

MADGRAPH

Tilman Plehn

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- Madgraph vs. Madevent
- few LHC studies (skipped here)
- structure of Madgraph + examples
- basics of Madevent + examples
- summary: speaker not a main author!

in name of:

F. Maltoni, J. Alwall, S. DeVisscher R. Frederix, M. Herquet,..., K. Hagiwara, D. Rainwater, T. Stelzer

MADGRAPH VS. MADEVENT

Old problem in collider phenomenology [Stelzer & Long]

- problem: (differential) tree-level cross sections for ILC, LHC
 - usually more complex than good old $2 \rightarrow 2$ [off-shell effects, jet radiation,...]
 - available for helicity amplitudes numerics: HELAS [Hagiwara, Murayama, Watanabe]
- ⇒ **Madgraph**: complicated process $(a, b \rightarrow c, d, e, f, \dots) \longrightarrow \overline{|\mathcal{M}|^2}$ [Fortran]

Included in Madgraph

- user-defined: particles & interactions [Standard Model, MSSM default]
 - user-defined: couplings in Fortran [Standard Model, MSSM default]
 - included: Feynman diagram calculator [including postscript file]
 - included: Fortran function $\overline{|\mathcal{M}|^2}$ [linked to HELAS library]
 - only in Madevent: phase space integrator/generator
 - only in Madevent: plotting routine, fast detector simulation...
- ⇒ **Madgraph for people who want to get hands dirty**

MADGRAPH VS. MADEVENT

Advanced web tool: Madevent [Maltoni, Stelzer, Alwall,...]

- there is such a thing as a good phase space generator
- writing a histogram routine is a waste of time
- Pythia/PGS interfaces are standardized
- ⇒ extended version of old Madgraph
- ⇒ highly complex public computer code [great if someone else maintains it]
- ⇒ **web-based out of Louvain-la-Neuve**

Beyond the (MS)SM [SUSY release paper: hep-ph/0601063; similar for 2HDM, Higgs-ET, UED, etc.]

- Madgraph: BSM processes only new particles, interactions files
- Madevent: originally complicated information transfer
- ⇒ now everything by Perl script
- ⇒ **BSM-Madevent the future**

Reference processes on the web [Smadgraph + Sherpa + Whizard]

Comparison of Automated Tools for Phenomenological Investigations of SuSy

2HDM IN MADEVENT

Higgs Basis [\(more info\)](#)

$$\begin{aligned}
 V = & \mu_1 H_1^\dagger H_1 + \mu_2 H_2^\dagger H_2 - (\mu_3 H_1^\dagger H_2 + \text{h.c.}) \\
 & \lambda_1 (H_1^\dagger H_1)^2 + \lambda_2 (H_2^\dagger H_2)^2 \\
 & + \lambda_3 (H_1^\dagger H_1) (H_2^\dagger H_2) + \lambda_4 (H_1^\dagger H_2) (H_2^\dagger H_1) \\
 & + \left[(\lambda_5 H_1^\dagger H_2 + \lambda_6 H_1^\dagger H_1 + \lambda_7 H_2^\dagger H_2) (H_1^\dagger H_2) + \text{h.c.} \right]
 \end{aligned}$$

lambda1	1
lambda2	1
lambda3	1
lambda4	0
lambda5	0
Norm of lambda6	0
Norm of lambda7	0
Phase of lambda6	0
Phase of lambda7	0
Mass of Charged Higgs (GeV)	300

Generic Basis [\(more info\)](#)

$$\begin{aligned}
 V = & \mu_1 \phi_1^\dagger \phi_1 + \mu_2 \phi_2^\dagger \phi_2 - (\mu_3 \phi_1^\dagger \phi_2 + \text{h.c.}) \\
 & + \frac{1}{2} \lambda_1 (\phi_1^\dagger \phi_1)^2 + \frac{1}{2} \lambda_2 (\phi_2^\dagger \phi_2)^2 \\
 & + \lambda_3 (\phi_1^\dagger \phi_1) (\phi_2^\dagger \phi_2) + \lambda_4 (\phi_1^\dagger \phi_2) (\phi_2^\dagger \phi_1) \\
 & + \left[\left(\frac{1}{2} \lambda_5 \phi_1^\dagger \phi_2 + \lambda_6 \phi_1^\dagger \phi_1 + \lambda_7 \phi_2^\dagger \phi_2 \right) (\phi_1^\dagger \phi_2) + \text{h.c.} \right]
 \end{aligned}$$

Tan(beta)=v2/v1	1
Phase of v2	0
Norm of mu3	0
lambda1	1
lambda2	1
lambda3	1
lambda4	0
Norm of lambda5	0
Norm of lambda6	0
Norm of lambda7	0
Phase of lambda5	0
Phase of lambda6	0
Phase of lambda7	0

Yukawa parameters

Higgs basis [\(more info\)](#)

$$\begin{aligned}
 \mathcal{L}_Y = & \frac{\overline{Q}_L \sqrt{2}}{v} \left[(M_d H_1 + Y_d H_2) d_R + (M_u \tilde{H}_1 + Y_u \tilde{H}_2) u_R \right] \\
 & + \frac{\overline{E}_L \sqrt{2}}{v} [(M_e H_1 + Y_e H_2) e_R]
 \end{aligned}$$

Generic Basis [\(more info\)](#)

$$\begin{aligned}
 \mathcal{L}_Y = & \frac{\overline{Q}_L \sqrt{2}}{v} \left[(\Delta_d \phi_1 + \Gamma_d \phi_2) d_R + (\Delta_u \tilde{\phi}_1 + \Gamma_u \tilde{\phi}_2) u_R \right] \\
 & + \frac{\overline{E}_L \sqrt{2}}{v} [(\Delta_e \phi_1 + \Gamma_e \phi_2) e_R]
 \end{aligned}$$

Yukawa couplings to the second Higgs doublet of the down type quarks (norm and phase)

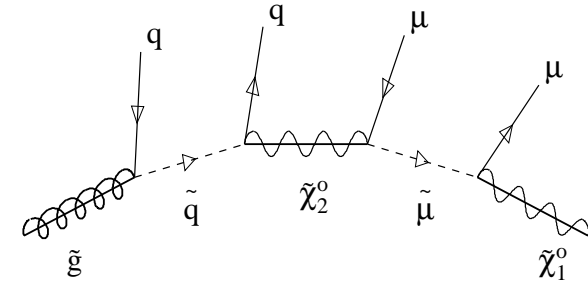
Y1D/G1D	0	0	Y1S/G1S	0	0	Y1B/G1B	0	0
Y2D/G2D	0	0	Y2S/G2S	0	0	Y2B/G2B	0	0
Y3D/G3D	0	0	Y3S/G3S	0	0	Y3B/G3B	0	0

[TwoHiggsCalc: Herquet, DeVisscher, Ovyn]

1 – SQUARKS AND GLUINOS WITH JETS

Inclusive and exclusive squark–gluino signatures

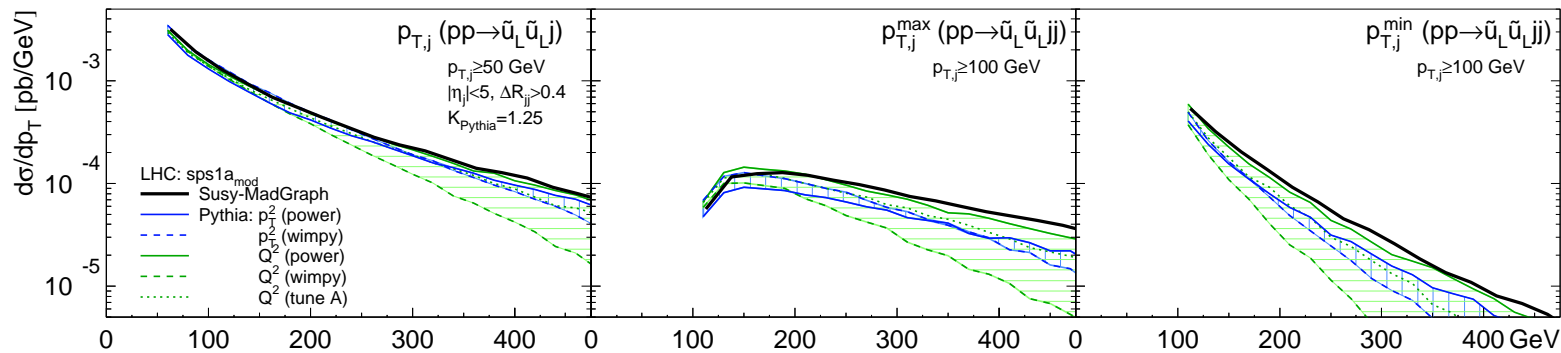
- decays to jets, missing energy, possibly leptons
 - inclusive: jet multiplicity 1 for \tilde{q} , 2 for \tilde{g}
 - exclusive: SUSY masses from thresholds & edges
- ⇒ effects of additional hard jets on analyses?



Comparison Pythia — Smadevent [TP, Rainwater, Skands]

- matrix element $\tilde{g}\tilde{g}+2j$ and $\tilde{u}_L\tilde{g}+2j$ [$p_{T,j} > 100$ GeV]
 - normalized $p_{T,j}$ distributions
 - Pythia shower tuned at Tevatron
- ⇒ **SUSY easier than tops** [QCD: the heavier the better]

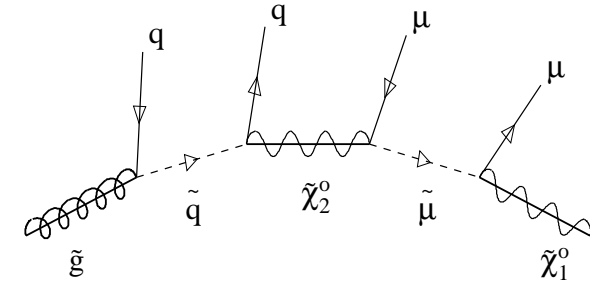
σ [pb]	$t\bar{t}_{600}$	$\tilde{g}\tilde{g}$	$\tilde{u}_L\tilde{g}$
σ_{0j}	1.30	4.83	5.65
σ_{1j}	0.73	2.89	2.74
σ_{2j}	0.26	1.09	0.85



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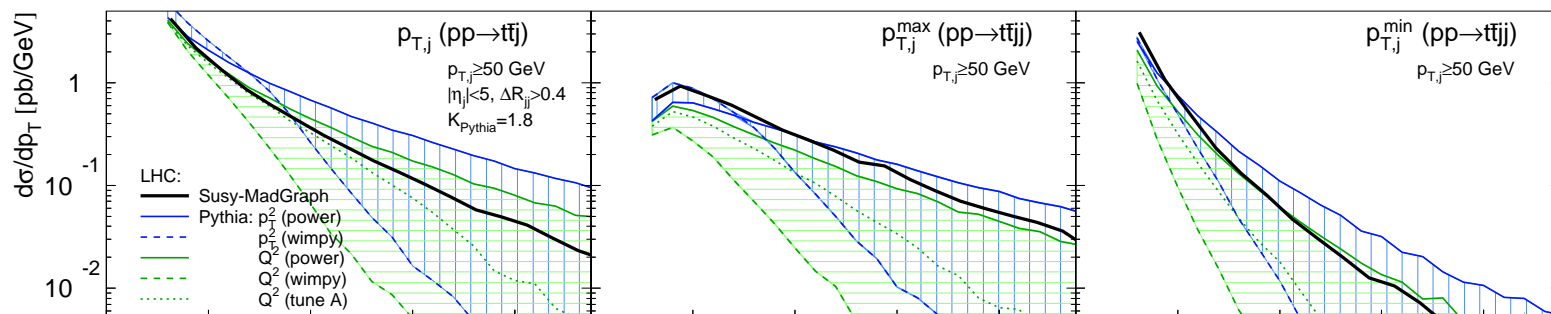
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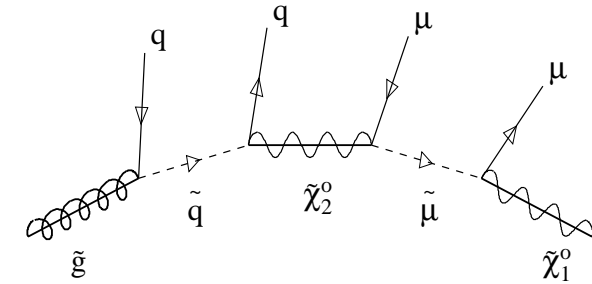
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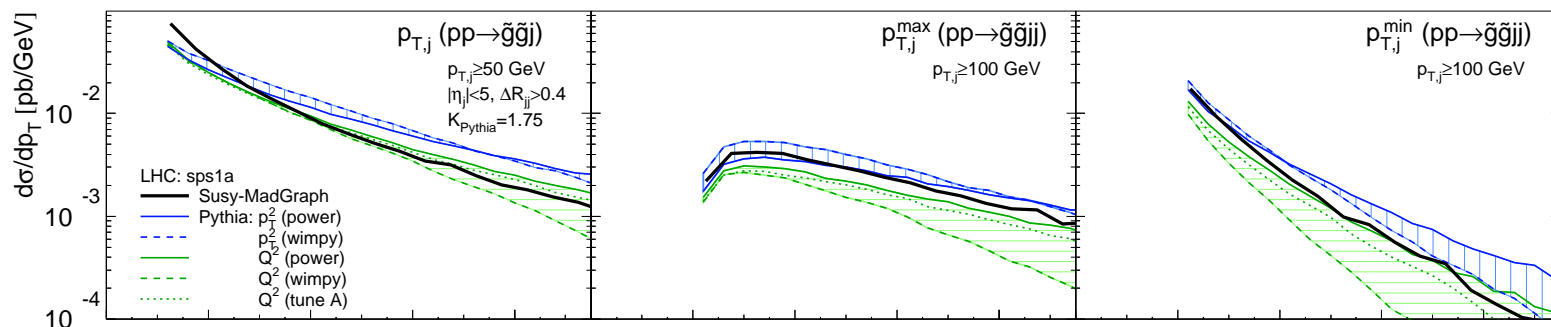
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2 – SUSY IN WEAK BOSON FUSION

Weakly interacting particles in weak boson fusion [Cho, Hagiwara, Kanzaki, TP, Rainwater, Stelzer]

- works great for Higgs (Standard Model or MSSM)
 - W, Z background the problem for DY-type $pp \rightarrow \tilde{\chi}\tilde{\chi}, \tilde{\ell}\tilde{\ell}$
 - trigger difficult for (neutral) stable sleptons
- ⇒ give it a try: $qq' \rightarrow q'q\tilde{\ell}\tilde{\ell}^*$ [cancellations deadly]

process	SPS 1a		SPS8	
	DY	WBF	DY	WBF
$\tilde{e}_L^+ \tilde{e}_L^-$	22.5	0.036	2.49	0.004
$\tilde{e}_R^+ \tilde{e}_R^-$	29.0	0.029	14.3	0.014
$\tilde{\tau}_1^+ \tilde{\tau}_1^-$	34.4	0.033	16.0	0.015
$\tilde{\tau}_2^+ \tilde{\tau}_2^-$	18.3	0.032	2.40	0.004

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 - trigger difficult for (neutral) stable sleptons
- ⇒ **WBF great, but really only for Higgs**

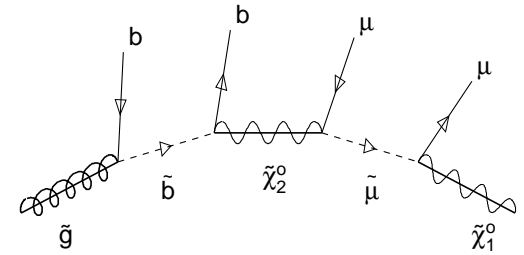
Theoretical side remark

- unitarity in $WW \rightarrow \tilde{\chi}\tilde{\chi}$ [s and t channel, like $WW \rightarrow t\bar{t}$]
 - e.g. parameter m_Z in s-channel propagator and $\tilde{\chi}\tilde{\chi}\Phi$ Yukawa coupling
[test of SUSY-protected coupling: Kilian, TP, Richardson, Schmidt]
 - mismatch in renormalization fixed by ripping scheme
 - similar for mixing scalars, mass matrix and $\tilde{f}\tilde{f}\Phi$ coupling [unitarity fine, F and D terms]
 - general problem: widths and couplings for Higgs and SUSY [Sdecay: Mühlleitner et al.]
- ⇒ **all fixed for Smadevent users**

3 – GLUINO SPIN DETERMINATION

Show it is SUSY–QCD [many ideas: Smillie & Webber]

- straw-man ‘bosonic SUSY’: universal extra dimensions
- compare entire cascade [use e.g. m_{lb} instead of angles]
- only normalized distributions [masses from endpoints]
- ⇒ if fermionic gluino, then Majorana [like–sign dileptons]



Cascade decays — Smadevent + UED–Madgraph [Alves, Eboli, TP]

- gluino decay chain as for mass measurement
- compare with first KK g , q , Z , and l
- decay asymmetry b vs. \bar{b} [instead of near/far b]
$$\mathcal{A} = [\sigma(bl^+) - \sigma(b\bar{l}^-)] / [\sigma(bl^+) + \sigma(b\bar{l}^-)]$$
- complication: $\tilde{\ell}_{LR}$ or $\tilde{\tau}_{LR}$ tied in with spin
- pure jet observables which work: ϕ_{bb}
- ⇒ **gluino spin sits in decay kinematics**

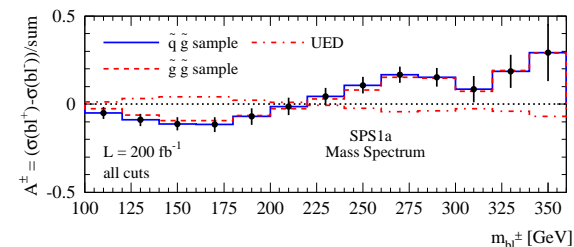
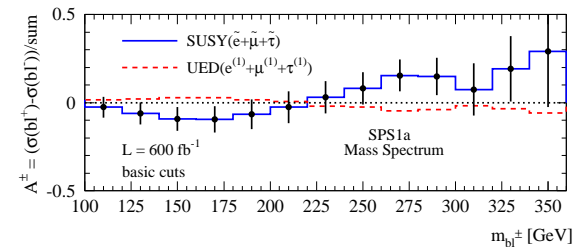
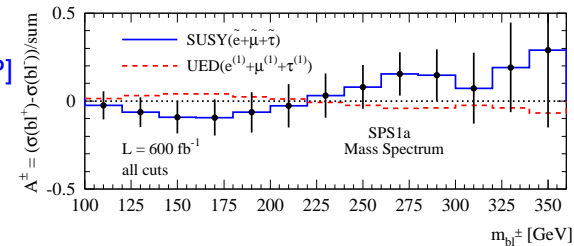
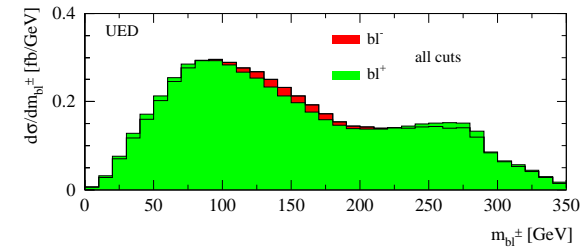
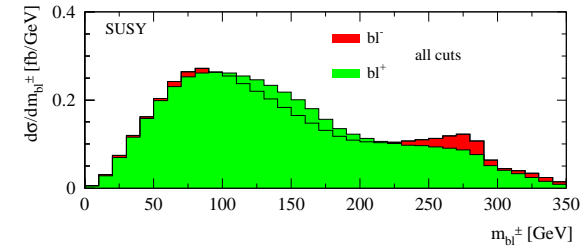
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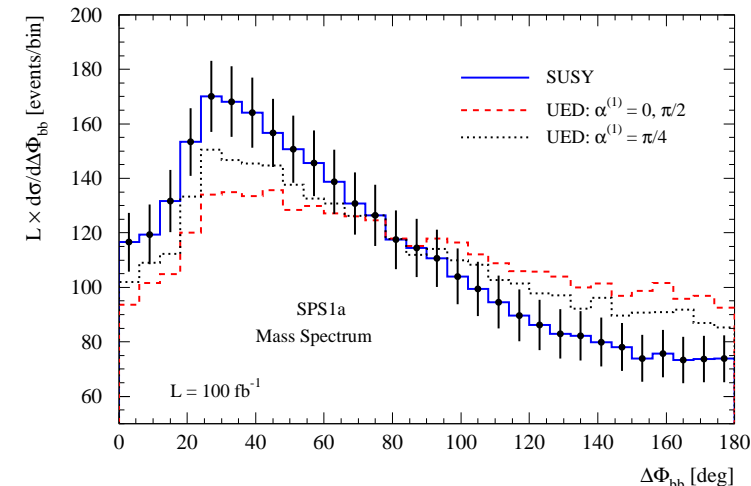
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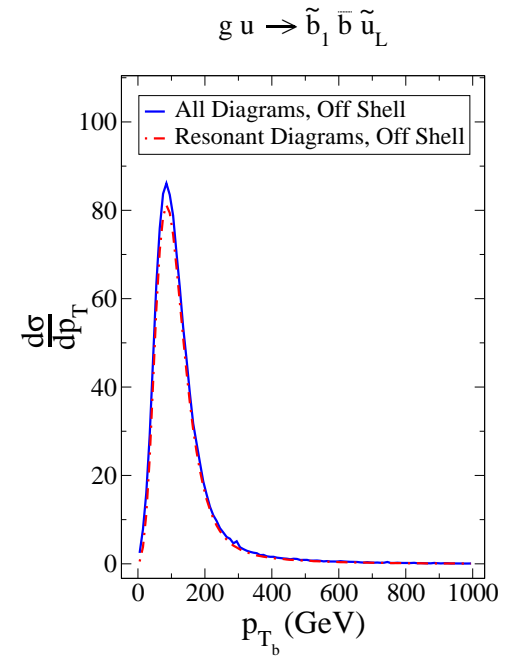
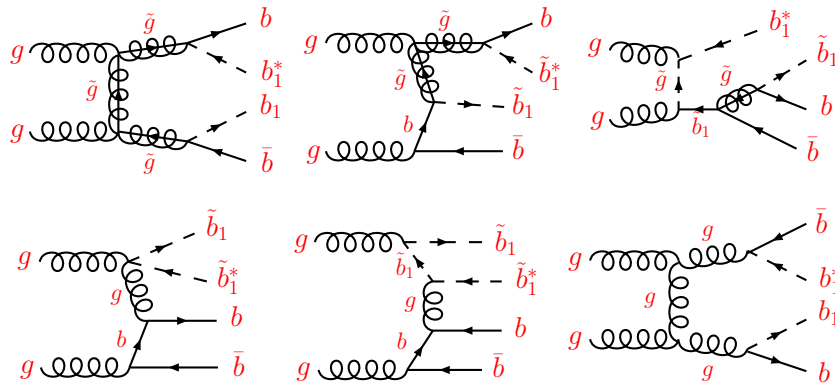
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4 – OFF-SHELL SQUARKS AND GLUINOS AT LHC

Example 1: $pp \rightarrow \tilde{g}\tilde{g} \rightarrow \tilde{b}\tilde{b}_1\tilde{b}\tilde{b}_1^*$ [Berdine, Rainwater,...]

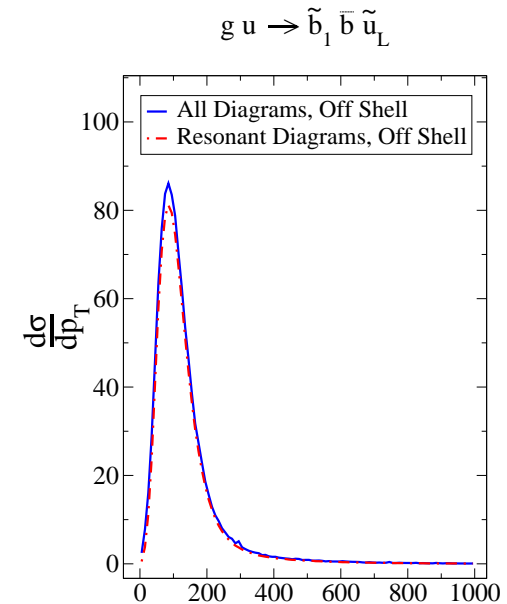
- naive expectations: corrections $\sim \Gamma_{\tilde{g}}/m_{\tilde{g}}$
 - rate up 16% [$\sigma_{\text{pole}}=108 \text{ fb}$; $\sigma_{\text{all}}=125 \text{ fb}$]
 - compare to NLO uncertainty $\sim 15\%$
- \Rightarrow detailed discussion in paper...



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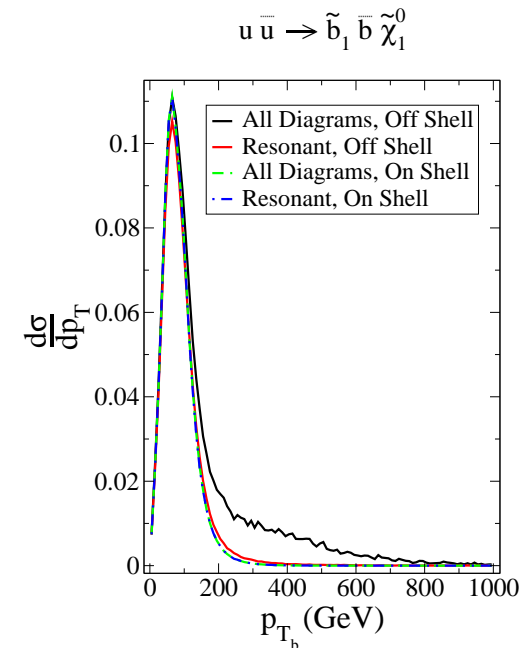
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- ⇒ detailed discussion in paper...



Example 2: $pp \rightarrow \tilde{g}\tilde{\chi}_1^0 \rightarrow \bar{b}\tilde{b}_1 \tilde{\chi}_1^0$

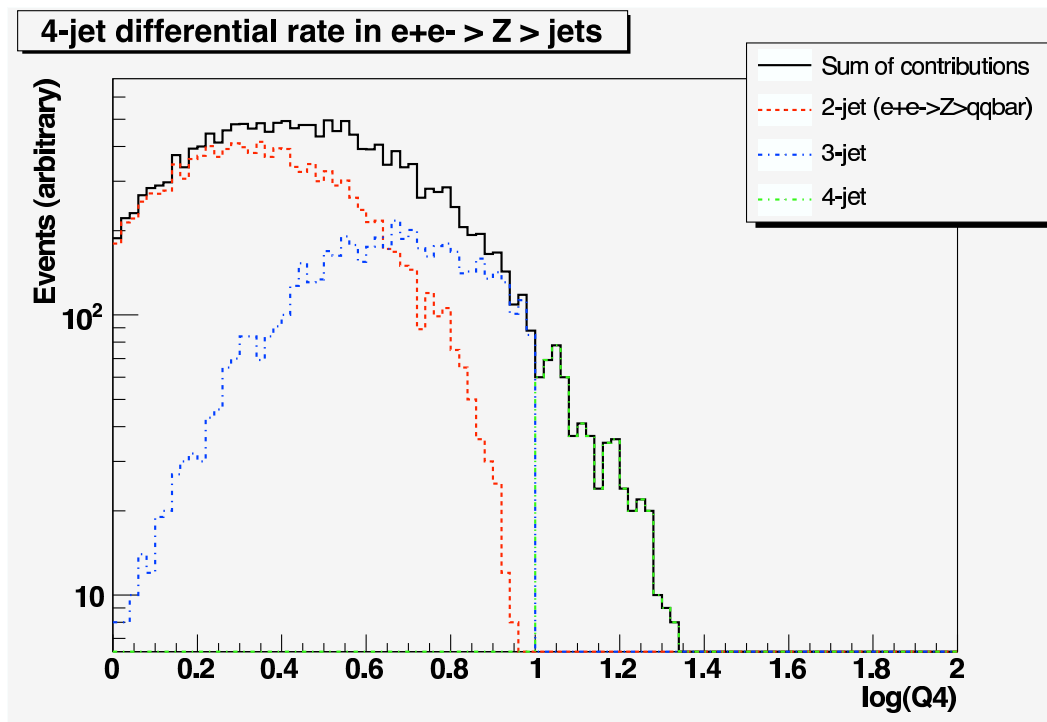
- rate up 50%!
- distributions spread...
- no interference, but new pole
- separable by jet/lepton edges?
- just a start as well...



MADEVENT AND JET MATCHING

Automatic matching of hard jets with parton shower

- combination of hard and collinear jets with hard process
- Madevent with new p_T -ordered Pythia shower [ask Johan Alwall for details]
- Madevent process definition $pp > Wj$, $pp > Wjj$, $pp > Wjjj$, ...
- $e^+e^- \rightarrow Z+jets$ testing ground



Madgraph/Madevent progress all over the place [mostly Louvain-la-Neuve]

- SUSY available [tested and used many times]
- 2HDM available
- higher–dimension Higgs couplings available
- UED on the way [only used for cascade decays and spins]
- PGS included
- jet matching next task

- watch: <http://madgraph.phys.ucl.ac.be>