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Standard Model Cross Sections for CMS at 8 TeV.

Contributors: Piergiulio Lenzi, Sanjay Padhi, Guillelmo Gomez Ceballos Retuerto, Frank Wuerthwein

WARNING: THE NUMBERS ARE THUS PRELIMINARY AND TO BE USED AT OWN RISK

Introduction

This page is a collection of cross sections for Standard Model processes to be used in the CMS analyses. The results have been determined by either running published code or by quoting publications available in the literature. Emphasis has been put everywhere to have a consistent set of numbers (in terms of input parameter settings), and also as much as possible consistent with the current Monte Carlo production in CMS.
In what follows you will find, list of processes aside, explanations on how the cross-sections and the associated theory errors have been determined, as well as guidelines on how to normalize your favorite SM backgrounds. This is a working document and changes have to be expected to appear, so please check back often.
For any general interest question or comment concerning the content of the following page, please use the CMS generator HyperNews: hn-cms-generators@cernSPAMNOT.ch

Central values and errors

Cross sections have been calculated by using the most appropriate and up to date public codes for the relevant processes. Where more recent analytical calculations are available in the literature, they are also quoted (when unambiguously comparable to our estimates). All numbers have been estimated/collected for proton-proton collisions at a centre of mass energy of 8 TeV. The main input parameter settings for performing the calculations are as follows:

- PDFs: CTEQ6M
- W mass: 80.398 GeV
- W width: 2.141 GeV
- Z mass: 91.1876 GeV
- Z width: 2.4952 GeV
- top mass: 172.5 GeV
- b mass: 4.8 GeV
- c mass: 1.27 GeV
- alpha_QED = 0.007297352

The codes (and respective versions) that have been used here are:

- MCFM **6.1**
- FEWZ

The theory error breakdown in the following table contains different contributions. They are, in detail:

- Scale uncertainties: these are determined by varying both factorisation and renormalisation scale by a factor 2 up and down. This is done by convention, and also by convention the two scales are taken as fully correlated.
- PDF uncertainties: in the simplest approach they are taken as the combination of the variations induced by the 20x2 fluctuations in the NLO PDF parameters. For uniformity with the CMS MC production, only the CTE6M are considered for now. The combination is such that what is reported corresponds to sqrt(Sum_i(max(abs(x_i_up-x),abs(x_i_down-x)))^2), where the sum spans the 20 parameters, x is the reference cross-section and x_i_up and x_i_down the induced up and down variations corresponding to the i-th parameter, respectively.

How to normalise your favourite process' cross-sections

The numbers presented in this page may serve to calculate simple K-factors (defined as inclusive N(^k)LO/LO) for your analysis. However, we would like to point out that this may sometime be a very inaccurate procedure, because a) cross-section calculations always depend on the applied phase space cuts and input settings and b) K-factors can be far from flat in the phase space. Here some hints on how to be sure to best normalize your background cross-sections to better calculations:

- Normalization only makes sense for distributions obtained in the same way, so with the same set of cuts. If this is not the case, because it was not possible to generate events and perform the N(^k)LO calculations in the same conditions, one should check the K-factor is reasonably stable for the different set of cuts, likely by using different codes. In the present page we have tried to produce a set of numbers as much as possible consistent with the current MC production in CMS.
- Applying an inclusive constant K factor to your background implicitly assumes that this is not sensitive to the details of your analysis. When this is not obvious, a check should be made by running the N(^k)LO in a configuration where similar cuts of your analysis are mimicked, and quote possible (small) differences as further systematic error on your background.
- If you are selecting your phase space in a region very sensitive to N(^k)LO effect, typically when cutting/checking distributions of extra jet productions, one should recalculate a K-factor only for the region of phase space one is selecting. Another possibility is to perform an event reweighting in a binned D-dimensional region at generator level (most of the time D=1) where every events in a bin gets a weight N(^k)LO/LO depending on the bin. The possible issue is that selected events get very high weights that need therefore to be propagated in the final systematic error.

A special case comes when dealing with ME-PS matched generations (say MadGraph, ALPGEN, Sherpa, ...) up to a certain QCD order. In this case there is less consensus on how a normalization should be performed, since a matched computation already includes higher LO real corrections (higher than NLO, often). The procedure that we suggest to adopt in CMS is to perform a rescaling to N(^k)LO pretty much like it is described above, using as "LO" cross section for the matched sample the sum of the cross-sections of all individual matched fixed-order sub-samples. Please notice this implies that the matching efficiencies should have been correctly included. This procedure implicitly assumes that all fixed -order contributions scale in the same way when going to a complete calculation, which is likely not true. This mistake should be absorbed as an error of the matching itself.

List of processes

Here you can find the first list of processes that have been evaluated. Everywhere, unless otherwise specified, the input parameter settings used are the ones above specified. The table specifies the various conditions of the calculation, the final state considered, and presents the results with the associated best estimate for the theory error, as discussed above.
In what follows, unless otherwise indicated, charge conjugation is implicit. The symbol a (a*) indicates everywhere a (virtual) photon.

56.0

Process	Generator/Source	Phase space cuts	Order	Final state	Cross-section (pb)	Error (pb) scales (+/- PDF)	Comments
W+	FEWZ 3.1	--	NNLO	W->lv, l=m	7213.4	+45.3 -21.3 (± 241.3)	Inclusive W production, BR(W->lv) included, l=m PDF error also includes alphas, muF=muR=mw
W-	FEWZ 3.1	--	NNLO	W->lv,	5074.7	+33.8	Inclusive W

				l=m		-18.3(±188.3)	production, BR(W->lv) included, l=m PDF error also includes alphas, muF=muR=mw
Total W	FEWZ 3.1	--	NNLO	W->lv, l=m	12234.4	+79.0 -39.7 (±414.7)	Inclusive W production, BR(W->lv) included, l=m, PDF error also includes alphas, muF=muR=mw
Z/a* (20)	FEWZ 3.1	m(ll)>20 GeV	NNLO	Z -> mm	1966.7	+19.8 -13.7 (± 87.7)	Inclusive Z production Z->ll, l=m; PDF errors also includes alphas, muF=muR=mz
Z/a* (50)	FEWZ 3.1	m(ll)>50 GeV	NNLO	Z -> mm	1177.3	+5.9 -3.6 (±38.8)	Inclusive Z production, Z->ll, l=m; PDF errors also includes alphas, muF=muR=mz
Z/a* (60-120)	FEWZ 3.1	60 < m(ll) < 120 GeV	NNLO	Z -> mm	1129.2	+5.5 -2.6 (±37.5)	Inclusive Z production, Z->ll, l=m; PDF errors also includes alphas, muF=muR=mz
ttbar	http://arxiv.org/pdf/1303.6254.pdf	--	NNLO	Inclusive	245.8	+2.5%, -3.4% (±2.6)	Top mass: m(top)=173.3GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
W+cbar	MCFM	--	NLO	Inclusive	2423.5		Massive c quark. Inclusive Wc production and inclusive W decay
W-c	MCFM	--	NLO	Inclusive	2624.6		Massive c quark. Inclusive Wc production and inclusive W decay
Total Wc	MCFM	--	NLO	Inclusive	5048.1		Massive c quark. Inclusive Wc production and inclusive W decay
Total Wb bbar	aMC@NLO	--	NLO	Inclusive	377.4	+19.5% -16.8%	Massive b quark. Inclusive Wbb
							production
Z/a*b bbar	MCFM	m(ll) > 50 GeV	LO	Inclusive	76.75		Massive b quark - Inclusive
W+tbar	Kidonakis	--	approx. NNLO	Inclusive	11.1	±0.3 (±0.7)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
W-t	Kidonakis	--	approx. NNLO	Inclusive	11.1	±0.3 (±0.7)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
Total tW	Kidonakis	--	approx. NNLO	Inclusive	22.2	±0.6 (±1.4)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
t+ (s-channel)	Kidonakis	--	approx. NNLO	Inclusive	3.79	±0.07 (±0.13)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
t- (s-channel)	Kidonakis	--	approx. NNLO	Inclusive	1.76	±0.01 (±0.08)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
Total t (s-channel)	Kidonakis	--	approx. NNLO	Inclusive	5.55	±0.08 (±0.21)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
t+ (t-channel)	Kidonakis	--	approx. NNLO	Inclusive	56.4	+2.1 -0.3 (±1.1)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
t- (t-channel)	Kidonakis	--	approx. NNLO	Inclusive	30.7	±0.7 (+0.9 -1.1)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt,

							PDF: MSTW2008 NNLO
Total t (t-channel)	Kidonakis	--	approx. NNLO	Inclusive	87.1	+2.8-1.0 (+2.0-2.2)	Top mass: m(top)=173GeV, Default scales: muF=muR=mt, PDF: MSTW2008 NNLO
Total WZ/a*	MCFM	m(ll) > 12 GeV	NLO	Inclusive	33.21 (CTEQ), 33.85 (MSTW), 33.72 (NNPDF)		---
ttbarW	MCFM	---	NLO	Inclusive	0.232	±0.067 (±PDF error:0.03)	arXiv:1204.5678
ttbarZ	NLO	--	NLO	Inclusive	0.2057	Scale error: +0.019, -0.024	arXiv:1208.2665
tqZ; q!=b	aMC@NLO	mll > 50 GeV	NLO	Z decays to leptons	0.02450	Scale error:+3.3% -2.6%	--
tbZ	aMC@NLO	mll > 50	NLO	Z decays to leptons	0.0114	Scale error: +19.4%, -15.1%	--
WWW	aMC@NLO	--	NLO	inclusive	8.058e-02	+4.7% -3.9%	--
WWZ	aMC@NLO	--	NLO	Inclusive	5.795e-02	+5.6% -4.6%	--
WZZ	aMC@NLO	--	NLO	Inclusive	1.968e-02	+6.0% -4.9%	--
ZZZ	aMC@NLO	--	NLO	Inclusive	5.527e-03	+2.7% -2.4%	--
4 TOPs	aMC@NLO	--	NLO	Inclusive	9.144e-04 +- 4.5e-06 pb	+36.3%, -27.0%	--
W+ W-	MCFM 6.6	0	NLO	W,W > ve	56.0	± 2.3 (± 2.0)	
W+ Z	MCFM 6.6	m(ll)Z > 12 GeV	NLO	W > uv, Z > ee	21.0	± 0.8 (± 0.7)	
W+ Z	MCFM 6.6	m(ll)Z > 40 GeV	NLO	W > uv, Z > ee	15.1	± 0.8 (± 0.5)	
W- Z	MCFM 6.6	m(ll)Z > 12 GeV	NLO	W > uv, Z > ee	12.6	± 0.5 (± 0.6)	
W- Z	MCFM 6.6	m(ll)Z > 40 GeV	NLO	W > uv, Z > ee	8.6	± 0.4 (± 0.4)	
Z/a* Z/a*	MCFM 6.6	m(ll)Z > 12 GeV	NLO	Z > uu, Z > ee	17.0	± 0.5 (± 0.5)	
Z/a* Z/a*	MCFM 6.6	m(ll)Z > 40 GeV	NLO	Z > uu, Z > ee	8.2	± 0.3 (± 0.3)	
t tbar	MCFM 6.6	0	NLO	t,tbar > veb	213.5	± 27.9 (± 17.0)	Dynamic scale: HT
t tbar	MCFM 6.6	0	NLO	t,tbar > veb	248.9	± 31.9 (± 20.0)	Dynamic scale: sqrt(M^2+pt(345)^2)

Future work

- Not included in the previous table, that we might/should consider including in a future, are processes like aW, aZ, a, aa. Maybe also some QCD and Higgs?
- We might consider producing root files of parton level events, where possible and for some specific process, in such a way that recalculating K-factors with different cuts, or setting in place a reweighing procedure, will be significantly simplified
- We might consider providing some of the cross sections calculated with MSTW
- We might consider adding the numbers for another centre of mass energy in the long run, and/or the energy dependence of the cross-sections

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-- SanjayPadhi - 18-Dec-2011