Closing (?) talk

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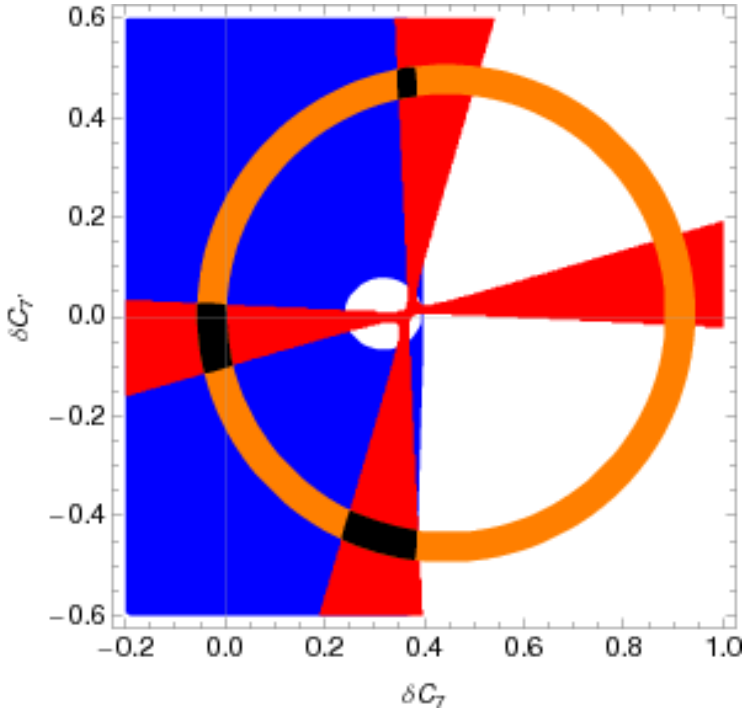
Beyond Flavour Anomalies IV, Barcelona, 21/4/23

A trip down memory lane

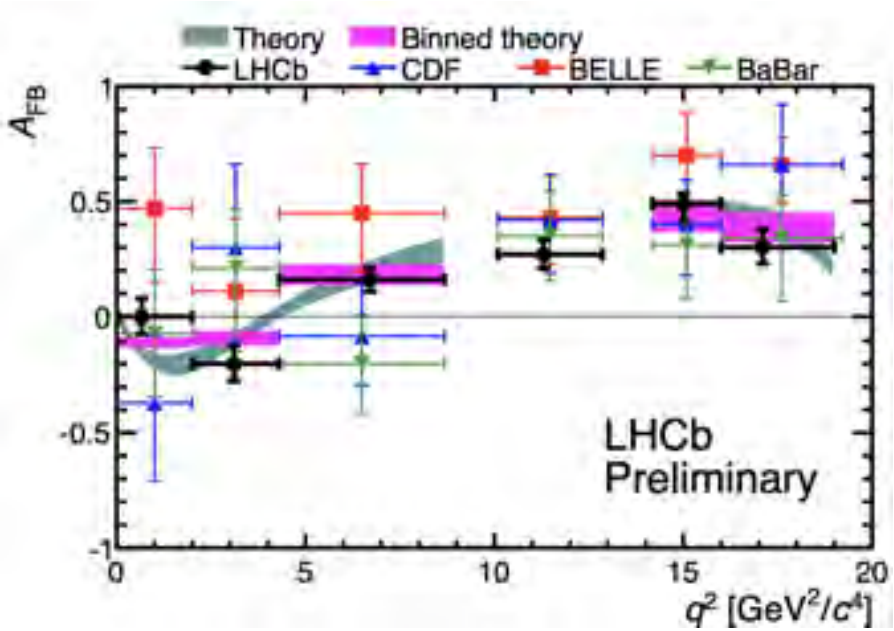


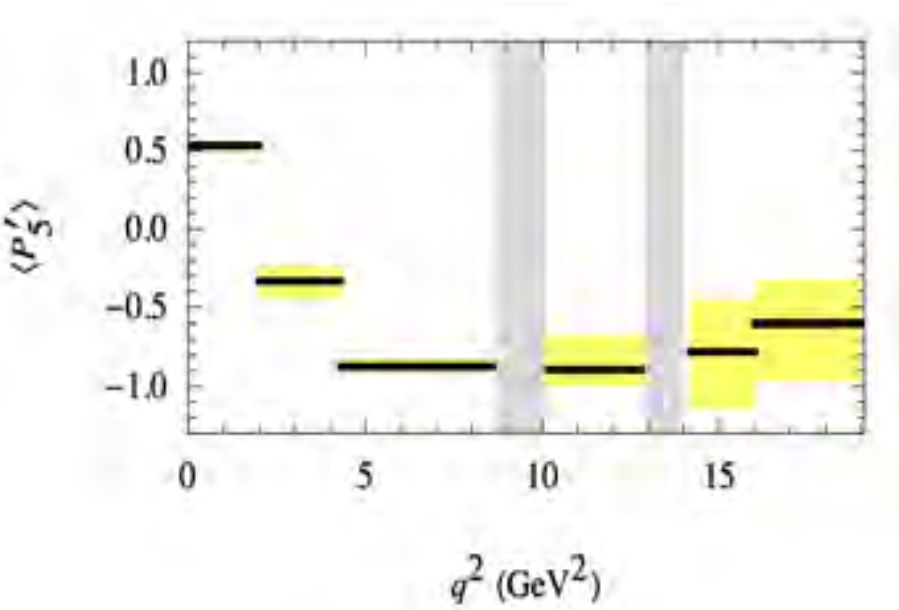
[1104.3342]

Stay for 3 months at UAB in 2010 supported by the Catalan govt

- At that moment, playing with Quim concerning rare hadronic decays to probe New Physics
- Revisiting Quim's works on $B \to K^* \ell\ell$ [F. Krüger, Th. Feldmann]
- Very pleasant and intense time, learning a lot about $b \to s\ell\ell$
- Idea of a "CKMfitter-like" global fit of Wilson coefficients, trying to understand the sensitivity/impact of each observable

The adventure starts



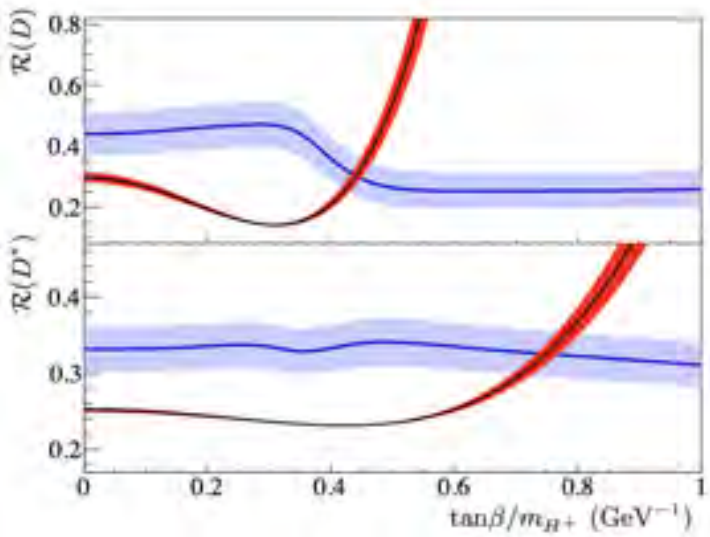


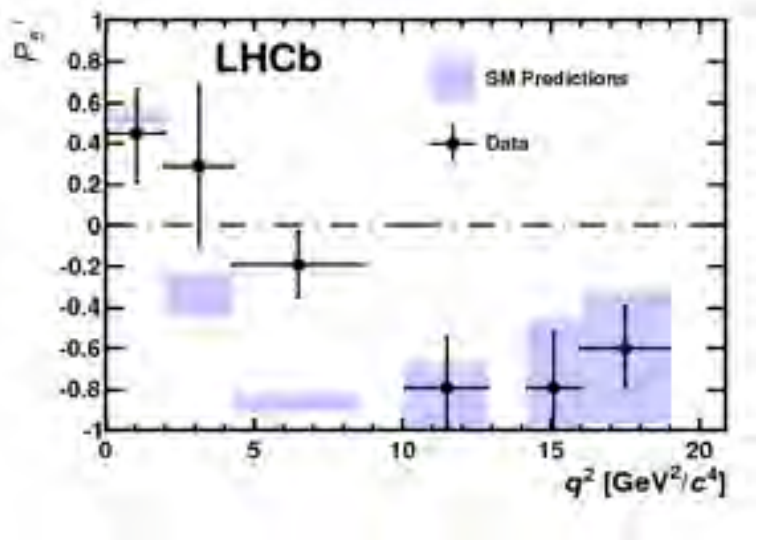
[LHCb, 1303.5794]

2010-2012

- First LHCb results on $b \to s\mu\mu$ modes
- "Disappointment" of no significant enhancement for $B_s \to \mu\mu$
- Optimised $B \to K^*\mu\mu$ angular observables, binning, foldings
- Use of effective theories for low- and large-recoil regimes
- First estimates of charm-loop contributions
- Tools and discussions for statistical analyses (pulls and p-values)

First surprises





[Babar, LHCb]

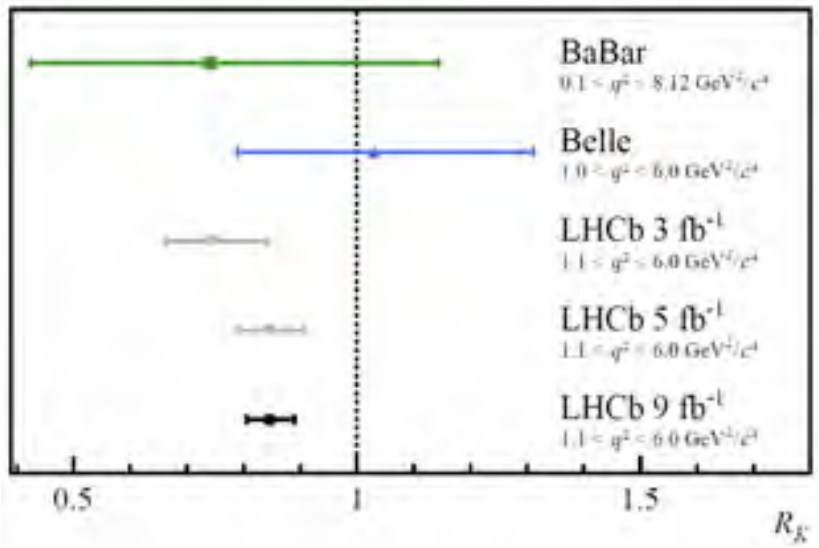
2012

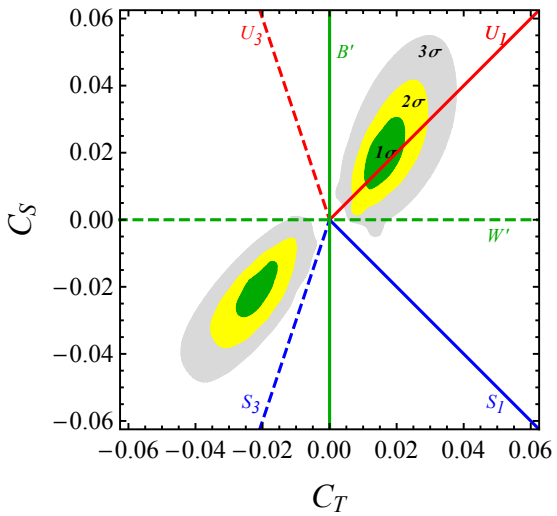
- R_D and R_{D^*} from Babar, P_5' from LHCb
- First evidence of $B_s \to \mu\mu$ from LHCb

Hectic theoretical activity

- Competing fitting groups, reminding of earlier days of CKM-fitting activities (healthy, but sometimes tense competition)
- Form factors: LCSR, lattice, dispersive bounds
- $c\bar{c}$ mixing: LCSR, dispersive relations, z-expansion
- SMEFT as a tool to analyse scenarios and connect sectors

Second surprises





[LHCb,1706.07808]

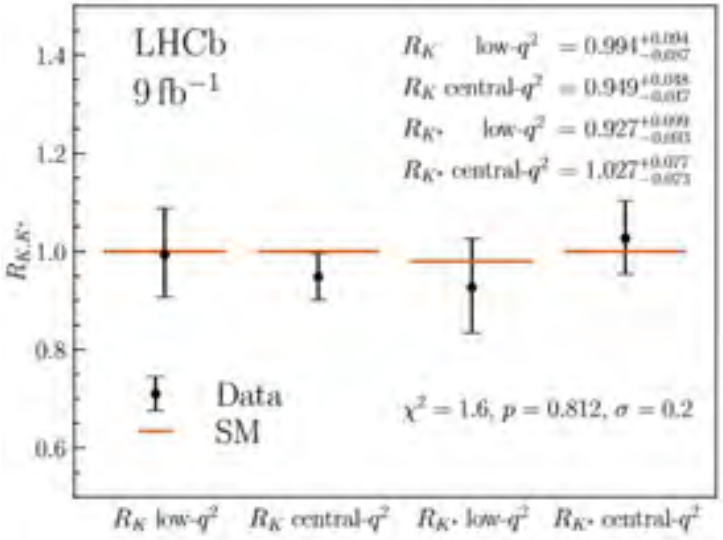
2014

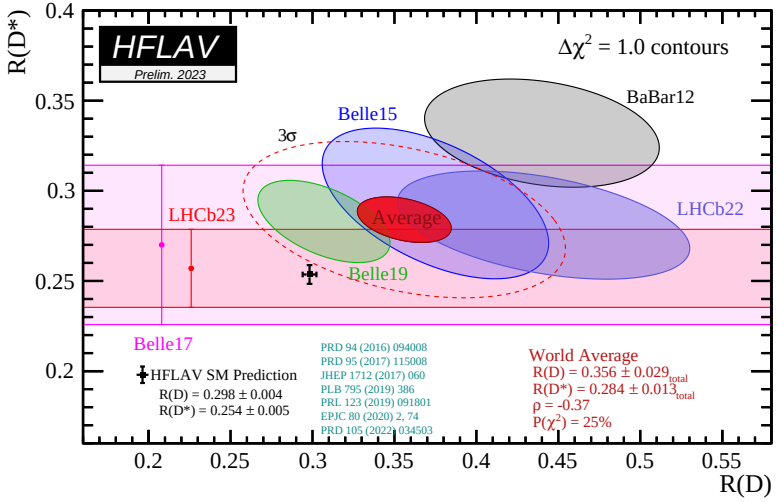
- Second surprise of R_K, R_{K^*} from LHCb
- Trying to find consistent scenarios for $b \to c\ell\nu$ and $b \to c\tau\nu$ independently, but also together inspire by SMEFT

2014-2012

- More data/observables from various modes (B_s, Λ_b...)
- Further inputs and controversies on form factors and charm loops
- Emergence of favoured scenarios (LFU + LFUV pieces, right-handed currents) and simplified models (leptoquarks)

El suflé se desinfla (un poco)





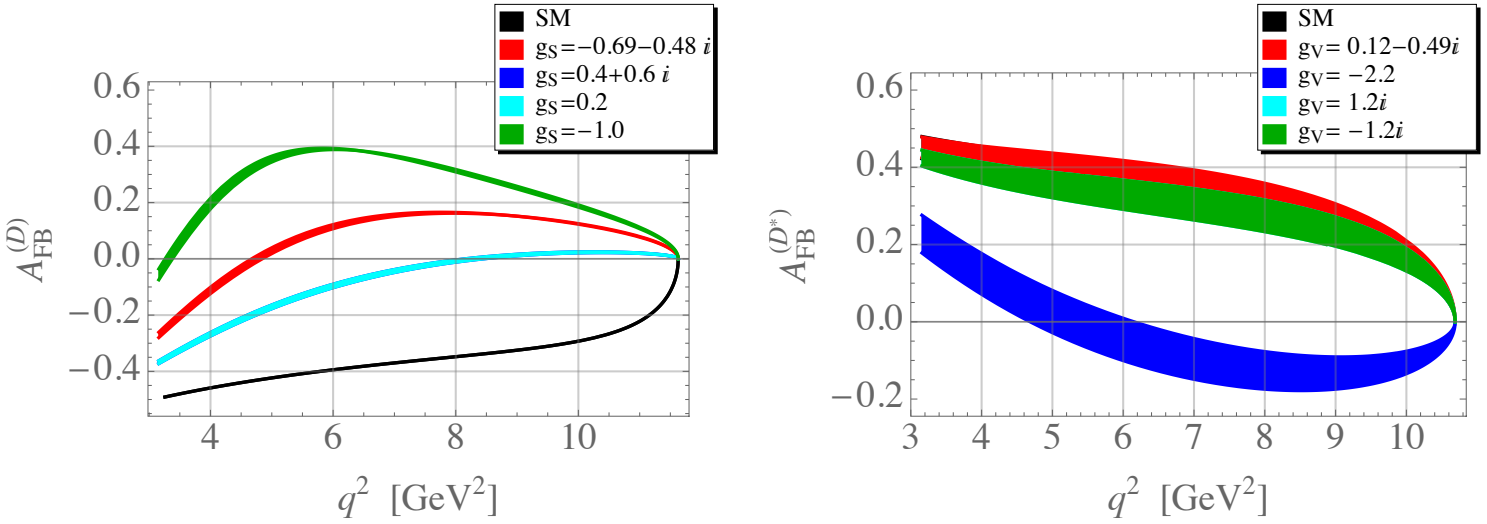
[LHCb, HFLAV]

2022

- R_{K,K^*}, R_{D,D^*} (to a lower extent)
- No large LFUV between e and μ, no right-handed currents
- Leptoquarks not so favoured, back to models that were studied earlier : charged Higgs, W', Z'
- Back to the blackboard. . . or the Monte Carlo data

Which ways to go ?

$b \to c\tau\nu$?



[1602.03030]

More observables please !

- R_{D,D^*}, polarisations in $B \to D^*\tau\nu$ not enough
- Differential decay rates: interesting to probe our understanding of form factors
- any possibility to get more angular coefficients (forward-backward asyms...) ? important to disentangle models at level of weak effective theoriy and to check what is happening for R_{D,D^*}

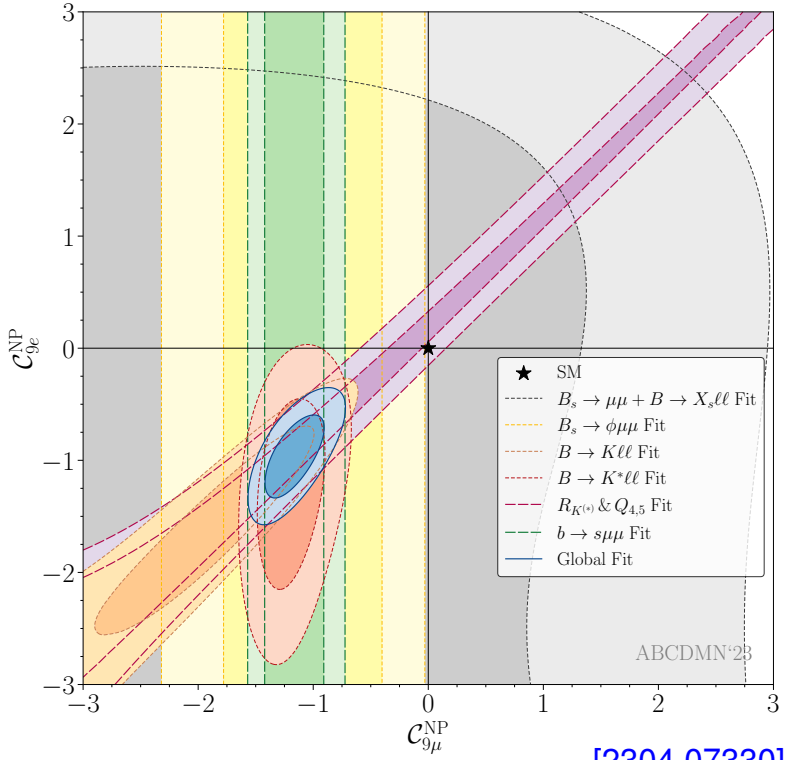
τ modelling (here and for $b \to s\tau\tau$)

LFV searches OK, but any possible Belle II-LHCb interaction ?

$b \to s\ell\ell$?

Mostly C_9^U. If nothing else, hard to convince the community (and beyond) for a long time, so more work ahead on form factors

- $B \to K\mu\mu$ branching ratios contributing significantly to (the (discrepancies of) the fit
- Improve dispersive constraints/representation
- Sanity check from $B_s \to \phi$ useful: does C_9^U + form factors yields accurate predictions for all angular observables ?
- $B \to K\pi\ell\ell$ on a larger $m_{K\pi}$ range: finite-width treatment, further info on non-resonant structures, S and D waves

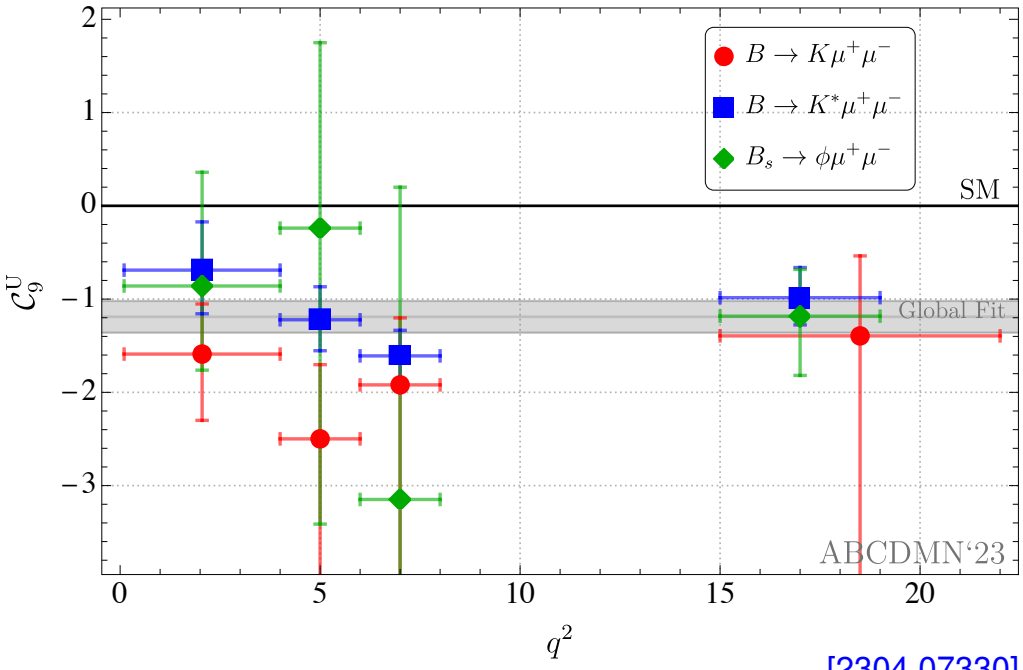


[2304.07330]

$b \to s\ell\ell$?

Mostly C_9^U. If nothing else, hard to convince the community (and beyond) for a long time, so more work ahead on non-local contributions

- Improve dispersive reprsentation + data + theory at low q^2 (really necessary ?)
- Cross-checks of the universality of the contributions (mode-by-mode, either bin-by-bin or unbinned)

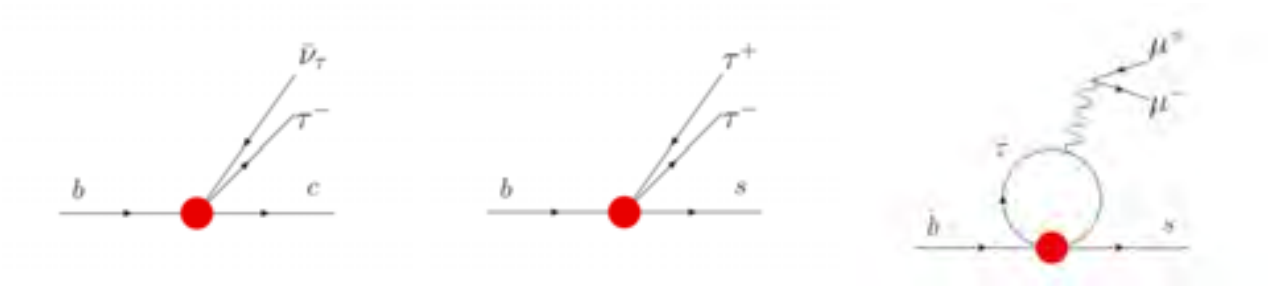


[2304.07330]

- Really worth agonising on the value of a specific mesonic triangle diagram (other channels, convergence) ?
- Main problem IMHO: no consensus not only on the answer but on what an acceptable answer could be

A more hopeful scenario ?

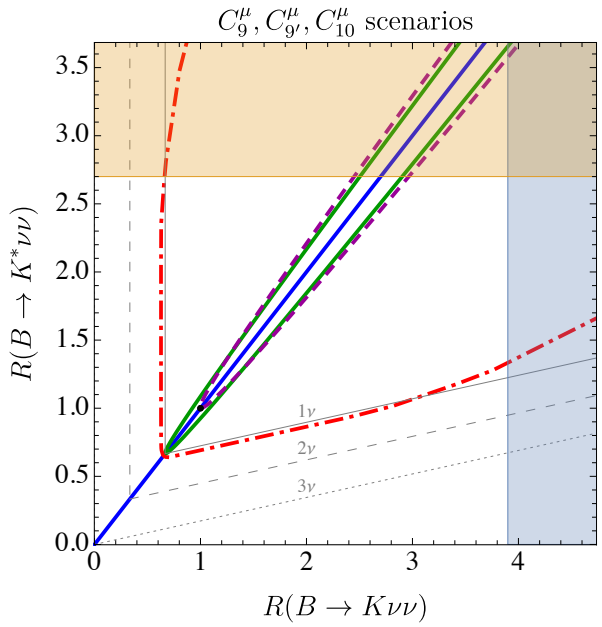
C_9^U with a pinch of something else, for instance $C_{9\mu}^V = -C_{10\mu}^V$ (although other options are available) which would nicely link everybody

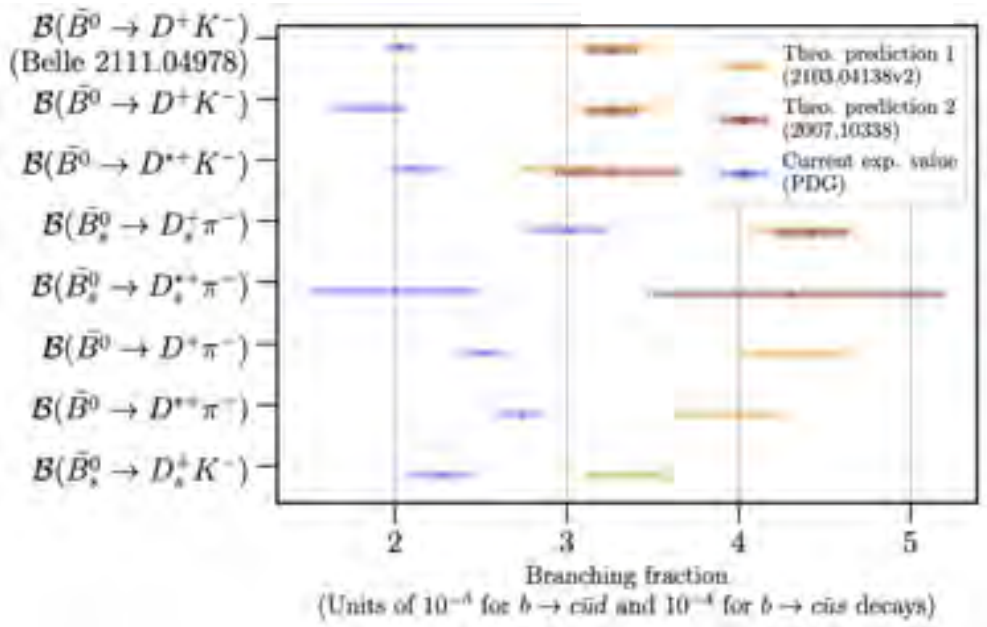


- R_{D,D^*} remains (likely) and confirmed by other $b \to c\tau\nu$ obs
- $b \to s\tau\tau$ measured much larger than SM
- R_{K,K^*} remain close to 1
- C_9^U consistent in various modes and finer bins, with increased accuracy of form factors and $c\bar{c}$
- $B_s \to \mu\mu$ quite close to SM, but not exactly
- high-P_T consequences through SMEFT

Nice concordance model, but may take a long time to prove it with a theo and exp accuracy satisfying for us and the rest of the community

Looking for other connections

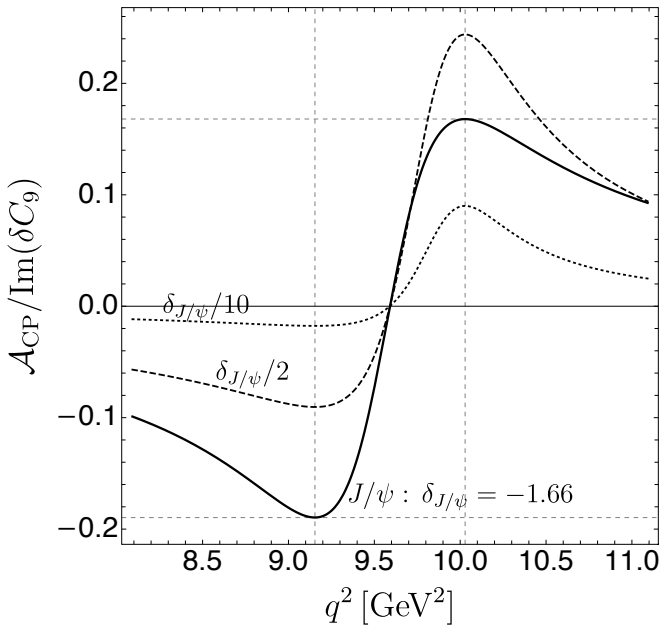


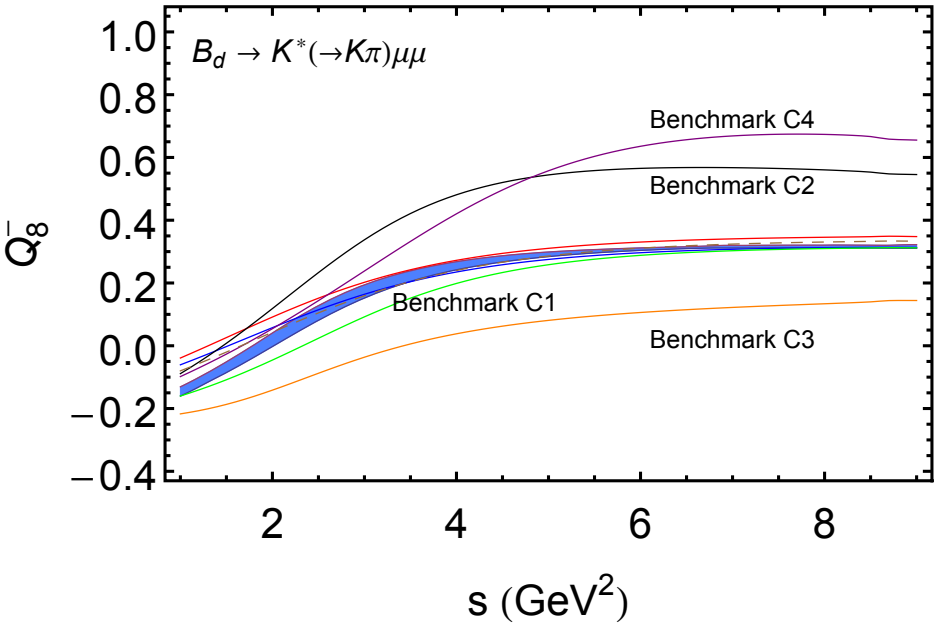


[2208.10880, A. Lenz's talk]

- Natural connection with $b \to s\nu\nu$
  - once again, not only branching ratio but also other observables (polarisation for $B \to K^* \nu\nu$)
  - caution : the previous "concordance model" set up to give no NP contribution to $b \to s\nu\nu$
- More tangent connection with hadronic $b \to sq\bar{q}$ or $b \to cq\bar{q}'$
  - less obvious
  - useful to orientate throughts about NP scenarios
  - but dynamics more difficult to handle

C_9^U with a twist ?





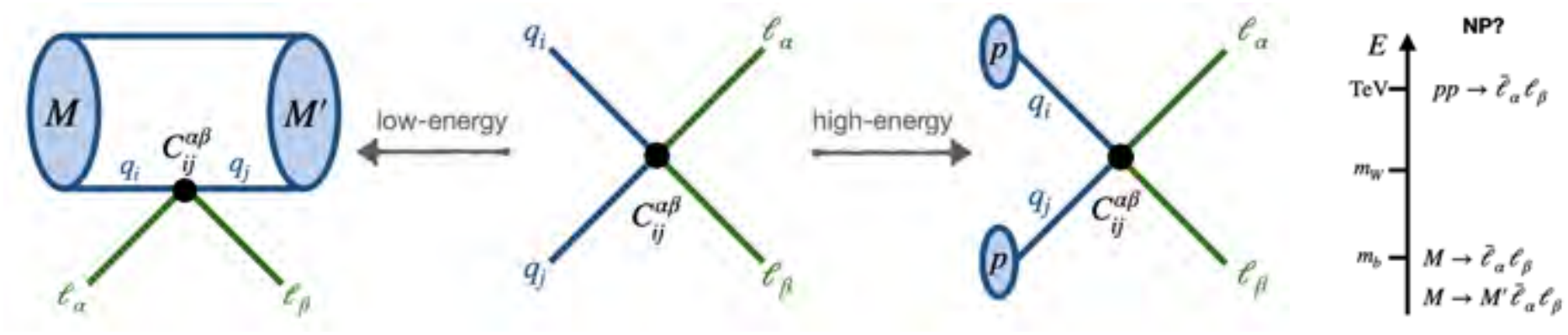
[2008.09064, 1502.05509]

Even if only C_9^U (or mostly), maybe there is a way out if it carries some weak phase ? That would be very cute:

- direct CP-asym near charmonium: strong phase variation
- time-dependent CP-asym: interferences between mixing and C_9^U

More generally, we should think more about CP-violation (additional observables) and CKM (always determined assuming SM)

High-energy connections



[F. Wilsch's talk]

SMEFT to connect low and high energies, and thus flavour results with

- specific models (leptoquarks, $W', Z' \ldots$)
- high-p_T LHC bounds (Drell-Yan...)

Challenges ahead due to the large number of different structures (electroweak and flavour) $\simeq$ 2500 coeffs

- Focus on subset of parameters: specific modes and models
- But RGE : many operators involved beyond tree level
- Some ingenuity to bound them (or back to model dependence)

When you do not know the destination

don’t be scared, enjoy the journey,
and learn along the way