Dalitz Plot Analyses of B meson decay to three charged tracks at *BABAR*

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Sian Morgan

University of Birmingham

BABAR Collaboration

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Introduction

We are interested in rare charmless decays of charged B-mesons such that:

$$B^{\pm} \to h^{\pm}h^{\pm}h^{\mp}$$

where h stands for a kaon or a pion.

Consider the $B^{+} \to K^{+}\pi^{+}\pi^{-}$ decay. As well as the non-resonant decay there are also a number of possible intermediate resonant states such as $K^{*0}(892)$ in the $K\pi$ mass spectrum and $\rho^{0}(770)$ in the $\pi\pi$ mass spectrum.

A full Dalitz Plot analysis is needed to corrrectly model the interference between these intermediate resonant quasi 2-body states.

- Consider the decay of a B-meson to three particles i, j and k
- The conventional Dalitz plot is defined in mass squared space where the masses are given by:

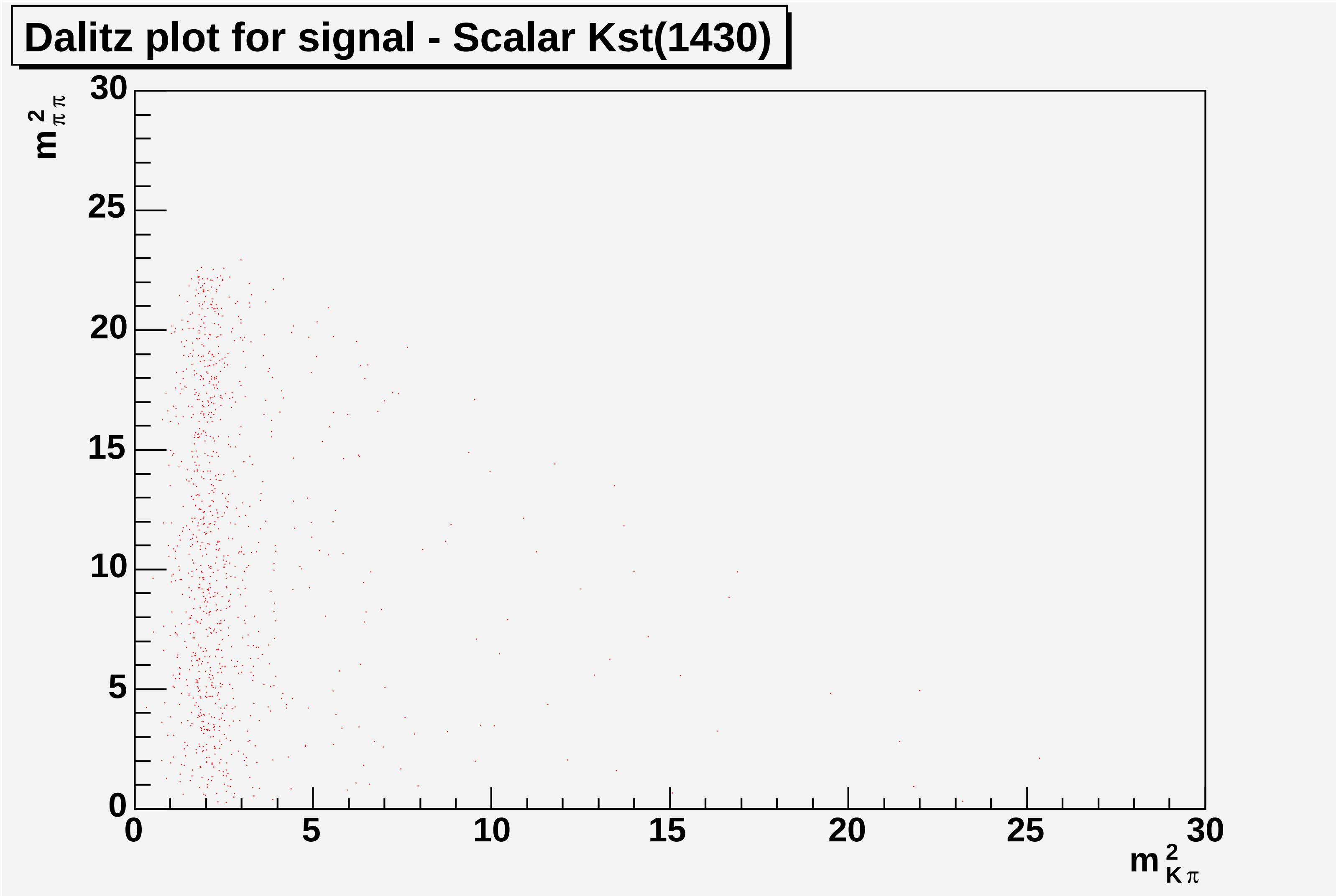
$$m_{ij}^2 = p_{ij}^2$$

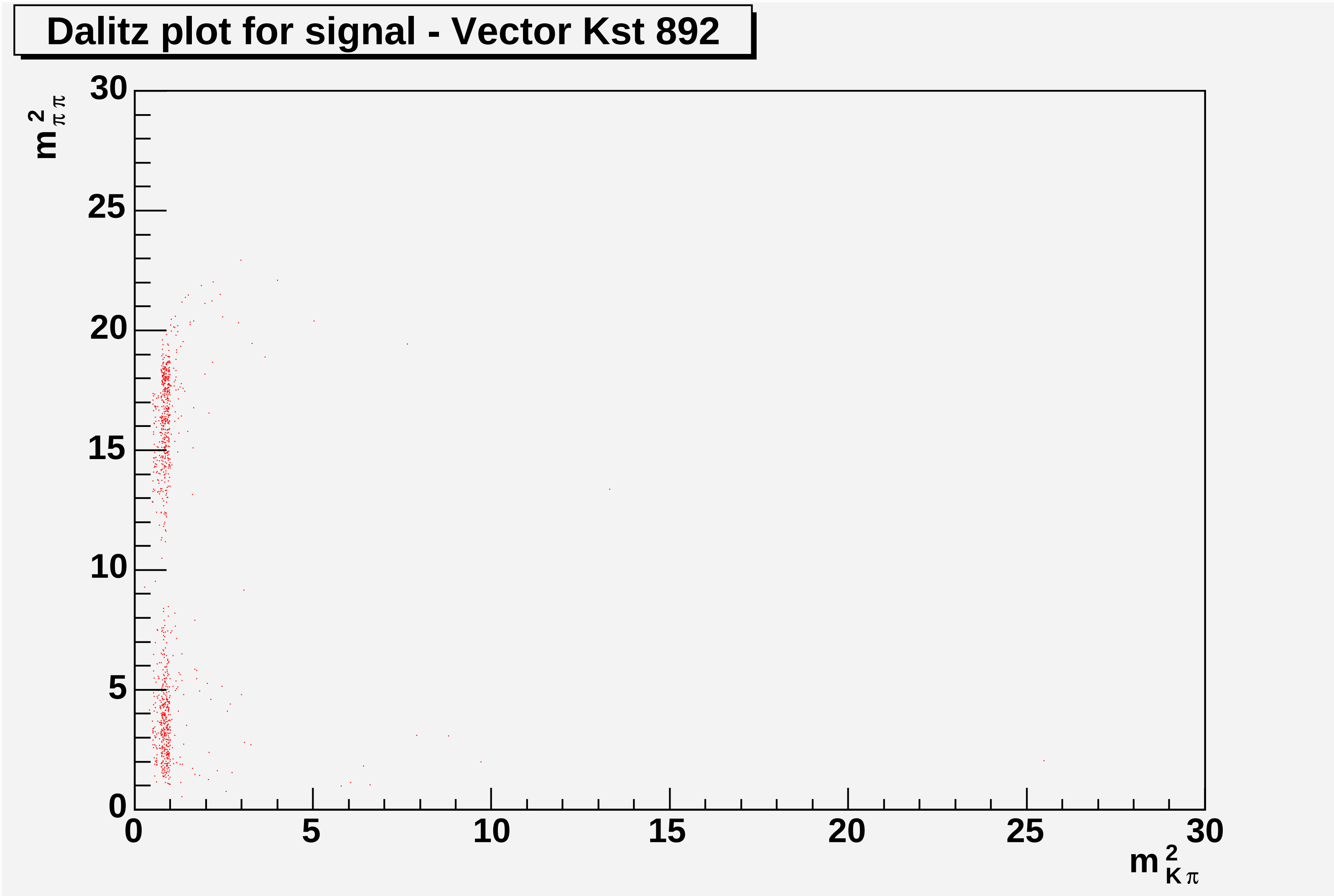
where

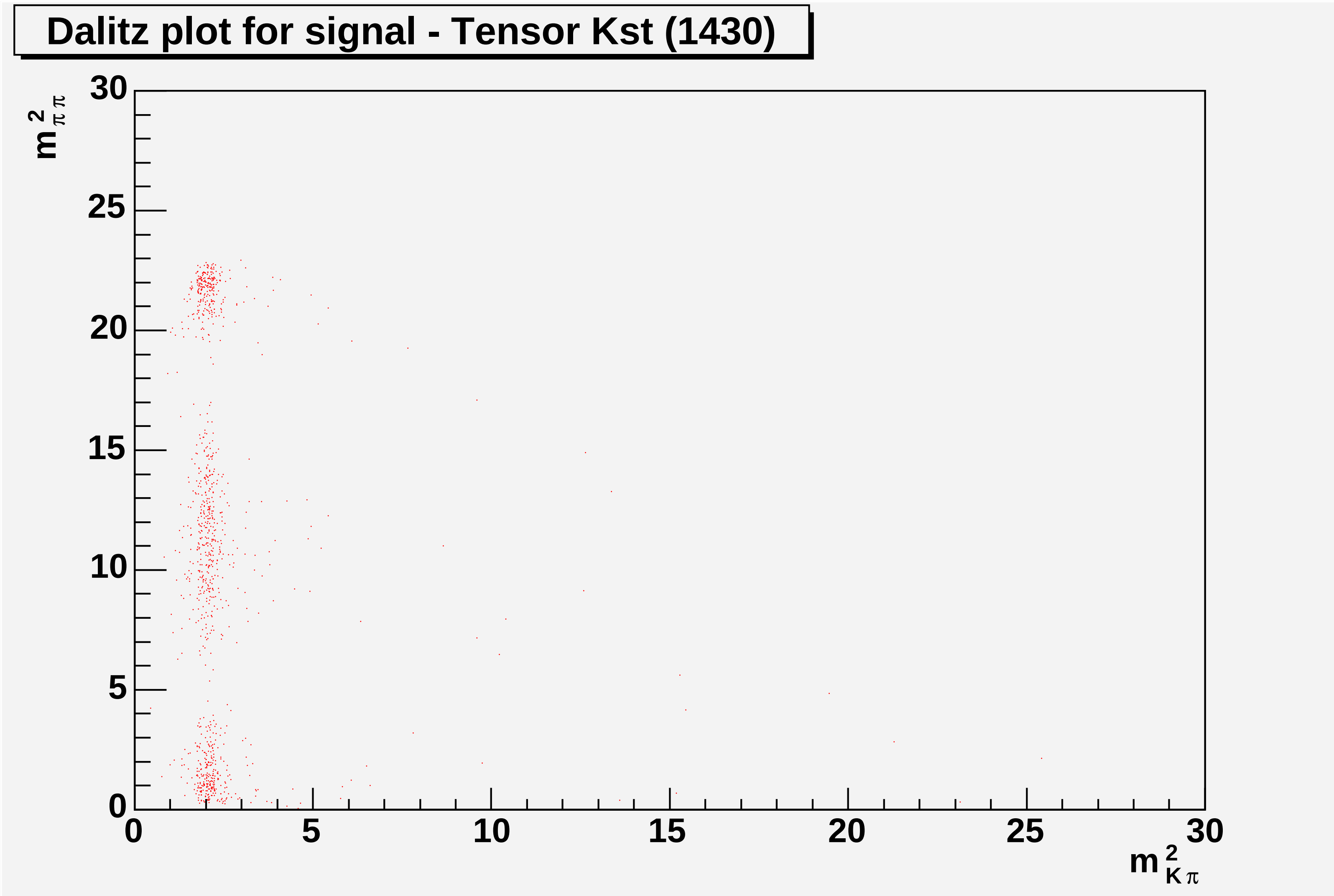
$$p_{ij} = p_i + p_j$$

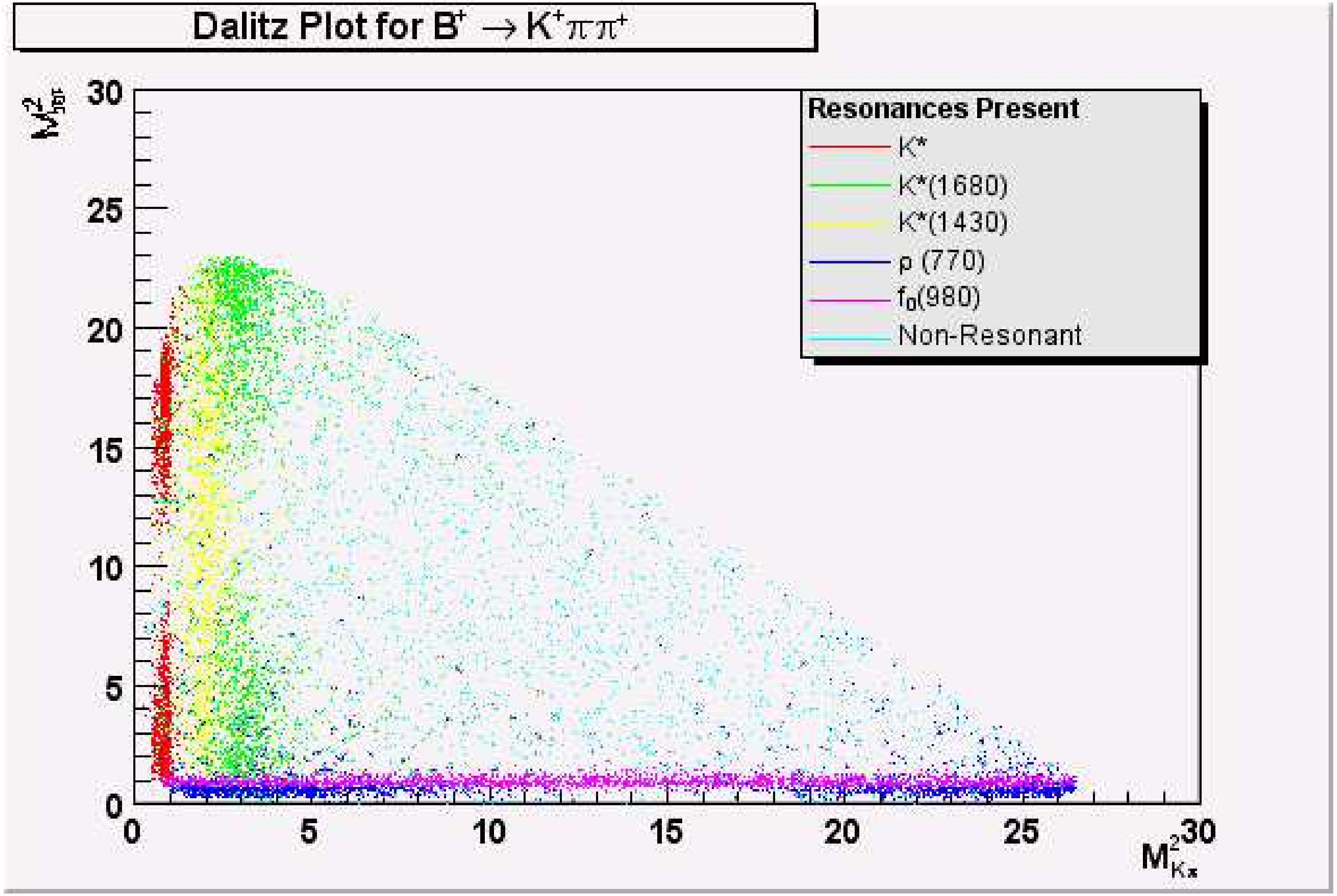
and p_i , p_j are the four-momenta of the daughter particles i and j respectively.

- The Dalitz Plot is a plot of m_{ij}^2 vs m_{ik}^2
- m_{ik}^2 can be related to $\cos\theta_{ij}$ where θ_{ij} is the helicity angle of pair ij
- θ_{ij} is defined as the angle between particles i and k in the ij rest frame


Dalitz plot for signal - Scalar Kst(1430)
$m^2_{\pi\pi}$
30
25
20
15
10
5
0
0
5
10
15
20
25
30
$m^2_{K\pi}$


Dalitz plot for signal - Vector Kst 892
$m^2_{\pi\pi}$
30
25
20
15
10
5
0
0
5
10
15
20
25
30
$m^2_{K\pi}$


Dalitz plot for signal - Tensor Kst (1430)
$m^2_{\pi\pi}$
30
25
20
15
10
5
0
0
5
10
15
20
25
30
$m^2_{K\pi}$



Dalitz Plot for B+ → K+ππ+
Resonances Present
K*
K*(1680)
K*(1430)
ρ (770)
f0(980)
Non-Resonant
0
5
10
15
20
25
30

Consider the case where there are only 3 possible resonant decays for the B^+ meson: $K^{*0}(892)\pi^+$, $\rho^0(770)K^+$ and $f_0(980)K^+$.

The total amplitude can be written as:

$$\begin{aligned} A(B^+) &= \left|c_K A_K + c_\rho A_\rho + c_f A_f\right|^2 \\ &= \left|c_K\right|^2 \left|A_K\right|^2 + \left|c_\rho\right|^2 \left|A_\rho\right|^2 + \left|c_f\right|^2 \left|A_f\right|^2 \\ &+ c_K c_\rho^* A_K A_\rho^* + c_K^* c_\rho A_K^* A_\rho \\ &+ c_K c_f^* A_K A_f^* + c_K^* c_f A_K^* A_f \\ &+ c_\rho c_f^* A_\rho A_f^* + c_\rho^* c_f A_\rho^* A_f \end{aligned}$$

The A_i's are the kinematic functions with the corresponding spin factor included depending on the scalar/vector/tensor nature of the resonance.

The c_i's are complex coefficients - the magnitudes of these coefficients can be measured from the amplitude squared terms but the phases must be determined from the interference regions.

It is these complex coefficients that we are trying to measure.

Signal Resonances

We currently have 3 models available for the lineshape of the various resonances

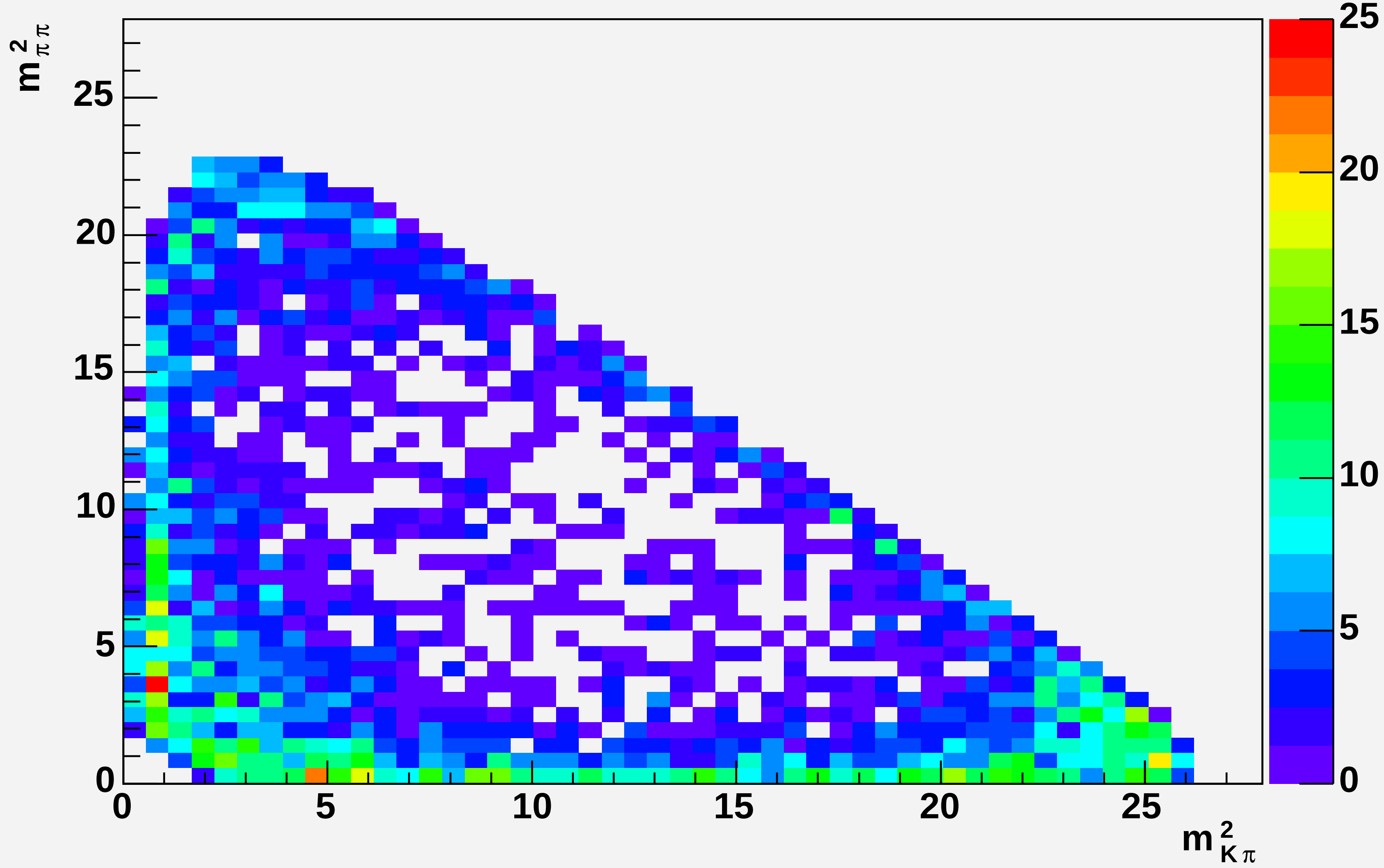
- Non-Relativistic Breit-Wigner
- Relativistic Breit-Wigner
- Flatte

together with a Non-Resonant function which is generated flat in phase space.

Continuum background events

These are combinatoric events which originate from $q\overline{q}$ decays rather than B-meson decay, where three of the tracks mimic our final state.
Depending on the identity of our charged tracks (pions vs kaons) then between 30-80% of our final data sample is continuum background events.
It is therefore very important to model the distribution of these events across the Dalitz Plot accurately.

Continuum Backgrounds



Charm Vetoes

An added complication when trying to measure the charmless resonant sub-modes is the presence of decays containing charm quarks.

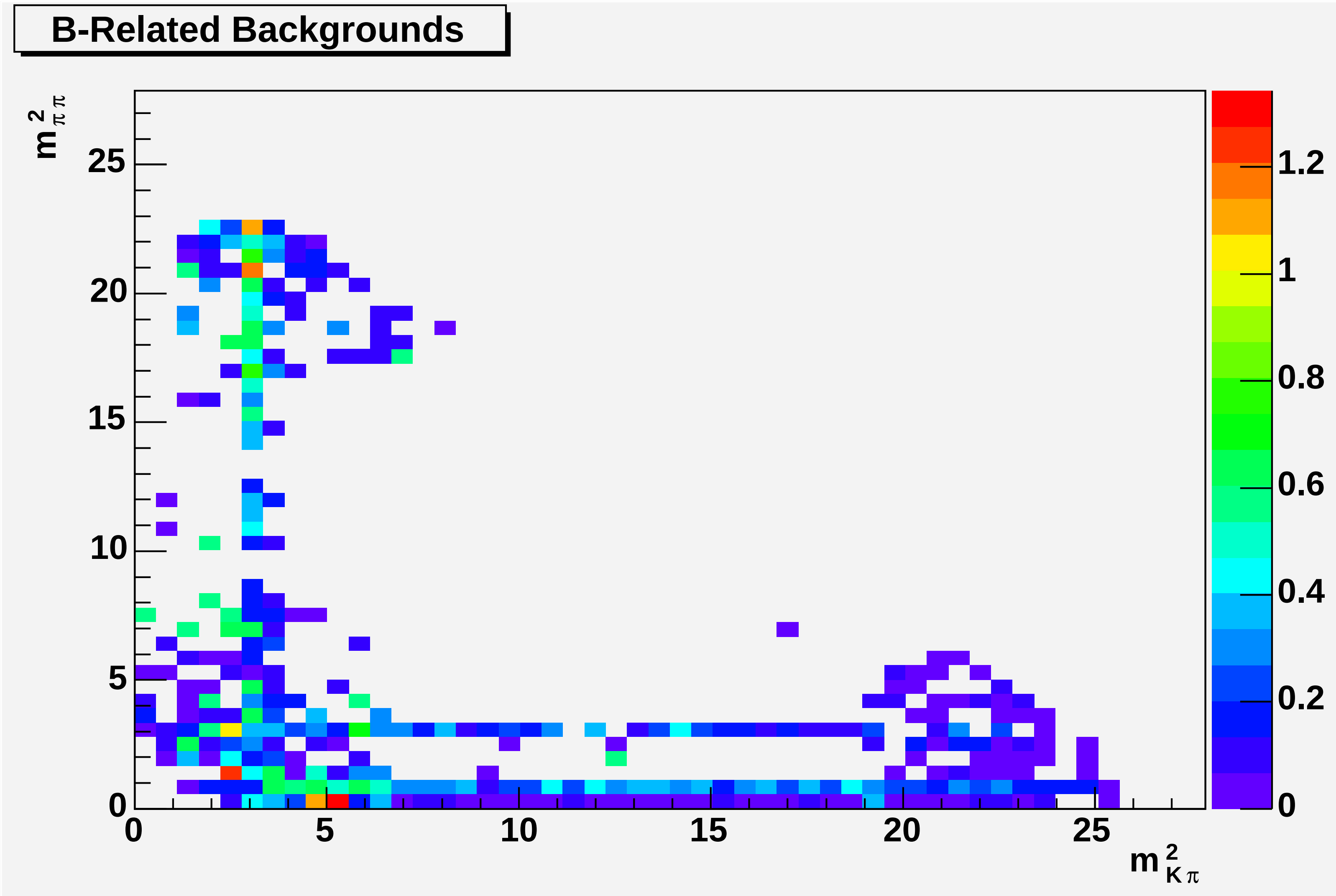
- These decays typically have Branching Fractions of similar order or greater than those of the 'charmless' decays we are interested in and would therefore swamp our signal
- They have very small widths and do not interfere with the other contributions to the Dalitz Plot
- We therefore veto the following decays:
  - $B^+ \to D^0\pi^+ \to K^+\pi^+\pi^-$
  - $B^+ \to J/\psi$ or $\psi(2S)K^+ \to K^+\mu^+\mu^-$, (where in these cases the muons are mis-identified as pions.)

B-related background events

These events are those that originate from B-meson decay - but to final states that can be easily misidentified as our final state. We then consider the background from $B\overline{B}$ events to mainly consist of contributions from:

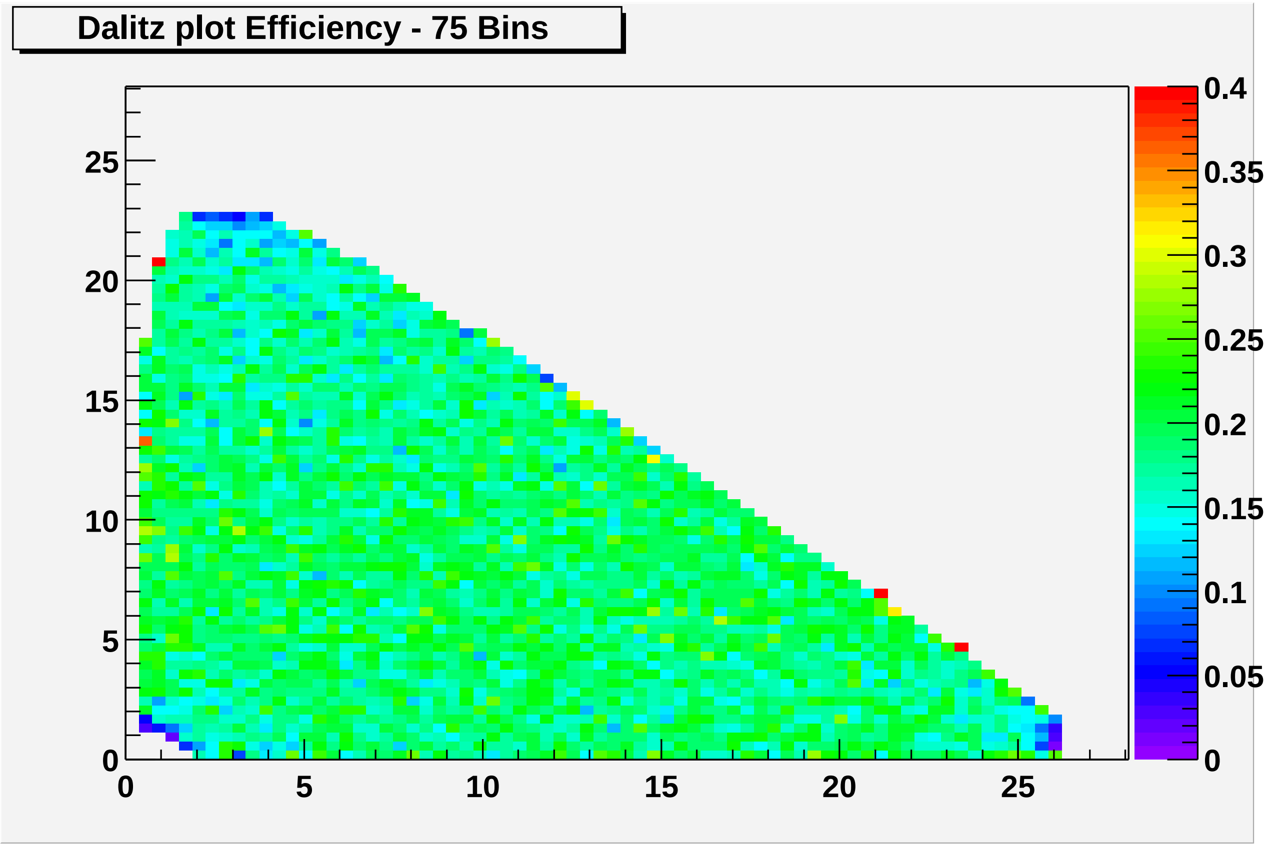
- $B^+ \rightarrow D^0\pi^+ \rightarrow K^+\pi^+\pi^-$
- $B^+ \rightarrow D^0\pi^+ \rightarrow K^+K^-\pi^+$
- $B^+ \rightarrow D^0\pi^+ \rightarrow K^+\pi^+\pi^-\pi^0$
- $B^+ \rightarrow D^0\rho^+ \rightarrow K^+\pi^+\pi^-\pi^0$
- $B^+ \rightarrow \eta' K^+ \rightarrow K^+\pi^+\pi^-\gamma$

The first background mode results from combinatorics where one of the tracks is picked up from the rest of the event, which explains why these events escape the D0 veto. The second mode results from the mis-ID of a pion as a kaon. The third, fourth and fifth modes have 4-Body final states but contaminate our signal when the π^0 or γ are not reconstructed.


B-Related Backgrounds
$m^2_{\pi\pi}$
$m^2_{K\pi}$
0
5
10
15
20
25
0
0.2
0.4
0.6
0.8
1
1.2

Efficiency

We also have to take into consideration variations in the signal efficiency across the Dalitz Plot



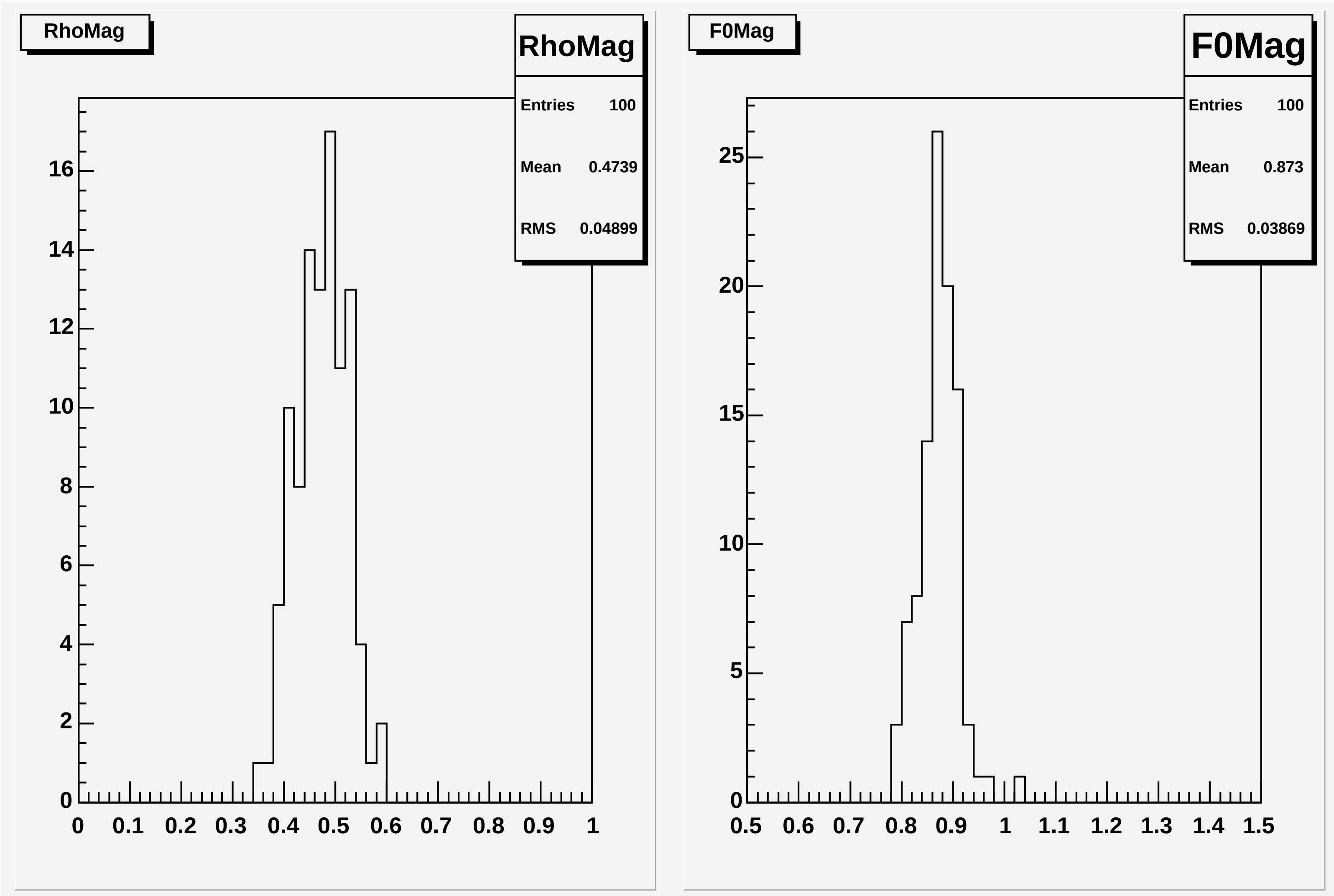
General Dalitz Plot Issues

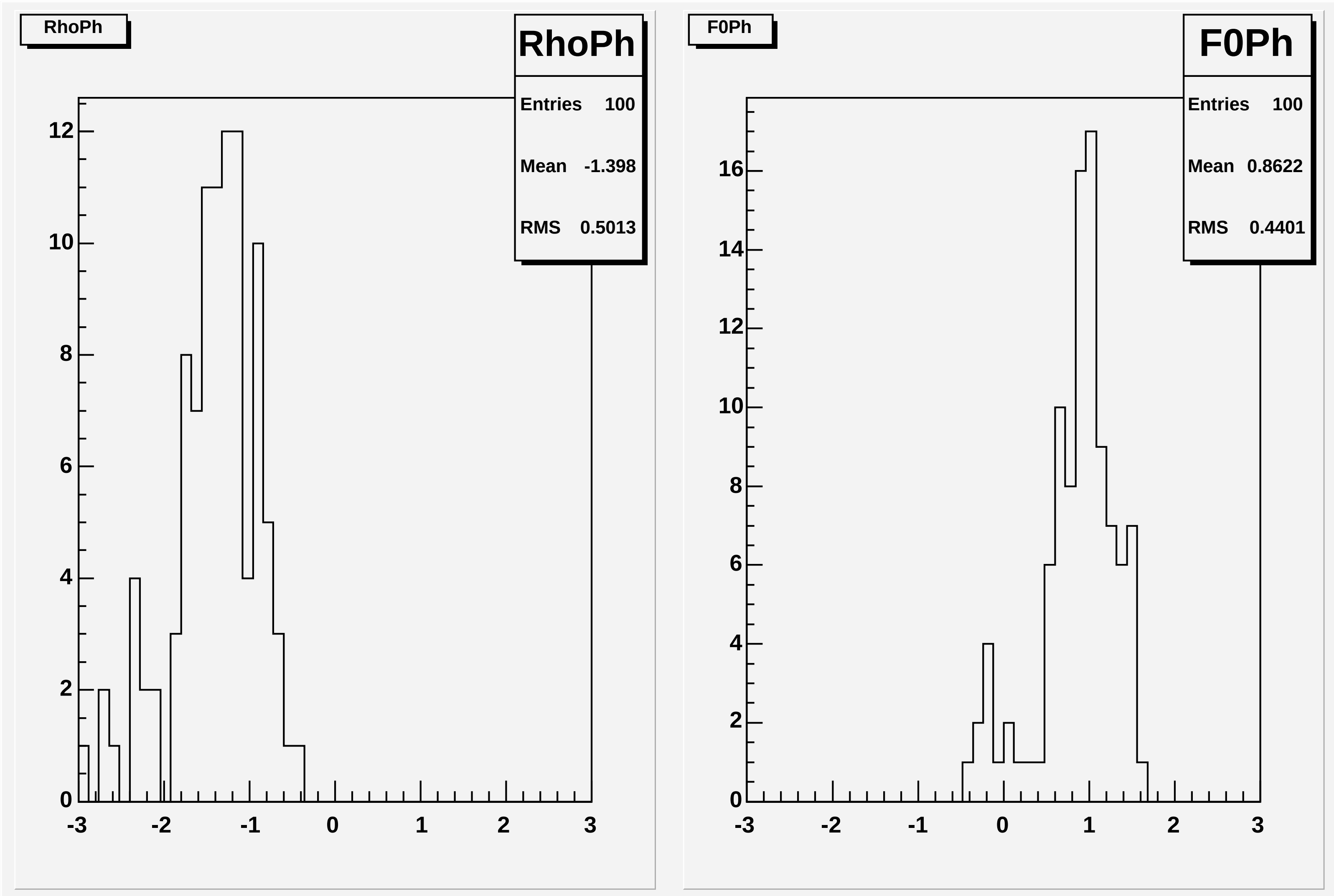
- Model Dependence
  - Which resonances to include?
  - Omission and Addition of Fit Components
- Fit Starting Point - Initial Amplitudes and Phases
  - MINUIT based fitting
  - Alternative - Genetic Algorithm

Toy Monte Carlo Studies

For a simplistic example we generate a model containing only three signal resonances (with arbitrarily chosen magnitudes and phases) together with continuum and B-related backgrounds.
We then generate a Monte Carlo dataset from this model. We subdivide this dataset into 100 experiments each containing 2000 events.
The input parameters are:

- 60% total background fraction - fixed in fit
- $K^{*0}(892)$ considered as the reference point - magnitude = 1.0 , phase = 0.0 - fixed in fit
- $\rho^0(770)$ generated with a magnitude of 0.478, phase of -1.347 - floated in fit
- $f_0(980)$ generated with a magnitude of 0.873, phase of 0.921 - floated in fit


RhoMag
RhoMag
Entries 100
Mean 0.4739
RMS 0.04899
0 2 4 6 8 10 12 14 16
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
F0Mag
F0Mag
Entries 100
Mean 0.873
RMS 0.03869
0 5 10 15 20 25
0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5


RhoPh
RhoPh
Entries 100
Mean -1.398
RMS 0.5013
F0Ph
F0Ph
Entries 100
Mean 0.8622
RMS 0.4401

Conclusions

- This is a very complex problem with many fit components that need to be modelled accurately
- There is now a growing number of people working on the analysis and we are hopeful of having results this summer