First mass measurements at LHCb

Roberta Cardinale[1] on behalf of the LHCb Collaboration
Department of Physics
University of Genova and INFN Genova,
I-16146 Genova, ITALY

At LHCb the first preliminary mass measurements of fully reconstructed b-hadron states in modes decaying to a J/ψ have been performed using $\sim$ 35 pb^{-1} of data collected during 2010. The systematics on the alignment of the tracking system and the momentum scale calibration are addressed. In this note precise mass measurements for B^0, B^+, B_s, B_c and Λ_b are presented.

1 Introduction

Hadrons are made of quarks and gluons bound together by the strong interaction described by QCD. The hadron mass is a simple property that can be used to test QCD.

The LHCb experiment is dedicated to explore CP violation and rare decays of b- and c-hadrons at the LHC [1]. The mass measurement relies both on the tracking system that combined with the dipole magnet, gives a good momentum resolution, and on the capability to identify muons of the muon detector.

2 Selection

Mass measurements have been performed using six exclusive decay modes (and charge-conjugate) with a J/ψ in the final state: $B^+ \to J/\psi K^+$, $B^0 \to J/\psi K^{*0}$, $B^0 \to J/\psi K^0_s$, $B^0_s \to J/\psi\phi$ and $\Lambda_b \to J/\psi\Lambda$, $B^+_c \to J/\psi\pi^+$ with $J/\psi \to \mu^+\mu^-$, $\phi \to K^+K^-$, $K^{*0} \to K^-\pi^+$, $K^0_s \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$. The selection [2, 3] is based on kinematic and topological variables such as goodness of the vertex fit, transverse momentum, impact parameter, b-hadron lifetime and Particle Identification (PID). A mass constrained vertex fit for J/ψ, K^0_s and Λ has been performed to improve the b-hadron mass resolution.

[1]roberta.cardinale@ge.infn.it

3 Selected Events Mass Distributions

The mass distributions of the selected candidates for two of the different considered channels are reported in Figure 1 together with the results of an unbinned maximum likelihood fit (gaussian plus an exponential for the background).

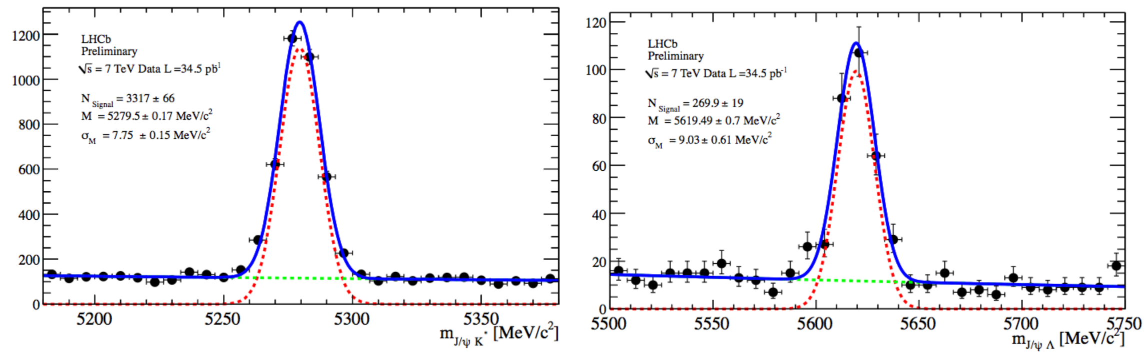

Figure 1: Mass distribution of the selected events for $B^0 \rightarrow J/\psi K^{*0}$ and $\Lambda_b \rightarrow J/\psi\Lambda$ channels.

4 Detector Alignment and Momentum Scale Calibration

A good alignment of the detector is essential to perform precise mass measurements. Both $J/\psi \rightarrow \mu^+\mu^-$ decay high momentum tracks and $D^0 \rightarrow K\pi$ decays have been used. A shift in the J/ψ mass across 2010 data taking period has been detected and has been correlated to temperature variations of the Trigger Tracker during 2010 data taking period (Figure 2). Since Trigger Tracker modules are mounted on aluminium cooling plate, the variation of temperature gives a contraction of the modules of 400 μm that is not negligible compared with the intrinsic resolution of the detector (50 μm). Therefore a run dependent alignment has been performed.

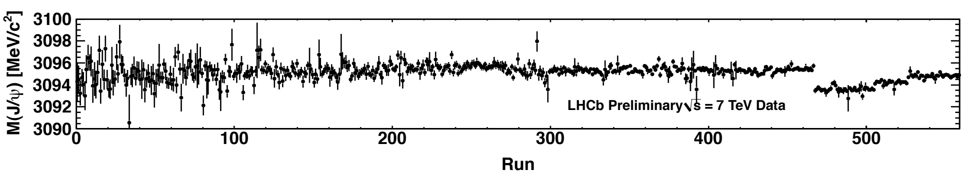

Figure 2: J/ψ mass across 2010 data taking period: three shifts corresponding to the three operating temperature changes are observed around run number 470, 510 and 530.

Decay	Measured mass [MeV/c^2]	PDG average [MeV/c^2]
$\Upsilon(1S) \to \mu^+\mu^-$	9459.90 ± 0.54	9460.30 ± 0.26
$J/\psi \to \mu^+\mu^-$	3096.97 ± 0.01	3096.916 ± 0.011
$D^0 \to K^-\pi^+$	1864.75 ± 0.07	1864.83 ± 0.14
$K^0_S \to \pi^+\pi^-$	497.62 ± 0.01	497.61 ± 0.02
$\psi(2S) \to J/\psi\pi^+\pi^-$	3686.12 ± 0.06	3686.09 ± 0.04

Table 1: Validation of the momentum scale using two body decays (Υ, D^0, K^0_s) and $\psi(2S) \to J/\psi\pi^+\pi^-$.

Another important step for mass measurements is the calibration of the momentum scale obtained using the $J/\psi \to \mu^+\mu^-$ decays. The momentum measurement has to be corrected with a precision better than 10^{-3}. After the run dependent alignment and the momentum scale calibration the variation of the J/ψ mass over time is at the level of $\Delta m/m = 10^{-5}$.The momentum scale calibration procedure has been validated using other two body resonance decay modes (Υ, D^0, K^0_s) and $\psi(2S) \to J/\psi\pi^+\pi^-$ decay. The agreement of the measured masses with the PDG values [4] is good (Table 1). The momentum scale factor from those decays has been evaluated to be known at the level of 10^{-4}.

5 Results and Systematic Uncertainties

Several systematics have been evaluated. Signal and background have been modeled using different functions. Systematic uncertainties are assigned associated with the precision of the momentum scale knowledge, of the detector description (energy loss correction) and of the detector alignment.

The measured mass at LHCb are reported below and compared with the other available measurements in Figure 3. If mass differences are considered the systematic error related to

$$\begin{aligned}
M(B^+ \to J/\psi K^+) &= 5279.27 \pm 0.11 \text{ (stat)} \pm 0.20 \text{ (syst) MeV/c}^2 \\
M(B^0 \to J/\psi K^{*0}) &= 5279.54 \pm 0.15 \text{ (stat)} \pm 0.16 \text{ (syst) MeV/c}^2 \\
M(B^0 \to J/\psi K^0_s) &= 5279.61 \pm 0.29 \text{ (stat)} \pm 0.20 \text{ (syst) MeV/c}^2 \\
M(B^0_s \to J/\psi\phi) &= 5366.60 \pm 0.28\text{(stat)} \pm 0.21\text{(syst) MeV/c}^2 \\
M(\Lambda_b \to J/\psi\Lambda) &= 5619.49 \pm 0.70 \text{ (stat)} \pm 0.19 \text{ (syst) MeV/c}^2 \\
M(B^+_c \to J/\psi\pi^+) &= 6268.0 \pm 4.0 \text{ (stat)} \pm 0.6 \text{ (syst) MeV/c}^2
\end{aligned}$$

the determination of the average momentum scale largely cancels.

$$\begin{aligned}
M(B^0 \to J/\psi K^*) - M(B^+ \to J/\psi K^+) &= 0.27 \pm 0.19\,(\text{stat}) \pm 0.12\,(\text{syst})\\
M(B^0 \to J/\psi K^0_S) - M(B^+ \to J/\psi K^+) &= 0.34 \pm 0.31\,(\text{stat}) \pm 0.10\,(\text{syst})\\
M(B^0_s \to J/\psi \phi) - M(B^+ \to J/\psi K^+) &= 87.33 \pm 0.30\,(\text{stat}) \pm 0.19\,(\text{syst})\\
M(\Lambda_b \to J/\psi \Lambda) - M(B^+ \to J/\psi K^+) &= 340.22 \pm 0.71\,(\text{stat}) \pm 0.08\,(\text{syst})\\
M(B^+_c \to J/\psi \pi^+) - M(B^+ \to J/\psi K^+) &= 988.7 \pm 4.0\,(\text{stat}) \pm 0.5\,(\text{syst})
\end{aligned}$$

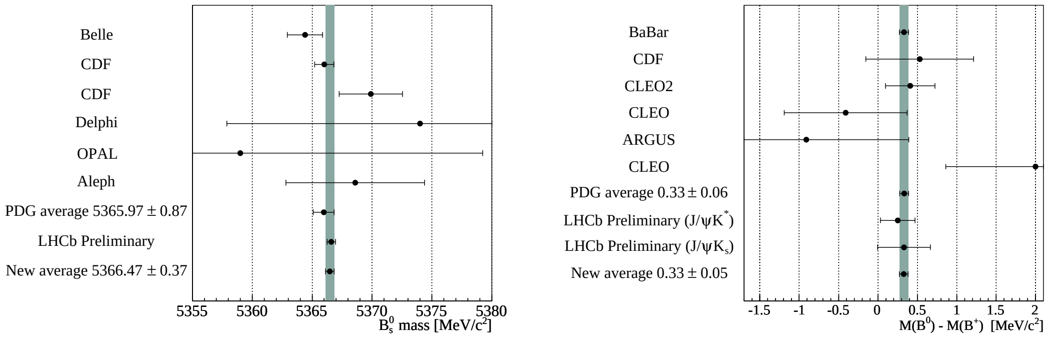

Figure 3: LHCb measurements for B^0_s and mass difference $M(B^0) - M(B^+)$ compared with current values from other experiments.

6 Conclusions

LHCb mass measurements of the b-hadrons $B^+, B^0, B^0_s, \Lambda_b$ and B^+_c agree with previous values and significantly improve the world average precision on these quantities. In particular, the measurements of the masses of B^+, B^0, B^0_s and Λ_b are the most precise results so far obtained. These measurements will be improved with more data, and measurements will also be performed of other hadrons such as the Ω_b and the excited B hadron states.

References

[1] LHCb collaboration, JINST **3** (2008) S08005, and references therein

[2] LHCb collaboration, *Selections and lifetime measurements for exclusive $b \to J/\psi X$ decays with $J/\psi \to \mu^+\mu^-$ with 2010 data*, CERN-LHCb-CONF-2011-001 (2011).

[3] LHCb collaboration, *Measurement of the B^+ to B^+ production cross-section ratio at* $\sqrt{s} = 7$ TeV *in LHCb*, CERN-LHCb-CONF-2011-017 (2011).

[4] K. Nakamura et al. [Particle Data Group], *Review of particle physics*, J. Phys. G **37** (2010) 075021.