The NMSSM implementation in WHIZARD

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with Felix Braam, Wolfgang Kilian, Thorsten Ohl,
(arXiv:0708.4233 and work in progress)

and contributions from Sebastian Schmidt and Christian Speckner

SUSY 09, Boston, June 7th, 2009

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

The WHIZARD Event Generator

Kilian/Ohl/JR

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 1.9x latest release v1.93: 2009, April, 15th

Web address: http://whizard.event-generator.org
http://projects.hepforge.org/whizard

Standard Reference for 1.93 + new versions: Kilian/Ohl/JR, 0708.4233

Major upgrade WHIZARD 2.0 (more later)

The WHIZARD team

F. Braam, W. Kilian, T. Ohl, H.-W. Poschmann, JR, S. Schmidt, C. Speckner, D. Wiesler

WHIZARD: Prerequisites and installation

Prerequisites:

- Standard tools: (like `make`, `sed`, `grep`, `Perl5` etc.)
- O'Caml (Objective Caml) compiler (Version $\geq$ 3.04)
- Fortran 95/03 compiler
  gfortran (v$\geq$4.3.0), Intel (v$\geq$10.0), NAG, Lahey, g95, still problematic: Portland pgf
- LHAPDF library for PDFs
- PYTHIA/HERWIG for showering/hadronization

  Optional:
  - LaTeX and MetaPost for on-line generation of histograms and plots
  - Non-hostile up to friendly contact to the authors

WHIZARD 1: Installation

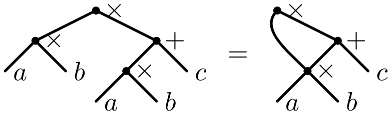
- Download tar-ball from `http:whizard.event-generator.org`
- unpack
- do `configure FC=<your compiler>`
- `make install` that's it!

O'Mega: Optimal matrix elements

Ohl/JR, 2001 Ω

∴ Replace forest of tree diagrams by Directed Acyclical Graph (DAG) of the algebraic expression.

$$ab(ab+c) =$$



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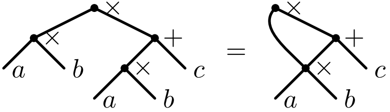
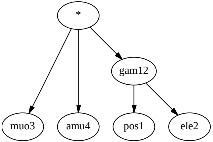


- simplest examples: $e^+e^- \to \mu^+\mu^-$, and

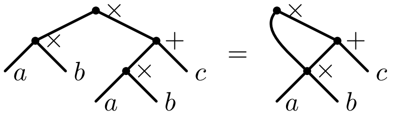


O'Mega: Optimal matrix elements

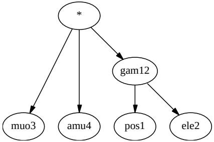
Ohl/JR, 2001 Ω

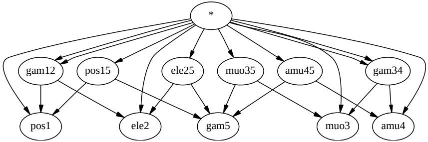
$\therefore$ Replace forest of tree diagrams by
Directed Acyclical Graph (DAG) of the algebraic expression.

$ab(ab+c) =$



- simplest examples: $e^+e^- \to \mu^+\mu^-$, $e^+e^- \to \mu^+\mu^-\gamma$ and





O'Mega: Optimal matrix elements

Ohl/JR, 2001 Ω

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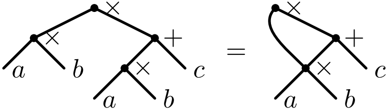
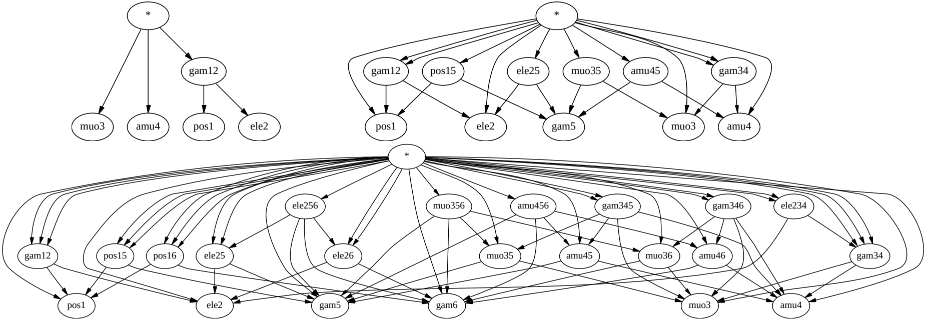
$$ab(ab+c) =$$



▶ simplest examples: $e^+e^- \to \mu^+\mu^-$, $e^+e^- \to \mu^+\mu^-\gamma$ and $e^+e^- \to \mu^+\mu^-\gamma\gamma$



WHIZARD – Overview over BSM Models

MODEL TYPE	with CKM matrix	trivial CKM
QED with e, μ, τ, γ	–	QED
QCD with d, u, s, c, b, t, g	–	QCD
Standard Model	SM_CKM	SM
SM with anomalous gauge couplings	SM_ac_CKM	SM_ac
SM with anomalous top couplings	SMtop_CKM	SMtop
SM with K matrix	—	SM_KM
MSSM	MSSM_CKM	MSSM
MSSM with gravitinos	—	MSSM_Grav
NMSSM	NMSSM_CKM	NMSSM
extended SUSY models	—	PSSSM
Littlest Higgs	—	Littlest
Littlest Higgs with ungauged $U(1)$	—	Littlest_Eta
Littlest Higgs with T parity	—	Littlest_Tpar
Simplest Little Higgs (anomaly-free)	—	Simplest
Simplest Little Higgs (universal)	—	Simplest_univ
3-site model (inoff.)	—	TSM
UED	—	UED
SUSY Xdim. (inoff.)	—	SED
Noncommutative SM (inoff.)	—	NCSM
SM with Z'	—	Zprime
SM with gravitino and photino	—	GravTest
Augmentable SM template	—	Template

easy to implement new models (more later)

```
./whizard
 ! WHIZARD 1.93 (Apr 15 2009)
 ! Reading process data from file whizard.in
 ! Reading process data from file nmssm.in
 ! Reading SUSY Les Houches Accord (SLHA) data
 ! SLHA: Spectrum calculator name:    NMSSMTools
 ! SLHA: Spectrum calculator version: 2
 ! Wrote whizard.out
 !
 ! Process uunn11:
 !    u a-u -> neu1 neu5
 !    8   4 ->    1    2
 ! Process energy set to     10000.     GeV
 ! Active structure functions for beam 1:
 !   LHAPDF:         p -> u
 *************************************
 *       LHAPDF Version 5.6.0        *
 *************************************

 >>>>>> PDF description: <<<<<<
 CTEQ6L1 - LO with LO alpha_s
 Reference:
 J. Pumplin, D.R. Stump, J. Huston, H.L. Lai, P. Nadolsky,
 W.K. Tung
 hep-ph/0201195
 >>>>>>                   <<<<<<

 Parametrization: CTEQ6

 ! Active structure functions for beam 2:
 !   LHAPDF:         p -> a-u
 ! Reading vertices from file whizard.mdl ...
 ! Model file:      804 trilinear vertices found.
 ! Model file:      783 vertices usable for phase space setup.
 ! Generating phase space channels for process uunn11...
 ! Phase space:       3 phase space channels generated.
 ! Scanning phase space channels for equivalences ...
 ! Phase space:       3 equivalence relations found.
 ! Wrote phase space configurations to file whizard.phx
 !
 ! Created grids:      3 channels,  4 dimensions with 20 bins
 !
 ! WHIZARD run for process uunn11:
 !=============================================================================
 ! It      Calls  Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
 !-----------------------------------------------------------------------------
 ! Reading cut configuration data from file whizard.cut1
 ! No cut data found for process uunn11
 ! Preparing (fixed weights):   3 samples of      10000 calls ...
   1      30000  4.0218388E-02  2.18E-04    0.54    0.94*  1.59    0.65   3
 !-----------------------------------------------------------------------------
 ! Adapting (variable wgts.):   8 samples of     100000 calls ...
   2     100000  4.0097118E-02  9.54E-05    0.24    0.75*  4.14
   3     100000  4.0409336E-02  5.06E-05    0.13    0.40* 12.26
   4     100000  4.0385730E-02  8.12E-05    0.20    0.64  13.01
   5     100000  4.0264449E-02  6.74E-05    0.17    0.53  14.88
   6     100000  4.0354093E-02  5.39E-05    0.13    0.42  23.92
   7     100000  4.0315041E-02  5.49E-05    0.14    0.43  25.59
   8     100000  4.0394325E-02  5.13E-05    0.13    0.40  24.92
   9     100000  4.0368262E-02  4.85E-05    0.12    0.38* 26.00
 !-----------------------------------------------------------------------------
 ! Integrating (fixed wgts.):   3 samples of     100000 calls ...
  10     300000  4.0323525E-02  2.73E-05    0.07    0.37* 22.40    0.70   3
 !-----------------------------------------------------------------------------
 !
 ! Time estimate for generating 10000 unweighted events:    0h 00m 01s
 !=============================================================================
 ! Summary (all processes):
 !-----------------------------------------------------------------------------
 ! Process ID      Integral[fb]  Error[fb]   Err[%]        Frac[%]
 !-----------------------------------------------------------------------------
   uunn11         4.0323525E-02  2.73E-05    0.07          100.00
 !-----------------------------------------------------------------------------
   sum            4.0323525E-02  2.73E-05    0.07          100.00
 !=============================================================================
 ! Wrote whizard.out
 ! Integration complete.
 ! No event generation requested
```

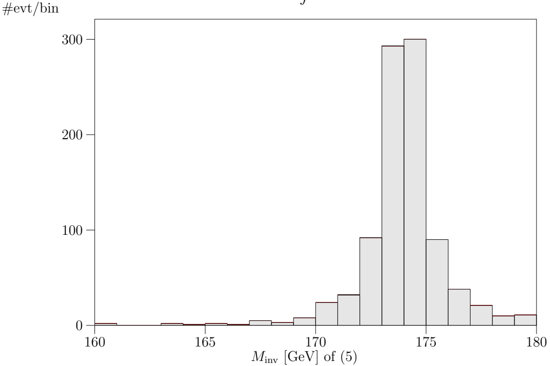
WHIZARD analysis package

Own WHIZARD graphics analysis package
(NOTE: New completely general cut syntax in v2.0)

`WHIZARD` **data analysis** March 16, 2007

Process: `qqttdec` $(u\bar{u} \to b\bar{b}W^+W^-)$

$\sqrt{s} = 500.0$ GeV $\int \mathcal{L} = 0.2754 \times 10^{-01}\ \text{fb}^{-1}$



$\sigma_{\text{tot}} = 36305. \quad \pm 310.$ fb $[\pm 0.85\ \%]$ $\quad n_{\text{evt, tot}} = 1000$

$\sigma_{\text{cut}} = 36305. \quad \pm 0.115 \times 10^{+04}$ fb $[\pm 3.16\ \%]$ $\quad n_{\text{evt, cut}} = 1000 \quad [100.00\ \%]$

The NMSSM: Implementation and conventions

- SLHA2 conventions [Allanach et al., arXiv:0801.0045]
- Implementation of the SLHA2 accord (also for CP and R parity violation)
- Additional particles: $\tilde{\chi}_5^0$, A_2^0, H_3^0
- SLHA2 fixes signs and phases:

$$W_{NMSSM} = W_{MSSM} - \epsilon_{ab} \lambda S H_1^a H_2^b + \frac{1}{3} \kappa S^3 + \mu' S^2 + \xi_F S$$

$$V_{\text{soft}} = V_{2,MSSM} + V_{3,MSSM} + m_{\mathrm{S}}^2 |S|^2 + (-\epsilon_{ab} \lambda A_\lambda S H_1^a H_2^b + \frac{1}{3} \kappa A_\kappa S^3 + m_S'^2 S^2 + \xi_S S + \text{h.c.})$$

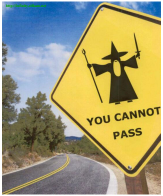
- Neutralino sector: positive masses, complex phase factors in couplings
- full CKM matrix, L/R sfermion mixing (all generations)
- No generation mixing
- Generalization to CP-nonconserving case easily possible

The Phantom Menace – the NMSSM

- NMSSM: 6669 couplings (with Goldstone/4-point)
- negative neutralino matrices: explicit factor of i
- Fully implemented, fully functional, not fully tested
- Model `NMSSM`
- Usage: SUSY Les Houches Accord (SLHA[2])

```
&process_input
 process_id ``your_susy_proc''
 ......................
 input_file = "nmssm_01"
 input_slha_format = T
```

What about tests?
Have we checked?



- correct MSSM limit of NMSSM
  $\lambda \to 0, \kappa \to 0, \langle S \rangle \to \infty, \langle S \rangle \lambda \to \mu$
- Unitarity Checks $2 \to 2, 2 \to 3$
- Ward-/Slavnov-Taylor identities for gauge symmetries and SUSY

Comparison of Automated Tools for Perturbative Interactions in SuperSymmetry

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

$\tau^+\tau^- \to X$

Process	status	Madevent 0.5 TeV	Madevent 2 TeV	WHIZARD 0.5 TeV	WHIZARD 2 TeV	Sherpa 0.5 TeV	Sherpa 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)
$h^0 h^0$	●	0.3533827(3)	0.0001242(2)	0.35339(2)	0.00012422(3)	0.35340(2)	0.000124218(6)
$h^0 H^0$	●	—	0.005167(4)	—	0.0051669(3)	—	0.0051671(3)
$H^0 H^0$	●	—	0.07931(3)	—	0.079301(6)	—	0.079311(4)
$A^0 A^0$	●	—	0.07975(3)	—	0.079758(6)	—	0.079744(4)
$Z h^0$	●	59.591(3)	3.1803(8)	59.589(3)	3.1802(1)	59.602(3)	3.1829(2)
$Z H^0$	●	2.8316(3)	4.671(5)	2.83169(9)	4.6706(3)	2.8318(1)	4.6706(2)
$Z A^0$	●	2.9915(4)	4.682(5)	2.99162(9)	4.6821(3)	2.9917(2)	4.6817(2)
$A^0 h^0$	●	—	0.005143(4)	—	0.0051434(3)	—	0.0051440(3)
$A^0 H^0$	●	—	1.4880(2)	—	1.48793(9)	—	1.48802(8)
$H^+ H^-$	●	—	5.2344(6)	—	5.2344(2)	—	5.2345(3)

Comparison for the NMSSM Braam/Fuks/JR $\longrightarrow$ Les Houches '09

$\tau^+\tau^- \to X$

Process	status	Madevent 0.5 TeV	Madevent 2 TeV	WHIZARD 0.5 TeV	WHIZARD 2 TeV
$\tilde\tau_1\tilde\tau_1^*$	●	xxx.xx(xx)	xx.xx(xx)	100.34(12)	57.67(57)
$\tilde\tau_2\tilde\tau_2^*$	●	xx.xx(x)	xx.xx(x)	40.17(4)	54.92(7)
$\tilde\tau_1\tilde\tau_2^*$	●	xxx.xx(xx)	xx.xx(x)	104.16(11)	65.47(9)
$\tilde\nu_\tau\tilde\nu_\tau^*$	●	xxx.x(x)	xxx.x(x)	641.6(7)	317.4(4)
$\tilde\chi_1^0\tilde\chi_1^0$	●	xxx.xx(xx)	xx.xx(x)	212.60(12)	25.97(2)
$\tilde\chi_1^0\tilde\chi_2^0$	●	xx.xx(x)	x.xxx(x)	28.15(2)	3.653(4)
$\tilde\chi_1^0\tilde\chi_3^0$	●	xx.xx(x)	x.xxx(x)	55.29(3)	7.100(8)
$\tilde\chi_1^0\tilde\chi_4^0$	●	—	x.xxxx(x)	—	0.5657(6)
$\tilde\chi_1^0\tilde\chi_5^0$	●	—	x.xxxx(x)	—	0.2478(2)
$\tilde\chi_2^0\tilde\chi_2^0$	●	x.xxx(x)	x.xxxx(x)	4.470(3)	0.5581(6)
$\tilde\chi_2^0\tilde\chi_3^0$	●	xx.xx(x)	x.xxx(x)	37.42(3)	5.358(6)
$\tilde\chi_2^0\tilde\chi_4^0$	●	—	x.xxxx(x)	—	0.4205(3)
$\tilde\chi_2^0\tilde\chi_5^0$	●	—	x.xxxx(x)	—	0.3307(3)
$\tilde\chi_3^0\tilde\chi_3^0$	●	—	xx.xx(x)	—	17.93(2)
$\tilde\chi_3^0\tilde\chi_4^0$	●	—	x.xxx(x)	—	1.099(1)
$\tilde\chi_3^0\tilde\chi_5^0$	●	—	x.xxxx(x)	—	0.4325(3)
$\tilde\chi_4^0\tilde\chi_4^0$	●	—	x.xxxxxx(x)	—	0.010181(5)
$\tilde\chi_4^0\tilde\chi_5^0$	●	—	xx.xxx(x)	—	10.524(9)
$\tilde\chi_5^0\tilde\chi_5^0$	●	—	x.xxxxx(x)	—	0.01639(2)
$\tilde\chi_1^+\tilde\chi_1^-$	●	xxx.x(x)	xx.xx(x)	322.8(3)	48.36(6)
$\tilde\chi_2^+\tilde\chi_2^-$	●	—	xx.xx(x)	—	27.08(2)
$\tilde\chi_1^+\tilde\chi_2^-$	●	—	x.xxx(x)	—	1.786(1)
$H_1^0 H_1^0$	●	x.xxxxxx(x)	x.xxxxxx(x)	0.004001(5)	0.001089(2)
$H_1^0 H_2^0$	●	x.xxxx(x)	x.xxxxxxx(x)	0.2386(3)	0.0006198(9)
$H_1^0 H_3^0$	●	—	x.xxxxxx(x)	—	0.00581438(6)
$H_2^0 H_2^0$	●	x.xxxx(x)	x.xxxxxx(x)	0.1130(1)	0.004243(6)
$H_2^0 H_3^0$	●	—	x.xxxx(x)	—	0.1530(2)
$Z H_1^0$	●	xx.xx(x)	x.xxx(x)	53.57(8)	3.054(5)
$A_1^0 A_1^0$	●	x.xxxxx(x)	x.xxxxxxx(x)	0.04173(6)	0.0002356(3)
$A_1^0 A_2^0$	●	—	x.xxxxxxxxx(x)	—	0.000001268(3)

How to add a new model?

Easiest and safest: invite (one of) the authors for a (couple of) beer

Version WHIZARD 2.0 brings major improvement:
CompHep-style model declarations/Interface to tools like FeynRules

```
particle e- e+ : spin=1/2, fermion, pdg=11, tex="e^-", tex.anti="e^+"
particle Z : spin=1, boson, pdg=23, tex="Z"
particle W+ W- : spin=1, boson, pdg=24, tex="W^{+}", tex.anti="W^{-}"

coupling e

% gauge
vertex e+, A, e- :   { e * <1|V.e2|3> }
vertex e+, Z, e- :   { gv * <1|V.e2|3> - ga * <1|A.e2|3> }
vertex e+, W-, nue : { g * <1|(V-A).e2|3> }

% triple gauge
vertex W+, Z, W- :   { g * ((k1 - k2).e3*e1.e2 + (k2 - k3).e1*e2.e3 + (k3 - k1).
e2*e3.e1) }

% Yukawa
vertex e+, H, e- :   { y*<1|S|3> }
vertex W+, H, W- :   { y*e1.e3 }

% NCQED
vertex e+, A, e- :   {   e * k2.[mu1]*[mu2].k3*<1|V.e2|3>
                       - e * k2.[mu1]*[mu2].e2*<1|V.k3|3>
                       - e * e2.[mu1]*[mu2].k3*<1|V.k2|3> }
```

Until then (if you dare to go the high road):

- Add your new particles and couplings in `main/omega-src/bundle/src/models5.ml` in the `template`
- Add the new particles and (trilinear) vertices to `main/conf/models/Template.mdl`
- Add the couplings constants in `main/whizard/models/parameters.Template.omega.f90`
- Do the debugging by yourself, no responsibility from the authors!

The FeynRules Interface

C. Speckner, T. Ohl, JR

- FeynRules (Duhr/Christensen) : tool to derive Feynman rules from Lagrangian input
- Implementation of models made easy
- Caveat: still needs for a careful debugging, exotics still complicated
- FeynRules-Interface for WHIZARD: first test case SM implementation
  - SM successfully tested
  - more complicated Lorentz/coupling/model structures will be added
  - Output either as
    - plain model file
    - Full-fledged O'Caml Code
      allows for full OO features of WHIZARD and O'Mega
      allows to cross-check back and debug FeynRules
- More will follow in Les Houches stay tuned!

WHIZARD 2.0

- **Physics**
  - cascade decays -> inclusive production w/ spin correlations
  - cuts/trigger, scale setting, matrix element reweighting, histograms: arbitrary expressions possible
  - flavor sums initial + final state (e.g. jet = quark:gluon)
  - Parton shower (complete ISR/FSR; by Sebastian Schmidt)
  - `FeynRules` interface (by C. Speckner)
- **Technics**
  - WHIZARD as a shared library / Parallelization
  - Unified user interface: process configuration, compilation, cuts, integration, simulation
  - Methods for user interface: input file, interactive shell, command line, library calls (e.g., from C); GUI foreseen
  - Native HepMC support (+ LHEF, StdHEP, HEPEVT, etc.)
- **Development**
  - Broader physics support, especially QCD: Underlying event (by H.-W. Boschmann)
  - (More advanced) parton shower matching
  - Dipole subtraction / NLO (GOLEM interface)

WHIZARD 2.0

New generalized input file:

```
model = "QCD"

alias q = u:d
alias Q = U:D
alias jet = q:Q:g

process qq   = g,  g ->  q, Q

compile ("proc") {
  fcflags = "-O3"
}

load ("proc")

beams (p, p) {
  cm_energy = 14 TeV
  strfun(1,2) = lhapdf

  include ("set_ptcut.in")

}

cuts =
  all Pt > 100 GeV (outgoing jet)

integrate (qq) {
  scale = 1 TeV
  iterations (4, 2000)
}

simulate (qq) {
  luminosity = 1 ifb
  write ("qq.dat")  { format = HepMC }
  write ("qq.lhef") { format = LHEF }
}
```

```
Process: qq

 !=====================================================================================
 ! It      Calls  Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]    Chi2 N[It
 !=====================================================================================
   1       1000  7.1623906E+06  5.62E+06   78.49   24.82*   0.55
   2       1000  8.2620285E+06  1.71E+06   20.75    6.56*   0.55
   3       1000  5.5333559E+06  6.60E+05   11.92    3.77*   2.72
   4       1000  5.0392115E+06  4.21E+05    8.35    2.64*   5.09
 !-------------------------------------------------------------------------------------
   4       4000  5.3158855E+06  3.47E+05    6.52    4.13    5.09    1.20   4
 !-------------------------------------------------------------------------------------
   5       2000  4.2414387E+06  2.31E+05    5.45    2.44*   4.54
   6       2000  5.6250511E+06  3.18E+05    5.66    2.53    3.79
   7       2000  3.7177191E+06  1.99E+05    5.35    2.39*   5.53
 !=====================================================================================
   7       6000  4.2497915E+06  1.36E+05    3.21    2.48    5.53   12.91   3
 !=====================================================================================
 integrate (qq)
 {
   scale =
+  SEQUENCE    <expr>  =  <term>
+  SEQUENCE    <term>  =  <factor>
|  +  SEQUENCE    <factor>  =  <integer_value>
|  |  +  SEQUENCE    <integer_value>  =  <integer_literal> TeV
|  |  |  +  INTEGER    <integer_literal>  =  1
|  |  |  +  KEYWORD    TeV  =  [keyword] TeV
   iterations (
 Evaluation tree:
o [const] = 4
   ,
 Evaluation tree:
o [const] = 1000
   )
   iterations (
 Evaluation tree:
o [const] = 3
   ,
 Evaluation tree:
o [const] = 2000
   )
 }
 generate 425 events
 simulate (qq)
 {
   luminosity =  Evaluation tree:
o [const] =   1.0000000000000000E-04
   write ("qq.dat") {
     format = HepMC
   }
   write ("qq.lhef") {
     format = LHEF
   }
 }

 * Cleanup
```

Conclusions/Outlook

- Status of the Event Generator WHIZARD:
  `http://whizard.event-generator.org`
- First MC implementation of the NMSSM completed
- Release of v2.0 very soon (α version testing phase)
  A lot more functionality, physics, etc.:
  - QCD: Shower, underlying event
  - Cascades for BSM models
  - Advanced analysis structure
  - Easier installation and structure
- Focus on BSM implementations: many different models implemented
- First implementation of the NMSSM in a Multi-Purpose Monte Carlo
- WHIZARD interface to `FeynRules`: new models easier
- Tools ready for the LHC era: eagerly awaiting data!!!