The measurement of f_s/f_d from hadronic modes in LHCb experiment

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Outline

1. Introduction
2. Analysis strategy
   - Selection procedure
   - Signal model
   - Background model
3. Fitting results
4. Systematic uncertainty
5. Results

Introduction

f_q – fragmentation functions, describe the probability that a b quark will hadronize into a B_q meson (where $q = u, d, s$) or Λ_b baryon, respectively.

- Signal
  - $B_d \to D\pi$ (tree + exchange topology)
  - $B_d \to DK$ (tree topology)
  - $B_s \to D_s\pi$ (tree topology)
- Data:
  - ~35 pb^{-1} of data collected in 2010
- Goal:
  - Measure f_s/f_d (important for many BR measurements, e.g. $B_s \to \mu\mu$) at 7 TeV
  - First step towards the measurement of the CP violation in the signal modes.

Introduction 2

$B_d \to DK / B_s \to D_s\pi$:

- Same final state (KKππ)
- Small theoretical uncertainty 7%

$$\frac{f_s}{f_d} = 0.0743 \times \frac{\tau_{B^0}}{\tau_{B_s^0}} \times \left[\frac{1}{\mathcal{N}_a \mathcal{N}_F} \frac{\epsilon_{DK}}{\epsilon_{D_s\pi}} \frac{N_{D_s\pi}}{N_{DK}}\right]$$

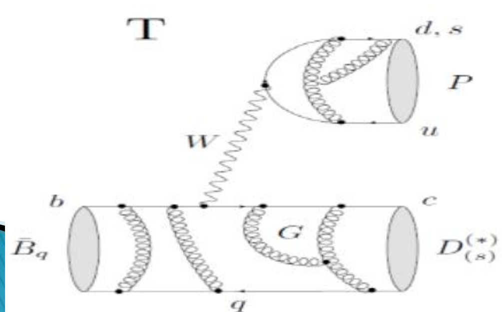
- arXiv:1004.3982v3

Deviation from factorization:

$$\mathcal{N}_a \equiv \left|\frac{a_1(D_s\pi)}{a_1(DK)}\right|^2 = 1.00 \pm 0.02$$

Form factor:

$$\mathcal{N}_F \equiv \left[\frac{F_0^{(s)}(m_\pi^2)}{F_0^{(d)}(m_K^2)}\right]^2 = 1.24 \pm 0.08$$



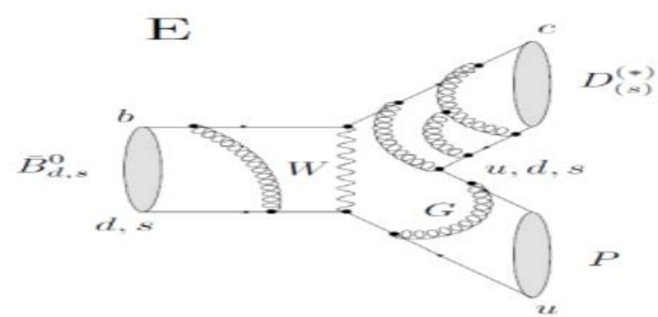
$B_d \to D\pi / B_s \to D_s\pi$:

- Similar final states
- Theoretical uncertainty of order of 9%

$$\frac{f_s}{f_d} = 0.982 \times \frac{\tau_{B^0}}{\tau_{B_s^0}} \times \left[\frac{1}{\tilde{\mathcal{N}}_a \mathcal{N}_F \mathcal{N}_E} \frac{\epsilon_{D\pi}}{\epsilon_{D_s\pi}} \frac{N_{D_s\pi}}{N_{D\pi}}\right]$$

- Additional contribution from the exchange diagrams

$$\mathcal{N}_E = 0.966 \pm 0.056$$



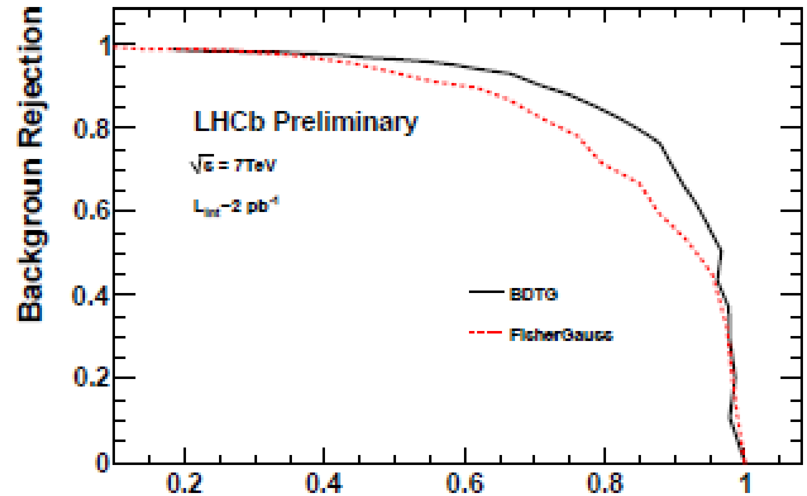
- arXiv:1012.2784v1

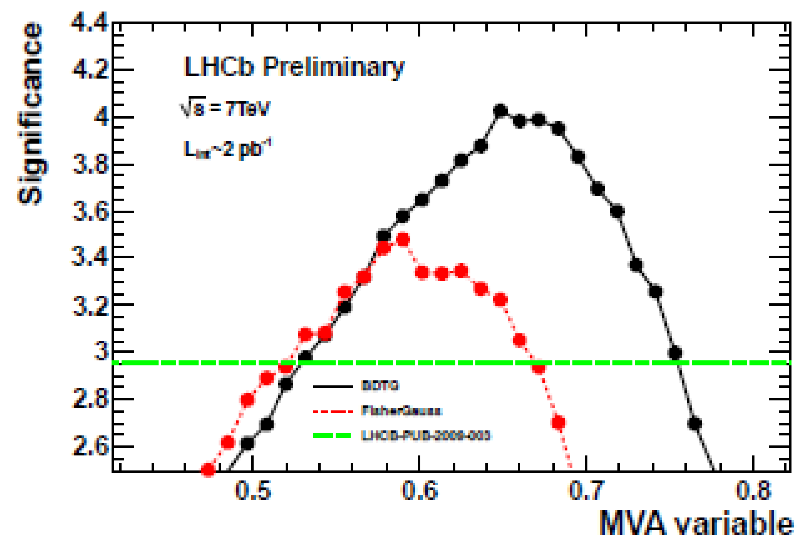
Analysis strategy:

Selection procedure

- Triggers and preselection the same for every signal mode – difference in the efficiencies arises due to *Bs* and *Bd* lifetime difference
- Offline selection
  - Using Gradient Boosted Decision Tree (BDTG) – one of MVA methods
  - Optimized for *DK* signal significance
  - Trained with 2 pb^{-1} of data, with Signal taken from the MC sample and background events from the *B* mass sidebands

Decay Channel	**Efficiency**
$B_d \to D\pi$	75.5 ± 0.8 %
$B_d \to DK$	76.3 ± 0.8 %
$B_s \to D_s\pi$	75.2 ± 0.4 %

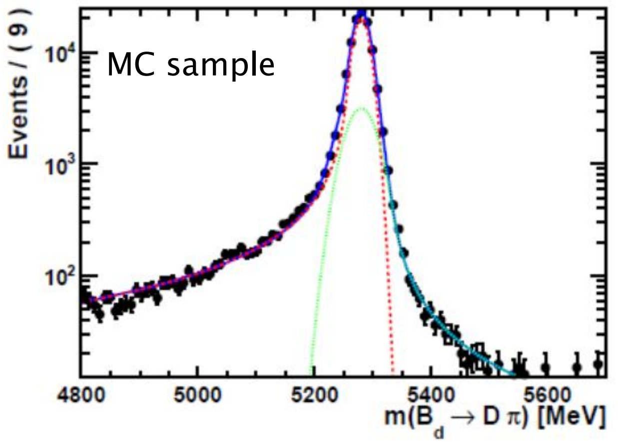




Analysis strategy:

Signal peak description

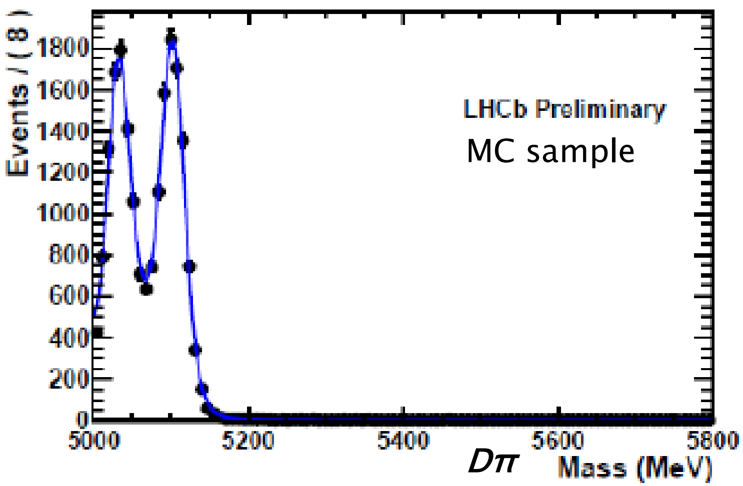
Double Crystal Ball function used for signal peak description
- Optimized using MC sample
- Left tail to account the radiative contribution
- Right tail to account non-Gaussian effects of the detector resolution

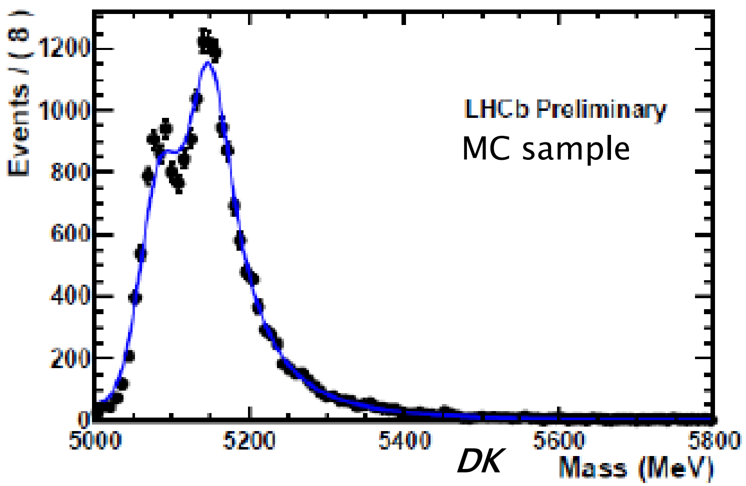


Parameter	$B^0 \to D^{\pm}\pi^{\mp}$	$B^0 \to D^{\pm}K^{\mp}$	$B_s^0 \to D_s^{\pm}\pi^{\mp}$	$B_s^0 \to D_s^{\pm}K^{\mp}$
Mean	5280.47 ± 0.06	5280.75 ± 0.06	5367.61 ± 0.04	5367.58 ± 0.05
α_1	1.79 ± 0.02	1.82 ± 0.03	1.56 ± 0.01	1.70 ± 0.01
α_2	-2.08 ± 0.04	-2.04 ± 0.04	-1.74 ± 0.07	-1.94 ± 0.18
n_1	1.06 ± 0.02	1.09 ± 0.02	1.24 ± 0.01	1.19 ± 0.01
n_2	1.26 ± 0.08	1.48 ± 0.08	3.04 ± 0.37	2.43 ± 0.55
σ_1	14.22 ± 0.15	13.29 ± 0.16	12.99 ± 0.05	12.28 ± 0.10
σ_2	26.46 ± 0.90	22.91 ± 0.80	18.95 ± 0.39	18.34 ± 0.25
Fract.	0.79 ± 0.02	0.73 ± 0.02	0.59 ± 0.02	0.55 ± 0.01

Analysis strategy:
Background description

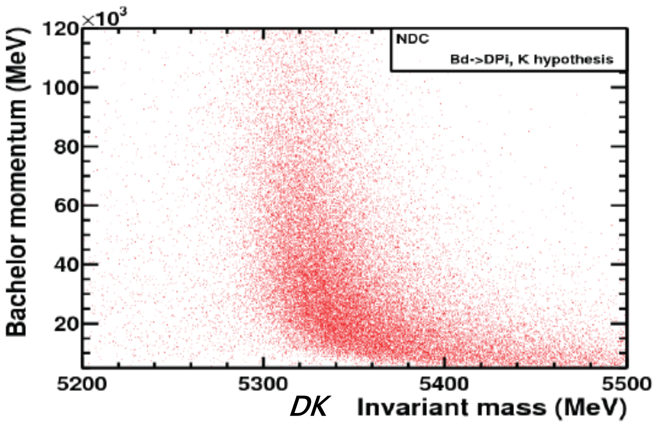
- Combinatoric background (prompt charm + pure combinatoric)
  - Single component describes with exponent/linear function (depends on the fitter)
- Partially reconstructed background e.g.: $B_d \to D^{*}\pi$ with missing π^0
  - Modelled with RooKeysPdf using MC samples
- Background from misidentification e.g. $B_d \to D\pi$ with $B_d \to DK$ mass hypothesis
  - Extracted from data using the reweighting procedure (see next slide)

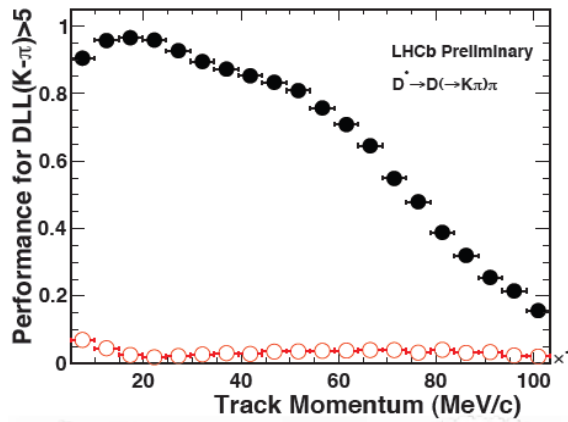


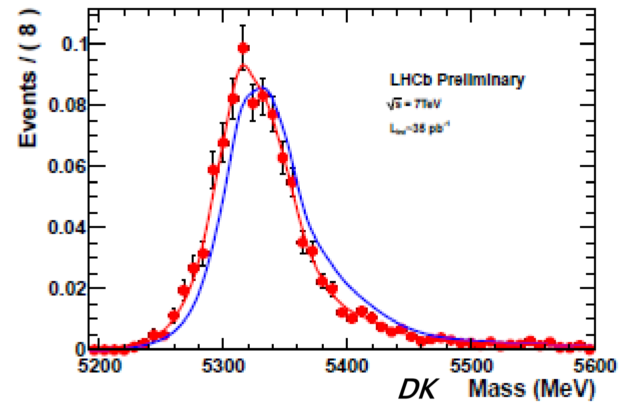


Analysis strategy:

Reweight procedure





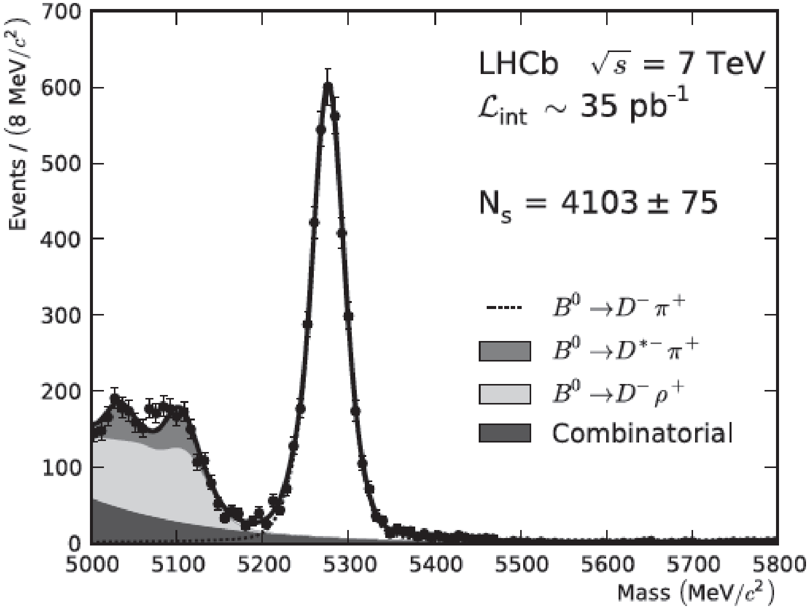


e.g.: Extracting $B_d \to D\pi$ mass shape with $B_d \to DK$ mass hypothesis:

1. Select ‚pure' $Bd \to D\pi$ sample under correct mass hypothesis
2. Correct momentum distribution for the distortion caused by this cut
3. Reweight according to the particle identification cut used for kaon bachelor selection
4. Fix the kaon mass hypothesis with a RooKeysPdf

Same procedure for all the mis-id backgrounds (e.g. $B_s \to D_s\pi$)

Fit results – $B_d \to D\pi$



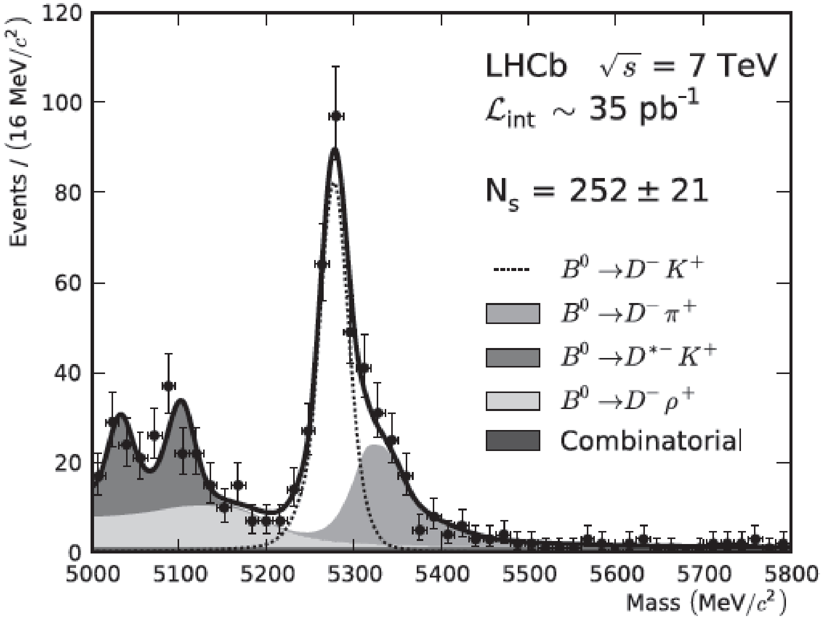
Parameter	Fitted value	Error
$N_{B^0 \to D^\pm \pi^\mp}$	4103	75
frac	0.58	0.06
mean	5276.3	0.4
σ_1	15.1	1.0
σ_2	27.1	1.2
N_{Comb}	1037	148
a_1	$-7.2 10^{-3}$	$0.5 10^{-3}$
$N_{D\rho}$	1631	198
$N_{D^*\pi}$	535	137

$B_d \to D\pi$:
4103 ± 75

Signal
Combinatorial
Partially Reconstructed

- Using bachelor PID cut to rule out the $B_d \to DK$ events
- All parameters free except the CB tails

Fit results – $B_d \to DK$



Expected number of $B_d \to D\pi$ (misID $\pi \to K$): **142**

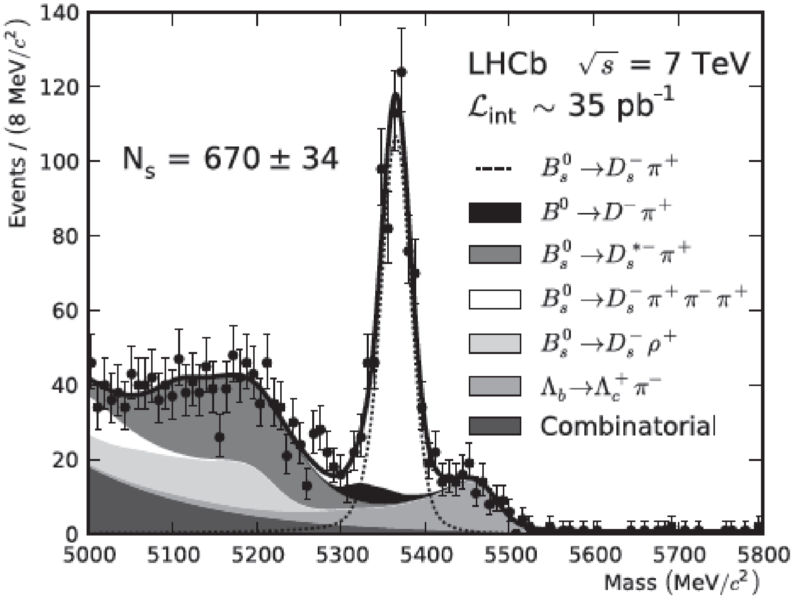
Parameter	Fitted value	Error
$N_{B^0 \to D^\pm K^\mp}$	252	21
frac	0.38	0.17
mean	5277.5	1.8
N_{Comb}	58	14
$N_{D\pi}$	131	19
$N_{D\rho}$	125	24
N_{D^*K}	123	19

$B_d \to D K$:
252 ± 21

Signal
Combinatorial
Partially Reconstructed

- Linear combintoric background
- Signal widths and CB tails are fixed

Fit results – $B_s \to D_s \pi$



- Linear combinatoric background
- Signal widths and CB tails are fixed
- Number of $B_d \to D\pi$ events gaussianly constrained
- The $B_s \to D_s^* \pi$ to $B_s \to D_s \rho$ ratio constrained (ratio taken from the $B_d \to D\pi$ fit results)

Expected number of $B_d \to D\pi$ (misID $\pi \to K$): **45**

Parameter	Fitted value	Error
$N_{B_s^0 \to D_s^\pm \pi^\mp}$	670	34
$frac_{sg}$	0.50	0.14
mean	5365.3	1.0
N_{Comb}	345	240
a_1	-6.610^{-3}	1.610^{-3}
$N_{D\pi}$	48	18
N_{Λ_b}	287	36
$N_{B_s^0 \to D_s 3\pi}$	79	79
N_{Part}	668	121
$frac_{Part}$	0.34	0.06

$B_s \to D_s \pi$: 670 ± 34

Systematic uncertainty

Source	For $D_s^\pm\ \pi^\mp$ and $D^\pm\ K^\mp$	For $D_s^\pm\ \pi^\mp$ and $D^\pm\ \pi^\mp$
PID calibration	1.0%	2.5%
B^0 fit model	2%	2%
B_s^0 fit model	2%	2%
L0 Trigger efficiency	2%	2%
$D_s^\pm \to KK\pi$ B.R	4.9%	4.9%
$D^\pm \to K\pi\pi$ B.R	2.2%	2.2%
$\frac{\tau_{B_s^0}}{\tau_{B^0}}$	1.5%	1.5%
Correction factors	2.2%	2.2%
Total	7.0%	7.4%

- All systematic uncertainties strongly correlated
- $B_s \to D_s\pi$/ $B_d \to DK$ more robust to PID systematics than $B_s \to D_s\pi$/ $B_d \to D\pi$

Results

- Results of f_s/f_d with

$B_s \to D_s\pi / B_d \to DK$ and $B_s \to D_s\pi / B_d \to D\pi$

$$\frac{f_s}{f_d} = 0.250 \pm 0.024^{\mathrm{stat}} \pm 0.017^{\mathrm{syst}} \pm 0.017^{\mathrm{theor}}$$

$$\frac{f_s}{f_d} = 0.256 \pm 0.014^{\mathrm{stat}} \pm 0.019^{\mathrm{syst}} \pm 0.026^{\mathrm{theor}}$$

- Combination of results:

$$\frac{f_s}{f_d} = 0.253 \pm 0.017^{\mathrm{stat}} \pm 0.017^{\mathrm{syst}} \pm 0.020^{\mathrm{theor}}$$

- In agreement with leptonic measurements of the f_s/f_d ratio in LHCb
- In agreement with latest results from CDF and LEP
- Result published in Phys. Rev. Lett. 107 (2011) 211801
- Now aiming towards the CP measurements using those modes

Thank you

Backup slides

Trigger & Stripping

Stripping cuts list

Parameter	Value
Global event cut	
Number of long tracks in the event	≤ 180
D selections	
χ^2/ndf for daughter tracks	< 5
p_T for daughter tracks	> 250 MeV/c
p for daughter tracks	> 2000 MeV/c
χ^2 of daughter IP to PV	> 4
χ^2 of IP to PV for at least one daughter	> 40,
Inv. mass window for D daughter combination	± 110 MeV/c^2
Inv. mass window for D after vertex fit	± 100 MeV
D vertex fit χ^2/ndf	< 12
p_T for D	1500 MeV
D DIRA	> 0.9
DOCA between D daughter tracks	< 1.5 mm
B selections	
Bachelor p_T	> 500 MeV/c
Bachelor p	> 5000 MeV/c
χ^2 of bachelor IP to PV	> 16
B vertex fit χ^2/ndf	< 12
chi^2 of B IP to PV	< 25
B proper time	> 0.2 ps
B DIRA	> 0.9998
Inv. mass window for B daughter combination	± 500 MeV/c^2

Selections

All particle momenta	> 2000 MeV
All particle IP χ^2	> 9
$D^{\pm}$ daughter p_t	> 300 MeV
$D^{\pm}$ p_t	> 2000 MeV
$D^{\pm}$ IP χ^2	> 9
$D^{\pm}$ vertex χ^2	< 15
$D^{\pm}$ FSPV (χ^2)	> 100
$D^{\pm}$ mass	$(1870, 1969)^{+24}_{-40}$
Bachelor p_t	> 500 MeV
B^0 vertex χ^2	< 10
B^0 IP χ^2	< 16
B^0 FSPV (χ^2)	> 144
B^0 $\cos\theta$	> 0.9999

Variables for BDTG

Selections

J/ψK* veto:

- No cut applied for D and B vertices separation thus small fraction of those can be reconstructed as Dπ
- Two final state tracks satisfy „isMuon" criterion
- Mass of those tracks is in ±40MeV J/ψ mass window