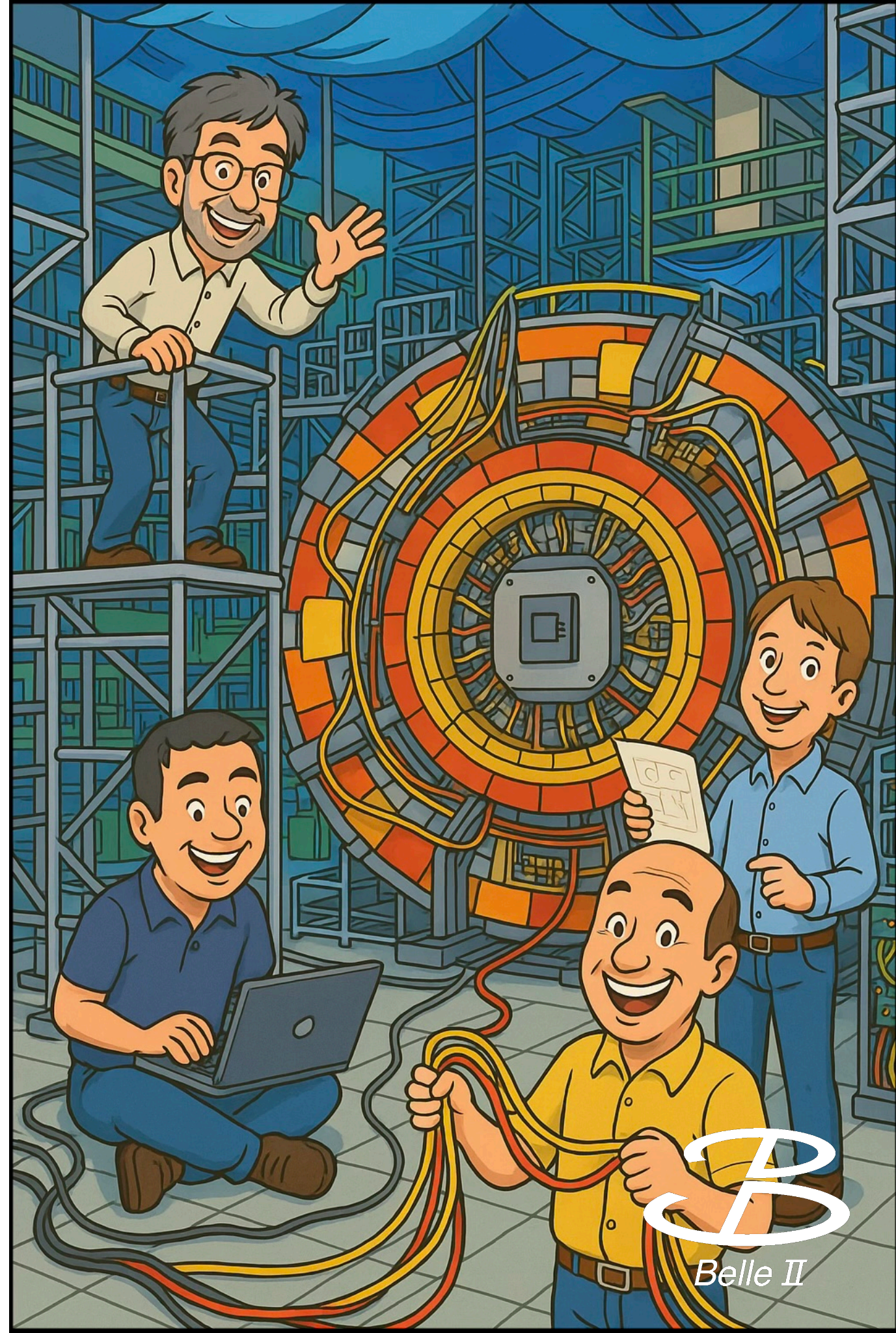


Status of SKB & Belle II

Belle II Germany Meeting

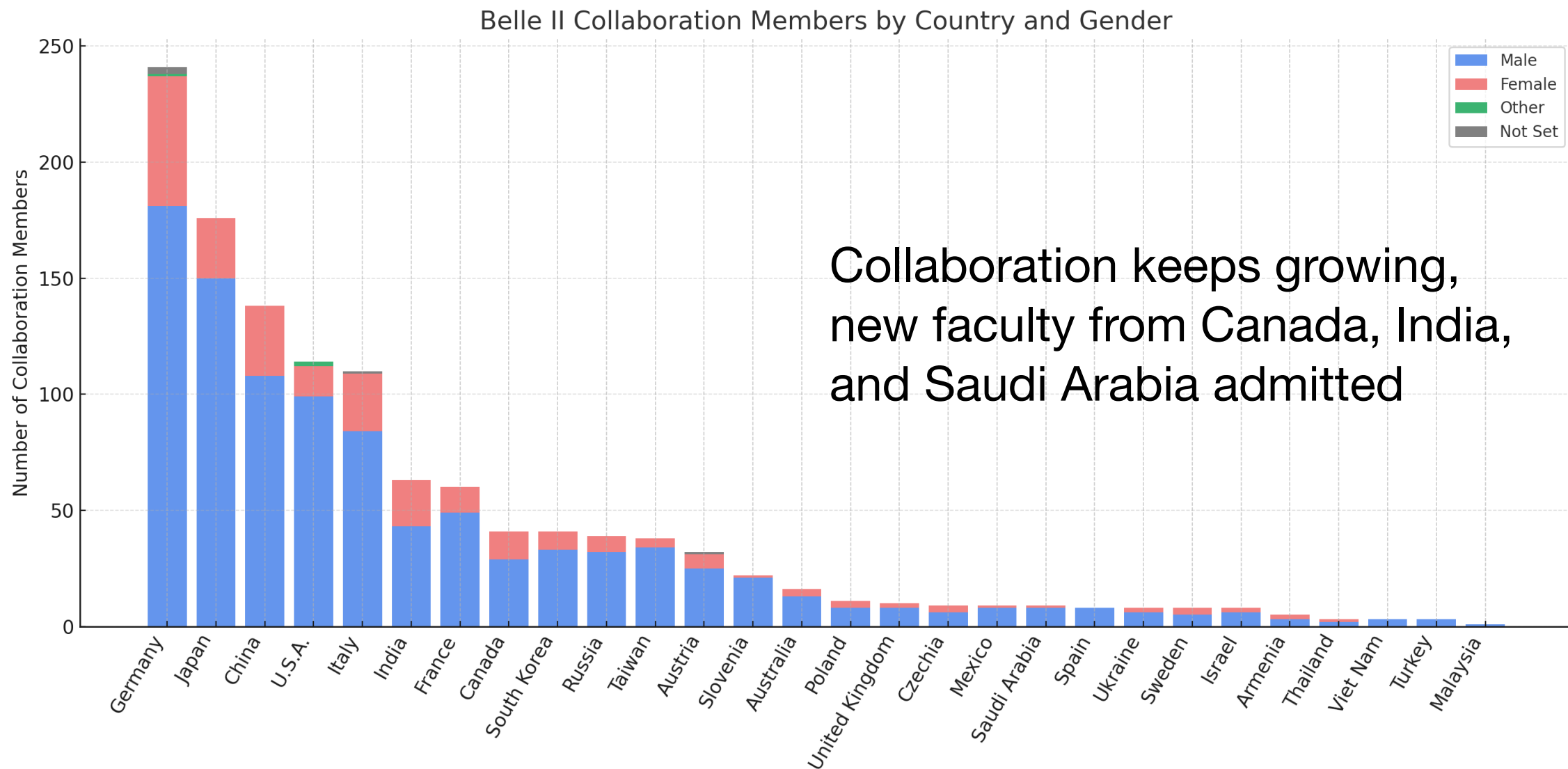
September 8, 2025

Florian Bernlochner
florian.bernlochner@uni-bonn.de



State of the Collaboration

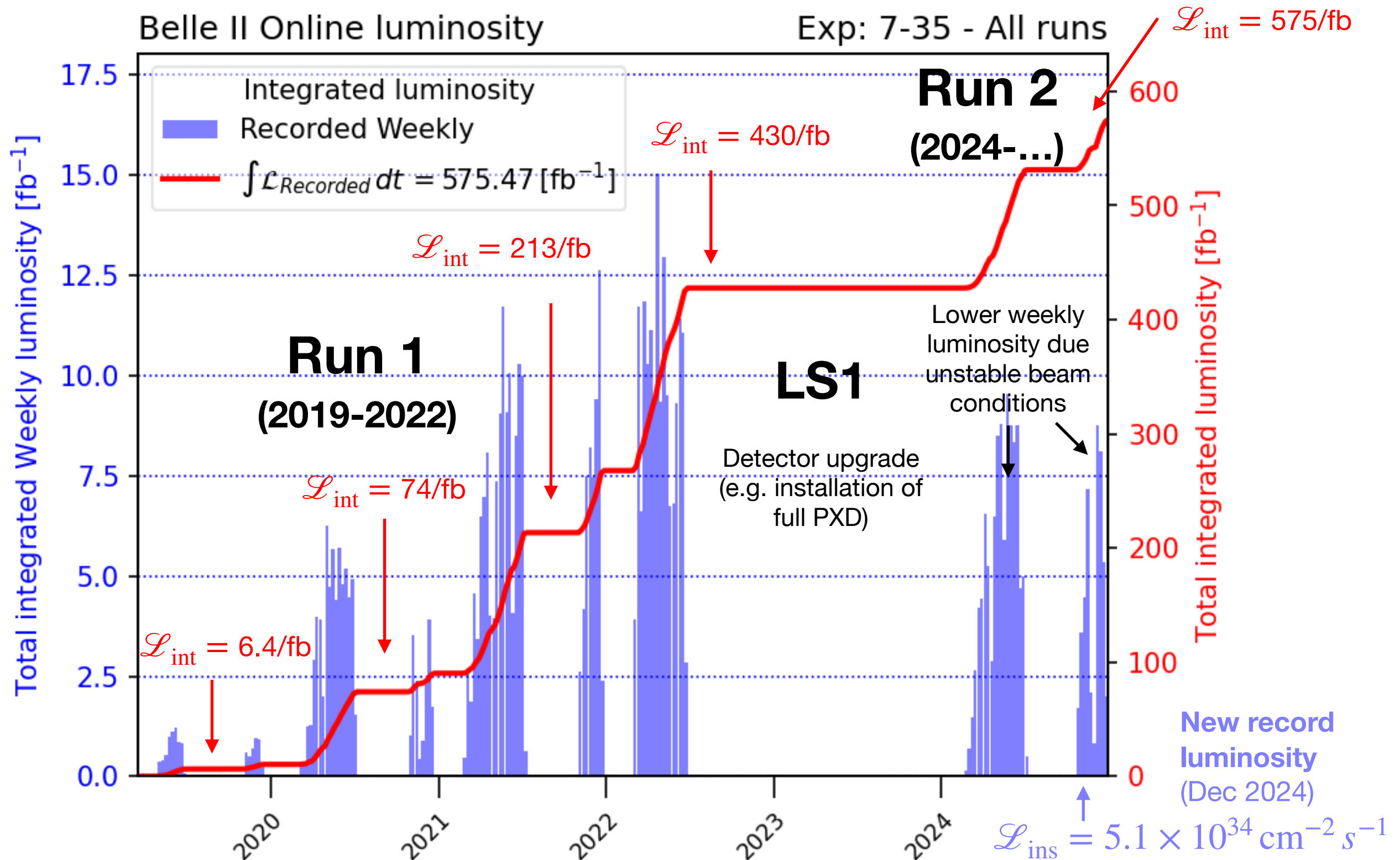
691 Collaborators (311 Faculty, 124 PDs, 256 PhDs)



Comparison with **LHCb**:

1165 Collaborators
(459 Faculty, 282 PDs, 424 PhDs)

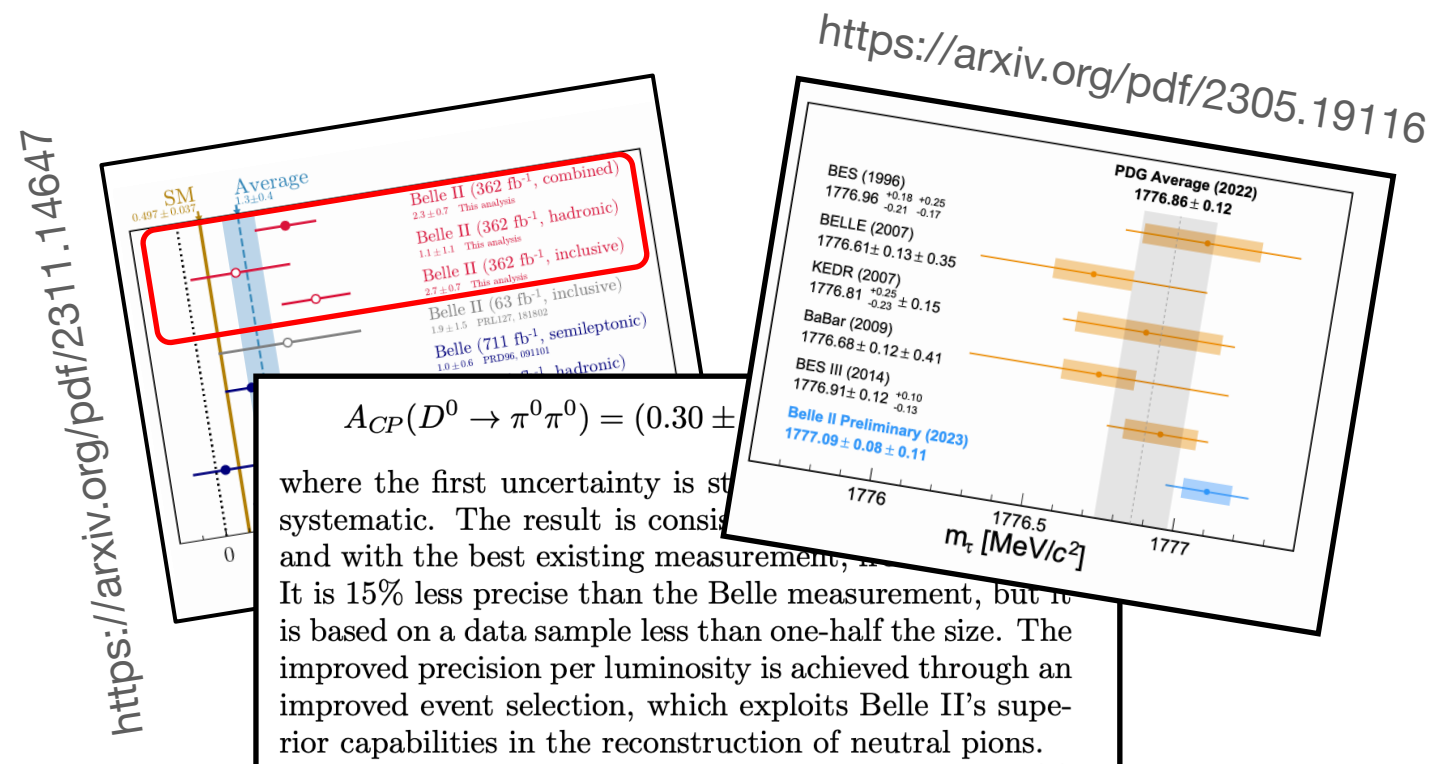
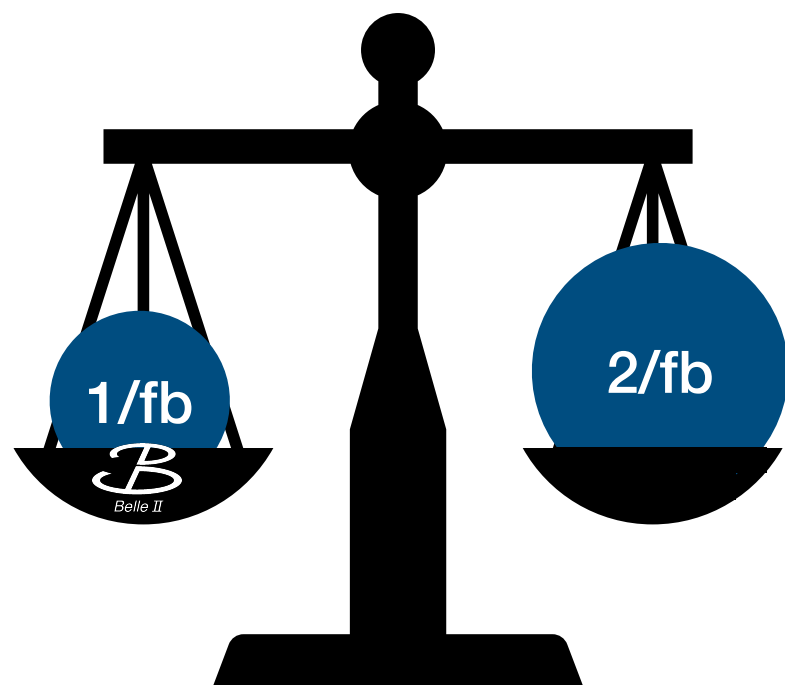
State of the Experiment



Currently Run 1 data (+ when relevant Belle data) used for **physics** ; Run 1 + 2 results in preparation

Belle II versus Belle / BaBar data

Belle II achieves **higher statistical power** than Belle & BaBar due to improved detector & modern analysis techniques.



Rough rule of thumb:

1/fb of Belle II data is worth 2/fb of BaBar or Belle data*

* exceptions of course do exist

→ Much effort ongoing to shift this fraction even further with new triggers, better reconstruction, novel ideas etc.

See e.g. <https://arxiv.org/pdf/2506.11196>

Aim to publish as many Run 1 (+Belle) analyses as possible until end of 2025

Summer Conference Plan

FPCP (June) - 5 new results
EPS (July), LP (August), CKM (September)

10 plenary & 34 parallel talks

20 analyses at RC stage towards CWR1; **10** more at WG level with good chance to be ready

Highlights

Inclusive $|V_{ub}|$, updated inclusive tag $B \rightarrow K^{(*)}\nu\bar{\nu}$, $B \rightarrow K\tau\tau$
 $\mathcal{R}(D^{(*)})$, $\tau \rightarrow \ell\gamma$, τ lifetime, Run 1 + 2 $A' \rightarrow \mu\mu$ search



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Review Procedure & Tools

Flow improving; **new analysis data base**; large **variance** in review

Belle II Publications Documents Analyses				
Dashboard Settings Logout (Florian Bernlochner)				
List of analyses by the Belle II Experiment				
In CWR1: #90 Pre CWR2: In CWR2:				
Measurement of inclusive $B \rightarrow X_u \ell \nu$ partial branching fractions and V_{ub} at Belle II	Note: BELLE2-NOTE-PH-2023-013 Paper: BELLE2-PUB-PH-2025-021	Semileptonic and Missing Energy Decay	Phys.Rev.D	Status: ongoing last update: June 23, 2025, 6:17 p.m. CWR1

→ **4-4.5 months between CWR1 & submission**

Reasons complex, PubCom and PC(s) are actively working on improving the situation

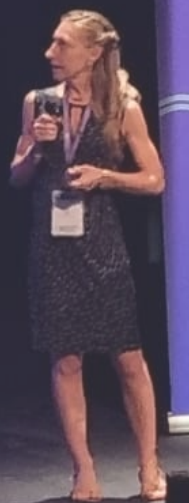
Start with why



"Beauty will save the world"

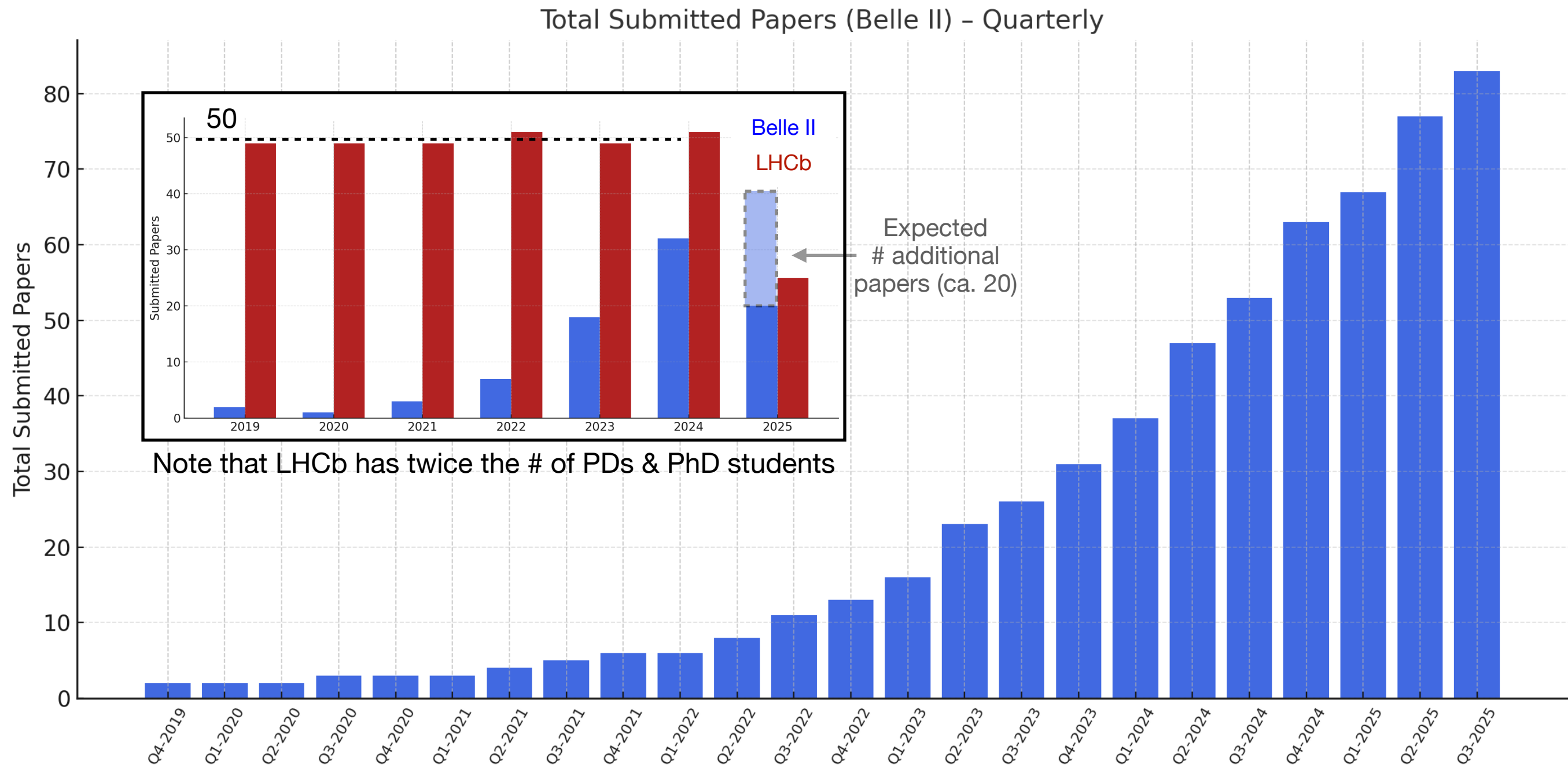
ima,
nber 2024

Extremely proud that Laura Zani won the
Young Experimental Physicist
Prize of the European Physical Society
for her work on Belle II



Paper Submission Status

83 paper submitted (75 accepted as of August 31st) :



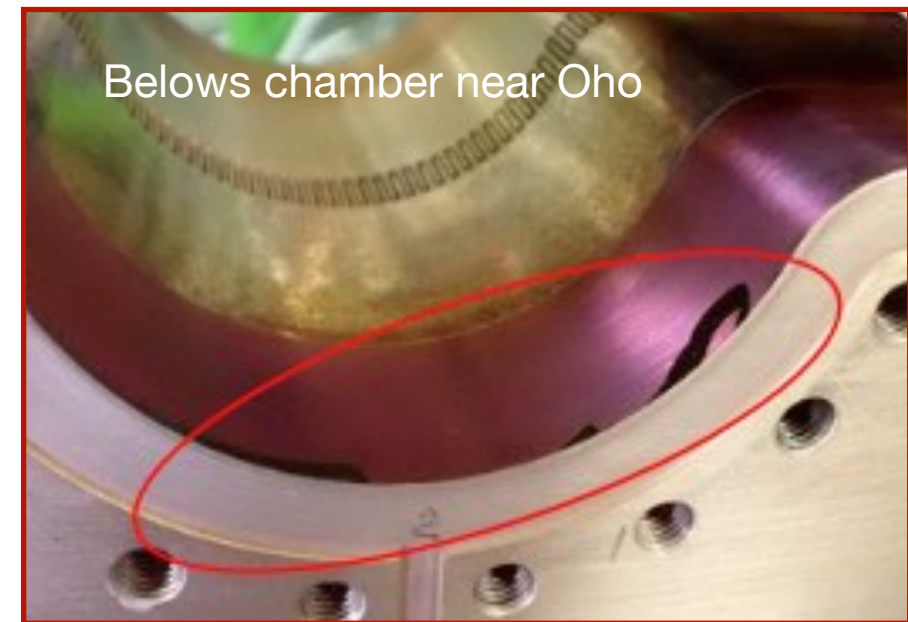
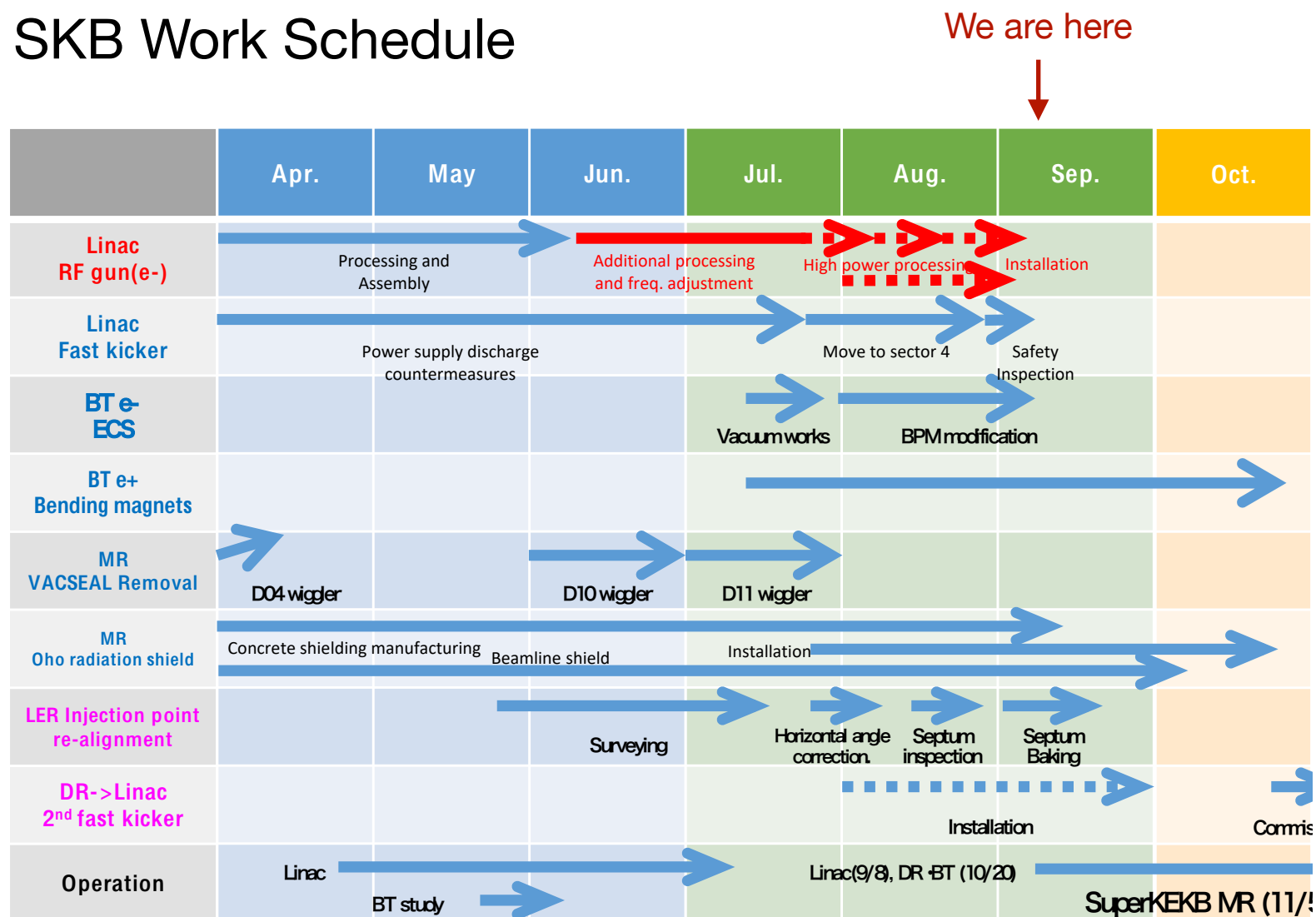
Our goal is to achieve **40 - 45 papers / year**

SKB Status & Preparations

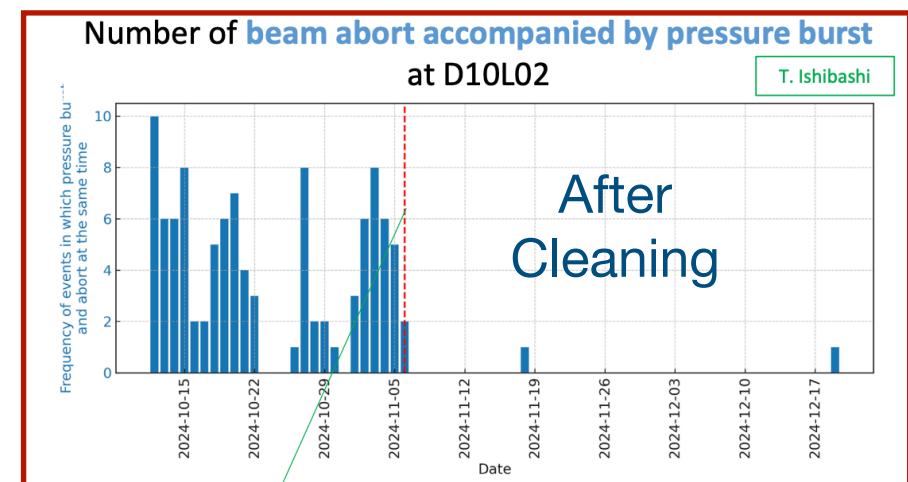
Much work ongoing over summer shutdown:

- **Removal of stains from vacuum sealant** →
- Construction of new electron gun
- New enhanced shielding near non-linear collimator @ Oho

SKB Work Schedule



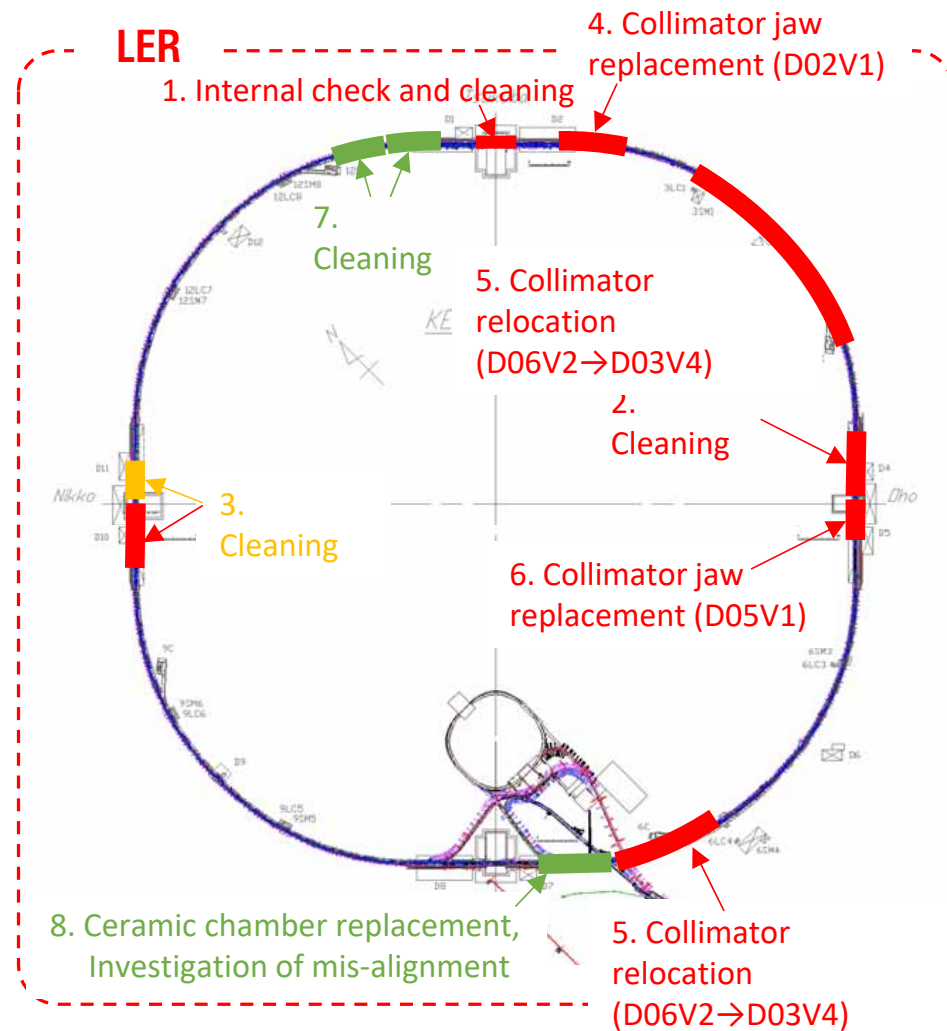
Sudden beam loss frequency



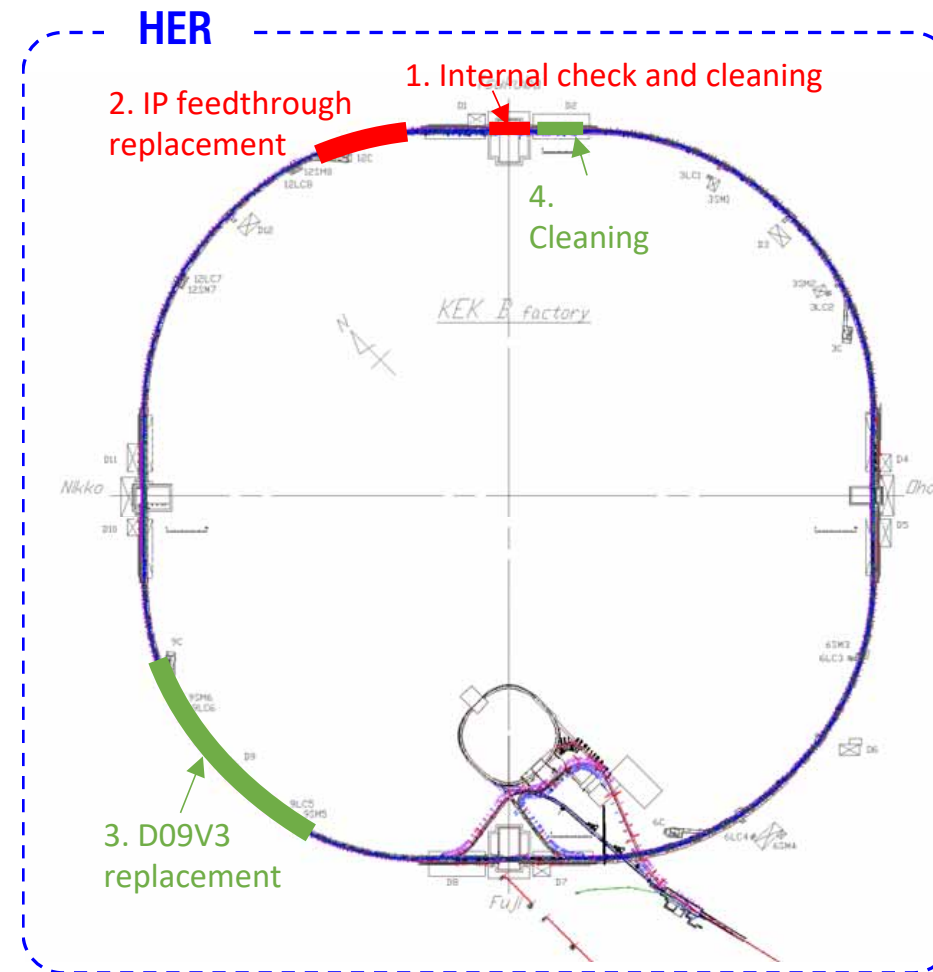
Work on LER & HER progress:

10

— Completed
— To be done

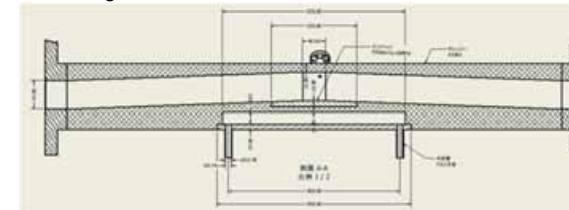


1. Internal inspection and cleaning of beam pipes in IR → **Completed**
2. Cleaning of beam pipes in the Oho wiggler section → **Completed**
3. Cleaning of beam pipes in the Nikko wiggler section → **Ongoing (May - July)**
4. Replacement of damaged jaws in the D02V1 collimator → **Completed**
5. Relocation of the D06V2 collimator to D03V4 → **Completed**
6. Replacement of damaged jaws in the D05V1 collimator → **Completed**
7. Cleaning of MO-flanges known to have used VACSEAL (location: around CCG D01_L10, D01_L15)
8. A) Replacement of ceramic chambers in the kicker magnets (to reduce residual kicks)
B) Alignment check and correction of beam pipes around the injection point.



1. Internal inspection and cleaning of beam pipes in the IR → **Completed**
2. Replacement of an ion pump feedthrough → **Completed**
- Vacuum leak was caused by abnormal discharge in the HV connector.
3. Replacement of the damaged jaw in the D09V3 collimator
- A new collimator with a cooling water channel is being manufactured. Installation is scheduled for the beginning of Nov.
4. Cleaning of MO-flanges known to have used VACSEAL. (location: SUS flanges around CCG D02_H22)

Drawing of HER vertical collimator with water channel



Expansion of radiation protection area @ Oho

to allow expanded use of non-linear collimator

[K. Watanabe]

Oct 2024



June 2025



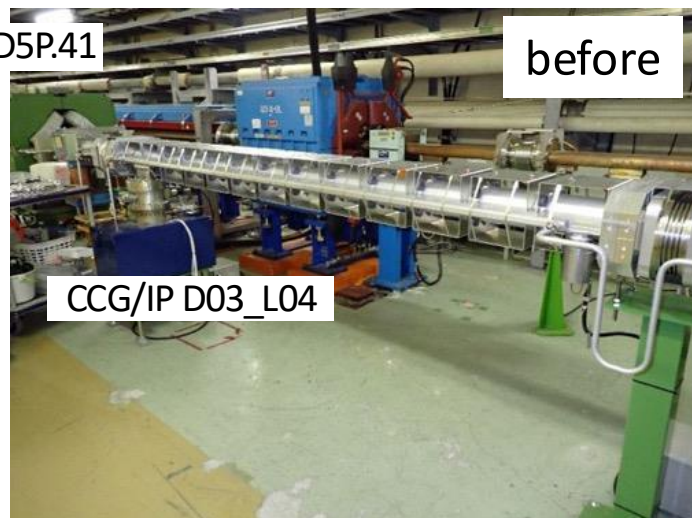
Relocation of D06V2 collimator to D03V4

to protect the IR and D02V1 better against SBLs

Location of D03V4

QD5P.41

before

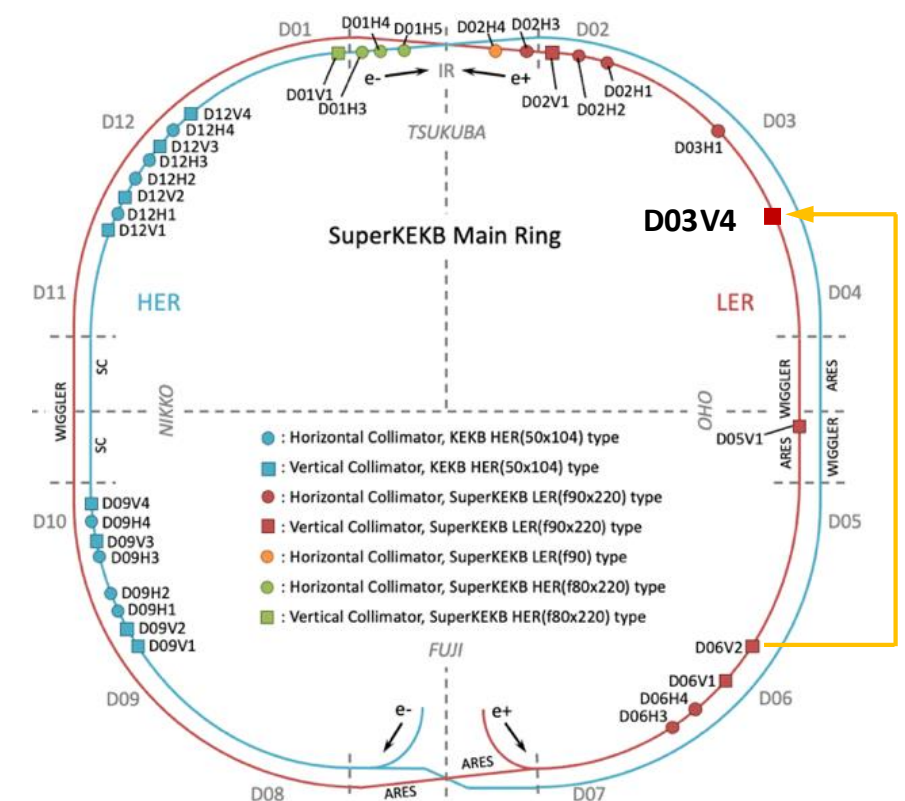


QD5P.41

after



Location of collimators

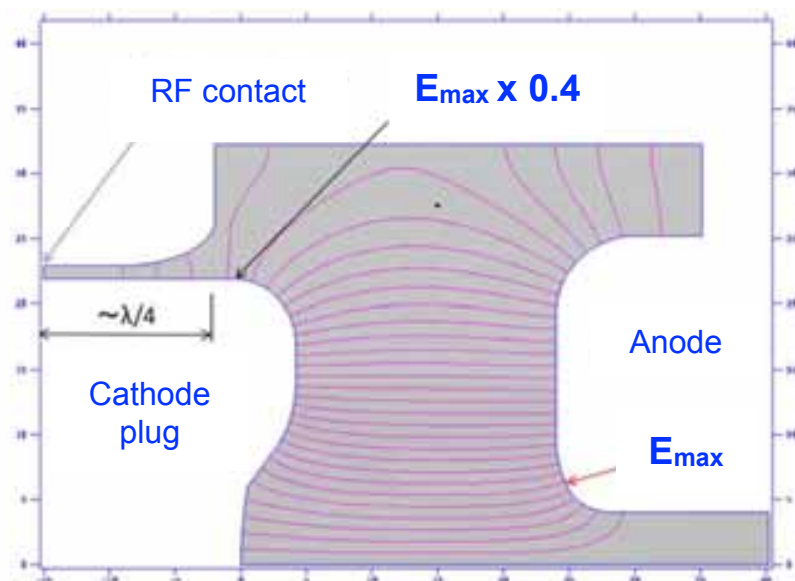


New RF gun

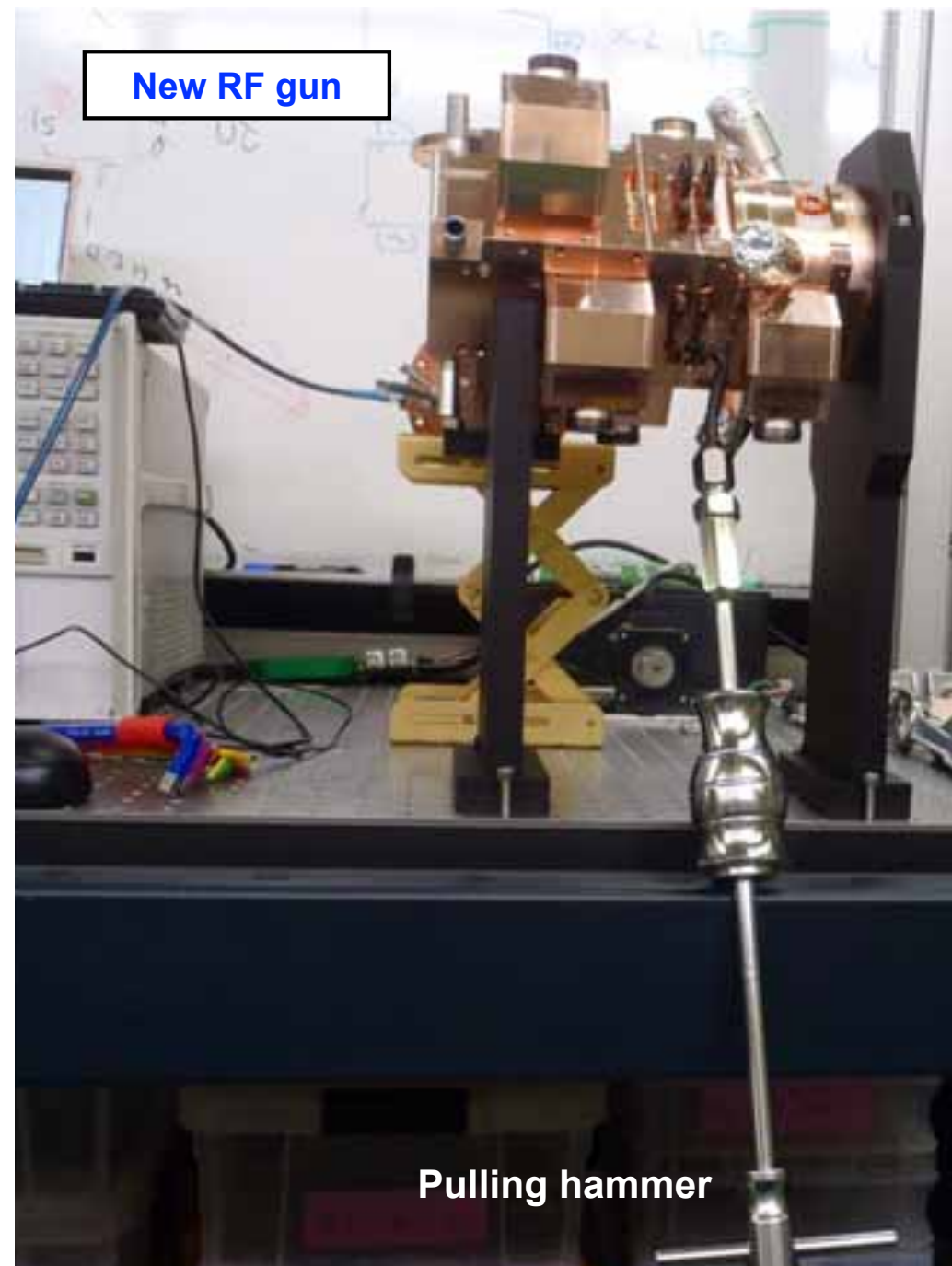
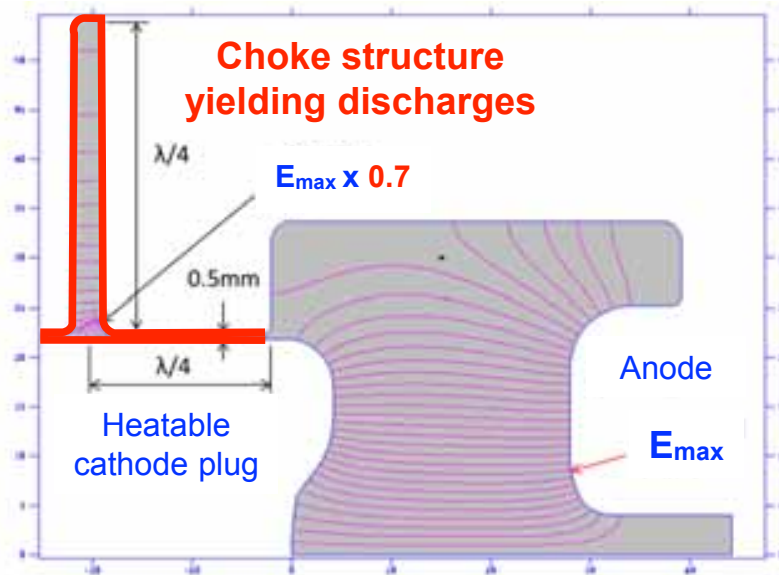
New gun has no choke as a countermeasure against discharges

Due to mishap in fabrication the RF frequency of the cavity has been changed, but successfully retuned. Tested at 5 MW, further conditioning ongoing. If successful installation will follow

Inner structure without choke



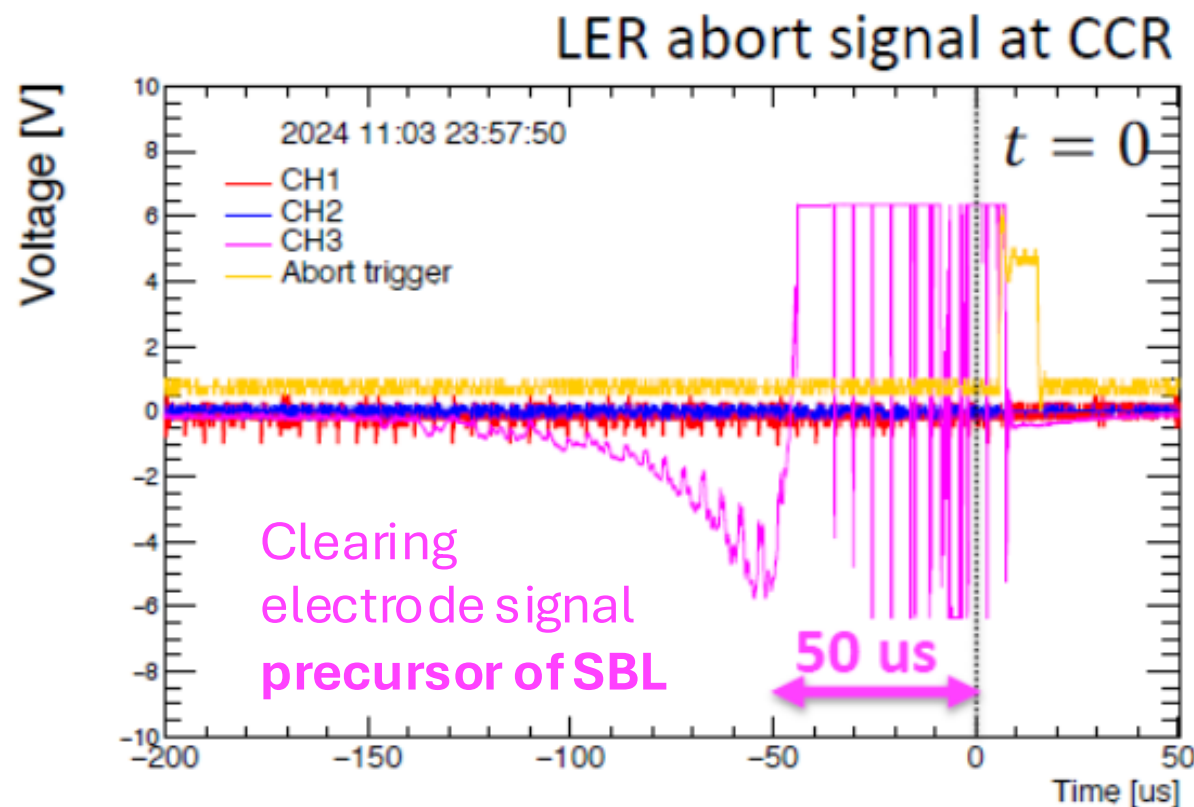
current RF gun



Belle II Status & Preparations

Preparations for **2025c** in full swing: Selection of activities

PXD will remain initially off ; progress on fast shutdown



Investigations ongoing if signal from **clearing electrodes** can be used as a precursor signal for SBL (Ca. 50 us)

↓
About 30 us for shutdown seem reachable, but system needs still improvements to avoid dangerous voltage crossings that might damage switchers

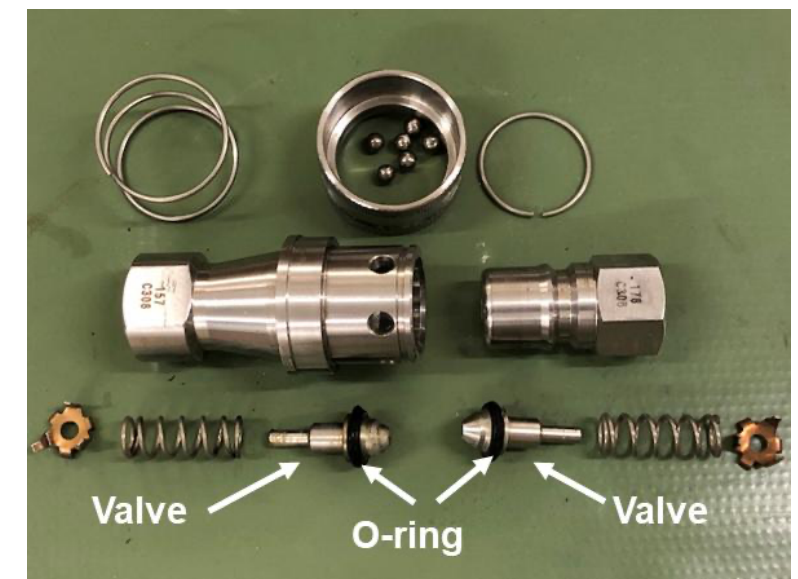
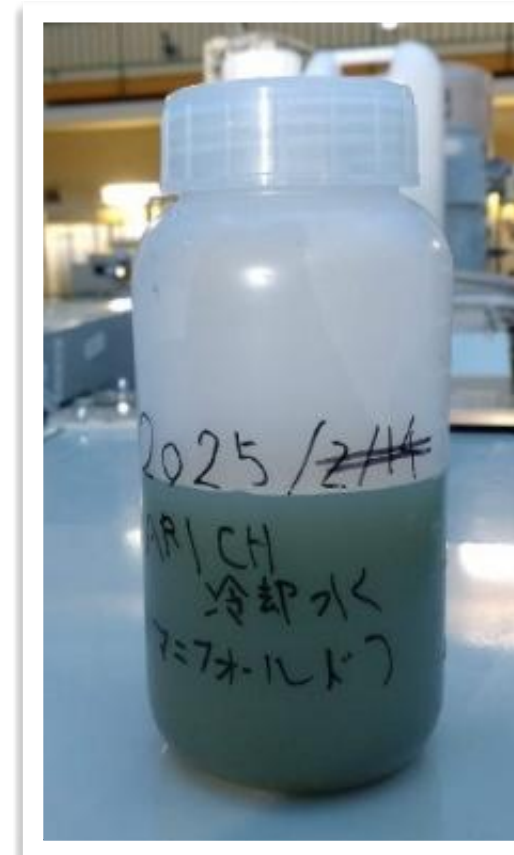
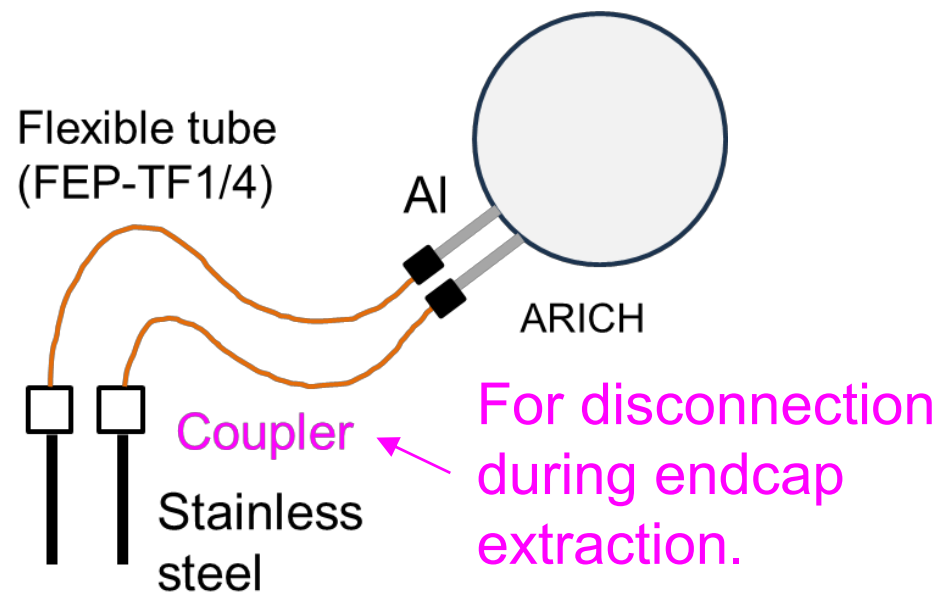
DHH readout upgrade almost completed & successfully tested with PXD on; PXD leader will be present at KEK in case we decide to switch system on ; working on concept on how a decision graph will look like about turning the PXD on

ARICH cooling issues solved

Observed significantly reduced flow rate, which lead to cooling issues in 2024c

About 13% of ARICH needed to be **turned off** to keep **temperature manageable**

End yoke was opened in June to gain access



Investigation with boroscope revealed **clogged couplers** at the FEP tube ends. **Removing the couplers restored full flow** and inspections confirmed **no serious** issues inside the **ARICH aluminum pipes**.

KLM firmware upgrade and progress on sudden turn off (STO)

STO: New HV module turns off suddenly without warning or error

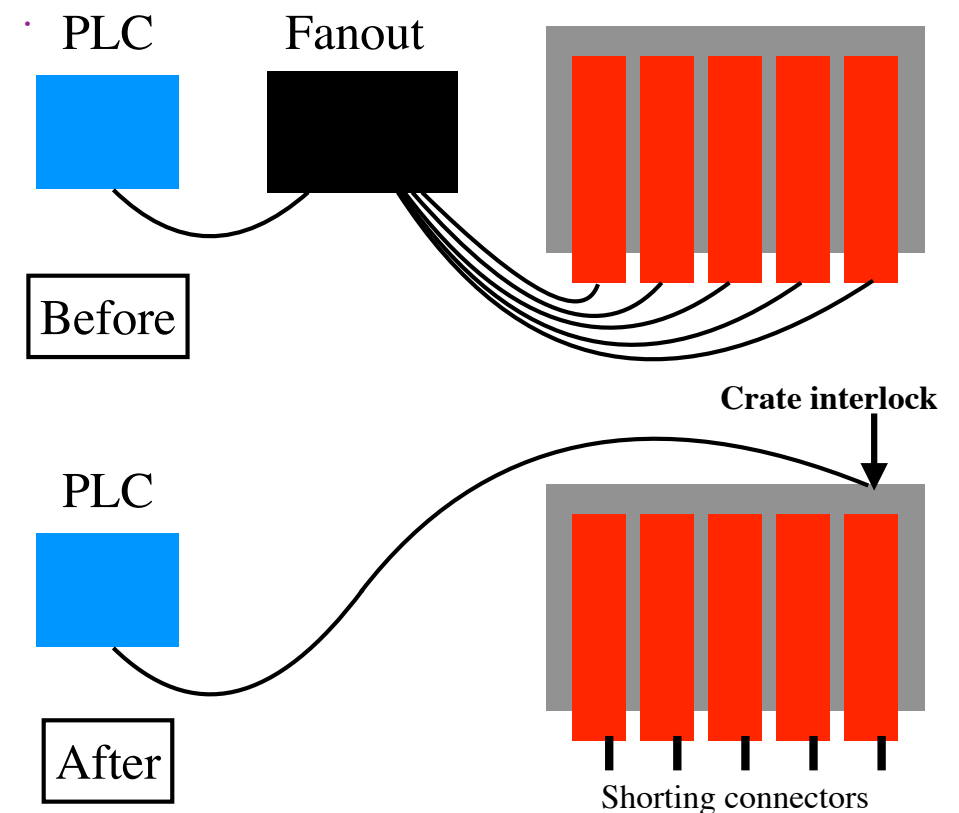
Started in January 2024

New firmware indicates that the board was interlocked, but no signal in the log

Suspected cabling and reorganized cabling to avoid fanout and give more stability

However, STO events **still show up**

Discussion with CAEN engineers ongoing ;
fallback is to use old module



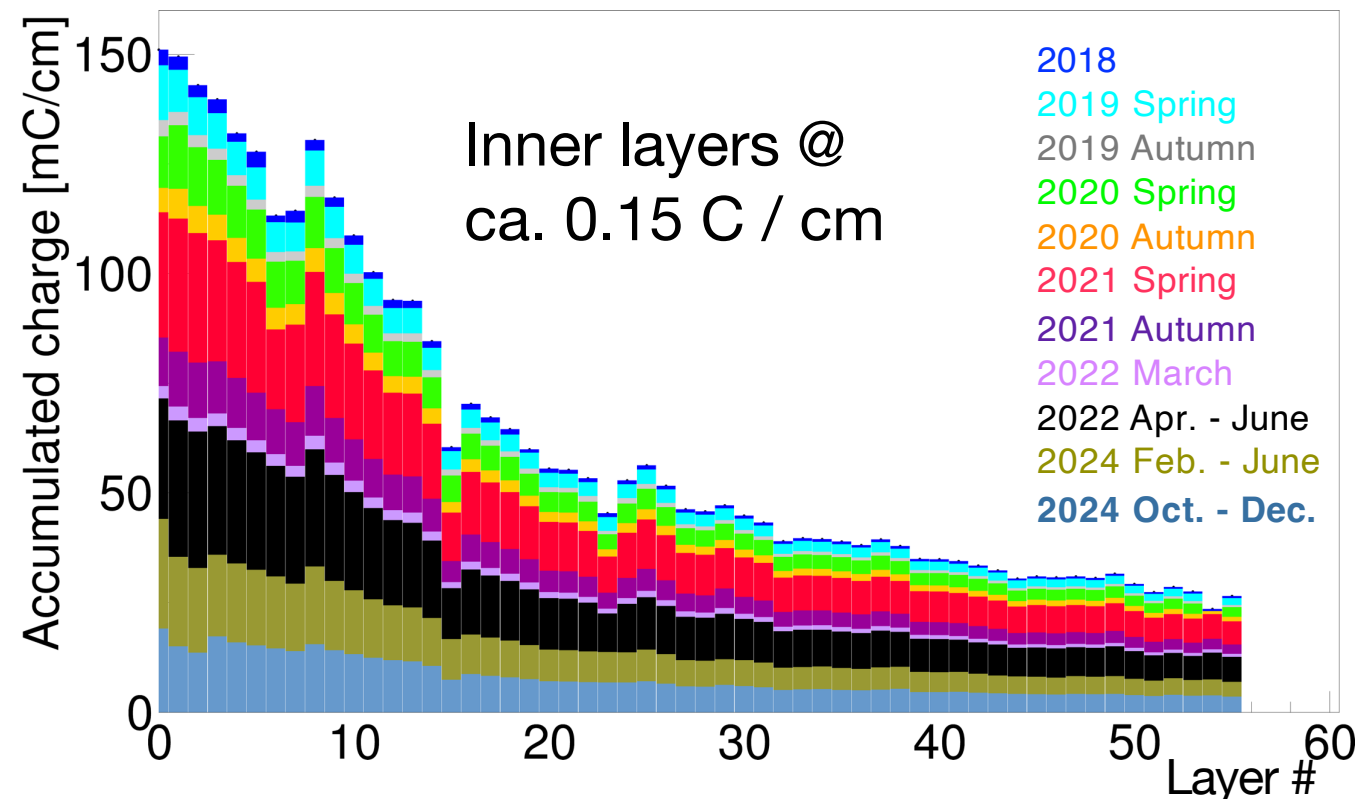
CDC gain drop investigations

Observed significant gain drop & instabilities that affect performance

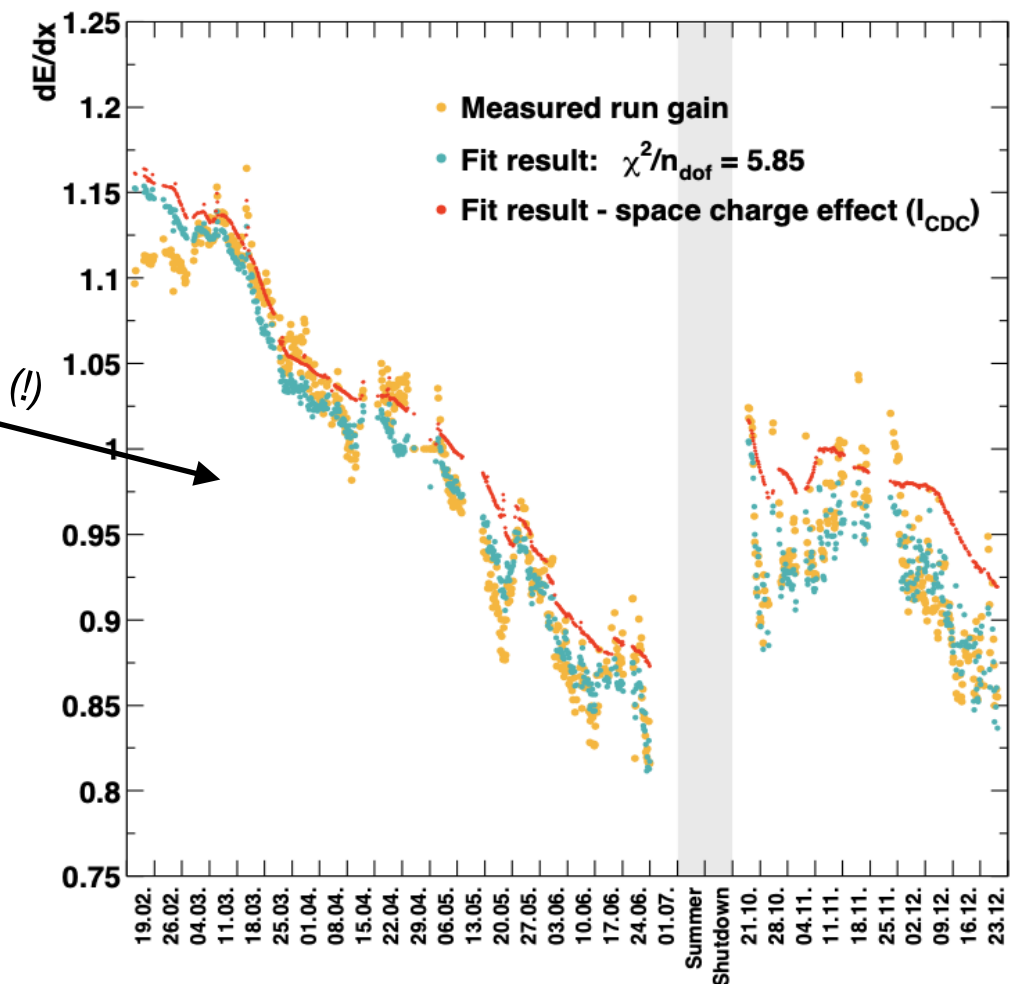
Gain does depend on **Gas conditions**, **background**, **contaminations**, **aging effects**

See indications that **aging** progressing **faster than expected**

Dedicated cosmic run ongoing with controlled gas conditions to clarify situation



Run gain in 2024 vs time



Expect 6% gain drop at 1 C / cm

CDC gain drop investigations

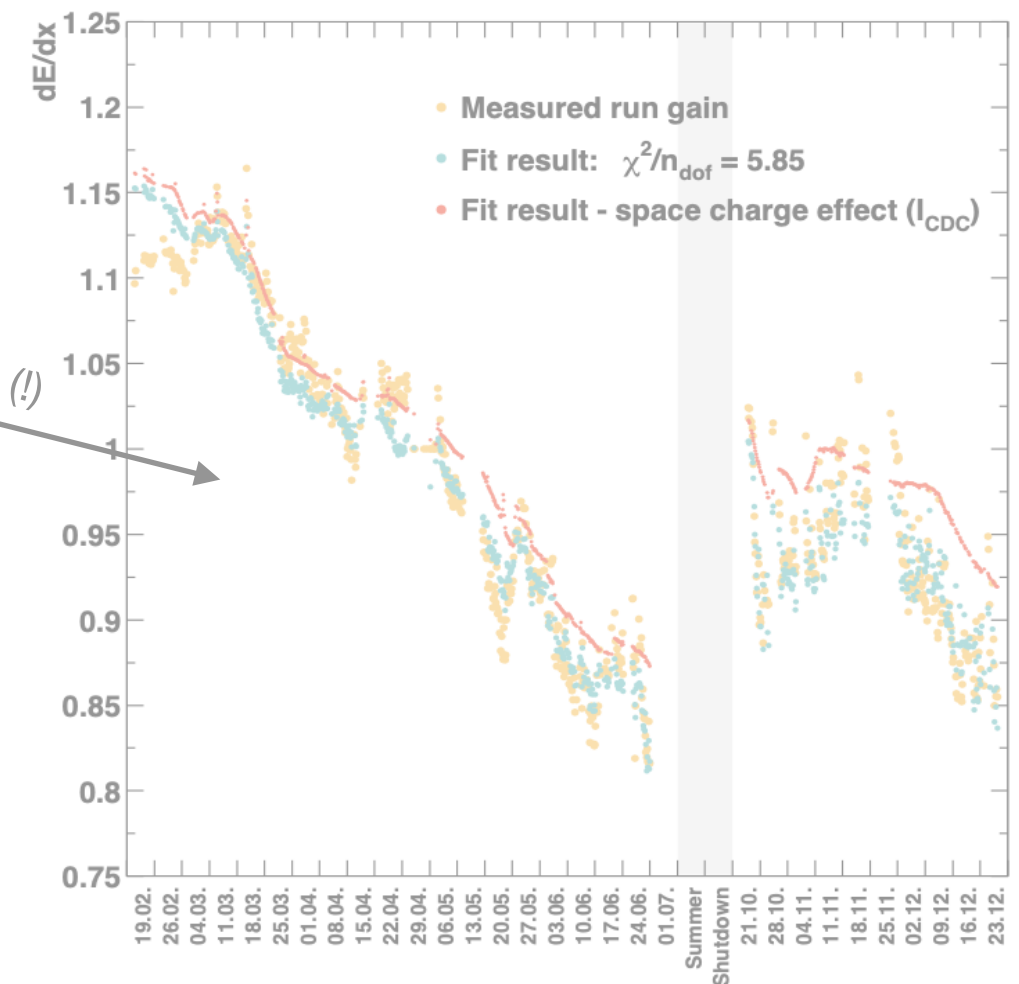
Observed significant gain drop & instabilities that affect performance

Gain does depend on **Gas conditions**, **background**, **contaminations**, **aging effects**

See indications that **aging** progressing **faster than expected**

Dedicated cosmic run ongoing with controlled gas conditions to clarify situation

Run gain in 2024 vs time



→ Prepare for **lower HV operation** to **reduce risk of Malter & aging**

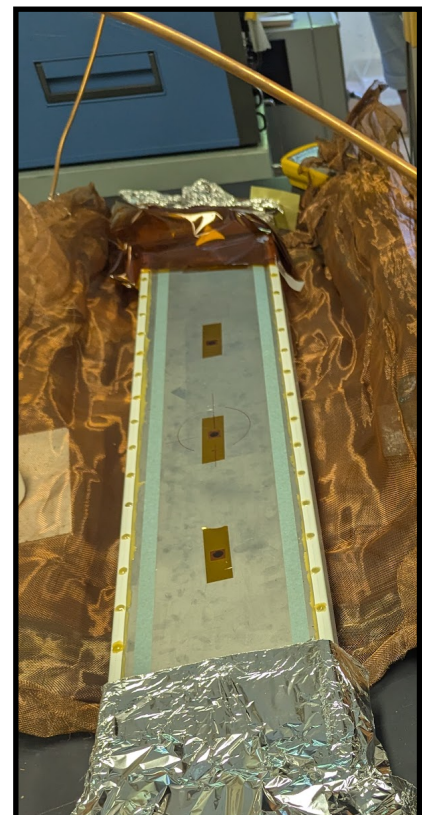
Performance impact of this under study

→ **Increase gas flow by factor of 10 & cosmic studies**

→ **Aging studies with test chamber ongoing**

Investigations if intense electron beam facility at Tohoku University can be used for irradiation

Effort to engage new groups **ongoing** (IHEP, Bonn gas detector group, Hawaii, UPenn, ...)



2025c & 2026a Timeline

The next run has **two goals** :

Push our recorded dataset to **1/ab**



Need close communication with SuperKEKB team to balance this; **physics** will be **priority**

← 80% of running time dedicated to physics

Show that there is path to reach luminosities of **$\sim 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$**

Plan: **7 month run**



Reaching **stable run conditions** in 2025c/2026ab will be key

Schedule:

- * SuperKEKB Main Ring operations plan to start **Nov 5th**
- * Christmas shutdown **Dec 24th - Jan 7th**
- * Continue run until **end of May** (precise date will depend on Budget)

Sketch of 2025c run plan:

Note: no machine maintenance days included (!)
just to to give a rough idea

MR operation
starts

October

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

November

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

December

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

2025c (cosmic run
starts)

Scrubbing ends &
First collisions

Winter
shutdown

Vacuum scrubbing will start on Nov 5th until Nov 17th up to ca. 1.8 A in LER

Nominal tuning ; study large vertical emittance in HER and other studies

Physics Collisions start Nov 17th and have stable physics run until Dec 24

Start with $\beta_y^* = 1$ mm and $\beta_x^* = 60$ mm for **HER / LER**

(17 days / 3 weeks)

Gradually increase beam currents

(1 CR on-site, one remote ; 1 BCG shifter)

Shift booking opened ; most shifts in 2025c covered ; strategy unchanged

Sketch of 2025c run plan:

Note: no machine maintenance days included (!)
just to to give a rough idea

MR operation
starts

October

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

↑
2025c (cosmic run
starts)

November

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

Scrubbing ends &
First collisions

December

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Winter
shutdown

Machine Studies (4 days / 3 weeks)

High bunch current & beam-beam effect
New Sextupole settings
Etc.

Once **LER beam current** exceeds 2 A → β_x^* will be squeezed further

Sketch of 2026ab run plan:

Note: no machine maintenance days included (!)
just to to give a rough idea

Start of 2026a

Start of 2026b

January						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

MR operation starts

February						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

March						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

April						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

May						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Machine Studies (4 days / 3 weeks)

Try to squeeze β_y^*

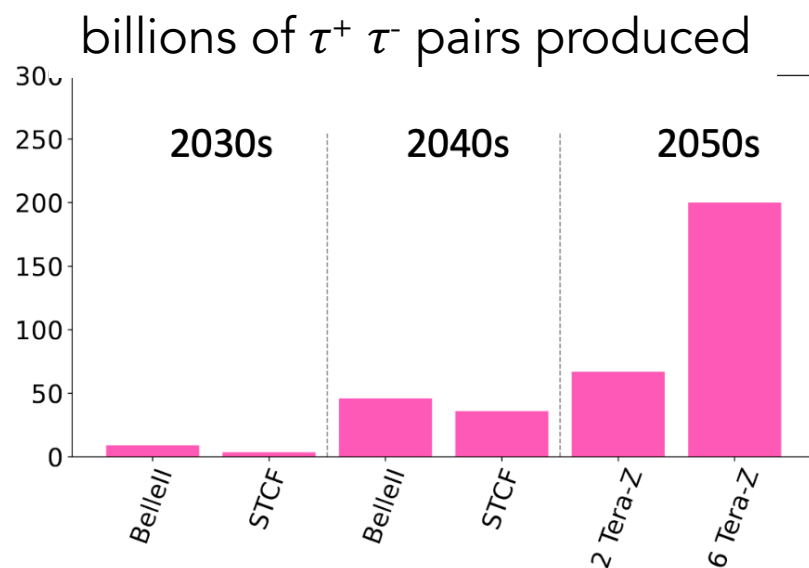
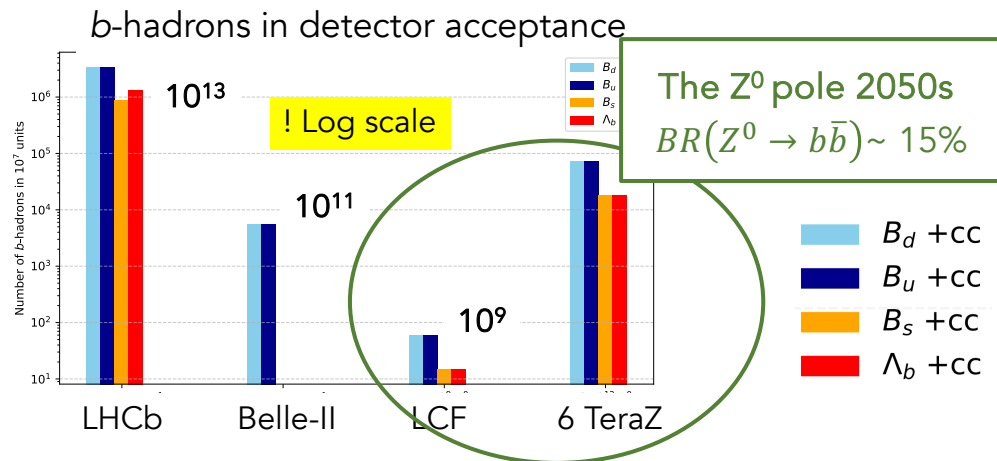
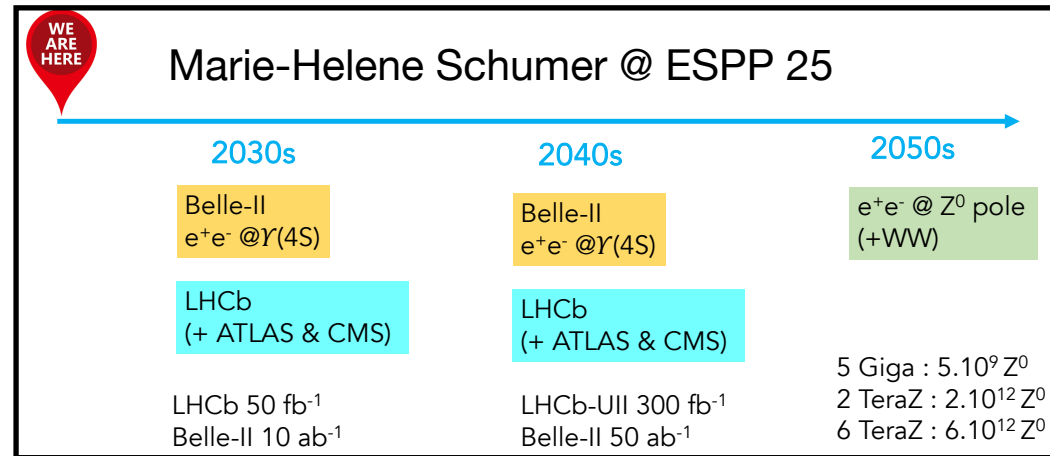
Shorter damping time in LER

Try synchrotron injection in HER

Beam current will increase gradually

Fiscal year	4	5	6	7	8	9	10	11	12	1	2	3
2025	2025b				●●			2025c			2026a	
2026	2026b				●●			2026c			2027a	

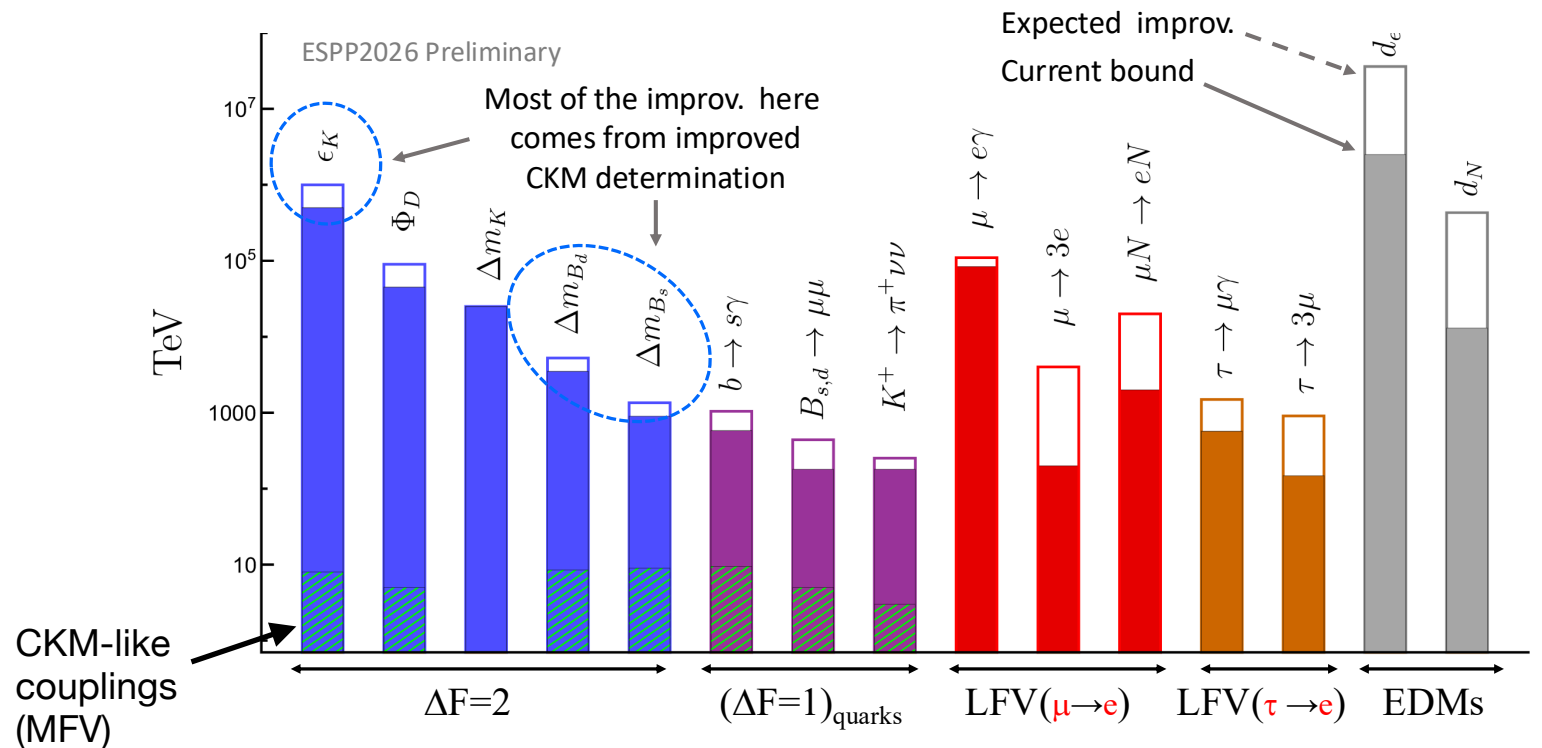
Belle II @ European Strategy of Particle Physics



Gino Isidori @ ESPP 25 in Venice

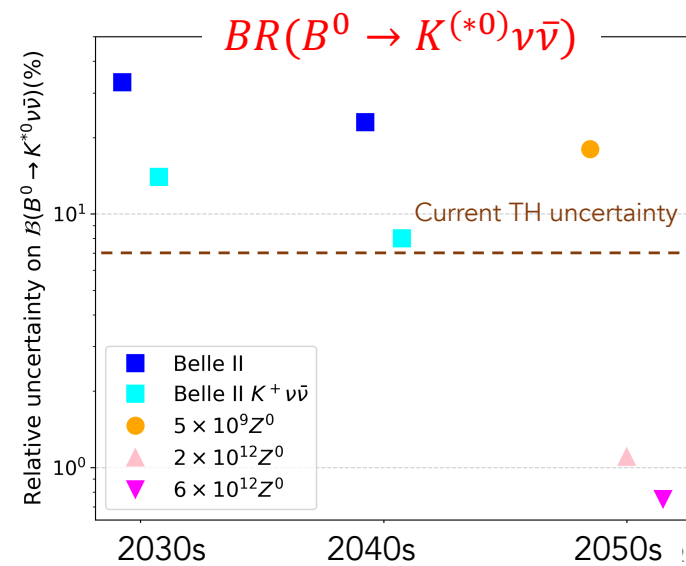
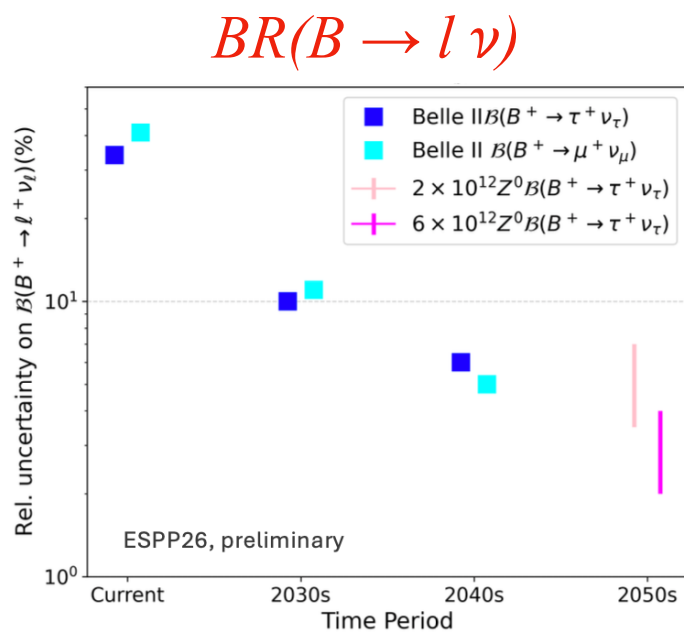
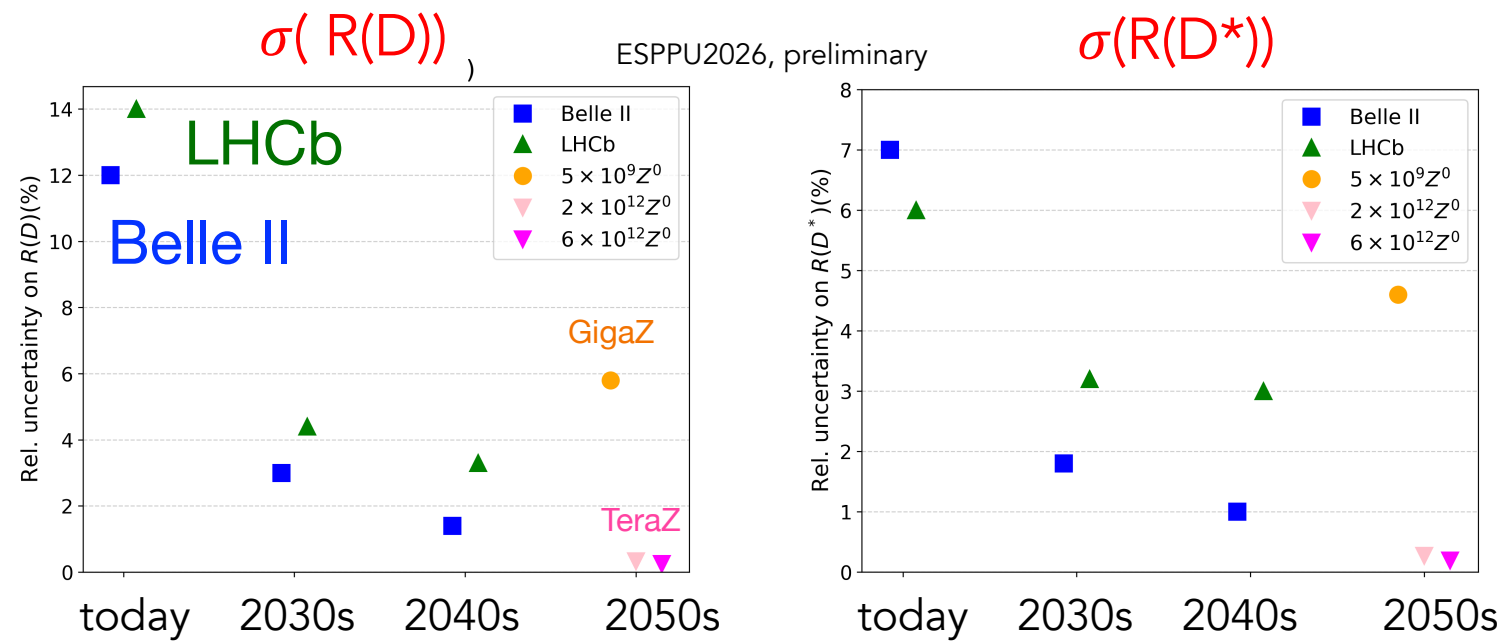
	γ	quarks	μ	e	τ	ν
$3_q \rightarrow 2_q$	$b \rightarrow s \gamma$	$B_s \leftrightarrow \bar{B}_s$	$b \rightarrow s \mu\mu$ $b \rightarrow c \mu\nu$	$R_{bs}(e/\mu)$ $R_{bc}(e/\mu)$	$b \rightarrow s \tau\tau$ $b \rightarrow c \tau\nu$	$b \rightarrow s \nu\nu$
$3_q \rightarrow 1_q$	$b \rightarrow s \gamma$	$B(B \rightarrow K^* \mu\mu),$ $A_{FB}(B \rightarrow K^* \mu\mu),$ $\square$	$b \rightarrow d \mu\mu$ $b \rightarrow u \mu\nu$	$R^{\tau/\mu}(D),$ $R^{\tau/\mu}(D^*), \dots$	$b \rightarrow d \tau\tau$ $b \rightarrow u \tau\nu$	$B(B \rightarrow K^* \nu\nu),$ $B(B \rightarrow K^* \nu\nu),$ $\square$
$2_q \rightarrow 2_q$	$c \rightarrow u \gamma$	$D \leftrightarrow \bar{D}$	$c \rightarrow u \mu\mu$ $c \rightarrow s \mu\nu$ $c \rightarrow d \mu\nu$	$R_{cu}(e/\mu)$ $R_{cs}(e/\mu)$ $R_{cd}(e/\mu)$		$c \rightarrow u \nu\nu$
$3_l \rightarrow 2_l$	$\tau \rightarrow \mu \gamma$ $\tau \rightarrow e \gamma$	$\tau \rightarrow \mu qq$ $\tau \rightarrow e qq$	$\tau \rightarrow \mu \mu\mu$ $\tau \rightarrow \mu ee$	$\tau \rightarrow \mu ee$ $\tau \rightarrow e ee$		$\tau \rightarrow \mu \nu\nu$ $\tau \rightarrow e \nu\nu$

N.B.: several observables for each transition

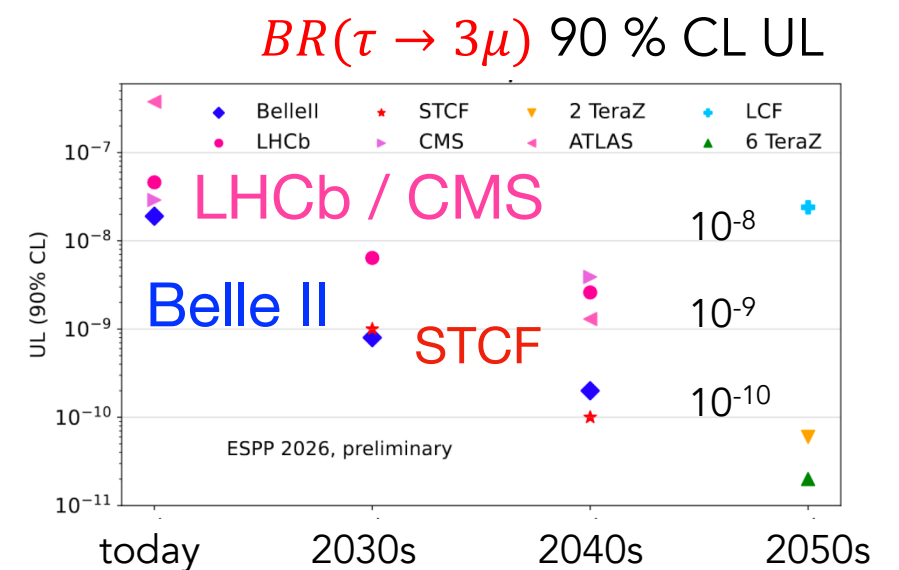
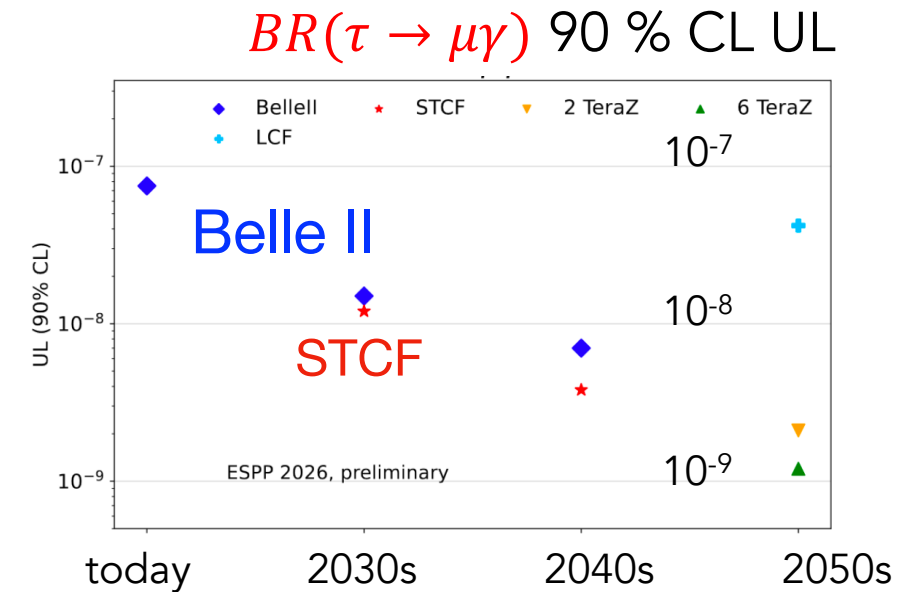


Belle II impact on key observables

B Program

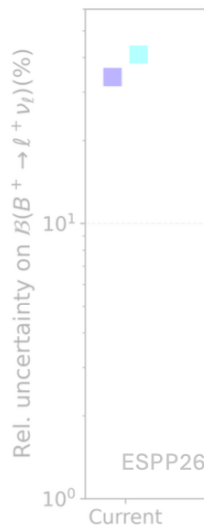


τ Program



Belle II impact on key observables

B Program

 τ Program

arXiv:2503.24155v1 [hep-ex] 31 Mar 2025

The Belle II Experiment at SuperKEKB Input to the European Particle Physics Strategy

The Belle II Collaboration

esppu-conveners@belle2.org

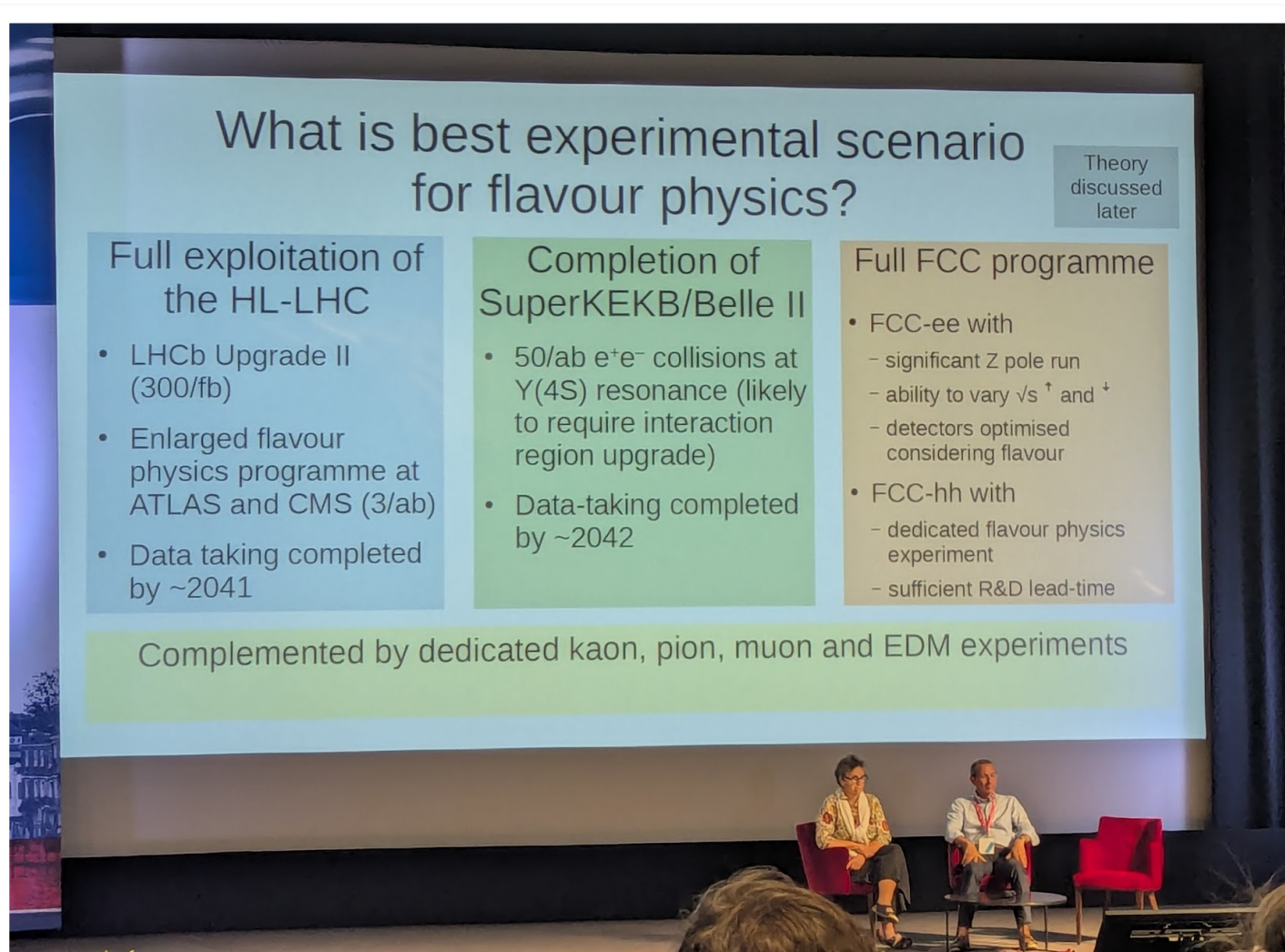
Belle II is an intensity-frontier experiment at the SuperKEKB collider in Tsukuba, Japan. Over the coming decades, it will record the decays of billions of bottom mesons, charm hadrons, and tau leptons produced in 10 GeV electron-positron collisions. The experiment's low-background environment and precisely known kinematics enable high-precision measurements of hundreds of Standard Model (SM) parameters while probing for new particles at mass scales far beyond the direct reach of high-energy colliders. We project Belle II's sensitivity for key measurements - where it will be uniquely positioned or world-leading - over datasets ranging from 1 to 50 ab^{-1} . By exploring previously uncharted regions of non-SM parameter space with high precision, Belle II will either reveal new physics or set stringent constraints, guiding future experimental and theoretical efforts. Additionally, we outline near-term upgrades to the Belle II detector and SuperKEKB accelerator, which will enhance sensitivity in searches for new physics beyond the SM across flavor, tau, electroweak, and dark sector physics. These improvements will ensure that Belle II remains both complementary to and competitive with the LHC and other experiments.

<https://arxiv.org/abs/2503.24155>



Venice Meeting Feedback

Successful completion of Belle II physic program to **50/ab** priority of **European HEP community**

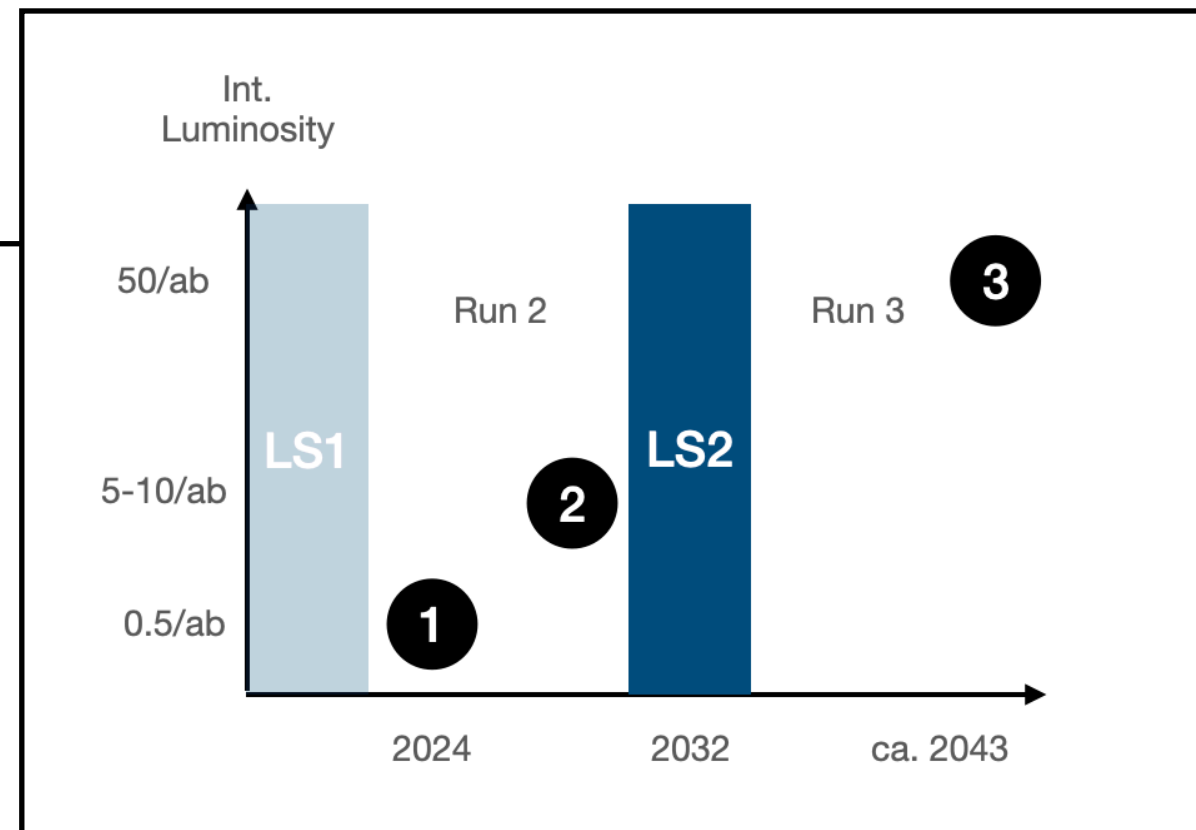


In line with KEK's vision as presented by Asai-san ; large emphasis on role CERN and other labs can play in understanding e^+e^- **high luminosity frontier @ SKB**

Upgrade & LS2 Plans

To reach 50/ab and $6 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ plan for **long shutdown 2** in 2032 to upgrade IR

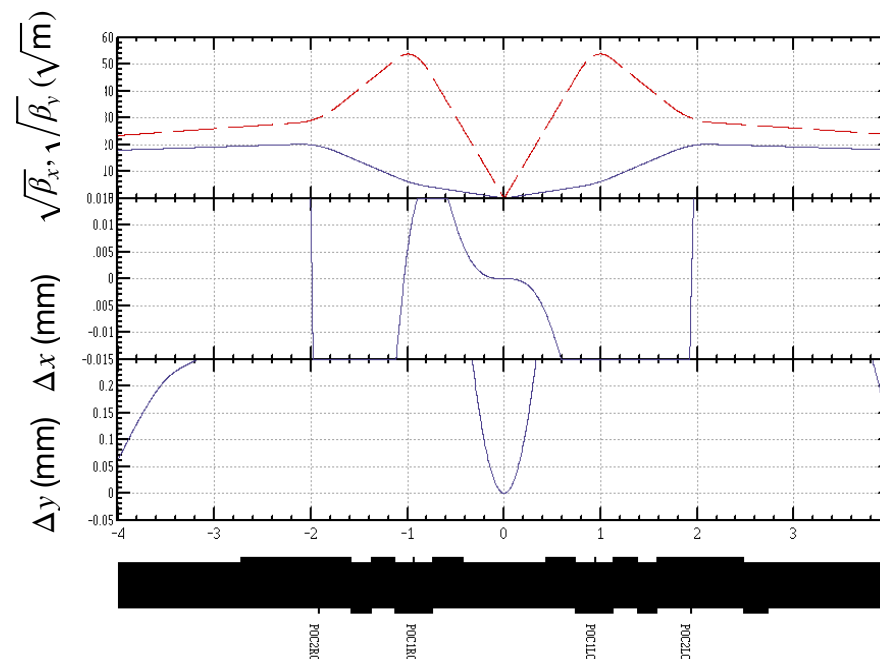
Redesign of final focusing magnets (QCS) essential



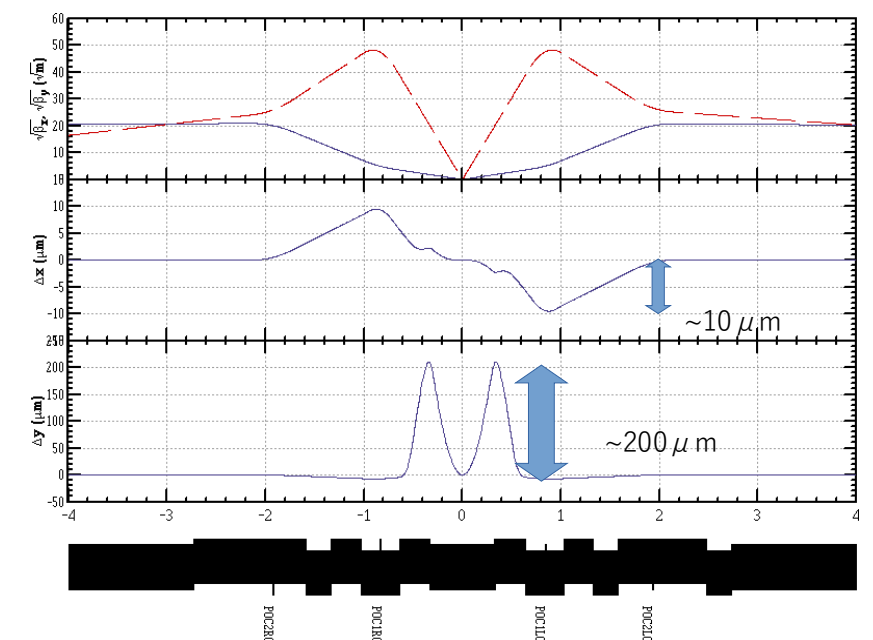
Current IR optics complicated, large chromatic xy coupling needed to achieve high luminosity

Proposed QCS modifications

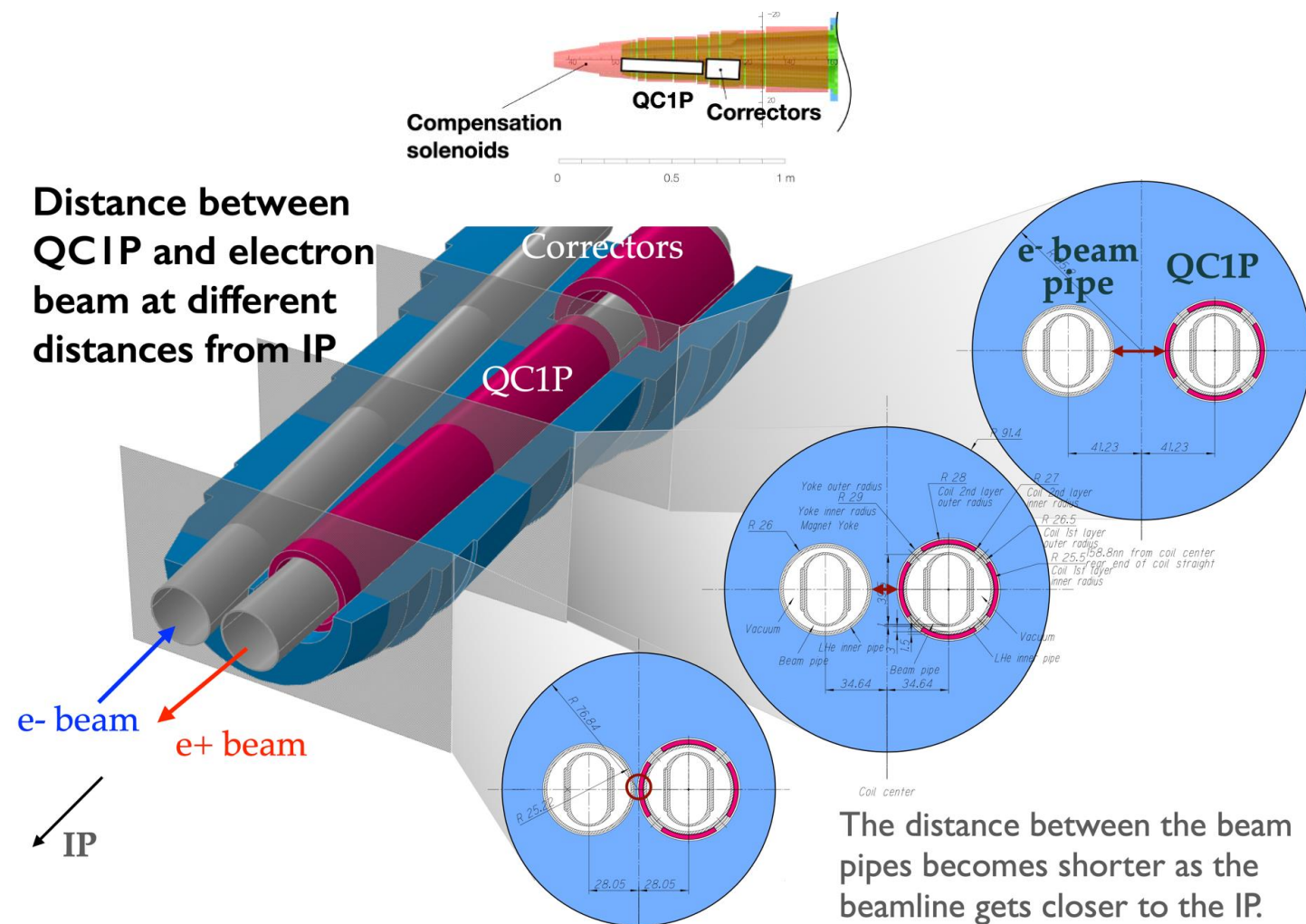
- QCIP 100 mm closer to IP
- Enlarge dynamic aperture of LER
- Extend the beam lifetime
- Change conductor of QCIP from NbTi to **Nb₃Sn**
- Decrease risk of beam-induced quench
- Install a compensation solenoid between the IP and QCIP
 - Simplify IR optics
 - Reduce chromatic xy coupling
 - Reduce emittance growth at IR



Orbit with Current Design



Candidate for new Design

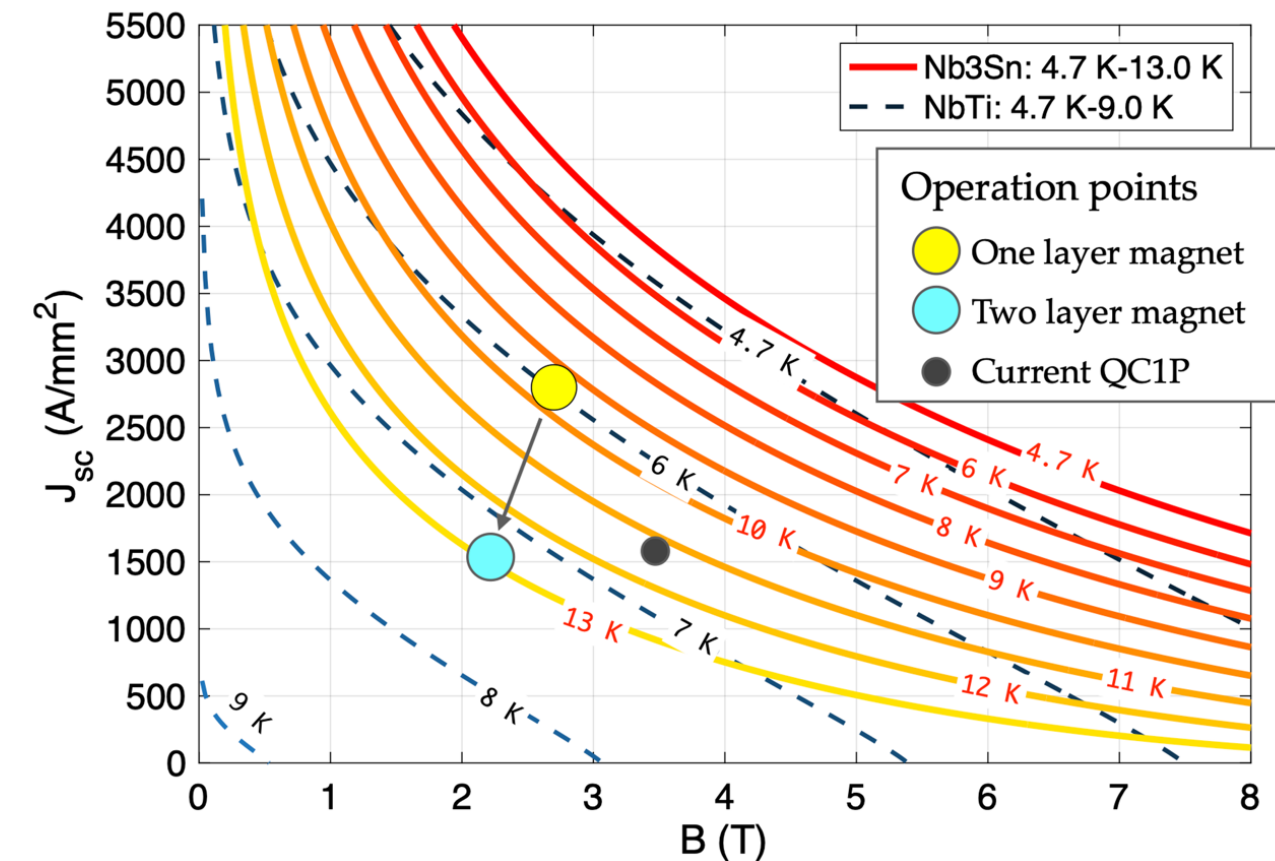


Limited space, need to produce thin coil with large packing factor

Ideally move to new material (**Nb3Sn** versus **NbTi**) to gain larger quenching temperature margin

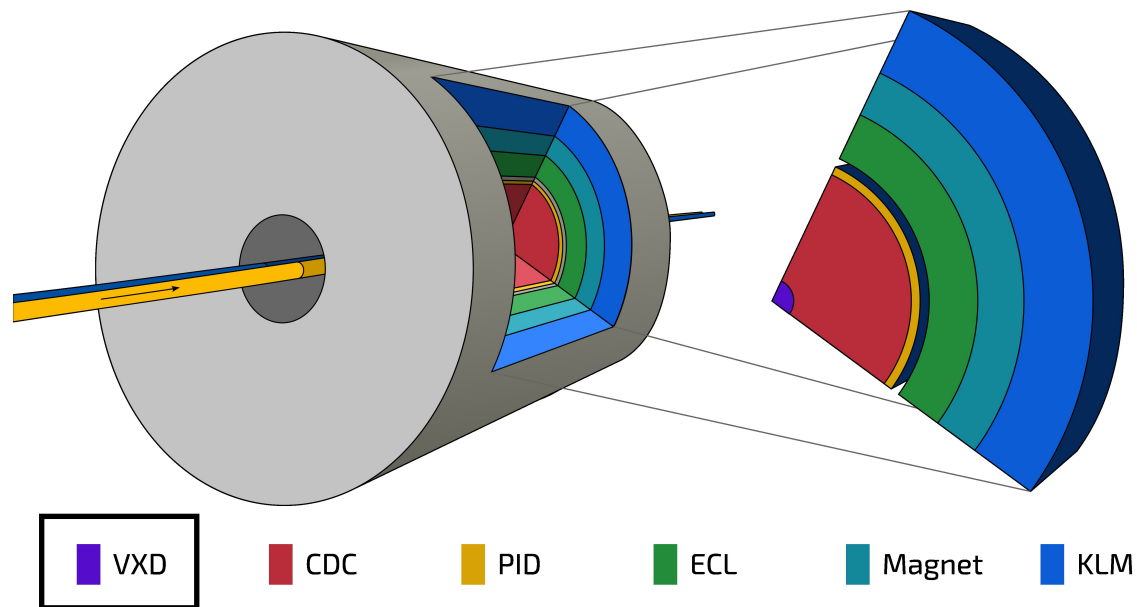
	New QC1P		New QC1P		Present QC1P
	Nb ₃ Sn		NbTi		
# of layer	1	2	1	2	2
Temp. margin	4K	8K	1K	2.5K	2K

Y. Arimoto @ARC Dec. 2024

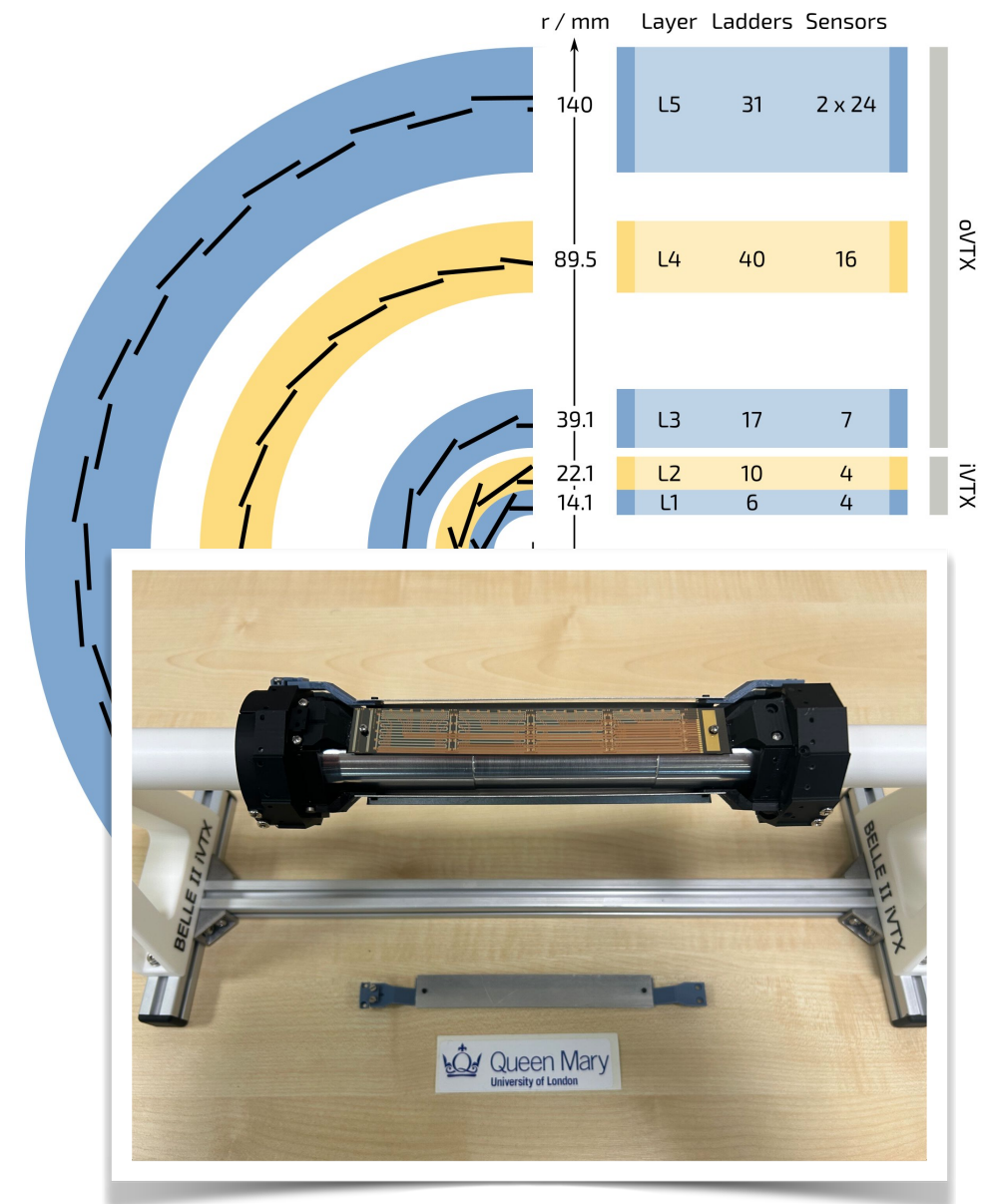
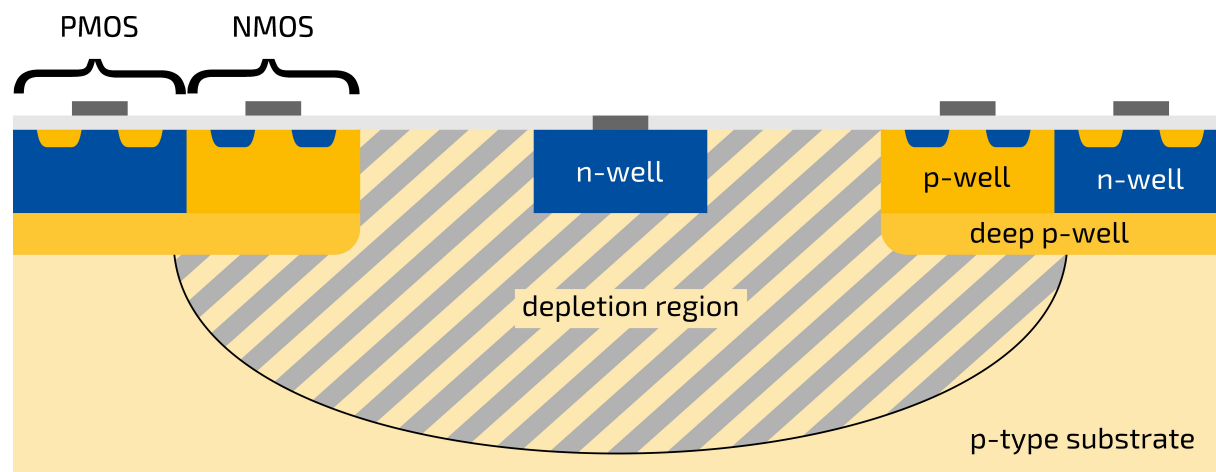


Belle II Upgrade Activities

Change in IR envelope necessitate construction of new **inner tracking detectors**



E.g. **VXD (PXD, SVD)** → **CMOS based VTX**



- Fully pixelated detector
- Low material budget ($\sim 2.5 \% X_0$)
- 5 layers design:
 - 2 inner layers (iVTX)
 - 3 outer layers (oVTX)
- 6 layers also still under discussion
- Proposed pixel sensor: OBELIX

Activities ongoing in most subdetector, first results documented in **CDR**:



<https://arxiv.org/pdf/2406.19421>
 BELLE2-REPORT-2024-042
 KEK-REPORT-2024-1
 4 July 2024

The Belle II Detector Upgrades Framework Conceptual Design Report

Abstract

We describe the planned near-term and potential longer-term upgrades of the Belle II detector at the SuperKEKB electron-positron collider operating at the KEK laboratory in Tsukuba, Japan. These upgrades will allow increasingly sensitive searches for possible new physics beyond the Standard Model in flavor, tau, electroweak and dark sector physics that are both complementary to and competitive with the LHC and other experiments.

2406.19421v2 [hep-ex] 4 Jul 2024

Upgrade also
discussed in ESPP
Belle II submission

arXiv:2503.24155v1 [hep-ex] 31 Mar 2025

The Belle II Experiment at SuperKEKB Input to the European Particle Physics Strategy

The Belle II Collaboration
 esppu-conveners@belle2.org

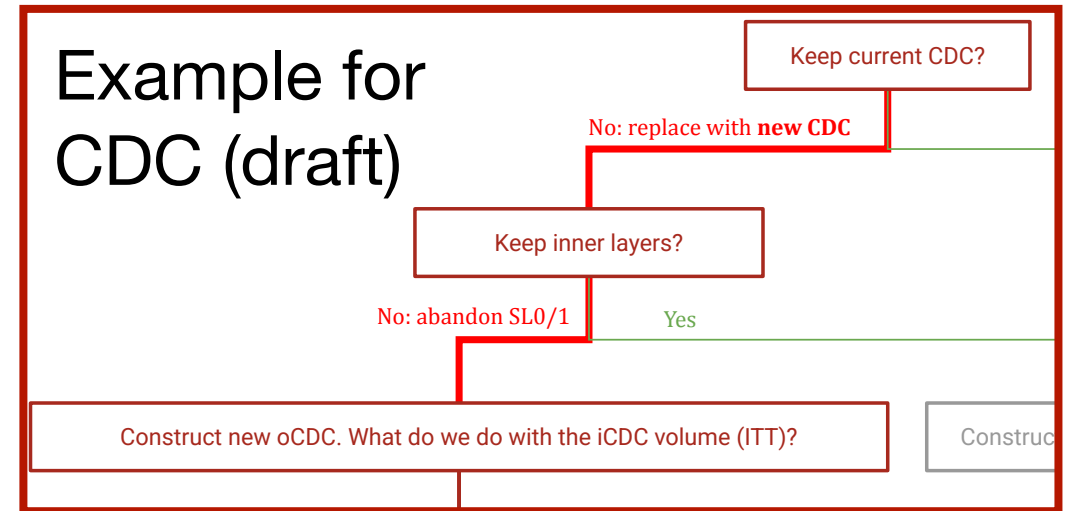
Belle II is an intensity-frontier experiment at the SuperKEKB collider in Tsukuba, Japan. Over the coming decades, it will record the decays of billions of bottom mesons, charm hadrons, and tau leptons produced in 10 GeV electron-positron collisions. The experiment's low-background environment and precisely known kinematics enable high-precision measurements of hundreds of Standard Model (SM) parameters while probing for new particles at mass scales far beyond the direct reach of high-energy colliders. We project Belle II's sensitivity for key measurements - where it will be uniquely positioned or world-leading - over datasets ranging from 1 to 50 ab^{-1} . By exploring previously uncharted regions of non-SM parameter space with high precision, Belle II will either reveal new physics or set stringent constraints, guiding future experimental and theoretical efforts. Additionally, we outline near-term upgrades to the Belle II detector and SuperKEKB accelerator, which will enhance sensitivity in searches for new physics beyond the SM across flavor, tau, electroweak, and dark sector physics. These improvements will ensure that Belle II remains both complementary to and competitive with the LHC and other experiments.

<https://arxiv.org/abs/2503.24155>

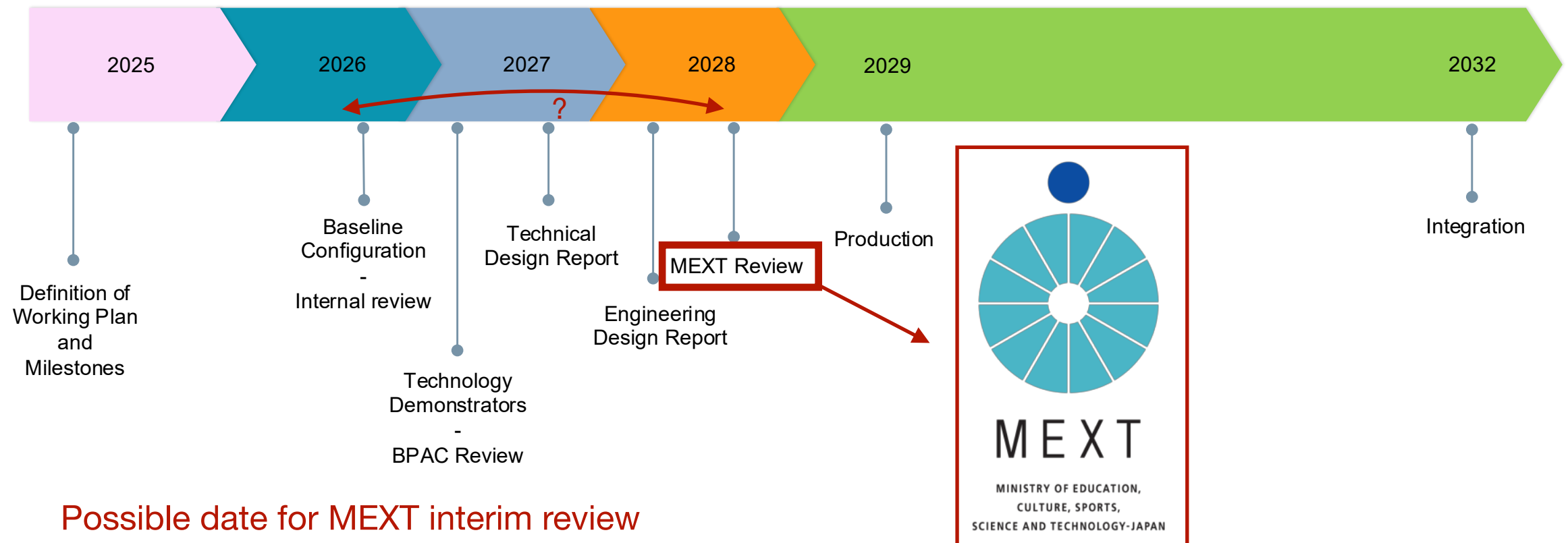
Collaboration ramping up upgrade R&D activities; Management actively recruiting new groups ; preparing creation of **Upgrade Project Office**

Upgrade priorities & timeline:

1. Establish limitations of current detectors
2. TDR by 2027
3. LS2 planned in 2032



Intend to establish clear path to demonstrators & **decision logic** on choices



Possible date for MEXT interim review
(under discussion) to approve update timeline

Alternative slot in 2026 (!)

German Participation & Priorities*



31

* this is of course my personal view, please complain to me during the coffee break ;-)

We need to ensure the operational safety of the PXD until the upgrade

This includes that we find a mode of operation to keep know-how intact whilst going into a purely operations mode

We have a strong footprint in software, computing, algorithms, trigger DESY collaborative services & NAF are essential infrastructure for Belle II

Very good exposure and long-term involvement ; should be maintained

We need to formulate a coherent upgrade participation and increase our footprint there

We need to discuss what our strategy is. I.e. are we planning on a joint-overarching project? Or participation on several projects?

Other important points: Sustainability ; Career development Opportunities for ECR ; Reasonable timelines for PhDs

In case the MEXT review is in 2026, we need to keep pulling our weight in the upcoming run to help Belle II and push out many high-quality results

The review will formulate a recommendation to prolong the program past 2032 ; we are doing very well on some metrics, but are behind in terms of integrated luminosity

~2/ab could be recorded if we can run for 7 months and at 1×10^{35}

[Annual plan] (Japanese fiscal year)												
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	
Research items	1 st year	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th and later	Remarks
1. Continue operation and improve accelerator performance in parallel with accumulating physics data												Continue performance improvement after 10 years.
Performance indicator	0.4				3					15		Integrated luminosity (/ab)
2. Maintenance/upgrade of major components												
Systematically conduct renewal of aging components to improve energy efficiency. Achieve the target performance by modifying the interaction region (IR). Improve the performance of the injector and beam transport line (BT) for efficient operation.												
Main ring												
Injector												
Belle II												
Performance indicator												
3. Report physics results obtained by analyzing the data, publish them in academic papers, and disseminate them widely. Open up a new paradigm in elementary particle physics, or show the next path necessary for that.												
Performance indicator	5											

This will be challenging

More likely between 5-10/ab

Here we are making good progress

Here we are exceeding expectations

Summary

SKB and Belle II preparations for next data taking in full swing

No major showstoppers ; expect **significant reduction of SBLs**

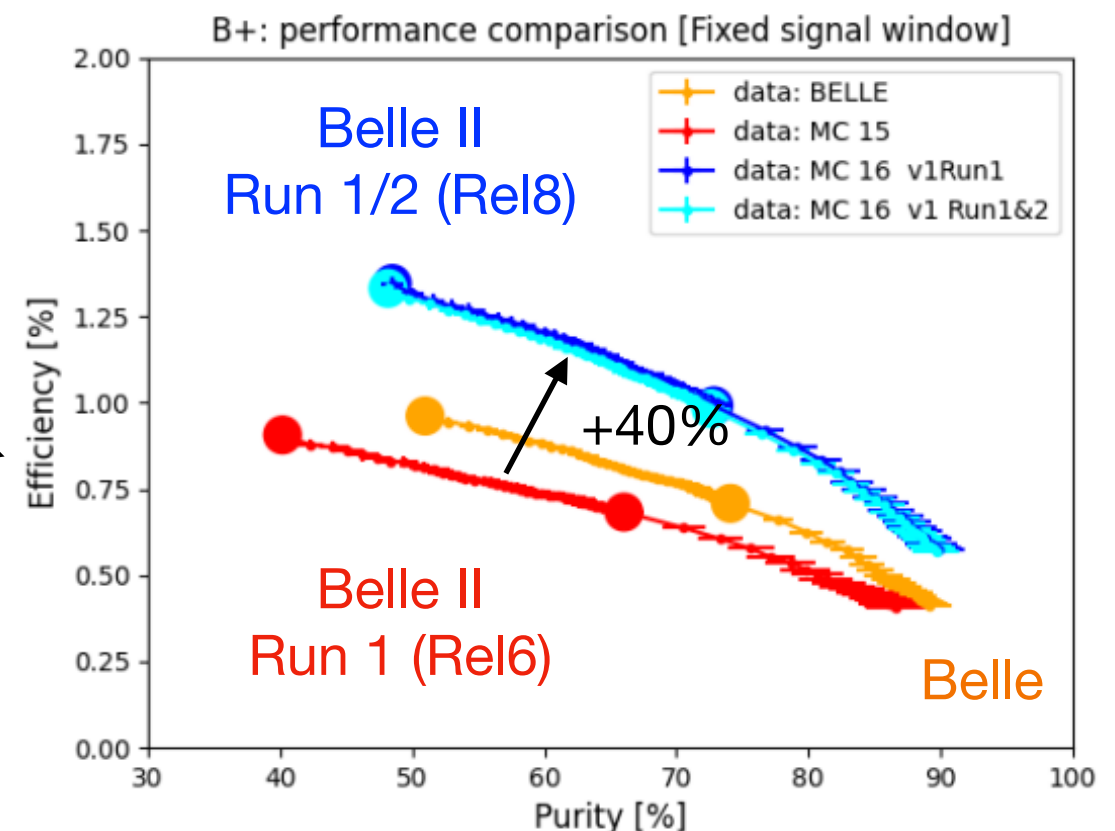
Belle II had a very **productive year** ; aim for ~40 papers in 2025

Showed several **key results** at summer conferences ; aim directly for publications

Improvements in understanding Belle II
paying off to increase value of data even further

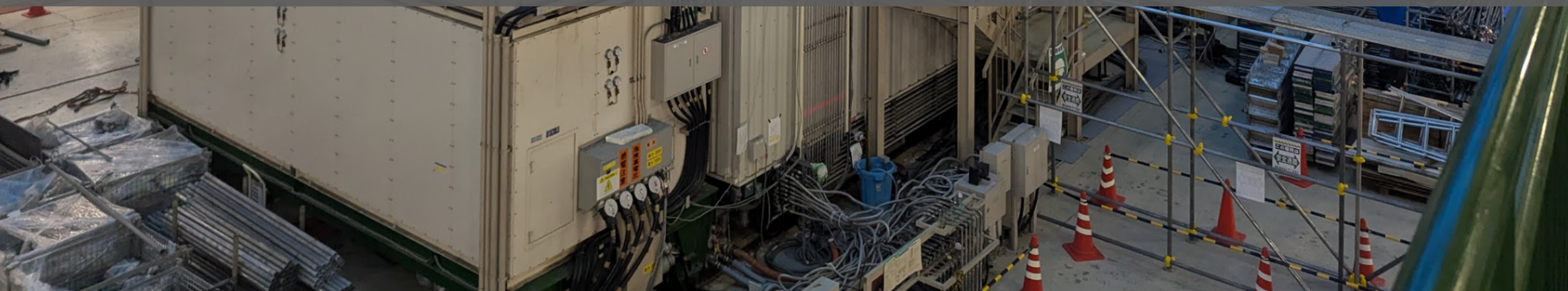
Upgrade Project is progressing

Contributions shaping up ; aim for demonstrators and **TDR** in **2027**





More Information



$B^+ \rightarrow K^+ \nu \bar{\nu}$ reinterpretation

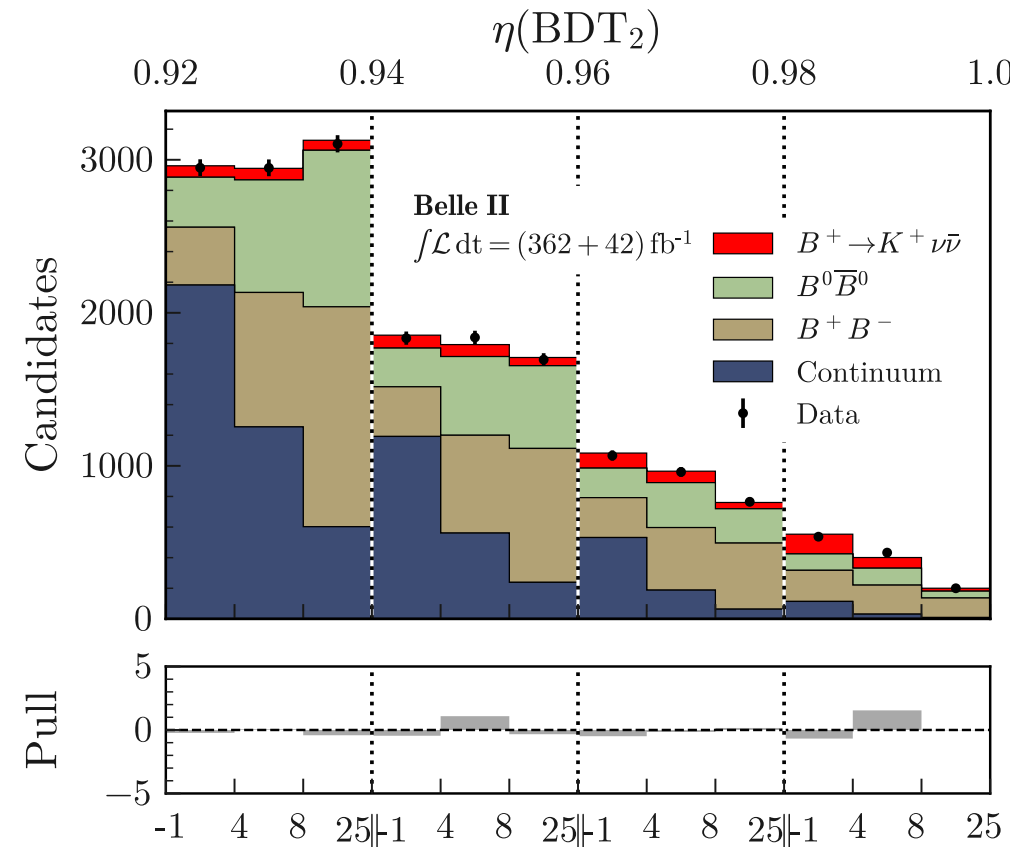
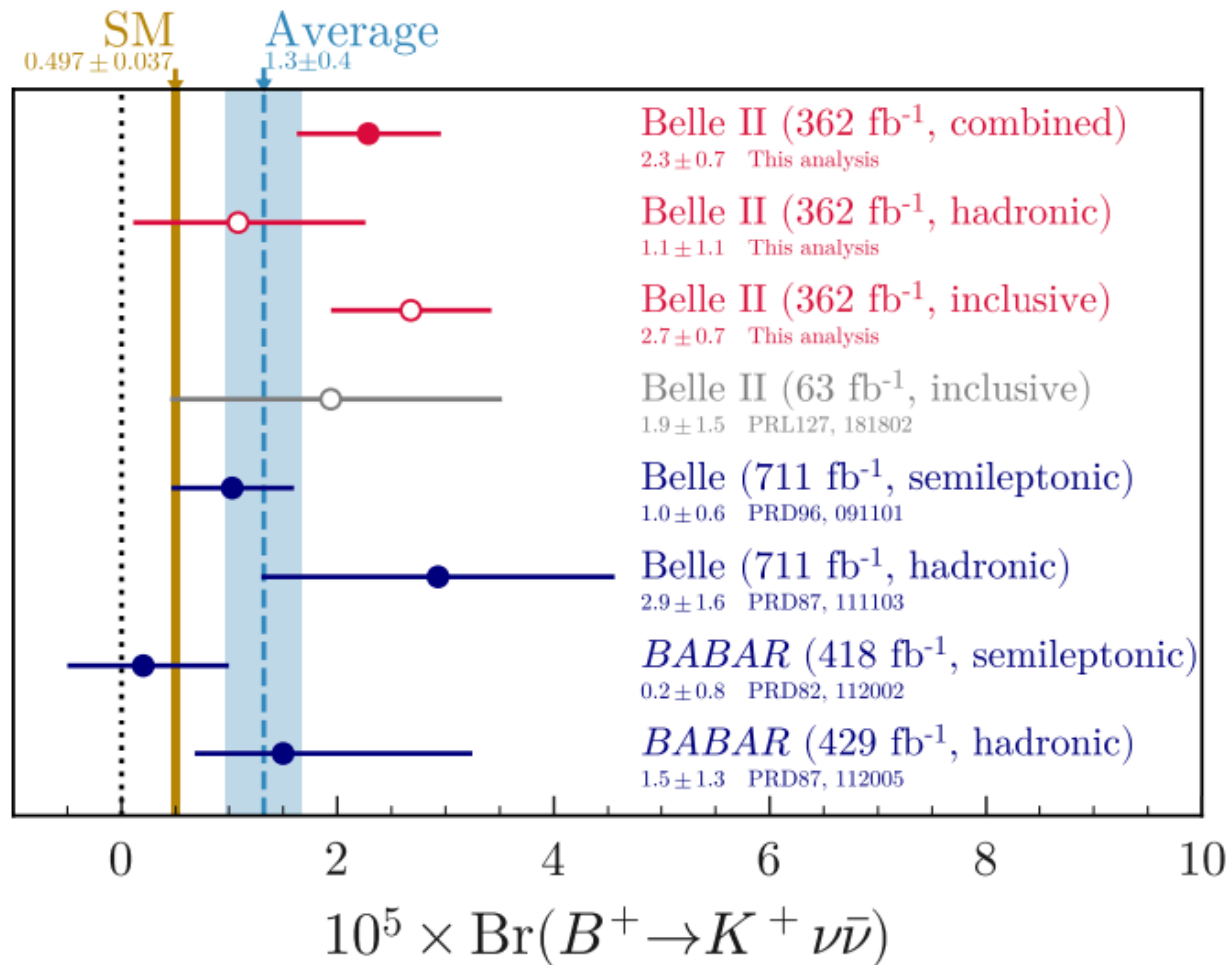
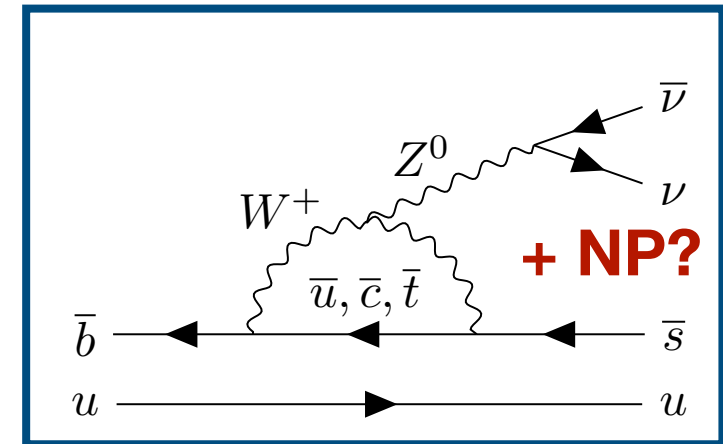
Submitted to PRD
arXiv:2507.12393

Belle II established first evidence for $B^+ \rightarrow K^+ \nu \bar{\nu}$

★ → BF **2.7 sigma** above SM ...

Phys. Rev. D 109, 112006 (2024)
arXiv:2311.14647

... could this be due to **NP?**



How to check, since **analysis assumes** SM shapes and efficiencies ...

$$q_{\text{rec}}^2 = \frac{s}{4} + m_K^2 - \sqrt{s} E_K^* \simeq (p_\nu + p_{\bar{\nu}})^2$$

Implementing the proposal of *L. Gärtner et al. Eur.Phys.J.C 84 (2024) 7, 693*

Model-independent analysis possible

Key idea: **derive correction map**

$$w(q^2) = \frac{\sigma_{\text{NP}}(q^2)}{\sigma_{\text{SM}}(q^2)}$$

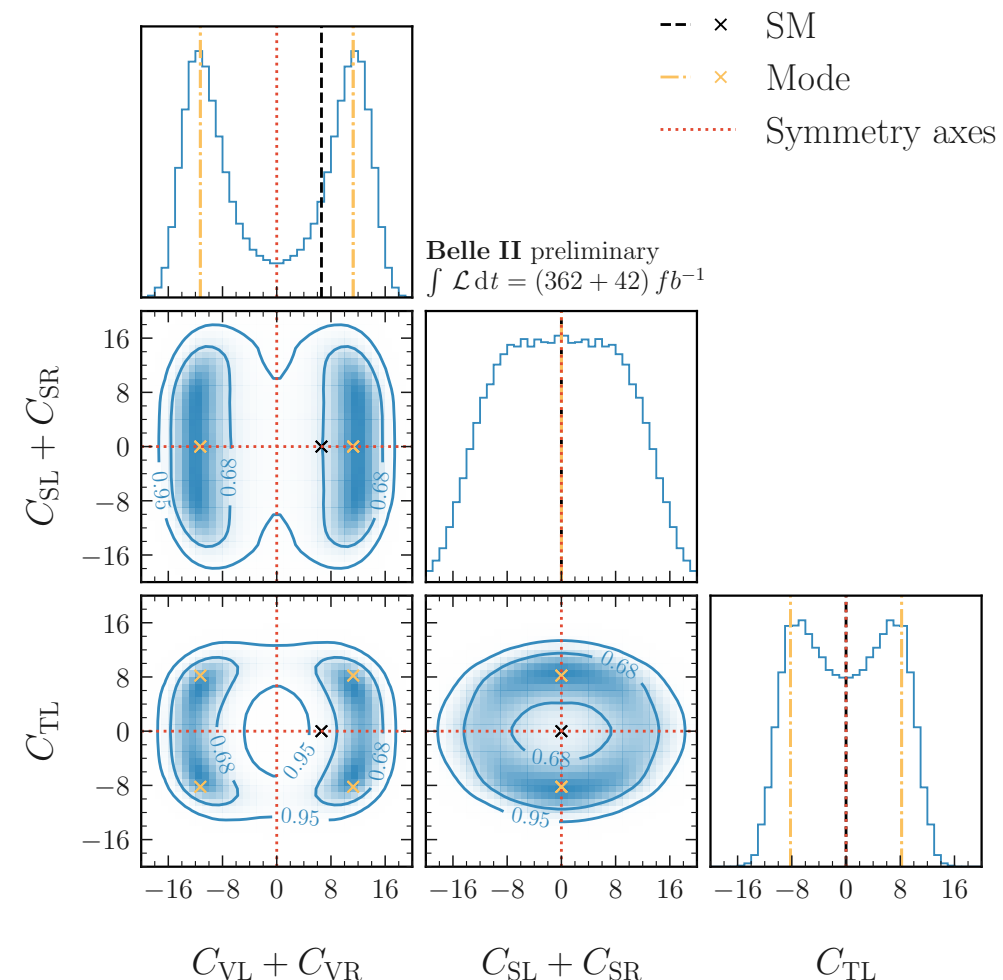
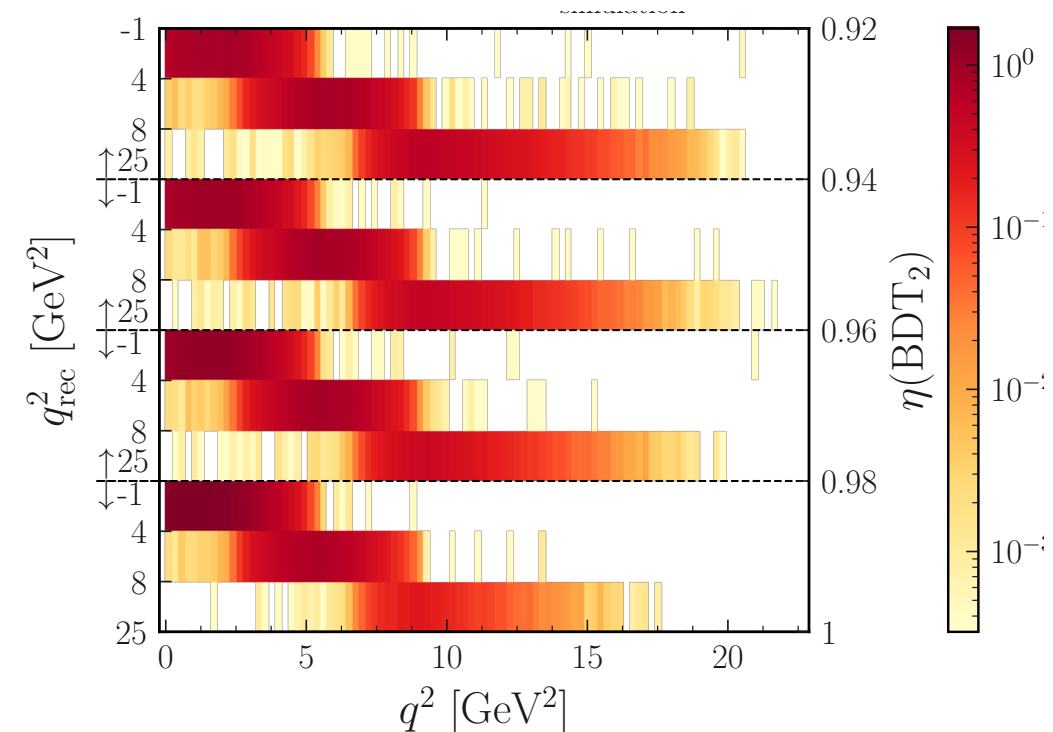
Which for a binned likelihood fit

Essentially is encoded in a mapping matrix

WET Analysis: SM $C_{\text{VL}} = 6.6 \pm 0.1$ and all others zero

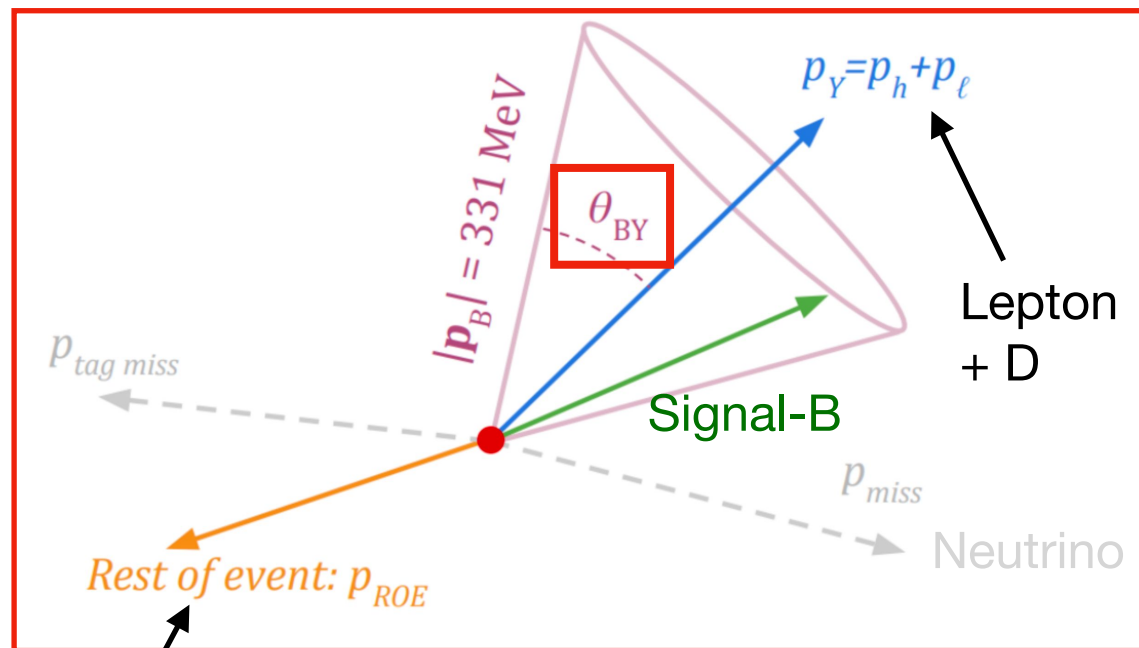
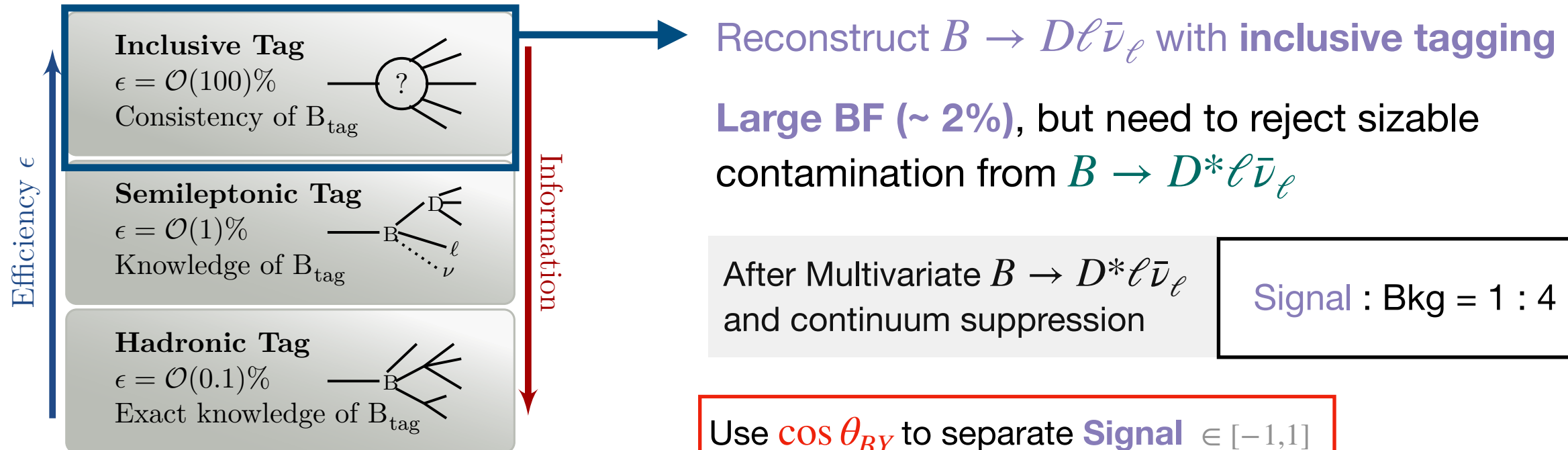
$$\begin{aligned} \frac{d\mathcal{B}}{dq^2} = & 3\tau_B \left(\frac{4G_F}{\sqrt{2}} \frac{\alpha}{2\pi} \right)^2 |V_{ts}^* V_{tb}|^2 \frac{\sqrt{\lambda_{BK}} q^2}{(4\pi)^3 M_B^3} \\ & \cdot \left[\frac{\lambda_{BK}}{24q^2} |f_+(q^2)|^2 |C_{\text{VL}} + C_{\text{VR}}|^2 \right. \\ & + \frac{(M_B^2 - M_K^2)^2}{8(m_b - m_s)^2} |f_0(q^2)|^2 |C_{\text{SL}} + C_{\text{SR}}|^2 \\ & \left. + \frac{2\lambda_{BK}}{3(M_B + M_K)^2} |f_T(q^2)|^2 |C_{\text{TL}}|^2 \right], \end{aligned}$$

Map will be published on HepData; allows outsiders to make correct interpretations

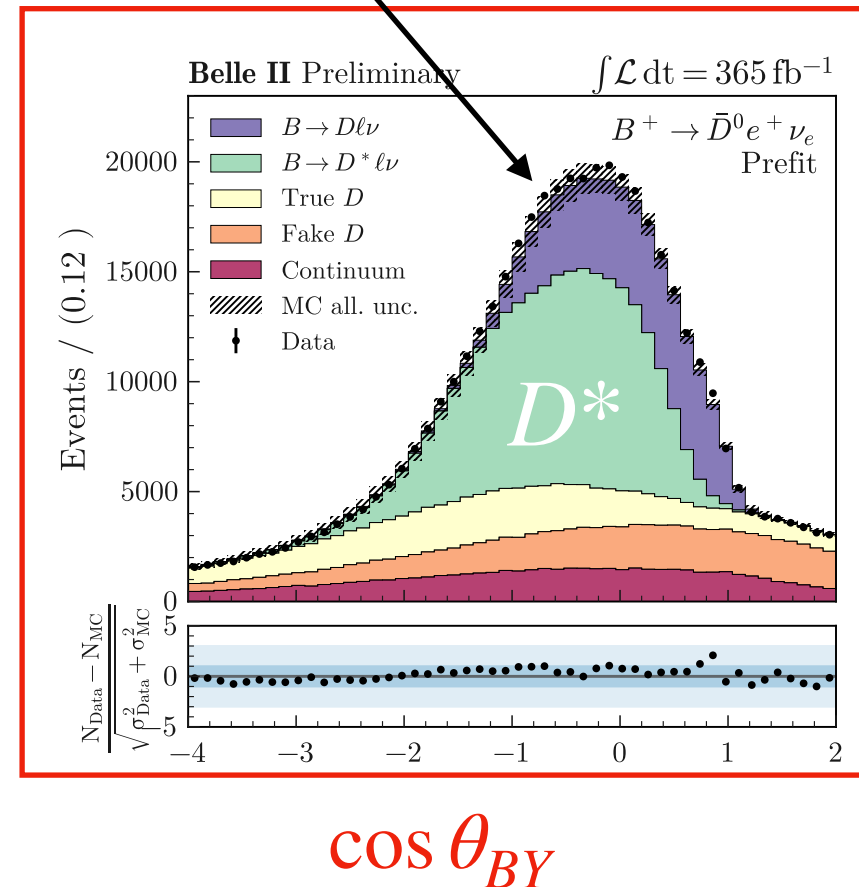


Precision Determinations of $|V_{cb}|$

Submitted to PRD
arXiv:2506.15256

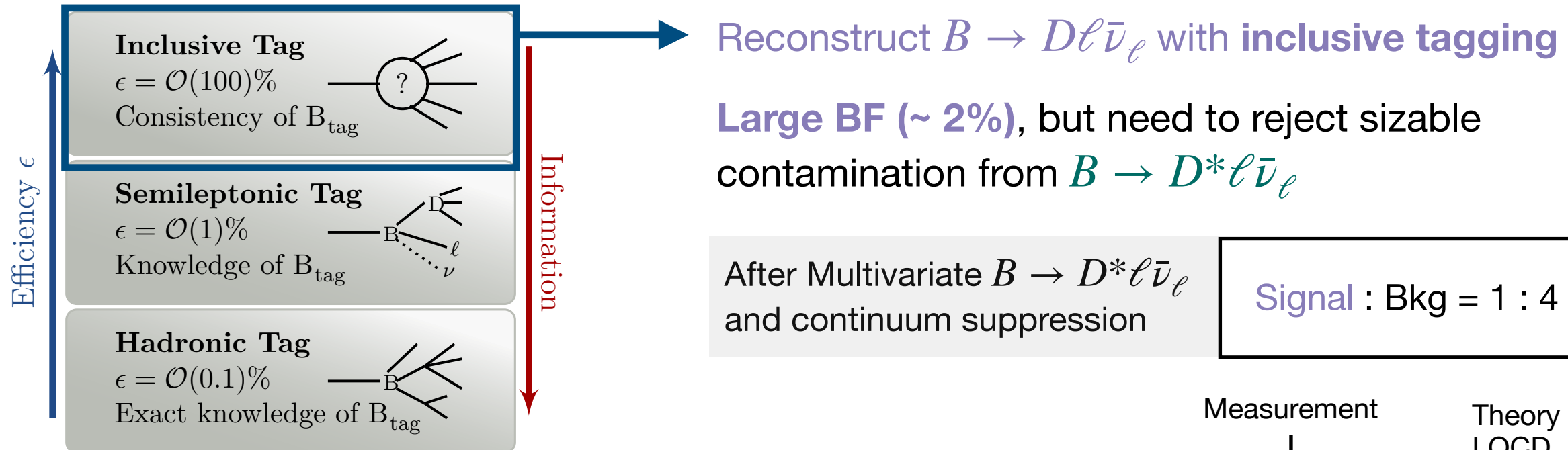


From inclusive tag

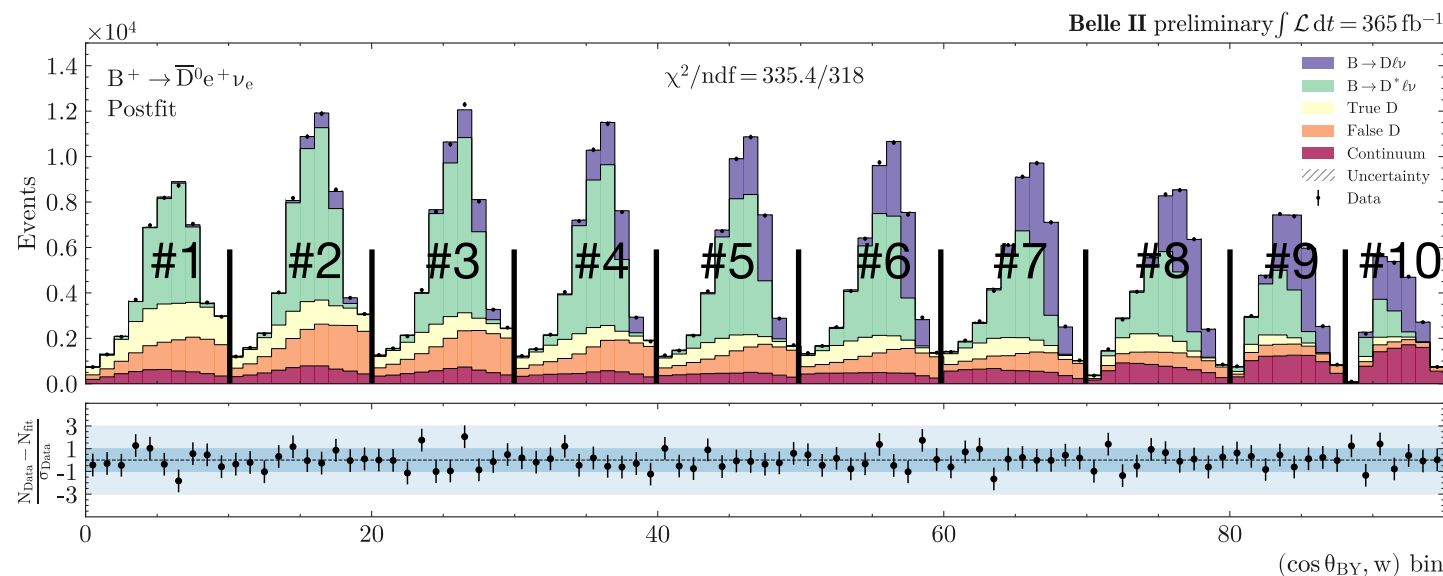


Precision Determinations of $|V_{cb}|$

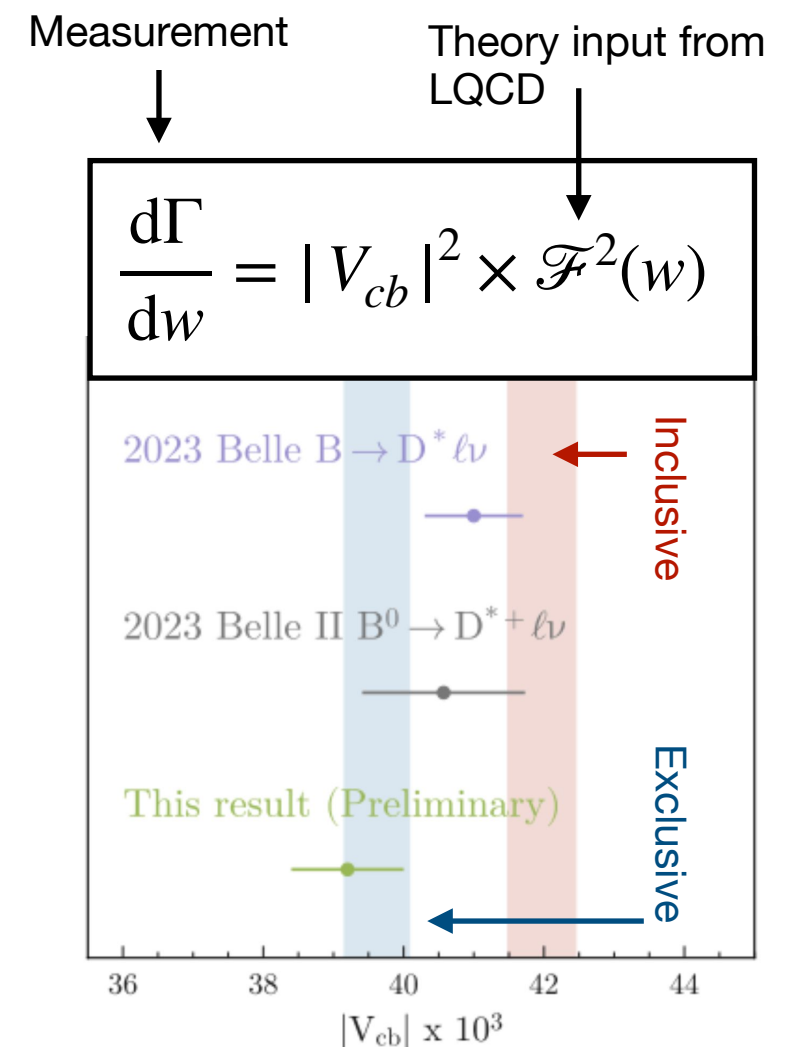
Submitted to PRD
arXiv:2506.15256



Reconstruct in bins of $w = v_B \cdot v_D = \frac{m_B^2 + m_D^2 - q^2}{2m_D m_B} \in [1, 1.5]$

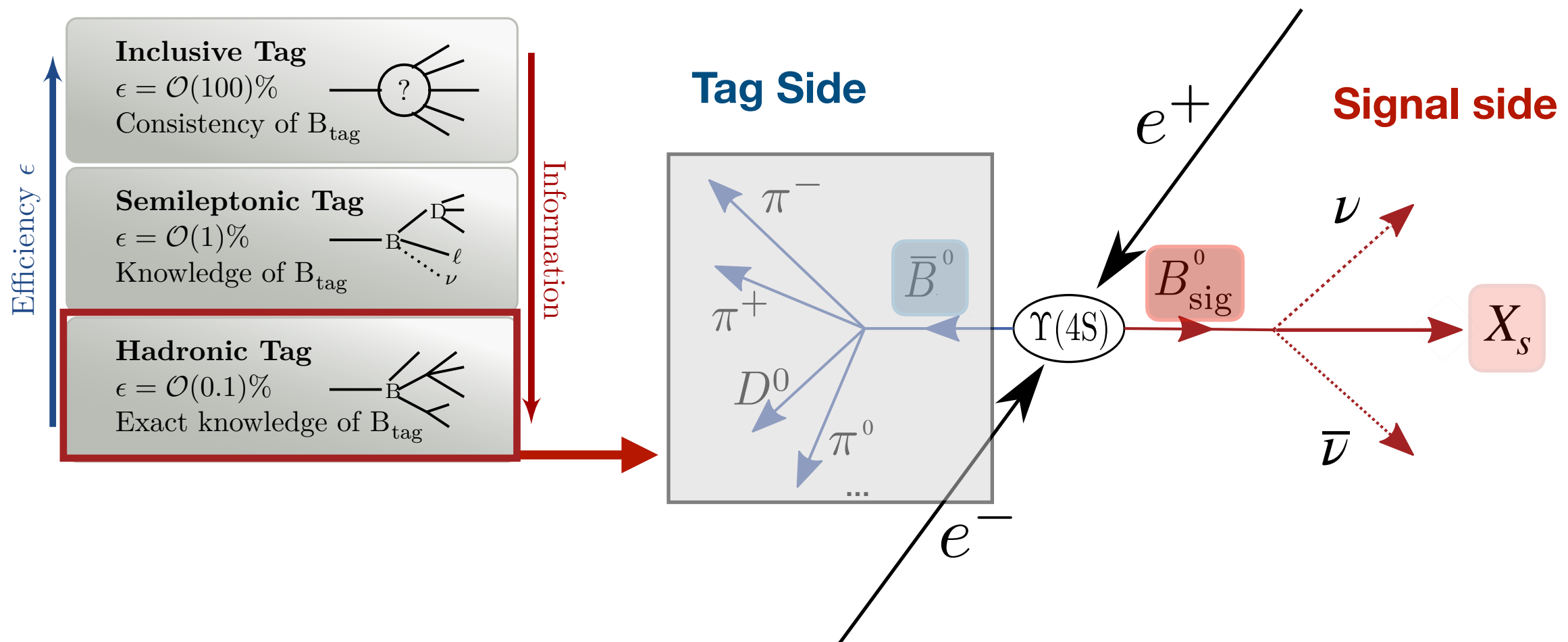


$|V_{cb}| \times 10^3 = (39.2 \pm 0.4 \pm 0.6) \longrightarrow$ Most precise from this decay ;
more precise than Belle II $B \rightarrow D^*\ell\bar{\nu}_\ell$



Search for $B \rightarrow X_s \nu \bar{\nu}$

To be submitted

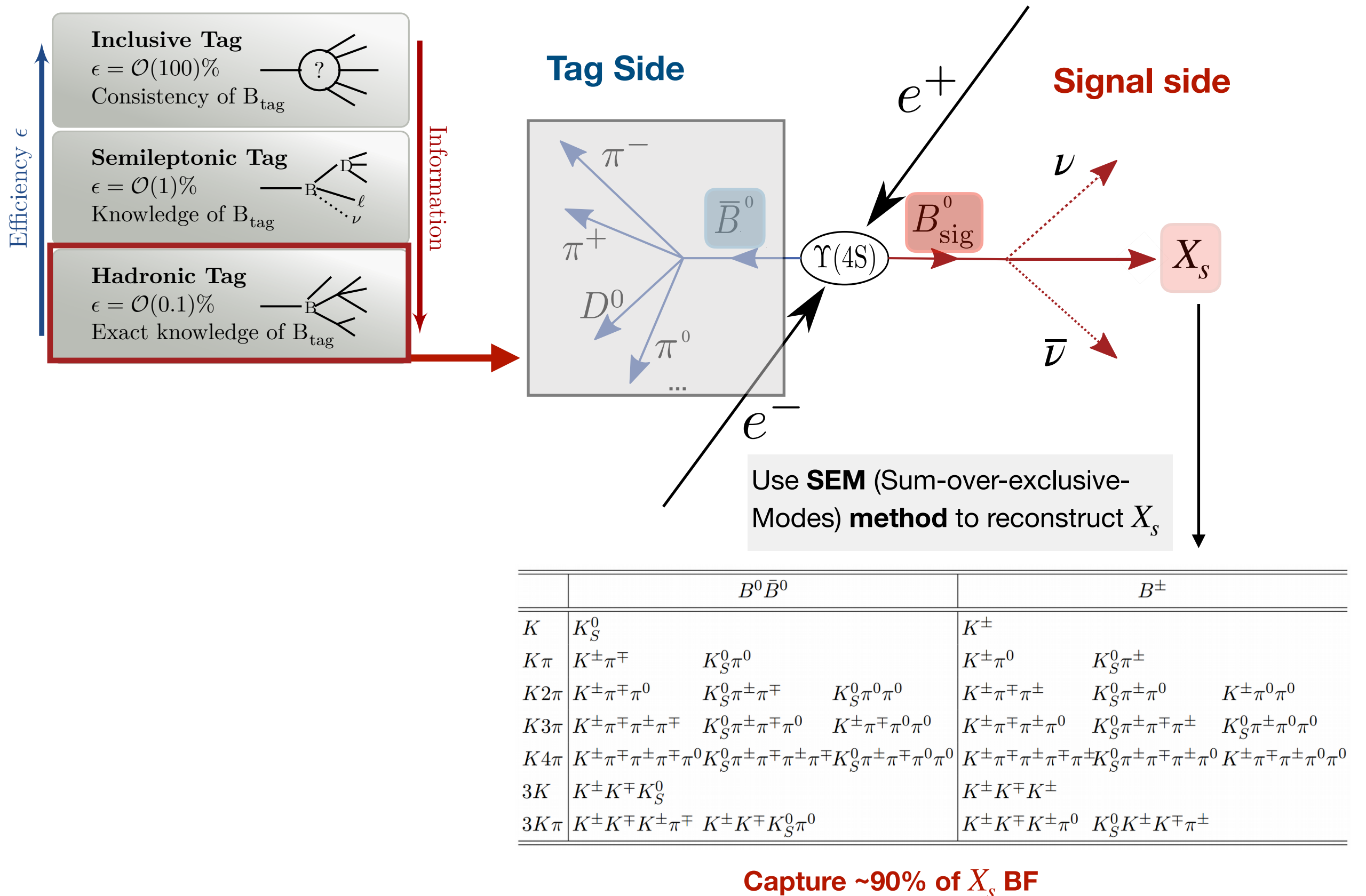


$$B_{\text{SM}} = (2.9 \pm 0.3) \times 10^{-5} \text{ [JHEP02 (2015) 184]}$$

$$B < 6.4 \times 10^{-4} \text{ at 90\% C.L. [ALEPH, EPJC 19 (2001) 213]}$$

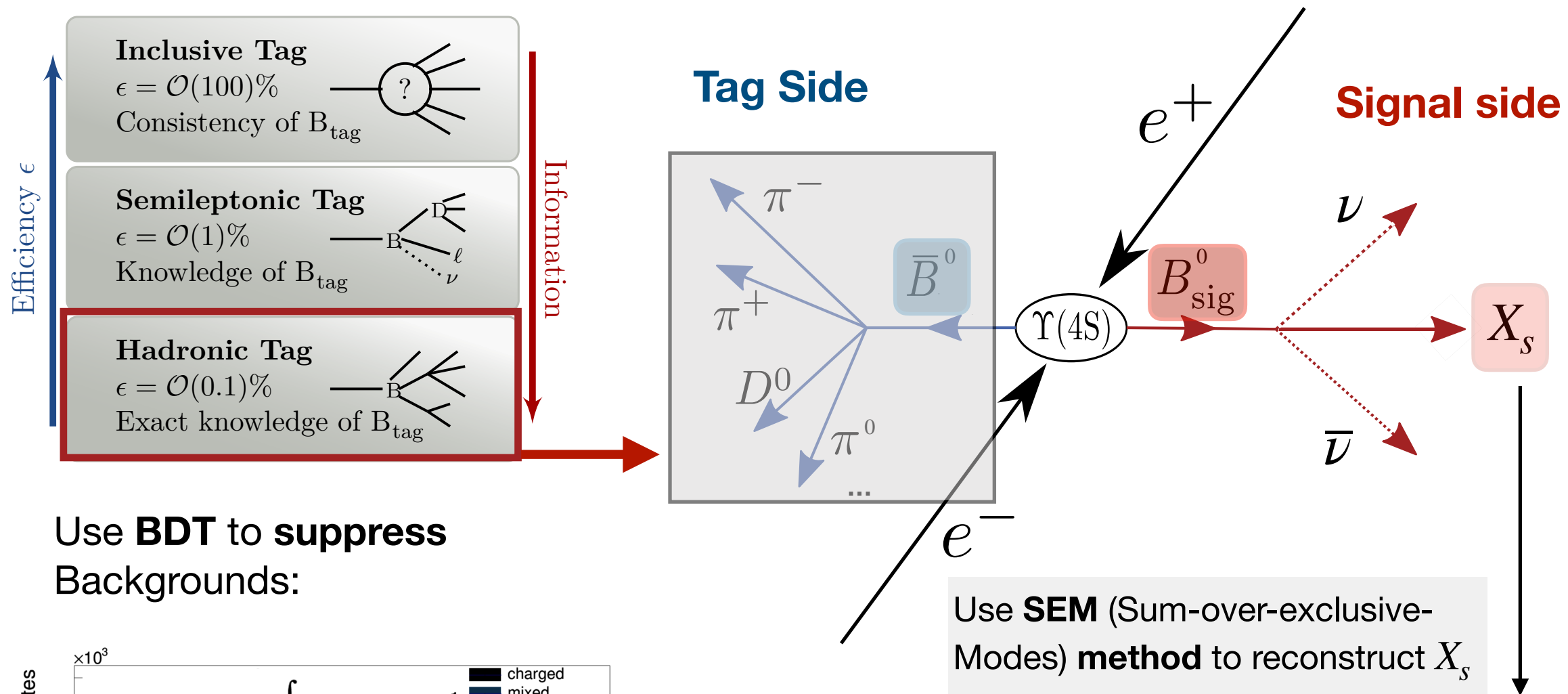
Search for $B \rightarrow X_s \nu \bar{\nu}$

To be submitted

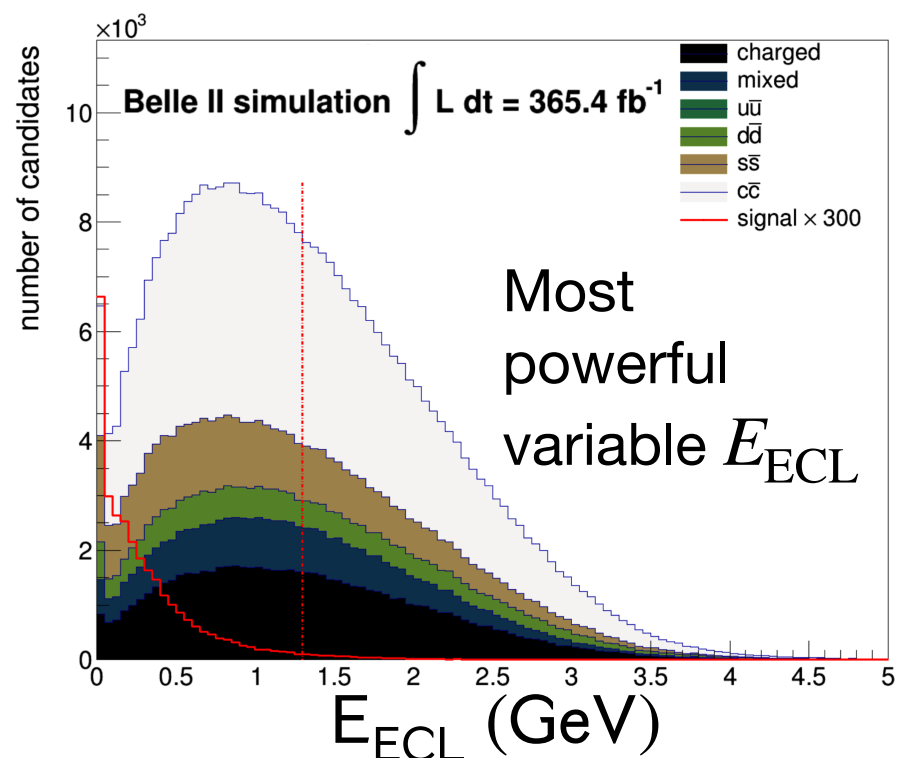


Search for $B \rightarrow X_s \nu \bar{\nu}$

To be submitted



Use **BDT** to suppress
Backgrounds:

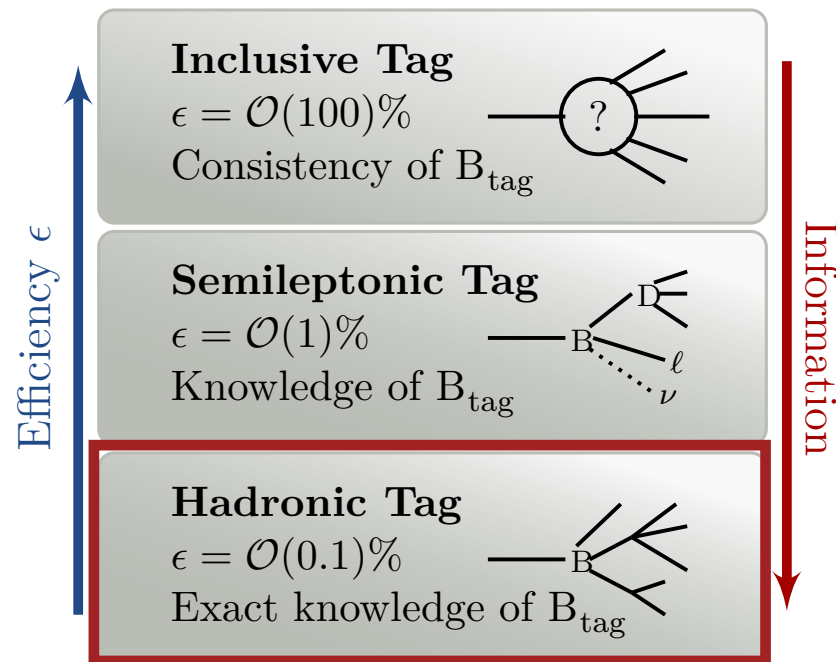


	$B^0 \bar{B}^0$			$B^\pm$		
K	K_S^0			$K^\pm$		
$K\pi$	$K^\pm \pi^\mp$	$K_S^0 \pi^0$		$K^\pm \pi^0$	$K_S^0 \pi^\pm$	
$K2\pi$	$K^\pm \pi^\mp \pi^0$	$K_S^0 \pi^\pm \pi^\mp$	$K_S^0 \pi^0 \pi^0$	$K^\pm \pi^\mp \pi^\pm$	$K_S^0 \pi^\pm \pi^0$	$K^\pm \pi^0 \pi^0$
$K3\pi$	$K^\pm \pi^\mp \pi^\pm \pi^\mp$	$K_S^0 \pi^\pm \pi^\mp \pi^0$	$K^\pm \pi^\mp \pi^0 \pi^0$	$K^\pm \pi^\mp \pi^\pm \pi^0$	$K_S^0 \pi^\pm \pi^\mp \pi^\pm$	$K_S^0 \pi^\pm \pi^0 \pi^0$
$K4\pi$	$K^\pm \pi^\mp \pi^\pm \pi^\mp \pi^0$	$K_S^0 \pi^\pm \pi^\mp \pi^\pm \pi^\mp$	$K_S^0 \pi^\pm \pi^\mp \pi^0 \pi^0$	$K^\pm \pi^\mp \pi^\pm \pi^\mp \pi^\pm$	$K_S^0 \pi^\pm \pi^\mp \pi^\pm \pi^0$	$K^\pm \pi^\mp \pi^\pm \pi^0 \pi^0$
$3K$	$K^\pm K^\mp K_S^0$			$K^\pm K^\mp K^\pm$		
$3K\pi$	$K^\pm K^\mp K^\pm \pi^\mp$	$K^\pm K^\mp K_S^0 \pi^0$		$K^\pm K^\mp K^\pm \pi^0$	$K_S^0 K^\pm K^\mp \pi^\pm$	

Capture ~90% of X_s BF

Search for $B \rightarrow X_s \nu \bar{\nu}$

To be submitted

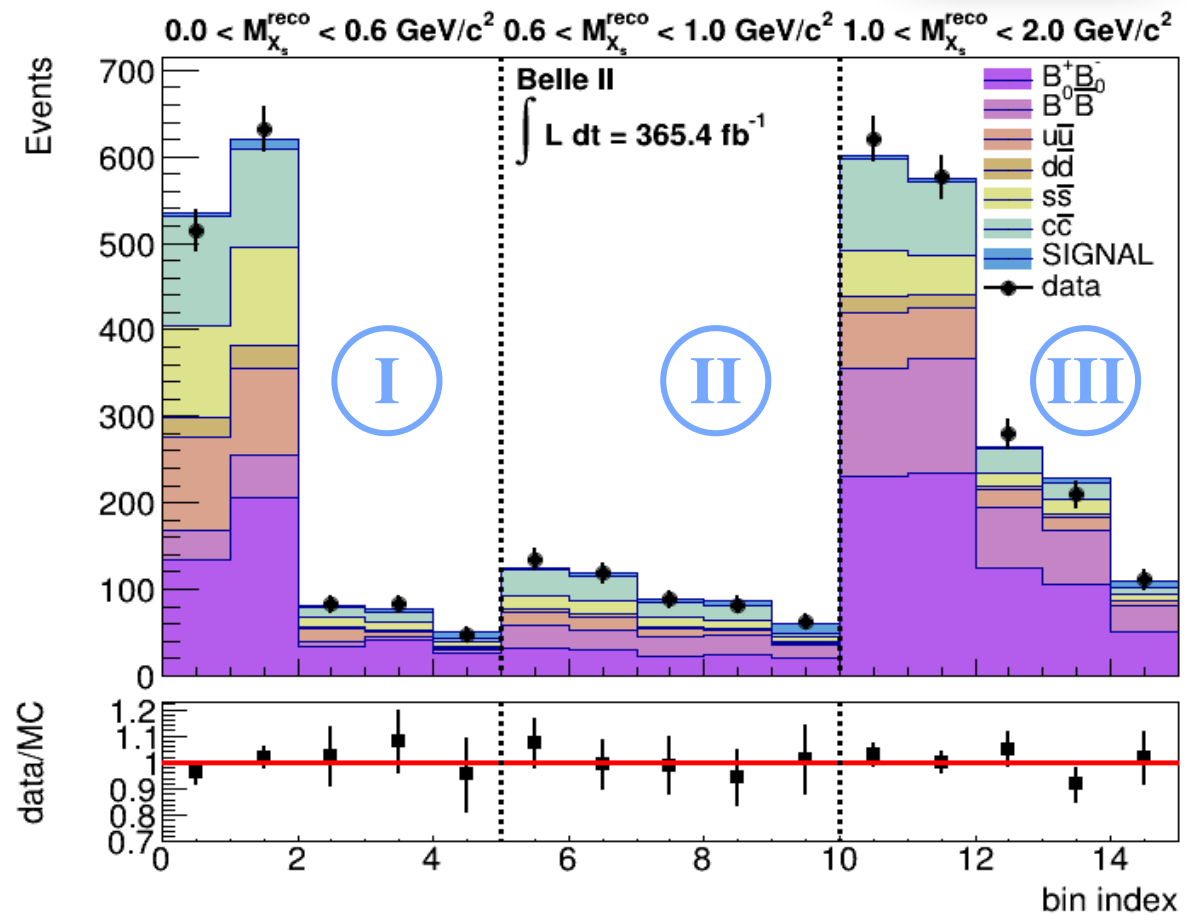


Fit BDT $\times M_{X_s}$:

$$\mathcal{B}(B \rightarrow X_s \nu \bar{\nu}) < \begin{cases} 2.5 \times 10^{-5} & (0.0 < M_{X_s} < 0.6 \text{ GeV}/c^2) \quad \text{I} \\ 1.0 \times 10^{-4} & (0.6 < M_{X_s} < 1.0 \text{ GeV}/c^2) \quad \text{II} \\ 3.5 \times 10^{-4} & (1.0 < M_{X_s}) \quad \text{III} \end{cases}$$

Main systematic uncertainties:

- MC statistics
- $\pm 20\%$ bkg normalization from sidebands
- Modelling of X_s decays



Combined:

$$\mathcal{B}(B \rightarrow X_s \nu \bar{\nu}) = [11.6 \pm_{8.6}^{8.9} (\text{stat}) \pm_{11.3}^{13.5} (\text{syst})] \times 10^{-5}$$

$$\mathcal{B}(B \rightarrow X_s \nu \bar{\nu}) < 3.6 \times 10^{-4} \text{ (90 \% CL)}$$

Most stringent limit of inclusive rate !

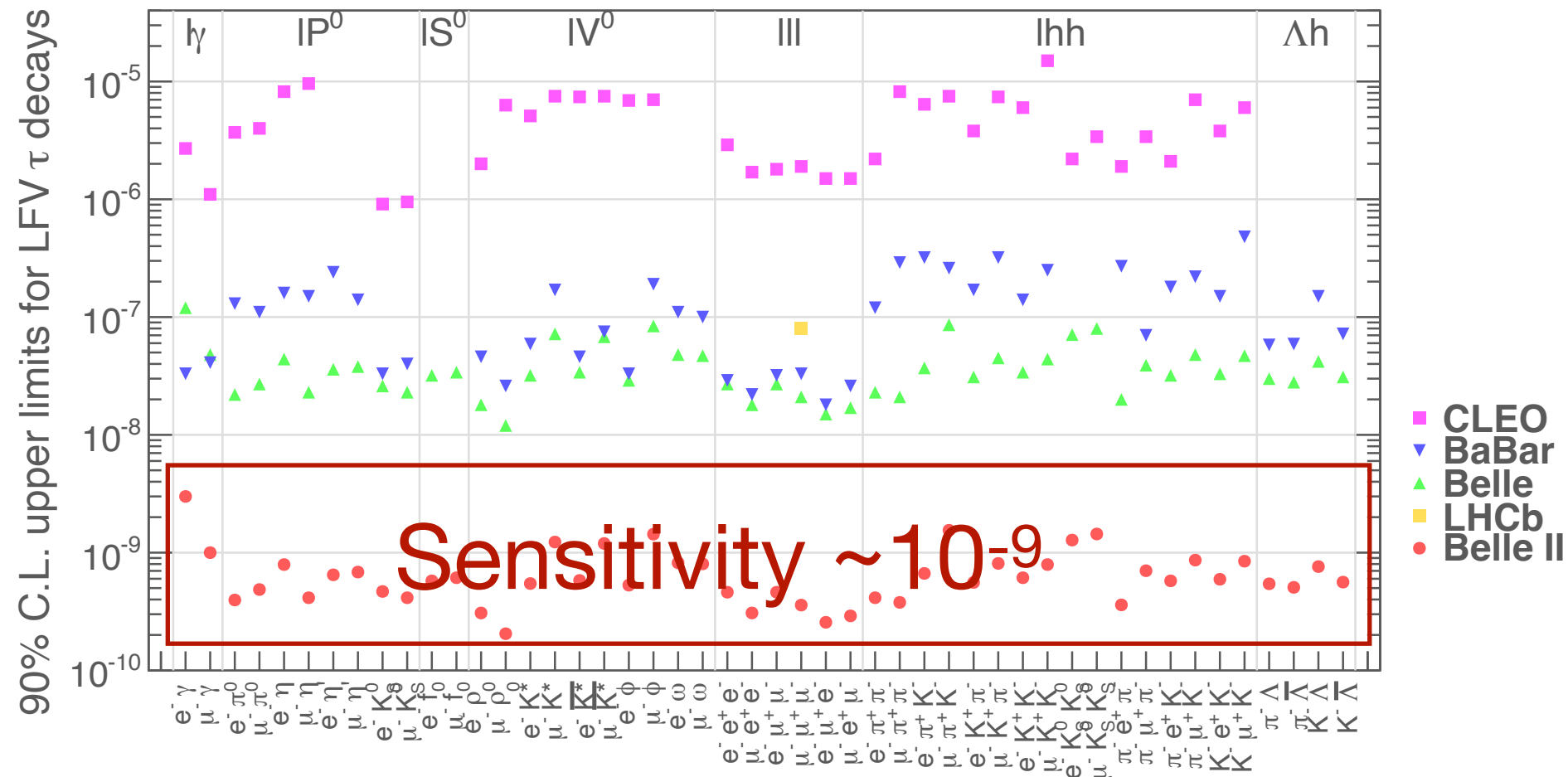
$$B_{\text{SM}} = (2.9 \pm 0.3) \times 10^{-5} \text{ [JHEP02 (2015) 184]}$$

$$B < 6.4 \times 10^{-4} \text{ at 90 \% C.L. [ALEPH, EPJC 19 (2001) 213]}$$

Search for $\tau \rightarrow 3\mu$

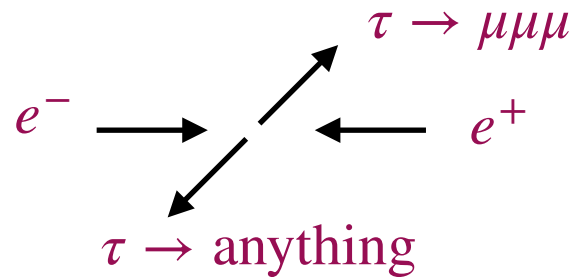
J. High Energ. Phys. 2024, 62 (2024)

Belle II is also a τ factory : $\sigma(e^+e^- \rightarrow \tau^+\tau^-) = 0.92 \text{ nb} @ \Upsilon(4S)$



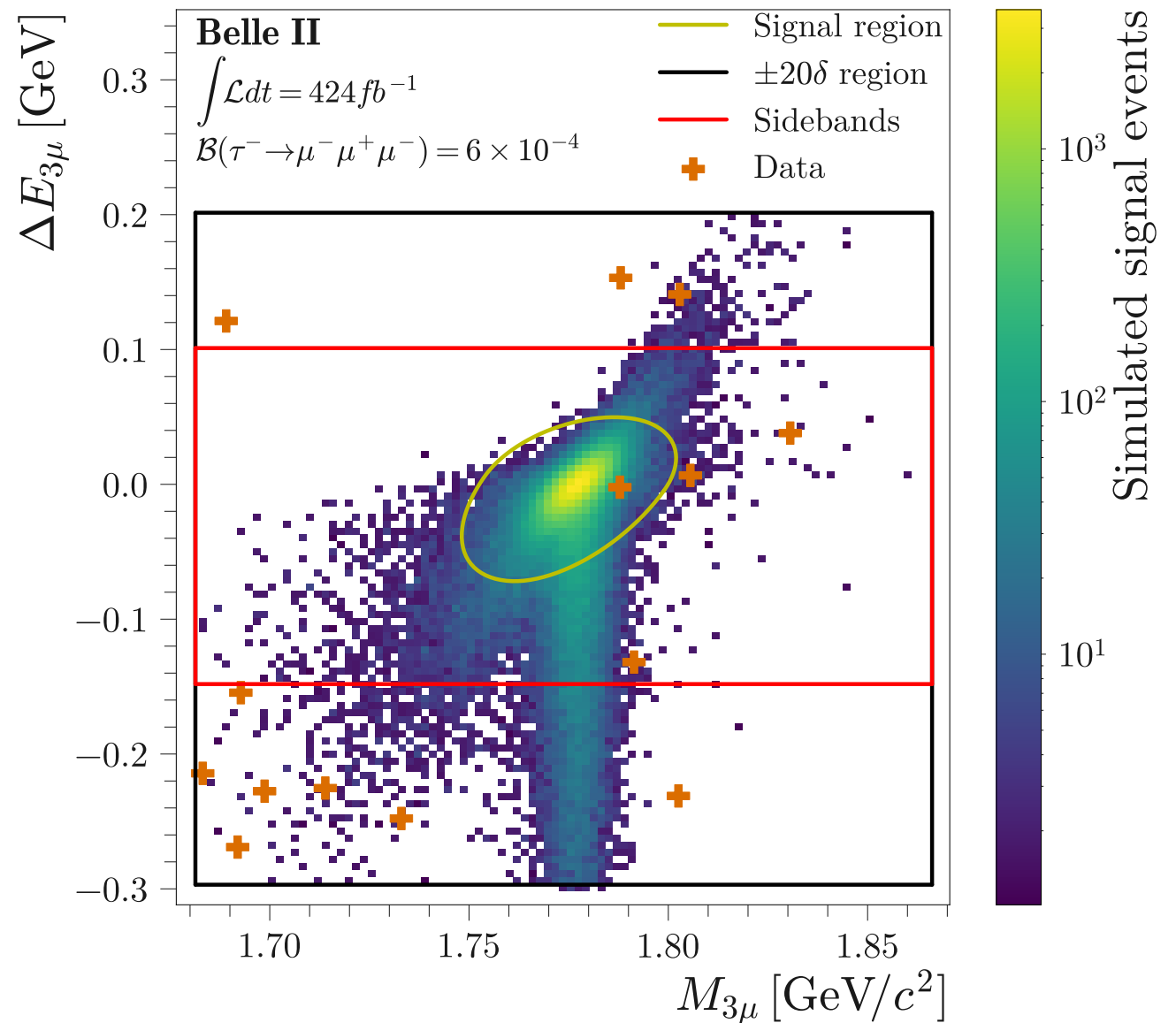
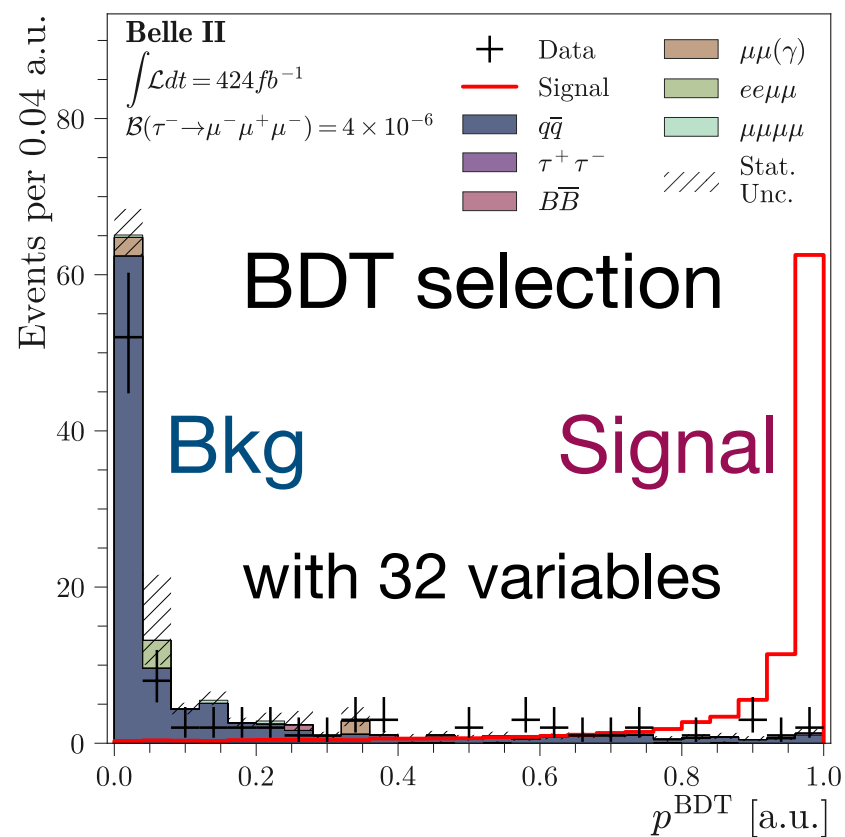
Test lepton flavor conservation ;
many NP models **break** this
symmetry

Model	Reference	$\tau \rightarrow \mu \gamma$	$\tau \rightarrow \mu \mu \mu$
SM+ ν oscillations	EPJ C8 (1999) 513	10^{-40}	10^{-55}
SM+ heavy Maj ν_R	PRD 66 (2002) 034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547 (2002) 252	10^{-9}	10^{-8}
SUSY SO(10)	PRD 68 (2003) 033012	10^{-8}	10^{-10}
mSUGRA+seesaw	PRD 66 (2002) 115013	10^{-7}	10^{-9}
SUSY Higgs	PLB 566 (2003) 217	10^{-10}	10^{-7}



Signal window with $\Delta E_{3\mu} = E_{\tau}^* - \sqrt{s}/2$
& $M_{3\mu}$

Reconstruct $\tau \rightarrow \mu\mu\mu$
& second τ **inclusively**



Most stringent limit of $\mathcal{B} < 1.9 \times 10^{-8}$ @ 90 % CL_s

CMS: $\mathcal{B} < 2.9 \times 10^{-8}$ @ 90 % CL_s

LHCb: $\mathcal{B} < 4.6 \times 10^{-8}$ @ 90 % CL_s

Search for $\tau \rightarrow e\ell\ell$

Submitted to JHEP

arXiv: 2507.18236

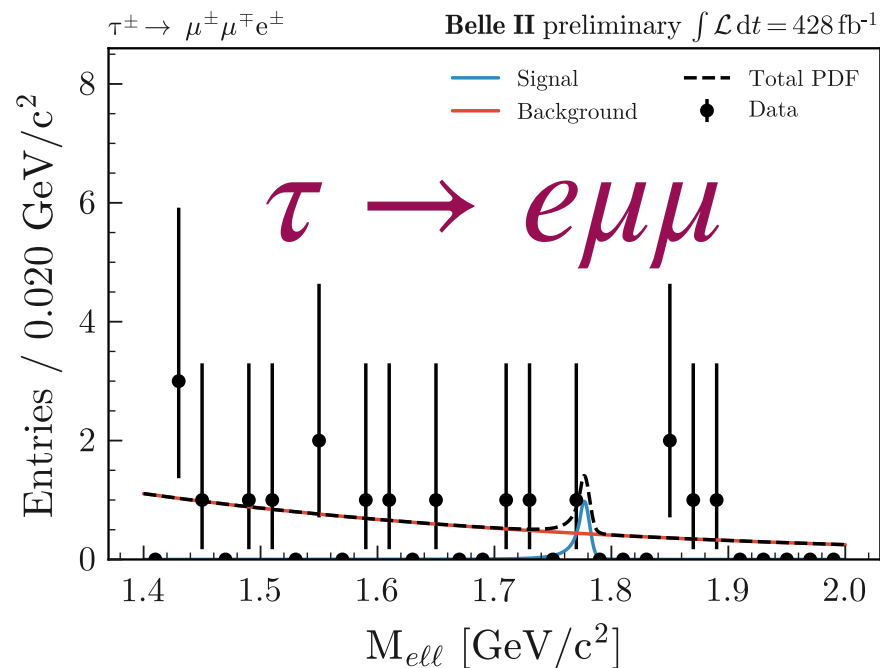
Similar approach: $\tau \rightarrow e\ell\ell$

Also use **BDT** for **background suppression** using ROE, trained on sidebands

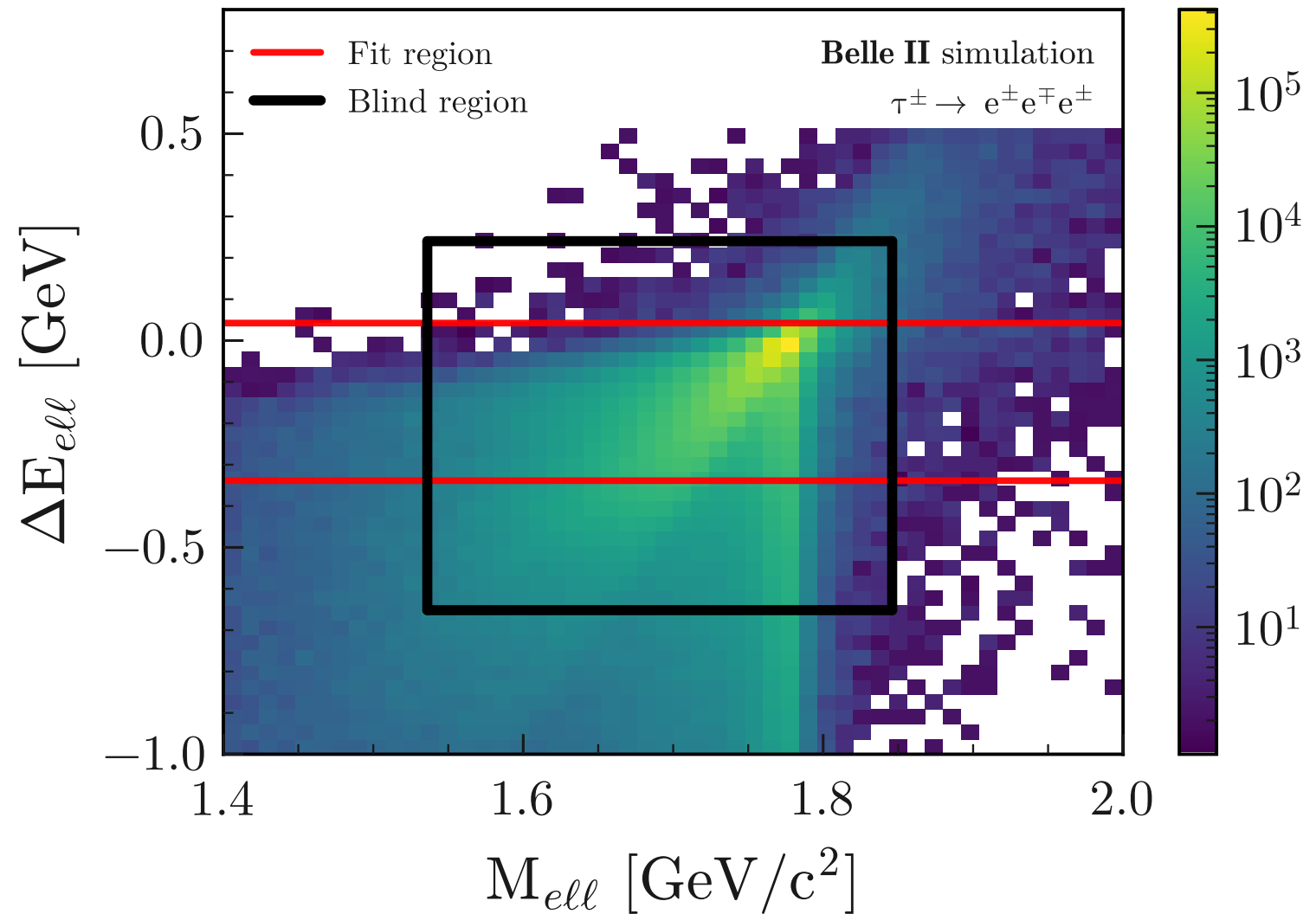
Define **signal window** in

$$\Delta E_{e\ell\ell} = E_\tau - \sqrt{s}/2 : M_{e\ell\ell}$$

Signal extraction via fit in $M_{e\ell\ell}$



No significant excesses seen; most stringent upper limits in all modes



	N_{exp}	N_{obs}	C_{bg}	$\mathcal{B} (10^{-8})$	$\mathcal{B}_{\text{exp}}^{UL} (10^{-8})$	$\mathcal{B}_{\text{obs}}^{UL} (10^{-8})$
$e^- e^+ e^-$	$6.1^{+4.3}_{-2.9}$	5	$0.52^{+2.64}_{-2.60}$	0	2.7	2.5
$e^- e^+ \mu^-$	$12.1^{+5.7}_{-4.3}$	12	$-0.40^{+1.67}_{-1.68}$	0	2.1	1.6
$e^- \mu^+ e^-$	$10.5^{+5.3}_{-4.3}$	17	$-2.90^{+1.48}_{-1.54}$	0	1.7	1.6
$\mu^- \mu^+ e^-$	$20.7^{+6.6}_{-5.5}$	18	$-2.50^{+1.45}_{-1.52}$	$0.48^{+0.90}_{-0.48}$	1.6	2.4
$\mu^- e^+ \mu^-$	$7.5^{+4.5}_{-3.2}$	9	$-0.34^{+1.93}_{-1.94}$	0	1.4	1.3

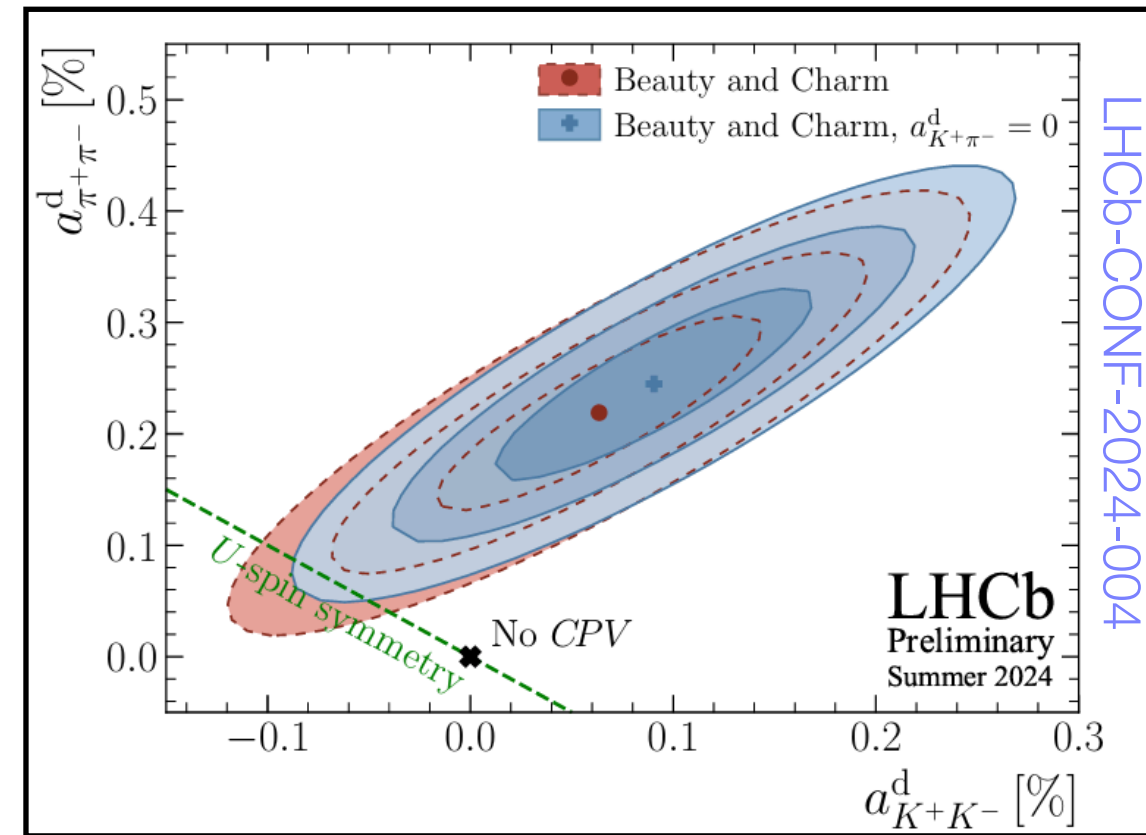
CPV in $D \rightarrow \pi\pi$

Only experimentally established observ.
of CPV in charm by **LHCb**

$$\Delta A_{CP}(D^0 \rightarrow KK, \pi\pi) = (-15.4 \pm 2.9) \times 10^{-4}$$

Origin unclear; could be NP but also due to **rescattering** effects

Isospin-conjugate modes $D^+ \rightarrow \pi^+\pi^0$ and $D^+ \rightarrow \pi^0\pi^0$ of great interest, as either **free** from rescattering diagram or connected via



LHCb

Belle II

LHCb & Belle II

$$R = \alpha \Delta A_{CP}(\pi^+\pi^-) + \beta \Delta A_{CP}(\pi^0\pi^0) + \gamma \Delta A_{CP}(\pi^+\pi^0)$$

$$\alpha = \frac{1}{1 + \frac{\tau_{D^-}}{\mathcal{B}_{\pm}} \left(\frac{\mathcal{B}_{00}}{\tau_{D0}} - \frac{2}{3} \frac{\mathcal{B}_{\pm}}{\tau_{D+}} \right)} \quad \beta = \frac{1}{1 + \frac{\tau_{D^-}}{\mathcal{B}_{00}} \left(\frac{\mathcal{B}_{\pm}}{\tau_{D0}} - \frac{2}{3} \frac{\mathcal{B}_{\pm}}{\tau_{D+}} \right)} \quad \gamma = \frac{1}{1 - \frac{3}{2} \frac{\tau_{D^-}}{\mathcal{B}_{\pm}} \left(\frac{\mathcal{B}_{00}}{\tau_{D0}} + \frac{\mathcal{B}_{\pm}}{\tau_{D0}} \right)} \quad \mathcal{B}_{ij} = \mathcal{B}(D \rightarrow \pi^i \pi^j)$$

$$\rightarrow R^{\text{HFLAV}} = (0.9 \pm 3.1) \times 10^{-3}$$

If all individual $\Delta A_{CP} \neq 0$ and $R = 0$
indicate NP contributions

Select $e^+e^- \rightarrow c\bar{c}$ decays and reconstruct $D^{*+} \rightarrow D^0\pi^+$ to tag production flavor

Goal is to measure

$$A^{\pi^0\pi^0} = \frac{N[D^{*+} \rightarrow (D^0 \rightarrow \pi^0\pi^0)\pi^+] - N[D^{*-} \rightarrow (\bar{D}^0 \rightarrow \pi^0\pi^0)\pi^-]}{N[D^{*+} \rightarrow (D^0 \rightarrow \pi^0\pi^0)\pi^+] + N[D^{*-} \rightarrow (\bar{D}^0 \rightarrow \pi^0\pi^0)\pi^-]}$$

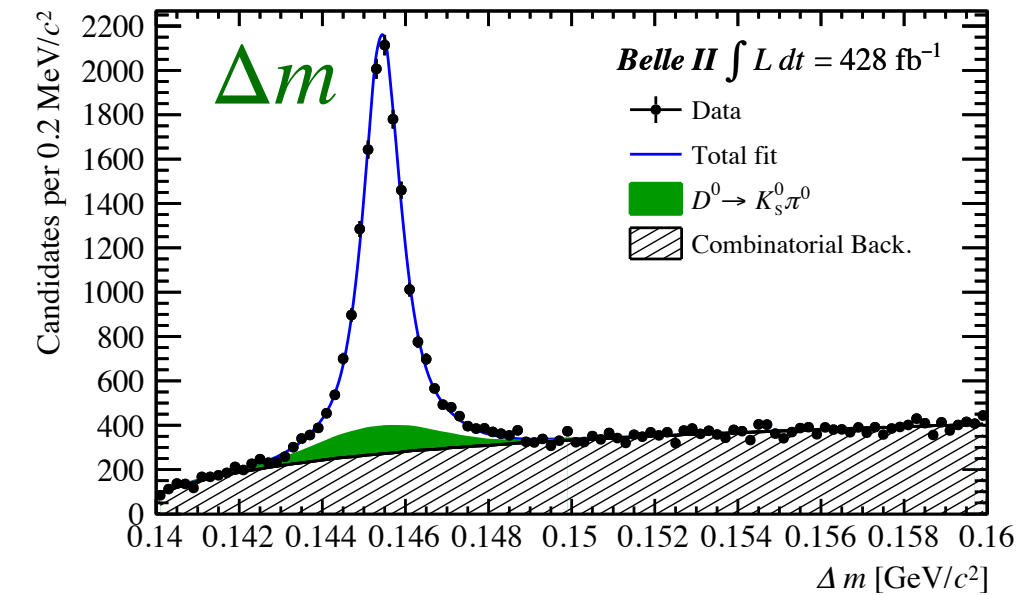
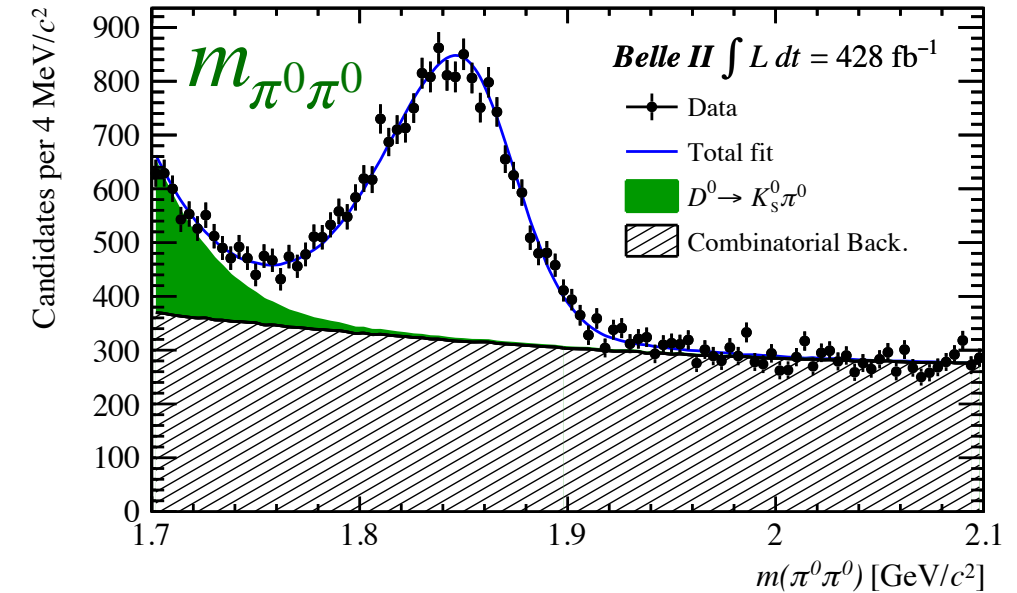
to determine

$$A^{\pi^0\pi^0} = A_{CP}(D^0 \rightarrow \pi^0\pi^0) + A_P^{D^{*+}} + A_\epsilon^{\pi_s}$$

D^{*+} Production asymmetry

Detection asymmetry

Determine $A^{\pi^0\pi^0}$ in **2D fit** in $m_{\pi^0\pi^0} : \Delta m = m_{\pi^+\pi^0\pi^0} - m_{\pi^0\pi^0}$

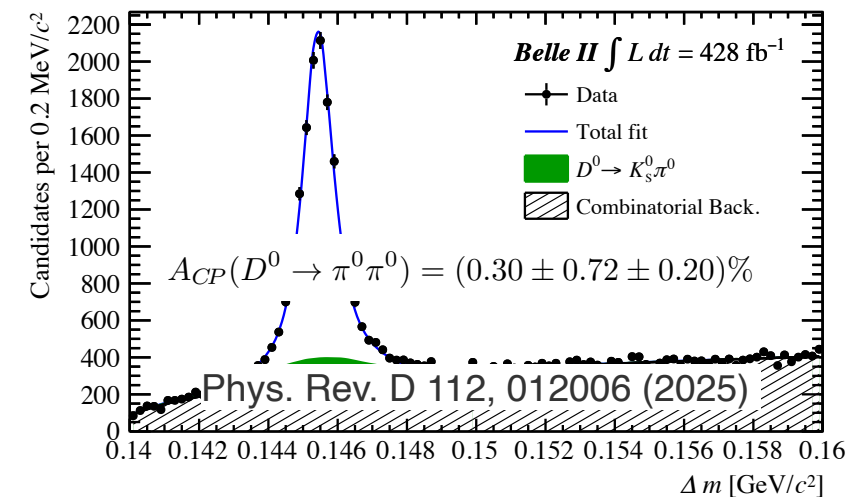
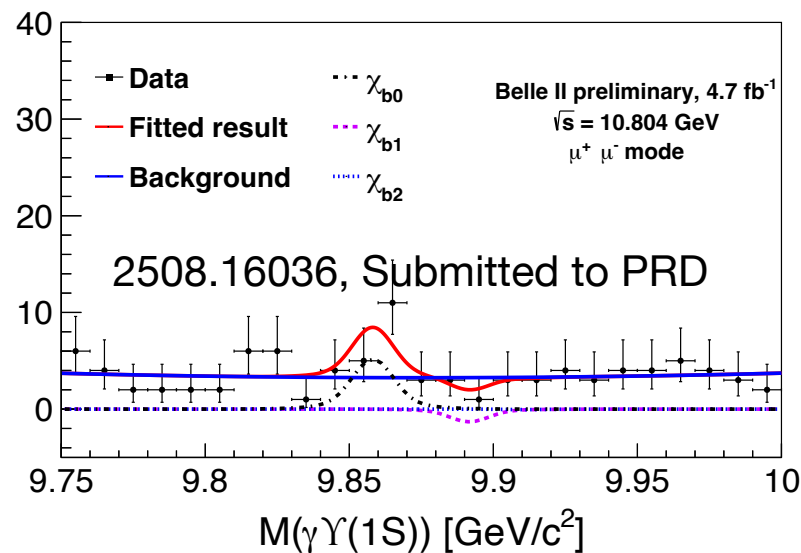
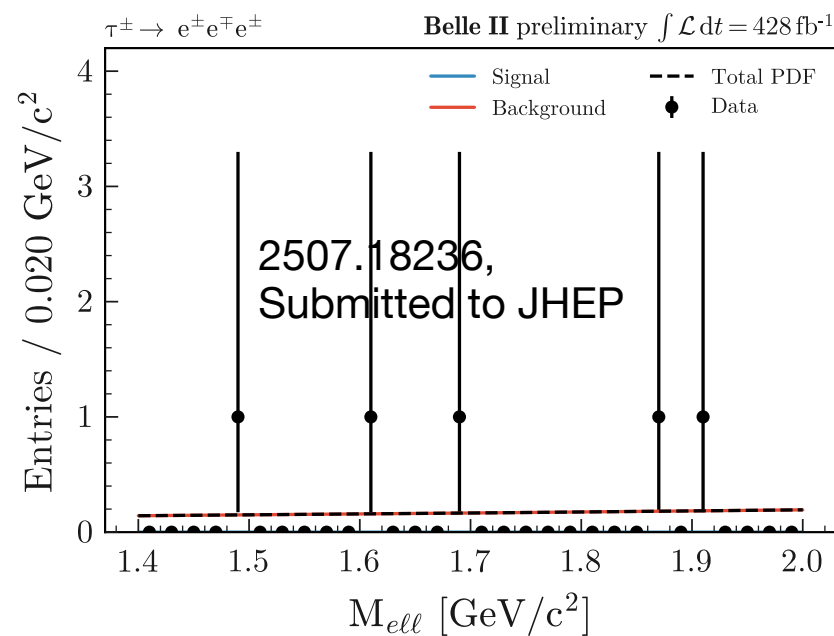
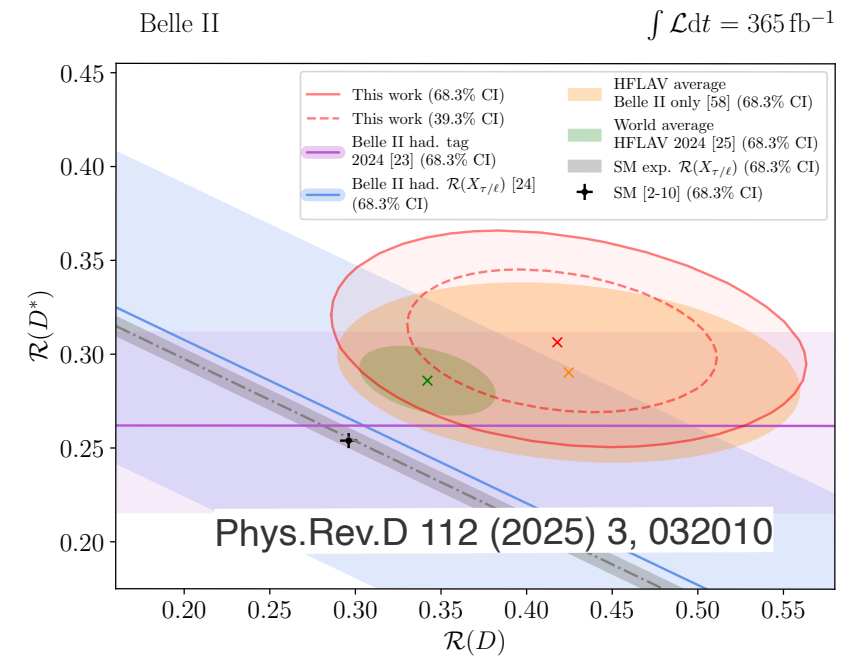
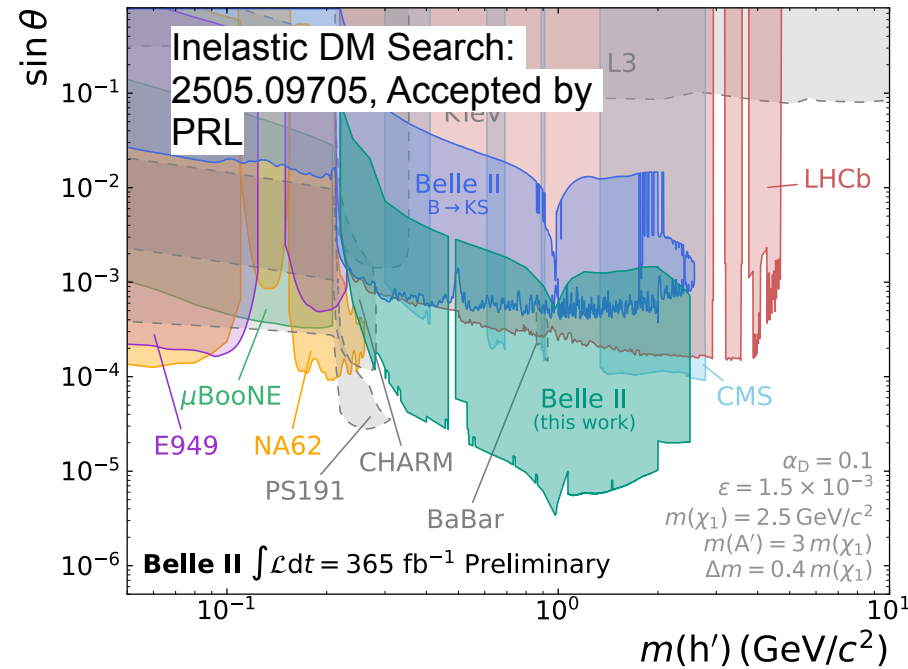
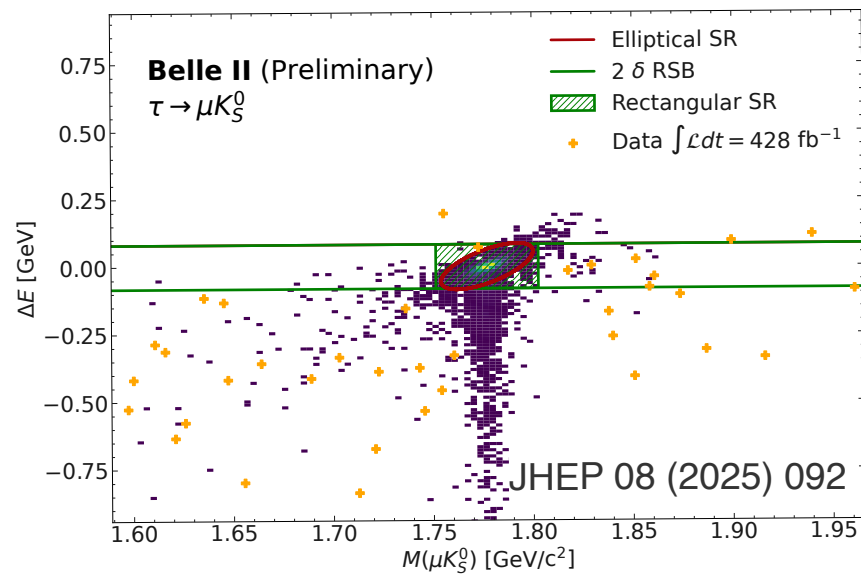


Improvement of 20%

$$A_{CP}(D^0 \rightarrow \pi^0\pi^0) = (0.30 \pm 0.72 \pm 0.20) \times 10^{-2} \rightarrow R = (1.5 \pm 2.5) \times 10^{-3}$$

$$A_{CP}(D^0 \rightarrow \pi^0\pi^0) = (-0.03 \pm 0.64 \pm 0.10) \times 10^{-2}$$

And much more ...



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