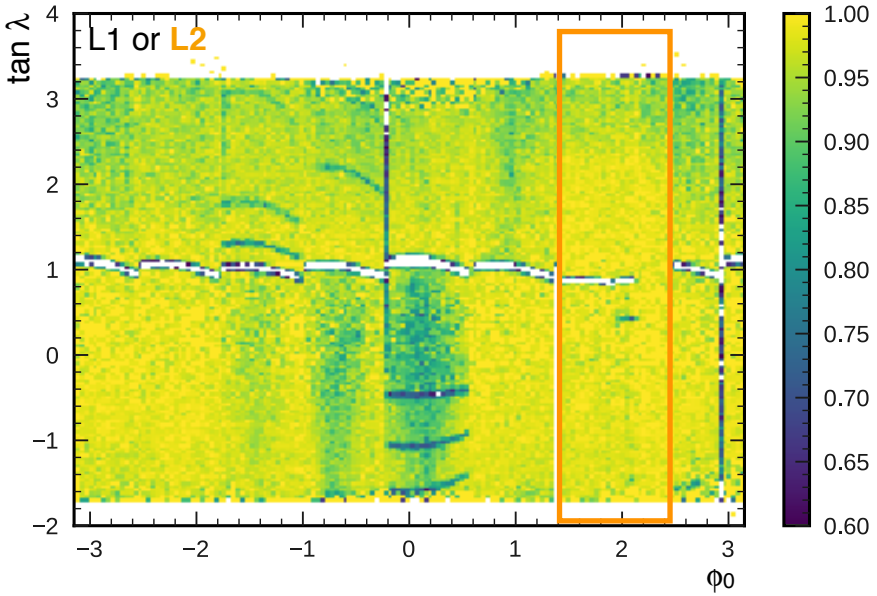
Issues of the Meeting

- Detector performance
  - reach next level in understanding to exploit full potential for physics
    - efficiency, reconstruction, alignment, resolution
- Readiness for coming autumn run period
  - establish sustainable operation scheme building on significantly improved online software
    - final goal: routine operation by CR shifter / PXD experts on-call
  - further optimise operation parameters $\Rightarrow$ improve overall availability and performance
  - establish routine operation with Gated Mode
- Radiation hardness
  - understand damage mechanisms during beam losses in May/June ($\rightarrow$beam test in Mainz)
  - increase robustness against bursts & future accidents $\Rightarrow$ establish fast emergency ramp down
- PXD21
  - good progress but some delays in ladder assembly and sensor production (not yet critical)
  - very strong push from KEK management for early start of 2021 shutdown (~February)
    - $\Rightarrow$ half shells have to be at KEK in a year from now
  - FWD: solve cable space issue and exploit options for improved shielding around bellows (CDC bkg)

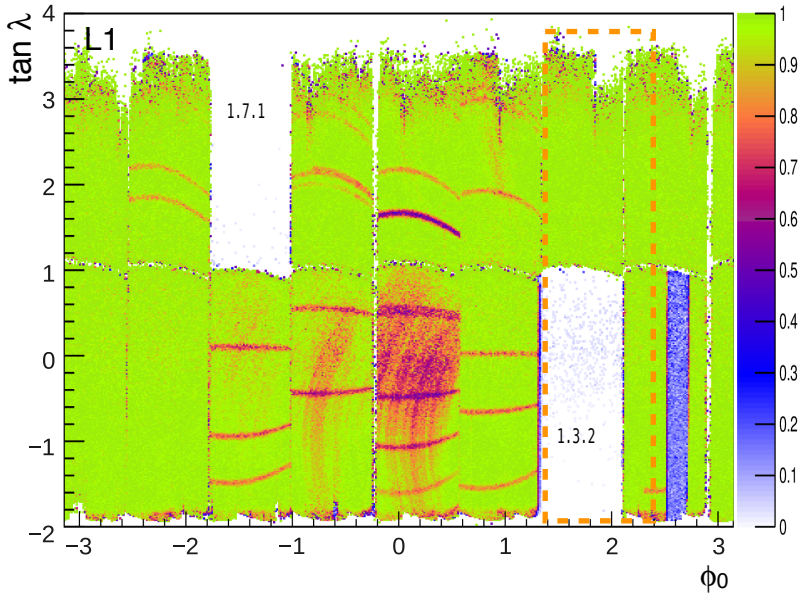
Evolution of PXD Status

May 21



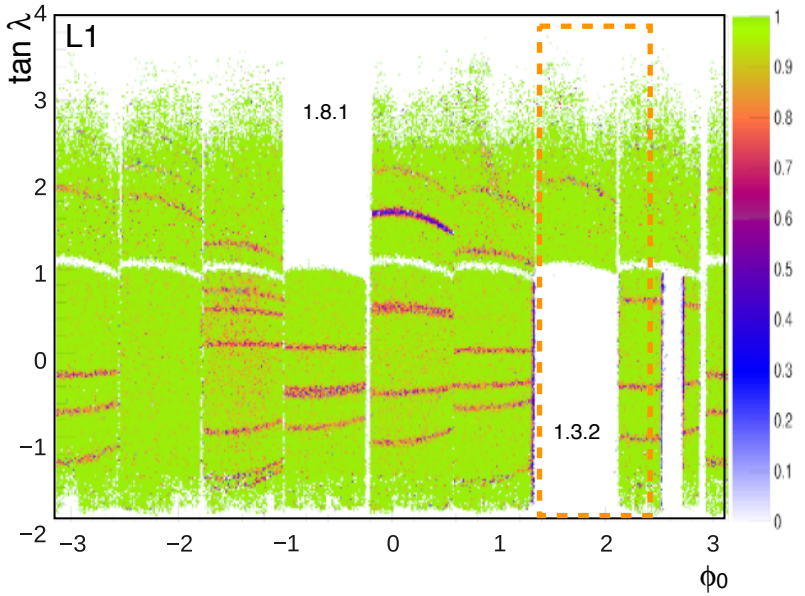
- Gaps between fwd & bwd modules and between half shells
- Several dead gates
- Few modules not yet at optimal working point
- Bad module 1.3.2 covered by module 2.4.2 in L2

After May 28



- 9 modules went into OVP
  - increased clear currents
- One module remained inoperable
  - 1.7.1 recovered only on Jun 7
- Many more dead gates
- Working point shifted further
- [Later lost one DHP link in 1.4.2]

After June 9

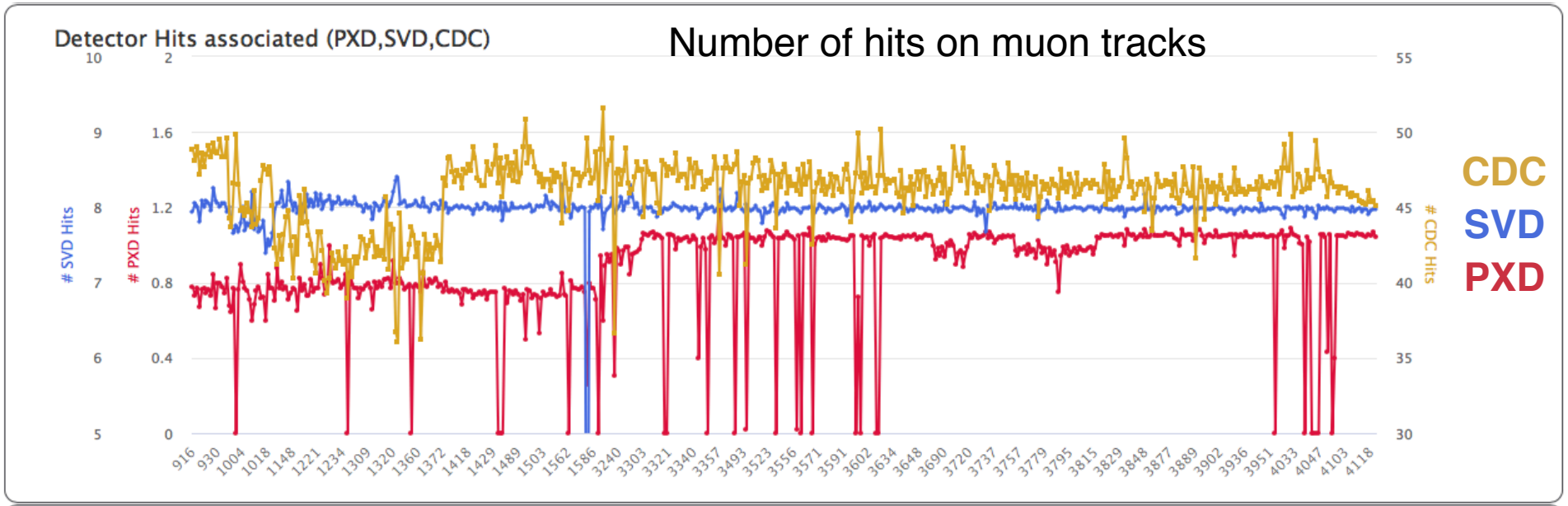


- LER lost ~150 mA within 40μs ⇒ damaged D02V1, QCSR quench and 3 rad accumulated dose
  - all modules triggered OVP
- Module 1.8.1 inoperable: current between clear and gate
- Many more dead gates (but a few were also recovered)

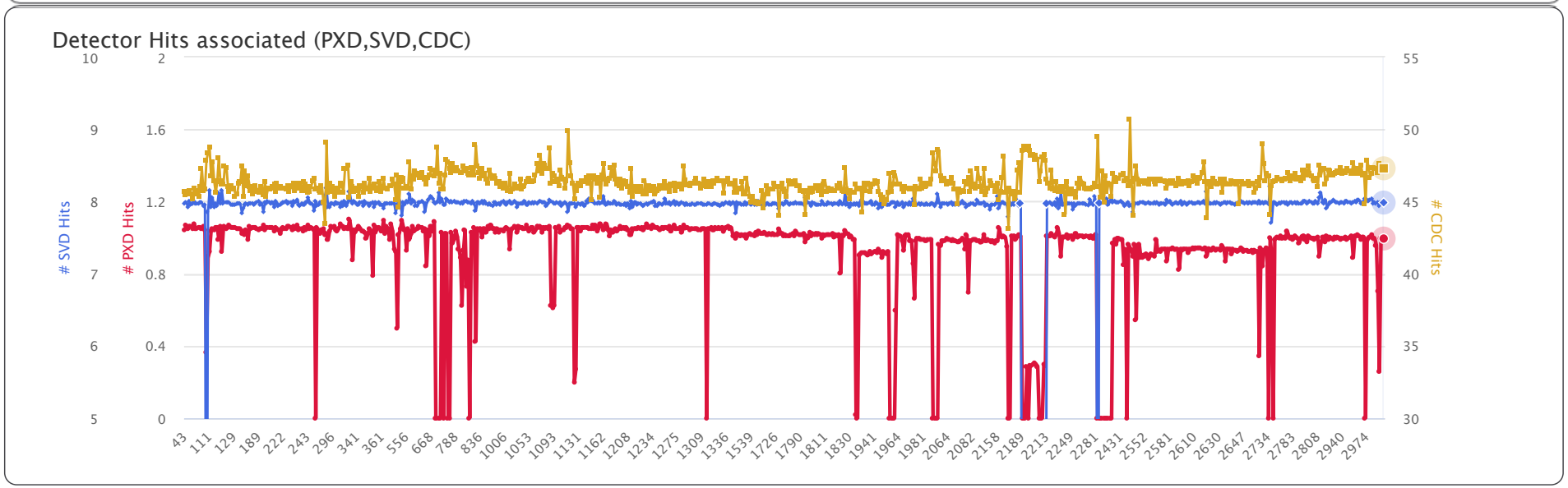
Evolution of PXD Performance in Phase 3.1

https://mirabelle.belle2.org

Experiment 7



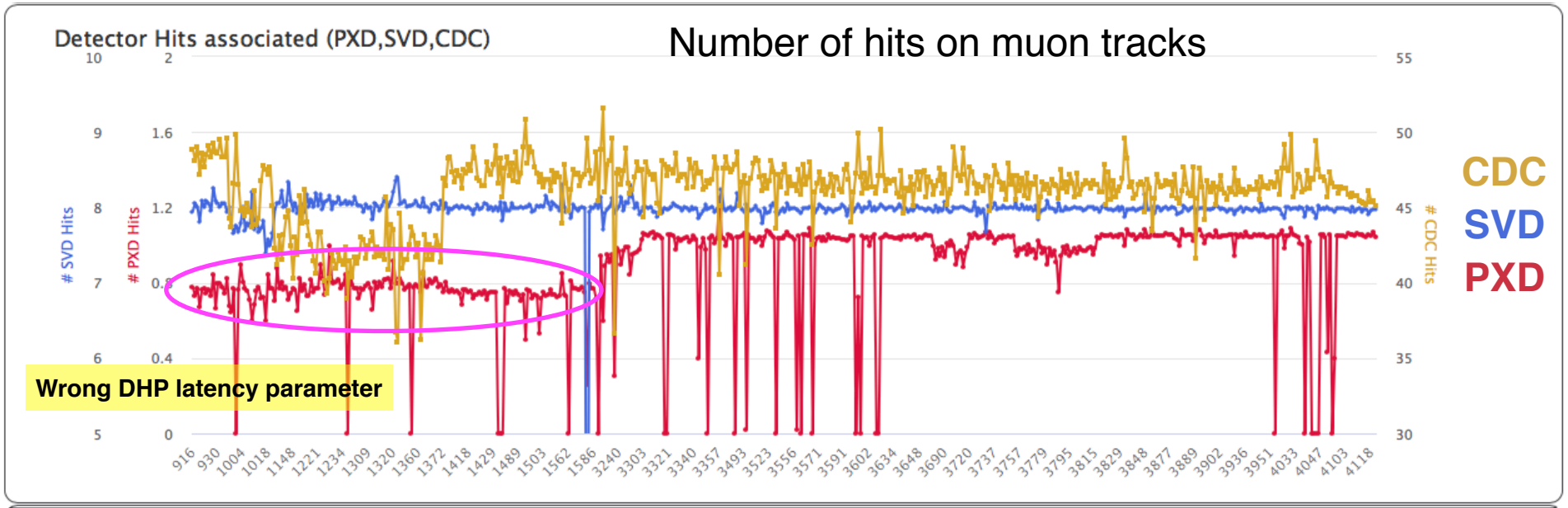
Experiment 8



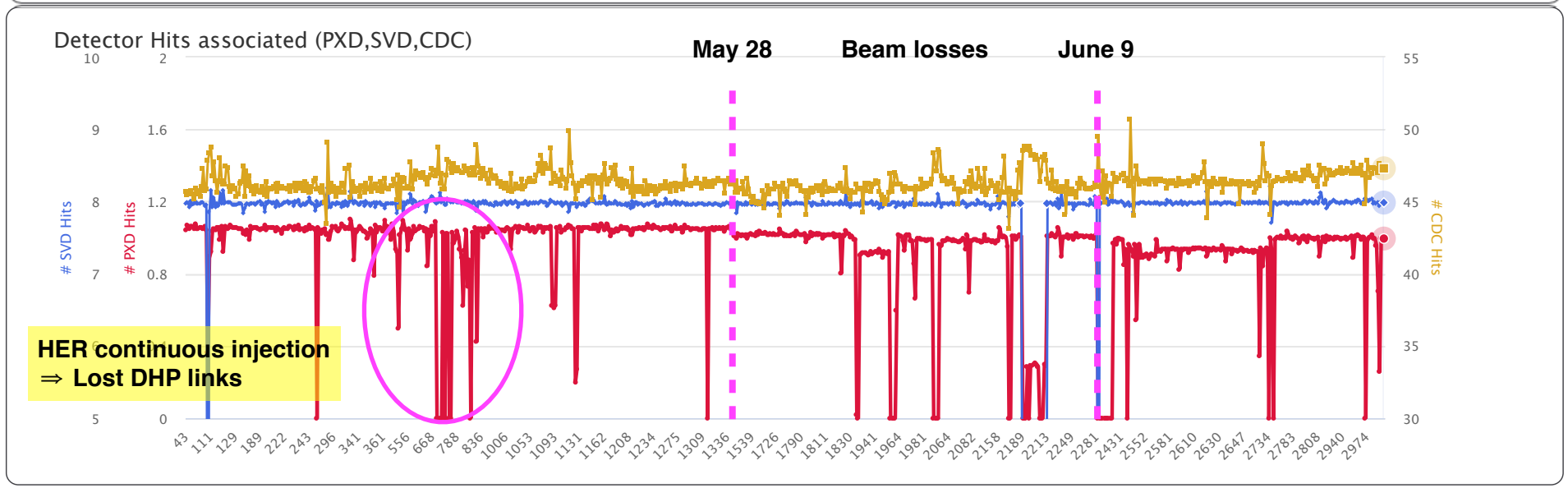
Evolution of PXD Performance in Phase 3.1

https://mirabelle.belle2.org

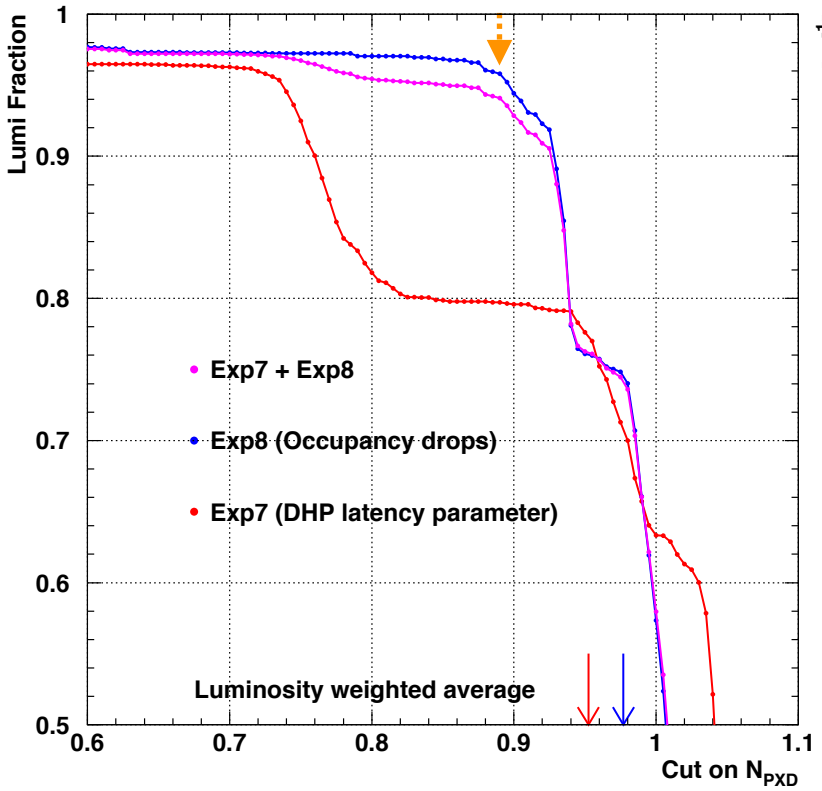
Experiment 7

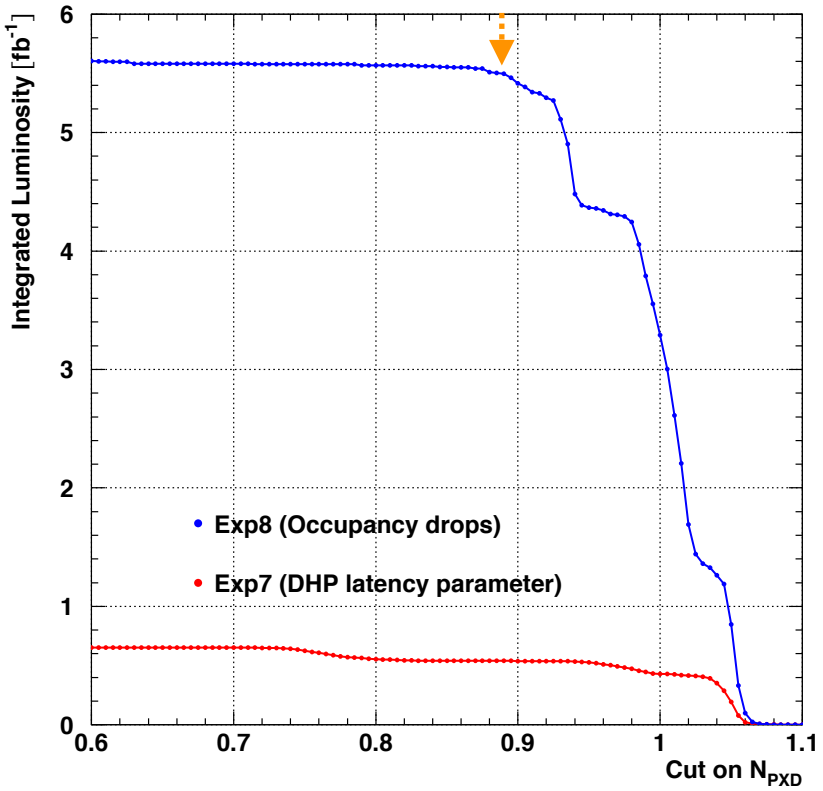


Experiment 8



PXD Run Quality

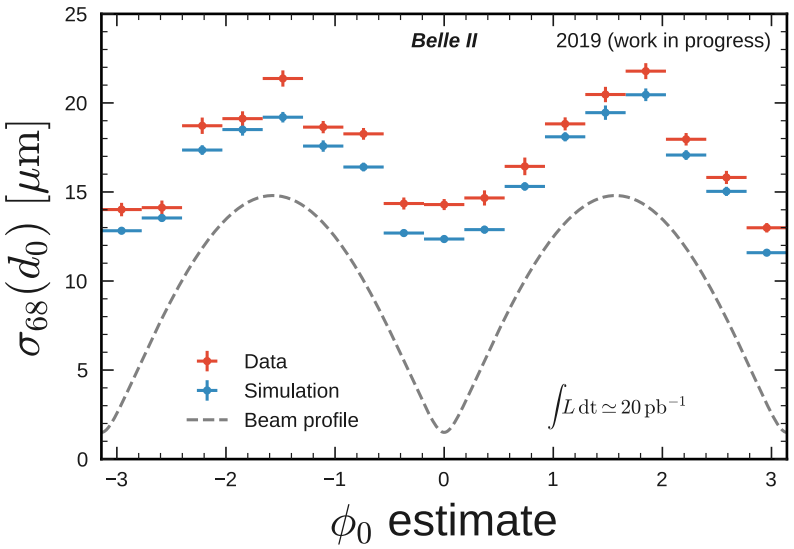


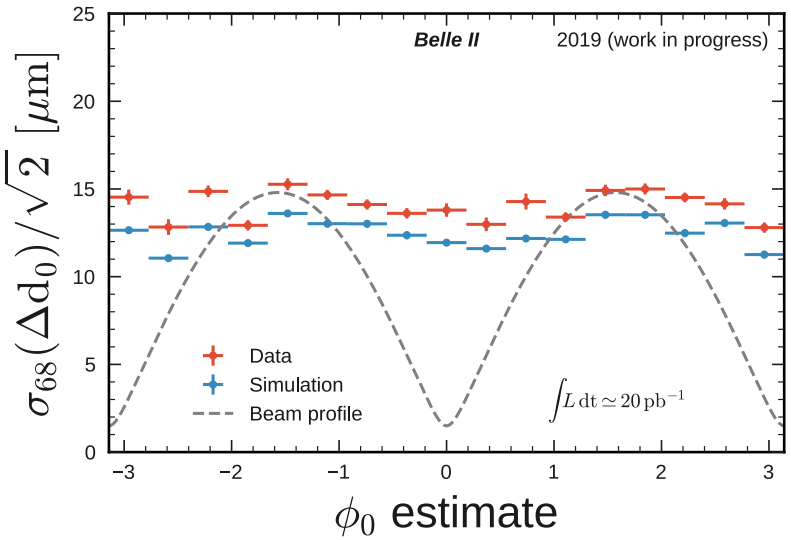


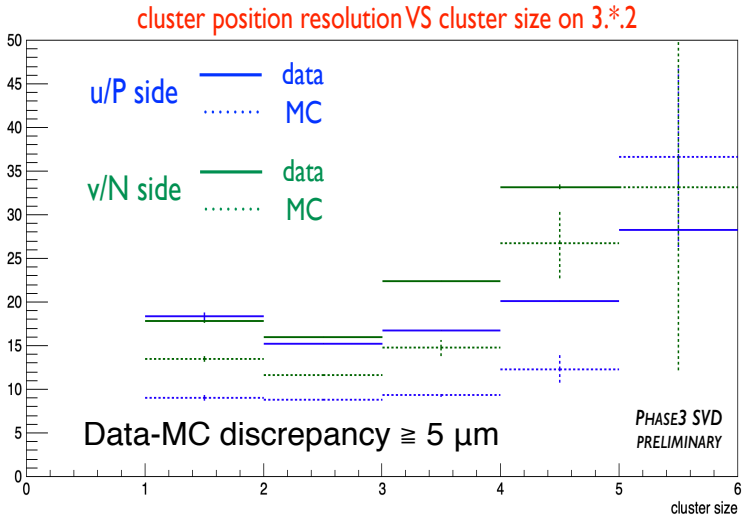
Cut on NPXD	Experiment 7+8		Additional loss due to cut on NPXD	
	Lost Lumi	Fraction	Lost Lumi	Fraction
0	335,0	5,2 %	0,0	0,0 %
0,5	408,3	6,4 %	73,3	1,1 %
0,7	431,1	6,7 %	96,1	1,5 %
0,89	489,6	7,6 %	154,6	2,4 %
0,9	568,9	8,9 %	233,9	3,6 %

- Cut $N_{PXD} > 0.89$ leads to an additional loss of luminosity of 2.4% (relative + ~50%)
- Not a disaster but leaves room for improvement …

Transverse Impact Parameter Resolution







LER: ε_x = 2.1 nm, β^*_x = 200 mm

HER: ε_x = 4.6 nm, β^*_x = 100 mm

Predicted horizontal beam spot size:

$$\widetilde{\sigma}_x = \frac{\sqrt{\varepsilon_x^{\mathrm{LER}} \cdot \beta_x^{\star\mathrm{LER}} + \varepsilon_x^{\mathrm{HER}} \cdot \beta_x^{\star\mathrm{HER}}}}{2}$$

$\widetilde{\sigma}_x = 14.8 \pm 0.5\,\mu\mathrm{m}$ (used for MC)

Measured ϕ_0 dependence:

$$\sigma_{d_0} = \sqrt{\sigma_i^2 + (\widetilde{\sigma}_x \sin\phi_0)^2 + (\widetilde{\sigma}_y \cos\phi_0)^2}$$

For 2-track (t– and t+) event,

$\Delta d_0 \equiv d_0(t-) + d_0(t+)$

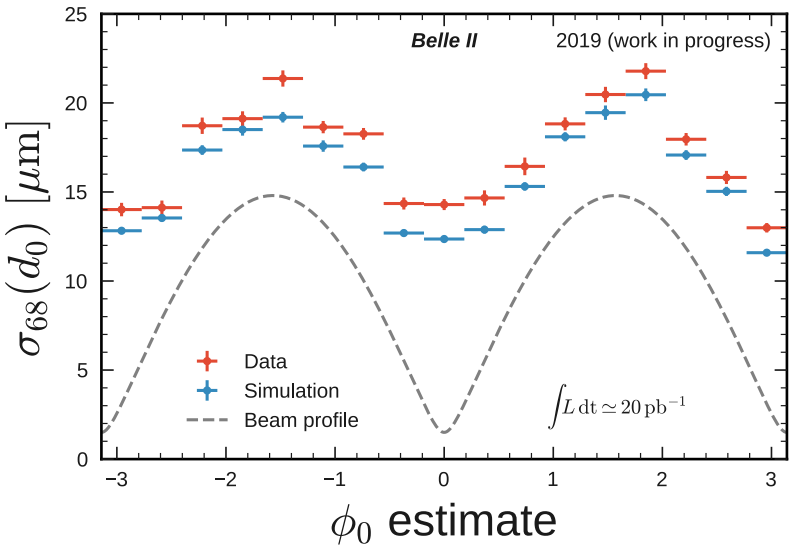
Width of $\Delta d_0/\sqrt{2}$ distribution used as estimate of **intrinsic** d_0 resolution σ_i

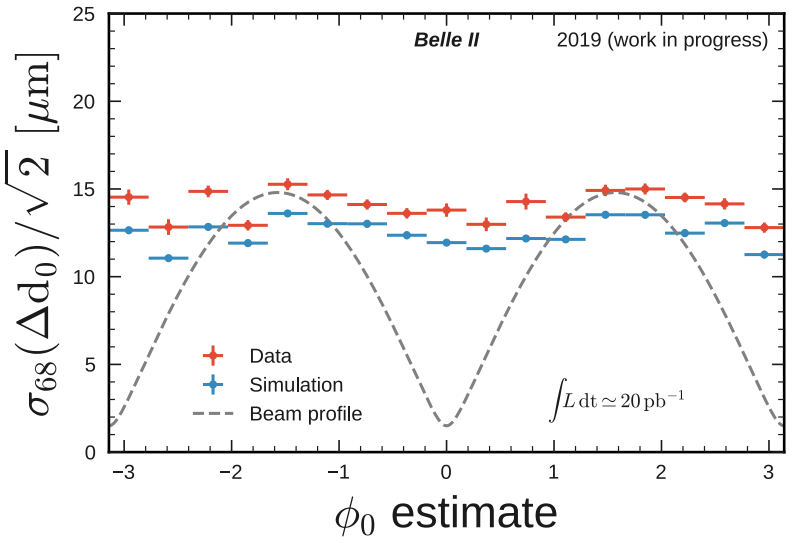
Data: $\sigma_i = 14.1 \pm 0.1\,\mu\mathrm{m}$

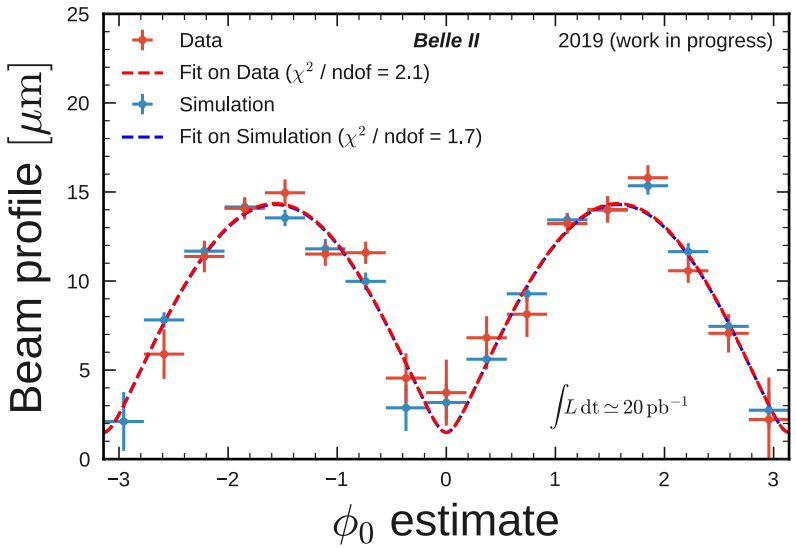
Simulation: $\sigma_i = 12.5 \pm 0.1\,\mu\mathrm{m}$

Difference affected by too optimistic MC expectation for SVD cluster position resolution.

Transverse Impact Parameter Resolution







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Simulation: $\sigma_i = 12.5 \pm 0.1\,\mu\mathrm{m}$

Difference affected by too optimistic MC expectation for SVD cluster position resolution.

Quadratically subtract σ_i from σ_{d0} and fit beam profile separately for data and MC with fixed $\widetilde{\sigma}_y = 1.5\,\mu\mathrm{m}$ determined from vertical beam scan.

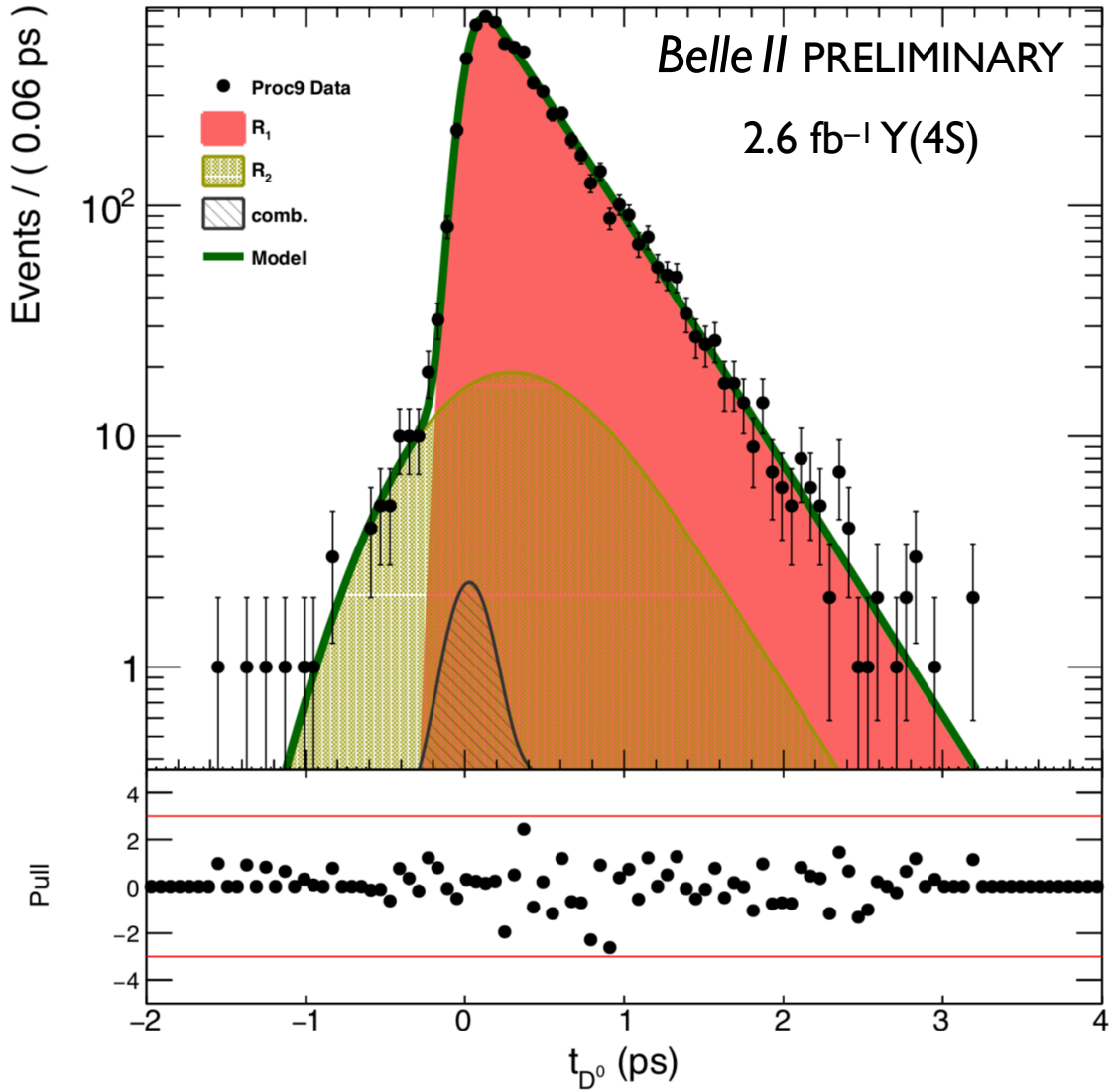
Data: $\widetilde{\sigma}_x = 14.4 \pm 0.9\,\mu\mathrm{m}$

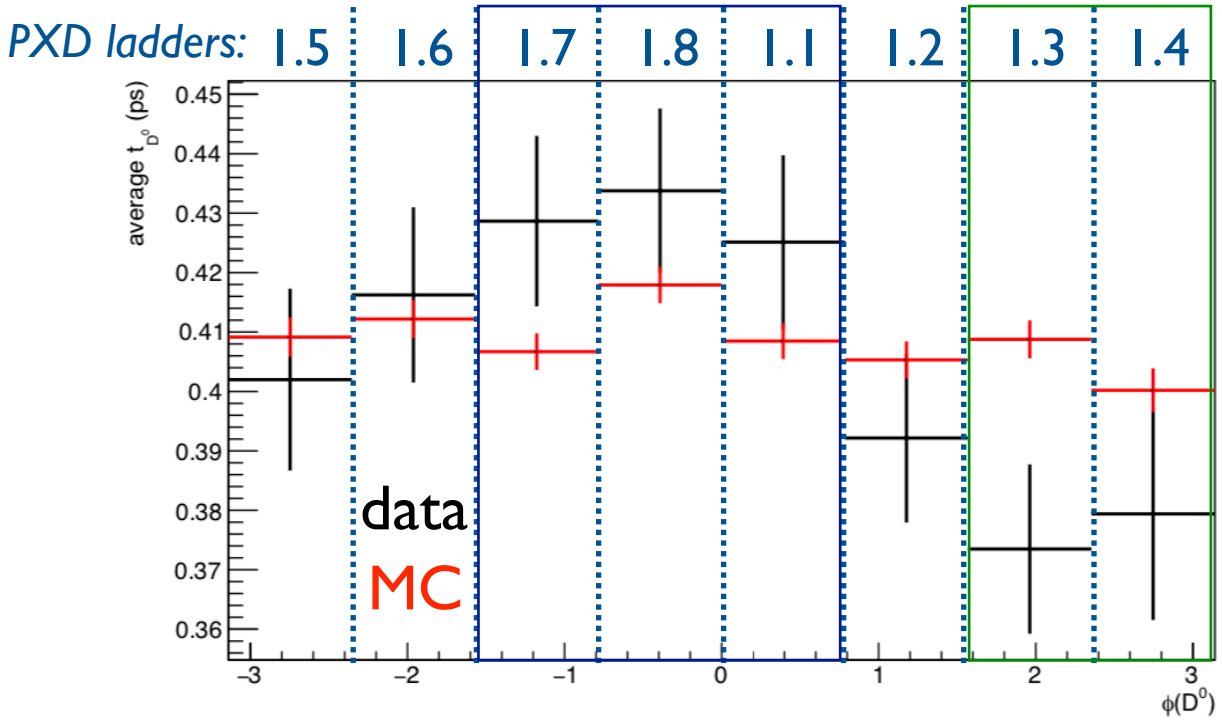
Simulation: $\widetilde{\sigma}_x = 14.3 \pm 0.6\,\mu\mathrm{m}$

Excellent agreement between data and MC and with the prediction based on machine parameters.

VXD Performance for Physics

Gaetano de Marino, Giulia Casarosa



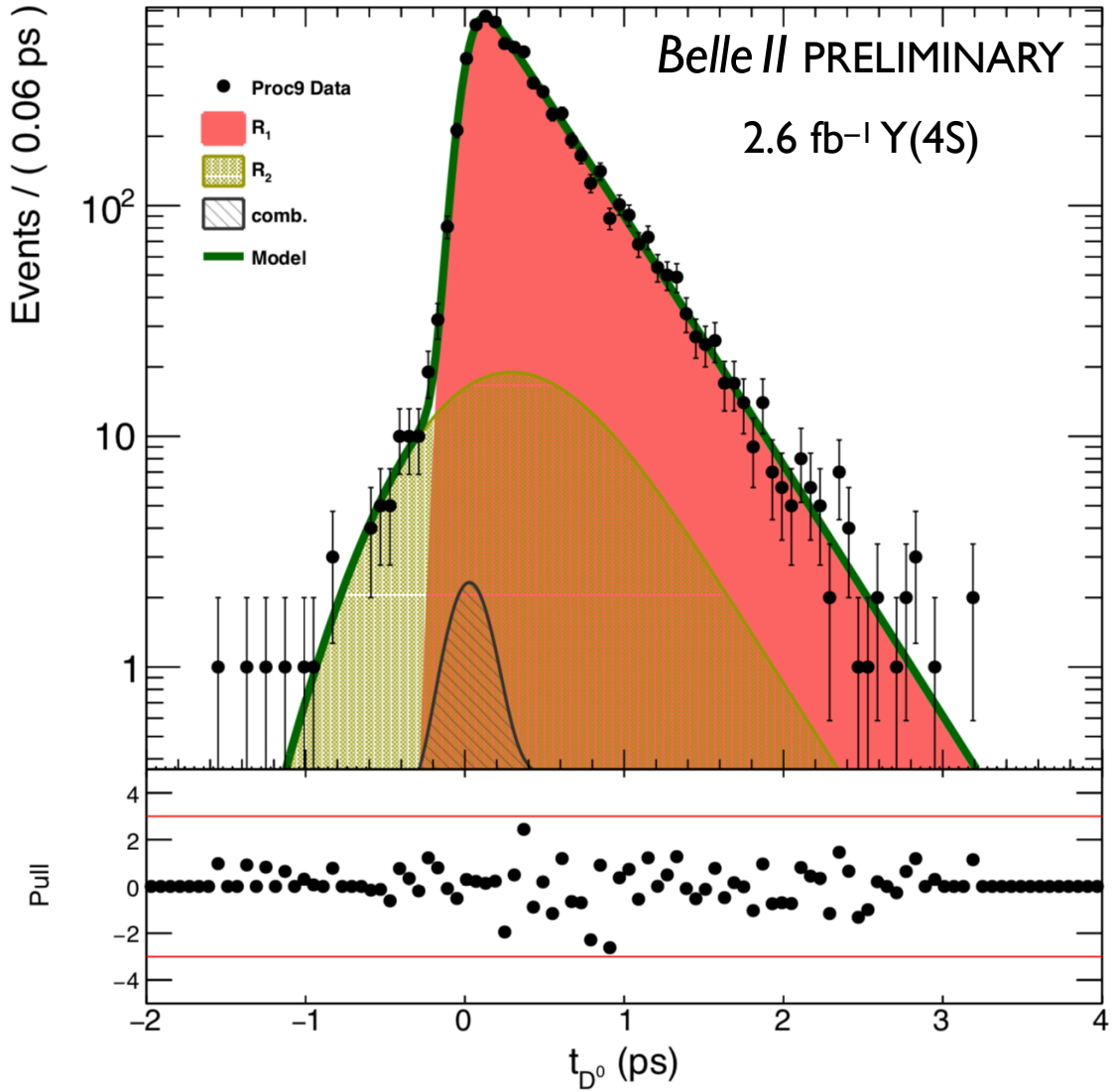


(a) Average proper time for each of the eight bins in which th range for the azimuthal angle ϕ of the D^0 is divided.

- Indication for remaining inconsistencies in alignment/reconstruction/run-vertex determination

VXD Performance for Physics

Gaetano de Marino, Giulia Casarosa

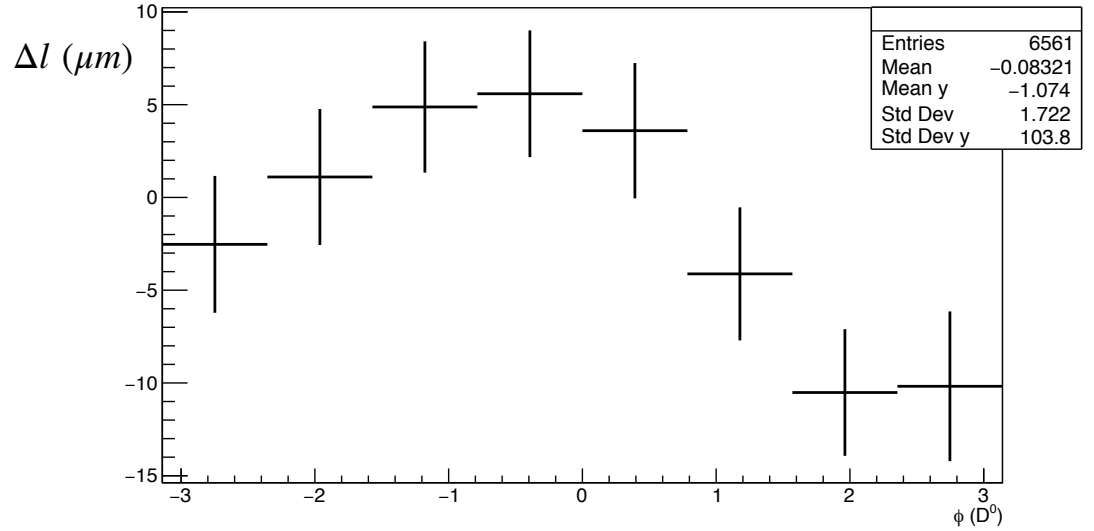


assuming that the lifetime can be estimated as the average of the proper time distribution

$$l = \beta\gamma ct \rightarrow < l > = \beta\gamma c\tau$$

then we can compare the average flight length $< l >$ with the one that we expect for D^0 candidates with the nominal lifetime:

$$\Delta l \simeq l - \beta\gamma c\tau_{PDG} = \beta\gamma c(\tau - \tau_{PDG})$$



- Indication for remaining inconsistencies in alignment/reconstruction/run-vertex determination

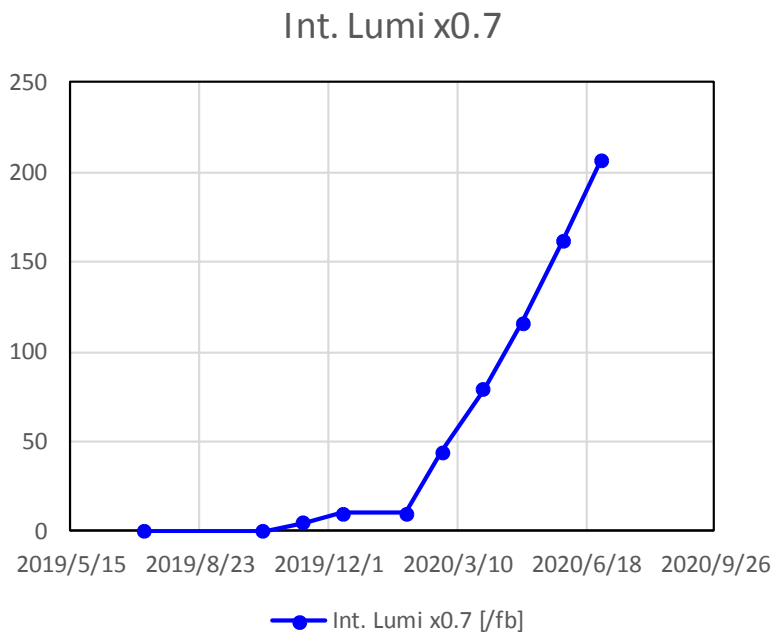
PXD Expert Shifts & Shifter Training Plans for Fall Run

- PXD operation scheme similar as in spring run
- At least one PXD expert on site (not permanently at KEK)
- Remote shifts mainly from Europe
  - following SuperKEKB operation plan highest priority to fill owl shifts and weekends
  - request to all PXD groups to fill new list **PXD_SHIFTS** in B2MMS ⇒ to be interfaced to ShifTool for registry and quota accounting
- Shift training
  - new people should sign up for shift training
  - require at least one shadow shift before taking first shift

Operation Plan

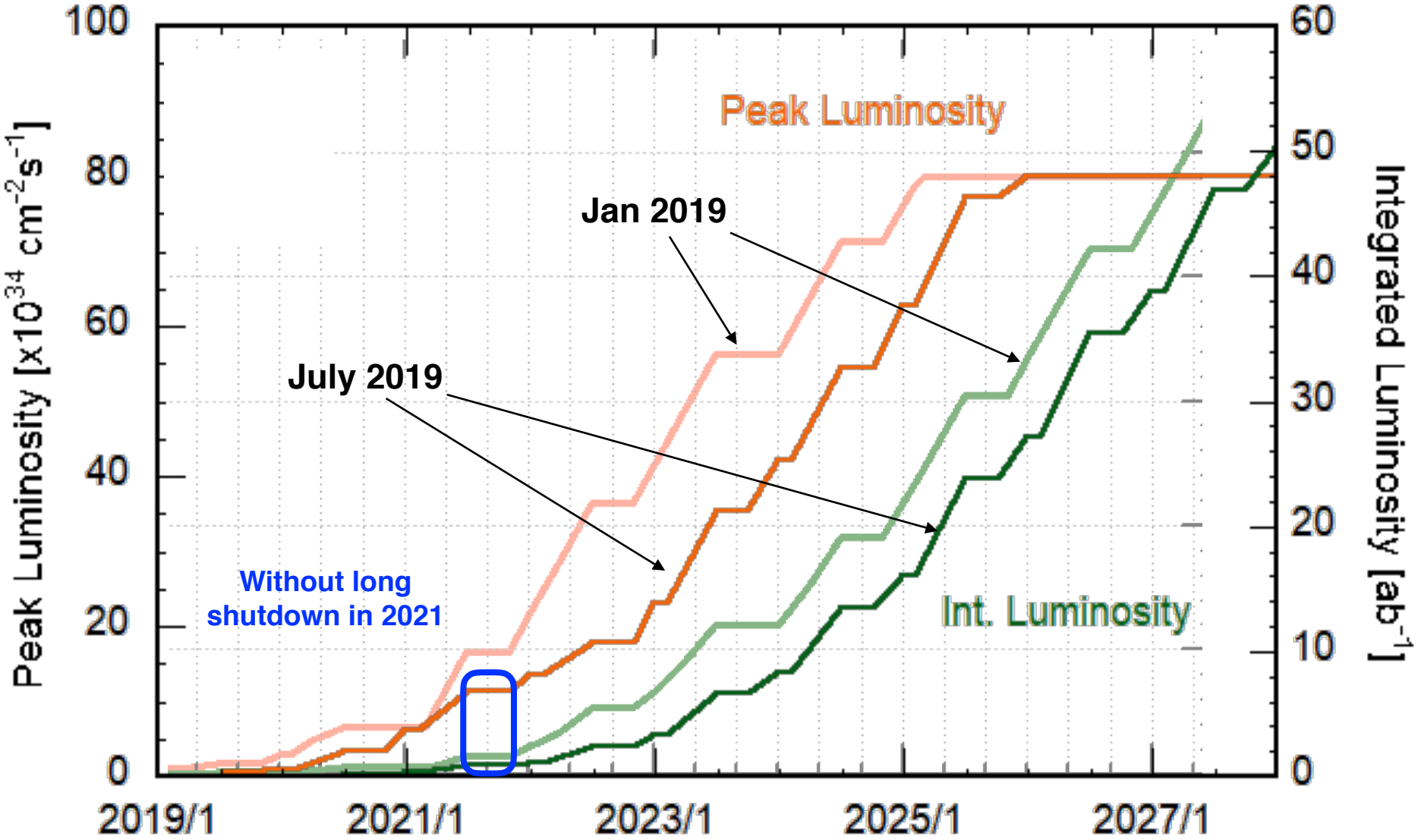
- Commissioning meeting at 6/Aug
- 2019 Autumn: Mainly focus on machine developments for increasing luminosity and reducing beam background.
  - Need vacuum scrubbing runs, especially around Oct., of course.
- 2020 Jan to Jun runs: Luminosity production run with target luminosity of 200/fb.

- Squeeze the beta* from 2 mm (achieved) to less than 1 mm (ex. 0.8mm) within two month.
  - Day and Swing shift will be used for machine tuning and background study
  - Owl shift and weekends will be used for the luminosity runs (with reduced beam currents and /or relaxed beta*_y)



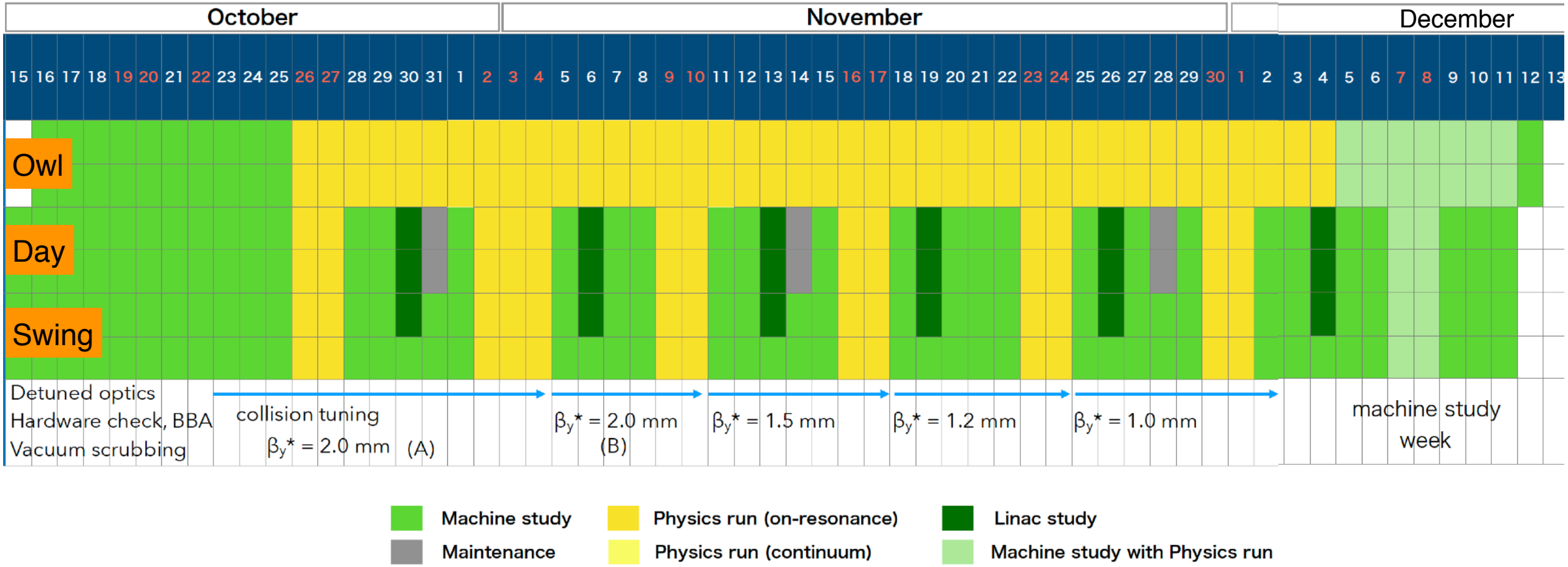
Update on Projected Luminosity

Makoto Tobiyama @ TB 04.09.19

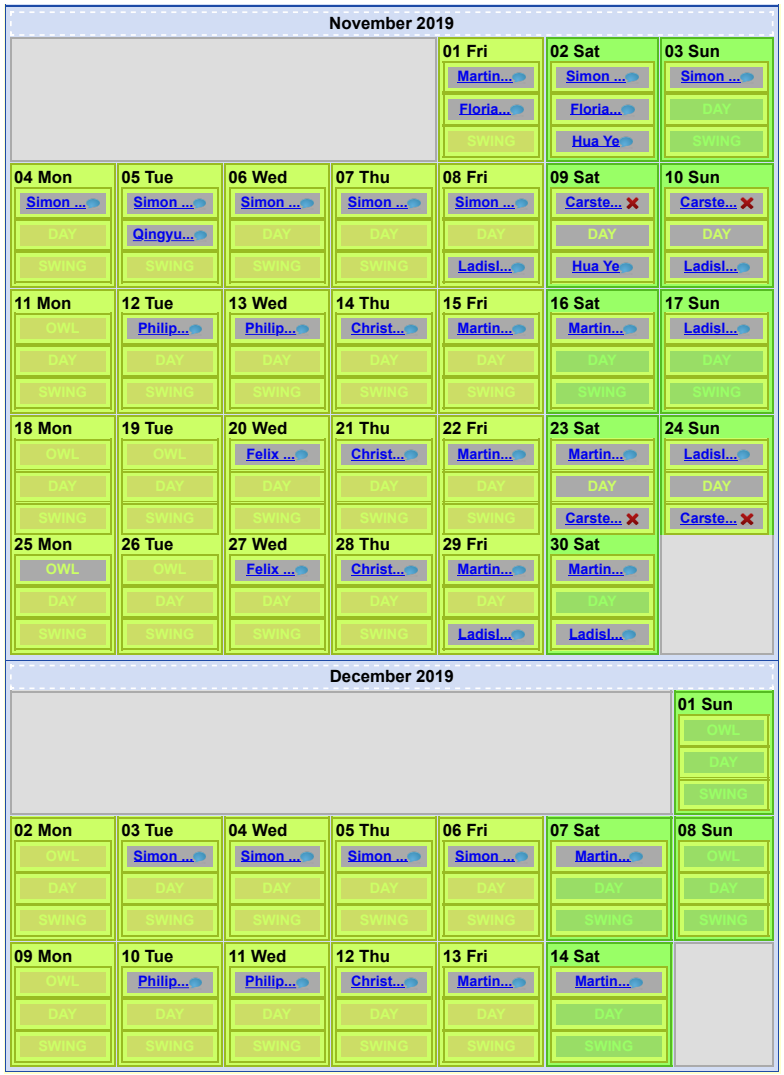


Phase 3.2 Run Schedule

Y. Ohnishi



PXD Shifts



- New list PXD_SHIFTS in B2MMS
  - to be interfaced to ShifTool for booking and quota accounting

- Please start booking shifts NOW
- Order of priority for remote shifts:
  - weekend → owl → swing

Further shift trainings will be scheduled in the near future: please register!

Dear IB members,

Please find attached a table with the PXD SHIFT QUOTA for each group.
The quota counts for the period starting in ~ two weeks to the end of this year's data taking (Dec. 14, 2019).

*** I would like to ask all groups to take this quota seriously and to start filling PXD shifts IMMEDIATELY.
*** The institute representatives are responsible for the shifts being filled according to their quota.
*** Otherwise we cannot guarantee a continuous operation of the PXD.

The PXD shifters that are present at KEK should mostly do day-time shifts (Japan time), while we would like to ask remote shifters
to preferentially fill the night and weekend shifts.
If we cannot find enough shifters for the latter, the PXD management will have to assign specific groups to these shifts.

We also hope that over the next few weeks more and more people will take the shift training and qualify as PXD shifter.

Here some information on how the quota was calculated:

- The quota is based on the number of PXD authors excluding technical staff and master students, for all PXD groups that are Belle II members.

- Since we urgently need to find shifters for the next three months, we did not consider the shift deficits or excesses accumulated so far (we will, however, take this into account for next year's quota).

- Unfortunately many groups have not yet replied to my email from last week.
  For all groups that have already set the group flag PXD_SHIFTS for their members, this number is used in the table.
  For all other groups (shown in blue), the quota is still based on the names in the short collaboration member list for shifts (created about half a year ago).
  I would like to ask these groups again to please set the flags (PXD and PXD_SHIFTS) for their members.

If there are questions or comments regarding the table/quotas, please let me know.
Thanks for your help!

Best wishes,
Jochen

BPAC Review: Short Summary

The committee congratulates the Belle II collaboration for the successful startup of the Phase 3 physics run with the full detector. After a couple of months of data taking, the collaboration is able to show not only **detector performance** of various subsystems, such as **impact parameter resolutions** and **particle identification capabilities for charged tracks**, but also **clean invariant mass distribution for reconstructed B and D mesons**. The committee is looking forward to seeing interesting physics results in the near future. It is also encouraging to see that the SuperKEKB machine could deliver luminosities well above 10^33 cm−2s−1 already at its early stage of the operation. There has also been progress in understanding of the machine behaviour resulting in, for example, effective deployment of the new collimators.

However, the collaboration has still to **deal with several outstanding issues**. Further understanding of the **machine related background** is clearly one of the **paramount problems** not only for protecting the detector but also for increasing the luminosities. Machine background produced by so called **"dust" interacting with the beam particles are particularly dangerous for the Pixel Detector (PXD) and the superconducting final focusing quadrupole magnets**, therefore **some measures must be considered**. The committee **recommends the implementation of a more sensitive and faster abort system**. A better understanding of the **beam dynamics** is necessary for the luminosity increase. There exists already a **good collaboration between the machine and detector groups**. This should be kept and strengthened to develop an **optimal start-up and operation scenario, where the safety for the detector and machine should be the highest concern**.

Although the current overall performance of the Belle II detector is good, some subsystems require additional care. While studies are in progress to address the problem of sustained dark current of the Central Drift Chamber (CDC) for both short and long term, one might face the situation where some of the layers have to be switched off for data taking. A clear action plan for addressing causes of the problem and possible mitigation should be prepared and in place. Its effect on the physics performance should also be investigated. Cross-talk remains a concern and further tuning effort should be made.

Being the closest to the beams, the **PXD is very vulnerable to the machine background**. Further protection schemes, such as **fast switching off of the power to ASICs**, as presented during the June BPAC meeting, should also be implemented soon. In this context, **construction of a new PXD with the two complete sensor layers should be finished to be ready for installation during the shutdown in early 2021**, although the actual timing of the installation needs to be carefully tuned considering the balance between the gains and losses. For the efficient operation of the detector with increasing luminosity, completing the **implementation of the gating** and ONSEN readout system is essential and should be made as soon as possible.

The committee is very pleased to see the successful effort to increase human resources for the online and computing work and encourages the collaboration to continue this effort. Although the trigger seems to work well for the moment, physics studies must be performed to make sure that physics opportunities are not lost due to the two missing components in the trigger, KLM and TOP triggers. They must be timely implemented in order to cope with the anticipated increasing luminosities. The committee acknowledges a well-developed strategy for the selection of a solution for the Belle II readout system upgrade and looks forward to hearing the result.

Accelerator Review Committee Report

31 pages

A) Executive Summary

SuperKEKB has carried out the Phase 2 commissioning from 19 March 2018 to 17 July 2018, and already operated 3-4 months in Phase 3, from 11 March to 1 July 2019. During these two running periods the vertical beta functions of both beams were squeezed in steps, down to 3 mm, and even to 2 mm with detector off, yielding peak luminosities of about 5×10^{33} $cm^{-2}s^{-1}$ and 1.2×10^{34} $cm^{-2}s^{-1}$, respectively. The β_y^* of 2 mm is almost 3 times smaller than at KEKB and sets a new world record for storage-ring colliders. The commissioning time to reach a luminosity of 10^{34} $cm^{-2}s^{-1}$ was 5 times shorter than for the previous KEKB. In Phase 3 the Belle II detector is almost fully installed. An integrated luminosity of about 6/fb was delivered to Belle II during about two months from end of April to June 2019.

At present, the most important challenges are:

1) fast beam losses leading to collimator damage, QCS quenches and beam showers hitting the Belle II pixel detector;
2) high detector background dominated by beam-gas scattering in the LER, which limits the beam current and minimum beta*, and jeopardizes the integrity of the detector; and
3) luminosity tuning with significant vertical emittance blow up and low beam-beam tune shift in collision.

The ARC has formulated recommendations on how to address the above issues; it supports an ambitious luminosity goal for the coming year.

B) Recommendations: The Committee has made recommendations throughout the different sections below. The most significant of these recommendations and a few more general recommendations are summarized here.

1. Develop priorities for the next year in collaboration with the Belle II detector group in order to achieve an integrated luminosity of about 200/fb by July 2020. (R1.1)

2. The ARC endorses the proposed operational goals for Phase 3.1, toward β_y^* of 0.64 mm, 2 kAh, 200/fb, $3 \times 10^{34} cm^{-2}s^{-1}$ by summer 2020. (R2.1)

3. By autumn 2019, evaluate different operating scenarios, select the one with the best risk-reward ratio, and establish a detailed commissioning plan for accelerator and background studies. (R2.2)

4. To avoid detector and QCS damage, separate the functions of machine protection and detector background reduction. The first role can be fulfilled by a robust collimator (lower Z material) placed at an adequate location close to the abort system, far from the experiment. The second one is taken by the existing collimators closer to the detector with a larger normalized gap. This approach implies the installation of additional collimators in the two main rings. (R14.4)

5. Once the main rings are in a safe condition, i.e. after the installation of the additional collimators, increase the beam current in steps and develop optimized beam-scrubbing scenarios to accumulate, before summer 2020, approximately 2000 Ah at the maximum possible beam current in accordance with the planning of the physics runs. (R14.6)

6. Ensure that a power converter trip does not cause the QCS magnets to quench. (R9.1)

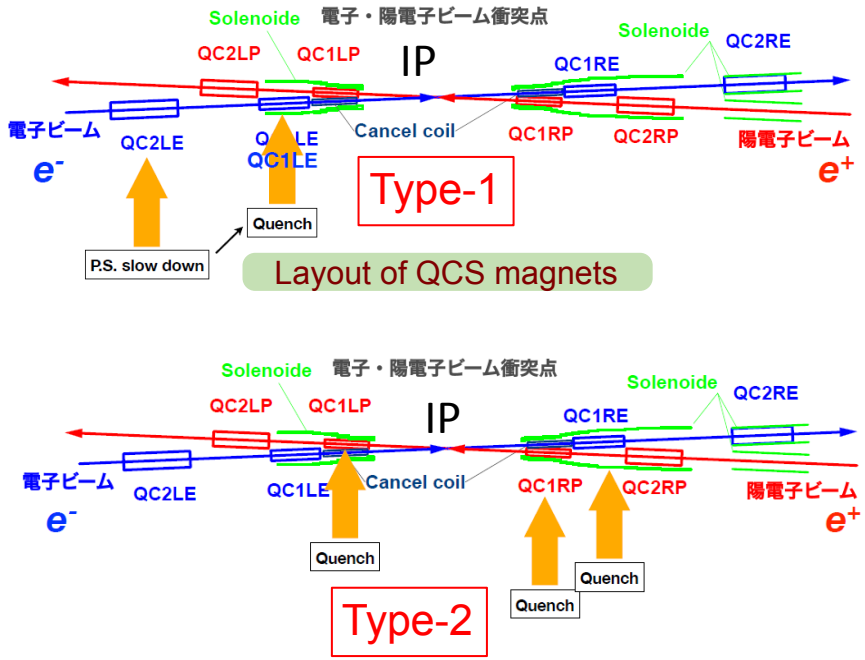
7. Perform a bakeout (T>100°C for several days) of vented vacuum sectors; evaluate the impact of the in-situ bakeout on the mechanical integrity of the vacuum system (vacuum chamber expansion, bellow compressions, fixed points). (R14.1)

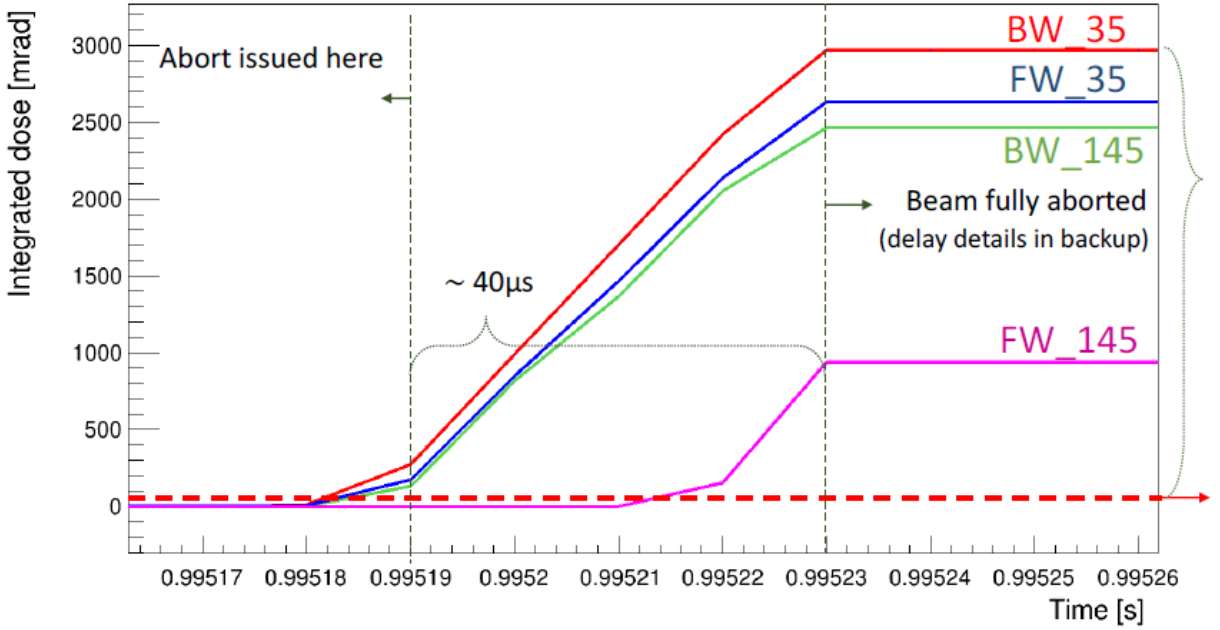
8. Allocate sufficient machine time for increasing the specific luminosity, including tuning the linear, chromatic, and nonlinear IP aberrations of both beams, and for optimizing their offsets, crossing angles, and betatron tunes, in order to increase the beam-beam tune shift and to reduce the vertical emittance blow up. (R5.6)

9. Develop a Crab-Waist lattice to mitigate the beam-beam blowup, even if it may not work with the final design value of β_y^*. DAFNE experience clearly indicates that the Crab-Waist optics can greatly improve the background, in addition to increasing the maximum beam-beam tune shift. (R2.6 and R5.11)

10. Develop a new nomenclature for the names of beam runs, e.g. “Phase 3.14 etc.” or “Run20S”. (R2.7)

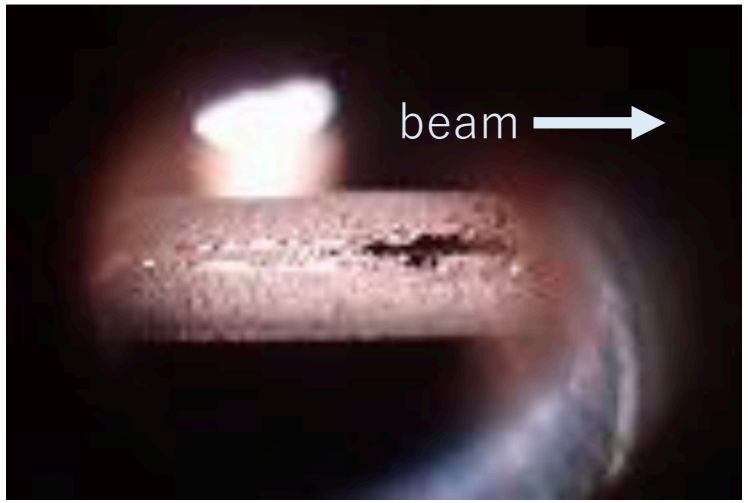
Recent Beam Losses



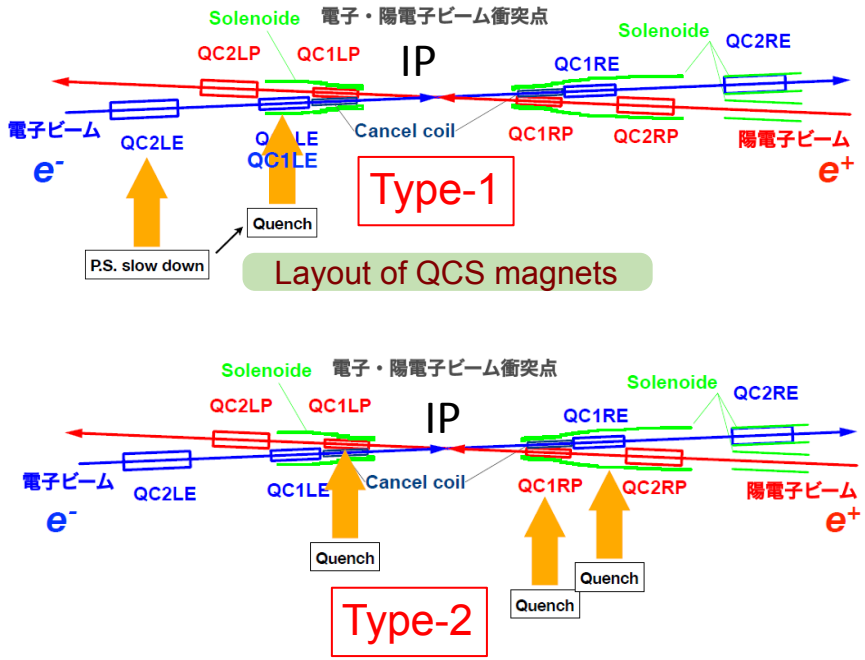


- Implementation of solution proposed by ARC will take ~3 years
- Intermediate solution
  - change collimator heads in LER D06
  - HER less clear since only KEKB type collimators
  - time scale summer shutdown 2020

Photo of a bottom jaw in D02V1 taken from a view port



Recent Beam Losses



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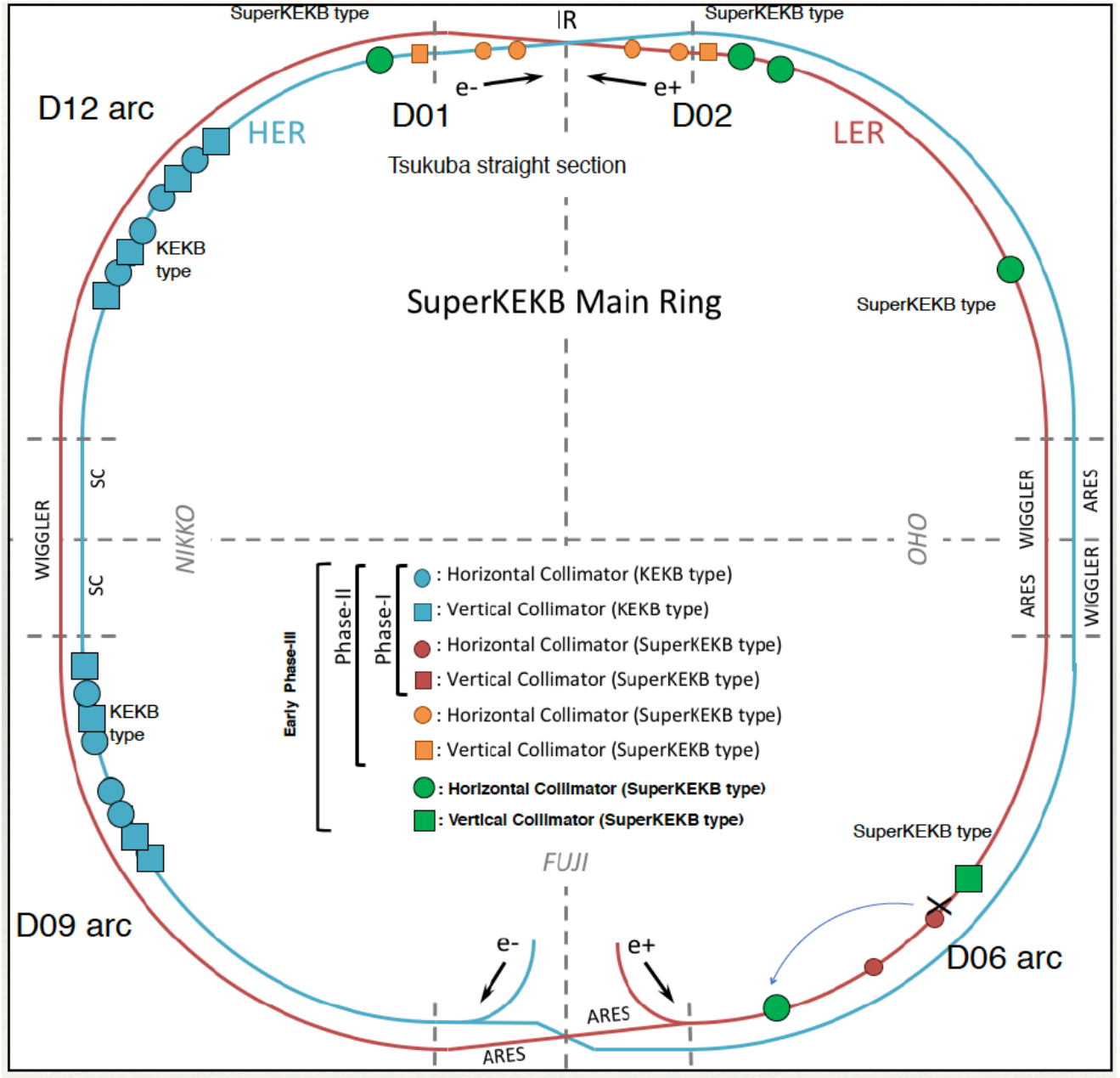
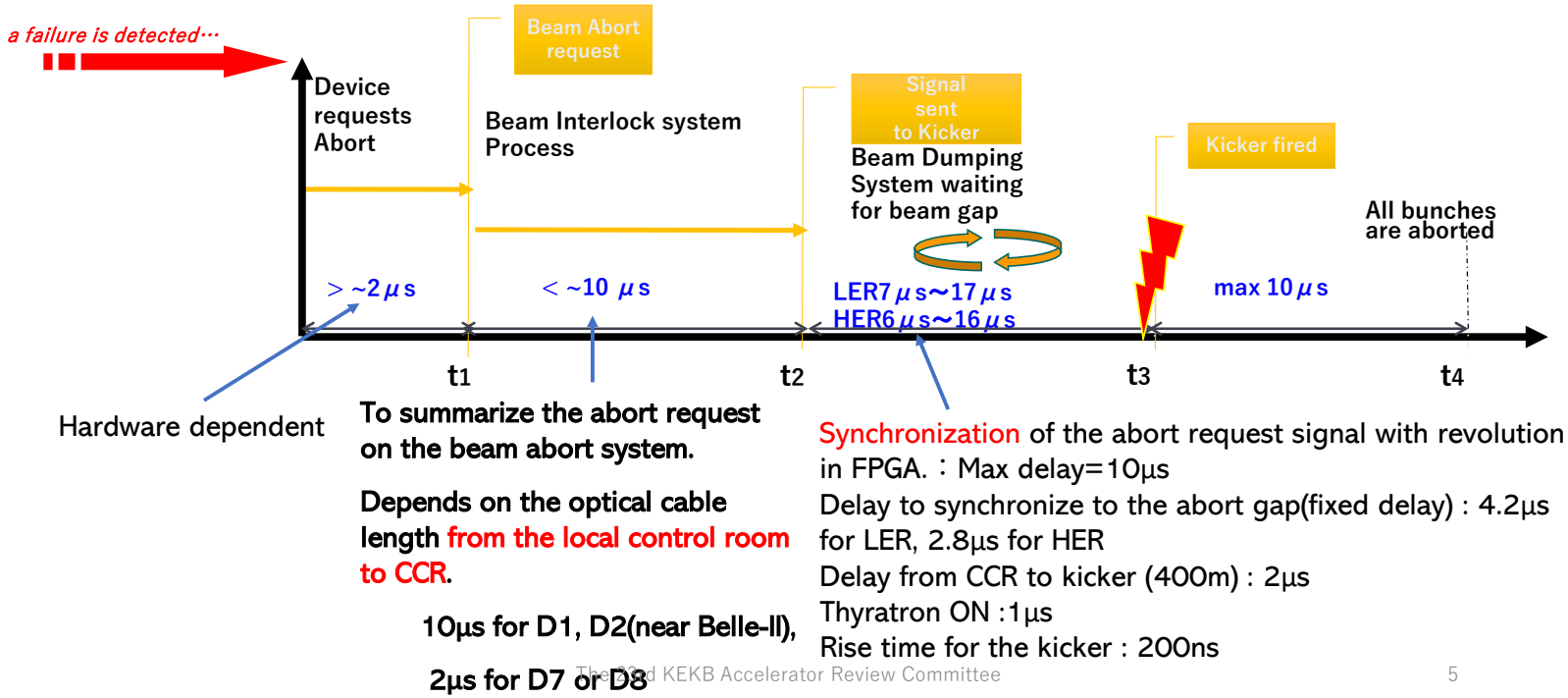


Improvements of Beam Abort Timing



- t1～10μs (Signal reach to I/L level at 2nd turn.)
  - +8μs @ D5F
  - +16μs@D6V2 collimator etc.
- t1→t2～10μs
- t2→t3～7to17μs
- t3→t4～10μs
- Sum=37～47μs

- t1～10μs (Signal reach to I/L level at 2nd turn.) →2 μ s
  - +8μs @ D5F→2 μ s
  - +16μs@D6V2 collimator etc. →2 μ s
- t1→t2～10μs→5 μ s
- t2→t3～7to17 μ s→7～12 μ s
- t3→t4～10 μ s
- Sum=37～47μs→24～29 μ s