Rejection of converted π^0

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Outline:

- the problem
- Conversion ID
- Reconstruction of tracks
- Geometrical features of converted pions
- Conclusions

The problem

- A large fraction of photons in $h \to \gamma\gamma$ decay convert in the tracker. The they can not be separated from the huge neutral pions bkg using their E/M calorimeter or the preshower shape – both have similar broad shower shapes. Can we recover converted photons without enhancing the QCD background?

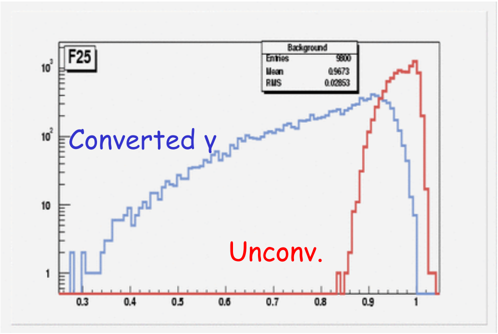
- How can we distinguish a converted π^0 from a converted photon?

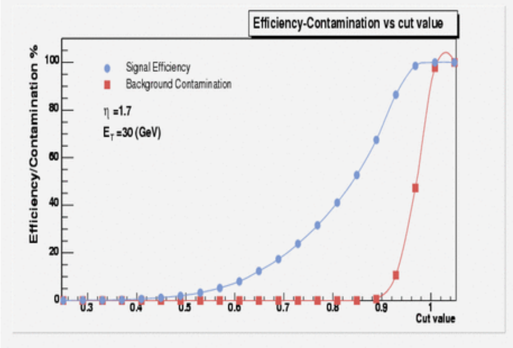
- Neutral pions have an extra photon ~ In most cases only one of the two photons converts.

- So far, rejection of converted π^0's was based on the extra Ecal energy (due to the presence of the unconverted photon) compared to the tracker momentum (E/P ratio and variations).

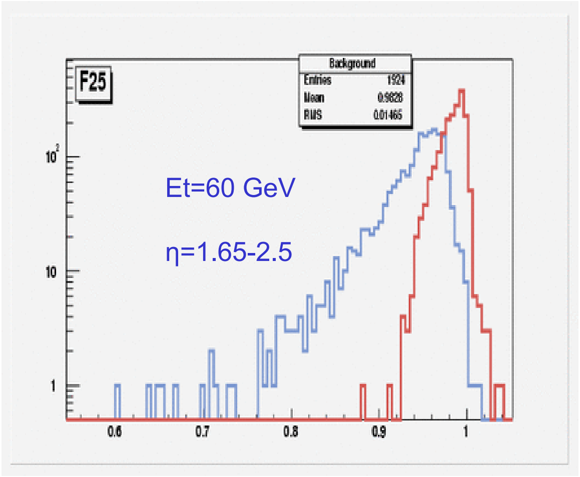
- The separation of converted/from unconverted photons is necessary (Conversion Identification) as well as good track reconstruction.

Conversion Identification (I)





- Lateral shower shape in E/M Calorimeter (& Preshower in the forward region) is different for converted/uncoverted photons.
- Single variables can be used like the fraction of supercluster(=cluster of clusters) energy in N crystals.
- Good separation for small Et (~15% contamination for 90% efficiency), but when going to large values fixed geometrical window is significantly less efficient as shower shape changes.



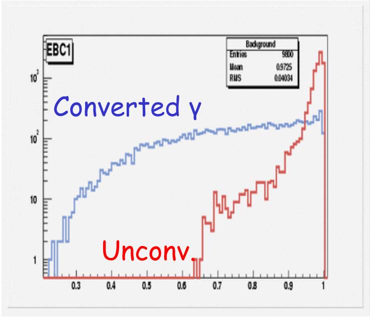
Conversion Identification (II)

- Use more than one variable to identify conversions? if lateral shape in Ecal is different for converted/unconverted photons → the same in preshower.

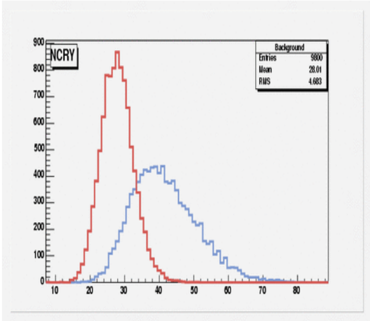
- Attempt to use many variables from both Ecal & Preshower (in the forward region) using likelihood and neural net methods.

- Ecal variables used : F_1, F_4, F_9, F_{25} where F_N is the fraction of supercluster (cluster of clusters) energy in N crystals. Also cluster variables such as the fraction of energy of 1^{st},2^{nd},3^{rd}+rest clusters's with respect to all of them , number of clusters, total num of crystals.

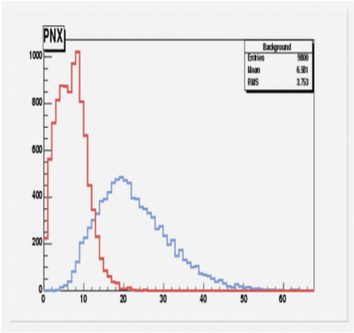
- Preshower variables can be used in the forward region, such as num of hits inX/Y plane, max energy & total energy in each plane.



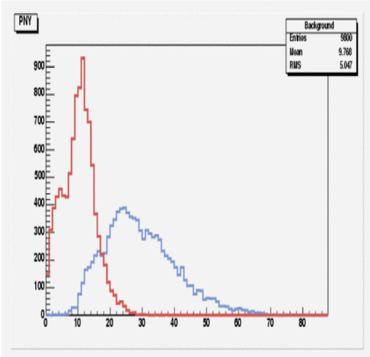
Fraction of 1^{st} cluster



Num of crystals

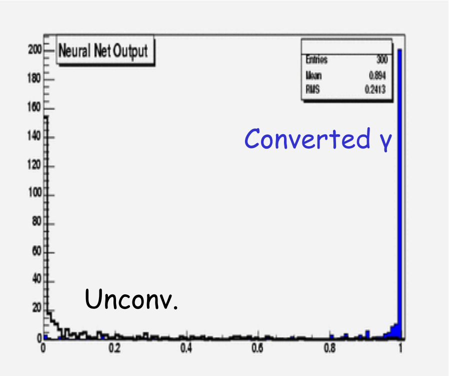


Num hits in X plane



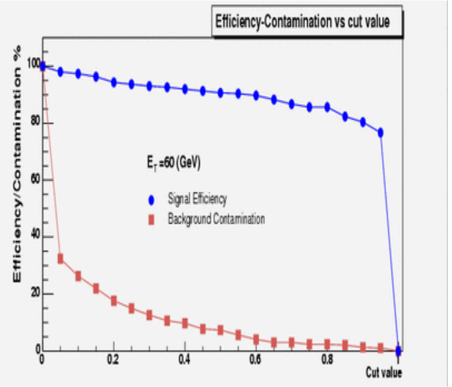
Num hits in Y plane

Conversion ID (III) - Neural net & Likelihood results



- For ~90% efficiency at Et=30 GeV, eta=1.7

	F4	F9	F25	Likelihood	Neural net
Contamination	8.1%	10.1%	15.4%	4.6%	1.7%



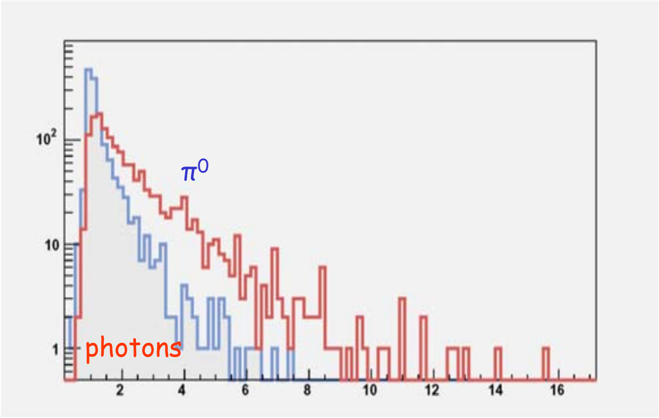
- For ~90% efficiency at Et=60 Gev, η=1.65-2.6 (worse case)

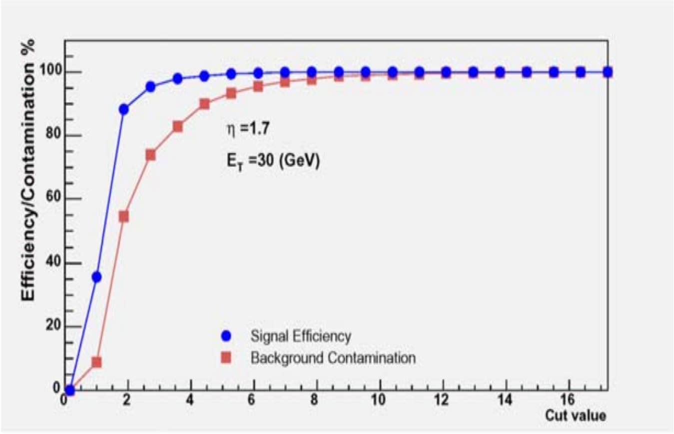
	F4	F9	F25	Likelihood	Neural net
Contamination	26.9%	21%	27%	16.48%	4.3%

Reconstruction Of tracks

- Kalman filter is a recursive formulation of the least squares method of fitting a set of measurements to a track model. Is is a local algorithm (LSF is global).
- It starts with a track seed and alternates between propagation steps and update steps.
- Seeds are initial track segments, starting from inside out (pixel detector) or outside in (calorimeters).
- In the propagation, the track state (parameters of curve and errors) is extrapolated to the next layer taking into account material effects and the magnetic field.
- In the updated step the extrapolated state is combined with the observation.
- The seed in this case was created from E/M calorimeter clusters (low track density compared to IP), looking for compatible hits in the silicon detector (taking into account the energy and the magnetic field).

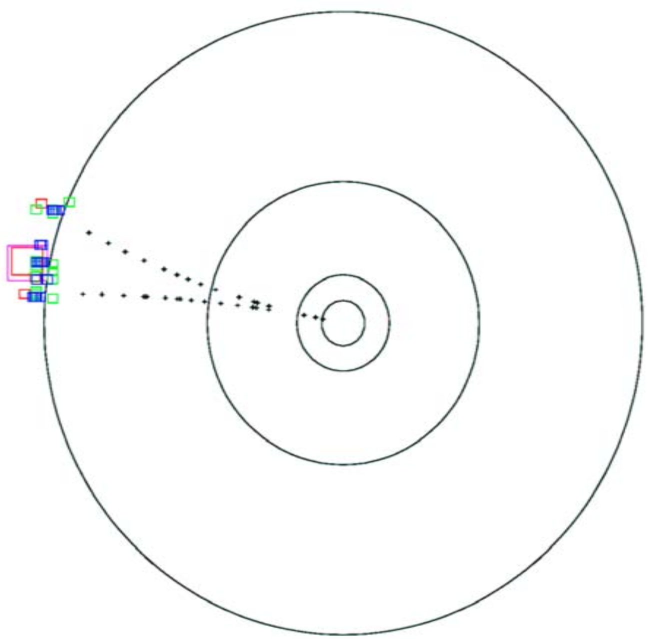
SuperCluster energy/trackMomentum (|p1|+|p2|)





- For efficiency ~90% the rejection of π^0 is ~ 41%.
- The asymmetrical decays of pions result in low E/P ratio π^0 events.

How a converted π^0 looks like?

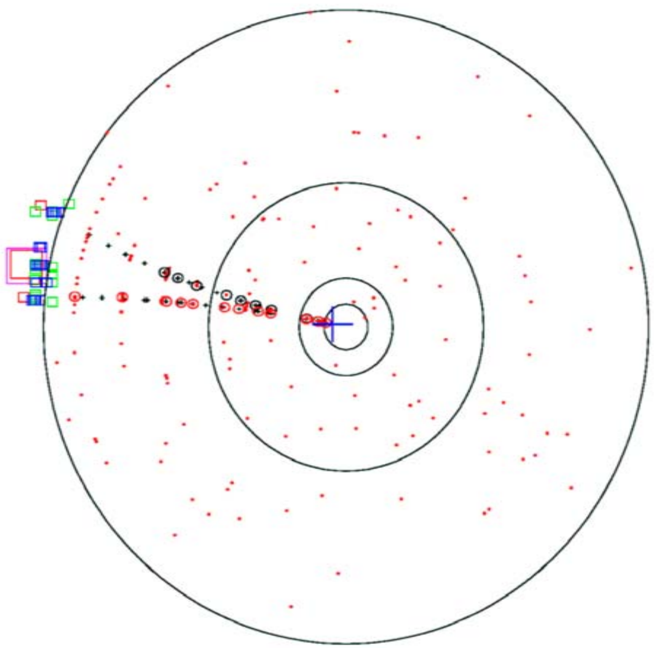


Simulated Tracks

Basic Clusters ☐

SuperClusters ☐

Preshower Clusters ☐ ☐



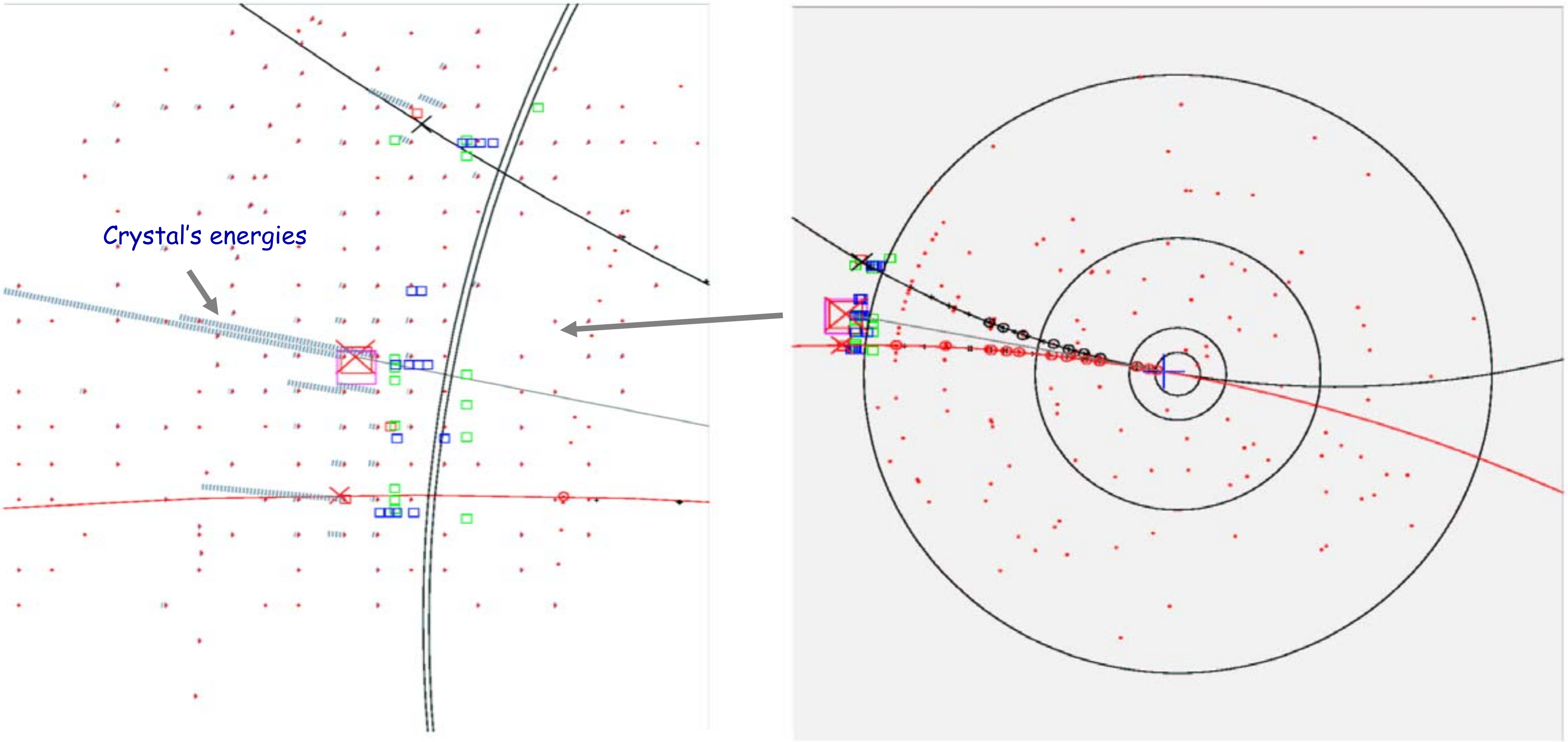
Reconstructed Tracks

Tracker hits : blue dots

hits in a circle: hits of a reconstructed track

Recon. vertex: blue cross

Can the physical objects (e^+,e^-,γ) be found?



- Extrapolation of tracks – find impact point in E/M Calorimeter.
- Calculate from vertex and momentum vector sum, the impact point of a possible unconverted photon.

description of method (I)

- Extrapolate the tracks to find impact points of e^+,e^- in the E/M Calorimeter.

- From reconstructed vertex point and the momentum vector sum of the tracks define a line.

- Find the impact point of this line in the Ecal. This is the region where we expect to find the unconverted π^0 photon and brems emitted close to the vertex.

- Define a line from the impact point of the electron & positron. This line divides the Ecal surface into two regions. If the event contains a π^0 with an uncoverted photon, one of the two regions will contain the extra photon.

- Try to exploit this asymmetry to construct observables that are correlated with the true energy of the unconverted π^0 photon.

description of method (II)

- The line that connects the electron & positron impact points in the E/M Calorimeter together with the vertical line to it that also passes through the possible photon position defines a 'natural' co-ordinate system for these events.

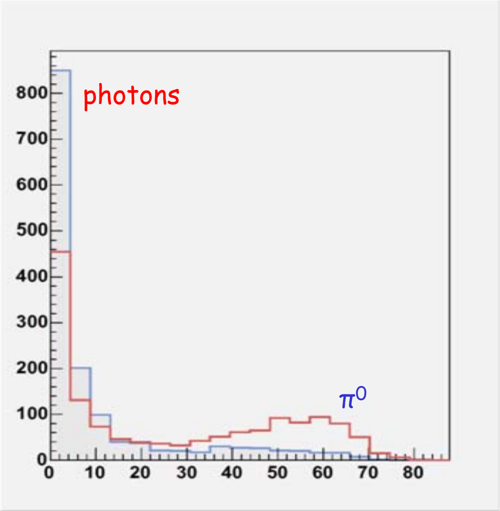
- Study the region of the 'reconstructed' physical objects e^+, e^-, γ and more specifically the ecal energy distribution in terms of clusters and crystal energy deposits close to them.

- For example

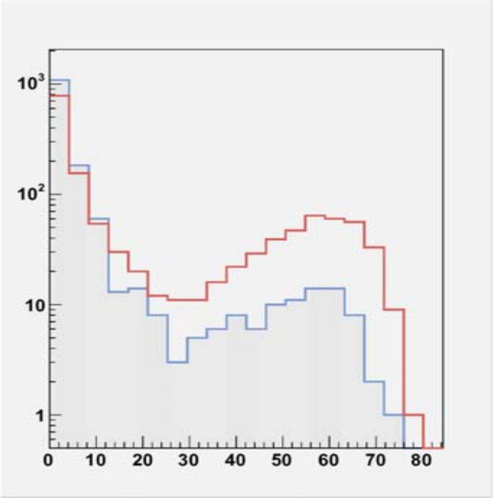
$$A = \mathrm{abs}\Big(\sum_{\text{region A}} \text{clusters} - \sum_{\text{region B}} \text{clusters} \Big)$$

B = the same with crystal's energies

observables using clusters

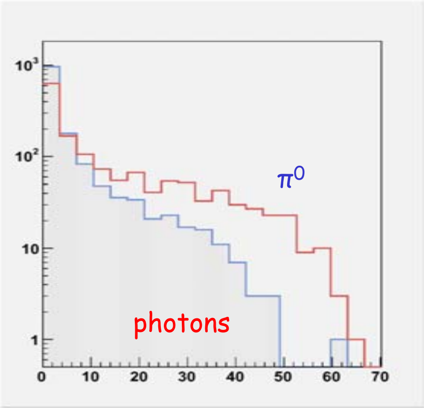


(A) type, but excluding clusters in a radius of 3 cm from both electron-positron.

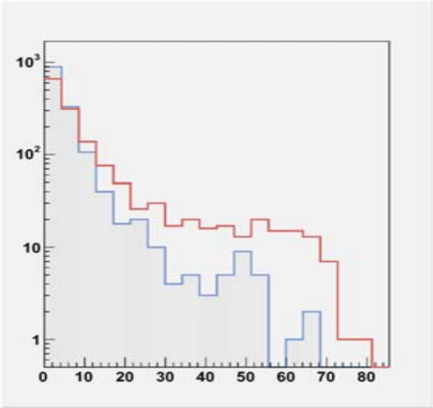


(A) type, but excluding clusters in a radius of 3cm from both electron-positron and closer than 1 cm from the line.

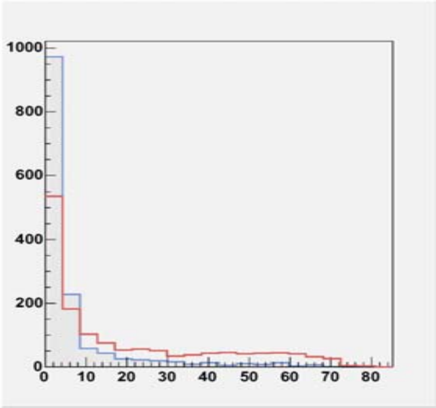
observables using crystal's energies



(B) type , but excluding hits in a radius of 3 cm from both electron, positron and photon.

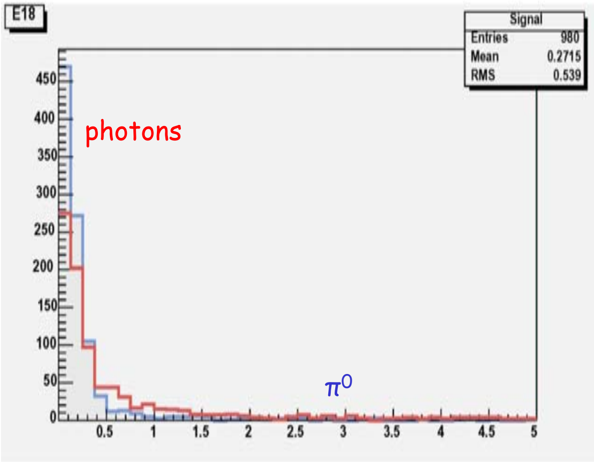


(B) type, but excluding hits in a radius of 3 cm from both electron,& positron and distance from photon < 3.

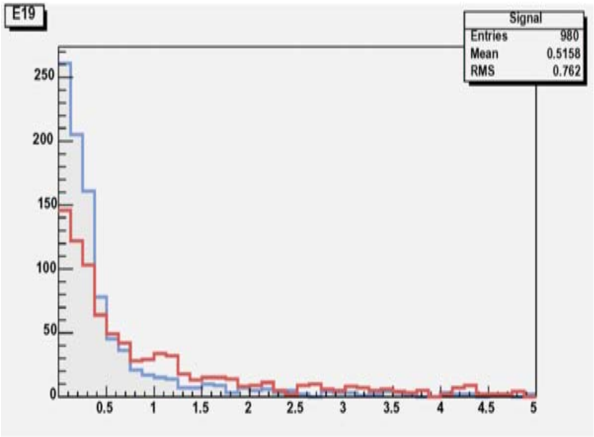


(B) type, but excluding hits in a radius of 3 cm from both electron & positron and distance from line<1.

Distance from line

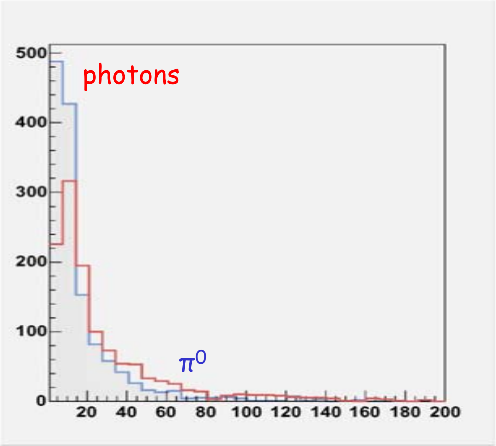


Distance of SuperCluster from the line

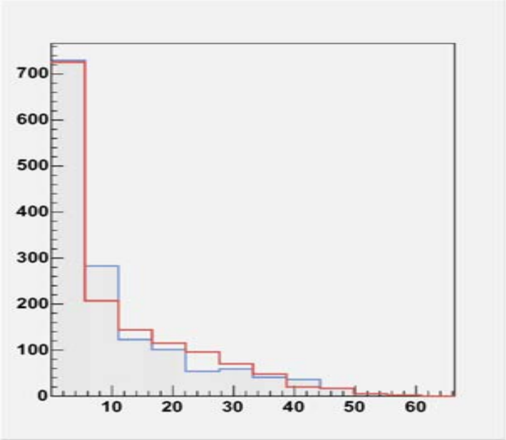


Distance of the cluster closest to the calculated photon position from the line

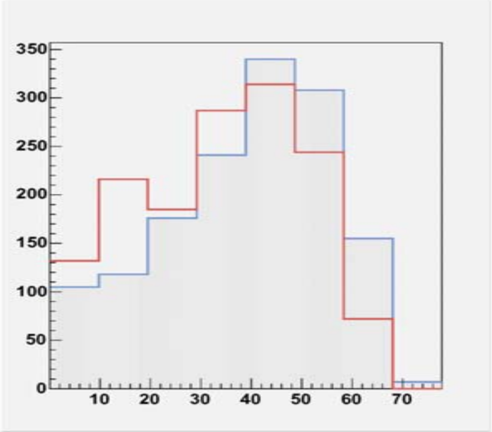
and some more …



Distance between electron-positron

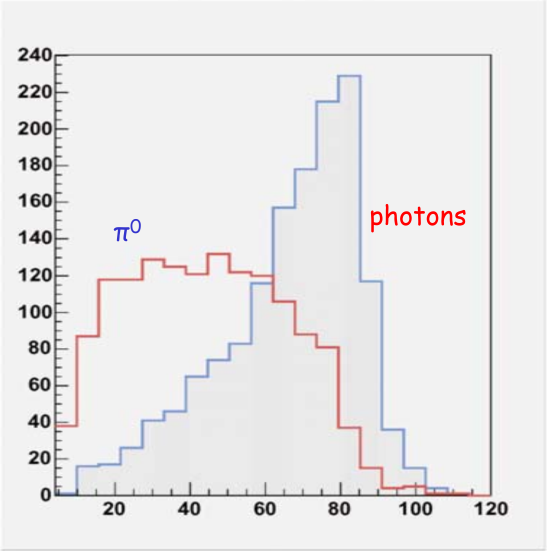


Energy of hit closest to calculated photon position.

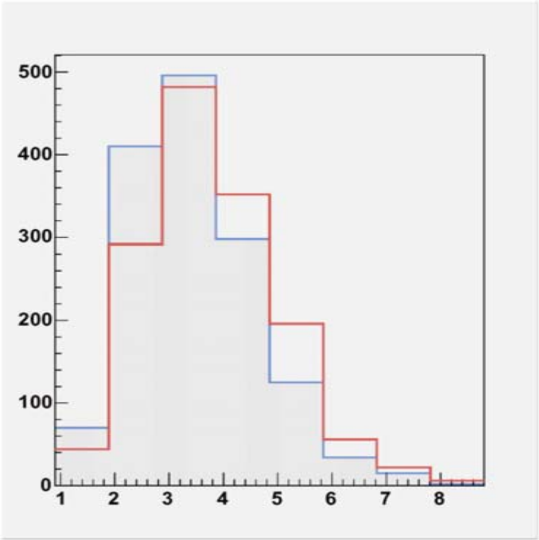


and the 3x3 crystal's energy content with the previous hit in the center

finally ..



Scalar sum of track momentum



Number of clusters

Conclusions

- Good conversion identification can be achieved using multivariable methods. Track reconstruction performed using kalman filter and starting from the calorimeter clusters.

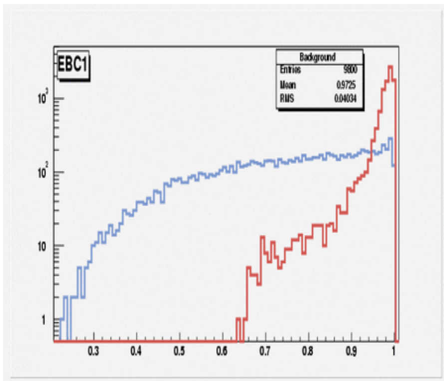
- In pions rejection: the method described attempts to find the physical objects of the converted π^0 in the SuperCluster by extrapolating the charged particles tracks and calculating possible photon position from the reconstructed vertex and momentum.

- Divides the Ecal surface into two regions by the line defined by the e^+e^-. A possible π^0 photon will cause an asymmetry in the energy distribution on these two regions. A 'natural' co-ordinate system for converted events is used.

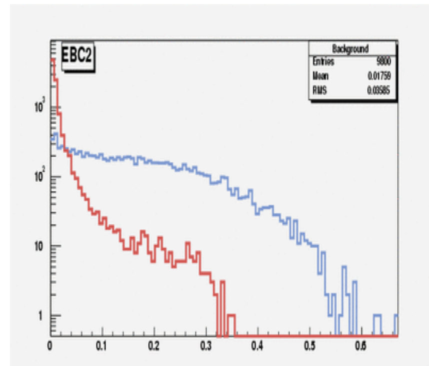
- A first combination of the new vars based on the geometric features of the events seems promising. Work currently with higgs events and QCD background .

Back-up slides

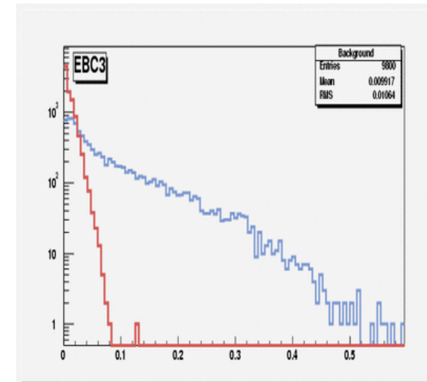
Conversion ID - Ecal vars



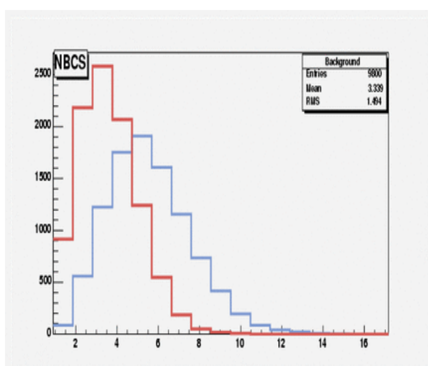
Fraction of 1st cluster



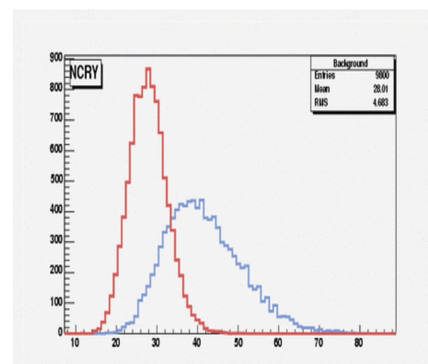
Fraction of 2nd cluster



Fraction of 3rd+ rest clusters

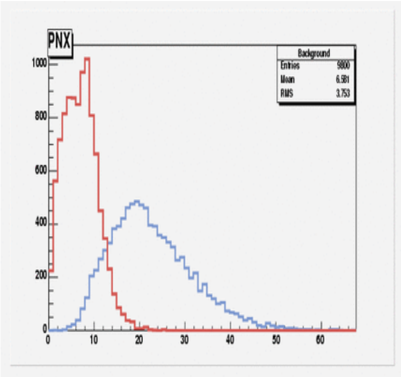


Num of clusters

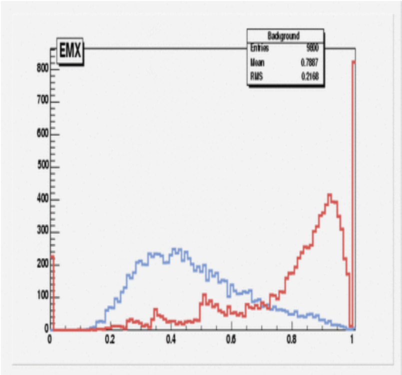


Num of crystals

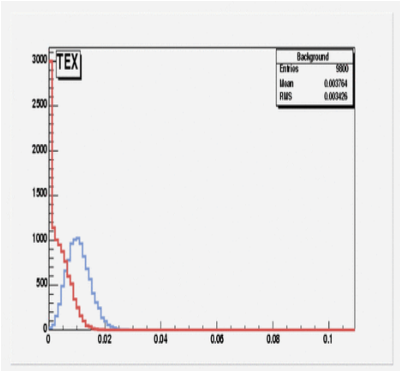
Conversion ID- Preshower vars



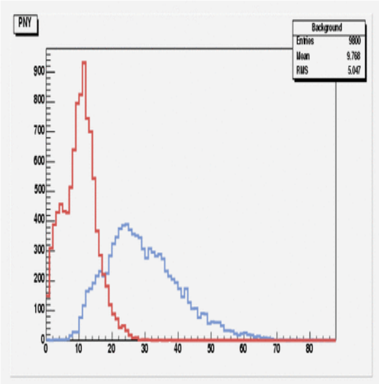
Num hits in X plane



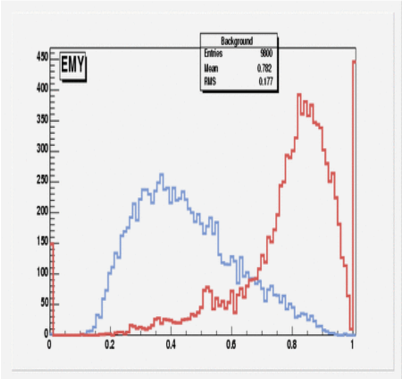
Energy of max cluster in X normalised to total X plane energy



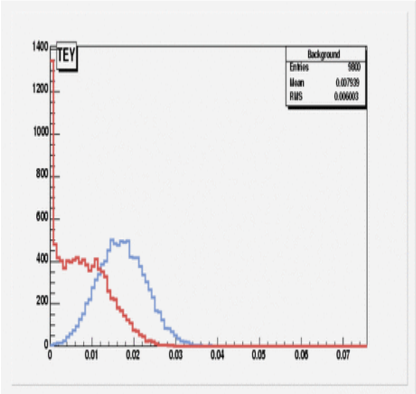
Total X plane energy



Num hits in Y plane



Energy of max cluster in Y normalised to total Y plane energy



Total Yplane energy

Reconstruction Of Tracks (II)

- a track state is created from the cluster taking into account the curvature of the magnetic field (corrected in phi).

- Look for hits in the silicon in an η, phi cone (0.1x0.2) around a cluster.

- a helix is fitted from the vertex, hit position and cluster position. The track state at the vertex of the helix is propagated (along momentum) / to the hit surface.

- From the propagated state and the hit an updated state is created.

- Kalman filter goes on this iterative process until layers with no hits are found.

- Using single photon/π^0 events with Et=30 GeV, η=1.7. Study events with 2 reconstructed tracks. These are ~half the converted events in this η. They contain a lot of the complexity and geometrical features – a good starting point.