Physics
OSAKA UNIVERSITY

New Physics in $\bar{B} \to D^{(*)} \tau \bar{\nu}$

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Based on works with Y.Sakaki, A.Tayduganov and R.Watanabe

Sept. 29, 2016 @ Tohoku U

Introduction

Brief history

1975 M. L. Perl: tau lepton

1977 L. Lederman: bottom quark

1987 ARGUS: B^0–$\bar{B}^0$ mixing

1989 CLEO: $b \to u$

1994 CDF, D0: top quark

2002 Belle, BaBar (B factories):
CP violation in B decays

....

2007~2016 Belle, BaBar, LHCb: $\bar{B} \to D^{(*)}\tau\bar{\nu}$

~4σ discrepancy

Plan of talk

1. Introduction
2. (Super) B factory
3. Semitauonic B decays
4. Summary

(Super) B factory

B factory experiments: BaBar and Belle

EPJC74(2014)3026

Asymmetric electron-positron colliders

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

$B^0\bar{B}^0$ mixing

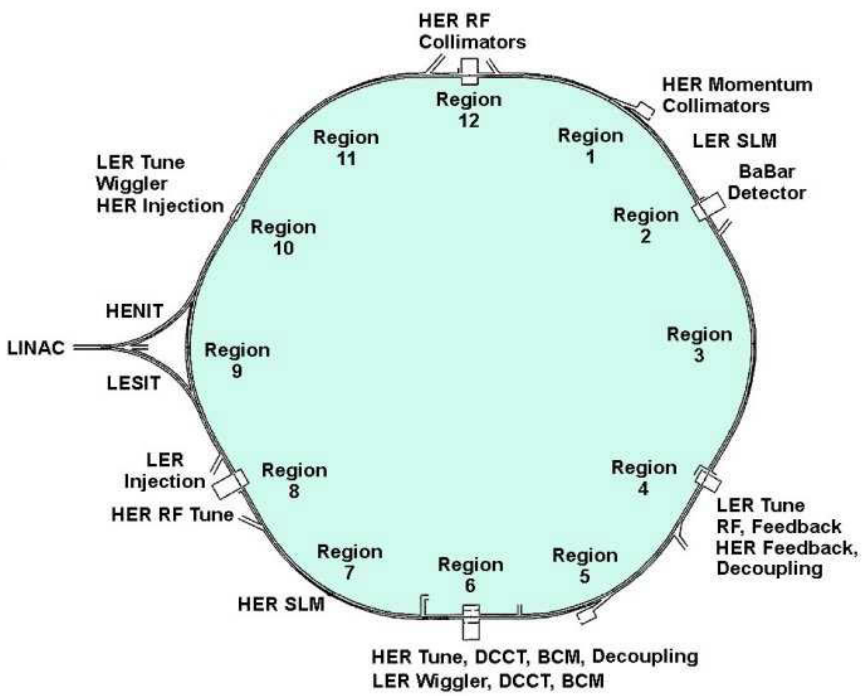
mixing-induced CP violation

time-dependent CP asymmetry

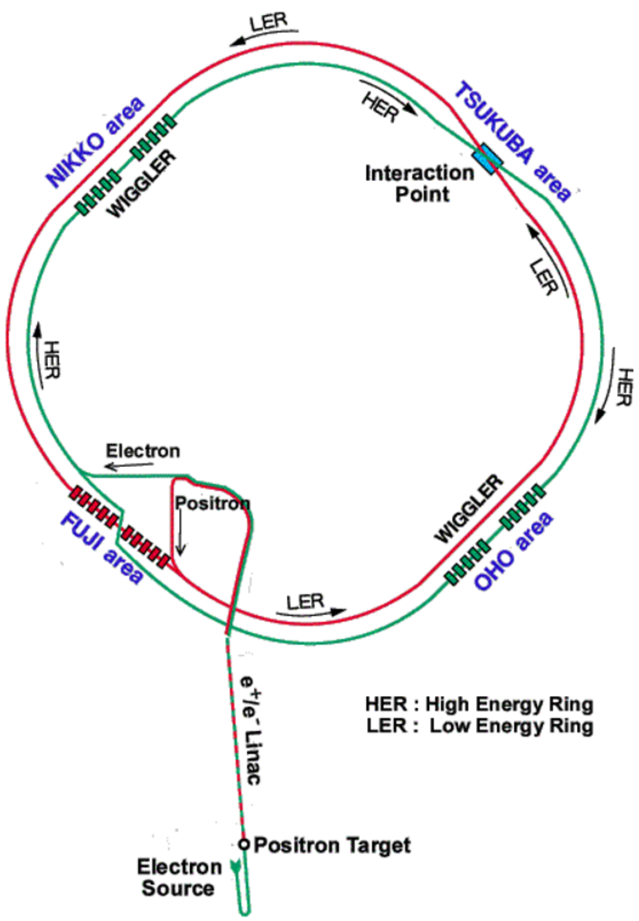
decay time $\longleftrightarrow$ decay position

$\tau \simeq 1.6$ ps $\quad c\tau \sim 500\ \mu$m

PEP-II

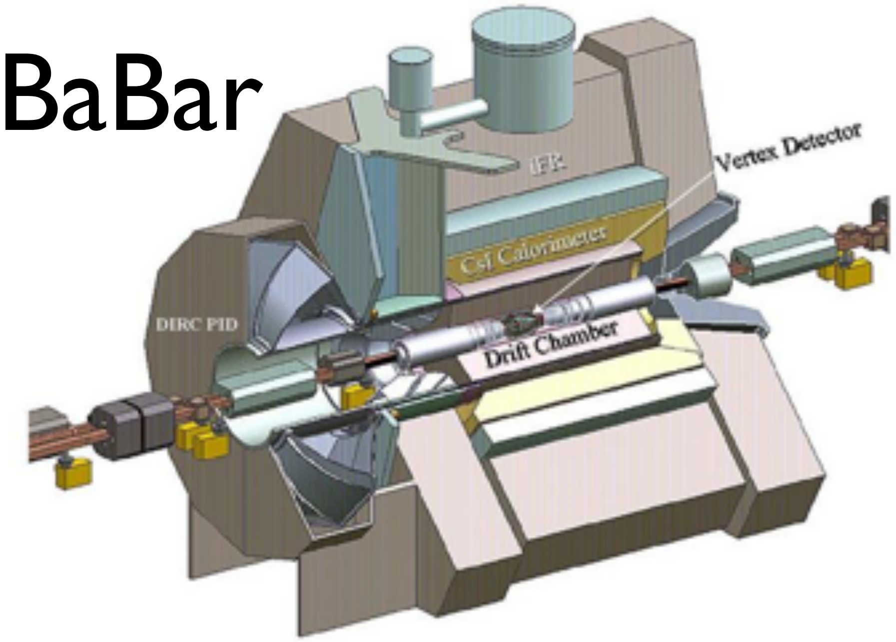


KEKB

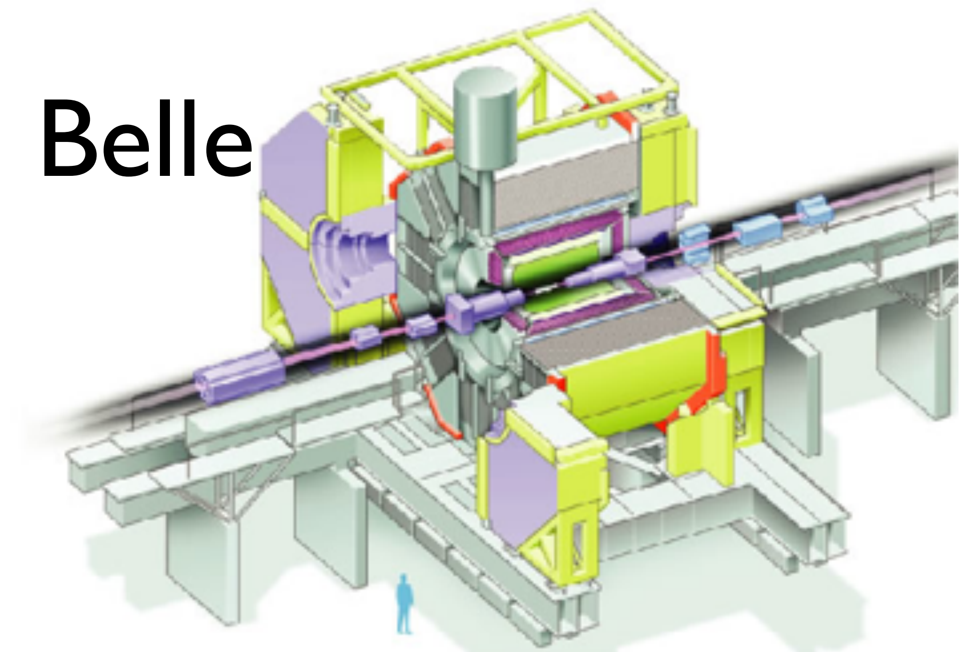


B Factory	e^- beam energy E_- (GeV)	e^+ beam energy E_+ (GeV)	Lorentz factor $\beta\gamma$	crossing angle φ (mrad)
PEP-II	9.0	3.1	0.56	0
KEKB	8.0	3.5	0.425	22

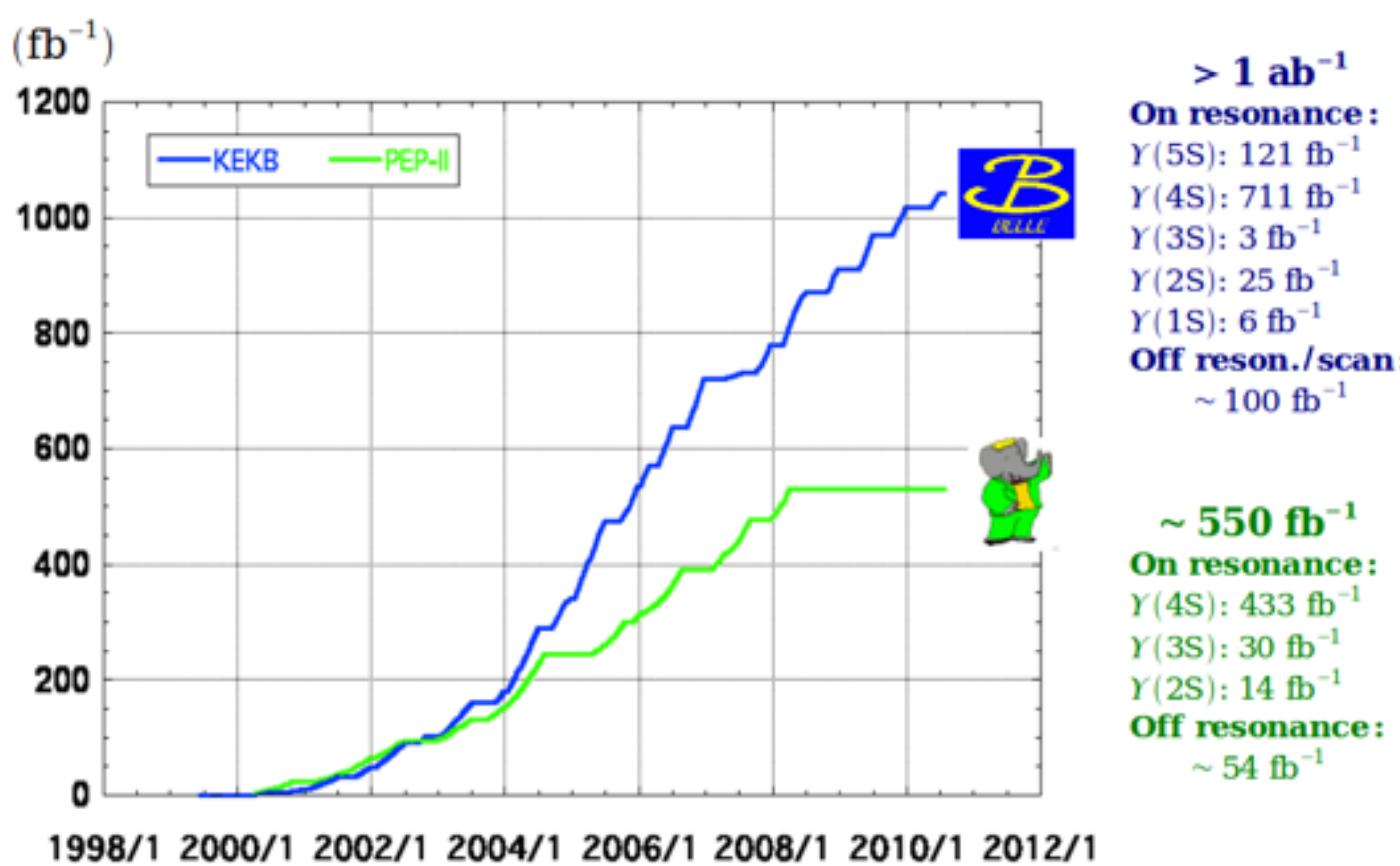
BaBar



Belle



Integrated luminosity of B factories

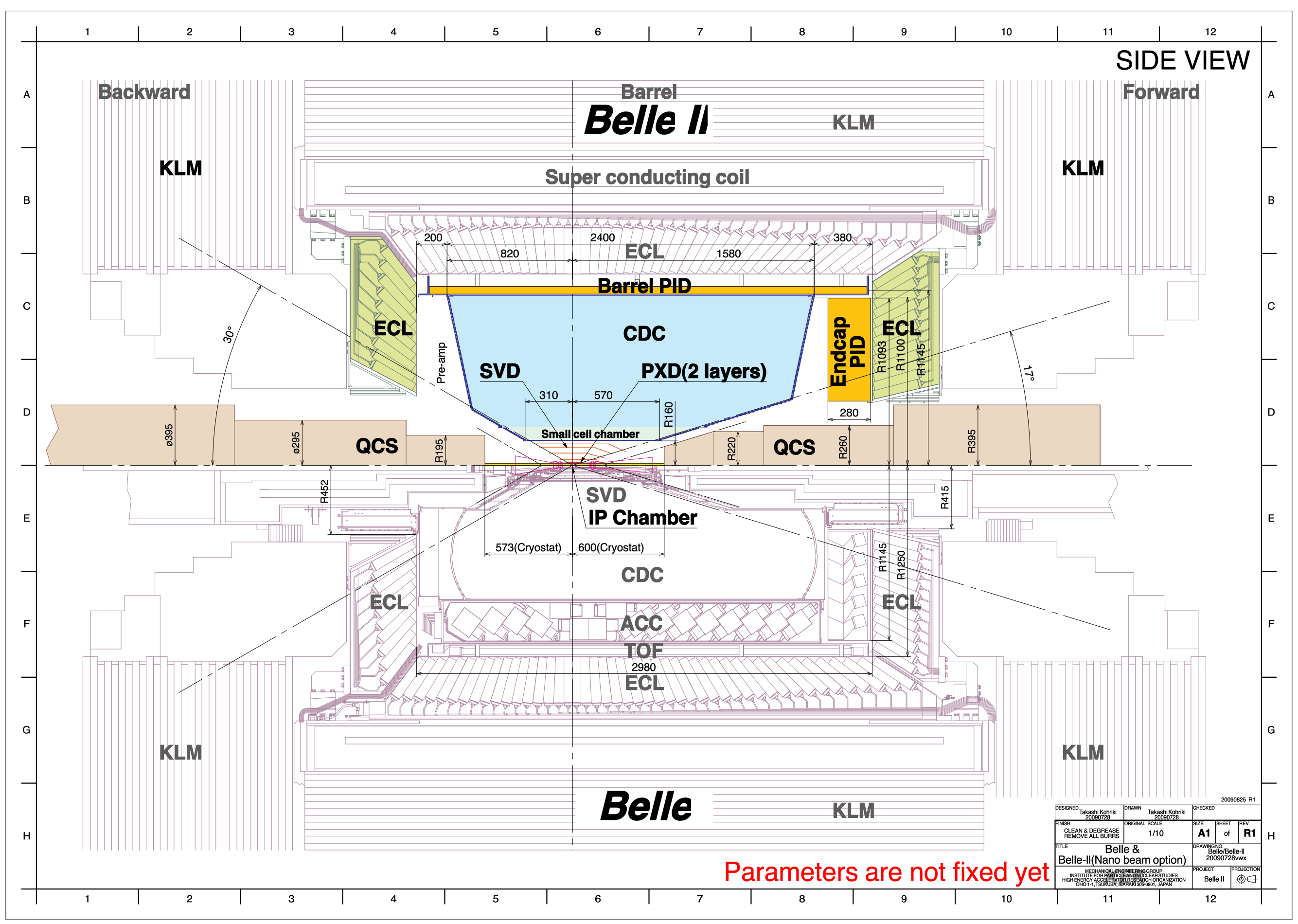


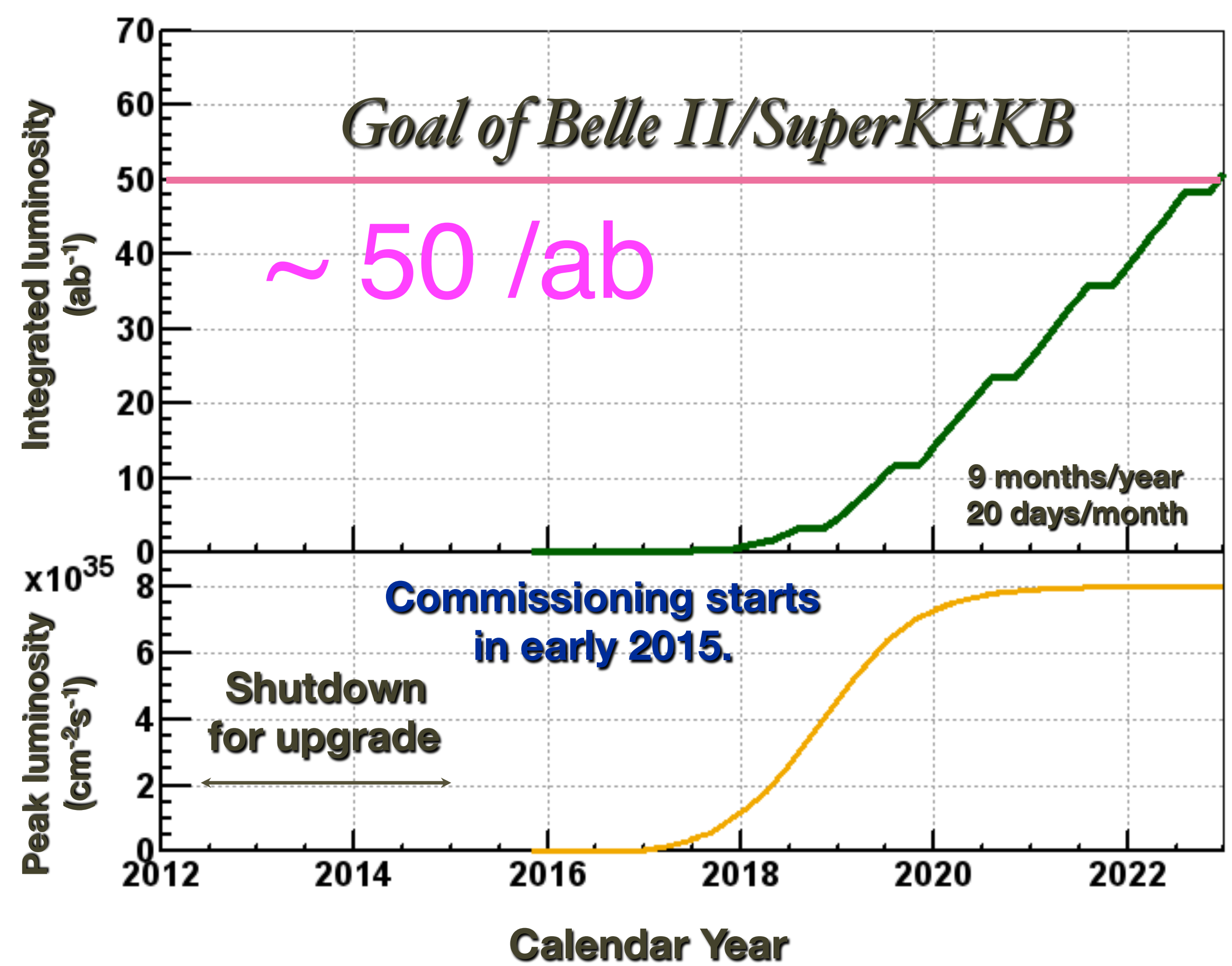
~1 /ab

SuperKEKB/Belle II

	KEKB Achieved	SuperKEKB
Energy (GeV) (LER/HER)	3.5/8.0	4.0/7.0
ξ_y	0.129/0.090	0.090/0.088
β_y^* (mm)	5.9/5.9	0.27/0.41
I (A)	1.64/1.19	3.60/2.62
Luminosity ($10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	2.11	80

x40



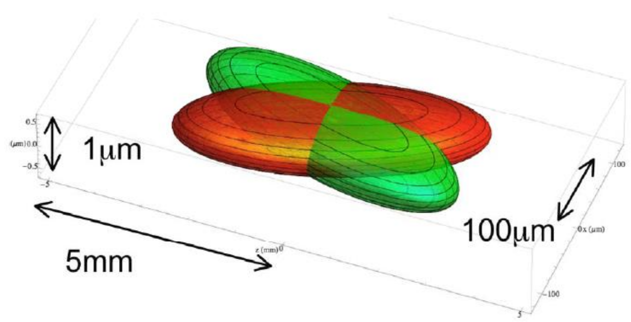


Accelerator Upgrade – SuperKEKB

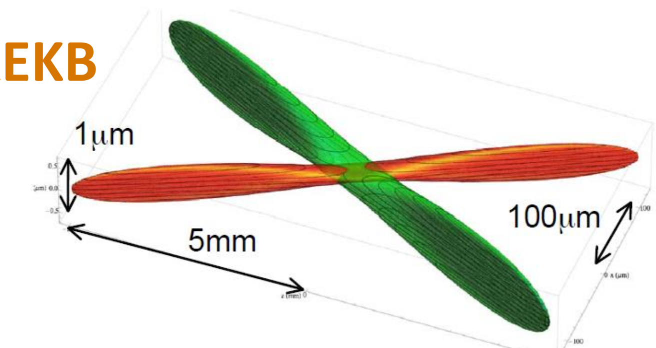
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

- **40x increase in luminosity**
- “Nano-beam” interaction point
- Increase in current

KEKB

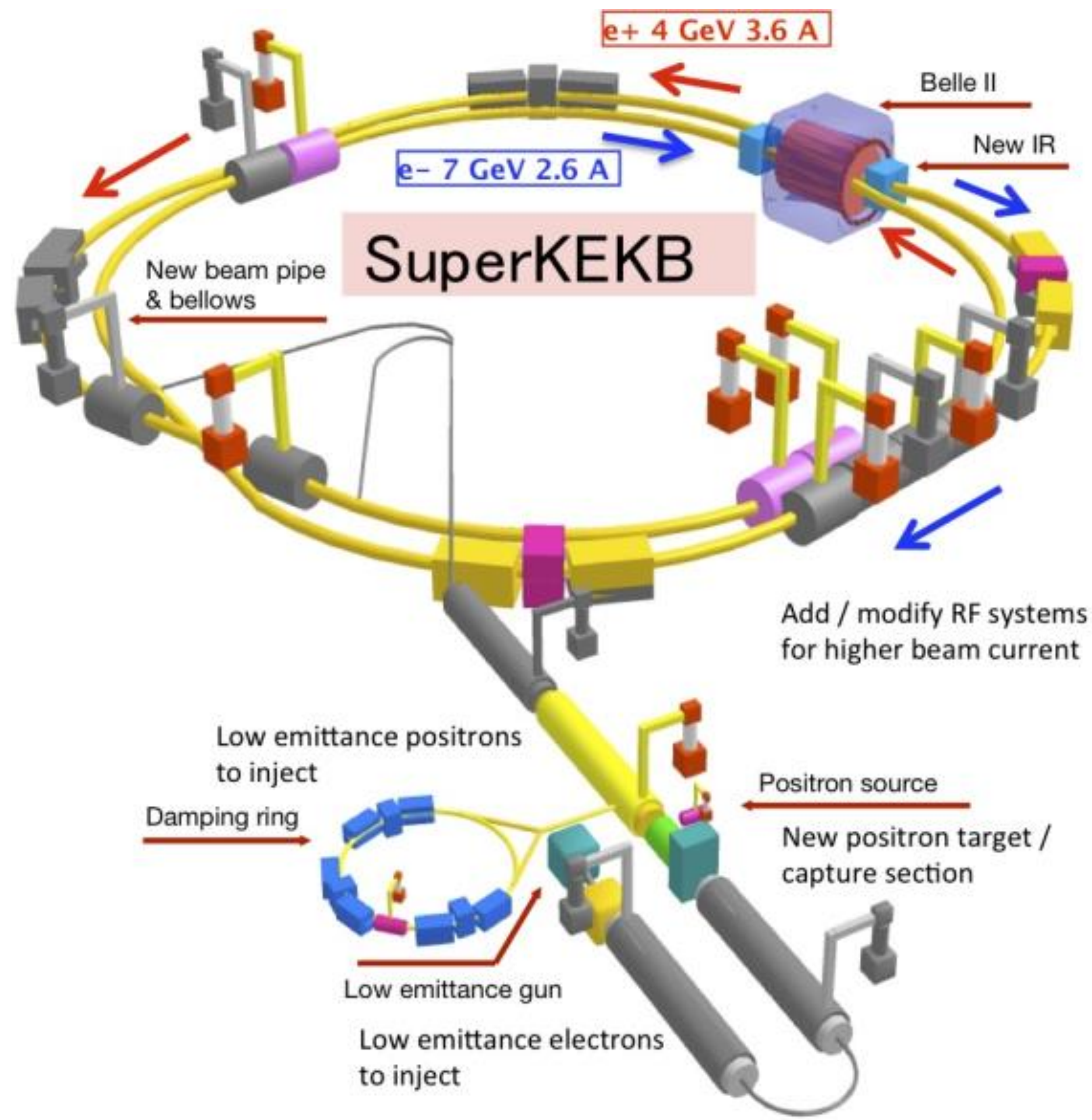


SuperKEKB



- **First turns achieved Feb 2016!**

See: Y. Onishi, ICHEP Highlights 08 Aug 12:10



Current Status and Schedule

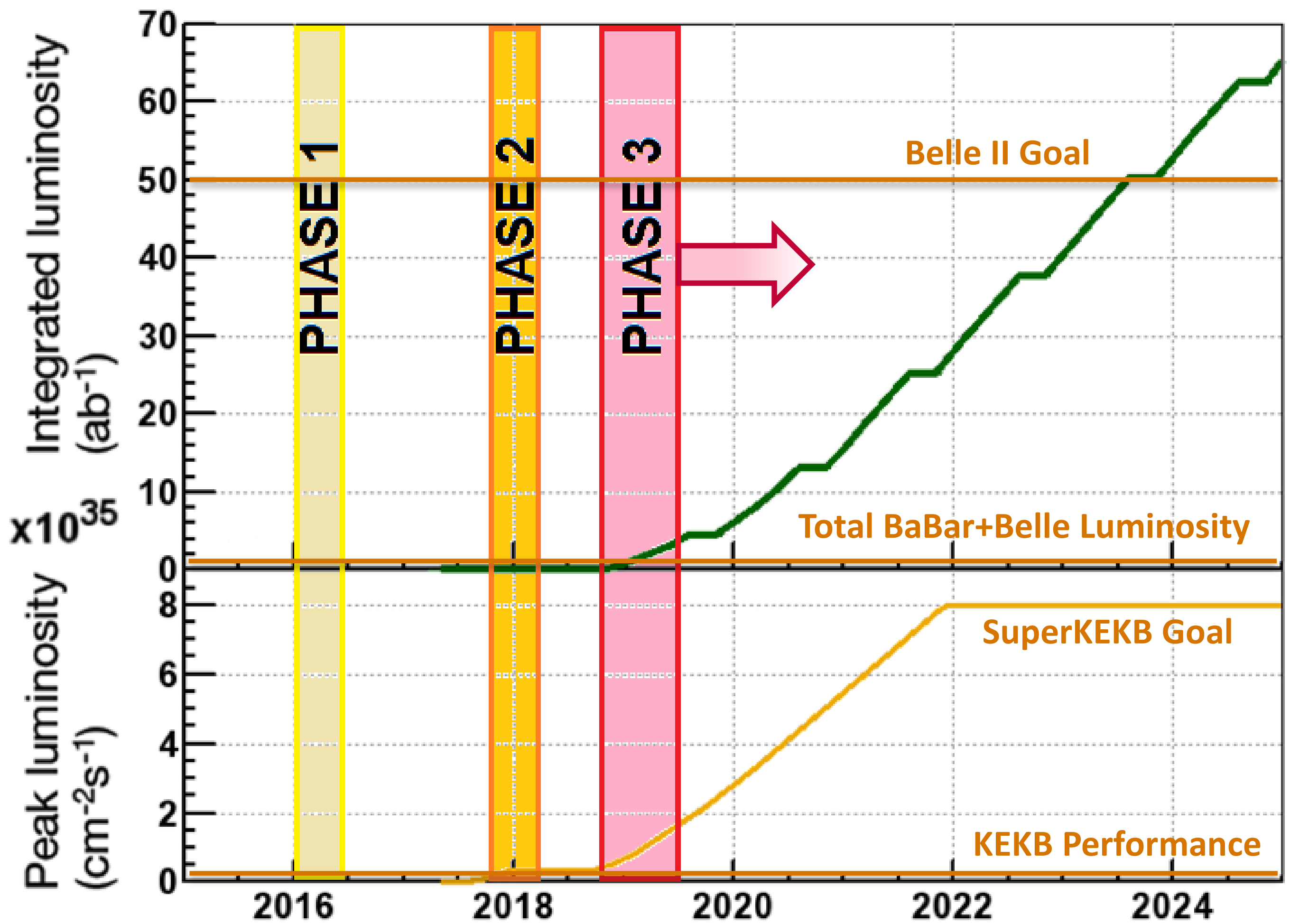
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Belle II Collaboration: ~700 members, ~100 institutions, 23 countries

- Phase 1 (complete)
  - Accelerator commissioning

See: P. Lewis, Detector 05 Aug 09:20

- Phase 2 (2017)
  - First collisions
  - Partial detector
  - Background study
  - Physics possible
- Phase 3 (“Run 1”)
  - Nominal Belle II start
- **Ultimate goal: 50 ab^{-1}**



Semitauonic B decays

$\bar{B} \to D^{(*)}\tau\bar{\nu}$

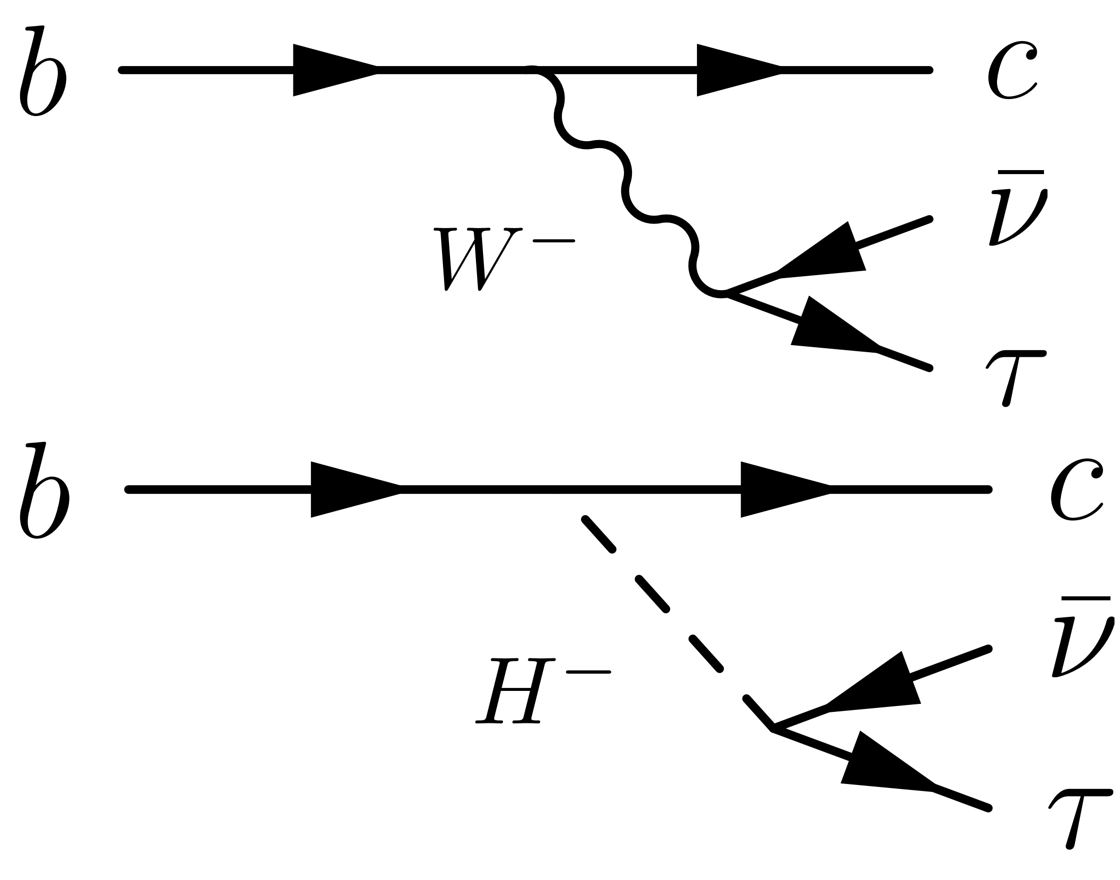
Br ~ 0.7+1.3 % in the SM

Not rare, but two or more missing neutrinos

Data available since 2007 (Belle, BABAR, LHCb)

Theoretical motivation

W.S. Hou and B. Grzadkowski (1992)



SM: gauge coupling

lepton universality

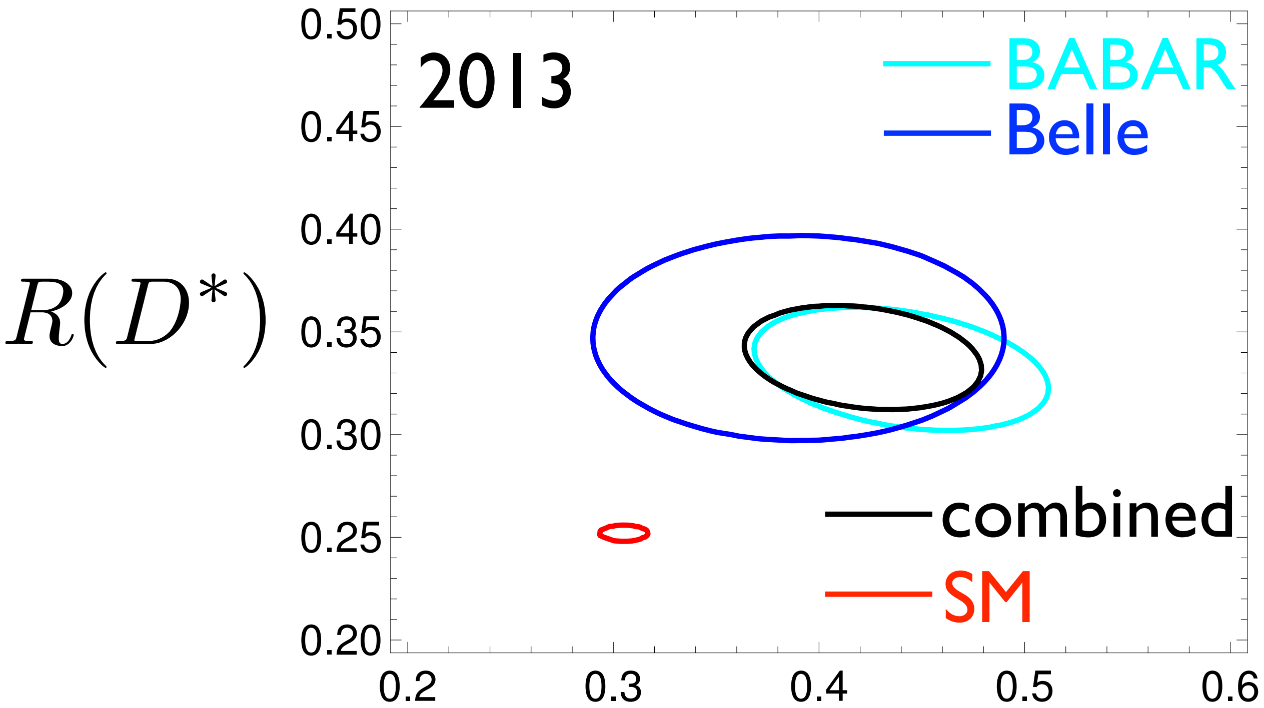
Type-II 2HDM (SUSY)

Yukawa coupling

$\propto m_b m_\tau \tan^2\beta$

Experiments

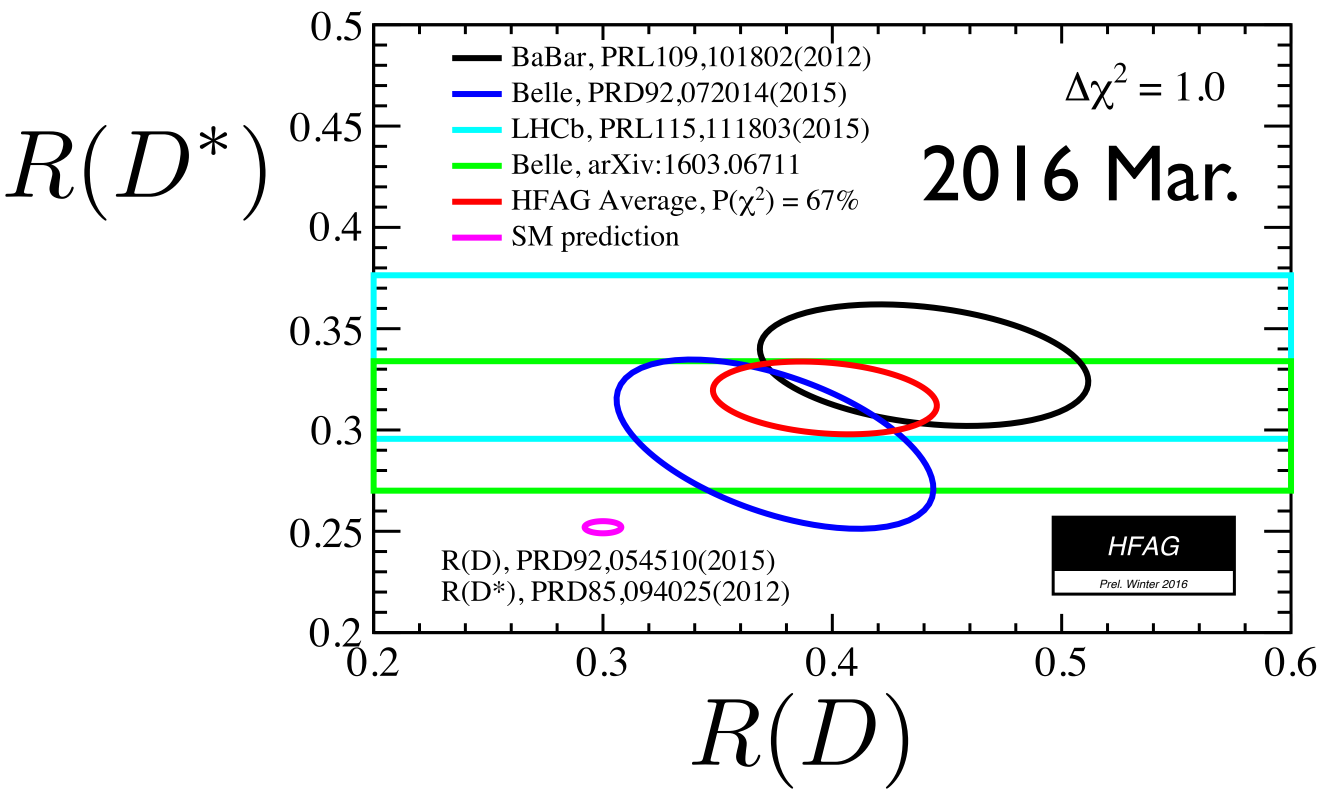
$$R(D^{(*)}) \equiv \frac{\mathcal{B}(\bar{B} \to D^{(*)}\tau\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^{(*)}\ell\bar{\nu}_\ell)}$$



$$R(D) = 0.421 \pm 0.058$$
$$R(D^*) = 0.337 \pm 0.025$$

~3.5σ

Y. Sakaki, MT, A. Tayduganov, R. Watanabe



$$R(D) = 0.397 \pm 0.040 \pm 0.028$$
$$R(D^*) = 0.316 \pm 0.016 \pm 0.010$$

~4.0σ HFAG

With Belle ICHEP2016

$$R(D^*) = 0.310 \pm 0.017$$

Standard model predictions

Theoretical uncertainty: form factors

data from $\bar{B} \to D^{(*)} \ell \bar{\nu}$ $(\ell = e, \mu)$

+ HQET or pQCD

+ lattice QCD

$R(D) = 0.296 \pm 0.016$ (Fajfer, Kamenik, Nisandzic)

0.302 ± 0.015 (Sakaki, MT, Tayduganov, Watanabe)

0.299 ± 0.011 (Bailey et al.)

$0.337^{+0.038}_{-0.037}$ (Fan, Xiao, Wang, Li)

$0.397 \pm 0.040 \pm 0.028$ (Exp. HFAG)

$R(D^*) = 0.252 \pm 0.003$ (Fajfer, Kamenik, Nisandzic)

0.252 ± 0.004 (Sakaki, MT, Tayduganov, Watanabe)

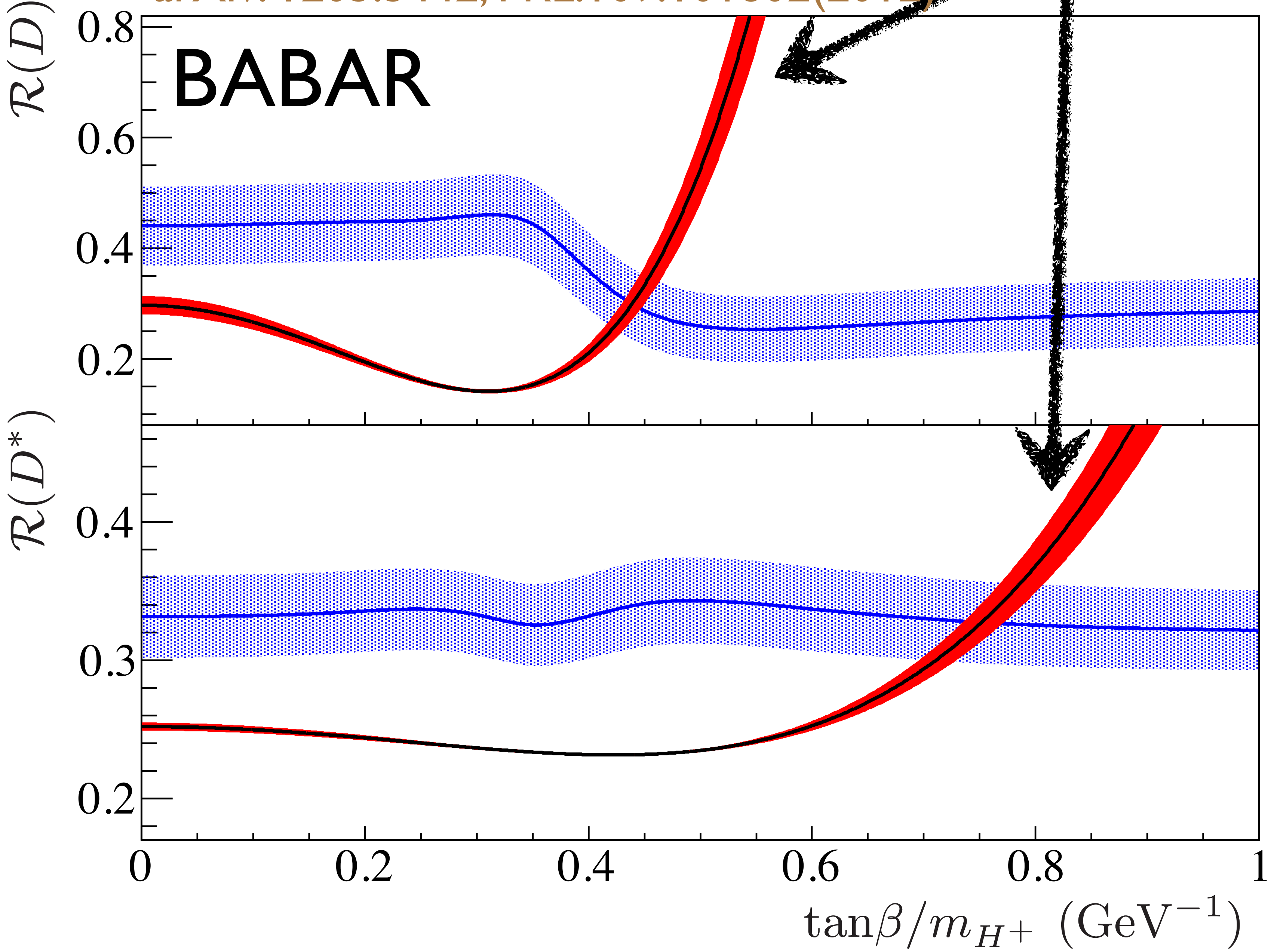
$0.269^{+0.021}_{-0.020}$ (Fan, Xiao, Wang, Li)

$0.316 \pm 0.016 \pm 0.010$ (Exp. HFAG)

Charged Higgs boson

predictions of 2HDM II

arXiv: 1205.5442, PRL.109.101802(2012)



Charged Higgs *excluded* at 99.8% CL

Model-independent approach

MT, R.Watanabe,arXiv1212.1878, PRD87.034028(2013).

Effective Lagrangian for $b \longrightarrow c\tau\bar{\nu}$

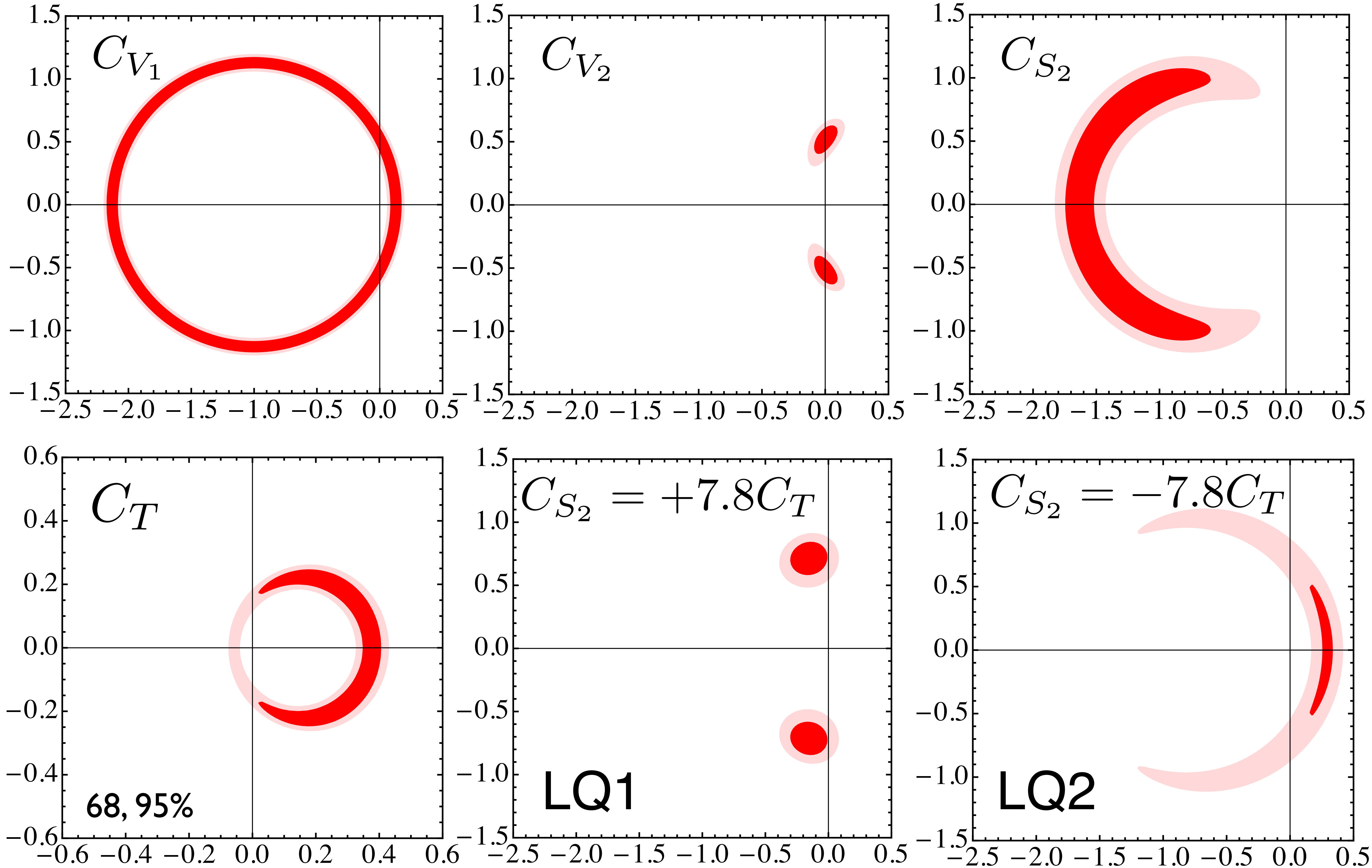
all possible 4f operators with LH neutrinos

$$-\mathcal{L}_{\rm eff} = 2\sqrt{2}G_F V_{cb} \sum_{l=e,\mu,\tau} \left[(\delta_{l\tau} + C^l_{V_1})\mathcal{O}^l_{V_1} + C^l_{V_2}\mathcal{O}^l_{V_2} + C^l_{S_1}\mathcal{O}^l_{S_1} + C^l_{S_2}\mathcal{O}^l_{S_2} + C^l_T\mathcal{O}^l_T\right]$$

SM

$\mathcal{O}^l_{V_1} = \bar{c}_L\gamma^\mu b_L\,\bar{\tau}_L\gamma_\mu\nu_{Ll}\,,$		SM-like, RPV, LQ,W'
$\mathcal{O}^l_{V_2} = \bar{c}_R\gamma^\mu b_R\,\bar{\tau}_L\gamma_\mu\nu_{Ll}\,,$		RH current
$\mathcal{O}^l_{S_1} = \bar{c}_L b_R\,\bar{\tau}_R\nu_{Ll}\,,$		charged Higgs II, RPV, LQ
$\mathcal{O}^l_{S_2} = \bar{c}_R b_L\,\bar{\tau}_R\nu_{Ll}\,,$		charged Higgs III, LQ
$\mathcal{O}^l_T = \bar{c}_R\sigma^{\mu\nu} b_L\,\bar{\tau}_R\sigma_{\mu\nu}\nu_{Ll}$		LQ

Allowed regions in complex Cx plane



Leptoquark models

Y. Sakaki, MT, A. Tayduganov, R. Watanabe
arXiv:1309.0301; PRD88, 094012(2013)

Six of ten types of LQ contribute.

Buchmueller, Ruckl, Wyler (1987)

	S_1	S_3	V_2	R_2	U_1	U_3
spin	0	0	1	0	1	1
$F = 3B + L$	-2	-2	-2	0	0	0
$SU(3)_c$	3^*	3^*	3^*	3	3	3
$SU(2)_L$	1	3	2	2	1	3
$U(1)_{Y=Q-T_3}$	$1/3$	$1/3$	$5/6$	$7/6$	$2/3$	$2/3$

$$C^l_{V_1} = \frac{1}{2\sqrt{2}G_F V_{cb}} \sum_{k=1}^{3} V_{k3}\left[\frac{g^{kl}_{1L} g^{23*}_{1L}}{2M^2_{S_1^{1/3}}} - \frac{g^{kl}_{3L} g^{23*}_{3L}}{2M^2_{S_3^{1/3}}} + \frac{h^{2l}_{1L} h^{k3*}_{1L}}{M^2_{U_1^{2/3}}} - \frac{h^{2l}_{3L} h^{k3*}_{3L}}{M^2_{U_3^{2/3}}}\right],$$

constrained by $\bar{B} \to X_s \nu \bar{\nu}$

$$C^l_{V_2} = 0,$$

$$C^l_{S_1} = \frac{1}{2\sqrt{2}G_F V_{cb}} \sum_{k=1}^{3} V_{k3}\left[-\frac{2g^{kl}_{2L} g^{23*}_{2R}}{M^2_{V_2^{1/3}}} - \frac{2h^{2l}_{1L} h^{k3*}_{1R}}{M^2_{U_1^{2/3}}}\right],$$

disfavored

$$C^l_{S_2} = \frac{1}{2\sqrt{2}G_F V_{cb}} \sum_{k=1}^{3} V_{k3}\left[-\frac{g^{kl}_{1L} g^{23*}_{1R}}{2M^2_{S_1^{1/3}}} - \frac{h^{2l}_{2L} h^{k3*}_{2R}}{2M^2_{R_2^{2/3}}}\right],$$

$$C^l_{T} = \frac{1}{2\sqrt{2}G_F V_{cb}} \sum_{k=1}^{3} V_{k3}\left[\frac{g^{kl}_{1L} g^{23*}_{1R}}{8M^2_{S_1^{1/3}}} - \frac{h^{2l}_{2L} h^{k3*}_{2R}}{8M^2_{R_2^{2/3}}}\right],$$

$$C_{S_2}(m_{\rm LQ}) = \pm 4 C_T(m_{\rm LQ})$$

RG

$$C_{S_2}(m_b) = \pm 7.8 C_T(m_b)$$

q2 distribution

Y. Sakaki, MT, A. Tayduganov, R. Watanabe
arXiv:1412.3761; PRD91, 14028 (2015)

Several possible NP scenarios (as of 2013)

$V_1 : C_{V_1} = 0.16\ (0.12)$ $\quad (\ldots)$ 2015 best fits

$V_2 : C_{V_2} = 0.01 \pm 0.60i\ (0.01 \pm 0.51i)$

$S_2 : C_{S_2} = -1.75\ (-1.67)$

$T : C_T = 0.33\ (0.34)$

$\mathrm{LQ}_1 : C_{S_2} = 7.8 C_T = -0.17 \pm 0.80i\ (-0.12 \pm 0.69i)$

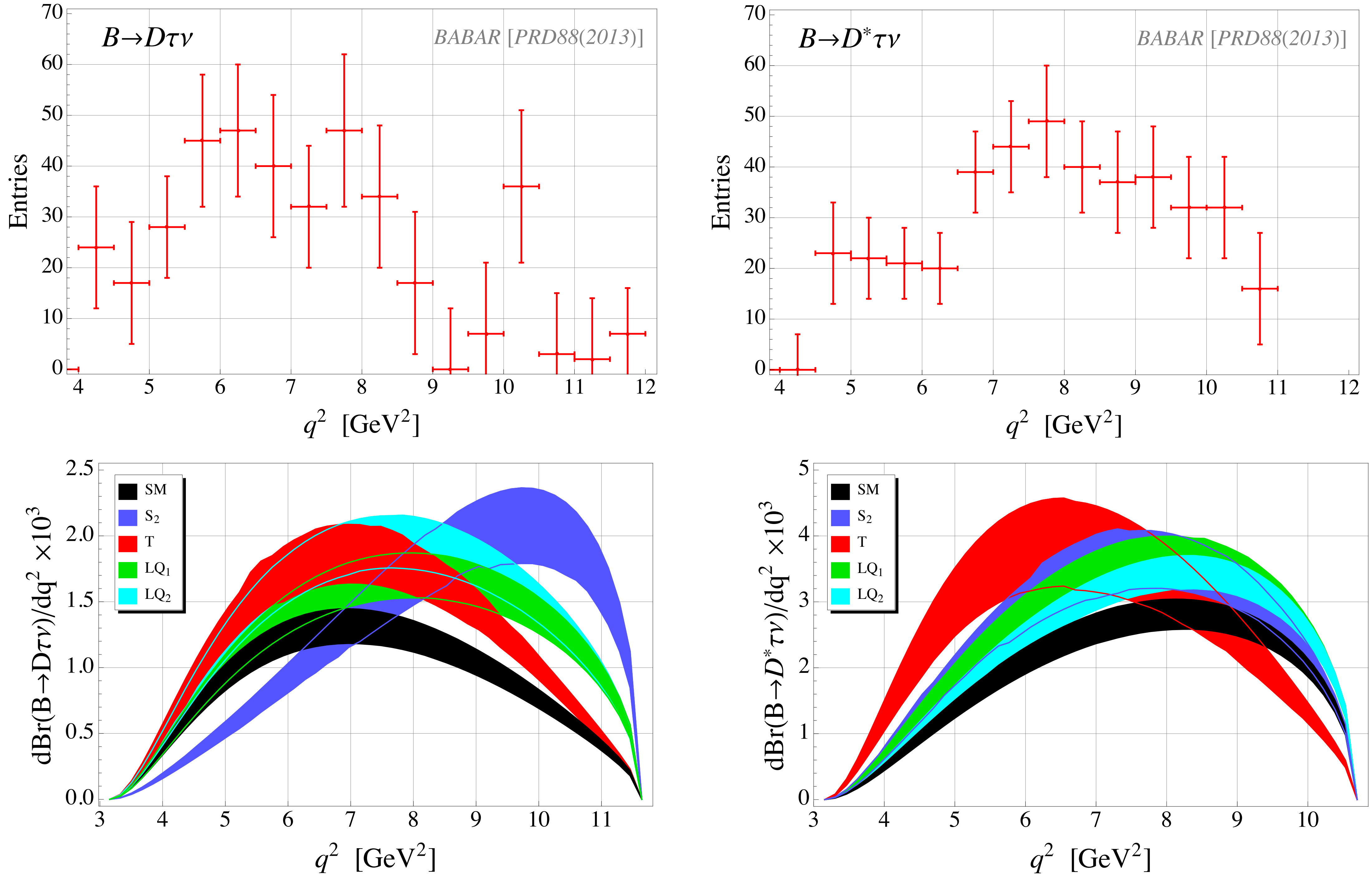
$\mathrm{LQ}_2 : C_{S_2} = -7.8 C_T = 0.34\ (0.25)$

How to discriminate: other observables

$A_{FB},\ P_\tau,\ P_{D^*}$ rather hard to measure

$q^2 = (p_B - p_{D^{(*)}})^2$ easier

Implication of the BABAR q2 data



p value

model	$\overline{B} \to D\tau\overline{\nu}$	$\overline{B} \to D^*\tau\overline{\nu}$	$\overline{B} \to (D+D^*)\tau\overline{\nu}$
SM	54%	65%	67%
V_1	54%	65%	67%
V_2	54%	65%	67%
S_2	0.02%	37%	0.1%
T	58%	0.1%	1.0%
LQ_1	13%	58%	25%
LQ_2	21%	72%	42%

$S_2,\ T$ disfavored

$\mathrm{LQ}_{1,2}$ (combinations of $S_2,\ T$) allowed

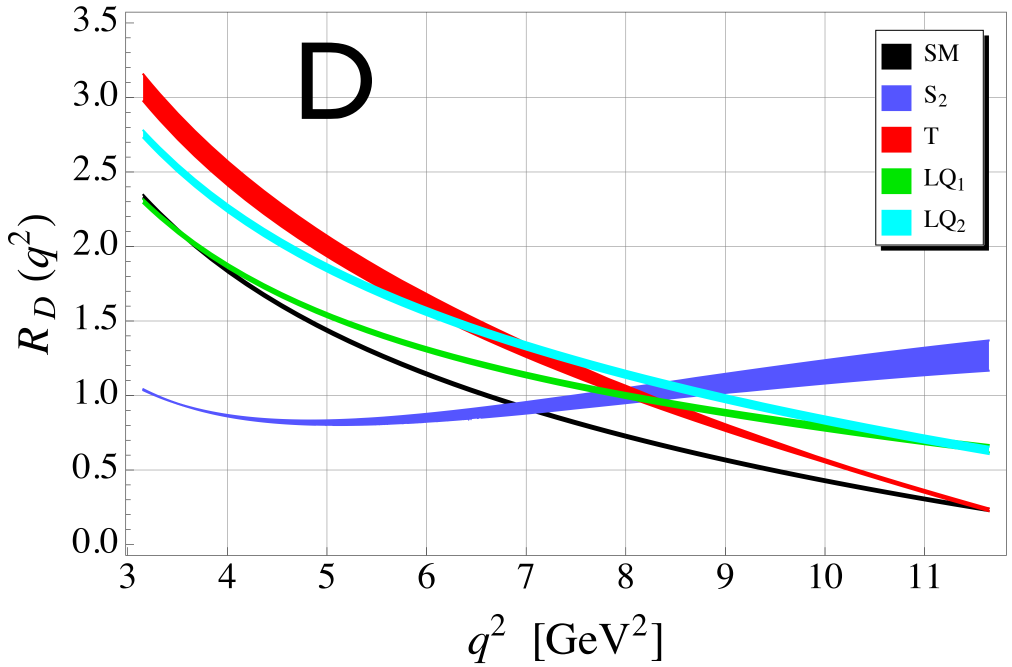
Ratio of the q2 distributions

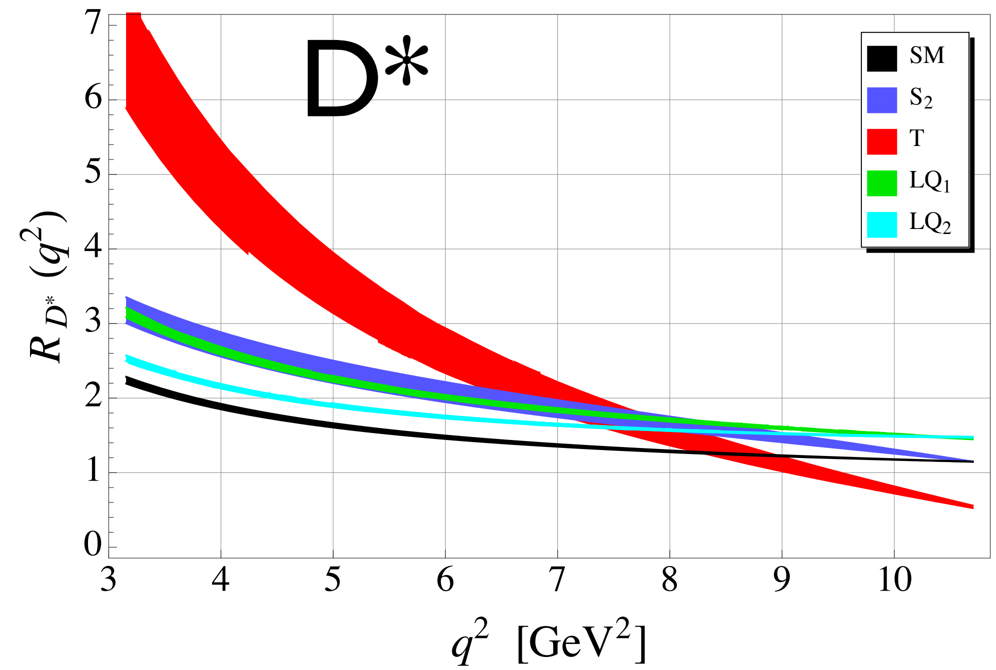
$$R_D(q^2) \equiv \frac{d\mathcal{B}(\overline{B} \to D\tau\overline{\nu})/dq^2}{d\mathcal{B}(\overline{B} \to D\ell\overline{\nu})/dq^2} \frac{\lambda_D(q^2)}{(m_B^2 - m_D^2)^2} \left(1 - \frac{m_\tau^2}{q^2}\right)^{-2}$$

$$R_{D^*}(q^2) \equiv \frac{d\mathcal{B}(\overline{B} \to D^*\tau\overline{\nu})/dq^2}{d\mathcal{B}(\overline{B} \to D^*\ell\overline{\nu})/dq^2} \left(1 - \frac{m_\tau^2}{q^2}\right)^{-2} .$$

$$\lambda_{D^{(*)}}(q^2) = ((m_B - m_{D^{(*)}})^2 - q^2)((m_B + m_{D^{(*)}})^2 - q^2)$$

No Vcb dependence, less form factor uncertainties





Simulated data vs benchmark models

χ^2 of the binned $R_{D^{(*)}}(q^2)$

Required luminosity to exclude the model

$\mathcal{L}$ [fb^{-1}]		model						
		SM	V_1	V_2	S_2	T	LQ$_1$	LQ$_2$
"data"	V_1	1170 (270)		10^6 (×)	500 (×)	900 (×)	4140 (×)	2860 (1390)
	V_2	1140 (270)	10^6 (×)		510 (×)	910 (×)	4210 (×)	3370 (1960)
	S_2	560 (290)	560 (13750)	540 (36450)		380 (×)	1310 (35720)	730 (4720)
	T	600 (270)	680 (×)	700 (×)	320 (×)		620 (×)	550 (1980)
	LQ$_1$	1010 (270)	4820 (×)	4650 (×)	1510 (×)	800 (×)		5920 (1940)
	LQ$_2$	1020 (250)	3420 (1320)	3990 (1820)	1040 (20560)	650 (4110)	5930 (1860)	

(...): integrated quantities

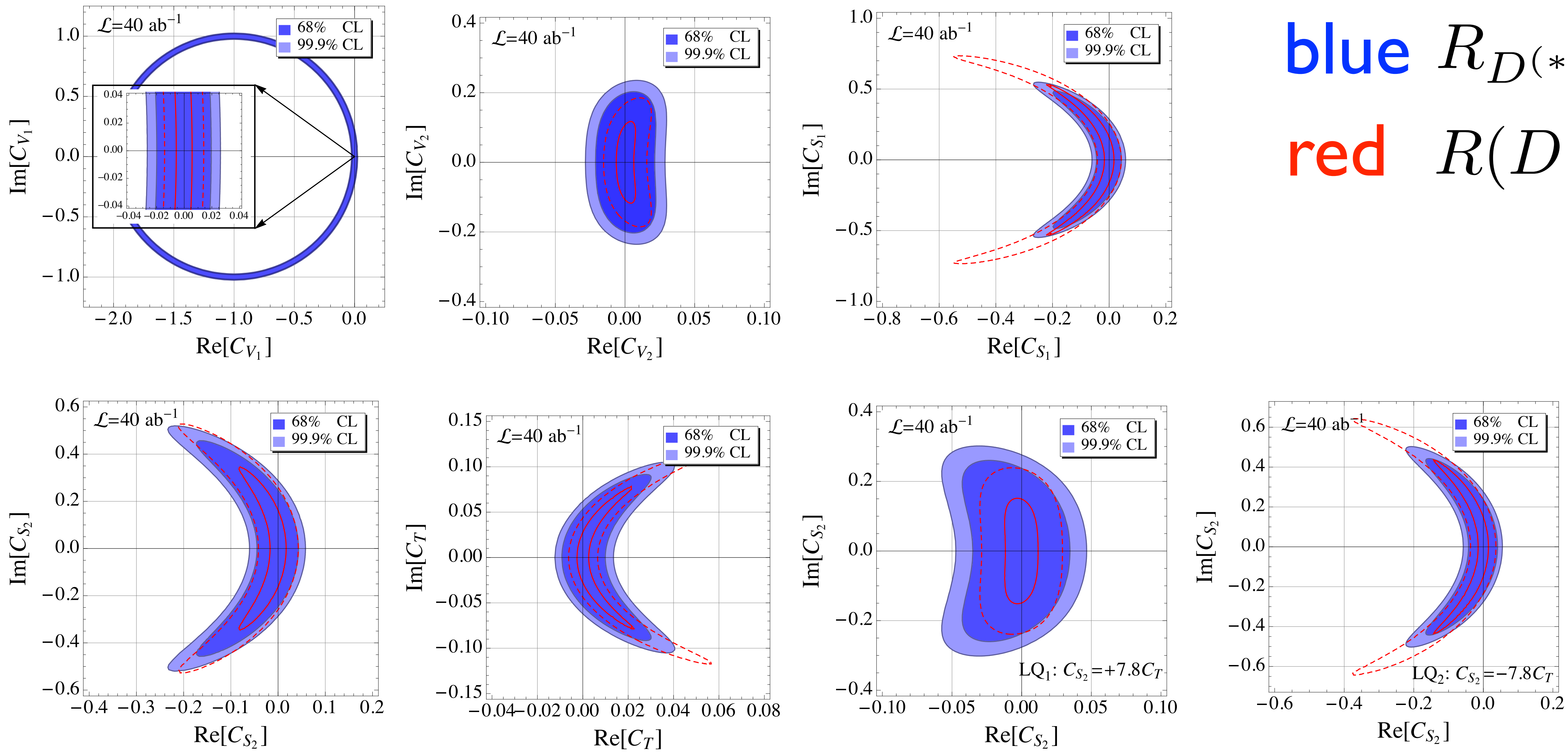
99.9 % CL

$L \lesssim 6 \text{ ab}^{-1}$ in most cases

→ A good target at an earlier stage of Belle II

Belle II sensitivity at 40/ab

Assuming exp. = SM for $R(D),\ R(D^*)$



blue $R_{D^{(*)}}(q^2)$

red $R(D^{(*)})$

$$M_{\rm NP} \equiv (2\sqrt{2} G_F V_{cb} C_X)^{-1/2}$$

$$\gtrsim \underset{V_{1,2}}{5(7)},\ \underset{S_{1,2}}{5(6)},\ \underset{T}{7(10)},\ \underset{\mathrm{LQ}_1}{5(7)},\ \underset{\mathrm{LQ}_2}{5(6)} \quad \text{TeV}$$

Other flavor signals of LQ

Scalar LQ $S_1\ (\mathbf{3}^*, \mathbf{1}, 1/3)$ Bauer, Neubert PRL116,141802 (2016)

Tree: $B \to X_s \nu\bar{\nu},\ K^{(*)}\nu\bar{\nu}$

$D \to \mu^+\mu^-$

Loop: $b \to s\ell\bar{\ell}$

$$R_K = \frac{\Gamma(B \to K\mu^+\mu^-)}{\Gamma(B \to K e^+ e^-)} = 0.745^{+0.090}_{-0.074} \pm 0.036$$

2.6σ LHCb (2014)

$(g-2)_\mu,\ \tau \to \mu\gamma$

Vector LQ $U_3\ (\mathbf{3}, \mathbf{3}, 2/3)$ Fajfer, Kosnik PLB755, 270 (2016)

Tree: $B \to X_s \nu\bar{\nu},\ K^{(*)}\nu\bar{\nu}$

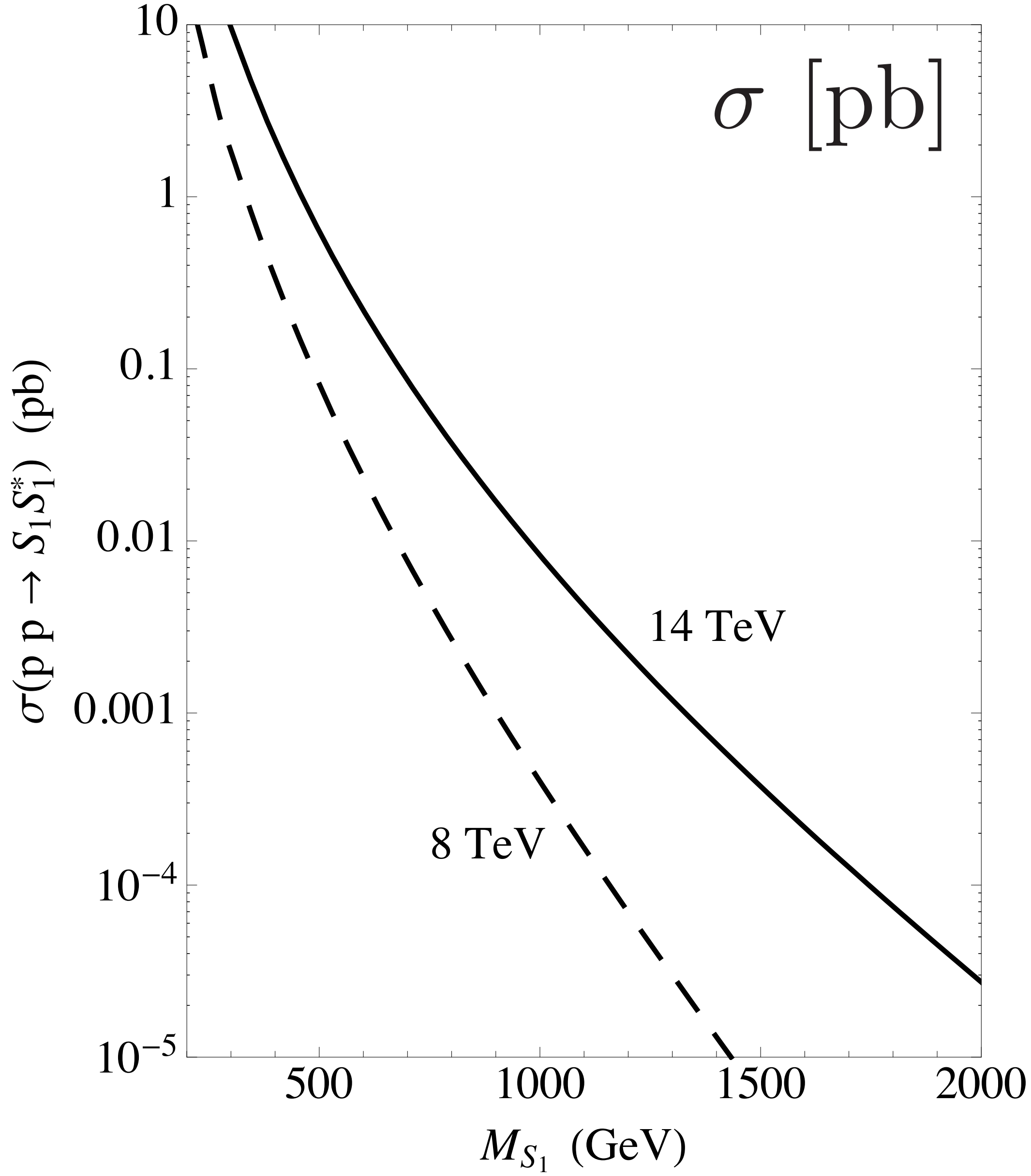
$b \to s\ell\bar{\ell},\ P_5',\ R_K$

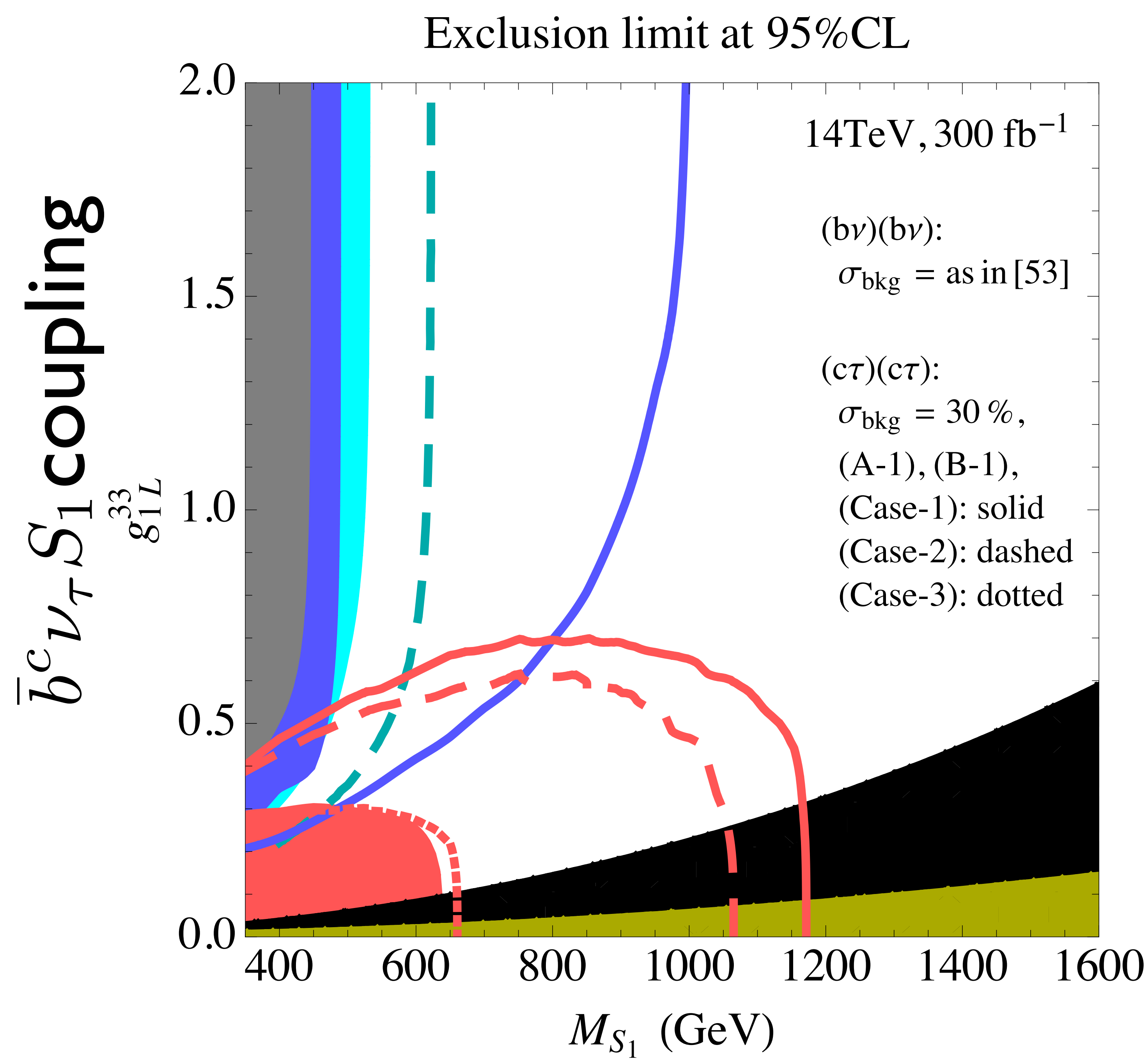
$t \to b\tau^+\nu$

Search for a scalar LQ at LHC

$S_1\ (\mathbf{3}^*, \mathbf{1}, 1/3)$

Dumont, Nishiwaki, Watanabe PRD94, 034001(2016)





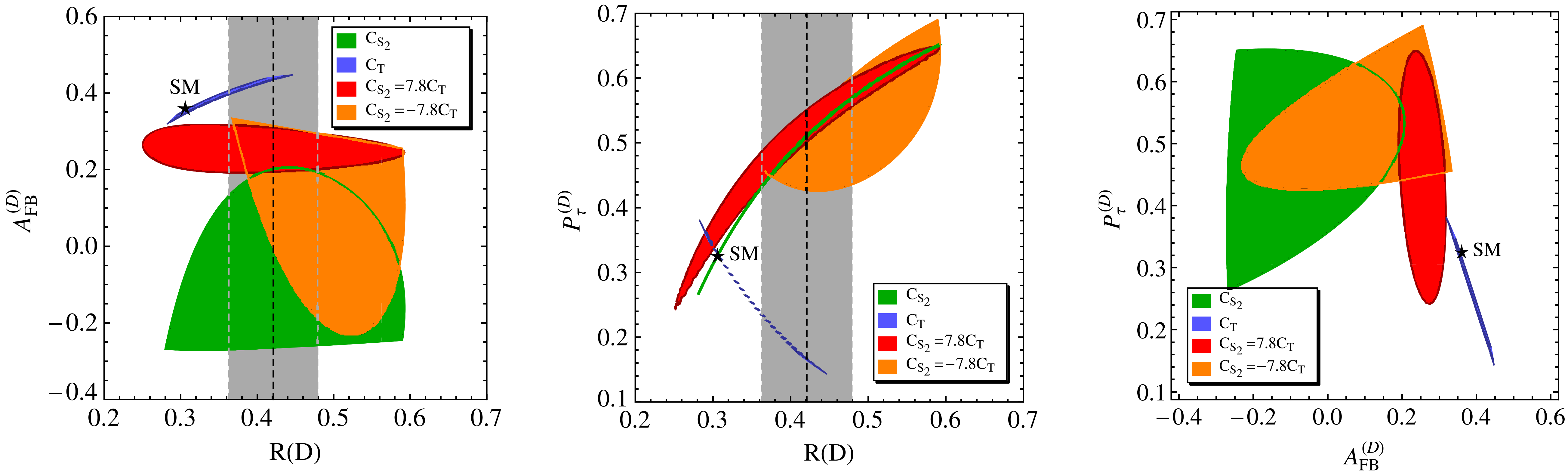
Other observables

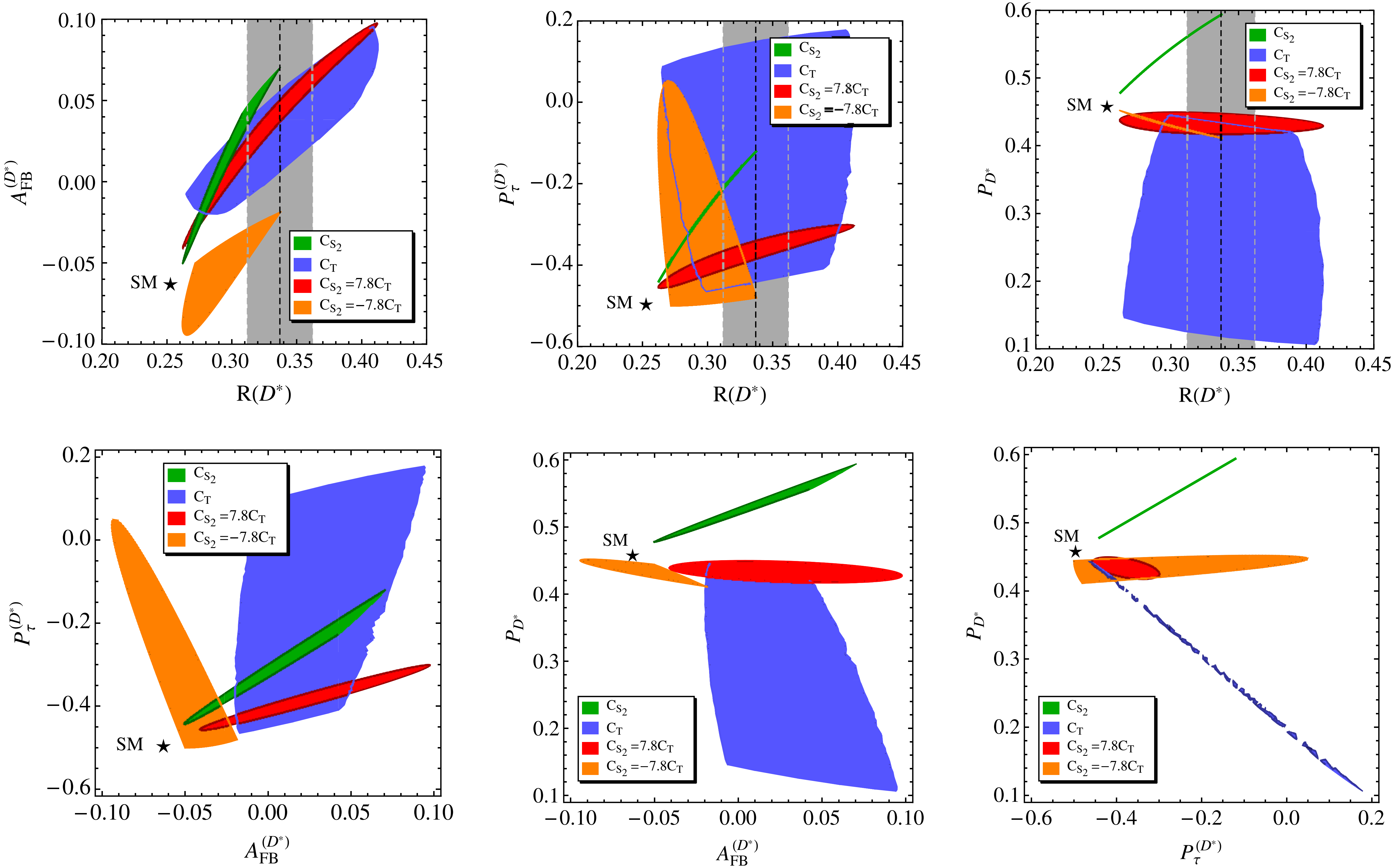
Y. Sakaki, MT, A. Tayduganov, R. Watanabe
arXiv:1309.0301; PRD88, 094012(2013)

$\mathcal{A}_{\rm FB}$: τ forward-backward asymmetry

P_τ : τ longitudinal polarization

P_{D^*} : D* longitudinal polarization



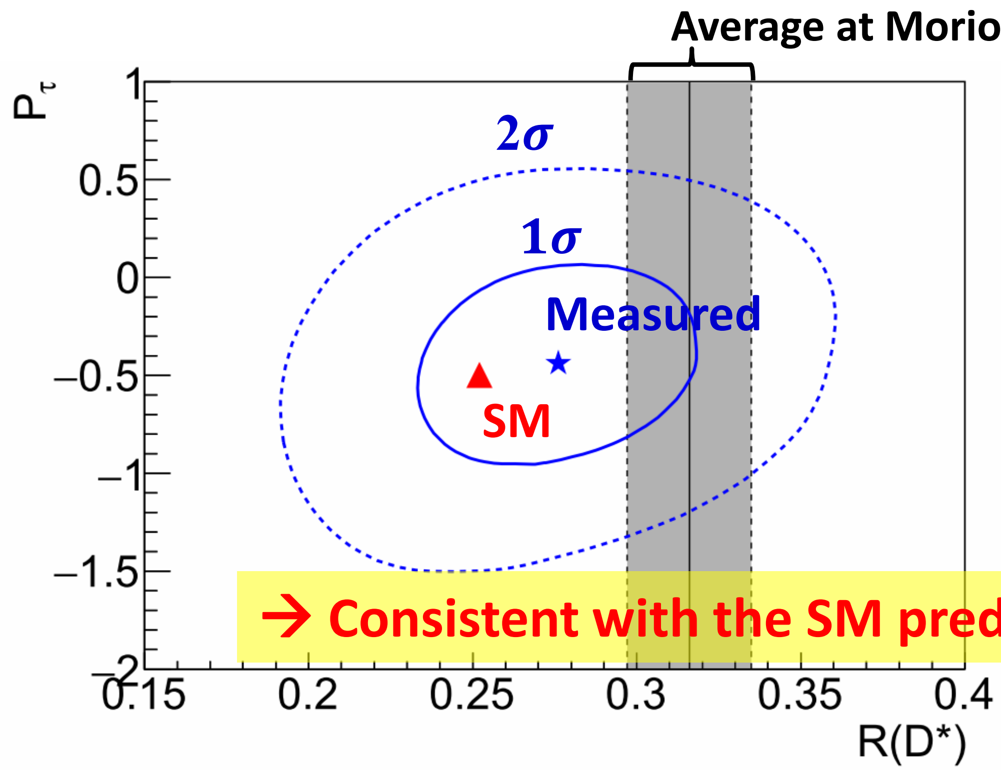


SM
C_{S_2}
C_T
$C_{S_2}=7.8C_T$
$C_{S_2}=-7.8C_T$
$R(D^*)$
$A_{FB}^{(D^*)}$
$P_\tau^{(D^*)}$
P_{D^*}

Result of $\mathcal{R}(D^*)$ and $\mathcal{P}_\tau$ Measurements

$\mathcal{R}(D^*)$ and $\mathcal{P}_\tau$ with Had-tag

- $\boxed{\mathcal{R}(D^*) = 0.276 \pm 0.034(\text{stat})^{+0.029}_{-0.026}(\text{syst})}$ ***Preliminary***
  - 7.1σ significance including systematic uncertainty.
  - Consistent with SM prediction and other measurements.
- $\boxed{\mathcal{P}_\tau = -0.44 \pm 0.47(\text{stat})^{+0.20}_{-0.17}(\text{syst})}$ ***Preliminary***
  - **First $\mathcal{P}_\tau$ measurements !**
  - Consistent with SM prediction (-0.497 ± 0.014) within uncertainty. *M. Tanaka, R. Watanabe, PRD 87, 034028 (2013)*
- Systematics arises mainly from hadronic B bkg, MC statistics.



→ Consistent with the SM prediction within 0.6σ

Model-independent analysis of $\bar{B} \to \pi\tau\bar{\nu}$

MT, R. Watanabe 1608.05207

Br ~ 0.007% in the SM

Exp. $\mathcal{B} = (1.52 \pm 0.72 \pm 0.13) \times 10^{-4}$ Belle 2015

Effective Lagrangian for $b \to u\tau\bar{\nu}$

$$-\mathcal{L}_{\rm eff} = 2\sqrt{2}G_F V_{ub}\Big[(1+C_{V_1})\mathcal{O}_{V_1} + C_{V_2}\mathcal{O}_{V_2} + C_{S_1}\mathcal{O}_{S_1} + C_{S_2}\mathcal{O}_{S_2} + C_T\mathcal{O}_T\Big]$$

$$\mathcal{O}_{V_1} = (\bar{u}\gamma^\mu P_L b)(\bar{\tau}\gamma_\mu P_L \nu_\tau) \qquad \mathcal{O}_{S_1} = (\bar{u}P_R b)(\bar{\tau}P_L\nu_\tau)$$

$$\mathcal{O}_{V_2} = (\bar{u}\gamma^\mu P_R b)(\bar{\tau}\gamma_\mu P_L \nu_\tau) \qquad \mathcal{O}_{S_2} = (\bar{u}P_L b)(\bar{\tau}P_L\nu_\tau)$$

$$\mathcal{O}_T = (\bar{u}\sigma^{\mu\nu}P_L b)(\bar{\tau}\sigma_{\mu\nu}P_L\nu_\tau)$$

$|V_{ub}|$ and form factors → uncertainty

$$R_\pi = \frac{\mathcal{B}(\bar{B}^0 \to \pi^+\tau^-\bar{\nu})}{\mathcal{B}(\bar{B}^0 \to \pi^+\ell^-\bar{\nu})}$$ smaller uncertainty

Form factors

Vector: $f_+(q^2),\ f_0(q^2)$

$$\langle\pi(p_\pi)|\bar{u}\gamma^\mu b|\bar{B}(p_B)\rangle = f_+(q^2)\left[(p_B+p_\pi)^\mu - \frac{m_B^2-m_\pi^2}{q^2}q^\mu\right] + f_0(q^2)\frac{m_B^2-m_\pi^2}{q^2}q^\mu$$

$\bar{B}\to\pi\ell\bar{\nu}$ exp. data + lattice Bailey et al. PRD92, 014024 (2015)

Scalar: $f_S(q^2)$

$$\langle\pi(p_\pi)|\bar{u}b|\bar{B}(p_B)\rangle = (m_B+m_\pi)f_S(q^2)$$

eq. of motion $f_S(q^2) = \dfrac{m_B-m_\pi}{m_b-m_u}f_0(q^2)$

$m_b \simeq 4.2\ \mathrm{GeV}$

Tensor: $f_T(q^2)$

$$\langle\pi(p_\pi)|\bar{u}\,i\sigma^{\mu\nu}\,b|B(p_B)\rangle = \frac{2}{m_B+m_\pi}f_T(q^2)\left[p_B^\mu p_\pi^\nu - p_B^\nu p_\pi^\mu\right]$$

lattice Bailey et al. PRL115, 152002 (2015)

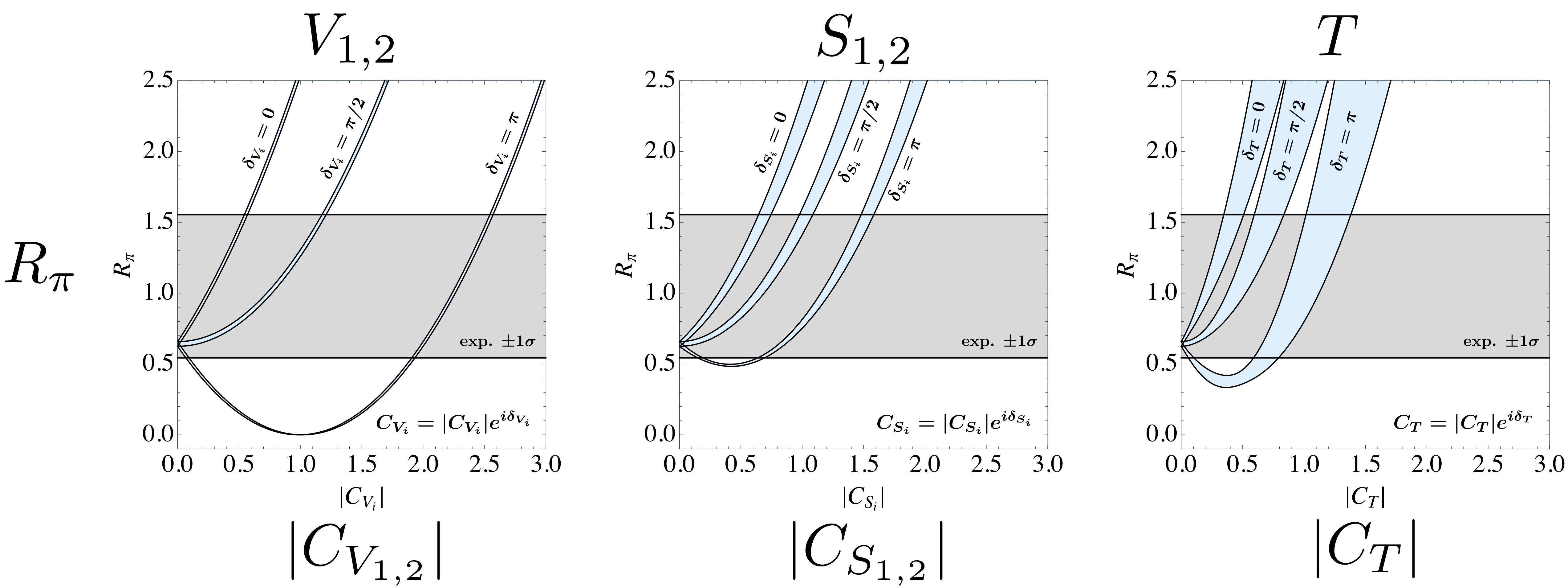
Ratio of branching fraction

$$R_\pi = \frac{\mathcal{B}(\bar{B}^0 \to \pi^+\tau^-\bar{\nu})}{\mathcal{B}(\bar{B}^0 \to \pi^+\ell^-\bar{\nu})}$$

$$R_\pi^{\rm exp} = 1.05 \pm 0.51$$

$\mathcal{B}(B \to \pi\ell\bar{\nu}) = (1.45 \pm 0.02 \pm 0.04) \times 10^{-4}$ HFAG

$$R_\pi^{\rm SM} = 0.641 \pm 0.016$$



Pure- to semi- leptonic ratio

$B^- \to \tau^- \bar{\nu}$ **described by** $\mathcal{L}_{\rm eff}(b \to u\tau\bar{\nu})$

$$\mathcal{B}(B \to \tau\bar{\nu}_\tau) = \frac{\tau_{B^-} G_F^2 |V_{ub}|^2 f_B^2}{8\pi} m_B m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 |1 + r_{\rm NP}|^2$$

$$r_{\rm NP} = C_{V_1} - C_{V_2} + \frac{m_B^2}{m_b m_\tau}(C_{S_1} - C_{S_2})$$

No tensor contribution

Uncertainties: $|V_{ub}|, \ f_B$

Taking a ratio to eliminate $|V_{ub}|$

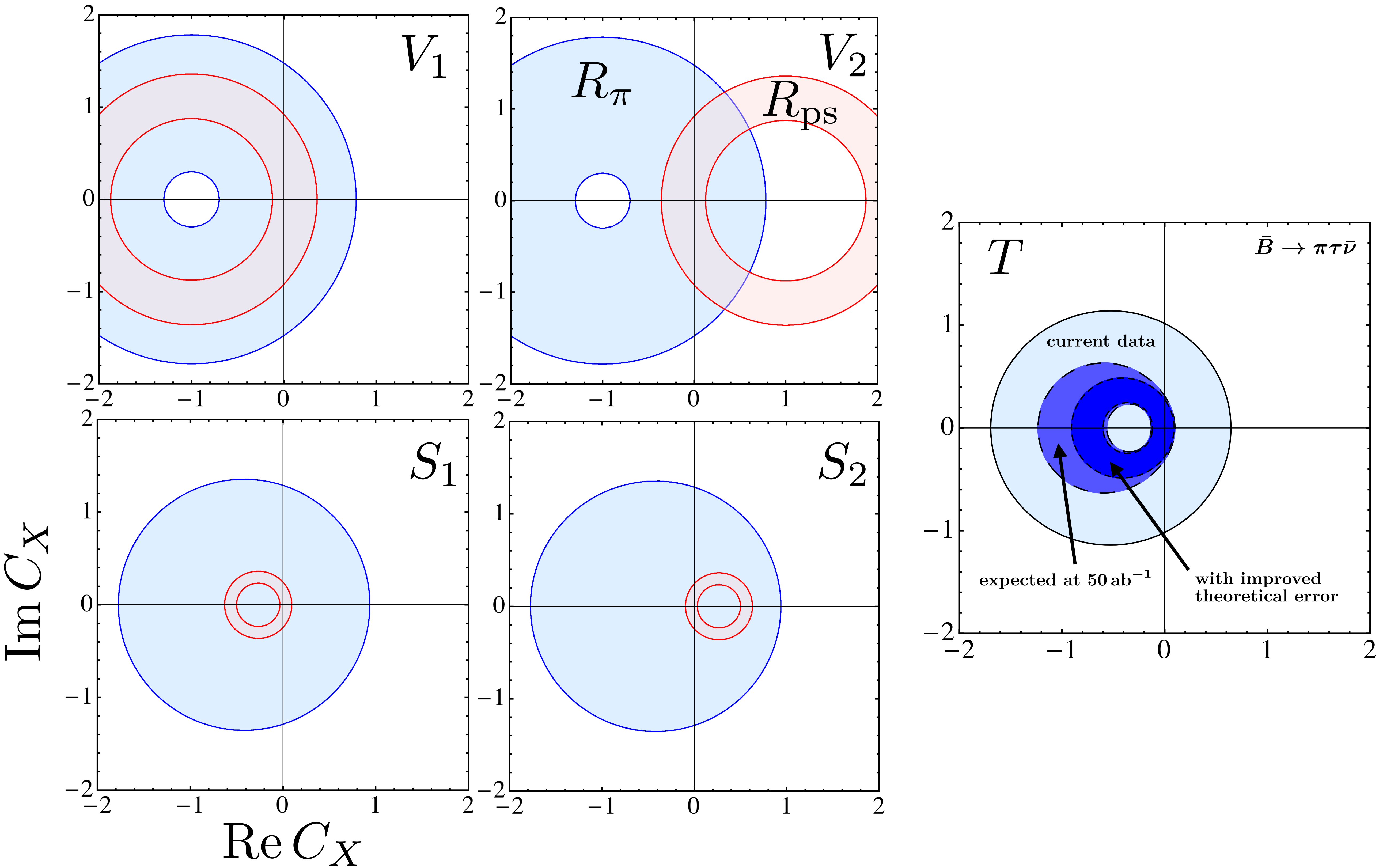
$$R_{\rm ps} = \frac{\Gamma(B^- \to \tau^- \bar{\nu}_\tau)}{\Gamma(\bar{B}^0 \to \pi^+ \ell^- \bar{\nu}_\ell)} = \frac{\tau_{B^0}}{\tau_{B^-}} \frac{\mathcal{B}(B^- \to \tau^- \bar{\nu}_\tau)}{\mathcal{B}(\bar{B}^0 \to \pi^+ \ell^- \bar{\nu}_\ell)}$$

Fajfer et al. PRL109, 161801(2012)

+ lattice $f_B = 192.0 \pm 4.3\ \text{MeV}$ FLAG 1607.00299

$$R_{\rm ps}^{\rm SM} = 0.574 \pm 0.046 \qquad R_{\rm ps}^{\rm exp} = 0.73 \pm 0.14$$

$\mathcal{B}(B^- \to \tau^- \bar{\nu}) = (1.14 \pm 0.22) \times 10^{-4}$ **BaBar, Belle**



Another ratio

$$R_{\rm pl} = \frac{\mathcal{B}(B \to \tau \bar{\nu}_\tau)}{\mathcal{B}(B \to \mu \bar{\nu}_\mu)} = \frac{m_\tau^2}{m_\mu^2} \frac{(1 - m_\tau^2/m_B^2)^2}{(1 - m_\mu^2/m_B^2)^2} |1 + r_{\rm NP}|^2 \simeq 222\,|1 + r_{\rm NP}|^2$$

practically no uncertainty in the SM prediction

$\mathcal{B}(B \to \mu \bar{\nu}_\mu)^{\rm exp.} < 1 \times 10^{-6}$ at 90% CL BaBar, Belle

$$\mathcal{B}(B \to \mu \bar{\nu}_\mu)^{\rm SM} = (0.41 \pm 0.05) \times 10^{-6}$$

likely to be observed at Belle II

Future prospect

Belle II ~50/ab   cf. Belle ~ 1/ab

Scaling the present errors as $1/\sqrt{\mathcal{L}}$

and the central values = SM

NP scenario	$R_\pi^{\text{Belle II}} = 0.641 \pm 0.071$	$R_{\text{ps}}^{\text{Belle II}} = 0.574 \pm 0.020$	$R_{\text{pl}}^{\text{Belle II}} = 222 \pm 47$
C_{V_1}	$[-0.12, 0.11]$	$[-0.08, 0.10]$	$[-0.23, 0.19]$
C_{V_2}	$[-0.12, 0.11]$	$[-0.10, 0.08]$	$[-0.19, 0.23]$
C_{S_1}	$[-0.31, 0.17]$	$[-0.02, 0.03]$	$[-0.06, 0.05]$
C_{S_2}	$[-0.31, 0.17]$	$[-0.03, 0.02]$	$[-0.05, 0.06]$
C_T	$[-0.13, 0.10]$	-	-

Summary

- Excess of $\bar{B} \to D^{(*)}\tau\bar{\nu}$

  $R(D), R(D^*)$ ~ 4σ

- Testing NP with the q2 distribution

  The earlier stage of Belle II ~ 5-10 /ab

- Other observables $A_{FB},\ P_\tau,\ P_{D^*},\ R(X_c)$

  Belle II, LHCb prospect?

- Flavor structure of possible NP

  $(\bar{u}b)(\bar{\tau}\nu)$ $B^- \to \tau\bar{\nu}\,,\ B \to \pi\tau\bar{\nu}$

  MFV Freytsis, Ligeti, Ruderman PRD92, 054018 (2015)

  U(2) Barbieri et al. EPJC76, 67 (2016)