“Oscillazioni del B_s a LHCb”

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a nome della collaborazione LHCb

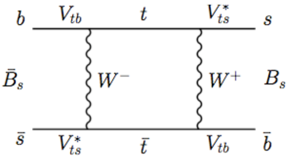
IFAE 2011 - Perugia, 27-29 Aprile 2011

Le oscillazioni $B_s^0 - \bar{B}_s^0$

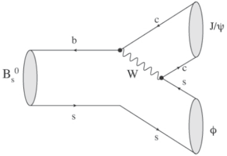
CPV in $B_s^0 \to J/\psi\phi$: interferenza fra mixing & decadimento
$\phi_s = \phi_M - 2\phi_D$

$$\begin{tikzcd} B_s^0 \arrow[rr, "\phi_D"] \arrow[dr, bend right, "\phi_M"'] & & J/\psi\phi \\ & \bar{B}_s^0 \arrow[ur, bend right, "-\phi_D"'] & \end{tikzcd}$$

Modello Standard: $\phi_s^{SM} \simeq -2\beta_s = -(0.0363 \pm 0.0017)$ rad



fase di mixing $\phi_M^{SM} = 2arg(V_{ts}V_{tb}^*)$
possibili contributi aggiuntivi di NP



contributo dominante $\bar{b} \to \bar{c}c\bar{s}$ (tree)
fase di decadimento: $\phi_D = arg(V_{cs}V_{cb}^*)$
+ contributo minore dovuto a diagrammi a "pinguino"

$\phi_s = \phi_s^{SM} + \Delta\phi^{NP}$

Misure al Tevatron (CDF public note 10206 (2010) & D0 note 6098-CONF (2010))

Verso la misura di ϕ_s

Roadmap: arXiv:0912.4179v2 [hep-ex]

- Selezione del segnale e di canali di controllo: LHCb-CONF-2011-001
  Misura delle vite medie $H_b \to J/\psi X$
- Analisi angolare dei canali $P \to VV$: LHCb-CONF-2011-002
  analisi angolare di $B_d^0 \to J/\psi K^*$
  analisi angolare, non "taggata", di $B_s^0 \to J/\psi\phi$: misura di $\Delta\Gamma_s$
- Tagging: identificazione del $b-$flavour prodotto LHCb-CONF-2011-003
  Verifica: misura della frequenza di mixing $B_{d/s}^0 - \bar{B}_{d/s}^0$ LHCb-CONF-2011-005,010
- Misura di $\sin(2\beta)$: LHCb-CONF-2011-004
  Verifica simmetria CP nota: analisi "taggata", dipendente dal tempo, di $B_d^0 \to J/\psi K_s^0$
- Misura di ϕ_s: LHCb-CONF-2011-006
  analisi angolare, "taggata", di $B_s^0 \to J/\psi\phi$

Selezione del segnale e dei canali di controllo

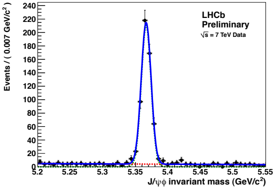
LHCb-CONF-2011-001

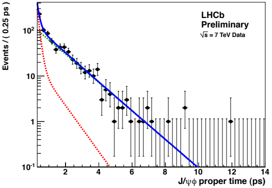
Selezione comune per tutti i decadimenti $H_b \rightarrow J/\psi X$: verifica e studio delle sistematiche
$(B^+ \rightarrow J/\psi K^+ \ , B^0 \rightarrow J/\psi K^{*0} \ , B_s^0 \rightarrow J/\psi \phi \ , B_d^0 \rightarrow J/\psi K_S^0 \ , \Lambda_b \rightarrow J/\psi \Lambda)$

- **dati 2010:** $\sqrt{s} = 7$ TeV, $\mathcal{L} \sim 36 pb^{-1}$
- **trigger**: di-muone, senza tagli IP (70%) ("life-time unbiased")
  singolo-muone, con tagli IP ("life-time biased")
- off-line: **t>0.3 ps** per rimuovere il picco di fondo "prompt"
- ottima **risoluzione di massa** ($\sigma_m \sim 7-10$ MeV), piccola contaminazione di fondo
- Dai dati stessi determinazione di:
  - **Risoluzione temporale** dal picco "prompt": $<\sigma_t> \sim 50$ fs
  - **Accettanza temporale** per gli eventi con trigger "biased":

$$\epsilon(t) = \frac{N.biased\&unbiased}{N.unbiased}$$

$B_s^0 \rightarrow J/\psi \phi$: $t > 0.3$ps (S/B=12.5)





Misura delle vite medie

Usando i soli eventi selezionati da trigger “unbiased”:

$t > 0.3$ps			
canale	ev. segnale	LHCb τ[ps]	PDG τ[ps]
$B^+ \to J/\psi K^+$	6741±85	1.689±0.022±0.047	1.638±0.011
$B^0 \to J/\psi K^{*0}$	2668±58	1.512±0.032±0.042	1.525±0.009
$B_s^0 \to J/\psi \phi$ [1]	570±24	1.447±0.064±0.056	$1.472^{+0.024}_{-0.026}$
$B_d^0 \to J/\psi K_S^0$	838±31	1.558±0.056±0.022	1.525±0.009
$\Lambda_b \to J/\psi \Lambda$	187±16	1.353±0.108±0.035	$1.391^{+0.038}_{-0.037}$

Sistematica principale: incertezza sulle funzioni di accettanza temporale (migliorabile).

Con i dati del 2011 le misure potranno essere competitive con le medie mondiali.

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[1] fit con singola esponenziale: $\Delta\Gamma_s = 0$

Analisi angolare

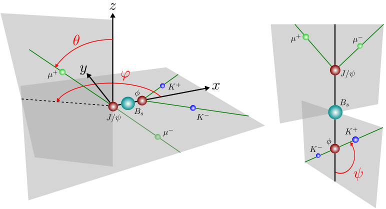
LHCb-CONF-2011-002

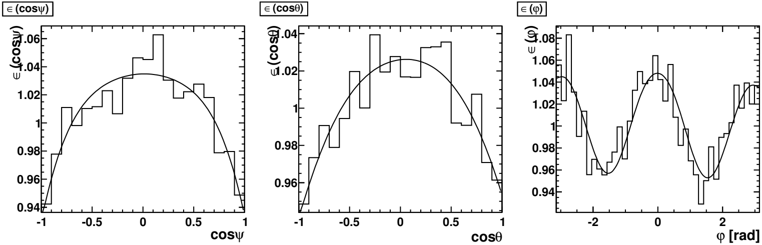
Nei decadimenti $P \to VV$ sono possibili diversi stati di polarizzazione: (ℓ= 0, 1, 2)
Nel caso di $B_s^0 \to J/\psi\phi$ essi corrispondono a 2 possibili autovalori di CP (-1, $+1$).

Separazione statistica con l'analisi angolare ($\cos\theta, \varphi, \cos\psi$) riferimento di trasversità.

Correzione per accettanza (detector & tagli di selezione):

- mappa 3D dal MonteCarlo
- Proiezioni 1D della accettanza angolare: correzioni entro ±5%



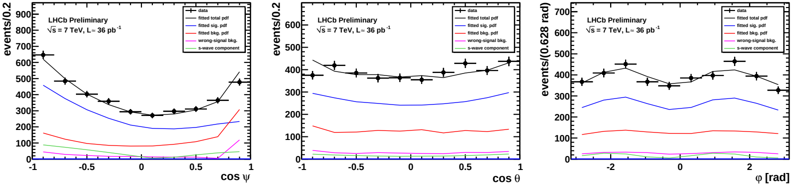


Analisi angolare di $B^0 \to J/\psi K^{*0}$

LHCb-CONF-2011-002

Verifica: misura delle ampiezze di polarizzazione di $B^0 \to J/\psi K^{*0}$: $P \to VV$

fit 5D $(m, t, \cos\theta, \varphi, \cos\psi)$
Parametrizzazione del fondo adattata sugli eventi nelle sidebands massa (S/B:3.4)
Contributo di $K\pi$ non risonante (S-wave) al segnale $5 \pm 2\%$



	$t > 0.3$ps	
parametro	LHCb (preliminare)	BaBar PRD 76, 031002
$\lvert A_{\parallel}\rvert^2$	0.252±0.020±0.016	0.211±0.010±0.006
$\lvert A_{\perp}\rvert^2$	0.178±0.022±0.017	0.233±0.010±0.005
$\delta_{\parallel}$ [rad]	-2.87±0.11±0.10	-2.93±0.08±0.04
$\delta_{\perp}[rad]$	3.02±0.10±0.07	2.91±0.05±0.03

Sistematiche principali: S-wave, accettanza, fondo.

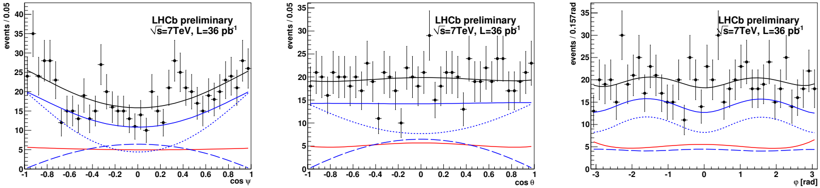
Risultati in buon accordo con le misure esistenti (BaBar), ma non ancora competitivi in termini di precisione (2011).

Analisi angolare non “taggata” di $B_s^0 \to J/\psi\phi$

LHCb-CONF-2011-002

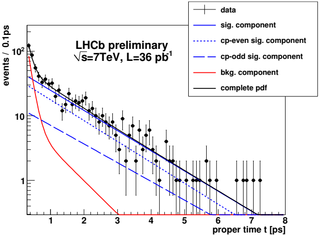
fit 5D $(m, t, \cos\theta, \cos\psi, \varphi)$

HP: $\phi_s = 0$



$t > 0.3$ps	
parametro	LHCb (preliminare)
Γ_s [ps^{-1}]	0.679±0.036±0.027
$\Delta\Gamma_s$ [ps^{-1}]	**0.077±0.119±0.021**
$\lvert A_0\rvert^2$	0.528±0.040±0.028
$\lvert A_\perp\rvert^2$	0.263±0.056±0.014
$\delta_{\vert\vert}$ [rad]	3.14±0.52±0.13

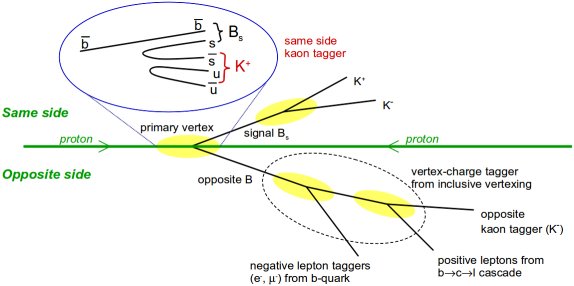
CDF note 10206, $\mathcal{L}$=5.2 fb^{-1}
$\Delta\Gamma_s = (0.075 \pm 0.035 \pm 0.010)$ ps^{-1}



570±24 eventi di segnale
(trigger “unbiased”)

Flavour Tagging

LHCb-CONF-2011-003



- $\epsilon_{tag} = \frac{R+W}{R+W+U}$, $\omega = \frac{W}{R+W}$, potere di tagging: $\epsilon_{eff} = \epsilon_{tag} D^2 = \epsilon_{tag}(1-2\omega)^2$
- ϵ_{tag} si misura in ciascun canale, ω può essere misurato in canali di controllo
  - η: probabilità di mistag (evento per evento) calibrata sui dati
- Algoritmi di tagging ottimizzati sui dati 2010 ($\mathcal{L} \sim 35pb^{-1}$) usando diversi canali: $B^0 \to D^{*-}\mu^+\nu_\mu$, $B^+ \to J/\psi K^+$ e $B^0 \to J/\psi K^{*0}$
  - Solo OS e SSπ: $\epsilon_{eff}^{OS} \sim 2\%$, $\epsilon_{eff}^{OS+SS\pi} \sim 2.8\%$
  - SSK: pochi eventi nel canale di controllo $B_s \to D_s^- \pi^+$ per calibrare (2011)

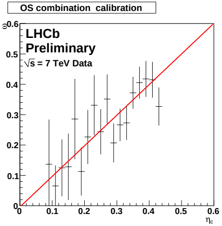
Flavour Tagging: calibrazione

LHCb-CONF-2011-003

Probabilità di mistag η (evento per evento) calibrata sui dati $B^+ \rightarrow J/\psi K^+$ (verificata con $B^0 \rightarrow J/\psi K^{*0}$).
$\omega = p_0 + p_1 \cdot (\eta - <\eta>)$

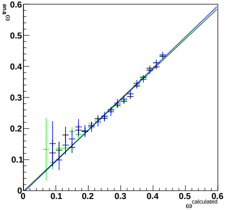
$p_0 = 0.339 \pm 0.012 \pm 0.004$ (OS)
$p_1 = 1.01 \pm 0.12 \pm 0.01$
$<\eta> = 0.339$

Dati: $B^+ \rightarrow J/\psi K^+$



La calibrazione può essere esportata ai canali $B \rightarrow J/\psi$ X

MonteCarlo: $B^+ \rightarrow J/\psi K^+$, $B^0 \rightarrow J/\psi K^{*0}$, $B_s^0 \rightarrow J/\psi \phi$

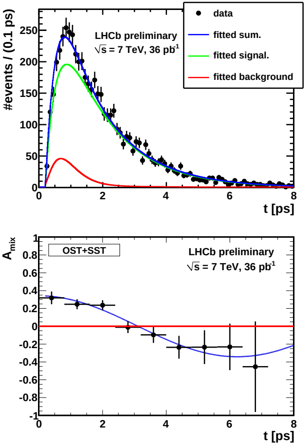


Tagging in $B_s^0 \rightarrow J/\psi \phi$ (OS):
$\epsilon_{tag} = 17\%$ (misurata)
$\omega_{eff} = 32 \pm 2\%$ (mistag evento per evento)
$\epsilon_{eff}^{OS} = 2.2 \pm 0.5\%$

Misura della frequenza di mixing $B_d^0 - \bar{B}_d^0$

LHCb-CONF-2011-010

Verifica del flavour tagging in misure di oscillazione dipendente dal tempo.
Misura di Δm_d in $B^0 \rightarrow D^-(K^+\pi^-\pi^-)\pi^+$ (6k eventi di segnale)



- risoluzione temporale: $<\sigma_t>$=49 fs (MC)
- accettanza temporale (MC)
- probabilità di mistag evento per evento (parametri di calibrazione liberi): $\epsilon_{eff}^{OS} = 3.4 \pm 0.9\%$, $\epsilon_{eff}^{OS+SS\pi} = 4.3 \pm 1.0\%$

$\Delta m_d = 0.499 \pm 0.032 \pm 0.003 \; ps^{-1}$

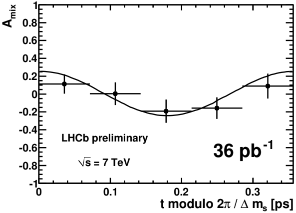
($\Delta m_d = 0.507 \pm 0.005 \; ps^{-1}$ world average, PDG)

Misura della frequenza di mixing $B_s^0 - \bar{B}_s^0$

LHCb-CONF-2011-005

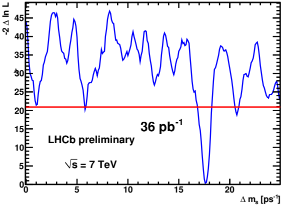
Misura di Δm_s in $B_s \rightarrow D_s^-(3)\pi^+$
(diversi modi di decadimento del D_s^-: totale $1.35k$ eventi di segnale)

- risoluzione temporale evento per evento: $<\sigma_t>$=36-44 fs (dati, usando "prompt" $D_s\&\pi$)
- accettanza temporale (MC)
- probabilità di mistag evento per evento (calibrazione con $B^0 \rightarrow D^-\pi^+$) $\epsilon_{eff}^{OS} = 3.8 \pm 2.1$ %



$\Delta m_s = {}^{a}\ 17.63 \pm 0.11 \pm 0.04\ ps^{-1}$

($\Delta m_s = 17.77 \pm 0.10 \pm 0.07\ ps^{-1}$ CDF, 2006)



Già raggiunta la precisione di CDF !!

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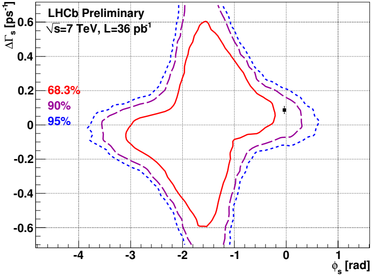
[a] Ipotesi: $\Delta\Gamma_s = 0.1 \times \Gamma_s$

Analisi angolare "taggata" di $B_s^0 \to J/\psi\phi$

LHCb-CONF-2011-006



- Segnale: 737±28 (trigger "unbiased" & "biased", $t > 0.3$ ps), $<\sigma_t>\sim$50 fs
- fit 7D $(m, t, tag, \eta, \cos\theta, \cos\psi, \varphi)$
- Curve di livello di confidenza (Feldman-Cousins) nel piano $(\Delta\Gamma_s,\ \phi_s)$
  - Incertezza statistica+sistematica dovuta al tagging (calibrazione) piccola.
- Tutte le sistematiche considerate sono trascurabili rispetto l'incertezza statistica.

$\phi_s \in [-2.7, -0.5]$ rad al 68% CL

$\phi_s \in [-3.5, 0.2]$ rad al 95% CL

$B_s^0 \to J/\psi\phi$	LHCb $\mathcal{L}$=36 pb^{-1}	CDF $\mathcal{L}$=5.2 fb^{-1}
n.eventi	836	6500
$<\sigma_t>$	50 fs	100 fs
ϵ_{eff}^{OS}	2.2±0.5%	1.2±0.2%
ϵ_{eff}^{SSK}	–	3.5±1.4%

Modello Standard P-valore = 22% (1.2σ) [a]

ϕ_s^{SM}=-0.0363±0.0017 rad

$\Delta\Gamma_s$=0.087±0.021 ps^{-1}

$\sigma(\phi_s)$=0.13 rad con il solo aumento della statistica (1 fb^{-1} nel 2011)

Con il SSK tagging: miglioramento significativo

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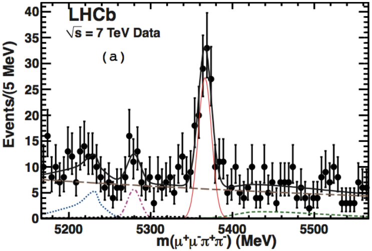
[a] A.Lenz, U.Nierste, arXiv:1102.4274

Osservazione di $B_s^0 \to J/\psi f_0(980)$

Phys.Lett.B 698 (2011) 115



Segnale: $B_s^0 \to J/\psi f_0(980)$ = 111±14
fondi: $B^+ \to J/\psi K^+$, $B^0 \to J/\psi K^{*0}$, $B \to J/\psi \pi\pi$

$$R_{f_0/\phi} = \frac{\Gamma(B_s \to J/\psi f_0, f_0 \to \pi^+\pi^-)}{\Gamma(B_s \to J/\psi \phi, \phi \to K^+K^-)} = 0.252^{+0.046+0.027}_{-0.032-0.033}$$

Possibilità di misura di ϕ_s nel futuro
$J/\psi f_0$ è puro autostato di CP: non necessita l'analisi angolare

Conclusioni

Con la statistica raccolta da LHCb nel 2010 ($\mathcal{L} \sim 36 pb^{-1}$) è stato possibile compiere tutti i passi verso la misura della fase di mixing del B_s^0:

- Misure delle vite medie di diversi canali $H_b \rightarrow J/\psi$ X: in accordo con le misure precedenti
- Analisi angolare di $B^0 \rightarrow J/\psi K^{*0}$: verifica delle ampiezze di polarizzazione
- Analisi angolare non "taggata" di $B_s^0 \rightarrow J/\psi\phi$: $\Delta\Gamma_s = 0.077 \pm 0.119 \pm 0.021$
- Ottimizzazione del tagging (OS e SSπ) e calibrazione della probabilità di mistag con i dati: $\epsilon_{eff}^{OS} = 2.2 \pm 0.5\%$ ($B_s^0 \rightarrow J/\psi\phi$)
- Misura delle frequenza di oscillazione del B_s^0: $\Delta m_s = 17.63 \pm 0.11 \pm 0.04$ ps^{-1}
- Analisi angolare "taggata" di $B_s^0 \rightarrow J/\psi\phi$: curve di livello di confidenza ($\Delta\Gamma_s, \phi_s$): valore SM 1.2σ $\phi_s \in [-2.7, -0.5]$ rad al 68% CL

Ottime prospettive di miglioramento delle misure con i dati di LHCb del 2011: diverse misure competitive, migliore determinazione di ϕ_s

Backup

Selection of $H_b \to J/\psi$ X

Trigger:

- L0: single muon ($p_T > 1.4$ GeV), di-muon ($p_{T,1} > 0.56$ GeV, $p_{T,2} > 0.48$ GeV)
- HLT1: candidate confimation, HLT2: full reconstruction + event selection: lifetime "unbiased" and "biased" (IP cuts)

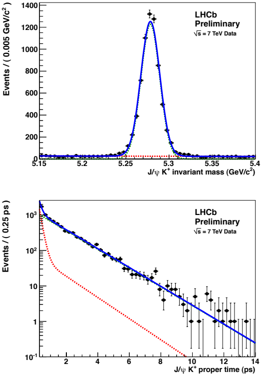
Selection:

- J/ψ: $p_T(\mu) > 0.5$ GeV, common vertex $\chi^2/ndf < 11$, $|m_{\mu\mu} - m_{J/\psi}|/\sigma_m < 4.2$
- $K^{*0} \to K^+\pi^-$: common vertex $\chi^2/ndf < 16$, $|m_{K\pi} - m_{K^{*0}}| < 70$ MeV, $p_T(K^{*0}) > 1$ GeV
- $B_d^0 \to J/\psi K^{*0}$: common vertex $\chi^2/ndf < 5$, $m_B \in [5100, 5450]$ MeV, $p_T(B^0) > 2$ GeV
- $\phi \to K^+K^-$: common vertex $\chi^2/ndf < 16$, $m_{KK} \in [1008, 1032]$ MeV, $p_T(\phi) > 1$ GeV
- $B_s^0 \to J/\psi\phi$: common vertex $\chi^2/ndf < 5$, $m_B \in [5200, 5550]$ MeV
- $< N_{PV} > = 2.2$ choose the PV with best $\chi^2_{IP}(B)$, remove events $\chi^2_{PUIP}(B) > 50$

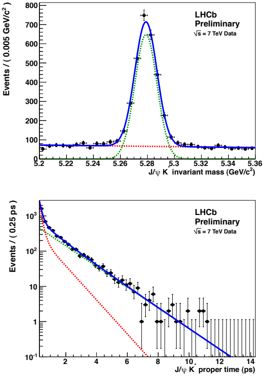
Plots for $H_b \to J/\psi$ X

t∈ [0.3 – 14] ps

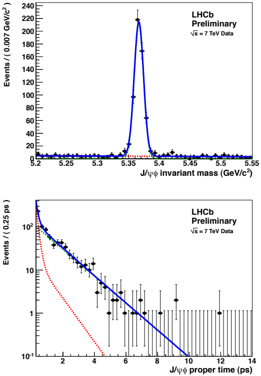
$B^+ \to J/\psi K^+$



$B^0 \to J/\psi K^{*0}$



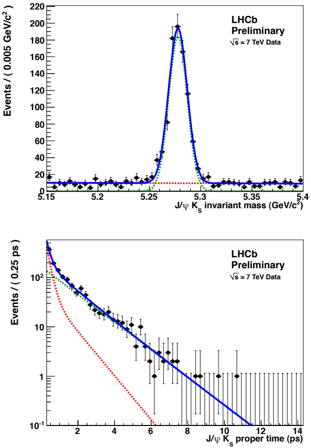
$B_s^0 \to J/\psi \phi$



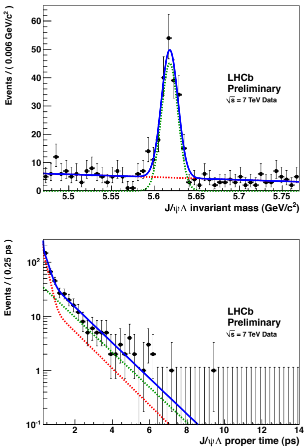
Plots for $H_b \to J/\psi$ X

t∈ [0.3 – 14] ps

$B_d^0 \to J/\psi K_S^0$



$\Lambda_b \to J/\psi\Lambda$



Amplitudes for $P \to VV$ (untagged)

$B_s^0 \to J/\psi\phi$ channel (hp: $\phi_s = 0$)

$$\begin{aligned}\frac{d^4\Gamma}{dtd\Omega} &= e^{-\Gamma_s t}\big[|A_0(0)|^2 f_1(\Omega) e^{-\frac{\Delta\Gamma_s}{2}t} + |A_{||}(0)|^2 f_2(\Omega) e^{-\frac{\Delta\Gamma_s}{2}t} \\ &\quad + |A_\perp(0)|^2 f_3(\Omega) e^{+\frac{\Delta\Gamma_s}{2}t} + \cos\delta_{||}|A_0(0)||A_{||}(0)| f_5(\Omega) e^{-\frac{\Delta\Gamma_s}{2}t}\big].\end{aligned}$$

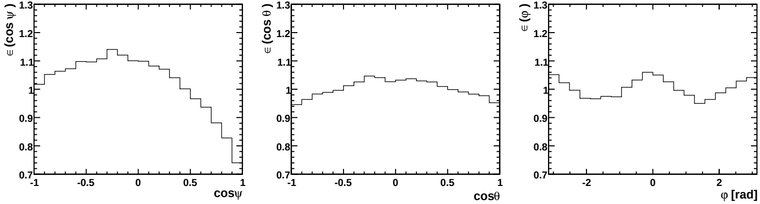
$B^0 \to J/\psi K^{*0}$ channel (hp: $\Delta\Gamma_d = 0$)

$$\begin{aligned}\frac{d^4\Gamma}{dtd\Omega} &= e^{-\Gamma_d t}\big[f_1(\Omega)|A_0(0)|^2 + f_2(\Omega)|A_{||}(0)|^2 + f_3(\Omega)|A_\perp(0)|^2 \\ &\quad \pm f_4(\Omega)\sin(\delta_\perp - \delta_{||})|A_{||}(0)||A_\perp(0)| \\ &\quad + f_5(\Omega)\cos\delta_{||}|A_0(0)||A_{||}(0)| \\ &\quad \pm f_6(\Omega)\sin\delta_\perp|A_0(0)||A_\perp(0)|\big].\end{aligned}$$

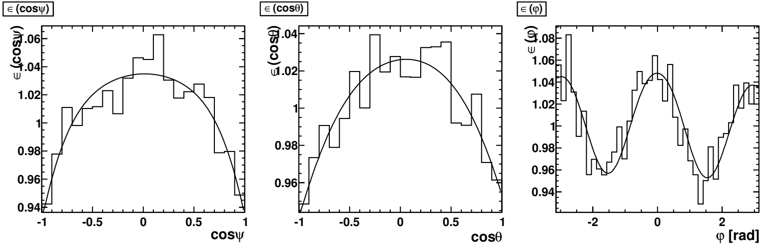
Here the upper (lower) sign is used for $K^+\pi^-$ ($K^-\pi^+$).
In contrast to the $B_s^0 \to J/\psi\phi$ decays the flavour specific decays provide access to both strong phases, $\delta_{||}$ and $\delta_\perp$.

Angular acceptance for $B^0 \to J/\psi K^{*0}$ and $B^0_s \to J/\psi \phi$

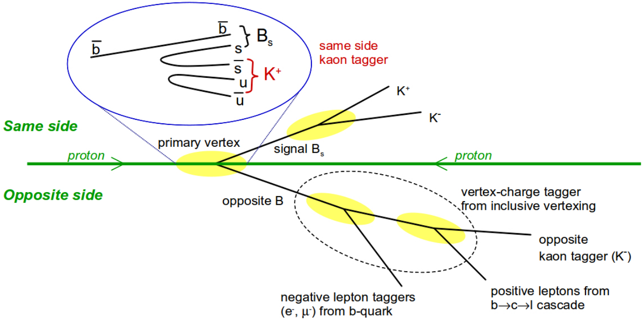
$B^0 \to J/\psi K^{*0}$ channel



$B^0_s \to J/\psi \phi$ channel



Tag the initial B flavour



OS tagging: exploit the properties of the decays of the b-hadron opposite to the signal B

- μ, e ($b \to c l^- \bar{\nu}_l$), K ($b \to c \to s$), Q_{vtx} (inclusive secondary vertex reconstruction)

SS tagging: exploit the hadronization process of the signal B, or in the decays of excited states B^{**}

- SSπ (tag the B_d and B^+), SSK (tag the B_s)

Flavour Tagging optimization

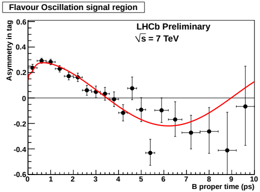
LHCb-CONF-2011-003

Tagging performance optimized on 2010 data ($\sqrt{s} = 7\,TeV$, $\int \mathcal{L} \cdot dt \sim 35 pb^{-1}$) with different flavour-specific channels.

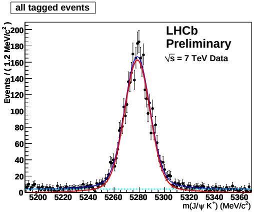
AIM: to find the set of cuts that maximize the ϵ_{eff} of **each tagger** and of the **combination of taggers**.
Each set split randomly into two to avoid over-tuning.

- $B^0 \rightarrow D^{*-}\mu^+\nu_\mu$ $\sim$48k signal events, B/S$\sim$0.3
  $\rightarrow$ fit to time dependent B_d oscillation to measure ω
- $B^+ \rightarrow J/\psi K^+$ $\sim$11k signal events, B/S$\sim$0.065 (t>0.3ps)
  $\rightarrow$ compare the tag decision with the $B^\pm$ charge, count W, R events $\rightarrow \omega$
- $B^0 \rightarrow J/\psi K^{*0}$ $\sim$3.3k signal evens, B/S$\sim$15
  $\rightarrow$ fit to time dependent B_d oscillation to measure ω (**cross-check**)
- $B_s^0 \rightarrow D_s^-(K^+K^-\pi^-)(3)\pi$: control channel for SSK tagger studies: too little statistics to optimize ($\sim$1 300).

$B^0 \rightarrow D^{*-}\mu^+\nu_\mu$



$B^+ \rightarrow J/\psi K^+$



Flavour Tagging optimized performance

OS	ϵ_{tag} (%)	ω (%)	ϵ_{eff} (%)
$B^0 \rightarrow D^{*-}\mu^+\nu_\mu$	18.3±0.2	33.6±0.8	1.97±0.18
$B^+ \rightarrow J/\psi K^+$	15.4±0.3	32.2±1.2	1.97±0.31
$B^0 \rightarrow J/\psi K^{*0}$	15.8±0.7	30.0±6.6	2.52±0.82
SSπ+OS	ϵ_{tag} (%)	ω (%)	ϵ_{eff} (%)
$B^0 \rightarrow D^{*-}\mu^+\nu_\mu$	28.9±0.2	34.2±0.8	2.87±0.32
$B^+ \rightarrow J/\psi K^+$	23.0±0.5	33.9±1.1	2.38±0.33
$B^0 \rightarrow J/\psi K^{*0}$	26.1±0.9	33.6±5.1	2.82±0.87

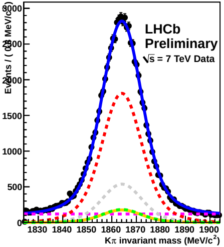
- Measured ω agree within the channels → can be used in other channels for *CP* measurement (if trigger and selection are similar).
- Asymmetries of the tagging performance of $B/\bar{B}$ mesons due to the detector efficiency/acceptance or to particle interaction with matter are found negligible within the present statistical error.

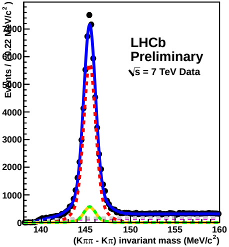
Analysis of the $B^0 \to D^{*-}\mu^+\nu_\mu$ channel

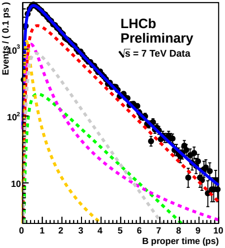
Reconstruction of $D^{*-} \to \bar{D}^0(\to K^-\pi^+)\pi^- + \mu^+$, described in LHCb-CONF-2010-012.

- no mass constraint due to the missing ν_μ
- B proper time corrected using the $k-$factor
- background sources:
    - B^+ decays $\to D^{*-}\mu^+\nu_\mu n\pi$ ($10.2 \pm 1.2\%$, from MC)
    - true $\bar{D}^0$ originated from a b-hadron decays ($7.5 \pm 0.1\%$, from data)
    - true D^* originated from prompt c-hadron decays ($9.5 \pm 0.4\%$, from data)
    - pure combinatorics ($4.0 \pm 0.1\%$, from data).

Fitting the observable ($m_{K\pi}$, $\Delta_m = m_{K\pi\pi} - m_{K\pi}$, t) of the *right* ($D^{*\pm}\mu^\mp$) and *wrong* ($D^{*\pm}\mu^\pm$) charge combinations the contributions can be disentangled.







Analysis of the $B^+ \to J/\psi K^+$ channel

Reconstruction of $B^+ \to J/\psi K^+$ decays with the same selection of LHCb-CONF-2011-001 (all trigger lines).

- select $t > 0.3\,ps$ to reject most of the "prompt" background
  →Remaining background: long-living background (from b-decay).

The two contribution can be separated exploiting the different mass (and time) distribution.

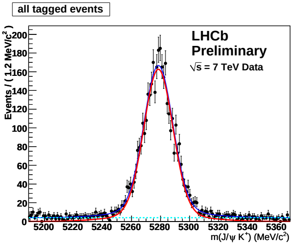
Fit parametrization:

$$\mathcal{P}(m,q) = (1-f_{\mathcal{B}})\mathcal{S}(m,q) + f_{\mathcal{B}}\mathcal{B}^{\mathrm{LL}}(m,q)$$

$$\mathcal{S}^{\mathrm{tag}}(q) = \begin{cases} \epsilon^s \cdot \{1-\omega^s\} & \text{if } q = 1\text{, right tag,} \\ \epsilon^s \cdot \omega^s & \text{if } q = -1\text{, wrong tag} \\ 1-\epsilon^s & \text{if } q = 0\text{, untagged,} \end{cases} \qquad (1)$$

Similarly for the background, which has independent parameters

signal, LL background

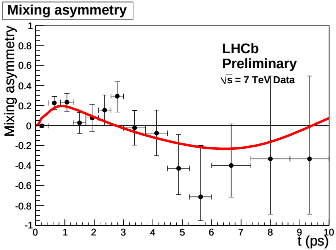


Analysis of the $B^0 \rightarrow J/\psi K^{*0}$ channel

The event selection for the $B^0 \rightarrow J/\psi K^{*0}$ channel is described in LHCb-CONF-2011-001.
Only events passing the "lifetime unbiased" trigger lines are kept.

- fit to signal oscillation to extract ω
- background components:
    - due to prompt J/ψ, peaking at $t = 0$
    - from b-hadron decays (with a lifetime)

they have independent, floating, tagging parameters



[2]

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[2] Tagged events with SSπ+OS, Δm_d=PDG

Calibration of the predicted mistag probability

After the calibration of the single taggers and of the OS

$B^+ \to J/\psi K^+$		
	$p_0 - <\eta>$	p_1
OS	-0.001±0.012±0.004	1.01±0.12±0.01
SSπ+OS	0.000±0.010±0.004	1.00±0.11±0.01

- The precisions found on p_0 and p_1 confirm expectation based on MC studies (LHCb-2009-20).
- The systematics were obtained with different fit assumptions on the η distributions of the signal and the background, studying the dependence on the B/S ratio and fitting the B lifetime with only "lifetime unbiased lines" triggered data.
- The precision on the calibration parameters should be propagated to the CP asymmetry fits.

Validation on data, using $B^0 \to J/\psi K^{*0}$:

$B^0 \to J/\psi K^{*0}$		
	$p_0 - <\eta>$	p_1
SSπ+OS	-0.017±0.025±0.003	0.71±0.26±0.24

$B_d^0 - \bar{B}_d^0$ oscillations

LHCb-CONF-2011-010

Use *per-event* mistag probability with free calibration parameters (different trigger&selection with respect to the $B^+ \rightarrow J/\psi K^+$ channel.)

	ϵ_{eff}	$p_0 - <\eta>$	p_1
OS	3.4±0.9%	-0.015±0.021±0.004	0.61±0.20±0.15
SSπ+OS	4.3±1.0%	-0.011±0.016±0.002	0.69±0.16±0.05

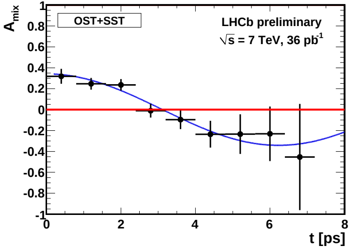
$\Delta m_d = 0.499 \pm 0.032 \pm 0.003\ ps^{-1}$

($\Delta m_d = 0.507 \pm 0.005\ ps^{-1}$ world average, PDG)

Systematic uncertainties on Δm_d

source	$\Delta(\Delta m_d)$ [ps^{-1}]
proper time resolution [40-63] fs	0.000
proper time acceptance	0.002
variation of PDF(η)	0.000
floating fit parameters	0.001
double Gaussian mass signal PDF	0.001
z-scale (∼0.1%)	0.0005
momentum scale (∼0.1%)	0.0005
Sum	**0.003**

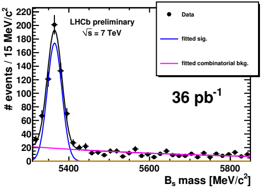
$B^0 \rightarrow D^-(K^+\pi^-\pi^-)\pi^+$ 6k (signal)



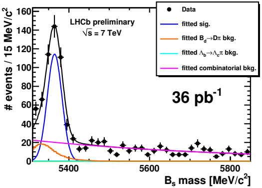
$B_s^0 - \bar{B}_s^0$ oscillations

LHCb-CONF-2011-005

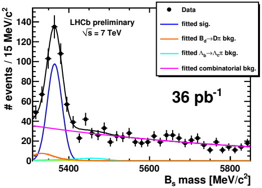
Combine several final states to add statistics:



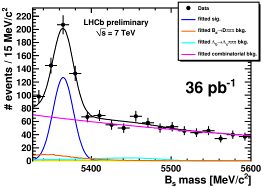
$B_s \to D_s^-(\phi\pi^-)\pi^+$: (515 ± 25 ev.)



$B_s \to D_s^-(K^*K)\pi^+$: (338 ± 27 ev.)



$B_s \to D_s^-(K^+K^-\pi^-)\pi^+$: (283 ± 27 ev.)



$B_s \to D_s^-(K^+K^-\pi^-)3\pi$: (245 ± 46 ev.)

σ_m=18.1 MeV/c^2 ($D_s\pi$), 12.7 MeV/c^2 ($D_s3\pi$)

$B_s^0 - \bar{B}_s^0$ mixing frequency

$\Delta m_s \ =^{3}$ 17.63±0.11±0.04 ps^{-1}

($\Delta m_s \ =$ 17.77±0.10±0.07 ps^{-1} CDF, 2006

Systematic uncertainties on Δm_s

source	$\Delta_{\Delta m_s}$[ps^{-1}]
proper time resolution $\mathcal{S}_{\sigma_t} = [1.2 - 1.4]$	0.006
proper time resolution model	0.001
proper time acceptance function	0.000
fixed parameters floating	0.003
diff. background shape in mass fit	0.010
phys. bkg mass templates	0.002
variation of η and σ_t PDFs	0.026
z-scale (0.1%)	0.018
momentum scale (0.1%)	0.018
$\Delta\Gamma_s = [0 - 0.2] \times \Gamma_s$	0.002
total systematic uncertainties	**0.038**

Nice prospects for an improvement of the Δm_s measurement in the (near) future

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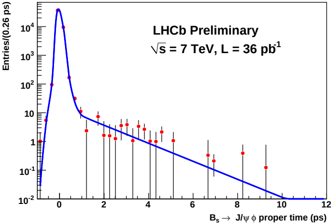
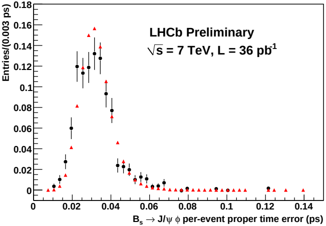
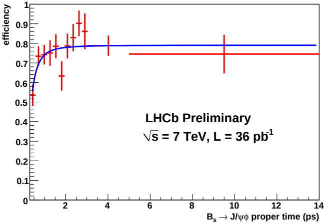
[3] Assumption: $\Delta\Gamma_s = 0.1 \times \Gamma_s$

Time acceptance and resolution for time dependent analysis of $B_s^0 \to J/\psi\phi$



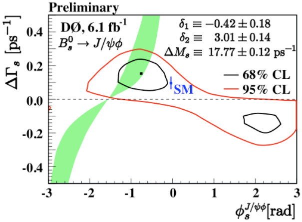


time acceptance for events triggered by “biased” lines:

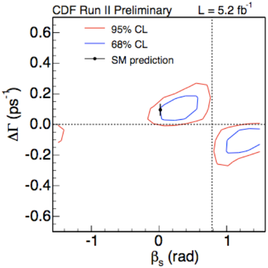


Comparison between ϕ_s results

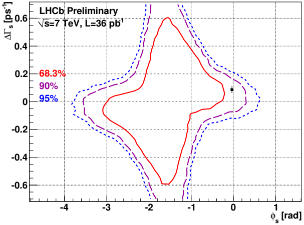
D0 (3400 signal events, $\epsilon_{eff} = 2.5\%$ OS)



CDF (6500 signal events, $\epsilon_{eff} = 4.7\%$ OS+SSK)
P-value SM = 44%

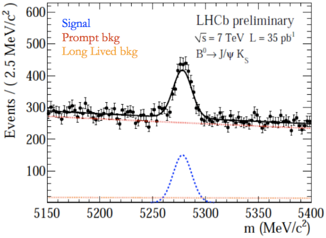


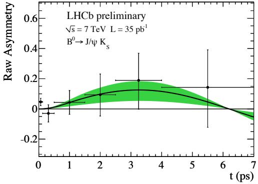
CDF: "S-wave contamination is ¡ 6.7 % @ 95 % C.L. and can be neglected" LHCb (737 signal events, $\epsilon_{eff} = 2.2\%$ OS) P-value SM = 22%



$sin(2\beta)$ measurement in $B_d^0 \rightarrow J/\psi K_S^0$

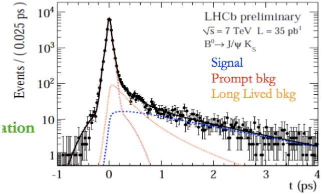
- 280 eventi di segnali “taggati” (trigger “unbiased” & “biased”)
- uso della probabilità di mistag evento per evento (calibrata su $B^+ \rightarrow J/\psi K^+$ e verificata in $B^0 \rightarrow J/\psi K^{*0}$)





$$S_{J/\psi K_S^0} = 0.53^{+0.28}_{-0.29} \pm 0.07$$

$\sin(2\beta) = 0.673 \pm 0.023$ World average



2Systematic uncertainties to S in absolute terms.

Source	uncertainty
tagger calibration	0.067
per-event mistags p.d.f.	0.012
Δm_d uncertainty, z scale	0.0017
proper time resolution	0.0085
high propertime acceptance	0.00065
biased events acceptance	0.0042
biased TIS events acceptance	0.0063
production asymmetry	0.016
total (sum in squares)	0.071