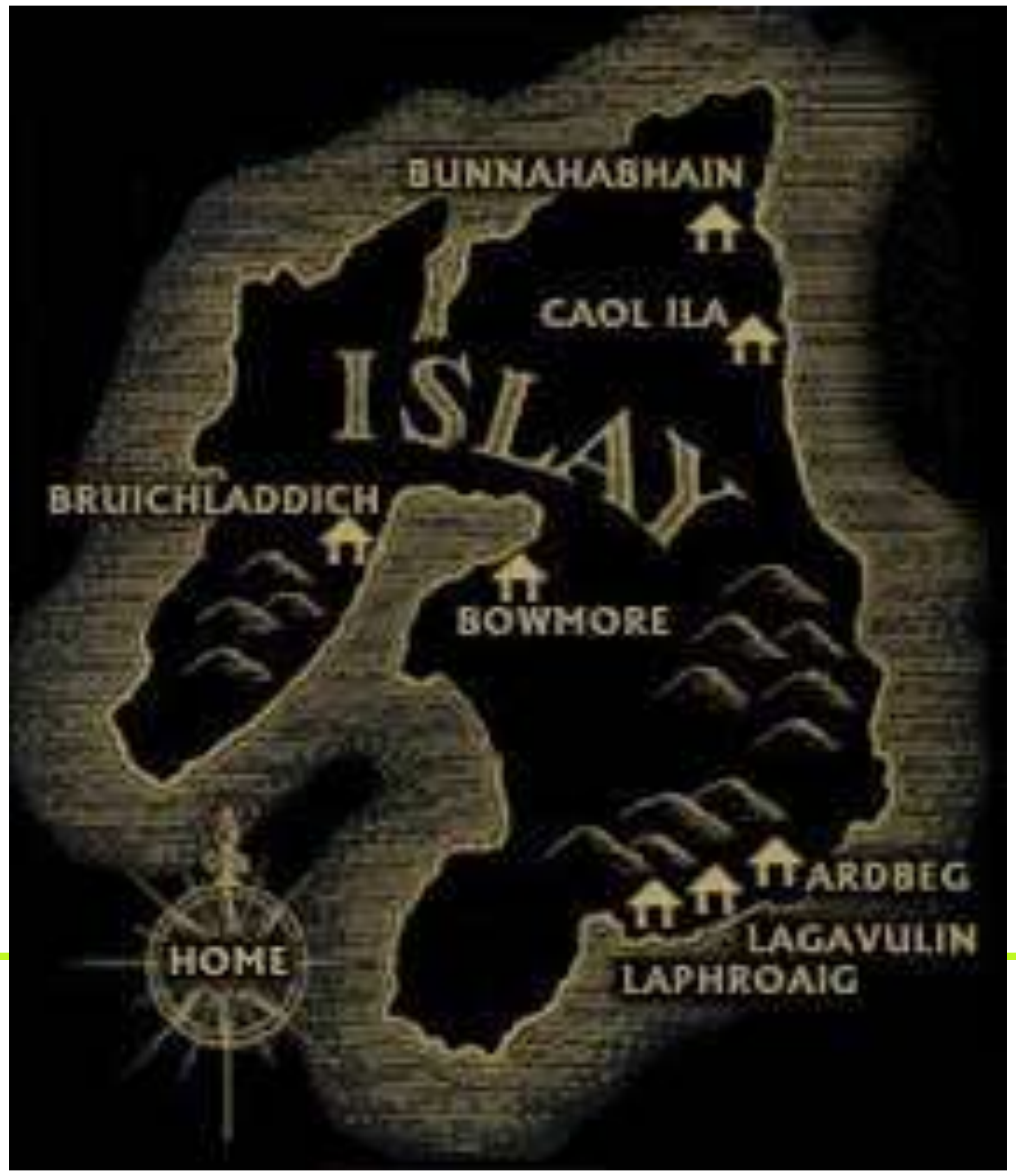
THEORY MOTIVATION:
WHAT MEASUREMENTS ARE NEEDED?

ALEXANDER LENZ SIEGEN UNIVERSITY 16TH SEPTEMBER 2021

Desired Observables:

Heavy Quarks and Leptons

Broad and interesting field



Due to my limited knowledge I will concentrate on observables related to b and c decays

See all the excellent talks presented at HQL2021

ν : J. Turner, S. Hickford, V. Singh, M. Nisa, R. Biondi, C. Ternes, Q. Wu, E. Atkin, Y. Oh, B.Yue,
Spectroscopy, g-2, top, Kaon….

Desired Observables:

Even within b and c quark decay observables

Huge number of interesting observables

Only 25 - 5 minutes time

Desired Observables:

- **The usual suspects** - can be found in any of the numerous future collider reports

- **Not so well-known**

- **Surprise/ Underdog**

The usual Suspects:

flavour anomalies

- Independent experimental check of **anomalies**: ATLAS, CMS, Belle II plus higher precision, R_X,…

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- High precision in γ^{CKM}, V_{CKM} in particular V_{cb} and V_{ub}, but maybe also direct info on V_{tx},...

D0 dimuon anomaly

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See e.g. Fleischer et al. or

Artuso, Borissov, AL 1511.09466

Peng $\approx \pm 1^\circ = \pm 17$ mrad

This is now the experimental precision!

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- CPV in charm
  - Direct CPV plus control measurements $\Delta A_{CP} = A_{CP}(D^0 \to K^+K^-) - A_{CP}(D^0 \to \pi^+\pi^-)$
  - CPV in mixing
  - Baryonic analogue of $D \to \pi^+\pi^-, K^+K^-$: e.g. $\Lambda_c \to p\pi^0, \Sigma K$

LHCb 1903.08726

See e.g. Fabio Ferrari, Yu Zhang Wilkinson, AL 2011.04443

All theorists agree:

ΔA_{CP} is clearly governed by NP!

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What is NP?

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Control hadronic contributions in charm system

P/T **can currently not be calculated from first principles**

Additional assumptions (ideologies) needed - they might be wrong!

- **Ideology I:** NP = Non-perturbative physics
  - *"Non-perturbative effects are known to be huge"*
    Analogy to the $\Delta I = 1/2$ rule
  - Good starting point for arguing:
    $\sin\phi \approx 1 \Rightarrow P/T = 1.3$ sufficient for $\Delta a_{CP} = -0.00329$
- **Ideology II:** NP = New physics
  - *"Heavy quark expansion and factorisation are known to work well"*
    Analogy to the b-system
  - Good starting point for arguing:
    $\sin\phi \approx 1/10 \Rightarrow P/T = 13$ needed for $\Delta a_{CP} = -0.00329$

The usual Suspects:

- High precision in γ^{CKM}

within the SM

See talk of **Alex Gilman**

$$\gamma = \left(65.4^{+3.8}_{-4.2}\right)^{\circ}$$

Allow BSM effects in tree-level

$$C_1(M_W) := C_1^{\text{SM}}(M_W) + \Delta C_1(M_W),$$
$$C_2(M_W) := C_2^{\text{SM}}(M_W) + \Delta C_2(M_W),$$

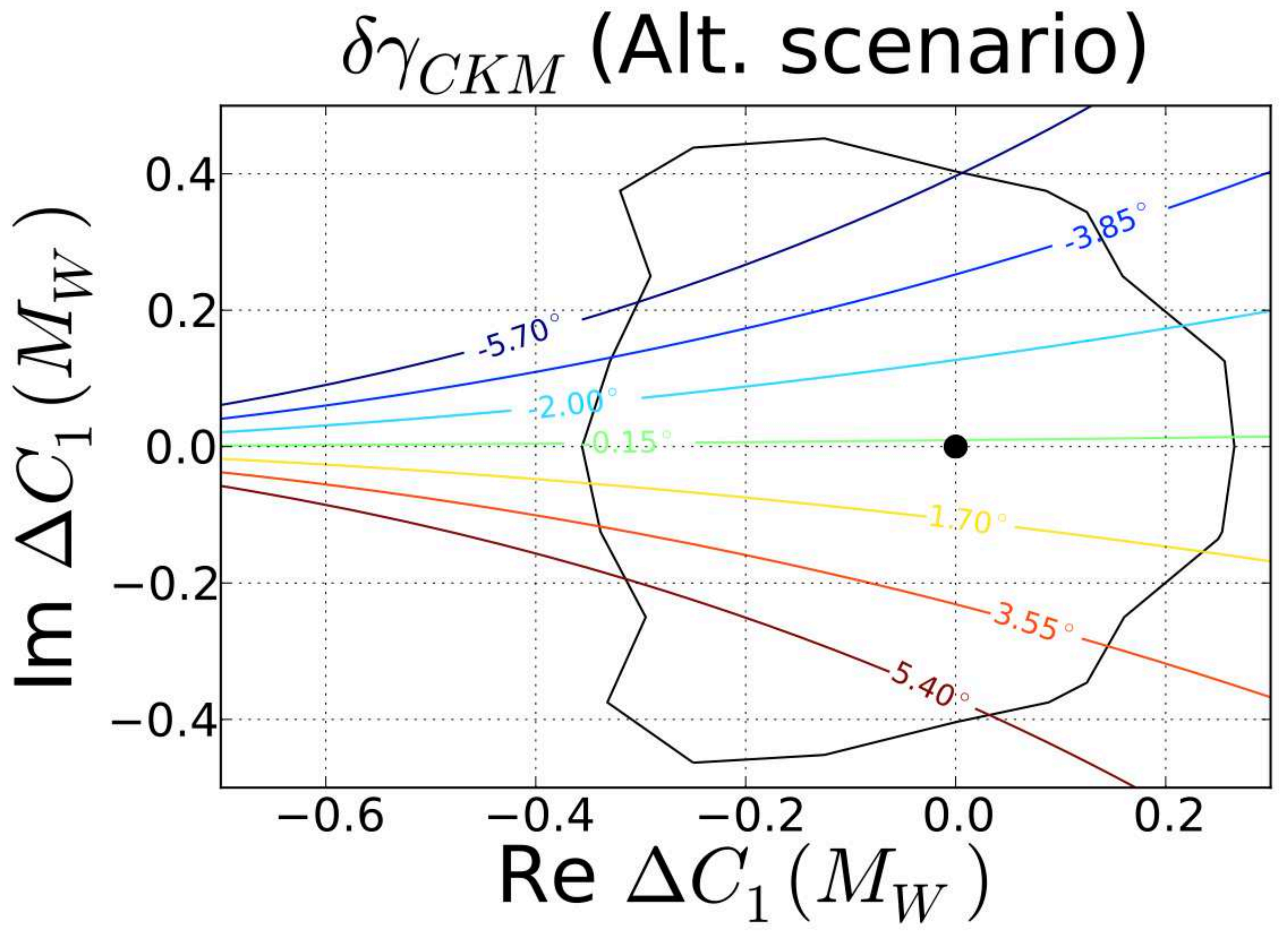
The ultimate theoretical error on γ from $B \to DK$ decays

Joachim Brod and Jure Zupan

Department of Physics, University of Cincinnati, Cincinnati, Ohio 45221, U.S.A.

E-mail: brodjm@ucmail.uc.edu, zupanje@ucmail.uc.edu

ABSTRACT: The angle γ of the standard CKM unitarity triangle can be determined from $B \to DK$ decays with a very small irreducible theoretical error, which is only due to second-order electroweak corrections. We study these contributions and estimate that their impact on the γ determination is to introduce a shift $|\delta\gamma| \lesssim \mathcal{O}(10^{-7})$, well below any present or planned future experiment.



Brod, AL, Tetlamatzi-Xolocotzi 1412.1446

AL, Tetlamatzi-Xolocotzi 1912.07621

The usual Suspects:

PHYSICAL REVIEW D **104**, 035028 (2021)

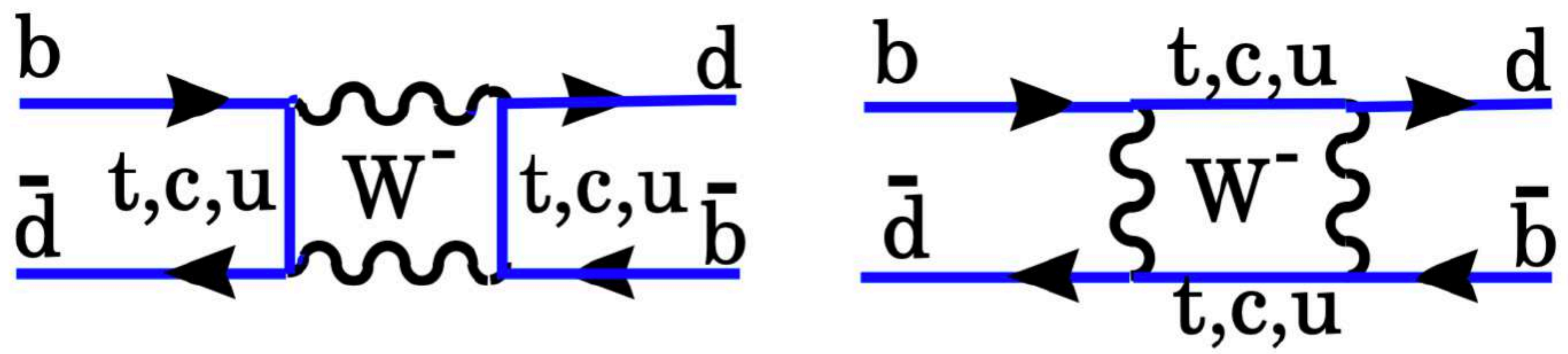
Editors' Suggestion

Collider signals of baryogenesis and dark matter from B mesons: A roadmap to discovery

Gonzalo Alonso-Álvarez[1,2,*] Gilly Elor[3,†] and Miguel Escudero[4,‡]

- Semileptonic CP asymmetries a^d_{sl}, a^s_{sl} - Could explain Baryon asymmetry…

B-MIXING



$|M_{12}|$, $|\Gamma_{12}|$ and $\phi_{12} = \arg(-M_{12}/\Gamma_{12})$ can be related to three observables:

- **Mass difference:** $\Delta M := M_H - M_L \approx 2|M_{12}|$ (off-shell)
  $|M_{12}|$: heavy internal particles: t, SUSY, ...
- **Decay rate difference:** $\Delta\Gamma := \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}|\cos\phi_{12}$ (on-shell)
  $|\Gamma_{12}|$: light internal particles: u, c, ... (almost) no NP!!!
- **Flavor specific/semi-leptonic CP asymmetries:** e.g. $B_q \to X l \nu$ (*semi-leptonic*)

$$a_{sl} \equiv a_{fs} = \frac{\Gamma(\overline{B}_q(t) \to f) - \Gamma(B_q(t) \to \overline{f})}{\Gamma(\overline{B}_q(t) \to f) + \Gamma(B_q(t) \to \overline{f})} = \left|\frac{\Gamma_{12}}{M_{12}}\right| \sin\phi_{12}$$

Semi-leptonic CP asymmetries

Relation to experiment

$$\Re\left(\frac{\Gamma_{12}^q}{M_{12}^q}\right) = -\frac{\Delta\Gamma_s}{\Delta M_q}$$

CP violating!

$$\Im\left(\frac{\Gamma_{12}^q}{M_{12}^q}\right) = a_{sl}^q$$

- Decay constants cancel completely
- Bag parameter cancel largely

SM predictions

$$a_{fs}^{s,\,\mathrm{SM}\,2019} = (2.06 \pm 0.18) \cdot 10^{-5} \qquad a_{fs}^{s,\,\mathrm{HFLAV}\,2019} = (-60 \pm 280) \cdot 10^{-5}$$

$$a_{fs}^{d,\,\mathrm{SM}\,2019} = -(4.73 \pm 0.42) \cdot 10^{-4} \qquad a_{fs}^{d,\,\mathrm{HFLAV}\,2019} = (-21 \pm 17) \cdot 10^{-4}$$

- **Very sensitive to BSM effects!**
- **Experimental number needed**

$$a_{fs}^q = 480 \cdot 10^{-5} \sin\phi_{12}^q$$

Talk by Matthew Kirk - CPV in anomalies

The usual Suspects:

- Semileptonic CP asymmetries a_{sl}^d, a_{sl}^s

BSM Contributions to Mixing

- General BSM contribution to $M_{12}^q = M_{12}^{\mathrm{SM,q}} |\Delta_q| e^{i\phi_q^\Delta}$ **(AL, Nierste, 0612167)**

  This phase arises e.g. in the extraction of β and β_s

  Experiment actually measures $\beta^{\mathrm{Exp}} = \beta^{\mathrm{SM}} + \frac{1}{2}\phi_d^\Delta + \beta_{Peng}^{\mathrm{SM}} + \beta_{Peng}^{\mathrm{BSM}}$

- General BSM contribution to $\Gamma_{12}^q = \Gamma_{12}^{\mathrm{SM,q}} |\tilde{\Delta}_q| e^{-i\tilde{\phi}_q^\Delta}$ **(AL, 1106.3200)**

  Mixing phase in the semi-leptonic asymmetries $\phi_{12}^q = \phi_{12}^{\mathrm{SM,q}} + \phi_q^\Delta + \tilde{\phi}_q^\Delta$

BSM Contributions to Mixing

- How large can the new physics phases be?

  $\beta^{\mathrm{Exp}} - \beta^{\mathrm{SM}} = 22.14^\circ - 23.7^\circ \pm 1.5^\circ = -1.56^\circ \pm 1.5^\circ$

  $\beta_s^{\mathrm{Exp}} - \beta_s^{\mathrm{SM}} = 1.46^\circ - 1.06^\circ \pm 0.7^\circ = 0.4^\circ \pm 0.7^\circ$

  $\Phi_q^\Delta < 5^\circ \Rightarrow a_{sl}^q < 42 \cdot 10^{-5}$

- BSM in tree level decays? **(AL, Tetlalmatzi-Xolocotzi 1912.07621)**

  $$-\frac{\Gamma_{12}^s}{M_{12}^s} = \frac{\Gamma_{12}^{s,cc}}{\tilde{M}_{12}^s} + 2\frac{\lambda_u}{\lambda_t}\frac{\Gamma_{12}^{s,cc} - \Gamma_{12}^{s,uc}}{\tilde{M}_{12}^s} + \left(\frac{\lambda_u}{\lambda_t}\right)^2 \frac{\Gamma_{12}^{s,cc} - 2\Gamma_{12}^{s,uc} + \Gamma_{12}^{s,uu}}{\tilde{M}_{12}^s}$$

  Small imaginary part in $b \to c\bar{c}d, s$ could have huge effect in $a_{sl}^{d,s}$

  $a_{sl}^q \leq a_{sl}^{\mathrm{Exp,q}} \approx \pm 280(170) \cdot 10^{-5}$

  Or can we do better?

  Some recent excitement about colour-allowed tree-level decays $> 5\sigma$

  2007.10338
  2008.01086
  2103.04138
  2103.10332

  Can a_{sl}^s be measured in $\bar{B}_s \to D_s^+ \pi^-$?

Many times β_{Peng}^{SM}, β_{Peng}^{BSM} and $\tilde{\phi}_q^\Delta$ neglected - this could be a very bad approximation, see 1106.3200

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My conclusion: any experimental improvement on a_{sl}^q is very interesting

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Not so well-known:

- $\tau(B_s)/\tau(B_d)$ and $\Delta\Gamma_d$ - see talk of **Matthew Kirk, …**

$\Delta\Gamma_d$: A Forgotten Null Test of the Standard Model

Tim Gershon[1]

Remember: D0 di muon asymmetry….

Measurement of the relative width difference of the B^0-$\bar{B}^0$ system with the ATLAS detector

The ATLAS collaboration

E-mail: atlas.publications@cern.ch

ABSTRACT: This paper presents the measurement of the relative width difference $\Delta\Gamma_d/\Gamma_d$ of the B^0-$\bar{B}^0$ system using the data collected by the ATLAS experiment at the LHC in pp collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 8$ TeV and corresponding to an integrated luminosity of 25.2 fb^{-1}. The value of $\Delta\Gamma_d/\Gamma_d$ is obtained by comparing the decay-time distributions of $B^0 \to J/\psi K_S$ and $B^0 \to J/\psi K^{*0}(892)$ decays. The result is $\Delta\Gamma_d/\Gamma_d = (-0.1 \pm 1.1\ \text{(stat.)} \pm 0.9\ \text{(syst.)}) \times 10^{-2}$. Currently, this is the most precise single measurement of $\Delta\Gamma_d/\Gamma_d$. It agrees with the Standard Model prediction and the measurements by other experiments.

JHEP06(2016)081

- $b \to d\ell\ell$, e.g. differential q^2 distr. & CP asym. in $B \to \pi\ell\ell$, see e.g. **Rusov 1911.12819**, R_π see **Marzia's talk**
- $b \to s\tau\tau$ transitions, e.g. **Cornella, Isidori, König, Liechti, Owen 2001.04470, Thanh Dong,**
- Inclusive $B \to X_s\ell\ell$, e.g. **Huber, Hurth, Jenkins, Lunghi, Qin, Vos 2007.04191**
- $B \to D^*\mu\nu$- angular distribution, or even better $B \to D^*\tau\nu$ distribution q^2 distribution not enough, as effects of some NP operators can only be seen in particular angular observables

Rusa Mandal, Clara Murgui, Ana Peñuelas, Antonio Pich 2004.06726

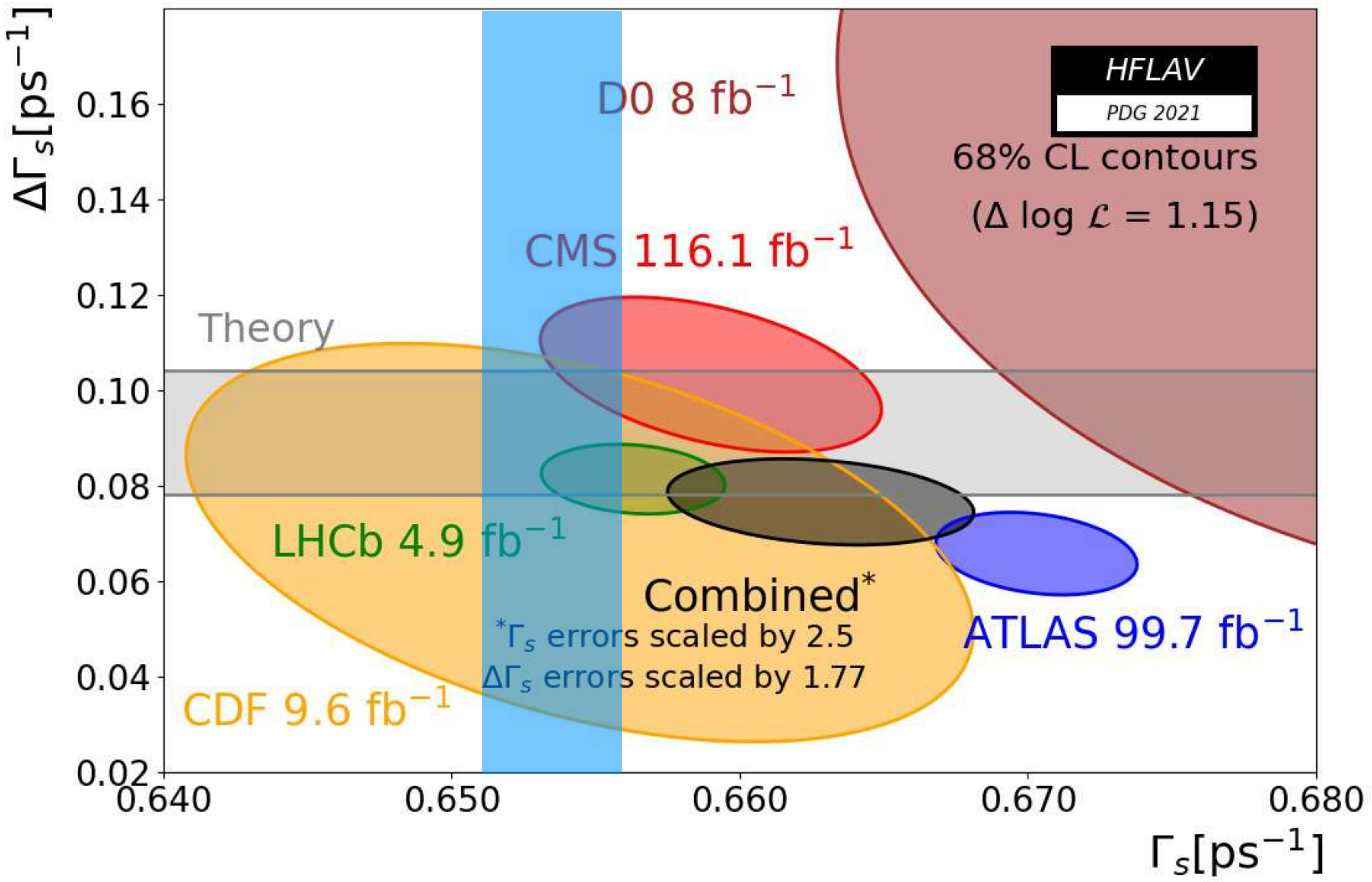
- **for a complete LCSR analysis of nonlocal effects (charm loop etc.) in $B_s \to \phi\ell\ell$,** accurate data on BR and amplitude decomposition are needed on hadronic B_s-decays such as $B_s \to \psi\phi$ where ψ are charmonia $J/\psi, \psi(2S)$ and above, also $B_s \to D^{(*)}\bar{D}\phi$ (for $B \to K$ and $B \to K^*$ channels this type of data is available)

The BR and angular distributions of hadronic decays are needed as inputs (pole residues) in the dispersion relation for the $B_s \to \phi\ell\ell$ nonlocal amplitude to be matched to the LCSR calculation

A. Khodjamirian

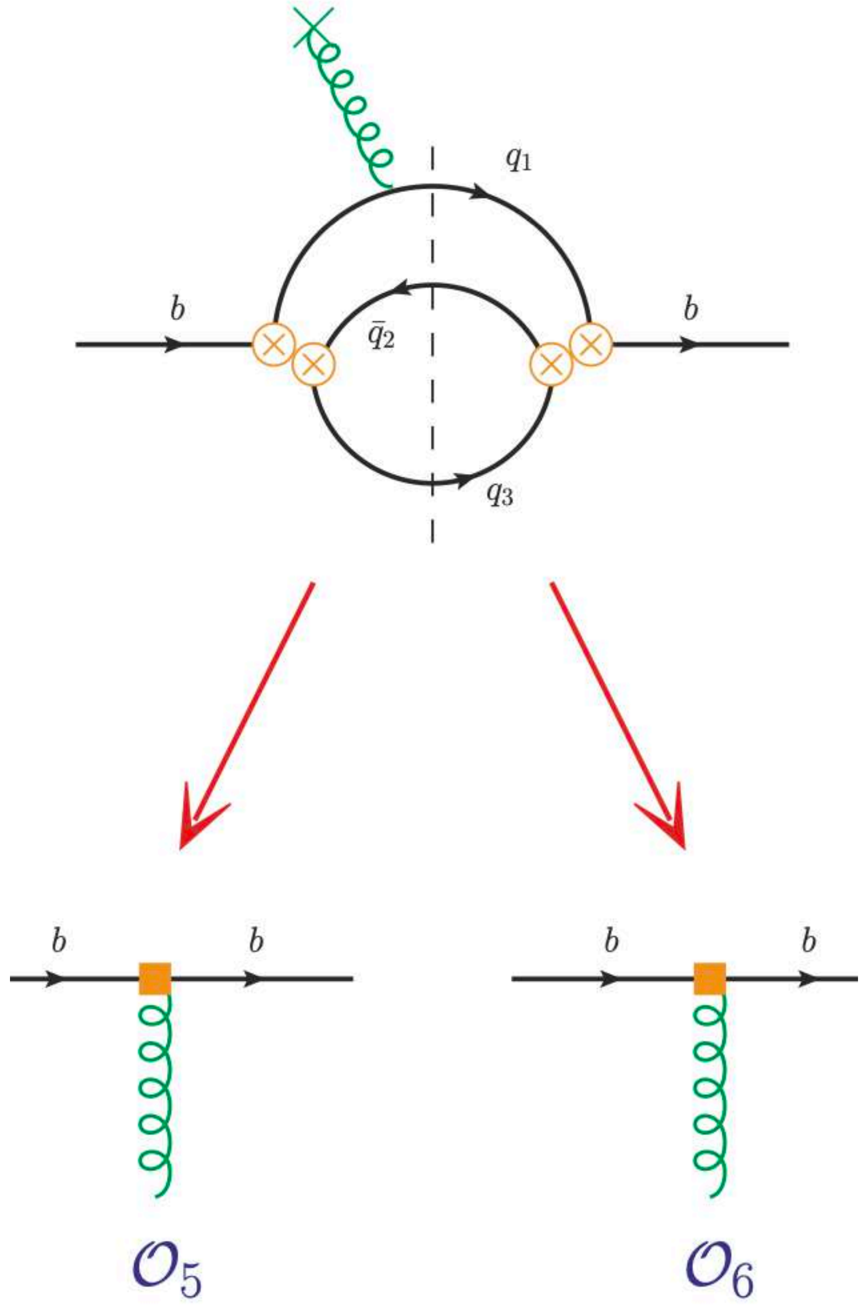
$\tau(B_s)/\tau(B_d)$

A less well known 4 sigma anomaly :-)



But be aware:

so far large Darwin term has not been included



AL, Piscopo, Rusov 2004.09527

Mannel, Moreno, Pivovarov 2004.09485

Dominant uncertainty

$$\rho_D^3(B_s) - \rho_D^3(B_d)$$

unknown **Known from inclusive V_{cb} determination**

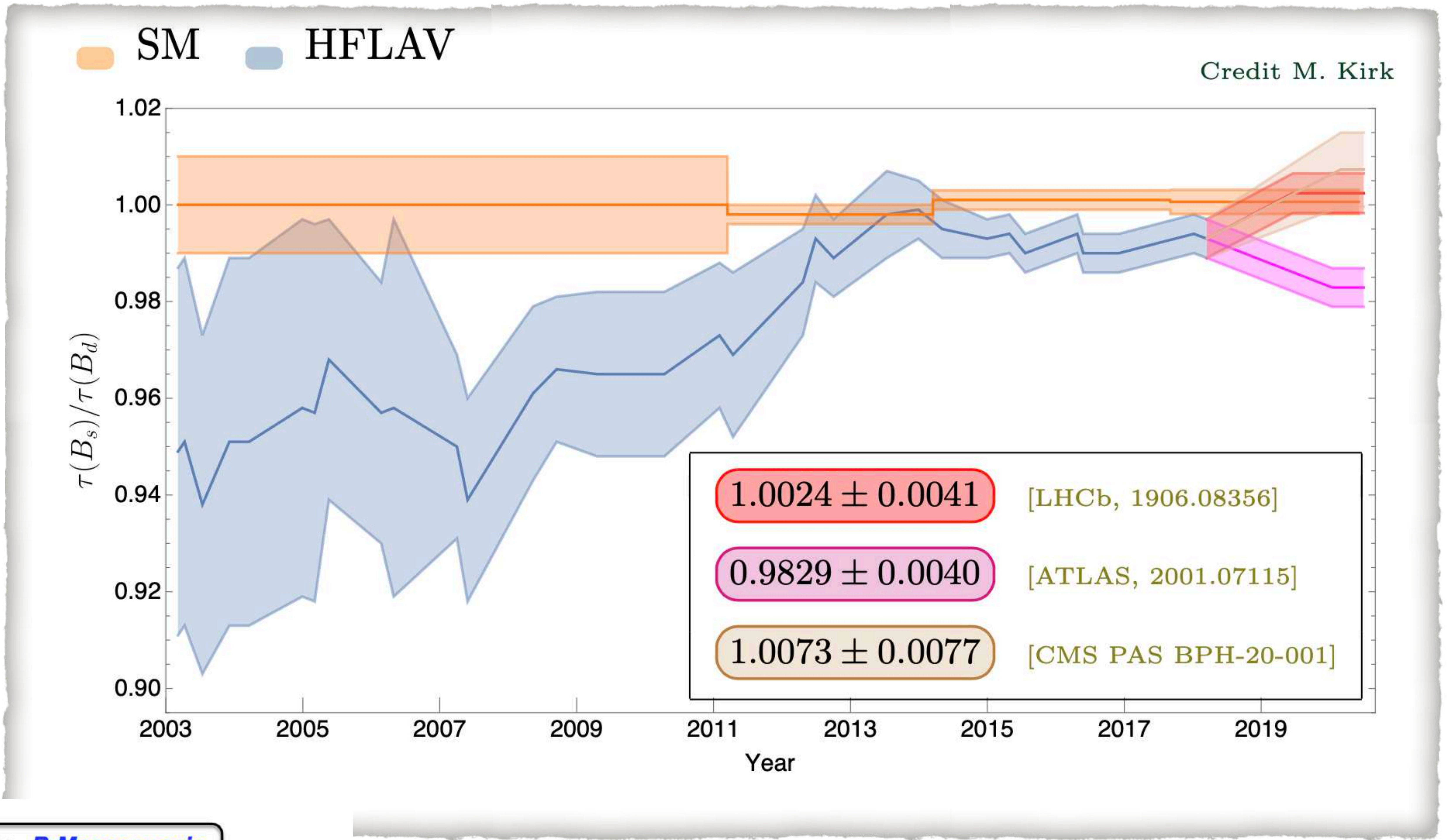
SM based on 1711.02100,
based on hep-ph/0202106
and hep-ph/0203089 - obtained via $\Gamma_s = 1/[\tau(B_s)/\tau(B_d)]^{HQE} * 1/\tau(B_d)^{EXP}$

$\tau(B_s)/\tau(B_d)$

Precise lifetime ratio in Exp. and Theory can be used to constrain BSM effects

$$\underbrace{\frac{\tau(B_s)}{\tau(B_d)}}_{\text{exp.}} \approx 1 + \underbrace{\tau(B_s)\left(\delta\Gamma^{\rm SM}_{B_d} - \delta\Gamma^{\rm SM}_{B_s}\right)}_{\text{theory}}$$
$$+ \underbrace{\left[\mathrm{BR}(B_d \to X)^{\rm BSM} - \mathrm{BR}(B_s \to X)^{\rm BSM}\right]}_{\text{indirectly constrained}}$$

Still higher experimental precision needed

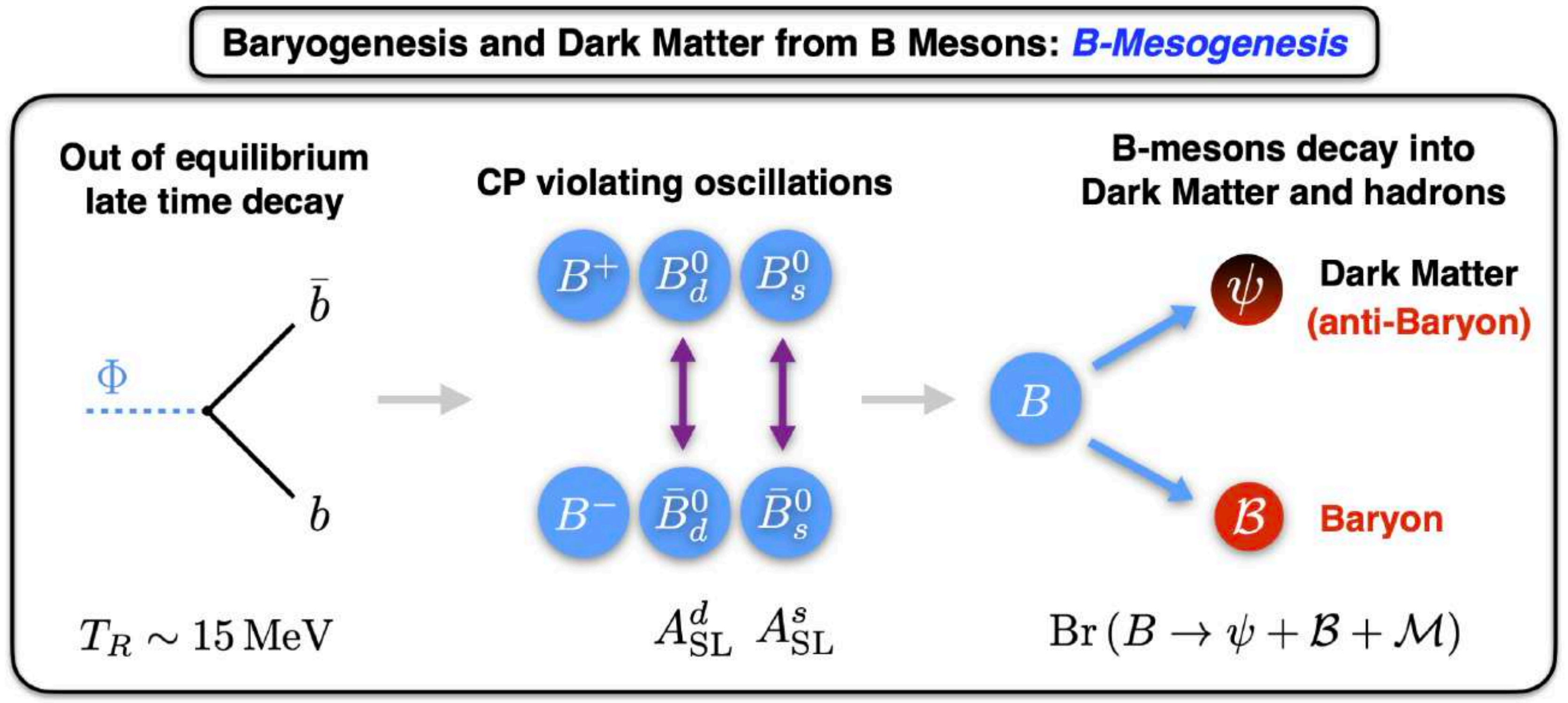


Examples:

- $b \to s\tau\tau$, see **Bobeth, Haisch 1109.1826**

Talk of
Matthew Kirk

- New non-leptonic tree-level operators
- B meson baryogengesis
- ....



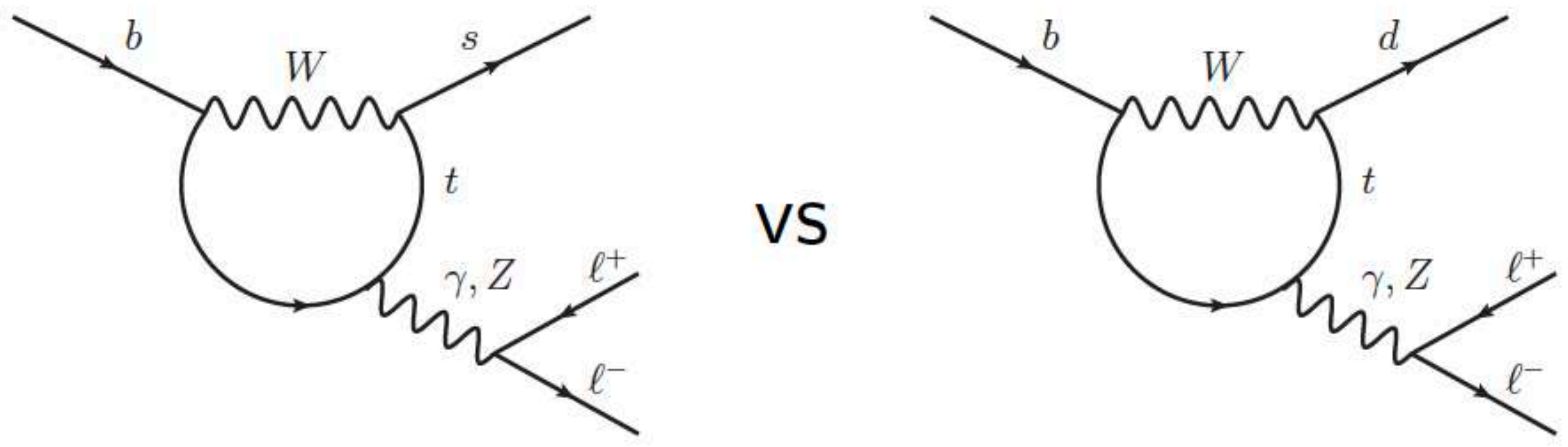
Ann Nelson,....
Gonzalo-Alvarez, Elor, Escudero

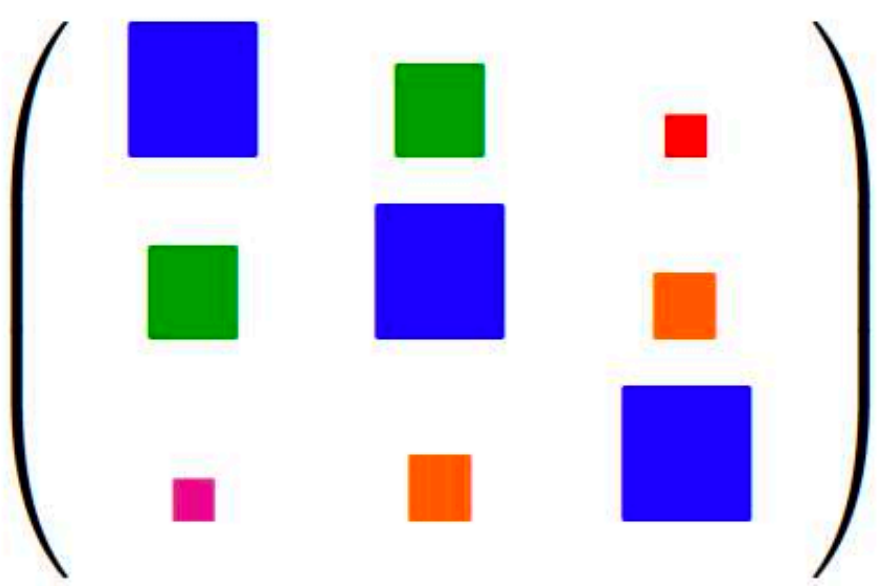
$b \to d\ell\ell$

Study also decays like

$B \to (\pi, \rho, \omega)\ell\ell$ and $B_s \to (\eta, K^*)\ell\ell$

$b \to d$ vs $b \to s$



$V_{\mathrm{CKM}} \sim$ 

- Additionally CKM suppressed

$$\left|\frac{V_{tb}V_{td}^*}{V_{tb}V_{ts}^*}\right| \approx 0.22 \quad \Rightarrow \quad \left|\frac{V_{tb}V_{td}^*}{V_{tb}V_{ts}^*}\right|^2 \approx 0.05$$

- $b \to d$ transitions induce non-vanishing direct CP-asymmetry
  - ▷ In $b \to s$:

$$|V_{tb}V_{ts}^*| \sim |V_{cb}V_{cs}^*| \sim \lambda^2 \gg |V_{ub}V_{us}^*| \sim \lambda^4$$

  - ▷ In $b \to d$:

$$|V_{tb}V_{td}^*| \sim |V_{cb}V_{cd}^*| \sim |V_{ub}V_{ud}^*| \sim \lambda^3$$

- Also sensitive to contribution from New Physics (NP)

Surprise and/or underdogs...:

- Inclusive semi-leptonic fit of moments in B_s decays at LHCb? Belle II? Lu Cao, P. Gambino, M. Bauer,
  Determine also non-perturbative matrix elements $\mu_G^2(B_s), \mu_\pi^2(B_s), \rho_D^3(B_s), \ldots$

- Inclusive semi-leptonic fit of moments of charm decays BESIII, Belle II? A. Gilman,
  Determine also non-perturbative matrix elements $\mu_G^2(D), \mu_\pi^2(D), \rho_D^3(D), \ldots$ Semi inclusive D -> K + X

- Non-leptonic tree-level decays: BSM in leading tree-level? $B \to K\pi$ puzzle S.Perazzini

- $B_c \to \tau\nu$: determination of V_{cb} depending only on decay constant f_{B_c}

- Very rare to impossible decays: $B_{(s)} \to \tau\mu, B \to K\tau\mu$,.... and also D decays B. Joshi, E. Occo,
  $\tau \to \mu\mu\mu$ and friends E. Passemar, A. Cerri;

- measurement of V_{us} from τ decays with reasonable precision, Belle II?
  Test Cabibbo anomaly, without any lattice input

Surprise and/or underdogs...:

Test of our theory tools:

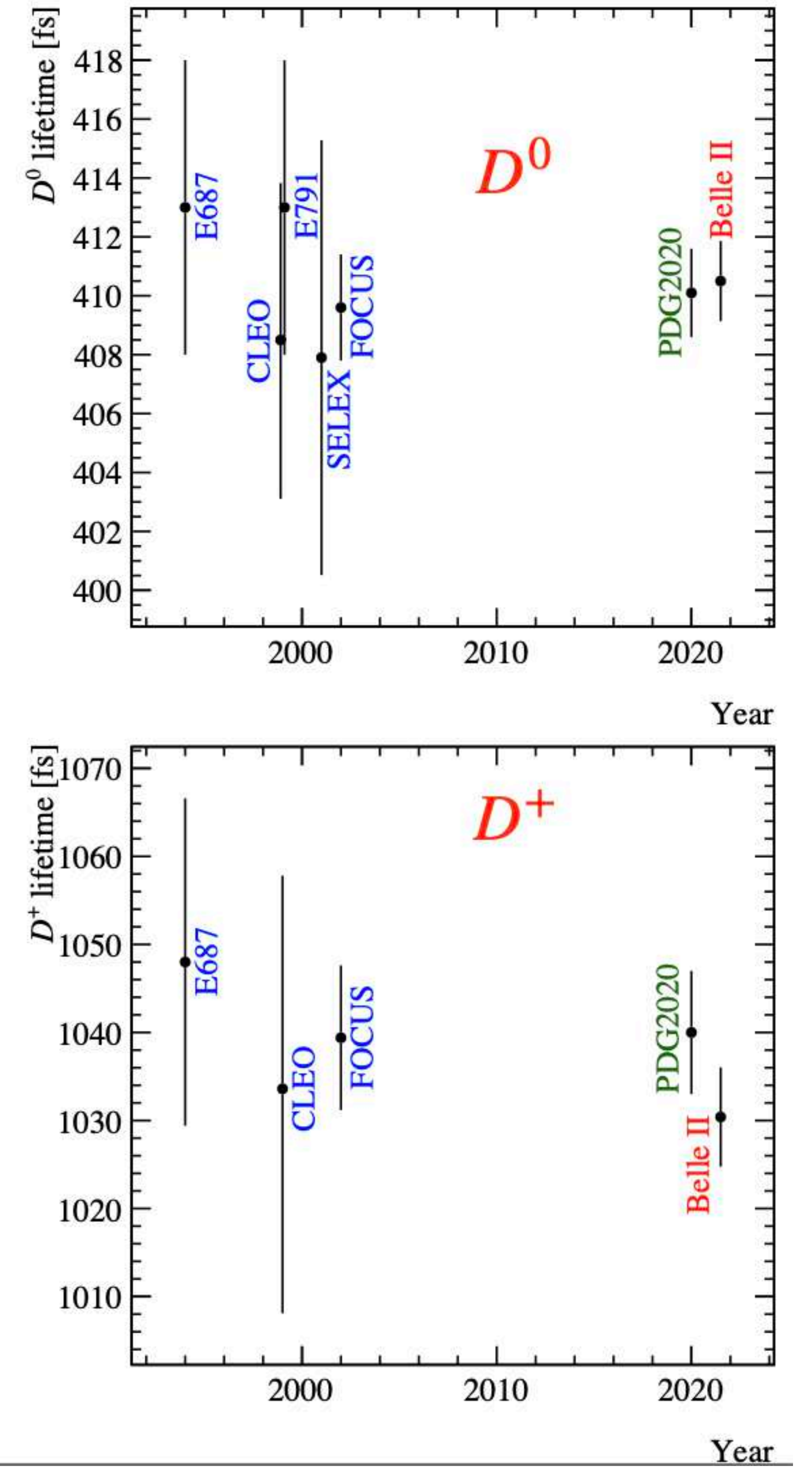
Results

$$\tau(D^0) = 410.5 \pm 1.1 \pm 0.8\,\text{fs}$$
$$\tau(D^+) = 1030.4 \pm 4.7 \pm 3.1\,\text{fs}$$

$$\tau(D^+)/\tau(D^0) = 2.510 \pm 0.015$$

determined considering correlations between (systematic) uncertainties

- Consistent with current world averages 410.1±1.5 fs (D^0) and 1040±7 fs (D^+).
- World's most precise measurements of the D^0 and D^+ lifetimes
- Few ‰ accuracy (3.5‰ for the D^0 and 5.4‰ for the D^+) establishes excellent performance of our detector!
- submitted to PRL, https://arxiv.org/abs/2108.03216

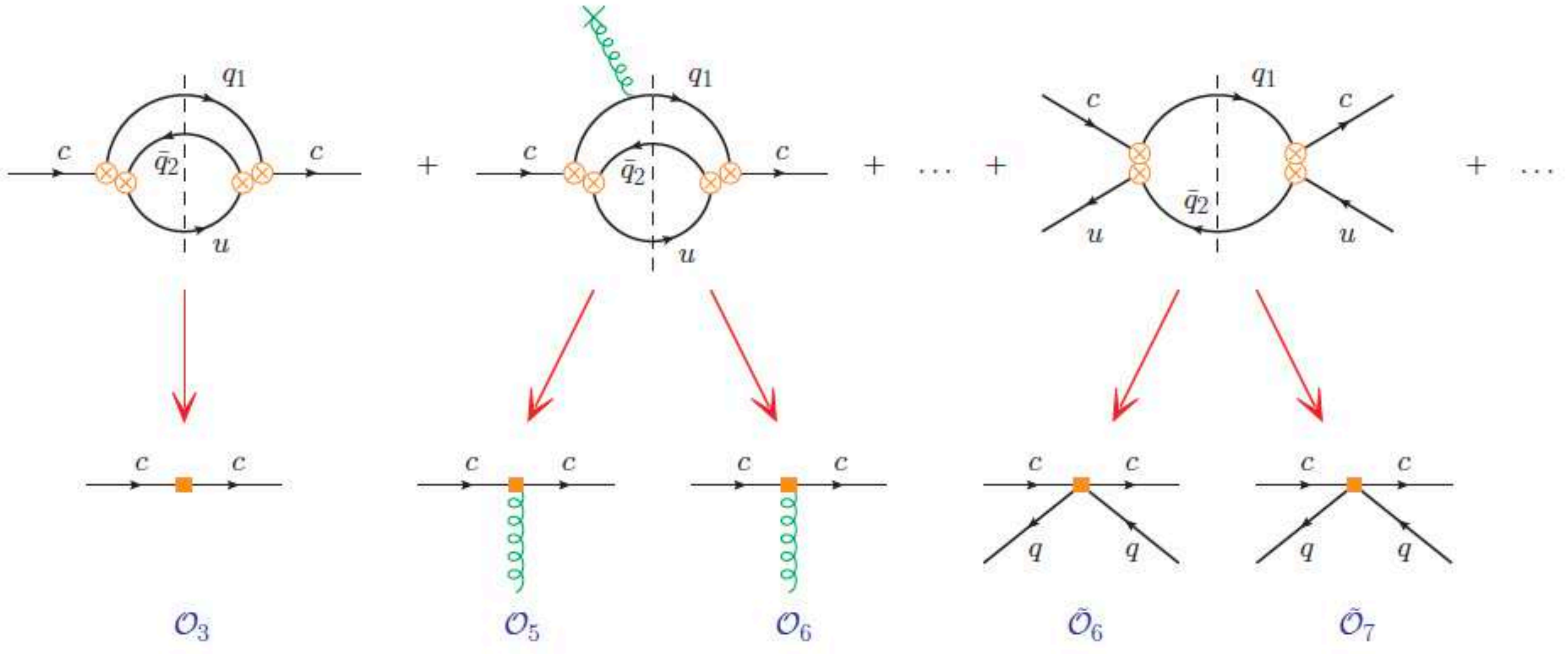


D lifetimes HQL2021

Giulia Casarosa

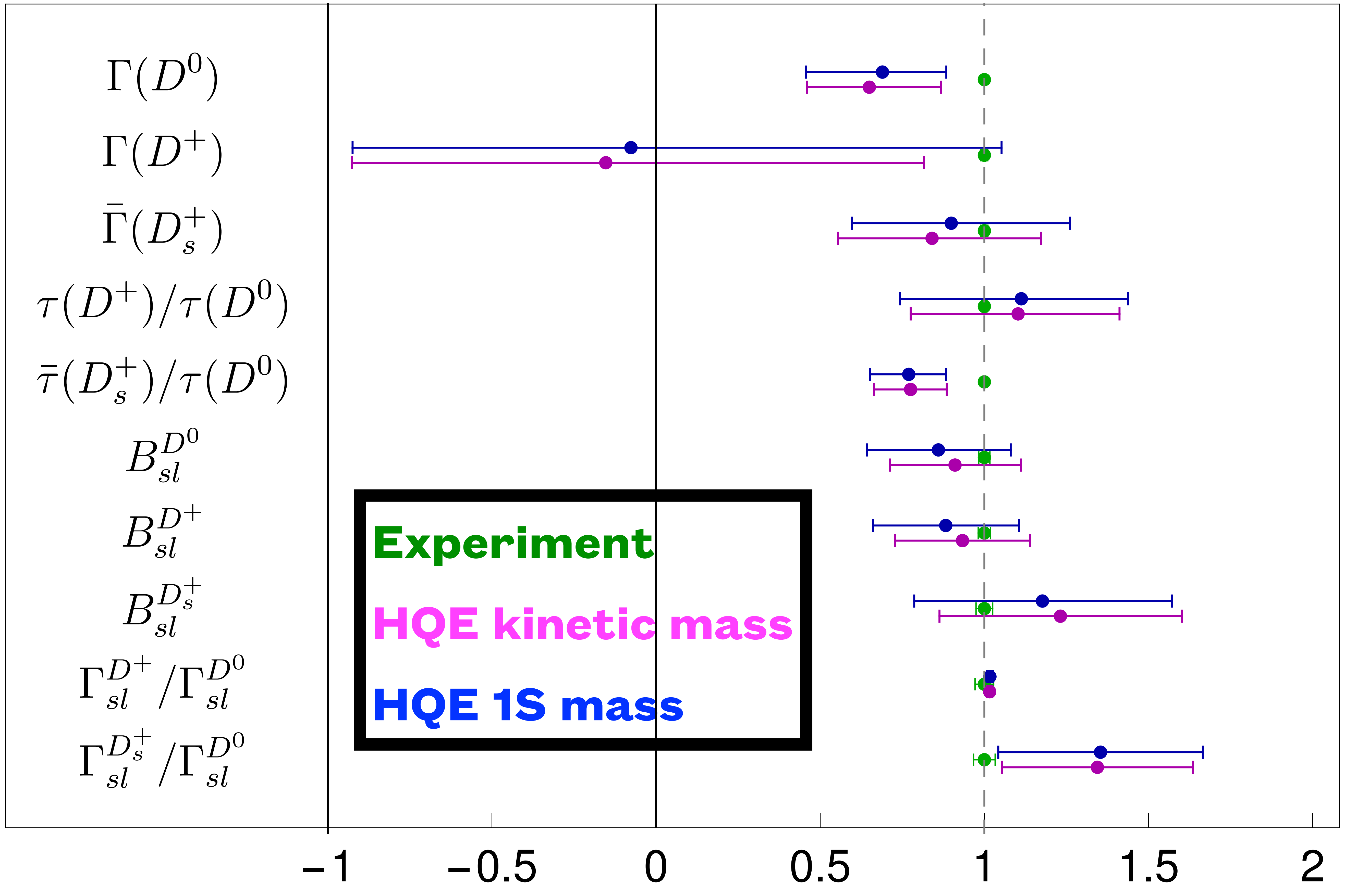
Total inclusive quantities, like lifetimes or inclusive semi-leptonic branching ratios: Theoretically well-behaved compared to crazy GIM cancellations in D- mixing

$$\Gamma(D) = \Gamma_3 + \Gamma_5 \frac{\langle \mathcal{O}_5 \rangle}{m_c^2} + \Gamma_6 \frac{\langle \mathcal{O}_6 \rangle}{m_c^3} + \ldots + 16\pi^2 \left(\tilde{\Gamma}_6 \frac{\langle \tilde{\mathcal{O}}_6 \rangle}{m_c^3} + \tilde{\Gamma}_7 \frac{\langle \tilde{\mathcal{O}}_7 \rangle}{m_c^4} + \ldots \right)$$



Surprise and/or underdogs...:

Convergence of HQE in the charm system?



NLO-QCD

LO-QCD

$$\Gamma(D) = \Gamma_3 + \Gamma_5 \frac{\langle \mathcal{O}_5 \rangle}{m_c^2} + \Gamma_6 \frac{\langle \mathcal{O}_6 \rangle}{m_c^3} + \ldots + 16\pi^2 \left(\tilde{\Gamma}_6 \frac{\langle \tilde{\mathcal{O}}_6 \rangle}{m_c^3} + \tilde{\Gamma}_7 \frac{\langle \tilde{\mathcal{O}}_7 \rangle}{m_c^4} + \ldots \right)$$

Assume
B = D
Take from
V_{cb} fit

EOM

3-loop

HQET SR

VIA

- **Huge uncertainties**
- **HQE covers experiment**
- $< 1\sigma$ **deviation for SU(3)F breaking in sl**

D. King, AL, M.L. Piscopo, T. Rauh, A. Rusov, C. Vlahos 2109.xxxxx

Surprise and/or underdogs...:

How to improve the precision of the HQE in the charm system?

$$\frac{\Gamma_{sl}^{D_s^+}}{\Gamma_{sl}^{D^0}} = 1 - 0.40\,[\mu_\pi^2(D_s) - \mu_\pi^2(D)] - 1.21\,[\mu_G^2(D_s) - \mu_G^2(D)] + 3.13\,[\rho_D^3(D_s) - \rho_D^3(D)]$$

$$-8.84\,\tilde{B}_1^s + 8.84\,\tilde{B}_2^s - 3.02\,\tilde{\epsilon}_1^s + 2.79\,\tilde{\epsilon}_2^s \underbrace{+0.00}_{\mathrm{dim-7,VIA}}$$

$$+0.35\,\tilde{\delta}_1^{qq} - 0.35\,\tilde{\delta}_2^{qq} + 6.60\,\tilde{\delta}_1^{qs} - 6.60\,\tilde{\delta}_2^{qs} - 0.52\,\tilde{\delta}_1^{sq} + 0.52\,\tilde{\delta}_2^{sq} + 9.68\,\tilde{\delta}_1^{ss} - 9.68\,\tilde{\delta}_2^{ss}$$

$$= 1 - 0.04\,\frac{\mu_\pi^2(D_s) - \mu_\pi^2(D)}{0.1\,\mathrm{GeV}^2} - 0.02\,\frac{\mu_G^2(D_s) - \mu_G^2(D)}{0.02\,\mathrm{GeV}^2} + 0.11\,\frac{\rho_D^3(D_s) - \rho_D^3(D)}{0.035\,\mathrm{GeV}^2}$$

$$\underbrace{+0.00}_{\mathrm{dim-6,7,VIA}} - 0.09\,\delta\tilde{B}_1^s + 0.09\,\delta\tilde{B}_2^s + 0.06\,\frac{\tilde{\epsilon}_1^s}{-0.02} - 0.06\,\frac{\tilde{\epsilon}_2^s}{-0.02}$$

$$+0.0009\,r_1^{qq} + 0.0006\,r_2^{qq} + 0.0112\,r_1^{qs} + 0.0079\,r_2^{qs}$$

$$-0.0013\,r_1^{sq} - 0.0009\,r_2^{sq} + 0.0223\,r_1^{ss} + 0.0165\,r_2^{ss}$$

Could probably be extracted from momentum analysis of inclusive semileptonic D meson decays by BESIII, Belle II,...

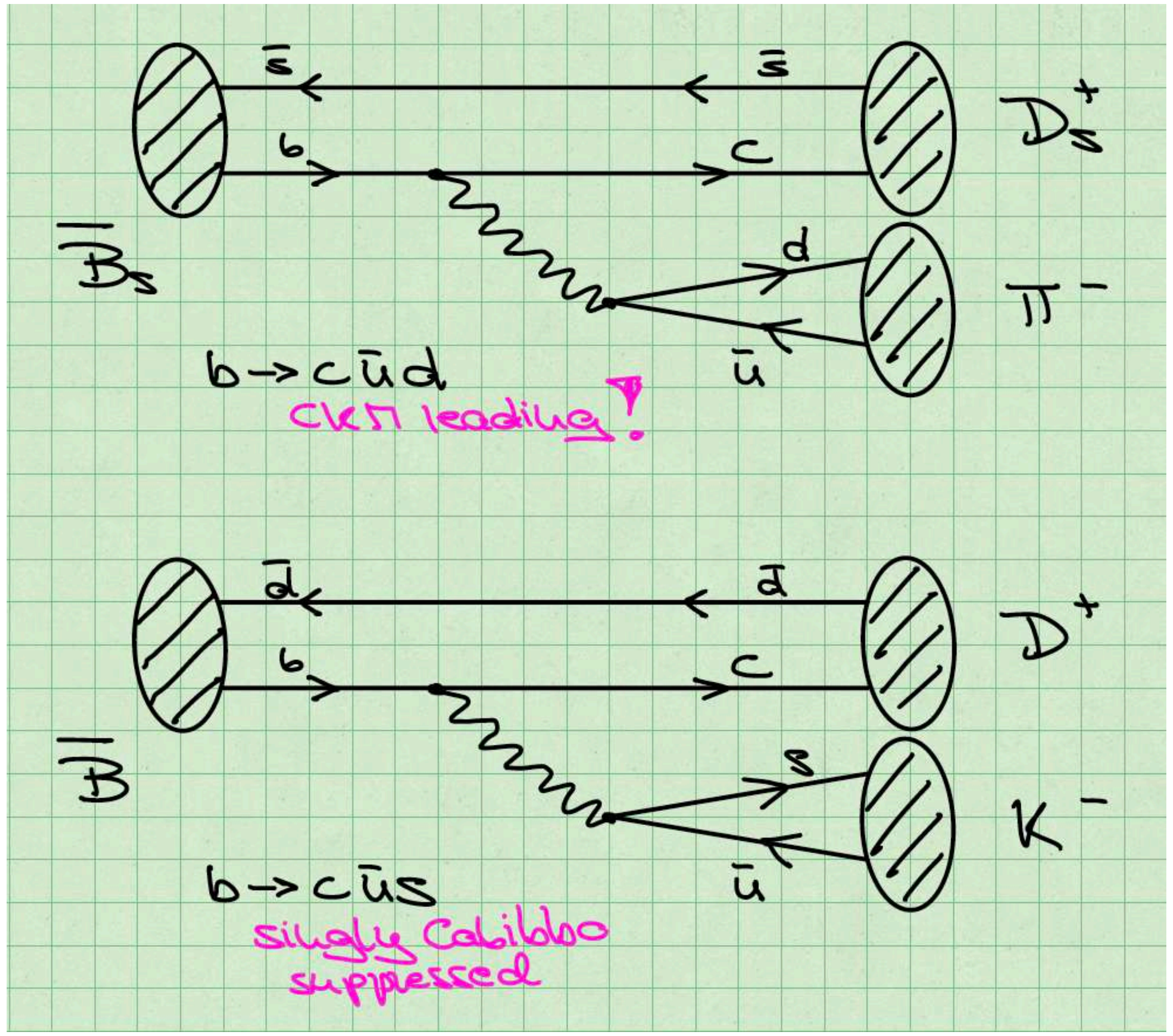
Bag parameter determined with 3-loop HQET sum rules:1711.02100
New: ms corrections King, AL, Rauh, to appear

New: first ever determination of eye-contractio
King, AL, Rauh, to appear

Lattice cross-check of HQET sum rules: Oliver Witzel, Matthew Black

Surprise and/or underdogs...:

BSM in non-leptonic, colour-allowed, tree-level decays:



https://indico.scc.kit.edu/event/2352/overview

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THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

A puzzle in $\bar{B}^0_{(s)} \to D^{(*)+}_{(s)}\{\pi^-, K^-\}$ decays and extraction of the f_s/f_d fragmentation fraction

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Source	PDG	Our fits (w/o QCDF)		Our fit (w/ QCDF, no f_s/f_d)		QCDF prediction	
Scenario	–	No f_s/f_d	$(f_s/f_d)^{7\ \text{TeV}}_{\text{LHCb,sl}}$	Ratios only	~~SU(3)~~	–	
χ^2/dof	–	2.5/4	3.1/5	4.6/6	3.7/4	–	
$\mathcal{B}(\bar{B}^0_s \to D_s^+\pi^-)$	3.00 ± 0.23	3.6 ± 0.7	3.11 ± 0.25	$3.11^{+0.21}_{-0.19}$	$3.20^{+0.20}_{-0.26}$ *	4.42 ± 0.21	4σ
$\mathcal{B}(\bar{B}^0 \to D^+K^-)$	0.186 ± 0.020	0.222 ± 0.012	0.224 ± 0.012	0.227 ± 0.012	0.226 ± 0.012	0.326 ± 0.015	$>5\sigma$
$\mathcal{B}(\bar{B}^0 \to D^+\pi^-)$	2.52 ± 0.13	2.71 ± 0.12	2.73 ± 0.12	2.74 ± 0.12	$2.73^{+0.12}_{-0.11}$	–	
$\mathcal{B}(\bar{B}^0_s \to D_s^{*+}\pi^-)$	2.0 ± 0.5	2.4 ± 0.7	2.1 ± 0.5	$2.46^{+0.37}_{-0.32}$	$2.43^{+0.39}_{-0.32}$	$4.3^{+0.9}_{-0.8}$	2σ
$\mathcal{B}(\bar{B}^0 \to D^{*+}K^-)$	0.212 ± 0.015	0.216 ± 0.014	0.216 ± 0.014	$0.213^{+0.014}_{-0.013}$	$0.213^{+0.014}_{-0.013}$	$0.327^{+0.039}_{-0.034}$	3σ
$\mathcal{B}(\bar{B}^0 \to D^{*+}\pi^-)$	2.74 ± 0.13	2.78 ± 0.15	2.79 ± 0.15	$2.76^{+0.15}_{-0.14}$	$2.76^{+0.15}_{-0.14}$	–	

Surprise and/or underdogs…:

BSM in non-leptonic, colour-allowed, tree-level decays:

What does this mean?

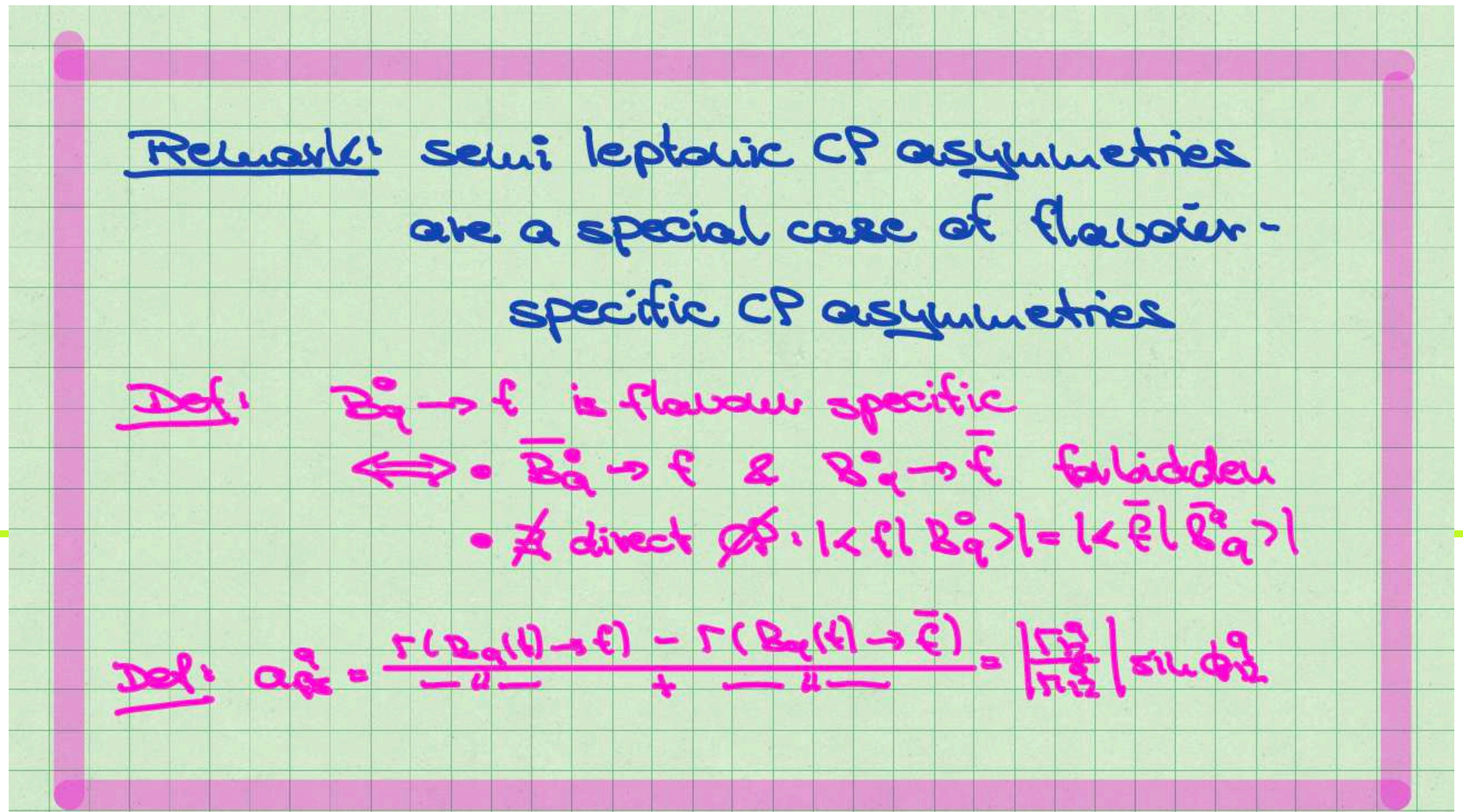
1. Failure of QCD factorisation in the "most simple" decays? Important lesson for QCD

2. Some hadronic uncertainty everybody has missed so far - Important lesson for QCD

3. BSM effects in tree-level decays? Might be visible in $\tau(B), a_{sl}^q, \Delta\Gamma^q, \ldots$

4. Measure with higher precision and by other experiments?

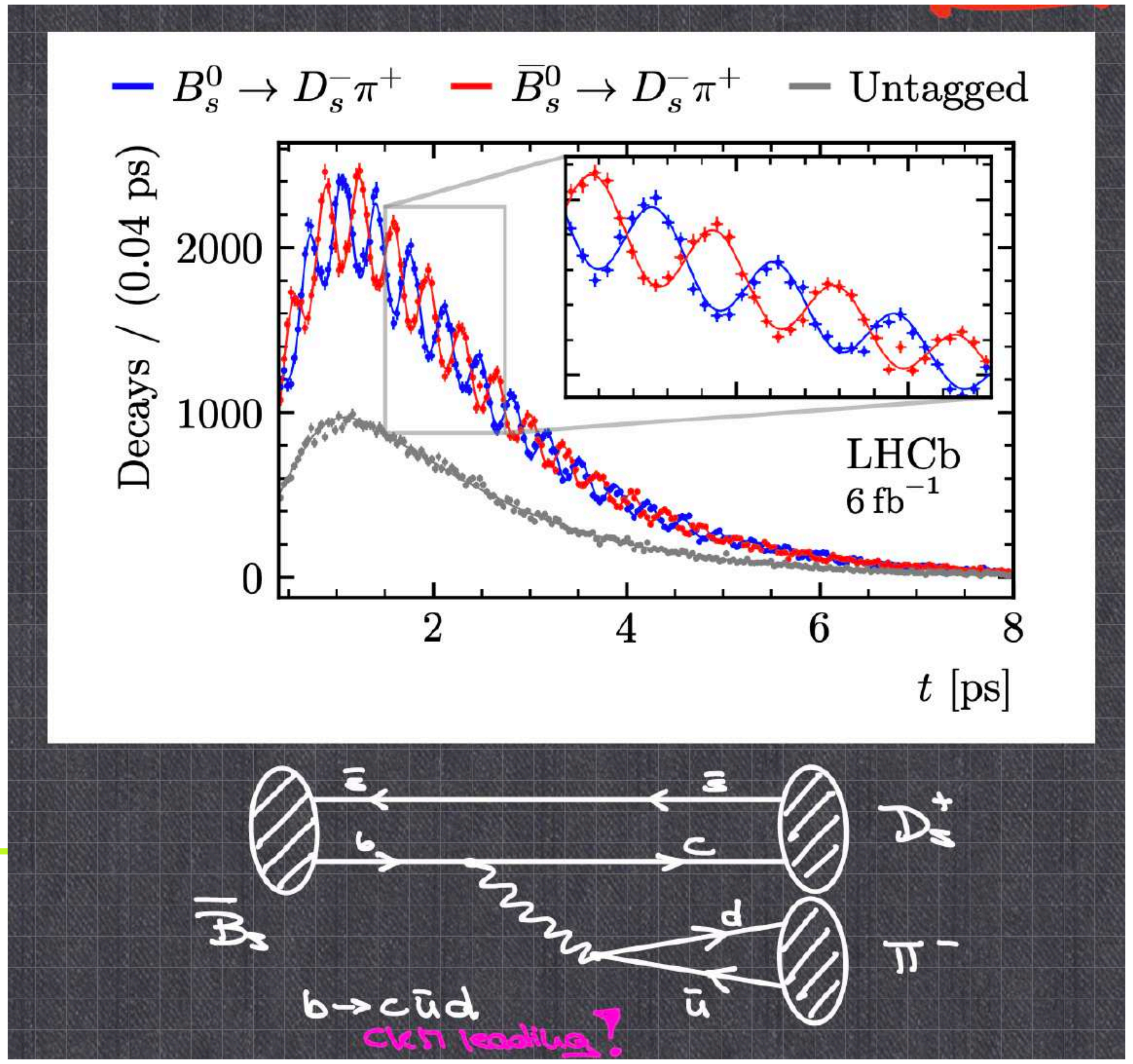
5. Measure flavour specific asymmetries in hadronic modes?



Remark: semi leptonic CP asymmetries are a special case of flavour-specific CP asymmetries

Def: $B_q^0 \to f$ is flavour specific
$\Leftrightarrow$ • $\bar{B}_q^0 \to f$ & $B_q^0 \to \bar{f}$ forbidden
• $\nexists$ direct $\cancel{CP}$: $|\langle f | B_q^0 \rangle| = |\langle \bar{f} | \bar{B}_q^0 \rangle|$

Def: $a_{fs}^q = \frac{\Gamma(\bar{B}_q(t) \to f) - \Gamma(B_q(t) \to \bar{f})}{\text{—"—} + \text{—"—}} = \left|\frac{\Gamma_{12}^q}{M_{12}^q}\right| \sin\phi_{12}^q$



So, work hard!!!