High Level Trigger

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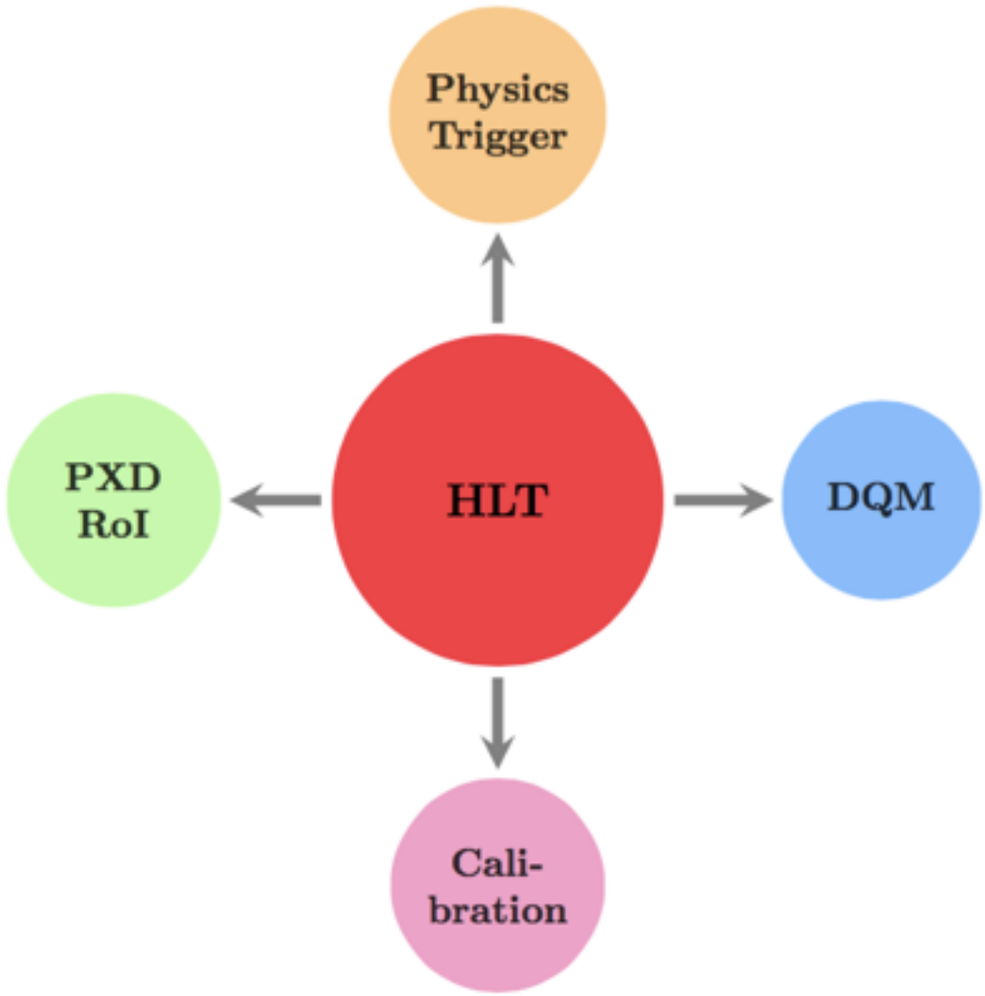
HLT

- Physics Trigger: suppress event rates from 30 kHz to 10 kHz

- PXD RoI: provide HLT trigger result and tracking information of SVD and CDC to calculate Region of Interest of PXD.

- Calibration: Flag samples for the calibration of detectors

- DQM: Information from Reconstruction for data quality monitoring



Bit assignment of HLT in mdst m_HLTSummary

Bit 0 → 9

Global	L3	Hadronic	Tautau	LowMulti	Bhabha	Mumu	Cosmic	Random	Injection

Bit 31 ← 10

…..	MAXALGO	BeamTest	Calib5	Calib4	Calib3	Calib2	Calib1

The HLT software is developed based on basf2

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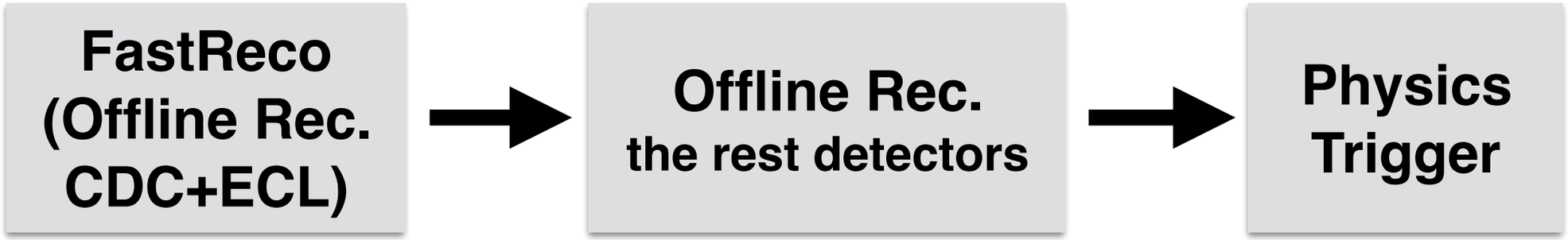
Trigger Scheme

Scheme 1

Kakuno Hidekazu

Chunhua Li

Scheme 2



Nils Braun
Thomas Hauth

Chunhua Li

See the next talk by Nils Braun about the software framework

Trigger Scheme

Scheme 1

L3:

- Dedicated reconstruction algorithm for CDC tracking and ECL clusters
- Fast processing time
- Possible to develop the trigger menu?

Offline Rec:

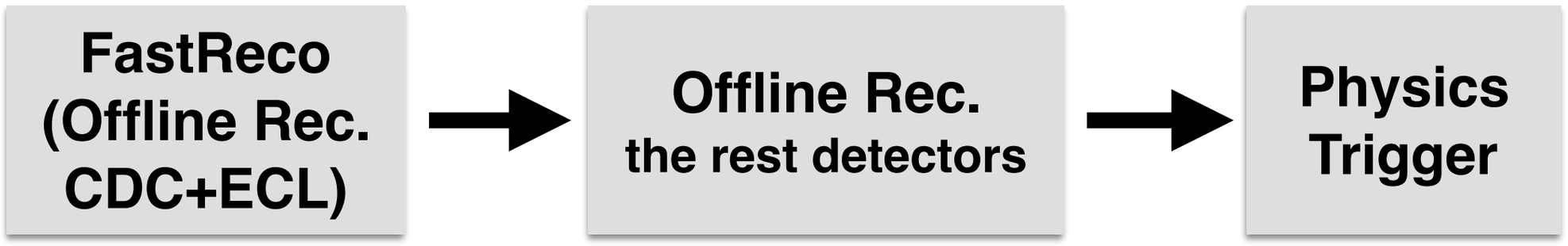
offline reconstruction algorithm with all detectors except PXD

Physics Trigger:

software developed based on the physics analysis framework.

Trigger Scheme

Scheme 2



- simplify rec. procedure on HLT: only offline rec. is applied
- simplify the optimization of trigger menu
- develop the trigger menu of FastReco

Development of Trigger Menu

L1 & HLT

Trigger Menu of L1

An abundant trigger menu of L1 is developed

Information of detectors used in the trigger logics

- 3D CDC tracking information: momentum, direction
- ECL cluster: energy, position
- CDC-ECL match
- KLM: number of fired layers, track direction

pre-scale as f(θ)

QED

- Bahbha and γγ
  - veto
  - accept

ID	Name	Logic	Prescale	Bhabha	$\gamma\gamma$	γ	$\mu^+\mu^-(\gamma)$	$h^+h^-(\gamma)$	τ 1 vs. 1	$\gamma\gamma^* \to \pi^0/\eta(')$	$\gamma\pi\pi$	$\gamma\gamma \to \pi^0\pi^0$	Comment
1	Bhabha veto	ECL bhabha veto && exactly 2 CDC tracks && both ECL clusters matched to CDC tracks	-										pure
2	Bhabha accept 1	ECL bhabha accept && $\geq$ 1 CDC track && at least 1 ECL cluster matched to CDC track	$f(\theta)$	•									efficient (missing 1 track)
3	Bhabha accept 2	$\geq$ 2 CDC tracks && a pair of CDC tracks in Bhabha configuration && at least 1 matched to a high energy ECL cluster	$f(\theta)$	•									efficient (missing 1 cluster)
4	gg veto	ECL bhabha veto && 0 CDC tracks	-										pure
5	gg accept	ECL bhabha accept && !Bhabha veto	10		•								efficient
6	single leg g trigger	at least one high energy ECL cluster not matched to CDC track	20		○	○							

Details are in L1 trigger menu note BELLE2-NOTE-PH-2015-011

Low Multi. Triggers

- two tracks
- one track one cluster
- one/two muons (ECL, KLM)
- two clusters
- three clusters

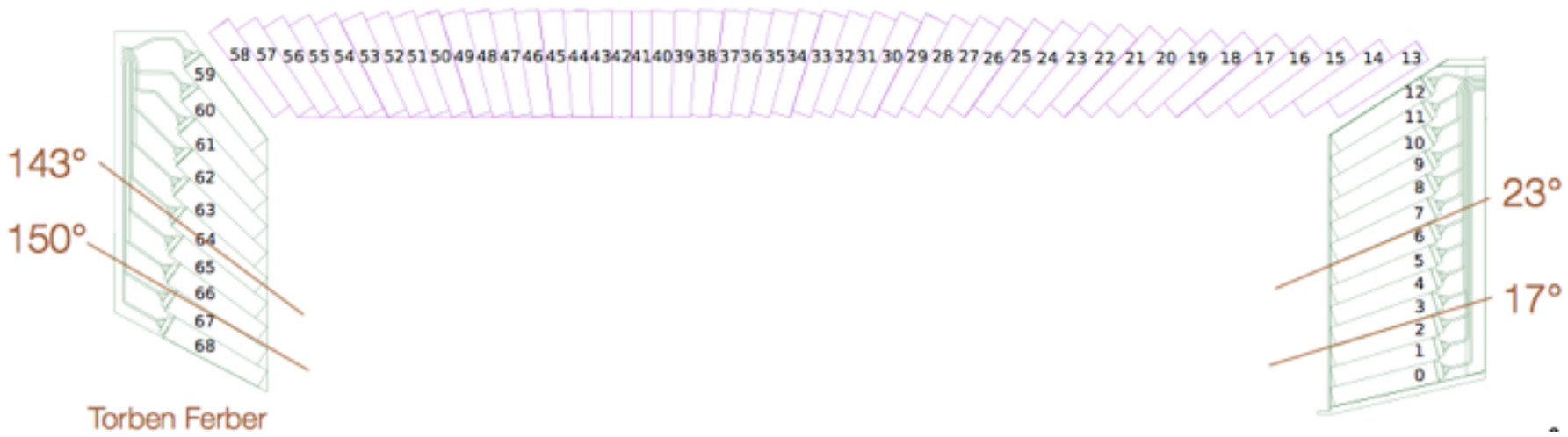
13	two tracks	two CDC tracks && !Bhabha veto	1				●	●	●		●		standard two track trigger
14	two tracks no veto	two CDC tracks	2000				o	o	o		o		
15	one tracks one muon	≥1 CDC track && ≥1 KLM muon separated by $\Delta\phi$ >45deg	1				●		●				
16	two KLM muons	≥2 KLM tracks $\Delta\phi$ >45deg	10				o						no CDC, no ECL
17	single KLM muon	high momentum CDC track matched to KLM cluster	1				●		●				single track, no ECL
18	single ECL muon	CDC track matched to ECL cluster < 0.5 GeV && !Bhabha veto	10				o		o				
21	two back to back tracks	2 CDC tracks separated by >45 deg && !Bhabha veto	1				o		●		●		looser track selection
22	two back to back tracks no veto	2 CDC tracks separated by >45 deg	2000						o				looser track selection
19	one track one cluster	≥1 ECL cluster >500 MeV && ≥1 CDC track separated by >45 deg && !Bhabha veto	1				o	●	●	●			
20	one track one cluster no veto	≥1 ECL cluster >500 MeV && ≥1 CDC track separated by >45 deg	2000				o	o	o	o			
23	back to back clusters	ECL clusters >500 MeV separated by >45 deg && !Bhabha veto && !gg veto	1						●	●		●	
24	back to back clusters no veto	2 ECL clusters >500 MeV separated by >45 deg	200	●	o					o			
25	total energy	Sum of ECL clusters >3 GeV	200	●	o					o			
26	two ECL muons	2 ECL clusters >100 MeV and <500 separated by >45 deg	100				o						
27	two ECL muons with KLM	2 ECL clusters >100 MeV and <500 separated by >45 deg, at least one matched to KLM cluster	10				o						with KLM
28	three clusters	3 ECL clusters > 100 MeV separated by η < 170 deg	1				o	o				●	

Single Photon Trigger of L1

‘Update on low-multiplicity L1 triggers’
—Christopher Hearty, 24th B2GM

“nominal” Bhabha veto:
- exactly 2 tracks, both associated with E*>3 GeV clusters, separated by >170°.

Aggressive Bhabha veto:
- $p_1^* > 3$ GeV/c, $p_2^* > 1$ GeV/c, separated by >143°, at least one of which is associated with E*>3 GeV cluster.



Single Photon Trigger of L1

'Update on low-multiplicity L1 triggers'
—Christopher Hearty, 24th B2GM

Single γ, 2 GeV:

- neutral cluster with E*>2 GeV in $23° < \theta_{lab} < 143°$
- not satisfying aggressive veto
- not satisfying $\gamma\gamma$ veto:
  - two clusters E*>2.5 GeV separated by >150°, no tracks

Single γ, 1 GeV:

- neutral cluster with E*>1 GeV in $23° < \theta_{lab} < 143°$
- not satisfying aggressive veto
- not satisfying $\gamma\gamma$ veto

Split single photon trigger into barrel and endcap

effective cross section

Trigger	Bhabha	$e^+e^- \to \gamma\gamma$	Total
2 leg $\gamma\gamma$	1.2	1.9	3.1/prescale
1 leg $\gamma\gamma$	1.4	2.2	3.6/prescale
single γ, 2 GeV	1.9	0.4	2.3
single γ, 1 GeV	2.4	0.5	3.0

Bhabha
Babayaga: (wide angle)
TEEGG: one particle is out of acceptance

Trigger Menu of L1

Estimation of efficiency and cross section with L1 emulator

30 kHz
8×10^{35} cm^{-2}s^{-1} → 37.5 nb

	Processes	T1:2trk	T2:1trk1mu	T3:1mu	T4:1trk1c	T1:bbc	T2:3g	T3:3t	Combine
ϵ(%)	$B^0\bar{B}^0$	-	96.5	50.0	82.9	44.8	93.4	99.4	> 99.9
	B^+B^-	-	96.5	51.7	84.1	46.2	92.6	99.5	> 99.9
	ccbar	-	96.8	65.9	89.4	52.1	84.8	98.0	> 99.9
	uds	-	96.5	68.0	89.1	50.0	81.1	97.2	> 99.9
	$\tau \rightarrow$generic	51.0	60.0	57.2	62.6	28.1	55.6	29.1	94.3
	$\tau\tau$(1v1)	81.0	58.1	61.8	61.3	27.9	47.4	-	97.3
	$\tau \rightarrow e\gamma$	80.0	55.1	56.0	91.7	52.3	85.7	-	99.0
	$\tau \rightarrow \mu\gamma$	76.1	48.1	46.2	87.7	57.9	82.2	-	97.1
	$\pi\pi(\gamma)$	67.9	51.9	67.4	80.0	43.4	42.5	-	97.4
	$\pi\pi(\gamma)$[0,1]	66.7	49.4	66.3	79.1	43.0	38.6	-	97.2
	$B \rightarrow \pi^0\pi^0$	11.1	83.4	35.4	96.3	92.4	17.0	81.7	> 99.9
	$\mu\mu$	98.9	94.5	99.7	-	-	-	-	> 99.9
σ(nb)	eeee	2.2	0.1	0.1	1.1	0.8	0.9	0.1	3.4
	$ee\mu\mu$	2.6	0.8	0.7	0.1	0.1	0.5	0.1	3.3
	$ee(\gamma)$	7.2	7.3	10.5	11.1	13.1	2.9	0.6	32.2

- L1 Emulator
  - emulator the logics of L1 trigger with information from offline reconstruction.
  - to understand of the background conditions
  - large uncertainty on border of detectors compared to L1 trigger simulation.
- For the signal efficiencies of low multi. processes in the table, the detector acceptance factor is ruled out.
- Single photon trigger is not included in this table

Details are in L1 trigger menu note BELLE2-NOTE-PH-2015-011

Trigger Menu of L3/FastReco

L3:

- High efficiency for BB and Low Multi.
- Rejection of background need to be studied.
- Possible to develop the trigger menu?

Number of good tracks >= 1

good track: |dr|<1cm && |dz|<4cm && p_T>0.3GeV/c

Energy sum of good clusters >= 4GeV

good cluster: ΣE>20MeV && E_{seed}>10MeV

Fast Reco:

- Trigger Menu is developed

The following variables are used for cuts after the FastReco:

- energy sum of high energetic ECL (>0.05 GeV)
- highest 2 ECL, highest 3 ECL
- max p_t in event
- mean(abs(z))
- mean(θ)

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.

Calibration Samples

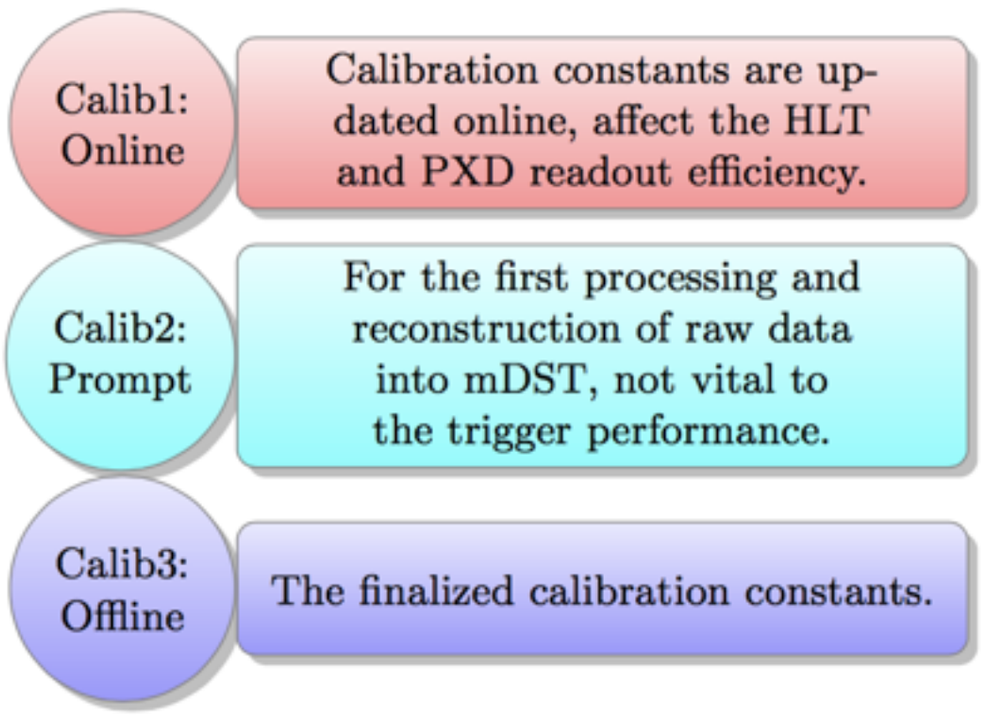
Bit 0 → 9

Global	L3	Hadronic	Tautau	LowMulti	Bhabha	Mumu	Cosmic	Random	Injection

Bit 31 ← 10

…..	MAXALGO	BeamTest	Calib5	Calib4	Calib3	Calib2	Calib1

- HLT flags the samples for the calibrations of Online, Prompt and Offline.



Calibration Samples

Samples for the calibration of detectors
- high purity
- efficiency is not essential
- particular selection criteria to avoid bias
- even sampling in time

Some samples
QED:
(radiative) Bhabha: flatten in cosθ, low energy radiative Bhabha
(radiative) Dimu
$\gamma\gamma \rightarrow ee$
$\gamma\gamma \rightarrow 4\pi$

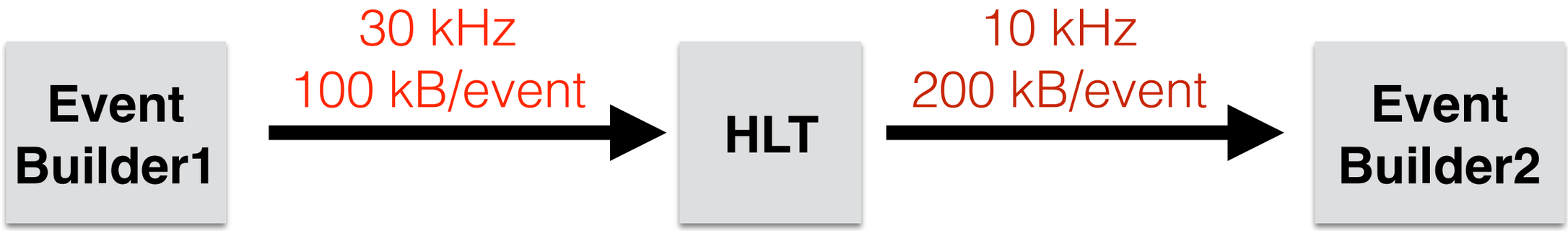
Hadronic process:
$D0 \rightarrow K\pi$
Ξ to $\pi^+\Lambda^0$ ($p\pi^-$)

Calibration group will provide the list of needed samples and the specific selection criteria

HLT-DQM

- The information used in HLT
  - number of tracks
  - total visible energy
  - total energy on ECL
  - topology of some processes e.g. Bhabha, Dimu
- M(J/psi, Ks, D0, D*) for the data quality monitoring.
- Trigger rate of each trigger Line.
- The fraction of events in each trigger category and their overlaps (Skim group)

Data output of HLT



- Input of HLT: raw data (detector information+ L1)
- Large size of data are produced in HLT reconstruction.
- Debug the trigger menu, study the trigger performance e.g. efficiency

- Output of HLT
  - raw data
  - HLT trigger results: HLTTag
  - Information used by HLT trigger menu: debug and study trigger performance
  - SVD+CDC tracks information for PXD RoI calculation ?
  - other information?

Summary

- Trigger menu of L1 and HLT
    - An L1 trigger menu of Low multiplicity is developed, the performance is studied preliminarily with L1 Emulator. This menu could keep high efficiencies of low multiplicity processes. The background study is in process.
        - Keep communication with TRG group on the development of L1 trigger menu.
        - Two HLT scheme candidates. The performance study and further developments are in process.
- The sample selections for calibration will be integrated into HLT.
- The HLT-DQM module is developed, more information for monitoring will be import.