# D* Reconstruction with HFT

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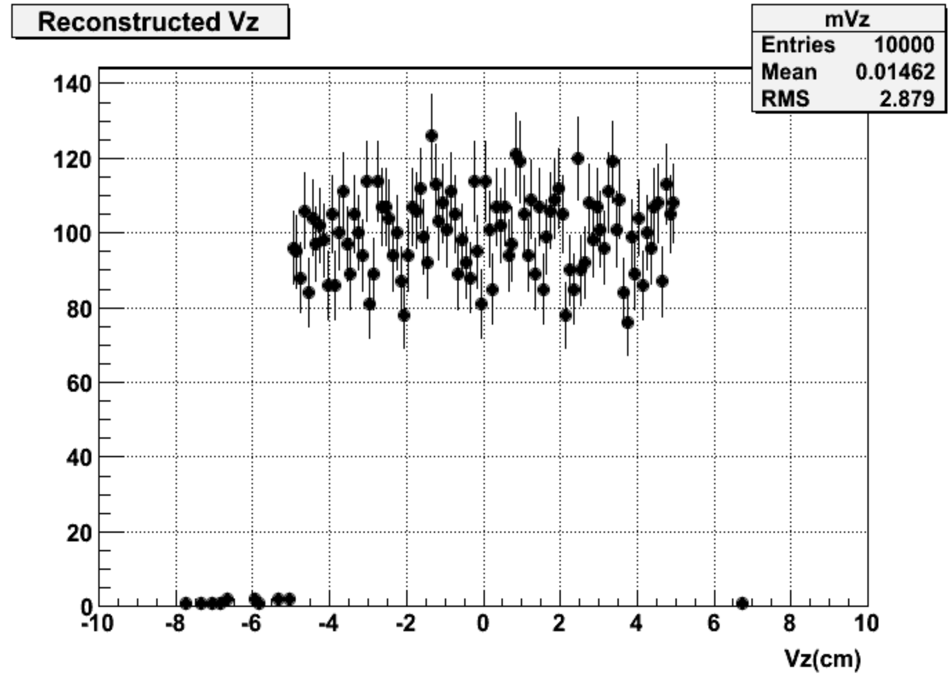
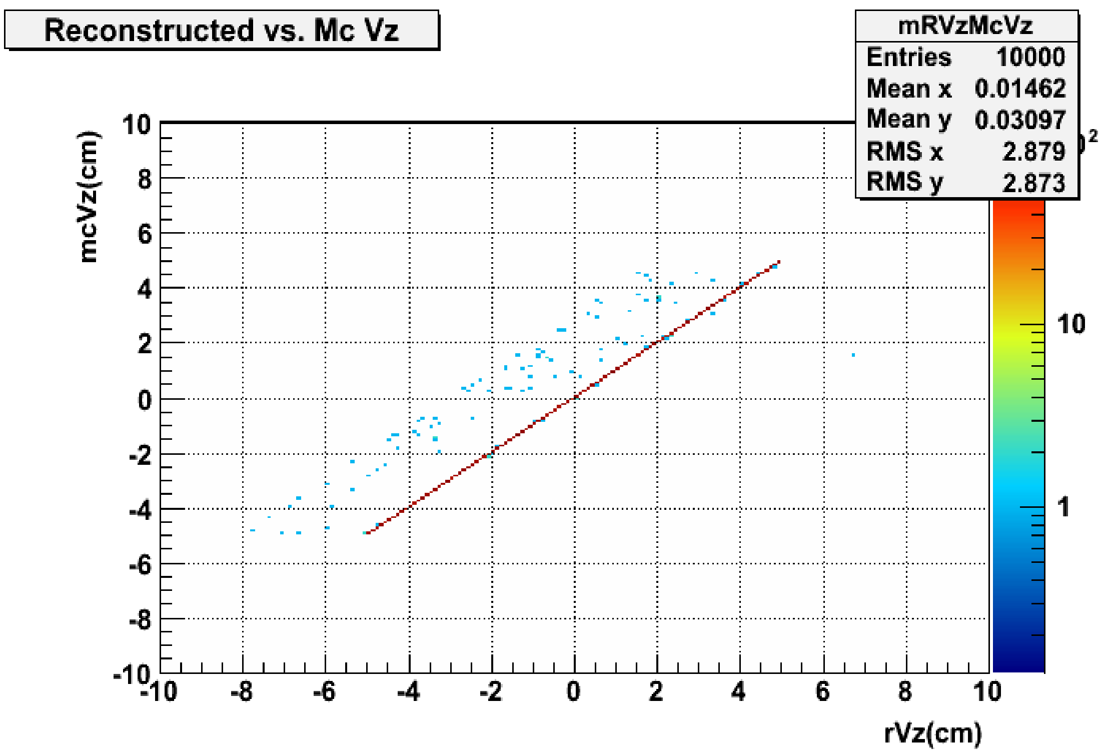
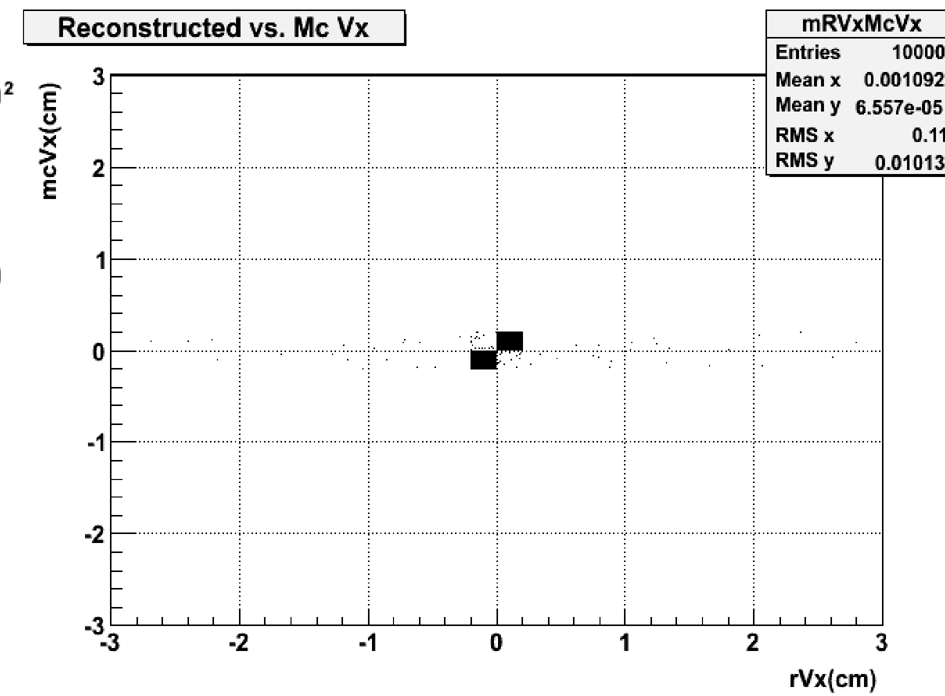
**Data:**

- 10,000 events $|Vz_{MC}| < 5.0$ cm
- 99.9% reconstructed $|Vz| < 5.0$ cm
- 10 D*+ -> D0 + pi+ (0-10 GeV/c flat)
- D* $|\eta| < 1.0$



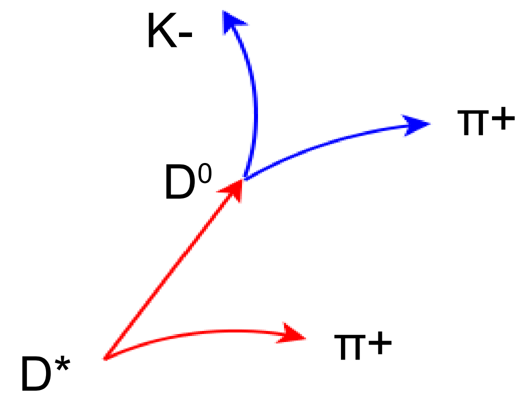



**PID:**

- Assuming Ideal PID for kaons and pions
- Global tracks for $D^0$ and primary tracks for the soft pion

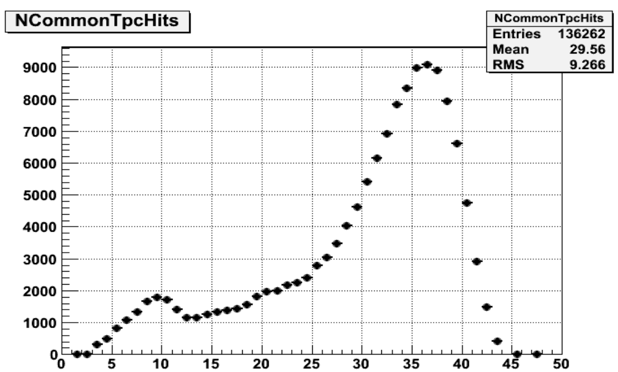
| Track Quality Cuts | |
|---|---|
| NumberOfFitPoints | >15 |
| NumberOfFitPoints/NumberOfPossiblePoints | >=0.52 |
| pT | >0.2 |
| Kaons & Pions \|η\| | <1.0 |

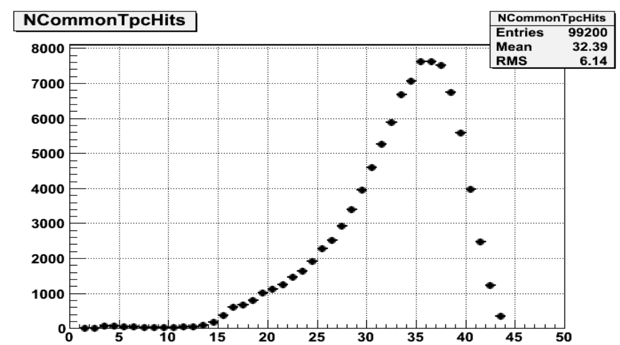



Before Track Cuts

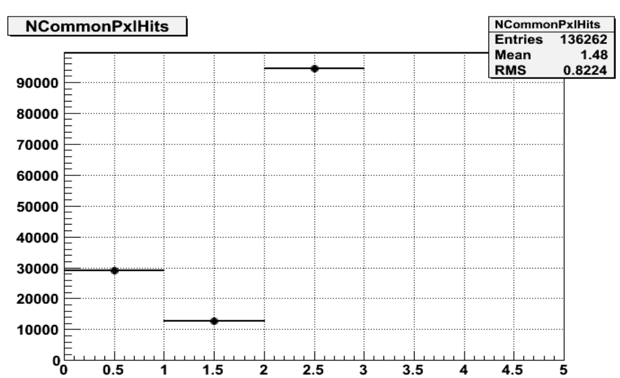
After Track Cuts

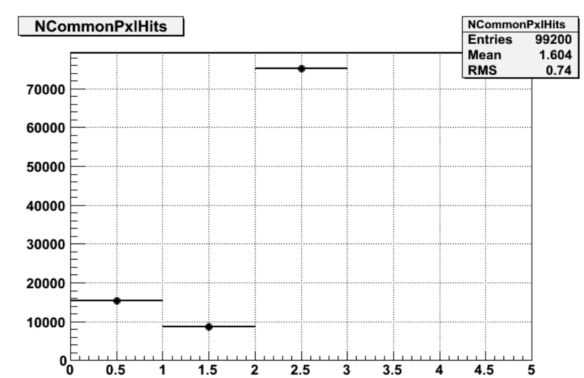
# common MC and RC TPC hits




# common MC and RC PXL hits



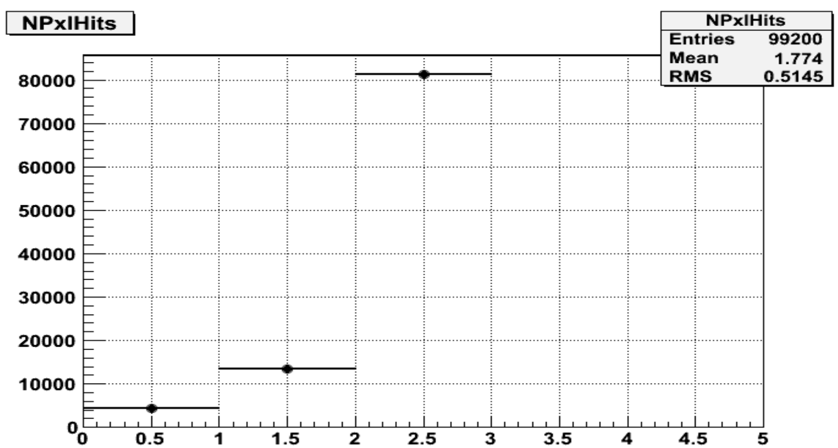

Plots above for $D^0$ daughter kaons and pions

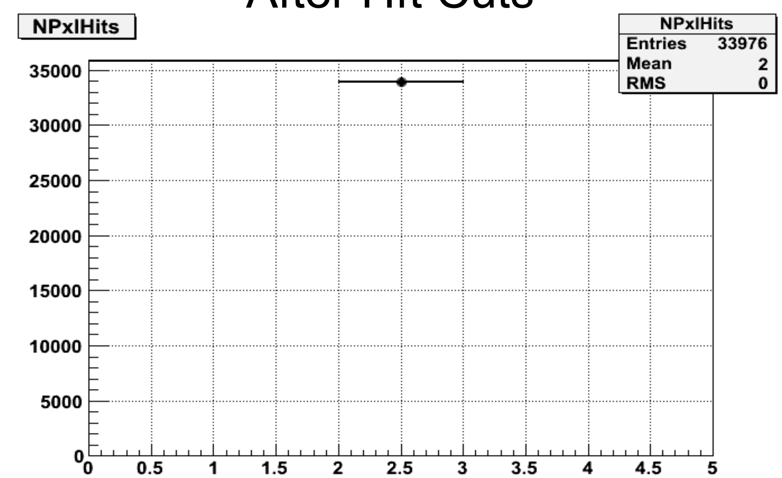
| $D^0$ HFT cuts from CDR | |
| --- | --- |
| PIXEL hits | 2 |
| DCA (primary vertex) | >= 50 μm |
| DCA_kπ | <= 50 μm |
| cos(θ) | >=0.98 |
| Δm | <= 35 MeV/c^2 |

Before Hft Cuts

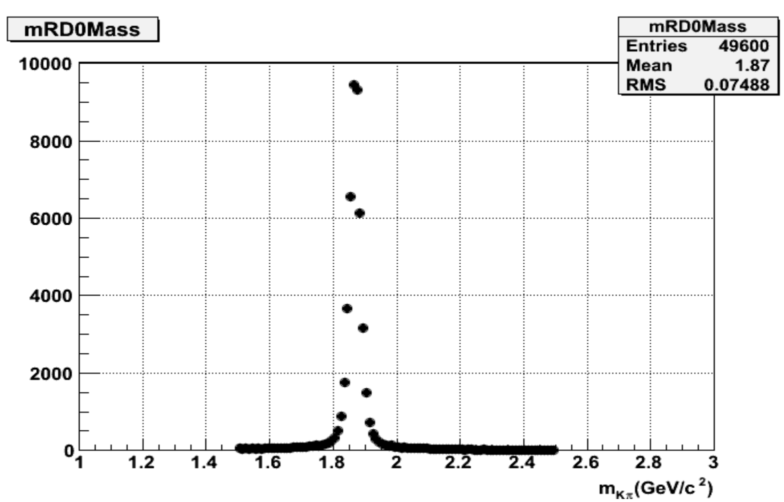
After Hft Cuts

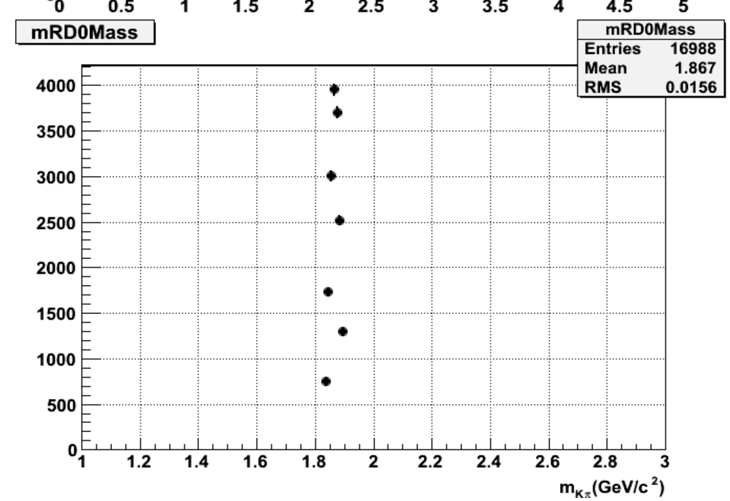
# PXL hits

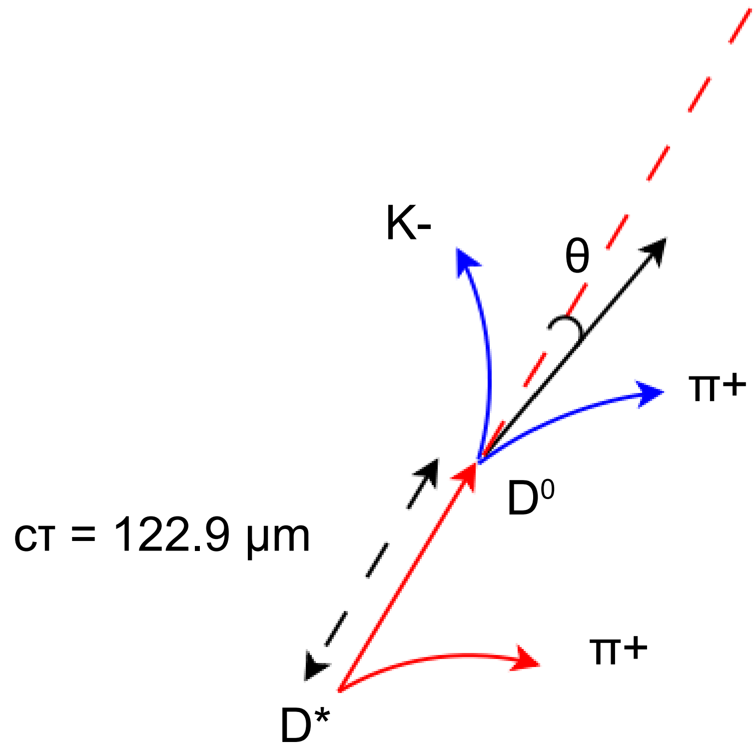



Reco. $D^0$ Mass



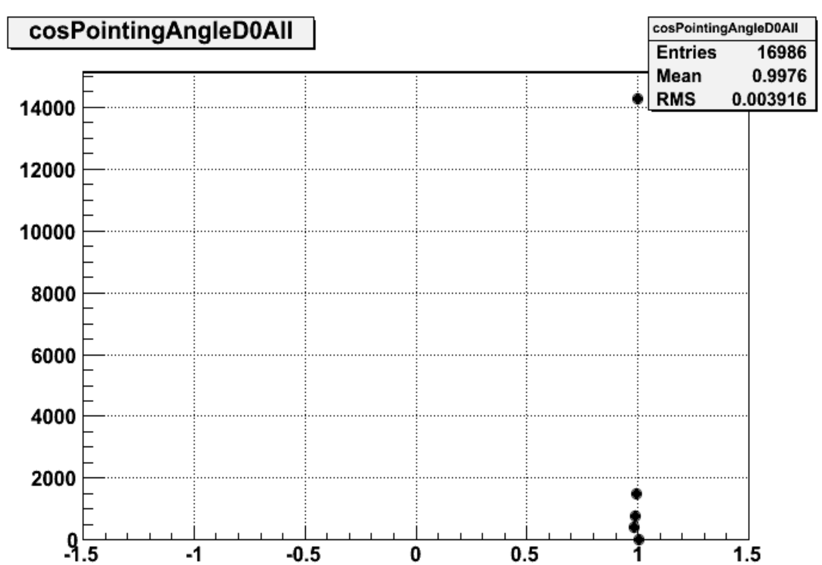



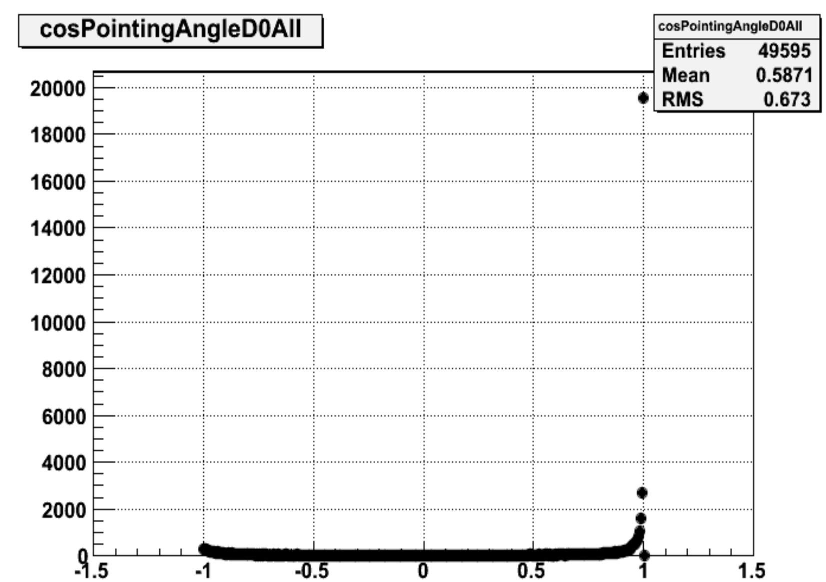



Before HFT Cuts

After HFT Cuts

cos(θ)



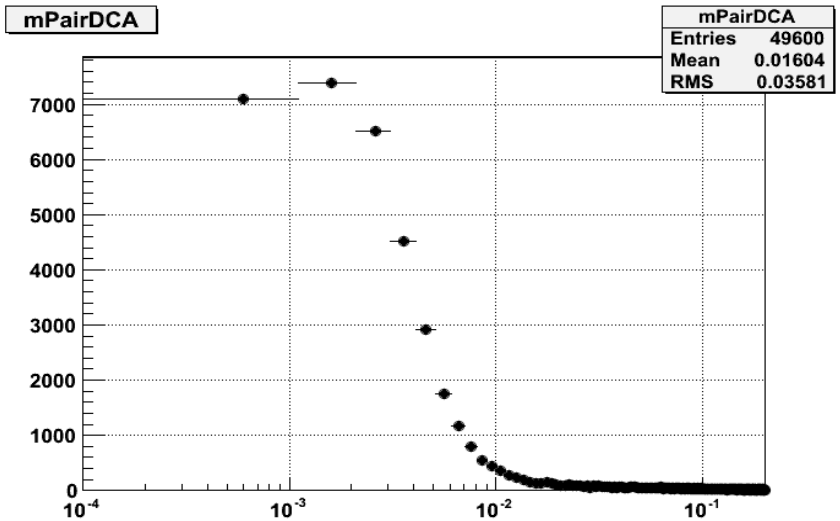


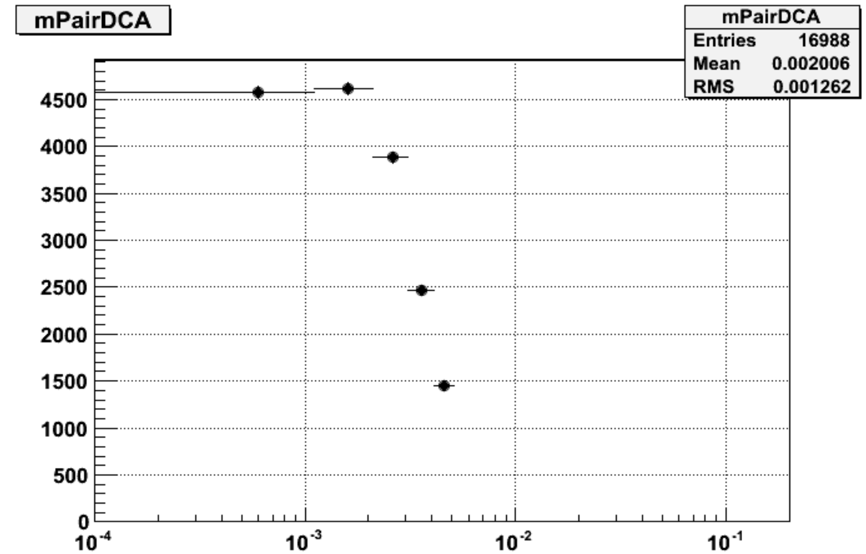

Plots above for $D^0$ daughter kaons and pions

Before HFT Cuts

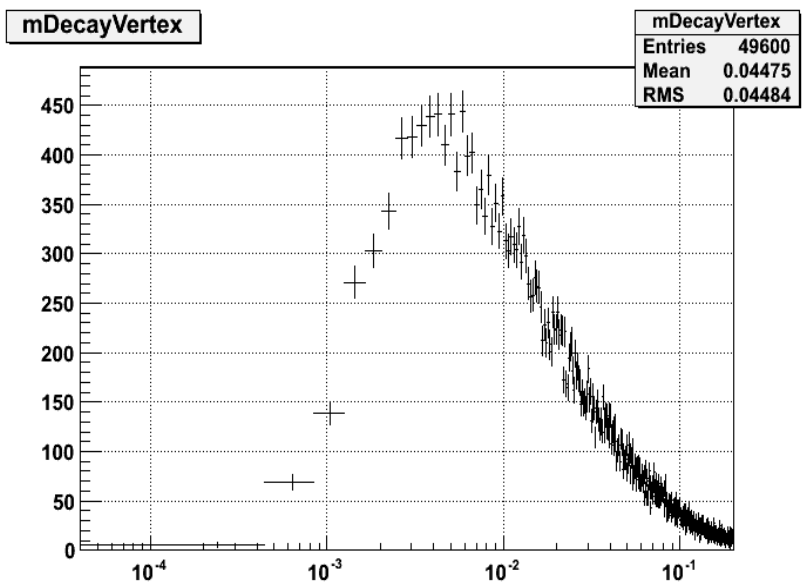
After HFT Cuts

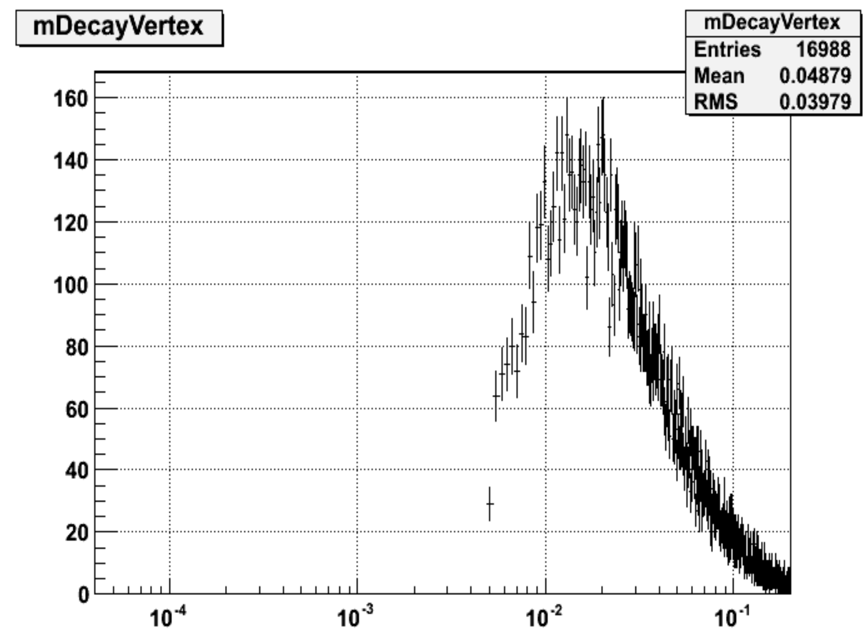
DCA_kπ




DCA
(primary vertex)





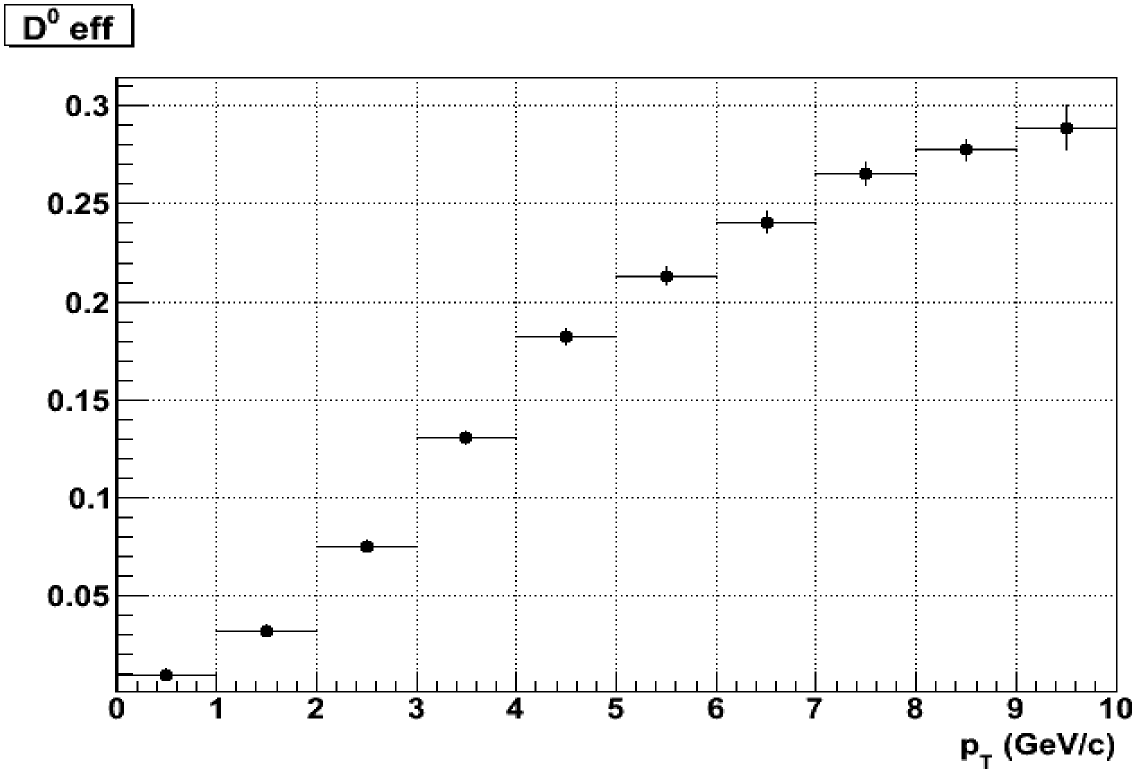

Plots above for $D^0$ daughter kaons and pions

# $D^0$ Efficiency

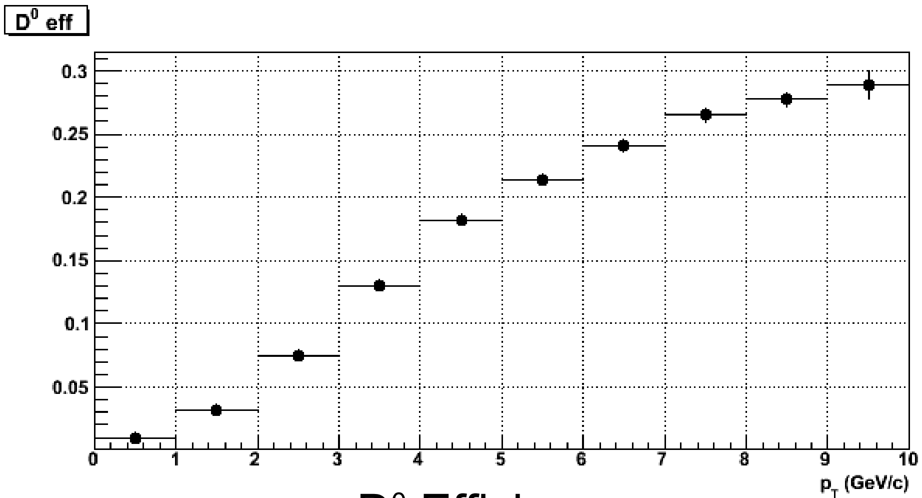
**Procedure:**

1) Find $D^0$ reconstructed kaons and pions which pass the track quality cuts
2) Reconstruct the $D^0$ mass by swimming global tracks
3) Calculate efficiency in each pT bin

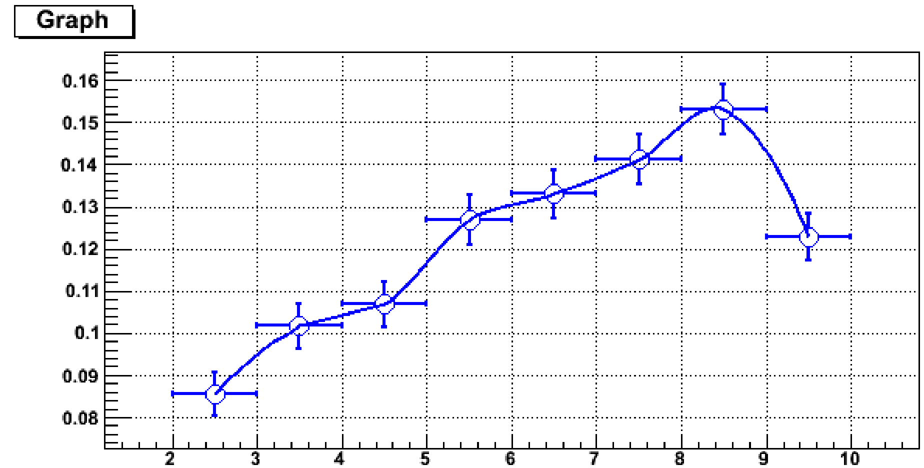
$$eff(p_T) = \frac{\frac{dN(D^0_{reco})}{dp_T}}{\frac{dN(D^0_{input})}{dp_T}}$$



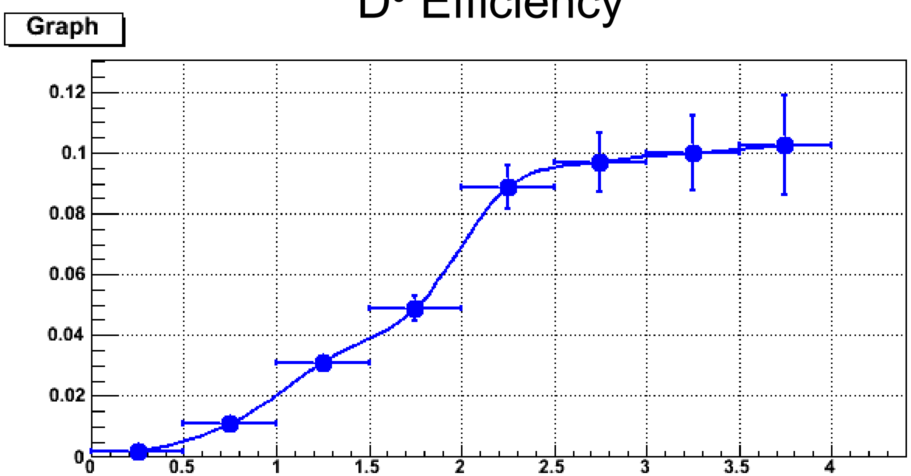
# Comparison to Yifei's CDR $D^0$ efficiency



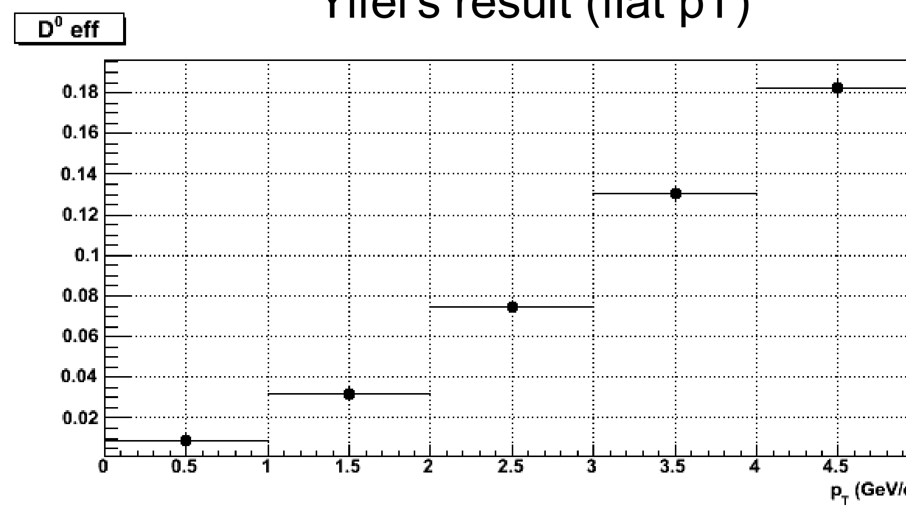

$D^0$ Efficiency




Yifei's result (flat pT)




Yifei's result real pT



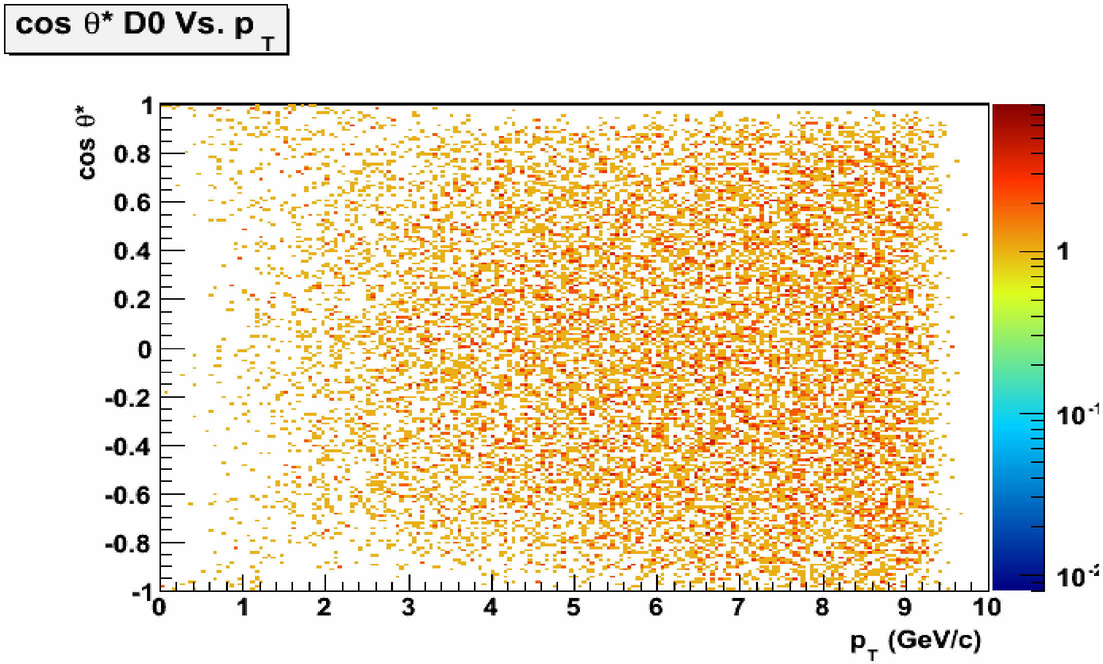

Zoom in on the efficiency plot

Note: Yifei used TOF PID

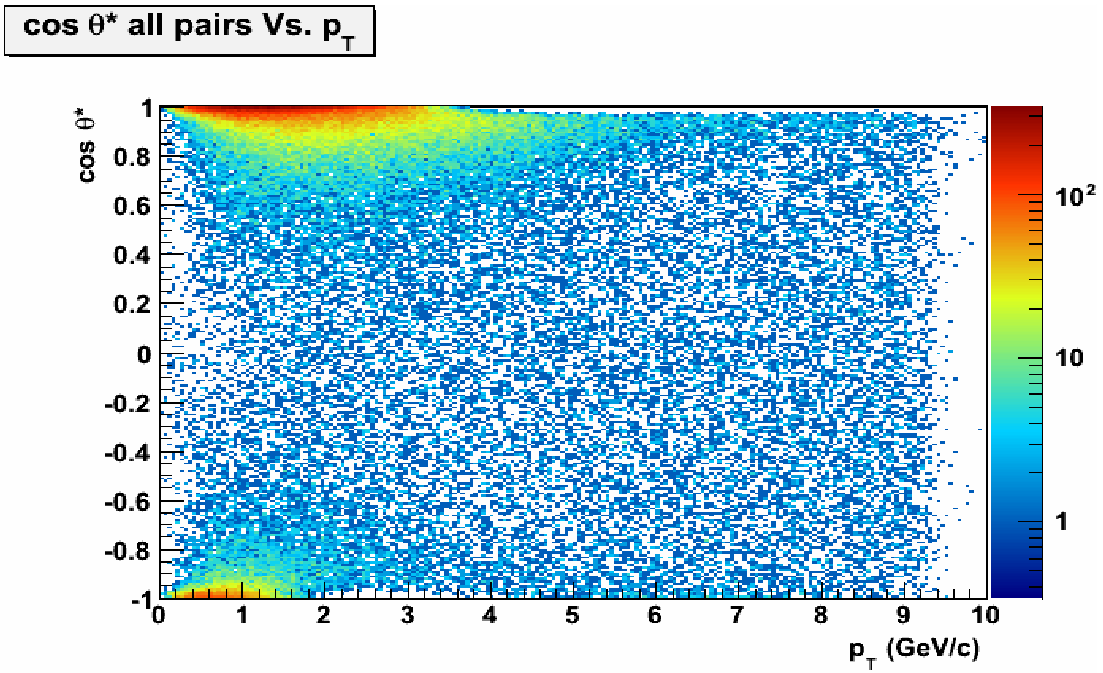
# Suggested more cuts

θ* is the angle between the kaon momentum in the D0 rest frame and the D0 momentum in the lab frame

cos(θ*) for D0 which passed the HFT cuts

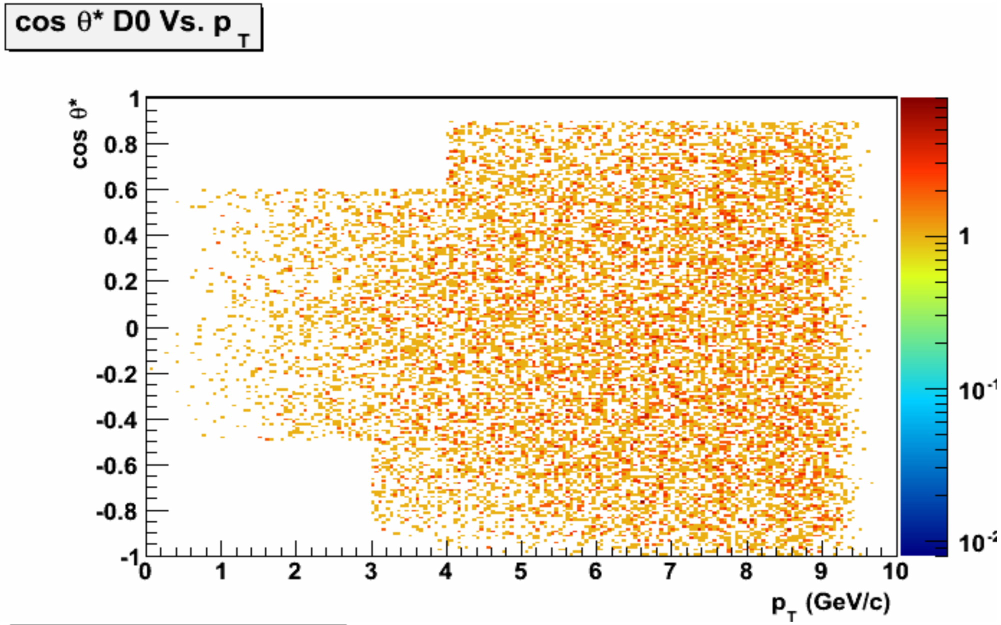



cos(θ*) for $k^{-}\pi^{+}$ which passed the HFT cuts

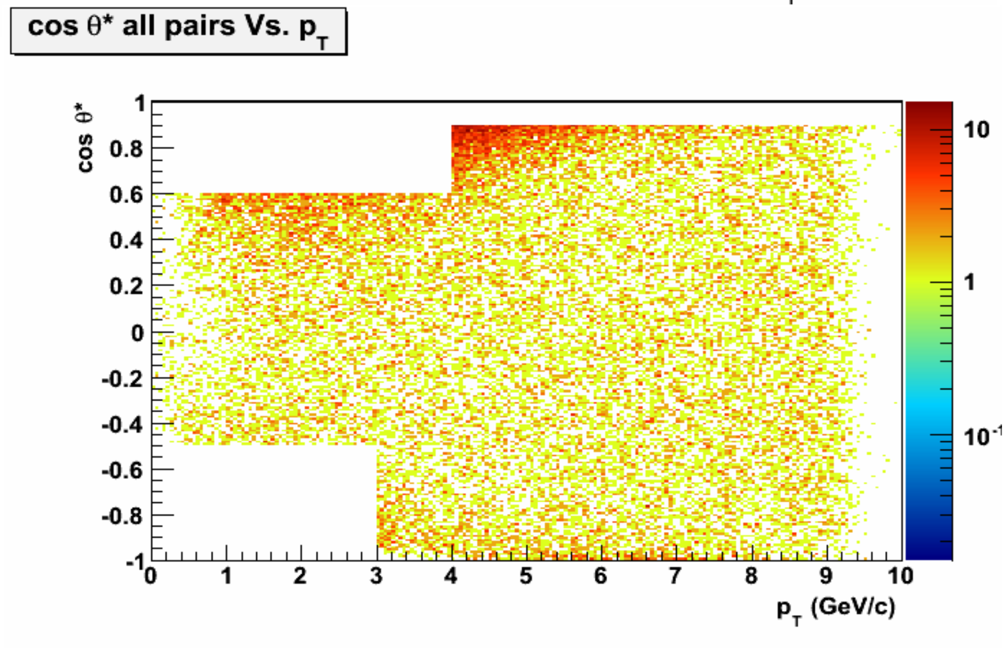


Rejected all kπ pairs which have:
1) cos(θ*) > 0.90
2) pT<4.0 && cos(θ*)>0.6
3) pT<3.0 && cos(θ*)<-0.5

cos(θ*) for D0




cos(θ*) for all pairs



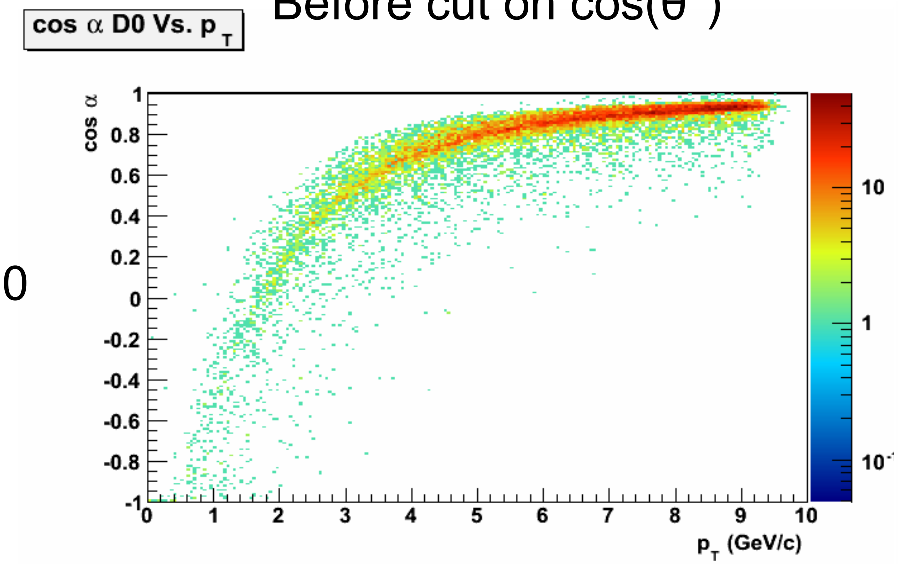
# Opening angle α

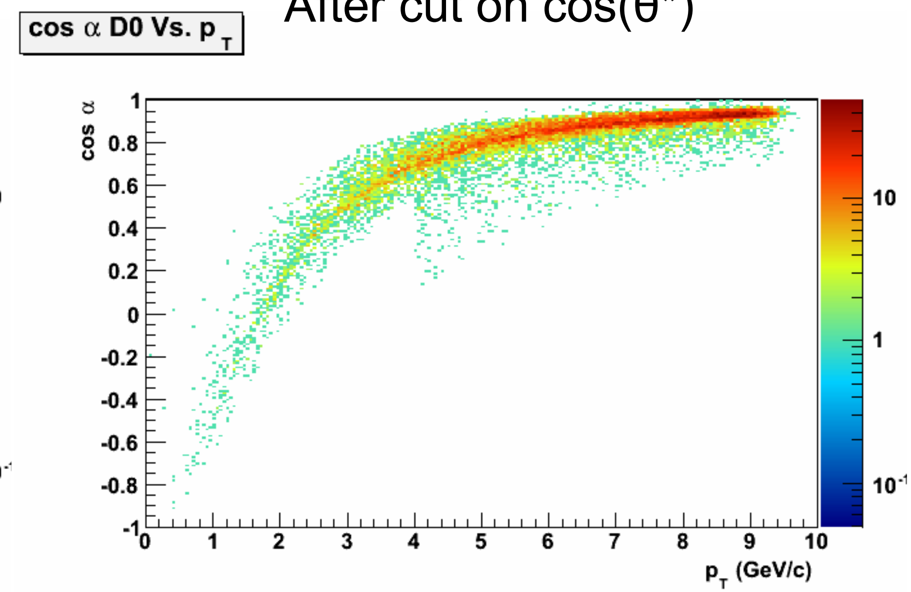
We can consider placing a cut on the opening angle.

Before cut on cos(θ*)

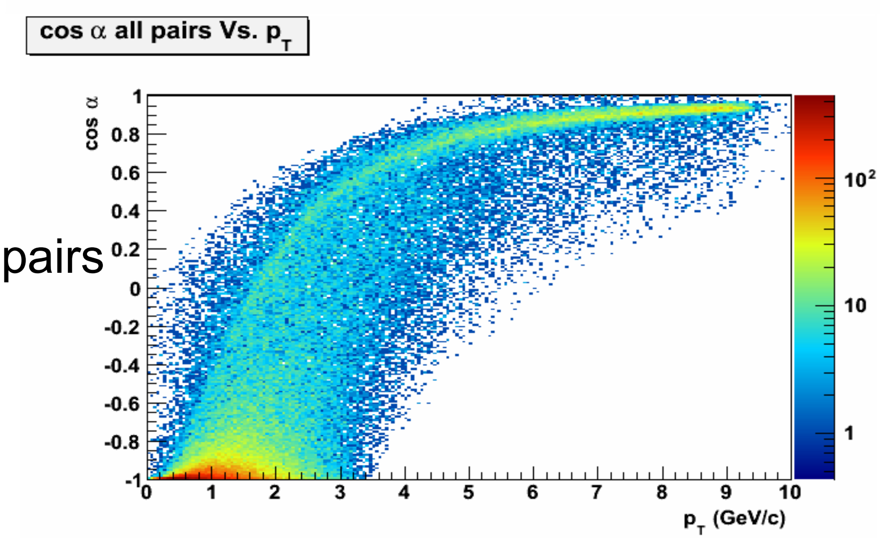
After cut on cos(θ*)

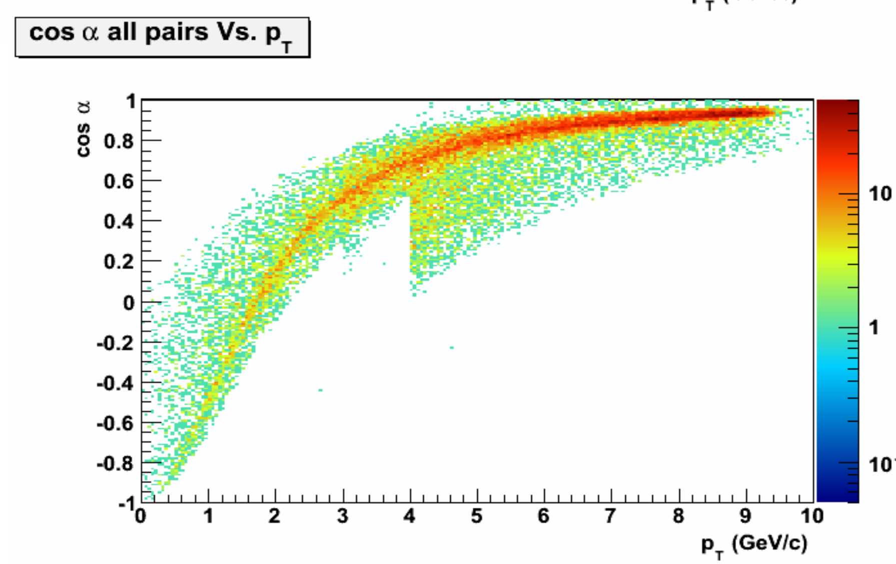
cos(α) for D0



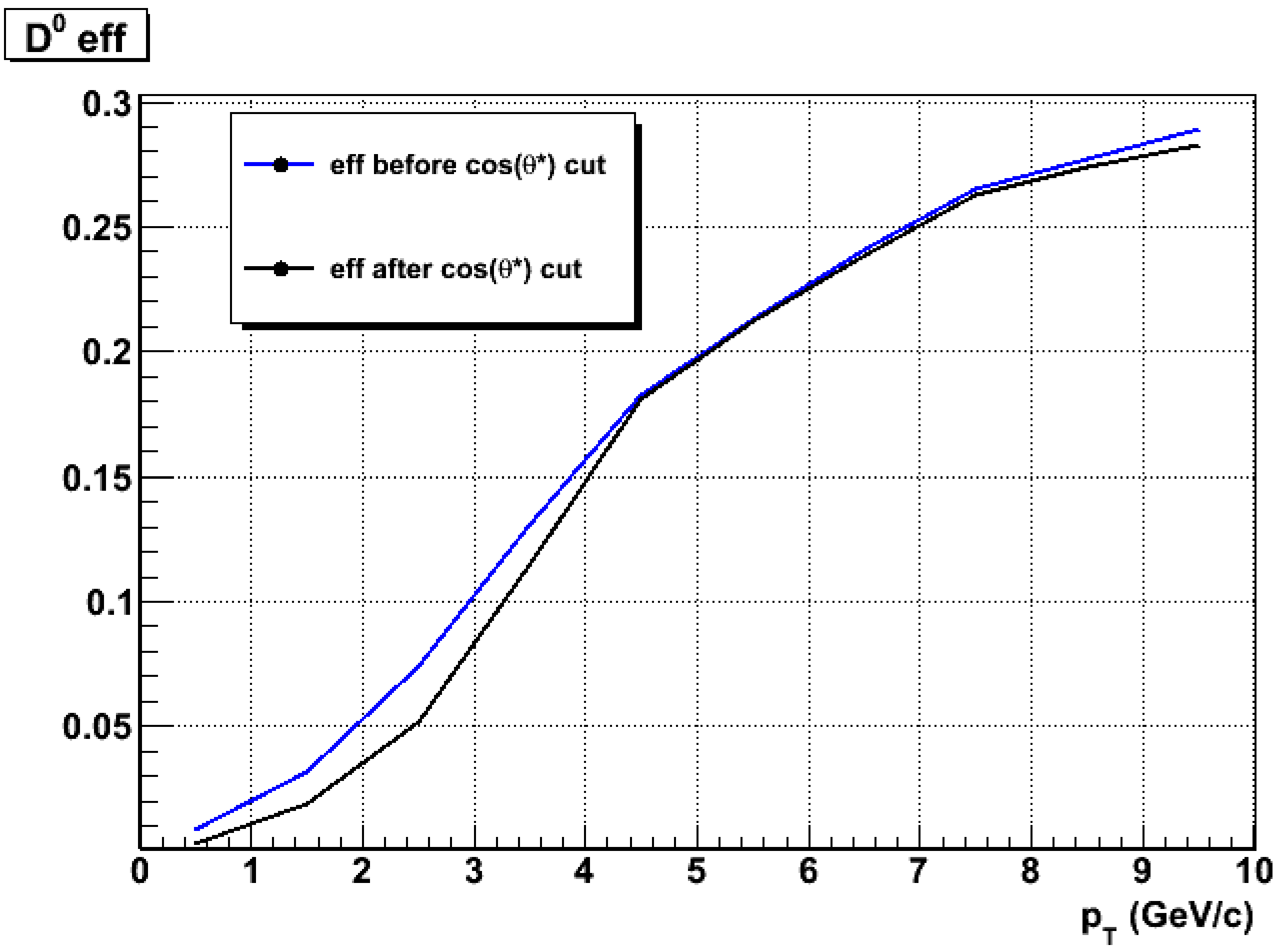




cos(α) for all pairs



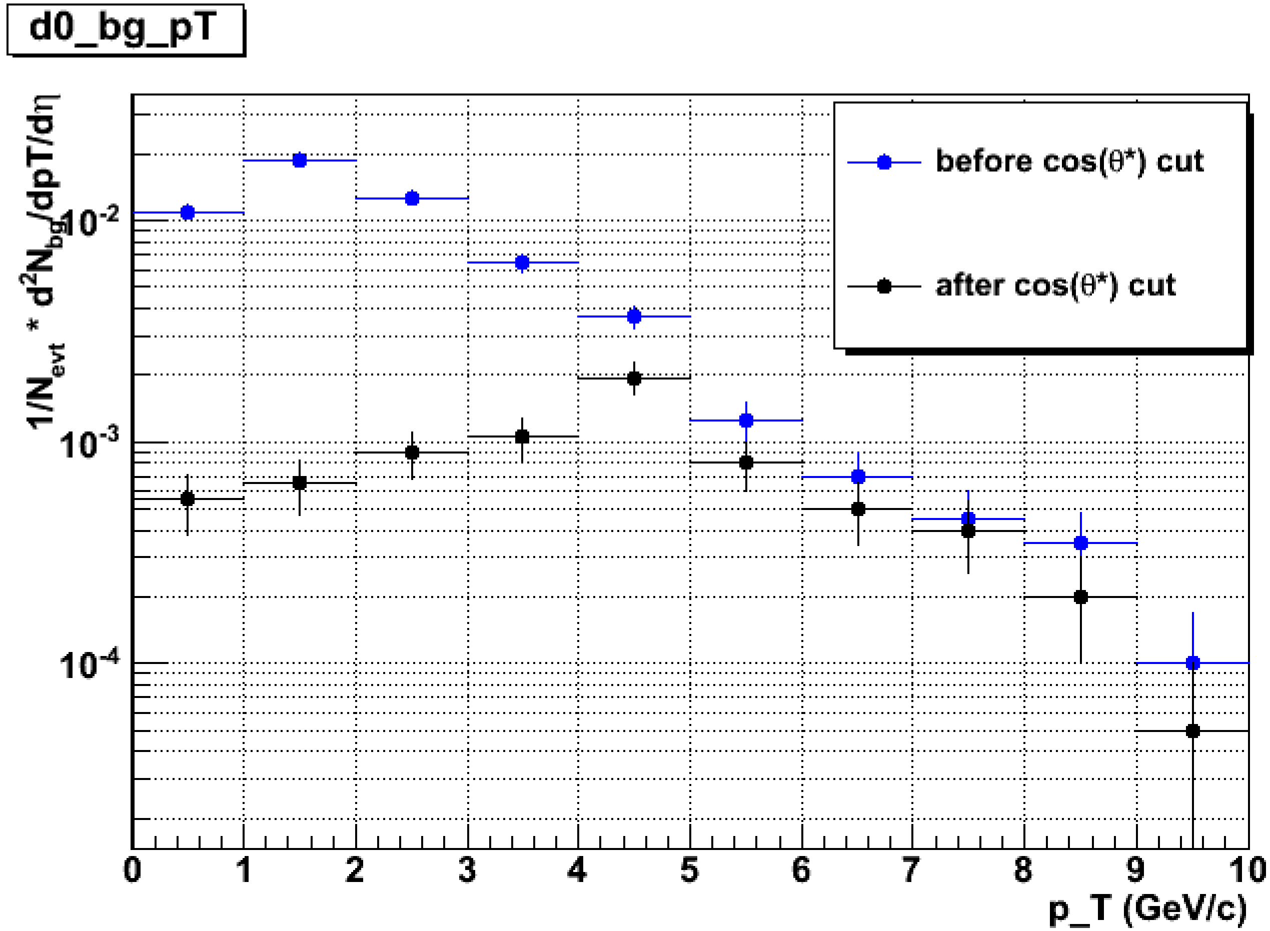



# $D^0$ Efficiency After cos(θ*) cut



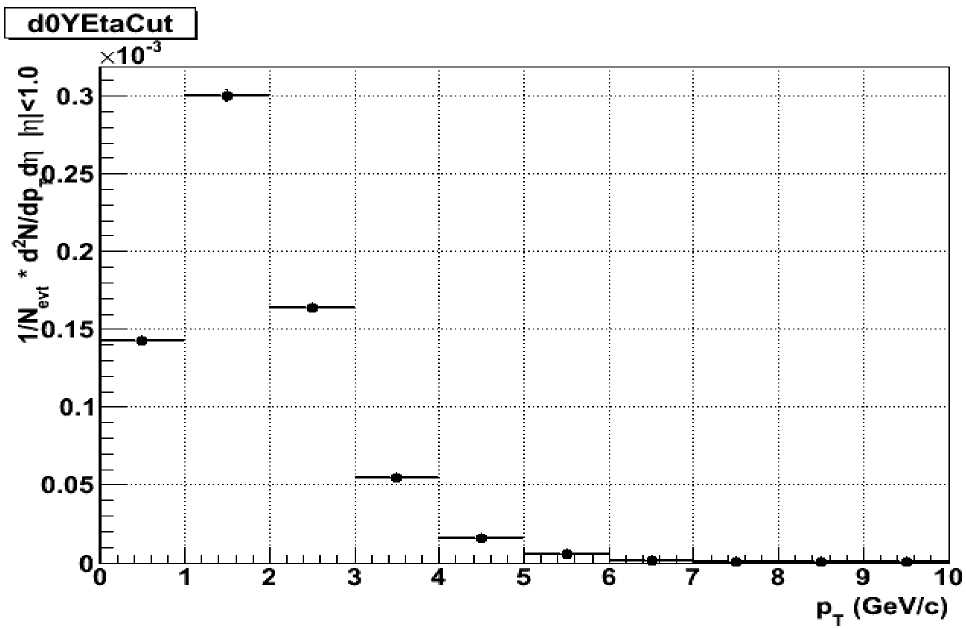
# $D^0$ background spectrum

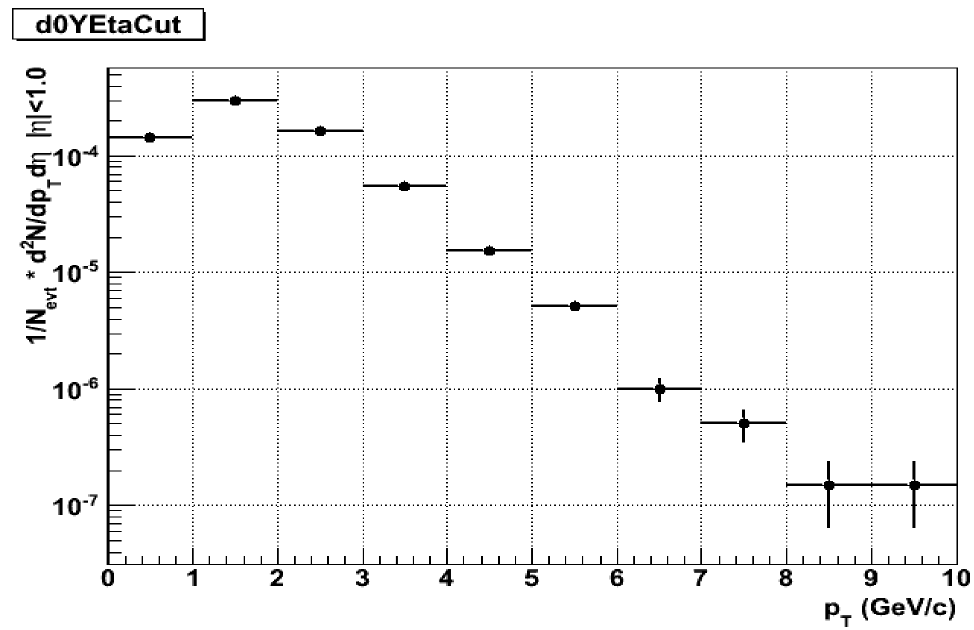
$$\frac{1}{N_{evt}} \frac{d^2 N_{bg}(p_T)}{dp_T d\eta}$$



# $D^0$ $p_T$ spectrum using PYTHIA

$$\frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\Big|_{p+p}$$




$$\frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\Big|_{Au+Au} = N_{binary} \frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\Big|_{p+p}$$

For most central events $N_{binary} = 10^3$

Note: PYTHIA is tuned to CDF Tune A Setting (CTEQ5L) + Peterson fragmentation function. Tuning details are available later in the slides and in the backup slides

# $D^0$ Yield in run14

$$\frac{d^2N(p_T)}{dp_T d\eta} = f_{cent} * \mathscr{L} * \sigma_{Au+Au} * \text{Duty Factor}$$

$$* \, \mathrm{Br}(\mathrm{D}^0 \to \mathrm{K}^-\pi^+) * \varepsilon_{reco}(p_T) * \varepsilon_{vtx} * \frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\Big|_{Au+Au}$$

For most central events $f_{cent}$ = 0.10

Max Luminosity = 21 $nb^{-1}$

Min Luminosity = 3.3 $nb^{-1}$

$\sigma_{Au+Au}$ = 7 b

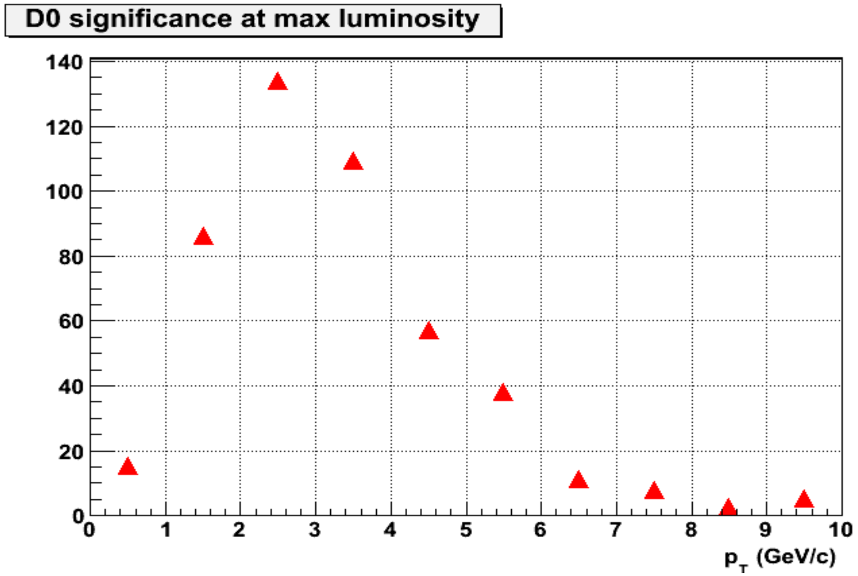
Duty Factor = 0.70

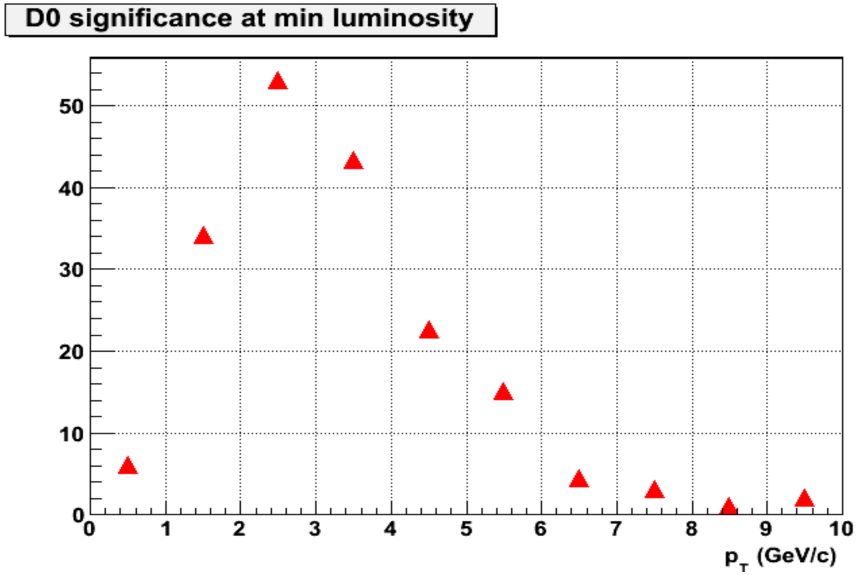
$Br(D^0 \text{->} k^- \pi^+)$ = 0.0389

$\varepsilon_{vtx}$ ($|V_z|$<5.0) = 0.20

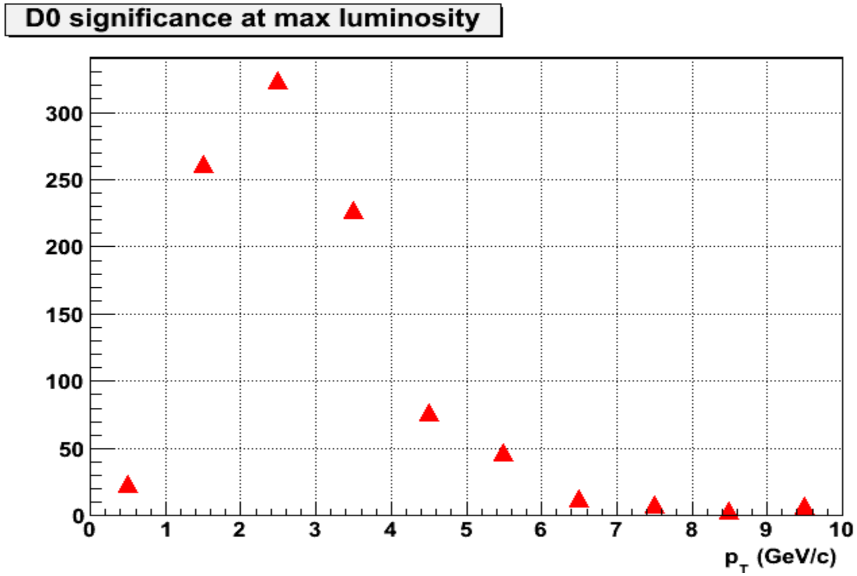
# Significance

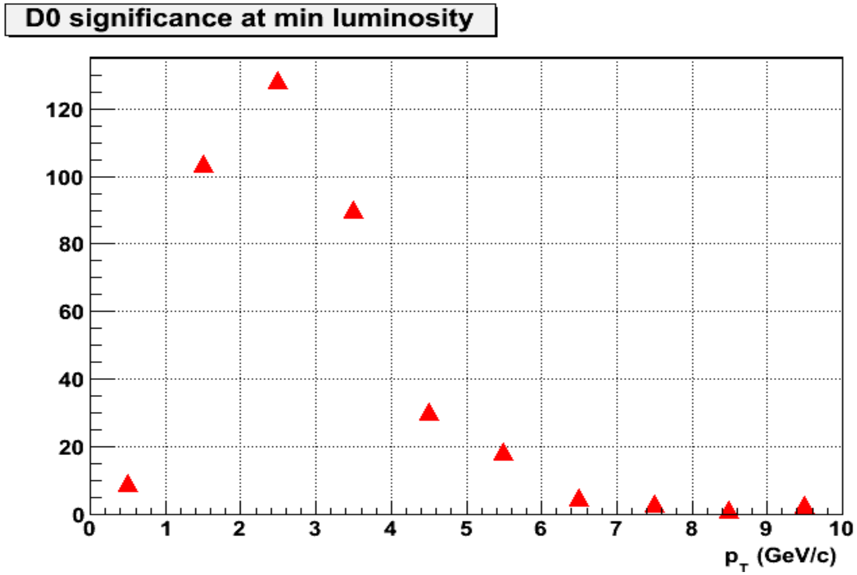
Before cut on cos(θ*)



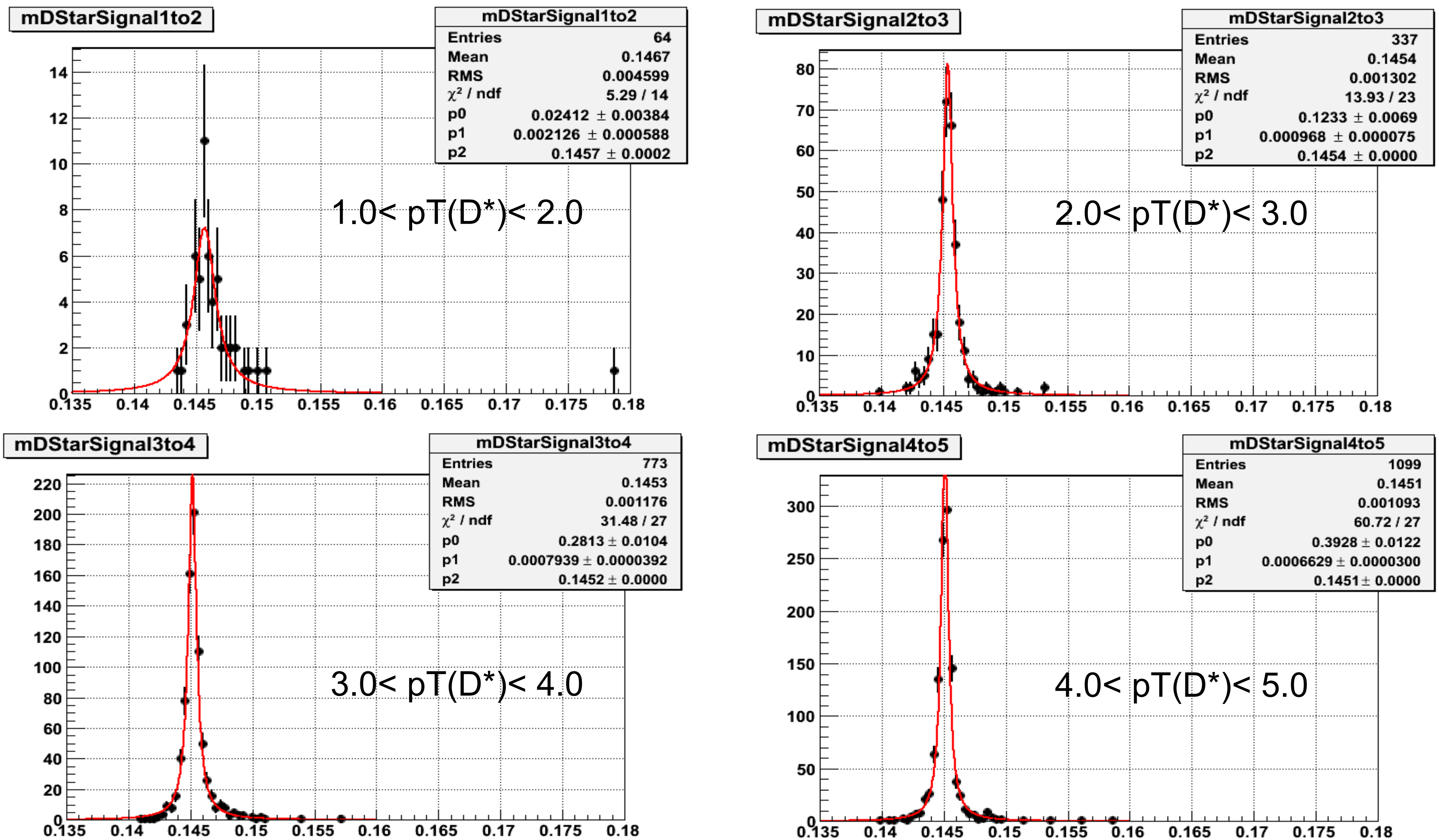




After cut on cos(θ*)

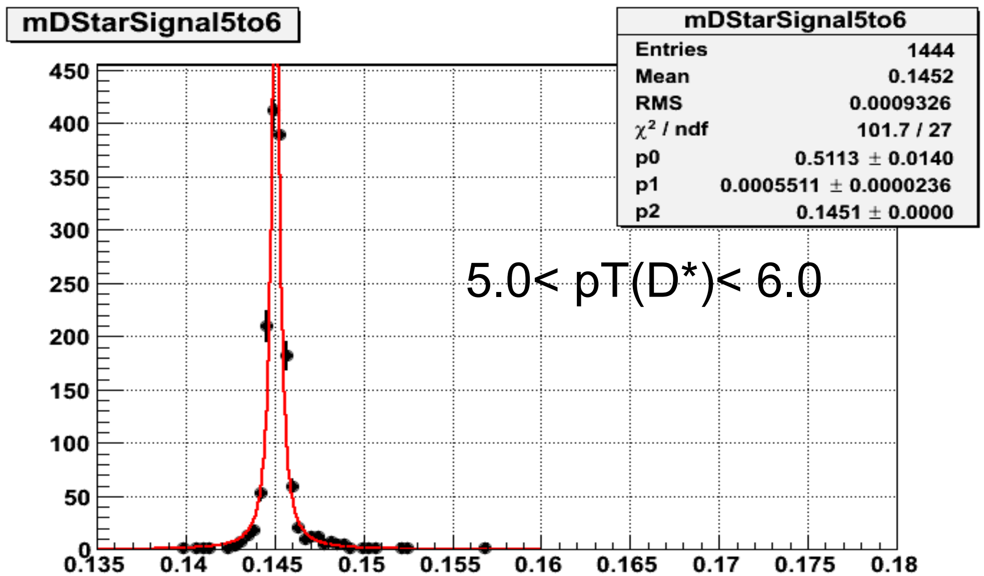


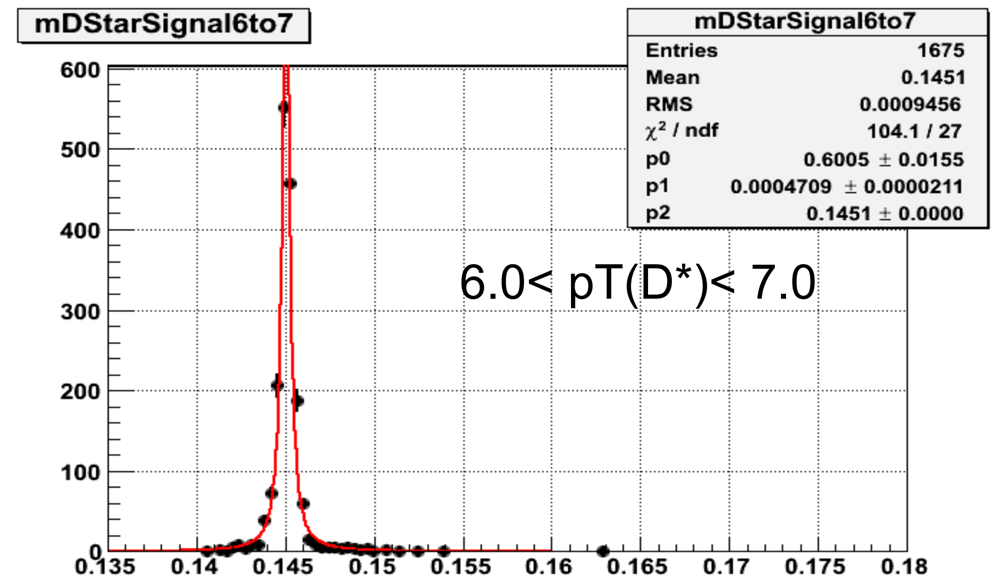



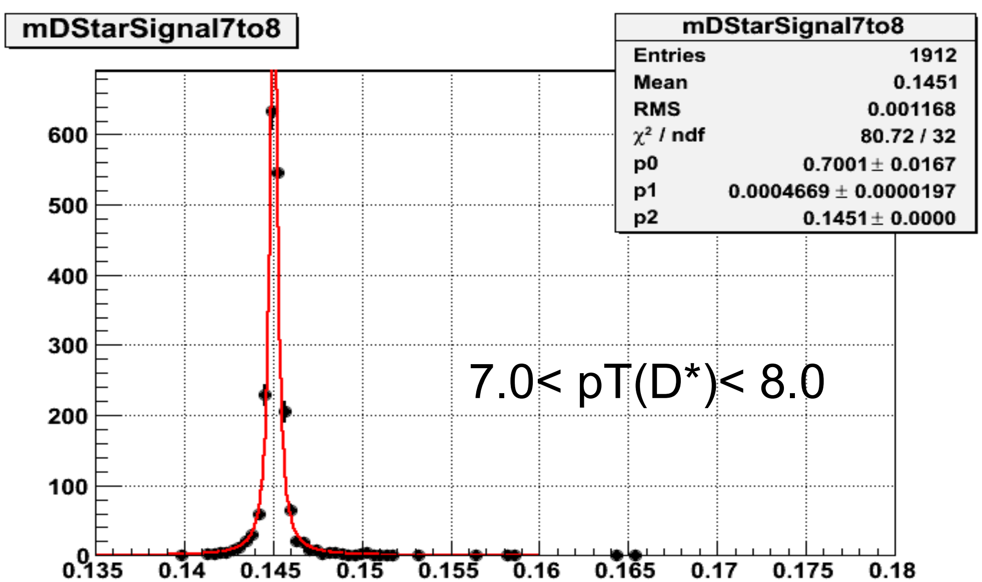
# Reconstructed D* signal

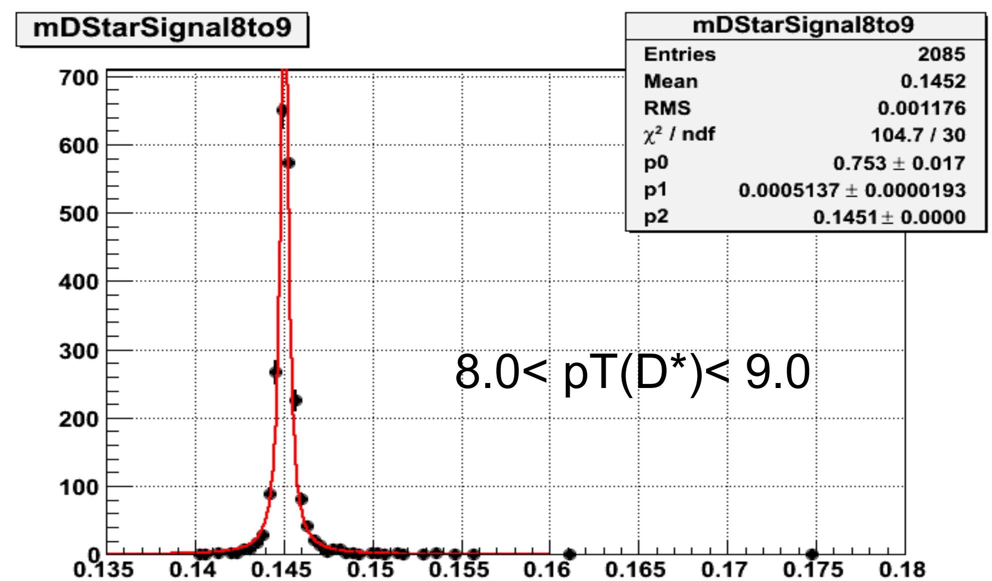



M(D*) - M(D⁰)

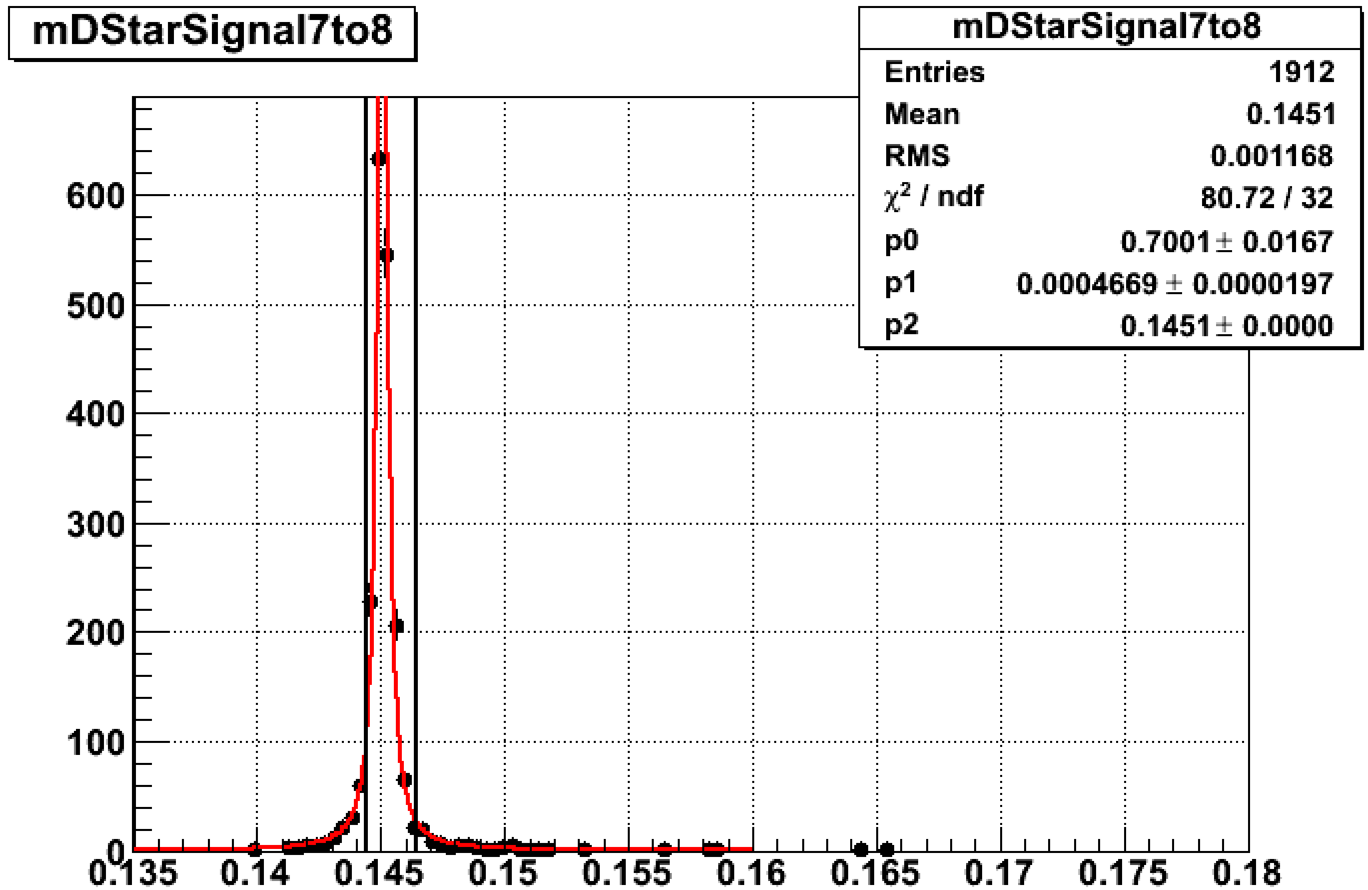

mDStarSignal5to6
mDStarSignal5to6
Entries 1444
Mean 0.1452
RMS 0.0009326
χ² / ndf 101.7 / 27
p0 0.5113 ± 0.0140
p1 0.0005511 ± 0.0000236
p2 0.1451 ± 0.0000
5.0< pT(D*)< 6.0


mDStarSignal6to7
mDStarSignal6to7
Entries 1675
Mean 0.1451
RMS 0.0009456
χ² / ndf 104.1 / 27
p0 0.6005 ± 0.0155
p1 0.0004709 ± 0.0000211
p2 0.1451 ± 0.0000
6.0< pT(D*)< 7.0

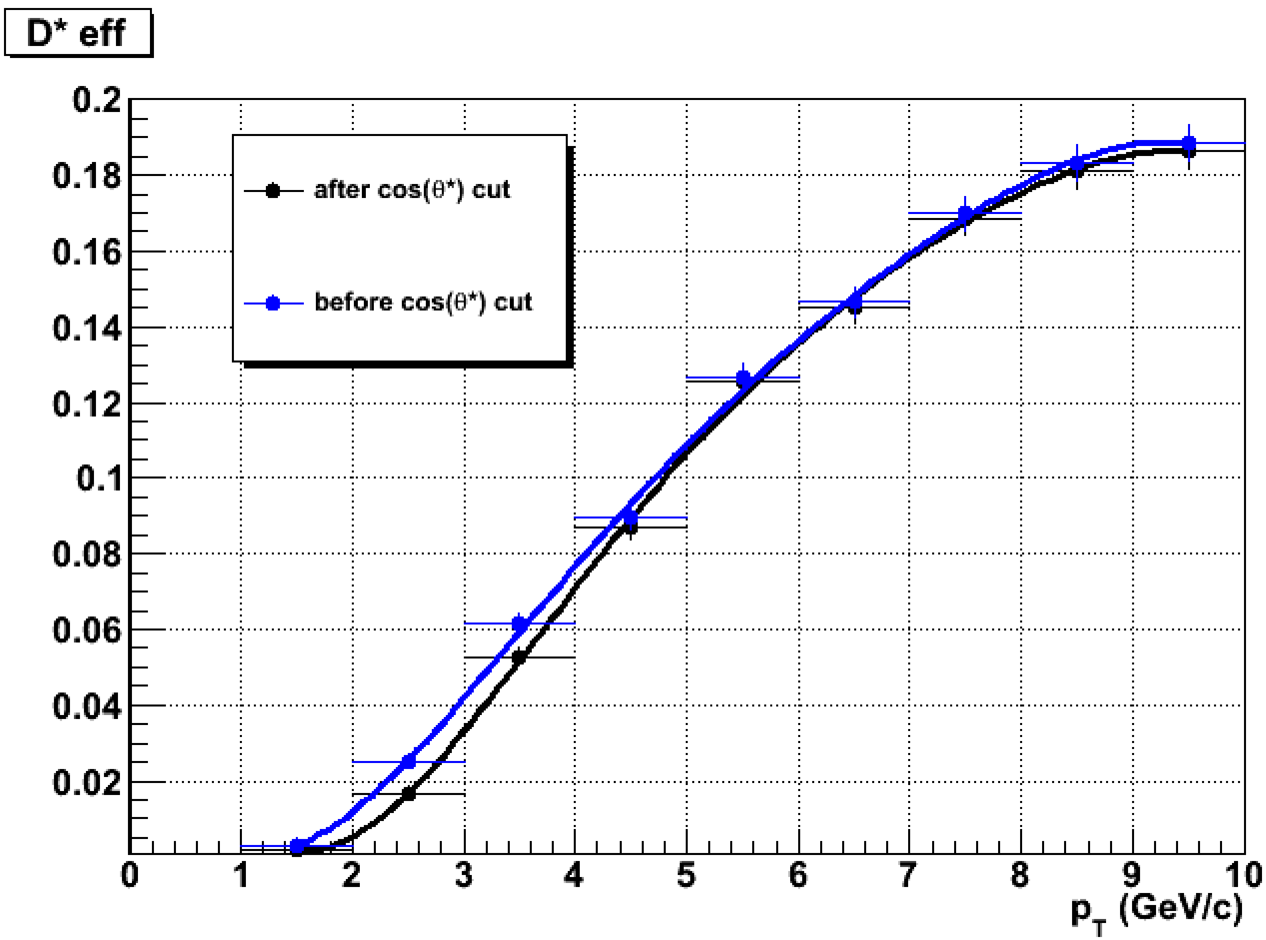

mDStarSignal7to8
mDStarSignal7to8
Entries 1912
Mean 0.1451
RMS 0.001168
χ² / ndf 80.72 / 32
p0 0.7001± 0.0167
p1 0.0004669 ± 0.0000197
p2 0.1451± 0.0000
7.0< pT(D*)< 8.0


mDStarSignal8to9
mDStarSignal8to9
Entries 2085
Mean 0.1452
RMS 0.001176
χ² / ndf 104.7 / 30
p0 0.753 ± 0.017
p1 0.0005137 ± 0.0000193
p2 0.1451± 0.0000
8.0< pT(D*)< 9.0

Placing a cut on 0.1444< M(D*) - M($D^0$) < 0.1464
PDG value is 0.1454 GeV/c^2
Δm = 1.0 MeV



# D* Efficiency



# D* $p_T$ spectrum using PYTHIA

10m p+p @ 200GeV minBias PYTHIA events

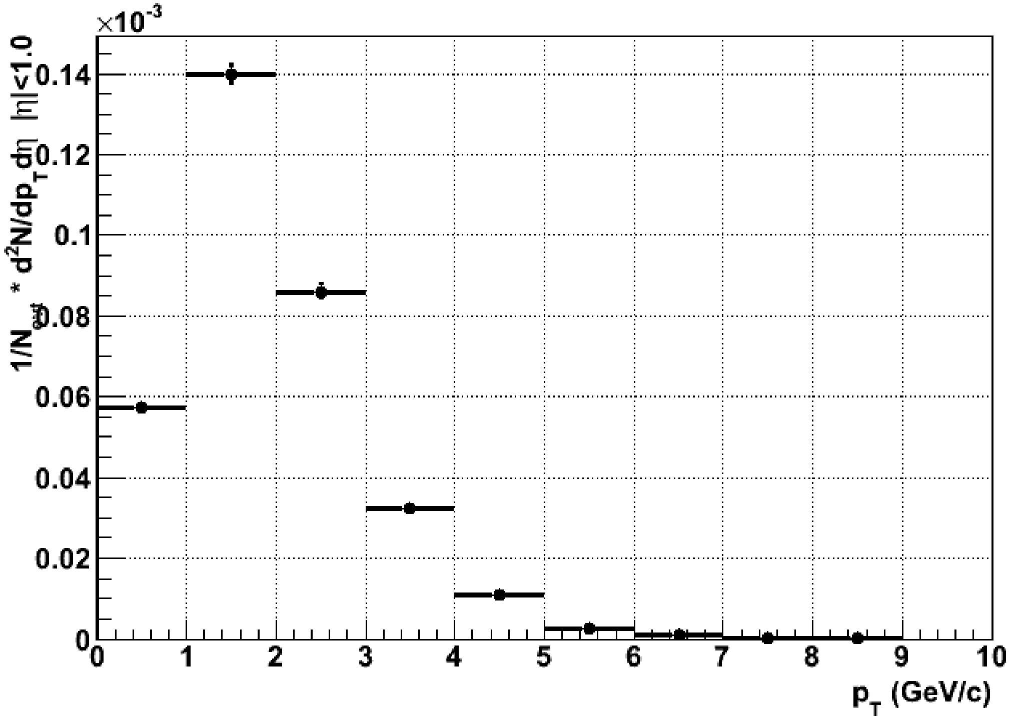
**Pythia Tunning:**

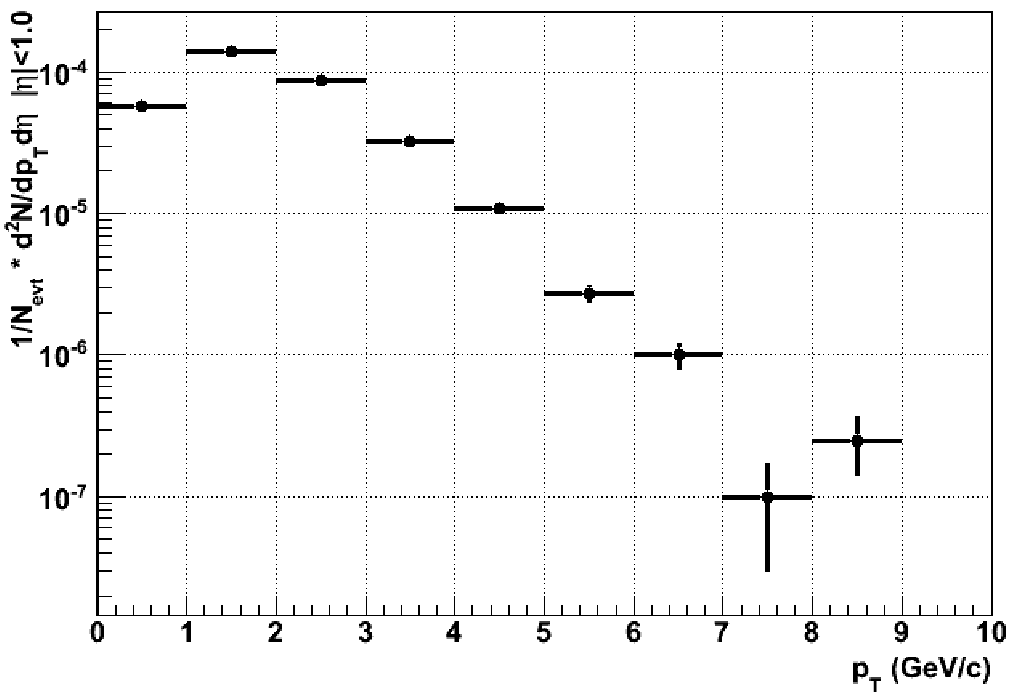
**// CDF Tune A Setting (CTEQ5L) http://www.phys.ufl.edu/~rfield/cdf/tunes/py_tuneA.html**
**// Peterson Fragmentation function**

```
 pythia->SetPARP(67,4.0); //Scale factor of the initial-state radiation
 pythia->SetMSTP(81,1); //Turns on multiple parton interactions
 pythia->SetMSTP(82,4); //Double Gaussian matter distribution
 pythia->SetPARP(82,2.0); // Cut-off for multiple parton interactions, PT0.
 pythia->SetPARP(83,0.5); //Warm Core: 50% of matter in radius 0.4.
 pythia->SetPARP(84,0.4); //Warm Core: 50% of matter in radius 0.4.
 pythia->SetPARP(85,0.9); //Probability that the MPI produces two gluons with color
connections to the "nearest neighbors".
 pythia->SetPARP(86,0.95); //Probability that the MPI produces two gluons
either as described by PARP(85) or as a closed gluon loop. The remaining fraction consists
 of quark-antiquark pairs.
 pythia->SetPARP(89,1800.0); //Determines the reference energy E0.
 pythia->SetPARP(90,0.25); // Determines the energy dependence of the cut-off PT0 as
follows PT0(Ecm) = PT0(Ecm/E0)PARP(90).PT0(Ecm) = PT0(Ecm/E0)^PARP(90)
 pythia->SetMSTJ(11,3);//Peterson Fragmentation
 pythia->SetMSEL(1); //.. Minimum-bias

 // ... and initialise it to run p+p at sqrt(200) GeV in CMS
 pythia->Initialize("cms", "p", "p", 200);
```

# D* $p_T$ spectrum p+p

$$\frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\bigg|_{p+p}$$




$$\frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\bigg|_{Au+Au} = N_{binary} \frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\bigg|_{p+p}$$

For most central events $N_{binary} = 10^3$

# D* Yield in run14

$$\frac{d^2N(p_T)}{dp_T d\eta} = f_{cent} * \mathscr{L} * \sigma_{Au+Au} * \text{Duty Factor}$$

$$* \,\text{Br}(\text{D}^* \rightarrow \text{D}^0\pi^+) * \text{Br}(\text{D}^0 \rightarrow \text{K}^-\pi^+)$$

$$* \,\varepsilon_{reco}(p_T) * \varepsilon_{vtx} * \frac{1}{N_{evt}} \frac{d^2N(p_T)}{dp_T d\eta}\Big|_{Au+Au}$$

For most central events $f_{cent} = 0.10$

Max Luminosity = 21 $nb^{-1}$

Min Luminosity = 3.3 $nb^{-1}$

$\sigma_{Au+Au} = 7$ b

Duty Factor = 0.70

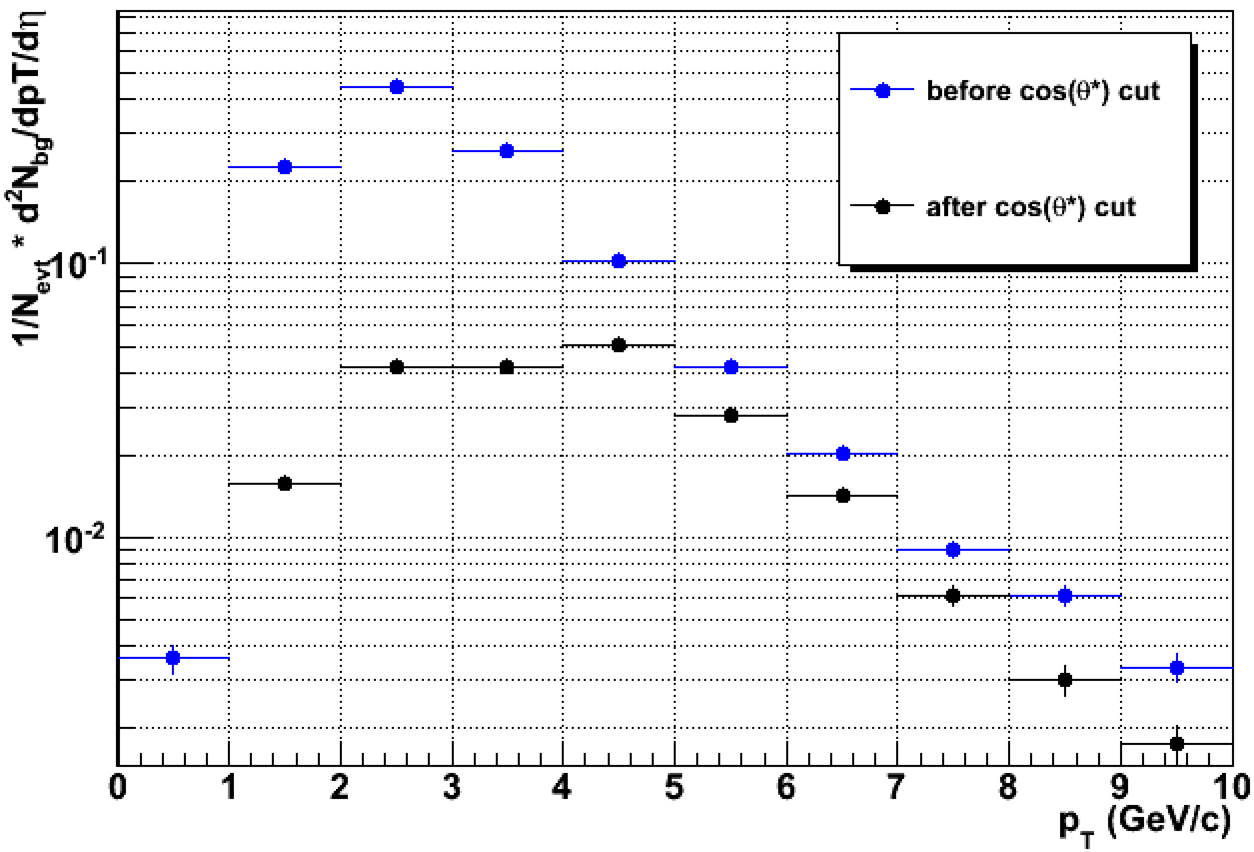
$Br(D^* \to D^0\pi^+) = 0.677$

$Br(D^0 \to k^- \pi^+) = 0.0389$

$\varepsilon_{vtx}$ ($|V_z|<5.0$) = 0.20

# D* background spectrum

$$\frac{1}{N_{evt}} \frac{d^2 N_{bg}(p_T)}{dp_T d\eta}$$



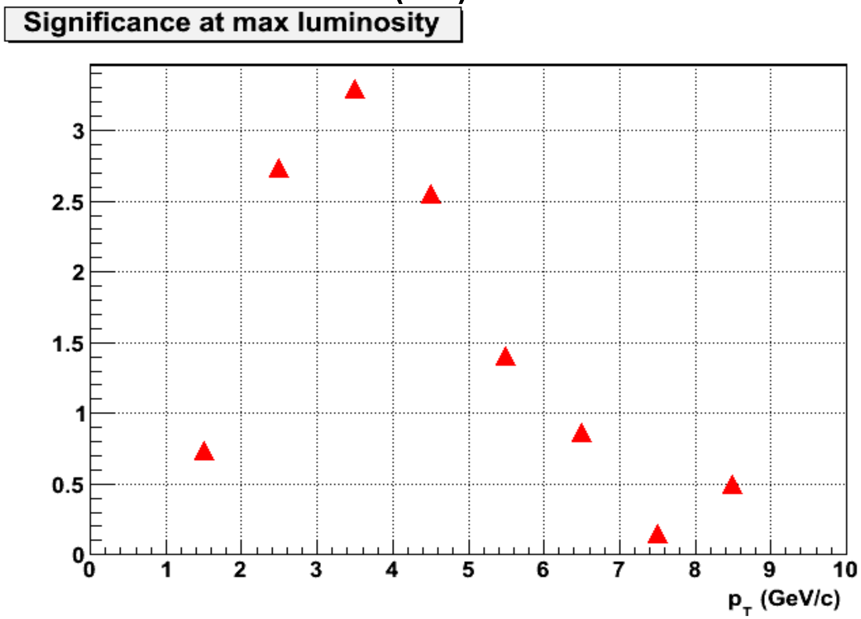
## Background in run14

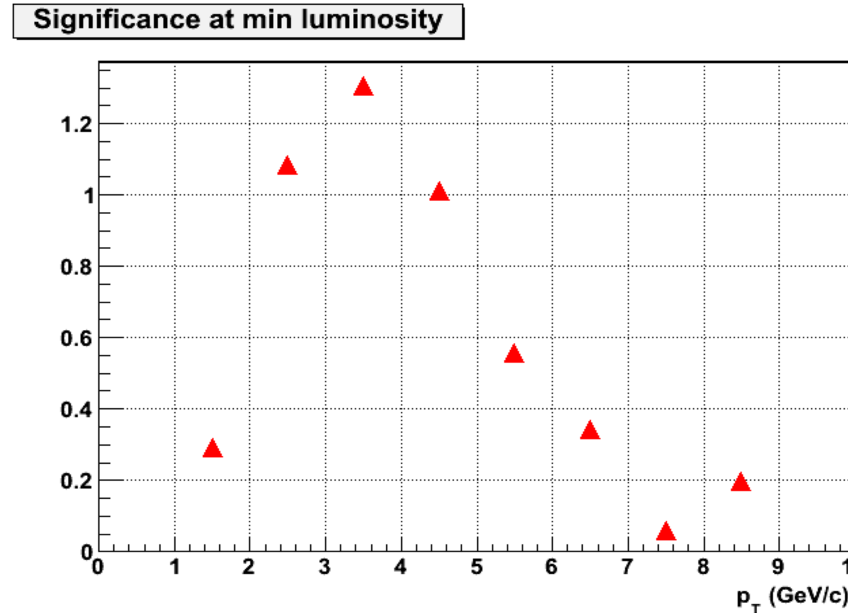
$$\frac{d^2N_{bg}(p_T)}{dp_T d\eta} = f_{cent} * \mathscr{L} * \sigma_{Au+Au} * \text{Duty Factor}$$

$$* \varepsilon_{vtx} * \frac{1}{N_{evt}} \frac{d^2N_{bg}(p_T)}{dp_T d\eta}$$

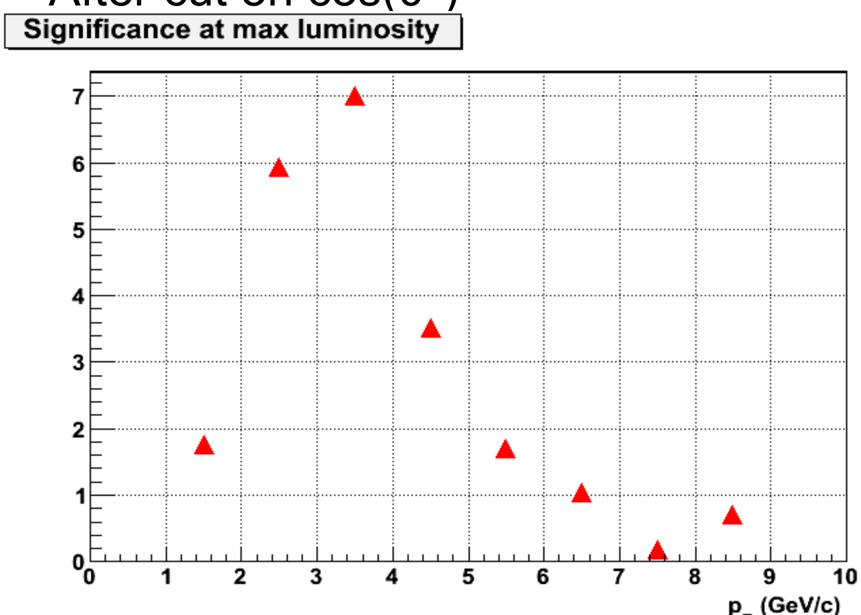
# Significance

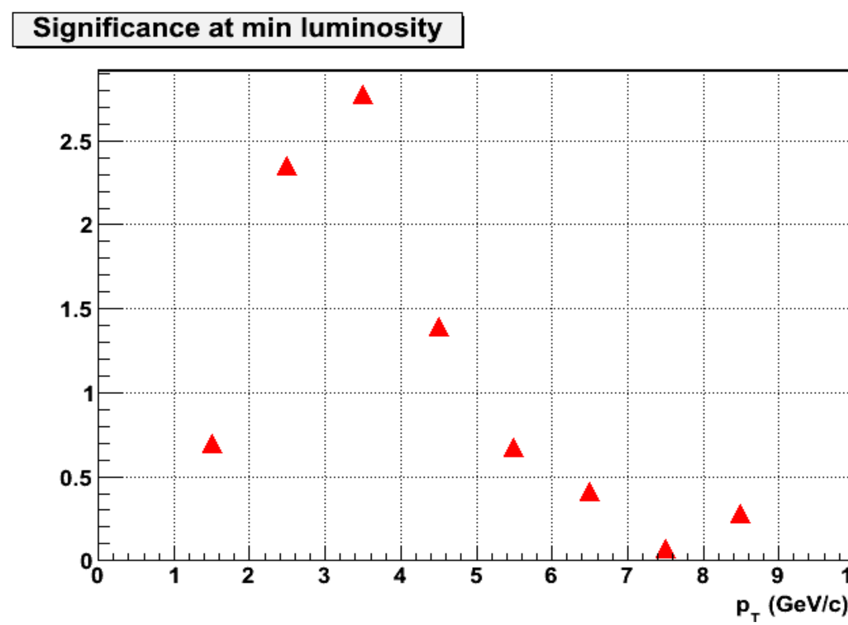
Before cut on cos(θ*)




After cut on cos(θ*)



# To be done

**1) Currently the background spectrum is done by removing the contribution from the embedded particles only. It needs to be revisited.**

**2) TOF PID.**

**3) Try to tune the different cuts and see their effect on the efficiency and significance.**

**4) Tune PYTHIA to the observed ccbar cross-sections at RHIC, I still need those. Please provide them if you have them.**

# Backup Slides

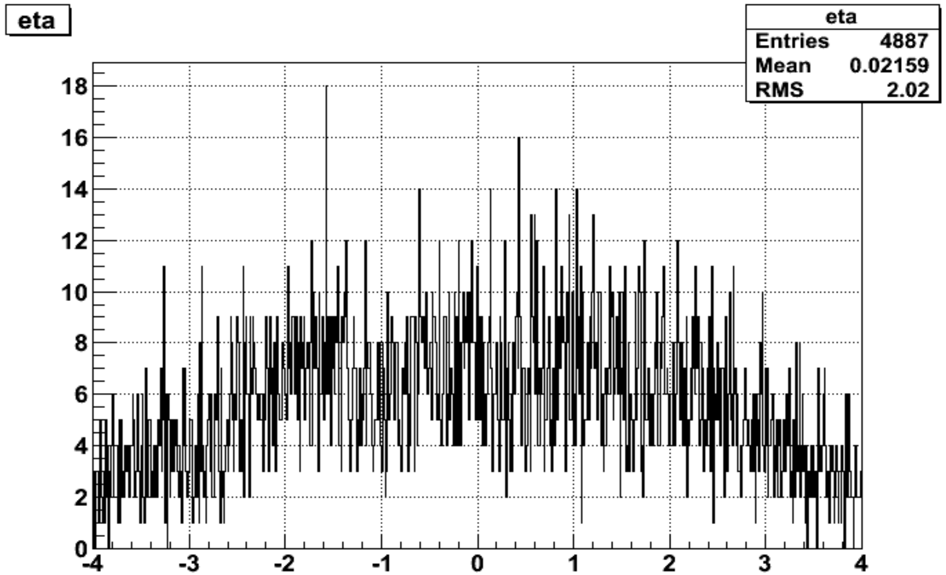
# Details of a short PYTHIA study with different tunings

# Tuned PYTHIA

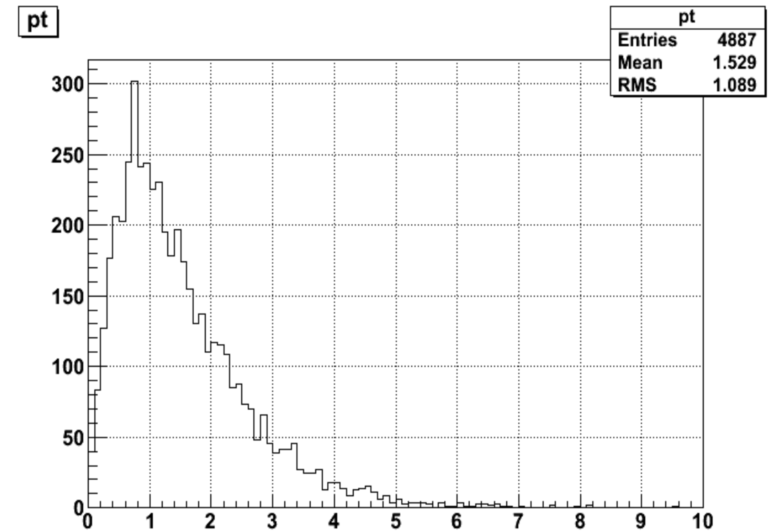
**1m pp @ 200GeV minBias pythia events**

**Pythia Tunning:**

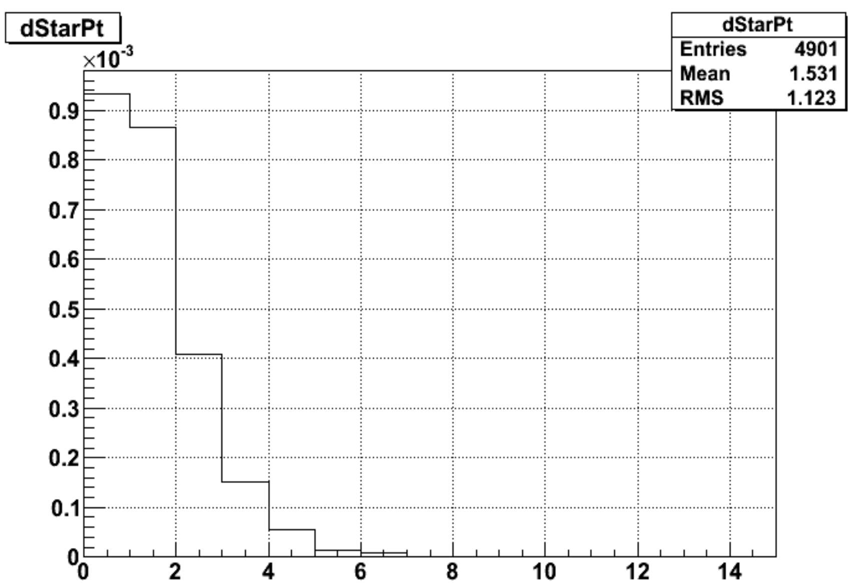
```
TPythia6* pythia = new TPythia6;

  pythia->SetMRPY(1, seed); //.. set random number seed.

  pythia->SetPARP(91, 1.5); //.. kT
  pythia->SetMSTP(33,1); //.. request the use of common K factor
  pythia->SetMSTP(32, 4); //.. Q2 scale option
  pythia->SetPARP(31, 3.5); //.. K factor for charm and bottom
  pythia->SetPMAS(5, 1, 4.1); //.. bottom mass
  pythia->SetPMAS(4, 1, 1.25); //.. charm mass

  pythia->SetMSEL(1); //.. Minimum-bias


  // ... and initialise it to run p+p at sqrt(200) GeV in CMS
  pythia->Initialize("cms", "p", "p", 200);
```



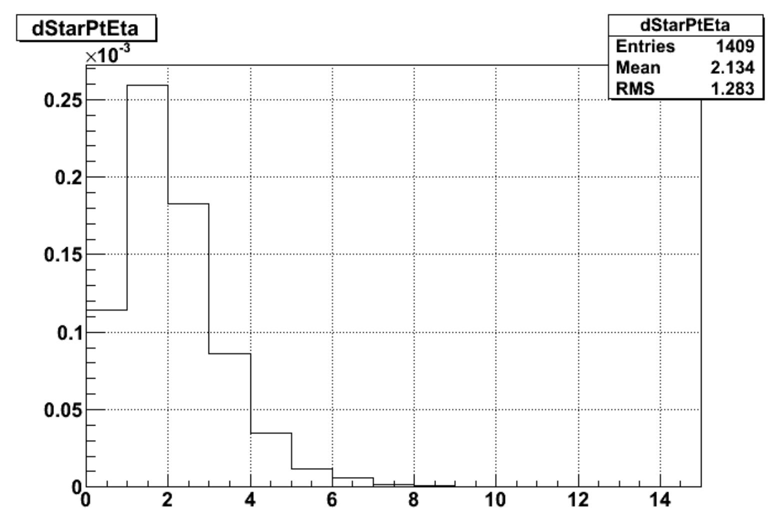

D* eta shape before eta cut.



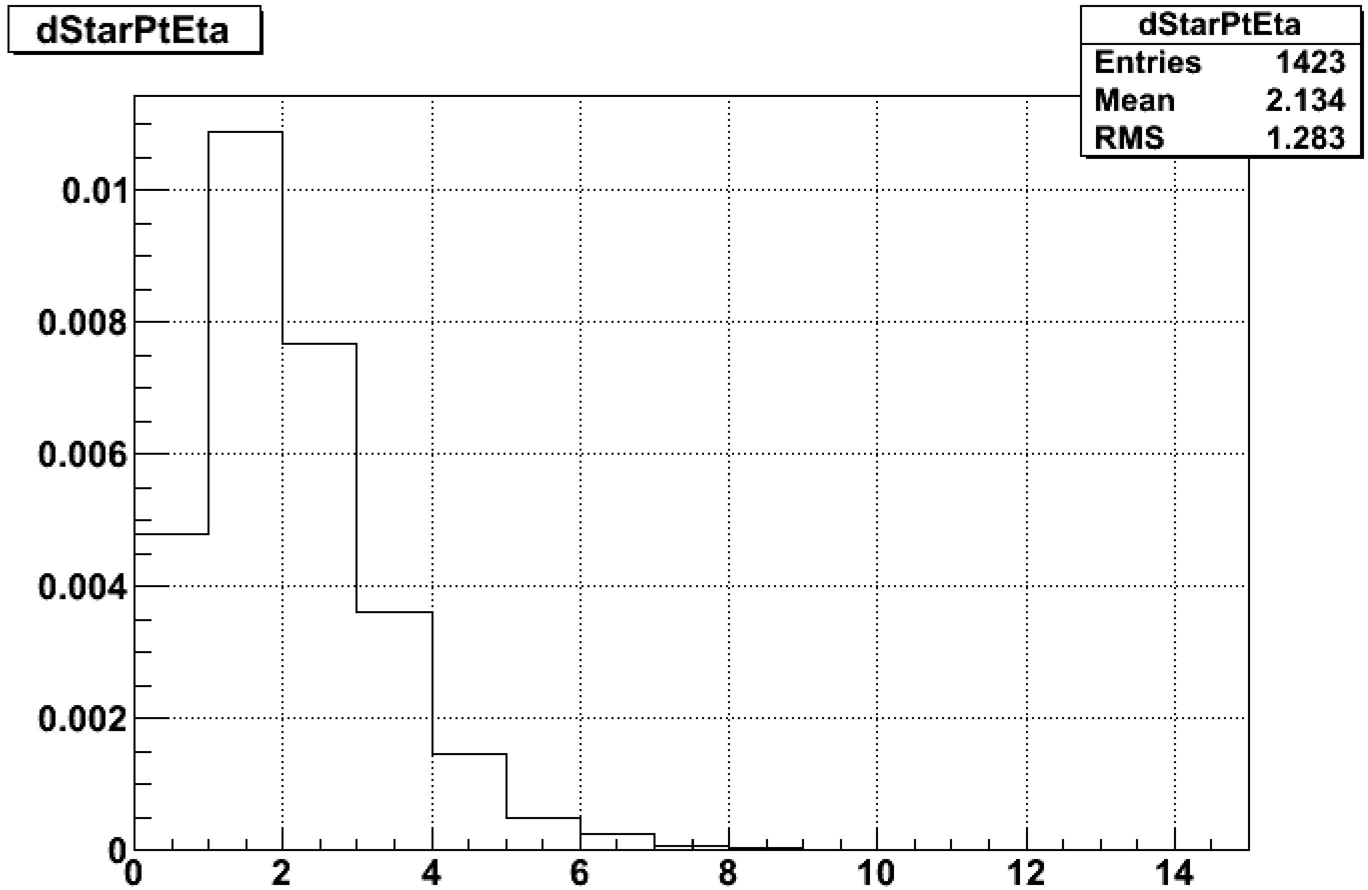

D* pT shape before eta cut.




$1/N_{evt} * d^2N/dpT/d\eta$




$1/N_{evt} * d^2N/dpT/d\eta$ ($|\eta| <1$) after $|\eta| <1.0$ cut




dσ/dη (|η|<1)

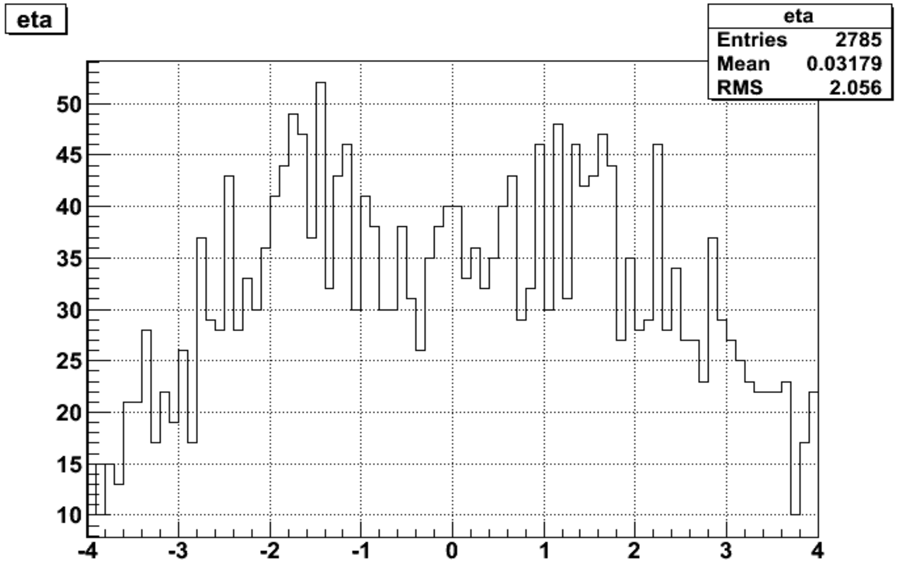
dσ/dη(|η|<1) = 42 (mb) * Integral(1/Nevt*dN/dpt/dη,0<pt<inf ) = 29 μb

# Default PYTHIA

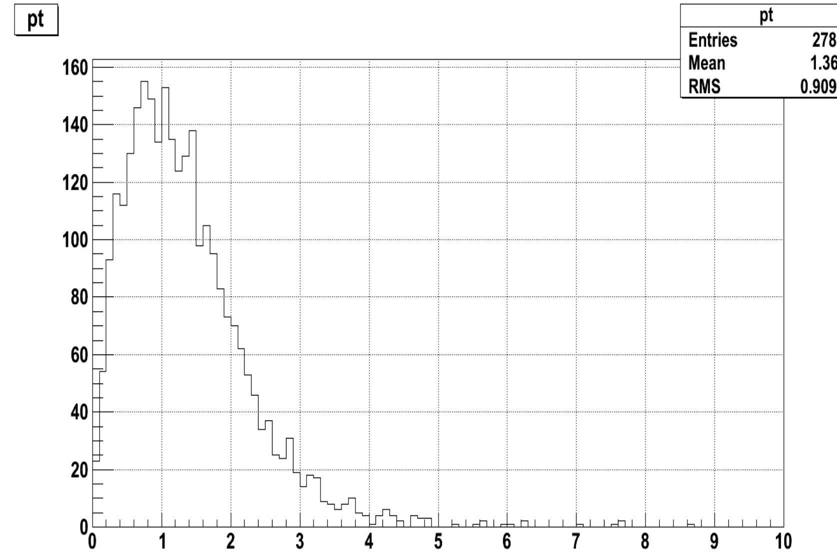
**1m pp @ 200GeV minBias pythia events**

**Pythia Tunning:**

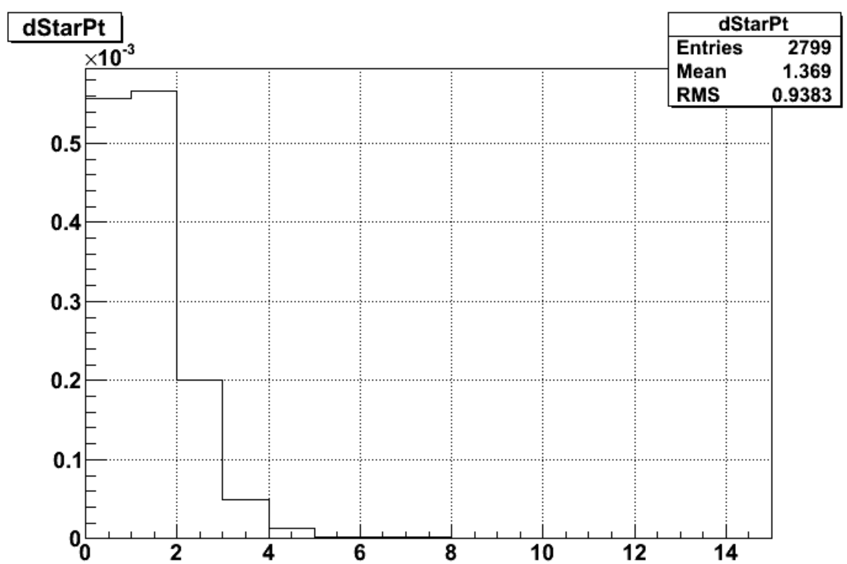
```
TPythia6* pythia = new TPythia6;

  pythia->SetMRPY(1, seed); //.. set random number seed.


  pythia->SetMSEL(1); //.. Minimum-bias


  // ... and initialise it to run p+p at sqrt(200) GeV in CMS
  pythia->Initialize("cms", "p", "p", 200);
```



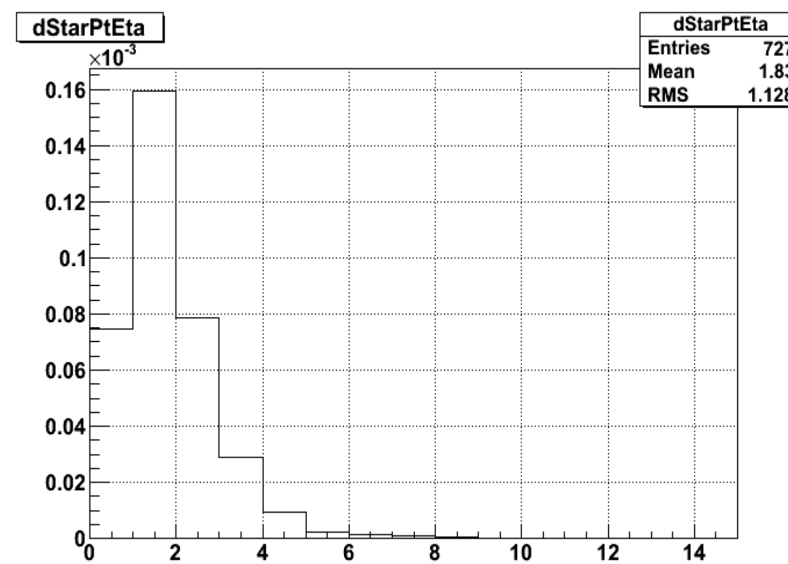

D* eta shape before eta cut.



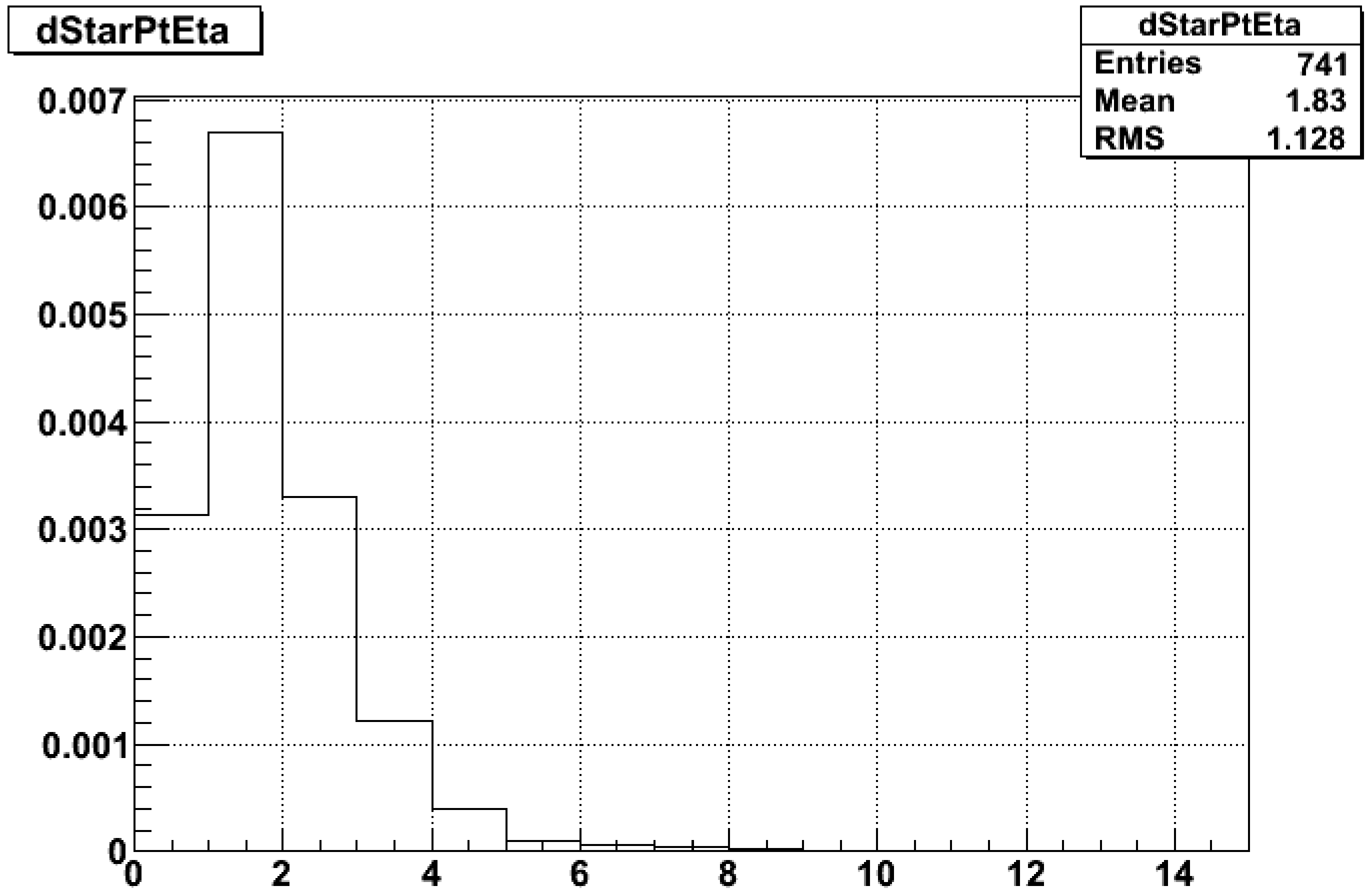

D* pT shape before eta cut.




$1/N_{evt} * d^2N/dpT/d\eta$




$1/N_{evt} * d^2N/dpT/d\eta$ ($|\eta| < 1$) after $|\eta| < 1.0$ cut




dσ/dη (|η|<1)

dσ/dη(|η|<1) = 42 (mb) * Integral(1/Nevt*dN/dpt/dη,0<pt<inf ) = 15 μb

# CDF Tune A PYTHIA

**10m p+p @ 200GeV minBias pythia events**

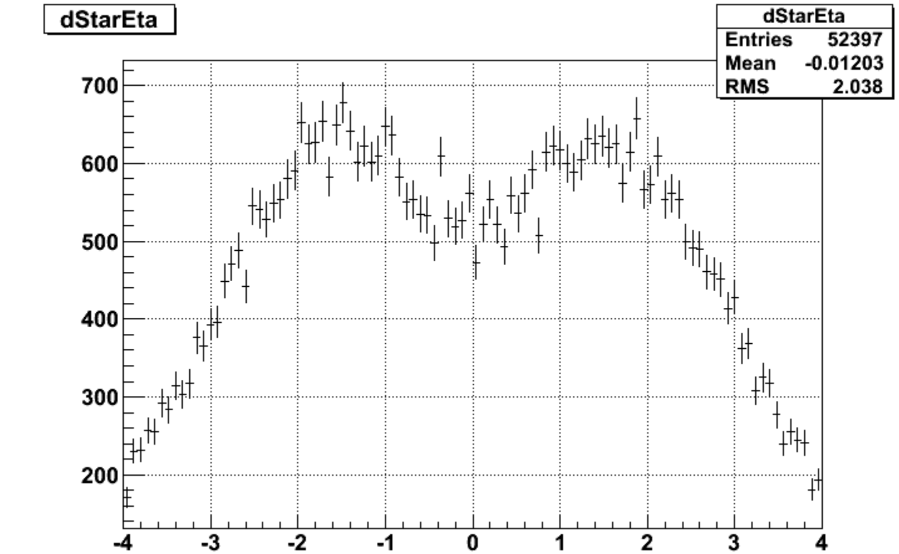
**Pythia Tunning:**

// CDF Tune A Setting (CTEQ5L) http://www.phys.ufl.edu/~rfield/cdf/tunes/py_tuneA.html

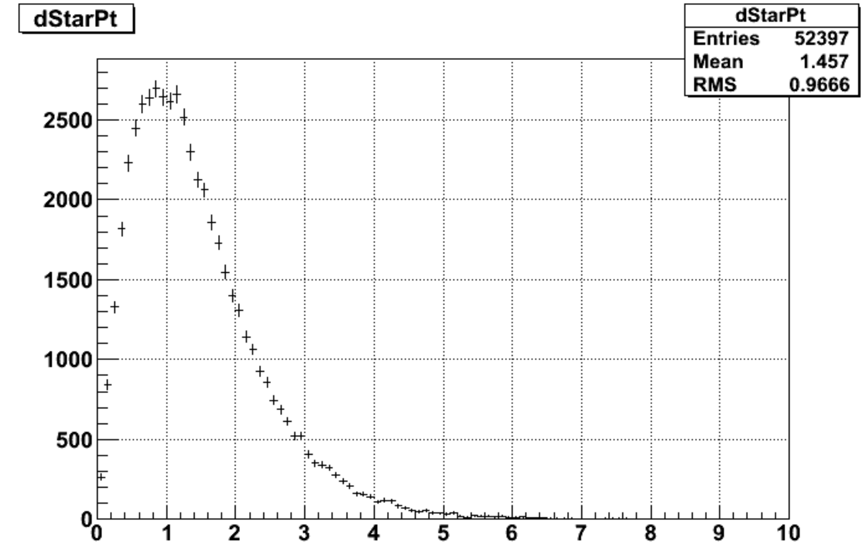
pythia->SetPARP(67,4.0); //Scale factor of the initial-state radiation
pythia->SetMSTP(81,1); //Turns on multiple parton interactions
pythia->SetMSTP(82,4); //Double Gaussian matter distribution
pythia->SetPARP(82,2.0); // Cut-off for multiple parton interactions, PT0.
pythia->SetPARP(83,0.5); //Warm Core: 50% of matter in radius 0.4.
pythia->SetPARP(84,0.4); //Warm Core: 50% of matter in radius 0.4.
pythia->SetPARP(85,0.9); //Probability that the MPI produces two gluons with color connections to the "nearest neighbors".
pythia->SetPARP(86,0.95); //Probability that the MPI produces two gluons either as described by PARP(85) or as a closed gluon loop. The remaining fraction consists of quark-antiquark pairs.
pythia->SetPARP(89,1800.0); //Determines the reference energy E0.
pythia->SetPARP(90,0.25); // Determines the energy dependence of the cut-off PT0 as follows PT0(Ecm) = PT0(Ecm/E0)PARP(90).PT0(Ecm) = PT0(Ecm/E0)^PARP(90)

pythia->SetMSEL(1); //.. Minimum-bias

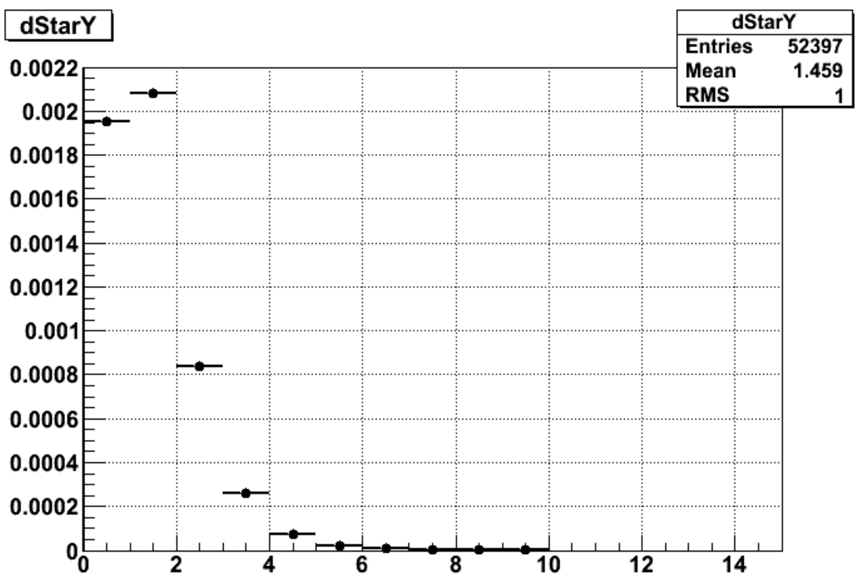
// ... and initialise it to run p+p at sqrt(200) GeV in CMS
pythia->Initialize("cms", "p", "p", 200);



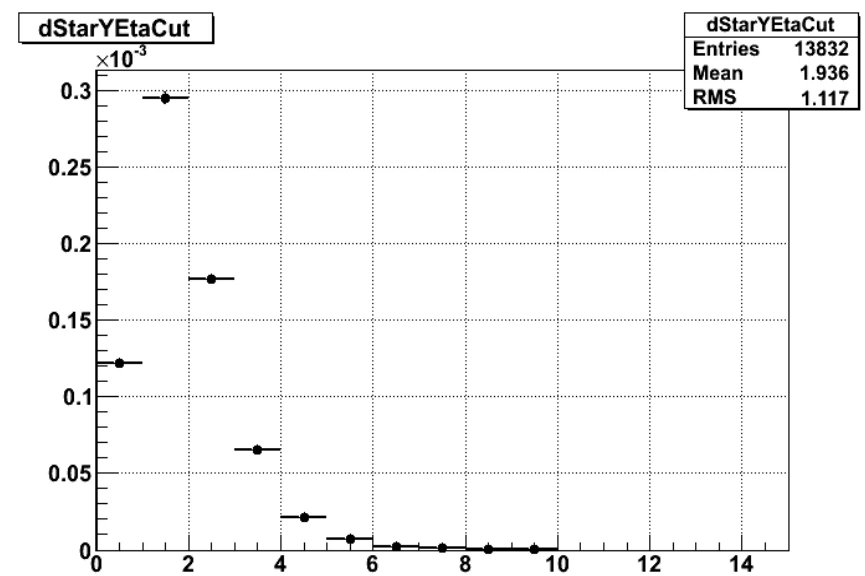

D*+D*bar eta shape before eta cut.



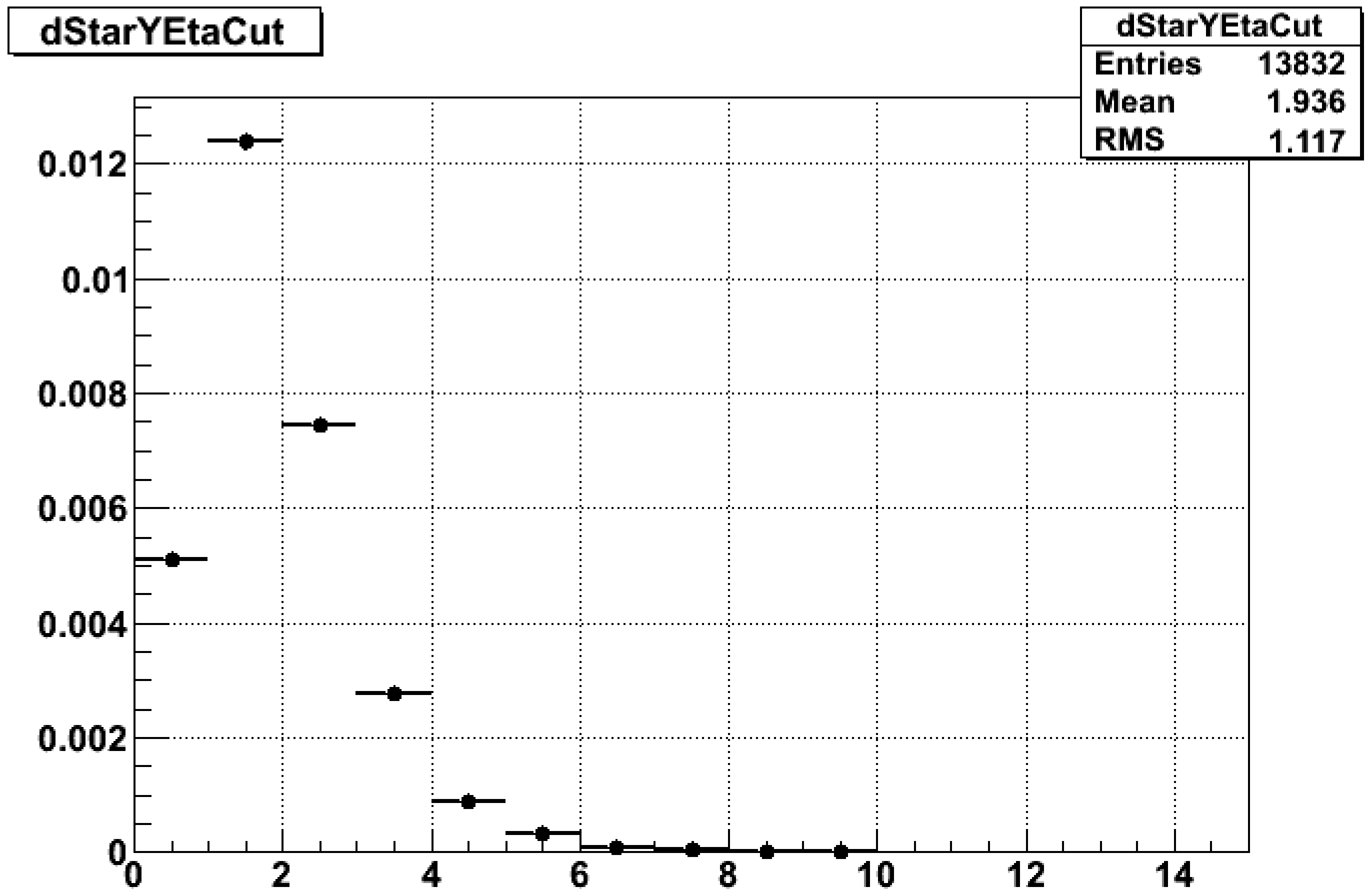

D*+D*bar pT shape before eta cut.




$1/N_{evt} * d^2N/dpT/d\eta$




$1/N_{evt} * d^2N/dpT/d\eta$ ($|\eta|$ <1) after $|\eta|$ <1.0 cut




dσ/dη (|η|<1)

$d\sigma/d\eta(|\eta|<1) = 42\ (\mathrm{mb}) * \mathrm{Integral}(1/\mathrm{Nevt}*\mathrm{dN}/\mathrm{dpt}/d\eta, 0<\mathrm{pt}<\mathrm{inf}\ ) = 32\ \mu b$

# $d\sigma/d\eta(\lvert\eta\rvert<1)$ and relative yields calculated from PYTHIA simulations

| $d\sigma/d\eta(\lvert\eta\rvert<1)$ Meson | Default | Tuned | Tune A | TuneA+Peterson Frag.Fun. |
|---|---|---|---|---|
| D*+D*bar | 30 μb | 58.6 μb | 29 μb | 28.9 μb |
| D0+D0bar | 63 μb | 119 μb | 58.7 μb | 58.9 μb |
| D+ + D- | 19 μb | 38 μb | 19.7 μb | 19.5 μb |
| D_s+ + D_s - | 12.5 μb | 22.5 μb | 11.8 μb | 11.5 μb |
| Total | 124.5 μb | 238.1 μb | 119.2 μb | 118.8 μb |

| Default | |
|---|---|
| D*+D*bar / D0+D0bar | 0.48 |
| D+ + D- / D0+D0bar | 0.30 |
| D_s+ + D_s - / D0+D0bar | 0.20 |

| Tuned | |
|---|---|
| D*+D*bar / D0+D0bar | 0.49 |
| D+ + D- / D0+D0bar | 0.34 |
| D_s+ + D_s - / D0+D0bar | 0.20 |

| CDF Tune A | |
|---|---|
| D*+D*bar / D0+D0bar | 0.51 |
| D+ + D- / D0+D0bar | 0.31 |
| D_s+ + D_s - / D0+D0bar | 0.13 |

| CDF Tune A + Peterson Frag. Func. | |
|---|---|
| D*+D*bar / D0+D0bar | 0.49 |
| D+ + D- / D0+D0bar | 0.33 |
| D_s+ + D_s - / D0+D0bar | 0.20 |

# σ and relative yields calculated from PYTHIA simulations

| σ<br>Meson | Default | Tuned | Tune A | TuneA+Peterson Frag. Func. |
|---|---|---|---|---|
| D*+D*bar | 240 μb | 414 μb | 220 μb | 220 μb |
| D0+D0bar | 486 μb | 850 μb | 447 μb | 447 μb |
| D+ + D- | 156 μb | 270 μb | 143 μb | 144 μb |
| D_s+ + D_s - | 90.5 μb | 156 μb | 85 μb | 85.5 μb |
| ~ total ccbar σ | 486.25 μb | 845 μb | 447.5 μb | 448.25 μb |

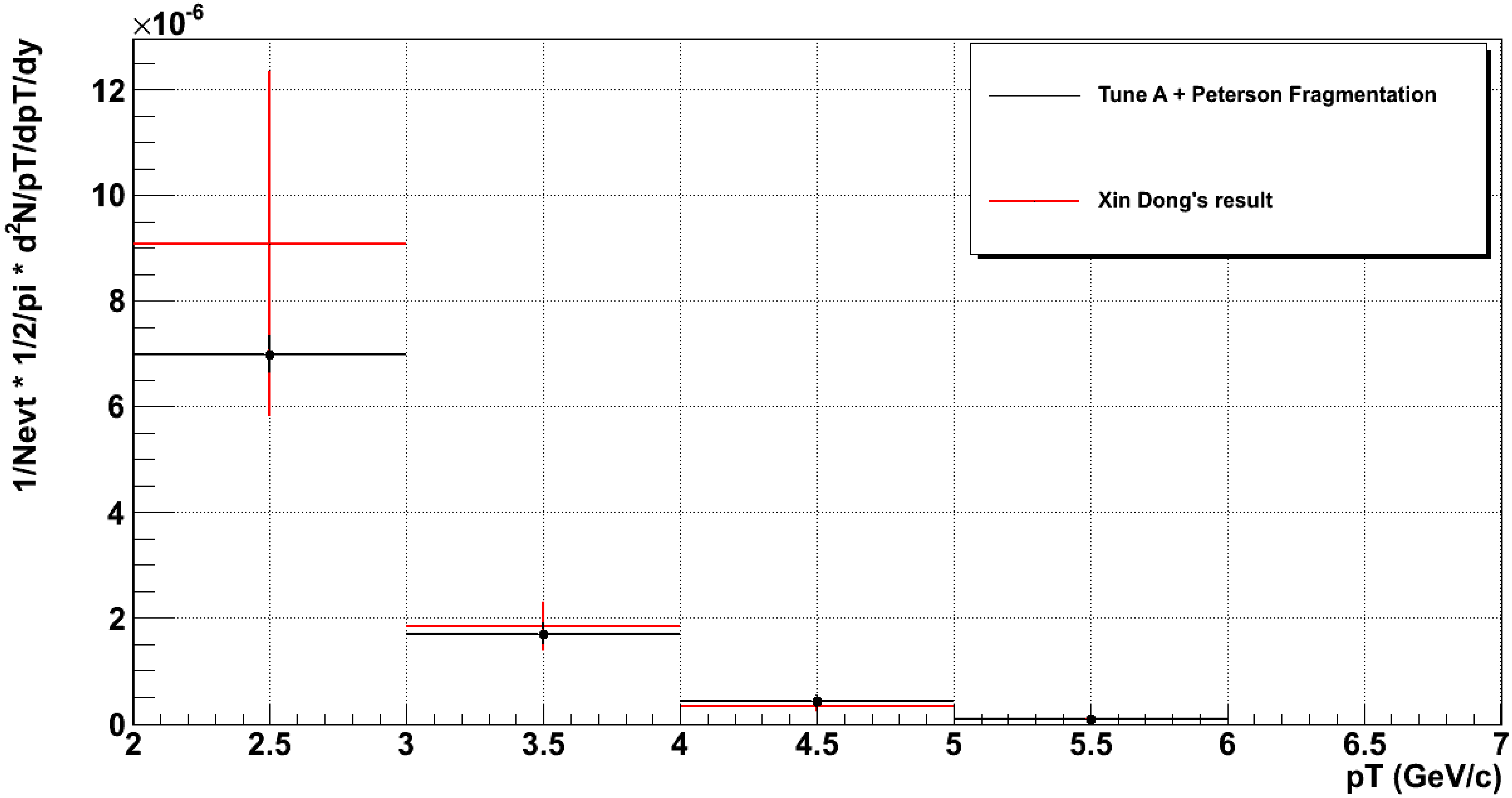
| Default | |
|---|---|
| D*+D*bar / D0+D0bar | 0.49 |
| D+ + D- / D0+D0bar | 0.32 |
| D_s+ + D_s - / D0+D0bar | 0.19 |

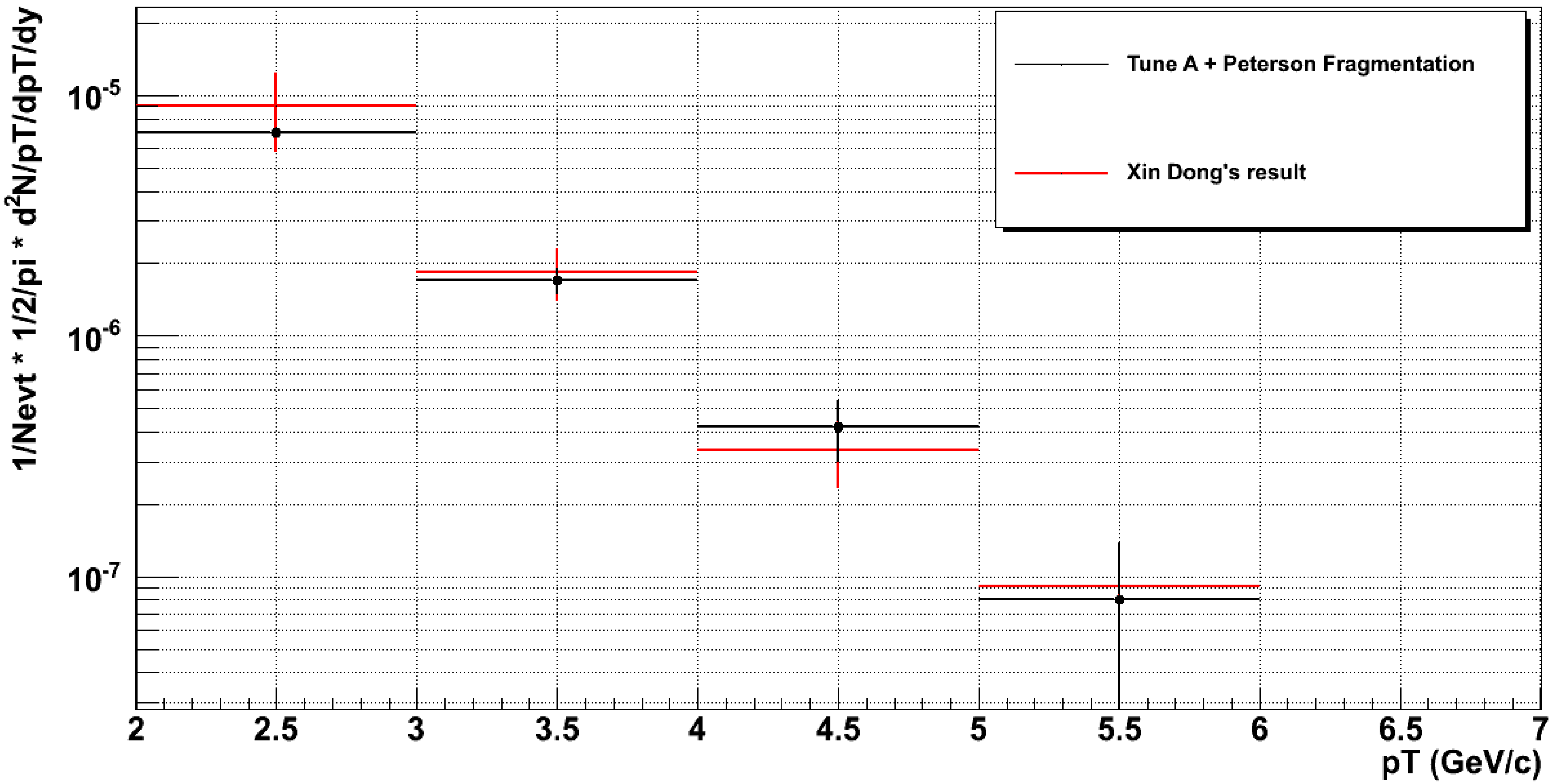
| Tuned | |
|---|---|
| D*+D*bar / D0+D0bar | 0.49 |
| D+ + D- / D0+D0bar | 0.32 |
| D_s+ + D_s - / D0+D0bar | 0.19 |

| Tune A | |
|---|---|
| D*+D*bar / D0+D0bar | 0.47 |
| D+ + D- / D0+D0bar | 0.30 |
| D_s+ + D_s - / D0+D0bar | 0.17 |

| CDF Tune A + Peterson Frag. Func. | |
|---|---|
| D*+D*bar / D0+D0bar | 0.49 |
| D+ + D- / D0+D0bar | 0.32 |
| D_s+ + D_s - / D0+D0bar | 0.19 |

# Comparison of D* invariant yield
# Xin Dong's result to CDF tune A (CTEQ5L) + Peterson Fragmentation function





Tune A + Peterson Fragmentation
Xin Dong's result
1/Nevt * 1/2/pi * d2N/pT/dpT/dy
10-5
10-6
10-7
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
pT (GeV/c)