Transverse Forward Physics at STAR (FMS)

April 29, 2010

Steve Heppelmann

Outline

- The Ideas
- Current STAR FPD/FMS Surprises
- Sensitivity of Future Measurements
- Photons
- Drell Yan
- Run 9 Setup Experience

The Ideas: Transverse Forward Physics in STAR

- pQCD with collinear factorization **should** explain hard scattering with longitudinal polarization but transverse SSA vanishes in that framework.
  - Vanishing parton helicity flip
  - Leading order "real" scattering amplitudes.
  - Transverse single spin asymmetry (SSA) require helicity flip and imaginary amplitude.
  - SSA not allowed (in leading order/twist)
- **Expanding the scope of pQCD.** Generalized extensions to collinear factorized**.**
  - physics beyond collinear factorization
    - Generalized Parton Distributions
    - orbital angular momentum of partons
    - Sivers effect
    - Collins fragmentation
    - QCD Beyond Factorization

PQCD
Collinear Factorization

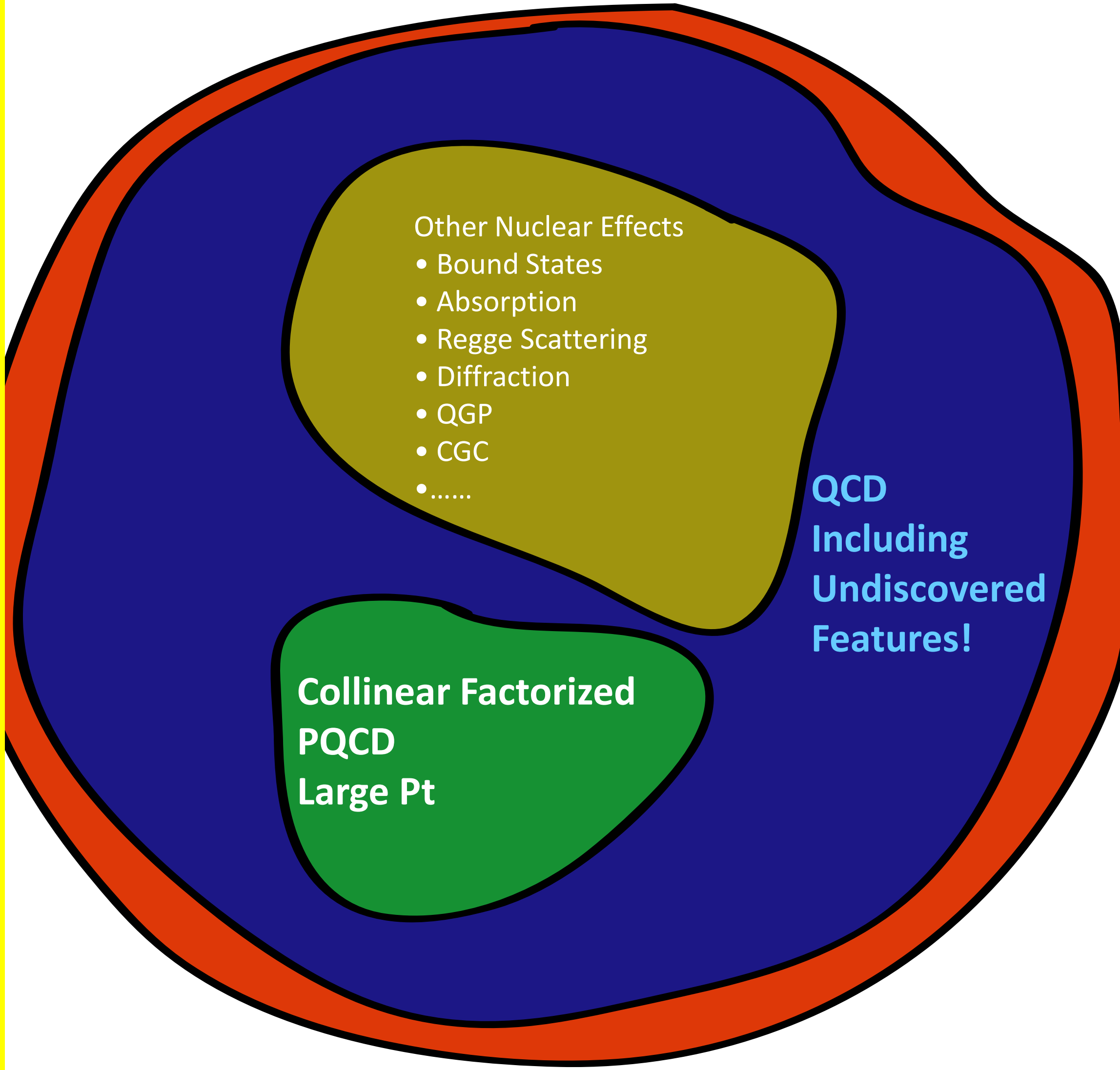
- Gives meaning to quark and gluon, the confined internal degrees of freedom (DOF) in QCD.

- Provides concrete connections between these internal DOF and experimental observables. (Jets, some hadrons, photons)

- Gives an experimental connection to a description of nucleon and non-perturbative bound state (Nucleon parton densities) .

- Provides a recipe for approximate calculation of cross sections for certain interactions in certain kinematic regions.

- Has a well defined kinematic region where calculations are most likely dependable.



Strong Interactions

Generalized Factorization PQCD++

- Applies to a wider variety of experimental measurements.

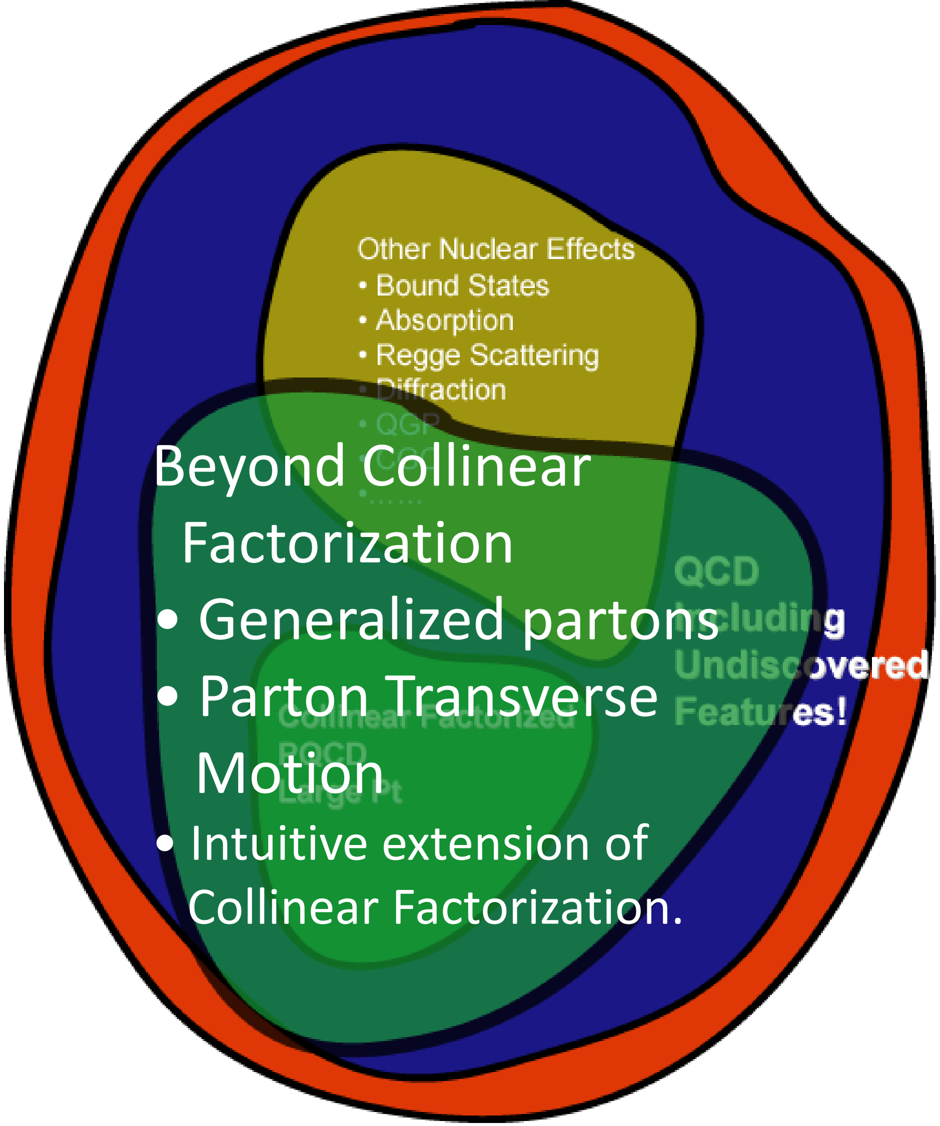
- Gives similar meaning to quark and gluon, the confined internal degrees of freedom (DOF) in QCD. (same)

- Provides concrete connections between these internal DOF and experimental observables.
  (Jets, some hadrons, photons) (same)

- Gives an experimental connection to a description of nucleon and non-perturbative bound state (Nucleon parton densities) . (same)

- Provides a recipe for approximate calculation of cross sections for certain interactions in certain kinematic regions??? (perhaps same)

- Has less clearly defined rules as to when calculations are most likely dependable.



Strong Interactions

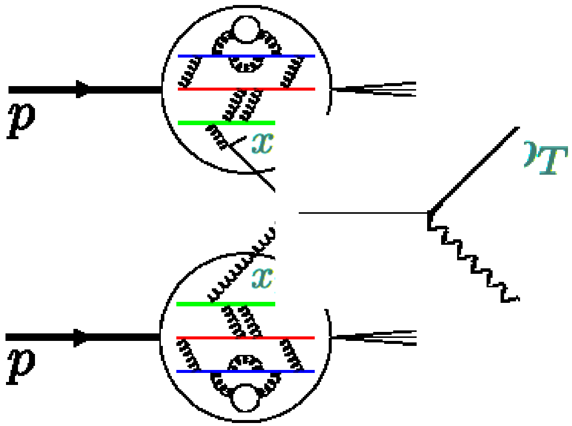
Collinear Factorization

Cross Section~ (Probability to select required parton A (x_1) from proton 1)
x (Probability to select required parton B (x_2) from proton 2)
x (Probability that partons A+B => C + X)
x (Probablity that parton C Fragments into observed final state)

$$f_1(x_1) \underset{x_1 \to 1}{\sim} (1-x_1)^3$$

$$f_2(x_2) \underset{x_2 \to small}{\sim} 1$$

$$D_{parton}^{\pi^0} \underset{z \to 1}{\sim} (1-z)^1$$



$$d\sigma_{pp} \propto f_1 \otimes f_2 \otimes \sigma_h \otimes D_f^h$$

For Forward Production of Pi/Eta ..

$$\sigma(x) \propto \int_{x_f}^{1} dz\, f_1\left(x \sim x_F/z\right) \sigma_{parton} \quad D_{parton}^{\pi^0}(z)$$

$$q(x) \sim (1-x)^3$$

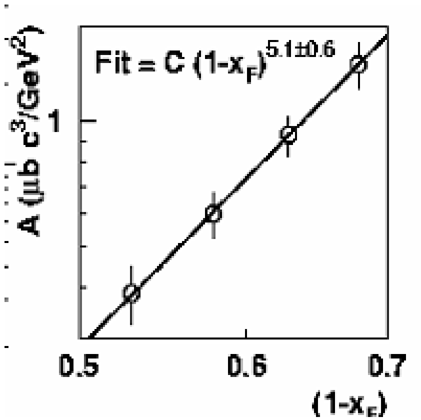
$$d(z) \sim (1-z)$$

$$\sigma(x) \propto (1-x_F)^5 + Order[(1-x_F)^6]$$

$$\sigma(x) \propto (1-x_F)^5$$

Forward Pi0 Cross Sections Scale Like seen in ISR.

At Large X_F (ie. $X_F>0.4$) , the Pi^0 fragment carries most of the of the jet momentum (<z> > 75%).



$$E\frac{d^3\sigma}{dp^3} \propto (1-x_F)^N p_T^{-B}$$

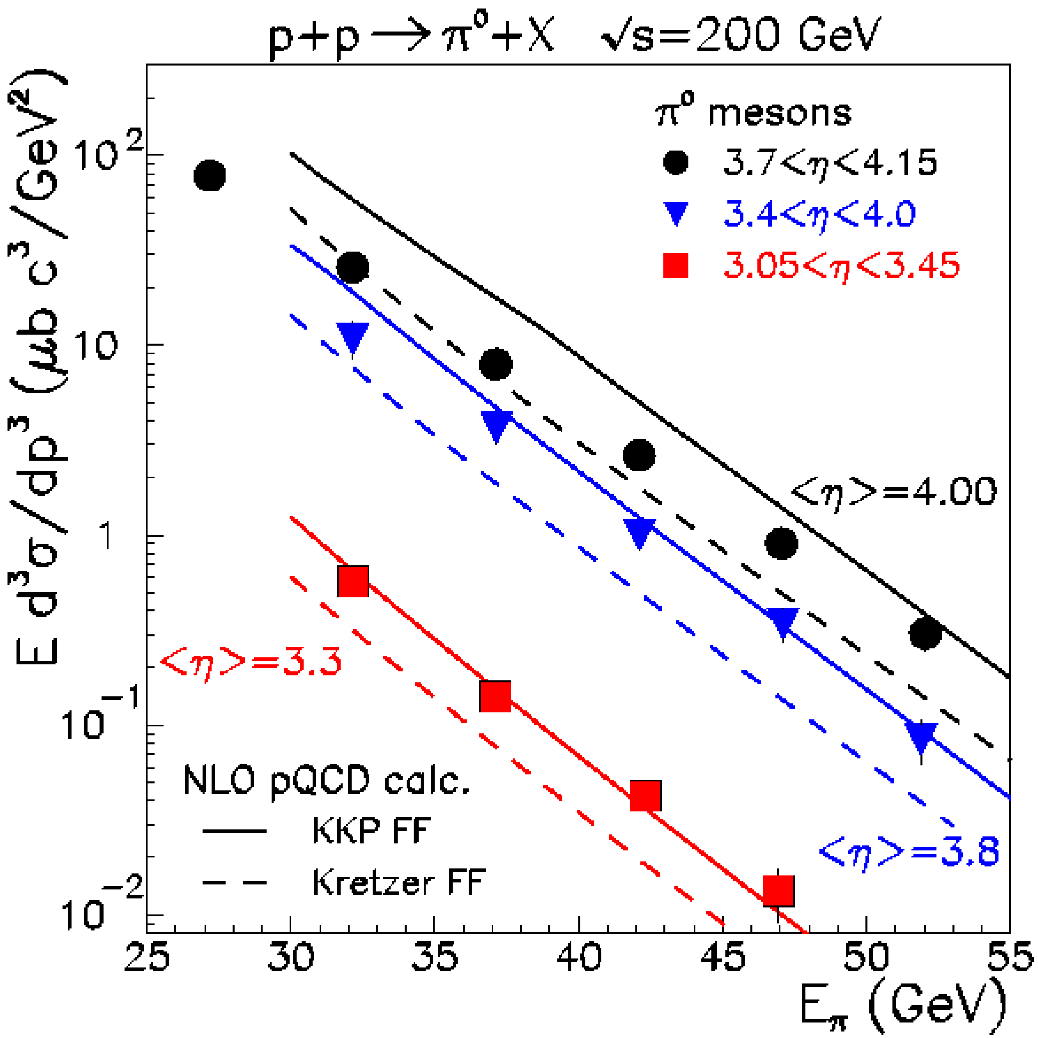
$$N \approx 5$$

$$B \approx 6$$

STAR Published Result is similar to to ISR analysis J. Singh, et al Nucl. Phys. B140 (1978) 189.

$$\propto e^{-\frac{2(N+B)}{100}E} = e^{-\frac{2(11)}{100}E} = e^{-.22\,E}$$

$$for\ \{20 < E < 80\} GeV$$



Alternatives to Factorized PQCD Lead to Very Different Cross Sections

- Preliminary look at invariant cross section are likely consistent with conventional

$$\frac{(1-x_F)^5}{p_T^{\ 6}}$$

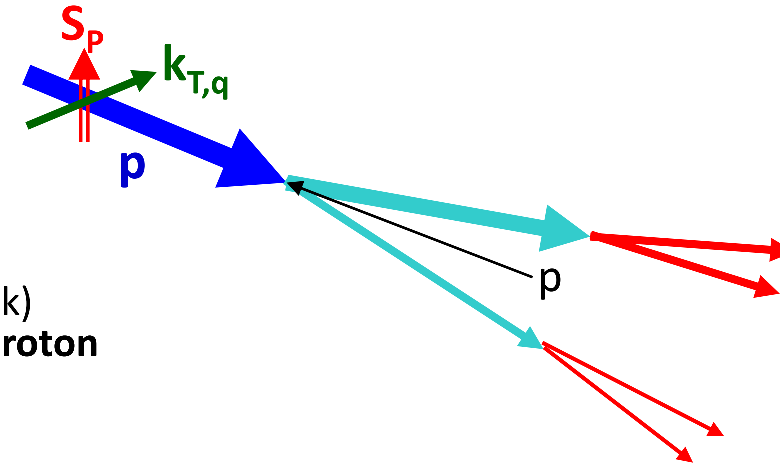
- In contrast, analysis of low p_T **Regge type processes** lead to **to a different form** for the dependence of the cross section on $(1-x_F)$ as Feynman x_F approach unity.

Regge Cross Section $\propto (1-x_F)^2$

L.L.FrankFurt and M.I. Strikman, Vol. 94B2 Physics Letters, 28 July 1980.
and Private Communication.

Sivers Model

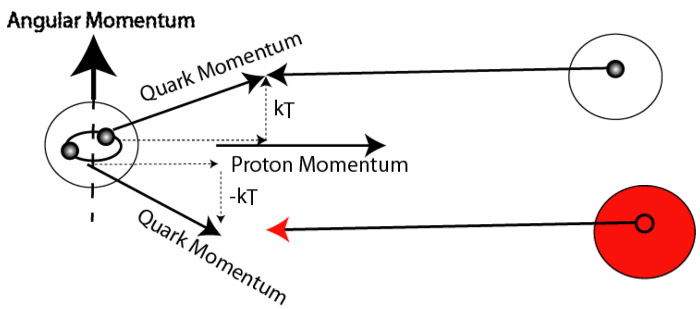
Difference Between pi0 and eta A_N?



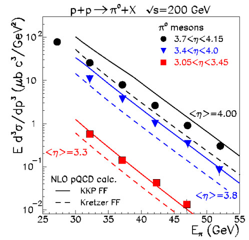
- A fast quark in the polarized proton (probably a u quark) has initial **transverse motion relative to the incident proton direction**. The sign of this transverse momentum is connected to the proton transverse spin.

- The jet has transverse momentum

$$P_T = p_T^{hard\ scattering} + k_T$$



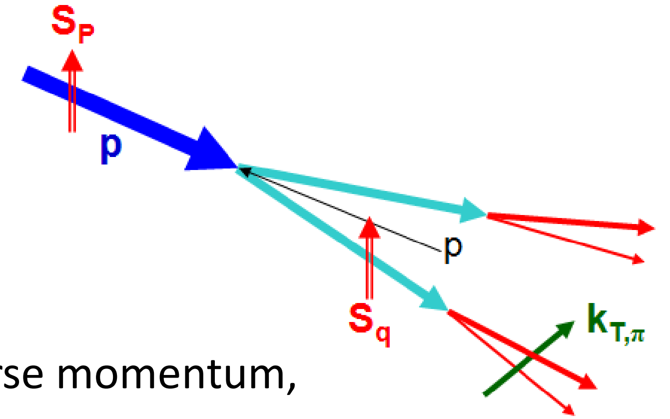
- $\langle k_T \rangle$ changes sign if the spin and angular momentum is reversed.
- “T” symmetrical “$-k_T$” amplitude absorbed as quark in one nucleon passes through gluon field of other nucleon. “Wilson Line”
  Breaking of Factorization!!!!
- The jet fragments with large z to produce a **meson that is moving in the direction of the jet**, with nearly p_T of the jet.
- Dependence of **initial state p_T** upon proton spin leads to Sivers A_N.
- Shape of **cross section similar for pi0 and eta**.
- This situation should be the **same whether** the jet fragments into a **pi0 or an eta**.



$$A_N(P_T) = \frac{\sigma\left(p_T + \langle k_T \rangle\right) - \sigma\left(p_T - \langle k_T \rangle\right)}{2\sigma(P_T)}$$

$$\sim \frac{1}{\sigma}\frac{d\sigma}{dP_T}\langle k_T \rangle$$

Collins Model



k_T and thus A_N vanishes as Z approaches 1

- Consider large eta **A_N** (perhaps of order unity)
  X_F~0.75 , **Z~ .9** and **p_T~3.9 GeV/c**.
- Any associated jet fragments will carry limited transverse momentum,

$$k_T \sim \frac{(1-Z)\,p_T}{2}$$

- If the cross section is given by $\frac{(1-x_F)^5}{p_T{}^6}$
- The Maximal asymmetry from fragmentation $p_T \to p_T + Sin(\phi)k_T$

$$\phi = fragmentation\ \ azimuthal\ \ angle\ from\ spin\ direction$$

- Leads to an **<u>extreme limit</u>** for A_N from fragmentation,

$$A_N < \frac{6k_T}{p_T} \sim 3(1-Z) \sim .6$$

This is the most extreme case including

- 100% transverse parton polarization
- the maximum possible Collins Fragmentation function.

Current STAR+FPD/FMS Surprises

P_t Dependence in Calculations of A_N

•**Sivers Effect** / **Collins Effect**

•introduce transverse spin dependent **offsets in transverse momentum** ….

•independent of the hard scattering (definition of factorization).

$$P_T \Rightarrow P_T \pm k_T$$

"±" depending on the sign of proton transverse spin direction. **Using our (STAR) measured cross section form:**

$$d\sigma^{\uparrow} \propto \frac{1}{(P_T - k_T)^6} \qquad d\sigma^{\downarrow} \propto \frac{1}{(P_T + k_T)^6}$$

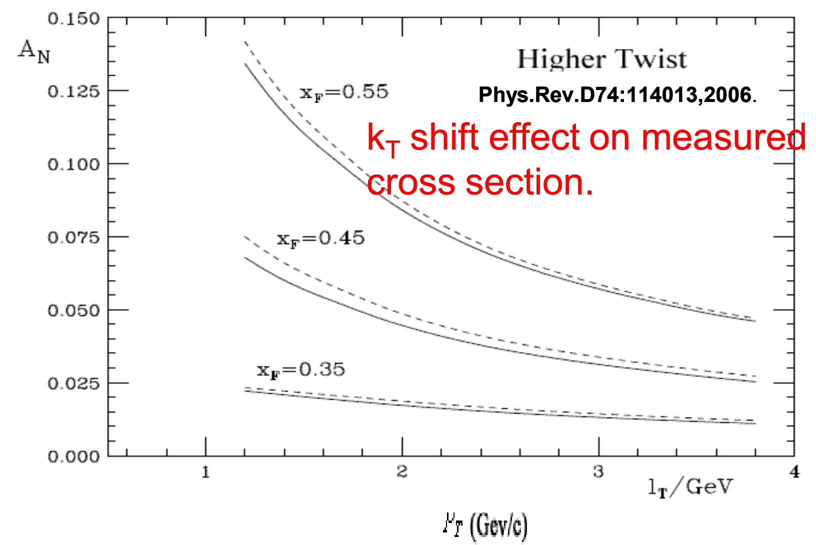
$$A_n \equiv \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}} = \frac{6k_T}{P_T} + O\left(\frac{k_T}{P_T}\right)^2$$

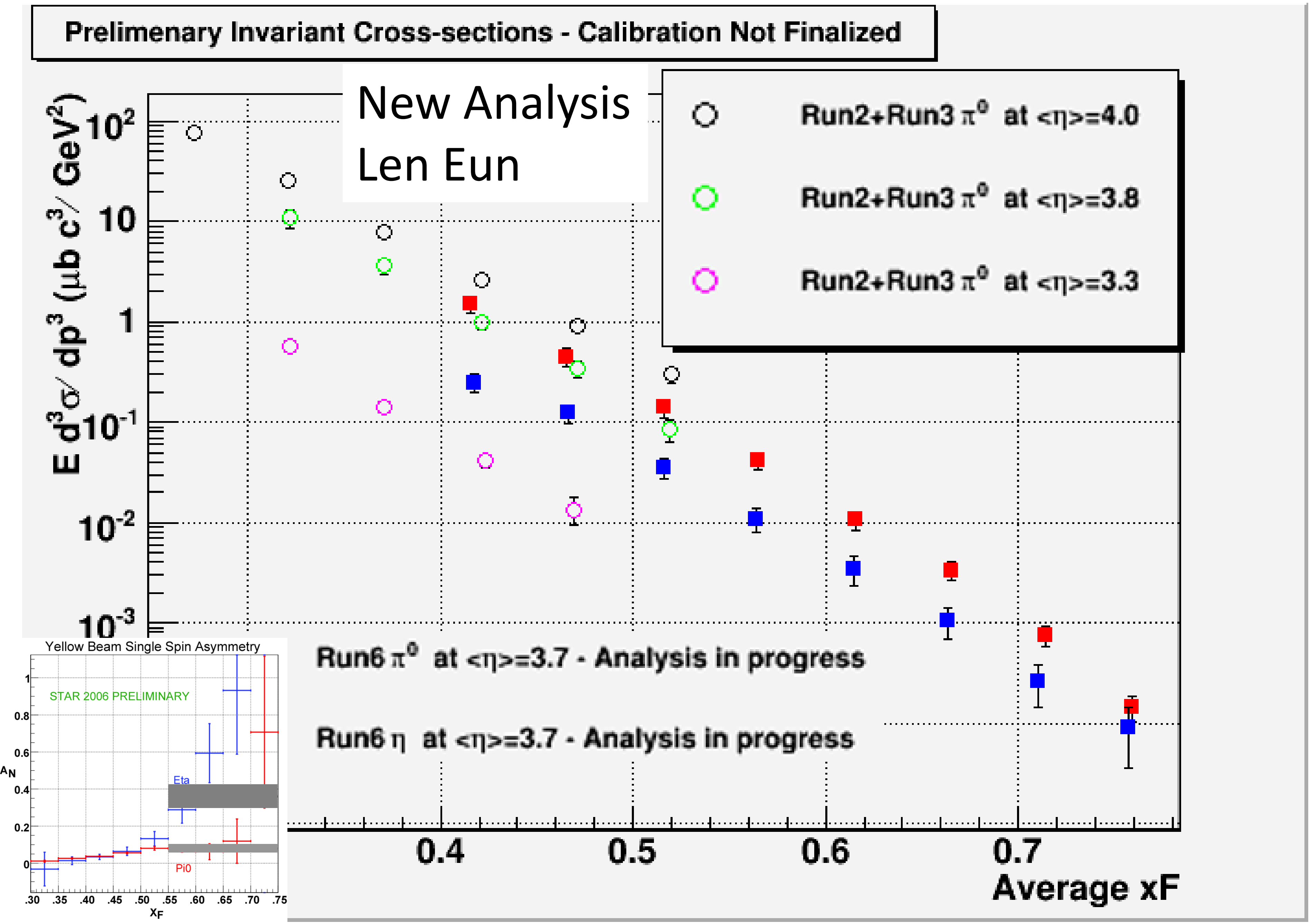
Higher Twist Effects:

Qiu and Sterman
Kouvaris et. al. **Phys.Rev.D74:114013,2006**.

A_N Fall as $1/P_T$ as required by definition of higher twist.

All of these models lead to $A_N \sim\propto 1/P_T$





Prelimenary Invariant Cross-sections - Calibration Not Finalized
New Analysis
Len Eun
Run2+Run3 π⁰ at <η>=4.0
Run2+Run3 π⁰ at <η>=3.8
Run2+Run3 π⁰ at <η>=3.3
E d³σ/ dp³ (μb c³/ GeV²)
Run6 π⁰ at <η>=3.7 - Analysis in progress
Run6 η at <η>=3.7 - Analysis in progress
Average xF
Yellow Beam Single Spin Asymmetry
STAR 2006 PRELIMINARY
Eta
Pi0
A_N
x_F

Comparison between *η* production and π^0 production?

- **Gluons** or ***η*** has **Isospin I=0**.
- **u quark** has **Isospin I=1/2**
- $\boldsymbol{\pi^0}$ has **Isospin I=1**.

- But we expect both mesons to come from **<u>fragmentation of quark jets</u>**.

$$I = 0 \quad \begin{cases} \eta \simeq \quad + d\bar{d} - s\bar{s}) \\ \eta' \simeq \quad + d\bar{d} + 2s\bar{s}) \end{cases}$$

$$I = 1 \quad \left\{ \pi^0 = \frac{1}{\sqrt{2}}\left(u\bar{u} - d\bar{d}\right) \right.$$

*Assume η, η' mixing angle: $\theta_P \sim -19.5°$

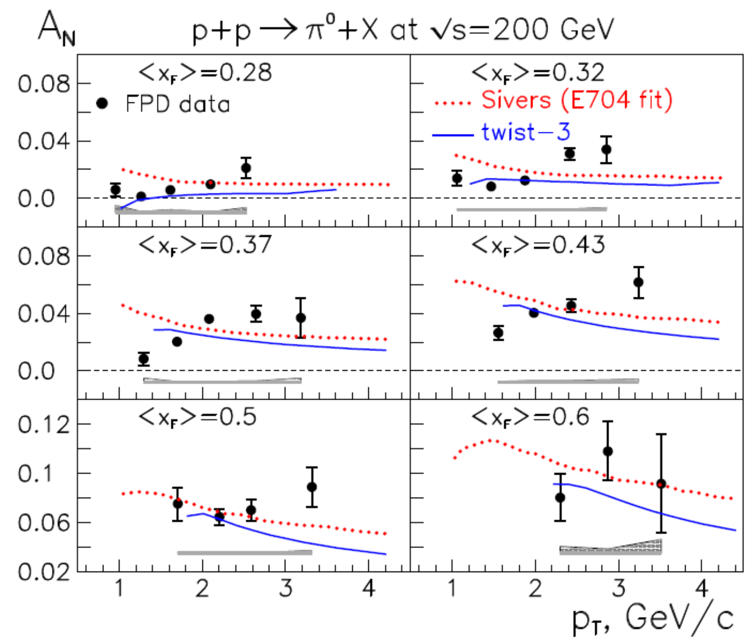
- **For Sivers Effect: Asymmetry is in the jet and should not depend on the details of fragmentation.**

- **For Collins Effect**: Asymmetry reflects fragmentation of the quark jet into a leading ***η*** or $\boldsymbol{\pi^0}$ meson. Differences in fragmentation could relate to:

  - Mass differences?
  - Isospin differences?
  - Role of Strangeness?
  - **But Collins Effect Should be suppressed when Z→1**

For Fixed X_F, the asymmetry A_N does not fall with P_t as predicted by models.

- NLO PQCD **does describe** the size and shape of this forward pp cross section.
- Model calculations (Sivers, Collins or twist-3) **can explain** the X_F dependence of A_N.
- Flat or increasing dependence of A_N on P_T



U. D'Alesio, F. Murgia, Phys. Rev. D **70**, 074009 (2004).
J. Qiu, G. Sterman, Phys. Rev. D **59**, 014004 (1998).

Theory Score Card For Factorized QCD Picture for Pi & Eta Transverse A_N

✓ Cross Section for Pi0 agrees with PQCD (Normalization and Shape)

✓ Dependence of cross section on X_F and Pt may be similar for Pi0 and Eta at large X_F as expected.

✓? Ratio Eta/Pi0 nominal 40% - 50% Yet to be determined.

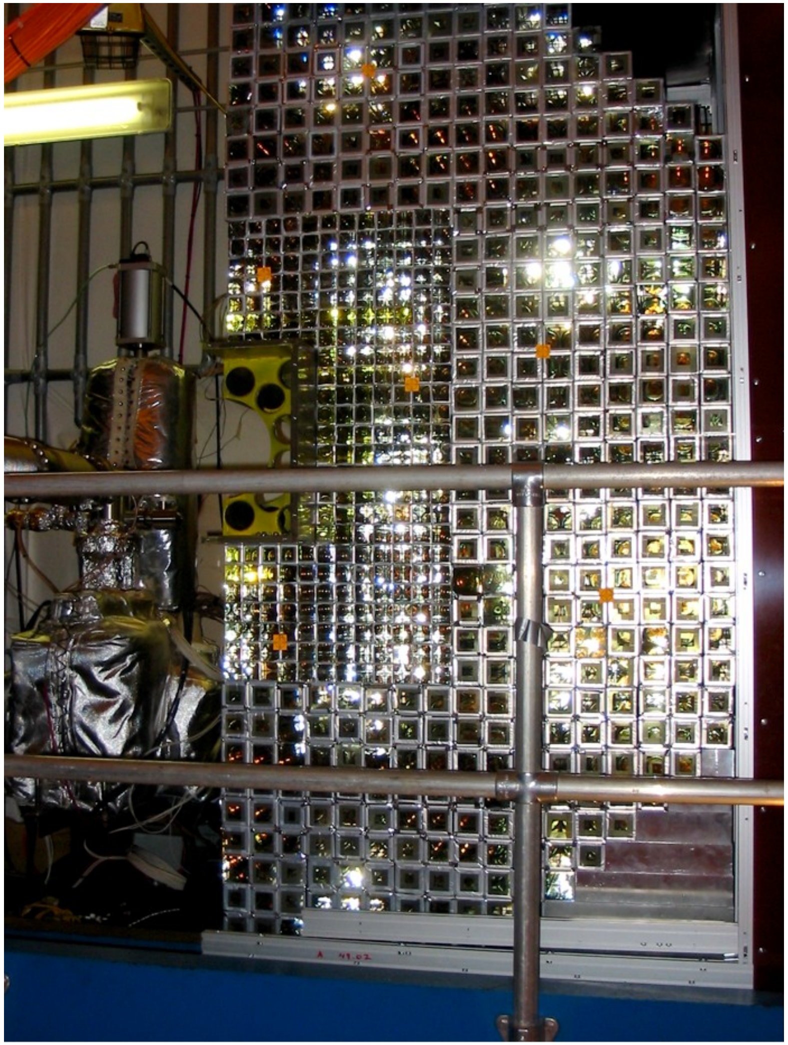
✗ Pt Dependence of Pi0 A_N .

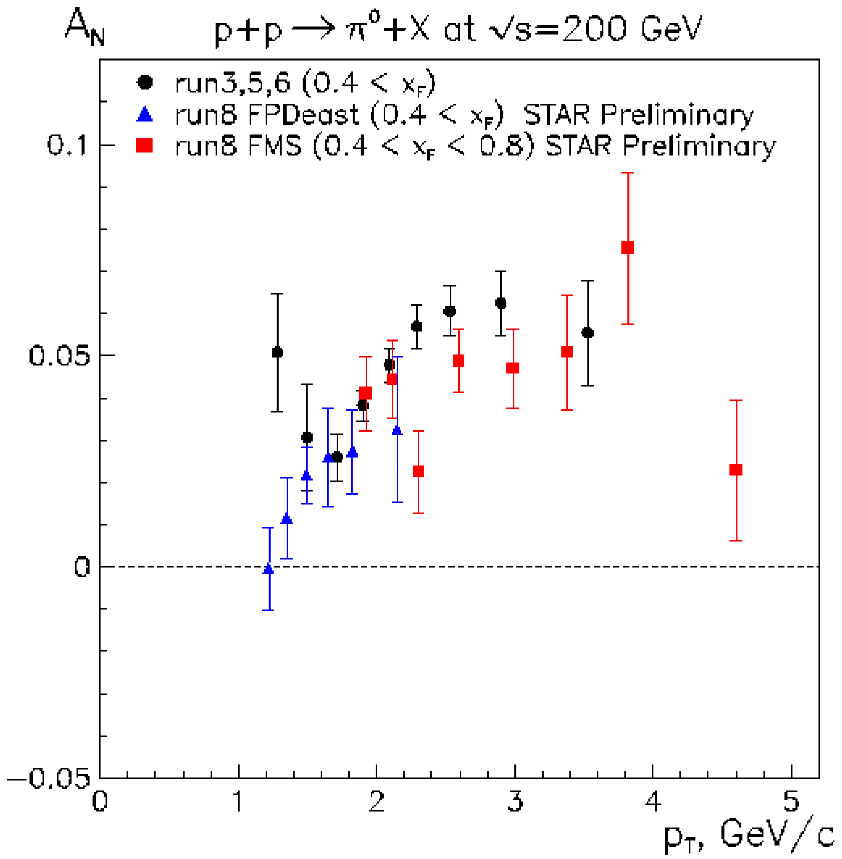
Inconsistent with $A_N \sim 1/p_T$.

Can a large difference in asymmetry between Pi0's and Eta's be understood in either Collins or SIvers Model?

With FMS, STAR has Expanded Rapidity Coverage -1<Y<4.2

STAR Forward Meson Spectrometer
2.5 < Y < 4.0





arXiv:0901.2763 +
A.Ogawa @CIPANP09

Sensitivity of Future Measurements

200 GeV Transverse Spin Program

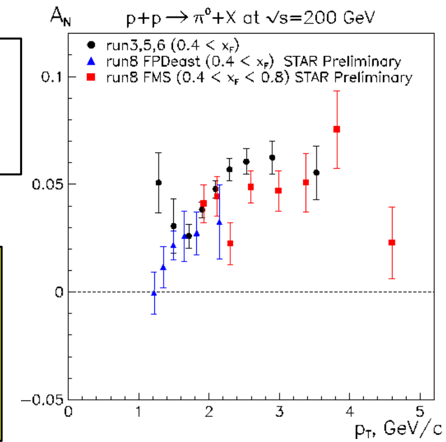
$\sqrt{s}$	Transverse Process	Collins	Sivers	Sivers SIDIS Sign Change	$\int L$	Detectors
	$p^{\uparrow} + p \rightarrow \pi^0 + X$	*	*			
	$p^{\uparrow} + p \rightarrow \eta + X$	*	*			FMS
	$p^{\uparrow} + p \rightarrow \gamma + X$		*	*	$30\ pb^{-1}$	
200 GeV	$p^{\uparrow} + p \rightarrow \pi^0 + \pi^0 + X$	*	*			
	$p^{\uparrow} + p \rightarrow \gamma + \pi^0 + X$		*	*		
	$p^{\uparrow} + p \rightarrow \pi^0 + \pi^0 + X$	*	*			FMS+EMC
	$p^{\uparrow} + p \rightarrow jet + X$	*	*			FMS+HCAL
	$p^{\uparrow} + p \rightarrow jet + \pi^0 + X$	*	*			
	$p^{\uparrow} + p \rightarrow \Lambda + X$	*	*			
	$p^{\uparrow} + p \rightarrow jet + jet + X$	*	*			FMS+EMC
	$p^{\uparrow} + p \rightarrow \gamma + jet + X$		*	*		HCAL +Tracking

500 GeV Transverse Spin Program

$\sqrt{s}$	Transverse Process	Collins	Sivers	Sivers SIDIS Sign Change	$\int L$	Detectors
500 GeV	$p^{\uparrow} + p \rightarrow \pi^0 + X$	*	*		$20\ pb^{-1}$	West FMS East FPD +Shower Max
	$p^{\uparrow} + p \rightarrow \eta + X$	*	*			
	$p^{\uparrow} + p \rightarrow \gamma + X$		*	*		
	$p^{\uparrow} + p \rightarrow \pi^0 + \pi^0 + X$	*	*			
	$p^{\uparrow} + p \rightarrow \gamma + \pi^0 + X$		*	*		
	$p^{\uparrow} + p \rightarrow \pi^0 + \pi^0 + X$	*	*			FMS+EMC
	$p^{\uparrow} + p \rightarrow jet + X$	*	*			FMS+HCAL
	$p^{\uparrow} + p \rightarrow jet + \pi^0 + X$	*	*			
	$p^{\uparrow} + p \rightarrow \Lambda + X$	*	*			
	$p^{\uparrow} + p \rightarrow jet + jet + X$	*	*			FMS+EMC HCAL +Tracking
	$p^{\uparrow} + p \rightarrow \gamma + jet + X$		*	*		
	$p^{\uparrow} + p \rightarrow e^+ + e^- + X$		*	*	$250\ pb^{-1}$	FMS+EMC +Tracking +PID

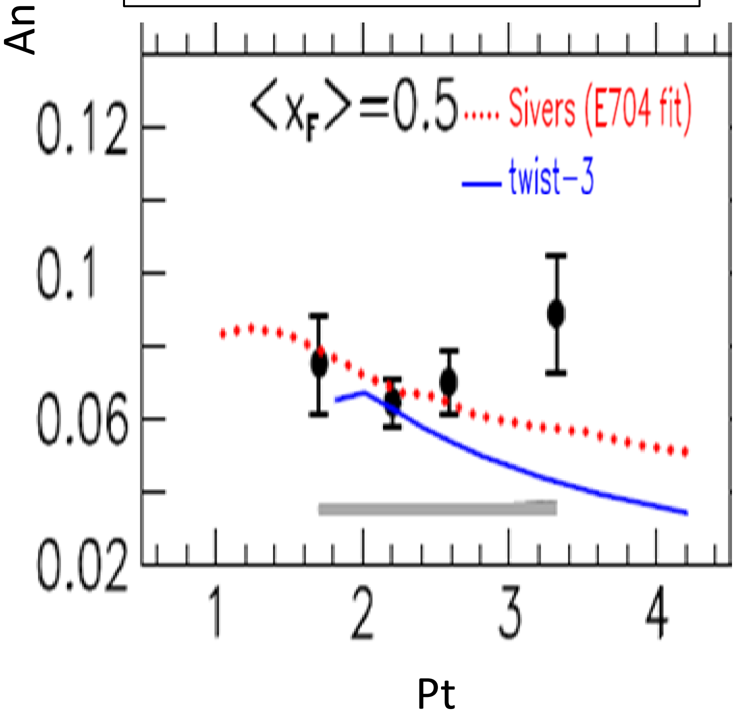
$A_N \ \pi^0$

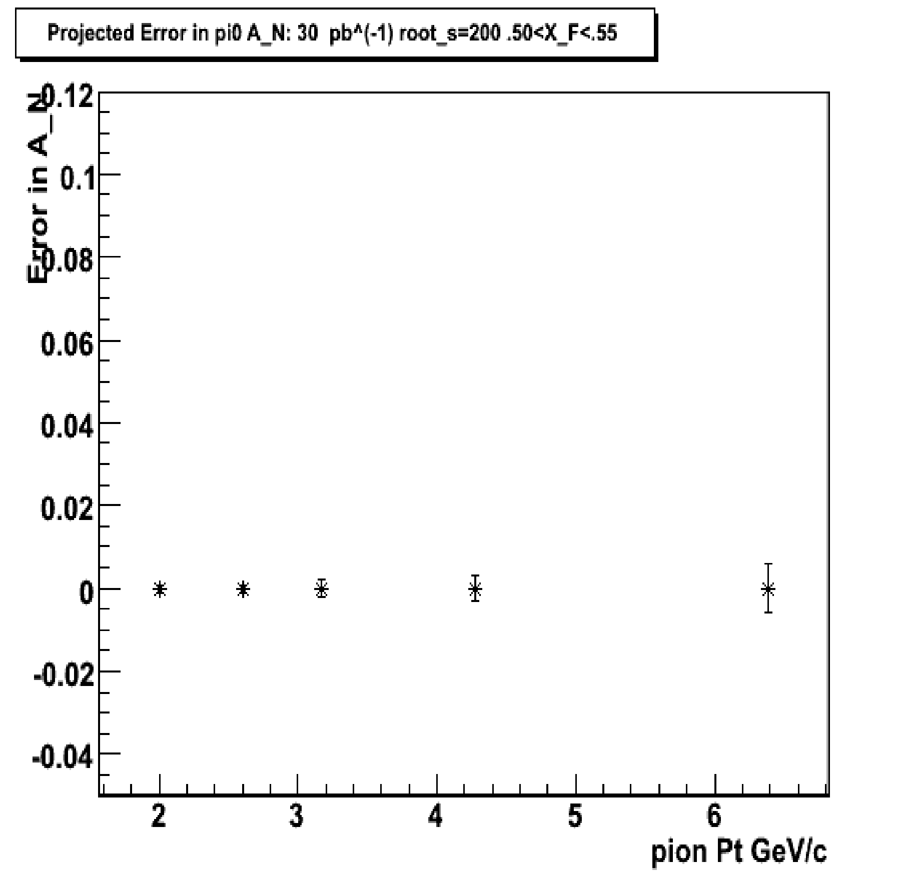
Run 6 FPD+ Run 8 FMS
Pt Dependence X_F>0.4



Run 6 FPD Pt Dependence
X_F ~ 0.5

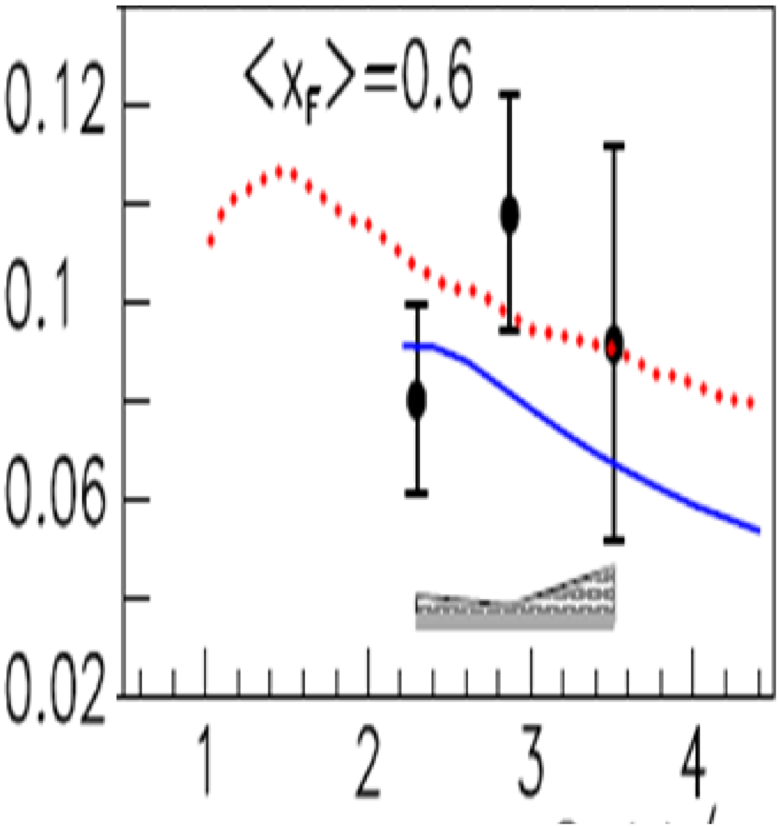
Errors for Projected
FMS Pt dependence
0.5< X_F <0.55



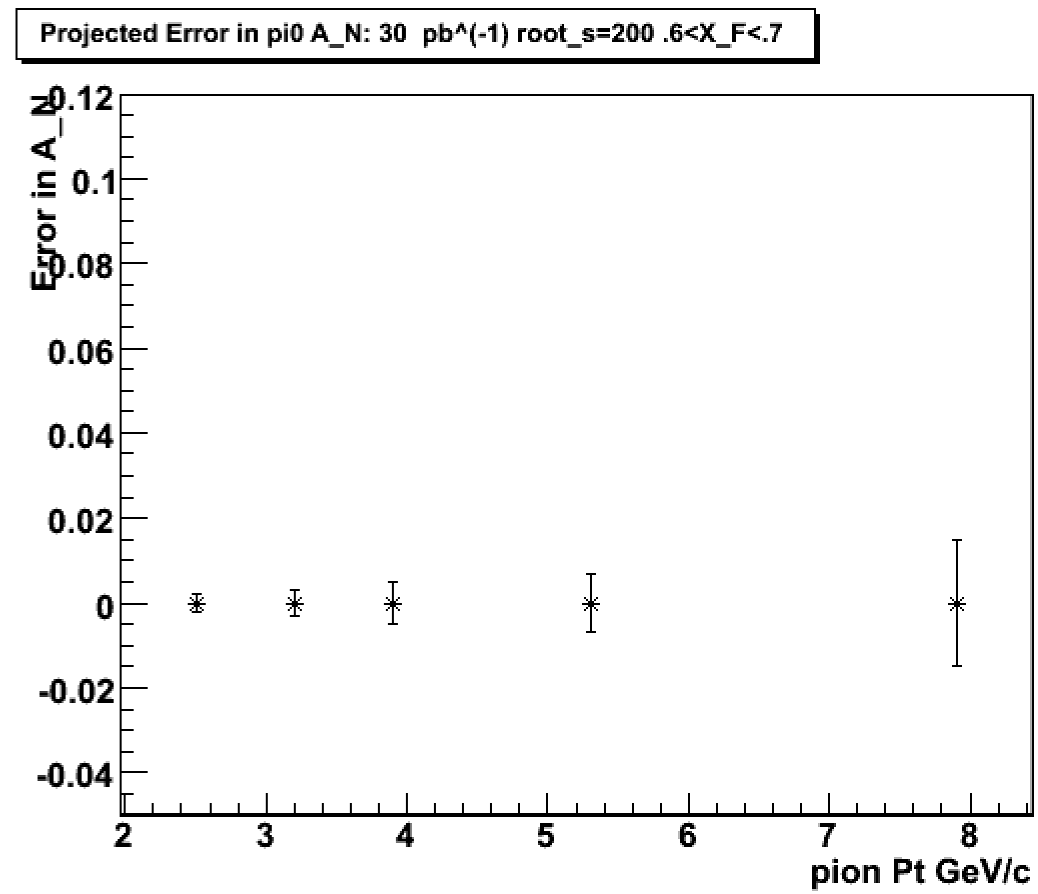


$A_N \ \pi^0$

Run 6 FPD Pt Dependence
$X_F \sim 0.6$

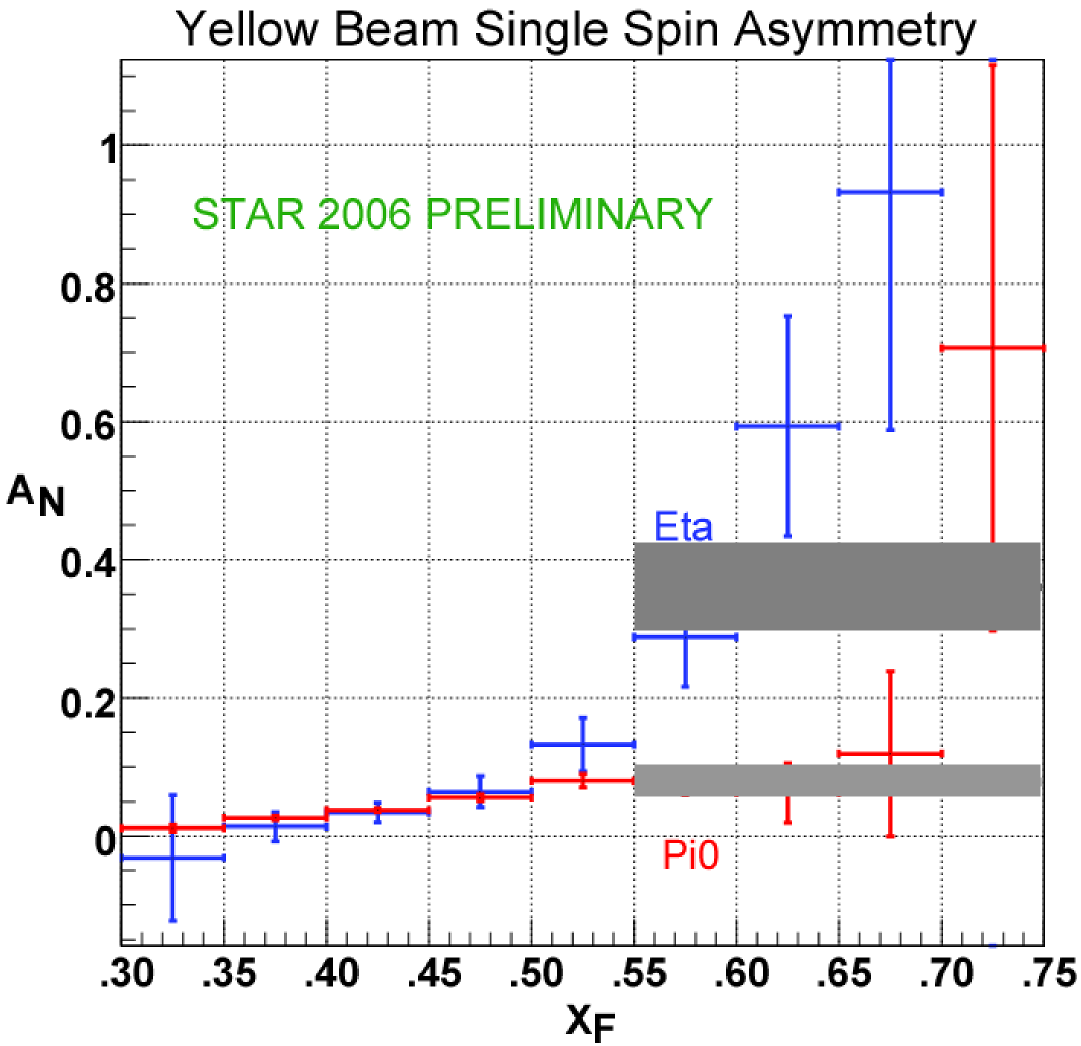


Errors for Projected
FMS Pt dependence
$0.6 < X_F < 0.65$



$A_N(x_F)$ in π^0 and Eta Mass Regions

$$p^{\uparrow} + p \rightarrow M + X \qquad M \rightarrow \gamma + \gamma \qquad \sqrt{s} = 200\,GeV$$



1. $N_{photon} = 2$
2. Center Cut (η and ϕ)
3. Pi0 or Eta mass cuts
4. Average Yellow Beam Polarization = 56%

$$.55 < X_F < .75$$

$$\langle A_N \rangle_\eta = 0.361 \pm 0.064$$

$$\langle A_N \rangle_\pi = 0.078 \pm 0.018$$

For $.55 < X_F < .75$ the asymmetry in the η mass region is greater than 5 sigma above zero, and about 4 sigma above the asymmetry in the π^0 mass region.

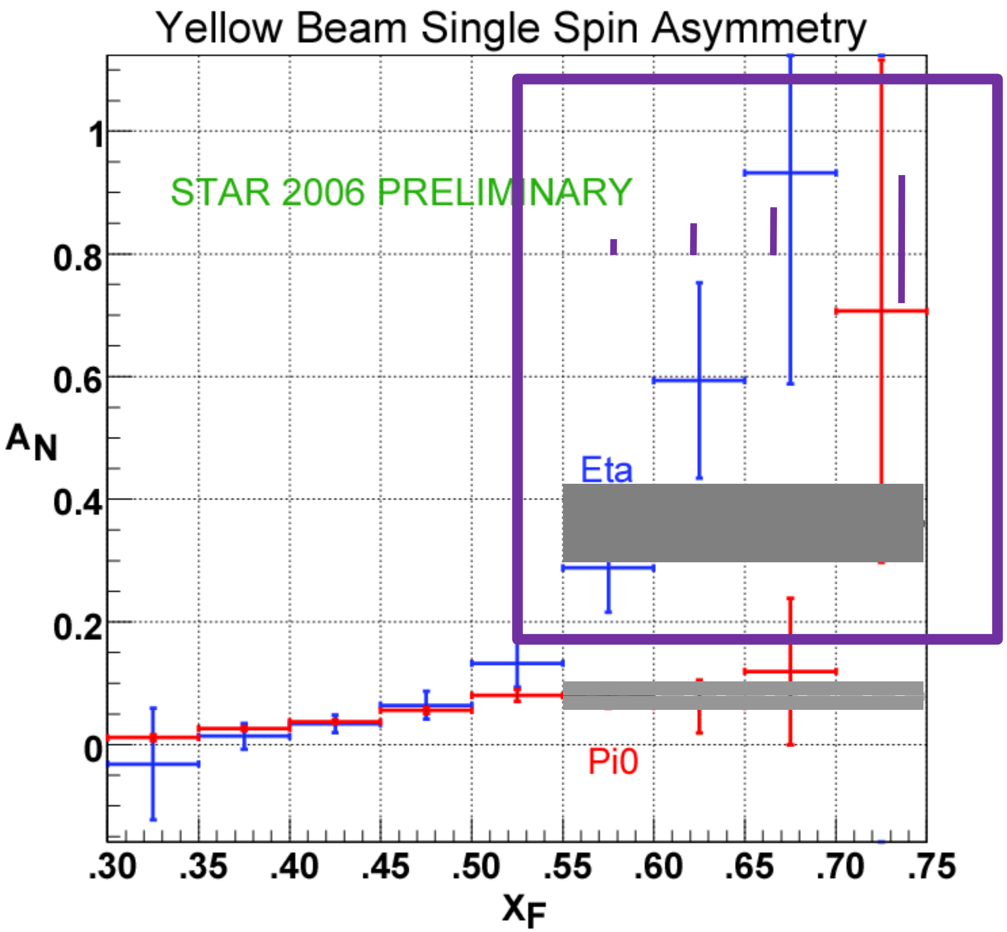
Run 6 FPD Result

$.55 < X_F < .75$

$\langle A_N \rangle_\eta = 0.361 \pm 0.064$

$\langle A_N \rangle_\pi = 0.078 \pm 0.018$

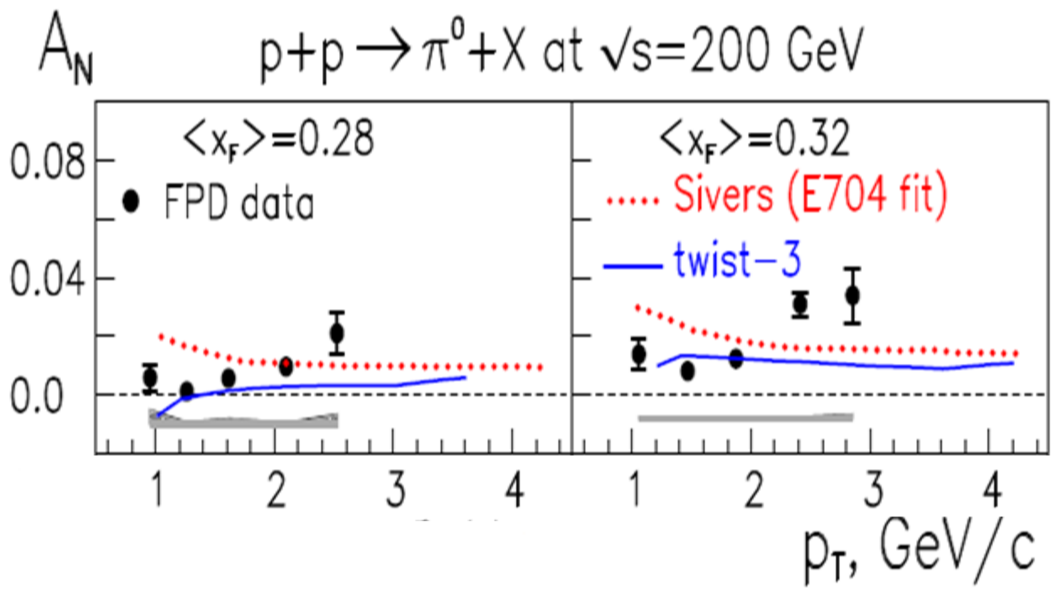
Projected Errors
For Eta A_N
200 GeV
30 pb^{-1}



	$.50 < x_F < .55$	$.55 < x_F < .60$	$.60 < x_F < .70$	$.70 < x_F < .90$
$2.6 < Y < 3.0$	0.043	0.070	0.105	0.333
$3.0 < Y < 3.4$	0.019	0.031	0.047	0.149
$3.4 < Y < 3.6$	0.015	0.024	0.037	0.116
$3.6 < Y < 3.8$	0.010	0.016	0.025	0.078
$3.8 < Y < 4.1$	0.005	0.008	0.012	0.038

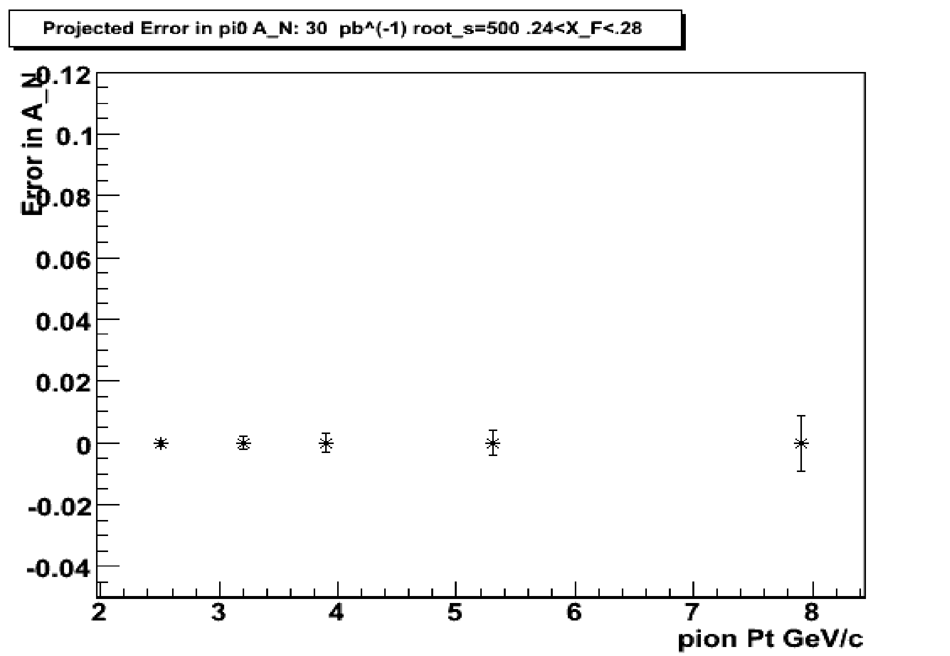
Table 5: Estimated error in A_N for η mesons for 200 GeV $30 pb^{-1}$ Data Set

Comparison between 200 GeV Measurement and 500 GeV Projections



Run 6 FPD Published A_N measurement

Sqrt(s) = 200 GeV

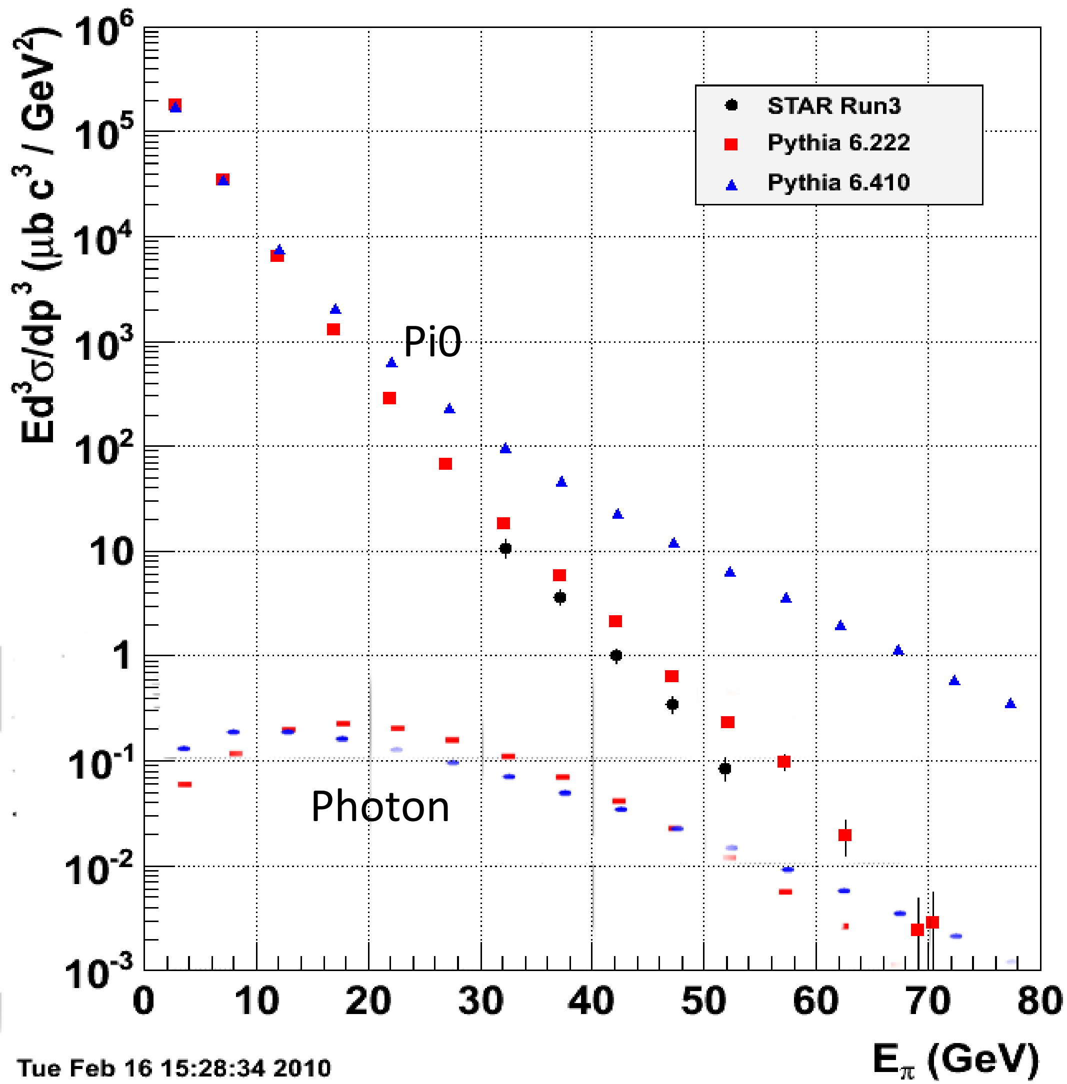


Projections for A_N statistical errors

Sqrt(s) = 500 GeV

20 pb^{-1}

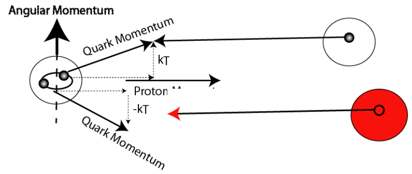
Photons



What Pythia says
For π^0 and γ

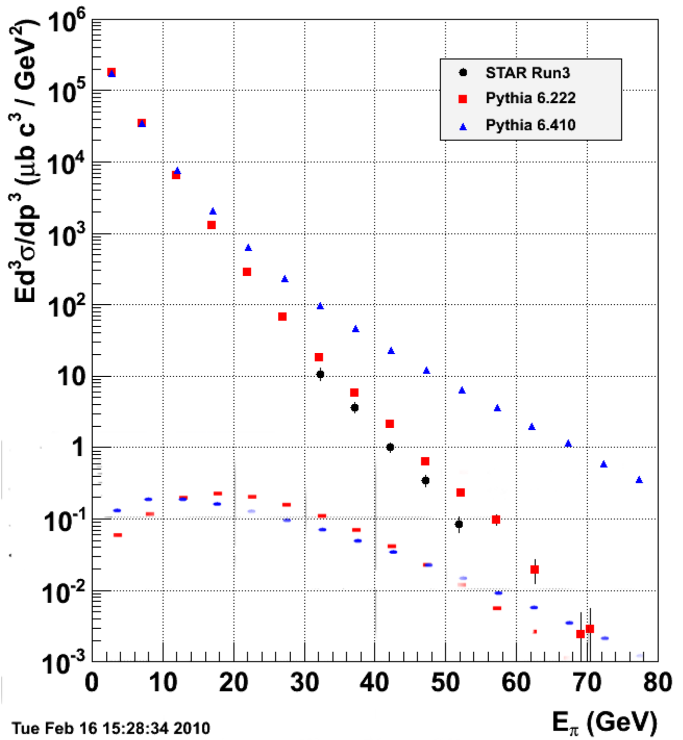
STAR data

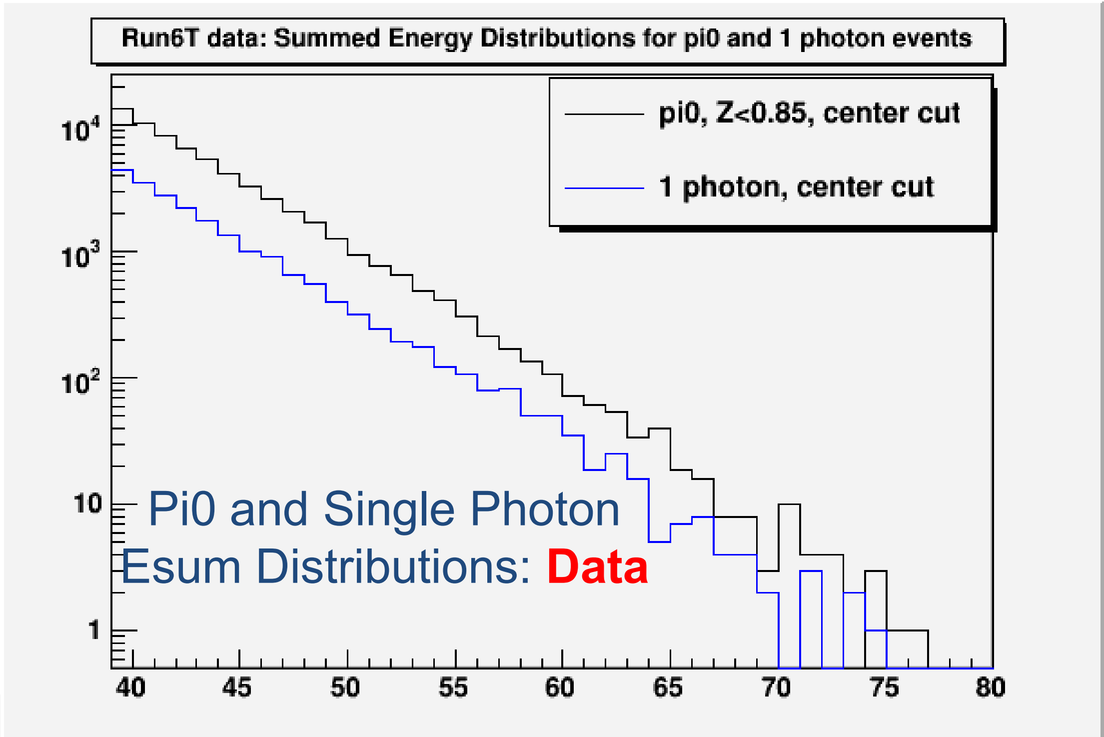
Direct Photon A_N Measurement

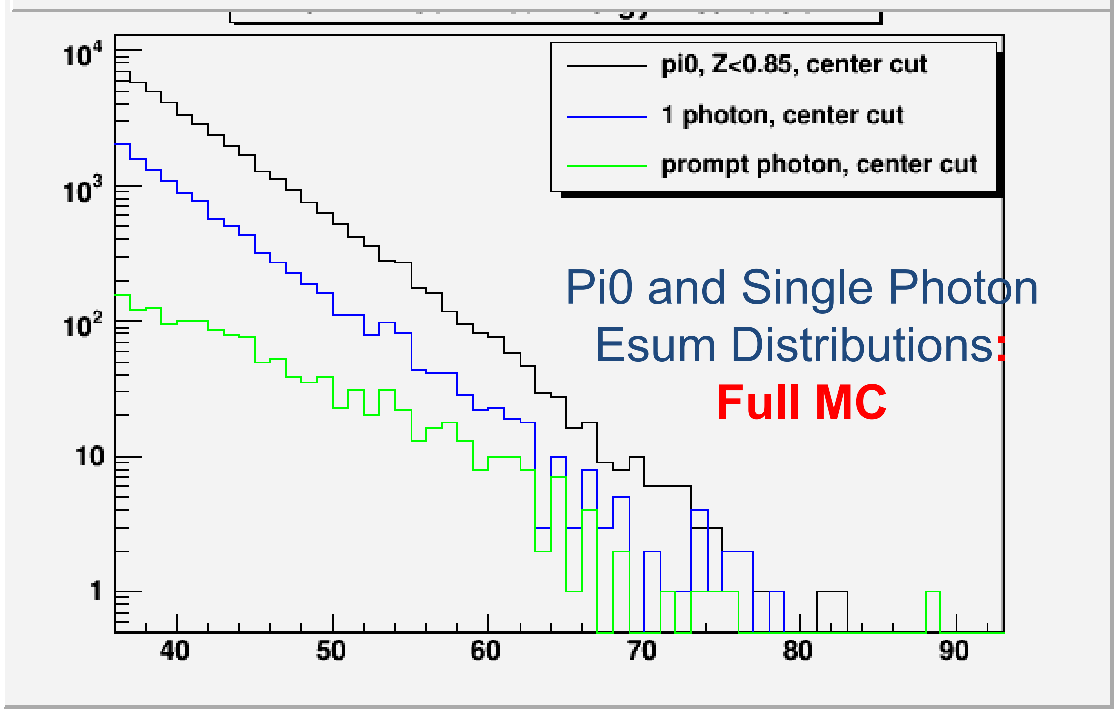


- Predicted violation of factorization
  - If Sivers is mechanism: a sign change is predicted between Direct Photon and DIS.
  - No Collins effect in Direct Photon A_N.
- **Measurement of predicted sign change vs A_N in DIS is a milestone goal from Nuclear Science Advisory Committee.**
- For X_F>.5, single photon cross section similar to π^0 cross section (see previous error estimates).
- Separation of 1 photon from 2 photon clusters based upon shower shape.
- Statistical errors similar to that for π^0.
- Full errors dominated by background subtraction. (π^0 and η).

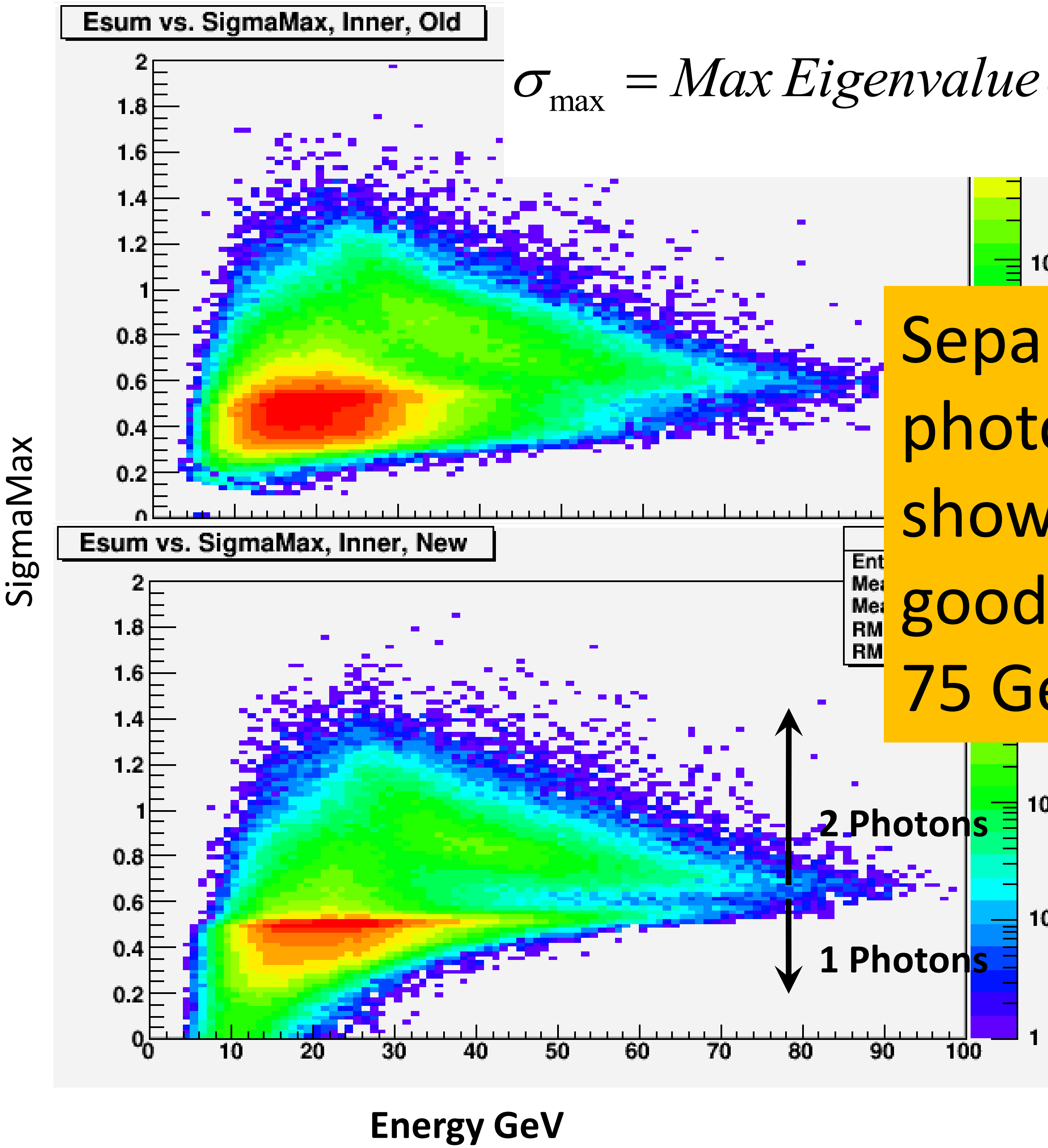
FPD Run 6 DATA and Simulations
2 Photon pi0 events
and 1 photon events
from Len Eun





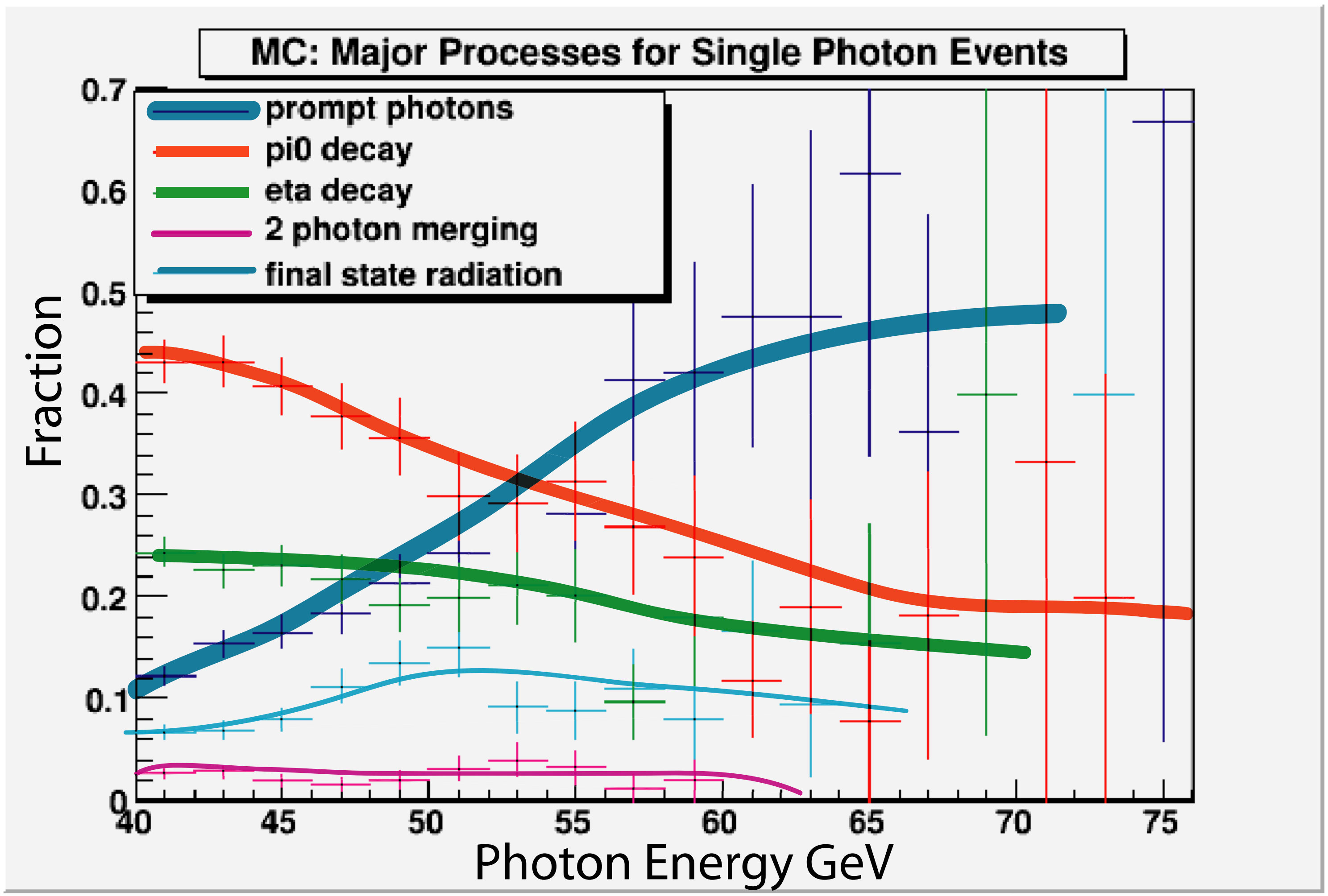


$$\sigma_{max} = Max\ Eigenvalue\ of \begin{bmatrix} \Delta\sigma_x{}^2 & \Delta\sigma_x\Delta\sigma_y \\ \Delta\sigma_y\Delta\sigma_x & \Delta\sigma_y{}^2 \end{bmatrix}$$



Separation of 1 vs 2 photons based on shower shape good to beyond 75 GeV

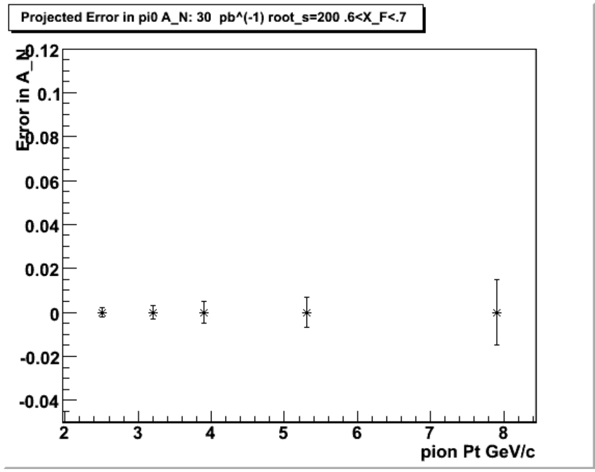
<u>Separation of single photon from two photon cluster based upon shower shape.</u>



MC: Major Processes for Single Photon Events
prompt photons
pi0 decay
eta decay
2 photon merging
final state radiation
Fraction
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
40
45
50
55
60
65
70
75
Photon Energy GeV

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.



• 30 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.

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

	$.50 < x_F < .55$	$.55 < x_F < .60$	$.60 < x_F < .70$	$.70 < x_F < .90$
$2.6 < Y < 3.0$	0.006	0.010	0.015	0.047
$3.0 < Y < 3.4$	0.003	0.004	0.007	0.021
$3.4 < Y < 3.6$	0.002	0.003	0.005	0.016
$3.6 < Y < 3.8$	0.001	0.002	0.003	0.011
$3.8 < Y < 4.1$	0.001	0.001	0.002	0.005

Table 3: **Projections for π^0 A_N: Entrys indicate the expected error in the transverse SSA (ΔA_N) for integrated luminosity of 30 pb^{-1} at $\sqrt{s} = 200GeV$. The values in table columns are for indicated vales of Feynman x_F and the rows are for indicated values of pseudorapidity.**

	$.50 < x_F < .55$	$.55 < x_F < .60$	$.60 < x_F < .70$	$.70 < x_F < .90$
$2.6 < Y < 3.0$	0.043	0.070	0.105	0.333
$3.0 < Y < 3.4$	0.019	0.031	0.047	0.149
$3.4 < Y < 3.6$	0.015	0.024	0.037	0.116
$3.6 < Y < 3.8$	0.010	0.016	0.025	0.078
$3.8 < Y < 4.1$	0.005	0.008	0.012	0.038

Table 5: Estimated error in A_N for η mesons for 200 GeV $30pb^{-1}$ Data Set

	$.2 < x_F < .22$	$.22 < x_F < .24$	$.24 < x_F < .28$	$.28 < x_F < .36$	$.36 < x_F < .4$
$2.6 < Y < 3.0$	0.004	0.006	0.009	0.030	0.188
$3.0 < Y < 3.4$	0.002	0.003	0.004	0.013	0.084
$3.4 < Y < 3.6$	0.001	0.002	0.003	0.010	0.065
$3.6 < Y < 3.8$	0.001	0.001	0.002	0.007	0.044
$3.8 < Y < 4.1$	0.0004	0.001	0.001	0.003	0.022

Table 7: Indicated the estimated error in the transverse SSA (A_N) for production of π mesons with integrated luminosity of 20 pb^{-1} at $\sqrt{s} = 500GeV$.

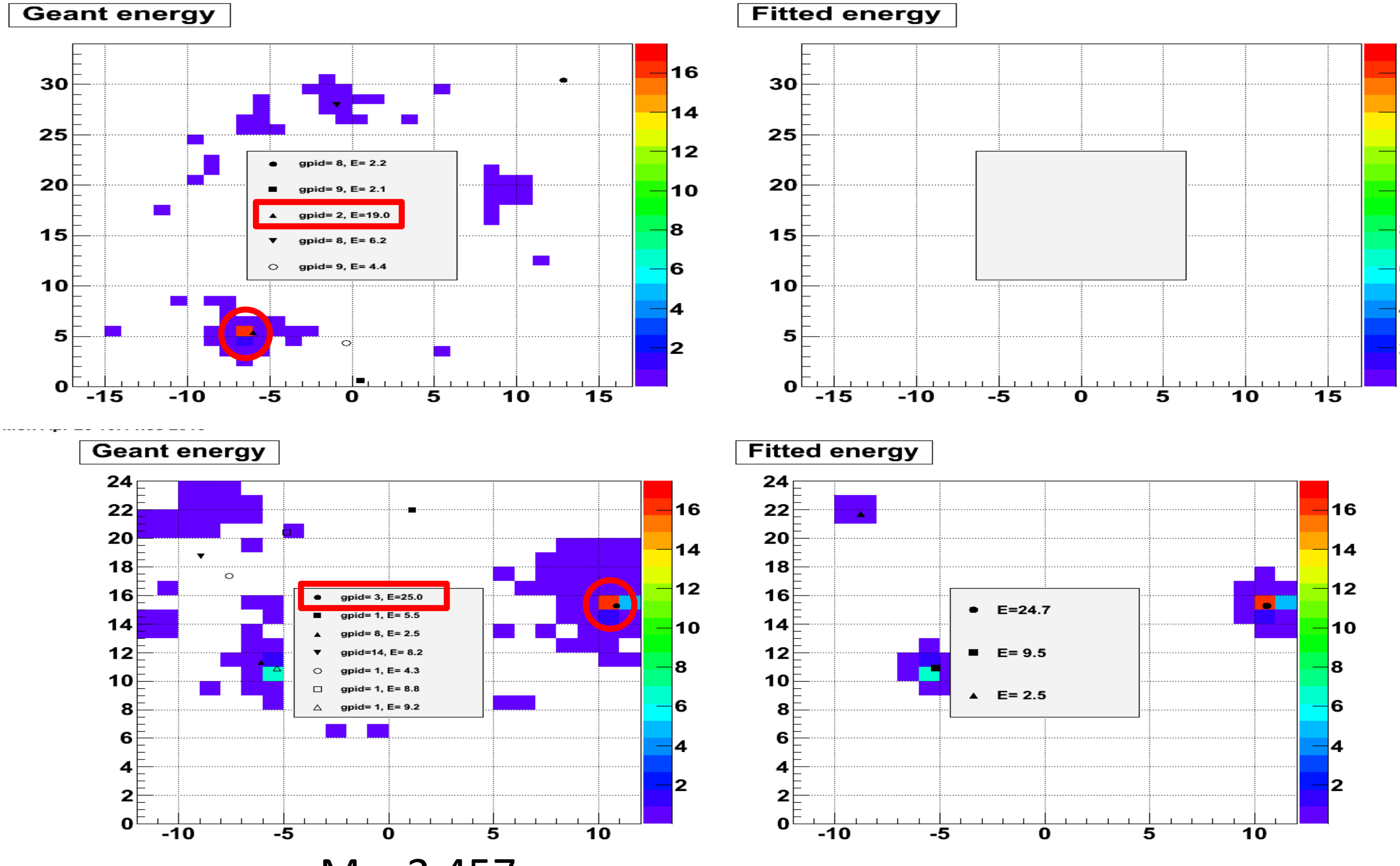
Drell Yan

Drell Yan 500 GeV

- FMS E1>20 GeV && E2>20 GeV && Mass> 4 GeV;
- 250 pb^{-1} -> 60k DY pairs -> $\Delta A_N \sim .01$ (statistical only)
- If neutral particles are rejected, the hadronic background due to hadronic energy deposited in the FMS may be comparable to the DY signal.
- Tests of backgrounds probably required!
  - Further background suppression is possible if magnetic charge sign and magnetic momentum determination is available. 30% momentum measurement on each of two tracks -> ~ 10^{-3} supression of background.
  - Further background suppression is possible if charge transition radiation detector is available. ~ 10^{-3} for two tracks.

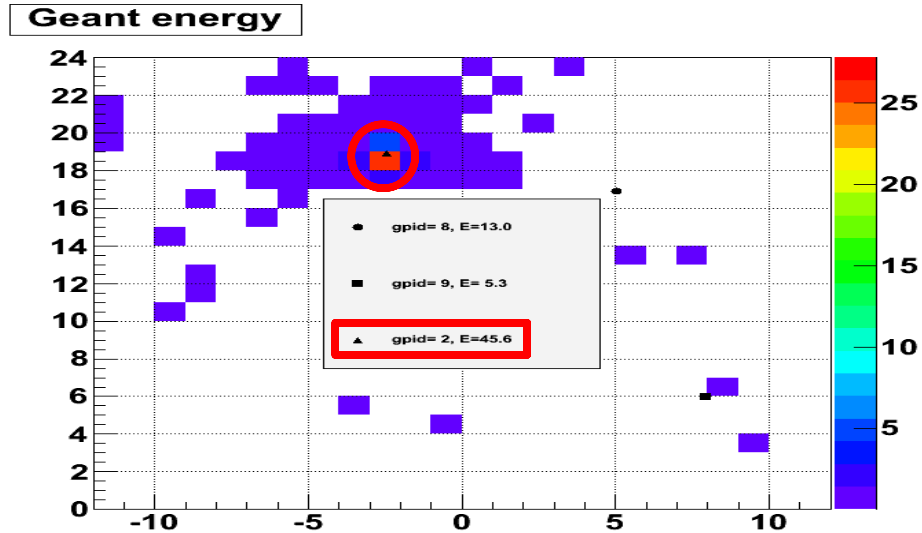
Simulated and Reconstructed Drell Yan Event

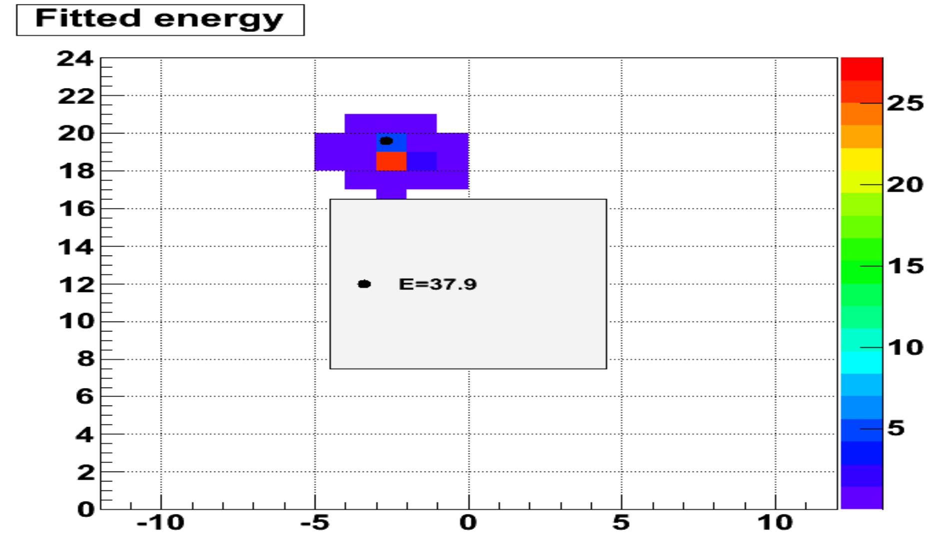
Event 1

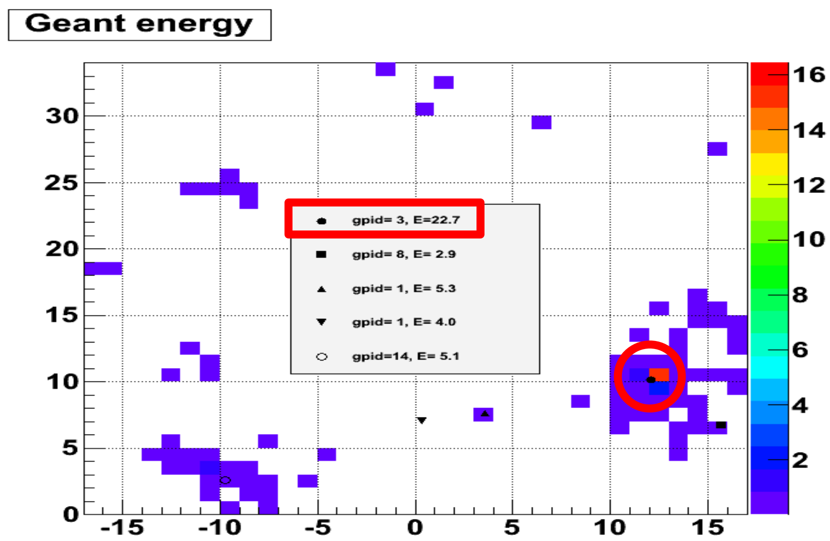


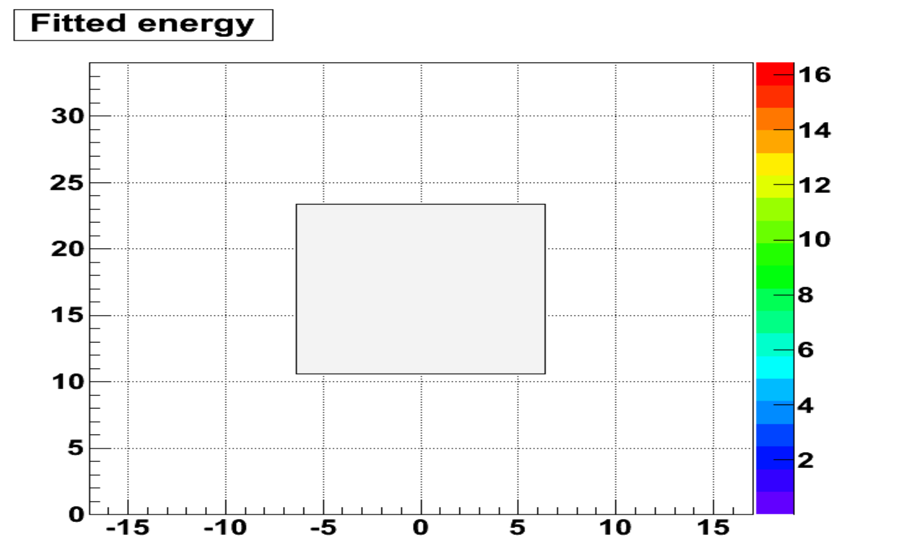
M = 3.457

Event 6

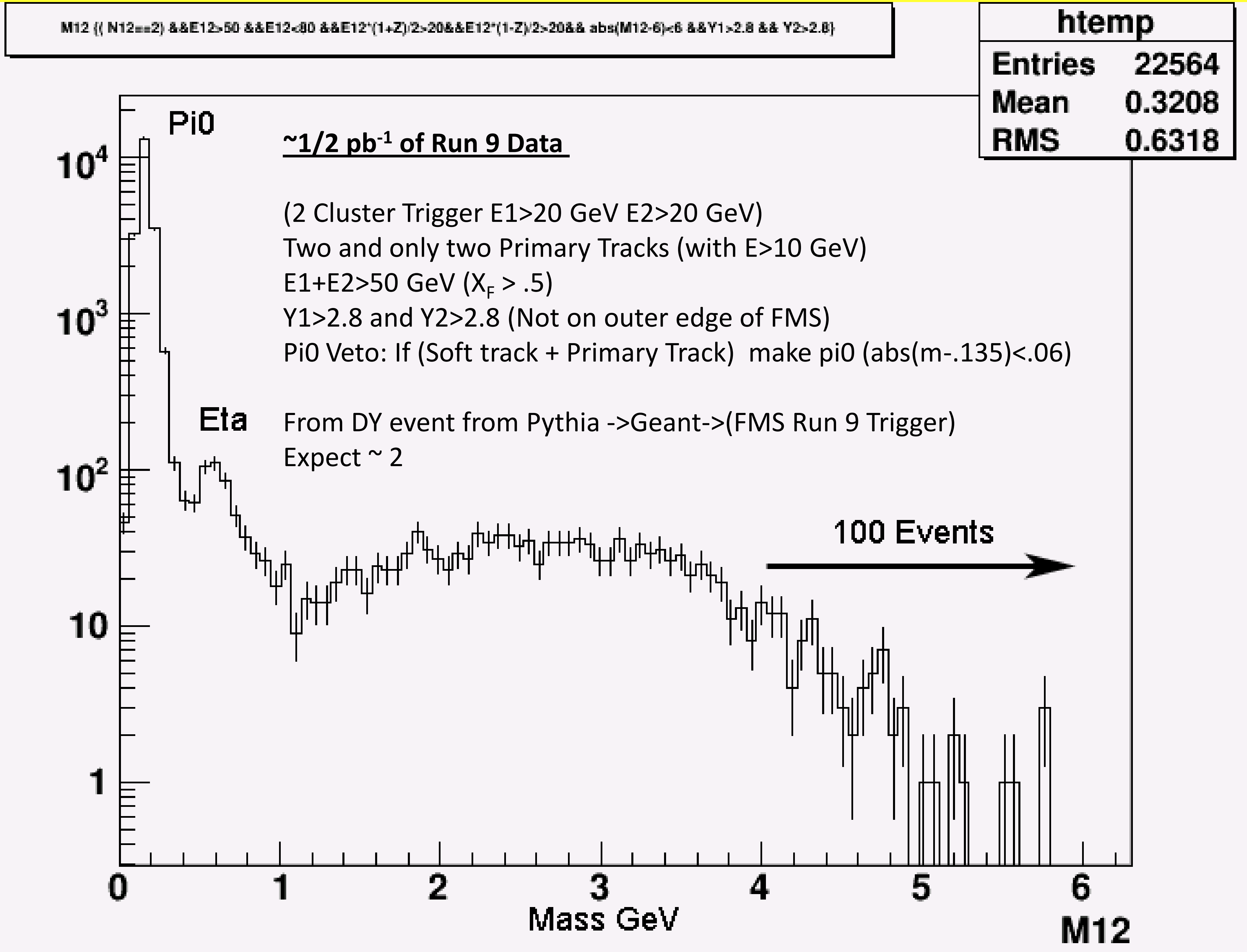






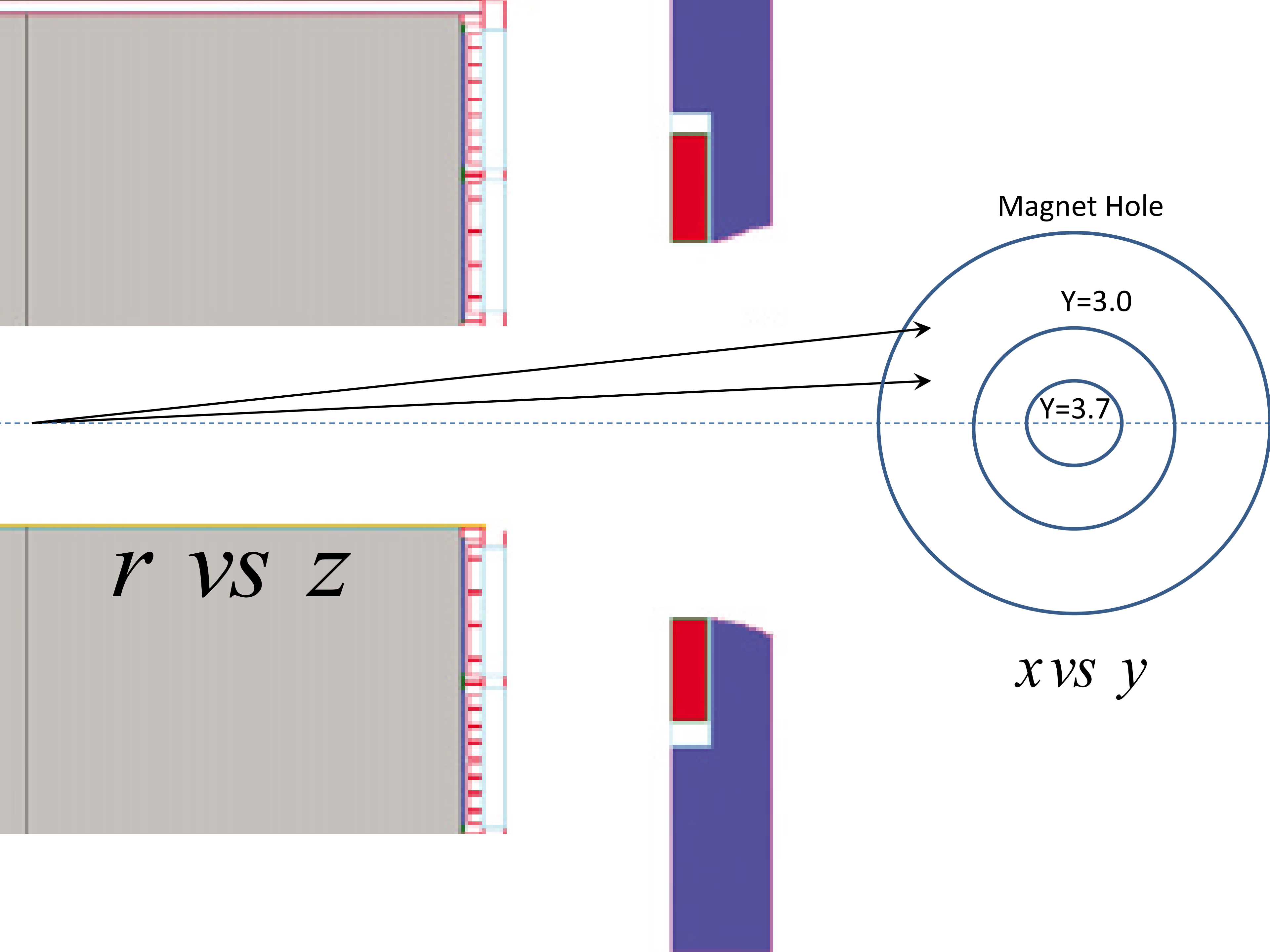


M = 4.128


M12 {(N12==2) &&E12>50 &&E12<80 &&E12*(1+Z)/2>20&&E12*(1-Z)/2>20&& abs(M12-6)<6 &&Y1>2.8 && Y2>2.8}
htemp
Entries 22564
Mean 0.3208
RMS 0.6318
Pi0
Eta
~1/2 pb-1 of Run 9 Data
(2 Cluster Trigger E1>20 GeV E2>20 GeV)
Two and only two Primary Tracks (with E>10 GeV)
E1+E2>50 GeV (XF > .5)
Y1>2.8 and Y2>2.8 (Not on outer edge of FMS)
Pi0 Veto: If (Soft track + Primary Track) make pi0 (abs(m-.135)<.06)
From DY event from Pythia ->Geant->(FMS Run 9 Trigger)
Expect ~ 2
100 Events
10^4
10^3
10^2
10
1
0
1
2
3
4
5
6
Mass GeV
M12

Additional Cuts that could help for Run 9 Data for DY Candidates

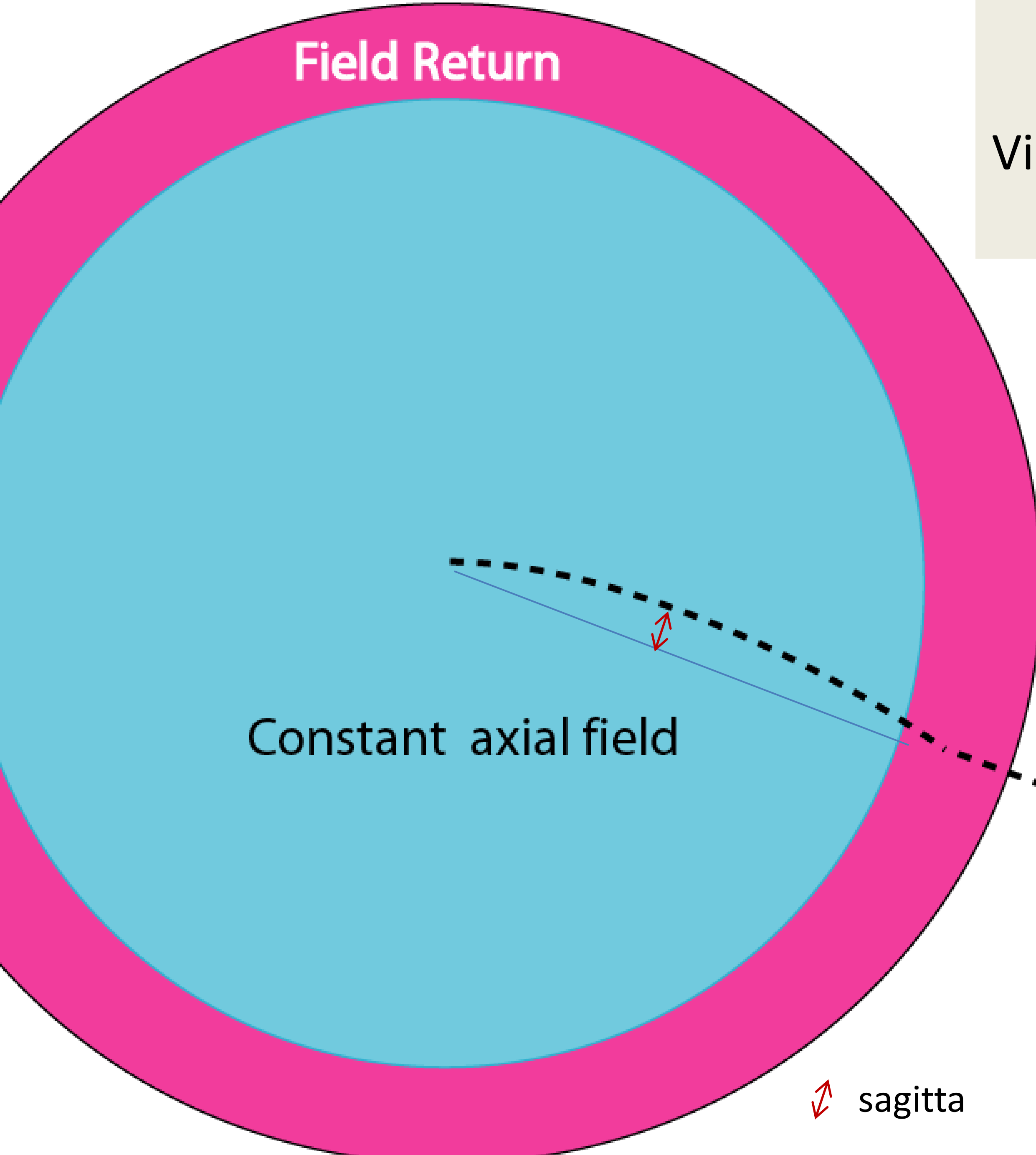
- Shower Shape to reject charged pions (0.25 * 0.25)=0.06.
- Charge tracks to veto photon contribution
- Tracking inside magnet (see below) charged track signs for e+ and e- momentum match between momentum from magnetic curvature and EM. (.1 * .1)=0.01 suppression of charged pions
- TRD electron id (.1 * .1) = 0.01 suppression of charged pions.



Magnet Hole
Y=3.0
Y=3.7
r vs z
x vs y

$r \ vs \ \phi$

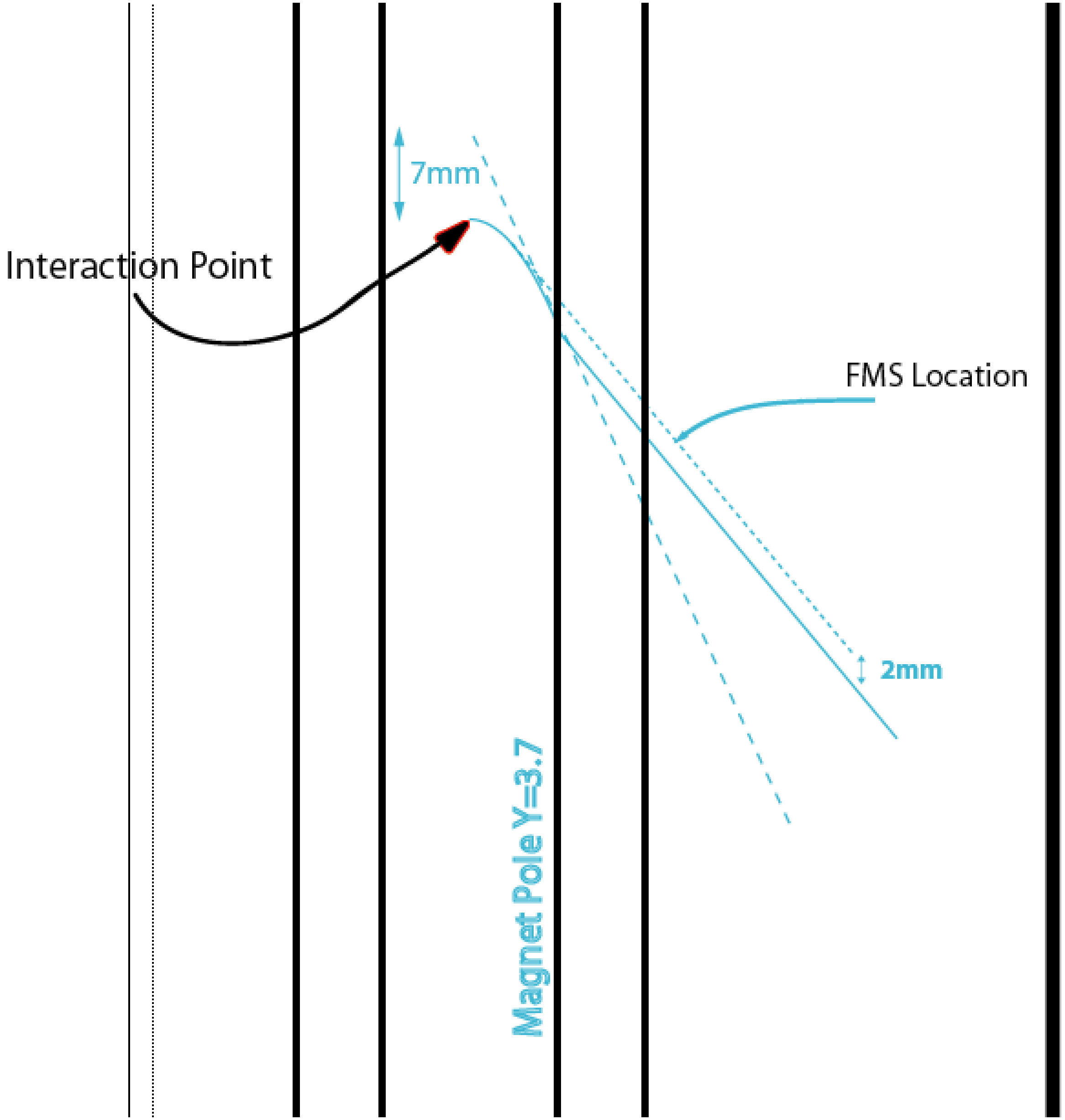
View of charged track in magnetic field



For a charged particle exiting the constant field of a solenoid magnetic field through the a hole in a flux returning cap,

about ½ of the angular bend in the constant field region is negated in the return region.

$r\phi$ vs r



For 20 GeV electron Y=3.7

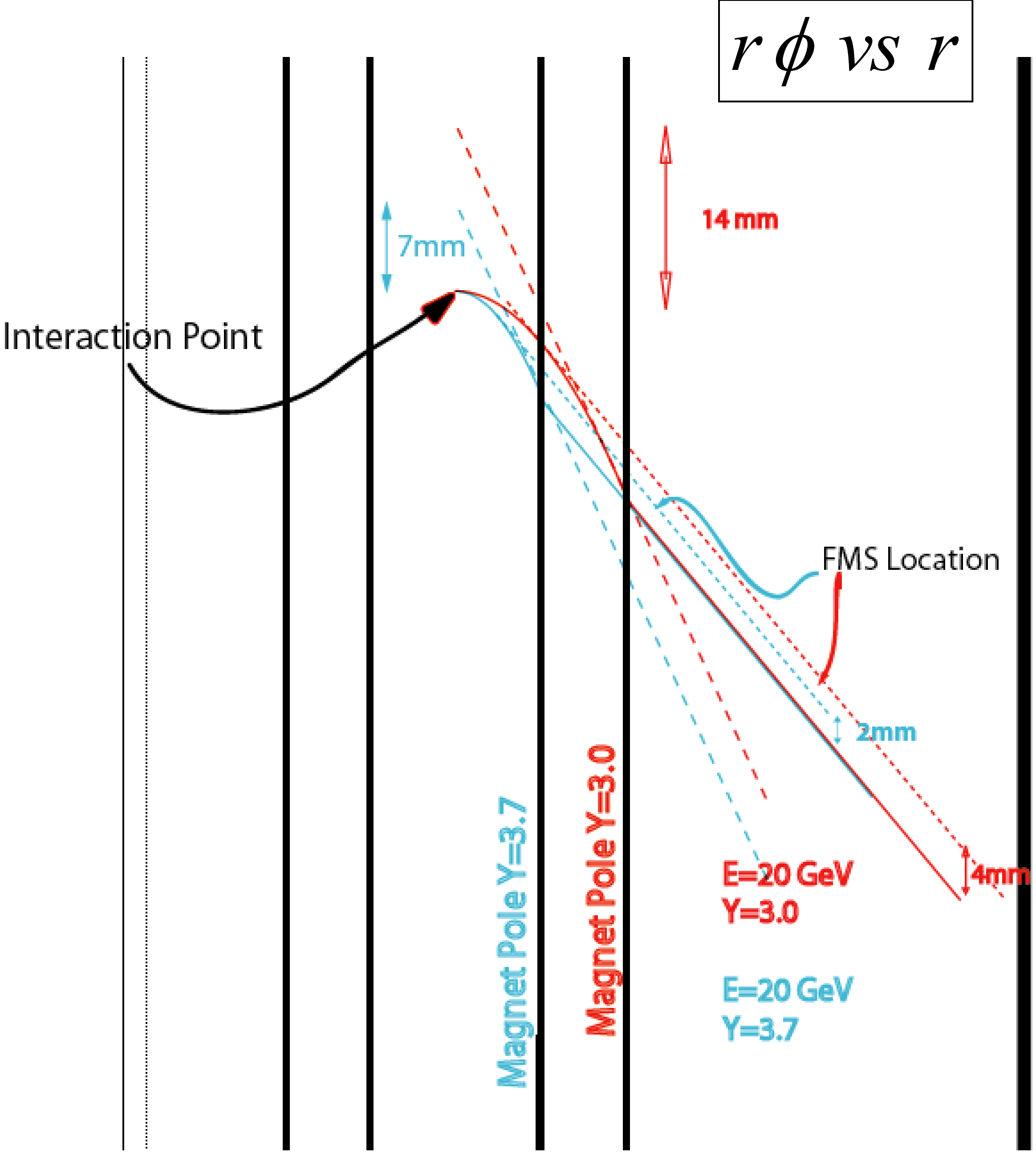
- Trajectory (r vs ϕ) measured just before exiting constant field

Projected back to vertex ….
Vertex displacement = 7 mm.

Projected forward to FMS …
FMS displacement = 7 mm.

- Trajectory measured at origin
  Projected to FMS …
  FMS displacement ~20 mm

- Trajectory measured at sagitta
  Projected to FMS …
  displacement ~ sagitta ~1.5 mm



For **20 GeV** electron **Y=3.0**

- Trajectory (r vs ϕ) measured just before exiting constant field

Projected back to vertex ….
Vertex displacement = 14 mm.

Projected forward to FMS …
FMS displacement = 14 mm.

- Trajectory measured at origin
  Projected to FMS …
  FMS displacement ~40 mm

- Trajectory measured at sagitta
  Projected to FMS …
  displacement ~ sagitta ~3 mm

Forward Magnetic Tracking Summary

A measurement of the charged track trajectory just inside the flux return (about 3 meters from the magnet center) can be projected to

- either the interaction vertex
- or to the FMS.

The displacement between the projected track and measured track will be called $D_\phi = r\Delta\phi$

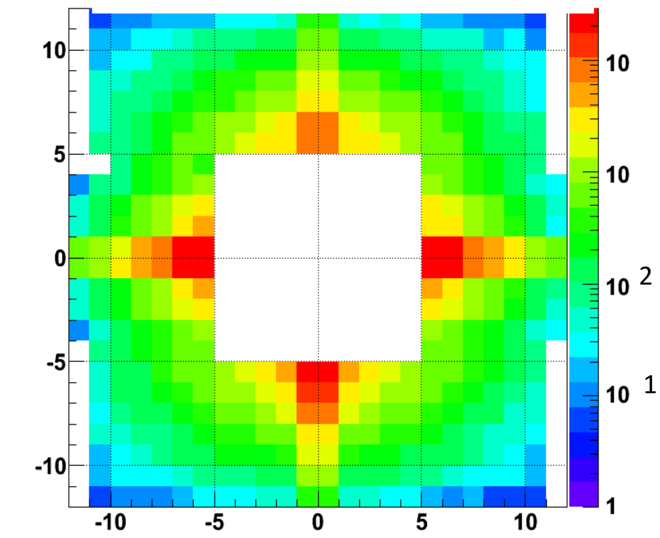
$$\frac{\Delta p_t}{p_t} = \frac{\Delta p}{p} = \frac{\Delta D_\phi}{D_\phi}$$

p_t, p	Y	For $\Delta D_\phi = 1mm$ $\frac{\Delta p}{p}$	For $\Delta D_\phi = 0.5\,mm$ $\frac{\Delta p}{p}$
1 GeV/c, 20GeV/c	3.7	15 %	8%
2 GeV/c,40GeV/c	3.7	30%	15%
2 GeV/c, 20 GeV/c	3.0	7%	4%
4 GeV/c, 40GeV/c	3.0	15%	7%

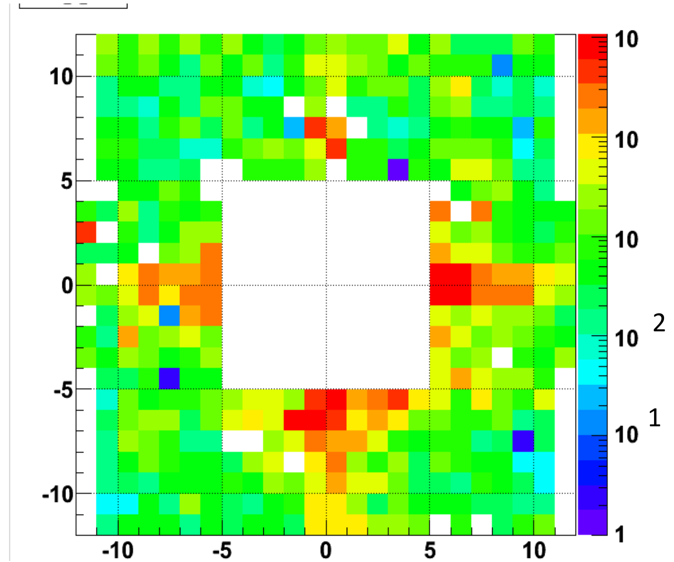
Run 9 Setup Experience

FMS Setup: Run 9 Experience (Jingguo Ma)

Simulated Trigger Rates Ideal Gains (3 Triggers)

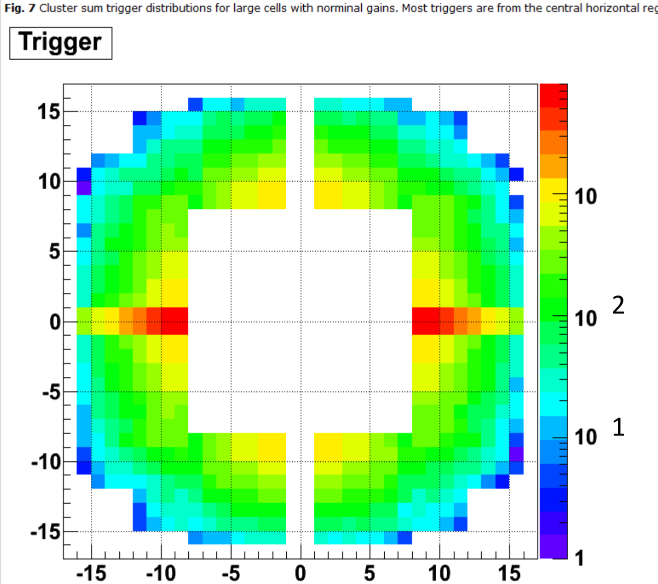


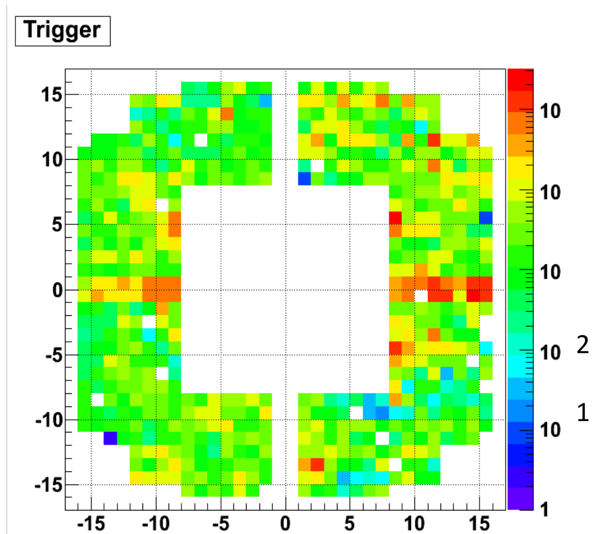
Run 9 Trigger Rates (analysis of Run 9 data) Ideal Gains (3 Triggers)



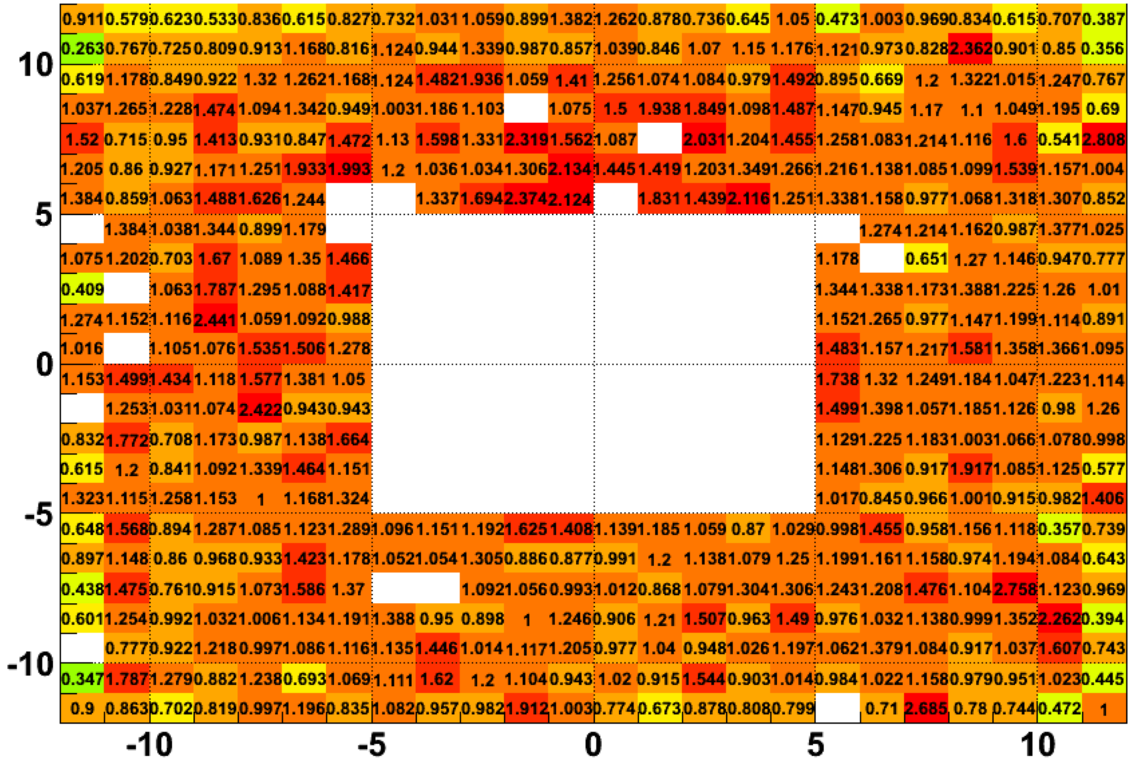
Small Cells

Fig. 7 Cluster sum trigger distributions for large cells with norminal gains. Most triggers are from the central horizontal region.

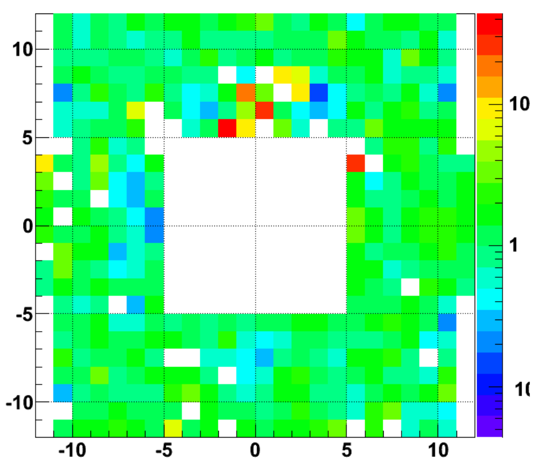




Large Cells



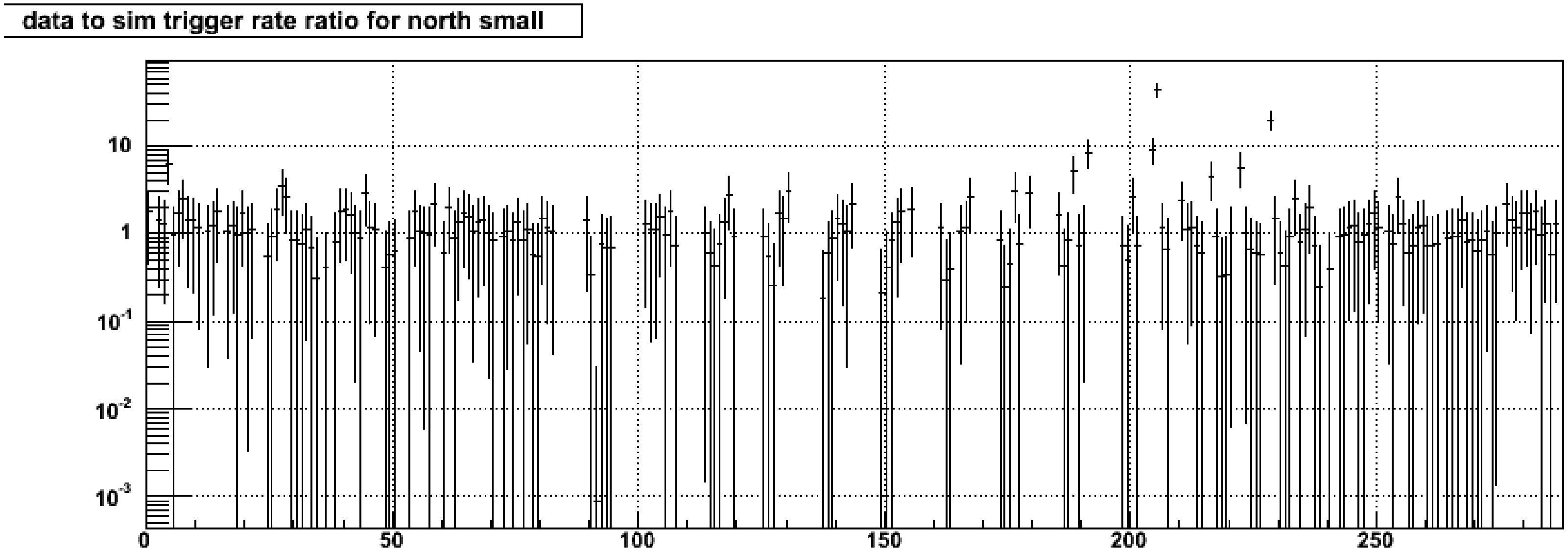
Current Best FMS
Gain Correction

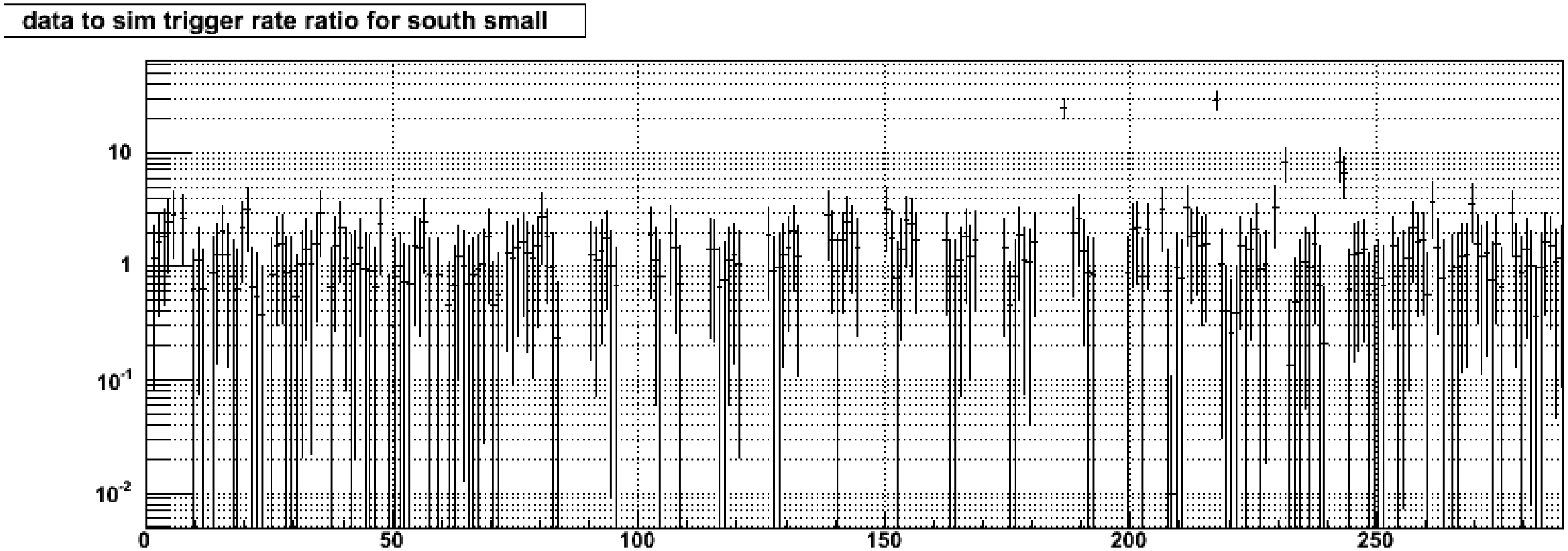


Ratio
Run 9 Trigger Rate to Simulated Rate

Ratio of Simulated Trigger Rates to Actual Rates

Sever Test of Calibration!





Goals:

* well matched gains
* FMS Gain Setup Without Pi0 Reconstruction Iteration?

Consequence: Real Time HV adjustment:

Fast: FMS Turn ON.