

#### Measurement of b hadron lifetimes in pp collision at CMS

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# **Motivation**

Lifetime measurements play an important role in the study of non-perturbative aspects of QCD.

- Recent Bc lifetime measurements by the LHCb experiment are significantly larger than those measured at Tevatron.
- Previous Λb lifetime measurements have relatively wide ranges. The issue of the Λb lifetime had not been solved.
- Understanding the Bs  $\rightarrow J/\Psi \pi\pi$  decay channel, which is a CP-odd eigenstate, is very important since it could be used to make CP-violation studies.
- We present measurements of the lifetimes of the Bs, Bd, Bu, Bc and Ab hadrons using different decay channels.

### **Experimental setup**



Compact Muon Solenoid: perfect detector for measuring muons



### Overview of the latest HF studies by CMS

- Precision lifetime measurements of b hadrons reconstructed in final states with a J/ $\psi$  meson. arXiv: 1710.08949
- Measurement of the P1 and P5' angular parameters of the decay  $B0 \rightarrow K^*\mu + \mu in proton-proton collisions at <math>\sqrt{s=8}$  TeV. PLB 753 (2016) 424
- Observation of Y(1S) pair production at CMS. JHEP 05 (2017) 013
- Measurement of the total and differential inclusive B+ hadron cross sections in pp collisions at √s= 13 TeV.
   <u>PLB 771 (2017) 435</u>
- Quarkonium production cross sections in pp collisions at  $\sqrt{s} = 13$  TeV. <u>PLB 780 (2018) 251</u>
- Search for the X(5568) state in B0s pi+- decays. arXiv:1712.06144
- Measurement of Lambdab polarization and the angular parameters of the decay Lambdab to J/psi Lambda.
   <u>PRD 97 (2018) 072010</u>
- Angular analysis of B+->K+mumu <u>CMS-PAS-BPH-15-001</u>
- Search for the Z->Jpsi(->mumu) II decay <u>CMS-PAS-BPH-16-001</u>

## Lifetime measurements

#### $B^{+} \rightarrow J/\Psi \ K^{+}$

#### **Reference channel**

- Very well-known lifetime
- Calibration and specific systematic studies

Contribution from partially reconstructed B mesons rejected by restricted mass window









Previous Ab lifetime measurements have relatively wide ranges.

Using  $5fb^{-1}$  at 7TeV and in the same channel CMS had performed a measurement of  $\Lambda b$  lifetime

The first CMS result was in the higher range of measurements





weak decay of the Bc meson can occur through either the b or c quark

#### shorter lifetime than other B mesons

Recent lifetime measurements by LHCb are significantly larger than those measured at the Tevatron

Additional measurement by CMS may help to resolve this discrepancy

CMS has studied the  $J/\psi\pi$  and  $J/\psi\pi\pi\pi$ modes with 5fb<sup>-1</sup> at 7TeV.

Relative BF of the two modes measured

<u>JHEP 01 (2015) 063</u>

# Bc→J/Ψπ

- Most of the lifetime measurements are based on the modeling of the ct,  $\sigma_{ct}$  and mass of the B hadrons.
- In the Bc Lifetime measurement a different approach (DeltaGamma) has been applied and it will be discussed later.
- Here L<sub>xy</sub> is the distance of the flight of the B hadron in xy plane.

#### Efficiency correction is needed

- Reconstruction and selection criteria generate a distortion
- Efficiency is taken from MC simulation
- The turn-on region is discarded selecting ct>200µm (100µm Bc)



# Efficiency

For each decay channel, the efficiency is determined as a function of *ct* by using fully simulated MC samples. The efficiency is defined as the *ct* distribution of the selected events after reconstruction divided by the *ct* distribution obtained from an exponential decay with the lifetime set to the value used to generate the events.





Efficiency is parameterized by an inverse power function, for ct>200µm

Table 1: Summary of the sources and values of systematic uncertainties in the lifetime measurements (in  $\mu$ m). The total systematic uncertainty is the sum in quadrature of the individual uncertainties.

Source	$  B^0 \rightarrow J/\psi K^*(892)^0$	$B^0 \rightarrow J/\psi K_S^0$	$B_s^0 \rightarrow J/\psi \pi^+ \pi^-$	$B_s^0 \rightarrow J/\psi \phi$	$\Lambda_{\rm b}^0 \rightarrow J/\psi \Lambda^0$
PV selection	0.7	0.7	0.7	0.7	0.7
Detector alignment	0.3	0.7	0.3	0.3	0.7
MC statistical uncertainty	1.1	2.4	2.0	0.6	2.3
Mass modelling	0.3	0.4	0.2	0.4	0.9
Efficiency modelling	0.3	0.5	0.6	0.2	0.6
ct resolution	0.0	0.1	0.1	0.1	0.2
ct modelling	0.1	0.1	0.4	0.0	0.1
B <sup>+</sup> contamination	<u> </u>		1.4	<u></u>	<u> </u>
Mass window of $\pi^+\pi^-$		( <del></del>	1.8	<del></del>	
$K^{\pm}\pi^{\mp}$ mass assignment	0.3			<u></u>	
<i>ct</i> range				0.1	
S-wave contamination	—	—	_	0.4	<u> </u>
Total (µm)	1.5	2.7	3.2	1.2	2.7

# Systematic uncertainties

Table 2: Summary of the systematic uncertainties in the  $\Delta\Gamma$  and  $c\tau_{B_c^+}$  measurements.

Source	$\Delta\Gamma [{ m ps}^{-1}]$	$c\tau_{\rm B_c^+}$ [ $\mu$ m]
PV selection	0.02	2.0
Detector alignment	0.01	0.6
MC statistical uncertainty	0.01	1.3
Mass modelling	0.04	3.7
<i>ct</i> binning	0.01	1.4
Total uncertainty	0.05	4.7

### B<sup>0</sup> lifetime

![](_page_13_Figure_1.jpeg)

lifetime measurements are totally in agreement in the two different  $B^0$  decay modes In agreement with world average (455.7±1.2 µm)

### B<sub>s</sub><sup>0</sup> Lifetime

![](_page_14_Figure_1.jpeg)

In agreent with world average (509 $\pm$ 12 µm)

The Bs $\rightarrow$ J/ $\psi\pi\pi$  channel is dominantly a CP-odd sate Its lifetime can be translated to  $\Gamma_{H}$ 

![](_page_14_Figure_4.jpeg)

In agreent with world average (443.4 $\pm$ 2.4  $\mu$ m)

![](_page_15_Figure_0.jpeg)

In agreement with world average (439.8±3.0 µm)

This result is in agreement with previous measurement from CMS

#### Follow the tendency for long lifetime

### **Bc Lifetime**

The measurement of Bc lifetime is obtained using the difference between the total width of the Bc and B+ mesons in the decays  $Bc \rightarrow J/\psi\pi$  + and  $B+\rightarrow J/\psi K$  + (Analogous to LHCb approach)

![](_page_16_Figure_2.jpeg)

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#### Bc lifetime

![](_page_17_Figure_1.jpeg)

This measurement confirms a Bc lifetime value higher than that measured at the Tevatron, and it is in agreement with the more recent LHCb measurements

# Summary

Precision lifetime measurements of b hadrons reconstructed in final states with a  $J/\psi$  meson.

- For some measurements the precision that we get is competitive with the world average.
- The measurement of the Bc lifetime confirms a longer lifetime than found by the Tevatron experiments, in agreement with results from LHCb.
- The precision of the  $\Lambda b$  lifetime measurement is also as good as all previous measurements in the J/ $\psi\Lambda$  channel.
- CMS shows its capability to make precision time-dependent measurements, including CP-violation studies.

# Thanks!

![](_page_19_Picture_1.jpeg)