

TOP VIEW

Forward

Belle II

Superconducting coil

High Level Trigger at Belle II

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超级陶粲装置研讨会，

兰州，2024/07/07-11

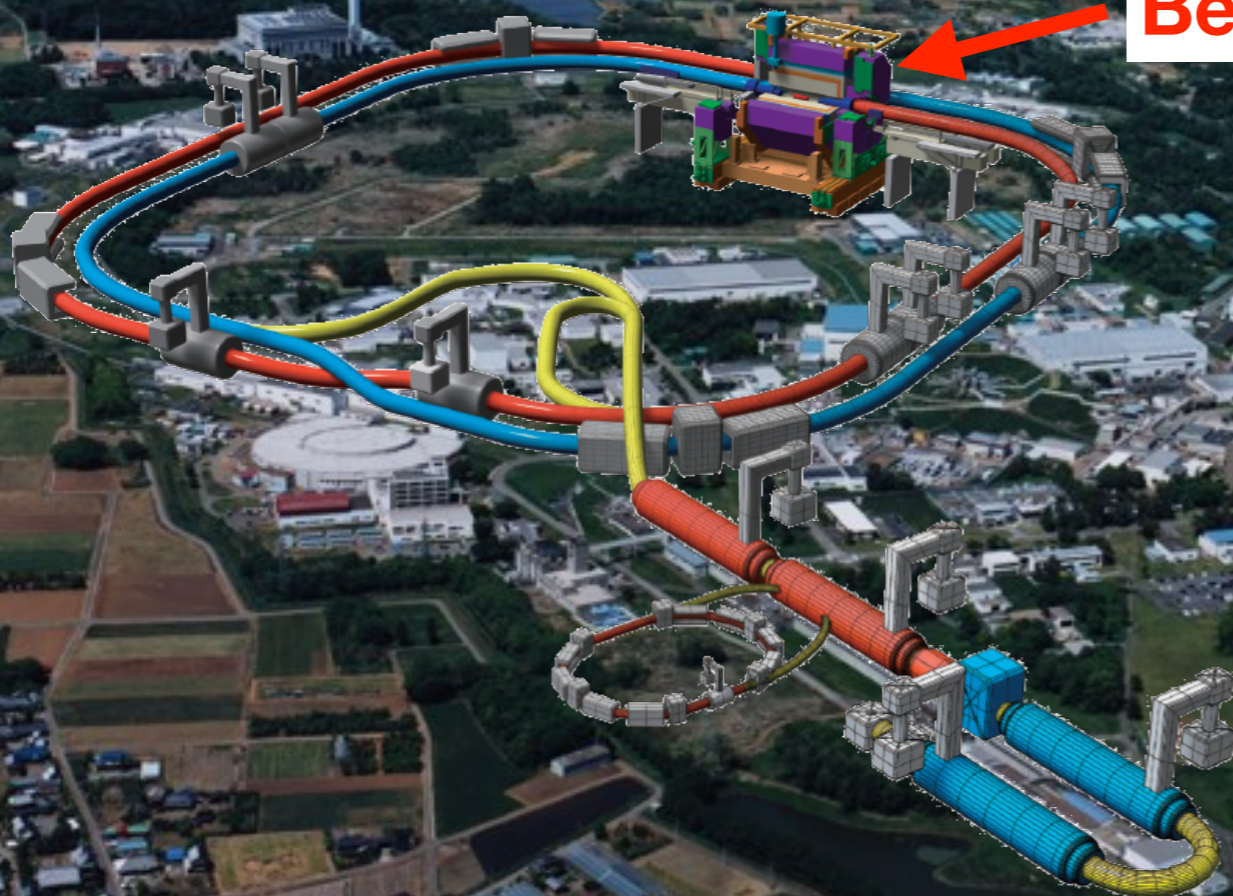
SuperKEKB

An asymmetric electron-positron collider

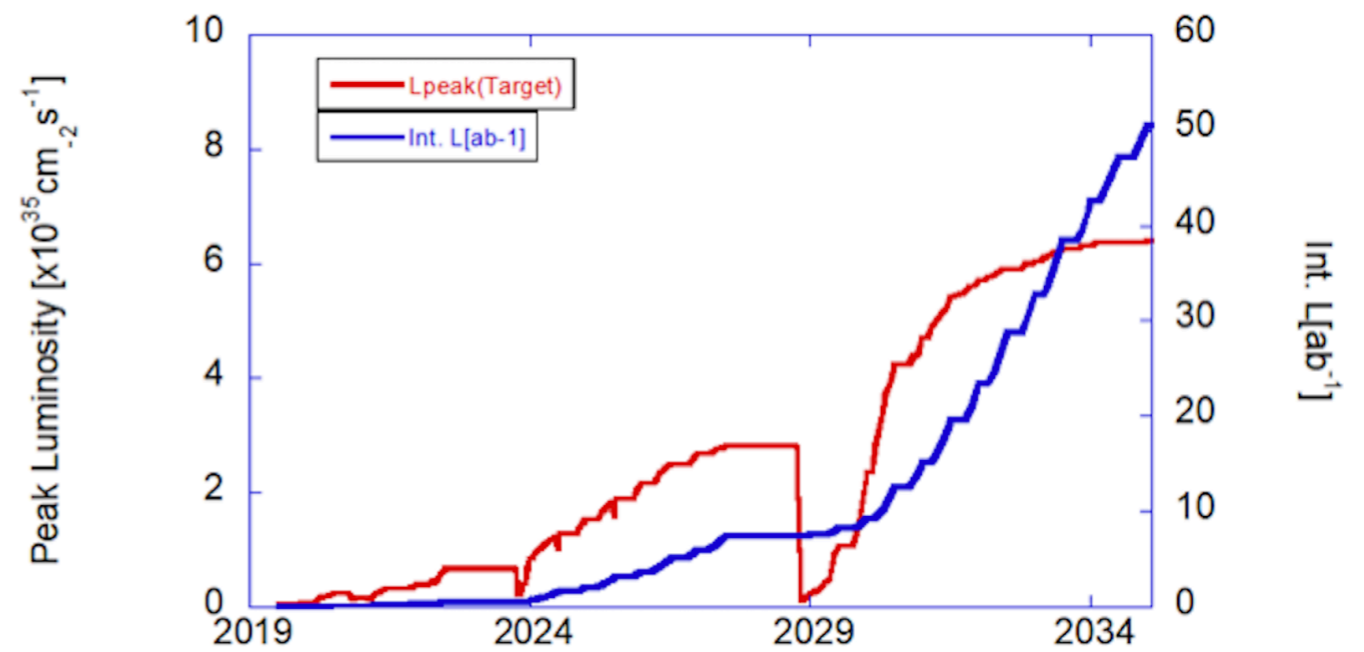
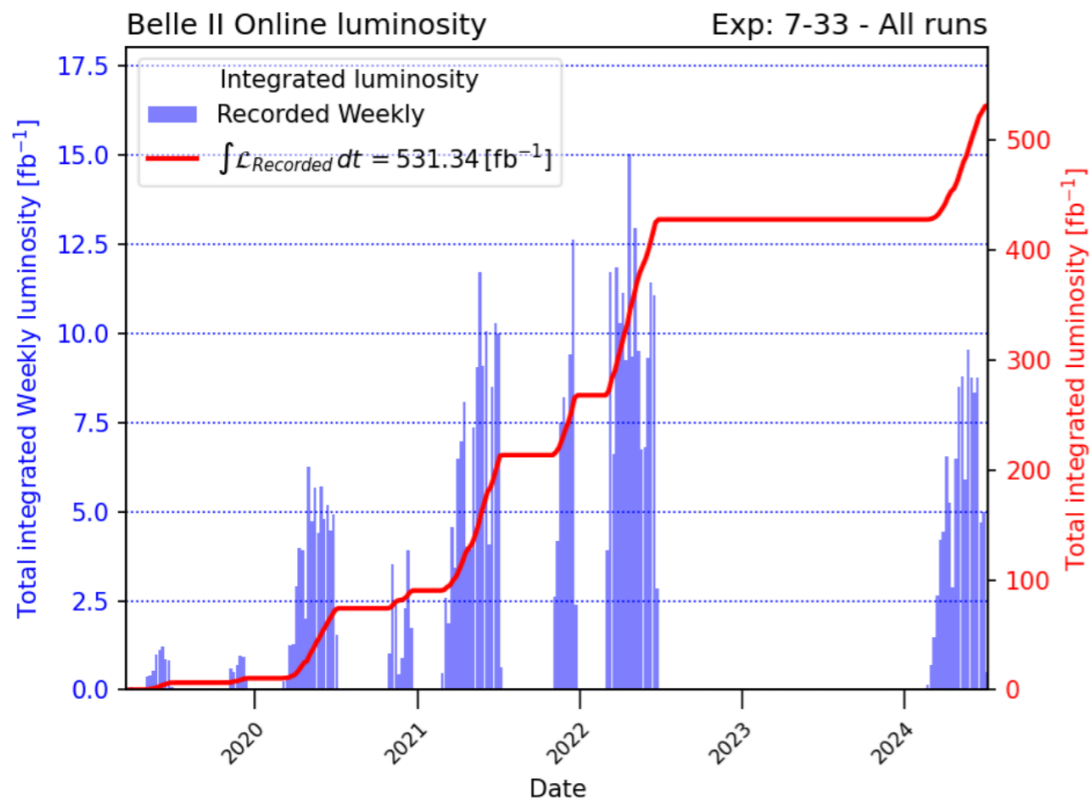
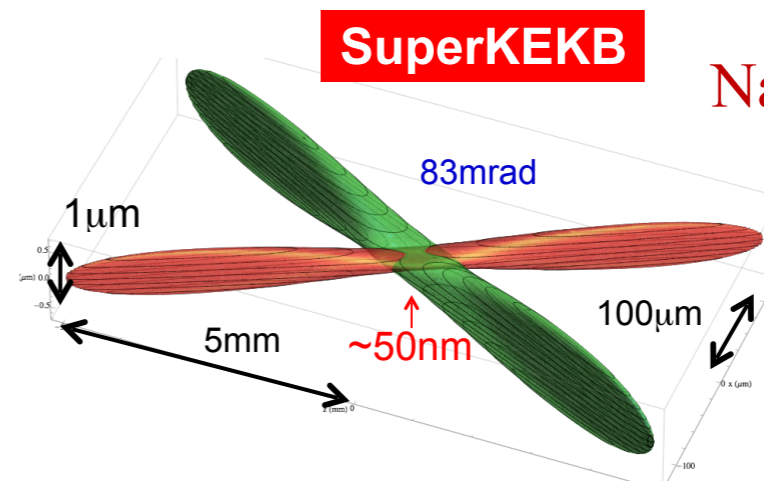
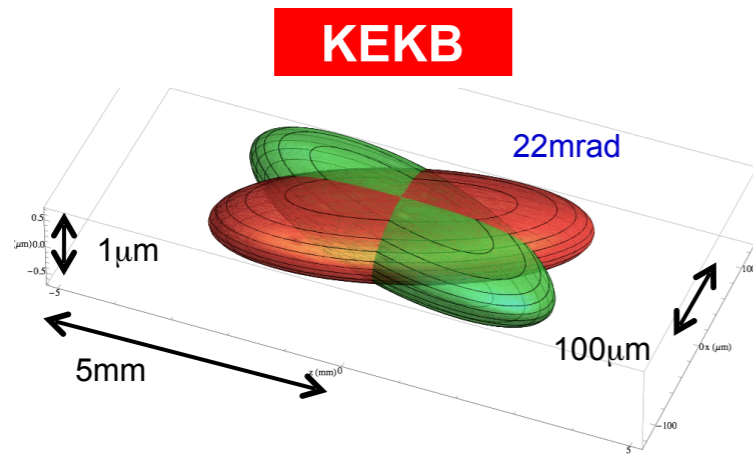
$e^+ \sim 4\text{GeV}$ $e^- \sim 7\text{GeV}$

$\sim 3\text{km}$ circumference

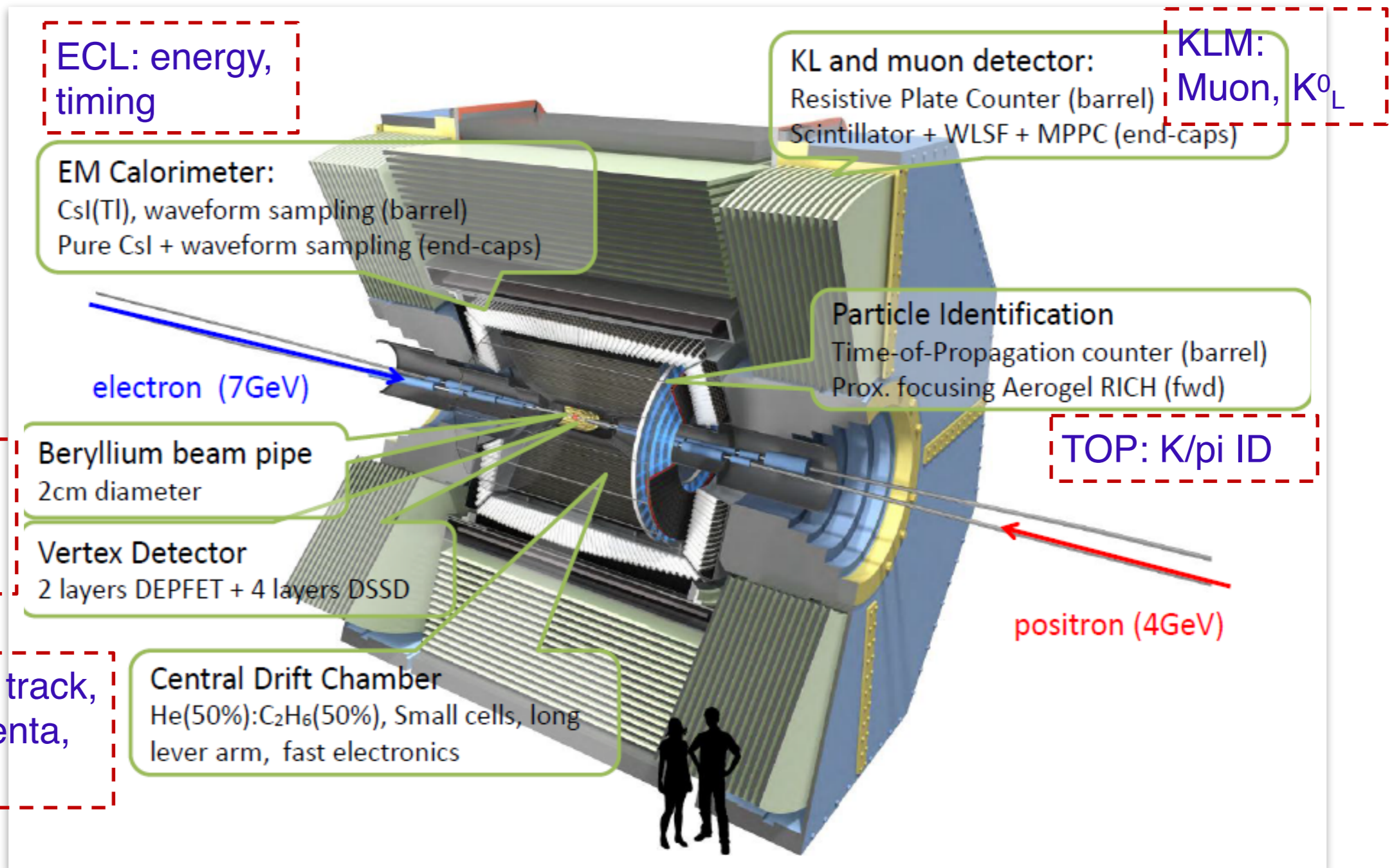
Belle II detector



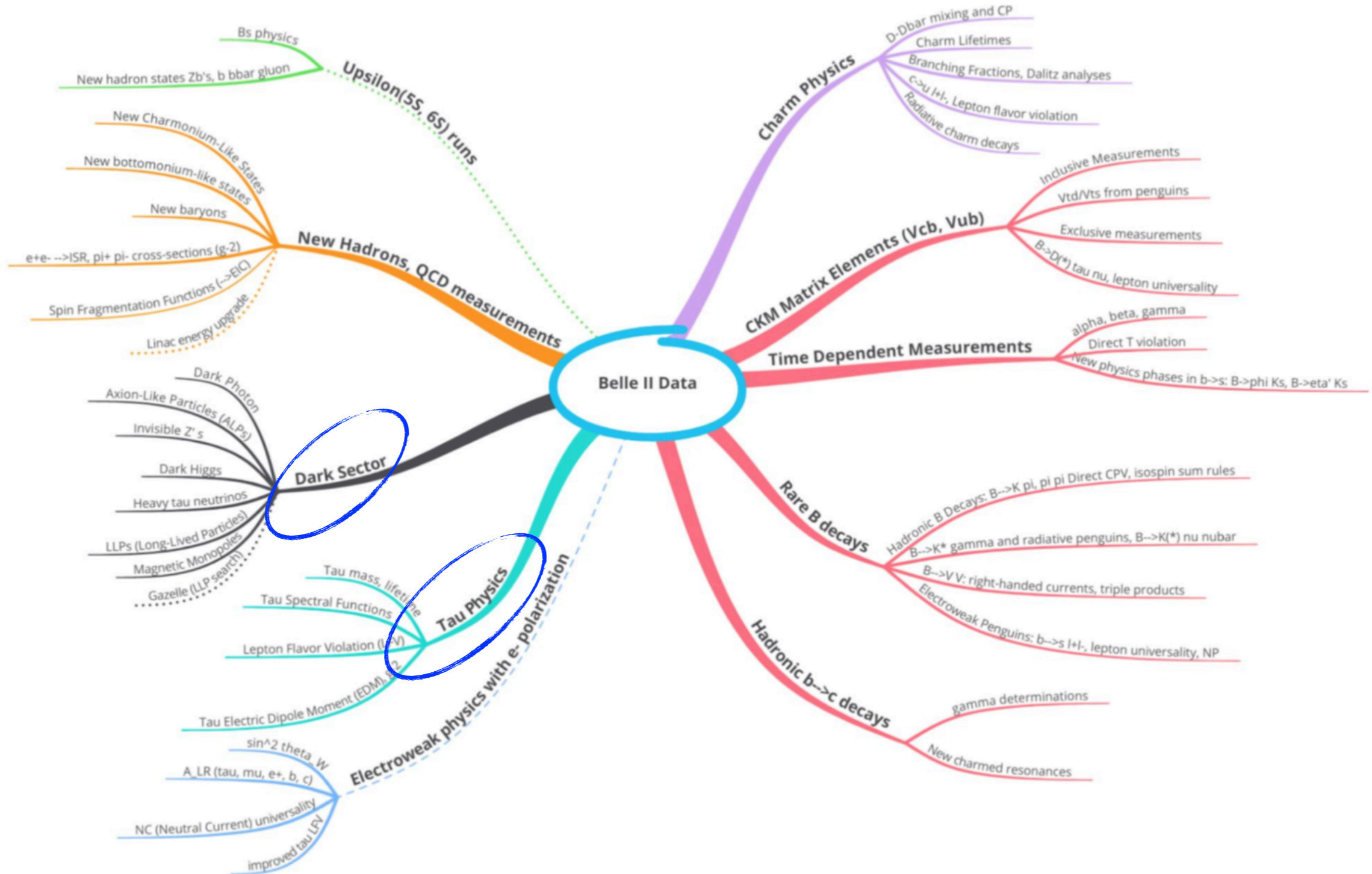
SuperKEKB



Belle II Detector



Belle II Physics



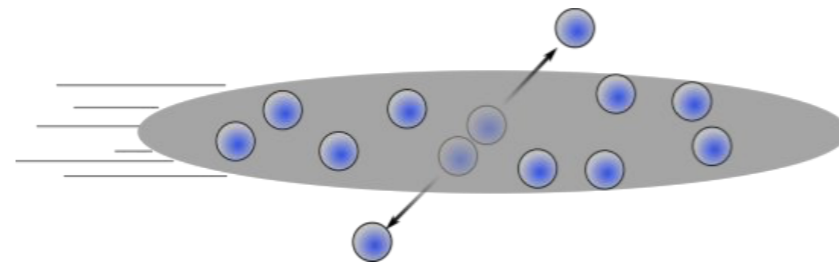
Belle II Beam Background

Due to the low final state particle multiplicity for dark matter processes, background from beams become a major challenge.

Total background is significantly higher than Belle

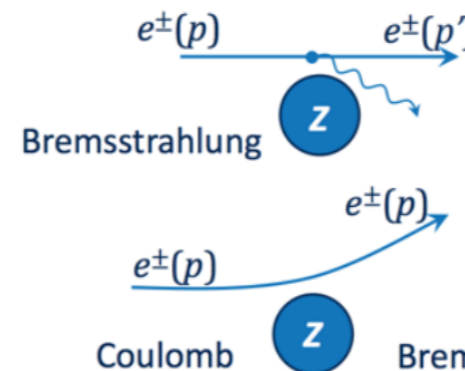
Touschek effect

- Intra bunch scattering
- Rate \propto the inverse beam size, number of bunches et.al
- Suppressed with movable collimators



Beam gas

- Coulomb and bremsstrahlung scattering by the residual gas atoms
- Rate \propto the vacuum level and the beam current

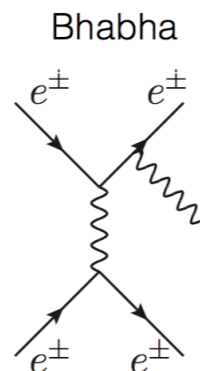


Synchrotron radiation

- Rate \propto the beam energy squared and magnetic field squared

Physical backgrounds

- Bhabha $ee \rightarrow (\gamma)ee$
- Two photon: $ee \rightarrow eeee$
- Rate \propto luminosity



Dominant when luminosity is high

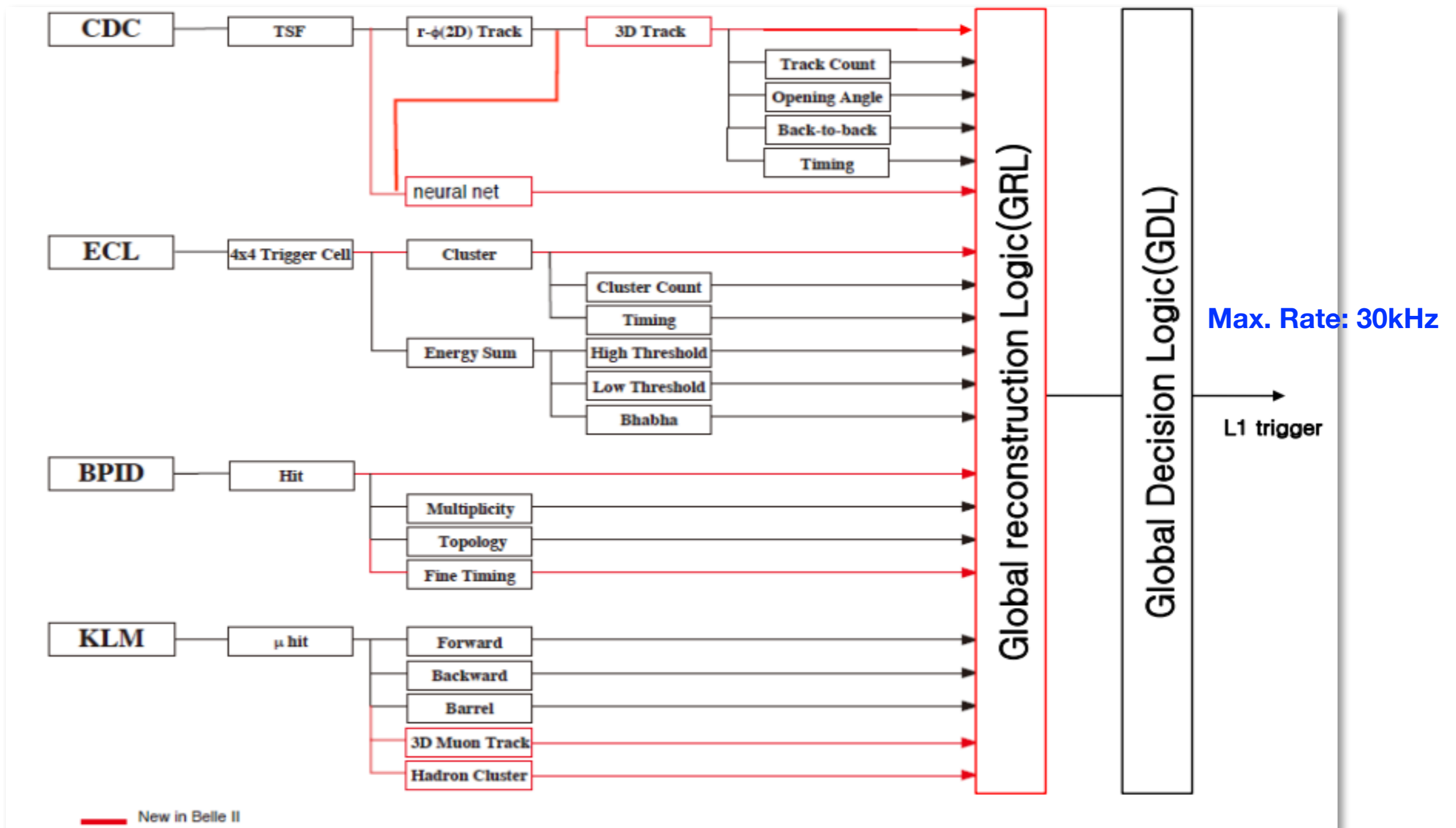
Trigger

Scheme: Hardware trigger + Software trigger

- Level 1 (L1): hardware based
- High Level Trigger (HLT): software based, a component of DAQ

L1 Trigger Scheme

Sub-Detector Triggers + Global Decision Logic (GDL)



L1 Trigger Menu

				e+e-	0.5 deg		
				122760	nb		
Bit	Description	Prescale	% Selected	exclusive	Rate		
0	3 or more 3D tracks	1	0.0047	0.0040	228		
1	2 3D tracks, ≥ 1 within 25 cm, not a trkBhabha	1	0.0213	0.0170	1046		
2	2 3D tracks, not a trkBhabha	20	0.0022	0.0010	106		
3	2 3D tracks, trkBhabha	1	0.0087	0.0000	425		
4	1 track, <25cm, clust same hemi, no 2 GeV clust	1	0.0037	0.0030	182		
5	1 track, <25cm, clust opp hemi, no 2 GeV clust	1	0.0120	0.0090	587		
6	≥ 3 clusters inc. ≥ 1 300 MeV, not an eclBhabha	1	0.0271	0.0140	1331		
7	2 GeV E^* in [4,14], not a trkBhabha	1	0.0041	0.0010	199		
8	2 GeV E^* in [4,14], trkBhabha	1	0.0084	0.0000	412		
9	2 GeV E^* in 2,3,15 or 16, not a trkBhabha or eclBhabha	1	0.0067	0.0030	327		
10	2 GeV E^* in 2,3,15 or 16, trkBhabha or eclBhabha	1	0.0239	0.0210	1171		
11	2 GeV E^* in 1 or 17, not a trkBhabha or eclBhabha	10	0.0048	0.0040	236		
12	2 GeV E^* in 1 or 17, trkBhabha or eclBhabha	10	0.0023	0.0010	110		
13	exactly 1 $E^* > 1$ GeV and 1 $E > 300$ MeV, in [4,15]	1	0.0042	0.0030	204		
14	exactly 1 $E^* > 1$ GeV and 1 $E > 300$ MeV, in 2,3 or 16	1	0.0068	0.0050	331		
15	clusters back-to-back in phi, both > 250 MeV, no 2 GeV	1	0.0034	0.0020	167		
16	clusters back-to-back in phi, 1 < 250 MeV, no 2 GeV	1	0.0281	0.0110	1380		
17	clusters back-to-back in 3D, no 2 GeV	1	0.0257	0.0110	1260		
Percentage selected by at least 1 trigger			0.1499	0.1090	7358		
Cross section (nb)			184	134			
Rate, phase2 backgrounds, luminosity (nb-1/s) =		40	7358				

L1 Trigger Menu

Bit	Description	e+e-	0.5 deg	Rate
0	3 or more 3D tracks			228
1	2 3D tracks, ≥ 1 within 25 cm, not a trkBhabha			1046
2	2 3D tracks, not a trkBhabha		10	106
3	2 3D tracks, trkBhabha		0.0000	425
4	1 track, <25cm, clust same hemi, no 2 GeV clust	1	0.0030	182
5	1 track, <25cm, clust opp hemi, no 2 GeV clust			587
6	≥ 3 clusters inc. ≥ 1 300 MeV, not an eclBhabha			11
7	2 GeV E^* in [4,14], not a trkBhabha			1171
8	2 GeV E^* in [4,14], trkBhabha			1171
9	2 GeV E^* in 2,3,15 or 16, not a trkBhabha or eclBhabha			236
10	2 GeV E^* in 2,3,15 or 16, trkBhabha or eclBhabha			110
11	2 GeV E^* in 1 or 17, not a trkBhabha or eclBhabha	10	0.0040	236
12	2 GeV E^* in 1 or 17, trkBhabha or eclBhabha	10		110
13	exactly 1 $E^* > 1$ GeV and 1 $E > 300$ MeV, in [4,15]			
14	exactly 1 $E^* > 1$ GeV and 1 $E > 300$ MeV, in 2,3 or 16			
15	clusters back-to-back in phi, both > 250 MeV, no 2 GeV			
16	clusters back-to-back in phi, 1 < 250 MeV, no 2 GeV			
17	clusters back-to-back in 3D, no 2 GeV			
Percentage selected by at least 1 trigger				7358
Cross section (nb)				184 134
Rate, phase2 backgrounds, luminosity (nb-1/s) =				40 7358

Hadronic events

Two-track events, $\tau\tau$, $\gamma\pi\pi$, $Y(1S)$ inv. decay et.al

w/ a large cluster events $\tau\tau$, $\gamma\pi\pi$, dark photon, et.al

Back-to-back clusters $\tau\tau$, $\gamma\pi\pi$, dark photon

L1 Trigger Menu

$$L = 4 \times 10^{34} \text{ cm}^{-2}/\text{s}$$

5% of nominal

Bit	Description	Efficiency	Rate
0	3 or more 3D tracks	0.0000	425
1	2 3D tracks >1 within 25 cm, not a trkBhabha	0.0030	182
9	2 GeV E* in 2,3,15 or 16, not a trkBhabha or eclBhabha	0.0040	236
10	2 GeV E* in 2,3,15 or 16, trkBhabha or eclBhabha	0.0040	110
11	2 GeV E* in 1 or 17, not a trkBhabha or eclBhabha	0.0040	110
12	2 GeV E* in 1 or 17, trkBhabha or eclBhabha	0.0040	110
13	exactly 1 E*>1 GeV and 1 E>300 MeV, in [4,15]	0.0040	110
14	exactly 1 E*>1 GeV and 1 E>300 MeV, in 2,3 or 16	0.0040	110
Percentage selected by at least 1 trigger			7358
Cross section (nb)			184
Rate, phase2 backgrounds, luminosity (nb-1/s) =			7358

Hadronic events

Two-track events, $\tau\tau$, $\gamma\pi\pi$, $Y(1S)$ inv. decay et.al

w/ a large cluster events $\tau\tau$, $\gamma\pi\pi$, dark photon, et.al

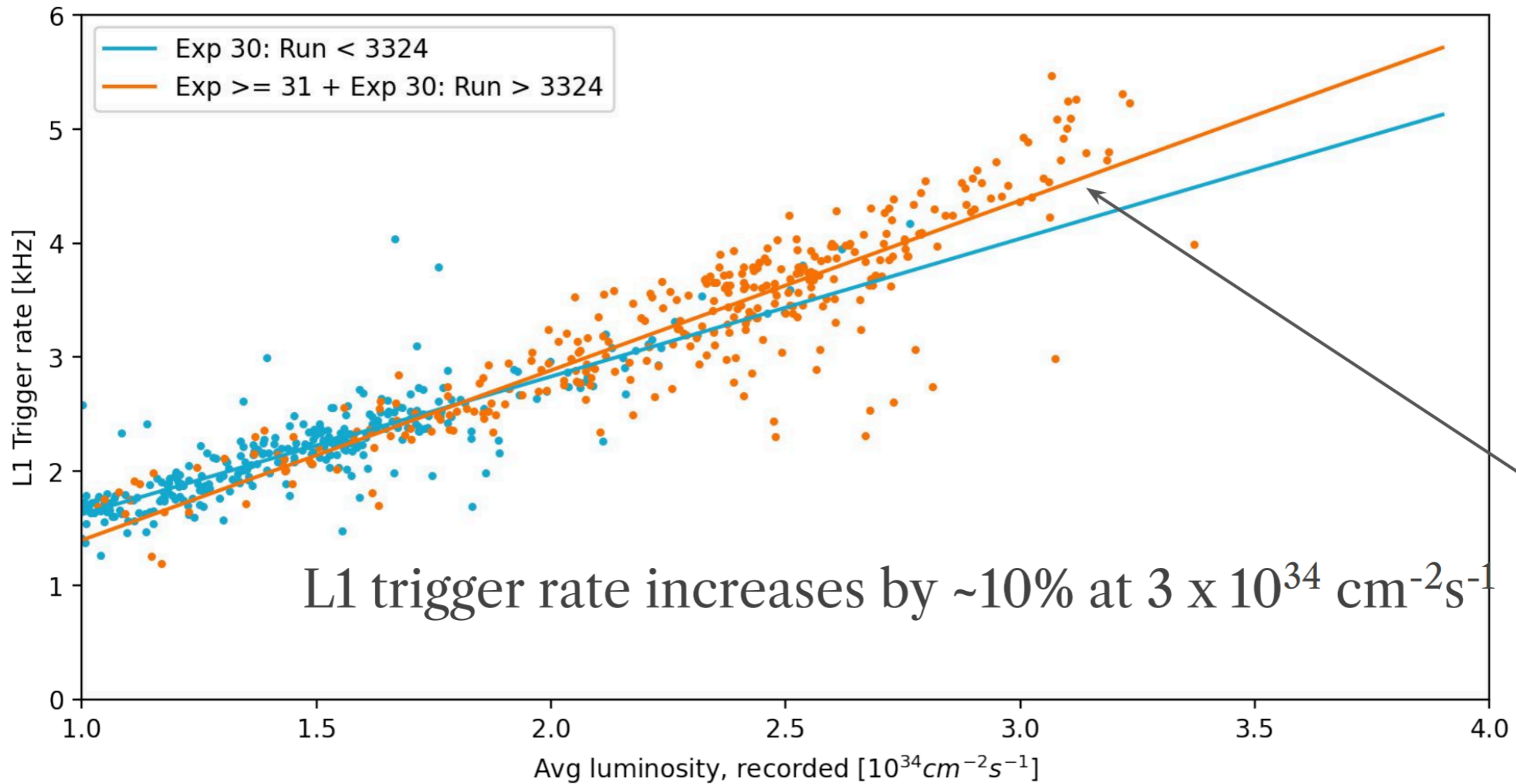
Back-to-back clusters $\tau\tau$, $\gamma\pi\pi$, dark photon

Some trigger lines are designed for

- Detector performance study
- Trigger efficiency
- Calibration
- Luminosity measurement

Tighten some trigger lines once the trigger and DAQ system can not undertake the rate.

L1 Trigger Rate



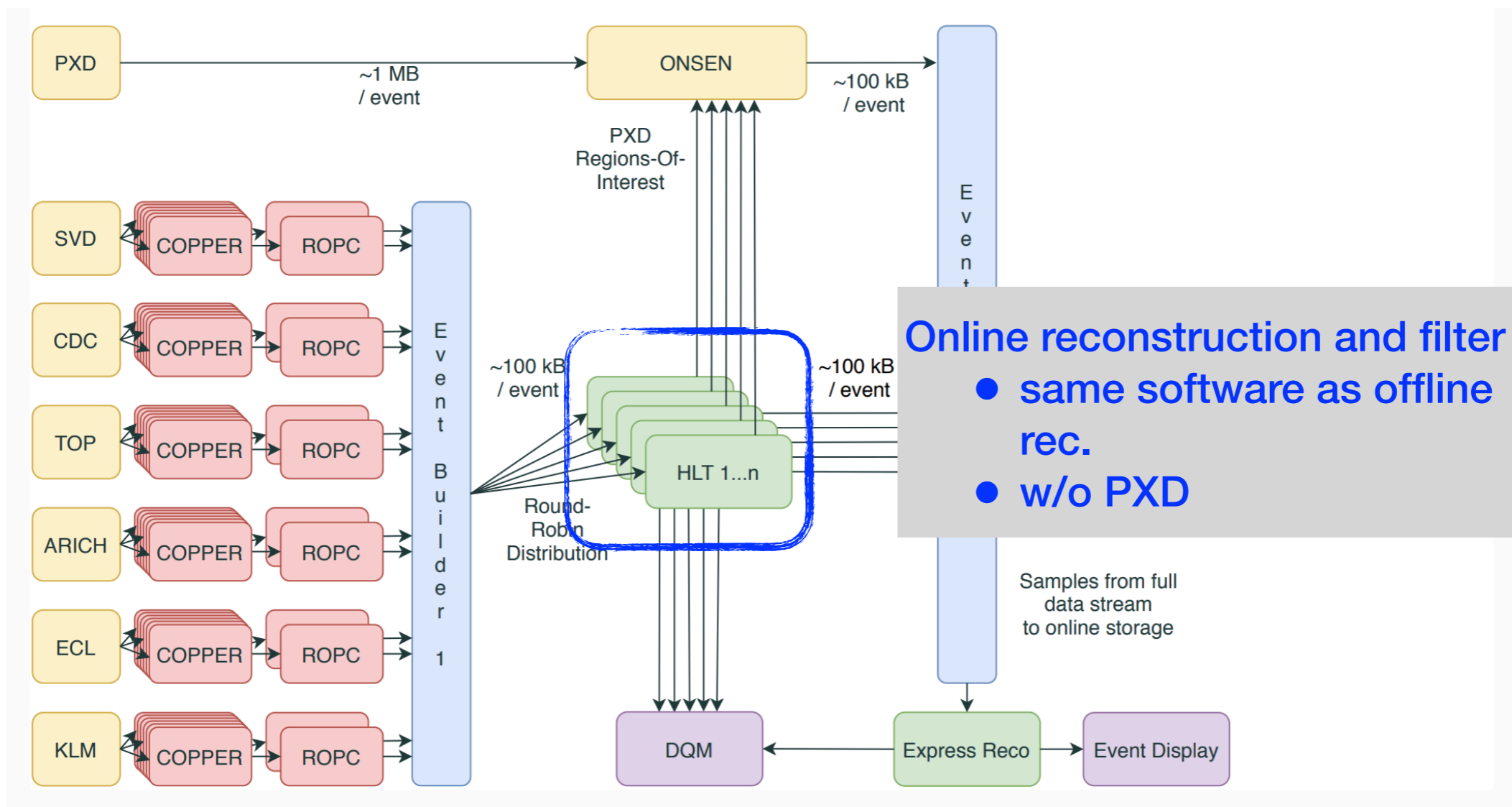
DAQ

Components:

- Unified data link (Belle2Link)
- Common pipeline platform for electronics readout (COPPER)
- Merge data pieces from all detectors (Event builder I)
- High level trigger (HLT): software based

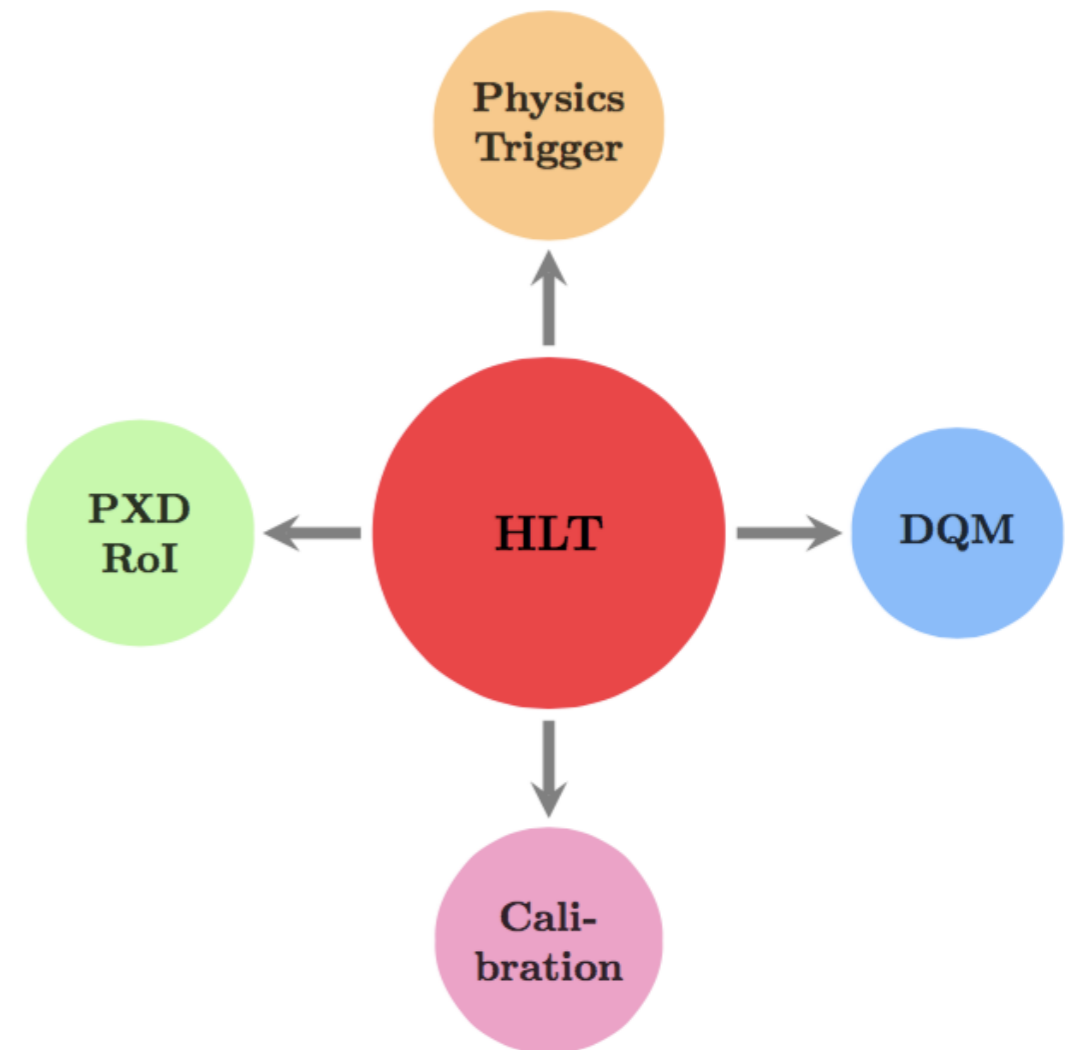
HLT in Belle II DAQ

- Parallel processing: Multi-core, Multi-node
- ~13 HLT units, ~6200 cores
- Input: 100kB/event, 30kHz/unit, Output: 200kB/event, 10kHz/unit



HLT

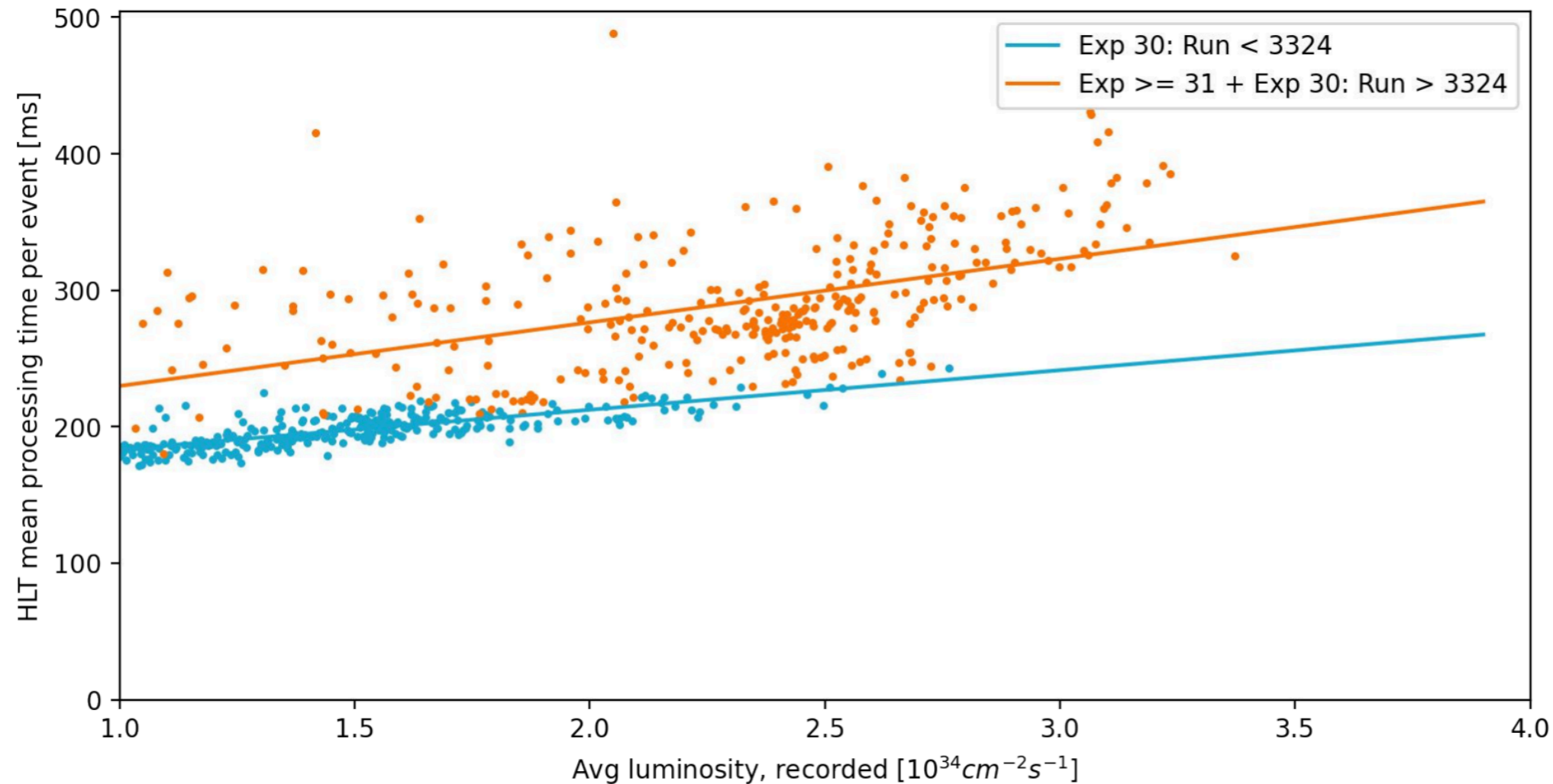
- **Physics Trigger:** suppress event rates from 30 kHz to 10 kHz
- **PXD RoI:** provide HLT trigger result and tracking information of SVD and CDC to calculate Region of Interest of PXD.
- **Calibration:** Flag samples for the calibration of detectors
- **DQM:** Information from Reconstruction for data quality monitoring



HLT Menu (example)

Filter name	Cut Condition	Cut Prescaling
0.3ltEstar_max_clustlt2_GeV_plus_2_others_gt_0.2_GeV	[[nElow >= 3] and [nEmedium >= 1] and [nEhigh == 0]]	100
1_Estartgt1_GeV_cluster_no_other_cluster_Estartgt0.3_GeV	[[nESingleClust == 1] and [nEmedium == 1]]	200
1_electron_Estartgt1_GeV_clust_in_32130_and_no_others_clust_Estartgt0.3_GeV	[[nESingleElectronExtendedBarrel == 1] and [nVetoClust <= 1]]	100
Abundant trigger menu for physics and systematics	[nESingleElectronBarrel == 1] and [nVetoClust <= 1]]	10
	[nReducedESinglePhotonReducedBarrel == 1] and [nVetoClust <= 1]]	1
1_photon_Estartgt1_GeV_clust_in_32130_and_no_others_clust_Estartgt0.3_GeV	[[nESinglePhotonExtendedBarrel == 1] and [nVetoClust <= 1]]	1
1_photon_Estartgt1_GeV_clust_in_45115_and_no_others_clust_Estartgt0.3_GeV	[[nESinglePhotonBarrel == 1] and [nVetoClust <= 1]]	1
1_photon_Estartgt1_GeV_clust_not_low_not_45115_no_others_clust_Estartgt0.3_GeV	[[nESinglePhotonEndcap == 1] and [nVetoClust <= 1]]	50
2_looseB_tracks_0.8ltpstarmaxlt4.5_GeVc_not_ee2leg_ee1leg1trk_eexx	[[nTrkLooseB == 2] and [maximumPCMSB > 0.8] and [maximumPCMSB < 4.5] and [ee2leg == 0] and [ee1leg1trk == 0] and [eexx == 0]]	1
2_looseB_tracks_inc_1_tightB_q==0_pstarmaxlt0.8_GeVc_not_eexx	[[nTrkLooseB == 2] and [nTrkTightB >= 1] and [netChargeLooseB == 0] and [maximumPCMSB < 0.8] and [eexx == 0]]	1
2_looseB_tracks_pstarmaxgt4.5_GeVc_not_ee2leg_ee1leg1trk_ee1leg1e_eeBremB_muonPairVB	[[nTrkLooseB == 2] and [maximumPCMSB > 4.5] and [ee2leg == 0] and [ee1leg1trk == 0] and [ee1leg1e == 0] and [eeBremB == 0] and [muonPairVB == 0]]	1
2_loose_tracks_0.8ltpstarmaxlt4.5_GeVc	[[nTrkLoose == 2] and [maximumPCMS > 0.8] and [maximumPCMS < 4.5]]	100
2_loose_tracks_0.8ltpstarmaxlt4.5_GeVc_not_ee2leg_ee1leg1trk_eexx	[[nTrkLoose == 2] and [maximumPCMS > 0.8] and [maximumPCMS < 4.5] and [ee2leg == 0] and [ee1leg1trk == 0] and [eexx == 0]]	9999
2_loose_tracks_inc_1_tight_q==0_pstarmaxlt0.8_GeVc_not_eexx	[[nTrkLoose == 2] and [nTrkTight >= 1] and [netChargeLoose == 0] and [maximumPCMS < 0.8] and [eexx == 0]]	9999

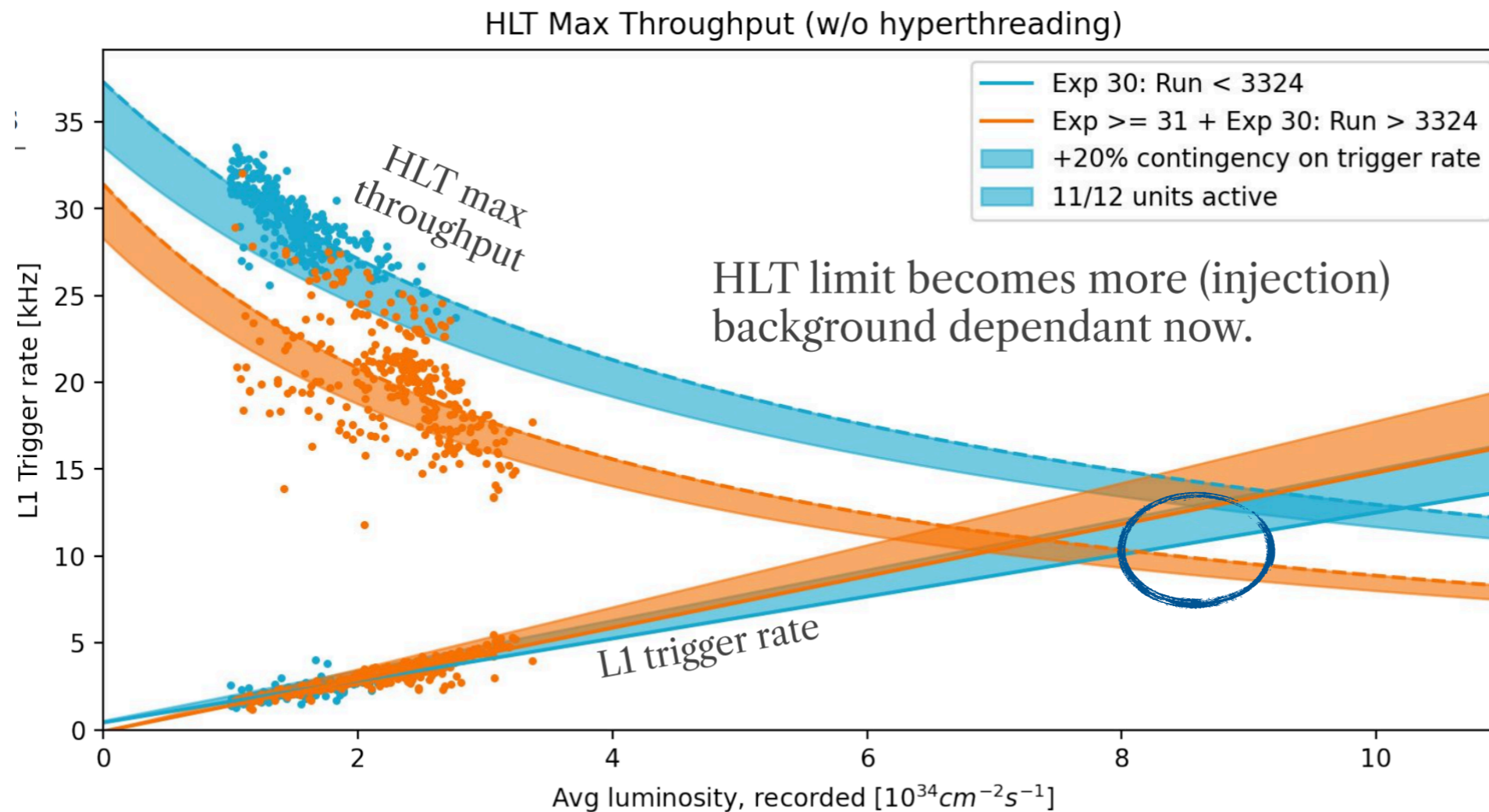
HLT Limits



HLT had to process 5-30% extra events, depending on the background conditions.

Mean processing time per event increases by $\sim 33\%$ (+large spread) at $3 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}$

HLT Limits



Based on early exp 30 \rightarrow can operate up to $9 \times 10^{34} / \text{cm}^2 / \text{s}$
Based on late exp 30 and exp 31, 32, 33 \rightarrow can operate up to $6.5 \times 10^{34} / \text{cm}^2 / \text{s}$

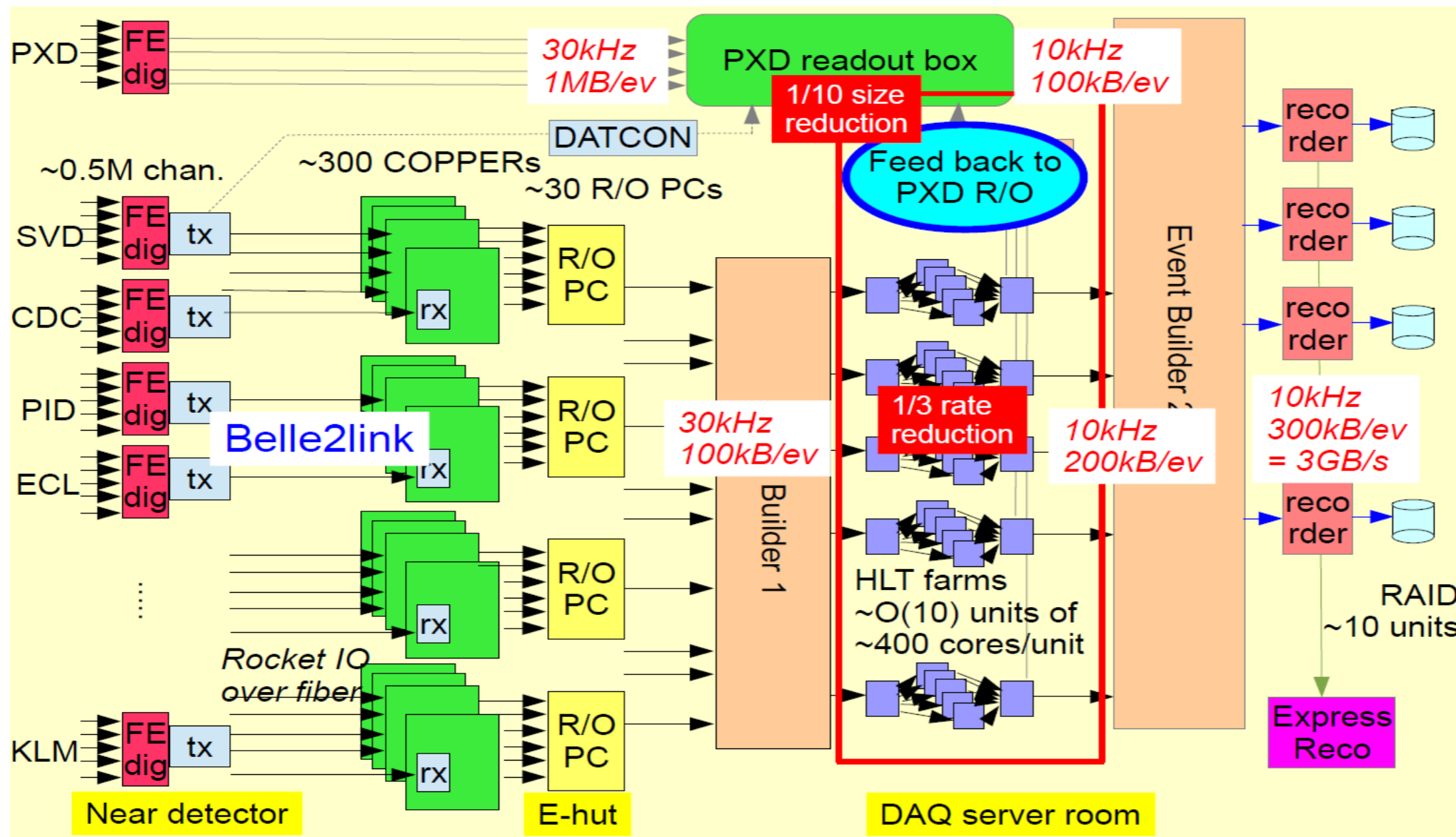
- **Optimization on HLT software is needed to handle higher luminosity!**

Summary

- The trigger system have been improved significantly compared to Belle
 - L1 trigger
 - 3D tracking, 3D ecl Bhabha logics.
 - Abundant trigger menu.
 - HLT
 - Large readout bandwidth, 3GB/s.
 - New scheme of software trigger at Belle II, powerful trigger capability.

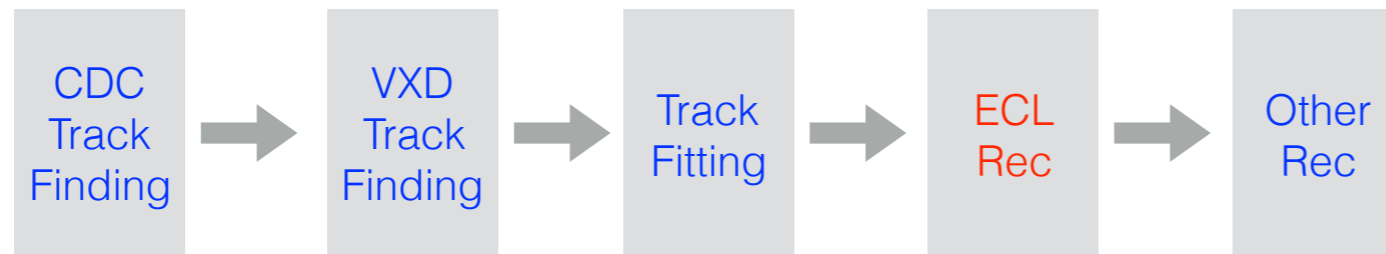
HLT in Belle II DAQ

- Parallel processing: Multi-core, Multi-node
- ~13 HLT units, ~6000 cpu
- Input: 100kB/event, 30kHz/unit, Output: 200kB/event, 10kHz/unit



HLT Software

Standard Offline Reconstruction



HLT Standard Reconstruction and Trigger



L1 Trigger

Requirements

- High efficiency for physics process (physics event rate $20\text{kHz}@8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$)
- Max. trigger rate 30kHz
 - Limit from DAQ
- Fixed latency $\sim 5\mu\text{s}$
 - Limit from SVD front-end
- Timing precision $\leq 10\text{ns}$
 - Request from SVD front-end
- Two-event separation $\geq 200\text{ns}$
 - Request from DAQ