Comments on the Workshop on $B \to D^{**}$ transitions

Alain Le Yaouanc, LPT

December 5, 2012

Abstract

Warning. We do not quote name of authors on purpose. Although I say "we", because "le moi est haïssable", there are some personal points of view, as well as most common to many of us, and a synthesis of their particular contributions. Anyway, the comments try to reflect the discussions in Orsay and outside. Experimentalists in SL, especially, will not agree on several comments, but one may hope to rise their doubts.

1 The "1/2 semileptonic puzzle"

Note that this formulation is better than "The 1/2 vs 3/2 puzzle" because it locates the problem where it is really present up to now : not in 3/2, which are well predicted, and not in NL.

As to discrepancies, it must be clear that if errors were rightly calculated in exact theory (QCD) and experiment, there would not be any discrepancy. So, to avoid metaphysics, let us stress what is the real question.

-"Theory" is meant not to be QCD but rather the **quark models**, and specifically our QM with GI wave functions inserted in the Bakamjian-Thomas framework for transitions. Presently, only this approach is able to formulate predictions for BR, the only ones which can be confronted to experiment. Present lattice QCD does not provide large w, which is what counts for BR; all the less at finite masses. The next step for QM is to give predictions at finite masses, which is straightforward.

Let us stress a point which is contrary to prejudice : there is no way to give an a priori error on the predictions of QM. Such a concept like a priori uncertainty is not well defined or not calculable. Only a posteriori comparisons with experiment, once experiment is known, can be made, or, where available, with lattice QCD. An extensive comparison with experiment for transitions, with the BT approach, which has not been performed, could give a qualitative idea. The comparison with lattice QCD on current densities suggests a good agreement at infinite mass, rather extensive in spatial dimensions. The $\xi(w)$ is a good fit to h_{A_1} or F, G as well, to the rough precision which is relevant. And the BR of $B \to Dl\nu$, which is the most safely measured (if a little less accurate), is quite good : 2% against expt. 2.2%

-As to **experiment**, 1) what is under discussion first is the exclusive NL or SL rates to resonances, not the $D^{(*)}\pi(\pi)$ semi-inclusive SL rates for which we have simply no prediction

2) we start from the experimental error bars as they are quoted; for the SL, note that they are unexpectedly narrow for the broad states $j = 1/2$: around 20%, although the statistics are small, and the systematics are expected to be very large, due to the difficulty of separating resonance and continuum for very broad states (cf. baryonic resonances) ; one may be surprised that with much more statistics, the errors for the NL case (charged B) are much larger .

-What is clear is that there is no **positive** indication of a serious problem in NL. Even more, there is **positively** an impressive semi-quantitative success, especially considering class III/class I, and taking into account $1/m_Q$ effects as discussed by Leibovich et al..

-Let us then reiterate that the main problem is on the SL, not NL.

The discrepancy of experiment with theory for $j = 1/2,\ 0^+$ state in SL is a factor 5 with lower edge of experimental error bars, and 7 with central value (see the table pp. 12 or 13 in the talk).

Could we have a theoretical error in SL so large as to comply with the claimed experimental numbers ? we doubt much from what has been said above.

Moreover, **enlarging the theoretical predictions for NL by a factor 5 would give numbers completely contradictory with the data** (as given in the table p.17 in the talk, table due to Patrick).

We would rather suspect the error bars in **SL experimental rates to $j = 1/2, 0^+$ resonance** (20%). bf The most probable is that a very broad resonance with small BR cannot be well identified with so few events as observed in SL. In broad baryonic resonances, such an accuracy is seldom obtained, although raw data are very much better, with Argand diagrams obtained.

This central point has not been discussed much in the colloquium- it also implies discussion on the Breit-Wigner forms far away from the peak, and of the continuum.

-Preferably, one should concentrate on narrow resonances, in SL and NL as well. This is the reason to propose the experimental study of the $Bs \to D_{sJ}$ transitions, which offers precidely the opportunity to measure $j = 1/2$ with very narrow widths. Once we have these, we could almost forget about the experimental nightmare of D^{**} in SL as to the magnitude of transition amplitudes, as to excesses of all sort,...,and use $SU(3)$.

-Moreover, from the discussions, one important point should emerge : that we must not try to **"solve"** the problem of SL decays in an isolated fashion, without paying attention to what would happen correspondingly in NL decays (see below).

2 NL versus SL

This seems to a central question for the future.

The general advantage of NL is : much more observed events. However, we must admit the important drawback : in Class I, where we could see directly the $B \to D^{**}$ transition, it interferes with a non exotic, therefore large, crossed channel $\pi\pi$ contribution. In Class III, one is freed from such a channel, but there is interference with the D^{**} emission contribution. f_D^{**} is perhaps not very well for BT, but it is the place for lattice QCD, and it has been calculated at finite mass and then one can tighten the predictions.

3 Inconsistencies or differences beetween Belle and BABAR

They are obvious in SL, especially in the $D^*\pi$ channel. They are also present in the NL ; here, only the $D\pi\pi$ channel has been studied by both ; there is a difference, but within compatibility. It would be very interesting to have an analysis of $D^*\pi\pi$ from BABAR.

Resolving these differences is certainly one of the main tasks on the experimental side. Could theoreticians have something to say about the modelling (e.g. : phase)?

4 "Excesses" of events in SL decays

Much has been said about excesses. It is useful to warn that one must distinguish two questions and two types of excesses :

1) admitting the experimental analyses of Belle and Babar, one can perceive definite excesses of raw data with respect to the fit at low masses, especially at Babar. Babar seems also to find such an excess in the electronic spectrum. The $D\pi$ data of Belle at low mass do not seem simply to be fitted by the claimed 0^+ BW.

2) admitting on the contrary small values of $tau_{1/2}$ as suggested by theory, how would one explain the events previously included in the high experimental rate for the resonance ?

We have presently no answer to such questions. Not even an indication on the partial waves which are involved.

4.1 Possible inconsistencies beetween NL and SL experimental analyses

One has a vague impression that "excesses " of types 1) and 2) described for SL have no clear counterpart in NL. It is a fact that in NL, **fits pass through the data point much better than in SL, where excesses are seen at low mass away from the fit line**. One must stress that **factorisation assumption is not implied at this stage**, only the quasi-two body approximation. As to excess of type 2), although the rate to 0^+ is much smaller in Belle than for SL (with respect to 3/2), they do not require a large compensating component. In Babar, a particular strong NR continuum is used, which is destructive, and the rate to resonace is then larger.

Are we facing another manifestations of the many doubts one may have on SL ?

True, nothing definite can be said by non experts as one should also consider the reflexion of the $\pi\pi$ channel, which may absorb some unknowns, etc ....

5 Non resonant continuum ("background" in old terms) and all that

In relation to the latter questions, a general question : should we insist on explaining theoretically NR continuums, since it is very difficult ? The tendency of modern hadronic physics has been to leave more and more aside this difficult task, except for very particular cases such as $\pi\pi$ or $K\pi$ scattering. One concentrates on resonances and, still more specifically, on their decay properties. A further step could be to concentrate on narrow states.

Anyway, there is not much of theory on this question, at least not of safe theory. Soft pion theorems call for extrapolations and corrections (unitarity corrections, higher order expansion..).

One has to be aware that, much like for baryonic resonances, "non resonant" could include contributions from the remote states, which indeed act as a non resonant continuum in the vicinity of the resonance.

5.1 Virtual D^*

Attention must be drawn to this question, because it is included in the background of Babar $D\pi$ events (SL), and not in Belle (which consider it only as an alternative to 0^+ in the signal. Where is the truth ? What is the magnitude of this contribution ? Is it fitted or predicted ? (from $g_{D^*D\pi}$ coupling)

6 Spectroscopy of D^{**}, $L = 1$; phase of scattering

It seems very encouraging that the two lattice methods, with or without inclusion of four quarks operators, converge and explain the experimental low mass of the 0^+ : 2300 GeV. A useful proposition could be that one abandons the misleading notation $D_0(2400)$

One important point has been the first results on $I = 1$ phase. Further steps can be envisaged : to have a more detailed prediction of $D\pi$ scattering phase, and to extract it experimentally from $B \to D\pi\pi$. The question would be : is there any serious shift with respect to the Breit-Wigner forms at low mass?

7 Spectroscopy of $D_s, L = 1$

One has also learned that the discrepancy with GI quark model in the location of D_{sJ} is not solved, in contrast to D^{**}. At least the $1^+_{1/2}$ is still predicted much too high. The more accurate method gives also a too high result for D_{s0}.

Although there is little doubt that these are $\bar{q}q$ states, could it be that rescattering effects alter the spectrum ? This is why, in my personal opinion, (amateuristic,)it could be worth considering also in this case the method including scattering states.

Another reason for doing this is the fact that the mixing of 1^+'s has been found to have a large imaginary component, unlike for D^{**} : this is an indication of large cupling channel effects.

8 Radial excitations

A lot of interesting discussions are in course, and experimantal tests are possible.

8.1 Missing pions

It has been suggested that states decaying into $D^{**}_{1/2}\pi$ could enhance the rate into $D^{**}_{1/2}$ if the additional pion is soft and then missed. In this case, this should be included in the error on the rate.

8.2 $B \to D^{(*)'}$

Once more, in theory, $B \to D^{(*)'}$ is presently accessible only to QM. In our opinion, whatever the wave functions, and with many variations on the transition model, we find much smaller BR than Galkin et al.. to the first excitation. **We doubt their calculation**. Our BT result is in agreement with the sum rules. As suggested, sum rules (curvature sum rule) can also be used roughly to bound from above the contribution of radial excitations if they are sufficiently regular ($m_Q \to \infty$). Once more, this suggest small contributions of the radial excitations (from their slope at $m_Q = \infty$)

As to experiment, it has been underlined that they are rather narrow states, so that they should be seen if their BR were sizable. Babar has attempted to see them in NL class I and found no signal.

Note added : D. has calculated the contribution of $D^{(*)'}$ in class I, expected from Galkin and finds it much to large to be accomodated by the data.

Patrick has given other arguments tending to the conclusion that the contribution in SL should be small

8.3 $B \to D^{(*)'}\pi$ in class III of NL

Lattice calculation of annihilation constants $f_{D^{(*)'}}$ in course allows to evaluate class III $B \to D^{(*)'}\pi$ through $D^{(*)'}$ emission -pion emission being presumably small for the above reason-. This could be tested experimentally.

8.4 OPE

Sums over transition to radial excitations can be calculated through OPE. It would be interesting to confront this with QM and other estimates.

Bibliography de "Proposal", à compléter

References

[1] Memorino on the '1/2 versus 3/2 puzzle' in $\bar{B} \to \ll \bar{\nu} X(c)$. I.I. Bigi, B. Blossier, A. Le Yaouanc, L. Oliver, O. Pene, J.-C. Raynal, A. Oyanguren, P. Roudeau. e-Print: hep-ph/0512270

[2] I.I. Bigi, B. Blossier, A. Le Yaouanc, L. Oliver, O. Pene, J.-C. Raynal, A. Oyanguren, P. Roudeau. Memorino on the '1/2 versus 3/2 puzzle' in $\bar{B} \to \ll \bar{\nu} X(c)$: A Year Later and a Bit Wiser. Published in Eur.Phys.J.C52:975-985,2007. e-Print: arXiv:0708.1621 [hep-ph]

[3] New exact heavy quark sum rules. Nikolai Uraltsev. Published in Phys.Lett.B501:86-91,2001. e-Print: hep-ph/0011124

[4] One interesting new sum rule extending Bjorken's to order $1/m_Q$. A. Le Yaouanc, D. Melikhov, V. Morenas, L. Oliver, O. Pene, J.C. Raynal. Published in Phys.Lett.B480:119-128,2000. e-Print: hep-ph/0003087

[5] Lattice measurement of the Isgur-Wise functions $\tau_{1/2}$ and $\tau_{3/2}$. D. Becirevic, B. Blossier, Philippe Boucaud, G. Herdoiza, J.P. Leroy, A. Le Yaouanc, V. Morenas, O. Pene. Published in Phys.Lett.B609:298-308,2005. e-Print: hep-lat/0406031

[6] Dynamical lattice computation of the Isgur-Wise functions tau(1/2) and tau(3/2). By ETM Collaboration (Benoit Blossier et al.). Talk given at 27th International Symposium on Lattice Field Theory (Lattice 2009), Beijing, China, 25-31 Jul 2009. Published in PoS LAT2009:253,2009. e-Print: arXiv:0909.0858 [hep-lat]

[7] Futur calcul reseau a masse finie

[8] Quantitative predictions for B semileptonic decays into D, D* and the orbitally excited D** in quark models a la Bakamjian-Thomas. V. Morenas, A. Le Yaouanc, L. Oliver, O. Pene, J.C. Raynal. Published in Phys.Rev.D56:5668-5680,1997. e-Print: hep-ph/9706265

[9] Exclusive semileptonic B decays to radially excited D mesons. D. Ebert, R.N. Faustov, V.O. Galkin. Published in Phys.Rev.D62:014032,2000. e-Print: hep-ph/9912357

[10] Semileptonic B decays into charmed p wave mesons and the heavy quark symmetry. Pietro Colangelo, Giuseppe Nardulli, Nello Paver. Published in Phys.Lett.B293:207-215,1992.

[11] Universal tau(1/2)(y) Isgur-Wise function at the next-to-leading order in QCD sum rules. P. Colangelo, F. De Fazio, N. Paver. Published in Phys.Rev.D58:116005,1998. e-Print: hep-ph/9804377

[12] Semileptonic B decays into excited charmed mesons from QCD sum rules. Yuan-ben Dai, Ming-qiu Huang. Published in Phys.Rev.D59:034018,1999. e-Print: hep-ph/9807461

[13] Theoretical analysis of $\bar{B} \to D^{**}\pi$ decays. M. Neubert. Published in Phys.Lett.B418:173-180,1998. e-Print: hep-ph/9709327

[14] The Decays $\bar{B} \to D^{**}\pi$ and the Isgur-Wise functions $\tau(1/2)(w)$, $\tau(3/2)(w)$. F. Jugeau, A. Le Yaouanc, L. Oliver, J.-C. Raynal, Published in Phys.Rev.D72:094010,2005. e-Print: hep-ph/0504206

[15] Study of $B^0 \to anti{-}D^{(*)}\ {}^0 pi{+}pi{-}$ decays. By Belle Collaboration (K. Abe et al.). BELLE-CONF-0460, ICHEP-04-11-0710, Dec 2004. 24pp. Presented at 32nd International Conference on High-Energy Physics (ICHEP 04), Beijing, China, 16-22 Aug 2004. e-Print: hep-ex/0412072

[16] K. Nakamura et al. (Particle Data Group), J. Phys. G 37, 075021 (2010) and 2011 partial update for the 2012 edition.

[17] B. Aubert *et al.*, BaBar Collaboration, Phys. Rev. **D74** 031103R, 2006.

[18] W.Bardeen, E. Eichten and C. Hill, hep-ph/0305049.

[19] S. Godfrey, hep-ph/0305122.

[20] http://www.slac.stanford.edu/xorg/hfag/index.html

[21] C. Schwanda *et al.*, Belle Collaboration, Phys. Rev. **D78** 032016, 2008.

[22] P. del Amo Sanchez *et al.*, BaBar Collaboration, Phys. Rev. Lett. **107**041804, 2011.

[23] K. Abe *et al.*, Belle Collaboration, Phys. Rev. **D69** 112002, 2004.

[24] B. Aubert *et al.*, BaBar Collaboration, Phys. Rev. **D79** 112004, 2009.

[25] K. Kuzmin *et al.*, Belle Collaboration, Phys. Rev. **D76** 012006, 2007.

[26] B. Aubert *et al.*, BaBar Collaboration, Phys. Rev. **D74** 012001, 2006.

[27] V. Balagura *et al.*, Belle collaboration, Phys. Rev. **D77** 032001, 2008; hep-ex/0709.4184.

[28]