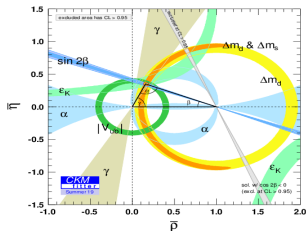


$\gamma$  analysis update in  $B^\pm \rightarrow (K^+K^-\pi^+\pi^-)_D K^\pm$  decays

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Oxford LHCb

28th June 2021



# Summary of last time

- $\gamma$  from  $B^\pm \rightarrow DK^\pm$ ,  $D \rightarrow K^+K^-\pi^+\pi^-$ , [arXiv:hep-ph/0611272](https://arxiv.org/abs/hep-ph/0611272)
- Model independent measurement with BESIII strong phase input
- Expected precision from signal-only study:  $\Delta\gamma = 12^\circ$
- $B$  candidate selection with BDT
- Currently only Run 2
- Initial mass fits

# Summary of analysis procedure

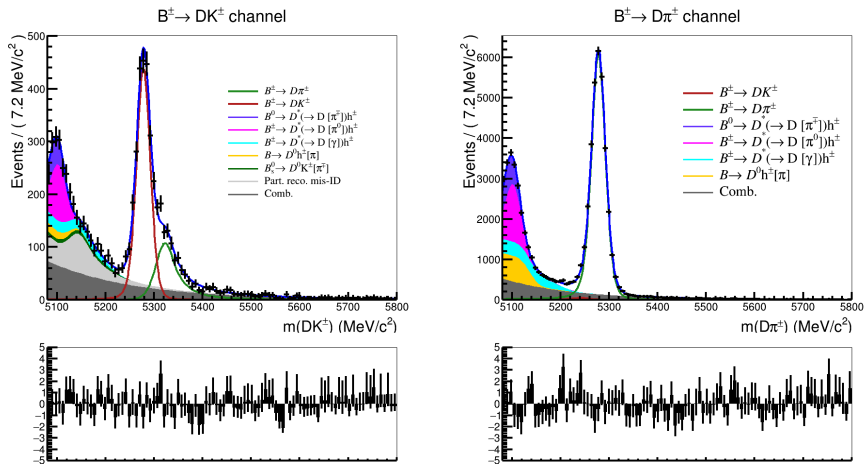
- 1 Perform global fit to fix yields and shapes
- 2 Separate  $B^\pm$  candidates by charge and into bins
- 3 Extract  $x_\pm$  and  $y_\pm$  with a simultaneous fit
- 4 Interpret  $x_\pm$  and  $y_\pm$  in terms of  $\gamma$

## CP observables

$$x_\pm = r_B^{DK} \cos(\delta_B^{DK} \pm \gamma), \quad y_\pm = r_B^{DK} \sin(\delta_B^{DK} \pm \gamma)$$
$$x_\xi^{D\pi} = \text{Re}(\xi^{D\pi}), \quad y_\xi^{D\pi} = \text{Im}(\xi^{D\pi}), \quad \xi^{D\pi} = \frac{r_B^{D\pi}}{r_B^{DK}} e^{i(\delta_B^{D\pi} - \delta_B^{DK})}$$

- 1 Global mass fit
- 2 Backgrounds
  - Mis-ID from  $D \rightarrow K\pi\pi\pi$
  - Charmless backgrounds
- 3 BDT cut optimization
- 4 Toy studies
  - Standard fits with 4 and 8 bins
  - Biases in CP observables
  - Systematics from  $c_i, s_i$
- 5 Summary and future work

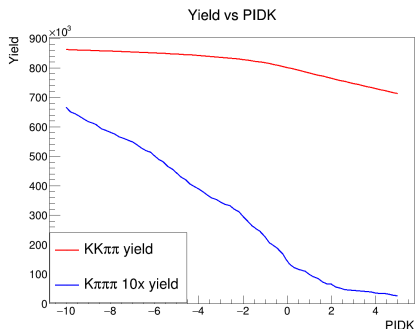
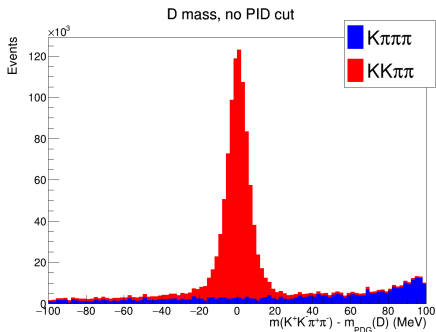
# Global mass fit



**Figure 1:** Global mass fit (left)  $B \rightarrow DK$  and (right)  $B \rightarrow D\pi$

# Mis-ID from $D \rightarrow K\pi\pi\pi$

- Mis-ID of  $D$  daughter  $\pi \rightarrow K$
- Peaks a much higher  $D$  mass
- Much higher branching ratio
- Similar background from  $D \rightarrow \pi\pi\pi\pi$  is negligible
- Pick cut at 0 for now



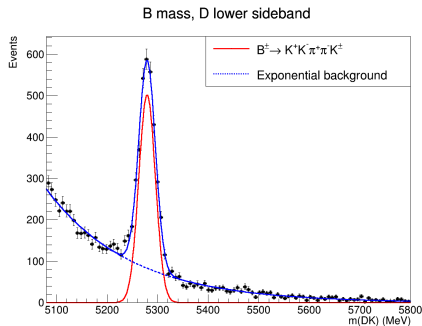
(a)  $D$  invariant mass for  $KK\pi\pi$  and  $K\pi\pi\pi$

(b) Yield of  $KK\pi\pi$  and  $K\pi\pi\pi$  vs PIDK

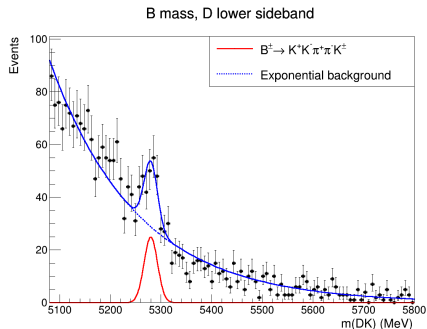
# Charmless backgrounds

- $B^\pm \rightarrow KK\pi\pi h^\pm$  background
- Flight significance (FS) cut at 2
- Use  $D$  mass sideband  $m(D) = [1770 \text{ MeV}, 1820 \text{ MeV}]$
- Train a separate BDT without  $\chi_{\text{DTF}}^2$
- Overlap between samples with (without) FS cut: 93.1% (90.7%)

# Total charmless background yield



(a) Without flight significance cut

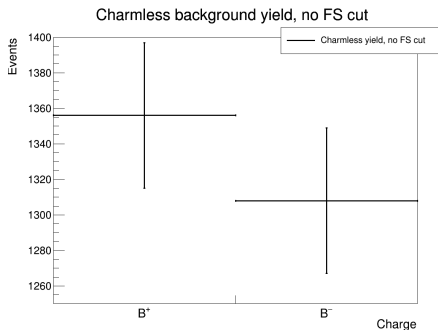


(b) With flight significance cut

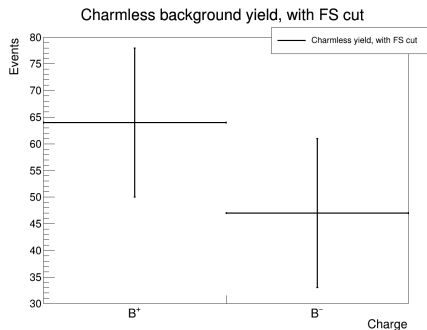
**Figure 3:** Charmless background in the  $D$  sideband



# Charmless backgrounds by charge



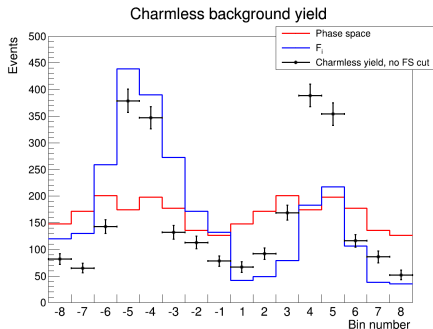
(a) Without flight significance cut



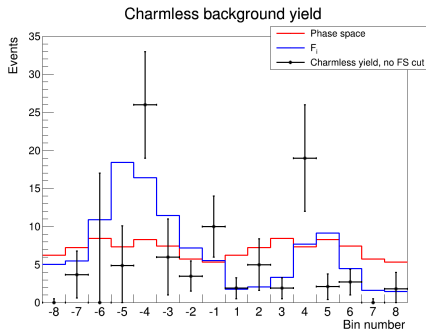
(b) With flight significance cut

**Figure 4:** Charmless background split by charge

# Charmless backgrounds by bins



(a) Without flight significance cut



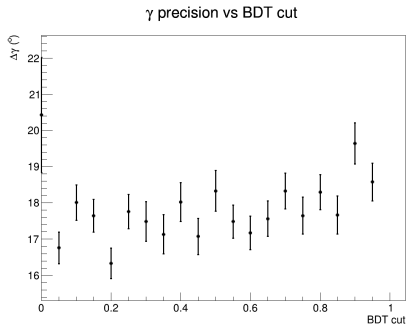
(b) With flight significance cut

**Figure 5:** Charmless background split by bins

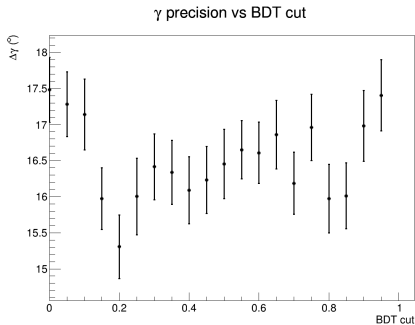
# BDT cut optimization

- Current BDT cut: 0.75
- Minimize statistical  $\gamma$  error
- Procedure:
  - ① Perform global fit to fix signal and background yields and PDF shapes
  - ② Generate 1000 toy datasets using the global fit parameters
  - ③ Fit for  $\gamma$
  - ④ Extract expected  $\gamma$  precision from  $\gamma$  distribution of toy datasets

# BDT cut optimization

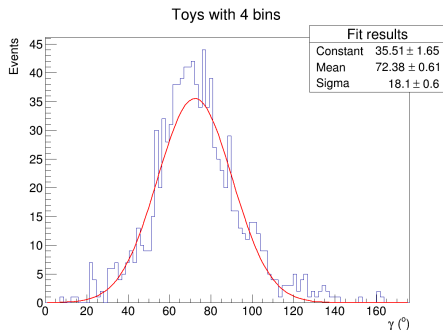


**(a)**  $\gamma$  precision vs BDT cut for 4 bins

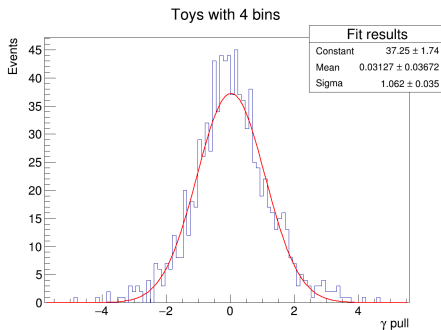


**(b)**  $\gamma$  precision vs BDT cut for 8 bins

# Standard toy studies with 4 bins

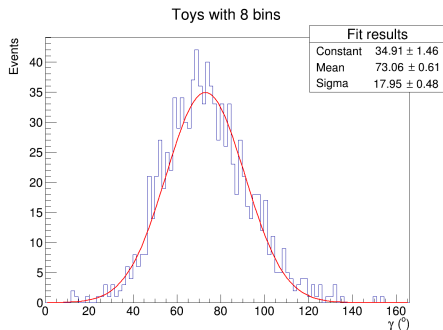


(a)  $\gamma$  from toys

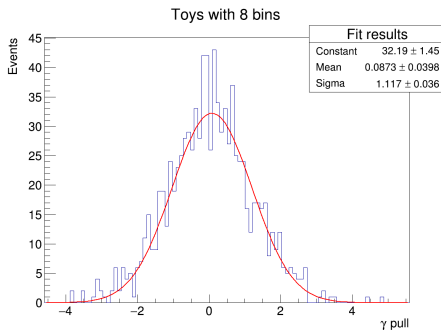


(b)  $\gamma$  pull distribution

# Standard toy studies with 8 bins

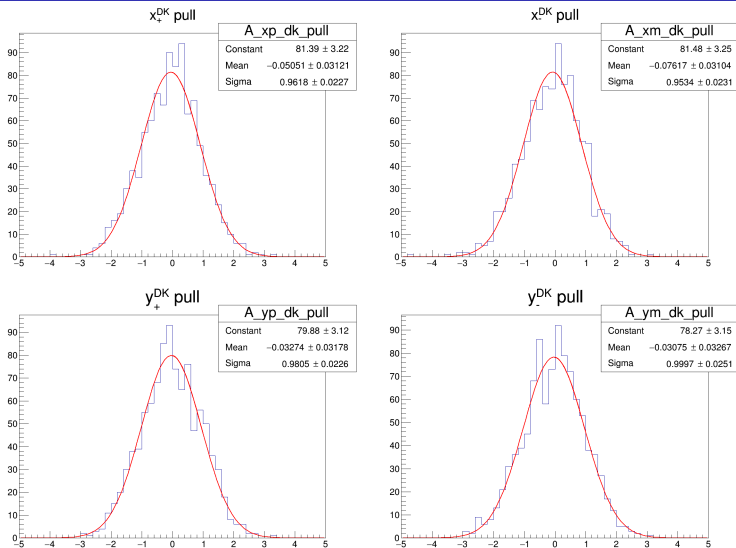


(a)  $\gamma$  from toys



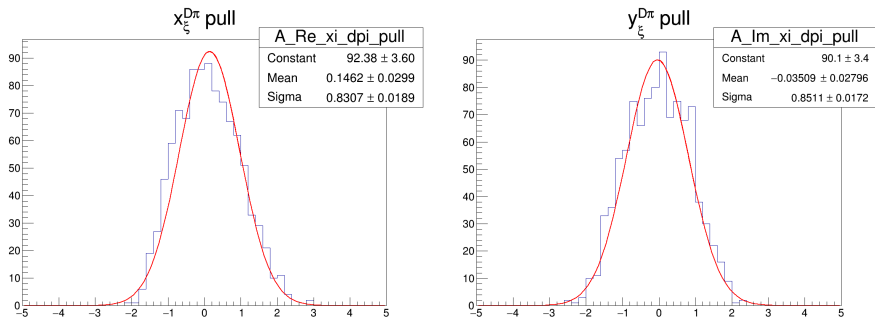
(b)  $\gamma$  pull distribution

# Biases in $B \rightarrow DK$ CP observables, 4 bins



**Figure 9:**  $B \rightarrow DK$  CP observable pull distributions

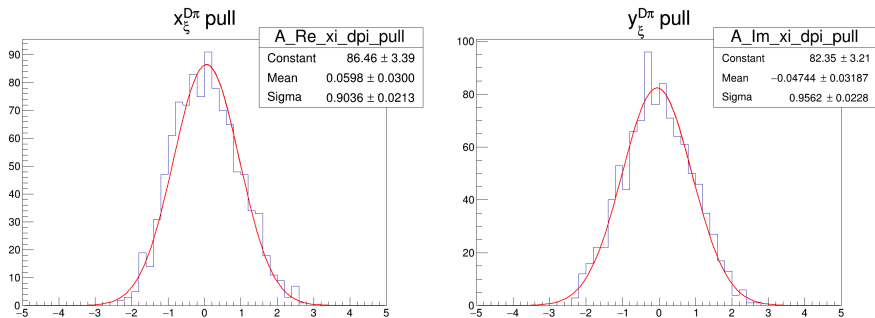
# Biases in $B \rightarrow D\pi$ CP observables, 4 bins



**Figure 10:**  $B \rightarrow D\pi$  CP observable pull distributions

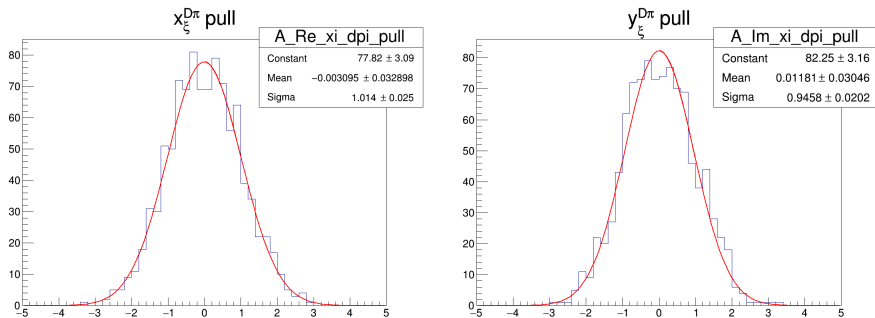


# Biases in $B \rightarrow D\pi$ CP observables, 4 bins, 2x statistics



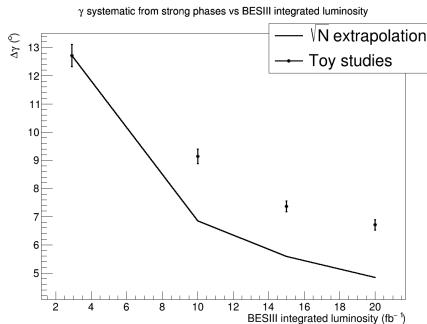
**Figure 11:**  $B \rightarrow D\pi$  CP observable pull distributions

# Biases in $B \rightarrow D\pi$ CP observables, 4 bins, 10x statistics

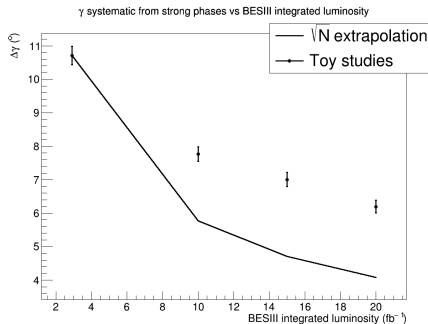


**Figure 12:**  $B \rightarrow D\pi$  CP observable pull distributions

# Systematics from $c_i, s_i$



(a) 4 bins



(b) 8 bins

**Figure 13:**  $c_i, s_i$  systematic uncertainty with extrapolated BESIII statistics

# Summary and future work

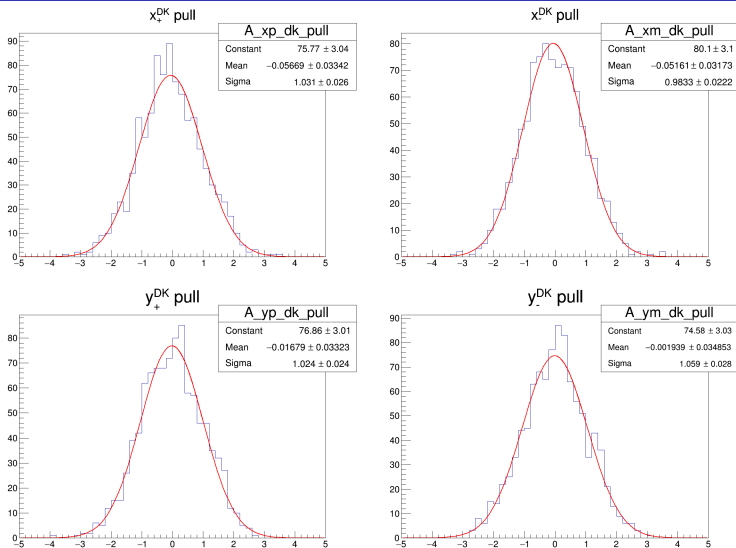
- Summary:

- ① Global mass fit looks promising
- ②  $D \rightarrow K\pi\pi\pi$  and charmless backgrounds under control
- ③ Toy studies show no suspicious behaviour
- ④ Expected  $c_i$  and  $s_i$  systematics are not too large

- Next steps:

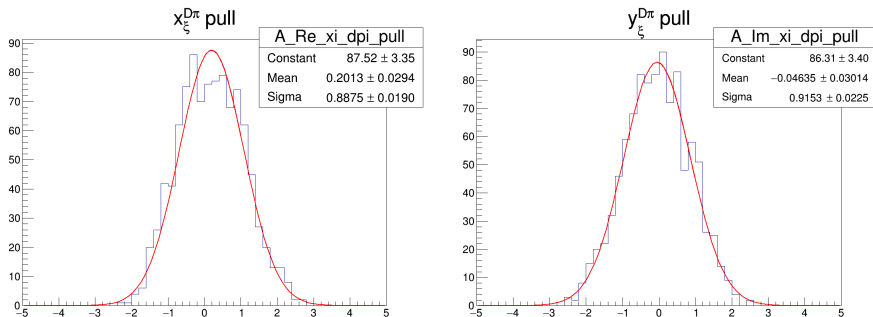
- ① Study semileptonic backgrounds in RapidSim
- ② Recalculate PID efficiencies with PIDCalib
- ③ Refit MC signal shapes
- ④ Rerun everything with Run 1 (finally!)

# Backup: Biases in $B \rightarrow DK$ CP observables, 8 bins



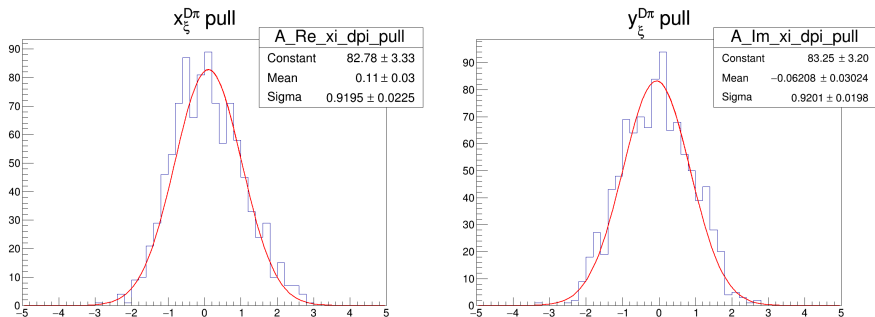
**Figure 14:**  $B \rightarrow DK$  CP observable pull distributions

# Biases in $B \rightarrow D\pi$ CP observables, 8 bins



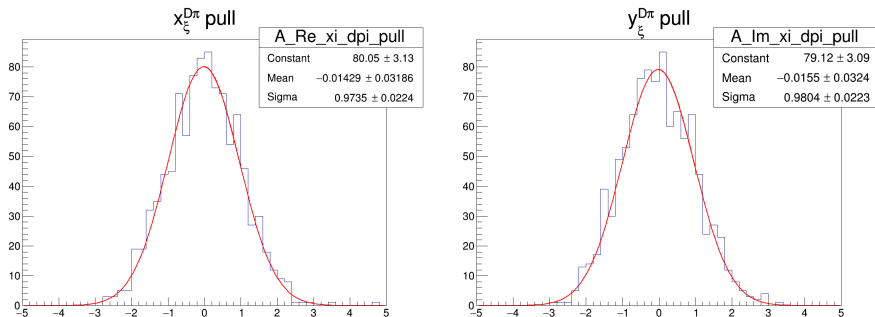
**Figure 15:**  $B \rightarrow D\pi$  CP observable pull distributions

# Biases in $B \rightarrow D\pi$ CP observables, 8 bins, 2x statistics



**Figure 16:**  $B \rightarrow D\pi$  CP observable pull distributions

# Biases in $B \rightarrow D\pi$ CP observables, 8 bins, 10x statistics



**Figure 17:**  $B \rightarrow D\pi$  CP observable pull distributions