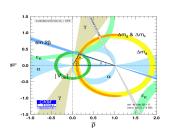
γ analysis update in $B^\pm o (K^+K^-\pi^+\pi^-)_D K^\pm$ decays

Martin Tat

Oxford LHCb

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Outline

- Summary of last time
- 2 Binning scheme
- 3 First look at LHCb data
- 4 BESIII double tag analysis
- Summary

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

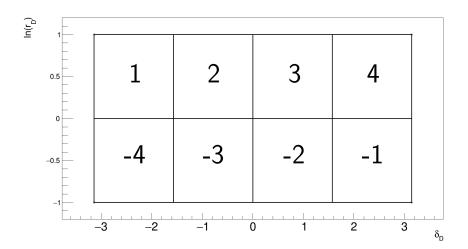
$$\begin{aligned} N_{i}^{+} &= h_{B^{+}} \Big(\bar{K}_{i} + \left(x_{+}^{2} + y_{+}^{2} \right) K_{i} + 2 \sqrt{K_{i} \bar{K}_{i}} \big(x_{+} c_{i} - y_{+} s_{i} \big) \Big) \\ N_{-i}^{+} &= h_{B^{+}} \Big(K_{i} + \left(x_{+}^{2} + y_{+}^{2} \right) \bar{K}_{i} + 2 \sqrt{K_{i} \bar{K}_{i}} \big(x_{+}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

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

Strong phase and amplitude ratio

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

Naive ampltiude binning scheme



Optimize bin widths

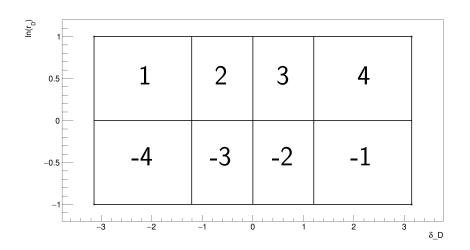
- Optimize x_{\pm} , y_{\pm} sensitivity
- ullet Vary bin edges, keep symmetric around $\delta_D=0$

Binning Q value

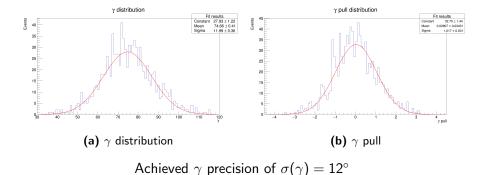
$$\begin{split} Q^2 &= 1 - \sum_i \frac{\kappa_i \bar{K}_i (1 - c_i^2 - s_i^2)}{N_i} \bigg/ \sum_i K_i \\ Q^2 &\approx \sum_i N_i (c_i^2 + s_i^2) \bigg/ \sum_i N_i \end{split}$$

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

Variable widths binning scheme

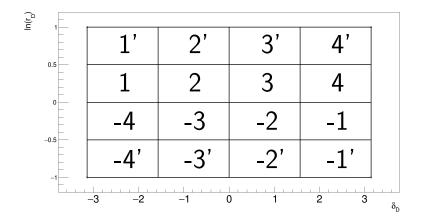


Pull study with variable widths binning



Binning along r_D

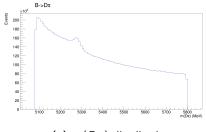
- \bullet Further optimization by binning along r_D
- Claim: Can use **same** c_i and s_i in bin i and i'
- Can push $\sigma(\gamma)$ down by $0.5^{\circ}-1^{\circ}$



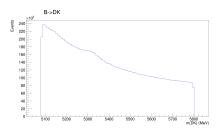
First look at LHCb data

- 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



(a) $m(D\pi)$ distribution

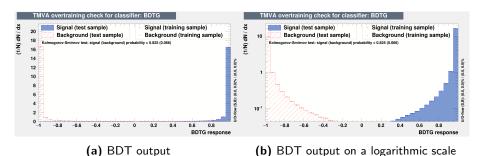


(b) m(DK) distribution

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: $5080 \, \text{MeV} < m(Dh) < 5800 \, \text{MeV}$
- Initial cuts:
 - Standard trigger requirements
 - Bachelor $P < 100 \, \text{GeV}$ 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

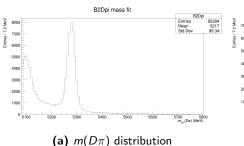


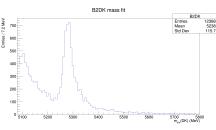
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Final selection

- 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 $\ln(\chi^2) < 3$
- *B-D* flight significance at 0.5
- BDT working point at 0.75
- Not optimized yet

Mass plots after final selection

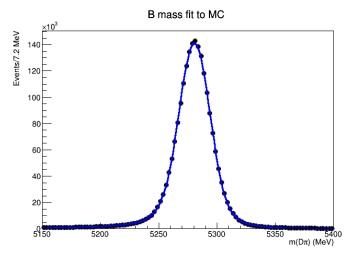




(b) m(DK) distribution

Mass fit

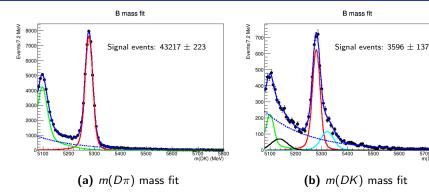
- Signal shape: Double Crystal Ball
 - ullet Tail parameters taken from fit to MC $B\to D\pi$
 - Width and mean is floated



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 $B \rightarrow DK$ 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

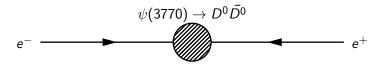
Mass fit plots



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

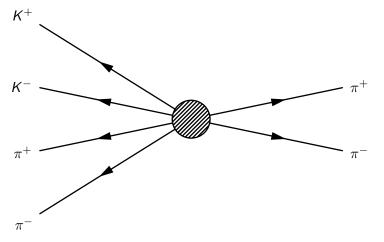
BESIII double tag analysis

Produce *D* mesons through $e^+e^- \rightarrow \psi(3770) \rightarrow D^0\bar{D^0}$:



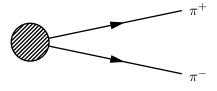
BESIII double tag analysis

Double tagged signal $(K^+K^-\pi^+\pi^-)$ with known CP tag $(\pi^+\pi^-)$



BESIII double tag analysis

Single tagged
$$(\pi^+\pi^-)$$



Double tag method

•
$$M_i = h(K_i \mp 2c_i\sqrt{K_i\bar{K}_i} + \bar{K}_i)$$

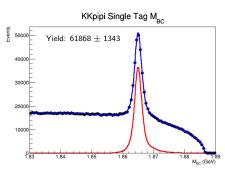
•
$$M_{ij} = h(K_i\bar{K}_j + \bar{K}_iK_j - 2\sqrt{K_i\bar{K}_iK_j\bar{K}_j}(c_ic_j + s_is_j))$$

• Normalization constant h depends on single tagged yields

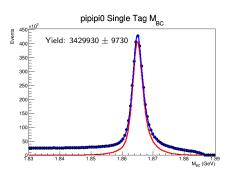
Double tag progress

- Implemented 14 tag modes so far, with another 5 to come (full list in backup slides)
- Run over the full 2010+2011 MC $D^0\bar{D^0}$ dataset
- Single tagged yield:
 - Fit $m_{BC} = \sqrt{E_{\text{beam}}^2 \mathbf{p}_D^2}$
 - Double Crystal Ball for signal
 - Argus PDF for background
- Double tagged yield
 - $\Delta E = E_D E_{\text{beam}}$ cut
 - ullet Fit double Gaussian and 2nd order polynomial to ΔE
 - Cut at $[-3\sigma, 3\sigma]$ ($[-4\sigma, 3\sigma]$ for π^0 modes)
 - Subtract flat background from sidebands

M_{BC} fits

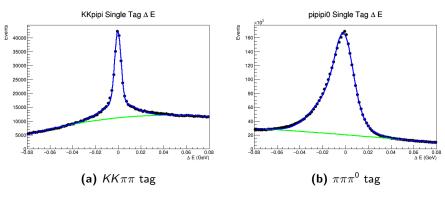


(a) $KK\pi\pi$ beam constrained mass



(b) $\pi\pi\pi^0$ beam constrained mass

ΔE fits



See backup for other tag modes

Summary

Summary:

- Binning scheme is satisfactory
- Started mass fits with LHCb data
- Most tag modes in BESIII analysis are ready

Next steps:

- Understand partially reconstructed backgrounds in LHCb data
- Finish implementing all tag modes in BESIII analysis, analyse peaking backgrounds

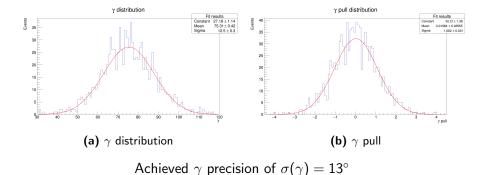
Thank you!

Backup slides: DaVinci error

DaVinci error message:

```
BZDPL_DZKKPIPL... INFO 'upleTolDecayTreefitter:: The INFO message is suppressed : Renaming duplicate to Bu_constDBPV_0B_plplus_0'
BZDPL_DZKKPIPL... INFO 'upleTolDecayTreefitter:: The INFO message is suppressed : Renaming duplicate to Bu_constDBPV_0B_plplus_1'
BZDPL_DZKKPIPL... ERROR TUpleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_1 D : Bu_constDBPV_0B_pkplus_1 D : StatusCode=FAILURE
BZDPL_DZKKPIPL... ERROR TUpleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX != Bu_constDBPV_0B_pkplus_1PX : StatusCode=FAILURE
BZDPL_DZKKPIPL... ERROR TUpleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX != Bu_constDBPV_0B_pkplus_1PX : StatusCode=FAILURE
BZDPL_DZKKPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX != Bu_constDBPV_0B_pkplus_1PX : StatusCode=FAILURE
BZDPL_DZKKPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX != Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : Bu_constDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : BU_ConstDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : BU_ConstDBPV_0B_pkplus_0PX := BU_DZKEPIPL... ERROR TupleTolDecayTreefitter:: Tuple entry error : BU_DZKEPIPL... ERROR TupleTo
```

Backup slides: Pull study naive amplitude binning



Backup slides: List of tag modes

- Flavour tags:
 - Κπ. Κππ⁰
- CP tags:
 - KK, ππ, πππ⁰
 - $K_S\pi^0$, $K_S\pi^0\pi^0$, $K_S^0\eta$, $K_S^0\eta'(\pi\pi\eta)$, $K_S^0\eta'(\rho\gamma)$
 - $K_S^0 \omega(\pi \pi \pi^0)$, $K_S^0 \eta(\pi \pi \pi^0)$, $K_S^0 \phi$
 - $K_{S}^{0}\pi^{+}\pi^{-}$
 - $K^+K^-\pi^+\pi^-$
- Will also include:
 - Κπππ, Κεν_ε
 - $K_L \pi^0$, $K_L \pi^0 \pi^0$, $K_L \omega$

Backup slides: Flat background in sidebands

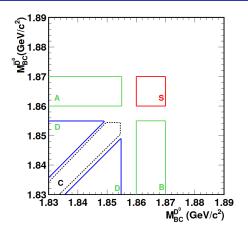
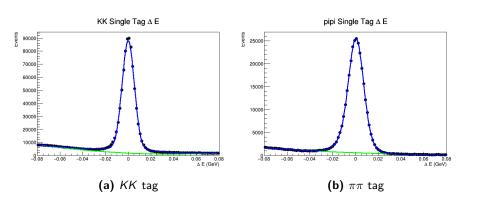
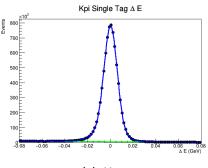


Figure 9: m_{BC} plane, BESIII $K_S^0K^+K^-$ MEMO

$$F = \frac{a_S}{a_D}D + \sum_{i=A,B,C} \frac{a_S}{a_i} \left(i - \frac{a_S}{a_i}D\right)$$

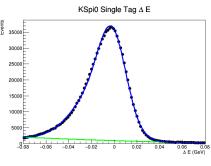




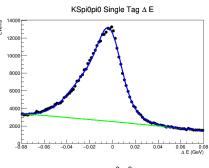
Kpipi0 Single Tag Δ E

To

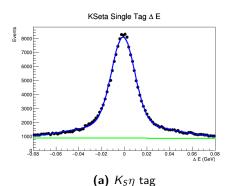
(b) $K\pi\pi^0$ tag



(a) $K_S\pi^0$ tag

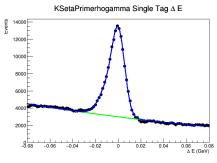


(b) $K_S \pi^0 \pi^0 tag$

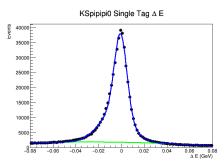


KSetaPrimepipieta Single Tag Δ E

(b) $K_S \eta'(\pi \pi \eta)$ tag



(a) $K_S \eta'(\pi \pi \gamma)$ tag



(b) $K_S(\eta,\omega)(\pi\pi\pi^0)$ tag

