



Belle II实验现状和展望

Status and prospects of the Belle II experiment

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第三届BESIII-Belle II-LHCb粲强子联合研讨会



Luminosity frontier: SuperKEKB

- Asymmetric e^+e^- collider
 - $e^+e^- \rightarrow \gamma(4S) \rightarrow B\bar{B}$
 - very clean and well-known initial state

Beam current: KEKB x ~ 1.5

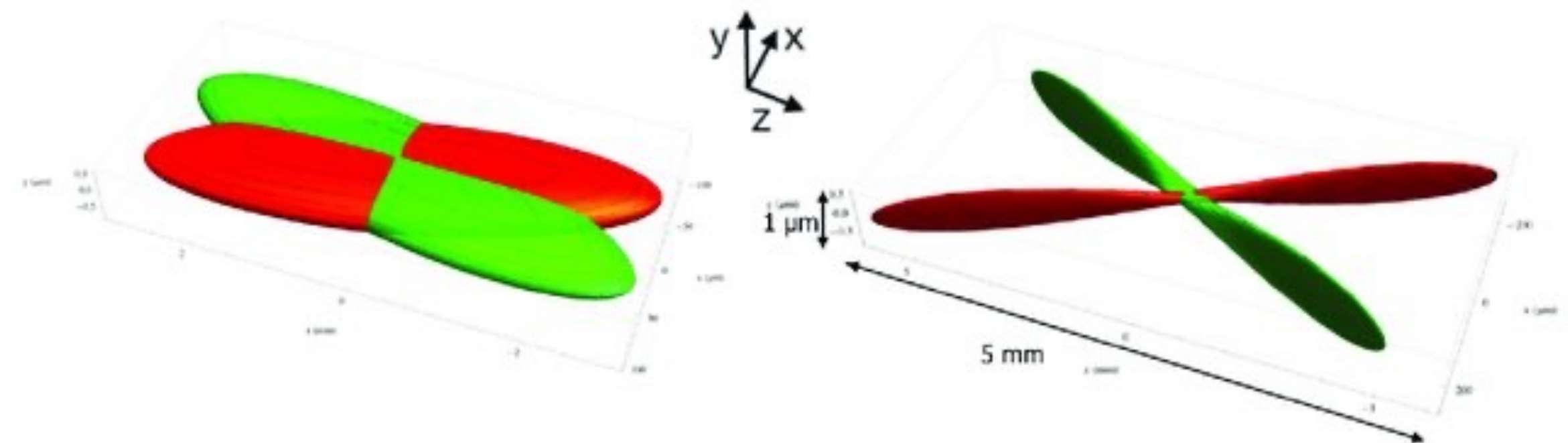
$$L = \frac{\gamma_{\pm}}{2e r_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*}\right) \frac{I_{\pm} \xi_{\pm y}}{\beta_y^*} \left(\frac{R_L}{R_y}\right)$$

Beam squeeze: KEKB / ~ 20

Nano beam scheme

Belle

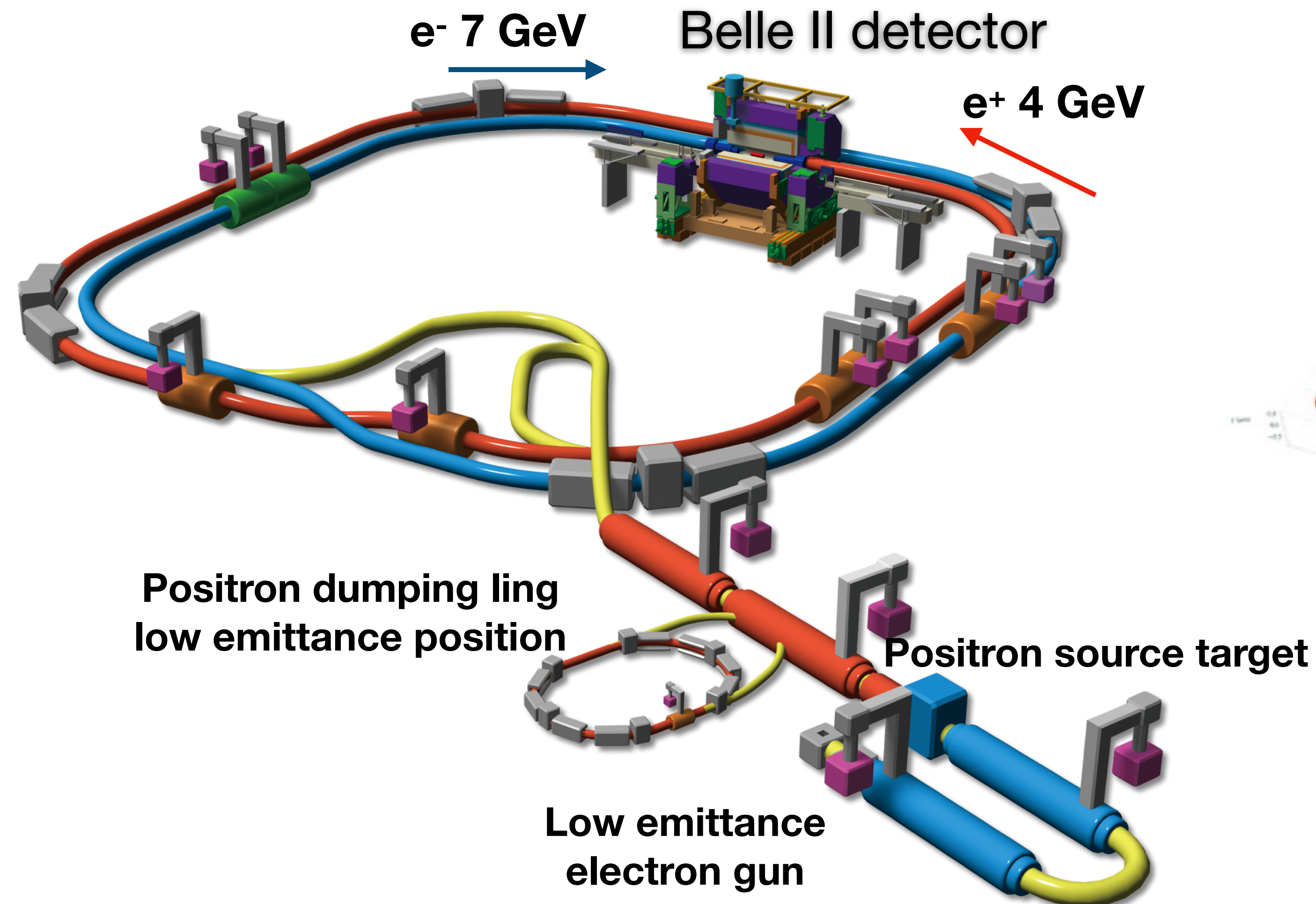
Belle II



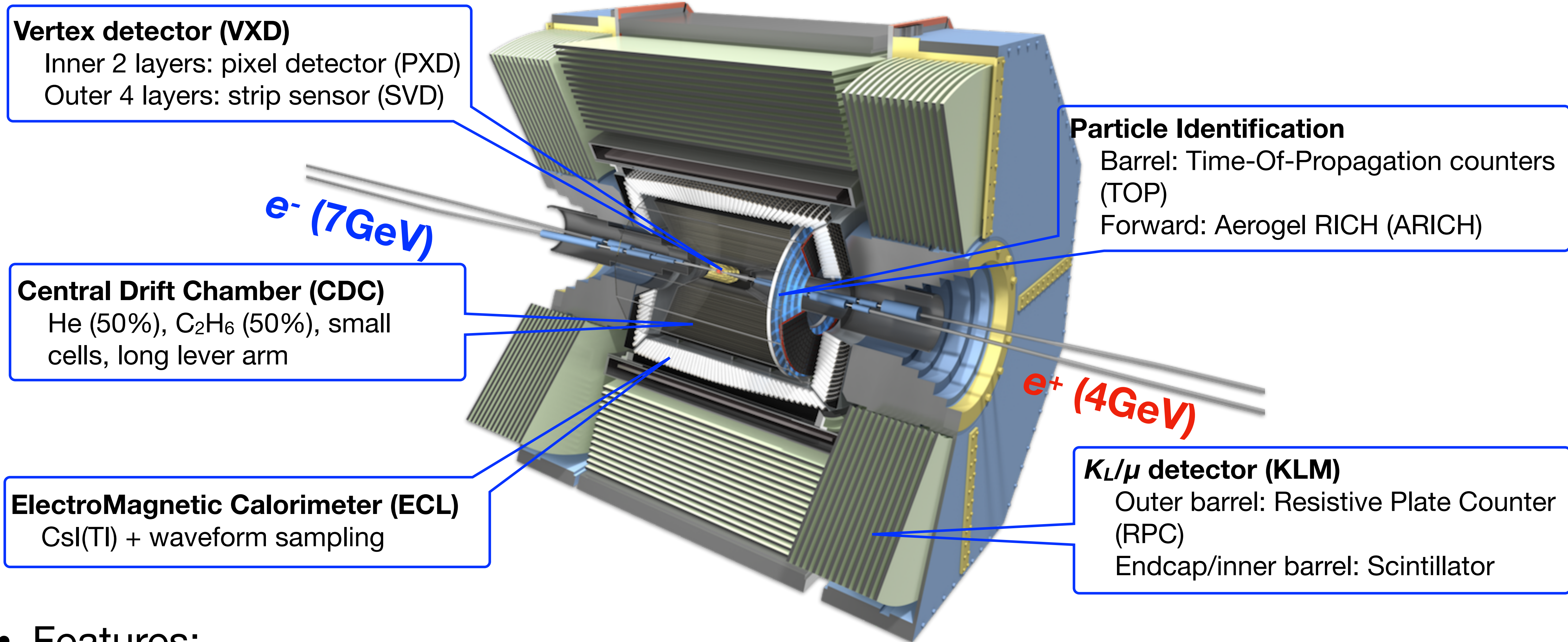
Target: $L = 60 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

Achieved : $5.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ (Record)

KEKB: $2.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

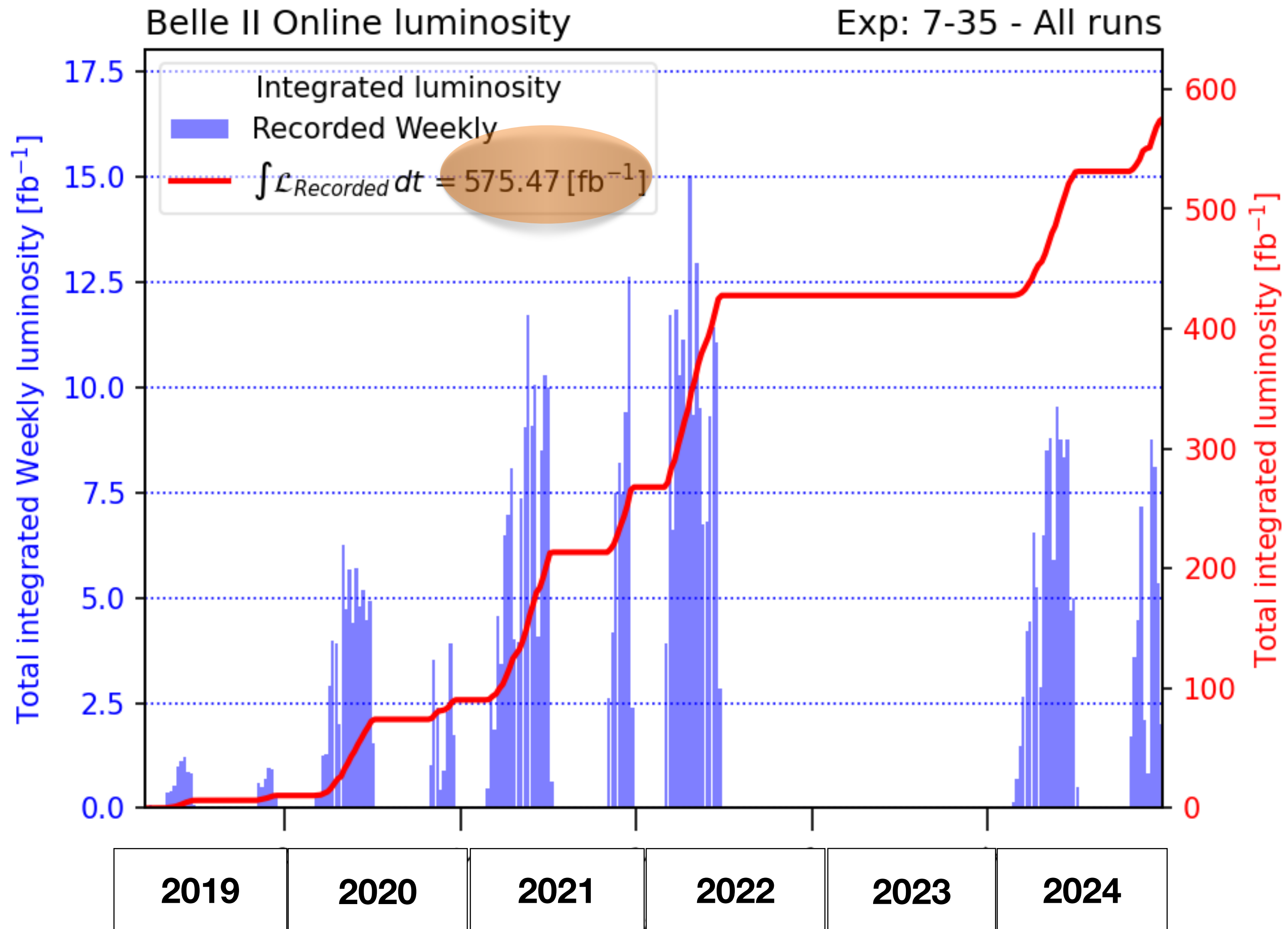


The Belle II detector



- Features:
 - Near-hermetic detector
 - Vertexing and tracking: σ vertex $\sim 15\mu\text{m}$, CDC spatial res. $100\mu\text{m}$ $\sigma(P_T)/P_T \sim 0.4\%$
 - Good at measuring neutrals, π^0 , γ , K_L ... $\sigma(E)/E \sim 2\text{-}4\%$

Data samples



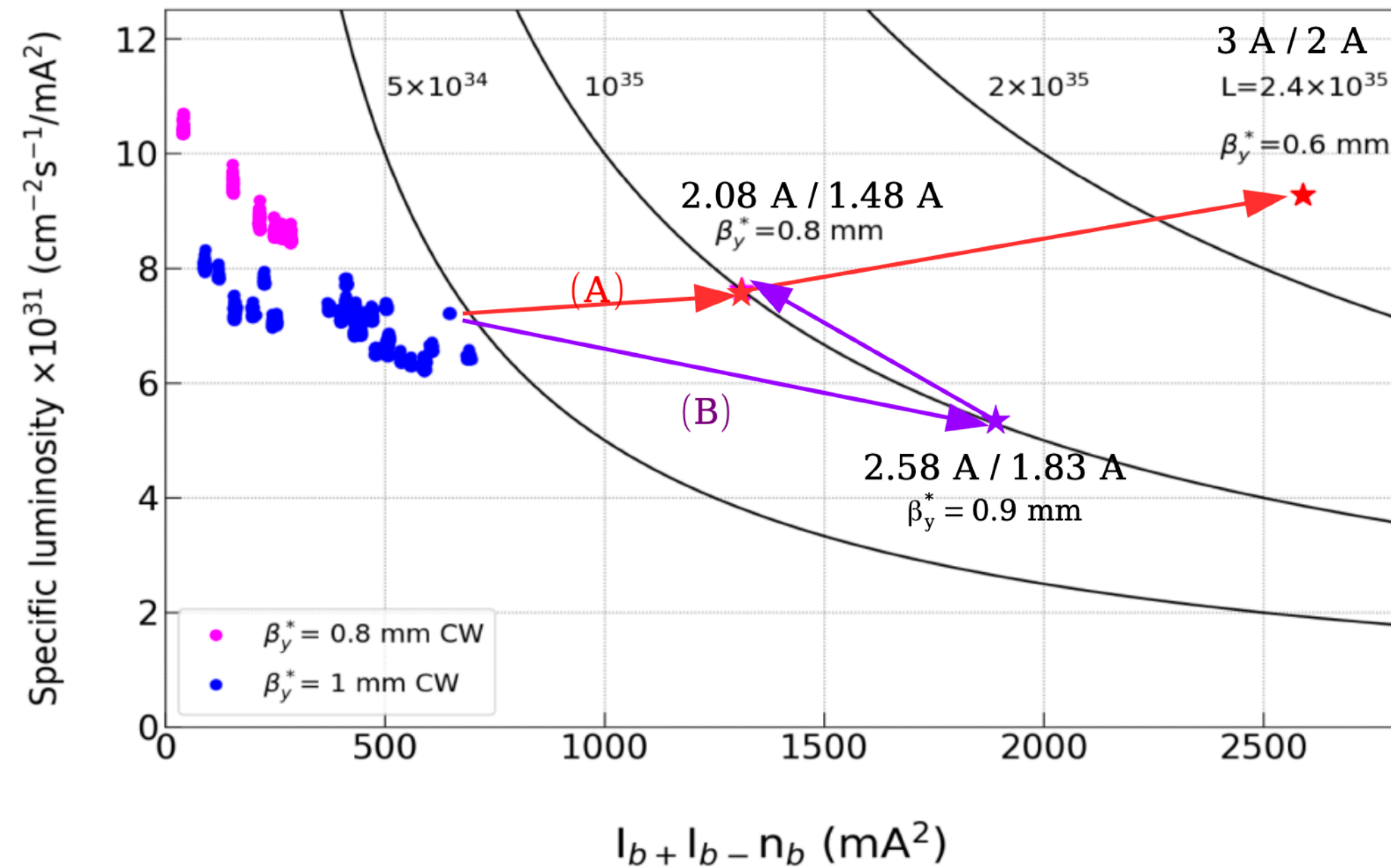
$L = 5.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (World record)

- Dec. 2024
- $I_{\text{LER}} = 1.26\text{A}$, $I_{\text{HER}} = 1.63\text{A}$
- $\beta_y^* = 1\text{mm}$

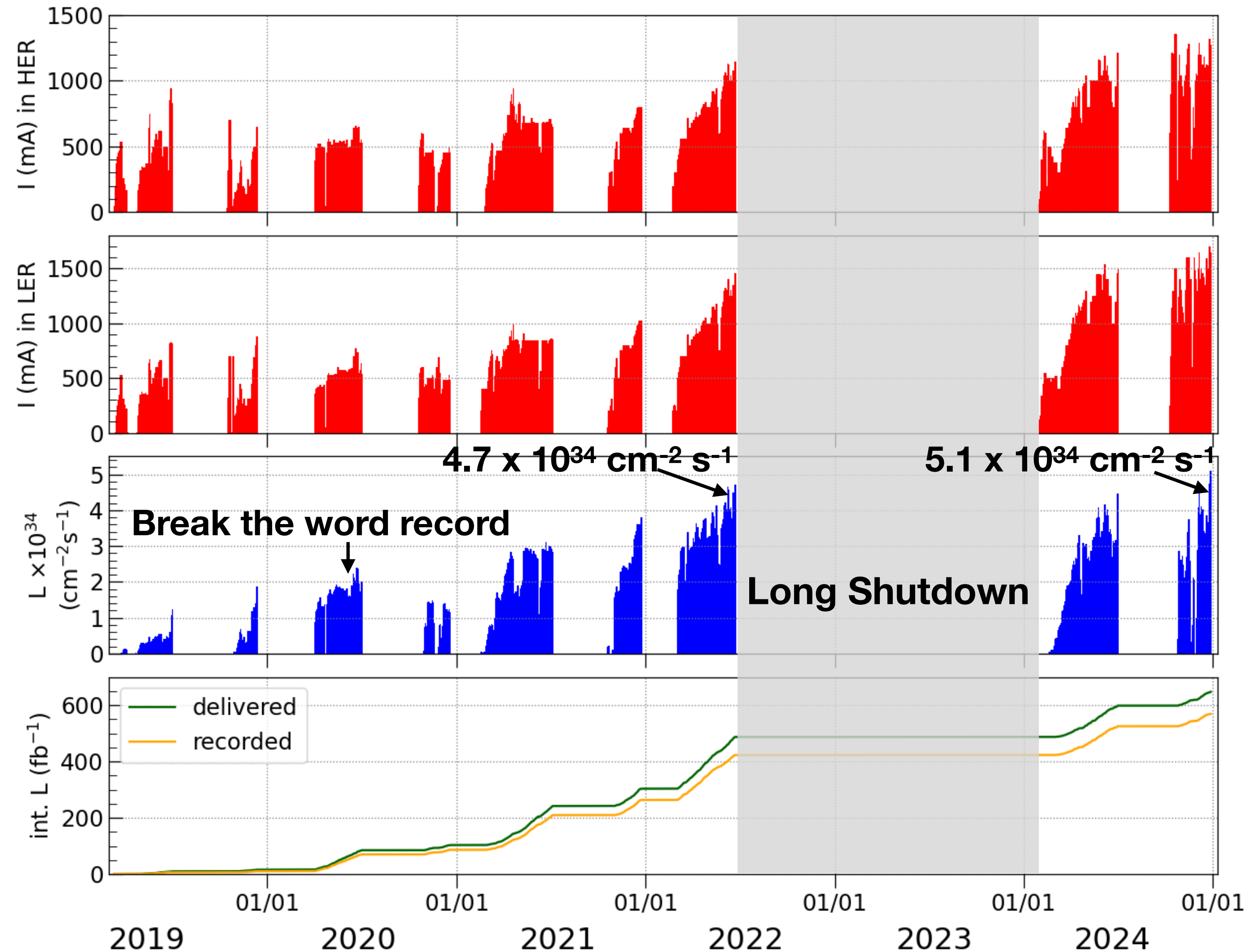
575 fb^{-1} (Belle II)

- Similar to BaBar
- 1000 fb^{-1} (Belle)
- Belle II target 50 ab^{-1}

Path towards higher luminosity

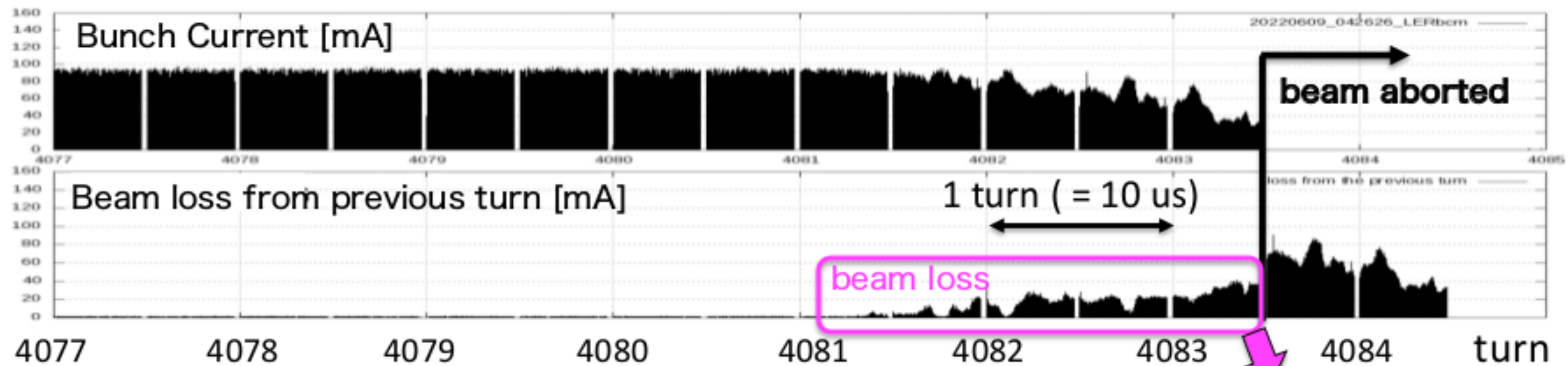


- Two bunch injection
- Squeezing β_y^*
- Mitigation of beam-beam effects



Sudden Beam Loss (SBL)

- SBL can cause QCS (final focusing magnet) quench or damage the detector
Temporary PXD2 off since May 7, 2024 to avoid further damage
- Radiation dose and frequency seem to be proportional to beam current
 - Have to be cautious when increasing currents
- Understanding SBL events and implementing countermeasures crucial to achieve high luminosity



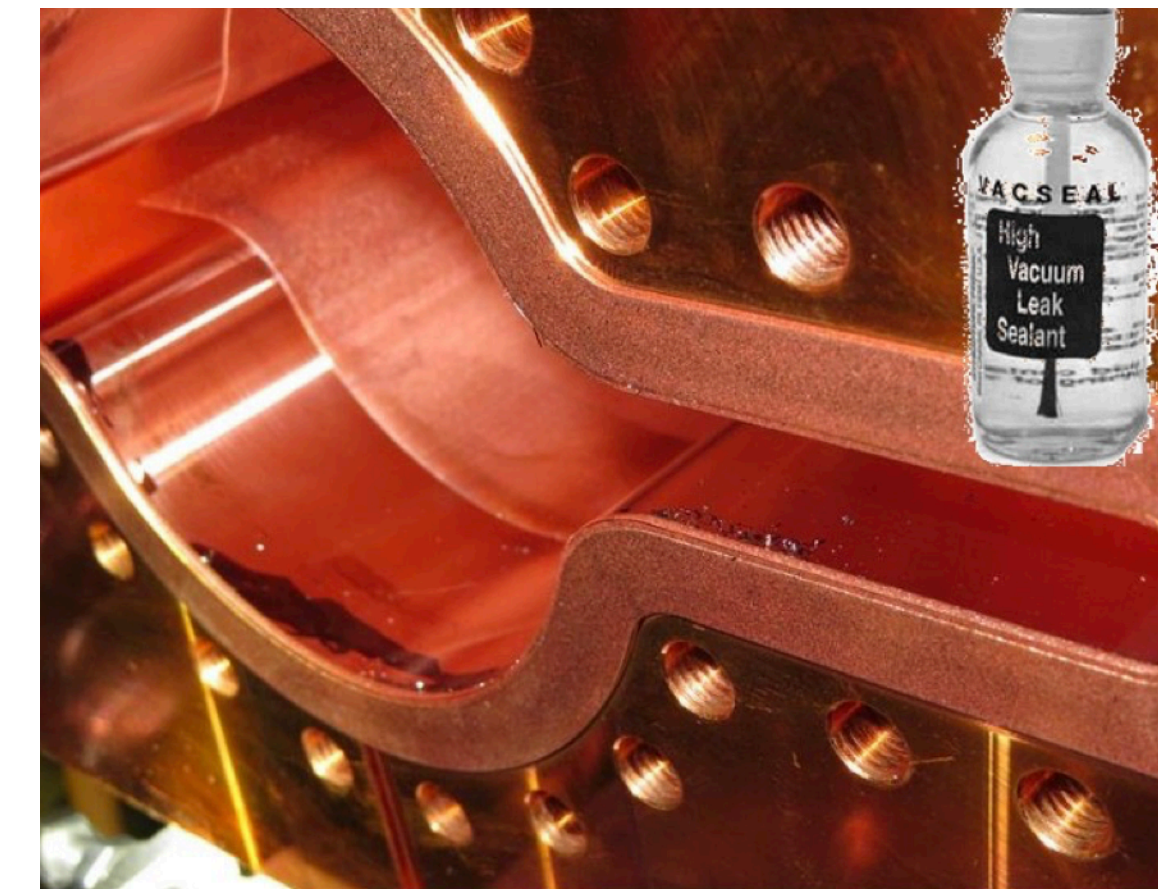
Damaged Belle II detector and accelerator equipment

- Temporary PXD off since May 7 to avoid further damage

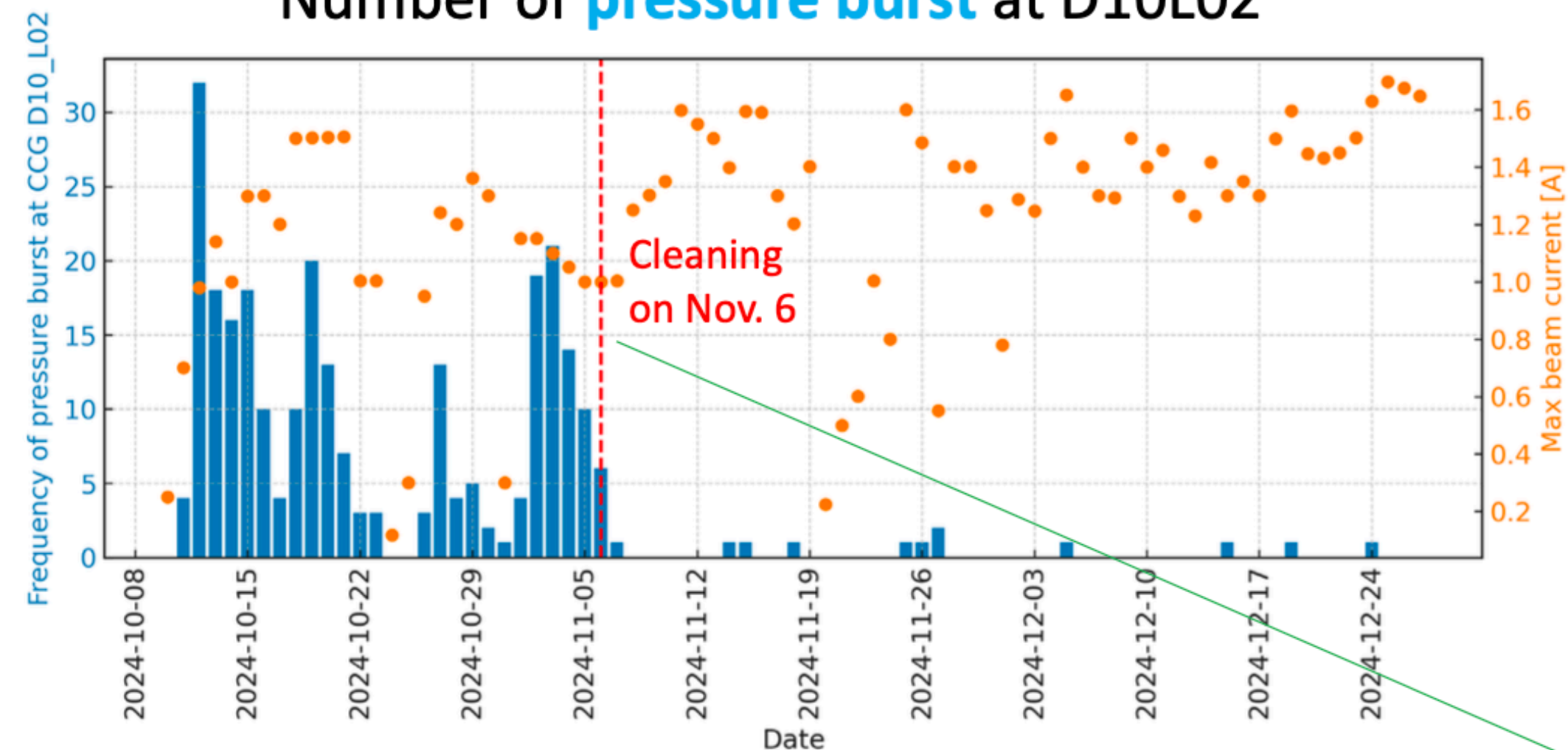


Countermeasure for SBL

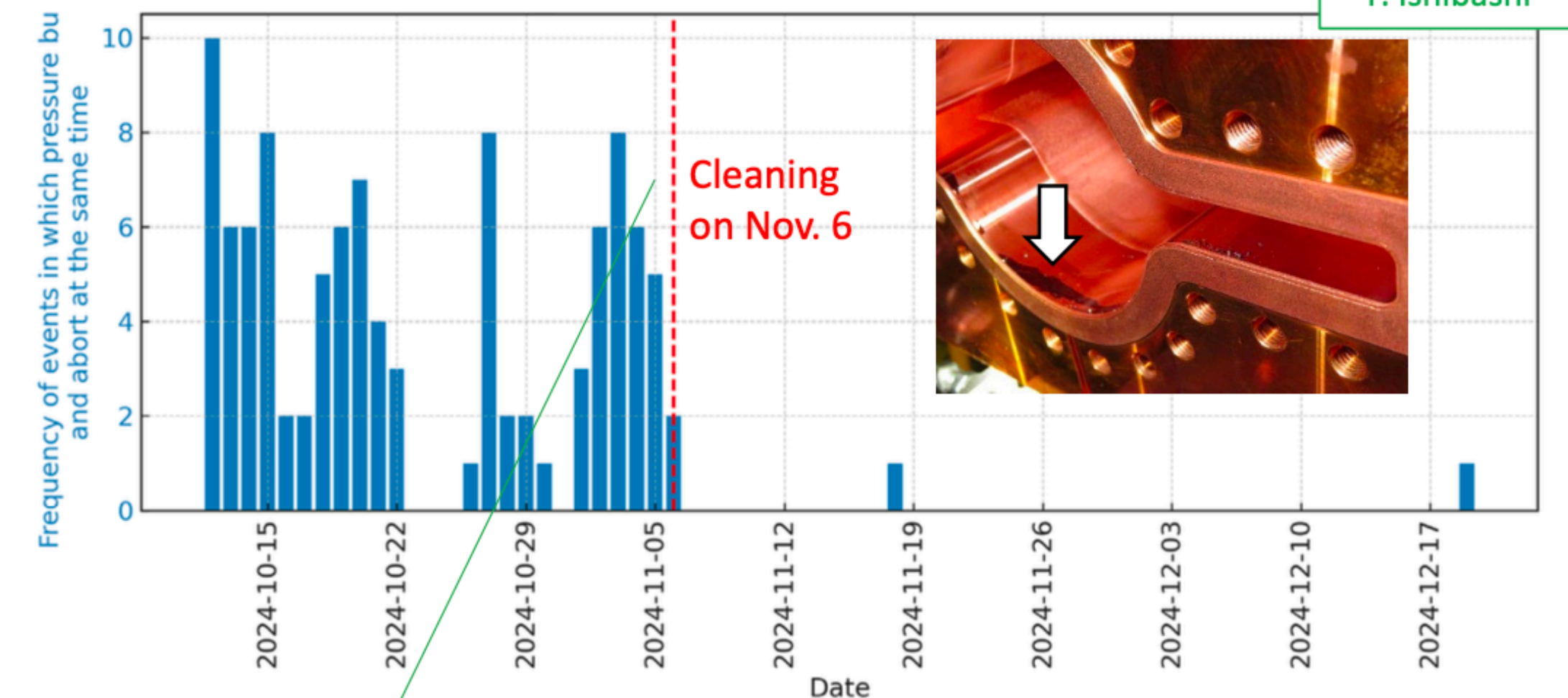
- Removal of black stains due to vecseal, was found to be effective in reducing frequency of pressure burst and SBL event (2025c run)



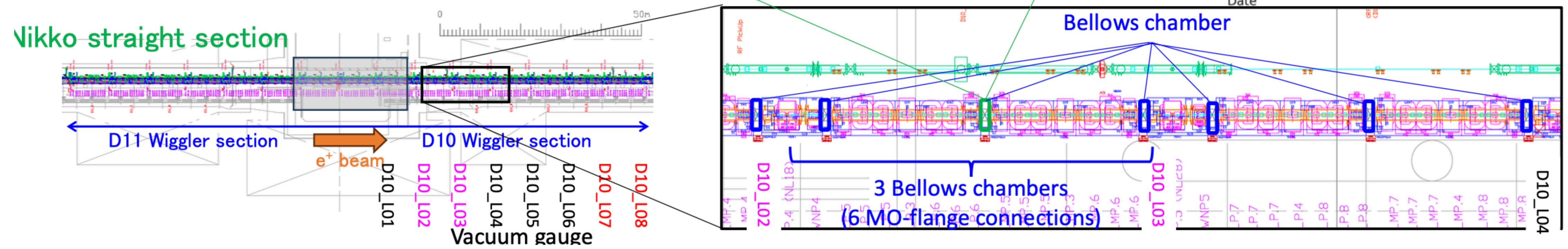
Number of **pressure burst** at D10L02



Number of **beam abort accompanied by pressure burst** at D10L02

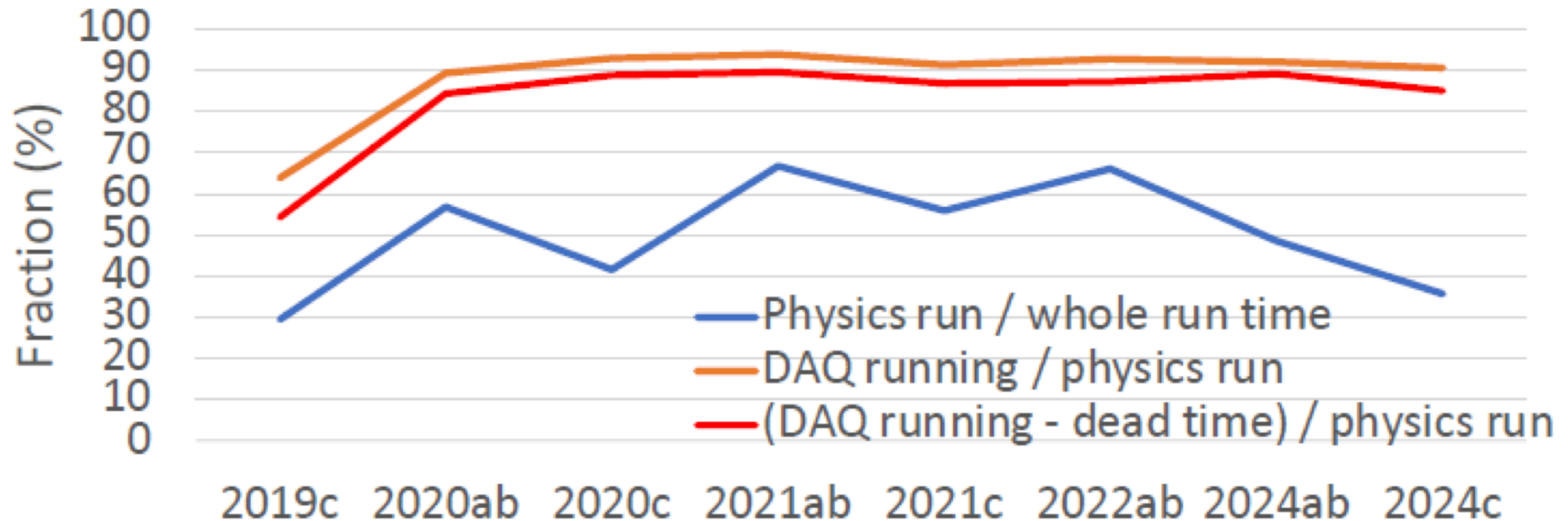


T. Ishibashi



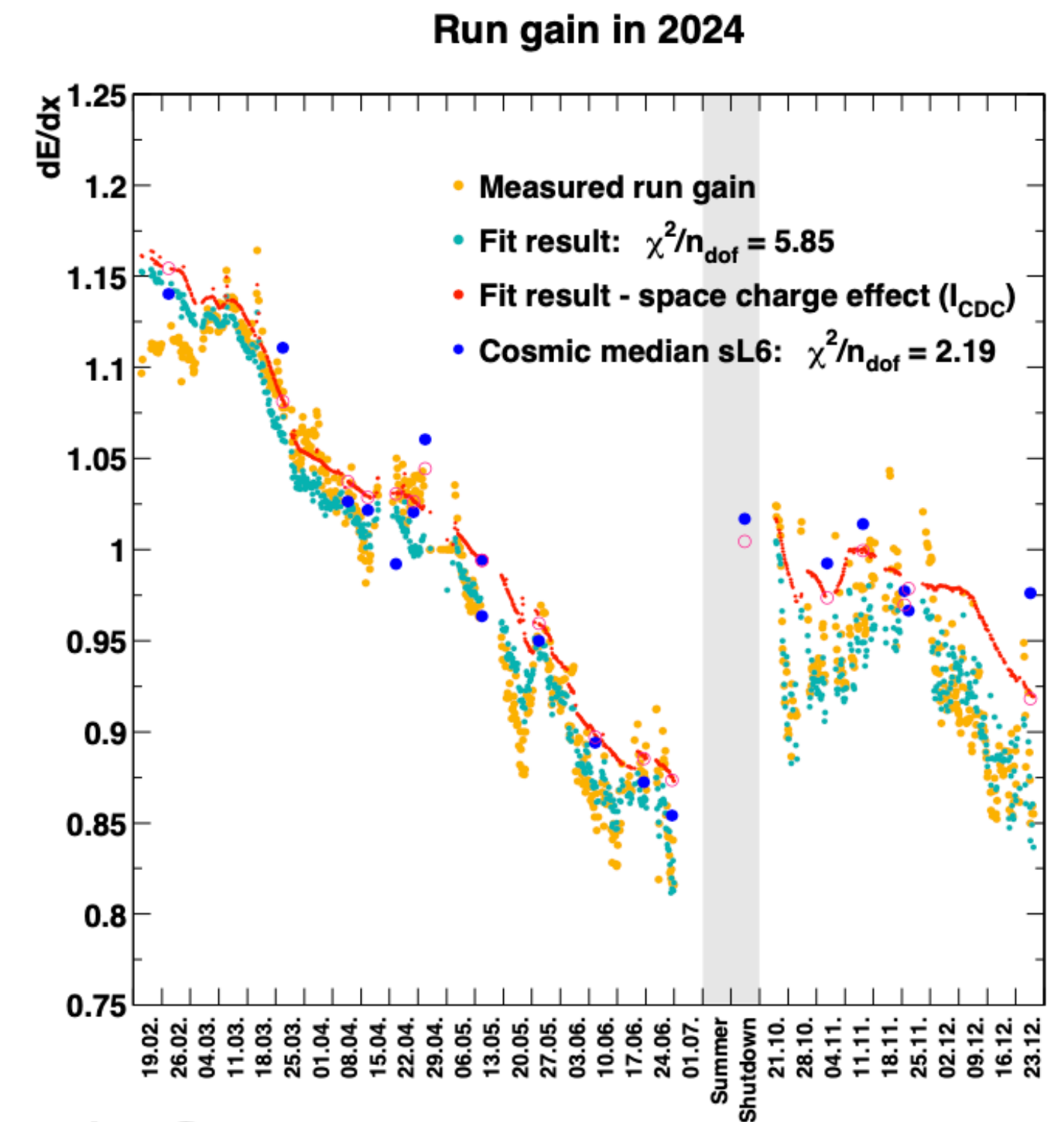
Belle II operation stability

- Belle II is running comparably stable: 85% eff., but raising issues vs. beam background
 - TOP: Frequent b2link errors (b2llost), SEU on Processing System (PS) in front-end
 - CDC: b2tt and b2link errors due to SEU on front-end FPGA
 - SVD: SEU on front-end ASIC (APV25)
 - Injection trigger-veto deadtime



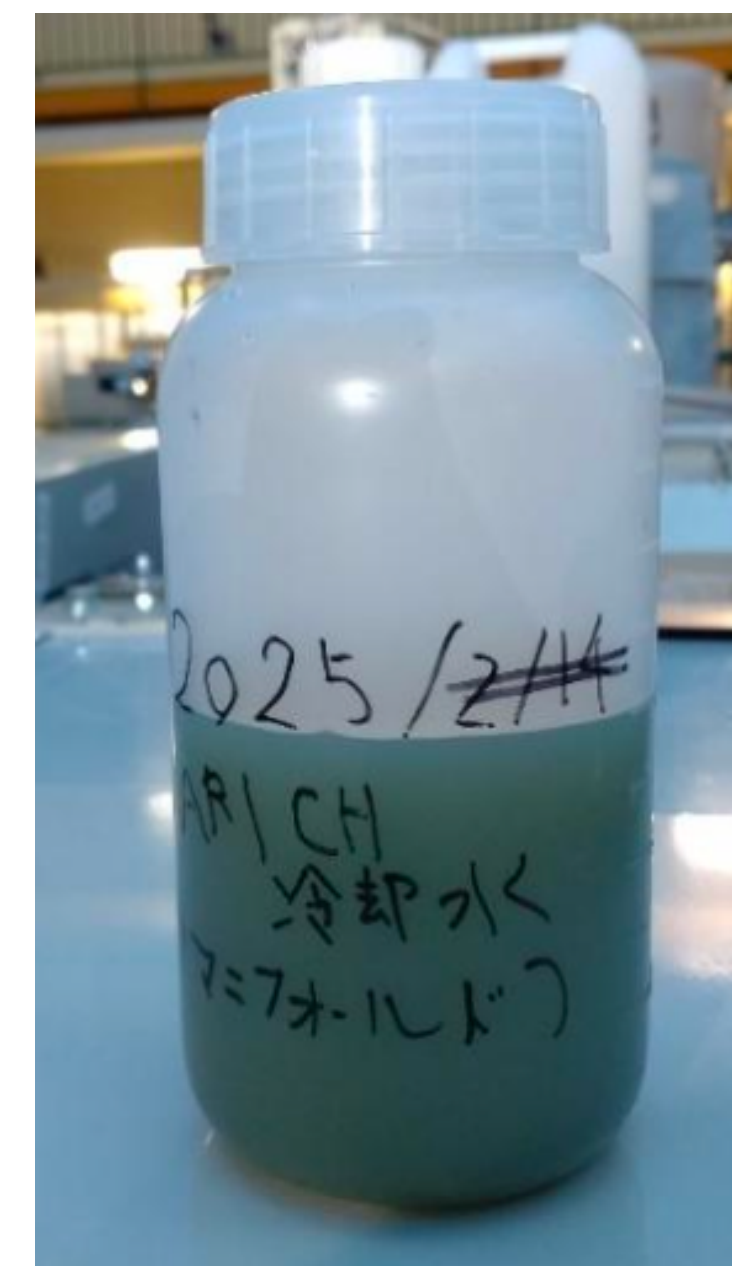
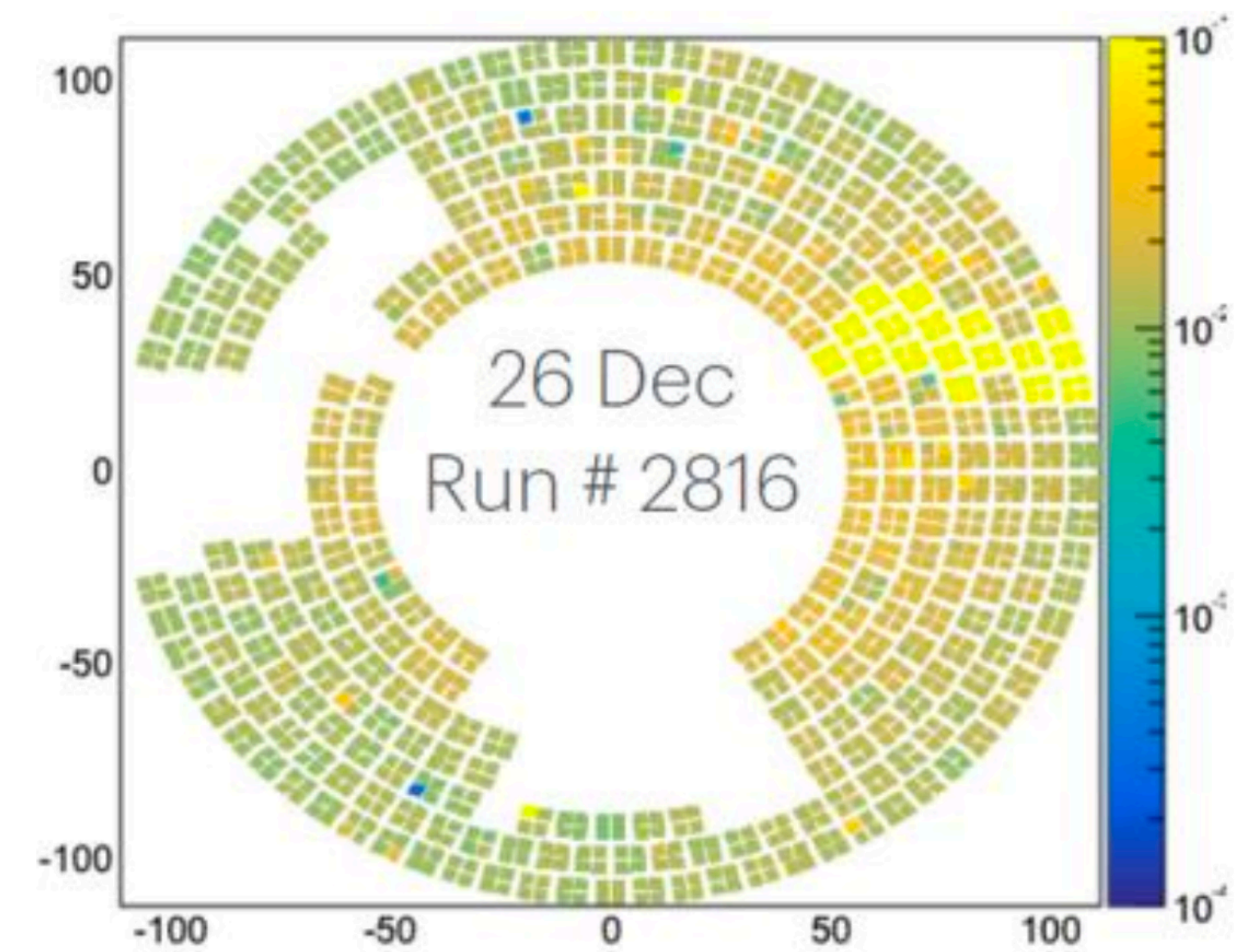
Belle II main issues in 2024c run

- Total PXD kept OFF to protect it from SBL
- ARICH water flow problem (next page)
 - Resulted in about 13% of dead area in ARICH at end of 2024c
- CDC current blow-up
 - Possibly Malter effect, which is an irreversible chamber damage
 - Different O2/H2O condition, lower operation voltage
 - Add O2 / increase fresh gas flow rate
- 5.3% deadtime in overall DAQ running time
- Using the shutdown period effectively, we must address and mitigate these issues as much as possible by the 2025c start.



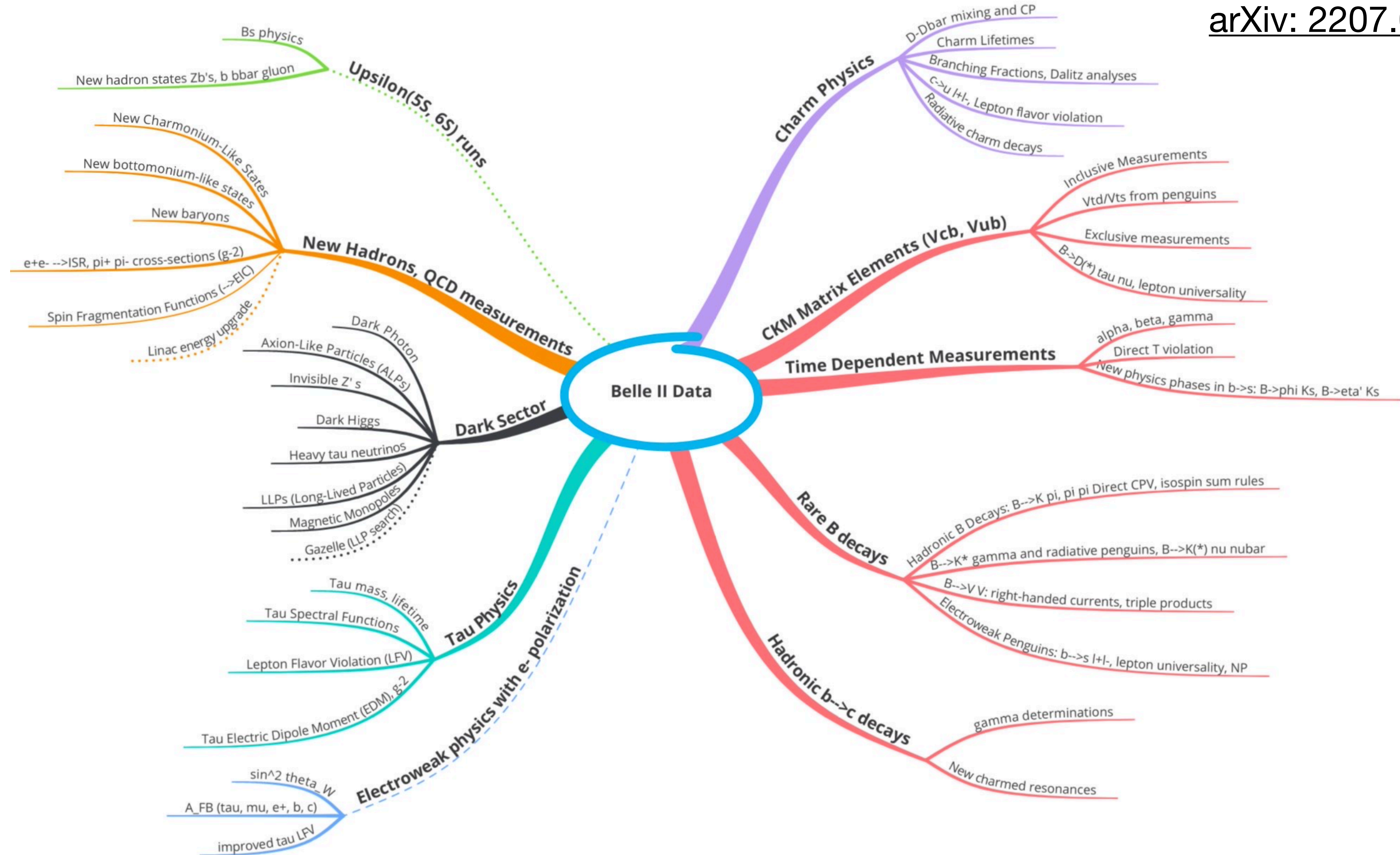
ARICH water flow issue

- ARICH suffered a problem of the cooling water flow in 2024c.
 - The flow was significantly reduced in 2 Sectors,
 - Turn off ~50% of the electronics in these sectors (**10-20%** of the entire ARICH)
- Aluminum pipe is used inside ARICH, while the new chiller includes copper components.
 - Mixture of copper, aluminum, and anti-corrosion
 - Flexible (FEP) tube: outgas from FEP tube due to radiation?
- Pipe near the detector, found green muddy impurities.
 - Probably this solid matter clogged the pipe



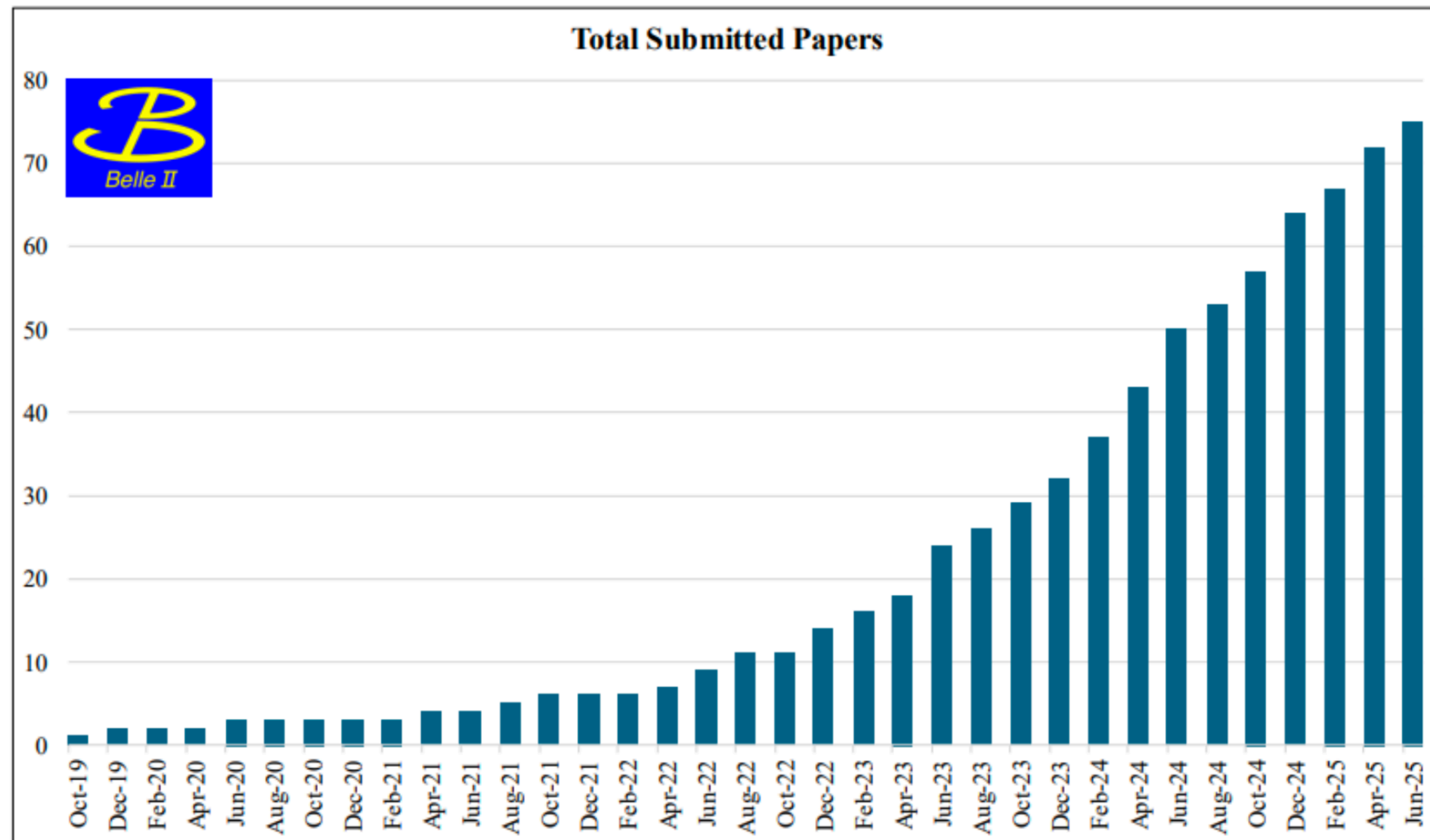
Belle II physics program

[arXiv: 2207.06307](https://arxiv.org/abs/2207.06307)



Physics output

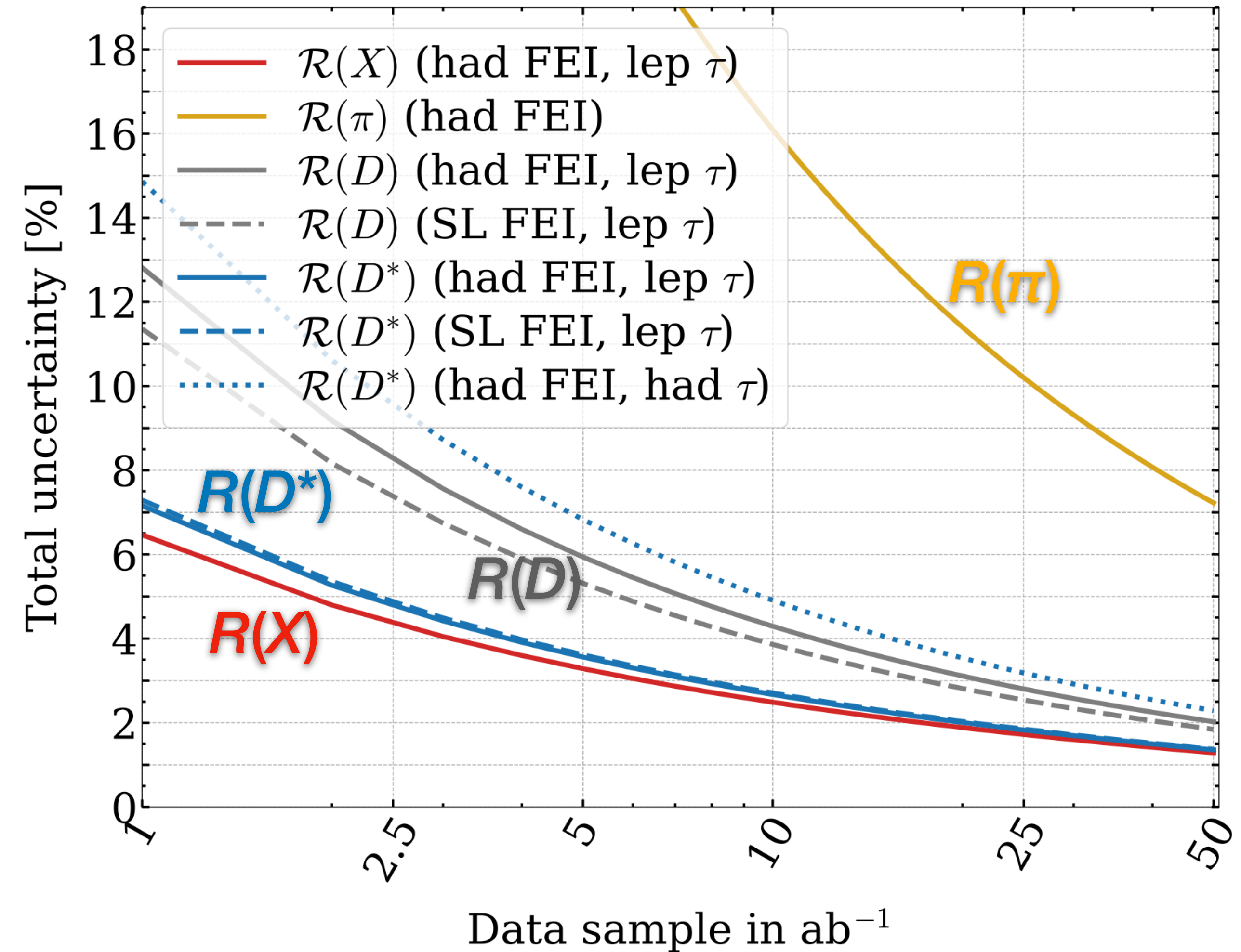
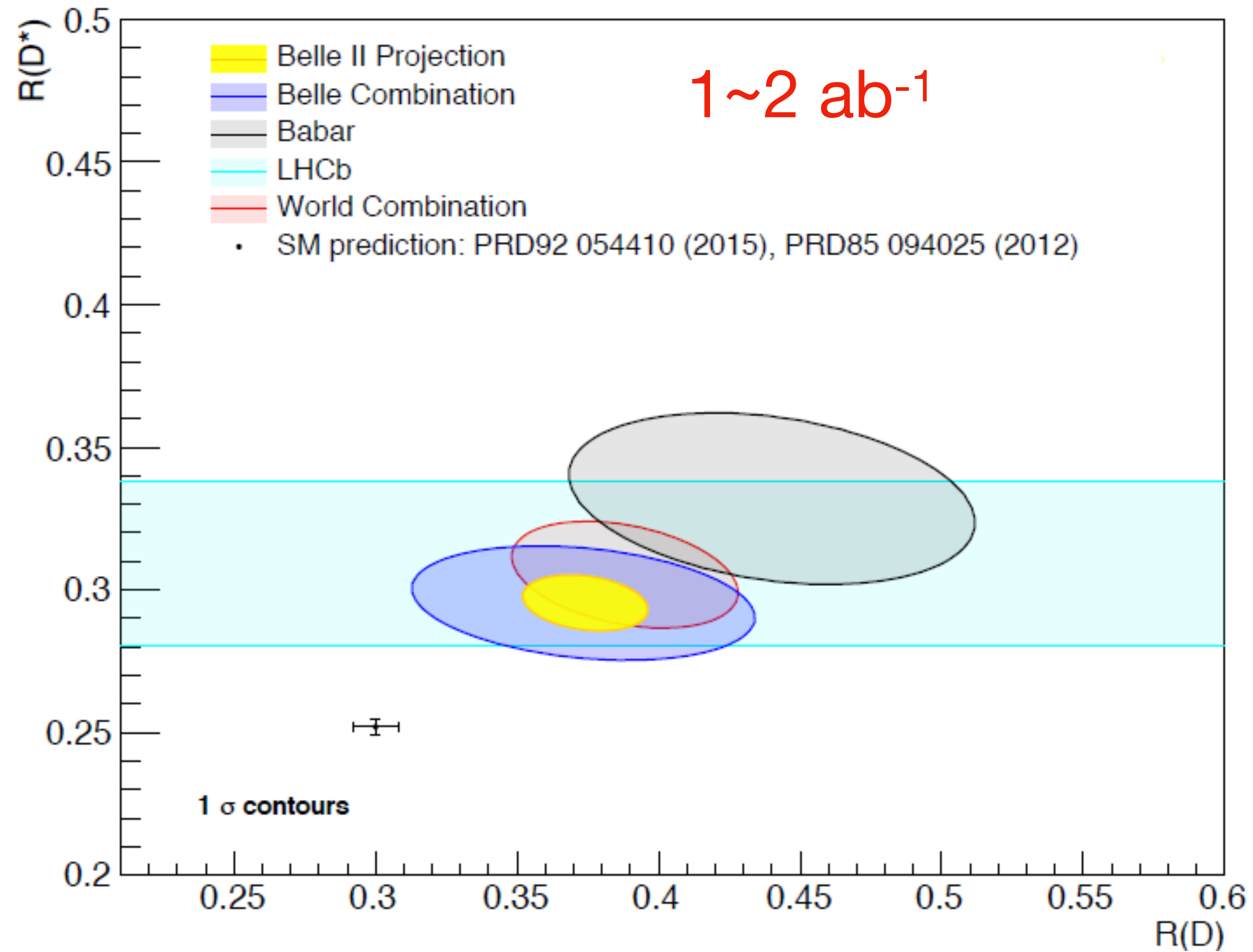
- Total of 76 submissions
 - 65 are accepted
- We have 10 preliminary results preparing for submission
- ~30 papers submitted in the last year



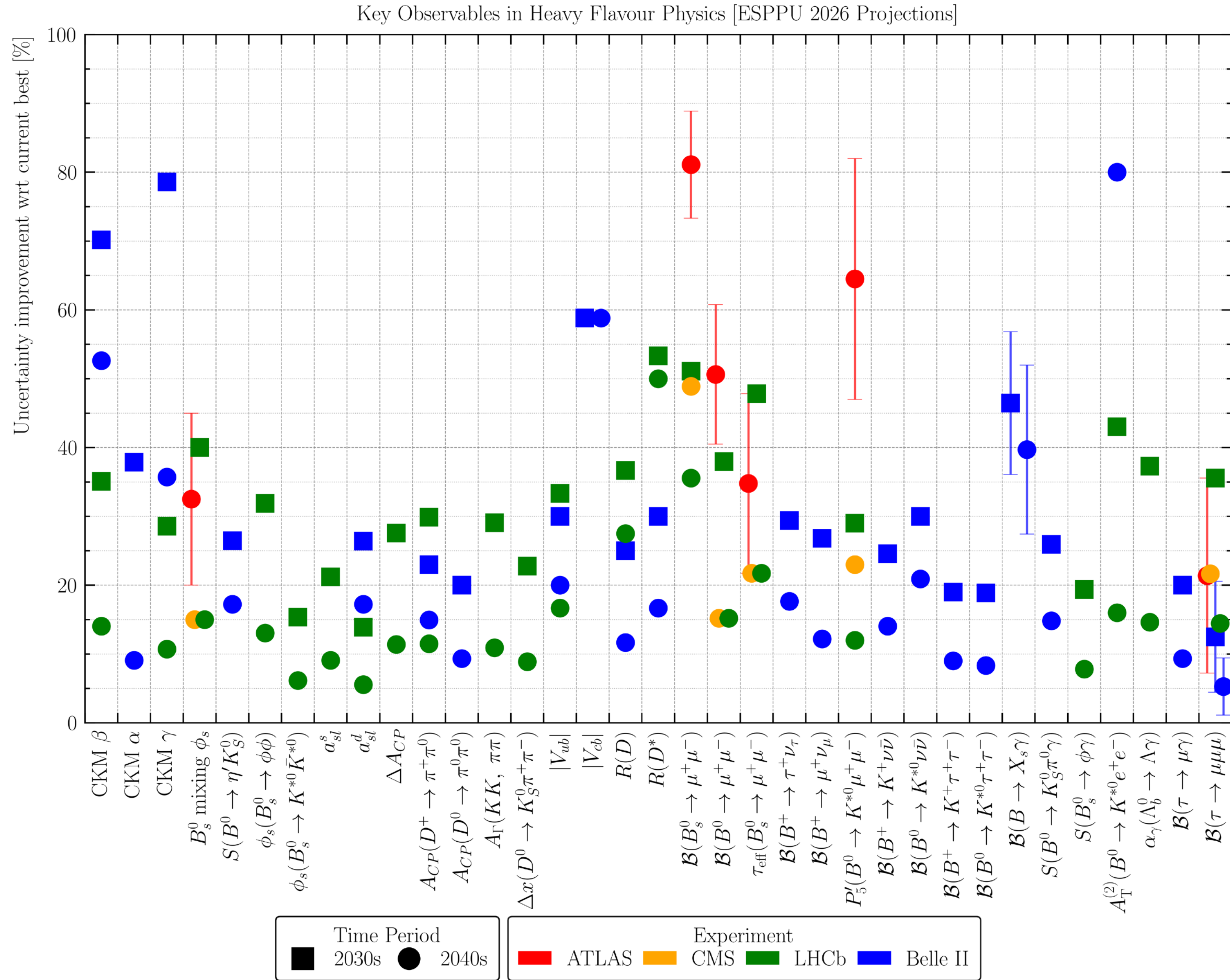
Expected sensitivity of LFU test at Belle II

The Belle II Physics Book, PTEP 2019, 123C01

arXiv:2207.06307



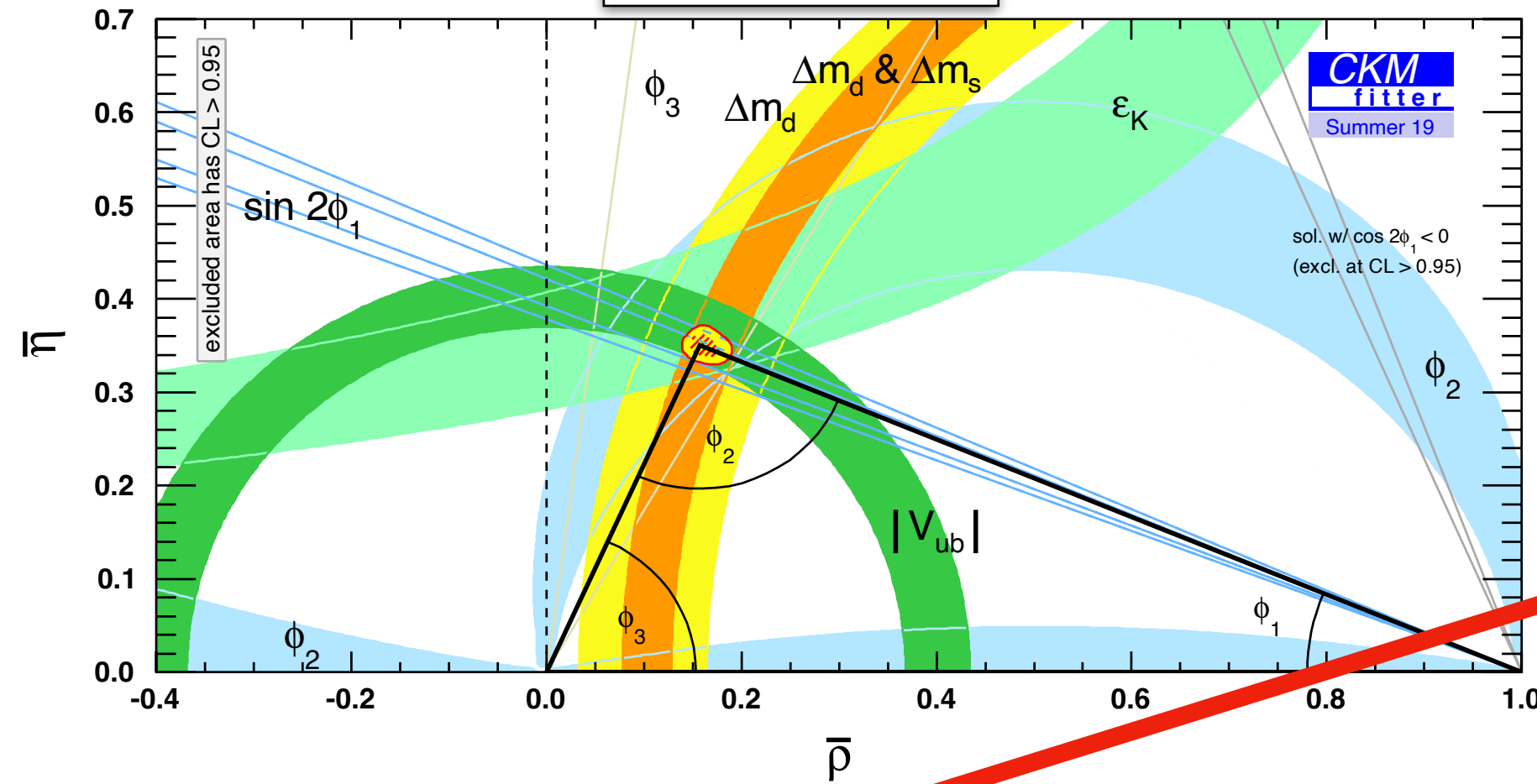
Projections of key observables



Unitarity Triangle fit extrapolation

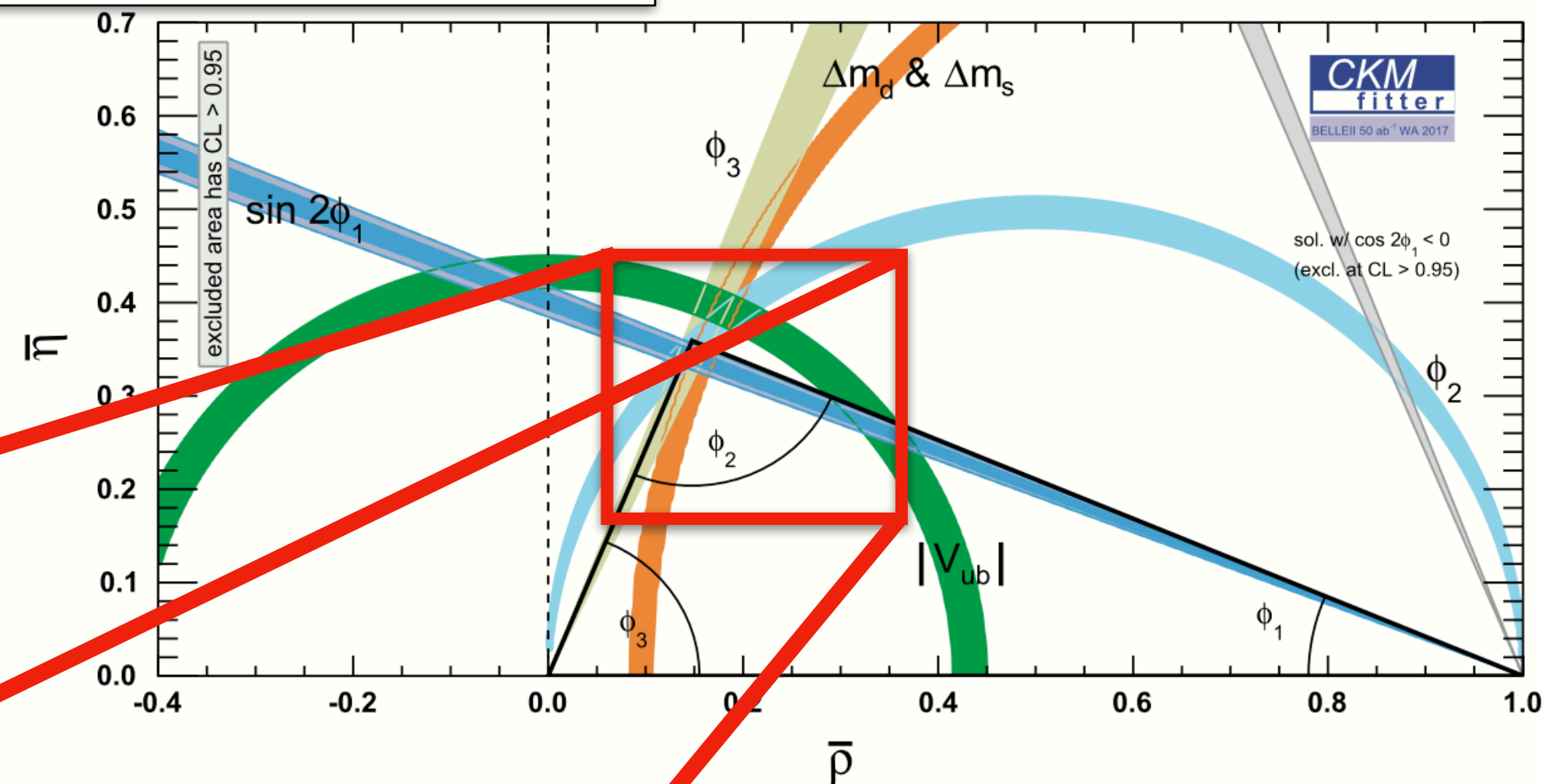
The Belle II Physics Book, PTEP 2019, 123C01

Current

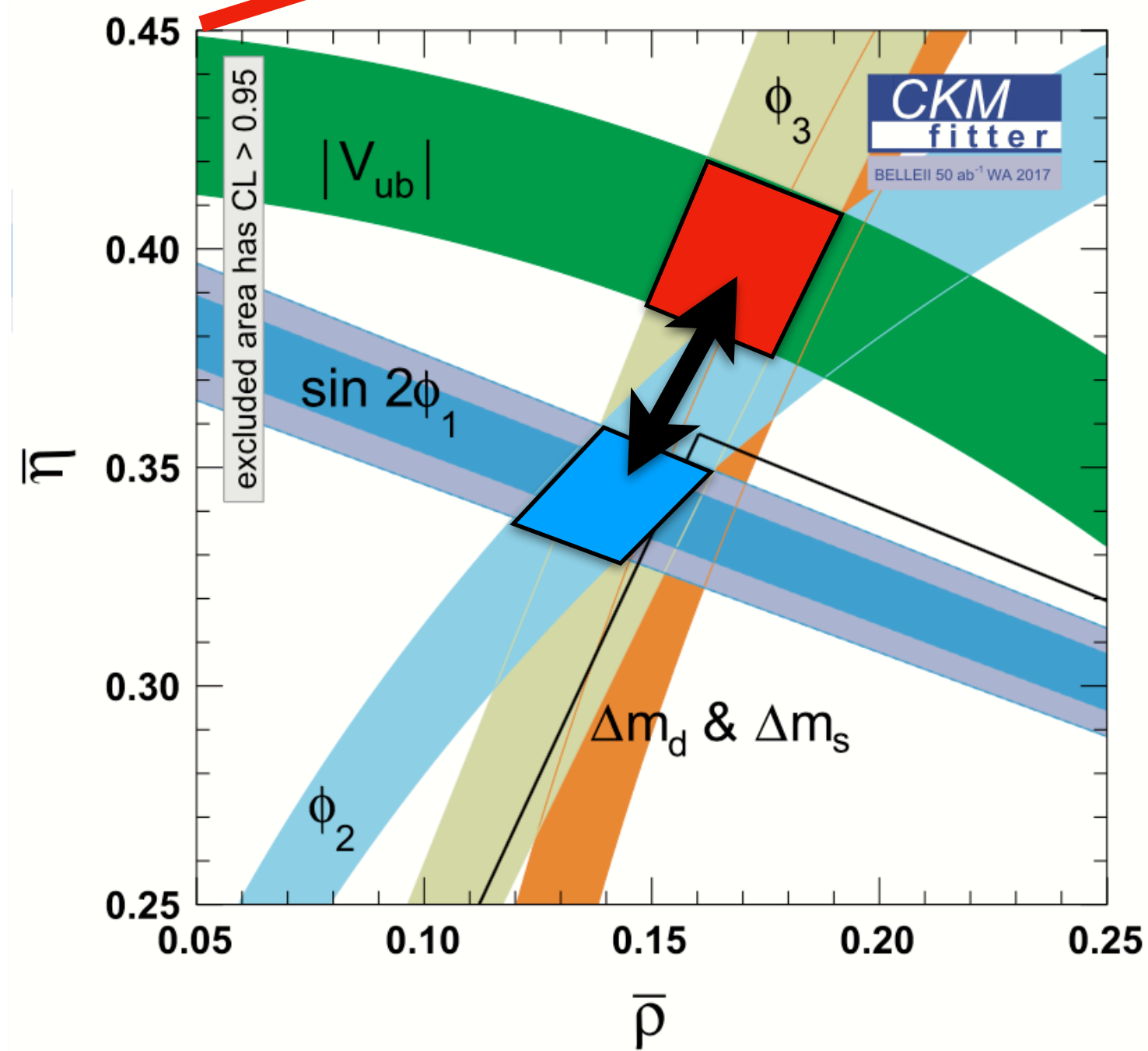


Belle II 50 ab^{-1}

If the current World Average hold



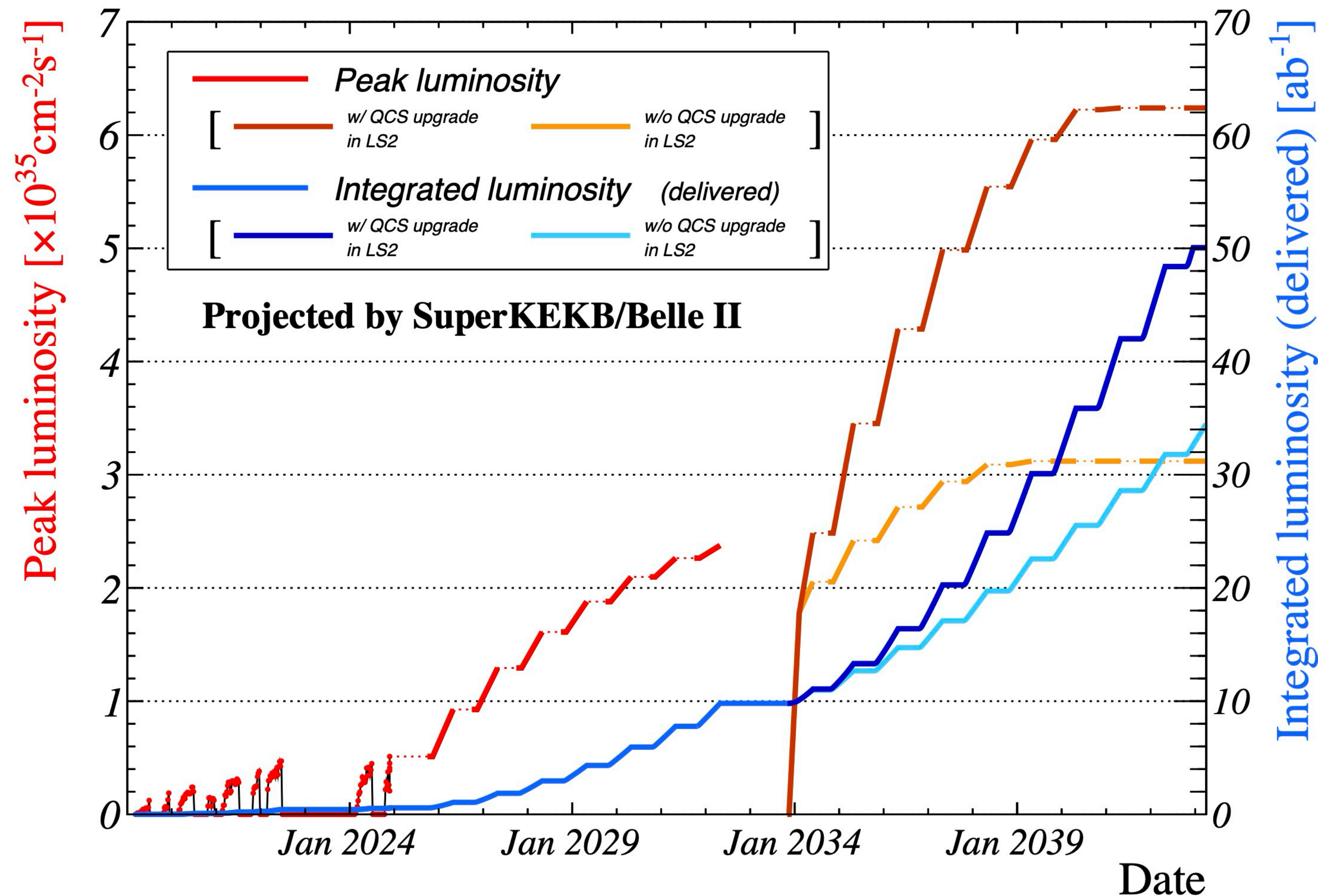
Zoom



- Tensions existed on V_{ub} and ϕ_1
 - UT can not close if keeping the central value for 50 ab^{-1}
- Differences between UT determined by **tree** (V_{ub} , ϕ_3) and **loop** (ϕ_1 , ϕ_2) can be discriminated with 50 ab^{-1} data-set

Luminosity projection

- Until 2026, accumulate 1 ab⁻¹ data, luminosity->1 x 10³⁵ cm⁻² s⁻¹
 - Comparable to Belle
- Until 2029, about 4 ab⁻¹ data



Summary and prospects

- SuperKEKB achieved new luminosity world record $5.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- Belle II accumulated 575 fb^{-1} data
- SBL has been a main issue for increasing luminosity
 - VECSEAL is most probability the main issue of SBL
- Belle II is running stable, but issues remain concerns
 - Detector stability vs. beam background
 - ARICH water flow issue
 - CDC performance degradation
- 76 results has been published at Belle II, on a increasing momentum
- Until 2026, accumulate 1 ab^{-1} data, luminosity- $\rightarrow 1 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
- Towards 50 ab^{-1} , need a large upgrade both accelerator and Belle II detector

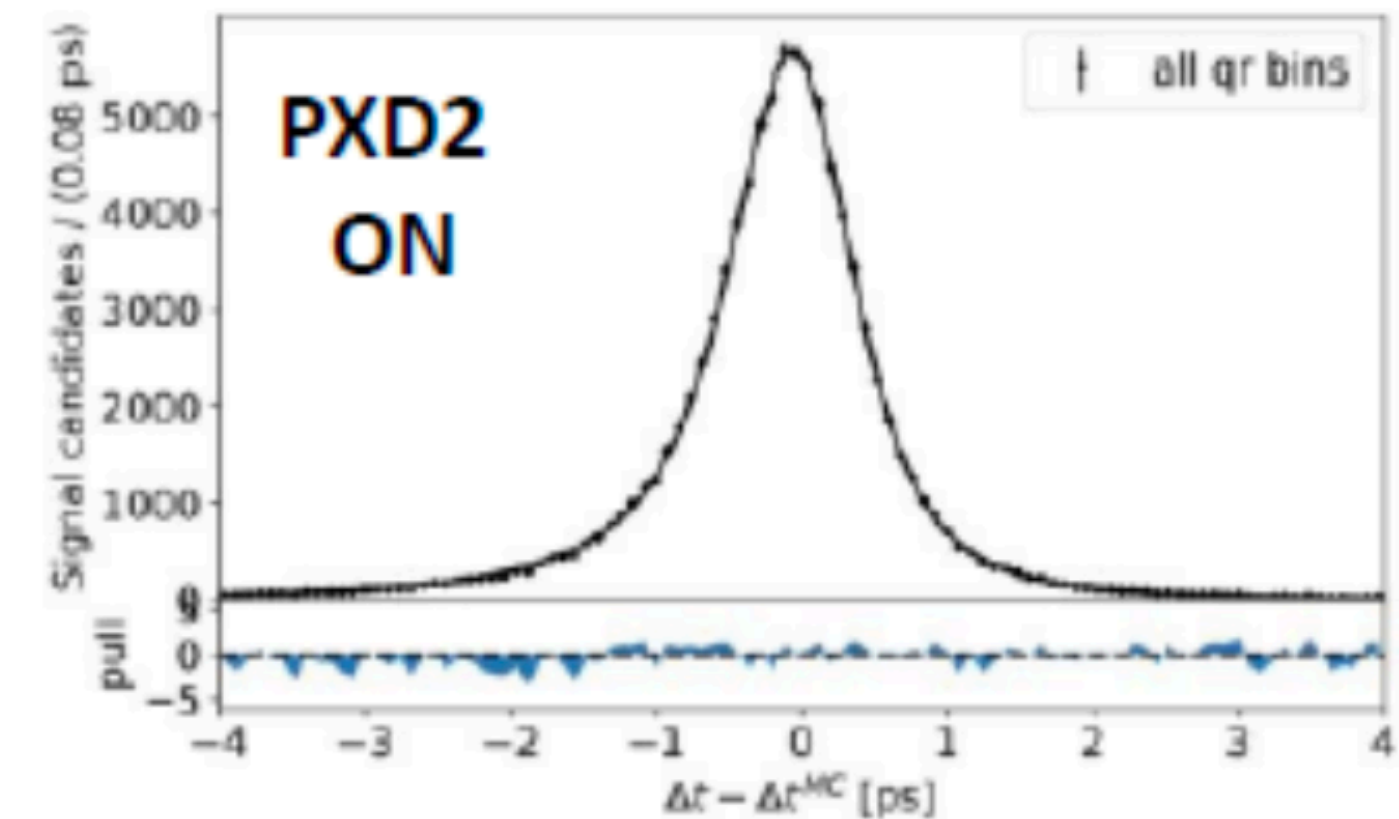
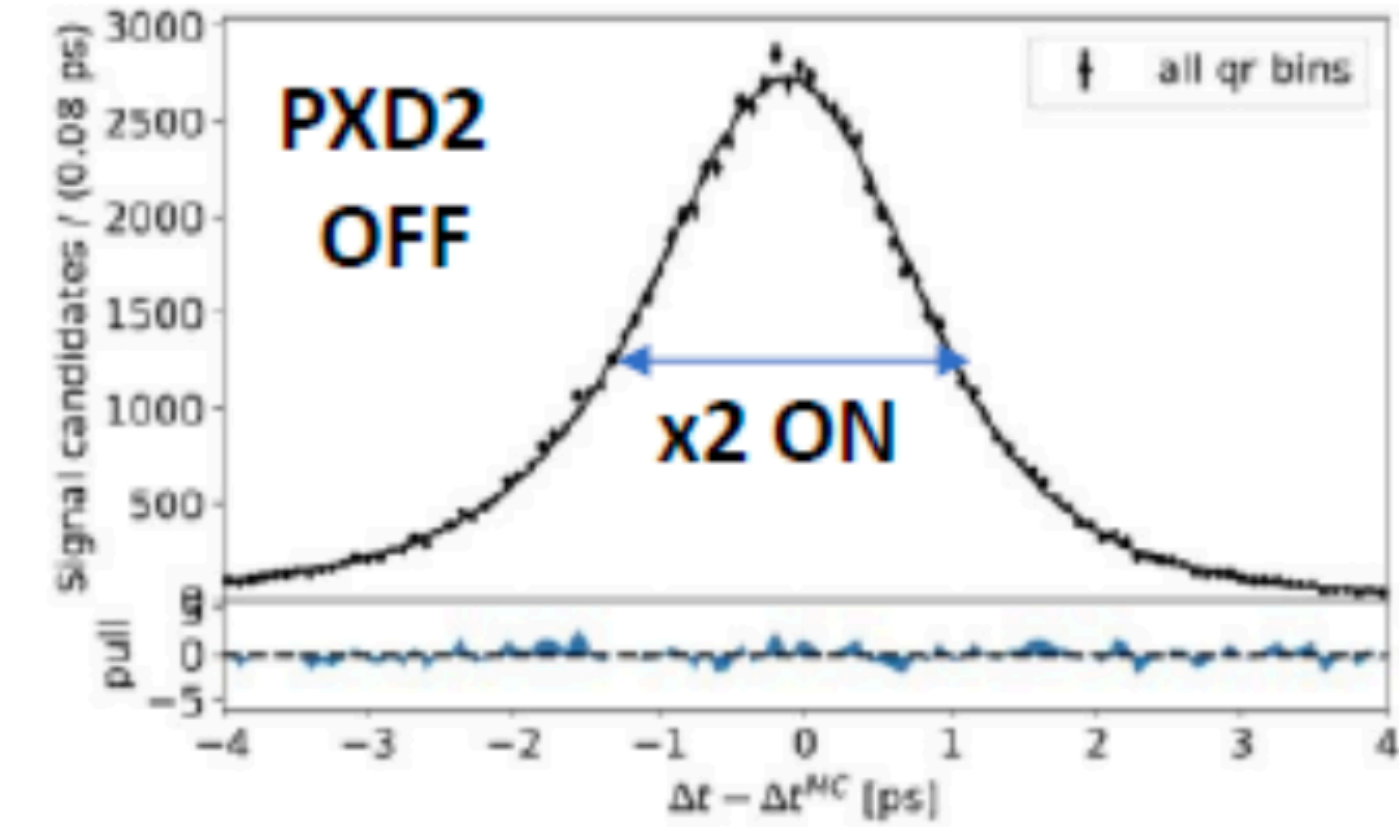
Stay tuned !

Backup

Effect of PXD off

Studies with PXD2 off

- Given 2024c data taking likely to be without PXD2 the time-dependent WG has investigated the impact on lifetime resolution and $\sin 2\beta$
- B-lifetime resolution $\sim 40\%$ worse
 - Two different beam background scenarios tested – similar results
- For $\sin 2\beta$ from $B \rightarrow J/\psi K_S$ the preliminary studies show a $\sim 20\%$ degradation
 - Study with sample with comparable size to current data

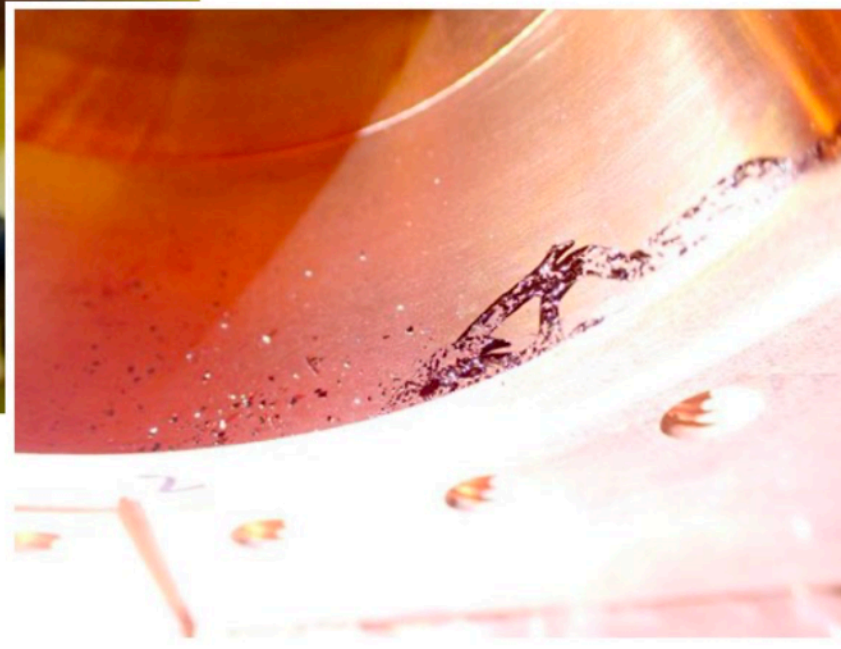
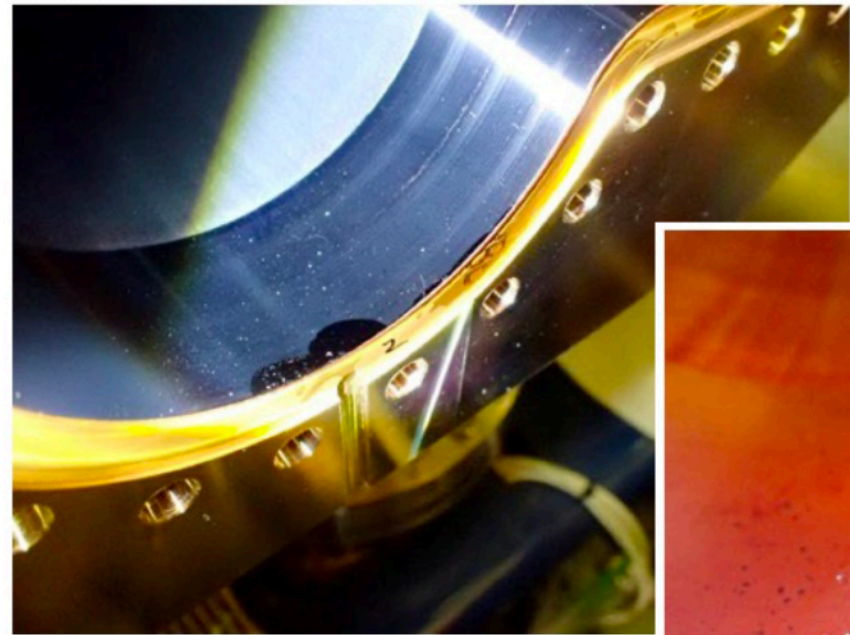


$\sin 2\beta$ value and uncertainty
with and without PXD

Exp 0	PXD ON	PXD OFF
mean	0.715 ± 0.003	0.713 ± 0.003
width	0.035 ± 0.002	0.042 ± 0.002

Countermeasure for SBL

K. Shibata @ BPAC



on clearing electrode upside down

upside down. (56 m/185 m = 30 %)

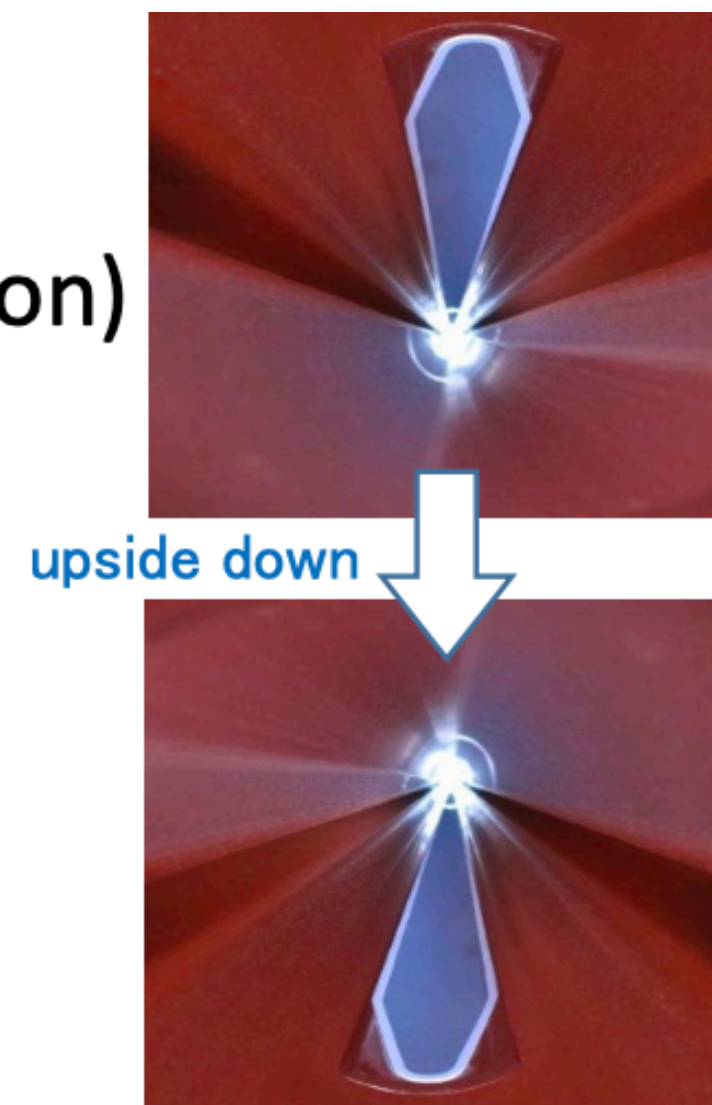
am pipes (D04 wiggler section) and 2/4 beam pipes (D05 NLC section)

progress now (until the end of September)

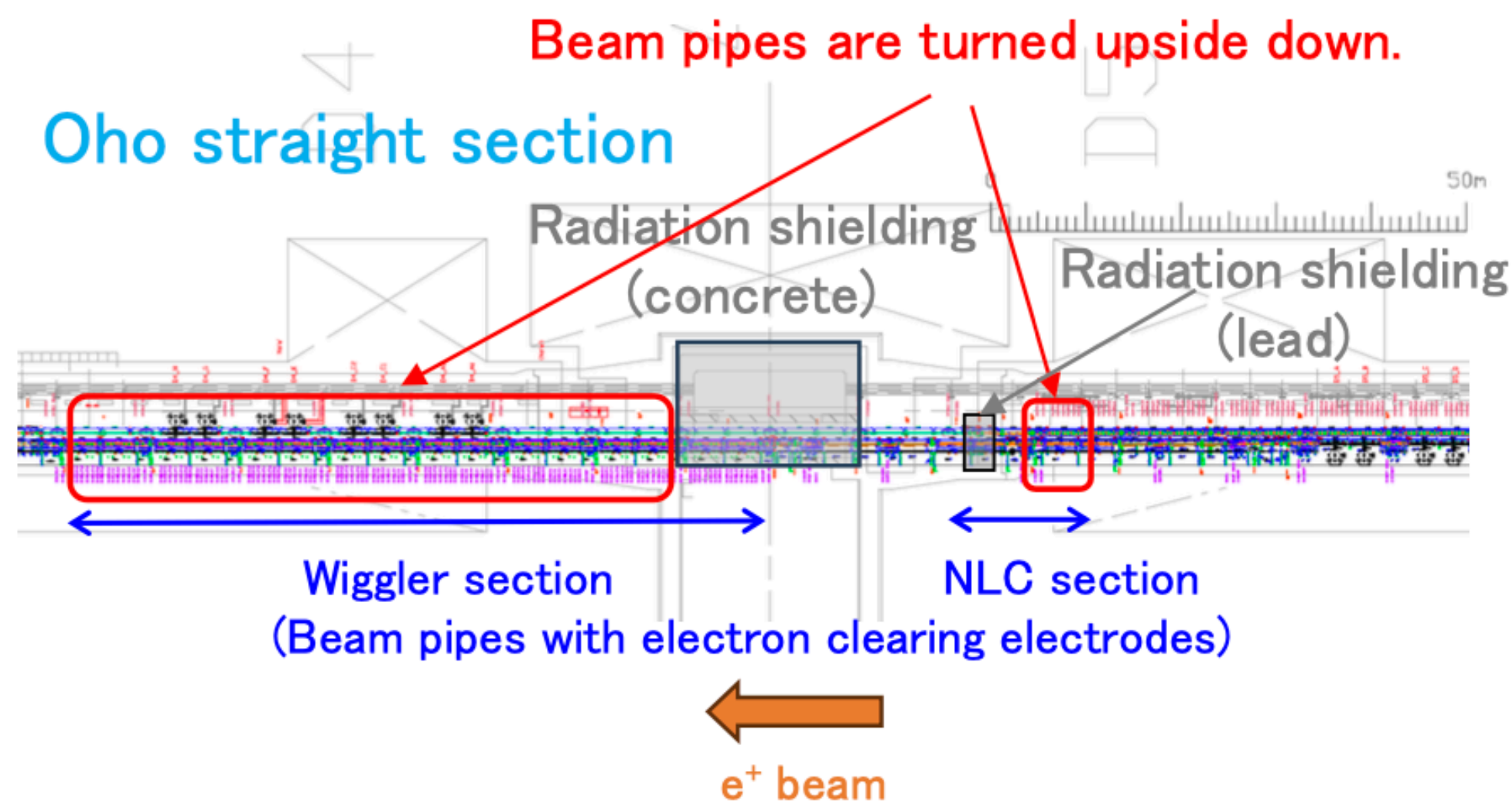
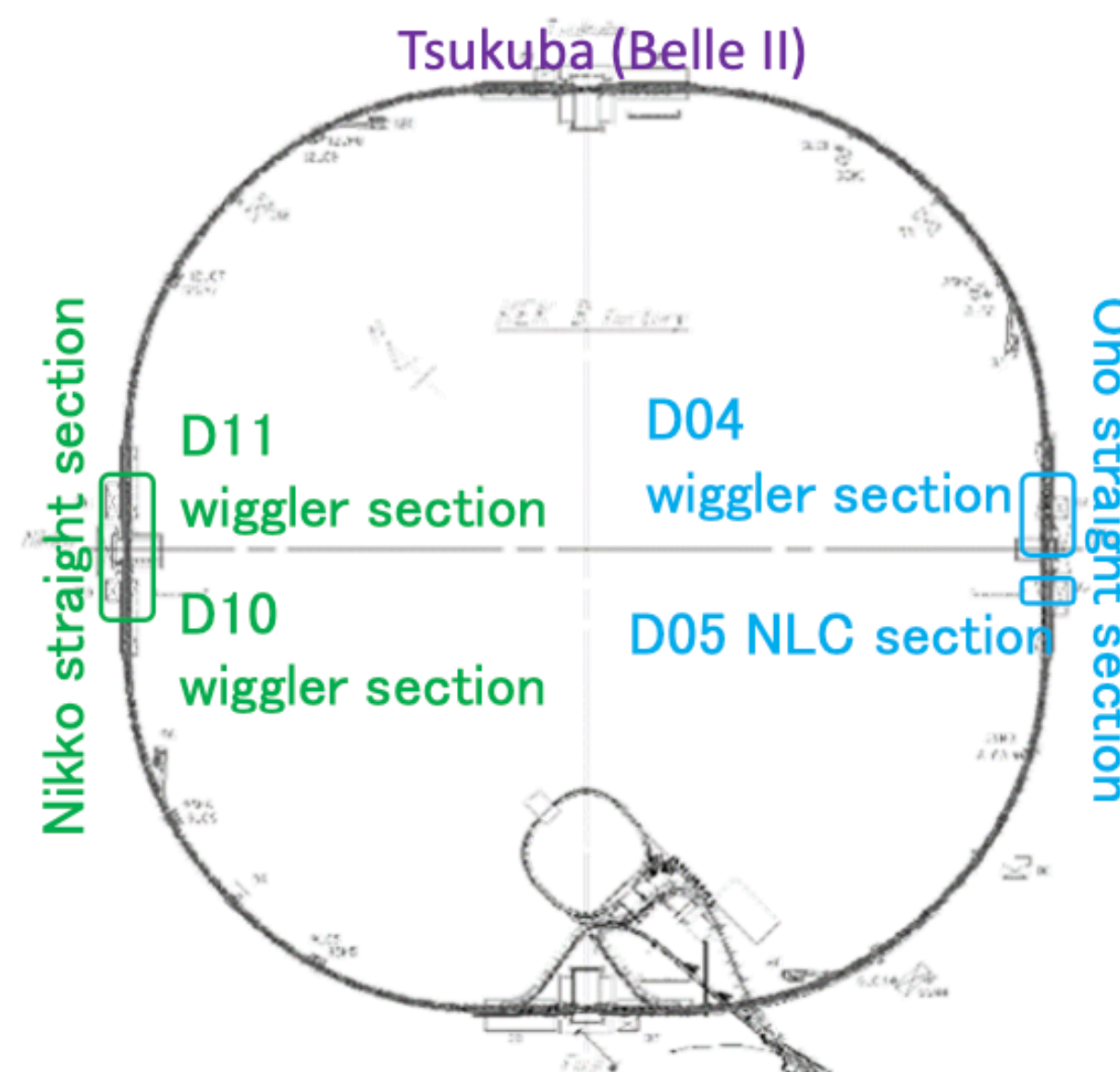
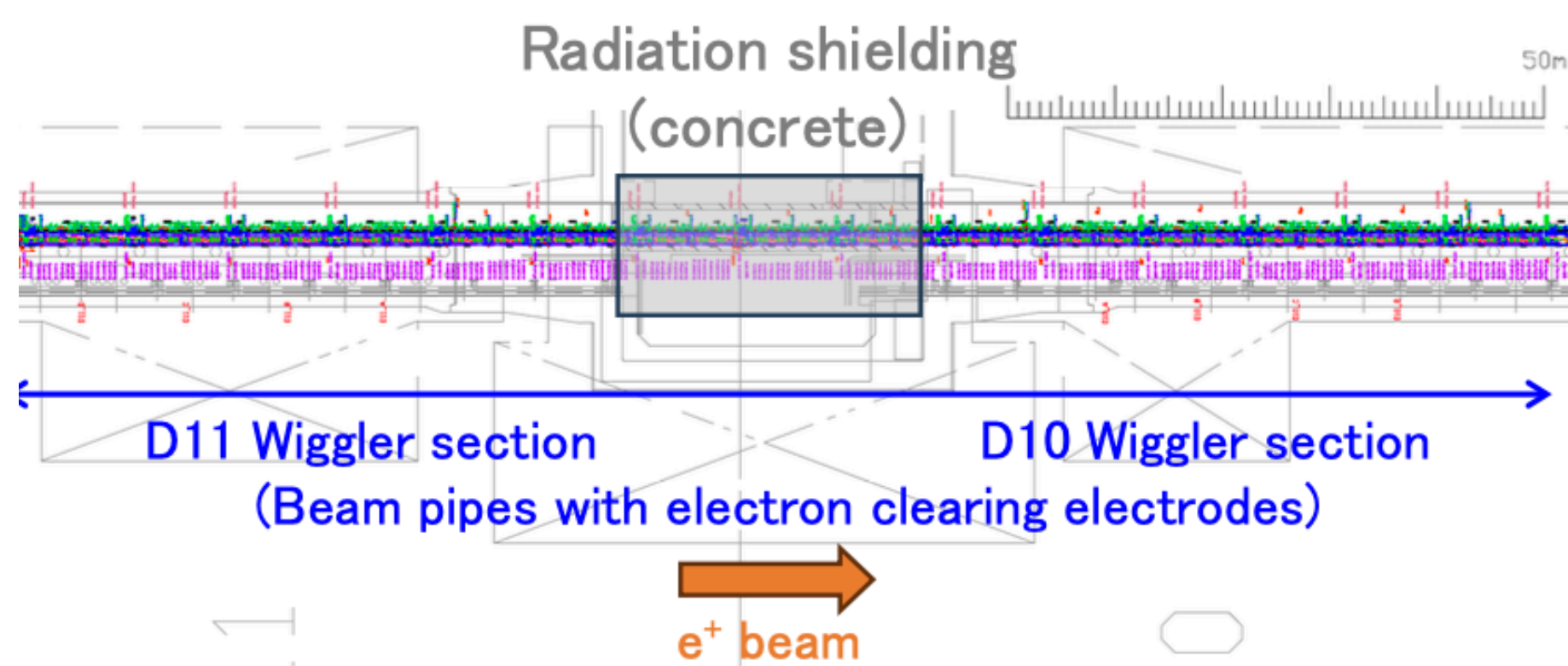
- **Nikko straight section** : 30 beam pipes at Nikko wiggler section will not be turned upside down.

- Visual check and dust cleaning of beam pipes which are turned upside down.

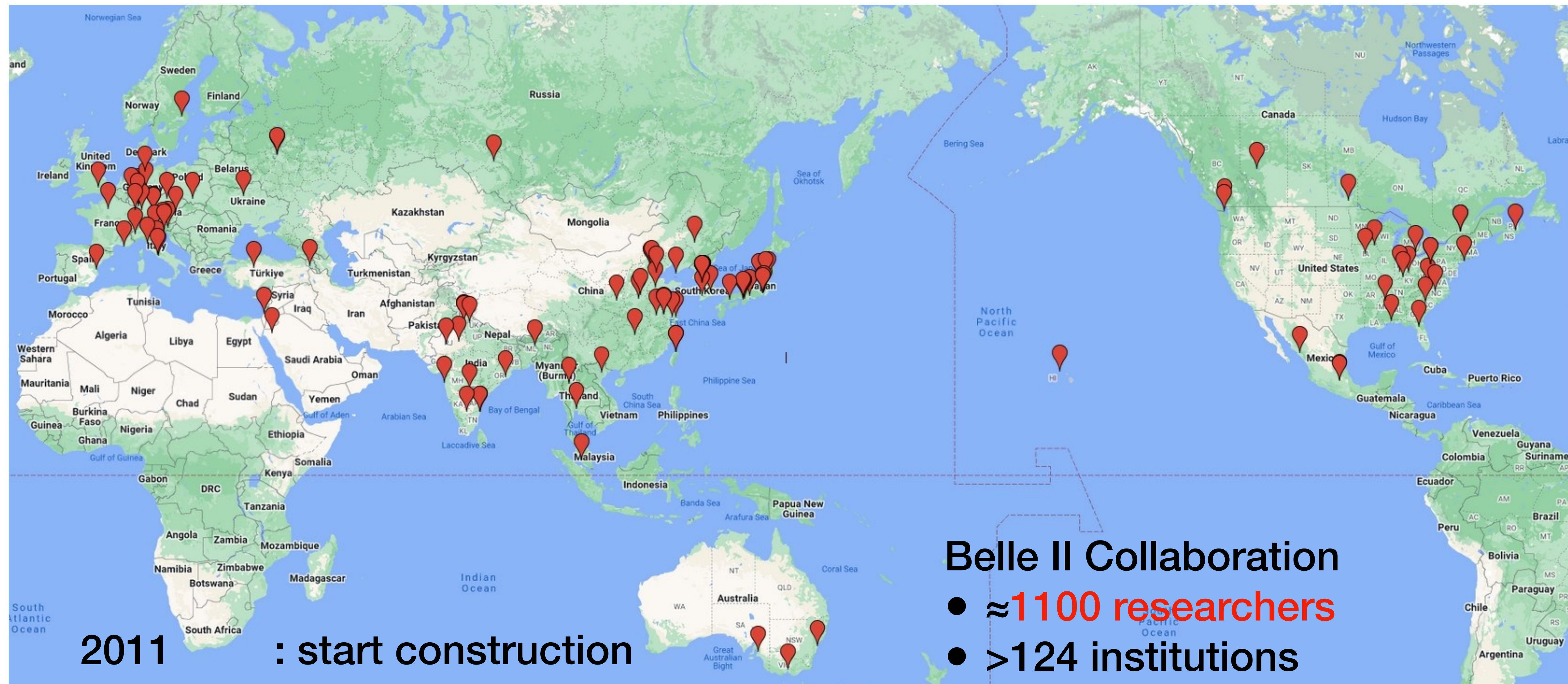
- Knocking as many beam pipes (with electron clearing electron or groove structure) as possible.



Nikko straight section



The Belle II Collaboration



2011 : start construction
Mar. 2019 : Physics run

- Belle II Collaboration**
- ≈ 1100 researchers
 - >124 institutions
 - ≈ 27 nations/regions

Belle II - LHCb comparison

