

université **PARIS-SAC**

New physics search with angular distribution of B**→**D*l **ν** decay

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Outline

Introduction

- •Angular distribution and new physics search
- •Form factor dependence

The impact of the new lattice data

- •Fermilab and JLQCD result on the form factors
- •Impacts of the lattice results

New Physics fit of experimental data including lattice data

•Toy study of unbanned analysis

Conclusions

Introduction

Introduction: B**→**D*l **ν** decay (l=e,mu)

Vcb(-Vub) puzzle:

- The observed discrepancy between exclusive and inclusive determination of Vcb (&Vub)
- CKM goal fit points Vcb inclusive measurement: problem in Vcb exclusive??? Motivation for
- Difficult to judge due to hadronic uncertainties…
	- 4

angular analysis!

Introduction: B→D^{*}I v decay (I=tau) The SM postulates the universality of the universality of the electroweak gauge bosons. The electroweak gauge

R(D)-R(D*) anomaly:

- R(D^(*)) is hadronic uncertainty FREE observable
- Thus, the observed anomaly is very intriguing
- Tau decays with missing energy: challenge for experiment

Inght made cirents by the helphy amphane, the window where the $J_i(i = 1 \sim 9)$ is written by the helicity amplitude and the Wilson coefficients left- and right-handed currents by $\frac{1}{2}$

$$
J_{1s} = \frac{3}{2}(H_{+}^{2} + H_{-}^{2})(|C_{V_{L}}|^{2} + |C_{V_{R}}|^{2}) - 6H_{+}H_{-}Re[C_{V_{L}}C_{V_{R}}^{*}]
$$

\n
$$
J_{1c} = \frac{3}{2}H_{0}^{2}(|C_{V_{L}}|^{2} + |C_{W_{R}}|^{2} - 2Re[C_{V_{L}}C_{V_{R}}^{*}])
$$

\n
$$
J_{2s} = \frac{1}{2}(H_{+}^{2} + H_{-}^{2})(|\tilde{C}_{V_{L}}|^{2} + |C_{W_{R}}|^{2}) - 2H_{+}H_{-}Re[C_{V_{L}}C_{V_{R}}^{*}]
$$

\n
$$
J_{2c} = \frac{3}{2}H_{0}^{2}(|C_{V_{+}}|^{2} + |C_{V_{R}}|^{2}) - 2H_{+}H_{-}Re[C_{V_{L}}C_{V_{R}}^{*}]
$$

\n
$$
J_{3} = -2H_{+}H_{-}(|C_{V_{L}}|^{2} + |C_{V_{R}}|^{2}) + 2(H_{+}^{2} + H_{-}^{2})Re[C_{V_{L}}C_{V_{R}}^{*}]
$$

\n
$$
J_{4} = (H_{+}^{2}H_{0} + H_{-}^{2}H_{0})(|\tilde{C}_{V_{L}}|^{2} + |\tilde{C}_{V_{R}}|^{2} - 2Re[C_{V_{L}}C_{V_{R}}^{*}])
$$

\n
$$
J_{5} = -2(H_{+}H_{0} - H_{-}H_{0})(|C_{V_{L}}|^{2} - |C_{V_{R}}|^{2})
$$

\n
$$
J_{6s} = -2(H_{-}^{2} - H_{-}^{2})(|C_{V_{-}}|^{2} - |C_{V_{-}}|^{2})
$$

Angular distribution is a powerful tool for new physics search: $J_7 = 0$ J_8 = $2(H_+H_0 - H_-H_0)\text{Im}[C_{V_L}C_{V_R}^*]$ J_9 = $2(H_+^2 - H_-^2)$ $[\text{m}[\mathcal{C}_{V_L}^T \mathcal{C}_{V_R}^T]$ For the $(B \to \bar{D}^* (\to \bar{D}\pi) \ell^+ \nu_\ell$ decay, all the terms are the same except, $\mathbb{G}_{R,R}$ becons its complex conjugate *C*⇤ *VL,R* not affect any term but *J*₈ and *J*₉, which flip sign. Indeed, these two terms are triple-product observable, which can generate true ε false CP violation (the former originates from the CP violating phase and the latter fr $\rm{Fe}\;\rm{the}\;\rm{vhe}$ i ts complex sign . Indeed false $\big\|$ P vio It can probe the different Dirac structure $\begin{array}{r} F_0 \text{ the } \\ \text{where} \\ F_1 \text{ the } \\ \text{where} \\ \end{array}$ Some observables are hadronic uncertainty FREE (unlike branching ratio measurement) Interesting challenge for experiment!

Angular analysis for |Vcb| fit (SM)

 $+J_7 \sin 2\theta_V \sin \theta_\ell \sin \chi + J_8 \sin 2\theta_V \sin \theta_V$ erential decay rate is given by accay rate is given by *HD*⇤ ^T*,*0(*q*2) = *ⁱ*✏¯ *^µ*()¯✏)h*D*⇤(*pD*⇤ *,* ✏ (*D*⇤))*|c*¯*µ*⌫(1 5)*b|B*¯(*pB*)i*,*

 $\frac{1}{2}$

$$
\begin{array}{rcl}\n\mathbf{B} & \rightarrow \mathbf{D}^{*} \mathbf{I} & \mathbf{v} \ \text{decay} & \mathbf{f} = \mathbf{e}_{r} \text{m} \mathbf{u}_{r} \mathbf{I}_{\text{sc}} \mathbf{S} \text{m} \math
$$

0 2 4

6

,,,,**,,**,,,,

4

6

0

 $+J_7 \sin 2\theta_V \sin \theta_\ell \sin \chi + J_8 \sin 2\theta_V \sin \theta_V$ erential decay rate is given by accay rate is given by *HD*⇤ ^T*,*0(*q*2) = *ⁱ*✏¯ *^µ*()¯✏)h*D*⇤(*pD*⇤ *,* ✏ (*D*⇤))*|c*¯*µ*⌫(1 5)*b|B*¯(*pB*)i*,*

 $\frac{1}{2}$

B**→**D*l **ν** decay (l=e,mu): angular analysis +*J*⁹ sin² ✓*^V* sin² ✓` sin 2 o where the *Ji*(*i* = 1 ⇠ 9) is written by the helicity amplitude and the Wilson coecients of left- and right-handed currents by *^J*1*^s* ⁼ ³ 2 (*H*² ⁺ + *H*²)(*|CV^L |* ² ⁺ *[|]CV^R [|]* ²) ⁶*H*+*H*Re[*CV^L ^C*⇤ *J*1*^c* = 2*H*² ⁰ (*|CV^L |* ² ⁺ *[|]CV^R [|]* ² 2Re[*CV^L ^C*⇤ *^V^R*]) *^J*2*^s* ⁼ ¹ 2 (*H*² ⁺ + *H*²)(*|CV^L |* ² ⁺ *[|]CV^R [|]* ²) ²*H*+*H*Re[*CV^L ^C*⇤ *^J*2*^c* ⁼ 2*H*² ⁰ (*|CV^L |* ² ⁺ *[|]CV^R [|]* ² 2Re[*CV^L ^C*⇤ *^V^R*]) *J*³ = 2*H*+*H*(*|CV^L |* ² ⁺ *[|]CV^R [|]* ²) + 2(*H*² ⁺ + *H*²)Re[*CV^L C*⇤ *J*⁴ = (*H*+*H*⁰ + *HH*0)(*|CV^L |* ² ⁺ *[|]CV^R [|]* ² 2Re[*CV^L ^C*⇤ *J*⁵ = 2(*H*+*H*⁰ *HH*0)(*|CV^L |* ² *[|]CV^R [|]* 2) *^J*6*^s* ⁼ 2(*H*² ⁺ *^H*²)(*|CV^L |* ² *[|]CV^R [|]* 2) *J*6*^c* = 0 *J*⁷ = 0 *J*⁸ = 2(*H*+*H*⁰ *HH*0)Im[*CV^L C*⇤ *^V^R*] *J*⁹ = 2(*H*² ⁺ *^H*²)Im[*CV^L C*⇤ *^V^R*] For the (*^B* ! *^D*¯ ⇤(! *^D*¯⇡) `⁺ ⌫`) decay, all the terms are the same except, *^CVL,R* becomes its complex conjugate *C*⇤ *VL,R* . This does not a↵ect any term but *J*⁸ and *J*9, which flip the sign. Indeed, these two terms are triple-product observable, which can generate true and false CP violation (the former originates from the CP violating phase and the latter from the CP conserving phase, such as strong interaction). Only the true CP violation can 4 i / r D W D e^V * B e*l l* **z** 10 *d*(*BD*⇤`) *dwd*cos*^V d*cos`*d* = 3*G*² *F* 4(4)⁴ *|Vcb|* ²*mBm*² *D*⇤ ^p*w*² 1(1 ²*wr* ⁺ *^r*²)⇥ [(1 cos`)²sin² *^V |H*+(*w*)*|* 2 +(1 + cos`)²sin²*^V [|]H*(*w*)*[|]* 2 +4sin²`cos²*^V [|]H*0(*w*)*[|]* 2 4sin`(1 cos`)sin*^V* cos*^V* cos*H*+(*w*)*H*0(*w*) +4sin`(1 + cos`)sin*^V* cos*^V* cos*H*(*w*)*H*0(*w*) 2sin²`sin² *^V* cos2*H*+(*w*)*H*(*w*)] where *Hi*(*w*) are called the helicity form factors. These form factors are related to another set of form factors, *h^V* (*w*), *h^A*¹ (*w*), *h^A*2(*w*) and *h^A*³ (*w*), as follows. IV. SEMILEPTONIC DECAYS In the massless lepton limit, the *^B*⁰ ! *^D*⇤`⁺⌫` differential decay rate is given by [4] *^d*(*B*⁰ ! *^D*⇤`⁺⌫`) *dwd* cos ✓`*d* cos ✓v*d* = ⌘2 EW3*mBm*² *D*⇤ 4(4⇡)² *^G*² *^F |Vcb|* 2 ^p*w*² 1(1 ²*wr* ⁺ *^r*²) (1 cos ✓`) ² sin² ✓v*H*² ⁺(*w*) + (1 + cos ✓`) ² sin² ✓v*H*² (*w*) +4 sin² ✓` cos² ✓v*H*² ⁰ 2 sin² ✓` sin² ✓^v cos 2*H*+(*w*)*H*(*w*) 4 sin ✓`(1 cos ✓`) sin ✓^v cos ✓^v cos *H*+(*w*)*H*0(*w*) +4 sin ✓`(1 + cos ✓`) sin ✓^v cos ✓^v cos *H*(*w*) *H*0(*w*)*}*(5) *,* where *r* = *m^D*⇤ */mB*, *G^F* = (1*.*6637 *±* 0*.*00001) ⇥ 10⁵~c²GeV² and ⌘EW is a small electroweak correction (Calculated to be 1.006 in Ref. [19]). In these equations the Blaschke factors, *P*¹*±*, are given by where *z^P* is defined as while *^t[±]* = (*m^B [±] ^m^D*⇤)² and *^m^P* denotes the masses of the *B*⇤ *^c* resonances. The product is extended to include all the *B^c* resonances below the *B D*⇤ threshold of 7.29 GeV*/*c² with the appropriate quantum numbers (1⁺ for *f*(*w*) and *F*1(*w*), and 1 for *g*(*w*)). We use the the *B^c* resonances listed in Table I. The *B^c* resonances also enter *^L*VL*/*^R = ¯✏*µ*()¯*u*`*µ*(1 ⌥ 5)*v*⌫¯` *^L*^P = ¯*u*`(1 5)*v*⌫¯` *L*^T *,*⁰ = *i*✏¯*µ*()¯✏⌫(⁰)¯*u*`*µ*⌫(1 5)*v*⌫¯` Both are written by ¯✏, the polarisation vector of *W* boson, and (⁰) ² *{*+*, ,* ⁰*, t}*, its polarisation. Note that ¯✏(*t*) is not orthogonal but proportional to *W*-momentum. The polarisation vectors are given in [69]. Then, using the completeness relation of the polarisation vectors of *W* boson, we square the hadronic and leptonic parts of the amplitudes separately. This allows us to evaluate each part in a convenient frame: we choose the *W* rest frame for the leptonic part and *B* rest frame for the hadronic part. The hadronic part is a complex function of form factors and we find *H±* ^V (*q*2) ⌘ *^H[±]* ^VL*,±*(*q*2) = *H*⌥ ^VR*,*⌥(*q*2) = (*M^B* ⁺ *^MD*⇤)*A*1(*q*2) ⌥ p*D*⇤ (*q*2) *M^B* + *MD*⇤ *V* (*q*2) *H*⁰ ^V(*q*2) ⌘ *^H*⁰ ^VL*,*0(*q*2) = *H*⁰ ^VR*,*0(*q*2) = *M^B* + *MD*⇤ 2*MD*⇤ p*q*² (*M*² *^B ^M*² *^D*⇤ *^q*2)*A*1(*q*2) + *D*⇤ (*q*2) (*M^B* ⁺ *^MD*⇤)² *^A*2(*q*2) ^P(*q*2) and the leptonic amplitudes are given as *^L*VL*/*^R = ¯✏*µ*()¯*u*`*µ*(1 ⌥ 5)*v*⌫¯` *^L*^P = ¯*u*`(1 5)*v*⌫¯` *L*^T *,*⁰ = *i*✏¯*µ*()¯✏⌫(⁰)¯*u*`*µ*⌫(1 5)*v*⌫¯` Both are written by ¯✏, the polarisation vector of *W* boson, and (⁰) ² *{*+*, ,* ⁰*, t}*, its polarisation. Note that ¯✏(*t*) is not orthogonal but proportional to *W*-momentum. The polarisation vectors are given in [69]. Then, using the completeness relation of the polarisation vectors of *W* boson, we square the hadronic and leptonic parts of the amplitudes separately. This allows us to evaluate each part in a convenient frame: we choose the *W* rest frame for the leptonic part and *B* rest frame for the hadronic part. The hadronic part is a complex function of form factors and we find ^V (*q*2) ⌘ *^H[±]* ^VL*,±*(*q*2) = *H*⌥ ^VR*,*⌥(*q*2) = (*M^B* ⁺ *^MD*⇤)*A*1(*q*2) ⌥ p*D*⇤ (*q*2) *M^B* + *MD*⇤ *V* (*q*2) *H*⁰ ^V(*q*2) ⌘ *^H*⁰ ^VL*,*0(*q*2) = *H*⁰ ^VR*,*0(*q*2) = *M^B* + *MD*⇤ 2*MD*⇤ p*q*² (*M*² *^B ^M*² *^D*⇤ *^q*2)*A*1(*q*2) + *D*⇤ (*q*2) (*M^B* ⁺ *^MD*⇤)² *^A*2(*q*2) *H[±] H*⁰ In SM:

B**→**D*l **ν** decay : hadronic form factor the pseudoscalar and tensor form factors to the vector and axial-vector form factors, b v wecay. $B \rightarrow D^*$ v decay : hadronic form factor (*M*² *^B ^M*² *^D*⇤)*q*² *<u>Dnic</u> for* n
In *J₁s sin* α *^V + <i>V* α ^V α ^V + *V* α ^V + α

In the lattice results, the form factors are parameterised using the so-called BGL

H±

H± ^V (*w*) = *f* ⌥ *gMB|p* PRD56, '97

ed
$$
w \equiv \frac{M_B^2 + M_{D^*}^2 - q^2}{2M_B M_{D^*}}
$$

Boyd, Grinstein Lebed

\n
$$
w \equiv \frac{M_B^2 + M_{D^*}^2 - q^2}{2M_B M_{D^*}} \qquad z \equiv \frac{\sqrt{w+1} - \sqrt{2}}{\sqrt{w+1} + \sqrt{2}}
$$

•BGL parameterisation: generic momentum expansion 1 rameteris *F*1 four form factors thanks to the relations given in Appendix A. aramererisarion: generic momentum expansion cients *Ji*(*i* = 1 ⇠ 9) are given in Tables 1 and 2.

$$
g(z) = \frac{1}{P_{1-}(z)\phi_g(z)} \sum_{n=0}^{\infty} a_n^g \lambda_n, \qquad f(z) = \frac{1}{P_{1+}(z)\phi_f(z)} \sum_{n=0}^{\infty} a_n^f \lambda^n,
$$

$$
\mathcal{F}_1(z) = \frac{1}{P_{1+}(z)\phi_{\mathcal{F}_1}(z)} \sum_{n=0}^{\infty} a_n^{\mathcal{F}_1} \lambda_n, \quad \mathcal{F}_2(z) = \frac{1}{P_{0-}(z)\phi_{\mathcal{F}_2}(z)} \sum_{n=0}^{\infty} a_n^{\mathcal{F}_2} \lambda_n,
$$

B**→**D*l **ν** decay : hadronic form factor the pseudoscalar and tensor form factors to the vector and axial-vector form factors, b v wecay. $B \rightarrow D^*$ v decay : hadronic form factor (*M*² *^B ^M*² *^D*⇤)*q*² *<u>Dnic</u> for* n
In *J₁s sin* α *^V + <i>V* α ^V α ^V + *V* α ^V + α

Hadronic form factor and new lattice results

B**→**D*l **ν** decay (l=e,mu): Belle (SM) analysis

- Belle data fit
- Here we don't use any lattice so no Vcb constraint
- In the plot, we scaled it with | Vcb|**η**EW=0.039

B**→**D*l **ν** decay : Lattice QCD

- •Fremilab: w=1.03,1.10, 1.17
- JLQCD: w=1.025, 1.05, 1.10
- •We extrapolate with the 2nd order BGL parameterisation

Fermilab-Milk: EPJC82, '22 JLQCD: arXiv:2306.05657

Belle (SM) data + Lattice data (JLQCD)

- Belle data + Lattice QCD combined fit
- Now we can obtain Vcb
- Two lattice results agree within the errors

Belle (SM) data + Lattice data (Fermilab)

- Belle data + Lattice QCD combined fit
- Now we can obtain Vcb
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Belle (SM) data + Lattice data Table 6: The BGL form factors and *|Vcb|*⌘EW obtained by a simultaneous fit of the Belle \blacksquare Dalla \blacksquare [624] data \blacksquare datice data by July (third column) collaborations. The first error is statistical and the second is systematic.

- The correlation between Vcb $\begin{array}{ccc} a_0 & a_1 & a_2 \ a_1^f & a_2^f & a_3^f \end{array}$ and the form factor parameter α_0 ^f is very strong. Fermilab-MILC data [64].
- \cdot The JLQCD data gives a slightly higher Vcb than Fermlab data.

Angular analysis for New Physics fit

B**→**D*l **ν** decay (l=e,mu): angular analysis $R \rightarrow \mathbb{R}^*$ w decay ℓ = multonian, anglycic In this article, we consider the new physics particle which contributes to the semiright-handed neutrinos:

F. Kappor, Z.R. Huang, E.K.

²⁰¹€ 124,8484,44888 arXive:2401.2401.11636 S*O*`

New Physics: ر
برا**D**ا برن ics:

$$
\mathcal{H}_{\text{eff}} = \frac{4G_F}{\sqrt{2}} V_{cb} \sum_{\ell=e,\mu} [C_{V_L}^{\ell} O_{V_L}^{\ell} + C_{V_R}^{\ell} O_{V_R}^{\ell} + C_{S}^{\ell} O_{S}^{\ell} + C_{P}^{\ell} O_{P}^{\ell} + C_{T}^{\ell} O_{T}^{\ell}]
$$

$$
O_{V_L}^{\ell} = (\bar{c}_L \gamma^{\mu} b_L)(\bar{\ell}_L \gamma_{\mu} \nu_{\ell L})
$$

$$
O_{V_R}^{\ell} = (\bar{c}_R \gamma^{\mu} b_R)(\bar{\ell}_L \gamma_{\mu} \nu_{\ell L})
$$

$$
O_{S}^{\ell} = (\bar{c}b)(\bar{\ell}_R \nu_{\ell L})
$$

$$
O_{T}^{\ell} = (\bar{c}_{R} \sigma^{\mu \nu} b_L)(\bar{\ell}_R \sigma_{\mu \nu} \nu_{\ell L})
$$

 $O'_1 = (c_R \sigma \sigma) L$

^T = (¯*cRµ*⌫*bL*)(¯`*Rµ*⌫⌫`*L*) *For the l=e/mu case, only R (Right-handed), P (Pseudoscalar), T (Tensor) operators contribute*

 $(m_D + r)$ $(m_B + n$

$$
\frac{d\Gamma(\bar{B}\rightarrow B^k\epsilon|\mathbf{w}_0)\cdot\mathbf{P}_0\cdot\mathbf{w}_0\cdot\mathbf{P}_1\cdot\mathbf{P}_2\cdot\mathbf{P}_3\cdot\mathbf{P}_4\cdot\mathbf{P}_5\cdot\mathbf{P}_5\cdot\mathbf{P}_6\cdot\mathbf{P}_7\cdot\mathbf{P}_7\cdot\mathbf{P}_7\cdot\mathbf{P}_8\cdot\mathbf{P}_9\cdot\mathbf{P
$$

the $(B \to \bar{D}^*(\to \bar{D}\pi)\ell^+\nu_\ell)$ decay, all the terms are the same except, \mathbb{G}_k *C***P**econserving phase, such as strong interaction). Only the true CP violation plex conjugate $C^{\ast}_{V_{L,R}}$. This does not affect any term but J_8 and J_9 , which flip the $\rightarrow \bar{D}^*(\rightarrow \bar{D}\pi)\ell^+\nu_{\ell}$ decay, all the terms are the same except, $\mathbb{G}_{\mathbb{F}_p}$ \mathbb{C} **Peconser**ving point points $C_{V_{\ell-1}}^*$. This does not affect any term but J_8 and J_9 , which flip the

B→D^{*}l v decay (l=e,mu): angular analysis

New Physics: w *B*hysics[.] cients **J**_i *J***_i**(*i*₁ and 2.1 **and 2.1** and 2.1 **and 2.1** and 2.1 **and 2.1** and 2.1 an

^M^B . The angular coe- T. Kappor, Z.R. Huang, E.K. arXive:2401.2401.11636

 S_M is $C_M = 1$ $Diahth and od model interactions with S_M$ **Extra 1908. • And the hadronic amplitude in Eq. (8). The columns contained in Eq. (8). The columns contained in Eq. (8). The contained in Eq. (8).** $\frac{1}{2}$ *SM is CVL=1. Right-handed model interferes with SM.*

the left- and right-handed contributions and their interference terms. The complete *Ji*-

B→D^{*}l **v** decay (l=e,mu): angular analysis

New Physics:

in Eq. (9). *H[±],*⁰

T. Kappor, Z.R. Huang, E.K. arXive:2401.2401.11636

Psudoscalar and Tensor terms don't interfere with SM.

^T and *H*^P are the hadronic amplitudes, defined in Eq. (8). The columns

Toy study of new physics fit 8(4⇡)⁴ *^G*² $\bm{\mathsf{S}}$ **r** $\bm{\mathsf{S}}$ or new pnysics times in the $\bm{\mathsf{S}}$ dence, we separate *w* in 10 bins and prepare the pdf for each bin. We express the decay T_{max} theory parameters to the said coecients and the following \sim

Then, *a*BGL*, C*NP) = (33) T. Kappor, Z.R. Huang, E.K. arXive:2401.11636

1. Generate "fake-data" with the Belle '18 fitted parameters. 2. Fit the fake-data with the theory formula including new physics parameters together with the lattice data 6*mBm*² 6h*J*⁰ ¹*s*i*w*bin+3h*J*⁰ *a*But the "fake-data" with the Belle 118 fitted parchy and the set of the set <u>Redata with the theory formula including new physics</u> 1. Generate "fake-data" with the Belle '18 fitted param
2. Fit the fake-data with the theory formula including ne parameters together with the lattice data \mathbf{a} $\ddot{\mathbf{v}}$ **V** is the virth the lattice data *p* is interested to get from the angular coefficients (see Appendix Box 4.1 σ

• 4 dimensional unbinned maximum likelihood analysis cluding new physics contribution. dimensional <mark>unbinned maximum likelihood ana</mark>l for details) while ^h*g*th *ⁱ* (~ *a*BGL*, C*NP)i are the theoretical expressions, which depend on the form factors and the form factors and α and α and α (i.e. the fitted form factors and *Vcb* in [62] as mentioned earlier). The detailed

$$
\chi^2_{\text{unbinned}}(\vec{a}_{\text{BGL}}, V_{cb}, C_{\text{NP}}) = \chi^2_{\text{angle}}(\vec{a}_{\text{BGL}}, C_{\text{NP}}) + \chi^2_{\text{latt}}(\vec{a}_{\text{BGL}}) + \chi^2_{\mathcal{B}}(\vec{a}_{\text{BGL}}, V_{cb}, C_{\text{NP}})
$$

• Angular distribution and Branching ratio: of the branching ratio, as in the branching ratio, as \mathbf{r} ribution and Branching ratio: **Acception** 2014 Now, we can fit the theory parameters to the 'experimentally' obtained angular • Angular distribution and Branching ratio:

 $\left(\begin{array}{ccc} \n\end{array} \right)$ $\left(\begin{array}{ccc} \n\end{array} \right)$ $\mathcal{F}\left(\sqrt{g_j} \quad / - \sqrt{g_j} \left(\frac{u_{\text{BGL}}, v_{\text{NP}}}{v} \right) \right) \right]_{w-\text{bin}}$ $C_{\text{N}}(d_{\text{PCT}}-C_{\text{NP}}) = \sum_{i=0}^{10} \left[N_{w-\text{bin}} \hat{V}_{i}^{-1} \left(\langle g_{i}^{\text{exp}} \rangle - \langle g_{i}^{\text{th}}(\vec{a}_{\text{RCT}},C_{\text{NP}}) \rangle \right) \left(\langle g_{i}^{\text{exp}} \rangle - \langle g_{i}^{\text{th}}(\vec{a}_{\text{RCT}},C_{\text{NP}}) \rangle \right) \right]$ $angle(wBGL, \cup N$ $\frac{10}{\sqrt{2}}$ $\left[\begin{array}{ccc} 0 & 1 \end{array} \right]$ 0.050 λ angle (\in DGL) \leq N1 \neq \geq \geq \sum 10 w -bin=1 $\left[N_{w-\text{bin}} \hat{V}_{ij}^{-1}\left(\langle g_i^{\text{exp}}\rangle - \langle g_i^{\text{th}}(\vec{a}_{\text{BGL}},C_{\text{NP}})\rangle\right)\left(\langle g_j^{\text{exp}}\rangle - \langle g_j^{\text{th}}(\vec{a}_{\text{BGL}},C_{\text{NP}})\rangle\right]$ \setminus w -bin $\chi^2_{\rm angle}(\vec{a}_{\rm BGL},C_{\rm NP}) = \sum \quad \left[N_{w-\rm bin} \hat{V}^{-1}_{ij} \left(\langle g^{\rm exp}_{i} \rangle - \langle g^{\rm th}_{i}(\vec{a}_{\rm BGL},C_{\rm NP}) \rangle \right) \left(\langle g^{\rm exp}_{j} \rangle - \langle g^{\rm th}_{j}(\vec{a}_{\rm BGL},C_{\rm NP}) \rangle \right) \right]$

^j ih*g*th

$$
\chi_{\mathcal{B}}^2(\vec{a}_{\text{BGL}}, V_{cb}, C_{\text{NP}}) = \left(\frac{\mathcal{B}^{\text{th}}(\vec{a}_{\text{BGL}}, V_{cb}, C_{\text{NP}}) - 0.0495}{0.0011}\right)^2
$$

$$
\langle g_i \rangle \equiv \frac{\langle J_i \rangle}{6 \langle J_{1s} \rangle + 3 \langle J_{1c} \rangle - 2 \langle J_{2s} \rangle - \langle J_{2c} \rangle}
$$

$$
\chi_{\mathcal{B}}^2(\vec{a}_{\text{BGL}}, V_{cb}, C_{\text{NP}}) = \left(\frac{6 - (a_{\text{BGL}}, v_{cb}, c_{\text{NP}}) - 0.0436}{0.0011}\right) \qquad (g_i) \equiv \frac{\langle J_i \rangle}{6 \langle J_{1s} \rangle + 3 \langle J_{1c} \rangle - 2 \langle J_{2s} \rangle - \langle J_{2c} \rangle}
$$

Fake data

Result of the Right-handed model

•Belle fake data combined with the lattice data to fit the new physics parameter C_{VR} along with SM parameter Vcb

 $C_{VR} \neq 0$ **ILEX New physics!**

> $\sqrt{\frac{1}{2}}$ $\frac{1}{2}$ is important to shook the servel ation between the ne \parallel Now, it is important to check the correlation between the new \parallel **physics parameters and hadronic parameters**

Result of the Right-handed model ¹ 0*.*004(50) 0*.*276(62) he Richt-hande *|Vcb|*⌘EW 0*.*0390(21) 0*.*0385(20)

· Belle fake data combined with the lattice data to fit the new physics parameter C_{VR} along with SM parameter Vcb ake data compined with the lattice data to 1

 \sim distinguish the effect of these two parameters. We can see *that a0g of JLQCD and Fermilab do not agree and that results in different values of CVR* \overline{a} part and Fermilabe-Sermilabe-Milcone data and Fermilabe-Milcone and to be real. The contract of the contract o i.e. *C*V^L , as such terms are proportional to the lepton mass, which is neglected. As a result the sensitivity to this parameter is quite poor. The fitted result is given in Table 9 where we find that *|C*P*|* is constrained only at 20-30% precision. As

mentioned earlier, the psuedoscalar form factor is obtained by relating it to the axial psuedoscalar form factor is obtained by relating it to the axial psuedoscalar form factor in the axial psuedoscalar form factor in the

Conclusions

- •Belle has been studying the angular distribution to constrain the form factors within SM.
- There are now three lattice QCD results on the B->D^{*} Form Factors.
- •Thus, we are ready to move to BSM fit!
- •We performed toy study of the unbanned maximum likelihood method of Belle data to new physics models including the lattice data.
- •The observed discrepancy in Right-handed model is intriguing and we need further investigation both from theory and experiment.
- •The pseudoscalar/tensor model doesn't interfere with SM, thus, the sensitivity is lower. Nevertheless, it has very little correlation to the form factors or Vcb so it is hadronic effect FREE.

B**→**D*l **ν** decay (l=**τ**): angular analysis *D*⇤=*±,*0 =*t,±,*0 0=*t,±,*0 **D** \rightarrow D \rightarrow IV decay (I I). angular and \rightarrow

$$
\frac{d\Gamma^{\text{r}}(\bar{B} \to D^*(\to D\pi)\tau^{-}(\to \ell\bar{\nu}_{\ell}\nu_{\tau})\bar{\nu}_{\tau})}{dwdE_{\ell}d\cos\theta_{D}d\cos\theta_{\ell}d\chi_{\ell}} = \frac{3G_{F}^{2}|V_{cb}|^{2}|\eta_{\text{EW}}|^{2}M_{D^*}\mathcal{B}(D^*\to D\pi)\mathcal{B}(\tau \to \ell\nu_{\tau}\bar{\nu}_{\ell})}{16(4\pi)^{5}M_{B}^{2}M_{P}^{6}|\vec{p}_{D}|^{2}} \times \frac{|\vec{p}_{D^*}(w)||\vec{p}_{\tau}(w)||E_{\ell}}{\sqrt{1+r^{2}-2wr}} \Big\{ J_{1s}^{\text{r}}\sin^{2}\theta_{D} + J_{1c}^{\text{r}}\cos^{2}\theta_{D} + (J_{2s}^{\text{r}}\sin^{2}\theta_{D} + J_{2c}^{\text{r}}\cos^{2}\theta_{D})\cos 2\theta_{\ell} + J_{3}^{\text{r}}\sin^{2}\theta_{D}\sin^{2}\theta_{\ell}\cos 2\chi_{\ell} + J_{4}^{\text{r}}\sin 2\theta_{D}\sin 2\theta_{\ell}\cos \chi_{\ell} + J_{5}^{\text{r}}\sin 2\theta_{D}\sin\theta_{\ell}\cos \chi_{\ell} + (J_{6s}^{\text{r}}\sin^{2}\theta_{D} + J_{6c}^{\text{r}}\cos^{2}\theta_{D})\cos\theta_{\ell} + J_{7}^{\text{r}}\sin 2\theta_{D}\sin\theta_{\ell}\sin \chi_{\ell} + J_{5}^{\text{r}}\sin 2\theta_{D}\sin \theta_{\ell}\sin \chi_{\ell} + J_{9}^{\text{r}}\sin^{2}\theta_{D}\sin^{2}\theta_{\ell}\sin 2\chi_{\ell}\Big\},
$$

B**→**D*l **ν** decay (l=**τ**): angular analysis sets of *J*-functions, *J*R1 *ⁱ* and *J*R2 *ⁱ* , with *i* 2 *{*1*s,* 1*c,* 2*s,* 2*c,* 3*,* 4*,* 5*,* 6*s,* 6*c,* 7*,* 8*,* 9*}*. These *B* → D^{*} | v decay (I=T): anaular analysis $t \mapsto t$ are given in a Mathematica file, available on the following link: \mathbb{R}^n and following link: \mathbb{R}^n

 \mathcal{L} and \mathcal{L} to \mathcal{L} to \mathcal{L} and \mathcal{L} We use **τ→μνν** decay

B. Bhattacharya, T. Browder, A. Datta, T. Kapoor E. Kou, and L. Mukherjee arXive:2411.xxxx Figure and Mukheries

Sensitivity study with B→D^{*}l **v** decay (l=**r**):
angular analysis
B. Bhattacharya, T. Browder,

We use **τ→μνν** decay (2k events)

A. Datta, T. Kapoor E. Kou, and L. Mukherjee arXive:2411.xxxx

(a) $C_{V_R} - V_{cb}$ correlation plot with JLQCD lattice data

(b) $C_{V_R} - V_{cb}$ correlation plot with Fermilab-MILC lattice data

CVR model can be constrained at the 7-8% level.

Sensitivity study with B→D^{*}l **v** decay (l=**r**):
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B. Bhattacharya, T. Browder,

We use **τ→μνν** decay (2k events)

A. Datta, T. Kapoor E. Kou, and L. Mukherjee arXive:2411.xxxx

(a) $C_T - V_{cb}$ correlation plot with JLQCD lattice data

(b) $C_T - V_{cb}$ correlation plot with Fermilab-MILC lattice data

Real CT model can be constrained at the 7-8% level.

Sensitivity study with B→D^{*}l **v** decay (l=**r**):
angular analysis
B. Bhattacharya, T. Browder,

We use **τ→μνν** decay (2k events)

A. Datta, T. Kapoor E. Kou, and L. Mukherjee arXive:2411.xxxx

(c) $C_{V_R} - V_{cb}$ correlation plot with JLQCD lattice data

including the ²

(d) $C_{V_R} - V_{cb}$ correlation plot with Fermilab-MILC lattice data

JLQCD (left column)/Fermilab (right column) lattice data for *B^d* ! *D*⇤(! *D*⇡)⌧ (! `⌫⌧ ⌫¯`)¯⌫⌧ \Box Imaginary C_{τ} model can be constrained at the 20% level $\left| \frac{1}{1 + \alpha} \right|$ range 1 range contours in the solid line is obtained by α *Imaginary CT model can be constrained at the 20% level.*

^Vcb constraint (as shown in Eq. (61)), while the contour with dotted line is

Conclusions

- •The theoretical formula for the B**→**D***τν** (**τ→μνν**) angular distribution is derived for the first time.
- •On top of the usual 3 angles and 1 momentum, the muon energy in the rest frame of W boson can be used to constraint the NP parameters.
- •As B**→**D***τν** angular analysis not available so far, we have performed a sensitivity study using the result of Belle's B**→**D*l**ν** $($ |= e , mu) fit.
- •We found that the right-handed or tensor model can be constrained at 7-8% level with ~2k events of Belle II data.