

Event Generation at Hadron Colliders

National Taiwan University

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National Taiwan University

MG/FR School, Beijing, May 22-26, 2013

Lectures and exercises found at https://server06.fynu.ucl.ac.be/projects/madgraph/wiki/SchoolBeijing





Outline of lectures

- Lecture I (Johan):
 - New Physics at hadron colliders
 - Monte Carlo integration and generation
 - Simulation of collider events
- Lecture II (Olivier):
 - Simulations with MadGraph 5
 - → (and much more!)
- Lecture III (Johan):
 - MLM Matching with MadGraph and Pythia





Aims for these lectures

- Get you acquainted with the concepts and tools used in event simulation at hadron colliders
- Answer as many of your questions as I can (so please ask questions!)





New Physics at hadron colliders

- The LHC has taken over from the Tevatron!
- Significant luminocities
 - Tevatron collected >10 fb⁻¹ in the last 10 years
 - Fantastic legacy, including several interesting excesses!
 - → LHC has collected 23 fb⁻¹ in its 8 TeV run!
 - ➡ Allows ever-more stringent tests of the SM!
 - → Found (what looks like) the Higgs boson in July 2012!
- How interpret excesses? How determine Standard Model backgrounds?
 - Monte Carlo simulation! (combined with data-driven methods)



^o Example: top-antiscippen asymmetry at Tevatron

CDF collaboration, arXiv:1211.1003, 1101.0034 DØ collaboration, arXiv: 1107.4995





• First: Look for Standard Model explanations



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Example: top-antitop asymmetry at Tevatron

• First: Look for Standard Model explanations



• First: Look for Standard Model explanations

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• Second: Look for possible New Physics contributions



Second: Look for possible New Physics contributions

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Second: Look for possible New Physics contributions

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• Check if the model can explain the data!



• Check if the model can explain the data! How?



• Check if the model can explain the data! How? Monte Carlo!

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• Check if the model can explain the data! How? Monte Carlo!







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Example: top-antitop asymmetry at Tevatron









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Example: top-antitop asymmetry at Tevatron





Flavor-changing Z'

	1.0			10.1	0.4				/				and s	
	1.2	-15.4	11.6	10.1	9.1	7.5	6.5	5.6	4.7	3.7	3.2	2.7	00,200	1.4
											~	Towed		
		- 12.9	9.6	8.	6.8	5.5	4.8	, 4.1	3.2	2.5	rol.61	1.6	1.4	0.6
										Leva				
	1.0	-10.2	7.3	5.8	4.7	4.	3.	2.5	1.9 /	1.6	1.	0.6	0.3	0.4
		7.4	F 1	20	122	2.4	10	11	1	0.4	0.4	0.2	0.2	0.3
~		/.4	5.1	3.0	3.2	2.4	1.9	1.4	1.	0.4	0.4	0.2	0.2	0.0
$f_{\rm F}$						1								
	0.8	- 5.	, 3.3	2.5	2.	1.2	0.9	0.6	0.4	0.2	0.1	-0.1	-0.1	-0.3
		3.1	2.	1.2	0.9	0.3	0.5	-0.2	0.1	-0.1	0.2	0.4	-0.3	-0.2
	06	1.4	0.9	0.1	0.2	0.1	0	0.4	-0.1	-0.2	-0.2	-0.1	-0.3	-0.1
	0.0	1.4	0.2	0.1		0.1	v	0. 1	0.1	0.2	0.2	0.1	0.2	0.1
		0.3	-0.1	0.1	-0.4	-0.1	0	-0.2	-0.2	0	-0.2	0.3	0	-0.1
		200		250		300		350		400		450		500
		M [GeV]											500	
	M_{Z} , [Gev]													

t-channel charge asymmetry

	1.2	-5.2	-5.3	-4.6	-3.7	-2.7	-2.2	-1.6	-1,1	-0.9	-0.2	-0.1	0.21	0.1
f_R	1.1	5.5	-5.5	-4.5	-3.3	-2.5	-2.1	-1.4	-0.7	-0.8	1070.31	0 ^{wed} -0.1	0.1	0.2
	1.0	-5.4	-5.3	-4.4	-3.5	-2:6	-1.9	-1.2	-0.7	-0.3	-0.3	-0.1	0.1	0.3
	0.9	5.1	-5.	-3.9	-2.9	-2.3	-1.6	-1.1	-0.6	-0.5	-0.3	0	0.2	0.1
	0.8	4.8	-4.4	-3.5	-2.5	-2.	-1.3	-0.9	-0.6	-0.3	-0.2	0	0.2	0.2
	0.7	4.4	-4.1	-3.1	-2.2	-1.7	-1.	-0.6	-0.7	-0.1	0	0.1	0.2	0.3
	0.6	-3.6	-3.2	-2.4	-1.9	-1.1	-0.9	-0.4	-0.2	-0.1	0	0.2	0.2	0.2
	0.5	-2.5	-2.5	-1.8	-1.2	-0.7	-0.4	-0.2	0	0.2	0.2	0.2	0.2	0.3
		200	Ī	250		300		350		400		450		500
	M_{7} [GeV]													

s-channel charge asymmetry

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• Now, think of ways to test the model (at the LHC!)



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→ Charge asymmetry A_C : $A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$.



- Now, think of ways to test the model (at the LHC!)
 - → Charge asymmetry A_C : $A_C = \frac{N(\Delta|y| > 0) N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$.
 - t+jet resonances

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Example: top-antitop asymmetry at Tevatron

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 - → Charge asymmetry A_C : $A_C = \frac{N(\Delta|y| > 0) N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$.

t+jet resonances





Flavor-changing Z'



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I. An excess is discovered in data





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- 2. Exhaust SM explanations for the excess





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 - Typically, using Monte Carlo simulations





- I. An excess is discovered in data
- 2. Exhaust SM explanations for the excess
- 3. Think of possible new physics explanations
 - Within or outside of conventional/high scale models
- 4. Find range of model parameters that can explain excess
 - Typically, using Monte Carlo simulations
- 5. Find other observables (collider as well as flavor/EWP/ cosmology) where the explanation can be verified/falsified
 - Note that flavor/EWP/cosmology can typically be modified by additional particles in the model spectrum

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Processes at Hadron Colliders

First: Understand our processes!

Cross sections at a collider depend on:

Coupling strength

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- Coupling to what? (light quarks, gluons, heavy quarks, EW gauge bosons?)
- Mass
- Single production/pair production





Processes at Hadron Colliders

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 $\hat{\sigma}_{ab\to X}(\hat{s},\ldots)$

Parton level cross section

• Parton level cross section from matrix element

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$$\hat{\sigma}_{ab\to X}(\hat{s},\ldots)f_a(x_1)f_b(x_2)$$

Parton levelParton densitycross sectionfunctions

- Parton level cross section from matrix element
- Parton density (or distribution) functions:
 Process independent, determined by particle type





$$\begin{split} \int \hat{\sigma}_{ab \to X}(\hat{s}, \ldots) f_a(x_1) f_b(x_2) \, dx_1 dx_2 d\Phi_{FS} \\ \text{Parton level} & \text{Parton density} & \text{Phase space} \\ \text{cross section} & \text{functions} & \text{integral} \end{split}$$

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- $\hat{s} = x_1 x_2 s$ (s = collision energy of the collider)





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- Parton level cross section from matrix element
- Parton density (or distribution) functions:
 Process independent, determined by particle type
- $\hat{s} = x_1 x_2 s$ (s = collision energy of the collider)
- Difference between colliders given by parton luminocities





Tevatron vs. the LHC





- Tevatron: 2 TeV proton-antiproton collider⁻
 - Most important: q-q annihilation (85% of t t)
- LHC: 8-14 TeV proton-proton collider
 - Most important: g-g annihilation (90% of t t)





Tevatron vs. the LHC





- Tevatron: 2 TeV proton-antiproton collider
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Parton densities

























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Calculations of cross section or decay widths involve integrations over high-dimension phase space of very peaked functions:



Calculations of cross section or decay widths involve integrations over high-dimension phase space of very peaked functions:

$$\sigma = \frac{1}{2s} \int |\mathcal{M}|^2 d\Phi(n)$$



Calculations of cross section or decay widths involve integrations over high-dimension phase space of very peaked functions:



Calculations of cross section or decay widths involve integrations over high-dimension phase space of very peaked functions:

General and flexible method is needed

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Integrals as averages





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$$I = \int_{x_1}^{x_2} f(x) dx \qquad \qquad \square \qquad \qquad \square \qquad \qquad I_N = (x_2 - x_1) \frac{1}{N} \sum_{i=1}^N f(x)$$

$$V = (x_2 - x_1) \int_{x_1}^{x_2} [f(x)]^2 dx - I^2 \quad \square \qquad V_N = (x_2 - x_1)^2 \frac{1}{N} \sum_{i=1}^N [f(x)]^2 - I_N^2$$
$$I = I_N \pm \sqrt{V_N/N}$$

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Integrals as averages



$$I = \int_{x_1}^{x_2} f(x) dx \qquad \qquad \square \qquad \qquad \square \qquad \qquad I_N = (x_2 - x_1) \frac{1}{N} \sum_{i=1}^N f(x)$$

$$V = (x_2 - x_1) \int_{x_1}^{x_2} [f(x)]^2 dx - I^2 \quad \square \qquad V_N = (x_2 - x_1)^2 \frac{1}{N} \sum_{i=1}^N [f(x)]^2 - I_N^2$$
$$I = I_N \pm \sqrt{V_N/N}$$

© Convergence is slow but it can be easily estimated Fror does not depend on # of dimensions! Improvement by minimizing V_N . Optimal/Ideal case: $f(x)=C \Rightarrow V_N=0$















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but... you need to know a lot about f(x)!

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but... you need to know a lot about f(x)!

Alternative: learn during the run and build a step-function approximation p(x) of $f(x) \longrightarrow VEGAS$





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many bins where f(x) is large





but... you need to know a lot about f(x)!

Alternative: learn during the run and build a step-function approximation p(x) of $f(x) \longrightarrow VEGAS$



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can be generalized to n dimensions:

 $\overrightarrow{p(x)} = p(x) \cdot p(y) \cdot p(z) \dots$





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but the peaks of $f(\vec{x})$ need to be "aligned" to the axis!





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can be generalized to n dimensions:

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This is not ok...





can be generalized to n dimensions:

 $\vec{p(x)} = p(x) \cdot p(y) \cdot p(z) \dots$

but the peaks of $f(\vec{x})$ need to be "aligned" to the axis!



but it is sufficient to make a change of variables!





Multi-channel



What do we do if there is no transformation that aligns all integrand peaks to the chosen axes? Vegas is bound to fail!




Multi-channel



What do we do if there is no transformation that aligns all integrand peaks to the chosen axes? Vegas is bound to fail!

Solution: use different transformations = channels

$$p(x) = \sum_{i=1}^{n} \alpha_i p_i(x) \quad \text{with} \quad \sum_{i=1}^{n} \alpha_i = 1$$

with each $p_i(x)$ taking care of one "peak" at the time



Multi-channel













Multi-channel





with

 $\sum_{i=1}^{n} \alpha_{i} = 1$ $\overline{i=1}$

Then, $I = \int f(x) dx = \sum_{i=1}^{n} \alpha_i \int \frac{f(x)}{p(x)} p_i(x) dx$



Example: QCD 2 \rightarrow 2 production



Three very different pole structures contributing to the same matrix element.

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Multi-channel based on single diagrams

Consider the integration of an amplitude |M|^2 at tree level which many contributing diagrams. We would like to have a basis of functions,

$$f = \sum_{i=1}^{n} f_i \quad \text{with} \quad f_i \ge 0, \quad \forall \ i,$$

such that:

I. we know how to integrate each one of them,

2. they describe all possible peaks,

n

giving us the combined integral

$$I = \int d\vec{\Phi} f(\vec{\Phi}) = \sum_{i=1}^{n} \int d\vec{\Phi} g_i(\vec{\Phi}) \frac{f_i(\vec{\Phi})}{g_i(\vec{\Phi})} = \sum_{i=1}^{n} I_i,$$



Multi-channel based on single diagrams

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Does such a basis exist?



Multi-channel based on single diagrams*

YES!
$$f_i = \frac{|A_i|^2}{\sum_i |A_i|^2} |A_{\text{tot}}|^2$$



Multi-channel based on single diagrams* YES! $f_i = \frac{|A_i|^2}{\sum_i |A_i|^2} |A_{tot}|^2$

- Key Idea
 - Any single diagram is "easy" to integrate (pole structures/ suitable integration variables known from the propagators)
 - Divide integration into pieces, based on diagrams
 - All other peaks taken care of by denominator sum
- Get N independent integrals
 - Errors add in quadrature so no extra cost
 - "Weight" functions already calculated during $|M|^2$ calculation
 - Parallel in nature
- What about interference?
 - Never creates "new" peaks, so we're OK!

*Method used in MadGraph









I. pick x





- I. pick x
- 2. calculate f(x)





- I. pick x
- 2. calculate f(x)
- 3. pick 0<y<fmax





- I. pick x
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- 3. pick 0<y<fmax
- 4. Compare:
 if f(x)>y accept event,





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What's the difference between weighted and unweighted? Weighted: Same # of events in areas of phase space with very different probabilities: events must have different weights







What's the difference between weighted and unweighted?

Unweighted:

events is proportional to the probability of areas of phase space: events have all the same weight ("unweighted")

Events distributed as in nature







else reject it.

much better efficiency!!!





MC integrator















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B





Simulation of collider events

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I. High- Q^2 Scattering

2. Parton Shower



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I. High- Q^2 Scattering



2. Parton Shower

where new physics lies 3. Hadronization 4. Underlying Event

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I. High- Q^2 Scattering



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I. High- Q^2 Scattering



2. Parton Shower

Image where new physics lies process dependent first principles description

3. Hadronization

4. Underlying Event

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I. High- Q^2 Scattering



2. Parton Shower





first principles description

it can be systematically improved

3. Hadronization

4. Underlying Event

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2. Parton Shower



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2. Parton Shower

QCD -"known physics"

3. Hadronization

4. Underlying Event

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2. Parton Shower

QCD -"known physics" universal/ process independent

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QCD -"known physics" universal/ process independent first principles description

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I. High- Q^2 Scattering

2. Parton Shower

3. Hadronization

 $real low Q^2$ physics

4. Underlying Event

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I. High- Q^2 Scattering

2. Parton Shower

$real low Q^2$ physics

universal/ process independent B

3. Hadronization

4. Underlying Event

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I. High- Q^2 Scattering

$real low Q^2$ physics universal/ process independent

model-based description

3. Hadronization

4. Underlying Event

2. Parton Shower

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I. High- Q^2 Scattering





3. Hadronization

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4. Underlying Event

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I. High- Q^2 Scattering

2. Parton Shower

 $real low Q^2$ physics energy and process dependent (F model-based description

3. Hadronization

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4. Underlying Event





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I. High- Q^2 Scattering

2. Parton Shower



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No. Subprocess	No. Subprocess	No. Subprocess	No. Subprocess	No. Subprocess	No. Subprocess
Heat OCD and and	Charles Barrow	435 m - 0.005 p(1)	Double Incl. Court :	19 $6\overline{L} \rightarrow \gamma \overline{Z}^0$	DRM Nautral Blazer
Hard QCD processes:	Closed heavy flavour:	430 $gq \rightarrow qcc[Y_1]$	Loopty mot. Scatt.:	00 (7 - W+	Boot Neutral Puggs
11 $I_i I_j \rightarrow I_i I_j$	$gg \rightarrow J/\psi g$	436 $gq \rightarrow q cc[^{*}F_{2}^{*}]$	10 $f_i f_j \rightarrow f_k f_l$	$20 \mu_j \rightarrow \gamma W$	151 $f_i f_i \rightarrow H^o$
12 $f_i \overline{f}_i \rightarrow f_k \overline{f}_k$	87 $gg \rightarrow \chi_{lk}g$	437 $q\bar{q} \rightarrow g c\bar{c} [^{\circ}F_{0}^{*}]$	99 $\gamma^* q \rightarrow q$	35 $I_i \gamma \rightarrow I_i Z^{\prime \prime}$	$152 \text{ gg} \rightarrow \text{H}^0$
13 $f_i \overline{f}_i \rightarrow gg$	88 $gg \rightarrow \chi_{ke}g$	438 $q\bar{q} \rightarrow g c\bar{c} [{}^{9}P_{1}^{(1)}]$	Photon-induced:	$36 f_i \gamma \rightarrow f_k W^*$	153 $\gamma \gamma \rightarrow H^0$
28 $f_{eff} \rightarrow f_{eff}$	89 $gg \rightarrow \chi_{2n}g$	439 $07 \rightarrow g \propto [^{3}P_{*}^{(1)}]$	33 $f_{\gamma} \rightarrow f_{\sigma}$	$69 \gamma \gamma \rightarrow W^+W^-$	171 $f_i \overline{f_i} \rightarrow Z^0 H^0$
53 $gg \rightarrow f_{2}\overline{f}_{2}$	$104 gg \rightarrow \chi_{2n}$	$A61 arr \rightarrow b D^{3} S^{(1)} 1 a$	24 62 - 62	$70 \gamma W^{\pm} \rightarrow Z^0 W^{\pm}$	172 $f\overline{A}_{i} \rightarrow W^{+}H^{0}$
68 00 - 00	105	402 m - 1D1 c(0) -	54 41-41	Liebt SM Higgs:	$173 66 \rightarrow 6618^{9}$
00 EE - EE	106 gg - Xie	402 gg → bol-Si lg	54 $g\gamma \rightarrow I_{k}I_{k}$	2 (T - b)	174 14 - 6610
Soft QCD processes:	$100 gg \rightarrow 3/\psi\gamma$	463 $gg \rightarrow bb[^{a}S_{0}^{a}]g$	5.8 $\gamma \gamma \rightarrow I_k I_k$	$3 4_{14} \rightarrow 11$	181 - 07 10
91 elastic scattering	$107 g\gamma \rightarrow 3/0g$	464 $gg \rightarrow b \bar{b} [^{a}P_{J}^{a}]g$	131 $f_i \gamma_T^* \rightarrow f_{ig}$	$24 I_{i}I_{i} \rightarrow Z^{*}II^{*}$	181 $gg \rightarrow Q_2 Q_3 H^{*}$
92 single diffraction (XB)	$108 \gamma \gamma \rightarrow J/\phi \gamma$	465 $gq \rightarrow qb\overline{b}[{}^{0}S_{1}^{(8)}]$	132 $f_i \gamma_L^* \rightarrow f_{ig}$	$26 i_i i_j \rightarrow W^a h^0$	$182 q_i q_i \rightarrow Q_k Q_k H^*$
93 single diffraction (AX)	421 $gg \rightarrow cc[{}^{\alpha}S_{1}^{(i)}]g$	466 gg $\rightarrow q b [c^{(6)}]$	133 $f_{1}\gamma_{1}^{\alpha} \rightarrow f_{1}\gamma$	32 $f_{dg} \rightarrow f_i h^0$	183 $f_i f_i \rightarrow g H^0$
94 double diffraction	422 $gg \rightarrow cc[{}^{3}S_{1}^{(8)}]g$	$A67 = a b \overline{b} \beta P_{1}^{(8)}$	134 $f_{12} \rightarrow f_{12}$	$102 \text{ gg} \rightarrow h^0$	184 $f_c g \rightarrow f_c H^0$
95 low-p. production	423 $gg \rightarrow c\overline{c}[{}^{1}S_{0}^{(8)}]g$	408 of - = = E(2c(8))	135 $g_{2}^{*} \rightarrow 4\overline{d}_{1}$	103 $\gamma \gamma \rightarrow h^0$	185 $gg \rightarrow gH^0$
Desert aboten	424 an - crap(8)1a	400 Q1 - g co[-51]	136 $m^2 \rightarrow 67$	110 $f_{i}T_{i} \rightarrow \gamma h^{0}$	156 $f_{i}\overline{d}_{i} \rightarrow A^{0}$
Prompt photons:	105 00 0000000000	$409 q\bar{q} \to g b b [50]$	127 atat - (7	111 $f_{L} \rightarrow gh^{0}$	157 $gg \rightarrow \Lambda^0$
14 $f_i f_i \rightarrow g \gamma$	425 $gq \rightarrow qcc[-3_1]$	470 $q\bar{q} \rightarrow g b\bar{b}[^{2}P_{f}^{(0)}]$	$i \sigma i \gamma \gamma \gamma \gamma \rightarrow i_1 i_1$	112 6	158 arr - N ⁰
18 $f_i f_i \rightarrow \gamma \gamma$	426 $gq \rightarrow qc\bar{c}[^{*}S_{0}^{*}]$	471 $gg \rightarrow b\overline{b}[{}^{5}P_{0}^{(1)}]g$	138 $\gamma_T \gamma_L \rightarrow M_i$	112 10 -10	170 17 30.0
29 $f_{cff} \rightarrow f_{c}\gamma$	427 $gq \rightarrow qc\bar{c}[^{3}P_{J}^{(8)}]$	472 $gz \rightarrow b\overline{D}^{3}F^{(3)}_{c}$	139 $\gamma_L^* \gamma_T^* \rightarrow \Omega_i$	115 gg - gh"	170 111 - 2'A'
114 $gg \rightarrow \gamma\gamma$	428 $q\bar{q} \rightarrow g \sigma [{}^{3}S_{1}^{(0)}]$	473 $g_{\rm Z} \rightarrow b \overline{D}{}^{3} P^{(3)}_{1} g$	140 $\gamma_{L}^{*}\gamma_{L}^{*} \rightarrow \Omega_{L}^{*}$	151 $52 \rightarrow G^{p}G^{p}\mu_{n}$	$177 I_i I_j \rightarrow W^- A^-$
115 $gg \rightarrow g\gamma$	429 $q\overline{q} \rightarrow g \sigma [{}^{1}S_{1}^{(0)}]$	474 m - + E0 p(l)	80 $q_i \gamma \rightarrow q_k \pi^*$	122 $Q_k \overline{Q}_k \rightarrow Q_k \overline{Q}_k h^0$	178 $f_i f_j \rightarrow f_i f_j A^o$
Oron hours flamour	430 $q\bar{q} \to q (q\bar{q} p^{(8)})$	and Ed - dool vo 1	W/Z production:	123 $f_i f_j \rightarrow f_i f_j h^0$	179 $f_i f_j \rightarrow f_k f_0 A^{\oplus}$
(che forth arout)	421 m	410 gq - qbb["1"]	1 $fL \rightarrow 2^{*}/2^{\circ}$	124 $f_i f_j \rightarrow f_k f_l h^0$	186 $gg \rightarrow Q_k \overline{Q}_k A^0$
(ago fourth generation)	$431 \underline{gg} \rightarrow cq \ F_0 \underline{gg}$	476 $gq \rightarrow qb \Sigma [^{0}P_{2}^{(i)}]$	2 (7	Heavy SM Higgs:	187 $q_i \overline{q}_i \rightarrow Q_b \overline{Q}_b A^0$
81 $f_{4}f_{4} \rightarrow Q_{4}Q_{4}$	432 $gg \rightarrow cc[F_1]g$	477 $q\bar{q} \rightarrow g b \bar{b} [{}^{3}P_{0}^{(1)}]$	$2 I_{ij} \rightarrow W$	5 2920 → h ⁰	188 $fd_i \rightarrow g\Lambda^0$
82 $gg \rightarrow Q_k Q_k$	433 $gg \rightarrow cc[{}^{\alpha}F_{2}^{\alpha}]g$	478 $q\bar{q} \rightarrow g b \overline{b} [^3 P_1^{(1)}]$	$22 I_{1}I_{4} \rightarrow Z^{*}Z^{*}$	e 10**11** b0	189 $f_{eff} \rightarrow f_{eff} \Lambda^{0}$
83 $q_k l_j \rightarrow Q_k l_l$	434 $gq \rightarrow qct[{}^{3}P_{0}^{(1)}]$	479 $aT \rightarrow g b \overline{b} [^3 P_{c}^{(1)}]$	$23 t_i t_j \rightarrow Z^{o_W a}$	E	190 $e_T \rightarrow e_{\Lambda^0}^0$
84 $g\gamma \rightarrow Q_k \overline{Q}_k$			$25 f_i f_i \rightarrow W^+ W^-$	$11 L_{L}L_{L} \rightarrow L_{L}L_{L}$	100 86 81
85 $\gamma \gamma \rightarrow F_k \overline{F}_k$			15 $f_if_i \rightarrow gZ^0$	$72 \mathcal{L}_{L}^{*}\mathcal{L}_{L}^{*} \rightarrow W_{L}^{*}W_{L}$	
			16 $f_i \overline{f}_j \rightarrow gW^{\pm}$	73 $Z_L^o W_L^o \rightarrow Z_L^o W_L^o$	
	No. Subprocess	No. Subprocess	$30 f_{eff} \rightarrow f_e Z^0$	76 $W_L^+W_L^- \rightarrow Z_L^0Z_L^0$	
	T. Asialar	Competence Competence	31 $f_{eff} \rightarrow f_{+}W^{\pm}$	77 $W_L^{\pm}W_L^{\pm} \rightarrow W_L^{\pm}W_L^{\pm}$	
	Technicolor:	Compositones:	N. O.L.	[N. 2.1]	[N. 6.]
No. Subprocess	149 $gg \rightarrow \eta_w$	146 $e\gamma \rightarrow e^{*}$	No. Subprocess	No. Subprocess	No. Subprocess
Channel Himme			1000 1000 10		
Charged Higgs	191 $I_iI_i \rightarrow \rho_{le}^{e}$	147 $dg \rightarrow d^*$	SUSY:	230 $f_i f_j \rightarrow \chi_2 \chi_1$	$263 kf_i \rightarrow t_1 t_2^* +$
143 $f_i \bar{f}_j \rightarrow H^+$	191 $t_i t_j \rightarrow \rho_{bc}^*$ 192 $t_i \overline{t}_j \rightarrow \rho_{bc}^*$	$147 dg \rightarrow d^*$ $148 ug \rightarrow u^*$	201 $f_i \overline{f}_i \rightarrow \overline{e}_L \overline{e}_L^*$	230 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 231 $i_i \bar{l}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^*$	263 $t_1 t_1 \rightarrow t_1 t_2^* +$ 264 $gg \rightarrow \tilde{t}_1 \tilde{t}_1^*$
143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i \alpha \rightarrow f_k H^+$	191 $t_i t_i \rightarrow \rho_w^a$ 192 $t_i \overline{t}_j \rightarrow \rho_w^a$ 193 $t_i \overline{t}_i \rightarrow \omega_w^a$	147 $ag \rightarrow a^*$ 148 $ug \rightarrow u^*$ 167 $q_iq_j \rightarrow d^*q_k$	SUSY: 201 $f_i \overline{f}_i \rightarrow \overline{e}_L \overline{e}_L^*$ 202 $f_i \overline{f}_i \rightarrow \overline{e}_R \overline{e}_R^*$	230 $td_j \rightarrow \tilde{\chi}_2 \tilde{\chi}_1^*$ 231 $td_j \rightarrow \tilde{\chi}_3 \tilde{\chi}_1^\pm$ 232 $td_j \rightarrow \tilde{\chi}_4 \tilde{\chi}_1^\pm$	$\begin{array}{ccc} 263 & kf_1 \rightarrow t_1 t_2^* + \\ 264 & gg \rightarrow \tilde{t}_1 \tilde{t}_1^* \\ 265 & gg \rightarrow \tilde{t}_2 \tilde{t}_2^* \end{array}$
Charged Higgs 143 $f_s \vec{l}_j \rightarrow H^+$ 161 $f_s \vec{q} \rightarrow f_b H^+$ 401 $g \vec{x} \rightarrow \vec{b} H^+$	191 $t_i t_i \rightarrow \rho_w^c$ 192 $t_i \overline{t}_j \rightarrow \rho_w^c$ 193 $t_i \overline{t}_i \rightarrow \omega_w^b$ 194 $t_i \overline{t}_i \rightarrow t_b \overline{t}_b$	147 $ag \rightarrow a^*$ 148 $ug \rightarrow u^*$ 167 $q_iq_j \rightarrow d^*q_k$ 168 $q_iq_j \rightarrow u^*q_k$	SUSY: 201 $f_i \overline{f}_i \rightarrow \overline{e}_L \overline{e}_L^*$ 202 $f_i \overline{f}_i \rightarrow \overline{e}_R \overline{e}_R^*$ 203 $f_i \overline{f}_i \rightarrow \overline{e}_L \overline{e}_L^*$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^a$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$	263 $i_{4}i_{4} \rightarrow i_{4}i_{2}^{+}$ 264 $gg \rightarrow \tilde{i}_{4}\tilde{i}_{4}^{*}$ 265 $gg \rightarrow \tilde{i}_{2}\tilde{i}_{2}^{*}$ 271 $i_{4}f_{j} \rightarrow \tilde{q}_{4}\tilde{x}\tilde{q}_{3}\tilde{x}$
Charged Higgs 143 $f_s \vec{l}_j \rightarrow H^+$ 161 $f_s \vec{q} \rightarrow f_b H^+$ 401 $g \vec{x} \rightarrow D_b H^+$ 402 $g \vec{\pi} \rightarrow D_b H^+$	191 $t_i I_i \rightarrow \rho_L^*$ 192 $t_i \overline{I}_j \rightarrow \rho_R^*$ 193 $t_i \overline{I}_i \rightarrow \omega_R^*$ 194 $t_i \overline{I}_i \rightarrow t_k \overline{I}_k$ 195 $t_i \overline{I}_j \rightarrow t_k \overline{I}_i$	147 $ag \rightarrow a^*$ 148 $ug \rightarrow u^*$ 167 $q_iq_j \rightarrow d^*q_k$ 168 $q_iq_j \rightarrow u^*q_k$ 169 $q_i\bar{q}_i \rightarrow u^*e^{i\pi}$	SUSY: 201 $t_i \overline{t}_i \rightarrow \overline{e}_L \overline{e}_L^*$ 202 $t_i \overline{t}_i \rightarrow \overline{e}_R \overline{e}_R^*$ 203 $t_i \overline{t}_i \rightarrow \overline{e}_L \overline{e}_R^*$ 204 $t_i \overline{t}_i \rightarrow \overline{e}_L \overline{e}_R^*$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^a$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$	263 $i_{4} \rightarrow i_{4}i_{2}^{+}$ 264 $gg \rightarrow \tilde{i}_{4}\tilde{i}_{4}^{*}$ 265 $gg \rightarrow \tilde{i}_{2}\tilde{i}_{2}^{*}$ 271 $i_{4}f_{j} \rightarrow \tilde{q}_{4}\tilde{x}\tilde{q}_{0}\tilde{x}$ 272 $i_{4}f_{j} \rightarrow \tilde{q}_{4}g\tilde{q}_{4}g$
Charged Higgs 143 $f_s \vec{f}_j \rightarrow H^+$ 161 $f_s \vec{g} \rightarrow f_b H^+$ 401 $g \vec{g} \rightarrow \vec{b} H^+$ 402 $q \vec{q} \rightarrow \vec{b} H^+$	191 $t_i I_i \rightarrow \rho_L^*$ 192 $t_i \overline{I}_j \rightarrow \rho_R^*$ 193 $t_i \overline{I}_i \rightarrow \omega_R^*$ 194 $t_i \overline{I}_i \rightarrow t_k \overline{I}_k$ 195 $t_i \overline{I}_j \rightarrow t_k \overline{I}_i$ 361 $t_i \overline{I}_i \rightarrow W_i^* W_i^-$	147 $ag \rightarrow a^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow e^k e^{i\pi}$ 165 $\mathbf{f}_{i_i}^{\overline{c}}(\rightarrow \gamma^*/Z^0) \rightarrow \mathbf{f}_k \overline{f}_k$	SUSY: 201 $t_i \overline{t}_i \rightarrow \overline{e}_L \overline{e}_L^*$ 202 $t_i \overline{t}_i \rightarrow \overline{e}_R \overline{e}_R^*$ 203 $t_i \overline{t}_i \rightarrow \overline{e}_L \overline{e}_R^*$ 204 $t_i \overline{t}_i \rightarrow \overline{\mu}_L \overline{\mu}_L^*$ 205 $t_i \overline{t}_i \rightarrow \overline{\mu}_L \overline{\mu}_L^*$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^a$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 235 $t\bar{d}_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$	263 $kf_i \rightarrow t_1t_2^{+}$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^{+}$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^{+}$ 271 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{jkl}$ 272 $kf_j \rightarrow \tilde{q}_kR\tilde{q}_{jkl}$ 273 $kf_i \rightarrow \tilde{q}_kR\tilde{q}_{ikl}$
Charged Higgs 143 $f_s \vec{f}_j \rightarrow H^+$ 161 $f_s \vec{g} \rightarrow f_b H^+$ 401 $g \vec{g} \rightarrow \vec{b} H^+$ 402 $q \vec{q} \rightarrow \vec{b} H^+$ Higgs pairs:	191 $t_i I_i \rightarrow \rho_L^*$ 192 $t_i \overline{I}_j \rightarrow \rho_R^*$ 193 $t_i \overline{I}_i \rightarrow \omega_R^*$ 194 $t_i \overline{I}_i \rightarrow t_k \overline{I}_k$ 195 $t_i \overline{I}_j \rightarrow t_k \overline{I}_i$ 361 $t_i \overline{I}_i \rightarrow W_L^* W_L^*$ 362 $t_i \overline{I}_j \rightarrow W_L^* W_L^*$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow e^+ e^{*\mp}$ 165 $f_i \overline{\ell}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{\ell}_k$ 166 $f_i \overline{\ell}_i (\rightarrow W^*) \rightarrow f_k \overline{\ell}_i$	SUSY: 201 $t_i \overline{t}_i \rightarrow \overline{v}_L \overline{v}_L^*$ 202 $t_i \overline{t}_i \rightarrow \overline{v}_R \overline{v}_R^*$ 203 $t_i \overline{t}_i \rightarrow \overline{v}_L \overline{v}_R^*$ 204 $t_i \overline{t}_i \rightarrow \overline{\mu}_L \overline{\mu}_L^*$ 205 $t_i \overline{t}_i \rightarrow \overline{\mu}_R \overline{\mu}_L^*$ 205 $t_i \overline{t}_i \rightarrow \overline{\mu}_R \overline{\mu}_L^*$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^*$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^*$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^*$ 235 $t\bar{d}_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^*$ 236 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$	263 $kf_i \rightarrow t_1t_2^{+}$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^{+}$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^{+}$ 271 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk}$ 272 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk}$ 273 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk}$ 273 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk}$ 274 $kf_i \rightarrow \tilde{q}_k\tilde{q}_{jk}$
Charged Higgs 143 $f_s \vec{f}_j \rightarrow H^+$ 161 $f_s \vec{g} \rightarrow f_b H^+$ 401 $g \vec{g} \rightarrow \vec{b}_b H^+$ 402 $q \vec{q} \rightarrow \vec{b}_b H^+$ Higgs pairs: 297 $f_s \vec{f}_j \rightarrow H^+ h^0$	191 $t_i I_i \rightarrow \rho_L^*$ 192 $t_i \overline{I}_j \rightarrow \rho_R^*$ 193 $t_i \overline{I}_i \rightarrow \omega_R^*$ 194 $t_i \overline{I}_i \rightarrow t_k \overline{I}_k$ 195 $t_i \overline{I}_j \rightarrow t_k \overline{I}_i$ 361 $t_i \overline{I}_i \rightarrow W_L^* W_L^*$ 362 $t_i \overline{I}_i \rightarrow W_L^* \pi_e^*$ 363 $t_i \overline{I}_i \rightarrow W_L^* \pi_e^*$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow e^+ e^{*\tau}$ 165 $f_i \overline{l}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{l}_k$ 166 $f_i \overline{l}_j (\rightarrow W^+) \rightarrow f_k \overline{l}_l$	SUSY: 201 $t_i \overline{t}_i \rightarrow \overline{v}_L \overline{v}_L^*$ 202 $t_i \overline{t}_i \rightarrow \overline{v}_R \overline{v}_R^*$ 203 $t_i \overline{t}_i \rightarrow \overline{v}_L \overline{v}_R^*$ 204 $t_i \overline{t}_i \rightarrow \overline{\mu}_L \overline{\mu}_L^*$ 205 $t_i \overline{t}_i \rightarrow \overline{\mu}_R \overline{\mu}_R^*$ 206 $t_i \overline{t}_i \rightarrow \overline{\mu}_L \overline{\mu}_R^*$ 206 $t_i \overline{t}_i \rightarrow \overline{\mu}_L \overline{\mu}_R^*$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^a$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 235 $t\bar{d}_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 236 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 237 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$	263 $kf_i \rightarrow t_1t_j^2 +$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^*$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^*$ 271 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk}$ 272 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk}$ 273 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk} +$ 274 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk} +$ 275 $kf_j \rightarrow \tilde{q}_k\tilde{q}_{jk}$
Charged Higgs 143 $f_s \vec{l}_j \rightarrow H^+$ 161 $f_s \vec{q} \rightarrow f_b H^+$ 401 $g \vec{q} \rightarrow \vec{0}_b H^+$ 402 $q \vec{q} \rightarrow \vec{0}_b H^+$ Higgs pairs: 297 $f_s \vec{l}_j \rightarrow H^+ h^0$ 298 $f_s \vec{l}_j \rightarrow H^+ H^0$	191 $t_i I_i \rightarrow \rho_L^*$ 192 $(\bar{I}_j \rightarrow \rho_R^*)$ 193 $t_i \bar{I}_i \rightarrow \omega_R^*$ 194 $t_i \bar{I}_i \rightarrow t_k \bar{I}_k$ 195 $t_i \bar{I}_j \rightarrow t_k \bar{I}_i$ 361 $t_i \bar{I}_i \rightarrow W_L^* W_L^*$ 362 $t_i \bar{I}_i \rightarrow W_L^* \pi_R^*$ 363 $t_i \bar{I}_i \rightarrow \pi_R^* \pi_R^*$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow e^+ e^{*\mp}$ 165 $f_i \overline{\ell}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{\ell}_k$ 166 $f_i \overline{\ell}_j (\rightarrow W^\pm) \rightarrow f_k \overline{\ell}_l$ Loft-right symmetry:	SUSY: 201 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 202 $t_i \overline{t}_i \rightarrow \bar{v}_R \bar{v}_R^*$ 203 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_R^*$ 204 $t_i \overline{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 205 $t_i \overline{t}_i \rightarrow \bar{\mu}_R \bar{\mu}_R^*$ 206 $t_i \overline{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_R^*$ 207 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_R^*$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^a$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 235 $t\bar{d}_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 236 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 237 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 238 $t\bar{d}_j \rightarrow \bar{\chi}_2$	263 $kf_i \rightarrow t_1t_2^2 +$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^*$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^*$ 271 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{jk}$ 272 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{jk}$ 273 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{jk}$ 274 $k(\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_{jk})$ 275 $k(\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_{jk})$ 275 $k(\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_{jk})$ 276 $k(\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_k)$
Charged Higgs 143 $f_s \vec{l}_j \rightarrow H^+$ 161 $f_s \vec{x} \rightarrow f_b H^+$ 401 $g \vec{x} \rightarrow \overline{b} H^+$ 402 $q \vec{n} \rightarrow \overline{b} H^+$ Higgs pairs: 297 $f_s \vec{l}_j \rightarrow H^b h^0$ 298 $f_s \vec{l}_j \rightarrow H^b H^0$ 299 $f_s \vec{l}_s \rightarrow \Lambda^0 h^0$	191 $t_i I_i \rightarrow \rho_L^*$ 192 $(\bar{I}_j \rightarrow \rho_R^*)$ 193 $t_i \bar{I}_i \rightarrow \omega_R^*$ 194 $t_i \bar{I}_i \rightarrow t_k \bar{I}_k$ 195 $t_i \bar{I}_j \rightarrow t_k \bar{I}_i$ 361 $t_i \bar{I}_i \rightarrow W_L^* W_L^*$ 362 $t_i \bar{I}_i \rightarrow W_L^* \pi_R^*$ 363 $t_i \bar{I}_i \rightarrow \tau_R^* \pi_R^*$ 364 $t_i \bar{I}_i \rightarrow \tau_R^* \pi_R^*$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow e^\pm e^{\pm \pi}$ 165 $f_i \overline{l}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{l}_k$ 166 $f_i \overline{l}_j (\rightarrow W^\pm) \rightarrow f_k \overline{l}_l$ Loft-right symmetry: 341 $\ell_i \ell_j \rightarrow H_L^{\pm\pm}$	SUSY: 201 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 202 $t_i \overline{t}_i \rightarrow \bar{v}_R \bar{v}_R^*$ 203 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_R^*$ 204 $t_i \overline{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 205 $t_i \overline{t}_i \rightarrow \bar{\mu}_R \bar{\mu}_R^*$ 206 $t_i \overline{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_R^*$ 207 $t_i \overline{t}_i \rightarrow \bar{v}_i \bar{v}_1^*$ 208 $t_i \overline{t}_i \rightarrow \bar{v}_l \bar{v}_l^*$	230 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^a$ 231 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^a$ 232 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 233 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 234 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^a$ 235 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 236 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^a$ 237 $id_i \rightarrow \bar{\chi}_1$ 238 $id_j \rightarrow \bar{\chi}_2$	263 $kf_i \rightarrow t_1t_2^2 +$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^*$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^*$ 271 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$ 272 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$ 273 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$ 273 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$ 275 $k\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$ 275 $k\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$ 276 $k\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$ 277 $k\tilde{t}_j \rightarrow \tilde{q}_k\tilde{t}_{0k}$
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Charged Higgs 143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i g \rightarrow f_k H^+$ 401 $gg \rightarrow \overline{0}_0 H^+$ Higgs pairs: 297 $f_i \overline{f}_j \rightarrow H^+ h^0$ 298 $f_i \overline{f}_j \rightarrow H^+ H^0$ 299 $f_i \overline{f}_i \rightarrow \Lambda^0 h^0$ 300 $f_i \overline{f}_i \rightarrow \Lambda^0 H^0$ 301 $f_i \overline{f}_i \rightarrow H^+ H^-$ New gauge bosons: 141 $f_i \overline{f}_i \rightarrow h^{(2)} f_i^{(2)}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow e^{\pm} e^{\pm \pi}$ 165 $f_i \overline{\ell}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{\ell}_k$ 166 $f_i \overline{\ell}_j (\rightarrow W^{\pm}) \rightarrow f_k \overline{\ell}_l$ Loft-right symmetry: 341 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 342 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 343 $\ell_i^{\pm} \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 344 $\ell_i^{\pm} \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 345 $\ell_i^{\pm} \gamma \rightarrow H_k^{\pm\pm} \mu^{\mp}$	SUSY: 201 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{L}\bar{v}_{L}^{*}$ 202 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{R}\bar{v}_{R}^{*}$ 203 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{L}\bar{v}_{R}^{*}$ 203 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{L}\bar{v}_{R}^{*}$ 205 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{\mu}_{L}\bar{\mu}_{L}^{*}$ 206 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{\mu}_{L}\bar{\mu}_{R}^{*}$ 207 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{1}\bar{v}_{R}^{*}$ 208 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{1}\bar{v}_{1}^{*}$ 209 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{1}\bar{v}_{1}^{*}$ 209 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{1}\bar{v}_{1}^{*}$ 209 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{1}\bar{v}_{1}^{*}$ 210 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{1}\bar{v}_{1}^{*}$ 211 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{1}\bar{v}_{1}^{*}$ 212 $\xi_{1}\overline{\ell}_{1} \rightarrow \bar{v}_{2}\bar{v}_{1}^{*}$	230 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 231 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^{+}$ 232 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 233 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^{+}$ 234 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^{+}$ 235 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 236 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 237 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 238 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 239 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 240 $id_4 \rightarrow \bar{\chi} \bar{\chi}_4$ 241 $id_j \rightarrow \bar{\chi} \bar{\chi}_1^{+}$ 242 $id_j \rightarrow \bar{\chi} \bar{\chi}_1^{+}$	263 $k_{1i} \rightarrow i_{1}i_{1}^{2} +$ 264 $gg \rightarrow \tilde{i}_{2}\tilde{i}_{1}^{2}$ 265 $gg \rightarrow \tilde{i}_{2}\tilde{i}_{2}^{2}$ 271 $k_{Ij}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{4}\chi$ 272 $k_{Ij}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{5}\chi$ 273 $k_{Ij}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{5}\chi$ 275 $k_{Ij}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{5}\chi$ 275 $k_{Ij}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{5}\chi$ 276 $k_{Ij}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{5}\chi$ 277 $k_{I}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{5}\chi$ 278 $k_{I}^{2} \rightarrow \tilde{q}_{4}\chi\tilde{q}_{5}\chi$ 279 $gg \rightarrow \tilde{q}_{4}\chi\tilde{q}_{4}\chi$ 280 $gg \rightarrow \tilde{q}_{4}\chi\tilde{q}_{4}\chi$
Charged Higgs 143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i g \rightarrow f_k H^+$ 401 $gg \rightarrow \overline{0}_b H^+$ Higgs pairs: 297 $f_i \overline{f}_j \rightarrow H^+ h^0$ 298 $f_i \overline{f}_j \rightarrow H^+ H^0$ 299 $f_i \overline{f}_i \rightarrow \Lambda^0 h^0$ 300 $f_i \overline{f}_i \rightarrow \Lambda^0 H^0$ 301 $f_i \overline{f}_i \rightarrow H^+ H^-$ New gauge bosons: 141 $f_i \overline{f}_i \rightarrow \gamma/Z^0/Z^0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow v^k v^{*\mp}$ 165 $f_i \overline{\ell}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{\ell}_i$ 166 $f_i \overline{\ell}_j (\rightarrow W^{\pm}) \rightarrow f_k \overline{\ell}_i$ 166 $f_i \overline{\ell}_j (\rightarrow W^{\pm}) \rightarrow f_k \overline{\ell}_i$ 167 $d_i \ell_j \rightarrow H_k^{\pm\pm}$ 341 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 342 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 343 $\ell_i^{\pm} \gamma \rightarrow H_k^{\pm\pm} v^{\mp}$ 344 $\ell_i^{\pm} \gamma \rightarrow H_k^{\pm\pm} v^{\mp}$ 345 $\ell_i^{\pm} \gamma \rightarrow H_k^{\pm\pm} V^{\mp}$	SUSY: 201 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 202 $t_i \overline{t}_i \rightarrow \bar{v}_R \bar{v}_R^*$ 203 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_R^*$ 203 $t_i \overline{t}_i \rightarrow \bar{v}_L \bar{v}_R^*$ 205 $t_i \overline{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 205 $t_i \overline{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_R^*$ 206 $t_i \overline{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_R^*$ 208 $t_i \overline{t}_i \rightarrow \bar{\eta}_L^*$ 208 $t_i \overline{t}_i \rightarrow \bar{\eta}_L^*$ 209 $t_i \overline{t}_i \rightarrow \bar{\eta}_L^*$ 209 $t_i \overline{t}_i \rightarrow \bar{\eta}_L^*$ 209 $t_i \overline{t}_i \rightarrow \bar{\eta}_L^*$ 210 $t_i \overline{t}_j \rightarrow \bar{\eta}_L \bar{v}_l^*$ 211 $t_i \overline{t}_j \rightarrow \bar{\eta}_L \bar{v}_l^*$ 213 $t_i \overline{t}_i \rightarrow \bar{\eta}_L \bar{v}_l^*$	230 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 231 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^{+}$ 232 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 233 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^{+}$ 234 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^{+}$ 235 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 236 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 237 $id_i \rightarrow \bar{\chi}_1 \bar{\chi}_1^{+}$ 238 $id_i \rightarrow \bar{\chi}_1$ 239 $id_i \rightarrow \bar{\chi}_1$ 240 $id_i \rightarrow \bar{\chi}_1^{+}$ 241 $id_j \rightarrow \bar{\chi}_1^{+}$ 242 $id_j \rightarrow \bar{\chi}_1^{+}$ 243 $id_i \rightarrow \bar{\chi}_1^{+}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
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Charged Higgs 143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i g \rightarrow f_k H^+$ 401 $gg \rightarrow \overline{0}_0 H^+$ Higgs pairs: 297 $f_i \overline{f}_j \rightarrow H^+ h^0$ 298 $f_i \overline{f}_j \rightarrow H^+ H^0$ 299 $f_i \overline{f}_i \rightarrow \Lambda^0 h^0$ 300 $f_i \overline{f}_i \rightarrow \Lambda^0 h^0$ 301 $f_i \overline{f}_i \rightarrow H^+ H^-$ New gauge bosons: 141 $f_i \overline{f}_i \rightarrow Y/Z^0/Z^0$ 142 $f_i \overline{f}_j \rightarrow W^+$ 144 $f_i \overline{f}_j \rightarrow R$	191 $t_i I_i \rightarrow \rho_L^{-}$ 192 $(\bar{I}_j \rightarrow \rho_w^{+})$ 193 $t_i \bar{I}_i \rightarrow \omega_w^{0}$ 194 $t_i \bar{I}_i \rightarrow t_k \bar{I}_k$ 195 $t_i \bar{I}_j \rightarrow t_k \bar{I}_i$ 361 $t_i \bar{I}_i \rightarrow W_L^{+} W_L^{-}$ 362 $t_i \bar{I}_i \rightarrow W_L^{+} \pi_w^{-}$ 363 $t_i \bar{I}_i \rightarrow \pi_w^{+} \pi_w^{-}$ 364 $t_i \bar{I}_i \rightarrow \pi_w^{+} \pi_w^{-}$ 365 $t_i \bar{I}_i \rightarrow \pi_w^{+} \pi_w^{-}$ 366 $t_i \bar{I}_i \rightarrow 2^0 \pi_w^{0}$ 367 $t_i \bar{I}_i \rightarrow 2^0 \pi_w^{0}$ 368 $t_i \bar{I}_i \rightarrow W_L^{+} \pi_w^{-}$ 368 $t_i \bar{I}_i \rightarrow W_L^{+} \pi_w^{0}$ 367 $t_i \bar{I}_j \rightarrow W_L^{+} \pi_w^{0}$ 367 $t_i \bar{I}_j \rightarrow W_L^{+} \pi_w^{0}$ 370 $t_i \bar{I}_j \rightarrow W_L^{+} \pi_w^{0}$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{l}_k \rightarrow e^{\pm} e^{\pm \pi}$ 165 $f_i \overline{l}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{l}_k$ 166 $f_i \overline{l}_j (\rightarrow W^{\pm}) \rightarrow f_k \overline{l}_l$ Loft-right symmetry: 341 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 342 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 343 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 344 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 345 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 346 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 347 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$	SUSY: 201 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 202 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 203 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 203 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 205 $t_i \bar{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 205 $t_i \bar{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 206 $t_i \bar{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 208 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{\nu}_L^*$ 209 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 209 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 210 $t_i \bar{t}_j \rightarrow \bar{v}_L \bar{v}_L^*$ 211 $t_i \bar{t}_j \rightarrow \bar{v}_L \bar{v}_L^*$ 213 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 214 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$	230 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^*$ 231 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 232 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 233 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^*$ 234 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 235 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 236 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 237 $id_4 \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 238 $id_4 \rightarrow \bar{\chi}_3 \bar{\chi}_1$ 239 $id_4 \rightarrow \bar{\chi}_3 \bar{\chi}_1$ 240 $id_4 \rightarrow \bar{\chi} \bar{\chi}_4$ 241 $id_j \rightarrow \bar{\chi} \bar{\chi}_1^*$ 242 $id_j \rightarrow \bar{\chi} \bar{\chi}_1^*$ 243 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 244 $id_j \rightarrow \bar{\chi} \bar{\chi}_1^*$ 245 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 246 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$	263 $kf_i \rightarrow t_1t_j^2 +$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^*$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^*$ 271 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LL}$ 272 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LR}$ 273 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LR}$ 274 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LR}$ 275 $k\tilde{t}_j \rightarrow \tilde{q}_L\tilde{q}_{LR}^*$ 276 $k\tilde{t}_j \rightarrow \tilde{q}_L\tilde{q}_{LR}^*$ 276 $k\tilde{t}_j \rightarrow \tilde{q}_L\tilde{q}_{LR}^*$ 277 $k\tilde{t}_i \rightarrow \tilde{q}_L\tilde{q}_{LR}^*$ 278 $k\tilde{t}_i \rightarrow \tilde{q}_L\tilde{q}_{LR}^*$ 279 $gg \rightarrow \tilde{q}_L\tilde{q}_{LL}^*$ 280 $gg \rightarrow \tilde{q}_L\tilde{q}_{LR}^*$ 281 $bq_i \rightarrow \tilde{b}_L\tilde{q}_{LR}$ 282 $bq_i \rightarrow \tilde{b}_L\tilde{q}_{LR}$
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\gamma \pi_w^{0}$ 365 $t_i \bar{I}_i \rightarrow \gamma \pi_w^{0}$ 366 $t_i \bar{I}_i \rightarrow 2^0 \pi_w^{0}$ 367 $t_i \bar{I}_i \rightarrow 2^0 \pi_w^{0}$ 368 $t_i \bar{I}_i \rightarrow W_L^{+} \pi_w^{0}$ 368 $t_i \bar{I}_i \rightarrow W_L^{+} \pi_w^{0}$ 369 $t_i \bar{I}_j \rightarrow W_L^{+} \pi_w^{0}$ 370 $t_i \bar{I}_j \rightarrow W_L^{+} \pi_w^{0}$ 371 $t_i \bar{I}_j \rightarrow W_L^{+} \pi_w^{0}$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_j \rightarrow d^* q_k$ 168 $q_i q_j \rightarrow u^* q_k$ 169 $q_i \overline{l}_k \rightarrow e^{\pm} e^{\pm \pi}$ 165 $f_i \overline{l}_i (\rightarrow \gamma^*/Z^0) \rightarrow f_k \overline{l}_k$ 165 $f_i \overline{l}_i (\rightarrow W^{\pm}) \rightarrow f_k \overline{l}_i$ 166 $f_i \overline{l}_j (\rightarrow W^{\pm}) \rightarrow f_k \overline{l}_i$ 167 $f_i \overline{l}_i (\rightarrow W^{\pm}) \rightarrow f_k \overline{l}_i$ 168 $f_i \overline{l}_j (\rightarrow W^{\pm}) \rightarrow f_k 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\bar{\chi} \bar{\chi}_4$ 241 $id_j \rightarrow \bar{\chi} \bar{\chi}_4^*$ 242 $id_j \rightarrow \bar{\chi} \bar{\chi}_1^*$ 243 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 244 $id_j \rightarrow \bar{\chi} \bar{\chi}_1^*$ 243 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 244 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 245 $id_4 \rightarrow \bar{\chi} \bar{\chi}_1$ 246 $id_6 \rightarrow \bar{\chi}_6 \bar{\chi}_5$	263 $kf_i \rightarrow t_1t_j^2 +$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^*$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^*$ 271 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LL}$ 272 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LR}$ 273 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LR}$ 274 $kf_j \rightarrow \tilde{q}_L\tilde{q}_{LR}$ 275 $k\tilde{t}_j \rightarrow \tilde{q}_L\tilde{q}_{LL}$ 276 $k\tilde{t}_j \rightarrow \tilde{q}_L\tilde{q}_{LL}^*$ 276 $k\tilde{t}_j \rightarrow \tilde{q}_L\tilde{q}_{LL}^*$ 277 $k\tilde{t}_i \rightarrow \tilde{q}_L\tilde{q}_{LL}^*$ 278 $k\tilde{t}_i \rightarrow \tilde{q}_L\tilde{q}_{LL}^*$ 279 $gg \rightarrow \tilde{q}_L\tilde{q}_{LL}^*$ 280 $gg \rightarrow \tilde{q}_L\tilde{q}_{LL}^*$ 281 $bq_i \rightarrow \tilde{b}_L\tilde{q}_{LL}$ 282 $bq_i \rightarrow \tilde{b}_L\tilde{q}_{LL}^*$ 284 $bq_i \rightarrow \tilde{b}_L\tilde{q}_{LL}^*$
Charged Higgs 143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i g \rightarrow f_k H^+$ 401 $gg \rightarrow \overline{0}_i H^+$ 402 $q\overline{q} \rightarrow \overline{0}_i H^+$ Higgs pairs: 297 $f_i \overline{f}_j \rightarrow H^+ h^0$ 298 $f_i \overline{f}_j \rightarrow H^+ H^0$ 299 $f_i \overline{f}_i \rightarrow \Lambda^0 H^0$ 300 $f_i \overline{f}_i \rightarrow \Lambda^0 H^0$ 301 $f_i \overline{f}_i \rightarrow H^+ H^-$ New gauge bosons: 141 $f_i \overline{f}_i \rightarrow \gamma/Z^0/Z^0$ 142 $f_i \overline{f}_j \rightarrow W^+$ 144 $f_i \overline{f}_j \rightarrow R$ Leptoquarks: 145 $q_i \ell_j \rightarrow L_0$	191 $t_i I_i \rightarrow \rho_L^*$ 192 $t_i \overline{I}_j \rightarrow \rho_u^*$ 193 $t_i \overline{I}_i \rightarrow \omega_u^*$ 193 $t_i \overline{I}_i \rightarrow \omega_u^*$ 194 $t_i \overline{I}_i \rightarrow t_b \overline{I}_b$ 195 $t_i \overline{I}_j \rightarrow t_b \overline{I}_i$ 361 $t_i \overline{I}_i \rightarrow W_L^* W_L^*$ 363 $t_i \overline{I}_i \rightarrow \pi_u^* \pi_u^*$ 363 $t_i \overline{I}_i \rightarrow \pi_u^* \pi_u^*$ 364 $t_i \overline{I}_i \rightarrow \gamma \pi_u^0$ 365 $t_i \overline{I}_i \rightarrow \gamma \pi_u^0$ 366 $t_i \overline{I}_i \rightarrow 2^0 \pi_u^0$ 367 $t_i \overline{I}_i \rightarrow Z^0 \pi_u^0$ 368 $t_i \overline{I}_i \rightarrow W_L^* Z_L^0$ 370 $t_i \overline{I}_j \rightarrow W_L^* Z_L^0$ 371 $t_i \overline{I}_j \rightarrow W_L^* Z_L^0$ 372 $t_i \overline{I}_j \rightarrow W_L^* \pi_u^0$ 373 $t_i \overline{I}_j \rightarrow \pi_u^* \pi_u^0$	147 $dg \rightarrow d^{*}$ 148 $ug \rightarrow u^{*}$ 148 $ug \rightarrow u^{*}$ 167 $q_{i}q_{j} \rightarrow d^{*}q_{k}$ 168 $q_{i}q_{j} \rightarrow u^{*}q_{k}$ 169 $q_{i}\overline{c}_{k} \rightarrow e^{\pm}e^{\mp}$ 165 $t_{k}\overline{l}_{i}(\rightarrow \gamma^{*}/\overline{Z}^{0}) \rightarrow t_{k}\overline{l}_{k}$ 166 $t_{k}\overline{l}_{j}(\rightarrow W^{\pm}) \rightarrow t_{k}\overline{l}_{l}$ Loft-right symmetry: 341 $\ell_{i}\ell_{j} \rightarrow H_{k}^{\pm\pm}$ 342 $\ell_{i}\ell_{j} \rightarrow H_{k}^{\pm\pm}$ 343 $\ell_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}e^{\mp}$ 344 $\ell_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}e^{\mp}$ 345 $\ell_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}\mu^{\mp}$ 346 $\ell_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}\mu^{\mp}$ 348 $\ell_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}\tau^{\mp}$ 349 $t_{k}\overline{l}_{i} \rightarrow H_{k}^{\pm\pm}H_{k}^{}$	SUSY: 201 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 202 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 203 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 203 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 205 $t_i \bar{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 205 $t_i \bar{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 206 $t_i \bar{t}_i \rightarrow \bar{\mu}_L \bar{\mu}_L^*$ 208 $t_i \bar{t}_i \rightarrow \bar{\tau}_L \bar{v}_L^*$ 209 $t_i \bar{t}_i \rightarrow \bar{\tau}_L \bar{v}_L^*$ 210 $t_i \bar{t}_j \rightarrow \bar{\tau}_L \bar{v}_L^*$ 211 $t_i \bar{t}_j \rightarrow \bar{\tau}_L \bar{v}_L^*$ 213 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 214 $t_i \bar{t}_i \rightarrow \bar{v}_L \bar{v}_L^*$ 215 $t_i \bar{t}_i \rightarrow \bar{\chi}_L \bar{\chi}_L$ 217 $t_i \bar{t}_i \rightarrow \bar{\chi}_L \bar{\chi}_L$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^*$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 235 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 236 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 237 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 238 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 239 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 240 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_4$ 241 $t\bar{d}_j \rightarrow \bar{g} \bar{\chi}_4^*$ 242 $t\bar{d}_j \rightarrow \bar{g} \bar{\chi}_1^*$ 243 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 244 $t\bar{d}_j \rightarrow \bar{g} \bar{\chi}_1^*$ 243 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 244 $t\bar{g} \rightarrow \bar{g} \bar{\chi}_1^*$ 245 $t\bar{g} \rightarrow \bar{g} \bar{\chi}_1^*$ 246 $tg \rightarrow \bar{g}_6 \bar{\chi}_1$ 247 $tg \rightarrow \bar{g}_6 \bar{\chi}_1$	263 $k_{ii} \rightarrow i_{1}i_{j}^{2} +$ 264 $gg \rightarrow \tilde{i}_{3}\tilde{i}_{1}^{2}$ 265 $gg \rightarrow \tilde{i}_{3}\tilde{i}_{2}^{2}$ 271 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}$ 272 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}$ 273 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}$ 275 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 275 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 276 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 277 $k_{i}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 278 $k_{i}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 279 $gg \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 280 $gg \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 281 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$ 282 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$ 283 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$ 284 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$
Charged Higgs 143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i g \rightarrow f_k H^+$ 401 $gg \rightarrow \overline{0}_i H^+$ 402 $q\overline{q} \rightarrow \overline{0}_i H^+$ Higgs pairs: 297 $f_i \overline{f}_j \rightarrow H^+ h^0$ 298 $f_i \overline{f}_j \rightarrow H^+ H^0$ 299 $f_i \overline{i}_i \rightarrow \Lambda^0 H^0$ 300 $f_i \overline{i}_i \rightarrow \Lambda^0 H^0$ 301 $f_i \overline{f}_i \rightarrow H^+ H^-$ New gauge bosons: 141 $f_i \overline{f}_i \rightarrow \gamma/Z^0/Z^0$ 142 $f_i \overline{f}_j \rightarrow W^+$ 144 $f_i \overline{f}_j \rightarrow R$ Leptoquarks: 145 $q_i \ell_j \rightarrow L_Q$ 162 $qg \rightarrow \overline{\ell}_{LQ}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	147 $dg \rightarrow d^{*}$ 148 $ug \rightarrow u^{*}$ 148 $ug \rightarrow u^{*}$ 167 $q_{i}q_{j} \rightarrow d^{*}q_{k}$ 168 $q_{i}q_{j} \rightarrow u^{*}q_{k}$ 169 $q_{i}\overline{c}_{k} \rightarrow e^{\pm}e^{\mp}$ 165 $t_{k}\overline{l}_{i}(\rightarrow \gamma^{*}/\overline{Z}^{0}) \rightarrow t_{k}\overline{l}_{k}$ 166 $t_{k}\overline{l}_{j}(\rightarrow W^{\pm}) \rightarrow t_{k}\overline{l}_{l}$ Left-right symmetry: 341 $l_{i}\ell_{j} \rightarrow H_{k}^{\pm\pm}$ 342 $l_{i}\ell_{j} \rightarrow H_{k}^{\pm\pm}$ 343 $l_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}e^{\mp}$ 344 $l_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}e^{\mp}$ 345 $l_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}\mu^{\mp}$ 346 $l_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}\mu^{\mp}$ 348 $l_{i}^{\pm}\gamma \rightarrow H_{k}^{\pm\pm}\tau^{\mp}$ 349 $t_{k}\overline{l}_{i} \rightarrow H_{k}^{\pm\pm}H_{k}^{}$	$\begin{array}{r} 30.8\mathrm{Y}:\\ 201 t_1\overline{t}_1 \rightarrow \bar{v}_L\bar{v}_L\\ 202 t_1\overline{t}_1 \rightarrow \bar{v}_L\bar{v}_L\\ 203 t_1\overline{t}_1 \rightarrow \bar{v}_L\bar{v}_L\\ 203 t_1\overline{t}_1 \rightarrow \bar{v}_L\bar{v}_L\\ 205 t_1\overline{t}_1 \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 205 t_1\overline{t}_1 \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{t}_1 \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{t}_1 \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 208 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 209 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 209 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 209 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 210 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 211 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 211 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 212 t_1\overline{t}_1 \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 213 t_1\overline{t}_1 \rightarrow \bar{\nu}_L\bar{\nu}_L\\ 214 t_1\overline{t}_1 \rightarrow \bar{\nu}_L\bar{\nu}_L\\ 216 t_1\overline{t}_1 \rightarrow \bar{\nu}_L\bar{\nu}_L\\ 216 t_1\overline{t}_1 \rightarrow \bar{\nu}_L\bar{\nu}_L\\ 218 t_1\overline{t}_1 \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 218 t_1\overline{t}_1 \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 218 t_1\overline{t}_1 \rightarrow \bar{\chi}_L\bar{\chi}_L \end{array}$	230 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^*$ 231 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 232 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 233 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^*$ 234 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^*$ 235 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 236 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 237 $id_4 \rightarrow \bar{\chi}_1$ 238 $id_4 \rightarrow \bar{\chi}_1$ 239 $id_4 \rightarrow \bar{\chi}_1$ 240 $id_4 \rightarrow \bar{\chi}_4$ 241 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 242 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 243 $id_4 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 244 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 243 $id_4 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 244 $id_4 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 245 $id_4 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 246 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 247 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 248 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 249 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 240 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 240 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 241 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$ 242 $id_6 \rightarrow \bar{\chi}_4 \bar{\chi}_1$	263 $k_{ii} \rightarrow i_{1}i_{j}^{2} +$ 264 $gg \rightarrow \tilde{i}_{3}\tilde{i}_{1}^{2}$ 265 $gg \rightarrow \tilde{i}_{3}\tilde{i}_{2}^{2}$ 271 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}$ 272 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}$ 273 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}$ 275 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 275 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 276 $k_{ij}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 277 $k_{i}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 278 $k_{i}^{2} \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 279 $gg \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 280 $gg \rightarrow \tilde{q}_{al}\tilde{q}_{al}^{2}$ 281 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$ 282 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$ 283 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$ 284 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$ 285 $bq_{i} \rightarrow \tilde{b}_{i}\tilde{q}_{al}$
Charged Higgs 143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i g \rightarrow f_k H^+$ 401 $gg \rightarrow \overline{0}_b H^+$ 402 $q\overline{q} \rightarrow \overline{0}_b H^+$ Higgs pairs: 297 $f_i \overline{f}_j \rightarrow H^+ h^0$ 298 $f_i \overline{f}_j \rightarrow H^+ H^0$ 299 $f_i \overline{t}_i \rightarrow \Lambda^0 H^0$ 300 $f_i \overline{t}_i \rightarrow \Lambda^0 H^0$ 301 $f_i \overline{t}_i \rightarrow H^+ H^-$ New gauge bosons: 141 $f_i \overline{f}_i \rightarrow \gamma/Z^0/Z^0$ 142 $f_i \overline{f}_j \rightarrow W^+$ 144 $f_i \overline{f}_j \rightarrow R$ Leptoquarks: 145 $q_i \ell_j \rightarrow L_Q$ 162 $qg \rightarrow \ell L_Q$ 163 $gg \rightarrow L_0 \overline{L}_0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_{ij} \rightarrow d^* q_k$ 168 $q_i q_{ij} \rightarrow u^* q_k$ 169 $q_i \overline{\ell}_k \rightarrow e^+ e^{*\tau}$ 165 $f_k \overline{\ell}_i (\rightarrow \gamma^*/\overline{Z}^0) \rightarrow f_k \overline{\ell}_k$ 166 $f_k \overline{\ell}_j (\rightarrow W^+) \rightarrow f_k \overline{\ell}_l$ Left-right symmetry: 341 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 342 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 343 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{i\gamma}$ 344 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{i\gamma}$ 345 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} \mu^*$ 346 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} \mu^*$ 348 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} \tau^{\mp}$ 349 $f_k \overline{\ell}_i \rightarrow H_k^{\pm\pm} H_k^{}$ 350 $f_k \overline{\ell}_i \rightarrow H_k^{\pm+} H_k^{}$ 351 $f_k \ell_j \rightarrow f_k \ell_i H_L^{\pm\pm}$	$\begin{array}{r} 30.8\mathrm{Y}:\\ 201 t_1\overline{d_1} \to \bar{u}_L\bar{u}_L\\ 202 t_1\overline{d_1} \to \bar{u}_L\bar{u}_L\\ 203 t_1\overline{d_1} \to \bar{u}_L\bar{u}_L\\ 203 t_1\overline{d_1} \to \bar{u}_L\bar{u}_L\\ 205 t_1\overline{d_1} \to \bar{\mu}_L\bar{\mu}_L\\ 205 t_1\overline{d_1} \to \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{d_1} \to \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{d_1} \to \bar{\mu}_L\bar{\mu}_L\\ 208 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 209 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 209 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 209 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 210 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 211 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 212 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 213 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 214 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 216 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 216 t_1\overline{d_1} \to \bar{\eta}_L\bar{\mu}_L\\ 216 t_1\overline{d_1} \to \bar{\eta}_L\bar{\eta}_L\\ 218 t_1\overline{d_1} \to \bar{\chi}_L\bar{\chi}_L\\ 218 t_1\overline{d_1} \to \bar{\chi}_L\bar{\chi}_L\\ 219 t_1\overline{d_1} \to \bar{\chi}_L\bar{\chi}_L \end{array}$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^*$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 235 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 236 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 237 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 238 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 239 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 240 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_4$ 241 $t\bar{d}_j \rightarrow \bar{g} \bar{\chi}_4^*$ 242 $t\bar{d}_j \rightarrow \bar{g} \bar{\chi}_4^*$ 243 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 244 $td \rightarrow \bar{g} \bar{\chi}_1$ 245 $td \rightarrow \bar{g} \bar{\chi}_1$ 246 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_1$ 247 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_1$ 248 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_1$ 249 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_2$ 249 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_2$	263 $kf_i \rightarrow t_1t_1^2 +$ 264 $gg \rightarrow \tilde{t}_1\tilde{t}_1^2$ 265 $gg \rightarrow \tilde{t}_2\tilde{t}_2^2$ 271 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 272 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 273 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 275 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 275 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 276 $kf_j \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 277 $kf_i \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 278 $kf_i \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 279 $gg \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 280 $gg \rightarrow \tilde{q}_k\tilde{t}_{kl}$ 281 $bq_i \rightarrow \tilde{b}_l\tilde{q}_{kl}$ 282 $bq_i \rightarrow \tilde{b}_l\tilde{q}_{kl}$ 283 $bq_i \rightarrow \tilde{b}_l\tilde{q}_{kl}$ 284 $bq_i \rightarrow \tilde{b}_l\tilde{q}_{kl}$ 285 $bq_i \rightarrow \tilde{b}_l\tilde{q}_{kl}$ 286 $bq_i \rightarrow \tilde{b}_l\tilde{q}_{kl}$ 287 $bq_i \rightarrow \tilde{b}_l\tilde{q}_{kl}$
Charged Higgs 143 $f_i \overline{f}_j \rightarrow H^+$ 161 $f_i g \rightarrow f_k H^+$ 401 $gg \rightarrow \overline{0}_0 H^+$ 402 $q\overline{q} \rightarrow \overline{0}_0 H^+$ Higgs pairs: 297 $f_i \overline{f}_j \rightarrow H^+ h^0$ 298 $f_i \overline{f}_j \rightarrow H^+ H^0$ 299 $f_i \overline{t}_i \rightarrow \Lambda^0 H^0$ 300 $f_i \overline{t}_i \rightarrow \Lambda^0 H^0$ 301 $f_i \overline{t}_i \rightarrow H^+ H^-$ New gauge bosons: 141 $f_i \overline{f}_i \rightarrow \gamma/Z^0/Z^0$ 142 $f_i \overline{f}_j \rightarrow W^+$ 144 $f_i \overline{f}_j \rightarrow R$ Leptoquarks: 145 $q_i \ell_j \rightarrow L_Q$ 162 $qg \rightarrow \ell L_Q$ 163 $gg \rightarrow L_Q \overline{L}_Q$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{r} 30.8\mathrm{Y}:\\ 201 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 202 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 203 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 203 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 205 t_1\overline{t}_1 \rightarrow \bar{\mu}_L \bar{\mu}_L\\ 205 t_1\overline{t}_1 \rightarrow \bar{\mu}_L \bar{\mu}_L\\ 206 t_1\overline{t}_1 \rightarrow \bar{\mu}_L \bar{\mu}_L\\ 206 t_1\overline{t}_1 \rightarrow \bar{\mu}_L \bar{\mu}_L\\ 208 t_1\overline{t}_1 \rightarrow \bar{\mu}_L \bar{\mu}_L\\ 209 t_1\overline{t}_1 \rightarrow \bar{\eta}_L \bar{v}_L\\ 210 t_1\overline{t}_1 \rightarrow \bar{\eta}_L \bar{v}_L\\ 211 t_1\overline{t}_1 \rightarrow \bar{\eta}_L \bar{v}_L\\ 212 t_1\overline{t}_1 \rightarrow \bar{\eta}_L \bar{v}_L\\ 213 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 214 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 216 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 216 t_1\overline{t}_1 \rightarrow \bar{v}_L \bar{v}_L\\ 218 t_1\overline{t}_1 \rightarrow \bar{\chi}_L \bar{\chi}_L\\ 219 t_1\overline{t}_1 \rightarrow \bar{\chi}_L \bar{\chi}_L\\ 220 t_1\overline{t}_1 \rightarrow \bar{\chi}_L \bar{\chi}_L \end{aligned}$	230 $td_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^*$ 231 $t\bar{d}_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^*$ 232 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 233 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 234 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 235 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 236 $t\bar{d}_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^*$ 237 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 238 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 239 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 240 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_4$ 241 $t\bar{d}_j \rightarrow \bar{g} \bar{\chi}_4^*$ 242 $t\bar{d}_j \rightarrow \bar{g} \bar{\chi}_4^*$ 243 $t\bar{d}_4 \rightarrow \bar{g} \bar{\chi}_1$ 244 $td \rightarrow \bar{g} \bar{\chi}_1$ 244 $td \rightarrow \bar{g} \bar{\chi}_1$ 245 $td \rightarrow \bar{g} \bar{\chi}_1$ 246 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_1$ 248 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_1$ 249 $td \rightarrow \bar{g} \bar{\chi}_1 \bar{\chi}_2$ 250 $td \rightarrow \bar{g} \bar{\chi}_1$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_{ij} \rightarrow d^* q_k$ 168 $q_i q_{ij} \rightarrow u^* q_k$ 169 $q_i \overline{\ell}_k \rightarrow e^+ e^{+\tau}$ 165 $\xi_k \overline{\ell}_i (\rightarrow \gamma^*/Z^0) \rightarrow \xi_k \overline{\ell}_k$ 166 $\xi_k \overline{\ell}_j (\rightarrow W^+) \rightarrow \xi_k \overline{\ell}_l$ Left-right symmetry: 341 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 342 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 343 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{i\tau}$ 344 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{i\tau}$ 345 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{i\tau}$ 346 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} \tau^{\pm\tau}$ 348 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} \tau^{\pm\tau}$ 349 $\xi_k \overline{\ell}_i \rightarrow H_k^{\pm\pm} H_k^{}$ 350 $\xi_k \overline{\ell}_i \rightarrow H_k^{\pm\pm} H_k^{}$ 351 $\xi_k f_j \rightarrow f_k f_i H_k^{\pm\pm}$ 353 $\xi_k \overline{\ell}_i \rightarrow Z_k^0$	$\begin{array}{r} 30.8\mathrm{Y}:\\ 201 t_1\overline{t_1} \rightarrow \bar{v}_L\bar{v}_L\\ 202 t_1\overline{t_1} \rightarrow \bar{v}_L\bar{v}_L\\ 203 t_1\overline{t_1} \rightarrow \bar{v}_L\bar{v}_L\\ 203 t_1\overline{t_1} \rightarrow \bar{v}_L\bar{v}_L\\ 205 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 205 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 208 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 209 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 209 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 210 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 211 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 211 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 212 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 213 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 214 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 214 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\nu}_L\\ 216 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 217 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 218 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 220 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 220 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 220 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L \end{array}$	230 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 231 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^{+}$ 232 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 233 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^{+}$ 234 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 235 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 236 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 237 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 238 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 239 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 240 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 241 $id_j \rightarrow \bar{g} \bar{\chi}_1^{+}$ 242 $id_j \rightarrow \bar{g} \bar{\chi}_1^{+}$ 243 $id_i \rightarrow \bar{g} \bar{g}$ 244 $gg \rightarrow \bar{g} \bar{\chi}_1^{+}$ 245 $id_i \rightarrow \bar{g} \bar{g}$ 246 $igg \rightarrow \bar{g} g \bar{\chi}_1$ 247 $igg \rightarrow \bar{g} g \bar{\chi}_1$ 248 $igg \rightarrow \bar{g} g \bar{\chi}_1$ 249 $igg \rightarrow \bar{g} g \bar{\chi}_2$ 250 $igg \rightarrow \bar{g} g \bar{\chi}_2$ 250 $igg \rightarrow \bar{g} g \bar{\chi}_2$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_{ij} \rightarrow d^* q_k$ 168 $q_i q_{ij} \rightarrow u^* q_k$ 169 $q_i \overline{q}_k \rightarrow e^+ e^{+\tau}$ 165 $\xi_k \overline{l}_i (\rightarrow \gamma^*/Z^0) \rightarrow \xi_k \overline{l}_k$ 166 $\xi_k \overline{l}_j (\rightarrow W^+) \rightarrow \xi_k \overline{l}_l$ Left-right symmetry: 341 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 342 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 343 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 344 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 345 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} q^{\mp}$ 346 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} q^{\mp}$ 347 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} q^{\mp}$ 348 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} q^{\mp}$ 349 $\xi_k \overline{l}_i \rightarrow H_k^{\pm\pm} H_k^{}$ 350 $\xi_k \overline{l}_i \rightarrow H_k^{\pm\pm} H_k^{}$ 351 $\xi_k f_j \rightarrow \xi_k f_k H_k^{\pm\pm}$ 353 $\xi_k \overline{l}_i \rightarrow Z_k^0$	$\begin{array}{r} 30.8\mathrm{Y}:\\ 201 t_1\overline{t_1} \rightarrow \bar{a}_L\bar{a}_L\\ 202 t_1\overline{t_1} \rightarrow \bar{a}_L\bar{a}_L\\ 203 t_1\overline{t_1} \rightarrow \bar{a}_L\bar{a}_L\\ 203 t_1\overline{t_1} \rightarrow \bar{a}_L\bar{a}_L\\ 205 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 205 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 206 t_1\overline{t_1} \rightarrow \bar{\mu}_L\bar{\mu}_L\\ 207 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 208 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 209 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 209 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 210 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 210 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 211 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 211 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 212 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 213 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 214 t_1\overline{t_1} \rightarrow \bar{\eta}_L\bar{\mu}_L\\ 216 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 217 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 218 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 220 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 220 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 220 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 221 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L\\ 222 t_1\overline{t_1} \rightarrow \bar{\chi}_L\bar{\chi}_L \end{array}$	230 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 231 $id_j \rightarrow \bar{\chi}_3 \bar{\chi}_1^{+}$ 232 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 233 $id_j \rightarrow \bar{\chi}_1 \bar{\chi}_1^{+}$ 234 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 235 $id_j \rightarrow \bar{\chi}_2 \bar{\chi}_1^{+}$ 236 $id_j \rightarrow \bar{\chi}_4 \bar{\chi}_1^{+}$ 237 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 238 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 239 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 240 $id_i \rightarrow \bar{g} \bar{\chi}_1$ 241 $id_j \rightarrow \bar{g} \bar{\chi}_1^{+}$ 242 $id_j \rightarrow \bar{g} \bar{\chi}_1^{+}$ 243 $id_i \rightarrow \bar{g} \bar{g}$ 244 $gg \rightarrow \bar{g} \bar{\chi}_1$ 245 $id_i \rightarrow \bar{g} \bar{g}$ 246 $igg \rightarrow \bar{g} g \bar{\chi}_1$ 247 $igg \rightarrow \bar{g} g \bar{\chi}_1$ 248 $igg \rightarrow \bar{g} g \bar{\chi}_1$ 249 $igg \rightarrow \bar{g} g \bar{\chi}_2$ 250 $igg \rightarrow \bar{g} g \bar{\chi}_2$ 250 $igg \rightarrow \bar{g} g \bar{\chi}_1$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	147 $dg \rightarrow d^*$ 148 $ug \rightarrow u^*$ 167 $q_i q_{ij} \rightarrow d^* q_k$ 168 $q_i q_{ij} \rightarrow u^* q_k$ 169 $q_i \overline{\ell}_k \rightarrow e^+ e^{+\tau}$ 165 $\xi_k \overline{\ell}_i (\rightarrow \gamma^*/Z^0) \rightarrow \xi_k \overline{\ell}_k$ 166 $\xi_k \overline{\ell}_j (\rightarrow W^+) \rightarrow \xi_k \overline{\ell}_l$ Left-right symmetry: 341 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 342 $\ell_i \ell_j \rightarrow H_k^{\pm\pm}$ 343 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 344 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 345 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} e^{\mp}$ 346 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} \pi^{\mp}$ 348 $\ell_i^* \gamma \rightarrow H_k^{\pm\pm} \pi^{\mp}$ 349 $\xi_k \overline{\ell}_i \rightarrow H_k^{\pm\pm} H_k^{}$ 350 $\xi_k \overline{\ell}_i \rightarrow H_k^{\pm\pm} H_k^{}$ 351 $\xi_k \ell_j \rightarrow \xi_k \ell_l H_k^{\pm\pm}$ 352 $\xi_k \ell_j \rightarrow \xi_k \ell_l H_k^{\pm\pm}$ 353 $\xi_k \overline{\ell}_i \rightarrow Z_k^0$ 354 $\xi_k \overline{\ell}_j \rightarrow W_k^{\pm}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	230 $id_j \rightarrow \bar{\chi}_{3}\bar{\chi}_{1}^{+}$ 231 $i\vec{d}_{j} \rightarrow \bar{\chi}_{3}\bar{\chi}_{1}^{+}$ 232 $i\vec{d}_{j} \rightarrow \bar{\chi}_{4}\bar{\chi}_{1}^{+}$ 233 $i\vec{d}_{j} \rightarrow \bar{\chi}_{3}\bar{\chi}_{1}^{+}$ 234 $i\vec{d}_{j} \rightarrow \bar{\chi}_{3}\bar{\chi}_{1}^{+}$ 235 $i\vec{d}_{j} \rightarrow \bar{\chi}_{3}\bar{\chi}_{1}^{+}$ 236 $i\vec{d}_{j} \rightarrow \bar{\chi}_{4}\bar{\chi}_{1}^{+}$ 237 $i\vec{d}_{i} \rightarrow \bar{g}\bar{\chi}_{1}$ 238 $i\vec{d}_{i} \rightarrow \bar{g}\bar{\chi}_{1}$ 239 $i\vec{d}_{i} \rightarrow \bar{g}\bar{\chi}_{1}$ 240 $i\vec{d}_{i} \rightarrow \bar{g}\bar{\chi}_{1}$ 241 $i\vec{d}_{j} \rightarrow \bar{g}\bar{\chi}_{1}^{+}$ 242 $i\vec{d}_{j} \rightarrow \bar{g}\bar{\chi}_{1}^{+}$ 243 $i\vec{d}_{i} \rightarrow \bar{g}\bar{g}$ 244 $i\vec{x} \rightarrow \bar{g}\bar{\chi}_{1}$ 245 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$ 246 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$ 247 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$ 248 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$ 249 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$ 249 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$ 240 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$ 241 $i\vec{x} \rightarrow \bar{g}_{k}\bar{\chi}_{1}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
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Event Generation at Hadron Colliders Johan Alwall 46

List of processes

implemented

in Pythia (by hand!)



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 High-Q2 scattering processes: In principle infinite number of processes for innumerable number of models





- High-Q2 scattering processes: In principle infinite number of processes for innumerable number of models
- Implementation by hand time-consuming, labor intensive and error prone





- High-Q2 scattering processes: In principle infinite number of processes for innumerable number of models
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- Instead: Automated matrix element generators
 - Use Feynman rules to build diagrams





- High-Q2 scattering processes: In principle infinite number of processes for innumerable number of models
- Implementation by hand time-consuming, labor intensive and error prone
- Instead: Automated matrix element generators
 - Use Feynman rules to build diagrams
- Given files defining the model content: particles, parameters and interactions, allows to generate any process for a given model!



- Automatic matrix element generators:
 - CalcHep / CompHep
 - MadGraph
 - AMEGIC++ (Sherpa)
 - ➡ Whizard
- Standard Model only, with fast matrix elements for high parton multiplicity final states:
 - AlpGen
 - ➡ HELAC
 - COMIX (Sherpa)

I. High- Q^2 Scattering

2. Parton Shower



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Parton Shower basics

Matrix elements involving $q \rightarrow q g$ (or $g \rightarrow gg$) are strongly enhanced when the final state particles are close in the phase space:

$$\frac{1}{(p_b + p_c)^2} \simeq \frac{1}{2\frac{E_b E_c(1 - \cos\theta)}{2}} = \frac{1}{t} \qquad (M_P) = \frac{1}{a} = \frac{1}{z} = \frac{1}{z + E_b/E_a}$$
soft and collinear divergencies

Collinear factorization:

$$|M_{p+1}|^2 d\Phi_{p+1} \simeq |M_p|^2 d\Phi_p \frac{dt}{t} \frac{\alpha_S}{2\pi} P(z) dz d\phi$$

when θ is small.

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- The result is a "cascade" or "shower" of partons with ever smaller virtualities.
- The procedure stops when the scale of the splitting is below some t_{cut} , usually close to 1 GeV, the scale where non-perturbative effects start dominating over the perturbative parton shower.
- At this point, phenomenological models are used to simulate how the partons turn into color-neutral hadrons.





From Parton Showers to Hadronization

- The parton shower evolves the hard scattering down to the scale of O(IGeV).
- At this scale, QCD is no longer perturbative. some hadronization model is used to describe the transition from the perturbative PS region to the non-perturbative hadronization region.
- Main hadronization models:
 - String hadronization (Pythia)

[Andersson,Gustafson,Ingelman,Sjöstrand (1983)]

Cluster hadronization (Herwig)

[Webber (1984)]

• Hadronization only acts locally, not sensitive to high- q^2 scattering.









Parton Shower MC event generators

- General-purpose tools
- Complete exclusive description of the events: hard scattering, showering, hadronization, underlying event
- Reliable and well tuned to experimental data. most well-known: PYTHIA, HERWIG, SHERPA
- You will hear much more about Parton Showers in coming lectures, including recent progress in taking PS to NLO in QCD





Detector simulation

- Detector simulation
 - Fast general-purpose detector simulators:
 Delphes, PGS ("Pretty good simulations"), AcerDet
 - Specify parameters to simulate different experiments
- Experiment-specific fast simulation
 - Detector response parameterized
 - Run time ms-s/event
- Experiment-specific full simulation
 - Full tracking of particles through detector using GEANT
 - Run time several minutes/event





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- Next lecture: Simulations with MadGraph 5