Analysis of the $\pi^+\pi^+\pi^-$ and $K^+K^-\pi^+$ final states

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Features of the three pion reaction

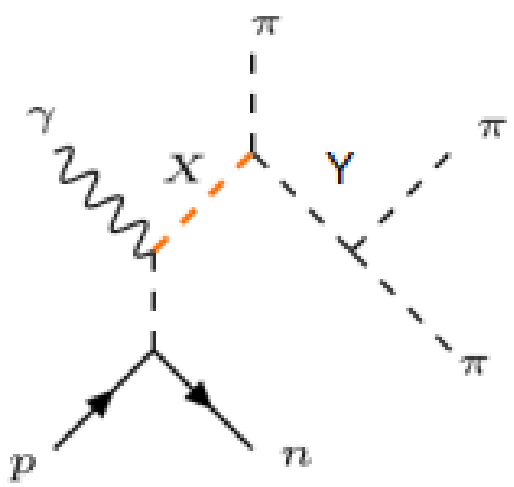


Figure: The three pion reaction

- The reaction is $\gamma p \rightarrow \pi^+\pi^+\pi^- n$
- The three pions are all detected in the forward detector
- The neutron is considered missing in this analysis
- Takes place at low Q^2: 0.007 - 0.3 GeV^2, the photon is called quasi-real for this reaction
- Some experimental evidence in other decay channels currently exists that the resonance labeled X is a hybrid

Within the MesonEx program

- The MesonEx trigger is defined by an electron in the Forward tagger and two charged hits in the Forward Detector.
- The electron is detected at small angles in the FT (2.5 - 4.5^o) and in the energy range 0.5 - 4.5 GeV.

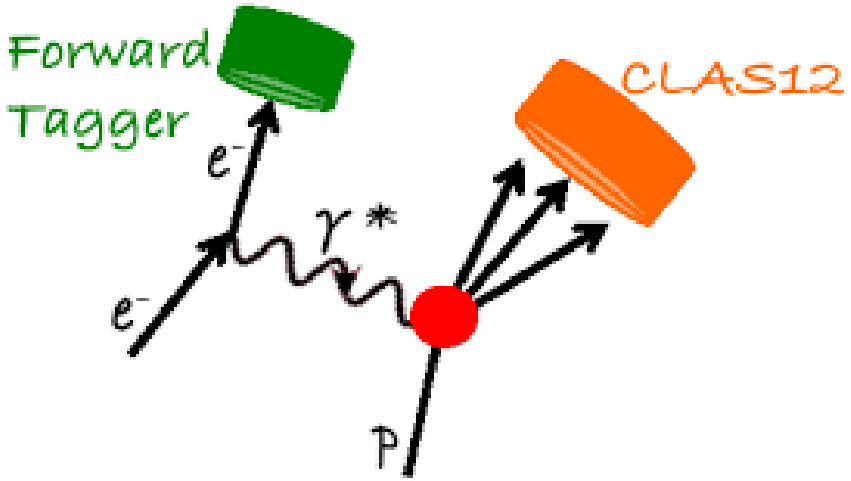


Figure: The Forward Tagger and CLAS12

Data Analysis Workflow

- All the available fall 2018 skim 3 data is being analysed - using both the inbending and outbending configuration.
- Data in hipo files is analysed using chanser that is built upon clas12root to produce root trees.[1]
- An sPlot fit is performed around the dependent variable - the missing mass in this case. This is done using brufit.[2]

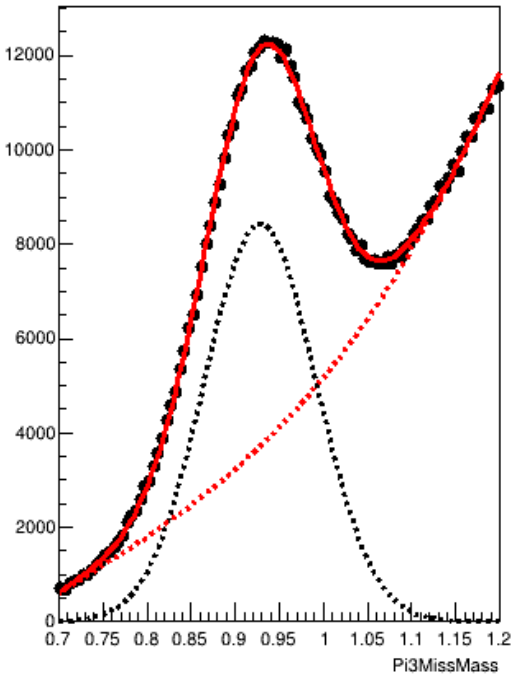
[1] https://github.com/dglazier/chanser
[2] https://github.com/dglazier/brufit

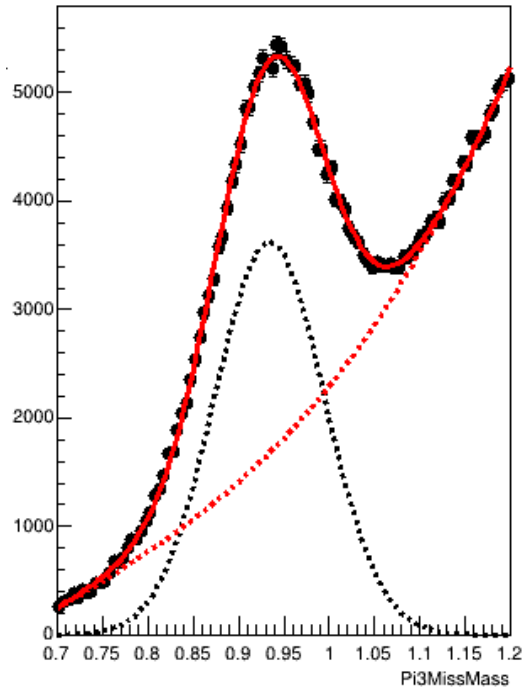
Data Analysis Workflow

- All inbending and outbending data from fall 2018 has been processed.
- Forward Tagger energy correction is applied to electrons.
- Start time correction found from e^- candidates in the FT.
- A series of cuts are applied:
  - 0.5ns timing cuts are placed on all particles, no EB pid condition applied
  - Only pions detected in the Forward Detector are considered
  - Events are required to have passed conditions of trigger bit 25
  - Relevant RG-A analysis note conditions: DC Fiducial cuts on the hadrons

Data Analysis Workflow

- Signal events are extracted from the data sample that passes the above mentioned cuts using the sPlot background subtraction technique performed in 'brufit'
- The fit is performed in this case by fitting a Gaussian distribution as the missing mass signal atop a second order Chebychev background for the $\pi^+\pi^+\pi^-$ final state.





Inbending signal yield: 267,017

Outbending signal yield: 109,937

Data Analysis Workflow

- A similar process is carried out on the $K^+K^-\pi^+$ final state
- The fit is performed in this case by fitting a Gaussian distribution as the missing mass signal atop a second order Chebychev background.

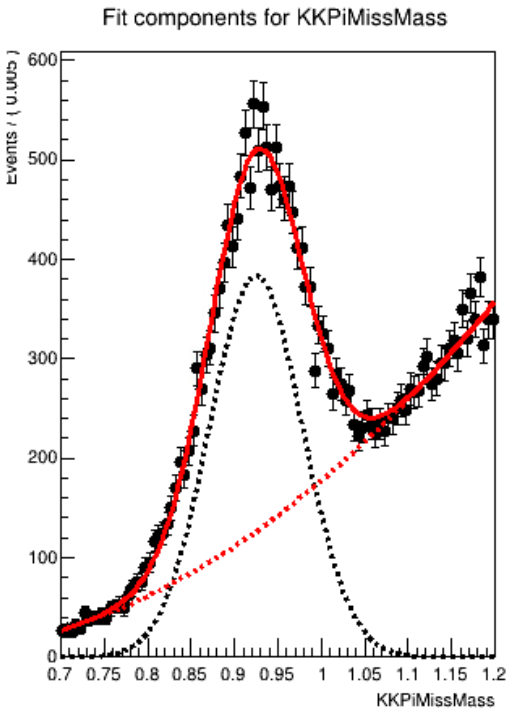


Figure: Inbending

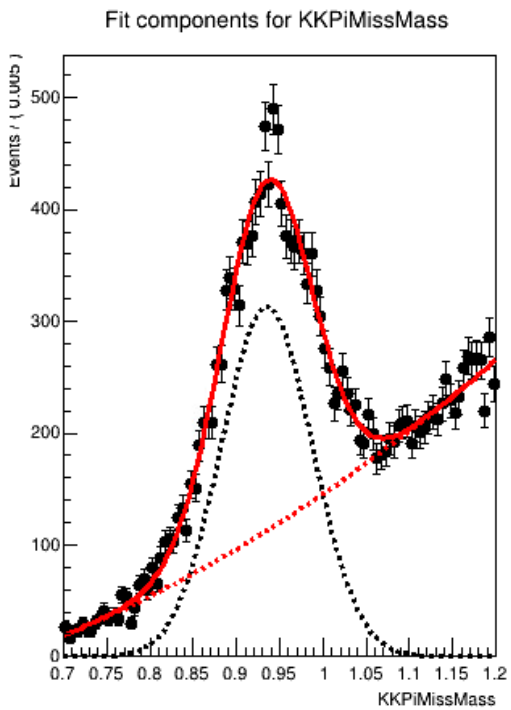


Figure: Outbending

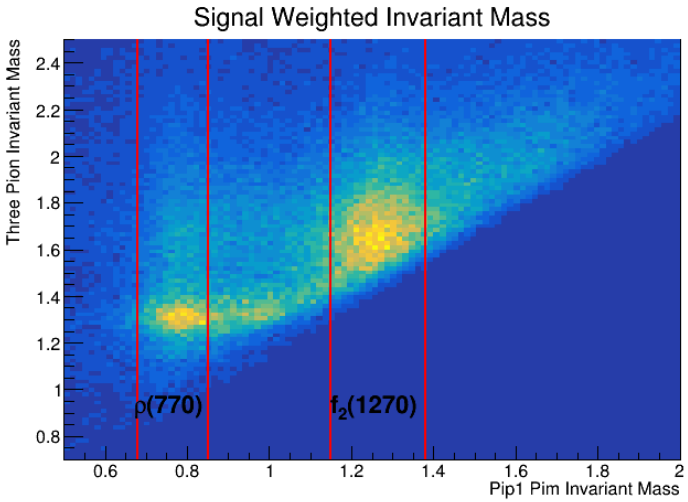
Inbending signal yield: 10,289

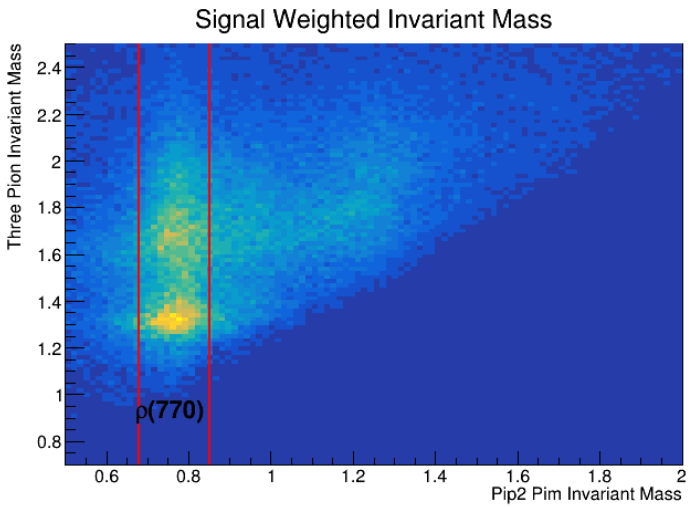
Outbending signal yield: 8,226

Signal Weighted Plots

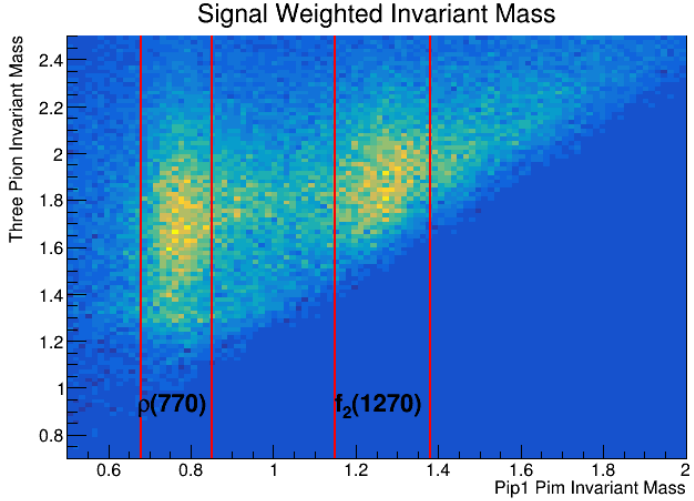
- The invariant mass plots are made from the signal weights of the sPlots fit ($\pi_1^+\pi^-$ top row, $\pi_2^+\pi^-$ bottom row).

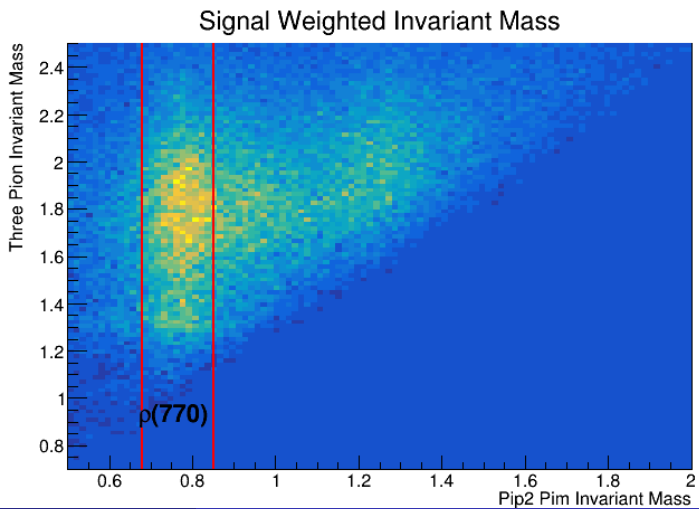
Inbending





Outbending

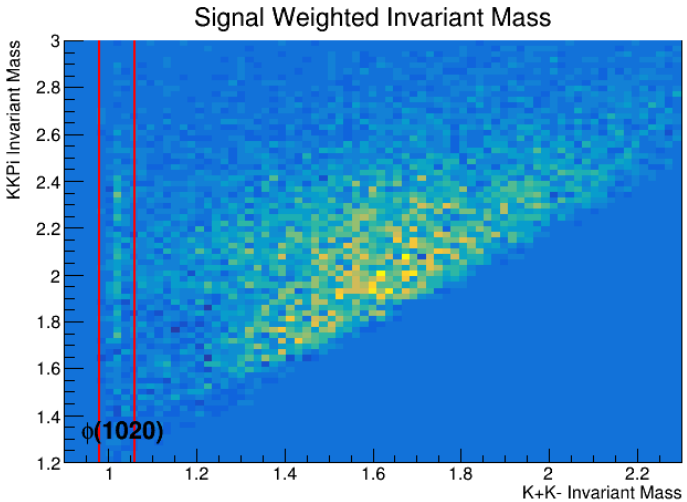


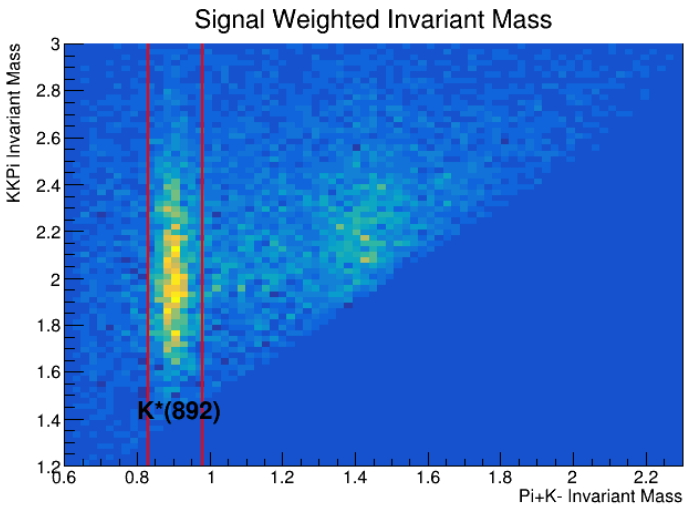


Signal Weighted Plots

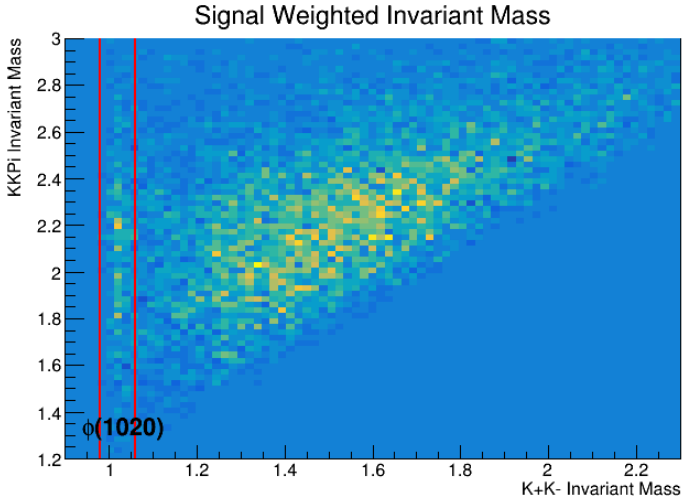
- The invariant mass plots for the $K^+K^-\pi^+$ final state are also shown (K^+K^- top row, $K^-\pi^+$ bottom row).

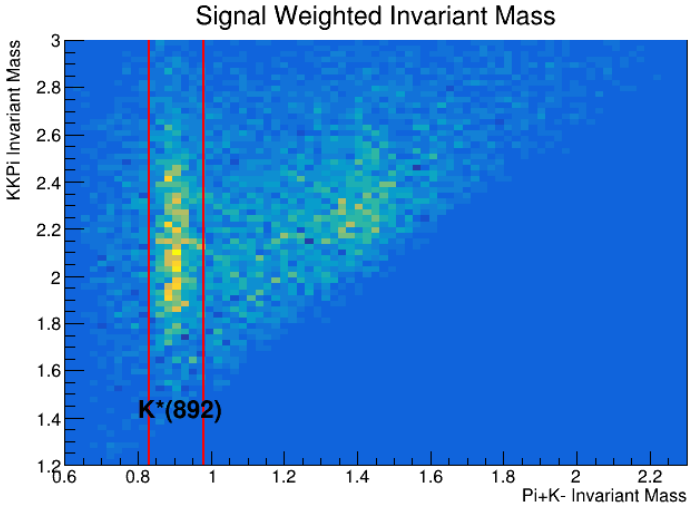
Inbending





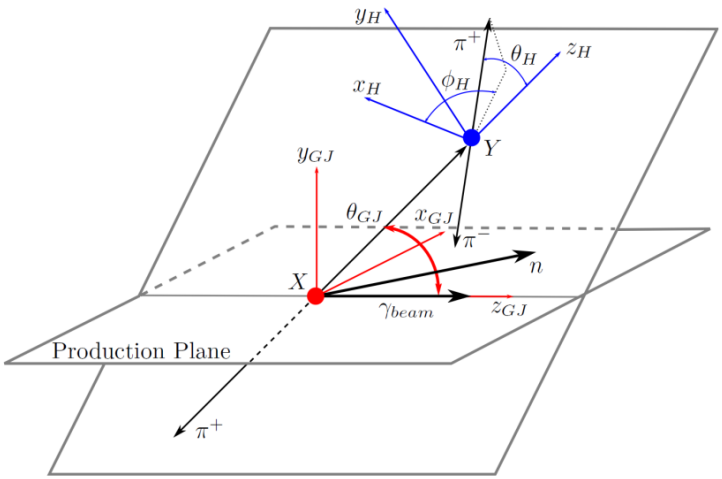
Outbending





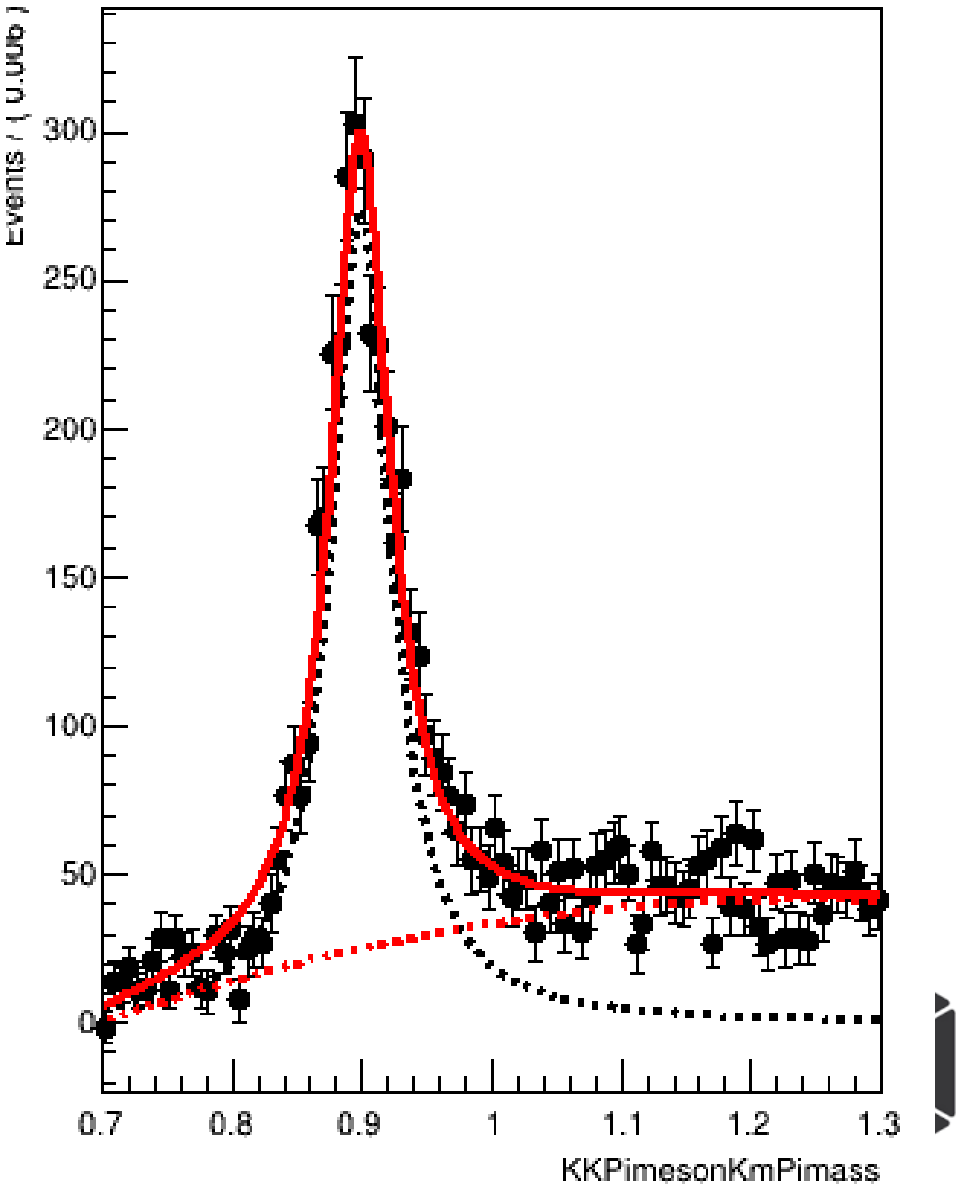
Decay Angles

- The reaction is described using the isobar model.
- The decay of the resonance X and of the isobar Y are boosted to a frame in which the daughter particles are back to back
- Consequently, there are four decay angles needed to describe the decay - the polar and azimuthal angles of each decay.
- There is also the complication of the isobar mass dependence in the decay and the interference effects between different decays.



Decay Angles

- One initial point of study has been the strong K^* isobar signal in the $KK\pi$ channel.
- It is possible to perform a second sPlot on the $K^-\pi^+$ invariant mass to isolate events decaying to the intermediate state K^*K^+
- This reduces the complexity of the decay model



The Fit process

- The intensity function that is used to fit the data is:

$$\mathcal{I}(\Omega) = \sum_{JMS\Lambda} \left(\frac{2J+1}{4\pi}\right)\left(\frac{2S+1}{4\pi}\right) H(JMS\Lambda) \times D^{J*}_{M,\Lambda}(\phi_{GJ}, \theta_{GJ}, 0) D^{S*}_{\Lambda,0}(\phi_{HF}, \theta_{HF}, 0),$$

  where $H(JMS\Lambda)$ are the moments - the parameters that we want to fit.

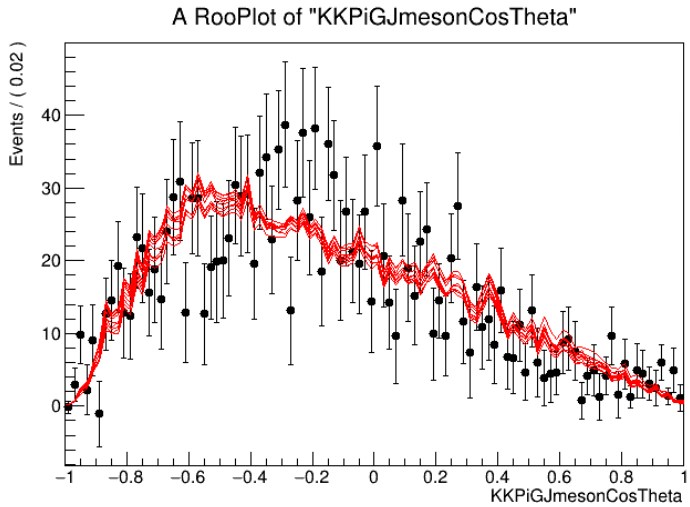
- The moments relate to the spin density matrix by:

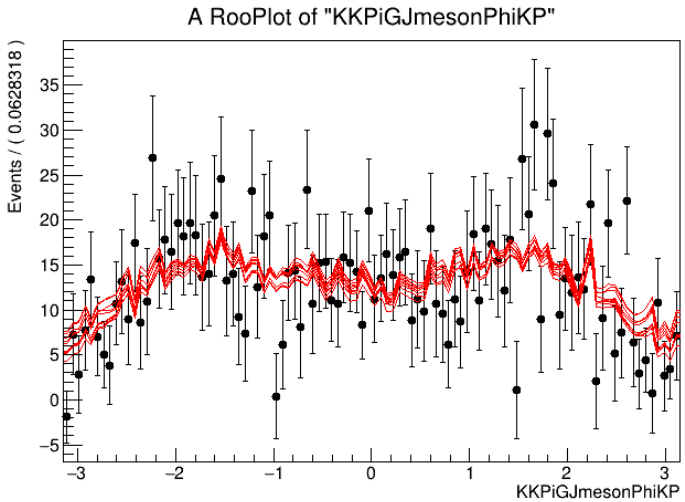
$$H(JMS\Lambda) = \sum_{b,b'}\sum_{\lambda,\lambda'} \left(\frac{\sqrt{(2l'+1)(2l+1)}}{2j'+1}\right)\left(\sqrt{\frac{2s+1}{2s'+1}}\right)(l,0;s,\lambda|j,\lambda) \times (l',0;s',\lambda'|j',\lambda')(s,\lambda;S,\Lambda|s',\lambda')(s,0;S,0|s',0)(j,m;J,M|j',m') \times (j,\lambda;J,\Lambda|j',\lambda') \times \rho_{bb'} \times R_{Yi}(m_Y) R^*_{Yi'}(m_Y). \quad (1)$$

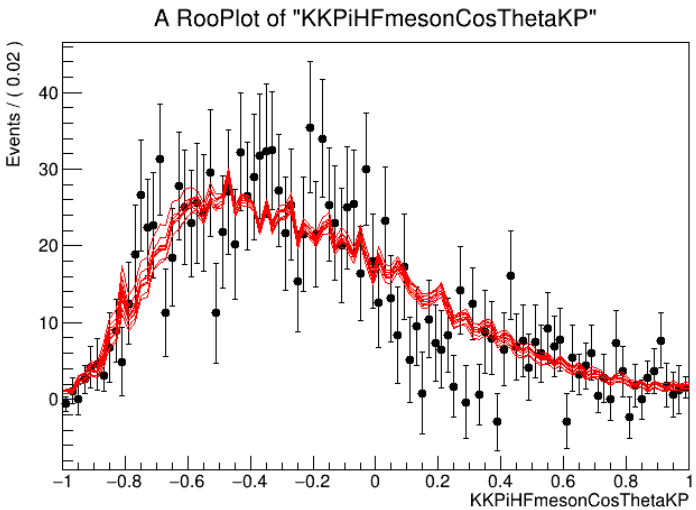
- The fit is done using an extended maximum likelihood fit with acceptance corrections incorporated using simulated events.

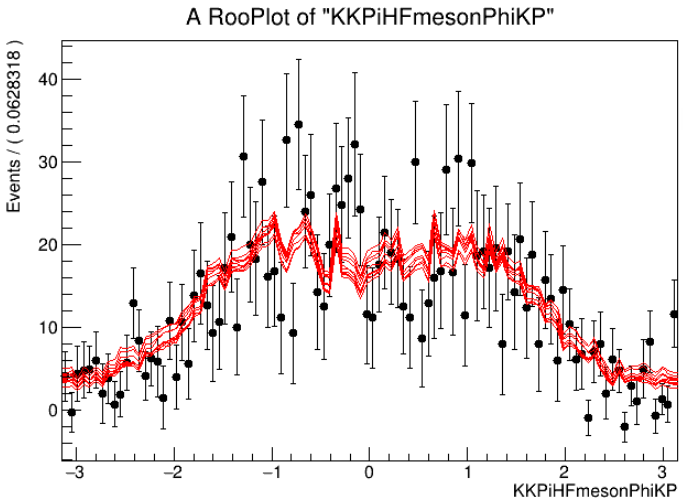
Decay Angles - 1.82 Mass Bin

- The intensity is given in terms of Wigner D-functions that are themselves dependent on the decay angles. The intensity is parameterised by the moments that we want to measure.









Current and Future work

- Validating the MCMC used to extract the moments from the K^*K fit.
- Working to get a method for a more general 3π or $KK\pi$ decay
- Using the extracted moments to determine partial waves in the decay
- Writing thesis!