# Toward A Direct Photon $A_N$ Measurement

20 $pb^{-1}$  200 GeV separation of 3 contributions @ E>65 GeV

- Direct Photon $A_N$
- Pi0 $A_N$
- Eta $A_N$

Compilation of Pi0 FMS Cross Sections (Pythia and STAR measurement)
(Pythia: 3.4 < eta < 4.0)
Compiled by: Jingguo Ma

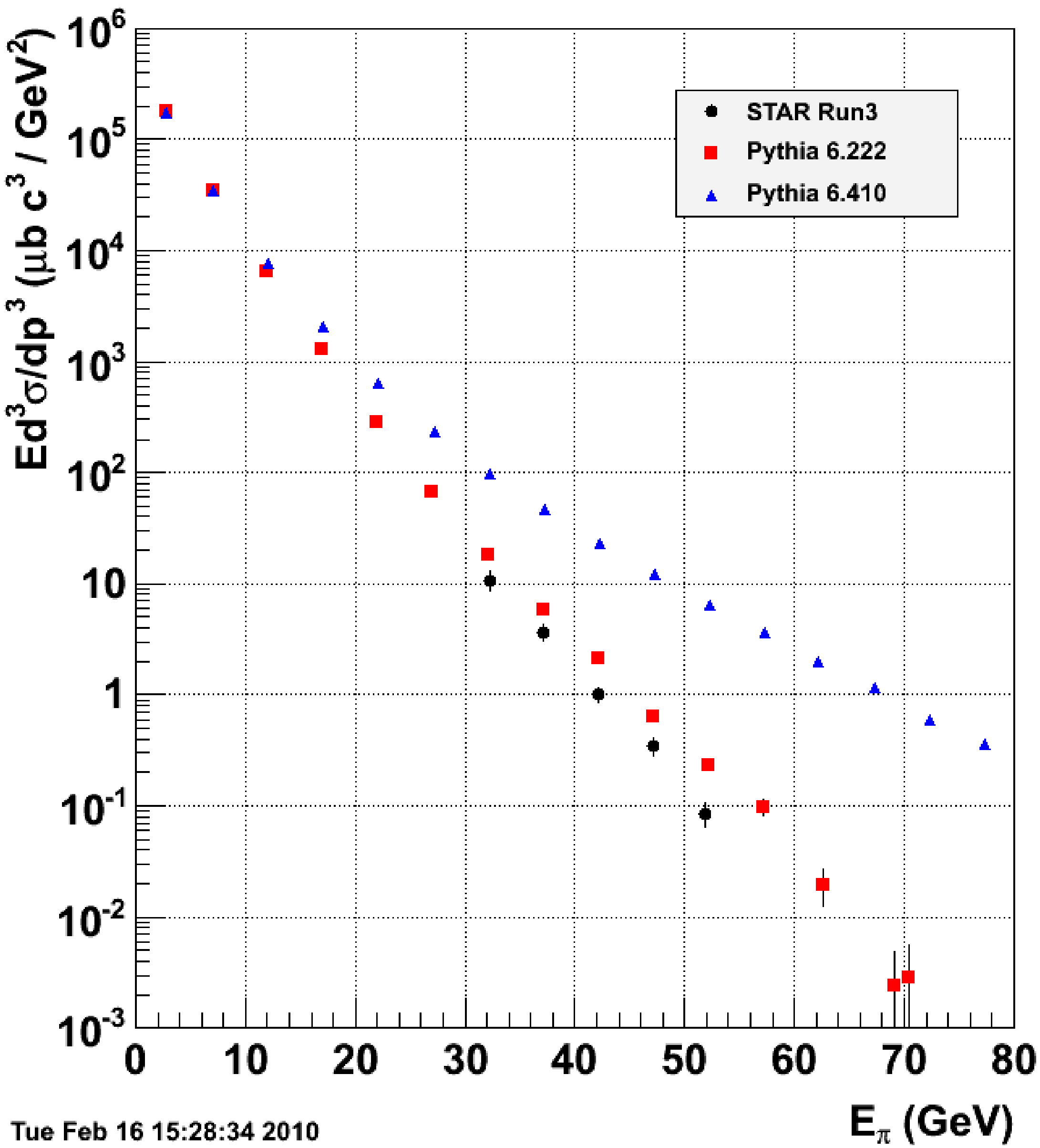



Fig. 2. Pi0 differential cross section from Pythia and STAR measurement. The STAR data is taken from 2003 paper Phys. Rev. Lett. **92** (2004) 171801. Same as for direct photons, the Pi0 spectrum has become much harder in Pythia 6.410 than in 6.222. When compare to STAR measurement, Pythia 6.222 gives a pretty good description of the measurement in the measured energy region.

8 Runs

10179001 10179006 10179009
10179019 10179031 10179032
10180021 10180022

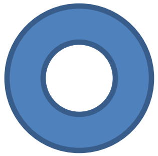
Run Time ~ 6 hrs
Estimate Luminosity

$$L = 30 \frac{\mu b^{-1}}{\sec}$$

$$\int L = 30 \times 2 \times 10^4 \mu b^{-1} = .6 pb^{-1} = 600 nb^{-1}$$

Jinggo' Ma's s pi0 cross section

$$@Y = 3.65 \quad E = 65 GeV$$

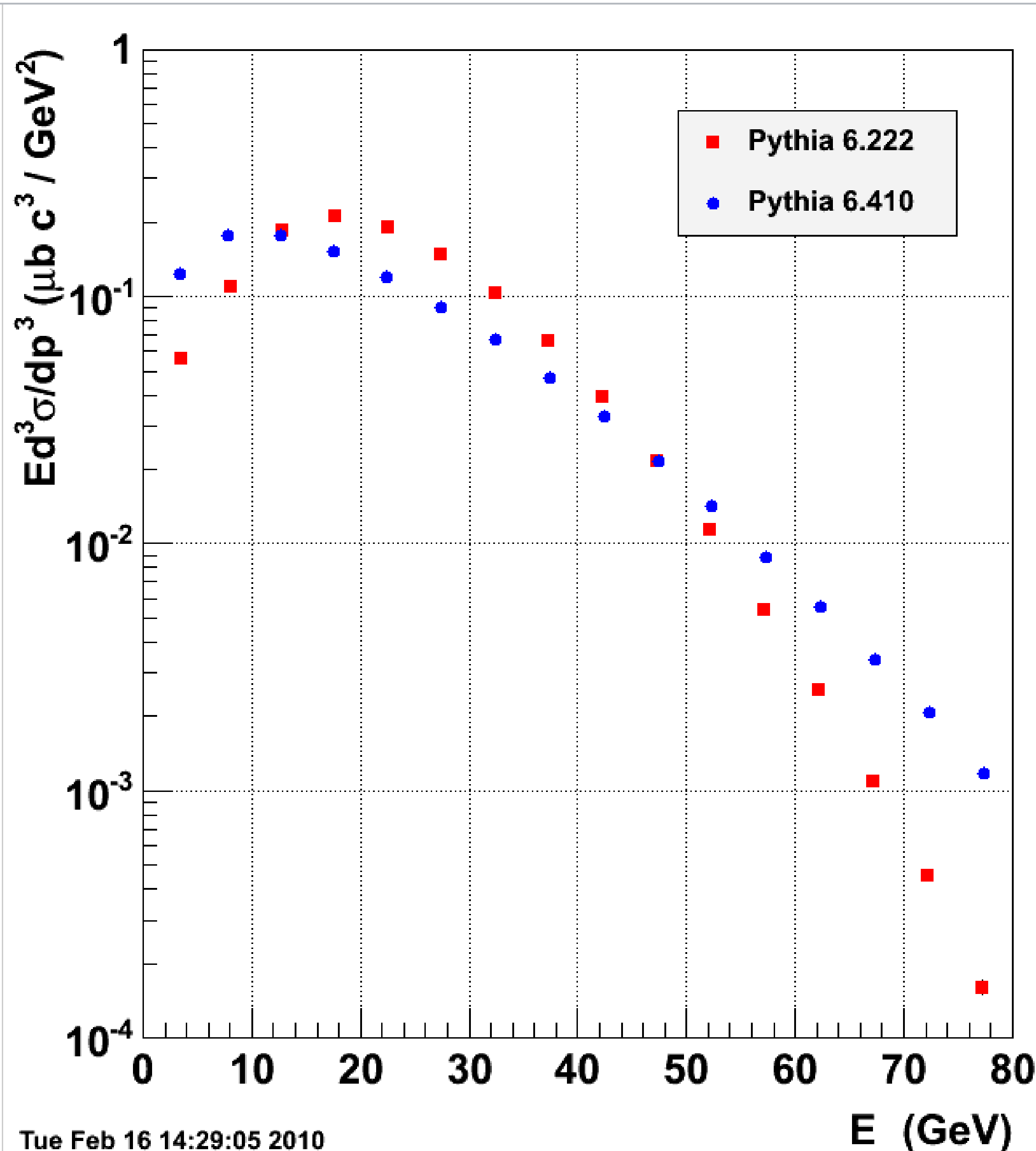


$$E \frac{d\sigma}{d^3 \vec{p}} = 2 \frac{nb}{GeV^2} = \frac{d\sigma}{\pi dY\, d(p_T{}^2)}$$

$$\frac{d\sigma}{dY\, d(p_T{}^2)} = 2\pi \frac{nb}{GeV^2}$$

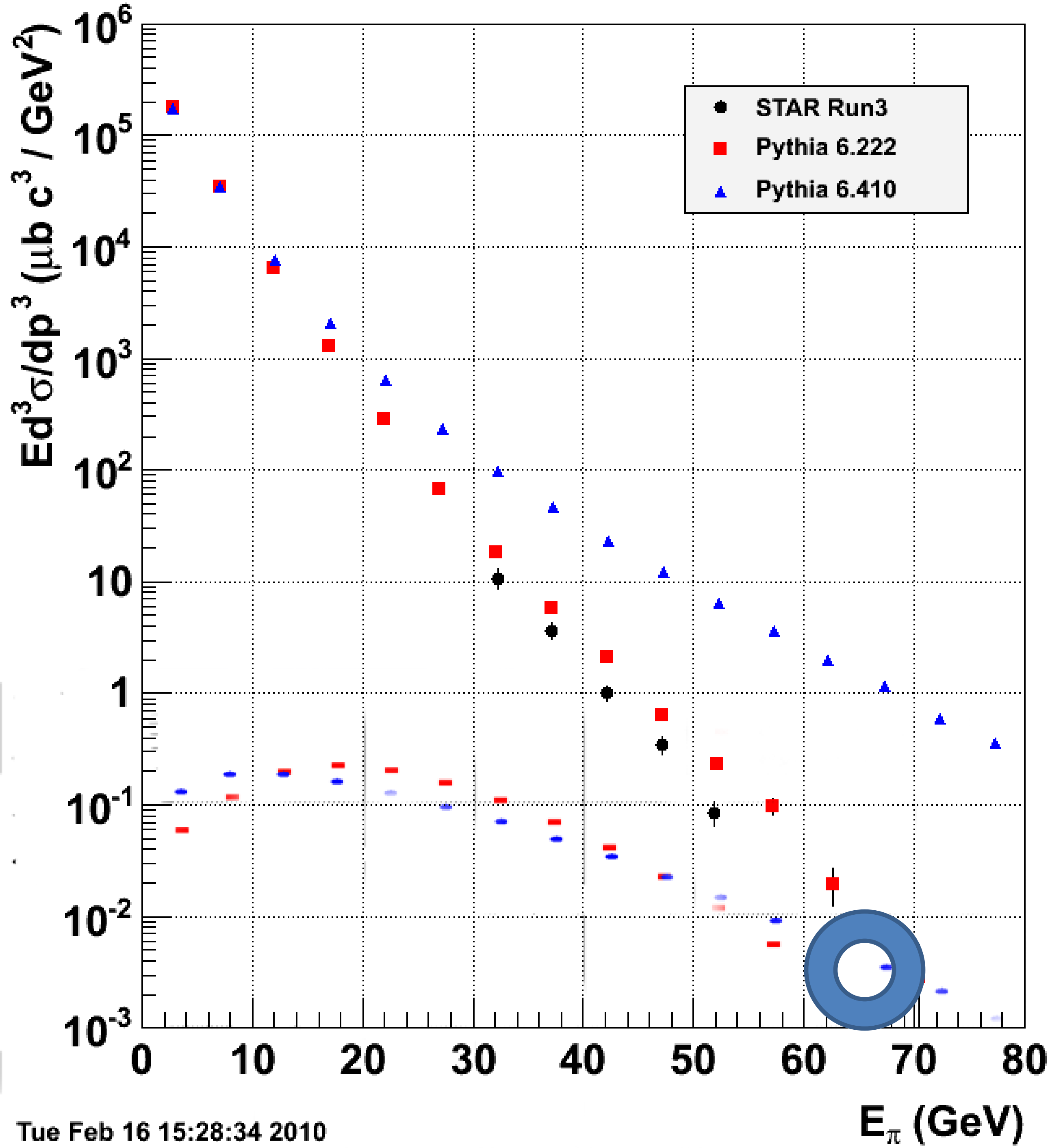
Luminosity x Cross Section
~ 400 Evnts

Compilation of FMS Direct Photon Cross Sections (Pythia 3.4 < eta < 4.0)
Compiled by: Jingguo Ma



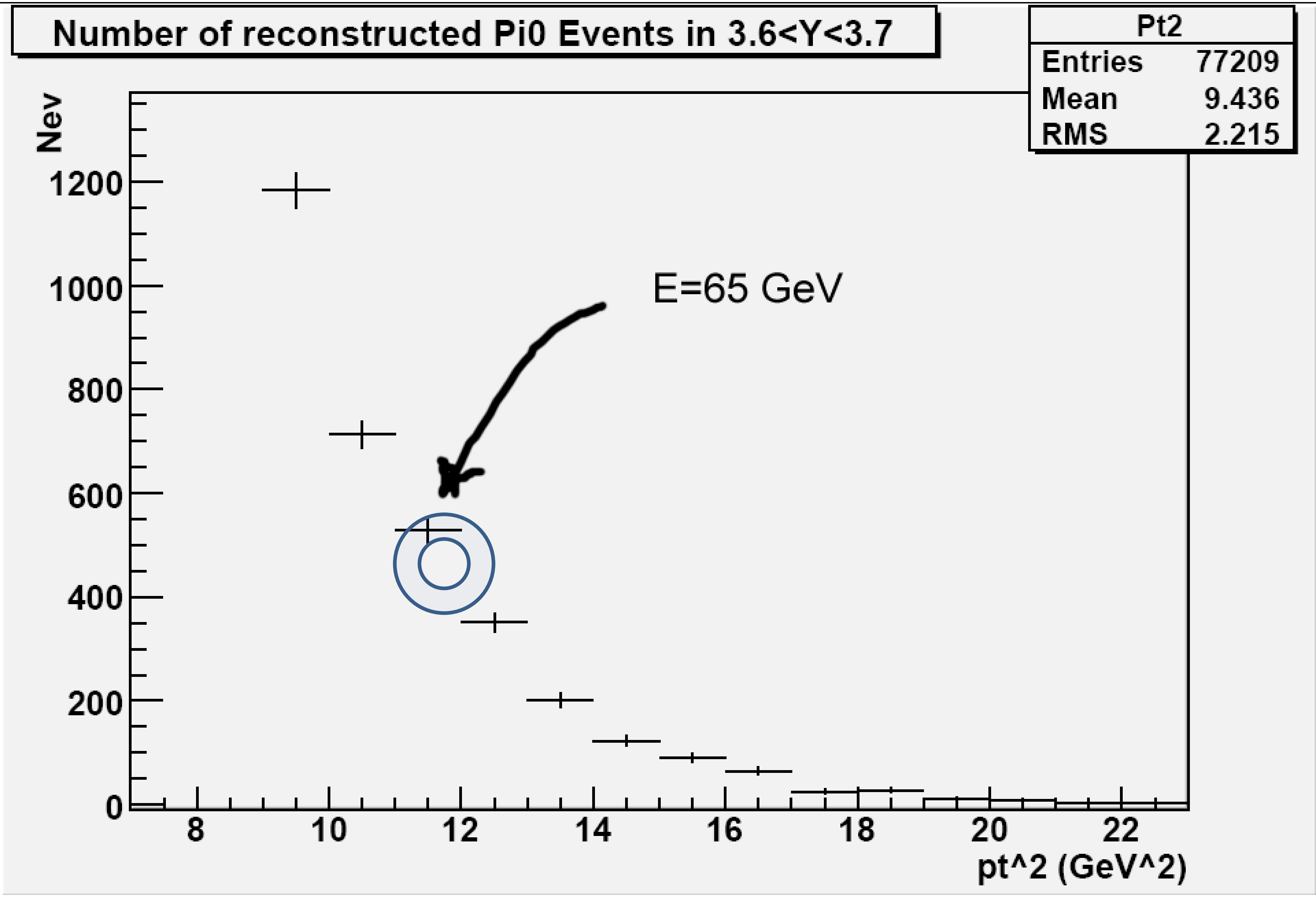

Direct photon and Pi0 cross section seems to the very different in different Pythia versions. Here shown is the invariant differential cross section for Pi0 and direct photon in Pythia 6.222 and 6.410.

Fig. 1. Direct photon cross section. The total cross section is 11.09 ub in both Pythia 6.222 and 6.410, but the shape of the differential cross section is different, with 6.410 being much harder.




Cross section
@ 65 GeV

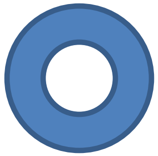
An extrapolation of
STAR 2003
measurement



Number of reconstructed Pi0 Events in 3.6<Y<3.7
Pt2
Entries 77209
Mean 9.436
RMS 2.215
Nev
1200
1000
800
600
400
200
0
8
10
12
14
16
18
20
22
pt^2 (GeV^2)
E=65 GeV

# Expected Event Rate for 1 Cell

$@Y = 3.65; E = 65\ GeV; p_T = 3.25\ GeV$



$$For\ Cell = 1\frac{pb}{Cell}$$

$$E\frac{d\sigma}{d^3\vec{p}} = 2\frac{nb}{GeV^2} \sim \frac{2d\sigma}{d\phi\, dp_z\ p_T d\theta} \sim \frac{2}{p_T}\frac{d\sigma}{[d\phi d\theta]dp_z}$$

$$\frac{d\sigma}{dY\, d(p_T{}^2)} = 2\pi\frac{nb}{GeV^2}$$

$$For\ Cell\,[d\phi d\theta] = 8\times 10^{-4}$$

$$@Y = 3.65; E = 65\ GeV; p_T = 3.25\ GeV$$

$$\frac{d\sigma}{dE} \sim 1.2[d\phi d\theta] \sim 1\frac{pb}{Cell}$$

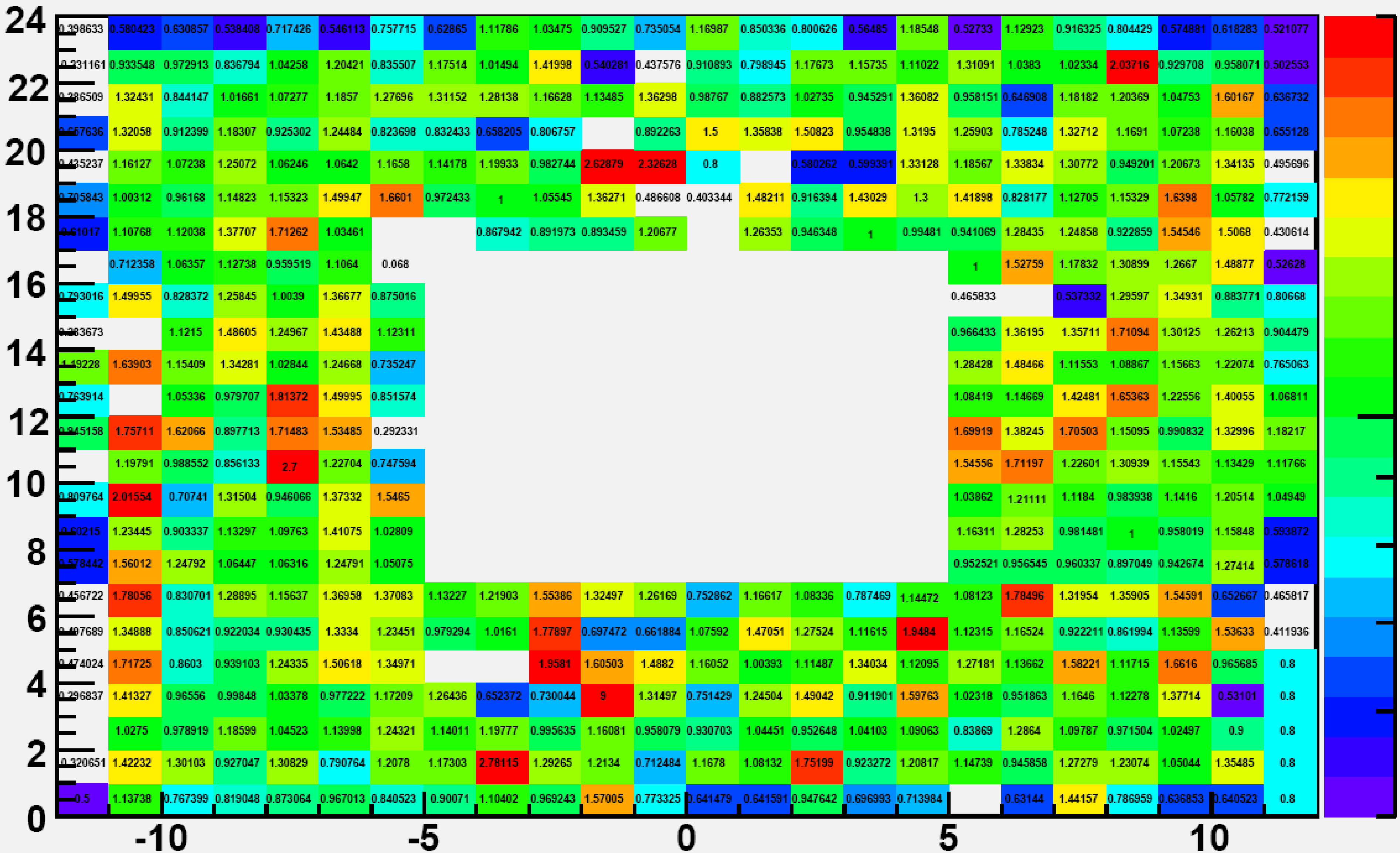
8 Runs (~1/3 Good Day)
Run Numbers:

10179001 10179006 10179009
10179019 10179031 10179032
10180021 10180022

$$\int L \sim 0.6\ pb^{-1}$$

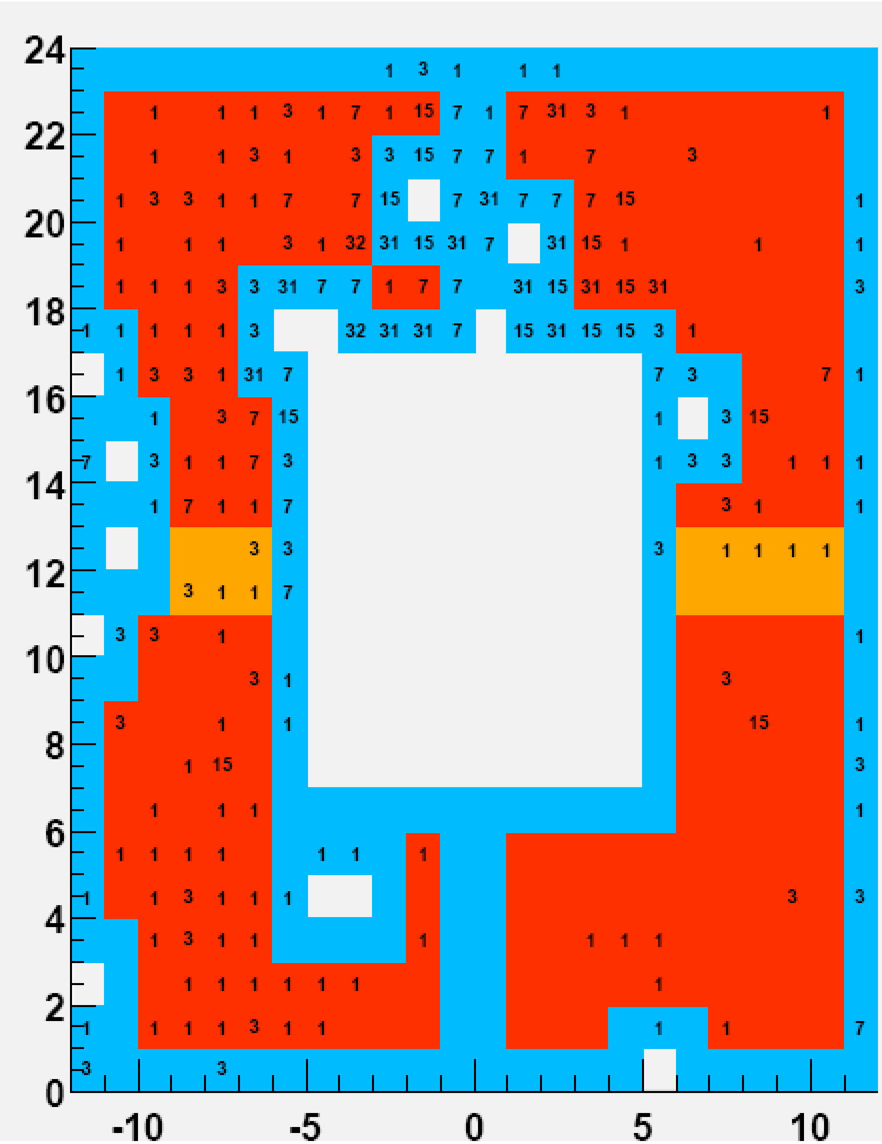
$$1Cell = .6\ \frac{Events}{Cell}$$

# Evolving **FMS Gain Correction Factors for Late Run 9 Data**

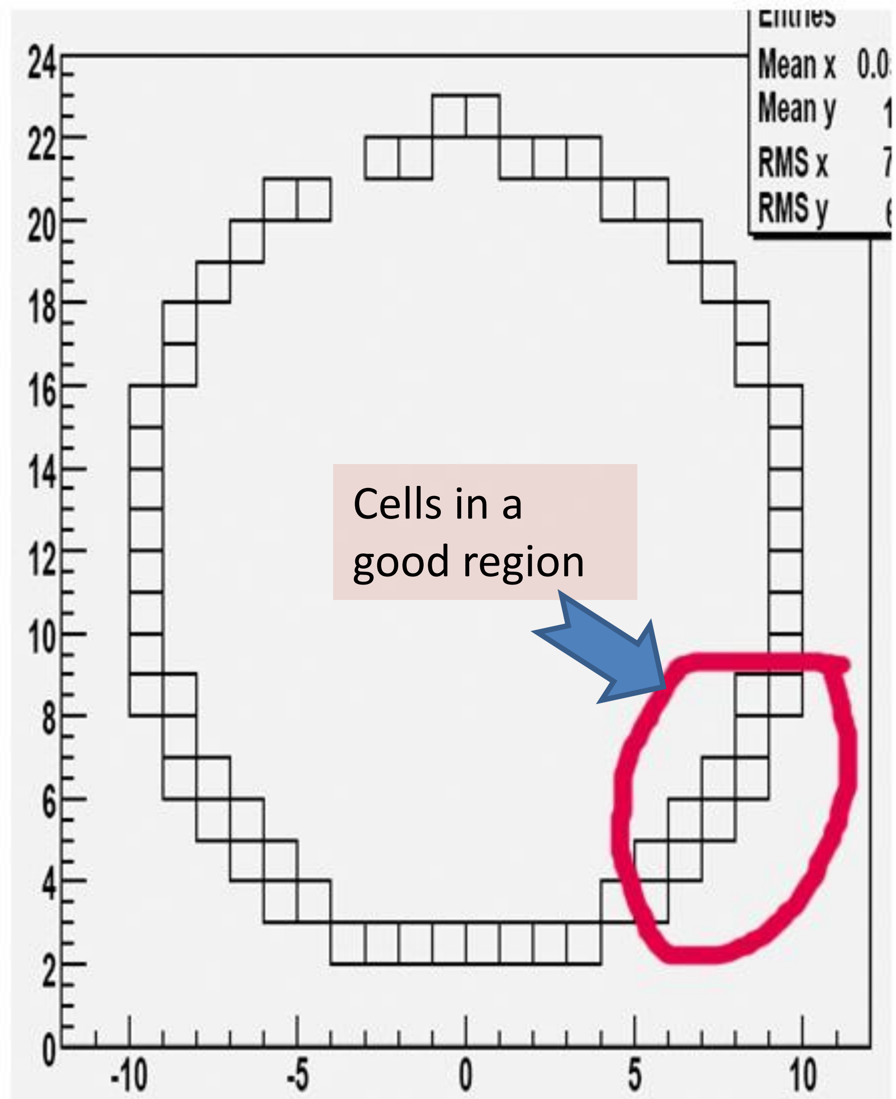


## Run 9 Dead and Wounded FMS Cells

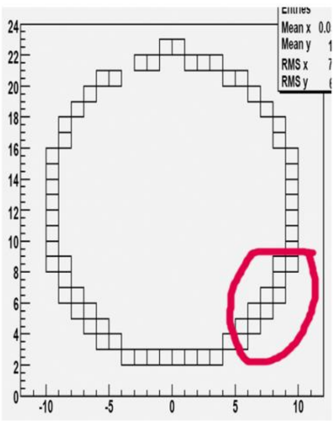
## Nominal Cell Position 3.6<Y<3.7



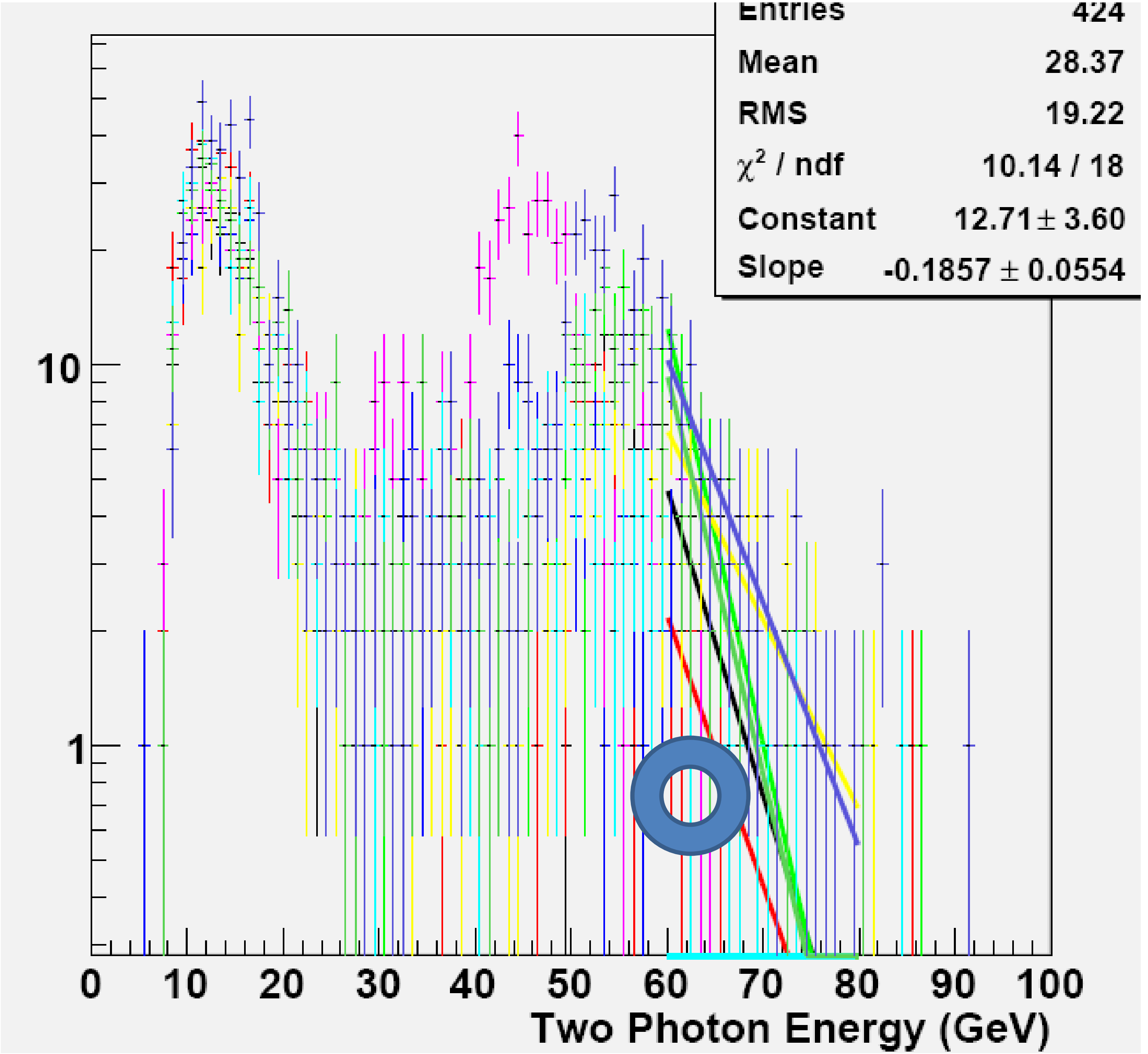

North South



The energy
distribution
for each cell in the
region
shown in red,




is represented
by a different color



# Possible Future Star Transverse Single Spin Measurements

| Energy $\sqrt{s}$ | Transverse pp Measurement | Collins | Sivers | Sivers: SIDIS sign change | Luminosity | Detectors |
|---|---|---|---|---|---|---|
| 200 GeV | $p^{\uparrow} + p \rightarrow \pi^{0} + X$ | ✓ | ✓ | | 30 $pb^{-1}$ | FMS |
| | $p^{\uparrow} + p \rightarrow \eta + X$ | ✓ | ✓ | | | FMS |
| | $p^{\uparrow} + p \rightarrow jet + X$ | ✓ | ✓ | | | FMS+EMC +(HCAL?) |
| | $p^{\uparrow} + p \rightarrow \pi^{0} + \pi^{0} + X$ | ✓ | ✓ | | | FMS+EMC |
| | $p^{\uparrow} + p \rightarrow jet + jet + X$ | ✓ | ✓ | | | FMS+EMC +(HCAL?) |
| | $p^{\uparrow} + p \rightarrow \gamma + X$ | | ✓ | ✓ | | FMS |
| | $p^{\uparrow} + p \rightarrow \Lambda + X$ | ✓ | ✓ | | | FMS+HCAL |
| 500 GeV | $p^{\uparrow} + p \rightarrow \gamma + X$ ( $p^{\uparrow} + p \rightarrow \pi^{0} + X$ ) | | ✓ | ✓ | 20 $pb^{-1}$ | East FPD +Shower Max |
| | $p^{\uparrow} + p \rightarrow \Lambda + X$ | ✓ | ✓ | | | FMS+HCAL |
| | $p^{\uparrow} + p \rightarrow \eta + X$ | ✓ | ✓ | | | FMS |
| | $p^{\uparrow} + p \rightarrow e^{+} + e^{-} + X$ | | ✓ | ✓ | 250 $pb^{-1}$ | STAR with FMS |
| | $p^{\uparrow} + p \rightarrow W + X$ | | ✓ | ✓ | | STAR with FMS |

# Straw Man Form for Pi0 Cross Section

Suppose: $$\frac{d\sigma(E,p_t)}{p_t\,dp_t\,dY} \propto f(x_F,p_t) = \frac{(1-x_F)^n}{p_t^{\;m}}$$

then: $$\frac{dN}{dE\;dY} \sim \frac{p_t^{\;2}}{E} f(E,y) \propto G(y)F(E)$$

$$\text{for large } |Y| : \; G(Y) \propto e^{(m-2)Y}$$

$$near \quad E = \frac{E_{max}}{2} : F(E) \propto e^{-kE}$$

$$k \sim \left[\frac{2(m+n-1)}{E_{Max}}\right]$$

so for m=6, n=5 and $E_{Max} = 100 GeV$

$$k \sim 0.2\,GeV^{-1}$$

$$\frac{dN}{dE\;dY} \propto e^{4Y} e^{-0.2E} \qquad E\,in\,GeV$$

$$\frac{dN}{dE\;d\theta} \propto e^{5Y} e^{-0.2E}$$

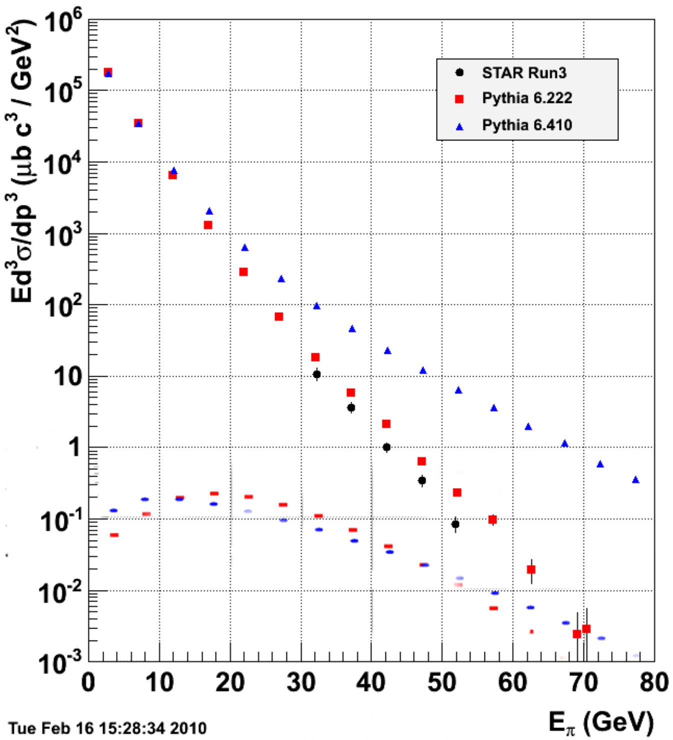
$$\frac{dN}{dE d\theta d\phi} \propto \frac{dN}{dE}_{Cell}$$

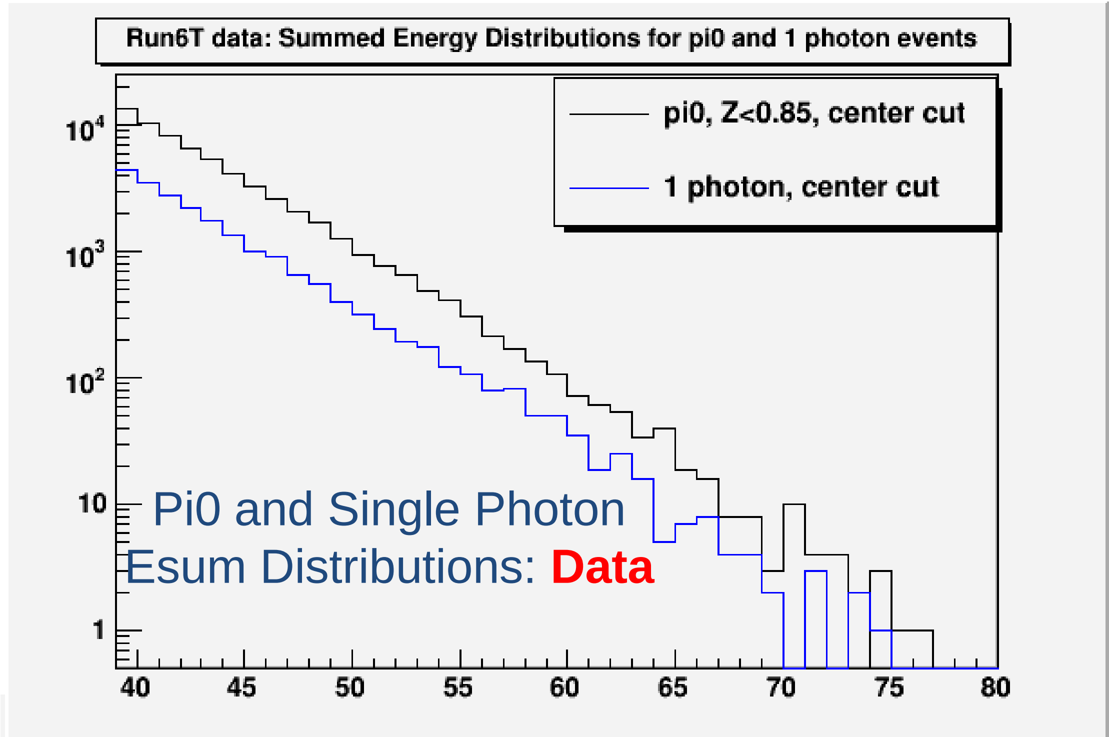
Speculative Form For Pi0 Cross Section in FMS

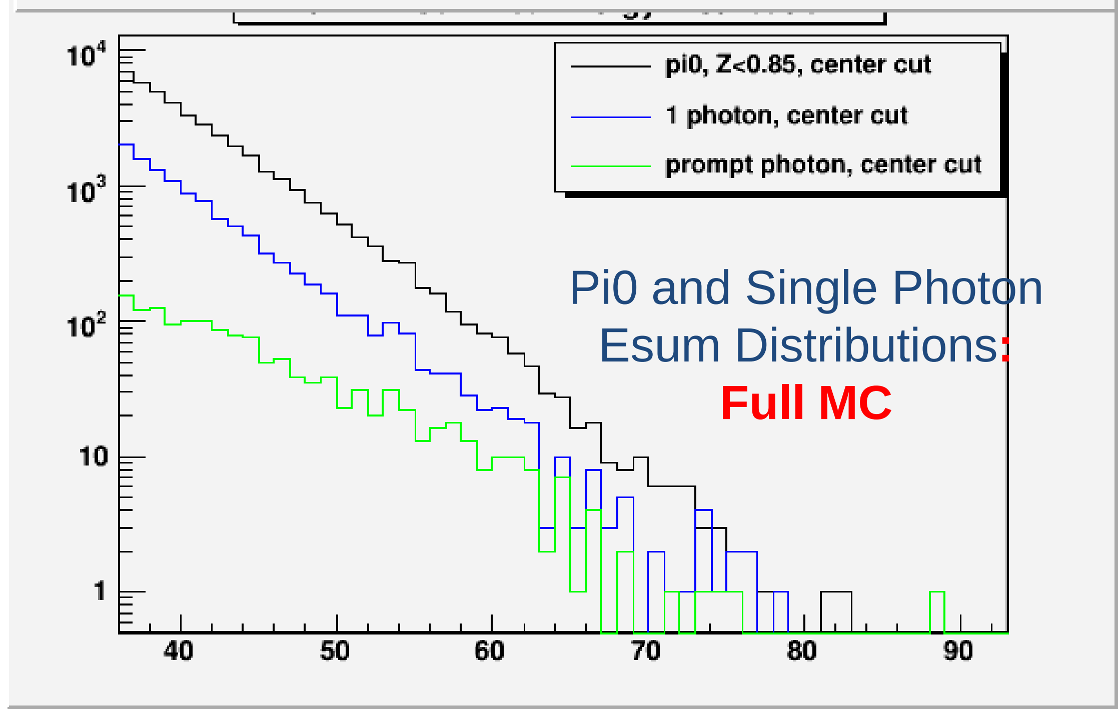
$$\frac{d\sigma}{dE}_{\text{Small Cells}} \propto e^{6(Y-3.65)} e^{-0.2(E-65)} \frac{pb}{GeV}$$

$$\frac{d\sigma}{dE}_{\text{Large Cells}} \propto 2.3 e^{6(Y-3.65)} e^{-0.2(E-65)} \frac{pb}{GeV}$$

FPD Run 6 DATA and Simulations
2 Photon pi0 events
and 1 photon events
from Len Eun

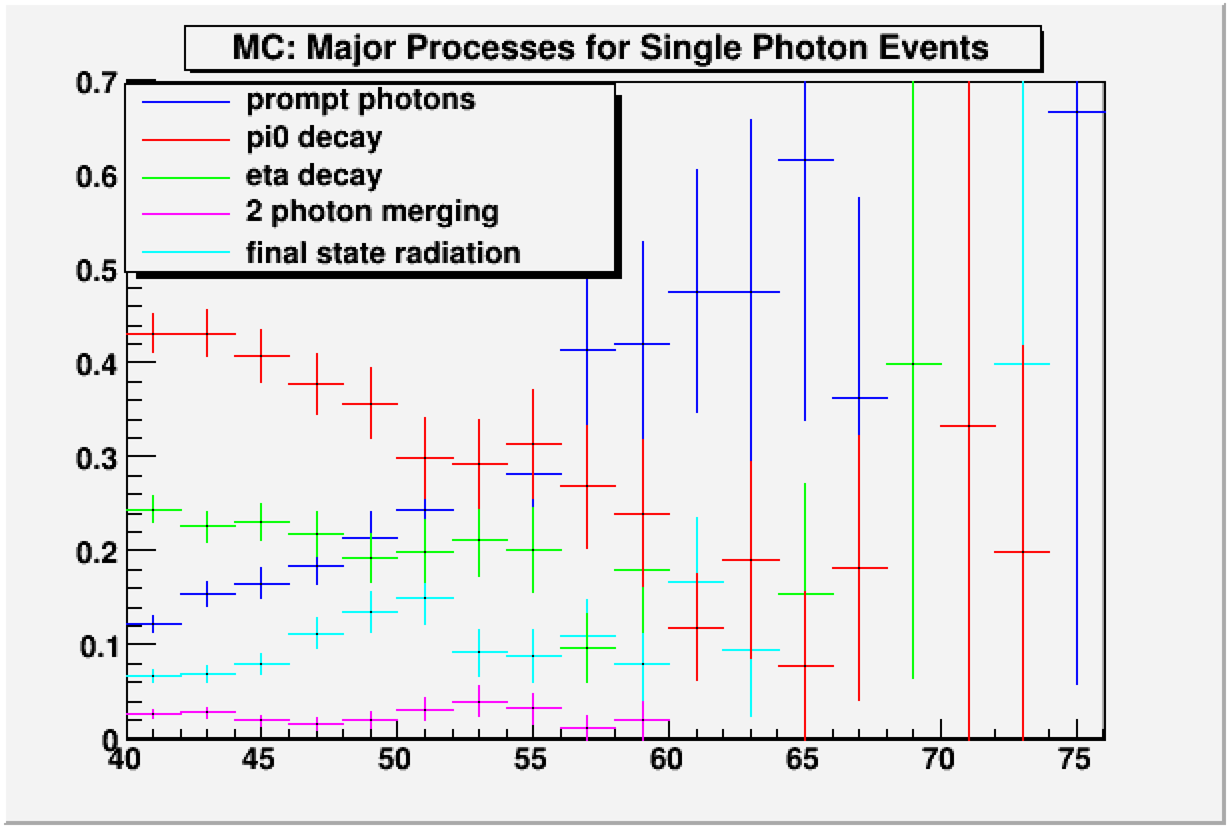


# Major Contributions to the Single Photon Signal in MC.

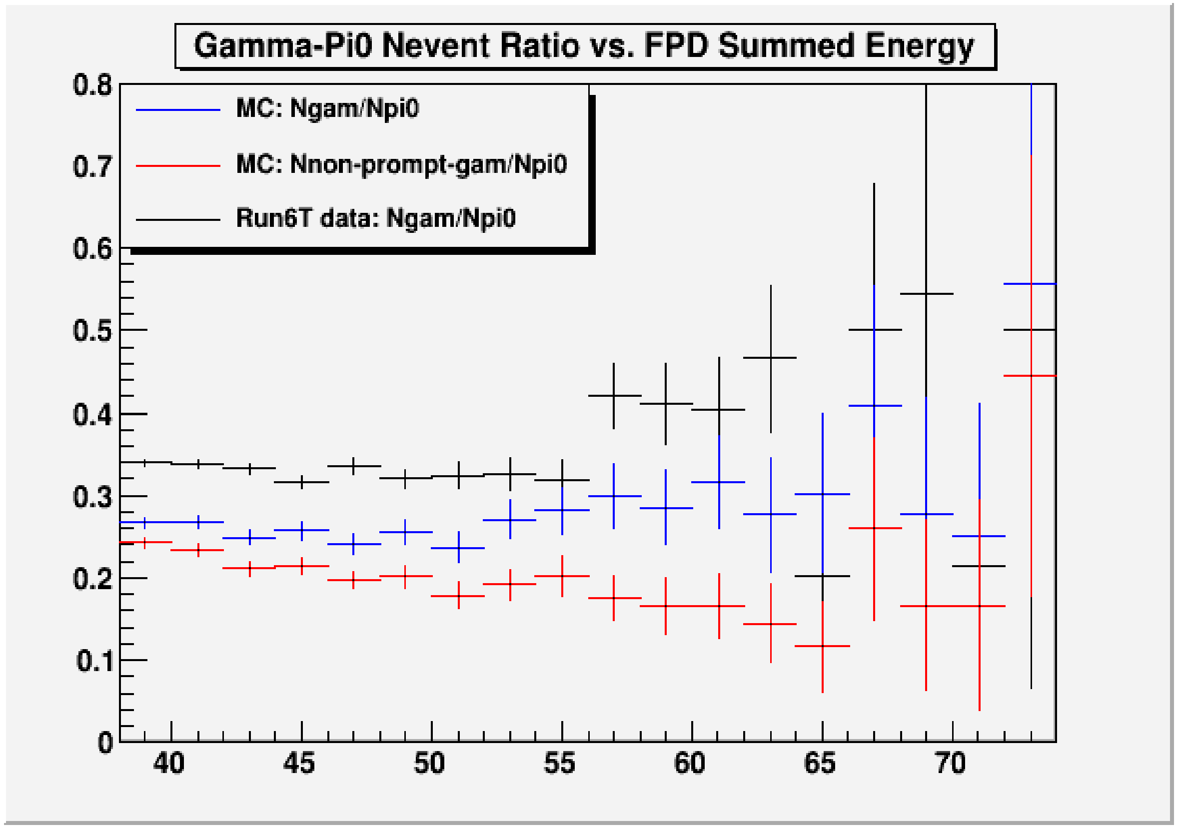
Len Eun




2-photon merging might be underestimated due to the inefficiency in track-photon association. If that is the case, most of those events would be classified as pi0 decays.

Final state radiation may have to be considered as prompt photon, even though the process code is regular QCD. These high energy photons descends from a quark that is the final state particle of the initial hard interaction, but the quark somehow gives most of its energy to the observed photon. It looks to be a multiple scattering scenario where the second scattering was a prompt photon production?

# Pi0 and Single Photon Esum Distributions
## from Len Eun




Here we look at the ratio between the number of single photon events and Pi0 events as a function of energy, for both data and MC. Now with the “junk” events removed, data actually has consistently higher gamma-pi0 ratio by ~10% than the simulation.

# Extracting Photon $A_N$

- FMS Run 9 data for energy > 65 GeV is approximately consistent with Pythia 6.222. This FMS data has little overlap with published FPD measurement.

- 20 pb of 200 GeV should produce
  - 50K pi0 with $E>65$ GeV ; $3.6<Y<3.7$
  - 20K 1 photon events for a 1% measurement of $A_N$
    - including 50% real direct photons
    - including 25% photons from pi0
    - including 25% photons from eta
  - Determination of Single Photon Asymmetry Must be associated with a **comparable determination of the Eta and Pi0 asymmetries** at high energy.

$$\Delta A = \frac{N^{\gamma} A^{\gamma} + N^{\pi^0} A^{\pi^0} + N^{\eta} A^{\eta}}{N^{\gamma} + N^{\pi^0} + N^{\eta}} = 0.5 A^{\gamma} + 0.25 A^{\pi^0} + 0.25 A^{\eta}$$

- At $3<Y<3.1$ the same number of events would be obtained above 45 GeV.

# Eta Mass Region in FMS Detector (Run 8)

# 2 photon Mass Distributions in four Pseudo-Rapidity Y Regions

# (Preliminary Energy Calibration )

# Eta ~ 10% of pi0

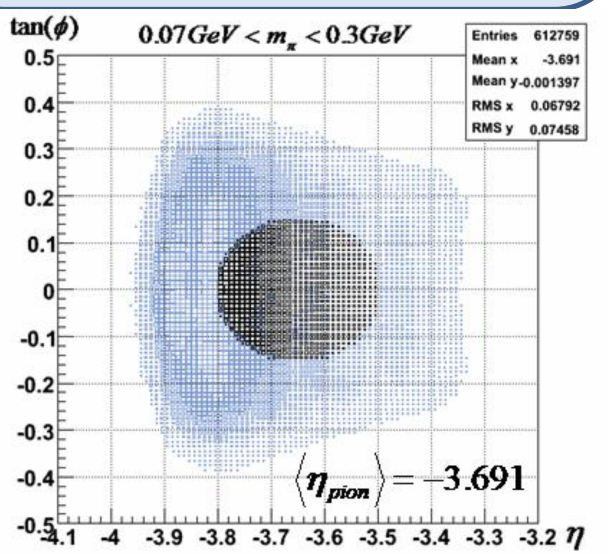
## Event Selection

2 Photons within cone

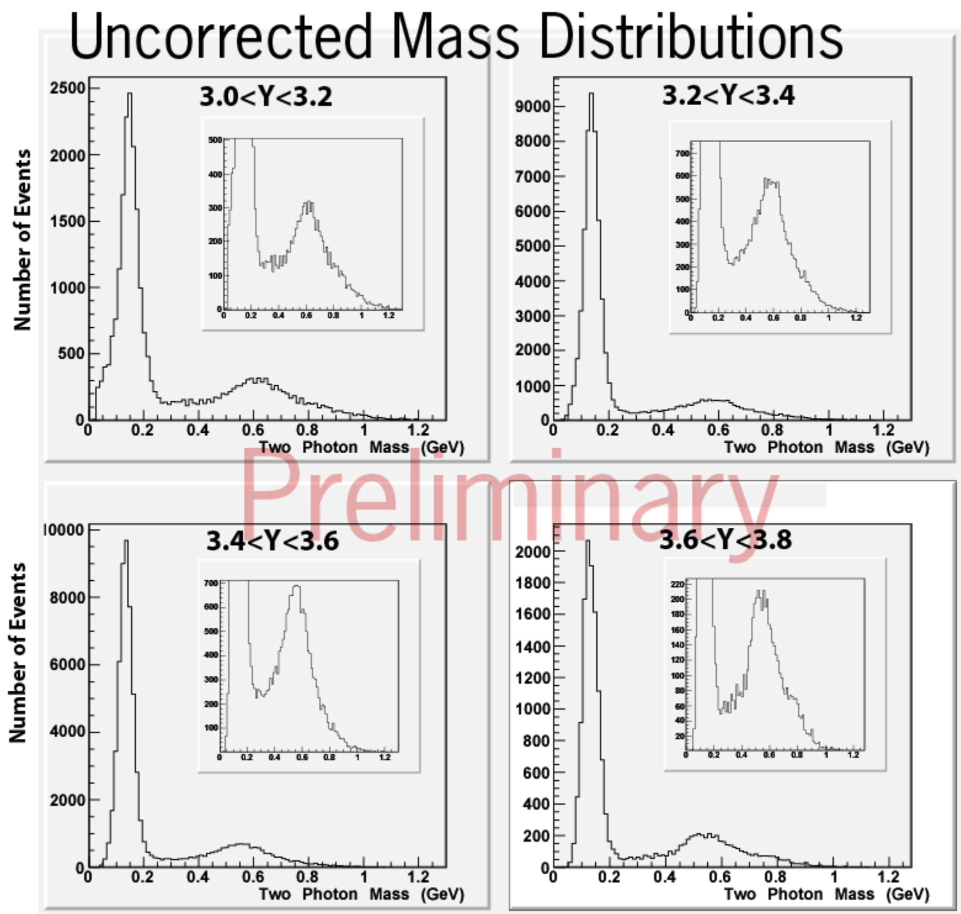
$$\sqrt{(Y_{Photons} - Y_{Eta})^2 + (\phi_{Photons} - \phi_{Eta})^2} < .85$$

$P_t > 2$ GeV/c

Z < .7




**Comparison to FPD Center Cut**




(~1/3 of Run 8 Transverse Data Set)

In Run 9, the trigger does not catch Eta's. The trigger must be modified to sort out the contribution from eta mesons!

20 pb of data with eta triggering could provide 5000 Eta triggers above 65 GeV Within 3.6<Y<3.65.

The Eta Asymmetry would then be determined to a few percent.
This should allow a 1% determination of the direct photon asymmetry.