Quelles déviations possibles dans les mesures de précision ?

...dans le domaine des saveurs

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Historically :

- Many discoveries from indirect measurements in flavour physics (top quark mass, 3 families …)

3 main axis:

- Very precise measurements of SM tree level processes
- Very precise measurements of processes allowed by loop diagrams in the SM or forbidden in the SM
- Better understanding of the strong interaction

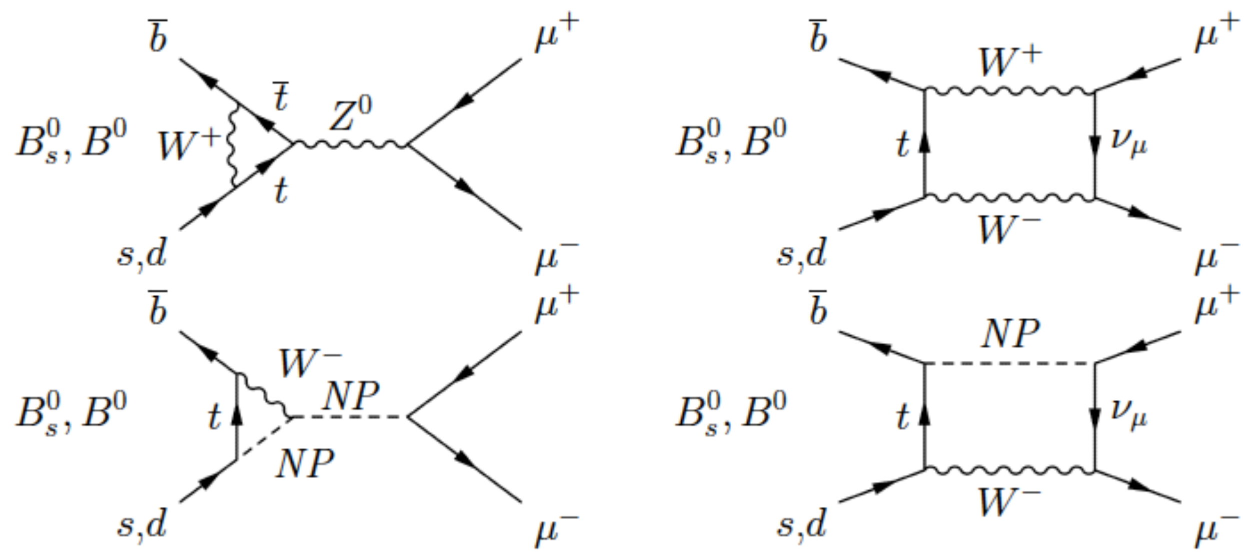
$$A\left(f_i \to f_j + X\right) = A_0 \left[\frac{C_{SM}}{M_W^2} + \frac{C_{NP}}{\Lambda_{NP}^2} \right]$$

Standard Model scale and couplings (CKM matrix elements)

New Physics **scale** and **coupling**

MS

NP



Coupling c	r=20% today	r=10% tomorrow	r=1% after tomorrow
Order 1	$\Lambda_{NP} \sim 20$ TeV	$\Lambda_{NP} \sim 30$ TeV	$\Lambda_{NP} \sim 100$ TeV
MFV	$\Lambda_{NP} \sim 180$ GeV	$\Lambda_{NP} \sim 250$ GeV	$\Lambda_{NP} \sim 800$ GeV

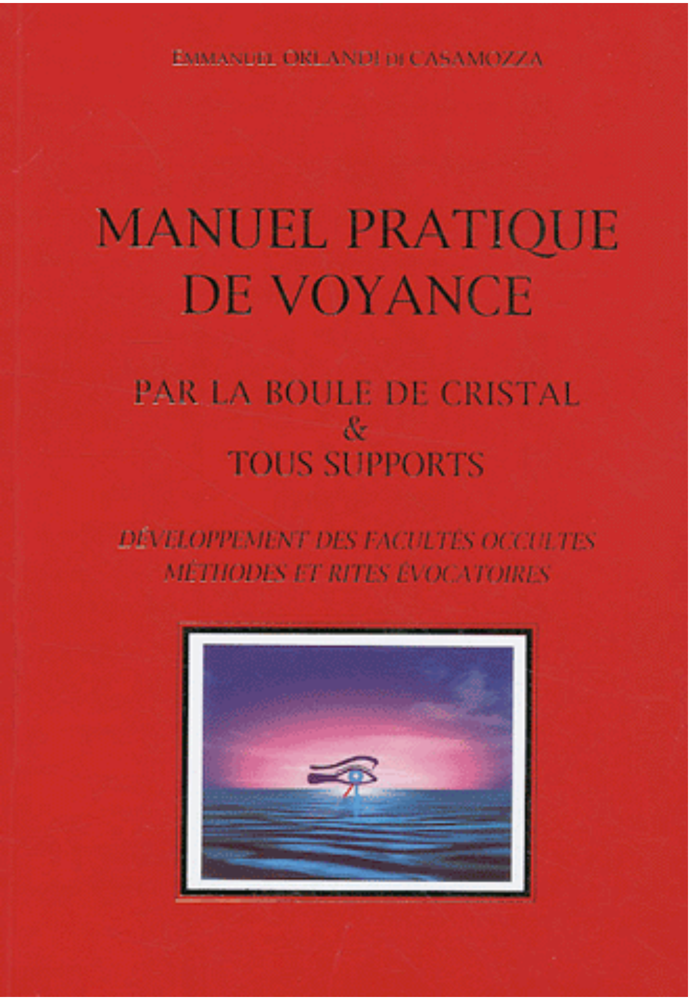
MFV ≡ no new sources of flavour and CP violation
NP contributions governed by SM Yukawa couplings.

an ad-hoc way to solve the 'Flavour problem', it has not been proven to be correct : … experimental tests !

$\Lambda_{NP} \sim 1$ TeV
+ flavour-mixing protected by additional symmetries (as MFV)

Couplings can be still large if
$\Lambda_{NP} > 1..10..$TeV

Quelles déviations possibles dans les mesures de précision dans le domaine de la physique des saveurs ?



Quelques exemples

Les mesures incontournables

Attention portée par les expériences pour éviter l'effet réverbère

The origin of mass

- $B_{d,s} \rightarrow \mu\ \mu$: could prove the existance of a non-minimal Higgs secttor

A drark matter candidate

- $B \rightarrow K/\pi\ \mu\ \mu$ sensitive to a Majorana neutrino
- $B \rightarrow K^* \mu\ \mu$ sensitive to neutralino

Better understanding of CP violation (matter/anti-matter)

- Over-constraining the SM by many measurement in the quark sector
- Compare tree measurements and loop measurements
- What about baryons ?

$B_{d,s} \rightarrow \mu\mu$

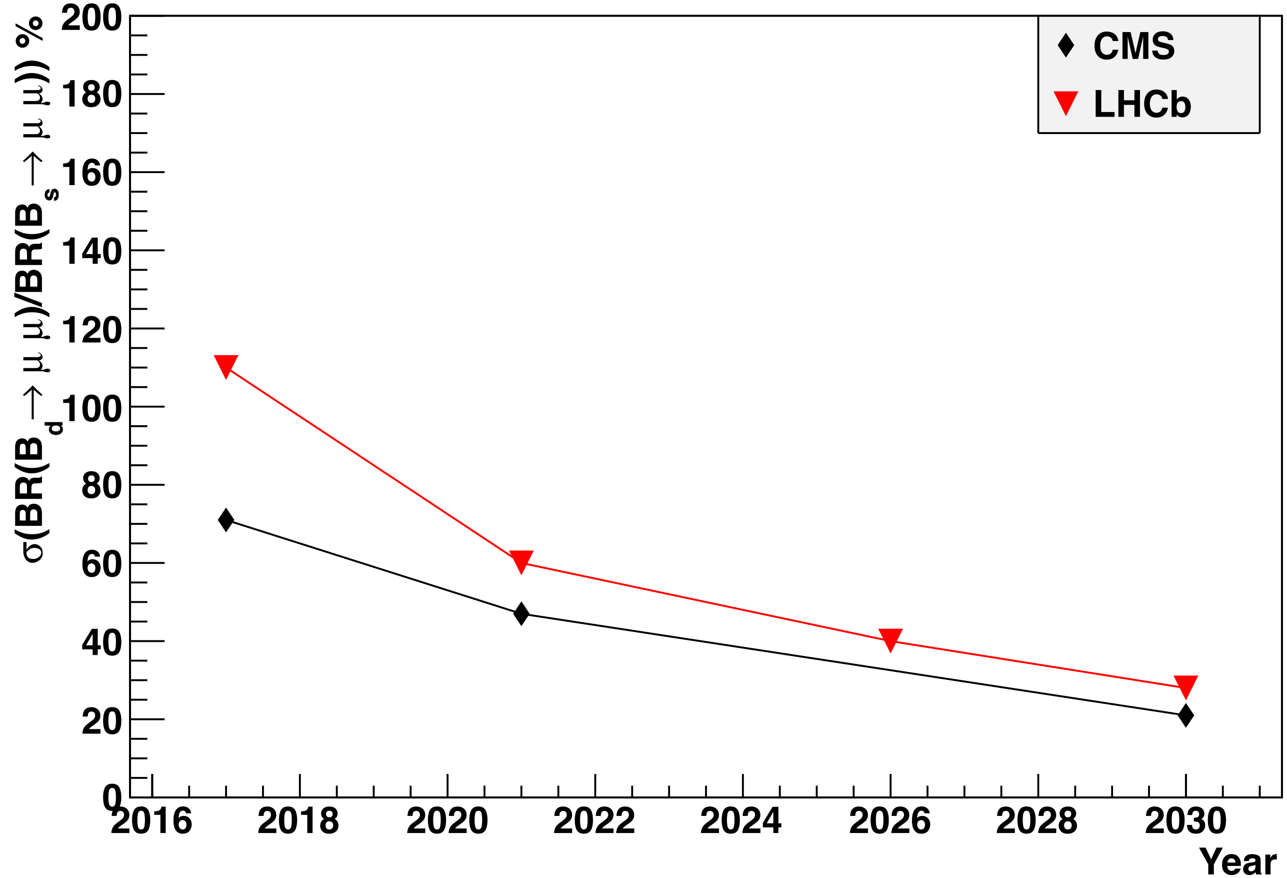
Observation of the rare $B_s^0 \rightarrow \mu^+\mu^-$ decay from the combined analysis of CMS and LHCb data

More than 25 years …

More than 3 σ separately for CMS & LHCb

Combinaison under review in both expts

$\sigma_{Th} << \sigma_{Exp}$



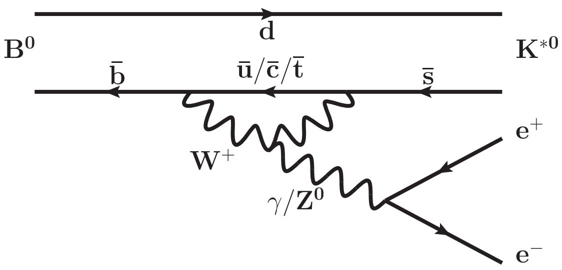
October 2013 ECFA-HL workshop

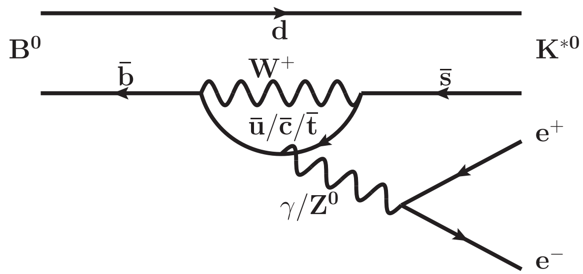
Theory error ~ 0.28

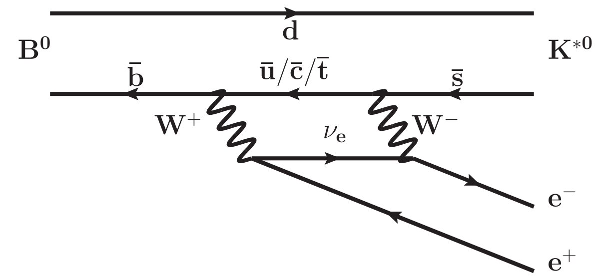
$B_d \to K^* ll$

In the SM decay possible only at loop level

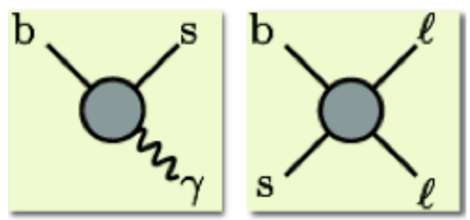
➔ SM and NP are on equal footing !







Interferences between

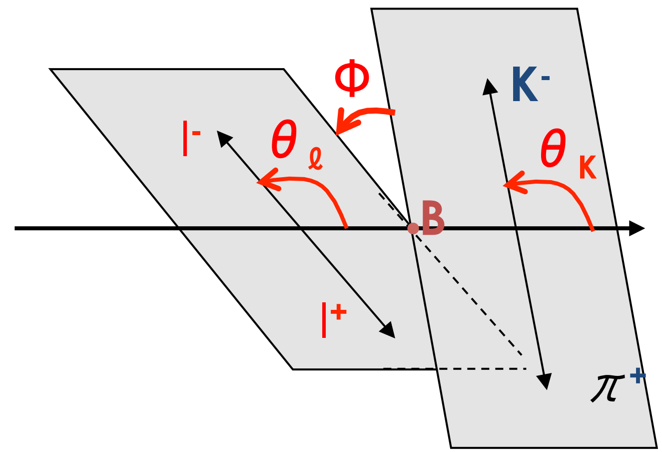


$O_{7\gamma}$ $O_{9,10}$

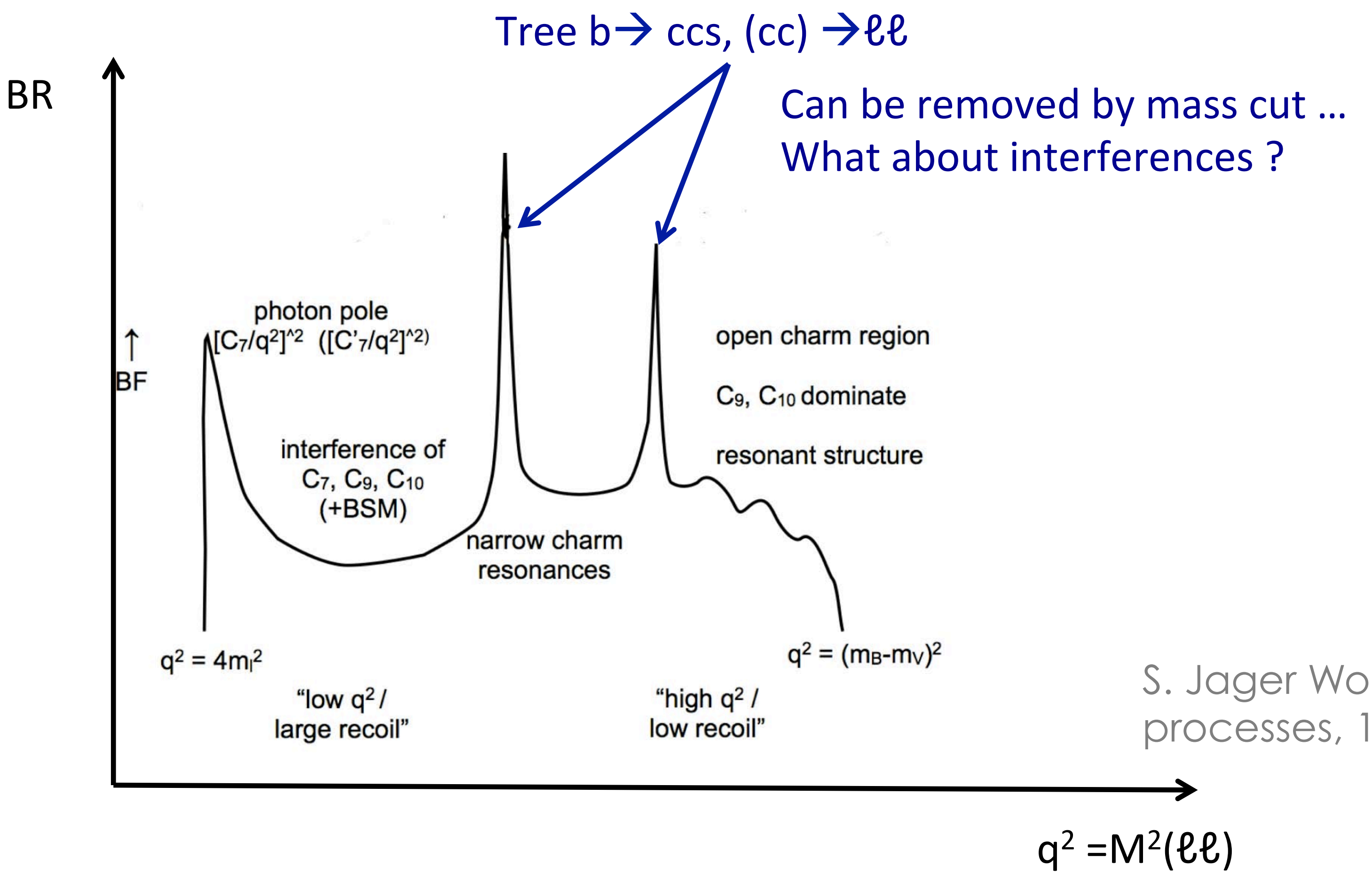
and their right-counter parts

4 particles final state : a large number of observables System described by

- $q^2 = M^2(\ell\ell)$
- 3 angles

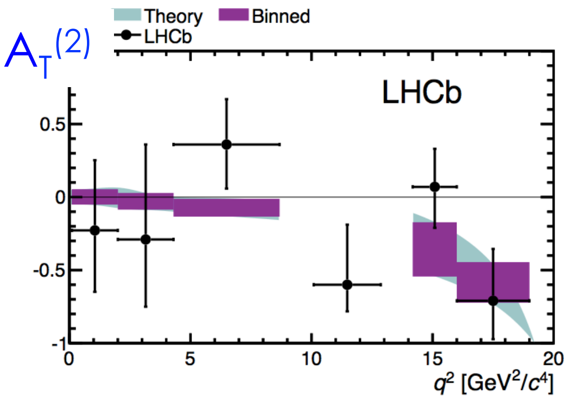


Rich and chalenging analyses



S. Jager Workshop on b → sll processes, 1-3 April 2014

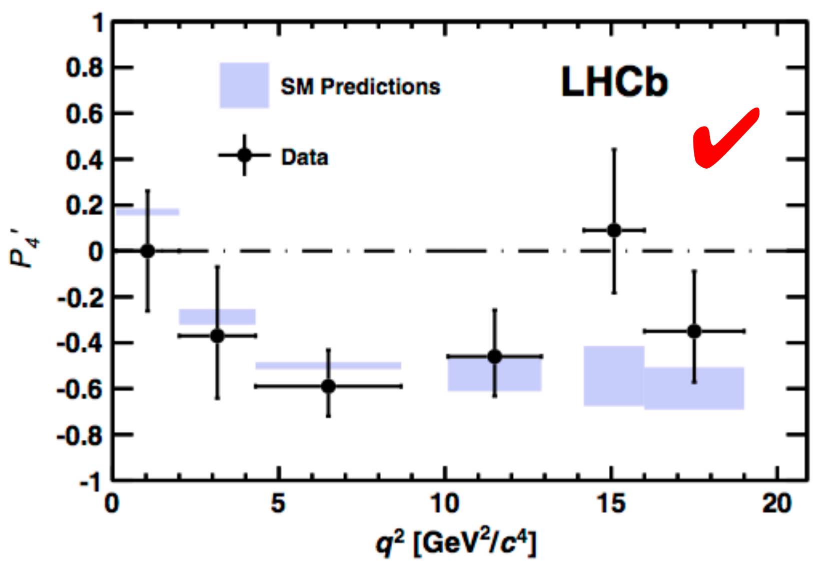
$$\frac{1}{\Gamma}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\left[\frac{3}{4}(1-F_\mathrm{L})\sin^2\theta_K + F_\mathrm{L}\cos^2\theta_K + \frac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K\cos 2\theta_\ell - F_\mathrm{L}\cos^2\theta_K\cos 2\theta_\ell + \frac{1}{2}(1-F_\mathrm{L})A_\mathrm{T}^{(2)}\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \sqrt{F_L(1-F_\mathrm{L})}P_4'\sin 2\theta_K\sin 2\theta_\ell\cos\phi + \sqrt{F_L(1-F_\mathrm{L})}P_5'\sin 2\theta_K\sin\theta \; (1-F_\mathrm{L})A_{Re}^\mathrm{T}\sin^2\theta_K\cos\theta_\ell + \sqrt{F_L(1-F_\mathrm{L})}P_6'\sin 2\theta_K\sin\theta_\ell\sin\phi + \sqrt{F_L(1-F_\mathrm{L})}P_8'\sin 2\theta_K\sin 2\theta_\ell\sin\phi + (S/A)_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\right]$$

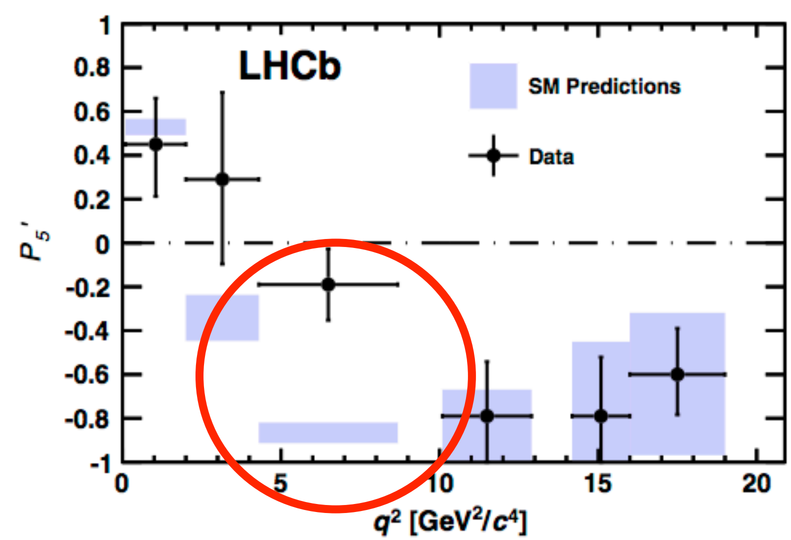


P6’ and P8’ are close to SM predictions, which are close to 0 for all q^2 bins

P4’ and P5’ have a less trivial structure :

some tension with the SM (3.7 σ in one bin) ; global significance 2.8 σ



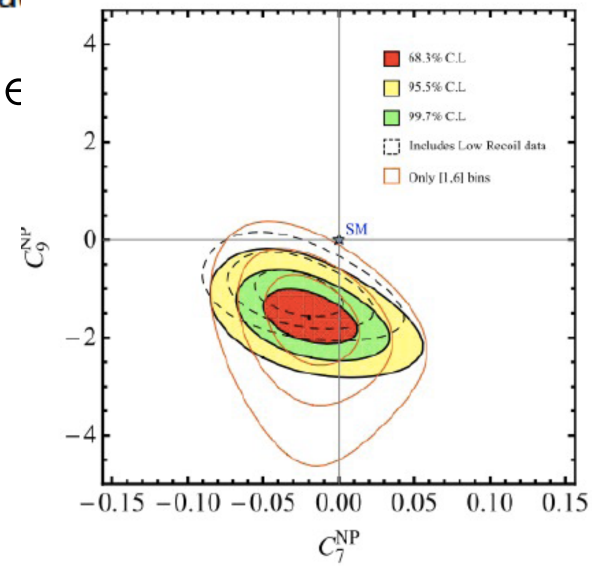


NP ?

Genon, Matias, Virto: arXiv:1307.5683
Altmannshofer, Straub: arXiv:1307.5683

Tension in P'5 and low B->K$^{(*)}$ll BR reduced with a unique fit of modified Wilson coefficients (mainly C_9)

The effective NP scale is high (~ 10 TeV)



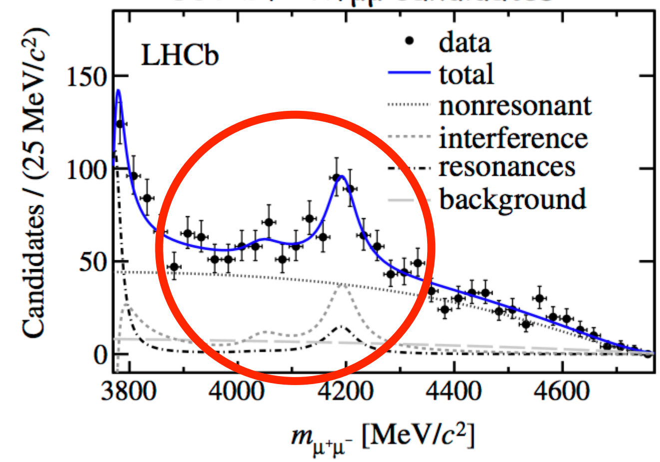
QCD ?

charm-resonance effects

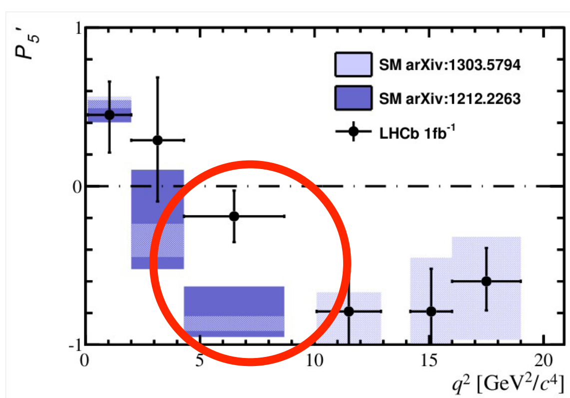
Main effect in P5' not far from cc threshold

Significance reduced with conservative estimates of nonfactorizable corrections

830 B+->K+μμ candidates



+BES III data

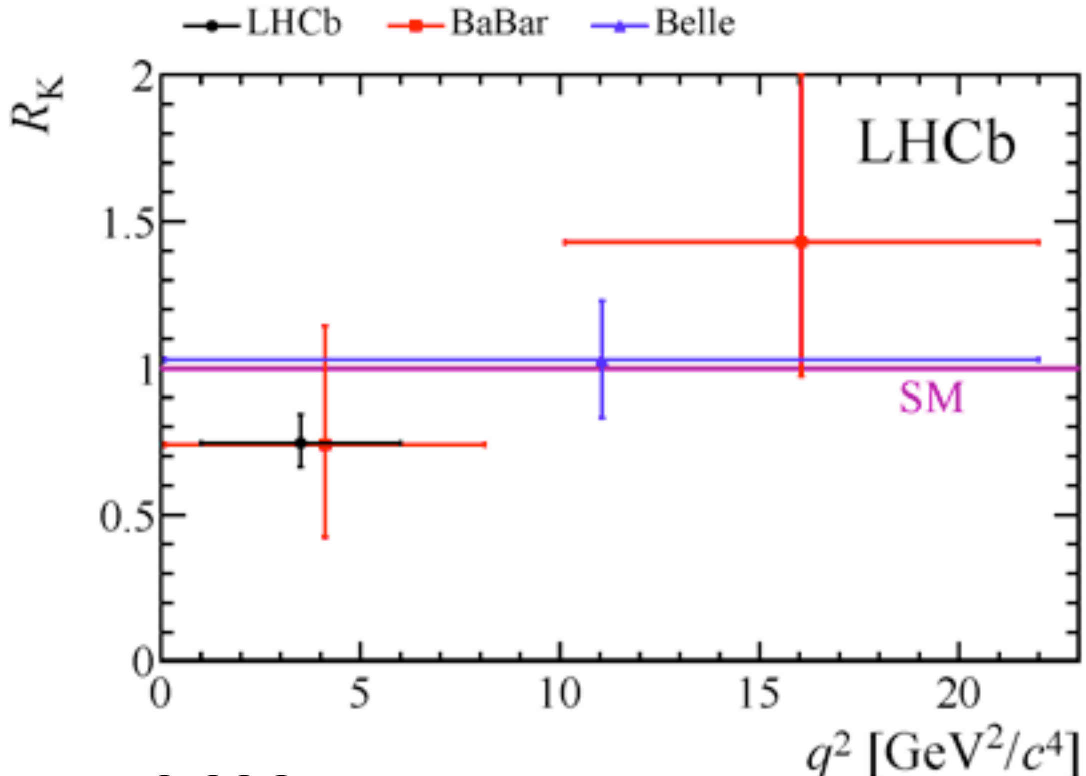


Jaeger *et al.* '12
Hambrock *et al.* '13
Hiller & Zwicky '13

Needs more data

Many other B→ Kll analyses

$R_K = BR(B \to K\mu\mu)/BR(B \to Kee)$



$R_K = 0.745^{+0.090}_{-0.074} \pm 0.036$

NO QCD uncertainty

In short :

B→K(*)ll is a very good place to search for NP

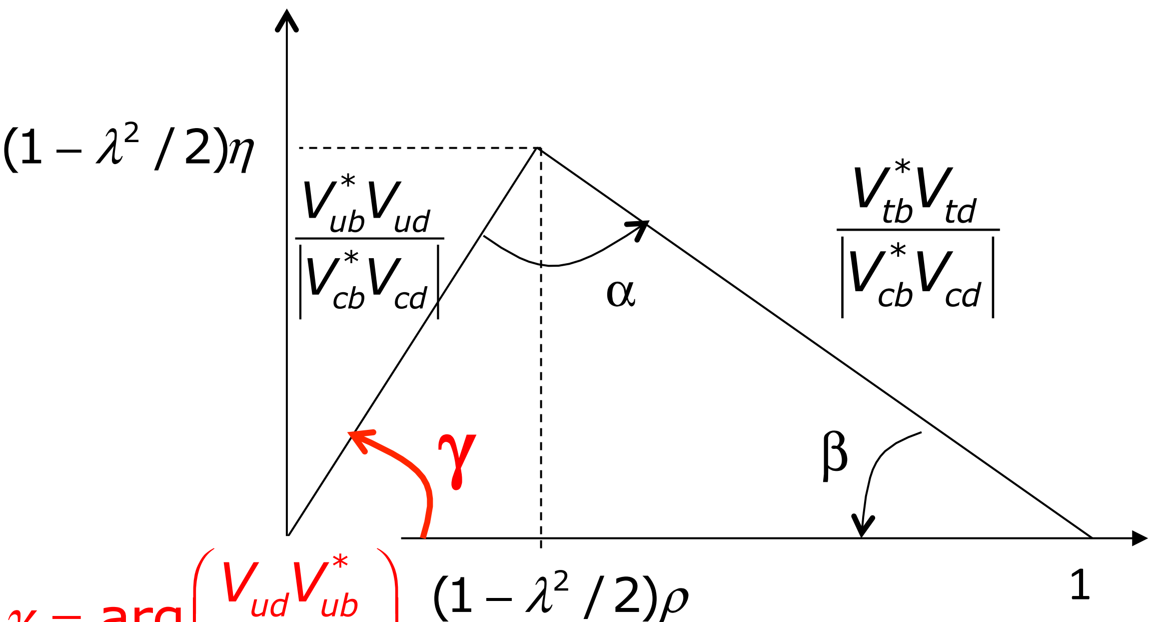
A very large sample is required in order

- to reach sensititivies comparable to theoretical uncertainties in the 'clean' q^2 regions : data closer to the psi(1S) and psi (2S) region + fine q2-binning
- Other K* and K modes : K* vs K ?
- to better understand QCD effects (Form Factor uncertainties)

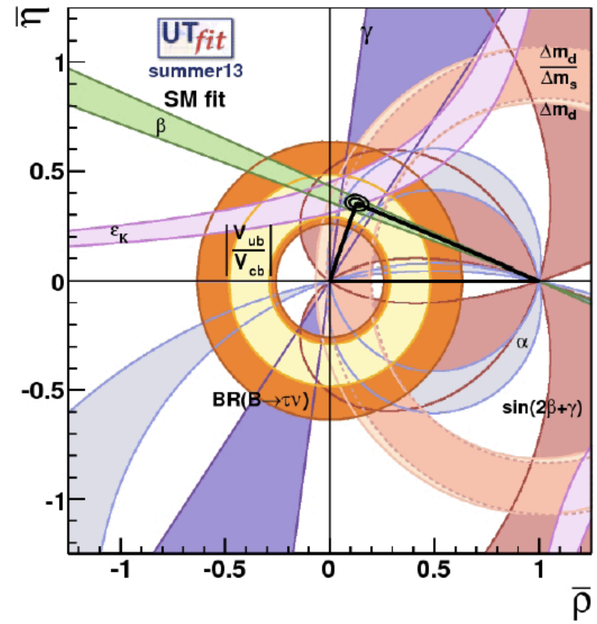
Study of inclusive modes

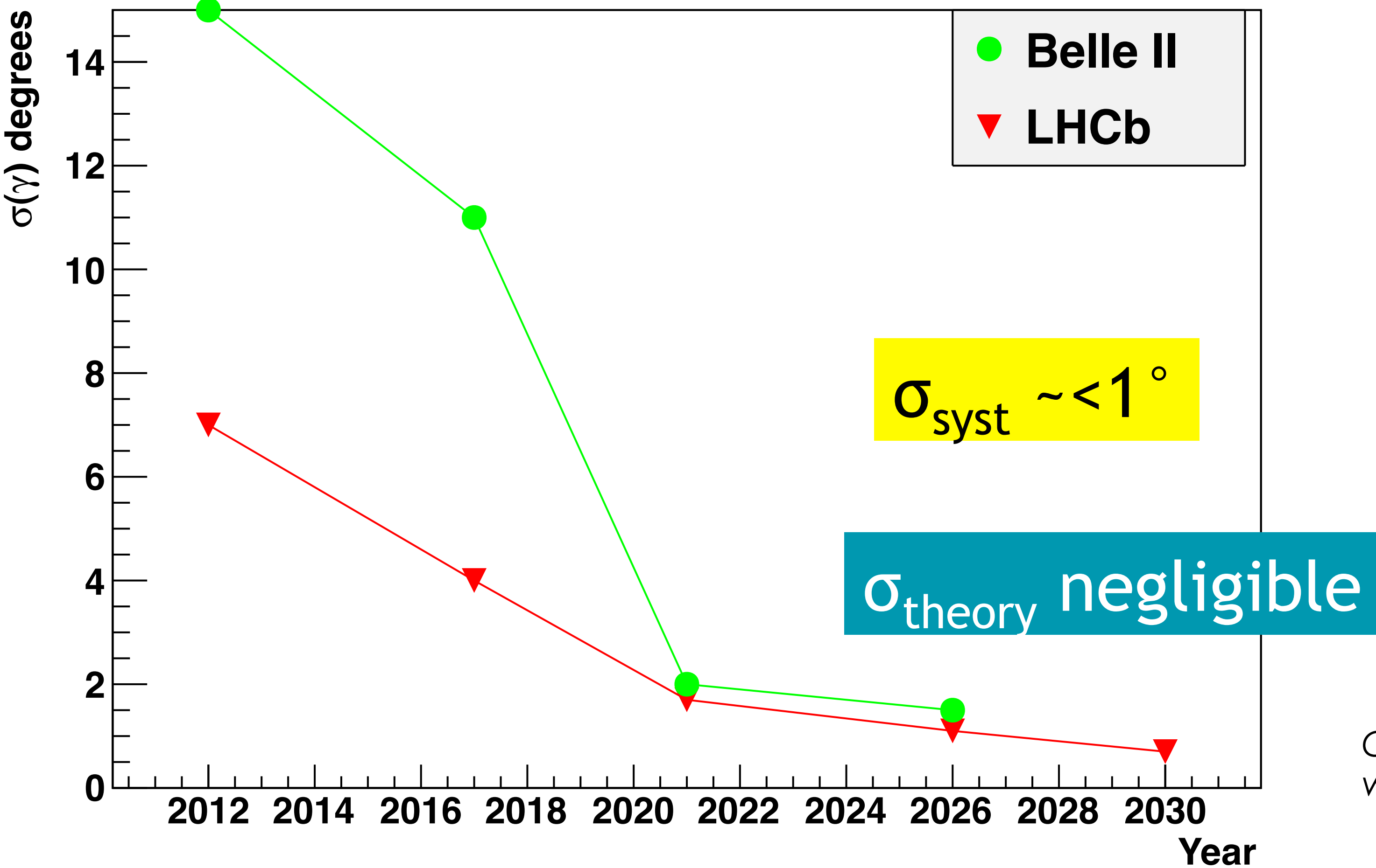
- BELLE-II
- A fully inclusive measurement using only the 2 muons (LHCb) ?

The γ angle



$$\gamma = \arg\left(\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$





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Even better than sin(2β)

β experimental precision ~ 2°

In $J/\psi K_s$ NP can enter in the mixing

But also :

A long standing problem in exclusive vs inclusive determination of V_{ub} (and V_{cb})

PDG 2013

$$|V_{cb}| = (42.4 \pm 0.9) \times 10^{-3} \text{ (inclusive)} \qquad |V_{ub}| = (4.41 \pm 0.15 \, {}^{+0.15}_{-0.17}) \times 10^{-3} \quad \text{(inclusive)},$$

$$|V_{cb}| = (39.5 \pm 0.8) \times 10^{-3} \text{ (exclusive)} \qquad |V_{ub}| = (3.23 \pm 0.31) \times 10^{-3} \quad \text{(exclusive)}.$$

Search for lepton flavour violation:

- in τ decays
- in B and D decays

Charm physics:

- FCNC in the up-type quark sector
- CPV

Explore the b-baryon world :

- CPV
- Rare decays

New 'exotic' particles:

- X, Y Z …

Summary

NP is still possible at the 10-20 % level

- Some tensions in the B sector ($B_{d,s} \rightarrow \mu\mu$, $B \rightarrow K^{*}ll$)
- Most of the results are still statistically dominated
- Most of the experimental uncertainties are still larger than the theoretical ones

BELLE-II is going to start ! This is a very good news

Next ? FCC-ee (10^{12} Z^0)

- $\sigma(\Delta m_d)_{DELPHI} = 3.6\ \sigma(\Delta m_d)_{LHCb\ or\ BELLE/BaBar}$
- $4.5\ 10^6\ Z^0$
- All species (but mainly interesting for non B_u B_d hadrons), potentialy high tagging performance, neutrals .
- Since the LEP time : access to B_s mixing (detectors)
- + LFV from Z^0 decays
- B_c and b-baryons physics
- V_{xb} taking advantage of the large boost