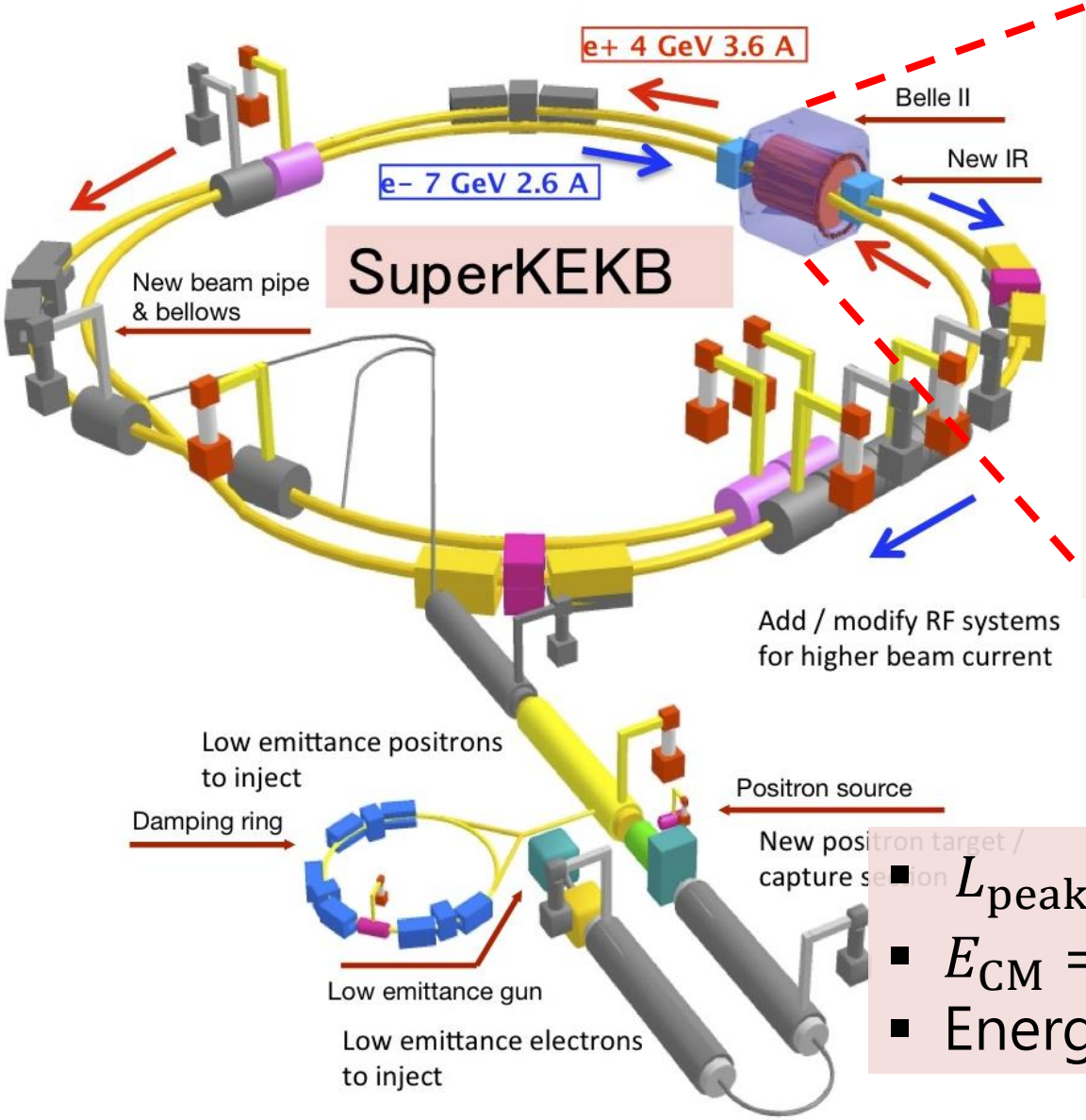
Summary of Belle II Results

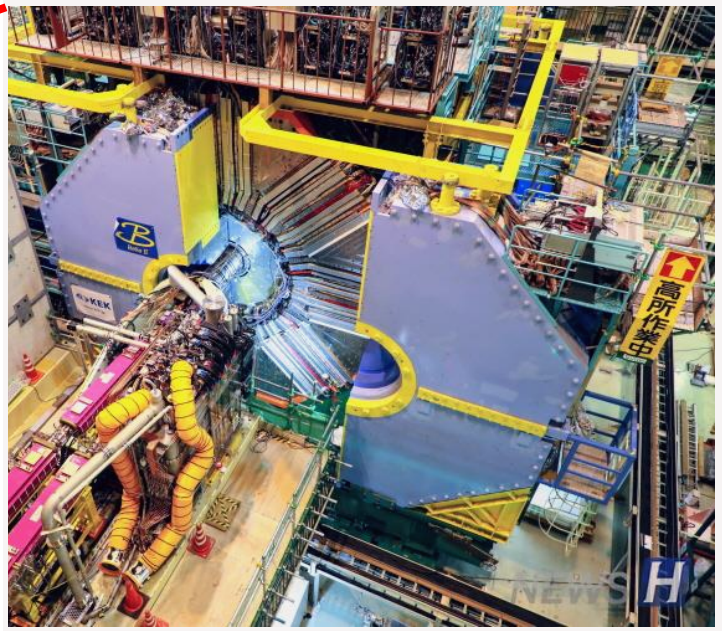
2023 Meeting of the Division of Particles and Fields of
the Korean Physical Society
December 21, 2023

Seongbae Yang (Korea University)
on behalf of Korean Belle II Collaboration

*Contents

1. SuperKEKB: the highest luminosity collider





- $L_{\mathrm{peak}} = 6 \times 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- E_{CM} = 'at or near' $\Upsilon(4S)$
- Energy-asymmetric collision

1. Belle II Detector: upgrade from Belle

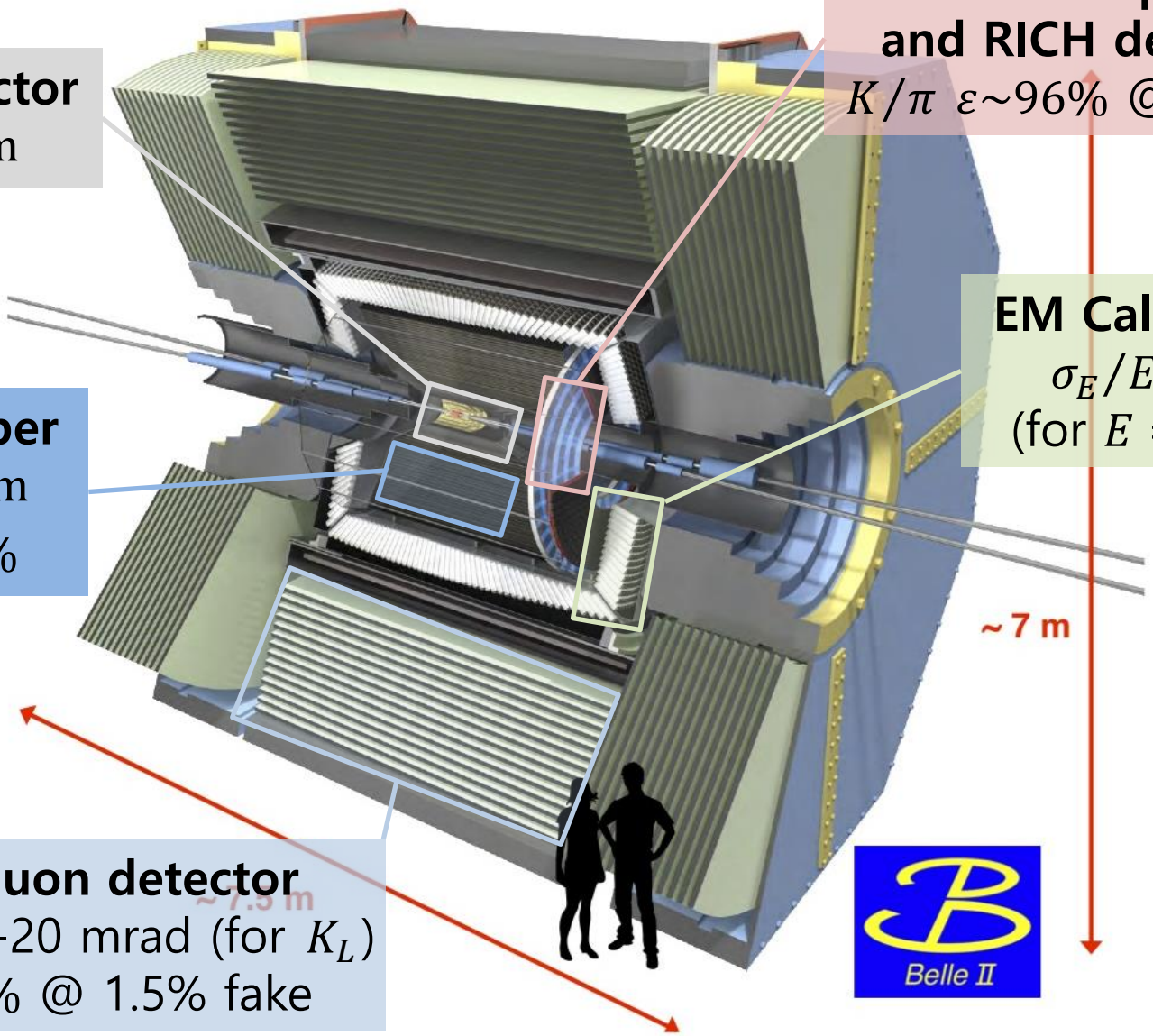
Vertex detector
σ_{z_0}~15 μm

Drift chamber
σ_{r_ϕ}~100 μm
$\sigma_{dE/dx}$~5%

Time of Propagation and RICH detectors
K/π ε~96% @ 1% fake

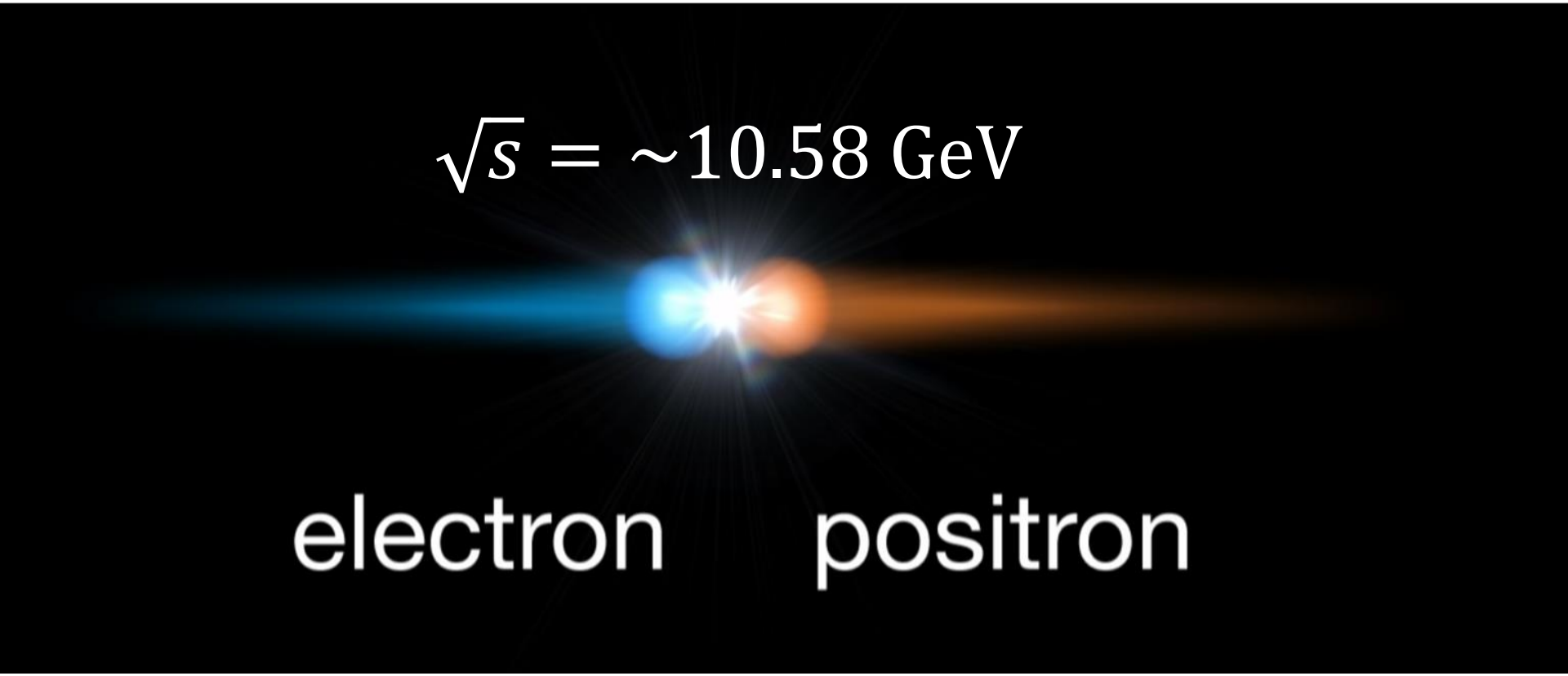
EM Calorimeter
$\sigma_E/E = 2\%$
(for $E = 1$ GeV)

K_L and Muon detector
$\Delta\phi = \Delta\theta$~10-20 mrad (for K_L)
μ/π ε~90% @ 1.5% fake



* The Belle II Physics Book, PTEP 2019, 123C01 (2019)

All particle physics with e^+e^- collision

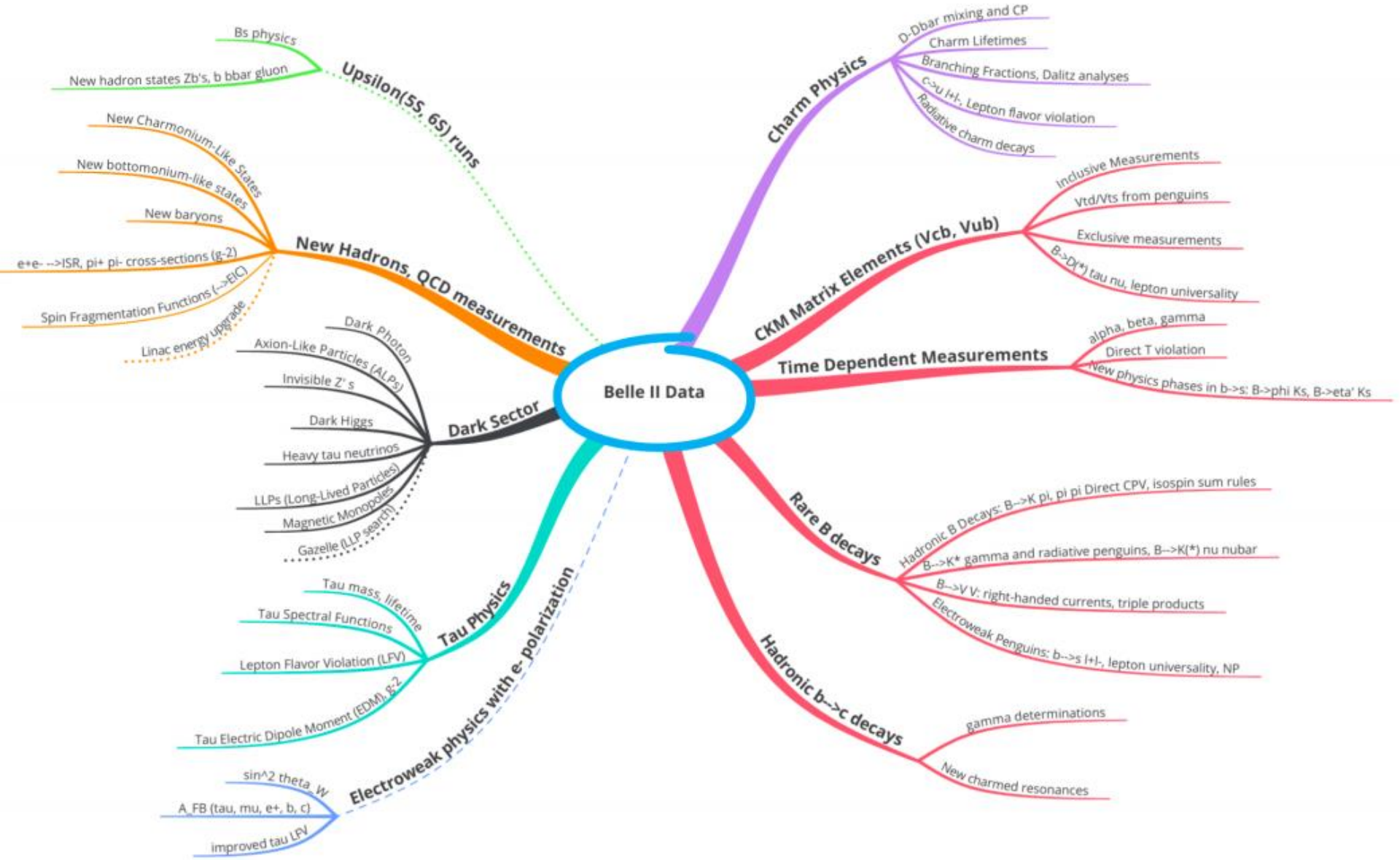


CKM Matrix | τ Physics | Hadron Spectroscopy

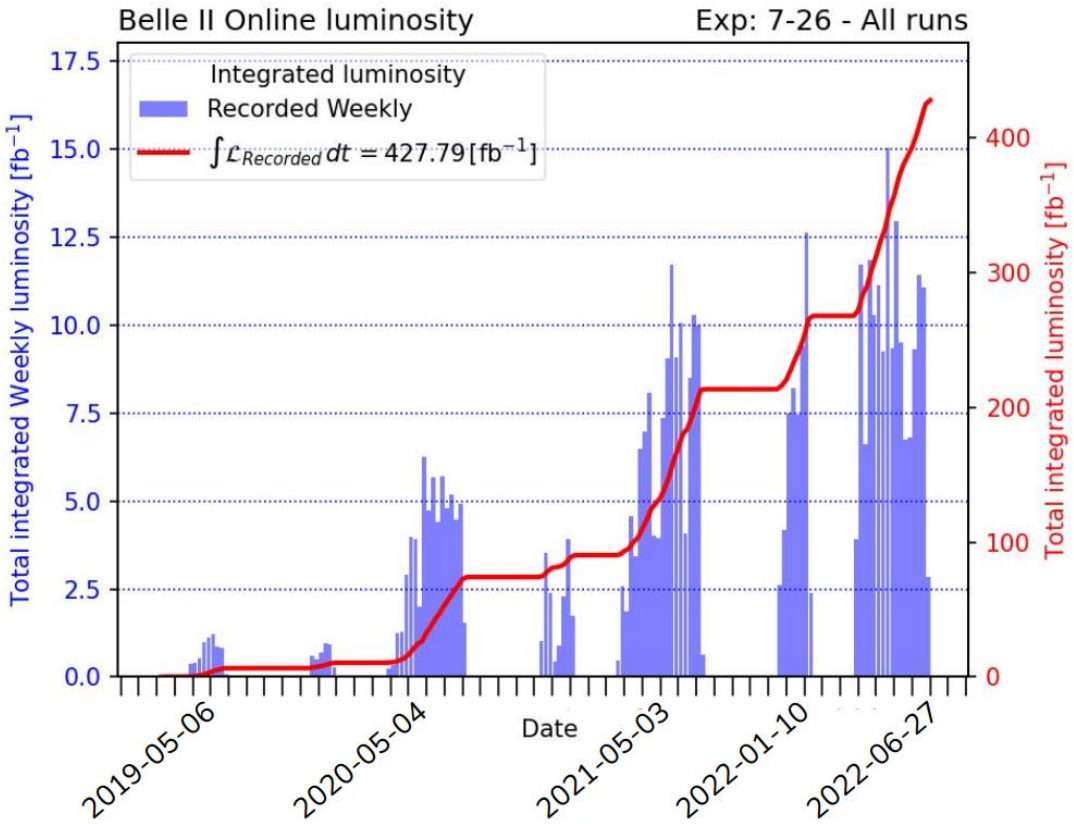
Rare Decays | FCNC | New Physics

1. Physics Program

* The Belle II Physics Book, PTEP 2019, 123C01 (2019)

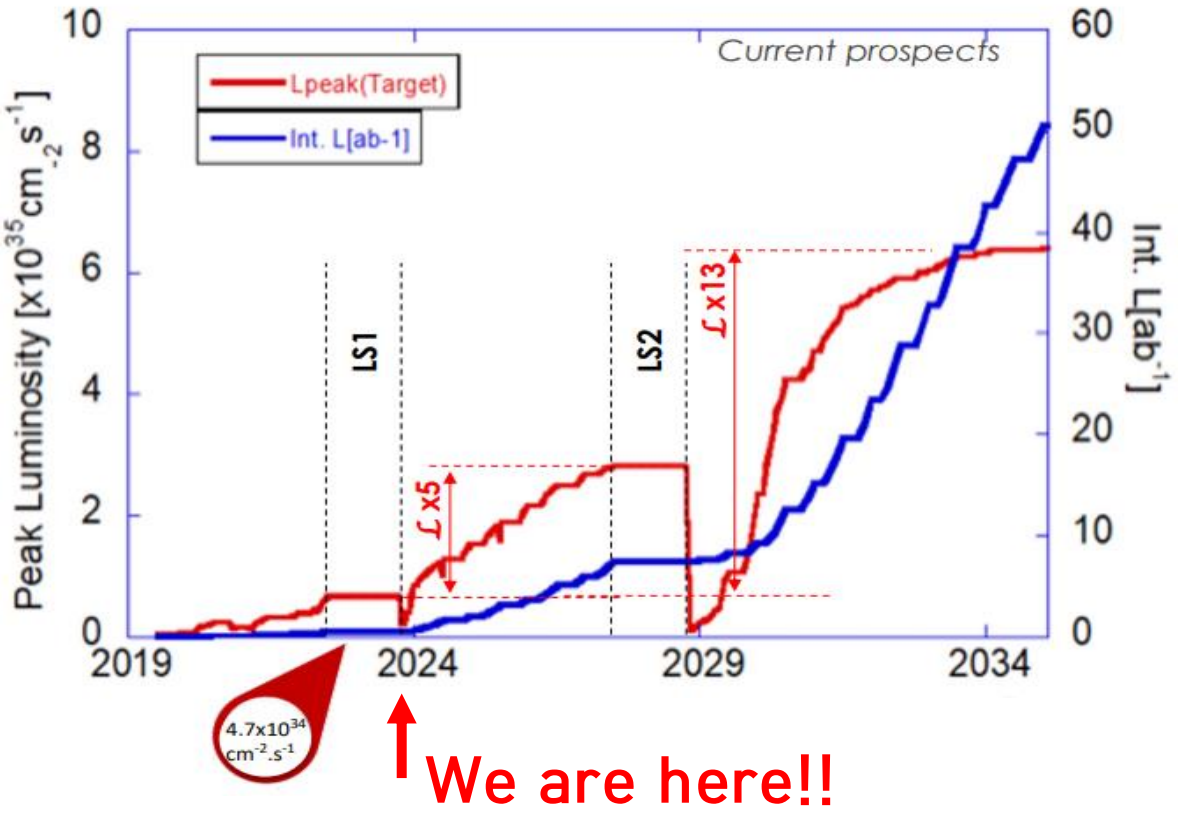


1. Operation Status: operation until 2022



- The world record of $L_{\mathrm{peak}} = 4.7 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$.
- Total integrated luminosity of $424\ \mathrm{fb}^{-1}$ until now.

1. Operation Status: LS1 (Jul. 2022 ~ Dec.2023)

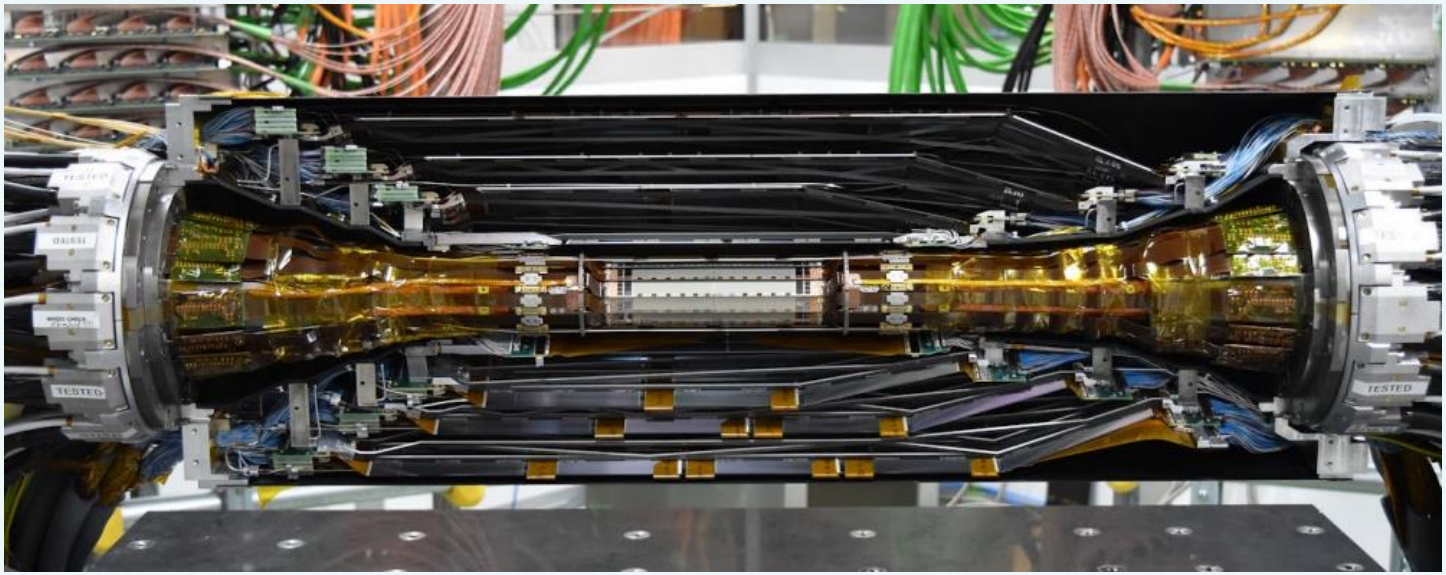


- Machine and detector upgrades for $L_{\mathrm{peak}} = 2 \times 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$.

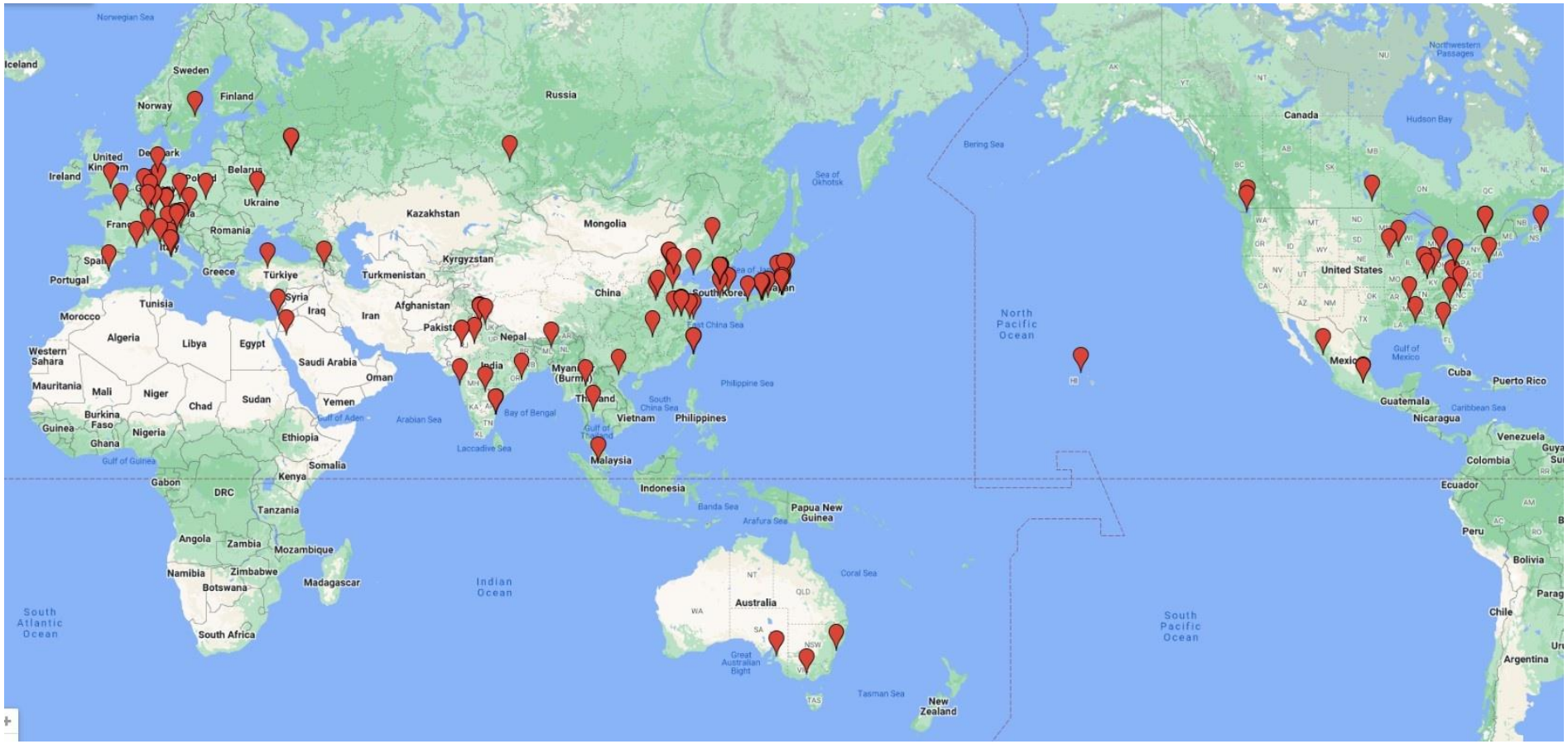
1. Operation Status: LS1 (Jul. 2022 ~ Dec.2023)

- Installation of complete PXD
- Replacement of PMTs in TOP
- Improved CDC gas distribution and monitoring
- DAQ system upgrade

PXD in 2023



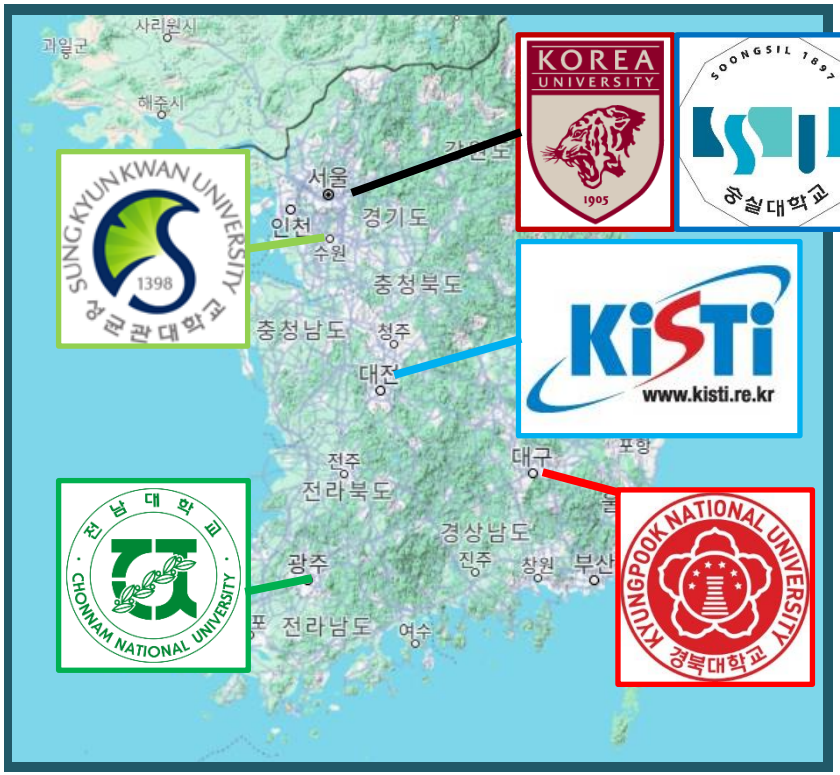
1. The Belle II Collaboration



*As of December 2023, approximately

- 1172 members, 123 institutes, 29 countries
  (독일 221 명, 일본 181 명, 미국 120 명, 이태리 110 명, 중국 103 명, …)

2. Korean Belle II Group



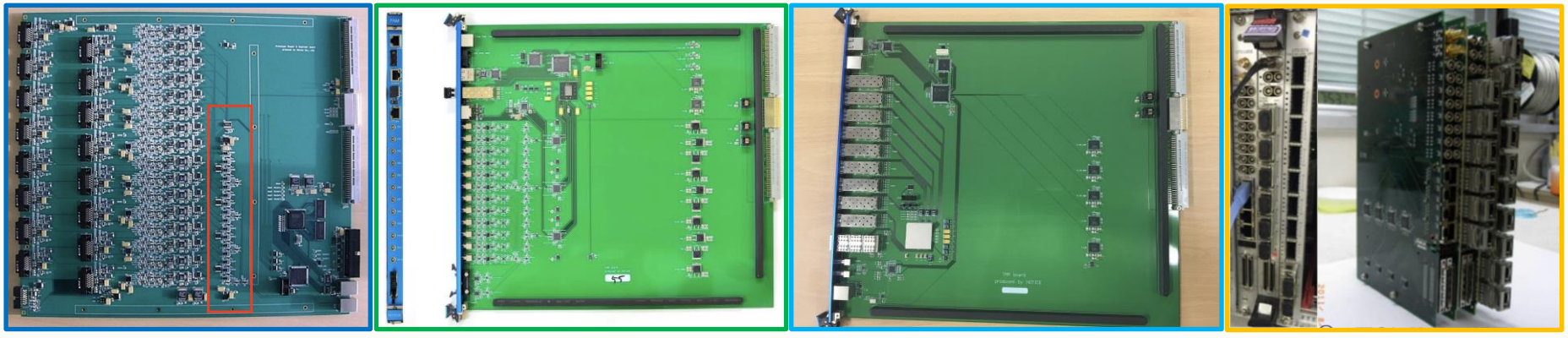
- 39 active members at 10 institutions

(경북대, 고려대, 서울대, **성균관대**, 숭실대, 연세대, 전남대, **중앙대**, 한양대, KISTI)

2. Korean Belle II Group

- Belle II HW/SW contribution
  - ECL calorimeter trigger construction
  - CDC track trigger firmware
  - SVD vertex detector assembly
  - DAQ slow control
  - Data production and Geant4 validation
  - Data handling system using AMGA

Shaper → FAM → TMM → ETM



2. Korean Belle II Group: 2023 news

- Elected as IB (기관대표자회의) chair
  - Prof. Doris Kim, Soongsil Univ.
  - 2023.06~2024.06

- KB(2)GM (twice a year)

~20 talks on ongoing analyses and Belle II operations.

KB2GM Dec. 8 @KU

2. Korean Belle II Group: 2023 news

- Research outcomes in 2023 (written by Korean group)

1. Search for double-charmonium state with $\eta_c J/\psi$ at Belle
J.H. Yin, Y.B. Li, E. Won, JHEP 08 (2023) 121

Exotic Hadron | Charm | Belle

2. Search for CP violation in $D^+_{(s)} \to K^+ K^0_S h^+ h^-$ $(h = K, \pi)$ decays and observation of the Cabibbo-suppressed decay $D^+_s \to K^+ K^- K^0_S \pi^-$
H. Moon, E. Won, to appear in PRD

CP Violation | Rare Decay | Belle

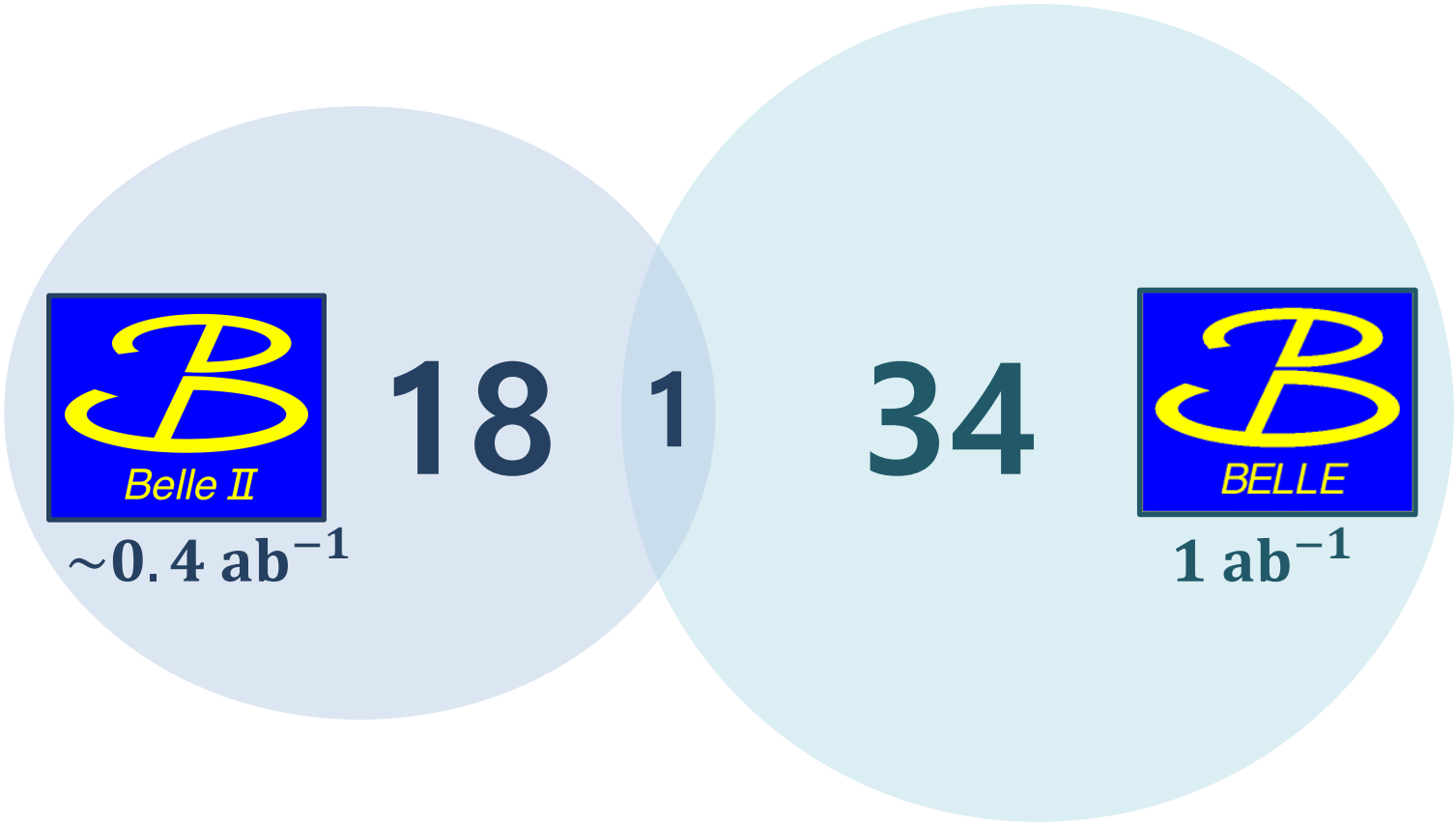
3. Observation of a threshold cusp at the $\Lambda\eta$ threshold in the pK^- mass spectrum with $\Lambda_c^+ \to pK^-\pi^+$ decays
S.B. Yang, K. Tanida, J.K. Ahn, PRD **108**, L031104 (2023)

Exotic Hadron | Hyperon | Threshold Cusp | Belle

4. Search for $X(3872) \to \pi^+\pi^-\pi^0$ at Belle
J.H. Yin, E. Won, PRD **107**, 052004 (2023)

Exotic Hadron | XYZ | Rare Decay | Belle

3. Physics Papers in 2023



- Total 53 physics papers in 2023
  - Integrated the data from Belle and Belle II.
  - Unified the publication processes.

3. Physics Papers in 2023

CKM

$|V_{cb}|$ in $\bar{B}^0 \to D^{*+} l^- \bar{\nu}_l$
(PRD **108**, 092013)

$|V_{ub}|$ in $B \to X_u l \bar{\nu}_l$
(PRL **131**, 211801)

CP

$B^0 \to \phi K_S^0$
(PRD **108**, 072012)

$B^\pm \to DK^\pm$ and $D\pi^\pm$
(JHEP 09(2023)146)

$B^0 \to K_S^0 \pi^0$
(PRL **131**, 111803)

$B^0 \to \pi^0 \pi^0$
(PRD **107**, 112009)

$B^+ \to \pi^+ \pi^0 \pi^0$
(PRL **130**, 181804)

$D^0 \to K_S^0 K_S^0 \pi^+ \pi^-$
(PRD **107**, 052001)

Lepton Physics

Light-Lepton Universality

(PRL **131**, 181801 and PRL **131**, 051804)

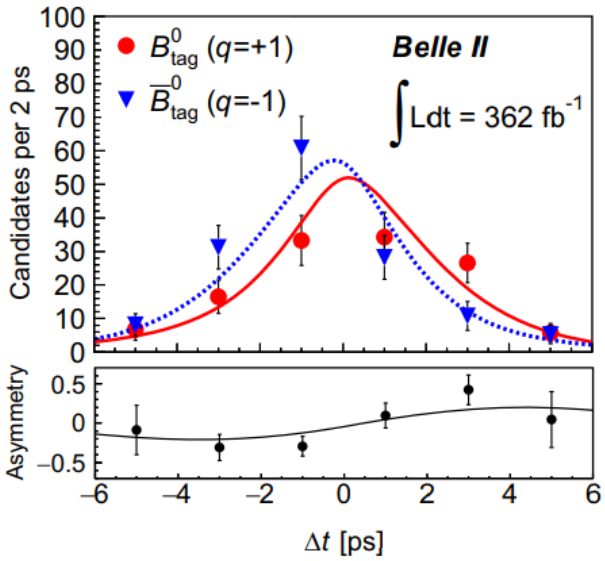
τ mass

(PRD **108**, 032006)

LFV

(PRL **130**, 181803, JHEP 06(2023)118, and PRL **130**, 261802)

CP in $B^0 \to K_S^0 \pi^0$



3. Physics Papers in 2023

Lifetime of Hadron

D_s^+ (PRL **131**, 171803)

B^0 (RRD **107**, L091102)

Ω_c^0 (PRD **107**, L031103)

Λ_c^+ (PRL **130**, 071802)

New Physics

Invisible Z'

(PRL **130**, 231801)

Dark Photon and Dark Higgs Boson

(PRL **130**, 071804)

$\tau^+\tau^-$ Resonance

(PRL **131**, 121802)

New Hadron

$\Upsilon(10753) \to \omega\chi_{bJ}$

(PRL 130, 091902)

New $\Lambda\pi^\pm$ peaks

(PRL 130, 151903)

A new excited charmed baryon

(PRL 130, 031901)

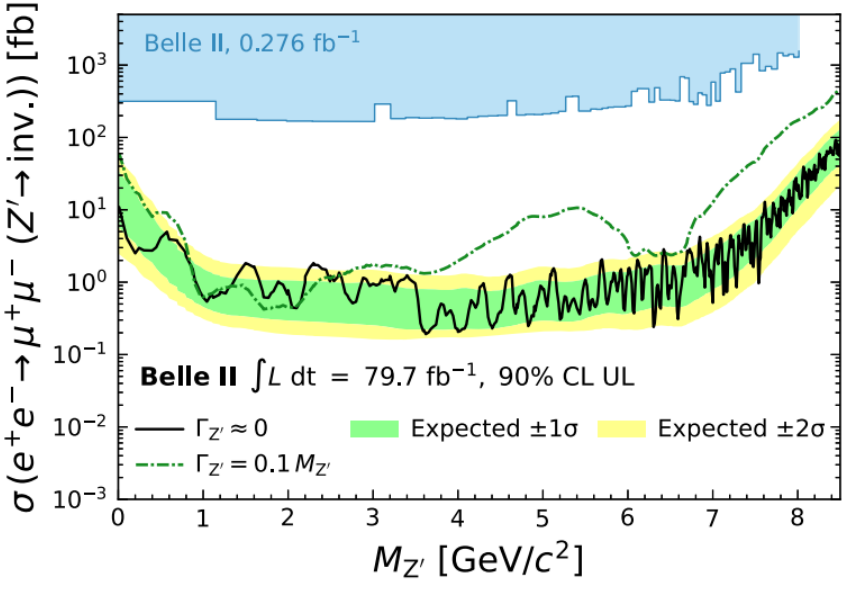
Double charmonium state

(JHEP 08(2023)121)

Threshold cusp

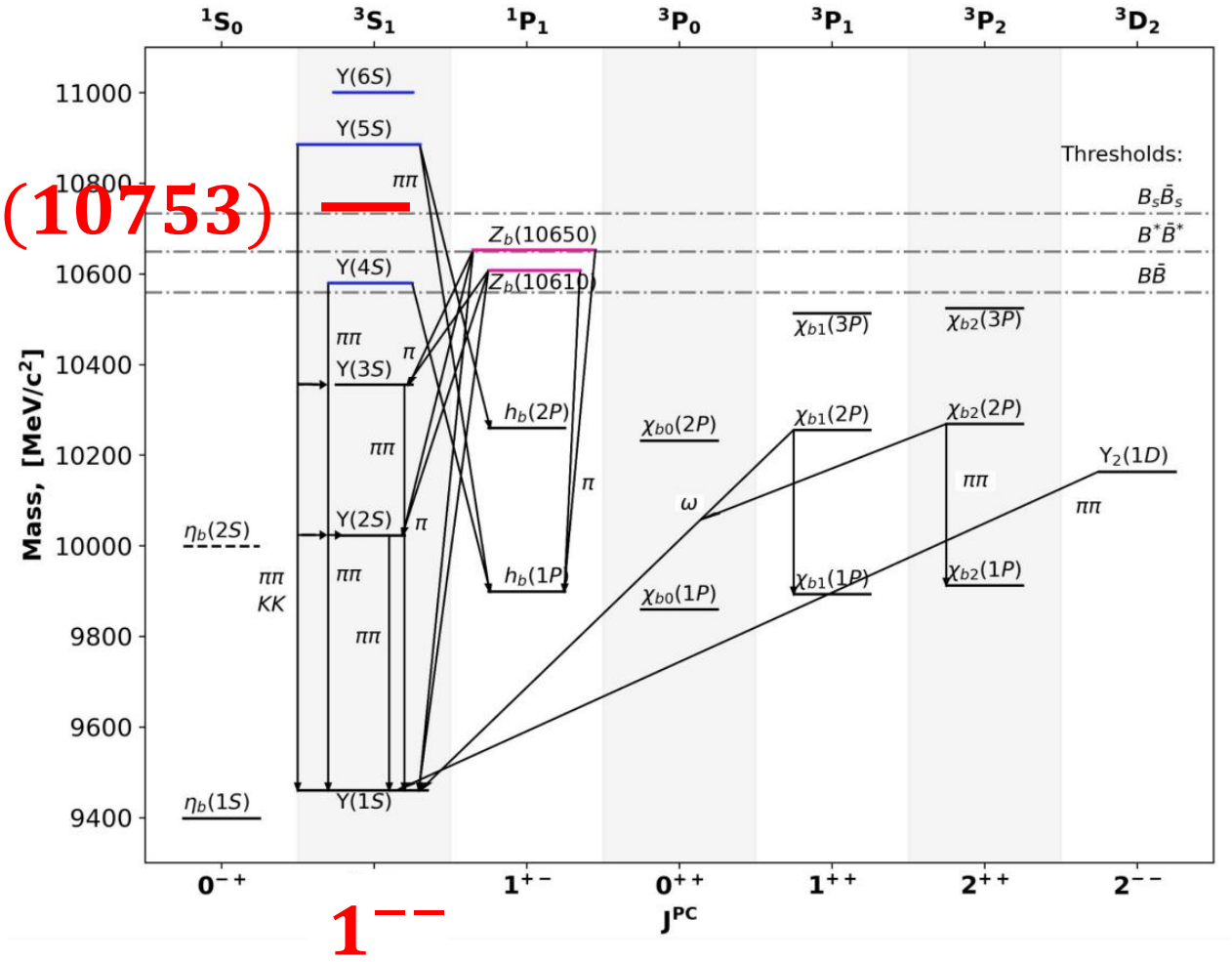
(PRD 108, L031104)

$\sigma(e^+e^- \to \mu^+\mu^- Z')$



3. $\Upsilon(10753) \to \omega\chi_{bJ}$

*PRL **130**, 091902

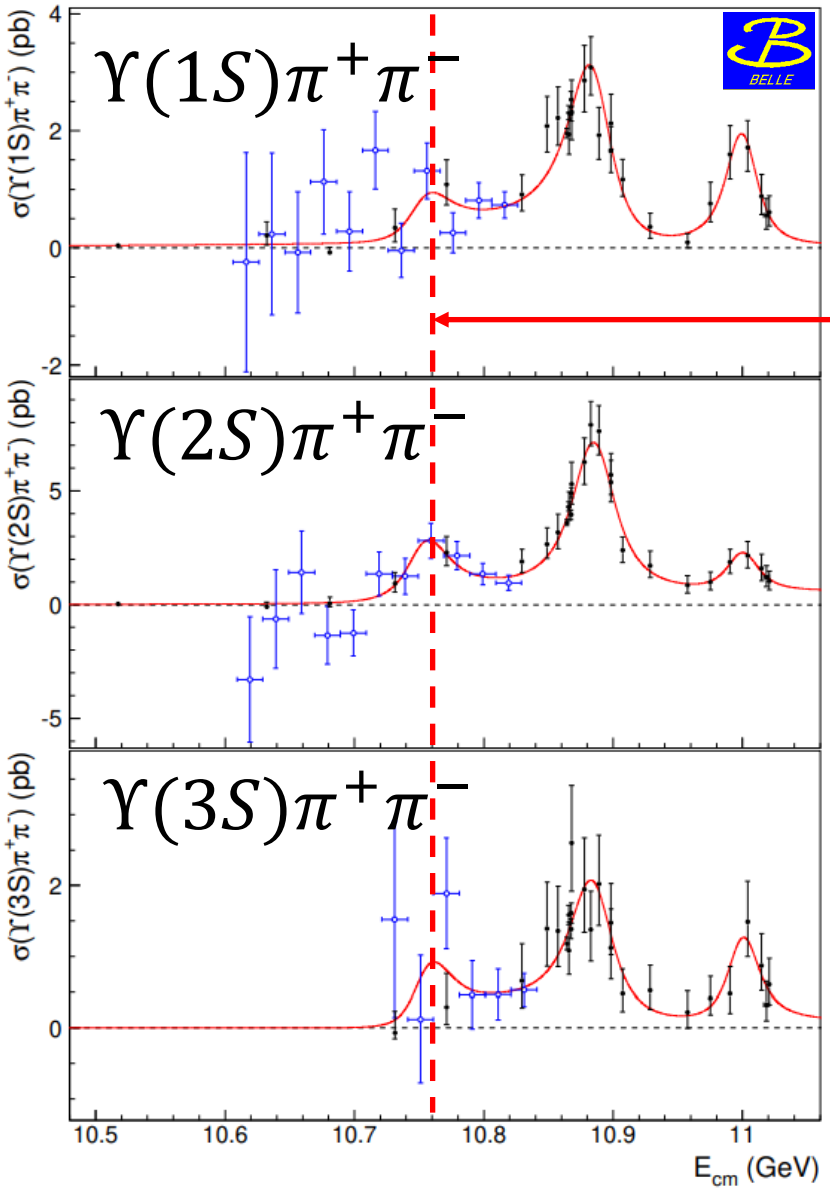


- Above $B\bar{B}$ threshold: unexpected properties are seen.

3. $\Upsilon(10753) \to \omega\chi_{bJ}$

*PRL **130**, 091902

- $e^+e^- \to \Upsilon(nS)\pi^+\pi^-$ cross sections in Belle

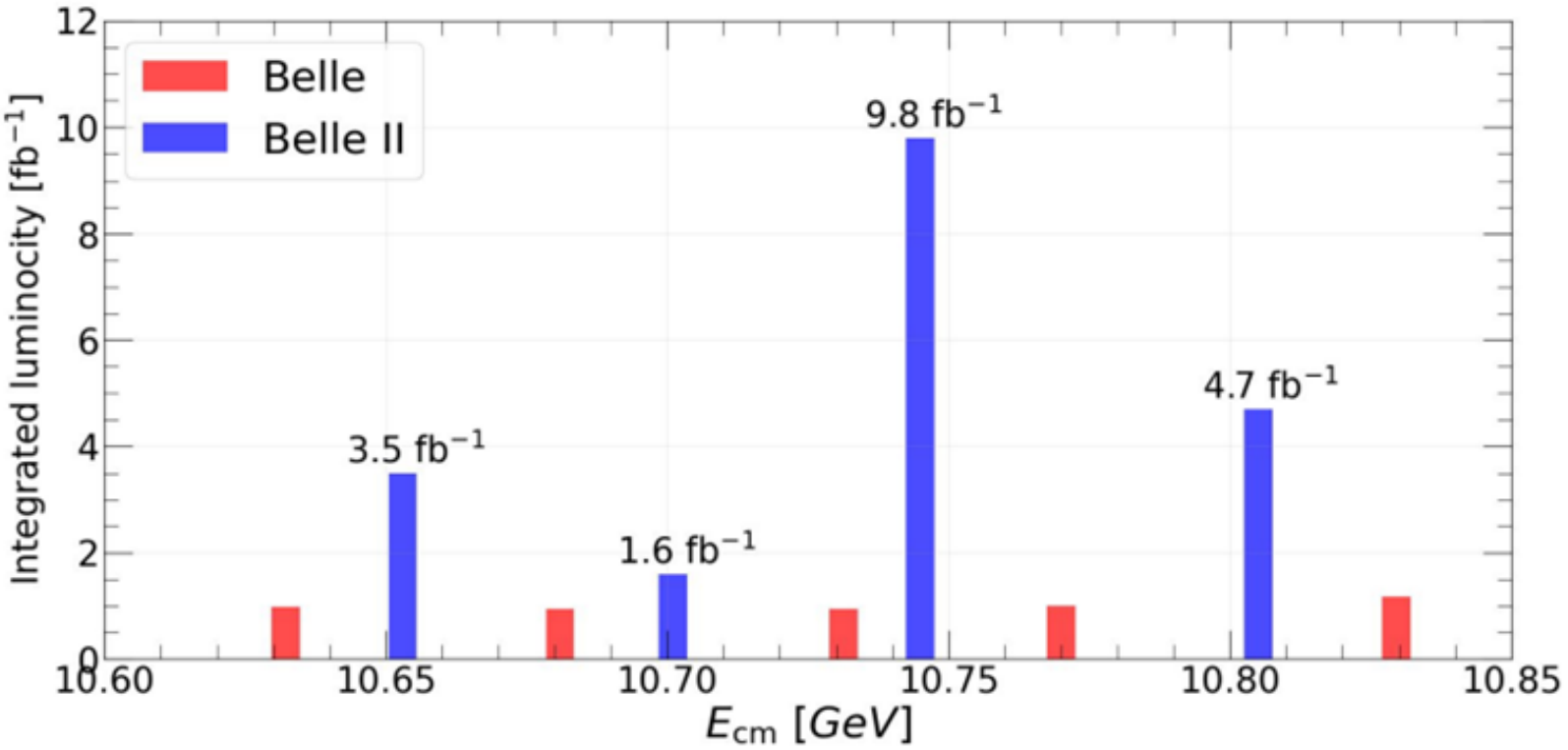


$\Upsilon(10753)$

*5.2σ significance

*JHEP **10** (2019) 220

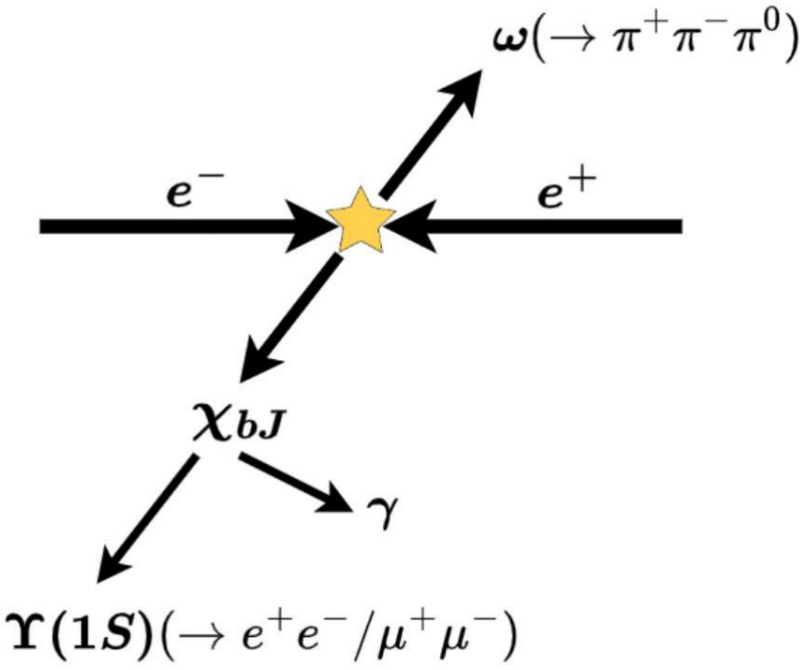
- In November 2021, Belle II collected unique energy scan data (19 fb^{-1}) around 10.75 GeV

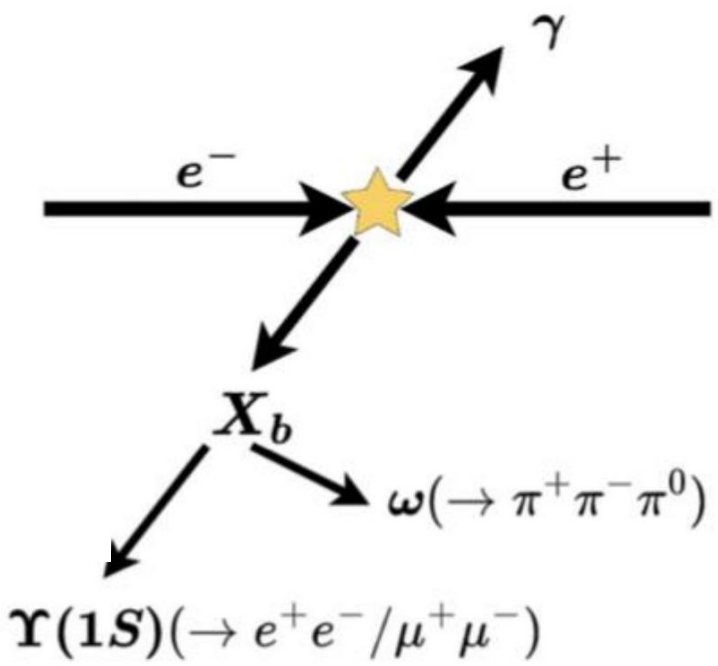


- $\boldsymbol{\Upsilon(10753)} \to \boldsymbol{\omega\chi_{bJ}}$ and $\boldsymbol{\gamma X_b}$
  - In charmonium, similar nature?

    $\boldsymbol{Y(4220)} \to \boldsymbol{\omega\chi_{c0}}$ and $\boldsymbol{\gamma X(3872)}$

    *BESIII, PRL 122, 232002 (2019) and PRD 99, 091103 (2019)





3. $\Upsilon(10753) \to \omega\chi_{bJ}$

*PRL **130**, 091902

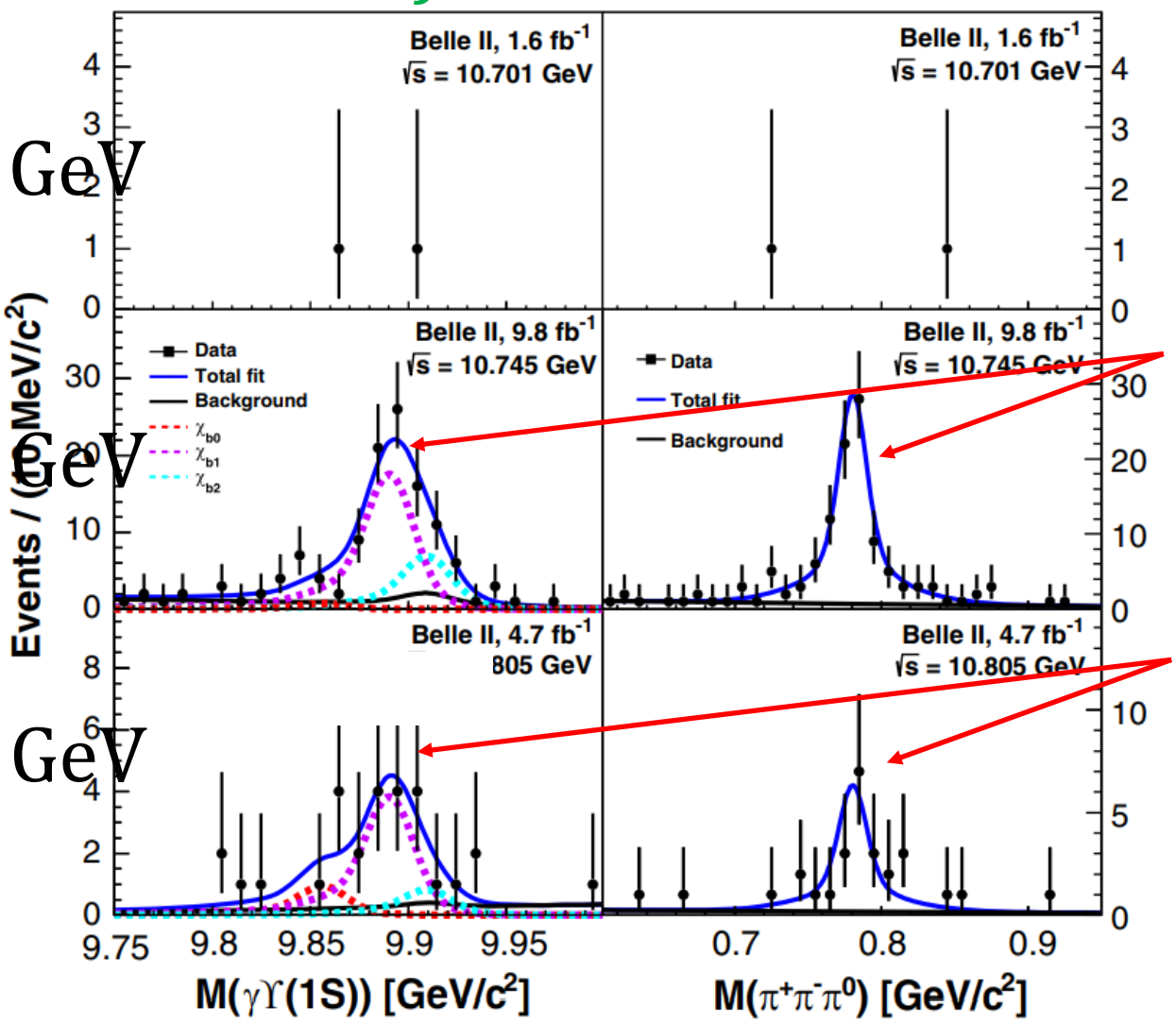
- 2D fit to $M(\gamma\Upsilon(1S))$ and $M(\pi^+\pi^-\pi^0)$ distributions

χ_{bJ} ω

10.701 GeV

10.745 GeV

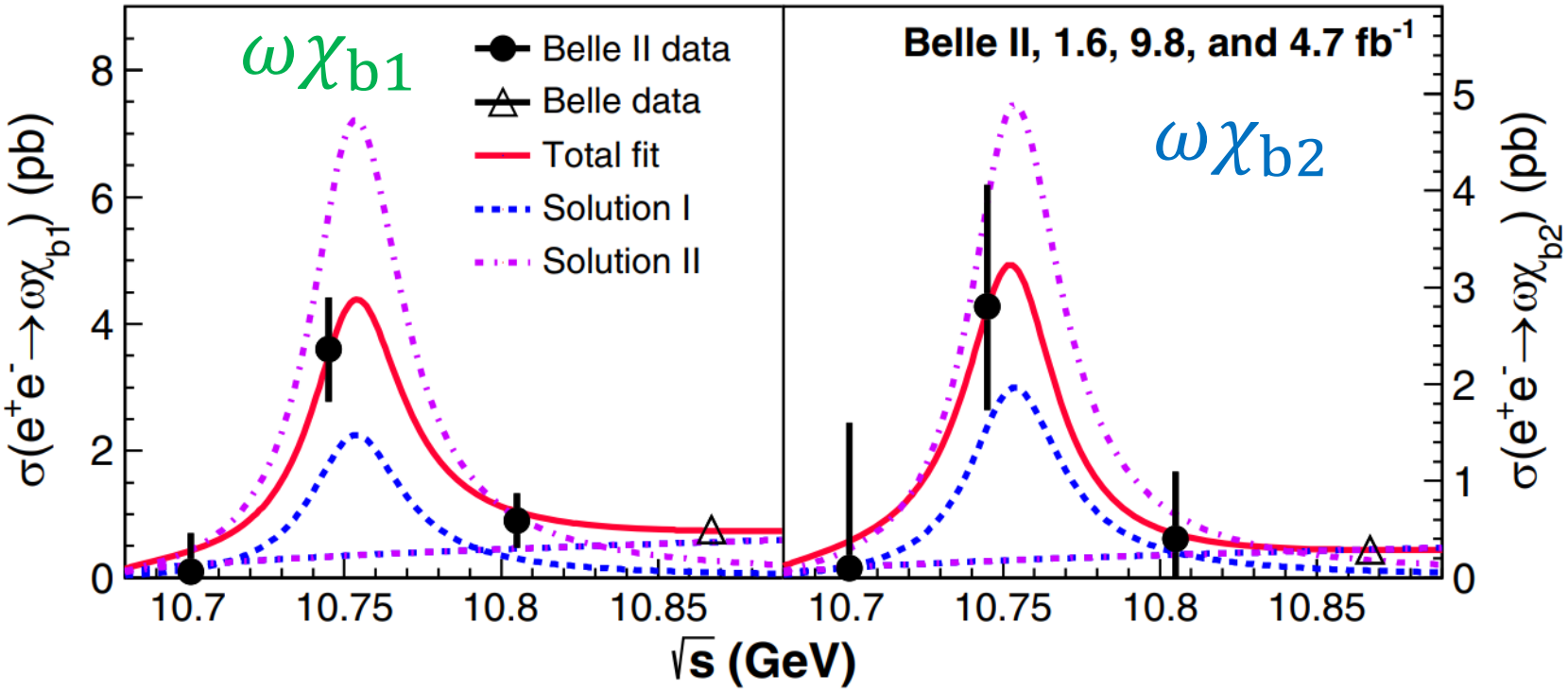
10.805 GeV



11.1σ

4.5σ

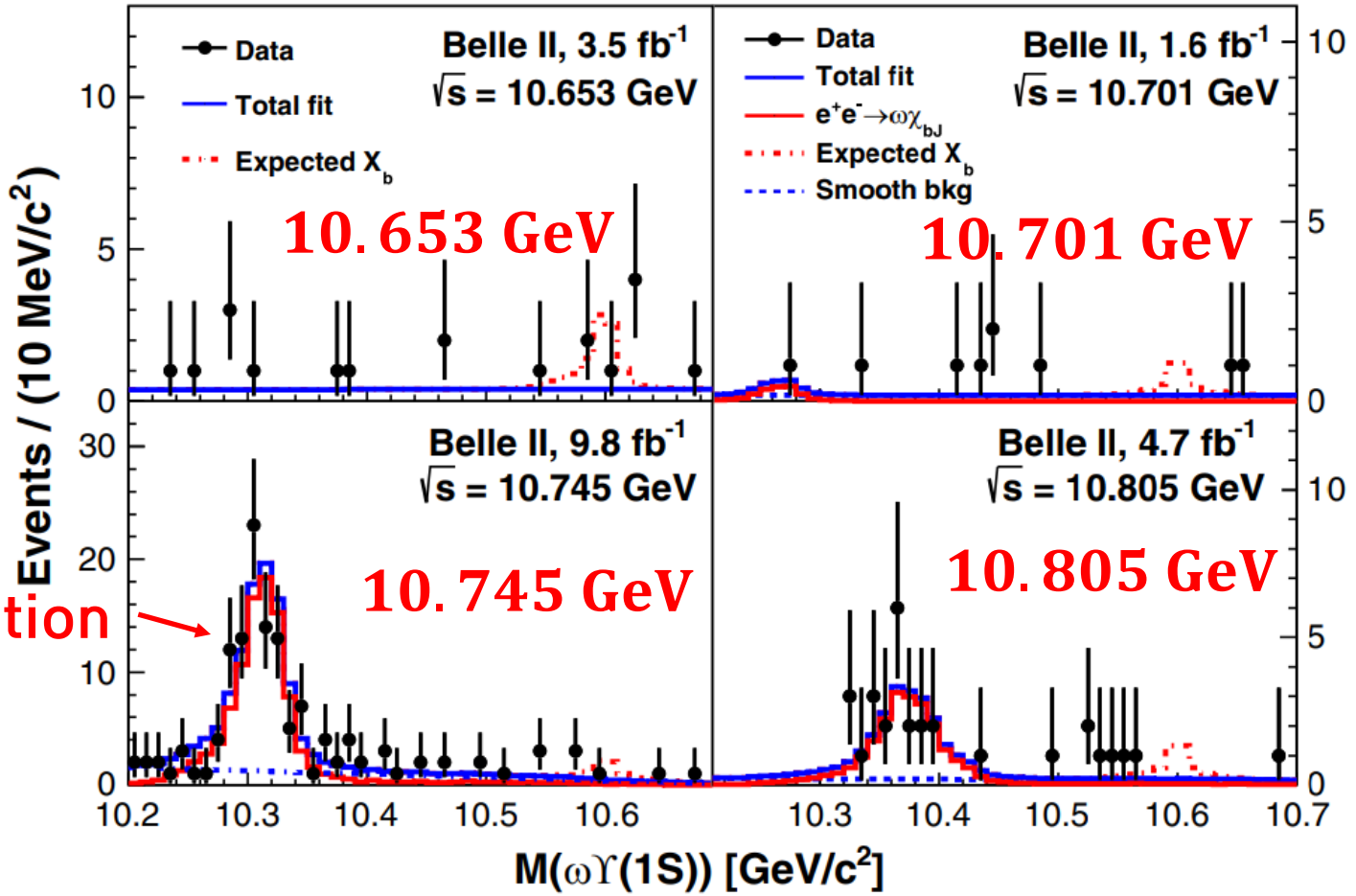
- Cross sections of $e^+e^- \to \omega\chi_{b1}$ and $\omega\chi_{b2}$



- $\frac{\sigma(e^+e^-\to\omega\chi_{bJ})}{\sigma(e^+e^-\to\Upsilon(nS)\pi^+\pi^-)} = \sim 1.5$ and $\frac{\sigma(e^+e^-\to\omega\chi_{b1}(1P))}{\sigma(e^+e^-\to\omega\chi_{b2}(1P))} = 1.3 \pm 0.6$

- Search for $\Upsilon(10753) \to \gamma X_b$

$$X_b \to \omega\Upsilon(1S)$$

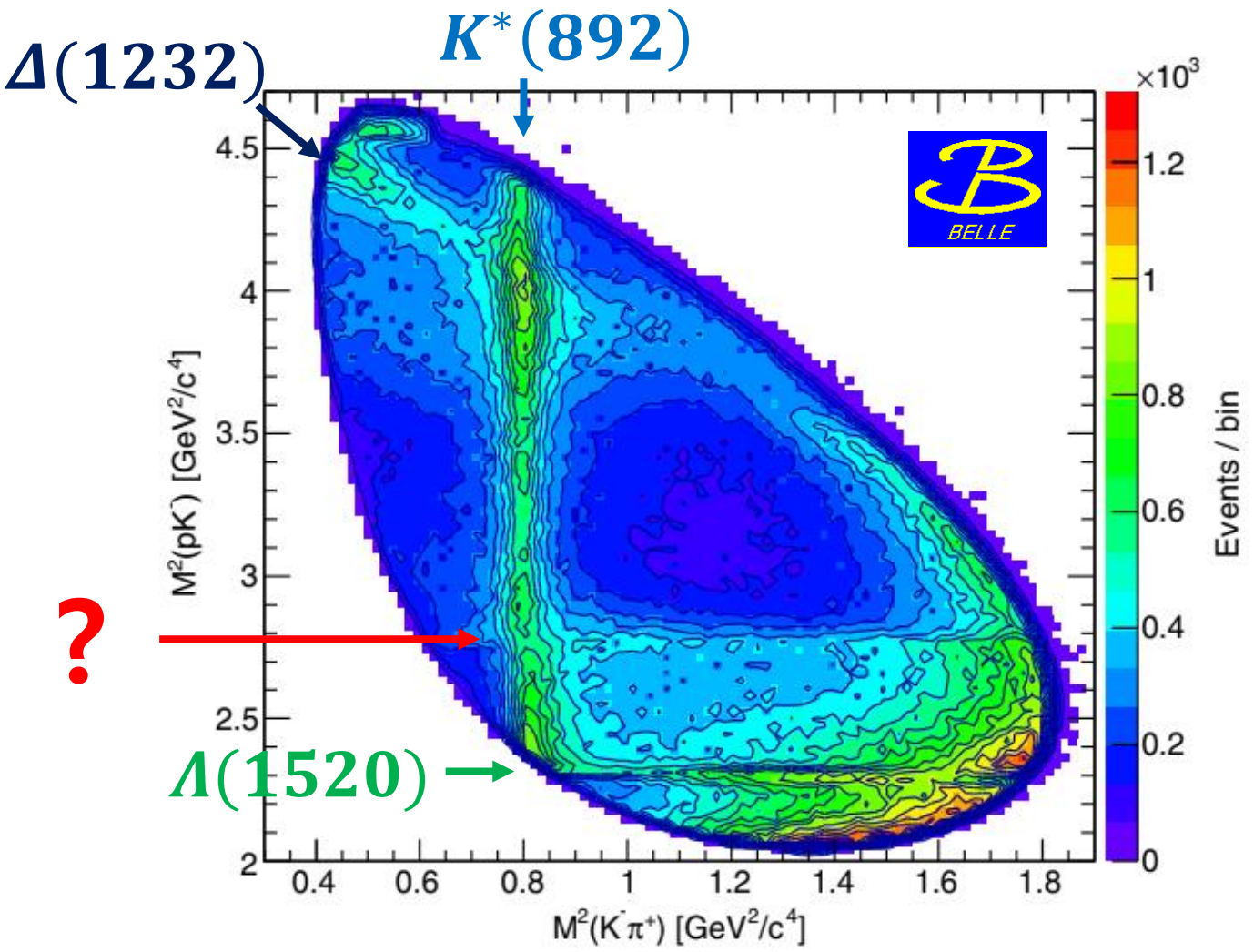


Reflection

→ No significant signal of X_b

* PRD **108**, L031104

- Dalitz plot of $\Lambda_c^+ \to pK^-\pi^+$,



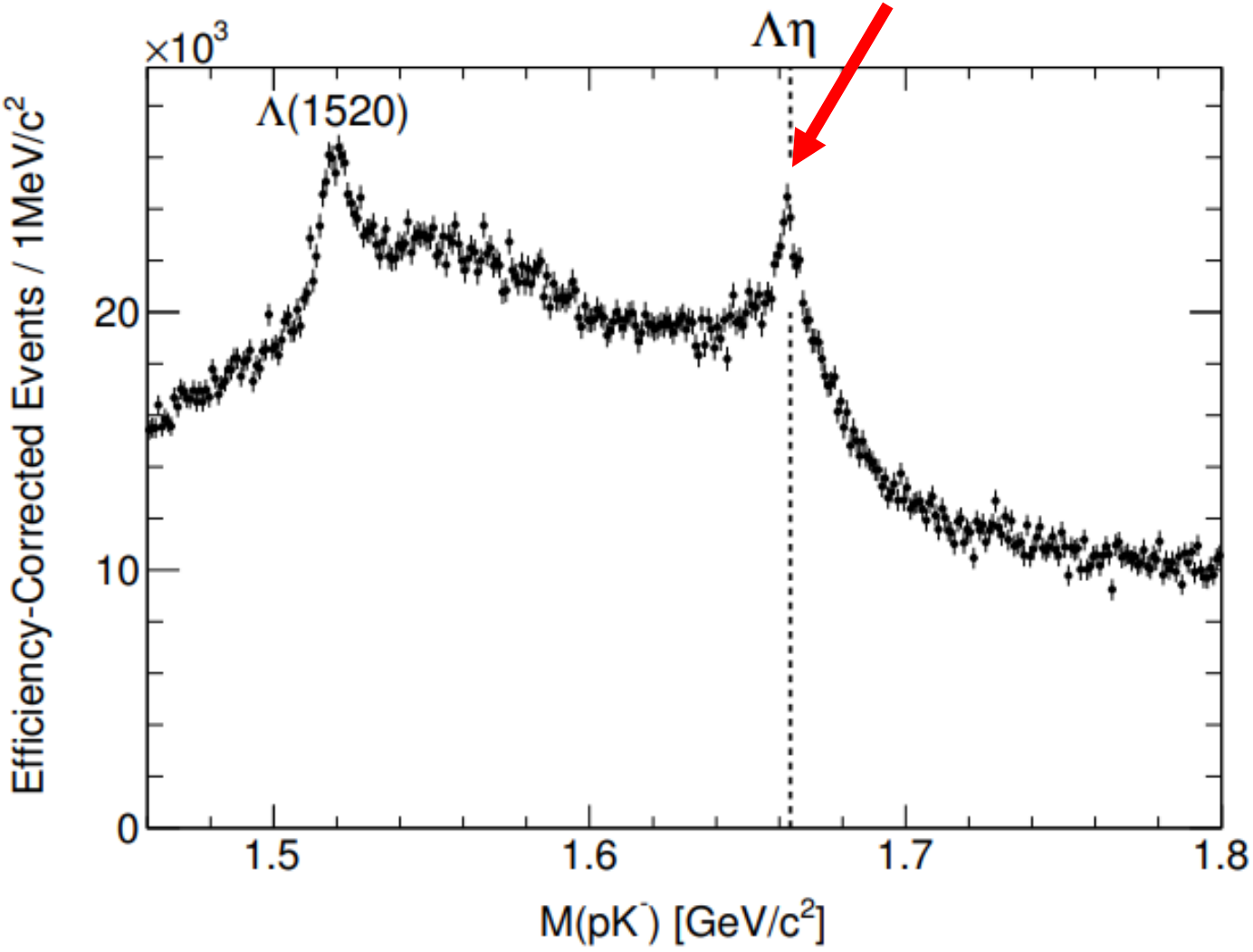
*PRL 117, 011801 (2016)

3. $\Lambda\eta$ Threshold Cusp

* PRD **108**, L031104

- $M(pK^-)$ distribution,

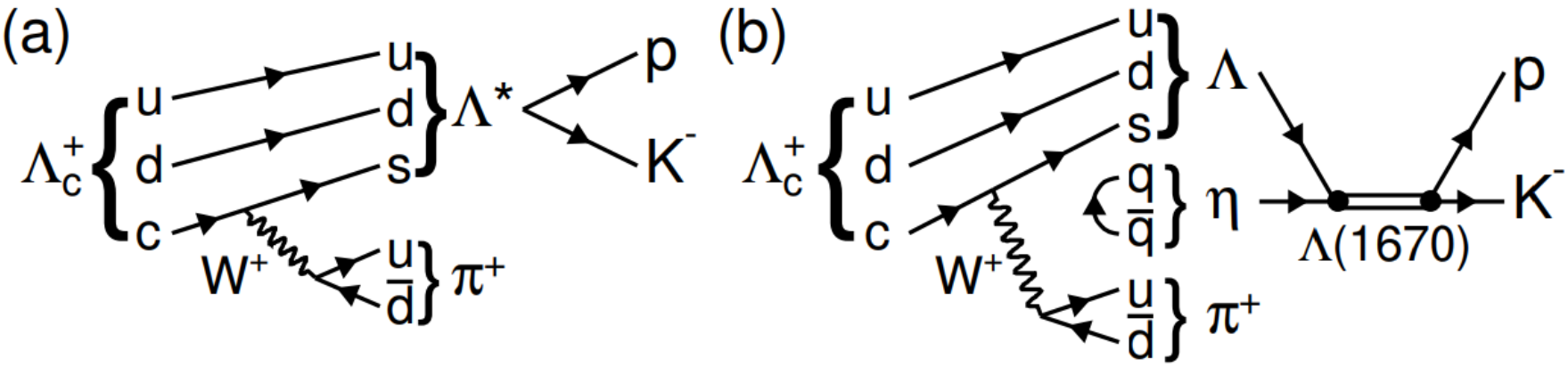
Narrower than $\Lambda(1520)$



3. $\Lambda\eta$ Threshold Cusp

* PRD **108**, L031104

- Two approaches to explain the narrow peaking structure.



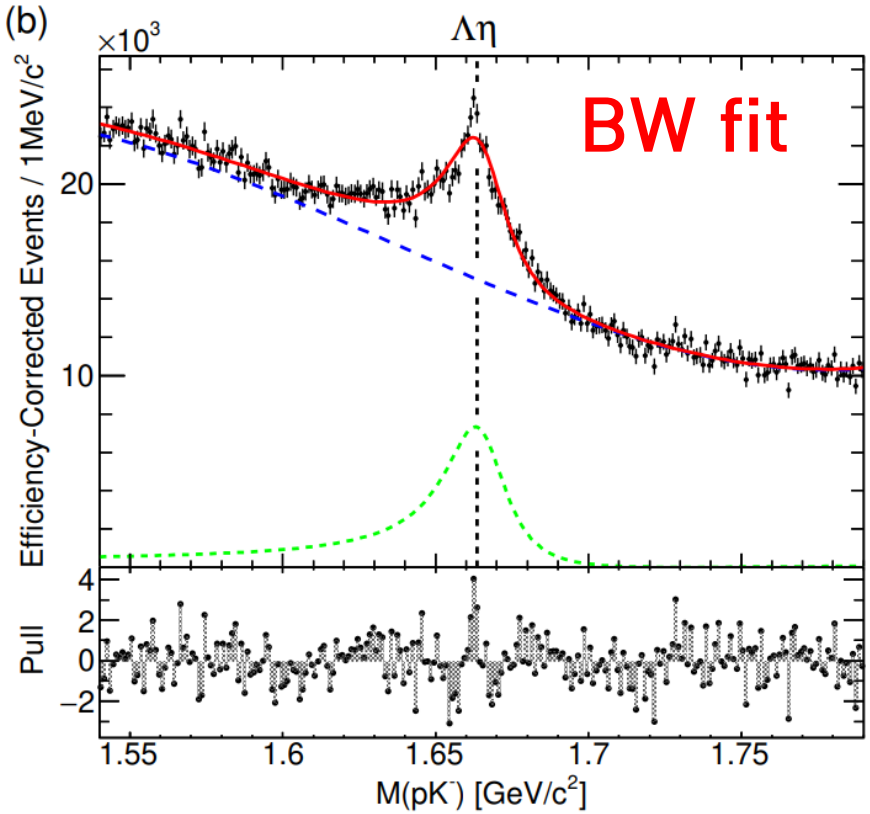
(a) Breit-Wigner function: a new resonance

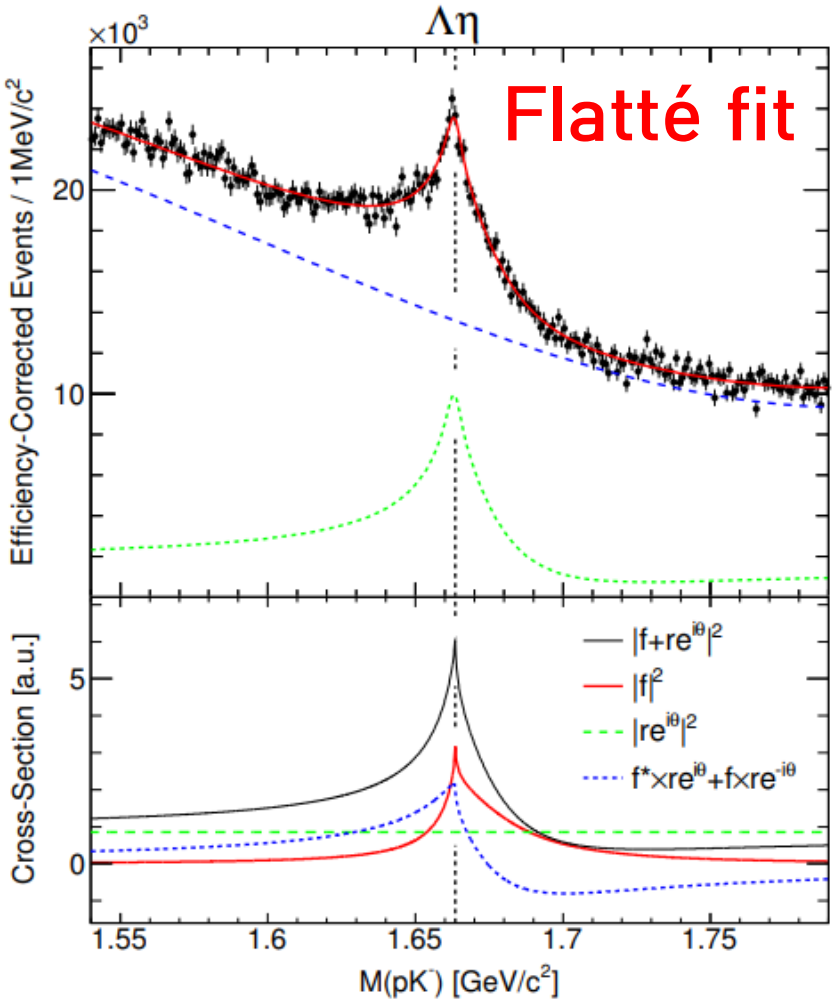
(b) Flatté function : a visible cusp enhanced by $\Lambda(1670)$ pole

3. $\Lambda\eta$ Threshold Cusp

* PRD 108, L031104

- One-dimensional fit results



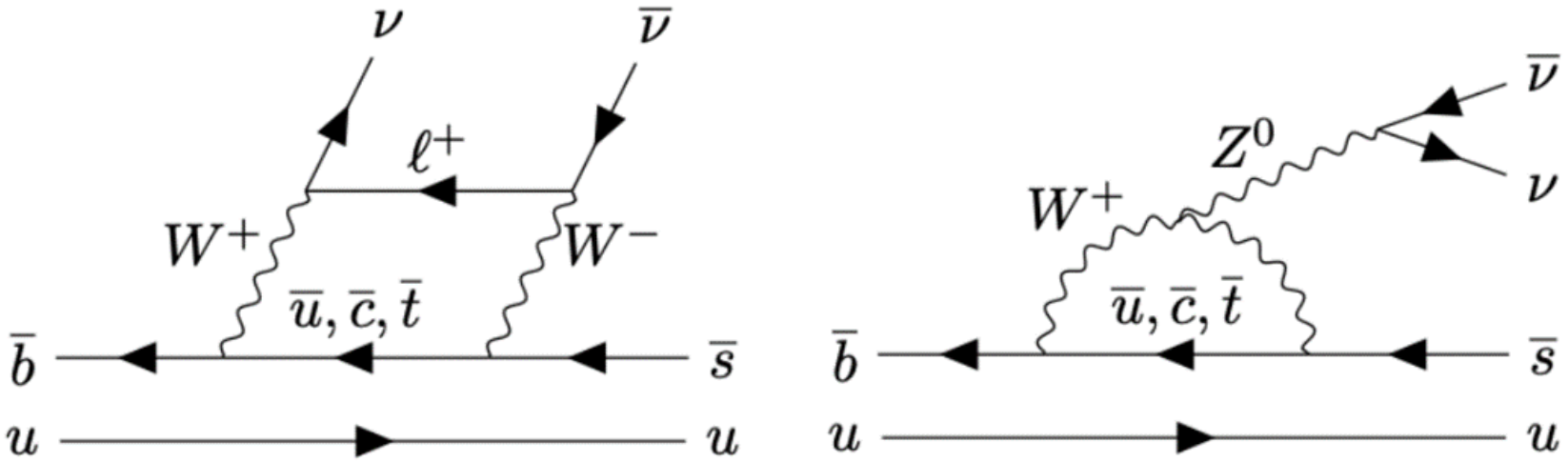


→ First observation of the specific structure of the threshold cusp

3. $\mathrm{B}(B^+ \to K^+ \nu\bar{\nu})$

* arXiv:2311.14647

*Diagrams for short distance contributions



- In the SM,

$$\mathrm{B}(B^+ \to K^+ \nu\bar{\nu}) = (5.0 \pm 0.4) \times 10^{-6}$$

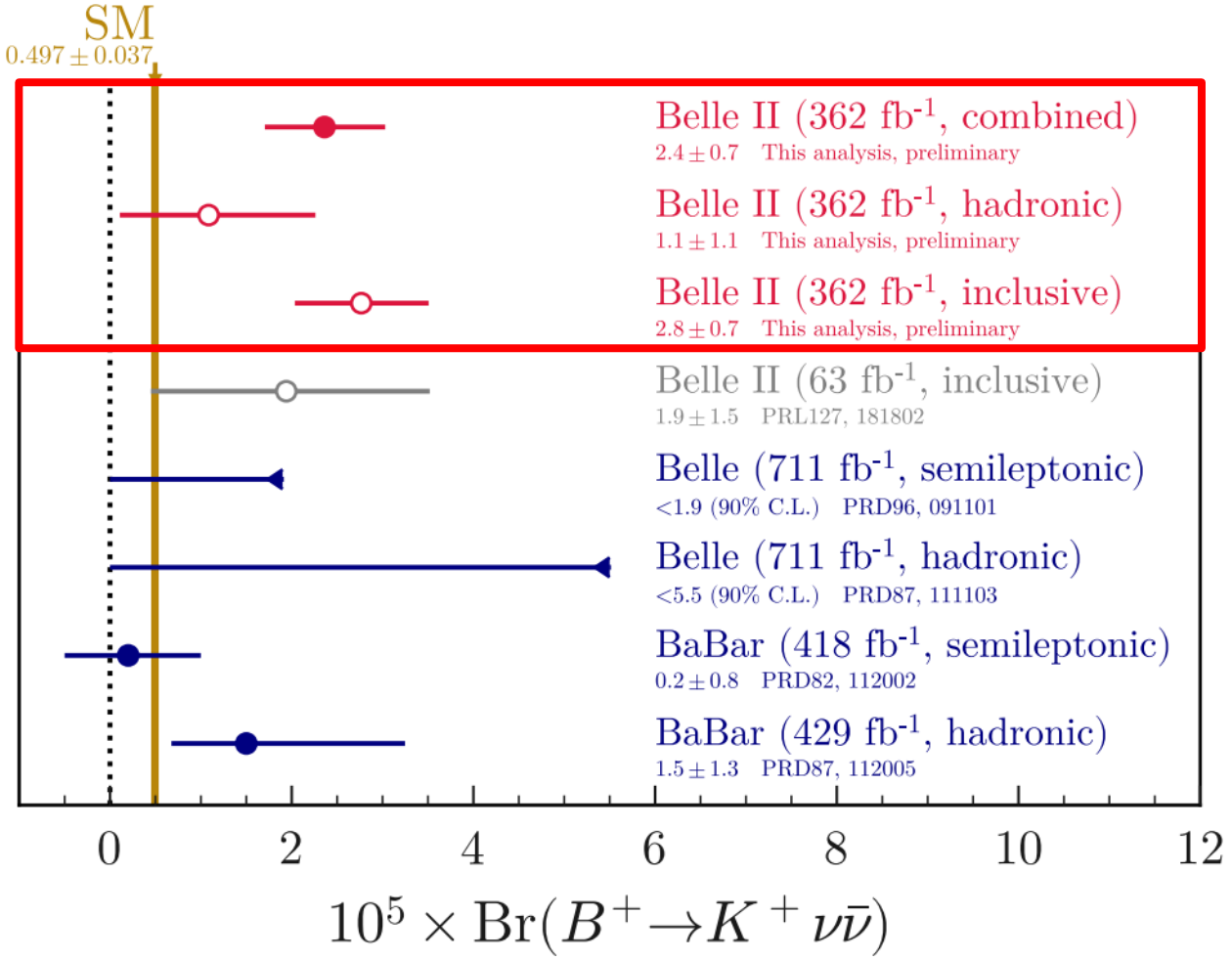
*only short distance contributions

*PRD 107, 119903 (2023)

- Good sample for testing SM. New physics?

3. $\mathrm{B}(B^+ \to K^+ \nu\bar{\nu})$

* arXiv:2311.14647



- $\mathrm{B}(B^+ \to K^+ \nu\bar{\nu}) = (2.4 \pm 0.5^{+0.5}_{-0.4}) \times 10^{-5}$
- 3.6σ significance and 2.8σ above SM

4. Summary

- Belle II: **the highest luminosity of e^+e^- collision + excellent detector system**
- In LS1 (2023), machine and detector upgraded for the next stage.
- Belle II will start **the next run in Jan. 2024**.
- Belle II has already reported various research findings in 2023.