Final Report: Meson Resonance Parametrizations for Partial-Wave Analysis at COMPASS

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Abstract. Within this summer student project, Monte Carlo data for diffractive scattering reactions of 190 GeV pions with 3 pions final states is simulated and analysed. Data generation and fitting is done with the root-based framework rpwa (*root partial-wave analysis*), a documentation of the setup and usage of this program is written. Effects on fit quality due to sample size and momentum dependent detector inefficiency are investigated.

The first step of my project was to install the root-based partial-wave analysis framework rpwa, which was developed at the COMPASS experiment. As the program consists of several parts and depends on a variety of other programs, it was a challenging but interesting task to get it compiled and running. During this process, I learned a lot about linux and the compilation of programs. One part of my project was the creation of a documentation of the setup and use of this framework.

Once rpwa was installed, I learned about the physics of the diffractive scattering reaction I would work on (fig. 1): a high energy pion interacts with a Pomeron, and then decays into three pions via a resonance.

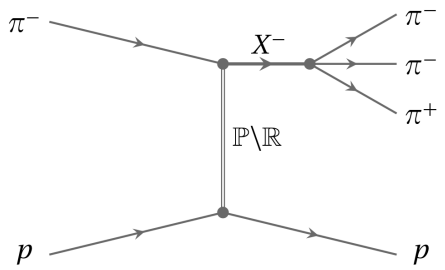
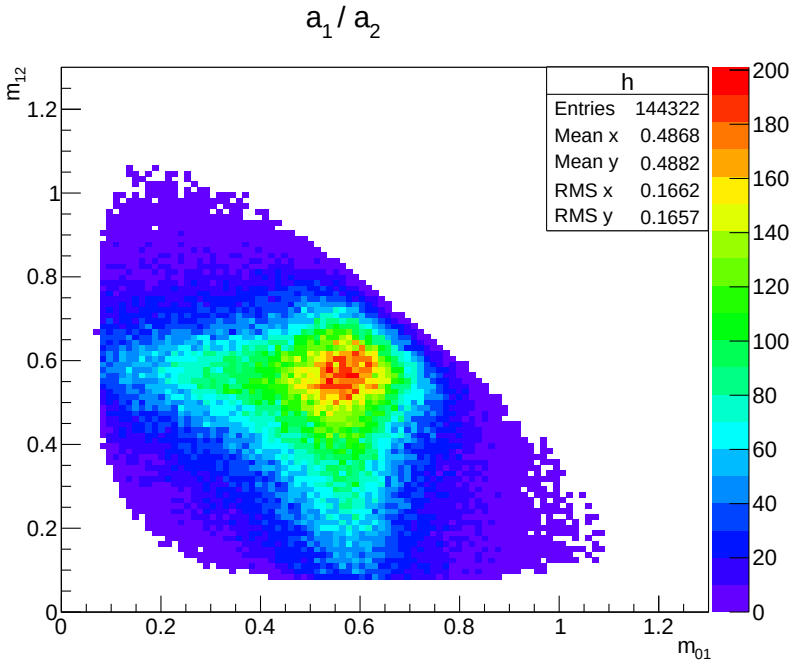


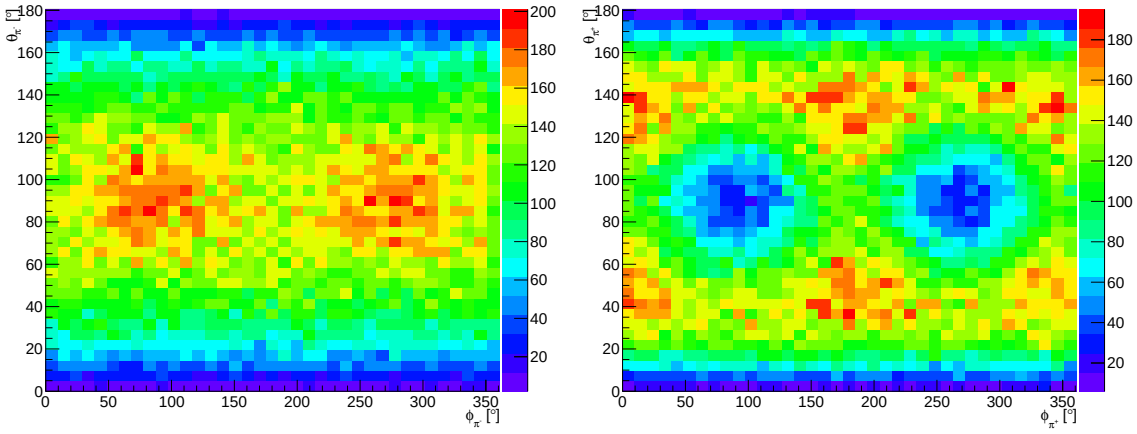
Figure 1. schematic of the diffractive scattering reaction π^- to $\pi^-\pi^+\pi^-$ (from F. Haas, PhD thesis, 2014)

There is a multitude of resonances and possible quantum numbers. Each possibility can be described by a wave. Partial wave analysis allows to extract both amplitude and phase of the waves that occur in the data, by analysing the angular and momentum distribution.

The next step involved learning root and the usage of rpwa. To generate simulated data one needs to describe the kinematics in a configuration file, generate events that are equally distributed in phase space, calculate the amplitude for each event for the waves that are supposed



(a) Dalitz plot



(b) $\pi^- : \theta$ vs. ϕ

(c) $\pi^- : \theta$ vs. ϕ

Figure 2. Visualized generated data, composited of waves from the a_1 and a_2 resonance

to be in the data, describe the composition of the output file, and prepare other necessary input files. The thus obtained root file contains events that are still isotropic in phase space, however with a weight corresponding on the amplitude assigned to each event. Now, a script is called that either accepts or rejects each event with a probability dependent on the amplitude. After calculating the amplitudes for the remaining events, the file is ready to be analysed. For this purpose, I calculated the Dalitz plot variables and the angles Θ and Φ describing the direction of the three pions in their center of mass system. As an example, the Dalitzplot (a), Φ vs. Θ for π^- (b) and π^+ (c) for generated data composited of waves from the a_1 and a_2 resonance is shown in figure 2.

Once familiar with the framework, I conducted little studies to investigate the changes in the

quality of the rpwa fit result, a) dependent on the number of events and b) in the case of an unaccounted inefficiency for pion detection dependent on the momentum. The rpwa fit result turned out to be robust towards low statistics and unaccounted detector inefficiency, however it was shown that an extraordinarily big unaccounted inefficiency can lead to a misinterpretation of the data. In particular, an a_1 resonance was partially fitted as a π_1 resonance, whose existence is controversially discussed.

I submitted a final report summarizing the results of these studies as well as the rpwa documentation to my supervisor.

I really enjoyed being a summer student at CERN. Through the work at COMPASS and the summer student lectures (some of them were really inspiring) I gained a very interesting insight into the world of particle physics. I learned a lot about QCD, and got experience with root and C++. Finally, I would like to thank my supervisor Dr. Jan Michael Friedrich for his guidance, patient explanations and interesting discussions. It was a great time.