A Comparison of the Perugia6 and TuneA Pythia Tunes for FOCAL Simulations

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Introduction

As part of the preparation for full simulations of the FOCAL detector design the FOCAL group a study was undertaken to determine the appropriate pythia settings for such simulations. The discussion quickly settled on two contenders – the venerable "TuneA" and a recent revision called the "Perugia" tunes[i]. We focus on one specific Perugia tune, called Perugia6, which is the Perugia tune combined with the CTEQ6 structure functions.

There are two primary concerns in these simulations, associated with the detection of direct photons in the FOCAL detector:

- How well does the simulation reproduce the sources of background associated with the detection of direct photons, primarily (but not limited to) neutral pions?
- How well does the simulation agree with NLO predictions for the direct photon cross section from W. Vogelsang (see Appendix A)?

To address these questions a set of simulations were run using a standard set of physics processes and two different pythia tunes, selected using the "pytune" mechanism. The latest version of Pythia6 (version 6.4.21, available online[ii]) was used for these simulations.

This study is by no means intended to be an exhaustive tuning of pythia to RHIC data. Instead, it is intended to set a reasonable and conservative baseline for FOCAL simulations and studies.

Simulations

To set a baseline, a reasonable set of "minimum bias" processes must be defined. We chose a minimum bias set of processes that are intended to represent a very wide selection of high cross section processes at RHIC, with one set of exceptions. The direct photon processes 14,18,29,114,115 were also enabled, allowing a small sample of direct photons to also be generated along with the minimum bias events. This allowed for quick checks of signal/background for the direct photon within the same sample of events. (These studies are not the subject of this analysis note.) Because we are looking forward of midrapidity we chose to include diffractive and elastic processes as well, but these events were found to have a negligible contribution within the FOCAL acceptance (1<y<3).

The processes chosen for these studies are listed below, more information can be found in the pythia manual[iii].

FOCAL Minimum Bias Process Selection:

```
msel    0       // turn on all prod. mechanisms manually
msub    10 1
msub    11 1    // QCD jets
msub    12 1
msub    13 1
msub    28 1
msub    53 1
msub    68 1
msub    83 1
msub    91 1    // elastic, diffractive and low-pT
msub    92 1
msub    93 1
msub    94 1
msub    95 1
msub    96 1
msub    14 1    // photon+jet
msub    29 1
msub    18 1
msub    114 1
msub    115 1
```

The same process configuration minus the direct photon processes can be obtained by simply setting msel=2.

<u>Additional Pythia Configuration</u>

The appropriate tunes were chosen using the “pytune” mechanism in pythia, which allows automatic selection of a set of tunes. The tune selection details are listed below. Perugia6 was chosen with “pytune 326” in the phpythia config file, while TuneA was chosen with the selection “pytune 100”.

For the 500GeV comparisons, a total of 200M events were run with Perugia6 and 80M events were run with TuneA. Results were aggregated from smaller runs of 10k events. The CKIN(3) parameter (the minimum p_T in the hard scattering) was set to 2.0 GeV for both tunes.

For the 200GeV comparisons the CKIN(3) variable was set to 1.8 GeV for both tunes and 80M events were run for both Perugia6 and TuneA. Results were aggregated from smaller runs of 10k events.

For the 500GeV comparisons a additional sample of data was run with the CKIN(3) parameter set to 4.5 GeV. This sample of events was originally intended to serve as an analysis sample for the FOCAL photon+jet studies, and the low-p_T cut is matched to the lowest photon p_T threshold we think we can reasonably trigger at. Instead, this sample has served as an excellent demonstration (and warning!) of what happens to relative cross sections in pythia when you play with the CKIN(3) parameter. This will be discussed at the end of this analysis note.

<u>“Perugia6” Pythia Tune</u>

The following pythia tuning was selected with the “pytune 326” selection:

```
******************************************************************************
*                                                                            *
*   PYTUNE v1.015  : Presets for underlying-event (and min-bias)             *
*                    Last Change : Jan 2009 - P. Skands                      *
*                                                                            *
*    326 Perugia 6                                                           *
*             P. Skands, Perugia MPI workshop October 2008                   *
*             and T. Sjostrand & P. Skands, hep-ph/0408302                   *
*             CR by M. Sandhoff & P. Skands, in hep-ph/0604120               *
*             LEP parameters tuned by Professor                              *
*   NB! This tune requires CTEQ6L1 pdfs to be externally linked              *
*                                                                            *
*     MSTP(51) =        10042   PDF set                                      *
*     MSTP(52) =            2   PDF set internal (=1) or pdflib (=2)         *
*     MSTP(64) =            3   ISR alphaS type                              *
*     PARP(64) =       1.0000   ISR renormalization scale prefactor          *
*     MSTP(67) =            2   ISR coherence option for 1st emission        *
*     PARP(67) =       1.0000   ISR Q2max factor                             *
*     MSTP(68) =            3   ISR phase space choice & ME corrections      *
*             (Note: MSTP(68) is not explicitly (re-)set by PYTUNE)          *
*     MSTP(70) =            2   ISR IR regularization scheme                 *
*     MSTP(72) =            1   ISR scheme for FSR off ISR                   *
*     PARP(71) =       2.0000   FSR Q2max factor for non-s-channel procs     *
*     PARJ(81) =       0.2570   FSR Lambda_QCD scale                         *
*     PARJ(82) =       0.8000   FSR IR cutoff                                *
*     MSTP(81) =           21   UE model                                     *
*     PARP(82) =       1.9500   UE IR cutoff at reference ecm                *
*             (Note: PARP(82) replaces PARP(62).)                            *
*     PARP(89) =    1800.0000   UE IR cutoff reference ecm                   *
*     PARP(90) =       0.2200   UE IR cutoff ecm scaling power               *
*     MSTP(82) =            5   UE hadron transverse mass distribution       *
*     PARP(83) =       1.7000   UE mass distribution parameter               *
*     MSTP(88) =            0   BR composite scheme                          *
*     MSTP(89) =            1   BR colour scheme                             *
*     PARP(79) =       2.0000   BR composite x enhancement                   *
```

```
 *     PARP(80) =       0.0500   BR breakup suppression                      *
 *     MSTP(91) =            1   BR primordial kT distribution               *
 *     PARP(91) =       2.0000   BR primordial kT width <|kT|>               *
 *     PARP(93) =      10.0000   BR primordial kT UV cutoff                  *
 *     MSTP(95) =            6   FSI colour (re-)connection model            *
 *     PARP(78) =       0.3300   FSI colour reconnection strength            *
 *     PARP(77) =       0.9000   FSI colour reco high-pT dampening streng    *
 *     MSTJ(11) =            5   HAD choice of fragmentation function(s)     *
 *     PARJ(21) =       0.3130   HAD fragmentation pT                        *
 *     PARJ(41) =       0.4900   HAD string parameter a                      *
 *     PARJ(42) =       1.2000   HAD string parameter b                      *
 *     PARJ(46) =       1.0000   HAD Lund(=0)-Bowler(=1) rQ (rc)             *
 *     PARJ(47) =       1.0000   HAD Lund(=0)-Bowler(=1) rb                  *
 *                                                                           *
 ******************************* END OF PYTUNE ******************************
```

“TuneA” Pythia Tune

The following pythia tuning was selected with the “pytune 100” selection:

```
 ****************************************************************************
 *                                                                          *
 *   PYTUNE v1.015  : Presets for underlying-event (and min-bias)           *
 *                    Last Change : Jan 2009 - P. Skands                    *
 *                                                                          *
 *    100 Tune A                                                            *
 *             see R.D. Field, in hep-ph/0610012                            *
 *             and T. Sjostrand & M. v. Zijl, PRD36(1987)2019               *
 *                                                                          *
 *     MSTP(51) =            7   PDF set                                    *
 *     MSTP(52) =            1   PDF set internal (=1) or pdflib (=2)       *
 *     PARP(62) =       1.0000   ISR IR cutoff                              *
 *     PARP(64) =       1.0000   ISR renormalization scale prefactor        *
 *     PARP(67) =       4.0000   ISR Q2max factor                           *
 *     MSTP(68) =            3   ISR phase space choice & ME corrections    *
 *             (Note: MSTP(68) is not explicitly (re-)set by PYTUNE)        *
 *     PARP(71) =       4.0000   FSR Q2max factor for non-s-channel procs   *
 *     PARJ(81) =       0.2900   FSR Lambda_QCD scale                       *
 *     PARJ(82) =       1.0000   FSR IR cutoff                              *
 *     MSTP(81) =            1   UE model                                   *
 *     PARP(82) =       2.0000   UE IR cutoff at reference ecm              *
 *     PARP(89) =    1800.0000   UE IR cutoff reference ecm                 *
 *     PARP(90) =       0.2500   UE IR cutoff ecm scaling power             *
 *     MSTP(82) =            4   UE hadron transverse mass distribution     *
 *     PARP(83) =       0.5000   UE mass distribution parameter             *
 *     PARP(84) =       0.4000   UE mass distribution parameter             *
 *     PARP(85) =       0.9000   UE gg colour correlated fraction           *
 *     PARP(86) =       0.9500   UE total gg fraction                       *
 *     MSTP(91) =            1   BR primordial kT distribution              *
 *     PARP(91) =       1.0000   BR primordial kT width <|kT|>              *
 *     PARP(93) =       5.0000   BR primordial kT UV cutoff                 *
 *     MSTJ(11) =            4   HAD choice of fragmentation function(s)    *
 *     PARJ(21) =       0.3600   HAD fragmentation pT                       *
 *     PARJ(41) =       0.3000   HAD string parameter a                     *
 *     PARJ(42) =       0.5800   HAD string parameter b                     *
 *     PARJ(46) =       1.0000   HAD Lund(=0)-Bowler(=1) rQ (rc)            *
 *                                                                          *
 ******************************* END OF PYTUNE ******************************
```

Highlights of the Differences Between Perugia6 and TuneA

The main difference between the Perugia6 and TuneA tunes is in the treatment of the “underlying event”, or the underlying soft particle production in p+p events. Both tunes use very different models to describe this physics. In addition, the Perugia6 tune makes some modifications to the fragmentation parameters in Jetset. The Fragmentation parameters in TuneA are tuned to the data from LEP.

External PDF Libraries

In order to make additional PDF sets available to pythia (most notably CTEQ6L for use with Perugia6, TuneA uses the old CTEQ5L), pythia was linked with the LHAPDF libraries version 5.7.1. More information on the LHAPDF library can be found online at:

http://projects.hepforge.org/lhapdf/

Pythia Summary Output

For reference, the pythia summary output is listed below for both Perugia and TuneA, at 200 and 500GeV.

Perugia 200GeV Summary Output:

```
==============================================================================
 I                                  I                            I            I
 I            Subprocess            I      Number of points      I    Sigma   I
 I                                  I                            I            I
 I----------------------------------I----------------------------I    (mb)    I
 I                                  I                            I            I
 I N:o Type                         I    Generated         Tried I            I
 I                                  I                            I            I
 ==============================================================================
 I                                  I                            I            I
 I   0 All included subprocesses    I        50000       1593323 I  5.154E+01 I
 I  11 f + f' -> f + f' (QCD)       I         6939             0 I  7.114E+00 I
 I  12 f + fbar -> f' + fbar'       I           16             0 I  1.640E-02 I
 I  13 f + fbar -> g + g            I           15             0 I  1.538E-02 I
 I  14 f + fbar -> g + gamma        I            1             1 I  4.336E-04 I
 I  18 f + fbar -> gamma + gamma    I            0             0 I  0.000E+00 I
 I  28 f + g -> f + g               I         8215             0 I  8.422E+00 I
 I  29 f + g -> f + gamma           I            1             4 I  1.891E-03 I
 I  53 g + g -> f + fbar            I          254             0 I  2.604E-01 I
 I  68 g + g -> g + g               I        11520             0 I  1.181E+01 I
 I  91 Elastic scattering           I         9121          9121 I  9.419E+00 I
 I  92 Single diffractive (XB)      I         4774          4774 I  5.001E+00 I
 I  93 Single diffractive (AX)      I         4826          4826 I  5.001E+00 I
 I  94 Double  diffractive          I         4318          4330 I  4.479E+00 I
 I  95 Low-pT scattering            I            0         26970 I  0.000E+00 I
 I 114 g + g -> gamma + gamma       I            0             0 I  0.000E+00 I
 I 115 g + g -> g + gamma           I            0             0 I  0.000E+00 I
```

```
 I                                  I                            I            I
 ==============================================================================
```

Perugia 500GeV Summary Output:

```
==============================================================================
 I                                  I                            I            I
 I            Subprocess            I      Number of points      I    Sigma   I
 I                                  I                            I            I
 I----------------------------------I----------------------------I    (mb)    I
 I                                  I                            I            I
 I N:o Type                         I    Generated         Tried I            I
 I                                  I                            I            I
 ==============================================================================
 I                                  I                            I            I
 I   0 All included subprocesses    I        50000       1286825 I  5.943E+01 I
 I  10 f + f' -> f + f' (QFD)       I            0             0 I  0.000E+00 I
 I  11 f + f' -> f + f' (QCD)       I         5713             0 I  6.803E+00 I
 I  12 f + fbar -> f' + fbar'       I           10             0 I  1.191E-02 I
 I  13 f + fbar -> g + g            I           13             0 I  1.548E-02 I
 I  14 f + fbar -> g + gamma        I            1             3 I  2.574E-04 I
 I  18 f + fbar -> gamma + gamma    I            0             0 I  0.000E+00 I
 I  28 f + g -> f + g               I         7663             0 I  9.126E+00 I
 I  29 f + g -> f + gamma           I            6            18 I  3.660E-03 I
 I  53 g + g -> f + fbar            I          296             0 I  3.525E-01 I
 I  68 g + g -> g + g               I        12690             0 I  1.511E+01 I
 I  83 f + q -> f' + Q, massive     I            0             0 I  0.000E+00 I
 I  91 Elastic scattering           I         9491          9491 I  1.134E+01 I
 I  92 Single diffractive (XB)      I         4554          4554 I  5.523E+00 I
 I  93 Single diffractive (AX)      I         4690          4690 I  5.523E+00 I
 I  94 Double  diffractive          I         4873          4886 I  5.619E+00 I
 I  95 Low-pT scattering            I            0         26394 I  0.000E+00 I
 I 114 g + g -> gamma + gamma       I            0             0 I  0.000E+00 I
 I 115 g + g -> g + gamma           I            0             0 I  0.000E+00 I
 I                                  I                            I            I
 ==============================================================================
```

TuneA 200GeV Summary Output:

```
==============================================================================
 I                                  I                            I            I
 I            Subprocess            I      Number of points      I    Sigma   I
 I                                  I                            I            I
 I----------------------------------I----------------------------I    (mb)    I
 I                                  I                            I            I
 I N:o Type                         I    Generated         Tried I            I
 I                                  I                            I            I
 ==============================================================================
 I                                  I                            I            I
 I   0 All included subprocesses    I        50000       1994634 I  5.154E+01 I
 I  11 f + f' -> f + f' (QCD)       I         6538             0 I  6.762E+00 I
 I  12 f + fbar -> f' + fbar'       I           15             0 I  1.551E-02 I
```

```
I  13 f + fbar -> g + g           I           18             0 I  1.862E-02 I
I  14 f + fbar -> g + gamma       I            1             2 I  2.777E-04 I
I  18 f + fbar -> gamma + gamma   I            0             0 I  0.000E+00 I
I  28 f + g -> f + g              I         8678             0 I  8.976E+00 I
I  29 f + g -> f + gamma          I            5             8 I  2.603E-03 I
I  53 g + g -> f + fbar           I          246             0 I  2.544E-01 I
I  68 g + g -> g + g              I        11226             0 I  1.161E+01 I
I  91 Elastic scattering          I         9147          9147 I  9.419E+00 I
I  92 Single diffractive (XB)     I         4838          4838 I  5.001E+00 I
I  93 Single diffractive (AX)     I         4934          4934 I  5.001E+00 I
I  94 Double  diffractive         I         4354          4362 I  4.483E+00 I
I  95 Low-pT scattering           I            0         27024 I  0.000E+00 I
I 114 g + g -> gamma + gamma      I            0             0 I  0.000E+00 I
I 115 g + g -> g + gamma          I            0             0 I  0.000E+00 I
I                                 I                            I            I
==============================================================================
```

TuneA 500GeV Summary Output:

```
==============================================================================
I                                 I                            I            I
I            Subprocess           I      Number of points      I    Sigma   I
I                                 I                            I            I
I---------------------------------I----------------------------I    (mb)    I
I                                 I                            I            I
I N:o Type                        I    Generated         Tried I            I
I                                 I                            I            I
==============================================================================
I                                 I                            I            I
I   0 All included subprocesses   I        50000       1716637 I  5.943E+01 I
I  10 f + f' -> f + f' (QFD)      I            1             2 I  4.937E-04 I
I  11 f + f' -> f + f' (QCD)      I         6035             0 I  7.174E+00 I
I  12 f + fbar -> f' + fbar'      I            4             0 I  4.755E-03 I
I  13 f + fbar -> g + g           I            8             0 I  9.509E-03 I
I  14 f + fbar -> g + gamma       I            0             4 I  3.979E-04 I
I  18 f + fbar -> gamma + gamma   I            0             0 I  0.000E+00 I
I  28 f + g -> f + g              I         7681             0 I  9.130E+00 I
I  29 f + g -> f + gamma          I            4            14 I  3.329E-03 I
I  53 g + g -> f + fbar           I          298             0 I  3.542E-01 I
I  68 g + g -> g + g              I        12408             0 I  1.475E+01 I
I  83 f + q -> f' + Q, massive    I            0             0 I  0.000E+00 I
I  91 Elastic scattering          I         9611          9611 I  1.134E+01 I
I  92 Single diffractive (XB)     I         4666          4666 I  5.523E+00 I
I  93 Single diffractive (AX)     I         4558          4558 I  5.523E+00 I
I  94 Double  diffractive         I         4726          4739 I  5.618E+00 I
I  95 Low-pT scattering           I            0         26596 I  0.000E+00 I
I 114 g + g -> gamma + gamma      I            0             0 I  0.000E+00 I
I 115 g + g -> g + gamma          I            0             0 I  0.000E+00 I
I                                 I                            I            I
==============================================================================
```

Results

The results of the pythia simulations are summarized in the plots that follow, showing the comparison between NLO predictions at 500GeV and the TuneA and Perugia6 predictions for pizeroes and direct photons. A comparison between the pythia tunes and published data from BRAHMS and STAR experiments are also shown in similar kinematic regions to the FOCAL acceptance.

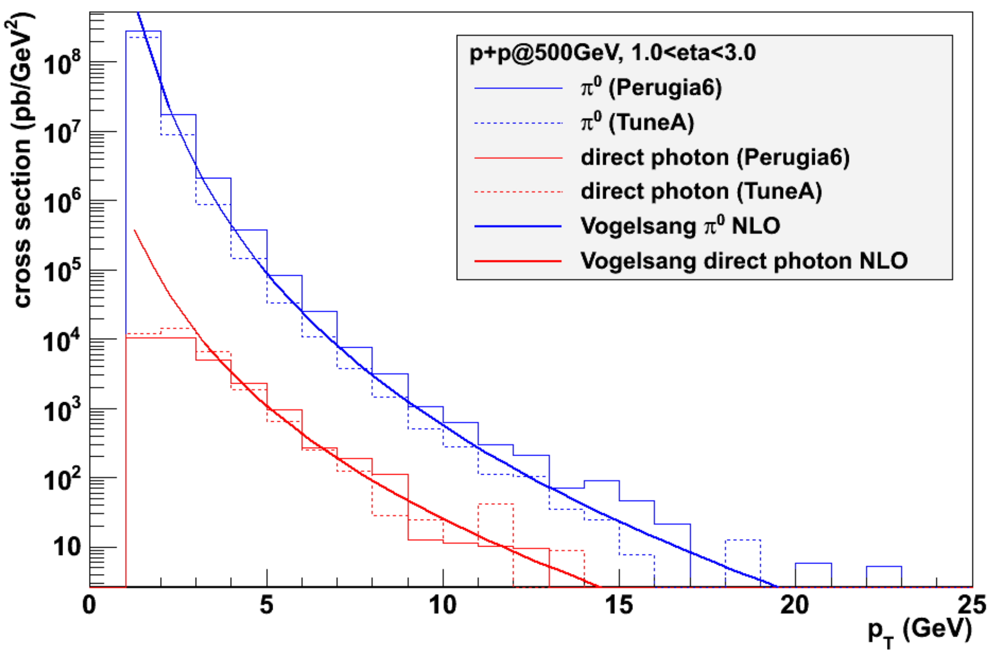

Figure 1: A comparison between TuneA and Perugia6 for direct photons and neutral pions between pseudorapidities of 1.0 and 3.0 (the FOCAL acceptance) at 500GeV. The direct photons are plotted for direct photons only, without the contribution from fragmentation photons. The NLO calculations for direct photons agree well with the pythia predictions for either tune, while the pizeroes for the Perugia tune is significantly above the NLO calculations. This is believed to be due to the larger "underlying event" contributions in the Perugia tune. The NLO calculation uses the KKP fragmentation function at $\mu=p_T$, see Figure 3 for a similar calculation with scale uncertainty included. A total of 20M events were used in making this plot.

Table 1: Perugia and TuneA cross section data from Figure 1 for neutral pions at 500GeV. The data was binned in p_T bins of 1.0GeV and in a pseudorapidity window $1<\eta<3$. The total cross section from the Preguia6 data was 59.44mb, while it was 59.41mb for TuneA.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
1.5	2.85E+08	150017	2.30E+08	134503
2.5	1.73E+07	28568.4	8.94E+06	20558
3.5	2.15E+06	8531.04	884283	5464.58
4.5	378171	3152.41	146559	1961.98
5.5	84217.1	1345.62	33889	853.382

6.5	24760.2	671.158	10928.3	445.773
7.5	7552.38	345.077	3750.64	243.118
8.5	3185.85	210.527	1473.93	143.161
9.5	1045.6	114.084	510.094	79.6633
10.5	619.416	83.5221	281.411	56.2822
11.5	298.201	55.3746	113.054	34.087
12.5	208.124	44.3722	104.009	31.36
13.5	70.0754	24.7754	35.02	17.51
14.5	89.7086	27.0482	24.4536	14.1183
15.5	45.7751	18.6876	7.62533	7.62533
16.5	21.5004	12.4133	0	0
17.5	0	0	0	0
18.5	0	0	12.7776	9.03511
19.5	0	0	0	0
20.5	5.7684	5.7684	0	0

Table 2: Perugia and TuneA cross section data from Figure 1 for direct photons at 500GeV (no fragmentation photons). The data was binned in p_T bins of 1.0GeV and in a pseudorapidity window $1<\eta<3$. The total cross section from the Preguia6 data was 59.44mb, while it was 59.41mb for TuneA.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
1.5	10406.2	905.743	12213.2	980.99
2.5	10358.9	699.989	14324.9	822.946
3.5	5034.17	412.415	6551.24	470.352
4.5	2286.21	245.107	1838.55	219.749
5.5	967.518	144.229	644.687	117.703
6.5	272.89	70.4598	254.569	68.0363
7.5	189.204	54.6184	126.072	44.5732
8.5	111.296	39.3492	27.81	19.6646
9.5	12.4476	12.4476	24.8826	17.5947
10.5	11.2621	11.2621	11.2564	11.2564
11.5	10.2828	10.2828	41.1105	20.5552
12.5	9.46018	9.46018	0	0
13.5	0	0	8.755	8.755
14.5	0	0	0	0

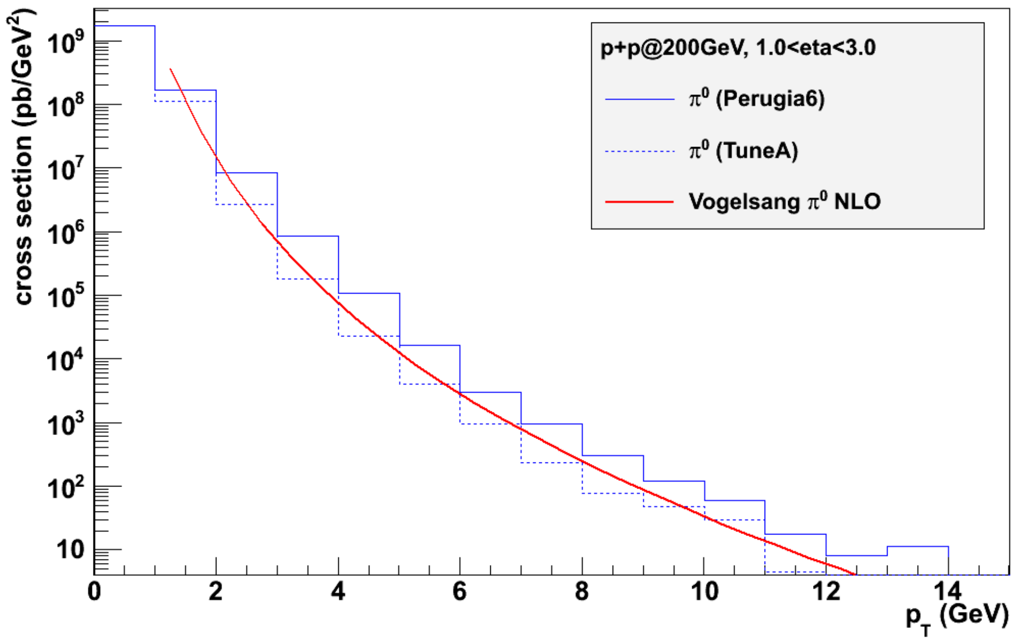

Figure 2: A comparison between TuneA and Perugia6 for direct photons and neutral pions between pseudorapidities of 1.0 and 3.0 (the FOCAL acceptance) at 200GeV. The NLO calculation agrees well with the TuneA results. The difference between TuneA and Perugia6 is thought to be the additional "underlying event" contributions in the Perugia tune. The NLO calculation uses the KKP fragmentation function at μ=p_T, see Figure 3 for a similar calculation with scale uncertainty included.

Table 3: Perugia and TuneA cross section data from Figure 2 for neutral pions at 200GeV. The data was binned in p_T bins of 1.0GeV and in a pseudorapidity window 1<η<3. The total cross section from the Preguia6 data was 51.56mb, while it was 51.55mb for TuneA. The Perugia data and TuneA data samples consist of a set of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
0.5	1.72E+09	420149	1.72E+09	420149
1.5	1.68E+08	75737.3	1.12E+08	61911.6
2.5	8.49E+06	13200.7	2.66E+06	7388.79
3.5	843815	3516.38	181515	1630.9
4.5	106884	1103.71	22589.4	507.403
5.5	16440	391.541	4047.07	194.265
6.5	3014.14	154.217	962.631	87.1525
7.5	957.371	80.9126	232.504	39.8742
8.5	301.693	42.6658	78.4401	21.7554
9.5	118.772	25.3222	48.5884	16.1961
10.5	58.6145	16.9206	29.3073	11.9646
11.5	17.8392	8.9196	4.4598	4.4598
12.5	8.20604	5.80254	0	0
13.5	11.3973	6.58022	0	0

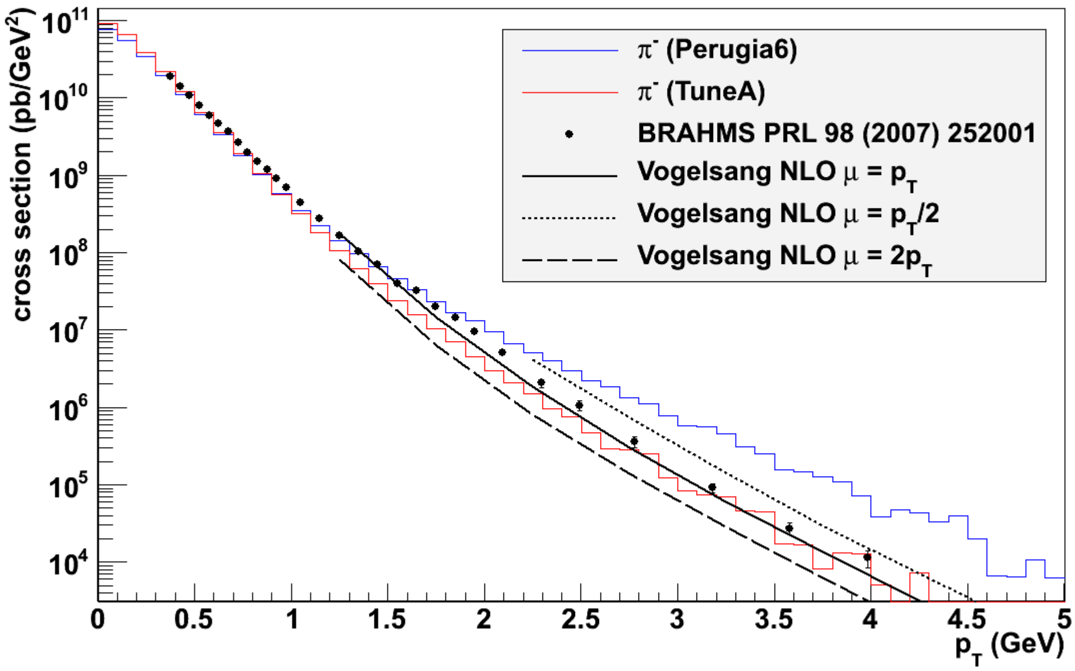

Figure 3: A comparison between TuneA, Perugia6 and negative pion data from BRAHMS at y=2.95. TuneA offers a fair representation of the data above a transverse momentum of 3GeV or so, while Perugia6 substantially overpredicts the data. The calculation from Werner Vogelsang is taken from Phys. Rev. Lett. 98 252001 (2007) and the data points are listed in Appendix B.

Table 4: Perugia and TuneA cross section data from Figure 2 (π- at 200GeV). The data was binned in p_T bins of 0.1GeV and rapidity bins of 0.1. The total cross section from the Preguia6 data was 51.56mb, while it was 51.55mb for TuneA. Both sets of data consist of a sample of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
0.05	7.70E+10	1.26E+08	9.15E+10	1.37E+08
0.15	5.56E+10	6.17E+07	6.54E+10	6.69E+07
0.25	3.42E+10	3.74E+07	3.92E+10	4.01E+07
0.35	1.97E+10	2.40E+07	2.20E+10	2.54E+07
0.45	1.10E+10	1.58E+07	1.20E+10	1.66E+07
0.55	6.05E+09	1.06E+07	6.51E+09	1.10E+07
0.65	3.32E+09	7.24E+06	3.55E+09	7.48E+06
0.75	1.82E+09	4.99E+06	1.92E+09	5.13E+06
0.85	1.02E+09	3.51E+06	1.04E+09	3.54E+06
0.95	5.89E+08	2.52E+06	5.70E+08	2.48E+06
1.05	3.54E+08	1.86E+06	3.24E+08	1.78E+06
1.15	2.22E+08	1.41E+06	1.83E+08	1.28E+06
1.25	1.44E+08	1.09E+06	1.06E+08	934226
1.35	9.72E+07	859300	6.19E+07	685895

1.45	6.61E+07	683893	3.99E+07	531214
1.55	4.63E+07	553326	2.43E+07	401321
1.65	3.30E+07	452625	1.57E+07	312633
1.75	2.36E+07	372145	1.03E+07	246064
1.85	1.70E+07	307064	7.01E+06	197166
1.95	1.33E+07	264587	4.50E+06	153783
2.05	9.60E+06	219193	2.96E+06	121618
2.15	6.73E+06	179149	2.07E+06	99372.3
2.25	5.11E+06	152638	1.50E+06	82800.6
2.35	3.99E+06	131962	973187	65169.4
2.45	2.94E+06	111008	753469	56160.3
2.55	2.18E+06	93735.3	474571	43687.8
2.65	1.83E+06	84183.7	294122	33738.1
2.75	1.33E+06	70476.6	279697	32296.6
2.85	1.11E+06	63164.6	251891	30106.7
2.95	785832	52272.8	121676	20567
3.05	585185	44362.7	84061.9	16812.4
3.15	556838	42582.5	74881.8	15613.9
3.25	451332	37742.3	69422.2	14800.9
3.35	309257	30772.3	45920.4	11856.6
3.45	249749	27249.8	44589.4	11512.9
3.55	156030	21233	17333.3	7076.3
3.65	146135	20265.3	16858.4	6882.43
3.75	125826	18552	8204.44	4736.84
3.85	109236	17059.8	13318.9	5956.39
3.95	72711.7	13741.2	12981.7	5805.6
4.05	37990.9	9809.21	5064.47	3581.12
4.15	46962.3	10773.9	0	0
4.25	43443.7	10239.8	7239.22	4179.56
4.35	33012.8	8823.04	0	0
4.45	39186.1	9504.03	2304.62	2304.62
4.55	20289.6	6763.22	0	0
4.65	6617.77	3820.77	2205.5	2205.5
4.75	6478.45	3740.33	0	0
4.85	10574.8	4729.19	0	0
4.95	6216.69	3589.21	0	0

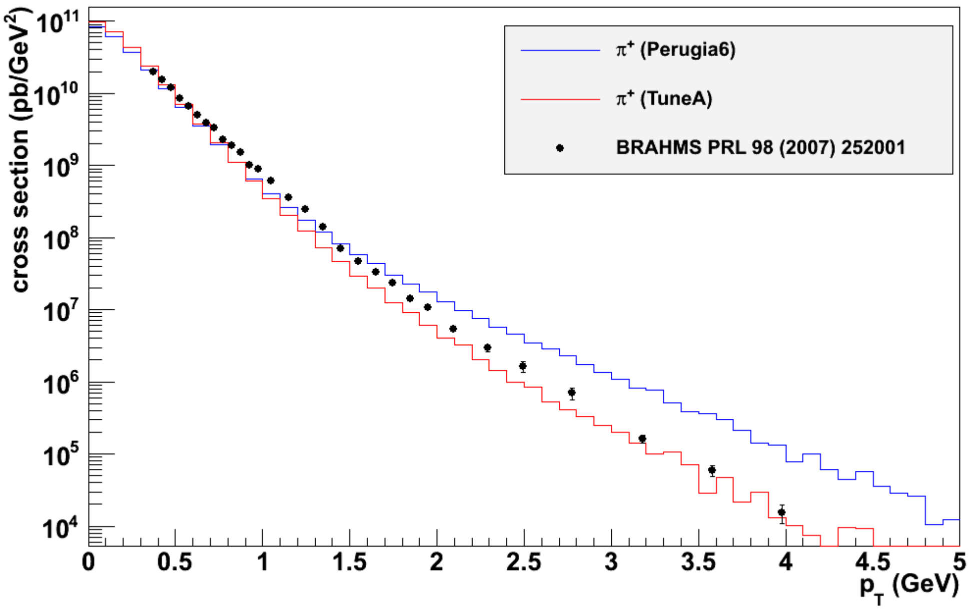

Figure 4: A comparison between TuneA, Perugia6 and positive pion data from BRAHMS at y=2.95. TuneA offers a fair representation of the data above a transverse momentum of 3GeV or so, while Perugia6 substantially overpredicts the data.

Table 5: Perugia and TuneA cross section data from Figure 3 (π+ at 200GeV). The data was binned in pT bins of 0.1GeV and rapidity bins of 0.1. The total cross section from the Preguia6 data was 51.56mb, while it was 51.55mb for TuneA. Both sets of data consist of a sample of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
0.05	8.20E+10	1.30E+08	9.65E+10	1.41E+08
0.15	6.08E+10	6.45E+07	7.15E+10	6.99E+07
0.25	3.73E+10	3.91E+07	4.31E+10	4.21E+07
0.35	2.12E+10	2.49E+07	2.39E+10	2.65E+07
0.45	1.17E+10	1.63E+07	1.29E+10	1.72E+07
0.55	6.38E+09	1.09E+07	6.97E+09	1.14E+07
0.65	3.51E+09	7.45E+06	3.75E+09	7.69E+06
0.75	1.95E+09	5.17E+06	2.05E+09	5.29E+06
0.85	1.11E+09	3.66E+06	1.11E+09	3.66E+06
0.95	6.56E+08	2.66E+06	6.17E+08	2.58E+06
1.05	4.07E+08	1.99E+06	3.49E+08	1.85E+06
1.15	2.61E+08	1.53E+06	2.01E+08	1.34E+06
1.25	1.73E+08	1.19E+06	1.21E+08	997507
1.35	1.18E+08	947886	7.29E+07	744322
1.45	8.15E+07	759181	4.60E+07	570183
1.55	5.87E+07	623266	2.94E+07	441375
1.65	4.35E+07	519754	1.98E+07	350831

1.75	3.01E+07	420107	1.26E+07	271858
1.85	2.24E+07	352727	9.22E+06	226133
1.95	1.75E+07	303414	5.99E+06	177495
2.05	1.28E+07	252673	4.01E+06	141586
2.15	9.74E+06	215592	3.23E+06	124204
2.25	7.60E+06	186079	2.01E+06	95609.9
2.35	5.78E+06	158825	1.44E+06	79277.2
2.45	4.59E+06	138606	987882	64305.6
2.55	3.44E+06	117690	848597	58419.8
2.65	2.85E+06	104940	526323	45131.8
2.75	2.27E+06	91973.5	413951	39290.5
2.85	1.73E+06	79017.3	327458	34326.9
2.95	1.34E+06	68314.8	250305	29498.7
3.05	1.07E+06	60067.4	198386	25827.7
3.15	830373	52000	139996	21349.3
3.25	763793	49098.4	100978	17850.5
3.35	508284	39450.5	107148	18111.2
3.45	380570	33637.9	71343	14562.8
3.55	358292	32175.5	28888.9	9135.47
3.65	297890	28933.7	47765.6	11584.9
3.75	213357	24157.9	21878.5	7735.22
3.85	141208	19396.4	29301.6	8834.76
3.95	132439	18545.2	12981.7	5805.6
4.05	78514.5	14101.6	10128.9	5064.47
4.15	98867.9	15632.4	7413.65	4280.28
4.25	60338.5	12067.7	4826.14	3412.6
4.35	44803.1	10278.5	9430.4	4715.2
4.45	57626.7	11525.3	9218.48	4609.24
4.55	36070.5	9017.62	0	0
4.65	28677	7953.57	0	0
4.75	25913.8	7480.67	0	0
4.85	10574.8	4729.19	2114.55	2114.55
4.95	12433.4	5075.91	2071.83	2071.83

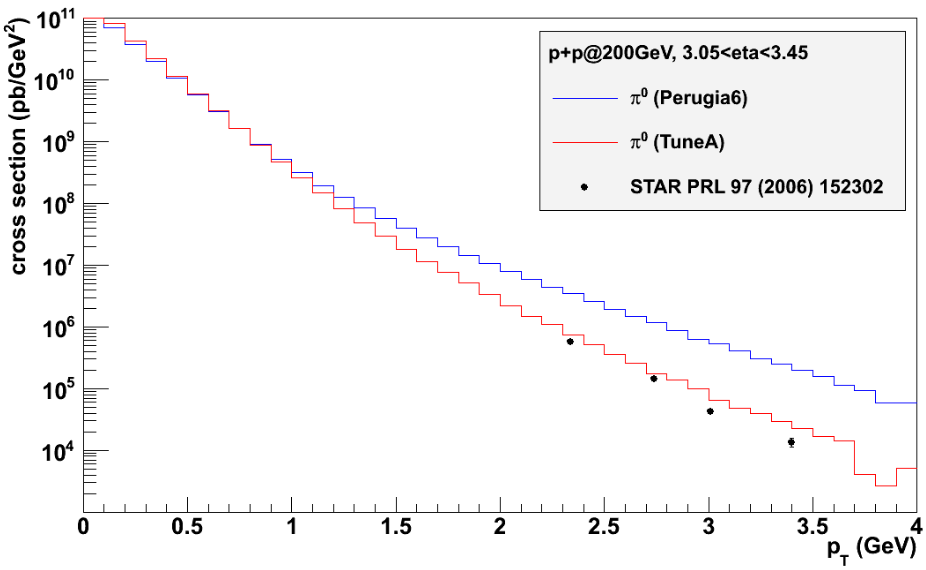

Figure 5: A comparison between TuneA, Perugia6 and neutral pion data from STAR for 3.05<eta<3.45. TuneA offers a fair representation of the data, while Perugia6 substantially overpredicts the data. It should be noted that the STAR data were binned in energy and reported with a $<p_T>$ for each bin. For this comparison we have ignored sharing between the bins and just plotted the data at $<p_T>$ for each bin.

Table 6: Perugia and TuneA cross section data from Figure 4 (π^0 at 200GeV). The data was binned in p_T bins of 0.1GeV and rapidity bins of 3.05<y<3.45. The total cross section from the Preguia6 data was 51.56mb, while it was 51.55mb for TuneA. Both sets of data consist of a sample of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
0.05	1.23E+11	7.94E+07	1.40E+11	8.46E+07
0.15	7.14E+10	3.49E+07	8.24E+10	3.75E+07
0.25	3.79E+10	1.97E+07	4.29E+10	2.10E+07
0.35	2.01E+10	1.21E+07	2.22E+10	1.27E+07
0.45	1.07E+10	7.81E+06	1.15E+10	8.09E+06
0.55	5.71E+09	5.16E+06	6.01E+09	5.30E+06
0.65	3.05E+09	3.47E+06	3.16E+09	3.53E+06
0.75	1.66E+09	2.38E+06	1.67E+09	2.39E+06
0.85	9.23E+08	1.67E+06	8.92E+08	1.64E+06
0.95	5.28E+08	1.19E+06	4.79E+08	1.14E+06
1.05	3.16E+08	878604	2.63E+08	801691
1.15	1.96E+08	661146	1.47E+08	571838
1.25	1.27E+08	510059	8.36E+07	414171
1.35	8.42E+07	399826	4.91E+07	305508
1.45	5.70E+07	317477	2.99E+07	230074
1.55	4.00E+07	257280	1.83E+07	173921
1.65	2.80E+07	208439	1.15E+07	133758
1.75	2.01E+07	171585	7.67E+06	105994
1.85	1.46E+07	142201	5.12E+06	84282.3

1.95	1.08E+07	119259	3.35E+06	66420.8
2.05	7.97E+06	99854.5	2.21E+06	52627.9
2.15	5.89E+06	83814.8	1.47E+06	41813.9
2.25	4.39E+06	70773.3	1.10E+06	35331.5
2.35	3.51E+06	61921.8	734397	28308.9
2.45	2.60E+06	52124.7	516017	23240.3
2.55	1.93E+06	44007.6	363037	19107.2
2.65	1.49E+06	37913.3	262245	15930.2
2.75	1.17E+06	32969	176243	12819.8
2.85	868292	27951.3	138567	11166
2.95	628492	23373.9	98229	9240.61
3.05	538101	21270.3	65581	7425.59
3.15	413558	18348.7	48031.4	6253.15
3.25	308515	15602.3	39452.1	5579.37
3.35	251846	13884.7	29088.6	4718.79
3.45	196975	12100.1	22299	4071.22
3.55	156030	10616.5	16614.3	3464.33
3.65	111709	8859.09	14051.4	3142
3.75	93001.7	7974.83	4103.02	1675.05
3.85	59280.6	6283.73	2664.3	1332.15
3.95	59078.3	6193.08	5193.69	1836.25

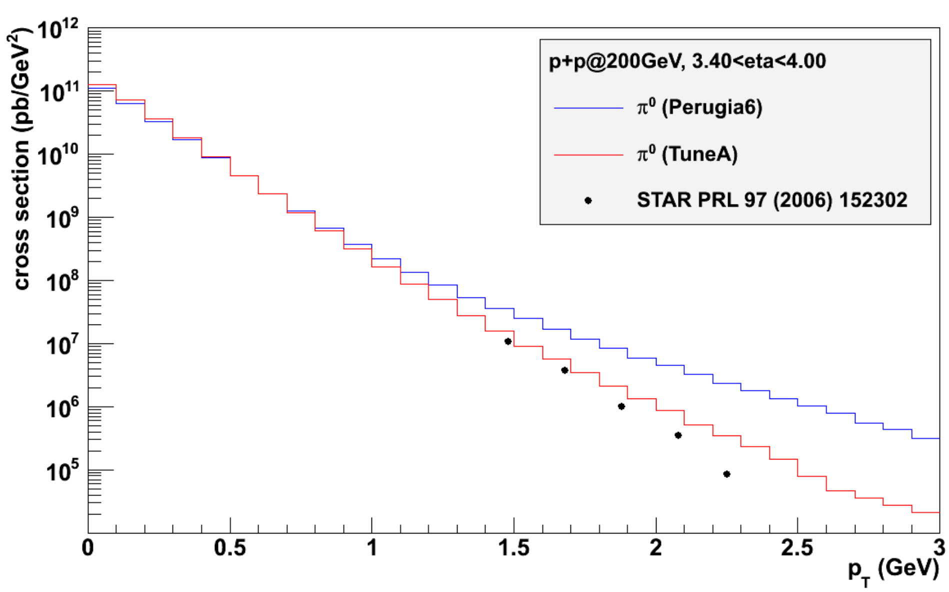

Figure 6: A comparion between TuneA, Perugia6 and neutral pion data from STAR for 3.40<eta<4.00. TuneA offers a fair representation of the data, but with a shallow slope so the disagreement grows as a function of transverse momentum. Perugia6 substantially overpredicts the data. It should be noted that the STAR data were binned in energy and reported with a $<p_T>$ for each bin. For this comparison we have ignored sharing between the bins and just plotted the data at $<p_T>$ for each bin.

Table 7: Perugia and TuneA cross section data from Figure 5 (π^0 at 200GeV). The data was binned in p_T bins of 0.1GeV and rapidity bins of 3.40<y<4.00. The total cross section from the Preguia6 data was 51.56mb, while it was 51.55mb for TuneA. Both sets of data consist of a sample of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
0.05	1.13E+11	6.20E+07	1.29E+11	6.64E+07
0.15	6.33E+10	2.69E+07	7.20E+10	2.86E+07
0.25	3.30E+10	1.50E+07	3.64E+10	1.58E+07
0.35	1.70E+10	9.10E+06	1.82E+10	9.42E+06
0.45	8.74E+09	5.76E+06	9.11E+09	5.88E+06
0.55	4.53E+09	3.75E+06	4.60E+09	3.78E+06
0.65	2.36E+09	2.49E+06	2.33E+09	2.48E+06
0.75	1.24E+09	1.68E+06	1.19E+09	1.65E+06
0.85	6.76E+08	1.17E+06	6.13E+08	1.11E+06
0.95	3.78E+08	825173	3.18E+08	756038
1.05	2.21E+08	599195	1.66E+08	520366
1.15	1.34E+08	446636	8.85E+07	362749
1.25	8.46E+07	340188	4.94E+07	259800
1.35	5.41E+07	261758	2.74E+07	186220
1.45	3.58E+07	205571	1.58E+07	136666
1.55	2.47E+07	165025	9.14E+06	100412
1.65	1.68E+07	132010	5.60E+06	76188
1.75	1.18E+07	107509	3.44E+06	57959.6
1.85	8.34E+06	87775.2	2.14E+06	44481.9
1.95	5.90E+06	71938.6	1.33E+06	34158.1
2.05	4.45E+06	60952.3	869806	26932.7
2.15	3.24E+06	50765.7	513672	20210.2
2.25	2.38E+06	42481.9	341158	16100.3
2.35	1.81E+06	36286.9	234250	13054.3
2.45	1.34E+06	30567.8	149328	10207.8
2.55	1.02E+06	26129.5	78440	7251.78
2.65	782541	22468.6	47094.4	5511.98
2.75	552664	18535.8	36056.8	4734.49
2.85	431297	16084.7	26993.5	4023.96
2.95	315840	13529.1	20862.8	3477.13

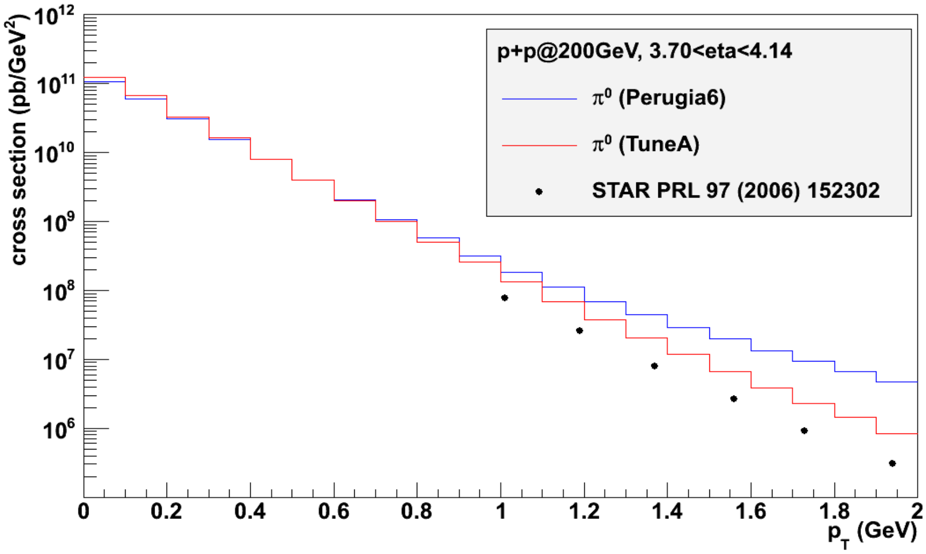

Figure 7: A comparison between TuneA, Perugia6 and neutral pion data from STAR for 3.40<eta<4.00. TuneA offers a fair representation of the data, but with a shallow slope so the disagreement grows as a function of transverse momentum. Perugia6 substantially overpredicts the data. It should be noted that the STAR data were binned in energy and reported with a $\langle p_T \rangle$ for each bin. For this comparison we have ignored sharing between the bins and just plotted the data at $\langle p_T \rangle$ for each bin.

Table 8: Perugia and TuneA cross section data from Figure 6 (π^0 at 200GeV). The data was binned in p_T bins of 0.1GeV and rapidity bins of 3.70<y<4.14. The total cross section from the Preguia6 data was 51.56mb, while it was 51.55mb for TuneA. Both sets of data consist of a sample of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
0.05	1.07E+11	7.06E+07	1.22E+11	7.56E+07
0.15	5.92E+10	3.03E+07	6.65E+10	3.21E+07
0.25	3.06E+10	1.69E+07	3.32E+10	1.76E+07
0.35	1.55E+10	1.02E+07	1.63E+10	1.04E+07
0.45	7.87E+09	6.38E+06	8.00E+09	6.44E+06
0.55	4.01E+09	4.12E+06	3.98E+09	4.11E+06
0.65	2.06E+09	2.72E+06	1.98E+09	2.67E+06
0.75	1.08E+09	1.83E+06	9.91E+08	1.75E+06
0.85	5.78E+08	1.26E+06	5.00E+08	1.17E+06
0.95	3.20E+08	886256	2.55E+08	791252
1.05	1.85E+08	641417	1.32E+08	541427
1.15	1.12E+08	476918	6.94E+07	375116
1.25	6.93E+07	359458	3.76E+07	264779
1.35	4.43E+07	276470	2.05E+07	188045
1.45	2.89E+07	215471	1.17E+07	137330
1.55	1.98E+07	172618	6.71E+06	100422

1.65	1.33E+07	136890	3.90E+06	74186.6
1.75	9.33E+06	111471	2.28E+06	55087.2
1.85	6.71E+06	91947.1	1.45E+06	42714.9
1.95	4.68E+06	74832.2	826103	31426.4

The Effect of the CKIN(3) Parameter

As was discussed previously, for the 500GeV comparisons a additional sample of data was run with the CKIN(3) parameter set to 4.5 GeV. This data is shown in Figure 8 below.

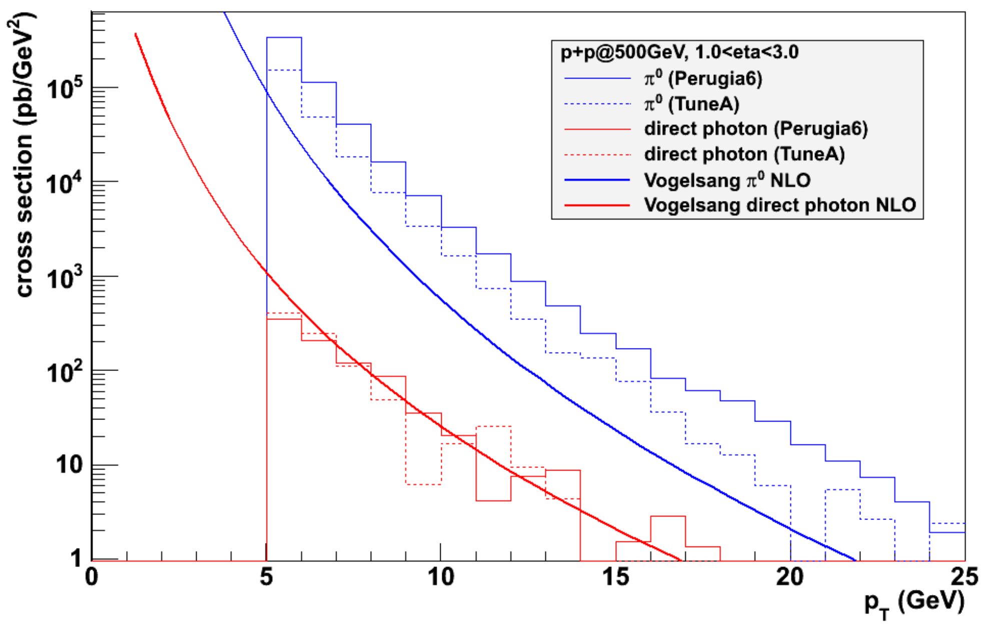

Figure 8: A comparison between TuneA and Perugia6 for direct photons and neutral pions between pseudorapidities of 1.0 and 3.0 (the FOCAL acceptance) at 500GeV, with the pythia CKIN(3) parameter raised to 4.5GeV. The direct photons are plotted for direct photons only, without the contribution from fragmentation photons. The NLO calculations agree well with the pythia predictions for either tune, but the pizeroes for both tunes significantly above the NLO calculations. This is due to the relative change in the partonic cross section induced by restricting the phase space with the CKIN(3) cutoff. The NLO calculation uses the KKP fragmentation function at $\mu=p_T$, see Figure 3 for a similar calculation with scale uncertainty included.

Table 9: Perugia and TuneA cross section data from Figure 8 for neutral pions at 500GeV. The data was binned in p_T bins of 1.0GeV and in a pseudorapidity window $1<\eta<3$. The total cross section from the Preguia6 data was 59.44mb, while it was 59.41mb for TuneA. The Perugia data consists of a set of 200M events, while the TuneA data consists of a sample of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
5.5	334748	1199.77	150857	1273.15
6.5	111335	636.472	48749.9	665.748
7.5	40779.7	358.6	18233.2	379.036

8.5	16193.6	212.267	7647.75	230.588
9.5	7162.35	133.532	3340.49	144.153
10.5	3277.28	85.9175	1632.18	95.8451
11.5	1733.68	59.7111	739.988	61.6657
12.5	872.228	40.6237	345.122	40.3935
13.5	483.52	29.1045	153.213	25.8976
14.5	247.922	20.1091	134.495	23.4126
15.5	167.842	16.0031	76.2533	17.0507
16.5	81.7015	10.8216	35.8159	11.326
17.5	60.8154	9.06583	16.8846	7.55104
18.5	47.3009	7.77622	12.7776	6.38879
19.5	29.1082	5.94169	6.06116	4.28588
20.5	16.1515	4.31668	0	0
21.5	11.0002	3.47857	5.49733	3.8872
22.5	7.35792	2.78103	2.6265	2.6265
23.5	4.02561	2.0128	0	0
24.5	1.93065	1.36517	2.41209	2.41209

Table 10 : Perugia and TuneA cross section data from Figure 8 for neutral pions at 200GeV. The data was binned in p_T bins of 1.0GeV and in a pseudorapidity window $1<\eta<3$. The total cross section from the Preguia6 data was 51.56mb, while it was 51.55mb for TuneA. The Perugia data and TuneA data samples consist of a set of 80M events.

Transverse Momentum (GeV)	Cross section (pb/GeV^2) Perugia6	Error (Perugia)	Cross Section (pb/GeV^2) TuneA	Error (TuneA)
5.5	348.307	38.7007	408.302	66.2353
6.5	207.396	27.4703	245.477	47.242
7.5	119.829	19.4388	110.313	29.4824
8.5	86.2546	15.4918	48.6675	18.3946
9.5	34.8533	9.31493	6.22066	6.22066
10.5	20.2718	6.75727	16.8846	9.74836
11.5	4.11312	2.90842	25.694	11.4907
12.5	7.56814	3.78407	9.4554	6.68598
13.5	8.75942	3.91733	4.3775	4.3775

It is clear that raising the CKIN(3) cutoff has changed the relative cross section for producing a π^0 as compared to a direct photon. A comparison of the pythia output shows that raising the CKIN(3) parameter has changed some of the partonic cross sections relative to others, resulting in a higher contribution from processes that result in π^0s in the final state. A comparison between the partonic cross section output from pythia is shown in Figure 9.

	BNL/RCF CKIN(3)=2.0			ISU CKIN(3)=4.5		
Subprocess	Number of points		Sigma	Number of points		Sigma
N:o Type	Generated	Tried	(mb)	Generated	Tried	(mb)
0 All included subprocesses	50000	1698777	5.943E+01	10000	697098	5.941E+01
10 f + f' -> f + f' (QFD)	0	1	1.998E-14	0	0	0.000E+00
11 f + f' -> f + f' (QCD)	6067	0	7.262E+00	1151	0	6.829E+00
12 f + fbar -> f' + fbar'	12	0	1.436E-02	1	0	5.933E-03
13 f + fbar -> g + g	11	0	1.317E-02	3	0	1.780E-02
14 f + fbar -> g + gamma	0	2	5.890E-05	0	0	0.000E+00
18 f + fbar -> gamma + gamma	0	0	0.000E+00	0	0	0.000E+00
28 f + g -> f + g	7615	0	9.115E+00	1720	0	1.020E+01
29 f + g -> f + gamma	6	19	4.188E-03	0	0	0.000E+00
53 g + g -> f + fbar	280	0	3.352E-01	72	0	4.272E-01
68 g + g -> g + g	12265	0	1.468E+01	2349	0	1.394E+01
83 f + q -> f' + Q, massive	0	0	0.000E+00	0	0	0.000E+00
91 Elastic scattering	9589	9589	1.134E+01	1973	1973	1.134E+01
92 Single diffractive (XB)	4701	4701	5.523E+00	949	949	5.523E+00
93 Single diffractive (AX)	4612	4612	5.523E+00	877	877	5.523E+00
94 Double diffractive	4842	4858	5.615E+00	905	911	5.597E+00
95 Low-pT scattering	0	26408	0.000E+00	0	5336	0.000E+00
114 g + g -> gamma + gamma	0	0	0.000E+00	0	0	0.000E+00
115 g + g -> g + gamma	0	0	0.000E+00	0	0	0.000E+00

Figure 9: A comparison of the partonic cross section output from pythia for the TuneA configuration for two different values of the CKIN(3) parameter. Note that the total number of events is five times larger in the CKIN(3)=2.0 output. Several partonic cross sections that contribute significantly to pizero production are substantially larger with the higher CKIN(3) cutoff, raising the overall pizero cross section relative to the direct photon production.

Conclusions

We make some general conclusions, relevant to FOCAL simulations, below:

- At 500GeV, both TuneA and Perugia6 reproduce the NLO cross-section results for direct photons.
- At 500GeV, Perugia6 generates a cross section that is higher than the NLO calculation, due to the stronger “underlying event” contributions from this tune
- At 200GeV, TuneA reproduces the NLO π^0 cross section, while Perugia is higher by a factor of 4-8.
- At 200GeV, TuneA is in fair agreement with the π^+ and π^- data from BRAHMS at y=2.95 above a p_T of 3GeV, and sits a little below the data at lower transverse momentum. Perugia6 substantially overpredicts charged pion production for p_t > 2 GeV in this kinematic region.
- At 200GeV, TuneA is in fair agreement with the STAR forward pizero data at the lowest rapidity range, but over predicts the data at higher rapidities. Perugia6 substantially overpredicts the data in all rapidity ranges.

- Great care must be taken when adjusting the pythia CKIN(3) parameter, especially when one is interested in the relative probability of more than one partonic process. In general, if one is interested in a collection of processes the CKIN(3) parameter should be left low (~2.0 GeV).

Based on this comparison, it would seem that a reasonable and conservative approach would be to estimate the FOCAL backgrounds using pythia events run with the TuneA configuration, as this does the best job of reproducing the BRAHMS and STAR pion data in a similar kinematic region to the FOCAL. If a sample of events with a higher background fraction is required for study, the Perugia events could be utilized for this purpose.

Appendix A: NLO Pizero and Direc t Photon Cross Sections from Werner Volgelsang

Stephan Bathe solicited NLO cross section calculations from Werner Vogelsang in the FOCAL acceptance 1<y<3 in 2007, and Werner provided calculations at both 200GeV and 500GeV center of mass energies. The original emails, with the explanations from Werner and Stefan, are included in this appendix. Note that for the direct photon cross section Werner includes direct photons, fragmentation photons, and the sum.

The first part of the message includes the 500GeV results, while the latter part includes the 200GeV results. These results were used in the comparisons show in this note.

> Dear all,
>
> Werner Vogelsang sent me pQCD calculations for prompt photon and pi0
> production in p+p at 500 GeV at forward rapidity (1<eta<3). (I had
> asked him for it as a cross check of PYTHIA simulations for the NCC.)
> I thought other people might me interested as well, so I append his
> message below (in German, but I translated it).
>
> Best regards,
> Stefan
>
> -------- Original Message --------
> Subject: Re: pQCD calculations for prompt photon and pi0 in p+p at 500 GeV
> Date: Wed, 19 Sep 2007 11:53:49 -0400 (EDT)
> From: Werner Vogelsang <vogelsan@quark.phy.bnl.gov>
> To: Stefan Bathe <bathe@bnl.gov>
> References: <46F01E56.5020800@bnl.gov>
>
> Hi Stefan,
>
> anbei zwei Resultate, einmal pi0, einmal gamma.
> In beiden Faellen ist es der inv. Querschnitt,
> E d^3 sig/dp^3, in pb/GeV^2, gemittelt ueber 1<eta<3.
> Skala ist jeweils pt (die uebliche Skalenabhkeit gibt
> es natuerlich). pdfs sind beidemal CTEQ6M. Fuer Pionen
> habe ich KKP fragmentationsfkt. Die Photonen sind nicht
> isoliert, ich benutze die GRV Photon-fragmentationsfkt.
> Isoliert waere etwas kleiner.
> Bei den Photonen sind die Spalten
> pt, direct, fragmentation, summe
>
> "attached are two results, one for pi0, the other for gamma. In both
> cases it's the invariant cross section, E d^3 sig/dp^3, in pb/GeV^2,
> averaged over 1<eta<3. The scale is pT in each case (the typical
> scale uncertainty applies of course). pdfs are CTEQ6M in both cases.
> For pions it's the KKP fragmentation function. Photons are not
> isolated [I guess that means there's no requirement], I use the GRV
> fragmentation function. Isolated would be a bit smaller.
> For the photons the columns are pt, direct, fragmentation, sum"
>
>
>

> Alles Gute, Werner
>
> --
> ---
> | Stefan Bathe, University of California at Riverside |
> | |
> | Stefan Bathe   Phone: +1-631-344-7394 |
> | P. O. Box 802   Fax: +1-631-344-3253 |
> | Upton, NY 11973   Email: bathe@bnl.gov |
> | USA   Skype: stefanbathe |
> ---
>
> 1.250E+00 8.234E+08
> 1.750E+00 1.148E+08
> 2.250E+00 2.206E+07
> 2.750E+00 5.676E+06
> 3.250E+00 1.822E+06
> 3.750E+00 6.813E+05
> 4.250E+00 2.825E+05
> 4.750E+00 1.299E+05
> 5.250E+00 6.364E+04
> 5.750E+00 3.334E+04
> 6.250E+00 1.830E+04
> 6.750E+00 1.052E+04
> 7.250E+00 6.272E+03
> 7.750E+00 3.820E+03
> 8.250E+00 2.402E+03
> 8.750E+00 1.552E+03
> 9.250E+00 1.019E+03
> 9.750E+00 6.849E+02
> 1.025E+01 4.665E+02
> 1.075E+01 3.238E+02
> 1.125E+01 2.282E+02
> 1.175E+01 1.617E+02
> 1.225E+01 1.170E+02
> 1.275E+01 8.548E+01
> 1.325E+01 6.308E+01
> 1.375E+01 4.680E+01
> 1.425E+01 3.515E+01
> 1.475E+01 2.666E+01
> 1.525E+01 2.037E+01
> 1.575E+01 1.563E+01
> 1.625E+01 1.212E+01
> 1.675E+01 9.427E+00
> 1.725E+01 7.379E+00
> 1.775E+01 5.796E+00
> 1.825E+01 4.612E+00
> 1.875E+01 3.651E+00
> 1.925E+01 2.928E+00
> 1.975E+01 2.350E+00
> 2.025E+01 1.894E+00
> 2.075E+01 1.538E+00
> 2.125E+01 1.246E+00
> 2.175E+01 1.021E+00
> 2.225E+01 8.375E-01
> 2.275E+01 6.873E-01
> 2.325E+01 5.662E-01

```
>  2.375E+01  4.682E-01
>  2.425E+01  3.890E-01
>  2.475E+01  3.227E-01
>  2.525E+01  2.694E-01
>
>  1.250E+00  3.739E+05  1.643E+06  2.017E+06
>  1.750E+00  1.202E+05  3.333E+05  4.536E+05
>  2.250E+00  4.432E+04  9.308E+04  1.374E+05
>  2.750E+00  1.869E+04  3.333E+04  5.202E+04
>  3.250E+00  8.763E+03  1.362E+04  2.239E+04
>  3.750E+00  4.481E+03  6.281E+03  1.076E+04
>  4.250E+00  2.450E+03  3.217E+03  5.666E+03
>  4.750E+00  1.413E+03  1.734E+03  3.147E+03
>  5.250E+00  8.546E+02  9.925E+02  1.847E+03
>  5.750E+00  5.352E+02  5.982E+02  1.133E+03
>  6.250E+00  3.459E+02  3.674E+02  7.133E+02
>  6.750E+00  2.299E+02  2.388E+02  4.686E+02
>  7.250E+00  1.562E+02  1.567E+02  3.129E+02
>  7.750E+00  1.083E+02  1.049E+02  2.132E+02
>  8.250E+00  7.651E+01  7.191E+01  1.484E+02
>  8.750E+00  5.487E+01  5.002E+01  1.049E+02
>  9.250E+00  3.997E+01  3.563E+01  7.560E+01
>  9.750E+00  2.946E+01  2.575E+01  5.521E+01
>  1.025E+01  2.197E+01  1.864E+01  4.061E+01
>  1.075E+01  1.656E+01  1.376E+01  3.033E+01
>  1.125E+01  1.262E+01  1.028E+01  2.290E+01
>  1.175E+01  9.704E+00  7.716E+00  1.742E+01
>  1.225E+01  7.519E+00  5.908E+00  1.343E+01
>  1.275E+01  5.869E+00  4.502E+00  1.037E+01
>  1.325E+01  4.617E+00  3.485E+00  8.102E+00
>  1.375E+01  3.654E+00  2.743E+00  6.397E+00
>  1.425E+01  2.911E+00  2.127E+00  5.037E+00
>  1.475E+01  2.334E+00  1.693E+00  4.027E+00
>  1.525E+01  1.881E+00  1.343E+00  3.225E+00
>  1.575E+01  1.524E+00  1.079E+00  2.603E+00
>  1.625E+01  1.240E+00  8.690E-01  2.109E+00
>  1.675E+01  1.015E+00  7.032E-01  1.718E+00
>  1.725E+01  8.340E-01  5.735E-01  1.407E+00
>  1.775E+01  6.876E-01  4.721E-01  1.160E+00
>  1.825E+01  5.696E-01  3.814E-01  9.509E-01
>  1.875E+01  4.737E-01  3.112E-01  7.848E-01
>  1.925E+01  3.947E-01  2.575E-01  6.522E-01
>  1.975E+01  3.309E-01  2.111E-01  5.420E-01
>  2.025E+01  2.780E-01  1.788E-01  4.568E-01
>  2.075E+01  2.342E-01  1.468E-01  3.810E-01
>  2.125E+01  1.975E-01  1.232E-01  3.208E-01
>  2.175E+01  1.673E-01  1.037E-01  2.710E-01
>  2.225E+01  1.423E-01  8.738E-02  2.297E-01
>  2.275E+01  1.211E-01  7.361E-02  1.947E-01
>  2.325E+01  1.033E-01  6.249E-02  1.658E-01
>  2.375E+01  8.846E-02  5.320E-02  1.417E-01
>  2.425E+01  7.586E-02  4.529E-02  1.211E-01
>  2.475E+01  6.523E-02  3.841E-02  1.036E-01
>  2.525E+01  5.618E-02  3.283E-02  8.901E-02
```

On 10/31/07, Stefan Bathe <bathe@bnl.gov> wrote:

>

> - Show quoted text -

> Dear All,

>

> a couple weeks ago I forwarded pQCD calculations by Werner

> Vogelsang for

> p+p at 500 GeV at forward rapidity (1<eta<3) to the list (see below).

> Here is now the same for 200 GeV, in case someone is interested (see

> attached).

>

> Best regards,

> Stefan

>

>

> --

>

>

>	1.250E+00	2.928E+05	1.037E+06	1.329E+06
>	1.750E+00	7.926E+04	1.730E+05	2.522E+05
>	2.250E+00	2.551E+04	4.193E+04	6.744E+04
>	2.750E+00	9.558E+03	1.337E+04	2.293E+04
>	3.250E+00	4.018E+03	4.943E+03	8.961E+03
>	3.750E+00	1.851E+03	2.039E+03	3.890E+03
>	4.250E+00	9.154E+02	9.348E+02	1.850E+03
>	4.750E+00	4.794E+02	4.511E+02	9.305E+02
>	5.250E+00	2.637E+02	2.335E+02	4.971E+02
>	5.750E+00	1.509E+02	1.279E+02	2.787E+02
>	6.250E+00	8.925E+01	7.196E+01	1.612E+02
>	6.750E+00	5.441E+01	4.261E+01	9.702E+01
>	7.250E+00	3.401E+01	2.558E+01	5.959E+01
>	7.750E+00	2.172E+01	1.583E+01	3.755E+01
>	8.250E+00	1.420E+01	9.948E+00	2.414E+01
>	8.750E+00	9.415E+00	6.443E+00	1.586E+01
>	9.250E+00	6.348E+00	4.255E+00	1.060E+01
>	9.750E+00	4.340E+00	2.852E+00	7.192E+00
>	1.025E+01	3.005E+00	1.926E+00	4.932E+00
>	1.075E+01	2.104E+00	1.320E+00	3.425E+00
>	1.125E+01	1.492E+00	9.178E-01	2.410E+00
>	1.175E+01	1.067E+00	6.401E-01	1.707E+00
>	1.225E+01	7.687E-01	4.551E-01	1.224E+00
>	1.275E+01	5.590E-01	3.235E-01	8.825E-01
>	1.325E+01	4.087E-01	2.342E-01	6.429E-01
>	1.375E+01	3.011E-01	1.713E-01	4.724E-01
>	1.425E+01	2.232E-01	1.243E-01	3.475E-01
>	1.475E+01	1.665E-01	9.250E-02	2.590E-01
>	1.525E+01	1.248E-01	6.856E-02	1.934E-01
>	1.575E+01	9.405E-02	5.135E-02	1.454E-01
>	1.625E+01	7.112E-02	3.848E-02	1.096E-01
>	1.675E+01	5.412E-02	2.915E-02	8.327E-02
>	1.725E+01	4.129E-02	2.215E-02	6.345E-02
>	1.775E+01	3.156E-02	1.686E-02	4.843E-02
>	1.825E+01	2.426E-02	1.274E-02	3.699E-02
>	1.875E+01	1.870E-02	9.699E-03	2.840E-02
>	1.925E+01	1.444E-02	7.432E-03	2.187E-02
>	1.975E+01	1.120E-02	5.693E-03	1.690E-02
>	2.025E+01	8.709E-03	4.441E-03	1.315E-02

```
>       2.075E+01  6.782E-03  3.397E-03  1.018E-02
>       2.125E+01  5.285E-03   2.643E-03  7.928E-03
>       2.175E+01  4.135E-03  2.053E-03  6.188E-03
>       2.225E+01  3.240E-03  1.603E-03  4.843E-03
>       2.275E+01  2.541E-03  1.250E-03  3.791E-03
>       2.325E+01  1.996E-03  9.743E-04  2.970E-03
>       2.375E+01   1.571E-03  7.639E-04  2.335E-03
>       2.425E+01  1.238E-03  5.980E-04  1.836E-03
>       2.475E+01  9.773E-04  4.691E-04  1.446E-03
>       2.525E+01  7.718E-04  3.680E-04  1.140E-03
>
>       1.250E+00  3.690E+08
>       1.750E+00   3.809E+07
>       2.250E+00  5.992E+06
>       2.750E+00  1.321E+06
>       3.250E+00  3.714E+05
>       3.750E+00  1.229E+05
>       4.250E+00  4.557E+04
>       4.750E+00  1.886E+04
>       5.250E+00  8.432E+03
>       5.750E+00  4.014E+03
>       6.250E+00  2.012E+03
>       6.750E+00  1.058E+03
>       7.250E+00  5.782E+02
>       7.750E+00  3.240E+02
>       8.250E+00  1.881E+02
>       8.750E+00  1.122E+02
>       9.250E+00  6.807E+01
>       9.750E+00  4.231E+01
>       1.025E+01   2.663E+01
>       1.075E+01  1.714E+01
>       1.125E+01  1.119E+01
>       1.175E+01  7.356E+00
>       1.225E+01  4.937E+00
>       1.275E+01  3.334E+00
>       1.325E+01  2.283E+00
>       1.375E+01  1.568E+00
>       1.425E+01  1.087E+00
>       1.475E+01  7.622E-01
>       1.525E+01  5.382E-01
>       1.575E+01  3.821E-01
>       1.625E+01  2.728E-01
>       1.675E+01  1.957E-01
>       1.725E+01  1.412E-01
>       1.775E+01  1.023E-01
>       1.825E+01  7.469E-02
>       1.875E+01   5.445E-02
>       1.925E+01  4.005E-02
>       1.975E+01  2.951E-02
>       2.025E+01  2.180E-02
>       2.075E+01  1.620E-02
>       2.125E+01  1.200E-02
>       2.175E+01  8.988E-03
>       2.225E+01  6.703E-03
>       2.275E+01  5.034E-03
>       2.325E+01  3.761E-03
>       2.375E+01  2.825E-03
```

```
>       2.425E+01  2.130E-03
>       2.475E+01  1.601E-03
>       2.525E+01  1.211E-03
```

Appendix B: π^- NLO Cross Sections from Werner Vogelsang (BRAHMS Data Comparison):

The data listed below is from Werner Vogelsang, courtesy of J.H. Lee (private communication, October 27, 2009). Cross sections are in mb/GeV^2.

```
pi- at y=2.95 in p+p at sqrt(s) = 200 GeV
NLO Calculations by W. Vogelsang
Fig.3 in Phys.Rev.Lett.98 252001 (2007)

---------------
KKP FF mu = pT
---------------
 pT      cs
---------------

1.25, 1.767e-01
1.75, 1.464e-02
2.25, 1.827e-03
2.75, 3.036e-04
3.25, 6.070e-05
3.75, 1.348e-05
4.25, 3.151e-06
4.75, 7.641e-07
5.25, 1.839e-07
5.75, 4.340e-08
6.25, 9.650e-09
6.75, 1.968e-09
7.25, 3.541e-10

---------------
KKP FF mu = 2*pT
---------------
1.25, 8.021e-02
1.75, 6.329e-03
2.25, 8.155e-04
2.75, 1.399e-04
3.25, 2.826e-05
3.75, 6.250e-06
4.25, 1.478e-06
4.75, 3.560e-07
5.25, 8.514e-08
5.75, 1.986e-08
6.25, 4.359e-09
6.75, 8.809e-10
7.25, 1.557e-10

---------------
KKP FF mu = pT/2
---------------
2.25, 4.076e-03
```

```
2.75, 7.295e-04
3.25, 1.410e-04
3.75, 2.989e-05
4.25, 7.049e-06
4.75, 1.739e-06
5.25, 4.207e-07
5.75, 1.009e-07
6.25, 2.266e-08
6.75, 4.716e-09
7.25, 8.642e-10
```

Endnotes:

i arXiv:0905.3418v1 [hep-ph] 20 May 2009

ii http://projects.hepforge.org/pythia6

iii The pythia 6.4 manual is available at http://home.thep.lu.se/~torbjorn/pythia/lutp0613man2.pdf