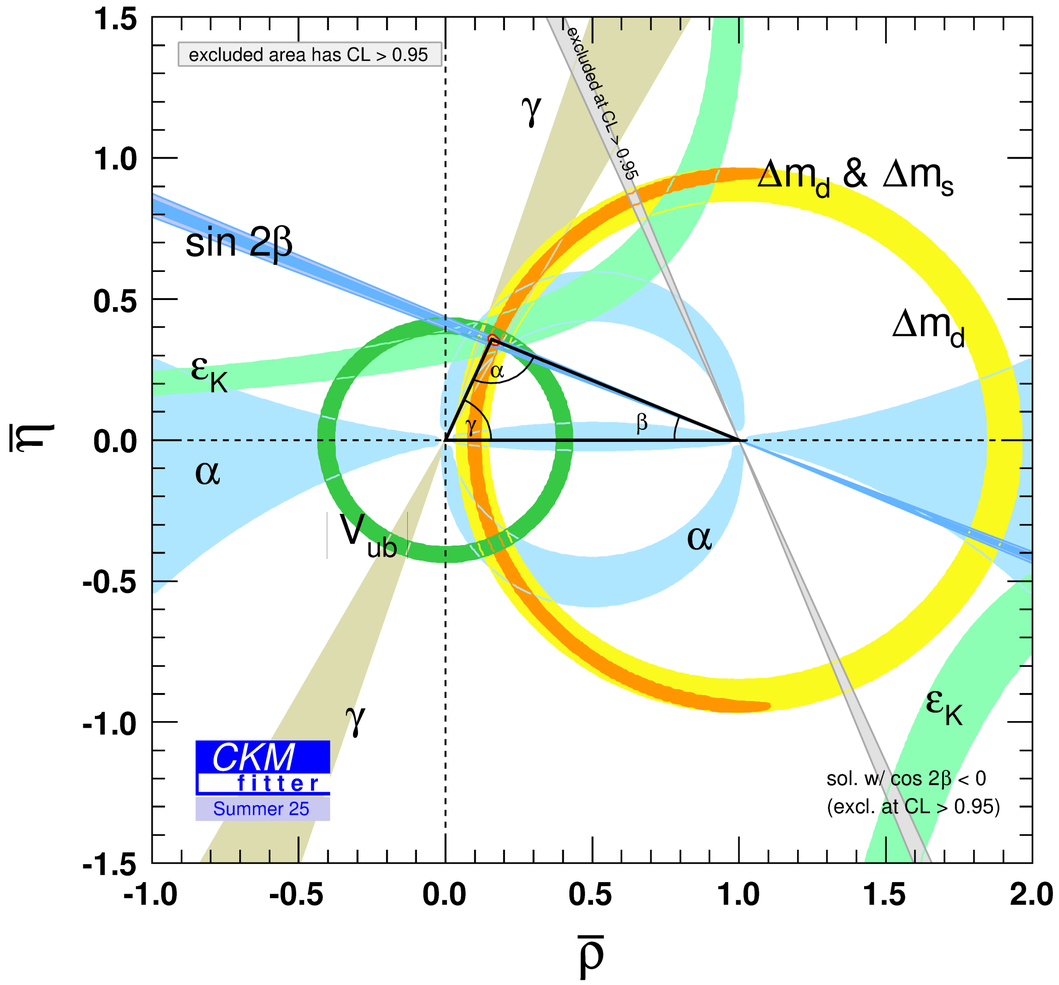
Flavour-tagged time-dependent analysis of the $B^0 \to K^0_S \eta'$ decay with Run2 + Run3 data

LHCb @ LPCA Interns Meeting

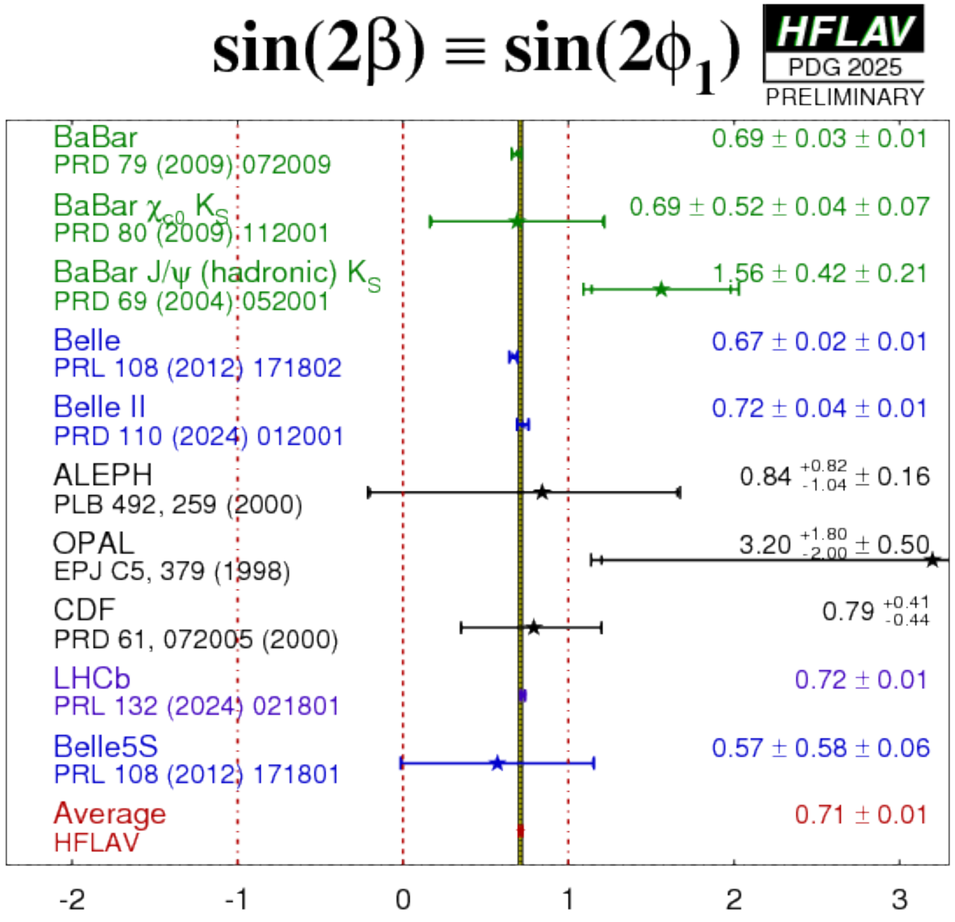
Pio Francesco Varrella - 27-04-2026

Unitary Triangle

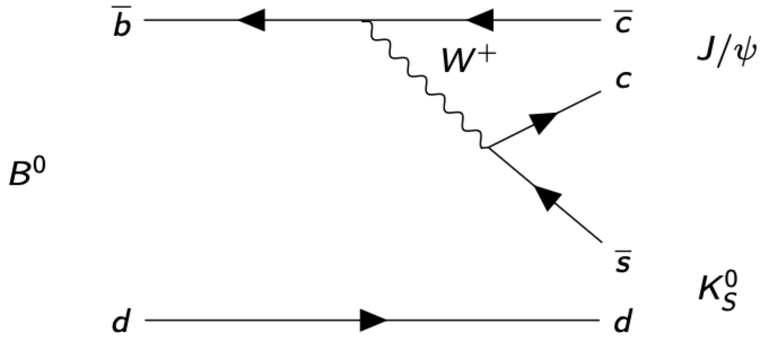


- Test the internal consistency of the CKM matrix and hence of the SM (Standard Model)
- Contributions from Physics beyond the SM entering loop diagrams

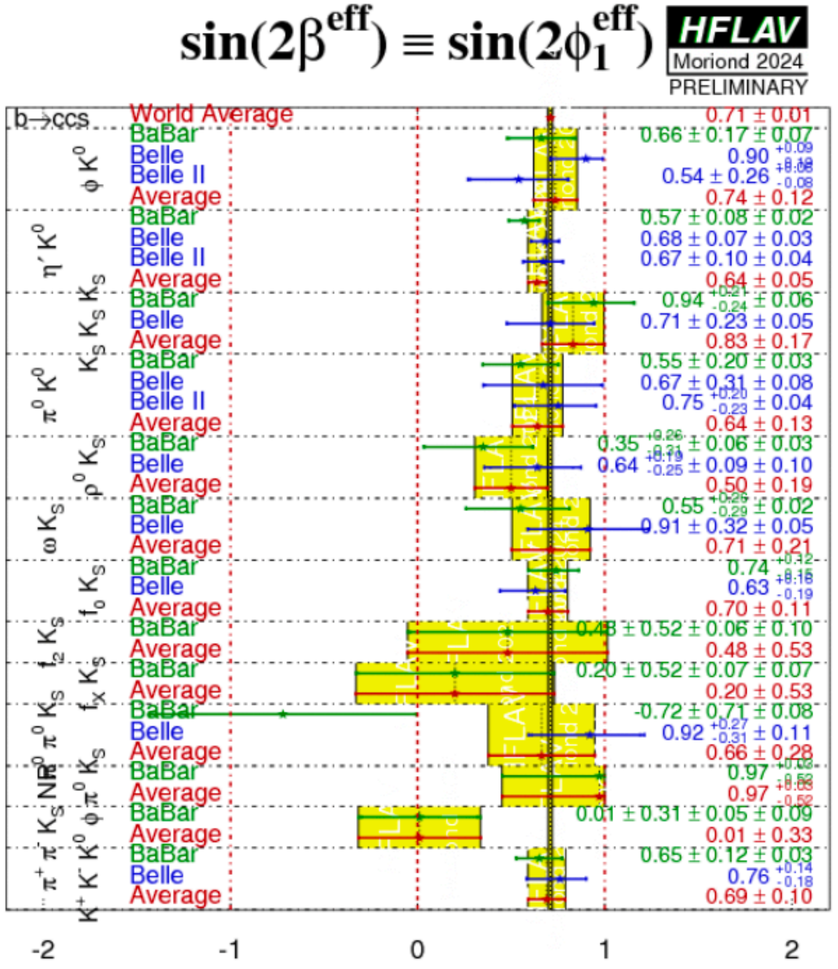
Status of $sin(2\beta)$ measurements



- $sin(2\beta)$ measurements via the Golden channel: $B^0 \to J/\psi K_S$
- LHCb is the most precise actor
- $B^0 \to J/\psi K_S$ mode is tree-level dominated



$sin(2\beta)$ measurements via other modes



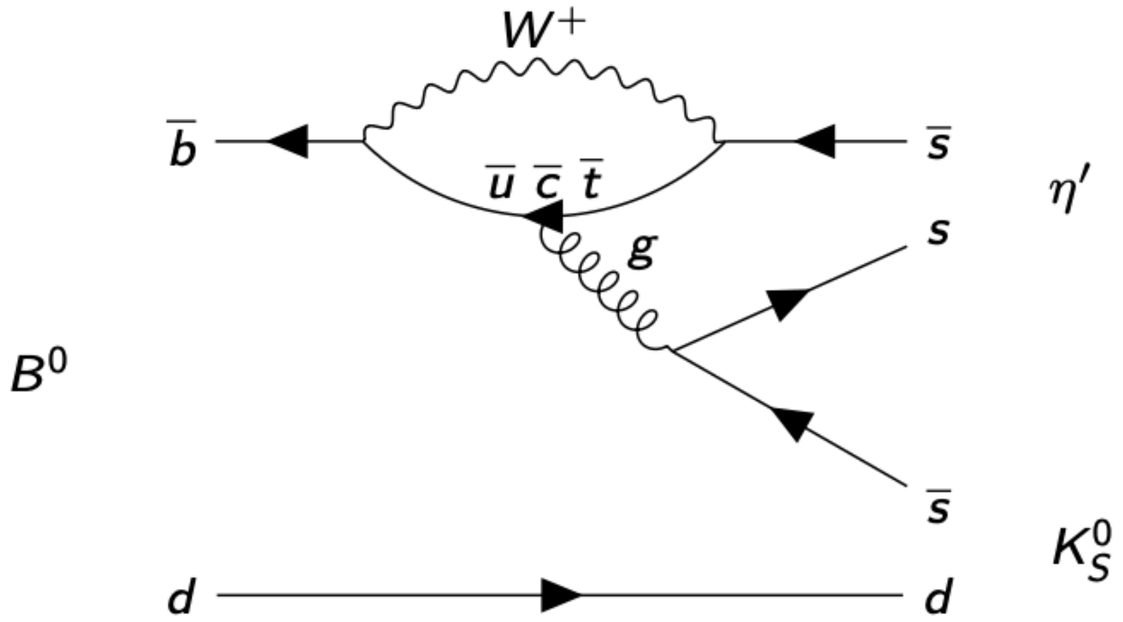
- LHCb non competitive on other modes
- $B^0 \to K_S\eta'$ is the most precise channel
- $B^0 \to K_S\eta'$ is a channel storically dominated by B-factories

Why $sin(2\beta)$ with $B^0 \to K^0_S \eta'$ decay ?

- Recent Belle II difficulties
- $B^0 \to K_S \eta'$ is dominated by loop-level transitions

$$\beta_{eff} = \beta + \Delta\phi_{NP}$$

- Potential contributions from BSM amplitudes
- Search for NP in a $\Delta F = 1$ transition



How to measure $sin(2\beta)$?

Consider CP Violation arising from the decay-mixing interference

$$A_{CP}(t) = \frac{\Gamma(\bar{B}^0(t) \to f) - \Gamma(B^0(t) \to f)}{\Gamma(\bar{B}^0(t) \to f) + \Gamma(B^0(t) \to f)} = S_f sin(\Delta m_d t) - C_f cos(\Delta m_d t)$$

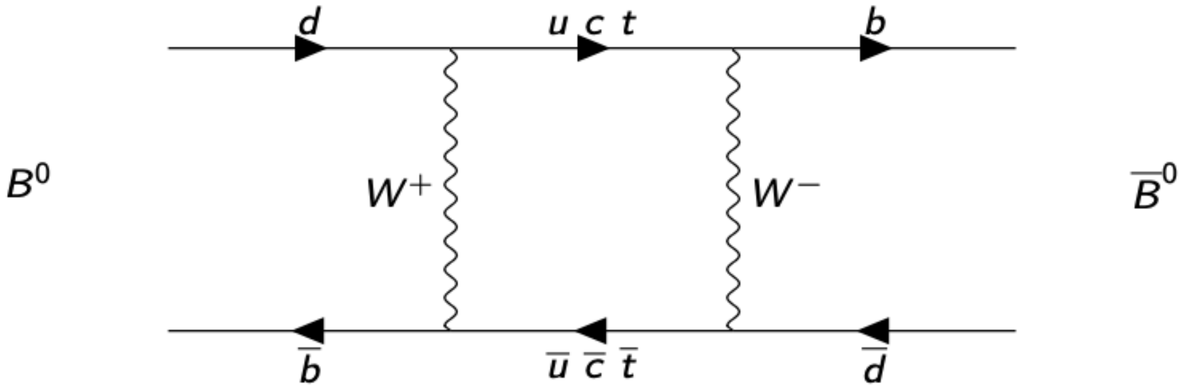
$$\boxed{A_{CP}(t) = S_f sin(\Delta m_d t)}$$

How to measure $sin(2\beta)$?

Consider CP Violation arising from the decay-mixing interference

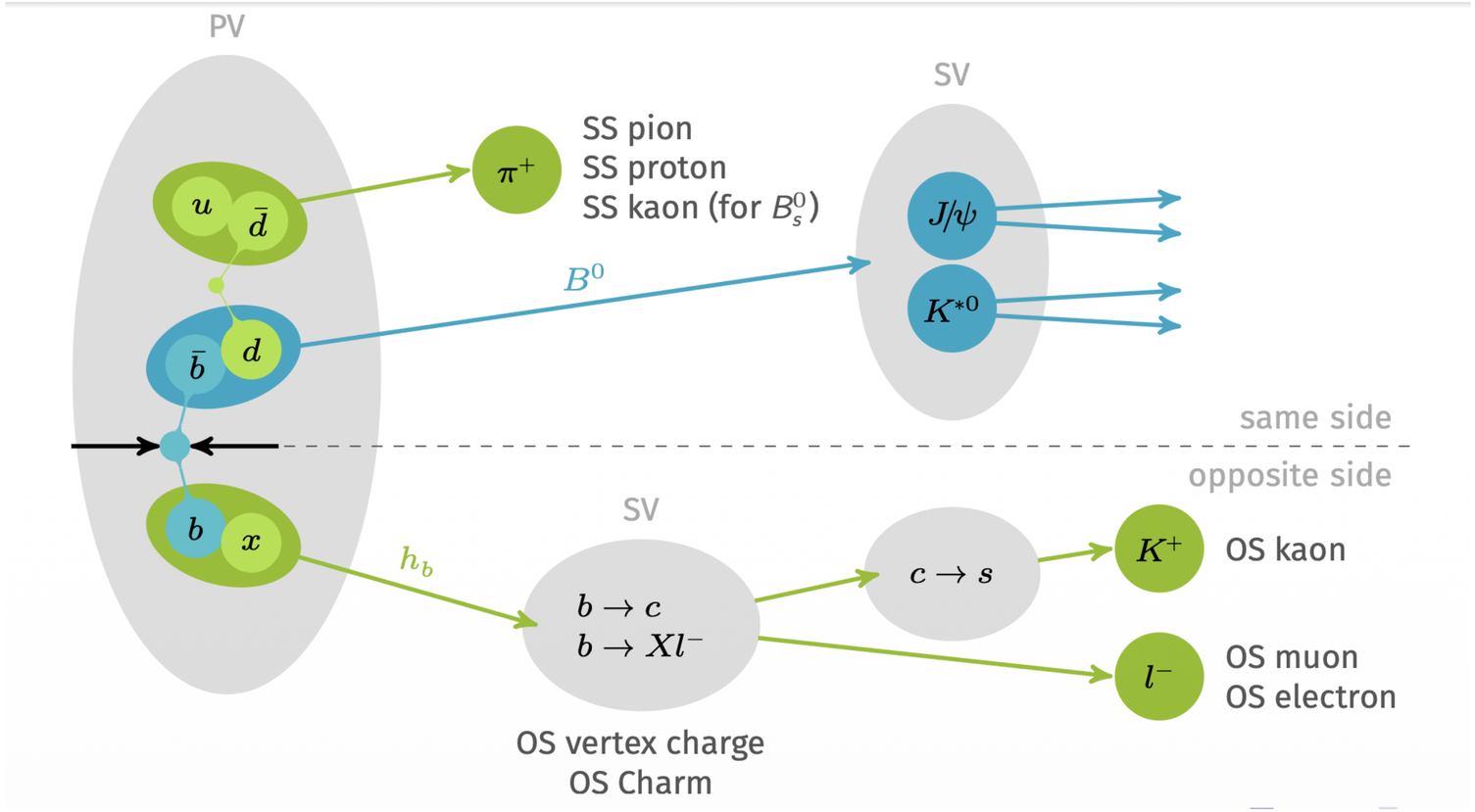
$$A_{CP}(t) = S_f sin(\Delta m_d t)$$

$$\frac{N(B^0) - N(\bar{B}^0)}{N(B^0) + N(\bar{B}^0)}$$



How to disentangle the $B^0/\bar{B}^0$ at production ?

Use of Same Side (SS) or Opposite Side (OS) particle information to tag the B flavour

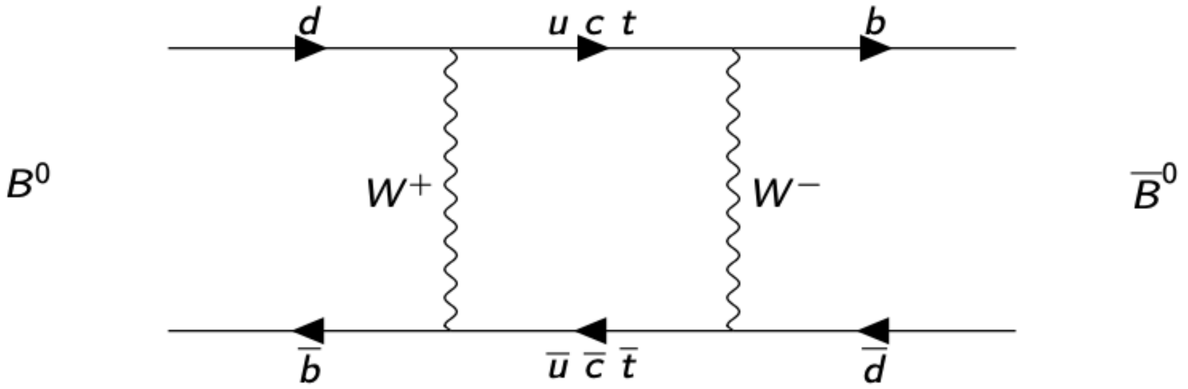


How to measure $sin(2\beta)$?

Consider CP Violation arising from the decay-mixing interference

$$A_{CP}(t) = S_f sin(\Delta m_d t)$$

$$\frac{N(B^0) - N(\bar{B}^0)}{N(B^0) + N(\bar{B}^0)}$$



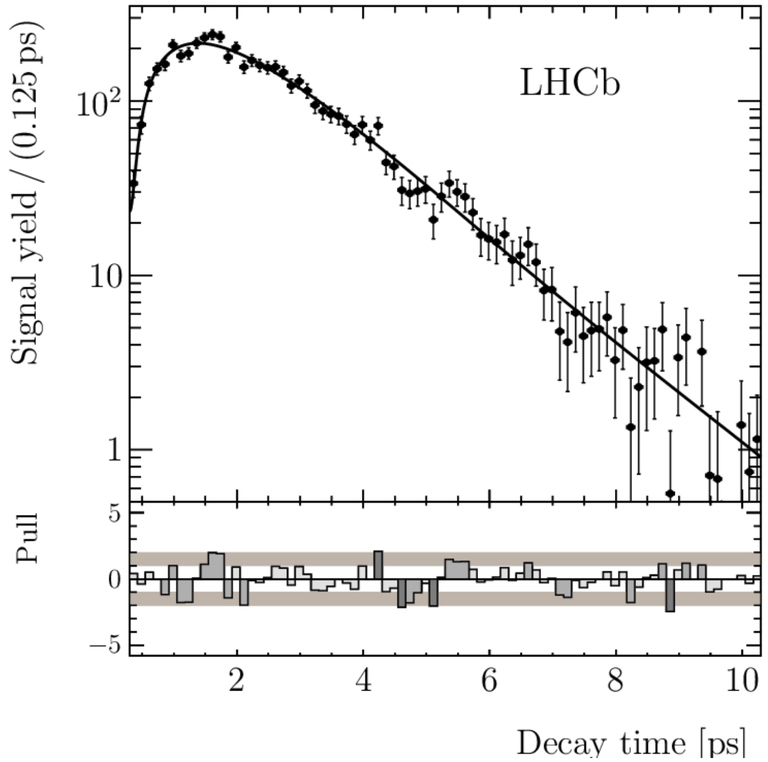
+ Flavour Tagging

How to measure $sin(2\beta)$?

Consider CP Violation arising from the decay-mixing interference

$$A_{CP}(t) = S_f sin(\Delta m_d t)$$

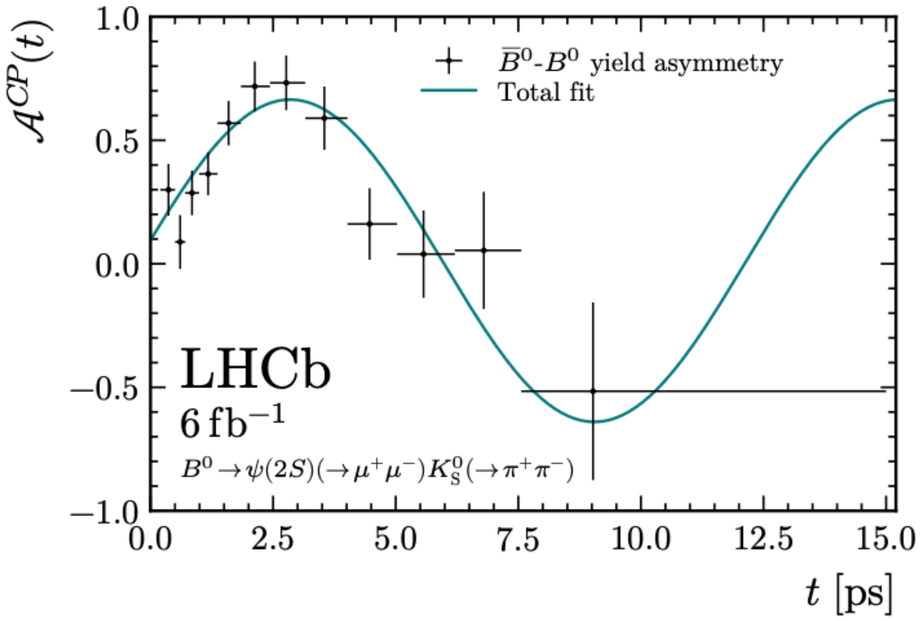
- Oscillations from decay-mixing interference
- Use of decay time to resolve the oscillations $sin(\Delta m\ t)$



How to measure $sin(2\beta)$?

Consider CP Violation arising from the decay-mixing interference

$$A_{CP}(t) = S_f sin(\Delta m_d t)$$



$$S_f \propto sin(2\beta)$$

...we put all together...hoping it works

How do you reconstruct the $B^0 \to K^0_S \eta'$ decay ?

Sense of considered final states

BR ($B^0 \to K^0 \eta'$) = (6.6±0.4) $\times 10^{-6}$

$B^0 \to K^0_S \eta'$

~69.2%

~29.5%

~42.5%

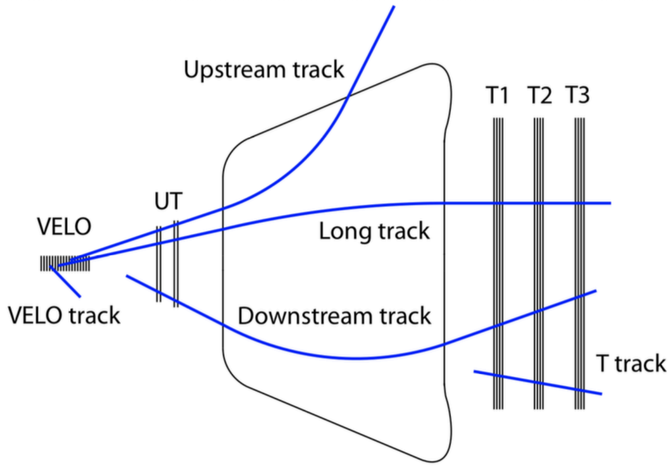
$\pi^+\pi^-$

$\pi^+\pi^-\gamma$

$\pi^+\pi^-\eta(\overset{\sim 39.4\%}{\to} \gamma\gamma)$

DD tracks

LL tracks



Lot of fun with photons!

What sensitivity do you expect on $sin(2\beta)$?

LHCb (Run 2)

- Signal yield: ~ 4600
- FT power ~ 3%

Belle II

- Signal yield: ~ 800
- FT power ~ 30%

- with Run 2 data only we are not competitive, need to use Run3 dataset

What sensitivity do you expect on $sin(2\beta)$?

LHCb Run 3 prospect

LHCb (Run 2)

- Signal yield: ~ 4600
- Int Lumi: 5.9 fb^{-1}
- FT power ~ 3 %
- 780 yields/fb^{-1}

LHCb (Run 3)

- Factor 1.5 improvement by the L0 trigger removal
- GFP Int Lumi expected: 11.81 fb^{-1} (2025) + 4 fb^{-1} (2026)
- ~ 18 700 yields expected for Run 3

GFP = Good For Physics

What sensitivity do you expect on $sin(2\beta)$?

LHCb Run 2+3 prospects over Belle II

LHCb (Run 2+3)

- Signal yield: ~ 23 300
- Assuming FT power ~ 3 %

Belle II

- Signal yield: ~ 800
- FT power ~ 30 %

→ Factor 3 better than Belle II in the yields

$sin(2\beta)$? → Factor $\sqrt{3}$ improvement expected