Status of the Event Generator WHIZARD

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The need for Multi-Particle Event Generators

New collider environments more complicated

Very complicated signal/background processes

New physics:

- DM: Conserved discrete parity: pair production, decay chains
- Complicated, quasi-degenerate spectrum at the Terascale
- High-multiplicity final states

ILC allows for precision measurements at least at per cent-level

Need for Multi-Particle Event Generators

JR, Snowmass 05; Hagiwara et al., 06; Hewett, 07; Kilian/JR

- BSM processes do not factorize into $2 \to 2$ production/decay
- Interferences of several (partially) resonant diagram groves
- Off-shell effects violate Breit-Wigner approximation

Berdine/Kauer/Rainwater 07; Berdine/Kauer/JR/Rainwater

The Multi-Particle Generator WHIZARD

Kilian/Ohl/JR, 07

Very high level of Complexity:

- $e^+e^- \to t\bar{t}H \to b\bar{b}b\bar{b}jj\ell\nu$ (110,000 diagrams)
- $e^+e^- \to ZHH \to ZWWWW \to bb + 8j$ (12,000,000 diagrams)
- $pp \to \ell\ell + nj, n = 0, 1, 2, 3, 4, \ldots$ (2,100,000 diagrams with 4 jets + flavors)
- $pp \to \tilde{\chi}_1^0\tilde{\chi}_1^0 bbbb$ (32,000 diagrams, 22 color flows, $\sim 10,000$ PS channels)
- $pp \to VVjj \to jj\ell\ell\nu\nu$ incl. anomalous TGC/QGC
- Test case $gg \to 9g$ (224,000,000 diagrams)

Current versions:

WHiZard 1.51 / O'Mega 000.011beta Ω $\to$ joint version:

WHIZARD 1.90 release date: TODAY, 2007, Nov., 23rd

one grand unified package (incl. VAMP, Circe, Circe 2, WHiZard, O'Mega)

New web address: `http://whizard.event-generator.org`

Standard Reference for 1.90 + new versions: Kilian/Ohl/JR, 0708.4233

- Major upgrade this winter: WHIZARD 2.0.0

Technical details about WHIZARD

Status of WHIZARD 1.90: Installation

- Download tar-ball from `http:whizard.event-generator.org`
- unpack, do `configure`, `make install` that's it!
- OK, granted: specify locations of external packages and O'Caml language (part of many Linux distributions, `http://caml.inria.fr`)

WHIZARD is written in Fortran 90/95. Compiler status?

- works w/ (almost) all commercial compilers: Intel, Lahey, NAG, Pathscale
- Portland has a severe compiler bug
- compiles with g95
- compiles with gfortran 4.3.0 (will be part of new Linux SuSe 11.0, Debian 4.1, ...)
- lots of Fortran2003 features coming (No need for reprogramming in C++)

Basic facts:

- Helicity amplitudes with complete avoidance of redundancies
- Iterative adaptive multi-channel phase space (viable for $2 \to 10$)
- **Unweighted events** (formats: binary, HEPEVT, ATHENA, LHA, STDHEP)
- Graphical analysis tool

Implemented Physics Content

Structured beams:

For Tevatron/LHC: PDFs from LHAPDF (or PDFLIB)
For ILC physics:

- ISR (implemented: Skrzypek/Jadach, Kuraev/Fadin)
- arbitrarily polarized beams
- beamstrahlung, photon collider spectra (CIRCE/CIRCE 2)

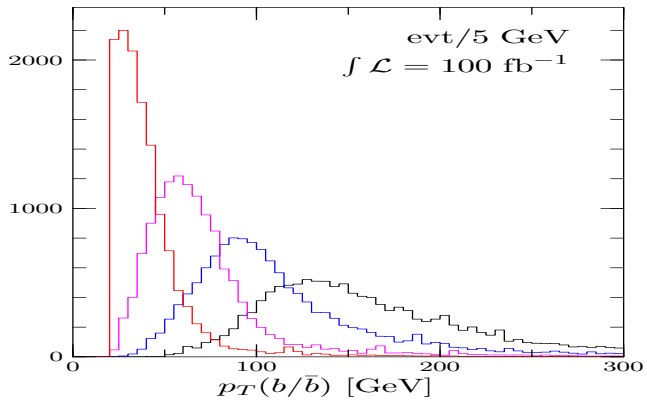
external (user-defined) beam spectra can be read in

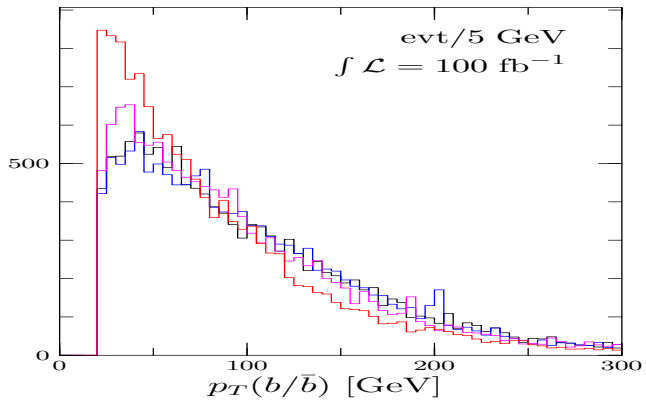
Supported Physics Models:

- Test models: QED, QCD
- SM
- Littlest/Simplest Little Higgs, Little Higgs Models with T parity
- Moose models: 3-site model
- MSSM, NMSSM, extended SUSY models, incl. gravitinos (SLHA/SLHA2)
- Graviton resonances, Universal extra dimensions, Randall-Sundrum
- Noncommutative Standard Model
- Higher-dimensional operators, SM effective field theory extensions
- Anomalous triple and quartic gauge couplings
- K-matrix/Padé unitarization, unitarized resonances Alboteanu/Kilian/JR

WHIZARD LHC/Tevatron Application/Projects

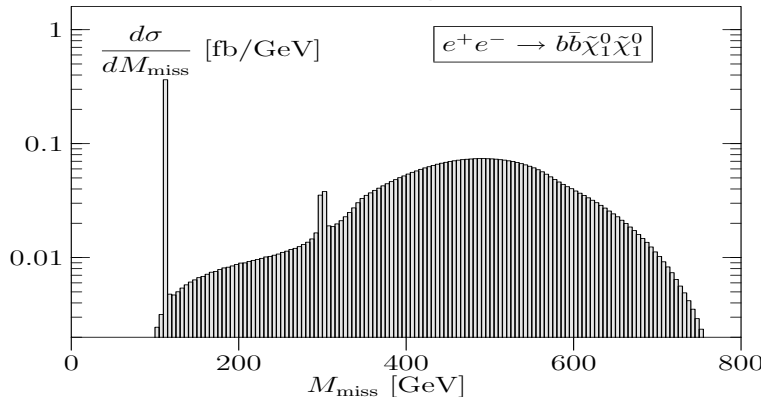
- SUSY Simulations and Studies — quasi World-Wide Study
- WW scattering + anomalous couplings — Bonn/Freiburg/Dresden/Siegen
- Determination of LHC signal significances — BNL/Edinburgh/Freiburg
- BSM mass spectrum determinations — CERN/Freiburg/UC Davis
- Lepton Flavor Violation — DESY/Manchester
- BSM CP properties — Bonn/Freiburg
- Little Higgs studies — Freiburg/Rochester/Siegen
- KK graviton studies — Freiburg/Moscow/Siegen
- general Z'/W' studies — Carleton/Freiburg/Madison
- noncommutative SM extensions — Würzburg
- Interplay ATLFAST2–MC development — Freiburg
- BSM Multijet studies — DESY/Dresden/Edinburgh/KEK/Rochester





WHIZARD ILC Applications/Projects

- SUSY simulations and studies — quasi World-Wide study
- Detector optimization studies — DESY/Fermilab
- Electroweak precision studies — DESY/Fermilab/Freiburg/SLAC
- WW scattering/Triple boson production — DESY/Rostock
- Photon collider studies — DESY/Würzburg
- Top and Higgs studies — DESY/Freiburg/London/RAL
- Little Higgs Studies — Carleton/Freiburg/Rochester/Siegen
- Dark matter studies — Bonn/DESY/Freiburg/SLAC
- Benchmarking/Standard Event Samples — DESY/SLAC
- ISR/beamstrahlung studies:



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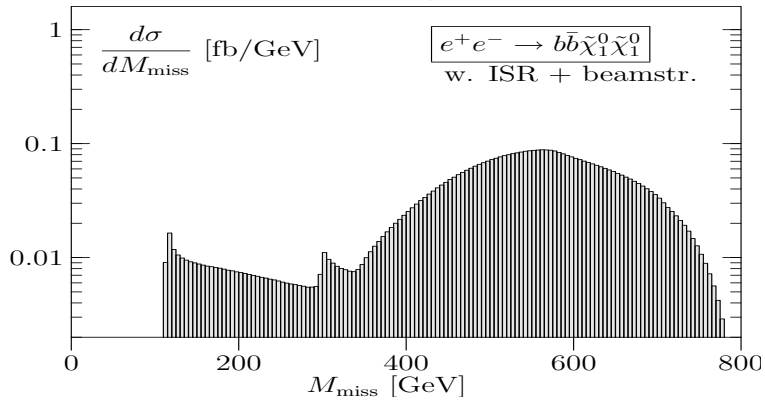

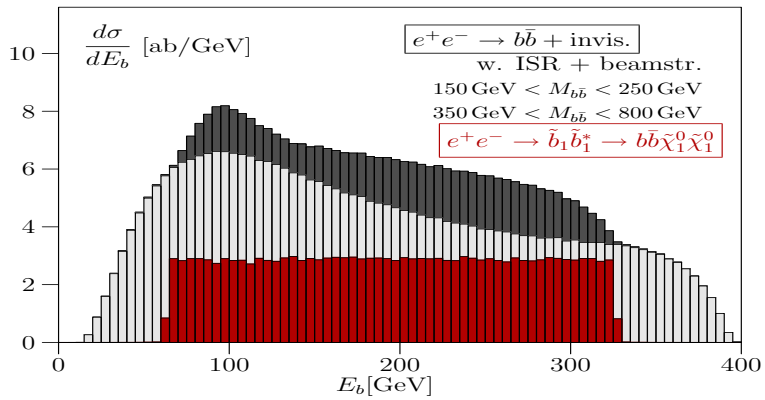

Comparison of Automated Tools for Perturbative Interactions in SuperSymmetry

cf. http://whizard.event-generator.org/susy_comparison.html

$\tau^+\tau^- \to X$							
Process	status	Madgraph/Helas		Whizard/O'Mega		Sherpa/A'Megic	
		0.5 TeV	2 TeV	0.5 TeV	2 TeV	0.5 TeV	2 TeV
$\tilde{\tau}_1\tilde{\tau}_1^*$	●	257.57(7)	79.63(4)	257.32(1)	79.636(4)	257.30(1)	79.638(4)
$\tilde{\tau}_2\tilde{\tau}_2^*$	●	46.55(1)	66.86(2)	46.368(2)	66.862(3)	46.372(2)	66.862(3)
$\tilde{\tau}_1\tilde{\tau}_2^*$	●	95.50(3)	19.00(1)	94.637(3)	19.0015(8)	94.645(5)	19.000(1)
$\tilde{\nu}_\tau\tilde{\nu}_\tau^*$	●	502.26(7)	272.01(8)	502.27(2)	272.01(1)	502.30(3)	272.01(1)
$\tilde{\chi}_1^0\tilde{\chi}_1^0$	●	249.94(2)	26.431(1)	249.954(9)	26.431(1)	249.96(1)	26.431(1)
$\tilde{\chi}_1^0\tilde{\chi}_2^0$	●	69.967(3)	9.8940(3)	69.969(2)	9.8940(4)	69.968(3)	9.8937(5)
$\tilde{\chi}_1^0\tilde{\chi}_3^0$	●	17.0387(3)	0.7913(1)	17.0394(1)	0.79136(2)	17.040(1)	0.79137(5)
$\tilde{\chi}_1^0\tilde{\chi}_4^0$	●	7.01378(4)	1.50743(3)	7.01414(6)	1.5075(5)	7.0141(4)	1.50740(8)
$\tilde{\chi}_2^0\tilde{\chi}_2^0$	●	82.351(7)	18.887(1)	82.353(3)	18.8879(9)	82.357(4)	18.8896(1)
$\tilde{\chi}_2^0\tilde{\chi}_3^0$	●	—	1.7588(1)	—	1.75884(5)	—	1.7588(1)
$\tilde{\chi}_2^0\tilde{\chi}_4^0$	●	—	2.96384(7)	—	2.9640(1)	—	2.9639(1)
$\tilde{\chi}_3^0\tilde{\chi}_3^0$	●	—	0.046995(4)	—	0.0469966(9)	—	0.046999(2)
$\tilde{\chi}_3^0\tilde{\chi}_4^0$	●	—	8.5852(4)	—	8.55857(3)	—	8.5856(4)
$\tilde{\chi}_4^0\tilde{\chi}_4^0$	●	—	0.26438(2)	—	0.264389(5)	—	0.26437(1)
$\tilde{\chi}_1^+\tilde{\chi}_1^-$	●	185.09(3)	45.15(1)	185.093(6)	45.147(2)	185.10(1)	45.151(2)
$\tilde{\chi}_2^+\tilde{\chi}_2^-$	●	—	26.515(1)	—	26.5162(6)	—	26.515(1)
$\tilde{\chi}_1^+\tilde{\chi}_2^-$	●	—	4.2127(4)	—	4.21267(9)	—	4.2125(2)
h^0h^0	●	0.3533827(3)	0.0001242(2)	0.35339(2)	0.00012422(3)	0.35340(2)	0.000124218(6)
h^0H^0	●	—	0.005167(4)	—	0.0051669(3)	—	0.0051671(3)
H^0H^0	●	—	0.07931(3)	—	0.079301(6)	—	0.079311(4)
A^0A^0	●	—	0.07975(3)	—	0.079758(6)	—	0.079744(4)
Zh^0	●	59.591(3)	3.1803(8)	59.589(3)	3.1802(1)	59.602(3)	3.1829(2)
ZH^0	●	2.8316(3)	4.671(5)	2.83169(9)	4.6706(3)	2.8318(1)	4.6706(2)
ZA^0	●	2.9915(4)	4.682(5)	2.99162(9)	4.6821(3)	2.9917(2)	4.6817(2)
A^0h^0	●	—	0.005143(4)	—	0.0051434(3)	—	0.0051440(3)
A^0H^0	●	—	1.4880(2)	—	1.48793(9)	—	1.48802(8)
H^+H^-	●	—	5.2344(6)	—	5.2344(2)	—	5.2345(3)

Upcoming Features

WHIZARD version 2.0.0 coming out this winter

- (More) Automatized installation tool
- New syntax for defining cuts, scales and analyses: allows for arbitrary functions of kinematical variables
- fancier (and faster) color structures from O'Mega
- WHIZARD uses O'Mega info for better/faster phase space generation
- Cascade decays (apply with great care!!!)
  WHIZARD calls itself recursively, breaks double decay chains down into subprocesses
- Leading order (QCD) parton shower
  (so only fragmentation/hadronization and PDFs by external routines)
- Dark matter relic density calculator
- Support for `ROOT` data format
- TAUOLA interface

All points close to finalization;
Major restructuring of the code

Upcoming Features / Future Features

$\longrightarrow$

Future features, 2008ish

- Parton shower matching to hard matrix elements
- New manual
- Graphical User Interface (partially already there)
- Standardized interface to FeynArts/FormCalc/LoopTools
- Full-fledged parallelization (partially under way)
- Own algebraic tool for deriving Feynman rules from Lagrangians
- Web interface

Classification of NLO corrections

- Loop corrections to SUSY production and decay processes
- nonfactorizable, maximally resonant photon/gluon exchange between production and decay
- real radiation of photons
- off-shell kinematics for the signal process
- irreducible background from all other SUSY processes
- reducible, experimentally indistinguishable SM background processes

Multi-pole approximation, justified from EW SM processes Denner et al., 0006307, 0502063, 0604011.

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implemented in Sherpa, Smadgraph, WHIZARD thoroughly checked

Hagiwara et al., 0512260; JR et al., 0512012

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Kilian/Robens/JR, ; JR et al., 0512012

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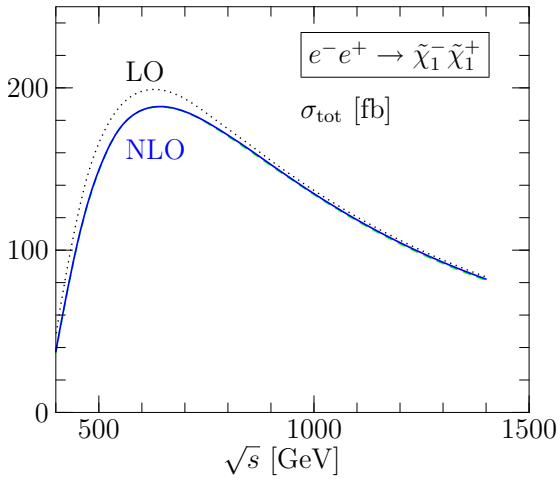
Example: NLO SUSY Simulations

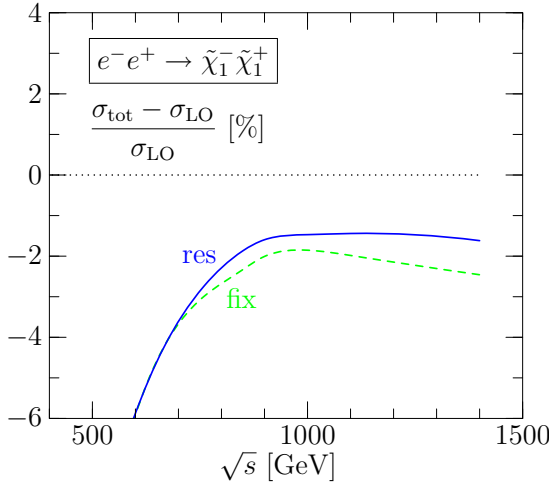
Kilian/JR/Robens,2006

$e^+e^- \to \chi_1^+\chi_1^-$:

NLO corrections -5% (Xsec max.)

-2% (-1.5%) fixed-order (re-summed) @ 1 TeV

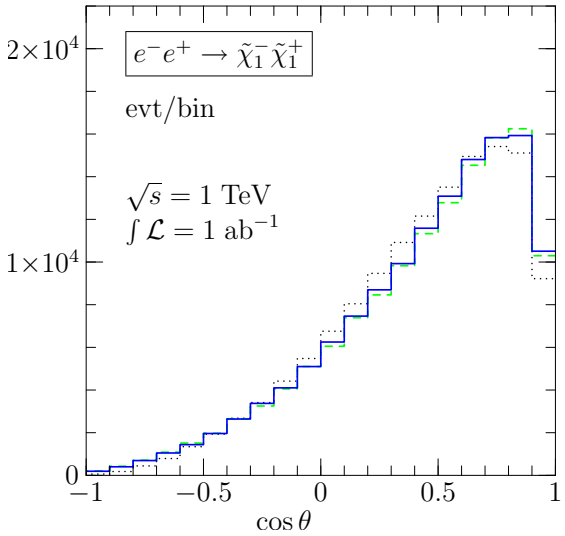


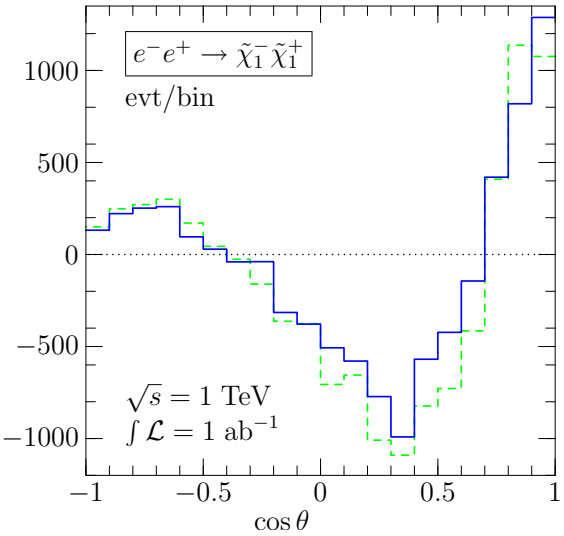


Binned distribution of chargino scattering angle

Cutoffs: $\Delta\theta_\gamma = 1^\circ$, $\Delta E_\gamma = 3$ GeV (fixed-order)

K-factor approach insufficient





Summary and Outlook

New version WHIZARD 1.90 → 2.0.0

`http://whizard.event-generator.org`

Reference: arXiv:0708.4233

Functional cut/analysis syntax, more models, recursive cascades, improved phase space, parton shower, ...

Extended WHIZARD: 1st NLO SUSY MC Event Generator for the ILC

- All possible distributions available at NLO
- Matching of resummed soft-coll. γ/virtual NLO avoids negative weights
- Interface to `FeynArts`: all MSSM $2 \to 2$ processes for ILC available

Important future developments:

- ME + PS matching
- Graphical and/or web interfaces
- semiautomatized QCD NLO generation

as usual: **we're open to users wish list!**