DOI : 10.1393/ncc/i2012-11119-7

LAPP-EXP-2011-01

Recent results from BaBar

V. TISSERAND, *on behalf of the BaBar Collaboration*
Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAPP),
Université de Savoie, CNRS/IN2P3, F-74941 Annecy-Le-Vieux, France

We present recent results on bottomonium spectroscopy, rare neutral D mesons decays, and semi-leptonic B_s mesons decays. They are based on datasets collected at the $\Upsilon(2S)$, $\Upsilon(3S)$, and $\Upsilon(4S)$ resonances and slightly below and above (up to twice the Λ_b mass) by the BaBar detector at the PEP-II storage rings at SLAC from year 2000 to 2008. All the results presented here are preliminary.

A search of $\eta_b(1S)$ and $\eta_b(2S)$ quarkonia is performed in radiative transitions using an experimental technique employing converted γ rays in the $\Upsilon(2S)$ and $\Upsilon(3S)$ decays. The $\mathrm{h_b(1P)}$ state is searched in the $\Upsilon(3S) \to \mathrm{h_b(1P)}\pi^0/\pi^+\pi^-$ decays, and an evidence of signal is seen in the channel with a neutral pion. A search of the rare FCNC $D^0 \to \gamma\gamma$ decay is presented and the channel $D^0 \to \pi^0\pi^0$ is accurately measured. Finally, we present a study of the semi-leptonic branching ratio of the B_s mesons and of the f_s fraction, the production of B_s mesons. It is based on the very last BaBar dataset collected in 2008 and corresponding to an energy scan above the $\Upsilon(4S)$ resonances performed at PEP-II.

PACS numbers: 14.40.Pq ,14.40.Lb , 13.20.He

I. BOTTOMONIUM SPECTOSCOPY

A. Introduction

The bottomonium spectroscopy bellow the $B\bar{B}$ mass threshold is somewhat richer than in the case of charmonium state [1, 2], bellow the $D\bar{D}$ mass threshold. The measurement of the bottomonium mass states and of the branching ratios ($\mathcal{B}$) are important tests of the heavy $q\bar{q}$ potential models and set constrains on lattice QCD, as well as on theories such as pNRQCD. Hadronic transitions probe non-perturbative QCD. While bottomonium states with quantum numbers $L = 0,\ 1$ and $S = 1$ have been observed and abundantly studied since 1977, not all the predicted states are yet observed. In particular no spin singlet have been observed until 2008 [3]. The first $D-wave$ state $\Upsilon(1D_{J=2})$ has only been observed in 2004 by CLEO, in the transition $\gamma\gamma\Upsilon(1S)$ and latter on in 2010 by BaBar, in the channel $\pi^+\pi^-\Upsilon(1S)$ [4]

At the end of its operation in 2008, the BaBar experiment collected large datasets of approximately 120M $\Upsilon(3S)$ and 100M $\Upsilon(2S)$ events, creating renewed possibilities for probes on bottomonium system. We present herein a study of the $\Upsilon(2S)$ and $\Upsilon(3S)$ inclusive converted photon spectrum, and the search for the $\mathrm{h_b(1P)}$ state in both $\Upsilon(3S) \to \pi^0\mathrm{h_b(1P)}[\eta_\mathrm{b}(1S)\gamma)]$ and $\pi^+\pi^-\mathrm{h_b(1P)}$.

B. Radiative transitions using converted γ rays

Following the success encountered in the observation the $\eta_b(1S)$ state in radiative decays of the $\Upsilon(3S)$ and $\Upsilon(2S)$ events [3], the BaBar collaboration has recently developed a technique to study inclusive converted photon spectrum of these events. The details of the analysis can be foun in Ref. [5] (see also references therein for previous and alternate measurements). The monochromatic γ radiated in the bottomonium transitions are reconstructed through the converted e^+e^- pair produced in the material of Silicon Vertex Tracker (SVT) [6] and which charged track trajectories are bent in the magnetic field of the axial 1.5 T solenoid. This techniques improves substantially the mass spectrum resolution (E^*_γ) wrt to the photons reconstructed in the Electro-Magnetic Calorimeter (EMC) (typically from 25 down to 5 MeV/c^2). This accurate measurement helps to resolve overlapping resonances γ rays. The price to pay is a relatively lower efficiency ($\sim 1/20$) as the material budget BaBar tracking system is quite limited [6].

The various monochromatic γ rays are studied with χ^2 fits to the recoil E^*_γ spectrum in the $\Upsilon(3S)$ and $\Upsilon(2S)$ events after subtraction on the combinatoric background. The γ spectra presented on Fig. 1 display the rich phenomenology accessible. In these spectra we study the decays: $\Upsilon(3S)/\Upsilon(2S) \to \gamma\eta_b(1S)$ and possibly $\Upsilon(3S) \to \gamma\eta_b(2S)$. It offers an alternate search of the states $\eta_b(1S, 2S)$ and possibly a more accurate mass measurement. In addition to combinatoric background coming $e^+e^-(\sqrt{s} = m_{\Upsilon(nS)}) \to \gamma_{ISR}\Upsilon(1S)$ transitions can more easily be unfolded and also one can study accurately the decays: $\chi_{bJ}(1P,\ 2P) \to \gamma\Upsilon(1S)$, $\chi_{bJ}(2P) \to \gamma\Upsilon(2S)$, and $\Upsilon(3S) \to \gamma\chi_{bJ}(1P)$. The recoil E^*_γ spectra are divided in 4 energy ranges ; for $\Upsilon(3S)$ "low": [180, 300] MeV, "medium": [300, 600] MeV, and "high": [600, 1100] MeV and for $\Upsilon(2S)$: [300, 800] MeV.

In the "low" $\Upsilon(3S)$ region we observe the transitions $\chi_{b1,2}(2P) \to \gamma\Upsilon(2S)$ with more than 12 and 8 statistical standard deviations, while the $\chi_{b0}(2P) \to \gamma\Upsilon(2S)$ is not

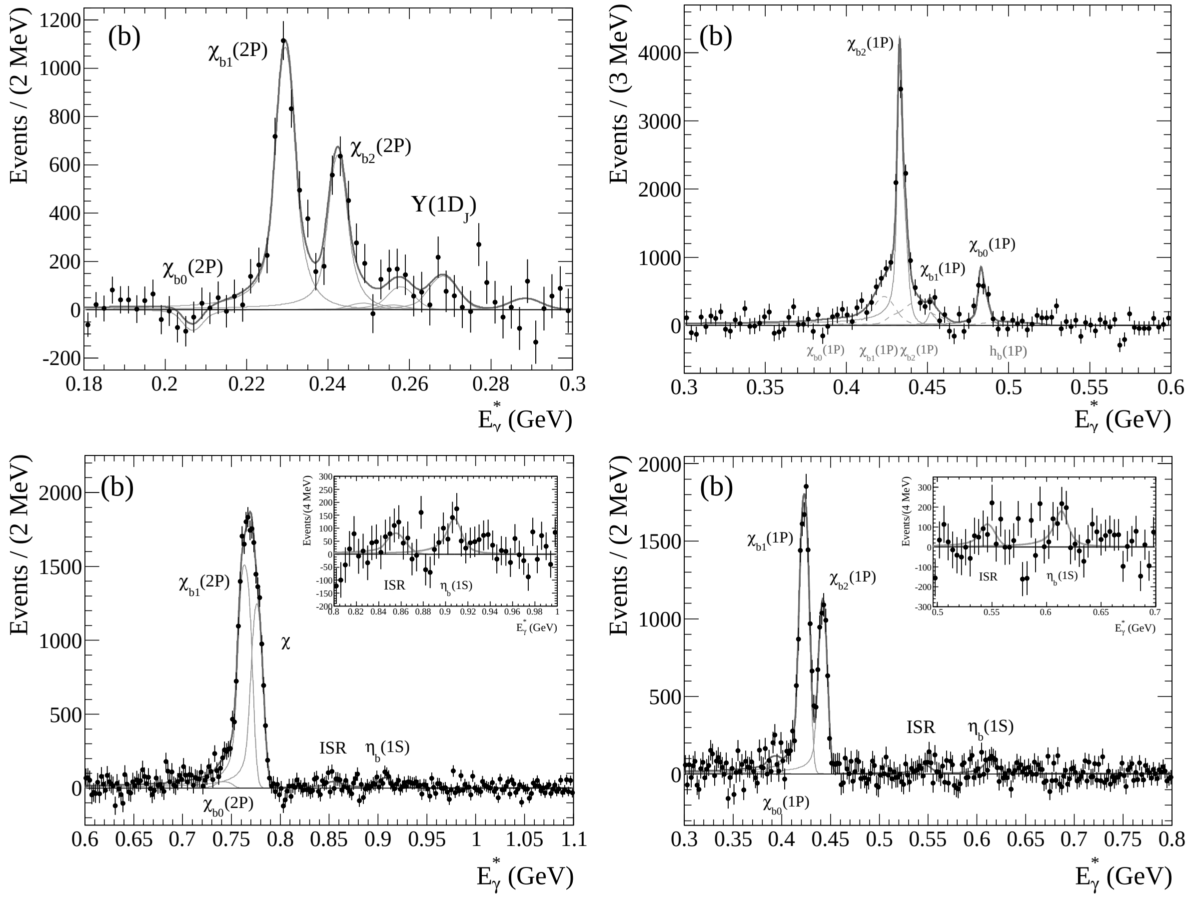

FIG. 1: . Fit to the E^*_γ spectrum in the $\Upsilon(3S)$ and $\Upsilon(2S)$ data. $\Upsilon(3S)$ top left: $[180,\ 300]\ MeV$, top right: $[300,\ 600]\ MeV$, and $[600,\ 1100]\ MeV$. $\Upsilon(2S)$ bottom right: $[300,\ 800]\ MeV$.

seen. It is consistent with previous works by CLEO and CUSB (1992) (see Refs. in [5]) and our measurements are more precise.

In the "medium" $\Upsilon(3S)$ region we observe the transitions $\Upsilon(3S) \to \gamma\chi_{b0,2}(1P)$ with more than 7 and 15 statistical standard deviations, while the $\Upsilon(3S) \to \gamma\chi_{b1}(1P)$ is not seen. This work is in agreement with recent measurements performed by CLEO [7]. An upper limit $\mathcal{B}(\Upsilon(3S) \to \gamma\eta_b(2S)) < 1.9 \times 10^{-3}$ is set at 90% C.L., for a scan of the resonance in the narrow range: $335 < E^*_\gamma < 375\ MeV$.

In the "high" $\Upsilon(3S)$ region we observe the transitions $\chi_{b1,2}(2P) \to \gamma\Upsilon(1S)$ with a much better accuracy than CLEO and CUSB, and confirm an absence of observation of the $\chi_{b0}(2P) \to \gamma\Upsilon(1S)$. For the $\eta_b(1S)$ state a 2.9 statistical standard deviation signal is seen (respectively 2.7 when including systematic uncertainties that are dominated by width assumption for the signal). The fitted mass of the quarkonium state is $(9403.6 \pm 2.8 \pm 0.9)\ MeV/c^2$ and is inconsistent with the PDG average by about 3.1σ deviations [2]. The measured $\mathcal{B}(\Upsilon(3S) \to \gamma\eta_b(1S)) = (5.9 \pm 1.6^{+1.4}_{-1.6}) \times 10^{-4}$ is however consistent with previous measurements [3].

Finally, for the $\Upsilon(2S)$ data spectrum one observes the transitions $\chi_{b1,2}(1P) \to \gamma\Upsilon(1S)$ with a much better accuracy than CLEO and CUSB, and confirms an absence of observation of the $\chi_{b0}(1P) \to \gamma\Upsilon(1S)$. For the $\eta_b(1S)$ state a non significant 1.7 statistical standard deviation signal when including systematic uncertainties is obtained (2.5σ for statistics only). The fitted mass of the quarkonium state is nevertheless fairly consistent with the PDG average [2]. One sets the upper limit: $\mathcal{B}(\Upsilon(2S) \to \gamma\eta_b(1S)) < 0.22\%$ at 90% of C.L.

The results of that analysis [5] are the best $\mathcal{B}(\chi_{bJ}(nP) \to \gamma\Upsilon(1S,\ 2S))$ available measurements and in good agreement with theory predictions [8]. We have the most accurate measurements of the transitions $\Upsilon(3S) \to \gamma\chi_{b0,2}(1P)$ and we don't observe the $\chi_{b1}(1P)$. This is inconsistent with any theory prediction but this is in good agreement with CLEO [7]. Unfortunately very few concluding informations are derived for the $\eta_b(1S,\ 2S)$ states as initially hoped.

C. Search for $\Upsilon(3S) \to \pi^0 \mathrm{h_b}(1\mathrm{P})$ and $\pi^+\pi^- \mathrm{h_b}(1\mathrm{P})$ transitions

The $\mathrm{h_b}$(1P) bottomonium state is the axial vector partner of the three $P - wave$ $\chi_{bJ}(1P)$ states and its mass is expected to be at the center of gravity of their masses: $m_{\mathrm{h_b(1P)}} = \Sigma_J[(2J+1)\times m_{\chi_{bJ}(1P)}]/\Sigma_J(2J+1) = (9900 \pm \mathcal{O}(3))\ MeV/c^2$.

The predicted production mechanisms in $\Upsilon(3S)$ decays are $\mathcal{B}(\Upsilon(3S) \to \pi^0 \mathrm{h}_b(1P)) \sim 10^{-3}$ and $\mathcal{B}(\Upsilon(3S) \to \pi^+\pi^- \mathrm{h}_b(1P)) \sim 10^{-5} - 10^{-3}$. Such predictions lead to a relative ratio of branching ratios of the 2 decay modes ($\pi^0/\pi^+\pi^-$) ranging from 5 to 20% [9]. The $\Upsilon(3S) \to \gamma \mathrm{h}_b(1P)$ decay is forbidden by C-Parity.

The expected $\mathrm{h_b}$(1P) decay width is less than 1 MeV. The particle decays to 3 gluons ($\sim$ 57%) or to 2 gluons plus a photon ($\sim$ 2%), and for $40 - 50\%$ of the time, to $\gamma\eta_b(1P)$. The latter mode offer an experimental signature that helps to reduce the background and that can be compared to the technique that was employed by CLEO in 2005 and latter on by BES in 2010 to observe the charmonium state h_c in the decay $\psi(2S) \to \pi^0 \mathrm{h}_c[\gamma\eta_c]$. More recently CLEO-c [10] measured the decay $e^+e^- \to \pi^+\pi^- \mathrm{h}_c$.

The existing information for the branching ratios are: $\mathcal{B}(\Upsilon(3S) \to \pi^+\pi^- \mathrm{h}_b(1P)) < 1.8 \times 10^{-3}$ and $\mathcal{B}(\Upsilon(3S) \to \pi^0 \mathrm{h}_b(1P)) < 2.7 \times 10^{-3}$ at 90% C.L. [2]. At this conference R. Mizuk [11], for the BELLE collaboration, has presented the first observation of the $\mathrm{h_b}$(1P) and $\mathrm{h_b}$(1P) states in $\Upsilon(5S) \to \pi^+\pi^- \mathrm{h}_b(1P,\ 2P)$ transitions.

We perform the search in the 2 channels $\Upsilon(3S) \to \pi^0 \mathrm{h}_b(1P)$ [12] and $\Upsilon(3S) \to \pi^+\pi^- \mathrm{h}_b(1P)$ [13] .

The $\Upsilon(3S) \to \pi^0 \mathrm{h}_b(1P)$ channel is reconstructed by requiring a photon with an energy E^*_γ consistent with the transition $\mathrm{h}_b(1P) \to \gamma\eta_b(1P)$ ([420, 540] MeV). Additional selection criteria are applied. They are based on the number of tracks, event shape, and we veto photons matching π^0. The global signal efficiency is about 16%. The number of signal event is extracted from fits to the distribution of the mass recoiling against the pion system in the $\Upsilon(3S)$ rest frame and in a mass region near the predicted $\mathrm{h}_b(1P)$ mass (9.9 GeV/c^2). The recoil mass window comprises 90 bins of 3 MeV/c^2 width each. Very precise fits to photon pairs are performed and account for accurate effects from re-weighted Monte Carlo simulation to data (the signal region is excluded in the procedure). The average reduced χ^2 of the fit presented in Fig. 2 (left) is 0.98 ± 0.03.

The fit to the recoil mass spectrum yields $9145 \pm 2804 \pm 1082$ signal events. This is an evidence for the signal at the level of 3.0 standard deviations and this number includes all the sources of uncertainties (statistical and systematic). The systematic uncertainties are dominated by the background and signal line shape models and the $m(\gamma\gamma)$ fits. The above signal significance is slightly higher (3.2σ) when the systematic uncertainties contributions are omitted . The mass of the $\mathrm{h}_b(1P)$ signal is $(9902 \pm 4 \pm 1)$ MeV/c^2 and is fully compatible with an expected value as the centre of gravity of the $\chi_{bJ}(1P)$ states.

When assuming $\mathcal{B}(\mathrm{h}_b(1P) \to \gamma\eta_b(1P)) = (45{\pm}5)\%$, we measure $\mathcal{B}(\Upsilon(3S) \to \pi^0 \mathrm{h}_b(1P)) = (3.7{\pm}1.1{\pm}0.4)\times 10^{-4}$. We also set the upper limit to be 5.8×10^{-4} at 90% of C.L. It is fully consistent with the prediction by Voloshin [9] and coherent the previous limits.

The $\Upsilon(3S) \to \pi^+\pi^- \mathrm{h}_b(1P)$ channel is reconstructed by requiring a pair of positively-charged track as the dipion pair. Additional criteria are applied. They are based on the event energy and shape, the number of tracks, and we also veto mainly $K^0_S \to \pi^+\pi^-$ decays and we reduce the also less worrying baryon decay $\Lambda \to p\pi^-$ and converted γ to a e^+e^- pair. The global signal efficiency is about 42%. Here also a search of a signal peak near 9.9 GeV/c^2 is performed by fitting the recoil mass against the dipion system. The signal resolution is expected to be of the order of $9MeV/c^2$.

The fit of the subtracted combinatoric background spectrum is displayed in Fig. 2 (right). A 1D χ^2 fit is performed to extract the signal and it comprises 7 components: the $\mathrm{h}_b(1P)$ signal, the $\Upsilon(3S) \to \pi^+\pi^-\Upsilon(2S)$ transition at the $\Upsilon(2S)$ mass, the $\Upsilon(2S) \to \pi\pi\Upsilon(1S)$ contribution slightly below 9.8 $GeV/^2$, the $\chi_{b1,2}(2P) \to \pi^+\pi^-\chi_{b1,2}(1P)$, the remaining $K^0_S \to \pi^+\pi^-$ pollution, and the non-peaking background (including ISR $e^+e^- \to \pi^+\pi^-\Upsilon(1S)$). No signal is seen. The fit yields a negative number of signal events: -1106 ± 2432 (statistical uncertainty only is included here). This leads to the upper limit: $\mathcal{B}(\Upsilon(3S) \to \pi^+\pi^- \mathrm{h}_b(1P)) < 1.2 \times 10^{-4}$ at 90% of C.L. The maximum significance over the scanned range is 2 standard deviations at most. The systematic uncertainties are dominated by the decay knowledge in the simulation for the charmless mesons and by the continuum model and residual K^0_S and ISR backgrounds.

We also extract the branching ratios of the transitions $\Upsilon(3S) \to X[\chi_{bJ}(2P) \to \pi^+\pi^-\ \chi_{bJ'}(1P)]$, where $J = J'$ and are equal to 1 or 2. We measure: $\mathcal{B}(J = J' = 1 \text{ or } 2) = (1.16{\pm}0.07{\pm}0.12)\times 10^{-3}$ or $(0.64{\pm}0.05{\pm}0.08)\times 10^{-3}$. And we improve the PDG [2] accuracy for the $\mathcal{B}[\Upsilon(3S) \to \pi^+\pi^-\Upsilon(2S)]$ and $\mathcal{B}[\Upsilon(3S) \to X(\Upsilon(2S) \to \pi^+\pi^-\Upsilon(1S))]$ decays. We measure respectively: $(3.00 \pm 0.02 \pm 0.14)\%$ and $(1.78 \pm 0.02 \pm 0.11)\%$.

Finally it is possible to estimate the ratio of branching ratios $\mathcal{B}(\Upsilon(3S) \to \pi^0 \mathrm{h}_b(1P))$ over $\mathcal{B}(\Upsilon(3S) \to \pi^+\pi^- \mathrm{h}_b(1P))$ from the above measurements. It is higher that $3.7 - 5.8$ and so far consistent with predictions from theory [9].

II. RARE $D^0 \to \gamma\gamma$ AND $D^0 \to \pi^0\pi^0$ DECAYS

In the Standard Model (SM) Flavor Changing Neutral Currents (FCNC) are forbidden at tree-level. These decays are allowed at higher order and have been measured in kaons and B mesons. For charm mesons the low mass of the down-type companion quark introduces a large suppression at the 1-loop level from the GIM mechanism.

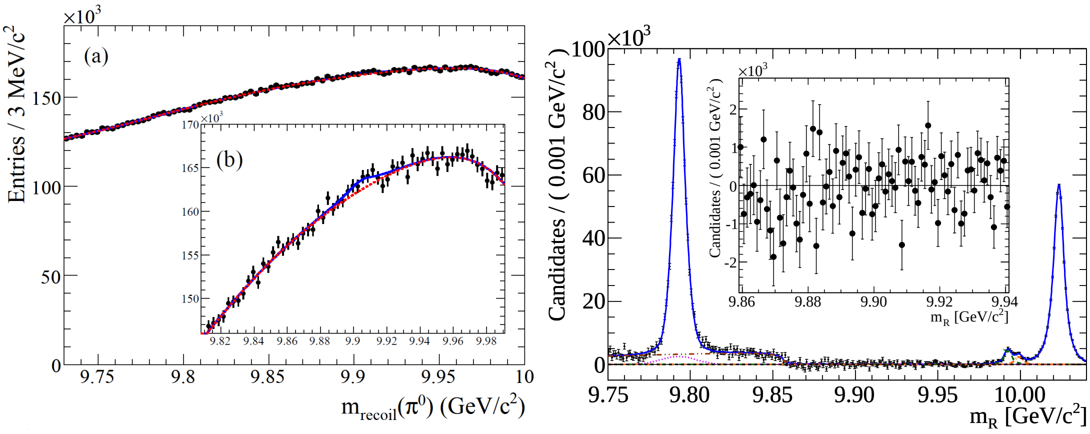

FIG. 2: Fitted recoil mass spectra for $\Upsilon(3S) \to \pi^0 \mathrm{h}_b(1P)$ (left) and $\Upsilon(3S) \to \pi^+\pi^- \mathrm{h}_b(1P)$ (right). The right-hand side plot is displayed after that the fitted combinatoric background has been subtracted.

So far no FCNC decays of charm mesons have been observed. The search of rare charmed meson decay such as $D^0 \to \gamma\gamma$ is one possible way to perform that search.

In the SM the process $D^0 \to \gamma\gamma$ is dominated by long distance effects [14]. At short range mainly 2-loops contribute and the branching ratio $\mathcal{B}$ of $D^0 \to \gamma\gamma$ is expected to be of the order of 3×10^{-11}. This is several order of magnitude below the sensitivity of current experiments. But in fact, the transition $D^0 \to \gamma\gamma$ is dominated by Vector Meson Dominance processes (VMD), so that the value of $\mathcal{B}(D^0 \to \gamma\gamma)$ is enhanced to $(3.5^{+4.0}_{-2.6}) \times 10^{-8}$. This larger value is confirmed in the $HQ\chi PT$ computations that predict $\mathcal{B}(D^0 \to \gamma\gamma) = (1.0 \pm 0.5) \times 10^{-8}$.

Such small values are anyhow still a bit far away from experimental capacities. But possible large enhancements arising from long distance New Physics (NP) effects are such that they can lead values as large as 6×10^{-6} for $\mathcal{B}(D^0 \to \gamma\gamma)$. This is in fact within the reach of present experiments a B-factories. Such effects may for example originate from gluino-exchange within the MSSM framework [15].

The BaBar experiment with about 470 fb^{-1} of data collected near the $\Upsilon(4S)$ resonance has such a discovery potential. This integrated luminosity corresponds to more than 610×10^6 $c\bar{c}$ quark pairs. The search of the process $D^0 \to \gamma\gamma$ is therefore an appealing, even difficult, mode for NP search. BaBar has effected such an analysis.

The existing upper limit on $\mathcal{B}(D^0 \to \gamma\gamma)$ is 2.7×10^{-5} at 90% of C.L. [2] and was obtained by the CLEO experiment [16]. The measurement of that branching ratio is normalized to the abundant, pure and precisely measured channel $D^0 \to K^0_S\pi^0$, which branching ratio is equal to $(1.22 \pm 0.5) \times 10^{-2}$ [2]. When employing that technique some systematic uncertainties cancel in the ratio of branching ratio.

The largest background for $D^0 \to \gamma\gamma$ channel is the decay mode $D^0 \to \pi^0\pi^0$. Is presently measured $\mathcal{B}$ is equal to $(8.0 \pm 0.8) \times 10^{-4}$ [2]. We also perform similarly the measurement of that latter channel using the normalization technique to the $D^0 \to K^0_S\pi^0$. Doing that measurement at the same time allows to have a better handling of the $D^0 \to \pi^0\pi^0$ background for the search of the $D^0 \to \gamma\gamma$ mode. The main backgrounds for $D^0 \to \pi^0\pi^0$ are the modes $D^0 \to K^0/\bar{K}^0\pi^0$ and $K^-\pi^+\pi^0$.

In order to remove $B\bar{B}$ backgrounds, we use $D^{*+} \to D^0\pi^+$ tagged events and require $P_{D^*} > 2.4 - 2.85$ GeV/c^2. We remove QED background by requiring at least 4 tracks or neutrals within the BaBar detector acceptance. The channels $D^{*0} \to D^0\pi^0/\gamma$ are the largest backgrounds for the normalization channel $D^0 \to K^0_S\pi^0$. Finally in the case of the $\gamma\gamma$ analysis, we perform a veto against photons that can be associated to another photon in the event to build a π^0 candidate. Such a veto is 66% efficient on D^0 signal and removes 95% of the photons originated from π^0.

For the $D^0 \to \pi^0\pi^0$ analysis the selection efficiencies of the $D^0 \to \pi^0\pi^0$ signal is 15.2% and it is 12.0% for the normalization channel $D^0 \to K^0_S\pi^0$. For the $D^0 \to \gamma\gamma$ analysis the selection efficiencies of the $D^0 \to \gamma\gamma$ signal is 6.1% and it is 7.6% for the normalization channel $D^0 \to K^0_S\pi^0$.

Figure 3 shows the fitted spectra of the $D^0 \to \pi^0\pi^0$ (left) and $D^0 \to \gamma\gamma$ (right) signals.

The $\pi^0\pi^0$ analysis fitted yield is 26010 ± 304 signal events, while for the normalization channel $K^0_S\pi^0$ the yield is 103859 ± 392 events. This corresponds to $\mathcal{B}(D^0 \to \pi^0\pi^0) = (8.4 \pm 0.1 \pm 0.4 \pm 0.3) \times 10^{-4}$, where the third uncertainty is related to uncertainty on the the world average for $\mathcal{B}(D^0 \to K^0_S\pi^0)$ [2]. This measurement is 40% more accurate than the present world average value.

For the $\gamma\gamma$ analysis the fit yields a negative number: -6 ± 15 events. It corresponds to an upper limit of 25.1 events at 90% of C.L. This number converts into an upper limit, computed from pseudo Monte Carlo experiments.

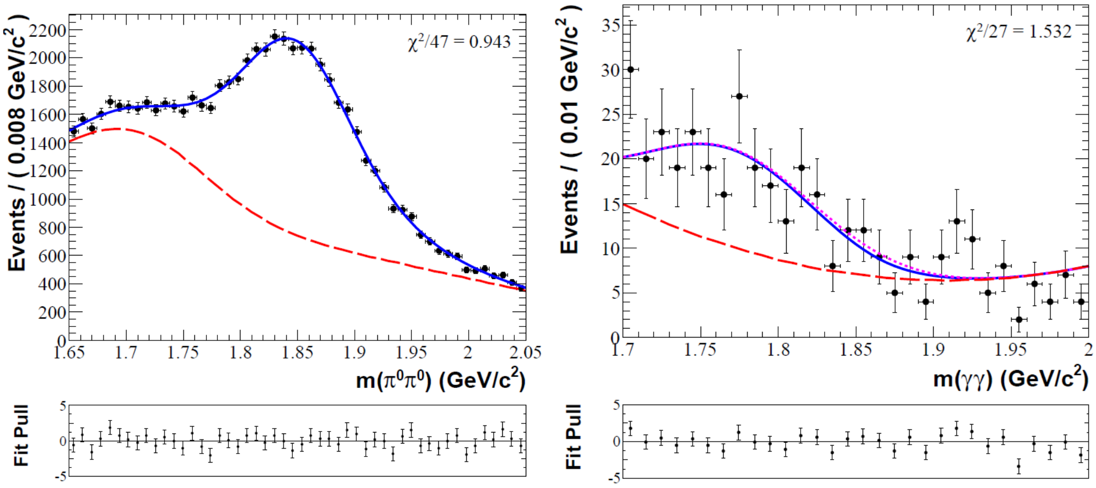

FIG. 3: Fitted mass spectra of the $D^0 \to \pi^0\pi^0$ (left) and $D^0 \to \gamma\gamma$ (right) signals. The dots with error bars are the data. On top we superimpose with the long dashed red curve the fitted combinatorial background component, the signal is shown with the solid blue line. In the case of the $\gamma\gamma$ analysis the signal is fitted together with the $D^0 \to \pi^0\pi^0$ background component which results in a negative signal (small dash purple curve). The fit is determined from unbinned maximum likelihood but the χ^2 value is determined from binned data and is provided as goodness-of-fit measure. The pull distributions show the differences between the data and the solid blue curve above with values and uncertainties normalized to the Poisson statistics.

That computation includes systematic uncertainties. We set the upper limit: $\mathcal{B}(D^0 \to \gamma\gamma) < 2.4 \times 10^{-6}$ at 90% of C.L. ($< 2.06 \times 10^{-6}$ without systematic uncertainties). Such a value is already constraining specific NP models [15]. It is an order of magnitude lower than the existing best world limit [16].

III. SEMI-LEPTONIC BRANCHING RATIO OF THE B_s MESONS AND THE FRACTION f_s ABOVE THE $\Upsilon(4S)$ RESONANCE

As opposed to the semi-leptonic $\mathcal{B}(B_{u,d} \to Xl^-\bar{\nu}_l)$, that are well known and equal to $(10.99 - 10.33 \pm 0.28)\%$, the existing measurements of the semi-leptonic branching ratio in B_s decays are still inaccurate [2]. It is expected to be from 1.5 to 3% lower than that of B_d [17]. Its world average is $(7.9 \pm 2.4)\%$, from LEP experiment at the Z^0 and they include the information on the fraction $P(b \to B_s) = (10.5 \pm 0.9)\%$. The alternate measurement $(10.2 \pm 0.8 \pm 0.9)\%$ is from the $\Upsilon(5S)$ data collected by the BELLE experiment [18]. The LHCb experiment has yet already started to contribute by providing measures of ratios of specific semi-exclusive decays to total inclusive semi-leptonic B_s decay [19].

Recently BaBar collaboration has performed the measurement of $\mathcal{B}(B_s \to Xl^-\bar{\nu}_l)$ ($\mathcal{B}(B_s)_{SL}$) and of f_s, the fraction of $B_s^{(*)}$ mesons produced above the $\Upsilon(4S)$ resonance. For this we use 4.1 fb^{-1} of data from a final energy scan performed in the last period of the data taking in 2008 [20]. In that energy scan, data were collected every 5 MeV above the $\Upsilon(4S)$ resonance, from which 3.15 fb^{-1} was taken in the range $[2mB_s, 2m\Lambda_B]$.

These 2 measurements are based on the counting of the yield of produced ϕ mesons and of ϕ mesons produced in correlation with a high -momentum lepton. Such signatures are more abundant in B_s decays than in $B_{u,d}$ decays. As a function of the center of mass energy in the scan, one can unfold the 2 parameters $\mathcal{B}(B_s)_{SL}$ and f_s from the 3 observables: the number of produced B hadrons, the ϕ mesons inclusive rate, and the rate of ϕ mesons produced in correlation with a high-momentum lepton.

The light $q\bar{q}$ ($q = u,\ u,\ s,\ c$) pair of quarks contribution are subtracted by using data collected 40 MeV below the $\Upsilon(4S)$ resonance. The $B_{u,d}$ contributions are computed from data collected at the $\Upsilon(4S)$ resonance. Many quantities derived from the PDG [2] such as $\mathcal{B}(B_s \to D_s X)$, $\mathcal{B}(D_s \to Xl^-\bar{\nu}_l)$, $\mathcal{B}(D_s \to \phi X)$, $\mathcal{B}(D_s \to \phi X l^-\bar{\nu}_l)$ (...) are exploited in the computation of $\mathcal{B}(B_s)_{SL}$ and f_s from the above enumerated 3 observables. The input $\mathcal{B}(B_s \to D_s X)$ is from far the less accurately known of the various input parameters. Its present world average is $(93 \pm 25)\%$.

Figure 4 displays the fitted value of $\mathcal{B}(B_s)_{SL}$ with respect to $\mathcal{B}(B_s \to D_s X)$ (left) and of f_s versus the value of the center of mass energy of the 2008 PEP-II scan (right). We measure $\mathcal{B}(B_s)_{SL} = (9.9^{+2.6}_{-2.1}(stat.)^{+1.3}_{-2.0}(syst))\%$. This branching ratio is consistent with previously mentioned measurements. The values of f_s for bins near the $\Upsilon(5S)$ resonance are fully compatible with those obtained by BELLE: $(18.0 \pm 1.3 \pm 3.2)\%$ and CLEO: $(16.8 \pm 2.6^{+6.7}_{-3.4})\%$ in 2007 [21].

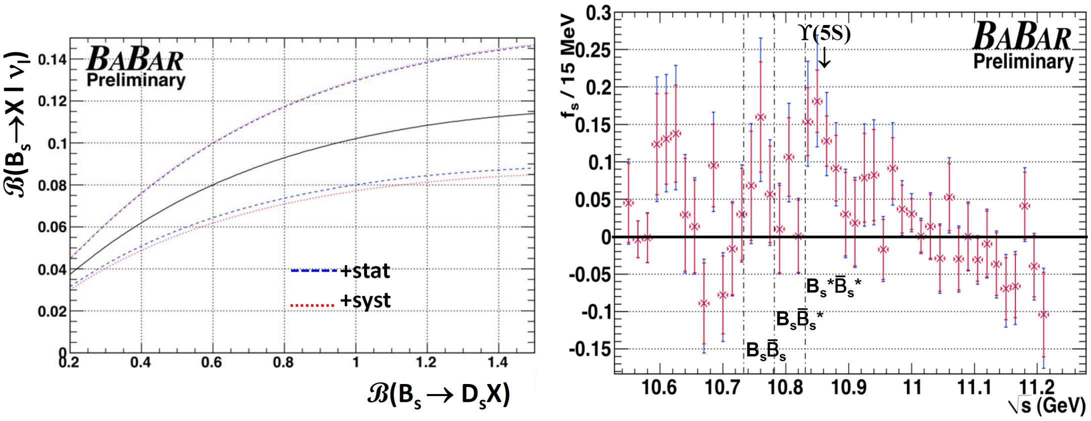

FIG. 4: Fitted value of $\mathcal{B}(B_s)_{SL}$ with respect to $\mathcal{B}(B_s \to D_sX)$ (left) and of f_s versus the value of the center of mass energy of the 2008 BaBar scan (right) [20]. The statistical and additional systematic uncertainties are plotted separately.

Acknowledgments

I would like to thank my BaBar colleagues for their help in the preparation of that presentation and their many useful comments and inputs during our discussions.

[1] E. Eichten *et al.*, Rev. Mod. Phys.80 (2008) 1161.
[2] K. Nakamura *et al.* (Particle Data Group), J. Phys. G37 (2010) 07502.
[3] B. Aubert *et al.* (the BaBar Collaboration), Phys. Rev. Lett.101 (2008) 071801 and Phys. Rev. Lett.103 (2009) 161801, and G. Bonvicini *et al.* (the CLEO Collaboration), Phys. Rev. D81 (2010) 031104(R).
[4] G. Bonvicini *et al.* (the CLEO Collaboration), Phys. Rev. D70 (2004) 032001 and P. del Amo Sanchez *et al.* (the BaBar Collaboration), Phys. Rev. D82 (2010) 111102(R).
[5] J-P. Lees *et al.* (the BaBar Collaboration), arXiv:1104.5254 (2011), submitted to *Phys. Rev. D.*
[6] B. Aubert*et al.* (the *BaBar* Collaboration), Nucl. Instrum. Methods Phys. Res. Sect. A479 (2002) 1.
[7] M. Kornicer *et al.* (the CLEO Collaboration), Phys. Rev. D83 (2011)054003.
[8] W. Kwong and J.L. Rosner , Phys. Rev. D38 (1988) 279.
[9] Y-P.Tuan *et al.*, Phys. Rev. D37 (1988) 1210; S. Godfrey and J.L. Rosner, Phys. Rev. D66 (2002) 014012; S. Godfrey , J. Phys. Conf. Ser.9 (2005) 123; M.B. Voloshin, Sov. J. Nucl. Phys.43 (1986) 1011.
[10] R.E. Mitchell (for the CLEO-c Collaboration), at CHARM 2010, arXiv:1102.3424 (2011).
[11] R. Mizuk (for the BELLE Collaboration), at La Thuile 2011, arXiv:1103.3419 (2011).
[12] J-P. Lees *et al.* (the BaBar Collaboration), arXiv:1102.4565 (2011), submitted to *Phys. Rev. Lett.*
[13] J-P. Lees *et al.* (the BaBar Collaboration), arXiv:1105.4234 (2011), submitted to *Phys. Rev. D.*
[14] G. Burdman *et al.*Phys. Rev. D66 (2002) 014009 ; S. Fajfer, P. Singer, and J. Zupan, Phys. Rev. D64 (2001) 074008 .
[15] S. Prelowsek and D. Wyler, Phys. Lett. B500 (2001) 304.
[16] T.E. Coan *et al.* (the CLEO Collaboration), Phys. Rev. Lett.90 (2003) 101801, P. Rubin *et al.* (the CLEO Collaboration), Phys. Rev. Lett.96 (2006) 081802, and H. Mendez *et al.* (the CLEO Collaboration), Phys. Rev. D81 (2010) 052013 .
[17] I.I. Bigi, T. Mannel and N. Uraltsev, arXiv:1105.4574 (2011).
[18] A. Drutskoy (for the BELLE Collaboration), at EPS07 and LP07, arXiv:0710.2548 (2007).
[19] R. Aajj *et al.* (The LHCb Collaboration), Phys. Lett. B698 (2011) 14.
[20] B. Aubert *et al.* (the BaBar Collaboration), Phys. Rev. Lett.101 (2008) 012001.
[21] A. Drutskoy *et al.* (the BELLE Collaboration), Phys. Rev. Lett.98 (2007) 052001 and G. S. Huang *et al.* (the CLEO Collaboration), Phys. Rev. D75 (2007) 012002 .