Pi zero analysis using likelihood event selection and BIER subtraction.

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Likelihood event selection

- How should we pick an events?
    - Let everything in and subtract later?
    - Choose events based upon some criteria?
- One method is to calculate likelihood.
    - Likelihood -- probability function at a certain point.
        - Prob(X @ x_o)
        - Always < 1 (if distribution is normalized)
    - Likelihoods can by multiplied.
        - By using many well defined parameters, one should be able to choose events with some confidence.
        - Prob(X @ x_o)*Prob(Y @ y_o)*Prob(A @ a_o)*....

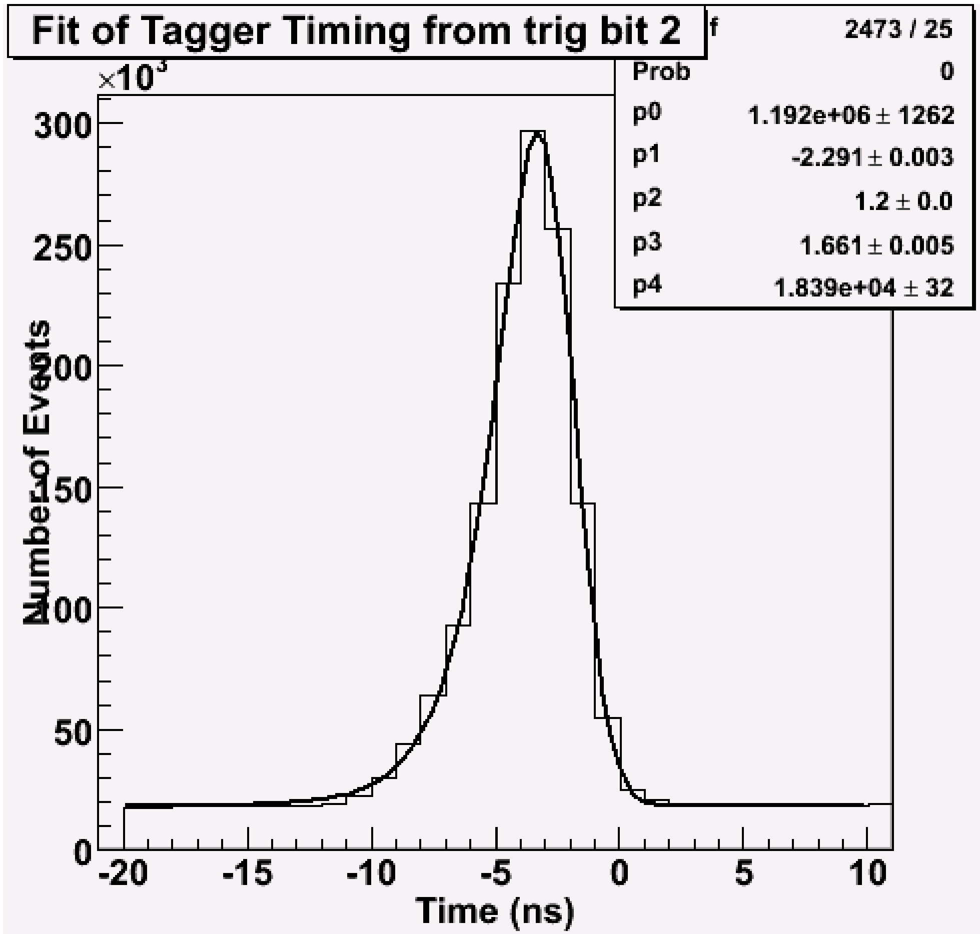
Why use a likelihood selection?

- It's not new. CLAS has done it-- e.g. note 03-017
- A way to eliminate combinatorial background
- Timing cut eliminated
  - OOT and IT events go to background
    - BIER method subtraction still required.
- Selects "Best" entry in a given event.
  - Also a weakness. Checks need to be made to minimize and understand "good" entry rejection.
    - No method is perfect, though.

What is likelihood of an entry?

- Define and characterize a number of parameters to determine likelihood of an entry.
  - Tagger/HyCal timing.
    - Using Trigger bit 2.
  - Pi0 invariant mass as a function of cluster pair type.
    - Tung-tung, glass-glass, Tung-Glass, and Glass-Tung
      - First of cluster pair has higher energy cluster for these pair types.
  - Elasticity as a function of cluster pair type.
    - Mass, Elasticity, and timing distributions are not regular gaussians.

Extracting the functional form for event timing



The skewed gaussian

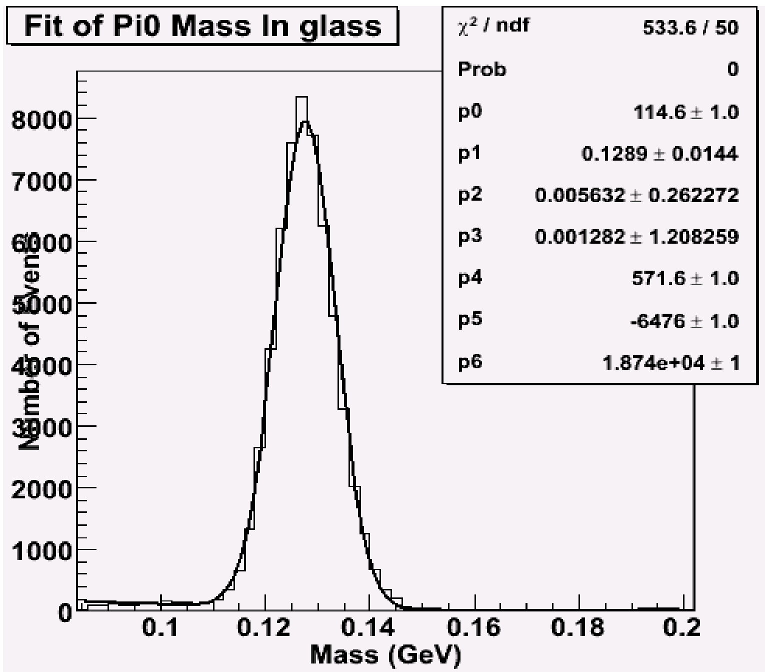
$$G(x) = \int_0^\infty \left(\frac{1}{a} e^{-y/a}\right) \frac{1}{\sigma\sqrt{2\pi}} e^{-(y-x^2)/2\sigma^2}\, dy$$

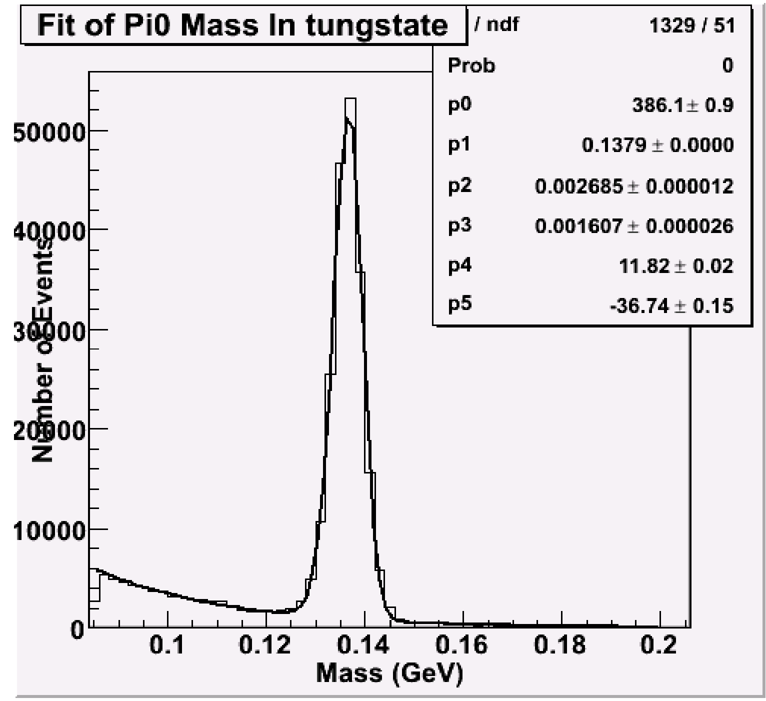
$$G(x) = \frac{1}{a} e^{\sigma^2/2a^2} e^{-x/a} \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\sigma^2}{\sigma\sqrt{2}}\right)\right]$$

Timing window = ±20 ns

Parameters 0,1,2, & 3 are the magnitude, centroid, width, and skewness of a skew gaussian. Parameters 4 belongs to the flat background.

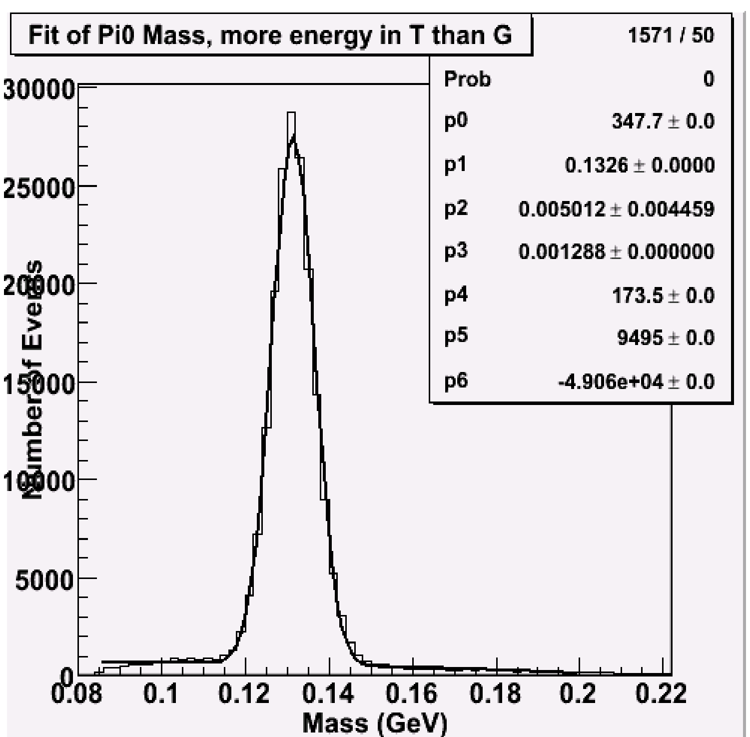
Extracting the functional forms for Pi0 Mass.

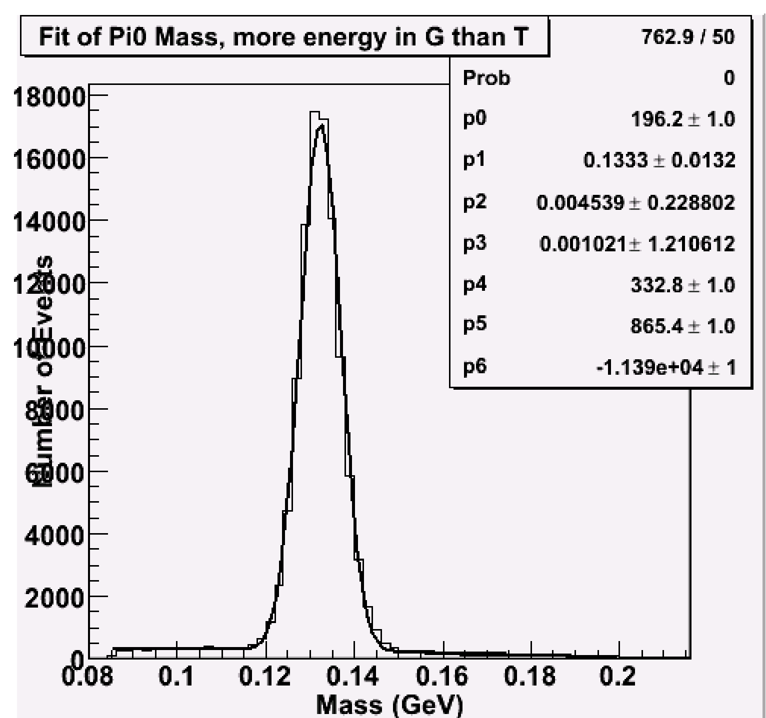




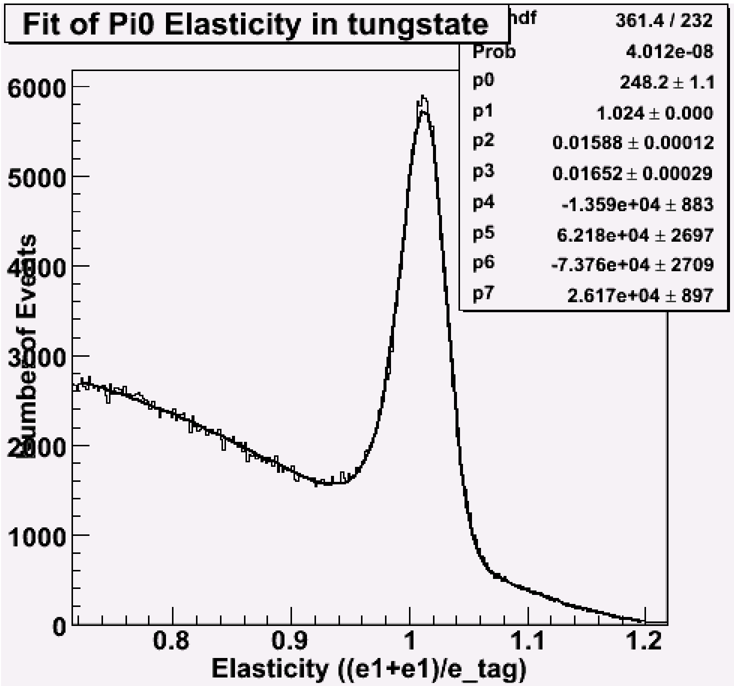
Timing window = ±20 ns

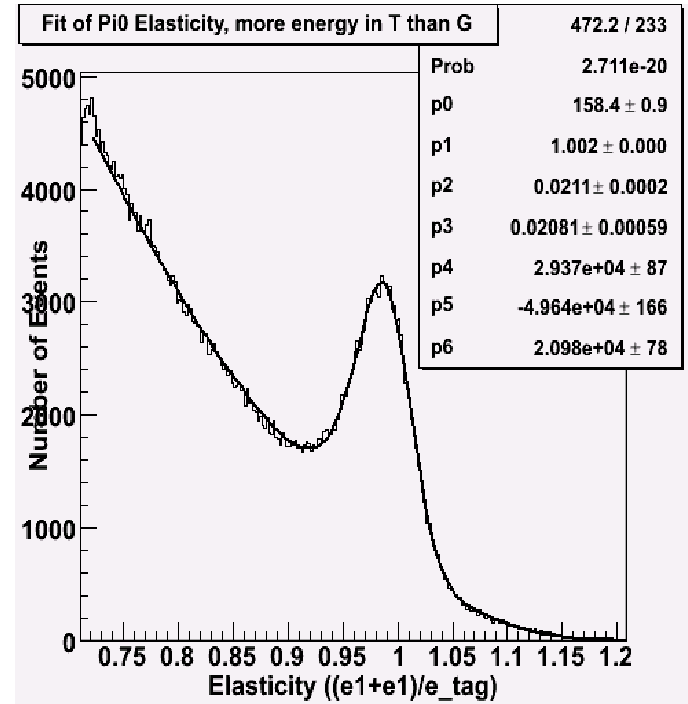
Parameters 0,1,2, & 3 are the magnitude, centroid, width, and skewness of a skew gaussian. Parameters 4 & 5 are exponential (tungstate) background and 4,5, & 6 belong to the polynomial (glass) background..



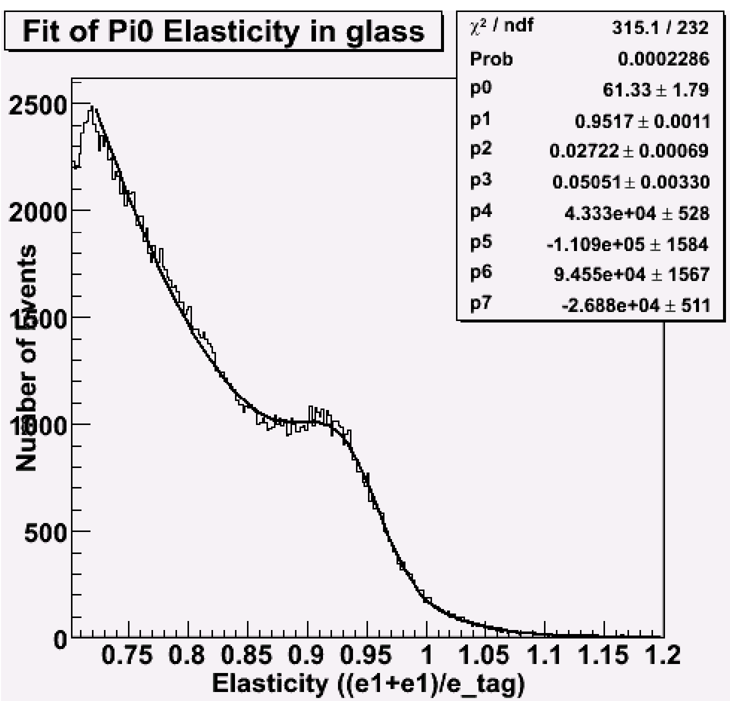


Extracting the functional forms for Pi0 Elasticity.

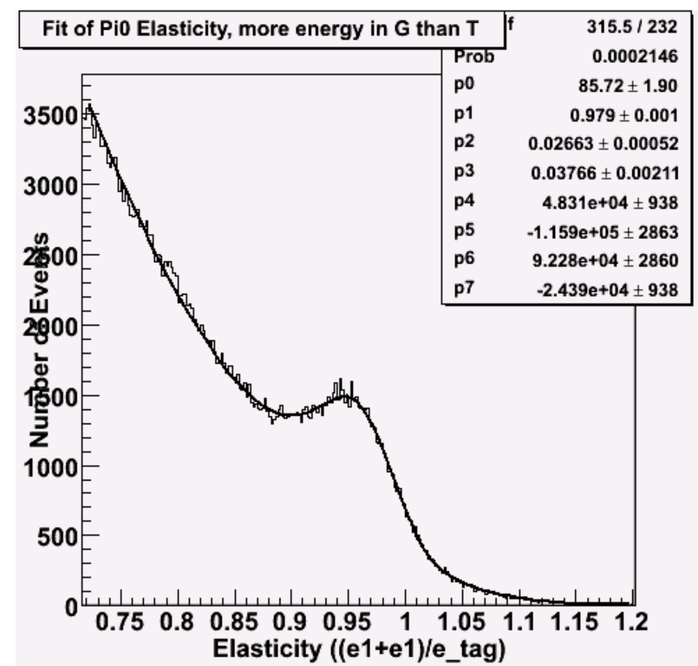




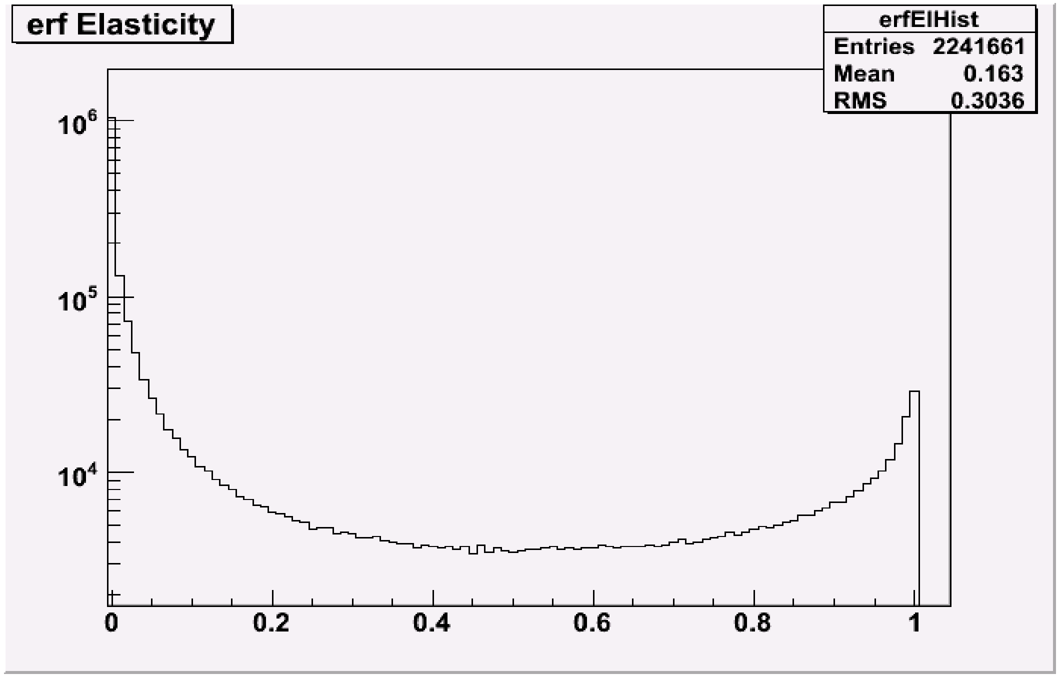
Timing window = ±20 ns

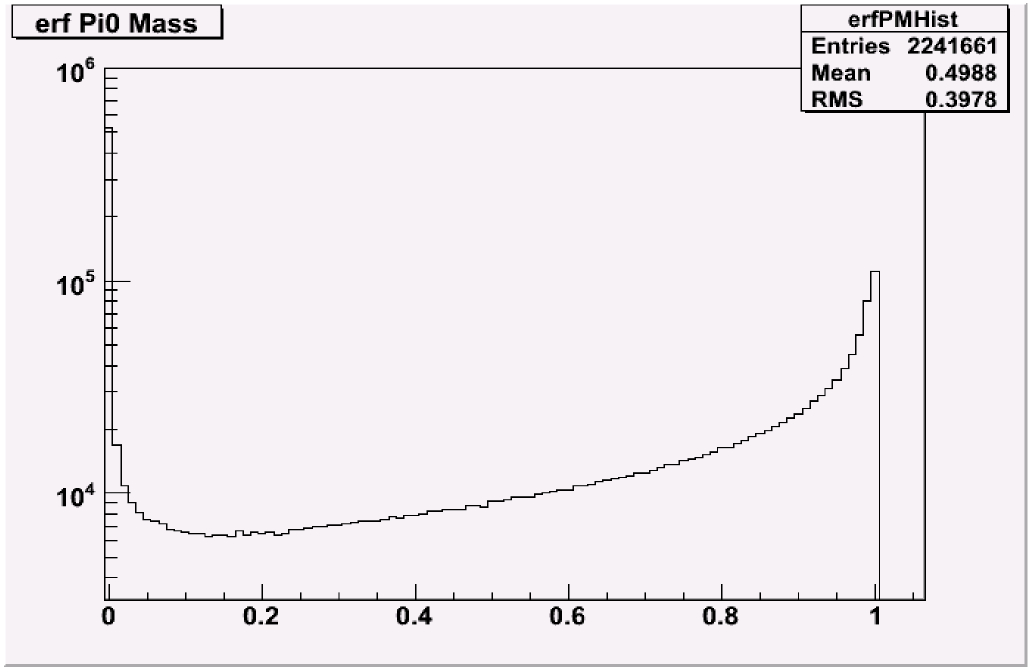


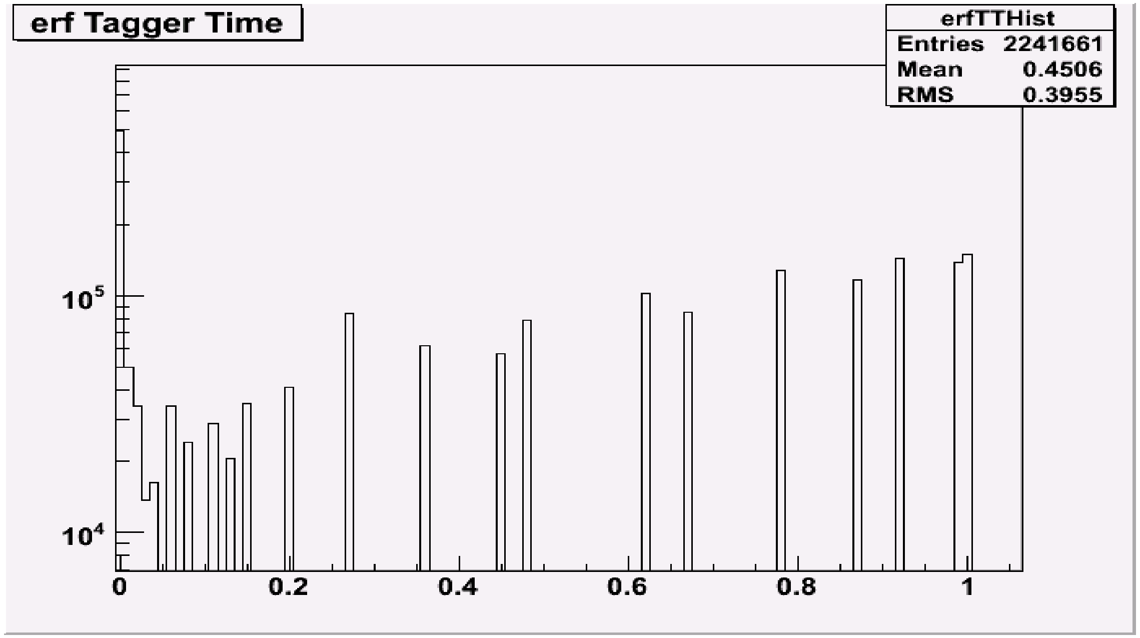
Parameters 0,1,2, & 3 are the magnitude, centroid, width, and skewness of a skew gaussian. Parameters 4, 5, 6, & 7 belong to the polynomial background.



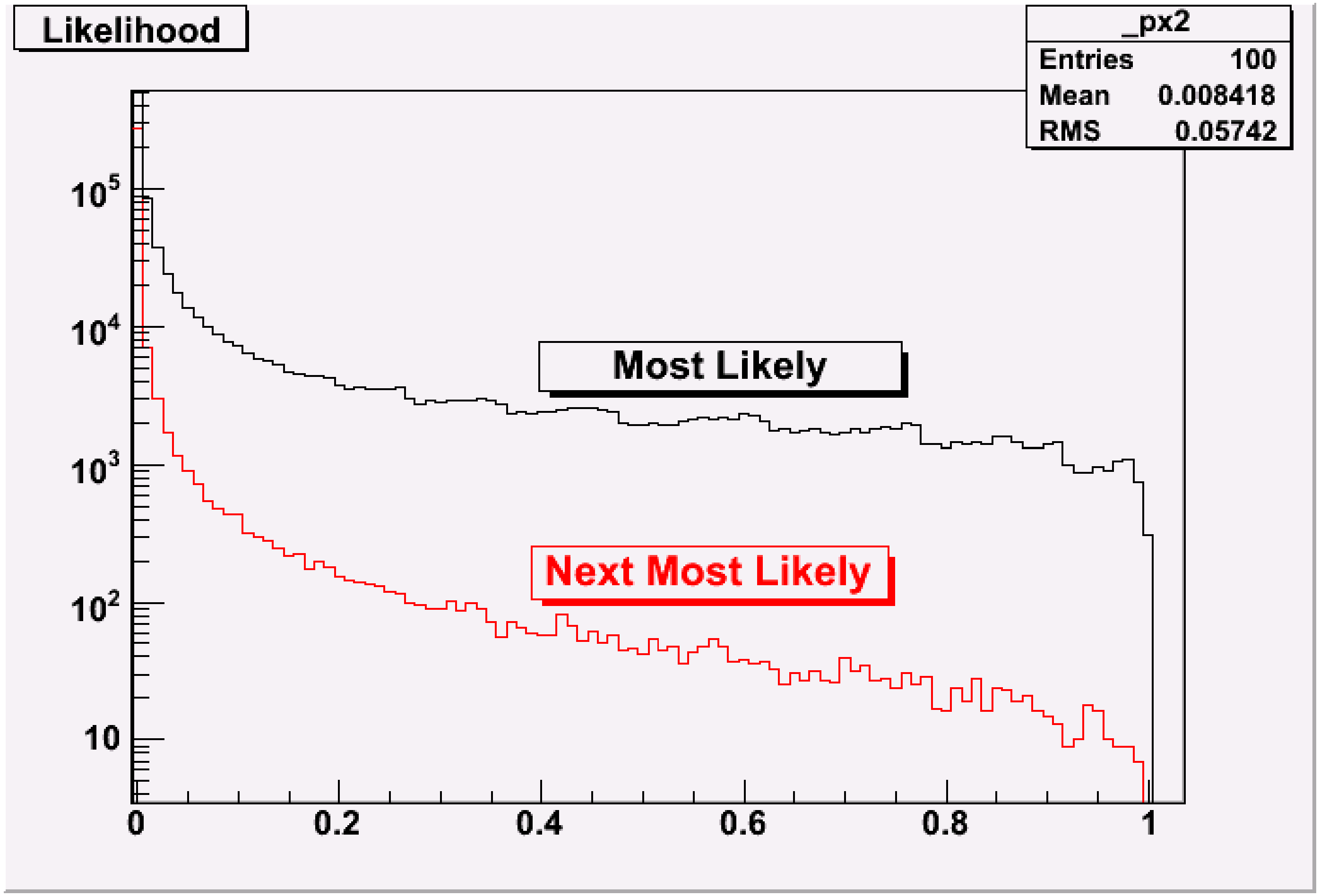
Likelihoods...



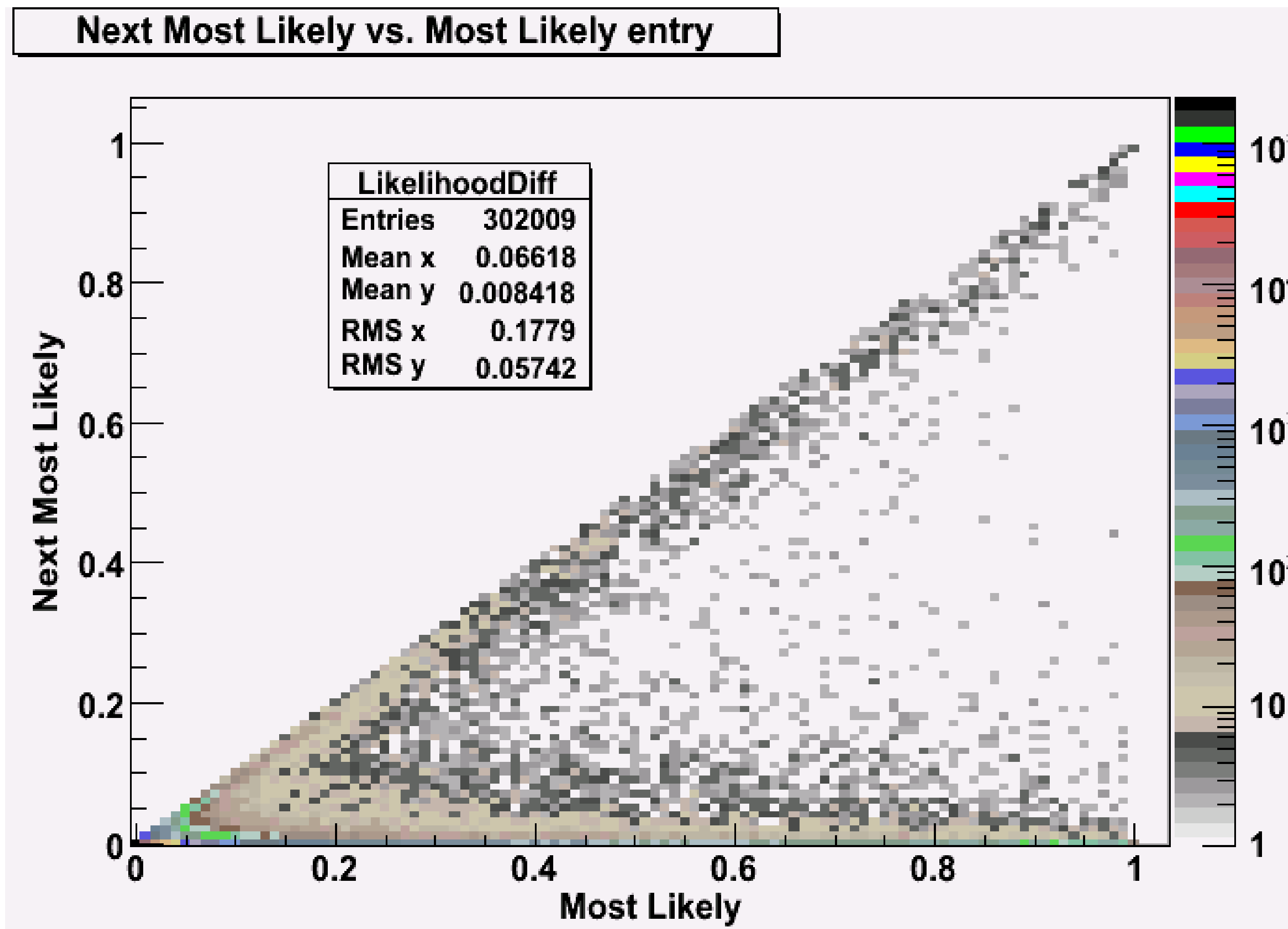




Final likelihood distribution

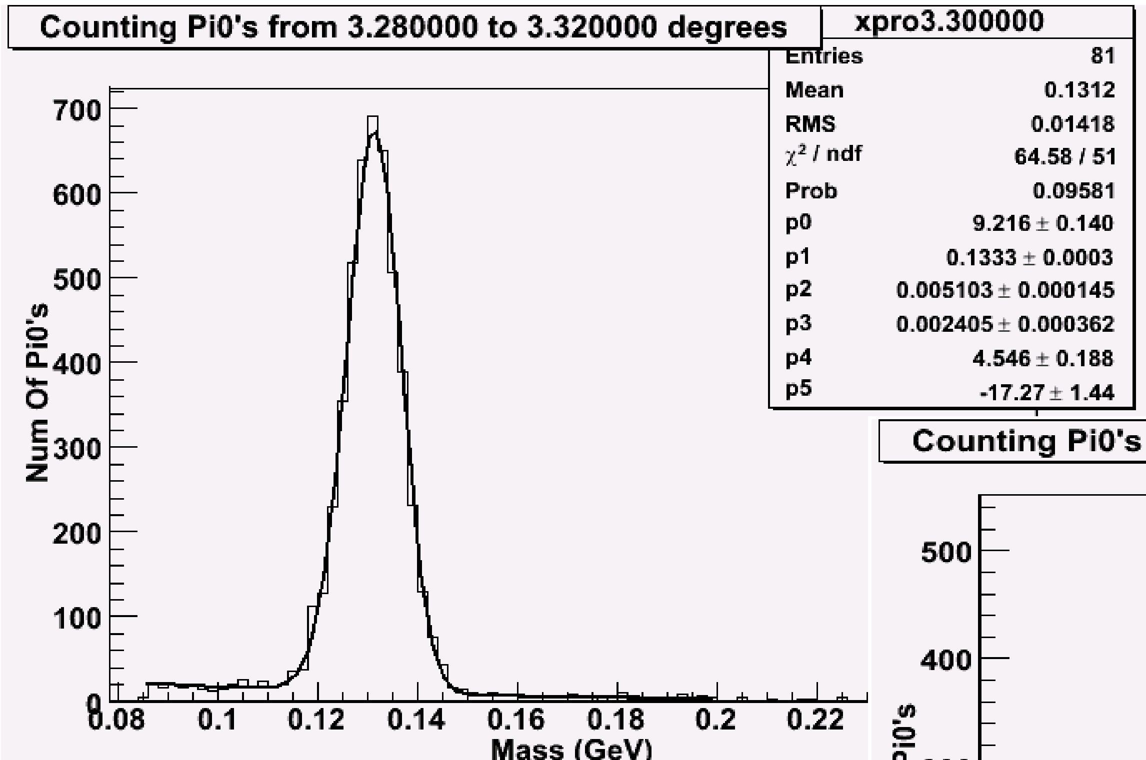


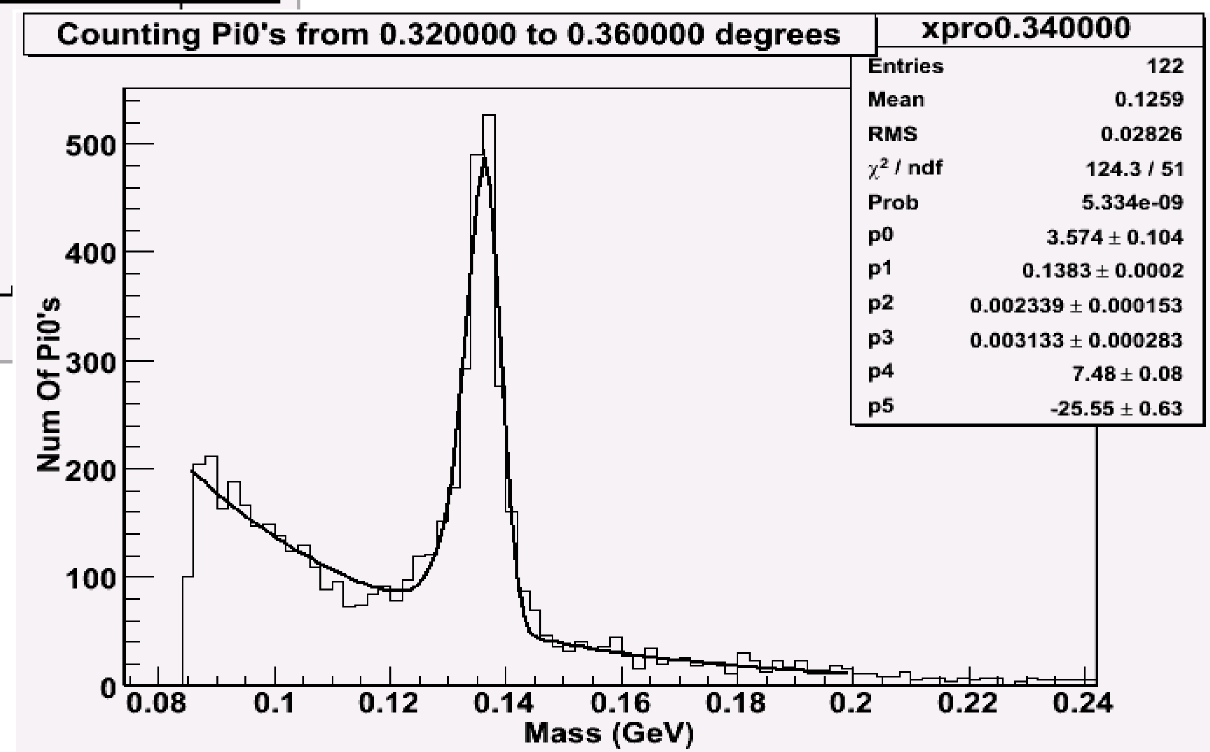
How good is our entry selection?



We have our events. Now what to do?

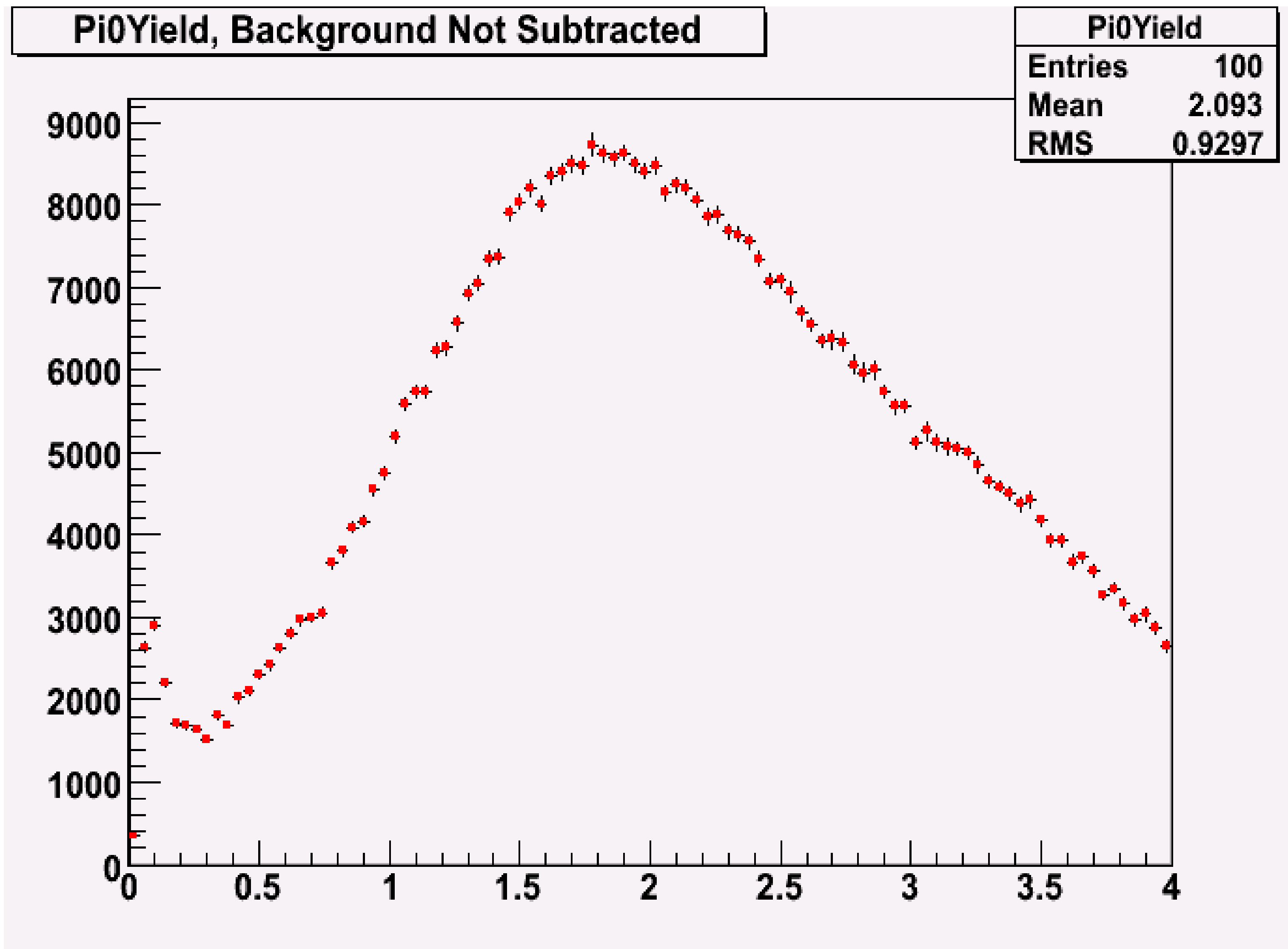
Mass fits----count Pi0's...





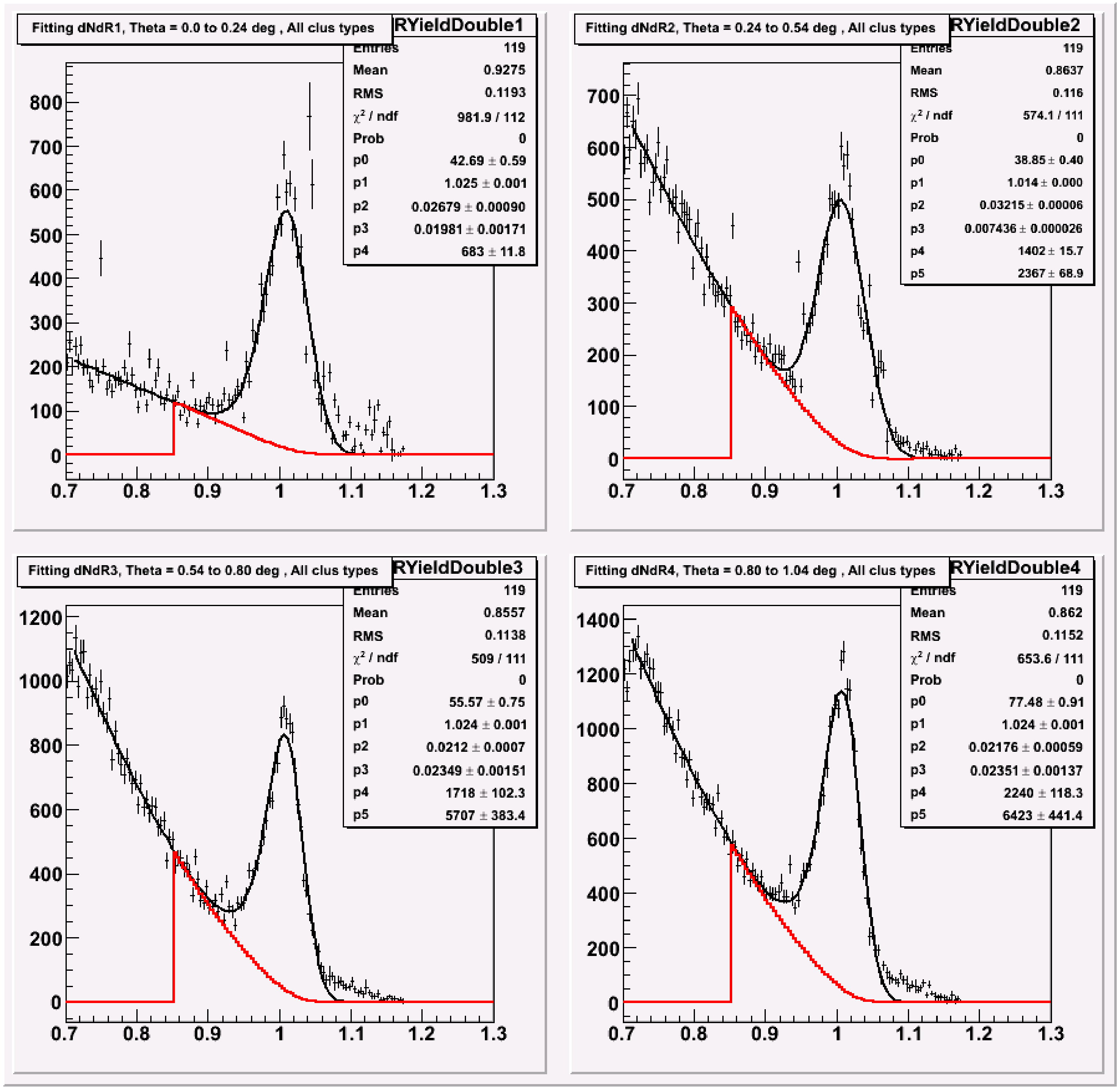
Sample mass fit. Parameters 0,1,2, & 3 are the magnitude, centroid, width, and skewness of a skew gaussian. Parameters 4 & 5 belong to the exponential background.

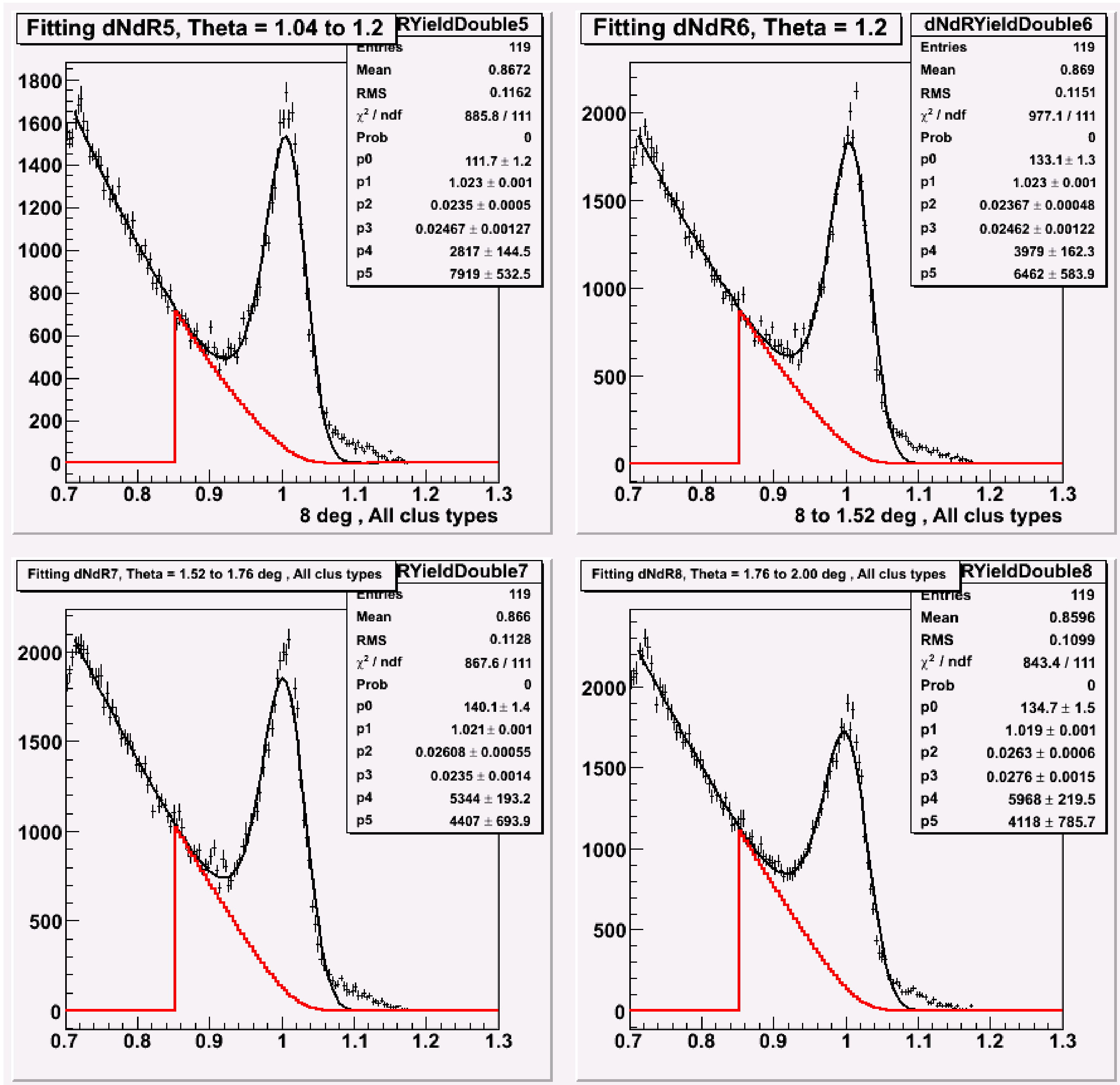
If one can make Invariant Mass fits, one can make yields.



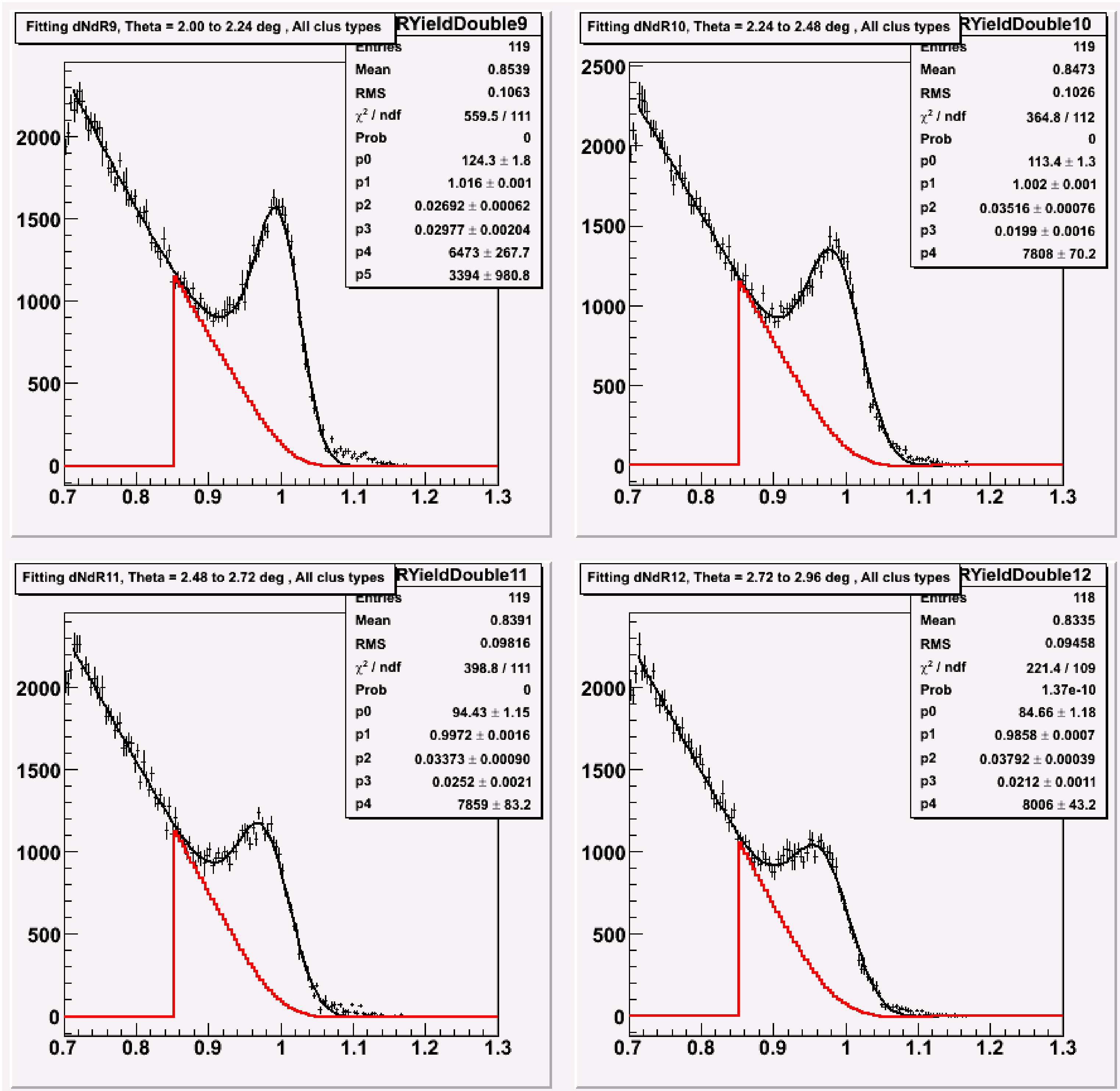
The Background in the Elastic Region (BEIR)

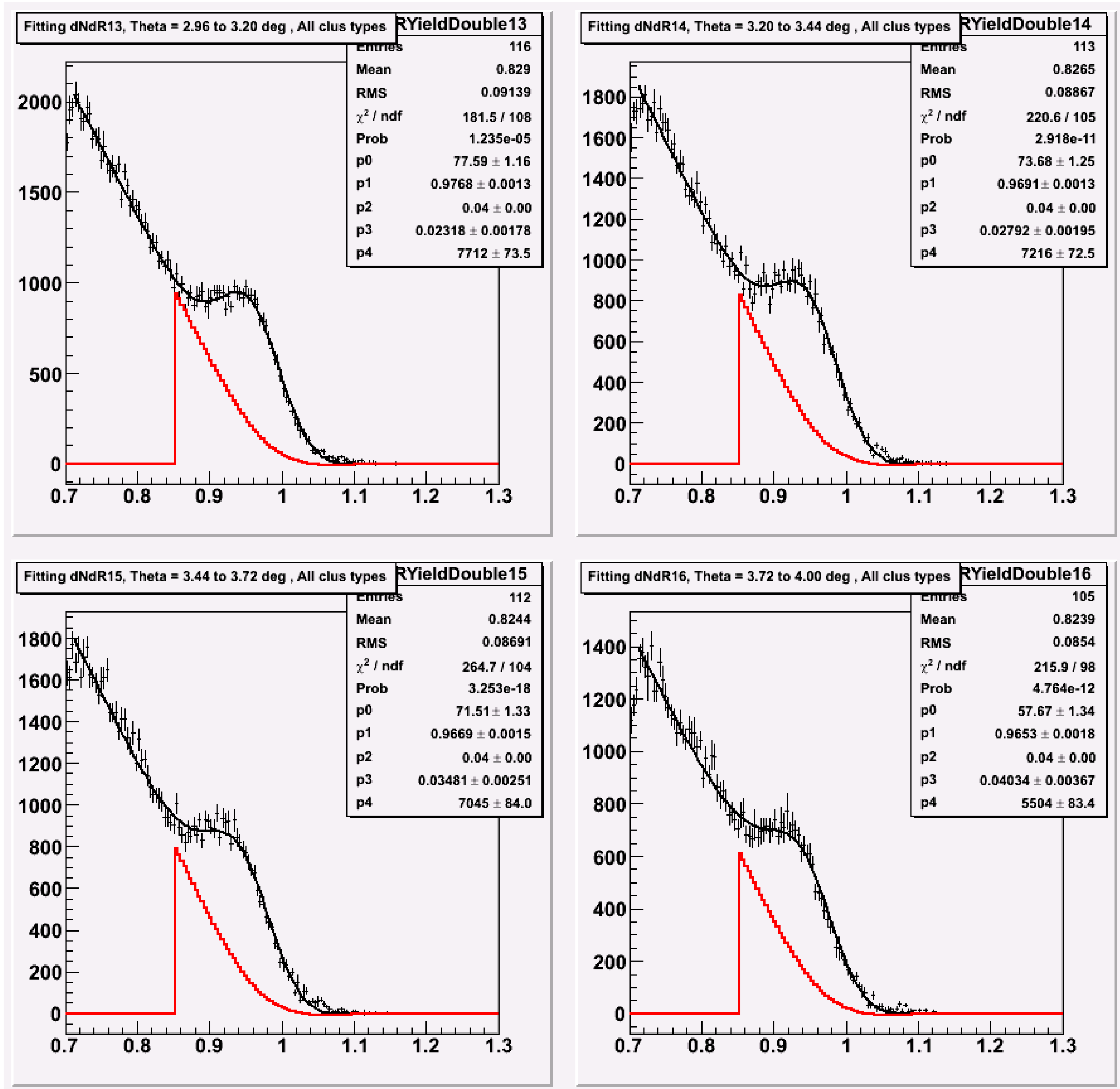
Lower elasticity limit is now 0.85—modest change from 0.88





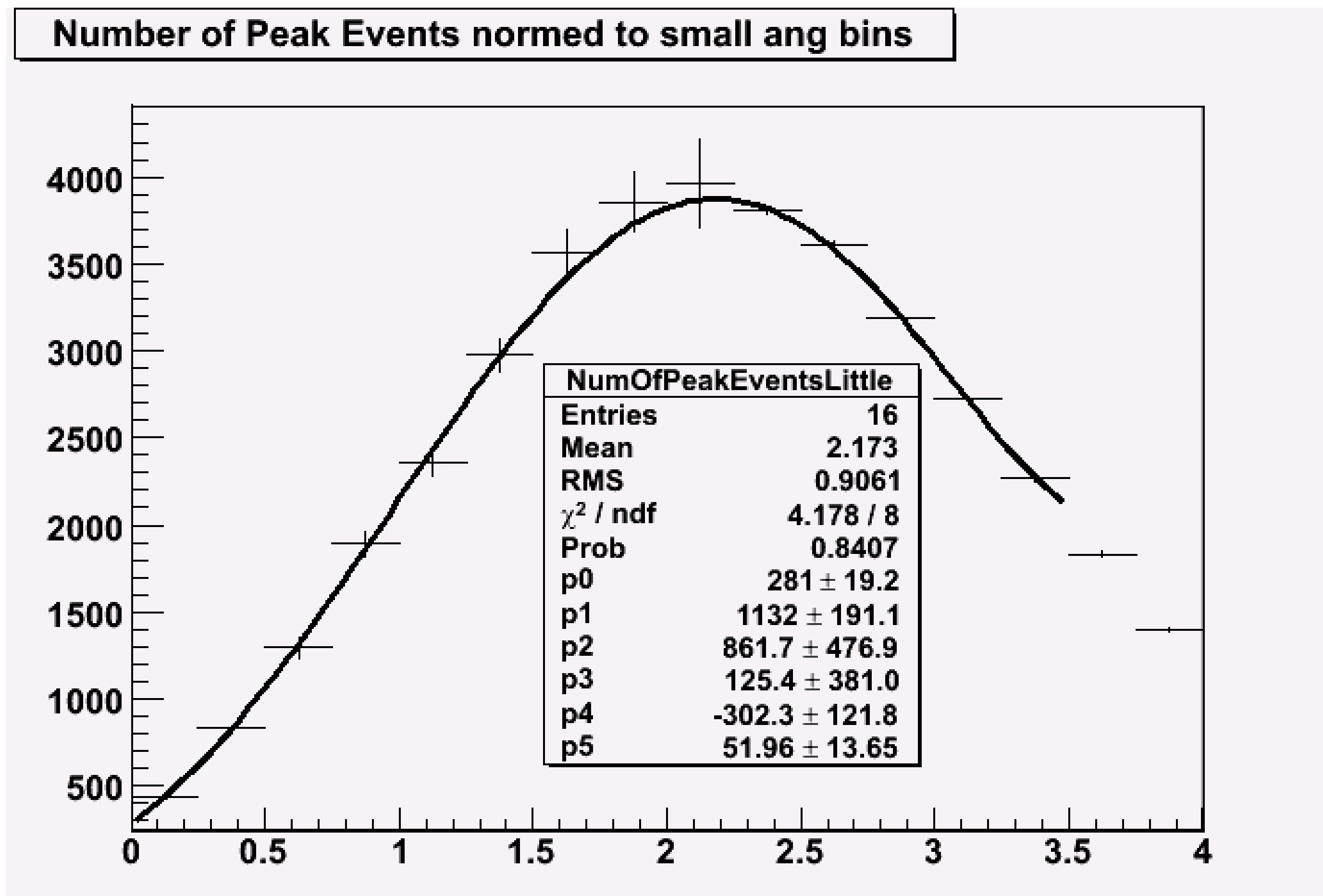
Time to use simple polynomials to pick up super elastic background?


Fitting dNdR9, Theta = 2.00 to 2.24 deg , All clus types
RYieldDouble9
Entries 119
Mean 0.8539
RMS 0.1063
χ² / ndf 559.5 / 111
Prob 0
p0 124.3 ± 1.8
p1 1.016 ± 0.001
p2 0.02692 ± 0.00062
p3 0.02977 ± 0.00204
p4 6473 ± 267.7
p5 3394 ± 980.8
Fitting dNdR10, Theta = 2.24 to 2.48 deg , All clus types
RYieldDouble10
Entries 119
Mean 0.8473
RMS 0.1026
χ² / ndf 364.8 / 112
Prob 0
p0 113.4 ± 1.3
p1 1.002 ± 0.001
p2 0.03516 ± 0.00076
p3 0.0199 ± 0.0016
p4 7808 ± 70.2
Fitting dNdR11, Theta = 2.48 to 2.72 deg , All clus types
RYieldDouble11
Entries 119
Mean 0.8391
RMS 0.09816
χ² / ndf 398.8 / 111
Prob 0
p0 94.43 ± 1.15
p1 0.9972 ± 0.0016
p2 0.03373 ± 0.00090
p3 0.0252 ± 0.0021
p4 7859 ± 83.2
Fitting dNdR12, Theta = 2.72 to 2.96 deg , All clus types
RYieldDouble12
Entries 118
Mean 0.8335
RMS 0.09458
χ² / ndf 221.4 / 109
Prob 1.37e-10
p0 84.66 ± 1.18
p1 0.9858 ± 0.0007
p2 0.03792 ± 0.00039
p3 0.0212 ± 0.0011
p4 8006 ± 43.2

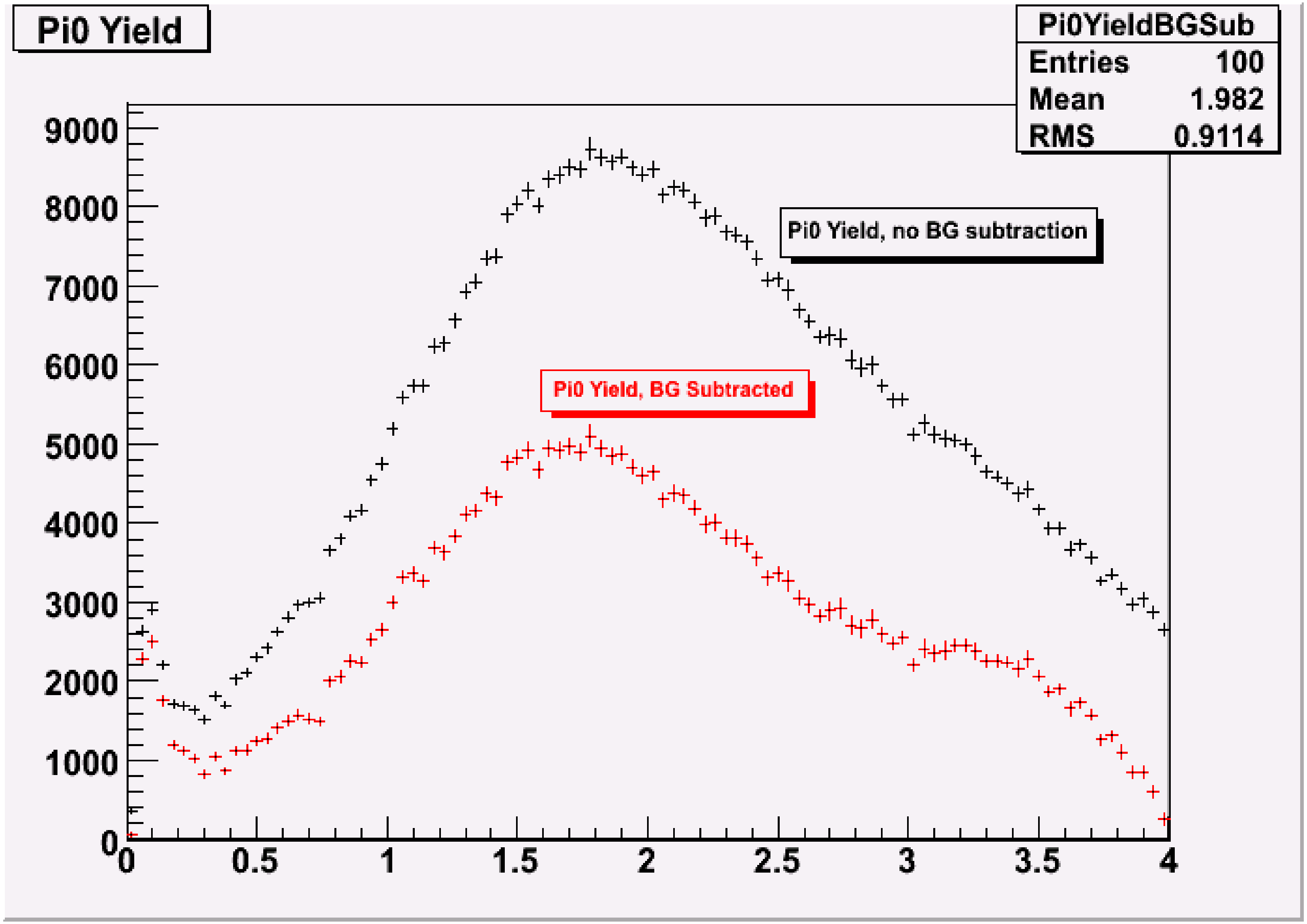

Fitting dNdR13, Theta = 2.96 to 3.20 deg , All clus types
RYieldDouble13
Entries 116
Mean 0.829
RMS 0.09139
χ² / ndf 181.5 / 108
Prob 1.235e-05
p0 77.59 ± 1.16
p1 0.9768 ± 0.0013
p2 0.04 ± 0.00
p3 0.02318 ± 0.00178
p4 7712 ± 73.5
Fitting dNdR14, Theta = 3.20 to 3.44 deg , All clus types
RYieldDouble14
Entries 113
Mean 0.8265
RMS 0.08867
χ² / ndf 220.6 / 105
Prob 2.918e-11
p0 73.68 ± 1.25
p1 0.9691 ± 0.0013
p2 0.04 ± 0.00
p3 0.02792 ± 0.00195
p4 7216 ± 72.5
Fitting dNdR15, Theta = 3.44 to 3.72 deg , All clus types
RYieldDouble15
Entries 112
Mean 0.8244
RMS 0.08691
χ² / ndf 264.7 / 104
Prob 3.253e-18
p0 71.51 ± 1.33
p1 0.9669 ± 0.0015
p2 0.04 ± 0.00
p3 0.03481 ± 0.00251
p4 7045 ± 84.0
Fitting dNdR16, Theta = 3.72 to 4.00 deg , All clus types
RYieldDouble16
Entries 105
Mean 0.8239
RMS 0.0854
χ² / ndf 215.9 / 98
Prob 4.764e-12
p0 57.67 ± 1.34
p1 0.9653 ± 0.0018
p2 0.04 ± 0.00
p3 0.04034 ± 0.00367
p4 5504 ± 83.4

The BIER function.

Background as a function of Pi0 angle.



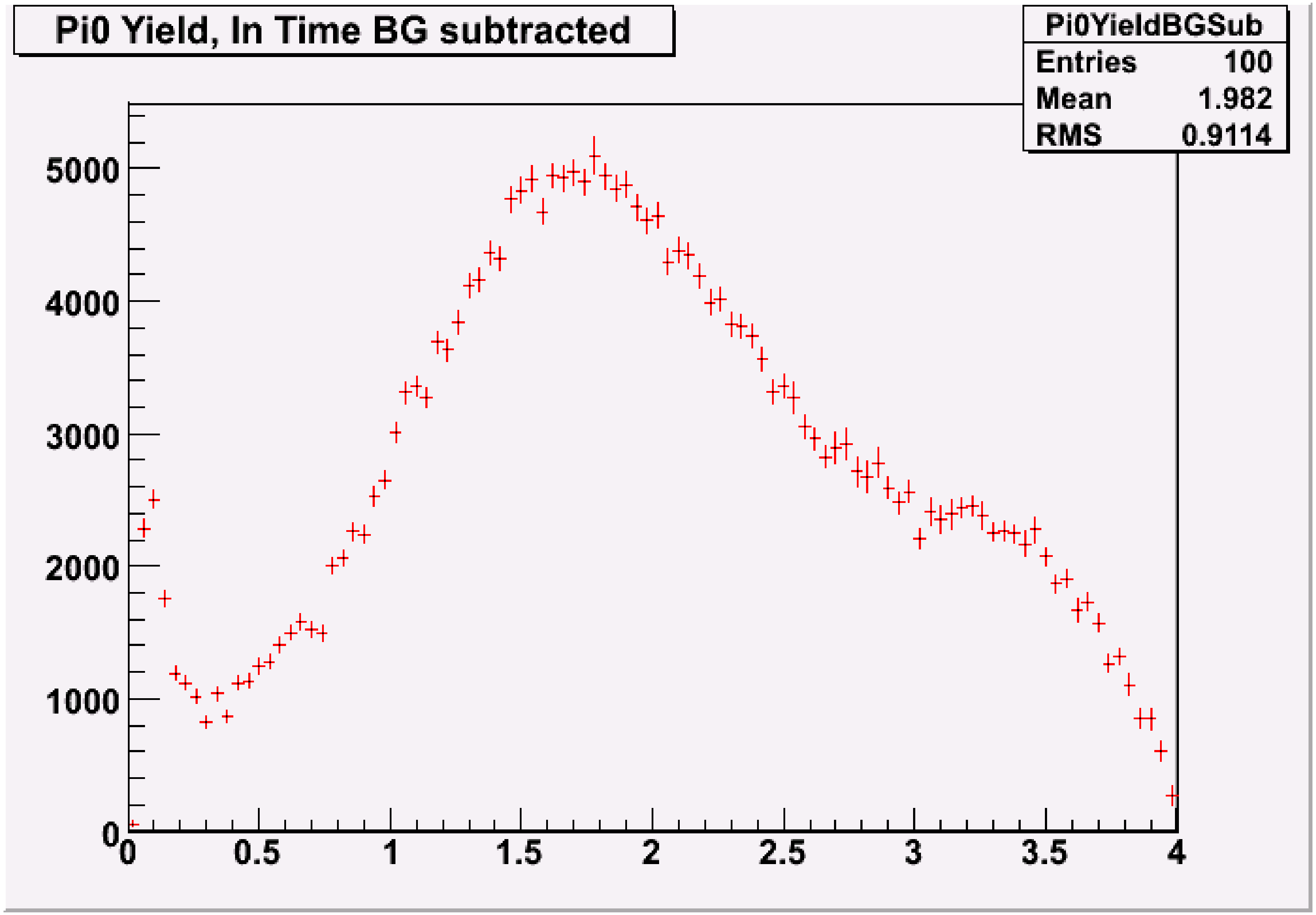
Got Everything for Background subtraction...



Background subtracted Pi0 yield.

9922 Pi0's from 0.0 -> 0.3 degrees

9922 Pi0s, $2.9066 \cdot 10^{12}$ photons



Inflection point of yield is from the subtraction function

Future work

- Fix the failing fits in my Elasticity yields.
- Go to simple polynomials in Elasticity Yields to pick up super-elastic background.
  - Should reduce nuclear coherent peak.
- Add Error Matrix/weighting function to Pi0 Mass and Elasticity likelihoods.
  - When someone else produces them...
  - This should enhance the separation of “Most” and “Next Most” likely entries.
- Try to finish up before year's end.