Calculating Cross Sections of Electroweak Processes at Arbitrary CM Energy

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Introduction

This document is meant to be a condensed, and by no means extensive, description of how to calculate the cross sections of select processes of deep inelastic proton-proton collisions at arbitrary CM energy scales. It is my hope that this document, along with the framework I have set up to calculate these cross sections, will allow you to go through the entire process from start to finish quickly and without that much grief.

Background

To calculate the cross sections of deep inelastic proton-proton collisions, both theory and experimental data are necessary: they cannot be calculated directly from experiment. The theory behind these calculations comes to play when trying to determine a Parton Distribution Function (PDF) for the observed data. This is somewhat arbitrary, so the cross sections obtained from each of these models must be averaged. There are a few well-known PDFs that attempt to accomplish this. I use CTEQ, MSTW, and NNPDF.

The input parameters to these distributions are also somewhat arbitrary. To calculate the error due to the choice of these parameters, each must me varied around some nominal value. The total number of fits that must be done given a specific process is then #(variationsUp)+#(variationsDown)+1 (the 1 comes from fitting to the nominal set). This is summarized below for how I vary the PDFs. The numbers given here can change depending on the specific implementation of each of the PDFs.

PDF	**Variations Up**	**Variations Down**	**Total Variations**
CTEQ	22	22	45
NNPDF	50	50	101
MSTW	20	20	41

Additionally, the set of input parameters to the actual script that calculates the cross sections has some arbitrariness. This script is called MCFM, two variations of which are used for this analysis. All in all, there are many cross sections that are eventually calculated for just one energy scale:

(Fit variations)*(# of final states in the collisions)*(MCFM variations) =
(45+41+101)*66*2=24,684

A CMS note co-authored by Sanjay Padhi that describes how to calculate the errors due to the PDF fits and how to average over the different PDF models is here:

http://hepuser.ucsd.edu/twiki2/pub/UCSDTier2/WorkForAlex/cmsnoteSMXsec.pdf

Description of Scripts

When you look at the various scripts that were written for this, you may wonder why there are so many. There are two reasons for this:

1) I started this analysis with a few scripts already written for me. There is some redundancy between these and the ones I have written.
2) You will be able to check the validity of the calculations at each step.

Reading downward on the following table gives the chronological order that these scripts are run. I highly recommend starting out where the green arrow begins. The only reason I include the steps before this is you may find some useful code not found later on.

All of the python scripts input/output some type of text files. All scripts (except the .sh scripts) are run in python. These scripts along with the directory structure that are referenced by these scripts are in a tarball called "generalXSec_mcfm.tar.gz"

Running ~25K processes through MCFM takes a few days to be processed in the cluster. The scripts that I have written can take up to a few minutes to run once all the cross sections have been calculated. I believe I have automated the whole process from start to finish so that you will be able to calculate the cross sections at arbitrary CM energies without too much undue pain or frustration.

*SIDENOTE: the 'up' and 'dn' in the process files that MCFM reads refer to the simultaneous up and downward variations of the factorization and renormalization scales by a factor of 2 and ½, respectively. The simultaneity of the variations is the agreed upon practice in the CMS group.

Script	Input	Output	Comments
adjust adjust8TeV	7TeV old process files	Process files w/ mcfm version updated	• Adjust keeps energy at 7TeV, Adjust8TeV changes this to 8TeV • Files are configured for MSTW only
adjustCteq66 adjustNNPDF	Outputs of the above step	Same files as above, but configured to NNPDF & to CTEQ	• Unfortunately, the CTEQ, NNPDF, and MSTW sets are configured incorrectly at this point. grandLoop* fixes this
doit doit8TeV xSecCalc_CTEQ xSecCalc_MSTW xSecCalc_NNPDF	CTEQ, NNPDF, MSTW new process files	Cross section for each process	• Cross section for just the nominal fit value
grandLoopCTEQ grandLoopMSTW grandLoopNNPDF	Outputs of the first step	Updated process files for CTEQ, MSTW, NNPDF for each of the fit variations	• Outputs are named the same (i.e. organization must be done at the directory level)
If you want to organize by name of the text file rather than at the directory level, change the naming convention of the outputs by using the bash command and running over all the necessary files: for f in `ls`; do mv $f `echo $f | sed 's/.DAT/_7TeV_CTEQ.DAT/'`; done			
send.sh receive.sh			• Calculate 24,864 cross sections in the cluster
finalDumper	Output from above	Text file with the cross section information saved	
finalError	Output from above	Text file with the error from the PDF fit	• Converts all results to units of pb
finalCross	Output from above	Averaged cross sections with associated error due to the PDF fit	

Setting up MCFM & LHAPDF

To set up LHAPDF

There are two configurations you can call from to set up your PDF files: .LHpdf and .LHgrid. The former calculates PDFs on-the-fly, the latter has a pre-calculated chart. The library we want to use is .LHgrid because it will allow for quicker calculations of the cross sections in our case.

1) ./Install
2) make
3) make install
4) inside bin: mkdir Pdfsets
5) inside Pdfsets: lhapdf-getdata --list

To set up MCFM

1) src/User/mdata.f specifies which ewk scheme to use (+-1,0,2,3)
2) ./Install
3) In the makefile, change the path of LHAPDFLIB to point to lib/ in the LHAPDF directory from above
4) In the makefile, change PDFROUTINES = NATIVE to PDFROUTINES = LHAPDF

*make sure the versions of MCFM & LHAPDF are compatible with one another

To properly use the LHAPDF library, you need to set global variables so that the mcfmEwkScheme will call the correct PDF data:

```
export LHAPDFSYS=/path/lhapdf
export PATH=${PATH}:${LHAPDFSYS}/bin
export LD_LIBRARY_PATH=${LD_LIBRARY_PATH}:${LHAPDFSYS}/lib
```

If you don't properly set up the LHAPDF library, mcfmScheme will pull data from some generic libraries that don't allow the input parameters of the pdf function to be varied: so make sure mcfmScheme pulls data correctly from the LHAPDF library. You can check this by looking at the output file of MCFM.