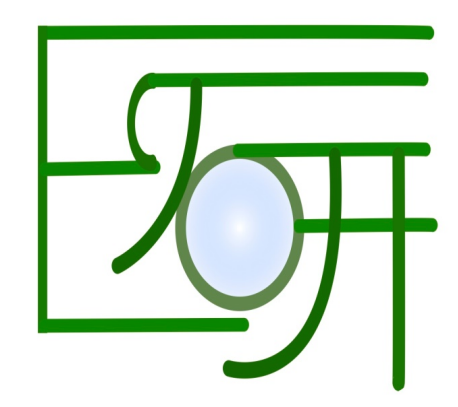




# Bayesian fit analysis to full distribution data of $B \rightarrow D^{(*)} \ell \nu$ : $|V_{cb}|$ determination and new physics constraints



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## Contents

We performed the Bayesian fit to determine the  $B \rightarrow D^{(*)}$  hadronic transition form factors, using the full distribution data from Belle and theoretical constraints. The fitted  $V_{cb}$  is consistent with the HFLAG average and the  $V_{cb}$  puzzle can not be resolved. Based on the fitted form factors, we discuss the  $B \rightarrow D^{(*)} \tau \nu$  process where the  $4\sigma$  level discrepancy between the SM prediction and the experimental average is known. Implications to the collider physic of the NP interpretation of  $R(D^{(*)})$  anomaly is discussed.

## Motivation

We want to determine  $V_{cb}$  accurately

Q. What is  $V_{cb}$ ?

A. One of a CKM matrix element

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

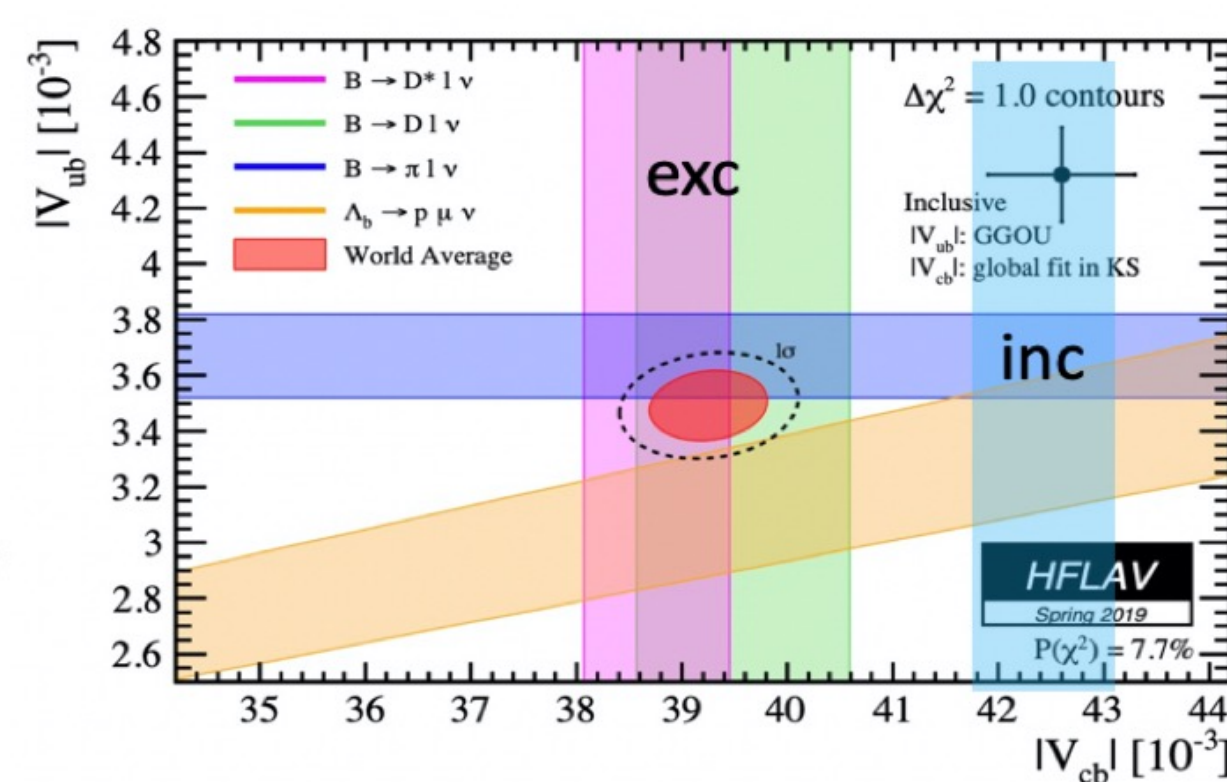
Q. Why we need to improve it?

A. There is deviation between inclusive and exclusive  $V_{cb}$

inclusive  $V_{cb}$ : determined from  $B \rightarrow X_c \ell \nu$  mode

Xc: all hadronic state containing a charmed hadron. 2-3 $\sigma$  deviation

exclusive  $V_{cb}$ : determined from  $B \rightarrow D^{(*)} \ell \nu$  mode

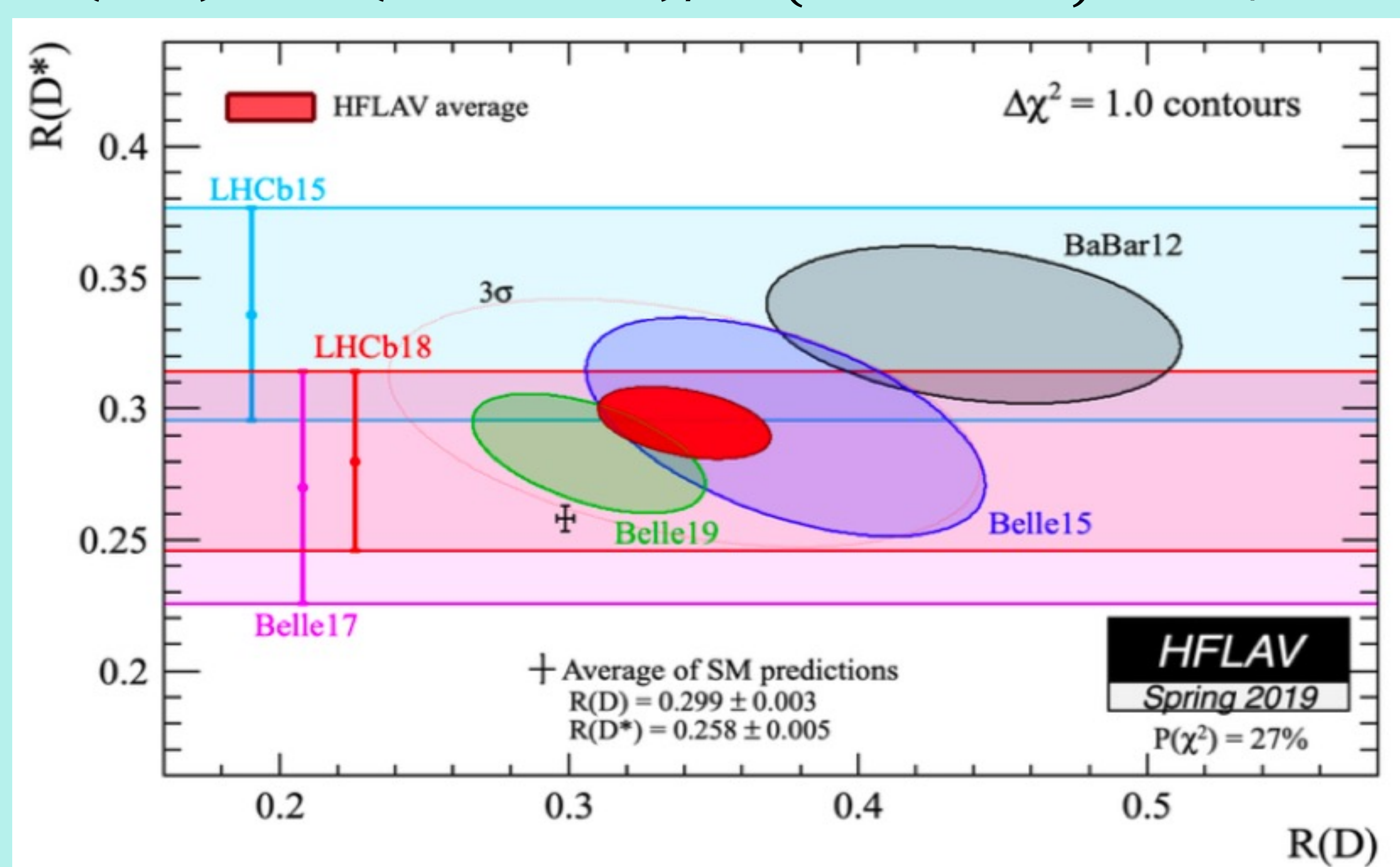


Q. How to improve  $V_{cb}$

A. We will fit  $V_{cb}$  with more accurate Form Factors (FFs) for  $B \rightarrow D^{(*)}$

## Suggestive anomalies in $R(D^{(*)})$

$$R(D^{(*)}) = Br(B \rightarrow D^{(*)} \tau \nu) / Br(B \rightarrow D^{(*)} \ell \nu) \quad \ell = \mu, e$$



## Vcb determination

### Form Factors in $B \rightarrow D, D^*$ transition

#### Conventional parametrization

- CNL parametrization (Caprini, Lellouch, Neubert 1997)  
-> too much simplified
- BGL parametrization (Boyd, Grinstein, Lebed 1997)  
-> too general to use for the NP analysis

#### Our approach

- General Heavy Quark Effective Theory(HQET) (Jung, Straub 2018)

$$\langle D | \bar{c} \gamma^\mu b | B \rangle_{\text{HQET}} = \sqrt{m_B m_D} [h_+(v+v')^\mu + h_-(v-v')^\mu],$$

$$\langle D^* | \bar{c} \gamma^\mu \gamma^5 b | B \rangle_{\text{HQET}} = \sqrt{m_B m_{D^*}} [h_{A_1}(w+1)\epsilon^{*\mu} - (\epsilon^* \cdot v)(h_{A_2}v^\mu + h_{A_3}v'^\mu)],$$

$$v^\mu = p_B^\mu / m_B, v'^\mu = p_{D^{(*)}}^\mu / m_{D^{(*)}}, w = v \cdot v' = (m_B^2 + m_{D^{(*)}}^2 - q^2) / (2m_B m_{D^{(*)}}),$$

Main difference:  $h_+$ ,  $h_-$ ,  $h_{A_1} \dots$  are described by common parameters

We want to determine  $h_v$  precisely.

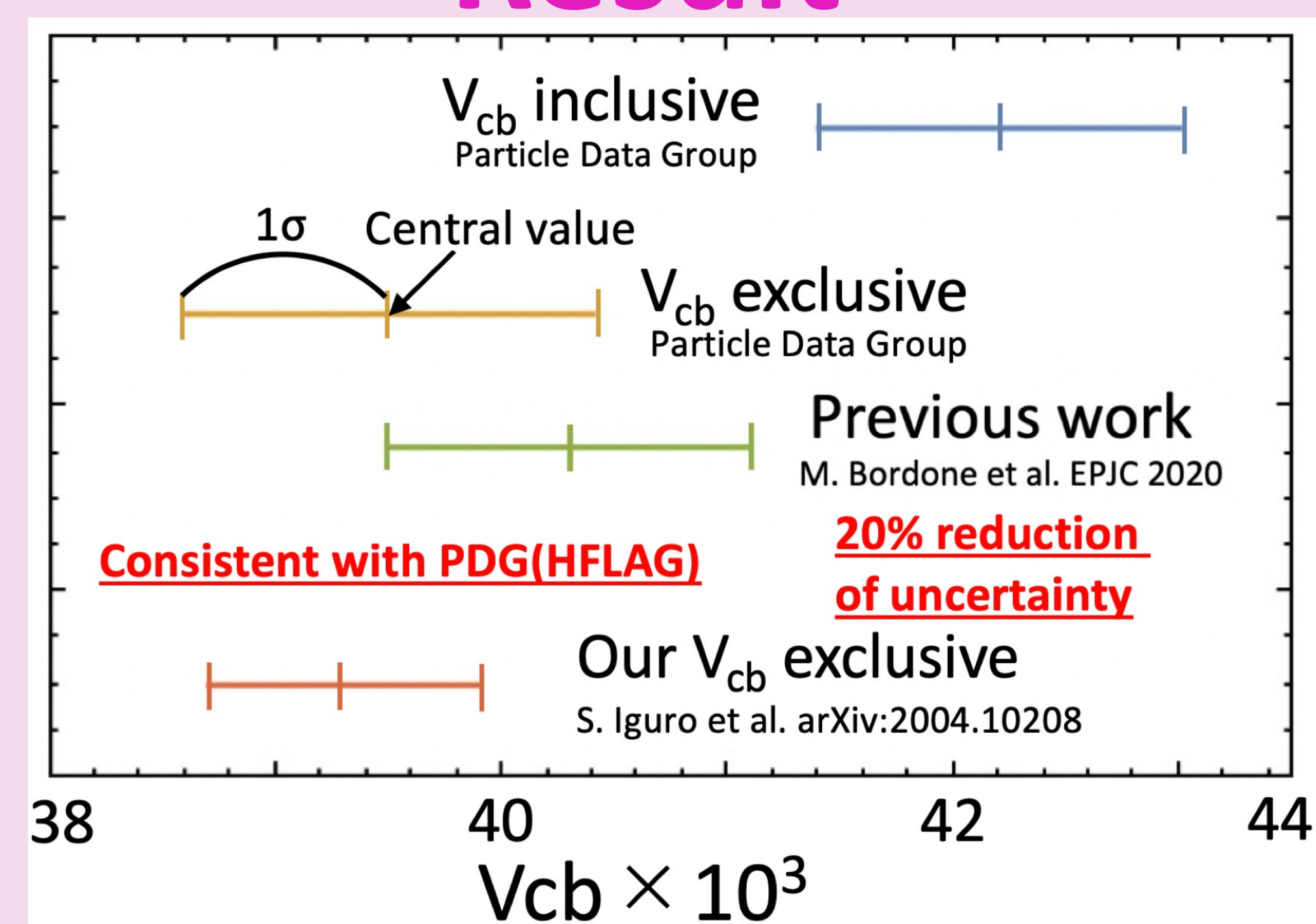
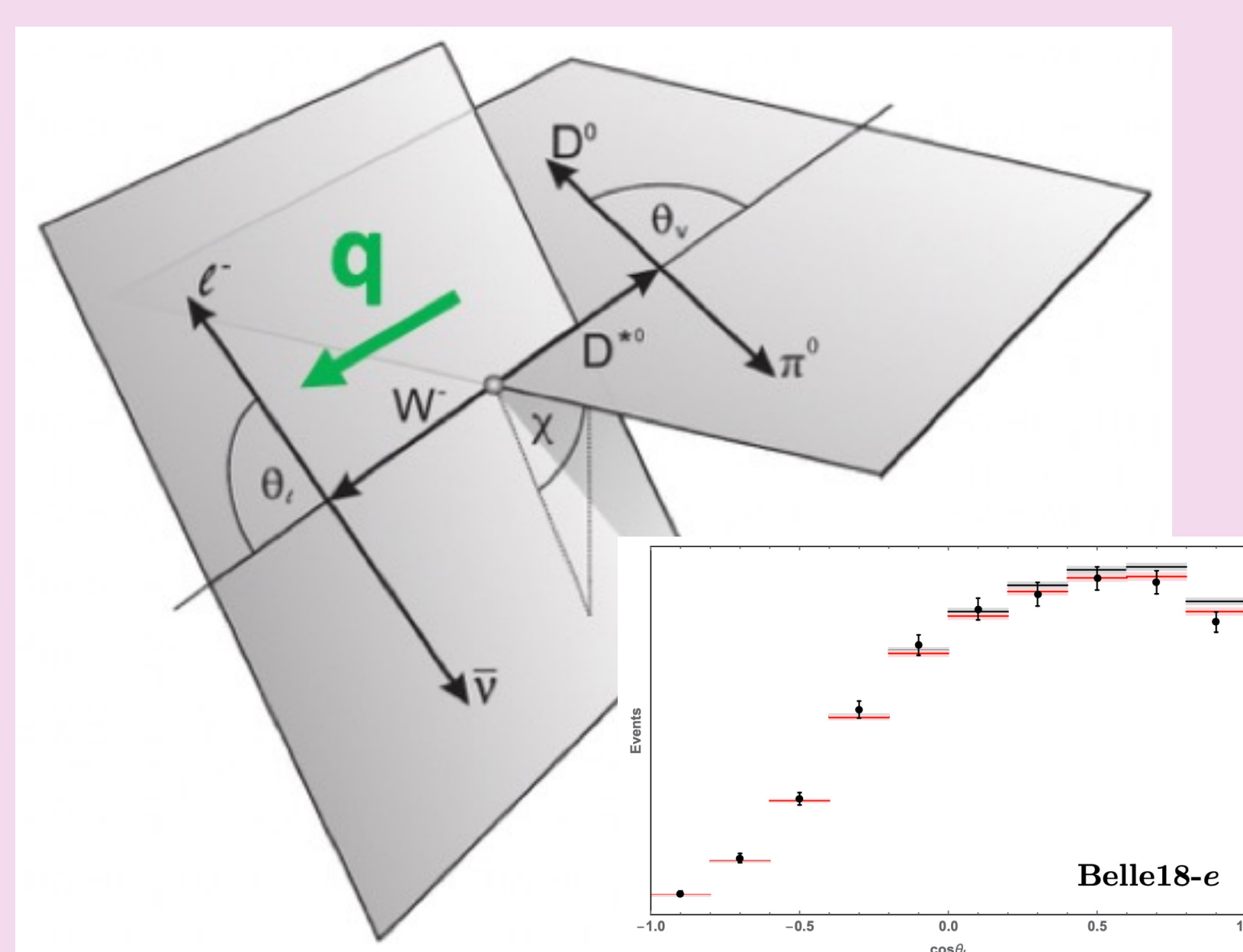
$$\hat{h}_X = \hat{h}_{X,0} + \frac{\alpha_s}{\pi} \delta \hat{h}_{X,\alpha_s} + \frac{\bar{\Lambda}}{2m_b} \delta \hat{h}_{X,m_b} + \frac{\bar{\Lambda}}{2m_c} \delta \hat{h}_{X,m_c} + \left( \frac{\bar{\Lambda}}{2m_c} \right)^2 \delta \hat{h}_{X,m_c^2},$$

M. Bordone et al. EPJC 2020

## What's new

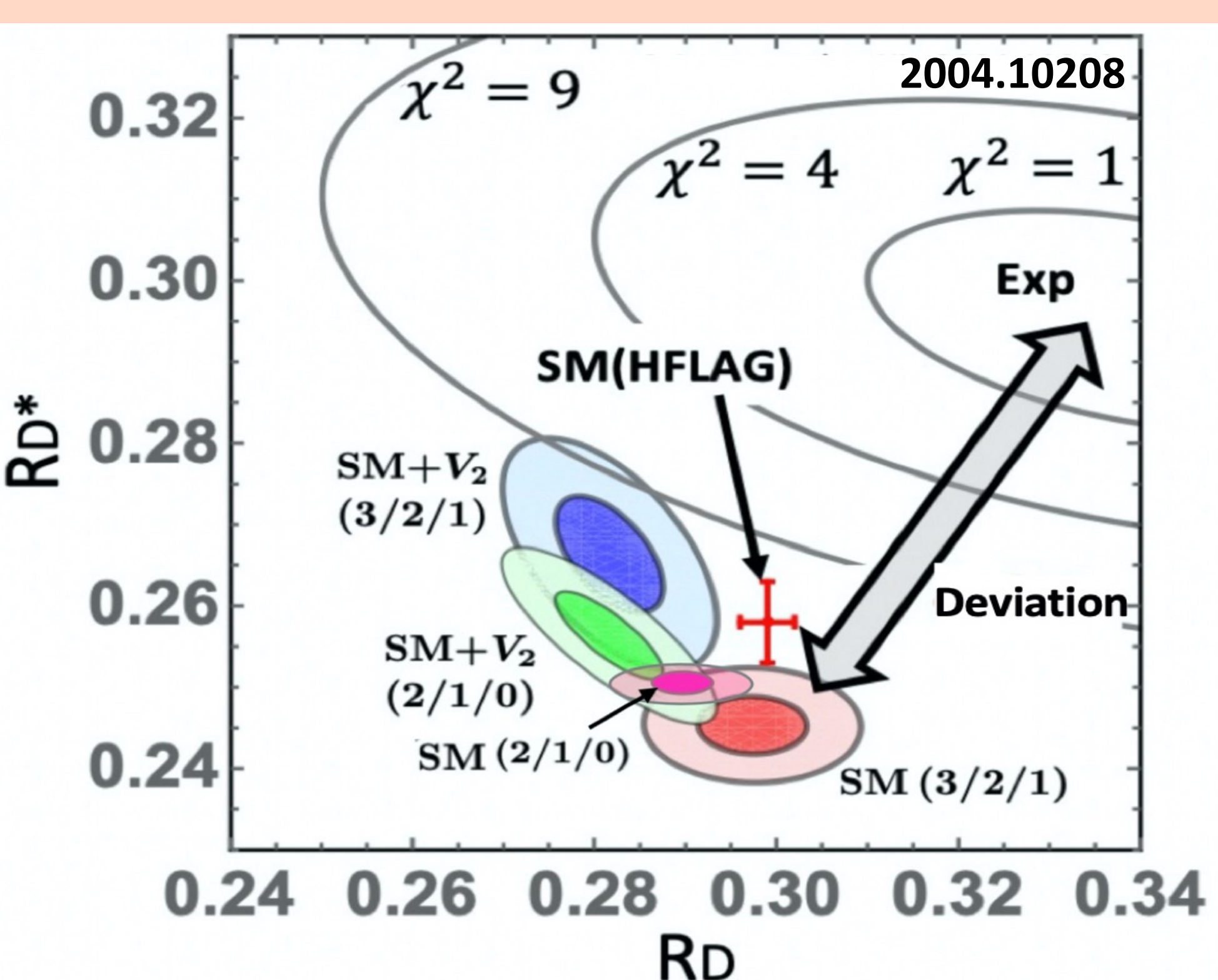
We also included the angular distribution data and performed the Bayesian fit to fix the form factors.

## Result



## $B \rightarrow D^{(*)} \tau \nu$ observables

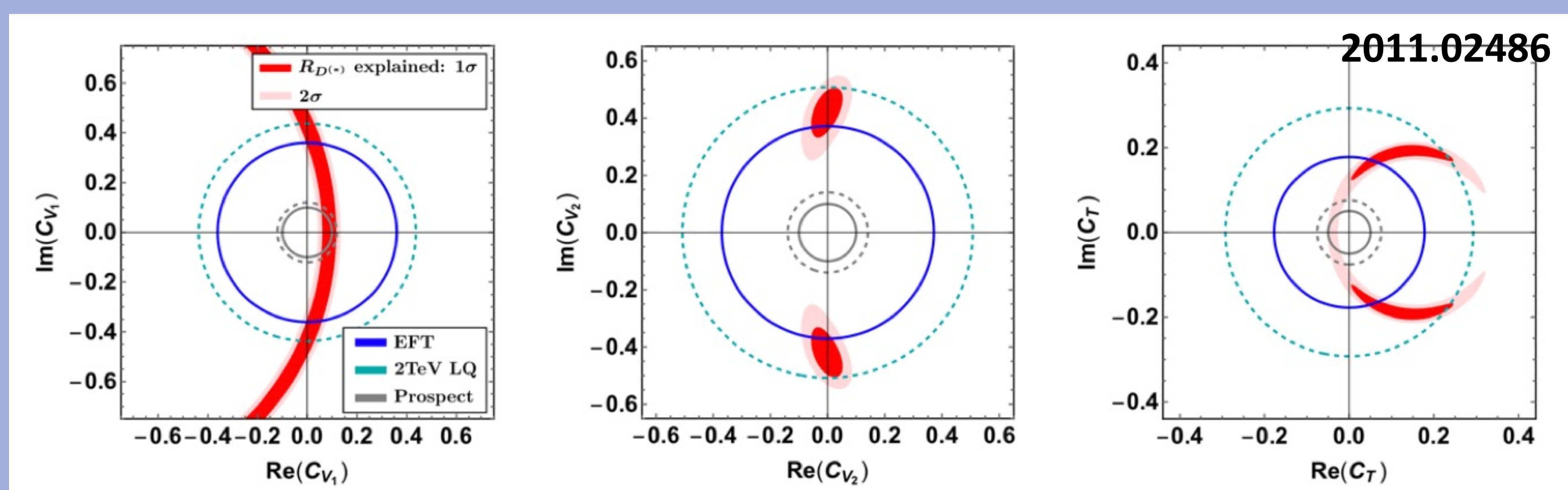
4.2 $\sigma$  deviation is found



## Implication for LHC

High pT mono  $\tau$  signal

$pp \rightarrow bc \rightarrow \tau \nu$  process



Mediator mass dependence is significant!