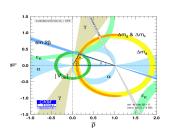
# $\gamma$ analysis update in $B^\pm o (K^+K^-\pi^+\pi^-)_D K^\pm$ decays

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### Outline

Summary of last time

② Binning scheme

3 First look at LHCb data

## Summary of last time

- $B^{\pm} \rightarrow DK^{\pm}$ ,  $D \rightarrow K^{+}K^{-}\pi^{+}\pi^{-}$ , arXiv:hep-ph/0611272
- Model independent measurement with BESIII strong phase input
- Estimate 2000 B events from LHCb Run 1 and 2
  - Benchmark:  $\sigma(\gamma) = 11^{\circ}$  from model dependent fit
  - LHCb amplitude model in AmpGen, arXiv:1811.08304
- Pull study to test and optimize binning scheme
  - Simulated 1000 experiments with 2000 events each
  - Strong phases from amplitude model using MC integration

### Binning scheme

• Aim: Pick binning scheme to maximize  $x_{\pm}$  and  $y_{\pm}$  sensitivity

#### Event yield in bin i

$$\begin{split} N_{i}^{+} &= h_{B^{+}} \Big( \bar{K}_{i} + \left( x_{+}^{2} + y_{+}^{2} \right) K_{i} + 2 \sqrt{K_{i} \bar{K}_{i}} \big( x_{+} c_{i} - y_{+} s_{i} \big) \Big) \\ N_{-i}^{+} &= h_{B^{+}} \Big( K_{i} + \left( x_{+}^{2} + y_{+}^{2} \right) \bar{K}_{i} + 2 \sqrt{K_{i} \bar{K}_{i}} \big( x_{+} c_{i} + y_{+} s_{i} \big) \Big) \\ x_{\pm} &= r_{B} \cos(\delta_{B} \pm \gamma), \quad y_{\pm} = r_{B} \sin(\delta_{B} \pm \gamma) \end{split}$$

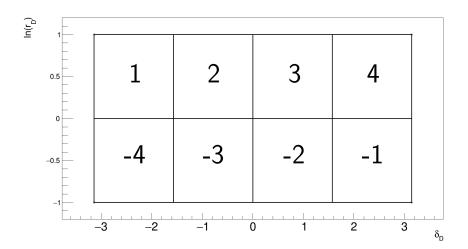
- Previously: Rectangular parameterization of 5D phase space
- Better and simpler:
  - Generate C++ source code for amplitude model using AmpGen
  - Evaluate amplitude directly in analysis
  - Decide bin based on strong phase and amplitude ratio directly

 $B^{\pm} \to (K^{+}K^{-}\pi^{+}\pi^{-})_{D}K^{\pm}$ 

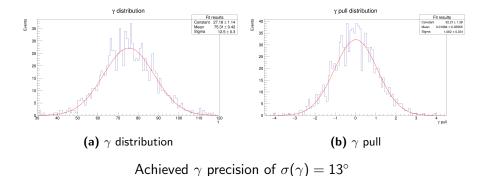
### Strong phase and amplitude ratio

$$\mathcal{A}(D^0)/\mathcal{A}(\bar{D^0}) = r_D \exp(i\delta_D)$$

# Naive ampltiude binning scheme



## Pull study naive amplitude binning



# Optimize bin widths

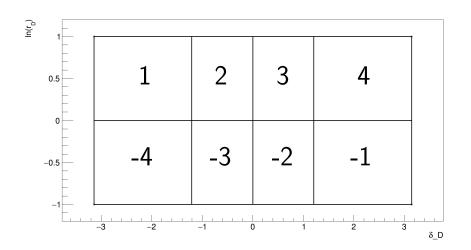
- Optimize  $x_{\pm}$ ,  $y_{\pm}$  sensitivity
- ullet Vary bin edges, keep symmetric around  $\delta_D=0$

### Binning Q value

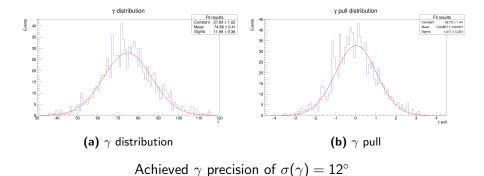
$$\begin{aligned} Q^2 &= 1 - \sum_i \frac{\kappa_i \bar{K}_i (1 - c_i^2 - s_i^2)}{N_i} / \sum_i K_i \\ Q^2 &\approx \sum_i N_i (c_i^2 + s_i^2) / \sum_i N_i \end{aligned}$$

• Can achieve  $Q \approx 0.90$  with 8 bins  $\implies$  expect  $\sigma(\gamma) = 12^{\circ}$ 

# Variable widths binning scheme

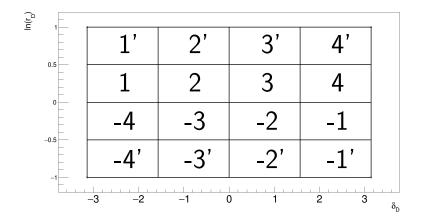


# Pull study with variable widths binning



## Binning along $r_D$

- $\bullet$  Further optmization by binning along  $r_D$
- Claim: Can use **same**  $c_i$  and  $s_i$  in bin i and i'
- $\bullet$  Can push  $\sigma(\gamma)$  down by  $0.5^{\circ}\text{-}1^{\circ}$

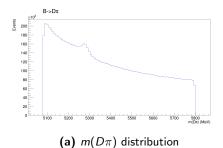


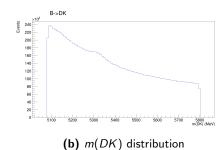
 $B^{\pm} \rightarrow \overline{(K^+K^-\pi^+\pi^-)_D K^{\pm}}$ 

#### First look at LHCb data

- DaVinci scripts from  $K_S\pi^+\pi^-$  analysis
- Have obtained full Run 2 data and MC
- DaVinci issues with Run 1, unable to run DecayTreeFitter
- Event selection:
  - Initial rectangular cuts
  - Gradient Boosted Decision Tree
  - Final cuts
  - Mass fit

#### First look at LHCb data

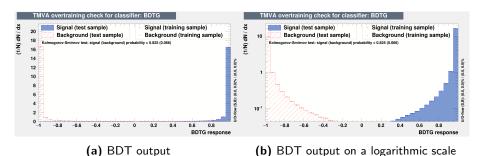




## BDT sample preparation

- Signal training sample:  $B \to D\pi$  MC samples
- Background training sample: High mass sideband in data
  - $5800 \, \text{MeV} < m(Dh) < 7000 \, \text{MeV}$
- Signal region:  $5080 \,\mathrm{MeV} < m(Dh) < 5800 \,\mathrm{MeV}$
- Initial cuts:
  - Standard trigger requirements
  - ullet Bachelor  $P < 100 \, \mathrm{GeV}$  and has RICH
  - ullet K $^{\pm}$  daughters  $P < 100\,\mathrm{GeV}$  and has RICH
  - DecayTreeFitter convergence
  - $|m(D) m_{PDG}(D)| < 25 \,\text{MeV}$

## BDT training

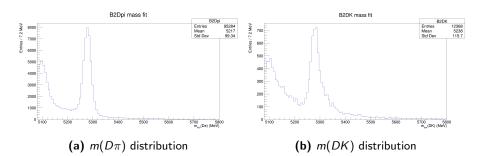


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#### Final selection

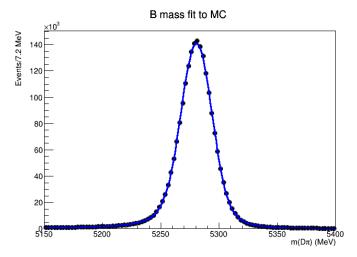
- PID cut for bachelor at 4
  - Bach\_PIDK > 4 for  $B \rightarrow DK$
  - Bach\_PIDK < 4 for  $B \rightarrow D\pi$
- $K^{\pm}$  daughter PID cut at -5
- ullet DecayTreeFitter  $\ln \left( \chi^2 
  ight) < 3$
- *B-D* flight significance at 0.5
- BDT working point at 0.75
- Not optimized yet

## Mass plots after final selection



#### Mass fit

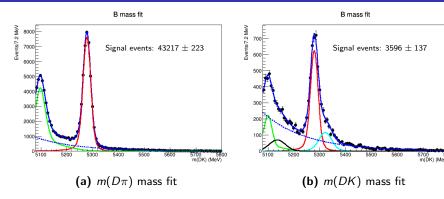
- Signal shape: Double Crystal Ball
  - ullet Tail parameters taken from fit to MC  $B\to D\pi$
  - Width and mean is floated



### Mass fit

- Combinatorial background: Exponential curve
- Partially reconstructed background:
  - Shape parameters taken from LHCb-ANA-2017-057.1
  - $B^{\pm} \rightarrow (D^{*0} \rightarrow D^0[\pi^0])\pi^{\pm}$ : HORNSdini
  - $B^0 \rightarrow (D^{*\pm} \rightarrow D^0[\pi^{\mp}])\pi^{\pm}$ : HORNSdini
  - $B^{\pm} \rightarrow D^0 \rightarrow (\rho^{\pm} \rightarrow \pi^{\pm} [\pi^0]) \pi^{\pm}$ : HORNSdini
  - $B^{\pm} \rightarrow (D^{*0} \rightarrow D^0[\gamma])\pi^{\pm}$ : HILLdini
- Further complication for  $B \to DK$  mode:
  - Cross-feed from  $B \to D\pi$ : Double Crystal Ball with same tail parameters as signal for now
  - Mis-ID of partially reconstructed background: Haven't considered yet, absorb into a Gaussian for now

### Mass fit plots



- Signal
- Partially reconstructed background
- Combinatorial background (dashed)
- Cross feed
- Mis-ID of partially reconstructed background

### Backup slides

#### DaVinci error message:

```
B2DPi D2KKPiPi....
                    INFO TupleToolDecayTreeFitter:: The INFO message is suppressed : 'Renaming duplicate to Bu constDOPV D0 piplus 0
BZDPi DZKKPiPi....
                    INFO TupleToolDecayTreeFitter:: The INFO message is suppressed : 'Renaming duplicate to Bu constD0PV D0 Kplus 1'
                   ERROR TupleToolDecayTreeFitter:: Tuple entry error : Bu constDOPV DO Kplus 0 ID != Bu constDOPV DO Kplus 1 ID StatusCode=FAILURE
B2DPL D2KKPLPL.... ERROR TupleToolDecayTreeFitter:: Tuple entry error : Bu constD0PV D0 Kplus 0 PE != Bu constD0PV D0 Kplus 1 PE StatusCode=FAILURE
                   ERROR TupleToolDecayTreeFitter:: Tuple entry error : Bu constDOPV D0 Kplus 0 PX != Bu constDOPV D0 Kplus 1 PX StatusCode=FAILURE
32DPi D2KKPiPi.... ERROR TupleToolDecayTreeFitter:: Tuple entry error : Bu constD0PV D0 Kplus 0 PY != Bu constD0PV D0 Kplus 1 PY StatusCode=FAILURE
                   ERROR TupleToolDecayTreeFitter:: Tuple entry error : Bu constD0PV D0 Kplus 0 PZ != Bu constD0PV D0 Kplus 1 PZ StatusCode=FAILURE
32DPI DZKKPIPI... FRROR TUDIEToolDecayTreeFitter:: Tuple entry error : Bu constD0PV D0 piplus 1 ID != Bu constD0PV D0 piplus 0 ID StatusCode=FAILUR
                   ERROR TUpleToolDecayTreeFitter:: Tuple entry error : Bu constD0PV D0 piplus 1 PE != Bu constD0PV D0 piplus 0 PE StatusCode=FAILUR
                   ERROR TUPLETOOLDECAYTreeFitter:: Tuple entry error : Bu constD0PV D0 piplus 1 PX != Bu constD0PV D0 piplus 0 PX StatusCode=FAILURE
32DP1_D2KKPlP1.... ERROR TupleToolDecayTreeFitter:: Tuple entry error : Bu_constD0PV_D0_piplus_1_PY != Bu_constD0PV_D0_piplus_0_PY StatusCode=FAILURE
B2DPl_D2KKPlPl.... ERROR TupleToolDecayTreeFitter:: Tuple entry error : Bu_constD0PV_D0_piplus_1_PZ != Bu_constD0PV_D0_piplus_0_PZ StatusCode=FAILURE
R2DPi D2KKPiPi
                   FATAL Tool 'TupleToolDecayTreeFitter' acting on particle 'Bu' returned a failure status.
```