Belle II status

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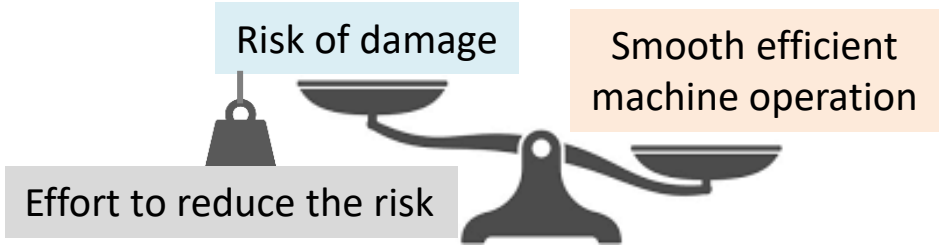
Basic strategy of Belle II operation

- Safe operation not to damage Belle II detector or machine components
- First priority on the peak luminosity (machine tuning and study)
  - Except for safety issues
- Physics data taking with a high efficiency
  - ➢ Mission of luminosity frontier experiments
  - Our first target: 90% of data taking efficiency
- Beam background control to suppress
  - Detector deterioration by integrated radiation dose
  - Detector performance degradation by high rate beam background
  - ➢ Required for precision experiments

Discussion about the abort threshold

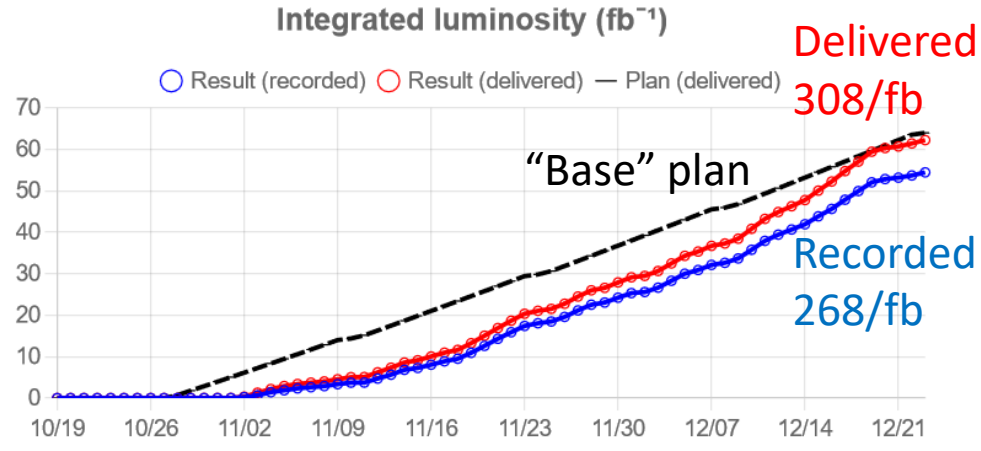
(See more detail in the backup slides)

- As the beam current and injection charge increased, beam aborts at injections without apparent trouble/failure happened more frequently.
  - e.g. 77 unnecessary beam aborts issued only by the diamond at LER injection
    - ~30 min to restore the beam current after each abort
- A relaxed diamond abort threshold might allow for smooth efficient machine operation, but it delays the abort trigger and increases the risk of damaging the detector/machine in case of huge beam loss, which is **not assessable**.
  - [Risk of relaxed threshold] = [frequency (reducible)] × [severity (**unknown**)]
- We had discussion about how to balance the machine operation and risk.
  - Decision is particularly delicate due to many huge beam losses, QCS quenches, collimator damages.
  - 4 → 6 mrad threshold for one diamond with Belle II off is prepared as a final resort.
- We continue our efforts to compensate the risk of the relaxed threshold.
  - e.g. 6 mrad threshold only during injections (which take place 1.5% of time at most) and additional faster abort systems are under consideration.



Integrated luminosity

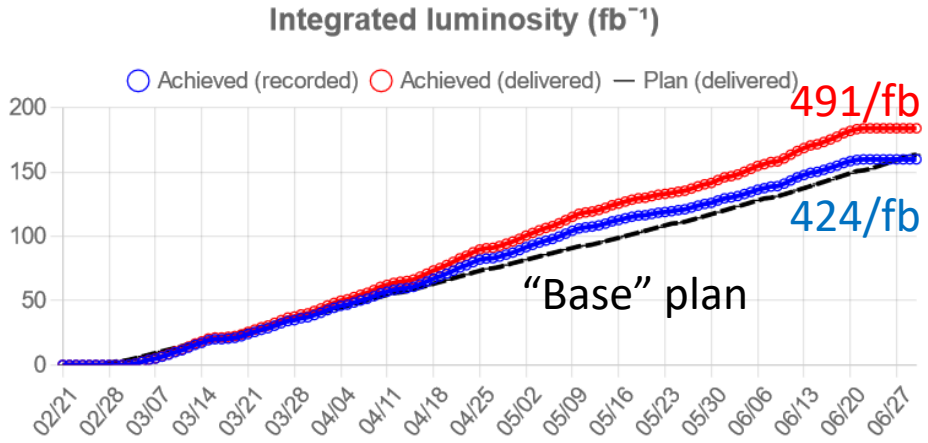
2021c



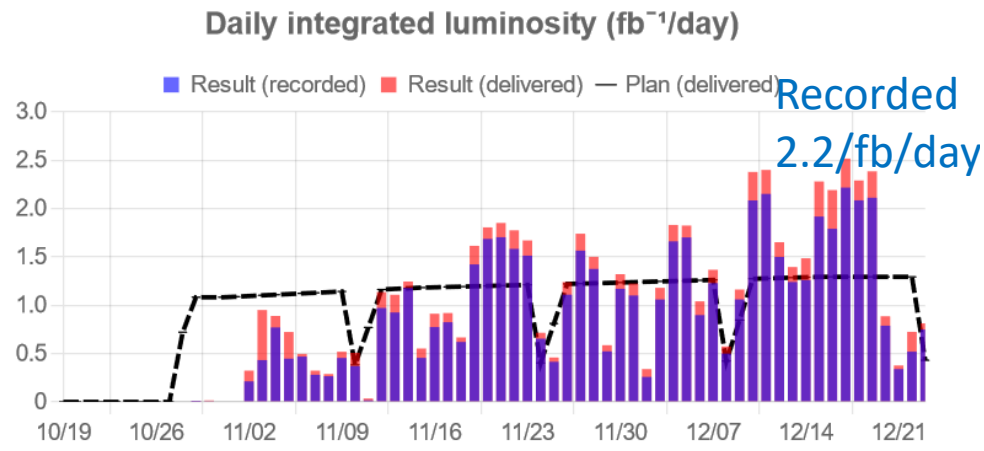
[Delivered $\int L(\text{plan})$] = $\sum$ [Daily delivered $\int L(\text{plan})$]

2022ab

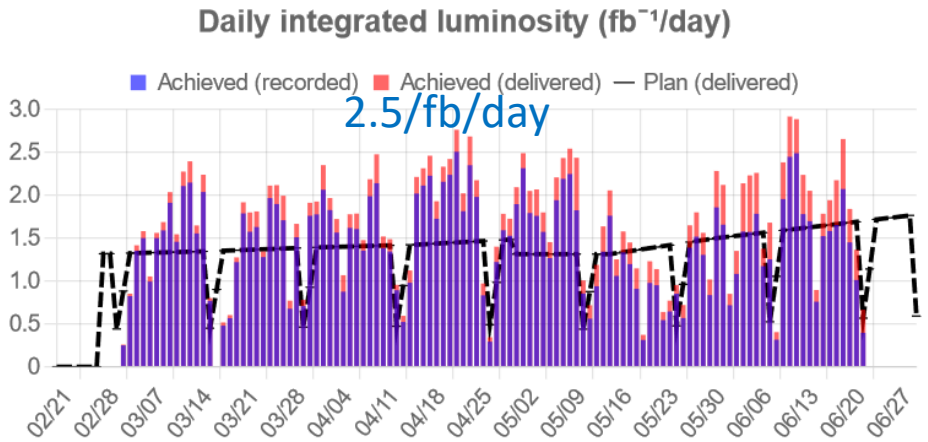
"Target" plan
620 /fb



[Delivered $\int L(\text{plan})$] = $\sum$ [Daily delivered $\int L(\text{plan})$]

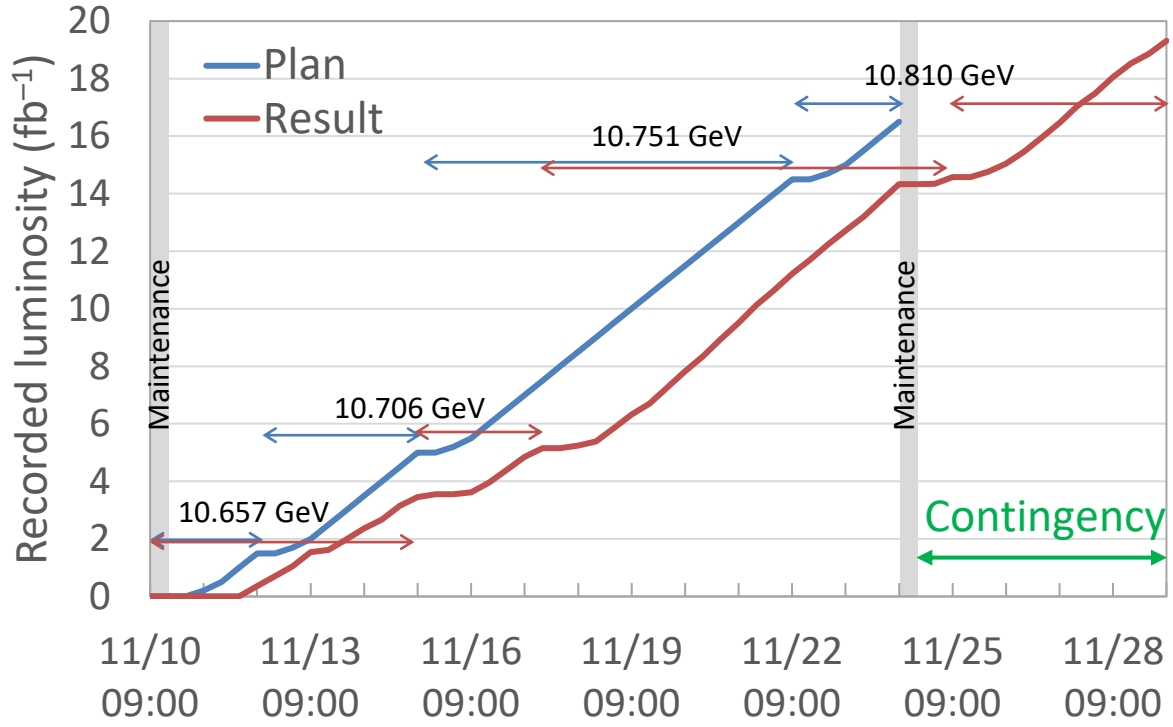


[Daily delivered $\int L(\text{plan})$] = [Delivered $L_{\text{peak}}(\text{plan})$] × [86400 sec] × [Daily efficiency (plan)]

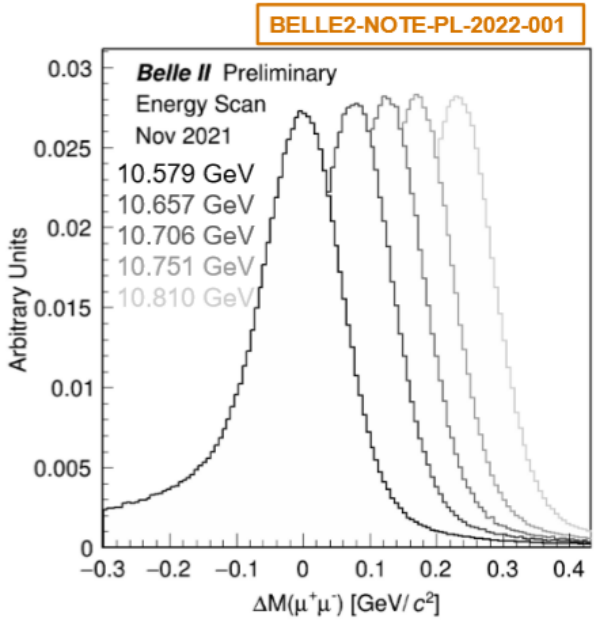


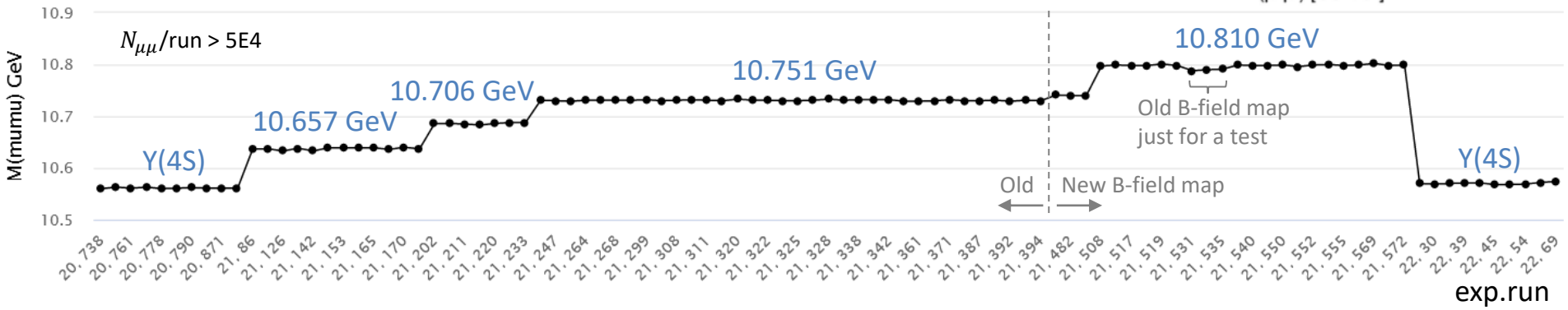
[Daily delivered $\int L(\text{plan})$] = [Delivered $L_{\text{peak}}(\text{plan})$] × [86400 sec] × [Daily efficiency (plan)]

Higher energy collisions above Y(4S)



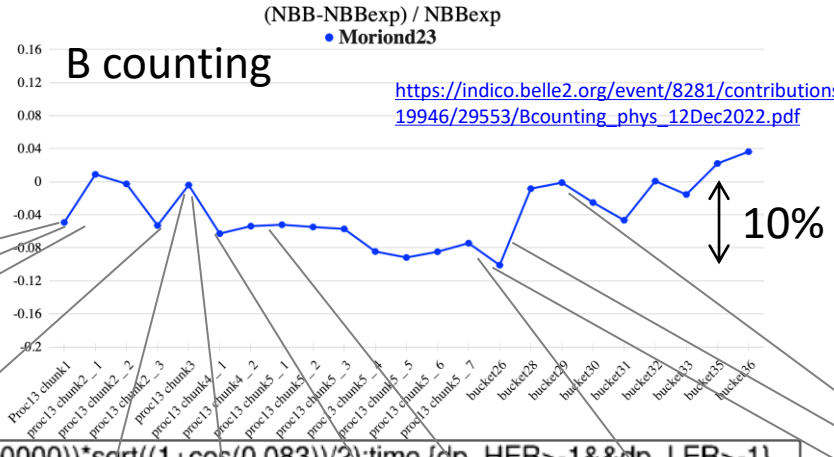
Online measurement of the relative center-of-mass energy



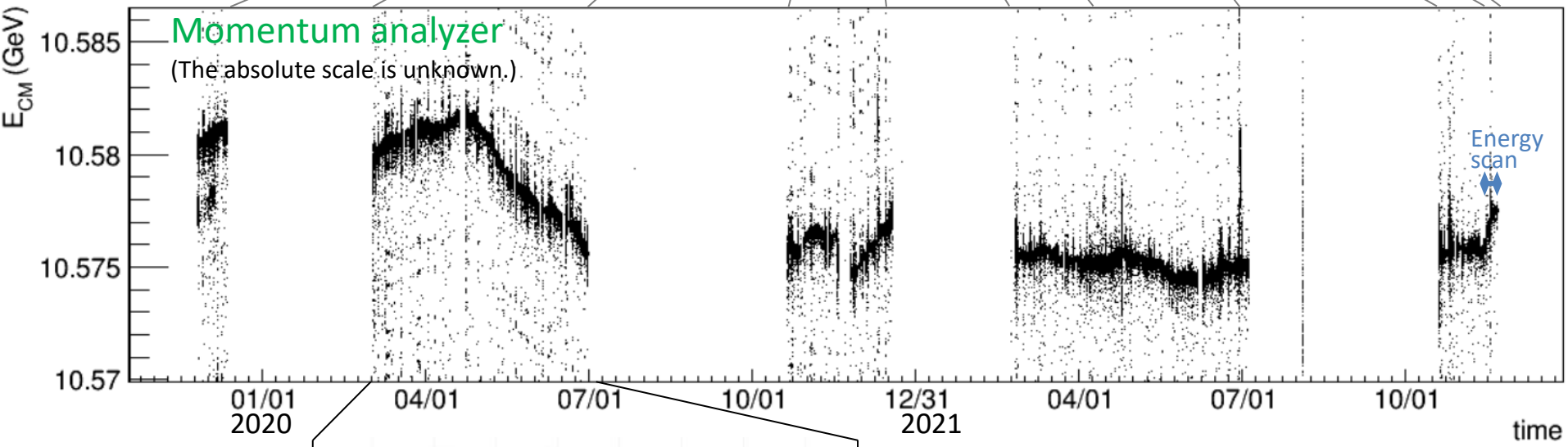


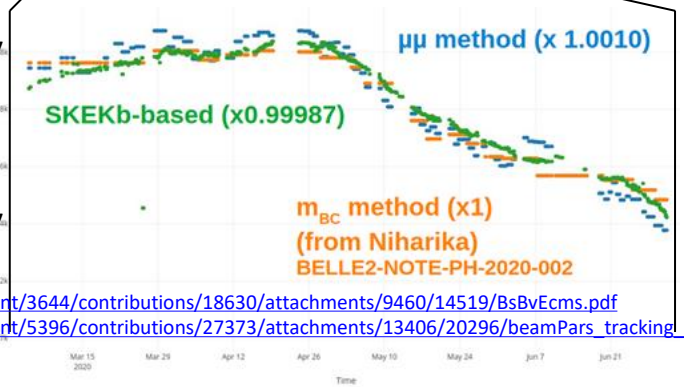
We appreciate great efforts by the accelerator team.

Collision energy



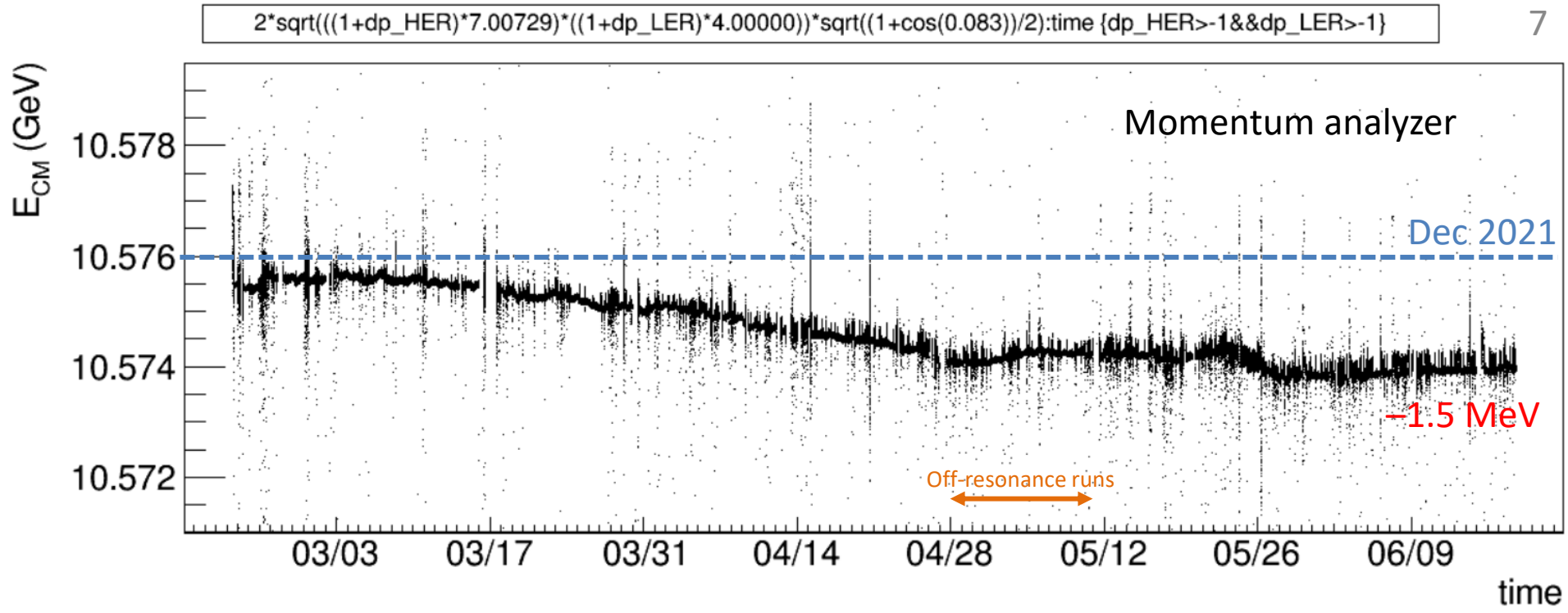
https://indico.belle2.org/event/8281/contributions/50205/attachments/19946/29553/Bcounting_phys_12Dec2022.pdf

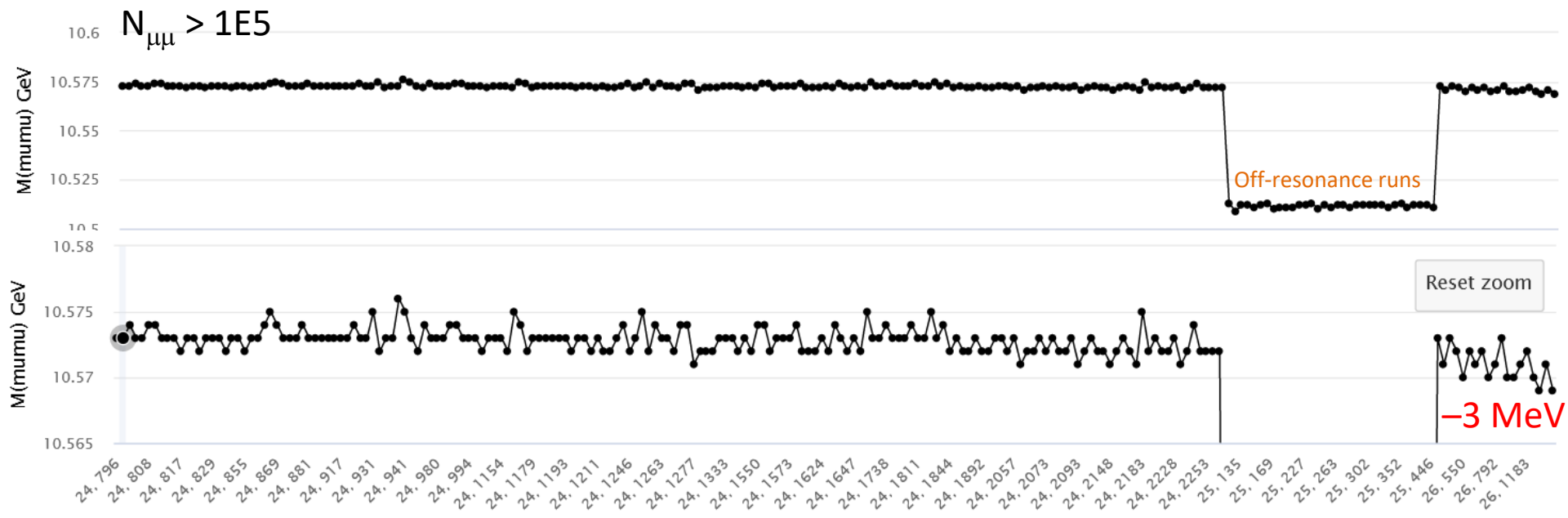




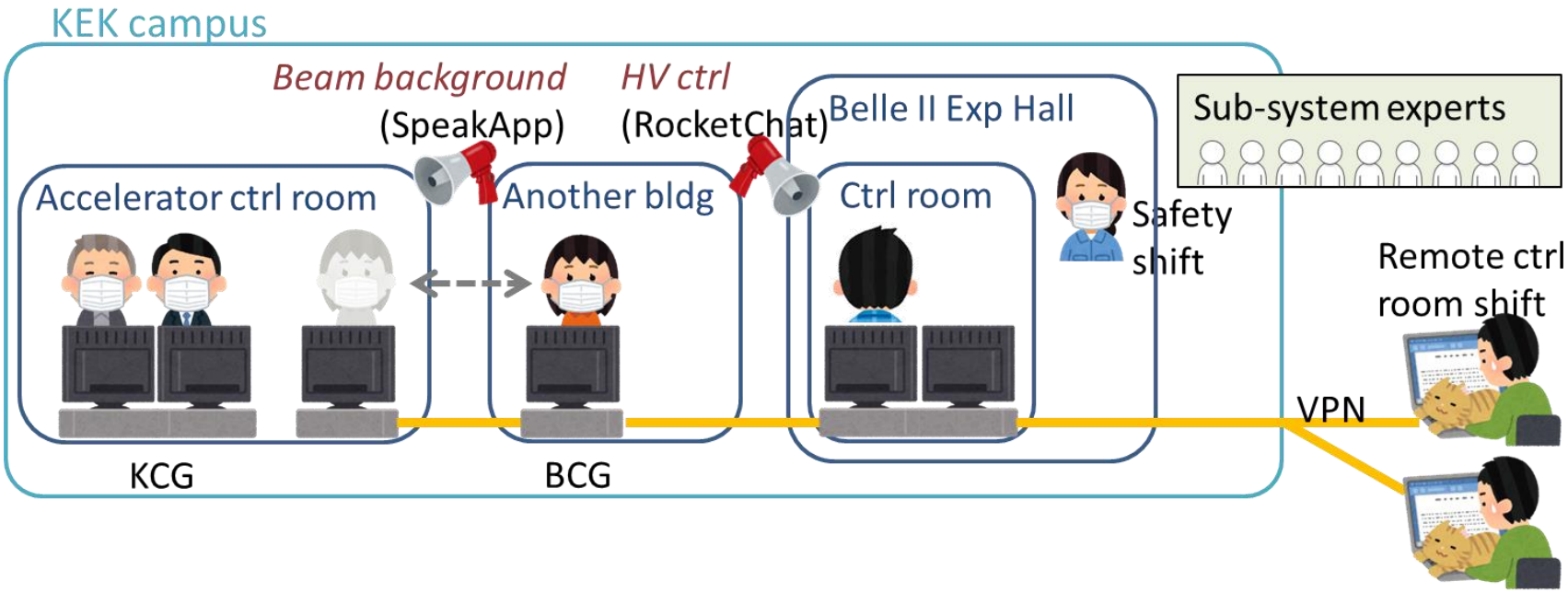
https://indico.belle2.org/event/3644/contributions/18630/attachments/9460/14519/BsBvEcms.pdf
https://indico.belle2.org/event/5396/contributions/27373/attachments/13406/20296/beamPars_tracking_2021_10_15.pdf

The collision energy had been shifted by ~4 MeV (5-7% loss of $B\bar{B}$) for 1.5 years


2*sqrt(((1+dp_HER)*7.00729)*((1+dp_LER)*4.00000))*sqrt((1+cos(0.083))/2):time {dp_HER>-1&&dp_LER>-1}
Momentum analyzer
E_{CM} (GeV)
10.578
10.576
10.574
10.572
Dec 2021
−1.5 MeV
Off-resonance runs
03/03
03/17
03/31
04/14
04/28
05/12
05/26
06/09
time


$N_{\mu\mu}$ > 1E5
M(mumu) GeV
10.6
10.575
10.55
10.525
Off-resonance runs
10.58
10.575
10.57
10.565
Reset zoom
−3 MeV
24, 796
24, 808
24, 817
24, 829
24, 855
24, 869
24, 881
24, 917
24, 931
24, 941
24, 980
24, 994
24, 1154
24, 1179
24, 1193
24, 1211
24, 1246
24, 1263
24, 1277
24, 1333
24, 1550
24, 1573
24, 1624
24, 1647
24, 1738
24, 1811
24, 1844
24, 1892
24, 2057
24, 2073
24, 2093
24, 2148
24, 2183
24, 2228
24, 2253
25, 135
25, 169
25, 227
25, 263
25, 302
25, 352
25, 446
26, 550
26, 792
26, 1183

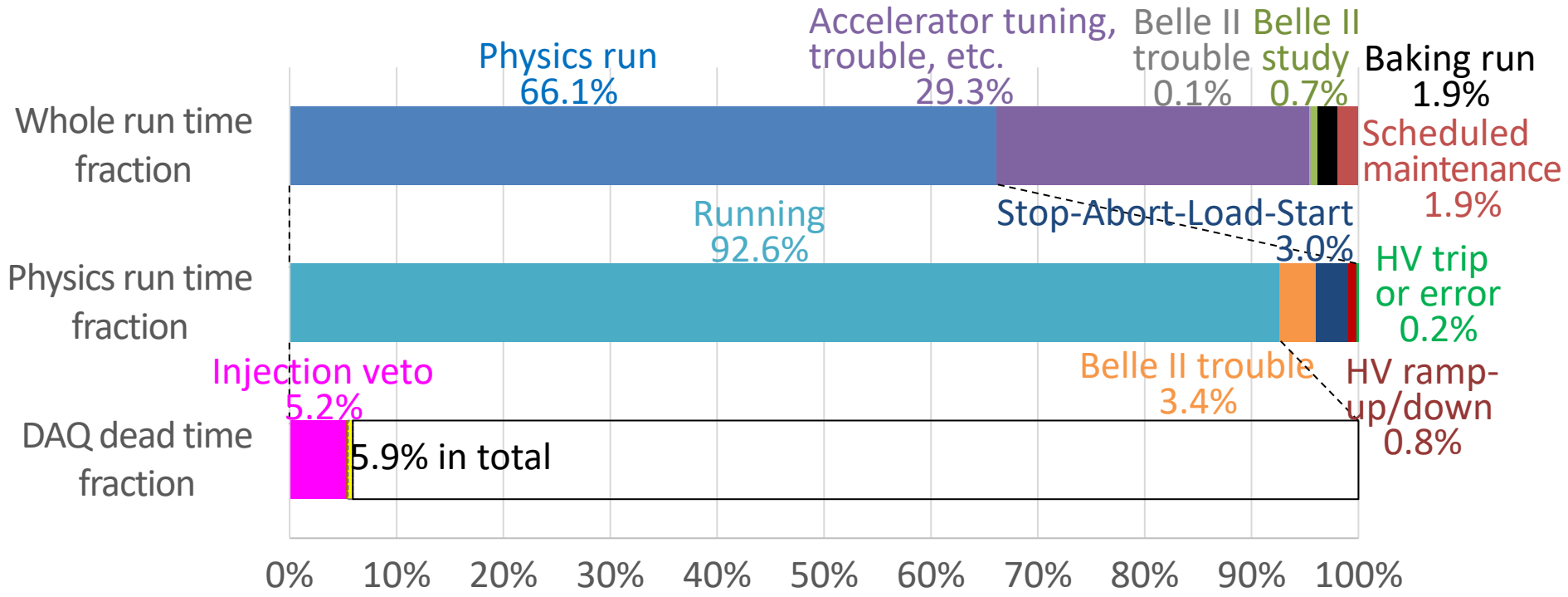
Belle II operation

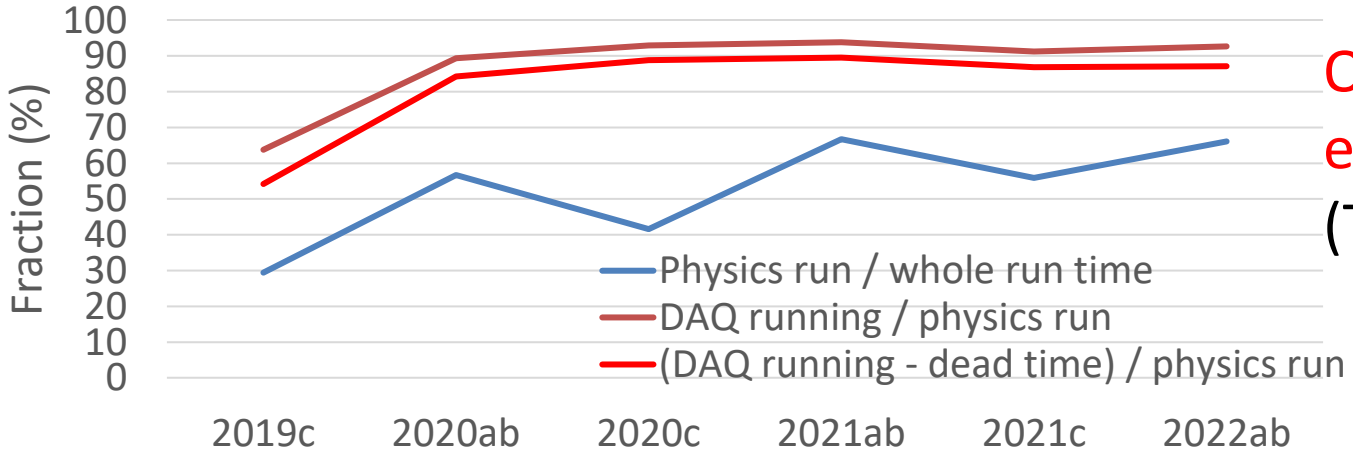


- There are 3 options of where to take the BCG shift:
  - Room 225 in 3-go-kan (from the beginning)
  - His/her own office in 3-go-kan as additional infection prevention (since Apr 25)
    - Prepared web tools so that anyone can easily see all the BCG monitors. https://skbsrv.kek.jp/bcg.html (KEK intranet)
  - Accelerator control room for better communication with KCG (since May 25)

Feb 21 - Jun 22, 2022

Data taking efficiency in 2022ab



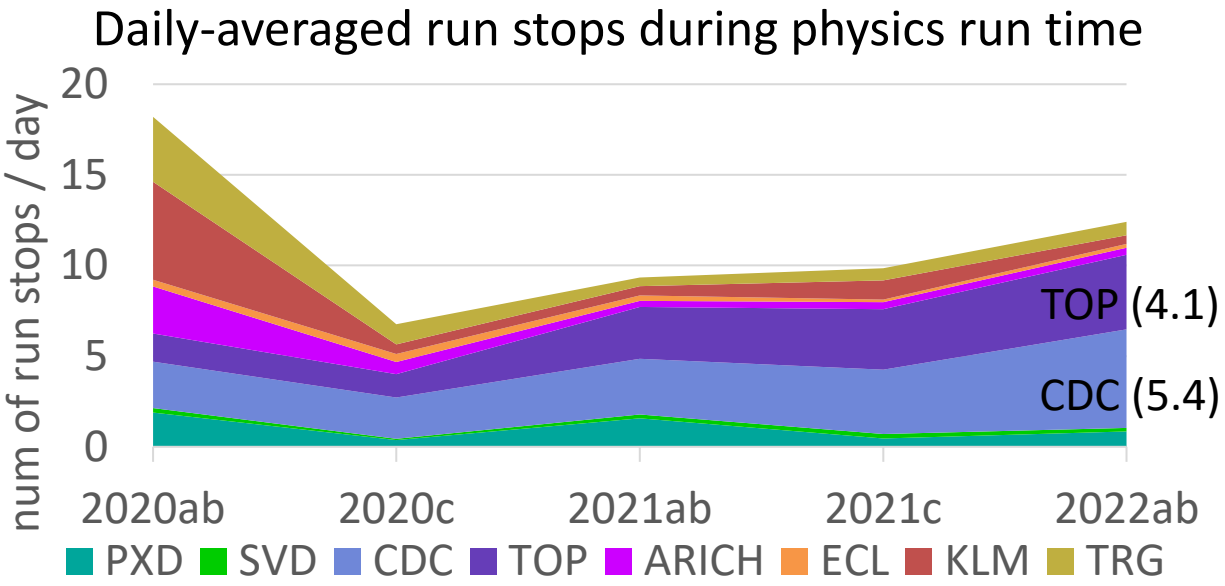


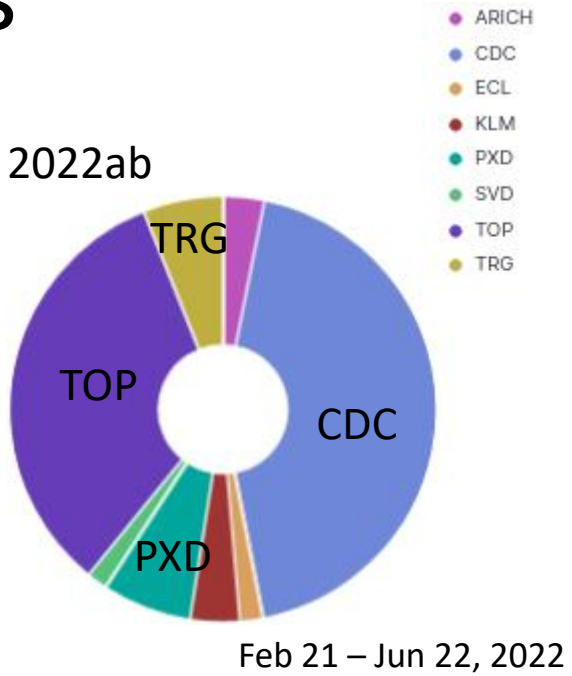
Overall data taking efficiency = 87.1%

(Target 90%)

Getting worse with the beam background.

Run stop reasons





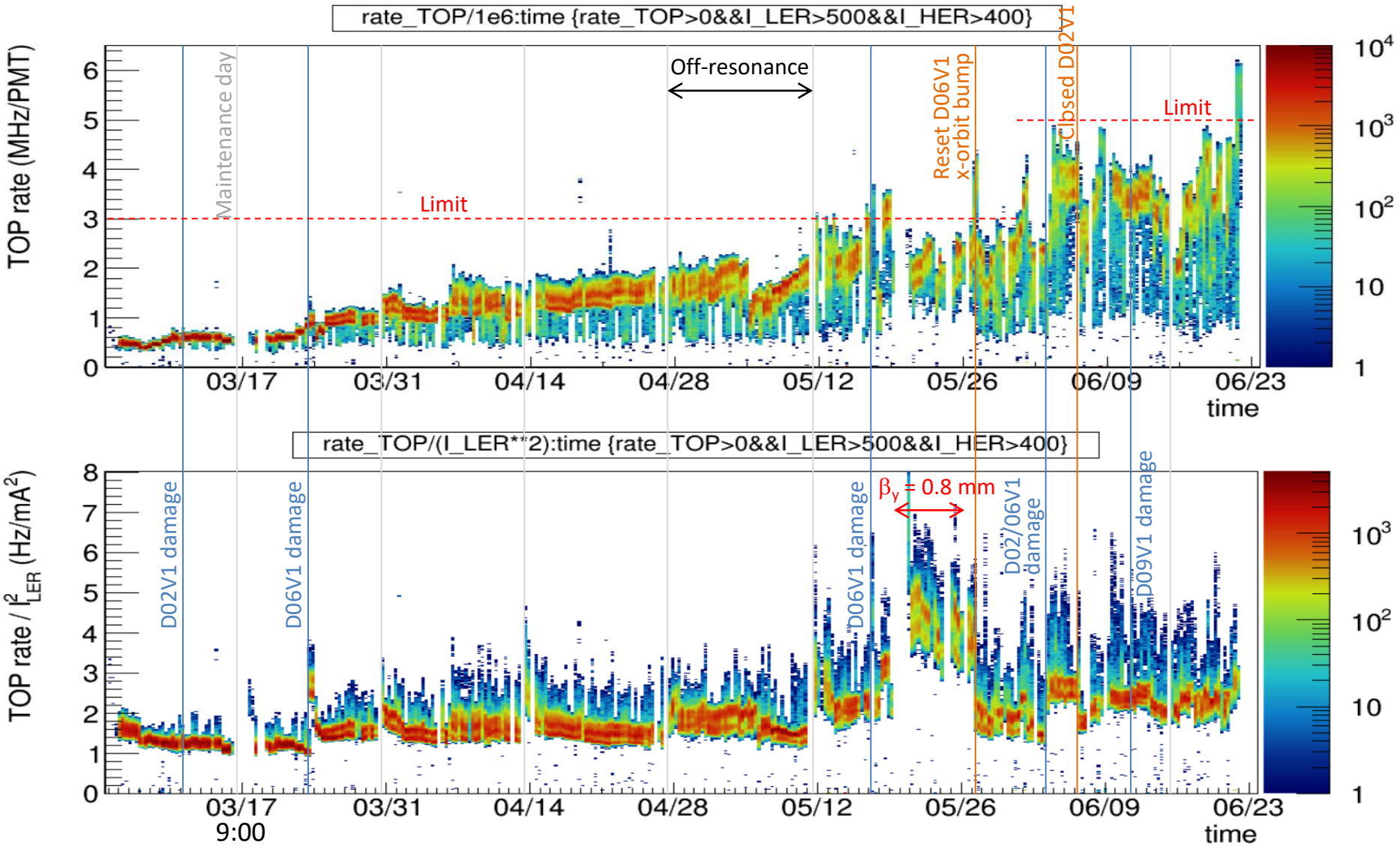
Feb 21 – Jun 22, 2022

FPGA Single Event Upsets on CDC and TOP front-end electronics is the major concern.

- Reduce recovery time
  - Reduction of time for HLT LOAD (~70 sec), which dominates time for Stop-Abort-Load-Start (~2 min)
- Reduce run-stopping errors
  - TOP firmware update to retire PS (Processing System) → It will eliminate almost all TOP-related run stops.
  - CDC software (and firmware) update to withstand corrupted data
    → Run stops will be reduced by ~30% (and more). Need more human resource to work on them.
- Reduce beam background
  - Additional neutron shield and shield at the QCS bellows
  - Non-linear collimator

Work in LS1

Increase of storage beam background

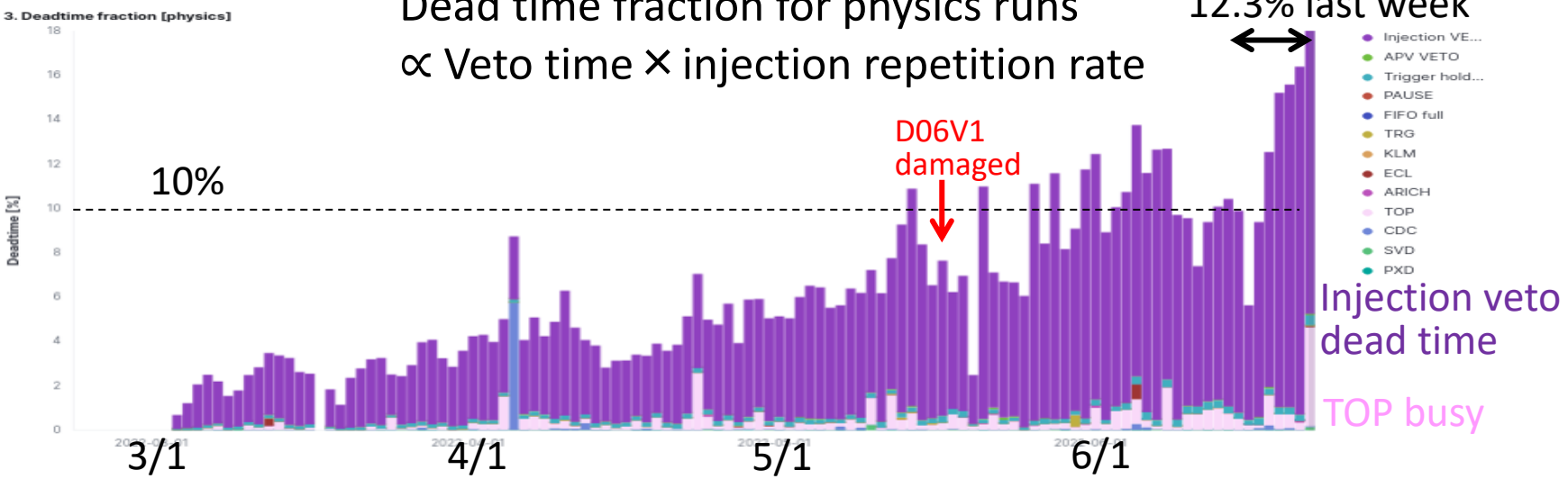


Damage of D06V1 collimator increased the storage background twice or more.

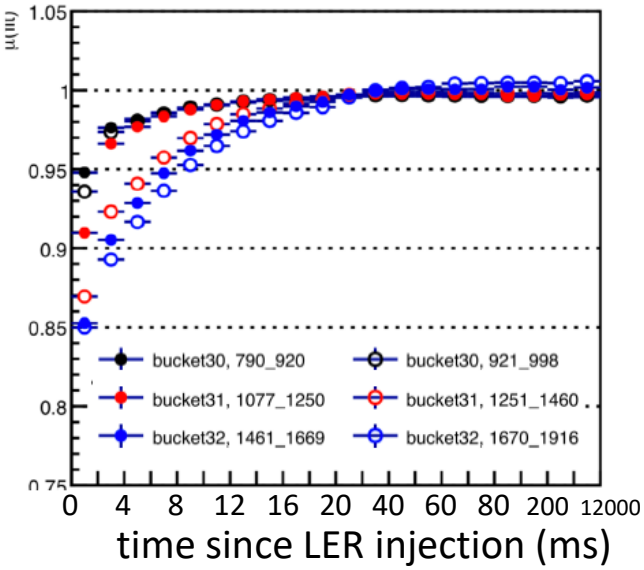
Performance degradation by injection background

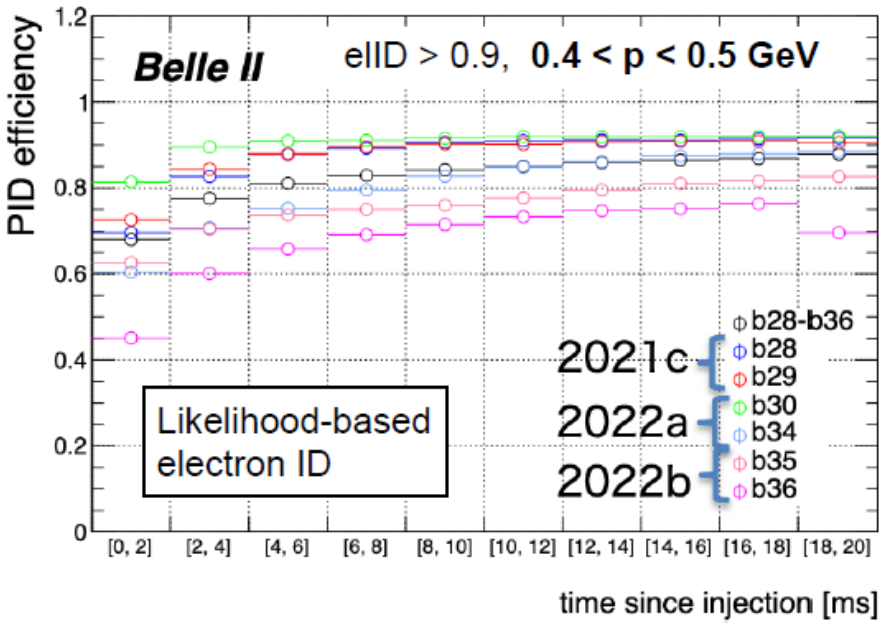
Dead time fraction for physics runs
∝ Veto time × injection repetition rate

12.3% last week

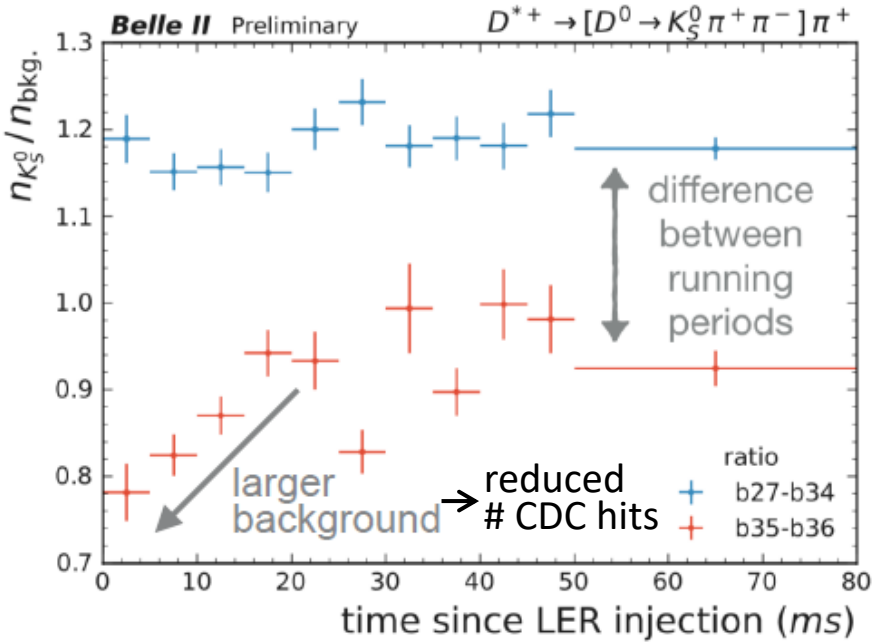


CDC dE/dx mean

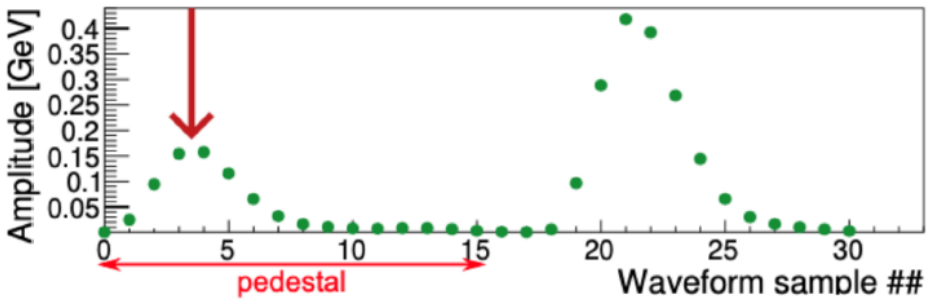


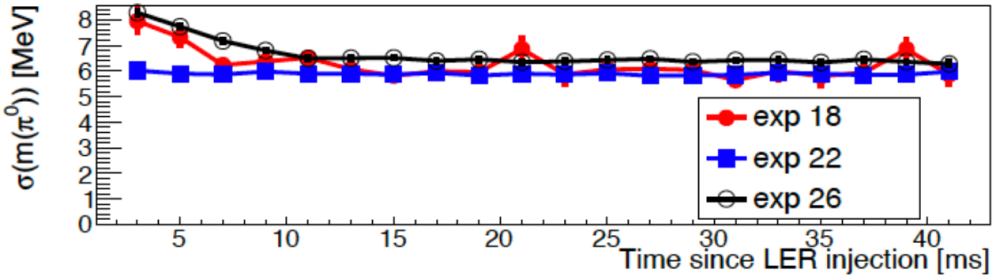


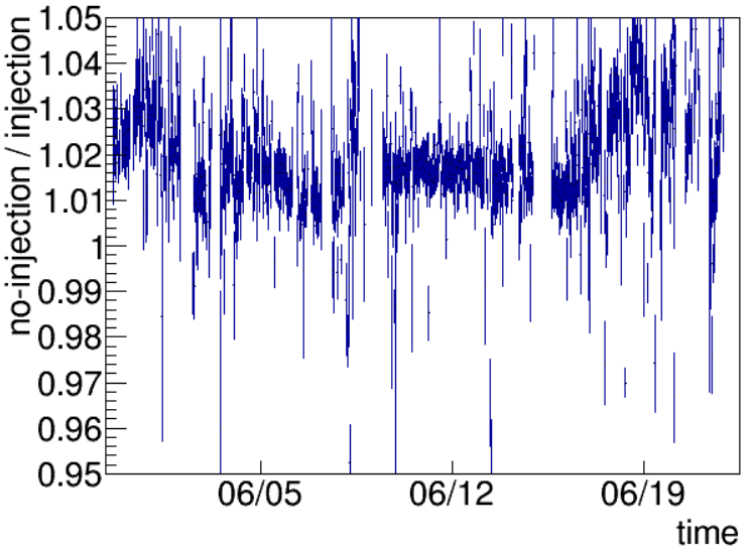
Performance degradation by injection background



ECL waveform data





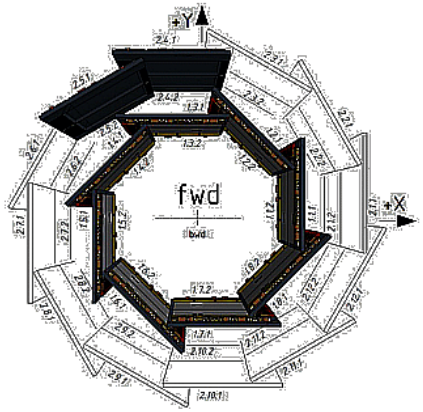


→ Pedestal calculation will be improved.

ECL online delivered luminosity dropped by a few % during LER injection (due to an event selection for background event rejection)

→ Considering injection veto

Major upgrades in LS1

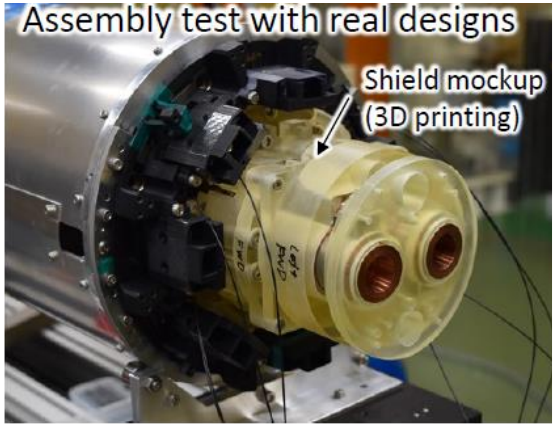


Belle II detector upgrade

- Exchange of PXD (pixel detector) for the full 2nd layer
- TOP conventional MCP-PMT replacement
- Migration to new back-end readout (COPPER → PCIe40)
- Buildup of HLT units (L1 limit: ~15 → ~20 kHz)

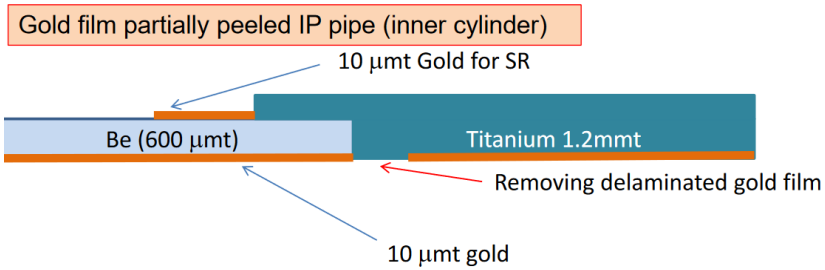
Beam background mitigation

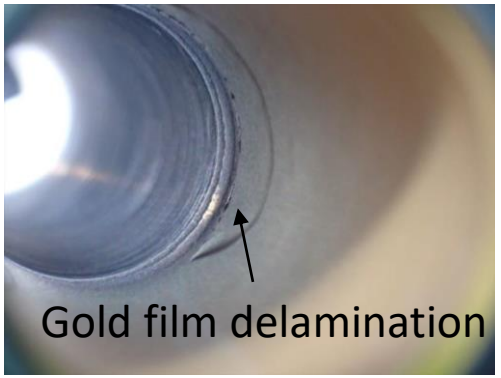
- IP beam pipe of new design to mitigate SR
- Additional shield on the QCS bellows
- Additional shield for neutron background
- Installation of a non-linear collimator



Protection of machine and Belle II

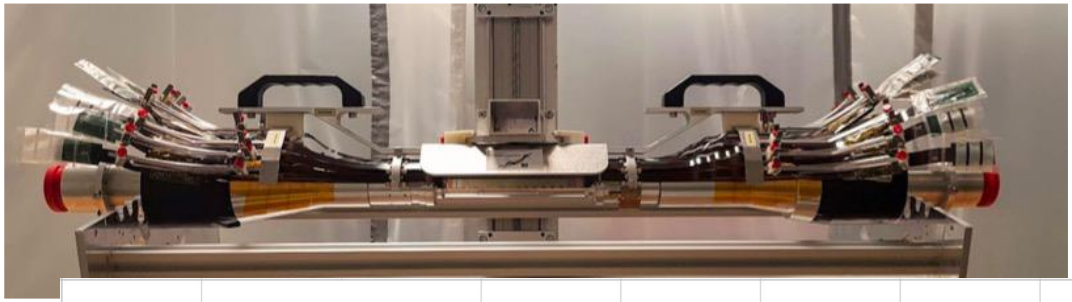
- Collimator heads of more robust material
- Faster beam abort system

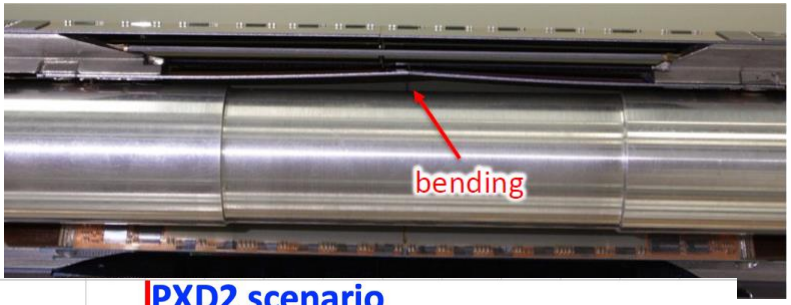


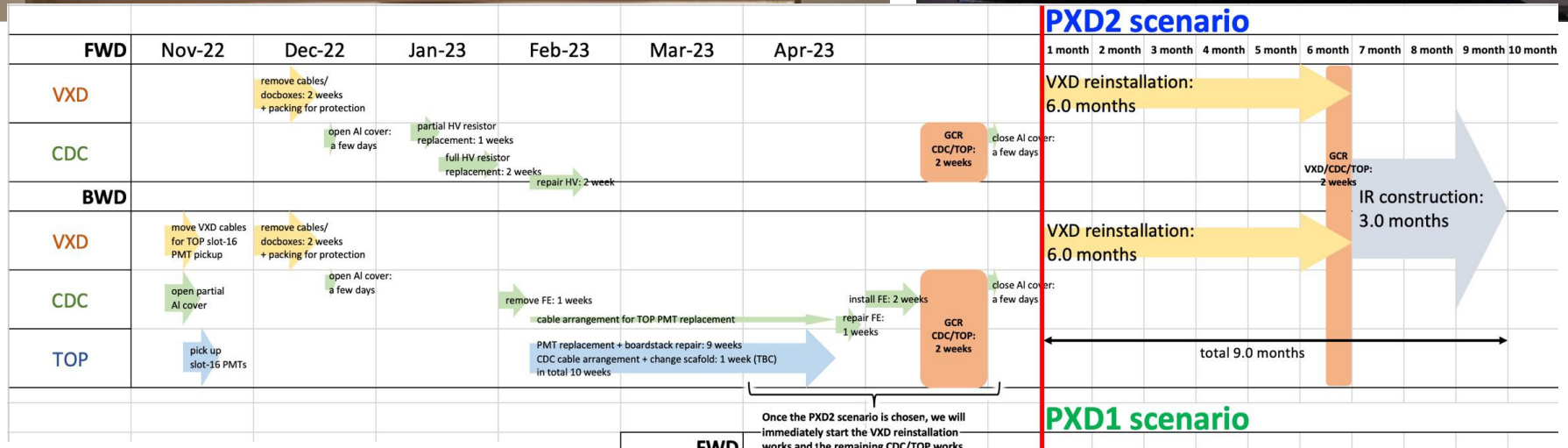


All acceptance criteria were passed.

PXD2 gliding mechanism issue







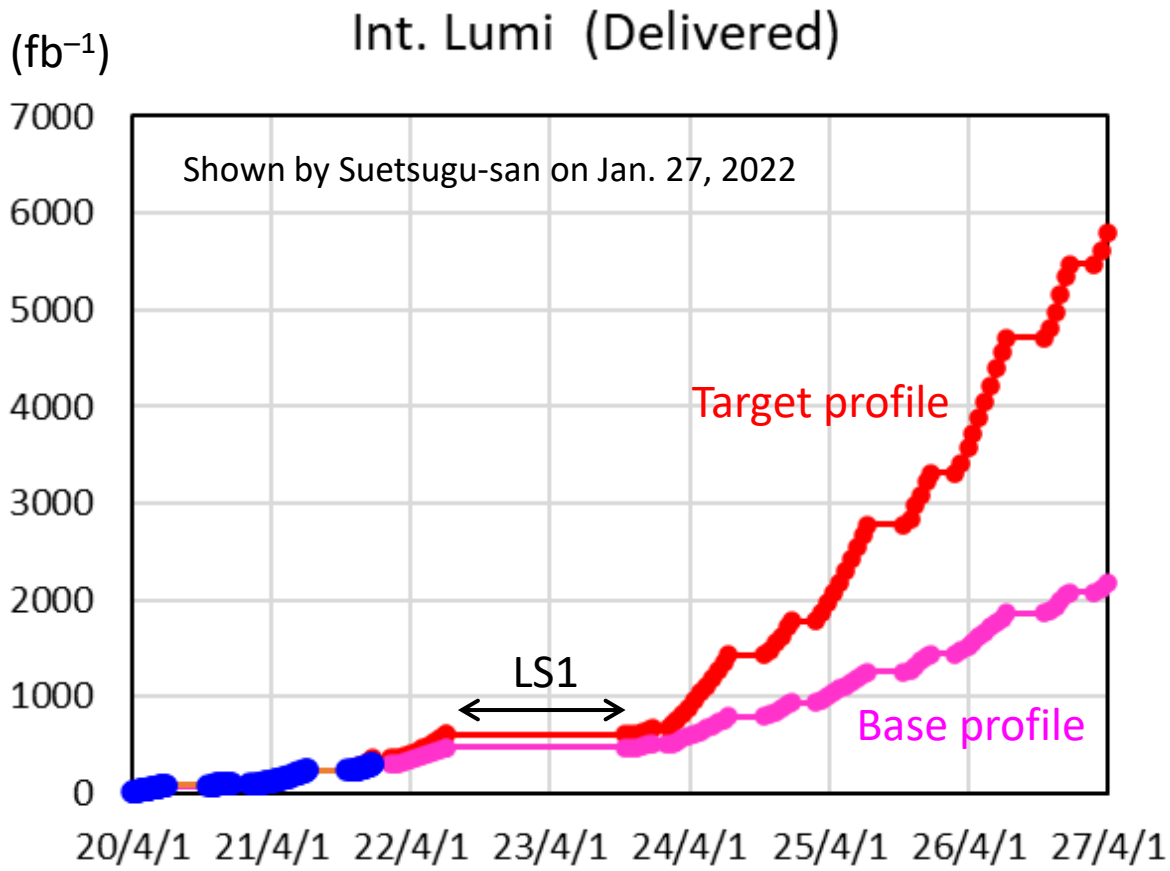
It was found gliding mechanism did not work.
The countermeasure is under investigation.
We will set time limit in Feb. to decide which scenario to take.

Summary

- We have improved our system for stable operation, but all our efforts were compensated by the increase of the beam background. 90% data taking efficiency is challenging.
- Impact of the beam background became notable in 2022.
  - Significant increase of the beam background not only by the increase of the beam current but also by collimator damage
  - Frequent stop of DAQ due to SEU of FPGAs by neutrons
  - Dead time (>10%) due to injection background veto
  - Performance degradation for CDC and ECL due to injection background
- Several upgrades are planned during LS1 to cope with the high beam background.

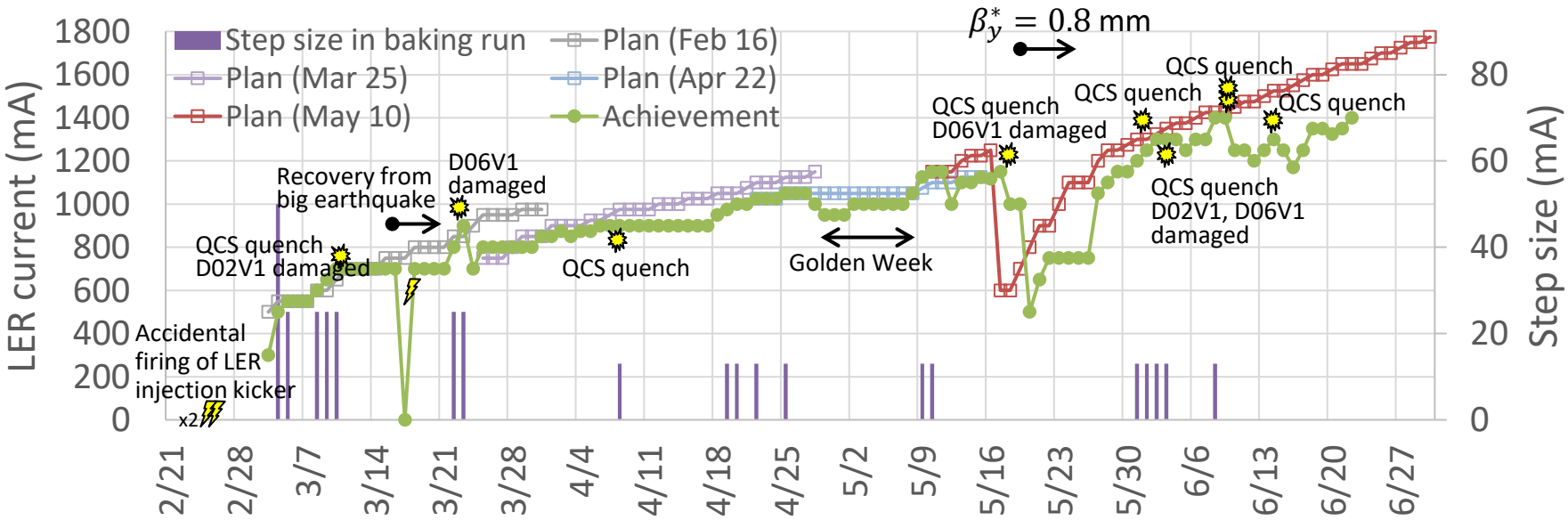
Summary

- We are on track to the base luminosity profile.
- The target profile is necessary for success of Belle II physics program.

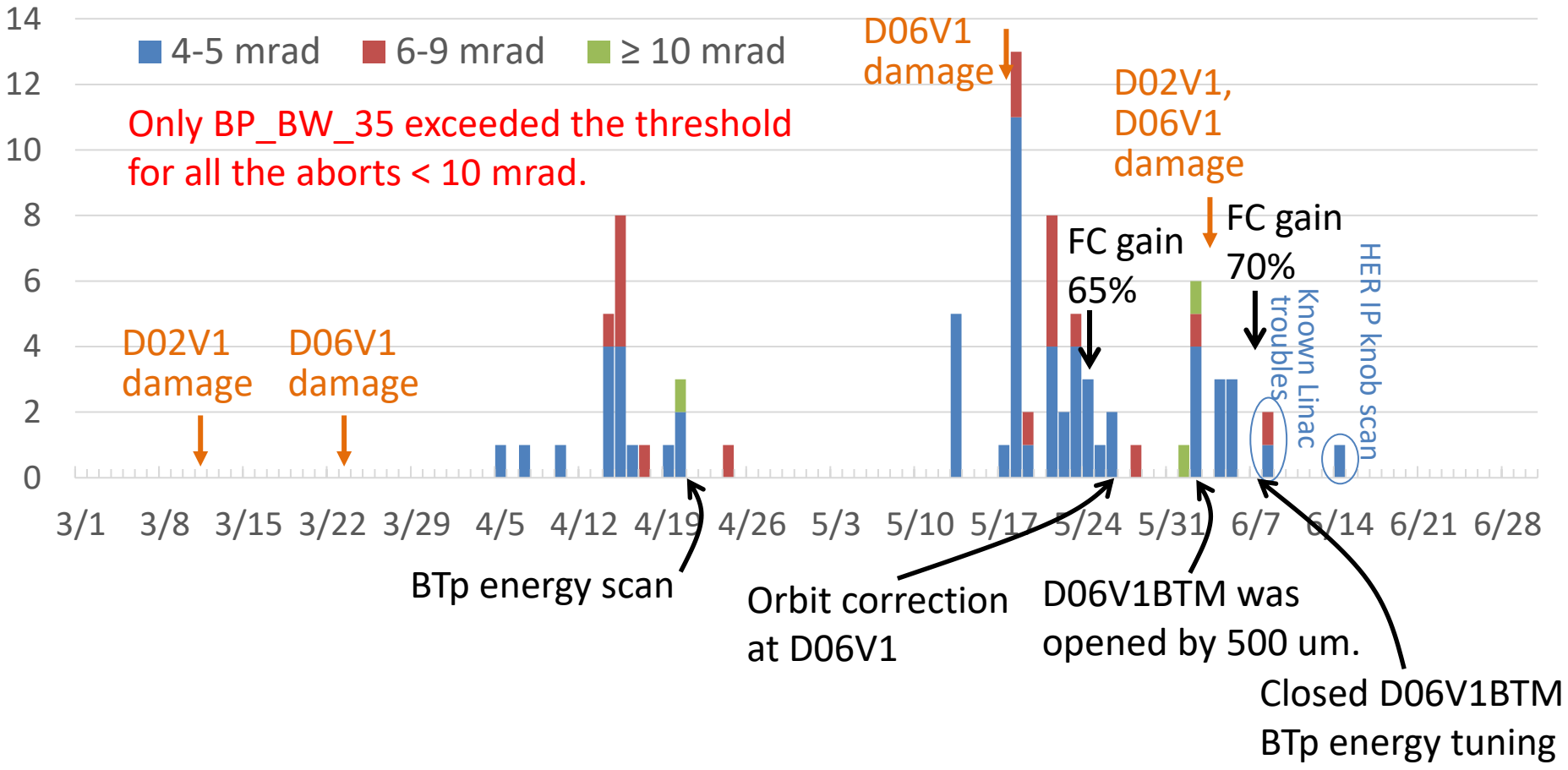


Baking run

- We set a protocol and plan for increasing the beam current:
  - Take a baking run (with collisions and Belle II HV standby) to increase the current step-by-step above the max achieved one in 2021c.
    - 10 mA step for 20 min.
    - [collimator alert], [3 beam aborts per ring], [time limit = $\frac{I_{\mathrm{target}}}{10\ \mathrm{mA}} \times 40\ \mathrm{min}$] are the stopper of the baking run.
  - Increase by 10 mA from 840 mA every weekday.
  - Keep the same total current during the day when N_{bunch} is increased.



Diamond beam aborts at LER injection (only when *I* > 60 mA)



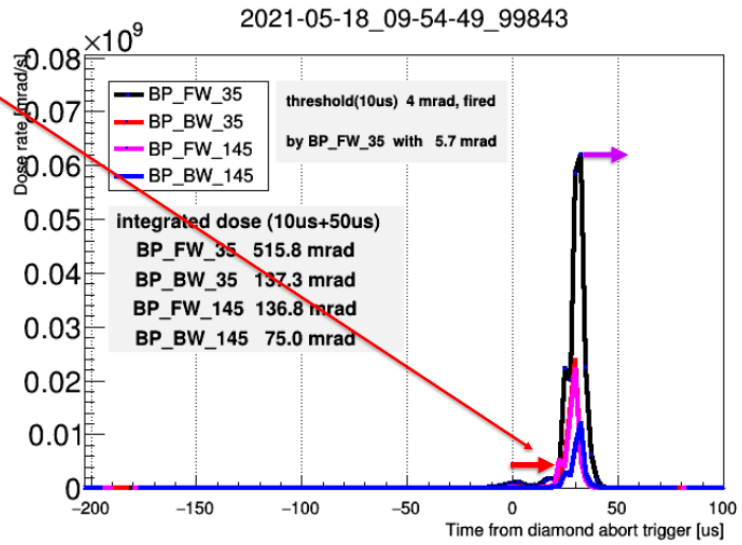
Only that particular diamond sensor (and CLAWS if not vetoed) issued "**unnecessary**" aborts very frequently. There must be some minor issue on the machine, but the beam loss at those aborts is not a problem. The frequent abort reduced the flexibility of the tuning and made the diagnosis of the cause very difficult. It was also a show-stopper for the machine progress (as we spent ~3 weeks to cope with these frequent aborts). Recently until Jun 7, it prevented us from increasing the LER beam current above 1.25 A and the injection charge to LER.

G. Rizzo

Increasing threshold → delay → higher dose by unknown amount

Increasing the threshold can also increase by the delay, by at least 2.5 μs
In some problematic situations, as this one definetely more:

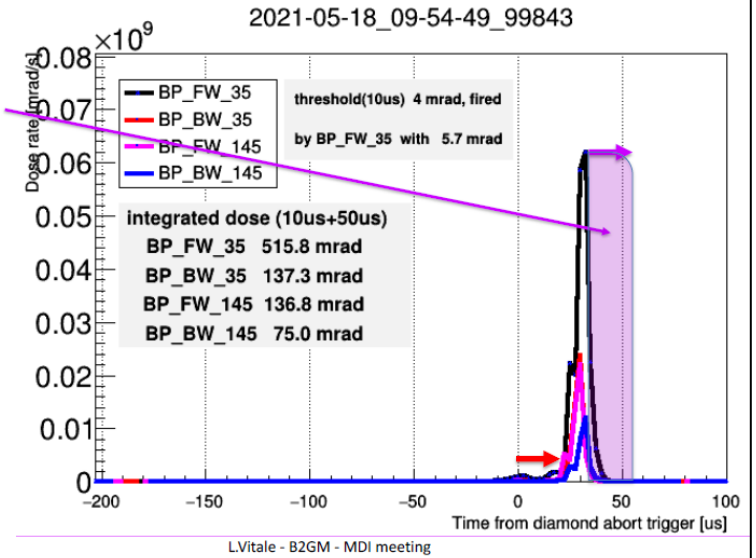
Delay For Triggering The abort



So, in some problematic situations, as this one,
Increasing the threshold can also increase by a huge amount the total dose

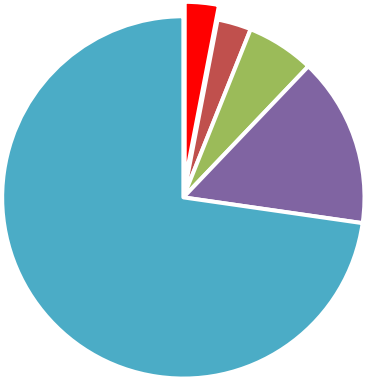
Delay

⇒ Total dose By unknown amount



Aborts with >100 mrad from 7 Jun 2021 to 5 Jun 2022 analyzed by G. Rizzo and L. Vitale

Delay in the case of 6 mrad threshold only for BW_35



- 2.5-5 us delay
- no delay (2.5-5 us delay without CLAWS)
- no delay (BW_35 at 6 mrad could trigger without delay)
- no delay (the other 3 triggered behind a little)
- no delay (the other 3 triggered first)

BW_35 triggered first

Statistics is small (33 abort events in total)

- Diamond abort was faster than CLAWS for 2 out of 33 abort events.
- CLAWS is inactive for 1.5% of time at most due to the injection veto.

- Higher dose **by unknown amount** for ~1/33 aborts is the risk we have to take by increasing the threshold from 4 to 6 mrad for BW_35 only in return for efficient machine operation.
- The balance of risk against benefit is not technical in this case and the decision rests with the Belle II management.
- We should consider how to reduce the risk. (e.g. divide BW_35 signal and apply 4 mrad (equiv.) for one with injection veto and 6 mrad (equiv.) for the other without veto.)