Designing the Time of Flight System

Rajendran Raja
Fermilab

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Preamble

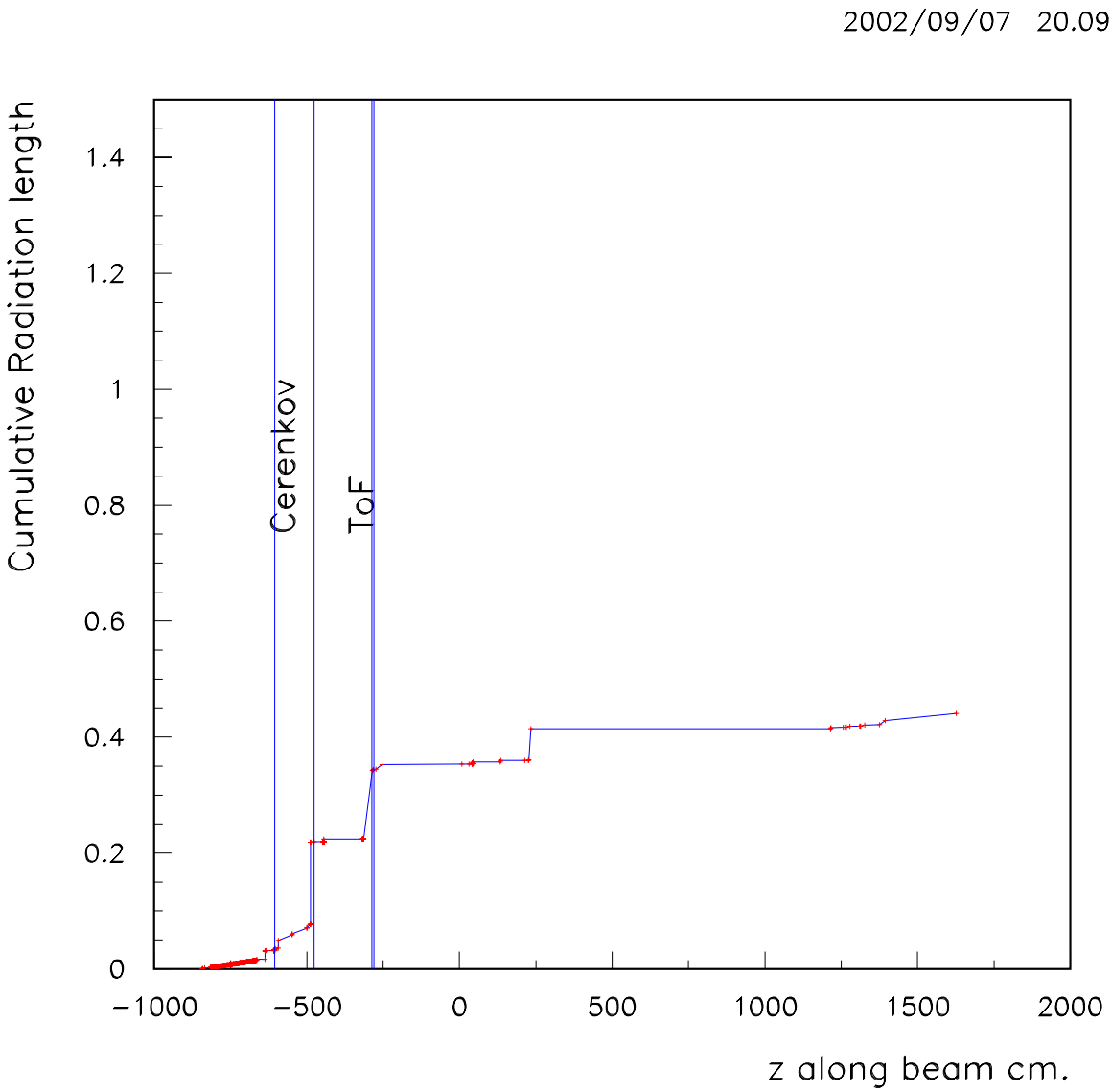
We consider a time of flight array of dimensions hdx,hdy,hdz = (230.0,120.0,2.5) cm, where hdx,hdy and hdz are the ***half*** lengths in x,y and z. The direction x is horizontal., y vertical and z is the beam direction. Each scintillator has hdx=2,5 cm. There are 92 counters in all in this array. The radiation length of scintillator in Geant is 42.2 cm and the interaction length is 88.7 cm. 5cm of scintillator in the beam direction is equivalent to 0.118 radiation lengths and 0.056 interaction lengths. The midpoint of the array is placed at –283.699 cm in z in the mother volume, the target being at –832.55cm and the center of the Jolly Green Giant being at –739.998 cm. The distance from the target to the center of the ToF system is 548.851 cm. The time taken by light to travel this distance is 18.307 ns. An accuracy of 150 ps in ToF measurement is thus a 0.819% measurement of the ToF.

Error analysis

The momentum p of the particle is related to its rest mass by the formula $p = m_0 \gamma \beta c$. Differentiating this leads to $\frac{\partial m_0}{m_0} = \frac{\partial p}{p} - \gamma^2 \frac{\partial \beta}{\beta}$. Since β is measured by measuring the time t taken to travel the length L, i.e. $\beta = \frac{L}{ct}$, this leads to $\frac{\partial m_0}{m_0} = \frac{\partial p}{p} - \gamma^2 (\frac{\partial L}{L} - \frac{\partial t}{t})$. These individual terms add in quadrature to give the percentage error in mass

$$\left(\frac{\partial m_0}{m_0}\right)^2 = \left(\frac{\partial p}{p}\right)^2 + \gamma^4 \left(\left(\frac{\partial L}{L}\right)^2 + \left(\frac{\partial t}{t}\right)^2\right)$$

MIPP Radiation lengths



Cumulative Radiation Length vs distance along beam

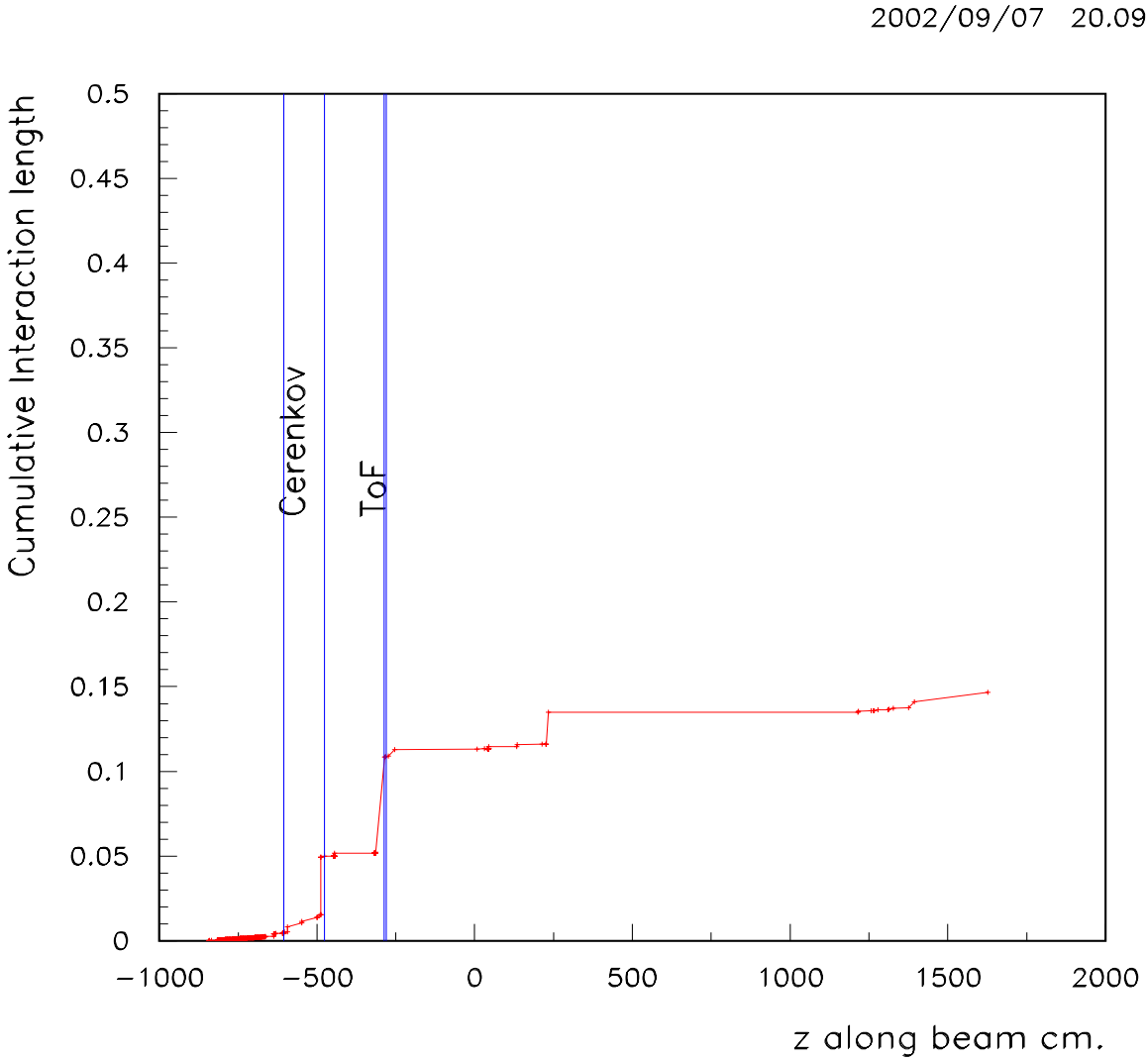
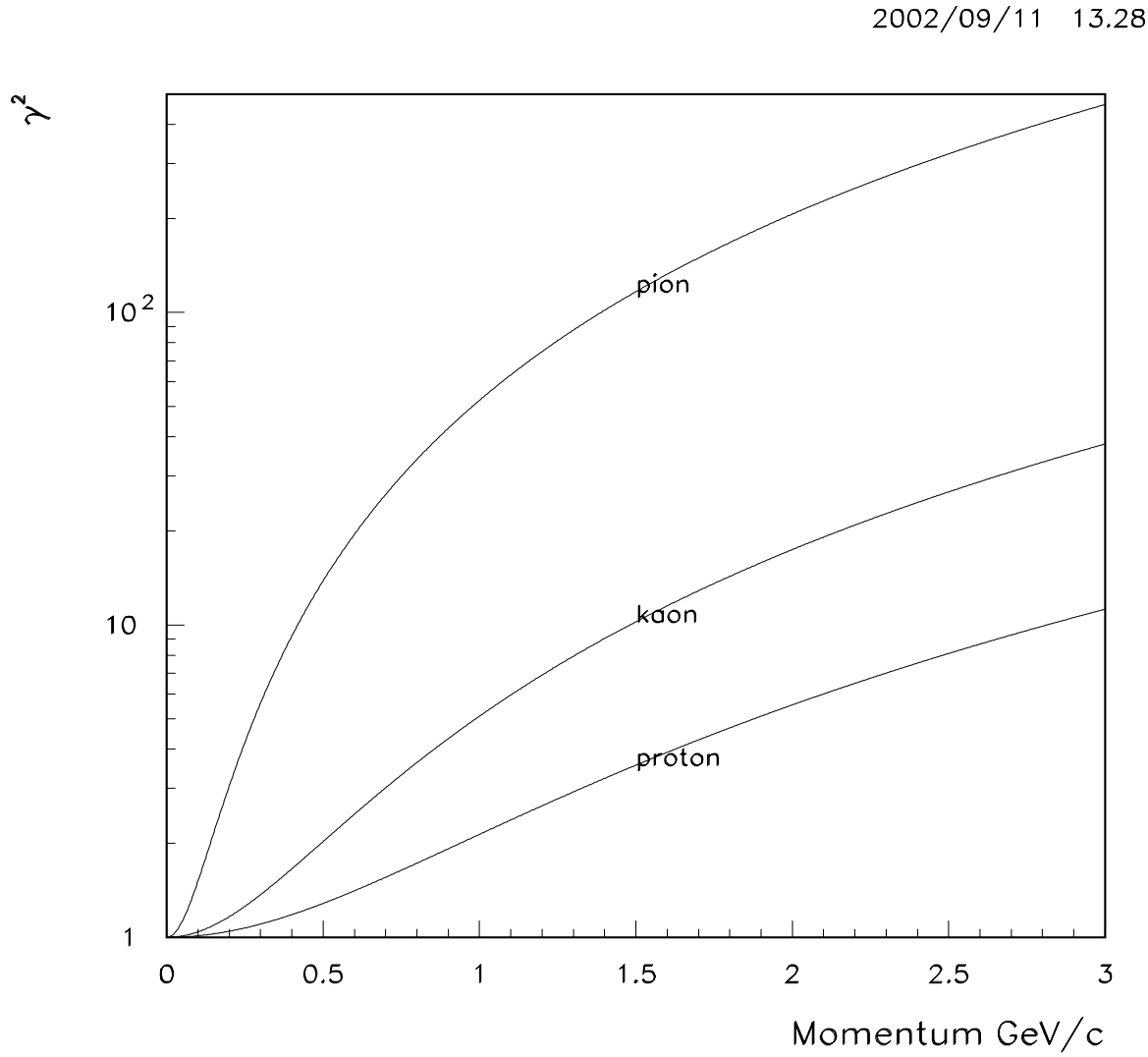
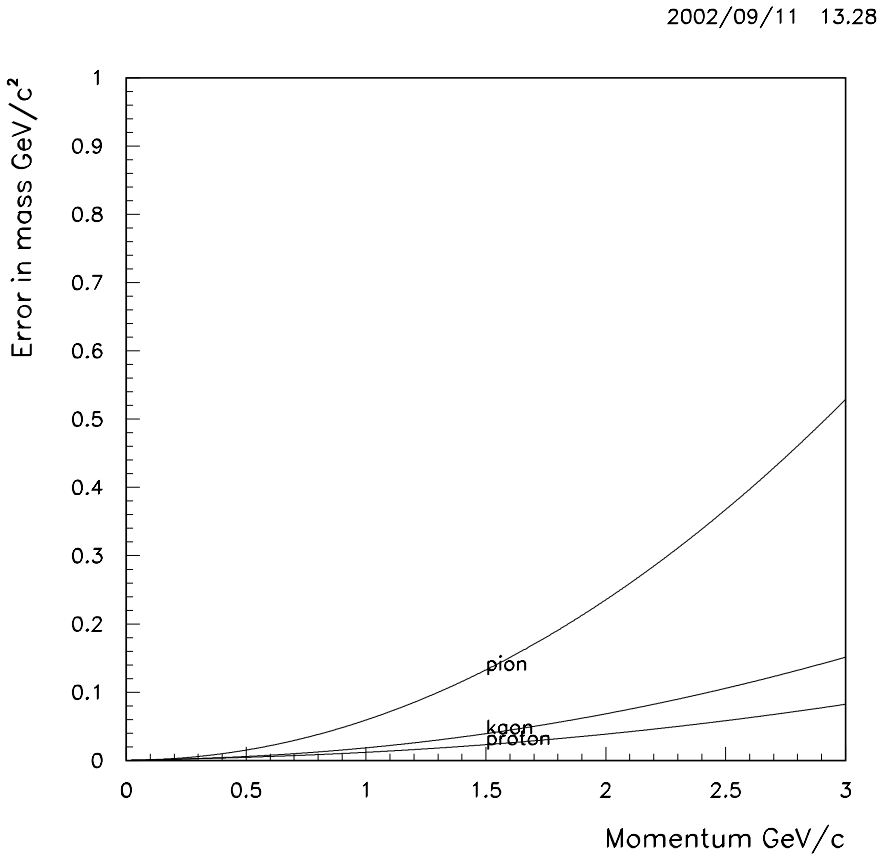


Figure 2

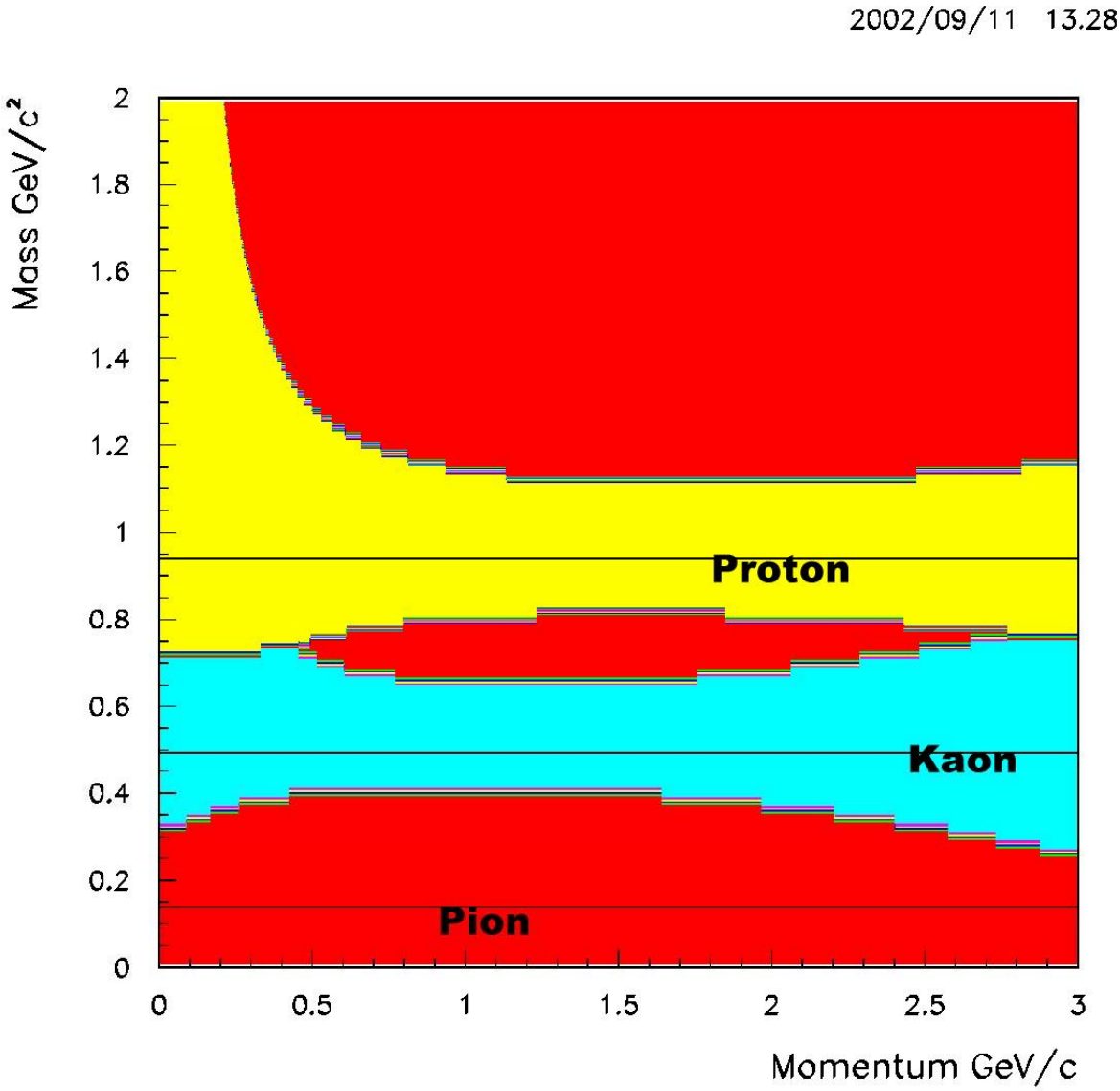
Cumulative Interaction length vs distance along beam



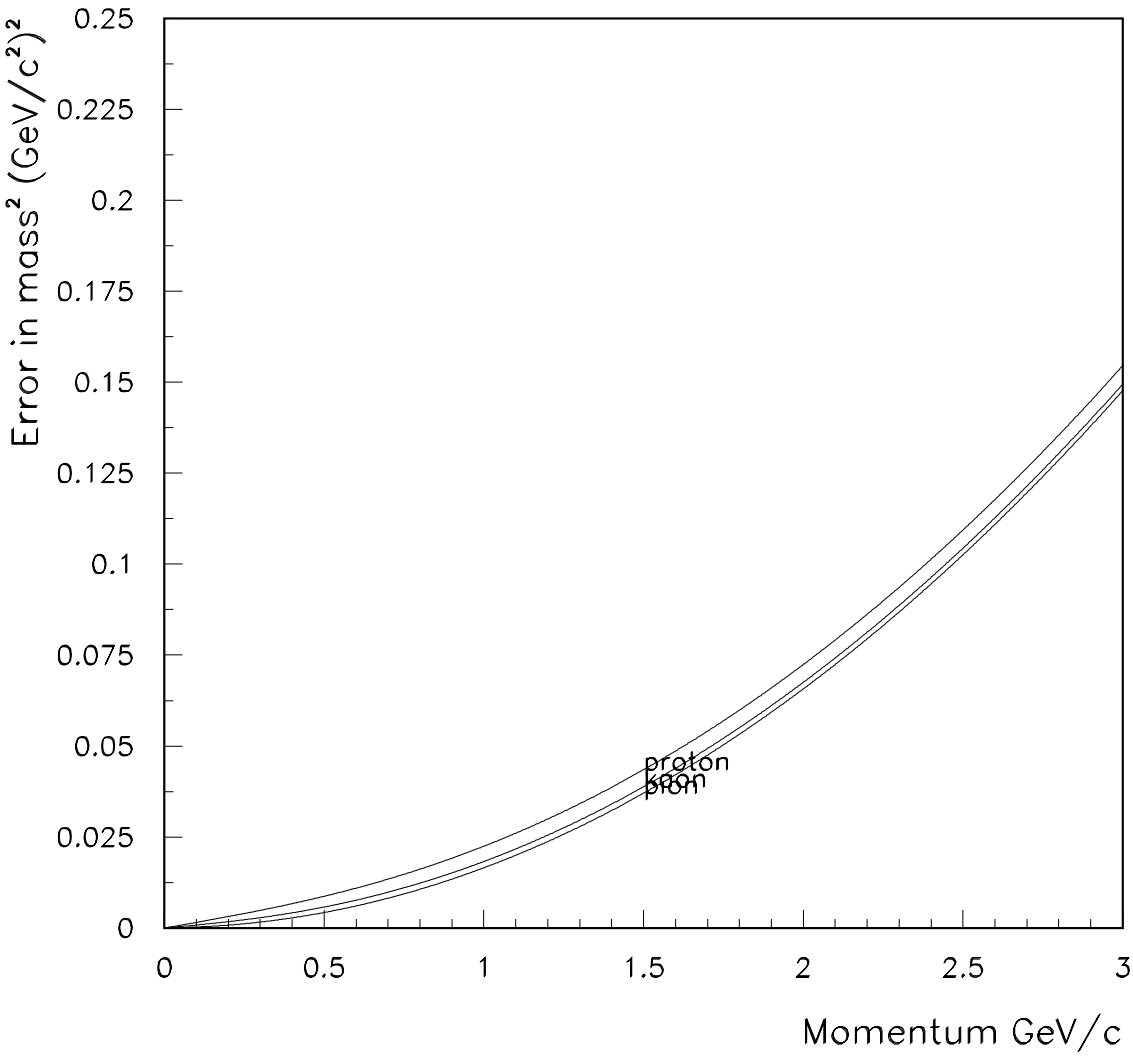
γ^2 as a function of momentum for the three particle types



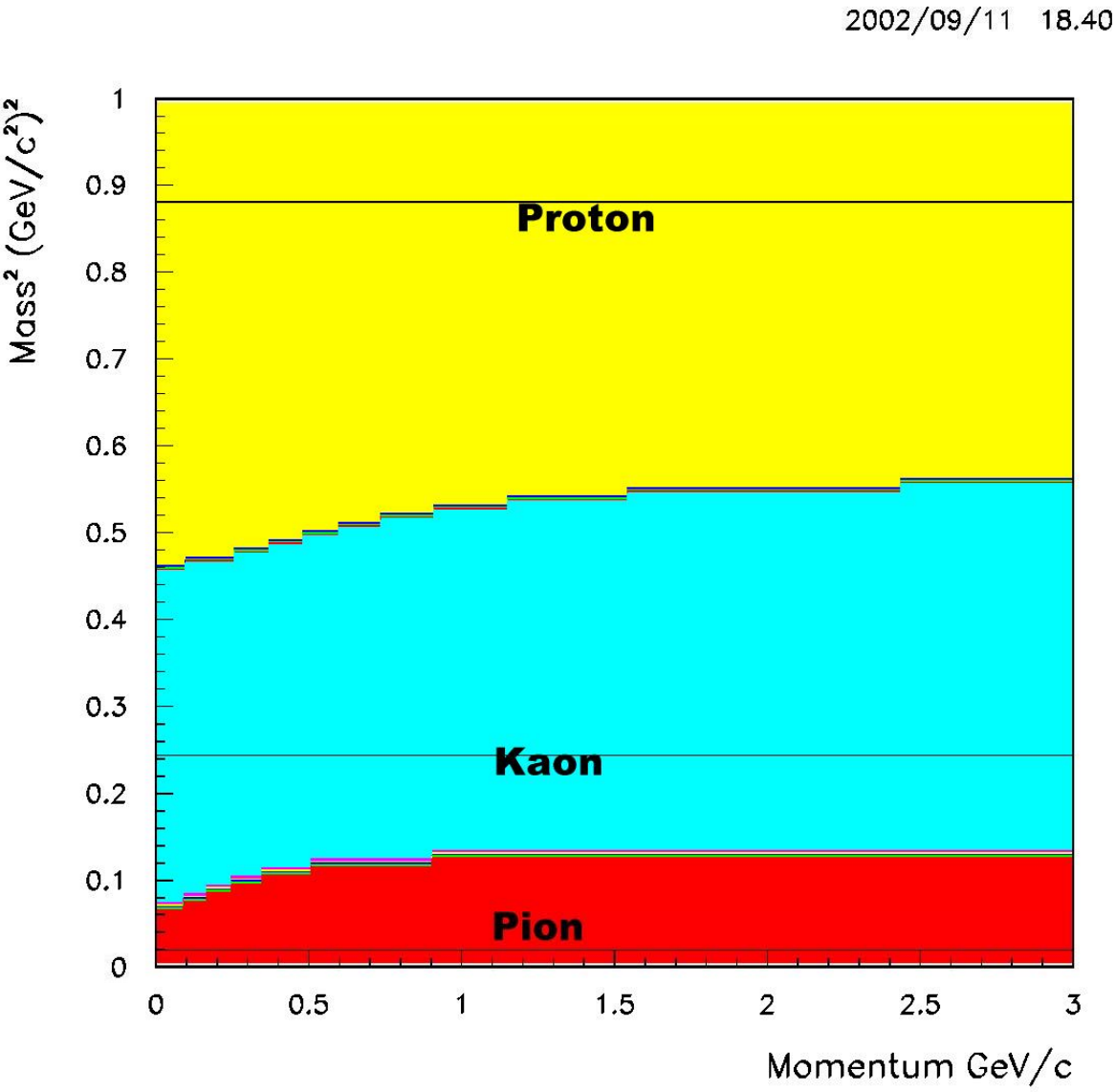
Error in the mass as a function of momentum



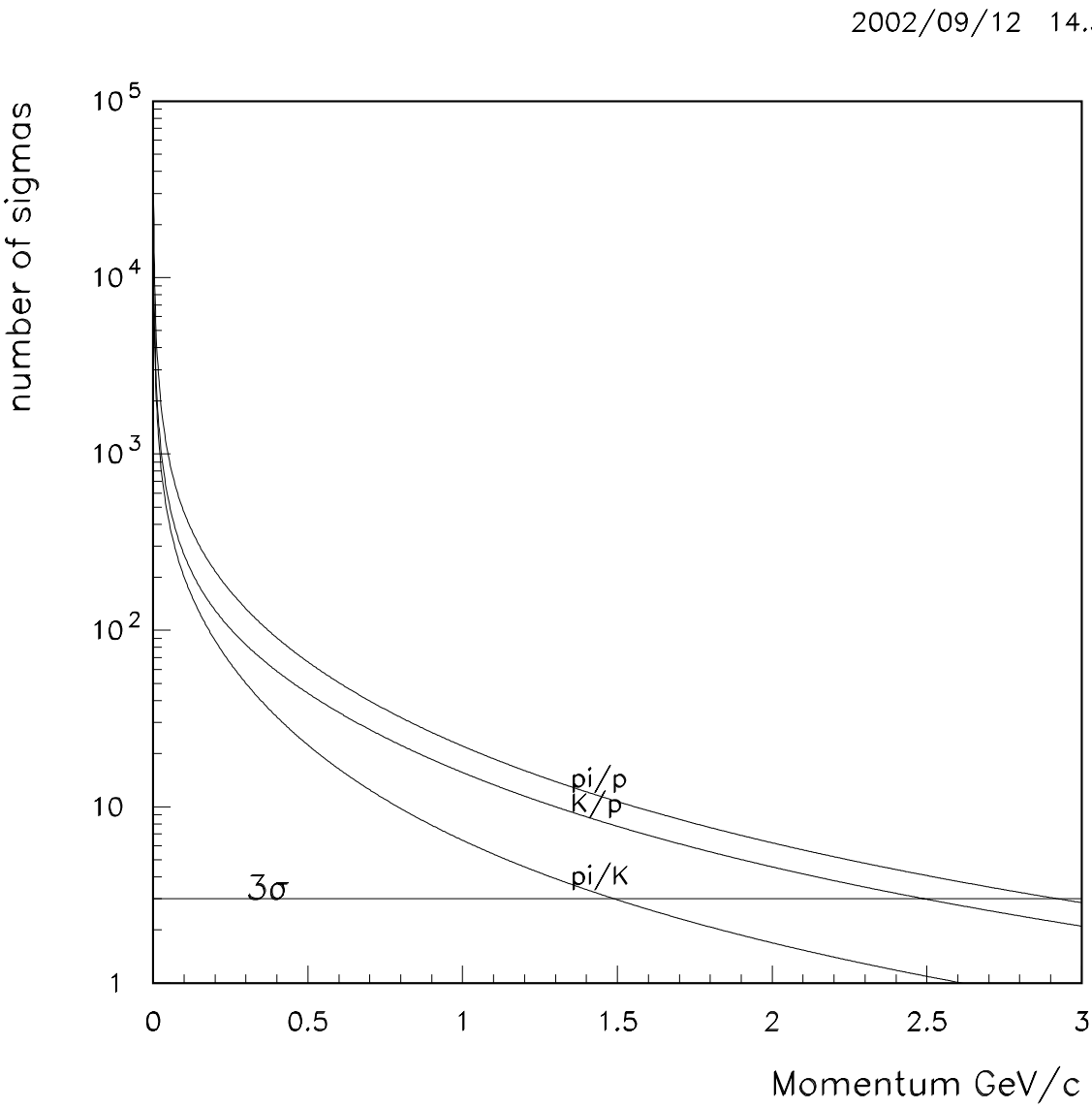
Mass hypothesis assignment contours. Red denotes pion, cyan denotes Kaon and yellow denotes proton. Horizontal lines are the nominal π,K p masses. Gaussian distributions in mass assumed



Error in m_0^2 as a function of momentum



Mass hypothesis assignment contours. Red denotes pion, cyan denotes Kaon and yellow denotes proton. Horizontal lines are the nominal π,K p masses. Gaussian distributions in mass^2 assumed



Number of σ's the equal likelihood contours are away from the mass hypotheses

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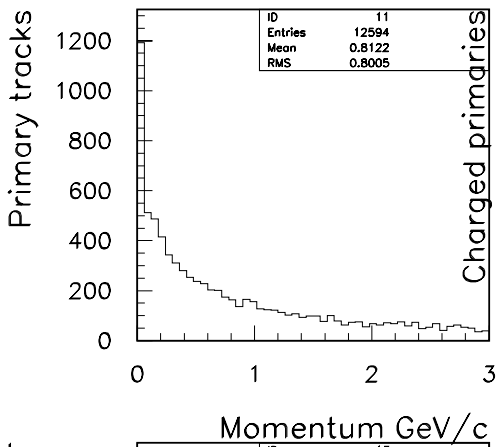
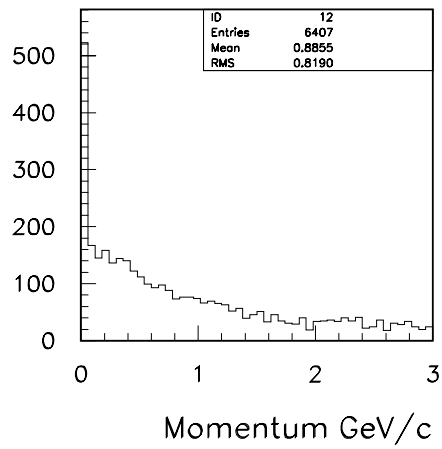
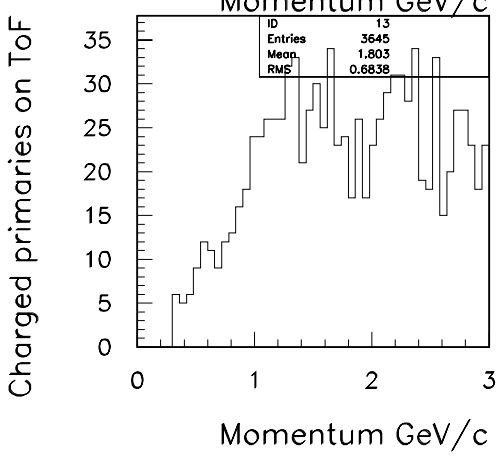






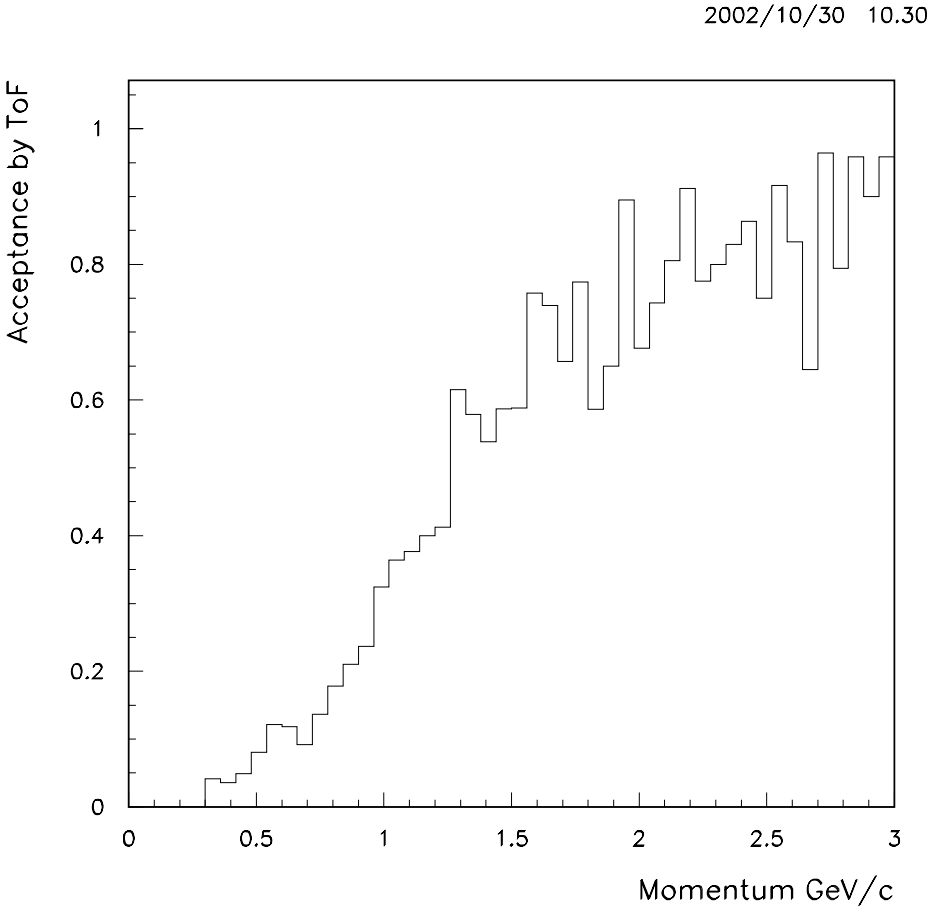
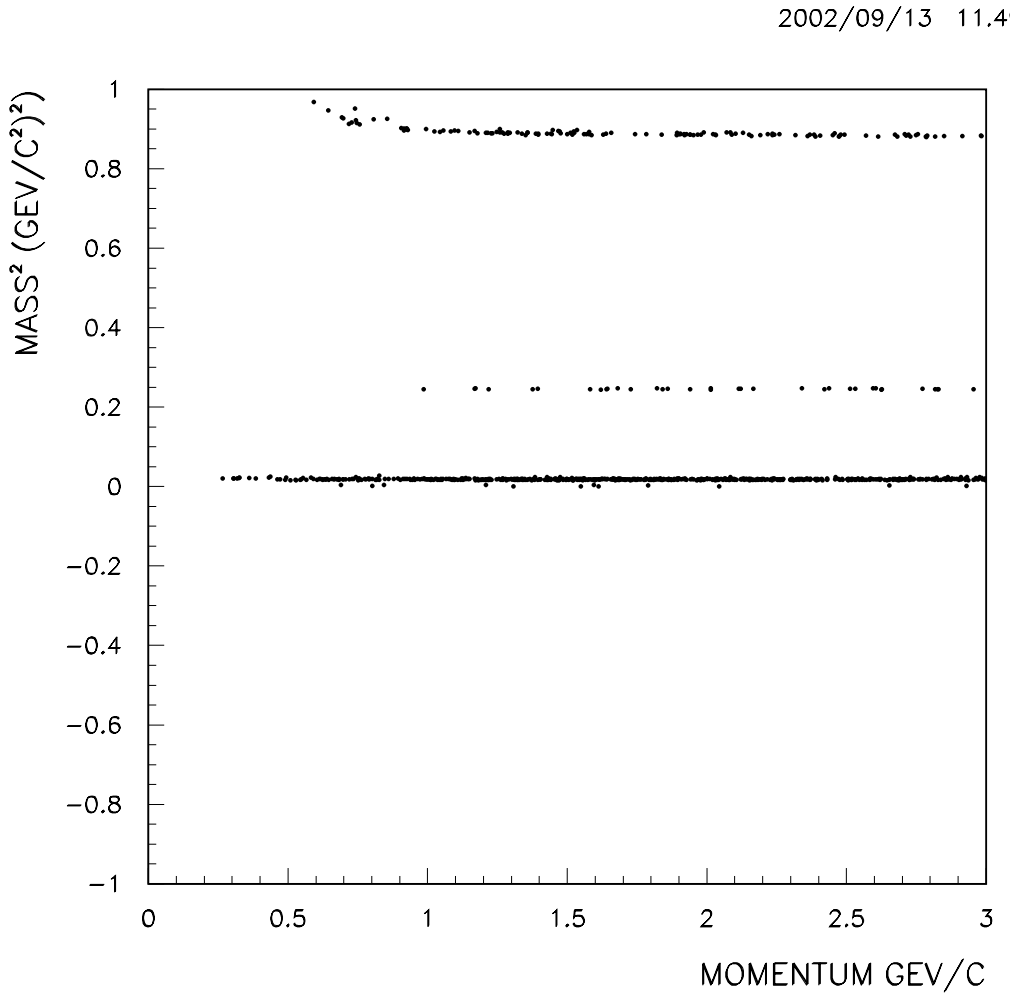
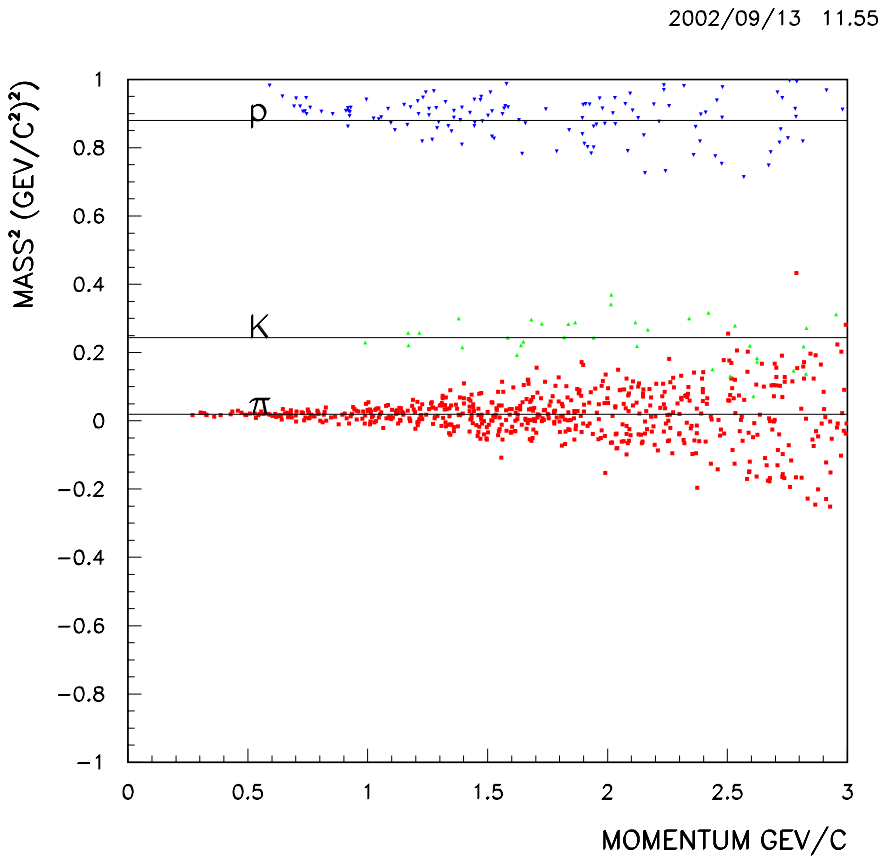


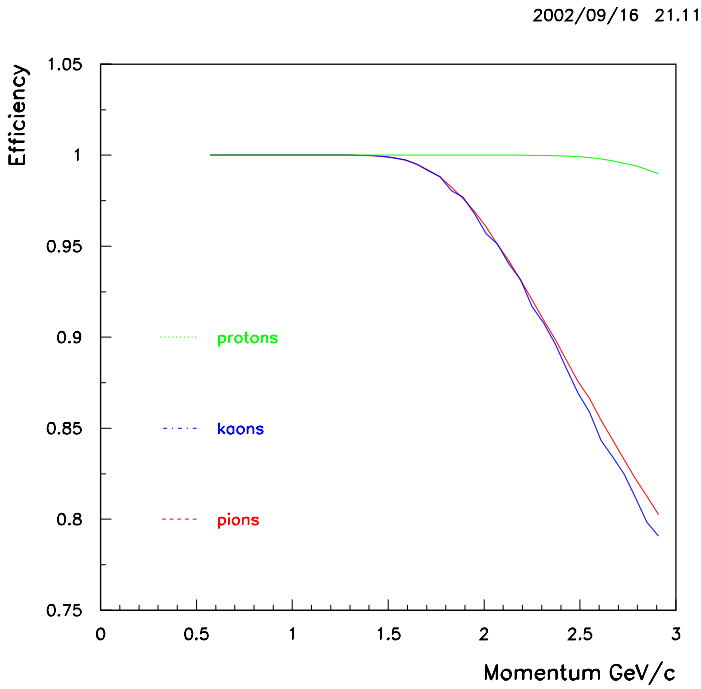
Figure shows the acceptance of the ToF system as a function of momentum



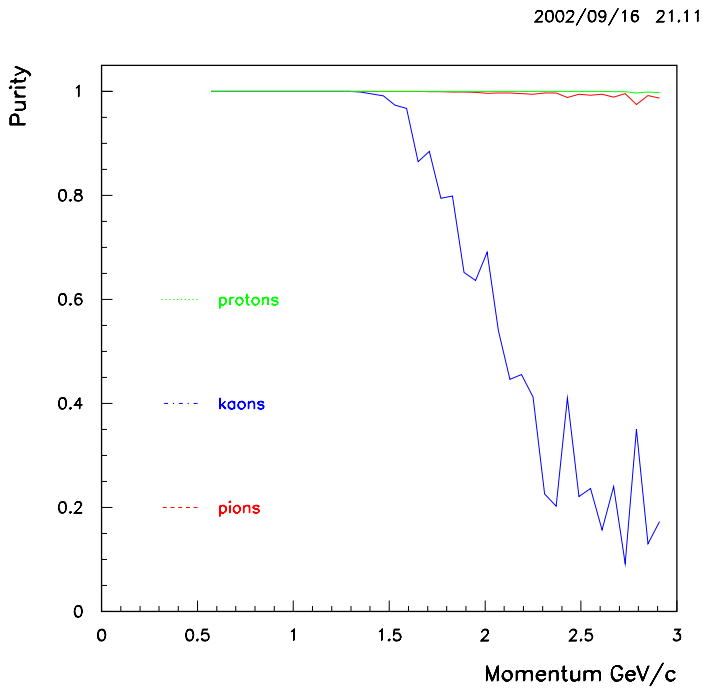
Mass^2 as a function of momentum with perfect time and length of flight measurements. Three bands are seen for the π, K and p hypotheses. The flatness of these curves is an indication of the correctness of the Geant tracking algorithm



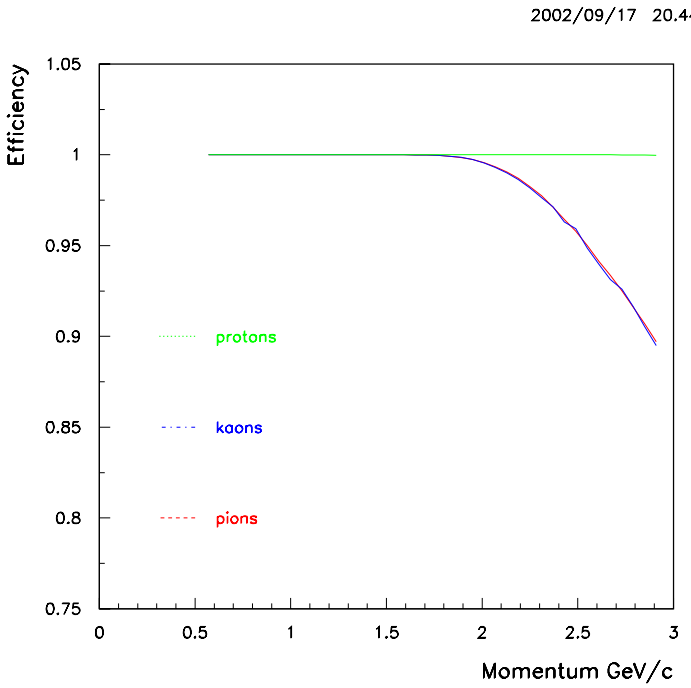
Same as previous figure, but with ToF resolution of 150ps



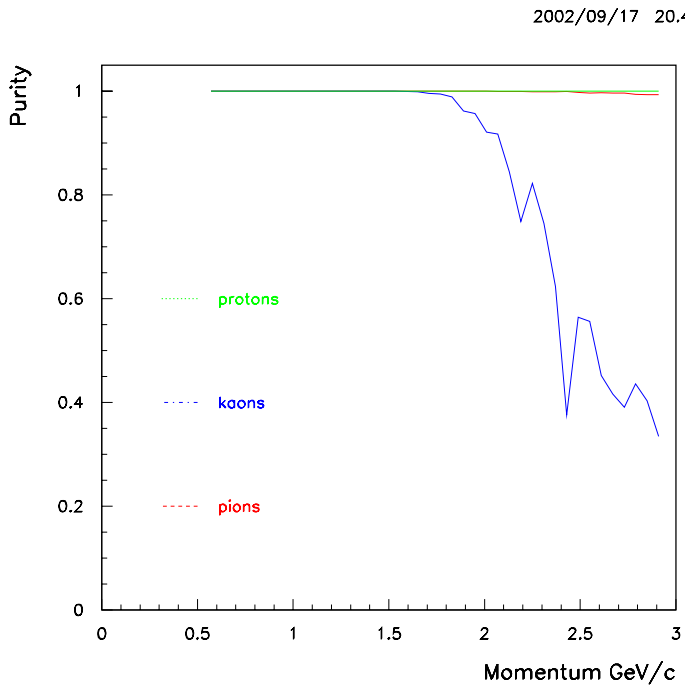
Efficiency curves for the three particle species as a function of momentum, ToF resolution=150ps



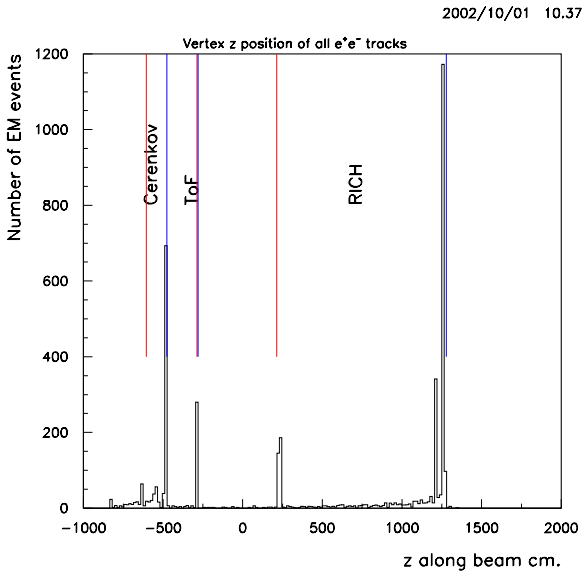
Purity Curves for the three particle species as function of momentum, ToF resolution=150ps



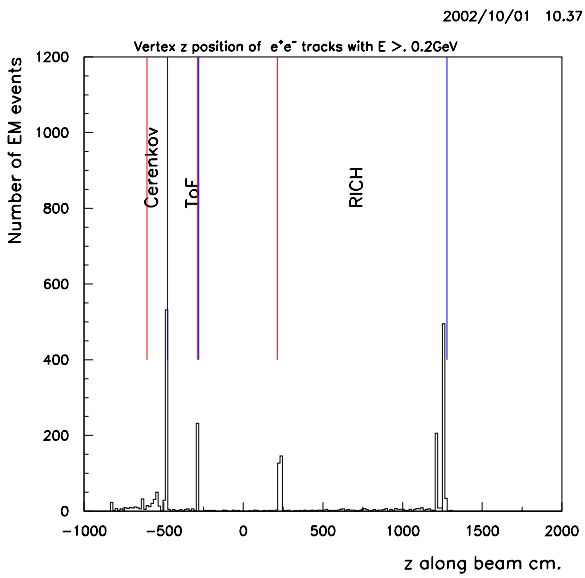
Efficiency curves for the three particle species as a function of momentum, ToF resolution=100ps



Purity Curves for the three particle species as function of momentum, ToF resolution=100ps



The vertex of origin of all e^+e^- pairs. Primary vertex is at –832.5cm. The upstream end (red) and the down stream end (blue) of the Cerenkov, ToF and RICH are shown.



The vertex of origin of e^+e^- pairs with energy >0.3 GeV. Primary vertex is at –832.5cm. The upstream end (red) and the down stream end (blue) of the Cerenkov, ToF and RICH are shown.

Optimizing the number of counters

The counters in the center have a large number of background tracks. The (signal/signal_background) ratio for the center counters is ~0.02 where as the loss in acceptance of tracks less than 2.5 GeV by removing one counter in the middle is ~ 0.01, assuming a roughly flat distribution in Figure 27. If one were to remove the center 6counters, this would leave a 25cm gap which will cause a 6 loss in acceptance in the ToF. This would ameliorate the photon conversion problem significantly. In addition, the average charged multiplicity of tracks in counters with $|x|>100$cm is < 0.02, if one increases the width of the counters to 10cm for $|x|>100$cm, then the average multiplicity of tracks in these counters will be <0.04. The number of counters would go from 92 to 66 with this modification. If one were to remove the central 6counters, we can get by with 60counters in all. This would represent a reduction in total number of phototubes from 194 to 120 i.e a reduction of 38% in phototube costs.