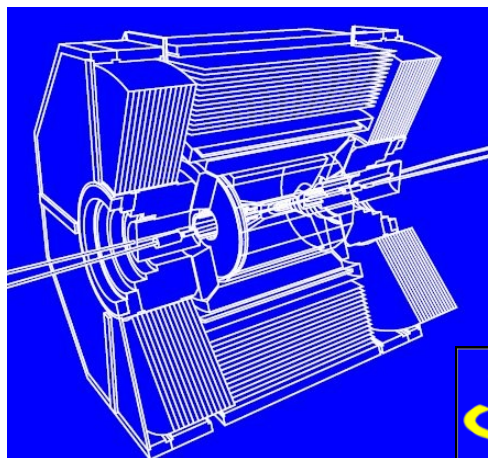
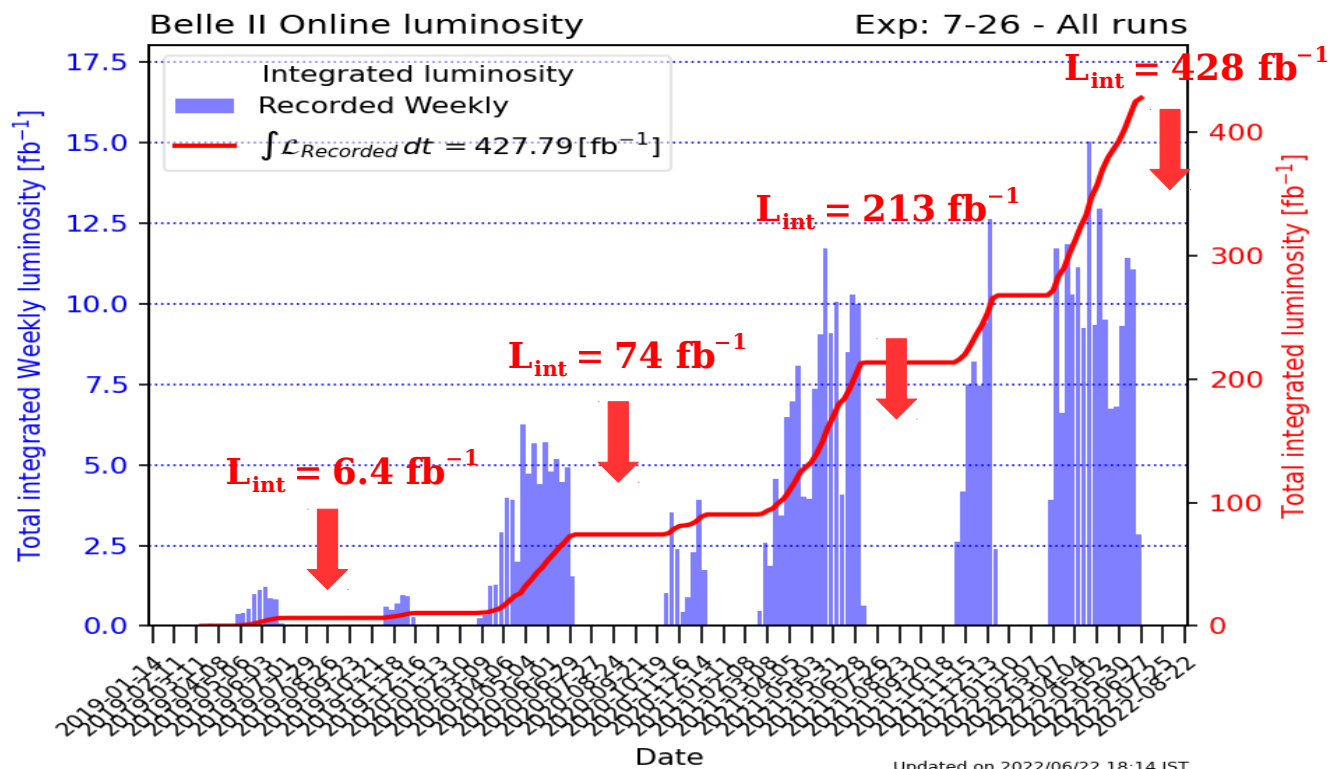




Belle II perspectives

K. Trabelsi
karim.trabelsi@in2p3.fr



Belle II run I (2019-2022)

data taking from March 2019 to June 2022

→ despite difficult conditions since March 2020 (Covid, war in Ukraine, energy cost...)

luminosity: $4.7 \times 10^{34} / \text{cm}^2 / \text{s}$! $> 2 \text{ fb}^{-1}$ per day!

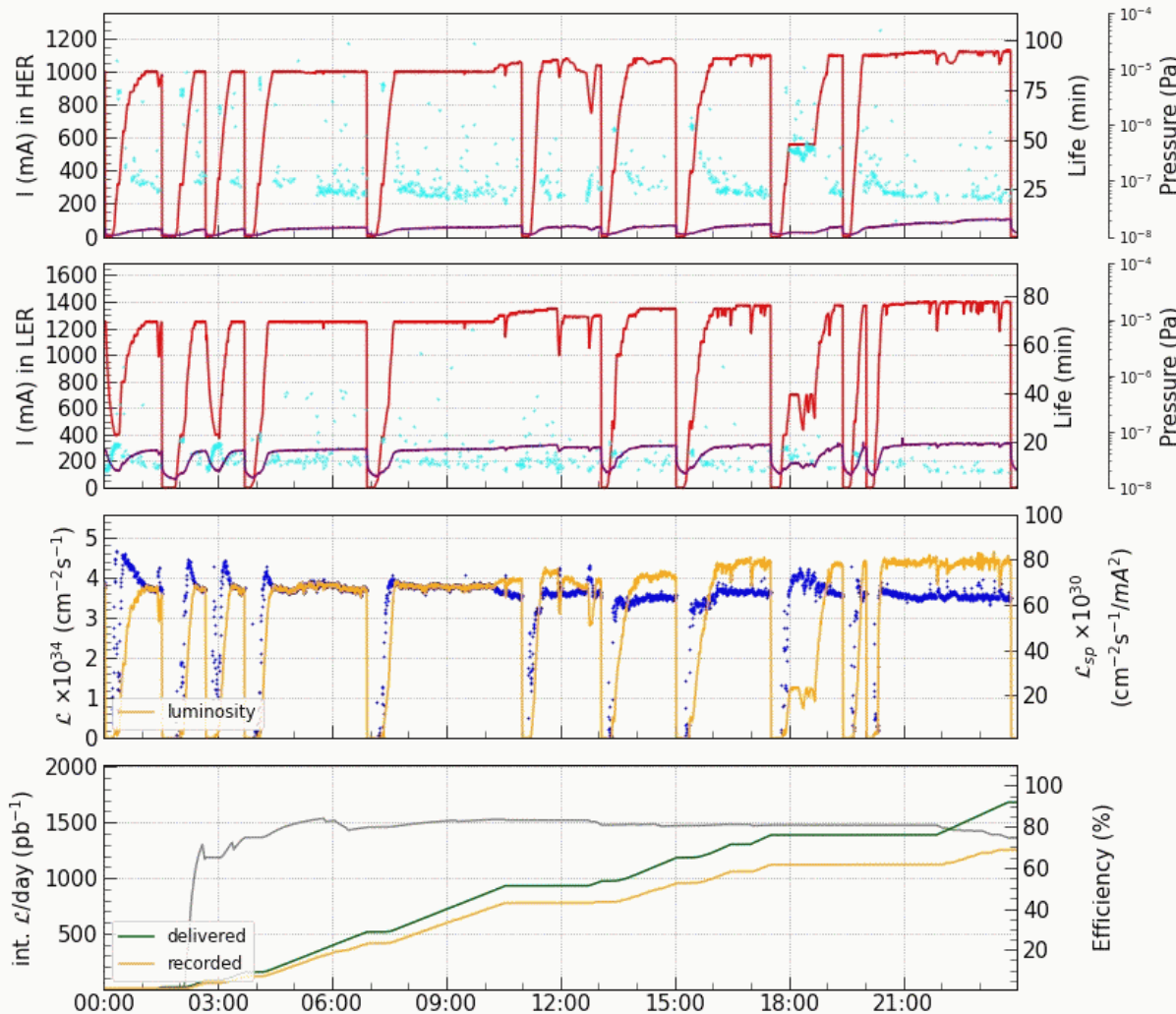
June, 2022

06/07 23:59:36 - 06/08 23:59:36, 2022 JST

\mathcal{L}_{peak} $4.653 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ @ 22:58:08 06/08
int. \mathcal{L}/day 1253 / 1681 pb^{-1}

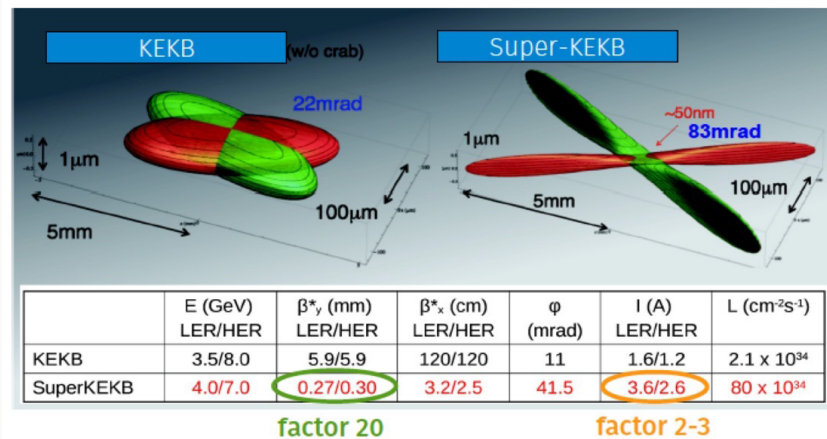
HER I_{peak} 1127 mA n_b 2249 β_x^*/β_y^* 60 / 1 mm
LER I_{peak} 1405 mA n_b 2249 β_x^*/β_y^* 80 / 1 mm

→ $\beta_y^* = 1 \text{ mm}$, $I_{LER/HER} = 1.4/1.1 \text{ A}$



record of KEKB/Belle
 $2 \times 10^{34} / \text{cm}^2 / \text{s}$ currents $> 1 \text{ A}$

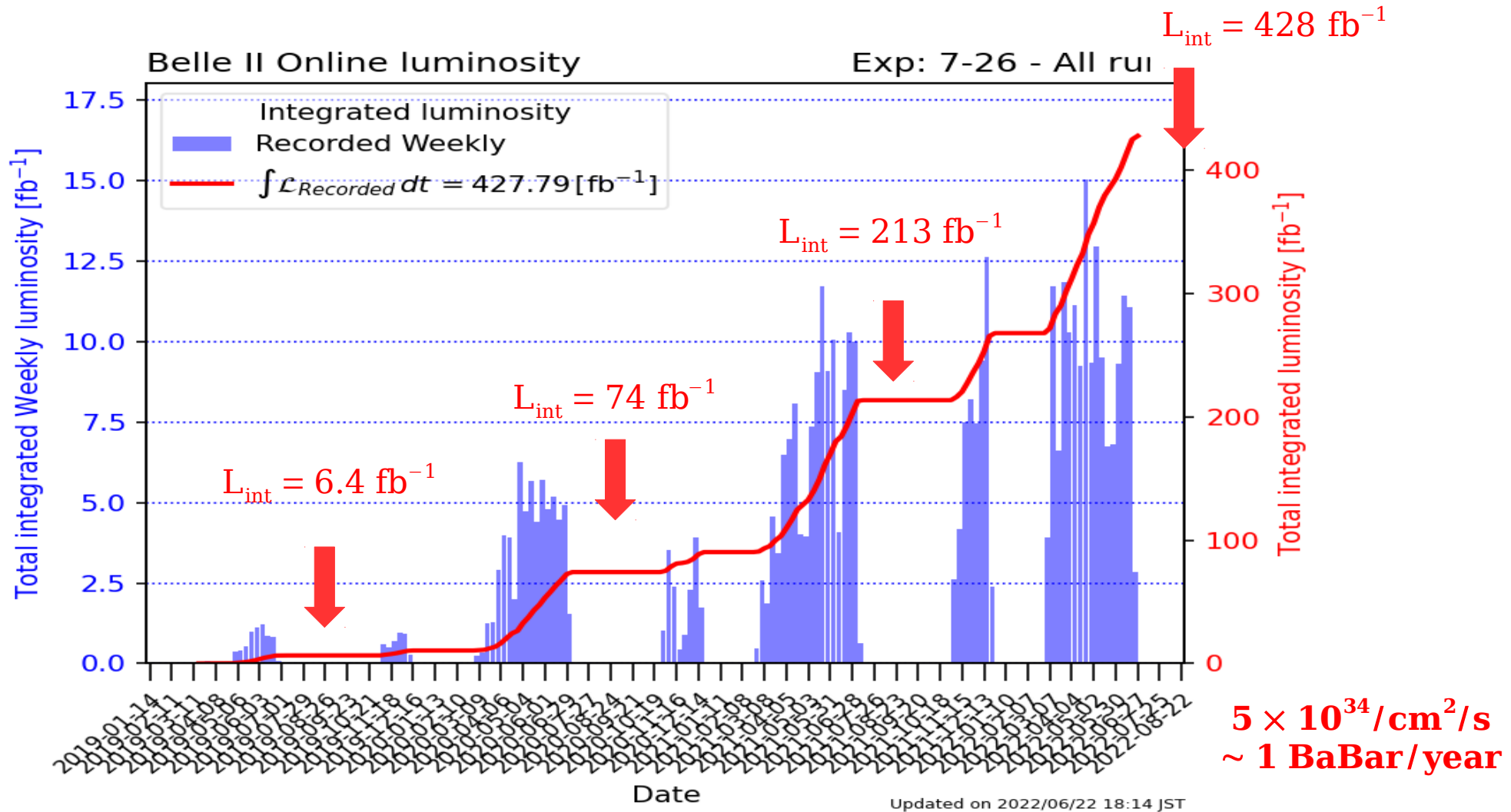
record of PEP-II/BaBar
 $1 \times 10^{34} / \text{cm}^2 / \text{s}$ currents $> 2 \text{ A}$



squeezing further β_y^* ($\rightarrow 0.6 \text{ mm}$)
doubling (or more) the currents
 $\Rightarrow L > 10^{35} / \text{cm}^2 / \text{s}$ after LS1

2022/06/08
HER : Baking Run
LER : Baking Run

Belle II run I (2019 - 2022)



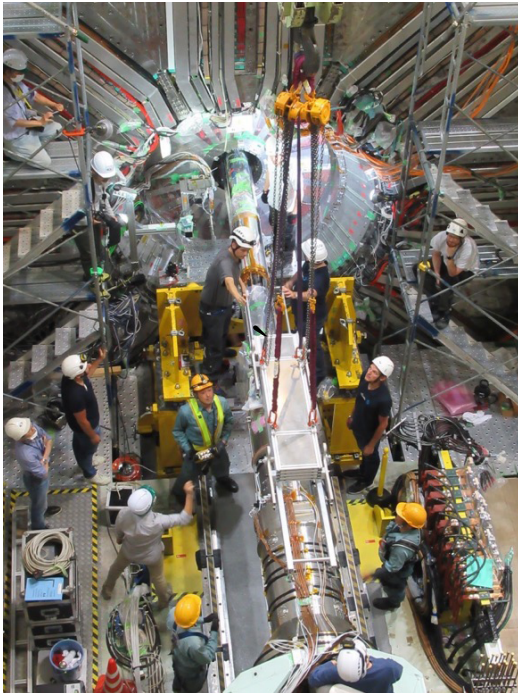
- ⇒ 362 fb^{-1} at the $Y(4S)$ resonance (rest off resonance, and scan)
- ⇒ Belle II recent results use either 189 fb^{-1} or 362 fb^{-1} , sometimes adding Belle data sample

Long-shutdown (LS1) activity and plans

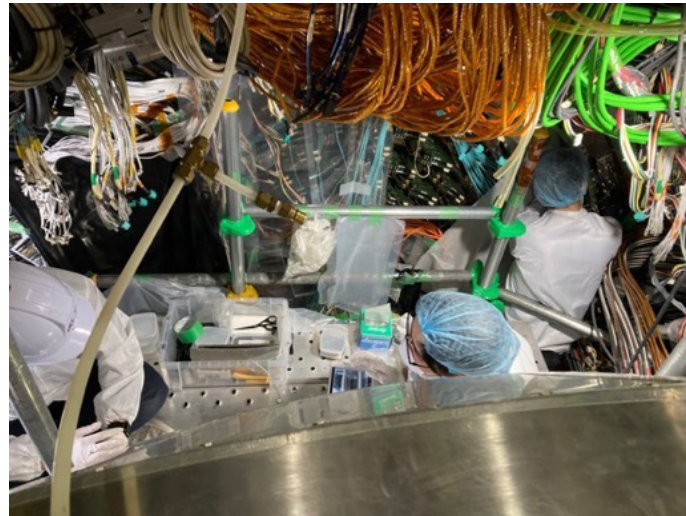
Belle II stopped taking data in Summer 2022 for a long shutdown (LS1)

- accelerator improvements: injection, non-linear collimators, monitoring...
- additional shielding and increased resilience against beam bckg
- replacement of beam-pipe
- installation of 2-layered pixel vertex detector
- replacement of photomultipliers of the central PID detector (TOP)
- completed transition to new DAQ boards (PCIe40)
- work on other detectors as CDC, KLM...
- improved data-quality monitoring and alarm system

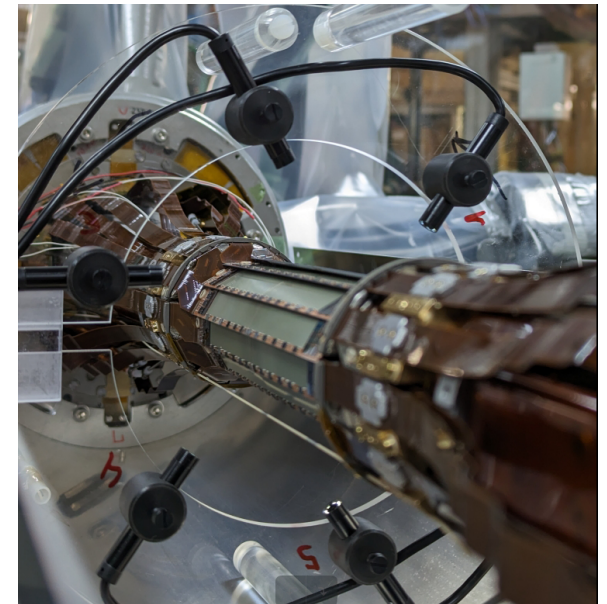
VXD extraction in May



TOP MCP-PMT replacement work



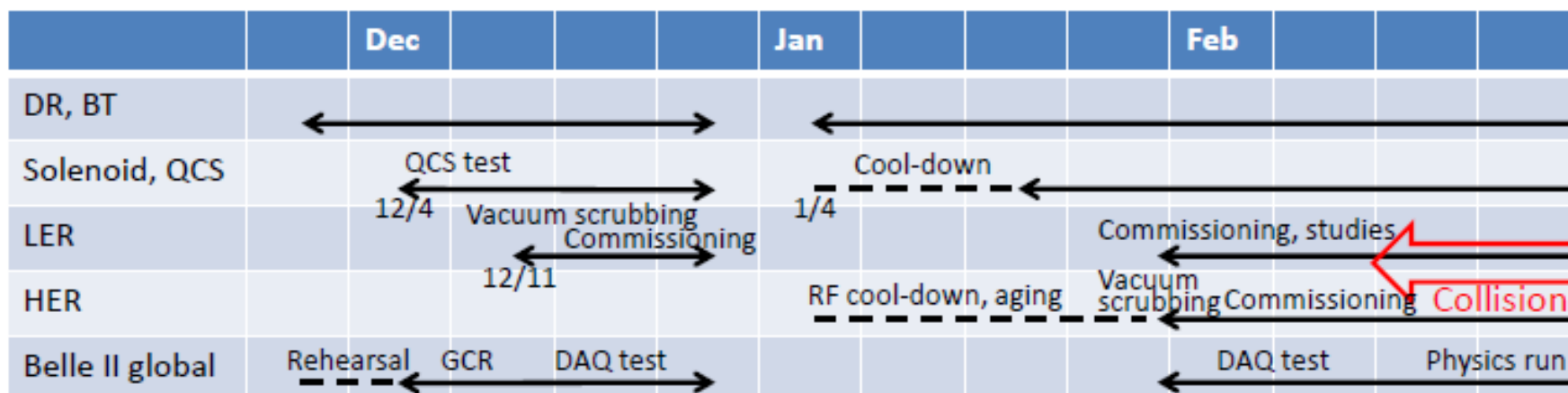
PXD2 at KEK since March



CDC FE reinstatement work



COMING SOON !!!



Arrows indicate the operation periods.

- Target first day of MR beam operation: Dec 11 (driven by Belle II)

<https://confluence.desy.de/display/BI/Run+Plan>

Fiscal year	4	5	6	7	8	9	10	11	12	1	2	3	
2021	2021b							2021c				2022a	
2022	2022b			LS1									
2023									2023c		①	2024a	
2024	2024b			③			2024c			②		2025a	
2025	2025b							2025c		①	2026a		
2026	2026b							2026c		①	2027a		

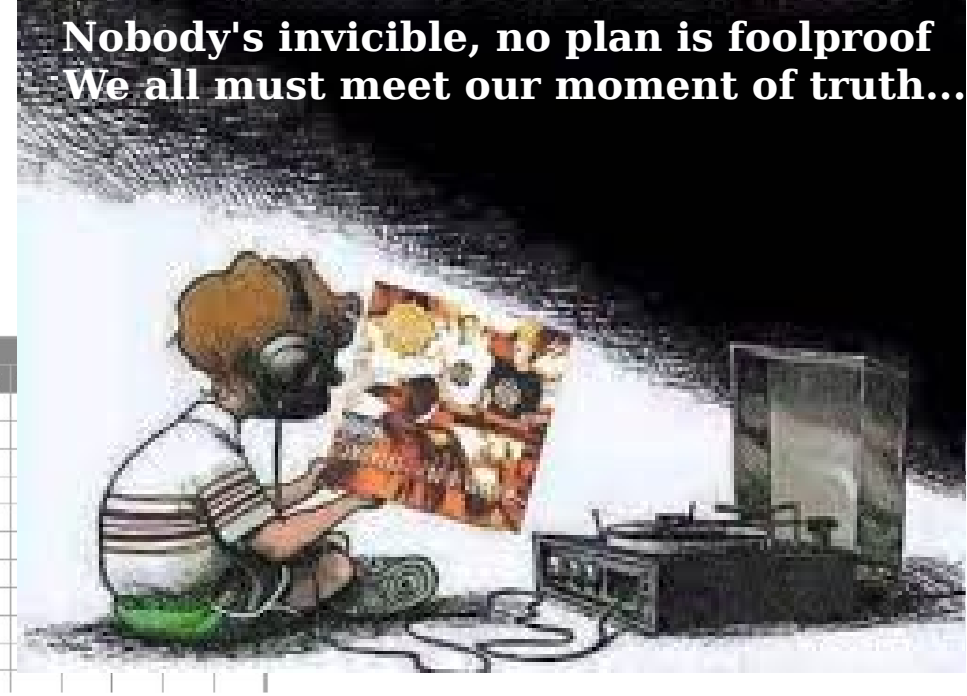
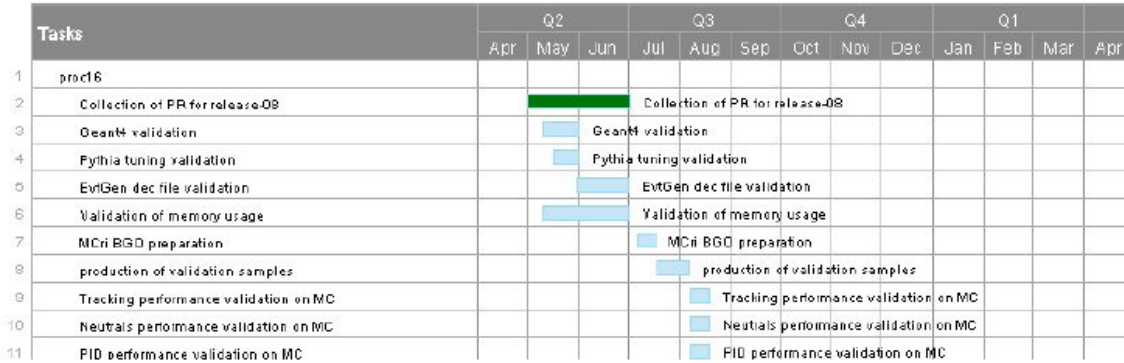
Assumption: 7 months operation per fiscal year with sufficient budget

moment of truth

more planning...

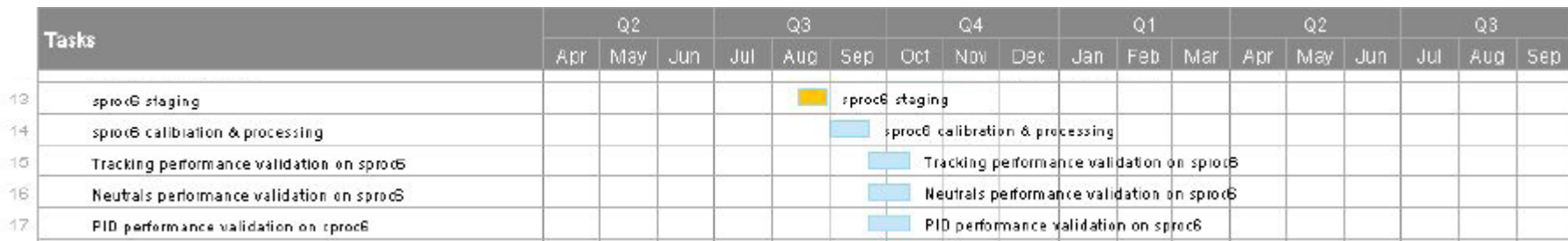
...from software, data production,
performance, physics

release-08

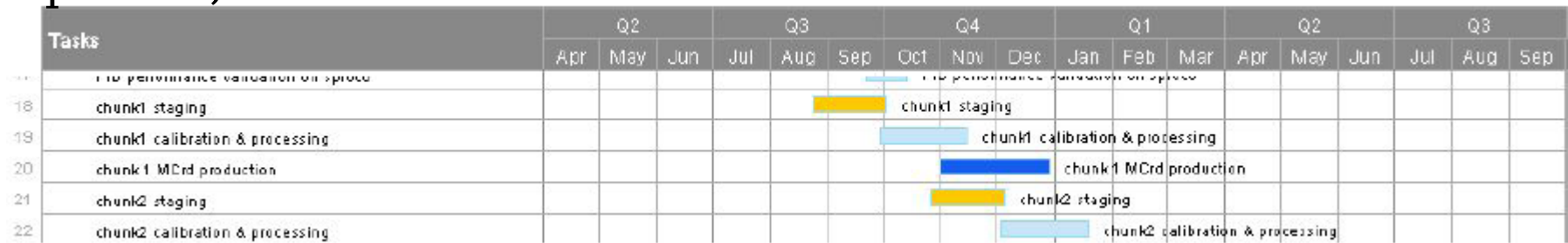


Nobody's invincible, no plan is foolproof
We all must meet our moment of truth...

more validation



proc16, MCrD



⇒ prepare for reprocessing with new release, efficient prompt during 2024,
performance and corresponding MCrD

What are our goals for 2024 ?

(please a clear and sound message)



Run stably at $10^{35}/\text{cm}^2/\text{s}$

Reach 150 fb^{-1} per month

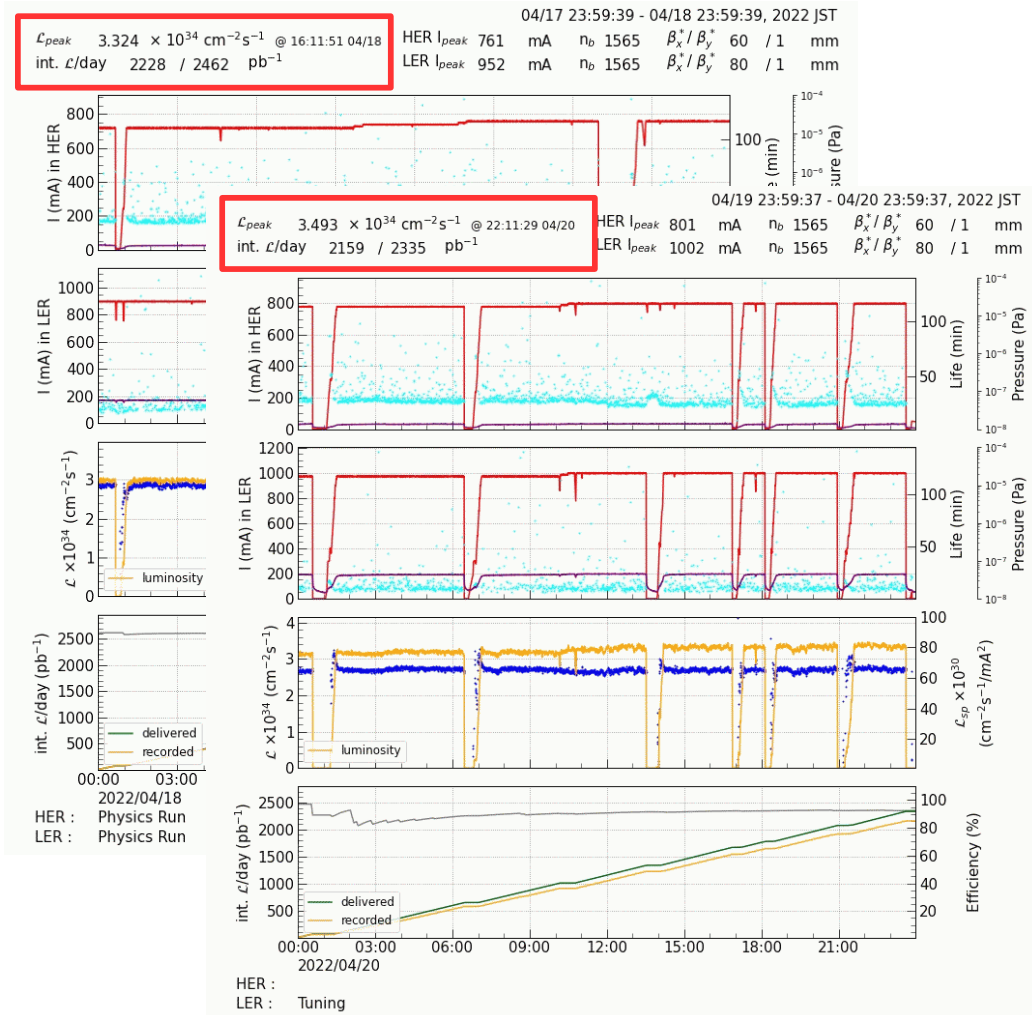
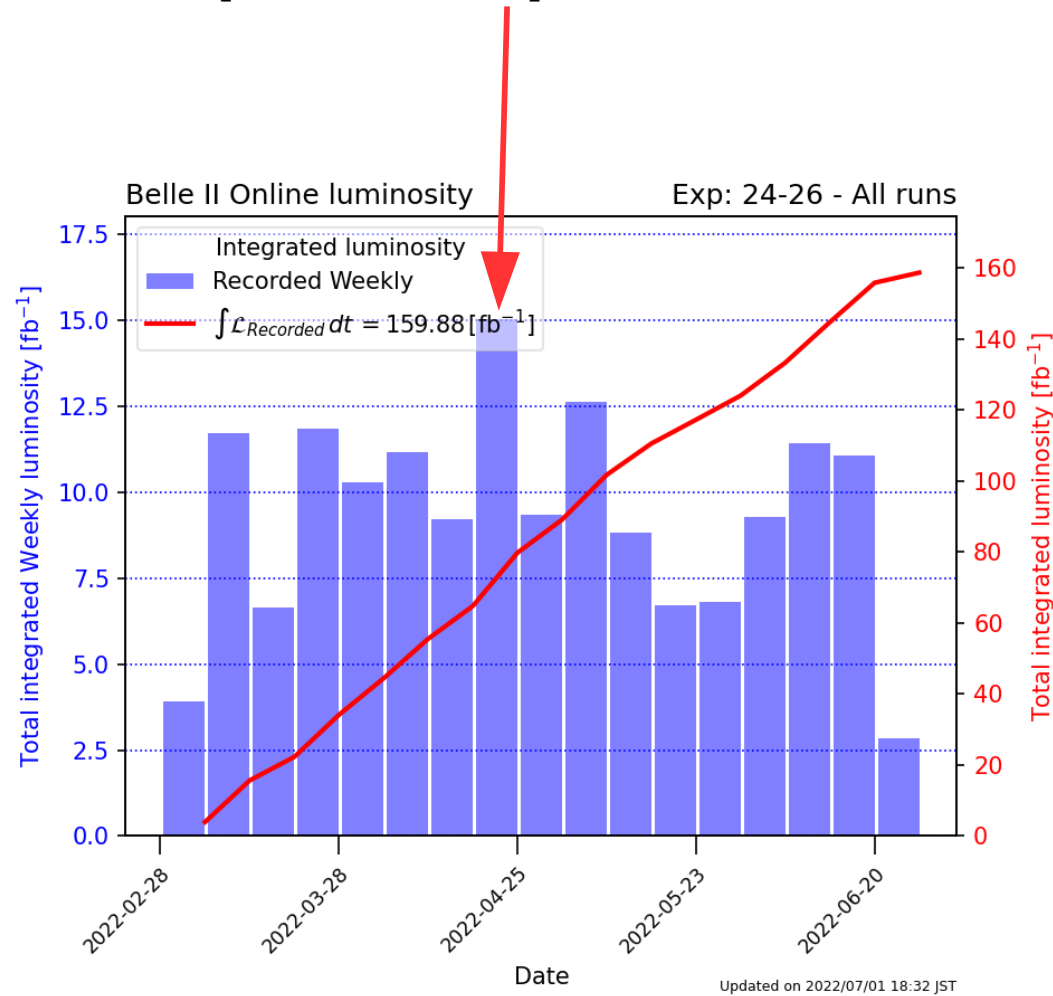
Exceed 1 ab^{-1}

(setting the pace for run 2)
(while doing good physics and working for the upgrade)

... 'This was their finest hour.'

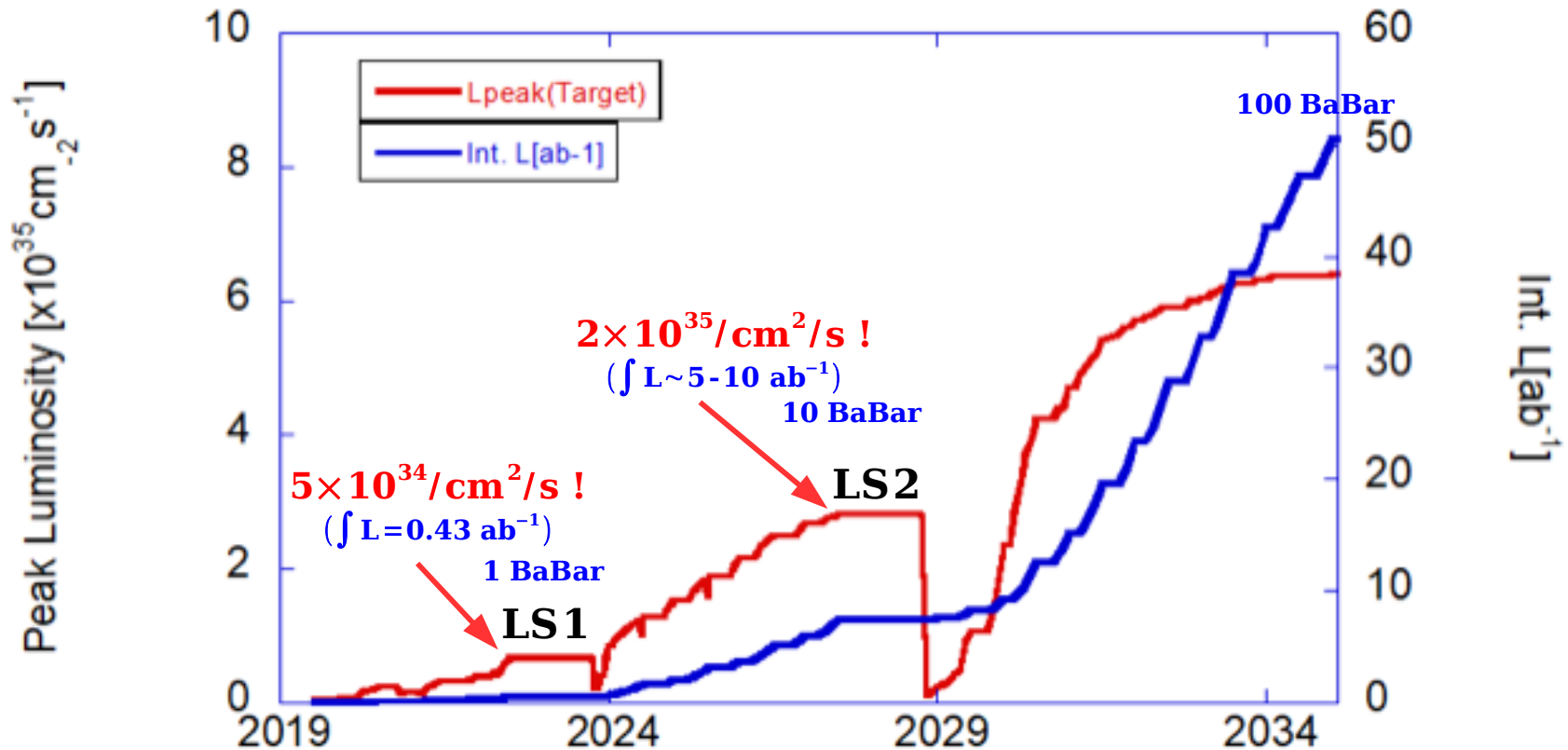
Reaching 150 fb^{-1} per month

In end of April 2022, 15/fb per week could be reached when instantaneous luminosity was $\sim 3.5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$



$\Rightarrow 15 \times 4 \times 2.5 = 150 \text{ fb}^{-1} / \text{month}$ at $L = 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ is possible

Belle II calendar



run 1 (\rightarrow June 2022): integrated luminosity $\sim 0.43 \text{ ab}^{-1}$, $5 \times 10^{34} / \text{cm}^2 / \text{s}$
 PXD complete (2 layers) to be installed during **LS1** (2022-2023)
 (+beampipe + TOP PMTs)

run 2 (\rightarrow ~ 2028): integrated luminosity $5-10 \text{ ab}^{-1}$, $2 \times 10^{35} / \text{cm}^2 / \text{s}$

LS2: collider upgrade (QCS+RF) \rightarrow installation upgraded detector

run 3 (\rightarrow 2035): 50 ab^{-1}

Merging analyses of Belle and Belle II

Belle+Belle II proposal to merge Belle and Belle II analyses

1. A deputy physics coordinator (current Belle physics coordinator) will assist the Belle II physics coordinator in taking care of the classification and review of Belle analyses.
2. No new Belle RC will be formed once this policy is accepted by Belle and Belle II.
3. Analyses of Belle data only will be classified and handled as follows:
 - 3.1 CWR + queue: ongoing Belle analyses currently in CWR and Belle analyses with an RC that are sufficiently close to CWR (as determined by the Belle II deputy physics coordinator and Belle II physics coordinator(s)). ==> will be handled according to standard Belle publication procedures.
 - 3.2 other ongoing Belle analyses: analyses without an RC (Belle note required) and those insufficiently close to CWR (as determined by the Belle II deputy physics coordinator and Belle II physics coordinator(s)). ==> will be handled according to standard Belle II approval and publication procedures (WG review -> RC review -> CWR).
Those analyses will be signed as "Belle and Belle II collaborations".
 - 3.3 new Belle analyses: proposals for new Belle analyses will be presented in the relevant Belle II WG, allowing all Belle II members, including Belle experts, to comment. Belle II physics coordinator(s) and deputy will decide if a new Belle ONLY analysis has sufficient scientific merit (for example if adopting a new method already applied to Belle II data only, or the usage of a unique data sample as Y(5S)).
==> if yes, the analysis will belong to class 3.2.
4. Belle II WG conveners only will formally handle the progress and review of Belle analyses of category 3.2 and 3.3. Belle II will provide to Belle-only members access to the information and infrastructure necessary for such Belle analyses.
5. Belle II will take care of Belle data sample and software. Belle II collaborators are encouraged, but not compelled, to do Belle+Belle II analyses, when relevant.
6. Following Belle endorsement, the procedure will be brought back to Belle II's IB for a final decision.
7. The transition and final approval should complete by or before the June 2023 B2GM.

Thanks
FOR YOUR GENEROUS DONATION!
you
are
SERIOUSLY
• THE •
BEST

*The proposal has been approved by the Belle IB
and also by Belle II IB on June 5, 2023.*

Belle II, a flavour-factory,

(Belle $\sim 1 \text{ ab}^{-1}$)

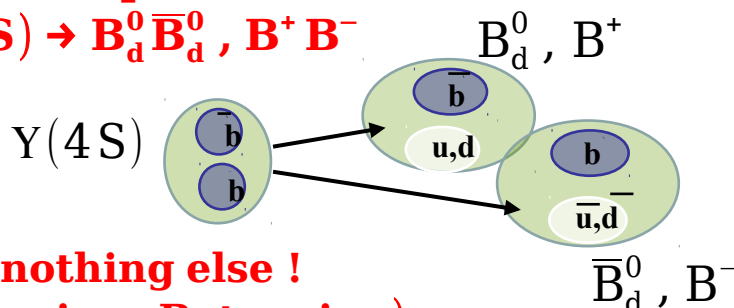
a rich physics program...

- We plan to ultimately collect many ab^{-1} of $e^+ e^-$ collisions at (or close to) the $Y(4S)$ resonance, so that we have:

– a (Super) B-factory ($\sim 1.1 \times 10^9 \text{ B}\bar{\text{B}}$ pairs per ab^{-1})

"on resonance" production

$e^+ e^- \rightarrow Y(4S) \rightarrow \text{B}_d^0 \bar{\text{B}}_d^0, \text{B}^+ \text{B}^-$



- 2 B's and nothing else !

(flavour tagging, B-tagging)

- 2 B mesons are created simultaneously in a $L=1$ coherent state

Time-dependent CP Violation Measurements at Belle II: S.Hazra

$b \rightarrow s$ Penguin results from Belle II ($b \rightarrow sll, b \rightarrow s\gamma$): L.Martel

Recent Belle II results related to B anomalies: Y.Fan

Measurements of $|V_{cb}|$ and $|V_{ub}|$ at Belle and Belle II: L.Cao

Charm Physics at Belle II: T.Higuchi

Quarkonium/QCD results at Belle II: MC Chang

– a (Super) charm factory ($\sim 1.3 \times 10^9 \text{ c}\bar{\text{c}}$ pairs per ab^{-1})

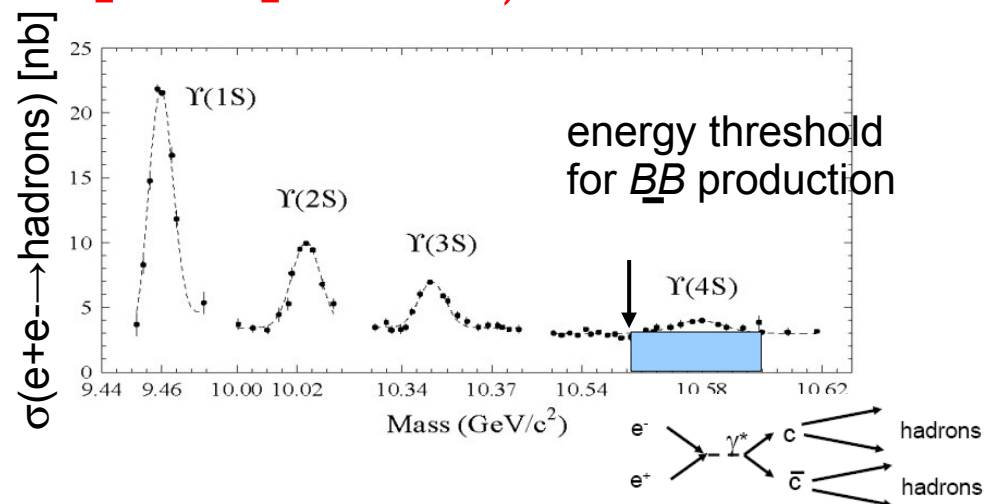
(but also charmonium, X, Y, Z, pentaquarks, tetraquarks, bottomonium...)

(scan data are also crucial here)

– a (Super) τ factory ($\sim 0.9 \times 10^9 \text{ }\tau^+ \tau^-$ pairs per ab^{-1})

Dark matter and tau results at Belle II: R.Leboucher

- exploit the clean $e^+ e^-$ environment to probe the existence of exotic hadrons, dark photons/Higgs, light Dark Matter particles, ALPs, LLPs ...

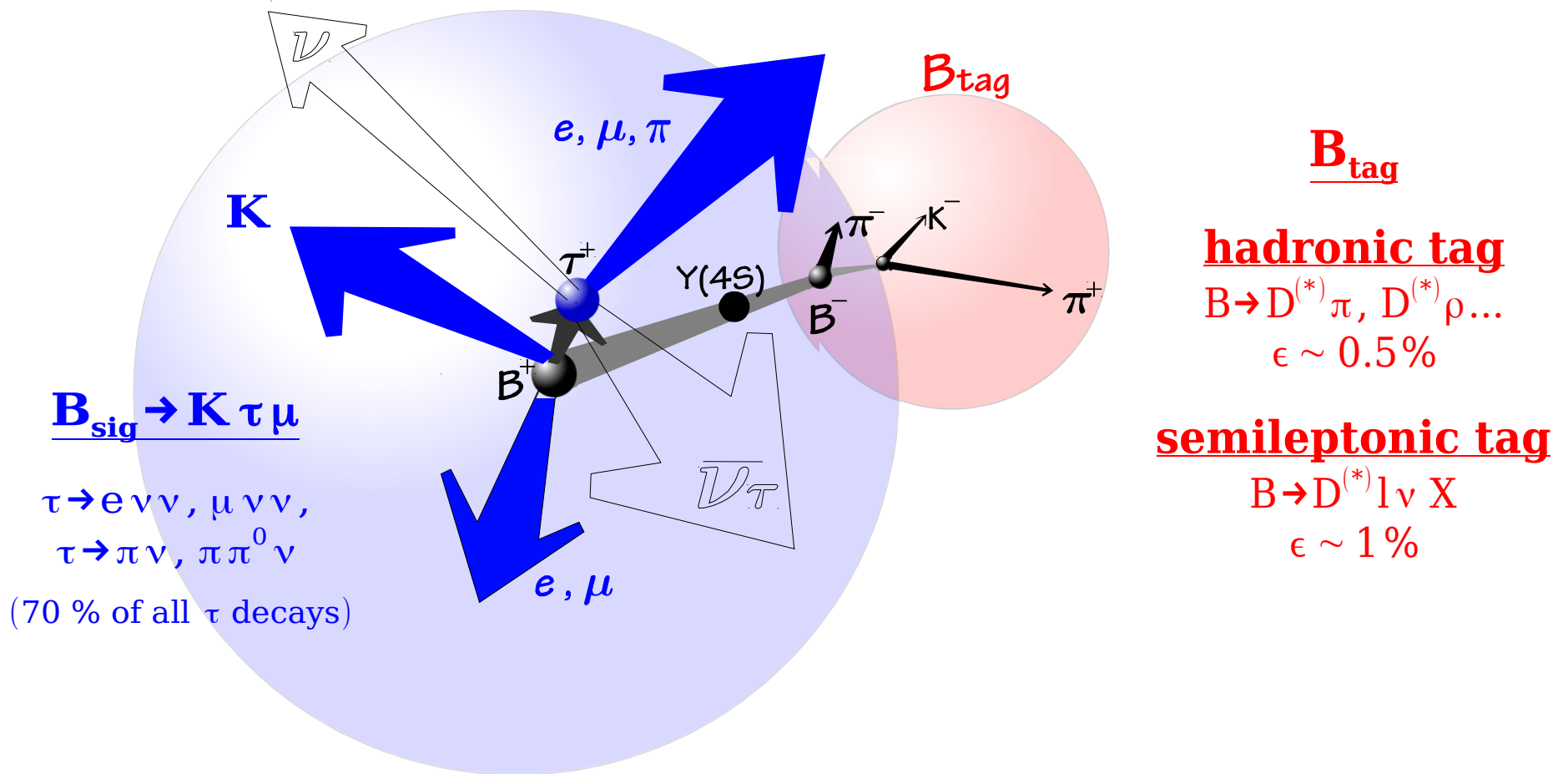


Many opportunities

- lot of detailed talks already at this workshop covering Belle II physics programme
 - Physics Overview (J.Bennett)
 - B Physics I (T.Browder)
 - CP Violation Physics (S.Prell)
 - Charm physics (M.Bertemes)
 - Anomalies (J.Cochran)
 - B Physics II (A.Schwartz)
 - Dark Searches (W.Jacobs)
 - Tau (S.Banerjee)
 -
- examples of measurements where Belle II should soon dominate
 - missing energy modes, $|V_{cb}|$, ...

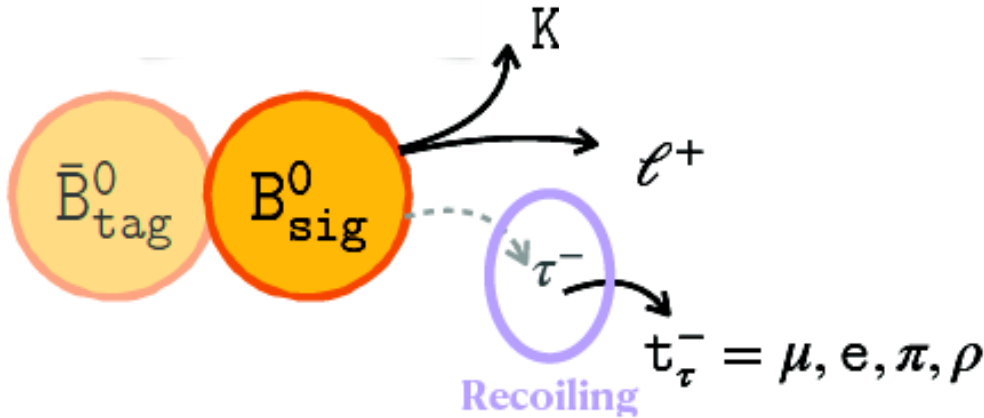
Missing energy modes and B-tagging

Many interesting B-physics studies involve missing energy: $D^{(*)}\tau\nu$, $K\tau l$, $K^{(*)}\tau\tau$, $K^{(*)}\nu\nu$, $\pi l\nu$, τl , $\tau\nu$, $\mu\nu\dots$ which require B-tagging.

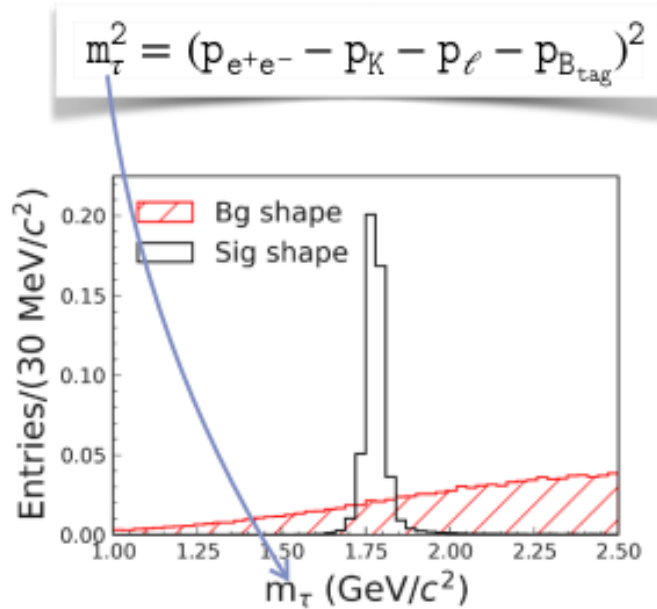


Missing energy modes and B-tagging

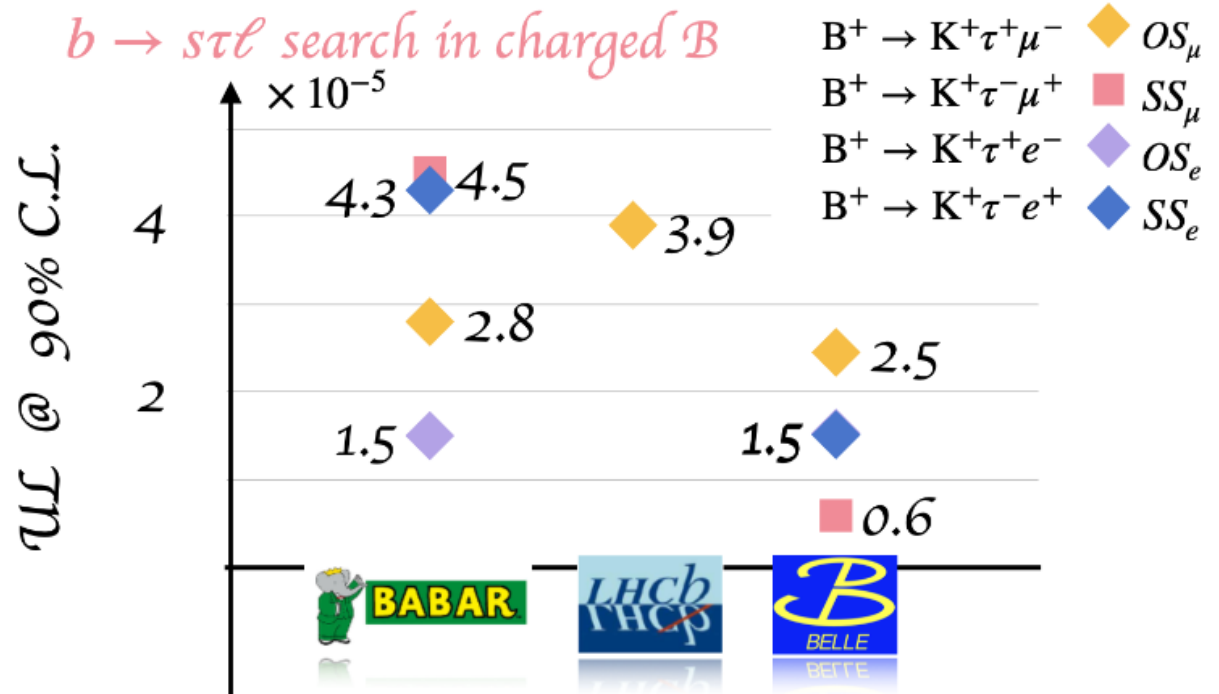
Many interesting B-physics studies involve missing energy: $D^{(*)}\tau\nu$, $K\tau\ell$, $K^{(*)}\tau\tau$, $K^{(*)}\nu\nu$, $\pi\ell\nu$, $\tau\ell$, $\tau\nu$, $\mu\nu$... which require B-tagging.



Hadronic B-tagging can provide the direction of the B.
Essential in some analysis like $B \rightarrow K\tau\ell$
Unique to B-factories!



$b \rightarrow s\tau\ell$ search in charged B

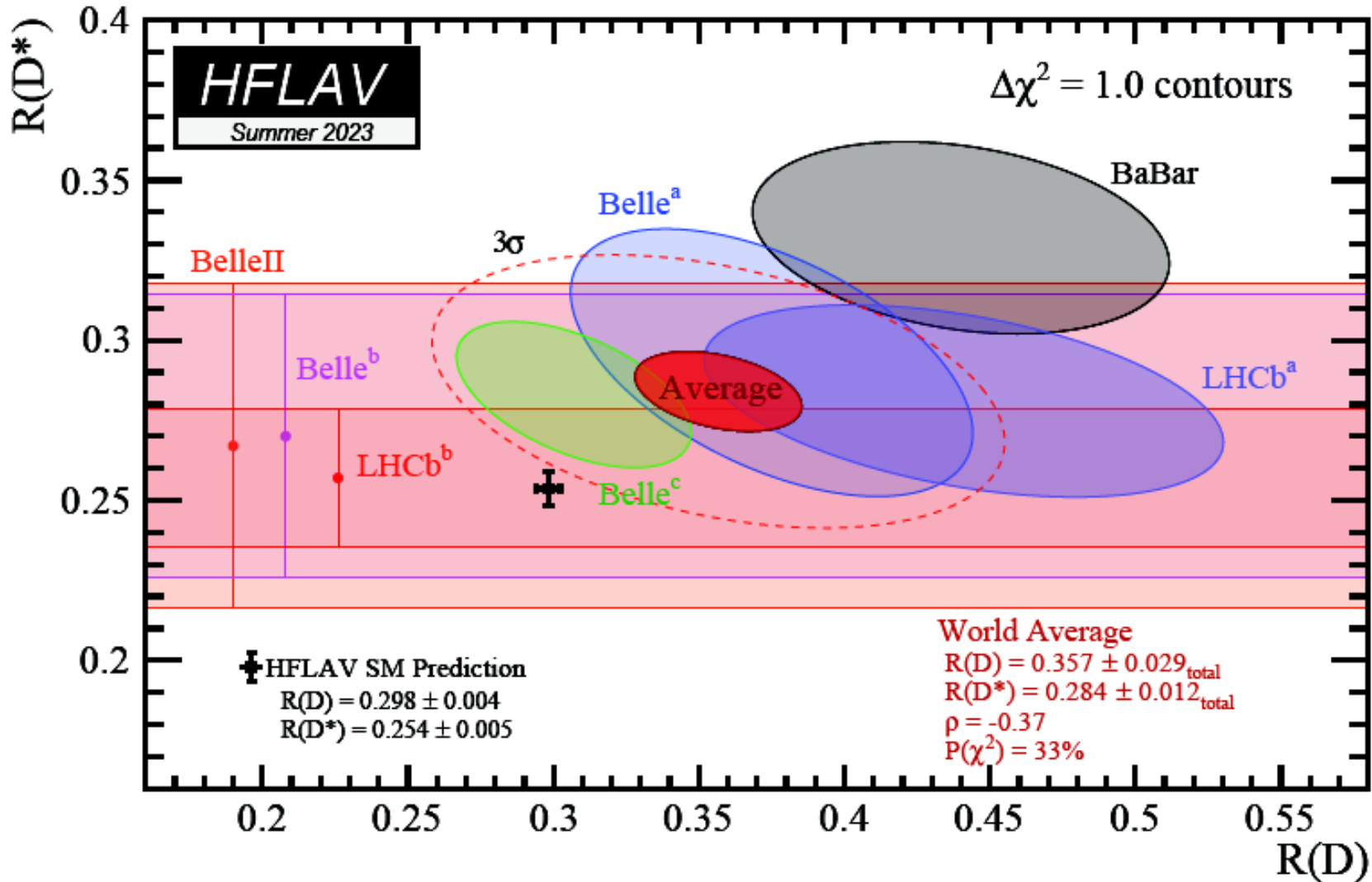


neutrinos are all coming from the tau here !

with only 1 ab^{-1} ... competitive with LHCb !

$$\underline{\mathbf{R}}(\mathbf{D}^{(*)}) \Rightarrow R(\mathbf{D}^{(*)}) = \frac{\text{BF}(B \rightarrow D^{(*)} \tau \nu_\tau)}{\text{BF}(B \rightarrow D^{(*)} l \nu_l)}$$

1st Belle II measurement ($R(D^*)$ with had B-tagging and 189 fb^{-1}) **already** interesting ...

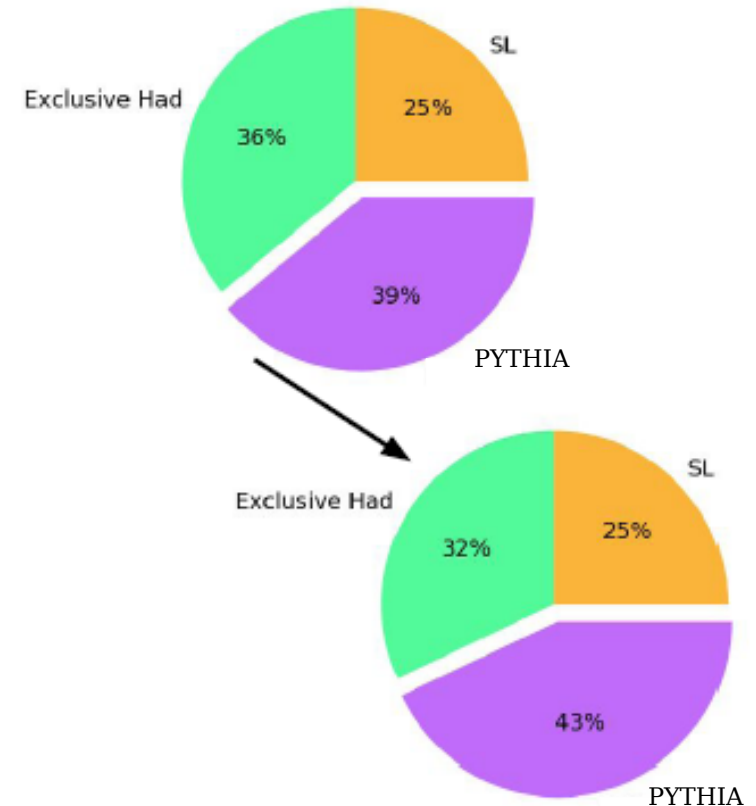
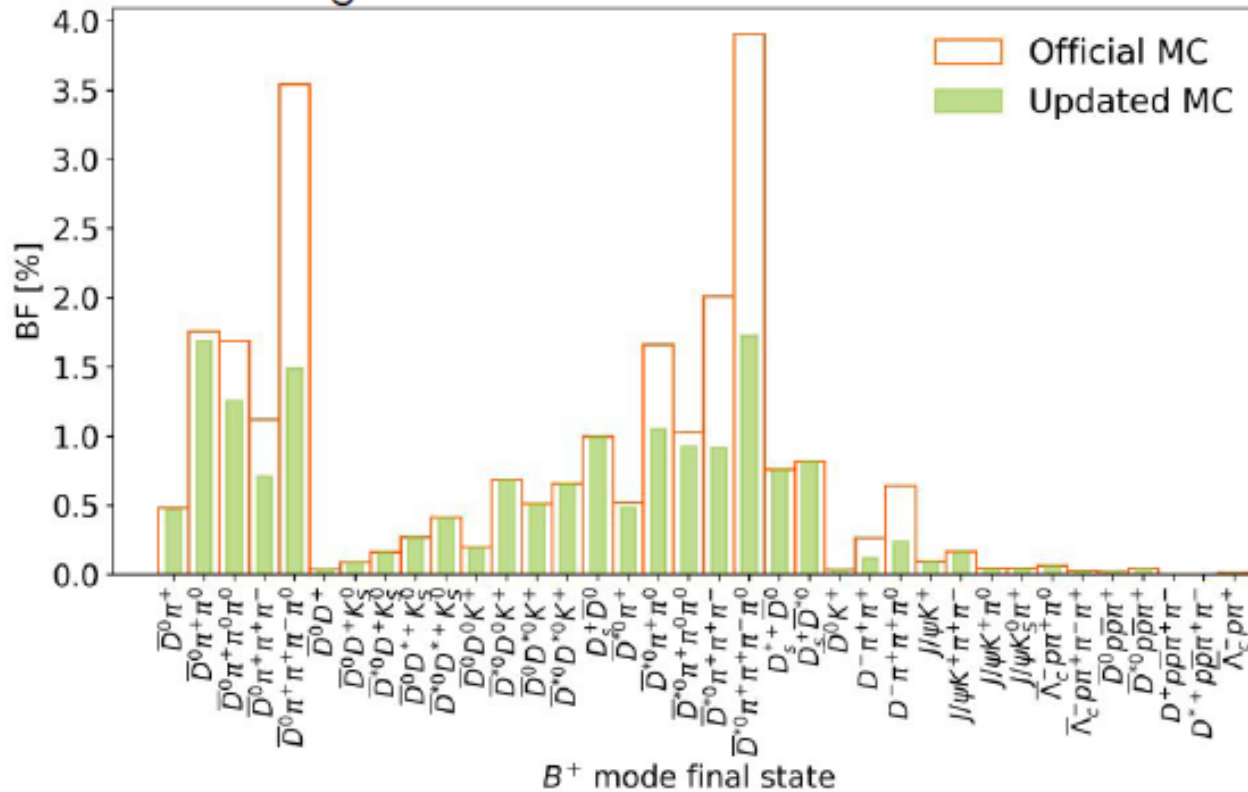


- for many other missing energy modes ($B \rightarrow \tau \nu, \mu \nu, K \nu \nu, K \tau \tau \dots$), **Belle II is the main/only actor**

B-tagging

- **key tool for missing energy analyses**
- low efficiency (efficiency for hadronic B-tagging < 1 %)
- and ML can't save you... B-tagging algorithms are trained using MC samples
- 40% of hadronic B decays generated by PYTHIA...
- and even among the EvtGen part... most BF's measured are from ARGUS, CLEO...

After correcting the modes that contribute to the 12 main FEI final states:



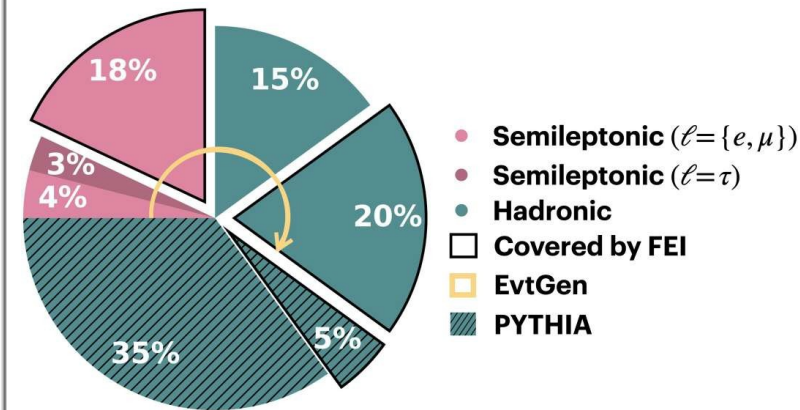
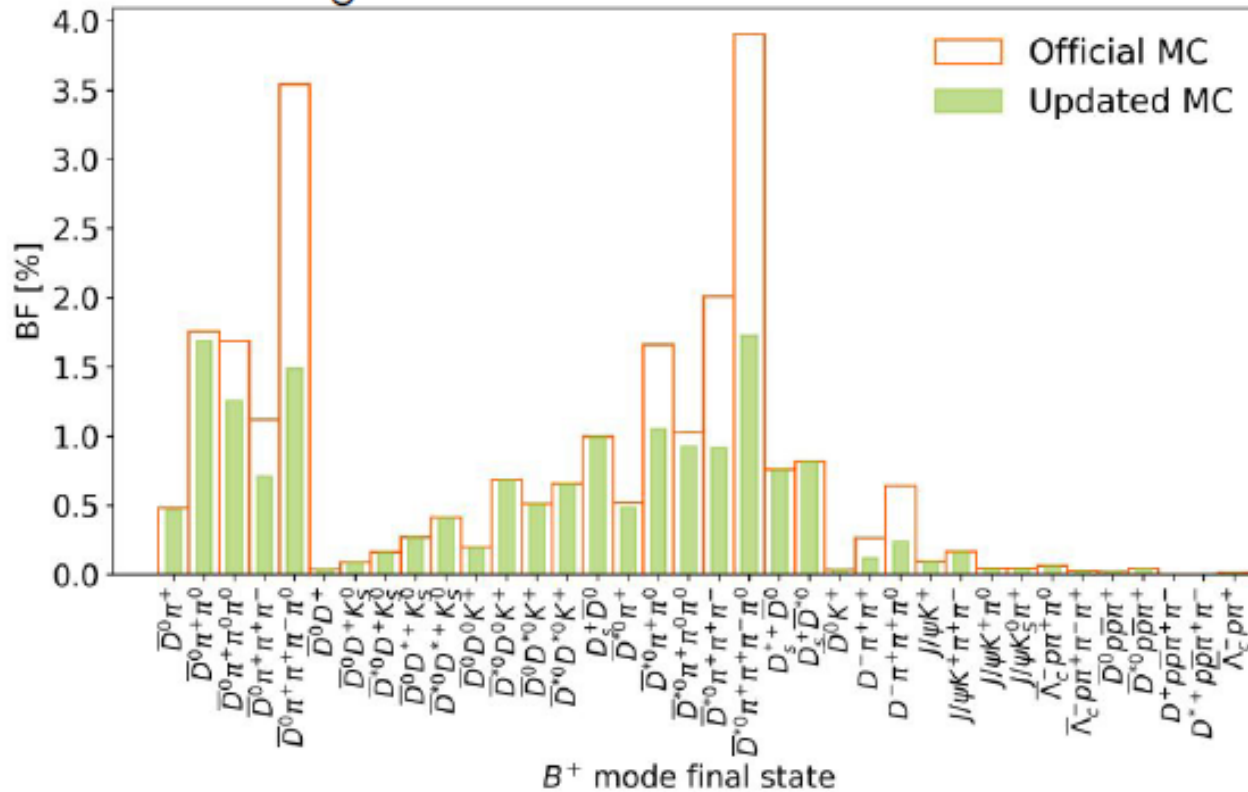
- lot of possible measurements:
 - to improve our simulation, Btag modes included → better FEI performance
 - also some opportunities to study those B decays and intermediate states
- improvements of FEI needed, differences with Belle version: too high momentum cut on π^0 , no π^0 mass constraint !!!

⇒ **after 4 years... still poor performance of B-tagging...**

B-tagging

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- \Rightarrow after 4 years... still poor performance of B-tagging ...**

Precise $|V_{cb}|$ measurement

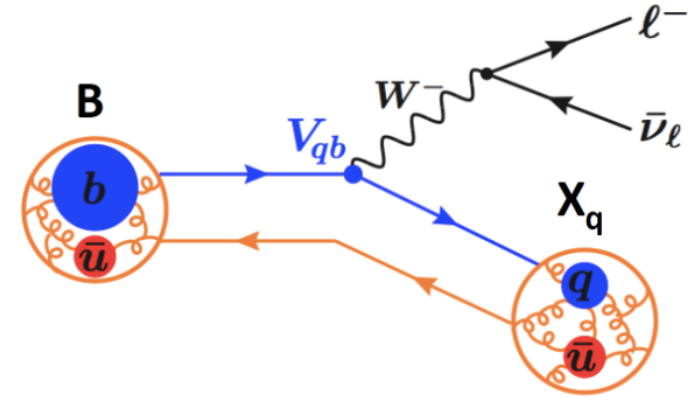
- Already precise with few ab^{-1} (one of the main goals of run II)
- Precious input for global fit (if we get it right)
- New physics in B meson mixing: limitation from $|V_{cb}|$
arXiv:2006.04824

IV. PERSPECTIVES AND LIMITATIONS ON $|V_{cb}|$ IMPROVEMENT

For our analysis, precise determinations of CKM parameters from tree-level measurements is essential. This is particularly important when one reaches the Phase II precision, where we identified the $|V_{cb}|$ precision (together with the hadronic mixing parameters) as the bottleneck for this analysis. This section aims at sketching novel ways to measure the matrix element $|V_{cb}|$.

Currently there is an approximately 3σ tension in the measurements of $B \rightarrow D^{(*)}\ell\nu$ semileptonic decays, when the rate to τ leptons is compared to the average of the e, μ modes [17, 45]. Furthermore, the inclusive $|V_{cb}|$ and $|V_{ub}|$ measurements also differ by more than 3σ from their exclusive counterparts [46], when considered together.

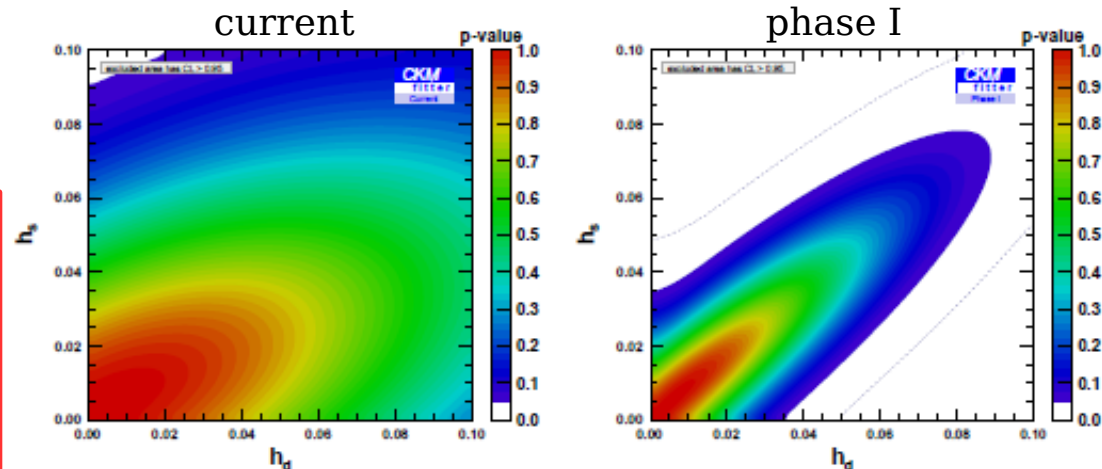
The tension between inclusive and exclusive $|V_{ub}|$ and $|V_{cb}|$ determinations might also remain a cause for concern [47]. If these discrepancies are not resolved and further established with higher significance in the coming years (by LHCb and Belle II), they would also impact the analysis of NP contributions to meson mixing.



M_{12} relates to the time evolution of the two-state neutral meson system

$$M_{12} = (M_{12})_{\text{SM}} \times (1 + h_{d,s} e^{2i\sigma_{d,s}})$$

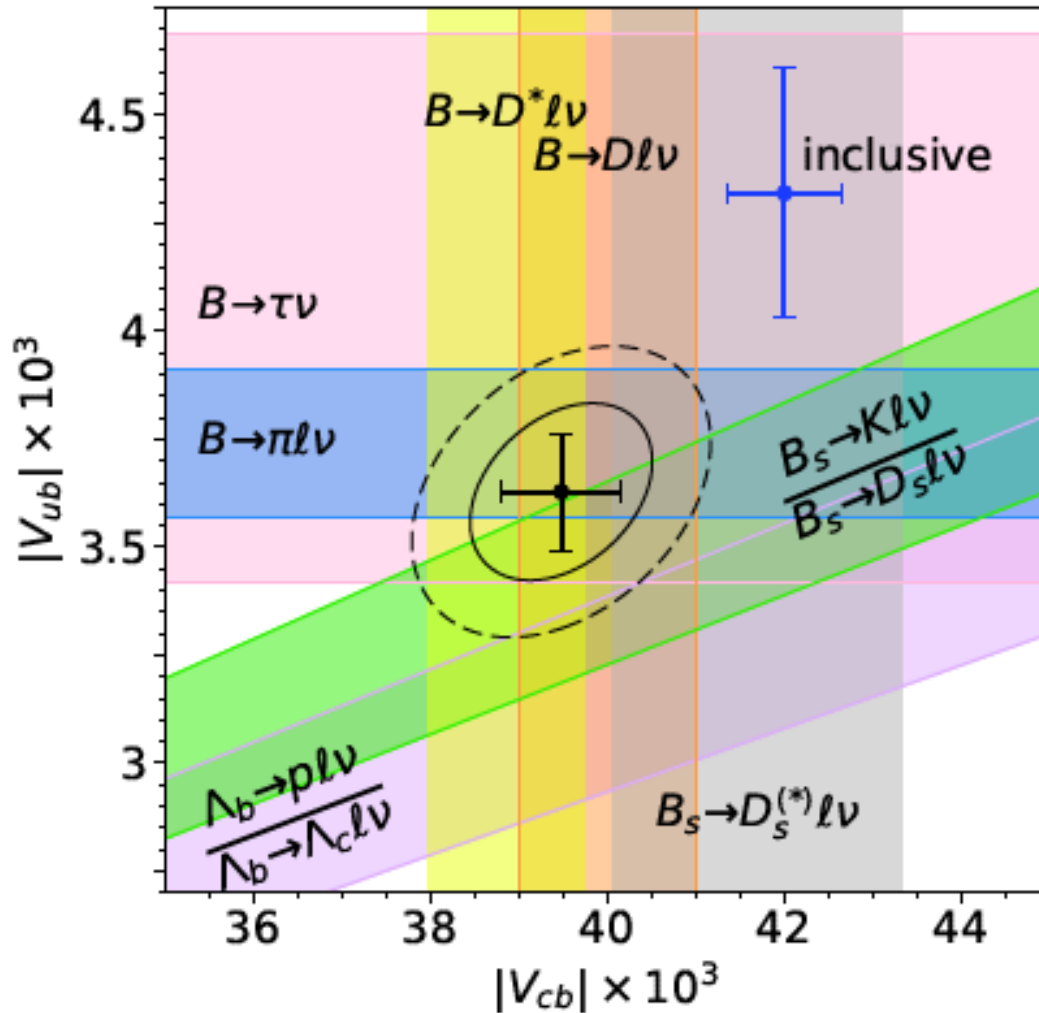
- Phase I: LHCb 50/fb, Belle II 50/ab (late 2020s);
- Phase II: LHCb 300/fb, Belle II 250/ab (late 2030s);



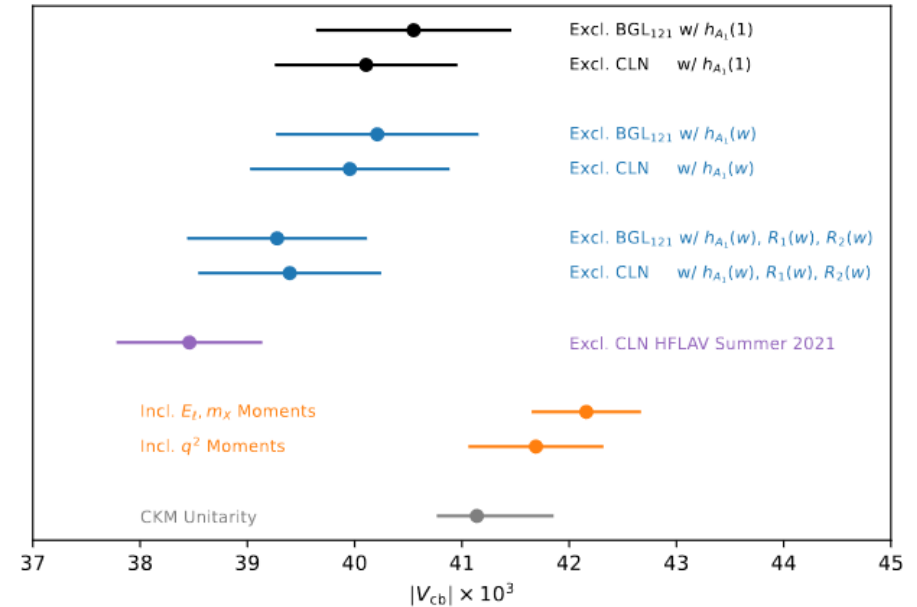
$|V_{cb}|$ measurement (s)

Long-standing discrepancy between inclusive/exclusive $|V_{cb}|$, $|V_{ub}|$

FLAG2021



Belle, arXiv:2301.07529



⇒ "Could indicate presence of non-SM partial widths"

but remember $R_{K^{(*)}}$!! need to do our job properly, precisely ...

on the $|V_{cb}|$ extraction (including theory), but also on the experimental side (e.g. SL-gap) important to improve charm inputs (valid also for R_X), look for more $B \rightarrow$ charm information

Belle II physics week 2023

[Oct 30 - Nov 3, 2023, at KEK]

- **organization committee**

from Belle II side: Lu Cao, Peter Lewis (SL), Mirco Dorigo (HadB),
from theory side: Rusa Mandal, Takashi Kaneko, Dean Robinson
+ physics coordinators: J.Libby, D.Tonelli

- **format**

a school (morning) and a workshop (afternoon), this year on |Vcb| and related topics

- **one week, from October 30th (right after B2GM)**

- **school on the model of previous editions**

Roma:<https://indico.belle2.org/event/5492/>, Valencia:<https://indico.belle2.org/event/7825/>
(add some starter kit between B2GM and the physics week ?)

- **workshop on one of the major measurements of Belle II**

related to BtoSL activities but not only !! how other activities should contribute (hadB, charm...)?

- **(short) KEK report after each workshop**

- **budget: Hashimoto-san, Iijima-san's grant**

(for speakers/lecturers when needed)

- **Regular meetings since one month to organize the program**

⇒ **be ready by end of June**

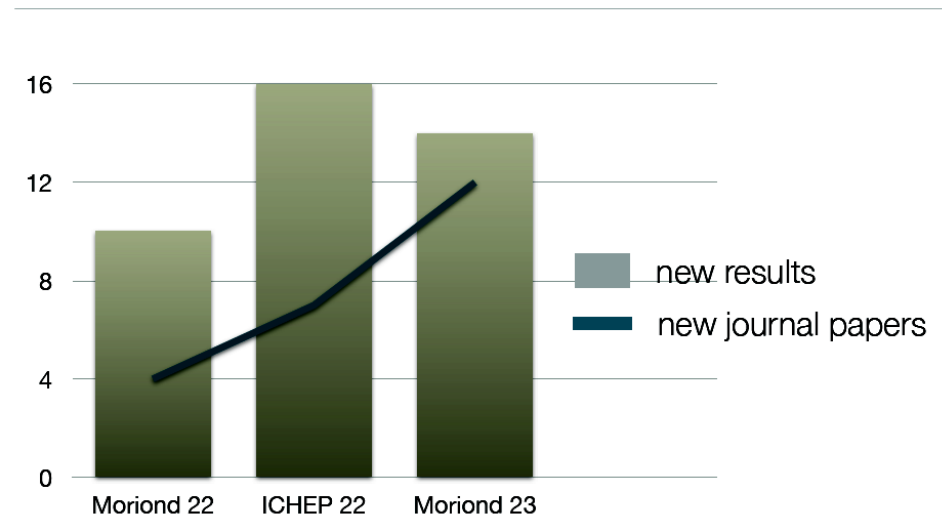
Please come at KEK for this event !!

LHCb 2023 list of publications

TITLE	DOCUMENT NUMBER	JOURNAL	SUBMITTED ON	CITED
Measurements of CP asymmetries and branching fractions of B^- decays to two charm mesons	PAPER-2023-007 arXiv:2306.09945 [PDF]	JHEP	16 Jun 2023	
Study of the Bose-Einstein correlations of identical pions in proton-lead collisions	PAPER-2023-002 arXiv:2306.09755 [PDF]	JHEP	16 Jun 2023	
Evidence for the decays $B^0 \rightarrow \bar{D}^{(*)0} \phi$ and updated measurements of the branching fractions of the $B_s^0 \rightarrow \bar{D}^{(*)0} \phi$ decays	PAPER-2023-003 arXiv:2306.02768 [PDF]	JHEP	05 Jun 2023	
Associated production of prompt J/ψ and Y mesons in pp collisions at $\sqrt{s} = 13\text{TeV}$	PAPER-2022-047 arXiv:2305.15580 [PDF]	JHEP	24 May 2023	
Measurement of the mass difference and relative production rate of the Ω_b^- and Ξ_b^- baryons	PAPER-2022-053 arXiv:2305.15329 [PDF]	PRD	24 May 2023	1
Measurement of Ξ_c^+ production in pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV at LHCb	PAPER-2022-041 arXiv:2305.06711 [PDF]	PRL	11 May 2023	
Test of lepton flavour universality using $B^0 \rightarrow D^{*-} \tau^+ \nu_\tau$ decays with hadronic τ channels	PAPER-2022-052 arXiv:2305.01463 [PDF]	PRD	02 May 2023	7
Study of charmonium decays to $K_S^0 K \pi$ in the $B \rightarrow (K_S^0 K \pi) K$ channels	PAPER-2022-051 arXiv:2304.14891 [PDF]	PRD	28 Apr 2023	
Precision measurement of CP violation in the penguin-mediated decay $B_s^0 \rightarrow \phi \phi$	PAPER-2023-001 arXiv:2304.06198 [PDF]	PRL	13 Apr 2023	
Search for $D^*(2007)^0 \rightarrow \mu^+ \mu^-$ in $B^- \rightarrow \pi^- \mu^+ \mu^-$ decays	PAPER-2023-004 arXiv:2304.01981 [PDF]	EPJC	04 Apr 2023	
Observation of the $B^+ \rightarrow J/\psi \eta' K^+$ decay	PAPER-2022-054 arXiv:2303.09443 [PDF]	JHEP	16 Mar 2023	
Search for CP violation in $D_{(s)}^+ \rightarrow K^- K^+ K^+$ decays	PAPER-2022-042 arXiv:2303.04062 [PDF]	JHEP	07 Mar 2023	
Observation of the $B_s^0 \rightarrow \chi_{c1}(3872) \pi^+ \pi^-$ decay	PAPER-2022-049 arXiv:2302.10629 [PDF]	JHEP	21 Feb 2023	1
Measurement of the $\Lambda_b^0 \rightarrow \Lambda(1520) \mu^+ \mu^-$ differential branching fraction	PAPER-2022-050 arXiv:2302.08262 [PDF]	PRL	16 Feb 2023	
Observation of new Ω_c^0 states decaying to the $\Xi_c^+ K^-$ final state	PAPER-2022-043 arXiv:2302.04733 [PDF]	PRL	09 Feb 2023	8
Measurement of the ratios of branching fractions $\mathcal{R}(D^*)$ and $\mathcal{R}(D^0)$	PAPER-2022-039 arXiv:2302.02886 [PDF]	PRL	06 Feb 2023	
A study of CP violation in the decays $B^\pm \rightarrow [K^+ K^- \pi^+ \pi^-]_D h^\pm$ ($h = K, \pi$) and $B^\pm \rightarrow [\pi^+ \pi^- \pi^+ \pi^-]_D h^\pm$	PAPER-2022-037 arXiv:2301.10328 [PDF]	EPJC	24 Jan 2023	

Summary

- The collaboration stepped up its game: steep increase in quantity and quality of results.
- Already competitive on many topics



- Room to improve (*) and prepare for few ab^{-1} data in the coming few years, as Belle II results will dominate some of the most important measurements in flavor physics

(*) better coordination between the WGs (common goals, tools, ...),
improving tools (new charm tagger, improved flavour tagging, better calibration...)

SuperKEKB, the first new collider in particle physics since the LHC in 2008 (electron-positron ($e^+ e^-$) rather than proton-proton (p-p))

Phase 1

Background, Optics commissioning
Feb - June 2016

Brand new 3km positron ring

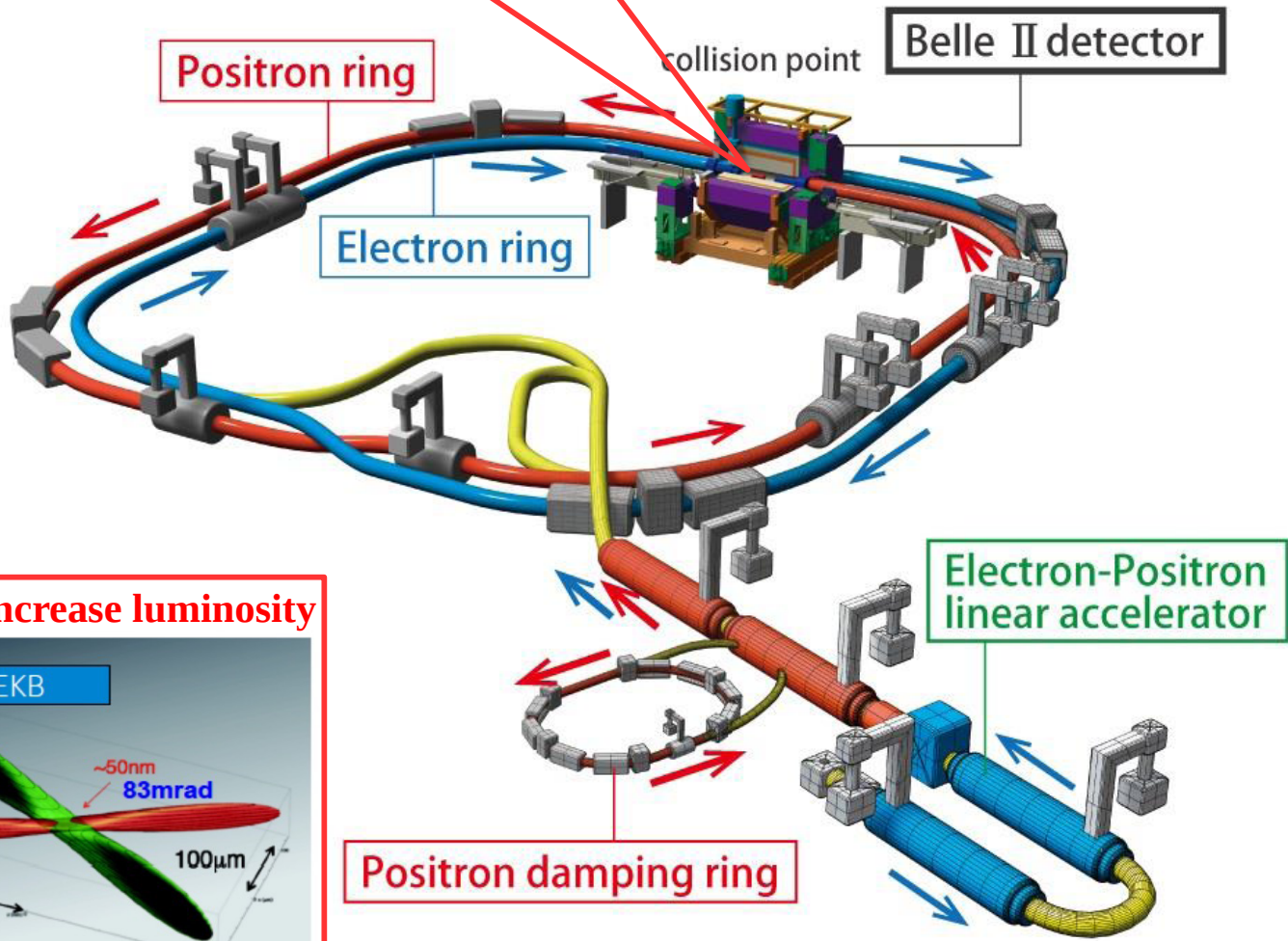
Phase 2: Pilot run

Superconducting Final Focus
add positron damping ring
First Collisions (0.5 fb^{-1})
April 27 - July 17, 2018

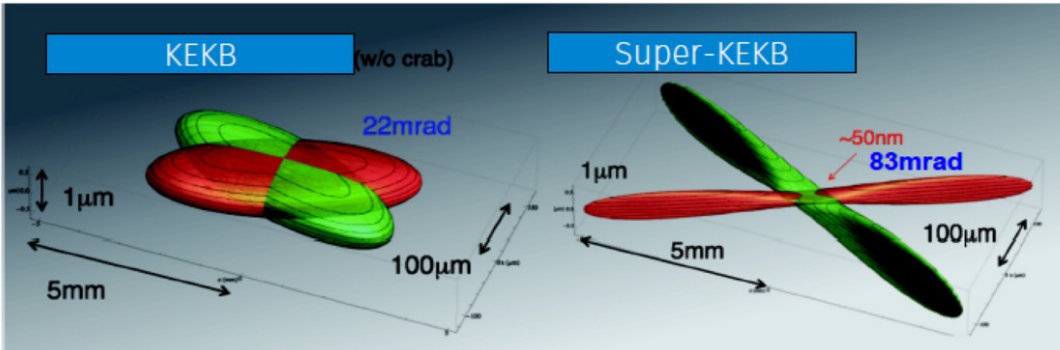
Phase 3: Physics run

Since April, 2019

Squeeze strongly at IP



Nano-beams and more beam current to increase luminosity



	E (GeV)	β_y^* (mm)	β_x^* (cm)	ϕ	I (A)	L ($\text{cm}^{-2}\text{s}^{-1}$)
	LER/HER	LER/HER	LER/HER	(mrad)	LER/HER	
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1×10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80×10^{34}

factor 20

factor 2-3

\Rightarrow to reach $\sim 6 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
 \Rightarrow cumulate 50 ab^{-1} by ~ 2035

LS1 (many upgrade works at SuperKEKB)

LINAC

- e- beam
 - Laser system has worked fine without any significant trouble.
 - DOE was installed also at 2nd laser line in the last summer maintenance, and it has worked fine.
 - In the run 2022a/b, bunch charge of 2 nC can be kept with bunch charge feedback.
 - 5 nC from gun was demonstrated. Further beam study is on-going during LS1.
 - New DOE with large area improve energy spread and emittance until HER injection.
 - BTe-ECS is planned to install at FY2024
- e+ beam
 - The new FC is working fine.
 - Reached bunch charge of 3.5 nC at BT end (final design 4 nC).
- Upgrade work during LS1
 - Pulsed Quads (x8) at J-ARC for the simultaneous dedicated matching of HER/LER injection beam
 - Pulsed Quads (x4) at Sector1, 2 for low beta optics of HER injection beam
 - New accelerating structure
 - Replacement of air conditioners at SectorA, B (in the accelerator tunnel)
 - Fast kicker for 2nd bunch orbit correction
- Issues
 - Emittance growth at end of BT2 for both of e- and e+ beam (BT report, Injection report)
 - Low e- injection efficiency of 2nd bunch
 - Increase the e- bunch charge while keeping small emittance

MR

- **Many upgrade & maintenance works are progressed during LS1.**
 - LS1 started in July 2022 and will end in November 2023.
 - Next beam operation is scheduled to restart in December 2023.
- **Progress of “IR works” & “NLC construction” were reported.**
 - And also, damaged collimator heads were replaced with new ones.
 - Most planed works will be completed by October 2023.
 - Beam operation will resumed from December 2023.
- **Sudden Beam Loss (SBL) is one of the concerned issues to be solved.**
 - Frequently, the beam suddenly disappears within few turns just before the abort.
 - The cause of SBL is still unknown. (Several candidates for the cause are considered.)
 - Continuation of investigation or study of SBL is needed to avoid it.

is this sufficient to solve our main issues during run 1 ?

SuperKEKB (K. Shibata)

Luminosity after LS1 : $\sim 2.4 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$

- ✓ Increasing total beam currents
- ✓ Increasing bunch current
- ✓ Squeezing β_y^*