I. Introduction

This report presents an analysis of the invariant mass distribution of Z^0 boson candidates using simulated data. The goal of this analysis is to estimate the central mass and the width of the Z^0 boson by fitting the distribution with a Breit-Wigner curve and assessing how well the model matches the data using a chi-squared test. The report also includes a clear introduction to the relevant physics concepts and detailed explanations of the methods used to generate plots and perform calculations.

II. The Invariant Mass Distribution and its Fit

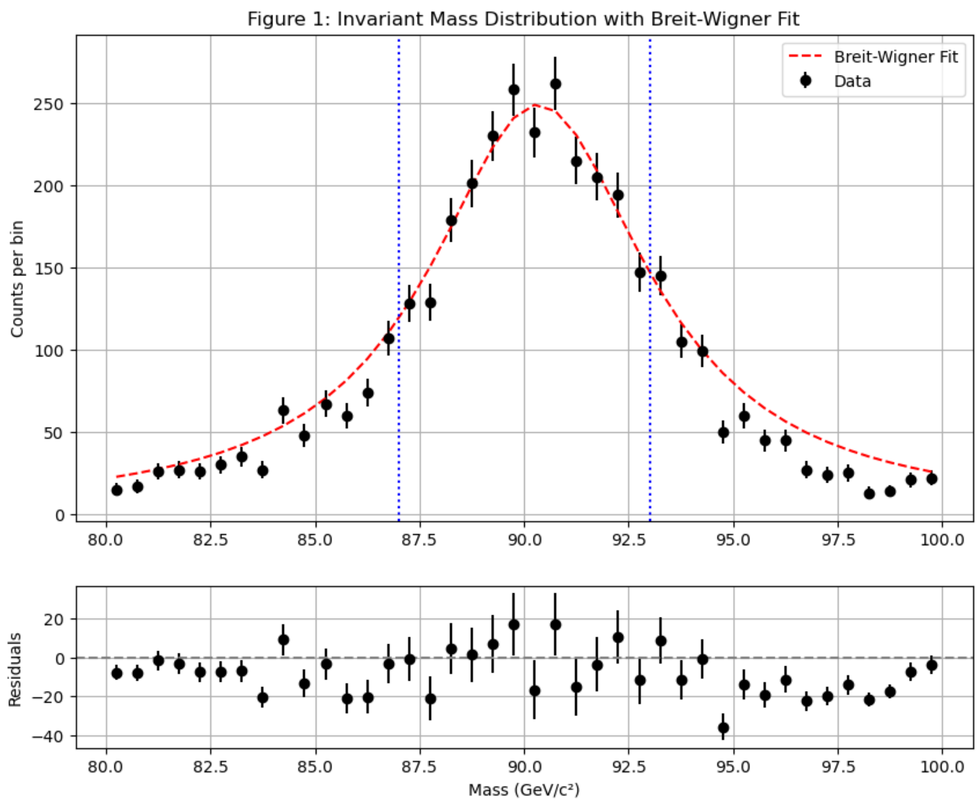

Figure 1 displays the histogram of the invariant mass distribution along with a fitted Breit-Wigner curve. The Breit-Wigner function models the resonance by describing how the number of detected events varies with the invariant mass of the candidate particle pairs. This model is appropriate for resonances such as the Z^0 boson, and it assumes that the observed mass distribution follows the shape determined by the resonance properties and detector resolution.

The histogram was constructed by binning the reconstructed invariant mass values of lepton pairs into 40 equal-width bins spanning the range from 80 GeV to 100 GeV. Each bin count represents the number of events with invariant masses within that range, and statistical uncertainties for each bin were calculated as the square root of the count ($\sqrt{N}$)

By applying the nonlinear least-squares fitting to the data, we obtained the following values, each reported to two decimal places:

- The fitted mass is 90.34× 10^4 GeV (4.c.i).
- The uncertainty on the fitted mass is ±0.09 GeV.
- The chi-squared value is 9.99.
- The number of degrees of freedom is 10.
- The p-value of the fit is 0.442.

The associated p-value = 0.442 means that there is a 44.2% chance of observing a chi-squared value as large or larger than 9.99 due to random statistical variation alone, assuming the model is correct. Since this is nearly 9 times greater than the common thresholds such as 0.05 (for 95% confidence), we conclude that there is no statistical reason to reject the null hypothesis that the Breit-Wigner model describes the data.

III. The 2D Parameter Sc

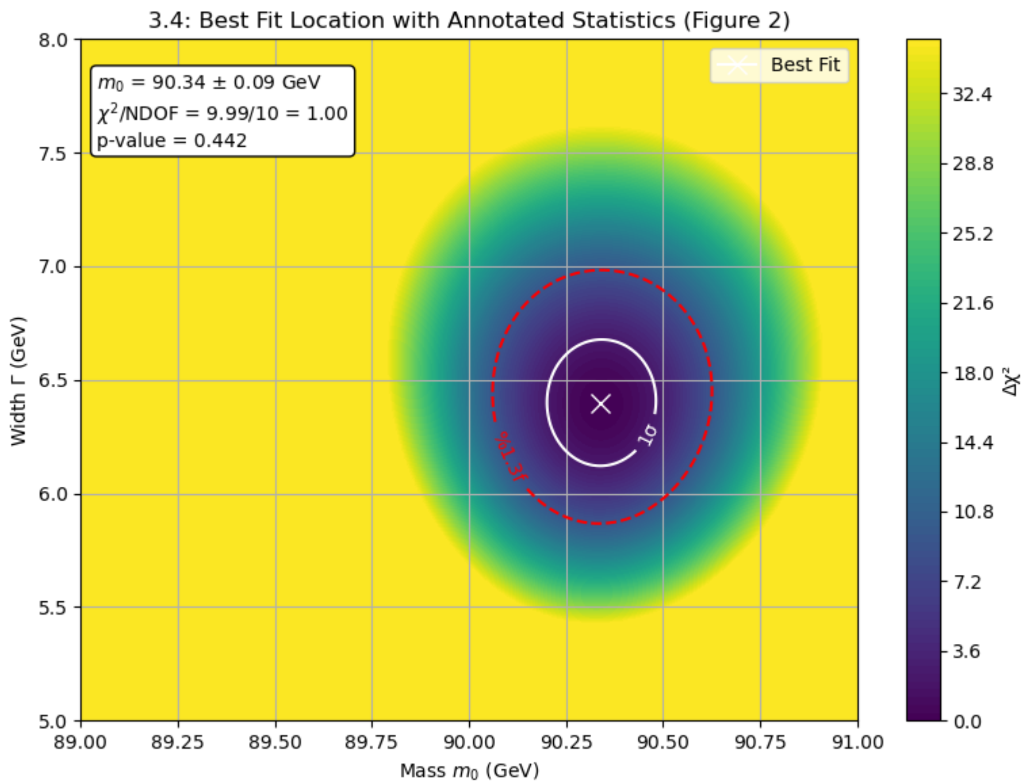

Figure 2 shows the results of a two-dimensional scan of the chi-squared values across a grid of mass and width values (using the Pearson's chi-squared statistic formula). The amplitude "A" in the Breit-Wigner function was not treated as a free parameter during the fit. Instead, it was fixed based on the total number of events in the dataset to simplify the parameter space and isolate the effect of varying mass and width. The minimum chi-squared value was subtracted from the map to form a delta chi-squared ($\Delta\chi^2$) surface, which was then clipped at a value of 35 to emphasize the most relevant contour region.

Contours representing the one- and three-standard-deviation confidence levels were drawn on the map at $\Delta\chi^2$ values of 2.30 and 9.21, respectively, as appropriate for two fit parameters in this case (The mass and the width). These values were obtained from the only citation in this report, table 40.2. These contours provide a visual representation of the parameter uncertainties and the correlation between mass and width, offering a more complete picture of the fit's precision and sensitivity. The region between the 1σ ($\Delta\chi^2 = 2.30$) and 3σ ($\Delta\chi^2 = 9.21$) contour lines represent parameter combinations that are statistically consistent with the data, but with less confidence than those within the 1σ contour. Specifically, this intermediate region corresponds to confidence levels between 68.3% and 99.0%, which includes the 90% and 95% confidence regions often used in scientific analysis. Points within this band are still likely given the data but deviate further from the best-fit values than those within the inner contour. This zone reflects moderate statistical support for alternative parameter values and highlights the uncertainty spread and correlation between mass and width estimates.

IV. Discussion and Future Work

The best-fit mass value of 90.34×10^4 GeV compared to the Particle Data Group's accepted value of approximately 91.18×10^4 GeV is 0.92% lower than the PDG's accepted value. This difference lies well within the statistical uncertainty, suggesting that the analysis is consistent with known physical results.

However, it is important to note that the current fit does not include systematic uncertainties or effects from detector resolution, which could affect the accuracy of the result. The simulated data are idealized, and do not account for sources of background noise or efficiency variations in the detector (6.b).

Future improvements could include collecting more events, modeling detector resolution effects through smearing, including background terms in the fit, fit and subtract known background processes, and include Systematic Uncertainties. These steps would improve the realism of the analysis and make it more representative of what would be observed in actual high-energy physics experiments.

Citations

"Particle Data Group - 2020 Review." https://pdg.lbl.gov/2020/reviews/rpp2020-rev-statistics.pdf.

Signed by **Christopher Sosa**

Signature