Topological Vertex Finder

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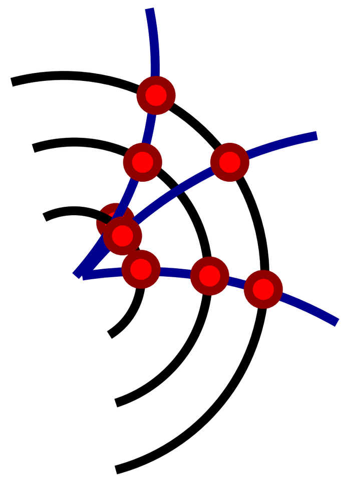


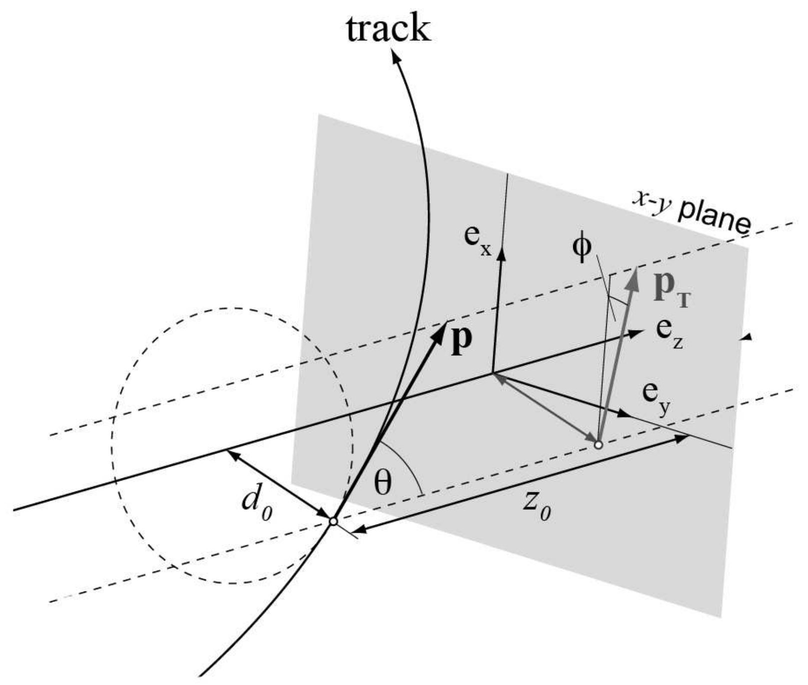
Vertex reconstruction is an important tool for many physics studies. It requires two basic iterative acts:

- **Vertex Finding**: identification of particle decay position and association of the decay products to the vertex.
- **Vertex Fitting**: more precise estimation of the vertex position and the track parameters at vertex.

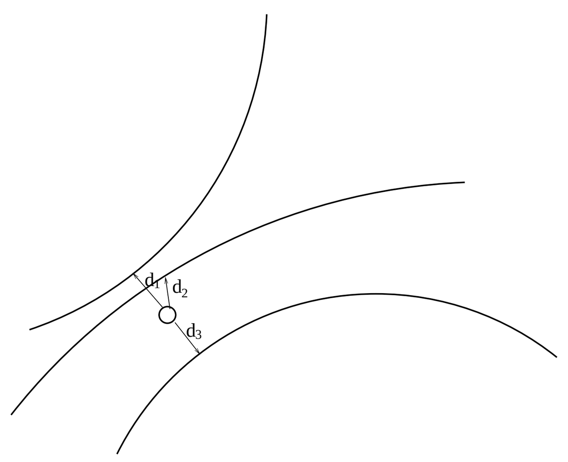
The trajectory of a particle in a magnetic field $\vec{B}(\vec{r})$ satisfies the following equation of motion:

$$\frac{\partial \vec{p}}{\partial t} = \frac{\partial (m\gamma \frac{\partial \vec{r}}{\partial t})}{\partial t} = c^2 \kappa q \vec{v}(t) \times \vec{B}(\vec{r}),$$

where κ is a proportionality factor, dependent on the chosen units. The solution is a helix, which can be parametrised through five parameters. Two local parameters depending on the chosen detector surface and three global parameters representing the particle momentum.



The vertex is the intersection point of all outgoing particles.



The vertex position is the solution of the minimalisation problem involving the residuals between the vertex parameters and the track trajectories in consideration of its errors. A Least Squares Method can be used to determine the best estimator.

A fast fitting method has been developed by P. Billior and S. Qian which uses local parametrisation of tracks and iterative linear fit.

Before starting to fit a vertex, one should define a set of tracks belonging to this vertex. The most simple ways to achieve this are:

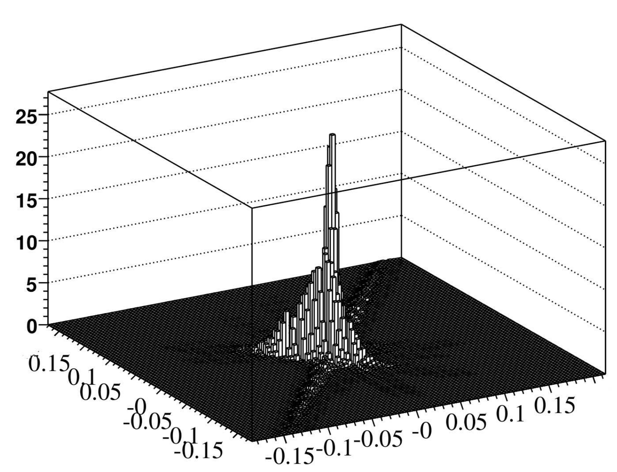
- tear-down procedure: to fit all tracks to one vertex, remove the less suited track, repeat until all unsuited tracks are removed.
- build-up procedure: to start with two best suited tracks and add remaining tracks one by one.

The main idea of the topological vertex finder is simultaneous reconstruction of all vertices based on a so called vertex probability function. Around each track a Gaussian tube is constructed, the width of the tube is given by the track errors:

$$f_i(\vec{r}) = exp(-\frac{1}{2} q^T(\vec{r}) cov^{-1} q(\vec{r})),$$

where $q(\vec{r})$ is the residual to track. Then the vertex probability function is defined as:

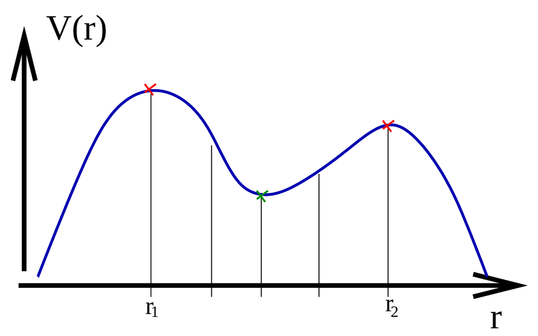
$$V(\vec{r}) = \frac{\left(\sum_{i=0}^{N} f_i(\vec{r})\right)^2 - \sum_{i=0}^{N} f_i^2(\vec{r})}{\sum_{i=0}^{N} f_i(\vec{r})}.$$



This plot shows a few track probability tubes around the interaction point. The vertex is at the position $\vec{r}$ where $V(\vec{r})$ is at its maximal value.

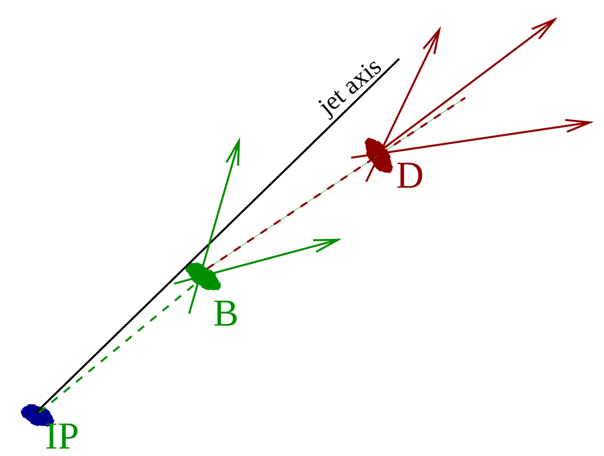
The number of reconstructed vertices depends on the cut value, which describes the spacial resolution.

Two vertices can be resolved if a pronounced dip in $V(\vec{r})$ between these two positions can be found.

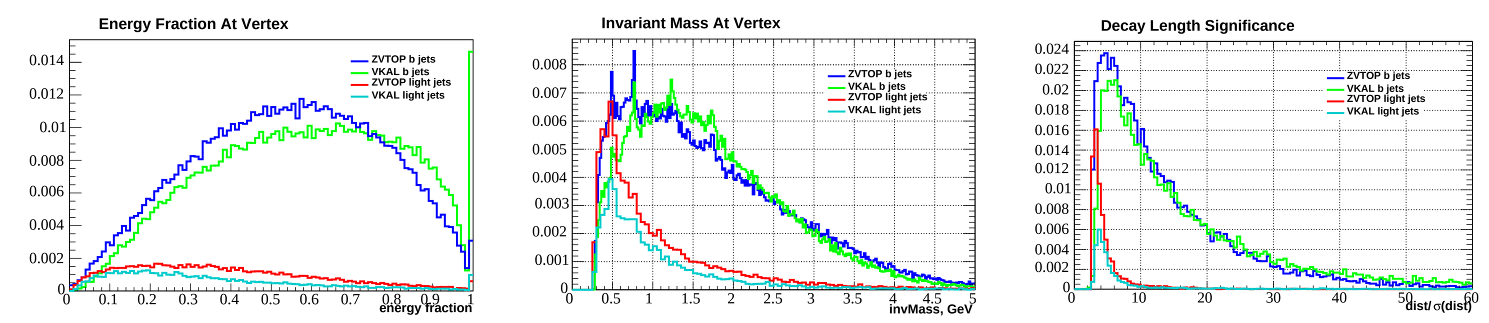


This method has been developed by David J. Jackson (Nucl.Instrum.Meth. A388: 247-253, 1997) and has been successfully applied to $Z \rightarrow bb$ events at SLD.

The main application of the topological vertex finder will be the reconstruction of vertices in jets.

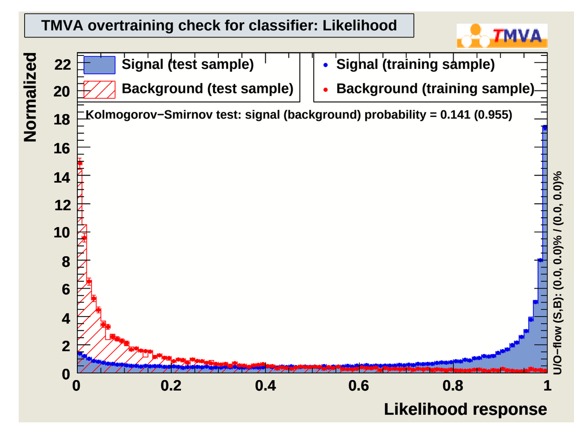


For example the decay chain B hadron $\rightarrow$ D hadron in bottom quark jets can be reconstructed. Existence of two vertices alone is a strong evidence for the bottom jets and is used to separate bottom/charm and light jets.



Additionally one can use the invariant mass of all associated tracks, the energy fraction of the jet carried by the tracks at vertex as well as the decay length significance to distinguish bottom and light jets. Above the shapes of these variables are shown for reconstructed secondary vertices in bottom and light jets for topological vertex finder (ZVTOP) and a build-up vertex finder(VKAL).

In the end all variables are combineted into one discriminant, e.g. a Likelihood classifier. Depending on the physics analysis, one can choose a working point, which define the bottom jet selection efficiency and purity versus other jets.



Now a few words about me...

I am working towards my PhD in experimental particle physics in Wuppertal. Beside B-tagging I am interested in reconstructing heavy top pair resonances. Many models beyond Standard Model predict heavy particles, which can decay into top pairs and will be produced at LHC.