

Comparison of Cut-based and Artificial Neural Network Selection of Signal

$B \rightarrow K\gamma\gamma$ Events

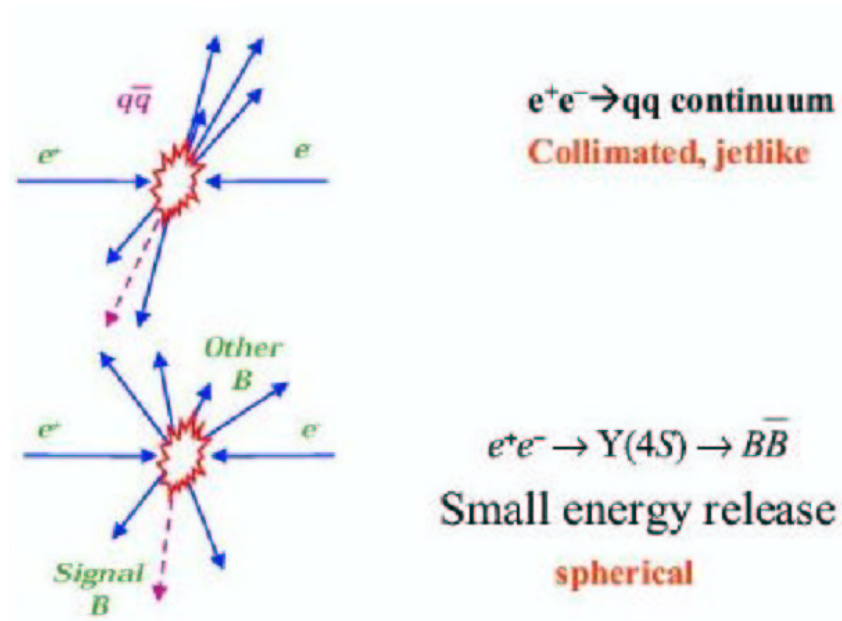
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January 6, 2004

- Electrons (e^-) collided with positrons (e^+) at the ' $\Upsilon(4S)$ resonance'
 - Approximately 98% of e^+e^- collisions result in 'continuum background'
 $e^+e^- \rightarrow q\bar{q}; q = u, d, s, c$ quarks
 - Approximately $10^{-7}\%$ of e^+e^- collisions result in 'signal' decays
 $e^+e^- \rightarrow \Upsilon(4S) \rightarrow B \rightarrow K\gamma\gamma$

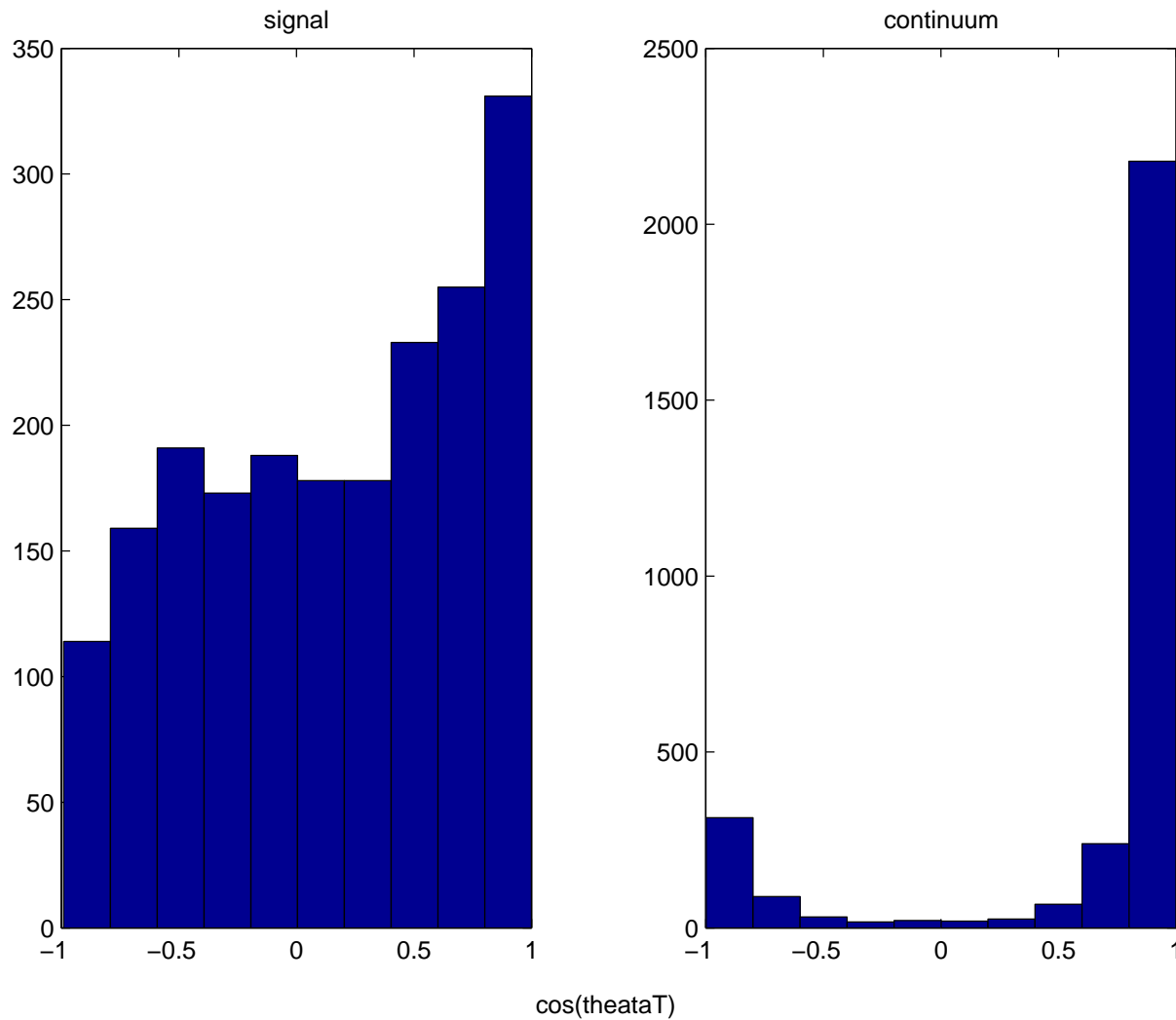
- Shape variables

- Shapes of continuum and signal events are dramatically different



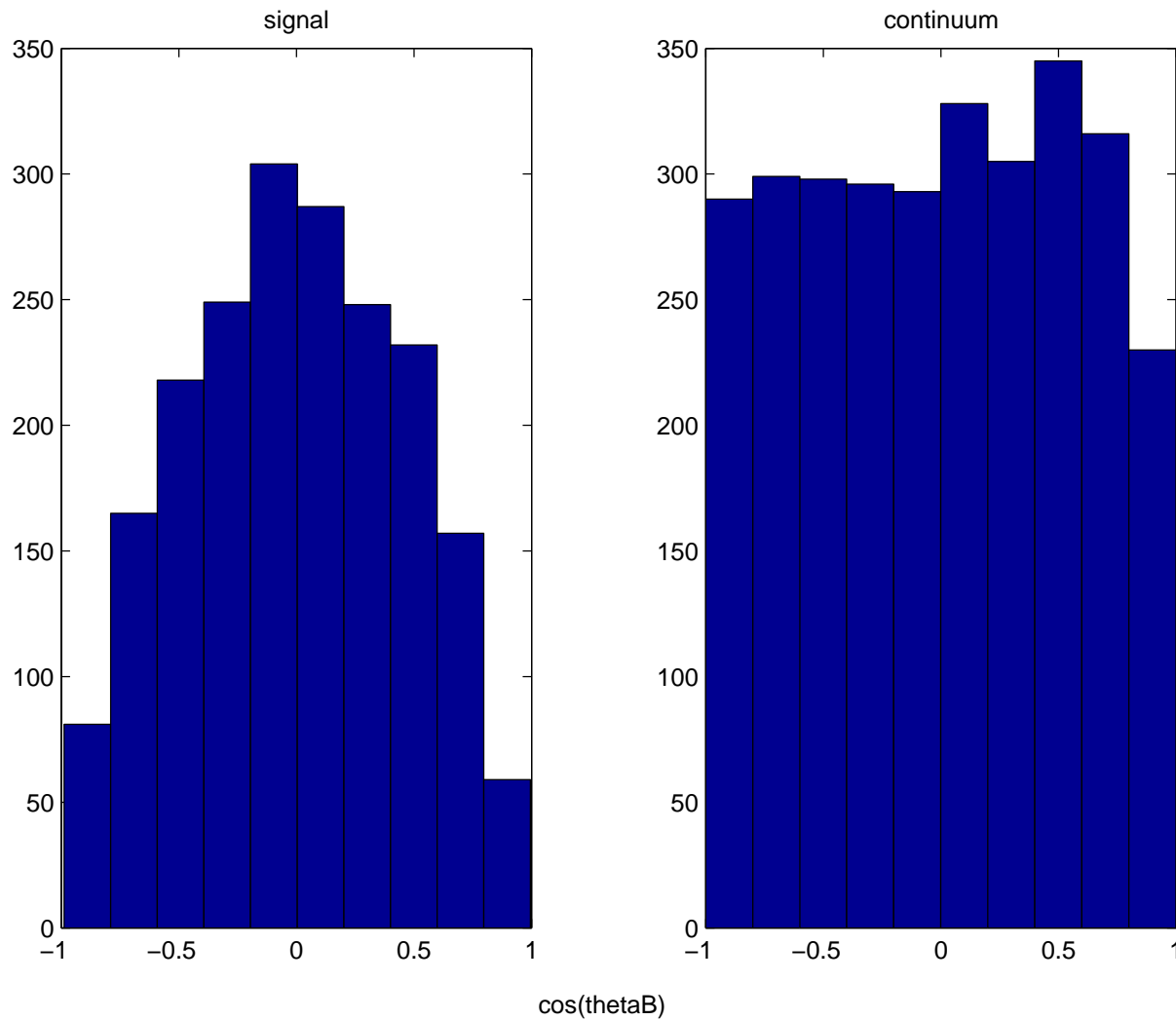
- Can eliminate events based on differences in distributions of shape variables for the two different types of events

$$\cos(\theta_T)$$



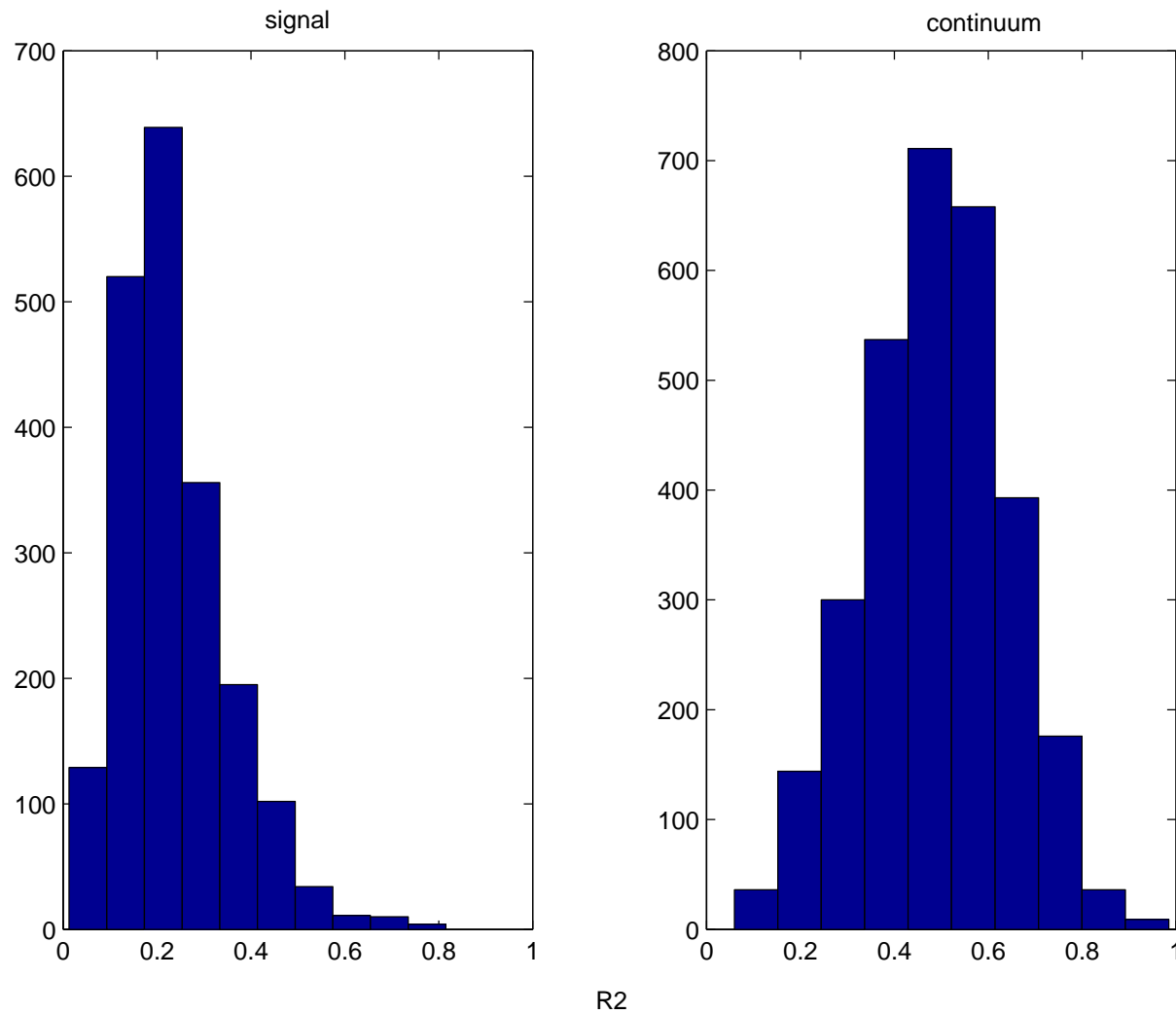
Eliminate events such that $|\cos(\theta_T)| > 0.8$ for cut based analysis.

$$\cos(\theta_B)$$



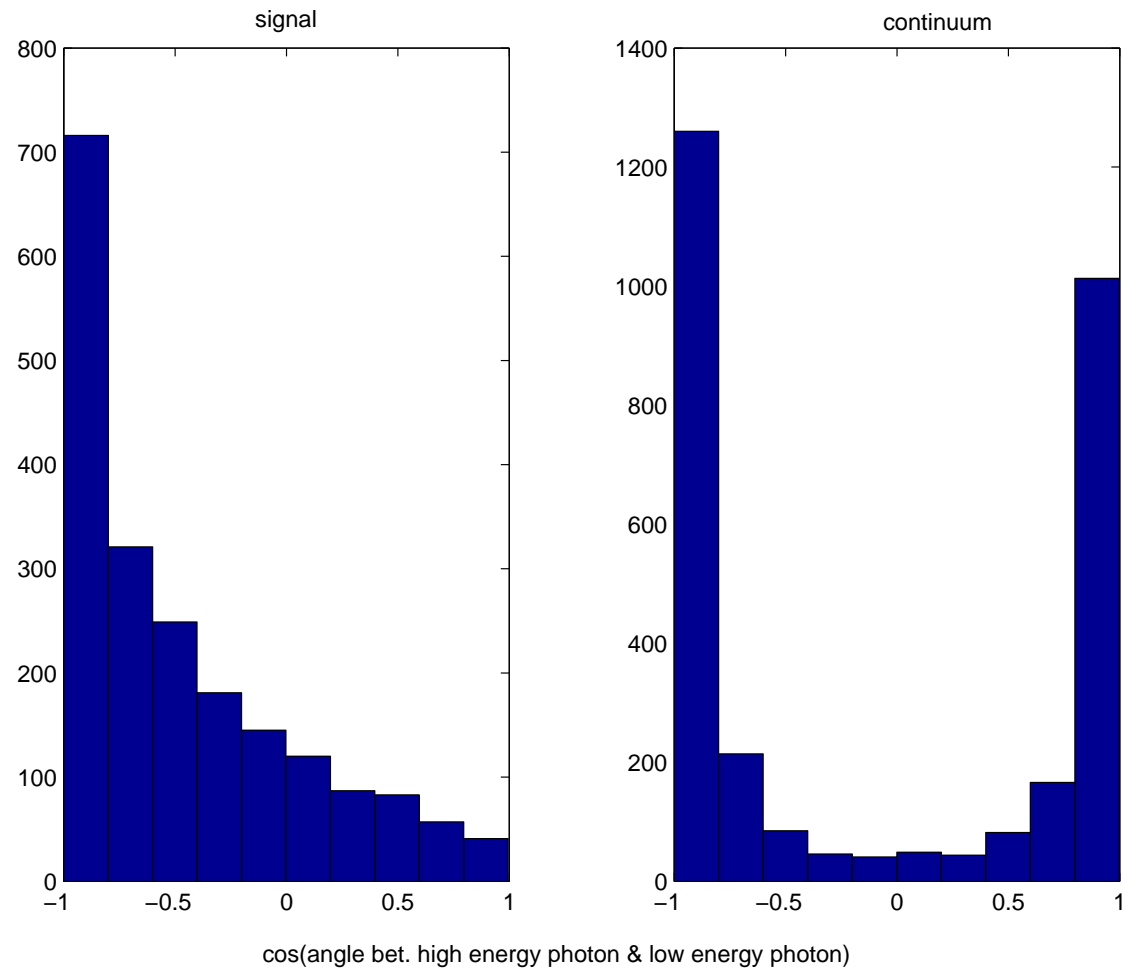
Eliminate events such that $|\cos(\theta_B)| > 0.75$ for cut based analysis.

R_2



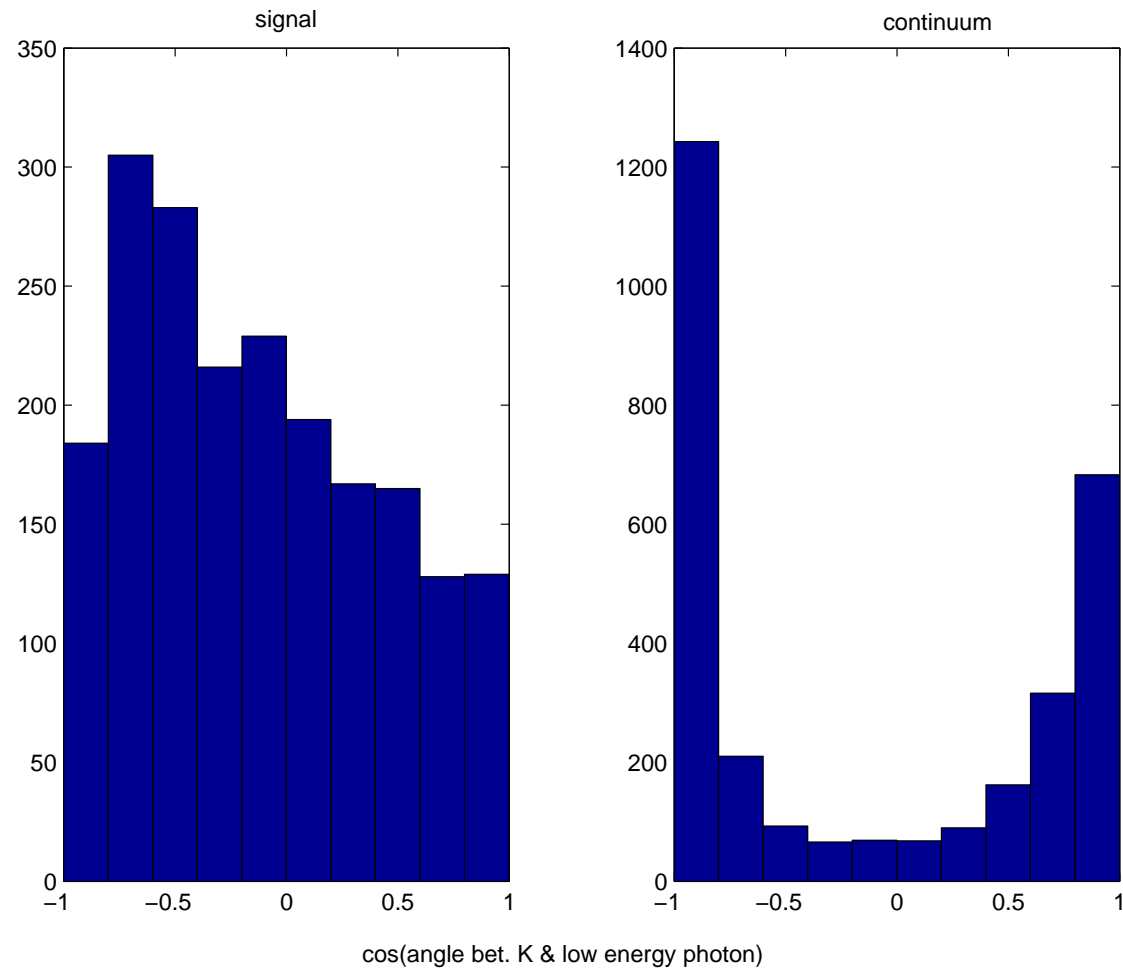
Eliminate events such that $R_2 > 0.6$ for cut based analysis.

$$\cos(\theta_{\gamma_{LOW}, \gamma_{HIGH}})$$



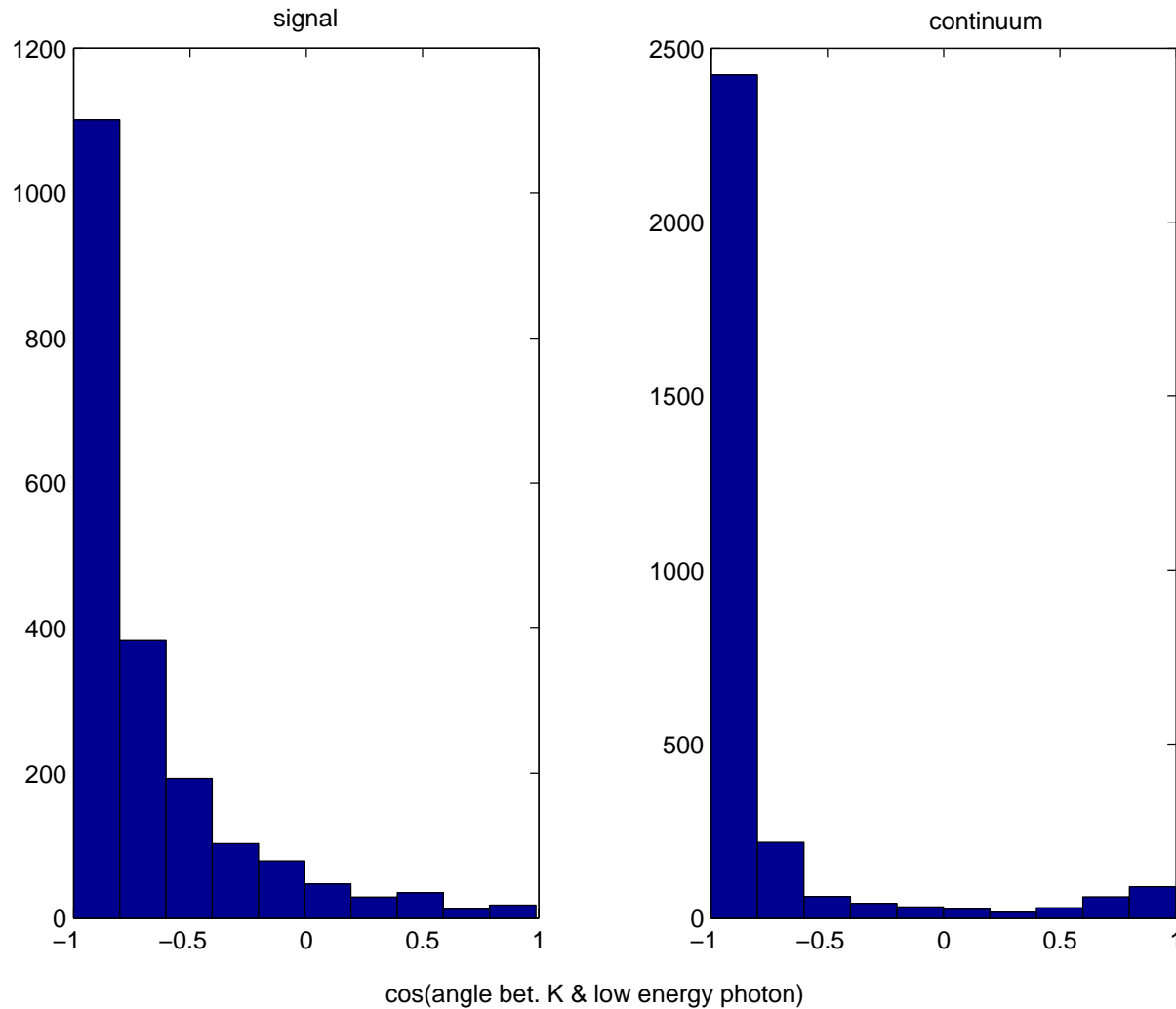
Eliminate events such that $\cos(\theta_{\gamma_{LOW}, \gamma_{HIGH}}) > 0.6$ for cut based analysis.

$$\cos(\theta_{K,\gamma_{LOW}})$$



Eliminate events such that $|\cos(\theta_{K,\gamma_{LOW}})| > 0.8$ for cut based analysis.

$$\cos(\theta_{K,\gamma_{HIGH}})$$



Eliminate events such that $|\cos(\theta_{K,\gamma_{HIGH}})| > 0.8$ for cut based analysis.

Cut-based results

Cut	Training Set		Testing Set	
	Signal	Background	Signal	Background
Before cuts	2000	3000	400	400
Total Yield	1146	153	226	21

- Goal: Reduce background yield leaving the signal yield unchanged using a single cut based on the ANN output.

ANN Configuration

- Used a back propagating multi-layer perceptron type NN with
 - $\alpha = 0.1$
 - $\mu = 0.8$
 - One hidden layer with 11 neurons
 - Maximum number of epochs = 10,000
 - Epoch size = 100
- Feature vectors normalized:
 - Mean of feature vector subtracted from all values of feature vector
 - Values of feature vector scaled from -1 to 1

ANN-based results: Training

Run	Cut value	Signal yield	Background yield
1	0.985	1146	55
2	0.943	1146	48
3	0.932	1147	61
4	0.976	1149	55
5	0.969	1146	61
6	0.967	1161	67
7	0.975	1147	69
8	0.948	1159	68
9	0.946	1148	66
10	0.98	1166	58
Average	0.962		

- The signal yield is the value closest to the signal yield that was achieved via cuts on the shape variables (1146).
- The cut on the NN output was varied from 0.9 to 1 in intervals of 0.001.
- Since signal events are classified as 1 and continuum background events are classified as 0, the signal yield is composed of all events for which $neural_net_output > cut$ is true.
- Conversely, the background yield is composed of all events for which $neural_net_output \leq cut$ is true.

ANN-based results: Testing

Applying the NN cut that was the average of the cuts (cut = 0.962) that gave us a signal yield of approximately 1146 on the training data:

Run	Signal yield	Background yield
1	270	17
2	186	11
3	244	15
4	180	6
5	224	11
6	262	14
7	264	20
8	294	21
9	136	7
10	200	11
Average	226	13

Discussion of Results

Comparison of results on testing data:

	Signal Yield	Background yield
Cut-based	226	21
NN-based (Ave. vals.)	226	13

- Signal yield has remained unchanged
- Background yield has been decreased by 62%
- ANN based method of eliminating background events more effective than cuts on shape variables.