

The search for hybrid mesons in the three pion decay channel

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Contents of this talk

- Motivation for this analysis
- Features of the three pion decay
- Analysis pathway
- Status of the data analysis



Features of the three pion reaction

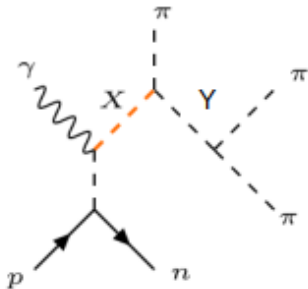


Figure: The three pion reaction

- The reaction is $\gamma p \rightarrow \pi^+ \pi^+ \pi^- n$
- 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
- RG-A data: proton target
- Some experimental evidence in other decay channels currently exists that the resonance labeled X is a hybrid



Experimental results in the search for exotic states

- The COMPASS experiment recorded a positive result from a data set published in 2010.
- This was performed from a pion beam impinging on a lead target with a $\pi^- \pi^+ \pi^+$ final state.
- The findings state the resonance with a mass of $(1660 \pm 10)\text{GeV}^2$ and a width of $(269 \pm 21)\text{MeV}^2$.

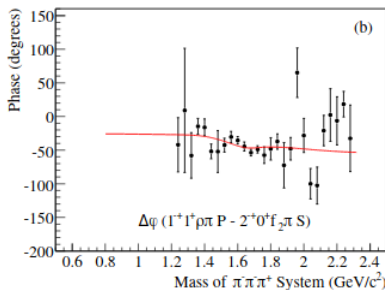
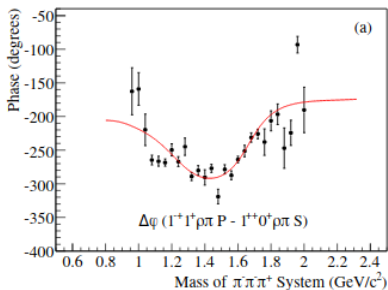
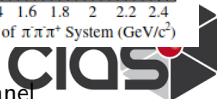


Figure: COMPASS results for the three pion channel



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 ($2.5 - 4.5^\circ$) and in the energy range $0.5 - 4.5$ GeV.

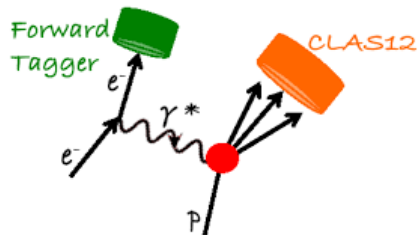


Figure: The Forward Tagger and CLAS12



Status of the Analysis

- All inbending and outbending data has been processed. Inbending: 2.8T, Outbending: 2.5T
- Forward Tagger energy correction is applied to electrons
- Start time correction applied to electrons in the FT, this is required as the z-vertex position is not known in the FT.
- Data processing is performed in 'chanser', employing a method of particle combinatorials
- A series of cuts are applied:
 - 0.5ns timing cuts are placed on all particles
 - 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: Hadron Chi2Pid and DC Fiducial cuts on the hadrons



Status of the Analysis

- 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.

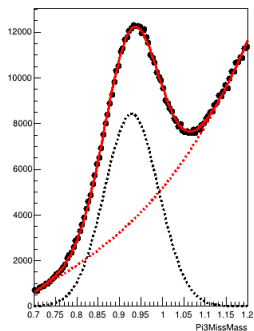


Figure: Inbending

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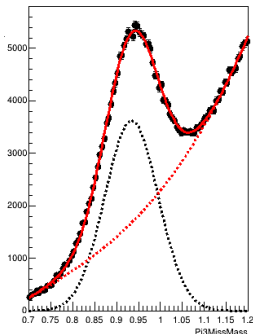


Figure: Outbending

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Inbending signal yield:
267,017
Outbending signal yield:
109,937

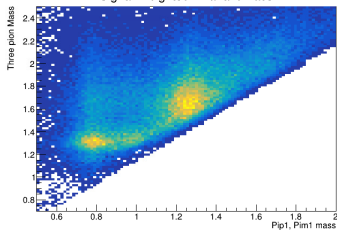


Signal Weighted Plots

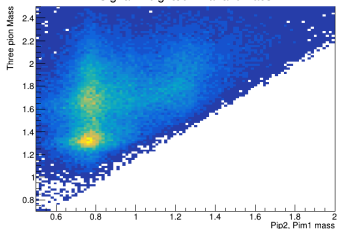
- The invariant mass plots are made from the signal weights of the sPlots fit ($\pi_1^+\pi^-$ top row, $\pi_2^+\pi^-$ bottom row).

Inbending

Signal Weighted Invariant Mass

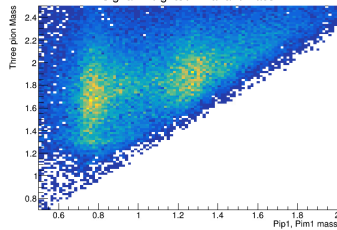


Signal Weighted Invariant Mass

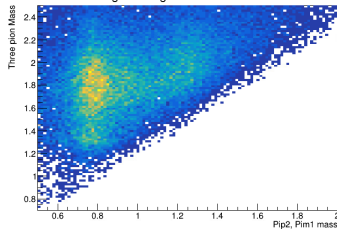


Outbending

Signal Weighted Invariant Mass

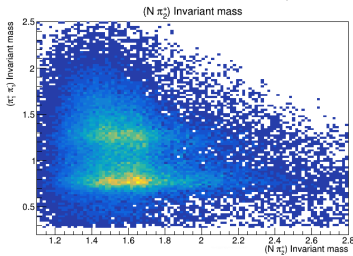
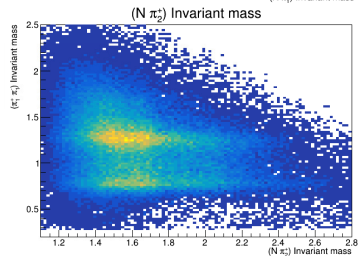
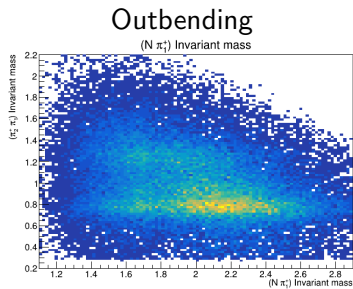
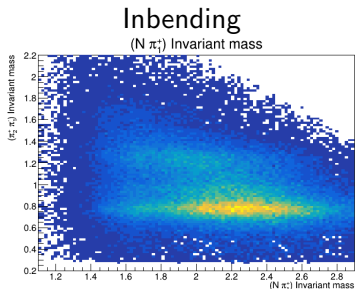


Signal Weighted Invariant Mass



Signal Weighted Plots

- For comparison, the plots of $N\pi$ are shown also.



Decay Angles

- The decay angle of the X resonance is plotted against the GJ decay angle
- The GJ decay angle as shown here is the polar angle between the direction of momentum of the resonance X and the direction of the beamline, in the rest frame of X

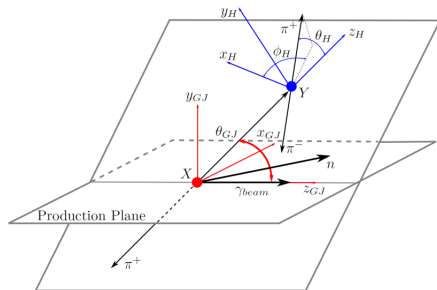


Figure: Visualisation of the Gottfried Jackson frame of reference

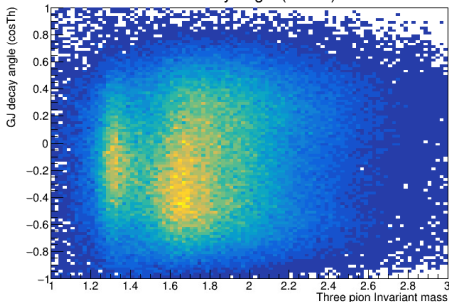


Decay Angles

- The decay angle of the X resonance is plotted against the GJ decay angle
- The following is the combination of the decay angle from $Y(\pi_1^+\pi^-)$ and $Y(\pi_2^+\pi^-)$

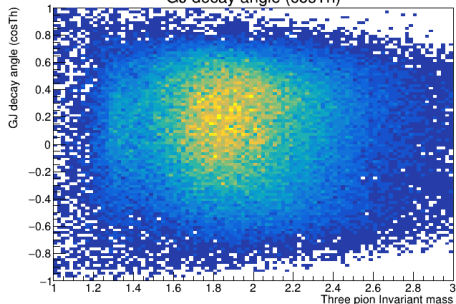
Inbending

GJ decay angle ($\cos\Theta$)



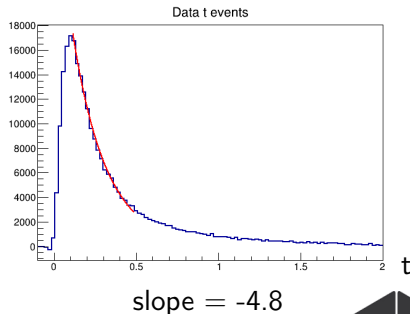
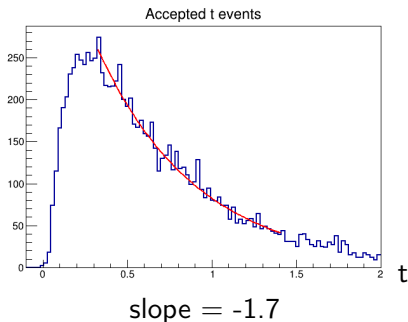
Outbending

GJ decay angle ($\cos\Theta$)



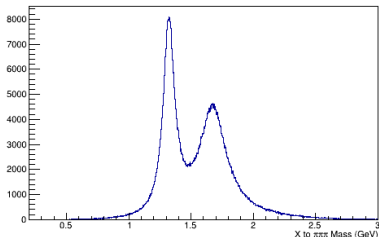
Current Work - Simulation

Comparison of the current simulation and data t slope.
The t slope of the event generator was set as -2.5 .



Visualisation of the acceptance of gemc.

Generated $\pi\pi\pi$ events

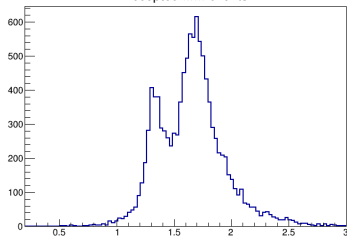


Generated invariant mass spectrum created with two Breit-Wigner distributions -

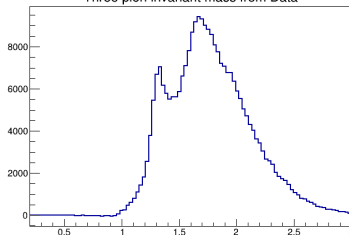
[BW1: mass = 1.32GeV, width = 0.11GeV.

BW2: mass = 1.67GeV, width = 0.26GeV]

Accepted $\pi\pi\pi$ events



Three pion invariant mass from Data



- Working on simulations to reproduce the structures seen in data and investigate acceptance effects
- Work towards a full amplitude analysis by looking at performing a partial wave analysis on the data set



Spare Slides



Experimental results in the search for exotic states

Data from COMPASS was analysed by the Joint Physics Analysis Center (JPAC) in 2018. They were looking for evidence of the $\pi_1(1400)$ and $\pi_1(1600)$ candidate exotic states.

They found evidence of the $\pi_1(1600)$ state but not of the $\pi_1(1400)$. The mass and width of the state were found to be $1564 \pm 24 \pm 86$ MeV and $492 \pm 54 \pm 102$ MeV

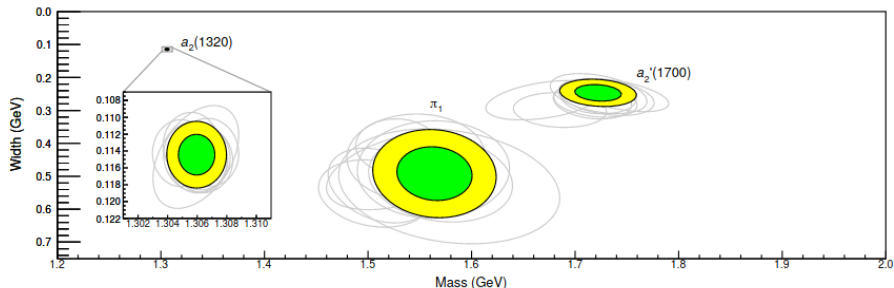
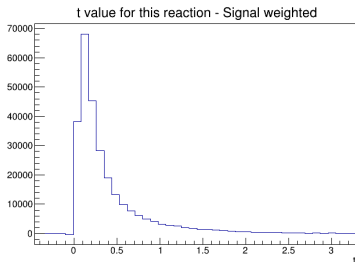
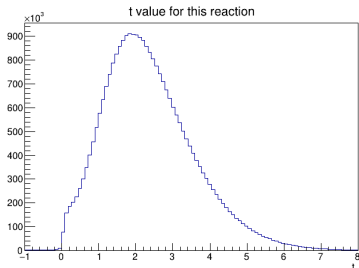
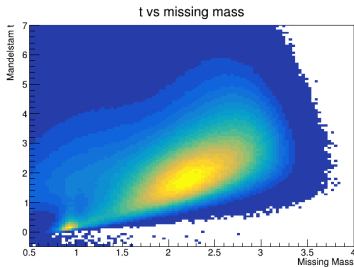


Figure: JPAC findings of the position and width of the $\pi_1(1600)$

Effect of the Background Subtraction method

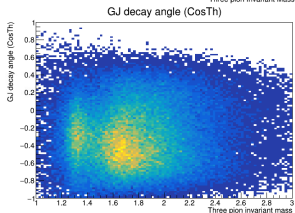
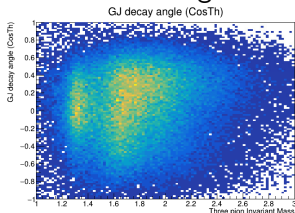
- The following can show the effect on the background subtraction for this process



Decay Angles

- The decay angle of the X resonance is plotted against the GJ decay angle
- Plots are shown for decay $X \rightarrow Y(\pi_1^+ \pi_1^-) \pi_2^+$ (above) and the decay $X \rightarrow Y(\pi_1^+ \pi_1^-) \pi_2^+$ (below)

Inbending



Outbending

