

# Check up of Mass Peak

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This study is to check the correctness of mass peak of identified particles in LEPS spectrometer during TPC experiment. The ntuples are generated by Fujimura-san with the start-timing from start counter. Ntuples are in the directory of '/np1b/n03/sp8lep/nt/Apr04\_STA/' on saho.

In this study, the cut conditions are listed below:

1.  $\text{abs}(p_y/p_z) > 0.01$   
Suppress  $e^+e^-$  events.

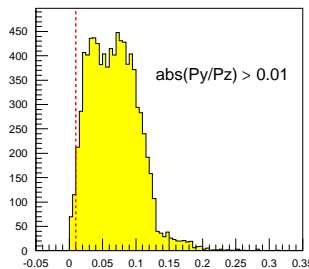


Figure 1: Cut condition 1 :  $\text{Abs}(P_y/P_z) > 0.01$

2.  $\text{adc\_sqr}(\text{ntof}) > 0.8$   
Charged particle's charge sum have to greater than 0.8.

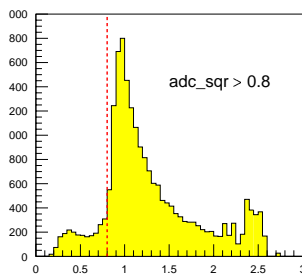


Figure 2: Cut condition 2 : Charge sum  $> 0.8$

3.  $5000 > \text{sleng} > 3000$

From tracking, the flight path must be in the range of  $5000 > \text{sleng}(\text{mm}) > 3000$ .

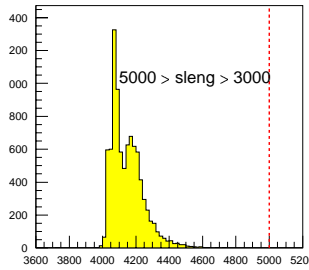


Figure 3: Cut condition 3 :  $5000 > \text{Length of Flight Path}(\text{mm}) > 3000$

4.  $\text{tof} > 10$

According to the range of flight path, the minimum of time-of-flight is 10 (nsec).

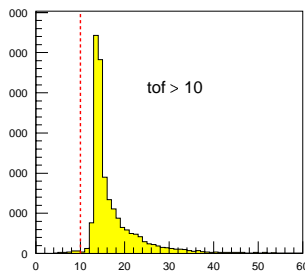


Figure 4: Cut condition 4 : Time-of-Flight  $> 10$  nsec

5.  $\text{prbchi2} > 0.1$

Probability of  $\chi^2$  comes from event tracking precision. To ask the precision must be greater than 0.1

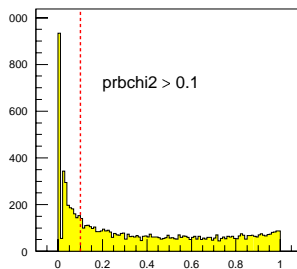


Figure 5: Cut condition 5 : Probability of  $\chi^2 > 0.1$

6. Momentum range : pion ( 0 - 1.0 GeV)  
                           kaon ( 0 - 1.0 GeV)  
                           proton ( 0 - 2.0 GeV)

7. No vertex constrain.

There are two major parts in this study. First one is about the mass peak position and mass spectrum width and the second one is the normalized yield of individual particle ( $\pi^+, \pi^-, k^+, k^-, p$ ). All the check is for the purpose of stability across runs.

## 1 Mass Peak and Mass width

In order to define particle boundary quantitatively, we use a  $m^2$  distribution instead of  $m$  distribution. Mass of particle is evaluated as  $m = \left[ p^2 \left( \frac{1-\beta^2}{\beta^2} \right) \right]^{\frac{1}{2}}$ . From this relation, the resolution of  $m^2$ ,  $\sigma_{m^2}^2$ , could be derived.

$$\sigma_{m^2}^2 = 4m^4 \left( \frac{\sigma_p}{p} \right)^2 + \frac{4p^4}{\beta^2} \left( \frac{\sigma_{TOF}}{L} \right)^2 \quad (1)$$

where  $m$  is particle's mass,  $L$  is length of flight path,  $\sigma_p$  is the momentum resolution and  $\sigma_{TOF}$  is TOF resolution.

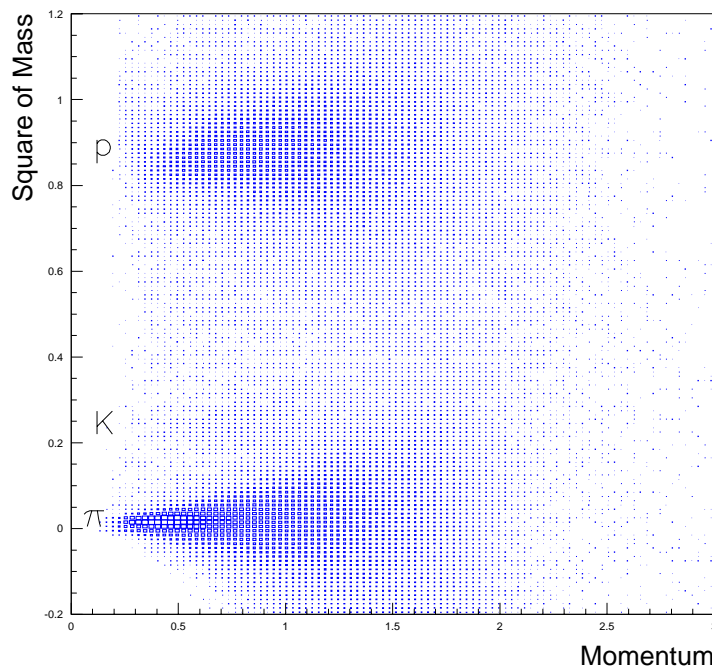


Figure 6:  $m^2$  spectrum with different momentums (for all runs)

As shown in Figure 6, the  $m^2$  distribution in different momentum is not uniform. To get a good PID, it is better to define curved boundaries for three particles.  $\sigma_{m^2}^2$  shows the widths of  $m^2$  spectrum in different momentum range. That is why to use  $m^2$  instead of  $m$  spectrum.

## 1.1 Momentum Slice

Use proton spectrum as an example in the following. According to Figure 5, it takes the proton's momentum range up to  $2.5(GeV/c)$ . Then, slice the momentum range to 25 different momentum bins ( $0.0 \leq p \leq 0.1(GeV/c)$ ,  $0.1 \leq p \leq 0.2(GeV/c)$ , ... ,  $2.4 \leq p \leq 2.5(GeV/c)$  ).

25 momentum bins are shown in Figure 7 with momentum increasing from up to down and from left to right. At each bin, it was fitted with Gaussian plus one-order polynomial function. Fitting range is  $0.8803549 \pm 0.2(GeV/c)$ .

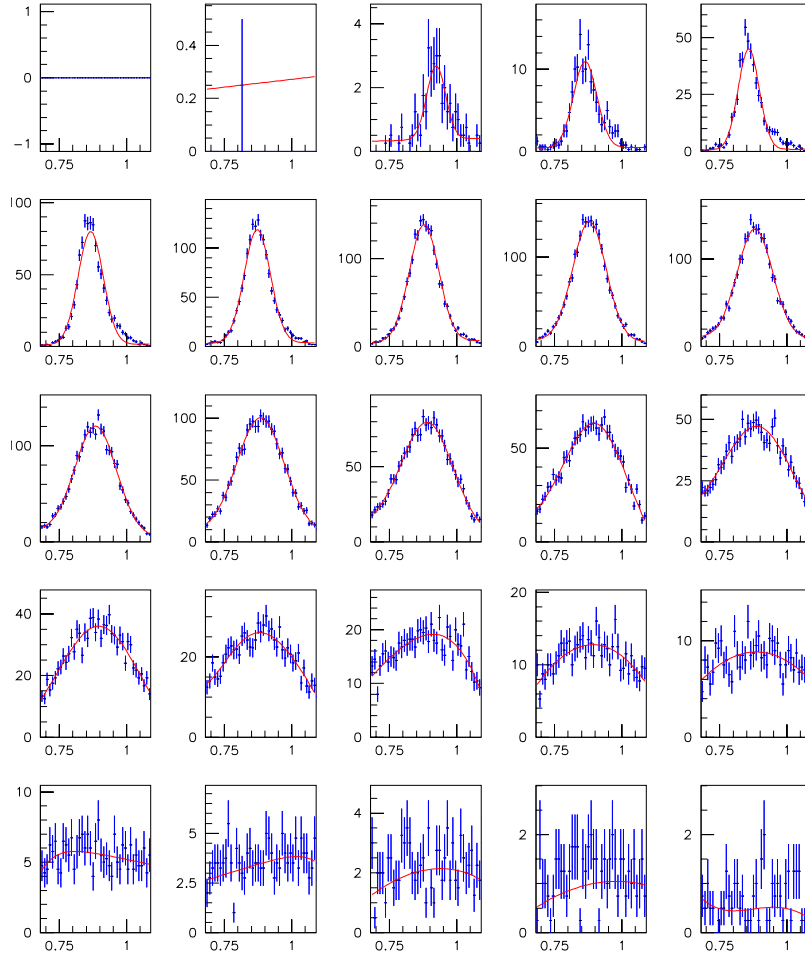


Figure 7: Momentum slice for proton

## 1.2 Get Fitting Parameters

After momentum-slice, the  $m^2$  peak position and  $m^2$  spectrum width could be obtained. They are plotted versus momentum in the Figure 8(a) and 8(b) respectively.

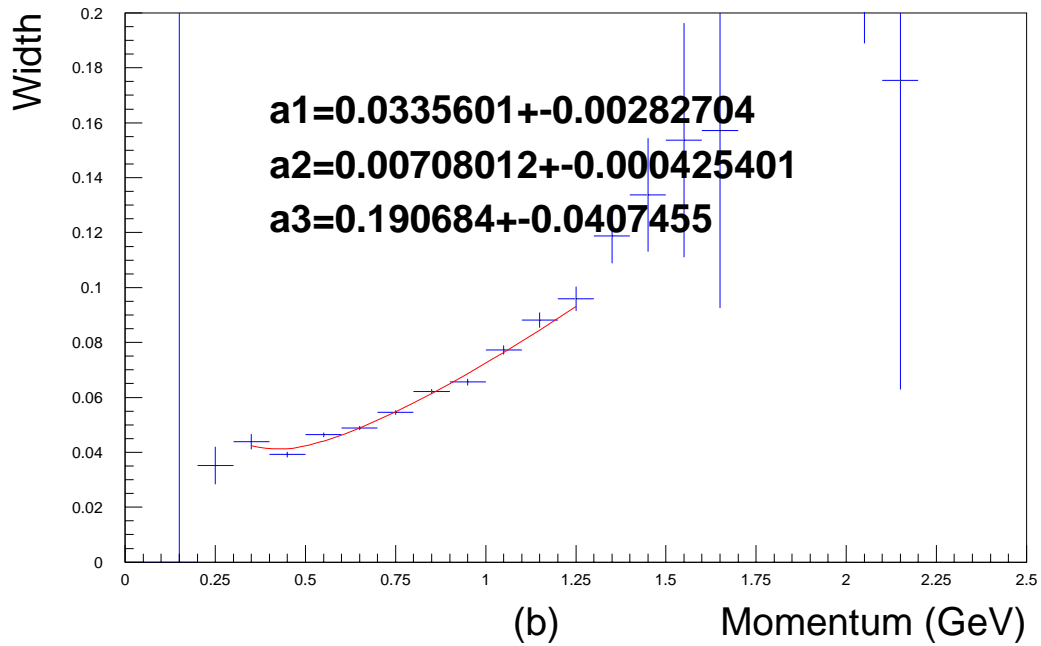
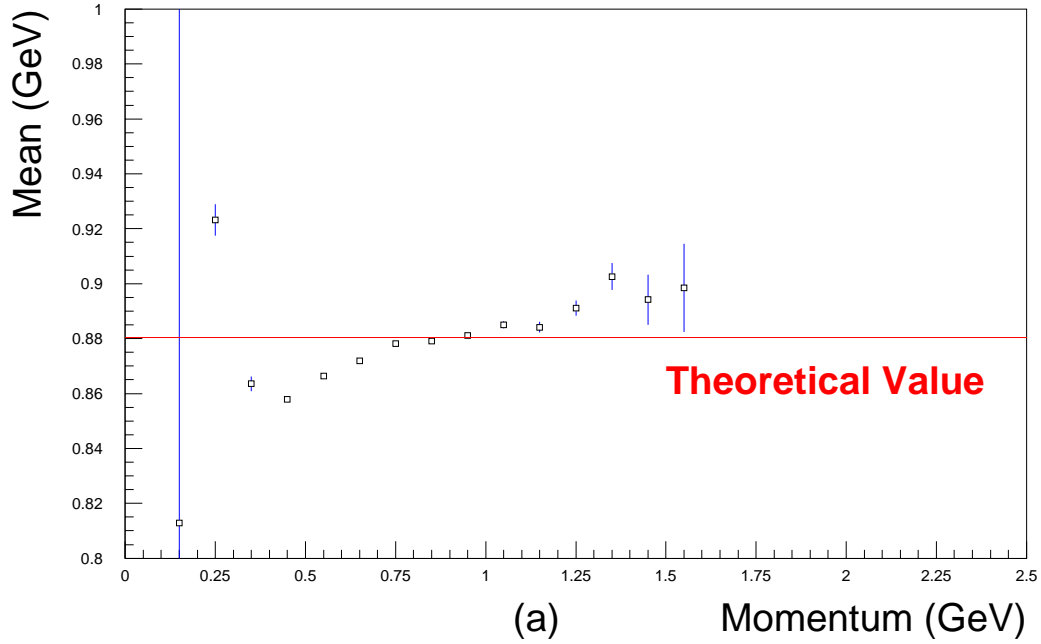


Figure 8: (a)  $m^2$  peak position and (b)  $m^2$  spectrum width

In Figure 8(b), it could not be fitted with  $\sigma_{m^2}^2$  relation directly. Eq.(1) have to do some changes.

$$\left(\frac{\sigma_p}{p}\right)^2 = a_1^2 p^2 + \frac{a_2^2}{\beta^2} \quad (2)$$

$$a_3 = \frac{\sigma_{TOF}}{L} \quad (3)$$

Substitute (2), (3) and  $\beta^2 = \frac{p^2}{p^2+m^2}$  into (1), then

$$\sigma_{m^2}^2 = 4m^4 p^2 a_1^2 + 4m^4 \left(1 + \frac{m^2}{p^2}\right) a_2^2 + 4p^2 (m^2 + p^2) a_3^2 \quad (4)$$

where  $a_1$ ,  $a_2$  and  $a_3$  are fitting parameters. Eq.(4) is the final fitting function. According to Figure 6, fitting range is from 4th bin to 13th bin. Fitting  $m^2$  spectrum width in Figure 3(b) with Eq.(4) to get fitting parameters. Three fitting parameters are also plotted in Figure 8(b).

The same analytic procedures are also applied on pion and kaon. Two sets of fitting parameters for pion and kaon could also be obtained. All fitting parameters are listed in Table 1. All momentum-slice figures are attached in Appendix A, and all get-fitting-parameters figures are in the Appendix B.

Table 1:  $\sigma_{m^2}^2$  fitting parameters

|        | $a_1$     | $a_2$        | $a_3$    |
|--------|-----------|--------------|----------|
| Pion   | 0.555756  | -0.000143901 | 0.319722 |
| Kaon   | 0.0594723 | 0.0124399    | 0.12583  |
| Proton | 0.0335601 | 0.00708012   | 0.190684 |

Depends on fitting parameters in Table 1, the PID boundary could be determined respectively. In Figure 9, the red curves show defined PID boundary. Those events lying between red curves are what we select for later study.

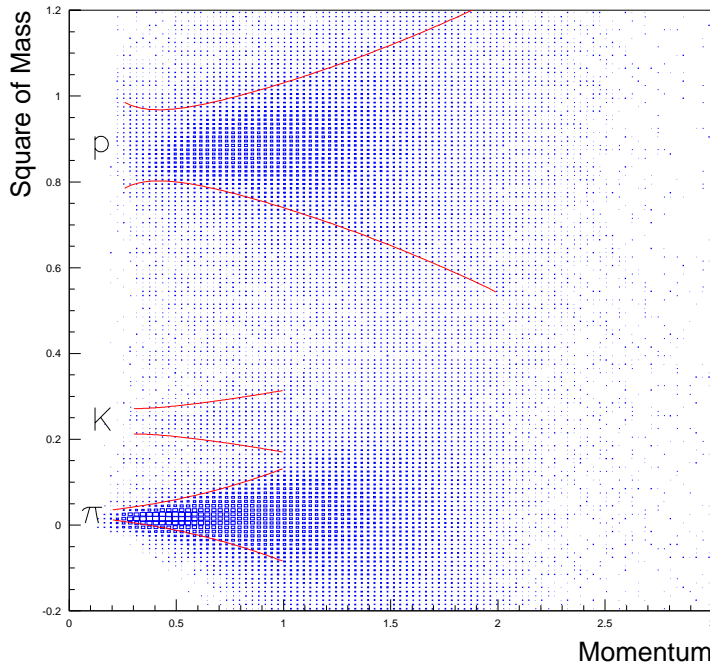


Figure 9: Particle Identification Boundary of Pion, Kaon and Proton.

### 1.3 Mass Peak and Mass Width

Collect the events lying between PID boundary run by run and then fit the *mass* spectrum for five particles ( $\pi^+$ ,  $\pi^-$ ,  $k^+$ ,  $k^-$ ,  $p$ ) respectively. For example, *mass* spectrum of Run\_28649 of Apr04STA ntuples is fitted with Gaussian for five particles to get mass peak position and mass width individually, as shown in Figure 10.

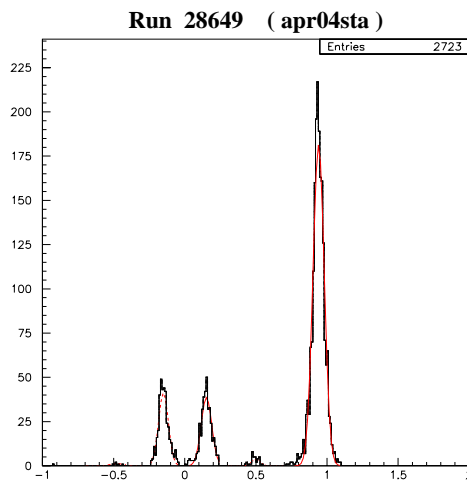


Figure 10: Fitting of *mass* spectrum

The Figures about the mass peak position and *mass* spectrum width run by run for five particles are attached in Appendix C. In each individual particle, such as pion+, the top plot is the mass peak position versus run number. The green line is the fitting line of all runs, its value, such as 'Mass Peak = 0.150139', is also shown in the top plot. The red line is the theoretical mass value of this particle. The bottom one is *mass* spectrum width versus run number.

The correctness of mass peak seems OK.

## 2 Normalized Yields

Just like the check of mass peak position, the check of normalized yield is also run by run. Normalized yields is number of individual particle events divided by number of total tvents. The number of individual particle comes from those events between PID boundary determined above. The total number of events are results from scal(24) in ntuple. The green fitting line and its value are also shown in both plots. The plots are also in Appendix D.

There is a difference between two figures. It results from different selection rule. In the top one, 'P-indep. Cut' , its selection rule is 'mass peak +- 50 MeV'. It is momentum independent. The bottom one, 'P-dep. Cut',its boundary is defined by PID boundary. It is momentum dependent.

From  $k^+$ ,  $k^-$  and  $p$ , the normalized yields with 'P-indep. Cut' and with 'P-dep. Cut' are quite similar. They don't have apparent difference.  $m^2$  spectra of both  $\pi^+$  and  $\pi^-$  expand rapidly, therefore, normalized yields with 'P-dep. Cut' include more events and it is greater then those with 'P-indep. Cut'.

From proton plots, it seems also decrease slowly from the beginning to R28763. After R28765, it seems stable.

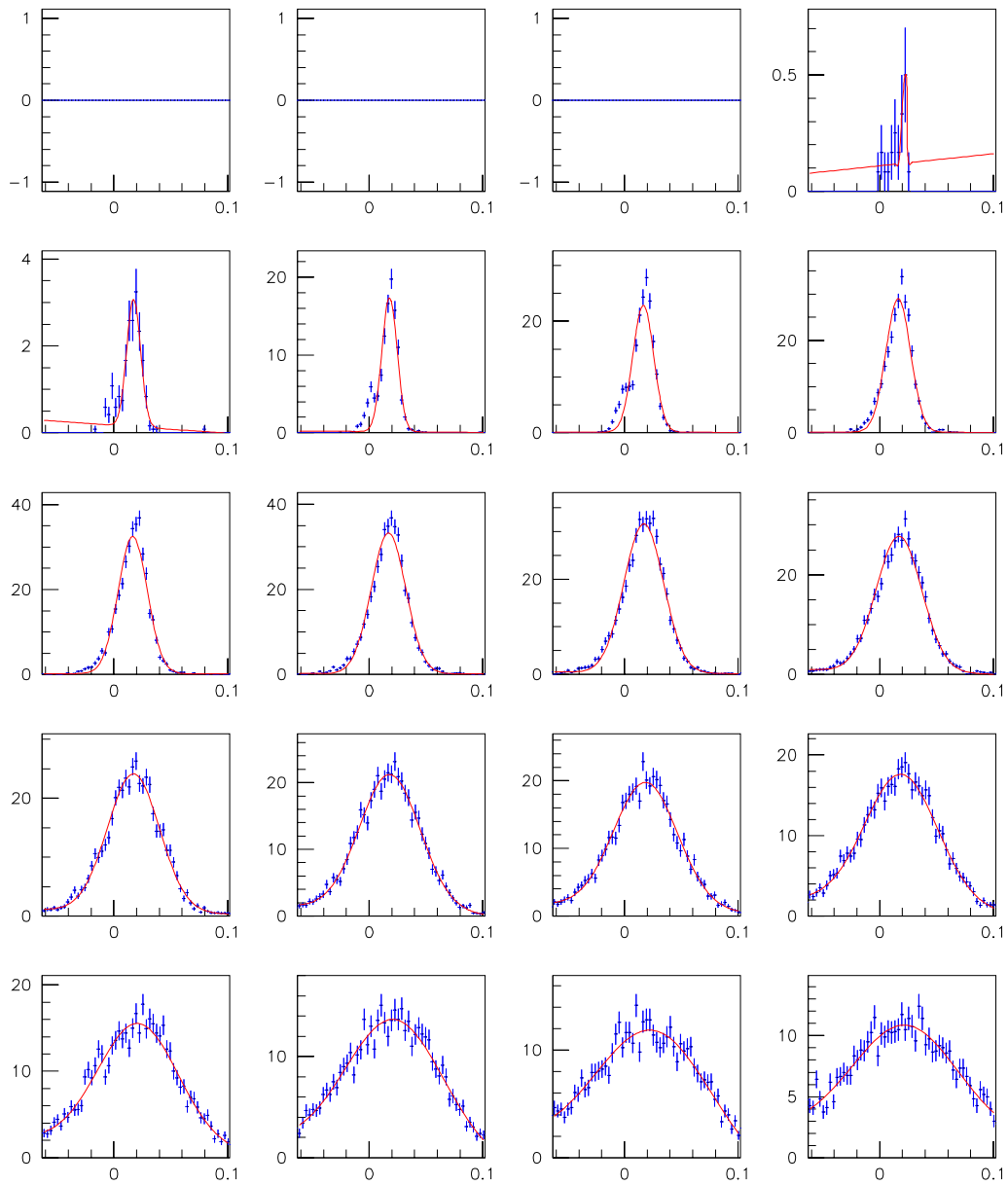
## 3 RF Timing Ntuples

Timing of above ntuples are determined by start counter. New ntuples use RF resonate to improve the start-timing. The same analytic methods are applied on new ntuples(Apr04\_RF). New ntuples are in the directory of '/np1b/n03/sp8lep/nt/Apr04\_RF/' on saho. For Apr04\_RF ntuples, 'Momentum Slice' figures are in Appendix E; 'Get Fitting Parameter' figures are in Appendix F; 'Mass Peak and Mass Width' figures are in Appendix G and 'Normalized Yields' figures are in Appendix H.

# A Momentum Slice

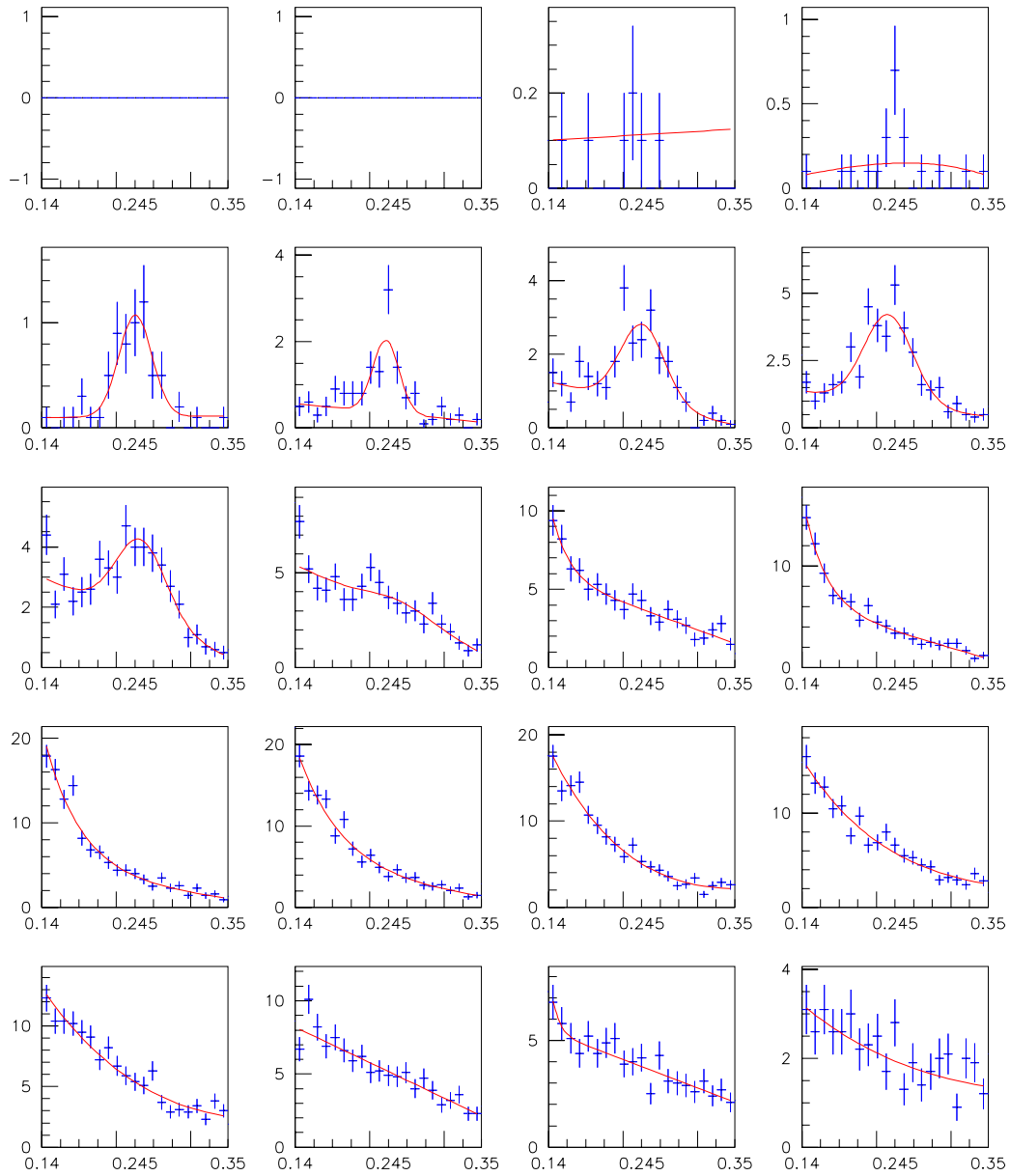
## A.1 Pion

### Pion (apr04sta ntuple)



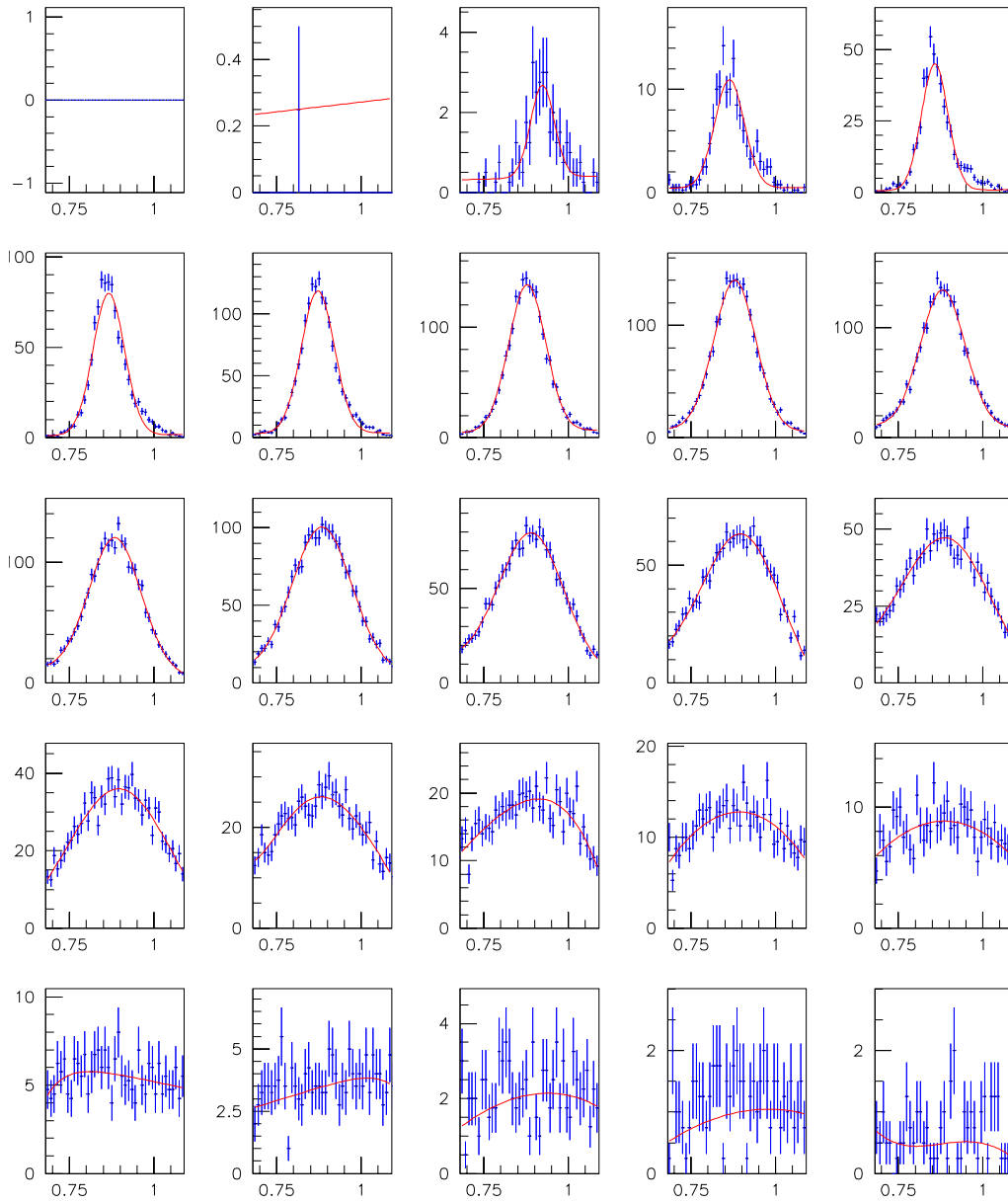
## A.2 Kaon

### Kaon (apr04sta ntuple)



## A.3 Proton

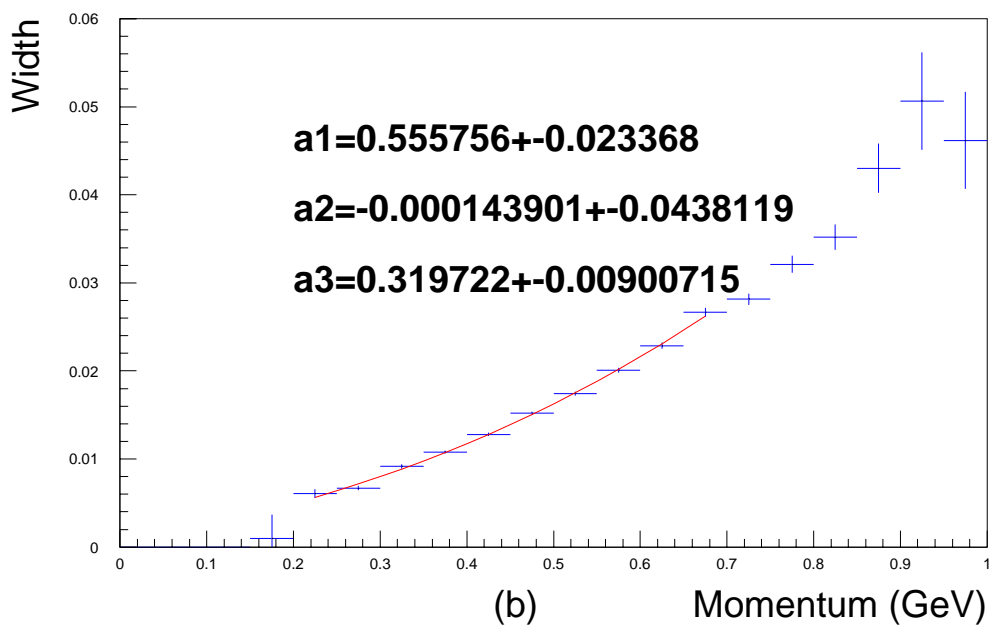
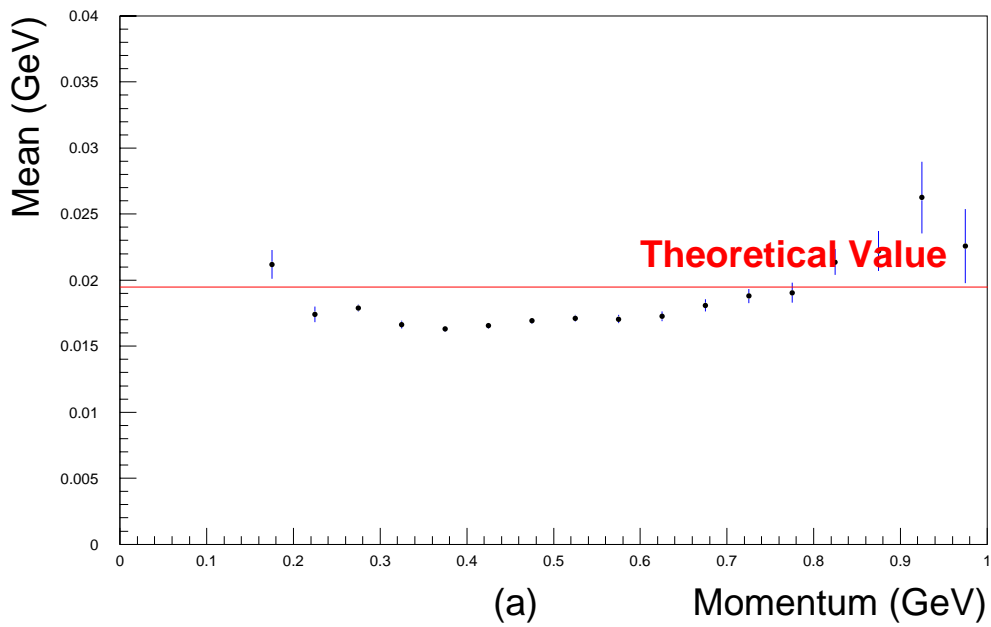
### Proton (apr04sta ntuple)



## B Get Fitting Parameters

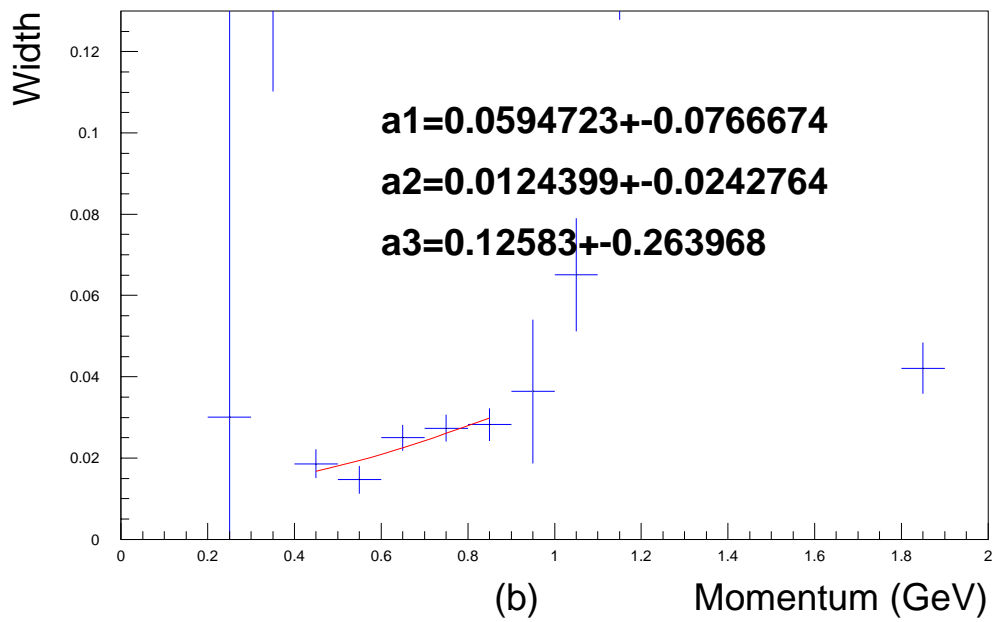
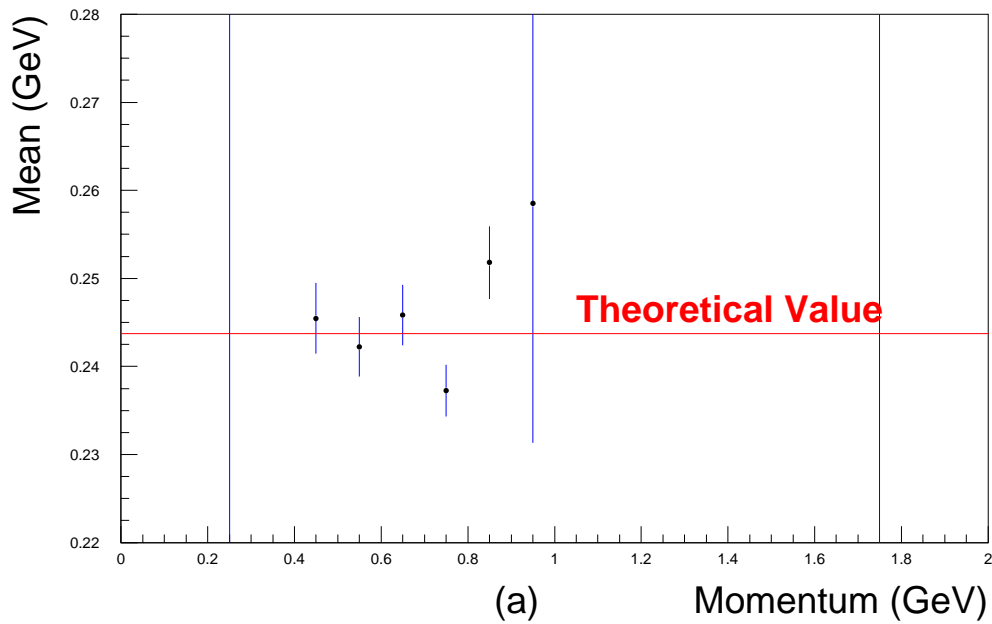
### B.1 Pion

#### Pion (All Apr04STA Ntuples)



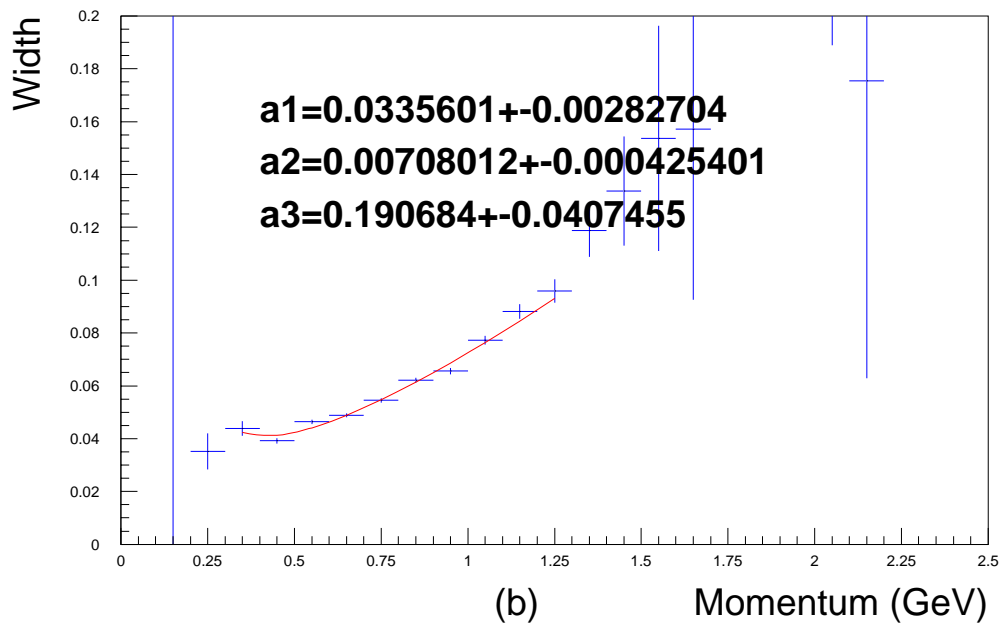
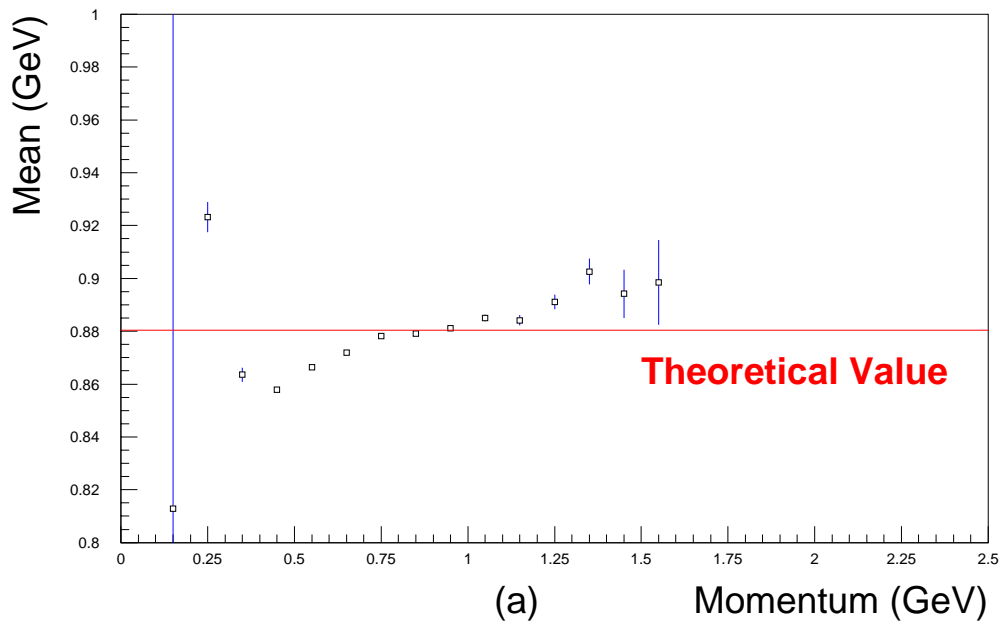
## B.2 Kaon

### Kaon (All Apr04STA Ntuples)



### B.3 Proton

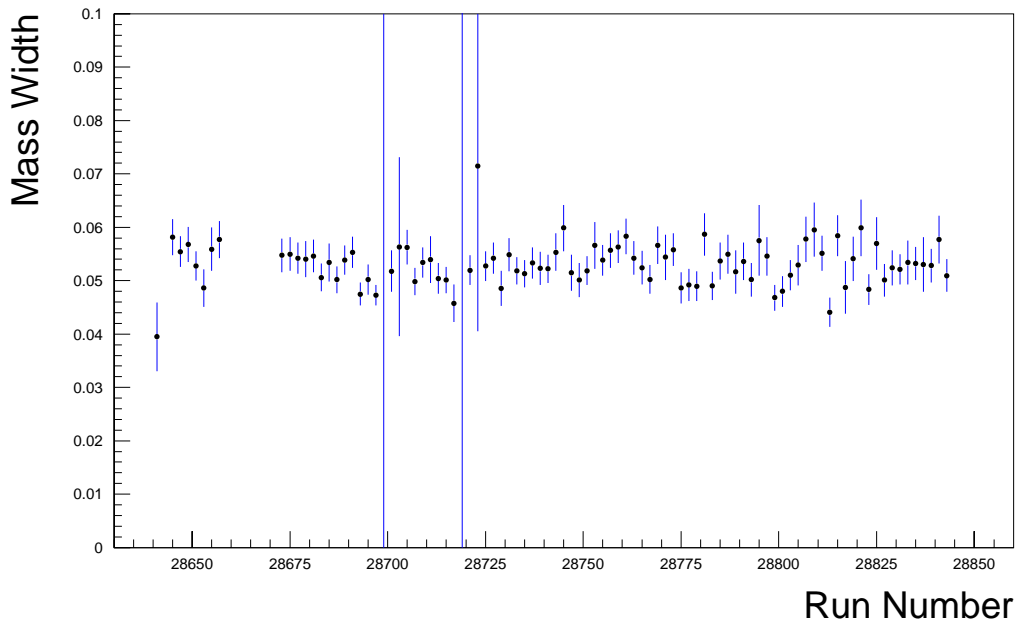
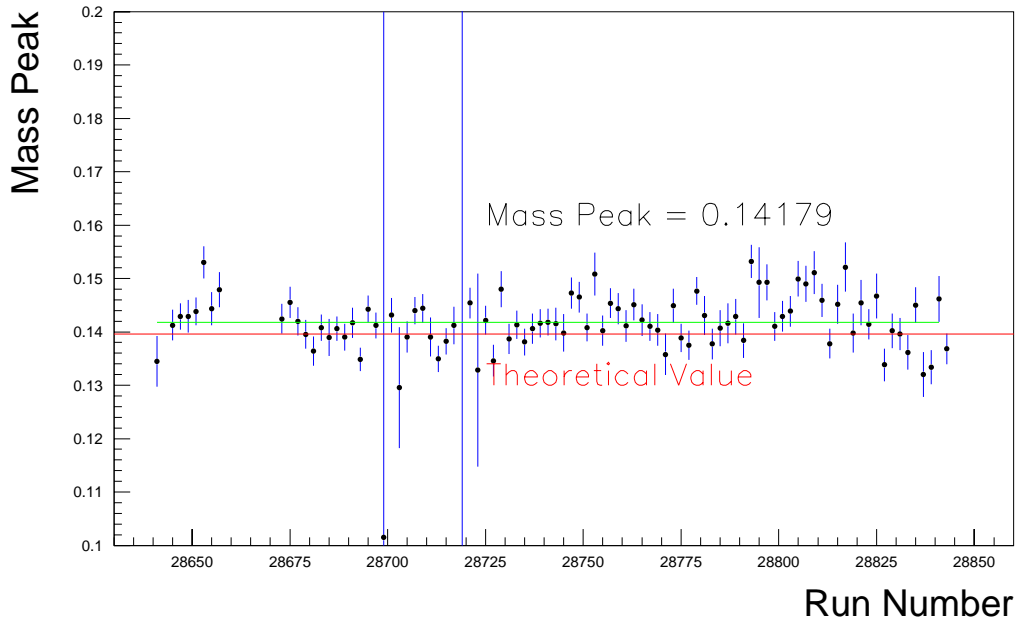
#### Proton (All Apr04STA Ntuples)



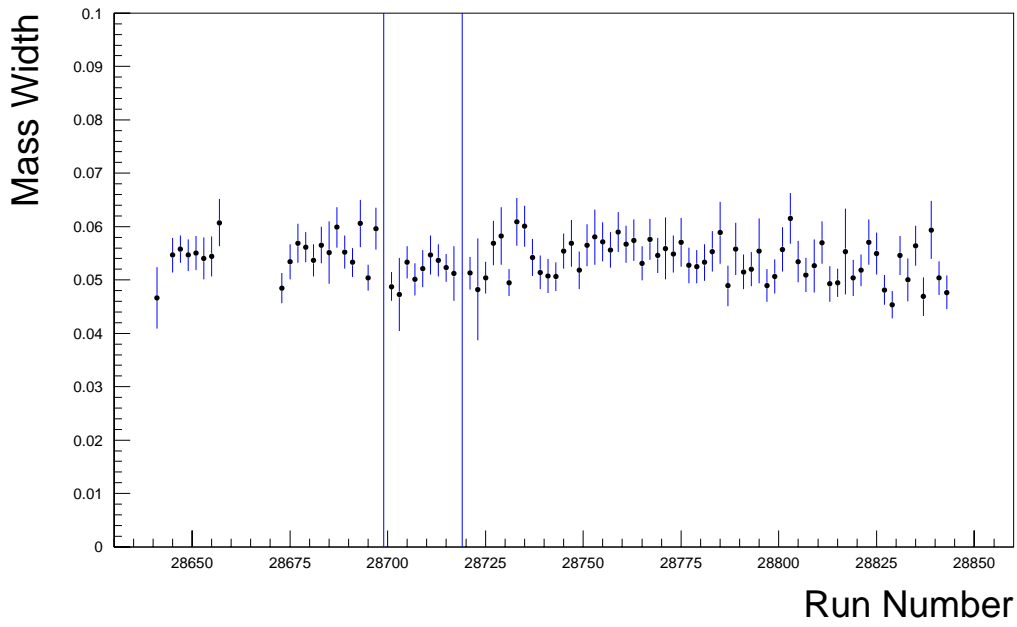
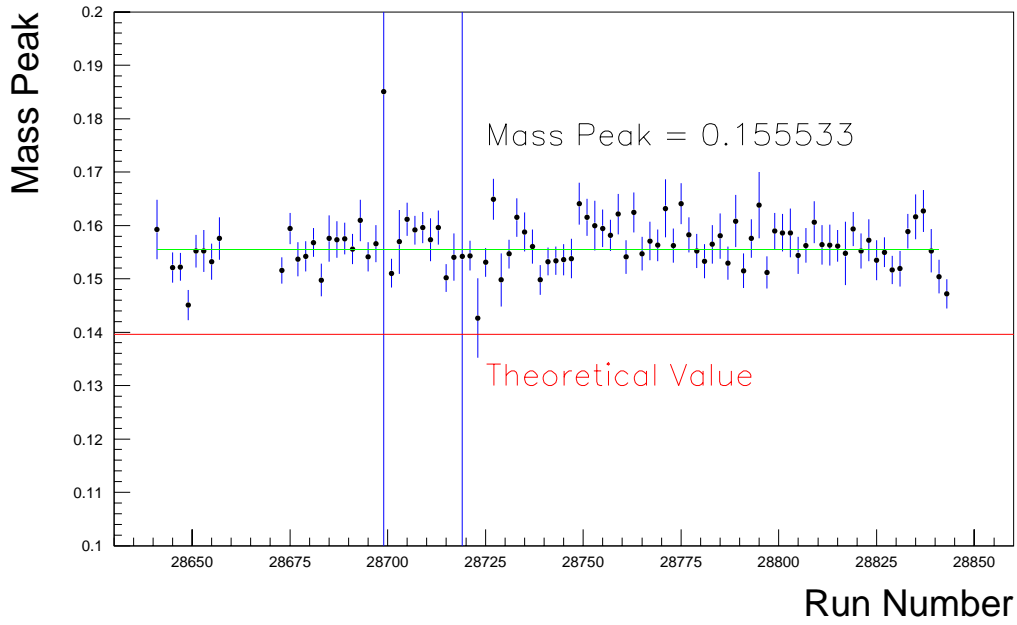
# C Mass Peak and Mass Width

## C.1 $\pi^+$

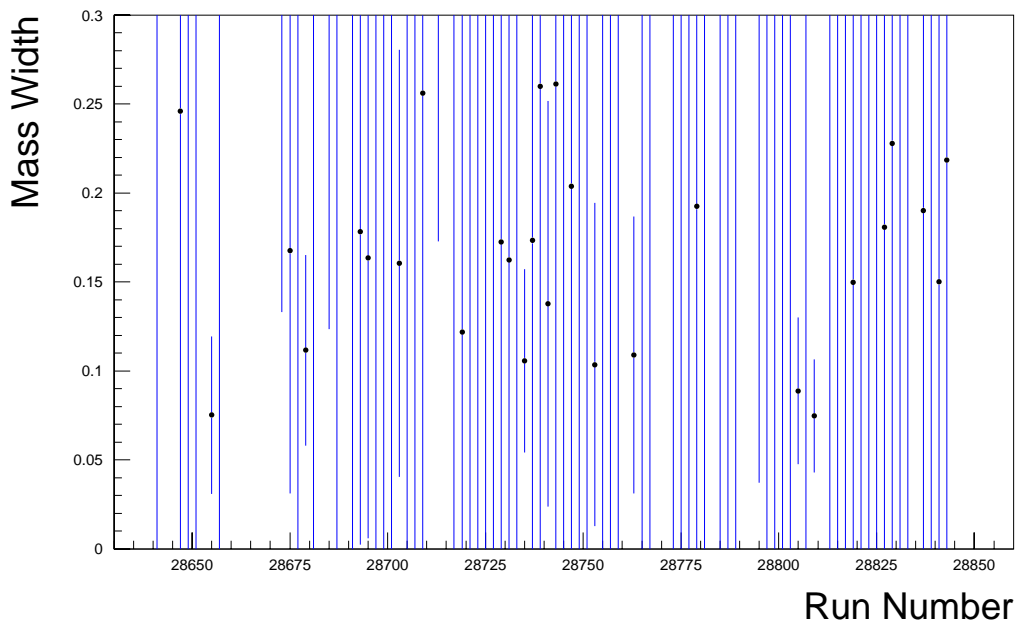
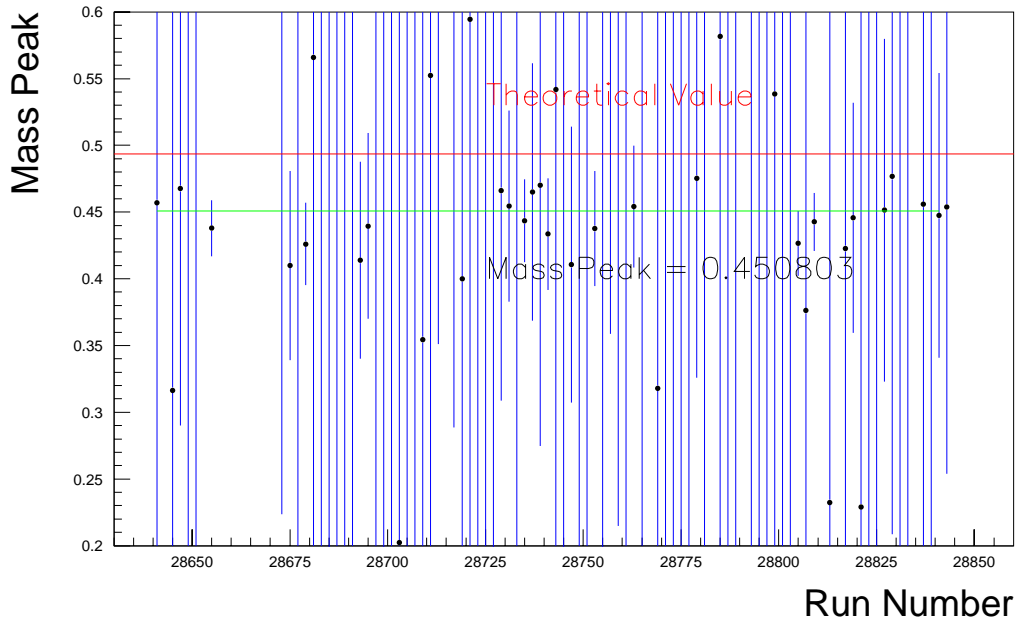
### Pion + ( apr04sta ntuples )



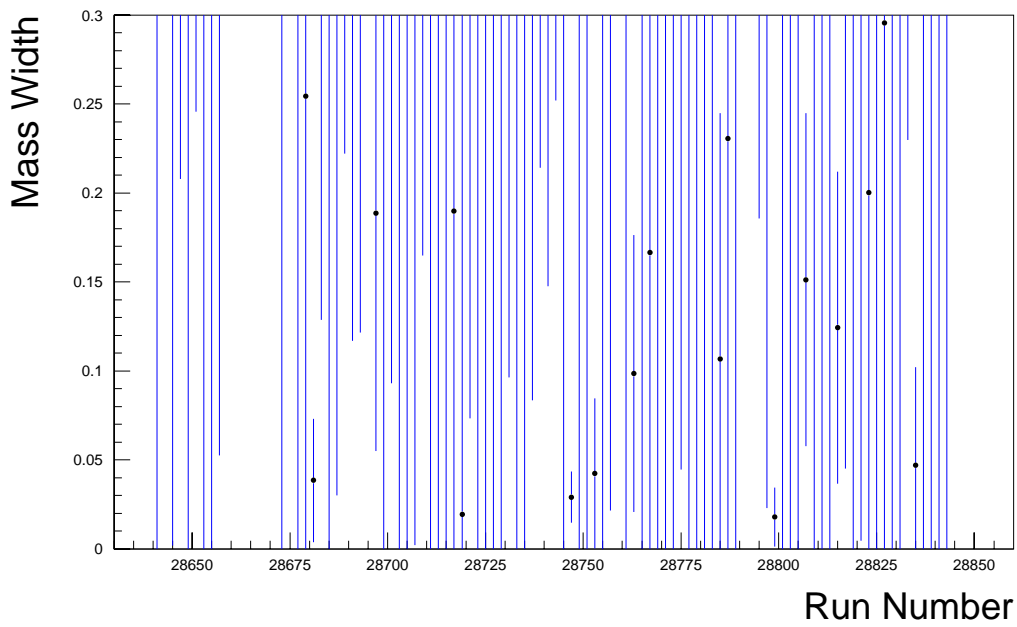
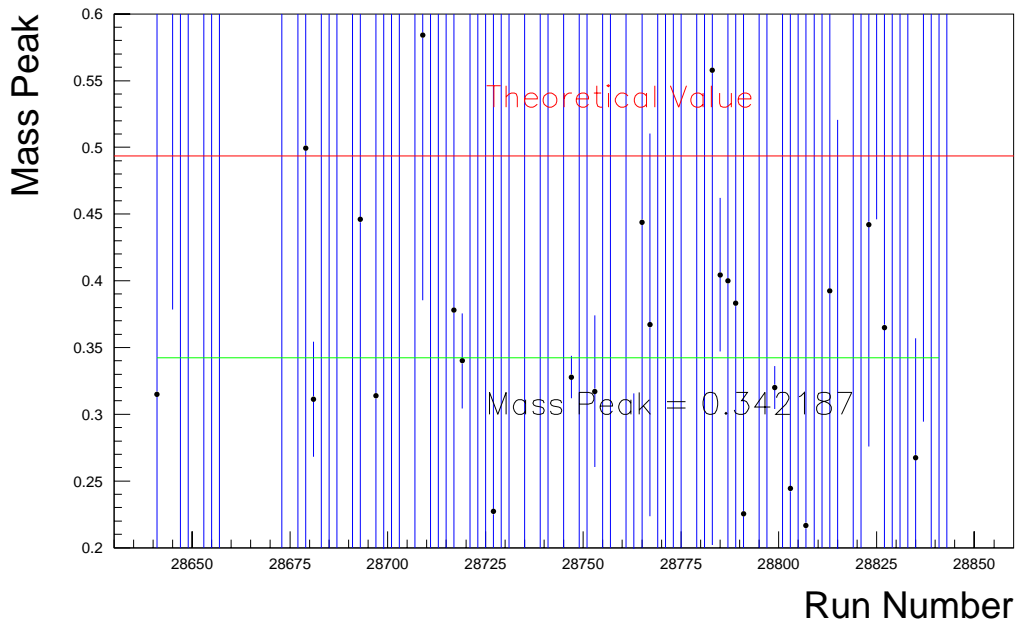
### Pion - ( apr04sta ntuples )



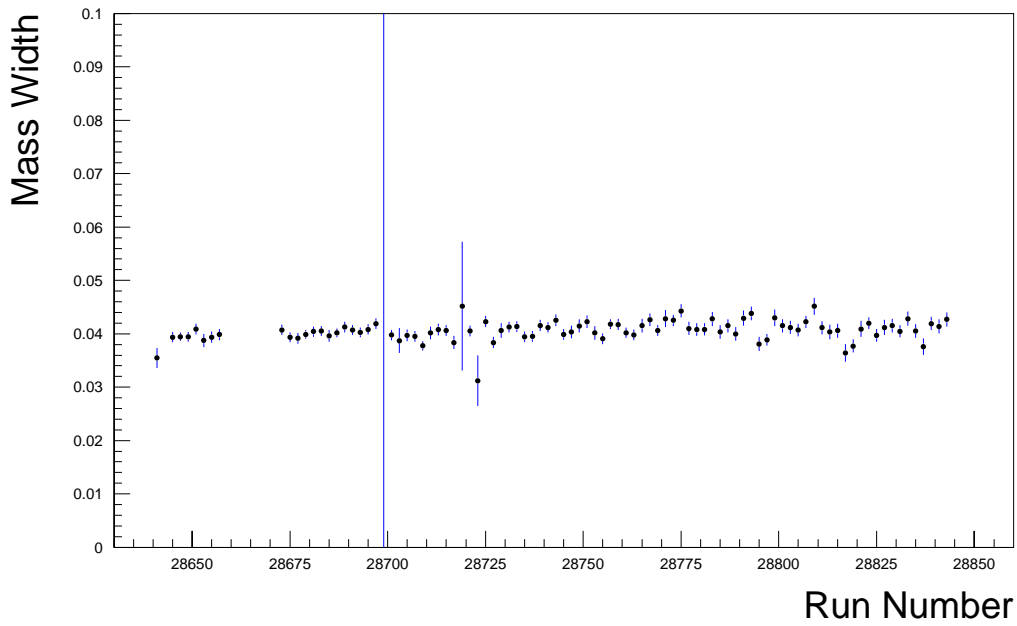
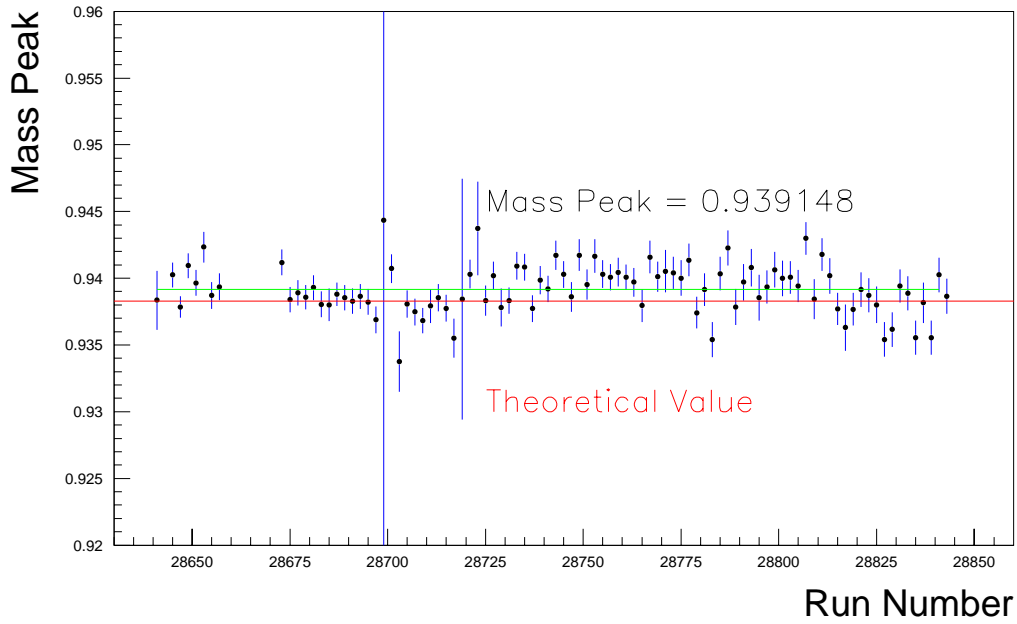
### Kaon + ( apr04sta ntuples )



### Kaon - ( apr04sta ntuples )



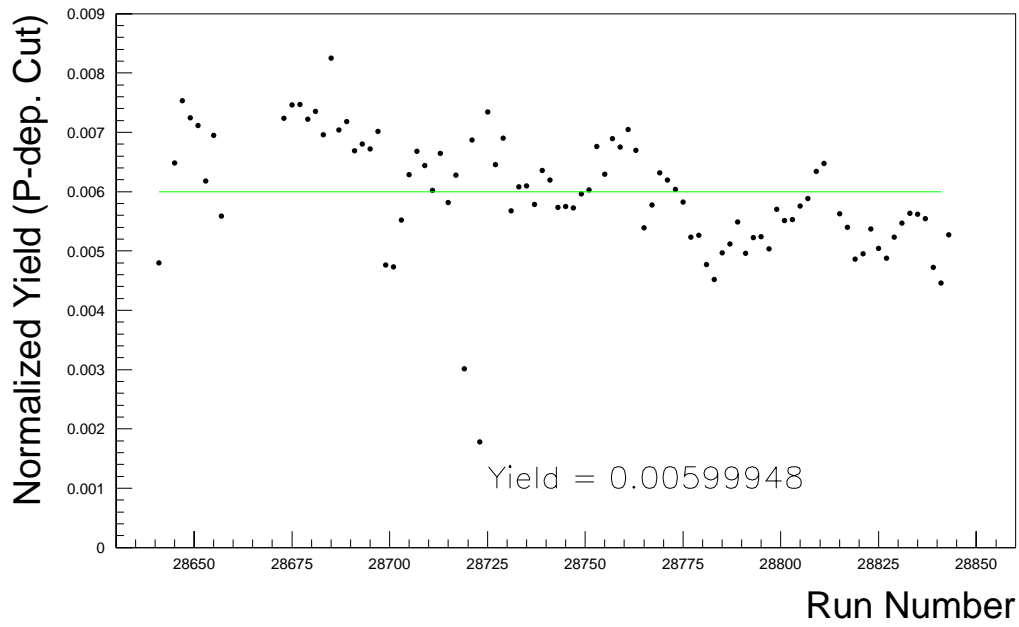
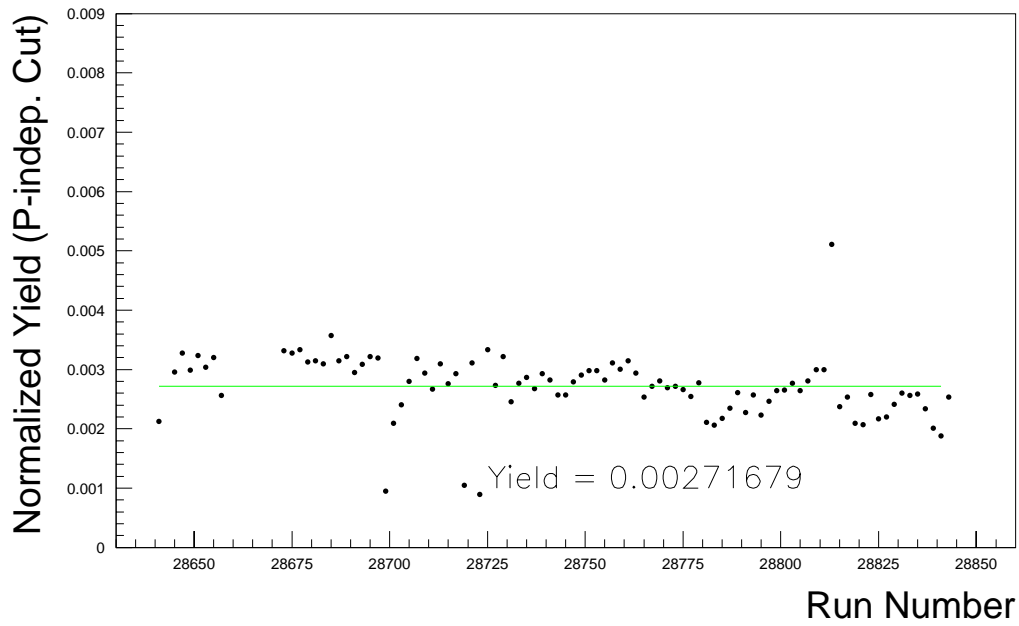
**Proton + ( apr04sta ntuples )**



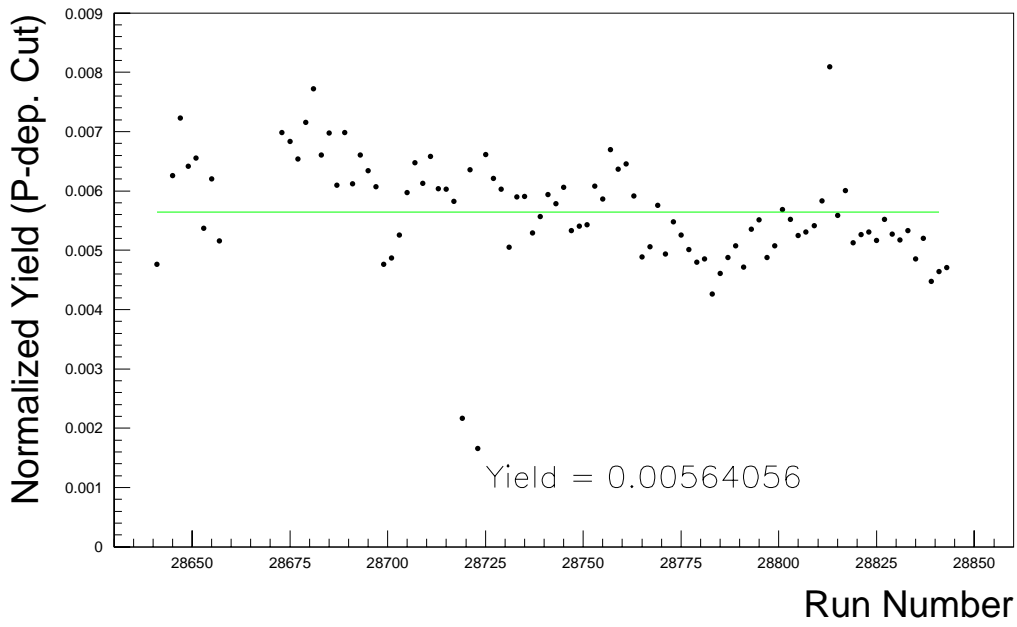
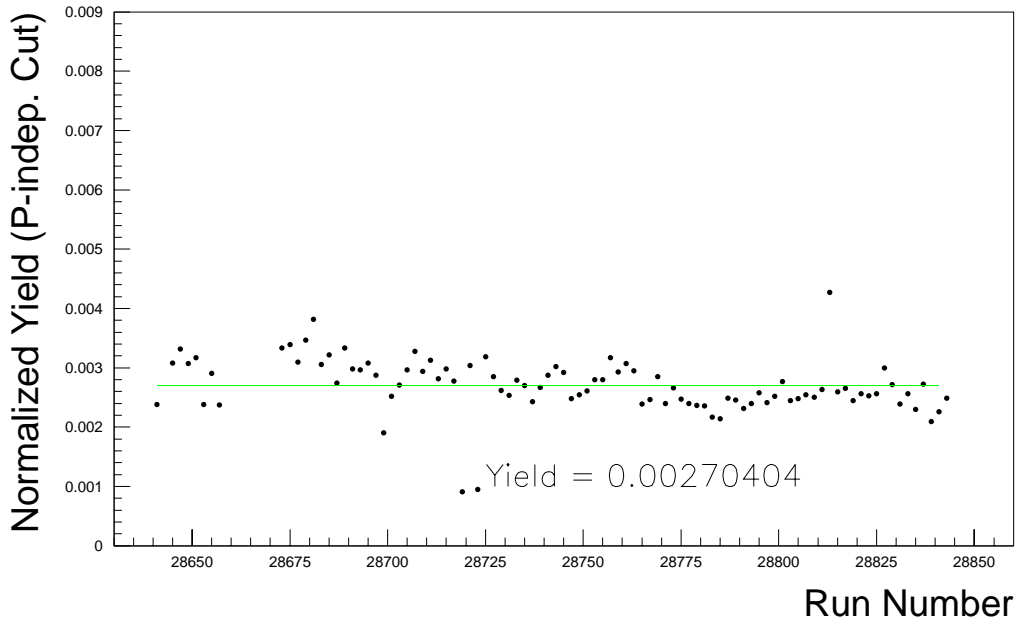
# D Normalized Yields

## D.1 $\pi^+$

### Pion + ( apr04sta ntuples )

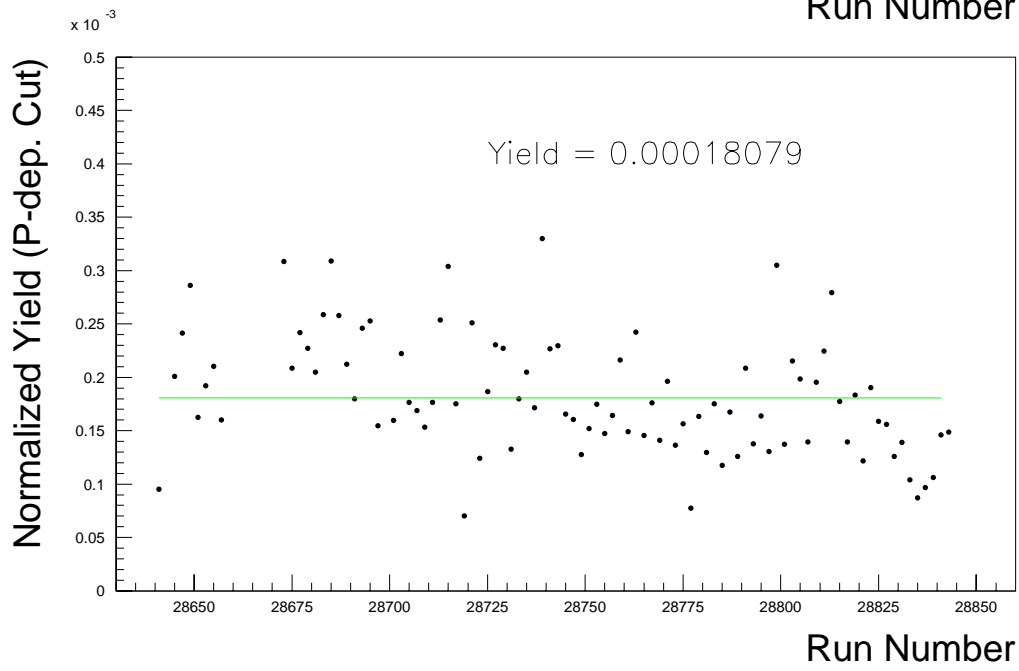
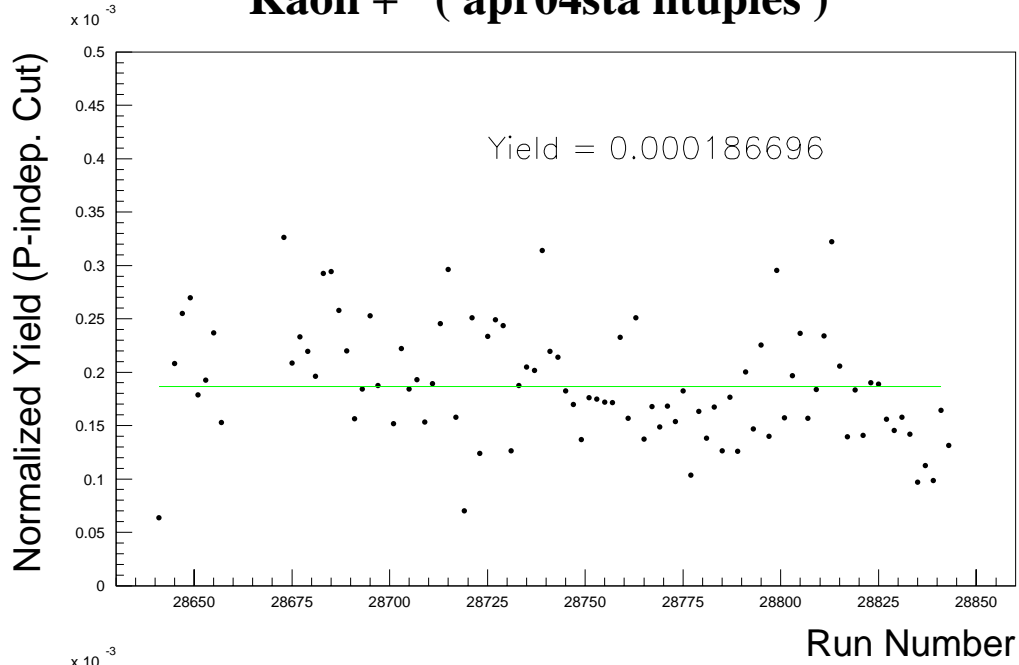


### Pion - ( apr04sta ntuples )



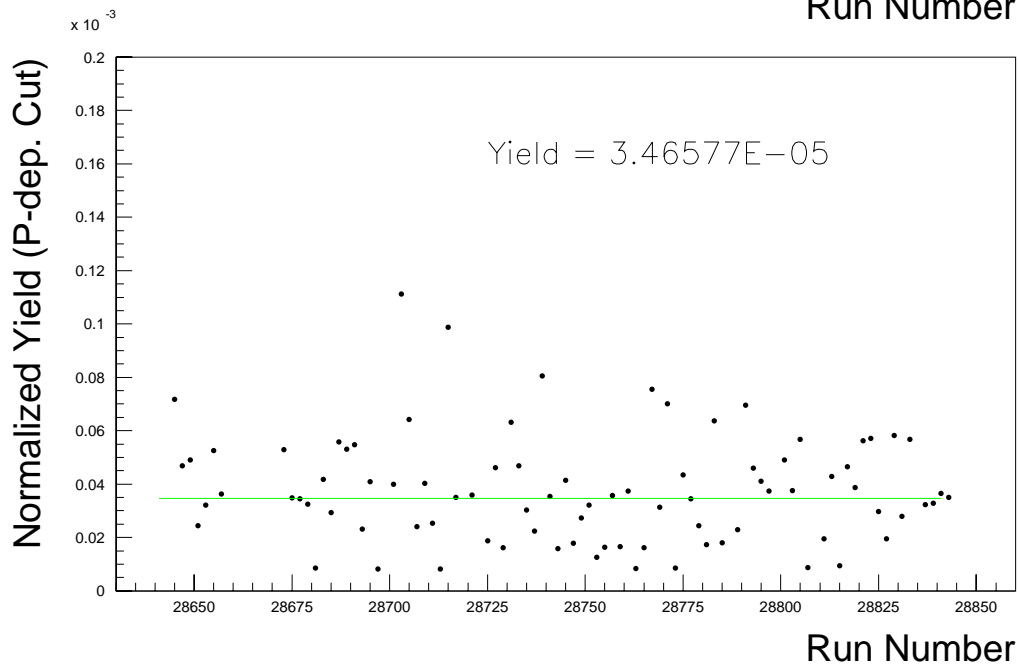
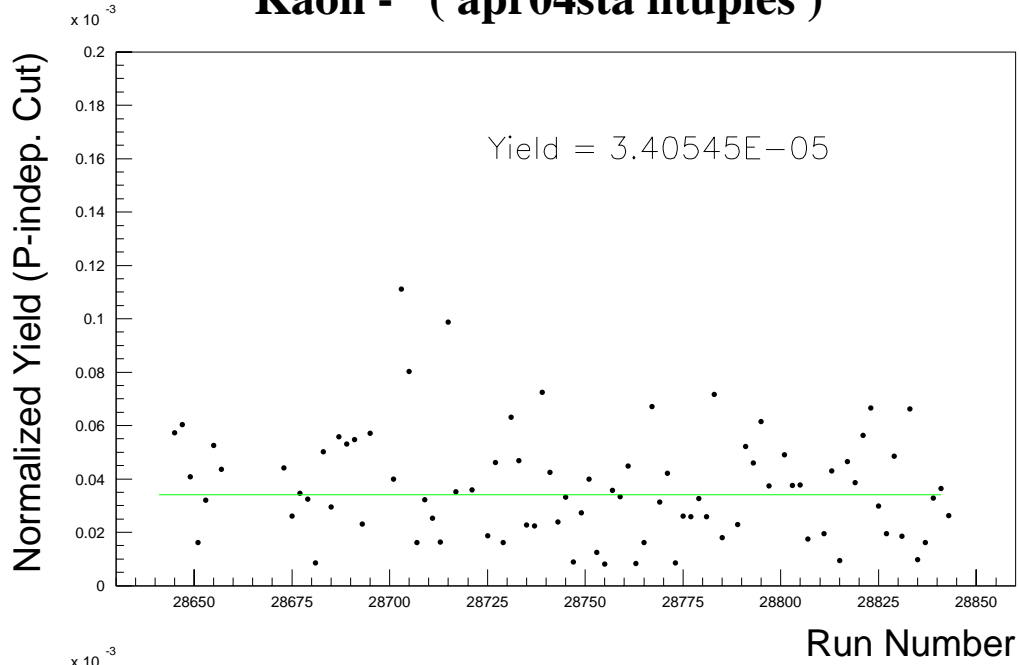
### D.3 $K^+$

#### Kaon + ( apr04sta ntuples )

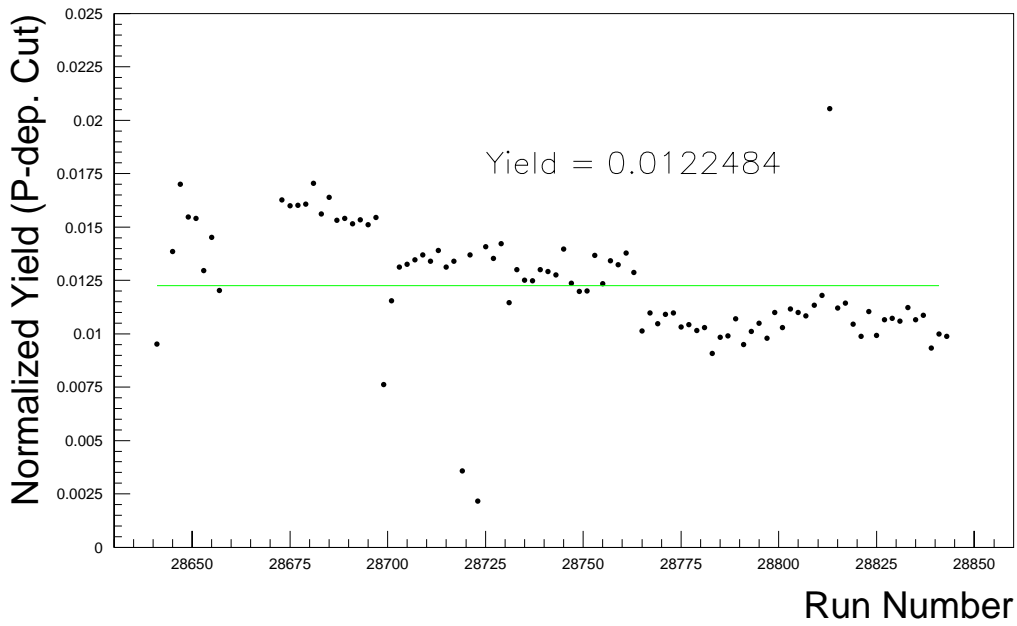
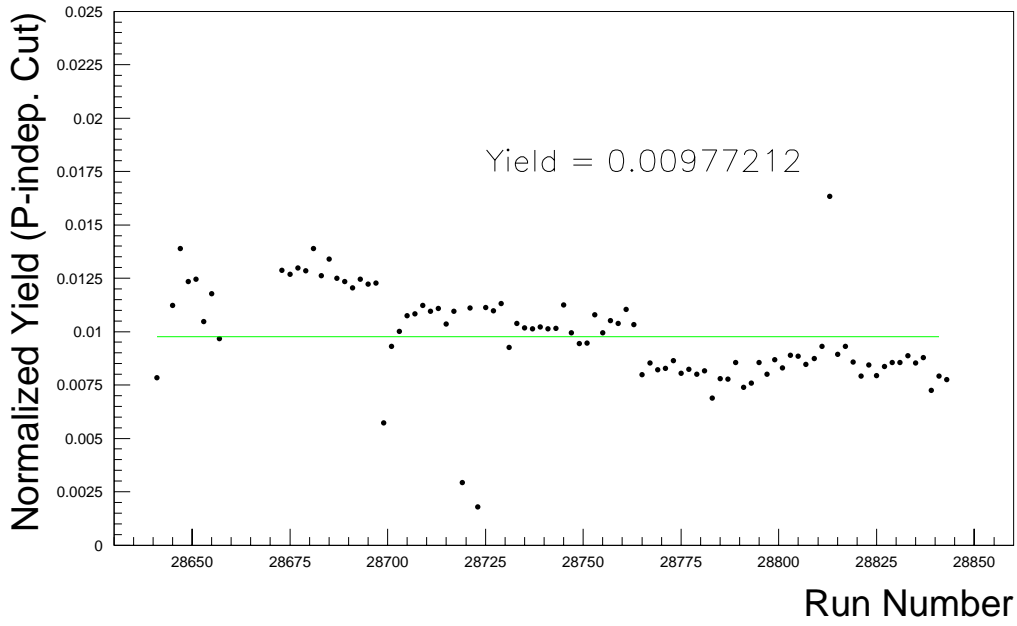


D.4  $K^-$

**Kaon - ( apr04sta ntuples )**



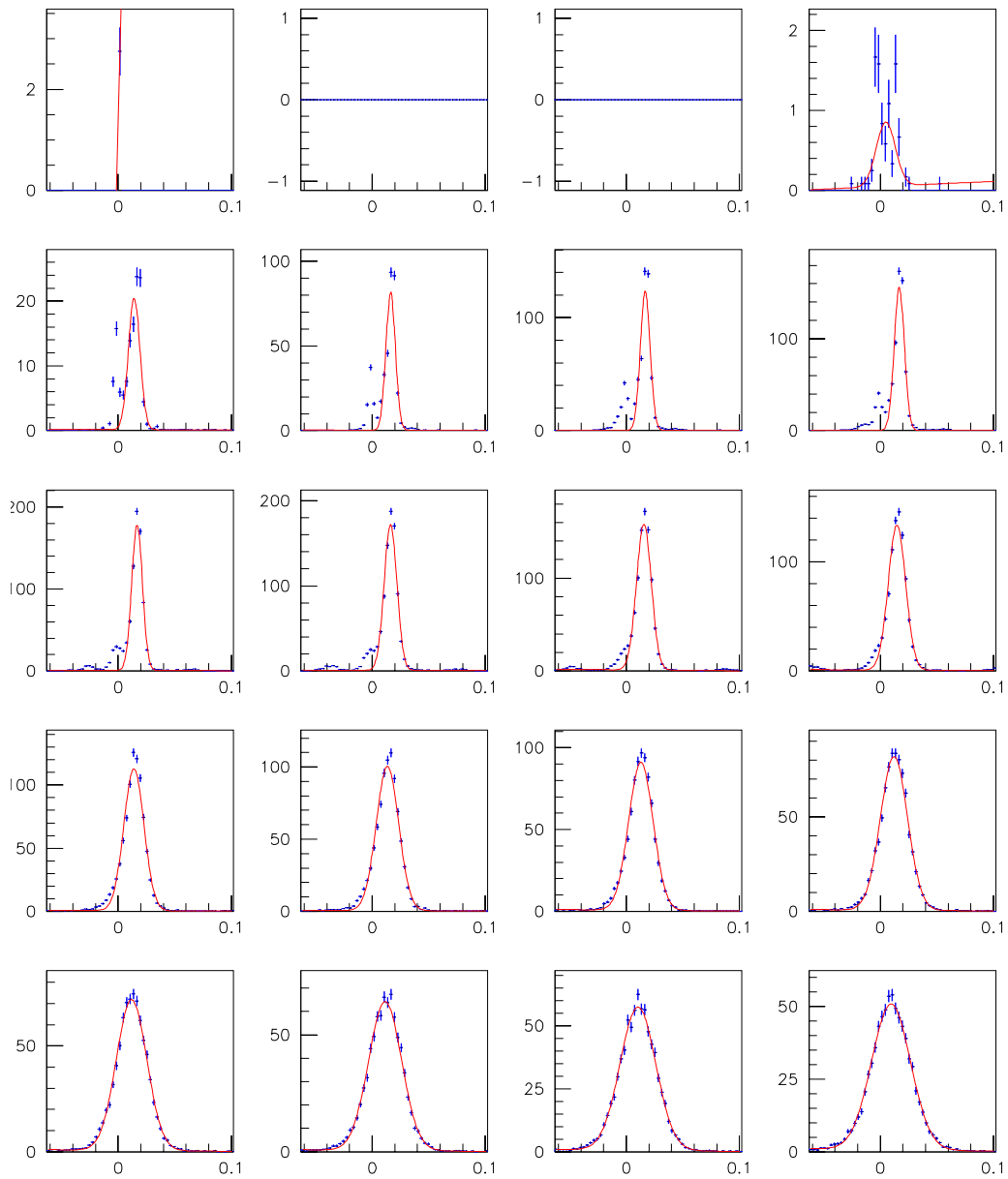
### Proton + ( apr04sta ntuples )



# E Momentum Slice

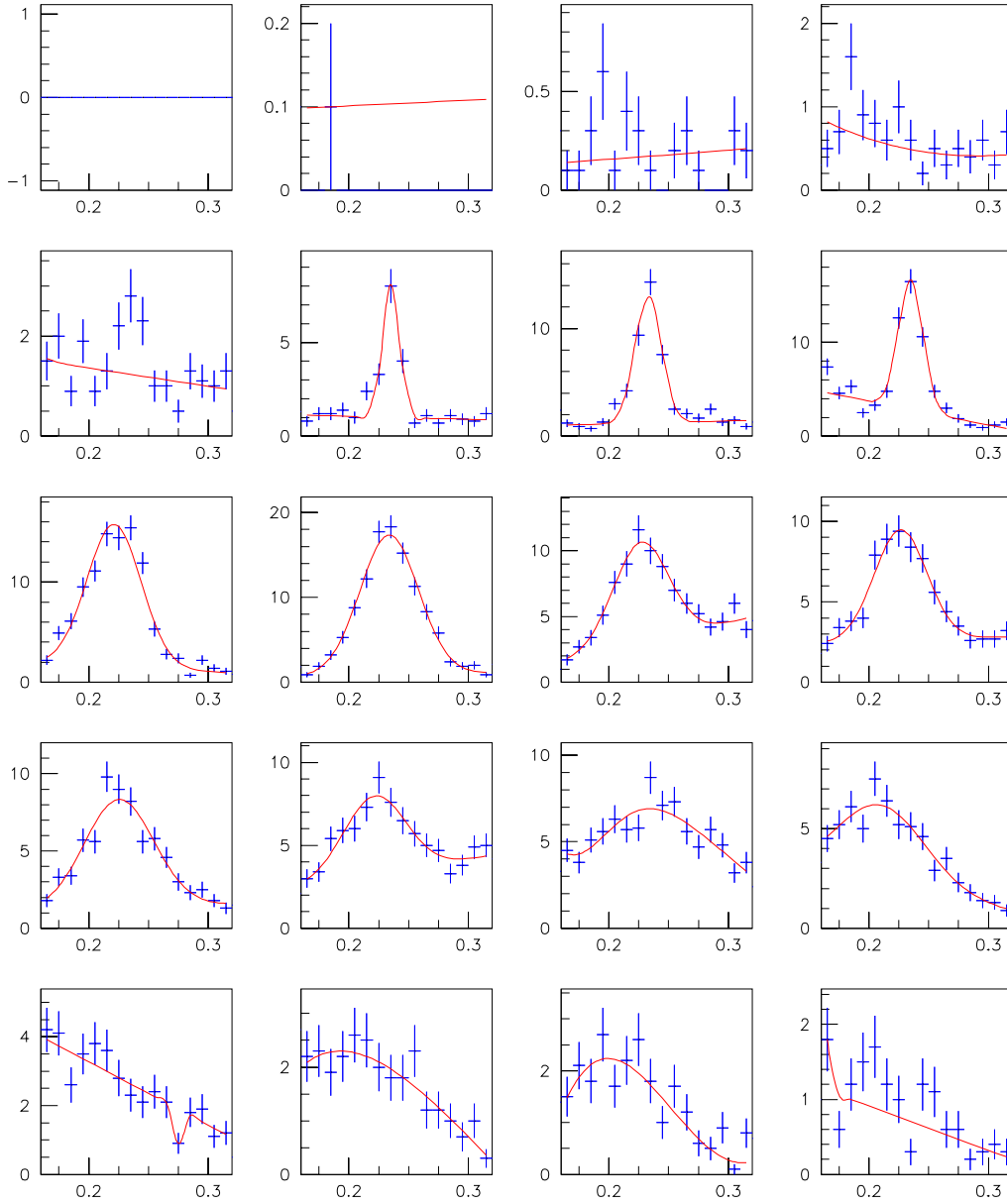
## E.1 Pion

### Pion (apr04rf ntuple)



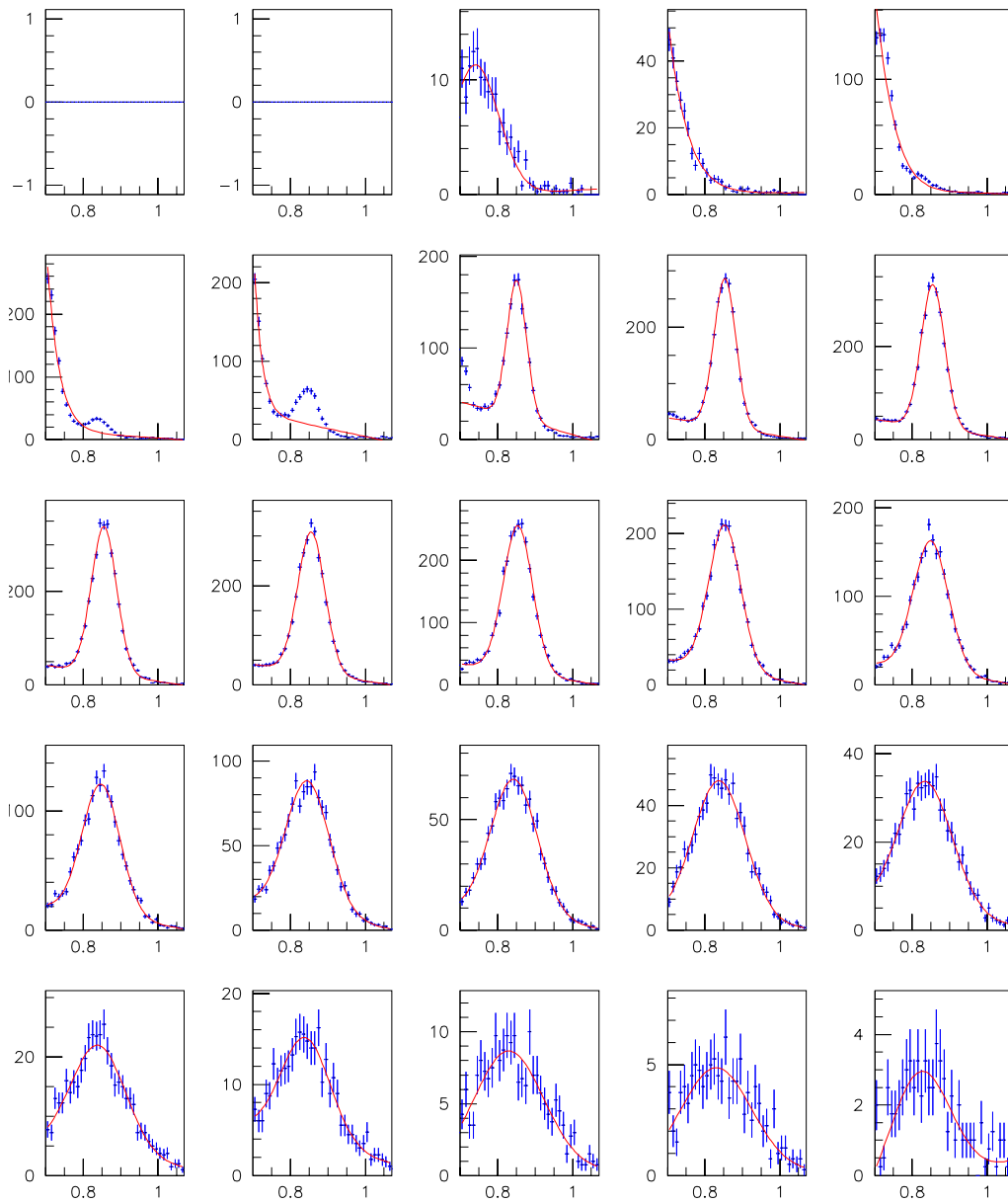
## E.2 Kaon

### Kaon (apr04rf ntuple)



### E.3 Proton

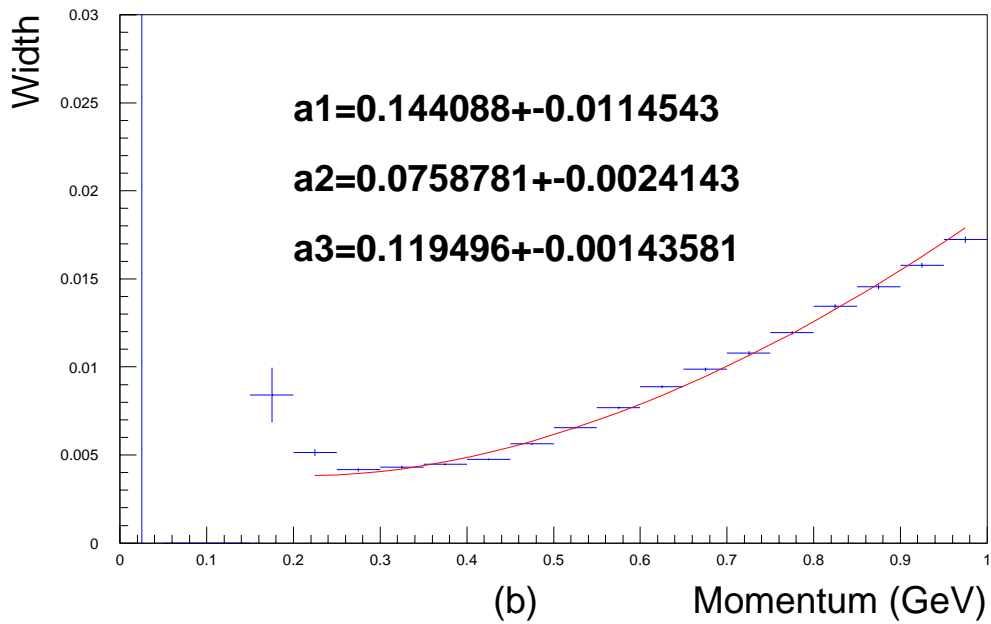
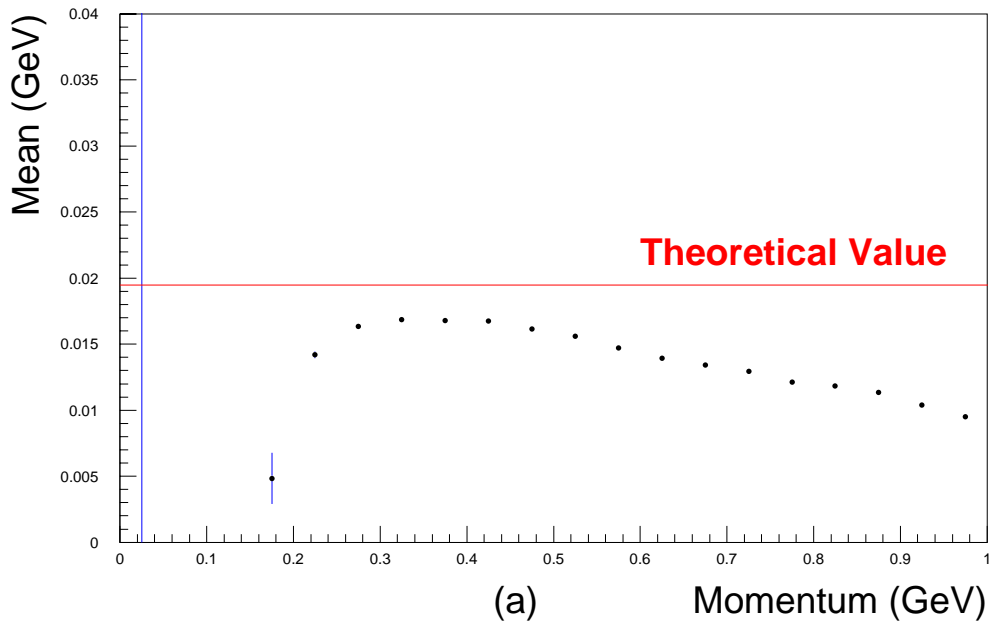
## Proton (apr04rf ntuple)



# F Get Fitting Parameters

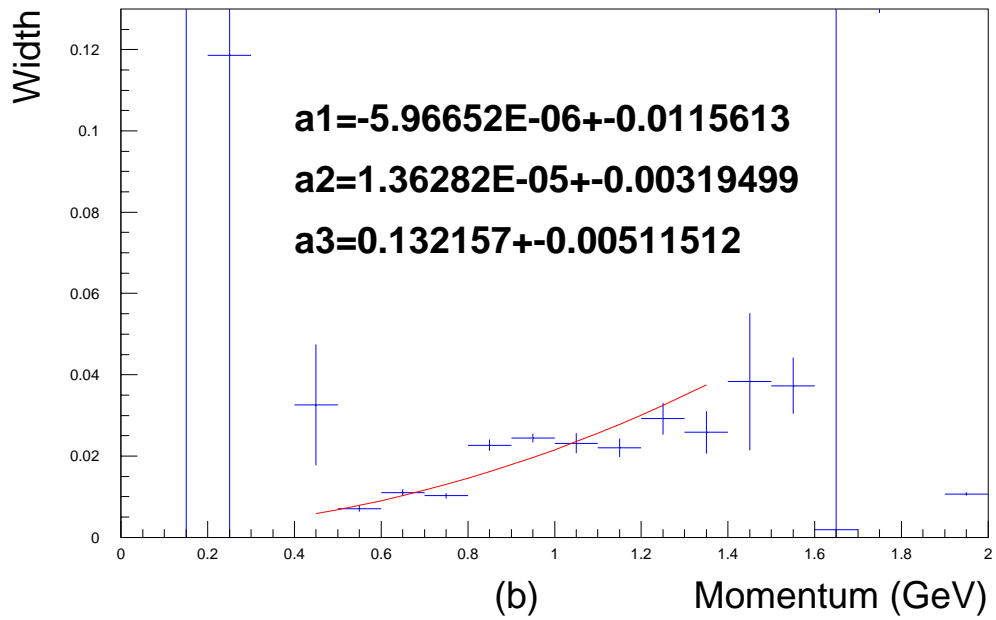
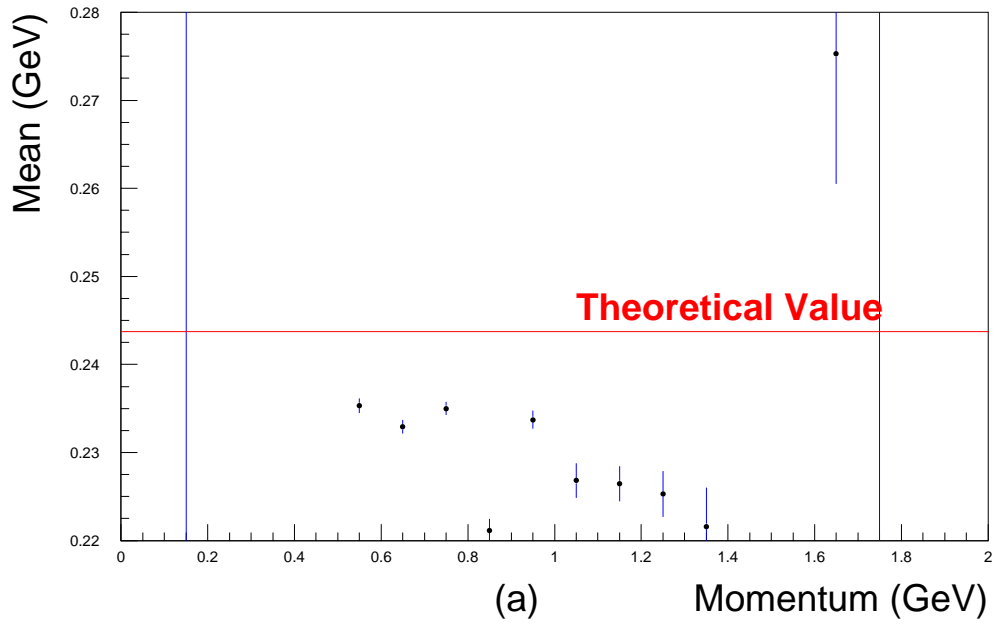
## F.1 Pion

### Pion ( apr04rf ntuples )



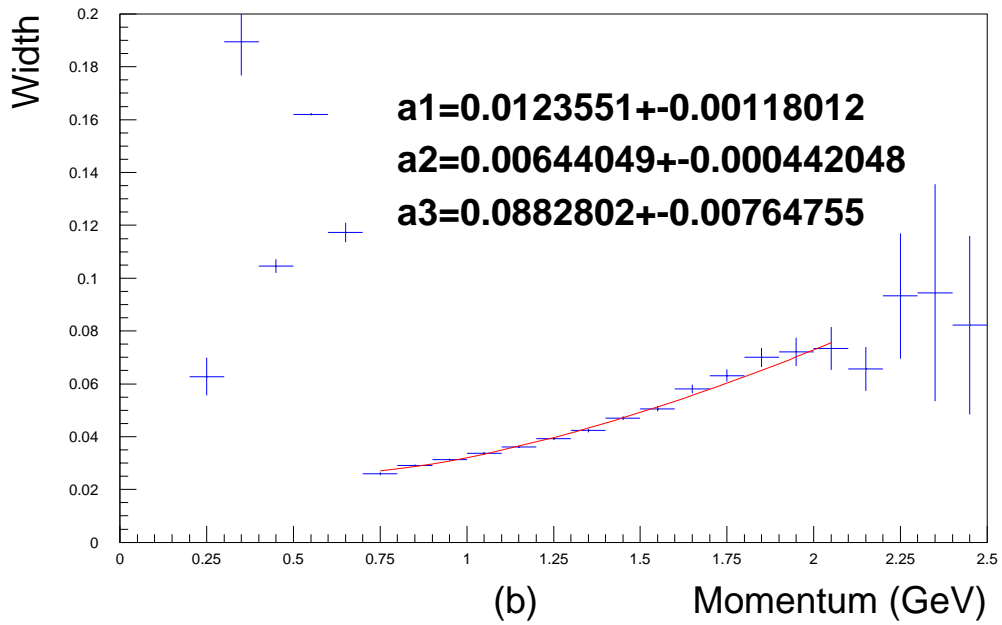
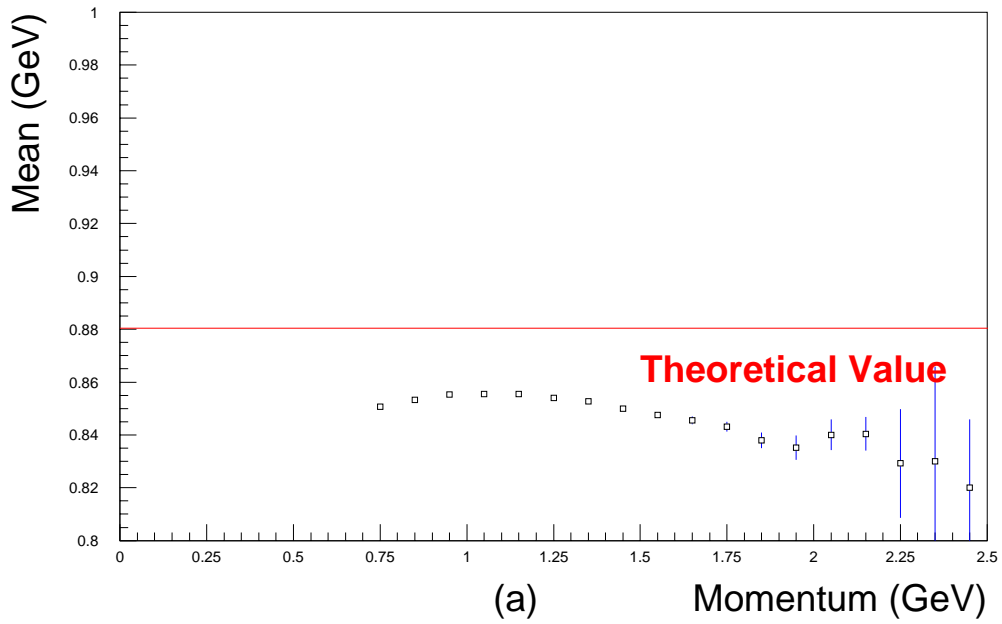
## F.2 Kaon

### Kaon ( apr04rf ntuples )



### F.3 Proton

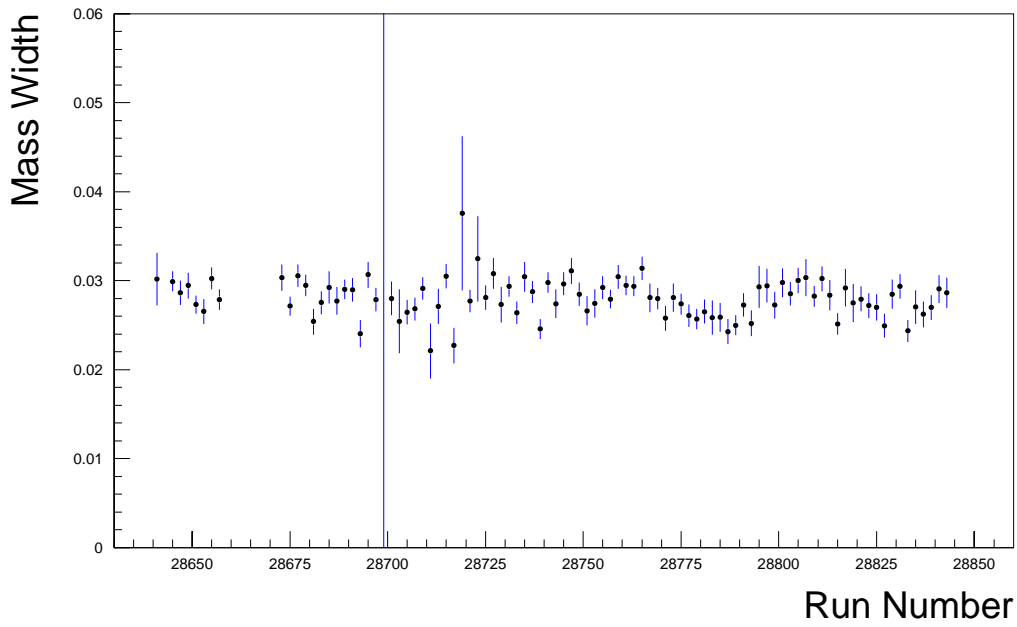
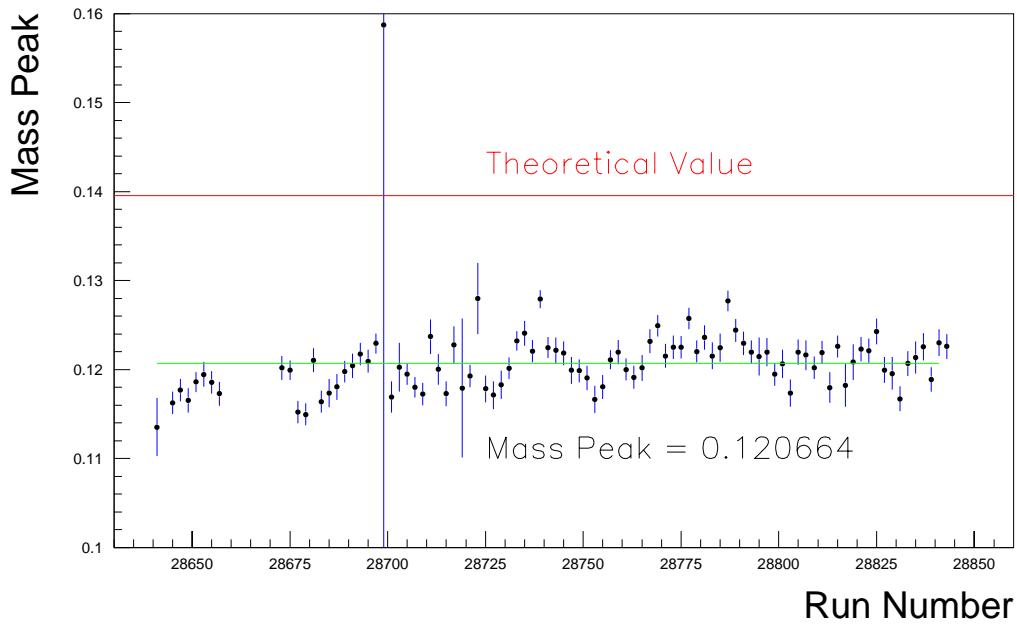
#### Proton ( apr04rf ntuples )



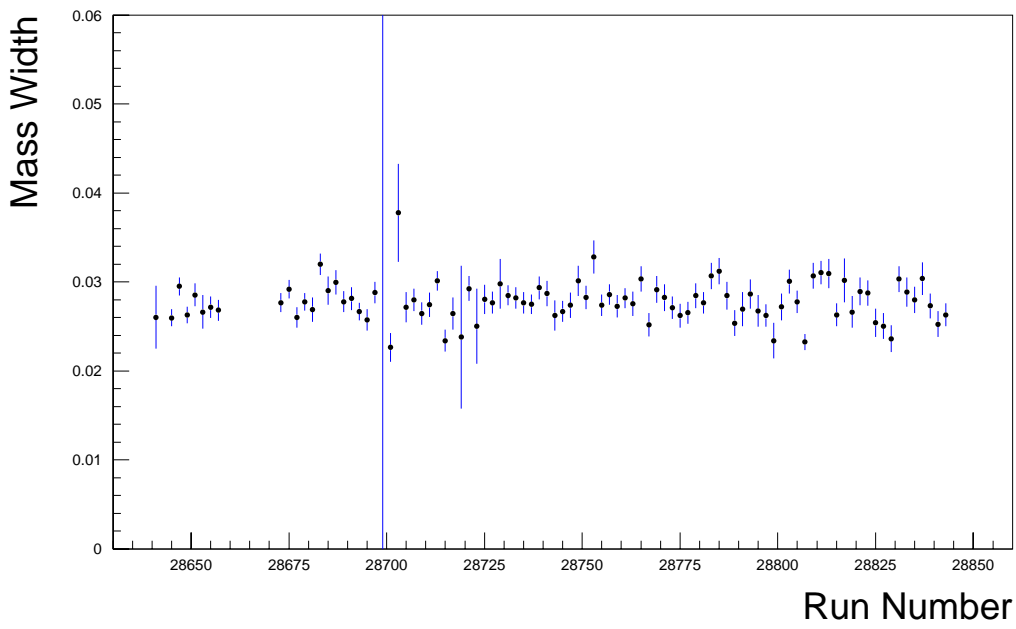
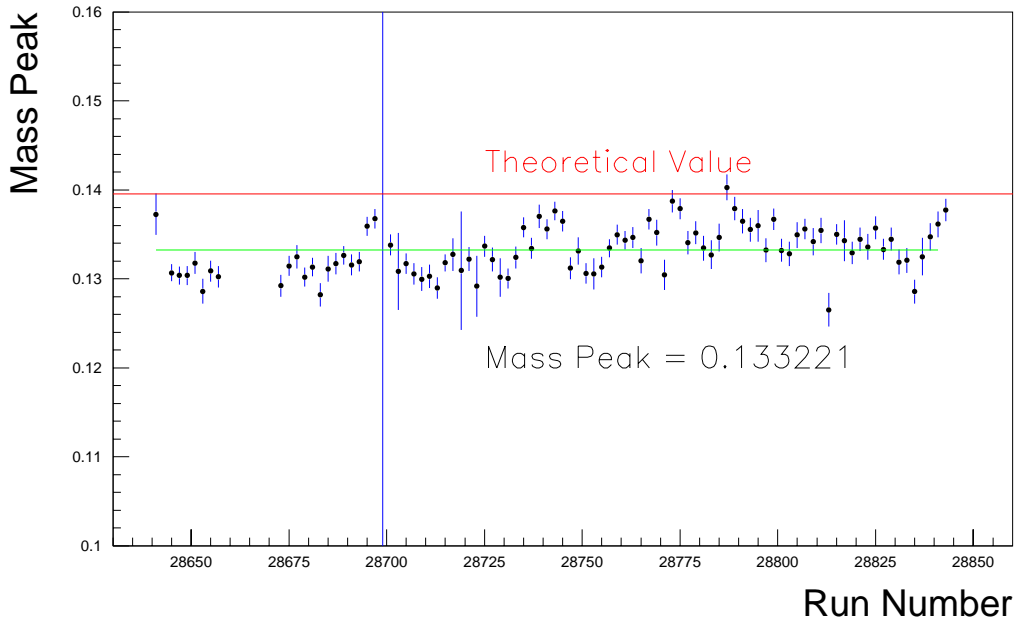
# G Mass Peak and Mass Width

## G.1 $\pi^+$

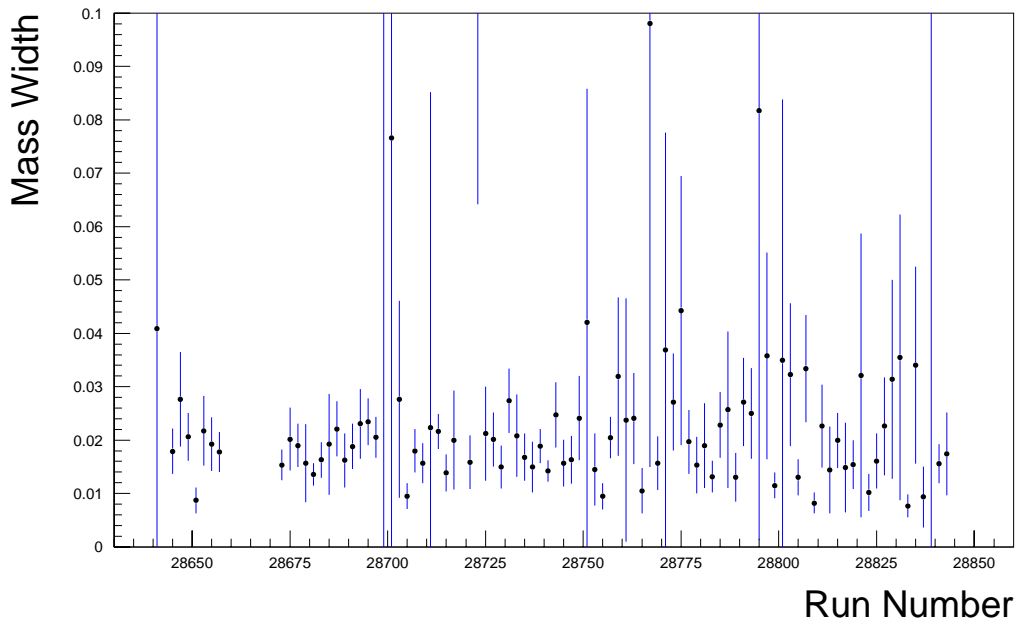
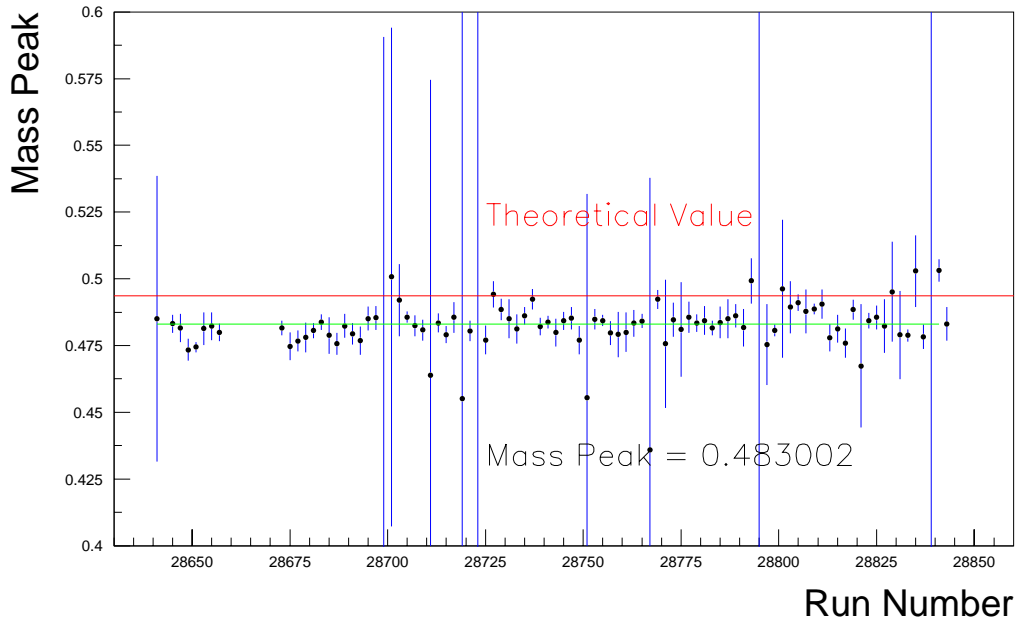
$\pi^+$  ( apr04rf ntuples )

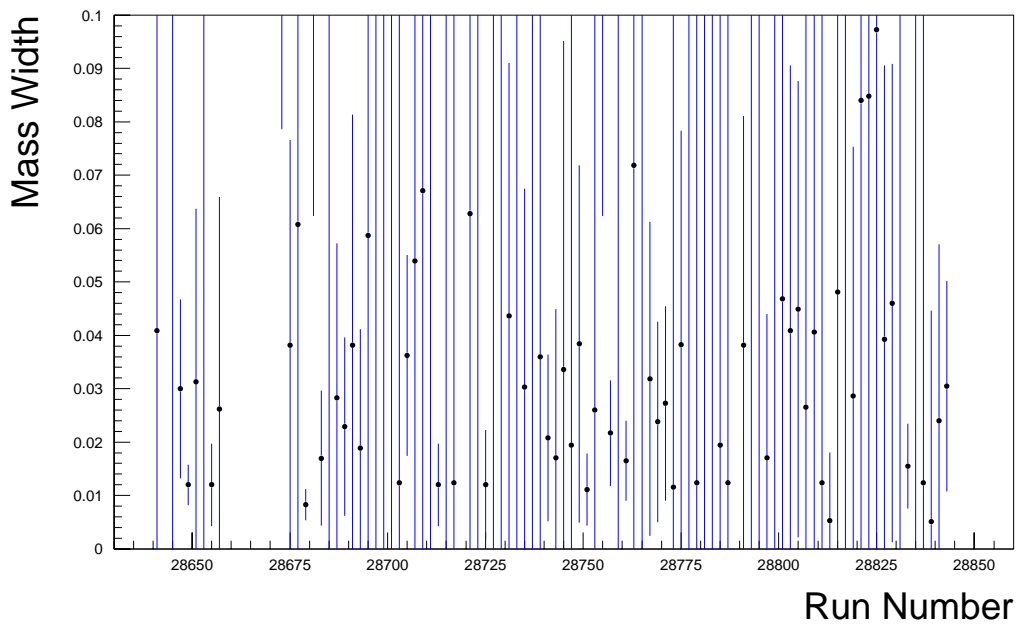
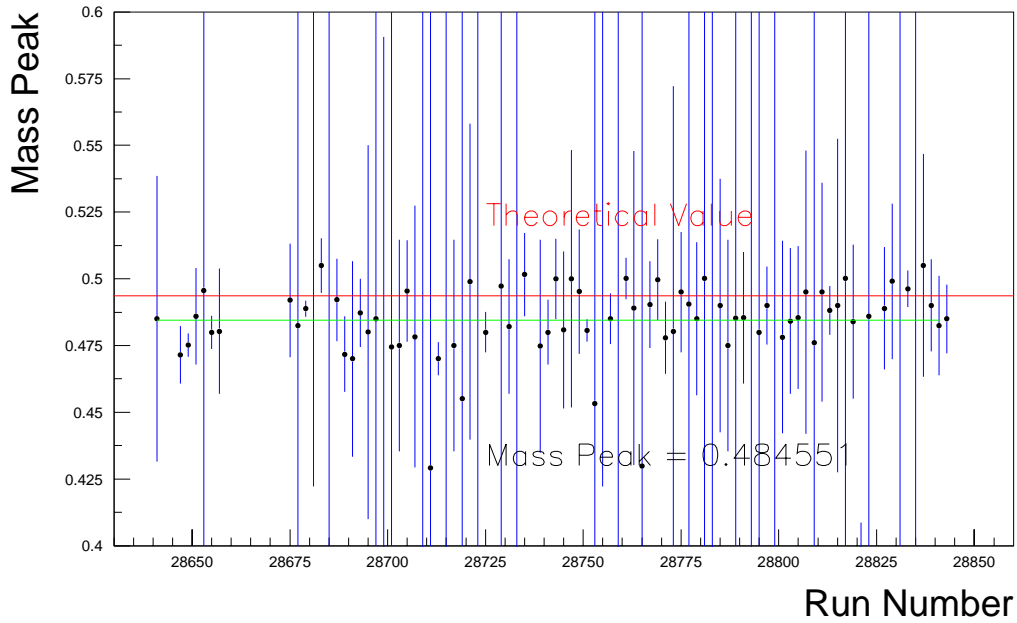


$\pi^-$  ( apr04rf ntuples )

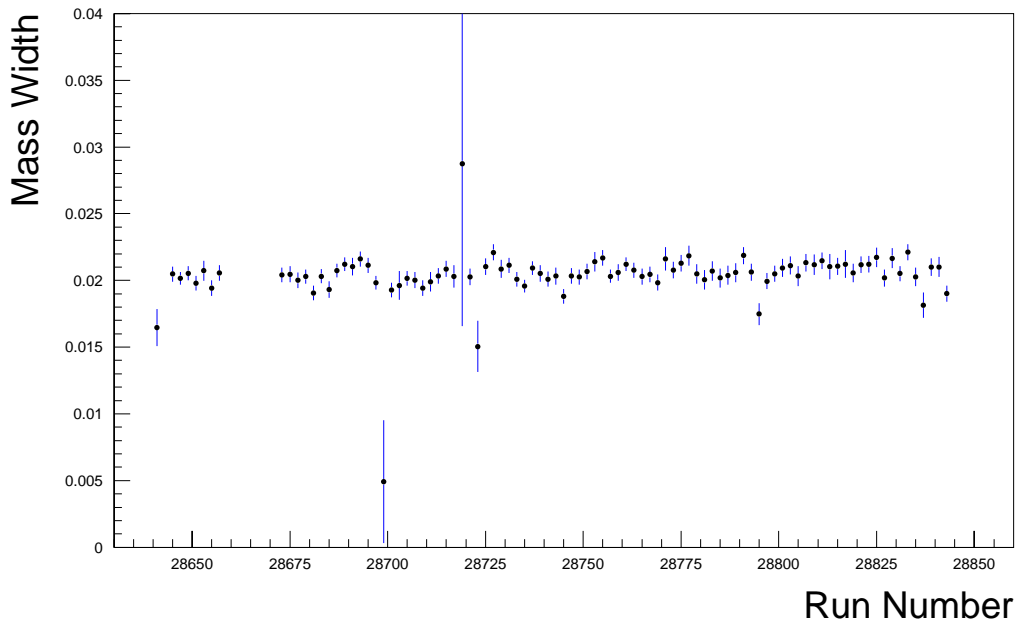
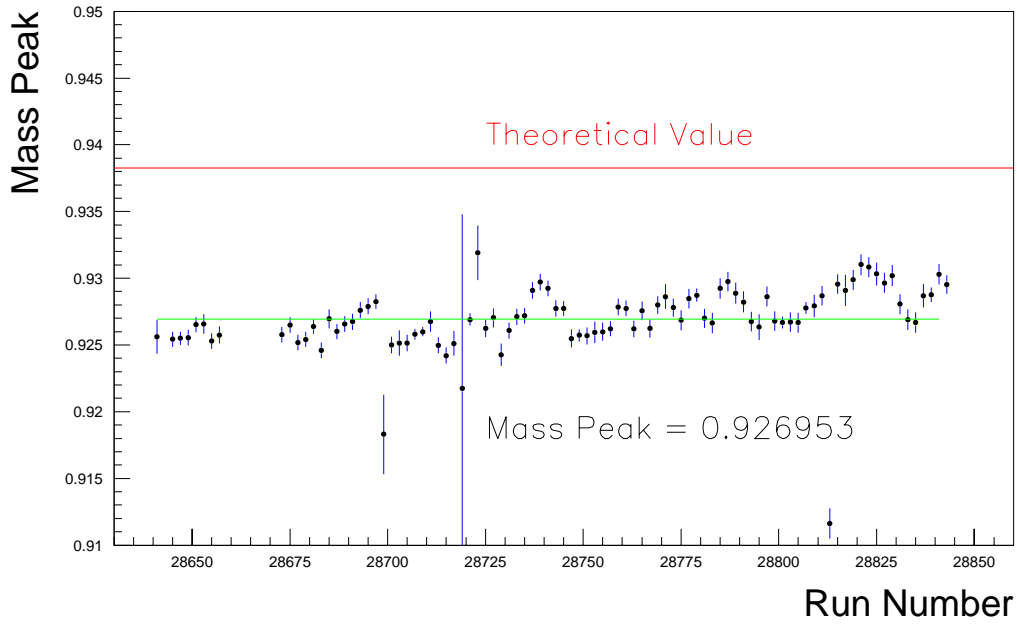


### $K^+$ ( apr04rf ntuples )



$K^-$  ( apr04rf ntuples )

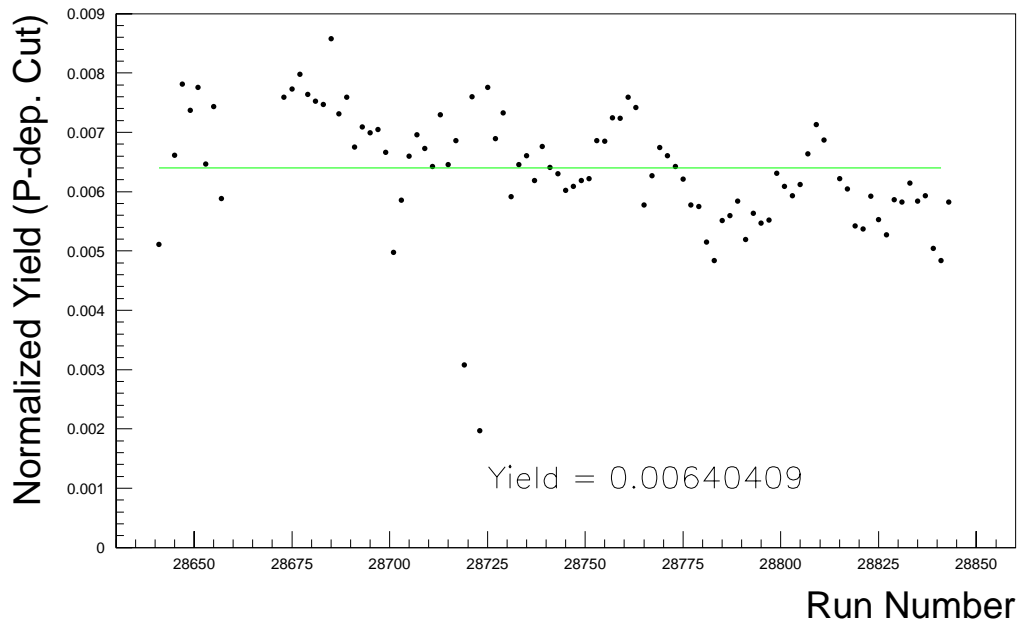
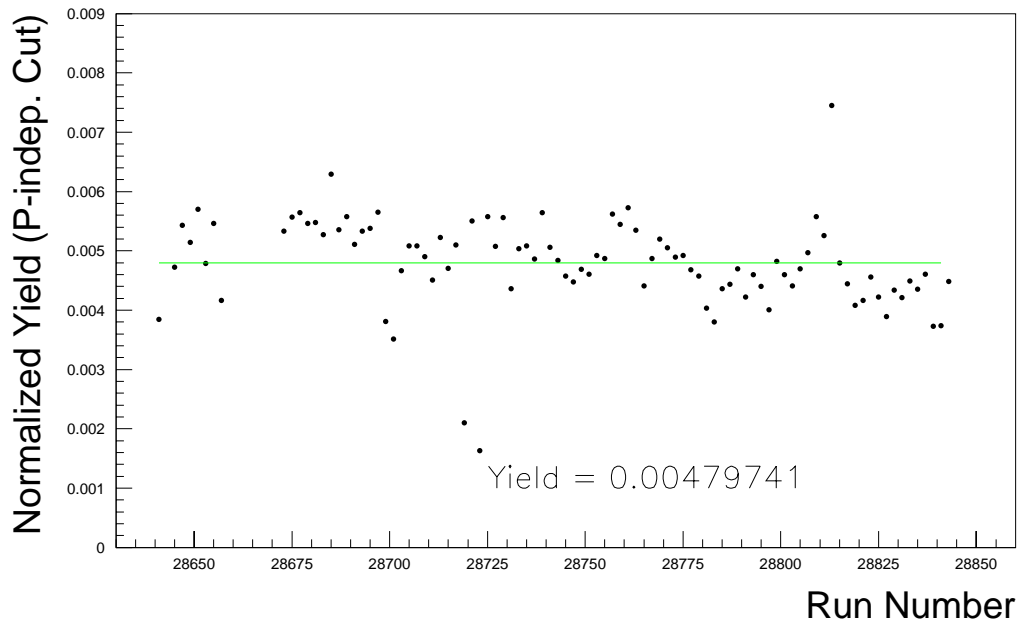
### $P^+$ ( apr04rf ntuples )



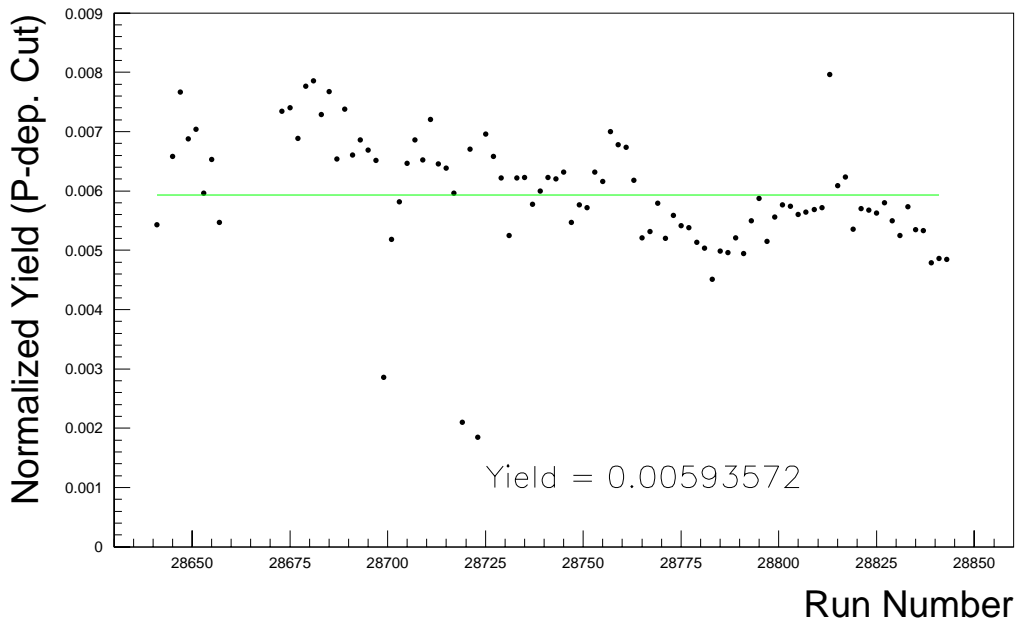
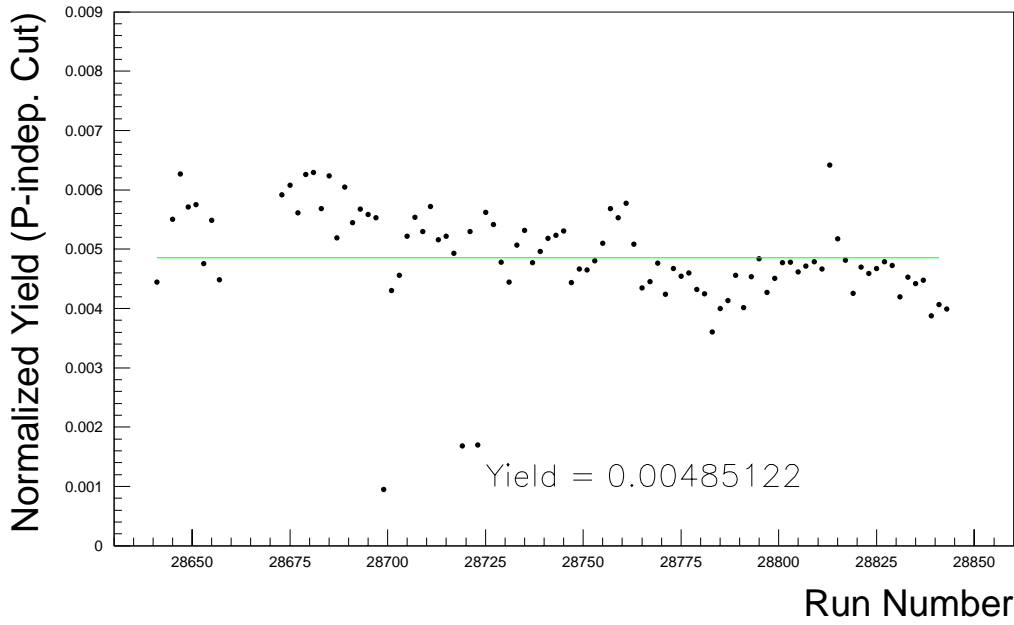
# H Normalized Yields

## H.1 $\pi^+$

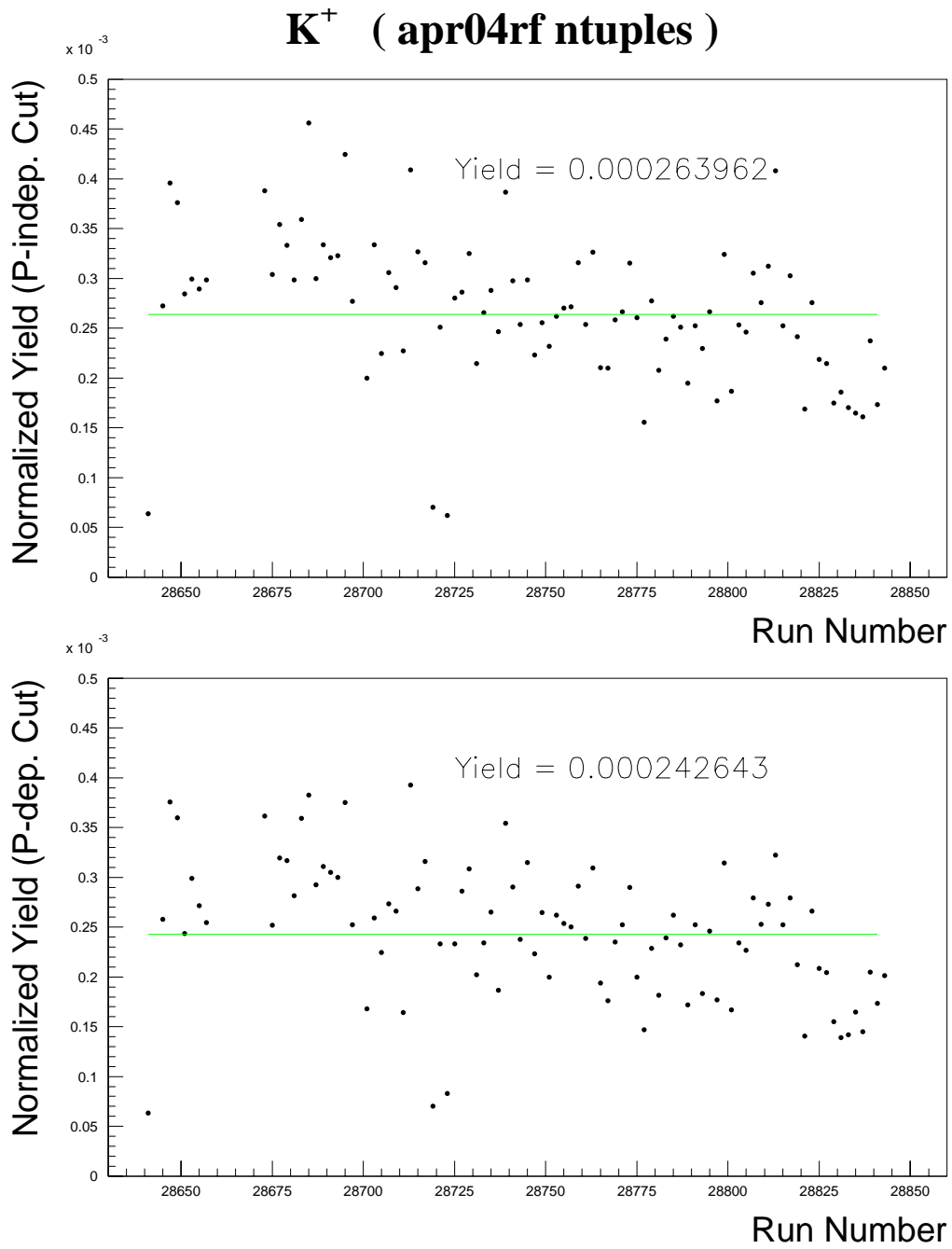
$\pi^+$  ( apr04rf ntuples )



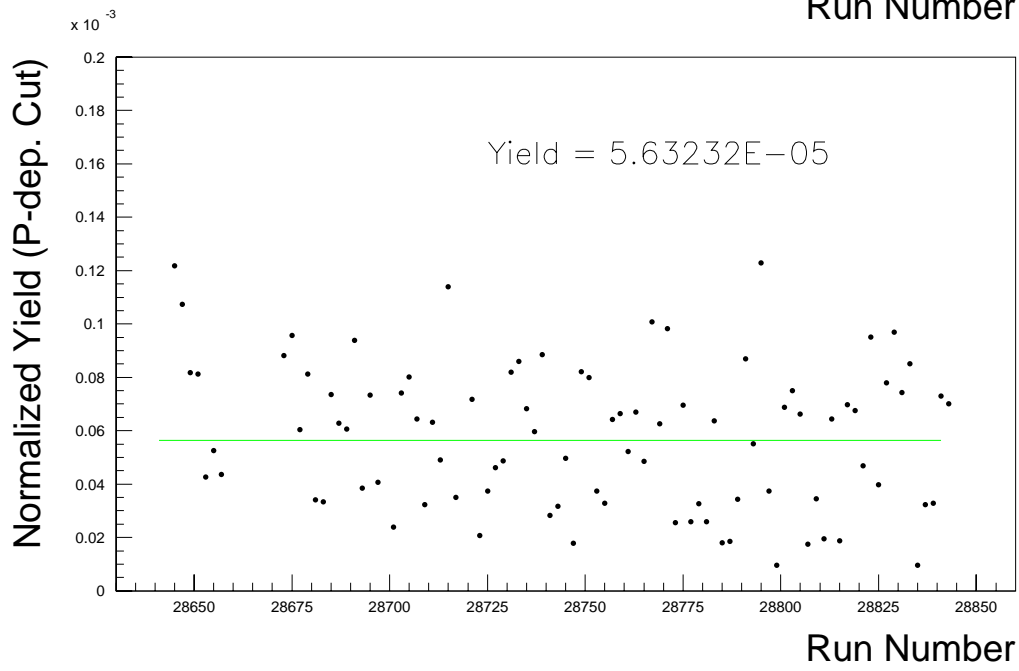
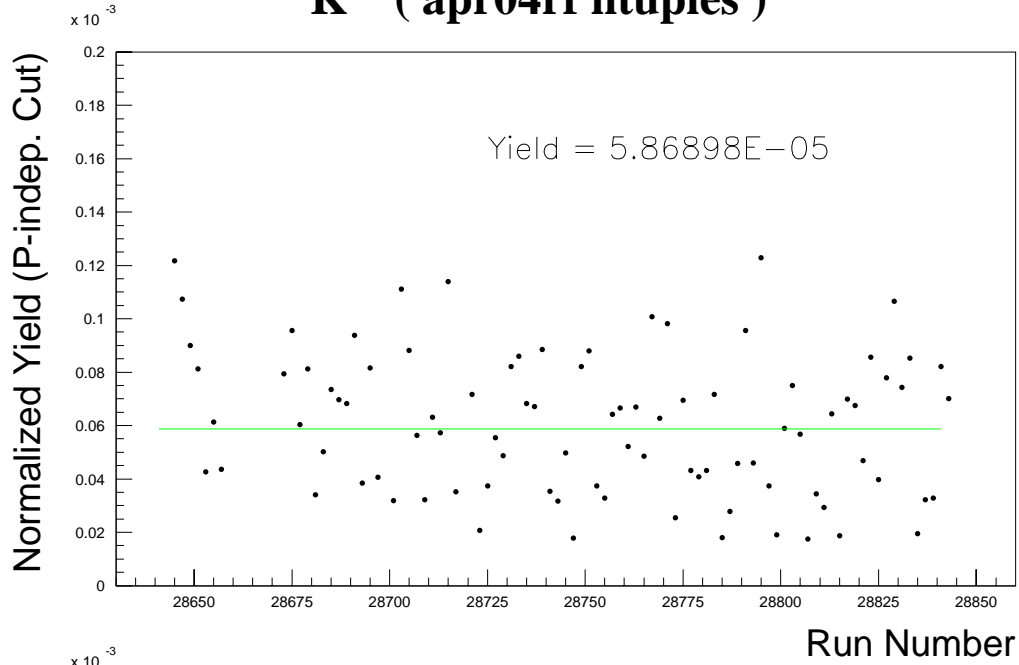
$\pi^-$  ( apr04rf ntuples )



### H.3 $K^+$



### $K^-$ ( apr04rf ntuples )



### $P^+$ ( apr04rf ntuples )

