LHCb summary

1 Week 1

- test data to analyse invariant mass of B mason assuming KKK decay, using known kaon mass
- looked at kaon/pion probabilities
- started analysing $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$ decay
  - selection: only include $P(kaon) > 0.9$ and $P(pion) > 0.7$
  - selection: also excluded all muons
  - assigned new variables for pion and kaon variables
  - selection: pion charge sums to 0
  - found invariant mass of B mason with same technique as before
- looked at two body resonance - intermediate decay via neutral particle
  - want to get rid of D mason decay as it decays via c quark and we are interested in b quark
  - selected data of B mason mass ± 60 MeV/c^2 from mass plot
  - three possible intermediate decays: $\pi^{+}\pi^{-}$, $K^{+}\pi^{+}$ and $K^{-}\pi^{+}$
  - computed invariant mass for all three possible cases
  - plot under condition that charges sum to zero - reoccurring events form peak
  - found multiple peaks: D mason from $K\pi$ decay and two relatively slightly shifted peaks in both $K\pi$ and $\pi\pi$
  - applied D mason cut: reject all events with D mason mass ± 30 MeV/c^2
  - no need to exclude muon tracks misidentified as pions - excluded muons from the start
  - *why do muon get easily misidentified as pions?* - similar mass
  - *check that none of the resonance peaks have c quarks*

2 Week 2

- Fitting:
  - Normalized Gaussian to signal and combinatorial background
  - Exponential to background
  - subtracted background and combinatorial background from histogram
  - separated B^{+} and B^{-} decays by considering K charge and plotted them individually
  - Gaussian integral divided by bin width gave counts in each peak
  - from this we could find value CP asymmetry - consistent with 0
- Dalitz plots:
  - created dalitz plots for simulation data
  - created dalitz plots for all data - including D mason. Clearly saw this on the plot
  - cut regions of 5284.37 ± 40 MeV/c^2 of B mason mass
  - did this individually for $B^{\pm}$
  - rough background subtraction by taking the background from the B mason mass data, just above the peak and subtracting that
  - background data is from higher mass region and therefore slightly larger on the Dalitz plot - hence we get negative entries on the upper edge
  - floor histograms to zero

3 Week 3

- Dalitz plots:
  - integrate background function under peak and the background used for subtraction and scale background used for subtraction
  - variable bin size so that fluctuations of number of bins across dalitz plots for $B^{\pm}$ are minimal - could have done by optimization, but only did it by eye to save time
  - calculate error in each bin first using the `hdalitzass->Sumw2();` function and then the `hdalitzass->GetBinError(a,b)` function
  - cut all errors > 0.4
  - set all bins to zero which have 0 entries in either of $B^{\pm}$ plots
  - produce significance plot: asymmetry / error - this shows us the most trustworthy regions
  - produced asymmerty plot with error cuts
- CP violation
  - best region found was $m^2_{K\pi} < 15\ GeV^2/c^4$ and $0\ GeV^2/c^4 < m^2_{\pi\pi} < 0.6\ GeV^2/c^4$
  - only for that region produced three body decay histograms with errorbars - both for $B^{\pm}$
  - see a clear difference in the peak - B^- decay leads to a much larger signal than $B^+ decay$
  - Now do a plot for B^+ and B^- combined and do a fit
  - now for individual plots, take a 2 sigma range around the mean and the width of the combined fit and set this as a range for the individual fits - there is no reason why width and mean should be different
  - found a good fit, which represents data well and a asymmetry value consistent with the value found in the paper
  - analysed region 2 : $21\ GeV^2/c^4 < m^2_{K\pi} < 25\ GeV^2/c^4$ and $1.2\ GeV^2/c^4 < m^2_{\pi\pi} < 3\ GeV^2/c^4$
  - found negative asymmetry, as expected
  - here we can not see and 4body background.
  - had to add additional restrictions to make the fitting work. these included setting amplitude and sigma of the 4body gaussian to above 0

4 Week 4

- changed standard error that assumes poisson, to error including errors from fit
- Systematic errors
  - The decay $B^{\pm} \to J/\psi K^{\pm}, J/\psi \to \mu^+\mu^-?$ serves as a control channel for $B^{\pm} \to h^{\pm}h^+h^-$ decay modes. Since it has negligible CP violation, the raw asymmetry observed in $B^{\pm} \to J/\psi K^{\pm}$ decays is entirely due to production and detection asymmetries.
    * remove all cuts except for probK ¿ 0.9 and introduce cut $3050\ MeV/c^2 < m_{\pi\pi} < 3150\ MeV/c^2$, which is the J/ψ mass
    * we can write all asymmetries as $A_{CP} = A_{raw} - A_{\Delta}$, where A_{CP} is the desired result, A_{raw} is what we measure and A_{Δ} is a correction term
    * we can estimate this correction term for J/ψ by measuring the asymmetry and subtracting the known value from PDG, errors added in quardature
    * this correction can be subtracted from all measurements as it represents detection/production asymmetry and the error on A_{Δ} is assigned as a type of systematic error
  - Magnet UP/DOWN:
    * first created asymmetry dalitz plots for magnet up and down individually with individual backgrounds
    * then we created a dalitz plot of significance : difference between the magnet polarity data divided by errors added in quadrature
    * took all the bins and plotted a 1D histogram of the significance in each bin
    * found that this follows a Bell curve, consistent with mean 0, suggesting that this systematic error is not significant for this analysis, the statistical error is much larger
    * Analysing the significance of the asymmetry difference, for the different magnet polarities, in every bin in the Dalitz plot, it was shown that this follows a normal distribution, as expected for data under no systematic influence.

  - different models:
    * took global asymmetry data and fit 4 models to the data
    * functions include: normalised gaussian, linear, exponential, landau
    * got different asymmetry from each
    * compute standard deviation from these to get systematic error
    * repeat for every A
    * A is still just from one model but get a systematic error from this

- Resonance state cut
  - took a region of $\rho(770) \pm 100\ MeV/c^2$ and cut this from the data and the we cut everything but this region
  - our region 1 in the dalitz plot contains $\rho(770)$ and therefore we saw a corresponding effect here.
  - when removing the region the asymmetry decreased drastically - also a larger error due to the fitting getting worse
  - on the contrary cutting everything but this region lead to a very large asymmetry
  - this suggests that CP asymmetry is caused by this resonance state
  - barely enough data points were available

5 Improvements

- more sophisticated background and signal fitting - maybe with physical / statistical reasoning behind it; this would reduce systematic uncertainty
- Dalitz plot optimisation - now we could have possible misidentification of certain regions
- further investigation on momentum dependence of systematic uncertainties - would affect some local regions more than others if present

6 Results

Global asymmetry

$$A_{CP} = -0.004\ \pm 0.013(\text{stat})\ \pm 0.007(\text{syst})\ \pm 0.007(J/\Psi)$$

Local negative asymmetry

$$A_{CP} = -0.225\ \pm 0.009(stat)\ \pm 0.018(syst)\ \pm 0.007(J/\Psi)$$

Local positive asymmetry

$$A_{CP} = \ 0.729\ \pm 0.051(\text{stat})\ \pm 0.048(\text{syst})\ \pm 0.007(J/\Psi)$$

$670 < M_{\pi\pi} < 870$ [MeV/c^2] :

$$A_{CP} = 0.746\ \pm 0.042(\text{stat})\ \pm 0.048(\text{syst})\ \pm 0.007(J/\Psi)$$

$M_{\pi\pi} < 670,\ M_{\pi\pi} > 870$ [MeV/c^2] :

$$A_{CP} = 0.452\ \pm 0.153(\text{stat})\ \pm 0.048(\text{syst})\ \pm 0.007(J/\Psi)$$