Probing new physics $\Lambda_b^0 \to \Lambda_c^+(\to \Lambda\pi^+)\tau\bar{\nu}_\tau$ decay

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Based on arxiv 2403.12155 along with Soumitra Nandi & Shantanu Sahoo

ICHEP 2024, Prague

Motivation

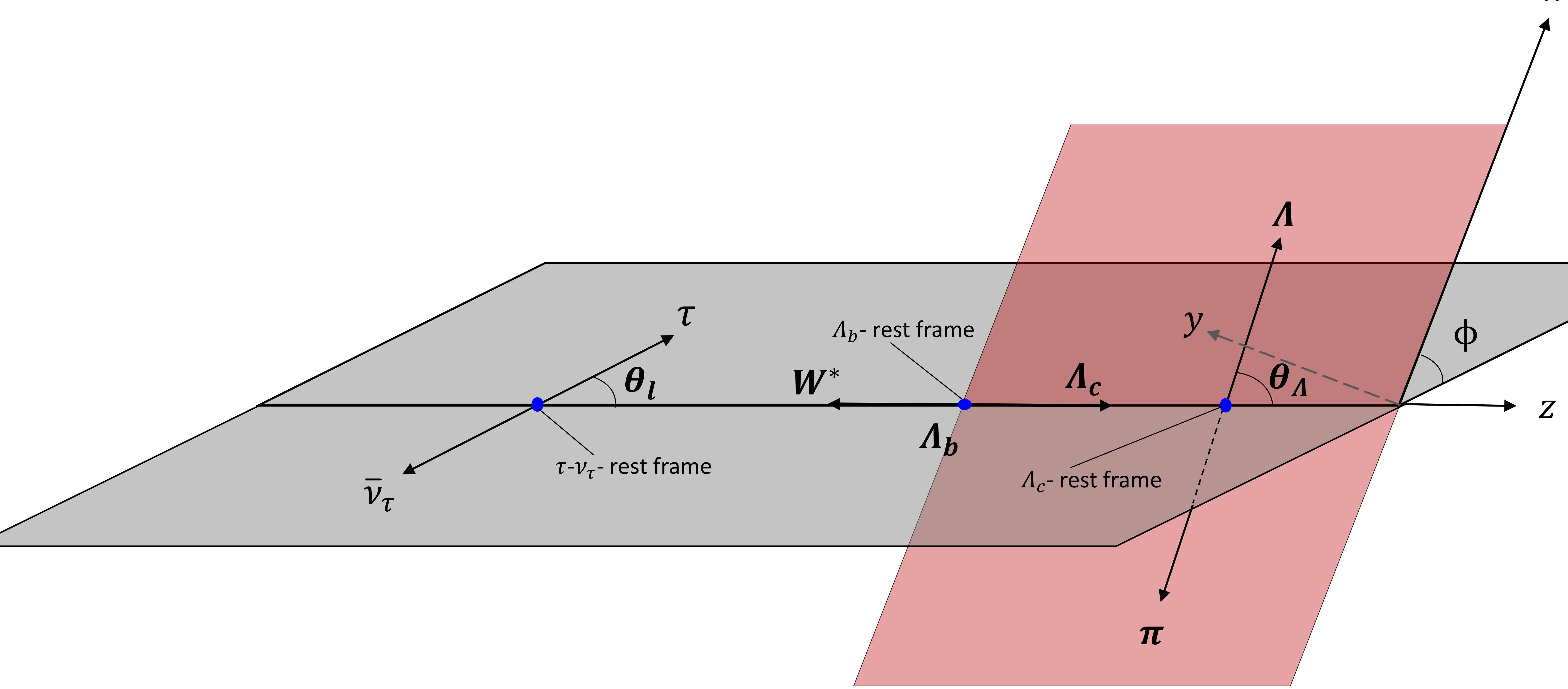
- $B \to D^{(*)}\ell\bar{\nu}$ decays are being studied theoretically and experimentally for the last decade extensively and shows anomaly in Lepton Universality(LU) ratios
- To ensure if any New Physics (NP) shows in these mesonic decays we need some complimentary decays too
- One such decay is $\Lambda_b^0 \to \Lambda_c^+(\to \Lambda^+\pi)\ell\bar{\nu}_\tau$
- Belle and Babar has B decay results but they cannot measure b-baryons
- LHCb can and recently measured the BR for $\Lambda_b^0 \to \Lambda_c^+\tau\bar{\nu}_\tau$
- Using DELPHI result for $\Lambda_b^0 \to \Lambda_c^+\mu\bar{\nu}_\mu$, LHCb provided LU ratio R_{Λ_c}
- so high time to analyse the current status of NP operators taking all the semileptonic b-decays

Hamiltonian

- The full hamiltonian for underlying $b \to c\tau\bar{\nu}$

$$\mathcal{H}_{eff} = \frac{G_F V_{cb}}{\sqrt{2}} \Big\{ \Big[(1 + C_{V_1}) \bar{c}\gamma_\mu (1-\gamma_5) b + C_{V_2} \bar{c}\gamma_\mu (1+\gamma_5) b \Big] \bar{\tau}\gamma^\mu (1-\gamma_5)\nu_\tau$$
$$+ \Big[C_{S_1} \bar{c}(1+\gamma_5) b + C_{S_2} \bar{c}(1-\gamma_5) b \Big] \bar{\tau}(1-\gamma_5)\nu_\tau + \Big[C_T \bar{c}\sigma^{\mu\nu}(1-\gamma_5) b \Big] \bar{\tau}\sigma_{\mu\nu}(1-\gamma_5)\nu_\tau + h.c \Big\},$$

- So we have $C_{V_1}, C_{V_2}, C_{S_1}, C_{S_2}, C_T$ as new physics operators
- taken the ν as left-handed for all the operators



Angular distribution

- the decay is constructed as consecutive 2-body decays: $\Lambda_b \to \Lambda_c W^*$ then $W^* \to \tau\bar{\nu}$ and $\Lambda_c \to \Lambda\pi$
- the 4-fold decay distribution is given by the kinematic variables $\theta_\ell, \theta_\Lambda$ and azimuthal angle ϕ and di-lepton mass q^2
- 10 observables: 8 survives in SM

$$\frac{d\Gamma}{dq^2 d\cos\theta_\ell d\cos\theta_\Lambda d\phi} = \frac{3}{8\pi} K(q^2, \cos\theta_\ell, \cos\theta_\Lambda, \phi)$$

$$\begin{aligned} K(q^2, \cos\theta_\ell, \cos\theta_\Lambda, \phi) = & \left(K_{1ss}\sin^2\theta_\ell + K_{1cc}\cos^2\theta_\ell + K_{1c}\cos\theta_\ell\right) \\ & + \left(K_{2ss}\sin^2\theta_\ell + K_{2cc}\cos^2\theta_\ell + K_{2c}\cos\theta_\ell\right)\cos\theta_\Lambda \\ & + \left(K_{3sc}\sin\theta_\ell\cos\theta_\ell + K_{3s}\sin\theta_\ell\right)\sin\theta_\Lambda\cos\phi \\ & + \left(K_{4sc}\sin\theta_\ell\cos\theta_\ell + K_{4s}\sin\theta_\ell\right)\sin\theta_\Lambda\sin\phi\,. \end{aligned}$$

important angular observables

- decay rate $\frac{d\Gamma}{dq^2} = 2K_{1ss} + K_{1cc}$
- leptonic forward-backward(FB) asymmetry: $A_{\rm FB}^{\ell} = \frac{3}{2}\frac{K_{1c}}{2K_{1ss} + K_{1cc}}$
- FB asymmetry coming from the daughter Λ_c decay: $A_{\rm FB}^{\Lambda_c} = \frac{1}{2}\frac{2K_{2ss} + K_{2cc}}{2K_{1ss} + K_{1cc}}$
- FB asymmetry coming from the coefficient of $\cos\theta_\ell \cos\theta_\Lambda$: $A_{\rm FB}^{\Lambda_c\ell} = \frac{3}{4}\frac{K_{2c}}{2K_{1ss} + K_{1cc}}$
- the τ-polarization asymmetry: $P_\tau^{(\Lambda_c)}(q^2) = \frac{\mathrm{d}\Gamma^{\lambda_\tau=1/2}/\mathrm{d}q^2 - \mathrm{d}\Gamma^{\lambda_\tau=-1/2}/\mathrm{d}q^2}{\mathrm{d}\Gamma/\mathrm{d}q^2}$
- Λ_c spin polarization asymmetry: $P_{\Lambda_c}(q^2) = \frac{\mathrm{d}\Gamma^{\lambda_{\Lambda_c}=1/2}/\mathrm{d}q^2 - \mathrm{d}\Gamma^{\lambda_{\Lambda_c}=-1/2}/\mathrm{d}q^2}{\mathrm{d}\Gamma/\mathrm{d}q^2}.$
- convexity parameter $C_F^{\ell}(q^2) = \frac{1}{d\Gamma/dq^2}\left(\frac{d}{d(\cos\theta_l)}\right)^2\left(\frac{d^2\Gamma}{dq^2 d\cos\theta_l}\right).$
- other normalised ang. observables $\hat{K}_i = \frac{K_i}{2K_{1ss} + K_{1cc}}$ (independent of $|V_{cb}|$)

Experiment results

R(D) [1]	R(D*) [1]	correlation [1]
0.357(29)	0.284(12)	−0.37

[1]HFLAV Collab 2023

$$R(D)_{SM} = 0.304 \pm 0.003,$$
$$R(D^*)_{SM} = 0.258 \pm 0.012.$$

more than 2σ taking correlation

$$F_L^{D^*} = 0.43 \pm 0.06 \pm 0.03.$$

compatible with SM

LHCb[2311.05224]

$R(D^{(*)})$and $R(\Lambda_c)$ has opposite dirctions

$$\mathcal{B}(\Lambda_b \to \Lambda_c \tau^- \nu_\tau) = (1.50 \pm 0.16 \pm 0.25 \pm 0.23)\%.$$

LHCb[2201.03497]

$$R(\Lambda_c)_{SM} = 0.330 \pm 0.010,$$

using DELPHI[2004] results on μ mode LHCb predicts : $\mathcal{R}(\Lambda_c^+) = 0.242 \pm 0.026 \pm 0.040 \pm 0.059,$

Fit procedure

- To perform a model-independent analysis, we did the χ^2-fit to the data with different NP Wilson coefficients C_k (all taken real):
- $V_{i,j}^{exp(th)}$ is the corresponding measured (theoretical) covariance matrix.
- the theory correlations will be between $R(D^*)$ and $F_L^{D^*}$ and between $R(\Lambda_c)$ and $\mathscr{B}(\Lambda_b \to \Lambda_c \tau \nu)$.

$$\chi^2(C_k) = \sum_{i,j} \left[\mathcal{O}_i^{th}(C_k) - \mathcal{O}_i^{exp}\right] (V^{exp} + V^{th})_{i,j}^{-1} \left[\mathcal{O}_i^{th}(C_k) - \mathcal{O}_i^{exp}\right].$$

- when we say 1-parameter scenario it means we take C_{V_1}, C_{V_2} etc one at a time in addition to SM current , there are such 5 scenarios for 5 NP operators
- we have also taken 2 parameter scenario i.e. taking 2 parameter at a time.
- we defined $\sigma_{dev} = \left| \frac{\mathcal{O}_i^{exp} - \mathcal{O}_i^{NP}}{\sqrt{\sigma_i^2|_{exp} + \sigma_i^2|_{NP}}} \right|$

One parameter fit

Parameter	One Parameter fit scenario			σ_{dev} (in σ)		
	Fit values	$\chi^2_{min.}$/DOF	P-Value	$R(D)$	$R(D^*)$	$R(\Lambda_c)$
$Re[C_{S_1}]$	0.104(45)	4.463/4	0.215	0.151	1.355	1.372
$Re[C_{S_2}]$	0.101(47)	5.187/4	0.159	0.098	1.709	1.297
$Re[C_{V_1}]$	0.050(22)	4.001/4	0.261	0.683	0.048	1.524
$Re[C_{V_2}]$	-0.0045(339)	9.176/4	0.027	1.564	1.029	1.128
$Re[C_T]$	-0.022(18)	7.903/4	0.048	1.971	0.343	1.385

tension b/w observable from fit and experimental data

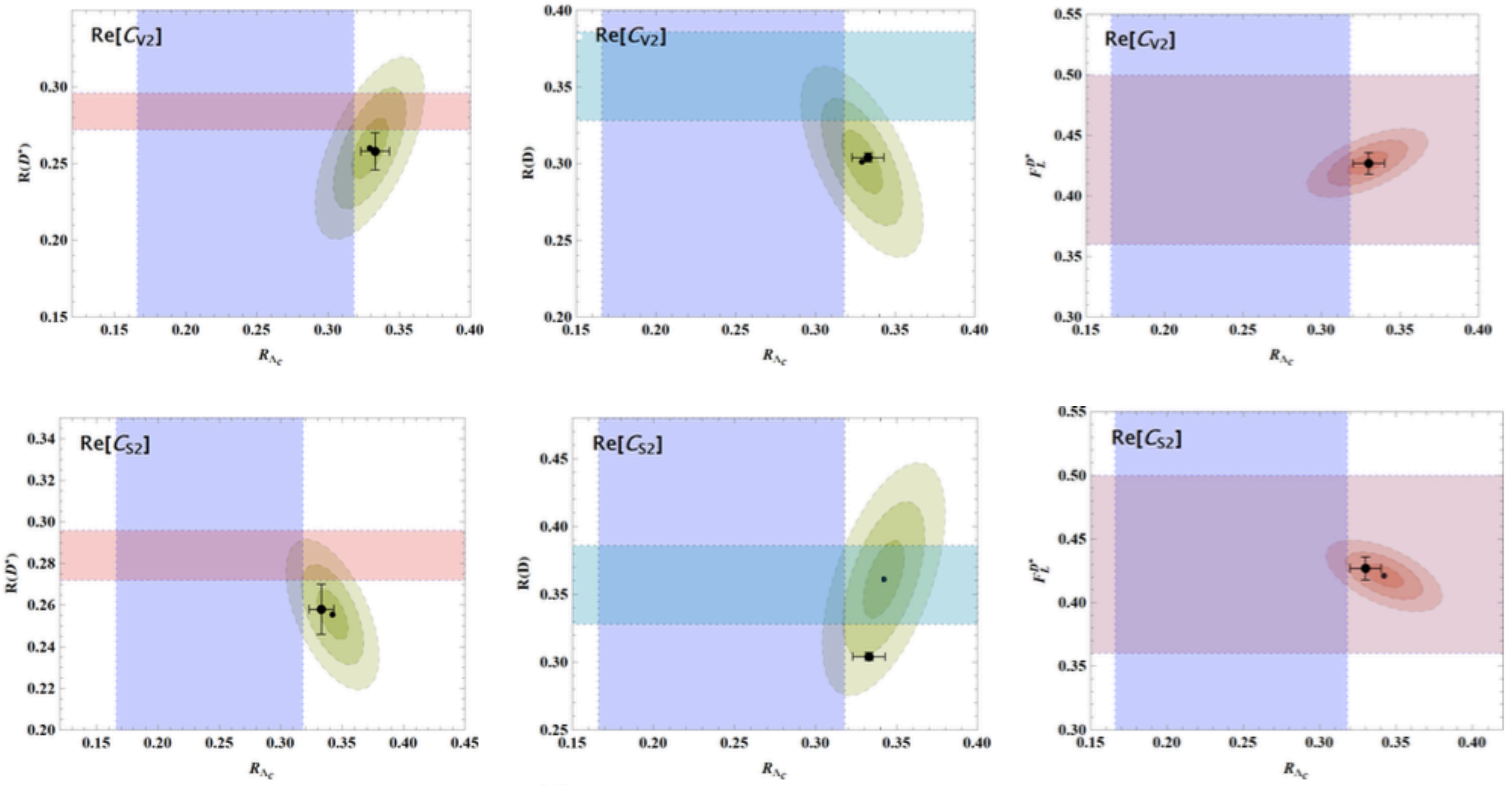
none of the one-operator scenarios could explain all three data within 1 σ

for C_{V_2}, none of the 3 data could be explained within 1 σ

Observables	Observables Prediction(One operator scenario)					Expt. Measurement
	$\mathbf{Re[C_{S_1}]}$	$\mathbf{Re[C_{S_2}]}$	$\mathbf{Re[C_{V_1}]}$	$\mathbf{Re[C_{V_2}]}$	$\mathbf{Re[C_T]}$	
$\mathbf{R(D)}$	0.363(27)	0.361(29)	0.335(14)	0.301(21)	0.299(5)	0.357(29) [1]
$\mathbf{R(D^*)}$	0.261(12)	0.255(12)	0.285(17)	0.260(20)	0.276(20)	0.284(12) [1]
$\mathbf{R(\Lambda_c)}$	0.348(14)	0.342(13)	0.361(18)	0.329(13)	0.352(23)	0.242(76)[52]
$\mathbf{F^\ell(D^*)}$	0.433(3)	0.421(3)	0.427(9)	0.427(3)	0.421(6)	0.430(70) [53]
$\mathbf{P^\tau(D^*)}$	-0.502(10)	-0.535(9)	-0.519(7)	-0.519(7)	-0.505(14)	-0.38(54) [34]
$\mathbf{P^\tau(D)}$	0.433(42)	0.431(45)	0.324(3)	0.324(3)	0.336(10)	N.A.

$F_l(D^*)$ and $P^\tau(D^*)$ can be explained comfortably in 1 σ

Correlation plot in 1 param. scenario



these 2 scenario can only explain all data within 3 σ

Two parameter scenario

$$
\begin{aligned}
K_{1cc} =N\bigg[&2\Big(\big|H^{\mathrm{SP}}_{-\frac{1}{2},0}\big|^2+\big|H^{\mathrm{SP}}_{\frac{1}{2},0}\big|^2+\big|H^{\mathrm{VA}}_{-\frac{1}{2},-1}\big|^2+\big|H^{\mathrm{VA}}_{\frac{1}{2},+1}\big|^2\Big)\\
&+8\Big(\big|H^{T,-\frac{1}{2}}_{-\frac{1}{2},+1,-1}\big|^2+\big|H^{T,\frac{1}{2}}_{\frac{1}{2},+1,-1}\big|^2+\big|H^{T,-\frac{1}{2}}_{-\frac{1}{2},t,0}\big|^2+\big|H^{T,\frac{1}{2}}_{\frac{1}{2},t,0}\big|^2\Big)\\
&-16\mathrm{Re}\Big[H^{T,-\frac{1}{2}*}_{-\frac{1}{2},+1,-1}H^{T,-\frac{1}{2}}_{-\frac{1}{2},t,0}+H^{T,\frac{1}{2}*}_{\frac{1}{2},+1,-1}H^{T,\frac{1}{2}}_{\frac{1}{2},t,0}\Big]\\
&+\frac{m_\ell}{\sqrt{q^2}}\bigg\{\mathrm{Re}\bigg[4\Big(H^{\mathrm{SP}*}_{-\frac{1}{2},0}H^{\mathrm{VA}}_{-\frac{1}{2},t}+H^{\mathrm{SP}*}_{\frac{1}{2},0}H^{\mathrm{VA}}_{\frac{1}{2},t}\Big)\\
&+8\Big(H^{\mathrm{VA}*}_{-\frac{1}{2},0}H^{T,-\frac{1}{2}}_{-\frac{1}{2},t,0}-H^{\mathrm{VA}*}_{-\frac{1}{2},0}H^{T,-\frac{1}{2}}_{-\frac{1}{2},+1,-1}-H^{\mathrm{VA}*}_{\frac{1}{2},0}H^{T,\frac{1}{2}}_{\frac{1}{2},+1,-1}+H^{\mathrm{VA}*}_{\frac{1}{2},0}H^{T,\frac{1}{2}}_{\frac{1}{2},t,0}\\
&+H^{T,\frac{1}{2}}_{-\frac{1}{2},-1,0}H^{\mathrm{VA}*}_{-\frac{1}{2},-1}-H^{T,-\frac{1}{2}}_{\frac{1}{2},+1,0}H^{\mathrm{VA}*}_{\frac{1}{2},+1}+H^{\mathrm{VA}*}_{-\frac{1}{2},-1}H^{T,\frac{1}{2}}_{-\frac{1}{2},t,-1}+H^{\mathrm{VA}*}_{\frac{1}{2},+1}H^{T,-\frac{1}{2}}_{\frac{1}{2},t,1}\Big)\bigg]\bigg\}\\
&+\frac{m_\ell^2}{q^2}\bigg\{2\Big(\big|H^{\mathrm{VA}}_{-\frac{1}{2},0}\big|^2+\big|H^{\mathrm{VA}}_{\frac{1}{2},0}\big|^2+\big|H^{\mathrm{VA}}_{-\frac{1}{2},t}\big|^2+\big|H^{\mathrm{VA}}_{\frac{1}{2},t}\big|^2\Big)\\
&+8\Big(\big|H^{T,\frac{1}{2}}_{-\frac{1}{2},-1,0}\big|^2+\big|H^{T,-\frac{1}{2}}_{\frac{1}{2},+1,0}\big|^2+\big|H^{T,\frac{1}{2}}_{-\frac{1}{2},t,-1}\big|^2+\big|H^{T,-\frac{1}{2}}_{\frac{1}{2},t,+1}\big|^2\Big)\\
&+16Re\Big[H^{T,\frac{1}{2}*}_{-\frac{1}{2},-1,0}H^{T,\frac{1}{2}}_{-\frac{1}{2},t,-1}-H^{T,-\frac{1}{2}*}_{\frac{1}{2},+1,0}H^{T,-\frac{1}{2}}_{\frac{1}{2},t,1}\Big]\bigg\}\bigg]
\end{aligned}
$$

$$
\begin{aligned}
K_{1ss} =N\bigg[&\big|H^{\mathrm{VA}}_{-\frac{1}{2},-1}\big|^2+\big|H^{\mathrm{VA}}_{\frac{1}{2},+1}\big|^2+2\Big(\big|H^{\mathrm{SP}}_{\frac{1}{2},0}\big|^2+\big|H^{\mathrm{SP}}_{-\frac{1}{2},0}\big|^2+\big|H^{\mathrm{VA}}_{-\frac{1}{2},0}\big|^2+\big|H^{\mathrm{VA}}_{\frac{1}{2},0}\big|^2\Big)\\
&+4\Big(\big|H^{T,-\frac{1}{2}}_{\frac{1}{2},+1,0}\big|^2+\big|H^{T,\frac{1}{2}}_{-\frac{1}{2},-1,0}\big|^2+\big|H^{T,\frac{1}{2}}_{-\frac{1}{2},t,-1}\big|^2+\big|H^{T,-\frac{1}{2}}_{\frac{1}{2},t,+1}\big|^2\Big)+8\mathrm{Re}\Big[H^{T,\frac{1}{2}*}_{-\frac{1}{2},-1,0}H^{T,\frac{1}{2}}_{-\frac{1}{2},t,-1}-H^{T,-\frac{1}{2}*}_{\frac{1}{2},+1,0}H^{T,-\frac{1}{2}}_{\frac{1}{2},t,1}\Big]\\
&+\frac{m_\ell}{\sqrt{q^2}}\bigg\{4\mathrm{Re}\Big[H^{\mathrm{SP}*}_{-\frac{1}{2},0}H^{\mathrm{VA}}_{-\frac{1}{2},t}+H^{\mathrm{SP}*}_{\frac{1}{2},0}H^{\mathrm{VA}}_{\frac{1}{2},t}\Big]\\
&+8\mathrm{Re}\Big[H^{\mathrm{VA}*}_{-\frac{1}{2},0}H^{T,-\frac{1}{2}}_{-\frac{1}{2},t,0}-H^{\mathrm{VA}*}_{-\frac{1}{2},0}H^{T,-\frac{1}{2}}_{-\frac{1}{2},+1,-1}-H^{\mathrm{VA}*}_{\frac{1}{2},0}H^{T,\frac{1}{2}}_{\frac{1}{2},+1,-1}\\
&+H^{\mathrm{VA}*}_{\frac{1}{2},0}H^{T,\frac{1}{2}}_{\frac{1}{2},t,0}+H^{T,\frac{1}{2}}_{-\frac{1}{2},-1,0}H^{\mathrm{VA}*}_{-\frac{1}{2},-1}-H^{T,-\frac{1}{2}}_{\frac{1}{2},+1,0}H^{\mathrm{VA}*}_{\frac{1}{2},+1}\\
&+H^{\mathrm{VA}*}_{-\frac{1}{2},-1}H^{T,\frac{1}{2}}_{-\frac{1}{2},t,-1}+H^{\mathrm{VA}*}_{\frac{1}{2},+1}H^{T,-\frac{1}{2}}_{\frac{1}{2},t,1}\Big]\bigg\}\\
&+\frac{m_\ell^2}{q^2}\bigg\{\big|H^{\mathrm{VA}}_{-\frac{1}{2},-1}\big|^2+\big|H^{\mathrm{VA}}_{\frac{1}{2},+1}\big|^2+2\Big(\big|H^{\mathrm{VA}}_{-\frac{1}{2},t}\big|^2+\big|H^{\mathrm{VA}}_{\frac{1}{2},t}\big|^2\Big)
\end{aligned}
$$

mass effects for τ ?

- as $\frac{d\Gamma}{dq^2} = 2K_{1ss} + K_{1cc}$
- in the decay rate terms the interference terms between the NP are coming proportional to m_ℓ
- so when we take only one C_i these terms are neglected
- for $m_\ell = m_\tau$ these terms contribute much significantly

Two parameter scenario fit results

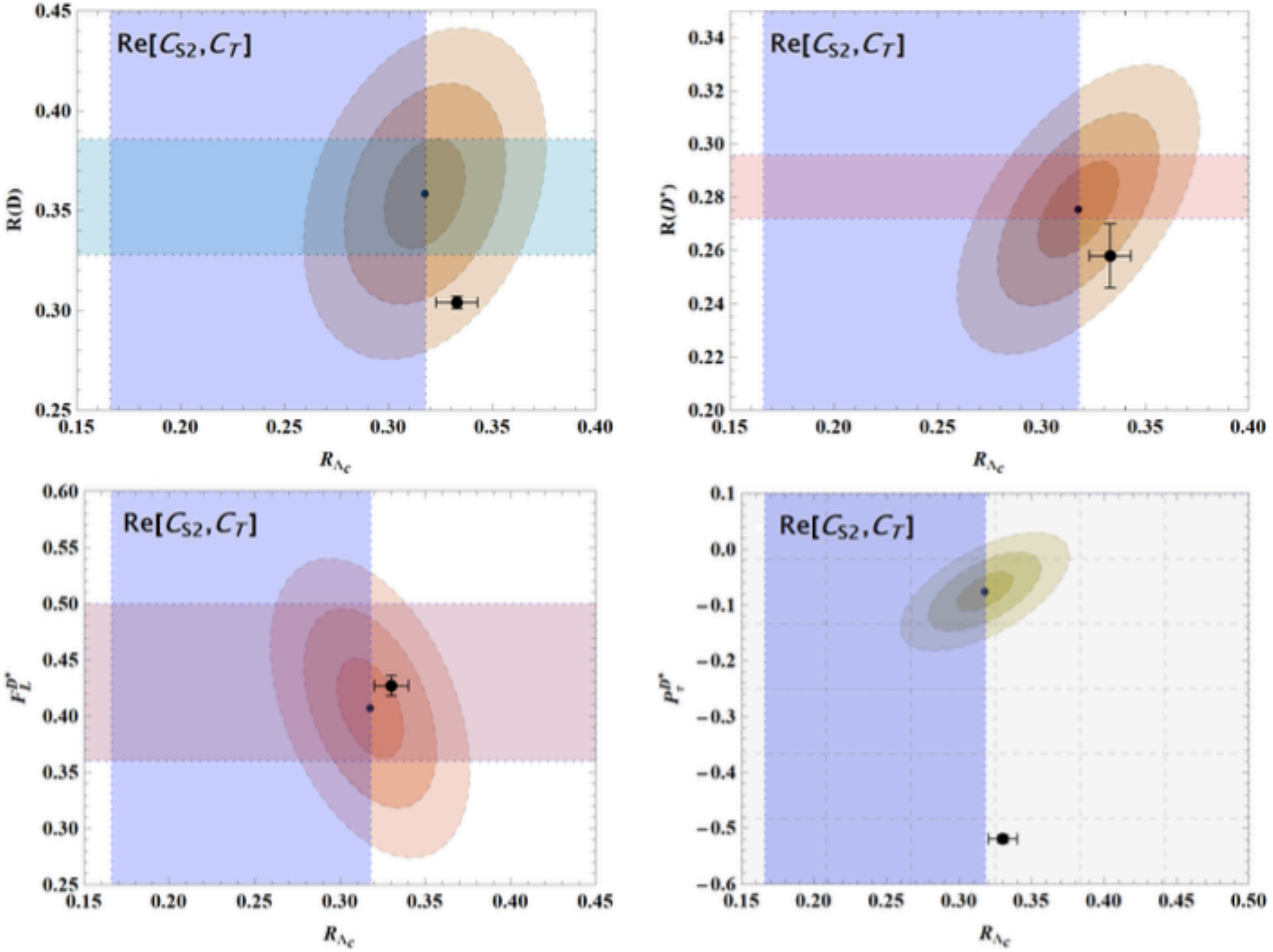
- all the 2 operator scenarios we can explain $B \to D^{(*)}\tau^-\bar{\nu}$ observables
- the scenario with $[\mathcal{O}_{S_2}, \mathcal{O}_T]$ is the only 2-op. scenario which could accommodate the data on $R(\Lambda_c)$ alongside $R(D)$, $R(D^*)$, $F_L^{D^*}$ within their 1 σ .
- also the best-fit scenario with largest p-value(67 %) among all others.

2 Operator Scenario	Two operator scenarios fit results: WC fit results		χ^2_{min}/DOF	P-Value	σ_{dev} (in σ): R(D)	R(D*)	R(Λ_c)	$F_L^{D^*}$
C_{S_1}, C_{S_2}	Re[C_{S_1}]	-2.268(207)	3.432/3	0.330	0.067	0.409	1.437	0.237
	Re[C_{S_2}]	0.904(220)						
C_{S_1}, C_T	Re[C_{S_1}]	0.098(46)	3.978/3	0.264	0.038	0.526	1.494	0.010
	Re[C_T]	-0.014(19)						
C_{S_2}, C_T	Re[C_{S_2}]	**-1.255(64)**	**1.553/3**	**0.670**	**0.039**	**0.391**	**0.963**	**0.278**
	Re[C_T]	**0.226(32)**						
C_{V_1}, C_{V_2}	Re[C_{V_1}]	-0.978(32)	3.557/3	0.313	0.113	0.303	1.503	0.013
	Re[C_{V_2}]	1.055(23)						
C_{V_1}, C_T	Re[C_{V_1}]	0.077(31)	2.827/3	0.419	0.148	0.466	1.296	0.006
	Re[C_T]	0.037(37)						
C_{V_2}, C_T	Re[C_{V_2}]	0.080(53)	5.829/3	0.120	0.435	0.560	1.634	0.389
	Re[C_T]	-0.059(28)						
C_{S_1}, C_{V_1}	Re[C_{S_1}]	0.051(73)	3.534/3	0.316	0.102	0.311	1.498	0.0004
	Re[C_{V_1}]	0.033(34)						
C_{S_1}, C_{V_2}	Re[C_{S_1}]	0.123(48)	3.511/3	0.319	0.106	0.301	1.494	0.098
	Re[C_{V_2}]	-0.033(33)						
C_{S_2}, C_{V_1}	Re[C_{S_2}]	0.045(65)	3.533/3	0.316	0.101	0.311	1.496	0.079
	Re[C_{V_1}]	0.038(29)						
C_{S_2}, C_{V_2}	Re[C_{S_2}]	0.139(54)	3.474/3	0.324	0.104	0.292	1.489	0.098
	Re[C_{V_2}]	-0.048(36)						

Prediction of Observables

Scenarios	Observables/Predictions					
	$\mathbf{R(D)}$	$\mathbf{R(D^*)}$	$\mathbf{R(\Lambda_c)}$	$\mathbf{F_L^{D^*}}$	$\mathbf{P_\tau^{D^*}}$	$\mathbf{P_\tau^{D}}$
$\mathbf{Re[C_{S_1}],Re[C_{S_2}]}$	0.354(29)	0.275(19)	0.354(19)	0.448(30)	-0.463(77)	0.421(47)
$\mathbf{Re[C_{S_1}],Re[C_T]}$	0.355(29)	0.272(20)	0.361(24)	0.429(11)	-0.496(14)	0.435(43)
$\mathbf{Re[C_{S_2}],Re[C_T]}$	0.359(28)	0.275(18)	0.318(19)	0.407(44)	-0.076(38)	0.196(81)
$\mathbf{Re[C_{V_1}],Re[C_T]}$	0.363(29)	0.273(20)	0.345(24)	0.4304(90)	-0.5319(95)	0.306(18)
$\mathbf{Re[C_{V_2}], Re[C_T]}$	0.339(29)	0.271(20)	0.374(27)	0.402(17)	-0.474(28)	0.354(14)
$\mathbf{Re[C_{V_1}],Re[C_{V_2}]}$	0.352(29)	0.277(20)	0.360(18)	0.4291(94)	-0.5197(66)	0.3238(27)
$\mathbf{Re[C_{S_1}],Re[C_{V_1}]}$	0.353(29)	0.277(20)	0.359(19)	0.430(10)	-0.511(13)	0.378(76)
$\mathbf{Re[C_{S_1}],Re[C_{V_2}]}$	0.353(29)	0.277(20)	0.359(18)	0.4370(100)	-0.499(11)	0.455(47)
$\mathbf{Re[C_{S_2}],Re[C_{V_1}]}$	0.353(29)	0.277(20)	0.359(19)	0.4244(97)	-0.526(12)	0.373(68)
$\mathbf{Re[C_{S_2}],Re[C_{V_2}]}$	0.353(29)	0.277(20)	0.358(18)	0.4231(94)	-0.5387(92)	0.472(52)
Measurement	**0.357(29)**	**0.284(13)**	**0.242(76)**	**0.430(70)**	**-0.38(54)**	N.A

Correlation b/w observables



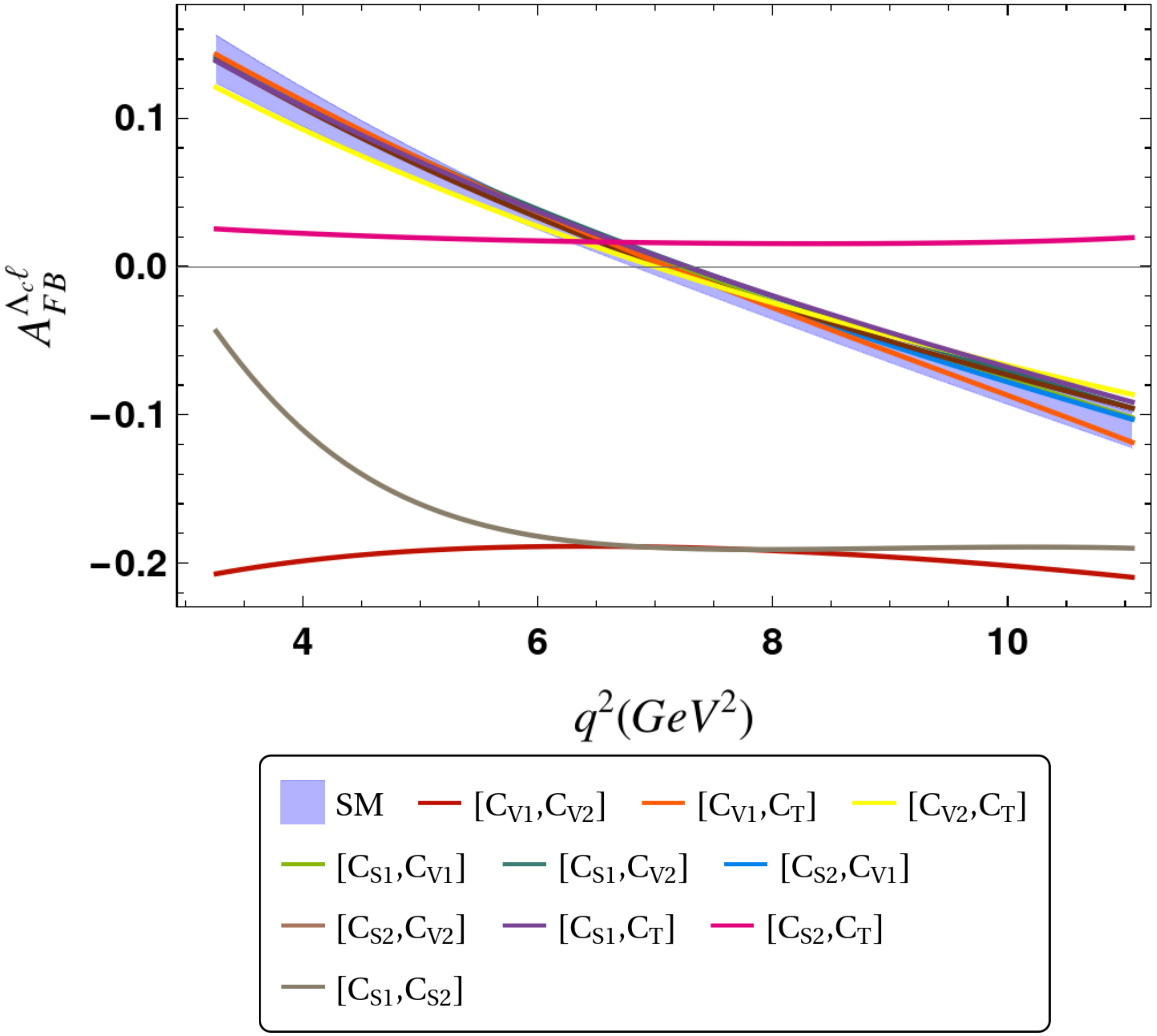
- the correlation plots indicates that we can comfortably explain $R(D)$, $R(D^*)$, R_{Λ_c} and $F_L^{D^*}$ along with $P^\tau(D^*)$

deviation for observables of $\Lambda_b \to \Lambda_c$

Scenario	Deviations w.r.t. SM predictions (in σ level)											
	$\hat{K}_{1cc}$	$\hat{K}_{1ss}$	$\hat{K}_{2cc}$	$\hat{K}_{2ss}$	$\hat{K}_{3sc}$	$\hat{K}_{3s}$	A_{FB}^{ℓ}	$A_{FB}^{\Lambda_c \tau}$	$A_{FB}^{\Lambda_c}$	P_{Λ_c}	$P_{\tau}^{(\Lambda_c)}$	C_F^{ℓ}
$[C_{S_1}, C_{S_2}]$	0.354	0.819	0.193	0.082	0.277	**4.22**	**20.051**	**9.856**	0.161	0.16	0.806	0.60
$[C_{S_1}, C_T]$	0.894	0.819	0.24	0.288	0.354	0.664	0.983	0.647	0.364	0.714	1.574	0.868
$[C_{S_2}, C_T]$	**3.328**	**4.915**	**6.209**	**5.794**	**2.683**	**2.507**	**6.116**	0.2	**7.343**	**7.532**	**8.831**	**4.389**
$[C_{V_1}, C_{V_2}]$	0.	0.	**13.133**	**13.136**	**12.021**	**4.468**	**19.279**	**9.753**	**18.11**	**70.863**	0.472	0.236
$[C_{V_1}, C_T]$	0.555	0.819	0.44	0.453	0.277	0.547	0.123	0.651	0.602	1.317	0.451	0.745
$[C_{V_2}, C_T]$	0.447	0.819	0.901	0.899	0.832	0.868	1.057	0.108	1.185	1.805	1.143	0.589
$[C_{S_1}, C_{V_1}]$	0.354	0.	0.	0.	0.	0.39	0.43	0.462	0.	0.	0.636	0.217
$[C_{S_1}, C_{V_2}]$	0.894	0.819	0.096	0.136	0.354	0.208	0.921	0.7	0.188	0.786	1.611	0.868
$[C_{S_2}, C_{V_1}]$	0.	0.	0.064	0.054	0.	0.469	0.193	0.325	0.081	0.324	0.572	0.118
$[C_{S_2}, C_{V_2}]$	0.894	0.819	0.354	0.36	0.354	0.139	0.064	0.217	0.497	1.658	1.089	0.759

- apart from $A_{FB}^{\Lambda_c \ell}$ all the observable show significant deviation for $[\mathcal{O}_{S_2}, \mathcal{O}_T]$ scenario
- in $[\mathcal{O}_{V_1}, \mathcal{O}_{V_2}]$ scenario significant deviation can be seen

$A_{FB}^{\Lambda_c \ell}$ prediction in full q^2

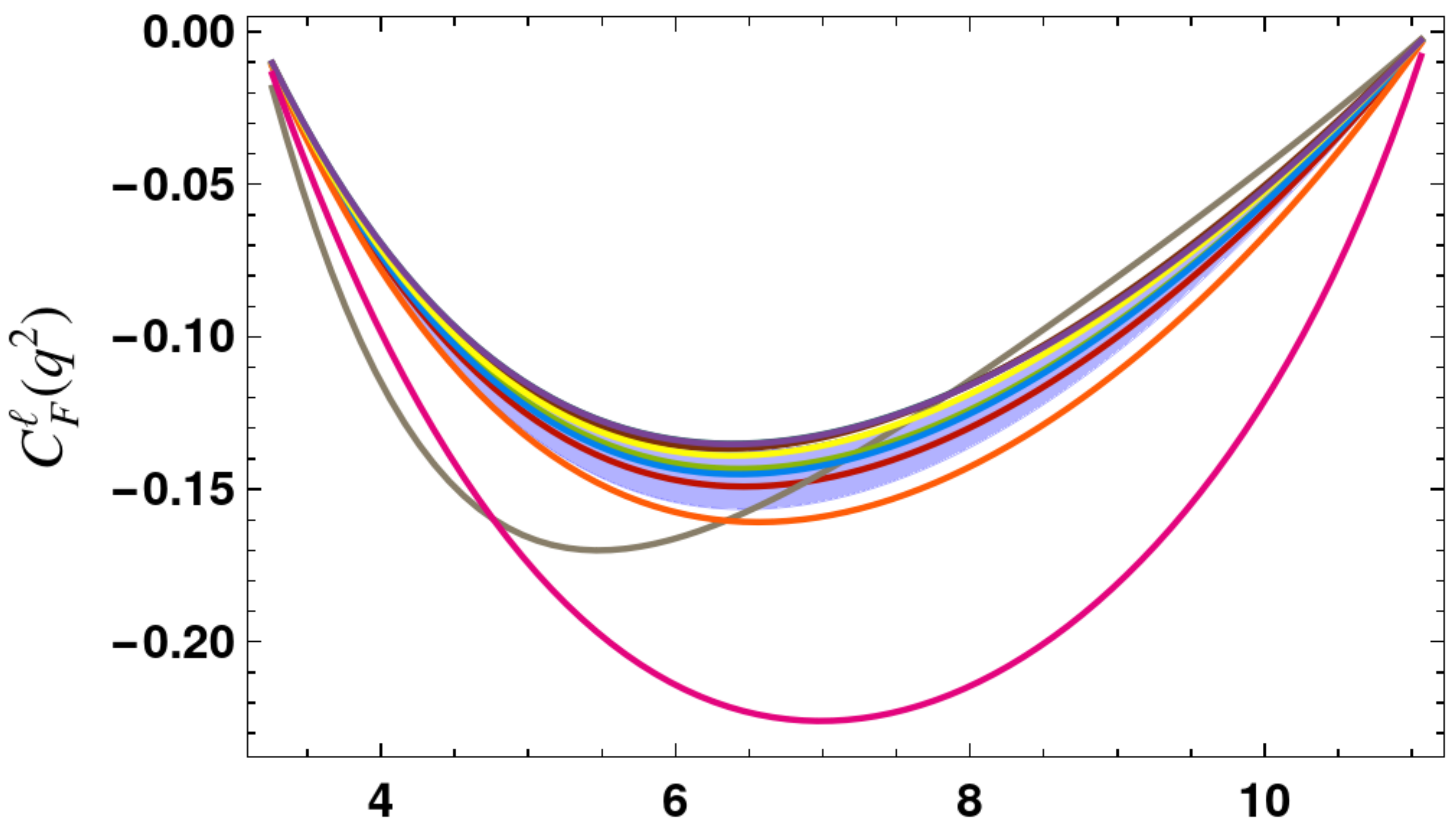


- very important observable but not discussed in literature
- in SM, zero crossing is there
- for $[\mathcal{O}_{S_2}, \mathcal{O}_T]$ the q^2 integrated $A_{FB}^{\Lambda_c \tau}$ are consistent with the SM.
- due to a relative cancellation in high and low q^2 region , the q^2integrated value becomes very small and consistent with the respective NP prediction.
- in both the high and low q^2 regions, NP predictions have discrepancies with SM.
- so only q^2 integrated value is not sufficient: bin predictions are needed

Angular obs for $\Lambda_b \to \Lambda_c \tau \bar{\nu}$

- In the scenario$[\mathcal{O}_{V_1}, \mathcal{O}_{V_2}]$, the predictions for $A_{FB}^{\Lambda_c}$, P_{Λ_c},$\hat{K}_{2ss}$, $\hat{K}_{2cc}$and $\hat{K}_{3sc}$have opposite sign of the respective SM predictions different
- for $[\mathcal{O}_{S_2}, \mathcal{O}_T]$ they show deviation

Observable predictions



- If the measurements show deviations only in C_F^τ, $\hat{K}_{1cc}$ and $\hat{K}_{1ss}$ this could be an indication for contributions from $[\mathcal{O}_{S_2}, \mathcal{O}_T]$.

Summary

- We discussed the full 4-body angular distribution for the decay
- various asymmetric and angular observables from the angular analysis $\Lambda_b \to \Lambda_c^+(\to \Lambda^+\pi)\tau^-\bar{\nu}$ decay
- Using the available data on $B \to D^{(*)}\ell^-\bar{\nu}$ decays and $R(\Lambda_c)$, we have extracted the new Wilson coefficients and noticed that only the C_{S_2}, C_{V_2} one operator scenario can explain all these data simultaneously within 3σ
- We have done the fits to data using two different operator scenarios and found that scenario $[\mathcal{O}_{S_2}, \mathcal{O}_T]$ is the only two operator scenarios which could accommodate comfortably all the measured data simultaneously
- In the other two operator scenarios, apart from $R(D^*)$, we are able to explain all the other data simultaneously if we take the uncertainties of our predictions at the 3σ level.
- We have studied the interesting correlations between the observables in different NP scenarios.
- we have also discussed the NP sensitivities of all the angular and asymmetric observables in all the two operator scenarios and found that many of them show distinguishable sensitivity to the operators $[\mathcal{O}_{S_2}, \mathcal{O}_T]$, $[\mathcal{O}_{V_1}, \mathcal{O}_{V_2}]$.

Thank You!