Discussion on
Data Rate/Size Reduction Strategy
in Belle II DAQ

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1. Trigger rate reduction

Expected physics rate @ L=8x10^{35} (from TDR)

Physics process	Cross section (nb)	Rate (Hz)
$\Upsilon(4S) \to B\bar{B}$	1.2	960
Hadron production from continuum	2.8	2200
$\mu^+\mu^-$	0.8	640
$\tau^+\tau^-$	0.8	640
Bhabha ($\theta_{lab} \geq 17^\circ$)	44	350 [a]
$\gamma\gamma$ ($\theta_{lab} \geq 17^\circ$)	2.4	19 [a]
2γ processes ($\theta_{lab} \geq 17^\circ$, $p_t \geq 0.1$ GeV/c)	~ 80	~ 15000
Total	~ 130	~ 20000

[a] rate is pre-scaled by a factor of 1/100

Goal :
* Maximize the efficiency for BB/Hadron and tau tau -> ~4kHz
* Modest efficiencies for other sources

BG rate:
* Basically unknown, but we usually assume 20 times larger BG of Belle's.

2. Belle II Trigger Scheme

1) Level 1 Trigger

- Sub-triggers from CDC, ECL, BPID and KLM
- CDC can give powerful reduction by 3D trigger.

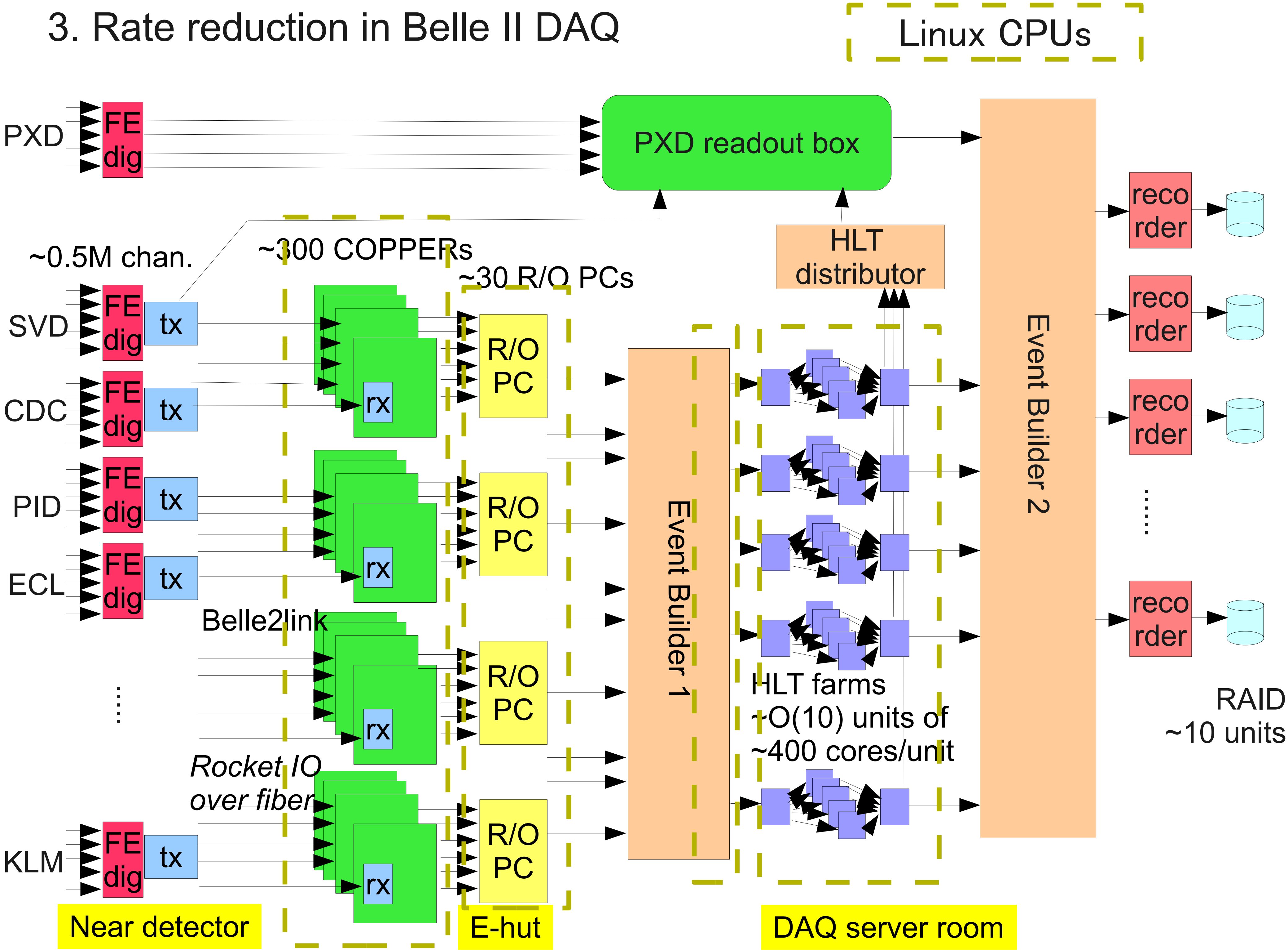
2) HLT (High Level Trigger)

- “Physics level” event selection based on
  * full reconstruction (w/o PXD)
  * Hadron BJ skim + tau skim
    <- pursue maximum efficiency
  * Monitor skim (ee,$\mu\mu$,2photon,etc)
    <- constant rate (by scaling) : kept well below 100Hz

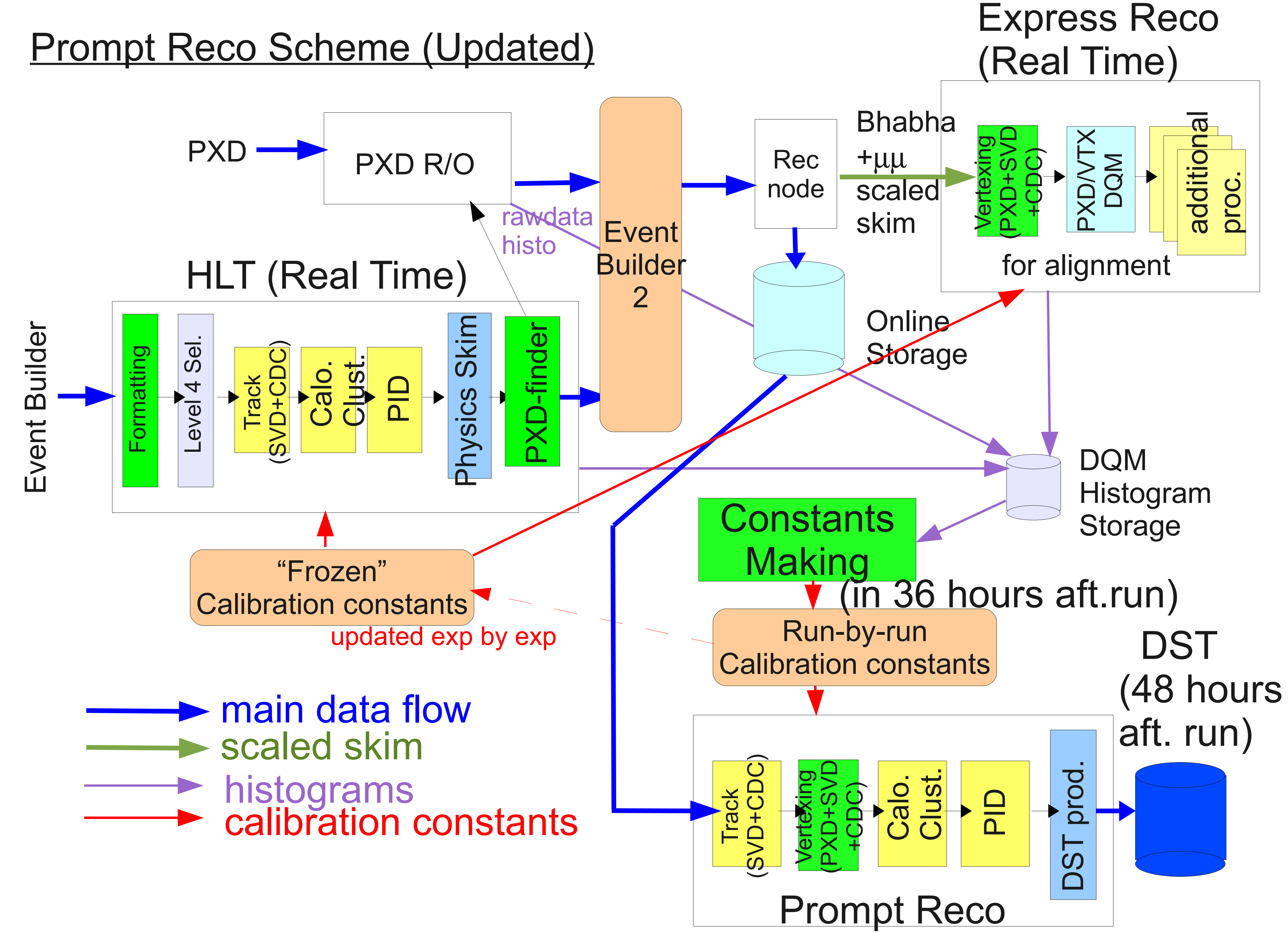
3) Prompt Reco

- Fine selection using the reprocessing results with
  * final calibration constants
  * PXD data.
- Final HadronBJ skim + tau skim

3. Rate reduction in Belle II DAQ



Prompt Reco Scheme (Updated)



Y.Iwasaki

TRG Rate Estimation

Based on Belle History

Lum ($cm^{-2}s^{-1}$)	Lum. Comp.	N/S=~0.5		N/S=~6	
		BG	Total	BG	Total
1×10^{34}	190 Hz	100 Hz	290 Hz	1100 Hz	1300 Hz
1×10^{35}	1.9 kHz	1.0 kHz	2.9 kHz	11 kHz	13 kHz
8×10^{35}	7.2 kHz	8 kHz	15 kHz	88 kHz	95 kHz

- **No reliable estimation**
  - for the beam induced background
  - We will simulate spent beams wher
- **If history repeats,**
  - Early stage : lower currents
  - Final stage : high currents w
- **We can tighten the TR**
  - New tools : CDC 3D trackin
  - Suppress two-photon events

We can assume ~20kHz trigger rate
@ all the time?
(just like “500Hz@Belle”)

The change in Belle's trigger rate was less than a factor of 2 throuhout the experiment although L was increased by a factor of more than 10!
(Avg.rate = 200 to 400 Hz all the time!)

Break down of software trigger components
- Experience @ Belle

- When we assume “20kHz avg L1 rate @ all the time”, the components are different in between “early time” runs and “stable” runs.

- Difference in L1 rate breakdown is shown in previous slide.

- What can be the realistic breakdown in software trigger at HLT?

  -> Check at Belle's experience on RFARM
  by looking at the log of
  “EVTCLS : event classification module”
  placed at the end of RFARM processing chain.

[Experience at Belle] Case I: early time (~2003)

L_{peak} ~ 0.5 x 10^{34}
L1 rate : ~ 350 Hz

	Fraction(%)	effective rate
L3/4 filter	51.4	179.9
Hadron BJ	7.1	24.9
tau tag	4.8	16.8

* Beam was still dirty.

Expected HLT rate @ typical L1 rate = 20kHz

Hadron BJ	~1.4kHz
tau tag	~1.0kHz

[Experience at Belle] Case II: Stable DAQ (Nov. 2006)

$L_{peak}=1.64\times10^{34}$

L1rate: ~ 450Hz

	Events remained	Fraction(%)	Effective rate (Hz)
DAQ taken	11612704	100.0	450.0
L3/4 filter	8298653	71.5	321.8
HadronBJ	2395456	20.6	92.8
tau tag	1700957	14.6	65.7
Bhabha tag	1026922	8.8	39.6
μμ tag	290542	2.5	11.3
two photon tag	1134019	9.8	44.1

Expected HLT rate @ typical L1 rate =20kHz

Hadron BJ	4.1kHz
tau tag	2.9kHz

Current assumption on HLT operation for t=0 (“early” operation)

- Reduction rate based on “early Belle” experience.
  * High L1 rate up to 20kHz, but physics rate is low.

- Powerful “Level 4” filter is assumed.
  * Fast tracking + Rough ECL clustering
    z(IP) < |15cm|, ECLsum > 1GeV.
    <- supposed to be provided by trigger group??
  * Alternative is CDC 3-D trigger. If it works as expected, we may not need Level 4.

- Hadron BJ + tautau selection are agreeable as the software trigger??
  * Could be too tight for t=0, and the selection will be loosened for some period from the beginning.
  * Hadron BJ and tautau skim are really OK for rare decays?

- Monitoring events : random trg, ee, $\mu\mu$, two photons, etc
  * They are supposed to be scaled to <100Hz in total.

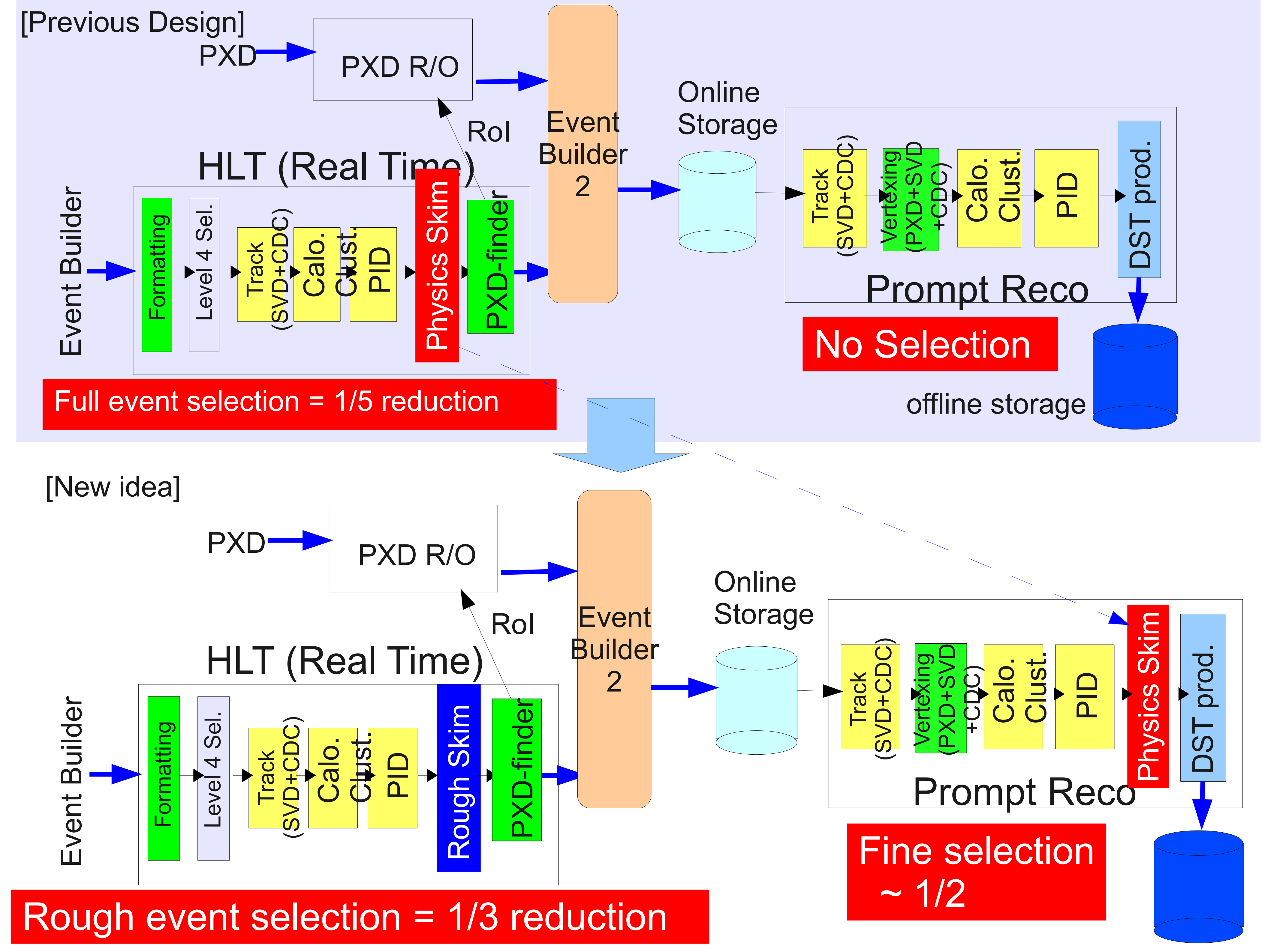
Proposal: Use of Prompt Reco as a final software trigger

- On HLT : Loosen selection criteria
  * Hadron A selection instead of Hadron BJ.
    - Hadron A has looser selection criteria.

```
       # of hadronic events : 3528666   <- Hadron A
     #hadronic w/ high mult : 2102071
      #hadronic w/ low mult : 1426595
 #hadronic from tight cuts : 1346292
#hadronic events w/ R2<0.2 : 445736
     #hadronA w/ Jpsi cand. : 385864    <- Hadron “J”
                   #hadronB : 2009592   <- Hadron B
       #hadronB w/ R2<0.2 : 642469
```

  * Loosen tautau selection + inclusion of some of two photon sel.
    => ~50 % increase in the HLT rate is expected.

- On Prompt Reco : Final tight selection
  * “HadronBJ” after the full event processing with
    - almost-final run-by-run calibration constants
    - tracking/vertexing with PXD
  * Physics oriented skims for intensive rare decay events
    (B->lν, B->hγ, τ->$\mu\gamma$, low multiplicty tau decays......)
  * “Full recon” selection using Hadron A


[Previous Design]
PXD
PXD R/O
RoI
Event Builder 2
Online Storage
HLT (Real Time)
Event Builder
Formatting
Level 4 Sel.
Track (SVD+CDC)
Calo. Clust.
PID
Physics Skim
PXD-finder
Track (SVD+CDC)
Vertexing (PXD+SVD +CDC)
Calo. Clust.
PID
DST prod.
Prompt Reco
No Selection
offline storage
Full event selection = 1/5 reduction
[New idea]
PXD
PXD R/O
RoI
Event Builder 2
Online Storage
HLT (Real Time)
Event Builder
Formatting
Level 4 Sel.
Track (SVD+CDC)
Calo. Clust.
PID
Rough Skim
PXD-finder
Track (SVD+CDC)
Vertexing (PXD+SVD +CDC)
Calo. Clust.
PID
Physics Skim
DST prod.
Prompt Reco
Fine selection ~ 1/2
Rough event selection = 1/3 reduction

Summary of “early” operation of software trigger

- Assume 20kHz L1 rate at t=0 because of a high background.

- L4 filter and/or CDC 3-D trigger reduces the rate to ½

- HLT selection:
  * Hadron A instead of Hadron BJ : looser selection
  * Loosened tau-tau selection
  * Monitor events (scaled to <100Hz)
  -> ~ ave. 7-8 kHz (1/3 reduction) with a max of 10 kHz.

- Prompt Reco selection
  * Hadron BJ + “intensive” selection for rare decays
  -> ~ a few kHz

4. Data size reduction

One page summary of FEE

	#ch	occ [%]	#link	/link [B/s]	FNS	#CPR	ch sz [B]	ev sz [B]	total [B/s]	/CPR [B/s]
PXD	8M	2	40	600M/DHH	—	—	4	800k	24G	—
SVD	243456	1.9	40	13.8M	HSLB	40	4	18.5k	555M	13.8M
CDC	15104	10	302	0.6M	HSLB	75	4	6k	175M	2.3M
BPID	8192	2.5	128	7.5M	DSP	16	16	4k	120M	8M
EPID	77760	1.3	138	0.87M	HSLB	35	0.5	4k	120M	15M
ECL	8736	33	52	7.7M	HSLB	26	4	12k	360M	15M
BKLM	21696	1	86	9.7M	HSLB	6	8	2K	60M	10M
EKLM	16800	2	66	19.5M	HSLB	5	4	1.4k	42M	5.3M
TRG					HSLB	~10				

Event size
PXD : ~ 1MB (@2% occupancy)
COPPERs : at most 100kB (with headers added)

PXD data reduction

- Noise hits are discarded in PXD readout box (ATCA cards) by associating with reconstructed tracks.

- The track info are provided by HLT (baseline option).

- For the association, PXD hit clustering is done in DHH.

- Further processing to recover PXD hits is supposed to be done in ATCA.

- The reduction rate is estimated to be 1/10.
  => * ~100kB at the output of PXD R/O box.
  * The data are sent for HLT accepted events only.
  (Rate reduction using HLT output).

Reduction of COPPER data

- The data from detector front-end are assumed to be well compacted already by FPGA processing.

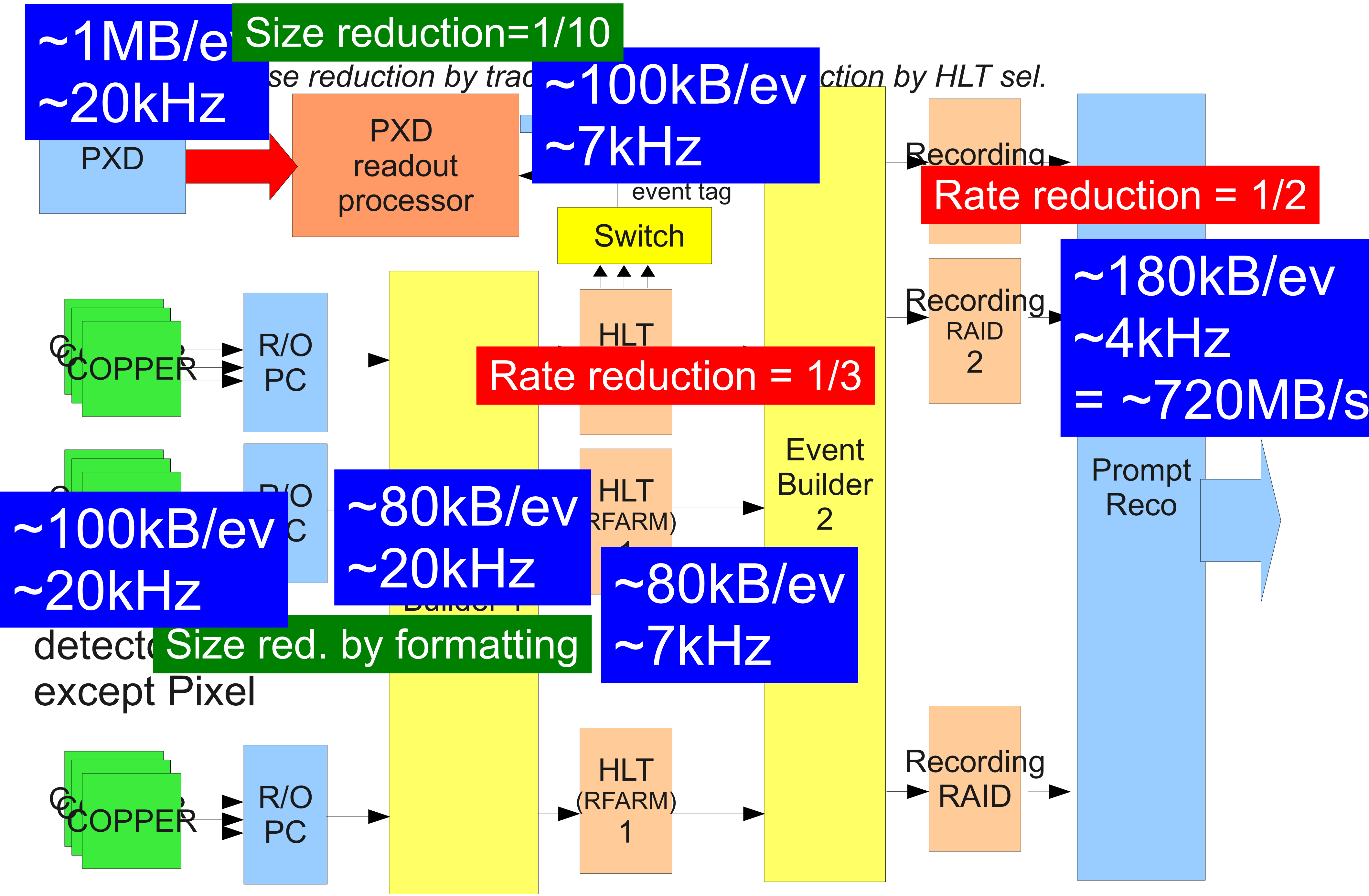
- Additional raw data processing is possible using COPPER CPU (Linux operated + basf2 environment), but mostly for data formatting and monitoring because of limited CPU power (ATOM 1.6GHz).

- Reduction is also possible at Readout PC under the same software environment (basf2 on linux).

Any processing required for data reduction on COPPER and R/O PC?

* In the data formatting, it is possible to remove redundant headers in the raw data sent through Belle2link (as we did in Belle's AMT readout) -> >20% reduction expected.
* The processing heavily depends on detector's own data format.

Expected data rate/size reduction in “early time” operation



Backup Slides

Output of Event Classification (EVTCLS) Module @ RFARM:

Taken by DAQ :11612704 events (456Hz(alive)/423Hz(accepted))
Level 4 filter : 8298653 events

```
---------------------------------------------
     results print out ....
---------------------------------------------
     # of total read events : 8298653
---------------------------------------------
       # of hadronic events : 3528666
     #hadronic w/ high mult : 2102071
      #hadronic w/ low mult : 1426595
  #hadronic from tight cuts : 1346292
 #hadronic events w/ R2<0.2 : 445736
     #hadronA w/ Jpsi cand. : 385864
                   #hadronB : 2009592
         #hadronB w/ R2<0.2 : 642469
---------------------------------------------
         # of Bhabha events : 1026922
          #collinear Bhabha : 941674( fired by CsI BBtrg: 312471 )
             #barrel Bhabha : 425466( fired by CsI BBtrg: 223514 )
            #forward Bhabha : 190196( fired by CsI BBtrg: 17 )
           #backward Bhabha : 990( fired by CsI BBtrg: 0 )
---------------------------------------------
    # of rad. Bhabha events : 1361396
         w/ large E deposit : 1093514
---------------------------------------------
     # of gamma-pair events : 124137
           #collinear gamma : 94578( fired by CsI BBtrg: 44289 )
              #barrel gamma : 48429( fired by CsI BBtrg: 34818 )
             #forward gamma : 1848( fired by CsI BBtrg: 0 )
            #backward gamma : 1836( fired by CsI BBtrg: 0 )
```

```
---------------------------------------------
    # of cal. Bhabha events : 2517305
            fired by bit#17 : 0
---------------------------------------------
        # of mu-pair events : 290542
          #collinear muons  : 247150
             #barrel muons  : 164113
                w/ TOF cut  : 160440
            #forward muons  : 6866
           #backward muons  : 6465
---------------------------------------------
   # of rad. mu-pair events : 60946
       w/  radiative photon : 47162
       w/o radiative photon : 13765
---------------------------------------------
       # of tau-pair events : 1700957
---------------------------------------------
     # of two-photon events : 1134019
               #two tracks  : 622044
                 #low mult  : 369748
            #low visible E  : 2
     #four trk w/ loose vtx : 126355
     #four trk w/ tight vtx : 15870
---------------------------------------------
           # of eeee events : 336581
---------------------------------------------
      # of gamma+phi events : 2022
---------------------------------------------
         # of cosmic events : 23907
          passing thru TOF : 13401
---------------------------------------------
        # of beam BG events : 0
---------------------------------------------
  # of beam gas mon. events : 2168657
---------------------------------------------
```