Purely leptonic b - c decays @ LHC(b)

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Introduction

Purely leptonic $B^{0,\pm}_{(s)}$ decays :

- a unique laboratory to detect new dynamics
- theoretically clean: only **one hadronic non perturbative input f_B**
- helicity suppression: $\mathcal{B}(decay) \propto m_\ell$

Charged currents	SM FCNC	LFV
$B^\pm \to \ell^\pm \nu_\ell$	$B^0_{(s)} \to \ell^\pm \ell^\mp$	$B^0_{(s)} \to \ell^\pm \ell'^{,\mp}$
missing energy clean environment	very rare (& missing energy for $\ell = \tau$) high statistic & clean environment	very rare (& missing energy for $\ell = \tau$) high statistic & clean environment

LHC experiments focused on $B^0_{(s)} \to \ell\ell^{(\prime)}$

None of these modes observed before the LHC

Main observables are branching ratios $\mathcal{B}$

... plus a plethora of angular observables & ratios of $\mathcal{B}$ sensitive to MFV & LFU departures

$B^0_{(s)} \to \ell\ell$ observables

$$\mathcal{H}_{eff} = -\frac{4G_F}{\sqrt{2}} V_{tb}V^\star_{tq} \frac{e^2}{16\pi^2} \left\{ C_{10}^{(\prime)} (\bar{b}\gamma^\mu P_{L(R)} q_d)(\bar{\ell}\gamma_\mu\gamma^5\ell) + C_P^{(\prime)} m_b (\bar{b}P_{L(R)}q_d)(\bar{\ell}\gamma^5\ell) + C_S^{(\prime)} m_b (\bar{b}P_{L(R)}q_d)(\bar{\ell}\ell) \right\}$$

- The expression for the CP-averaged $\mathcal{B}$ at $t = 0$ is $\left(\beta_\ell \equiv 1 - 4\frac{m_\ell^2}{M^2_{B_q}}\right)$

$$\mathcal{B}(B^0_q \to \ell^+\ell^-) \propto f^2_{B_q} \left\{ \left| 2\frac{m_\ell}{M_{B_q}} (\mathcal{C}_{10} - \mathcal{C}'_{10}) + (\mathcal{C}_P - \mathcal{C}'_P) \right|^2 + \beta_\ell |\mathcal{C}_S - \mathcal{C}'_S|^2 \right\}$$

- In the SM:
  - $\mathcal{C}^{(\prime)}_{S,P}, \mathcal{C}'_{10} \simeq 0$
  - helicity suppression
- NP scenarios:
  - $\mathcal{C}^{(\prime)}_{S,P}, \mathcal{C}'_{10} \neq 0$, $\mathcal{C}_{10} = \mathcal{C}^{SM}_{10} + \delta\mathcal{C}^{NP}_{10}$
  - No helicity suppression

- one hadronic input ($f_{B_s} = 227.7 \pm 4.5\ \mathrm{MeV}$) [FLAG, '13]
- $\mathcal{B}$ constrains only the differences $\mathcal{C}_i - \mathcal{C}'_i$
- $\mathcal{B}$ can be enhanced or suppressed wrt to the SM prediction

in SM only $B^0_{q,H} \to \ell^+\ell^-$

$$\mathcal{A}_{\Delta\Gamma} \equiv \frac{R^H_{\ell\ell} - R^L_{\ell\ell}}{R^H_{\ell\ell} - R^L_{\ell\ell}} = 1$$

with $\Gamma(B^0_{H,L}(t) \to \ell\ell) \equiv R^{H,L}_{\ell\ell} e^{-\Gamma_{H,L}t}$

- $\mathcal{A}_{\Delta\Gamma}$ measurable through

$$\tau_{\ell\ell} = \frac{\tau_B}{1 - y_s^2}\left[\frac{1 + 2\mathcal{A}_{\Delta\Gamma} y_s + y_s^2}{1 + \mathcal{A}_{\Delta\Gamma} y_s}\right]$$

being

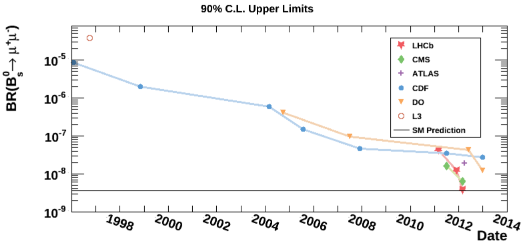
$$y_s \equiv \frac{\Gamma_H - \Gamma_L}{\Gamma_H + \Gamma_L} = 0.061 \pm 0.006$$

$B^0_{(s)} \to \ell\ell$ SM predictions

SM predictions [Bobeth *et al.*, PRL 112(2014)101801]:

$$\mathcal{BR}(B^0 \to \mu^+\mu^-) = (1.06 \pm 0.09) \times 10^{-10}$$
$$\mathcal{BR}(B^0_s \to \mu^+\mu^-) = (3.65 \pm 0.23) \times 10^{-9}$$

$$\mathcal{BR}(B^0 \to \tau^+\tau^-) = (2.22 \pm 0.19) \times 10^{-8}$$
$$\mathcal{BR}(B^0_s \to \tau^+\tau^-) = (7.73 \pm 0.49) \times 10^{-7}$$



b-c hadron leptonic decays searches with Run 1 data

- $D^0 \to \mu\mu$ [LHCb, arXiv:1305.5059]
- $B^0_{(s)} \to e^{\pm}\mu^{\mp}$ [LHCb, PRL 111 (2013) 141801]
- $B^0_{(s)} \to \mu^+\mu^-\mu^+\mu^-$ [LHCb, PRL 110, 211801 (2013)]

$B^0_{(s)} \to \mu\mu$ milestones

- first evidence $B^0_s \to \mu\mu$ [LHCb, PRL 110, 021801 (2013)]
- first observation $B^0_s \to \mu\mu$
  first evidence $B^0 \to \mu\mu$ [LHCb & CMS, Nature 522 (2015) 68]

Recent activities in $B^0_{(s)} \to \ell\ell$

- search for $D^0 \to e^{\pm}\mu^{\mp}$ [LHCb, Phys. Lett. B754 (2016) 167]
- search for $B^0_{(s)} \to \mu\mu$ [ATLAS, EPJ C76 (2016) 513]
- **update $B^0_s \to \mu\mu$**
- **first search $B^0_s \to \tau\tau$**

$\Big\}$ [LHCb '17]

Today

$B^0_{(s)} \to \mu^+\mu^-$ - Run 1 & 2 - [LHCb, arXiv:1703.05747, submitted to PRL]

The strategy is unchanged with respect to previous LHCb analyses

$$\mathcal{B}(B^0_q \to \mu^+\mu^-) = \frac{1}{\epsilon}\frac{\mathcal{N}^{\text{obs}}_{B^0_q\to\mu^+\mu^-}}{\mathcal{N}^{\text{tot}}_{B_q}}$$

Dataset: 4.4 fb^{-1} (1+2+1.4 fb^{-1} @ 7,8,13 TeV)

Analysis flow

- candidates reconstruction
- selection
- $m_{\mu\mu}\otimes$ geometry classification
- normalization
- signal yield extraction and conversion to $\mathcal{B}$

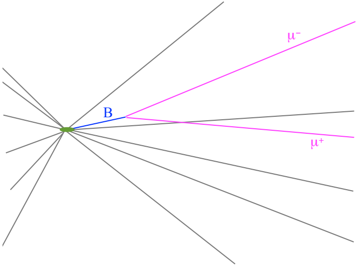
Normalization channels

- same topology: $B^0 \to K^+\pi^-$
- 2 μ from one vertex: $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$

Main improvements:

- Particle Identification ($\pi, K \to \mu$ misID)
- MVA classification

Candidates reconstruction



- pair of $\mu^{\pm}$
- $0.25 < p_T < 40$ GeV & $p < 500$ GeV
- large Impact Parameter (IP) wrt PV
- good quality vertex well displaced PV
- **tight μ ID requirements**

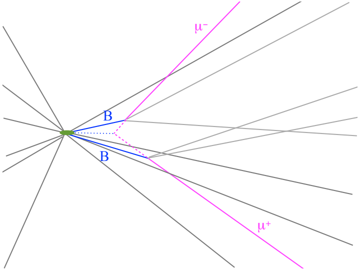
- $m_{\mu\mu} \in [4900, 6000]$ GeV
- veto on $m_{\mu\mu^{\star}} \in [m_{J/\psi} \pm 30]$ MeV,
  $\mu^{\star}$ any other μ track in the event
- loose cut on MVA output with kinematic & geometrical inputs

drop of 50% misID $B^0 \to hh'$ $(h^{(\prime)} = K, \pi)$ for 90% signal efficiency

total selected candidates for $\mathcal{B}$ measurement: 78241

Background

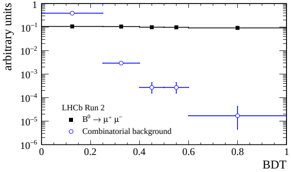
the most abundant source of noise are random combinations of μ tracks from b-hadron decays in the same event



Combinatorial background candidate

Discrimination achieved through a BDT classifier

- Inputs
  - pointing related variables
  - vertex quality
  - **isolation variables**



output flat by design for signal MC

Correlation with $m_{\mu\mu} \sim 3\%$

$\sim$ 50% less combinatorial bkg in BDT>0.25 wrt previous LHCb analyses

b-hadron decays

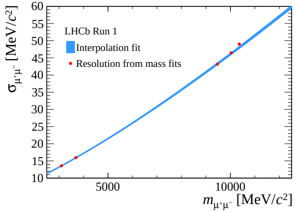
Two categories

- with misID $K, \pi \to \mu$
  - $B^0_{(s)} \to hh^{(\prime)}$, $B^0_{(s)} \to h\mu^+\nu_\mu$, $\Lambda^0_b \to p\mu^-\bar{\nu}_\mu$
- with 2 μ from same vertex
  - $B_c^+ \to J/\psi(\to \mu\mu)\mu^+\nu_\mu$, $B^{0(+)} \to \pi^{0,(+)}\mu^+\mu^-$

mode	yield in BDT>0.5
$B^0_{(s)} \to hh^{(\prime)}$	2.9 ± 0.3
$B_c^+ \to J/\psi\mu^+\nu_\mu$	1.2 ± 0.2
$\Lambda^0_b \to p\mu^-\bar{\nu}_\mu$	0.7 ± 0.2
$B^0_{(s)} \to h\mu^+\nu_\mu$	0.8 ± 0.06

BDT & $m_{\mu\mu}$ shape

- **Signal PDF**
  - BDT from $B^0 \to K^+\pi^-$ in data
  - $m_{\mu\mu}$ Crystal Ball:
    - power-law tail exponent and transition point from simulations
    - resolution from interpolation of $\mu\mu$ resonances: $\sigma_{\mu\mu} = 23$ MeV



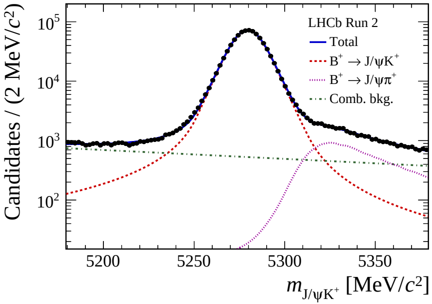
- **combinatorial background**
  - BDT from $m_{\mu\mu}$ sidebands
  - $m_{\mu\mu}$ extrapolated from $m_{\mu\mu}$ sidebands
- ***b*-hadron decays**: $m_{\mu\mu}$ & BDT from simulation

Normalization

$$\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-) = \frac{\mathcal{B}_{norm}}{N_{norm}} \cdot \frac{\varepsilon_{norm}}{\varepsilon_{sig}} \cdot \frac{f_{norm}}{f_{d(s)}} \cdot N_{sig} \equiv \alpha^{norm}_{B^0_{(s)}} \cdot N^{d(s)}_{sig}$$

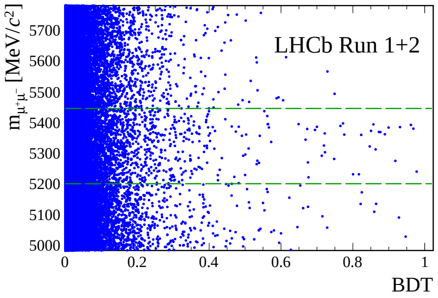
N_{norm} for $B^+ \to J/\psi K^+$: $(1964.2 \pm 1.5) \cdot 10^3$

- yield of normalization channel events
- total efficiencies
  - trigger: data driven method
  - acceptance,reconstruction, selection: using simulation
  - tracking, PID: on data through control channels
- hadronization factor
  - measured by LHCb [LHCb JHEP 04 (2013) 001], LHCb-CONF-2013-011

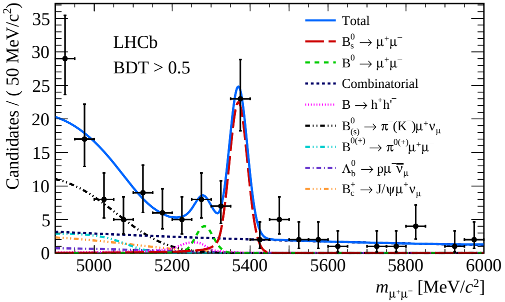


$$\alpha^{norm}_{B^0_s} = (5.7 \pm 0.4) \cdot 10^{-11}, \quad \alpha^{norm}_{B^0} = (1.60 \pm 0.04) \cdot 10^{-11}$$

Results



BDT$\times$ $m_{\mu\mu}$



No evidence for $B^0 \to \mu^+\mu^- \Rightarrow$ Upper Limit @ 95%

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 3.4 \cdot 10^{-10}$$

7.8σ excess for $B_s^0 \to \mu^+\mu^-$. **First single experiment observation**

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = 3.0 \pm 0.6^{+0.3}_{-0.2} \cdot 10^{-9}$$

$\tau_{\mu\mu}$ measurement

The strategy:

- Selection of $B_s^0 \to \mu^+\mu^-$ candidates
- evaluation of bias due to reconstruction & selection: acceptance function
- *sPlot* technique to statistically separate signal & background
- fit to signal decay time distribution

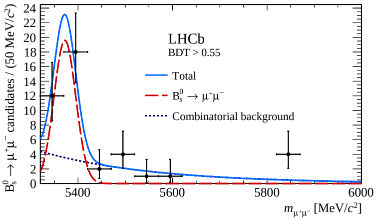
$B_s^0 \to \mu^+\mu^-$ selection

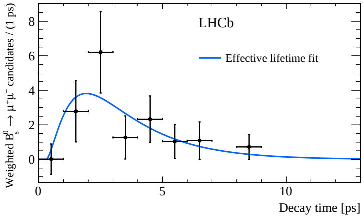
- similar requirements of $\mathcal{B}$ measurement, except
  - reduced $m_{\mu\mu}$ ($[5320, 6000]$ MeV) range $\Rightarrow$ remove B^0 & exclusive decays
  - looser PID requirements $\Rightarrow$ increase of the statistics
  - cut on BDT output > 0.55

42 candidates in selected sample

$\tau_{\mu\mu}$ measurement

- Mass fit
  - only $B_s^0 \to \mu^+\mu^-$ & combinatorial
  - same parametrization used for $\mathcal{B}$ measurement
  - correlation between $m_{\mu\mu}$ & $\tau_{\mu\mu} \lesssim 3\%$
- $B_s^0 \to \mu^+\mu^-$ acceptance
  - Effects of trigger and selection evaluated on simulations
  - cross-check on $B^0 \to K^+\pi^-$
- $t_{\mu\mu}$ fit





background subtracted $\tau_{\mu\mu}$ distribution

$$\tau_{\mu\mu} = 2.04 \pm 0.44 \pm 0.05 \text{ ps}$$

$\tau_{\mu\mu}$ **consistent with** $\mathcal{A}_{\Delta\Gamma} = 1(-1)$ **@** $1.0(1.4)\ \sigma$

"this result establishes the potential of the effective lifetime measurement in constraining New Physics scenarios with the datasets that LHCb is expected to collect in the coming years"

$B^0_{(s)} \to \tau^+\tau^-$ @ LHCb - Run 1 [LHCb, arXiv:1703.02508, accepted in PRL]

Status before LHC

- $\mathcal{B}(B^0_d \to \tau^+\tau^-) < 4 \cdot 10^{-3}$ @ 90% CL by BaBar [PRL 96 (2006) 241802]
- $\mathcal{B}(B^0_s \to \tau^+\tau^-)$ only indirect constraints $\sim$ %

Pioneering analysis at an hadron machine

Dataset: 3 fb^{-1} (1+2 fb^{-1} @ 7,8 TeV)

exploits the $\boldsymbol{\tau^- \to \pi^+\pi^-\pi^-\nu_\tau}$ final state

- only two undetected ν_τ
- $\tau^\pm$ decay vertexes reconstructible
- Non trivial Dalitz structure of $\pi^+\pi^-\pi^-$ system
- intermediate resonances: $\boldsymbol{\tau^- \to a_1^-(\to \rho^0(\to \pi^+\pi^-)\pi^-)\nu_\tau}$
- $\boldsymbol{\mathcal{B}(\tau \to \pi^+\pi^-\pi^-\nu_\tau) = (9.31 \pm 0.05)\%}$

Analysis strategy:

- Reconstruction & selection
- Extraction of signal yield
- Use of $B^0 \to D^+ D_s^-$ as **normalization & control** channel
- Computation of Upper Limit (UL)

Signal modeled with simulated events

Data-driven techniques to describe the background sources

Candidate reconstruction & Dalitz plane structure

Candidate reconstruction similar for signal and normalization mode:

$\pi^\pm$ requirements

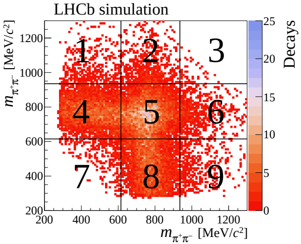
- Particle Identification,
- track quality,
- Impact Paramenter wrt primary vertexes

$\tau^\pm$ reconstruction

- 3 tracks forming a good vertex

$B^0_{(s)}$ reconstruction

- pair of $\tau^\pm$
- requirements on transverse momentum of B, τ and π

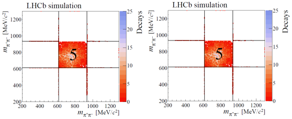


signal region $m_{\pi^+\pi^-} \in [0.615, 0.935]$ GeV

optimized for $B^0_s \to \tau\tau$ sensitivity using pseudoexperiments

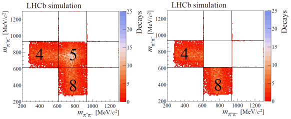
Dalitz plane used as handle to deal with huge amount of background (from $b \to c$ transitions)

Signal Region (SR)



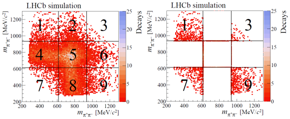
Signal search

Control Region (CR)



Background model

Signal Depleted Region (SDR)



Optimize selection

Candidates selection & classification

Requirement on reconstructed $B^0_{(s)}$ candidates:

- Dalitz plane selection
- charged tracks & neutral clusters isolations
- variables from analytic reconstruction [CERN-THESIS-2015-264]
- output of a Neural Network (NN) classifier combining kinematic, topology, & isolation variables

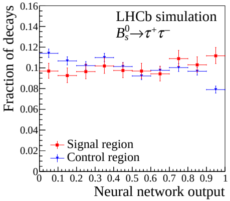
- efficiency of $B^0_{(s)}$ the selection (including geometrical acceptance): $2.2(2.4)\times 10^{-5}$
- expected number of events in SM: 0.02
- fraction of selected candidates in regions:

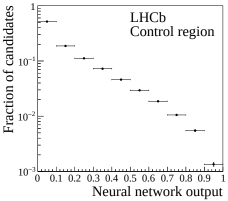
	SR	CR	SDR
$B^0_{(s)} \to \tau\tau$ MC	**16 %**	58 %	13 %
Data	**7 %**	47 %	37 %

14700 candidates selected in data SR

Discriminating variable

- output of a NN with 29 input variables
- trained on signal simulated events, and data from SDR
- output flat in [0,1] by design for signal MC
- NN range divided in 10 bins
- [0.7,1.0] not investigated till the fit strategy is fixed





Fit model

- The NN distribution is fitted to extract the signal yield
- Fit model given by:

$$\mathcal{N}^{SR}_{data} = s \cdot \hat{\mathcal{N}}^{SR}_{MC} + f_b \cdot \left(\mathcal{N}^{CR}_{data} - s \cdot \frac{\varepsilon^{CR}}{\varepsilon^{SR}} \cdot \hat{\mathcal{N}}^{CR}_{MC} \right)$$

  - signal yield
  - scaling factor for background template
  - correction for presence of signal candidates in CR ($\varepsilon^{SR(CR)}$ signal efficiency in SR(CR))

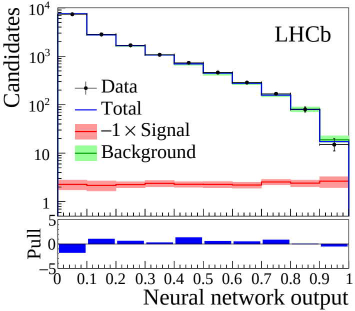
- NN templates $\mathcal{N}^{SR,CR}_{MC,data}$ are taken
  - from simulation for $B^0_s \to \tau\tau$
  - from data CR for background

- Reliability of background NN template extrapolation from the CR to SR checked on
  - data for NN background dominated bin
  - generic $b\bar{b}$ sample
  - specific simulated background modes (e.g. $B^0 \to D^-\pi^+\pi^-\pi^+$, $D^- \to K^0\pi^+\pi^-\pi^-$, $B^0_s \to D^-_s(\to \tau\bar{\nu}_\tau)\pi^+\pi^-\pi^+$)

Systematic uncertainties & fit results

Main sources of systematic uncertainties

- <u>for signal</u>:
  - mismodel of NN input variables in the simulation
  - NN shape computed after re-weighting
  - differences in NN shape wrt the nominal are assigned as systematics
- <u>for background</u>
  - extrapolation from the CR to SR
  - gaussian constraint on bin yield
  - range from difference of NN shape in control region subsamples



The signal yield is found being

$$s = -23 \pm 63(stat) \pm 31(syst)$$

Normalization

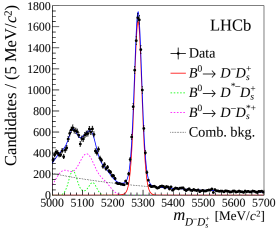
The measured signal yield is converted into a value of the branching fraction using the $B^0 \to D^- D_s^+$ normalization mode

$$\mathcal{B}(B_s^0 \to \tau\tau) = \alpha_s \cdot s$$

with

$$\alpha_{s,d} \equiv \frac{1}{N^{obs}_{D^- D_s^+}} \cdot \frac{\epsilon^{D^- D_s^+}}{\epsilon^{\tau\tau}_{B_{s,d}}} \cdot \frac{f_d}{f_s} \cdot \frac{\mathcal{B}(B^0 \to D^- D_s^+) \cdot \mathcal{B}(D^- D_s^+ \to \textit{final states})}{[\mathcal{B}(\tau \to 3\pi\nu_\tau)]^2}$$

- from fit: 10629±114
- measured by LHCb
- from simulation
- known



$$\alpha_s = (4.07 \pm 0.70) \times 10^{-5},\ \alpha_d = (1.16 \pm 0.19) \times 10^{-5}$$

Results

No evidence for signal is found

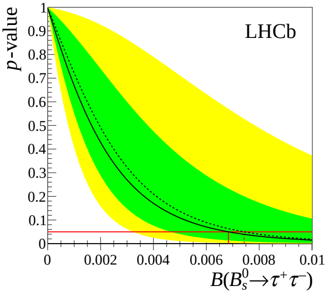
Computation of the 90%(95%) upper limit using the CL_s method

- Assuming no signal from B^0, the **first experimental UL for the B_s^0** is

$$\mathcal{B}(B_s^0 \to \tau^+\tau^-) = 5.2(6.8) \cdot 10^{-3}$$

- Assuming no signal from B_s^0, the **world best UL for the B^0** is

$$\mathcal{B}(B^0 \to \tau^+\tau^-) = 1.6(2.1) \cdot 10^{-3}$$



Conclusions

- Purely leptonic decays are a theoretically clean laboratory to look for new degrees of freedom
- Offer a wide range of observables in addition to $\mathcal{B}$
  - effective lifetime sensitive to different contributions of mass eigenstates
  - angular distributions (for τ final states) sensitive to ℓ polarization (left/right handed currents)
  - ratio of $\mathcal{B}$ sensitive to MFV or LFU departures
- LHC experiment main target have been searches in FCNC with μ
  - large statistics sample
  - excellent detectors performances with μ
  - golden mode is $B^0_{(s)} \to \mu^+\mu^-$
- **First single experiment observation of $B^0_s \to \mu^+\mu^-$ from LHCb**
  - evidence for $B^0_s \to \mu^+\mu^-$ @ 7.8 σ
  - *waiting for* $B^0 \to \mu^+\mu^-$
  - first measurement of $\tau_{\mu\mu}$
  - no significant deviations from SM are observed
- **First search of $B^0_{(s)} \to \tau^+\tau^-$ from LHCb**
  - First upper limit on $B^0_s \to \tau^+\tau^-$
  - World best Upper limit in $B^0 \to \tau^+\tau^-$
  - LHCb can deal with τ
  - relevant the interplay with Belle 2

Backup

$B \to \tau\tau$ signal simulation

- pp collision: PYTHIA
- hadron decay: EvtGen
- final state radiation: PHOTOS
- interaction with detector: GEANT4

- $\tau \to 3\pi^{\pm}\nu_{\tau}$ resonance chiral lagrangian
- TAUOLA with BaBar results
- $\tau \to \pi^{-}\pi^{0}\pi^{0}\nu_{\tau}$ from CLEO

Effect of CLEO model:

- 20% higher efficiency:
- different intermediates resonances
- lower limit
- no impact on NN distribution

NN input variables

selection NN: 8 variables

- $\tau^{\pm}$ mass & decay time
- $\pi^{\pm}$ isolation
- B^0 neutral isolation
- one variable from analyitic reconstruction method

classification NN: 29 variables

- kinematic & geometrical
- $\pi^{\pm}$ isolation
- B^0 neutral isolation
- 8 variables from analyitic reconstruction method

Normalization factor

Uncertainties on normalization factor

- $B^0 \to D^- D_s^+$ fit model
  - Signal: Hypatia $\to$ 2 gaussians with same mean and power law
  - combinatorial: exponential $\to$ second order Chebychev
  - exclusive: add $B_S^0 \to D^- D_s^{\star +}$ & $B^0 \to a_1(1260)^- D_s^{\star +}$
  - relative uncertainty on α_s from $N^{obs}_{D^- D_s^+}$: 1.7 %
- external inputs
  - branching ratios
  - hadronization factor: accounts for 17% of total uncertainty on α_s

- finite size of simulated samples
- uncertainty from correction to simulation
  - control channels: $J/\psi \to \mu^+\mu^-$ & $D^0 \to K^-\pi^+$
  - corrections to tracking, PID, hardware trigger efficiencies
- relative uncertainties on α_s from these two sources: 2.9 %

All the errors are added in quadrature to give

$$\alpha_s = (4.07 \pm 0.7) \cdot 10^{-5}$$

Systematic uncertainties

Main sources of systematic uncertainties
For signal:

- mismodel of NN input variables in the simulation
  - check distributions on $B^0 \to D^- D_s^+$ control sample in data
  - retrain NN with corrected input variable distributions
  - difference in NN output shape assigned as systematic
- $\tau \to 3\pi\nu_\tau$ decay model in simulation
  - checked using simulated data with a different τ decay model
  - can affect both the selection efficiencies and the signal template shape
  - negligible effect on the NN output shape
  - 20% effect on the efficiency $\to$ assigned as systematic

$B \to \mu\mu$ BDT input variables

BDT selection

- $B^0_{(s)}$ candidate direction
- $B^0_{(s)}$ impact parameter wrt its PV
- separation between $\mu^{\pm}$ tracks and IP wrt any PV

BDT classification

- μ isolation
- min χ^2 of $\mu^{\pm}$ wrt B candidate PV
- $\hat{p}_B \cdot \hat{r}_B$ pointing
- B vertex fit χ^2 and IPχ^2

isolation variables function of distance between the μ & other tracks

proximity quantified by a MVA output with inputs:

- angular and spatial separation between μ & other track
- signed distance between μ track and B candidate PD
- kinematic and impact parameter information of μ track

$\frac{f_s}{f_b}$ measurement LHCb

$\frac{f_s}{f_b}$ @ 7 TeV measured by LHCb

$$\frac{f_s}{f_b} = 0.259 \pm 0.015$$

- stability @ 8 & 13 TeV evaluated looking at variation of ratio of $B_s^0 \to J/\psi\phi$ & $B^+ \to J/\psi K^+$
- effect of increase in $\sqrt{s}$
  - negligible for 8 TeV
  - scaling factor of 1.068 ± 0.046 applied for 13 TeV

$B \to \mu\mu$ Fit details

- Run 1 & 2 *each* divided into 5 BDT BDT bins [0.0,0.25,0.4,0.5,0.6]
- $\mathcal{B}(B^0_{(s)} \to \mu\mu$ determined through a simultaneous fit to $m_{\mu\mu}$ in 5⊗2 BDT bins
- free parameters:
  - $\mathcal{B}(B^0_{(s)} \to \mu\mu$
  - parameters of Crystal Ball constrained to their expectation within their errors
- combinatorial: common shape in BDT bins of a dataset, free yield
- exclusives:
  - included as separate components in the fit
  - total and single BDT bin gaussianly constrained to their expectations
  - mass shape from simulations for each BDT bin

Dependence on $\mathcal{A}_{\Delta\Gamma}$

- affects selection efficiency & BDT output
- Fit done assuming the SM value $\mathcal{A}_{\Delta\Gamma} = 1$

• model dependence evaluated repeating the fit with $\mathcal{A}_{\Delta\Gamma} = 0, -1$

• manifests an increase of $\mathcal{B}(B^0_{(s)} \to \mu\mu$ wrt SM of 4.6% & 10.9%

• dependence approximately linear in the physical region

$\tau_{\mu\mu}$ acceptance function

- variation of trigger and selection efficiency with decay time corrected by introducing and acceptance function
- acceptance function determined through simulated events, weighted to match properties observed in data
- Validation of simulation through control channel $B^0 \to K^+\pi^-$

$$\tau_{K\pi} = 1.52 \pm 0.03(stat)$$

in agreement with world average

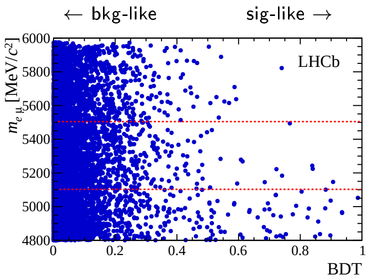
- statistical uncertainty on $\tau_{K\pi}$ assigned as systematic due to use of simulation to determine acceptance function

Title

$B^0_{(s)} \to e^{\pm}\mu^{\mp}$ [PRL 111 (2013) 141801]

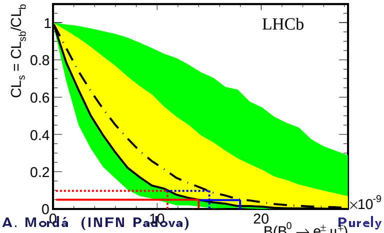
Strategy á la $B^0_{(s)} \to \mu\mu$

- Dataset: 1 fb^{-1} collected in 2011 at $\sqrt(s)$= 7 TeV
- $B^0 \to K\pi$ as normalization channel
- events classification in $m_{e\mu}$ - BDT plane



No excess over background is seen ⇒ upper limit on $BR(B^0_{(s)} \to e\mu)$ is obtained using the CL_s method

$B^0_s \to e\mu$, background-only expectation



Results

$BR(B^0_s \to e\mu) < 1.1(1.4) \cdot 10^{-8}$ @ 90(95)% CL

$BR(B^0 \to e\mu) < 2.8(3.7) \cdot 10^{-9}$ @ 90(95)% CL

$\sim$ 20 times more stringent than previous limits