BABAR Analysis Document 537
Version 2
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Tagging using $B \to D\ell\nu(X)$ decays.

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Abstract

We present a description of tagging using $B \to D\ell\nu(X)$ decays in *BABAR* . This tagging technique provides a flexible, semi-exclusive reconstruction method which has proved useful in rare decay analyses where missing energy is present, usually in the form of neutrinos. The tagging technique provides a high efficiency and good purity. This note outlines the reconstruction of $B \to D\ell\nu(X)$ decays, tagging efficiency and usefulness of such a technique for tagging charged and neutral B mesons. Appendices include information about the $B \to D\ell\nu(X)$ skim in CM2 and updated information regarding *BToDlnuXUser*.

Contents

Note To Reader

This is version #2 of BAD 537. We have included some major sections since the first version. There are two appendices, the first documents the $B \to D\ell\nu(X)$ skim in the new computing model and the second describes the code included in the *BToDlnuXUser* package. The main reason for uploading this version is the documentation of the skim. This is currently the most important issue and so we wanted something uploaded that users could look at and comment on.

The rest of the document remains, for the most part, unchanged and so there are places where the information about the skim and information describing $B \to D\ell\nu(X)$ tags used in current analyses are in contradiction. Please bear with us on this matter. We intend to upload subsequent versions with more consistent documentation, more updated plots and added description soon.

1 Introduction

The high luminosities and large data sets achieved at the B-factories, provide an oppurtunity to search for and analyse many rare decays that would be otherwise inaccessible. Since the $\Upsilon(4S)$ resonance decays exclusively to $B\overline{B}$ pairs, the need to tag the flavour and reconstruct the decay products of one of the B mesons in order to study the properties of the other B decay is apparent. This is a necessity when searching for rare decays in which the signal contains a considerable amount of missing energy. To enable a high efficiency search for such decay modes, the $B \to D\ell\nu(X)$ tagging technique has been developed and used in analyses such as the search for $B^+ \to K^+\nu\overline{\nu}$ [1,2] and $B^+ \to \tau^+\nu$ [3]. However, this technique may find a broader use in other analyses and in validating complimentary tagging techniques.[1]

To tag B^- candidates we reconstruct the decay $B^- \to D^0\ell^-\overline{\nu}$. The ℓ denotes either an electron or a muon. After imposing kinematic requirements on the D^0-ℓ combination, the X is usually either nothing or a soft transition pion or photon from a higher mass charm state. The subsequent D meson decay is reconstructed as either $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$ or $D^0 \to K^-\pi^+\pi^0$. These D^0 decay modes are chosen since they provide both the highest statistics hadronic decay modes and they are the cleanest. Neutral modes are studied via the $\overline{B}^0 \to D^+\ell^-\overline{\nu}$ decay and the subsequent charged D meson decay, $D^+ \to K^-\pi^+\pi^+$. Although we do not require the reconstruction of a $D^{*+}\,\ell^-\overline{\nu}$, if an acceptable D^{*+} candidate can be formed by combining a found D^0 with a low momentum charged pion, it is used in place of the D^0 candidate. If an acceptable D^{*+} candidate can be reconstructed this is considered a suitable $\overline{B}^0$ tag. Using these methods, missing particles in the tag B are not a problem provided that the detected particles are properly assigned. In this respect this method can be thought of as a semi-exclusive reconstruction technique.

This note is intended to provide a description of $B \to D\ell\nu(X)$ tagging, how it has already been applied in *BABAR* and to offer examples as to how users may execute jobs to utilise the tagging algorithms themselves. We shall begin with a discussion of the reconstruction and outline the various options available to exploit through this method. A set of sample selection criteria will be outlined that have been applied to a specific analysis [1] however the emphasis will be placed on the broader context in which the technique itself can be used and examples are given only as a guide to possible applications. Data/Monte Carlo comparisons are shown and the tagging efficiency for a given set of constraints is calculated.

A section is also devoted to the process of "double-tagging", where both B's in the $B\overline{B}$ pair decay via $B \to D\ell\nu(X)$. The high reconstruction efficiency provides a large sample of such events which are useful for extracting quantities pertinent to an analysis, specifically in the context of systematic errors.

Examples of code and how to run an analysis job in the most recent release (currently `analysis-13b` at time of writing) are given in a collection of appendices. A description of the *BToDlnuXUser* package is provided in appendix B. All $D\ell\nu(X)$ candidates are stored along with information about their daughter particles (tracks, neutrals). Lists of composites

[1] Herein we will refer to a reconstructed semi-leptonic decay as the "tag" B meson. There has been some contention regarding this nomenclature. It is hoped that this wording will elucidate the need to reconstruct one B decay in order to study the properties of a rare B decay where missing energy is present and there are limit kinematic constraints to impose.

(K^0_S, K^0_L, K^{*+}, K^{*0}) are stored along with a collection of event shape variables. Further information is provided in appendix B.

2 Reconstruction Technique

Herein the selection criteria used to select a suitable $B \rightarrow D\ell\nu(X)$ tag will be described. Events are initially chosen via a set of filters and preselectors and suitable composite candidates are taken from relevant lists in the event. One such criteria demands there be a charged lepton within the range $1.0 < \mathrm{p}^* < 2.8$. The user is free to define other preselection criteria such as the number of charged tracks and neutrals in the event in order to both reduce ntuple size and to remove events unlikely to be of interest.

For a $B^- \rightarrow D^0\ell^-\overline{\nu}(X)$ candidate to be formed a suitable D^0 must be reconstructed, whereas for $\overline{B}^0 \rightarrow D^{(*)+}\ell^-\overline{\nu}$ a suitable D^+ or D^{*+} candidate must be reconstructed. Table 1 gives the nominal PDG [4] D^0 mass and the respective branching fractions for the modes considered. The D^0 modes that are considered in this reconstruction technique are shown in table 2. Note that in tables 1, 2 and 3 we include the $D^0 \rightarrow K^0_s\pi^+\pi^-$ mode whereas this is not considered for the results that are presented in section 3. This mode is included for completeness and is already included in the code that is discussed in appendix B. They modes used are combined into the *D0MainLoose* list in *CompositionSequences*, and are defined by the following loose criteria (which are further tightened for our analysis as outlined in table 3):

- $D^0 \rightarrow K^-\pi^+$: pairs of entries in the *GoodTracksVeryLoose* list having an invariant mass within 40 MeV of the nominal D^0 mass.

- $D^0 \rightarrow K^-\pi^+\pi^0$, $\pi^0 \rightarrow \gamma\gamma$: pairs of entries in the *GoodTracksVeryLoose* list combined with an entry from the *pi0DefaultMass* list having an invariant mass within 70 MeV of the nominal D^0 mass.

- $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$: sets of four entries from the *GoodTracksVeryLoose* list with an invariant mass within 40 MeV of the nominal D^0 mass.

D^+ candidates for $\overline{B}^0 \rightarrow D^+\ell^-\overline{\nu}$ reconstruction are used in only one mode:

- $D^+ \rightarrow K^-\pi^+\pi^+$: three entries in the *GoodTracksVeryLoose* list having an invariant mass within 40 MeV of the nominal D^- mass.

The mass ranges and input lists given in the above definitions are simply the defaults that are included in put in the lists themselves. These can be changed by the user in their tcl scripts. As an example in the analyses described in [1,3] the D^0 mass window was loosened in order to study events populating sideband regions in this variable. Note that all invariant masses are calculated with respect to the geometric vertex decay-product tracks.

Different possibilities exist depending on whether the user wishes to tag charged or neutral B.

For B^- tags there are 2 options:

- $B^- \rightarrow D^0\ell^-\overline{\nu}$ or $B^- \rightarrow D^{*0}\ell^-\overline{\nu}$ where $D^{*0} \rightarrow D^0\pi^0/\gamma$.

Table 1: Decay modes represented in composition lists which are used by this event selection. The D^0 mass is that used in the Monte Carlo. For the states which proceed via intermediate resonances ($D^0 \to K^-\pi^+\pi^+\pi^-$ and $D^0 \to K^-\pi^+\pi^0$) the branching ratios are summed over resonant and non-resonant contributions in the Monte Carlo, and include intermediate branching ratio factors for resonance decay into the final state shown in the table.

Parent D mass	Decay Mode	Branching Ratio
	$D^0 \to K^-\pi^+$	3.83%
1.865 GeV/c^2	$D^0 \to K^-\pi^+\pi^+\pi^-$	7.49%
	$D^0 \to K^-\pi^+\pi^0$	13.90%
	$D^0 \to K^0_s\pi^+\pi^-$ ($K^0_s \to \pi^+\pi^-$)	1.35%
1.869 GeV/c^2	$D^+ \to K^-\pi^+\pi^+$	9.1%

Table 2: The selection modules that construct the D^0 modes used to derive the tag-side. Each of these modules appends to the globally accessible list `D0DefaultVtx`.

D Mode	Selection Module
$D^0 \to K^-\pi^+$	`D0ToKPi_DefaultVtx`
$D^0 \to K^-\pi^+\pi^0$	`D0ToKPiPi0_DefaultVtx`
$D^0 \to K^-\pi^+\pi^-\pi^+$	`D0ToK3Pi_DefaultVtx`
$D^0 \to K^0_S\pi^+\pi^+$	`D0ToKsPiPi_DefaultVtx`
$D^+ \to K^-\pi^+\pi^+$	`DcToKPiPi_DefaultVtx`

- The D^0 then subsequently decays. For the purposes of this note only the cleanest hadronic decays of the D^0 will be considered. Therefore we reconstruct D^0 decays to $K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$ and $K^-\pi^+\pi^0$.

For $\overline{B}^0$ tags there are also 2 options:

- $\overline{B}^0 \to D^+\ell^-\overline{\nu}$ or $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}$ where $D^{*+} \to D^0\pi^+/D^+\pi^0$(or γ).
- The D^+ then subsequently decays. The only mode that is considered here is $K^-\pi^+\pi^+$. The D^0 decays considered are the same as those for the B^- tags.

After reconstructing the D^0, we proceed to complete the tag-side by vertexing the D^0 and primary lepton (ℓ) candidates to produce a list of possible $D\ell$ candidates. The final list of $D\ell$ candidates, `BTo(DorDstar)lnuX`, is obtained by combining two lists of candidates:

- `BchToDlnuVTightSignal`, made from:
  - `BchToDlnuVTightElec` (See Table 4)
  - `BchToDlnuVTightMuon` (See Table 4)
- `B0ToDstarlnuVTightSignal`, made from:

Table 3: Mode-level TCL modular parameters for D^0 selection. Depending on the specific D^0 mode, the analysis module takes as an input a number of lists (2, 3 or 4) of potential daughter particles and tries to construct the D^0 candidate from the members of these input lists. The input tracks are vertexed to produce candidates on the single output list, `D0DefaultVtx` for D^0's and one for D^+'s, `DcDefaultVtx`.

TCL Identifier	$K^-\pi^+$	$K^-\pi^+\pi^0$	$K^-\pi^+\pi^+\pi^-$	$K^0_S\pi^+\pi^-$	$K^-\pi^+\pi^+$
kaon input list	`KMicroNotPion`	`KMicroNotPion`	`KMicroNotPion`	`KsDefault`	`KMicroNotPion`
1^{st} pion input list	`GoodTracksVeryLoose`				
2^{nd} pion input list		`pi0AllDefault`	`GoodTracksVeryLoose`		
3^{rd} pion input list			`GoodTracksVeryLoose`		
output list	`D0DefaultVtx`				`DcDefaultVtx`

Table 4: Mode-level TCL modular parameters for selection of $D(e,\mu)\nu$ from $B^{\pm}$decay.

TCL Identifier	`BchToDlnuVTightElec`	`BchToDlnuVTightMuon`
input list	`D0DefaultVtx`	`D0DefaultVtx`
input list	`GoodTracksTight`	`GoodTracksTight`
Use only right–signed combinations?	yes	yes
Minimum lepton p^*	1.0 GeV	1.0 GeV
electron criterion	tight	N/A
muon criterion	N/A	tight
$D\ell$ vertexed?	yes	yes
output list	`BchToDlnuTightElec`	`BchToDlnuTightMuon`

– `B0ToDstarlnuVTightElec` (See Table 5)

– `B0ToDstarlnuVTightMuon` (See Table 5)

D-hadron candidates that enter into these $D\ell$ lists already have a p$^*(D_{\rm had})$ cut of 0.5 GeV $<$ p$^*(D_{\rm had}) <$ 2.5 GeV applied to them. The requirement that the kaon and primary lepton be oppositely charged is made at this level, as illustrated in tables 4 and 5 (*rightSignOnly*). Lists a created using a progressively tighter set of criteria in the *CompBToDlnuSequence* code which is situated in the *CompositionSequences* package. The user can decide which list is most suitable for their need or decide to create a list of their own based on what exists. These changes can be instigated through a correctly constructed TCL sequence.

All $B \to D\ell\nu X$ candidates are stored as output after running over the `BTo(DorDstar)lnuX` list. Hence all overlapping candidates are kept at this stage which can in principle provide many candidates per event. The choice of which candidate is considered as the *best Dl* is made from this list.

Table 5: Mode-level TCL modular parameters for selection of $D^*(e,\mu)\nu$ from B^0decay

TCL Identifier	B0ToDstarlnuVTightElec	B0ToDstarlnuVTightMuon
input list	DstarLoose	DstarLoose
input list	GoodTracksTight	GoodTracksTight
Use only right–signed combinations?	yes	yes
Minimum lepton p^*	1.0 GeV	1.0 GeV
electron criterion	veryTight	N/A
muon criterion	N/A	veryTight
$D^*\ell$ vertexed?	yes	yes
output list	B0ToDstarlnuTightElec	B0ToDstarlnuTightMuon

Table 6: B decay modes considered as tagging candidates. The PDG mass and branching fraction is given for each of the four possibilities.

D meson mass (GeV/c^2)	Decay Mode	Branching Ratio
1.865	$B \rightarrow D\ell\nu X$	1.86%
2.007	$B^+ \rightarrow \overline{D}^{*0}\ell^+\nu$	5.30%
1.869	$B^0 \rightarrow D^-\ell^+\nu$(X)	2.00%
2.010	$B^0 \rightarrow D^{*-}\ell^+\nu$	4.60%

3 Results

We will elucidate the methodology by providing results from a specific analysis that relied heavily on $B \to D\ell\nu(X)$ tags, that of the search for $B^+ \to K^+\nu\overline{\nu}$ [1]. This analysis used a semi-leptonic charged B tag for one of the reconstructed B's and searched the remainder of the event for consistency with the signal mode. Various preselection criteria are imposed to isolate those events of interest in which the signal search was carried out. This set of primordial cuts are shown, mode-by-mode, in table 7. The signal-side track multiplicity is tightened for the final selection to 1 track. Only the best $D\ell$ candidate is chosen in the final selection. Therefore the criteria that constitute the best $D\ell$ candidate need to be defined. In the analysis outlined in [1] the $\cos\theta_{B,D\ell}$ variable (defined later in this section) was used to chose the best $D\ell$. The candidate with $\cos\theta_{B,D\ell}$ closest to zero was used in the search. Although not necessarily the optimal choice this decision was used so as to avoid utilising the D^0 invariant mass distribution in the best $D\ell$ selection. The D^0 mass remains unbiased by making this choice and allows the sidebands of the distribution to be used to estimate (or subtract) background in the signal region. In the analysis described in [3] the D^0 mass of the decay modes considered was used to select the best $D\ell$. The PDF from each D^0 decay mode was created and the one reconstructed $D\ell$ candidate with the largest PDF value was chosen as the best $D\ell$. Otherwise the cuts outlined in table 7 constitute a major part of the final selection criteria of this analysis. Only $D\ell$ candidates passing all of those criteria are considered when choosing the best $D\ell$. After imposing these criteria the only other handles to apply are on the signal side, and they are limited. We require exactly one track, consistent with being a kaon with momentum above 1.5 GeV. The remaining neutral energy in the calorimeter need be less than 500 MeV. This constitues almost all of the cuts with only two others criteria applied (a shape cut using the cosine of the angle between the signal candidate kaon and the lepton used in the tag rejects continuum decays and a cut on the number of neutral IFR clusters removes some background events containing K_L^0's). Of course these are the specific selection criteria for the analysis discussed here and are not entirely dependent on changes to those cuts on the tag-side of the event.

The majority of the results shown here will therefore be isolated to tagging charged B's. Some effort will be made in this note to elaborate on the methods of neutral B tagging also although at time of writing this method has yet to be used for 'completed' analysis with *BABAR*[2].

Of the cuts on the tag-side, the cosine of the angle between the direction of the B and the sum of the D and lepton momenta, $\cos\theta_{B,D\ell}$, calculated in the $\Upsilon(4S)$ rest frame is the most stringent in restricting selected events to originating from semi-leptonic B-decays. This angle is not measured directly since there is no handle on the B direction. Instead, the following equation is used assuming the only particle missed in our reconstruction is a massless neutrino,

$$\cos\theta_{B,D\ell} = \frac{(2\,E_B E_{D\ell} - m_B^2 - m_{D\ell}^2)}{2\,|\vec{p}_B||\vec{p}_{D\ell}|}$$

A loose selection is applied to this variable in order to allow for the possibility of missing

[2] Several analyses are underway that could potentially use this tagging method and so as much as possible the methods, techniques and plots that are shown are totally complimentary using a neutral B tag as using a changed B.

Table 7: Final selection criteria for suitably tagged events. Since some criteria are mode dependent the table has been split according to the D decay mode. Note that the D^{*+} reconstruction does not apply to D^+ decays.

	$D^0 \to K^-\pi^+$	$D^0 \to K^-\pi^+\pi^+\pi^-$	$D^0 \to K^-\pi^+\pi^0$	$D^+ \to K^-\pi^+\pi^+$
N J/ψ	0	0	0	0
P(D Vtx)	$> 1\times10^{-3}$	$> 5\times10^{-3}$	$> 5\times10^{-3}$	$> 5\times10^{-3}$
P($D\ell$ Vtx)	$> 1\times10^{-3}$	$> 5\times10^{-3}$	$> 5\times10^{-3}$	$> 5\times10^{-3}$
$D\ell$ mass(GeV)	> 3.0	> 3.0	> 3.0	> 3.0
D momentum(GeV)	> 0.5	> 0.5	> 0.5	> 0.5
D^{*-} mass window (MeV)	$\pm$ 3	$\pm$ 3	$\pm$ 3	-
$\cos\theta_{B,D\ell}$ window	-2.5 $\to$ 1.1	-2.5 $\to$ 1.1	-2.5 $\to$ 1.1	-2.5 $\to$ 1.1
$p^*_{\text{tag lepton}}$ (GeV)	> 1.0	> 1.0	> 1.0	> 1.0
D mass window	$\pm\, 3\sigma$	$\pm\, 3\sigma$	$\pm\, 3\sigma$	$\pm\, 3\sigma$
N Track remaining	3+2$V0$	3+2$V0$	3+2$V0$	3+2$V0$

Table 8: Measurements of the tagging efficiency using the three $B^- \to D^0\ell^-\overline{\nu}\, X$ decay channels

Tag decay channel	Tag efficiency
$D^0 \to K^-\pi^+$	$(1.57 \pm 0.08)\times10^{-3}$
$D^0 \to K^-\pi^+\pi^+\pi^-$	$(1.52 \pm 0.07)\times10^{-3}$
$D^0 \to K^-\pi^+\pi^0$	$(2.29 \pm 0.09)\times10^{-3}$
Total	$(5.38 \pm 0.14)\times10^{-3}$

a soft particle when reconstructing the tag. Such events would normally give a negative $\cos\theta_{B,D\ell}$. The non-physical upper bound at 1.1 is made to allow for resolution effects in the calculation of this quantity.

As can be seen from figure 2 there is good signal-to-noise in each of the three D^0 decay modes considered when the other B decays into a low multiplicity final state. This allows the use of modes that would otherwise not have sufficient purity to be used in this way (note that this is particularly true for the $D^0 \to K^-\pi^+\pi^0$ mode). The ability to use these modes greatly increases the reconstruction efficiency which will in turn improve the sensitivity of an analysis that employs this technique. The high reconstruction efficiency for a technique that semi-exclusively reconstructs one of the B meson decays in order to search for an exclusive final state from the other B decay can be seen from table 8. Indeed the efficiencies quoted in table 8 are improved upon when the criteria imposed on the $p^*_{\text{tag lepton}}$ is changed from greater than 1.3 GeV to 1.0 GeV. Further improvements can be made by considering other D decay modes (such as $D^0 \to K^0_s\pi^+\pi^-$) and further relaxing selection criteria. As can be seen from figure 2 the off-peak contribution is flat throughout the whole region of the D^0 invariant mass distribution. This enables a sideband subtraction to be performed which can remove any off-peak contributions from potentially contributing to the signal yield extracted in a search using a blind analysis strategy.

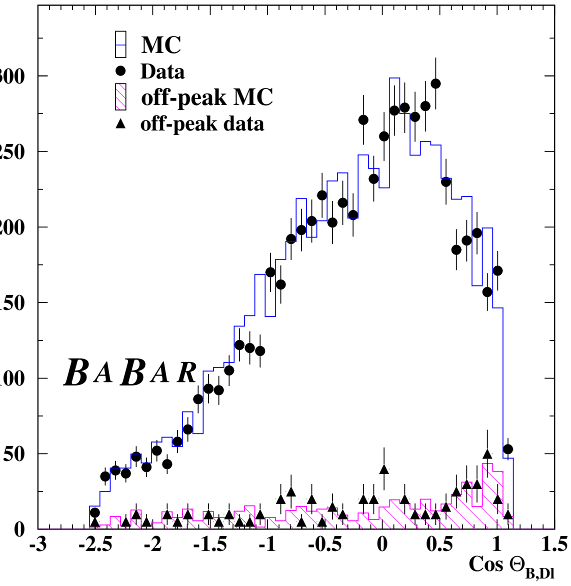

Figure 1: A plot of the $\cos\theta_{B,D\ell}$ for all modes using off-peak MC ($C\overline{C}$, $\tau^+\tau^-$, uds), all MC ($B\overline{B}$ and off-peak MC) with off-peak data and on-peak data overlayed. The off-peak contributions are scaled to the on-peak data luminosity.

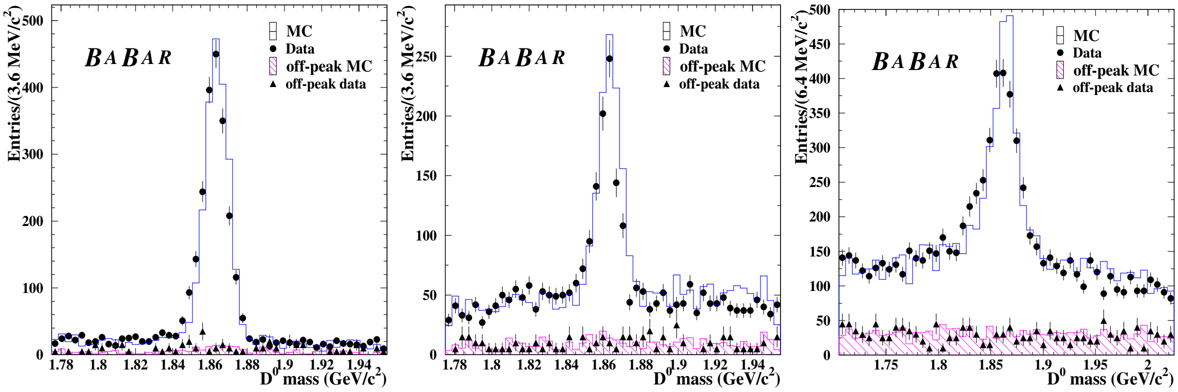

Figure 2: D^0 mass distribution with sideband regions included. Each plot $D^0 \rightarrow K^-\pi^+$ (left), $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$ (center), $D^0 \rightarrow K^-\pi^+\pi^0$ (right)) is made using off-peak MC ($C\overline{C}$, $\tau^+\tau^-$, uds), all MC ($B\overline{B}$ and off-peak MC) with off-peak data and on-peak data overlayed. The off-peak contributions are scaled to the on-peak data luminosity.

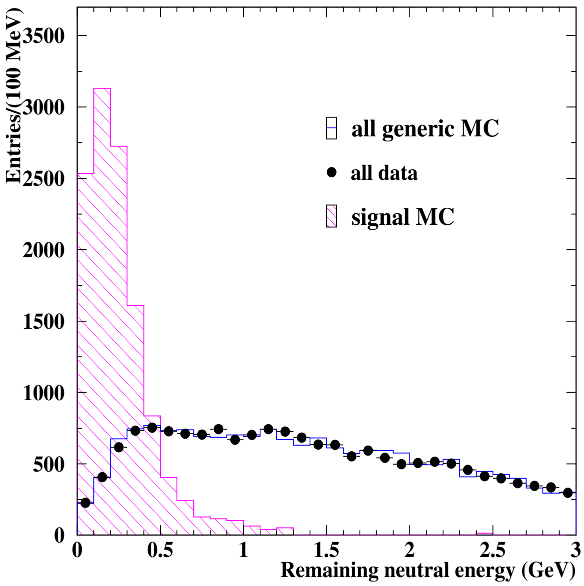

Figure 3: Total left over neutral energy for $B^+ \to K^+\nu\overline{\nu}$ signal Monte Carlo, with scaled MC and data overlayed.

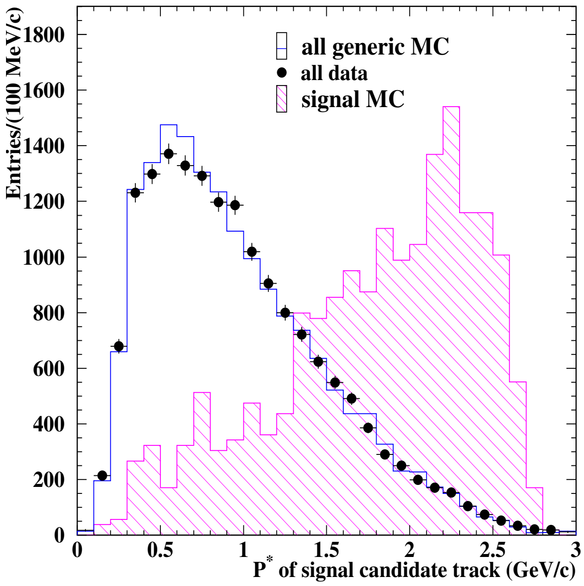

Figure 4: Momentum in the center-of-mass frame for the remaining kaon candidate for $B^+ \to K^+\nu\overline{\nu}$ signal Monte Carlo , with scaled MC and data overlayed.

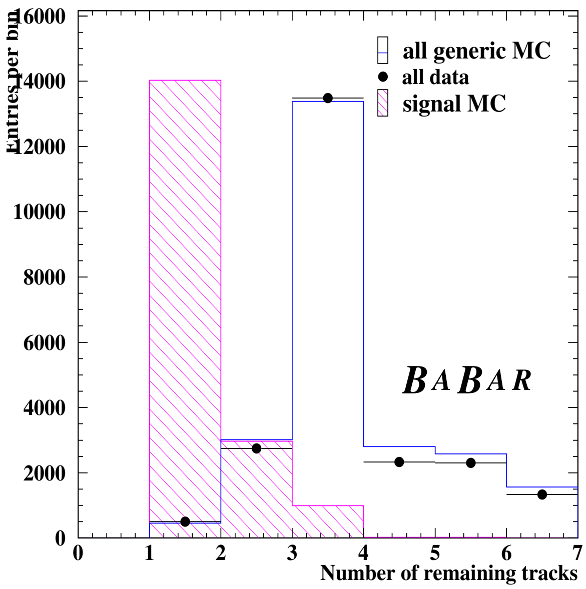

Figure 5: Number of tracks remaining in the event after removal of the tag candidate. Signal MC, all MC and all data are overlayed.

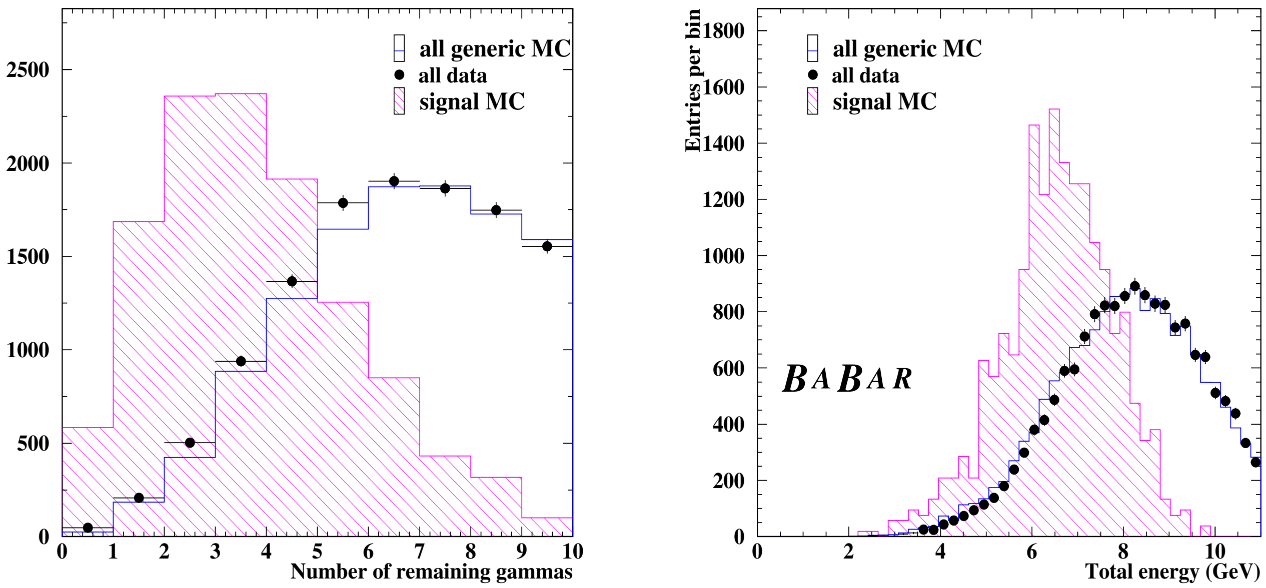

Figure 6: Number of gammas remaining after removal of the tag candidate, and the total energy in the event. Signal MC, all MC and all data are overlayed.

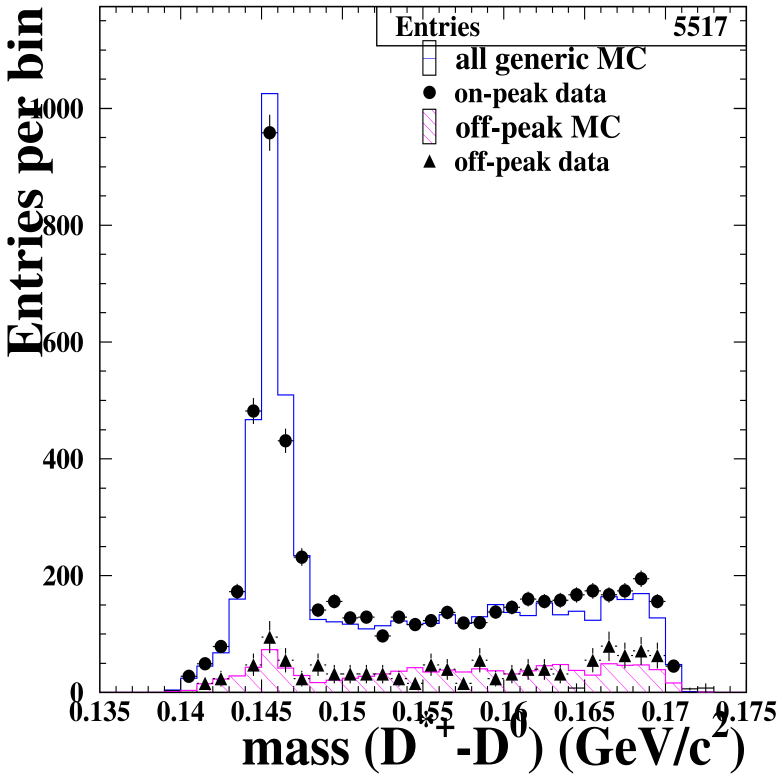

Figure 7: The difference between the reconstructed D^{*+} mass and the daughter D^0 mass. For true D^{*+} candidates the should be a sharp peak around 0.1454 GeV, as seen.

4 Double-tagged Events

The high tagging efficiency in the $B^- \to D^0 \ell^- \overline{\nu}\ X$ channel results in a sizeable number of events where both B decays are reconstructed in this mode and such events will be refered to herein as double-tagged events. These double-tagged events can be used to compare the data and simulation in various ways, as will be discussed below.

The selection of double-tagged events proceeds as follows. Given the superior signal to noise ratio in the $D^0 \to K^-\pi^+$ mode, the double tags studied are required to include at least one decay in this mode, hereafter referred to as a $(K^-\pi^+)\ell$ candidate. In each event we search for two distinct, independent (non-overlapping) double-tagged events, one of which must be a $(K^-\pi^+)\ell$ candidate. Hence, only two candidates that do not share any particles are considered. If more than two $D\ell\nu$ candidates exist in an event the two with the smallest value of $|cos\theta_{\mathrm{B-(K^-\pi^+)\ell}}|$ are retained. Although one of the B's must be reconstructed in the $(K^-\pi^+)\ell$ mode the other B decay is searched for in any of the 3 D^0 decay modes considered in this analysis. By considering the $(K^-\pi^+)\ell$ candidate as our "signal" mode in this case we are able to extract a $B^- \to D^0 \ell^- \overline{\nu}\ X$ tagging efficiency from both data and simulation. Using the data and full simulation allows the tagging efficiency to be calculated in a more realistic environment than is permitted by using signal Monte Carlo alone. Such a calculation then allows us to weight the tagging efficiency from signal MC accordingly to account for any data/MC differences. Upon reconstruction of a double-tagged event further additional restrictions can then be applied. The number of charged tracks in the event that are not assigned to either $B^- \to D^0 \ell^- \overline{\nu}\ X$ candidate can be studied or simply set to zero. Setting the number of unassigned tracks to zero mimics the criteria imposed in searches such as that for $B^+ \to K^+ \nu \overline{\nu}$.

The number of expected double tags is calculated, assuming the yields are dominated by B^+B^- events, as follows:

$$N_{\mathrm{D\ell-(K^-\pi^+)\ell}} = N_{\mathrm{B^+B^-}} \left(\varepsilon_{\mathrm{(K^-\pi^+)\ell}} * (2\varepsilon_{\mathrm{D\ell}} - \varepsilon_{\mathrm{(K^-\pi^+)\ell}}) \right) \ .$$

Using the efficiencies calculated using the signal MC in the $B^+ \to K^+ \nu \overline{\nu}$ analysis one would expect 3394 events in the whole B^+B^- Monte Carlo sample, 3302 events were measured. From these measurements the tagging efficiency can be calculated as follows:

In Generic B^+B^- decays:

$$\frac{(K^-\pi^+)\ell \ \ \mathrm{vs} \ \ D\ell\nu}{(K^-\pi^+)\ell \ \ \mathrm{vs} \ \ \mathrm{generic}\ B} = \frac{3302}{484292} = 6.82 \pm 0.12 \times 10^{-3}$$

In 2000 onpeak data:

$$\frac{(K^-\pi^+)\ell \ \ \mathrm{vs} \ \ D\ell\nu}{(K^-\pi^+)\ell \ \ \mathrm{vs} \ \ \mathrm{generic}\ B} = \frac{352}{64385} = 5.47 \pm 0.29 \times 10^{-3}$$

$$\begin{aligned} N_{\mathrm{data\ double\ tag}} &= ??\pm?? \\ N_{\mathrm{MC\ double\ tag}} &= ??\pm?? \end{aligned}$$

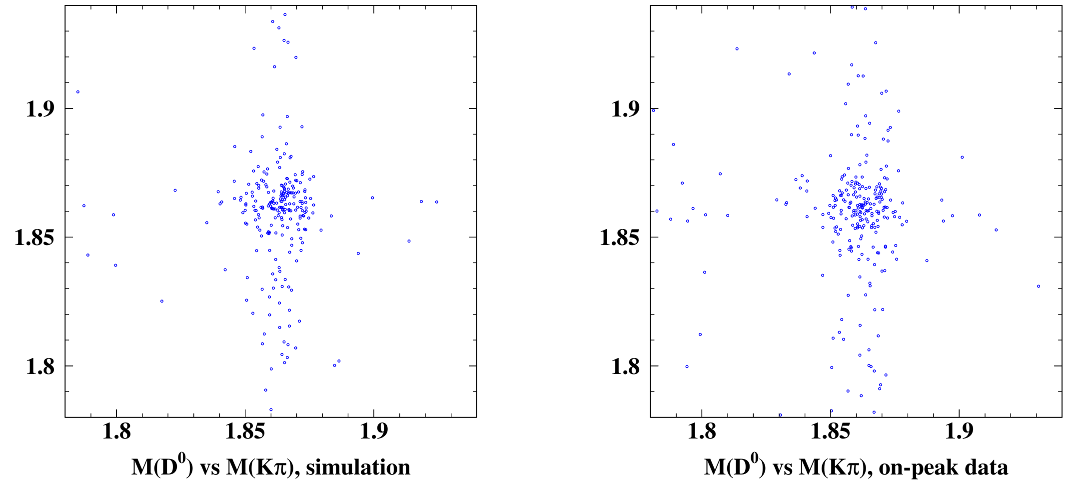

Figure 8: D^0 mass scatter plot for double tags.

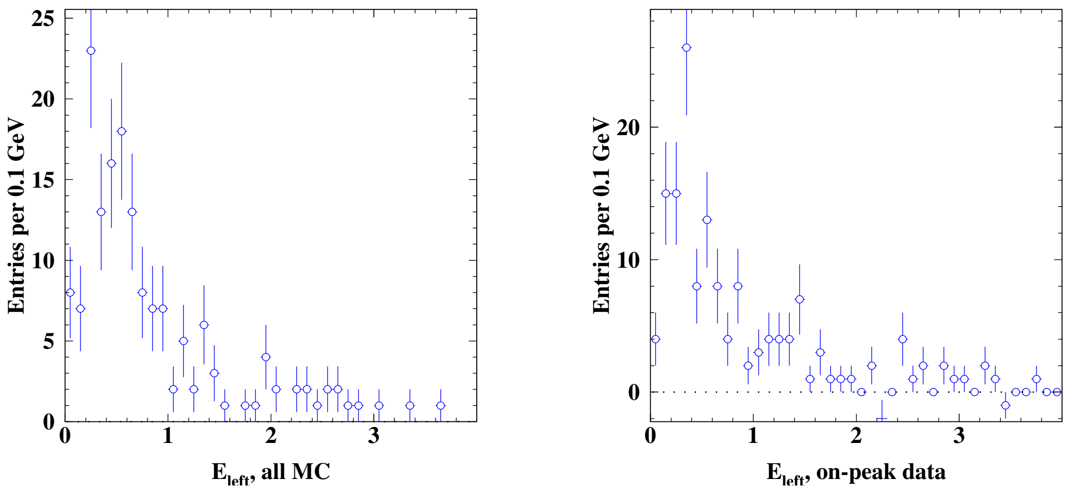

Figure 9: Double tag plots of the amount of remaining neutral energy in the EMC.

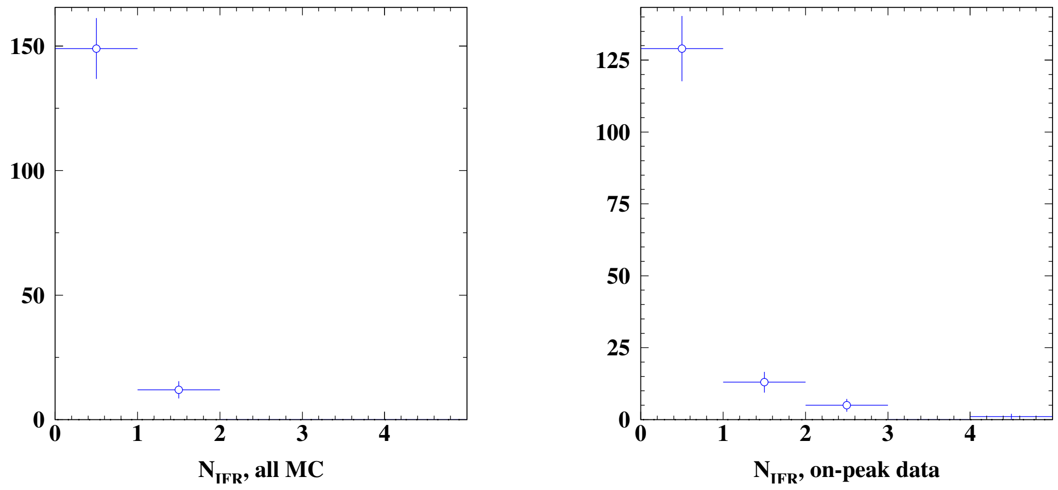

Figure 10: Double tag plots of the number of remaining neutral IFR clusters.

5 Summary

We have studied tagging both charged and neutral B decays in the $B \to D\ l\nu$ mode. We find that this semi-exclusive approach provides a high efficiency and can be used to search for rare decays in a high statistics subset of a large $B\overline{B}$ data sample.

With the size of the *BABAR* dataset continuing to increase, high efficiency tagging methods will play a prominent role in the search and discovery potential of rare B decay modes. A robust semi-leptonic method will be useful for the study of $B^+ \to \tau^+\nu$, $B^+ \to K^+\nu\overline{\nu}$, $\overline{B}^0 \to \overline{K}^{*0}\nu\overline{\nu}$, $B^0 \to \nu\overline{\nu}$ [5]. Such a method may potentially be used to study exclusive semi-leptonic decays in the recoil of the tagged B. Decays such as $B^- \to \pi^0\ell^-\overline{\nu}$, $B^- \to \rho\ell^-\overline{\nu}$ or other exclusive modes studying the quark level sub processes $b \to u\ell\nu$ and $b \to c\ell\nu$ may prove fruitful to study in this way.

Indeed any final state where missing energy is present, usually in the form of neutrinos, or that is difficult to reconstruct exclusively due to unreconstructed particles (decays with undetected K^0_L for example) or particles lost from the acceptance may be studied using this method.

References

[1] C. Hearty, P. D. Jackson, R. V. Kowalewski, "Search for $B^+ \to K^+\nu\overline{\nu}$ using semi-leptonic tags", *BABAR* Analysis Document #293.

[2] C. Hearty, P. D. Jackson, R. V. Kowalewski, "Search for $B^+ \to K^+\nu\overline{\nu}$ using semi-leptonic tags", *BABAR* Analysis Document #416.

[3] M. Datta, S. Sekula, "A search for $B^+ \to \tau^+\nu$ using semi-leptonic tags", *BABAR* Analysis Document #417.

[4] K. Hagiwara et al., Physical Review **D 66**, 0100001 (2002).

[5] J. Albert, "Supporting document for $B^0 \to$ invisible analysis using semileptonic tag" *BABAR* Analysis Document #525.

[6] "http://www.slac.stanford.edu/BFROOT/www/doc/workbook/workbook.html"

A A skim for $B \to D\ell\nu X$ in CM2

A.1 Skim definition

In order to take advantage of the new computing model to be used within the collaboration a number of skims have been outlined to provide users with a means of accessing events. One such skim will be based on $B \to D\ell\nu X$ semi-leptonic decays. This skim will replace the old ISL (initial state lepton) filtered events for some analyses and for others simply provide an interface to select events of interest. The charge of the skim is to facilitate usage for two distinct types of analyses:

- "Recoil" analyses, where users require one B be reconstructed in order to study the decay properties of the other B in the event
- Semileptonic studies, where one may want just one particular decay mode with a high purity i.e. $D^*\ell\nu$ for measurements of $\mathrm{V_{cb}}$ and/or related form factors.

All events pertaining to the study of these two types of analyses should be included in the skim. Due to the amount of information stored as part of this skim it will naturally be quite large in size. Tests have shown that for very loose criteria about 20% of generic $B\overline{B}$ MC and $\sim$2% of onpeak data will be selected by the skim. *User data* information is produced to reduce the number of events to read and the CPU time for some users. This should allow those users interested in a small subset of the total skim, such as a specific exclusive decay channel, to select a smaller sample of events of particular relevance to them. Tables 10, 11 and 12 provide the lists and selection criteria used in the definition of the $B \to D\ell\nu X$ skim. A new module has been created in *CompositionSequences* named *CompBToDlnuProdSequence*. This either refines existing lists or creates new lists with the necessary criteria applied for events to be selected in the skim. Specific K^0_S, D^0, D^+ and D^* lists are used with loose enough criteria to satisfies all users wishing to take the skim as a basis for their analysis. The composite D mesons are then combined into lists that contain all relevant modes and subsequently charged and neutral B lists are formed by combining these composites with charged leptons. For the most part these lists provide a loose framework to accomodate various possibilities for different analyses. The data will still need to be reduced further using the skim as a starting point. In each event there will be at least one suitable $D\ell\nu$ candidate that satisfies the given criteria, although in many events there will be more than one (the average number of $D\ell\nu$ candidates/event is $\sim$10). When there are multiple candidates one will need to use some criteria to select what is considered the "best candidate" (referred to herein as `bestDl`).

For the purposes for B tagging the $\cos\theta_{B,D\ell}$ and $D^{(*)}$ mass are used in a similar way to that of m_{ES} and ΔE in the "semi-exclusive" Breco tagging. However selecting the best candidate using the D mass is not plausible since we wish to leave this quantity unbiased to allow sideband subtraction. Therefore we choose to select the best candidate per mode based on the smallest $|\cos\theta_{B,D\ell}|$. If, as is often the case, many modes have candidates we rank them by purity (in generic $B\overline{B}$ MC) and select the most pure mode. For D^0 decays

Table 9: The selection modules that construct the D^0 modes used to derive the D candidates used in the skim.

D Mode	Selection Module
$D^0 \to K^-\pi^+$	D0ToKPiLooseBToDlnu
$D^0 \to K^-\pi^+\pi^0$	D0ToKPiPi0LooseBToDlnu
$D^0 \to K^-\pi^+\pi^-\pi^+$	D0ToK3PiLooseBToDlnu
$D^0 \to K^0_S\pi^+\pi^+$	D0ToKsPiPiLooseBToDlnu
$D^+ \to K^-\pi^+\pi^+$	DcToKPiPiLooseBToDlnu
$D^+ \to K^0_S\pi^+$	DcToKsPiLooseBToDlnu

Table 10: Mode-level TCL modular parameters for D^0 selection. Depending on the specific D^0 mode, the analysis module takes as an input a number of lists (2, 3 or 4) of potential daughter particles and tries to construct the D^0 candidate from the members of these input lists. The input tracks are not vertexed at this point and the single output list, `D0AllBToDlnu` is written.

TCL Identifier	$K^-\pi^+$	$K^-\pi^+\pi^0$	$K^-\pi^+\pi^+\pi^-$	$K^0_S\pi^+\pi^-$
kaon input list	KMicroNotPion	KMicroNotPion	KMicroNotPion	KsDefaultBToDlnu
1^{st} pion input list	GoodTracksVeryLoose			
2^{nd} pion input list	-	pi0AllDefault	GoodTracksVeryLoose	
3^{rd} pion input list	-	-	GTVL	-
output list	D0AllBToDlnu			

Table 11: Mode-level TCL modular parameters for D^+ selection. Depending on the specific D^+ mode, the analysis module takes as an input a number of lists (2 or 3) of potential daughter particles and tries to construct the D^+ candidate from the members of these input lists. The input tracks are not vertexed at this stage and the single output list, `DcAllBToDlnu` is written.

TCL Identifier	$K^-\pi^+\pi^+$	$K^0_S\pi^+$
kaon input list	KMicroNotPion	KsDefaultBToDlnu
1^{st} pion input list	GoodTracksVeryLoose	
2^{nd} pion input list	GoodTracksVeryLoose	-
output list	DcAllBToDlnu	

Table 12: Mode-level TCL modular parameters for D and lepton selection. These are criteria that must be satisfied for a suitable $D-\ell$ candidate. The output list contains all $D^0\ell$, $D^+\ell$, $D^{*0}\ell$ and $D^{*+}\ell$ satisfying these constraints. All candidates are combined into one output list, `BToDorDstarlnuAll`.

Cuts	$K^-\pi^+$	$K^-\pi^+\pi^0$	$K^-\pi^+\pi^+\pi^-$	$K^0_S\pi^+\pi^-$	$K^-\pi^+\pi^+$	$K^0_S\pi^+$
D mass(MeV/c^2)	±60	±100	±60			
K^0_S list	-			KsBToDlnu	-	KsBToDlnu
K^0_S flight length cut(cm)	-			0.2	-	0.2
p*lepton(MeV/c)	800					
electron criterion	PID likelihood					
muon criterion	tight					
D^0 vertexed?	no					
$D\ell$ vertexed?	no					

the $K^-\pi^+$ is clearly the purist while the others are all of similar purity. We choose to rank in the following order: $K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, $K^-\pi^+\pi^0$ and $K^0_S\pi^+\pi^-$. This choice is motivated by the good mass resolution in $K^-\pi^+\pi^+\pi^-$ decays and the low yield in $K^0_S\pi^+\pi^-$ decays. For D^+ decays we are only considering two modes and choose to rank them as follows: $K^-\pi^+\pi^+$ then $K^0_S\pi^+$. In making this consideration we were motivated primarily by the significantly higher yield in the $K^-\pi^+\pi^+$ mode since the purities are similar.

All of these charged and neutral D decay modes are considered when studying the decay of a D daughter of a D^*. D^*'s are considered in both charged ($D^{*+}\to D^0\pi^+$ and $D^{*+}\to D^+\pi^0$) and neutral ($D^{*0}\to D^0\pi^0$) modes. The $D^{*0}\to D^0\gamma$ transition is not clean enough to be useful in our opinion. Loose selection criteria are applied to the D^*'s and they are combined in the same `CompBToDlnuProdSequence` module as the D lists are defined. The output lists contain all $D^0\ell$, $D^+\ell$, $D^{*0}\ell$ and $D^{*+}\ell$ satisfying these imposed criteria. All candidates are combined into one output list, `BToDorDstarlnuAll`. This list is used as input to the FilterTools module `BToDlnuXFilter`. Therefore, the majority of the pertinent selection is done in CompositionSequences. The skim code is described in more detail in section A.3.

A.1.1 User Data

These pieces of information should allow users to select a specific decay mode or type of decay modes with ease and if applicable use the persisted β candidates to decide which $B\to D\ell\nu X$ decay to use (see section A.2.1). Operationally it is necessary to persist all β candidates and so the user data that we were considering storing has been modified to suit this. Accessing kinematic quantities from these candidates is simple by using the BtaSemilepCand module in BetaTools. It is proposed that the `user data` will allow both a reduction in the number of events to be read in and a reduced CPU usage for some analyses. There are on avergage 10 $D^{(*)}\ell$ candidates per event and all candidates will now be persisted. The user can select which modes they are interested in and subsequently use the kinematic quantities to further reduce their data set. `User data` can be categorized in two types, event data and candidate

data.
Event data will be stored to answer the question:
Was the decayMode, "X", found in the event ?
Exclusive analyses interested in only a specific decay mode can then select the subset of events they wish to study by scanning this variable. A further piece of event data will be stored in the form of the decayType. This will tell users if there is a $D^0\ell^-\overline{\nu}$, $D^{*0}\ell^-\overline{\nu}$, $D^+\ell^-\overline{\nu}$ or $D^{(*)+}\ell^-\overline{\nu}$. It is envisioned that this might be used for recoil analyses interested in selecting a specific B decay to tag by. The event data quantities decayMode and decayType will be stored in the form of bit masks.

```
For decayMode:
unsigned int j=0;
if ( isD0KPilnu)               j = j | 1;
if ( isD0K3Pilnu)              j = j | 2;
if ( isD0KPiPi0lnu)            j = j | 4;
if ( isD0KsPiPilnu)            j = j | 8;
if ( isDstar0D0Pi0KPilnu)      j = j | 16;
if ( isDstar0D0Pi0K3Pilnu)     j = j | 32;
if ( isDstar0D0Pi0KPiPi0lnu)   j = j | 64;
if ( isDstar0D0Pi0KsPiPilnu)   j = j | 128;
if ( isDchKPiPilnu)            j = j | 256;
if ( isDchKsPilnu)             j = j | 512;
if ( isDstarD0PiKPilnu)        j = j | 1024;
if ( isDstarD0PiK3Pilnu)       j = j | 2048;
if ( isDstarD0PiKPiPi0lnu)     j = j | 4096;
if ( isDstarD0PiKsPiPilnu)     j = j | 8192;
if ( isDstarDchPi0KPiPilnu)    j = j | 16384;
if ( isDstarDchPi0KsPilnu)     j = j | 32768;
_decayMode=i;

For decayType:
int i=0;
if ( isD0lnu )       i = i | 1;
if ( isDchlnu )      i = i | 2;
if ( isDstarlnu )    i = i | 4;
if ( isDstar0lnu )   i = i | 8;
_decayType=i;
```

- decayMode. The 16 individual decay modes are accessible through the _decayMode user data interface. The numbernig scheme is outlined above and the form of the bit mask is given.
- decayType. Candidates can be chosen as satisfying one of the 4 decay types using this piece of event data. Where the types are $D^0\ell$, $D^+\ell$, $D^{*0}\ell$ and $D^{*+}\ell$.

A.2 Skim usage

Examples of how to apply the information stored in the $B \to D\ell\nu X$ skim will be outlined here using specific use cases. As mention in section A.1 there are two distinct types of analyses that will likely use this skim.

A.2.1 Use Case 1: "Recoil" Analyses

This case applies to any analysis that uses the skim as a means to reconstruct the decay products of one B in the event in order to study the properties of the other. The reconstructed B will be referred to as the "tag" B and the other as the "recoil" B. In these analyses one removes the decay products of the tag B from the event in order to treat the recoil B as a single-B beam. This technique has been particularly useful in searches for rare decays where the recoil B decays into a mode where missing energy is present, usually in the form of neutrinos. Since there are limited kinematic constraints that can be applied in these cases this dictates that the tag B need be reconstructed as exclusively as possible in order to surpress backgrounds. The example we will use here is the exclusive semileptonic mode $B^- \to \pi^0\ell^-\overline{\nu}$. However, it is important to point out that the same general principle would hold for analyses such as: $B^- \to \rho\ell^-\overline{\nu}$, $B^- \to \omega\ell^-\overline{\nu}$, $B^+ \to \tau^+\nu$, $B^+ \to K^+\nu\overline{\nu}$ and others. A charged B decay mode has been used as the use case. Similar principles will apply to studying neutral B decays although the restructed tag will be a B^0 or $\overline{B}^0$ instead of B^+ or B^- in this case. For an analysis of $B^- \to \pi^0\ell^-\overline{\nu}$ "in the recoil" the user will first need to loop over all of the $B \to D\ell\nu X$ candidates and select the $B^\pm$ tags. Once this is done the user will then need to use the stored β candidates to select the `bestDl` in the event from the collection of $D^{(*)0}\ell\nu$ candidates selected. Storing the `bestDl` as a persisted β candidate saves the user from running a $B \to D\ell\nu X$ selection routine to obtain their tag B candidates which should cut back considerably on CPU usage for some users. With this collection of events and `bestDl` candidates the user can then study the remaining tracks and clusters in the event. For $B^- \to \pi^0\ell^-\overline{\nu}$ the selection of a second lepton in the event and the further constraint on $|\cos\theta_{B,\pi\ell}|$ should provide good discrimination between signal and background. Selecting events with little neutral energy remaining in the events after the assignment of any neutral clusters to that tag B should also prove useful as it has in other recoil analyses. In this framework the user is free to decide which $B \to D\ell\nu X$ decay modes they consider fit for their analysis and select only those modes accordingly. It is also left to the user to decide whether they wish to explicitly reconstruct the $D^{*0}\ell\nu$ or use $D^0\ell\nu\ X$ as both will be stored as β candidates. However, all recoil analyses will likely apply further selection criteria on vertexing, mass windows, particle lists and kinematics which could potentially differ among analyses depending on the users prejudices.

A.2.2 Use Case 2: Semileptonic Analyses

This case applies to analyses interested in studying one (or a small number of) exclusive semileptonic decay modes. $B^0 \to D^{*-}\ell^+\nu$ will be used as the example. This mode will also be used for recoil analyses looking for neutral B decay modes but the usage will differ to that presented here. In this case the user would begin by looping over the list of stored candidates and selecting those events which contain one or more $B^0 \to D^{*-}\ell^+\nu$ decays. This can be done with the `User Data` by looking at the decayType to find if a $B^0 \to D^{*-}\ell^+\nu$ decay was present in the event. If a particular D decay is required for increased purity then the decayMode could be used to select only events containing a candidate in the mode of interest. In the first case one would check the bit mask for consistency with *isDstarlnu* being true. This will then select only those events with a $B^0 \to D^{*-}\ell^+\nu$ although the user should note that there may be other candidates per event. For a particular decay mode such as $D^{*+} \to D^0\pi^+$ with $D^0 \to K^-\pi^+$ the user would select the decayMode *isDstarD0PiKPilnu* using the bit mask. Upon selection of an event it is likely that the analysis will require some more sophisticated cuts in order to separate signal and background. The user will probably wish to make constraints on the $B^0 \to D^{*-}\ell^+\nu$ by vertexing, applying tighter particle identification, cut harder on $\cos\theta_{B,D\ell}$. Further cuts on charged and neutral multiplicity will reduce the yield dramatically. The `bestDl` candidate will not be the optimal choice in all cases and will probably not be of interest in these analyses. In the event that there are multiple candidates the best can be selected by some means the user may see fit to define. The `user data` will store useful information to allow users to cut down on the number of events they read in, and CPU time. By selecting events satisfying specific selection criteria it is envisioned that the user can easily simplify their event selection.

A.3 Skim Code

The code to implement this skim as part of the new computing model will reside in several packages in releases in the *BABAR* framework.

- FilterTools: BToDlnuPath.tcl, BToDlnuXLeptonFilter.cc.hh
- CompositionSequences: CompBToDlnuProdSequence.tcl.cc,.hh
- UsrTools: UsrWriteBToDlnu.tcl
- Other necessary code: In BetaTools an up-to-date version of BtaSemilepCand must be used to include the $D^+ \to K^0_S\pi^+$ mode.

The path and prefilter code for the skim have been written to be incorporated into FilterTools.

B The BToDlnuXUser package

B.1 Description of package contents

The *BToDlnuXUser* package is intended to simplify the creation of user-specific "Beta" analysis executables and ntuples where a $B \to D\ell\nu X$ tag would be favourable for the analysis. The package is based on the model of BetaUser and other XxxUser packages which provide a similar framework. Several environment variables are used to control linking the Beta job and the specific capabilities of the executable. See the BetaUser/doc/guide.* files for more detailed information. Upon linking this package the executable "*BToDlnuXApp*" will be created. This can then be used instead of a standard BetaApp to run data from properly coordinated tcl scripts. There are several files of code that are included in this package for the benefit of users.

\- *BToDlnuX*
This is the main piece of code in this package. It drives the selection of $D\ell$ candidates and provides many blocks of charged, neutral and composite particles in the event. We search for $D\ell$ combinations in the data/MC. Loose selection criteria are applied to these combinations, most of which can be tightened at the tcl stage. The output of this file, including its preselector and lepton filter, is a set of 4 ntuples:

1 (N) cut results in BtoTauNuPreselector
2 (N) cut results in BtoTauNuLeptonFilter
3 (N) BToDlnuX ntuple
4 (N) cut results in BToDlnuX

Of these the preselector/filter carry little information except for the number of events passing the cuts on charged track multiplicity, lepton momentum and other event selection quantities. Each of the cuts applied in given in the corresponding file. The cut results are useful to extract the number of events successfully passing each stage of the anaylsis. Most of the useful quantities are contained in ntuple 3. Herein, ALL $B \to D\ell\nu X$ candidates are stored, regardless of overlapping tracks and neutral clusters, and quantites specific to these candidates are stored. Candidates satisfying criteria of $\overline{B}^0 \to D^+\ell^-\overline{\nu}$, $B^- \to D^0\ell^-\overline{\nu}$, $\overline{B}^0 \to D^{*+}\ell^-\overline{\nu}$ and $B^- \to D^{*0}\ell^-\overline{\nu}$ are all allowed even if two candidates are made using some of the same tracks and clusters. Blocks of entries are filled for γ, π^0, K^0_S, K^0_L, K^{*0}, K^{*+}, D^0, D^+, $D\ell$, charged tracks, neutrals, MC truth and many other miscellaneous quantities. The user has the option of turning off some of this output in tcl to reduce the size of the ntuple to the more essential entries for their specific analysis. Another block is included to tag using hadronic events via the $D^0\pi$ mode. This is turned off by default in .tcl as it will be of limited use to most users and greatly increases the ntuple size. All tcl parameters and default lists used are described elsewhere within the *BToDlnuXUser* package.

\- *BToDlnuXLeptonFilter*

The lepton prefilter only selects those events with an electron or muon with centre-of-mass momentum between 1.0 and 2.8 GeV/c.

- *BToDlnuXPreselector*
The preselector imposes loose constraints on the number of charged tracks (12 is the maximum allowed), number of neutral candidates (less than 100) and other book keeping variables. These are essentially used to limit the size of the analysis ntuple to contain only those events that might interest us. One caveat to this selection is that the charged track multiplicity is allowed to be greater than 12 in the event that a suitable $D^0(K\pi)\ell\nu$ candidate is found. In such cases no restriction is made on the track multiplicity in order to study an unbiased sample of these tags for the purposes of "double-tagging".

- *EventShapeVariables*
This contains the calculation and definition of any event shape variables imposed in the $D\ell$ selection.

- *ShowerContamination* This piece of code finds the closest track (at the EMC) to an EMC shower. It returns the index of that track, the angle between the shower centre and the closest track and the delta theta and phi between shower centre and closest track.

- *findDdecaymode*
A selection to define and the decay modes of the D^+ used in the D^+ selection block in BToDlnuX.cc

- *mcDinfo*
The MC information stored for the charged D candidates of interest. Returns the D decay mode ID.

B.2 HOWTO run a test job in analysis-13b

This will be specific to running an analysis job on data/MC using objectivity to create a set of ntuples. Therefore one is expected to have the ability to run at SLAC, or have enough understanding of the *BABAR* framework to enable the user to switch the relevant commands contained herein to permit running in the KANGA micro-DST format at RAL. No attempt is made in what is to follow to make the commands consistent with running in KANGA, this is left to the user.
To begin with one will need to logon to a Linux24 machine (working at SLAC one can chose between many of the noric machines, noric10→noric15) and set up a standard test release. The command to do this is:

- newrel -t -s [your scratch area] analysis-13b anal13b

Table 13: Packages needed in order to compile and link *BToDlnuXUser*. These are the packages that the *BToDlnuXUser* package are dependent on, along with others to correctly incoporate PID-killing, gamma smearing and other corrections.

release	Package	Tag version
	BToDlnuXUser	pdj-31March03
	BetaCoreTools	V00-00-31-01
	BetaMicro	yumiceva-06Aug02-ana13
	BetaMicroTruth	V00-00-06-01
	BetaPid	V00-01-42-01
analysis-13b	BetaSequences	V00-10-09-01
	BetaTools	pdj-14March03
	CompositionFactory	V00-00-17
	CompositionSequences	pdj-7April03
	CompositionUtils	V00-00-21
	PackageList	V00-06-59
	workdir	V00-04-08

This will create a directory anal13b in the users current working directory and a set of symbolic links in this directory to the defined scratch space.[3] For more information on test releases and the *BABAR* framework the user should consult the workbook for offline users [6]. One should then change directory into the new anal13b directory and add some packages as shown in table 13.
There are some untagged additions to these packages which are required for consistency with the tcl scripts and analysis code. The correction can be copied from :
/nfs/farm/babar/AWG10/LeptBc/BToDlnuXProduction/analysis-13b
Additions are needed to the BetaCoreTools and BetaTools packages. Users are asked to check the packages they have checked out using the 'addpkg' command with those contained in the above directory. Furthermore, once packages are added one needs to set certain environment variables prior to compiling and linking the executable. These are given in table 14 for MC and data.
One must also type:

- srtpath 10.4.4-physics-1b Linux24

- setboot;physboot(for data);simuboot(for MC)

One should at this point be able to compile and link the executable by typing the following:

- gmake lib;gmake BToDlnuXUser.bin

This will create a *BToDlnuXApp* in your bin/Linux24 directory. This executable can subsequently be used to run a job just as one would do with a *BetaApp* executable. For a

[3]One should ensure that the scratch space defined actually exists prior to "using" it.

Table 14: Environment variables needing to be set in order to run BToDlnuXUser.

MC	Data
setenv BetaBdbAll no	setenv BetaBdbAll no
setenv BetaBdbMicro yes	setenv BetaBdbMicro yes
setenv BetaDisplayMicro no	setenv BetaDisplayMicro no
setenv BetaPhysAll no	setenv BetaPhysAll no
setenv BetaKanga no	setenv BetaKanga no
setenv BetaPhysMicro yes	setenv BetaPhysMicro yes
setenv BtaTrkKill yes	unsetenv BtaTrkKill
setenv BetaMCMicro yes	unsetenv BetaMCMicro
setenv BDB_SINGLE_CONTEXT no	setenv BDB_SINGLE_CONTEXT no
setenv BtaPidKilling yes	unsetenv BtaPidKilling
setenv BtaGamSmear yes	unsetenv BtaGamSmear
unsetenv BetaMC	unsetenv BetaMC

suitable set of .tcl scripts there is a directory contained within the *BToDlnuXUser* package that contains what is needed. These .tcl files should be copied into the users workdir. The corresponding file for data or SP4 Monte Carlo can then be called prior to any suitable file containing links to the data, or simulated data, files. An example file should look something like this:

```
source ../BToDlnuXUser/tcl/objy-bknunu-sp4.tcl
source myObjyMCFile.tcl
mod talk HbkTupleEnv
histFileName set hbookname
quit
if [ info exists env(MaxEvents) ] {
echo Running $env(MaxEvents) events
ev beg -nev $env(MaxEvents)
} else {
ev beg
}
exit
```

In order to include the PID-killing corrections, photon smearing and re-scaling along with the tracking efficiency it is suggested the user follow the outlines given in the links contained from this webpage:
http://www.slac.stanford.edu/BFROOT/www/Physics/Tools/BetaTools/MicroKilling-Run2.html
Softlinks are required to be created in the users workdir to access the correct pidtable and track efficiency information. Of course if such corrections are not necessary for a particular user or analysis the corresponding environment variables outlined for Monte Carlo in table 14 should simply be 'unset' and the jobs can be run without these settings.