

$$B \rightarrow K^{(*)} \nu \bar{\nu} @ 10^{36}$$

*Second 10^{36} workshop
Oct 22-24, 2003*



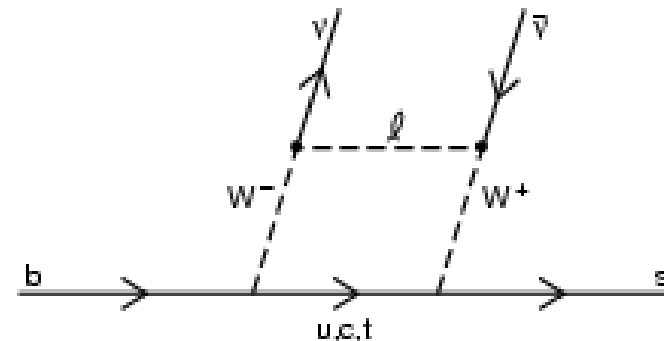
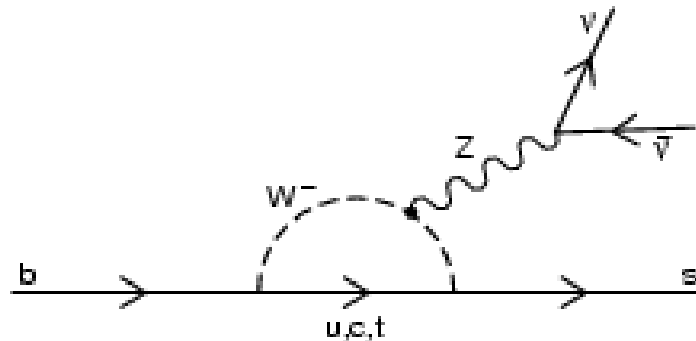
Steven Robertson



$b \rightarrow s \nu \bar{\nu}$



- **FCNC process occurring via SM loop and box diagrams:**
 - Potential for significant enhancement from additional non-SM diagrams



- **Physics is similar to $b \rightarrow s l^+ l^-$ but without the EM penguin diagram (i.e. $b \rightarrow s \gamma$) and without complications due to strong interaction effects (i.e. enhancements to $B \rightarrow K^{(*)} l^+ l^-$ from $J/\psi, \phi, \phi' \rightarrow l^+ l^-$)**
- **Inclusive rate for $B \rightarrow X_s \nu \bar{\nu}$ is $\sim 4 \times 10^{-5}$ in SM calculations**
- **Obviously $b \rightarrow s \nu \bar{\nu}$ is “experimentally challenged” compared with $b \rightarrow s l^+ l^-$ due to the presence of two unobserved neutrinos**

Current status



- Like $b \rightarrow s l^+ l^-$, it is (in principle) possible to perform both inclusive and exclusive searches
- Best inclusive limit is from ALEPH:

$$\text{Br}(b \rightarrow s \nu \bar{\nu}) < 6.4 \times 10^{-4} \quad @90\%$$

- Exploits collimation of B-jets at LEP to identify signal B decay daughter particles (very different environment at PEP!)
- Best (prelim) exclusive limit is from BABAR:

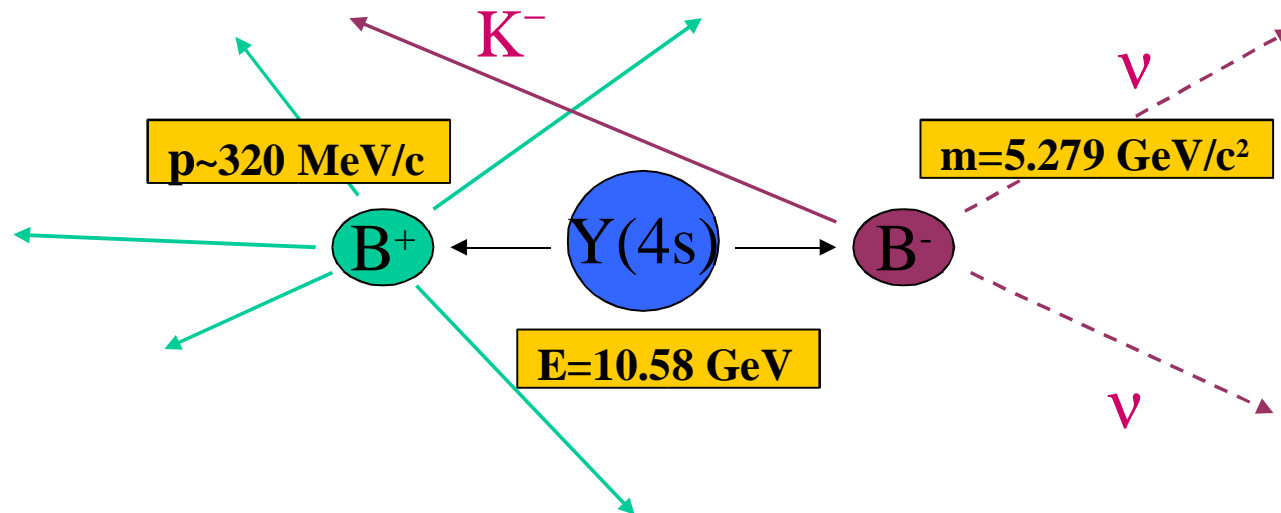
$$\text{Br}(B^+ \rightarrow K^+ \nu \bar{\nu}) < 7.0 \times 10^{-5}$$

- Physics sensitivity is roughly comparable to ALEPH result
- SM prediction $\text{Br}(B^+ \rightarrow K^+ \nu \bar{\nu}) \sim 4 \times 10^{-6}$
 - lots of room for improvement!

Method



- Cannot distinguish signal decay daughters from other particles produced in the $Y(4S) \rightarrow B\bar{B}$ (or continuum) event
- Instead, look for known decay of one of the B mesons then look at whatever is left over
 - Exclusively reconstruct B decays exploiting large $b \rightarrow c$ branching ratios and the usual B decay kinematics (m_{ES} and ΔE etc.)
 - What's “left over” unfortunately includes not only signal decay, but also all the extra detector junk

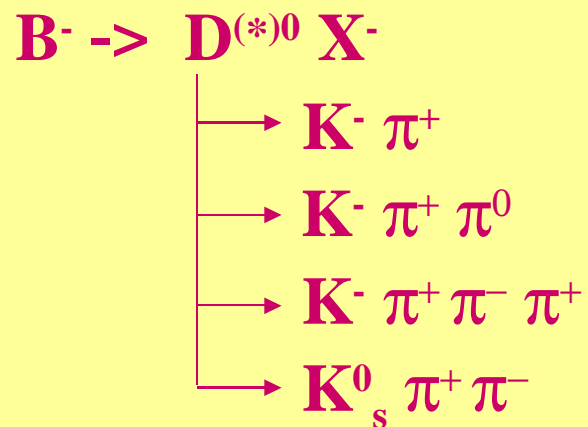


“Tag B” reconstruction



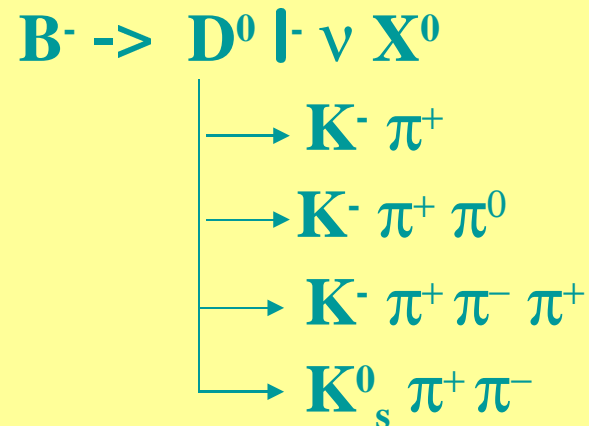
- Exploit instead the kinematics of the $Y(4S)$ system and the known centre of mass energy
 - Exclusively reconstruct one B, then use event missing energy and signal event topology as “signature” of the signal decay
 - Use two independent but complementary “tag-B” samples:

Hadronic B sample



X^- system: up to five charged tracks (K, π) and two additional π^0

Semileptonic B sample



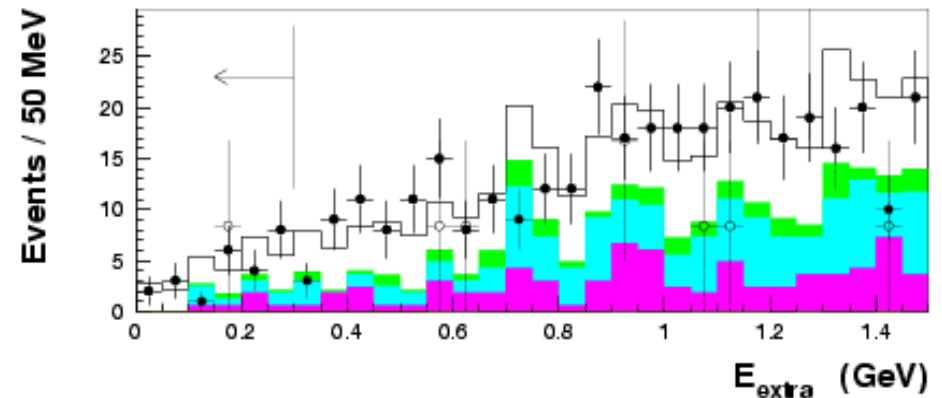
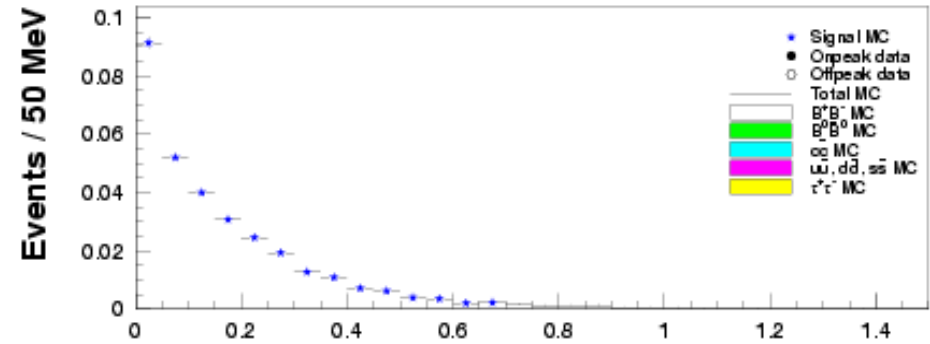
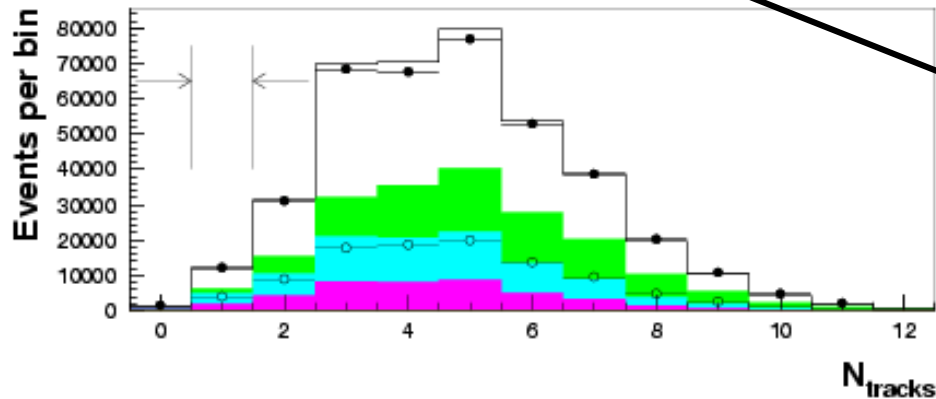
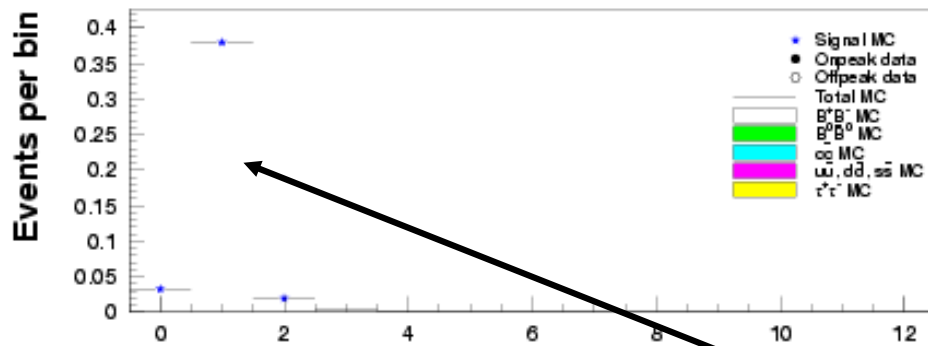
X^0 system: γ or π^0 candidates from possible $D^{(*)0} \rightarrow D^0 \gamma / \pi^0$ transitions

- Overall reconstruction efficiency ~0.5%

$B^+ \rightarrow K^+ \nu \bar{\nu}$ signal selection



- Signal “signature” is a single kaon and nothing else recoiling against the opposing reconstructed B

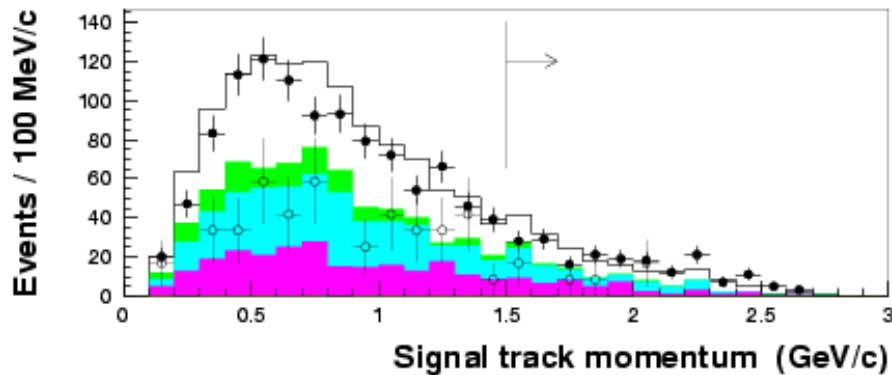
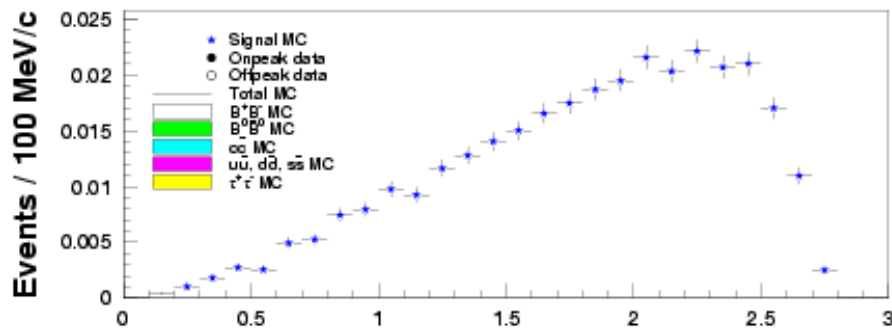
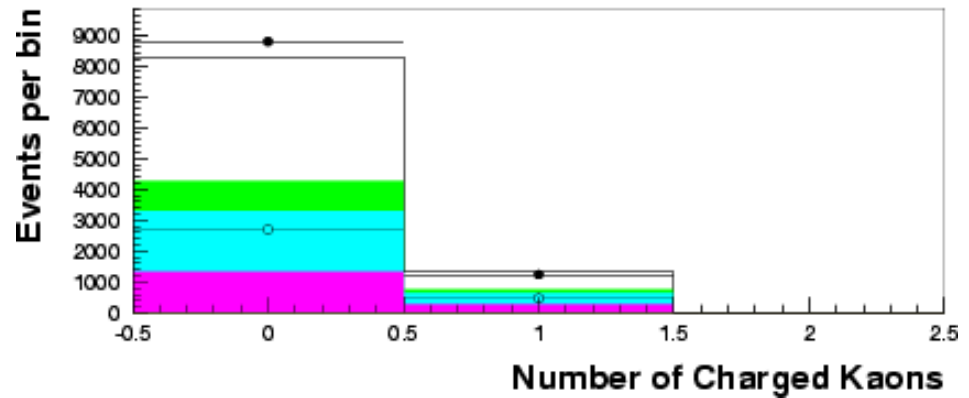
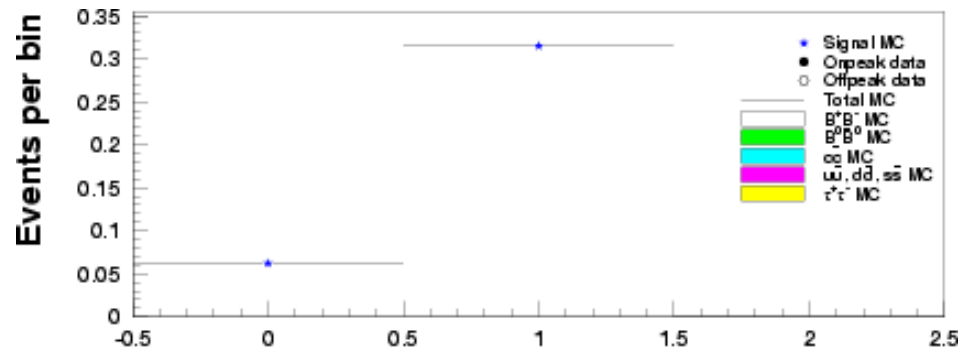


Significant background rejection results from low signal multiplicity and total calorimeter energy!

$B^+ \rightarrow K^+ \nu \bar{\nu}$ signal selection



- In addition to “topological” constraints, additional background rejection from PID and momentum spectrum of the signal kaon
 - Model dependence?

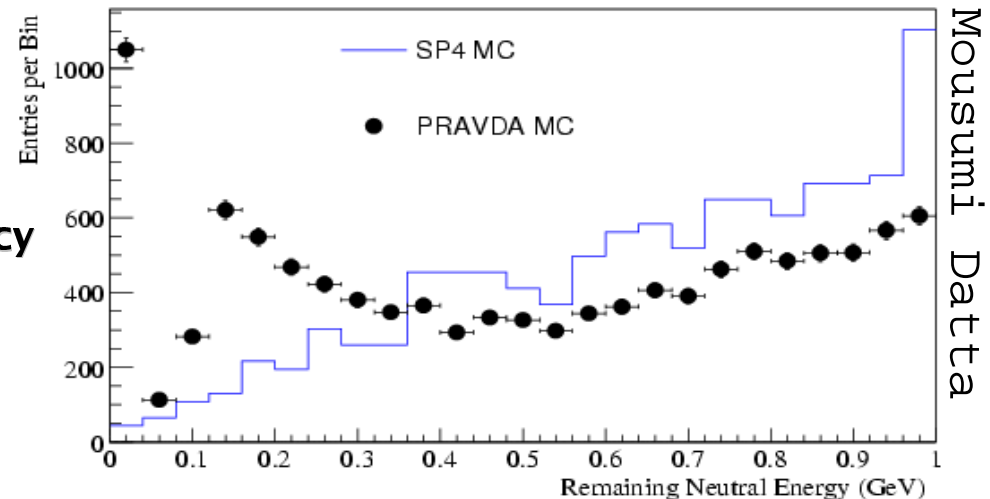


- In the case of $B^+ \rightarrow K^{*+} \nu \bar{\nu}$, there is an additional constraint from $K^* \rightarrow K \pi$ reconstruction, but also higher inherent background due to higher multiplicity

Simulation



- **Fast simulation not very useful for these sorts of analyses!**
 - We already know what the “physics” backgrounds are:
 - generic semileptonic decays, events with neutral hadrons etc.
 - Signal efficiencies and background estimates are highly dependent on detector performance:
 - EMC neutral reconstruction
 - Track-cluster matching
 - EMC & IFR neutral hadron efficiency
 - EMC beam backgrounds
 - Bremsstrahlung photons
 - Hadronic split-offs
- **Signal efficiency dominated by tag-B reconstruction efficiency**
 - Will likely improve with time, but otherwise be comparable at 10^{36} to what is currently
 - No significant correlation observed between tag-B and signal-B reconstruction efficiencies



Extrapolation



- Assuming all else is equal @ 10^{36} :

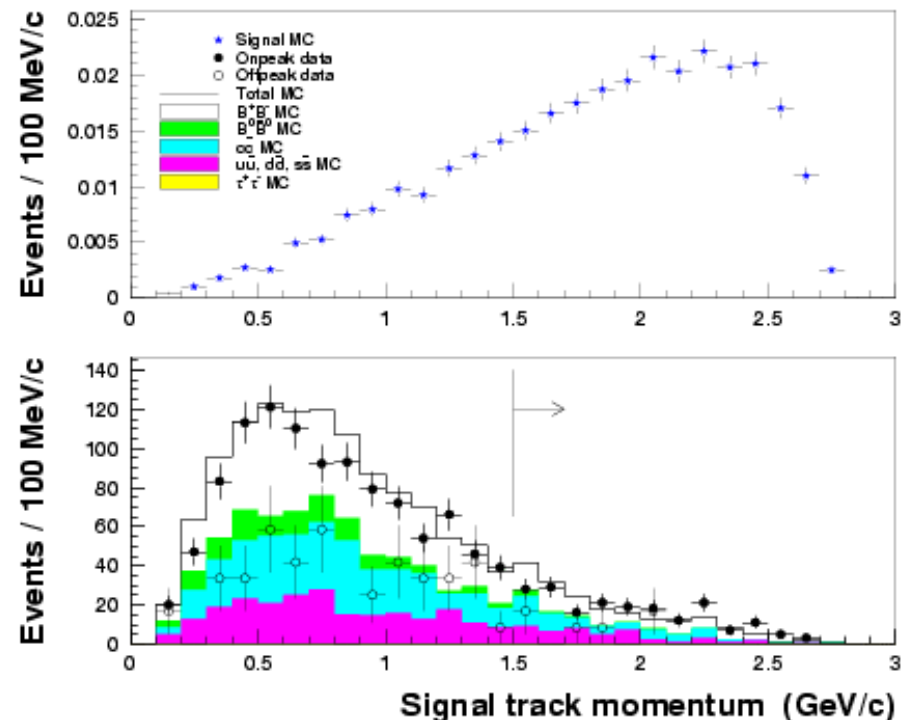
Mode	Current analysis ($\sim 80\text{fb}^{-1}$)	1 ab^{-1}	10 ab^{-1}
$B^+ \rightarrow K^+ \nu\bar{\nu}$	$Br < 7.0 \times 10^{-5}$ SM total $Br \sim (1 \times 10^{-5})$	3-10 evts	30-100 evts
$B^0 \rightarrow K^0_s \nu\bar{\nu}$			
$B^+ \rightarrow K^{*+} \nu\bar{\nu}$		O(10) evts	O(100) evts
$B^0 \rightarrow K^{*0} \nu\bar{\nu}$			

- Expect factor ~ 2 lower yield for B^0 modes due to tag B reconstruction efficiency
- Backgrounds of ~ 50 events for $B^+ \rightarrow K^+ \nu\bar{\nu}$ with 1 ab^{-1} of data with current analysis cuts
- No studies yet available for neutral B modes or K^* ,

Future improvements



- **Currently a significant fraction of observed background is from continuum events**
 - Improvements in tag-B reconstruction and/or tightening of event-shape cuts can dramatically reduce this background
- **Additional information can be extracted from Kaon momentum distribution**
 - fit signal yield rather than cut (should do this anyway to aid interpretation of results)
- **Backgrounds can be reduced through improvements in detector performance**
 - K_L , neutral reconstruction...



Inclusive $B \rightarrow X_s \nu \bar{\nu}$??



- **“Inclusive” $B \rightarrow X_s \nu \bar{\nu}$ measurement has much higher rate and much smaller theoretical uncertainties than exclusive modes**
 - If we could actually do it, this would be the preferred method
- **Like “sum of exclusive modes” analysis of $B \rightarrow X_s \ell^+ \ell^-$ search, but without m_{ES} and ΔE constraints on signal B**
 - Rely on multiplicity and missing energy (E_{extra}) cuts to suppress background
- **$K+n\pi$ signal topology will likely generate significant physics backgrounds for $n>1$**
 - Not clear how much we would gain compared to the exclusive $B \rightarrow K \nu \bar{\nu} + B \rightarrow K^* \nu \bar{\nu}$ analysis
- **No studies yet**

Summary/conclusions



- **Assuming similar detector performance @ 10^{36} , we expect to have sensitivity to $b \rightarrow s\nu\bar{\nu}$ in exclusive modes beginning at a few ab^{-1}**
- **Tag B reconstruction is dominant contribution to signal efficiency**
 - likely to be similar to current efficiency
- **Backgrounds (and hence also signal efficiency due to cut optimization) are strongly dependent on details of detector performance**
 - predictions not reliable without detailed, realistic simulation
- **Studies of $B^+ \rightarrow K^{*+}\nu\bar{\nu}$ and neutral B modes still to be done**