Project B_05
Increasing sensitivities to physics beyond the SM in B physics

Koji Hara (KEK)

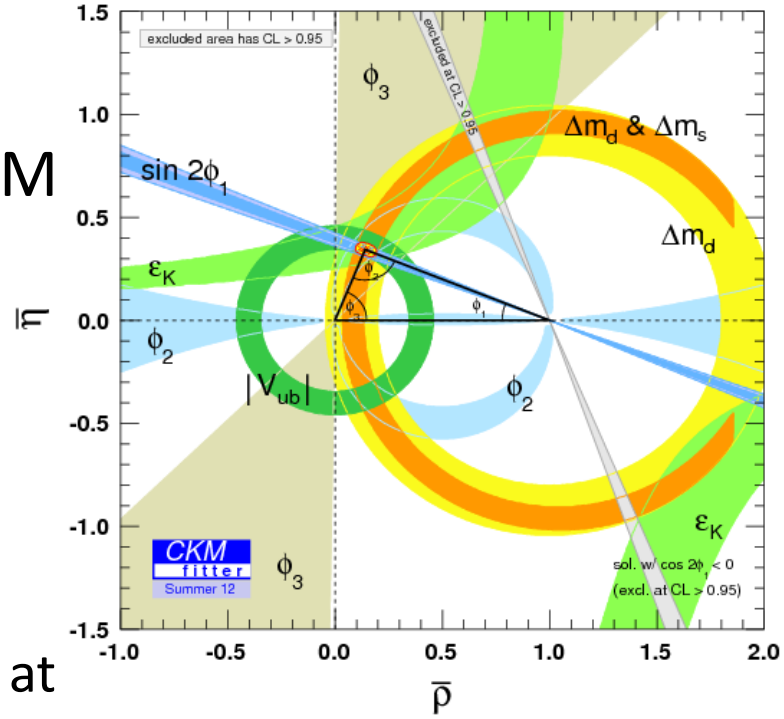
2013 Joint Workshop of the TYL(FJPPL) and FKPPL

Role of B physics

In Belle and BaBar era

- Confirmation of CKM model in the SM

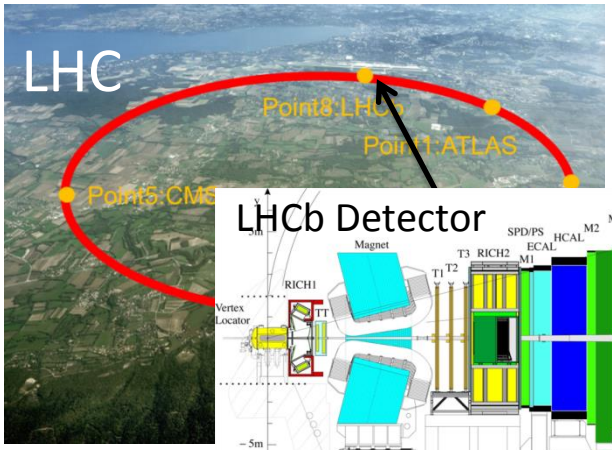
→Consistency confirmed at 5% level



- Still room for New Physics (NP)
  - Need additional CP violation phase to explain matter-dominated universe
  - LHC may find new particles beyond SM at TeV scale

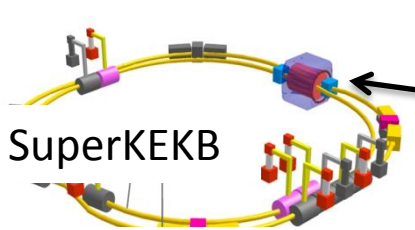
- Next target: Search for NP and determine the NP model

Complementary B physics Experiments: Belle II and LHCb

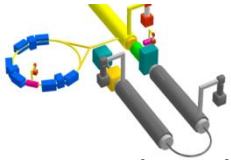


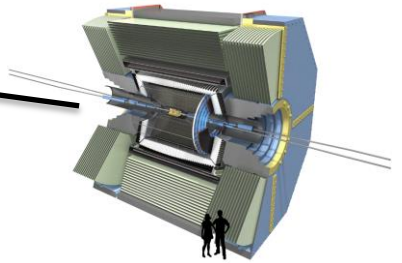
- b physics experiment at LHC
- Huge bb production rate, many kinds of B hadrons
- Higher sensitivity for B decays with charged particles

Recorded 2.1 fb^{-1}(2012) + 1.1 fb^{-1} (2011)
→ 26 x 10^{10} $b\bar{b}$



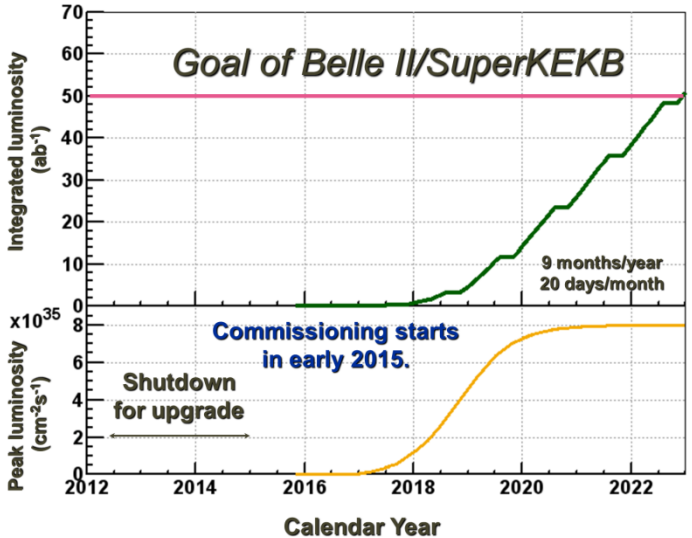
Target: L = $8 \times 10^{35}/cm^2/s$





Belle II detector

- BB pair produced by 4 GeV e^+ + 7GeV e-
- No additional particles to the $B\bar{B}$ pair
- Higher sensitivity for B decays with neutrals and missing energy



Goal of the Project

- Maximize the B physics sensitivities to NP
- Key method: Global Fit including NP effects
  - Search for a hint of New Physics combining experimental and theoretical inputs
  - NP model determination if it is found
- Need detailed study of
  - Theoretical uncertainties: not only SM but also NP model calculation
  - Experimental uncertainties in the analyses at different experiments (Belle and LHCb)
  - Observables that sensitive to NP in terms of both theory and experiment

→Establish a collaboration between experiments and theorists
→Establish the bench mark models

Project Members

JP

KEK

Koji Hara

Ryosuke Itoh

Exp. Belle/ Belle II

Kavli IPMU

Takeo Higuchi

KEK

Shoji Hashimoto

Toru Goto

Th.

FR

LAL/IN2P3

Marie-Helene Schune

Martino Borsato

Exp. LHCb

LPNHE/IN2P3

Francesco Polci

LAL/IN2P3

Emi Kou

LPT/INP

Benoit Blossier

Th.

→ Establish collaboration of Belle II and LHCb experiments, and theorists

Current Activities of Project Members

- 1st Meeting have been held on May 21
  - Exchanged information of on-going projects at Japan and France

On-going Japan group projects

- NP(New Physics)-Japan and JLQCD

On-going France group projects

- Experimental and theoretical analysis of $B \rightarrow K^* \mu^+ \mu^- / K^* e^+ e^- / K_1 \gamma$

NP(New Physics)-Japan

Member

- 13 Experimentalists (Belle)

  R. Itoh, K. Hara, T. Higuchi et al.

- 9 Theorists

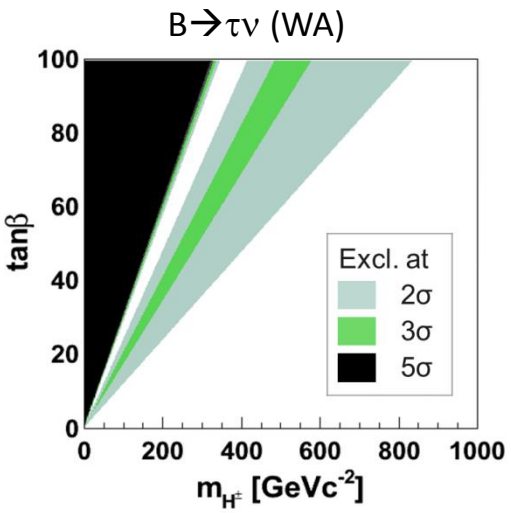
  S. Hashimoto, T. Goto, et al.

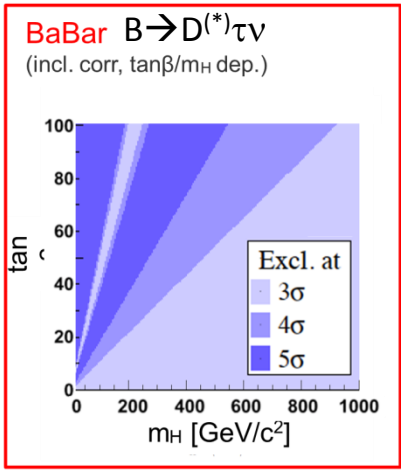
Original Target: Develop strategy to search for New Physics using Belle II

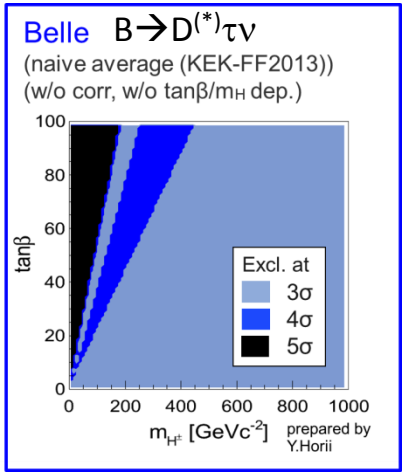
- Search for a hint of new physics by the Global Fit
- Search for the physical observables which is sensitive to the new physics
- NP model determination
- Combine theoretical and experimental studies

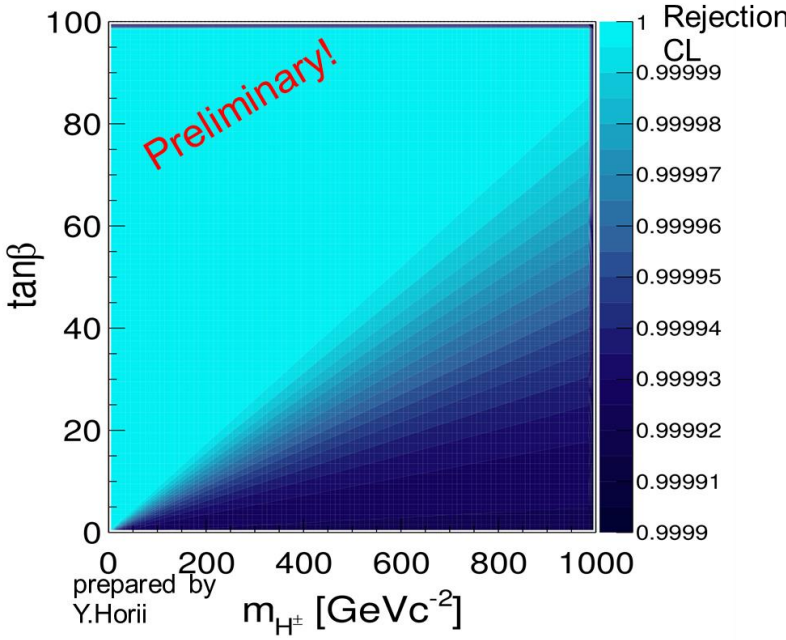
Global Fitter including NP

- Developing global Fitter including NP effects (R. Itoh et al.)
  - Example: simultaneous fit of $B \to \tau\nu$ and $B \to D(*)\tau\nu$ for the charged Higgs effect of 2HDM TypeII
    - Using Br. Measurements of Belle and BaBar









2HDM Type II is rejected at more than 99.99% CL in the shown range by $B \to \tau\nu$ + $B \to D^{(*)}\tau\nu$

B→D(*)τν MC Event Generator including New Physics Effects

- For the NP sensitivity study with the full detector simulation
  - Ratio of Br. to B→D(*)lν
  - Experimental sensitivity of other observables: q^2, polarization of τ, D*
  - NP model dependence (not only 2HDM Type II)
  - Any other physical observables sensitive to NP?

- K. Hara collaborating with theorists (M. Tanaka (Osaka) et al.)

- B→D(*)τν MC Event Generator including New Physics effect is under development
  - **Model independent approach** based on [M. Tanaka and R. Watanabe PRD87, 034028 (2013)]

Parameterization using Wilson Coefficients: (T.Goto, KEK)

$$\mathcal{L}_{\text{eff}} = \mathcal{L}(\text{QCD} + \text{QED}) + \sum_i C_i \mathcal{O}_i.$$

$\mathcal{O}_i$: Effective operators (Dimension > 4)

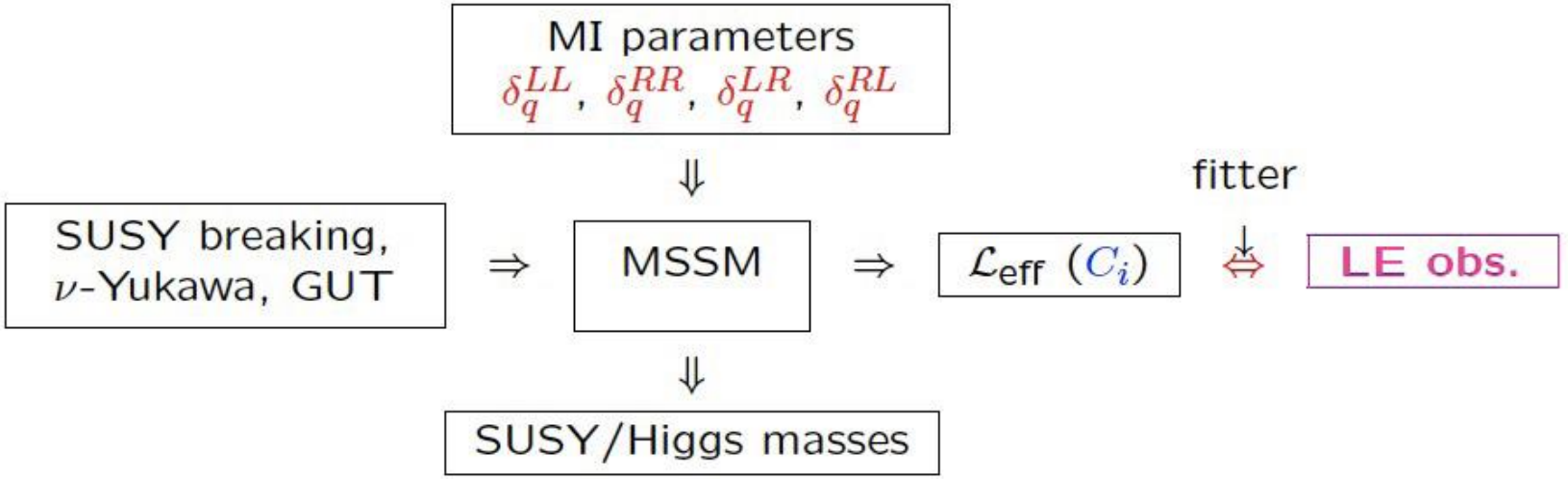
- 4-fermi interaction (dim-6): $(\overline{\psi}_1 \gamma^\mu \psi_2)(\overline{\psi}_3 \gamma_\mu \psi_4)$,
- dipole moment (dim-5): $\overline{\psi}_1 \sigma^{\mu\nu} \psi_2 F_{\mu\nu}$,

etc..

C_i: Wilson Coefficient

Discussing a way to determine Wilson coefficients by Global Fit

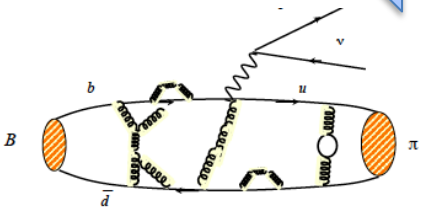
Example: expansion of MSSM to Effective Theory

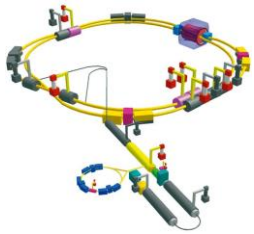


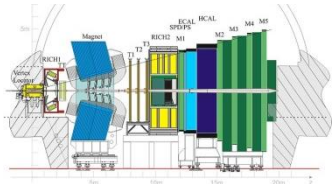
Lattice QCD studies for B physics

Standard Model
or New Physics

⊗ QCD correction = Exp







- Lattice QCD calculation
  - provides ab-initio calculation of Quantum Chromodynamics (QCD)
  - **an integral part of the B physics : form factors, etc.**
- JLQCD collaboration (spokesperson: S. Hashimoto)
  - O(10-20) members Japanese universities
  - machine: Hitachi SR16000, IBM Blue Gene/Q (KEK)
  - new series of simulations with fine lattices, new formulation for heavy quark
  - Now generating data, expecting another year for generation; physics calculations will follow.
  - Need close communication with phenomenologists and experimenters.

B→K*μμ and B→K*ee with LHCb

Martino Borsato (PhD) , Samuel Coquereau (PhD), Francesco Polci, Marie-Helene Schune

B→K*μμ
Part of a more global effort in LHCb
Full angular analysis performed with $1fb^{-1}$
Effect of the S-wave
Threshold effects

Analysis of the full dataset ($3fb^{-1}$) ongoing

B→K*ee
Only for the low q2 region (.0009 – 1 GeV^2) where it brings specific information
BR measurement for $1fb^{-1}$
Full angular analysis performed with 3 fb^{-1}

LAL-LPNHE:
$1fb^{-1}$ data: New results on forward-backward asymmetry obtained.
3fb-1 data: Improving the analysis taking into account various systematic effects.

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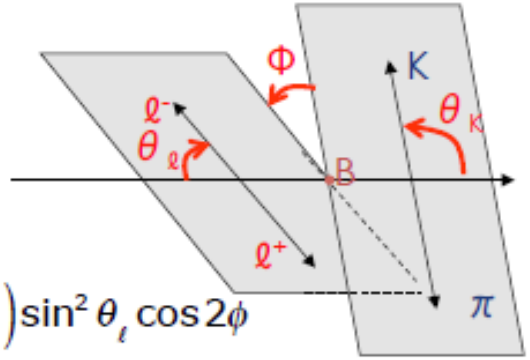
Only for the low q2 region (.0009 – 1 GeV^2) where it brings specific information
BR measurement for 1fb^{-1}
Full angular analysis performed with 3 fb^{-1}

LAL-LPNHE:
1fb^{-1} data: Signal of 4.6 sigma significance.
3fb^{-1} data: Angular analysis to study the photon polarization started!

B→K*μμ and B→K*ee with LHCb

Kruger and Matias hep-ph 0502060

$$\frac{d\Gamma}{dq^2 d\cos\theta_K d\cos\theta_\ell d\phi} = \frac{9}{32\pi} I\left(q^2, \cos\theta_K, \cos\theta_\ell, \phi\right)$$



The $C^{(\prime)}_{7..10}$ are encoded in the $I_{i=1,..9}$

$$I = I_1\left(q^2,\cos\theta_K\right) + I_2\left(q^2,\cos\theta_K\right)\cos 2\theta_\ell + I_3\left(q^2,\cos\theta_K\right)\sin^2\theta_\ell\cos 2\phi$$
$$+I_4\left(q^2,\cos\theta_K\right)\sin 2\theta_\ell\cos\phi + I_5\left(q^2,\cos\theta_K\right)\sin\theta_\ell\cos\phi +$$
$$I_6\left(q^2,\cos\theta_K\right)\cos\theta_\ell + I_7\left(q^2,\cos\theta_K\right)\sin\theta_\ell\sin\phi +$$
$$I_8\left(q^2,\cos\theta_K\right)\sin 2\theta_\ell\sin\phi + I_9\left(q^2,\cos\theta_K\right)\sin^2\theta_\ell\sin 2\phi$$

Goal of the project:
Angular analysis to test the left-handedness of the weak interaction and search for new physics

Model independent approach using OPE:

Right handed part (suppressed in SM)

$$H_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{tb}V_{ts}^* \sum_{i=7,9,10}\left(C_i(\mu)\times O_i(\mu) + C'_i(\mu)\times O'_i(\mu)\right)$$

C_i : short distance Wilson coefficient (pert.)

O_i : long distance operator (non-pert.)

B→K*μμ and B→K*ee with LHCb

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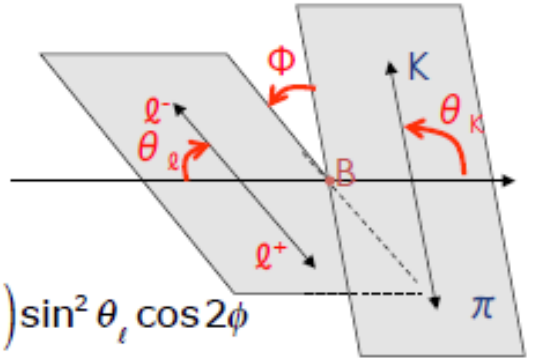

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TYL collaboration:
Which theoretical parameters should be extracted?
What information we will learn?
How to improve the analysis?

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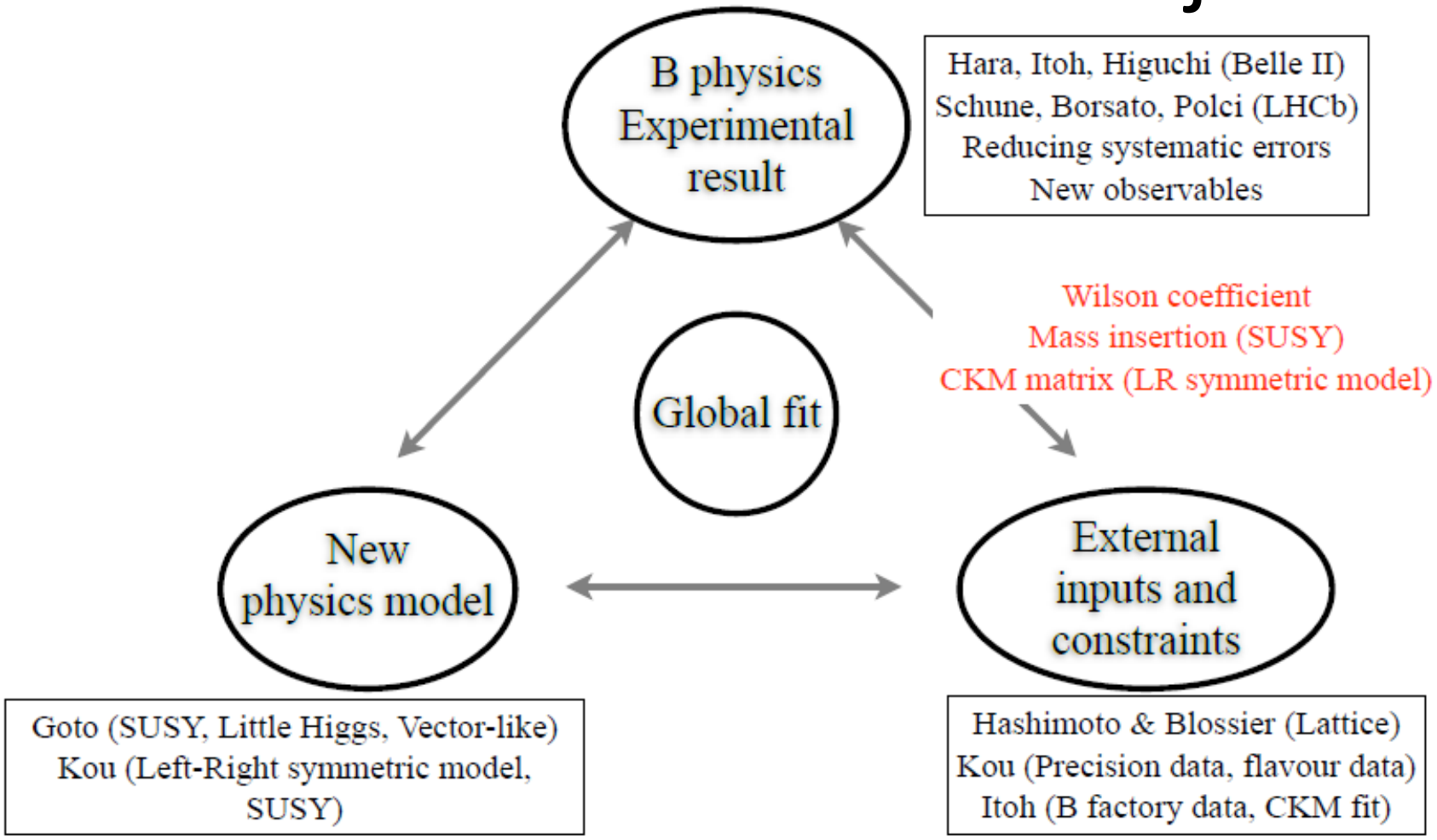
Global Picture of the Project



Key point: **Global fit** to search for the new physics

Close communication between Japan and France groups is important:

between experiments Belle II and LHCb, theorists, theory and experiment

Conclusion

- Global Fit is one of the key methods of new physics search
  - Search hint of new physics combining inputs
  - Determination of the NP if it is found

- Detailed both experimental and theoretical studies are important
  - NP model calculation
  - Theoretical and experimental uncertainties
  - Selection of observables that are sensitive to NP

→By this TYL project, we would like to establish a collaboration of Belle II and LHCb experimentalists and theorists for these studies.

→ Establish the benchmark models

cpmplementary measurements at LHCb and Belle II

[G. Isidori, Y. Nir, G. Perez arxiv:1002.0900]

Observable	SM prediction	Theory error	Present result	Future error	Future Facility
$\|V_{us}\|$ $[K \to \pi\ell\nu]$	input	$0.5\% \to 0.1\%_{\rm Latt}$	0.2246 ± 0.0012	0.1%	K factory
$\|V_{cb}\|$ $[B \to X_c\ell\nu]$	input	1%	$(41.54 \pm 0.73) \times 10^{-3}$	1%	Super-B
$\|V_{ub}\|$ $[B \to \pi\ell\nu]$	input	$10\% \to 5\%_{\rm Latt}$	$(3.38 \pm 0.36) \times 10^{-3}$	4%	Super-B
γ $[B \to DK]$	input	$< 1°$	$(70^{+27}_{-30})°$	3°	LHCb
$S_{B_d \to \psi K}$	$\sin(2\beta)$	$\lesssim 0.01$	0.671 ± 0.023	0.01	LHCb
$S_{B_s \to \psi\phi}$	0.036	$\lesssim 0.01$	$0.81^{+0.12}_{-0.32}$	0.01	LHCb
$S_{B_d \to \phi K}$	$\sin(2\beta)$	$\lesssim 0.05$	0.44 ± 0.18	0.1	LHCb
$S_{B_s \to \phi\phi}$	0.036	$\lesssim 0.05$	—	0.05	LHCb
$S_{B_d \to K^*\gamma}$	few $\times$ 0.01	0.01	-0.16 ± 0.22	0.03	Super-B
$S_{B_s \to \phi\gamma}$	few $\times$ 0.01	0.01	—	0.05	LHCb
$A^d_{\rm SL}$	-5×10^{-4}	10^{-4}	$-(5.8 \pm 3.4) \times 10^{-3}$	10^{-3}	LHCb
$A^s_{\rm SL}$	2×10^{-5}	$< 10^{-5}$	$(1.6 \pm 8.5) \times 10^{-3}$	10^{-3}	LHCb
$A_{CP}(b \to s\gamma)$	< 0.01	< 0.01	-0.012 ± 0.028	0.005	Super-B
$\mathcal{B}(B \to \tau\nu)$	1×10^{-4}	$20\% \to 5\%_{\rm Latt}$	$(1.73 \pm 0.35) \times 10^{-4}$	5%	Super-B
$\mathcal{B}(B \to \mu\nu)$	4×10^{-7}	$20\% \to 5\%_{\rm Latt}$	$< 1.3 \times 10^{-6}$	6%	Super-B
$\mathcal{B}(B_s \to \mu^+\mu^-)$	3×10^{-9}	$20\% \to 5\%_{\rm Latt}$	$< 5 \times 10^{-8}$	10%	LHCb
$\mathcal{B}(B_d \to \mu^+\mu^-)$	1×10^{-10}	$20\% \to 5\%_{\rm Latt}$	$< 1.5 \times 10^{-8}$	[?]	LHCb
$A_{\rm FB}(B \to K^*\mu^+\mu^-)_{q^2_0}$	0	0.05	(0.2 ± 0.2)	0.05	LHCb
$B \to K\nu\bar{\nu}$	4×10^{-6}	$20\% \to 10\%_{\rm Latt}$	$< 1.4 \times 10^{-5}$	20%	Super-B
$\|q/p\|_{D-\rm mixing}$	1	$< 10^{-3}$	$(0.86^{+0.18}_{-0.15})$	0.03	Super-B
ϕ_D	0	$< 10^{-3}$	$(9.6^{+8.3}_{-9.5})°$	2°	Super-B
$\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu})$	8.5×10^{-11}	8%	$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$	10%	K factory
$\mathcal{B}(K_L \to \pi^0\nu\bar{\nu})$	2.6×10^{-11}	10%	$< 2.6 \times 10^{-8}$	[?]	K factory
$R^{(e/\mu)}(K \to \pi\ell\nu)$	2.477×10^{-5}	0.04%	$(2.498 \pm 0.014) \times 10^{-5}$	0.1%	K factory
$\mathcal{B}(t \to cZ, \gamma)$	$\mathcal{O}(10^{-13})$	$\mathcal{O}(10^{-13})$	$< 0.6 \times 10^{-2}$	$\mathcal{O}(10^{-5})$	LHC ($100\,{\rm fb}^{-1}$)