

B05: Flavour physics: joint efforts towards searching for physics beyond the SM

Emi Kou (LAL-IN2P3)
on behalf of M.-H. Schune & K. Hara

26th May 2014 @ Bordeaux

Flavour Physics

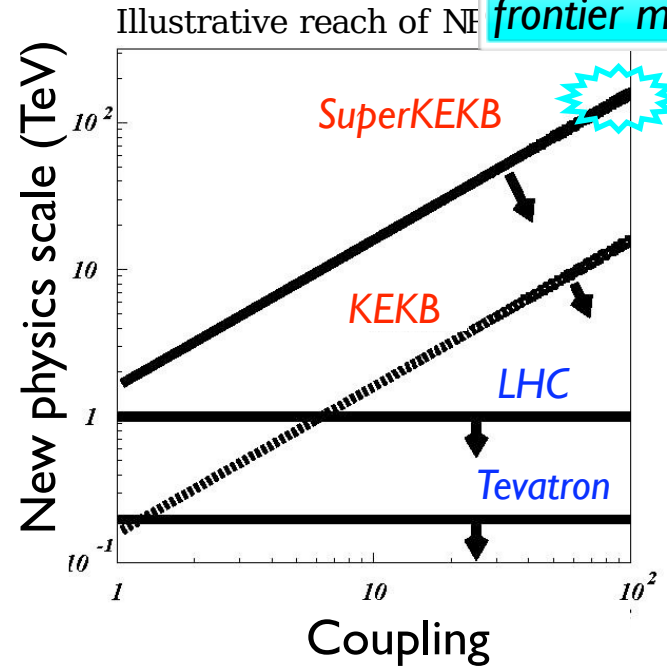
Discovery of New Physics



Energy Frontier?
ATLAS, CMS, (ILC)

Intensity Frontier?
LHCb, Belle II, (ILC)

Indirect probe
beyond the energy
frontier machines!



Observable/mode	Current $\sim 1 \text{ ab}^{-1}$	LHCb (2017) 5 fb^{-1}	Belle II (2022) 50 ab^{-1}	LHCb upgrade 50 fb^{-1}	Theory
τ Decays					
$\tau \rightarrow \mu\gamma$	Yellow	Green	Green	Yellow	Green
$\tau \rightarrow e\gamma$	Yellow	Green	Green	Yellow	Green
$B_{u,d}$ Decays					
$B \rightarrow \tau\nu, \mu\nu$	Yellow	Red	Blue	Red	Blue
$B \rightarrow K^{(*)}\nu\bar{\nu}$	Red	Green	Green	Red	Green
S in $B \rightarrow K_s^0\pi^0\gamma$	Yellow	Red	Green	Red	Yellow
S (other penguin modes)	Yellow	Yellow	Green	Blue	Yellow
$A_{CP}(B \rightarrow X_s\gamma)$	Blue	Yellow	Green	Yellow	Green
$\text{BR}(B \rightarrow X_s\gamma)$	Blue	Yellow	Green	Yellow	Yellow
$\text{BR}(B \rightarrow X_s ll)$	Yellow	Red	Green	Red	Green
$\text{BR}(B \rightarrow K^{(*)} ll)$	Yellow	Blue	Green	Red	Yellow
B_s Decays					
$B_s \rightarrow \mu\mu$	Red	Blue	Red	Green	Green
β_S from $B_s \rightarrow J/\psi\phi$	Red	Blue	Red	Red	Green
$B_s \rightarrow \gamma\gamma$	Red	Red	Blue	Red	Green
a_{st}	Red	Blue	Green	Green	Green
D Decays					
Mixing parameters	Yellow	Blue	Green	Green	Green
CP Violation	Red	Blue	Green	Green	Green

- Very precise 😊😊😊
- Precise 😊
- Moderate precise 😞
- No result 😞😞😞

LHCb and Belle II are perfectly complementary!

This TYL project
Belle II-LHCb joint effort

This TYL project

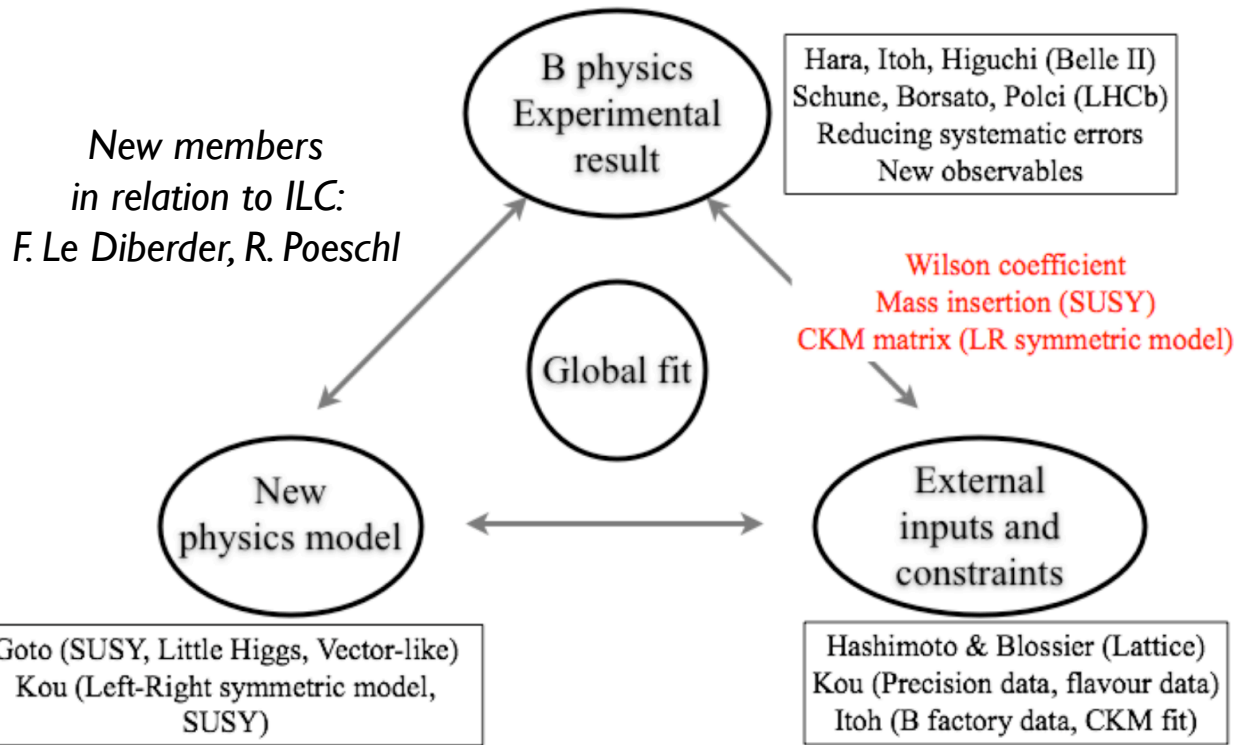
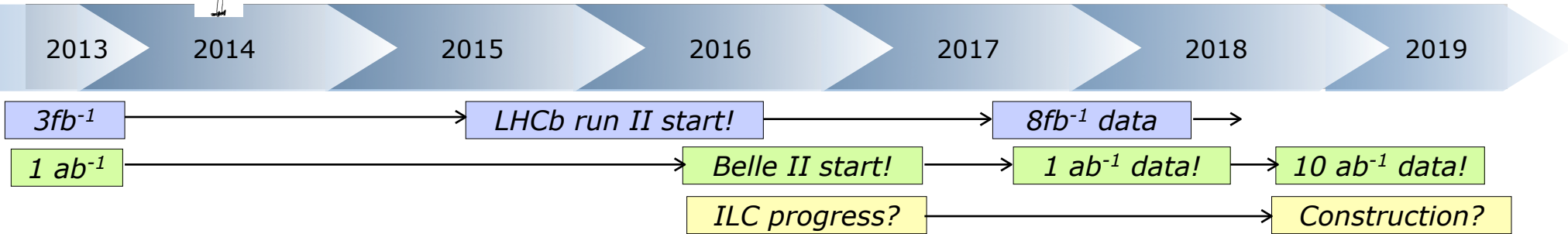
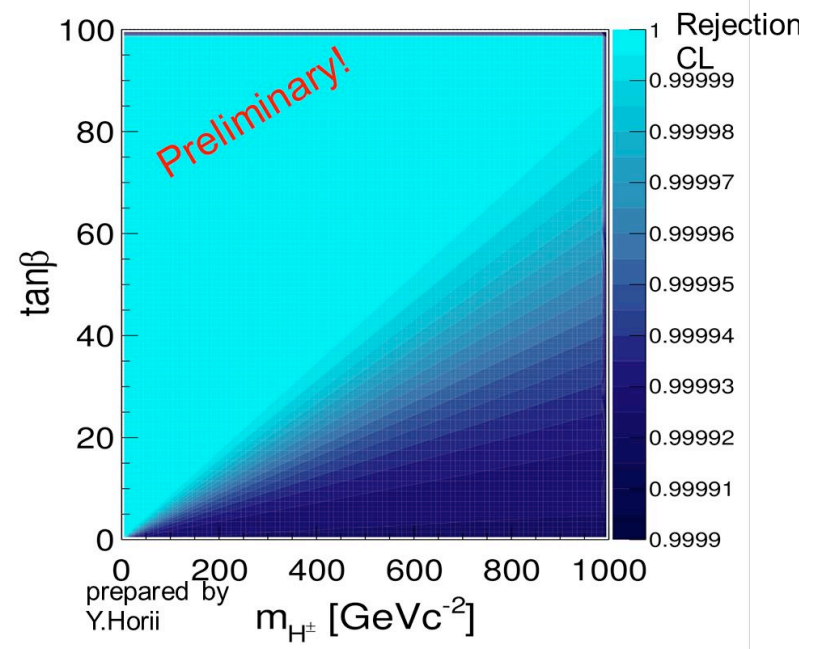
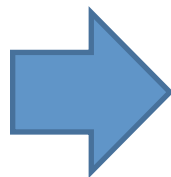
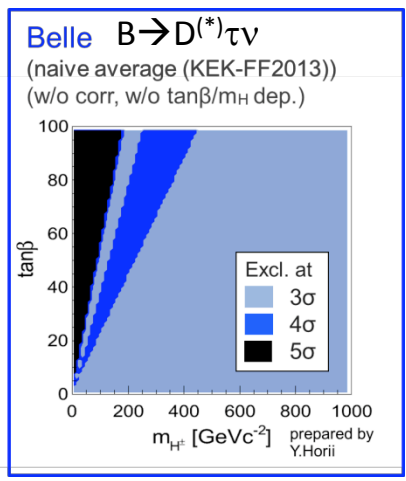
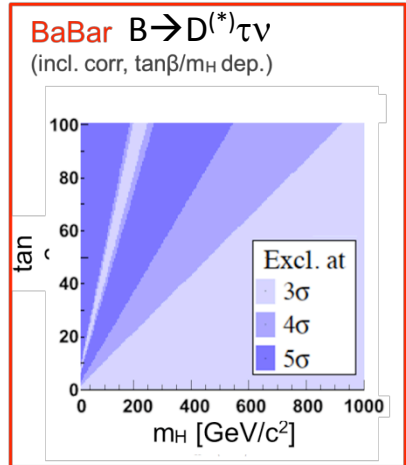
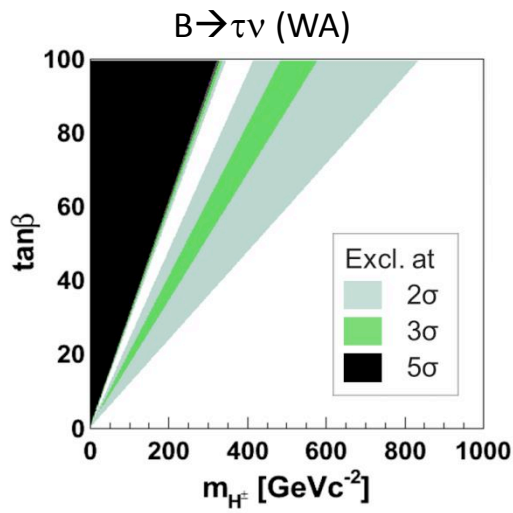


Figure 1: Schematic description of our project.
from our proposal

- ✓ Re-examine the **viability of the new physics models** taking into account the LHC 7-8 TeV results.
- ✓ Determine the new **benchmark models and their search strategies** for the forthcoming experiments.
- ✓ This project combines two joint efforts towards this goal:
 - i) LHCb-Belle II-theory common discussion towards a **global fit of the new physics parameters**,
 - ii) Contributions to **the theory-experiment working group towards Belle II start-up (B2TiP)**.

Global Fitter including NP

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



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

Model independent framework

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

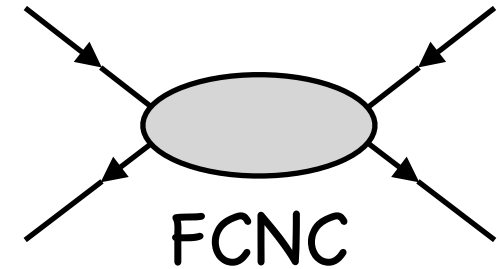
$$\mathcal{L}_{\text{eff}} = \mathcal{L}(\text{QCD} + \text{QED}) + \sum_i C_i \mathcal{O}_i.$$

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

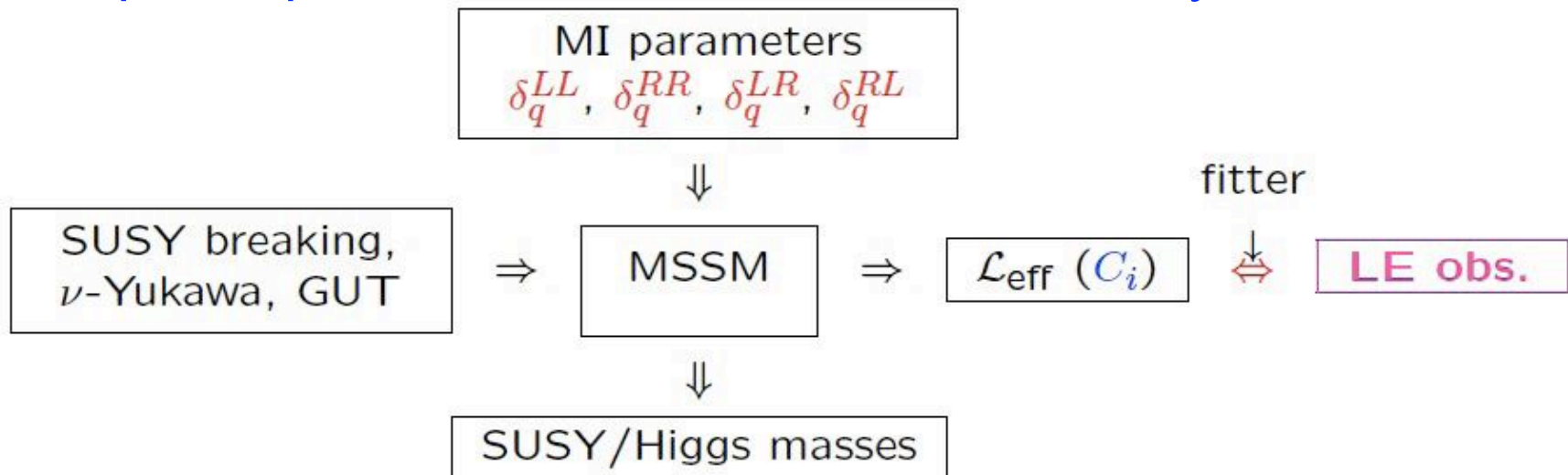
- 4-fermi interaction (dim-6): $(\bar{\psi}_1 \gamma^\mu \psi_2)(\bar{\psi}_3 \gamma_\mu \psi_4)$,
- dipole moment (dim-5): $\bar{\psi}_1 \sigma^{\mu\nu} \psi_2 F_{\mu\nu}$,
etc..

C_i : Wilson Coefficient

Discussing a way to determine
Wilson coefficients by Global Fit



Example: expansion of MSSM to Effective Theory



Belle II-LHCb & Belle II-ILC collaboration



$B \rightarrow K^* (K_S^0 \pi^0) \gamma$
time-dependent CPV

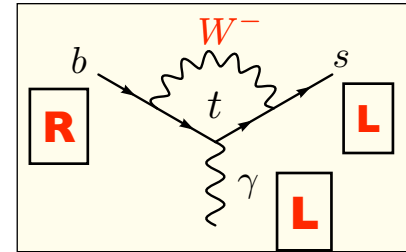
time-dependent decays rate of $B \rightarrow f_{CP}$
S and A: CP violating parameters

Golden channel

$$P(B^0 \rightarrow f; \Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau} [1 + S_{CP}^f \sin(\Delta m \Delta t) + A_{CP}^f \cos(\Delta m \Delta t)]$$



$B \rightarrow K^* \mu\mu$ and $B \rightarrow K^* ee$ with LHCb



SM

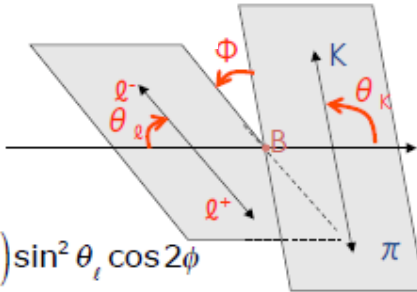
Polarization measurement :
It has never measured at a high precision,
important challenge for Belle II and LHCb

Kruger and Matias hep-ph 0502060

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

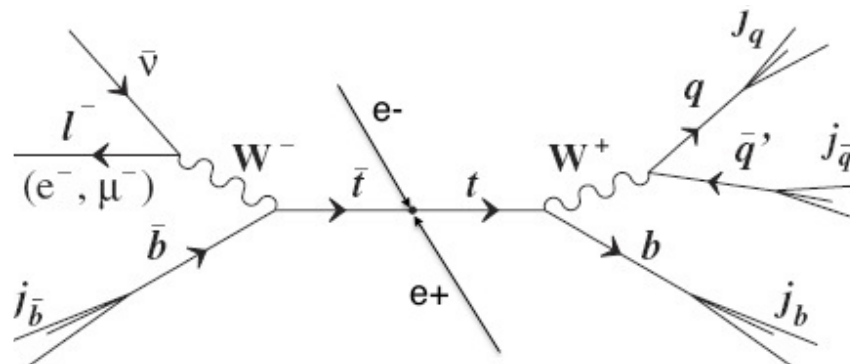
The $C^{(i)}_{7..10}$ are encoded in the $I_{i=1..9}$

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



Top electroweak coupling

- Sensitive to the models e.g. related to neutrinos
- ✓ SUSY GUT models
- ✓ LR symmetric model



t tbar
→ (bW)(bW)
→ (bqq)(blnu)

Forward-Backward asymmetry

A new activity this year : B2TiP

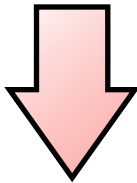
Long-term relationship established with KEK through TYL-FJPPL



I) 2006-2009: A. Stocchi - M. Hazumi (KEK-Belle)
 Italian-SuperB and Belle II common physics case study
 II) 2009-2012 E. Kou - S. Hashimoto (KEK-theory)
 Theoretical issues and analysis problems for super B factories
 III) 2013-2015 M.-H. Schune (LHCb-LAL) - K. Hara (KEK-Belle II)
 Combined study of LHCb and Belle II new physics constraints and Transformation of SuperB physics activity to Belle II

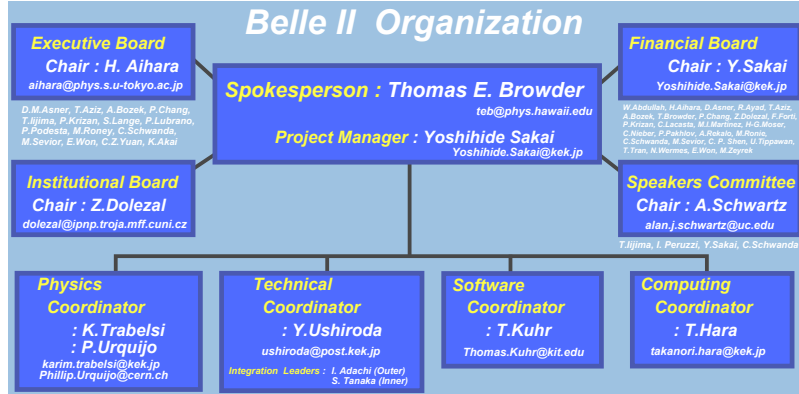
Belle II visit (oct. 2013) initiated by I. Ripp-Baudot

(from 2014)



Proposition of “Belle II-Theory Interface Platform (B2TiP)”
 Theorist-experimentalist joint efforts to elucidate the physics case of Belle II

Feb. 2014: Approval at the Executive board of Belle II





Overview

The "Belle II-Theory Interface Platform" is an initiative to coordinate a joint theory-experiment effort to study the potential impacts of the Belle II program.

We plan to organize meetings twice a year gathering theory experts and Belle II members, starting from June 2014 until the end of 2016.

One of the expected outcomes of the project is a "KEK Report", summarizing all the important observables which will be measured at Belle II, their experimentally achievable precision and their impact on our understanding of the theory (Standard Model and New Physics). This report should also include a "milestones table" clarifying the targets for the first 5 to 10 ab⁻¹ of data as well as for the final goal at 50 ab⁻¹.

Workshop Dates

The 2014 meetings will be held at KEK in June and November, as a satellite meeting of the Belle and Belle II General meetings. There is a possibility of holding one workshop in 2015 at an external location. Individual working groups may choose to hold additional meetings. Please register for the meetings on the linked indico pages.

Committees

Organising Committee

Toru Goto	KEK
Emi Kou	LAL
Karim Trabelsi	KEK
Phillip Urquijo (B2 Physics Coord.)	Melbourne

Ex Officio

Hiroaki Aihara (B2 EB Chair)	Tokyo
Thomas Browder (B2 Spokesperson)	Hawaii
Marco Ciuchini (KEK FF Advisory)	Rome
Thomas Mannel (KEK FF Advisory)	Siegen

Report Editors

Christoph Schwanda	HEPHY Vienna
Theory TBC	

Advisory Committee

Tim Gershon	Warwick
Bostjan Golob	IJS Ljubljana
Shoji Hashimoto	KEK
Francois Le Diberder	LAL
Zoltan Ligeti	LBL
Hitoshi Murayama	IPMU
Matthias Neubert	Mainz
Yoshihide Sakai	KEK
Junko Shigemitsu	Ohio

— TYL member
 former TYL member

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We p
theo
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One
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target
final

✓ **Deliverable:** KEK report by the end of 2016. This **KEK report** should contain all the important observable which will be measured at Belle II, their impact on our understanding of SM as well as BSM.

✓ Defining milestone of 5, 10, 50 ab^{-1} of data.

✓ **Workshop twice a year ('14, '15, '16):** typically combined with Belle II Collaborations meeting in June & November.

Workshop Dates

The 2014 meetings
November, as a sat
General meetings. T
workshop in 2015 a
working groups may
Please register for the meetings on the linked indico pages.

We are trying to make some common application (bilateral project, MEXT international etc) to raise some money but it is very difficult to find a big grant for this year.

Thus, the TYL budget is extremely important for us!

(KEK FF	Rome	Neubert	Mainz
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Schwanda	Vienna
Theory TBC	

— TYL member
..... former TYL member

Our activity for '14



B2TiP working group structure

Lattice QCD Working group

▶ Theoretical input

**Belle II and
New Physics Working group**

▶ Benchmark models and point at 5, 10, 50 ab^{-1} of data.

▶ Public code for the model dependent/independent new physics fit

▶ Correlation to other experiments

KEK
report editors



This TYL project:
Belle II-LHCb-ILC joint effort

- ✓ Our activity will be integrated in **a more global framework (B2TiP)**, for which the members of TYL will play the central role.
- ✓ Ambitious goal is to establish **a public code for B physics** needed for the global fit.
- ✓ Our member, R. Itoh (KEK) is selected as a coordinator of New Physics working group. He will organize one of the **working group meetings in France this 2014**.
- ✓ French team will actively contribute to the B2TiP workshops.

Backup

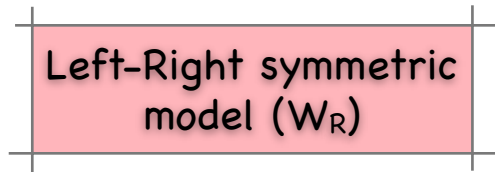
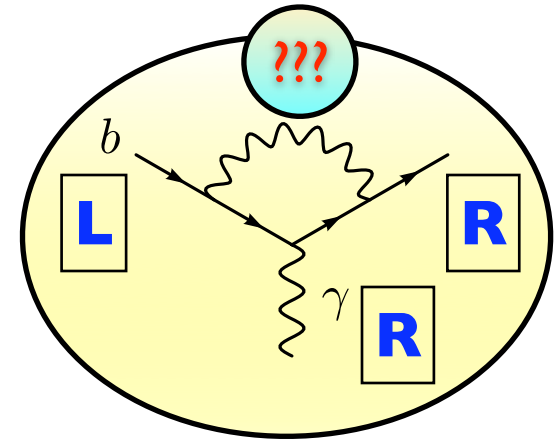
$B \rightarrow D(^*)\tau\nu$ MC Event Generator including New Physics Effects

- For the NP sensitivity study with the full detector simulation
 - Ratio of Br. to $B \rightarrow D(^*)\nu$
 - 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.)
- $B \rightarrow D(^*)\tau\nu$ MC Event Generator including New Physics effect is under development
 - **Model independent approach** based on [M. Tanaka and R. Watanabe PRD87, 034028 (2013)]

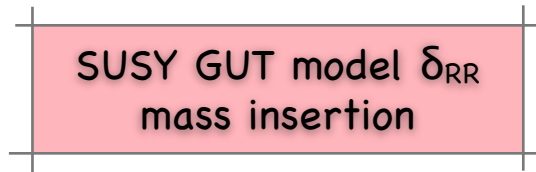
Right-handed: which NP model?

► What types of new physics models?

For example, models with right-handed neutrino, or custodial symmetry in general induces the right handed current.



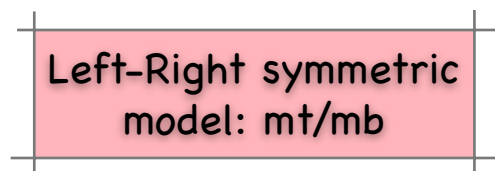
Blanke et al. JHEP1203



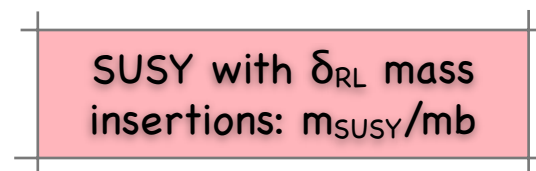
Girrbach et al. JHEP1106

► Which flavour structure?

The models that contain new particles which change the chirality inside of the $b \rightarrow s \gamma$ loop can induce **a large chiral enhancement!**



Cho, Misiak, PRD49, '94
Babu et al PLB333 '94

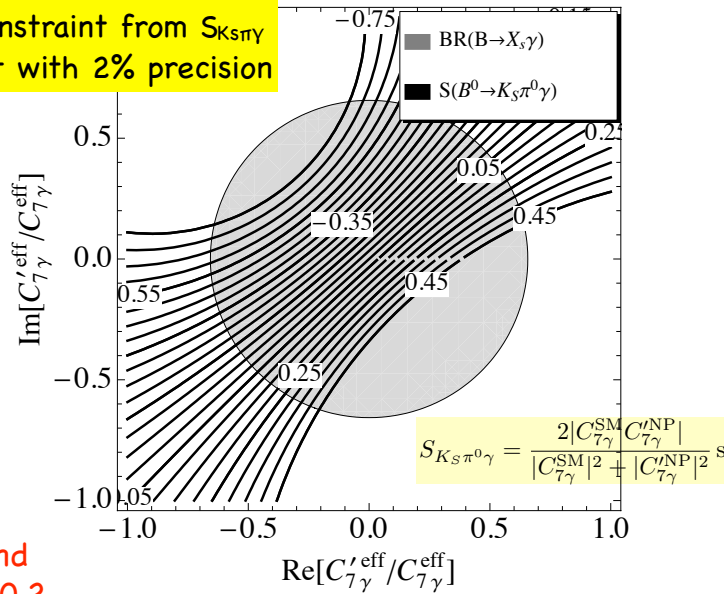


Gabbiani, et al. NPB477 '96
Ball, EK, Khalil, PRD69 '04

NP signal beyond the constraints from B_s oscillation parameters possible.

Method I

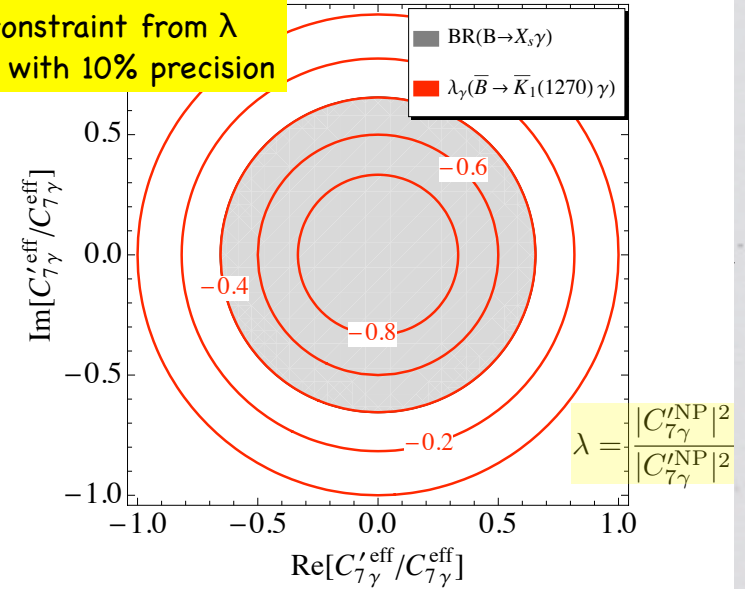
Expected constraint from $S_{K_S\pi\gamma}$ measurement with 2% precision



Current bound
 $S_{K_S\pi^0\gamma} = -0.15 \pm 0.2$

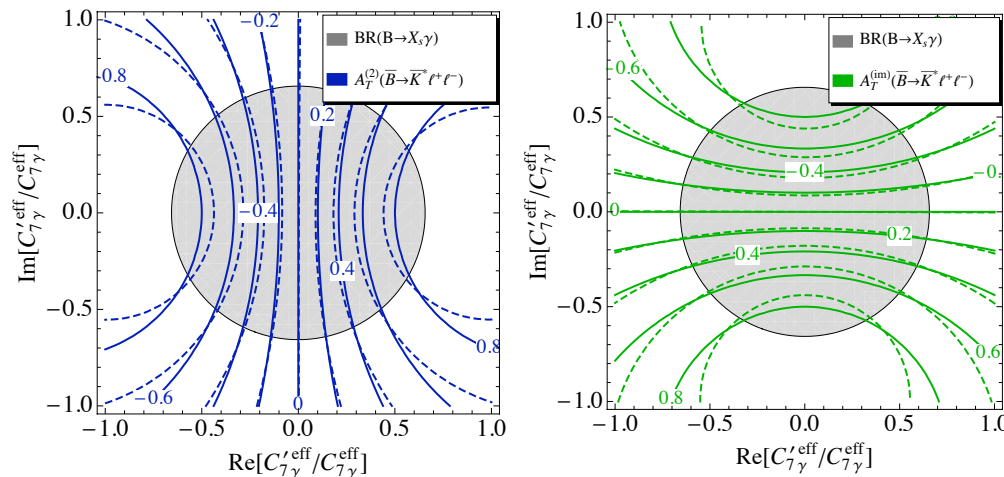
Method III

Expected constraint from λ measurement with 10% precision



Method II

Expected constraint from $A_T^{(2)}, A_T^{(im)}$ measurement with 10% precision



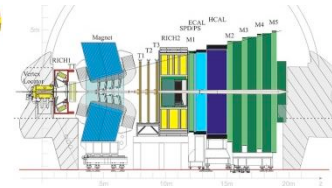
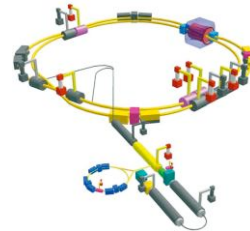
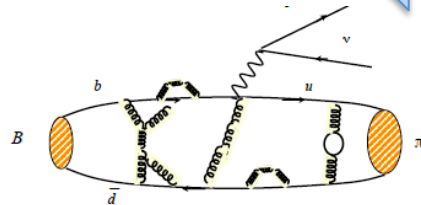
Assumption for γ^*/Z penguin (C_9, C_{10} contributions) necessary!

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.**