Global fit to $b \to c \tau \nu$

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Inspire
web page

IAP

Theoretical
Particle Physics

18/09/2023

Santiago de Compostela

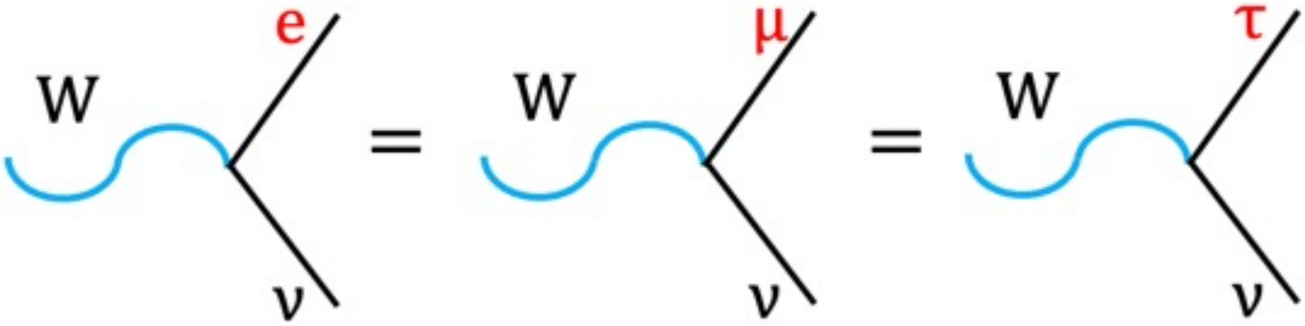
Mainly based on 2210.10751 (v3 coming soon)

and many papers with Teppei Kitahara, Yuji Omura, Ryoutaro Watanabe, Hantian Zhang, Monika Blanke, Ulrich Nierste, Fedele Marco, Andreas Crivellin,,,

$R_{D^{(*)}}$ anomaly

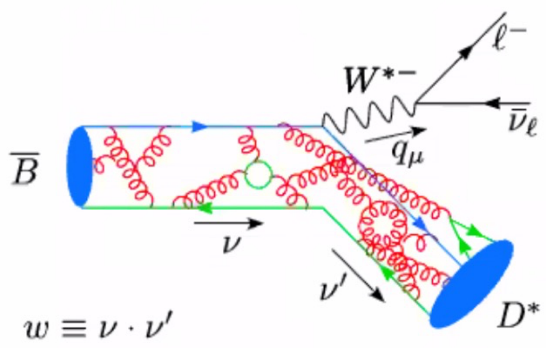
Now persisting more than 10 years

SM: gauge symmetry guarantees



$$R_{D^{(*)}} = \frac{BR\left(B \to D^{(*)} \tau \nu\right)}{BR\left(B \to D^{(*)} l \nu\right)} \; , \; l = \mu, \mathrm{e}$$

The lepton flavor universality violating (LFUV) effect comes from the lepton mass

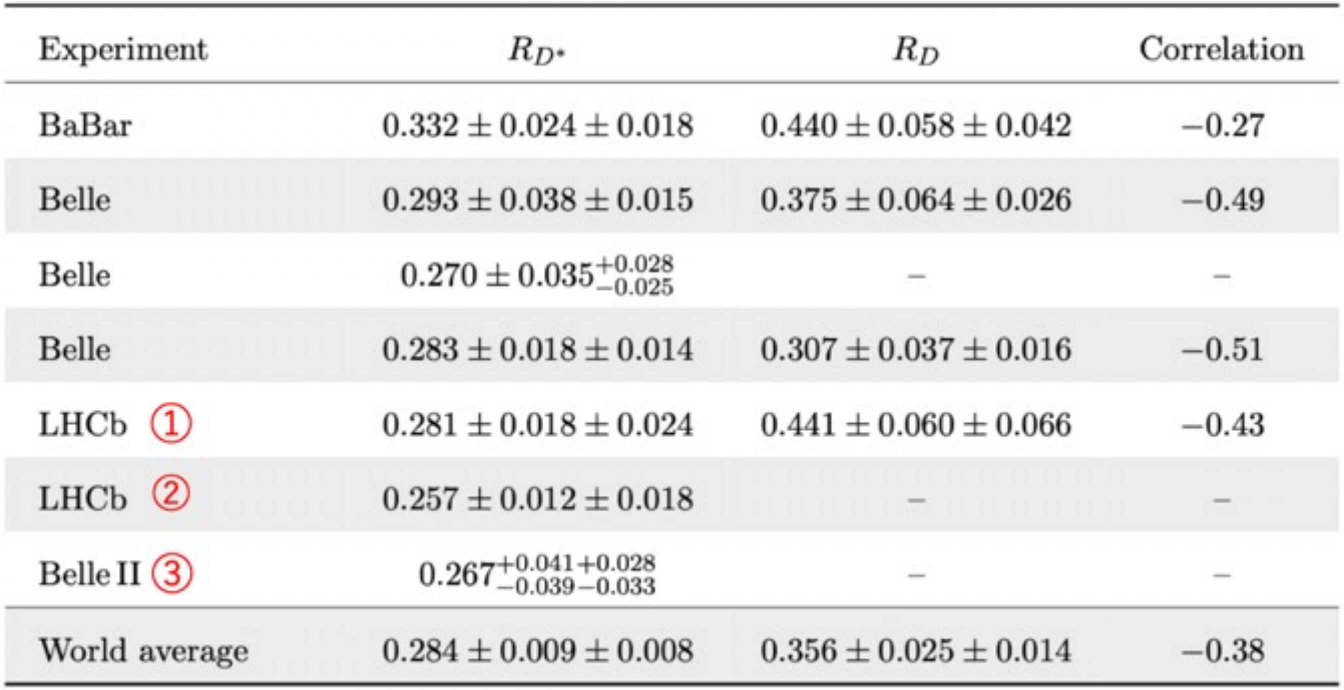


Hadronic form factors (FFs) uncertainty is largely cancelled in ratio, V_{cb} also

Good measure to test the LFUV and hence great window to new physics

Experimental update

We had three new data this 1-year



Experiment	R_{D^*}	R_D	Correlation
BaBar	$0.332 \pm 0.024 \pm 0.018$	$0.440 \pm 0.058 \pm 0.042$	-0.27
Belle	$0.293 \pm 0.038 \pm 0.015$	$0.375 \pm 0.064 \pm 0.026$	-0.49
Belle	$0.270 \pm 0.035^{+0.028}_{-0.025}$	–	–
Belle	$0.283 \pm 0.018 \pm 0.014$	$0.307 \pm 0.037 \pm 0.016$	-0.51
LHCb ①	$0.281 \pm 0.018 \pm 0.024$	$0.441 \pm 0.060 \pm 0.066$	-0.43
LHCb ②	$0.257 \pm 0.012 \pm 0.018$	–	–
Belle II ③	$0.267^{+0.041+0.028}_{-0.039-0.033}$	–	–
World average	$0.284 \pm 0.009 \pm 0.008$	$0.356 \pm 0.025 \pm 0.014$	-0.38

① LHCb 2022 Oct. τ->μνν
② LHCb 2023 Feb. Hadronic τ (τ_h)
③ Belle II first result 2023 July τ_h

} Run 1

∼200fb^{-1}

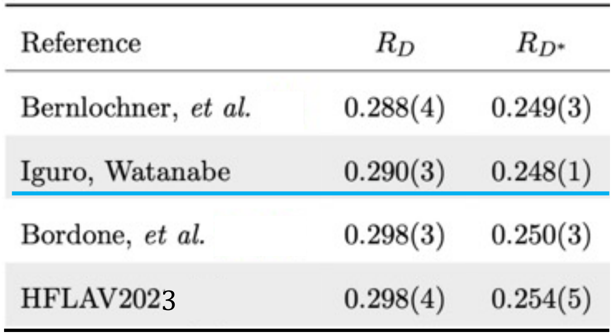
Now we have data from four experiments!

p-value got improved (0.92 x 10^{-3} ->0.33) = more consistent experimental situation

There are new data of relevant processes, $B_c \to J/\psi\tau\nu$, $B \to X_c\tau\nu$ EPS2023

Wish list: CMS B-parking, further Belle II data, LHCb Run 2, BaBar

SM prediction



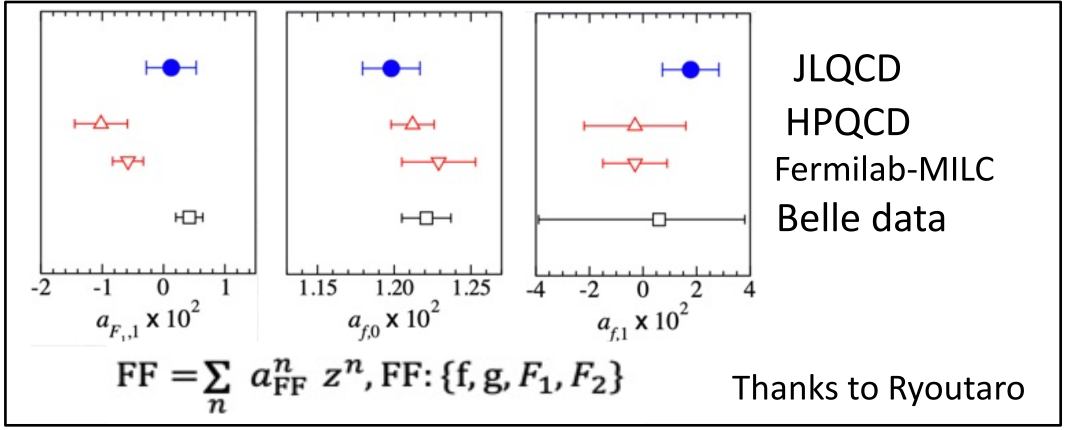
Reference	R_D	R_{D^*}
Bernlochner, *et al.*	0.288(4)	0.249(3)
Iguro, Watanabe	0.290(3)	0.248(1)
Bordone, *et al.*	0.298(3)	0.250(3)
HFLAV2023	0.298(4)	0.254(5)

looks relatively stable

See next talk by Prim

New Lattice results for B->D* are not conclusive

see talk by Kaneko



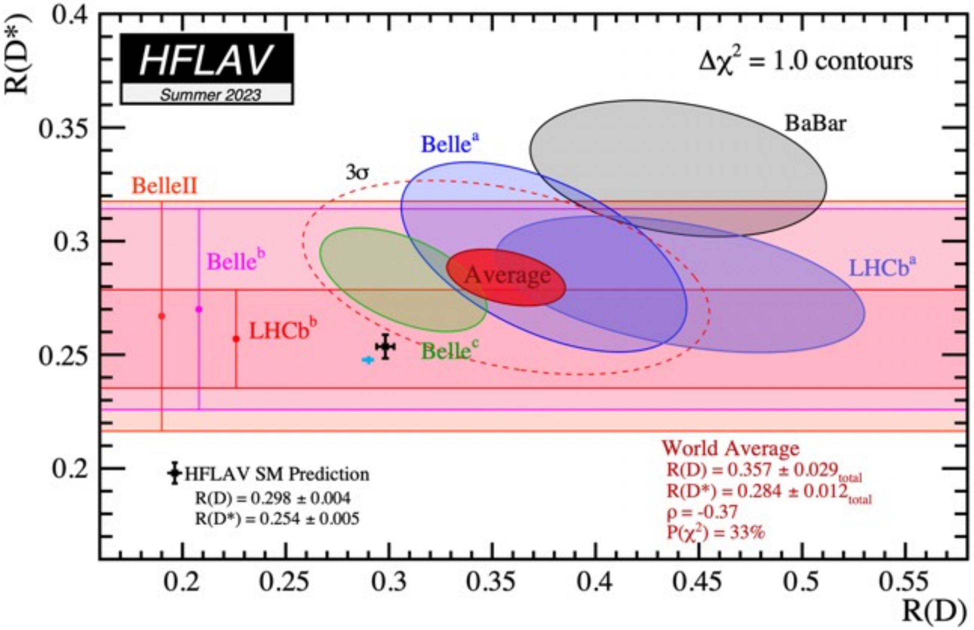
$$\mathrm{FF} = \sum_n a^n_{\mathrm{FF}}\, z^n, \mathrm{FF}: \{\mathrm{f}, \mathrm{g}, F_1, F_2\}$$

Thanks to Ryoutaro

Regarding the inconsistency of dispersive method based on Fermilab-MILC see talk by Fedele

Current status

HFLAV and 2004.10208



3.3–4σ discrepancy

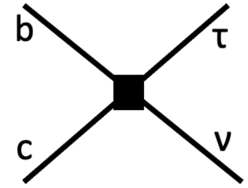
without BaBar ∼ 2.5-3.2σ

Larger (smaller) discrepancy in R_D (R_{D^*}).

We will discuss implication to NP interpretation

Light lepton philic NP can not explain this

Effective Lagrangian for b ->c τ ν



$$H_{eff} = \frac{4G_F}{\sqrt{2}} V_{cb}\,[(1 + C_{VL})O_{VL} + C_{VR}O_{VR} + C_{SR}O_{SR} + C_{SL}O_{SL} + C_T O_T]$$

Dimension 6 due to the size of the discrepancy -> finite particle candidates

Operator basis

candidates

$$O_{SR} = (\bar{c}P_R b)(\bar{\tau}P_L \nu_\tau)$$

$$O_{SL} = (\bar{c}P_L b)(\bar{\tau}P_L \nu_\tau)$$

Scalar H^- **$B_c^- \rightarrow \tau\bar{\nu}$**

$$O_{VL} = (\bar{c}\gamma^\mu P_L b)(\bar{\tau}\gamma^\mu P_L \nu_\tau)$$

$$O_{VR} = (\bar{c}\gamma^\mu P_R b)(\bar{\tau}\gamma^\mu P_L \nu_\tau)$$

Vector ~~W'~~ Bs mixing & bb > ττ

$$O_T = (\bar{c}\sigma^{\mu\nu} P_L b)(\bar{\tau}\sigma_{\mu\nu} P_L \nu_\tau)$$

Tensor LQ

Relaxed BR($B_c^- \rightarrow \tau\bar{\nu}$) bound

Previous constraint

~~< 30%~~ R.Alonso et al 1611.06676

~~< 10%~~ A.G.Akeroyd et al 1708.04702

$\Gamma_{Bc} \propto m_Q^5$ + large error in charm mass

-> large error for Γ_{Bc}

Current constraint

< 63% B.Grinstein et al 2105.02988

M.Blanke et al 1811.09603

Summary of model prediction: correlation

Relaxed $B_c \to \tau\nu$ bound and shifted $R_{D^{(*)}}$ 2210.10751 (v3 soon)

	Spin	Charge	Operators	R_D	R_{D^*}	LHC	Flavor
$H^\pm$	0	$(\mathbf{1},\mathbf{2},1/2)$	O_{S_L}	✓	✓	$b\tau\nu$	$B_c\to\tau\nu$, $F_L^{D^*}$, P_τ^D, M_W
S_1	0	$(\bar{\mathbf{3}},\mathbf{1},1/3)$	O_{V_L}, O_{S_L}, O_T	✓	✓	$\tau\tau$	ΔM_s, P_τ^D, $B\to K^{(*)}\nu\nu$
$\mathrm{R}_2^{(2/3)}$	0	$(\mathbf{3},\mathbf{2},7/6)$	O_{S_L}, O_T, (O_{V_R})	✓	✓	$b\tau\nu$, $\tau\tau$	$R_{\Upsilon(nS)}$, $P_\tau^{D^*}$, M_W
U_1	1	$(\mathbf{3},\mathbf{1},2/3)$	O_{V_L}, O_{S_R}	✓	✓	$b\tau\nu$, $\tau\tau$	$R_{K^{(*)}}$, $R_{\Upsilon(nS)}$, $B_s\to\tau\tau$
$\mathrm{V}_2^{(1/3)}$	1	$(\bar{\mathbf{3}},\mathbf{2},5/6)$	O_{S_R}	✓	2σ	$\tau\tau$	$B\to\tau\nu$, $B_s\to\tau\tau$, $B\to K\tau\tau$

LQ

See also Angelescu et al, 2103.12504, Athron et al 2104.03691 for the previous version of LQs

$$\text{Pull} \equiv \sqrt{\chi^2_{\text{SM}} - \chi^2_{\text{NP-best}}}\ (\sigma)$$

based on $R_{D^{(*)}}$, $F_L^{D^*}$

$\mu_b = \mu$

$C_{S_L} = -0.88 \pm 0.88i$ Pull=4.3σ $H^\pm$

$C_{S_L} = -8.9C_T = 0.19$ Pull=3.9σ S_1

$C_{S_L} = 8.4C_T = -0.07 \pm 0.58i$ Pull=4.0σ R_2

$C_{V_L} = 0.07 = C_{S_R}/(-3.7)\times e^{-i\phi_R}$, $\phi_R = 0.54\pi$ Pull=4.1σ U_1

$C_{S_R} = -0.2$ Pull=3.8σ V_2

Similar goodness of fit

Model discrimination is possible via these correlated predictions

Also, τ polarization in $B \to D^{(*)}\tau\nu$ is important @ Belle II

NP model dependent recent topics

- Revived Charged Higgs interpretation with sizable C9

- Testing U_1 LQ with EDM experiments

necromancer

- LHC proposal: τν+b final state

If time allows

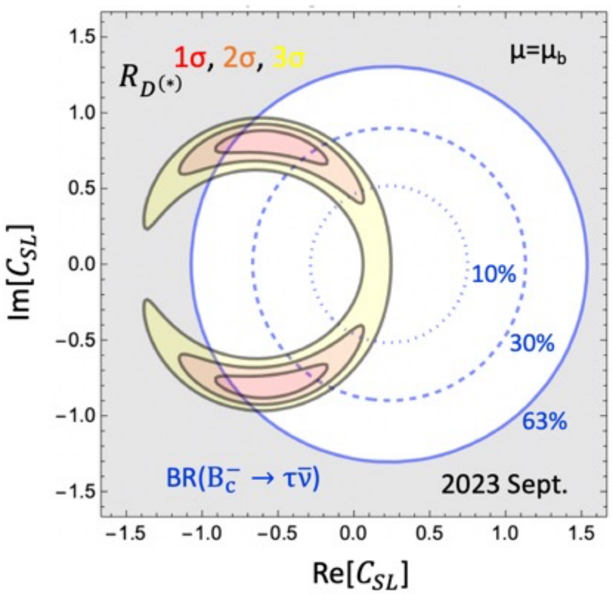
- Another revival, V_2 leptoquark

Since the size of the deviation implies up to O(1) TeV new particle, LHC searches should see something already or soon!

Scalar operator revived

Iguro 2201.06565

$O_{SL} = (\bar{c}P_L b)(\bar{\tau}P_L \nu_\tau)$



Thanks to the relaxed upper bound from $B_c^- \to \tau\bar{\nu}$ scalar scenario is still viable!

Only scalar can (slightly) enhance $F_L^{D^*}$

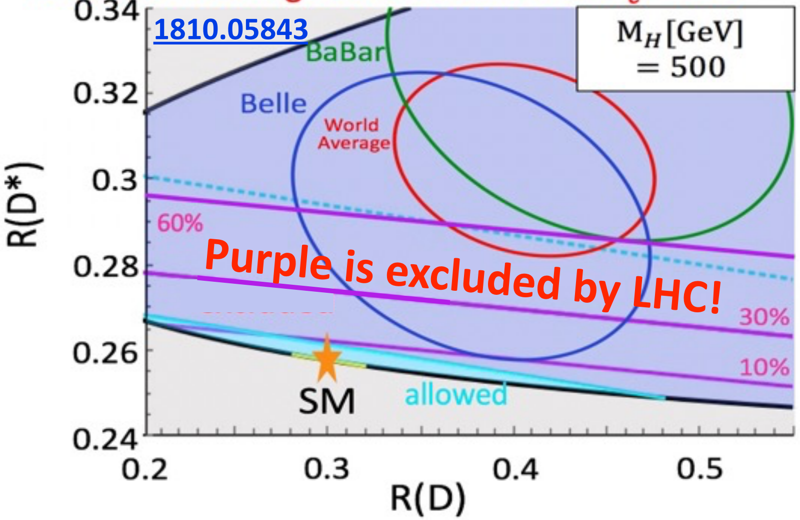
$$F_{L\,exp}^{D^*} = 0.60 \pm 0.09, \quad F_{L\,SM}^{D^*} = 0.46 \pm 0.01$$

We need complex WC

=> Complex Yukawa in type III (General) 2HDM

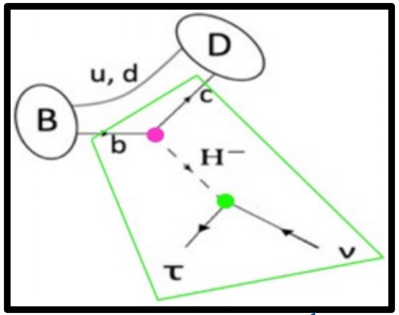
Reinterpreting **τν resonance search** from the CMS(36fb^{-1}) excludes the scenario with $m_{H^+} > 400\text{GeV}$

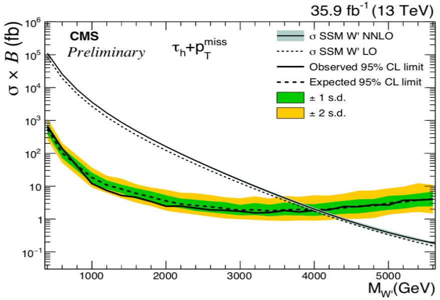
Much more stringent constraint than $B_c^- \to \tau\bar{\nu}$



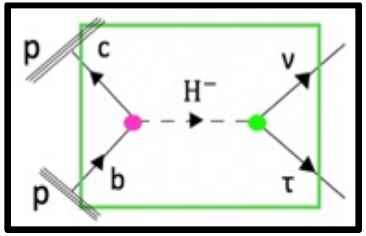
1810.05843

Purple is excluded by LHC!





correlation



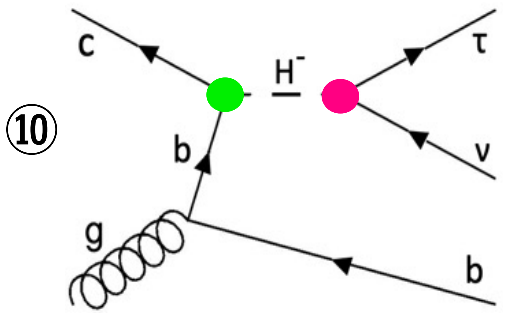
There is no data available for $m_{H^+} < 400\text{GeV}$

Additional b-jet would suppress the trigger rate

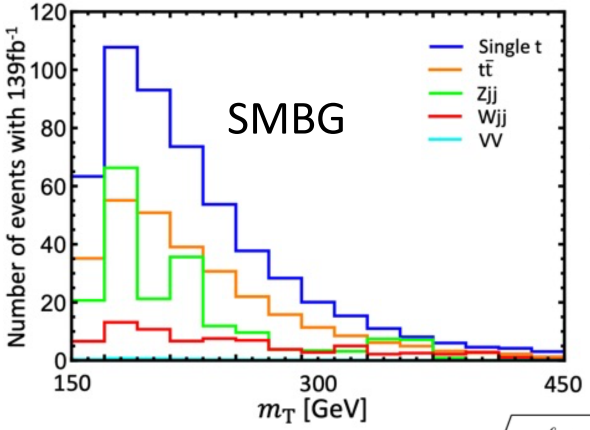
Closing the low mass window with τν+b search!

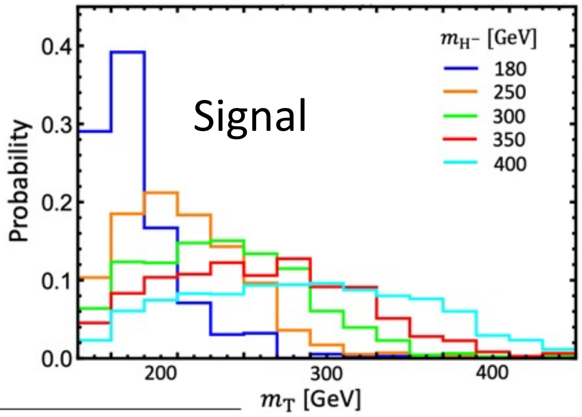
Iguro, Zhang, Blanke 2202.10468

$180\text{GeV} < m_{H^+} < 400\text{GeV}$



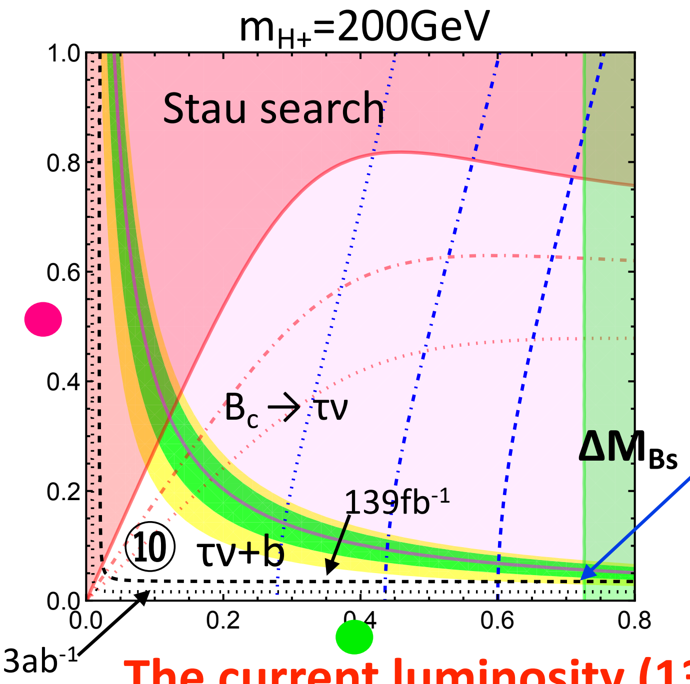
b-tagging suppress the SMBG

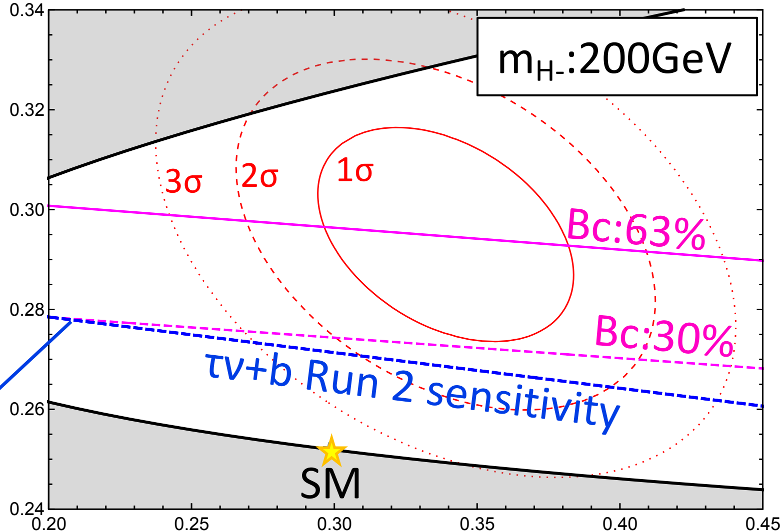




$$m_T = \sqrt{2p_T^{\ell} E_T^{\rm miss}(1-\cos\theta_{\ell\nu})}$$

NP signal event number (with parameters to explain the anomaly) is comparable with SMBG!





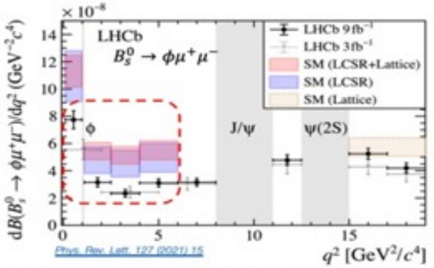
Very conservative syst. error is assigned

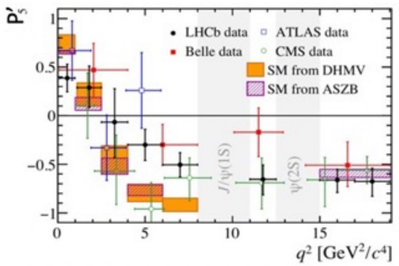
Heavier scenario is more easy due to smaller BG!

The current luminosity (139fb^{-1}) is already enough to judge the model!

Flavor universal C9 ?

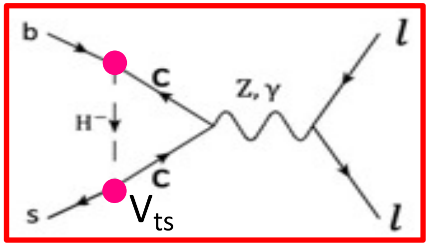
Iguro 2302.08935 Iguro Omura 1802.01732



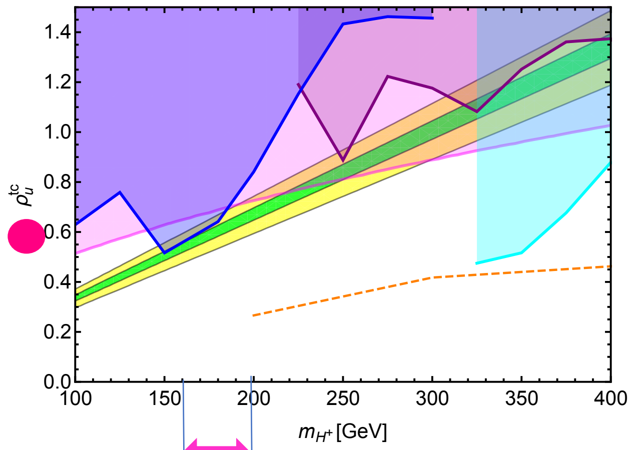


SU(2)$_L$ doublet

$$\begin{pmatrix} H^+ \\ \frac{1}{\sqrt{2}}(H+iA) \end{pmatrix}$$



Parameter space



Green and yellow are interesting $C_9^U \sim -1 \pm 0.2$

Bs mixing and di-jet also put interesting constraints

Stringent upper bound from same sign top (SST) search
2307.14759

Although this can be avoided by taking m_A=m_H at O(1) GeV

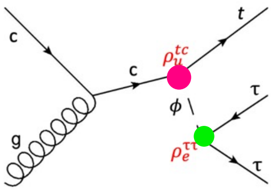
$m_{A,H}$<m_t is also excluded by multi tau lepton search

➡ O(1) GeV turning or $m_t < m_{A,H} < 200$ GeV

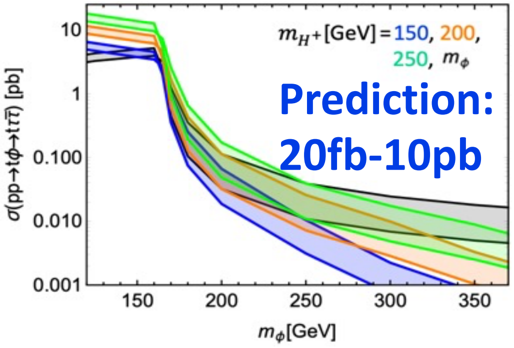
mass window

How to test the remaining mass window?

FCNC top production
(cg→ t+ττ)

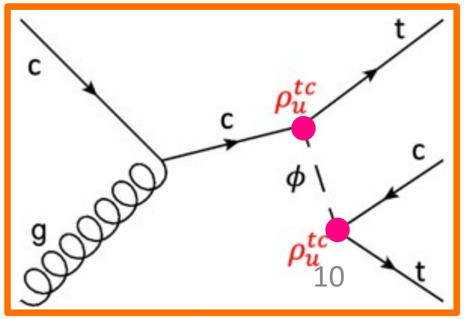


Naïve Run 2 sensitivity:
100fb for $m_{\tau\tau}$ =125 GeV, 2011.03652 (CMS)
but we have heavier resonance -> small BG



Prediction:
20fb-10pb

Diagram for SST



Bridging $R_{D^{(*)}}$ and EDMs

Iguro, Kitahara 2307.11751

U(2) flavored U1 LQ : leading candidate (Zurich model)

See also 2002.01400, 1809.09114

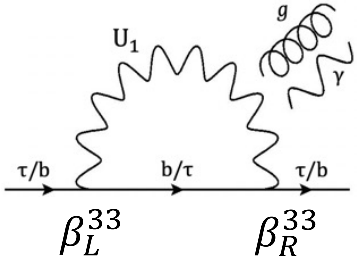
Recent finding

$$\mathcal{L} \supset \left(\beta_L^{ij}\overline{Q}_i\gamma_\mu P_L L_j + \beta_R^{ij}\overline{d}_i\gamma_\mu P_R e_j\right)U_1^\mu + \text{h.c.}\,.$$

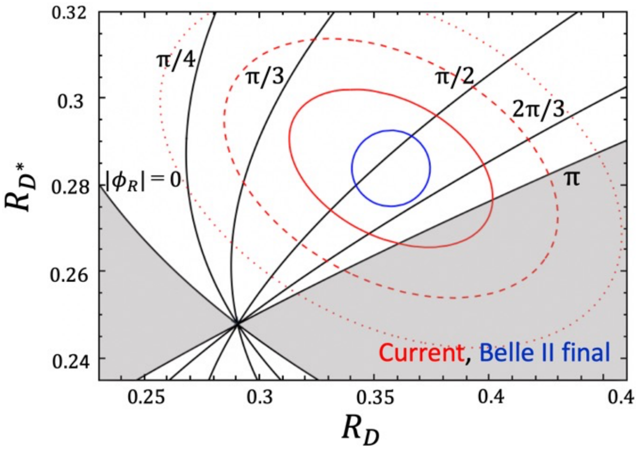
$$\beta_L^{ij} \simeq \begin{pmatrix} 0 & 0 & -c_d s_{q_2} s_\chi \left|\frac{V_{td}}{V_{ts}}\right| \\ 0 & 0 & c_d s_{q_2} s_\chi \\ 0 & 0 & c_\chi \end{pmatrix}, \quad \beta_R^{ij} \simeq \underline{e^{i\phi_R}} \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \underline{1} \end{pmatrix},$$

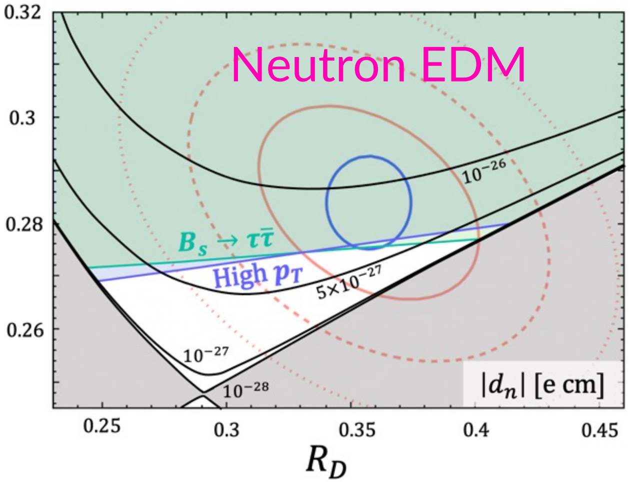
Javier, Claudia, Gino,, 1903.11517, 1909.02519,,,

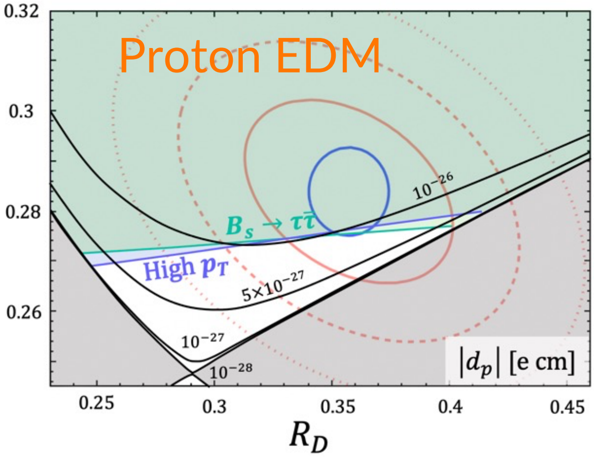
$$C_{S_R}(\mu_b) \simeq -3.7e^{-i\phi_R}C_{V_L}(\mu_b)$$



Bottom induced Weinberg operator contributes to neutron and proton EDMs
Haisch, Hala 1909.08955







ϕ$_R$=0 is not good => CPV

$d_n \sim -d_p = \mathrm{O}(10^{-26\sim27})$ e cm, well within future reach while $d_e \sim \mathrm{O}(10^{-32})$ e cm

Bridging R_{D^*} and EDMs

Iguro, Kitahara 2307.11751

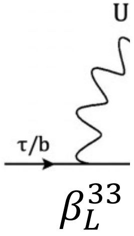
U(2) flavored U1 LQ : leading

Recent finding

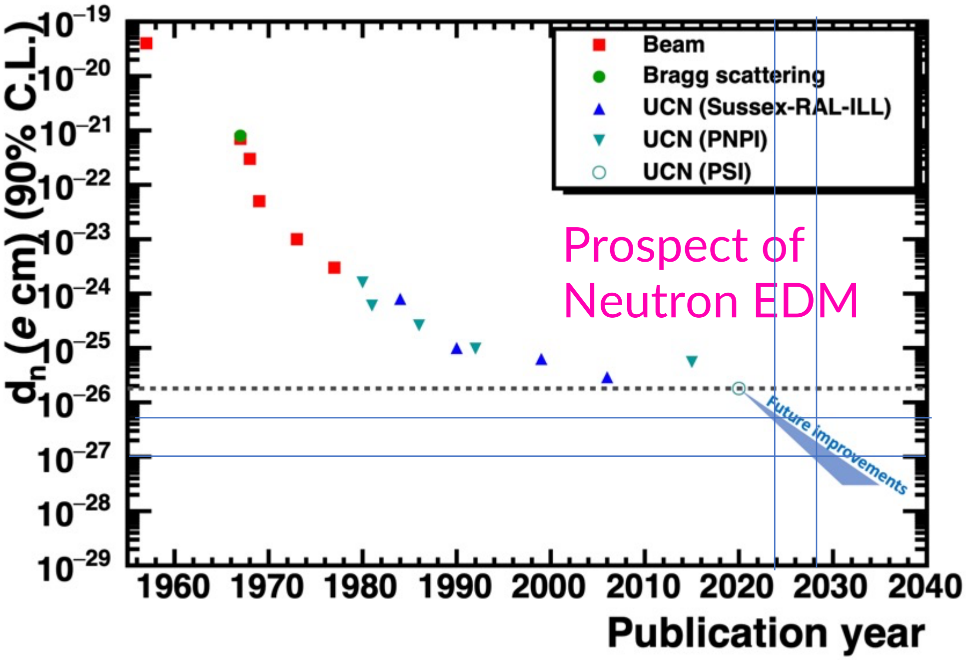
$$\mathcal{L} \supset \left(\beta_L^{ij}\overline{Q}_i\gamma_\mu P_L L_j + \beta_R^{ij}\overline{d}_i\gamma_\mu P_R e_j\right) U_1^\mu +$$

Javier, Claudia, Gino,, 1903.11517, 1

$$C_{S_R}(\mu_b) \simeq -3.7 e^{-i\phi_R} C_{V_L}(\mu_b)$$



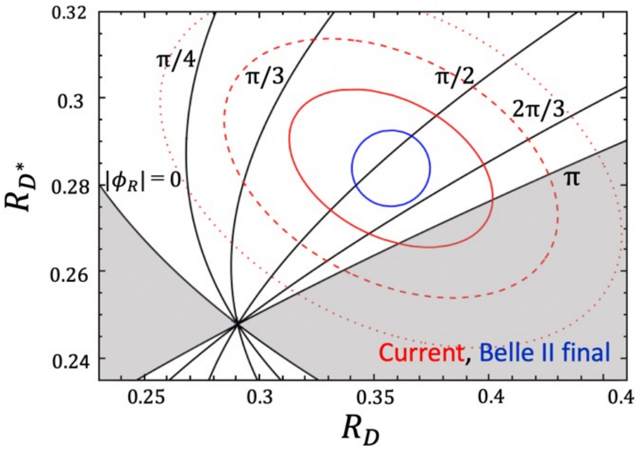
β_R

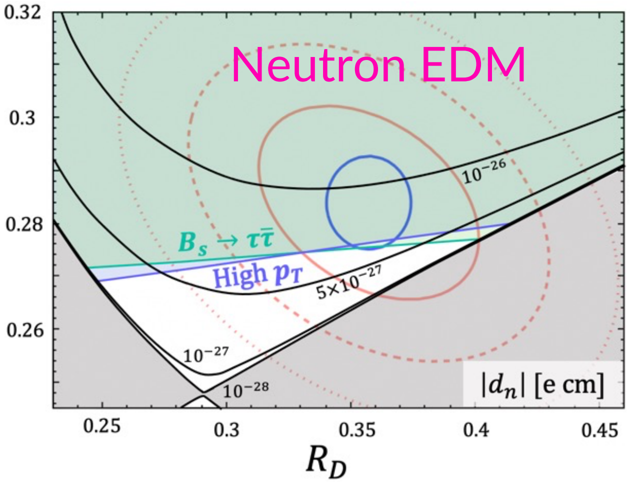


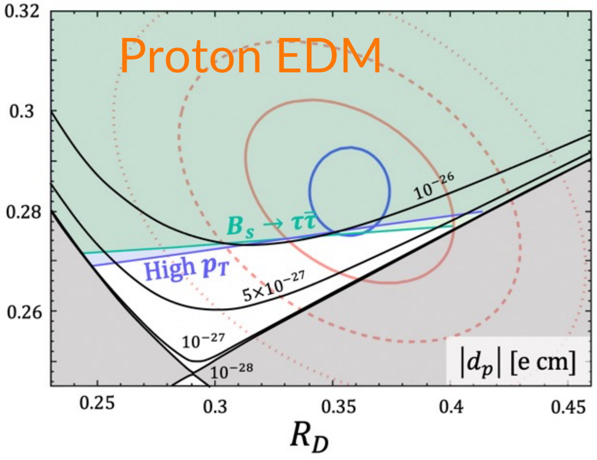
Prospect of Neutron EDM

β_L^{33}

Ms



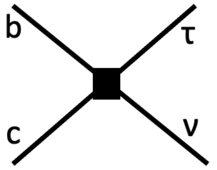


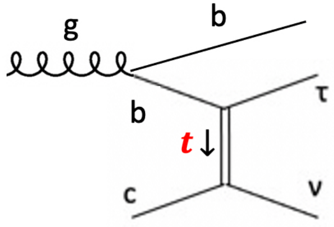


ϕ_R=0 is not good => CPV

$d_n \sim -d_p = O(10^{-26\sim27})$ e cm, well within future reach while $d_e \sim O(10^{-32})$ e cm

Improving LHC search in τν mode
with again, additional b-tagging

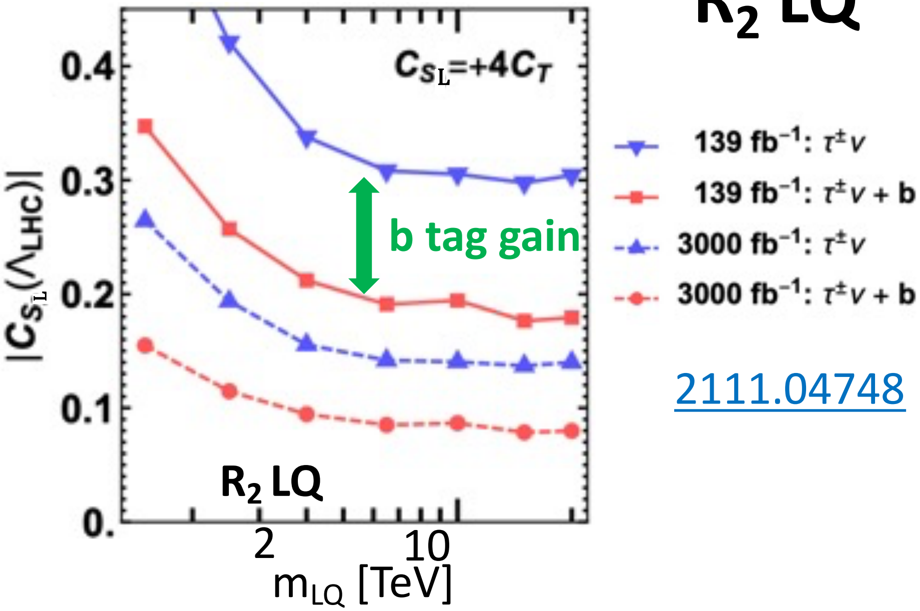




A. Soni et al 1704.06659, Iguro-Tobe 1708.06176

Significant mass dependence

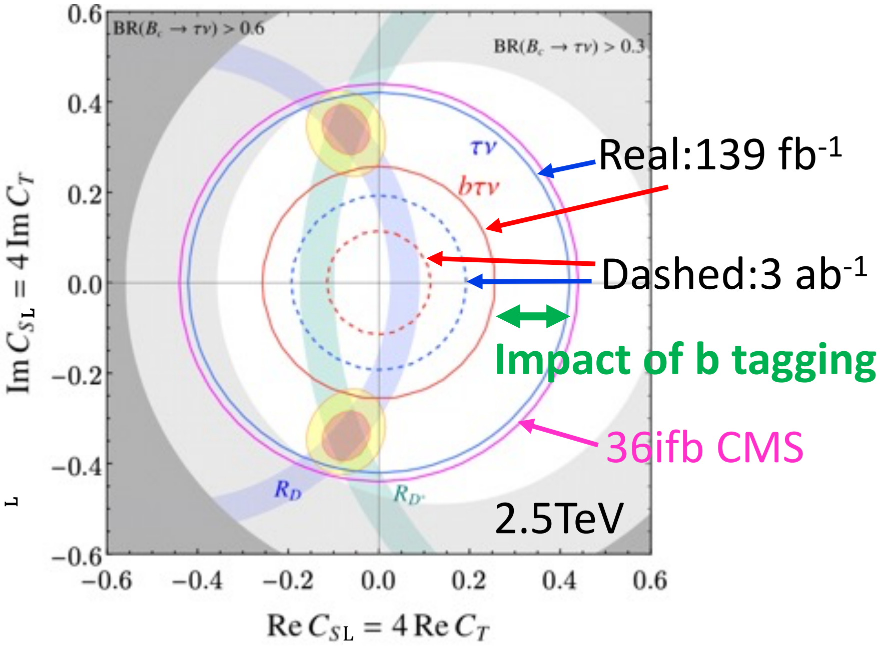
R_2 LQ



b tag gain

2111.04748

Outside of the circle can be probed!



Real:139 fb^{-1}

Dashed:3 ab^{-1}

Impact of b tagging

36ifb CMS

2.5TeV

See also 1811.07920, 2008.07541, 2206.09717

Run 2 data is enough to judge the R_2 LQ scenario!

Comparable sensitivity with conventional ττ+b searches

but not performed experimentally

excess in ττ final state @CMS (not in ττ +b), no excess @ ATLAS

V_2 LQ solution for b→cτν

See also Kingman 2204.05942

Iguro, Omura 2306.00052 (v2 soon)

V_2 $(\bar{3}, 2, 5/6)$ contributes to $(\bar{c}P_R b)(\bar{\tau}P_L\nu)$: this solution revived recently!

$$\mathcal{L}_{V_2} = h_1^{ij}(\overline{d_i^C}\gamma_\mu P_L L_j^b)\varepsilon^{ab}V_2^{\mu,a} + h_2^{ij}(\overline{Q_i^{C,a}}\gamma_\mu P_R e_j)\varepsilon^{ab}V_2^{\mu,b} + h_3^{ij}(\overline{Q_i^C}\gamma_\mu P_R u_j)V_2^{\mu *} + \text{h.c.} \qquad V_2 = \begin{pmatrix} V_2^{4/3} \\ V_2^{1/3} \end{pmatrix}$$

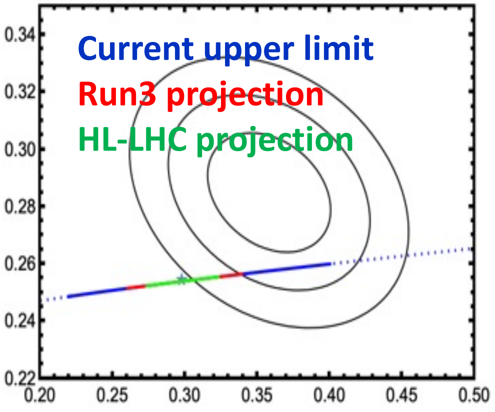
Assigning approximate τ number to this doublet the fermion interaction is given as

$$h_1^{ij} = \begin{pmatrix} 0 & 0 & h_1^{13} \\ 0 & 0 & h_1^{23} \\ 0 & 0 & \underline{h_1^{33}} \end{pmatrix}, \quad h_2^{ij} = \begin{pmatrix} 0 & 0 & h_2^{13} \\ 0 & 0 & \underline{h_2^{23}} \\ 0 & 0 & h_2^{33} \end{pmatrix}, \quad h_3 = 0$$

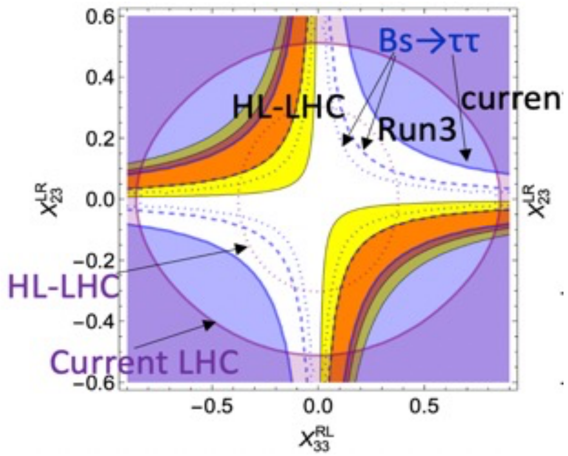
proton decay, K_L→eμ does not occur!

Bottom-up approach

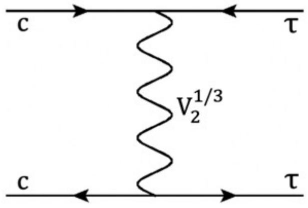
Minimal scenario: $h_1^{33}, h_2^{23} \Rightarrow C_{SR}$

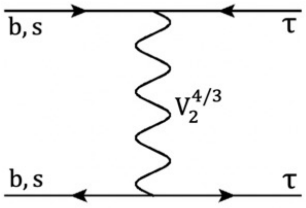


Bs→ττ vs. $R_{D^{(*)}}$



B→Kττ at Belle II is also important





LHC: di-tau final state

Relevant flavor processes

Coupling product	$V^{4/3}$	$V^{1/3}$
$h_1^{33}\times h_2^{23}$	$b\to s\tau\bar{\tau}$ $B_s\to\tau\bar{\tau}, B\to K\tau\bar{\tau}$	$b\to c\tau\bar{\nu}_\tau$ $B\to D^{(*)}\tau\bar{\nu}_\tau$ $B_c\to\tau\nu_\tau, B\to\tau\bar{\nu}$
$h_1^{33}\times h_2^{13}$	$b\to d\tau\bar{\tau}$ $B\to\tau\bar{\tau}, B\to\pi\tau\bar{\tau}$	$b\to u\tau\bar{\nu}_\tau$ $B\to D^{(*)}\tau\bar{\nu}_\tau$ $B\to\tau\nu_\tau, B\to\pi\tau\bar{\nu}_\tau$
$h_1^{33}\times h_2^{33}$	$b\bar{b}\to\tau\bar{\tau}$ ~~$\Upsilon(nS)\to\tau\bar{\tau}$~~	$t\to b\tau\bar{\nu}_\tau$ —
$h_1^{33}\times h_1^{13}$	$b\to d\tau\bar{\tau}$ $B\to\tau\bar{\tau}, B\to\pi\tau\bar{\tau}$	$b\to d\nu\bar{\nu}$ ~~$B\to\nu\bar{\nu}$~~, $B\to\pi\nu\bar{\nu}$
$h_1^{33}\times h_1^{23}$	$b\to s\tau\bar{\tau}$ $B_s\to\tau\bar{\tau}, B\to K\tau\bar{\tau}$	$b\to s\nu\bar{\nu}$ ~~$B_s\to\nu\bar{\nu}$~~, $B\to K\nu\bar{\nu}$
$h_1^{13}\times h_2^{23}$	$s\to d\tau\bar{\tau}$ —	$c\to d\tau\bar{\nu}$ $D\to\tau\bar{\nu}$
$h_1^{23}\times h_2^{23}$	$s\bar{s}\to\tau\bar{\tau}$ —	$c\to s\tau\bar{\nu}$ $D_s\to\tau\bar{\nu}$
$h_2^{13}\times h_2^{23}$	$s\to d\tau\bar{\tau}$ —	$c\to u\tau\bar{\tau}$ —
$h_2^{33}\times h_2^{23}$	$b\to s\tau\bar{\tau}$ $B_s\to\tau\bar{\tau}, B\to K\tau\bar{\tau}$	$t\to c\tau\bar{\tau}$ —

V_2 LQ solution for b→cτν

See also Kingman 2204.05942
Iguro, Omura 2306.00052 (v2 soon)

V_2 $(\bar{3}, 2, 5/6)$ contributes to $(\bar{c}P_R b)(\bar{\tau}P_L\nu)$: this solution revived recently!

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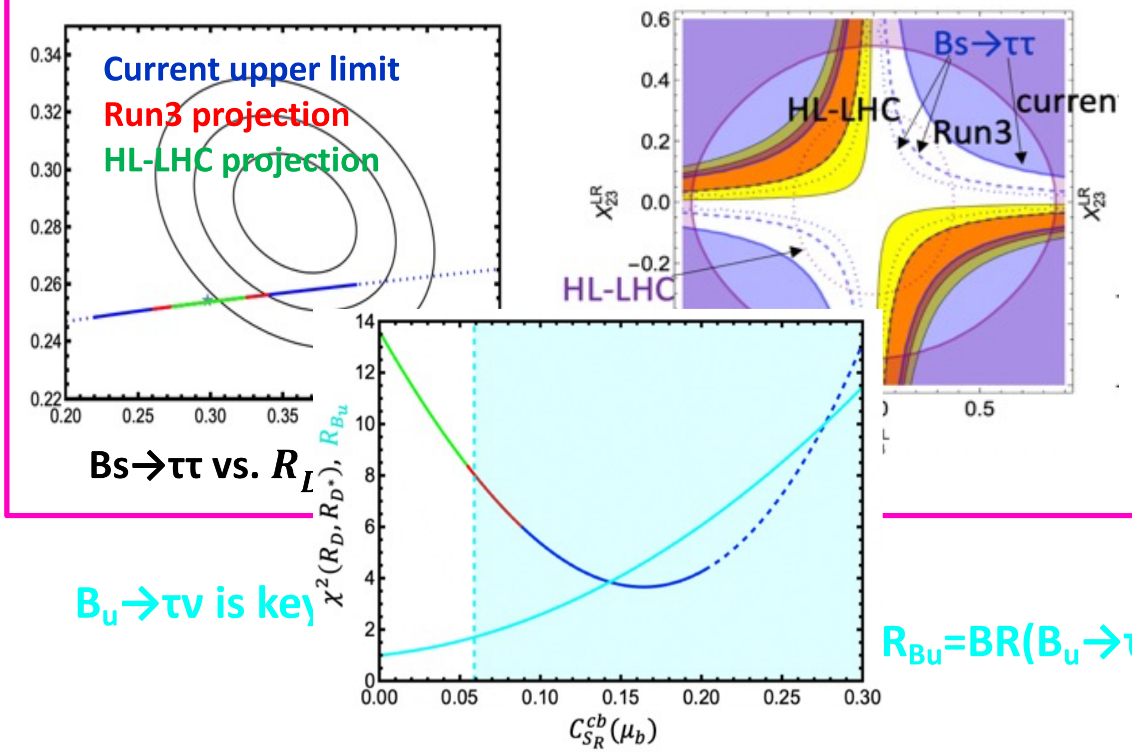
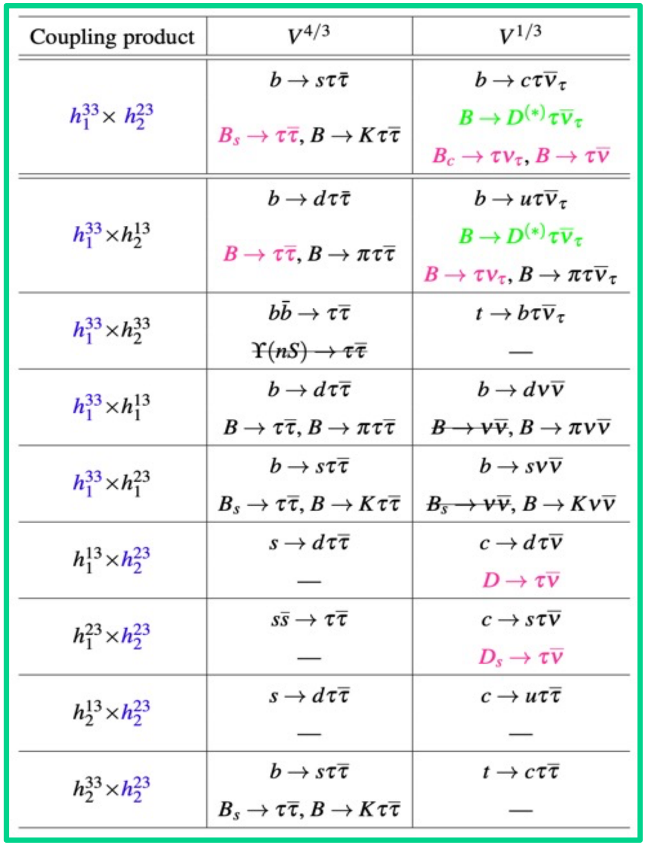


Bs→ττ vs. R_L

B_u→τν is ke

R_{Bu}=BR(B_u→τν)/BR(B_u→τν)$_{SM}$

Relevant flavor processes



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$h_1^{33} \times h_2^{13}$	$b \to d\tau\bar{\tau}$ $B \to \tau\bar{\tau}, B \to \pi\tau\bar{\tau}$	$b \to u\tau\bar{\nu}_\tau$ $B \to D^{(*)}\tau\bar{\nu}_\tau$ $B \to \tau\nu_\tau, B \to \pi\tau\bar{\nu}_\tau$
$h_1^{33} \times h_2^{33}$	$b\bar{b} \to \tau\bar{\tau}$ ~~$\Upsilon(nS) \to \tau\bar{\tau}$~~	$t \to b\tau\bar{\nu}_\tau$ —
$h_1^{33} \times h_1^{13}$	$b \to d\tau\bar{\tau}$ $B \to \tau\bar{\tau}, B \to \pi\tau\bar{\tau}$	$b \to d\nu\bar{\nu}$ ~~$B \to \nu\bar{\nu}$~~, $B \to \pi\nu\bar{\nu}$
$h_1^{33} \times h_1^{23}$	$b \to s\tau\bar{\tau}$ $B_s \to \tau\bar{\tau}, B \to K\tau\bar{\tau}$	$b \to s\nu\bar{\nu}$ ~~$B_s \to \nu\bar{\nu}$~~, $B \to K\nu\bar{\nu}$
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$h_1^{23} \times h_2^{23}$	$s\bar{s} \to \tau\bar{\tau}$ —	$c \to s\tau\bar{\nu}$ $D_s \to \tau\bar{\nu}$
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$h_1^{33} \times h_2^{13}$	$b \to d\tau\bar{\tau}$ $B \to \tau\bar{\tau}, B \to \pi\tau\bar{\tau}$	$b \to u\tau\bar{\nu}_\tau$ $B \to D^{(*)}\tau\bar{\nu}_\tau$ $B \to \tau\nu_\tau, B \to \pi\tau\bar{\nu}_\tau$
$h_1^{33} \times h_2^{33}$	$b\bar{b} \to \tau\bar{\tau}$ ~~$\Upsilon(nS) \to \tau\bar{\tau}$~~	$t \to b\tau\bar{\nu}_\tau$ —
$h_1^{33} \times h_1^{13}$	$b \to d\tau\bar{\tau}$ $B \to \tau\bar{\tau}, B \to \pi\tau\bar{\tau}$	$b \to d\nu\bar{\nu}$ ~~$B \to \nu\bar{\nu}$~~, $B \to \pi\nu\bar{\nu}$
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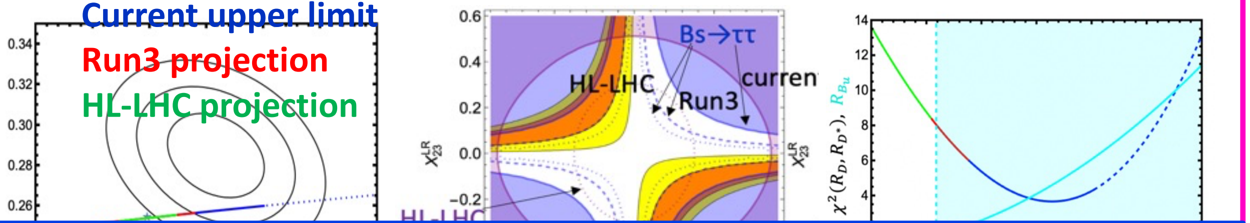
Minimal scenario: $h_1^{33}, h_2^{23} \Rightarrow C_{SR}$ is excluded by B_u→τν



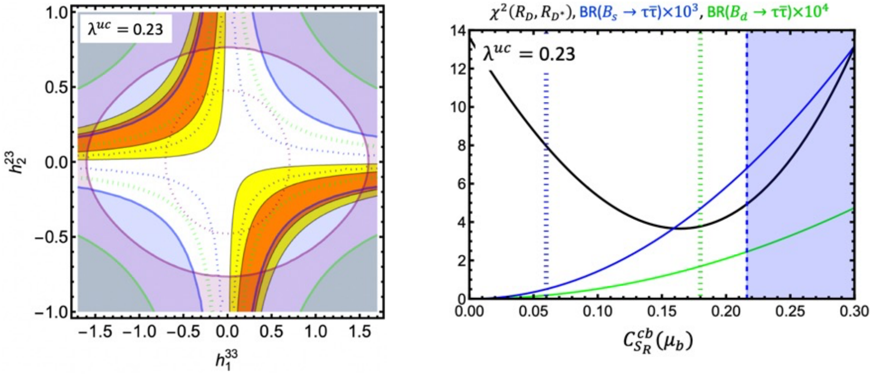
Next to minimal scenario: $h_1^{33}, h_2^{23}, h_2^{13}$ can explain $R_{D^{(*)}}$

$$h_2^{23} = -\lambda_{uc} h_2^{13}$$

$\lambda_{uc} = 0.23$

cancels B_u→τν

0.16<λ_{uc}<0.37 is allowed for 2σ explanation



V_2 LQ solution for b→cτν

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$h_1^{33}\times h_2^{13}$	$b\to d\tau\bar{\tau}$ $B\to\tau\bar{\tau}, B\to\pi\tau\bar{\tau}$	$b\to u\tau\bar{\nu}_\tau$ $B\to D^{(*)}\tau\bar{\nu}_\tau$ $B\to\tau\nu_\tau, B\to\pi\tau\bar{\nu}_\tau$
$h_1^{33}\times h_2^{33}$	$b\bar{b}\to\tau\bar{\tau}$ ~~$\Upsilon(nS)\to\tau\bar{\tau}$~~	$t\to b\tau\bar{\nu}_\tau$ —
$h_1^{33}\times h_1^{13}$	$b\to d\tau\bar{\tau}$ $B\to\tau\bar{\tau}, B\to\pi\tau\bar{\tau}$	$b\to d\nu\bar{\nu}$ ~~$B\to\nu\bar{\nu}$~~, $B\to\pi\nu\bar{\nu}$
$h_1^{33}\times h_1^{23}$	$b\to s\tau\bar{\tau}$ $B_s\to\tau\bar{\tau}, B\to K\tau\bar{\tau}$	$b\to s\nu\bar{\nu}$ ~~$B_s\to\nu\bar{\nu}$~~, $B\to K\nu\bar{\nu}$
$h_1^{13}\times h_2^{23}$	$s\to d\tau\bar{\tau}$ —	$c\to d\tau\bar{\nu}$ $D\to\tau\bar{\nu}$
$h_1^{23}\times h_2^{23}$	$s\bar{s}\to\tau\bar{\tau}$ —	$c\to s\tau\bar{\nu}$ $D_s\to\tau\bar{\nu}$
$h_2^{13}\times h_2^{23}$	$s\to d\tau\bar{\tau}$ —	$c\to u\tau\bar{\tau}$ —
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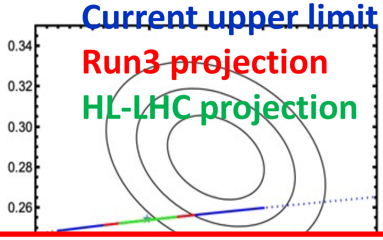
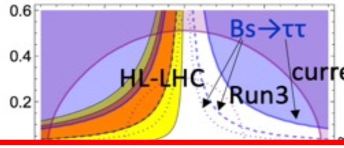
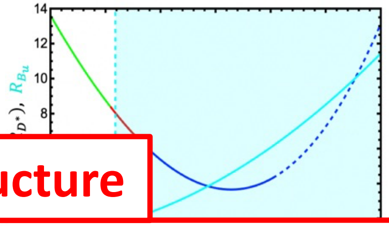






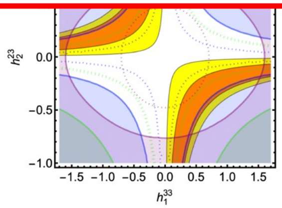
Favored flavor structure

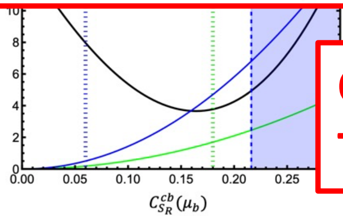
$$h_1^{ij} \simeq \begin{pmatrix} 0 & 0 & \mathcal{O}(10^{-3}) \\ 0 & 0 & \mathcal{O}(10^{-2}) \\ 0 & 0 & \mathcal{O}(1) \end{pmatrix}, \quad h_2^{ij} \simeq \begin{pmatrix} 0 & 0 & -0.23h_2^{23} \\ 0 & 0 & \mathcal{O}(1) \\ 0 & 0 & \mathcal{O}(0.1) \end{pmatrix}$$

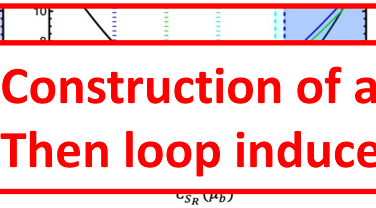
$\lambda_{uc} = 0.23$

cancels B_u→τν

$0.16<\lambda_{uc}<0.37$ is allowed







Construction of an UV model is necessary

Then loop induced obs. should be calculated

Summary

To be honest I thought that there is nothing to do more (Feb. 2022)

- Situation has been changed gradually with new experimental data, Lattice input,,,
- Discrepancy in RD,RD* remains but scalar contribution would be more interesting
- Key predictions of H^+ solution to RD,RD* and C_9 is found
- Connection to nucleon EDM is clarified within U(2) flavored U_1 LQ model
- τν+b provide a powerful collider probe
- V_2 LQ model now is possible to explain the anomaly and b->sττ is key process

Implication of $\Lambda_b \to \Lambda_c \tau\nu$ data and b→cτν sum rule, see Marco's talk

Stay tuned for new inputs from LHC, B-factories

Backyard start from the next

Apology: sorry for forgetting your papers

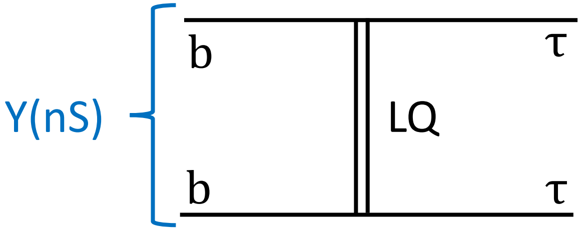
New process: LFUV in Upsilon decay

Upsilon Y(nS) [n=1,2,3,,,] is $b\bar{b}$ resonance

See also D. Aloni. et al 1702.07356

Leptonic decays of Y(nS) provides new LFU test of $b\bar{b} \rightarrow \tau\bar{\tau}$

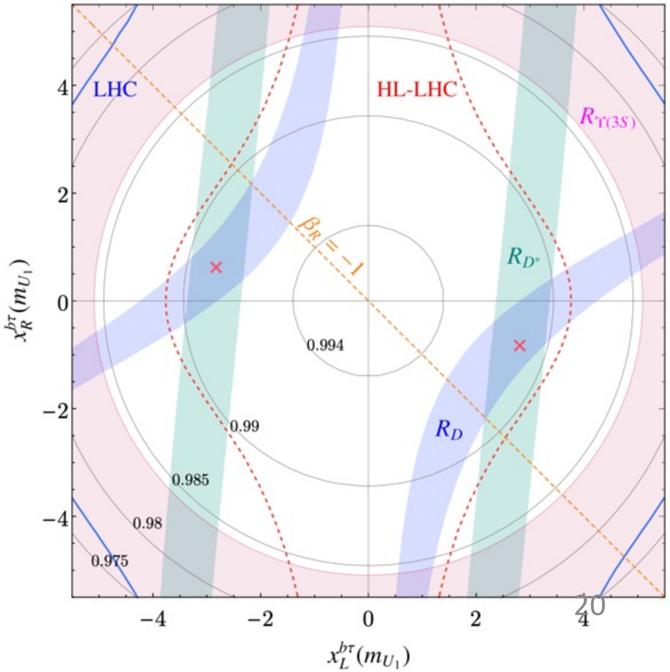
$$\boxed{R_{\Upsilon(nS)} = \frac{\mathcal{B}(\Upsilon(nS) \to \tau^+\tau^-)}{\mathcal{B}(\Upsilon(nS) \to \ell^+\ell^-)},}$$



$$R^{\rm exp}_{\Upsilon(3S)} = 0.968 \pm 0.016 \quad R^{\rm SM}_{\Upsilon(3S)} = 0.9948 \pm \mathcal{O}(10^{-5})$$

BaBar+CLEO

Systematic dominant



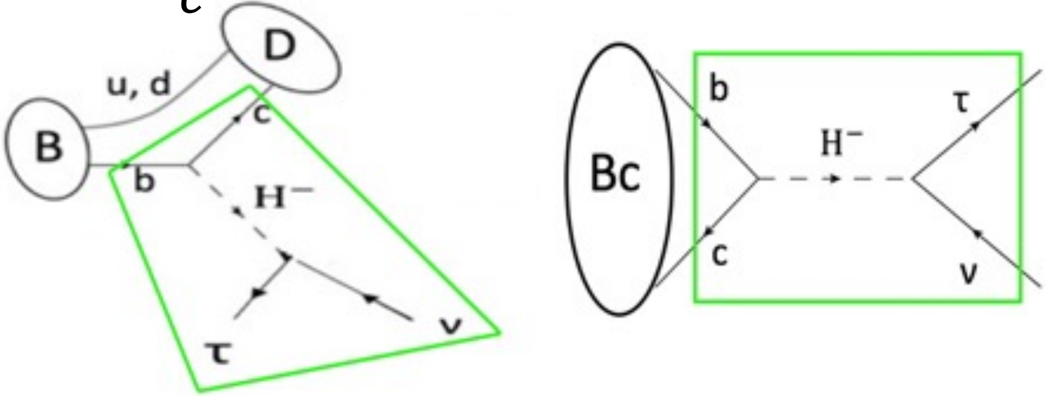
Nevertheless Belle II can improve

Less than 1% accuracy is necessary

For instance U_1 LQ scenario predicts ~1% deviation

Importance of $B_c^- \to \tau\bar{\nu}$ bound

Vector and scalar operators for $\mathrm{R(D^{(*)})}$ automatically contributes to $B_c^- \to \tau\bar{\nu}$



$\mathrm{BR}(\mathrm{B_c^-} \to \tau\nu)$=

$$\mathrm{BR}(\mathrm{B_c^-} \to \tau\bar{\nu})_{\mathrm{SM}} \times \left| 1 + C_{V1} - C_{V2} + \boxed{\frac{\mathrm{m_{Bc}^2}}{\mathrm{m_\tau(m_b + m_c)}}} (C_{S1} - C_{S2}) \right|^2$$

$\mathrm{BR}(\mathrm{B_c^-} \to \tau\bar{\nu})_{\mathrm{SM}} = 2\%$

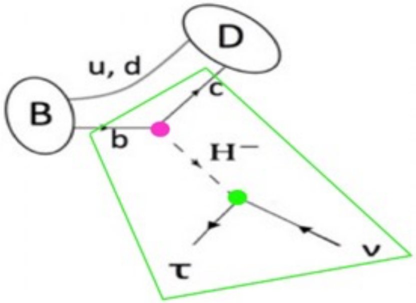
~ 4.35

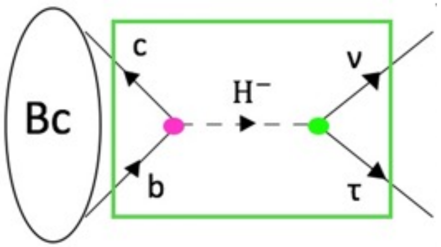
Scalar operator drastically enhances $\mathrm{BR}(\mathrm{B_c^-} \to \tau\bar{\nu})$

Limitation of the bound:
charm mass uncertainty, LEP data of N(B,Bc-> $\tau\bar{\nu}$)

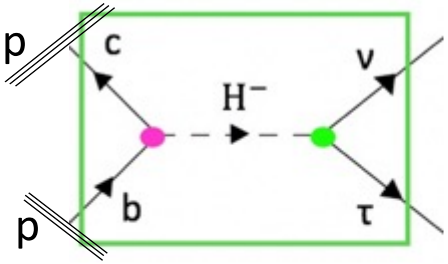
H^- interpretation of R_D , R_{D*} anomalies silently revived

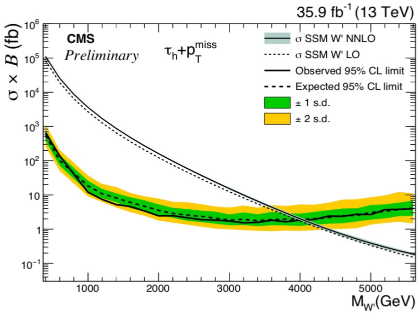
Summary of the status and prospect are discussed Syuhei Iguro, **2201.06565**



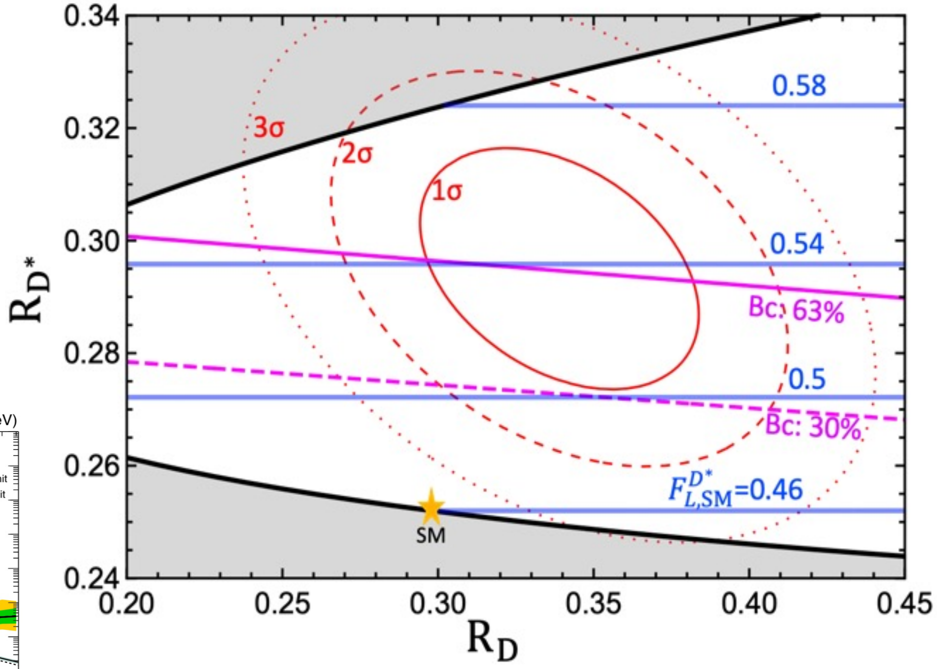


Due to the charm mass scheme dependence,
The bound is relaxed BR(Bc→τν)<63% Grinstein 2021





τν resonance search at LHC gives more stringent constraint for m_{H-} > 400GeV Iguro 2018



$F_{L,SM}^{D^*}$=0.46, $F_{L,Belle}^{D^*}$=0.60 ± 0.09

Only scalar can enhance $F_L^{D^*}$

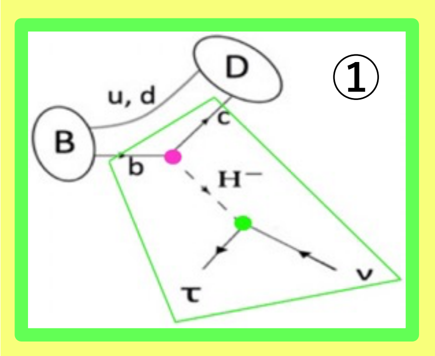
τν resonance search result for m_{H-} < 400GeV is not available at $\sqrt{s}$=13TeV probably because

- they originally search for W’ in SSM and wanted to push up the lower bound on $m_{W'}$
- SMBG (W-> τν tail) is huge at low mT

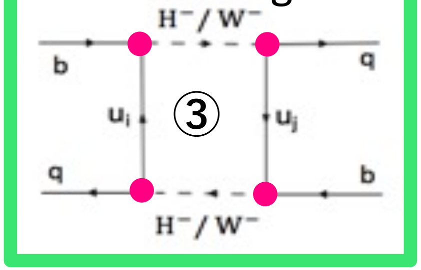
How is the situation and prospect for m_{H-} < 400GeV ?

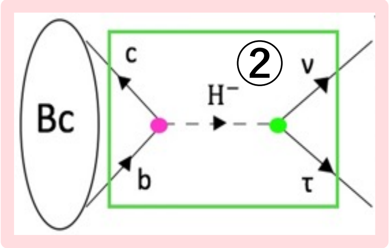
Various bounds are very complementary

HL-LHC can probe large parameter space!

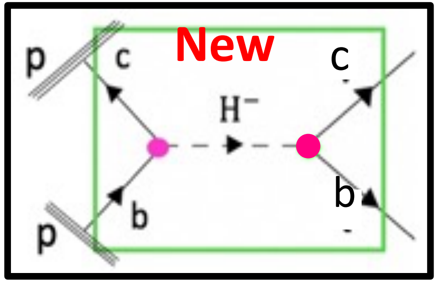


B mixings





Single production



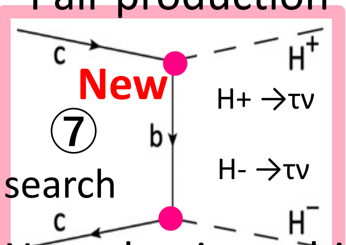
3 categories of bounds

1. right to left e.g. ③, ④, ⑤

2. above to bellow ⑦

3. constrain ↙ e.g. ②

Pair production



Stau search

EW production+ this

bb resonance search

$\sqrt{s}$=8TeV ④

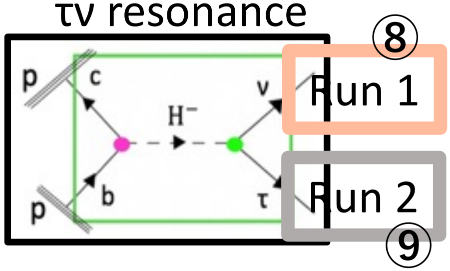
bb + photon search

$\sqrt{s}$=13TeV ⑤

Flavor inclusive di-jet

$\sqrt{s}$=13TeV ⑥

τν resonance



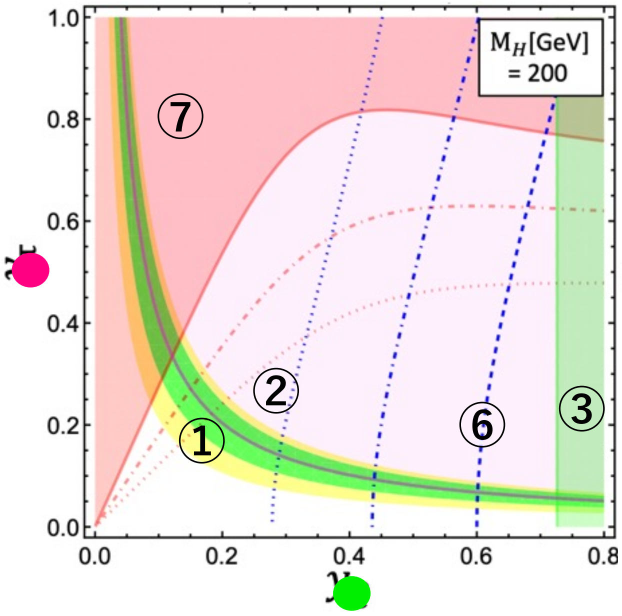
Luminosity

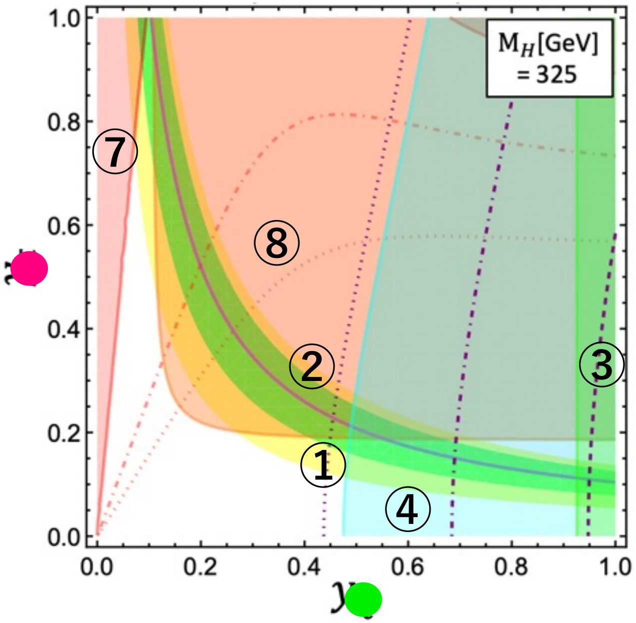
—— Current

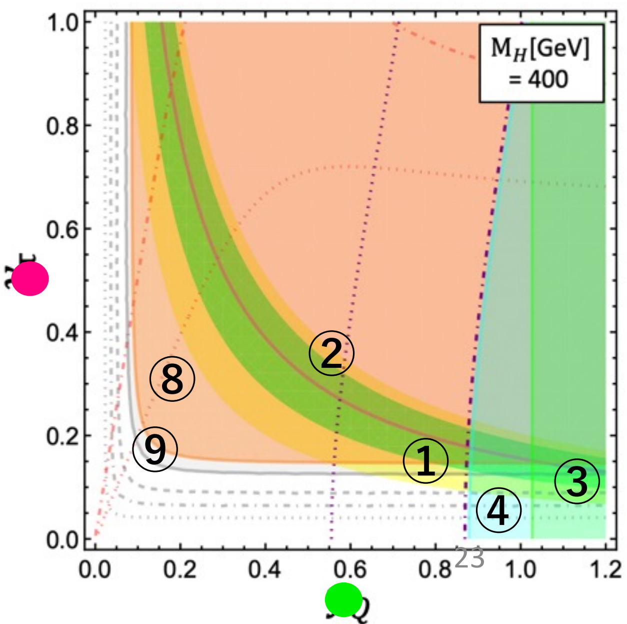
— · · 500fb^{-1}

– – · 139fb^{-1}

·········· 3ab^{-1}







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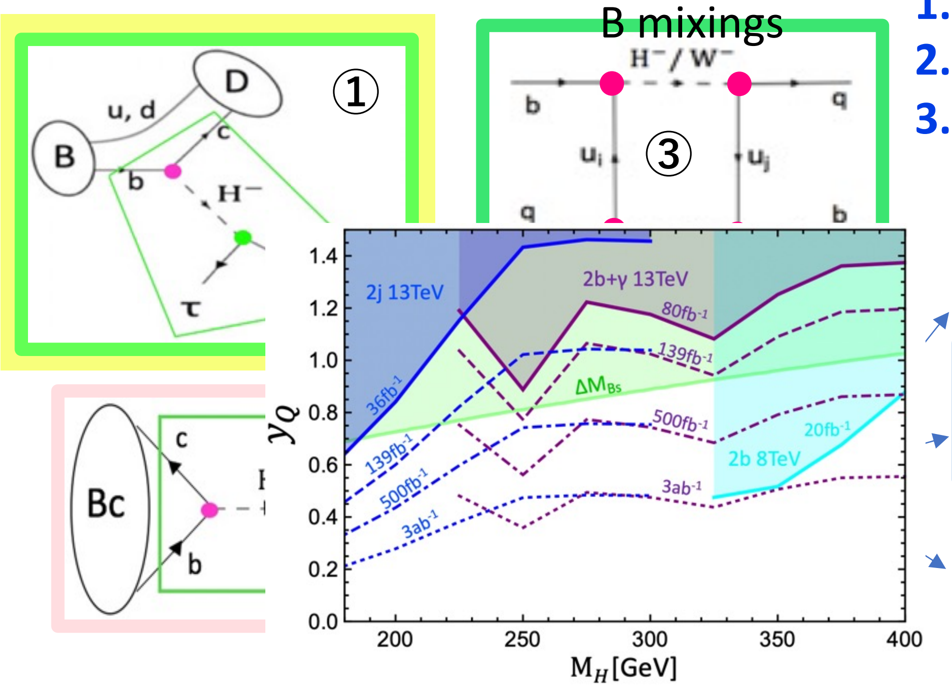

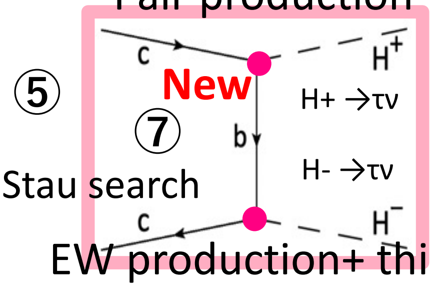

Pair production

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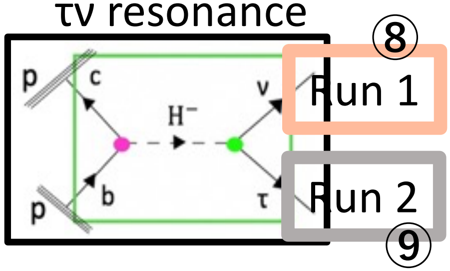
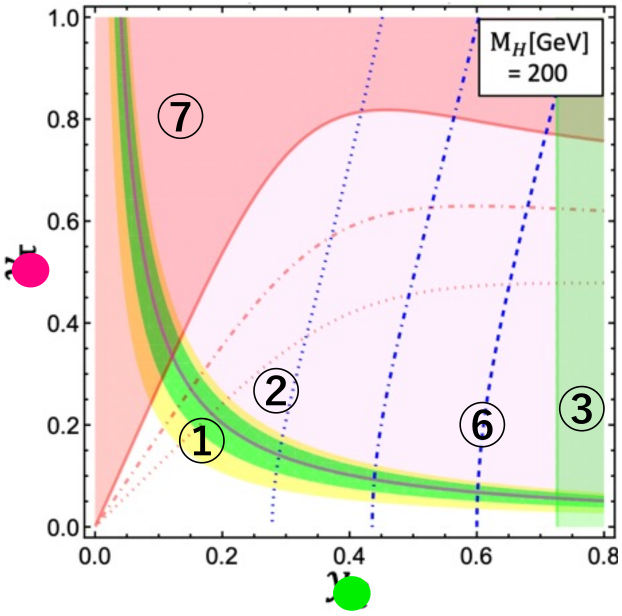
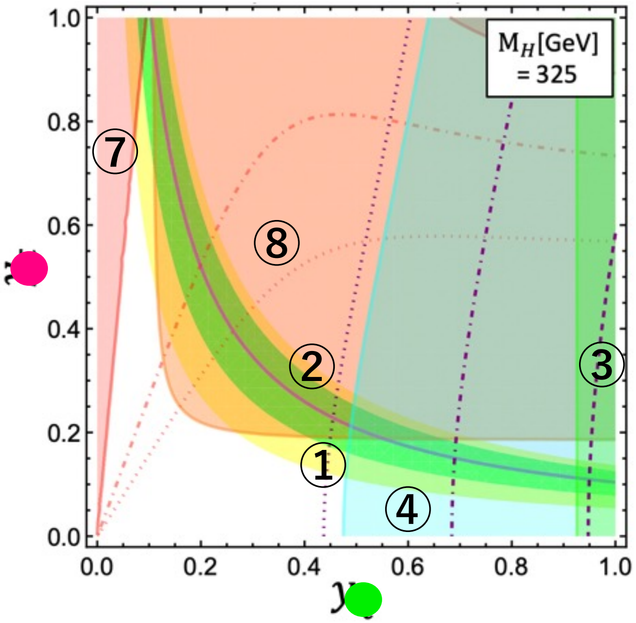
τν resonance

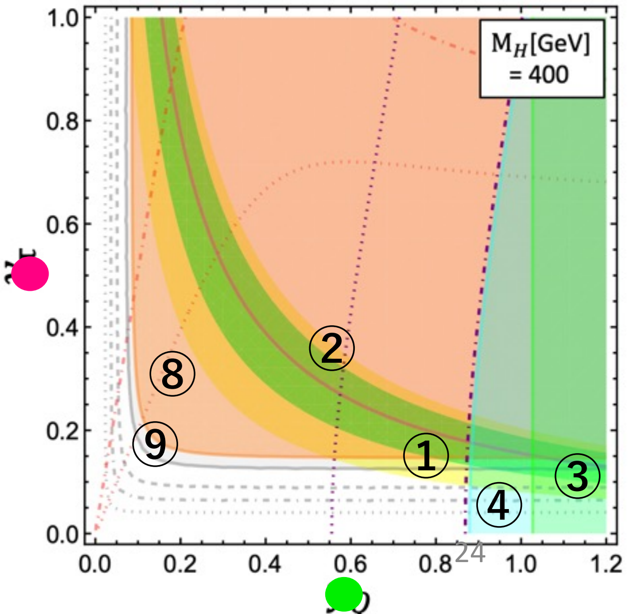


Luminosity

- —— Current
- — · · 500fb⁻¹
- – – · 139fb⁻¹
- ……… 3ab⁻¹







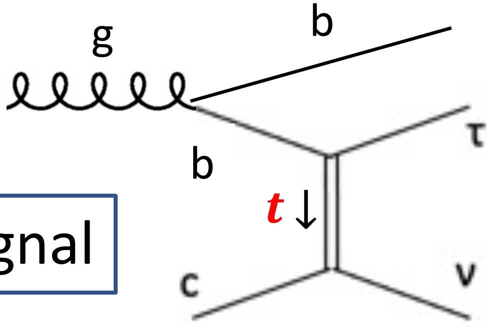
Improving LHC search in τν mode

again, additional b-tagging

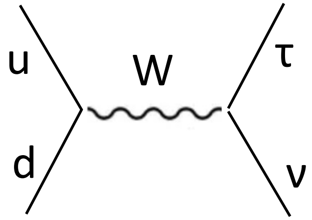
A. Soni et al 1704.06659, Iguro-Tobe 1708.06176

Importance of b-tagging
1. smaller BG, 2. different BG → semi-independent cross check
3. specifying interaction one of quarks in 4-fermi is b

Signal

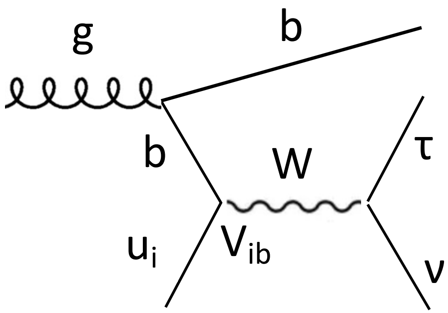


Greljo et al. 1811.07920

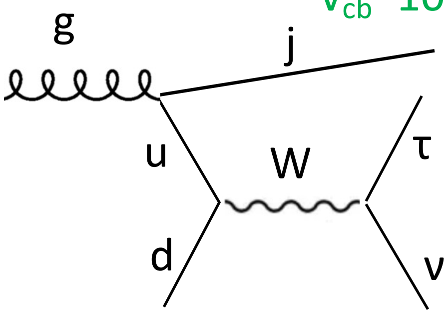


No b-jet previous

BG



V_{cb}~10^{-2}, V_{ub}~10^{-3}



j->b mis tag less than 1%

Within the EFT framework,
an additional b-jet tagging improve WC sensitivity by 30-40% Minho et al 2008.07541

We keep mediator mass dependence even with b-jet tagging Iguro et al 2111.04748

WZ, single t ,,, are also important

Implication of Λ_b→ $\Lambda_c\tau\nu$ data and b→cτν sum rule

Syuhei Iguro, M. Fedele, U. Niesrte, T.Kitahara, R. Watanabe, M. Blanke, A. Crivellin

2211.14172

Currently we have discrepancy in b→cτν

Experimental mistake? Statistical Fluctuation?
Underestimation of uncertainties?
Wrong SM prediction? New physics?

$$R_{D^{(*)}} = \frac{BR(B \to D^{(*)}\tau\nu)}{BR(B \to D^{(*)}l\nu)}, R_{J/\psi} = \frac{BR(B_c \to J/\psi\tau\nu)}{BR(B_c \to J/\psi\mu\nu)}, R_{\Lambda_c} = \frac{BR(\Lambda_b \to \Lambda_c\tau\nu)}{BR(\Lambda_b \to \Lambda_c\mu\nu)}$$

They all are described by b→cτν transition.

Compared to the SM predictions, curretnt experimental results are

Larger +4σ Larger +2σ Smaller -2σ

Based on the updated sum rule which connects different ratios,
we investigated whether the currents data can be explained within a generic Model.

Sum rule

$$\frac{\mathcal{R}(\Lambda_c)}{\mathcal{R}_{\rm SM}(\Lambda_c)} = 0.280\,\frac{\mathcal{R}(D)}{\mathcal{R}_{\rm SM}(D)} + 0.720\,\frac{\mathcal{R}(D^*)}{\mathcal{R}_{\rm SM}(D^*)} + \delta_{\Lambda_c}$$

correction

$$\begin{aligned}\delta_{\Lambda_c} = {} & \mathrm{Re}\left[\left(1+C_{V_L}^\tau\right)\left(0.314\,C_T^{\tau *} - 0.003\,C_{S_R}^{\tau *}\right)\right] \\ & + 0.014\,\left(|C_{S_L}^\tau|^2 + |C_{S_R}^\tau|^2\right) \\ & + 0.004\,\mathrm{Re}\left(C_{S_L}^\tau C_{S_R}^{\tau *}\right) - 1.30\,|C_T^\tau|^2\,.\end{aligned}$$

How to derive this?

Detail: sum rule

Based on the our FF we updated the sum rule proposed in 1905.08253 (KIT group).

$$\left\{\begin{aligned}
\frac{\mathcal{R}(\Lambda_c)}{\mathcal{R}_{\rm SM}(\Lambda_c)} &= \left|1+C^{\tau}_{V_L}\right|^2 + 0.50\,{\rm Re}\left[\left(1+C^{\tau}_{V_L}\right)C^{\tau *}_{S_R}\right] + 0.33\,{\rm Re}\left[\left(1+C^{\tau}_{V_L}\right)C^{\tau *}_{S_L}\right] + 0.52\,{\rm Re}\left(C^{\tau}_{S_L}C^{\tau *}_{S_R}\right) \\
&\quad + 0.32\,\left(|C^{\tau}_{S_L}|^2 + |C^{\tau}_{S_R}|^2\right) - 3.11\,{\rm Re}\left[\left(1+C^{\tau}_{V_L}\right)C^{\tau *}_{T}\right] + 10.4\,|C^{\tau}_{T}|^2\,, \\
\frac{R_D}{R_D^{\rm SM}} &= |1+C_{V_L}+C_{V_R}|^2 + 1.01|C_{S_L}+C_{S_R}|^2 + 0.84|C_T|^2 \\
&\quad + 1.49{\rm Re}[(1+C_{V_L}+C_{V_R})(C^*_{S_L}+C^*_{S_R})] + 1.08{\rm Re}[(1+C_{V_L}+C_{V_R})C^*_T]\,, \\
\frac{R_{D^*}}{R_{D^*}^{\rm SM}} &= |1+C_{V_L}|^2 + |C_{V_R}|^2 + 0.04|C_{S_L}-C_{S_R}|^2 + 16.0|C_T|^2 \\
&\quad - 1.83{\rm Re}[(1+C_{V_L})C^*_{V_R}] - 0.11{\rm Re}[(1+C_{V_L}-C_{V_R})(C^*_{S_L}-C^*_{S_R})] \\
&\quad - 5.17{\rm Re}[(1+C_{V_L})C^*_T] + 6.60{\rm Re}[C_{V_R}C^*_T]\,,
\end{aligned}\right.$$

Eliminating interference terms

2211.14172

$$\boxed{\frac{\mathcal{R}(\Lambda_c)}{\mathcal{R}_{\rm SM}(\Lambda_c)} = 0.280\,\frac{\mathcal{R}(D)}{\mathcal{R}_{\rm SM}(D)} + 0.720\,\frac{\mathcal{R}(D^*)}{\mathcal{R}_{\rm SM}(D^*)} + \delta_{\Lambda_c}\,,}$$

Small correction

$$\begin{aligned}
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&+ 0.014\,\left(|C^{\tau}_{S_L}|^2 + |C^{\tau}_{S_R}|^2\right) \\
&+ 0.004\,{\rm Re}\left(C^{\tau}_{S_L}C^{\tau *}_{S_R}\right) - 1.30\,|C^{\tau}_{T}|^2\,.
\end{aligned}$$

$\mathcal{R}(\Lambda_c)$ =0.367±0.013

Prediction form RD,RD*

$R^{LHCb}_{\Lambda c}$ = 0.24 ± 0.08,

$R^{Ligeti}_{\Lambda c}$ = 0.285 ± 0.073

Solid correlation

Small RD* is more consistent but we need more data to conclude

Even if we include the NP in light lepton mode, we can not explain all.

Implication of $\Lambda_b \rightarrow \Lambda_c \tau\nu$ data and $b \rightarrow c\tau\nu$ sum rule

Syuhei Iguro, M. Fedele, U. Niesrte, T.Kitahara, R. Watanabe, M. Blanke, A. Crivellin

2211.14172

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$$\begin{aligned}\delta_{\Lambda_c} = {\rm Re}\left[\left(1 + C^\tau_{V_L}\right)\left(0.314\,C^{\tau*}_T - 0.003\,C^{\tau*}_{S_R}\right)\right]\\ + 0.014\,\left(|C^\tau_{S_L}|^2 + |C^\tau_{S_R}|^2\right)\\ + 0.004\,{\rm Re}\left(C^\tau_{S_L} C^{\tau*}_{S_R}\right) - 1.30\,|C^\tau_T|^2\,.\end{aligned}$$

New LHCb data prefers smaller (larger) deviation in $R_D (R_{D^*})$.
Nevertheless, R_{Λ_c} is still 2σ off from the sum rule.

Conclusion

Even if we allow the New physics in both τ and light lepton modes,
satisfactory simultaneous explanation of all $R_{D^{(*)}}$, $R_{J/\psi}$, R_{Λ_c} is not possible within QFT.
This result implies that the current data is something wrong and needs reanalysis or more data.

Generic formulae updated!

2210.10751

Syuhei Iguro, T.Kitahara, R. Watanabe

We updated generic NP formulae based on the updated $\bar{B} \to D^{(*)}$ form factors Iguro-Watanabe 2020 and performed global fit

$$P_\tau(D^{(*)}) = \frac{\Gamma\left(B \to D^{(*)}\tau^{\lambda=+1/2}\nu\right) - \Gamma\left(B \to D^{(*)}\tau^{\lambda=-1/2}\nu\right)}{\Gamma\left(B \to D^{(*)}\tau\nu\right)}$$

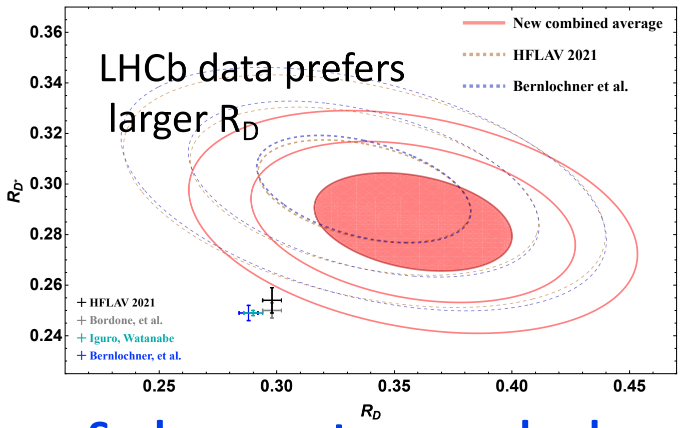
$$\frac{R_D}{R_D^{\rm SM}} = |1+C_{V_L}+C_{V_R}|^2 + 1.01|C_{S_L}+C_{S_R}|^2 + 0.84|C_T|^2 \\ + 1.49{\rm Re}[(1+C_{V_L}+C_{V_R})(C_{S_L}^*+C_{S_R}^*)] + 1.08{\rm Re}[(1+C_{V_L}+C_{V_R})C_T^*]\,,$$

$$\frac{P_\tau^D}{P_{\tau,\rm SM}^D} = \left(\frac{R_D}{R_D^{\rm SM}}\right)^{-1} \times \Big(|1+C_{V_L}+C_{V_R}|^2 + 3.04|C_{S_L}+C_{S_R}|^2 + 0.17|C_T|^2 \\ + 4.50{\rm Re}[(1+C_{V_L}+C_{V_R})(C_{S_L}^*+C_{S_R}^*)] - 1.09{\rm Re}[(1+C_{V_L}+C_{V_R})C_T^*]\Big)$$

$$\frac{R_{D^*}}{R_{D^*}^{\rm SM}} = |1+C_{V_L}|^2 + |C_{V_R}|^2 + 0.04|C_{S_L}-C_{S_R}|^2 + 16.0|C_T|^2 \\ - 1.83{\rm Re}[(1+C_{V_L})C_{V_R}^*] - 0.11{\rm Re}[(1+C_{V_L}-C_{V_R})(C_{S_L}^*-C_{S_R}^*)] \\ - 5.17{\rm Re}[(1+C_{V_L})C_T^*] + 6.60{\rm Re}[C_{V_R}C_T^*]\,,$$

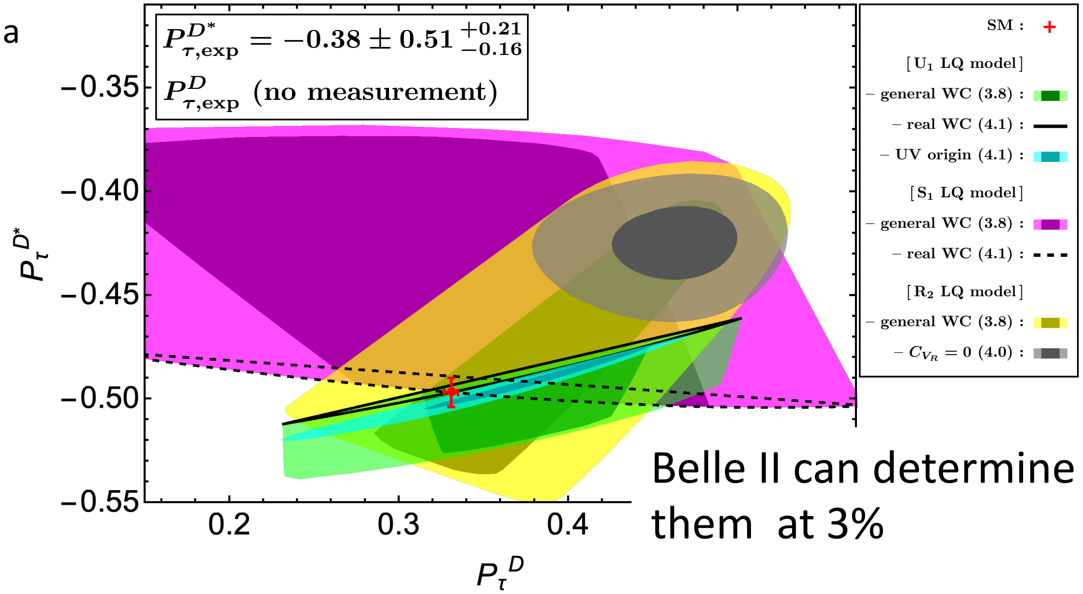
$$\frac{P_\tau^{D^*}}{P_{\tau,\rm SM}^{D^*}} = \left(\frac{R_{D^*}}{R_{D^*}^{\rm SM}}\right)^{-1} \times \Big(|1+C_{V_1}|^2 + |C_{V_2}|^2 - 0.07|C_{S_1}-C_{S_2}|^2 - 1.85|C_T|^2 \\ - 1.79{\rm Re}[(1+C_{V_L})C_{V_R}^*] + 0.23{\rm Re}[(1+C_{V_L}-C_{V_R})(C_{S_L}^*-C_{S_R}^*)] \\ - 3.47{\rm Re}[(1+C_{V_L})C_T^*] + 4.41{\rm Re}[C_{V_R}C_T^*]\Big)\,,$$

We also discussed the uncertainty of the formula



LHCb data prefers larger R_D

Scalar operator came back

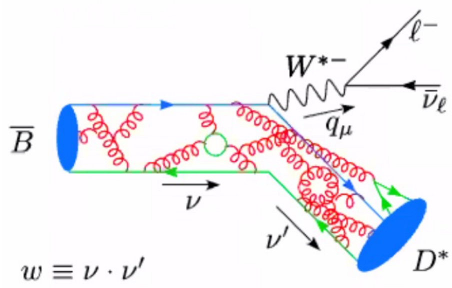


Belle II can determine them at 3%

τ polarization in $\bar{B} \to D^{(*)}$τν is crucial to test the NP possibilities!

Although large part of the uncertainty cancels precise non-perturbative input ($B \to D^{(*)}$ transition form factor) is necessary

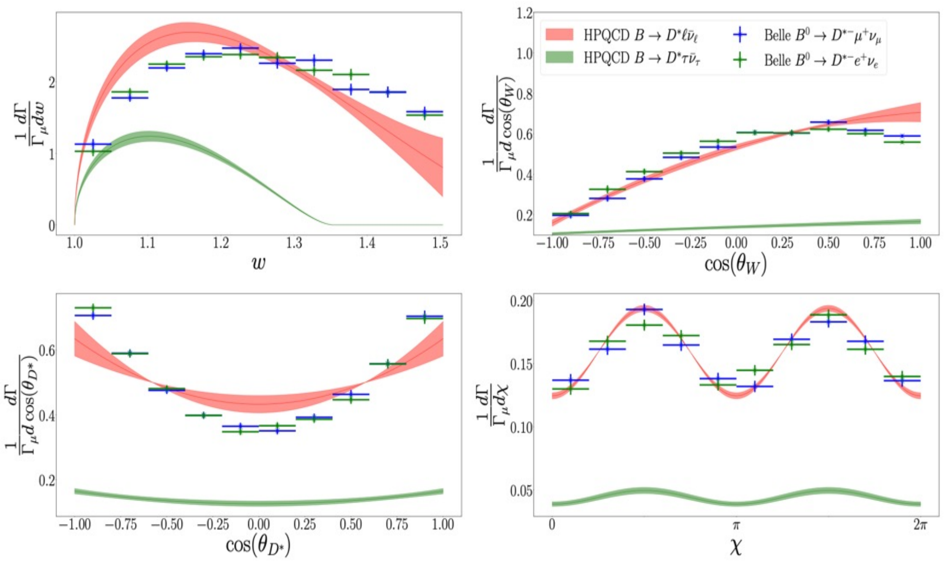
$$R_{D^{(*)}} = \frac{BR\left(B\to D^{(*)}\tau\nu\right)}{BR\left(B\to D^{(*)}l\nu\right)}\ , \quad l = \mu, \mathrm{e}$$



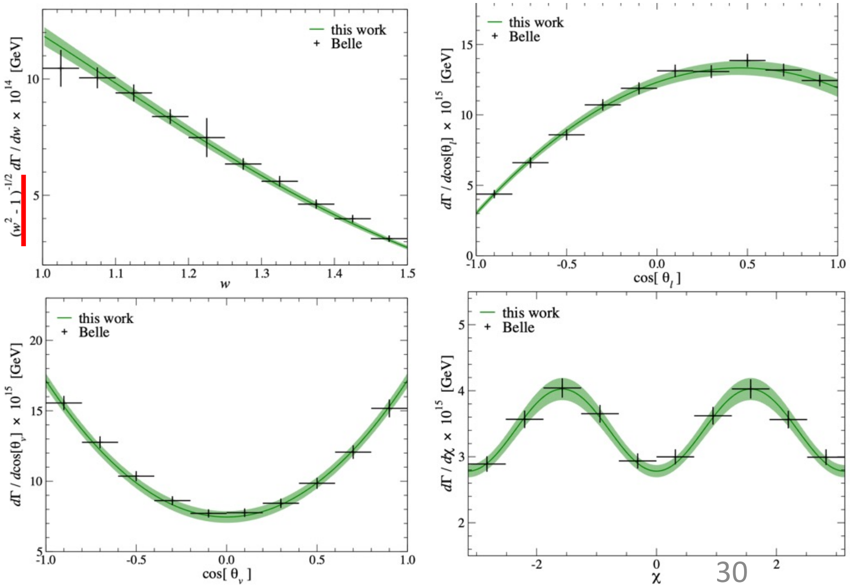
Non-perturbative information extracted from Lattice, experiments, QCDSR,,,,

- New Lattice results for B->D* at non-zero recoil

HPQCD 2304.03137



JLQCD 2306.05657



Lattice results are not stable

Dispersive method (DM) can solve all?

Di Carlo, et al, 2105.02497; Martinelli, et al, 2105.07851

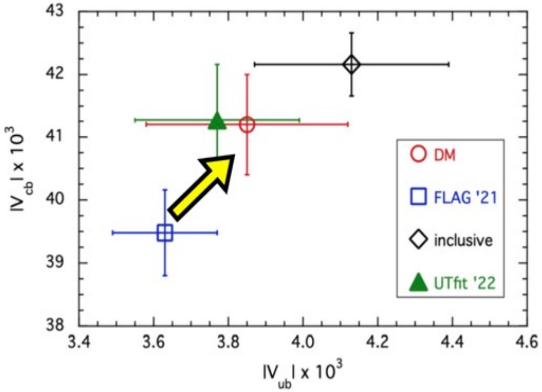
Usually form factor parameterization relies on heavy quark expansion and describe the different currents with common functions (Isger-Wise function)

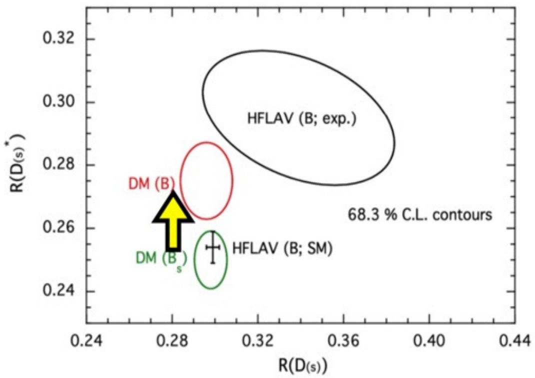
or assume the simple polynomial in terms of conformal valiable z= <<1 e.g. Boyd-Grinstein-Lebed(BGL) method

While DM method, with only lattice data (Fermi-MILC) and unitarity condition gives a parameterization independent form factor

Interestingly this DM method would simultaneously relax the tension

Since DM method yields considerably different result from others, it is natural to ask if this is really compatible with other observables?





We found that the DM method at least in B->D* transition conflicts with angular distribution data by more than 3σ => we have discrepancies!

Playing with FLD*$(\boldsymbol{e}, \mu)$

$$F_L^{D^*}(e) = \frac{\mathrm{BR}(B \to D_L^* e\nu)}{\mathrm{BR}(B \to D^* e\nu)}$$

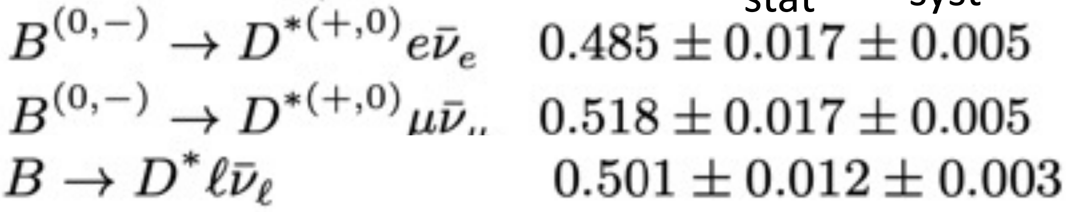
1903.03102 1ab^{-1}
Belle K. Adamczyk

FLD∗(e) = 0.56 ± 0.02 unpublished

2301.07529
Belle M. Prim

1ab^{-1}

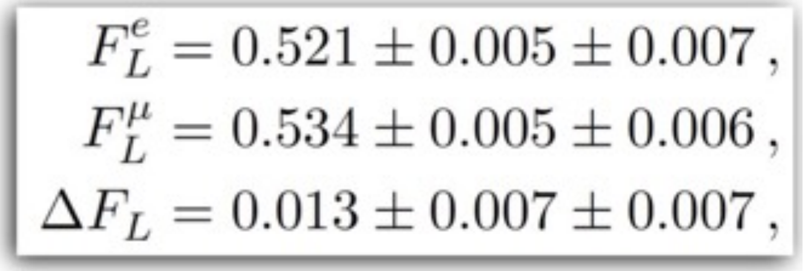
stat syst



$B^{(0,-)} \to D^{*(+,0)} e\bar{\nu}_e$	$0.485 \pm 0.017 \pm 0.005$
$B^{(0,-)} \to D^{*(+,0)} \mu\bar{\nu}_\mu$	$0.518 \pm 0.017 \pm 0.005$
$B \to D^* \ell\bar{\nu}_\ell$	$0.501 \pm 0.012 \pm 0.003$

Preliminary

Belle II 189fb^{-1}



$$F_L^e = 0.521 \pm 0.005 \pm 0.007\,,$$
$$F_L^\mu = 0.534 \pm 0.005 \pm 0.006\,,$$
$$\Delta F_L = 0.013 \pm 0.007 \pm 0.007\,,$$

ALPS2023 Chaoyi Lyu

Why statistic uncertainty is smaller than Belle?

this Belle II data is based on untagged events and hence statistics is better

---

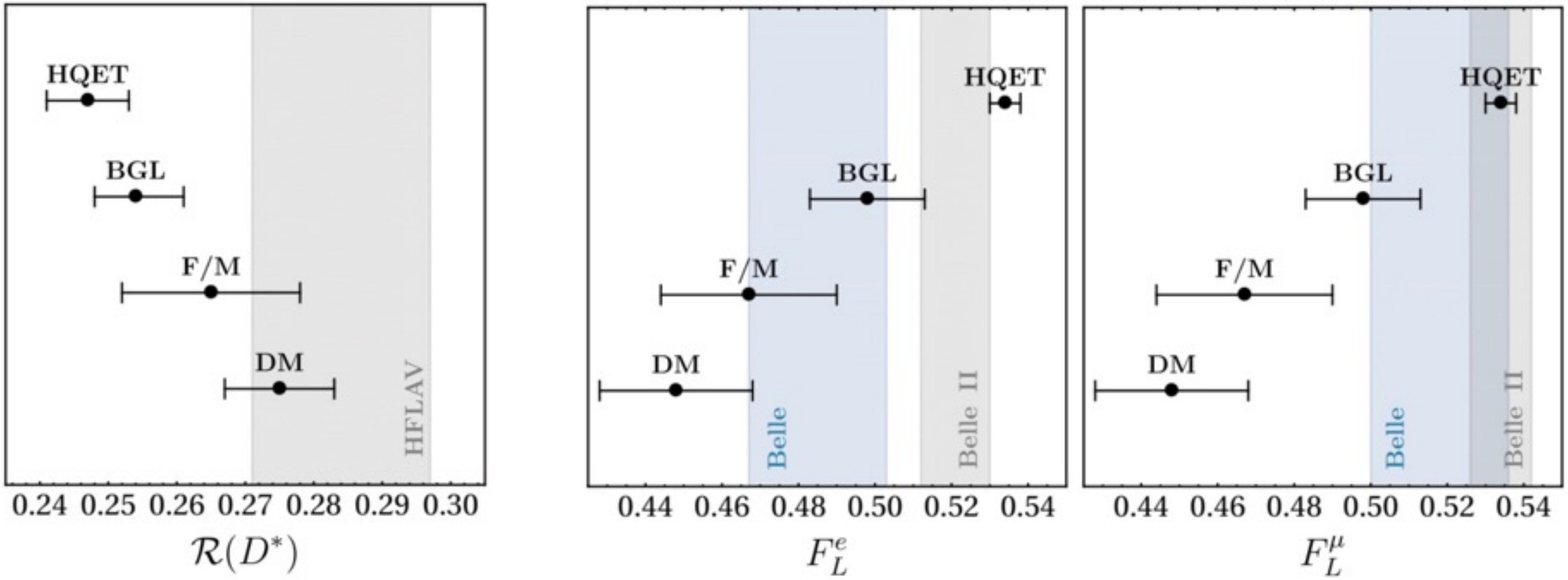
Theoretical prediction

Iguro-Watanabe	0.534 ± 0.002	RD*(SM)=0.249±0.001
DM method	0.45 ± 0.02	RD*(SM)=0.272±0.014

M.Fedele. et al **2305.15457**

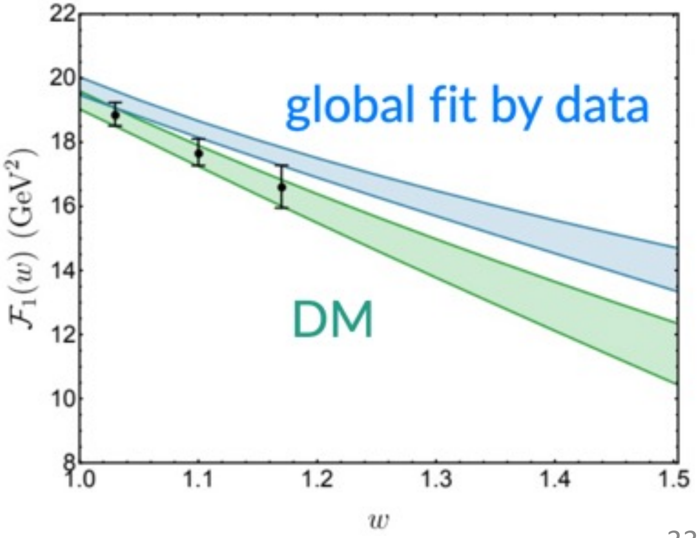
F/M:Fermi-MILC

DM method conflicts with angular distribution data more than 3σ



If we perform the global fit including angular observables, the fitted form factor is considerably different from the original one.

This global fitted DM yields discrepancies again.
Conclusion: DM method with F/M data also
has difficulty



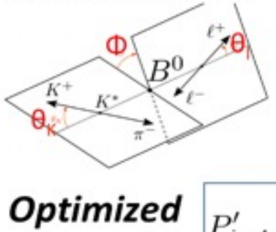
Flavor universal C9 ?

$$\mathcal{L} = \frac{\alpha G_F V_{td_i} V^*_{td_k}}{\sqrt{2}\pi}\Big[m_b C_7(\bar{s}\sigma_{\mu\nu}P_R b)F^{\mu\nu} + m_b C_8(\bar{s}\sigma_{\mu\nu}T^a P_R b)G^{a,\mu\nu} \underline{+C_9^\ell(\bar{s}\gamma_\mu P_L b)}(\bar{\ell}\gamma_\mu\ell) + C_{10}^\ell(\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma_\mu\gamma_5\ell)\Big],$$

The tensions in BR(Bs → ϕμμ), BR(Λb → Λμμ), BR(B → K(∗)μμ) and angular observable P_5' in B → K(∗)μμ

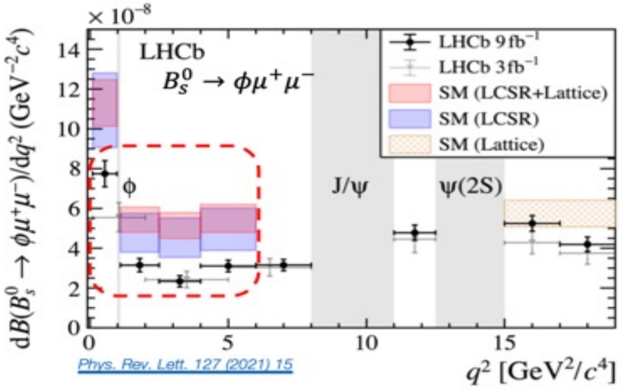
$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell\, d\cos\theta_K\, d\phi\, dq^2} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi + S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big]$$

Matias 11

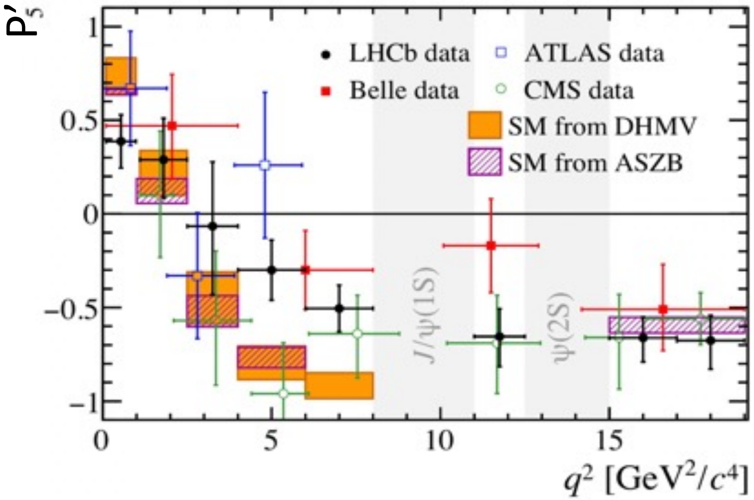


Optimized observable

$$\boxed{P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_L(1-F_L)}},}$$



Phys. Rev. Lett. 127 (2021) 15

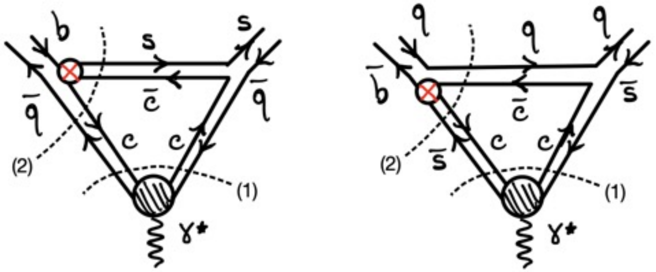


Global fit

Hurth, et al 2210.07221

$$\underline{C_9^l(\mu_b)} = -0.95 \pm 0.13$$

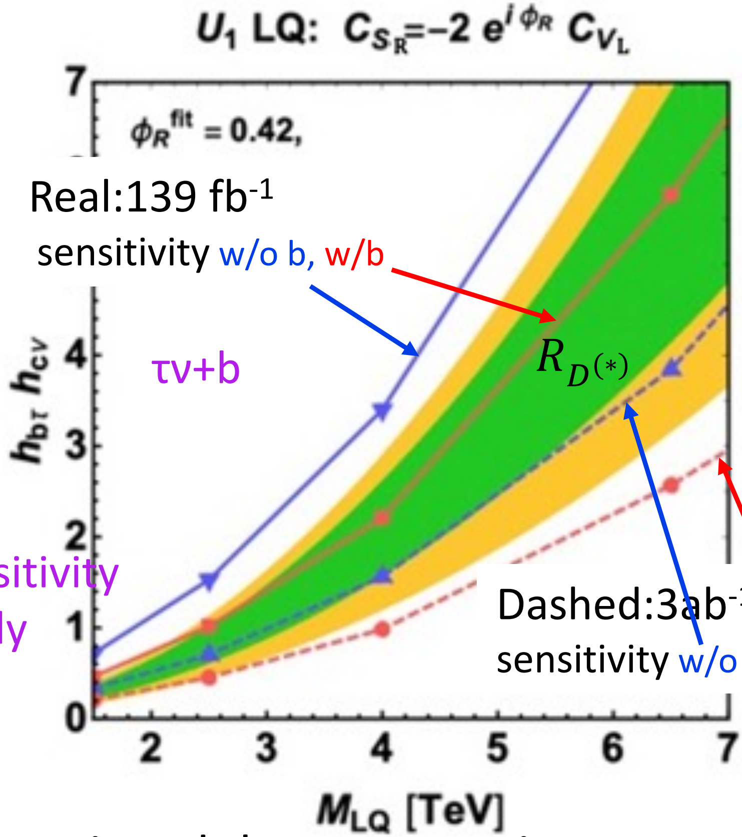
Similar result is obtained (2212.10516)
if charm rescattering contribution is small.



New physics would account for Lepton flavor universal C_9

Other scenarios: U_1 LQ with U(2) flavor symmetry

2111.04748



Real:139 fb^{-1}

sensitivity w/o b, w/b

$R_{D^{(*)}}$

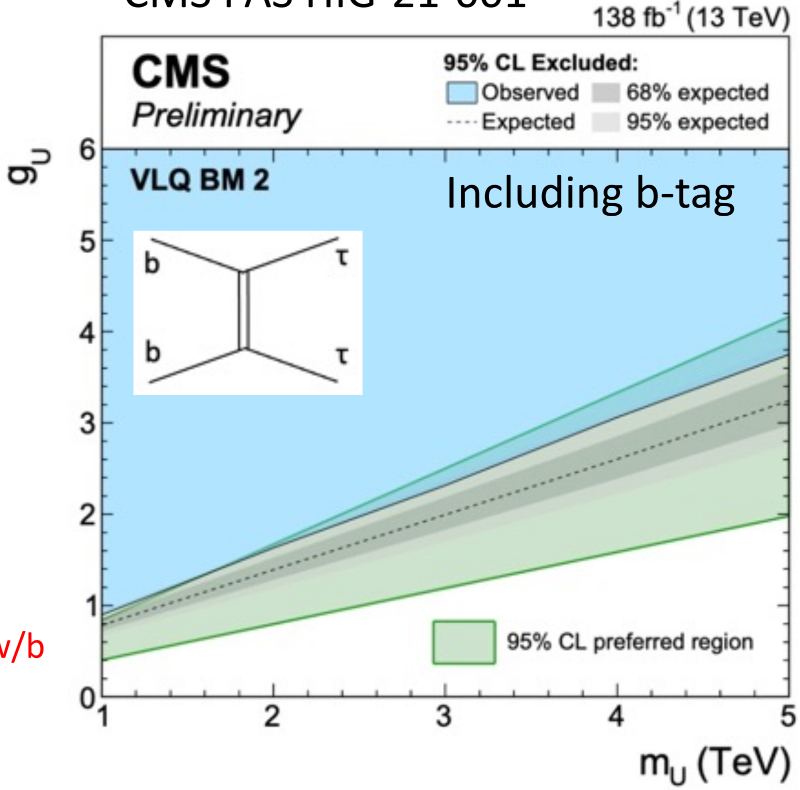
τν+b

Sensitivity study

Dashed:3ab^{-1}

sensitivity w/o b, w/b

CMS PAS HIG-21-001



Including b-tag

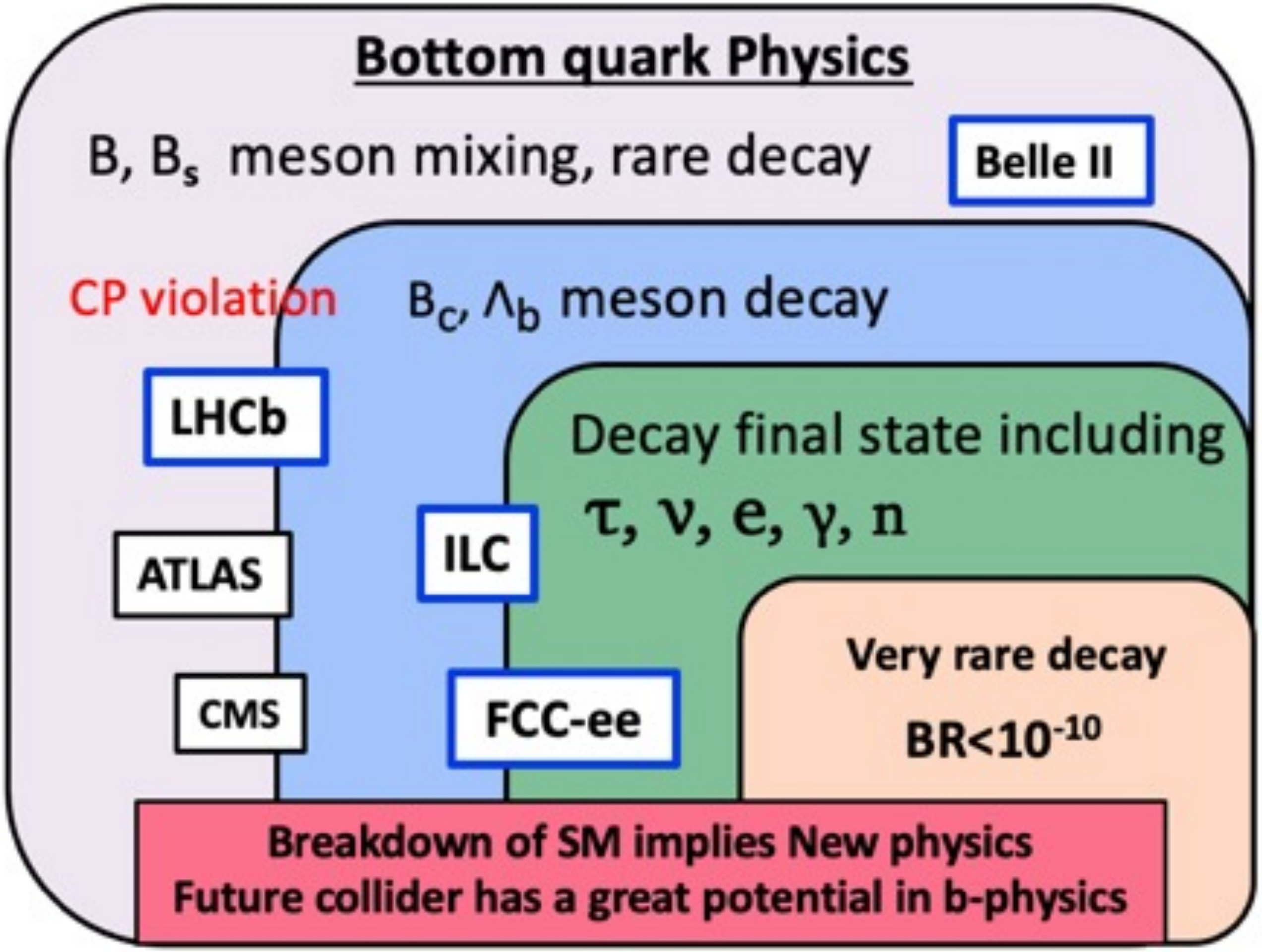
We assigned the conservative uncertainty corresponding to the one with 36 fb^{-1} to estimate the sensitivity with 139 fb^{-1} → our sensitivity is conservative.

We can touch the interesting region with the LHC.

An additional b-tagging is important but not performed yet

Global view: B physics at future lepton colliders

In which field future machine plays a role?



Bottom quark Physics

B, B_s meson mixing, rare decay

Belle II

CP violation

B_c, Λ_b meson decay

LHCb

ATLAS

CMS

ILC

FCC-ee

Decay final state including

τ, ν, e, γ, n

Very rare decay

BR<10^{-10}

Breakdown of SM implies New physics
Future collider has a great potential in b-physics

We are waiting for your suggestion (process) to evaluate the potential!

$B_{u,c}$→τν at FCC-ee

2305.02998

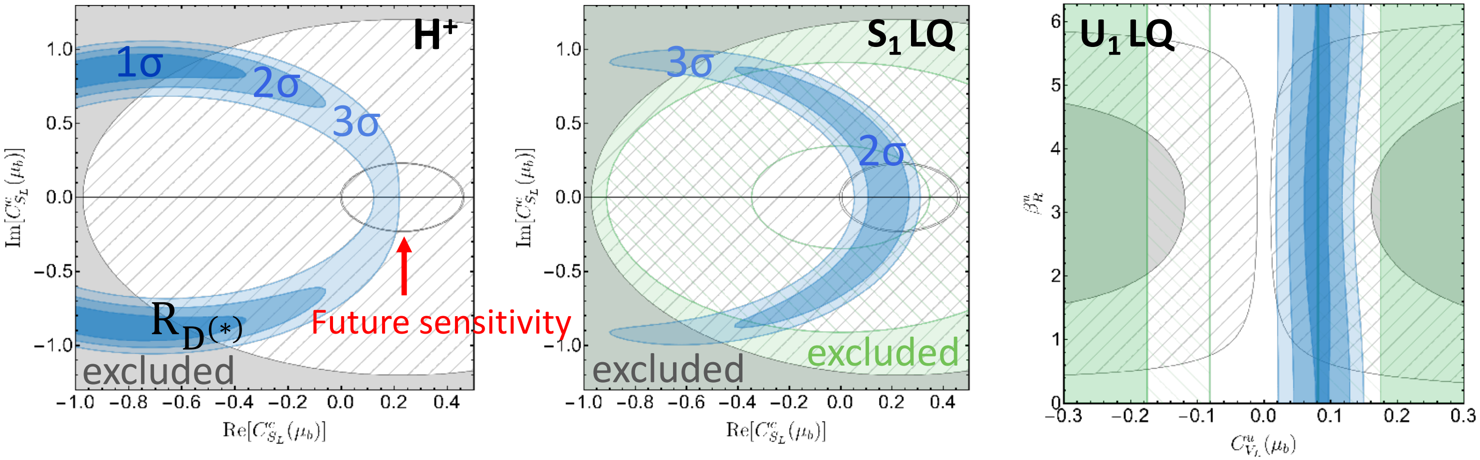
Syuhei Iguro, Marco Fedele, Xunwu Zuo,,,,

Improving $B_{u,c}$→τν accuracy is super important for V_{ub}, V_{cb}, $R_{D^{(*)}}$ and testing the SM and HQET.

At the previous Z pole e^+e^- collider, the number of the produced b quark is smaller than BaBar, Belle. LHCb has tremendous number of b, however, not suitable for precision physics.

FCC-ee is an unique opportunity for τ, ν, involving precision B physics with O(10^{11}) b-hadron!

They can determine BR(**B_c→τν**) at O(1)% of the SM prediction



FCC-ee and HL-LHC can search

▨ ▨ meshed region

Except for the thin ring, we can probe whole region for **H⁺** and **S_1**.
FCC-ee can probe the broader parameter space than HL-LHC.

FCC-ee is super powerful tool not only EW precision physics but also heavy flavor physics!

$B_{u,c} \to \tau\nu$ at FCC-ee

2305.02998

Syuhei Iguro, Marco Fedele, Xunwu Zuo,,,,

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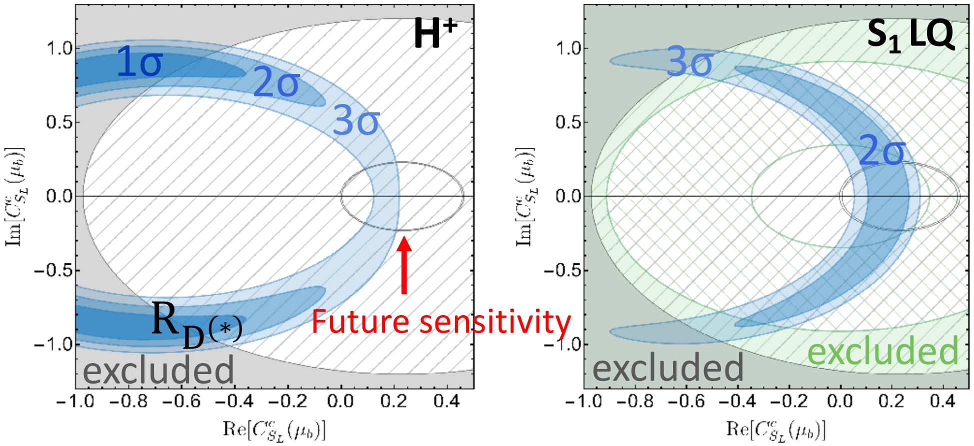
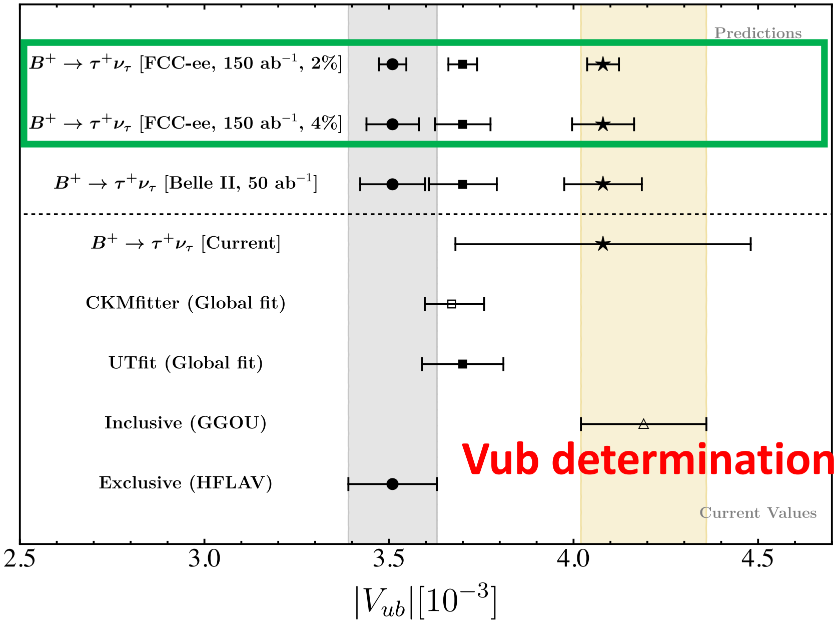
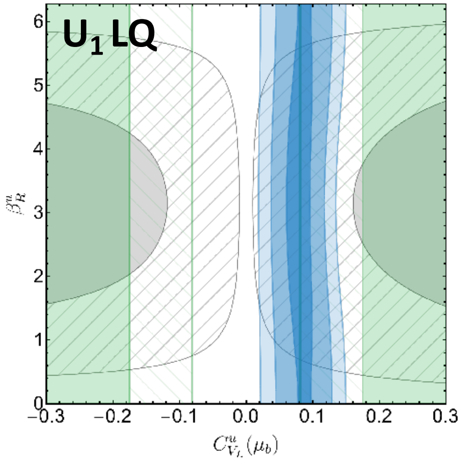




Vub determination



FCC-ee and HL-LHC can search

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Except for the thin ring, we can probe whole region for **H⁺** and **S_1**. FCC-ee can probe the broader parameter space than HL-LHC.

FCC-ee is super powerful tool not only EW precision physics but also heavy flavor physics!

Future $B \to \tau\nu$ is the independent third cross check of V_{ub}. This determination is free from form factors and inclusive hadronic parameters

Other interesting modes e.g. Λb decays at FCC-ee are waiting for the detailed analysis!

Global fit to b → c τ ν

KIT
Karlsruher Institut für Technologie

TTP

IAP
Theoretical
Particle Physics

Syuhei Iguro

Inspire
web page

Mainly based on 2210.10751 v3(coming soon)

and many papers with Teppei Kitahara, Yuji Omura, Ryoutaro Watanabe, Hantian Zhang,
Monika Blanke, Ulrich Nierste, Fedele Marco, Andreas Crivellin,,,