Status of Vertex and Kinematic fitting for Panda

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Outline:

- Introduction
- Vertex and kinematic Fitting with constraints
- Tests of Vertex & kinematic fitters
- Steps towards decay tree fitting
- Summary & Outlook

Introduction:

- Vertex Fitting: To find the vertex position compatible with reconstructed tracks, Also its errors with fit probability

- Kinematic Fitting : Kinematic relation between particles imposed, fit probability to make cuts

- Improved track parameters for the daughter particles and new covariance matrix

- Track parameter of virtual particles and its covariance matrix

Vertex and Kinematic Fitting Methods:

Solution can be obtained by using the least square minimization (LSM)

$$\chi^2 = (\alpha - \alpha_0)^T V_{\alpha 0}{}^{-1} (\alpha - \alpha_0)$$

α_0 Track parameters from track fit , $V_{\alpha 0}$ Covariance Matrix from track fit

α New parameters, Iterations are needed to converge to the real solution

Methods :

i) Lagrange multiplier method

ii) Kalman Filter technique

Vertex and kinematic Fitting method :

Constraint equations are applied for Vertex and kinematic fitting .

The constraint equation $H(\alpha) = 0$ is linearized around suitable point (α_a, x_a)

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

D is derivative w.r.t α,

E is derivative w.r.t x,

d is the value, $H(\alpha_a, x_a)$

Minimize χ^2 with respect to α , x and λ

Vertex Fitting Outputs :

New Track parameters : $\alpha = \alpha_0 - V_{\alpha 0} D^T \lambda$

New Covariance Matrix : $V_\alpha = V_{\alpha 0} - V_{\alpha 0} D^T V_D D V_{\alpha 0} + V_{\alpha 0} D^T V_D E V_x E^T V_D D V_{\alpha 0}$

New Vertex Position : $x = x_0 - V_{x0} E^t \lambda$

Track parameters for the vertexed particle : $x_V = x$; $p_V = \boldsymbol{A}\,\alpha + \boldsymbol{B}\,x$

Vertex Covariance matrix : V_x & $cov(\alpha, x) = -V_{\alpha 0} D^T V_D E V_x$

Covariance Matrix for the vertexed particle :

Based on notes by Paul Avery

Constrained Vertex Fitting :

Vertex Constraint : Tracks pass through an unknown point,

For a solenoid field (along z direction) this leads to two equations

$$p_{xi}\Delta y_i - p_{yi}\Delta x_i - (a_i/2)(\Delta x_i^2 + \Delta y_i^2) = 0$$

$$\Delta z_i - (p_{zi}/a_i)\ \sin^{-1}[a_i\ (p_{xi}\Delta x_i + p_{yi}\Delta y_i)/p_{Ti}^2] = 0$$

A good start point is needed specially for displaced vertices.

Start point : Vertex finder, (crossing point , point of minimum distance)

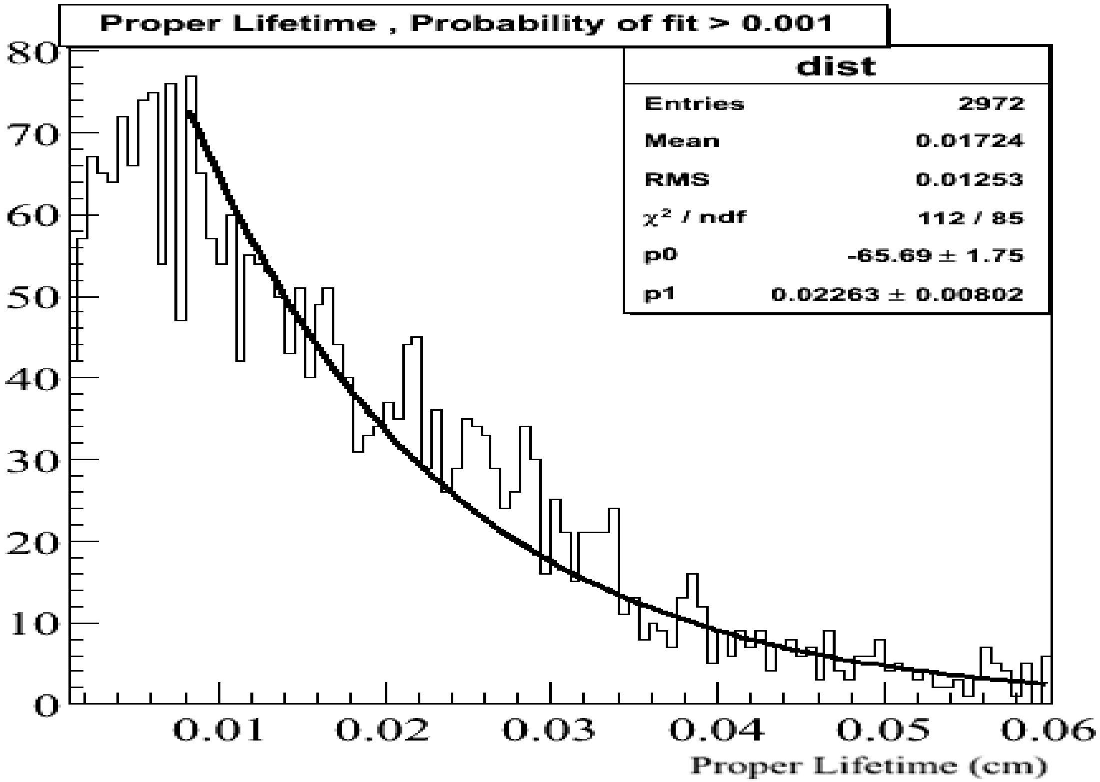
Propagation of the track parameters and covariance matrix to the start point

Pointing Constraint : Reconstructed vertex points to another known vertex

(e.g. primary vertex)

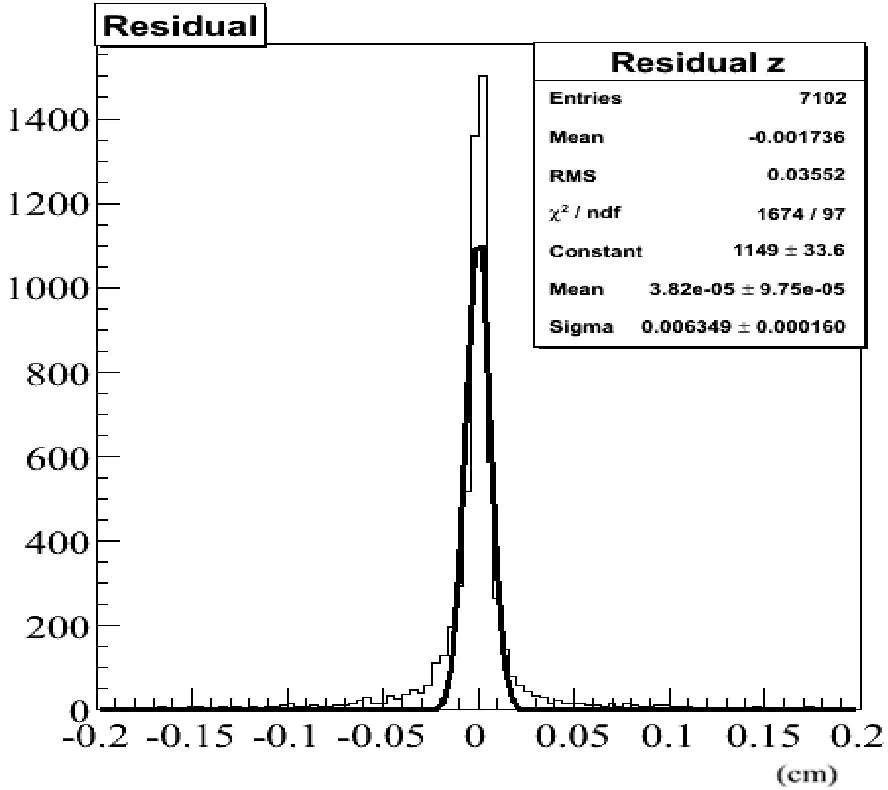
D_s Reconstruction and Vertex Fitting:

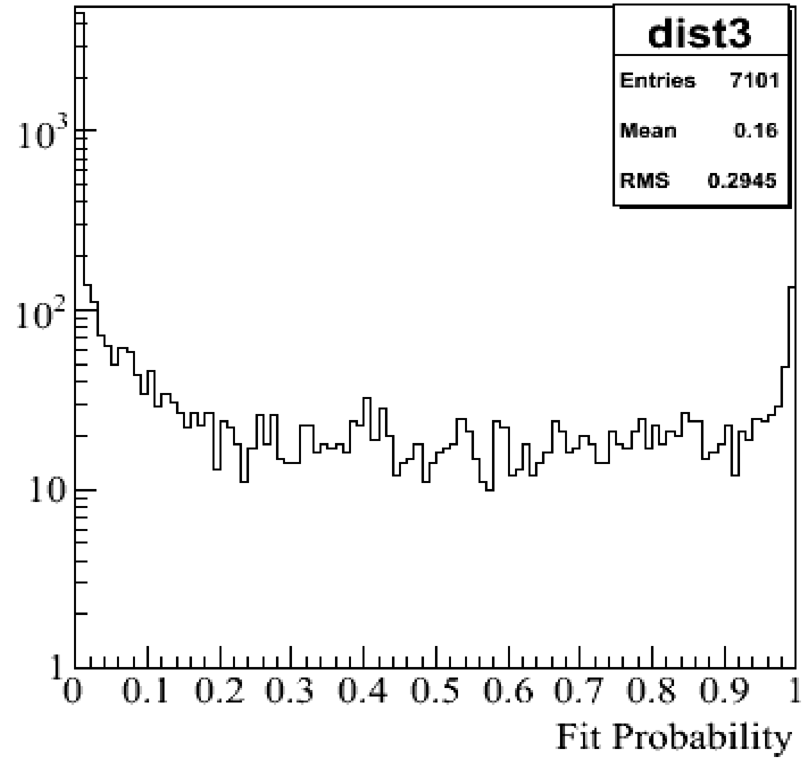
$$\bar{p}\ p \rightarrow Ds^{\pm}\, Ds^{\mp};\quad Ds \rightarrow K^{+}K^{-}\pi$$



Fitted D_s proper Lifetime = 152 µm, PDG Value =147 µm

Quality of the fit:





Kinematic Fitting with Constraints:

One or more constraints can be used in combination (PndKinFitter) :

Kinematic constraints:

i) 4 vector constraint : (Add4MomConstraint (TLorentzvector lv)

ii) momentum constraint (AddMomConstraint (Tvector3 v)

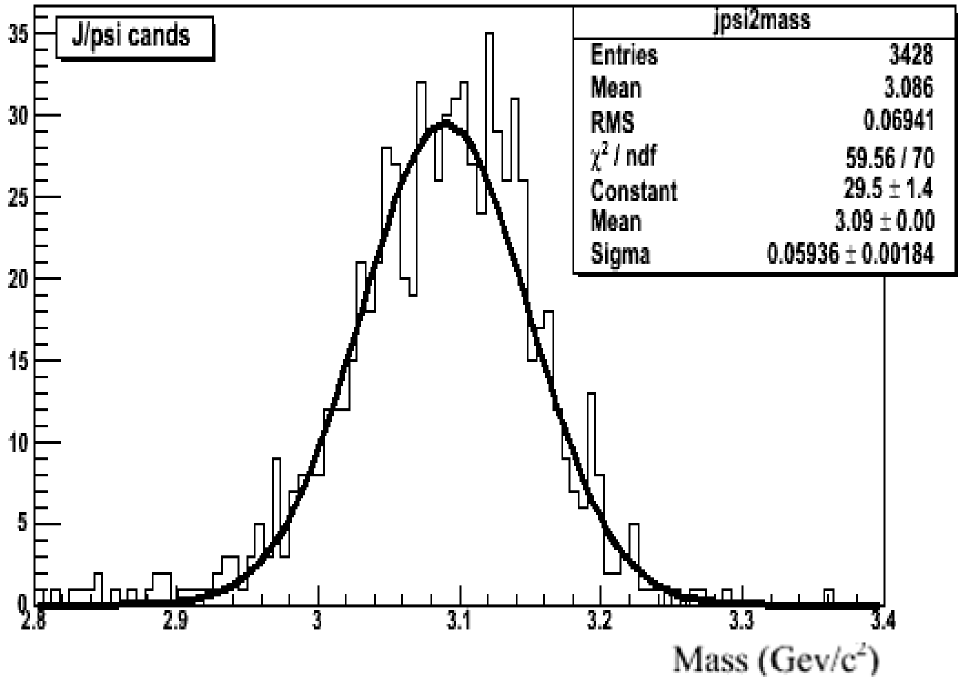
iii) Total energy /Momentum (AddTotEConstraint (double E)

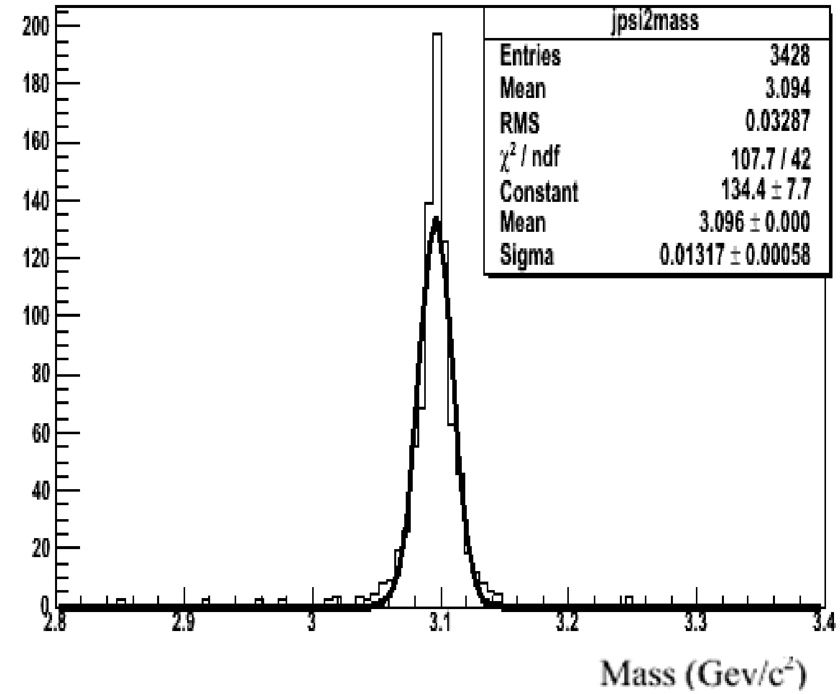
iv) Mass constraint (AddMassConstraint double mass)

Possibility to include them in combination : (Global Fitting)

Kinematic 4 Momentum Fitting:

ppbar -> J/ψ $\pi^+\pi^-$ 4 Momentum fit for the ppbar system

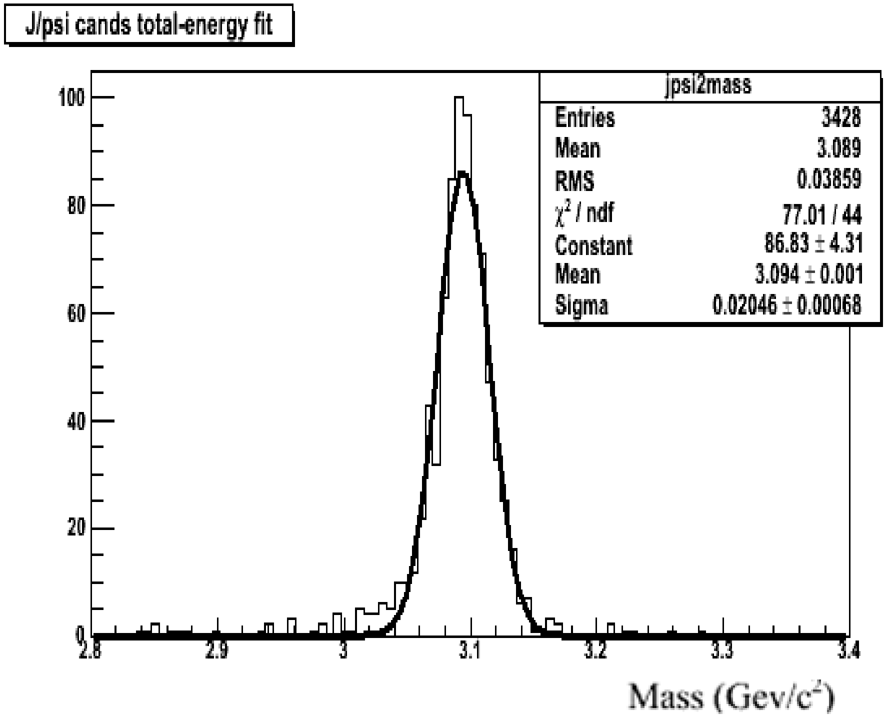




$\sigma = 0.059\ GeV/c^2$ $\sigma = 0.013\ GeV/c^2$

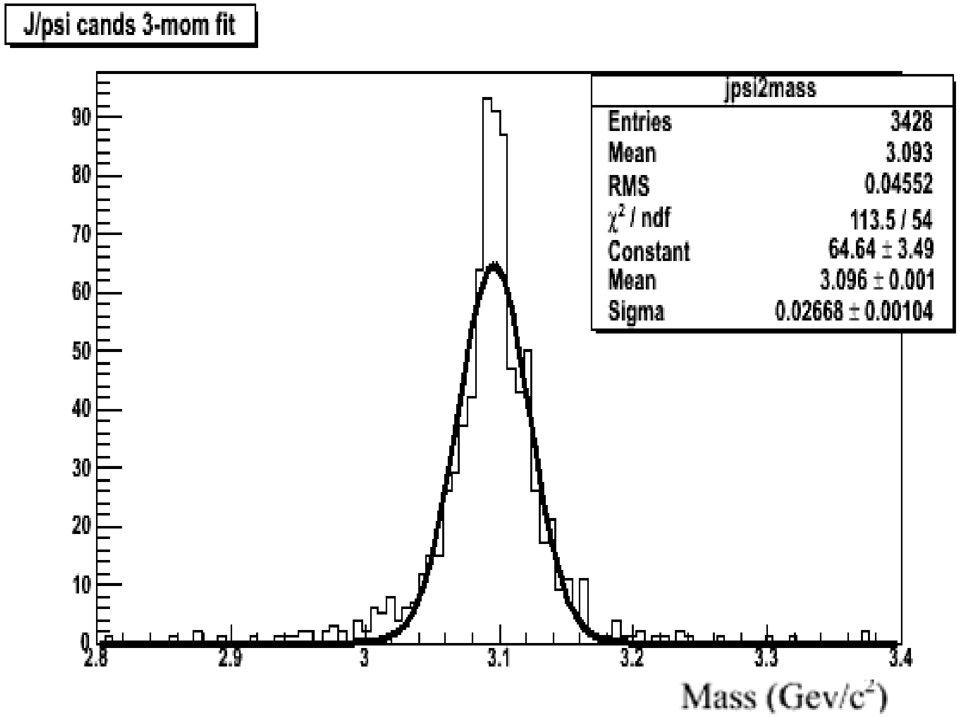
Kinematic Fitting :

Total Energy Constraint



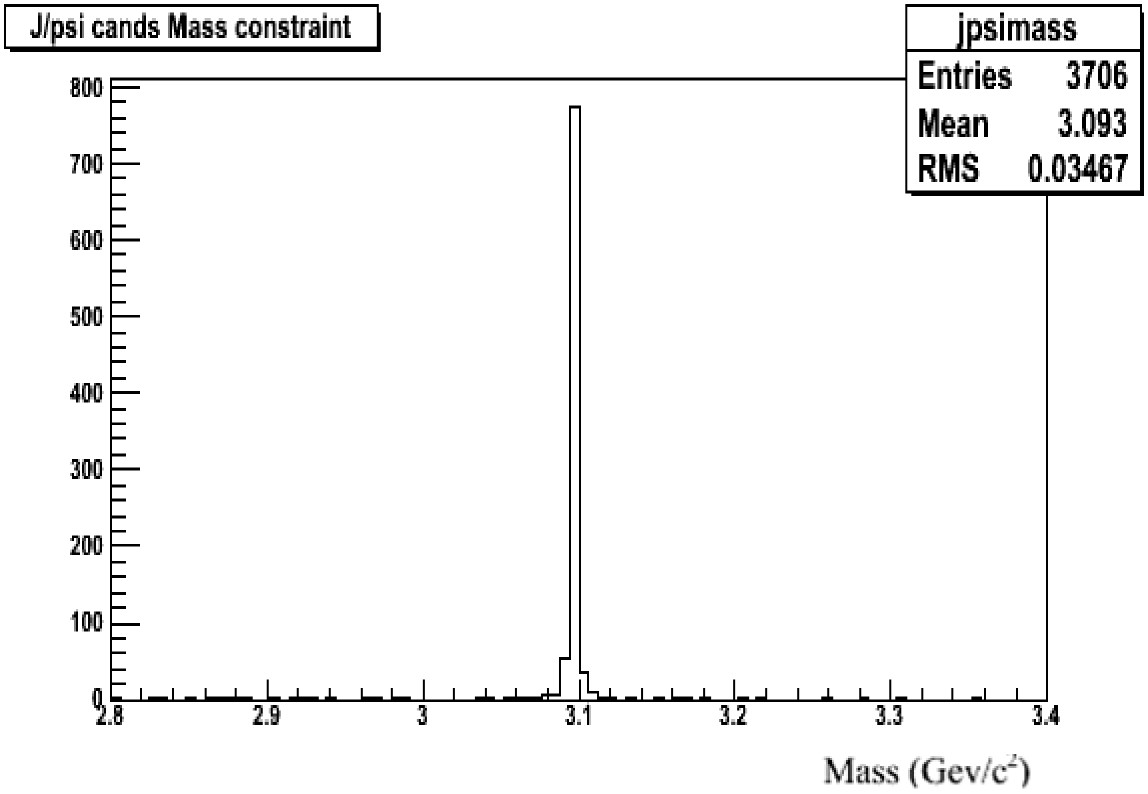
σ =0.021 GeV/c^2

3-momentum Constraint

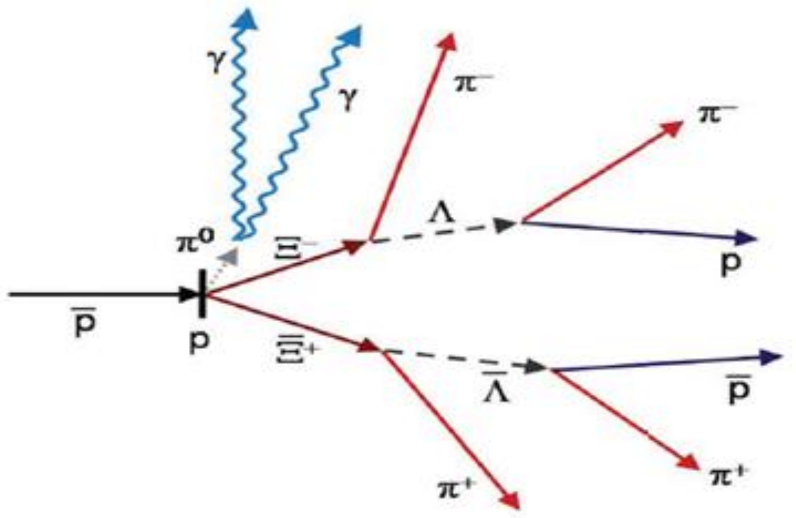


σ =0.026 GeV/c^2

Kinematic Fitting Mass Constraint :



Fitting the complete Decay tree:



Four class of particles (objects) :

i) Reconstructed Track as hypothesis

ii) Reconstructed as cluster

iii) Composites or virtual particles :

a) prompt decay (resonances)

b) Macroscopic decay length (composites)

iv) Missing particles

Fitting the decay tree:

Sequential : Constraints applied sequentially to build the decay chain

The bottom up approach ,

Generating new composite particles /resonances along the way

Composite has all the information of daughter tracks in linear approx

Global : All constraints are applied simultaneously for complete tree

Better treatment of non-linearities and track-track correlation

Large Matrices to be inverted

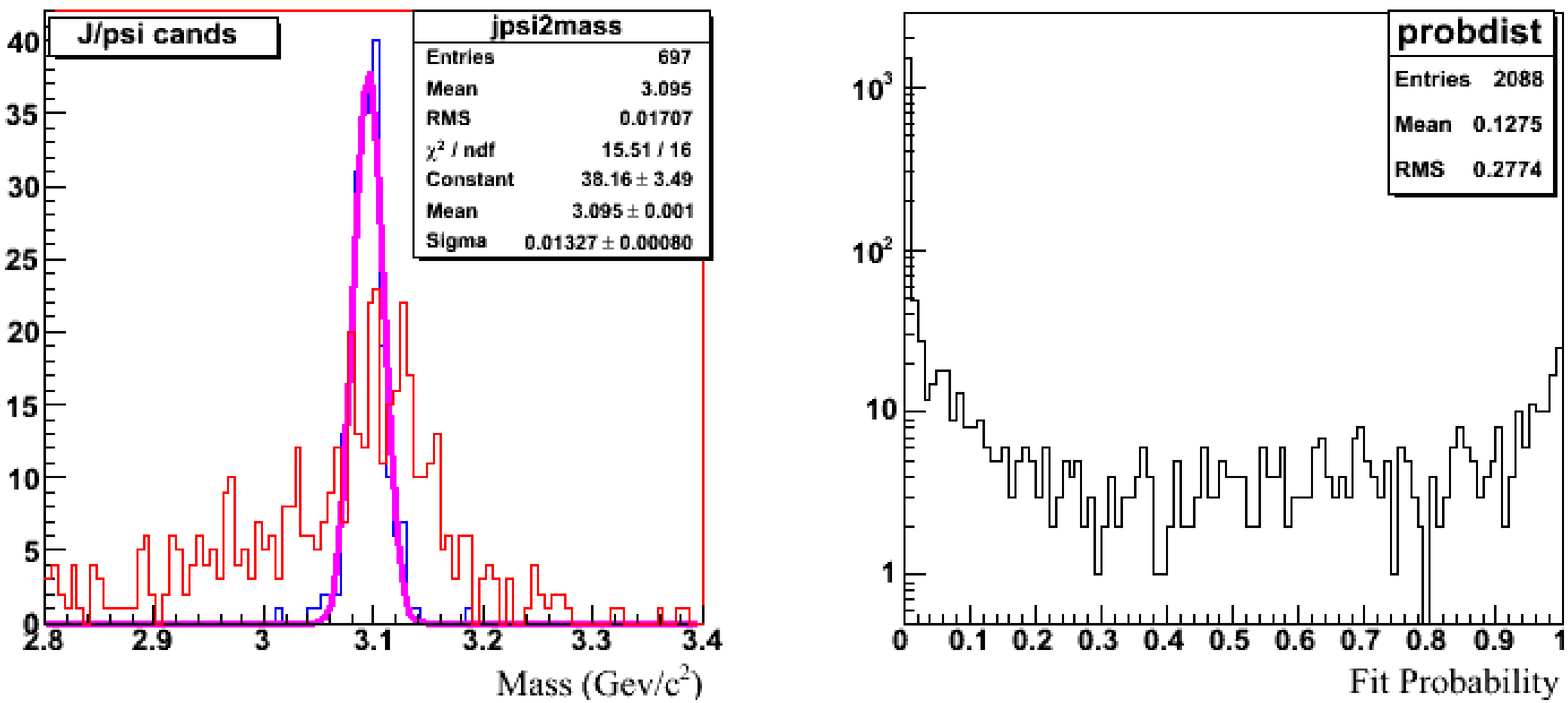
Progressive fit based on Kalman filter can be used.

Sequential Fitting I:

Constraints applied sequentially to build the decay chain

1st step pbar -> J/ψ $\pi^+\pi^-$

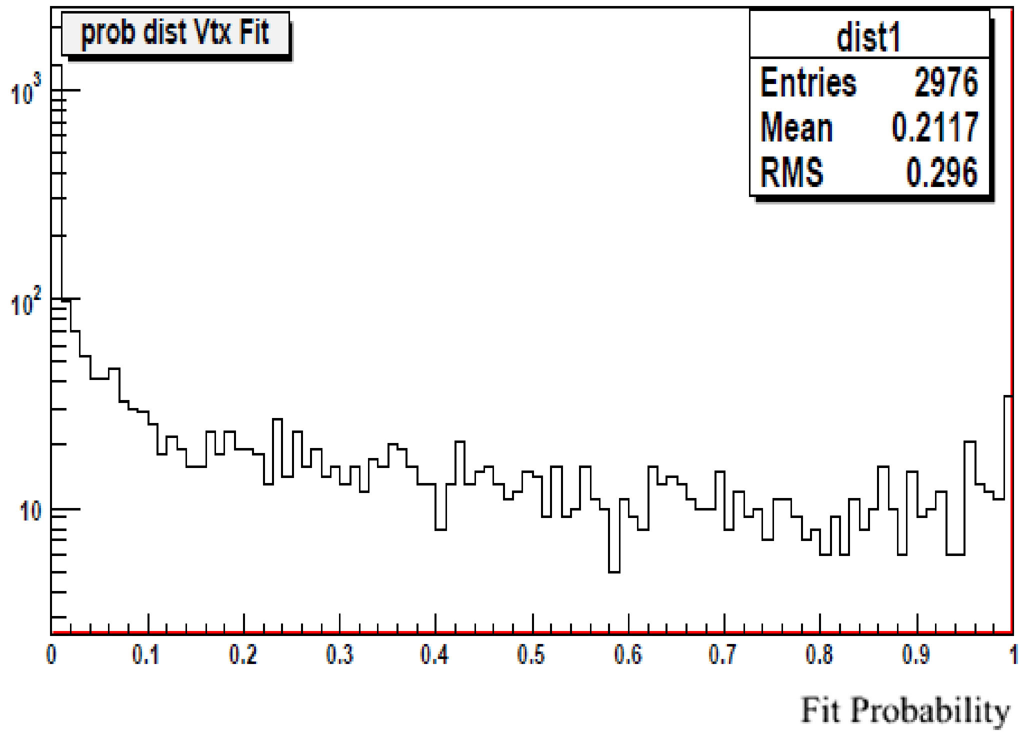
4 Momentum fit for the ppbar system :



Sequential Fitting II :

2nd Step : Probability of the Vertex fit for the pbar p vertex

after the 4-momentum fit :



Summary :

Vertex Fitters have been implemented

Kinematic fitters with many constraints have been included.

Tests of their performance have been made.

Outlook :

Detailed tests of the fitters needs to be done (Questions of efficiencies and reliability of covariance matrices)

Tests of the full decay tree fitting