

# The discovery of CP violation

## PROPOSAL FOR $K_2^0$ DECAY AND INTERACTION EXPERIMENT

J. W. Cronin, V. L. Fitch, R. Turlay

(April 10, 1963)

### I. INTRODUCTION

The present proposal was largely stimulated by the recent anomalous results of Adair et al., on the coherent regeneration of  $K_1^0$  mesons. It is the purpose of this experiment to check these results with a precision far transcending that attained in the previous experiment. Other results to be obtained will be a new and much better limit for the partial rate of  $K_2^0 \rightarrow \pi^+ + \pi^-$ , a new limit for the presence (or absence) of neutral currents as observed through  $K_2 \rightarrow \mu^+ + \mu^-$ . In addition, if time permits, the coherent regeneration of  $K_1$ 's in dense materials can be observed with good accuracy.

### II. EXPERIMENTAL APPARATUS

Fortuitously the equipment of this experiment already exists in operating condition. We propose to use the present  $30^\circ$  neutral beam at the A.G.S. along with the di-pion detector and hydrogen target currently being used by Cronin, et al. at the Cosmotron. We further propose that this experiment be done during the forthcoming  $\mu$ -p scattering experiment on a parasitic basis.

The di-pion apparatus appears ideal for the experiment. The energy resolution is better than 4 Mev in the  $m^*$  or the Q value measurement. The origin of the decay can be located to better than 0.1 inches. The 4 Mev resolution is to be compared with the 20 Mev in the Adair bubble chamber. Indeed it is through the greatly improved resolution (coupled with better statistics) that one can expect to get improved limits on the partial decay rates mentioned above.

### III. COUNTING RATES

We have made careful Monte Carlo calculations of the counting rates expected. For example, using the  $30^\circ$  beam with the detector 60-ft. from the A.G.S. target we could expect 0.6 decay events per  $10^{11}$  circulating protons if the  $K_2$  went entirely to two pions. This means that one can set a limit of about one in a thousand for the partial rate of  $K_2 \rightarrow 2\pi$  in one hour of operation. The actual limit is set, of course, by the number of three-body  $K_2$  decays that look like two-body decays. We have not as yet made detailed calculations of this. However, it is certain that the excellent resolution of the apparatus will greatly assist in arriving at a much better limit.

If the experiment of Adair, et al. is correct the rate of coherently regenerated  $K_1$ 's in hydrogen will be approximately 80/hour. This is to be compared with a total of 20 events in the original experiment. The apparatus has enough angular acceptance to detect incoherently produced  $K_1$ 's with uniform efficiency to beyond  $15^\circ$ . We emphasize the advantage of being able to remove the regenerating material (e.g., hydrogen) from the neutral beam.

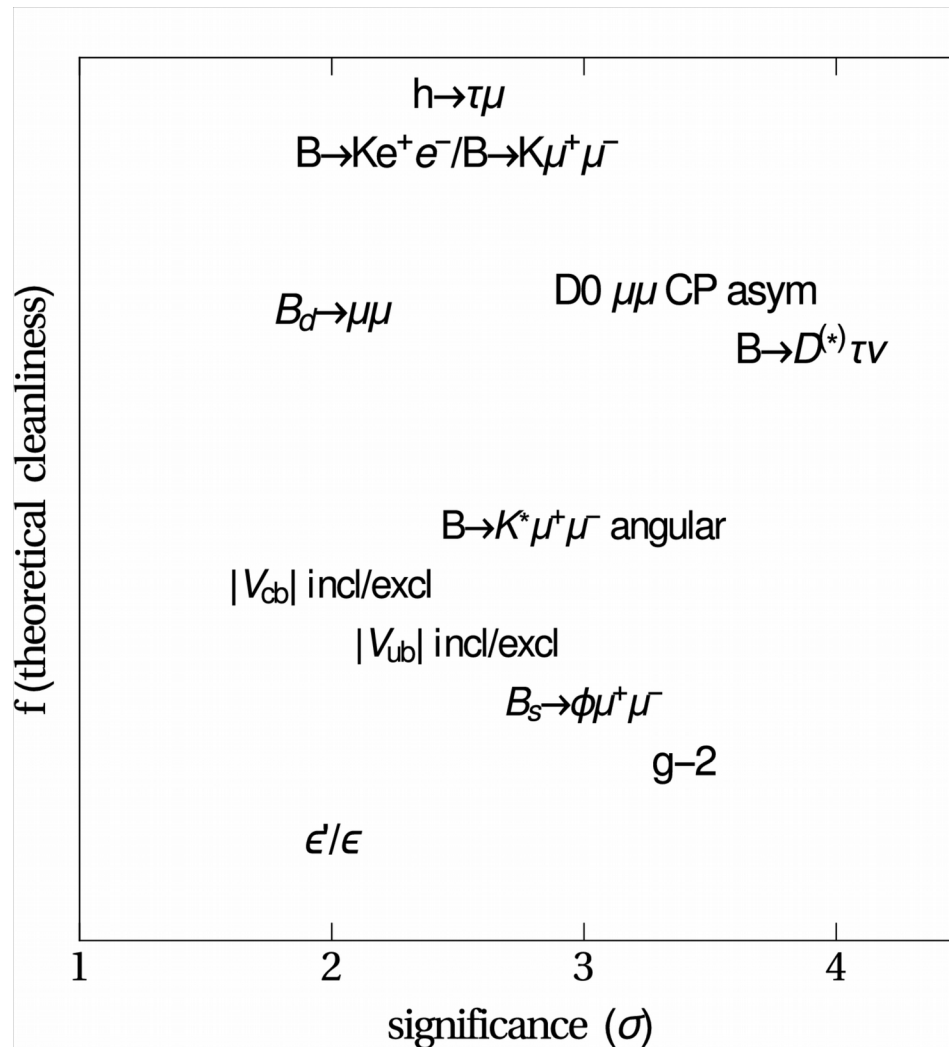
### IV. POWER REQUIREMENTS

The power requirements for the experiment are extraordinarily modest. We must power one 18-in. x 36-in. magnet for sweeping the beam of charged particles. The two magnets in the di-pion spectrometer are operated in series and use a total of 20 kw.

⇒ Cronin & Fitch, Nobel Prize, 1980

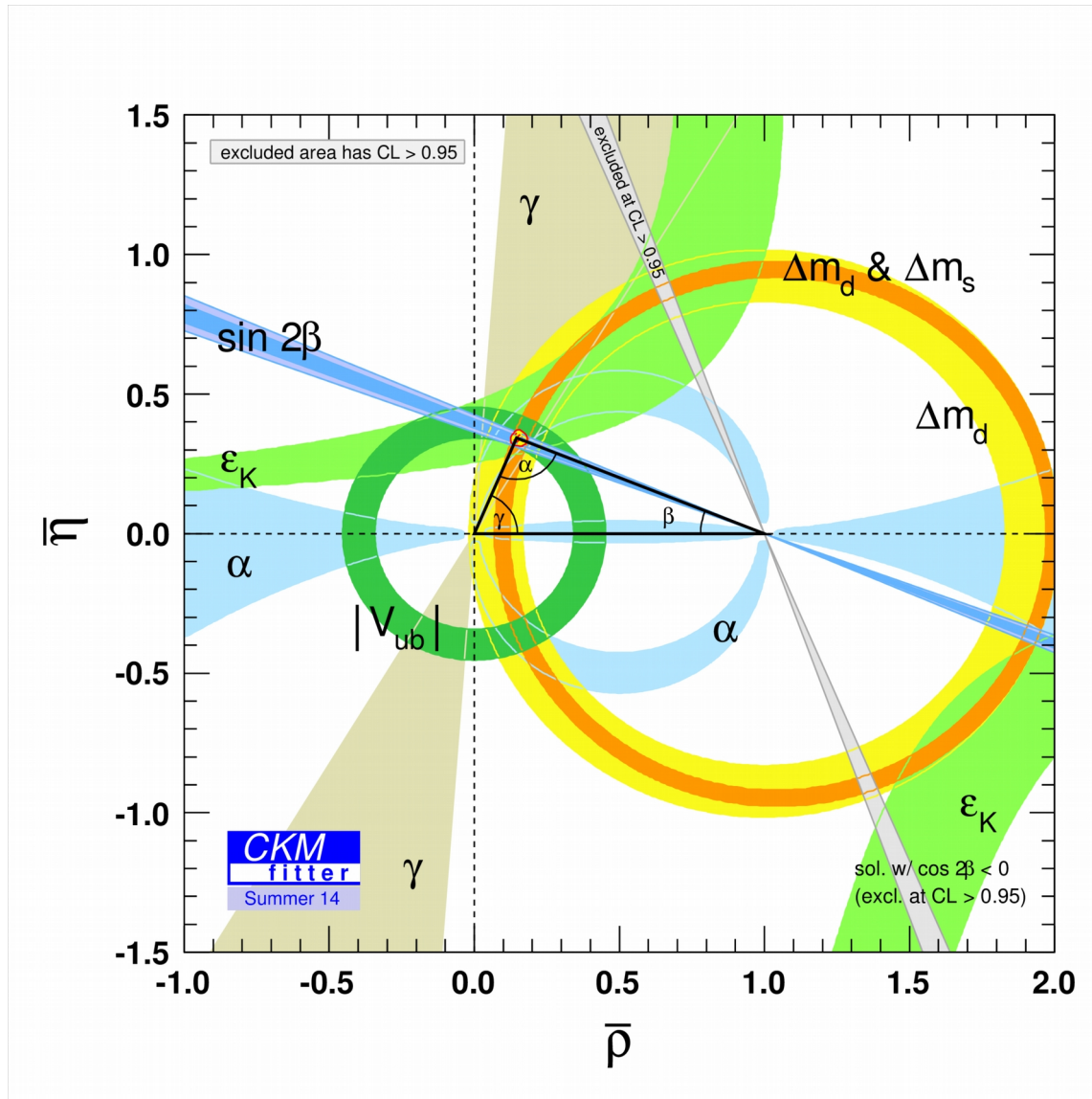
⇒ 3 generations, Kobayashi & Maskawa, Nobel Prize, 2008

# Tensions with the SM

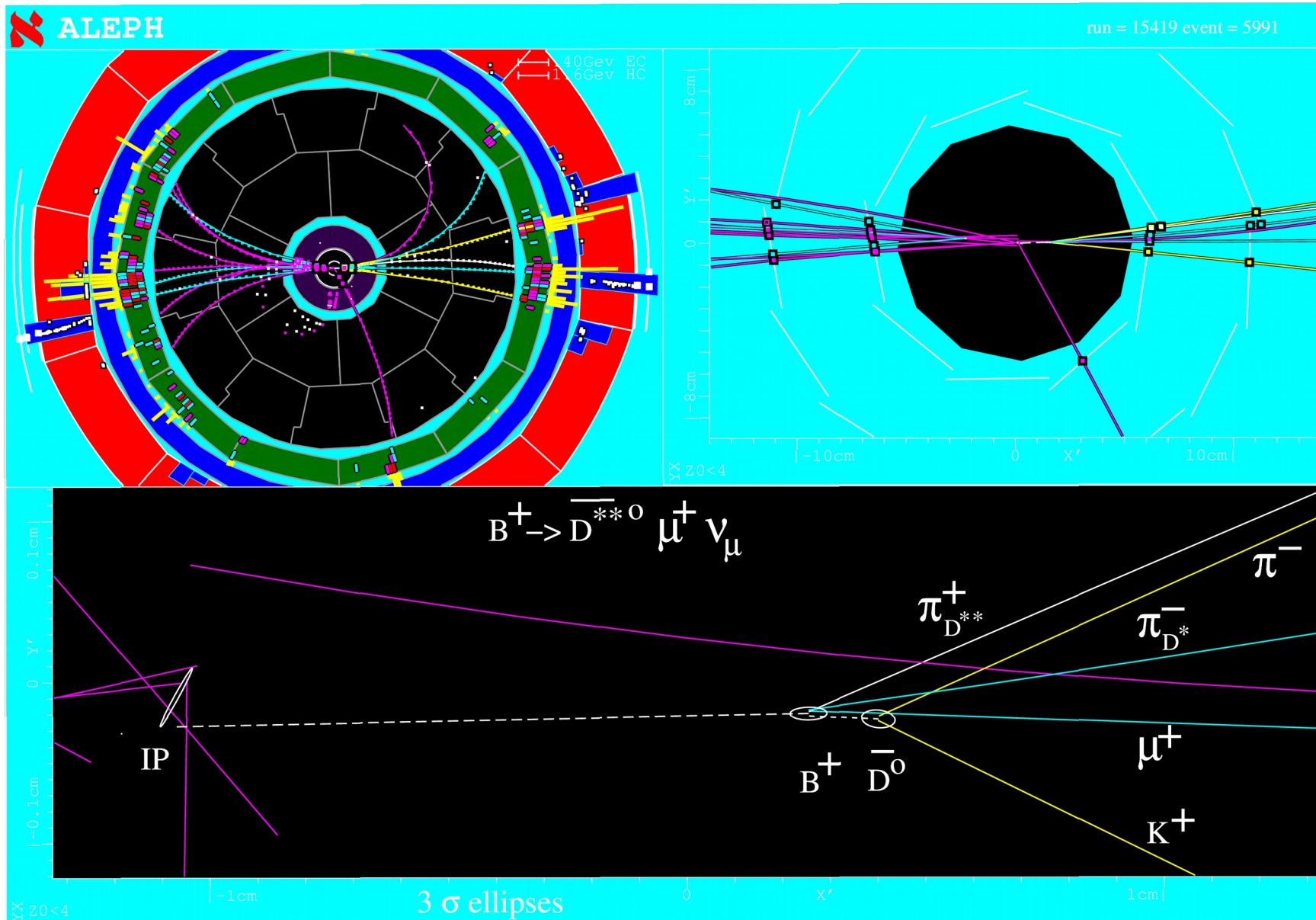


[1606.02756]

# CKM fit in the SM

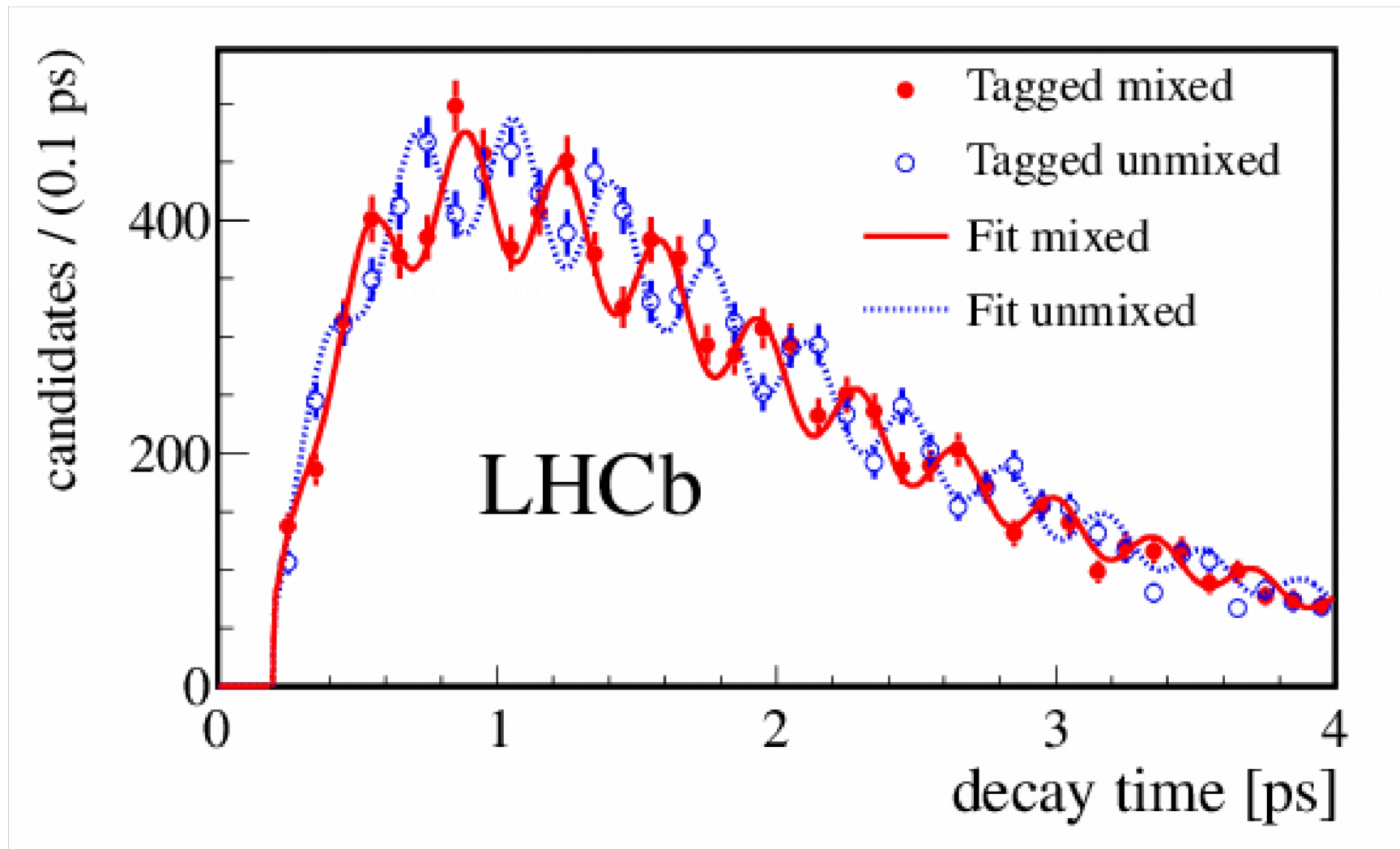


# Long B meson lifetime

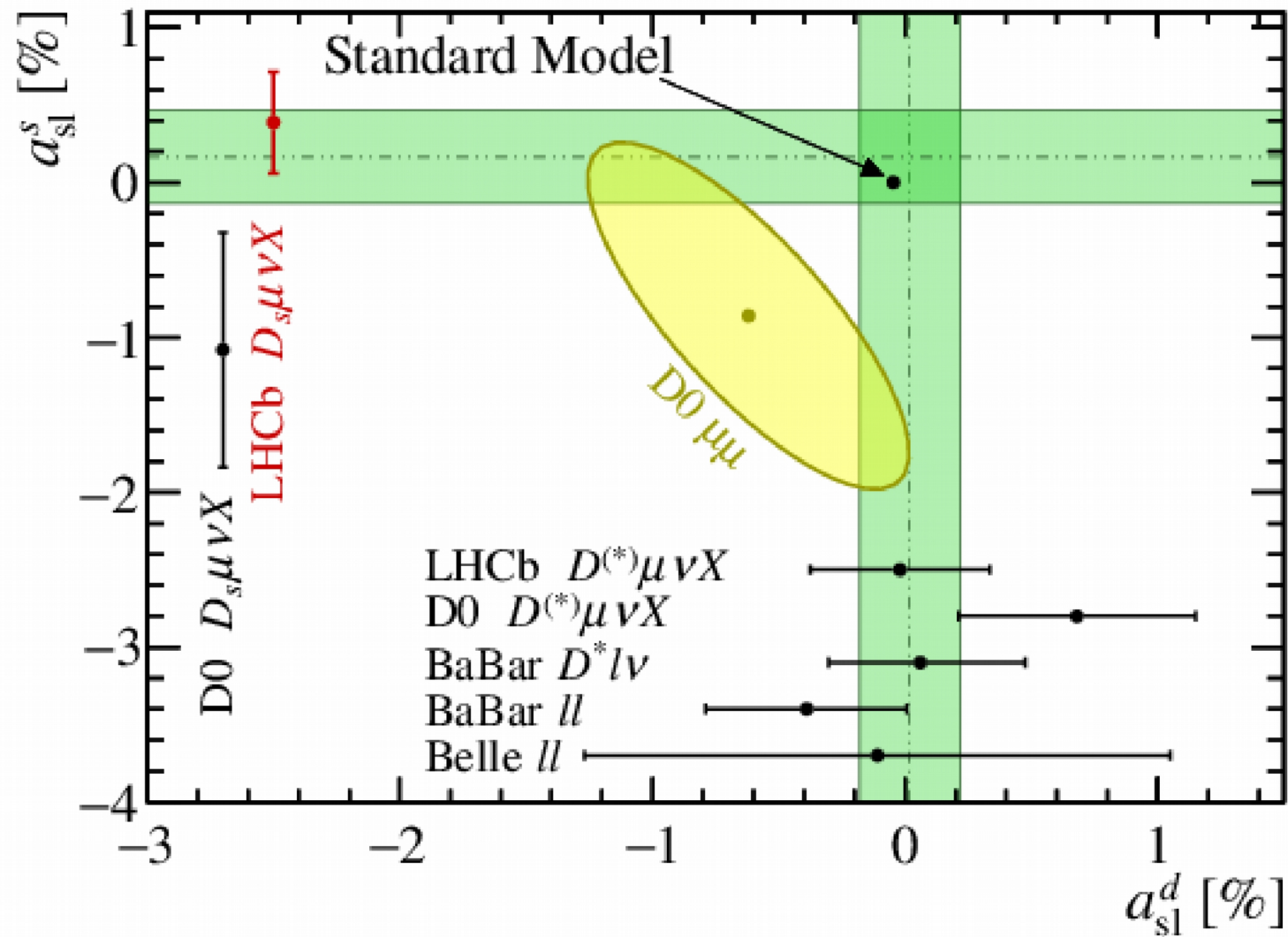




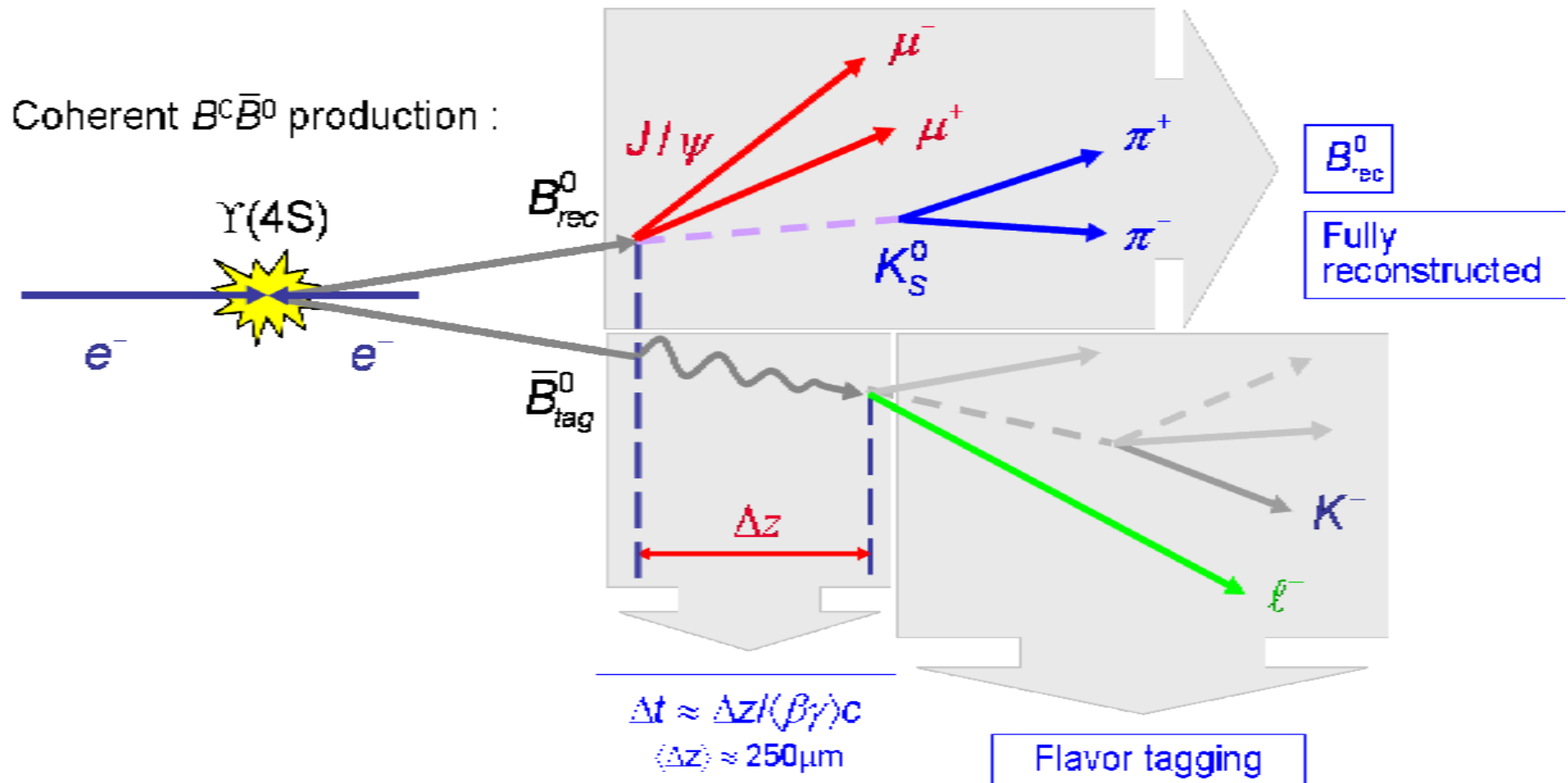
# $B_s$ oscillation – good time resolution



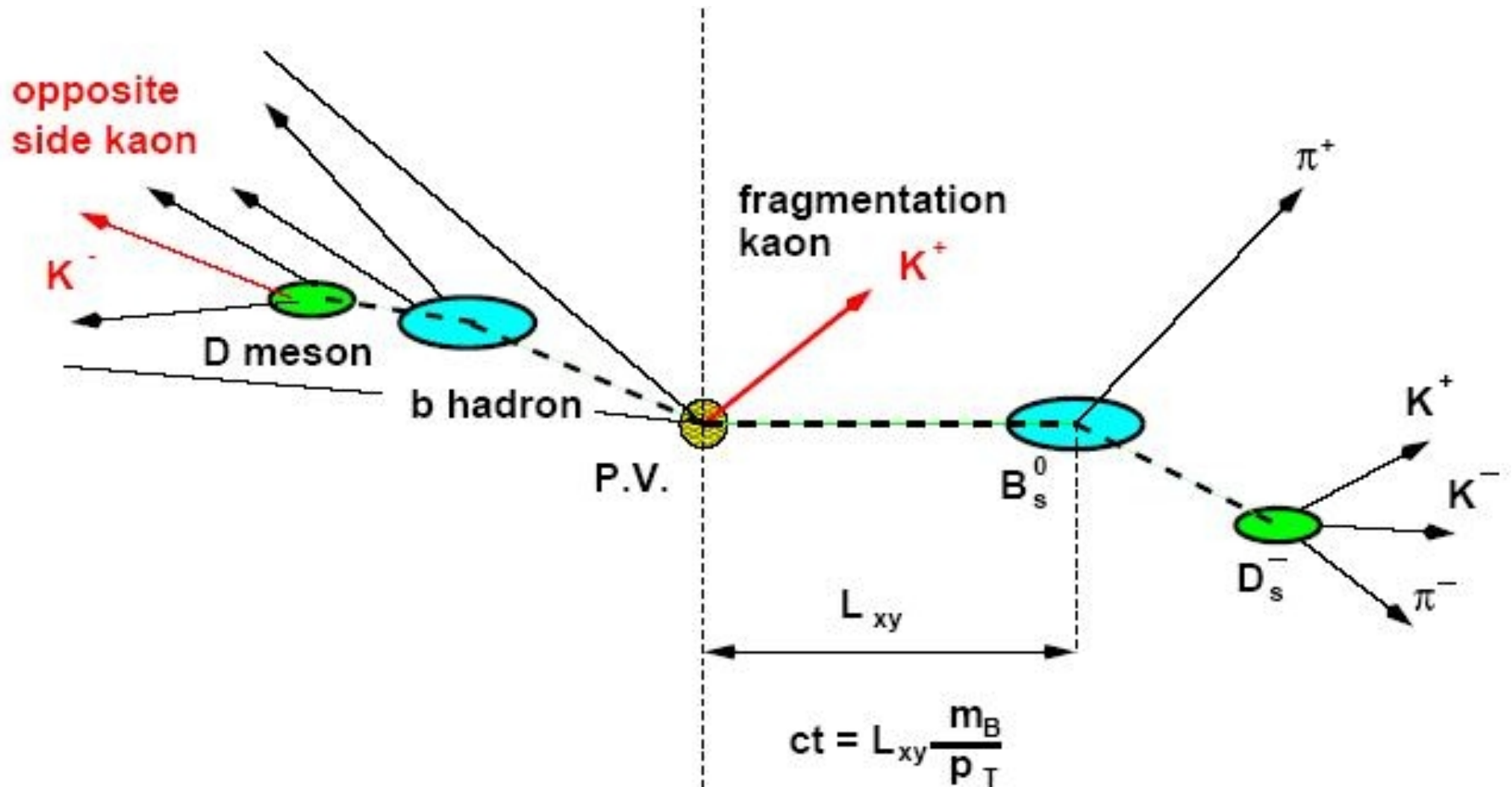
# Semileptonic CP asymmetry



# Time dependence ( $e^+e^-$ )

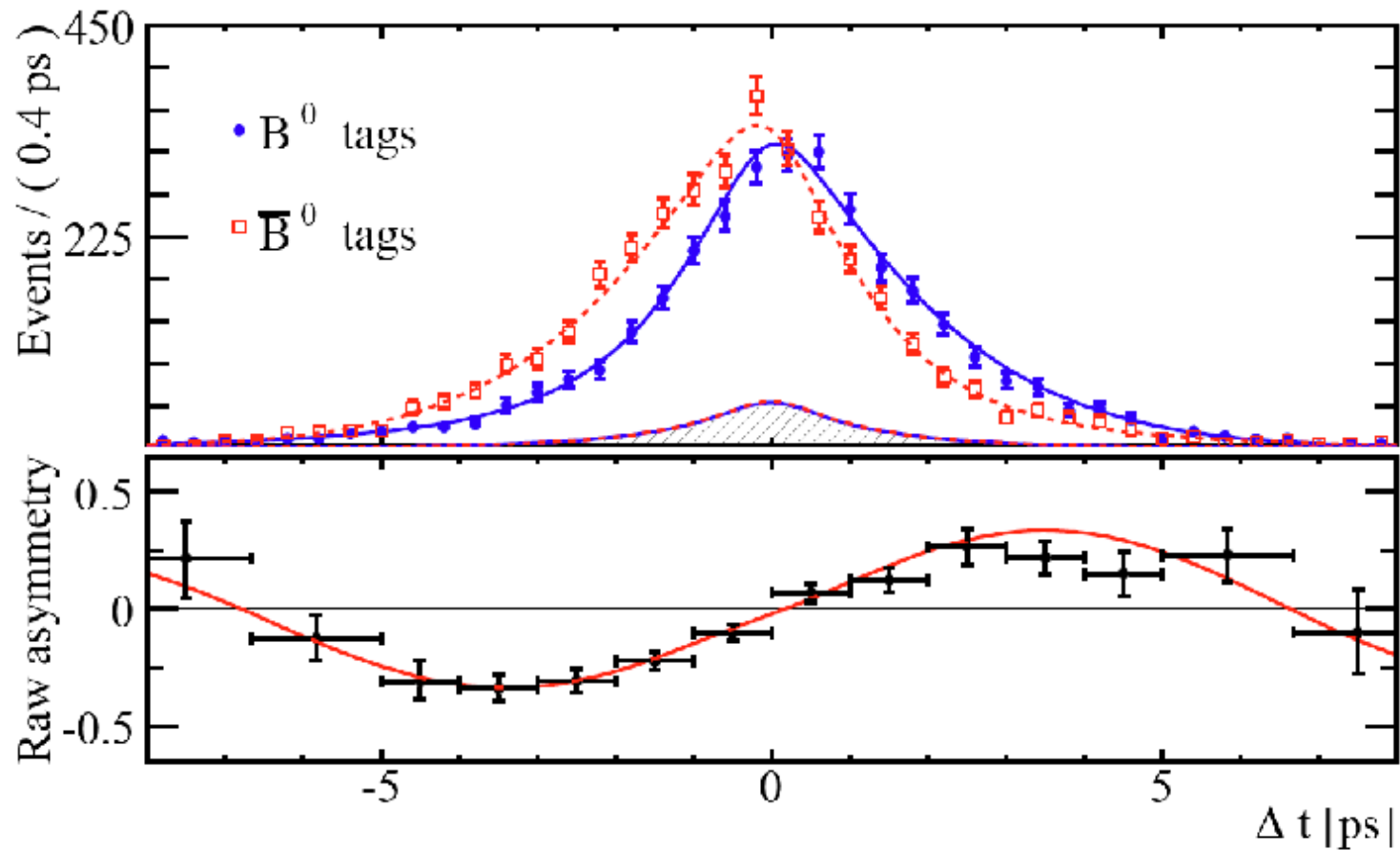


# Time dependence (pp)

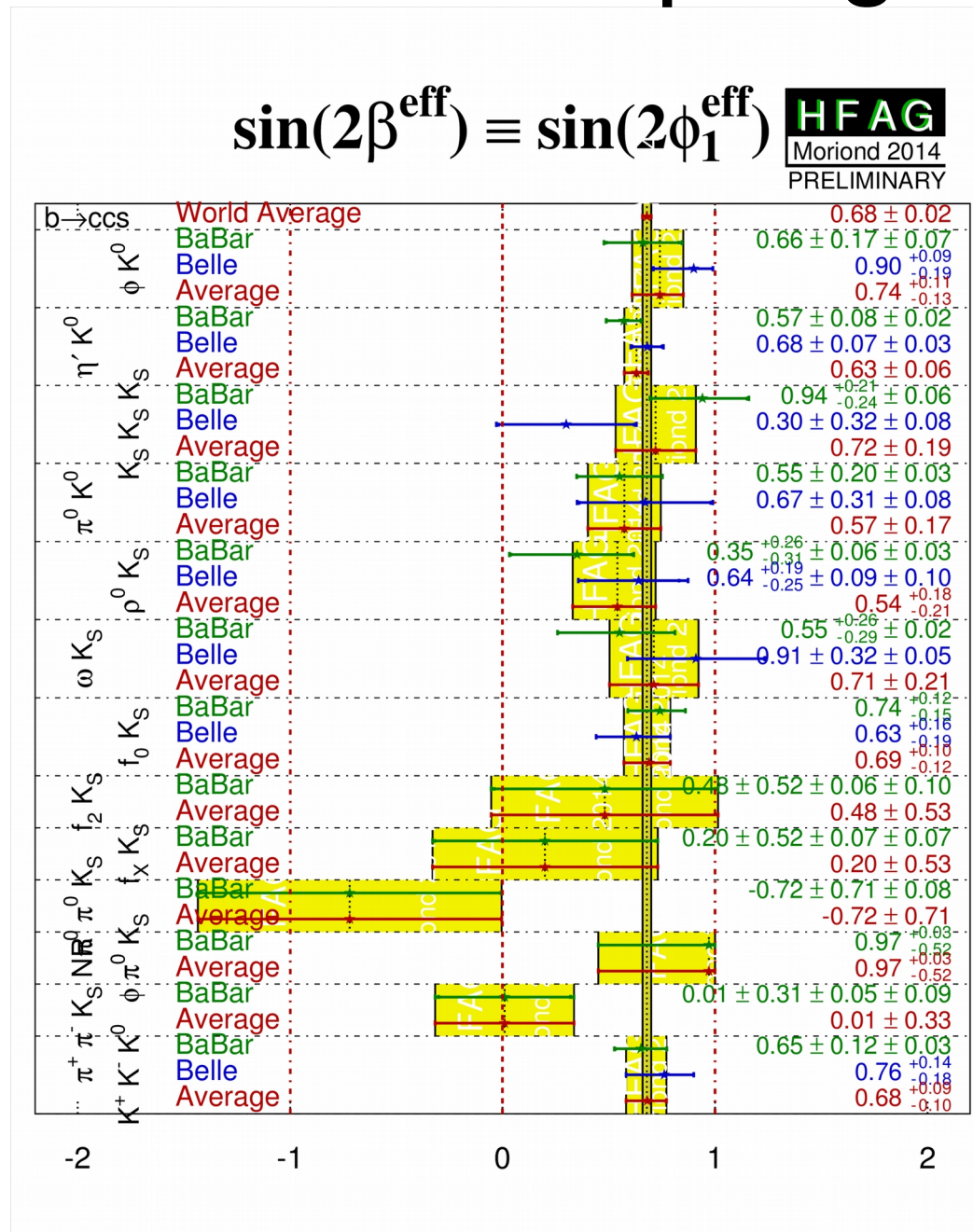




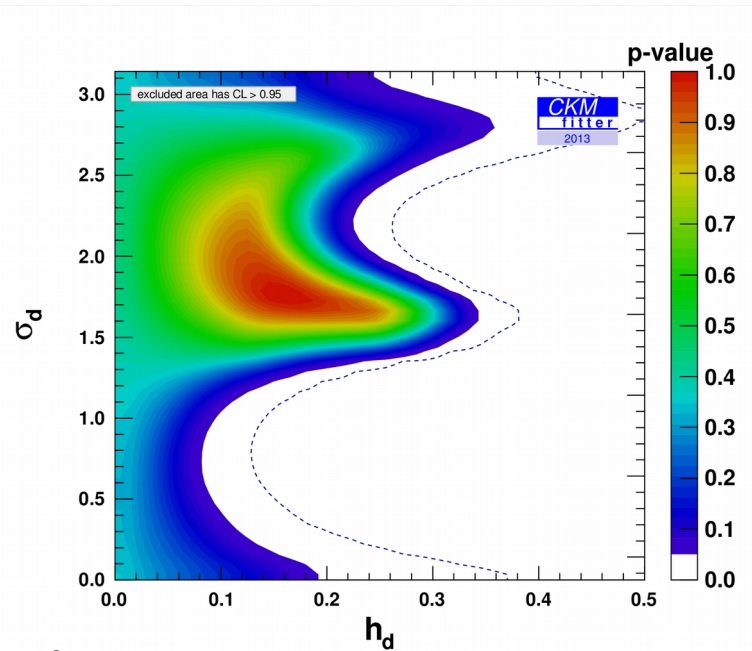
# CP asymmetry in $B \rightarrow J/\psi K$



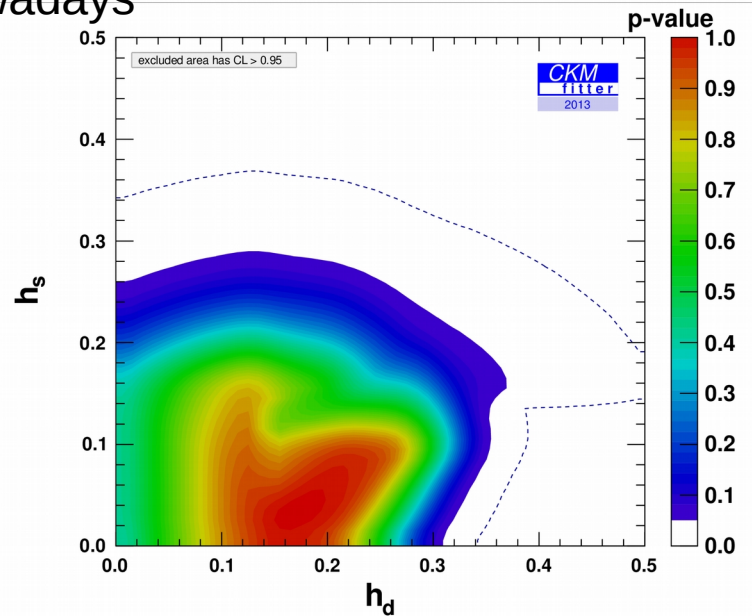
# CP asymmetries in “penguin modes”



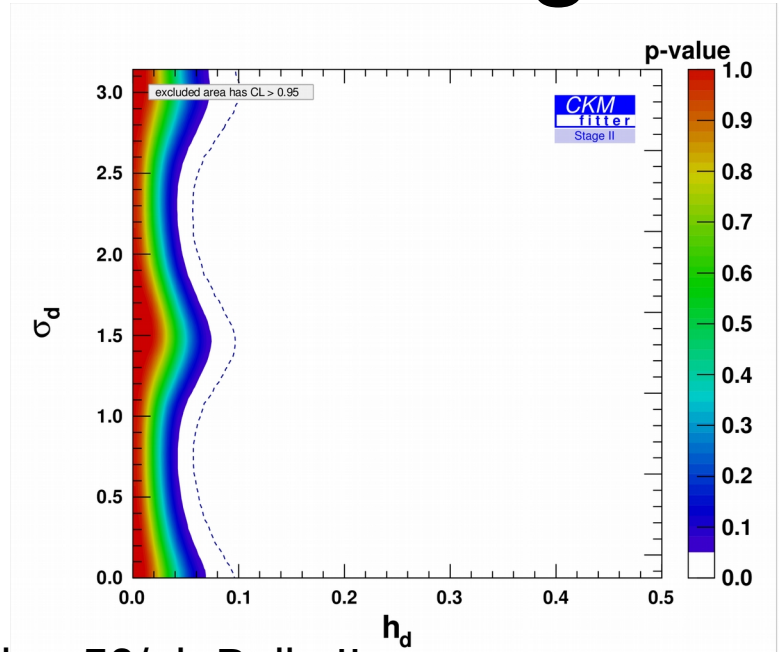
# Sensitivity to NP in B mixing



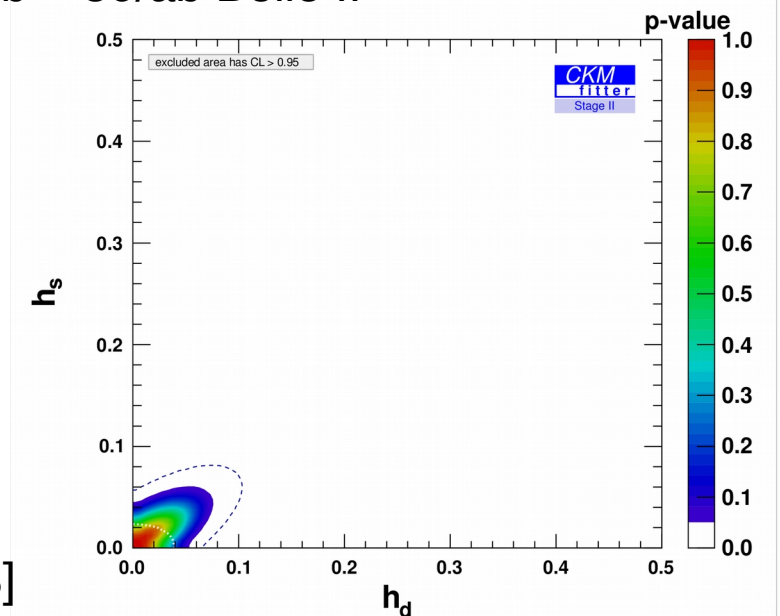
“nowadays”



50/fb LHCb + 50/ab Belle II



[1309.2293]



# $B \rightarrow D^* \ell \nu$ decay distributions

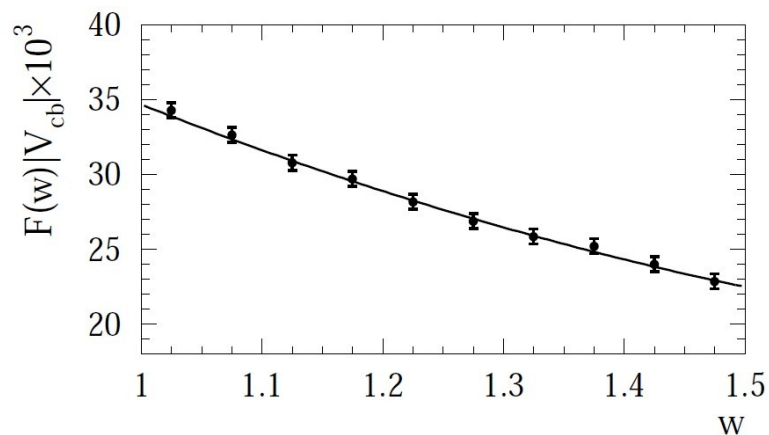
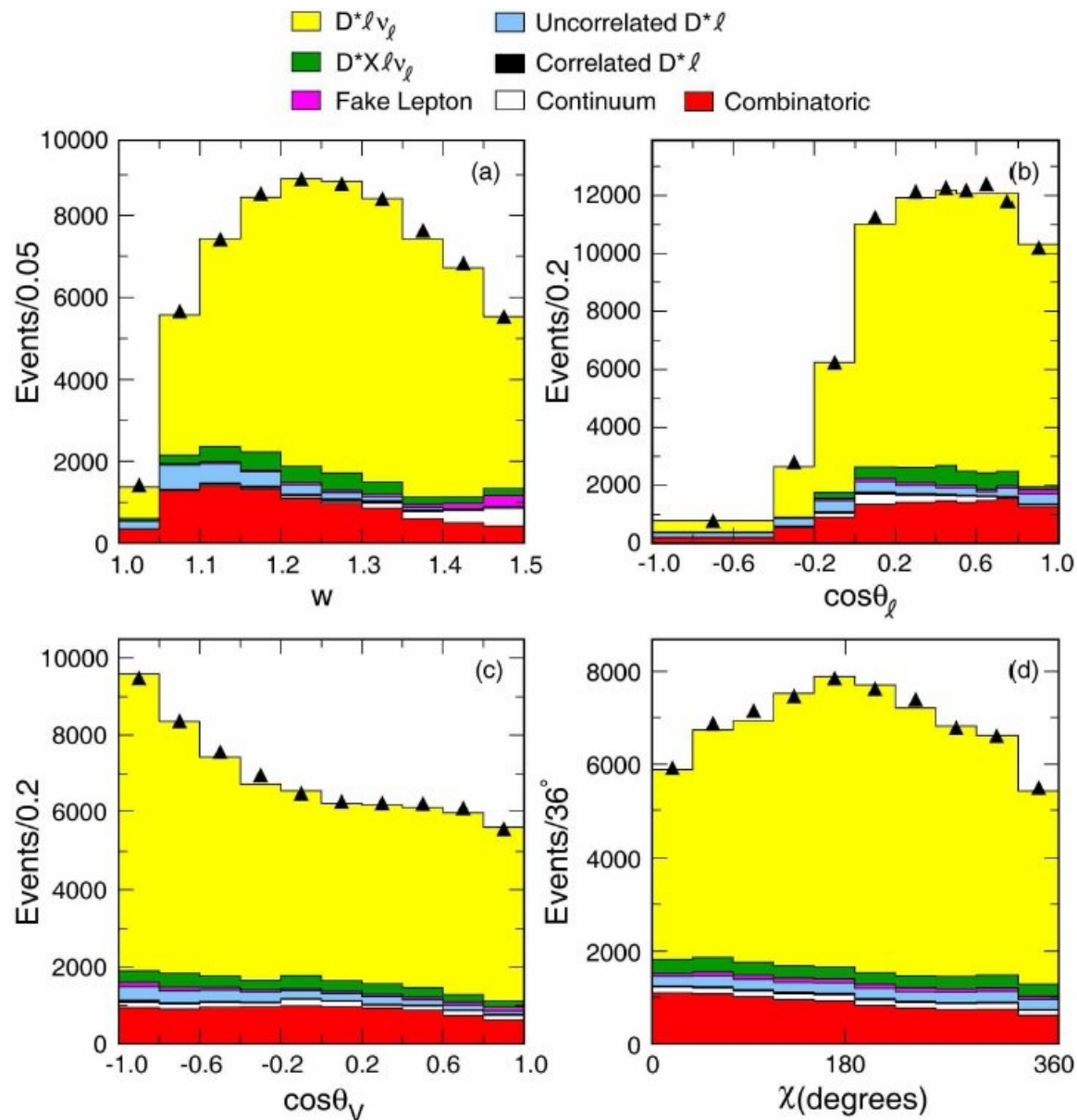


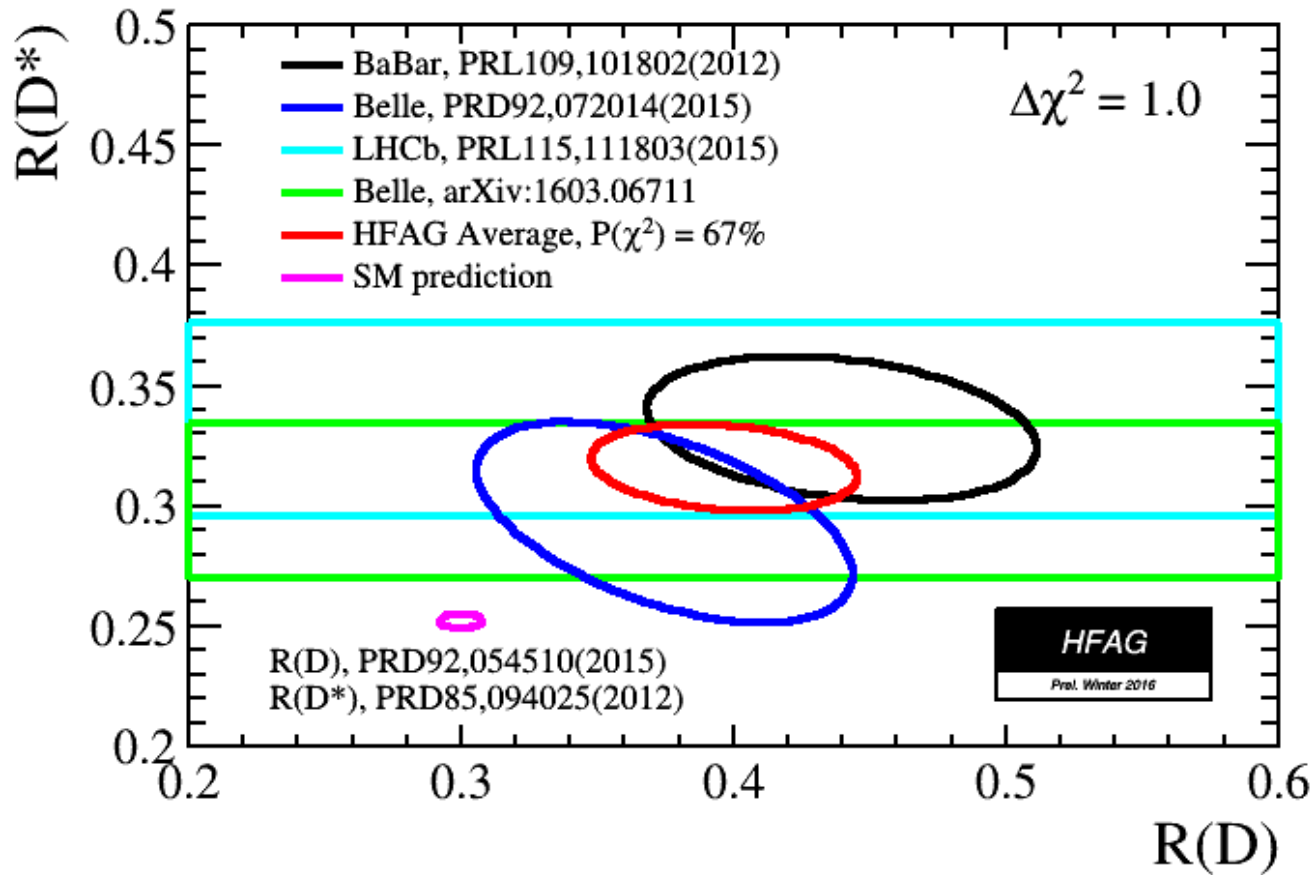
FIG. 6: The measured  $w$  dependence of  $\mathcal{F}(w)|V_{cb}|$  (data points) compared to the theoretical function with the fitted parameters (solid line). The experimental uncertainties are too small to be visible.

[BaBar, 0705.4008]

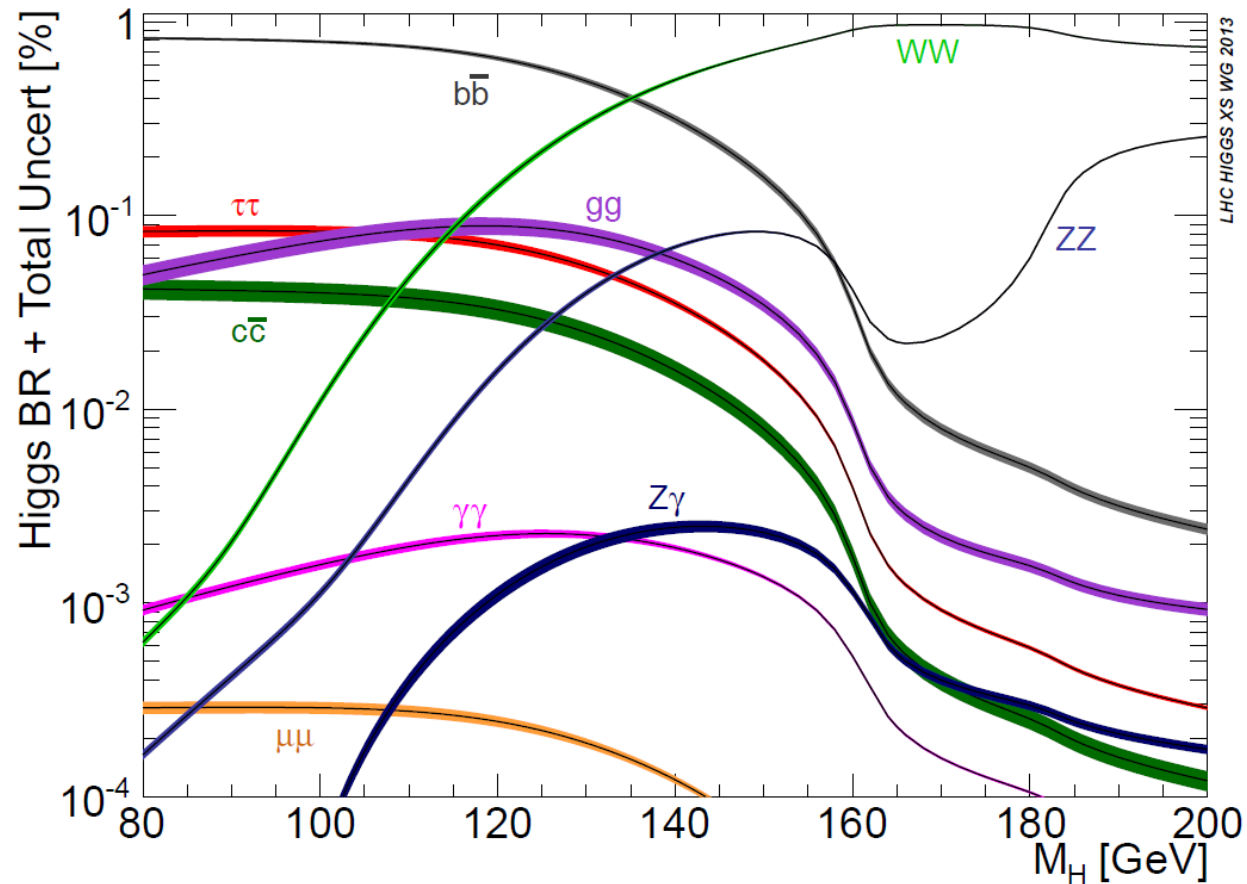




# $R(D^{(*)})$ measurements

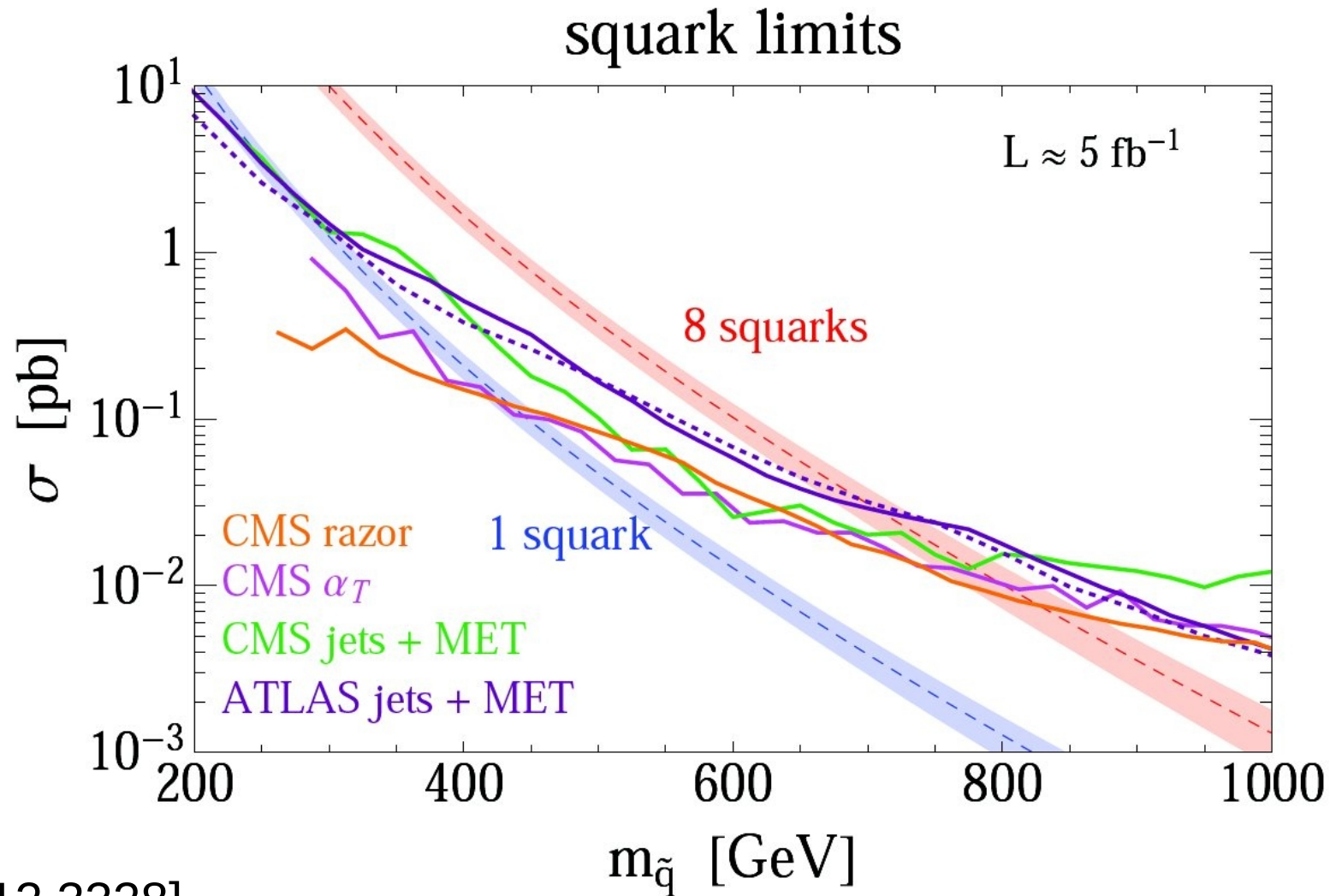


# Source of richness: Yukawas + $m_h$



How would pattern change if  $m_{\text{top}} = 50$  GeV?

# Bounds on (non)degenerate squarks



[1212.3328]