1. Physics of B mesons

a gentle intro for kids

2. Studies of leptons and photons from B mesons
— a seminar for grown-ups

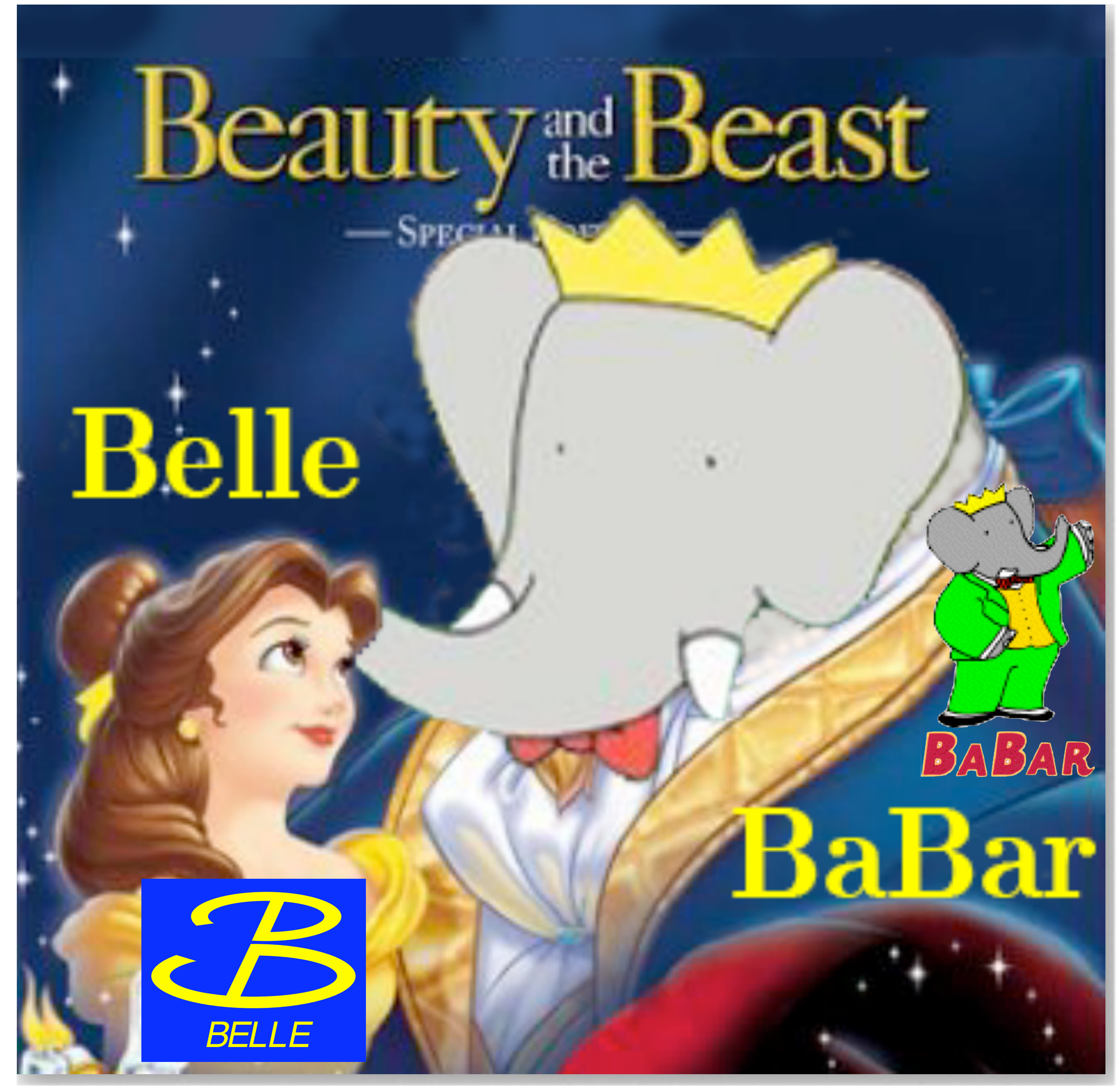
Youngjoon Kwon
Yonsei University

K-CMS Schoo, Dec. 14, 2021

Prologue

Once upon a time, there was a beauty (with her name Belle) and a beast (with his name BaBar).

And people called them the B-Factories...



The B-Factories (1st Gen.)

$$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ \boxed{b} \end{pmatrix}$$

Beauty and the B…

The forefathers ...

$$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$$

The B-Factories (now)

Outline

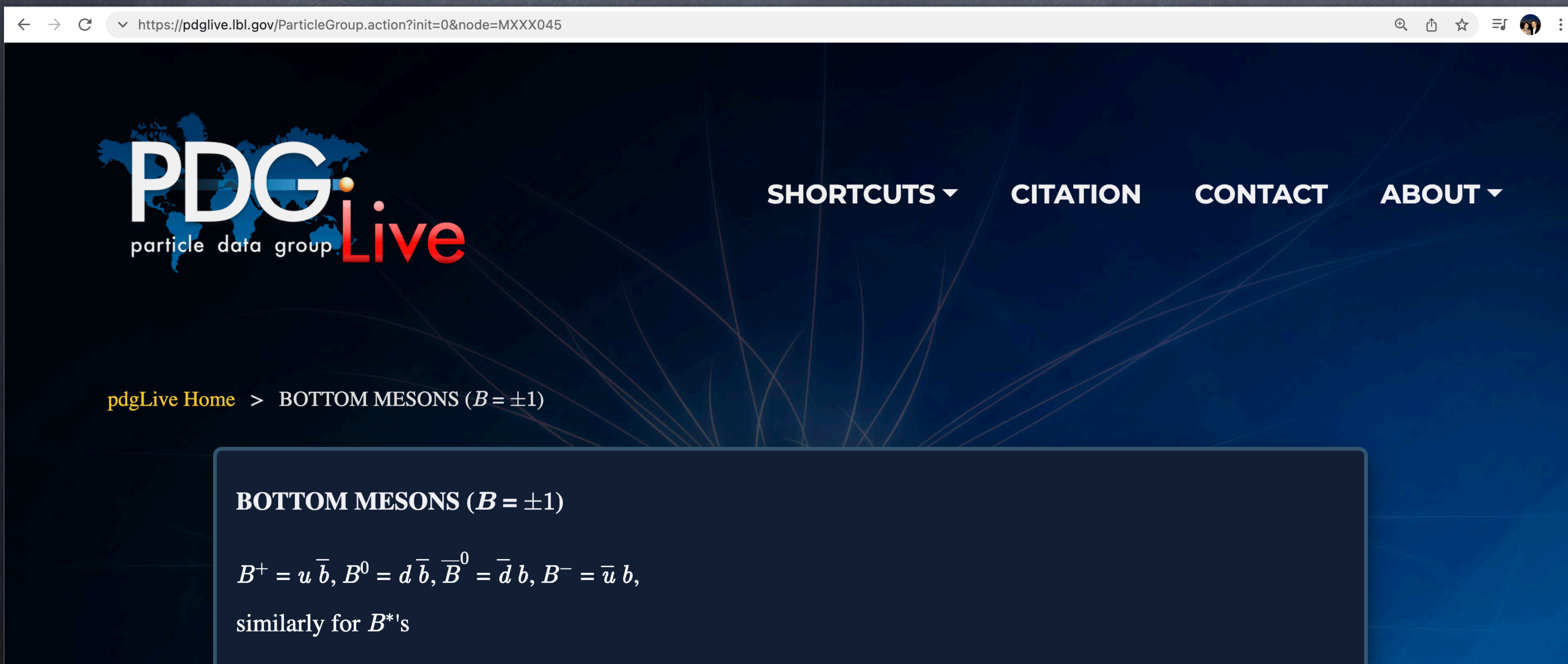
- Part 1, basic stuffs for kids
  - collider and luminosity
    Belle & Belle II
  - *age of endarkenment?*

- Part 2, for the grown-ups
  - Probing the dark world with Belle & Belle II
    - ✓ dark photon and dark Higgs
    - ✓ CP-odd Higgs
    - ✓ dark sector via B decays
    - ✓ Z' of $L_\mu - L_\tau$
    - ✓ axion-like particles

What is B? Why B?

- b: a lighter member of the 3rd generation quark doublet (proposed by K & M, 1973)
- B: a meson containing b and a light quark

$$\begin{bmatrix} u \\ d' \end{bmatrix} \begin{bmatrix} c \\ s' \end{bmatrix} \begin{bmatrix} t \\ b' \end{bmatrix}$$



What is B? Why B?

- b: a lighter member of the 3rd generation quark doublet (proposed by K & M, 1973)
- B: a meson containing b and a light quark

$$\begin{bmatrix} u \\ d' \end{bmatrix} \begin{bmatrix} c \\ s' \end{bmatrix} \begin{bmatrix} t \\ b' \end{bmatrix}$$

Quiz

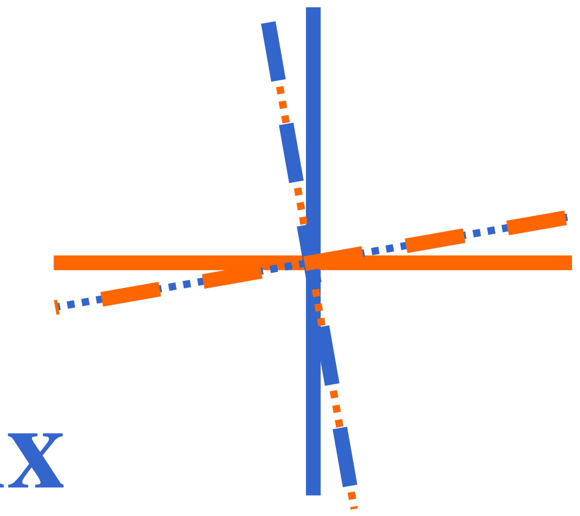
level: ☆

- Why {d′, s′, b′}, not {d, s, b}?

$$\begin{bmatrix} u \\ d' \end{bmatrix} \begin{bmatrix} c \\ s' \end{bmatrix} \begin{bmatrix} t \\ b' \end{bmatrix}$$

Flavor mixing and CKM matrix

- For quarks,
  - weak interaction eigenstates ≠ mass eigenstates
  - mixing of quark flavors through a **unitary matrix**



$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \left(V_{CKM} \right) \begin{pmatrix} d \\ s \\ b \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Wolfenstein parametrization

$$V_{CKM} \approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

$|\lambda| \approx O(0.1)$

3 real parameters (λ, A, ρ) and 1 phase (η)

What is B? Why B?

- b: a lighter member of the 3rd generation quark doublet (proposed by K & M, 1973)
- B: a meson containing b and a light quark
- decays via gen.-changing processes

  mostly via b –> c

  rarely, b –> s(d), u

$$\begin{bmatrix} u \\ d' \end{bmatrix} \begin{bmatrix} c \\ s' \end{bmatrix} \begin{bmatrix} t \\ b' \end{bmatrix}$$

- long life-time

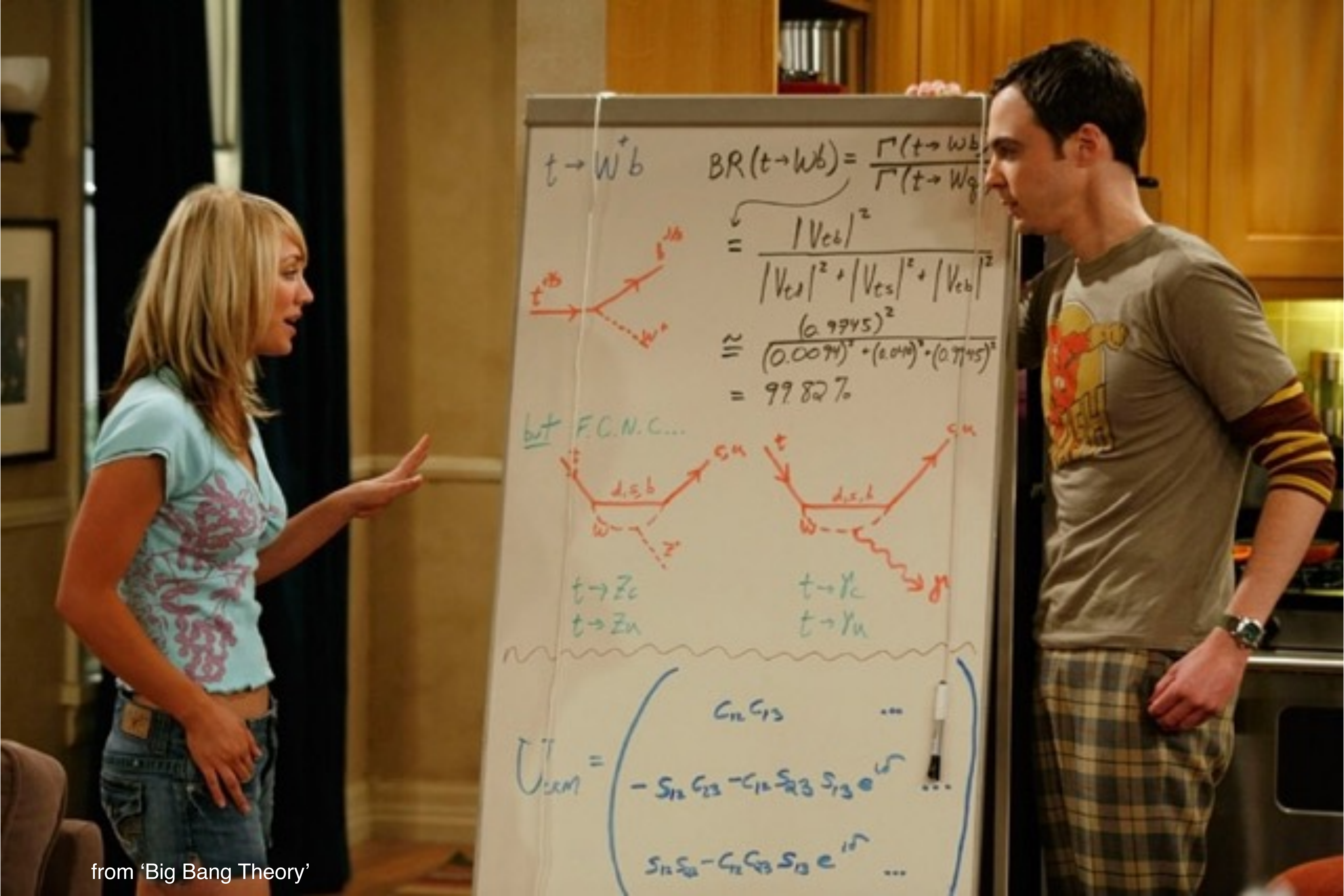
–> many interesting things can happen, and be studied!

What can we do with B?

- CP violation
  - KM mechanism explains CP violation w/in SM
  - in particular, in B decays

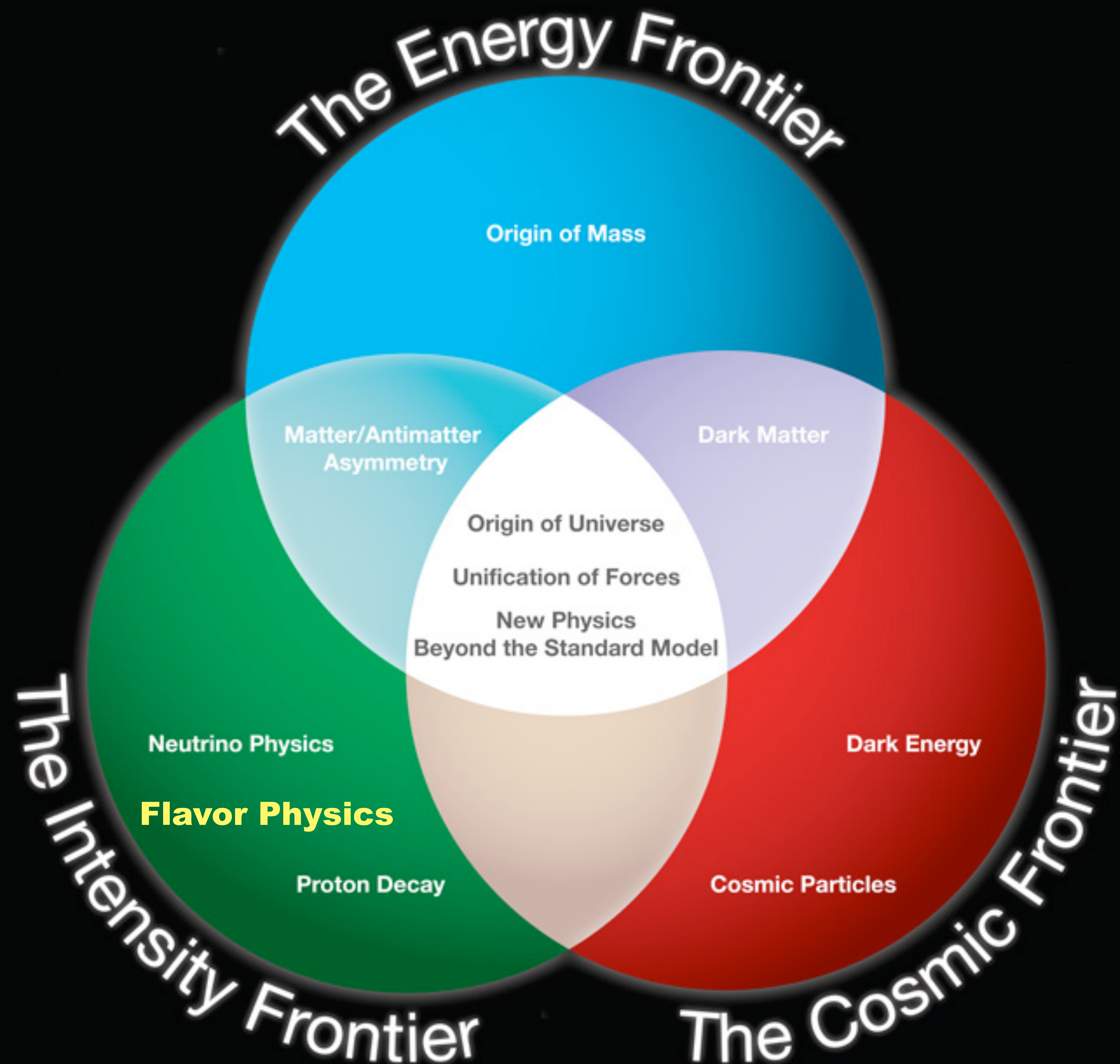
    --> ***Test the internal consistency of the KM mechanism in the CKM U.T.***

- Search for rare/forbidden decays
  - for a precision test of the SM; and
  - ***indirect search for PBSM***

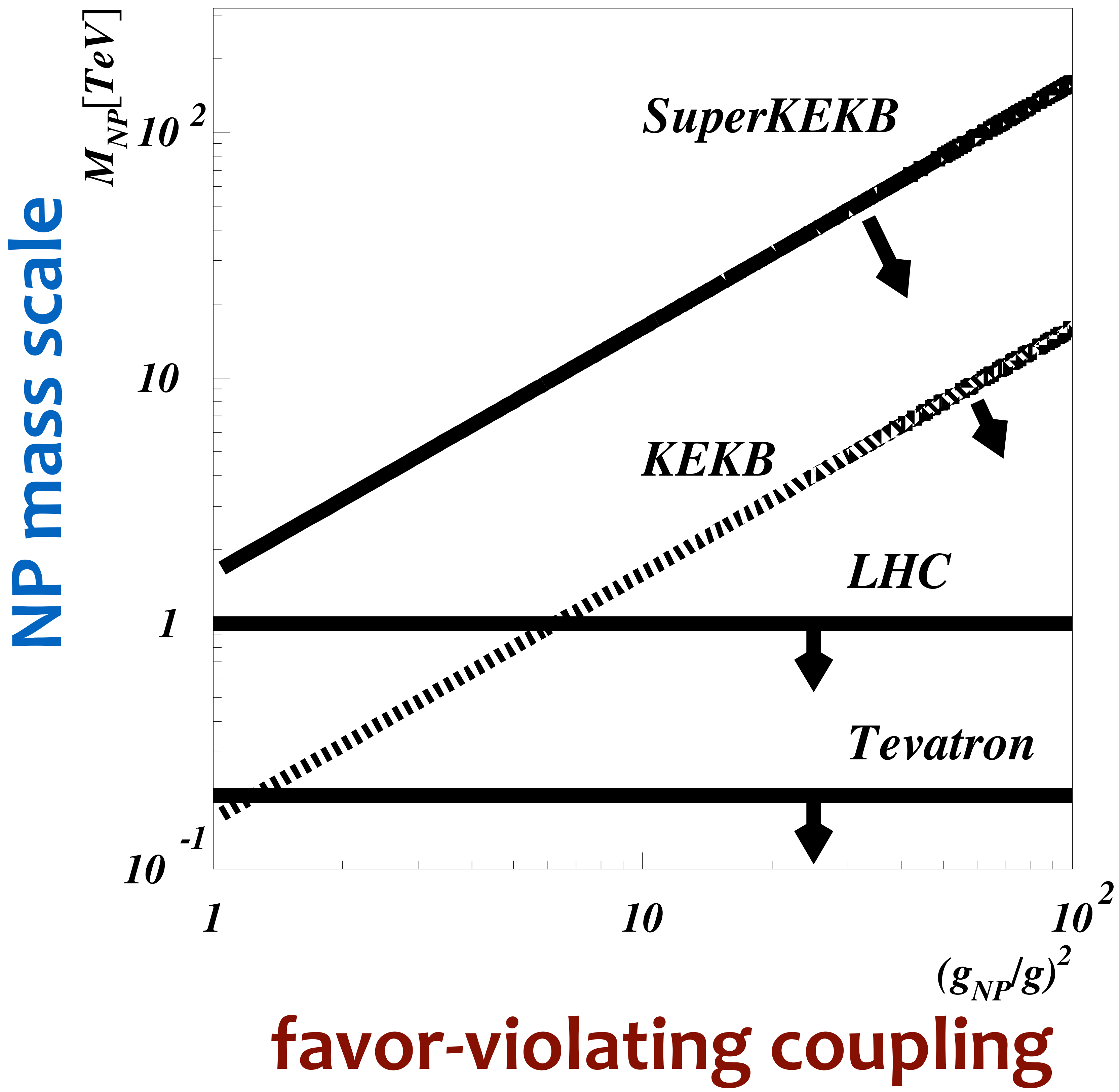


from ‘Big Bang Theory’

The three frontiers

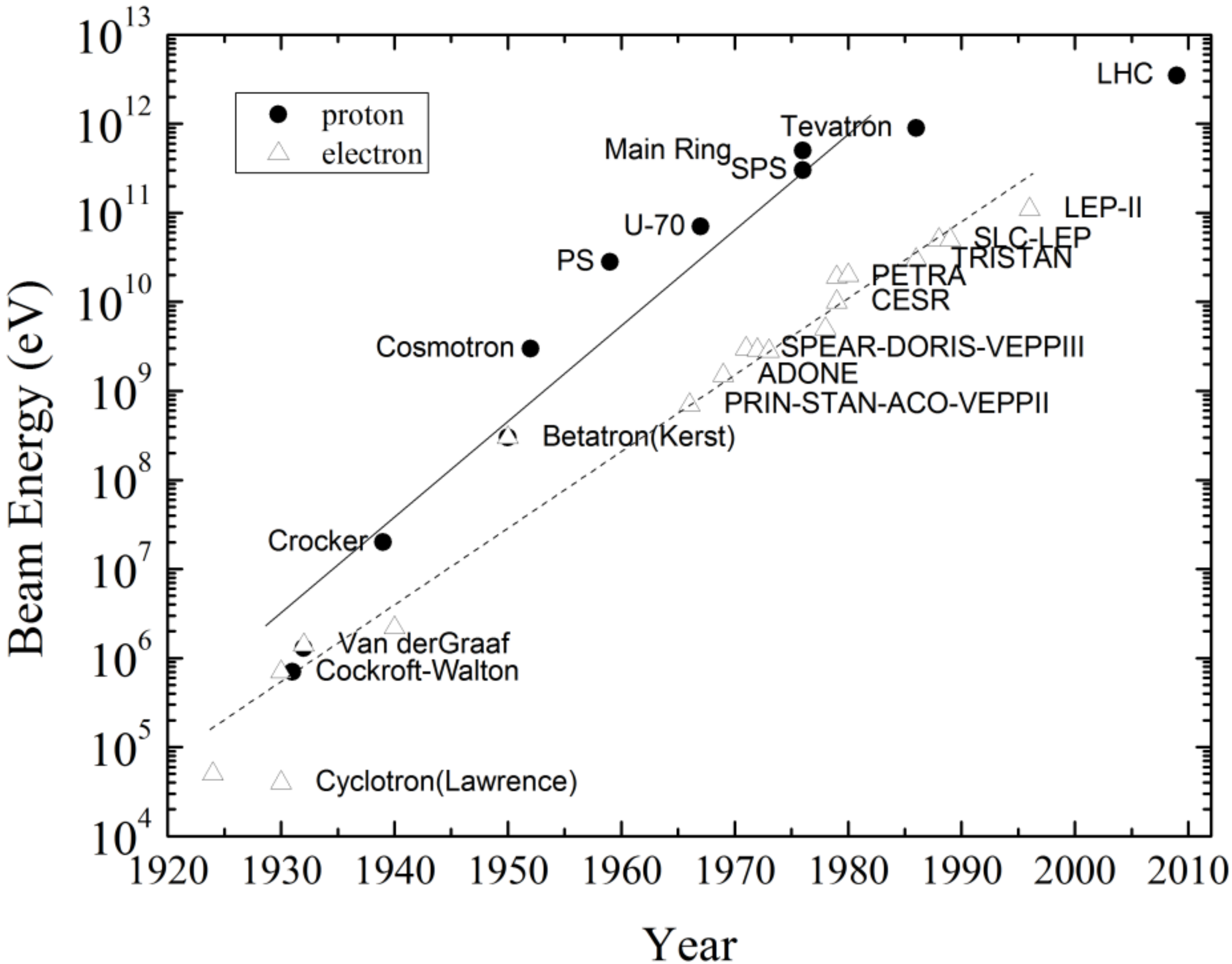


Energy vs. Intensity Frontiers

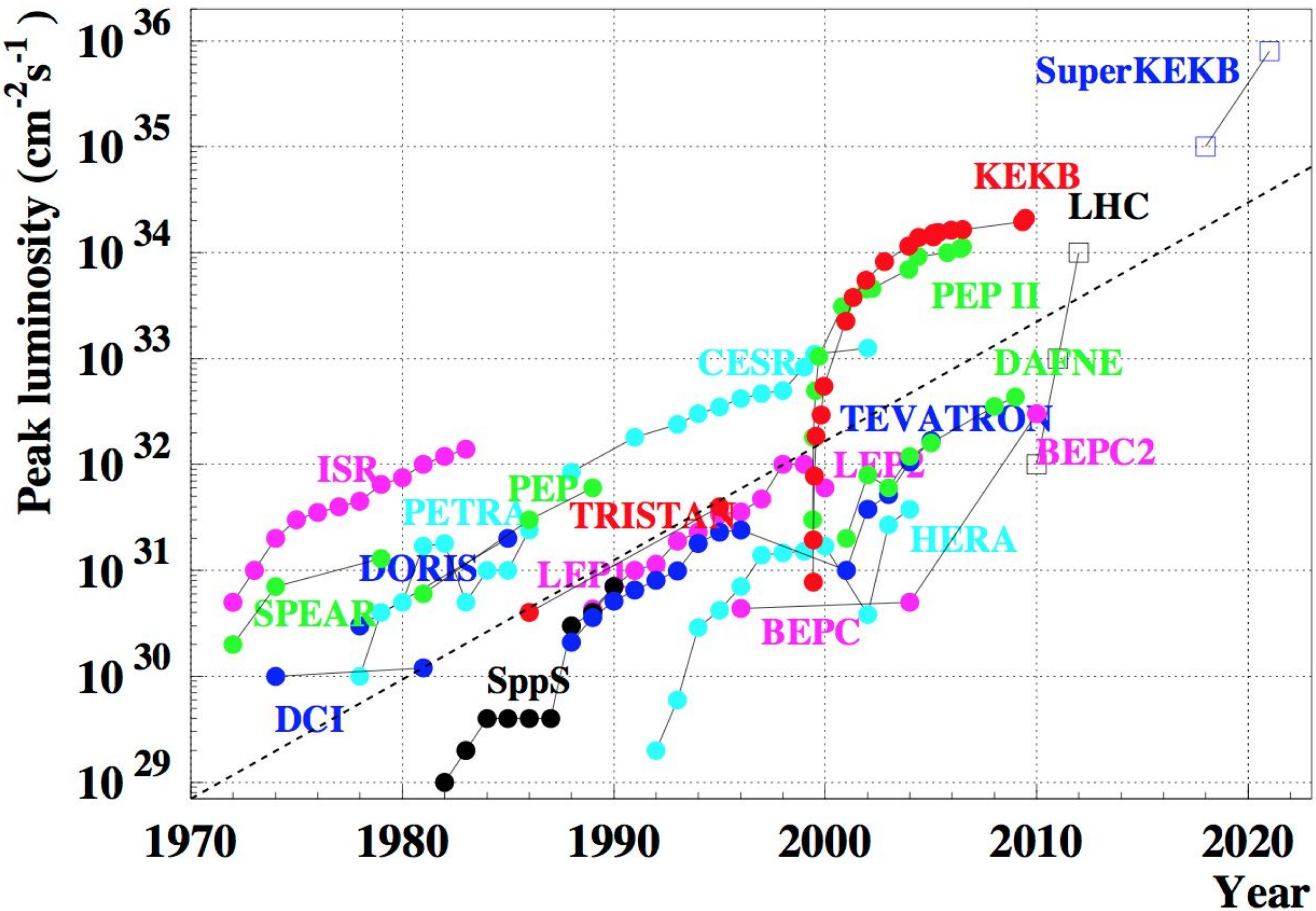


- Intensity Frontier is **complementary** to the Energy Frontier
- If LHC finds NP
  - * precision flavor input is essential to further clarify those discoveries
- Even if no new NP is found
  - * high-statistics flavor sector measurements (on b, c, and τ) can provide beyond-TeV-scale probe for NP

The Energy Frontier



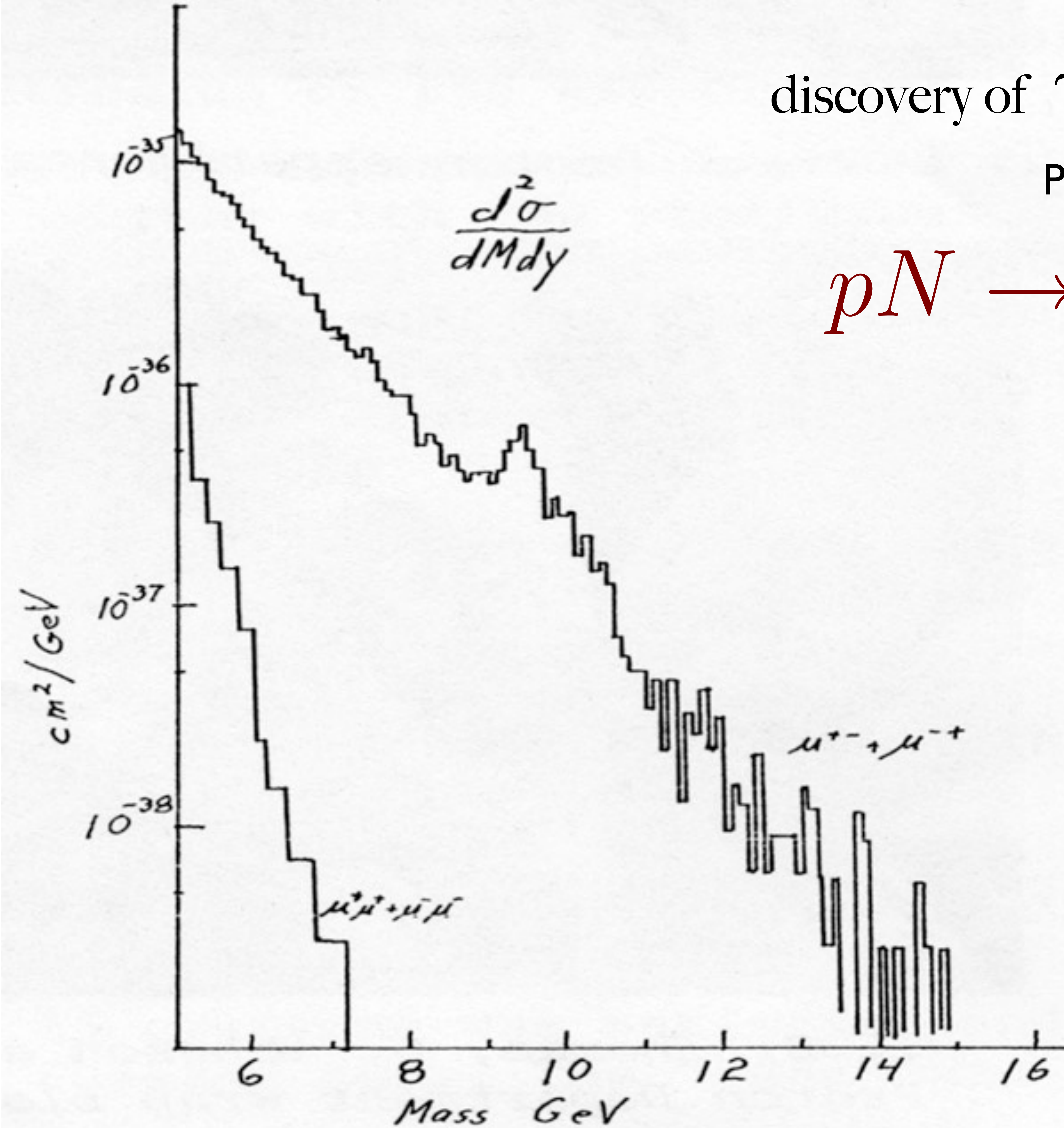
The Luminosity ("intensity") Frontier



How to study *B*?

- making *B*'s at hadron colliders (e.g. LHCb)
  - huge number of *B* mesons are produced, but
  - no info. on p_B^μ, unless you actually reconstruct the *B* meson
    $\Rightarrow$ will be of little use for modes with invisible particle(s)

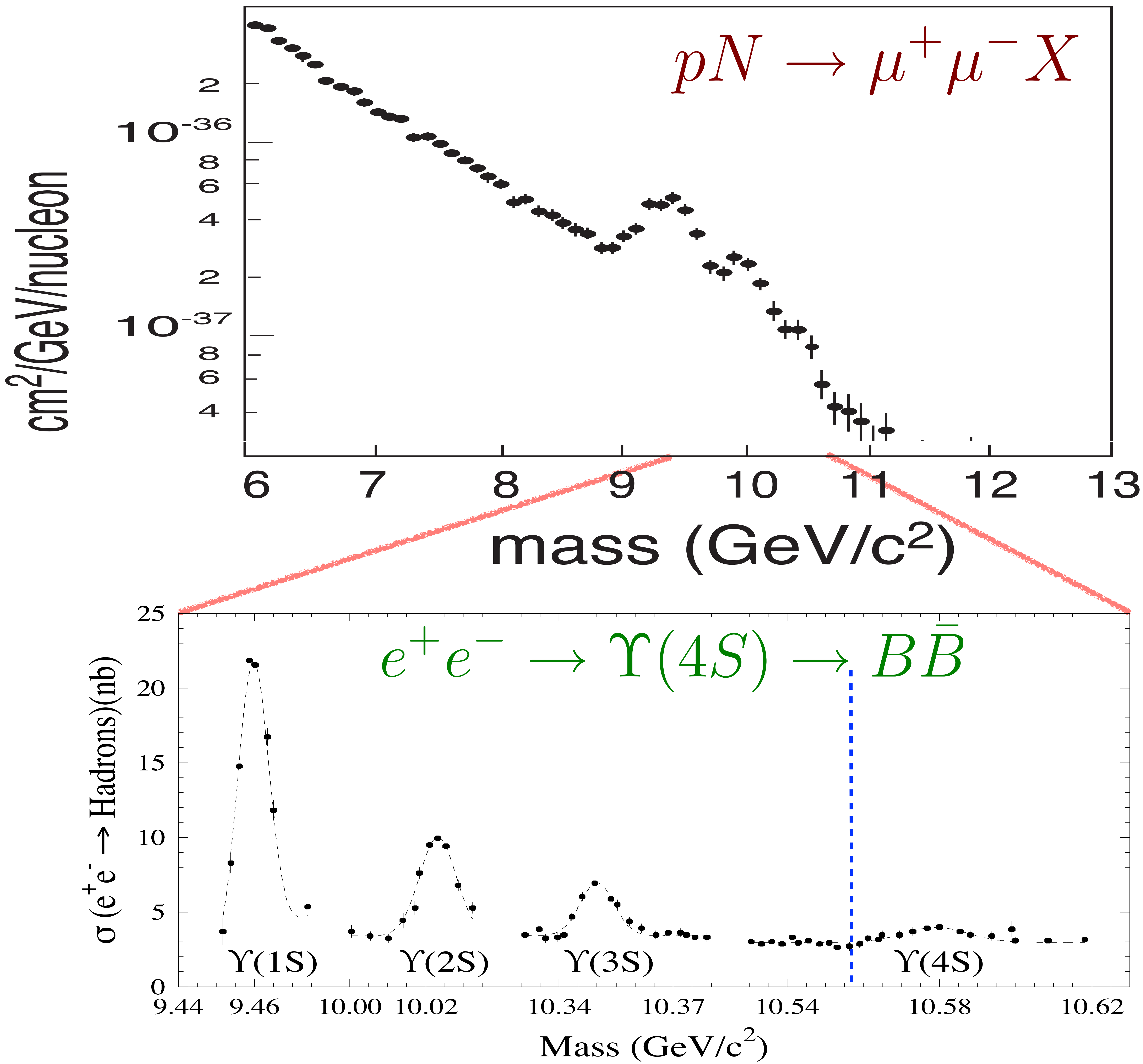
- making *B*'s at e^+e^- colliders with $\sqrt{s} = m(\Upsilon(4S))$
  - a moderate number of *B* mesons are produced
  - $E_B = \sqrt{s}/2 \ \sim 5.29$ GeV ; $|\vec{p}_B| \sim 0.35$ GeV/c
  - but.. direction of $\vec{p}_B$?



discovery of Υ resonances

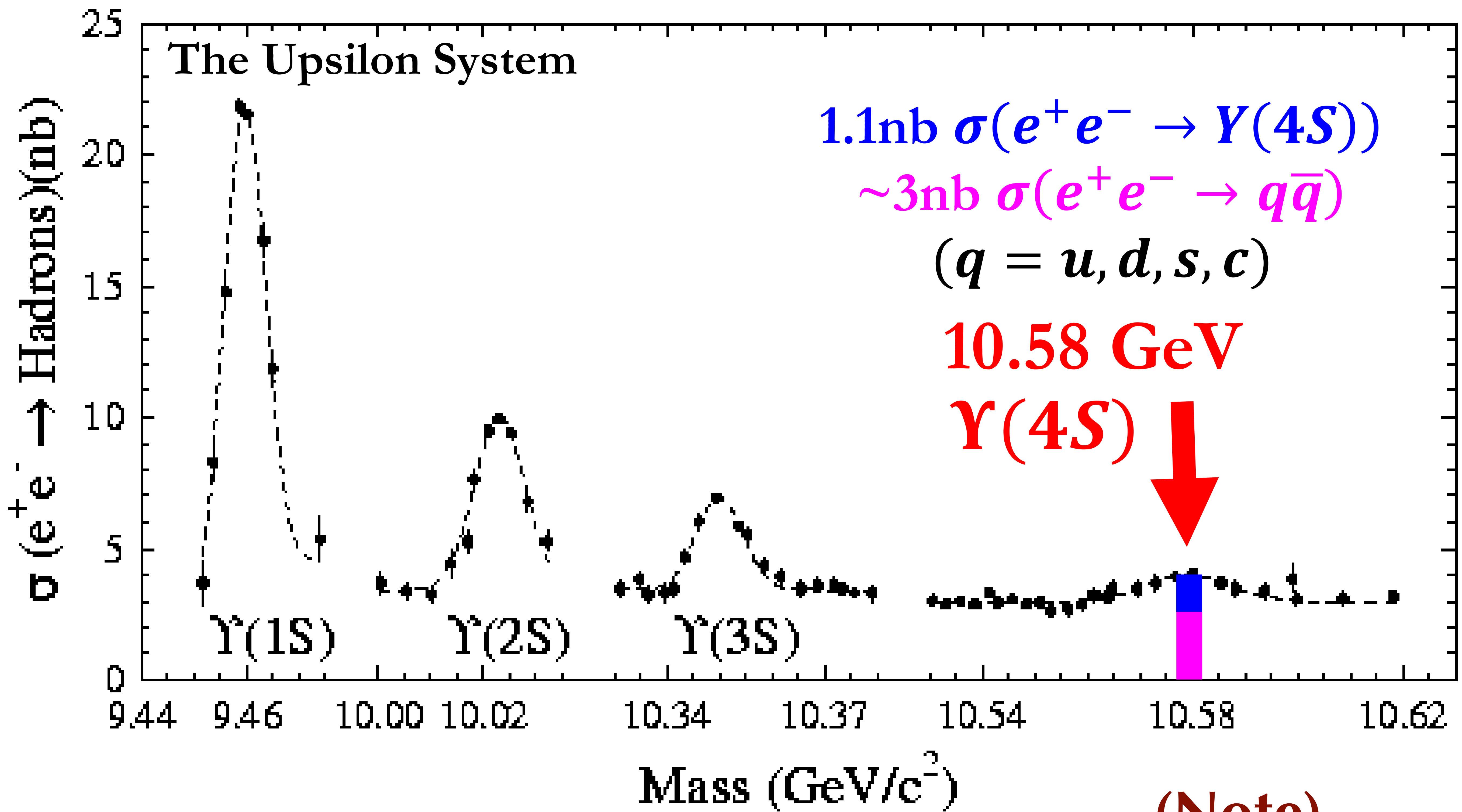
PRL 39, 252 (1977)

$$pN \to \mu^+\mu^- X$$ @ 400 GeV



$pN \to \mu^+\mu^- X$
cm²/GeV/nucleon
mass (GeV/c²)
$e^+e^- \to \Upsilon(4S) \to B\bar{B}$
σ (e⁺e⁻ → Hadrons)(nb)
Υ(1S)
Υ(2S)
Υ(3S)
Υ(4S)
Mass (GeV/c²)

$e^+e^- \to \Upsilon(4S)$ as a B-factory

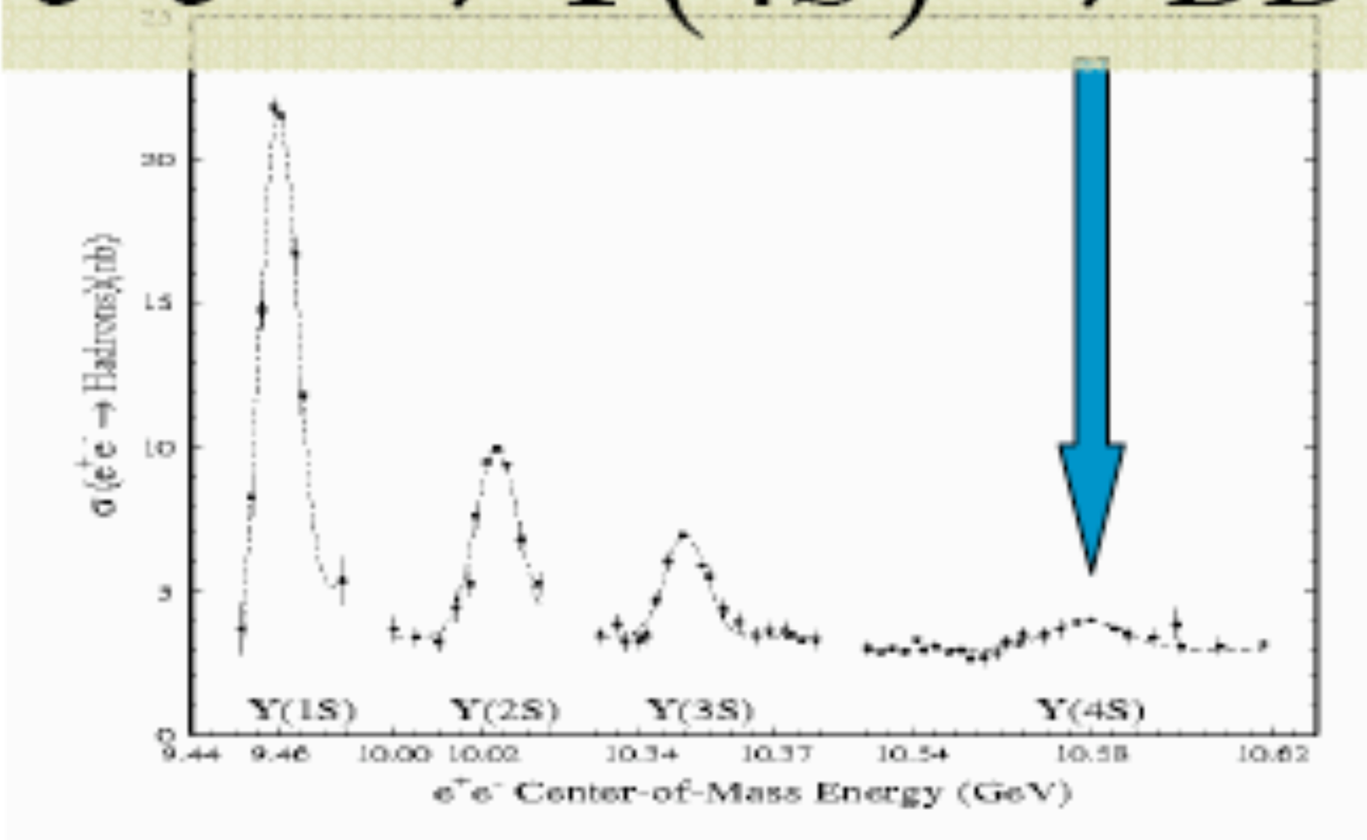


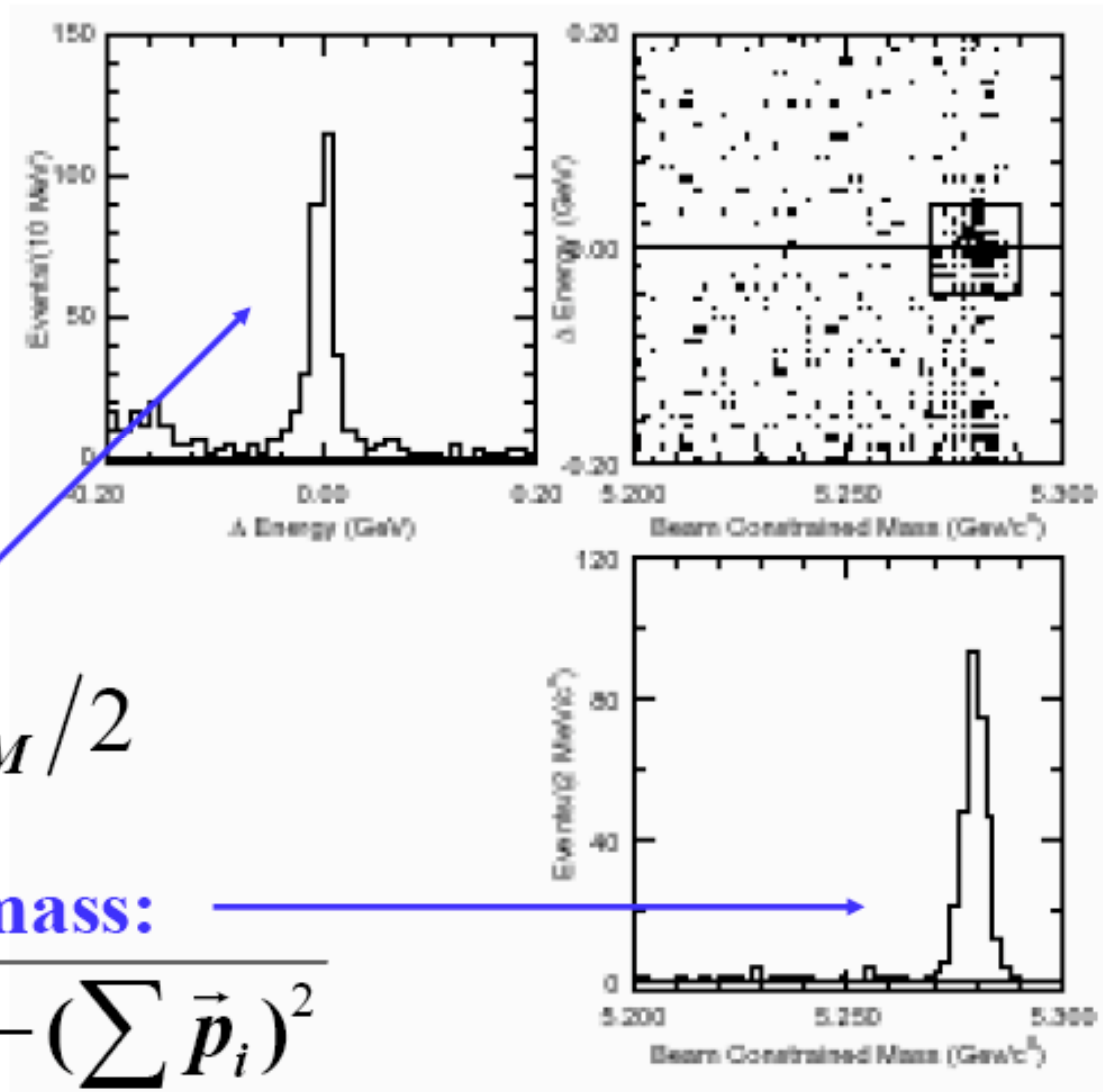
(Note)
m_B = 5.28 GeV

- $\mathcal{B}(\Upsilon(4S) \to B\overline{B}) > 96\%$, with $p_B^{CM} \sim 0.35$ GeV/c
- nothing else but $B\overline{B}$ in the final state
  $\therefore$ if we know $(E, \vec{p})$ of one B, the other B is also constrained

Two main variables for Belle

$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\overline{B}$$





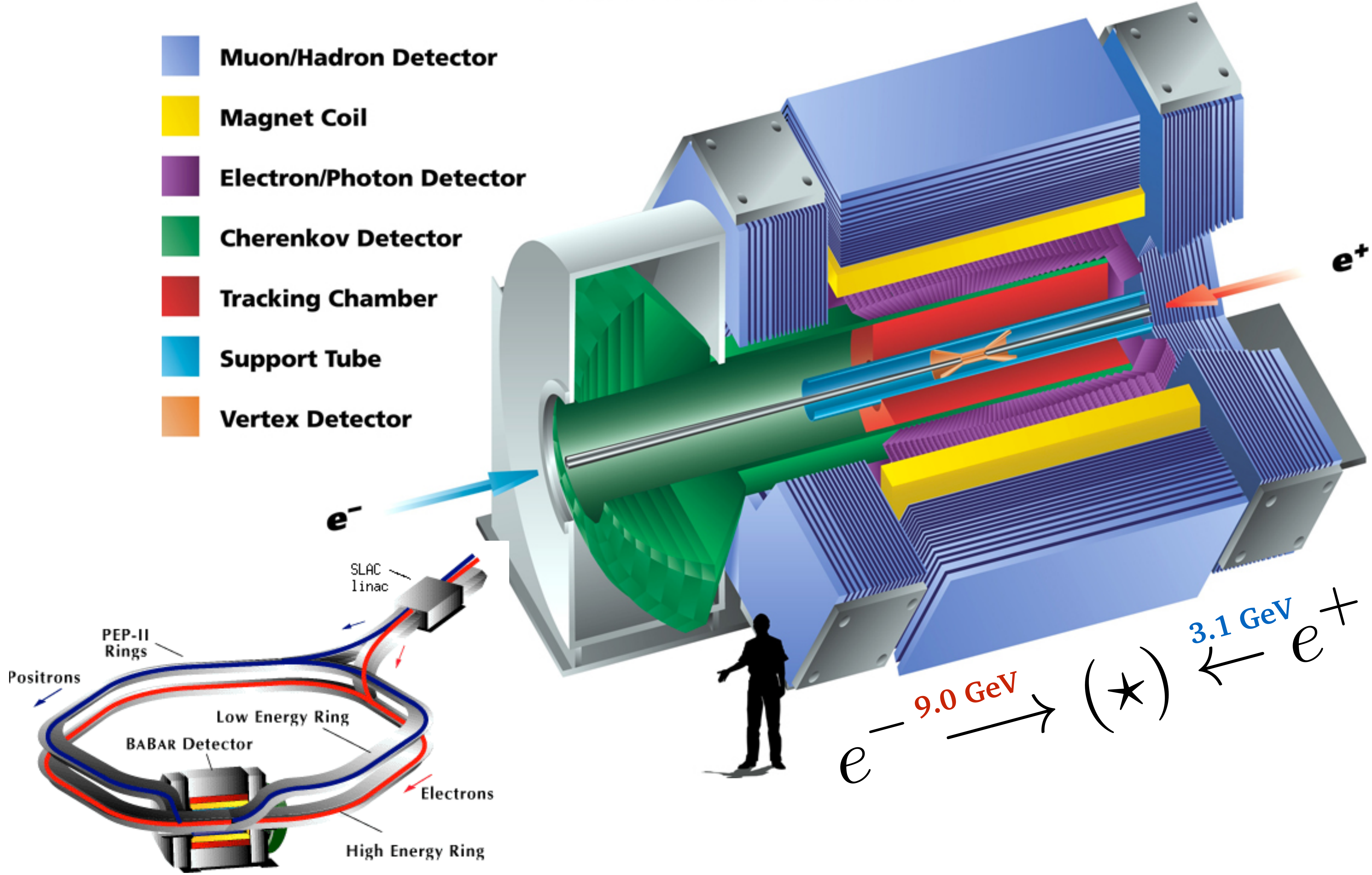
Energy difference:

$$\Delta E \equiv \sum E_i - E_{CM}/2$$

Beam-constrained mass:

$$M_{bc} = \sqrt{(E_{CM}/2)^2 - (\sum \vec{p}_i)^2}$$

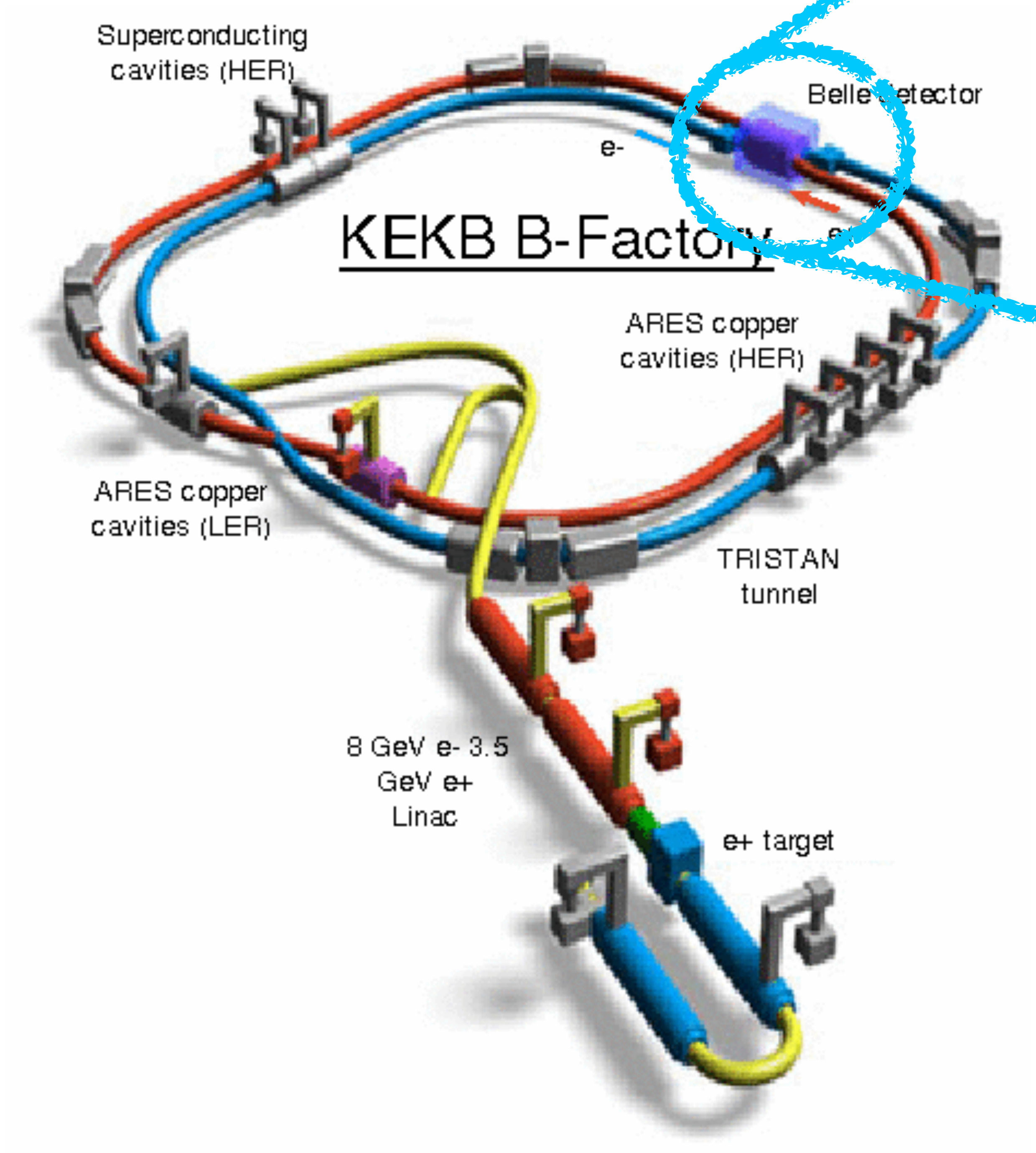
BABAR Detector

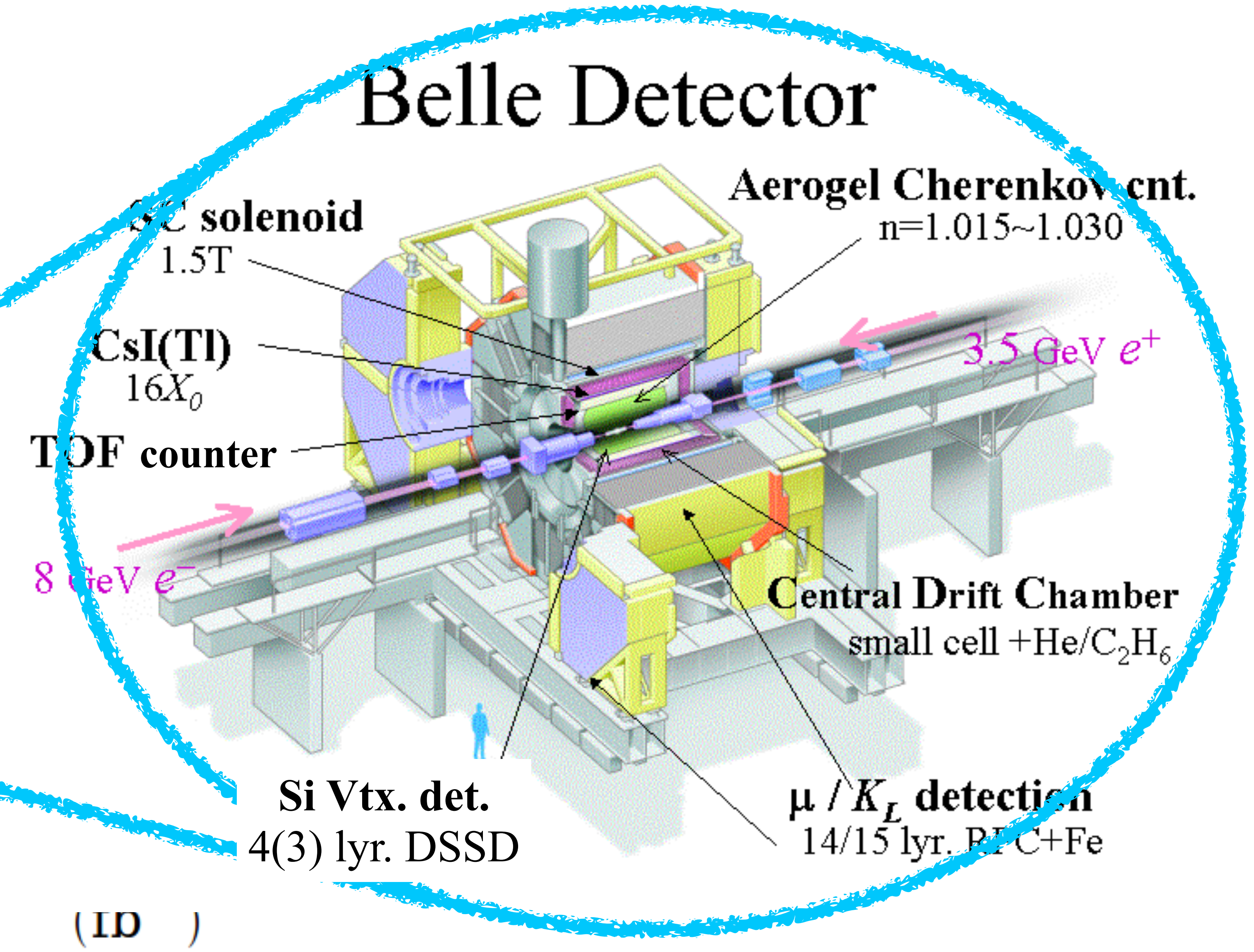


$$e^- \xrightarrow{9.0\ \text{GeV}} (\star) \xleftarrow{3.1\ \text{GeV}} e^+$$

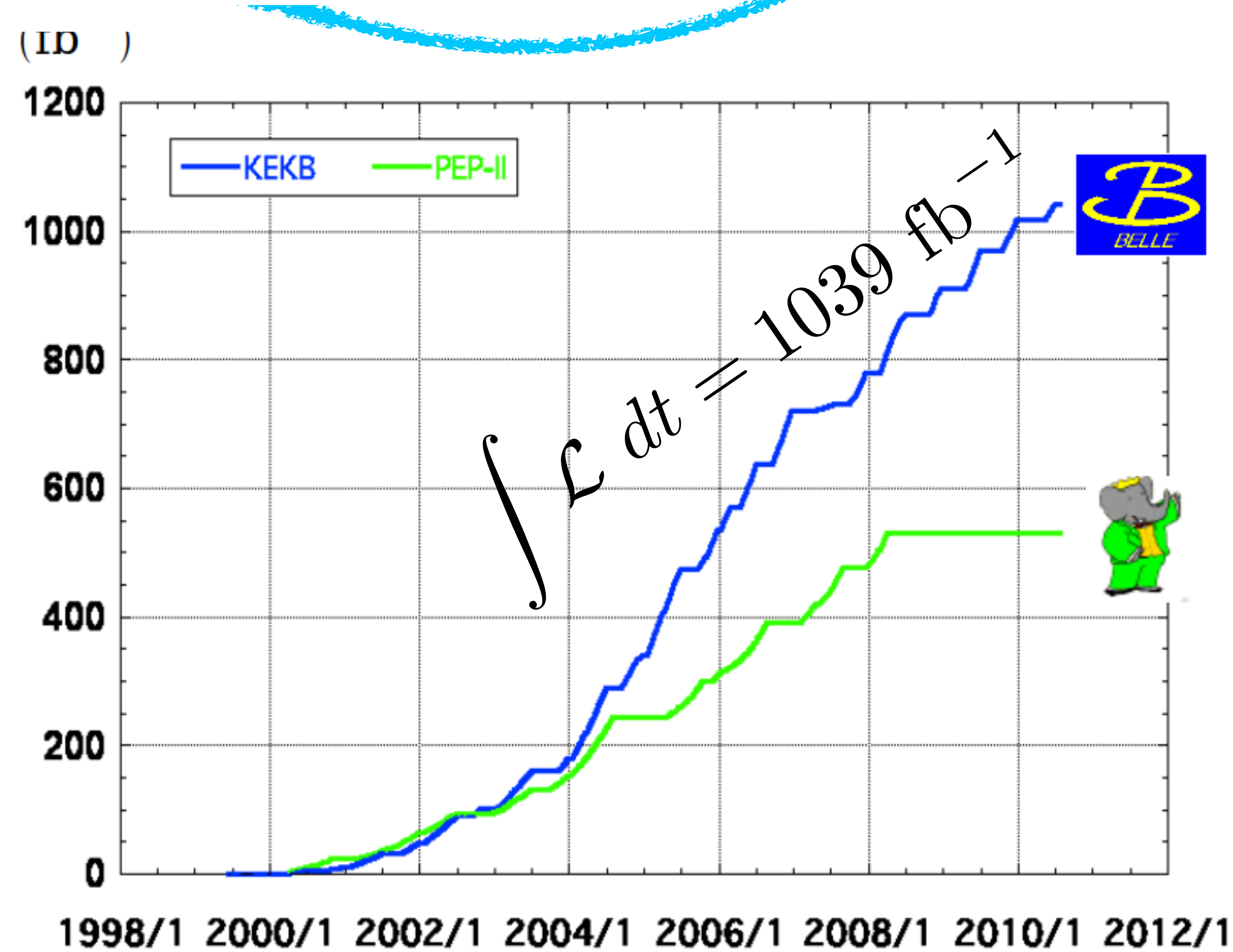
22 countries
100 institutions
~450 members

$$\mathcal{L}_{\text{peak}} = 21.1\ \text{nb}^{-1}\text{s}^{-1}$$



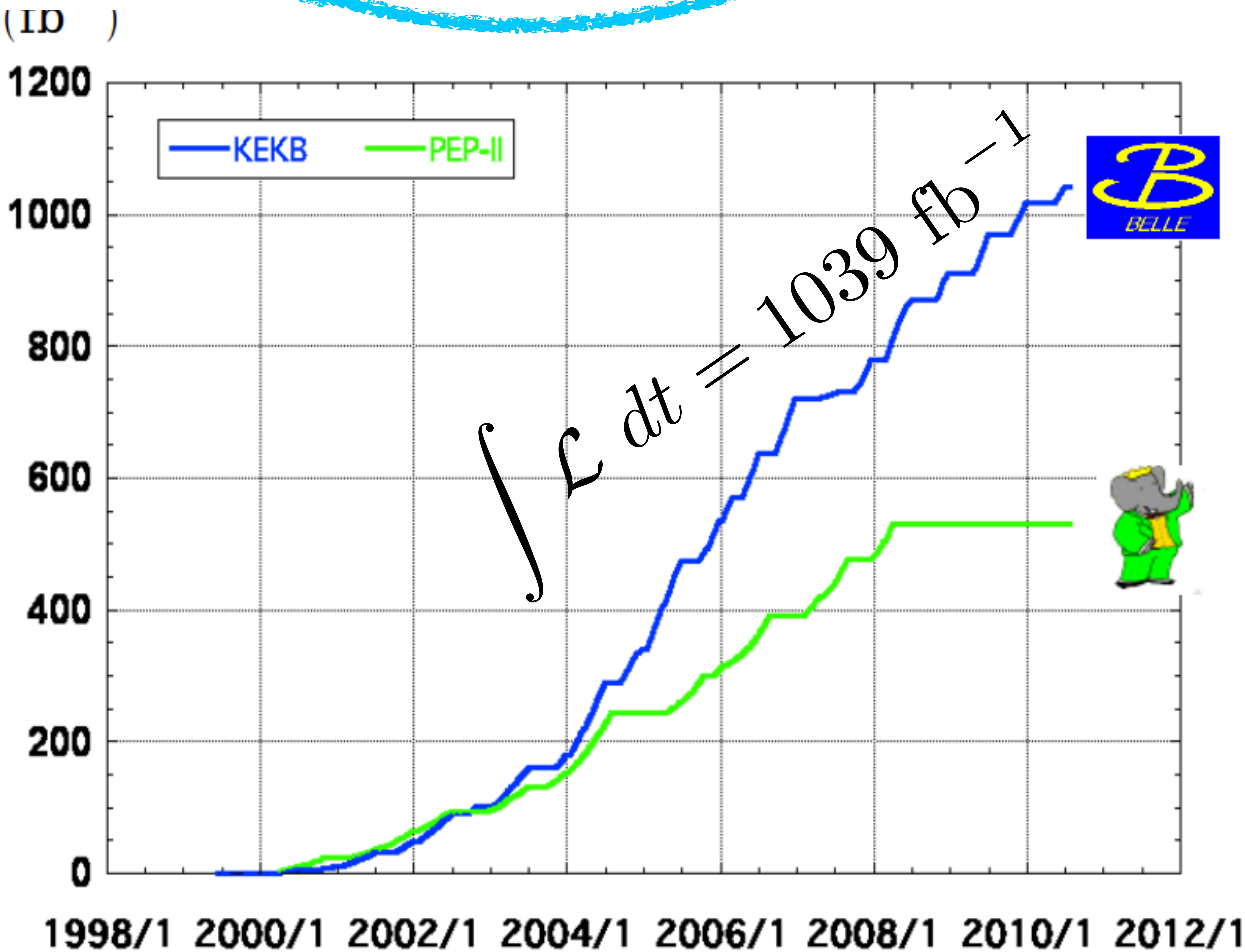


$$e^- \xrightarrow{\text{8 GeV}} (\star) \xleftarrow{\text{3.5 GeV}} e^+$$



> 1 ab^{-1}
On resonance:
$\Upsilon(5S)$: 121 fb^{-1}
$\Upsilon(4S)$: 711 fb^{-1}
$\Upsilon(3S)$: 3 fb^{-1}
$\Upsilon(2S)$: 25 fb^{-1}
$\Upsilon(1S)$: 6 fb^{-1}
Off reson./scan:
~ 100 fb^{-1}

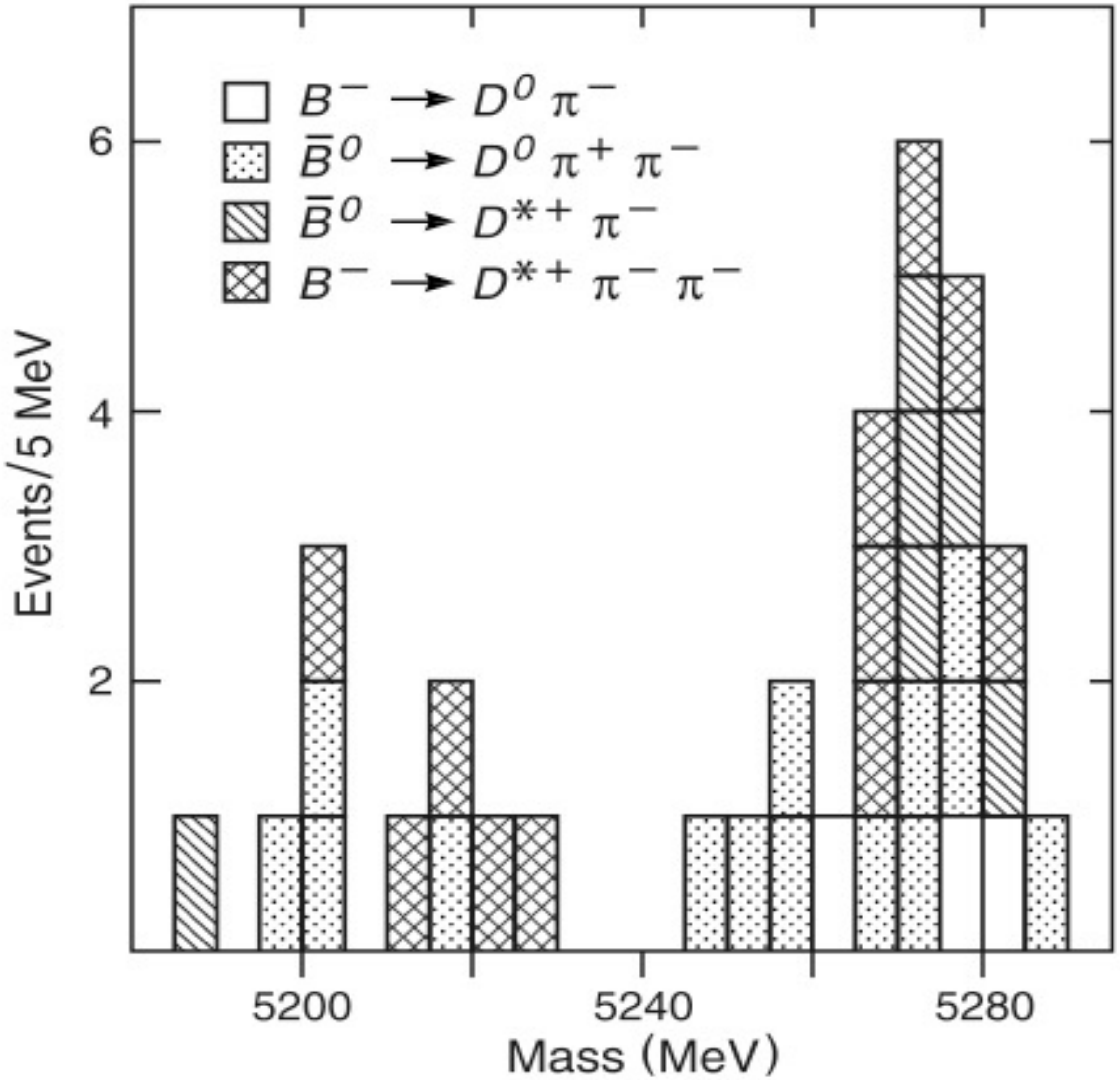
~ 550 fb^{-1}
On resonance:
$\Upsilon(4S)$: 433 fb^{-1}
$\Upsilon(3S)$: 30 fb^{-1}
$\Upsilon(2S)$: 14 fb^{-1}
Off resonance:
~ 54 fb^{-1}



> 1 ab^{-1}
On resonance:
$\Upsilon(5S)$: 121 fb^{-1}
$\Upsilon(4S)$: 711 fb^{-1}
$\Upsilon(3S)$: 3 fb^{-1}
$\Upsilon(2S)$: 25 fb^{-1}
$\Upsilon(1S)$: 6 fb^{-1}
Off reson./scan:
~ 100 fb^{-1}

~ 550 fb^{-1}
On resonance:
$\Upsilon(4S)$: 433 fb^{-1}
$\Upsilon(3S)$: 30 fb^{-1}
$\Upsilon(2S)$: 14 fb^{-1}
Off resonance:
~ 54 fb^{-1}

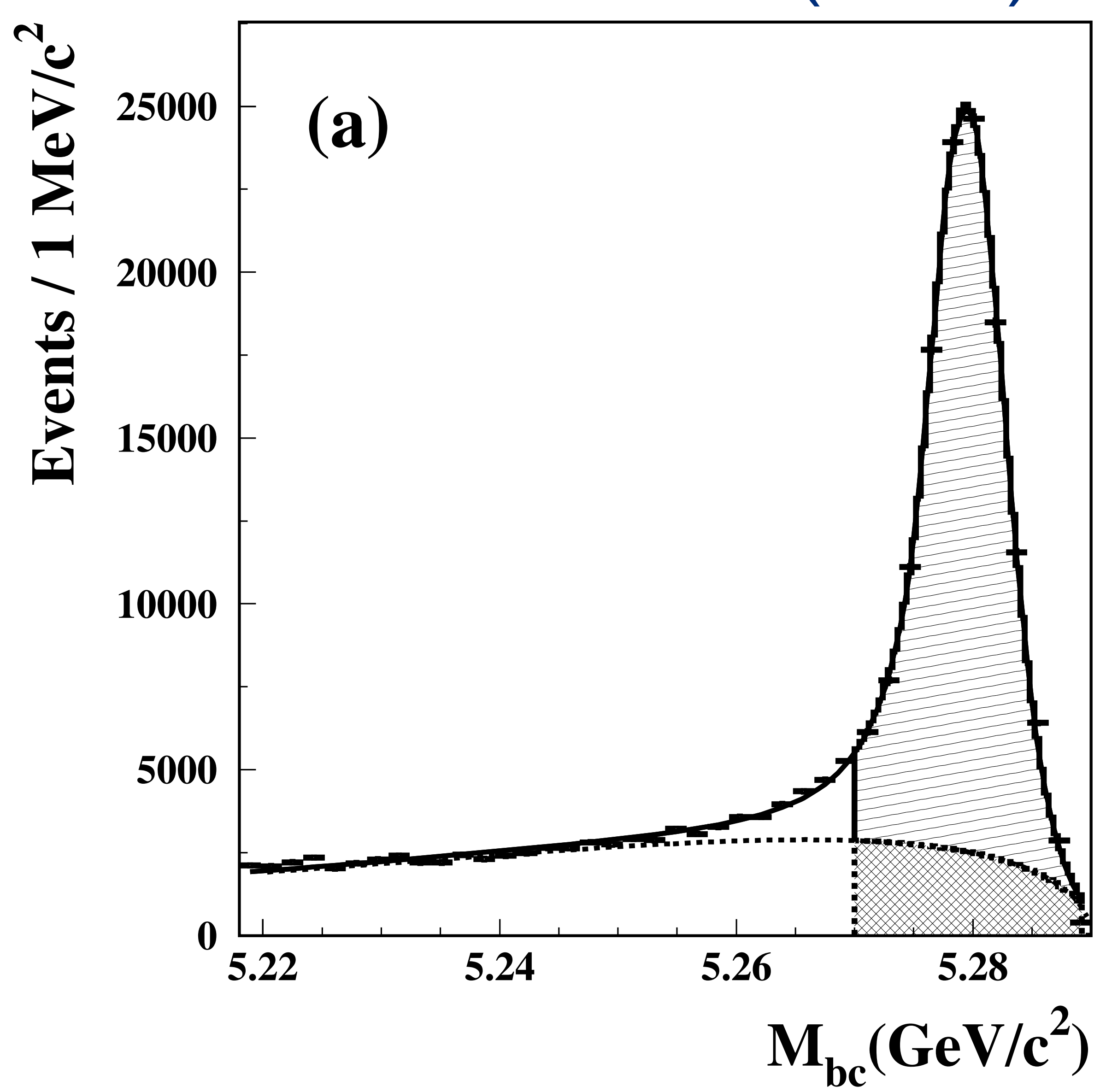
$e^+e^- \to \Upsilon(4S) \to B\bar{B}$



discovery of ***B*** mesons (CLEO)

PRL 50, 881 (1983)

Belle (2005)



Kobayashi-Maskawa (KM) ansatz

"CPV is due to an irreducible phase in the quark mixing matrix in 3 generations"

of Theoretical Physics, Vol. 49, No. 2, February 1973

CP-Violation in the Renormalizable Theory of Weak Interaction

Makoto KOBAYASHI and Toshihide MASKAWA

Department of Physics, Kyoto University, Kyoto

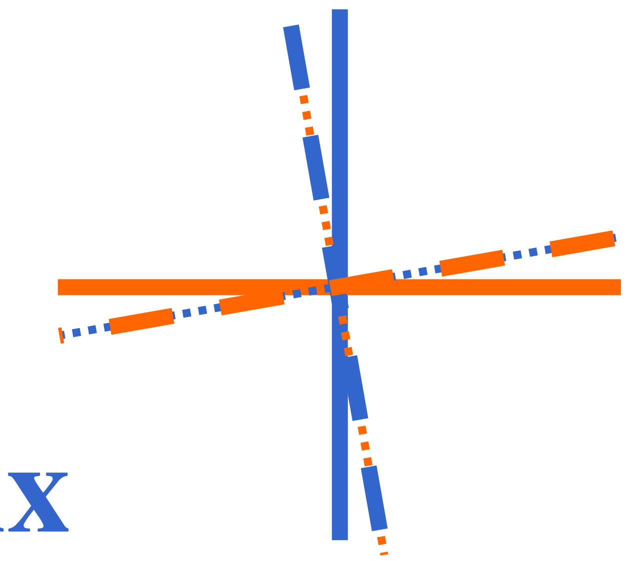
(Received September 1, 1972)

In a framework of the renormalizable theory of weak interaction, problems of *CP*-violation are studied. It is concluded that no realistic models of *CP*-violation exist in the quartet scheme without introducing any other new fields. Some possible models of *CP*-violation are also discussed.

When we apply the renormalizable theory of weak interaction[1)] to the hadron system, we have some limitations on the hadron model. It is well known that there exists, in the case of the triplet model, a difficulty of the strangeness changing neutral current and that the quartet model is free from this difficulty. Fur-

First 3rd-gen. particle (τ) seen in 1975

Flavor mixing & CKM matrix



- For quarks,
  - weak interaction eigenstates ≠ mass eigenstates
  - mixing of quark flavors through a **unitary matrix**

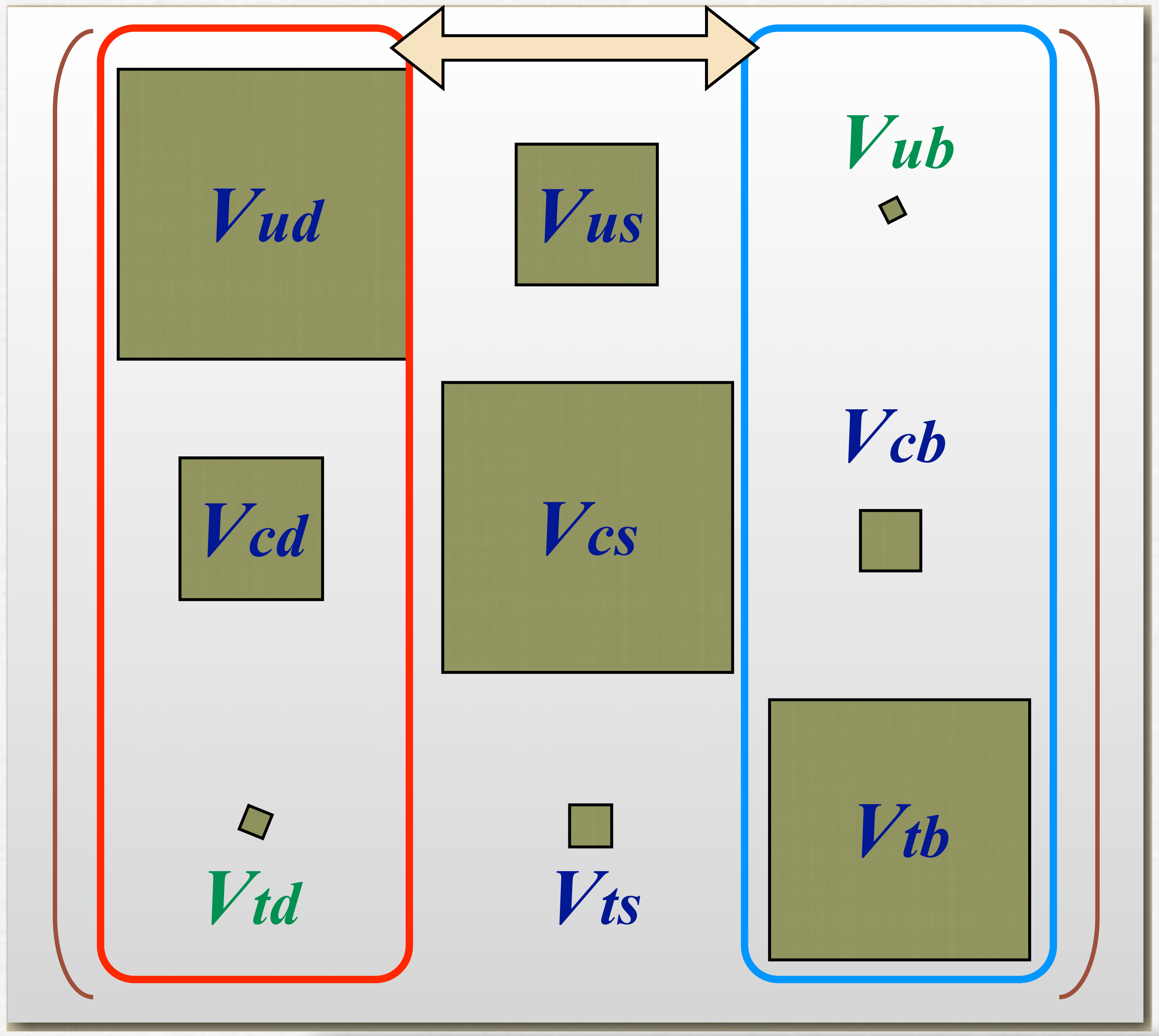
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \left(\mathrm{V}_{\mathrm{CKM}}\right)\begin{pmatrix} d \\ s \\ b \end{pmatrix} = \begin{pmatrix} \mathrm{V}_{ud} & \mathrm{V}_{us} & \mathrm{V}_{ub} \\ \mathrm{V}_{cd} & \mathrm{V}_{cs} & \mathrm{V}_{cb} \\ \mathrm{V}_{td} & \mathrm{V}_{ts} & \mathrm{V}_{tb} \end{pmatrix}\begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Wolfenstein parametrization

$$\mathrm{V}_{\mathrm{CKM}} \approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & \underline{A\lambda^3(\rho-i\eta)} \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ \underline{A\lambda^3(1-\rho-i\eta)} & -A\lambda^2 & 1 \end{pmatrix}$$

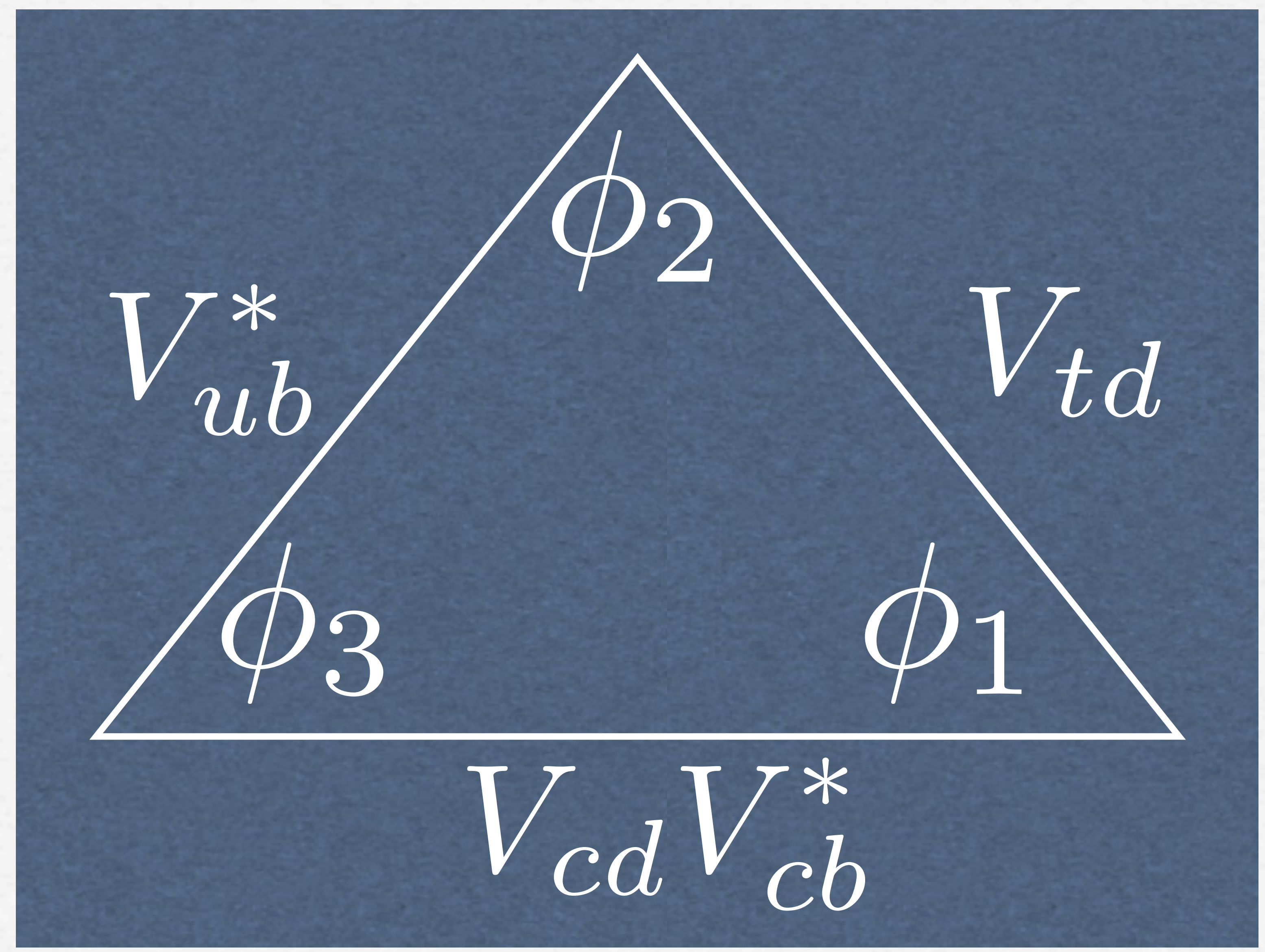
$|\lambda| \approx O(0.1)$

3 real parameters (λ, A, ρ) and 1 phase (η)



$$V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0$$

$$V_{ud} \cong V_{tb} \cong 1$$



Unitarity triangle angles			
BABAR:	β	α	γ
BELLE:	ϕ_1	ϕ_2	ϕ_3
This talk:	易	難	魔

Z. Ligeti, from plenary talk @ ICHEP 2004

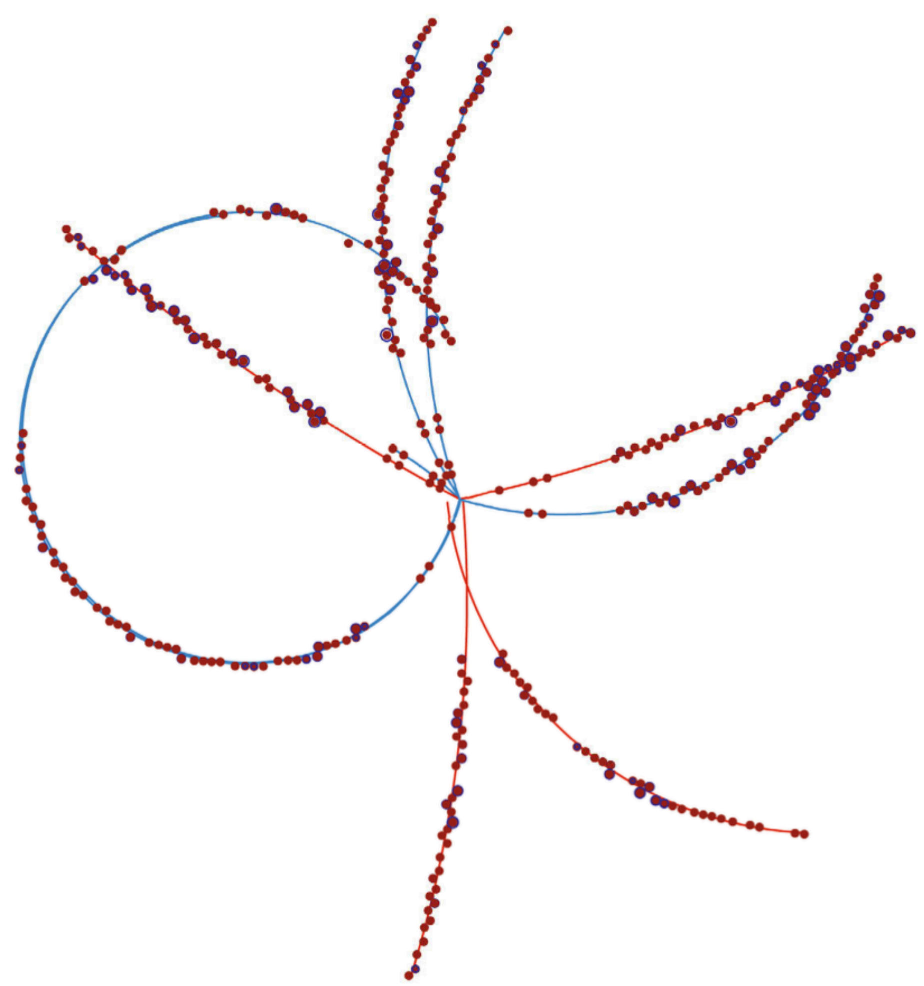
Eur. Phys. J. C (2014) 74:3026
DOI 10.1140/epjc/s10052-014-3026-9

THE EUROPEAN PHYSICAL JOURNAL C

Review

The Physics of the B Factories

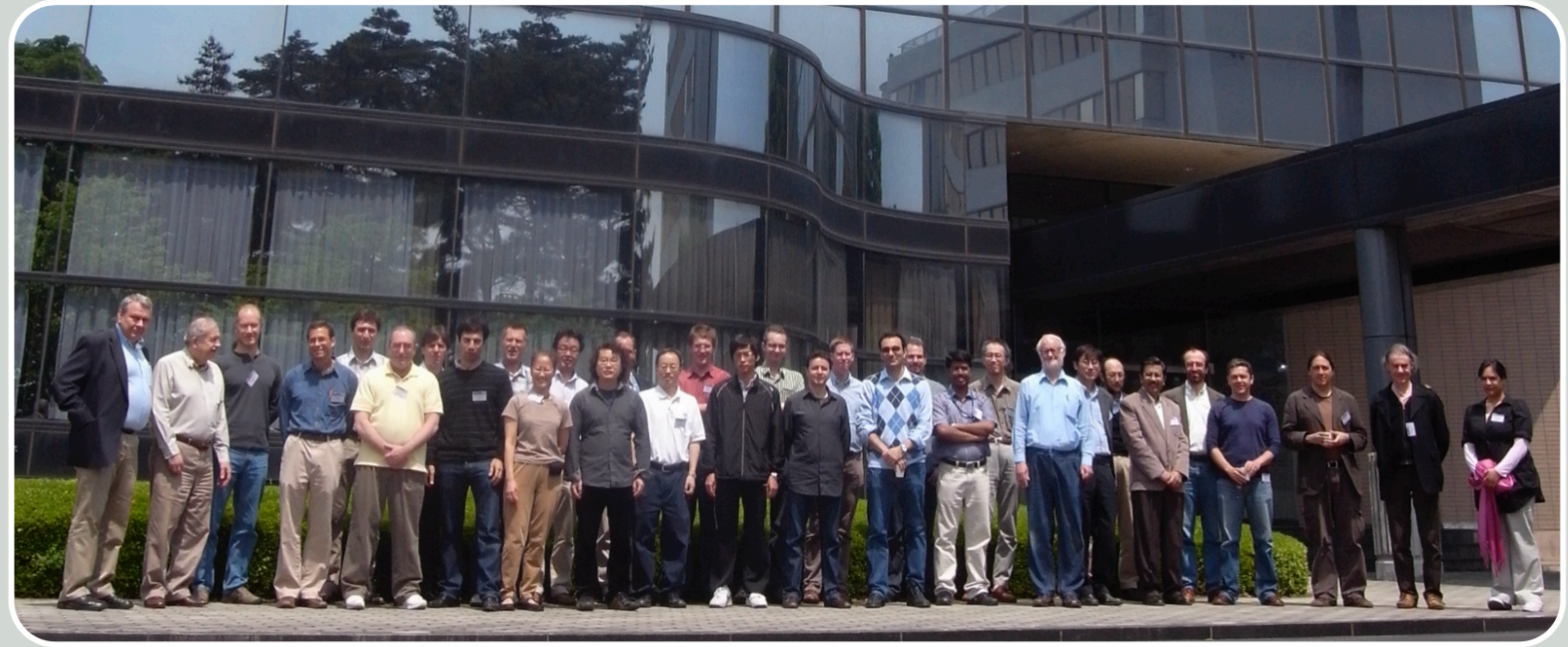
Received: 29 July 2014 / Accepted: 29 July 2014 / Published online: 19 November 2014



Springer

June 2, 2010

FEATURE STORY



The participants of the second Physics of B Factories workshop held at KEK on May 17-18, 2010.

The legacy of Belle and BaBar

[B Factory, Belle, BaBar, Physics Book, Unitarity Triangle]

On May 18, 2010, the world's two major B Factory collaborations, Belle and BaBar, met in a seminar room to toss a coin. The two have used different sets of notation for more than a decade, but must now pick a consistent notation for their upcoming joint physics book. The book will discuss the detectors, the analysis tools used, the physics results, and the interpretation of these results. Read on for a short history of the two projects, and to find out the results of the coin toss.

Most physicists would agree that the specific set of symbols used to describe physics is not important. Rather, the physics itself is what's important. Unfortunately, that doesn't mean physicists can easily agree on what notation to use. Change can be hard, especially when they've used a particular notation for over a decade. This time, physicists' conventional method of decision making, called 'discussion,' provided agreement on a way to find a solution through a rather unscientific method: a coin toss.

The discussion finally came to a head at KEK on May 17-18, 2010. Here, the world's two giant B-Factory collaborations, Belle at KEK and BaBar at SLAC, met for the second time to discuss the editing work of their B-Factory physics book, straightforwardly titled The Physics of the B-Factories. The ceremonial coin toss was scheduled for the end of the workshop.

The parameters that sparked the discussion are the angles of the unitarity triangle, an abstract triangle representing the interactions of quarks, the elementary constituents of matter. The shared objective of the two B-Factory experiments was to determine the shape of the triangle. For as long as they have existed, the two collaborations have had different notation for the physical parameters of this triangle. The most prominent example is that Belle has called the angles phi-1, phi-2, and phi-3, while BaBar has called them beta, alpha, and gamma, respectively.

Now, the two B-Factory collaborations are putting heads together, to write their first and last joint physics book. “We are in the stage where both collaborations have invested twenty years in doing [B-Factory] physics. The

One of the general editors of the Belle-BaBar Physics Book, Dr. Bruce Yabsley of the University of Sidney tosses a coin to decide between the notations to be used for fundamental B-Factory parameters in the book.

The participants of the second Physics of B Factories workshop held at KEK on May 17-18, 2010.

The legacy of Belle and BaBar

[B Factory, Belle, BaBar, Physics Book, Unitarity Triangle]

On May 18, 2010, the world's two major B Factory collaborations, Belle and BaBar, met in a seminar room to toss a coin. The two have used different sets of notation for more than a decade, but must now pick a consistent notation for their upcoming joint physics book. The book will discuss the detectors, the analysis tools used, the physics results, and the interpretation of these results. Read on for a short history of the two projects, and to find out the results of the coin toss.

Most physicists would agree that the specific set of symbols used to describe physics is not important. Rather, the physics itself is what's important. Unfortunately, that doesn't mean physicists can easily agree on what notation to use. Change can be hard, especially when they've used a particular notation for over a decade. This time, physicists' conventional method of decision making, called 'discussion,' provided agreement on a way to find a solution through a rather unscientific method: a coin toss.

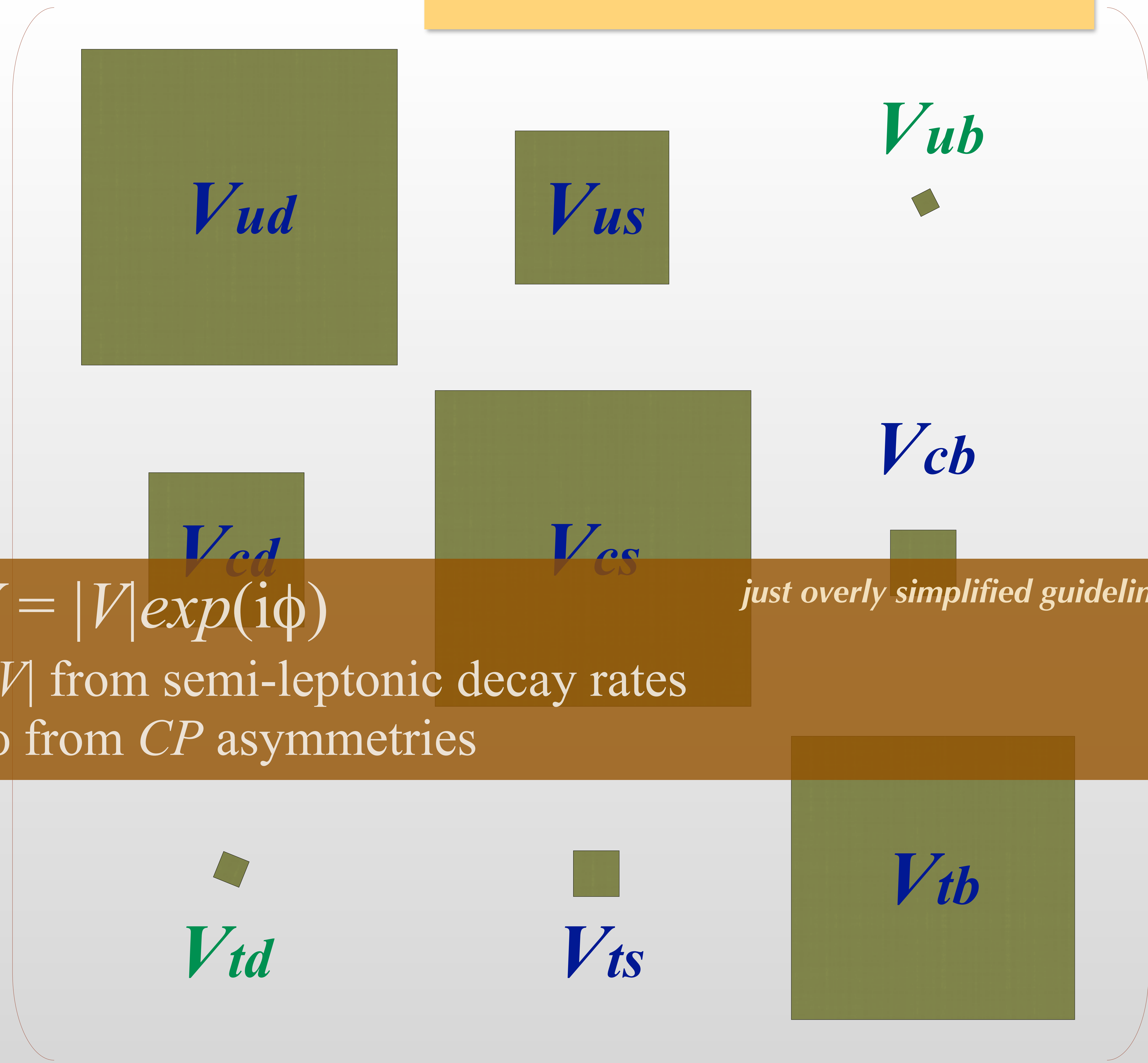
The discussion finally came to a head at KEK on May 17-18, 2010. Here, the world's two giant B-Factory collaborations, Belle at KEK and BaBar at SLAC, met for the second time to discuss the editing work of their B-Factory physics book, straightforwardly titled The Physics of the B-Factories. The ceremonial coin toss was scheduled for the end of the workshop.

The parameters that sparked the discussion are the angles of the unitarity triangle, an abstract triangle representing the interactions of quarks, the elementary constituents of matter. The shared objective of the two B-Factory experiments was to determine the shape of the triangle. For as long as they have existed, the two collaborations have had different notation for the physical parameters of this triangle. The most prominent example is that Belle has called the angles phi-1, phi-2, and phi-3, while BaBar has called them beta, alpha, and gamma, respectively.

Now, the two B-Factory collaborations are putting heads together, to write their first and last joint physics book. “We are in the stage where both collaborations have invested twenty years in doing [B-Factory] physics. The

One of the general editors of the Belle-BaBar Physics Book, Dr. Bruce Yabsley of the University of Sidney tosses a coin to decide between the notations to be used for fundamental B-Factory parameters in the book.

How to measure?



just overly simplified guidelines

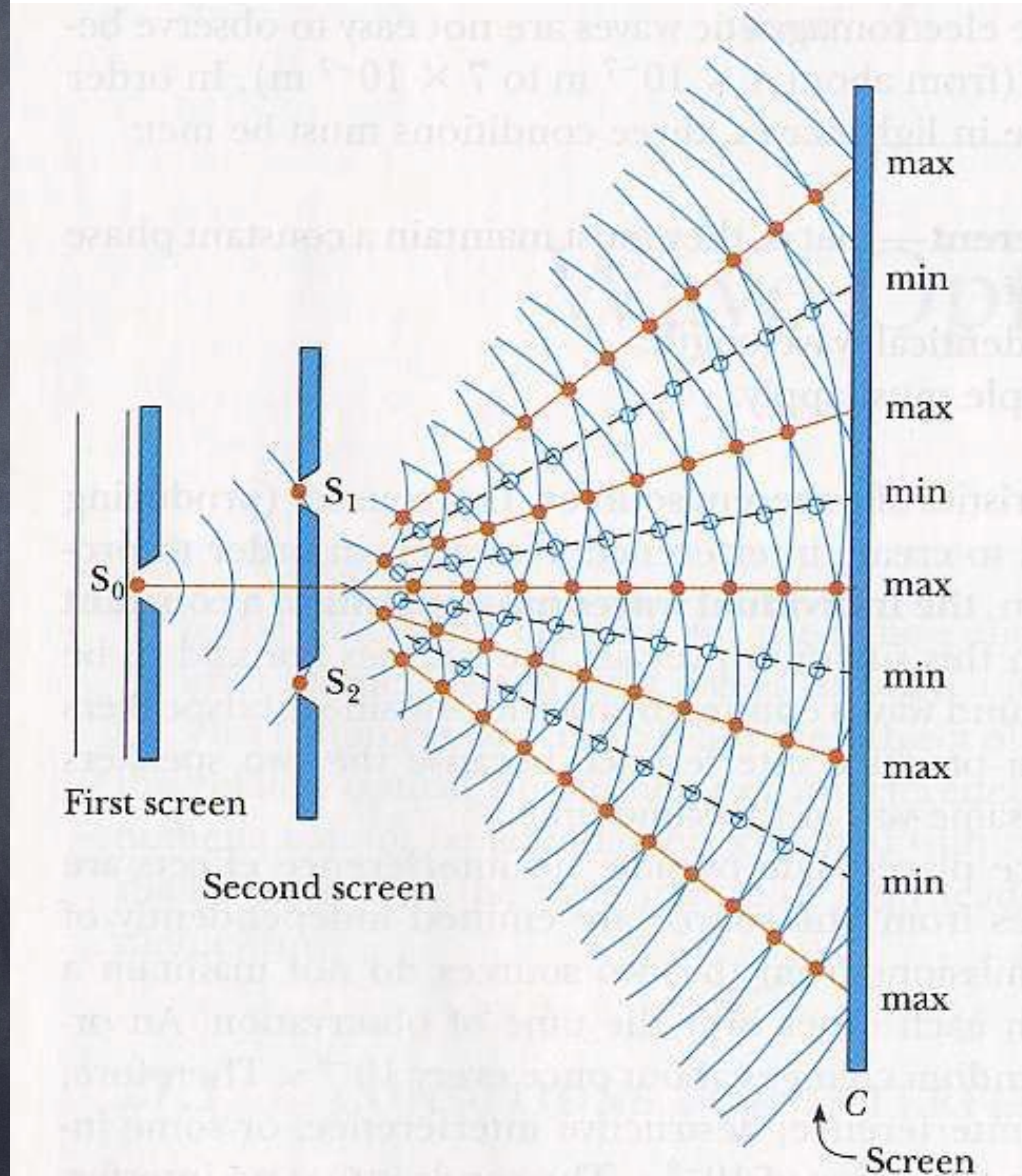
$V = |V| exp(i\phi)$

- $|V|$ from semi-leptonic decay rates
- ϕ from *CP* asymmetries

How to make CPV happen?

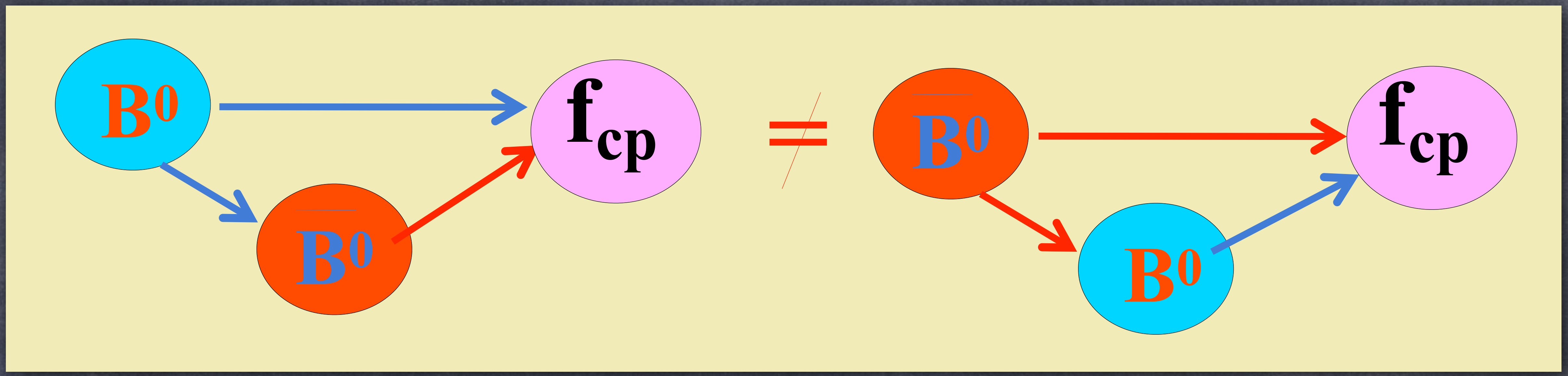
by interference of 2 amplitudes

- case (1) : mixing-induced
- case (2) : b/w tree & penguin

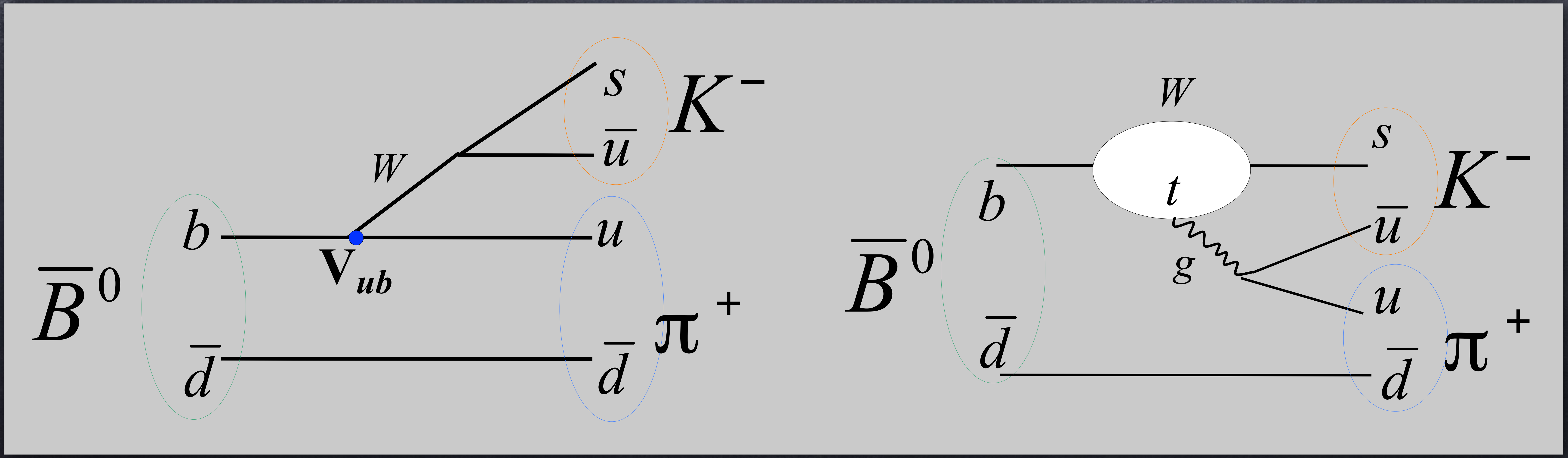


How to get interference?

- mixing-induced



- interference of different decay amplitudes



CP violation from interference of two amplitudes

Conside a reaction $B \to f$

and its CP-conjugate reaction $\bar{B} \to \bar{f}$

Let $f = f_1 + f_2$

$$= f_0 (1 + x e^{i(\phi+\delta)})$$

ϕ: weak int. phase

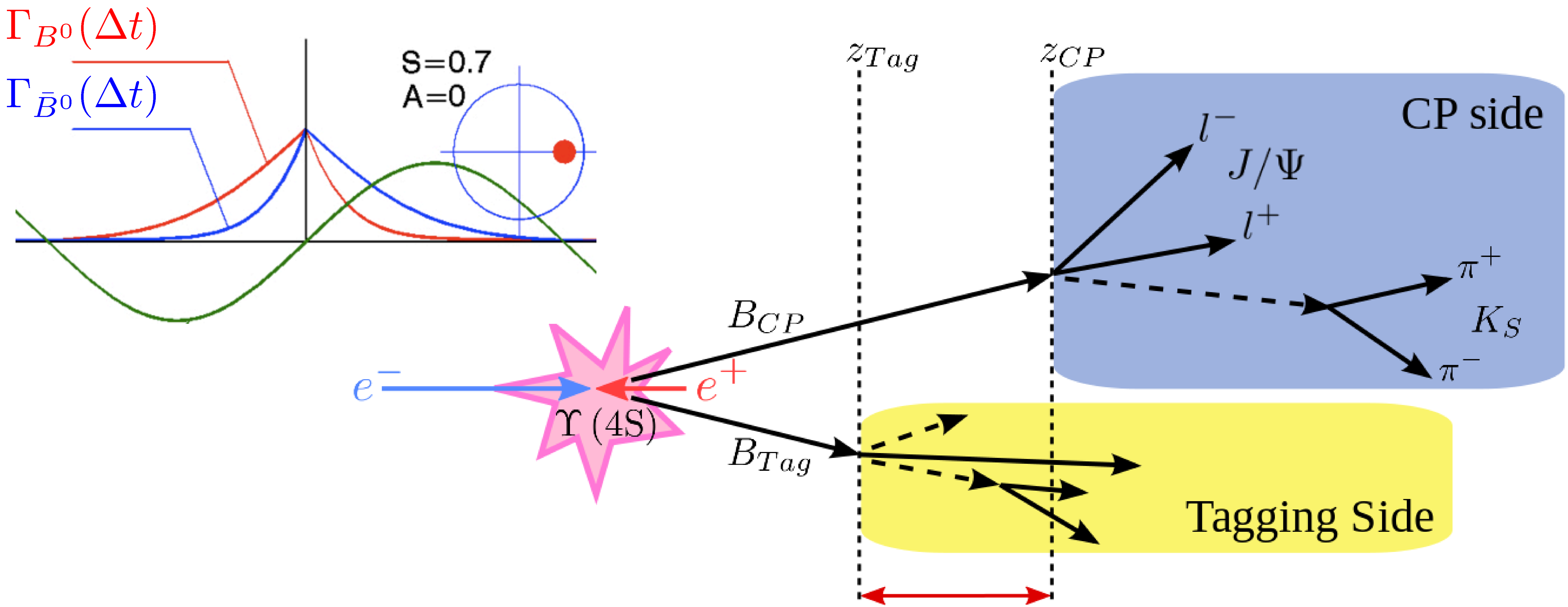
δ: Strong int. phase

Then, under CP-conjugation,

$\phi \to -\phi$, but $\delta \to \delta$.

$$\Rightarrow \quad \bar{f} = \bar{f}_0 (1 + x e^{i(\delta-\phi)})$$

time-dependent A_{CP} measurement



$\Delta z = \beta\gamma c\Delta t, \quad \langle|\Delta z|\rangle \approx 200\,\mu m$

$$A_{CP}(\Delta t) = \frac{\Gamma\left(\bar{B}^0(\Delta t) \to f_{CP}\right) - \Gamma\left(B^0(\Delta t) \to f_{CP}\right)}{\Gamma\left(\bar{B}^0(\Delta t) \to f_{CP}\right) + \Gamma\left(B^0(\Delta t) \to f_{CP}\right)} = \mathcal{S}_f \sin(\Delta m \Delta t) + \mathcal{A}_f \cos(\Delta m \Delta t)$$

$$\mathcal{S}_f = \frac{2\,\mathrm{Im}(\lambda_f)}{|\lambda_f^2| + 1} \qquad \mathcal{A}_f = \frac{|\lambda_f^2| - 1}{|\lambda_f^2| + 1} \qquad \lambda_f = \frac{q}{p}\frac{\bar{A}(f_{CP})}{A(f_{CP})}$$

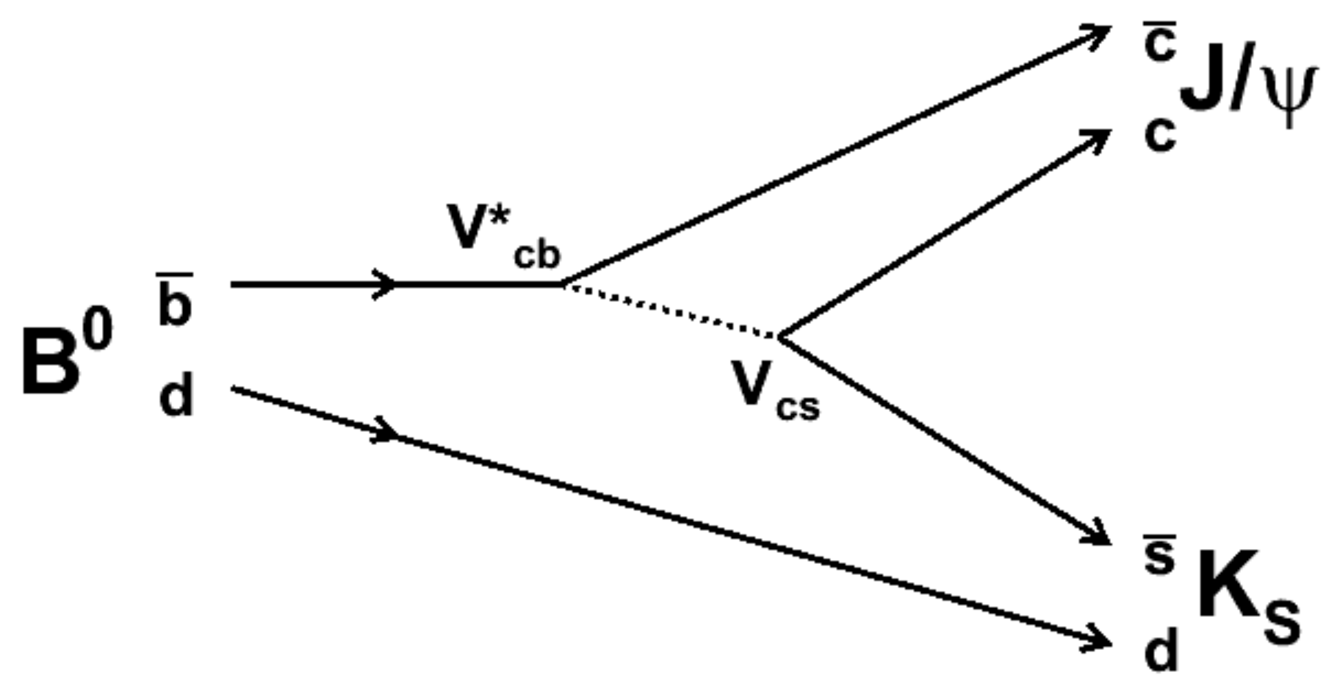
mixing-induced CPV

direct CPV

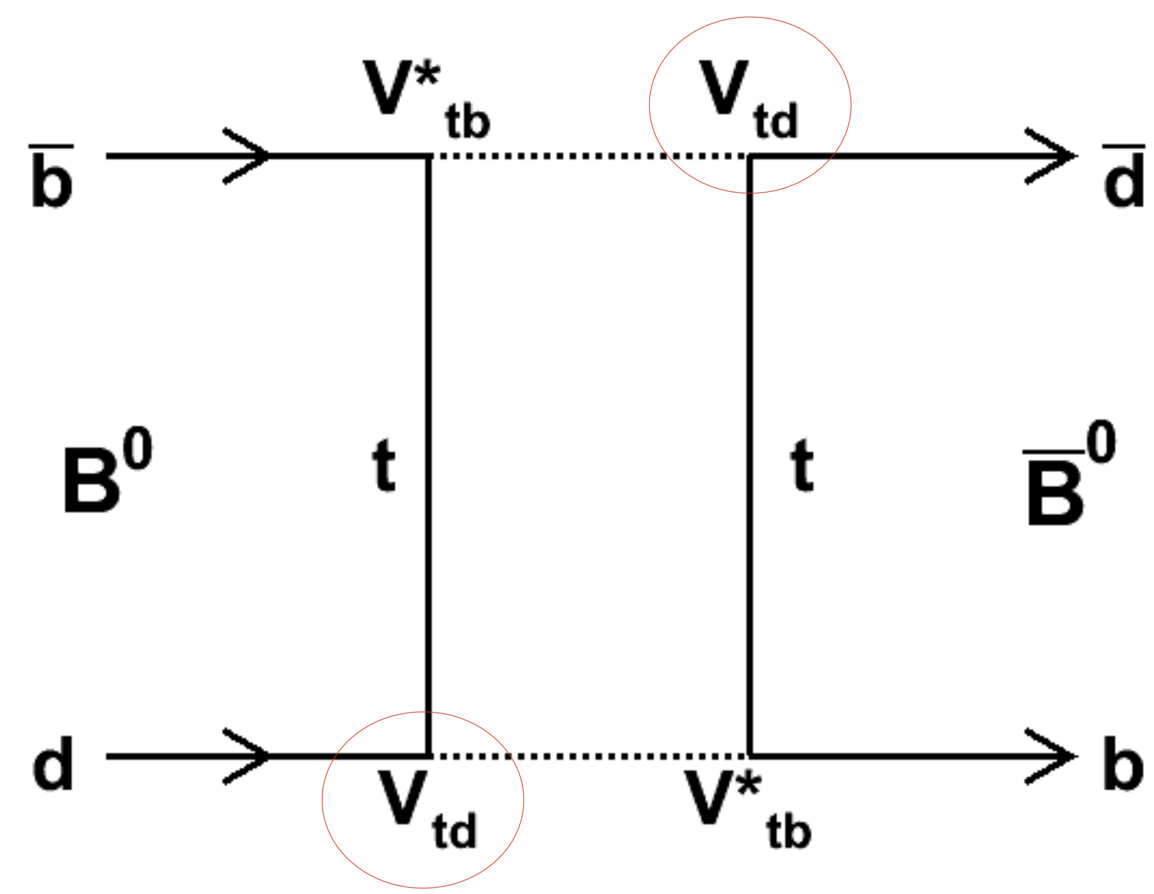
The Golden mode for ϕ_1

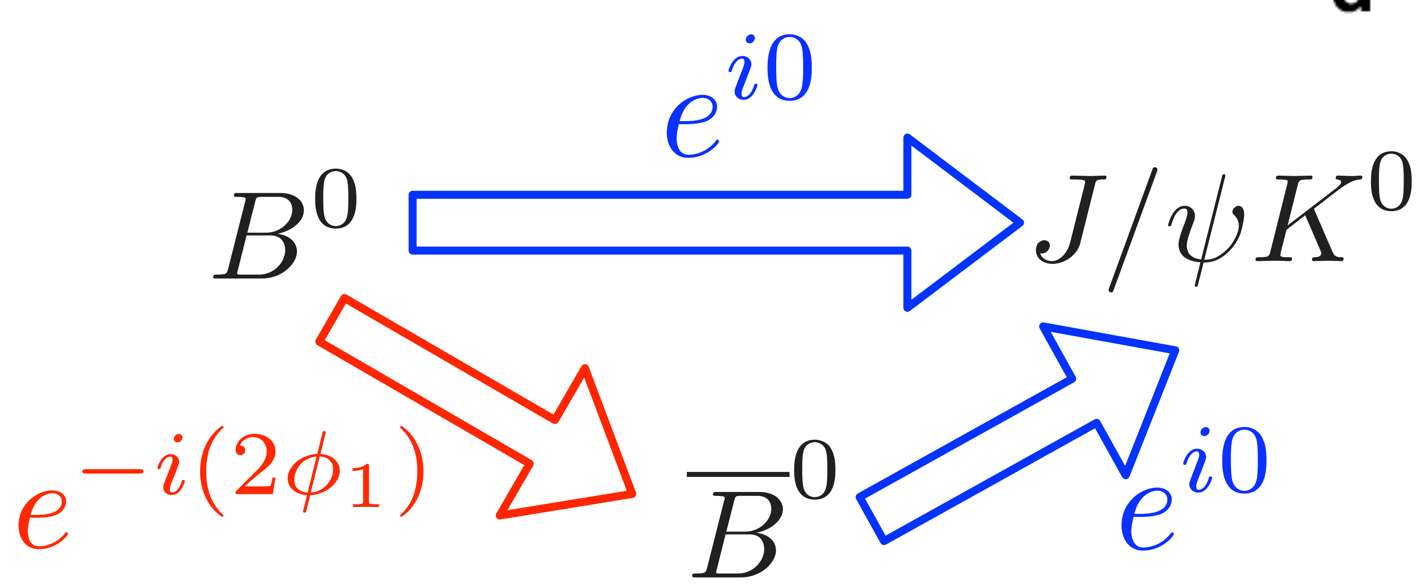
$B^0 \to J/\psi K^0$: high rate, theoretically clean

No CKM phase e^{i0}



Two V_{td} vertices $e^{-i(2\phi_1)}$

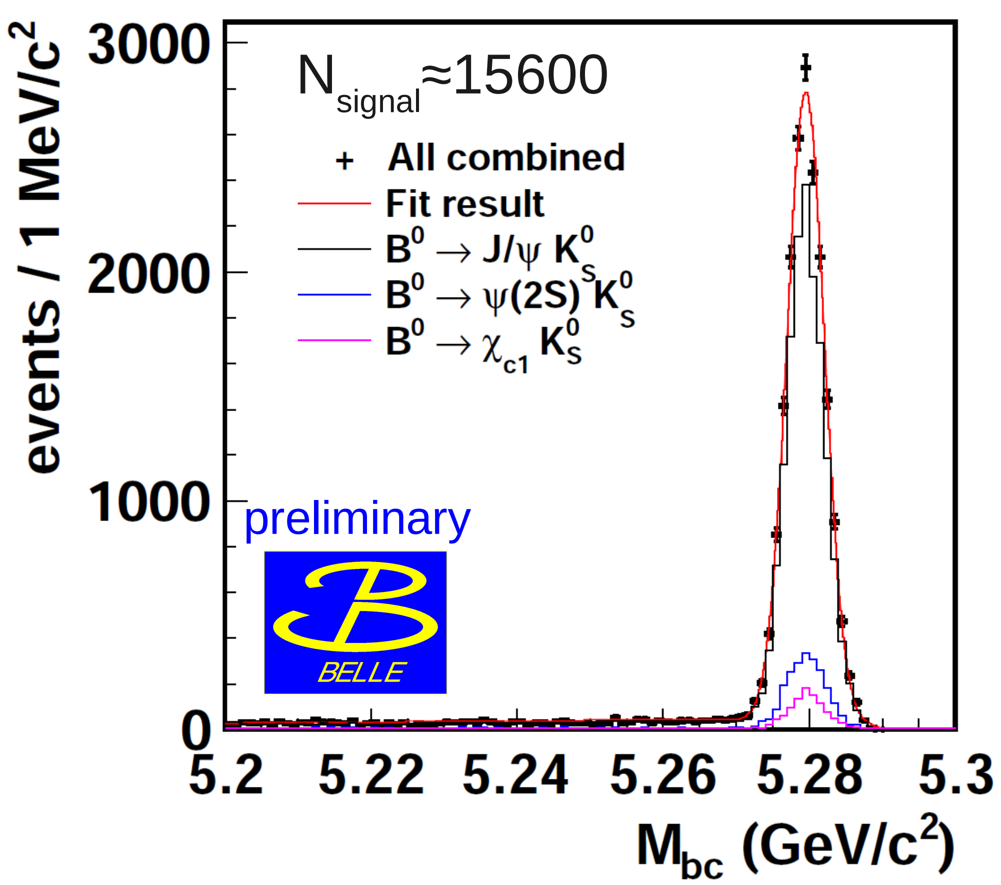


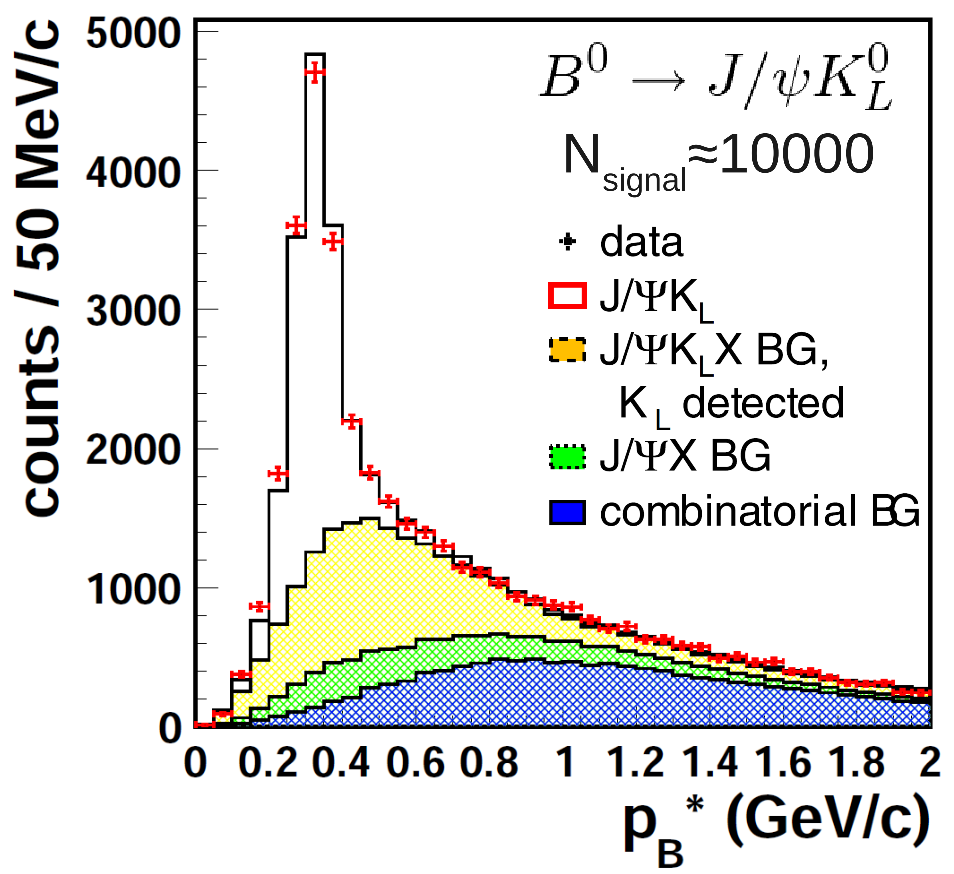


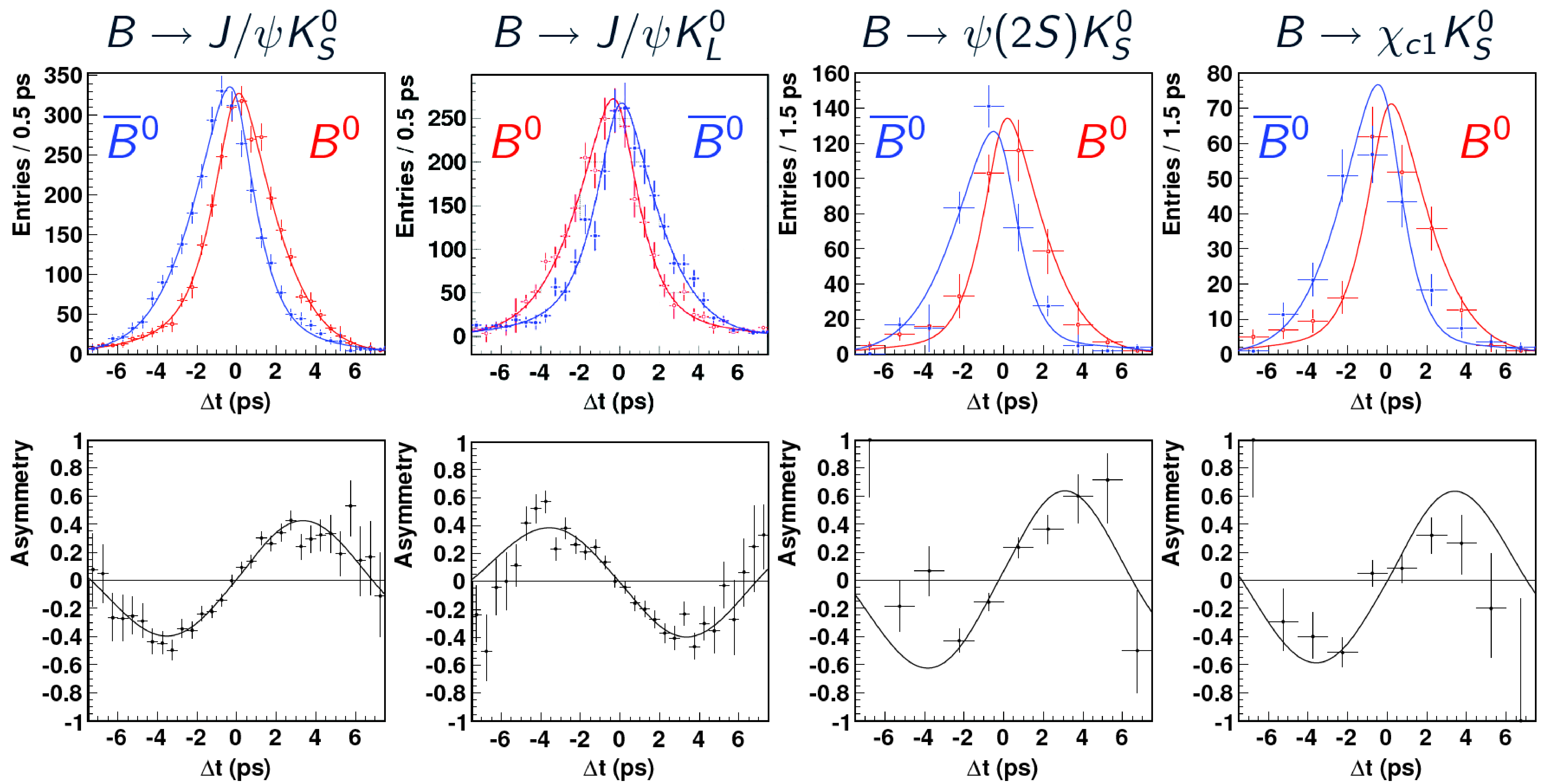
Note: true for any B^0 decay with no phase from decay amplitude

$$\Longrightarrow A_{CP}^{J/\psi K^0}(\Delta t) = -\xi_f \sin(2\phi_1) \sin(\Delta m \Delta t)$$

Belle's final result on $\sin(2\phi_1)$





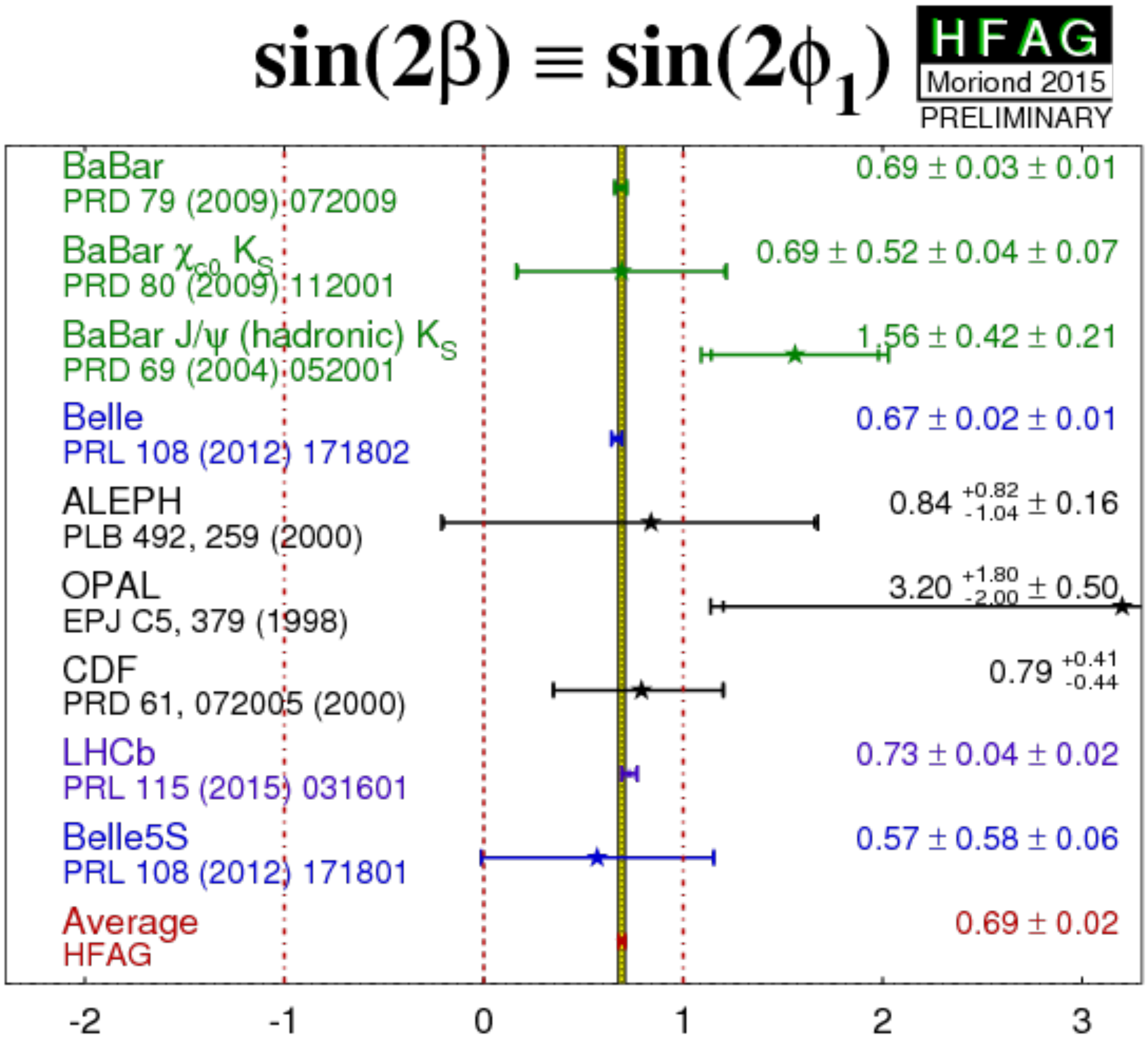


Belle with 772×10⁶ BB:

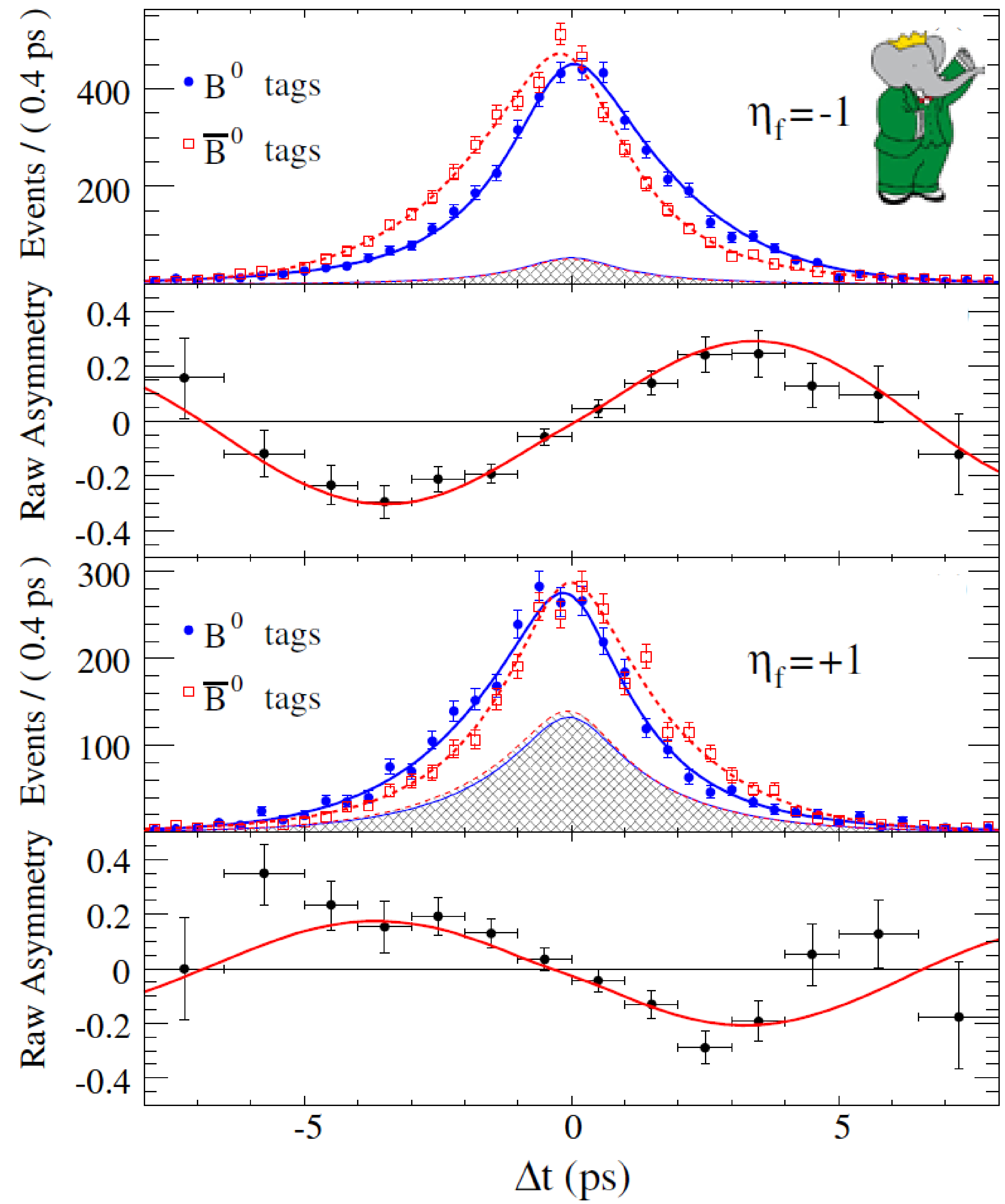
$$\mathcal{A} = 0.007 \pm 0.016\,(\mathrm{stat}) \pm 0.013\,(\mathrm{syst})$$

$$\sin(2\phi_1) = 0.668 \pm 0.023 \pm 0.013$$

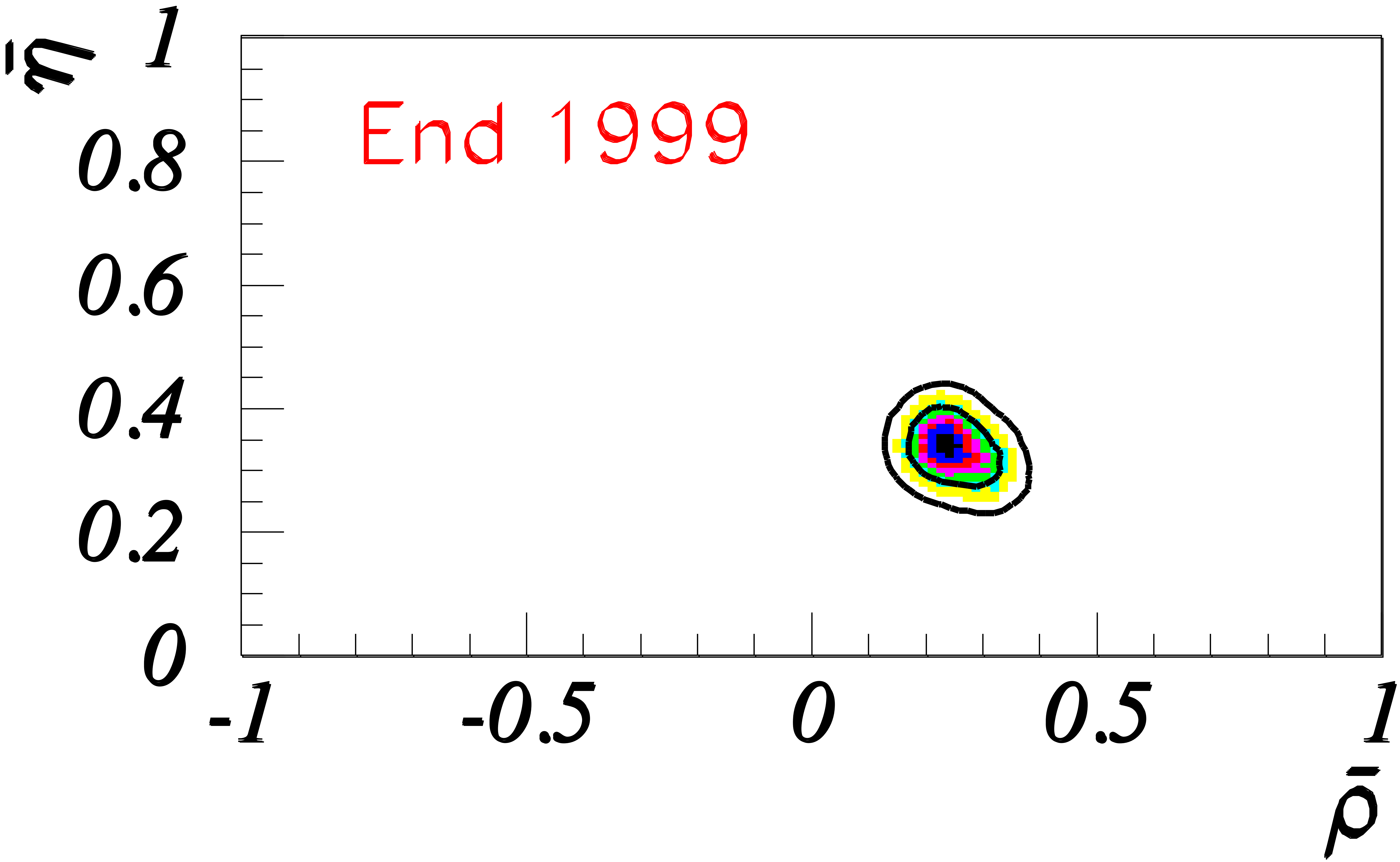
preliminary



sin(2β) ≡ sin(2φ1)
HFAG
Moriond 2015
PRELIMINARY
BaBar
PRD 79 (2009) 072009
0.69 ± 0.03 ± 0.01
BaBar χc0 KS
PRD 80 (2009) 112001
0.69 ± 0.52 ± 0.04 ± 0.07
BaBar J/ψ (hadronic) KS
PRD 69 (2004) 052001
1.56 ± 0.42 ± 0.21
Belle
PRL 108 (2012) 171802
0.67 ± 0.02 ± 0.01
ALEPH
PLB 492, 259 (2000)
0.84 +0.82 -1.04 ± 0.16
OPAL
EPJ C5, 379 (1998)
3.20 +1.80 -2.00 ± 0.50
CDF
PRD 61, 072005 (2000)
0.79 +0.41 -0.44
LHCb
PRL 115 (2015) 031601
0.73 ± 0.04 ± 0.02
Belle5S
PRL 108 (2012) 171801
0.57 ± 0.58 ± 0.06
Average
HFAG
0.69 ± 0.02
-2
-1
0
1
2
3

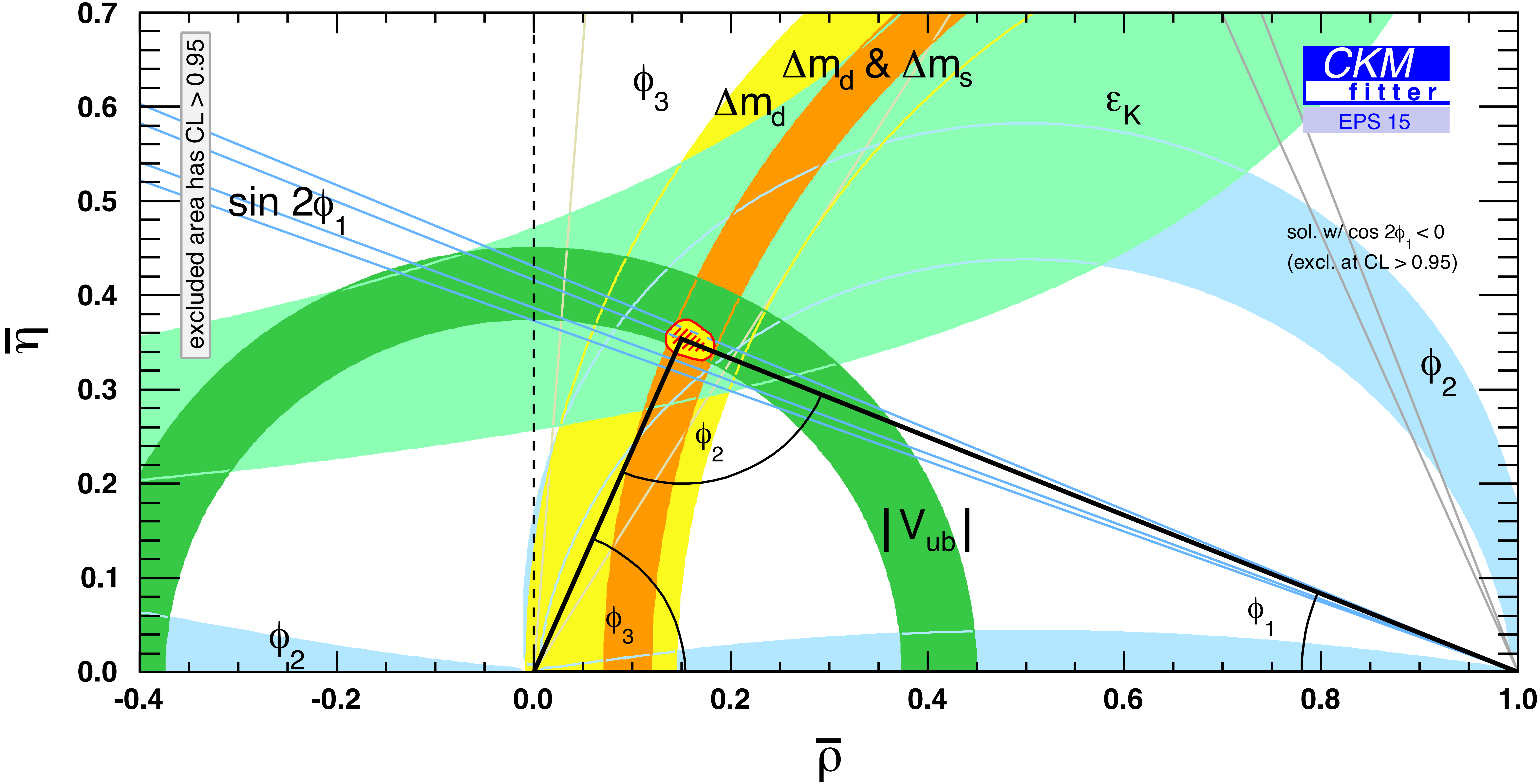


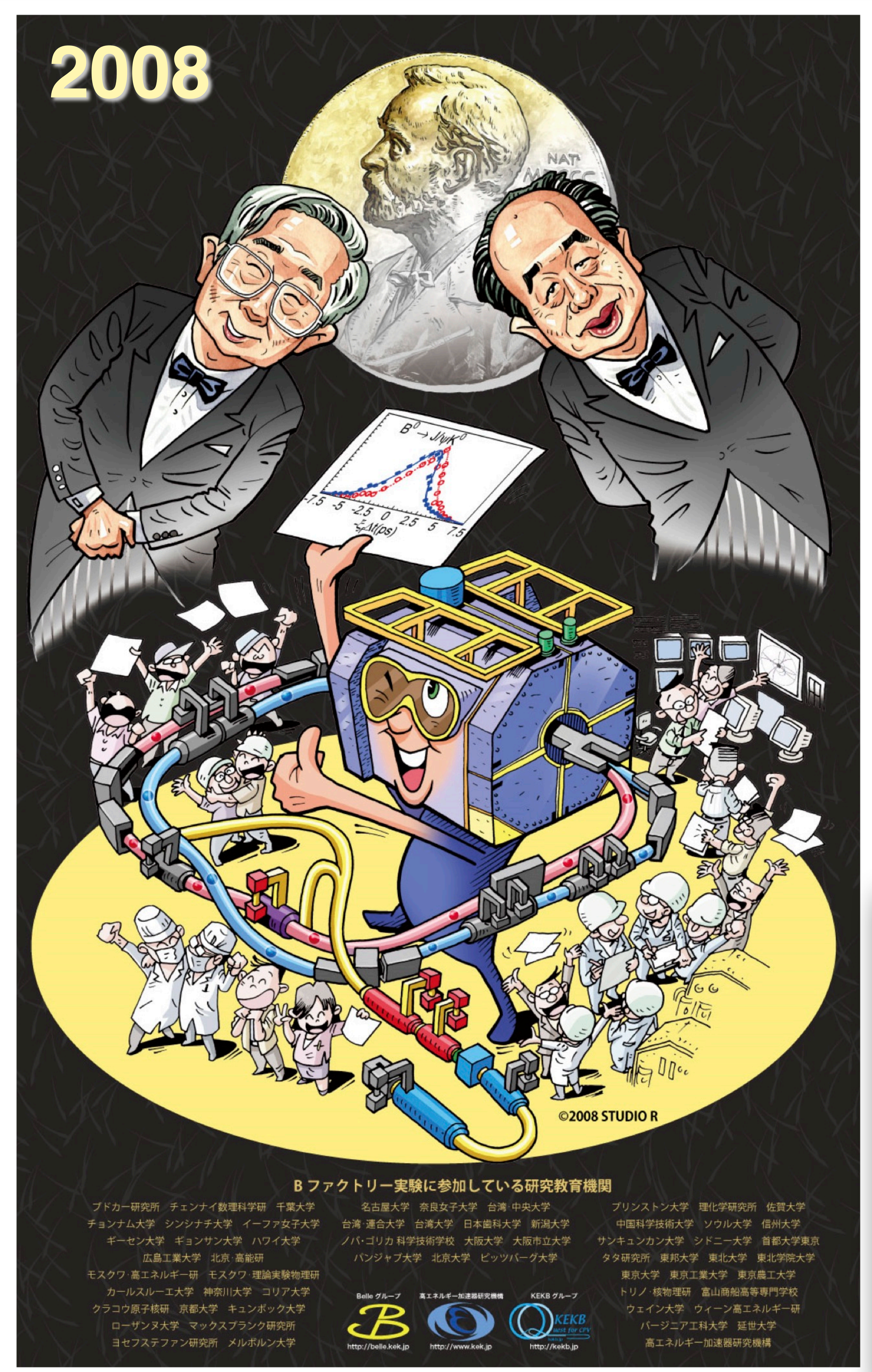
B0 tags
B̄0 tags
ηf=-1
ηf=+1
Events / (0.4 ps)
Raw Asymmetry
Δt (ps)
-5
0
5



End 1999
$\bar{\eta}$
1
0.8
0.6
0.4
0.2
0
-1
-0.5
0
0.5
1
$\bar{\rho}$

CKM UT as of 2015





Belle (and BaBar, too) achievements include:

- CPV, CKM, and rare decays of B mesons (and B_s, too)
- Mixing, CP, and spectroscopy of charmed hadrons, e.g. $D^*_{s0}(2317)^+$
- Quarkonium spectroscopy and discovery of (*many*) exotic states, e.g. $X(3872)$, $Z_c(4430)^+$
- Studies of τ and 2γ

Belle $\Longrightarrow$ Belle II

still not solved

- CP violation from KM hypothesis is not large enough to explain the matter-antimatter asymmetry in our Universe

--> We need New Physics!

- The origin of the Flavor structure of Standard Model is totally unknown

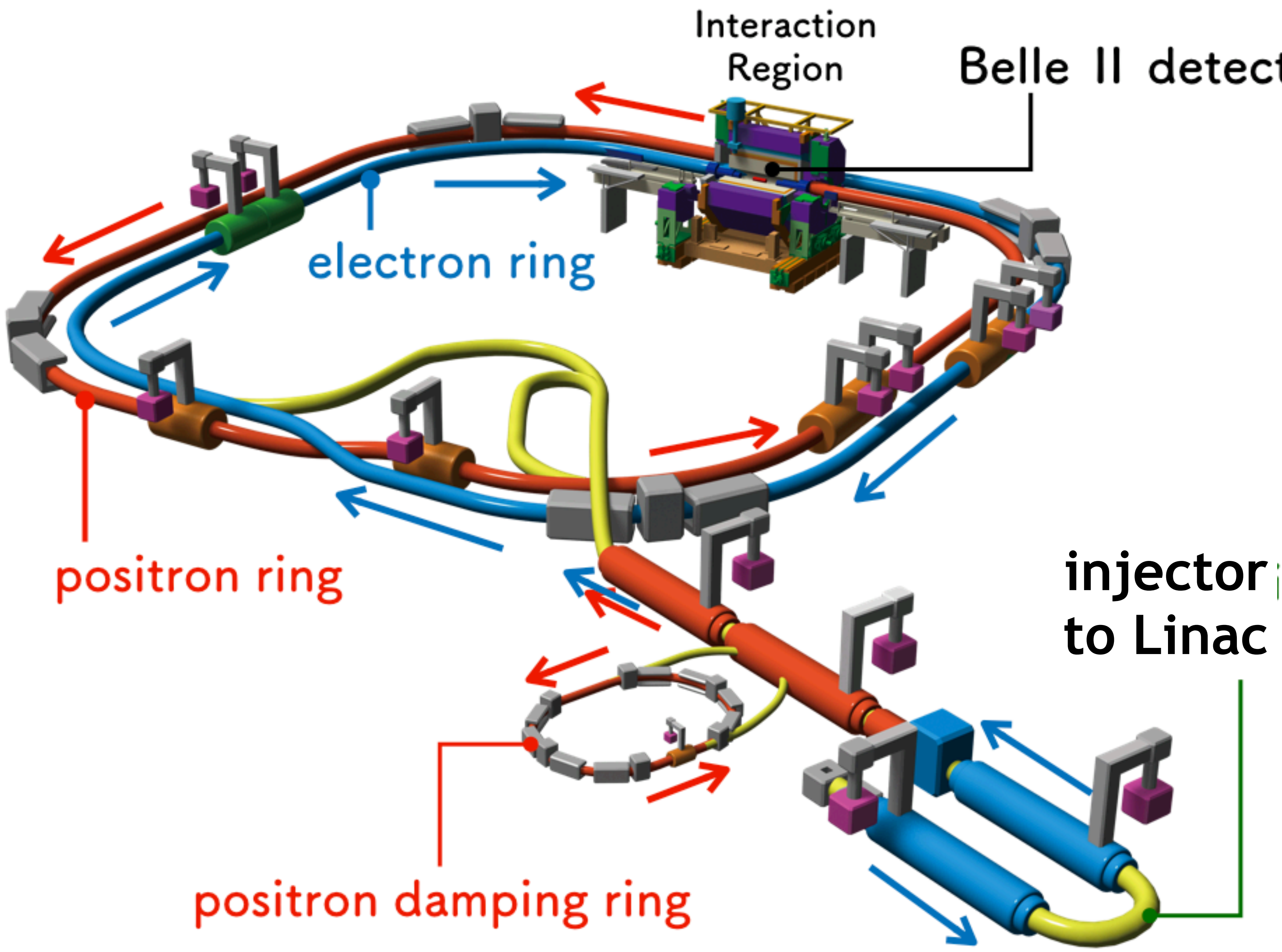
upgrade Belle —> Belle II

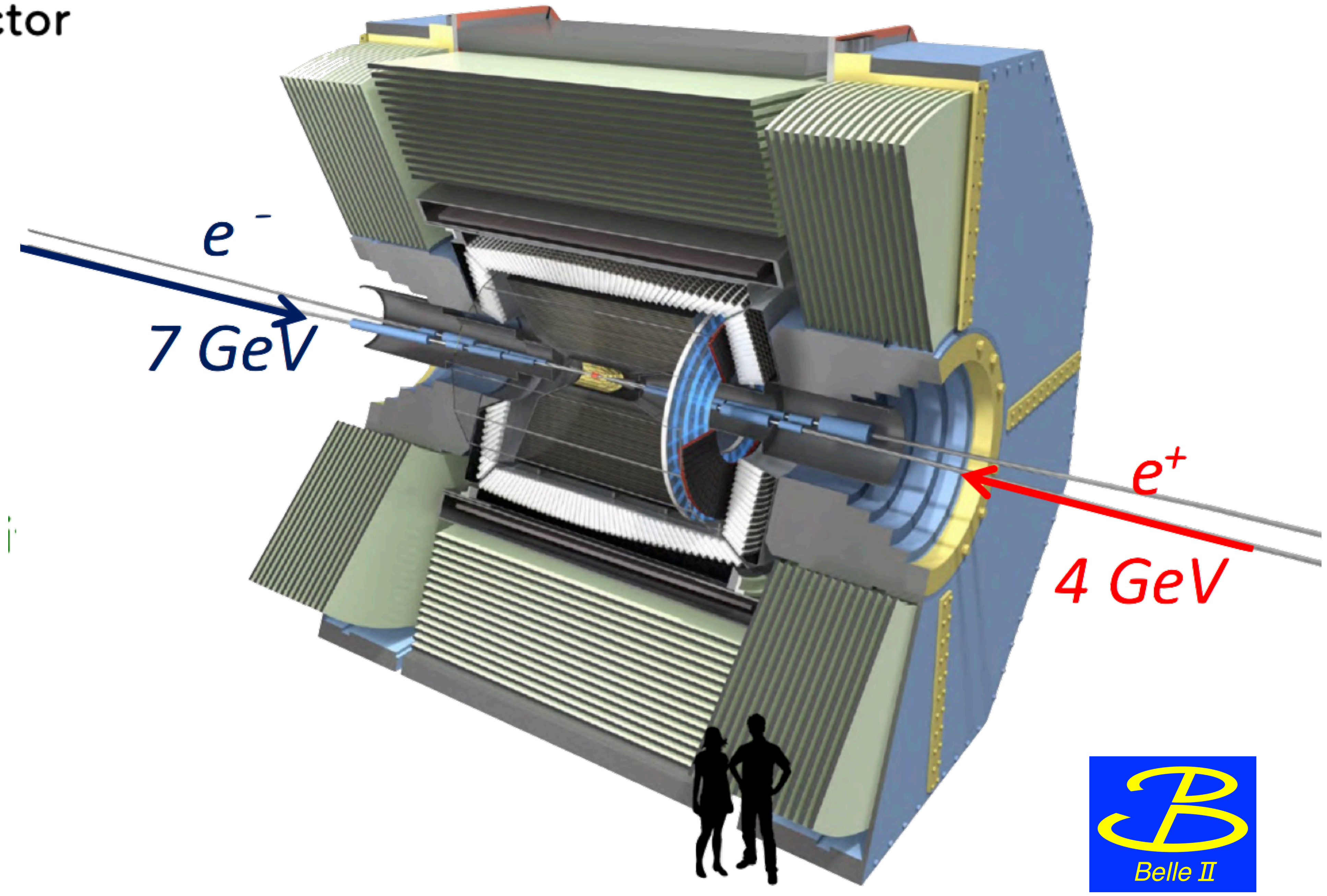
- KEKB is upgraded to SuperKEKB (x30 peak luminosity)
- aiming at x50 total data size
- Belle detector is also upgraded to Belle II
- 총예산 약 6,500 억원

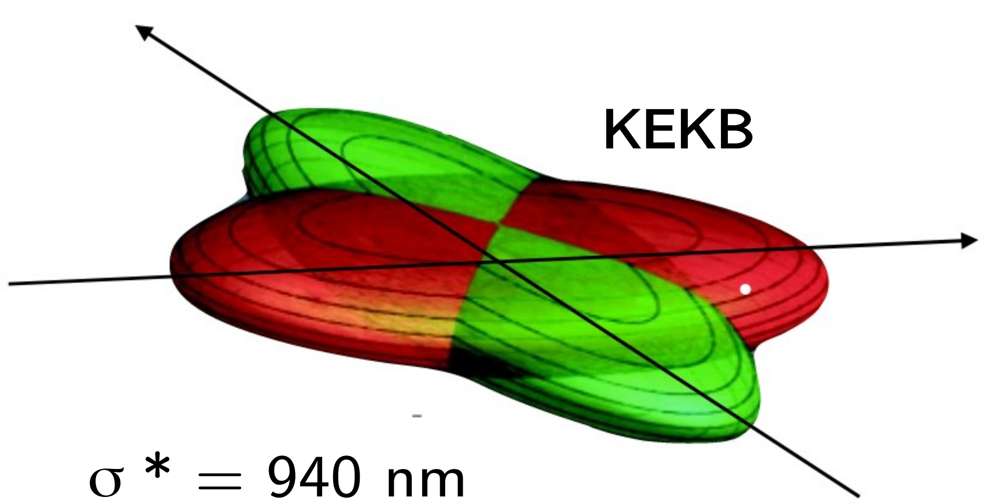
$$\mathcal{L}_{\rm peak} = 6.5 \times 10^{35}\ {\rm cm}^{-2}{\rm s}^{-1}$$

$$\int^{\rm goal} \mathcal{L}\ dt = 50\ {\rm ab}^{-1}$$

SuperKEKB $e^- \xrightarrow{7\text{ GeV}} (\star) \xleftarrow{4\text{ GeV}} e^+$ Belle II



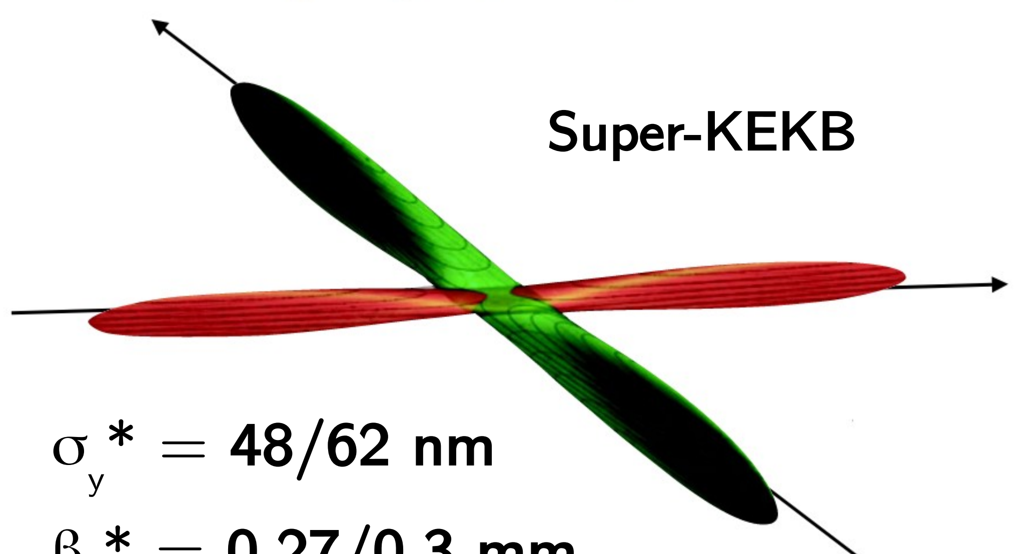




$\sigma_y{}^* = 940$ nm

$\beta_y{}^* = 5.9$ mm

$\sigma_x{}^* = 147/170$ μm



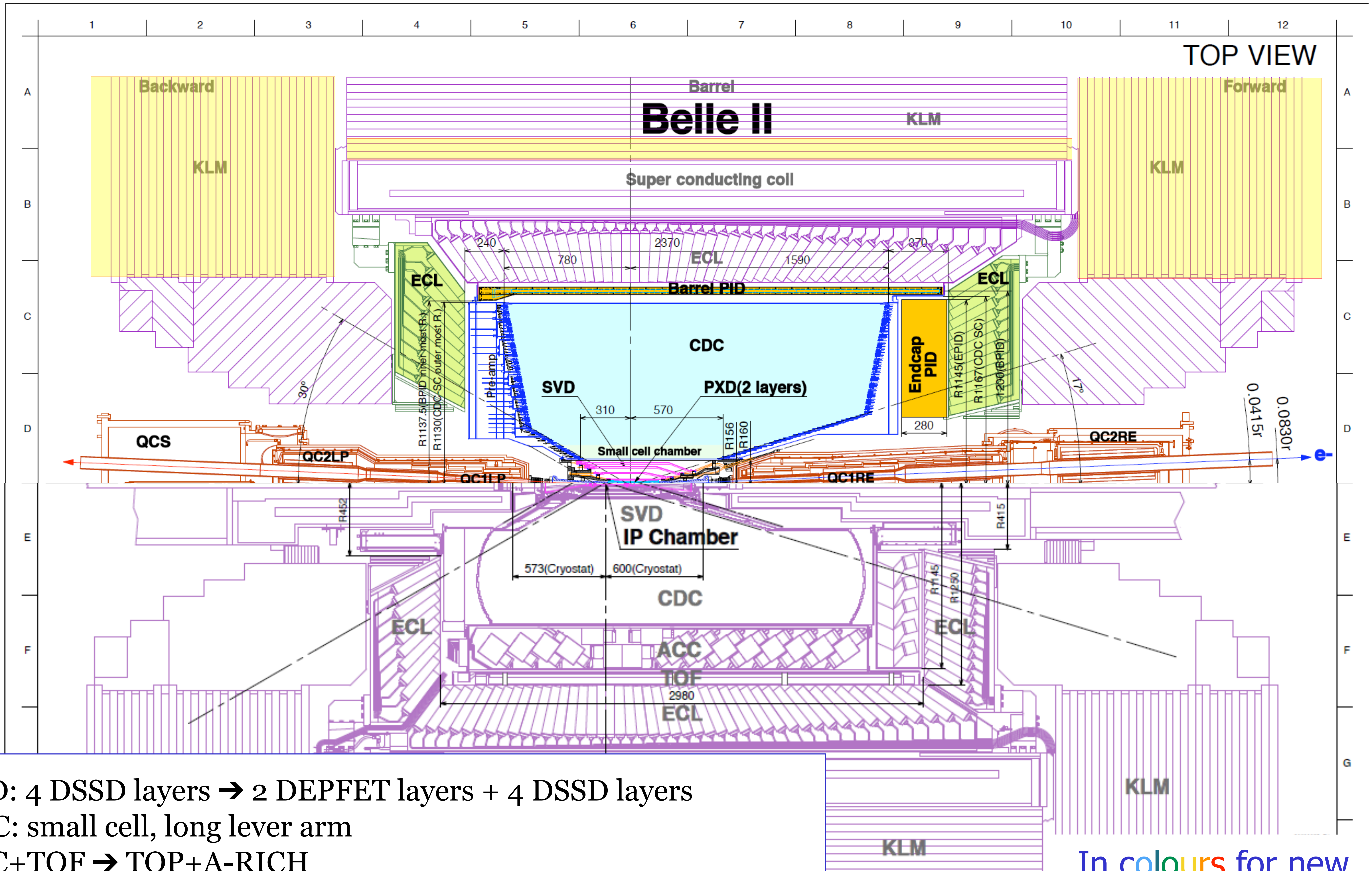
$\sigma_y{}^* = 48/62$ nm

$\beta_y{}^* = 0.27/0.3$ mm

$\sigma_x{}^* = 10.1/10.7$ μm

$$\mathcal{L}_{\text{II}}^{\text{peak}} \approx 30 \times \mathcal{L}_{\text{I}}^{\text{peak}}$$

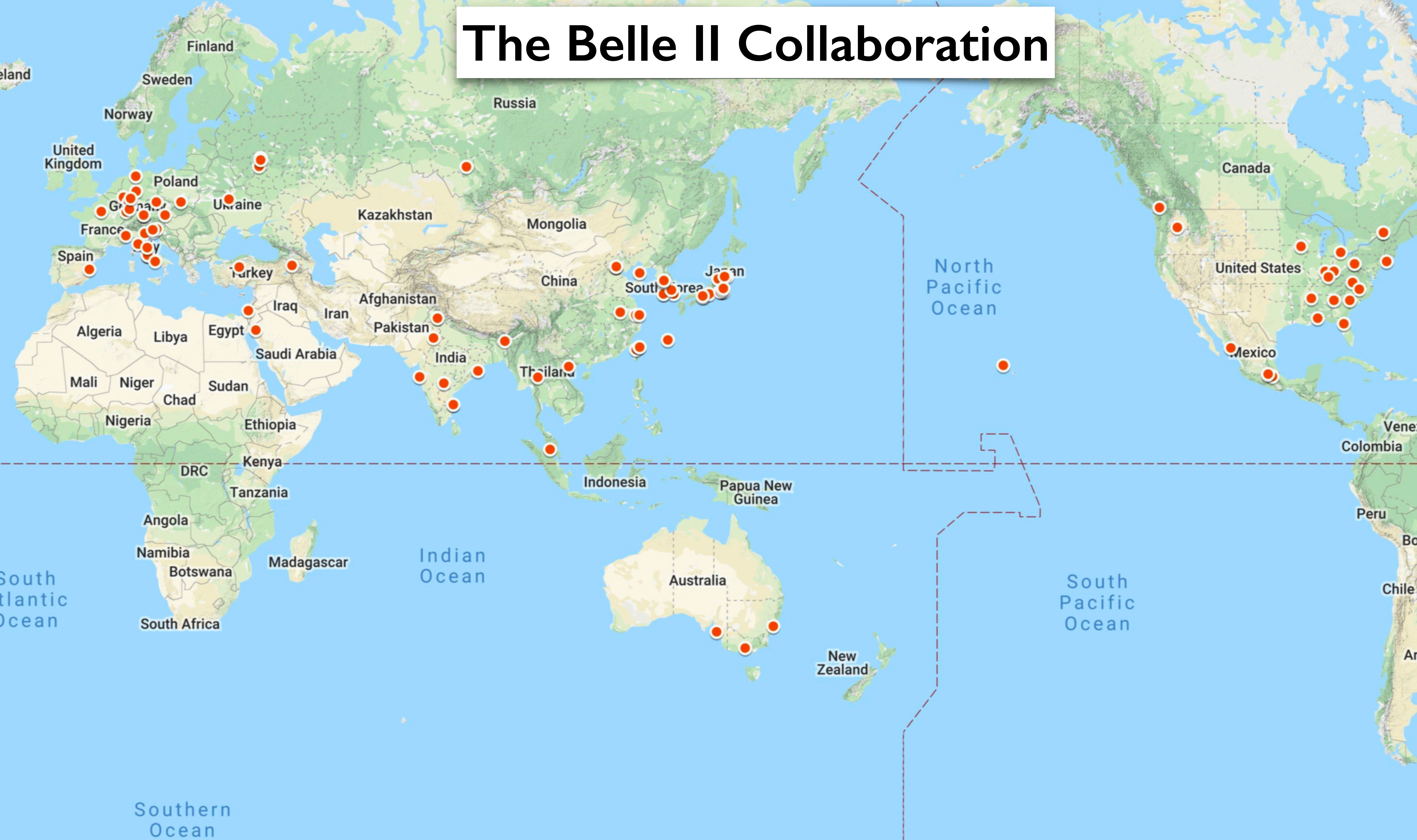
$$\int^{\text{goal}} \mathcal{L}_{\text{II}}\, dt = 50\ \text{ab}^{-1} \approx 50 \int \mathcal{L}_{\text{I}}\, dt$$



SVD: 4 DSSD layers ➔ 2 DEPFET layers + 4 DSSD layers
CDC: small cell, long lever arm
ACC+TOF ➔ TOP+A-RICH
ECL: waveform sampling
KLM: RPC ➔ Scintillator +MPPC (endcaps, barrel inner 2 lyrs)

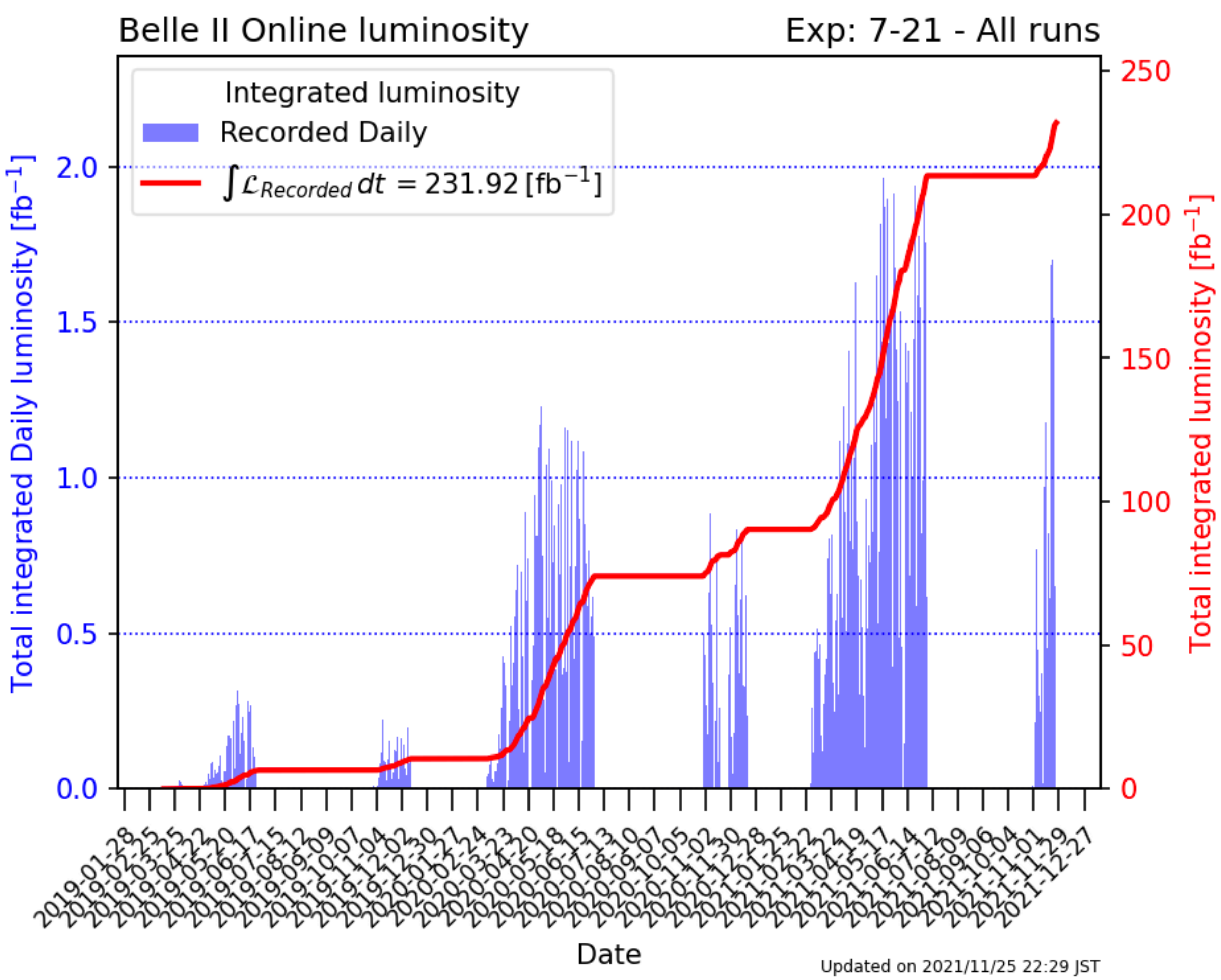
In colours for new components

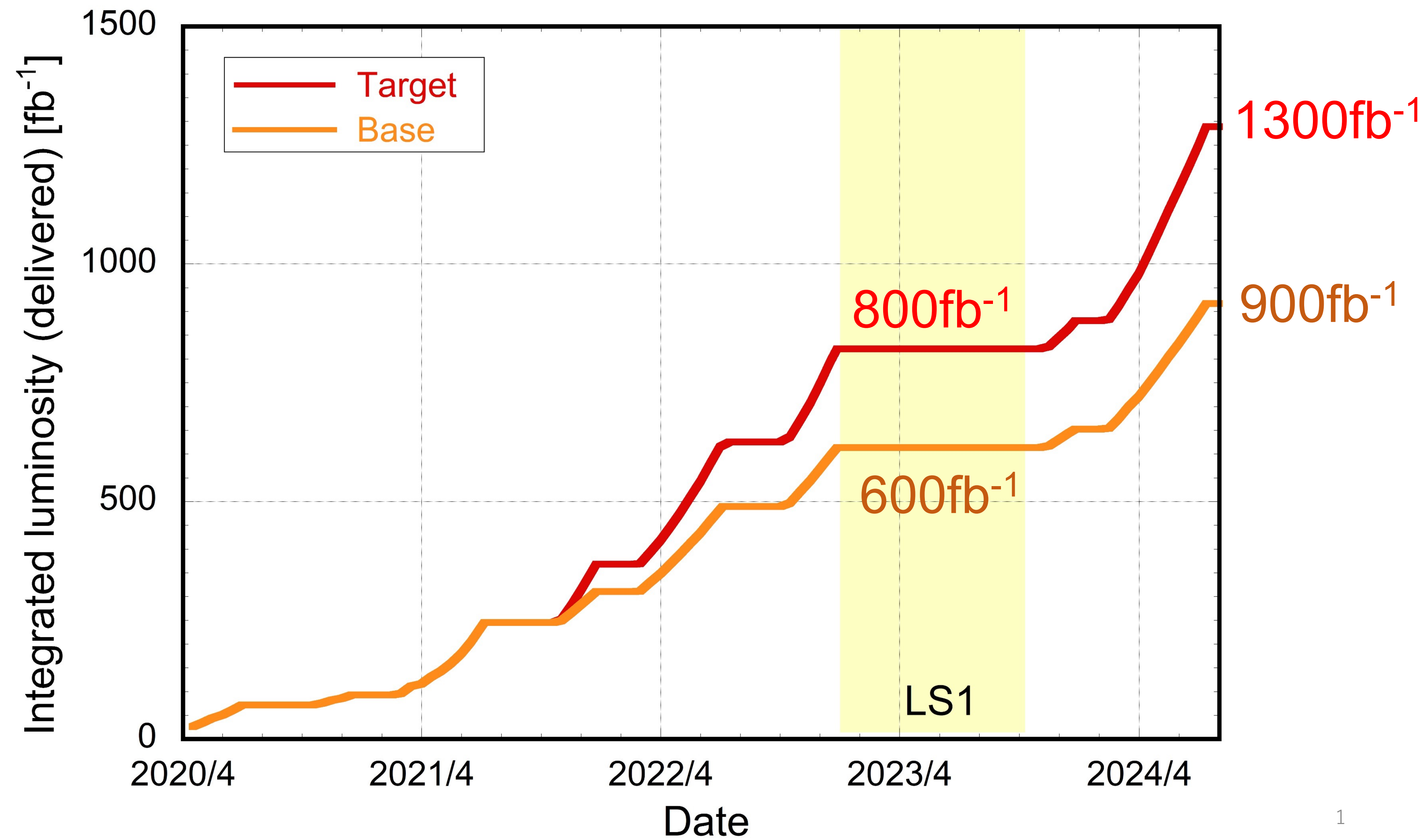
The Belle II Collaboration



26 countries/regions, ~120 institutions, ~1000 collaborators

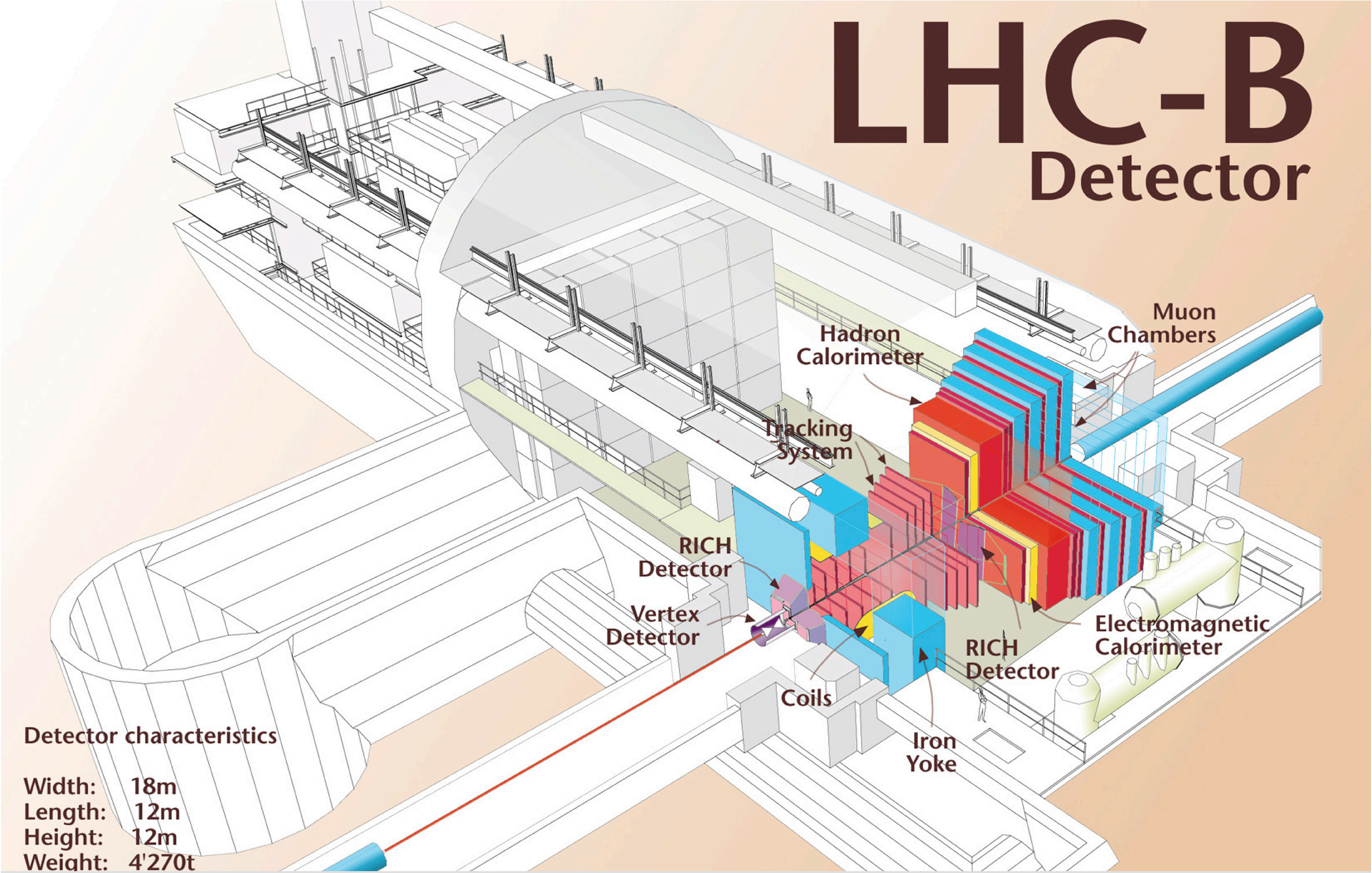
Belle II Luminosity - past & prospects





Belle II has been in operation through the Pandemic era, with modified working mode in accordance with the anti-pandemic policy. (*See back-up slide!*)

LHC-B Detector



Detector characteristics

Width: 18m
Length: 12m
Height: 12m
Weight: 4'270t

Position of Belle (II) in world HEP

- 입자물리학의 “Three Frontiers” (US/DOE)
  - Energy Frontier / Intensity Frontier / Cosmic Frontier
- Intensity Frontier의 두 주역
  - LHCb 실험 vs. Belle II 실험
- “Belle II 실험은 π^0, missing ν, full-recon tagging 등 LHCb에서는 할 수 없는 고유의 연구 영역을 확보하고 있는 세계 유일의 실험이기에 독창적이고, Intensity Frontier 연구, 특히 입자물리 맛깔 구조 연구에 가장 적합한 실험이다.”

Belle II vs. LHCb

complementarity at a glance

Observable	SM prediction	
$\lvert V_{us}\rvert$ $[K \to \pi\ell\nu]$	input	
$\lvert V_{cb}\rvert$ $[B \to X_c\ell\nu]$	input	Belle II
$\lvert V_{ub}\rvert$ $[B \to \pi\ell\nu]$	input	Belle II
γ $[B \to DK]$	input	LHCb/Belle II
$S_{B_d\to\psi K}$	$\sin(2\beta)$	Belle II/LHCb
$S_{B_s\to\psi\phi}$	0.036	LHCb
$S_{B_d\to\phi K}$	$\sin(2\beta)$	Belle II/LHCb
$S_{B_s\to\phi\phi}$	0.036	LHCb
$S_{B_d\to K^*\gamma}$	few $\times$ 0.01	Belle II
$S_{B_s\to\phi\gamma}$	few $\times$ 0.01	LHCb
$A^d_{\rm SL}$	-5×10^{-4}	Belle II/LHCb
$A^s_{\rm SL}$	2×10^{-5}	LHCb
$A_{CP}(b\to s\gamma)$	< 0.01	Belle II
$\mathcal{B}(B\to\tau\nu)$	1×10^{-4}	Belle II
$\mathcal{B}(B\to\mu\nu)$	4×10^{-7}	Belle II
$\mathcal{B}(B_s\to\mu^+\mu^-)$	3×10^{-9}	LHCb
$\mathcal{B}(B_d\to\mu^+\mu^-)$	1×10^{-10}	LHCb
$A_{\rm FB}(B\to K^*\mu^+\mu^-)_{q_0^2}$	0	LHCb
$B\to K\nu\bar{\nu}$	4×10^{-6}	Belle II
$\lvert q/p\rvert_{D-\rm mixing}$	1	Belle II
ϕ_D	0	Belle II
$\mathcal{B}(K^+\to\pi^+\nu\bar{\nu})$	8.5×10^{-11}	
$\mathcal{B}(K_L\to\pi^0\nu\bar{\nu})$	2.6×10^{-11}	
$R^{(e/\mu)}(K\to\pi\ell\nu)$	2.477×10^{-5}	
$\mathcal{B}(t\to c\,Z,\gamma)$	$\mathcal{O}(10^{-13})$	

adapted from

1. **Flavor Physics Constraints for Physics Beyond the Standard Model**
Gino Isidori (Frascati & TUM-IAS, Munich), Yosef Nir, Gilad Perez (Weizmann Inst.). Feb 2010. 33 pp.
Published in **Ann.Rev.Nucl.Part.Sci. 60 (2010) 355**

End of Part I

Any questions?