Expected L1 rate in future

2022/11/24

T.Koga

Motivation

-Present L1 rate status

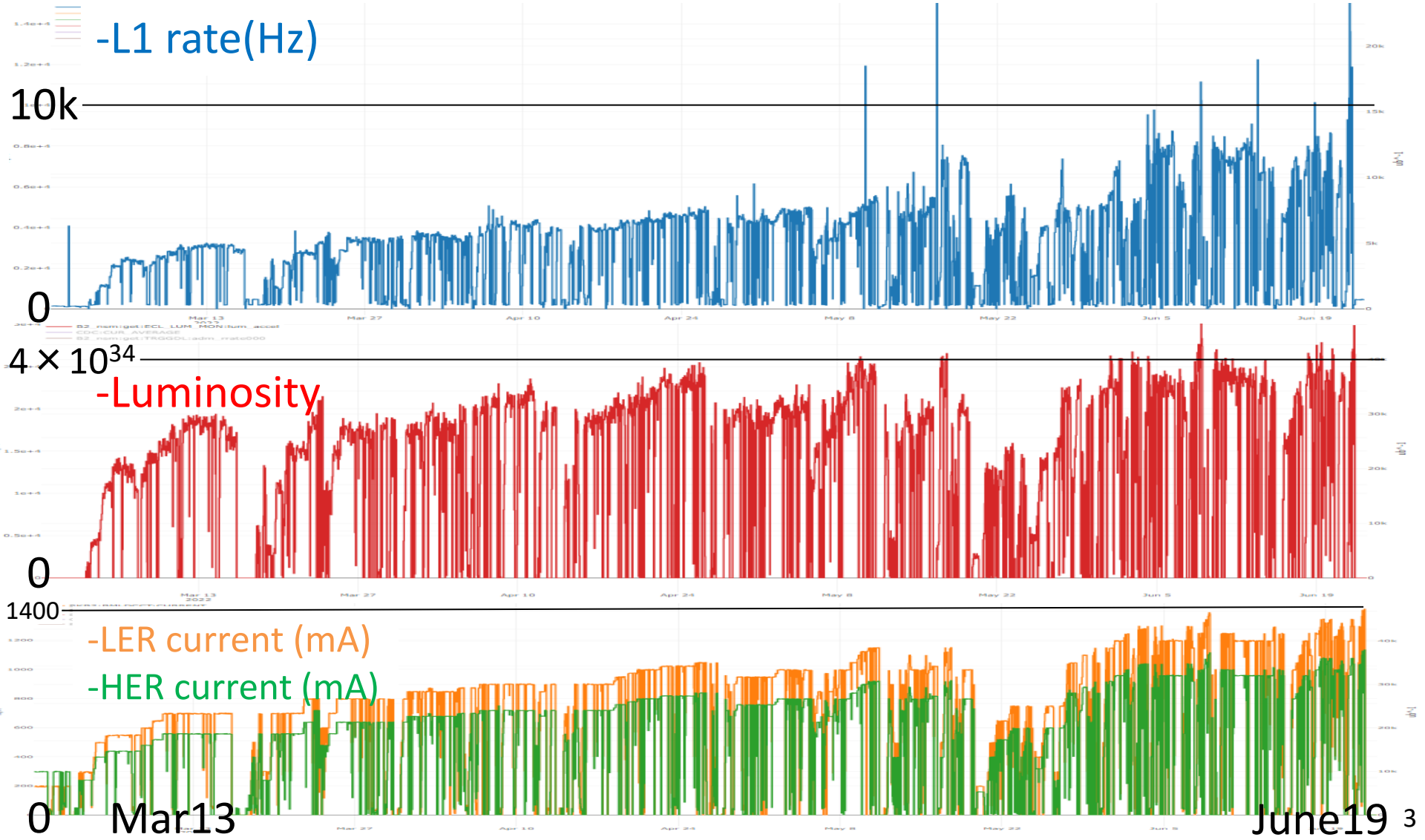
-Estimate expected L1 rate in future

-some discussions

L1 rate in 2022ab

-L1 rate reached ~13kHz at maximum. It is almost DAQ limit.

-Reduction of L1 rate and reinforcement of HLT are needed during LS1.



Trigger menu and rate @ 2022/6/9, exp26r1261

-Total L1 rate=~11.5kHz, Luminosity=~4.5 × 10^34

-Rate of standard bits (ffy+fyo+c4+hie) = 4.7kHz: need to keep until end of BelleII

-Others are 6.8kHz

event triggered by upper bits are excluded in lower bits in table

Category	Bit name and condition	Raw rate (kHz)	Exclusive rate (kHz)
CDC ~~B physics~~ standard bits	**ffy**: #full track>=3, |z|<20cm **fyo**: #full track>=2, Δϕ>90deg, |z|<20cm	2.18 1.77	2.18 0.73
ECL ~~B physics~~ standard bits	**c4**: #cluster>=4 **hie**: Energy sum>1GeV	0.47 2.02	0.26 1.54
Subtotal		**4.7**	**4.7**
KLM τ/dark	**klmb2b, eklmb2b, beklm**: Back to back sector hits **cdcklm, seklm, ecleklm**: #CDC-KLM, ECL-KLM matching>=1	0.51 1.11	0.46 0.83
CDC τ/dark	**stt**: #full track>=1, |z|<15cm, p>0.7GeV **syo**: #full track>=1, #short track>=1, Δϕ>90deg, |z|<20cm **fy30**: #full track>=2, Δϕ>30deg, |z|<20cm	2.93 1.93 2.59	1.37 0.63 0.22
ECL τ/dark	**lml**: several combination of #cluster and energy **eclmumu**: back to back low energy hit	3.92 0.63	2.18 0.01
Calibration with prescale>1	PID (two photon) Other (Bhabha, γγ, random, trg)	0.35 1.00	0.16 0.60
Total L1	**OR of all bits**	**11.5**	**11.5**

Modification of TRG during LS1

-CDCTRG: aim to reduce trigger rate ~50%

- -modify most of CDCTRG firmware with UT4
- -Still R&D is on-going

CDCTRG Modified Module	Required rate reduction to achieve 50%
CDCFE crosstalk filter, ADC	~10% (not yet)
CDCTRG 2D	~20% (achieved by simulation)
CDCTRG NN, 3D, 3DHough	~30% (not yet)
Total	~50%
(CDC-ECL matching)	~30% (achieved by data, not used)

-Trigger menu: prescale part of lowmulti physics bits

- -need discussion during LS1
- -I temporary exclude these bits for trigger rate extrapolation

discarded bit name	alternative bit name
cdcklm seklm	ycdcklm ecleklm
syo, syb	syoecl, sybecl
hie	hie3
lml2	--

discarded bit name	alternative bit name
lml7	--
lml9	--
lml10	eclmumu
lml16	--

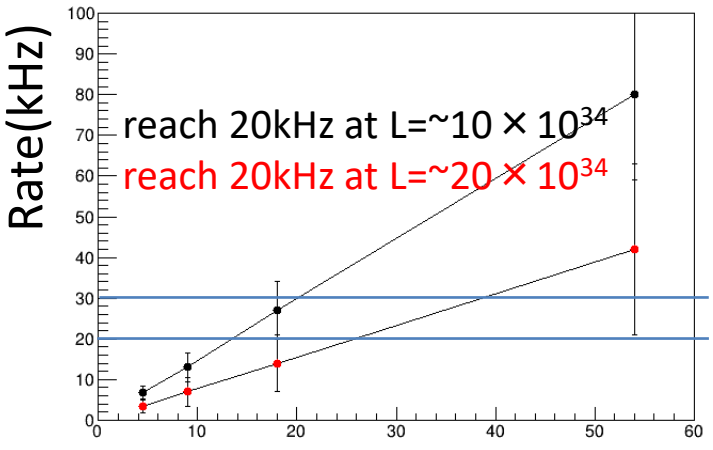
L1 rate expectation: luminosity scaling

-L1 rate is extrapolated by assuming (L1 rate)∝(Luminosity)

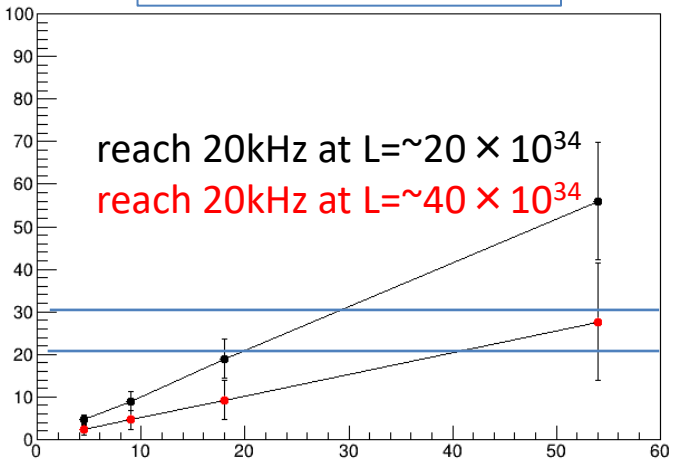
-not so reliable but not so bad assumption

-factor ~2 uncertainty of beamBG as experienced so far

CDCTRG rate no change



CDCTRG rate 50%



-Standard bits of ffy+fyo+c4+hie3:

-Even if CDCTRG rate reduced ~50%, L1 rate exceeds 20kHz @L=~40 × 10^{34}

→Further development of CDCTRG and HLT reinforcement are needed

-More effort needed for low multi physics

L1 rate expectation: luminosity scaling

-L1 rate is extrapolated by assuming (L1 rate)∝(Luminosity)

-Fraction of trigger rate in each bit

Category	Bit	Exclusive rate @L=4.5e^{34}(kHz)	Exclusive rate @L=9e^{34}(kHz)	Exclusive rate @L=18e^{34}(kHz)	Exclusive rate @L=54e^{34}(kHz)
CDC ~~B physics~~ standard bits	ffy	1.8	3.6	7.2	21
	fyo	0.6	1.2	2.4	7
ECL ~~B physics~~ standard bits	c4	0.26	0.5	1.0	3
	hie3	0.8	1.6	3.2	9
Subtotal	**OR of above bits**	**3.5**	**7.0**	**14**	**42**
KLM τ/dark	klmb2b, eklmb2b, beklm	0.23	0.23	0.23	0.23
	cdcklm, ecleklm	0.36	0.7	1.4	4
CDC τ/dark	stt	1.37	2.8	5.6	17
	syo	0.10	0.2	0.4	1
	fy30	0.18	0.4	0.8	2
ECL τ/dark	lml (exclude part of them)	0.54	1.0	2.0	6
	eclmumu	0.51	1.0	2.0	6
Total	**OR of all bits**	**6.7**	**13**	**27**	**80**

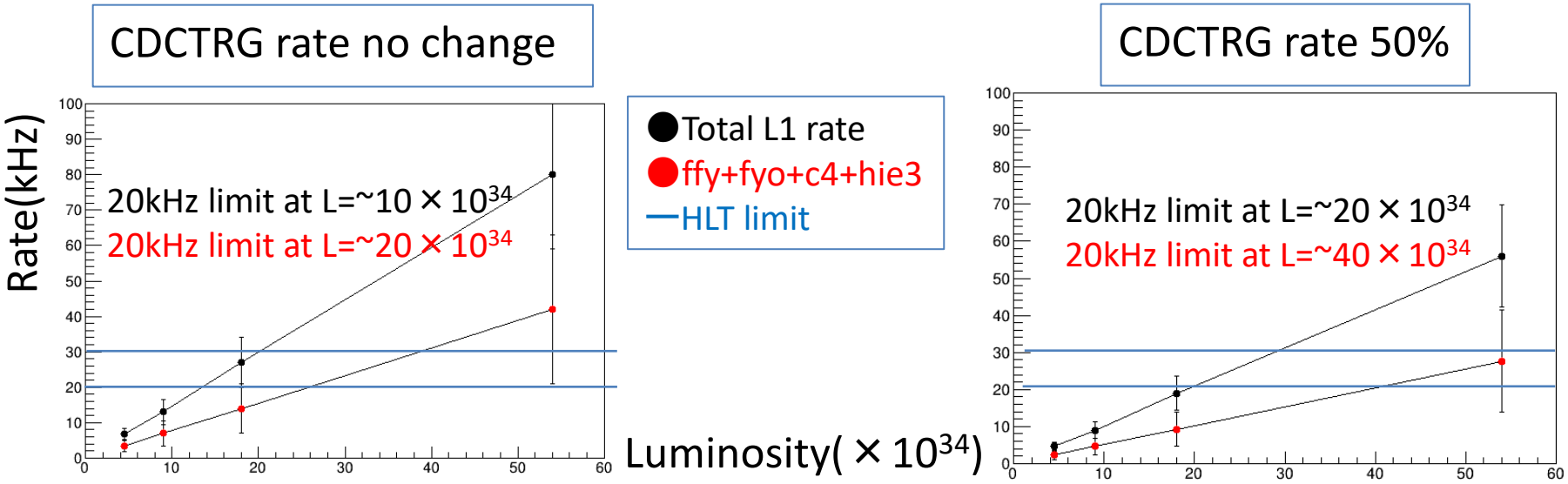
Summary

-Present L1 rate status

- -Total L1 rate=~11.5kHz, Luminosity=~4.5 × 10^34
- -Rate of standard bits (ffy+fyo+c4+hie) = 4.7kHz: need to keep until end of BelleII
- -Others = 6.8kHz
- -During LS1, modification of CDCTRG and trigger bit menu are needed

-Estimate expected L1 rate in future

- -B physics: Further development of CDCTRG and HLT reinforcement are needed
- -Low multi: Priority of trigger bits, CDC-ECL matching are needed in addition



Discussion: HLT and TRG development

-Which is easier to reduce L1 rate or increase HLT limit?

-TRG rate can reduce by improving core logic:
cost performance highly depends on idea of new logic

-HLT limit can increase
- -Add more HLT unit
- -Modification of HLT software
- -Fast Reco

On-going Upgrade	Reduction of L1 Increase of HLT limit	Cost	Human power
Upgrade of CDCTRG2D and TSF	~6kHz at designed lumi (~20% of CDCTRG)	~14 UT4 ~56,000,000 JPY	1~2 student
Upgrade of CDCTRGNN	~9kHz at designed lumi (~30% of CDCTRG)	one HLT ~15,000,000 JPY (?)	2~3 students + 1~2 postdoc
Add one HLT	~2kHz	one HLT ~15,000,000 JPY (?)	~1 postdoc (?)
Modify HLT software	?	no cost	?
Fast Reco	~10kHz ?	no cost	?

Discussion

-Better naming of trigger bit and HLT menu ?

-TRG example

Category	Bit	Exclusive rate @L=4.5e^{34}(kHz)	Exclusive rate @L=9e^{34}(kHz)	Exclusive rate @L=18e^{34}(kHz)	Exclusive rate @L=54e^{34}(kHz)
CDC ~~B physics~~	ffy	1.8	3.6	7.2	21
standard bits	fyo	0.6	1.2	2.4	7
ECL ~~B physics~~	c4	0.26	0.5	1.0	3
standard bits	hie3	0.8	1.6	3.2	9

-HLT example

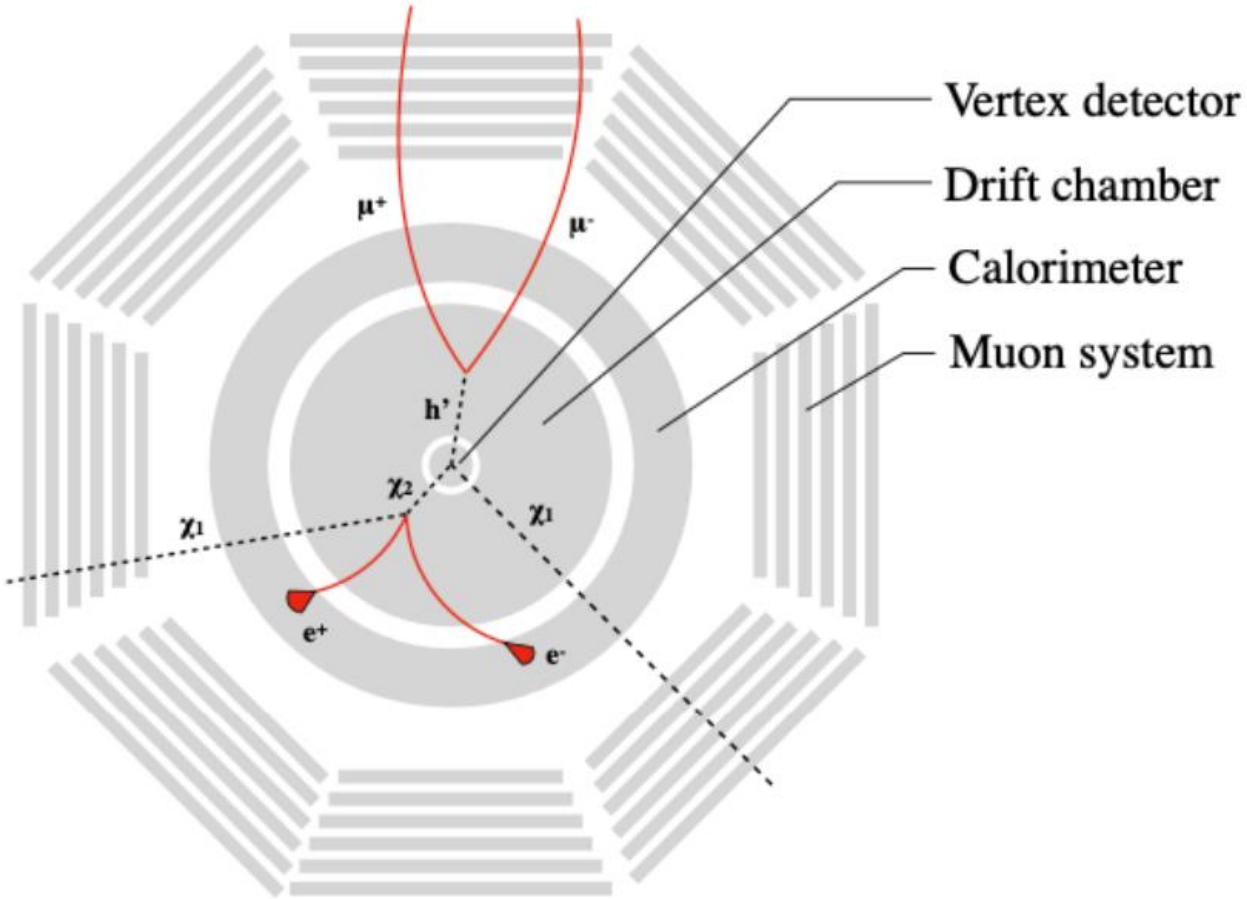
```
CDC - Physics
filter ge3 loose tracks inc 1 tight not ee2leg                                  43 (  8.78%)   43 (  8.78%)      1.0
filter 2 loose tracks inc 1 tight q==0 pstarmaxlt0.8 GeVc not eexx                8 (  1.63%)    8 (  1.63%)      1.0
filter 2 loose tracks 0.8ltpstarmaxlt4.5 GeVc not ee2leg ee1leg1trk eexx        392 ( 80.00%)  392 ( 80.00%)      1.0
filter 2 loose tracks pstarmaxgt4.5 GeVc not ee2leg ee1leg1trk ee1legle eeBrem  20 (  4.08%)   20 (  4.08%)      1.0


ECL - Physics
filter Elab gt 0.3 plus 3 others with Elab gt 0.18 plus no clust with Ecms gt 2.0      151 ( 30.82%)  151 ( 30.82%)      1.0
filter Elab gt 0.5 plus 2 others with Elab gt 0.18 plus no clust with Ecms gt 2.0       57 ( 11.63%)   57 ( 11.63%)      1.0
filter ge1 Estargt2 GeV neutral clst 2232 or 130145 not gg2clst ee2clst ee1leg eeBrem    4 (  0.82%)    4 (  0.82%)      1.0
filter ge1 Estargt2 GeV neutral clst 32130 not gg2clst ee1leg1clst ee1leg1trk eeBrem    52 ( 10.61%)   52 ( 10.61%)      1.0
```

Discussion: displaced vertex

-TRG is aiming to trigger displaced vertex in future (LS1—LS2)

-even with some prescale

-HLT does not have displaced vertex trigger menu: need modification



Discussion: HLT error when exceed L1 limit ?

-When L1 rate is high, ~13kHz, at the end of 2022b, DAQ crashed frequentry

-Not all HLT is included for global DAQ always

-It is not clear where is the L1 rate limit

-Can we identify it make a warning or error message ?

backup

Trigger rate extrapolation with single beam run

-Detailed study with single beam BG was done in the past (Koga Junhao):

(Trigger rate) = (beamGas) + (Tousheck) + (Luminosity)

$= A \times I \cdot P + B \times T \cdot I / I^2/\sigma_y n_b + C \times \text{Luminosity}$

A,B,C: constant, I: beam current, σ: beam size, n:#bunch

but there is no ~20% difference with the luminosity scaling.

①fit result at $L=0.8 \times 10^{34}$, 2019

	fff (Hz)	ffo (Hz)	hie (Hz)	c4 (Hz)
Single LER	50 + 50	104 + 72	-	-
Single HER	5 + 4	10 + 9	-	-
Luminosity	52	88	232	39
Total	**161**	**283**	**232**	**39**

②extrapolation at $L=3.2 \times 10^{34}$

	fff (Hz)	ffo (Hz)	hie (Hz)	c4 (Hz)
Single LER	195 + 199	416 + 289	-	-
Single HER	18 + 17	40 + 38	-	-
Luminosity	208	352	928	156
Total	**637**	**1135**	**928**	**156**

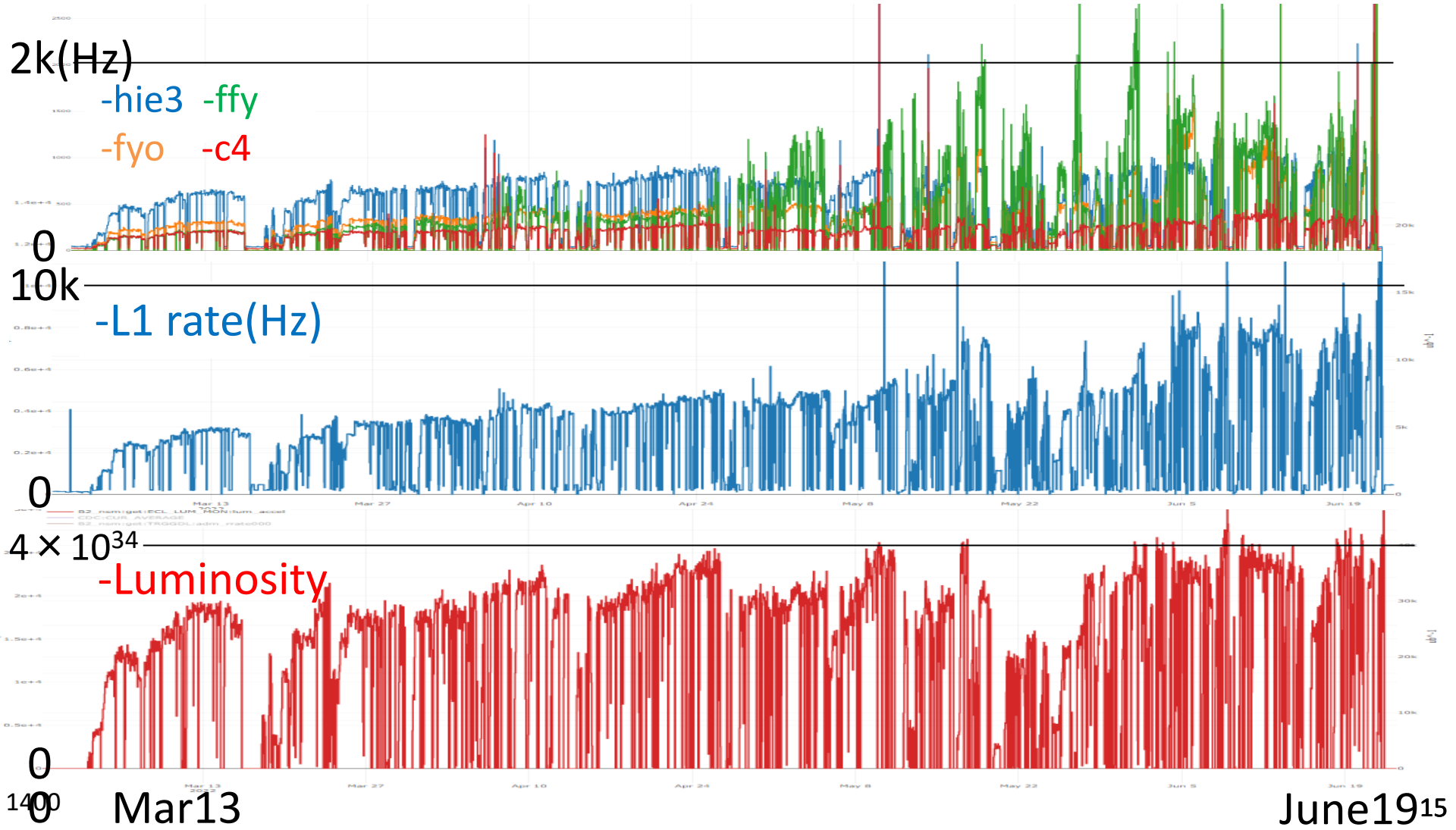
646 646

L1 rate expectation: luminosity scaling

-L1 rate is extrapolated by assuming (L1 rate)∝(Luminosity)

-not so reliable but not so bad assumption. for ECLTRG, nice agreement.

-factor ~2 uncertainty of beamBG as experienced so far



Trigger menu and each rate @ 2022/6/9

-Total L1=~11.5kHz, L=~4.5 × 10^34 (exp26r1261, beam_reco_monitor)
-breakdown of each trigger bit

event triggered by upper bits are excluded in lower bits in table

Category	Bit name and condition	Raw rate (kHz)	Exclusive rate (kHz)
CDC ~~B physics~~ standard bits	**ffy**: #full track>=3, |z|<20cm **fyo**: #full track>=2, Δϕ>90deg, |z|<20cm	2.18 1.77	2.18 0.73
ECL ~~B physics~~ standard bits	**c4**: #cluster>=4 **hie**: Energy sum>1GeV	0.47 2.02	0.26 1.54
KLM τ/dark	**klmb2b, eklmb2b, beklm**: Back to back sector hits **cdcklm, seklm, ecleklm**: #CDC-KLM, ECL-KLM matching>=1	0.51 1.11	0.46 0.83
CDC τ/dark	**stt**: #full track>=1, |z|<15cm, p>0.7GeV **syo**: #full track>=1, #short track>=1, Δϕ>90deg, |z|<20cm **fy30**: #full track>=2, Δϕ>30deg, |z|<20cm	2.93 1.93 2.59	1.37 0.63 0.22
ECL τ/dark	**lml**: several combination of #cluster and energy **eclmumu**: back to back low energy hit	3.92 0.63	2.18 0.01
Calibration with prescale>1	PID (two photon) Other (Bhabha, γγ, random, trg)	0.35 1.00	0.16 0.60
Total L1	OR of all bits	11.5	11.5

Reduction of L1 rate during LS1: trigger menu

-By arrangement of trigger bit menu, L1 rate can reduce by ~30%

-disable or replace high-rate trigger bits for low multi physics

-discussion is on-going with tau, dark groups

discarded bit name	alternative bit name	Change of logic	Raw rate reduction (kHz)	Exclusive rate reduction (kHz)	Physics target
cdcklm seklm	ycdcklm ecleklm	require NN track	1.1->0.53	0.83->0.36	single μ(barrel) single μ(endcap)
syo, syb	syoecl, sybecl	apply CDC-ECL matching	1.8->0.40	0.46->0.10	tau, PID
hie	hie3	loose Bhabha veto	2.0->1.2	1.5->0.8	B, τ, single photon with E>1GeV
lml2	--	disable	0.61->0	0.34->0	γ with wide θ range
lml7	--	disable	0.38->0	0.25->0	single photon sideband
lml9	--	disable	0.67->0	0.49->0	ALP
lml10	eclmumu	change acceptance cut	1.1->0.63	0.70->0.51	μμ
lml16	--	disable	1.0->0	0.66->0	single photon with E>0.5GeV

Total L1 rate reduces from 11.5kHz to 6.7kHz

L1 rate expectation

-L1 rate extrapolation by disable the trigger bits listed in the last page

-assume the L1 rate is linearly proportional to the luminosity! not reliable!

-We will reach DAQ limit @ L=~10×10^{34} (with DAQ limit=~20kHz)

-improvement of CDCTRG performance is needed

Category	Bit	Exclusive rate (kHz) @L=4.5e^{34}	Exclusive rate (kHz) @L=9e^{34}	Exclusive rate (kHz) @L=18e^{34}	Exclusive rate (kHz) @L=54e^{34}
CDC ~~B physics~~ standard bits	ffy	1.8	3.6	7.2	21
	fyo	0.6	1.2	2.4	7
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	hie3	0.8	1.6	3.2	9
KLM τ/dark	klmb2b, eklmb2b, beklm cdcklm, ecleklm	0.23	0.23	0.23	0.23
		0.36	0.7	1.4	4
CDC τ/dark	stt	1.37	2.8	5.6	17
	syo	0.10	0.2	0.4	1
	fy30	0.18	0.4	0.8	2
Subtotal	**OR of above bits**	**5.7**	**11**	**22**	**66**
ECL τ/dark	lml	0.54	1.0	2.0	6
	eclmumu	0.51	1.0	2.0	6
Total	**OR of all bits**	**6.7**	**13**	**27**	**80**

Summary of lml triggers

*** = physics events not kept by other triggers
** = useful, but rate is not sustainable
* = trigger or systematic studies

Already prescaled

lml	Description	Rate Hz	Fraction hie	Physics	Notes
0	(NCL≥3, at least 1 CL≥300 MeV(Lab) (with ID = 1~17), not an ECL 3D Bhabha	494	0.42	**	loose trigger for tau; replace with lml12
1	one CL≥2 GeV(CM) with ID = 4~14	270	0.36	**	single cluster trigger
2	one CL≥2 GeV(CM) with ID = 2, 3, 15, or 16 and not an ECL 3D Bhabha	196	0.93	***	ISR, pi0 FF, ALP; wider theta than hie
3	one CL≥2 GeV(CM) with ID = 2, 3, 15, or 16 and an ECL 3D Bhabha	428	0.00	*	trigger studies of lml2
4	one CL≥2 GeV(CM) with ID = 1 or 17 and not an ECL 3D Bhabha	651	0.15	**	ISR, pi0 FF, ALP
5	one CL≥2 GeV(CM) with ID = 1 or 17 and an ECL 3D Bhabha	352	0.00	*	trigger studies of lml5
6	only one CL≥1 GeV(CM) with ID = 4~15 and no other CL≥300 MeV(Lab) anywhere	91	0.87	***	single photon analysis
7	only one CL≥1 GeV(CM) with ID = 2, 3, or 16 and no other CL≥300 MeV(Lab) anywhere	131	0.77	***	single photon side band
8	170° < ΔphiCM< 190°, both CL>250 MeV(Lab), no 2 GeV(CM) CL in an event	74	0.37	***	two-photon fusion, e.g. ALP
9	170° < ΔphiCM < 190°, one CL<250 MeV(Lab), the other CL>250 MeV(Lab), no 2 GeV(CM) CL in an event	128	0.23	***	two-photon fusion, e.g. ALP
10	160° < ΔphiCM < 200°, 170° < ΣθCM < 200°, no 2GeV(CM) CL in an event	249	0.15	***	muon pairs; tighter than eclmumu
12	(NCL≥3, at least 1 CL≥500 MeV(Lab) (with ID = 2~16), not an ECL 3D Bhabha	175	0.84	***	tau physics
13	only one CL>0.5 GeV(CM) with ID = 6~11 and no other CL≥300 MeV(Lab) anywhere	228	0.22	**	high mass dark photon

prescale candidate

may need work

Trigger menu and each rate @ 2022/6/9

-Raw rate of all trigger bits