B MESON DECAYS

KIRBY HERMANSEN - JULIA CLINE

MOTIVATION

We want to measure the ratio of the lifetime of B^0 and B_s^0 mesons.

$$B^0 \rightarrow D^- \mu^+ \nu \rightarrow K^+ K^- \pi^- \mu^+ \nu$$
$$B_s^0 \rightarrow D_s^- \mu^+ \nu \rightarrow K^+ K^- \pi^- \mu^+ \nu$$

- Only a difference of quarks between the two
- Several other decays present (Julia)

GOAL

Create a method of measuring the B^0 decay times from the B_s^0 decay times or vice versa.

Why is this useful?

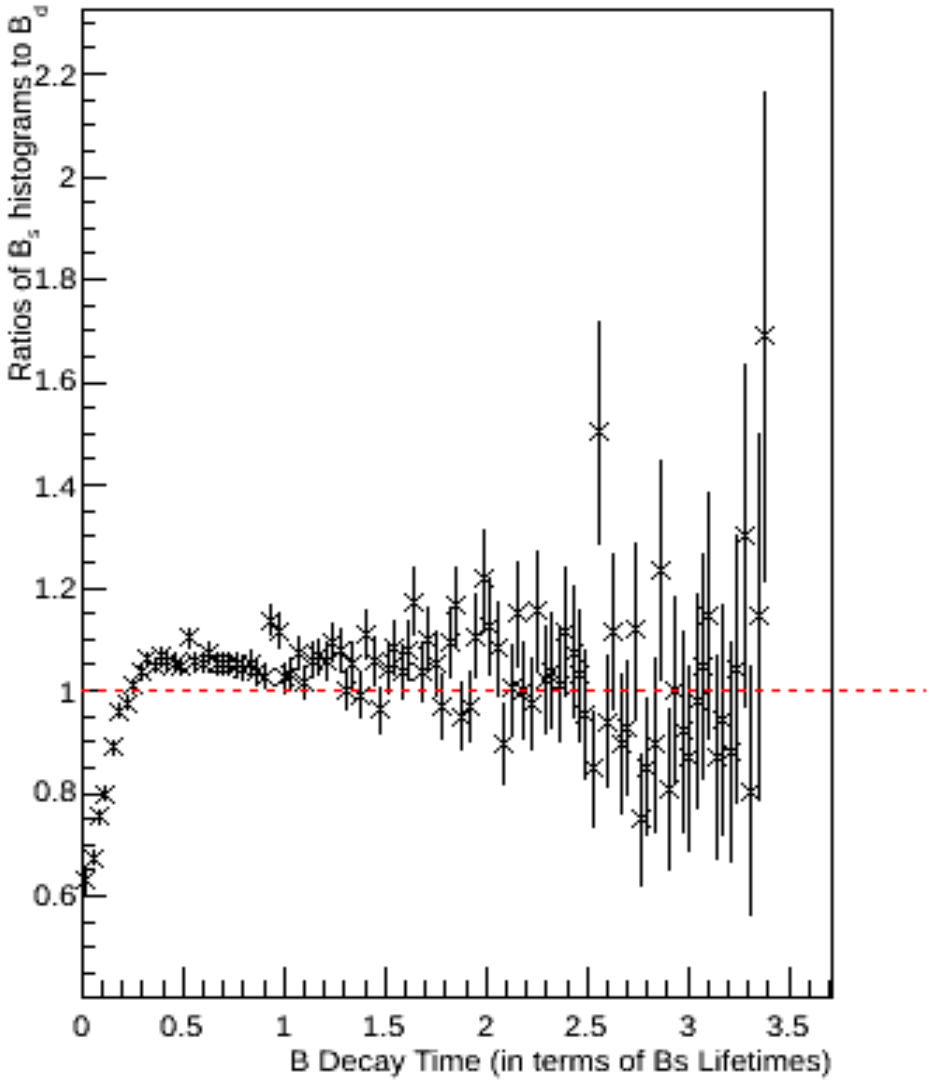
We can use lifetimes to tune models that predict the occurrences of certain decays. If observed rates are different than the prediction, we have found certain decays that could be part of non-standard model physics!

SO WHAT CAN WE DO?

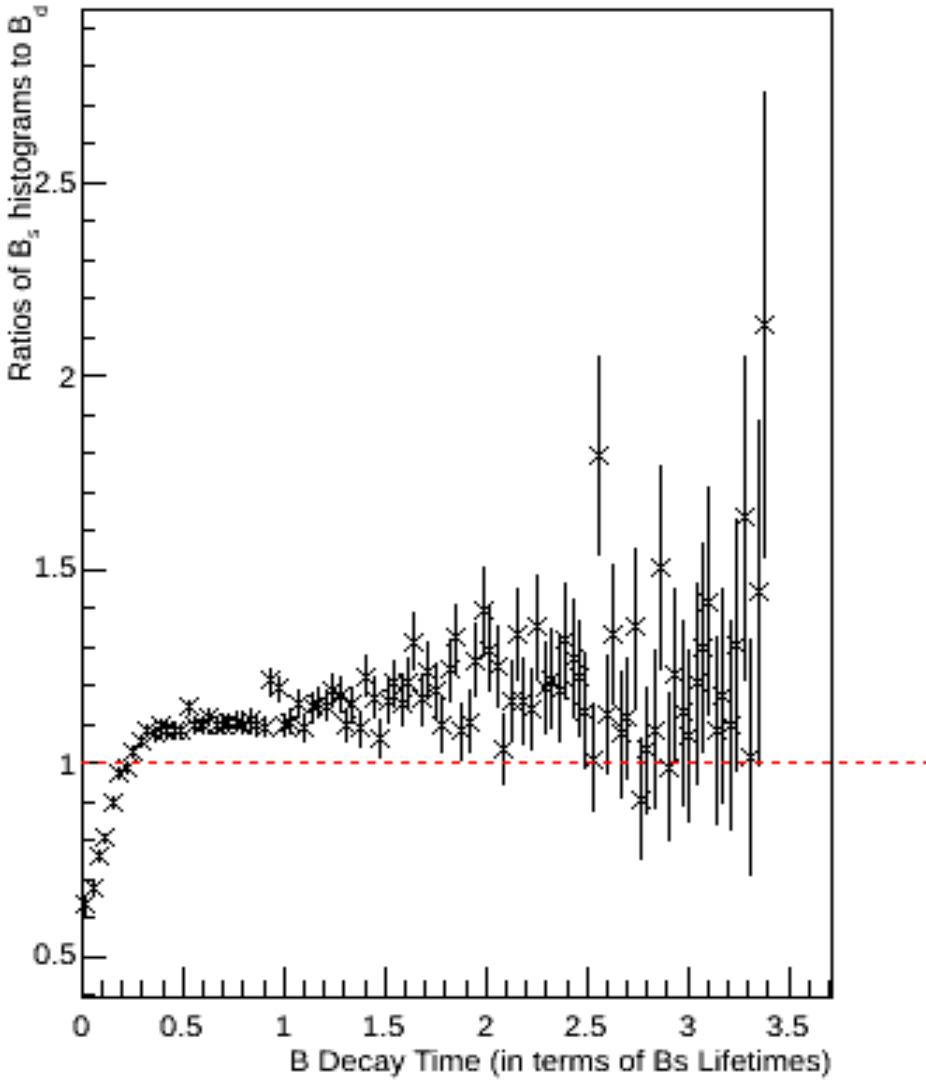
- Reconstruct the visible part of the decays (no neutrino)
- Although the neutrino biases the decay times, a *ratio* of decay times partially corrects this bias
- But reconstruction efficiencies select decays based on their kinematics (momenta and lifetime-related observables), and different physical properties introduce differences in detector acceptances vs. decay time, which is problematic
- Goal: We try to mitigate these differences

ACCEPTANCES

Unweighted w/o Acceptances



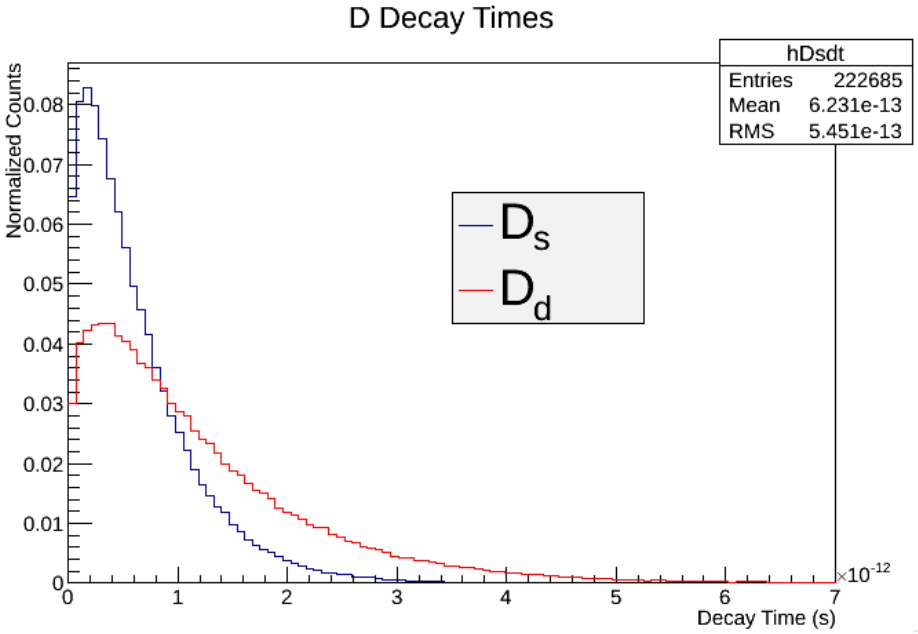
Unweighted w/ Acceptances

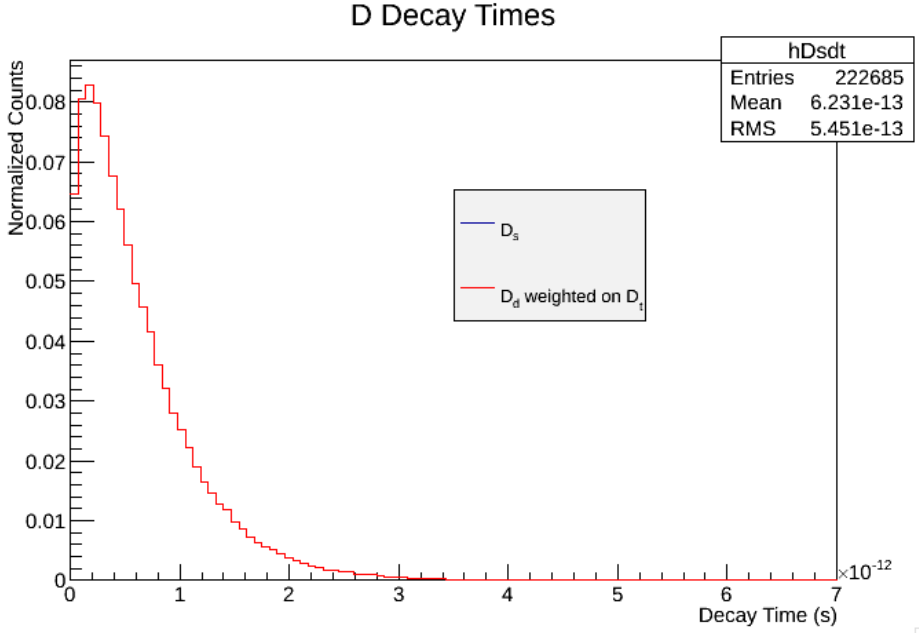


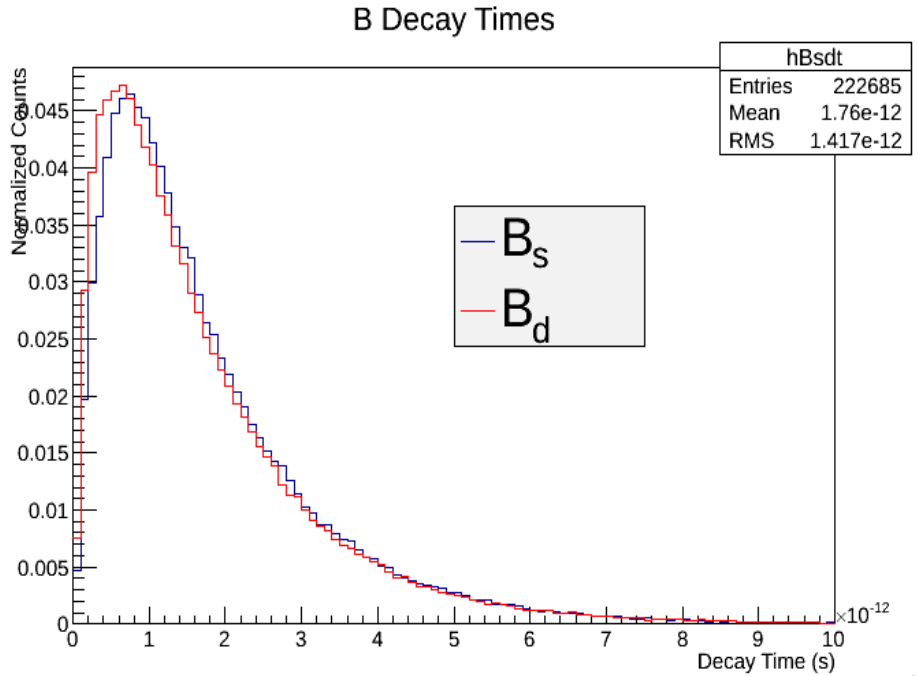
HOW?

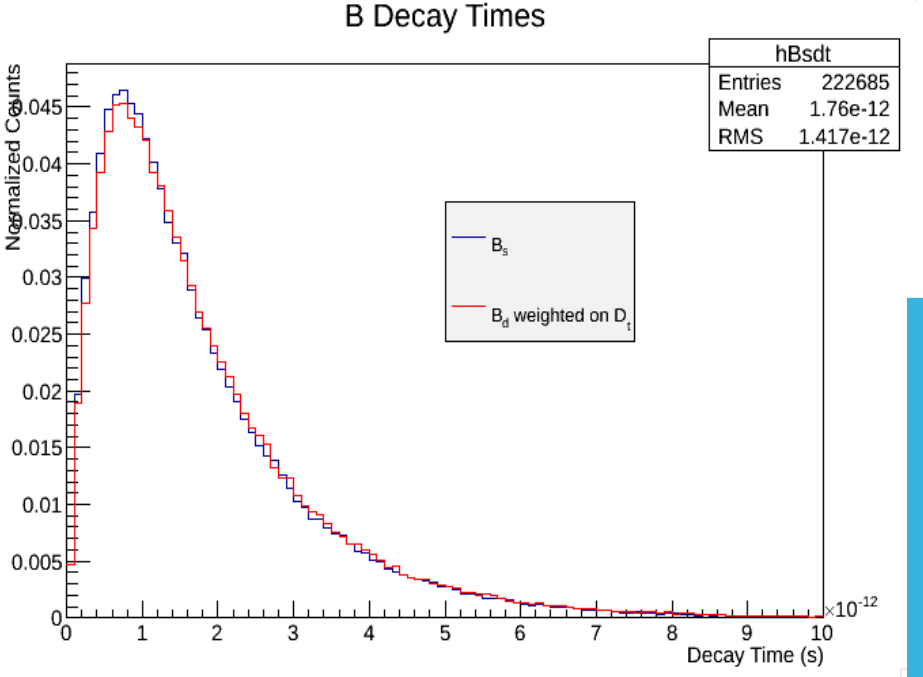
- Eliminate kinematic dependencies across the two decays by reweighting
- But we do not have enough events to reweight *all* the variables, so we identify a subset of relevant variables
- Distributions such as Z-Momentum, Transverse-Momentum, decay angles, decay times, etc. for particles involved in the decay
- Compare these many options and pick the best one (or two or three)

THE WEIGHTING (IS THE HARDEST PART)

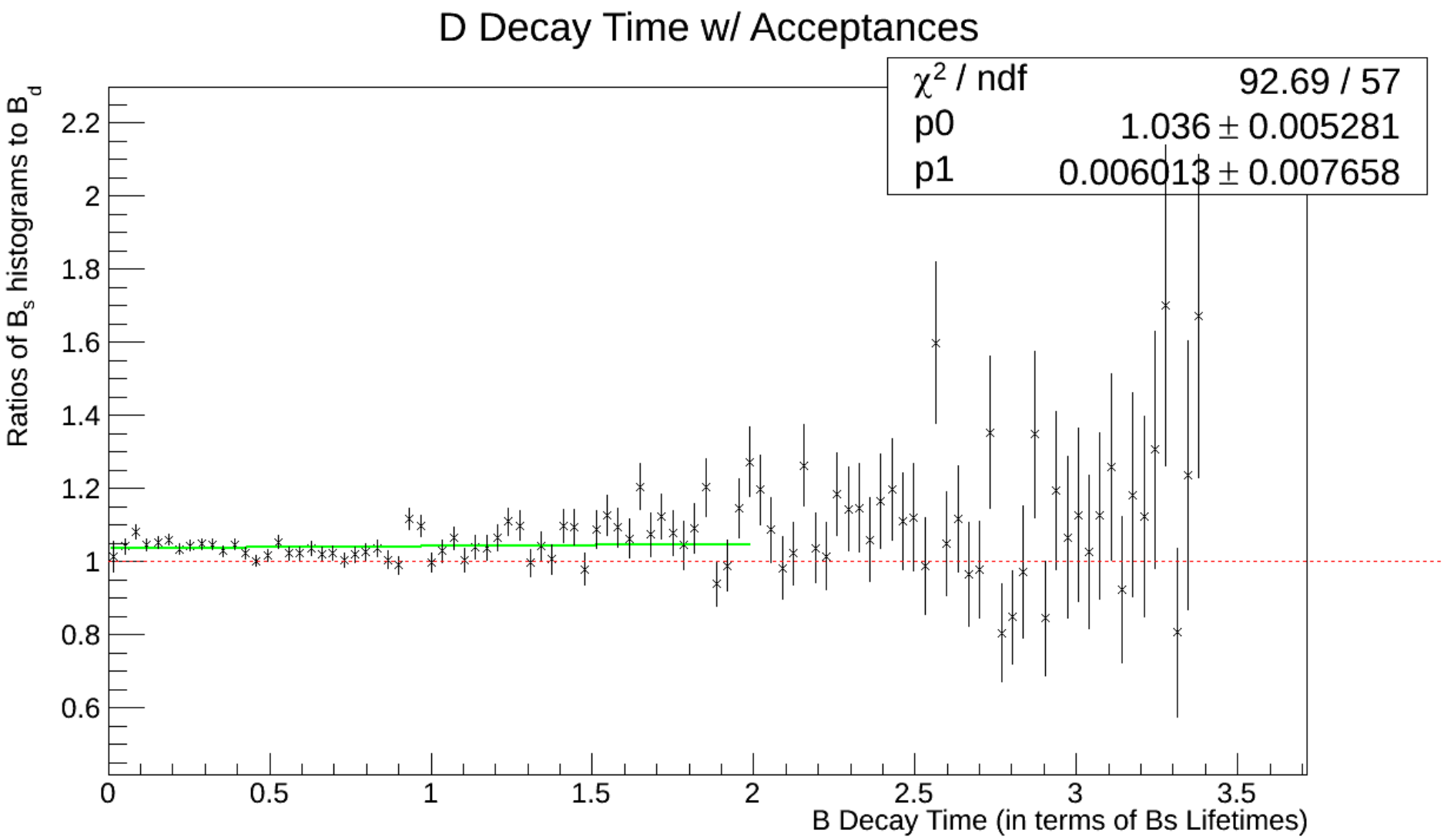








A GOOD START


D Decay Time w/ Acceptances
χ^2 / ndf 92.69 / 57
p0 1.036 ± 0.005281
p1 0.006013 ± 0.007658
Ratios of B_s histograms to B_d
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0
0.5
1
1.5
2
2.5
3
3.5
B Decay Time (in terms of Bs Lifetimes)

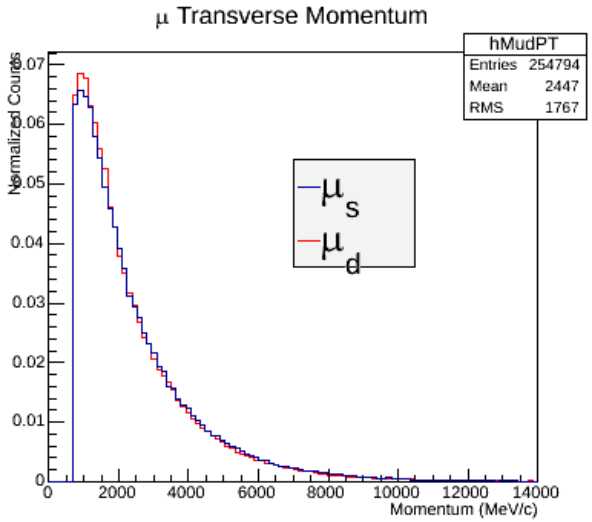
OTHER KINEMATIC DISTRIBUTIONS

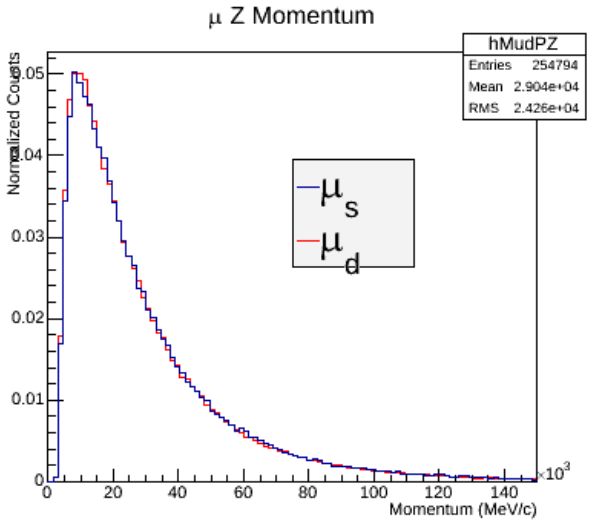
- Muon Transverse and Z momentums
- B Transverse and Z momentums
- Opening angles of the B and D decays
- Invariant masses

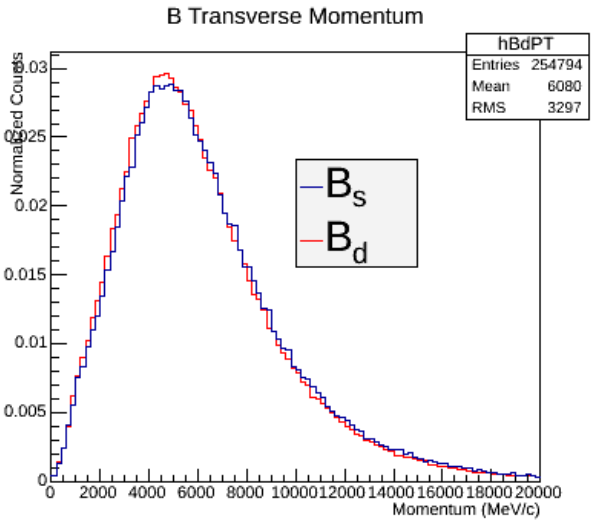
WHY THESE?

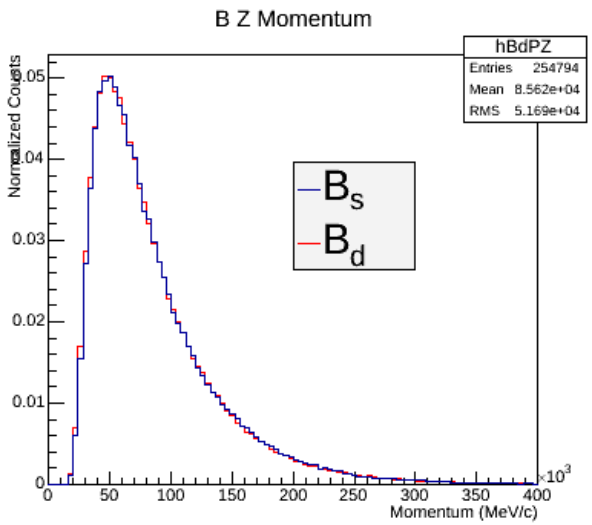
- Decay time and momentum are obvious (differences will clearly bias results)
- Angle and mass differences implicitly bias results

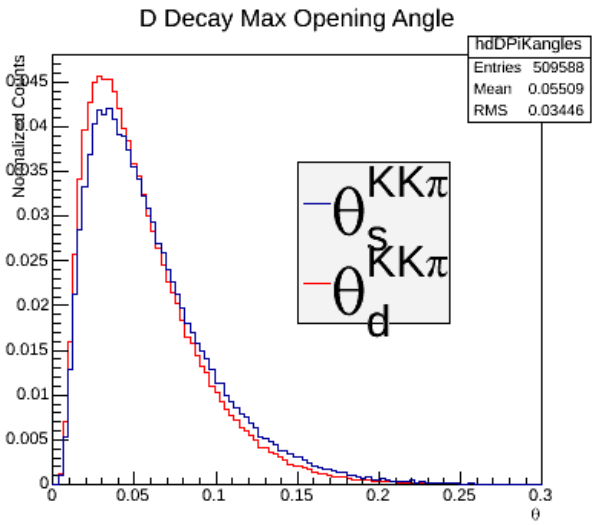
BEST OPTIONS

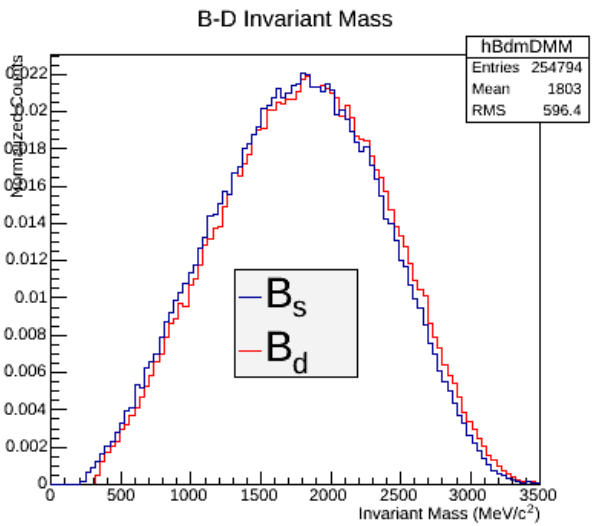




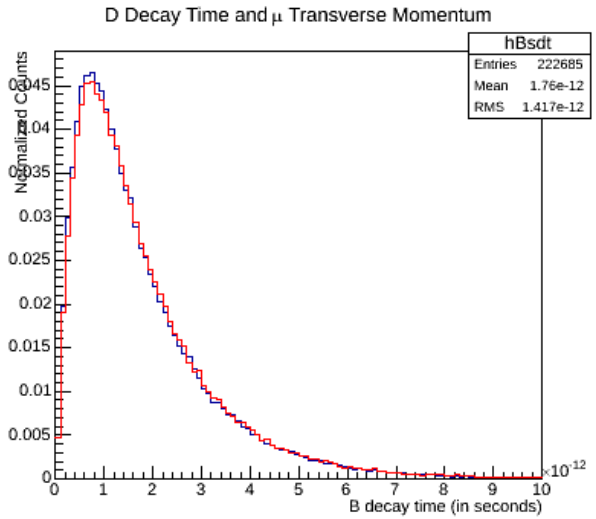


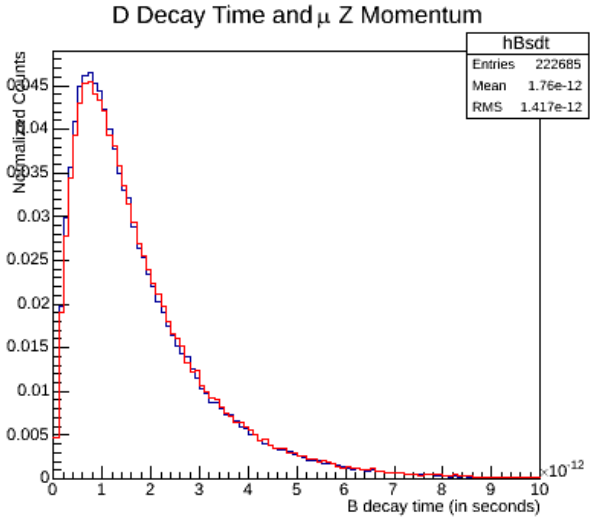


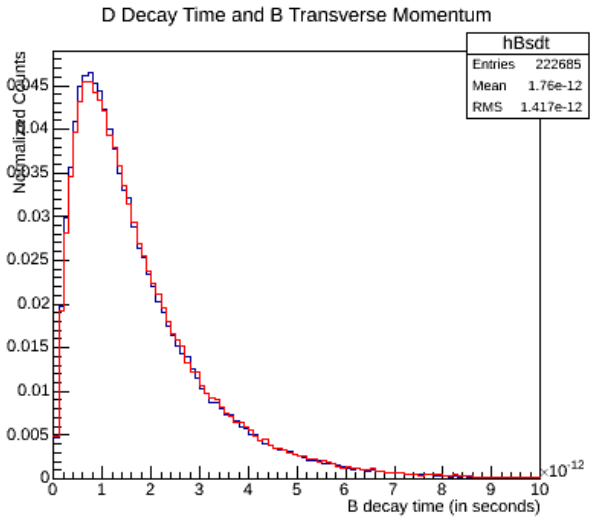


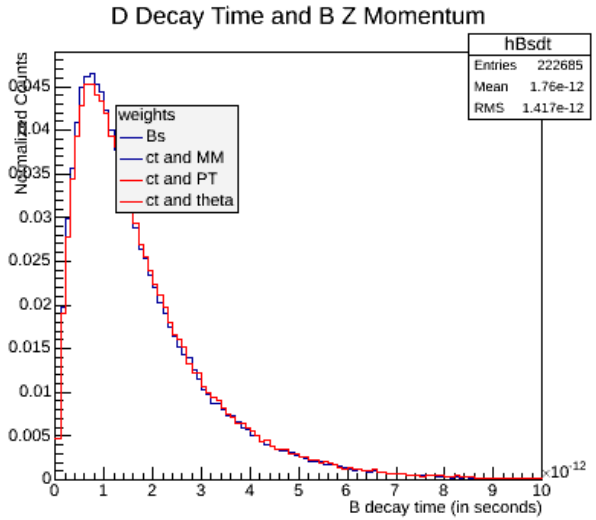


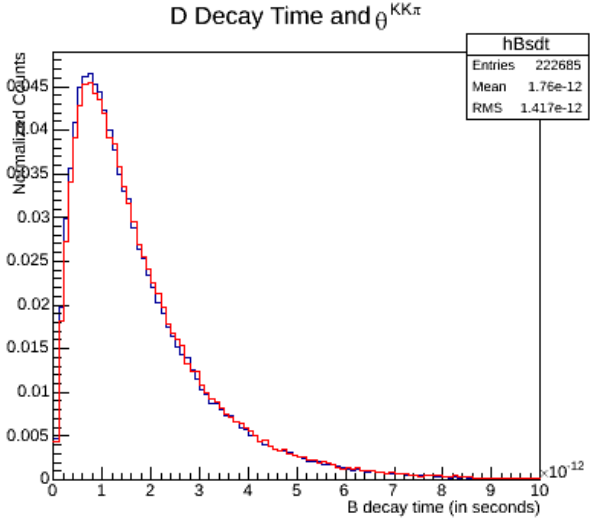
A FIRST GLIMPSE

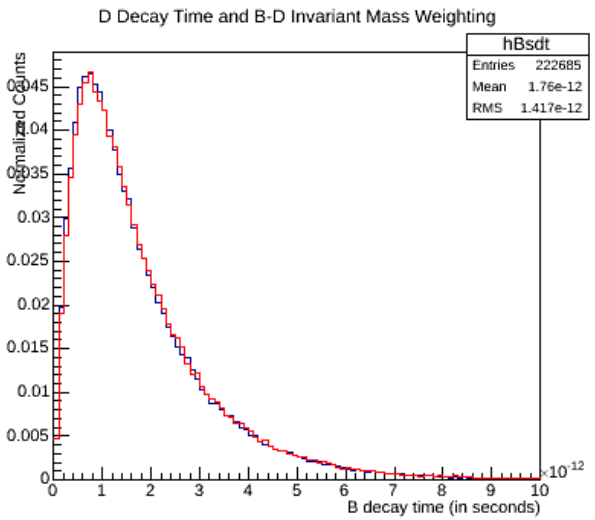




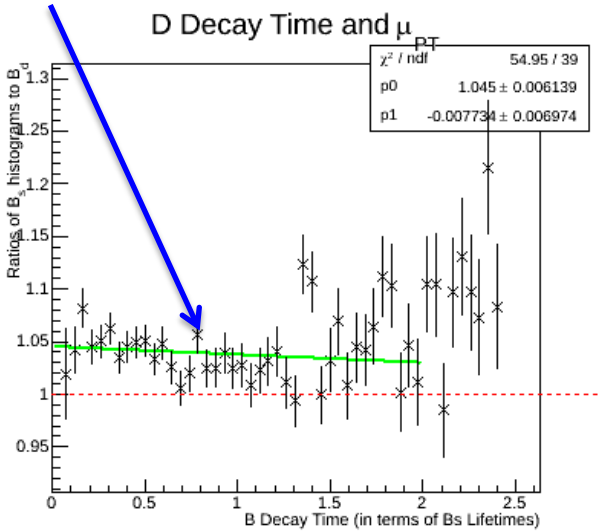


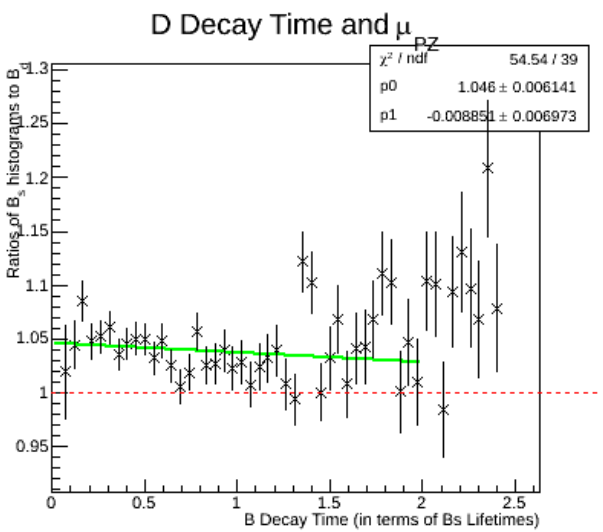


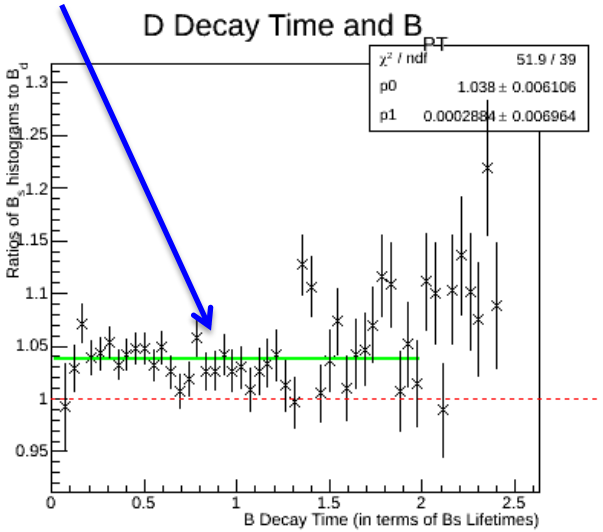


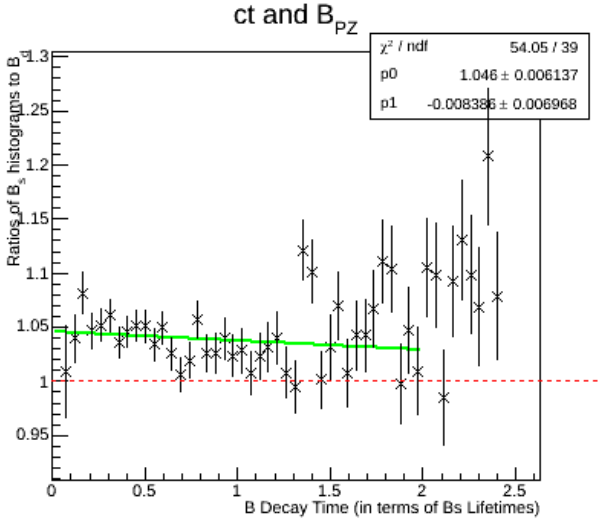


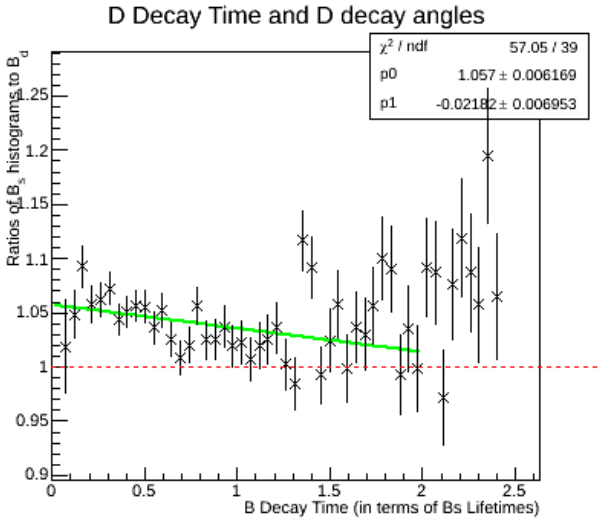
RATIO OF VISIBLE DECAY-TIME ACCEPTANCES

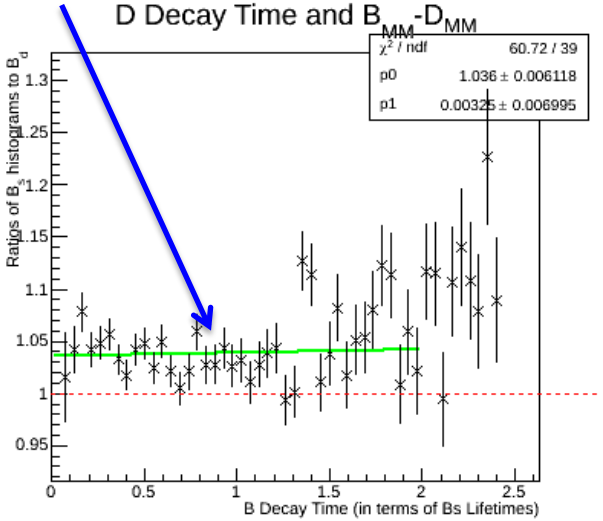












CONCLUSIONS/FUTURE

SUMMARY

- We now have a procedure to resolve the kinematic differences between decays through reweighting
- An extensive revision of the possible weighting options reveals two or three candidates that flatten the acceptances towards 1/1

WHAT'S NEXT?

- Apply these weights to new MC Ntuples (more events)
- Include various selection techniques to eliminate background (Julia)
- Look at possible 3-D weighting
- Apply weights to ACTUAL DATA!

Beauty Meson Sample Composition

The core of my project is to assess the sample composition, but I also work with Kirby on weighting and acceptances.

Previously, I was working on detector acceptances.

Now, I am working on

- Isolating B^0 decays from the mixture of B^+ and B^0 decays
- Then, within the B^0 decays, isolating the particular decay mode.

Isolating Decay Modes of B^0

Our desired decay mode:

$$B^0 \rightarrow D^-(\rightarrow K^+K^-\pi^-)\mu^+\upsilon$$

But there are many other decay modes that generate the products we observe!

Why does this matter?

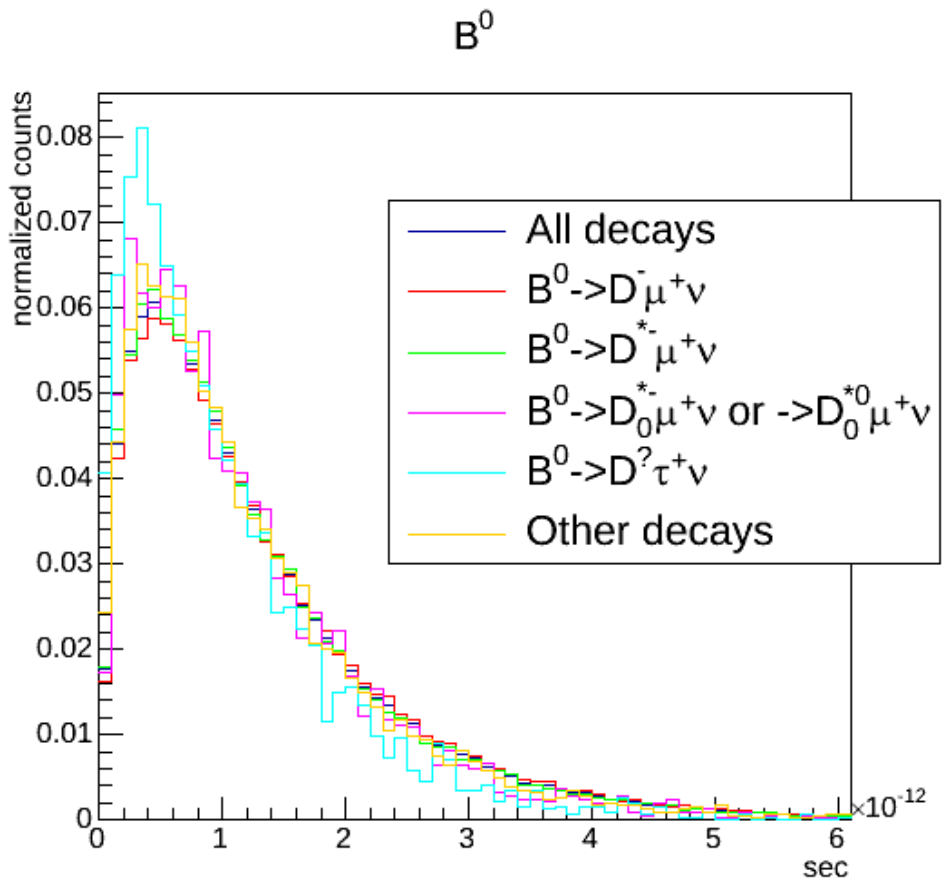
We are finding the ratio of lifetimes of the B^0 and the B_s^0 to try to achieve a cancellation of instrumental effects. But this only works if the B^0 and B_s^0 decay dynamics and topology are the same. It doesn't work if other decay modes are contaminating our B^0 and B_s^0 samples in a way we don't control.

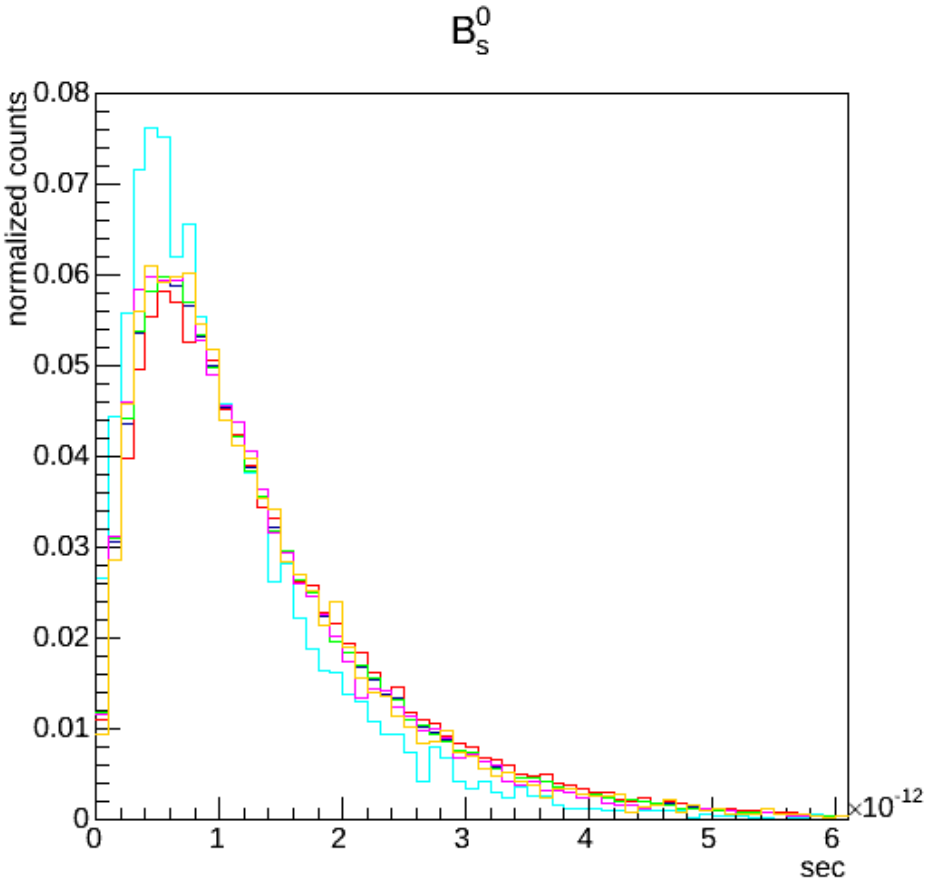
Decay Modes and Intermediate Resonances of B^0

(1) $B^0 \to D^-(\to K^+K^-\pi^-)\mu^+\upsilon$
(2) $B^0 \to D^{*-}(\to D^-(\to K^+K^-\pi^-)\pi^0)\mu^+\upsilon$
(3) $B^0 \to D_0^{*-}(\to D^-(\to K^+K^-\pi^-)\pi^0)\mu^+\upsilon$
(4) $B^0 \to D_0^{*0}(\to D^-(\to K^+K^-\pi^-)\pi^0)\mu^+\upsilon$
(5) $B^0 \to D^?(\to K^+K^-\pi^-)\tau(\to \mu^+\upsilon\upsilon)\upsilon$
(6) Other

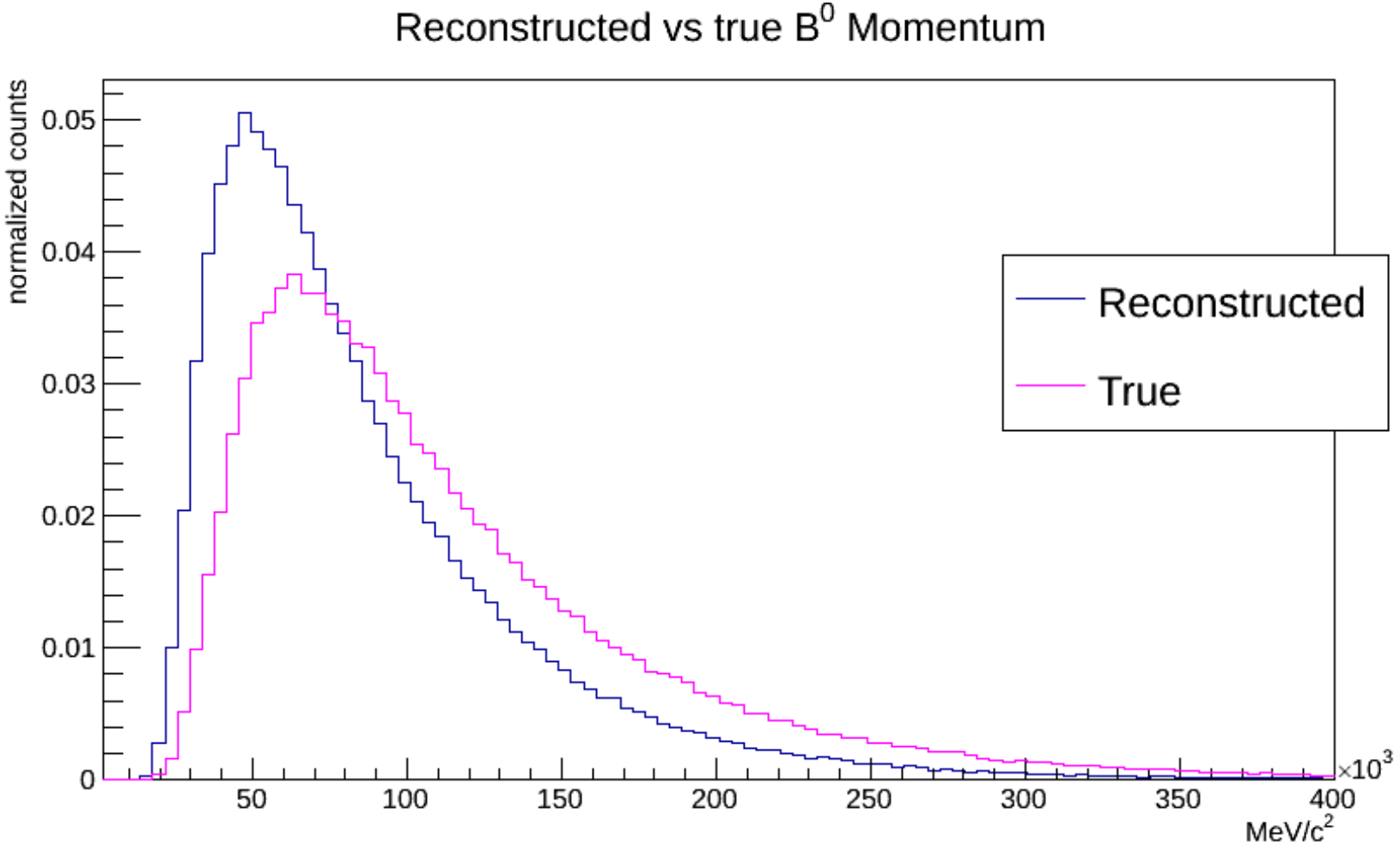
Decay Mode	Percent of Total Decays (that generate KKπμν)
(1)	52.6
(2)	38.1
(3)+(4)	1.7
(5)	1.3
(6)	6.3

Observed Decay Times for Different Decays (normalized)



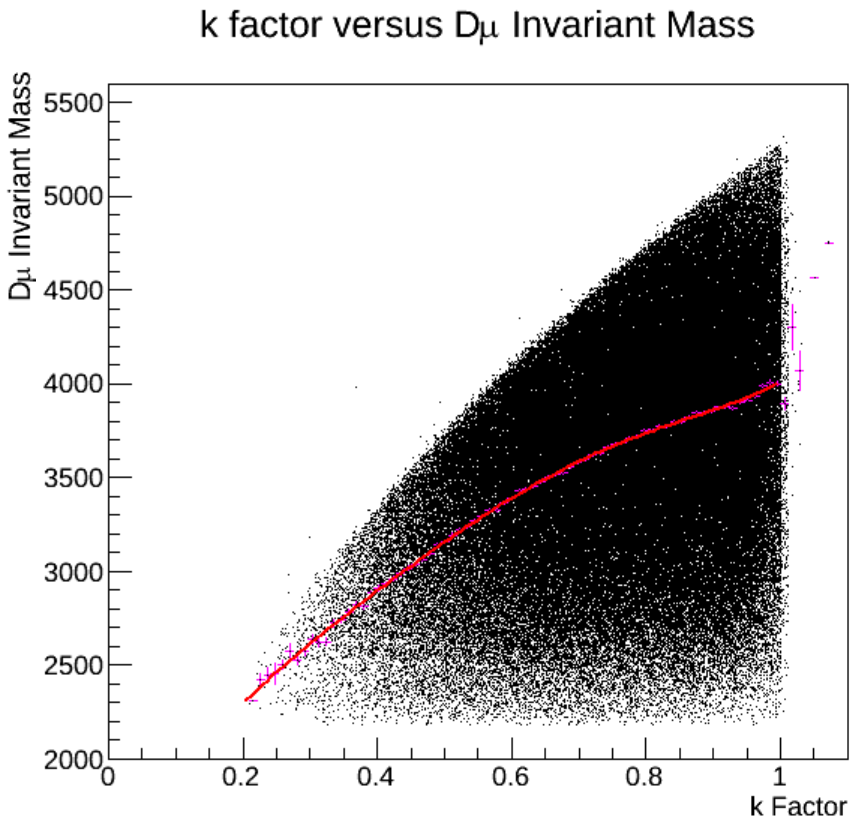


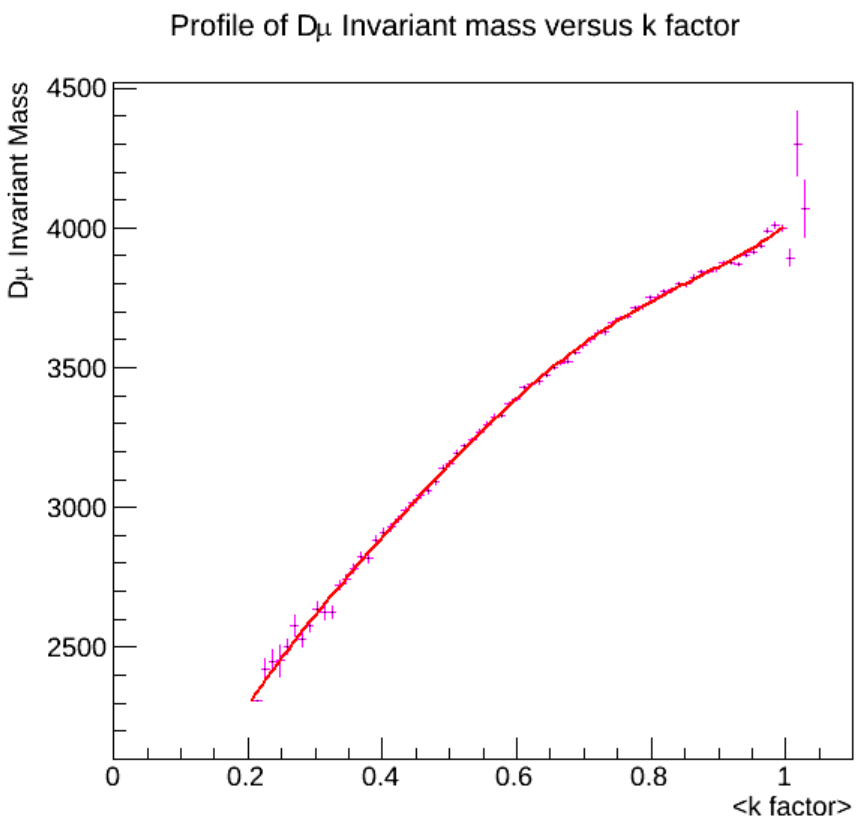
Missing Neutrino



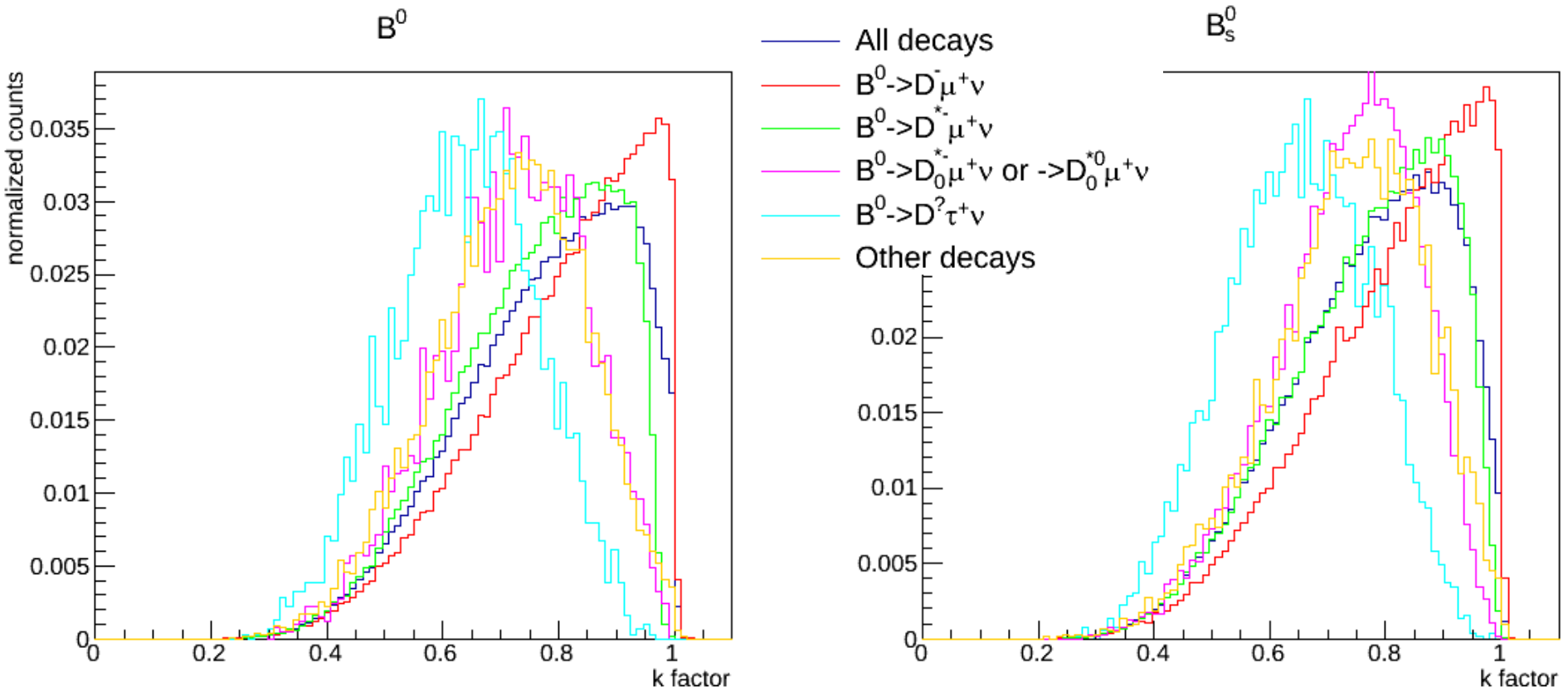
K-Factor Correction

$$k = \frac{p_B^{rec}}{p_B^{true}} = \frac{p\,(KK\pi\mu)}{p\,(KK\pi\mu\upsilon)}$$





K-factors for Different Decays (normalized)



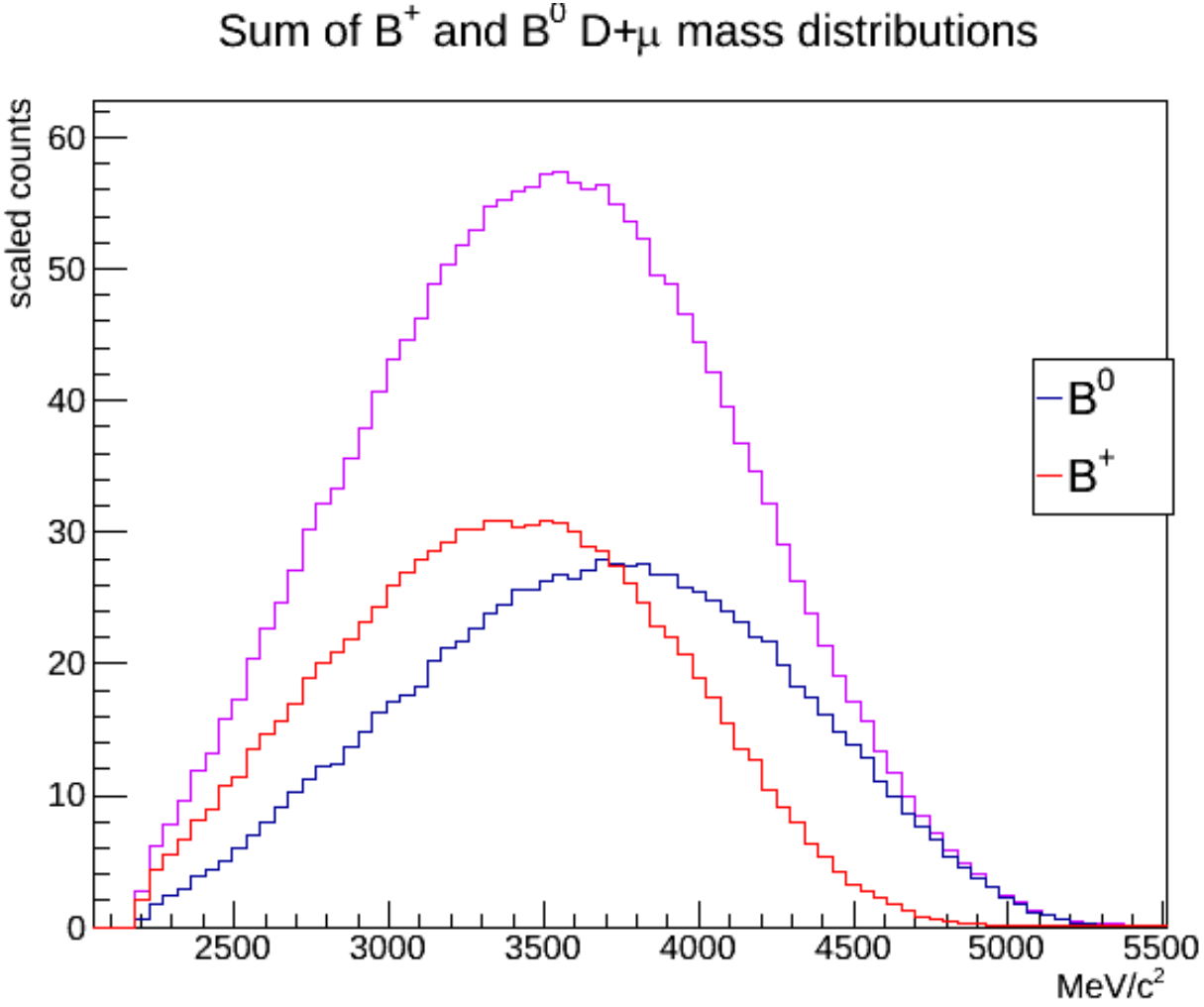
For the future: need to estimate the effect of differing k-factors on the final lifetime measurement

Distinguishing Between B^+ and B^0

$$B^+ \rightarrow D^-(\rightarrow K^+K^-\pi^-)\pi^+\mu^+\upsilon$$

The B^+ can decay to a final state similar to the one we are interested in. This decay is about 1/10th as frequent as that of the B^0, so it provides a significant background.

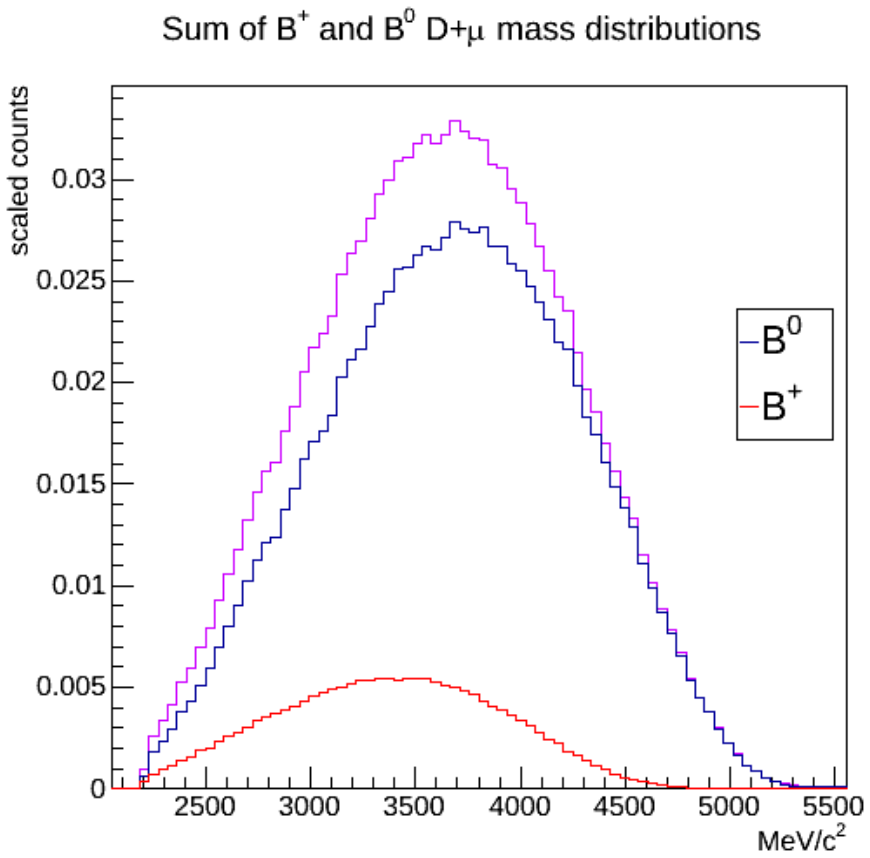
Distinguishing Between B^+ and B^0

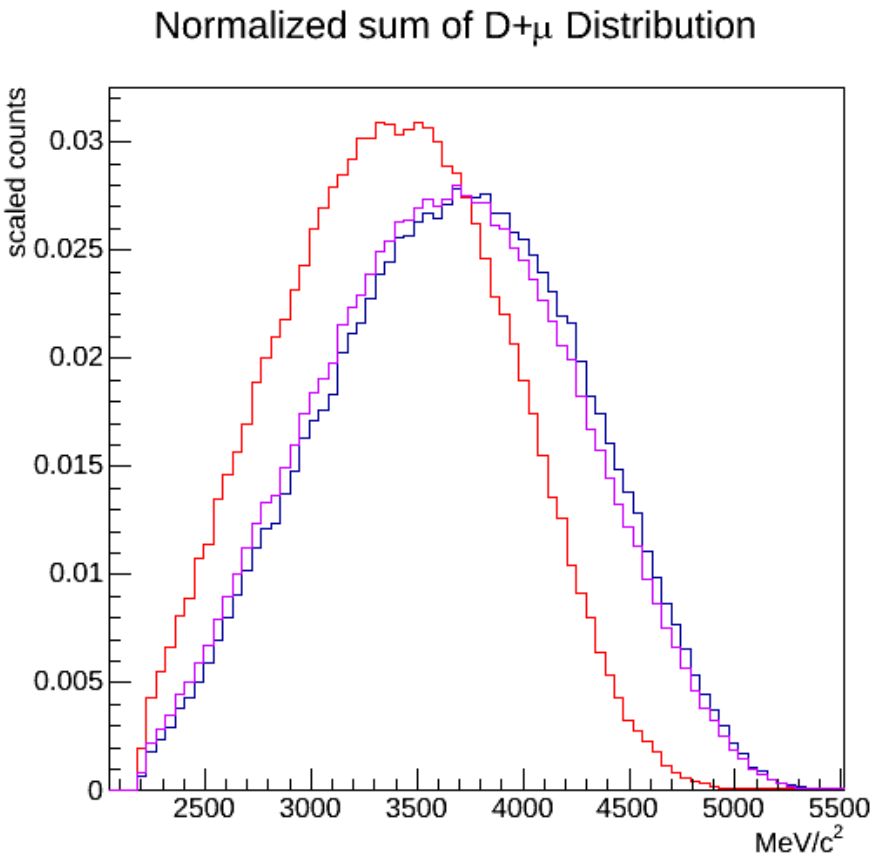


An Additional Complication

So far, we have had equal amounts of $B^+$and B^0 entries. What if the amount of entries are not equal?

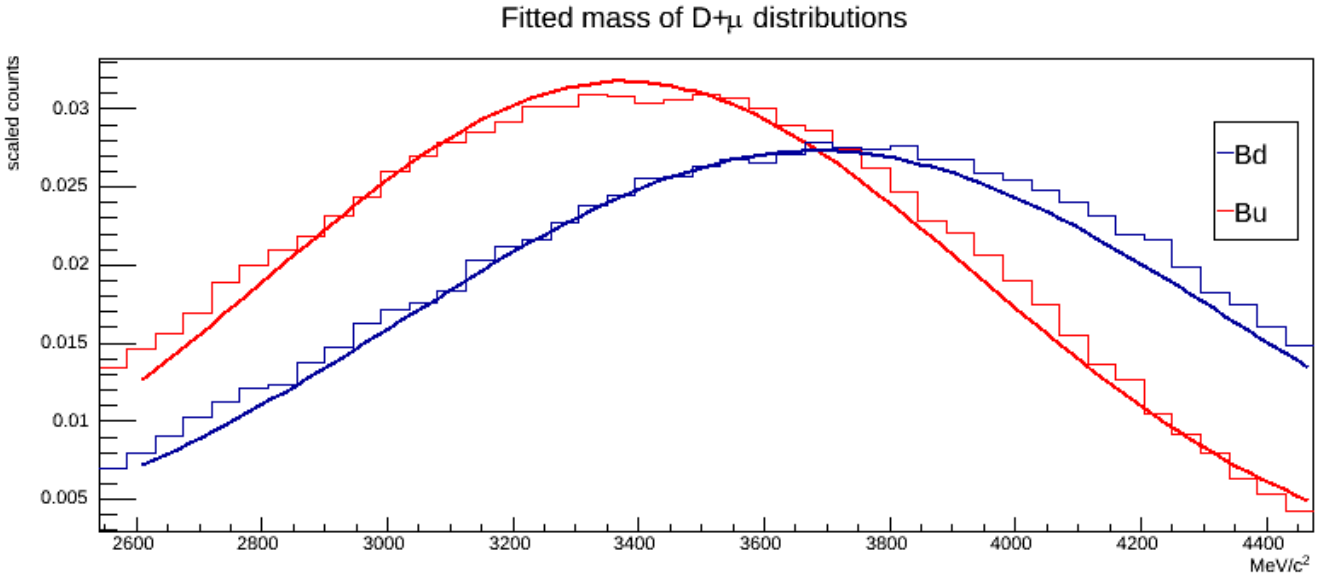
For 15% B^+ entries:





Solution: Fitting

Idea: fit Gaussians to the B^+ and B^0 mass distributions, call them G_{B^+}, G_{B^0}

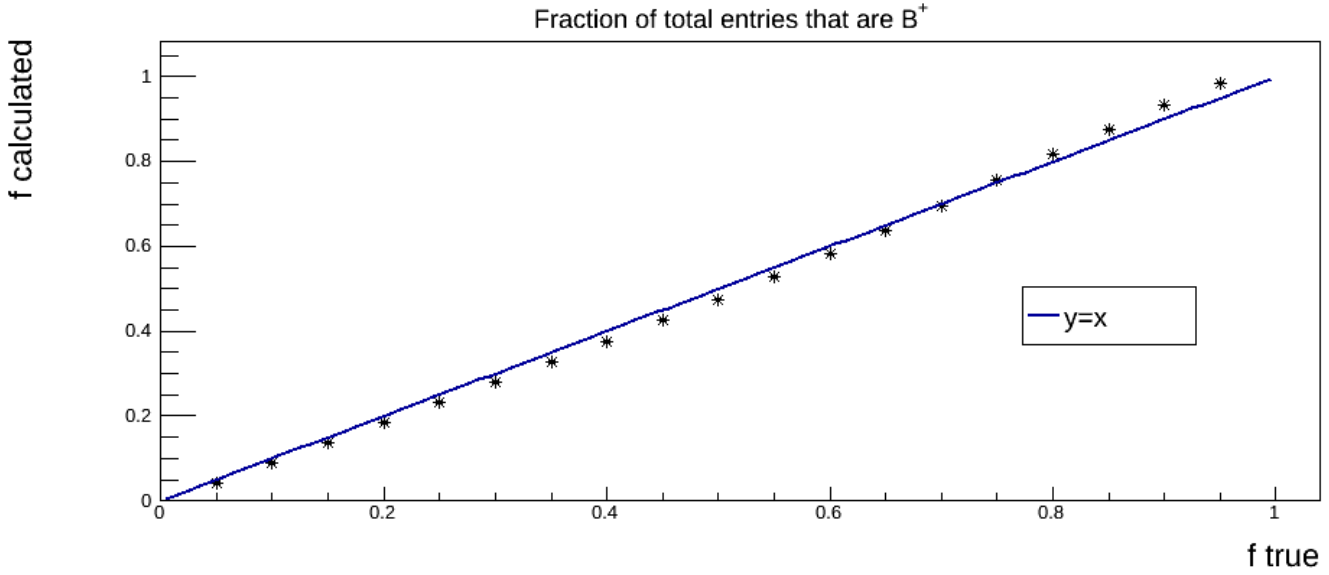


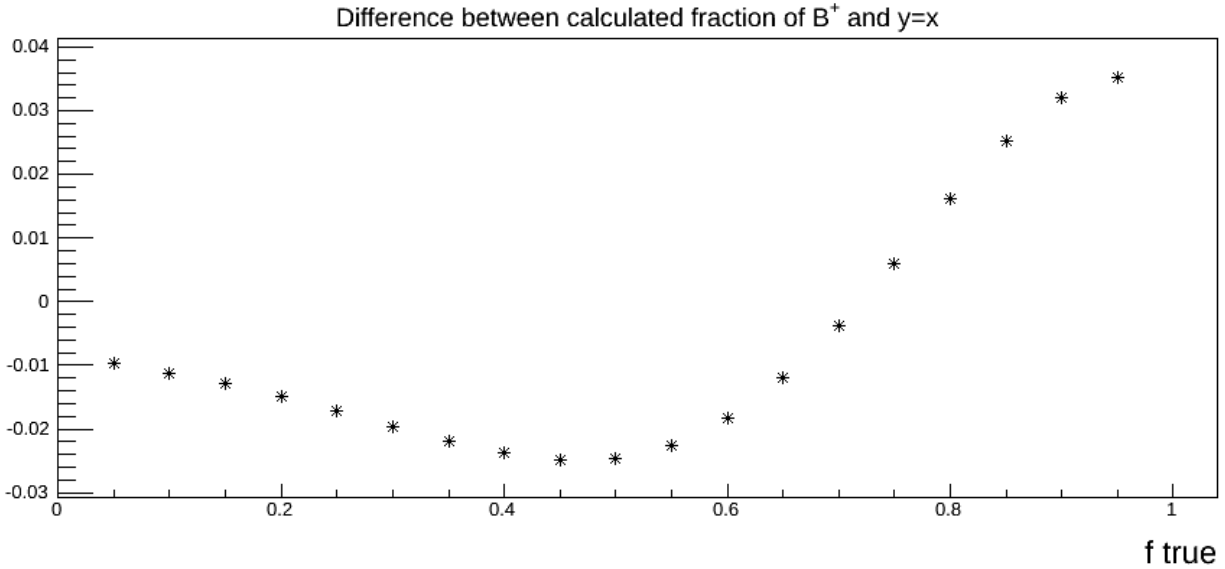
Then fit the following function to the unknown distribution:

$$h(f) = N(f * G_{B^+} + (1 - f) * G_{B^0})$$

f = fraction that is B^+
N = constant
G_{B^+}, G_{B^0} normalized Gaussians

How Accurately can we Reconstruct the Composition of the Simulation?





Summary

Decay modes

- The shape of the lifetime distribution is dependent on the decay mode. The k-factor distribution significantly varies with decay mode.

Differentiating between $B^+$and B^0

- The fit I developed can determine the percent of B^+ background fairly well.

ACKNOWLEDGEMENTS – SPECIAL THANKS

Diego Tonelli (CERN)

Angelo Di Canto (CERN)