Toward A Direct Photon A_N Measurement

20 pb⁻¹ 200 GeV separation of 3 contributions @ E>65 GeV

- Direct Photon A_N
- PiO A_N
- Eta A_N

Compilation of PiO 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 PiO 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

$$L = 30 \frac{\mu b^{-1}}{\text{sec}}$$
$$\int L = 30 \times 2 \times 10^4 \,\mu b^{-1} = .6 \,p b^{-1} = 600 \,n b^{-1}$$

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



Expected Event Rate for 1 Cell

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

$$E\frac{d\sigma}{d^{3}\vec{p}} = 2\frac{nb}{GeV^{2}} \sim \frac{2d\sigma}{d\phi dp_{z} p_{T} d\theta} \sim \frac{2}{p_{T}} \frac{d\sigma}{[d\phi d\theta] dp_{z}}$$
$$\frac{d\sigma}{dY d(p_{T}^{2})} = 2\pi \frac{nb}{GeV^{2}}$$
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

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





Evolving FMS Gain Correction Factors for Late Run 9 Data

24	<u>0 3</u> 98633	0.580423	0.630857	0.538408	0.717426	0.546113	0.757715	0.62865	1.11786	1.03475	0.909527	0.735054	1.16987	0.850336	0.800626	0.56485	1.18548	0.52733	1.12923	0.916325	0.804429	0.574881	0.618283	0.521077
<u></u>	0 231161	0.933548	0.972913	0.836794	1.04258	1.20421	0.835507	1.17514	1.01494	1.41998	0.540281	0.437576	0.910893	0.798945	1.17673	1.15735	1.11022	1.31091	1.0383	1.02334	2.03716	0.929708	0.958071	0.502553
22	0.286509	1.32431	0.844147	1.01661	1.07277	1.1857	1.27696	1.31152	1.28138	1.16628	1.13485	1.36298	0.98767	0.882573	1.02735	0.945291	1.36082	0.958151	0.646908	1.18182	1.20369	1.04753	1.60167	0.636732
20	9.057636	1.32058	0.912399	1.18307	0.925302	1.24484	0.823698	0.832433	0.658205	0.806757		0.892263	1.5	1.35838	1.50823	0.954838	1.3195	1.25903	0.785248	1.32712	1.1691	1.07238	1.16038	0.655128
20	0.435237	1.16127	1.07238	1.25072	1.06246	1.0642	1.1658	1.14178	1.19933	0.982744	2.62879	2.32628	0.8		0.580262	0.599391	1.33128	1.18567	1.33834	1.30772	0.949201	1.20673	1.34135	0.495696
18	0.705843	1.00312	0.96168	1.14823	1.15323	1.49947	1.6601	0.972433	1	1.05545	1.36271	0.486608	0.403344	1.48211	0.916394	1.43029	1.3	1.41898	0.828177	1.12705	1.15329	1.6398	1.05782	0.772159
	0.6 1017	1.10768	1.12038	1.37707	1.71262	1.03461			0.867942	0.891973	0.893459	1.20677		1.26353	0.946348	1	0.99481	0.941069	1.28435	1.24858	0.922859	1.54546	1.5068	0.430614
16	0.700040	0.712358	1.06357	1.12738	0.959519	1.1064	0.068											1	1.52759	1.17832	1.30899	1.2667	1.48877	0.52628
		1.49935	0.828372	1.23845	1.0039	1.36677	0.875016											0.465833		0.537332	1.29397	1.34931	0.883771	0.80668
14	4.49229	1 62902	1.1215	1.48605	1.24967	1.43488	1.12311											1 28428	1.36195	1.35711	1.71094	1.30125	1.26213	0.904479
	0.763914	1.03003	1.05336	0.979707	1.81372	1,49995	0.851574											1.08419	1.14669	1,42481	1.65363	1.22556	1,40055	1.06811
12	0.945158	1.75711	1.62066	0.897713	1.71483	1.53485	0.292331											1.69919	1.38245	1.70503	1.15095	0.990832	1.32996	1.18217
	=	1.19791	0.988552	0.856133	2.7	1.22704	0.747594											1.54556	1.71197	1.22601	1.30939	1.15543	1.13429	1.11766
0	0.809764	2.01554	0.70741	1.31504	0.946066	1.37332	1.5465											1.03862	1.21111	1.1184	0.983938	1.1416	1.20514	1.04949
_	0.60215	1.23445	0.903337	1.13297	1.09763	1.41075	1.02809											1.16311	1.28253	0.981481	1	0.958019	1.15848	0.593872
8	0.578442	1.56012	1.24792	1.06447	1.06316	1.24791	1.05075											0.952521	0.956545	0.960337	0.897049	0.942674	1.27414	0.578618
~	0. <u>4</u> 56722	1.78056	0.830701	1.28895	1.15637	1.36958	1.37083	1.13227	1.21903	1.55386	1.32497	1.26169	0.752862	1.16617	1.08336	0.787469	1.14472	1.08123	1.78496	1.31954	1.35905	1.54591	0.652667	0.465817
6	9 497689	1.34888	0.850621	0.922034	0.930435	1.3334	1.23451	0.979294	1.0161	1.77897	0.697472	0.661884	1.07592	1.47051	1.27524	1.11615	1.9484	1.12315	1.16524	0.922211	0.861994	1.13599	1.53633	0.411936
A	0.474024	1.71725	0.8603	0.939103	1.24335	1.50618	1.34971			1.9581	1.60503	1.4882	1.16052	1.00393	1.11487	1.34034	1.12095	1.27181	1.13662	1.58221	1.11715	1.6616	0.965685	0.8
4	0.296837	1.41327	0.96556	0.99848	1.03378	0.977222	1.17209	1.26436	0.652372	0.730044	9	1.31497	0.751429	1.24504	1.49042	0.911901	1.59763	1.02318	0.951863	1.1646	1.12278	1.37714	0.53101	0.8
2	E	1.0275	0.978919	1.18599	1.04523	1.13998	1.24321	1.14011	1.19777	0.995635	1.16081	0.958079	0.930703	1.04451	0.952648	1.04103	1.09063	0.83869	1.2864	1.09787	0.971504	1.02497	0.9	0.8
2	<u>0 3</u> 20651	1.42232	1.30103	0.927047	1.30829	0.790764	1.2078	1.17303	2.78115	1.29265	1.2134	0.712484	1.1678	1.08132	1.75199	0.923272	1.20817	1.14739	0.945858	1.27279	1.23074	1.05044	1.35485	0.8
0	0.5	1.13738	0.767399	0.819048	0.873064	0.967013	0.840523	0.90071	1.10402	0.969243	1.57005	0.773325	0.641479	0.641591	0.947642	0.696993	0.713984		0.63144	1.44157	0.786959	0.636853	0.640523	0.8
U		-1	0				-	5				()					5				1	0	

Run 9 Dead and Wounded FMS Cells

Nominal Cell Position 3.6<Y<3.7



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				Sivers:		Detectors
\sqrt{s}	Transverse pp	Collins	Sivers	SIDIS	Luminosity	
	Measurement			sign		
				change		
	$p^{\uparrow} + p \to \pi^0 + X$	✓				FMS
	$p^{\uparrow} + p \to \eta + X$	~	~			FMS
	$p^{\uparrow} + p \rightarrow jet + X$	~	~			FMS+EMC +(HCAL?)
200	$p^{\uparrow} + p \to \pi^0 + \pi^0 + X$	~	~		20 - 1-1	FMS+EMC
Gev	$p^{\uparrow} + p \rightarrow jet + jet + X$	~	~		30 pb -	FMS+EMC +(HCAL?)
	$p^{\uparrow} + p \to \gamma + X$		~	~		FMS
	$p^{\uparrow} + p \to \Lambda + X$	~	~			FMS+HCAL
	$p^{\uparrow} + p \to \gamma + X$		~	~		East FPD
500	($p^{\uparrow} + p \rightarrow \pi^0 + X$)				20 nh ⁻¹	+Shower Max
GeV	$p^{\uparrow} + p \to \Lambda + X$	~	~			FMS+HCAL
	$p^{\uparrow} + p \to \eta + X$	\checkmark	~			FMS
	$p^{\uparrow} + p \rightarrow e^+ + e^- + X$		~	\checkmark	25 0 L ⁻¹	STAR with FMS
	$p^{\uparrow} + p \to W + X$		~	~	250 pb ⁻	STAR with FMS



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Straw Man Form for PiO 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:

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

for large
$$|Y|$$
: $G(Y) \propto e^{(m-2)Y}$
near $E = \frac{E_{\max}}{2}$: $F(E) \propto e^{-kE}$

$$\frac{dN}{dE \ dY} \propto e^{4Y} e^{-0.2E} \quad E \text{ in } GeV$$

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

$$\frac{dN}{dE \ d\theta} \propto \frac{dN}{dE \ d\theta}$$

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

so for m=6, n=5 and $E_{\rm Max} = 100 GeV$ $k \sim 0.2 GeV^{-1}$



FPD Run 6 DATA and Simulations2 Photon pi0 eventsand 1 photon eventsfrom 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 gammapi0 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 PiO asymmetries** at high energy.

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

• 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







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.