

Implementation and Application of Kinematic Vertex Fitting in the Software Environment of the ILD Recent Developments on the MarlinRave Plugin

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Overview

Expectations and Input

Association and Reconstruction

Reconstruction of ZZ events?

Appendix: Vertexing with MarlinRave

Kinematics of a $WW \rightarrow qqqq$ event

Indexing scheme:

$$e_\alpha e_\beta \rightarrow W_A W_B \rightarrow q_1 q_2 q_3 q_4 \quad (1)$$

Four-momentum conservation:

$$\vec{p}_\alpha + \vec{p}_\beta = \vec{p}_A + \vec{p}_B = \overbrace{\vec{p}_1 + \vec{p}_2}^{\vec{p}_A} + \overbrace{\vec{p}_3 + \vec{p}_4}^{\vec{p}_B} = \vec{0} \quad (2)$$

$$E_\alpha + E_\beta = E_A + E_B = E_1 + E_2 + E_3 + E_4 = 500.0 \text{ GeV} \quad (3)$$

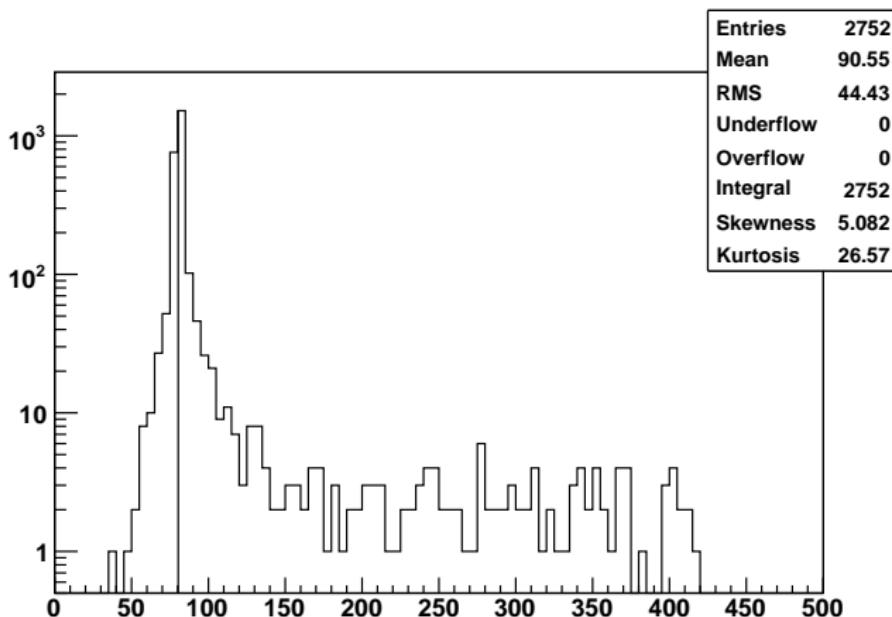
Correlation of the W masses:

$$\sigma(s) \propto \int_0^s ds_A \int_0^{s-s_A} ds_B \sqrt{\kappa(s, s_A, s_B)} \rho(s_A) \rho(s_B) \quad (4)$$

$$\rho(s_i) = \frac{1}{\pi} \frac{\Gamma_W(s_i) \sqrt{s_i}}{(s_i - M_W^2)^2 + s_i (\Gamma_W(s_i))^2} \quad (5)$$

$$\kappa(a, b, c) = \sqrt{(a - b - c)^2 - 4bc} \quad (6)$$

The generated W masses (Pythia)

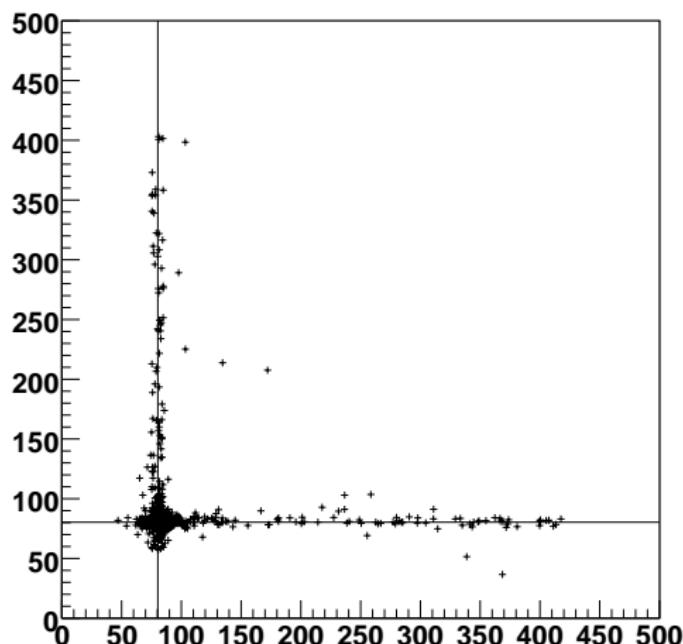


Attention

Here the y-axis uses a logarithmic scale.

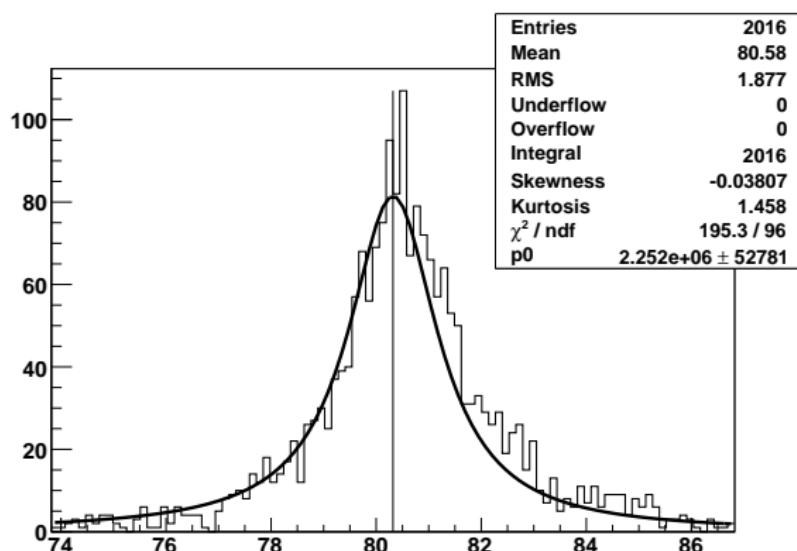
The generated W masses: scatterplot

Entries 1376



- Each cross represents one event
- The lines mark the true means
- The correlation is negligible
- Very high masses are generated surprisingly frequent

Statistics and event selection



- This is a zoom of the input Monte-Carlo masses
- Events outside this histogram were cut away

Error model

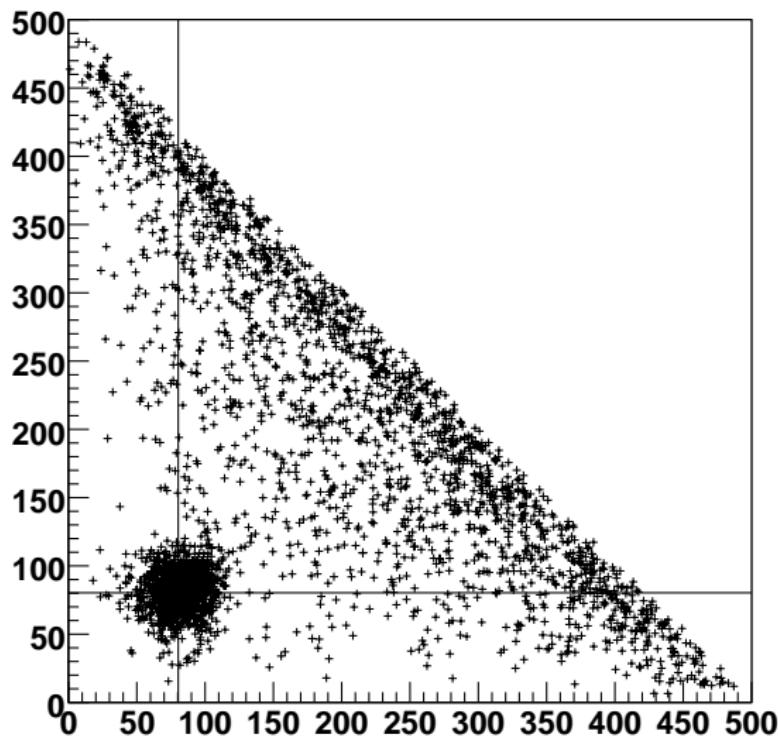
- No jet parameter errors available from reconstructed jets.
- Using a deliberate guess of the quality of the reconstructed jets:

Energy resolution	$\sigma_E/E = 30\%/\sqrt{E}$
Direction resolution	$\sigma_\theta = \sin(\theta)\sigma_\phi = 10 \text{ mrad}$

Table: Guess of performance for jet reconstruction at the ILD experiment.

- The covariance matrix used in the fit was calculated from these assumptions.

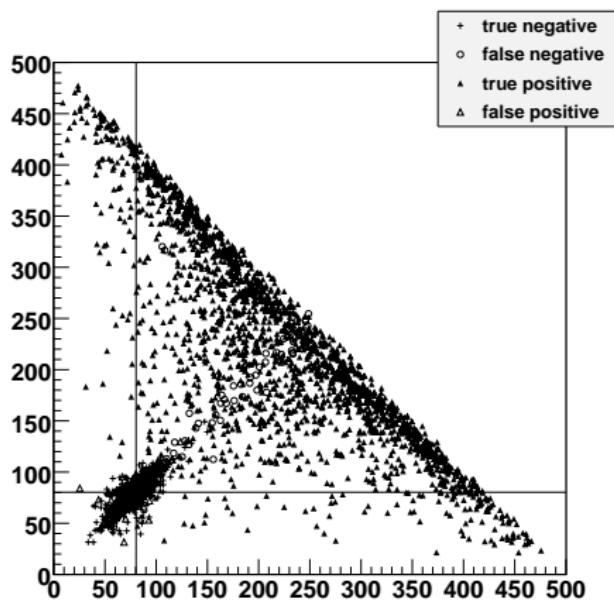
All possible combinations of jets



- Each cross is one combination.
- Each event produces three crosses.
- So far no calculation has been done.

The similar mass hypothesis

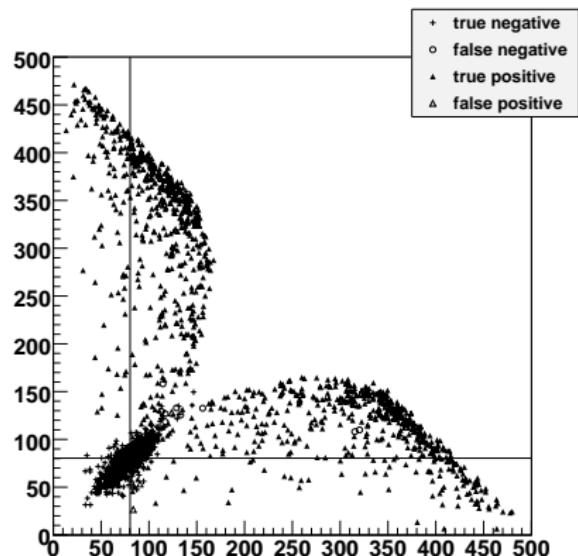
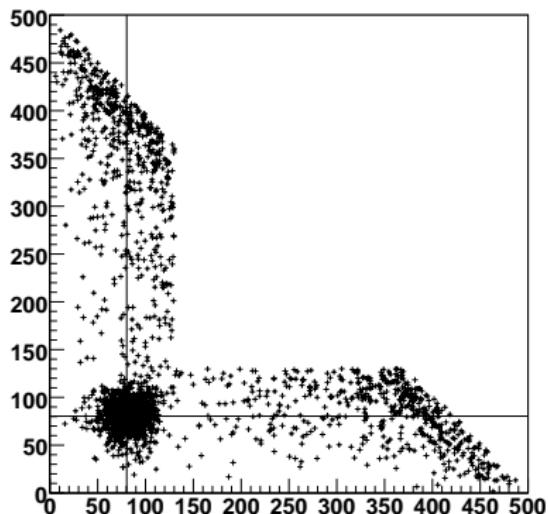
$$M(\vec{\alpha}_m, \bar{m}) = [\vec{\alpha}_m - \vec{\alpha}_c]^T \vec{V}_c^{-1} [\vec{\alpha}_m - \vec{\alpha}_c] + \sum_{i=1,2} \frac{(m_i(\vec{\alpha}_m) - \bar{m})^2}{\sigma_t^2} \quad (7)$$



- The $\vec{\alpha}_c$ are the refitted jet parameters after the kinematic fit.
- Minimized w.r.t. $\vec{\alpha}_m$ and \bar{m} .

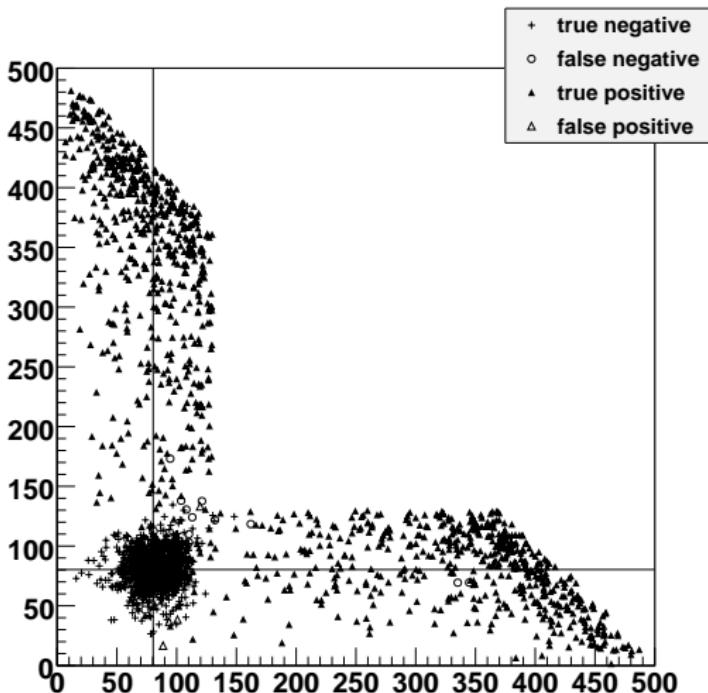
The low-correlation hypothesis

Cut on an upper limit of 130 GeV at least one of the masses must not exceed.



Final scatter plot

The similar-mass constraint is removed again but the association information is kept.

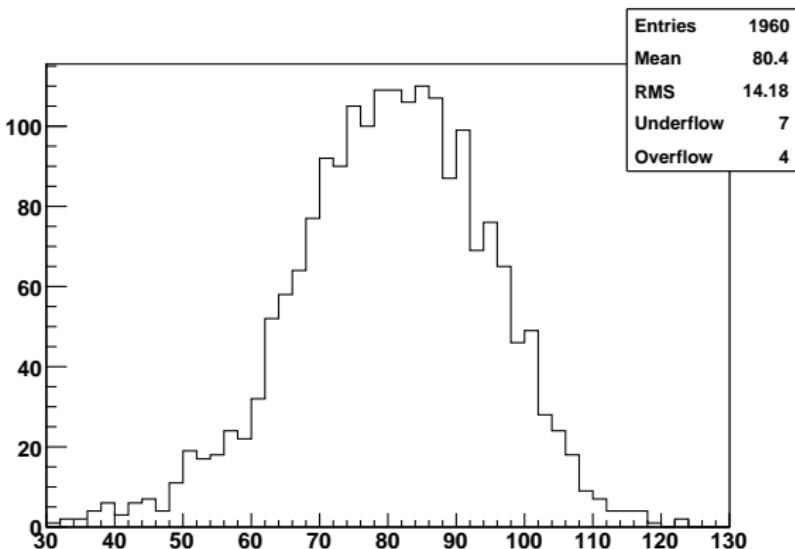


Association performance

Association step	error type	full sample	selected events
Similar Mass hypothesis only	type 1	13.5 %	6.0 %
	type 2	7.0 %	3.2 %
Low Correlation hypothesis only	type 1	0.1 %	0.1 %
	type 2	55.8 %	55.6 %
Both combined	type 1	6.2 %	1.6 %
	type 2	3.2 %	0.9 %

W masses histogram 1

Fitted only with four-momentum constraint

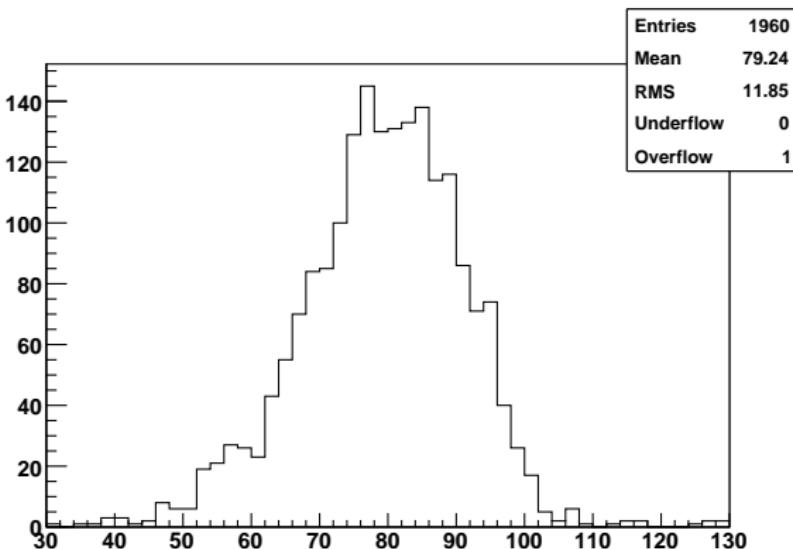


$$\bar{m}_W = 80.40 \text{ GeV/c}$$

$$\sigma_{\bar{m}_W} = \frac{\sigma_{m_W}}{\sqrt{N}} = 0.32 \text{ GeV/c}$$

W masses histogram 2

Fitted with four-momentum constraint and similar-mass “soft-constraint”



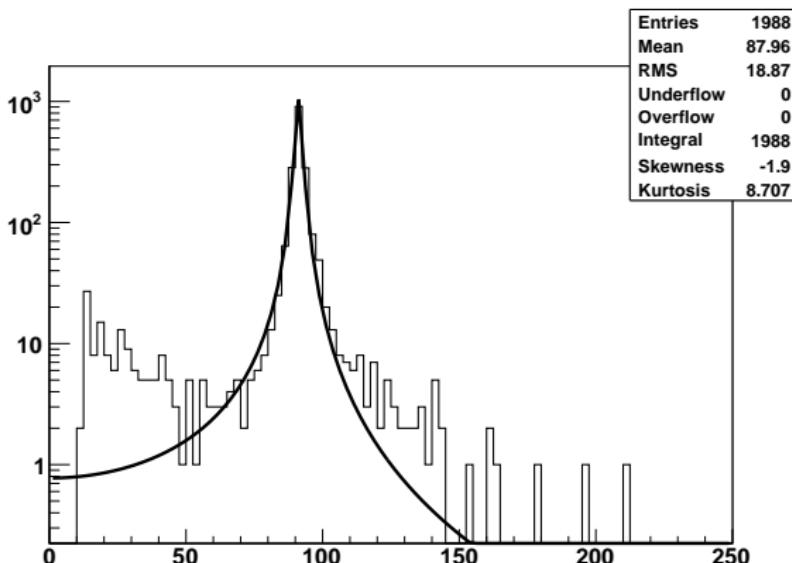
$$\bar{m}_W = 79.24 \text{ GeV/c}$$

$$\sigma_{\bar{m}_W} = \frac{\sigma_{m_W}}{\sqrt{N}} = 0.27 \text{ GeV/c}$$

Distribution of the Z masses in 1D

How the Monte-Carlo information compares to a Breit-Wigner distribution

Sample: DST01-04_ppr002_ZZ_qqqq_250_LDCPrime_02Sc_LCP_ep+0.0_em+0.0_0001.slcio



Attention:

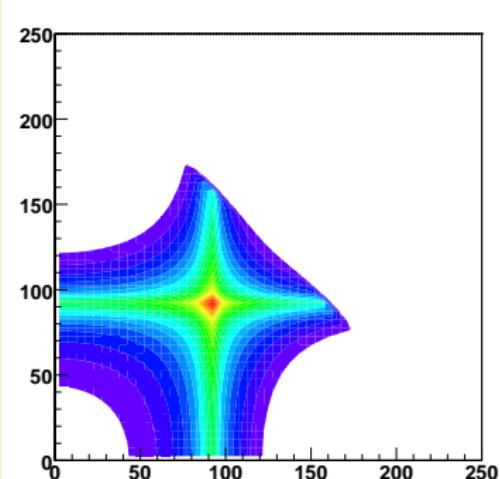
The y-axis is plotted with a logarithmic scale!



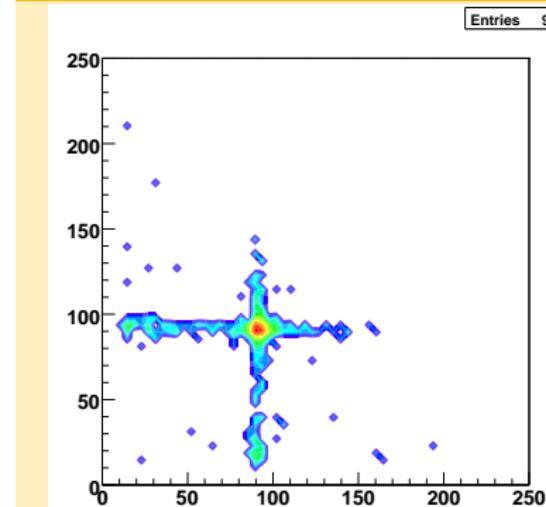
Distribution of the Z masses in 2D

How the Monte-Carlo information compares to a Breit-Wigner distribution

Convoluted Breit-Wigner distributions



Monte-Carlo information

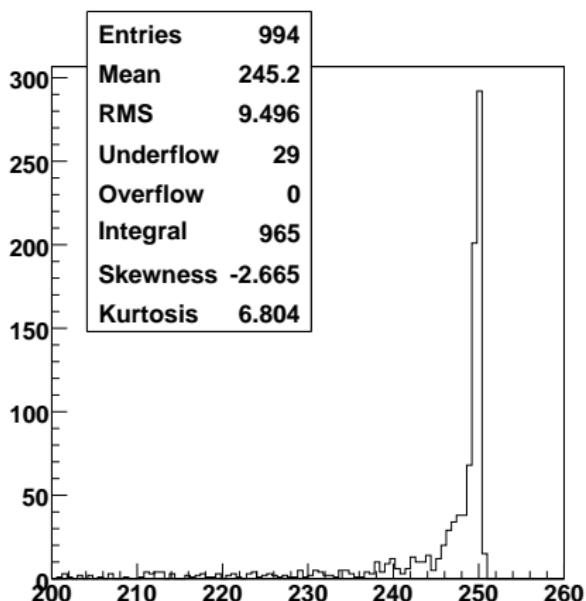


Attention:

The colors are chosen on a logarithmic scale!



Total energy of Monte-Carlo Zs

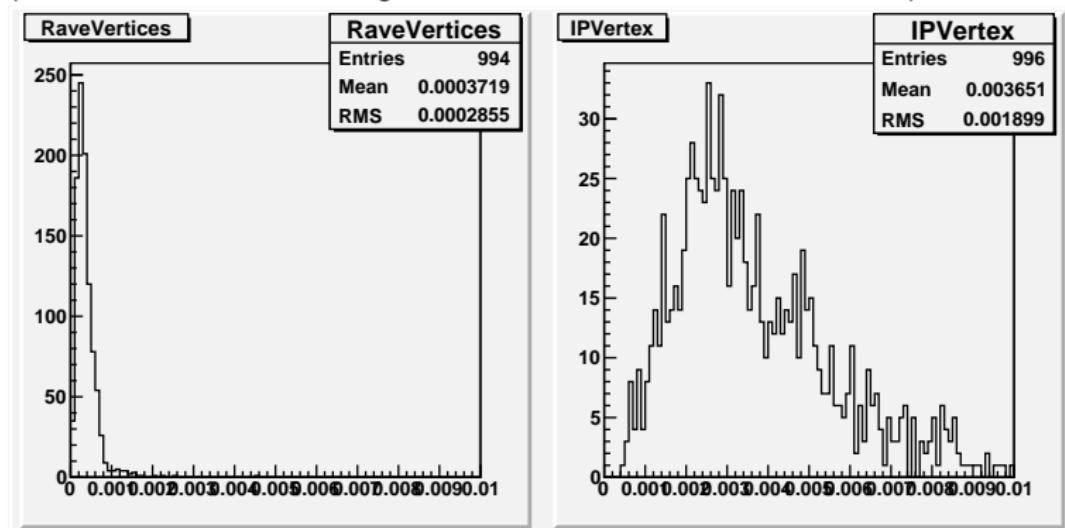


Attention

This renders energy-conservation constraints unusable.

Comparison of IP finding performance

Distance of the found interaction points from the origin
 (MarlinRave used the avf algorithm to reconstruct the RaveVertices):



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Summary

- Kinematic reconstruction inside Marlin using MarlinRave is at a usable stage and ready for performance evaluation.
- A four-momentum constrained fit has been demonstrated.
- Covariance matrices associated with the reconstructed jets are needed for more realistic performance of the constrained fit.
- The vertex finding and fitting provided by MarlinRave is ready for comparison with existing tools.
- Documentation and instructions on how to use MarlinRave are online at:

<http://stop.itp.tuwien.ac.at/publications/marlinrave/doxygen/>