V^0 Finder Status Report

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Quick Reminder

V^0 are neutral particle that decay into two charged particles away from the interaction point

type	Q	$c\tau$
$K_S^0(497) \to \pi^-\pi^+$	$206\,\mathrm{MeV}/c$	$2.68\,\mathrm{cm}$
$\Lambda(1115) \to p\pi^-$	$101\,\mathrm{MeV}/c$	$7.89\,\mathrm{cm}$
$\bar{\Lambda}(1115) \to \bar{p}\pi^+$	$101\,\mathrm{MeV}/c$	$7.89\,\mathrm{cm}$
$\gamma \to e^-e^+$	0	∞ (in all material)

Experimental signature:

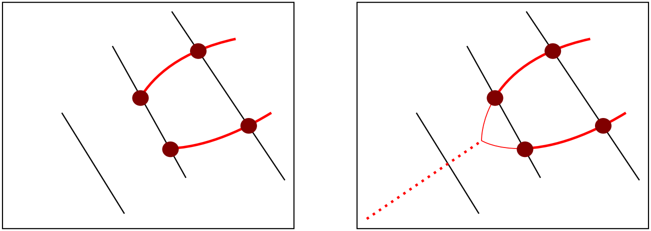

Figure : Example V^0 decay after tracking (left), with interpretation (right)

Patterns

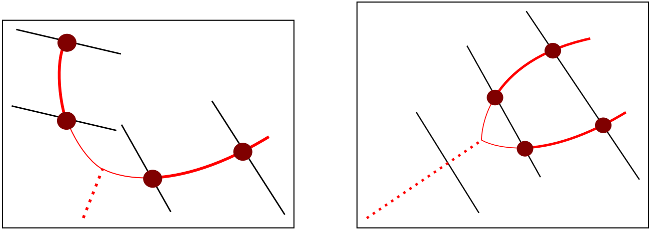

Figure : For very slow particles, the decay products can point in opposite directions (left).

For very slow V^0s, where the breakup momentum exceeds the V^0 momentum, the tracks can be emitted at large angles. This is not likely to happen outside the beam pipe.

Goal

The goal is to

- find V^0s outside (and on) the beam pipe,
- store them in mdst,
- so that analysis doesn't have to deal with material effects.

Additionally V^0s can be beneficial for alignment

- they look at the detector from a perspective away from the IP
- they come with an absolute length scale (the inverse mass of the K_S^0 or Λ)
- momenta will in general be relatively low, leading to comparatively large material effects

Nevertheless, mass resolutions are an important check and converted photons allow for a precise measurement of the radiation length budget, i.e. the material distribution.

Vertex Fit, Kinematic Fit

Vertex Fit

- least-squares fit
- given two tracks yields vertex position, track parameters in vertex
- χ^2 measure of deviation of measured parameters from hypothesis of common point of origin (= vertex)

Kinematic Fit

- least-squares fit
- allows refinement of track parameters given further input ("constraints" such as K_S^0 mass or point of origin)
- χ^2 measure of the additional change needed to track parameters

By the Pythagorean theorem, sum of χ^2s is the same whether constraints are applied sequentially or all together or directly during the vertex fit (in the linear approximation).
Simple test: kinematic fits should improve residuals.

Test sample

All studies were done with a test sample of 1.7 MEvents

- EvtGen, $\Upsilon \to B\bar{B}$ events
- tag B generic
- $B \to J/\psi K_S^0$ on signal side, $K_S^0 \to \pi^-\pi^+$ always

Giulia gave an efficiency of roughly 80% for pions from K_S^0 decays, i.e. around 64% efficiency for a K_S^0 (if no correlations) can be achieved.

Momentum Distribution

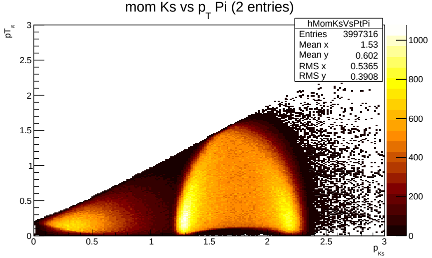

Figure : K_S^0 momentum (horizontal) vs. pion transverse momenta (vertical). Generated (left), reconstructed (right). The distribution has two parts: one from signal B decays, one from the tag side.

The algorithm achieves about 50% efficiency (no cut on geometrical acceptance). We see a cut at low p_T, and decreased efficiency for slow K_S^0, but this may be due to a cut on minimal distance from IP.

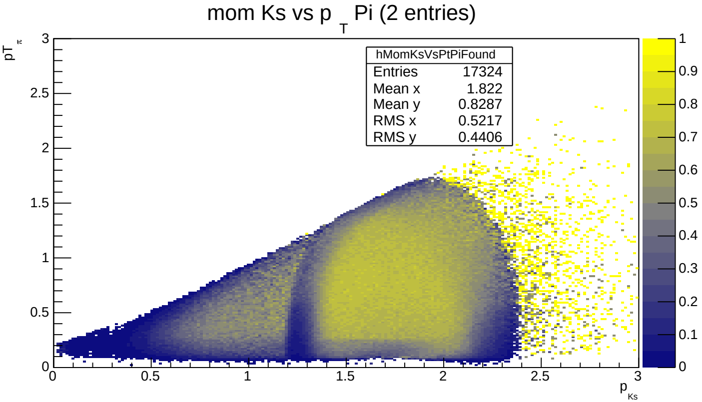

Figure : Efficiency, same variables as before.

Something weird happening for $p(K_S^0) = 1.2\,\mathrm{GeV}$? Perhaps angular separation too large for cut, but too large for slow V^0 recovery. Or the angular distribution is really different from generic K_S^0?

A few quality indicators

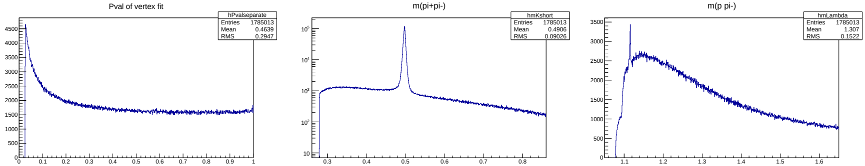

Figure : Quality indicators: vertex fit P-value (left), $m(\pi^-\pi^+)$ distribution (log-scale, middle), $m(p\pi^-)$ distribution (right).

We see a (fairly) flat P-value distribution, sharp K_S^0 and Λ peaks. The K_S^0 mass resolution is approx. $3\,\mathrm{MeV}/c^2$. The highest bin is one bin to the left of the nominal mass.

Pulls of Vertex Fit

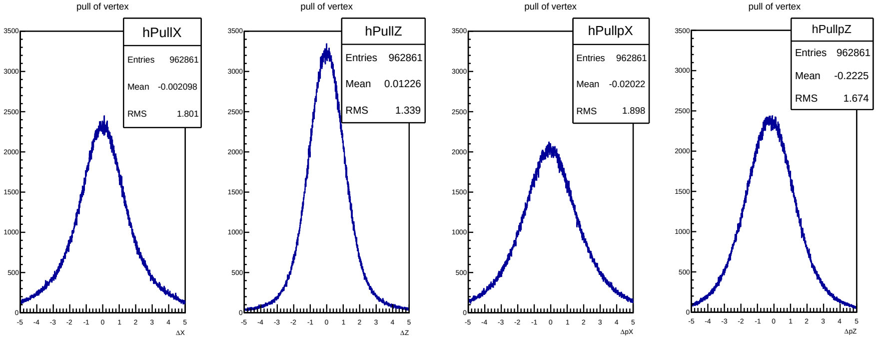

Figure : Pulls of the vertex fit compared to MC truth. X, Z, ΔX, ΔZ. Expectation: Gaussian with $\sigma = 1$. Y looks like X. Momenta are of the K^0_S.

The vertex fit doesn't appear too happy with what it gets from tracking. I have to verify that it actually uses GENFIT for extrapolation.

Kinematic Fits

I revived a code from my thesis for kinematic fitting, and played with the following three constraints:

1. reconstructed mass = K_S^0 mass
2. V^0 momentum points to line $x = y = 0$ (where the signal K_S^0 is emitted)
3. V^0 momentum points to $x = y = z = 0$ (two constraints, includes previous)

If all is well, using only the second constraint should improve the mass peak (but doesn't). Using either or both of the first two should improve residuals. The last constraint is more playful, and we should be able to actually see the B propagation in the Z residual.

Caveat emptor! Perhaps $x = y = 0$ is over-optimistic? Collision angle, $\Upsilon(4S)$ breakup momentum effect may be larger than I guessed? This needs to be verified. Two constraints would be very nice for studies, I could of course constrain the origin to the MC truth instead of $x = y (= z) = 0$.

Effect of KinFit on Residuals

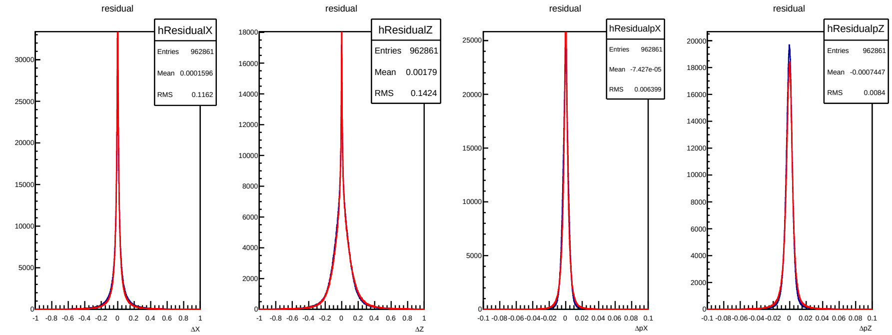

Figure : Residuals before (blue) and after (red) kinematic fit with $m = m(K_S^0)$, origin on $x = y = 0$.

Kinematical fit

- slightly improves X, Z residuals
- Δp_X peak becomes higher, but edges wider
- Δp_Z peak broadens

The mdst Data Structure

```
 *  @param trackPairPositive  A pair of the Track forming one
 *  part of the V0 and the result of the refitting.
 *  @param trackPairNegative  @sa trackPairPositive
 */
V0(const std::pair<Track*, TrackFitResult*>& trackPairPositive,
   const std::pair<Track*, TrackFitResult*>& trackPairNegative);
```

Is refitting supposed to mean a kinematic fit or a vertex fit? In both cases this would lose correlations and 3D information on the vertex. In my opinion the ideal thing to save would be

- track parameters close to the vertex, and to make computing more efficient
- the 6 parameters of the V0 after a mass-constrained kinematic fit (P-value would allow a "weighted" mass cut, covariance matrix can be recalculated from above)

But this doesn't solve the problem which particle hypothesis to use. Also, mass-constrained fits don't make much sense for conversion γs.

Summary of Available Information

Pre-vertex fit:

- track parameters and their covariance matrices, they can be different for different particle hypotheses

Post vertex fit:

- vertex location, momenta in vertex (9 values) and their covariance matrix, where the covariance between the two tracks is redundant (9 elements)
- χ^2 or P-value of vertex fit
- V^0 masses for various particle hypotheses (to be distinguished from p.h. during track fit

The mass-constrained kinematic fit add

- χ^2 or P-value which contains almost the same information as the mass before the fit (but weighted with track errors)
- the parameters that will actually enter a subsequent analysis

Relation P-value to mass cut

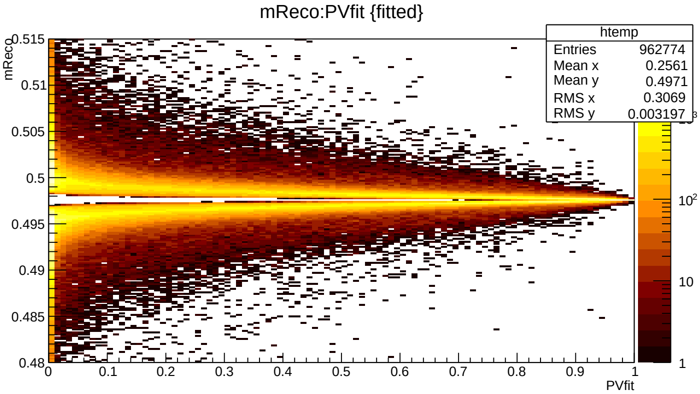

Figure : P-value vs. reocnstructed mass for mass-constrained fit

The relation between decreasing P-value and worse reconstructed mass is clearly visible and expected: the fit goes in the direction of increasing or decreasing mass for as long as is needed to reach the nominal mass, the farther it goes, the larger χ^2.

Residuals for the full 3C kinfit

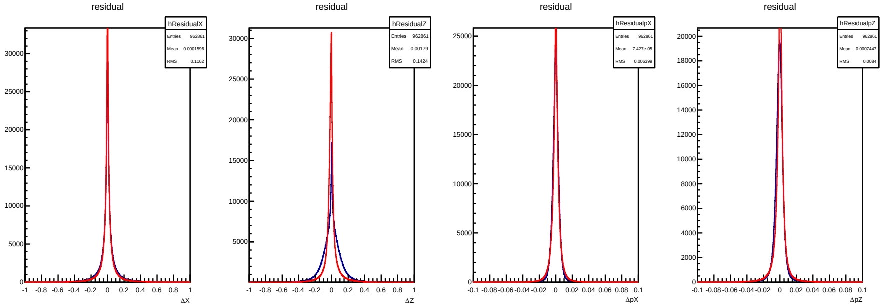

Figure : Residuals for the kinfit with mass constraint and requiring the K_S^0 to come from the IP.

The propagation of the B can be clearly discerned. Notice the nevertheless huge improvement in z of the decay vertex. Again, wings of momentum measurement negatively affected.

Conversion pairs

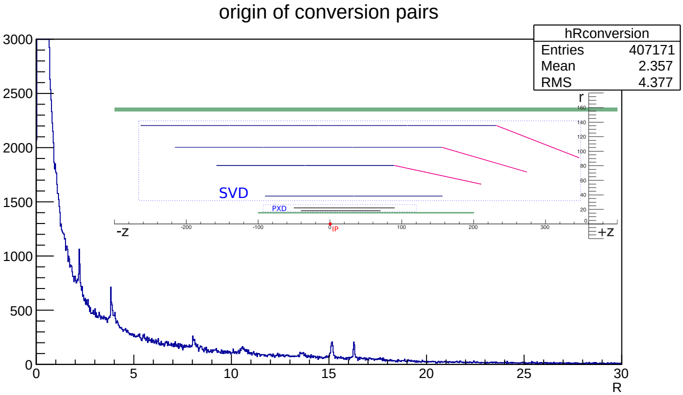

Figure : R of V^0 vertices with a K_S^0 anti-cut.

Some material can be already radiographed with my data sample.