Preview: Results from Analysis of Run 11 Transverse Asymmetries at 500 GeV

Steve Heppelmann

Penn State

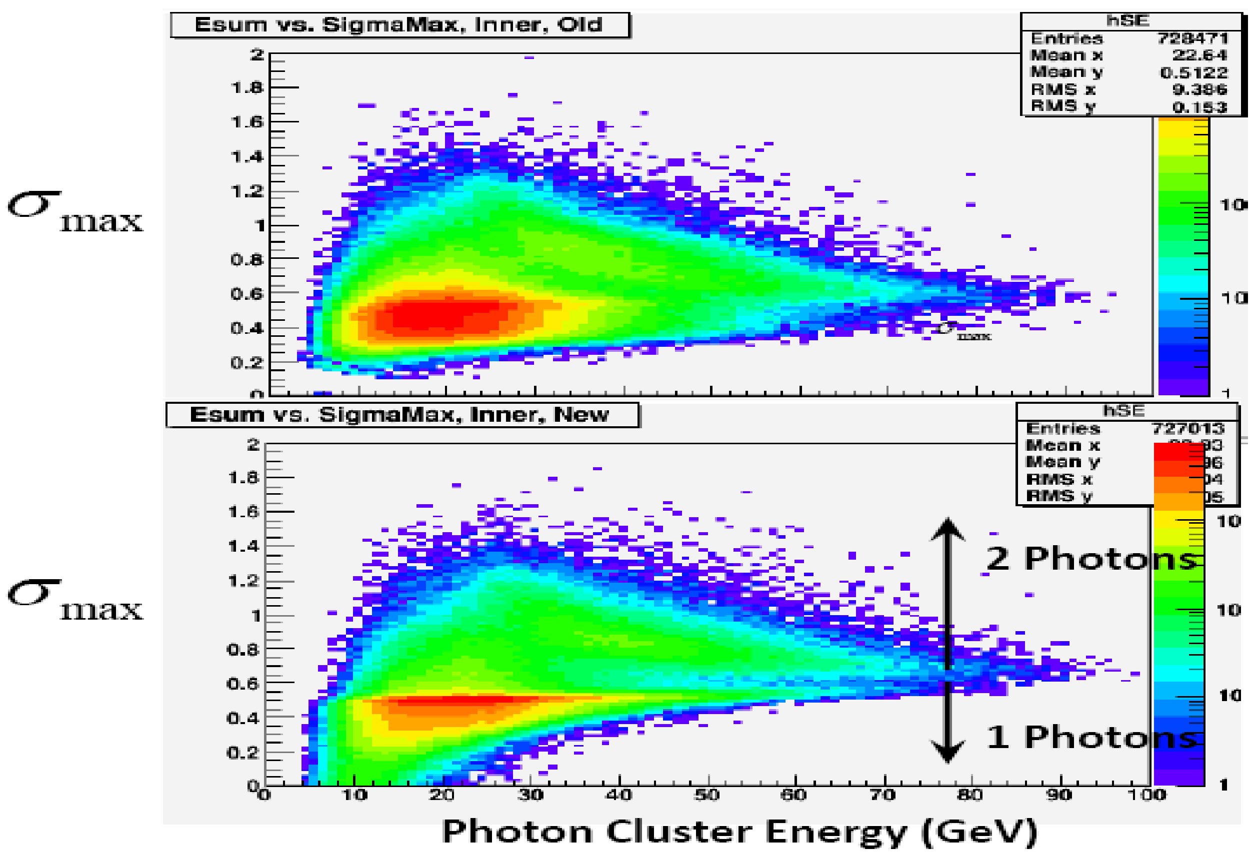
To be done:

- Improve time LED drift compensation (Yux1) %80 completed
- Improve Shower Shape (Saraj) 60% completed
- Smooth out calibration (improve marginal cell callibration) Chris 50% (see talk)
- Simulation Thomas, Alan, Me 10%

$$\Delta\sigma_x{}^2 = \frac{\sum\limits_{i\,(e_i>e_0)} (x_i - x_0)^2 \ln(e_i/e_0)}{\sum\limits_{i\,(e_i>e_0)} \ln(e_i/e_0)} \qquad \Delta\sigma_x\Delta\sigma_y = \frac{\sum\limits_{i\,(e_i>e_0)} (x_i - x_0)(y_i - y_0)\ln(e_i/e_0)}{\sum\limits_{i\,(e_i>e_0)} \ln(e_i/e_0)}$$

<u>Separation of single photon cluster from two photon cluster based upon distribution of shower energy along a preferred axis.</u>

$$\sigma_{\max} \equiv Max\ Eigenvalue\ of \begin{bmatrix} \Delta\sigma_x{}^2 & \Delta\sigma_x\Delta\sigma_y \\ \Delta\sigma_y\Delta\sigma_x & \Delta\sigma_y{}^2 \end{bmatrix}$$



Old algorithm with
Energy weighted moments

Improved algorithm with
log energy weighted moments.

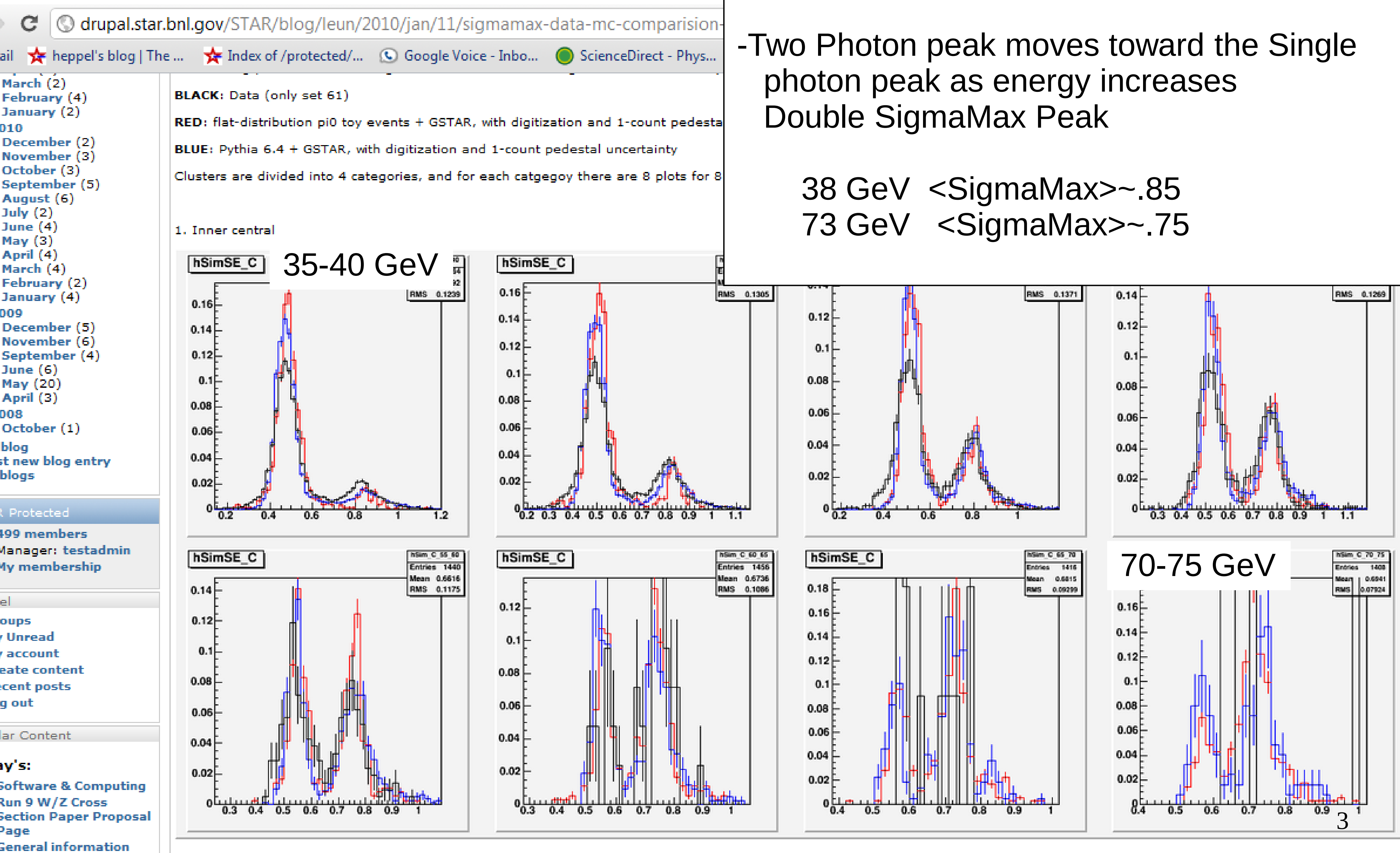
Provides clearer separation
Between π^0 and single photon.
Clusters up to ~80 GeV.

From Len's Analysis,

-Single Photon peak changes little with Energy
Single peak at SigmaMax~.5

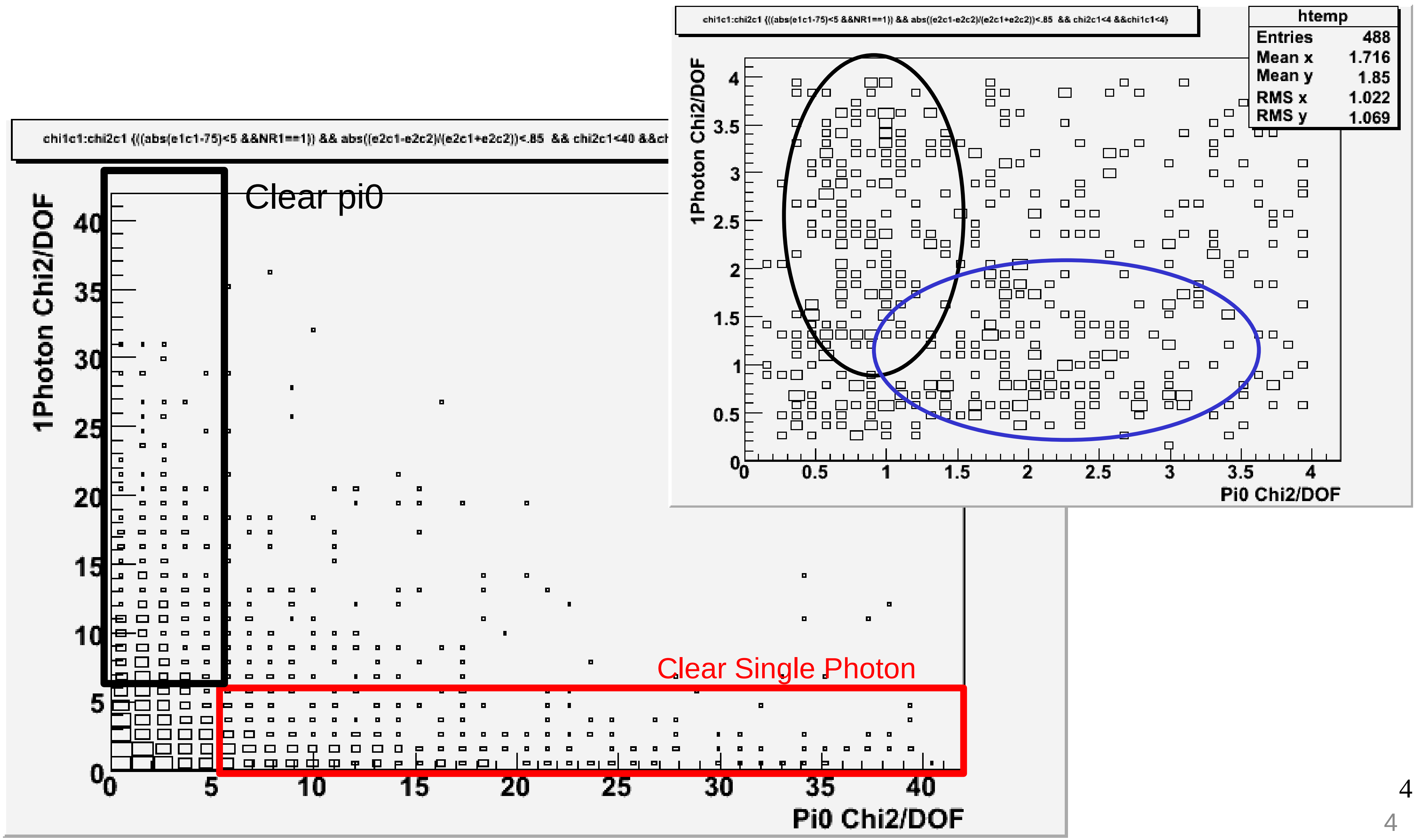
-Two Photon peak moves toward the Single photon peak as energy increases
Double SigmaMax Peak

38 GeV <SigmaMax>~.85
73 GeV <SigmaMax>~.75



Geant4 Simulation
70-80 GeV Single Cluster Events.

- N =1870
- N chi2(photon)<5 && chi2(pi0)<5=488 (33%)
- N Clear pi0 = 460 (30%)
- N Clear Single Photon = 540 (37%)

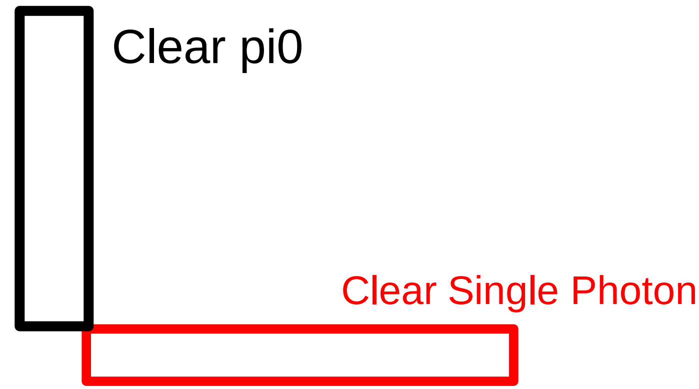


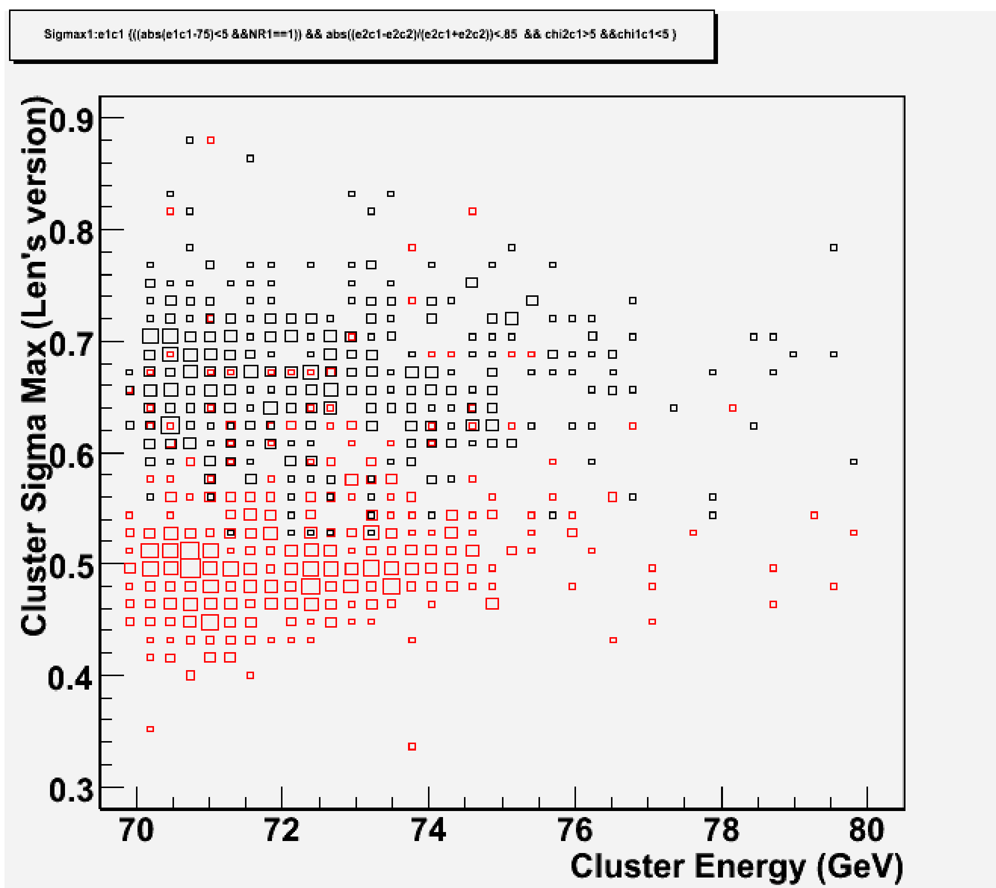
4

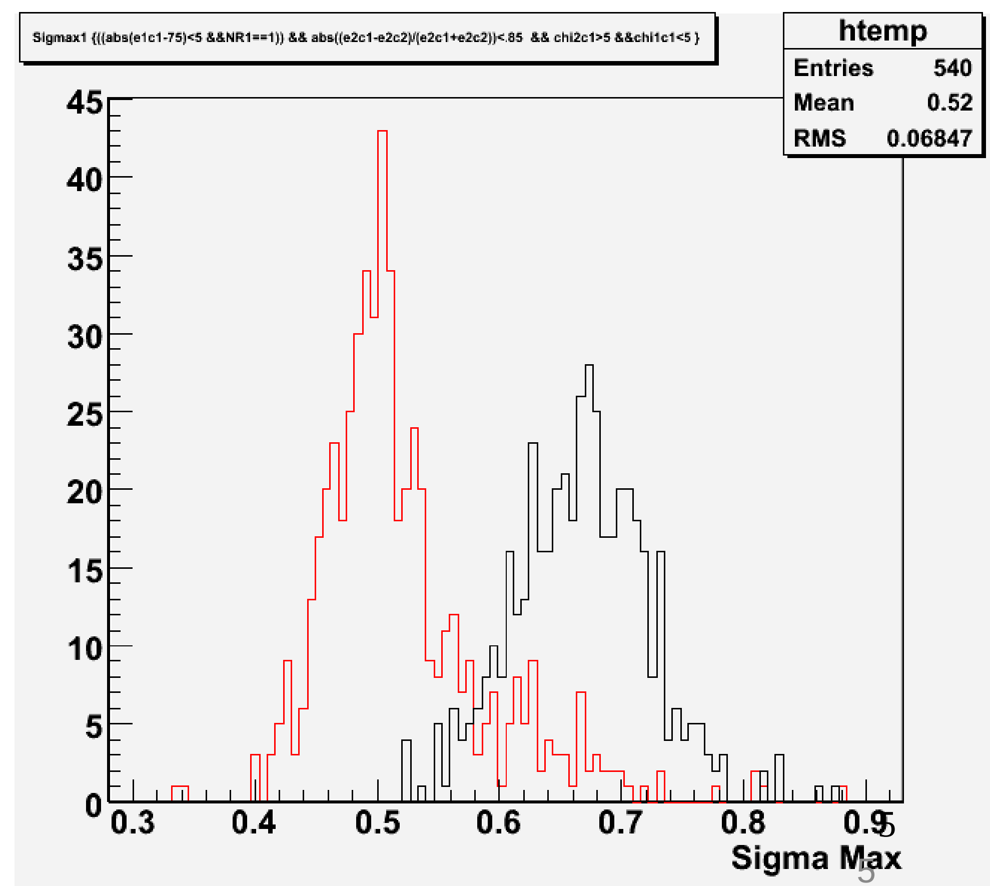
Sigma Max for the 67% of events that have well separated pi0 and single photon.

Using the “one cluster” events (70 to 80 GeV) from the previous page:
We now look at “Len’s Sigma Max” variable that is used to categorize Clusters.

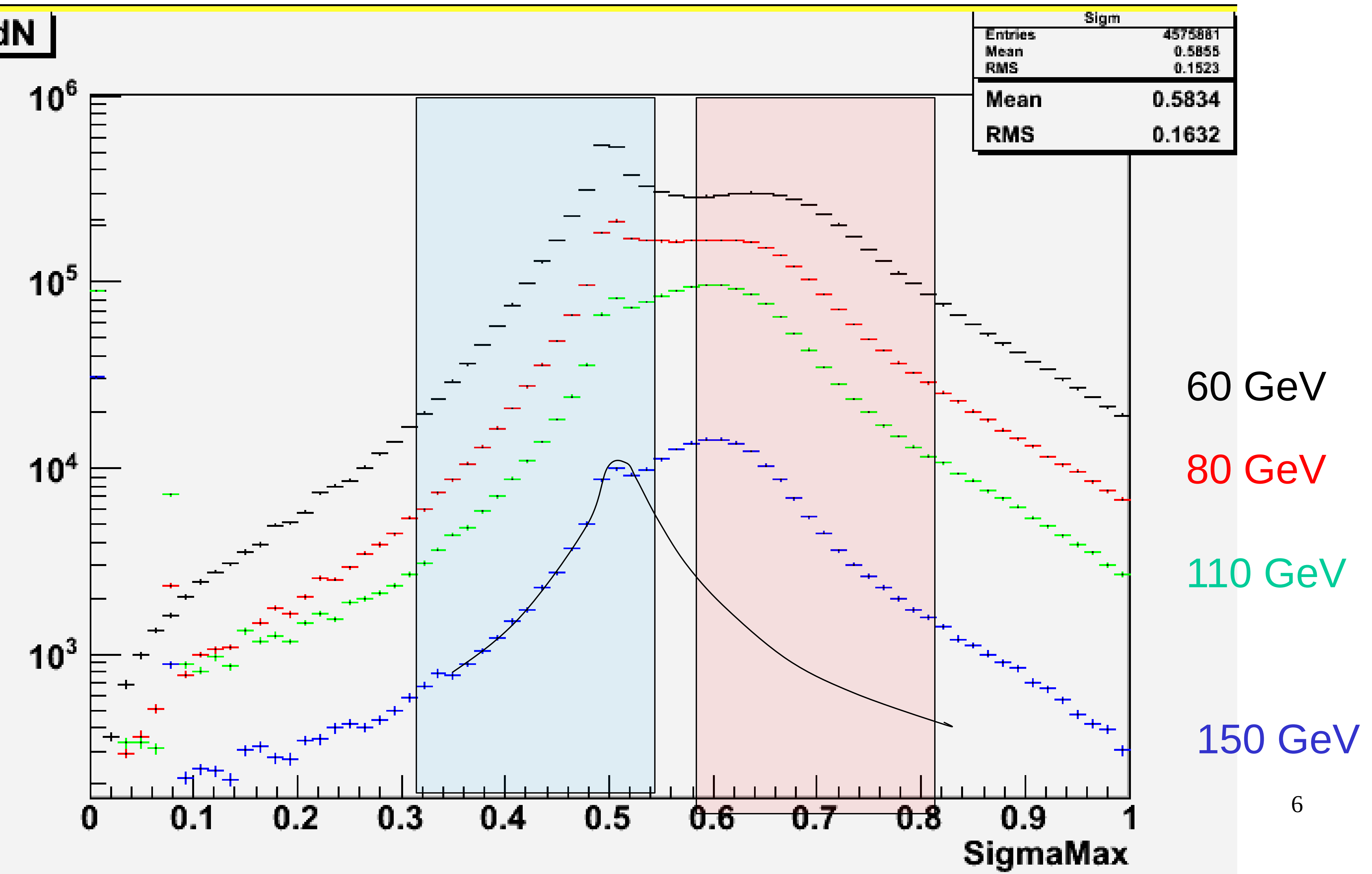
In the figures below, the “Sigma Max” distributions are shown.
The red represents events with chi2(pi)>5 && chi2(gamma)<5.
The black represents events with chi2(pi)<5 && chi2(gamma)>5.



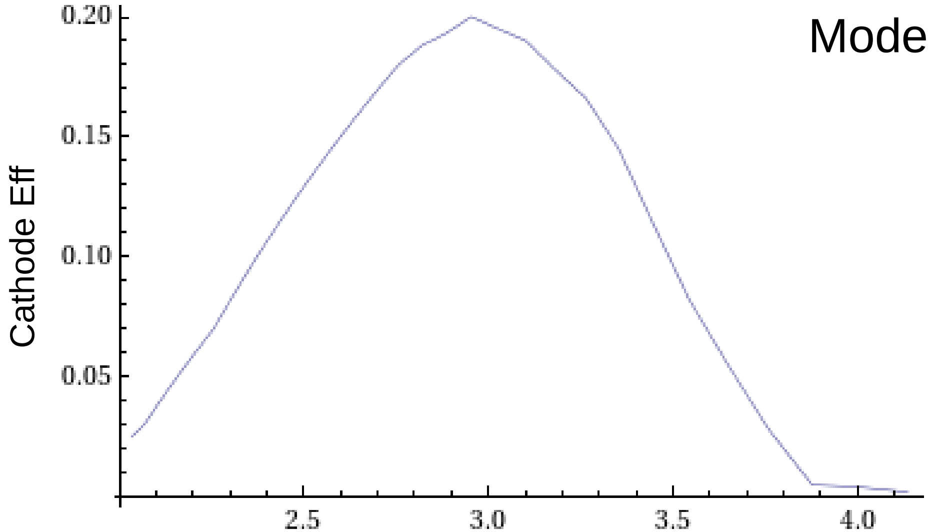


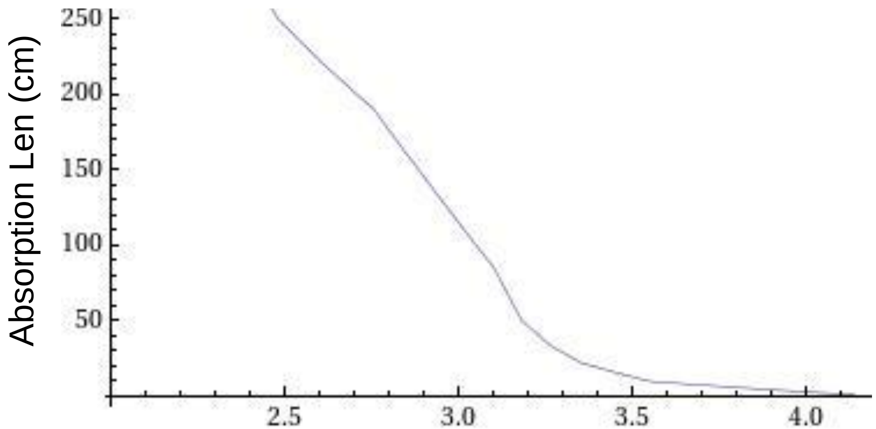


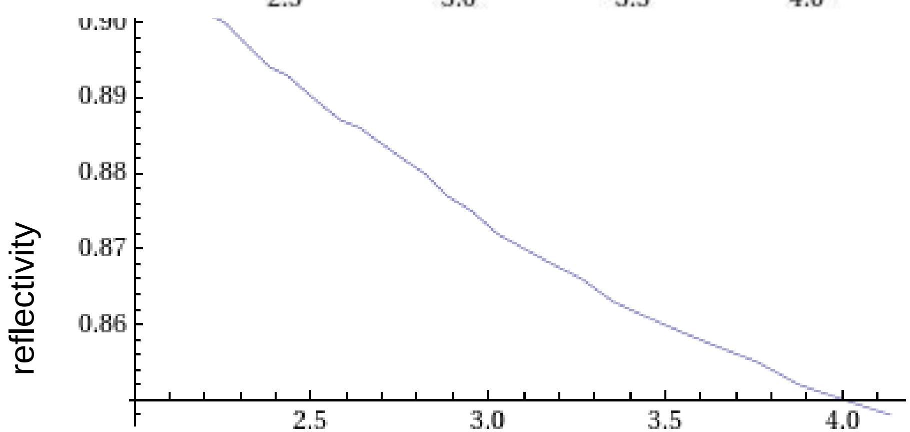
Run 11 distributions of SigmaMax as a indicator of single photon vs pi0 only slowly degrades with higher energy.



Model 1







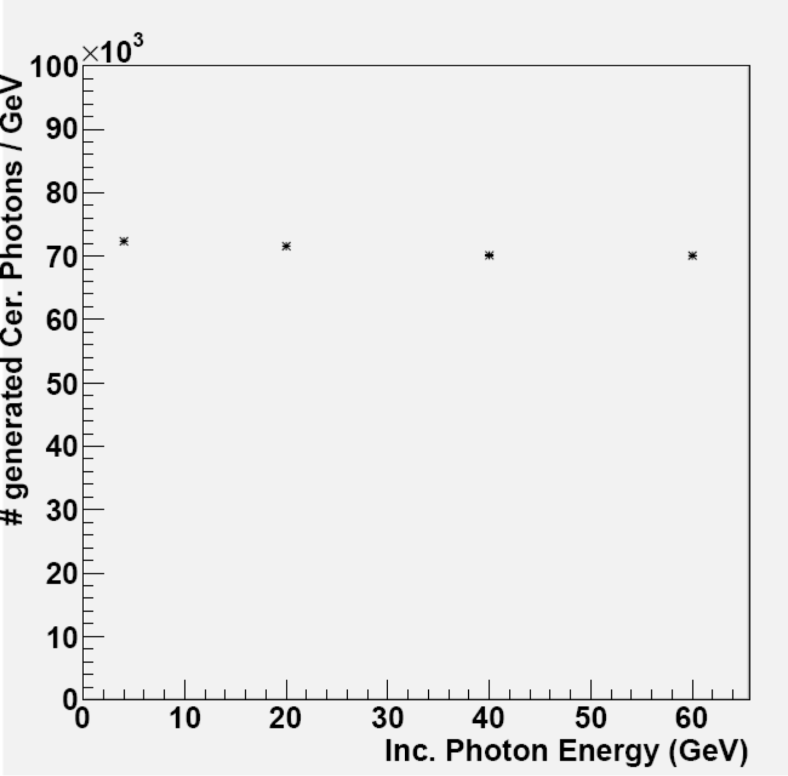
This is a study of a Geant4 based model of a 7x7 Small Cell
FPD type detector.

In the following presentation

- The signal is modeled both as **energy deposited** in cells and simultaneously as **Number of Cerenkov** produced in the cell and detected at the photo cathode

• Simulation involves a single photon directed in the center of the center cell of a 7x7 array of cells. The cells are arranged with their long axis along the z axis and the photon momentum is in the z direction.

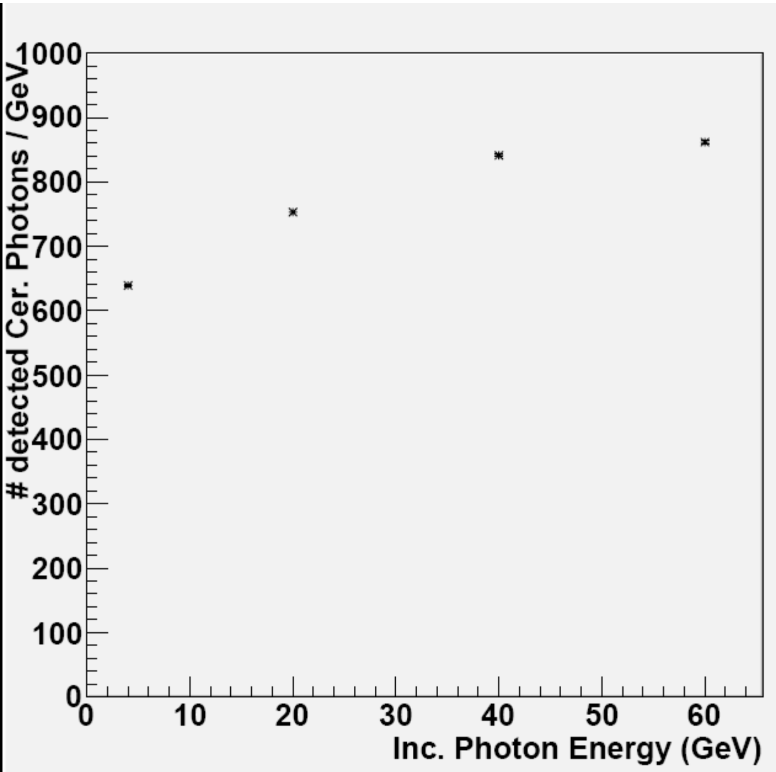
- The detected Cerenkov signal is reduced from the number of produced Cerenkov by three factors
  - Photocathode efficiency as a function of photon energy
  - Absorption length of glass as a function photon energy
  - Reflectivity of Cell surfaces as a function of energy.



Number of Generated Cerenkov Photons

~ 70000 Photons/GeV

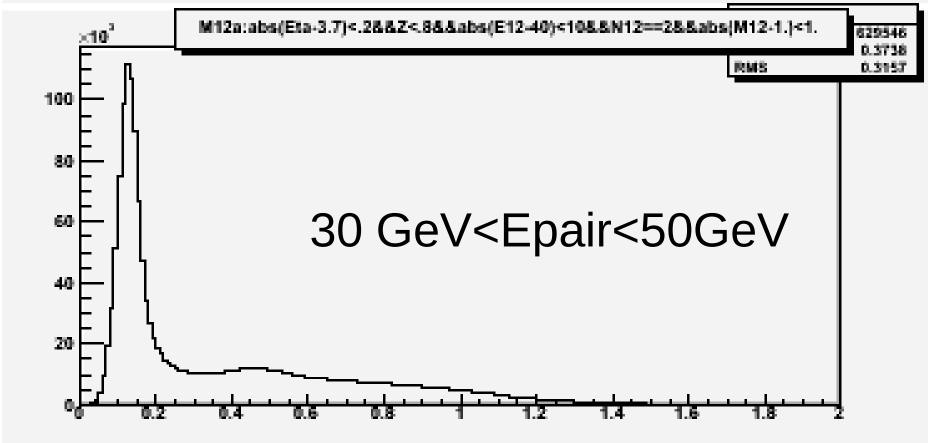
Independent of Photon Energy

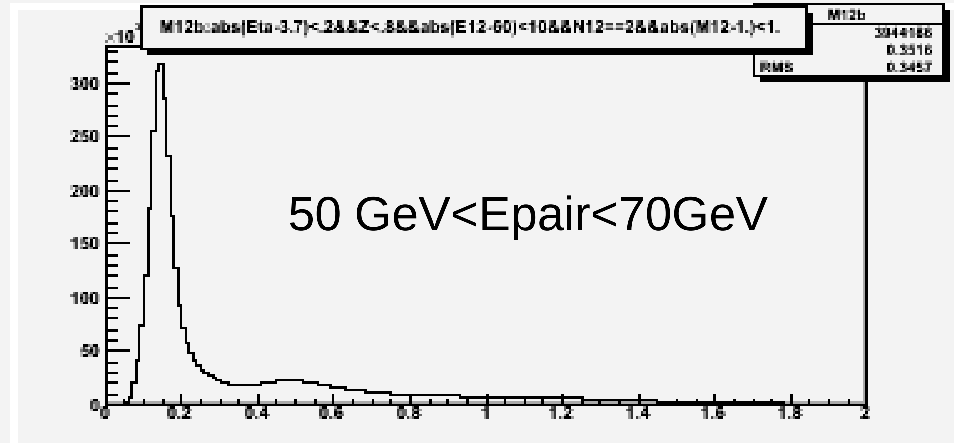


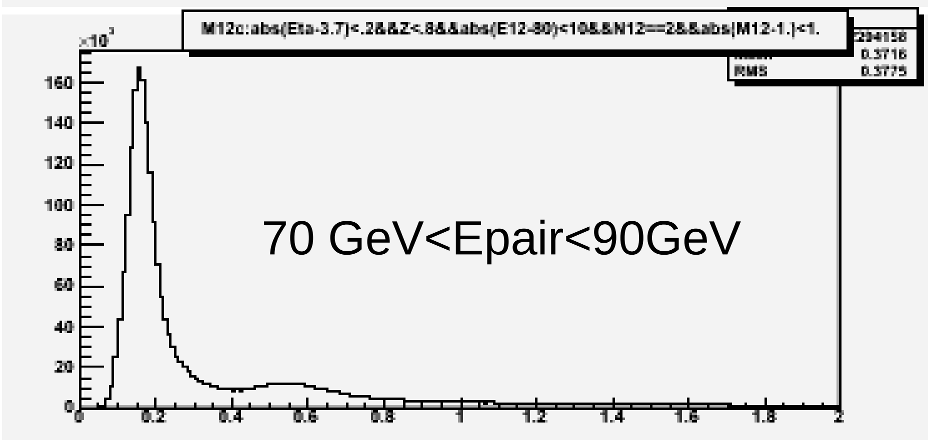
Number of Detected Cerenkov Photons

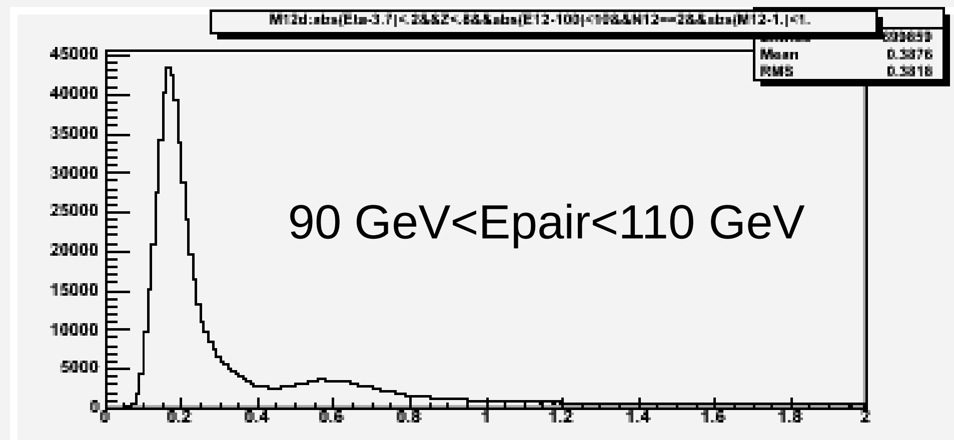
600 to 800 Photons/GeV

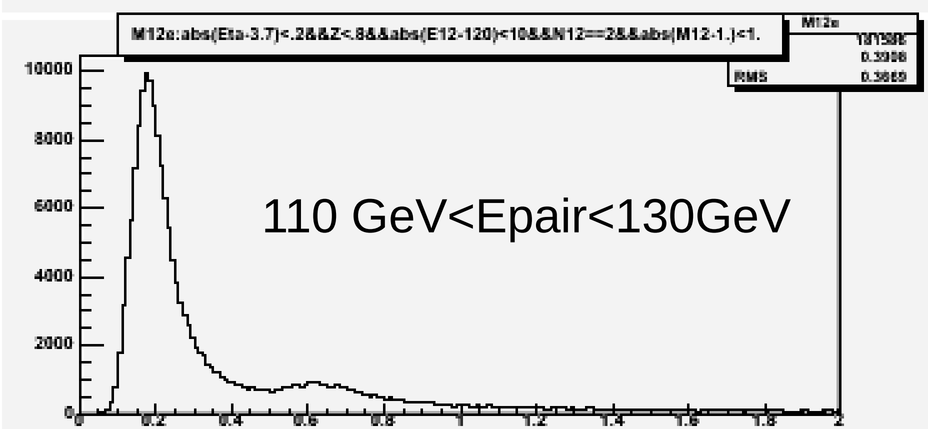
30% CHANGE IN NUMBER
for Energy from 4 to 60 GeV

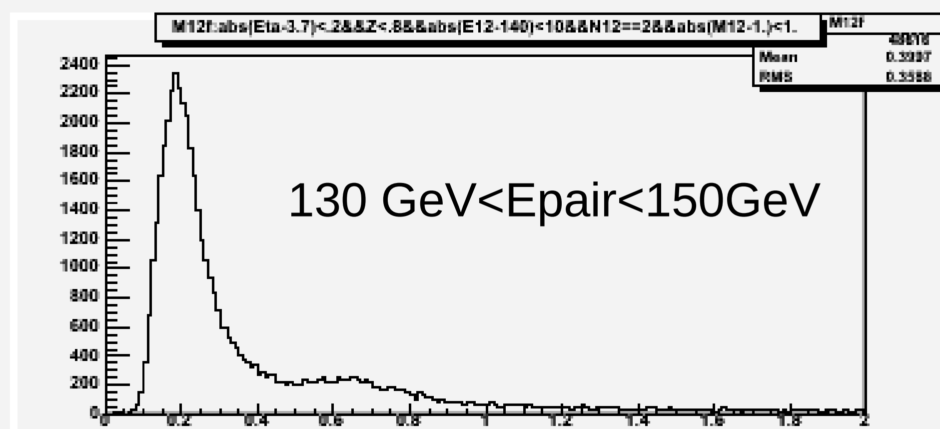

M12a:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-40)<10&&N12==2&&abs(M12-1.)<1.
30 GeV<Epair<50GeV

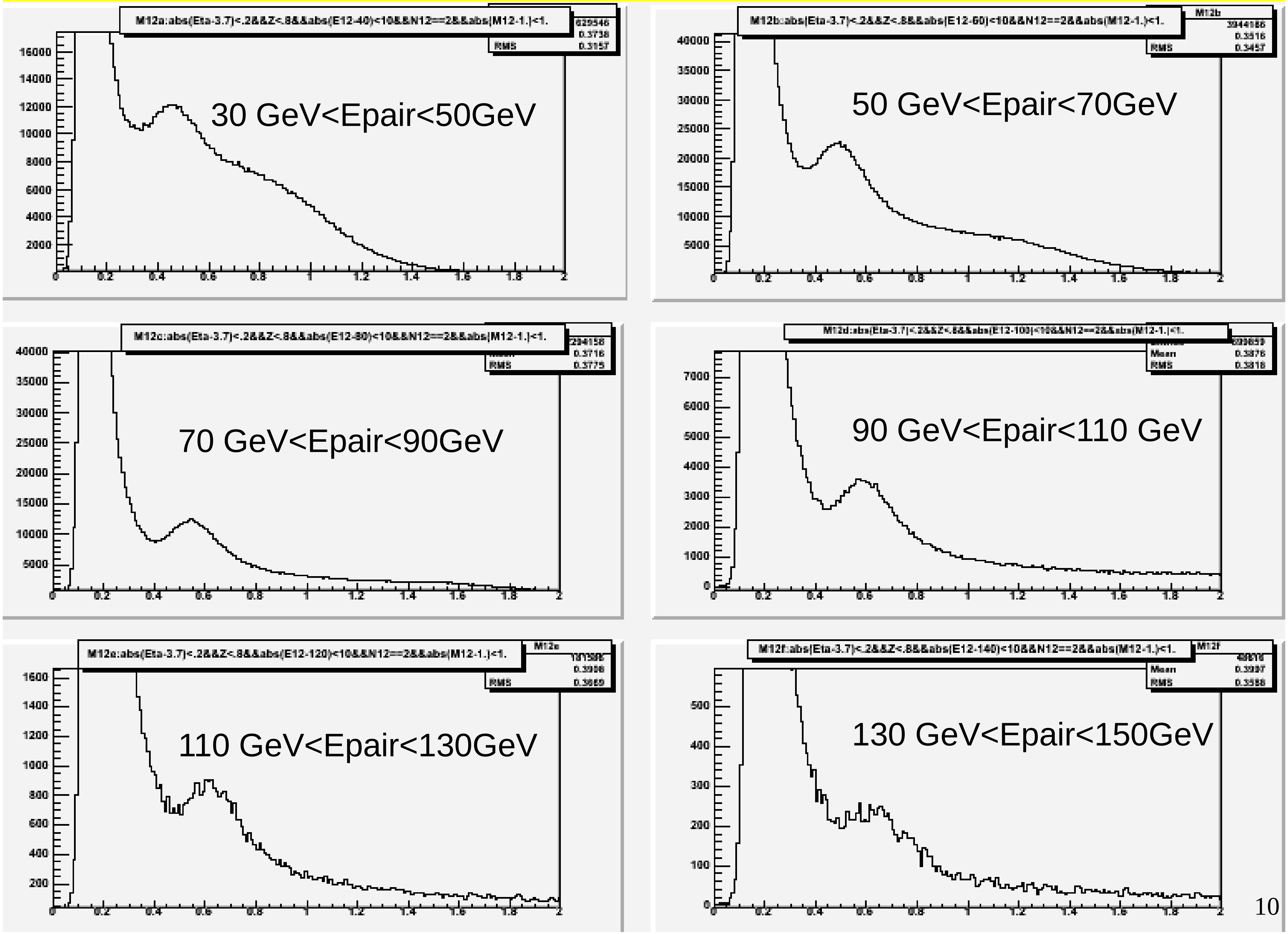

M12b:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-60)<10&&N12==2&&abs(M12-1.)<1.
50 GeV<Epair<70GeV


M12c:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-80)<10&&N12==2&&abs(M12-1.)<1.
70 GeV<Epair<90GeV


90 GeV<Epair<110 GeV


M12e:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-120)<10&&N12==2&&abs(M12-1.)<1.
110 GeV<Epair<130GeV


M12f:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-140)<10&&N12==2&&abs(M12-1.)<1.
130 GeV<Epair<150GeV


M12a:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-40)<10&&N12==2&&abs(M12-1.)<1.
30 GeV<Epair<50GeV
M12b:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-60)<10&&N12==2&&abs(M12-1.)<1.
50 GeV<Epair<70GeV
M12c:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-80)<10&&N12==2&&abs(M12-1.)<1.
70 GeV<Epair<90GeV
90 GeV<Epair<110 GeV
M12e:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-120)<10&&N12==2&&abs(M12-1.)<1.
110 GeV<Epair<130GeV
M12f:abs(Eta-3.7)<.2&&Z<.8&&abs(E12-140)<10&&N12==2&&abs(M12-1.)<1.
130 GeV<Epair<150GeV

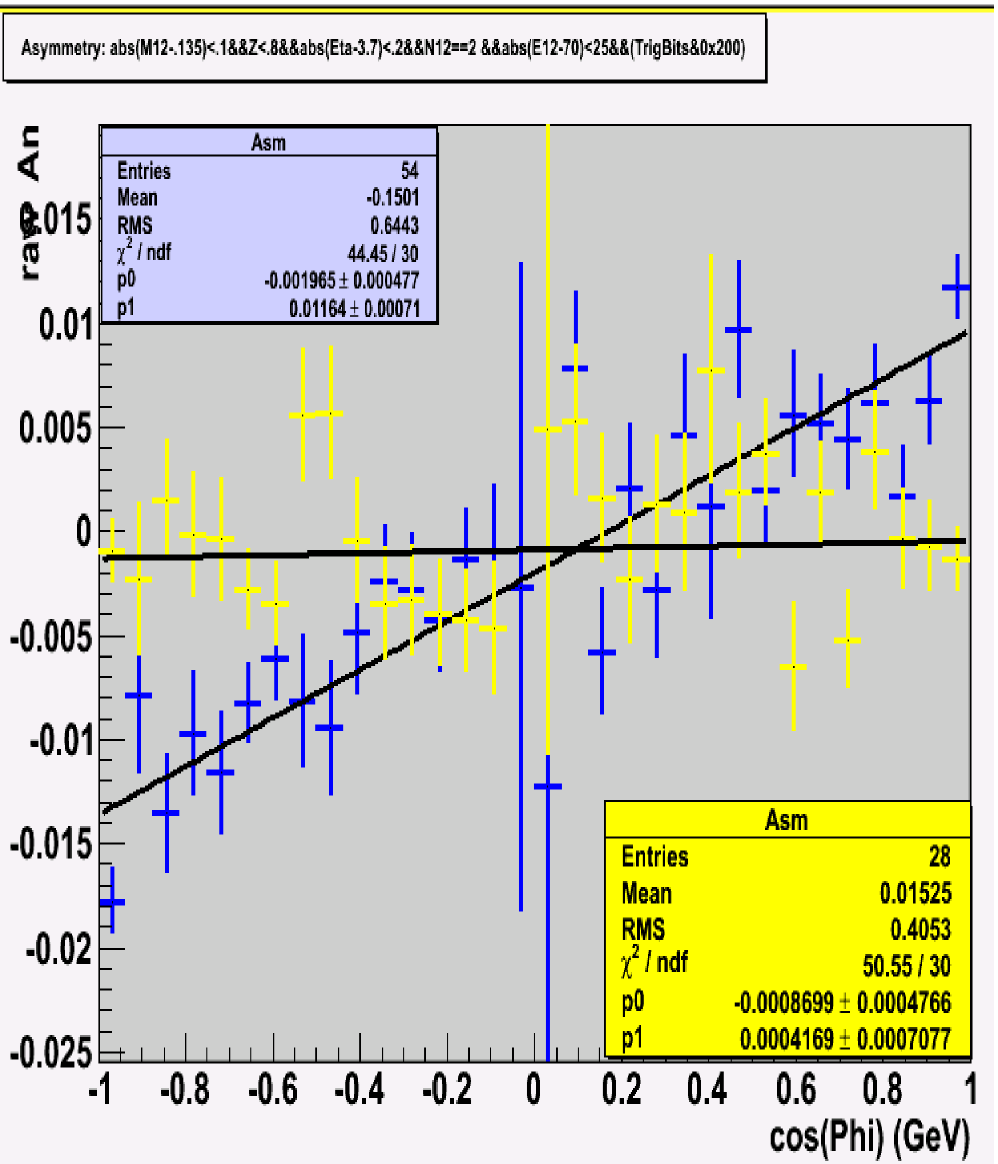
Raw AN vs Cos(Phi) Distributions for yellow and blue beams (colors indicate beams)

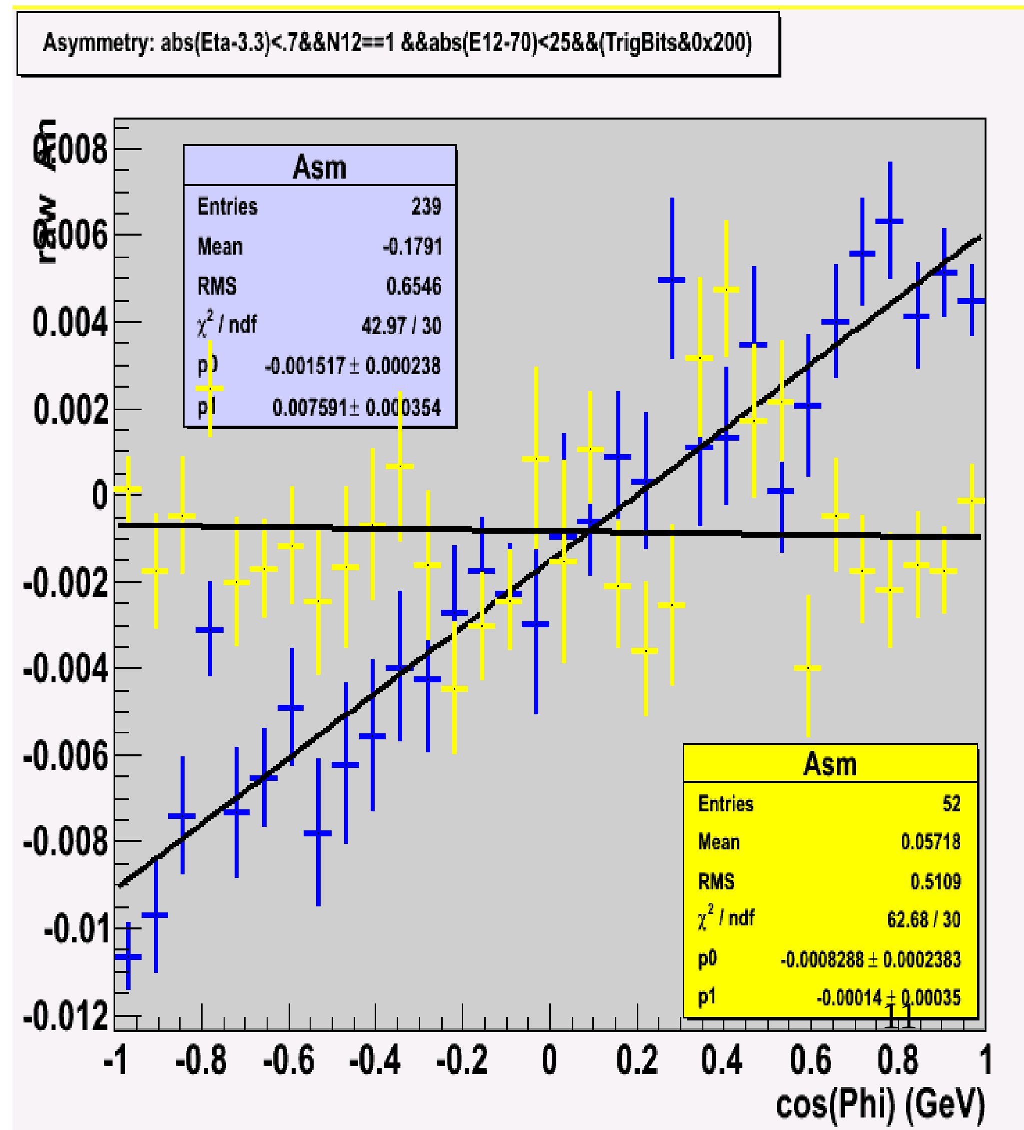
Left: pi0 events (3.5<Y<3.9) && (45 GeV< Epair<95 GeV)

<raw A_N(blue)>=1.16% +/- 0.07% **<raw A_N(yellow)>=-0.04% +/- 0.07%**

Right: Single Photon events (2.6<Y<4.1) && (45 GeV< Epair<95 GeV)

<raw A_N(blue)>=0.76% +/- 0.03% **<raw A_N(yellow)>=-0.01% +/- 0.03%**





The rest of these slides will display

Blue Beam Single Spin Asymmetries.

Cross Ratios are calculated using definitions of Left and Right with

$$\left|\cos(\phi)\right| > 0.5$$

$$\left\langle\left|\cos(\phi)\right|\right\rangle \sim 0.8$$

$$Pol = 0.5$$

All SSA that follow are calculated using

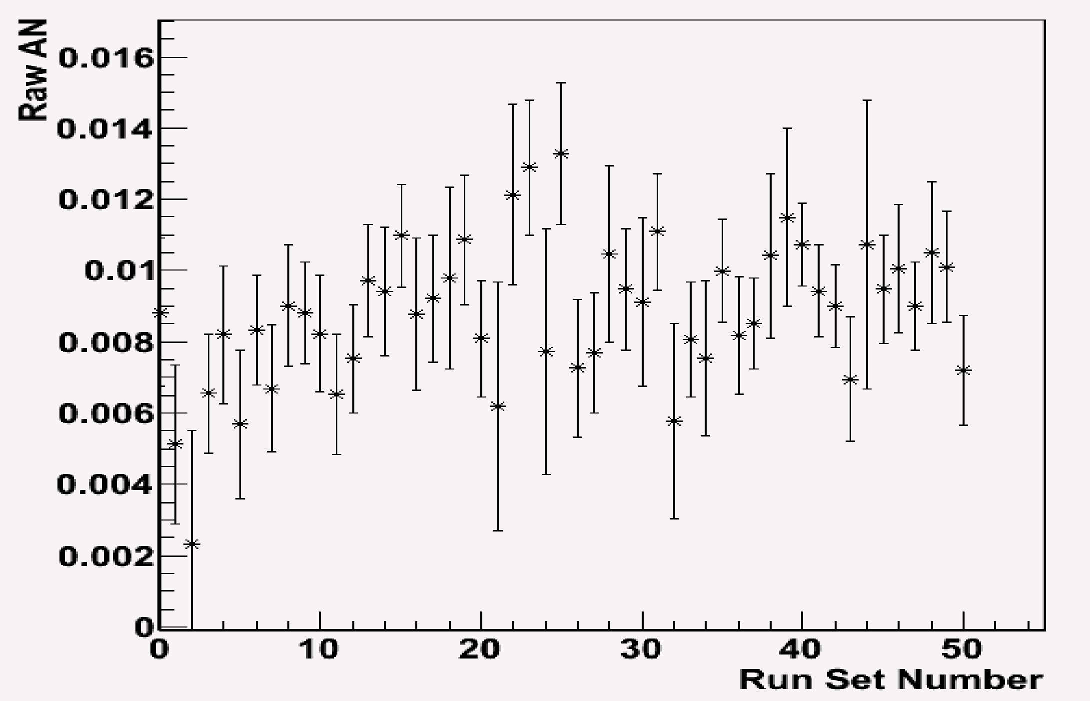
- **High Threshold Jet Trigger**
- **~250 Runs in day 79-98 range**
- **Blue Beam**
- **Pol ~ 0.5**
- **|Cos(Phi)|>0.5 (<|Cos(Phi)|>=0.8**

Raw Asymmetry of 1 and 2 photon events vs run set number: (Run 11: day 79 – day 98)

Selection Cuts:
abs(Eta-3.3)<.7
&& ((N12==1) || (abs(M12-.135)<.09 && N12==2))
&& abs(E12-70)<25

0 Outputset079a.root
1 Outputset079b.root
2 Outputset079c.root
3 Outputset080a.root
4 Outputset080b.root
5 Outputset080c.root
6 Outputset081a.root
7 Outputset081b.root
8 Outputset082a.root
9 Outputset083a.root
10 Outputset083b.root
11 Outputset083c.root
12 Outputset083d.root
13 Outputset084a.root
14 Outputset084b.root
15 Outputset085a.root
16 Outputset086a.root
17 Outputset086b.root
18 Outputset086c.root
19 Outputset087a.root
20 Outputset087b.root
21 Outputset087c.root
22 Outputset088a.root
23 Outputset088b.root
24 Outputset088c.root
25 Outputset089a.root
26 Outputset090a.root
27 Outputset090b.root
28 Outputset090c.root
29 Outputset091a.root
30 Outputset091b.root
31 Outputset091c.root
32 Outputset091d.root
33 Outputset092a.root
34 Outputset092b.root
35 Outputset092c.root
36 Outputset093a.root
37 Outputset093b.root
38 Outputset093c.root
39 Outputset093d.root
40 Outputset094a.root
41 Outputset094b.root
42 Outputset095a.root
43 Outputset095b.root
44 Outputset096a.root
45 Outputset096b.root
46 Outputset096c.root
47 Outputset097a.root
48 Outputset097b.root
49 Outputset098a.root
50 Outputset098b.root

Raw Asymmetry (Blue) for 1 & 2 photon events



Data Reanalyzed at PSU 8-12-11 through 8-17-11

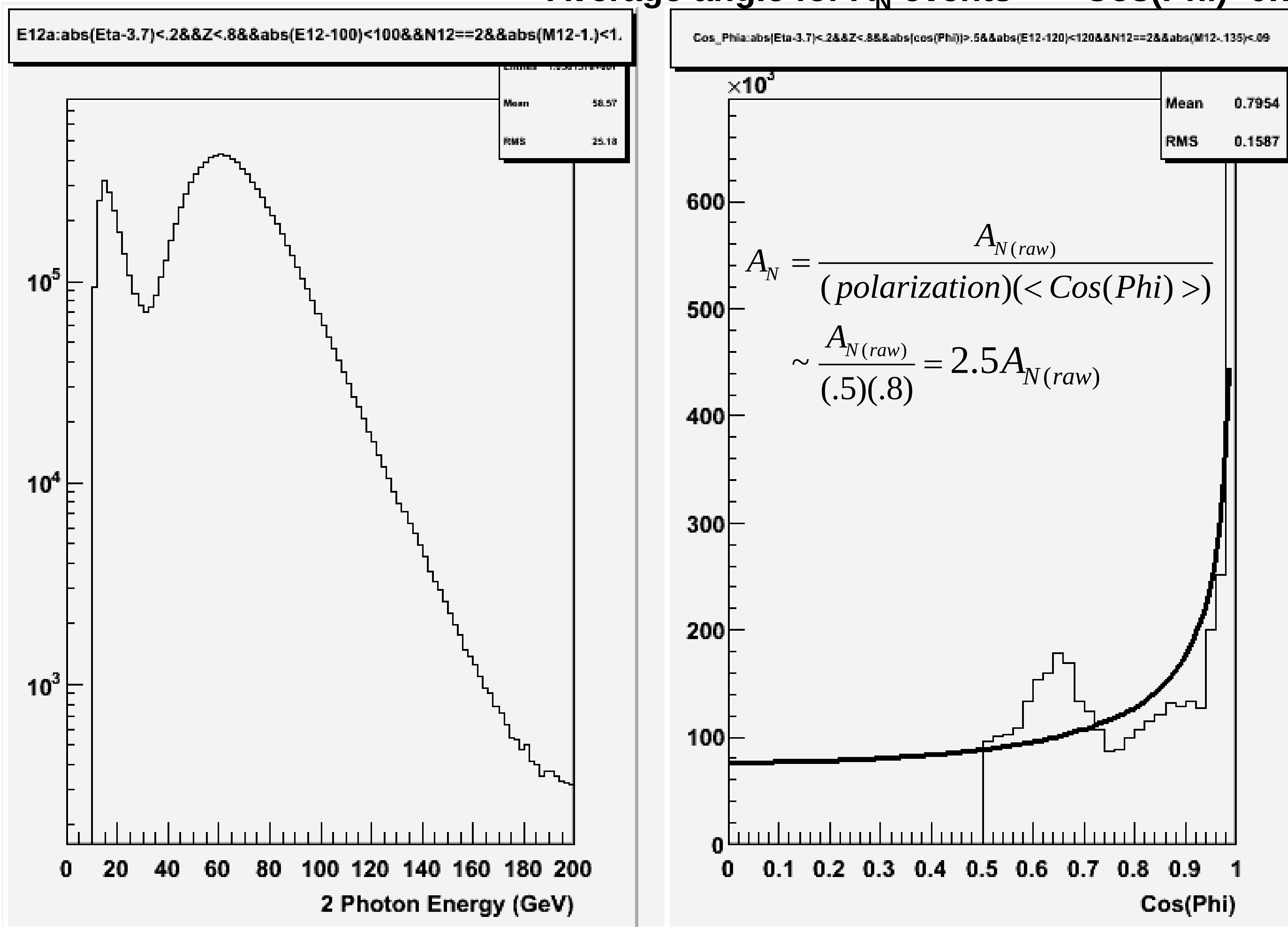
- Improved day 95 based calibration
- LED Corrections with small cell LED recalibration on daily basis
- Turn on **SigmaMax** based single cluster analysis (categories 0-2).

Pion/Single Photon analysis based on Red Sets
Eta analysis based on all sets (~300 runs)

Left: Two Photon Energy Distribution for (M12<2 && abs(Eta-3.7)<.2 && N12==2) &&Z<.7)
(Photons collected independently within .07 radians)

Right: Cosine Azimuthal Angle Distribution For (above cuts && abs(M12-.135)<09)

Average angle for A_N events = <Cos(Phi)=0.795



$$A_N = \frac{A_{N(raw)}}{(polarization)(<Cos(Phi)>)}$$

$$\sim \frac{A_{N(raw)}}{(.5)(.8)} = 2.5A_{N(raw)}$$

A guess might be that Asymmetries will be similar at 500GeV to 200 GeV when plotted against X_F and P_T .

For Asymmetric (forward) parton collisions,

- X_F reflects the momentum fraction of the forward parton.
- P_T reflects the inverse of the distance scale over which parton trajectories scatter coherently (in Phase).
  Higher twist means more partons squeezed into a distance scale $1/P_T$.
  Higher twist amplitudes fall with additional factors of $1/P_T$ reflecting the geometric improbability of finding more partons within a smaller and smaller transverse region.

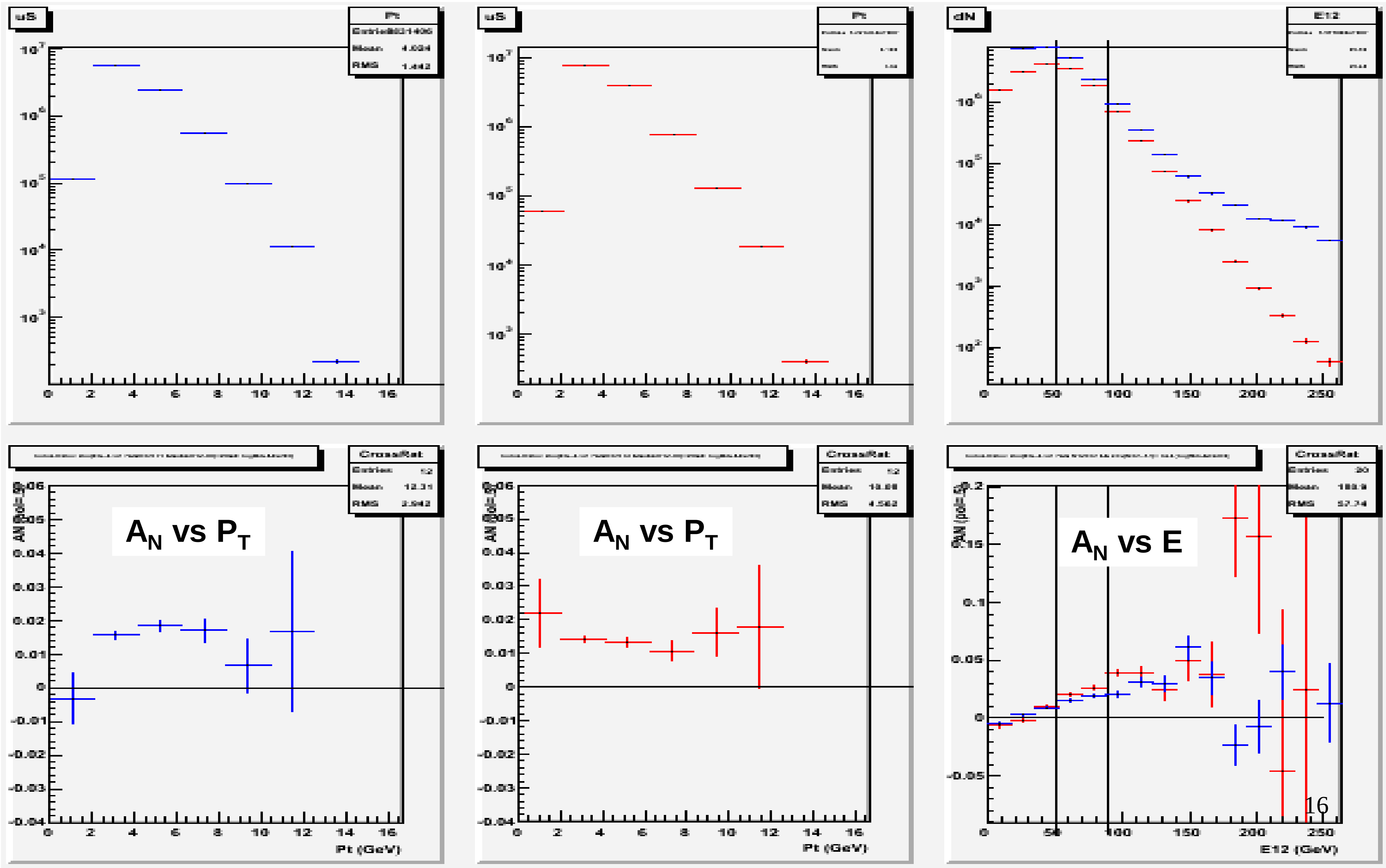
If Asymmetries don't fall with factors $1/P_T$ it implies

- Leading Twist physics (violating helicity conservation and inconsistent with known phases of leading twist processes)
- Non-perturbative effects like scattering in a classical background field.

The P_T dependence of Asymmetries is extremely important in unraveling the nature of forward spin physics.

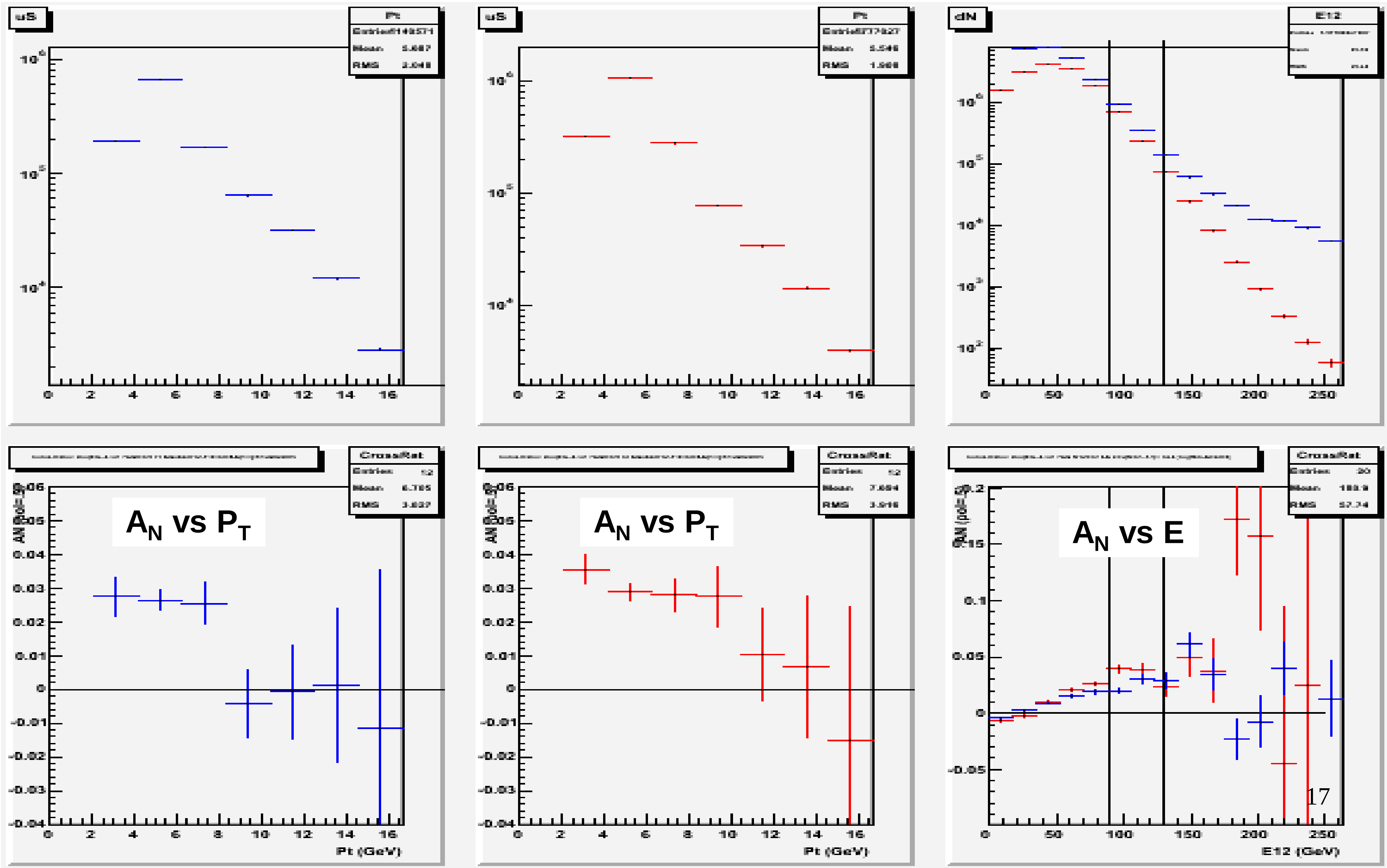
Yield (top row) and Single Spin Transverse Asymmetry (bottom row) vs Pt and Energy.
Pt dependence for 50 GeV<E12<90 GeV .

Single Photon (blue) **Pi0 (red)**



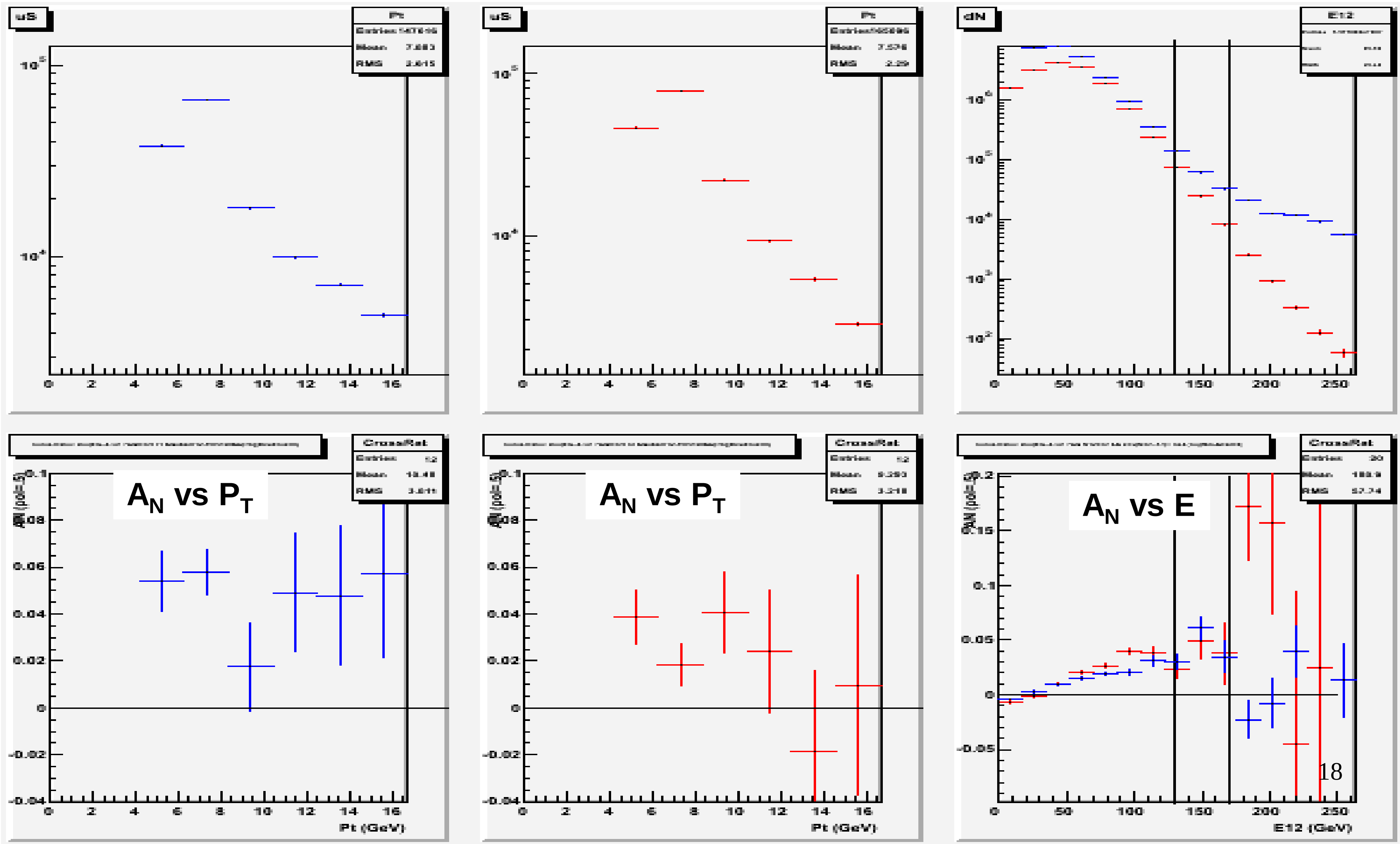
Yield (top row) and Single Spin Transverse Asymmetry (bottom row) vs Pt and Energy.
Pt dependence for 90 GeV<E12<130 GeV .

Single Photon (blue) **Pi0 (red)**

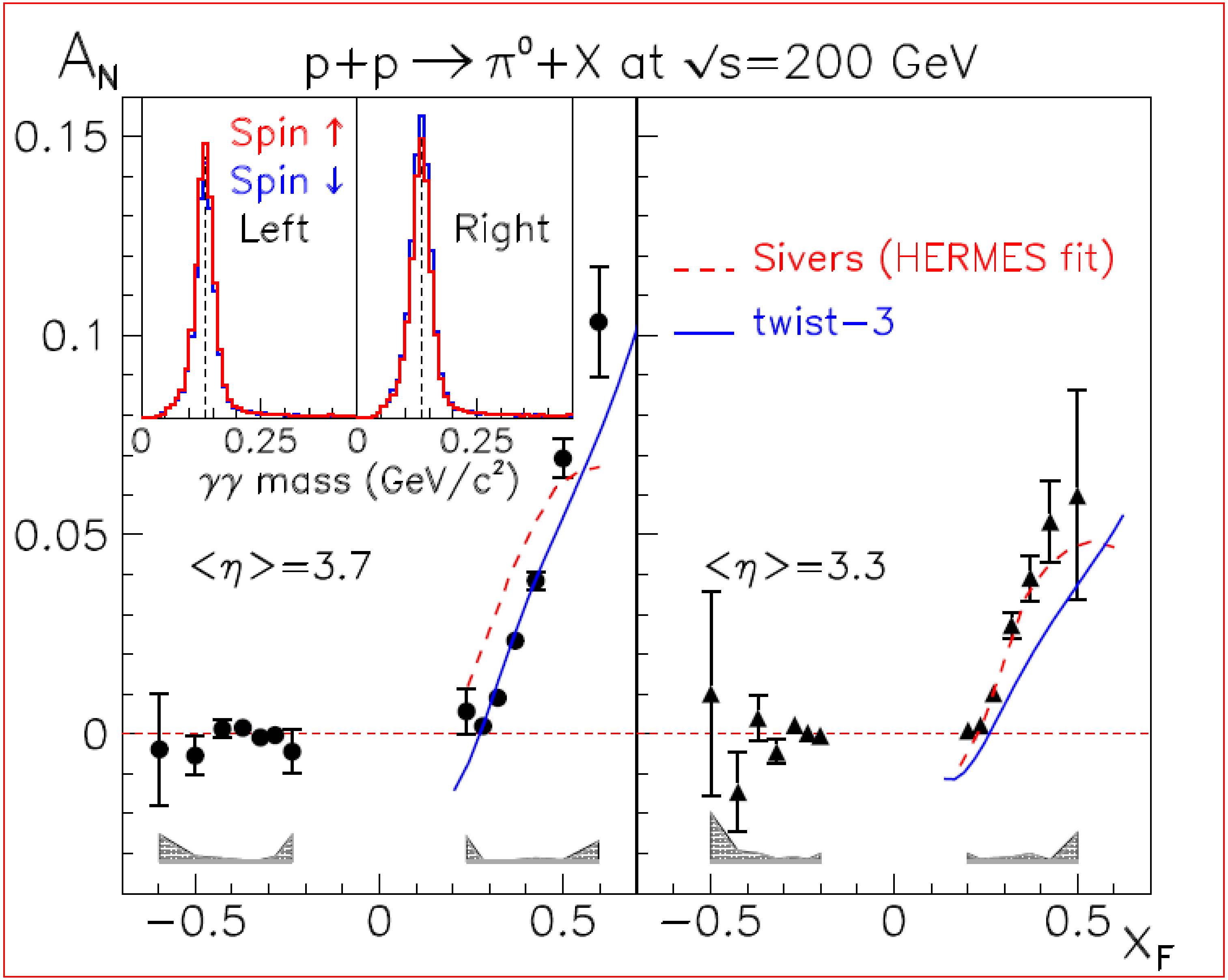


Yield (top row) and Single Spin Transverse Asymmetry (bottom row) vs Pt and Energy.
Pt dependence for 130 GeV<E12<150GeV .

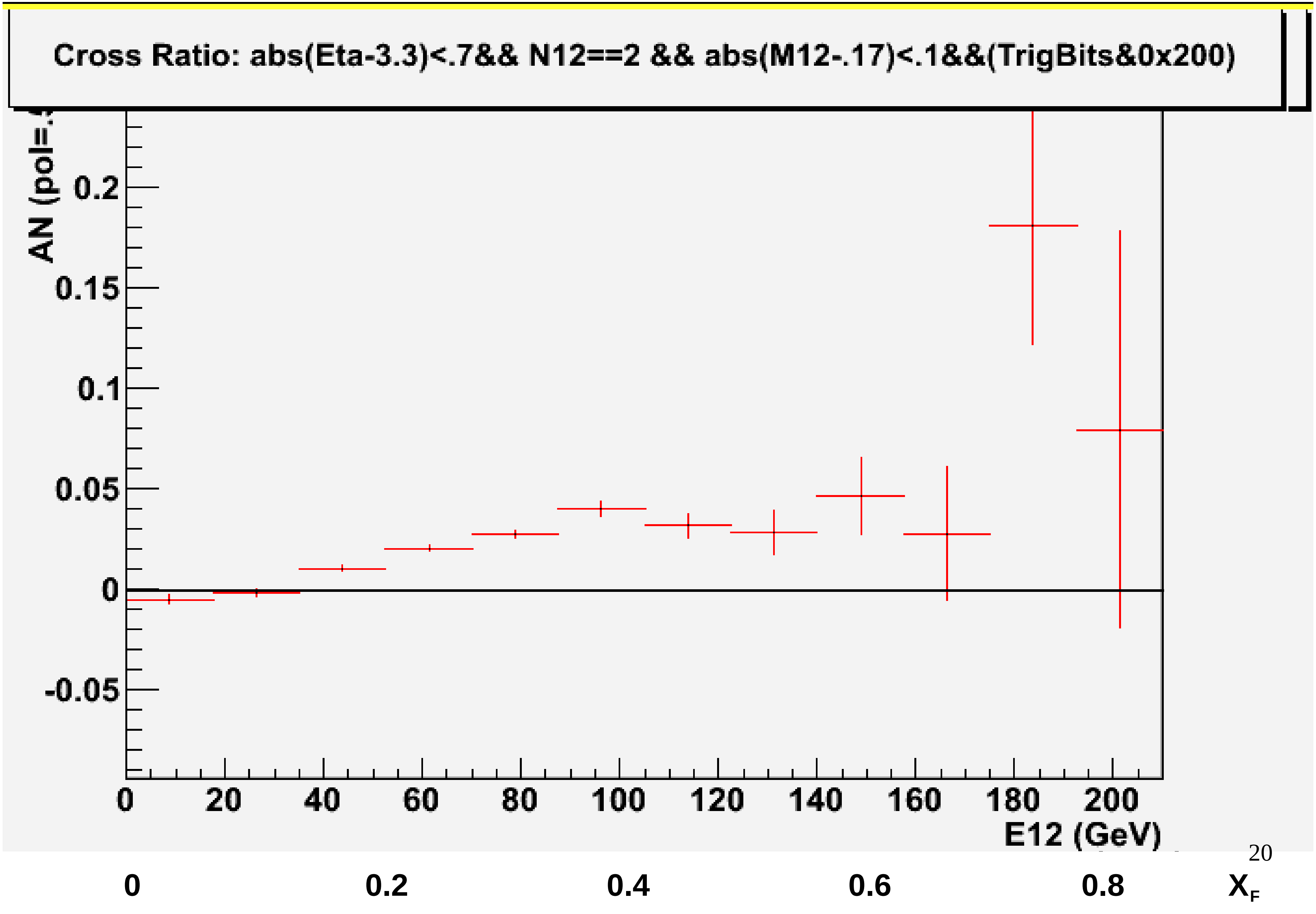
Single Photon (blue) **Pi0 (red)**



STAR Published Run 6



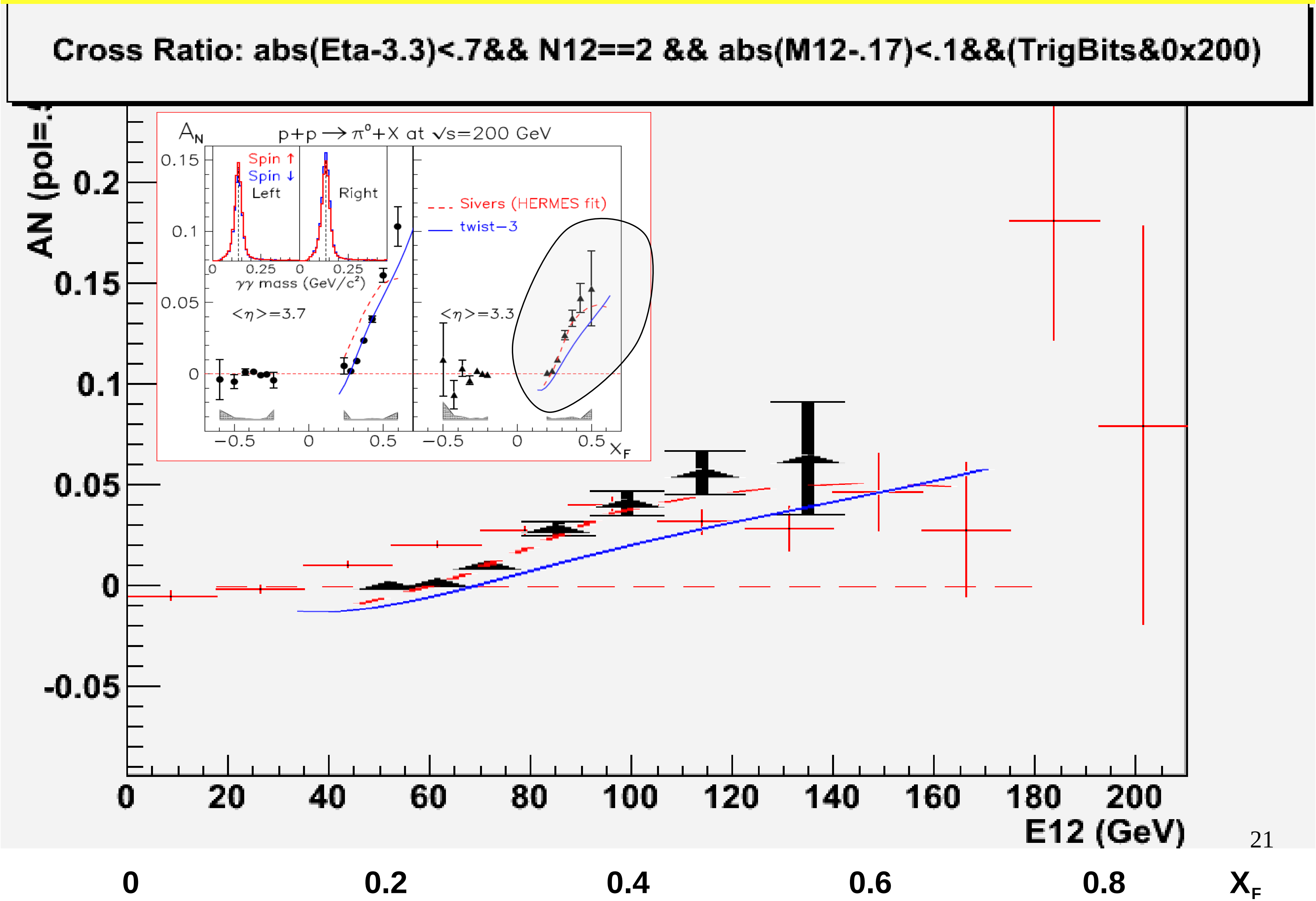
Energy Dependenced of A_N for selected Pi0



Compare X_F Dependence:

Run 11 (500 GeV) 2.6<Eta<4.0 √s=500 GeV

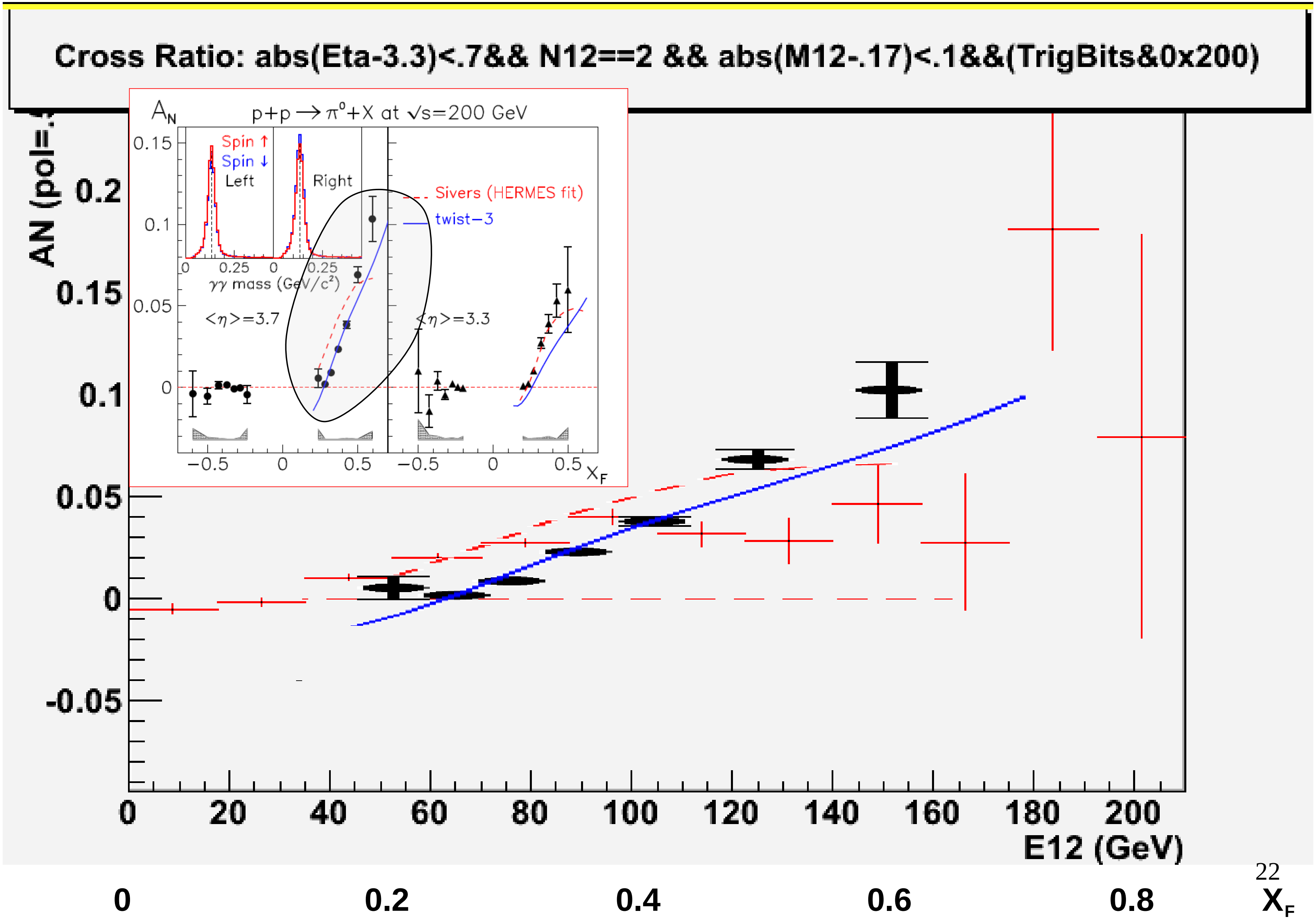
to Run 6 (200 GeV) <Eta>=3.3 √s=200 GeV



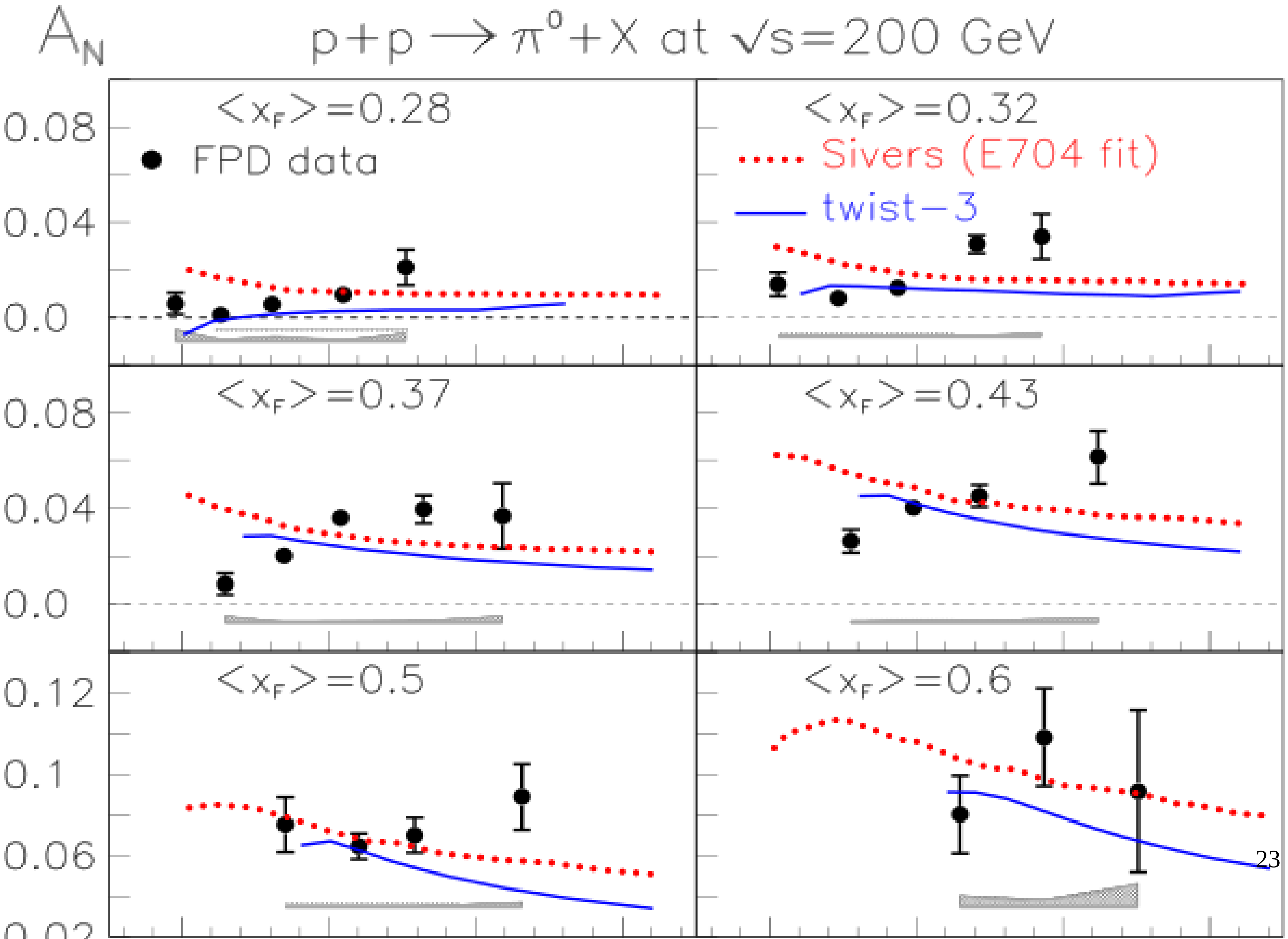
Compare X_F Dependence:

Run 11 (500 GeV) 2.6<Eta<4.0 √s=500 GeV

to Run 6 (200 GeV) <Eta>=3.7 √s=200 Gev



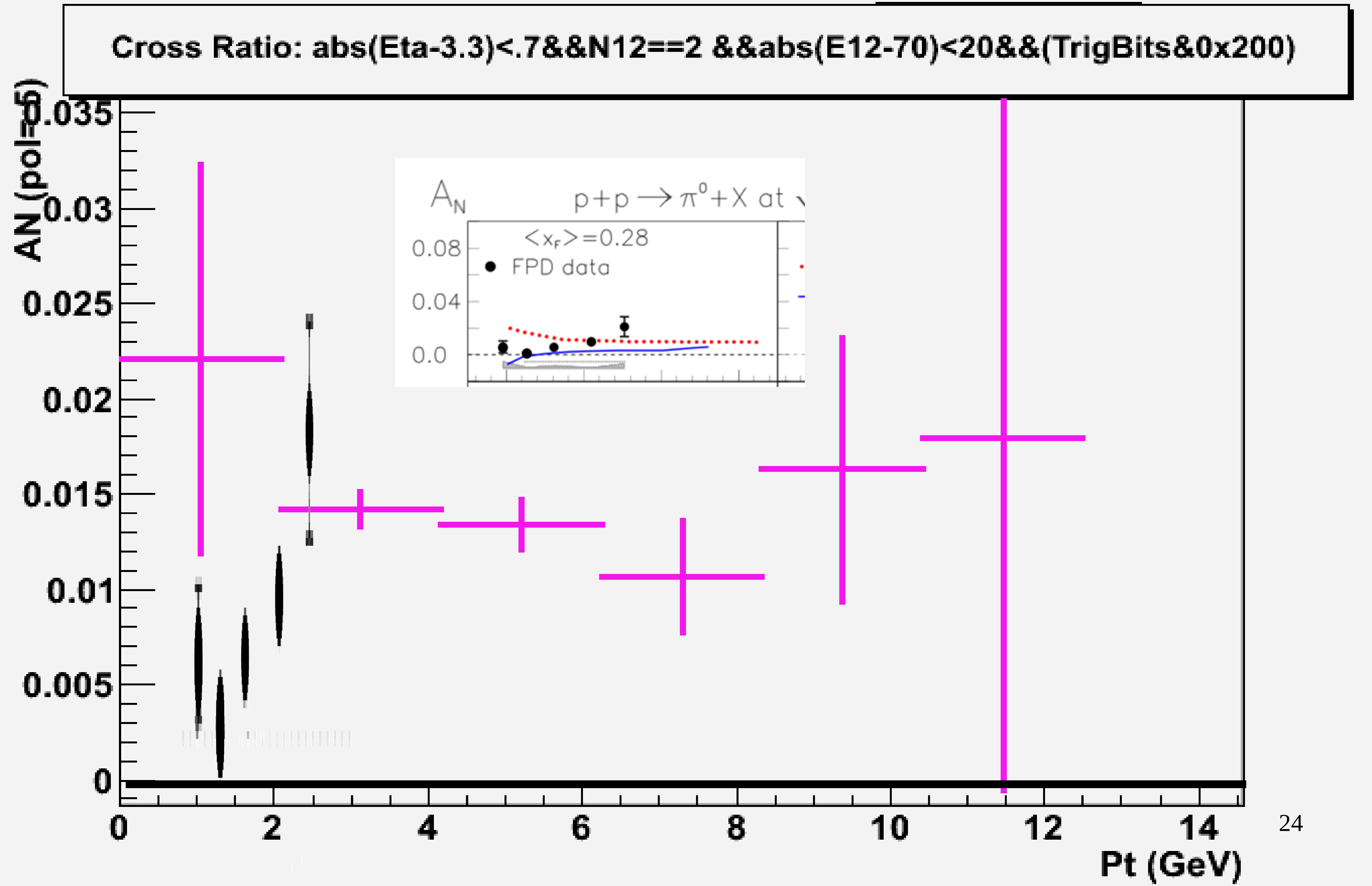
STAR Published Run 6



Compare P_T Dependence:

Run 11 ($.2<X_F<.36$)

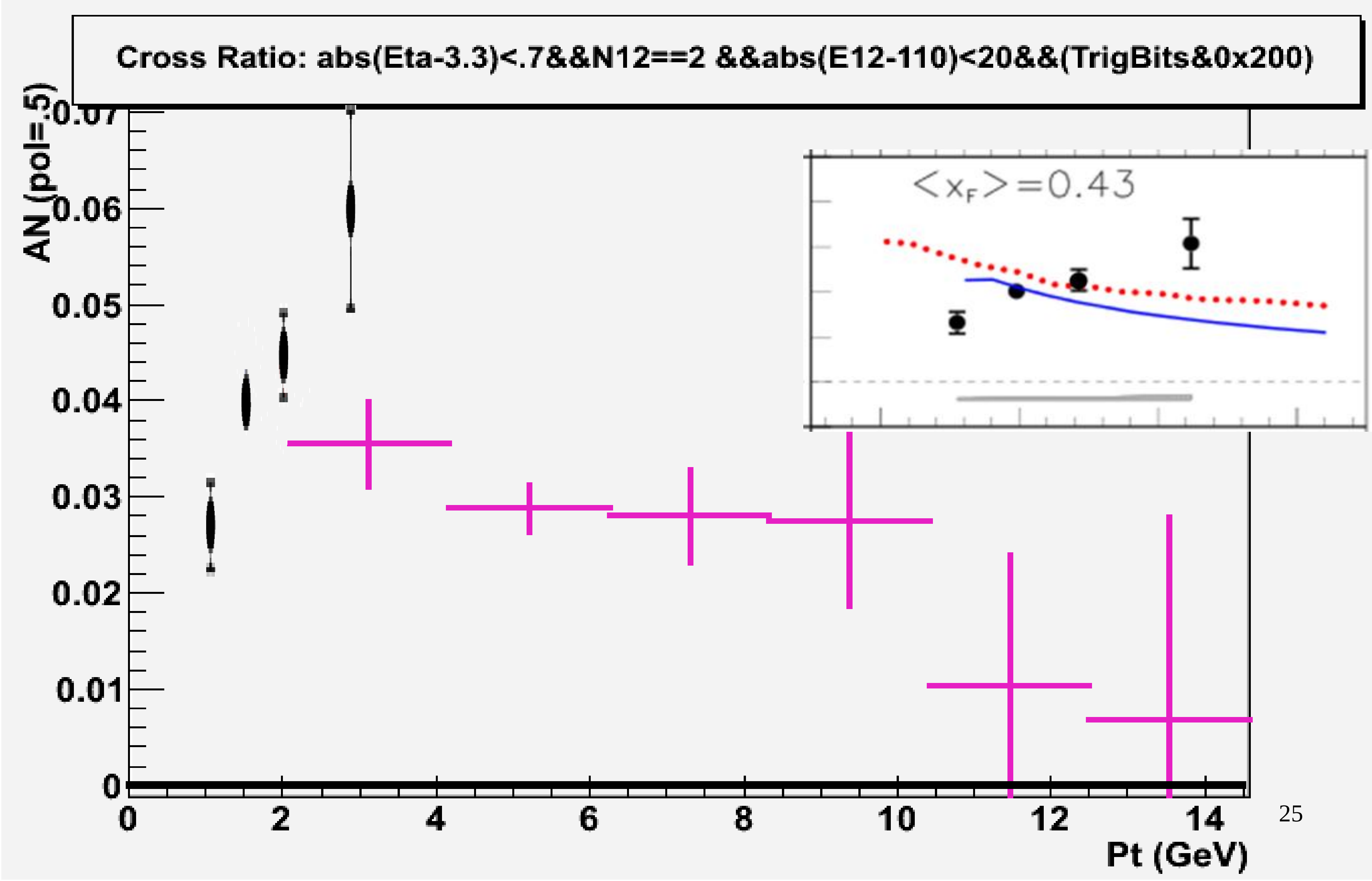
to Run 6 ($<X_F>=.28$)



Compare P_T Dependence:

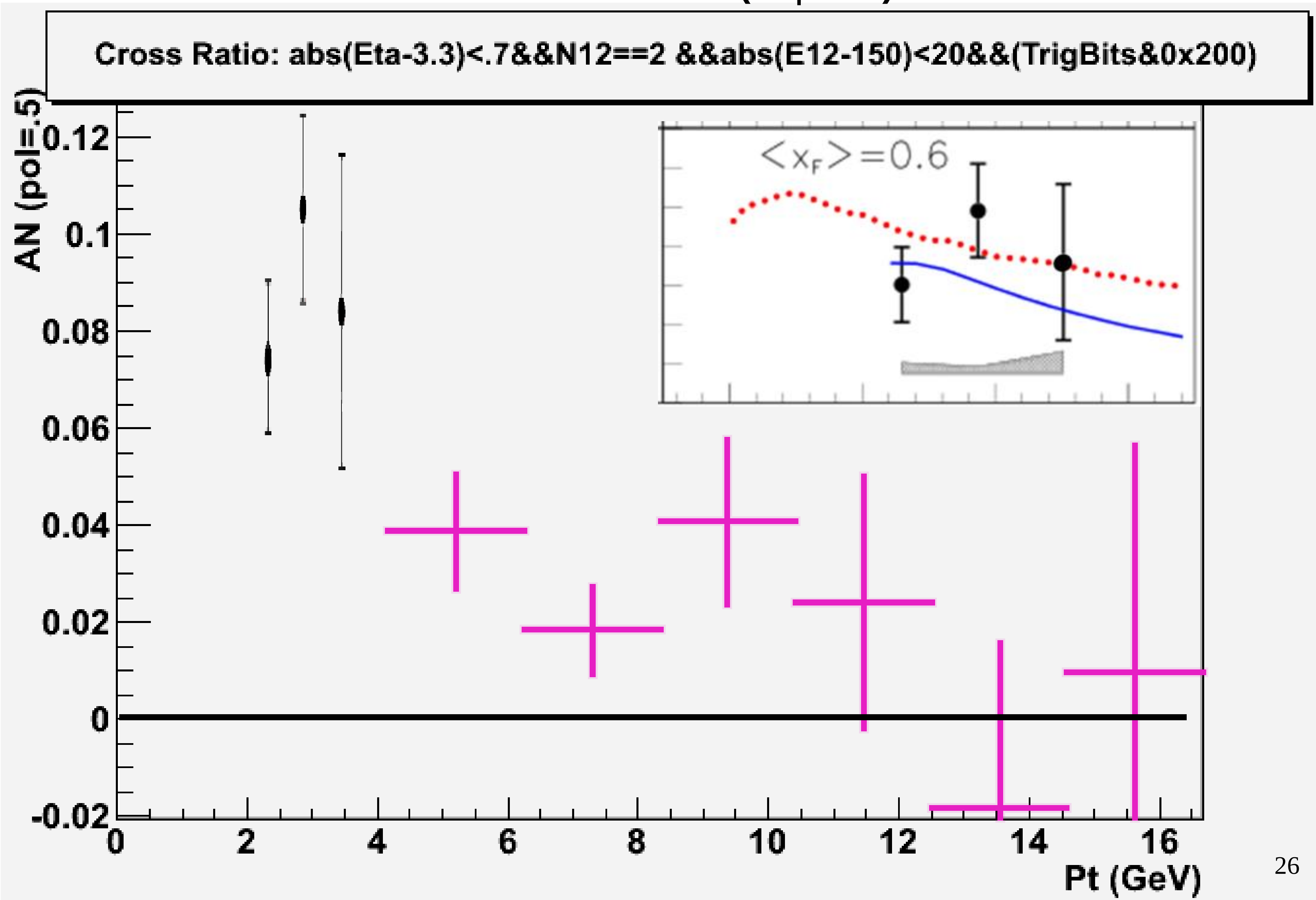
Run 11 ($.36<X_F<.52$)

to Run 6 ($<X_F>=.43$)



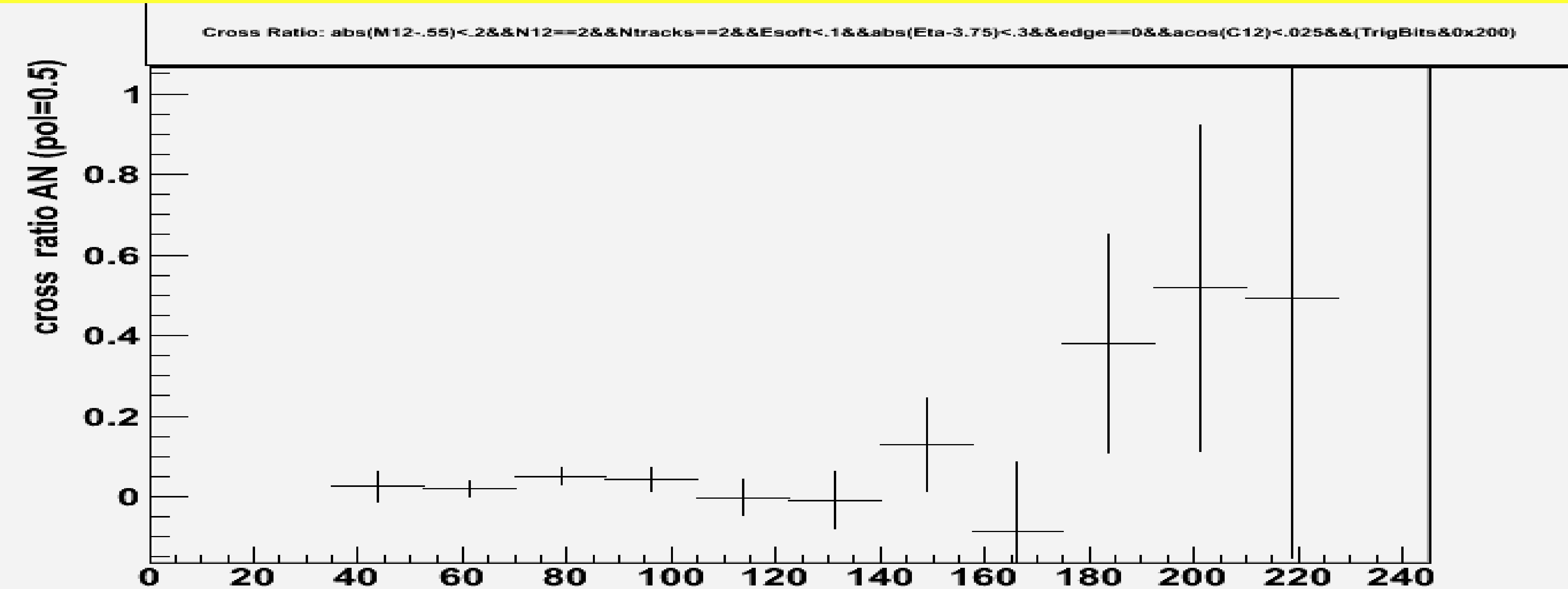
Compare P_T Dependence:

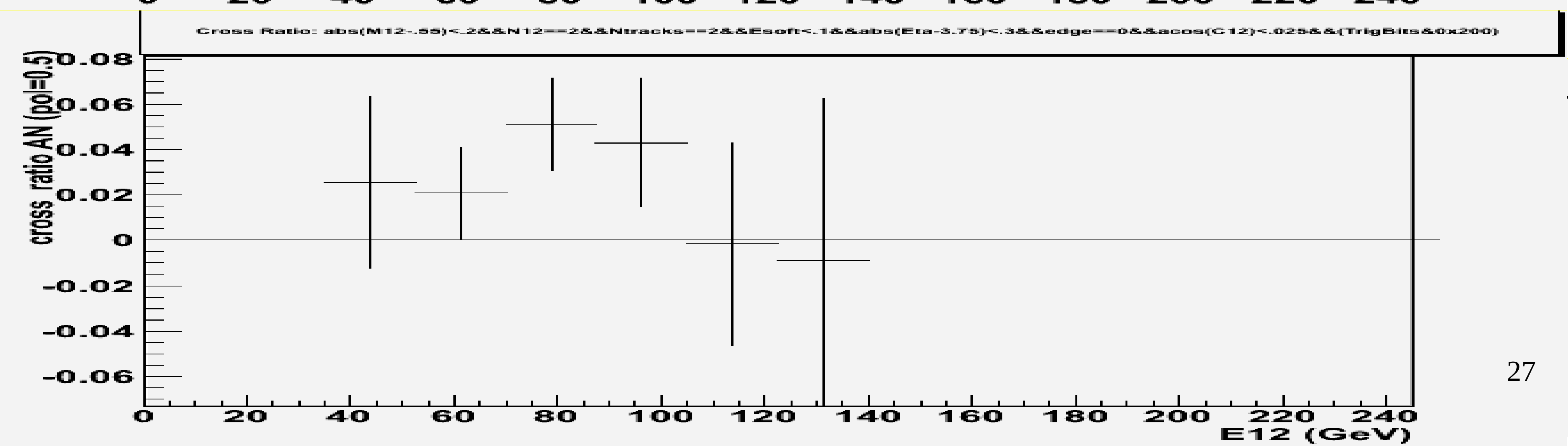
Run 11 ($.52<X_F<.68$)
to Run 6 ($<X_F>=.6$)



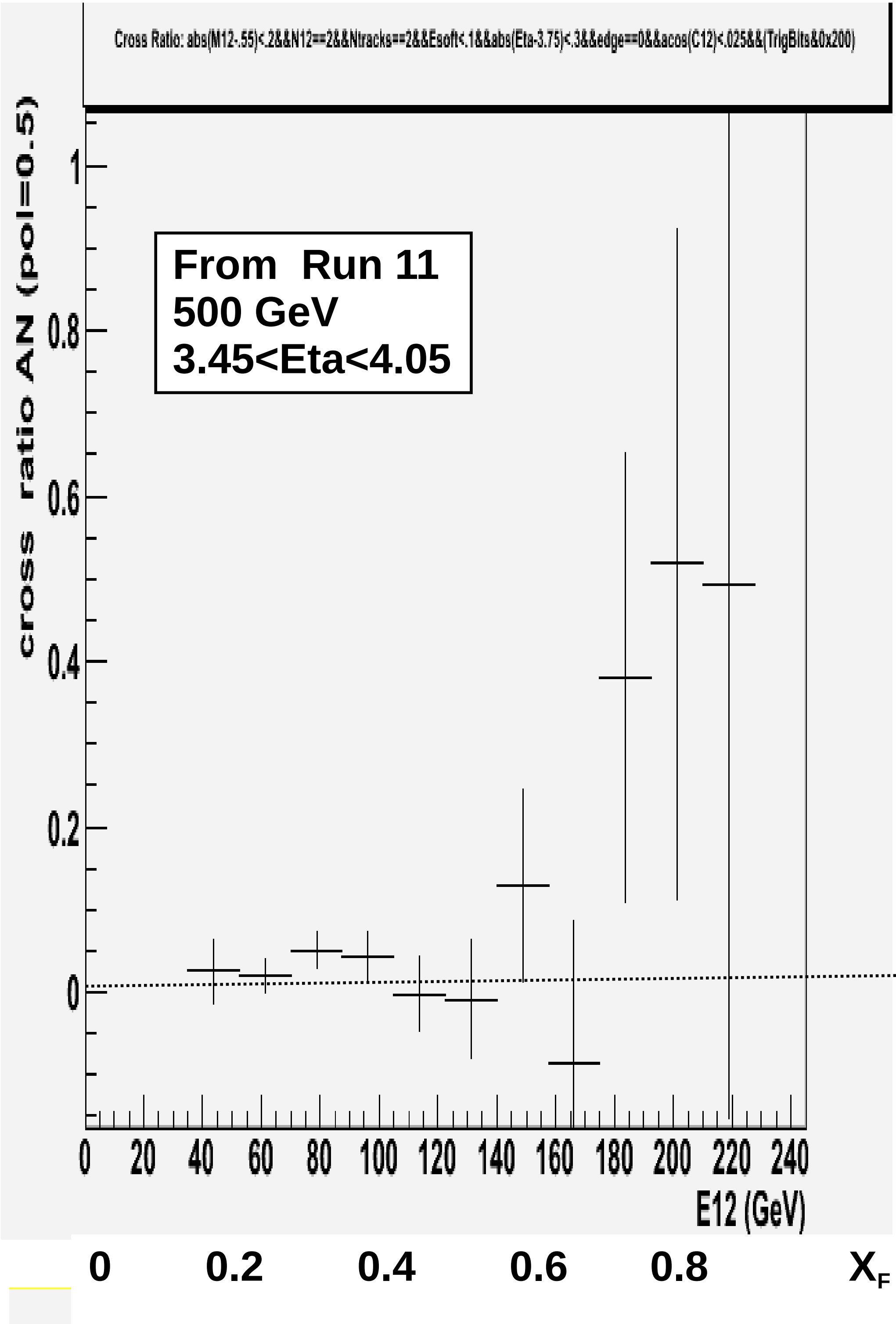
A_N vs Two Photon Energy for Eta Mass (.35 GeV< Mpair < .75 GeV)

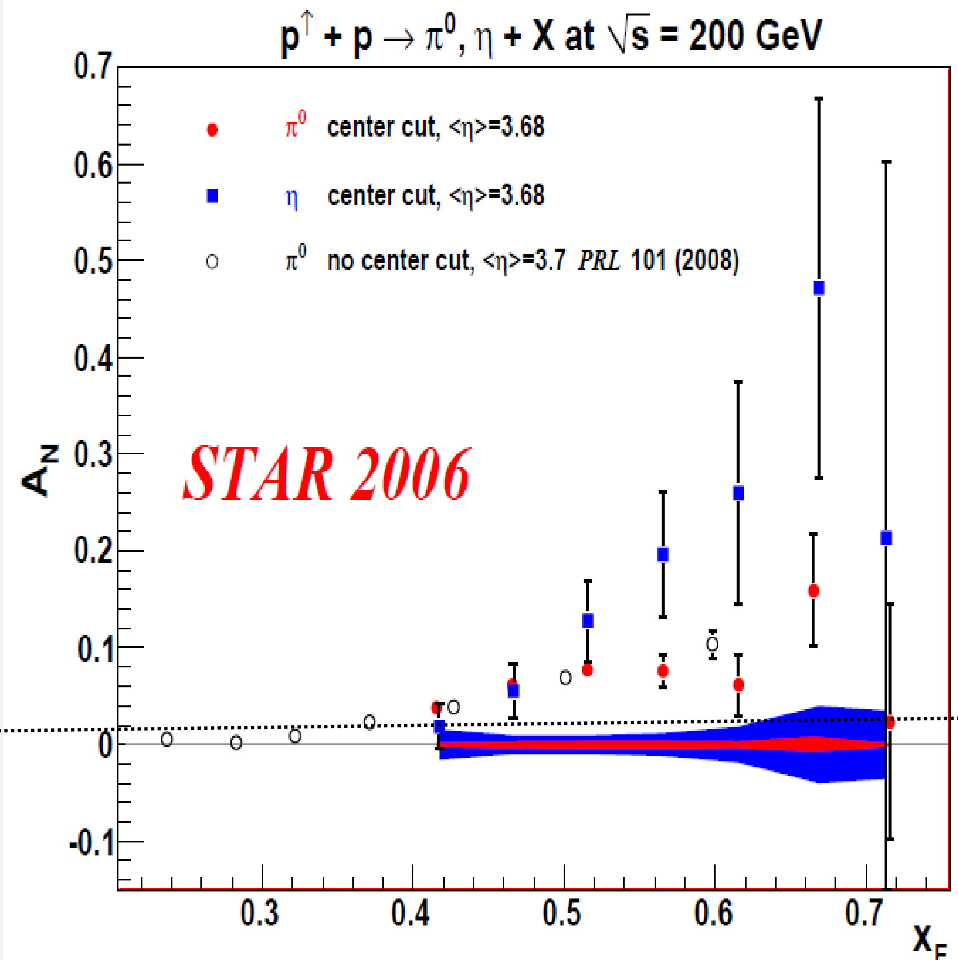
3.45<Eta<3.85





A_N vs Two Photon Energy for Eta Mass

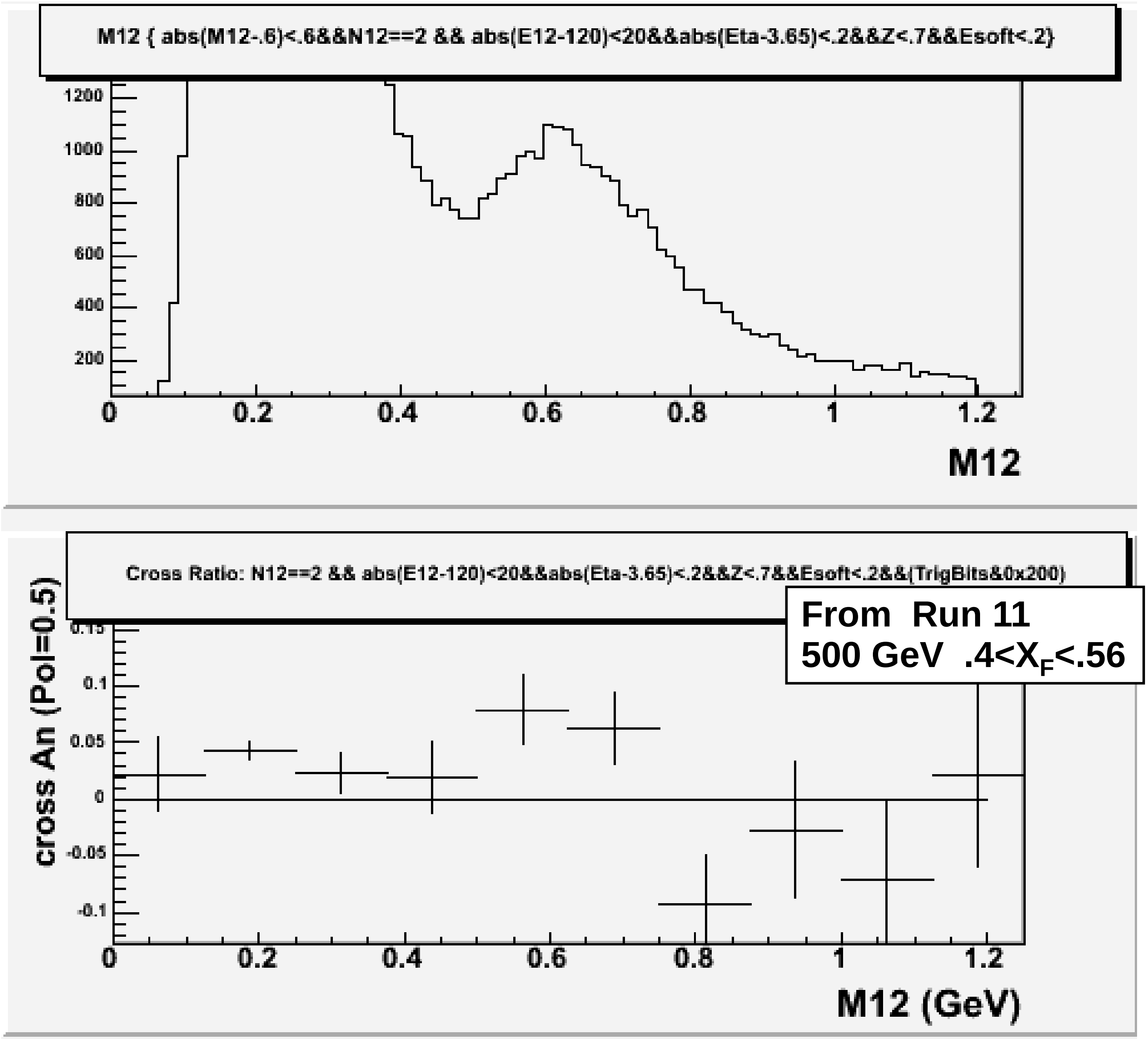




From Run 6
200 GeV
Eta~ 3.68 (Center Cut)

A_N vs Two Photon Mass   100 GeV< Epair < 140 GeV

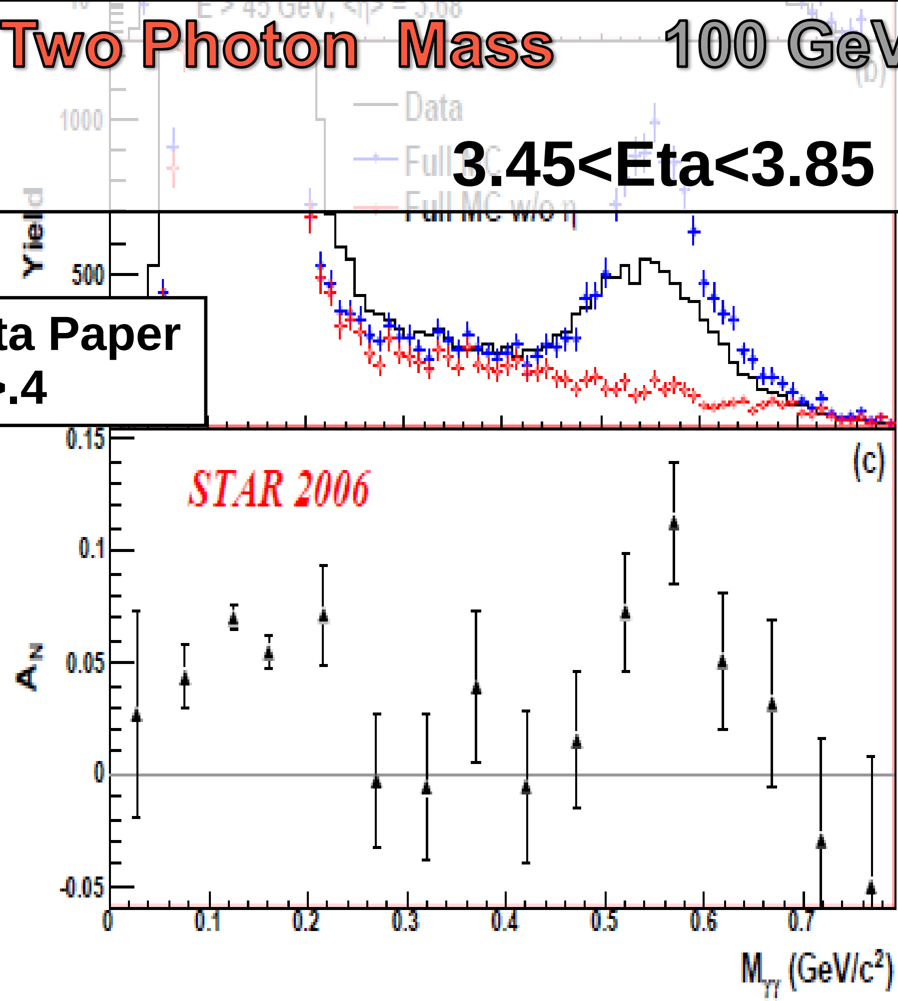
3.45<Eta<3.85

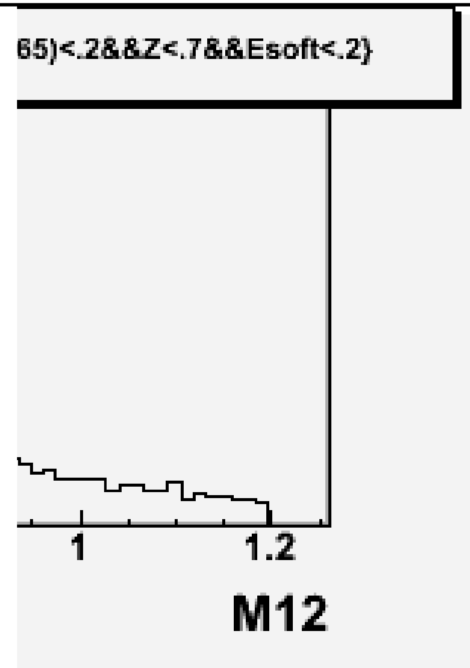


A_N vs Two Photon Mass   100 GeV< Epair < 140 GeV

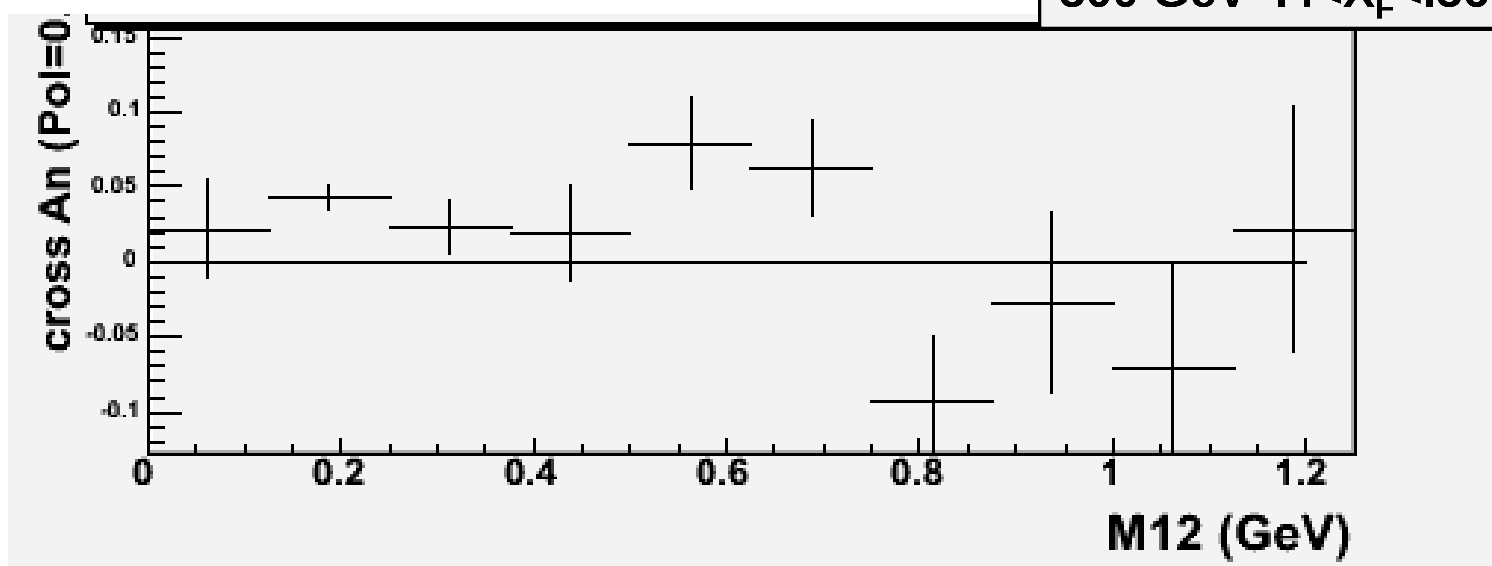
3.45<Eta<3.85

From New Eta Paper
200 GeV XF>.4

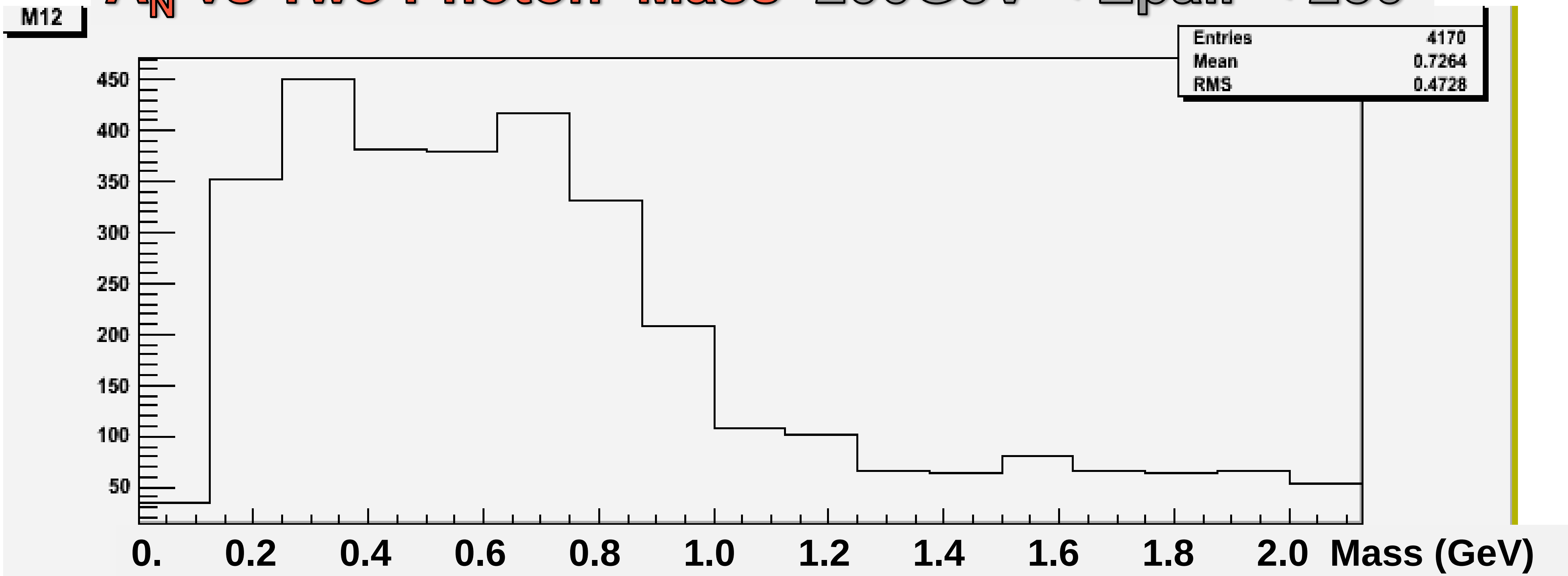


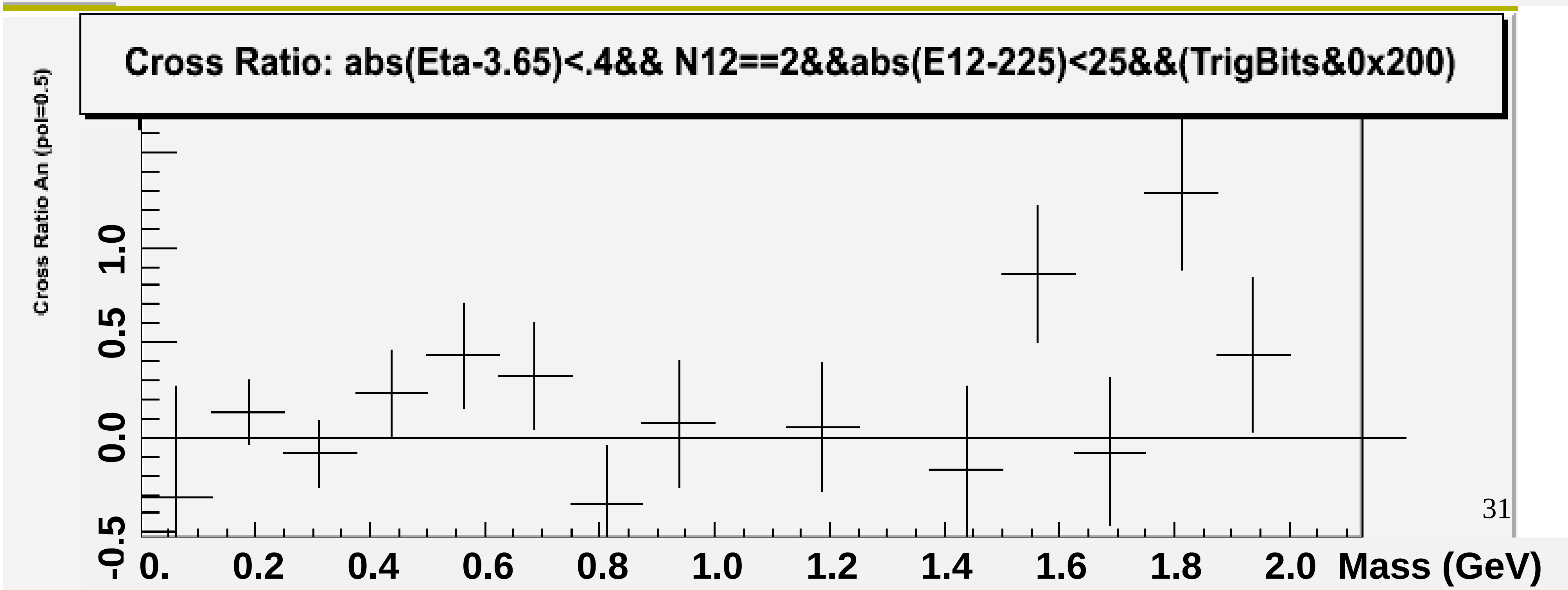


From Run 11
500 GeV .4<X_F<.56



A_N vs Two Photon Mass 200GeV < Epair < 250





Conclusion:

- The separation of π^0 from single photons is considered Up to 100 GeV, sigmamax separation is fairly good. Above 100 GeV, some mixing occurs but enriched π^0 and single photon signals can still be produced. More study of this is needed.

- 500 GeV π^0 measurements cover a similar X_F as that from Run 6 but in a higher P_T region.
  - For X_F <.4 the 500 GeV SSA's are larger than at 200 GeV.
  - For X_F >.4 the 500 GeV SSA's are smaller than at 200 GeV.
- The 500 GeV π^0 SSA is fairly constant (or slowly falling) in P_T out to P_T of 10 GeV/c.
- Extracting single photon may be possible with more work on shower shape.
- More work is needed for Eta meson asymmetry but the X_F dependence of A_N may be similar to that found in our new 200 GeV measurement.