Ω_b Observation: Frequently Asked Questions v1.9 11/08/09

Q1: *What is the origin of the difference in Ω_b baryon mass between the D0 result and the recently reported CDF result?*
A: The mass difference between the CDF and D0 measurement is approximately six standard deviations and is therefore not consistent within quoted uncertainties. D0 has studied heavy baryon mass reconstruction with known resonances, such as the Λ_b and the Ξ_b. In all cases, the results are consistent with the PDG values. The reconstructed Ω_b mass in MC events is consistent with the input value within systematic uncertainties quoted by D0. The largest systematic uncertainty on the measured mass comes from varying the event selection requirements. These variations are about a factor ten smaller than the difference between the masses measured by CDF and D0 and within the systematic uncertainty quoted by D0.
D0 is working on an update of this measurement with an increased data set which might help to address the mass discrepancy.

Q2: *What is the origin of the difference in Ω_b baryon production between D0 and the recently reported CDF result?*
A: D0 and CDF have both measured the rate of Ω_b *p*roduction with respect to Ξ_b baryon production. Within the quoted statistical and systematic uncertainties, the production rates measured by both experiments are in agreement.

Q3: *How do you know you are observing the Ω_b baryon?*
A: The decay mode where we observe a significant resonance is one of the Ω_b decay channels, and we measure a mass consistent with the theoretical expectation for the Ω_b. While we have not performed a measurement of the lifetime yet, owing to the limited available statistics, we have made a comparison of the proper decay length distribution between the candidate events and Ω_b MC with a lifetime of 1.5 ps (within the range of theoretical predictions of 0.83-1.67 ps), and found reasonable agreement. So far all pieces of evidence point to this resonance being the Ω_b.

Q4: *Does the significance include systematic uncertainties or the fact that you don't know where to look?*
A: What we report is purely the statistical significance based on the ratio of likelihoods under the signal-plus-background and background-only hypotheses. The significance of 5.4 standard deviations quoted in the published Phys. Rev. Lett. article is reduced to 5.05 standard deviations once a trials factor is included allowing for the test mass of the two-body final state $(J/\psi + \Omega)$ to lie in the 5.6-7.0 GeV mass region where we are searching for this particle. This interval covers the entire mass region between the mass of the lowest-lying b baryon, the Λ_b, and about 1 GeV above the upper value of the theoretical prediction for the Ω_b mass. This mass interval is chosen in a conservative way compared to the well known and comparatively narrow mass resolution for the Ω_b, 34 MeV. The significance of the observed signal with an optimized event selection

where the transverse momentum requirement on the Ω_b candidate was increased from 6 to 7 GeV is 5.8 standard deviation taking into account the trial factor.

Q5: *Given the good agreement between the predicted and measured masses for other charmed and bottom baryons, your measured Ω_b mass appears higher than what would be expected based on heavy-quark symmetry or flavor-independence. Could you comment on that?*
A: We have compared our mass measurement to available theoretical predictions: (1) Heavy Quark Effective Theory, (2) Feynman-Hellmann theorem+empirical formulas, and (3) Lattice non-relativistic QCD. At the time of our publication, the theoretical uncertainties quoted for the Ω_b mass in these predictions were in the range of 50-100 MeV, significantly larger than our experimental uncertainty. Our measurement was higher than the theoretical predictions by ~1.5-2 standard deviations, and therefore consistent with them. Several new Ω_b mass predictions with reduced theoretical uncertainties have been published since we released our first observation. The theoretical uncertainty is now of the order of 25 MeV and our result is now significantly higher than these predictions. We are working toward an update of this measurement with an larger dataset, to understand the origin of this discrepancy.

Q6: *Why is the systematic uncertainty on the measured Ω_b mass so large?*
A: We have adopted an approach where the systematic uncertainty on the mass is estimated by comparing the measured mass value after performing small variations to the analysis (e.g. different selection criteria). At this level of statistics, this introduces a significant statistical component to this systematic uncertainty which is expected to be reduced in the future with larger data sets or simply by performing a more refined evaluation of the systematic uncertainty via large MC samples. This is also one of the main reasons for the large systematic uncertainty on our recent measurement of the Ξ_b mass.

Q7: *The yields for Ω_b and Ξ_b reported in the respective D0 publications using the same data set are similar. Is this consistent with expectations?*
A: Due to the shorter Ω decay length and the harder p_T spectrum of the kaon from the Ω decay, we have significantly larger reconstruction efficiency for the Ω_b. We are confident that we understand our yields and efficiencies within the stated errors and we look forward to theoretical interpretations of our measured production fraction times branching fraction with respect to the Ξ_b. It is worth pointing out that there is at least one theoretical calculation, referenced in our publication, that predicts a larger branching fraction for the $\Omega_b \rightarrow J/\psi\ \Omega$ than the $\Xi_b \rightarrow J/\psi\ \Xi$ because the former does not require a spin-flip in the $b \rightarrow c$ transition (due to the $J = 3/2$ Ω in the decay products). When combining our measurement of the relative production fraction times branching fraction with such theoretical prediction, as well as with the lifetimes for both particles, we conclude the production rate for Ω_b is only a fraction of that for Ξ_b, in qualitative agreement with what would be expected based on the fragmentation model.

Q8: *Given the comparable yields, is there some significant cross-feed between the Ξ_b and the Ω_b?*
A: In the Ω_b analysis, we veto Ξ_b candidates. In the Ξ_b analysis, the Ω_b backgrounds that survive the Ξ mass requirement are removed by the lifetime significance cut that we use in the Ξ_b analysis. We apply no cuts on the Ω_b lifetime since it is expected to be considerably less than for the other b hadrons.

Q9: *The current result is based on 1.3 fb^{-1} of integrated luminosity, which is only a fraction of the total integrated luminosity recorded by D0 to date. Why are you reporting the result on this data set? Haven't you analyzed the rest of the data set yet?*
A: We approached this analysis on two independent paths. First, optimize the selection in the first 1.3 fb^{-1} data set, or Run IIa, that was used to discover the Ξ_b. Second, reprocess the rest of the data, Run IIb, and add it in when the reprocessing is complete. The splitting of the data set in these two periods is natural at D0 since the silicon tracker was upgraded for Run IIb to include an additional layer close to the beam pipe.
We finalized the optimization of the Run IIa analysis to the best level we could so it made sense to report the results for the Run IIa data. We are still working on the verification of the reprocessing of the Run IIb data. We have several handles within the data set to validate our reprocessing, particularly the inclusive K_s and Λ yields before and after reprocessing. The reprocessing of the Run IIb data is not yet validated, so currently we are not in a position to make a statement about the Run IIb data set.

Q10: *What does the reprocessing involve and why is it required?*
A: In order to limit the processing CPU time, the standard tracking algorithm at D0 makes an upper cut on the impact parameter of candidate tracks to be smaller than 2.5 cm. Since the Ω_b decay chain involves particles with average decay lengths in the range of 2.5-8 cm, a modified tracking algorithm able to reconstruct tracks up to much larger impact parameter values is required in order to efficiently reconstruct the signal events. Reconstructing events which such a tracking algorithm is time-consuming and we therefore restrict the reprocessing to $J/\psi \to \mu\mu$ candidate events, constituting only ~5% of the data set. As indicated previously, we are in the process of determining the optimal procedure to perform this reprocessing for the Run IIb data set.

If you have any further questions, please contact the D0 Physics Coordinators (gregorio@fnal.gov, mverzocc@fnal.gov)