Emerging patterns of New Physics with and without Lepton Flavour Universal contributions

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Based on: [arXiv: 1903.09578] + [arXiv: 1809.08447]

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$bs\ell\ell$, September 2019, Lyon

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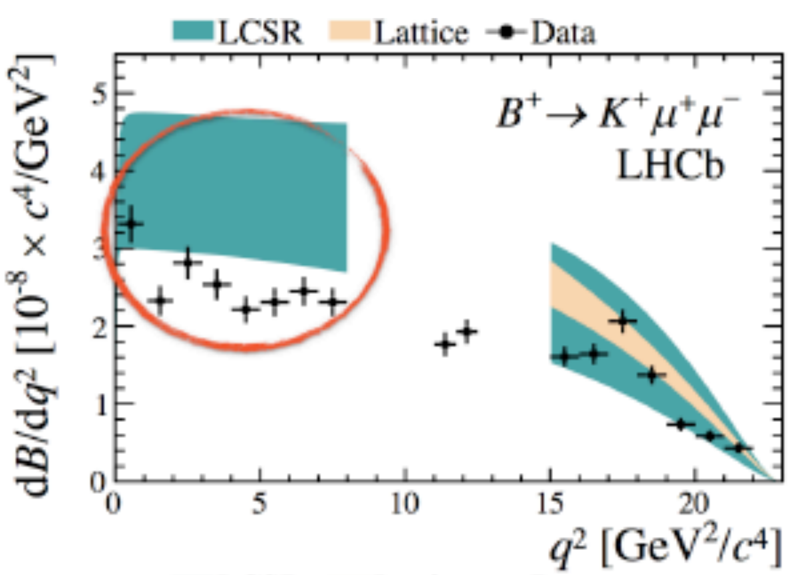
Outline

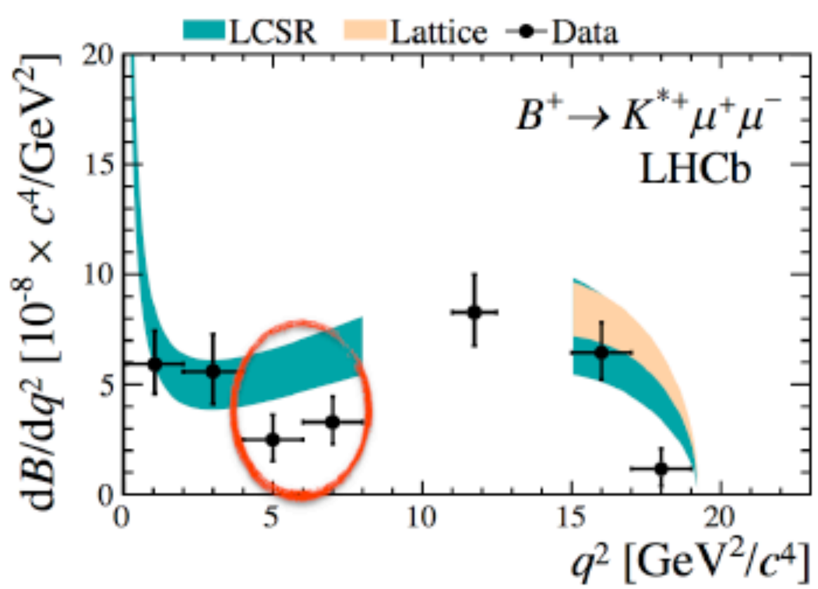
- Motivation
  - Pattern of New Physics from $b \to s\ell\ell$ anomalies
- Anatomy of Fits
- State-of-the-art (2017 vs 2019)
- What's new?
- Discussion on models
- Conclusions and Outlook

Motivation

Pattern of $b \to s\ell\ell$ anomalies

Coherent pattern of deviations → deficit in muons in different channels
@ large and low recoil:

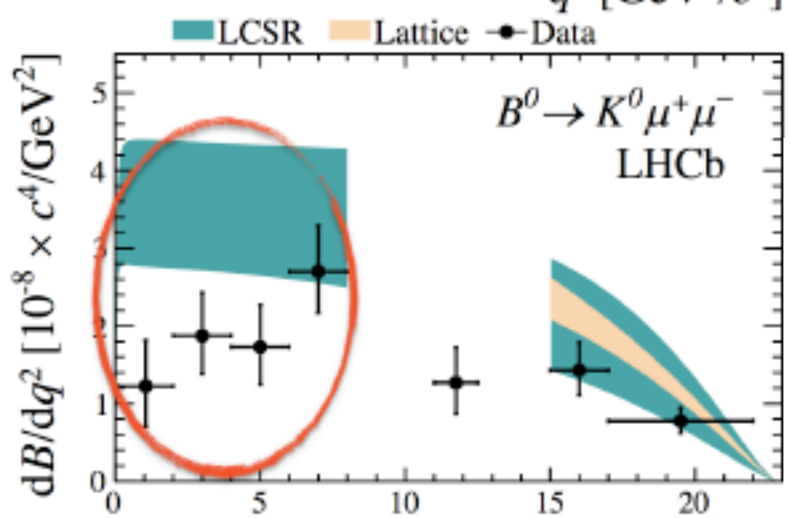




1st bin SM-like ($\mathcal{C}_7$ dominates & radiative corrections are constrained)

↓

Issue: Excess in the electron channel in 1st bin explains deficit in R_{K^*}



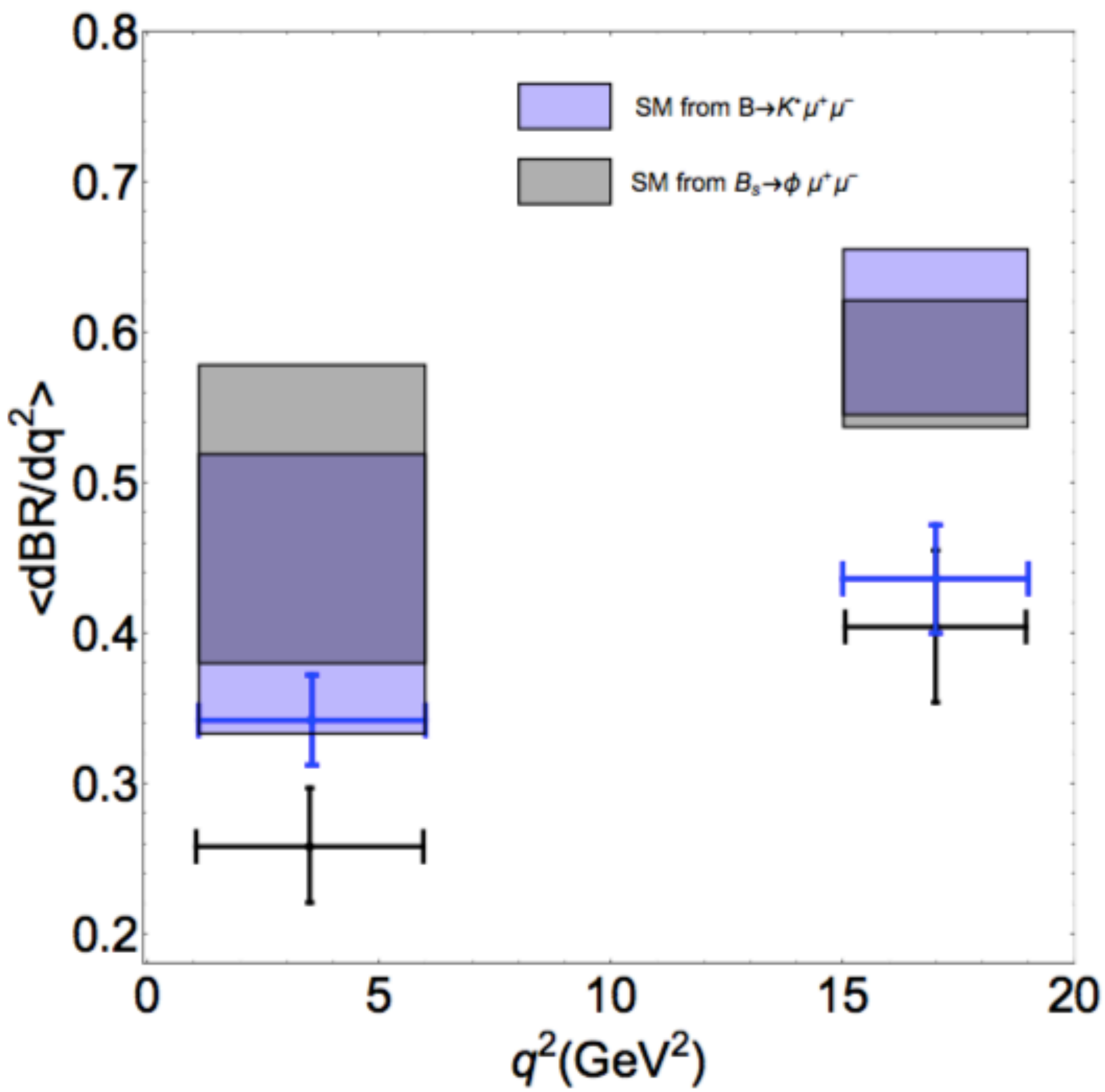
JHEP 06 (2014) 133

$b \to s\mu^+\mu^-$ $(\times 10^7)$	bin	SM	EXP	Pull
$\mathrm{BR}(B^0 \to K^0\mu^+\mu^-)$	[15,19]	0.91 ± 0.12	0.67 ± 0.12	+1.4
$\mathrm{BR}(B^0 \to K^{*0}\mu^+\mu^-)$	[16,19]	1.66 ± 0.15	1.23 ± 0.20	+1.7
$\mathrm{BR}(B^+ \to K^{*+}\mu^+\mu^-)$	[15,19]	2.59 ± 0.25	1.60 ± 0.32	**+2.5**
$\mathrm{BR}(B_s \to \phi\mu^+\mu^-)$	[15,18.8]	2.20 ± 0.17	1.62 ± 0.20	**+2.2**

Pattern of $b \to s\ell\ell$ anomalies

[Algueró et al JHEP07 (2019) 096]

Tension observed in $\mathcal{B}(B_s \to \phi\mu\mu)$ between Large and Low Recoil



Low- q^2: Pred. from sum rules using full FF with BSZ

High- q^2 : Pred. from lattice

- No computations using B meson DA of KMPW available for $B_s \to \phi\mu\mu$
- At Low Recoil, $\mathcal{B}(B \to K^*\mu\mu)$ slightly larger than $\mathcal{B}(B_s \to \phi\mu\mu)$ (data follows same trend)
- **BUT:** At Large Recoil, $\mathcal{B}(B_s \to \phi\mu\mu)$ larger than $\mathcal{B}(B \to K^*\mu\mu)$ (data is reversed)

More data needed! to clarify if problem in Th. Prediction or statistical fluctuation

Pattern of $b \to s\ell\ell$ anomalies

$$\frac{d^4\Gamma(\bar{B}_d \to K^*(\to K\pi)\mu^+\mu^-)}{dq^2 d\cos\theta_\ell d\cos\theta_K d\phi} = \frac{9}{32\pi}\sum_i J_i(q^2) f_i(\theta_\ell, \theta_K, \phi)$$ → Optimized angular observables

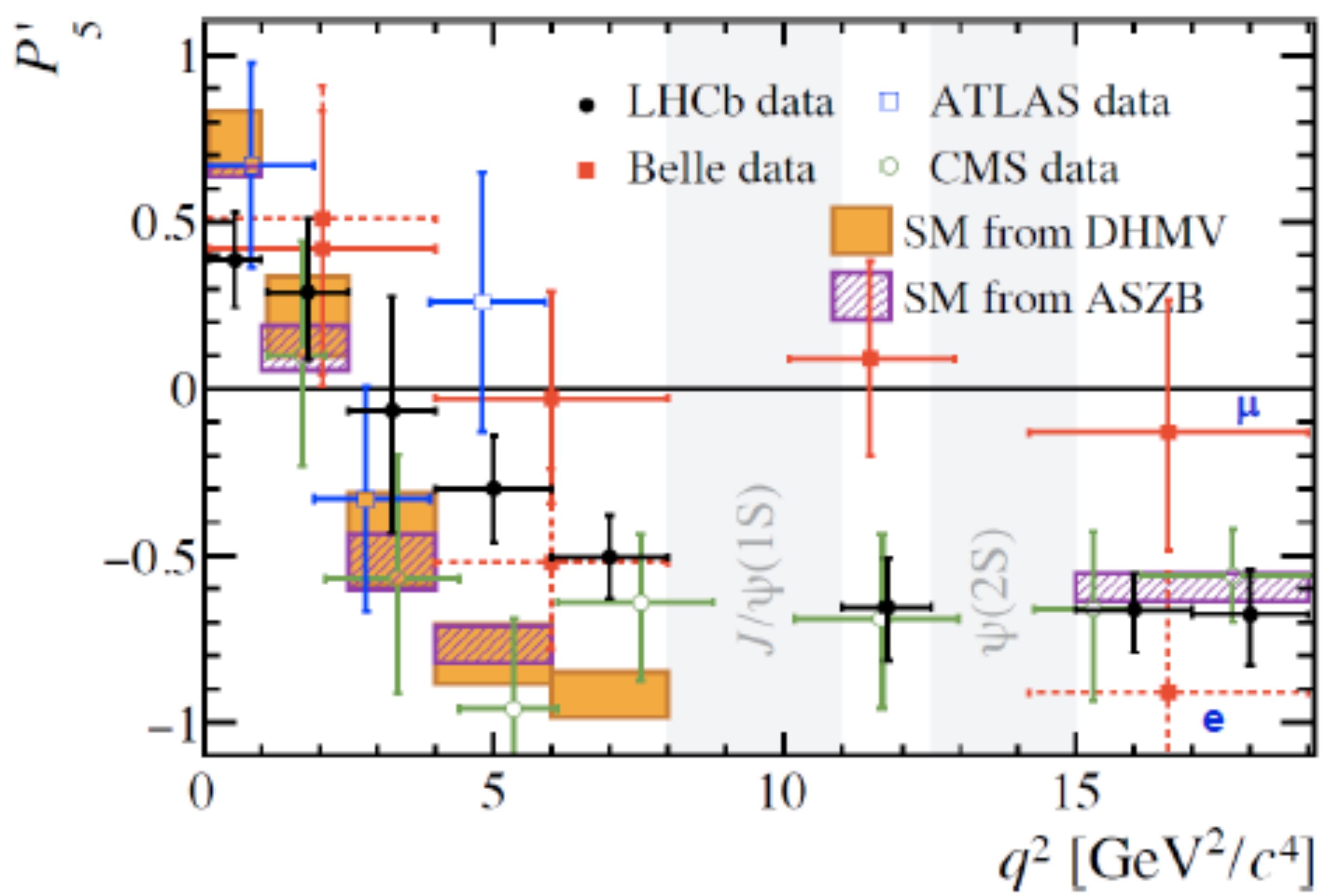
[DMRV,JHEP1301(2013)048]

$$P_5' = \frac{J_5}{2\sqrt{-J_{2s}J_{2c}}} = P_5^\infty(1 + \mathcal{O}(\alpha_s\xi_\perp) + p.c.)$$

Optimized = Cancellation of SFF $\xi_{\|,\perp}$ @ LO

↓

Sensitivity to hadronic uncertainties suppressed



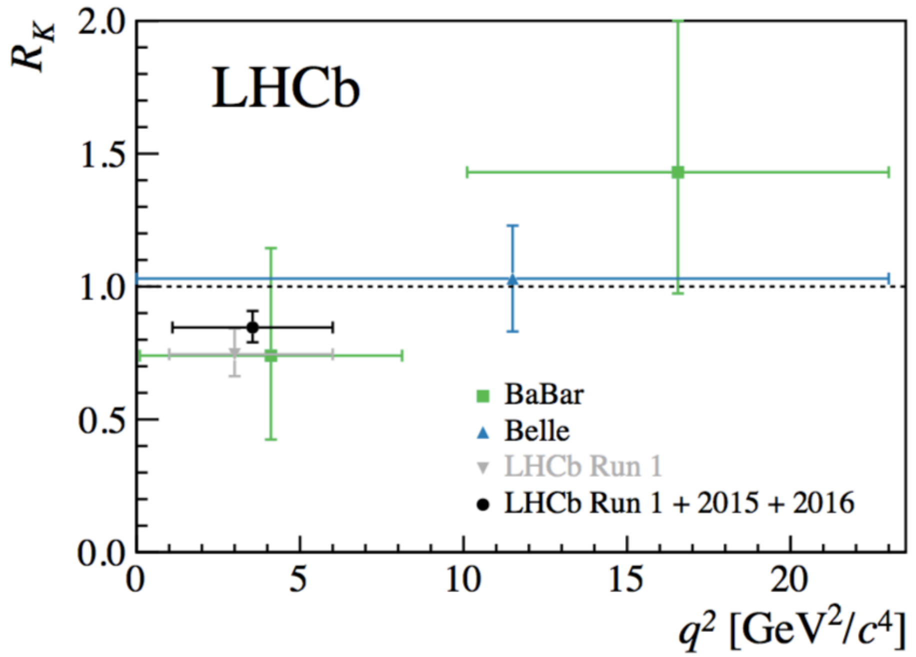
$(q^2 = s_{\mu\mu})$

- **LHCb** & **Belle** consistent
- ATLAS also shows deviation
- CMS compatible with SM but different procedure → Suggestion: extract correlations of F_L, P_1, P_5' from same PDF. Use analytical integration of 3D PDFs

Pattern of $b \to s\ell\ell$ anomalies

Anomalies also in **Lepton Flavour Universality Violating (LFUV)** observables

[LHCb: 1406.6482]

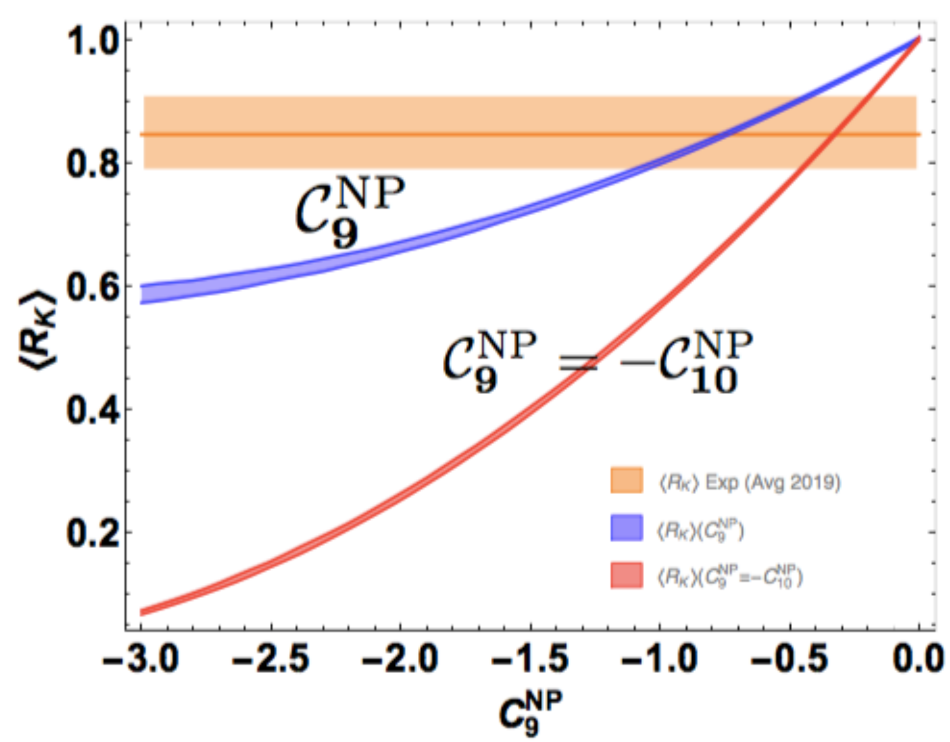


$$R_{K_{\rm LHCb}}^{[1,6]} = 0.846^{+0.060+0.016}_{-0.054-0.014}$$

Still at 2.5σ from SM

- $R_K = 1$ in the SM
- NP couples $\neq \mu$ and e

Coherent deviation (deficit in muons)



Clean observable within NP

Pattern of $b \to s\ell\ell$ anomalies

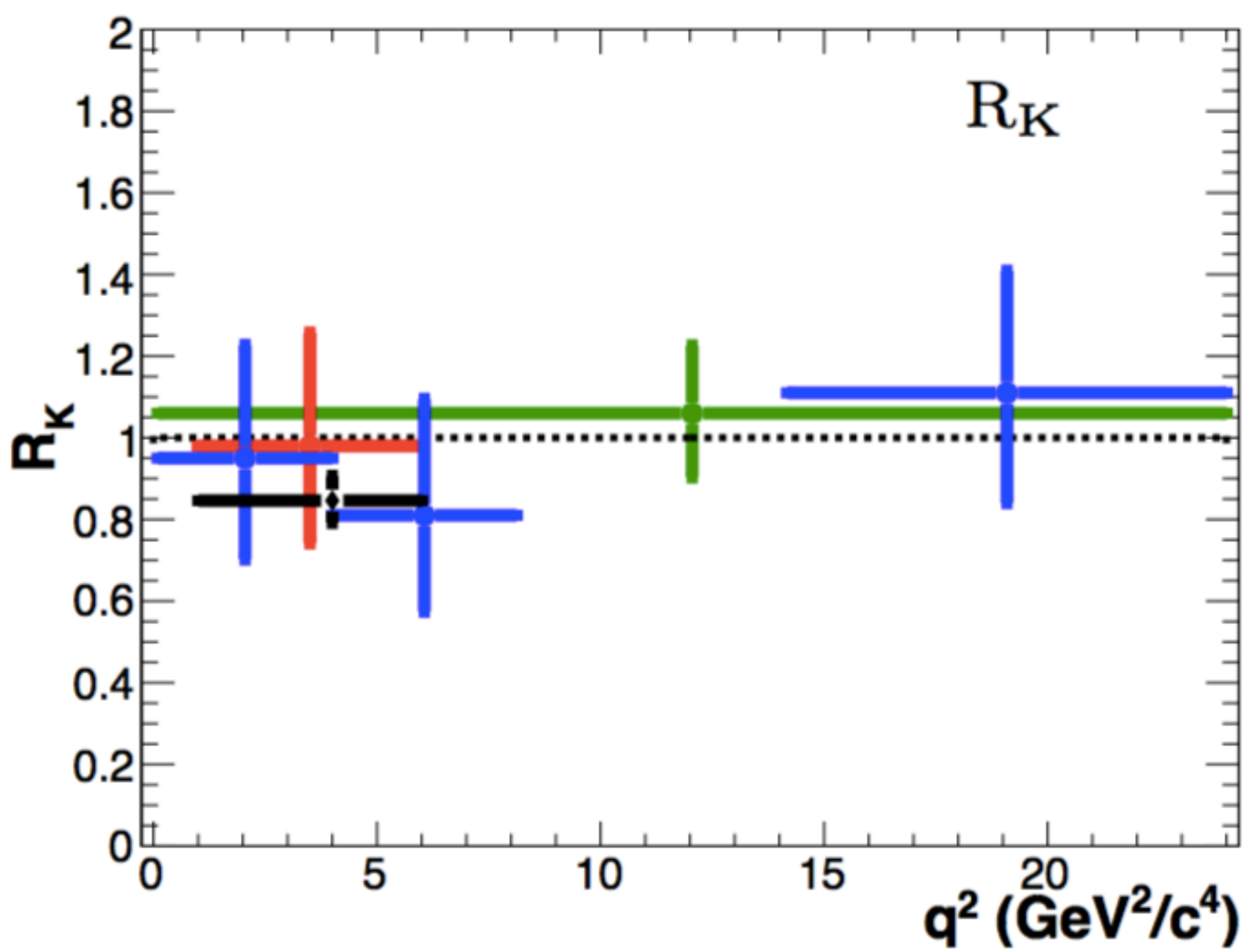
Belle released new measurement of R_K in the low and high kinematic range

[Belle: EPS-HEP Conference 2019]

$$R_{K_{\rm Belle}}^{[1,6]} = 0.98^{+0.27}_{-0.23} \pm 0.06$$

$$R_{K_{\rm Belle}}^{[q^2>14.18]} = 1.11^{+0.29}_{-0.26} \pm 0.07$$

Data from neutral and charged currents



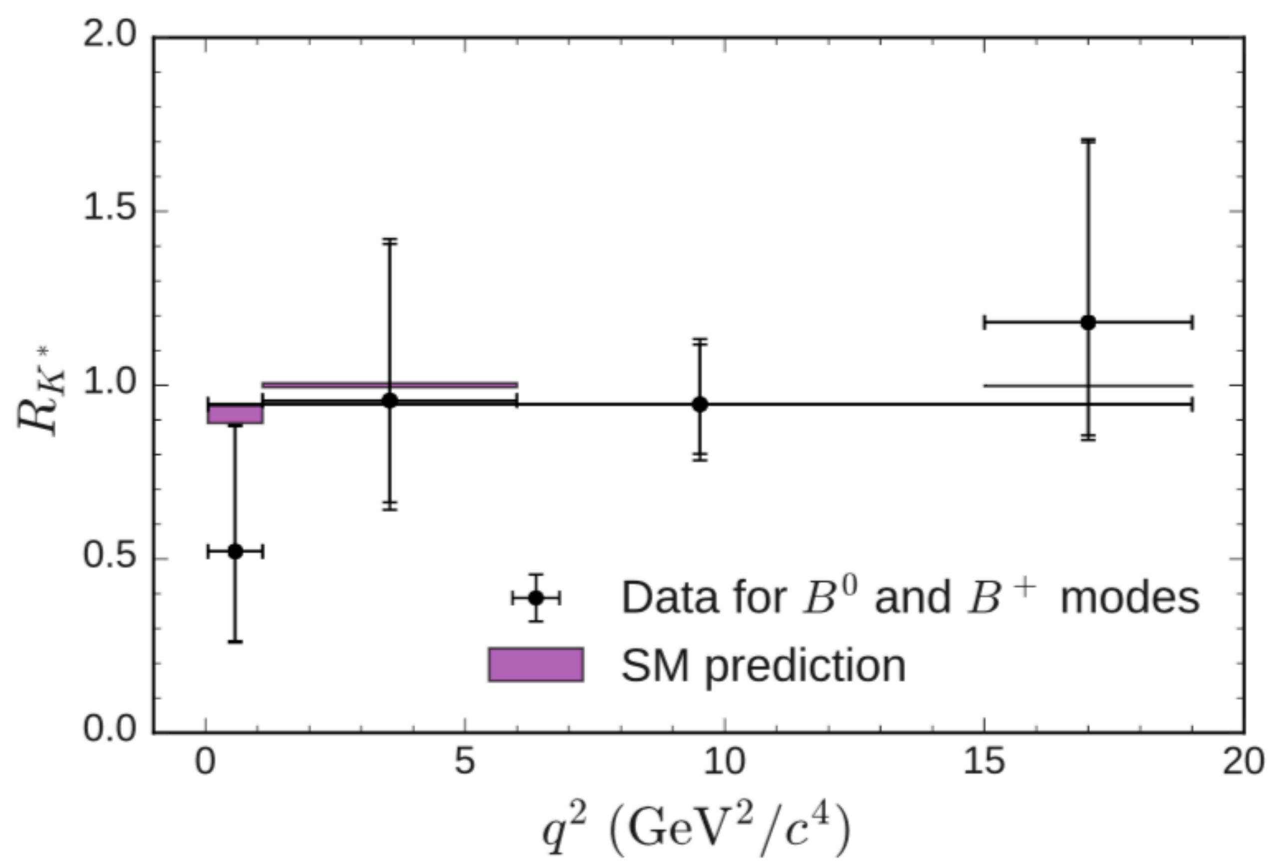
Bin	R_{K^+}	R_{K^0}	R_K
$0.1 < q^2 < 4$	$0.92^{+0.27}_{-0.24} \pm 0.05$	$1.5^{+1.2}_{-1.0} \pm 0.1$	$0.95^{+0.27}_{-0.24} \pm 0.06$
$4 < q^2 < 8.12$	$1.22^{+0.42}_{-0.37} \pm 0.07$	$0.50^{+0.39}_{-0.30} \pm 0.03$	$0.81^{+0.28}_{-0.23} \pm 0.05$
$1 < q^2 < 6$	$1.31^{+0.34}_{-0.31} \pm 0.07$	$0.53^{+0.44}_{-0.33} \pm 0.03$	$0.98^{+0.27}_{-0.23} \pm 0.06$
$q^2 > 14.18$	$1.08^{+0.30}_{-0.27} \pm 0.06$	$1.52^{+1.23}_{-0.97} \pm 0.10$	$1.11^{+0.29}_{-0.26} \pm 0.07$
whole q^2	$1.04^{+0.16}_{-0.15} \pm 0.06$	$1.25^{+0.50}_{-0.44} \pm 0.08$	$1.06^{+0.15}_{-0.14} \pm 0.07$

Long bin **[1,6]** compatible with SM but also with LCHb (large errors)

Pattern of $b \to s\ell\ell$ anomalies

Another **LFUV** observable showing a sizeable deviation:

$$R_{K^{*0}} = \frac{\text{Br}(B^0 \to K^{*0}\mu^+\mu^-)}{\text{Br}(B^0 \to K^{*0}J/\Psi(\to \mu^+\mu^-))} \Bigg/ \frac{\text{Br}(B^0 \to K^{*0}e^+e^-)}{\text{Br}(B^0 \to K^{*0}J/\Psi(\to e^+e^-))}$$



$$R_{K^{*0}} = \begin{cases} 0.66^{+0.11}_{-0.07} \pm 0.03 & q^2 \in [0.045, 1.1]\ \text{GeV}^2 \\ 0.69^{+0.11}_{-0.07} \pm 0.05 & q^2 \in [1.1, 6]\ \text{GeV}^2 \end{cases}$$

[LHCb: 1705.05802]

Belle combined data from neutral and charged channels:

$$R_{K^*}^{[0.045,1.1]} = 0.52^{+0.36}_{-0.26} \pm 0.05$$
$$R_{K^*}^{[1.1,6]} = 0.96^{+0.45}_{-0.29} \pm 0.11$$
$$R_{K^*}^{[15,19]} = 1.18^{+0.52}_{-0.32} \pm 0.10$$

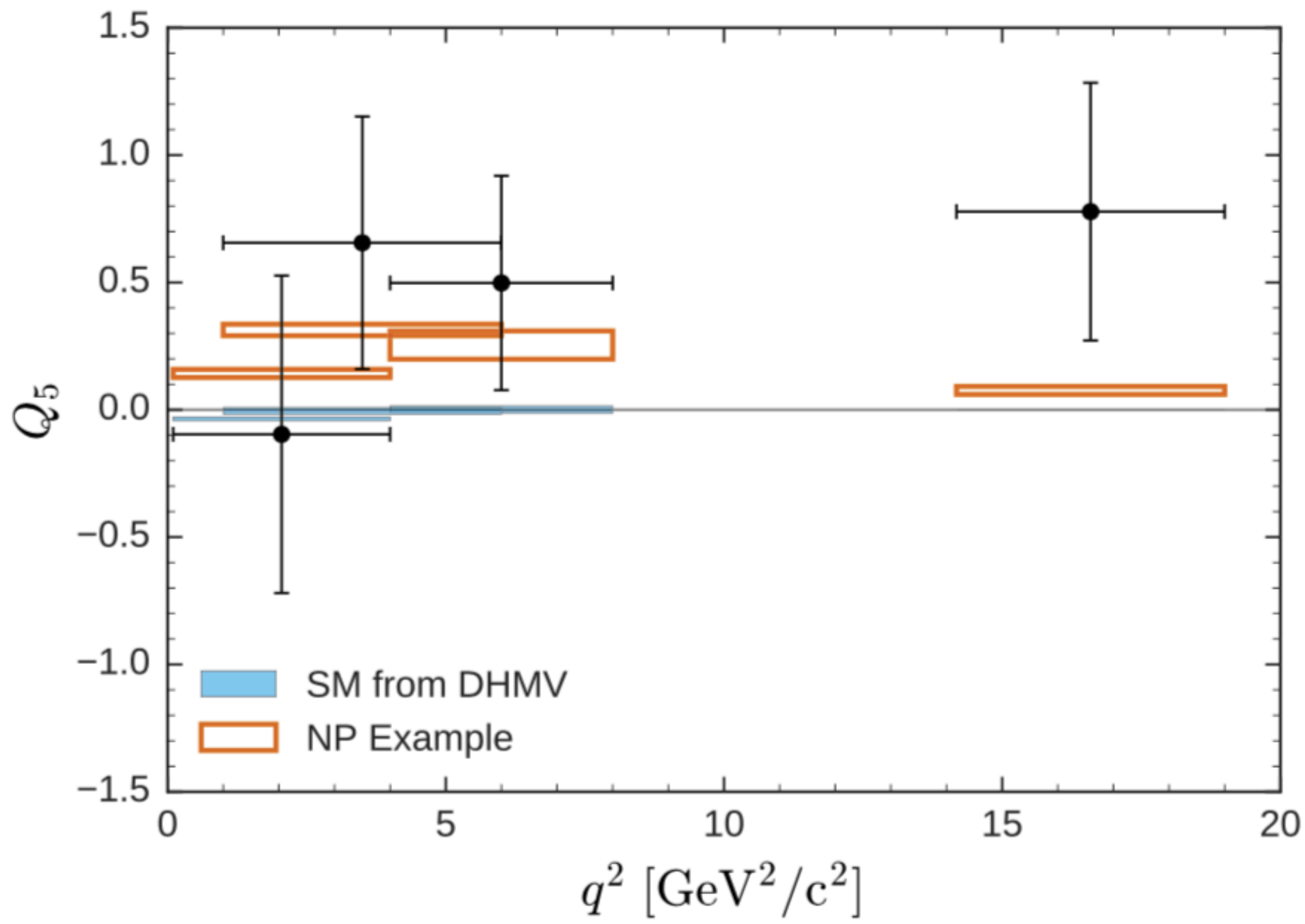
[Belle: 1904.02440]

- More complex structure, 6-8 amplitudes and 7 FF
- If NP or $q^2 < 1\,\text{GeV}^2$ **hadronic uncertainties return**

Pattern of $b \to s\ell\ell$ anomalies

Another **LFUV** observable: $Q_5 = P'_{5\mu} - P'_{5e}$

Belle, PRL118 (2017)



Only measured by Belle:

$$Q_5^{[1,6]} = 0.656 \pm 0.485 \pm 0.103$$

More precision needed!
but coherent with present anomalies ($\mathcal{C}_{9\mu}^{\rm NP} < 0$)

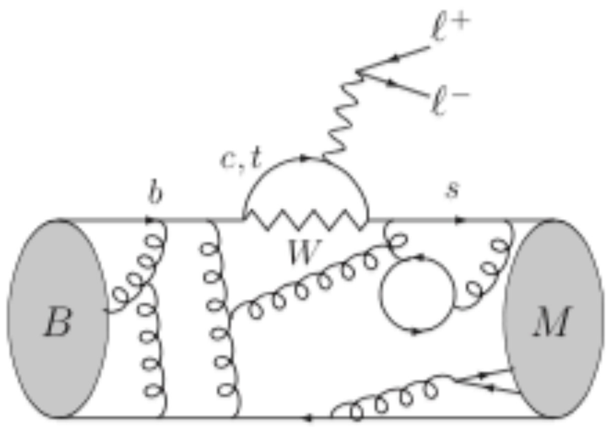
It **must** be included in analysis

↓

LFUV test

Anatomy of the Fits

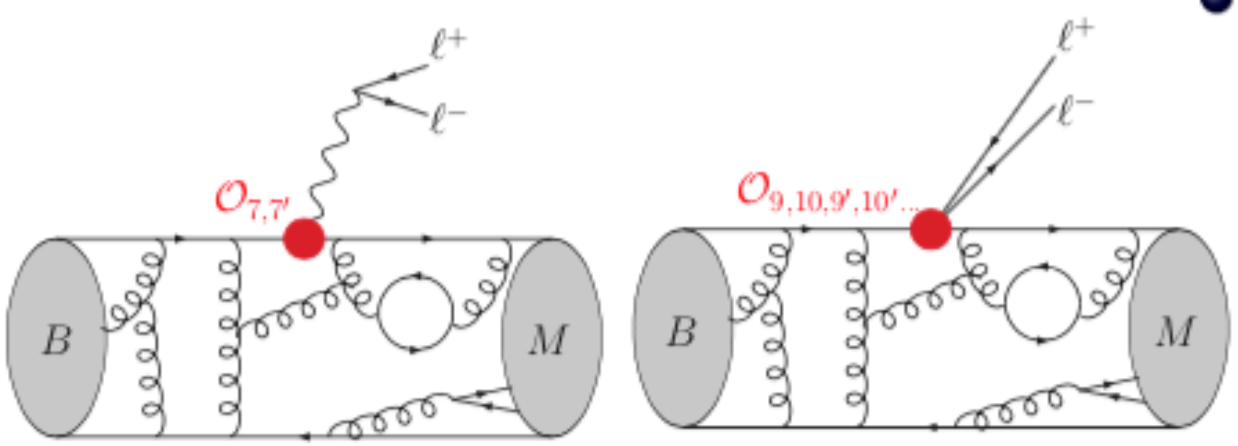
Weak Effective Hamiltonian



$$\mathcal{H}^{SM}_{\triangle F=1} \propto \sum V^*_{ts} V_{tb} \mathcal{C}_i \mathcal{O}_i + \dots$$

separate short and long distances $(\mu = m_b = 4.8)$

- $\mathcal{O}_7 = \frac{e}{16\pi^2} m_b \bar{s}\sigma^{\mu\nu}(1+\gamma_5)F_{\mu\nu}\, b$ [real or soft photon]
- $\mathcal{O}_9 = \frac{e^2}{16\pi^2} \bar{s}\gamma_\mu(1-\gamma_5)b\, \bar{\ell}\gamma^\mu \ell$ [$b \to s\mu\mu$ via Z/hard $\gamma \dots$]
- $\mathcal{O}_{10} = \frac{e^2}{16\pi^2} \bar{s}\gamma_\mu(1-\gamma_5)b\, \bar{\ell}\gamma^\mu\gamma_5 \ell$ [$b \to s\mu\mu$ via Z]



$\mathcal{C}_7^{\rm SM} = -0.29$, $\mathcal{C}_9^{\rm SM} = 4.1$, $\mathcal{C}_{10}^{\rm SM} = -4.3$

$A = \mathcal{C}_i$ (short dist) $\times$ Hadronic quantities (long dist)

Interesting directions:

$\mathcal{C}_9 = -\mathcal{C}_{10} \Rightarrow L_q \otimes L_\ell$

$\mathcal{C}_{9'} = -\mathcal{C}_{10'} \Rightarrow R_q \otimes L_\ell$

$\mathcal{C}_9 = -\mathcal{C}_{9'} \Rightarrow A_q \otimes V_\ell$

Global Fits

180 observables from (LHCb, Belle, ATLAS and CMS, no CP-violating obs)

- $B \to K^* \mu\mu$ ($P_{1,2}, P'_{4,5,6,8}, F_L$ in 5 large-recoil bins + 1 low-recoil bin)+available electronic obs.

  ...latest update $\mathrm{Br}(B \to K^* \mu\mu)$ in small bins.

  ...LHCb results on R_{K^*}

- $B_s \to \phi\mu\mu$ ($P_1, P'_{4,6}, F_L$ in 3 large-recoil bins + 1 low-recoil bin)

+ 2 bins of R_K from Belle

- $B^+ \to K^+\mu\mu$, $B^0 \to K^0\ell\ell$ (BR) ($\ell = e, \mu$) (new average $R_K = 0.846^{+0.060+0.016}_{-0.054-0.014}$)
- $B \to X_s\gamma$, $B \to X_s\mu\mu$, $B_s \to \mu\mu$ (BR).
- Radiative decays: $B^0 \to K^{*0}\gamma$ (A_I and $S_{K^*\gamma}$), $B^+ \to K^{*+}\gamma$, $B_s \to \phi\gamma$

► Belle measurements for the isospin-averaged but lepton-flavour dependent ($Q_{4,5} = P'^{\mu}_{4,5} - P'^{e}_{4,5}$):

[3rd test of LFUV]

$$P'^{\ell}_i = \sigma_+ P'^{\ell}_i(B^+) + (1-\sigma_+) P'^{\ell}_i(\bar{B}^0) \qquad \sigma_+ = 0.5 \pm 0.5$$

similar treatment of new Belle isospin-averaged result on R_{K^*} (3-bins)

► ATLAS measurement of whole basis of P_i and CMS measurements of P_1 and P'_5.

► ATLAS update of $B_s \to \mu\mu$ (averaged with LHCb & CMS) and latest f_{Bs} lattice update.

State-of-the-art 2019

Fit Results

Frequentist approach: $\mathcal{C}_i = \mathcal{C}_i^{SM} + \mathcal{C}_i^{NP}$, with $\mathcal{C}_i^{NP}$ assumed to be real (no CPV)

[JHEP01(2018)093]

	All					LFUV				
1D Hyp.	Best fit	$1\ \sigma$	$2\ \sigma$	$\mathrm{Pull}_{\mathrm{SM}}$	p-value	Best fit	$1\ \sigma$	$2\ \sigma$	$\mathrm{Pull}_{\mathrm{SM}}$	p-value
$\mathcal{C}_{9\mu}^{\mathrm{NP}}$	-1.11	$[-1.28, -0.94]$	$[-1.45, -0.75]$	5.8	68	-1.76	$[-2.36, -1.23]$	$[-3.04, -0.76]$	3.9	69
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}$	-0.62	$[-0.75, -0.49]$	$[-0.88, -0.37]$	5.3	58	-0.66	$[-0.84, -0.48]$	$[-1.04, -0.32]$	4.1	78
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}'_{9\mu}$	-1.01	$[-1.18, -0.84]$	$[-1.34, -0.65]$	5.4	61	-1.64	$[-2.13, -1.05]$	$[-2.52, -0.49]$	3.2	32
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -3\mathcal{C}_{9e}^{\mathrm{NP}}$	-1.07	[-1.24,-0.90]	[-1.40,-0.72]	5.8	70	-1.35	$[-1.82, -0.95]$	$[-2.38, -0.59]$	4.0	72

[1903.09578]

	All				LFUV			
1D Hyp.	Best fit	$1\ \sigma/2\ \sigma$	$\mathrm{Pull}_{\mathrm{SM}}$	p-value	Best fit	$1\ \sigma/\ 2\ \sigma$	$\mathrm{Pull}_{\mathrm{SM}}$	p-value
$\mathcal{C}_{9\mu}^{\mathrm{NP}}$	-0.98	$[-1.15, -0.81]$ $[-1.31, -0.64]$	5.6	65.4 %	-0.89	$[-1.23, -0.59]$ $[-1.60, -0.32]$	3.3	52.2 %
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}$	-0.46	$[-0.56, -0.37]$ $[-0.66, -0.28]$	5.2	55.6 %	-0.40	$[-0.53, -0.29]$ $[-0.63, -0.18]$	4.0	74.0 %
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{9'\mu}$	-0.99	$[-1.15, -0.82]$ $[-1.31, -0.64]$	5.5	62.9 %	-1.61	$[-2.13, -0.96]$ $[-2.54, -0.41]$	3.0	42.5 %
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -3\mathcal{C}_{9e}^{\mathrm{NP}}$	-0.87	$[-1.03, -0.71]$ $[-1.19, -0.55]$	5.5	61.9 %	-0.66	$[-0.90, -0.44]$ $[-1.17, -0.24]$	3.3	52.2 %

$\mathcal{C}_{9\mu}^{\mathrm{NP}}$ preferred in All Fit

$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}$ preferred in LFUV Fit

Same hierarchies except
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$R_K \sim 1$

Pull_{SM}: how much the SM is disfavoured with respect to a New Physics hypothesis to explain data.
$\rightarrow$ A scenario with a large SM-pull $\Rightarrow$ big improvement over SM and better description of data.

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$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{10\mu}^{\text{NP}}$	-0.62	$[-0.75, -0.49]$	$[-0.88, -0.37]$	5.3	58	-0.66	$[-0.84, -0.48]$	$[-1.04, -0.32]$	4.1	78
$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}'_{9\mu}$	-1.01	$[-1.18, -0.84]$	$[-1.34, -0.65]$	5.4	61	-1.64	$[-2.13, -1.05]$	$[-2.52, -0.49]$	3.2	32
$\mathcal{C}_{9\mu}^{\text{NP}} = -3\mathcal{C}_{9e}^{\text{NP}}$	-1.07	[-1.24,-0.90]	[-1.40,-0.72]	5.8	70	-1.35	$[-1.82, -0.95]$	$[-2.38, -0.59]$	4.0	72

[1903.09578]

1D Hyp.	All: Best fit	1 σ/2 σ	Pull_{SM}	p-value	LFUV: Best fit	1 σ/ 2 σ	Pull_{SM}	p-value
$\mathcal{C}_{9\mu}^{\text{NP}}$	-0.98	$[-1.15, -0.81]$ $[-1.31, -0.64]$	5.6	65.4 %	-0.89	$[-1.23, -0.59]$ $[-1.60, -0.32]$	3.3	52.2 %
$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{10\mu}^{\text{NP}}$	-0.46	$[-0.56, -0.37]$ $[-0.66, -0.28]$	5.2	65.6 %	-0.40	$[-0.53, -0.29]$ $[-0.63, -0.18]$	4.0	74.0 %
$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{9'\mu}$	-0.99	$[-1.15, -0.82]$ $[-1.31, -0.64]$	5.5	62.9 %	-1.61	$[-2.13, -0.96]$ $[-2.54, -0.41]$	3.0	42.5 %
$\mathcal{C}_{9\mu}^{\text{NP}} = -3\mathcal{C}_{9e}^{\text{NP}}$	-0.87	$[-1.03, -0.71]$ $[-1.19, -0.55]$	5.5	61.9 %	-0.66	$[-0.90, -0.44]$ $[-1.17, -0.24]$	3.3	52.2 %

$\mathcal{C}_{9\mu}^{\text{NP}}$ preferred in All Fit

$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{10\mu}^{\text{NP}}$ preferred in LFUV Fit

Same hierarchies except $\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{9'\mu}$

$R_K \sim 1$

Pull_{SM}: how much the SM is disfavoured with respect to a New Physics hypothesis to explain data.
$\rightarrow$ A scenario with a large SM-pull $\Rightarrow$ big improvement over SM and better description of data.

Fit Results

Frequentist approach: $\mathcal{C}_i = \mathcal{C}_i^{SM} + \mathcal{C}_i^{NP}$, with $\mathcal{C}_i^{NP}$ assumed to be real (no CPV)

[JHEP01(2018)093]

	All					LFUV				
1D Hyp.	Best fit	1 σ	2 σ	$\mathrm{Pull_{SM}}$	p-value	Best fit	1 σ	2 σ	$\mathrm{Pull_{SM}}$	p-value
$\mathcal{C}_{9\mu}^{\mathrm{NP}}$	-1.11	$[-1.28, -0.94]$	$[-1.45, -0.75]$	5.8	68	-1.76	$[-2.36, -1.23]$	$[-3.04, -0.76]$	3.9	69
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}$	-0.62	$[-0.75, -0.49]$	$[-0.88, -0.37]$	5.3	58	-0.66	$[-0.84, -0.48]$	$[-1.04, -0.32]$	4.1	78
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}'_{9\mu}$	-1.01	$[-1.18, -0.84]$	$[-1.34, -0.65]$	5.4	61	-1.64	$[-2.13, -1.05]$	$[-2.52, -0.49]$	3.2	32
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -3\mathcal{C}_{9e}^{\mathrm{NP}}$	-1.07	[-1.24,-0.90]	[-1.40,-0.72]	5.8	70	-1.35	$[-1.82, -0.95]$	$[-2.38, -0.59]$	4.0	72

[1903.09578]

	All				LFUV			
1D Hyp.	Best fit	1 σ/2 σ	$\mathrm{Pull_{SM}}$	p-value	Best fit	1 σ/ 2 σ	$\mathrm{Pull_{SM}}$	p-value
$\mathcal{C}_{9\mu}^{\mathrm{NP}}$	-0.98	$[-1.15, -0.81]$ $[-1.31, -0.64]$	5.6	65.4 %	-0.89	$[-1.23, -0.59]$ $[-1.60, -0.32]$	3.3	52.2 %
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}$	-0.46	$[-0.56, -0.37]$ $[-0.66, -0.28]$	5.2	65.6 %	-0.40	$[-0.53, -0.29]$ $[-0.63, -0.18]$	4.0	74.0 %
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{9'\mu}$	-0.99	$[-1.15, -0.82]$ $[-1.31, -0.64]$	5.5	62.9 %	-1.61	$[-2.13, -0.96]$ $[-2.54, -0.41]$	3.0	42.5 %
$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -3\mathcal{C}_{9e}^{\mathrm{NP}}$	-0.87	$[-1.03, -0.71]$ $[-1.19, -0.55]$	5.5	61.9 %	-0.66	$[-0.90, -0.44]$ $[-1.17, -0.24]$	3.3	52.2 %

$\mathcal{C}_{9\mu}^{\mathrm{NP}}$ preferred in All Fit

$\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}$ preferred in LFUV Fit

Same hierarchies except $\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{9'\mu}$

$R_K \sim 1$

Pull_{SM}: how much the SM is disfavoured with respect to a New Physics hypothesis to explain data.
$\rightarrow$ A scenario with a large SM-pull $\Rightarrow$ big improvement over SM and better description of data.

Fit Results

Frequentist approach: $\mathcal{C}_i = \mathcal{C}_i^{SM} + \mathcal{C}_i^{NP}$, with $\mathcal{C}_i^{NP}$ assumed to be real (no CPV)

[JHEP01(2018)093]

	All					LFUV				
1D Hyp.	Best fit	1 σ	2 σ	Pull$_{\rm SM}$	p-value	Best fit	1 σ	2 σ	Pull$_{\rm SM}$	p-value
$\mathcal{C}_{9\mu}^{\rm NP}$	-1.11	$[-1.28,-0.94]$	$[-1.45,-0.75]$	5.8	68	-1.76	$[-2.36,-1.23]$	$[-3.04,-0.76]$	3.9	69
$\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{10\mu}^{\rm NP}$	-0.62	$[-0.75,-0.49]$	$[-0.88,-0.37]$	5.3	58	-0.66	$[-0.84,-0.48]$	$[-1.04,-0.32]$	4.1	78
$\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{9\mu}'$	-1.01	$[-1.18,-0.84]$	$[-1.34,-0.65]$	5.4	61	-1.64	$[-2.13,-1.05]$	$[-2.52,-0.49]$	3.2	32
$\mathcal{C}_{9\mu}^{\rm NP}=-3\mathcal{C}_{9e}^{\rm NP}$	-1.07	[-1.24,-0.90]	[-1.40,-0.72]	5.8	70	-1.35	$[-1.82,-0.95]$	$[-2.38,-0.59]$	4.0	72

[1903.09578]

	All				LFUV			
1D Hyp.	Best fit	1 σ/2 σ	Pull$_{\rm SM}$	p-value	Best fit	1 σ/ 2 σ	Pull$_{\rm SM}$	p-value
$\mathcal{C}_{9\mu}^{\rm NP}$	-0.98	$[-1.15,-0.81]$ $[-1.31,-0.64]$	5.6	65.4 %	-0.89	$[-1.23,-0.59]$ $[-1.60,-0.32]$	3.3	52.2 %
$\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{10\mu}^{\rm NP}$	-0.46	$[-0.56,-0.37]$ $[-0.66,-0.28]$	5.2	65.6 %	-0.40	$[-0.53,-0.29]$ $[-0.63,-0.18]$	4.0	74.0 %
$\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{9'\mu}$	-0.99	$[-1.15,-0.82]$ $[-1.31,-0.64]$	5.5	62.9 %	-1.61	$[-2.13,-0.96]$ $[-2.54,-0.41]$	3.0	42.5 %
$\mathcal{C}_{9\mu}^{\rm NP}=-3\mathcal{C}_{9e}^{\rm NP}$	-0.87	$[-1.03,-0.71]$ $[-1.19,-0.55]$	5.5	61.9 %	-0.66	$[-0.90,-0.44]$ $[-1.17,-0.24]$	3.3	52.2 %

$\mathcal{C}_{9\mu}^{\rm NP}$ preferred in All Fit

$\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{10\mu}^{\rm NP}$ preferred in LFUV Fit

Same hierarchies except $\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{9'\mu}$

$R_K \sim 1$

Pull$_{SM}$: how much the SM is disfavoured with respect to a New Physics hypothesis to explain data.
$\rightarrow$ A scenario with a large SM-pull $\Rightarrow$ big improvement over SM and better description of data.

Fit Results

Update in 2D Fits

[JHEP01(2018)093]

	All			LFUV		
2D Hyp.	Best fit	Pull_{SM}	p-value	Best fit	Pull_{SM}	p-value
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{10\mu}^{\text{NP}})$	(-1.01,0.29)	5.7	72	(-1.30,0.36)	3.7	75
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_7')$	(-1.13,0.01)	5.5	69	(-1.85,-0.04)	3.6	66
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{9'\mu})$	(-1.15,0.41)	5.6	71	(-1.99,0.93)	3.7	72
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{10'\mu})$	(-1.22,-0.22)	5.7	72	(-2.22,-0.41)	3.9	85
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{9e}^{\text{NP}})$	(-1.00,0.42)	5.5	68	(-1.36,0.46)	3.5	65
Hyp. 1	(-1.16,0.38)	5.7	73	(-1.68,0.60)	3.8	78
Hyp. 2	(-1.15, 0.01)	5.0	57	(-2.16,0.41)	3.0	37
Hyp. 3	(-0.67,-0.10)	5.0	57	(0.61,2.48)	3.7	73
Hyp. 4	(-0.70,0.28)	5.0	57	(-0.74,0.43)	3.7	72

[1903.09578]

	All			LFUV		
2D Hyp.	Best fit	Pull_{SM}	p-value	Best fit	Pull_{SM}	p-value
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{10\mu}^{\text{NP}})$	(-0.91,0.18)	5.4	68.7 %	(-0.16,0.56)	3.4	76.9 %
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{7'})$	(-1.00,0.02)	5.4	67.9 %	(-0.90,-0.04)	2.9	55.1 %
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{9'\mu})$	(-1.10,0.55)	5.7	75.1 %	(-1.79,1.14)	3.4	76.1 %
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{10'\mu})$	(-1.14,-0.35)	5.9	78.6 %	(-1.88,-0.62)	3.8	91.3 %
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{9e}^{\text{NP}})$	(-1.05,-0.23)	5.3	66.2 %	(-0.73,0.16)	2.8	52.3 %
Hyp. 1	(-1.06,0.26)	5.7	75.7 %	(-1.62,0.29)	3.4	77.6 %
Hyp. 2	(-0.97,0.09)	5.3	65.2 %	(-1.95,0.25)	3.2	66.6 %
Hyp. 3	(-0.47,0.06)	4.8	55.7 %	(-0.39,-0.13)	3.4	76.2 %
Hyp. 4	(-0.49,0.12)	5.0	59.3 %	(-0.48,0.17)	3.6	84.3 %
Hyp. 5	(-1.14,0.24)	5.9	78.7 %	(-2.07,0.52)	3.9	92.5 %

$\text{Hyp.1} : (\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\text{NP}} = \mathcal{C}_{10'\mu})$

$\text{Hyp.2} : (\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\text{NP}} = -\mathcal{C}_{10'\mu})$

$\text{Hyp.3} : (\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{10\mu}^{\text{NP}}, \mathcal{C}_{9'\mu} = \mathcal{C}_{10'\mu})$

$\text{Hyp.4} : (\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{10\mu}^{\text{NP}}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

$\text{Hyp.5} : (\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

- Small increase ($\sim 0.2\sigma$) for some RHC scenarios opposite to 1D cases
- R_K closer to SM prefers $\mathcal{C}_{9'\mu} > 0$ and $\mathcal{C}_{10'\mu} < 0$
- A $R_q \otimes L_\ell$ for $\mathcal{O}_{9',10'}$ clearly prefers V structure over L_ℓ for leptons

Fit Results

Update in 2D Fits

[JHEP01(2018)093]

2D Hyp.	All: Best fit	All: $\mathrm{Pull_{SM}}$	All: p-value	LFUV: Best fit	LFUV: $\mathrm{Pull_{SM}}$	LFUV: p-value
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10\mu}^{\rm NP})$	(-1.01,0.29)	5.7	72	(-1.30,0.36)	3.7	75
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_7')$	(-1.13,0.01)	5.5	69	(-1.85,-0.04)	3.6	66
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu})$	(-1.15,0.41)	5.6	71	(-1.99,0.93)	3.7	72
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10'\mu})$	(-1.22,-0.22)	5.7	72	(-2.22,-0.41)	3.9	85
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9e}^{\rm NP})$	(-1.00,0.42)	5.5	68	(-1.36,0.46)	3.5	65
Hyp. 1	(-1.16,0.38)	5.7	73	(-1.68,0.60)	3.8	78
Hyp. 2	(-1.15, 0.01)	5.0	57	(-2.16,0.41)	3.0	37
Hyp. 3	(-0.67,-0.10)	5.0	57	(0.61,2.48)	3.7	73
Hyp. 4	(-0.70,0.28)	5.0	57	(-0.74,0.43)	3.7	72

[1903.09578]

2D Hyp.	All: Best fit	All: $\mathrm{Pull_{SM}}$	All: p-value	LFUV: Best fit	LFUV: $\mathrm{Pull_{SM}}$	LFUV: p-value
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10\mu}^{\rm NP})$	(-0.91,0.18)	5.4	68.7 %	(-0.16,0.56)	3.4	76.9 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{7'})$	(-1.00,0.02)	5.4	67.9 %	(-0.90,-0.04)	2.9	55.1 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu})$	(-1.10,0.55)	5.7	75.1 %	(-1.79,1.14)	3.4	76.1 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10'\mu})$	(-1.14,-0.35)	5.9	78.6 %	(-1.88,-0.62)	3.8	91.3 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9e}^{\rm NP})$	(-1.05,-0.23)	5.3	66.2 %	(-0.73,0.16)	2.8	52.3 %
Hyp. 1	(-1.06,0.26)	5.7	75.7 %	(-1.62,0.29)	3.4	77.6 %
Hyp. 2	(-0.97,0.09)	5.3	65.2 %	(-1.95,0.25)	3.2	66.6 %
Hyp. 3	(-0.47,0.06)	4.8	55.7 %	(-0.39,-0.13)	3.4	76.2 %
Hyp. 4	(-0.49,0.12)	5.0	59.3 %	(-0.48,0.17)	3.6	84.3 %
Hyp. 5	(-1.14,0.24)	5.9	78.7 %	(-2.07,0.52)	3.9	92.5 %

Hyp.1 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10'\mu})$

Hyp.2 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\rm NP} = -\mathcal{C}_{10'\mu})$

Hyp.3 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = \mathcal{C}_{10'\mu})$

Hyp.4 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

Hyp.5 : $(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

- Small increase ($\sim 0.2\sigma$) for some RHC scenarios opposite to 1D cases
- R_K closer to SM prefers $\mathcal{C}_{9'\mu} > 0$ and $\mathcal{C}_{10'\mu} < 0$
- A $R_q \otimes L_\ell$ for $\mathcal{O}_{9',10'}$ clearly prefers V structure over L_ℓ for leptons

Fit Results

Update in 2D Fits

[JHEP01(2018)093]

2D Hyp.	All: Best fit	All: $\mathrm{Pull_{SM}}$	All: p-value	LFUV: Best fit	LFUV: $\mathrm{Pull_{SM}}$	LFUV: p-value
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{10\mu}^{\rm NP})$	(-1.01,0.29)	5.7	72	(-1.30,0.36)	3.7	75
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{7}')$	(-1.13,0.01)	5.5	69	(-1.85,-0.04)	3.6	66
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{9'\mu})$	(-1.15,0.41)	5.6	71	(-1.99,0.93)	3.7	72
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{10'\mu})$	(-1.22,-0.22)	5.7	72	(-2.22,-0.41)	3.9	85
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{9e}^{\rm NP})$	(-1.00,0.42)	5.5	68	(-1.36,0.46)	3.5	65
Hyp. 1	(-1.16,0.38)	5.7	73	(-1.68,0.60)	3.8	78
Hyp. 2	(-1.15, 0.01)	5.0	57	(-2.16,0.41)	3.0	37
Hyp. 3	(-0.67,-0.10)	5.0	57	(0.61,2.48)	3.7	73
Hyp. 4	(-0.70,0.28)	5.0	57	(-0.74,0.43)	3.7	72

[1903.09578]

2D Hyp.	All: Best fit	All: $\mathrm{Pull_{SM}}$	All: p-value	LFUV: Best fit	LFUV: $\mathrm{Pull_{SM}}$	LFUV: p-value
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{10\mu}^{\rm NP})$	(-0.91,0.18)	5.4	68.7 %	(-0.16,0.56)	3.4	76.9 %
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{7'})$	(-1.00,0.02)	5.4	67.9 %	(-0.90,-0.04)	2.9	55.1 %
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{9'\mu})$	(-1.10,0.55)	5.7	75.1 %	(-1.79,1.14)	3.4	76.1 %
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{10'\mu})$	(-1.14,-0.35)	5.9	78.6 %	(-1.88,-0.62)	3.8	91.3 %
$(\mathcal{C}_{9\mu}^{\rm NP},\mathcal{C}_{9e}^{\rm NP})$	(-1.05,-0.23)	5.3	66.2 %	(-0.73,0.16)	2.8	52.3 %
Hyp. 1	(-1.06,0.26)	5.7	75.7 %	(-1.62,0.29)	3.4	77.6 %
Hyp. 2	(-0.97,0.09)	5.3	65.2 %	(-1.95,0.25)	3.2	66.6 %
Hyp. 3	(-0.47,0.06)	4.8	55.7 %	(-0.39,-0.13)	3.4	76.2 %
Hyp. 4	(-0.49,0.12)	5.0	59.3 %	(-0.48,0.17)	3.6	84.3 %
Hyp. 5	(-1.14,0.24)	5.9	78.7 %	(-2.07,0.52)	3.9	92.5 %

Hyp.1 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10'\mu})$

Hyp.2 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\rm NP} = -\mathcal{C}_{10'\mu})$

Hyp.3 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = \mathcal{C}_{10'\mu})$

Hyp.4 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

Hyp.5 : $(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

- Small increase ($\sim 0.2\sigma$) for some RHC scenarios opposite to 1D cases
- R_K closer to SM prefers $\mathcal{C}_{9'\mu} > 0$ and $\mathcal{C}_{10'\mu} < 0$
- A $R_q \otimes L_\ell$ for $\mathcal{O}_{9',10'}$ clearly prefers V structure over L_ℓ for leptons

Fit Results

Update in 2D Fits

[JHEP01(2018)093]

2D Hyp.	All: Best fit	All: $\mathrm{Pull_{SM}}$	All: p-value	LFUV: Best fit	LFUV: $\mathrm{Pull_{SM}}$	LFUV: p-value
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10\mu}^{\rm NP})$	(-1.01,0.29)	5.7	72	(-1.30,0.36)	3.7	75
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_7')$	(-1.13,0.01)	5.5	69	(-1.85,-0.04)	3.6	66
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu})$	(-1.15,0.41)	5.6	71	(-1.99,0.93)	3.7	72
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10'\mu})$	(-1.22,-0.22)	5.7	72	(-2.22,-0.41)	3.9	85
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9e}^{\rm NP})$	(-1.00,0.42)	5.5	68	(-1.36,0.46)	3.5	65
Hyp. 1	(-1.16,0.38)	5.7	73	(-1.68,0.60)	3.8	78
Hyp. 2	(-1.15, 0.01)	5.0	57	(-2.16,0.41)	3.0	37
Hyp. 3	(-0.67,-0.10)	5.0	57	(0.61,2.48)	3.7	73
Hyp. 4	(-0.70,0.28)	5.0	57	(-0.74,0.43)	3.7	72

[1903.09578]

2D Hyp.	All: Best fit	All: $\mathrm{Pull_{SM}}$	All: p-value	LFUV: Best fit	LFUV: $\mathrm{Pull_{SM}}$	LFUV: p-value
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10\mu}^{\rm NP})$	(-0.91,0.18)	5.4	68.7 %	(-0.16,0.56)	3.4	76.9 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{7'})$	(-1.00,0.02)	5.4	67.9 %	(-0.90,-0.04)	2.9	55.1 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu})$	(-1.10,0.55)	5.7	75.1 %	(-1.79,1.14)	3.4	76.1 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10'\mu})$	(-1.14,-0.35)	5.9	78.6 %	(-1.88,-0.62)	3.8	91.3 %
$(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9e}^{\rm NP})$	(-1.05,-0.23)	5.3	66.2 %	(-0.73,0.16)	2.8	52.3 %
Hyp. 1	(-1.06,0.26)	5.7	75.7 %	(-1.62,0.29)	3.4	77.6 %
Hyp. 2	(-0.97,0.09)	5.3	65.2 %	(-1.95,0.25)	3.2	66.6 %
Hyp. 3	(-0.47,0.06)	4.8	55.7 %	(-0.39,-0.13)	3.4	76.2 %
Hyp. 4	(-0.49,0.12)	5.0	59.3 %	(-0.48,0.17)	3.6	84.3 %
Hyp. 5	(-1.14,0.24)	5.9	78.7 %	(-2.07,0.52)	3.9	92.5 %

Hyp.1 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10'\mu})$

Hyp.2 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\rm NP} = -\mathcal{C}_{10'\mu})$

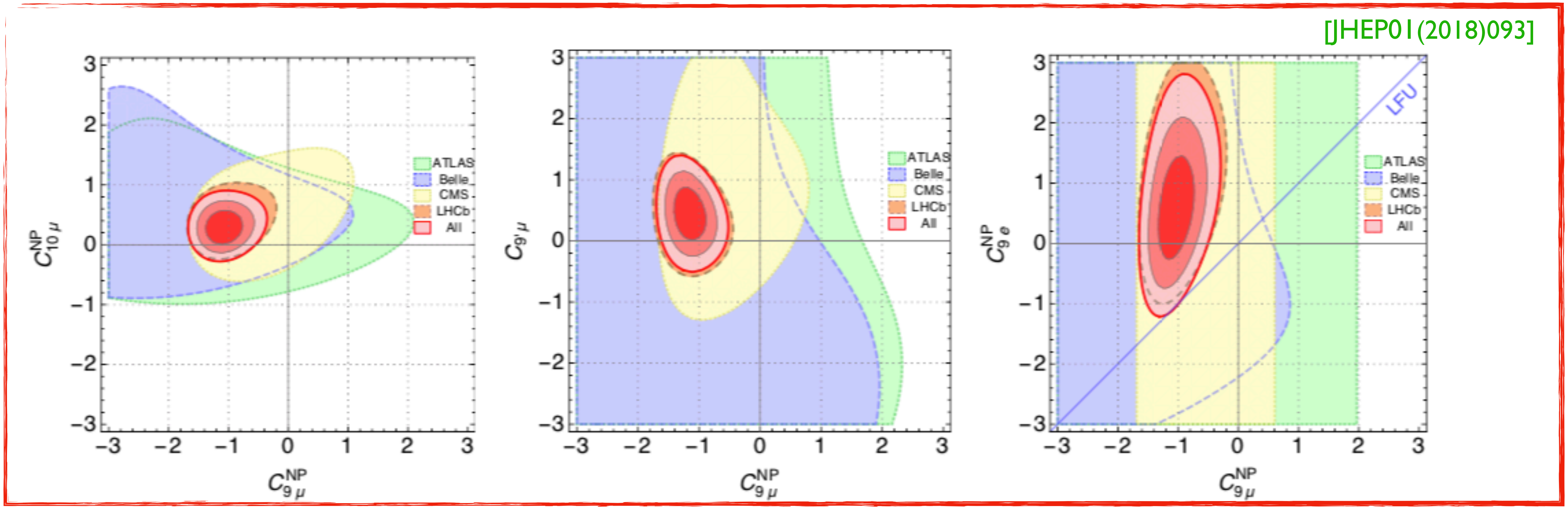
Hyp.3 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = \mathcal{C}_{10'\mu})$

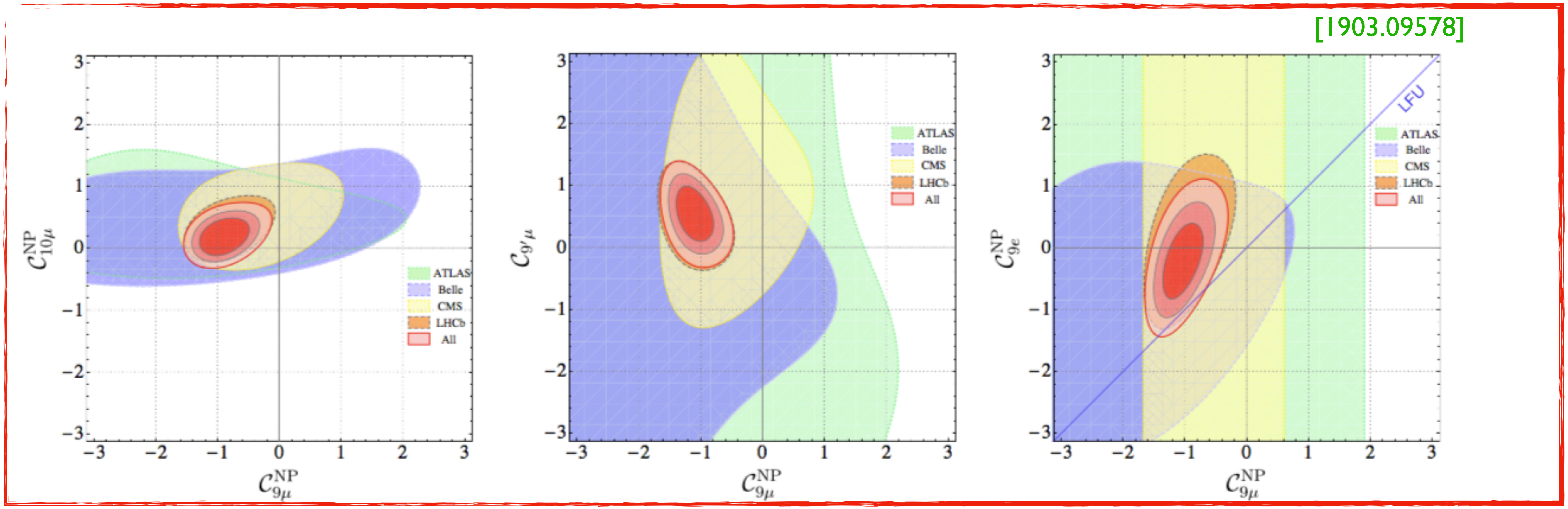
Hyp.4 : $(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

Hyp.5 : $(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu})$

- Small increase ($\sim 0.2\sigma$) for some RHC scenarios opposite to 1D cases
- R_K closer to SM prefers $\mathcal{C}_{9'\mu} > 0$ and $\mathcal{C}_{10'\mu} < 0$
- A $R_q \otimes L_\ell$ for $\mathcal{O}_{9',10'}$ clearly prefers V structure over L_ℓ for leptons

- 2D Fits: 1σ CL for fit All and 3σ CL for individual experiments





Fit Results

Concerning the 6D Fit:

[JHEP01(2018)093]

	$\mathcal{C}_7^{\rm NP}$	$\mathcal{C}_{9\mu}^{\rm NP}$	$\mathcal{C}_{10\mu}^{\rm NP}$	$\mathcal{C}_{7'}$	$\mathcal{C}_{9'\mu}$	$\mathcal{C}_{10'\mu}$
Best fit	+0.03	-1.12	+0.31	+0.03	+0.38	+0.02
1 σ	$[-0.01, +0.05]$	$[-1.34, -0.88]$	$[+0.10, +0.57]$	$[+0.00, +0.06]$	$[-0.17, +1.04]$	$[-0.28, +0.36]$
2 σ	$[-0.03, +0.07]$	$[-1.54, -0.63]$	$[-0.08, +0.84]$	$[-0.02, +0.08]$	$[-0.59, +1.58]$	$[-0.54, +0.68]$

[1903.09578]

	$\mathcal{C}_7^{\rm NP}$	$\mathcal{C}_{9\mu}^{\rm NP}$	$\mathcal{C}_{10\mu}^{\rm NP}$	$\mathcal{C}_{7'}$	$\mathcal{C}_{9'\mu}$	$\mathcal{C}_{10'\mu}$
Best fit	+0.01	-1.10	+0.15	+0.02	+0.36	-0.16
1 σ	$[-0.01, +0.05]$	$[-1.28, -0.90]$	$[-0.00, +0.36]$	$[-0.00, +0.05]$	$[-0.14, +0.87]$	$[-0.39, +0.13]$
2 σ	$[-0.03, +0.06]$	$[-1.44, -0.68]$	$[-0.12, +0.56]$	$[-0.02, +0.06]$	$[-0.49, +1.23]$	$[-0.58, +0.33]$

No significant changes except:

- 5.0σ (2017) → **5.1σ** (2019)
- Opposite sign for b.f.p. of $\mathcal{C}_{10'}$ but $\mathcal{C}_{10} - \mathcal{C}_{10'}$ stays the same

What’s new?

Are we overlooking LFU NP?

[Algueró, Capdevila, SDG, Masjuan, Matias, PRD'19]

Before: NP only **LFUV**

muons:

$$\mathcal{C}_{9\mu}^{\rm NP} = \mathcal{C}_{9\mu}^{\rm V}$$

$$\mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10\mu}^{\rm V}$$

electrons:

$$\mathcal{C}_{9e}^{\rm NP} = 0$$

$$\mathcal{C}_{10e}^{\rm NP} = 0$$

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electrons: $\mathcal{C}_{9e}^{\rm NP} = 0$, $\mathcal{C}_{10e}^{\rm NP} = 0$

Now: NP

LFUV: $\mathcal{C}_{9\mu}^{\rm V}$, $\mathcal{C}_{10\mu}^{\rm V}$

LFU: $\mathcal{C}_{9}^{\rm U}$, $\mathcal{C}_{10}^{\rm U}$

$$\mathcal{C}_{9\mu}^{\rm NP} = \mathcal{C}_{9\mu}^{\rm V} + \mathcal{C}_{9}^{\rm U}$$

$$\mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10\mu}^{\rm V} + \mathcal{C}_{10}^{\rm U}$$

$$\mathcal{C}_{9e}^{\rm NP} = \mathcal{C}_{9}^{\rm U}$$

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2 parameters

Now: NP

LFUV: $\mathcal{C}_{9\mu}^{\rm V}$, $\mathcal{C}_{10\mu}^{\rm V}$

LFU: $\mathcal{C}_{9}^{\rm U}$, $\mathcal{C}_{10}^{\rm U}$

$$\mathcal{C}_{9\mu}^{\rm NP} = \mathcal{C}_{9\mu}^{\rm V} + \mathcal{C}_{9}^{\rm U}$$
$$\mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10\mu}^{\rm V} + \mathcal{C}_{10}^{\rm U}$$
$$\mathcal{C}_{9e}^{\rm NP} = \mathcal{C}_{9}^{\rm U}$$
$$\mathcal{C}_{10e}^{\rm NP} = \mathcal{C}_{10}^{\rm U}$$

4 parameters (2+2)

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muons: $\mathcal{C}_{9\mu}^{\rm NP} = \mathcal{C}_{9\mu}^{\rm V}$, $\mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10\mu}^{\rm V}$ — **2 parameters**

+

electrons: $\mathcal{C}_{9e}^{\rm NP} = 0$, $\mathcal{C}_{10e}^{\rm NP} = 0$ — **2 parameters = 0**

Now: NP

LFUV: $\mathcal{C}_{9\mu}^{\rm V}$, $\mathcal{C}_{10\mu}^{\rm V}$

LFU: $\mathcal{C}_{9}^{\rm U}$, $\mathcal{C}_{10}^{\rm U}$

→

$$\mathcal{C}_{9\mu}^{\rm NP} = \mathcal{C}_{9\mu}^{\rm V} + \mathcal{C}_{9}^{\rm U}$$
$$\mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10\mu}^{\rm V} + \mathcal{C}_{10}^{\rm U}$$
$$\mathcal{C}_{9e}^{\rm NP} = \mathcal{C}_{9}^{\rm U}$$
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+

electrons: $\mathcal{C}_{9e}^{\rm NP} = 0$, $\mathcal{C}_{10e}^{\rm NP} = 0$ — **2 parameters = 0**

Now: NP

LFUV: $\mathcal{C}_{9\mu}^{\rm V}$, $\mathcal{C}_{10\mu}^{\rm V}$

LFU: $\mathcal{C}_{9}^{\rm U}$, $\mathcal{C}_{10}^{\rm U}$

$$\mathcal{C}_{9\mu}^{\rm NP} = \mathcal{C}_{9\mu}^{\rm V} + \mathcal{C}_{9}^{\rm U}$$
$$\mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10\mu}^{\rm V} + \mathcal{C}_{10}^{\rm U}$$
$$\mathcal{C}_{9e}^{\rm NP} = \mathcal{C}_{9}^{\rm U}$$
$$\mathcal{C}_{10e}^{\rm NP} = \mathcal{C}_{10}^{\rm U}$$

4 parameters (2+2)

- Change of paradigm! Now same **LFU** piece in electrons, muons and tau different from **LFUV**
- Assumption: hadronic uncertainties well controlled → $\mathcal{C}_{9}^{\rm U}$ is NP
- New mechanism to fulfill $\mathcal{B}(B_s \to \mu^+\mu^-) \propto |\mathcal{C}_{10}^{\rm V} + \mathcal{C}_{10}^{\rm U}|^2$

Are we overlooking LFU NP?

Update of scenarios with LFU

[Algueró et al, 1809.08447]

		Best-fit point	1 σ	$\mathrm{Pull}_{\mathrm{SM}}$	p-value
Sc. 5	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-0.16	$[-0.94, +0.46]$	5.8	78 %
	$\mathcal{C}_{10\mu}^{\mathrm{V}}$	$+1.00$	$[+0.18, +1.59]$		
	$\mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}$	-0.87	$[-1.43, -0.14]$		
Sc. 6	$\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}$	-0.64	$[-0.77, -0.51]$	6.0	79 %
	$\mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}$	-0.44	$[-0.58, -0.29]$		
Sc. 7	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-1.57	$[-2.14, -1.06]$	5.7	72 %
	$\mathcal{C}_{9}^{\mathrm{U}}$	$+0.56$	$[+0.01, +1.15]$		
Sc. 8	$\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}$	-0.42	$[-0.57, -0.27]$	5.8	74 %
	$\mathcal{C}_{9}^{\mathrm{U}}$	-0.67	$[-0.90, -0.42]$		

[Algueró et al, 1903.09578]

		Best-fit point	1 σ	2 σ	$\mathrm{Pull}_{\mathrm{SM}}$	p-value
Sc. 5	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-0.36	$[-0.86, +0.10]$	$[-1.41, +0.52]$	5.2	71.2 %
	$\mathcal{C}_{10\mu}^{\mathrm{V}}$	$+0.67$	$[+0.24, +1.03]$	$[-1.73, +1.36]$		
	$\mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}$	-0.59	$[-0.90, -0.12]$	$[-1.13, +0.68]$		
Sc. 6	$\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}$	-0.50	$[-0.61, -0.38]$	$[-0.72, -0.28]$	5.5	71.0 %
	$\mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}$	-0.38	$[-0.52, -0.22]$	$[-0.64, -0.06]$		
Sc. 7	$\mathcal{C}_{9\mu}^{\mathrm{V}}$	-0.78	$[-1.11, -0.47]$	$[-1.45, -0.18]$	5.3	66.2 %
	$\mathcal{C}_{9}^{\mathrm{U}}$	-0.20	$[-0.57, +0.18]$	$[-0.92, +0.55]$		
Sc. 8	$\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}$	-0.30	$[-0.42, -0.20]$	$[-0.53, -0.10]$	5.7	75.2 %
	$\mathcal{C}_{9}^{\mathrm{U}}$	-0.74	$[-0.96, -0.51]$	$[-1.15, -0.25]$		

- Significances remain basically unchanged
- Sc. 6 (LFUV V-A, LFU V+A) still describes data well
- Sc. 7 changed → preference for LFUV-$\mathcal{C}_9$ if only V contributions allowed
- Sc. 8 LFUV left-handed lepton structure provides better description with LFU in $\mathcal{C}_9$

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	$\mathcal{C}^{\text{V}}_{10\mu}$	+1.00	[+0.18, +1.59]		
	$\mathcal{C}^{\text{U}}_{9} = \mathcal{C}^{\text{U}}_{10}$	−0.87	[−1.43, −0.14]		
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	$\mathcal{C}^{\text{V}}_{10\mu}$	+0.67	[+0.24, +1.03]	[−1.73, +1.36]		
	$\mathcal{C}^{\text{U}}_{9} = \mathcal{C}^{\text{U}}_{10}$	−0.59	[−0.90, −0.12]	[−1.13, +0.68]		
Sc. 6	$\mathcal{C}^{\text{V}}_{9\mu} = -\mathcal{C}^{\text{V}}_{10\mu}$	−0.50	[−0.61, −0.38]	[−0.72, −0.28]	5.5	71.0 %
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- Sc. 8 LFUV left-handed lepton structure provides better description with LFU in $\mathcal{C}_9$

↓

LFU-NP dependent on structure of **LFUV-NP**

Are we overlooking LFU NP?

New scenarios with **LFU** in RHC

Scenario 9	$\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}$	-0.57	$[-0.73, -0.41]$	$[-0.87, -0.28]$	5.0	60.2 %
	$\mathcal{C}_{10}^{\rm U}$	-0.34	$[-0.60, -0.07]$	$[-0.84, +0.18]$		
Scenario 10	$\mathcal{C}_{9\mu}^{\rm V}$	-0.95	$[-1.13, -0.76]$	$[-1.30, -0.57]$	5.5	69.5 %
	$\mathcal{C}_{10}^{\rm U}$	$+0.27$	$[0.08, 0.47]$	$[-0.09, 0.66]$		
Scenario 11	$\mathcal{C}_{9\mu}^{\rm V}$	-1.03	$[-1.22, -0.84]$	$[-1.38, -0.65]$	5.6	73.6 %
	$\mathcal{C}_{10'}^{\rm U}$	-0.29	$[-0.47, -0.12]$	$[-0.63, 0.05]$		
Scenario 12	$\mathcal{C}_{9'\mu}^{\rm V}$	-0.03	$[-0.22, 0.15]$	$[-0.40, 0.32]$	1.6	15.7 %
	$\mathcal{C}_{10}^{\rm U}$	$+0.41$	$[0.21, 0.63]$	$[0.02, 0.83]$		
Scenario 13	$\mathcal{C}_{9\mu}^{\rm V}$	-1.11	$[-1.28, -0.91]$	$[-1.41, -0.71]$	5.4	78.7 %
	$\mathcal{C}_{9'\mu}^{\rm V}$	$+0.53$	$[0.24, 0.83]$	$[-0.10, 1.11]$		
	$\mathcal{C}_{10}^{\rm U}$	$+0.24$	$[0.01, 0.48]$	$[-0.21, 0.69]$		
	$\mathcal{C}_{10'}^{\rm U}$	-0.04	$[-0.28, 0.20]$	$[-0.48, 0.42]$		

$\mathcal{C}_{10(')}^{\rm U}$ contributions naturally from modified Z couplings

↓

- Sc. 9 via Two-Higgs Doublet
- Sc. 11-13 via vector-like quarks @ tree level

- Extension of **LFU** contributions to RHC (motivated by 2D results) $\Rightarrow$ natural connection to models
- A contribution to $\mathcal{C}_{10}^{\rm U}$ prefers a V lepton structure (opposite to Sc. 8)
- Sc. 11 shows a slight preference for $\mathcal{C}_{10'}^{\rm U}$ over $\mathcal{C}_{10}^{\rm U}$
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New scenarios with LFU in RHC

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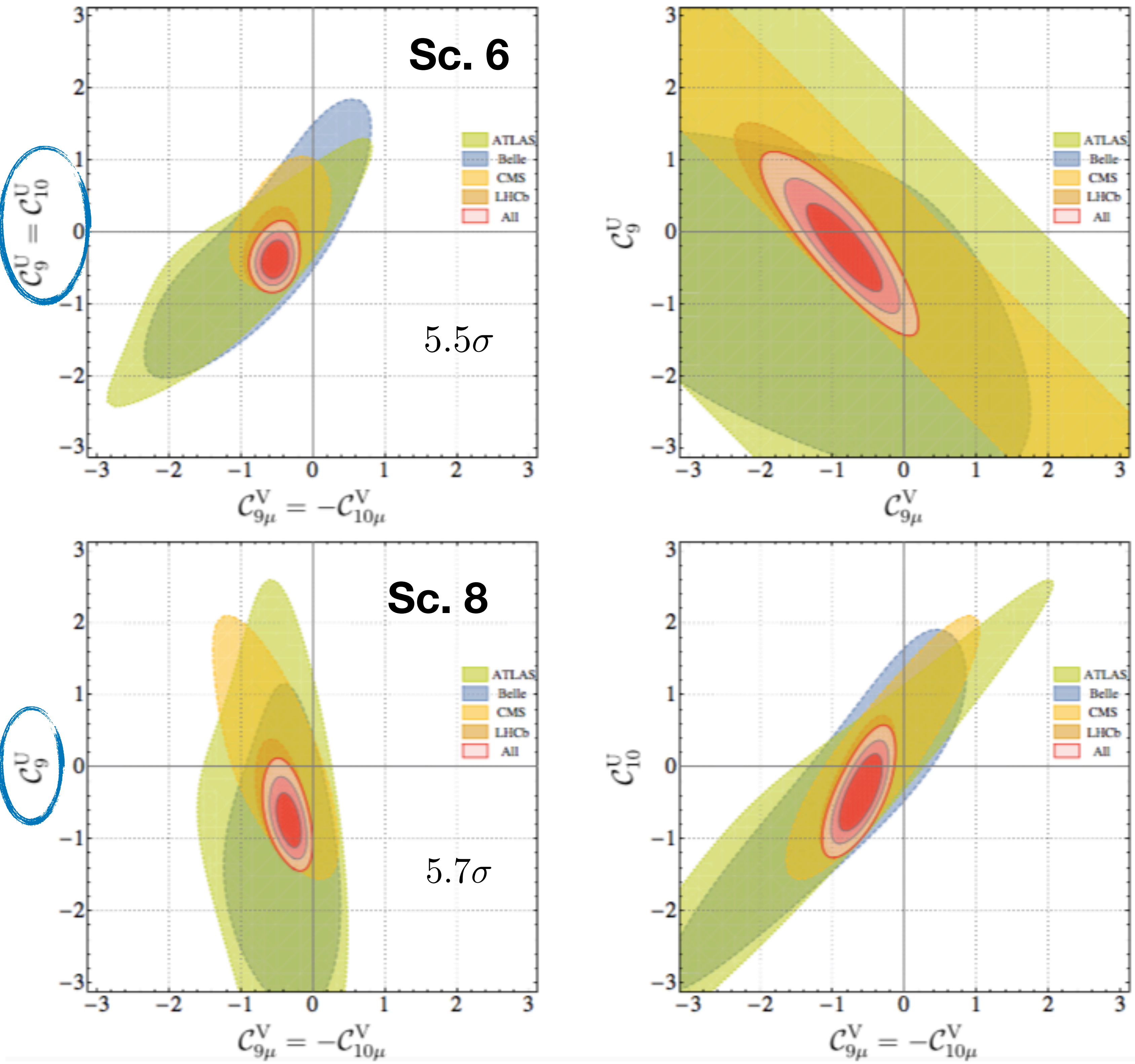
Are we overlooking LFU NP?



Assuming loop-level scale of NP and no MFV

$$\Lambda_i^L \sim \frac{v}{s_w g} \frac{1}{\sqrt{2|V_{tb}V_{ts}^*|}} \frac{1}{|\mathcal{C}_i^{\rm NP}|^{1/2}}$$

Mild preference

Scenario 6: $\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}$, $\mathcal{C}_9^{\rm U} = \mathcal{C}_{10}^{\rm U}$

LFUV-NP $L_q \otimes L_\ell$

$\Lambda_i^{\rm LFUV} \sim 4.0$ TeV

LFU-NP $L_q \otimes R_\ell$

$\Lambda_i^{\rm LFU} \sim 4.6$ TeV

Scenario 8: $\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}$, $\mathcal{C}_9^{\rm U}$

LFUV-NP $L_q \otimes L_\ell$

$\Lambda_i^{\rm LFUV} \sim 5.1$ TeV

LFU-NP $L_q \otimes V_\ell$

$\Lambda_i^{\rm LFU} \sim 3.3$ TeV

[Matias, 19th Lomonosov Conf.]

Discussion on models

Discussion on models

Framework: SMEFT → $\Lambda_{\rm NP} >> m_{t,W,Z}$ [Grzadkowski, Iskrzynski, Misiak, Rosiek; Alonso, Grinstein, Camalich]

Model independent connection between $b \to s\ell\ell$ and $b \to c\tau\nu$ (3.1σ) anomalies through **Sc. 8**

$$\mathcal{C}^{\rm V}_{9\mu} = -\mathcal{C}^{\rm V}_{10\mu} \qquad \mathcal{C}^{\rm U}_{9}$$

↓

- SMEFT with $\mathcal{C}^{(1)} = \mathcal{C}^{(3)}$ in terms of $SU(2)_L$ inv. operators

$$\begin{cases} \mathcal{O}^{(1)}_{ijkl} = [\bar{Q}_i\gamma_\mu Q_j][\bar{L}_k\gamma^\mu L_l] \\ \mathcal{O}^{(3)}_{ijkl} = [\bar{Q}_i\gamma_\mu\sigma^I Q_j][\bar{L}_k\gamma^\mu\sigma^I L_l] \end{cases}$$

[Capdevila, Crivellin, SDG, Hofer, JM, PRL'18]

3rd lepton generation Op. → $R_{D^{(*)}}$

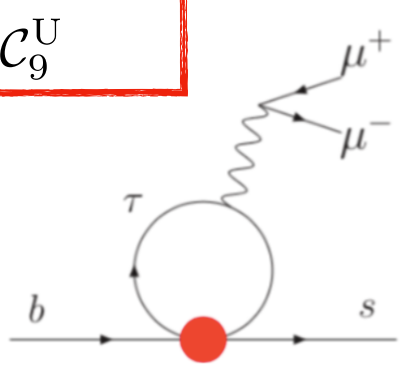
2nd lepton generation Op. → LFUV effect in $b \to s\mu^+\mu^-$

- Constraint from $b \to c\tau\nu$ + invariance → enhance $b \to s\tau^+\tau^-$ **But** also mixes into $\mathcal{O}_9$

↓

Rad Corr w/ insertion of

$\mathcal{O}_{2333}$ → $\mathcal{C}^{\rm U}_{9}$



Assuming **generic flavour structure:**

$$\mathcal{C}^{\rm U}_9 \approx 7.5\left(1-\sqrt{\frac{R_{D^{(*)}}}{R_{D^{(*)}\rm SM}}}\right)\left(1+\frac{\log(\Lambda^2/(1{\rm TeV}^2))}{10.5}\right)$$

Discussion on models

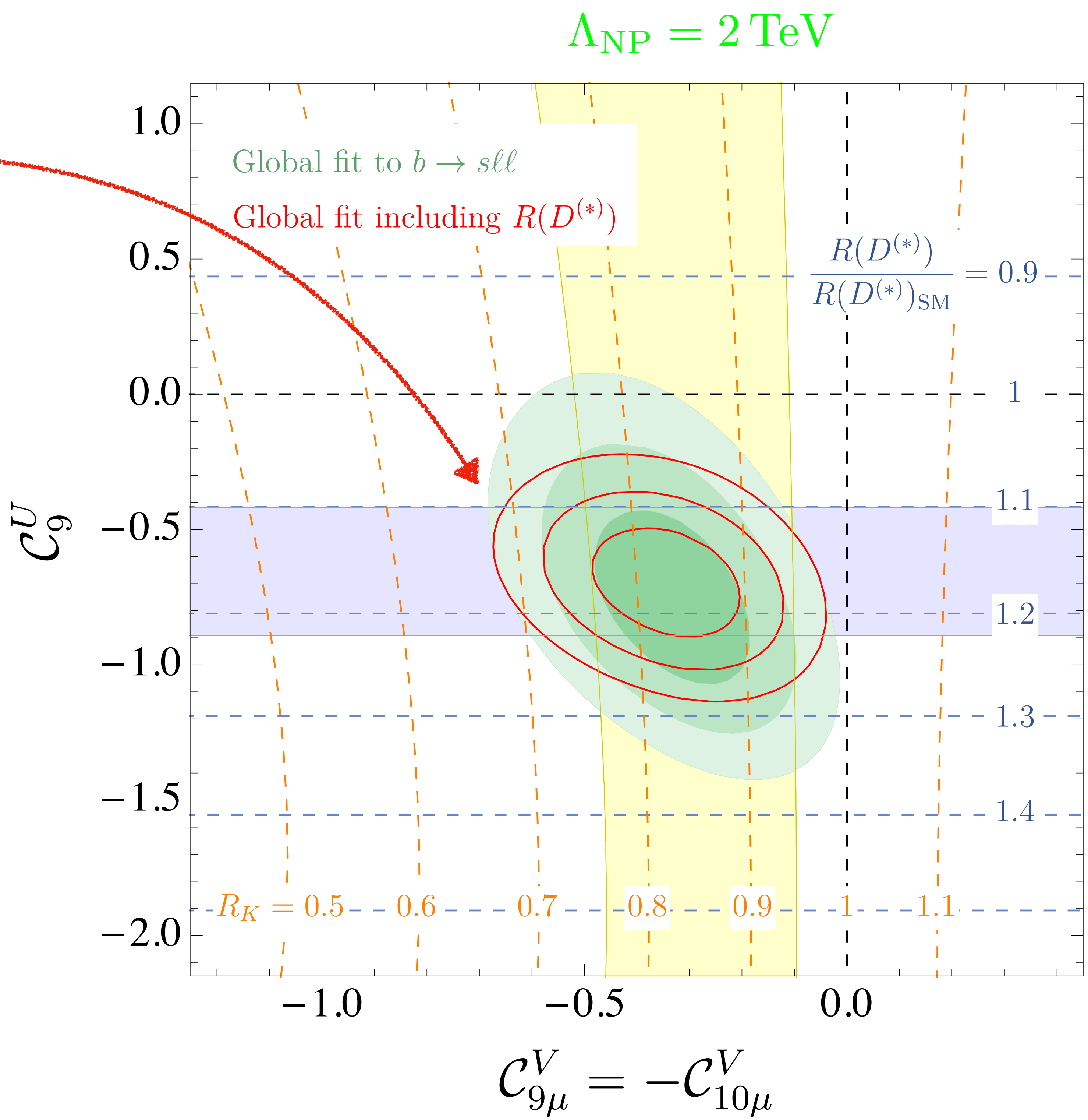
1-3σ CL Regions including $R_{D^{(*)}}$ from Belle

Now Sc. 8 has **7σ** due to inclusion of $R_{D^{(*)}}$

See explicit UV completions by A. Crivellin et al PRL 2019

Blue (**yellow**) band consistent with $R_{D^{(*)}}(R_K)$ @ 2σ

Good agreement with results from Aebischer et al, arXiv:1903.10434



A possible candidate?

A very promising candidate:

Vector leptoquark $SU(2)$ singlet:

$U_1(3,1,2/3)$

Coupled mainly to 3rd generation

See talk from J. Fuentes

Why:

1) Explains charged and neutral anomalies @ same time
2) Allows $\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}$ and generates $\mathcal{C}_9^{\rm U}$
3) Avoids contributions to $b \to s\nu\bar{\nu}$
4) Safe concerning LHC searches

Conclusions and Outlook

- Coherent pattern of deviations in $b \to s\ell\ell$ and also **LFUV** (among other flavour anomalies)
- **Similar big picture (and pattern of NP)** after LHCb and Belle new measurements:
  - 1D hypotheses show same hierarchy (Global fit better explained by $\mathcal{C}_{9\mu}^{\rm NP}$ while LFUV observables prefer $\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{10\mu}^{\rm NP}$)
  - New emerging scenarios including RHC seen in 2D Fits
- New scope for NP ➞ 2 sectors: **LFU**+**LFUV** ➞ same level of significance
- **LFU-NP** structure dependent on **LFUV-NP** structure ($\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}$ provides good description only in presence of $\mathcal{C}_9^{\rm U}$) ➞ Need strategy to disentangle (Q_5)
- Promising candidate ➞ Vector LeptoQuark **U(3,1,2/3)**

Thanks!

Back-up

Are we overlooking LFU NP?

- Change of paradigm! Now same **LFU** piece in electrons, muons and tau different from **LFUV**
- Assumption: hadronic uncertainties well controled → $\mathcal{C}_9^{\rm U}$ is NP
- New mechanism to fulfill $\mathcal{B}(B_s \to \mu^+\mu^-) \propto |\mathcal{C}_{10}^{\rm V} + \mathcal{C}_{10}^{\rm U}|^2$

LFUV observables explained mainly by $\mathcal{C}_{i\mu}^{\rm V}$

LFD observables (like P_5') explained by $\mathcal{C}_{i\mu}^{\rm V} + \mathcal{C}_i^{\rm U}$

$$4\mathrm{D} \to \{\mathcal{C}_{9\mu}^{\rm V}, \mathcal{C}_{10\mu}^{\rm V}, \mathcal{C}_9^{\rm U}, \mathcal{C}_{10}^{\rm U}\}$$

$$3\mathrm{D} \to \{\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}, \mathcal{C}_9^{\rm U}, \mathcal{C}_{10}^{\rm U}\}$$

$$3\mathrm{D} \to \{\mathcal{C}_{9\mu}^{\rm V}, \mathcal{C}_{10\mu}^{\rm V}, \mathcal{C}_9^{\rm U} = \mathcal{C}_{10}^{\rm U}\}$$

$$2\mathrm{D} \to \{\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}, \mathcal{C}_9^{\rm U} = \mathcal{C}_{10}^{\rm U}\}$$

$$2\mathrm{D} \to \{\mathcal{C}_{9\mu}^{\rm V}, \mathcal{C}_9^{\rm U}\}$$

$$2\mathrm{D} \to \{\mathcal{C}_{9\mu}^{\rm V} = -\mathcal{C}_{10\mu}^{\rm V}, \mathcal{C}_9^{\rm U}\}$$

Our strategy: 4D → 3D → 2D

[Algueró et al, 1809.08447]

Correlation Matrices Fits

$$\mathrm{Corr}(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10\mu}^{\rm NP}) = \begin{pmatrix} 1.00 & 0.30 \\ 0.30 & 1.00 \end{pmatrix}$$

$$\mathrm{Corr}(\mathcal{C}_{9\mu}^{\rm NP} = -\mathcal{C}_{9'\mu}, \mathcal{C}_{10\mu}^{\rm NP} = \mathcal{C}_{10'\mu}) = \begin{pmatrix} 1.00 & -0.17 \\ -0.17 & 1.00 \end{pmatrix}$$

$$\mathrm{Corr}(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu}) = \begin{pmatrix} 1.00 & -0.39 \\ -0.39 & 1.00 \end{pmatrix}$$

$$\mathrm{Corr}(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9'\mu} = -\mathcal{C}_{10'\mu}) = \begin{pmatrix} 1.00 & -0.34 \\ -0.34 & 1.00 \end{pmatrix}$$

$$\mathrm{Corr}(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{10'\mu}) = \begin{pmatrix} 1.00 & 0.33 \\ 0.33 & 1.00 \end{pmatrix}$$

$$\mathrm{Corr}(\mathcal{C}_{9\mu}^{\rm NP}, \mathcal{C}_{9e}^{\rm NP}) = \begin{pmatrix} 1.00 & 0.51 \\ 0.51 & 1.00 \end{pmatrix}$$

$$\mathrm{Corr}_{6\mathrm{D}} = \begin{pmatrix} 1.00 & -0.34 & -0.07 & 0.06 & 0.02 & -0.03 \\ -0.34 & 1.00 & 0.24 & -0.06 & 0.04 & 0.24 \\ -0.07 & 0.24 & 1.00 & -0.13 & 0.61 & 0.59 \\ 0.06 & -0.06 & -0.13 & 1.00 & -0.13 & -0.08 \\ 0.02 & 0.04 & 0.61 & -0.13 & 1.00 & 0.85 \\ -0.03 & 0.24 & 0.59 & -0.08 & 0.85 & 1.00 \end{pmatrix}$$

Correlation Matrices Fits

$$\text{Corr}(\mathcal{C}_{9\mu}^{\text{V}}, \mathcal{C}_{9}^{\text{U}} = \mathcal{C}_{10}^{\text{U}}, \mathcal{C}_{10\mu}^{\text{V}}) = \begin{pmatrix} 1.00 & -0.93 & 0.91 \\ -0.93 & 1.00 & -0.94 \\ 0.91 & -0.94 & 1.00 \end{pmatrix}$$

$$\text{Corr}(\mathcal{C}_{9\mu}^{\text{V}} = -\mathcal{C}_{10\mu}^{\text{V}}, \mathcal{C}_{10}^{\text{U}}) = \begin{pmatrix} 1.00 & 0.69 \\ 0.69 & 1.00 \end{pmatrix}$$

$$\text{Corr}(\mathcal{C}_{9\mu}^{\text{V}} = -\mathcal{C}_{10\mu}^{\text{V}}, \mathcal{C}_{9}^{\text{U}} = \mathcal{C}_{10}^{\text{U}}) = \begin{pmatrix} 1.00 & 0.17 \\ 0.17 & 1.00 \end{pmatrix}$$

$$\text{Corr}(\mathcal{C}_{9\mu}^{\text{V}}, \mathcal{C}_{10}^{\text{U}}) = \begin{pmatrix} 1.00 & 0.05 \\ 0.05 & 1.00 \end{pmatrix}$$

$$\text{Corr}(\mathcal{C}_{9\mu}^{\text{V}}, \mathcal{C}_{9}^{\text{U}}) = \begin{pmatrix} 1.00 & -0.85 \\ -0.85 & 1.00 \end{pmatrix}$$

$$\text{Corr}(\mathcal{C}_{9\mu}^{\text{V}}, \mathcal{C}_{10'}^{\text{U}}) = \begin{pmatrix} 1.00 & 0.20 \\ 0.20 & 1.00 \end{pmatrix}$$

Possible UV completions

- $SU(4)\times SU(3)'\times SU(2)_L\times U(1)_Y$ + Vector-like fermions
  L. Di Luzio, A. Greljo, M. Nardecchia, arXiv:1708.08450
- $SU(4)\times U(2)_L\times SU(2)_R$ + vector-like fermions
  L. Calibbi, AC, T. Li, arXiv:1709.00692
- $SU(4)\times SU(4)\times SU(4)$
  M. Bordone, C. Cornella, J. Fuentes-Martin, G. Isidori, arXiv:1712.01368
- $SU(4)\times U(2)_L\times SU(2)_R$ including scalar LQs and light right-handed neutrinos
  J. Heeck, D. Teresi, arXiv:1808.07492
- $SU(8)$ might even explain ε'/ε
  S. Matsuzaki, K. Nishiwaki and K. Yamamoto, arXiv:1806.02312
- $SU(4)\times U(2)\times SU(2)_R$ in RS background
  M. Blanke, AC, arXiv:1801.07256

Towards a decision tree:

R_K and Q_5

Disentangling Scenarios

Significances very similar → What is the best scenario?

Is there any observable that could disentangle among scenarios/hypotheses?

$$Q_{4,5} = P'^{\mu}_{4,5} - P'^{e}_{4,5}$$

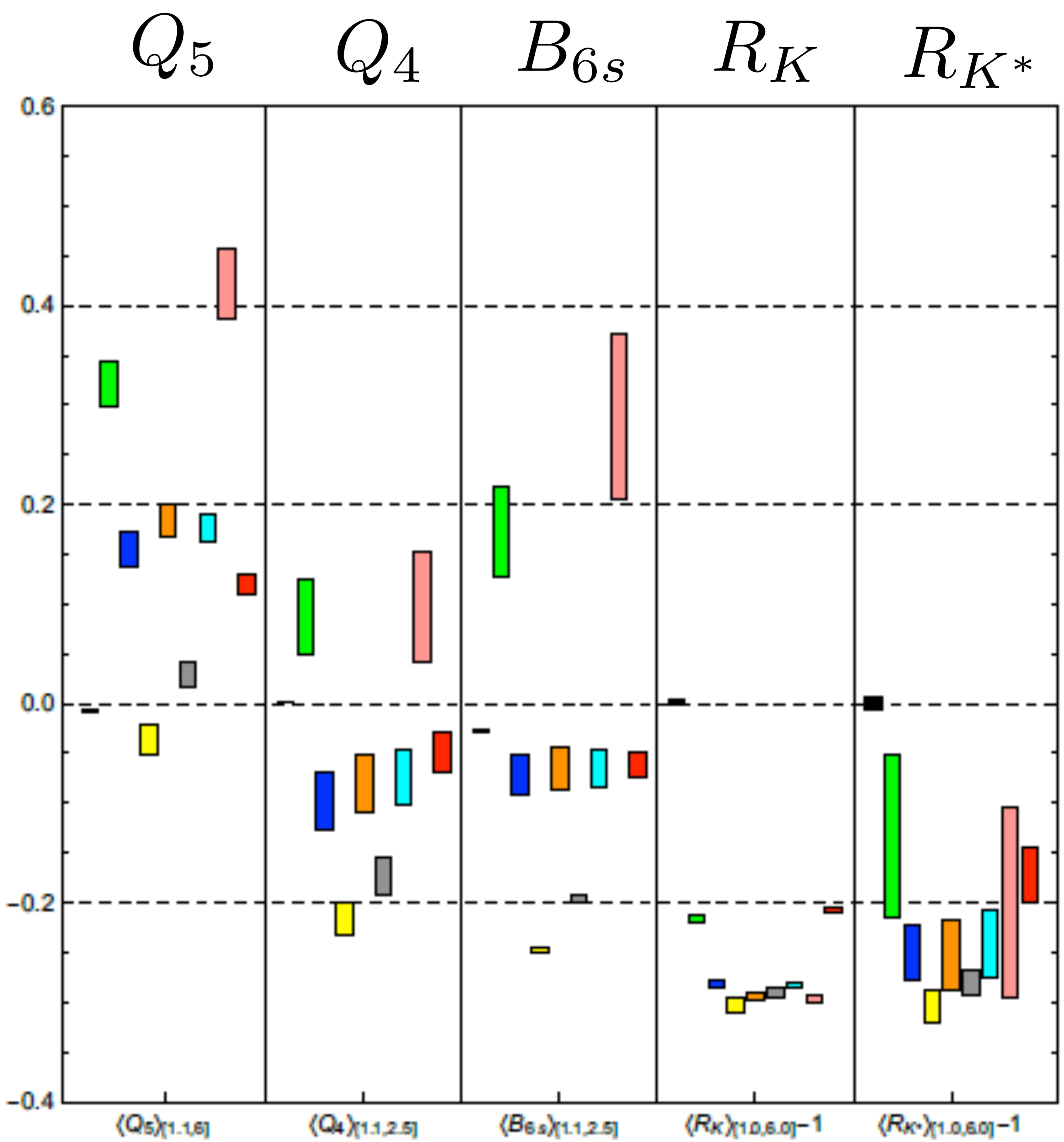
Several **LFUV** observables:

$$B_{6s} = \frac{J^{\mu}_{6s}}{J^{e}_{6s}} - 1$$

$$R_{K^{(*)}} = \frac{BR(B \to K^{(*)}\mu^+\mu^-)}{BR(B \to K^{(*)}e^+e^-)}$$

Disentangling Scenarios

[Algueró et al, 1809.08447]

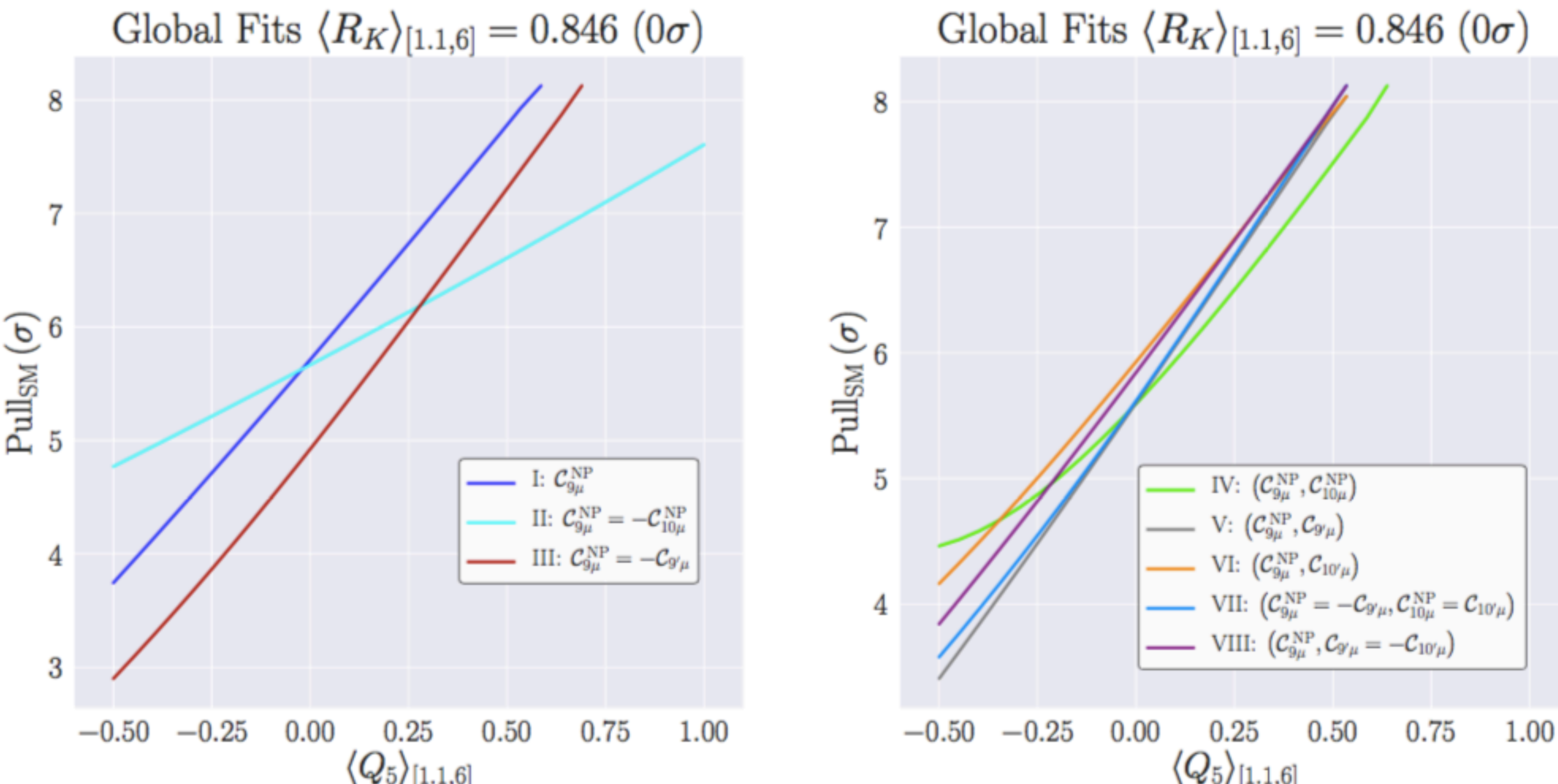


Scenarios	Pull
$\{\mathcal{C}_{9\mu}^{\rm NP}\}\,\&\,(\mathcal{C}^U=0)$	5.6
$\{\mathcal{C}_{9\mu}^{\rm NP}=-\mathcal{C}_{10\mu}^{\rm NP}\}\,\&\,(\mathcal{C}^U=0)$	5.2
$\{\mathcal{C}_{9\mu}^{\rm V},\,\mathcal{C}_{10\mu}^{\rm V},\,\mathcal{C}_{9}^{\rm U},\,\mathcal{C}_{10}^{\rm U}\}$	5.6
$\{\mathcal{C}_{9\mu}^{\rm V}=-\mathcal{C}_{10\mu}^{\rm V},\,\mathcal{C}_{9}^{\rm U},\,\mathcal{C}_{10}^{\rm U}\}$	5.7
$\{\mathcal{C}_{9\mu}^{\rm V},\,\mathcal{C}_{10\mu}^{\rm V},\,\mathcal{C}_{9}^{\rm U}=\mathcal{C}_{10}^{\rm U}\}$	5.2
$\{\mathcal{C}_{9\mu}^{\rm V}=-\mathcal{C}_{10\mu}^{\rm V},\,\mathcal{C}_{9}^{\rm U}=\mathcal{C}_{10}^{\rm U}\}$	5.5
$\{\mathcal{C}_{9\mu}^{\rm V},\,\mathcal{C}_{9}^{\rm U}\}\&(\mathcal{C}_{10\mu}^{\rm V}=\mathcal{C}_{10}^{\rm U}=0)$	5.3
$\{\mathcal{C}_{9\mu}^{\rm V}=-\mathcal{C}_{10\mu}^{\rm V},\,\mathcal{C}_{9}^{\rm U}\}\&(\mathcal{C}_{10}^{\rm U}=0)$	5.7

Disentangling Scenarios

[Algueró et al JHEP07 (2019) 096]

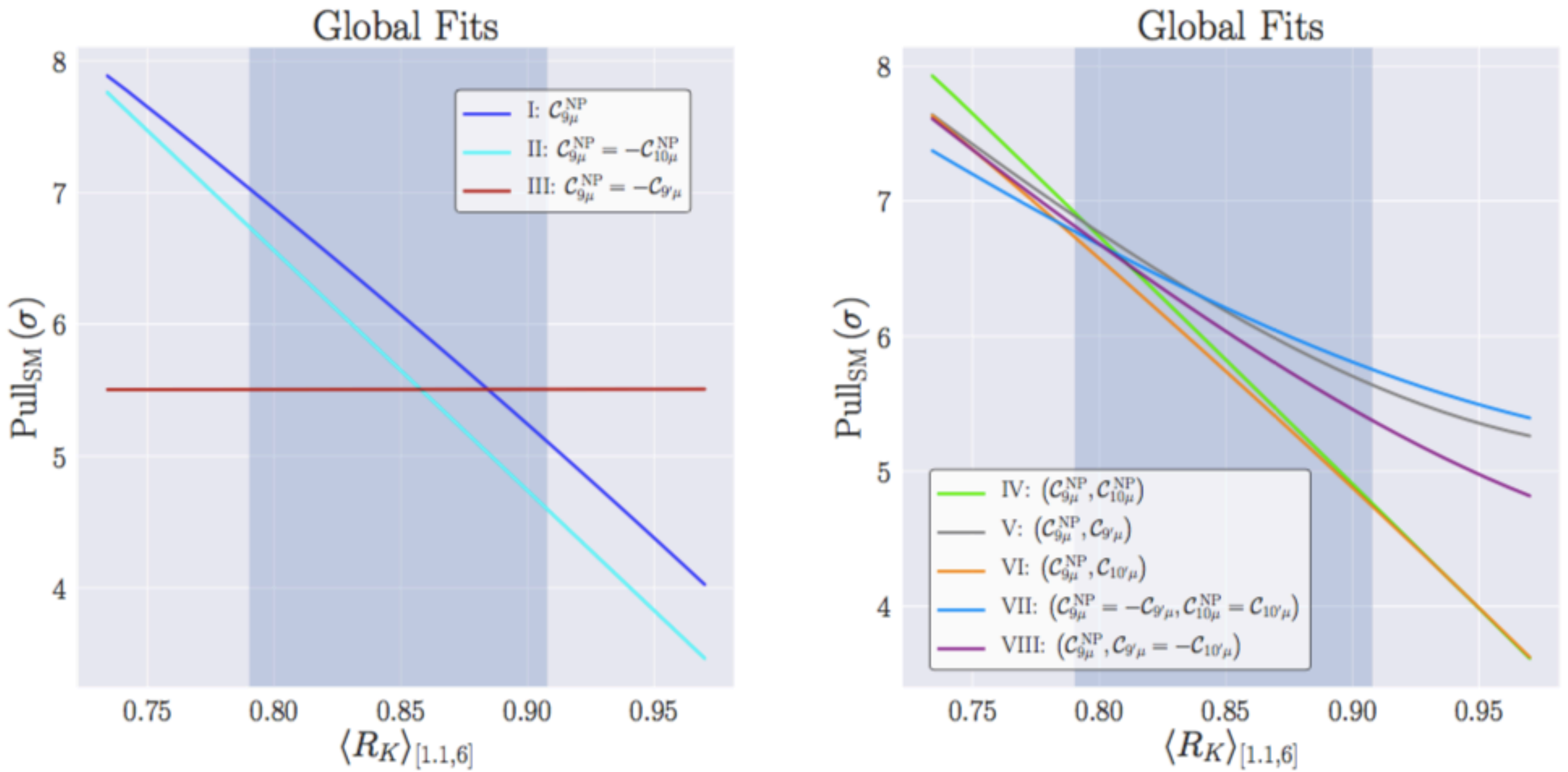
R_K cannot disentangle among scenarios **BUT** together with Q_5 :



$$Q_5 > 0.2 \Rightarrow \mathcal{C}_{9\mu}$$
$$Q_5 < 0 \Rightarrow \mathcal{C}_{9\mu} = -\mathcal{C}_{10\mu}$$

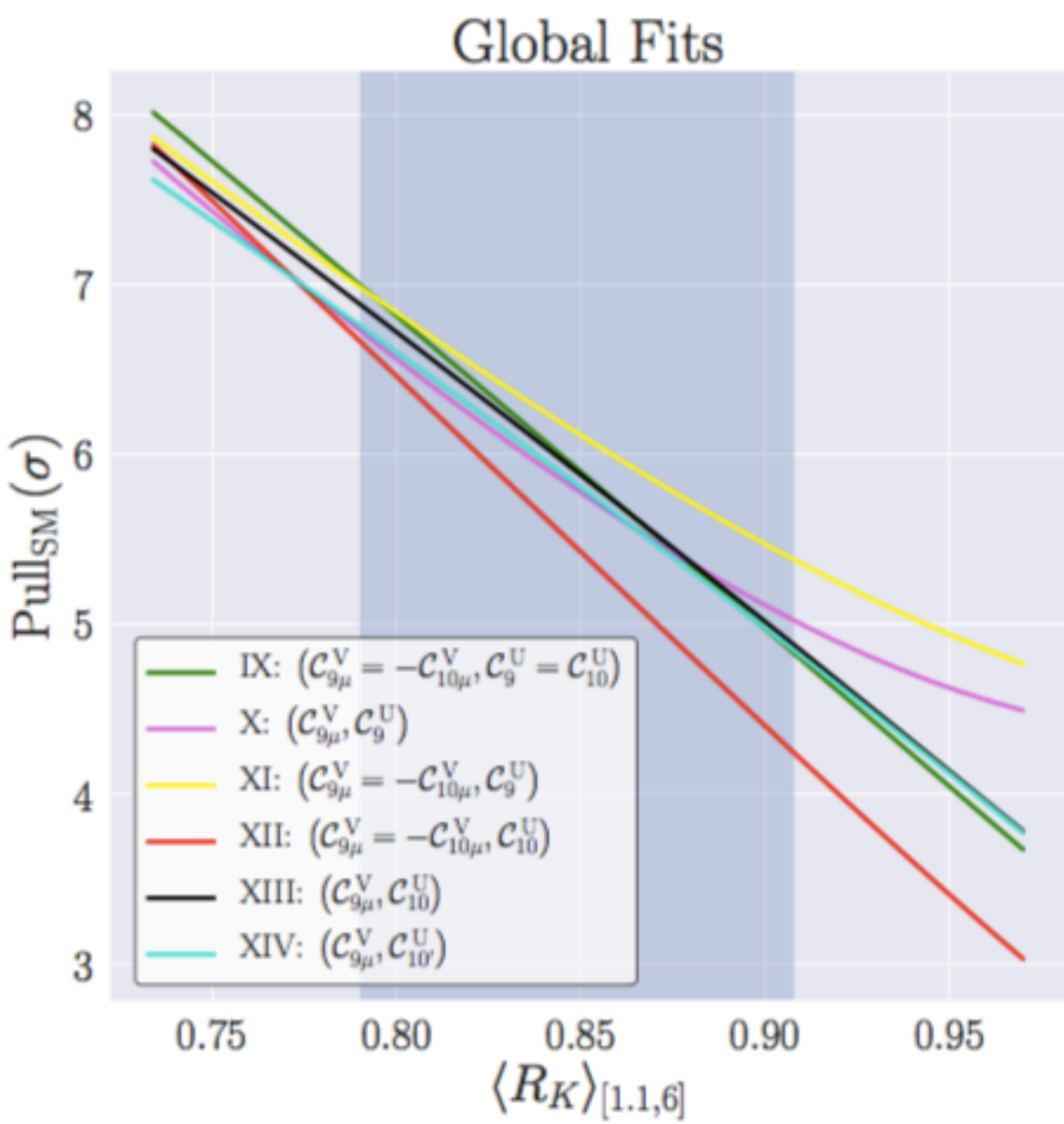
Disentangling Scenarios

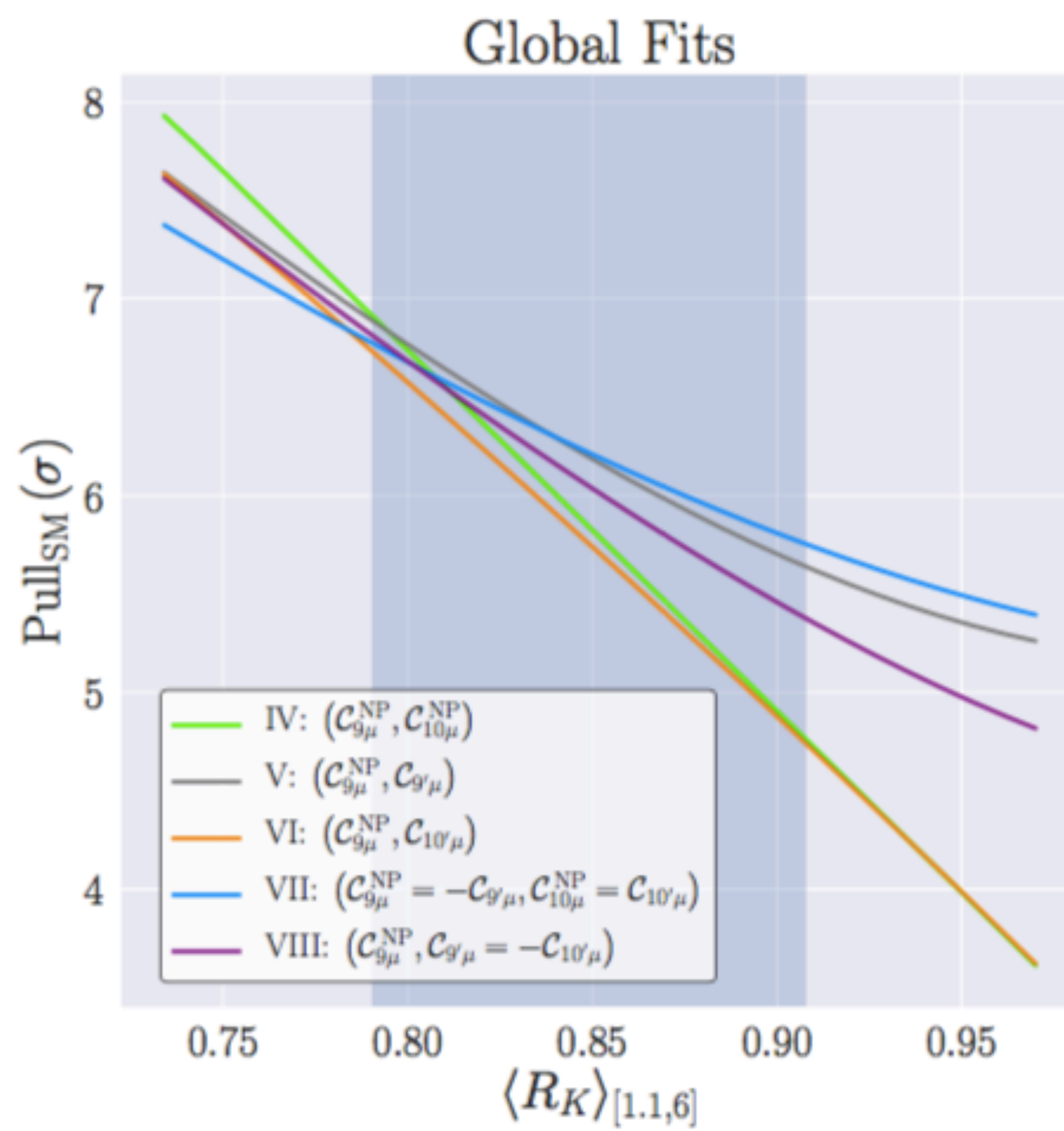
[Alguero et al, 1902.04900]



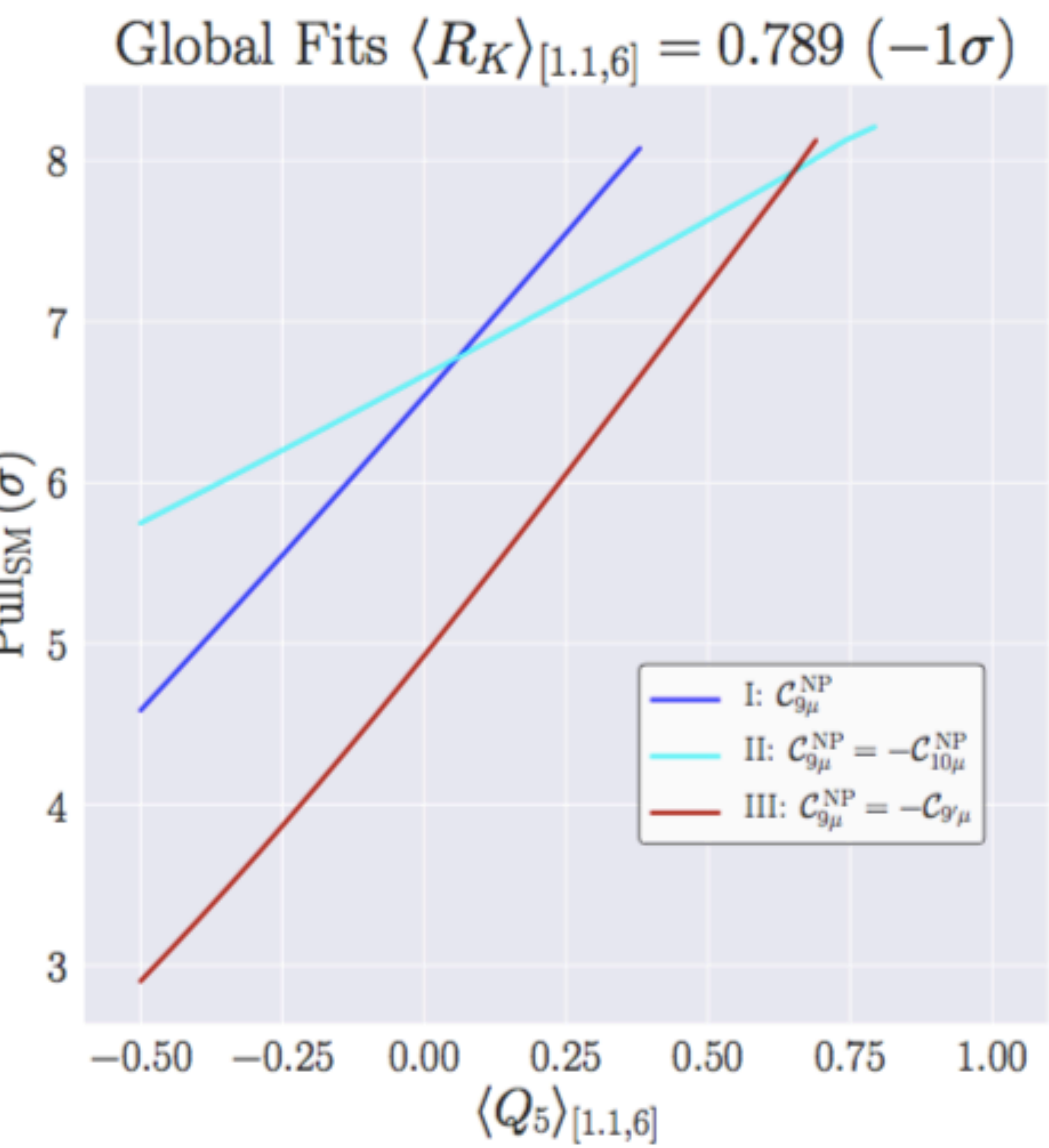
Disentangling Scenarios

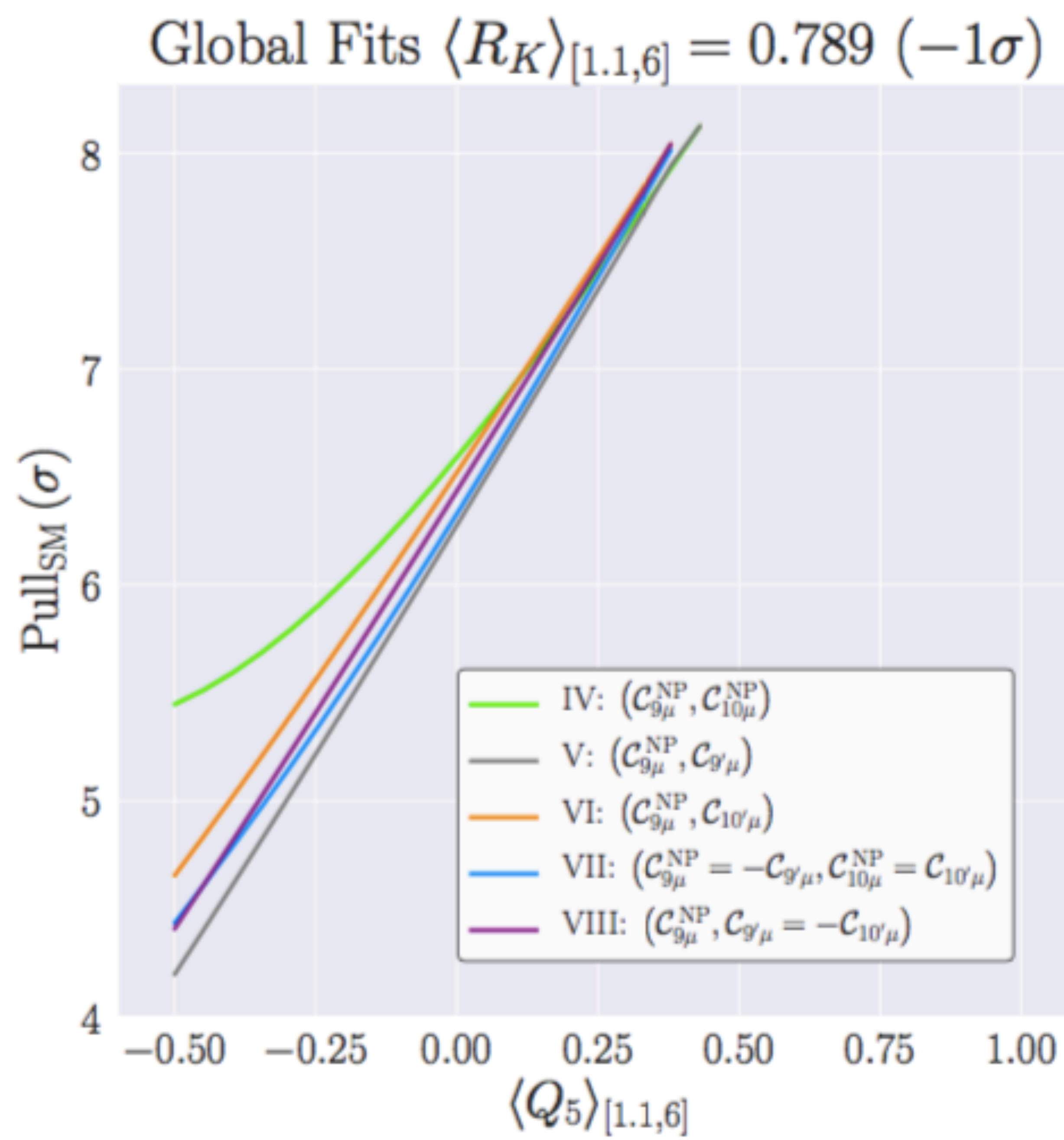
[Alguero et al, 1902.04900]





Disentangling Scenarios





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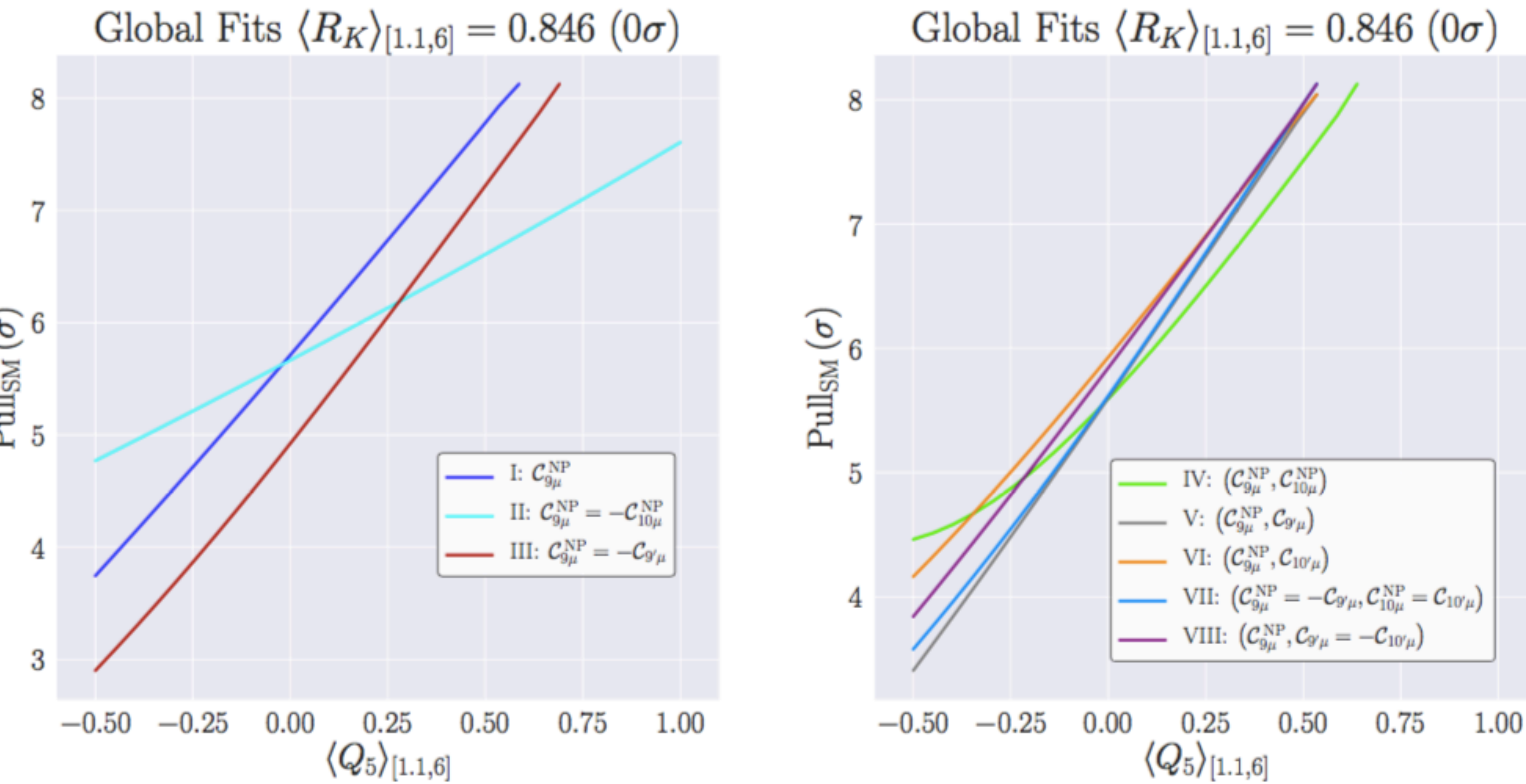

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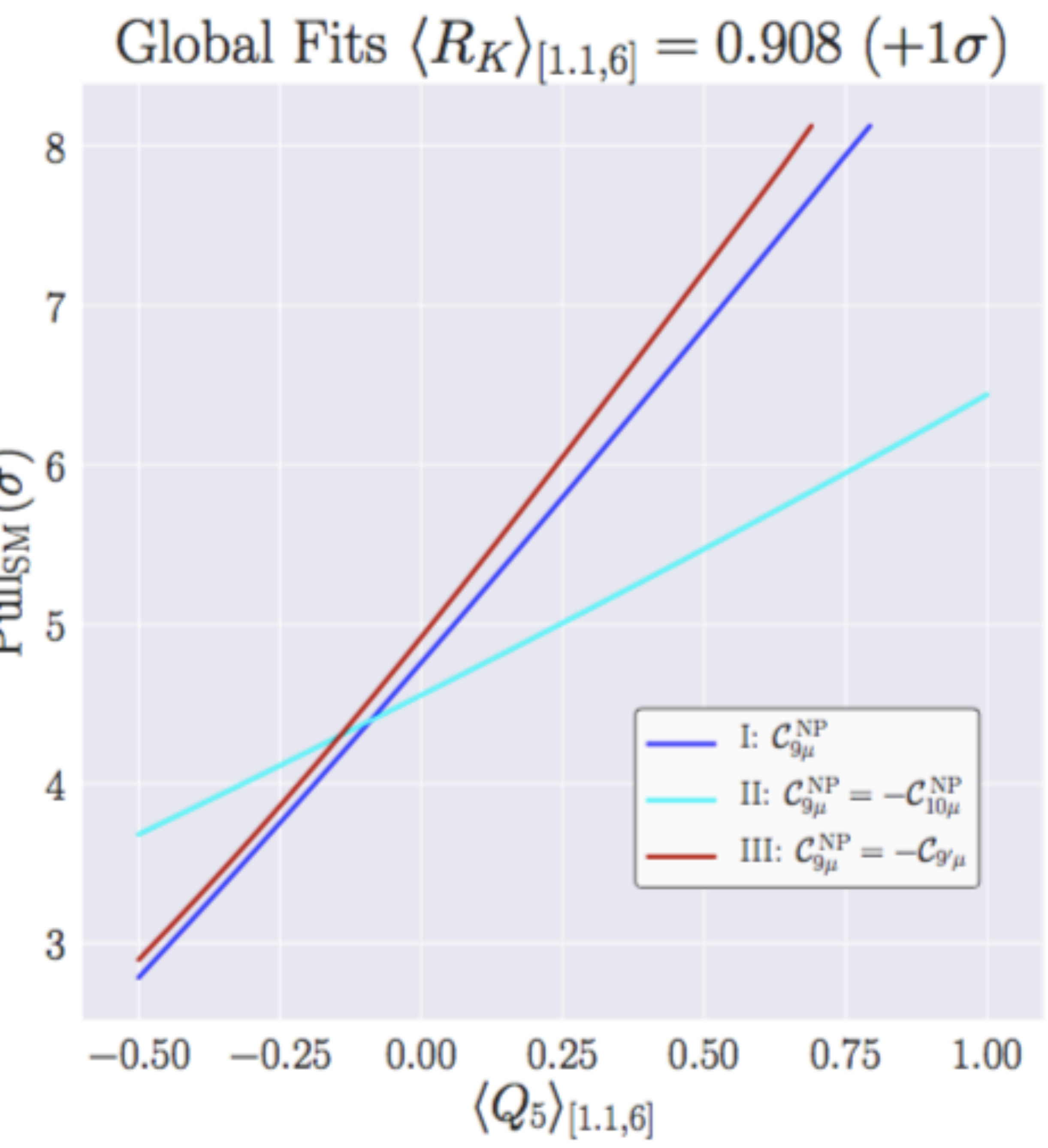

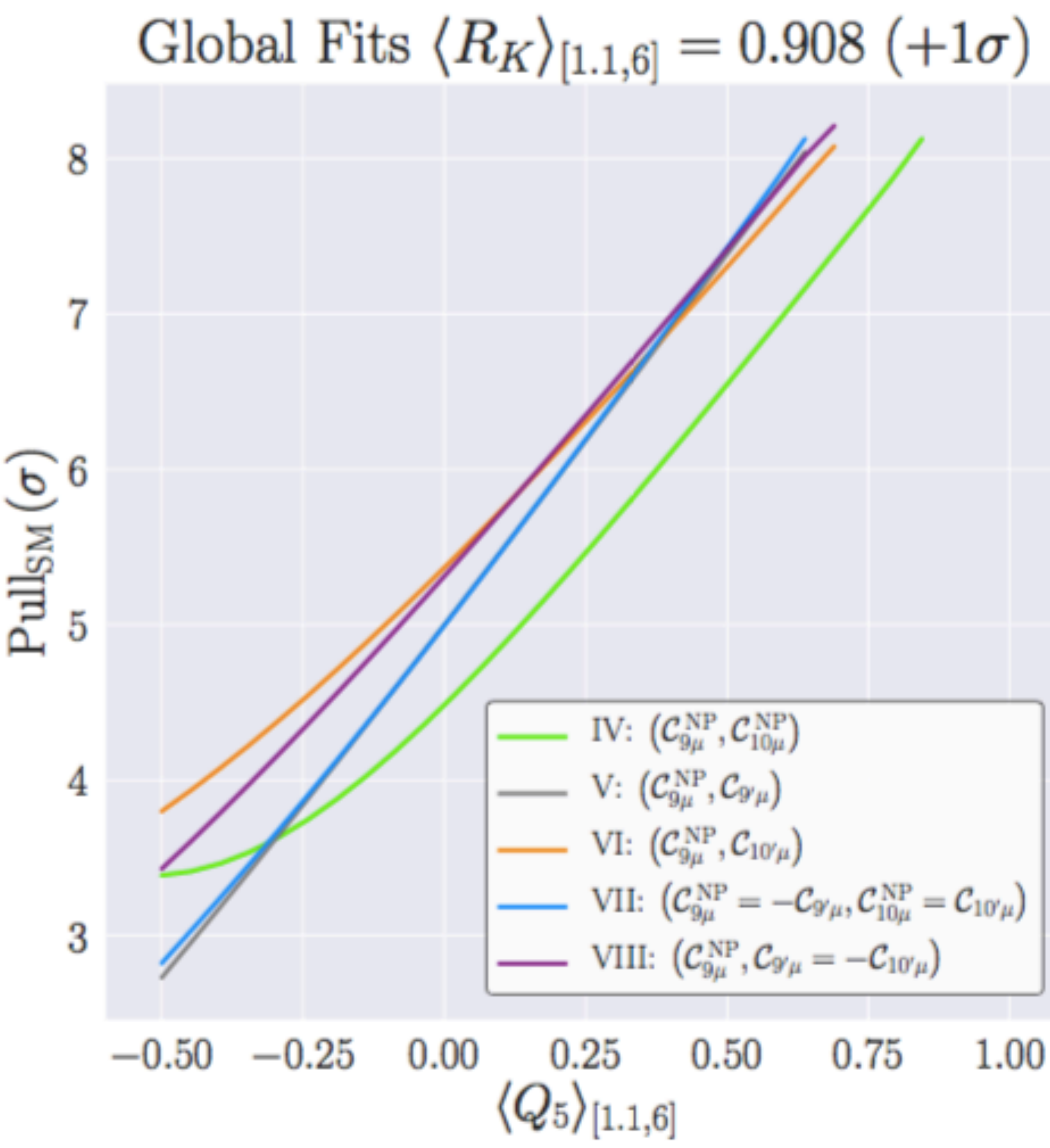

Inner tensions of the global fit

Inner tensions

- We can see how inner tensions behave under NP Hypotheses

- We define pull: $\mathrm{pull}_i^{\mathrm{obs}} = \sqrt{\chi^2_{\mathrm{min}} - \chi^2_{\mathrm{min\,w/o\,obs}\,i}}$

$$\chi^2 = \sum_{ij} (\mathcal{O}^{th} - \mathcal{O}^{exp})_i V_{ij}^{-1} (\mathcal{O}^{th} - \mathcal{O}^{exp})_j \,,$$

$$\chi^2_{\mathrm{w/o\,obs}\,i} = \sum_{i \neq j} (\mathcal{O}^{th} - \mathcal{O}^{exp})_i V_{ij}^{-1} (\mathcal{O}^{th} - \mathcal{O}^{exp})_j \,,$$

[Hyp. I] $\{\mathcal{C}_{9\mu}^{\mathrm{V}}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}}\}$

[Hyp. II] $\{\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}}\}$

[Hyp. III] $\{\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{9'\mu}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{9'\mu}^{\mathrm{NP}}\}$

[Hyp. IV] $\{\mathcal{C}_{9\mu}^{\mathrm{V}}, \mathcal{C}_{10\mu}^{\mathrm{V}}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}}, \mathcal{C}_{10\mu}^{\mathrm{NP}}\}$

[Hyp.V] $\{\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}, \mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}} + 2\mathcal{C}_{9e}^{\mathrm{NP}}, \mathcal{C}_{9e}^{\mathrm{NP}} = \mathcal{C}_{10e}^{\mathrm{NP}}\}$

[Hyp.VI] $\{\mathcal{C}_{9\mu}^{\mathrm{V}}, \mathcal{C}_{9}^{\mathrm{U}}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}}, \mathcal{C}_{9e}^{\mathrm{NP}}\}$

[Hyp.VII] $\{\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}, \mathcal{C}_{9}^{\mathrm{U}}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}} + \mathcal{C}_{9e}^{\mathrm{NP}}, \mathcal{C}_{10\mu}^{\mathrm{NP}}, \mathcal{C}_{9e}^{\mathrm{NP}}\}$

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Reduction 👍

No reduction or worse 👎

$$\chi^2 = \sum_{ij} (\mathcal{O}^{th} - \mathcal{O}^{exp})_i V_{ij}^{-1} (\mathcal{O}^{th} - \mathcal{O}^{exp})_j \,,$$

$$\chi^2_{\mathrm{w/o\,obs}\,i} = \sum_{i \neq j} (\mathcal{O}^{th} - \mathcal{O}^{exp})_i V_{ij}^{-1} (\mathcal{O}^{th} - \mathcal{O}^{exp})_j \,,$$

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[Hyp.V] $\{\mathcal{C}_{9\mu}^{\mathrm{V}} = -\mathcal{C}_{10\mu}^{\mathrm{V}}, \mathcal{C}_{9}^{\mathrm{U}} = \mathcal{C}_{10}^{\mathrm{U}}\} \to \{\mathcal{C}_{9\mu}^{\mathrm{NP}} = -\mathcal{C}_{10\mu}^{\mathrm{NP}} + 2\mathcal{C}_{9e}^{\mathrm{NP}}, \mathcal{C}_{9e}^{\mathrm{NP}} = \mathcal{C}_{10e}^{\mathrm{NP}}\}$

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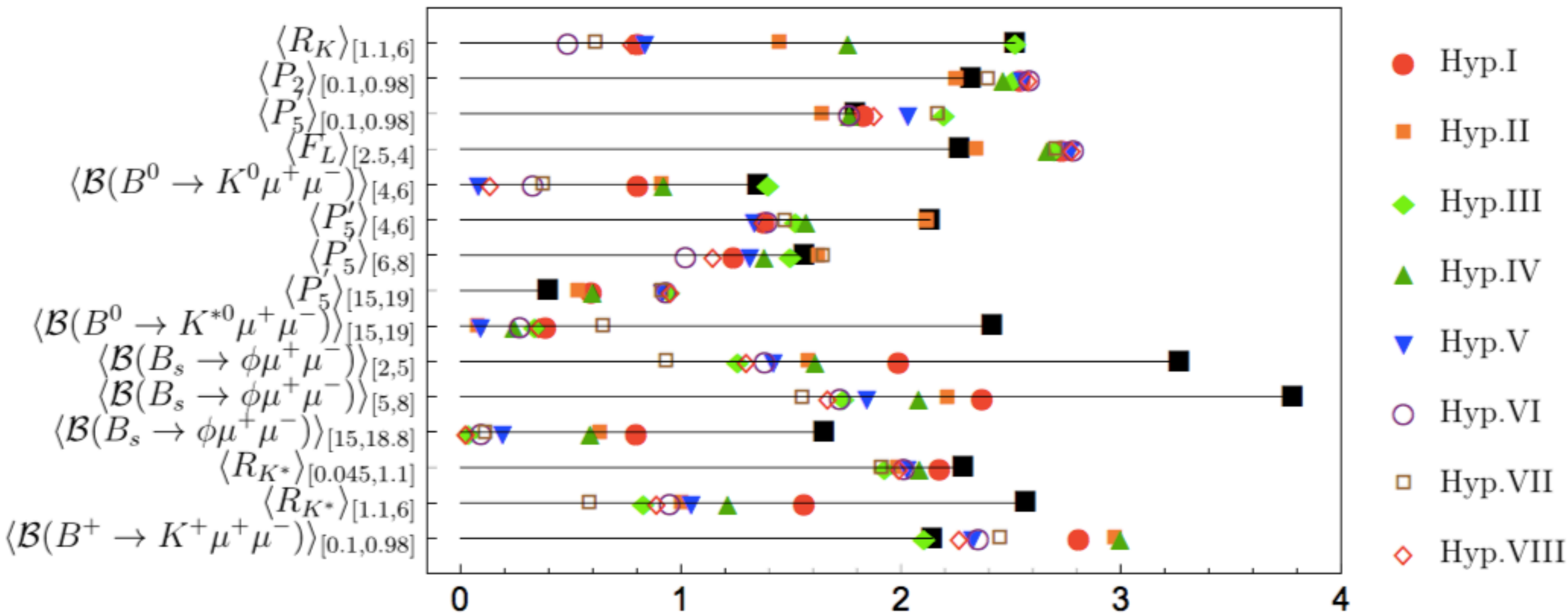
Inner tensions

- List of observables with larger pull_i^{obs} in SM (black square)

[Alguero et al, 1902.04900]



Inner tensions

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[Alguero et al, 1902.04900]