking + ECL clustering.
    - Cut in the track |z| position and ECL energy sum
  * Full event reconstruction using all detector signals except PXD
  * Software trigger using physics event skim codes (Hadronic/tau event selection....) + Monitor trigger -> 1/3 reduction

Expected rate reduction : 1/3 = ~1 kHz/unit at output.

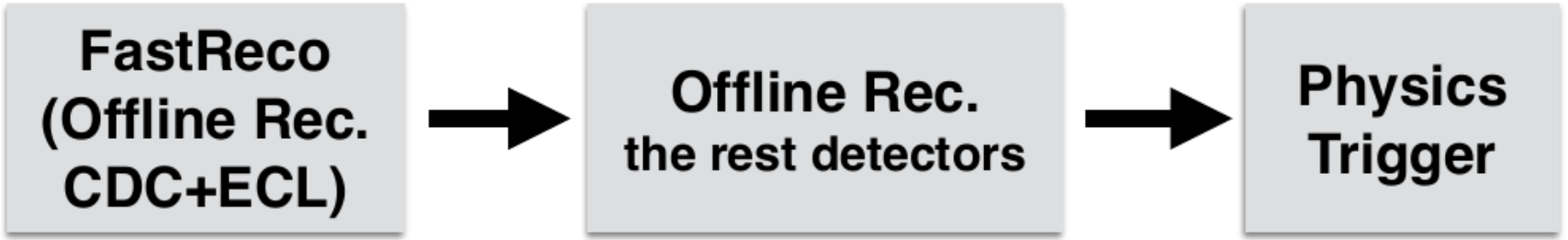
HLT Software Trigger Scheme

Scheme 1

Kakuno Hidekazu

Chunhua Li

Scheme 2

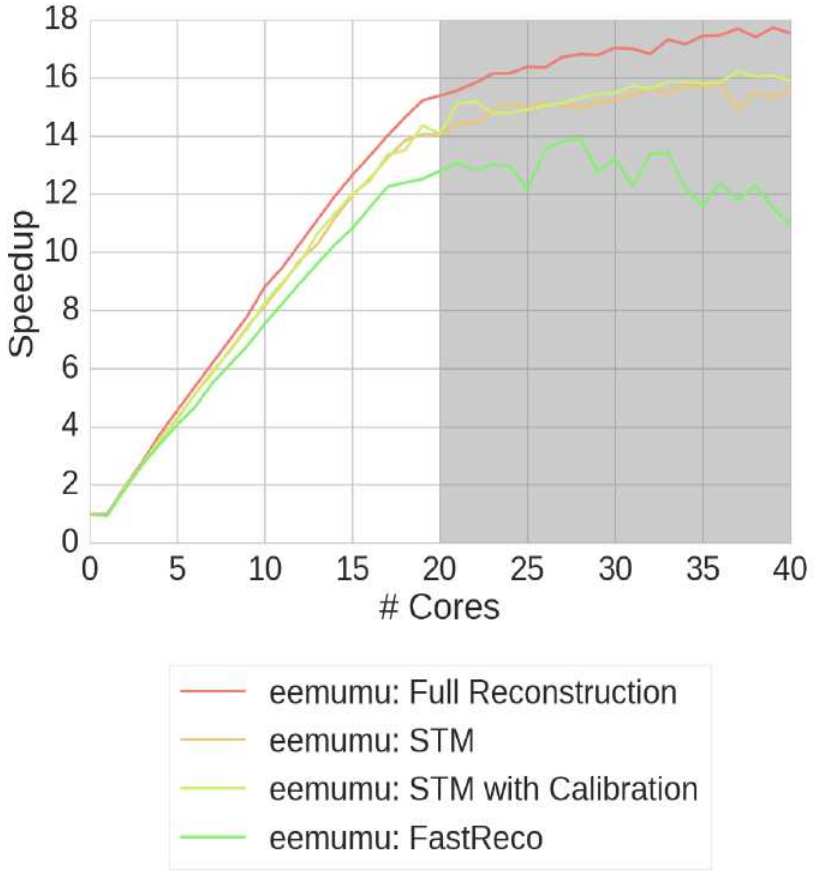


Nils Braun
Thomas Hauth

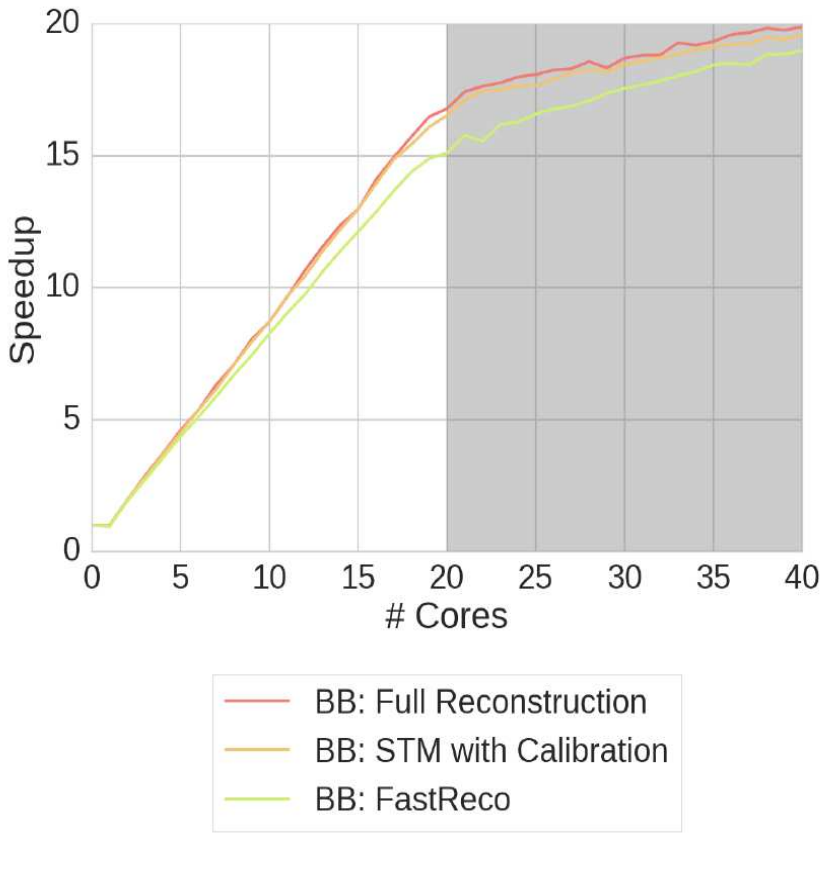
Chunhua Li

Parallel processing performance on a 20 core server of HLT

Low multiplicity events (eemm)

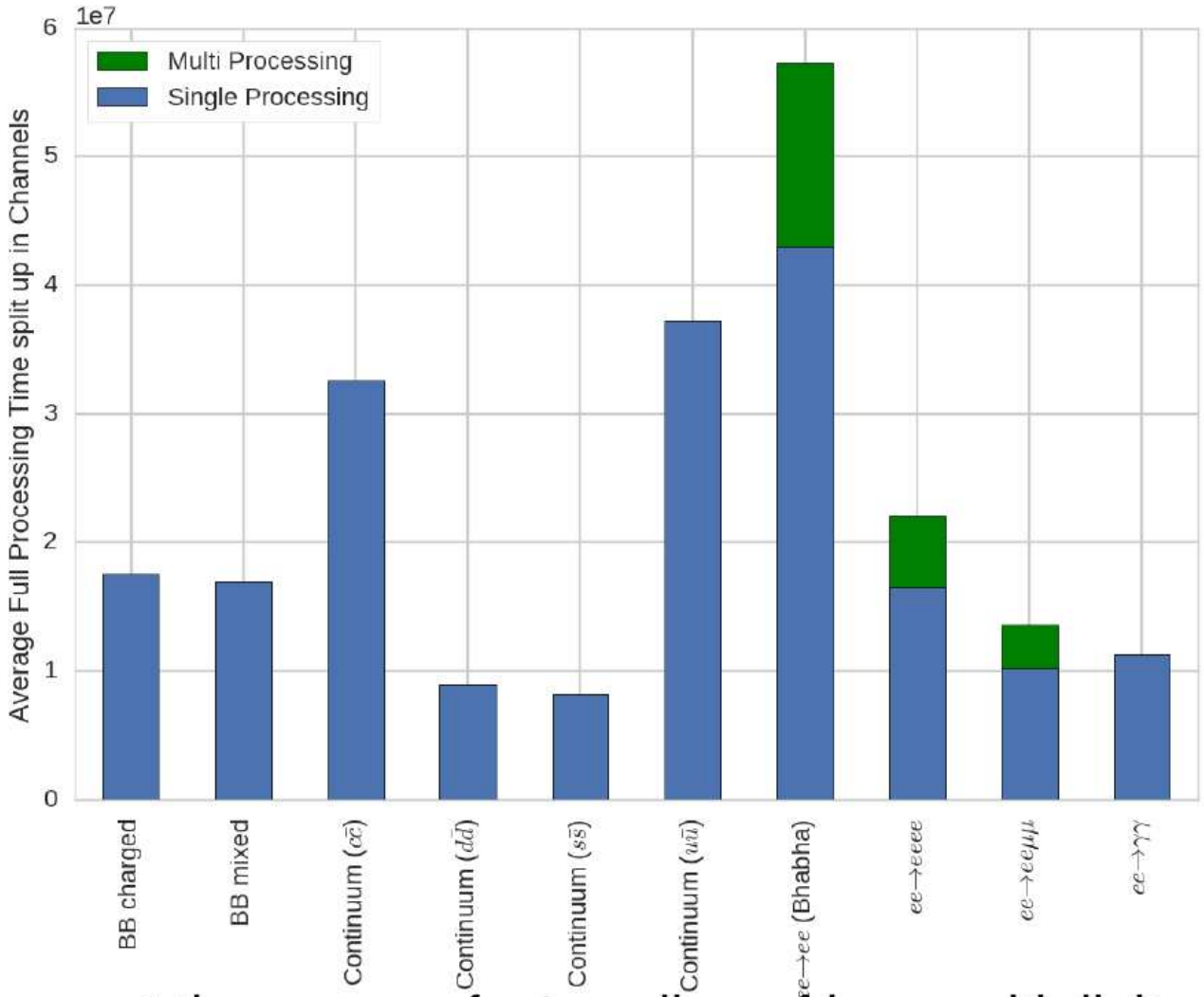


Hadronic events (BB)



Processing time normalized by cross section+trigger rate of each channel

Thomas Hauth



Taking into account the non-perfect scaling of low-multiplicity events, the average processing time is **0.24 s** (which correspond to a maximal rate of 26 kHz after Level1).

The time satisfies the requirement of <0.33 sec.

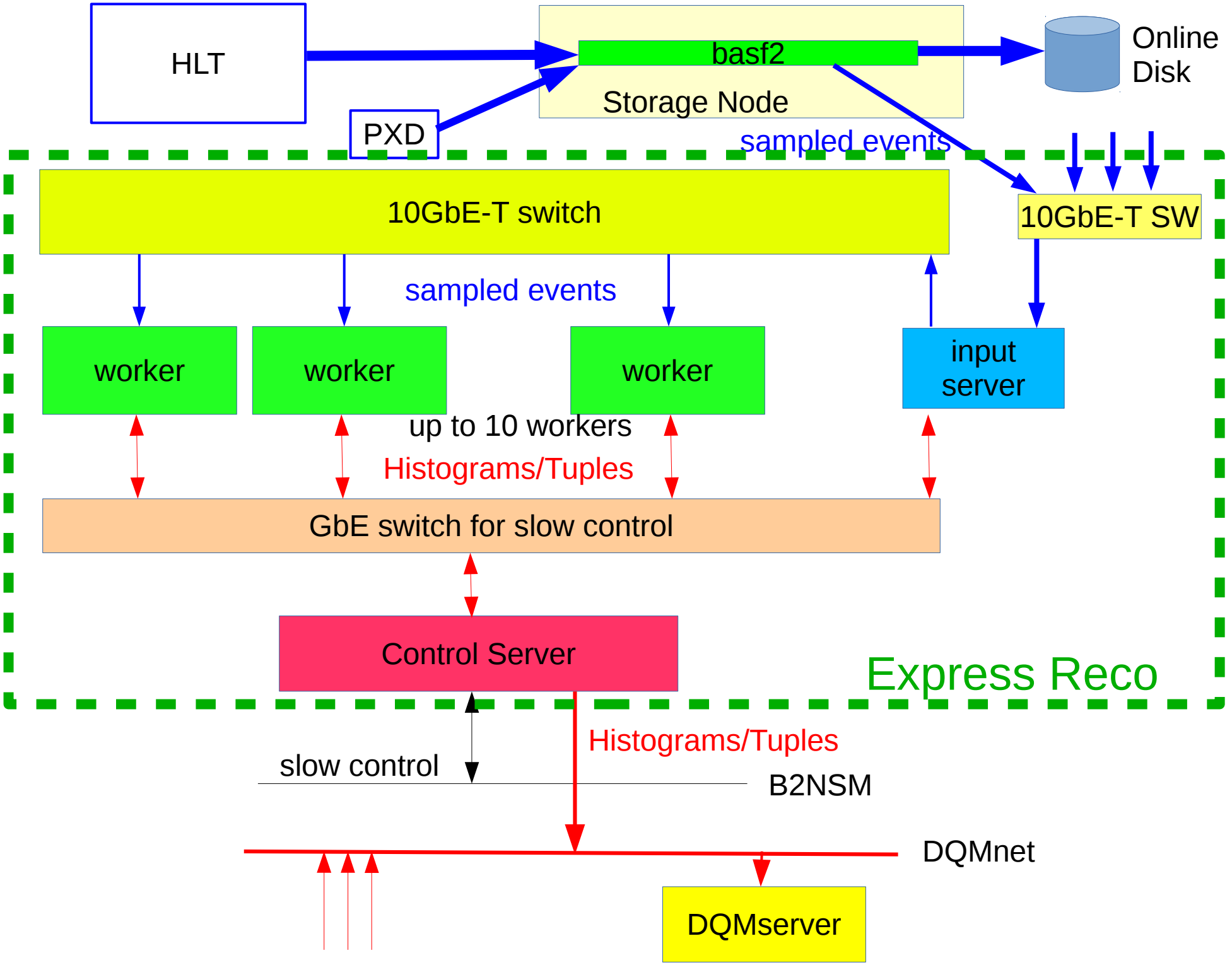
5. Express Reco

- Assembly of 1st unit has been completed.
  * Consists of 8 processing nodes for now.

- Network connection to storage unit 1 to 5 has been completed.

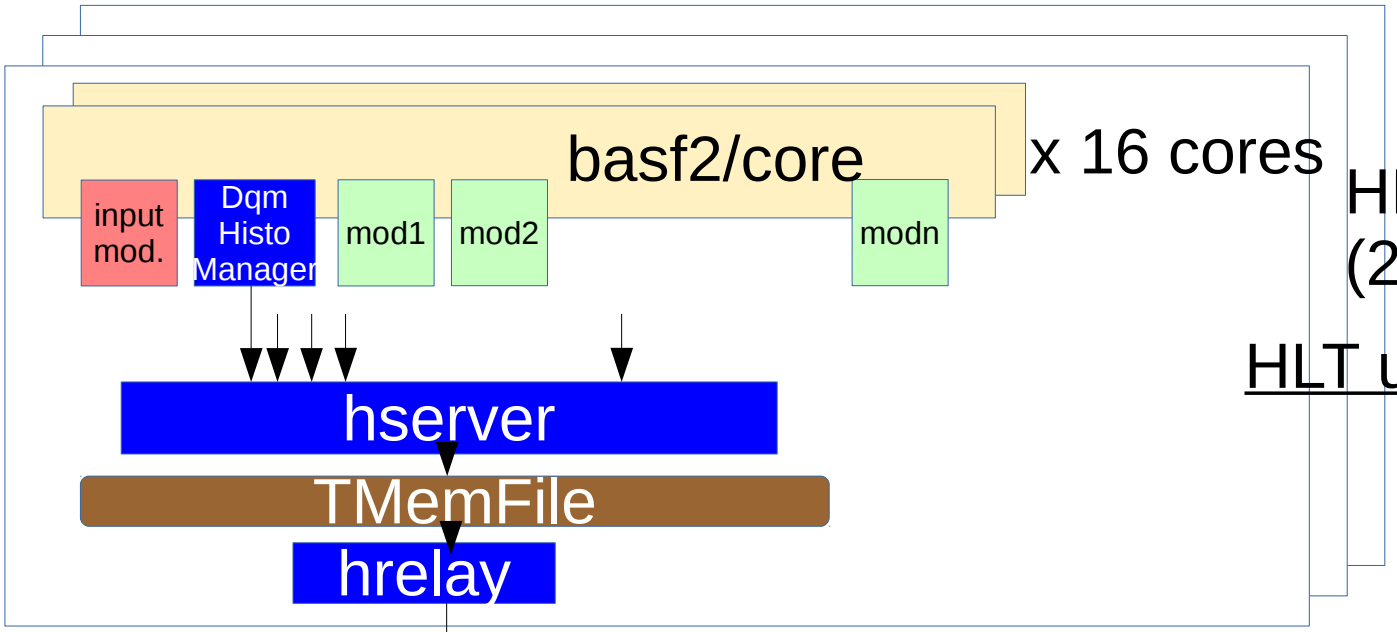
- ExpReco framework has been extended (from DESY expreco) to use multiple processing nodes.
  -> Data flow was confirmed to work.

- Event sampling scheme (which was working in DESY expreco for event display) has been implemented.
  * Being tested now.


HLT
basf2
Storage Node
Online
Disk
PXD
sampled events
10GbE-T switch
10GbE-T SW
sampled events
worker
worker
worker
input
server
up to 10 workers
Histograms/Tuples
GbE switch for slow control
Control Server
Express Reco
Histograms/Tuples
slow control
B2NSM
DQMnet
DQMserver

6. DQM: Histogram Accumulation and Collection

In cosmic ray run



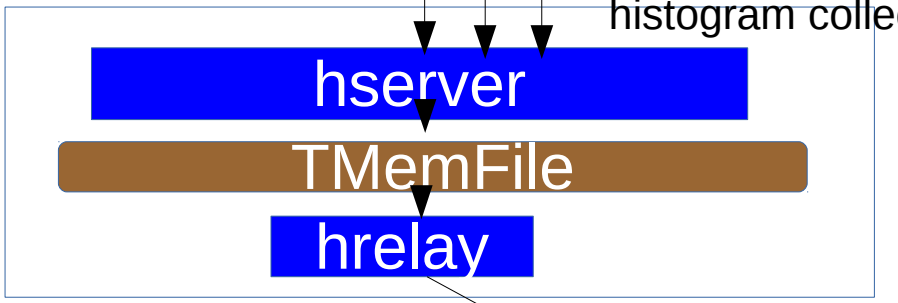
HLT worker nodes
(20 nodes:hltwk01-20)

HLT unit 1

socket connection

HLT slow control net

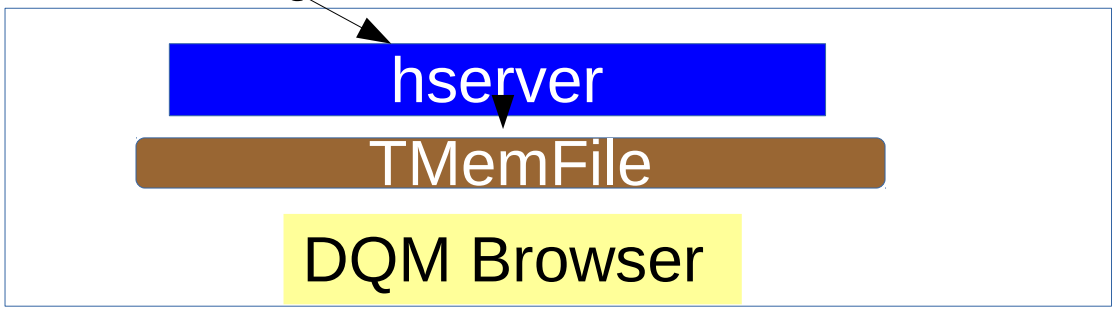
histogram collection from 20 servers



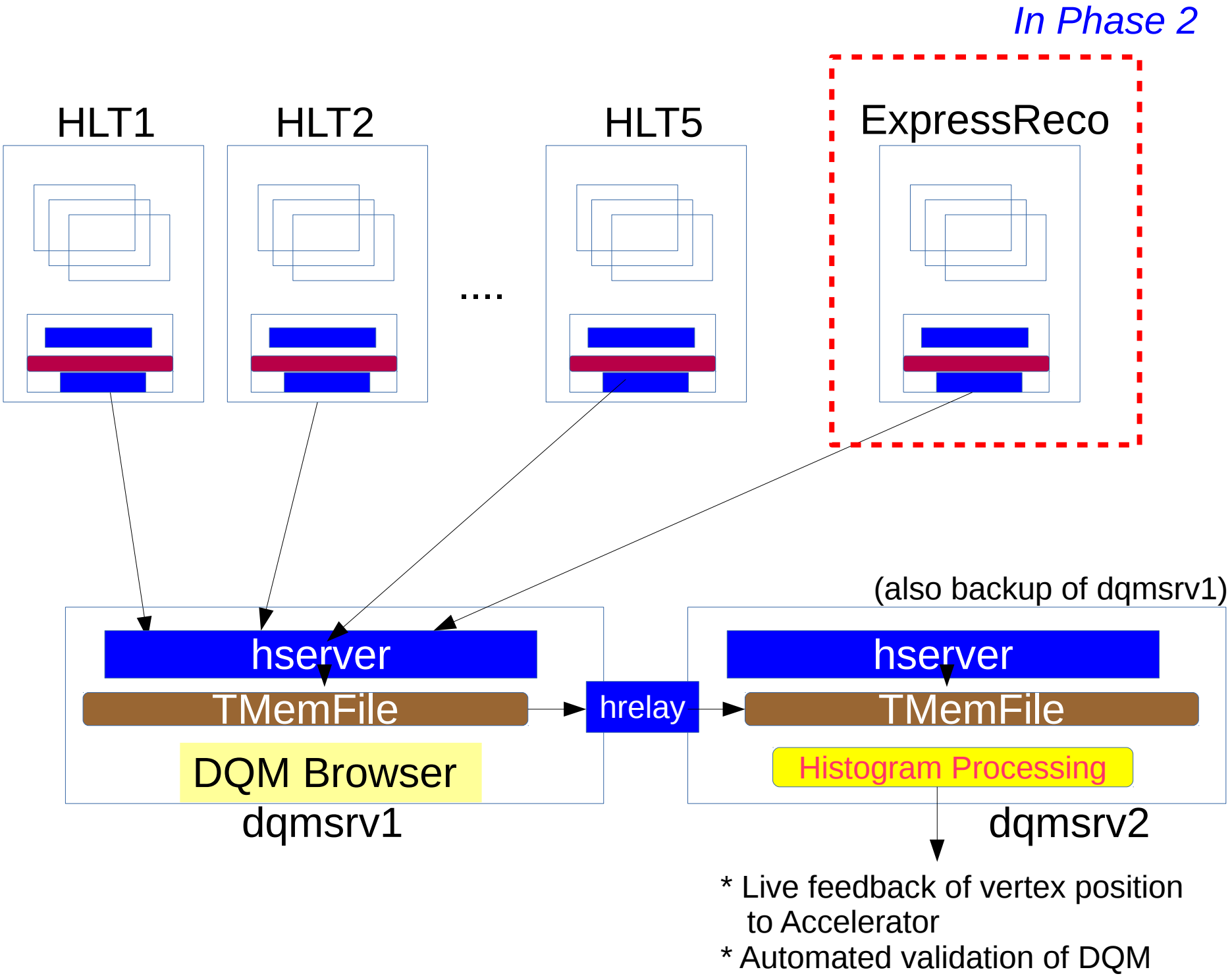
hlt control node
(hltctl)

* The overall control is not yet implemented in slow control.

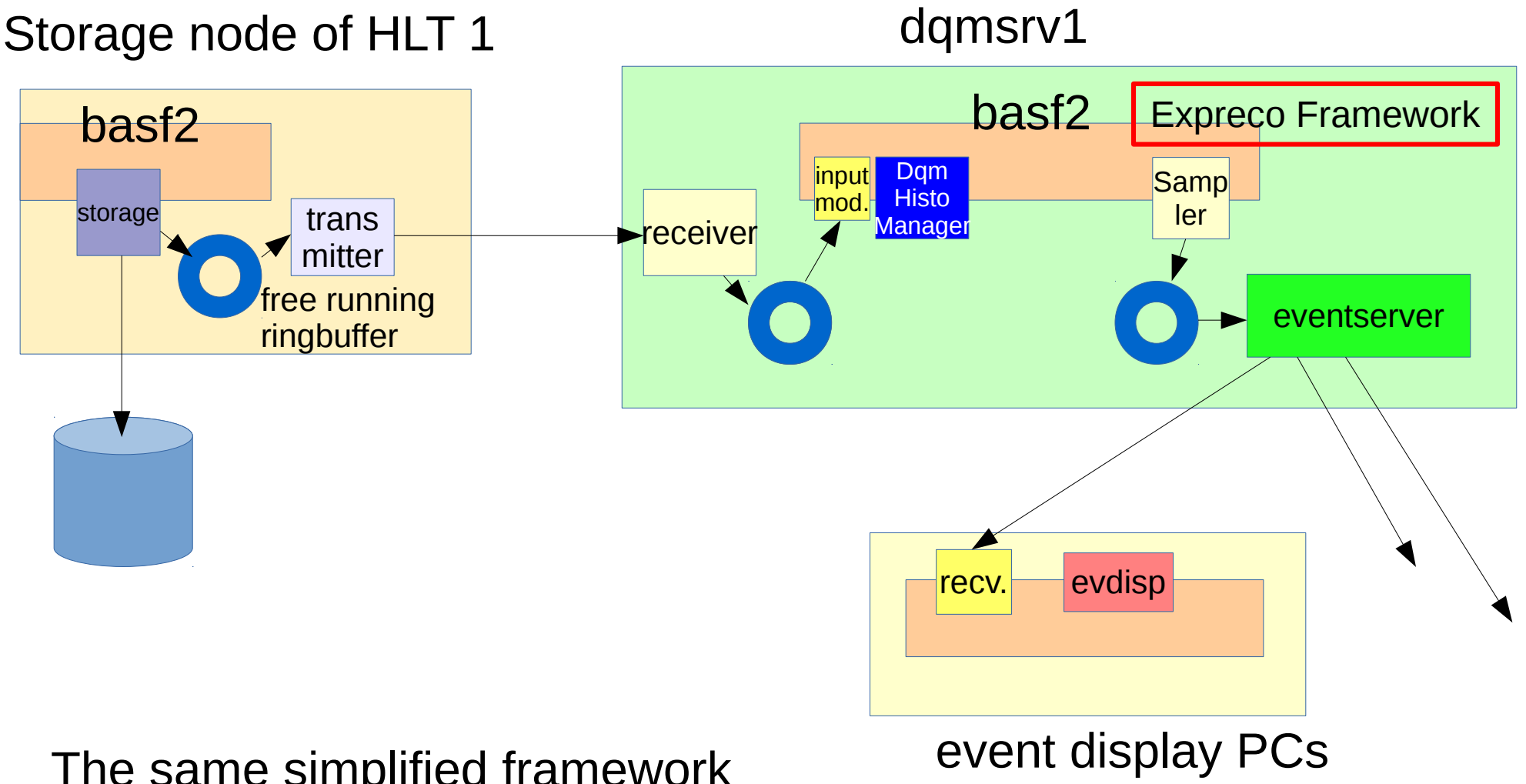
DQMnet



dqmsrv1
(DQM
master PC)

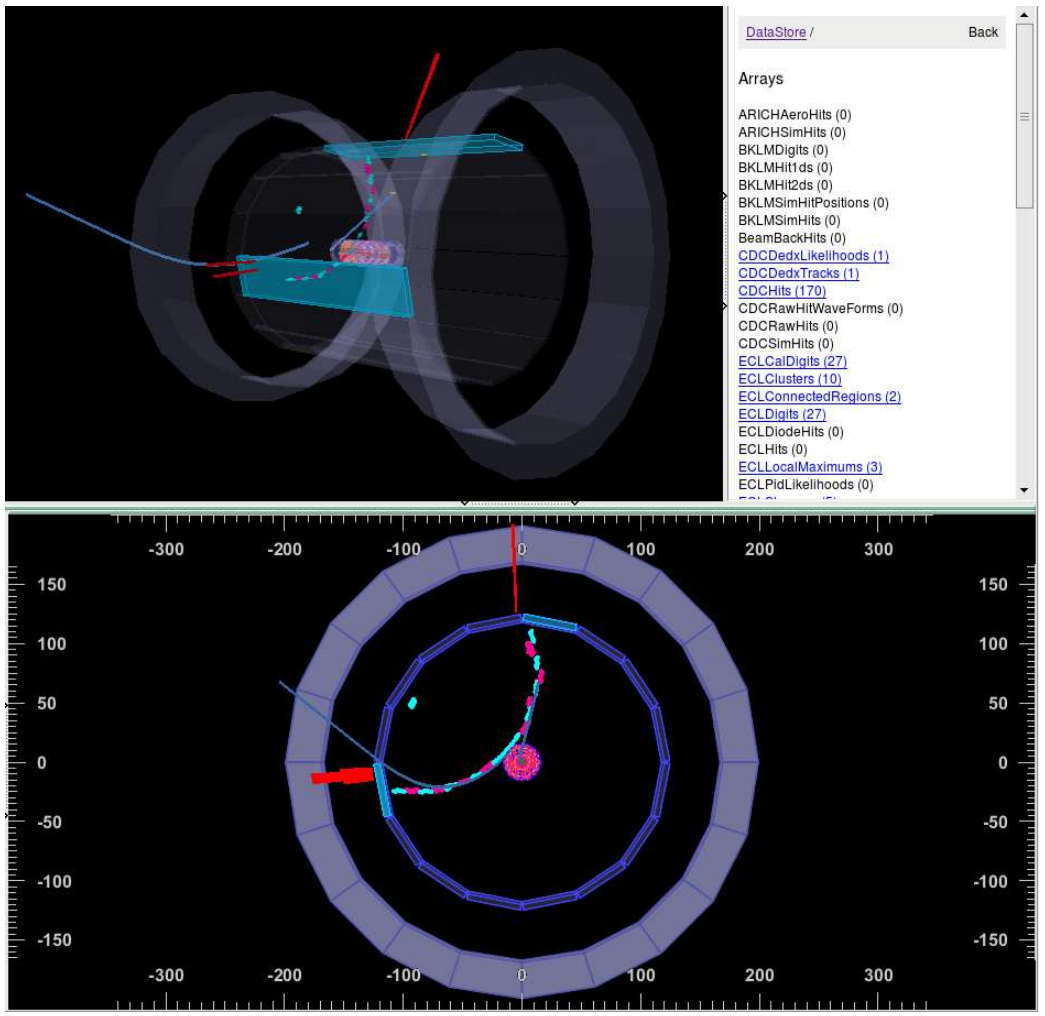

In Phase 2
HLT1
HLT2
HLT5
ExpressReco
....
(also backup of dqmsrv1)
hserver
TMemFile
DQM Browser
dqmsrv1
hrelay
hserver
TMemFile
Histogram Processing
dqmsrv2
* Live feedback of vertex position
to Accelerator
* Automated validation of DQM

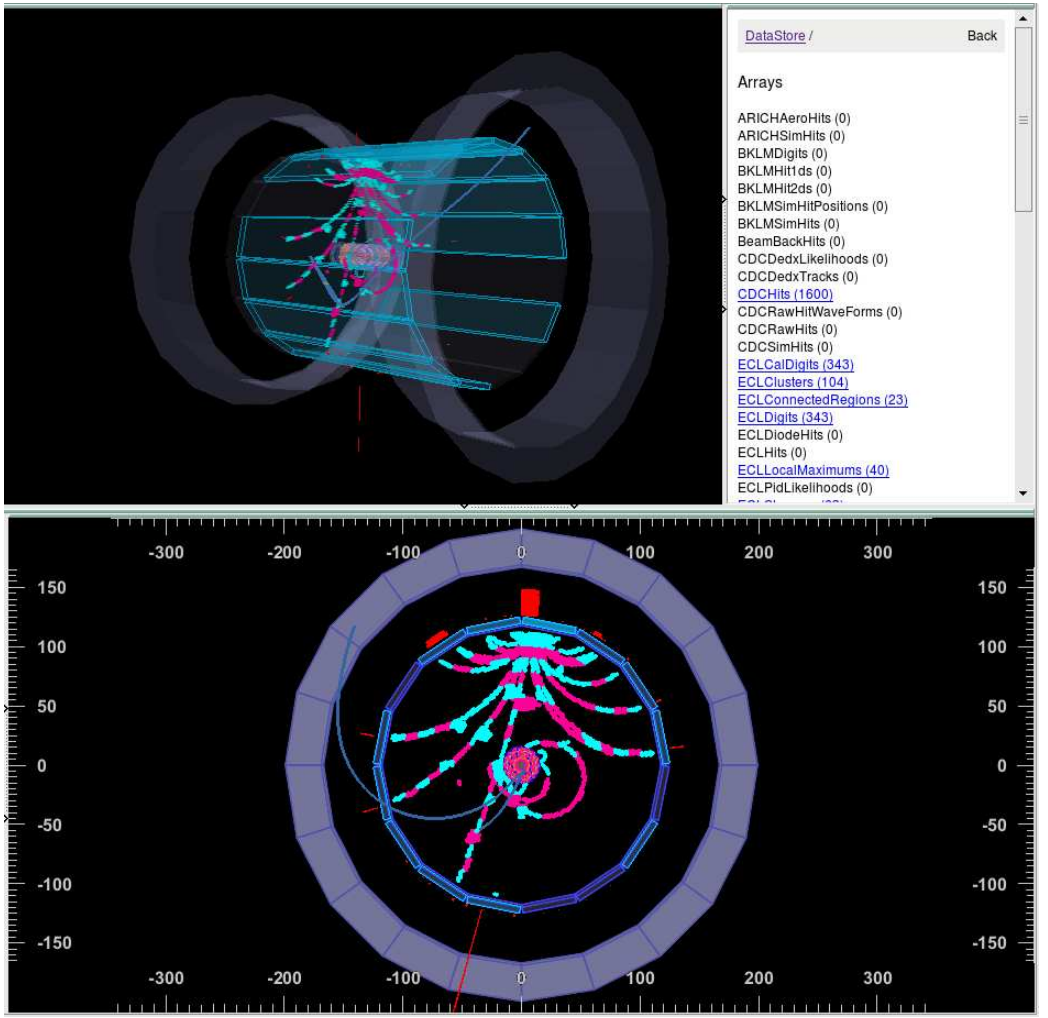
7. Live event sampling for monitoring (inc. event display)



The same simplified framework
as that used in DESY-TB

Live Event Display





- CDCHits, ECLClusters + TOPDigits reconstructed on HLT are shown lively in the online event display.

- Lively reconstructed tracks on HLT are also shown.

8. Summary

- HLT framework was confirmed to work in both cosmic ray runs and DESY test beam runs.

- The optimization of operation parameters have to be done carefully in coming phase 2 operation.

- A simplified framework of ExpressReco was/is used in DESY test beam and cosmic ray runs. It was/is working well in both.

- The 1st unit of ExpressReco is being prepared and current simplified framework will be switched to the extended one soon.

- The histogram transport (for DQM) and event sampling (for evdisp) over network are established and working well.

Backup Slides

Example of study of physics trigger performance by HLT

Physics Trigger Menu

Category	Physics Target
BhabhaHLT	ee
DimuHLT	μμ
GGHLT	γγ
TauHLT	Generic tau, two tracks
ISRHLT	Two tracks, 2-prongs ττ
HardronHLT	BB+continuum

Process	σ (nb)	ϵ (%)	σ (nb) after Physics Trigger
BB	1.1	99.7	1.1
udsc	3.7	99.0	3.7
$\tau\tau$	0.9	85.2	0.8
$\mu\mu(\gamma)$	0.9	67.6	0.6
$ee(\gamma)$	125	-	2.1
$\gamma\gamma(\gamma)$	3.9	-	0.1
eeee	38.8	-	1.5
$ee\mu\mu$	22.1	-	1.6
Sum	196	-	11.5

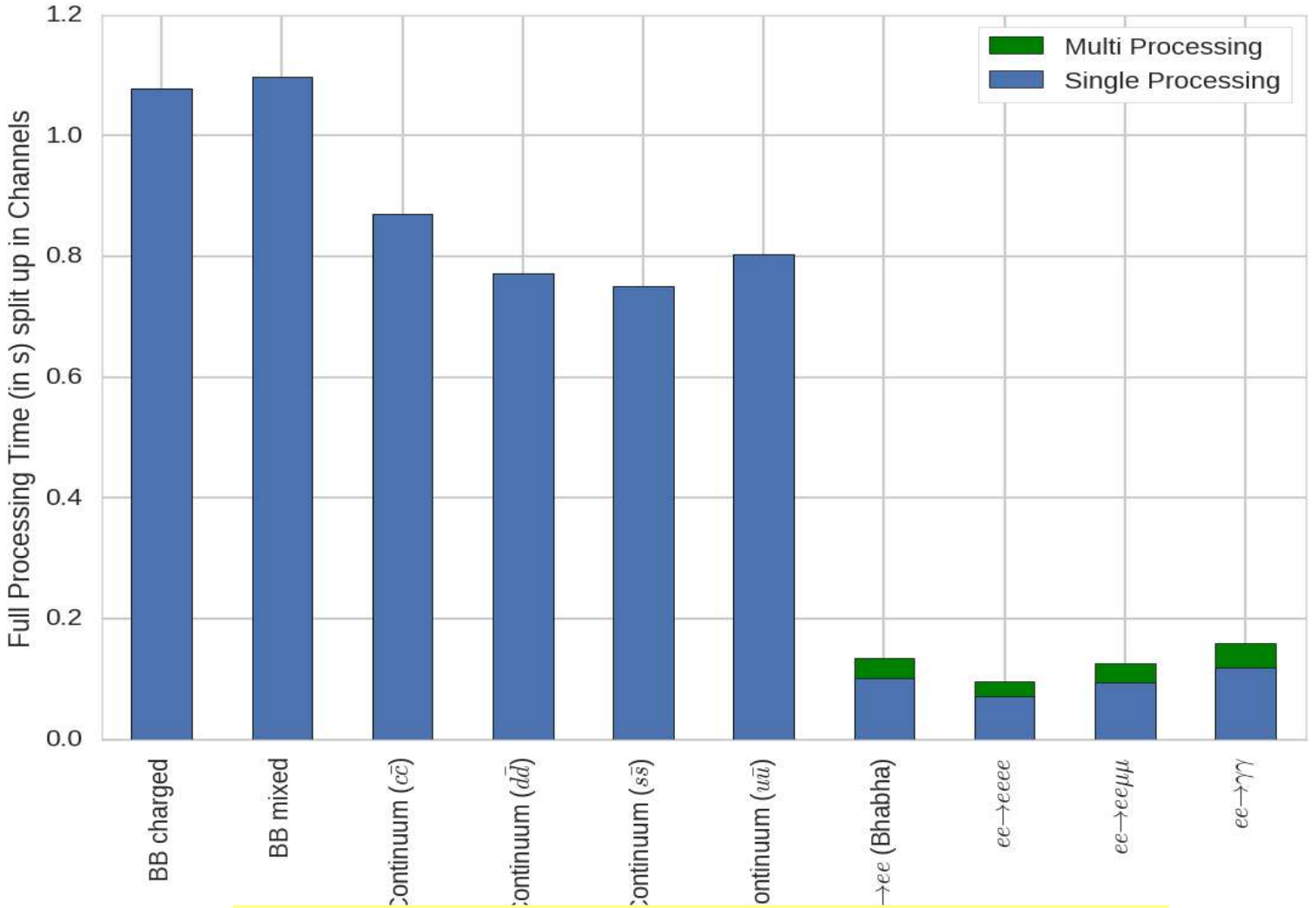
	ττ: 2-prongs	τ:eνν, τ:1-prong	τ:μνν, τ:1-prong	B->$\pi^0\pi^0$	B->νν	B->$\rho^0\gamma$
ε(%)	94.2	92.2	94.5	97.6	96.1	99.1

it is the efficiency of physics trigger only

Single photon trigger

- Not include here
- The trigger of HLT is developed based on the feature of backgrounds e.g Bahbah, 4e, eeμμ after L1.

Measured processing time/core/event on HLT processing node

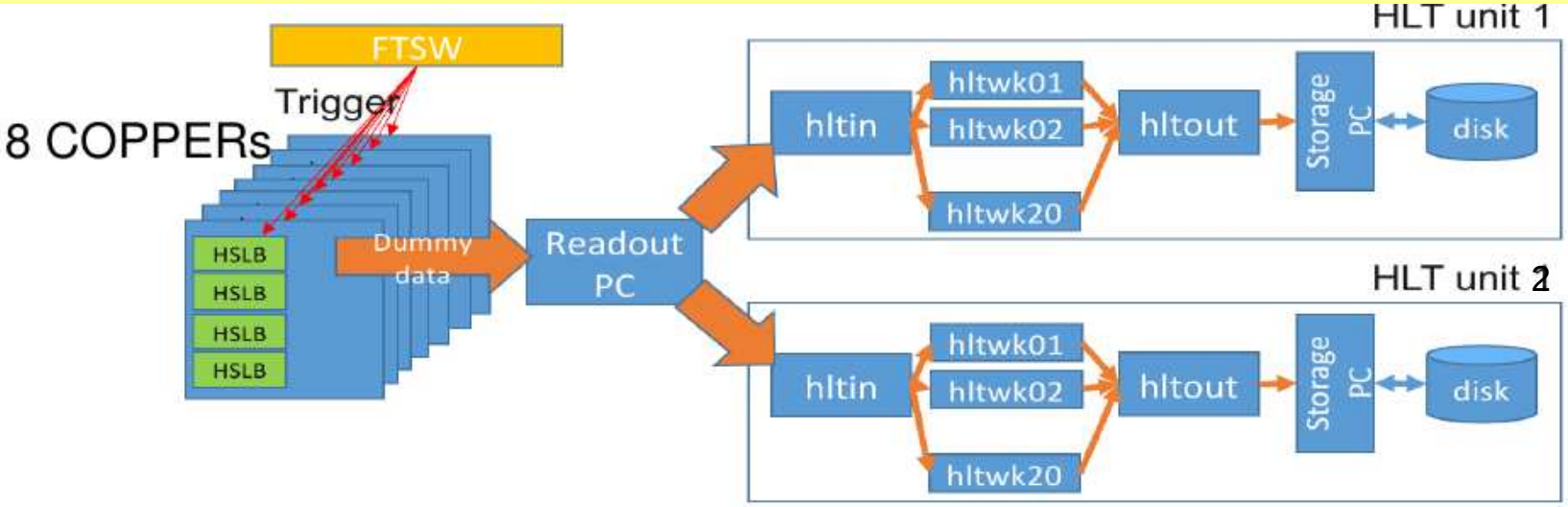


~ 1sec for hadronic events
~ 0.1 sec for low multiplicity events
<= They are just as expected.

High rate system test

- The performance of HLT framework was tested in the real DAQ.
- The dummy data are generated on 8 COPPERs and sent to 2 HLT units through event builder 1.

Note: The software version is old (last winter), and the data size is small (~1kB/ev).



- Dummy data are generated on Belle2link receiver cards (HSLB) whenever a trigger is recovered from FTSW.

Input rate(kHz)	Event size /HSLB(bytes)	Output rate(kHz)
30	44	30
40	44	38
30	88	30

* Event size(44Bytes/HSLB) is the estimated typical size.

Realistic test using simulated raw data + full recon is performed soon.