Vertex and kinematic fitting for the Panda experiment

V. Jha[1*] and J. Ritman[2]
[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[2]*IKP, Forschungszentrum, Juelich D52425, GERMANY*

Introduction

PANDA (An acronym for Antiproton Annihilation at Darmstadt) experiment plans to address the fundamental questions of QCD in the non-perturbative regime, mainly by the hadron spectroscopy upto the region of charm quarks and through search of the exotic states like glueballs and hybrids [1]. The efficient reconstruction of the primary and secondary vertex is crucial for the data analysis in many cases of PANDA physics programme. The vertex position of a set of tracks can be determined by varying the track parameters such that the error is minimized under the condition that the tracks pass through a common vertex point. In addition, the kinematic information of various particles in a particular decay chain can be used as the constraints, for the better determination of track parameters. These methods lead to an improvement in the momentum and the mass resolution of the measured particles and a larger signal to background ratio.

The Algorithm

The algorithms based on constraints for the vertex and kinematic fitting have been implemented in the Pandaroot software package. It incorporates constraints by the Lagarange multipliers method [2]. The calculation uses a track repesentation in a cartesian frame for the particle tracks with parameters. The trajectory parametrization consists of a three-dimensional position along the trajectory, the particle momentum at this position and the particle energy. The initial track parameters and the covariance matrix are obtained through the conformal mapping based track finder and subsequent track fitting using a kalman filter procedure in the Pandaroot software. The cartesian track parameters are obtained by converting the helix representation track parameters and assigning a mass to the final-state particle.

The constraints used for the vertex fitting are expressed in terms of a vector of equations $\mathbf{H}\ (\alpha,\ \mathbf{x}) = \mathbf{0}$, where α is a vector of track parameters for all tracks included in the fit and $\mathbf{x}$ is the vertex position. The constraint equation in linearised form can be included using the Lagrange multiplier variable λ in the χ^2 function which is written as:

$$\chi^2 = (\alpha - \alpha_0)^T\ V_{\alpha 0}^{-1}(\alpha - \alpha_0) + 2\lambda^T(D\delta\alpha\ +\ E\delta x\ +\ d) \quad (1)$$

where d is the vector of values of the constraint equations at a suitable expansion point, D is the matrix of partial derivatives of the constraint equations at the expansion point with respect to the track parameters and E is the matrix of the partial derivatives of the constraint equations at the expansion point with respect to the vertex coordinates. The χ^2 function to be minimized has contributions from errors in track parameters relative to initial values α_0 with covariance matrices $V_{\alpha 0}$ and due to inclusion of constraints.

The values of improved track parameters α and the vertex position x that satisfy the given set of constraints can then be found by minimising the χ^2 equation with respect to α, x and λ. Finally, the fitting procedure provides the quality of the vertex and kinematic fits in terms of a normalized χ^2 probability distribution for applying the cuts to improve the signal to background ratio.

Simulation and Tests

The performance of the vertex fitter has been tested by reconstructing the short lived

*Electronic address: vjha@barc.gov.in

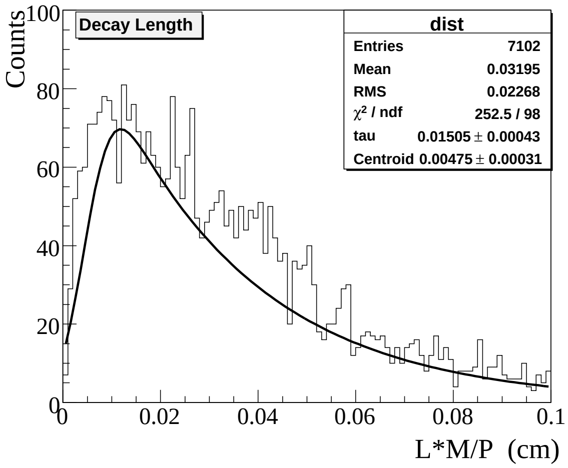

FIG. 1: Proper time distribution in terms of decay length for the reconstructed $D_s^{\pm}$ candidates with the reconstructed mass (M) and 4-momentum (P) .

decay particles $D_s^{\pm}$ mesons using the simulated events from the reaction $p\bar{p} \rightarrow D_s^{\pm} D_s^{*\mp}$. The decay particle $D_s^{\pm}$ has been reconstructed in the $D_s^{\pm} \rightarrow \pi^{\pm} K^{+} K^{-}$ decay modes. The proper time distribution in terms of decay length of the reconstructed $D_s^{\pm}$ particles has been calculated, using the reconstructed mass (M) and 4-momentum of the vertexed particle (P) obtained at the vertex point. A fit to the proper time distribution is performed using the function which is the convolution of an exponential and a gaussian (with the width derived from the fit to the residual of the position distribution) as shown in the Fig. 1. The slope gives a decay length value of ($c\tau = 150 \ \pm \ 4 \ \mu m$) in good agreement with the PDG value ($c\tau = 147 \ \mu m$) with which the simulated events were generated.

In addition to the vertex fit, the possibility to include other kinematic constraints such as mass constraint, total momentum constraint, total energy constraint, four momentum constraints etc. have been developed and tested. Depending on the physics case, one or many constraints can be used for the analysis. We have studied the simulated $p\bar{p} \rightarrow J/\psi\pi^{+}\pi^{-}$

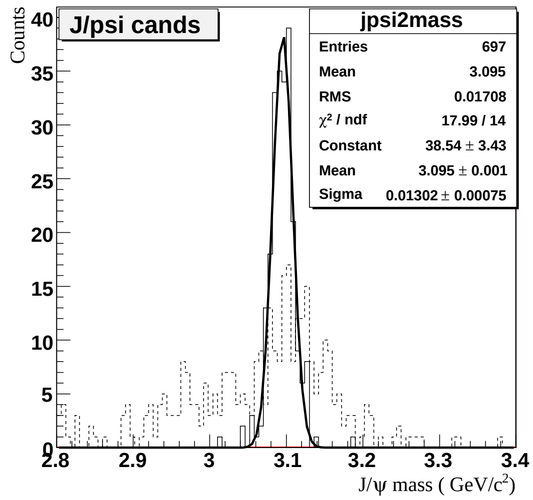

FIG. 2: Reconstructed mass of the Mass of J/ψ resonance state without (dashed line) and with (solid line) the 4-momentum fit.

events with the events generated at the centre of mass energy corresponding to $\psi(2S)$ resonance. After reconstruction of J/ψ resonance through the $J/\psi \rightarrow e^{+}e^{-}$ decay channel, a 4-momentum kinematic fit using the energy momentum of the initial $p\bar{p}$ system has been performed. The kinematic fitting leads to improved track parameters for the daughter particles and a better resolution of the mass for the J/ψ resonance as shown in Fig. 2. In summary, the analysis tools of vertex and kinematic fitting have been developed and tested for the studies of PANDA physics programme.

References

[1] Panda Physics book arxiv.org/pdf/0903.3905.

[2] P. Avery, Fitting theory write-ups, http://www.phys.ufl.edu/∼avery /fitting.html(1998).