MadGraph5_aMC@NLO

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- Several outputs are possible, both as standalone (to be used in native or independent applications) or as a full-fledged codes that generate events (MadEvent at LO, aMC@NLO at NLO).
- Full **BSM** support at LO, starts at NLO.







- Mass production in MadGraph5
- •aMC@NLO
- Conclusion







use in Full Sim -> minimize number of events

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•Idea: use one (un)weighted generations and associate additional weights from different hypothesis. $|M|^2$

•Can be run on the flight inside MG5





Remark



- •This is NOT a 1D histogram re-weighting
 - This is a Fully differential re-weighting
- •This assume that the Phase-Space is the same
 - Bad for scan over mass
 - → Good for scan over coupling
- Output in LHEF version 3 format

Non Definite positive





Idea:

• Compute them separately

• Have a new syntax for such selection (NP^2=)

Status:

• Release this week







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9





• Why automation?

- Time: Don't have to wait for a theorist!
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• Why automation?

- Time: Don't have to wait for a theorist!
- ➡Robust: Easier to test, to trust
- •Why NLO?
 - ➡Reliable prediction of the total rate
 - Reduction of the theoretical uncertainty
- •Why matched to the PS?
 - Matching cure some fix-order ill behaved observables





•Is it Really automatic?









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MCNET School 2014





•launch the code [./bin/mg5_aMC]

→Exactly like MG5 !!!

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● ⊖ ⊖		Terminal — P	ython - 201x58				RN N
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WELCOME to MADGRAPH 5	:						
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 VERSION 2.0.0.beta3 2013-02-14 							
 The MadGraph Development Team - Please visit 	us at •						
 https://server@6.fynu.ucl.ac.be/projects/madg 	raph +						
a Turn the let fas in line hele							
 Type 'tutorial' to learn how MGS works 							
 Type 'tutorial aMCatNLO' to learn how aMCgNLO 	works *						
 Type 'tutorial MadLoop' to learn how MadLoop 	works *						
*							
load MG5 configuration from /Users/omatt/.mg5/mg5	configuration.txt						
load MG5 configuration from input/mg5_configuratio	n.txt						
set lhapdf to lhapdf-config	only/fastiat/big/fastia	- readia					
Loading default model: sm	ours/rastjet/util/rastje	c-contrag					
INFO: load particles							
INFO: load vertices							
INFO: Restrict model sm with file models/sm/restri INFO: Run "set stdout level DEBNG" before import f	loc_default.dat .						
INFO: Change particles name to pass to MG5 convent	ion						
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MG5>	a ve vii vt e- iiu- ve- v	n- 4(- 6+ mu+ t D t- D- 2	w+ n w- ta- ta+				





You can enter ANY process! →add [QCD] for NLO functionalities generate $p p > t t \sim [QCD]$ generate p p > e+ e- mu+ mu- [QCD]generate p p > w + w - j j [QCD]MG5>generate p p > t t~ [QCD] Switching from interface MG5 to aMC@NLO The default sm model does not allow to generate loop processes. MG5 now loads 'loop_sm' instead. import model loop sm INF0: load particles INFO: load vertices INFO: Restrict model loop_sm with file models/loop_sm/restrict_default.dat . INFO: Run "set stdout_level DEBUG" before import for more information. INFO: Change particles name to pass to MG5 convention Kept definitions of multiparticles l- / j / vl / l+ / p / vl~ unchanged Defined multiparticle all = g gh gh~ d u s c d~ u~ s~ c~ a ve vm vt e- mu- ve~ vm~ vt~ e+ mu+ b t b~ t~ z w+ h w- ta- ta+ INFO: Generating FKS-subtracted matrix elements for born process: g g > t t~ [QCD] INFO: Generating FKS-subtracted matrix elements for born process: u u~ > t t~ [QCD] INFO: Generating FKS-subtracted matrix elements for born process: c c~ > t t~ [QCD INFO: Generating FKS-subtracted matrix elements for born process: d d~ > t t~ [QCD INFO: Generating FKS-subtracted matrix elements for born process: s s \sim > t t \sim [QCD INFO: Generating FKS-subtracted matrix elements for born process: u~ u > t t~ [QCD INFO: Generating FKS-subtracted matrix elements for born process: c~ c > t t~ [QCD INFO: Generating FKS-subtracted matrix elements for born process: d~ d > t t~ [QCD INFO: Generating FKS-subtracted matrix elements for born process: s~ s > t t~ [QCD] INFO: Generating virtual matrix elements using MadLoop: INFO: Generating virtual matrix element with MadLoop for process: g g > t t~ [QCD] INFO: Generating virtual matrix element with MadLoop for process: u u~ > t t~ [QCD] INFO: Generating virtual matrix element with MadLoop for process: c c~ > t t~ [QCD] INFO: Generating virtual matrix element with MadLoop for process: d d~ > t t~ [QCD INFO: Generating virtual matrix element with MadLoop for process: s s~ > t t~ [QCD INFO: Generating virtual matrix element with MadLoop for process: u~ u > t t~ [QCD INFO: Generating virtual matrix element with MadLoop for process: c~ c > t t~ [QCD] INFO: Generating virtual matrix element with MadLoop for process: d~ d > t t~ [QCD] INFO: Generating virtual matrix element with MadLoop for process: s~ s > t t~ [QCD] INFO: Generated 9 subprocesses with 136 real emission diagrams, 11 born diagrams and 157 virtual diagrams aMC@NL0>





Create your aMC@NLO code
output PATH
Run it:
launch [PATH]





Create your aMC@NLO code output PATH

•Run it:

aMC@NLO>launch

INF0:	***************************************	*******
*		*
*	WELCOME to MADGRAPH 5	*
*	a M C @ N L O	*
*		*
*	* *	*
*	* ** *	*
*	* * * * 5 * * * *	*
*	* ** *	*
*	* *	*
*		*
*	VERSION 2.0.0.beta3 2013-02-14	*
*		*
*	The MadGraph Development Team - Please visit us at	*
*	http://amcatnlo.cern.ch	*
*		*
*	Type 'help' for in-line help.	*
*		*

```
***********************
```

INFO: load configuration from /Users/omatt/.mg5/mg5_configuration.txt INFO: load configuration from /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNL0_loop_sm_0/Cards/amcatnlo_configuration.txt INFO: load configuration from /Users/omatt/MadGraph5_v2_0_0_beta3/input/mg5_configuration.txt INFO: load configuration from /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNL0_loop_sm_0/Cards/amcatnlo_configuration.txt set group_subprocesses Auto set ignore_six_quark_processes False set loop_optimized_output True set gauge unitary set complex_mass_scheme False launch auto Which programs do you want to run? 0 / auto : NLO event generation and -if cards exist- shower and madspin. 1 / NLO : Fixed order NLO calculation (no event generation). 2 / aMC@NL0 : NLO event generation (include running the shower). 3 / noshower : NLO event generation (without running the shower). : Fixed order LO calculation (no event generation). 4 / LO 5 / aMC@LO : LO event generation (include running the shower). 6 / noshowerLO : LO event generation (without running the shower). +10 / +madspin : Add decays with MadSpin (before the shower). [0, auto, 1, NLO, 2, aMC@NLO, 12, aMC@NLO+madspin, 3, ...][60s to answer] >





Create your aMC@NLO code
output PATH
Run it:
launch [PATH]

First Question:

The following switches determine which operations are executed: 1 Perturbative order of the calculation: order=NL0 2 Fixed order (no event generation and no MC@[N]LO matching): fixed_order=OFF 3 Shower the generated events: shower=ON 4 Decay particles with the MadSpin module: madspin=OFF Either type the switch number (1 to 4) to change its default setting, or set any switch explicitly (e.g. type 'order=L0' at the prompt) Type '0', 'auto', 'done' or just press enter when you are done. [0/2, 1, 2, 3, 4, auto, done, order=L0, order=NL0, ...][60s to answer] >[timer stopped]





Create your aMC@NLO code
output PATH
Run it:
launch [PATH]

Second Question:

INF0: will run in mode: aMC@NL0
Do you want to edit a card (press enter to bypass editing)?
1 / param : param_card.dat
2 / run : run_card.dat
3 / madspin : madspin_card.dat
4 / shower : shower_card.dat
you can also
- enter the path to a valid card or banner.
- use the 'set' command to modify a parameter directly.
The set option works only for param_card and run_card.
Type 'help set' for more information on this command.
[0, done, 1, param, 2, run, 3, madspin, 4, enter path, ...][60s to answer]





INFO: For gauge cancellation, the width of 't' has been set to zero. INFO: Using built-in libraries for PDFs INFO: Compiling source... INFO: ...done, continuing with P* directories INFO: Compiling directories... INFO: Compiling on 8 cores Compiling P0_gg_ttx... INFO: Compiling P0_uux_ttx... INFO: INFO: Compiling P0_uxu_ttx... P0 uux ttx done. INF0: INFO: P0_uxu_ttx done. P0_gg_ttx done. INFO: INFO: Checking test output: INF0: P0_gg_ttx INFO: Result for test_ME: INFO: Passed. Result for test MC: INFO: INF0: Passed. Result for check_poles: INFO: Poles successfully cancel for 20 points over 20 (tolerance=1.0e-05) INFO: INF0: P0_uux_ttx Result for test_ME: INFO: INF0: Passed. INF0: Result for test MC: INFO: Passed. Result for check_poles: INFO: Poles successfully cancel for 20 points over 20 (tolerance=1.0e-05) INFO: INFO: P0_uxu_ttx Result for test_ME: INFO: INFO: Passed. Result for test_MC: INF0: INFO: Passed. Result for check_poles: INFO: INF0: Poles successfully cancel for 20 points over 20 (tolerance=1.0e-05)

Compilation

Check Poles cancelation





INFO: Starting run INFO: Using 8 cores INFO: Cleaning previous results INFO: Doing NLO matched to parton shower INFO: Setting up grid INFO: Idle: 2, Running: 8, Completed: 0 [current time: 22h58] INFO: Idle: 1, Running: 8, Completed: 1 [7.1s] INFO: Idle: 0, Running: 8, Completed: 2 [7.2s] INFO: Idle: 0, Running: 7, Completed: 3 [13.6s] INF0: Doing reweight INFO: Idle: 0, Running: 6, Completed: 4 [21s] INFO: Idle: 0, Running: 5, Completed: 5 [21s] Idle: 0, Running: 4, Completed: 6 [current time: 23h13] INF0: INFO: Idle: 0, Running: 4, Completed: 6 [1m 5s] Idle: 0, Running: 3, Completed: 7 [0.51s] INF0: INFO: Idle: 0, Running: 3, Completed: 7 [1m 5s] Idle: 0, Running: 2, Completed: 8 [0.53s] INF0: INFO: Idle: 0, Running: 2, Completed: 8 [6m 38s] INFO: Idle: 0, Running: 1, Completed: 9 [6m 43s] INFO: Idle: 0, Running: 1, Completed: 9 [1.6s] INFO: Idle: 0, Running: 0, Completed: 10 [6m 52s] INFO: Idle: 0, Running: 0, Completed: 10 [1.8s] INFO: Determining the number of unweighted events per channel INFO: Collecting events Intermediate results: INF0: Random seed: 33 Summary: Total cross-section: 1.775e+02 +- 2.1e+00 pb Total abs(cross-section): 2.633e+02 +- 1.6e+00 pb Process $p p > t t \sim [QCD]$ Run at p-p collider (6500 + 6500 GeV) Total cross-section: 6.843e+02 +- 4.1e+00 pb INFO: Computing upper envelope INFO: Idle: 2, Running: 8, Completed: 0 [current time: 23h05] Ren. and fac. scale uncertainty: +10.4% -12.1% INFO: Idle: 1, Running: 8, Completed: 1 [8.7s] Number of events generated: 10000 INFO: Idle: 0, Running: 8, Completed: 2 [8.9s] Parter HERWIG6 INFO: Idle: 0, Running: 7, Completed: 3 [16.3s] INFO: Idle: 0, Running: 6, Completed: 4 [25.7s action of negative weights. INFO: Idle: 0, Running: 5, Completed: 5 [25.7s] Total running time : 1m 41s INFO: Idle: 0, Running: 4, Completed: 6 [1m 16s] INFO: Idle: 0, Running: 3, Completed: 7 [1m 18s INFO: Idle: 0, Running: 2, Completed: 8 [6m 38s INFO: Idle: 0, Running: 1, Completed: 9 [6m 46s INFO: Idle: 0, Running: 0, Completed: 10 [7m 4s] INFO: Updating the number of unweighted events per channel Intermediate results: Random seed: 33 Total cross-section: 1.770e+02 +- 1.7e+00 pb Total abs(cross-section): 2.630e+02 +- 1.2e+00 pb INFO: Generating events INFO: Idle: 2, Running: 8, Completed: 0 [current time: 23h12] INFO: Idle: 1, Running: 8, Completed: 1 [0.52s] INFO: Idle: 0, Running: 8, Completed: 2 [0.71s] INFO: Idle: 0, Running: 7, Completed: 3 [1.7s] INFO: Idle: 0, Running: 6, Completed: 4 [1.8s] INFO: Idle: 0, Running: 5, Completed: 5 [3.9s] INFO: Idle: 0, Running: 4, Completed: 6 [14.5s] INFO: Idle: 0, Running: 3, Completed: 7 [19.7s INFO: Idle: 0, Running: 2, Completed: 8 [21.4s] INFO: Idle: 0, Running: 1, Completed: 9 [31.7s] INFO: Idle: 0, Running: 0, Completed: 10 [36.4s] INFO: Doing reweight



1	Process	Syntax		Cross se	ction (ph)	
Th	ne vector basans +jet		LO 13 Tr	N .	NLO 13 T	2V
c.1	$pp \rightarrow W^+W^-W^{\pm}(4f)$	pp>x+x-xps	$1.307 \pm 0.003 \cdot 10^{-1}$	+0.05 +0.05	$2.109 \pm 0.006 \cdot 10^{-1}$	-1.1% -1.4
6.2	$pp \rightarrow ZW^+W^-$ (4f)	9 9 2 8 W W-	$9.658 \pm 0.065 \cdot 10^{-2}$	+248 +478	$1.679 \pm 0.005 - 10^{-1}$	+258 +12
c.3	$pp \rightarrow ZZW^{\pm}$	p p ⊨ z z vpa	$2.996 \pm 0.036 \cdot 10^{-2}$	+1.05 +5.05	$5.550 \pm 0.020 \cdot 10^{-2}$	+6.85 +13
c.4	$pp \rightarrow ZZZ$		$1.085 \pm 0.002 \cdot 10^{-2}$	138 138	$1.417 \pm 0.005 - 10^{-2}$	191 11
6.5	$pp \rightarrow \gamma W^+W^-(4l)$	p p > a u+ u-	$1.427 \pm 0.011 - 10^{-1}$	+1.85 +5.55	$2.581 \pm 0.008 - 10^{-1}$	-13 -13
c.6	pp→22₩**	p p ≻ a a vpa	2.681 ± 0.007 · 10 ⁻²	+4.45 +1.05	$8.251 \pm 0.032 \cdot 10^{-2}$	+145 +14
e.7	pp->->2W1	p p > a z vpa	$4.994 \pm 0.011 \cdot 10^{-2}$	1945 1145	$1.117 \pm 0.004 - 10^{-1}$	123 113
6.8	pp-+>ZZ	pp>azz	$2.320 \pm 0.005 \cdot 10^{-2}$	+2.05 +1.05	$3.118 \pm 0.012 - 10^{-2}$	+2.8% +1.8
c.9	PP-+772	pp>***	$3.078 \pm 0.007 \cdot 10^{-3}$	+6.05 +1.05	$4.634 \pm 0.020 - 10^{-5}$	1445 112
e.10	PP -> 777	****	$1.269 \pm 0.063 \cdot 10^{-2}$	20.0% +2.0%	$3.441 \pm 0.012 \cdot 10^{-8}$	+11.8% +1.
c.11	$pp \rightarrow W^+W^-W^+j$ (4f)	pp>v+v-vpsj	$9.167 \pm 0.039 \cdot 10^{-2}$	+12.03 +1.03	$1.197\pm0.004\cdot10^{-1}$	+5.9% +1.0
c.12*	$pp \rightarrow ZW^+W^-j$ (4f)	p p > z ++ +- j	$8.340 \pm 0.039 \cdot 10^{-2}$	+11.4% +1.4%	$1.096 \pm 0.003 \cdot 10^{-1}$	+1.5% +1.8
e.13*	$pp \rightarrow ZZW^{+}j$	p p > a a vpa j	$2.810 \pm 0.004 \cdot 10^{-2}$	+12.19 +139	$2.660 \pm 0.013 \cdot 10^{-2}$	+185 +13
6.14"	$pp \rightarrow ZZZj$	pp>zzzj	$4.823\pm0.011\cdot10^{-3}$	+14.25 +1.45	$6.341 \pm 0.025 \cdot 10^{-3}$	+4175 +1.4
e.15*	$pp \rightarrow \gamma W^+W^- j$ (4f)	p p > a w* w- 1	$1.182 \pm 0.004 \cdot 10^{-1}$	10.65 12.65	$1.233 \pm 0.004 - 10^3$	1875 110
6.16	$pp \rightarrow \gamma\gamma W^{\pm}j$	p p > a a ups j	$4.107 \pm 0.015 \cdot 10^{-2}$	+11.8% +0.8%	$5.807 \pm 0.023 - 10^{-2}$	10.8% 10.3
e.17*	pp->->ZW [±] j	p p ≥ a z vpn j	$5.833 \pm 0.023 \cdot 10^{-9}$	+54.4% +0.7%	$7.764 \pm 0.025 - 10^{-5}$	+8.15 =0.8
e.18*	pp-3-5ZZj	PP>***1	$9.995 \pm 0.013 \cdot 10^{-3}$	+12.55 +1.25	$1.371 \pm 0.005 \cdot 10^{-8}$	+5.85 +5.8
e.19*	pp-aggZj	pp>aazj	$1.372 \pm 0.063 \cdot 10^{-9}$	+14.9% +1.0%	$2.051 \pm 0.011 \cdot 10^{-9}$	state state
0.397	PP-+2221	pp>sssj	$1.031 \pm 0.006 \cdot 10^{-2}$	+14.25 +0.95	$2.020 \pm 0.008 - 10^{-5}$	+12.8% +0.

P	Process Systax			Сгонь нек	rties (pb)	
Boary	y quarks and jets		LO 1 TeV		NLO 1 TeV	
1.1	$e^+e^- \rightarrow jj$	** *- > j j	$6.223 \pm 0.005 \cdot 10^{-1}$	+0.0%	$6.389\pm0.013\cdot10^{-1}$	+0.25
2	$e^+e^- \rightarrow jjj$	** ** >]]]]	$3.401 \pm 0.002 - 10^{-1}$	+9.8%	$3.166 \pm 0.019 - 10^{-1}$	+0.2
.8	$e^+e^- \rightarrow jjjjj$	** ** > 3 3 3 3	$1.047 \pm 0.001 - 10^{-1}$	+20.0%	$1.090 \pm 0.006 - 10^{-1}$	+0.0
4	$e^+e^- \rightarrow jjjjjj$	** ** > ; ; ; ; ; ;	$2.211 \pm 0.006 - 10^{-2}$	+38.4%	$2.771 \pm 0.021 \cdot 10^{-2}$	+4.4
.5	$e^+e^- \rightarrow t\bar{t}$	e+ e+ > t t+	$1.662 \pm 0.002 \cdot 10^{-1}$	10.0%	$1.745\pm0.006\cdot10^{-1}$	10.4
.6	$c^+c^- \rightarrow t\bar{t}j$	e* e- > t t~ j	$4.813 \pm 0.005 - 10^{-2}$	12.8%	$5.276 \pm 0.022 \cdot 10^{-2}$	118
.77	$e^+e^- \rightarrow t\bar{t}jj$	** ** > t t~ j j	$8.614 \pm 0.009 - 10^{-3}$	+19.4%	$1.094 \pm 0.005 - 10^{-5}$	+5.0
87	$e^+e^- \rightarrow t\bar{t}jjj$	** ** > t t~ j j j	$1.044 \pm 0.002 \cdot 10^{-3}$	+30.8%	$1.546 \pm 0.010 - 10^{-3}$	+10.4
97	$e^+e^- \rightarrow t\bar{t}t\bar{t}$	et et > t t~ t t~	$6.456\pm0.005\cdot10^{-7}$	+19.1%	$1.221 \pm 0.005 - 10^{-6}$	+13.
.10*	$e^+e^- \rightarrow t\bar{t}t\bar{t}j$	## #* > t t~ t t~ j	$2.719\pm0.005\cdot10^{-8}$	+29.9%	$5.338 \pm 0.027\cdot 10^{-8}$	+18.1
.11	$e^+e^- \rightarrow b\bar{b}$ (4f)	e+ e+ > b b+	$9.198\pm0.004\cdot10^{-2}$	+0.8%	$9.242\pm0.031\cdot10^{-2}$	+6.8
.12	$e^+e^- \rightarrow b\bar{b}j$ (42)	e+ e- > b b~ j	$5.029 \pm 0.003 \cdot 10^{-2}$	19.4%	$4.826\pm0.026\cdot10^{-2}$	10.2
.137	$e^+e^- \rightarrow b\bar{b}j\bar{j}$ (4f)	e+ e- > b b~ j j	$1.621 \pm 0.001 - 10^{-2}$	120.0%	$1.817 \pm 0.009 - 10^{-2}$	108
.14*	$c^+c^- \rightarrow b\bar{b}jjj$ (4f)	e* e- > b b~ j j j	$3.641 \pm 0.009 - 10^{-3}$	101.4%	$4.936 \pm 0.038 \cdot 10^{-3}$	14.0
117	$e^+e^- \rightarrow b\bar{b}b\bar{b}$ (4f)	e* e* > b b~ b b~	$1.644 \pm 0.063 - 10^{-4}$	+19.9%	$3.601 \pm 0.017 \cdot 10^{-4}$	+15.
.16*	$e^+e^- \rightarrow hbhij$ (4f)	e* e* > b b~ b b~ j	$7.660\pm0.022\cdot10^{-5}$	+31.3%	$1.537\pm0.011\cdot10^{-4}$	+111
17*	$e^+e^- \rightarrow t\bar{t}b\bar{b}$ (4f)	e# e= > t t v b bv	$1.819 \pm 0.003 \cdot 10^{-4}$	+18.5%	$2.923 \pm 0.011 \cdot 10^{-4}$	+8.5
187	\$"\$"	at as hit to block by t	4.045 ± 0.011 - 10-5	+ 30.5%	7.049 ± 0.052 - 10-5	+15

	Process	Syntax			tion (ph)	
10,	gs pair production		LO 13 %	N .	NLO 13 T	W.
6.1	$pp \rightarrow HH$ (Loop improved)	pp>bb	$1.772 \pm 0.006 \cdot 10^{-2}$	-14.25 -11.25	$2.763 \pm 0.008 \cdot 10^{-2}$	+11.03 +1.13
h.2	$\mu\mu \rightarrow HM_{JJ}$ (VBP)	pp>hhjj\$6 w* w- z	$6.303 \pm 0.019 \cdot 10^{-4}$	110	$6.820 \pm 0.026 \cdot 10^{-6}$	-1.05 -1.75
b.3	$pp \rightarrow NMW^{-1}$	p p > h h upa	4.303 ± 0.005 - 10 ⁻¹	-1.25 -1.55	$5.802 \pm 0.014 \cdot 10^{-8}$	-128 -148
h.4*	$pp \rightarrow HMW^+j$	p p ≻ h h vpn j	$1.922 \pm 0.002 \cdot 10^{-11}$		$2.218 \pm 0.009 \cdot 10^{-8}$	1275 1245
b.5*	$pp \rightarrow NMW^{-1}\gamma$	p p > h h vpn h	$1.957 \pm 0.004 \cdot 10^{-6}$	112 1722	$2.347 \pm 0.007 \cdot 10^{-6}$	12 12
5.6	$pp \rightarrow HMZ$	99>bbs	$2.701 \pm 0.007 \cdot 10^{-4}$	-1.10 -1.10	$2.120\pm0.008\cdot10^{-8}$	11.05 12.05
6.7*	$pp \rightarrow HMZ_j$	pp>hhzj	$1.211 + 0.001 - 10^{-4}$	-14.05 -1.45	$1.394 \pm 0.006 \cdot 10^{-4}$	1278 1128
5.87	$pp \rightarrow HMZ\gamma$	pp>hhza	$1.307 \pm 0.003 \cdot 10^{-4}$	110 110	$1.604 \pm 0.005 \cdot 10^{-6}$	신철 선물
b.9*	$pp \rightarrow HMZZ$	pp>hhaa	$2.309 + 0.005 \cdot 10^{-6}$	-195 -225	$2.754 \pm 0.009 \cdot 10^{-6}$	1215 1215
b.10*	PD -> N.M.230*1	ppbhhzyp	3.705 + 0.013 - 10 ⁻⁴	-1.45 +2.35	$4.904\pm0.029\cdot10^{-6}$	12.00 12.00
6.11*	$pp \rightarrow MMW^+W^-(4l)$	p p > h h u+ u-	$7.524 \pm 0.070 \cdot 10^{-6}$	-1.02 +2.02	$9.368 \pm 0.000 \cdot 10^{-6}$	10 10
6.12	$pp \rightarrow HM\pi i$	pp>hht.t~	$6.756 \pm 0.007 \cdot 10^{-4}$		$7.301 \pm 0.024 \cdot 30^{-4}$	11.05 12.05
6.18	$\mu p \rightarrow HMij$	p p > h h tt j	$1.891 \pm 0.008 \cdot 10^{-1}$	+1.05 +1.85	$2.441 \pm 0.009 \cdot 10^{-1}$	*175 *145
6.54*	$pp \rightarrow HMb\bar{b}$	*****	$7.849 \pm 0.022 \cdot 10^{-6}$	-11.05 +1.75	$1.084 \pm 0.012 \cdot 10^{-7}$	+1.05 +5.75 -0.45 -5.75

	Process.	Syntax		Cross se	ction (ph)	
1	Four vector bosons		LO 13 Te	w	NLO 13 T	W.
c.21*	$pp \rightarrow W^+W^-W^+W^-$ (4f)	$p \ p \ > \ u_{n} \ u_{n} \ u_{n}$	$5.721 \pm 0.014 \cdot 10^{-4}$	+3.7% +3.9%	$9.909 \pm 0.035 \cdot 10^{-4}$	+5.4% +1.7
c.22*	$pp \rightarrow W^+W^-W^\pm Z'(4l)$	p p > v+ v- vpa z	$6.391 \pm 0.076 \cdot 10^{-4}$	-4.15 -1.85	$1.188 \pm 0.004 \cdot 10^{-3}$	-6.45 -1.2
c.23*	$pp \rightarrow W^+W^-W^\pm\gamma$ (4f)	pp>u+u-upsa	$8.115 \pm 0.064 \cdot 10^{-4}$	+5.55 +5.95	$1.546 \pm 0.005 \cdot 10^{-3}$	+5.85 +1.5
c.24*	$pp \rightarrow W^+W^-ZZ$ (4f)	p p ≥ u= u- z z	$4.320 \pm 0.013 \cdot 10^{-4}$	+1.1% +1.1%	$7.107 \pm 0.020 \cdot 10^{-4}$	+7.05 +1.8
c.25*	$pp \rightarrow W^+W^-Z\gamma$ (47)	p p > x+ x- z a	$8.403 \pm 0.016 \cdot 10^{-4}$	+528 +536	$1.483 \pm 0.004 \cdot 10^{-3}$	-146 -14
c.26*	$pp \rightarrow W^+W^-\gamma\gamma$ (41)	p p > u+ u- a a	$5.196 \pm 0.012 \cdot 10^{-4}$	+125 +115	$9.381 \pm 0.032 \cdot 10^{-4}$	+67% +13
e.27*	$pp \rightarrow W^{\perp}ZZZ$	p p > vps z z z	$5.862 \pm 0.010 \cdot 10^{-5}$	+5.1% +5.1%	$1.240 \pm 0.004 \cdot 10^{-4}$	+8.05 +17
e.28*	$pp \rightarrow W^{*+}ZZ\gamma$	p p > vps z z a	$1.148 \pm 0.003 \cdot 10^{-4}$	148 128	$2.945 \pm 0.008 \cdot 10^{-4}$	-8.76 -1
1.29*	$pp \rightarrow W^{+}Z\gamma\gamma$	pp> vps z a a	$1.054 \pm 0.004 \cdot 10^{-4}$	+1.7% +2.1%	$3.033 \pm 0.010 \cdot 10^{-4}$	+ 20.47% + 1.
e.30*	$pp \rightarrow W^{\pm}\gamma\gamma\gamma$	p p > vps a a a	$3.600 \pm 0.013 \cdot 10^{-5}$	+0.4% +2.0%	$1.246 \pm 0.005 \cdot 10^{-4}$	-8.15 -0.8
e.31*	$pp \rightarrow ZZZZ$	p p > z z z z	$1.989 \pm 0.002 \cdot 10^{-5}$	+3.8% +2.2%	$2.629 \pm 0.008 \cdot 10^{-5}$	+3.8% +2.2
e.32*	$pp \rightarrow ZZZ\gamma$	pp>xxx*	$3.945 \pm 0.007 \cdot 10^{-5}$	+1.9% +2.1%	$5.234 \pm 0.016 \cdot 10^{-5}$	+3.8% +2.5
$e.33^{*}$	$pp \rightarrow ZZ\gamma\gamma$	pp>zzaa	$5.543 \pm 0.017 \cdot 10^{-5}$	+0.05 +2.15	$7.518 \pm 0.032 \cdot 10^{-5}$	+548 +20
e.34*	$pp \rightarrow Z\gamma\gamma\gamma$	pp>zeee	$4.790\pm0.012\cdot10^{-5}$	+2.15 +2.05	$7.163\pm0.026\cdot10^{-5}$	+3.45 +1.8
6.35*	PP-+1111	pp>====	$1.594 \pm 0.004 \cdot 10^{-5}$	+4.9E +1.0E	$3.389 \pm 0.012 \cdot 10^{-5}$	+1.05 +1.5

1	Process	Syntax		Cross see	tion (pb)	
The	toe voctor bosons +jet		LO 13 T	N.	NLO 13 T	éV
c.1	$pp \rightarrow W^+W^-W^{\pm}$ (4f)	pp>x+x-xpa	$1.307 \pm 0.003 \cdot 10^{-1}$	+0.05 +0.05	$2.109 \pm 0.006 \cdot 10^{-1}$	+5.15 +1.65
c.2	$pp \rightarrow ZW^+W^-(4l)$	p p > z u+ u-	$9.658 \pm 0.065 \cdot 10^{-2}$	+2.45 +8.75	$1.679 \pm 0.005 - 10^{-1}$	+2.56 +1.26
c.3	$pp \rightarrow ZZW^{\pm}$	p p ⊨ z z vpa	$2.996 \pm 0.016 \cdot 10^{-2}$	+1.05 +1.05	$5.550 \pm 0.020 - 10^{-2}$	+0.8% +1.5%
e.4	$pp \rightarrow ZZZ$		$1.085 \pm 0.002 \cdot 10^{-2}$	-1.52 -1.52	$1.417 \pm 0.005 - 10^{-2}$	192 142
e.5	$pp \rightarrow \gamma W^+W^-(4f)$	9 9 > a v+ v-	$1.427 \pm 0.011 \cdot 10^{-3}$	+1.85 +1.55	$2.581 \pm 0.008 - 10^{-1}$	118 118
c.6	00-200W ¹	p p > a a you	2.681 ± 0.007 - 10 ⁻²	+4.45 +1.95	8.251 ± 0.032 - 10 ⁻²	+145 +145
67	nn-1-5211*1	3 5 2 A 8 105	$4.994 \pm 0.011 \cdot 10^{-7}$	-122-122	$1.117 \pm 0.004 - 10^{-1}$	-728-128
	10.0077		2 220 + 0.005 - 10-2	+2.05 +1.05	3115-0012-10-2	-2.40 -1.40
- 8	pp 1 jaz	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	3,078 + 0,007 - 10-7	-2.9% -1.5% +6.4% +1.9%	4.635 + 0.020 - 30-7	-178 -1.48 1448 11/8
- 10	Ma + Jun	****	1.000 + 0.002 - 10	-0.8% -1.8%	2.634 + 0.020 - 10	-1.0% -1.9%
e.10	10-1777	, , , , , , , , , , , , , , , , , , ,	1.269 ± 0.063 + 10 *	-11.0K -1.0K	3.441 ± 0.015 - 18 -	-11.05 -1.05
c.11	$pp \rightarrow W^+W^-W^\pm j$ (42)	p p > u+ u- upa j	$9.167 \pm 0.039 \cdot 10^{-2}$	+10.0% +1.0%	$1.197 \pm 0.004 - 10^{-1}$	+5.9% +1.0%
c.12*	$pp \rightarrow ZW^+W^-j$ (4f)	p p > z ** *- j	$8.340 \pm 0.030 \cdot 10^{-2}$	+12.5% +1.5%	$1.066 \pm 0.003 - 10^{-1}$	-1.5% -1.8%
e.13*	$pp \rightarrow ZZW^{\pm}j$	p p > a a vpa 1	$2.810 \pm 0.004 \cdot 10^{-2}$	+12.1% +1.5%	$3.660 \pm 0.013 \cdot 10^{-2}$	+188 +138
c.14"	$pp \rightarrow ZZZ_j$	pp>zzzj	$4.823 \pm 0.011 \cdot 10^{-3}$	+14.8% +1.4%	$6.341 \pm 0.025 \cdot 10^{-3}$	+4.05 +1.45
e.15*	nn-1-5W+W-1(40)	5 5 2 5 W* W- 1	$1.182 \pm 0.004 \cdot 10^{-1}$	10845 1945	$1.233 \pm 0.004 - 10^3$	128-275 11-275
6.16	an-securit	8 8 2 3 3 We 1	$4.107 \pm 0.015 \cdot 10^{-2}$	112 122	5.807 ± 0.023 - 10-7	10.85 10.75
0.175	PP 10 211 1		5 833 + 0.073 - 10 ⁻⁹	+14.4% +0.7%	7 764 + 0.025 - 18-9	+8.1% +0.4%
- 191	10 10 221	h h h a a a a a a	0.005 + 0.003 - 10	-12.0% -0.4%	1 271 - 0.005 - 10-7	-1.10 -0.00
0.45	Maria and		1 200 + 0.013 - 10 -	-10.4% -0.4%	1.001 + 0.005 - 10	-1.0% -0.9%
0.19	Mr. 1.11x1	*****	1.372 + 0.003 - 10	+14.25 +0.25	2.001 + 0.011 - 10	-6.3% -0.8%
6 . The second	1000 - 1 TOTATA 2		LINE WEIGHT - HIT		T 45.81 0 11 18 PL - 18	

hundreds of processes

P	TUCKIN	Syntax	Cross section (pb)			
Single	Higgs production		LO 13 Te	ev.	NLO 13 1	WV .
6.1 6.2 6.3	$pp \rightarrow H$ (HEFT) $pp \rightarrow Hj$ (HEFT) $pp \rightarrow Hjj$ (HEFT)	p p > h p p > h j p p > h j j	$\begin{array}{c} 1.533 \pm 0.003 \cdot 10^{1} \\ 8.367 \pm 0.003 \cdot 10^{8} \\ 3.000 \pm 0.002 \cdot 10^{8} \end{array}$	-34.85 +1.25 -36.05 +1.25 +84.05 +1.25 -34.05 +1.25 -34.05 +1.45 -34.05 +1.45	$\begin{array}{c} 3.261 \pm 0.010 \cdot 10^{1} \\ 1.422 \pm 0.006 \cdot 10^{1} \\ 5.124 \pm 0.009 \cdot 10^{9} \end{array}$	
84 85	$pp \rightarrow Hjj$ (VDF) $pp \rightarrow Hjjj$ (VDF)	pp>hjj₩v+v-z pp>hjj₩v+v-z	$\frac{1.987\pm0.002\cdot10^9}{2.824\pm0.005\cdot10^{-1}}$	+1 7% +1.8% -20% -1.4% +117% +1.4% -127% -1.0%	$\begin{array}{c} 1.900 \pm 0.006 + 10^{5} \\ 3.085 \pm 0.010 + 10^{+5} \end{array}$	+8.4% +8.4% -8.9% -1.5% +1.0% +1.0 -3.0% -1.7
88 87 88	$pp \rightarrow BW^{\pm}$ $pp \rightarrow BW^{\pm}j$ $pp \rightarrow BW^{\pm}jj$	pp>hvyn pp>hvynj pp>hvynj	$\begin{array}{c} 1.185 \pm 0.002 - 10^{0} \\ 4.008 \pm 0.003 - 10^{-1} \\ 1.198 \pm 0.016 - 10^{-1} \end{array}$	+1.5% +1.8% +107% +1.9% +30% +1.9% +30% +0.9% +30% +0.9%	$\begin{array}{c} 1.419 \pm 0.005 \cdot 10^9 \\ 4.842 \pm 0.017 \cdot 10^{-1} \\ 1.574 \pm 0.014 \cdot 10^{-1} \end{array}$	+1.1% +1.8% -2.4% -1.4% +1.4% +1.9 +1.4% +1.8 +1.4% +1.8 +1.4% +1.8
g.9 g.30 g.11*	$pp \rightarrow HZ$ $pp \rightarrow HZ j$ $pp \rightarrow HZ jj$	pp>hx pp>hxj pp>hzjj	$\begin{array}{l} 6.468 \pm 0.008 & -10^{-1} \\ 2.225 \pm 0.001 & -10^{-1} \\ 7.262 \pm 0.012 & -10^{-2} \end{array}$	+1.8% +1.9% -1.5% -1.4% +244% +1.7% -8.7% -1.8% +26.7% +1.4%	$\begin{array}{c} 7.674 \pm 0.097 \cdot 10^{-1} \\ 2.667 \pm 0.010 \cdot 10^{-1} \\ 8.758 \pm 0.087 \cdot 10^{-2} \end{array}$	
8.12° 8.33° 8.34° 8.33°	$pp \rightarrow HW^{\pm}W^{+}$ (41) $pp \rightarrow HW^{\pm}\gamma$ $pp \rightarrow HZW^{\pm}$ $pp \rightarrow HZZ$	р b > p × v b b > p × m b = m	$\begin{array}{c} 8.325 \pm 0.139 & 10^{-3} \\ 2.518 \pm 0.006 & 10^{-3} \\ 3.763 \pm 0.007 & 10^{-3} \\ 2.003 \pm 0.003 & 10^{-3} \end{array}$	10月12月 -0月1-1月 10月1-1月 -1月1-1月 -1月1-1月 -1月1-1月 -1月1-1月 -1月1-1月 -1月1-1月 -1月1-1月 -1月1-1月 -1月1-1月 -1月1-1 -1 1-1 1	$\begin{array}{c} 1.065 \pm 0.003 \cdot 10^{-2} \\ 3.309 \pm 0.011 \cdot 10^{-3} \\ 5.292 \pm 0.015 \cdot 10^{-3} \\ 9.538 \pm 0.007 \cdot 10^{-5} \end{array}$	12.05 10
£-16 8-17 8-18	$pp \rightarrow B \eta \tilde{l}$ $pp \rightarrow B \eta \tilde{j}$ $pp \rightarrow B h \tilde{h} (4l)$	pp>htt; pp>httj pp>hbb~	$\begin{array}{c} 3.579 \pm 0.003 \cdot 10^{-1} \\ 4.994 \pm 0.005 \cdot 10^{-2} \\ 4.983 \pm 0.002 \cdot 10^{-1} \end{array}$	·····································	$\begin{array}{c} 4.608 \pm 0.016 \cdot 10^{-1} \\ 6.328 \pm 0.022 \cdot 10^{-2} \\ 6.085 \pm 0.026 \cdot 10^{-1} \end{array}$	
5.79 5.20°	$pp \rightarrow H1ij$ $pp \rightarrow Hb\bar{n}j$ (4f)	pp>hii~j pp>hbb/j	$2.671 \pm 0.041 \cdot 10^{-1}$ 7.367 $\pm 0.002 \cdot 10^{-2}$	*1145 +145 *125 +125	$\begin{array}{c} 3.264 \pm 0.025 \cdot 10^{-1} \\ 9.034 \pm 0.032 \cdot 10^{-2} \end{array}$	100 100 100 100

Pe	ACCESS.	Syntax	c	ross section (pb)
Top o	aarks +bosons		LO 1 TeV	NLO 1 TeV
j.1	$e^+e^- \rightarrow t\bar{t}H$	et e- > 5 5~ h	$2.018 \pm 0.003 \cdot 10^{-3}$	+0.0% 1.911 + 0.006 - 10 ⁻³ +0.4%
1.2"	$e^+e^- \rightarrow t\bar{t}Hj$	e+ e- > t t~ h j	$2.533 \pm 0.003 \cdot 10^{-4}$	$^{+9.2\%}_{-7.4\%}$ 2.658 + 0.009 $\cdot 10^{-4}$ $^{+0.5\%}_{-1.5\%}$
1.8*	$e^+e^- \rightarrow t\bar{t}Hjj$	et e= > 1 1~ h]]	$2.663 \pm 0.004 \cdot 10^{-5}$	+19.5% 3.278 + 0.017 · 10 ⁻⁵ +4.0%
j.4*	$e^+e^- \rightarrow ll\gamma$	et e- > 5 t~ a	$1.270 \pm 0.002 \cdot 10^{-2}$	+0.0% -0.0% $1.335 \pm 0.004 \cdot 10^{-2}$ $+0.0\%$
3.5*	$e^+e^- \rightarrow l\bar{l}\gamma j$	e! e- > t t~ a j	$2.355 \pm 0.002 \cdot 10^{-3}$	+9.9% 2.617±0.010 · 10 ⁻³ +1.6%
1.6*	$e^+e^- \rightarrow l l \gamma j j$	** ** > 5 5~ 8 3 3	$3.103 \pm 0.005 \cdot 10^{-4}$	+18.5% 4.002±0.021 · 10 · 4 +5.6%
j.7*	$e^+e^- \rightarrow t\bar{t}Z$	e* e- > t t~ z	$4.642 \pm 0.006 \cdot 10^{-3}$	+0.5% 4.949±0.014 · 10 * +0.5%
3.8*	$e^+e^- \rightarrow t\bar{t}Zj$	e+ e- > 5 5~ 2 j	$6.059 \pm 0.006 - 10^{-4}$	+6.95 6.940 ± 0.028 - 10-4 +5.05
j.9*	$e^+e^- \rightarrow t\bar{t}Zjj$	e+ e= > t t~ z j j	$6.351 \pm 0.028 \cdot 10^{-5}$	+16.4% 8.439±0.051 · 10 ⁻⁵ •5.4%
j.10*	$e^+e^- \rightarrow t \bar{t} W^\pm j j$	e+ e- > 5 5~ vpm j j	$2.400 \pm 0.004 \cdot 10^{-7}$	$^{+16.3\%}_{-14.9\%}$ 3.723 $\pm 0.012 \cdot 10^{-7}$ $^{+6.6\%}_{-9.1\%}$
j.11*	$e^+e^- \rightarrow t\bar{t}HZ$	e* e- > t t~ h z	$3.600\pm 0.006\cdot 10^{-5}$	$^{+0.0\%}_{-0.0\%}$ 3.579 $+ 0.013 \cdot 10^{-5}$ $^{+0.0\%}_{-0.0\%}$
j.12*	$e^+e^- \rightarrow l\bar{l}\gamma Z$	et er > t t~ a z	$2.212 \pm 0.003 - 10^{-4}$	+0.0% 2.364±0.006 - 10 -4 +0.8%
j.13*	$e^+e^- \rightarrow ll\gamma H$	et e- > t t~ a h	$9.756 \pm 0.016 \cdot 10^{-5}$	+0.0% 9.423±0.032 · 10 · +0.5%
j.14*	$e^+e^- \rightarrow l\bar{l}\gamma\gamma$	et e- > t t~ a a	$3.650 \pm 0.008 \cdot 10^{-4}$	+0.0% 3.833±0.013 · 10 · 4 +0.0%
j.15*	$e^+e^- \rightarrow t\bar{t}ZZ$	e+ e- > t t~ z z	$3.788 \pm 0.004 \cdot 10^{-8}$	+0.0% 4.007±0.013-10-5 +0.5%
j.16*	$e^+e^- \rightarrow t\bar{t}HH$	e* e- > t t~ h h	$1.358 \pm 0.001 \cdot 10^{-8}$	$^{+5.0\%}_{-0.0\%}$ 1.206 ± 0.003 · 10 ⁻⁵ $^{+5.9\%}_{-1.1\%}$
j.17*	$e^+e^- \rightarrow t\bar{t}W^+W^-$	e+ e- > 5 5~ ¥+ ¥-	$1.372 \pm 0.003 - 10^{-4}$	+6.8% 1.540 ± 0.006 - 10-4 +1.0%

	Process	Syntax	Cross see	tion (ph)
	Single-top		LO 13 TeV	NLO 13 TeV
	$pp \rightarrow tj$ (t-channel) $pp \rightarrow t\gamma j$ (t-channel) $pp \rightarrow tZj$ (t-channel) $pp \rightarrow thj$ (t-channel, 4ℓ) $pp \rightarrow thj\gamma$ (t-channel, 4ℓ) $pp \rightarrow thj\gamma$ (t-channel, 4ℓ)	p p > 16 j 48 ur u- p p > 16 a j 48 ur u- p p > 16 a j 48 ur u- p p > 16 a j 48 ur u- p p > 16 bè j 48 ur u- p p > 16 bè j 48 ur u-	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
£7 £8° £9°	$\begin{array}{l} pp \rightarrow th \; (s \mbox{-channel}, \; 4f) \\ pp \rightarrow th\gamma \; (s \mbox{-channel}, \; 4f) \\ pp \rightarrow thZ \; (s \mbox{-channel}, \; 4f) \end{array}$	ррзиянски, ррзиенски ррзиянски, ррзиенски ррзиянски, ррзиенски	$\begin{array}{c} -11.78 \\ -10.78 \\ +1.03$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

P	boeess	Syntax	Cross se	etion (pb)
Beary	quarks ; vector bosons		LO 13 TeV	NLO 13 TeV
e.1	$pp \rightarrow W^{\pm} b\bar{b}$ (4f)	pp>vpabb~	$3.074 \pm 0.002 - 16^2 + 46.38 + 5.08$ -20.26 - 1.08	8.162±0.034 - 10 ² - 28-85 +1.55
v.2	$pp \rightarrow Z b\bar{b} (4\ell)$	p p ≥ z b b~	$6.993 \pm 0.003 - 10^2 + \frac{35}{-26} \frac{56}{-1.45}$	$1.235 \pm 0.004 \cdot 10^3 + 0.05 \pm 0.05$
e.3	$pp \rightarrow \gamma \delta \bar{b} (4l)$	p p ≥ a b b~	$1.731 \pm 0.001 - 10^3 + 51.8\% + 1.0\% - 36.8\% - 2.1\%$	$4.171 \pm 0.015 - 10^3 + \frac{95}{27.18} + \frac{1.75}{-1.06}$
$e.4^{\circ}$	$pp \rightarrow W^{\pm} b \bar{b} j$ (4f)	p p ≥ spa b b~ j	$1.861 \pm 0.003 - 10^2 + 42.8\% + 0.7\% - 0.7\%$	$3.957 \pm 0.013 - 10^2 + 27.0\% + 0.7\% - 0.075$
e.5*	$pp \rightarrow Z b\bar{b} j$ (4f)	p p > a b b~ j	$1.604 \pm 0.001 \cdot 10^2 + 12.4\% + 0.9\%$	2.805±0.009-30 ² +21.05 +0.85
$e.6^{*}$	$pp \rightarrow \gamma b\bar{b} j (4l)$	p p > a b b~ j	$7.812 \pm 0.017 \cdot 10^2 + 1.126 + 1.06$ -30.05 - 1.75	$1.233 \pm 0.004 - 10^8$ $+ \frac{56.26}{-16.95} + 1.05$
0.7	$pp \rightarrow t\bar{t}W^{\pm}$	pp>tt~upt	3.777+0.003-10 ⁻¹ +23.9K +2.1K	5.662 + 0.021 - 10 ⁻¹ +11.28 +1.18
e.8	$pp \rightarrow t\bar{t} Z$	p p > t t~ x	5.273 ± 0.004 - 10 ⁻¹ + 90.5% + 1.8%	7.588 + 0.026 - 10-1 +9.7% +1.9%
c.9	$pp \rightarrow t\bar{t}\gamma$	pp>11~*	$1.204 \pm 0.001 - 10^{5}$ $^{+29.0\%}_{-71.33} \pm 1.8\%$	1.744 ± 0.005 - 10 ^A +9.85 +1.95 -11.05 - 2.05
e.10"	$pp \rightarrow t\bar{t}W^{\pm}j$	pp≻tt~vpaj	$2.352 \pm 0.002 - 10^{-1}$ $+ \frac{+0.05}{-27.1\%} + 1.0\%$	3.404±0.011-10 ⁻¹ +11.9% +1.9%
e.11"	$pp \rightarrow t\bar{t}Zj$	p p > t t~ z j	3.953 ± 0.004 - 10-1 +36.95 +5.75	5.074 ± 0.016 - 10-1 +7.0% +8.5%
e.12"	$pp \rightarrow t\bar{t}\gamma j$	pp> t t~ a j	$8.726 \pm 0.000 - 10^{-1}$ $^{+45.4\%}_{-24.1\%}$ $^{+2.3\%}_{-2.4\%}$	$1.135 \pm 0.004 - 10^{10}$ $^{+7.28}_{-12.26}$ $^{+2.28}_{-2.86}$
c.13"	$pp \rightarrow t\bar{t}W^-W^+$ (4f)	p p > 1 1~ v* v-	6.675±0.006-10-3 +31.95 +2.15	9.904±0.026-10-3 +10.9% +2.1%
e.14"	$pp \rightarrow d\bar{t} W^{\pm} Z$	pp>tt~vptz	2.404±0.002-10-3 =52.2% =5.5%	3.525±0.010-10-3 +1526 +536
v.18"	$pp \rightarrow t\bar{t} W^{\pm} \gamma$	pp≥t t~vps a	2.718±0.003-10-3 -10.28 +1.56	3.927±0.013-10-3 +1534 +534
e.16"	$pp \rightarrow t\bar{t}ZZ$	pp>ttvzz	1.349±0.004-10-3 +H-5K +17K	1.840±0.007-10-3 +1.85+1.75
$v.17^{\circ}$	$pp \rightarrow t\bar{t}Z\gamma$	p p > t t~ z a	2.548±0.003-10-3 +5016 +176	3.656 ± 0.012 - 10-3 +0.75 +1.45
v.18"	$pp \rightarrow t\bar{t}\gamma\gamma$	pp>tt~aa	$3.272 \pm 0.006 - 10^{-3} + 10.18 + 1.58$	4.402±0.015-10-3 +T.85 +1.75

1	rocens	Syntax	Cross	oction (pb)
Heav,	y quarks and jets		LO 13 TeV	NLO 13 TeV
d.1	$pp \rightarrow jj$	p p > j j	$1.162 \pm 0.001 \cdot 10^6 {}^{+24.9\%}_{-18.8\%} {}^{+0.8\%}_{-0.9\%}$	$1.580 \pm 0.007 \cdot 10^{6}$ $^{+8.4\%}_{-9.05}$ $^{+0.7\%}_{-0.85}$
d.2	$pp \rightarrow jjj$	pp>jjj	$8.940 \pm 0.021 \cdot 10^4 + 43.8\% + 1.2\% - 38.4\% - 1.4\%$	$7.791 \pm 0.037 \cdot 10^4 + 2.9\% + 1.1\% - 33.9\% - 1.0\%$
d.3	pp → bb (4f)	pp>bb~	$3.743 \pm 0.004 \cdot 10^3$ $^{+26.2\%}_{-18.9\%}$ $^{+1.0\%}_{-1.8\%}$	$6.438 \pm 0.028 \cdot 10^3$ $^{+15.9\%}_{-13.9\%}$ $^{+1.0\%}_{-1.7\%}$
dA^*	$pp \rightarrow b\bar{b}j$ (4f)	p p > b b~ j	$1.050 \pm 0.002 \cdot 10^3$ $^{+44.1\%}_{-28.5\%} \pm 1.0\%$	$1.327 \pm 0.007 \cdot 10^3 \xrightarrow{+0.00}_{-11.6\%} \xrightarrow{+1.0\%}_{-1.8\%}$
$d.5^{\circ}$	$pp \rightarrow b\bar{b}jj$ (4f)	pp>bb~jj	$1.852 \pm 0.006 \cdot 10^{5} \pm 41.8\% \pm 2.1\% = 35.6\% \pm 2.4\%$	$2.471 \pm 0.012 \cdot 10^3 ^{+8.2\%}_{-16.4\%} ^{+2.0\%}_{-2.3\%}$
d.6	$pp \rightarrow b\bar{b}b\bar{b}$ (4f)	$p \ p > b \ b \sim \ b \ b \sim$	$5.050 \pm 0.007 \cdot 10^{-1}$ $^{+61.7\%}_{-35.6\%}$ $^{+2.96}_{-3.49}$	$\frac{1}{6}$ 8.736 + 0.034 · 10 ⁻¹ +20.96 +2.96 -22.05 -3.45
d.7	$pp \rightarrow t\bar{t}$	p p > t t~	$4.584 \pm 0.003 \cdot 10^2 \begin{array}{c} +99.0\% + 1.4\% \\ -21.1\% \end{array}$	$6.741 \pm 0.023 \cdot 10^2 \xrightarrow{+0.83}_{-10.9\%} \xrightarrow{+1.8\%}_{-2.1\%}$
d.8	$pp \rightarrow t\bar{t}j$	p p > t t∼ j	$3.135 \pm 0.002 \cdot 10^2 + \frac{+31.15}{-29.05} + \frac{5.95}{-2.85}$	$4,106 \pm 0.015 \cdot 10^2 + 4.1\% + 5.1\% - 12.2\% - 2.5\%$
d.9	$pp \rightarrow t\bar{t}jj$	p p > t t~ j j	$1.361 \pm 0.001 \cdot 10^{2}$ $^{+61.4\%}_{-38.6\%}$ $^{+2.0\%}_{-3.0\%}$	$1.795 \pm 0.006 - 10^2 + 9.991 + 2.4% - 16.1\% - 2.9\%$
d.10	$pp \rightarrow t\bar{t}t\bar{t}$	p p > t t∼ t t∼	4,505 ± 0.005 · 10 ⁻³ +98.8% +6.45 -36.5% -5.75	$ \begin{array}{c} 9.201 \pm 0.028 \cdot 10^{-3} & +30.8\% & +0.0\% \\ & -25.6\% & -5.9\% \end{array} $
d.11	$pp \rightarrow t\bar{t}b\bar{b}$ (4f)	p	$6.119 \pm 0.001 \cdot 10^{0} {}^{+60.1\%}_{-80.7\%} {}^{+9.9\%}_{-8.7\%}$	$1.452 \pm 0.005 - 10^{1}$ $^{+37.6\%}_{-27.6\%}$ $^{+9.9\%}_{-8.6\%}$

Mattelaer Olívíer





- •Only NLO in QCD (Electroweak well in progress)
- •Mainly the SM
 - Tools for creating NLO-UFO
 - →2HDM is under validation
- Support for Merging at NLO
 - →FxFx (Herwig6)
 - →FxFx (Pythia8 -> Friday release)
 - UnLops (Pythia8 -> Friday release)



MadSpin



•How to handle the decay of particle?

- WISH-LIST:
 - ➡For a sample of events include the decay of unstable final states particles.
 - Keep full spin correlations and finite width effect
 - Keep unweighted events
 - Decay LO accurate



MadSpin





- WISH-LIST:
 - ➡For a sample of events include the decay of unstable final states particles.
 - Keep full spin correlations and finite width effect
 - Keep unweighted events
 - Decay LO accurate

•Can be done via ME re-weighting

[Frixione, Leanen, Motylinski, Webber (2007)]



MadSpin



•Fully automatic

- →Fully integrated in MG5 [LO and NLO]
- -Can do BSM decay (from SM production)





Conclusion



Madgraph5:

- Various Method for Mass production @LO
 - ME re-weighting
 - Non Definite Matrix-Element

