Study of the decay $B^0 \to \rho^0 K^*(892)^0$

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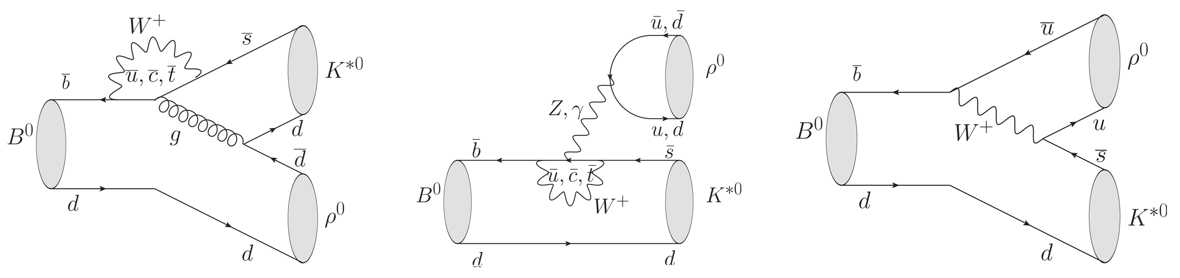
1. The $B^0 \to \rho^0 K^*(892)^0$ decay

- B^0 meson decay into two **vector resonances** reconstructed as:

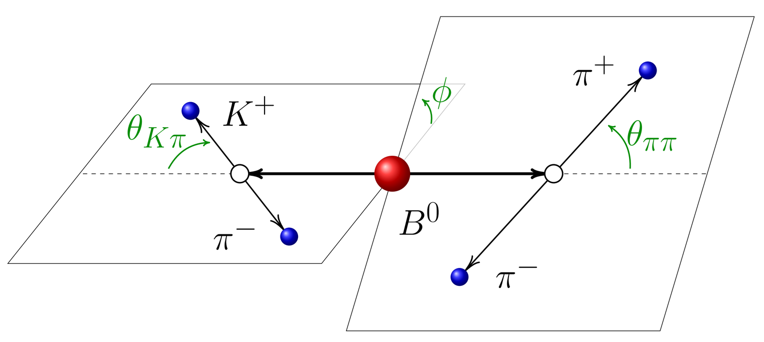
$$B^0 \to (\pi^+\pi^-)(K^+\pi^-)$$

- Decay proceeding via the **three interfering diagrams**:



$\rightarrow$ Sensitivity to $\mathcal{CP}$-violating effects comparing B^0 and $\overline{B}^0$ decay rates.

- Angular phenomenology:



Polarisation fractions and phase differences[1,2]**:**

$$f_i = \frac{|A_i|^2}{\sum_\lambda |A_\lambda|^2}\ (i, \lambda = L, ||, \perp)$$

$$\delta_{||-(L,\perp)} = arg(A_{||}/A_{(L,\perp)})$$

True&Fake Triple Products[3]

$$\mathcal{A}_T^B = f_\perp f_{(L,||)} \sin(\delta_\perp - \delta_{(L,||)})$$

$$\mathcal{A}_{\text{T-}true} = \frac{\mathcal{A}_T^B - \mathcal{A}_T^{\overline{B}}}{2}$$

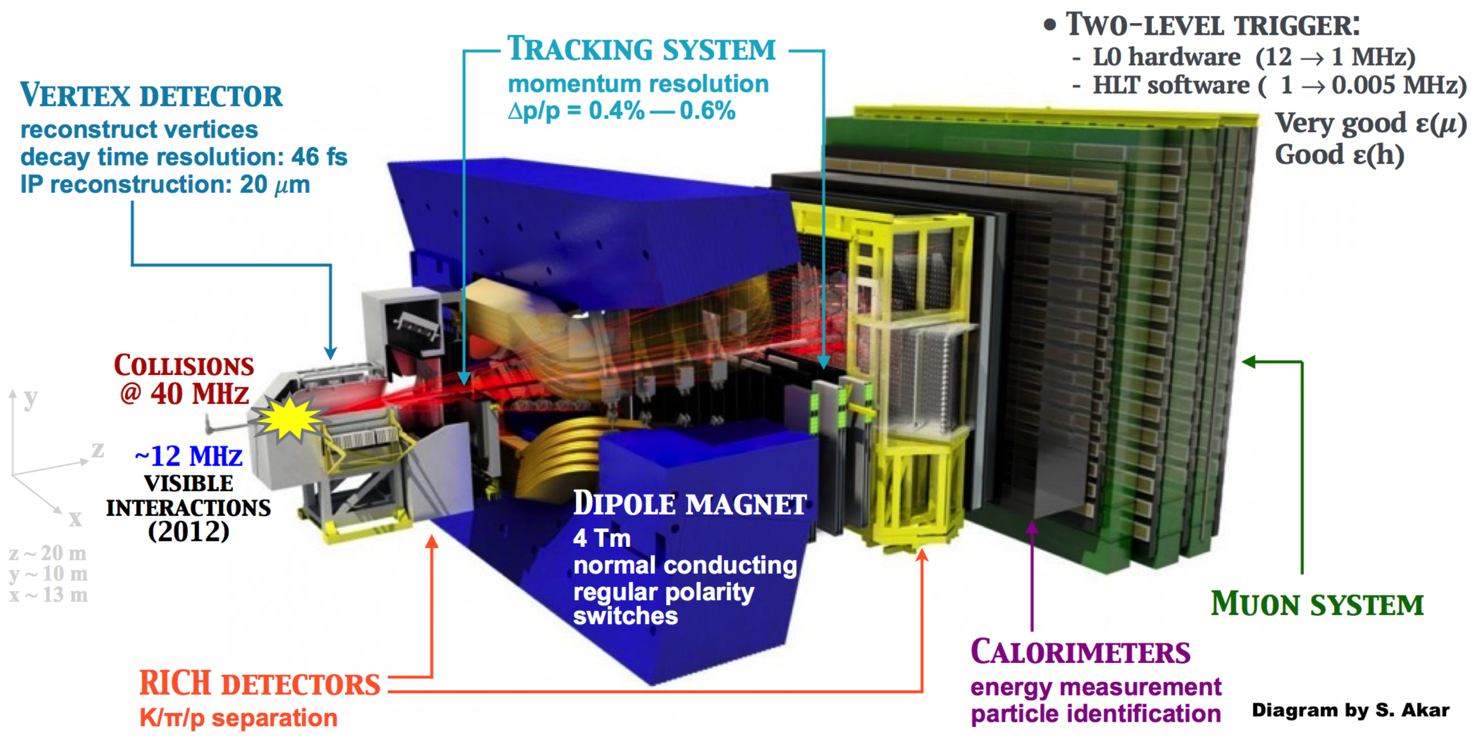
$\rightarrow$ Input to "$B \to \pi K$" and polarisation *puzzles*.

$\rightarrow$ Theoretical predictions available in pQCD and QCDF frameworks.

[1] M. Beneke, J. Rohrer, and D. Yang, *Branching fractions, polarisation and asymmetries of $B \to VV$ decays*, Nucl. Phys. B774 (2007) 64.
[2] Z.-T. Zou et al., *Improved estimates of the $B(s) \to VV$ decays in perturbative QCD approach*, Phys. Rev. D91 (2015) 054033.
[3] M. Gronau, J. L. Rosner, *Triple Product asymmetries in K, $D(s)$ and $B(s)$ decays*, Phys. Rev. D 84, 096013.

2. The LHCb detector

Single arm **forward spectrometer**, covering $2 < \eta < 5$. Run-1 conditions:



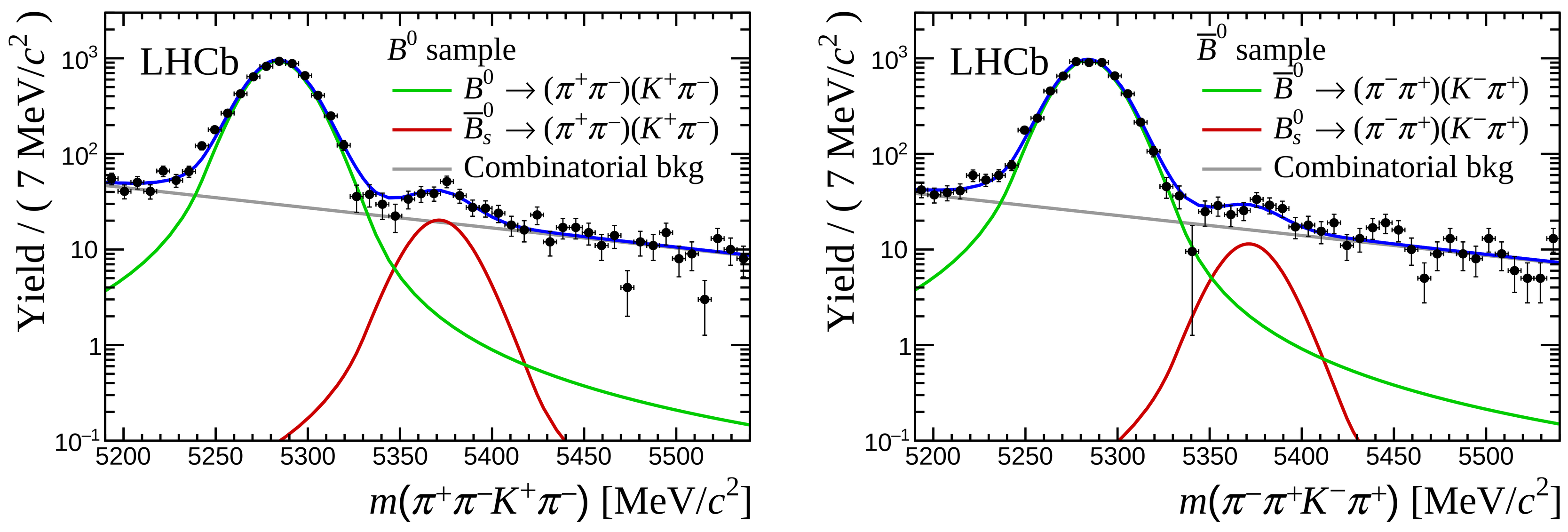
Ref.: LHCb collaboration, Alves Jr., A. A. et al., The LHCb detector at the LHC. J. Instrum. 3 (2008) S08005.

3. Event selection

Data sample: **LHCb Run-1 data**, corresponding to $3fb^{-1}$ at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 8 TeV for 2011 and 2012, respectively.

Events **selected** by requirements on: Trigger on final state hadrons + Particle identification + Invariant mass windows + Multivariate analysis.

Background subtracted sample obtained from a fit to the **4-body invariant mass spectrum**:



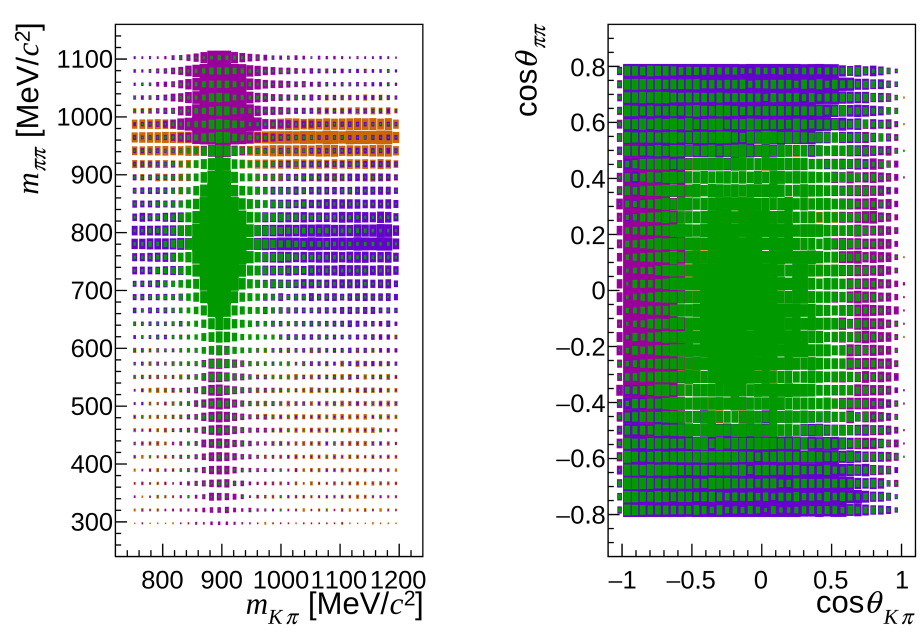
Yields	B^0	$\overline{B}^0$
$N_{B^0\to K\pi\pi\pi}$	5473 ± 81	5593 ± 79
$N_{B_s^0\to K\pi\pi\pi}$	119 ± 19	68 ± 17
N_{Comb}	1120 ± 52	930 ± 47

1. Remove $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$ contribution with **negatively weighted**[4] **simulated events**.
2. Parameterise the 4−body invariant mass spectrum:
   - B^0 and B_s^0 PDF: Hypatia[5] function.
   - Combinatorial background: exponential shape.
3. Obtain the signal weights using the ***s*Plot**[6] technique.

[4] LHCb collaboration, *Measurement of $\mathcal{CP}$ asymmetries and polarisation fractions in $B_s^0 \to K^{*0}\overline{K}^{*0}$ decays*, JHEP 07 (2015) 166.
[5] D. Martínez Santos and F. Dupertuis, *Mass distributions marginalized over per-event errors*, Nucl. Instrum. Meth. A764 (2014) 150.
[6] M. Pivk and F. R. Le Diberder, *sPlot: A statistical tool to unfold data distributions*, Nucl. Instrum. Meth. A555 (2005) 356.
Ref. LHCb collaboration, *Study of the $B^0 \to \rho(770)^0K^*(892)^0$ decay with an amplitude analysis of $B^0 \to (\pi^+\pi^-)(K^+\pi^-)$ decays*, arXiv:1812.07008.

4. Amplitude analysis method

$B \to (p_1p_2)(p_3p_4)$ **decays** can be **fully described** in terms of **three helicity angles** $(\theta_{\pi\pi}, \theta_{K\pi}, \phi)$ and **two invariant masses** $(m_{\pi\pi}, m_{K\pi})$



Partial waves:

VV: $\rho K^*, \omega K^*$, **VS**: $\rho(K\pi), \omega(K\pi)$,
SV: $[f_0(500), f_0(980), f_0(1370)]K^*$,
SS: $[f_0(500), f_0(980), f_0(1370)](K\pi)$

$\leftarrow$ Illustrative plots

Using the **isobar** model to build the **decay rate**:

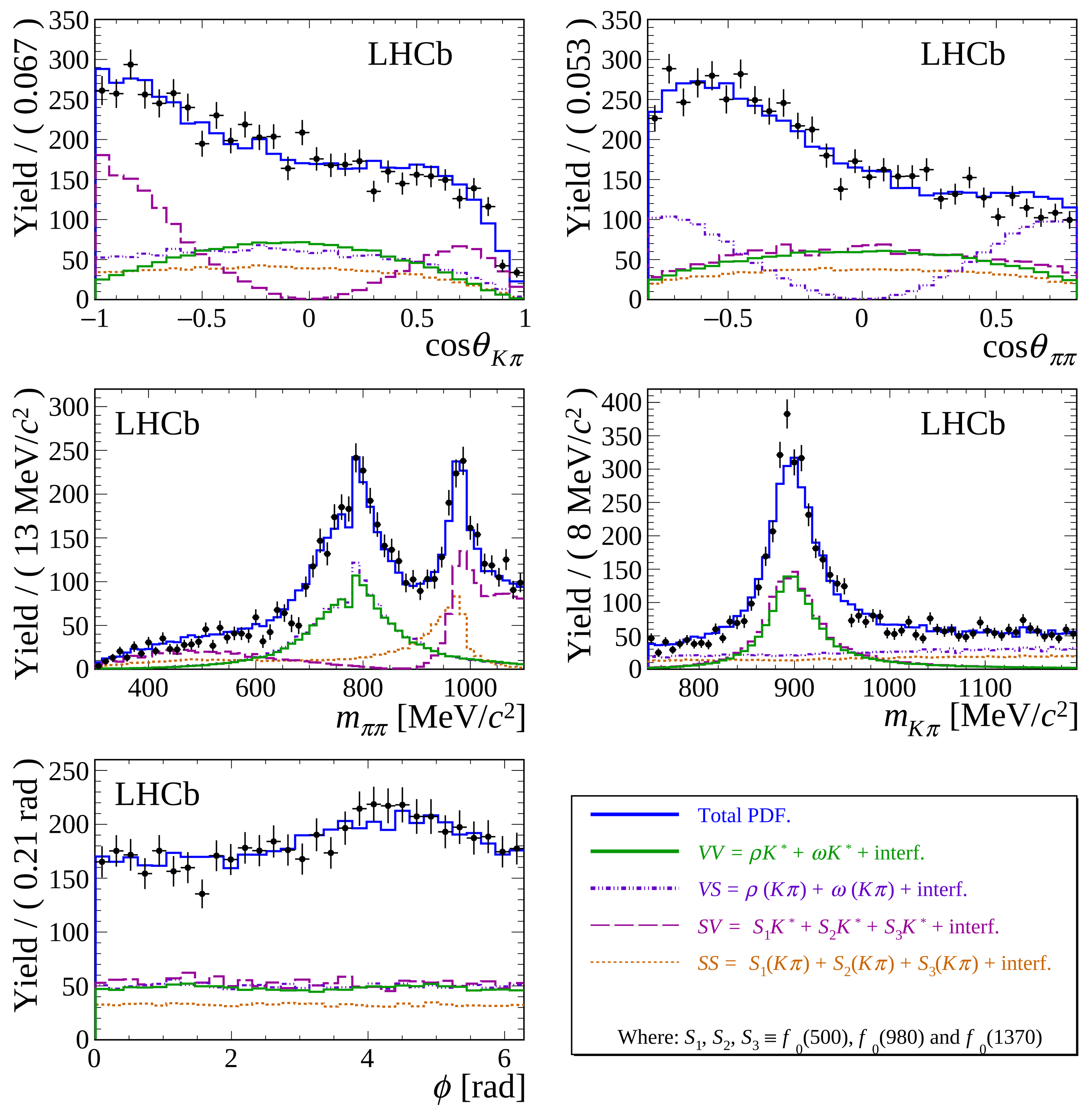
$$\frac{d^5\Gamma}{d\cos\theta_{\pi\pi} d\cos\theta_{K\pi} d\phi dm_{\pi\pi} dm_{K\pi}} \propto |\mathcal{A}_T(\theta_{\pi\pi}, \theta_{K\pi}, \phi, m_{\pi\pi}, m_{K\pi})|^2 \equiv \left|\sum_{i=1}^N A_i \cdot g_i(\cos\theta_{\pi\pi}, \cos\theta_{K\pi}, \phi) \cdot M_i(m_{\pi\pi}, m_{K\pi})\right|^2$$

Key features:

- g_i and M_i combination **unique per contribution**.
- Description of **detector acceptance** $\rightarrow$ **from simulated data**
- **Fit with 14 contributions**: each VV wave contributes with 3 amplitudes $(0, ||, \perp)$ and any S with one (relative strengths measured w.r.t. $B^0 \to \rho(K^+\pi^-)$.
- **High dimensional fit**, with 26 free parameters to a weighted data sample $\rightarrow$ **MultiNest**[7] algorithm to perform the minimisation.

[7] F. Feroz, M. P. Hobson, and M. Bridges, *MultiNest: an efficient and robust Bayesian inference tool for cosmology and particle physics*, Mon. Not. Roy. Astron. Soc. 398 (2009) 1601.

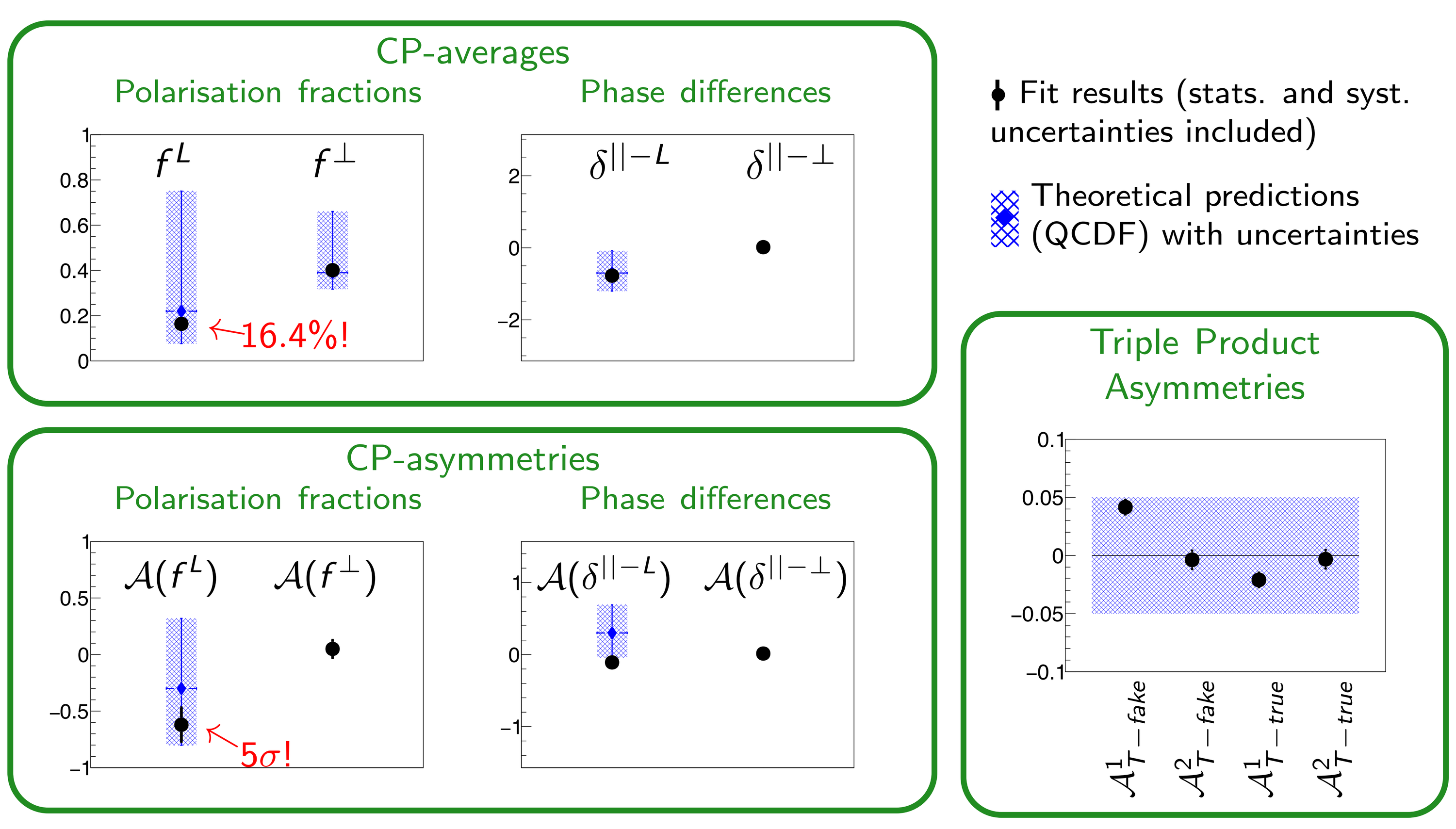
5. Projections of the fitted model (B^0 sample)



Ref. LHCb collaboration, *Study of the $B^0 \to \rho(770)^0K^*(892)^0$ decay with an amplitude analysis of $B^0 \to (\pi^+\pi^-)(K^+\pi^-)$ decays*, arXiv:1812.07008.

6. Summary of $B^0 \to \rho^0 K^*(892)^0$ results

Results for the $B^0 \to \rho^0 K^{*0}$ related observables compared with QCDF predictions:



Ref. LHCb collaboration, *Study of the $B^0 \to \rho(770)^0K^*(892)^0$ decay with an amplitude analysis of $B^0 \to (\pi^+\pi^-)(K^+\pi^-)$ decays*, arXiv:1812.07008.