# WHiZard/O'Mega Tutorial

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W. Kilian, T. Ohl, JR, 1998-20xx, always in progress

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# The WHiZard/O'Mega Generator Generator

SM/BSM at "future" colliders

- high-multiplicity multi-particle final states
- interferences signal/signal, signal/background
- complicated collider/detector environments
- $2 \to 2$ wrong, even at LHC
  (therefore: Pythia, Herwig, Isajet strongly non-recommended)

Level of Complexity:

- $e^+e^- \to ZHH \to ZWWWW \to bbjjjjjjjj$ (12,000,000 diagrams)
- $pp \to \tilde{\chi}_1^0\tilde{\chi}_1^0 bbbb$ (32,000 diagrams, 22 color flows, $\sim 10,000$ PS channels)
- $pp \to VVjj \to jj\ell\ell\nu\nu$ incl. anomalous TGC/QGC

Current versions: WHiZard 1.51 / O'Mega 000.011beta

`http://theorie.physik.uni-wuerzburg.de/~ohl/omega/`

`http://www-ttp.physik.uni-karlsruhe.de/whizard/`

Actual are (will be) available from my homepage:

`http://www.physics.carleton.ca/~reuter`

Major upgrade this spring/summer:

WHiZard 2.0 / O'Mega 1.0

# Prerequisites for WHiZard/O'Mega

Standard GNU tools (like `make`, `sed`, `grep` etc.)

`O'Mega`

- `O'Caml` (Objective Caml) programming language interpreter/compiler (Version $\geq$ 3.04)
- `Fortran 90/95` compiler
  Intel 8.x + 9.x, NAG, Lahey, still problematic: Portland pgf, g95

`Perl5` for glueing scripts (might become obsolete in future)

`Fortran77` for interoperation with old libraries (CERNLIB)

**Optional:**

- STDHEP library
- CERNLIB for PDFs and Pythia hadronization
- LHAPDF library for PDFs
- $\LaTeX$ and MetaPost for on-line generation of histograms and plots
- Non-hostile to friendly contact to the authors

# O'Mega installation

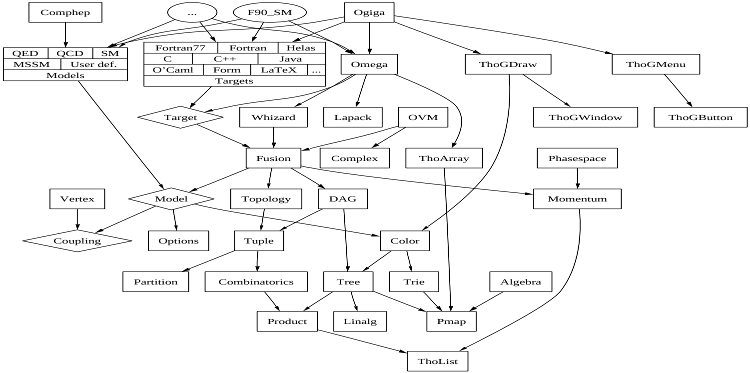
## O'Caml installation

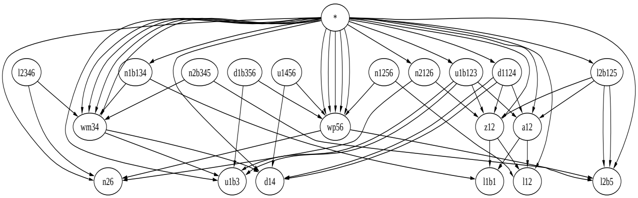
- Contained in most Linux distribution (ask your SysAdmin)
- available from `http://pauillac.inria.fr` (3.09.3)
- precompiled binaries for most OS (even It-which-must-not-be-named)
- otherwise do: `./configure --prefix make world.opt`, `umask 022; make install`

## O'Mega installation

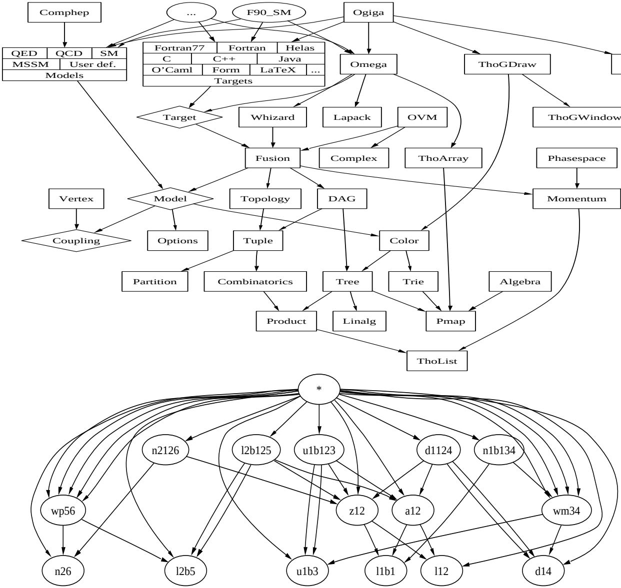
- unpack the O'Mega tarball with `tar --xzf`
- From the main directory do `./configure`
- Create the binaries by `make bin opt`
- Compile the libraries by `make f95`
- Binaries (e.g. `f90_SM.opt`) and testbeds (e.g. `test_omega95`) are located in e.g. `arch/i686-suse-linux/bin`

# How O'Mega works – The Dark Side of the Black Box



# How O'Mega works – The Dark Side of the Black Box



# O'Mega Usage

- In `web/` subdir.: Documented source code (`omega.ps`, 1100 pages)
- Short online manual:
  `http://theorie.physik.uni-wuerzburg.de/~ohl/omega/`
- Just do: `f90_MyModel.opt -scatter "e+ e- -> mu+ mu-"`

```
usage: ./f90_SM.opt [options]
[e-|nue|u|d|e+|nuebar|ubar|dbar|mu-|numu|c|s|mu+|numubar|cbar|sbar|tau-|nutau|t|b|tau+|nutaubar|
 tbar|bbar|A|Z|W+|W-|g|H|phi+|phi-|phi0|gx]

-target:function function name
-target:90 don't use Fortran95 features that are not in Fortran90
-target:....................
-model:constant_width use constant width (also in t-channel)
-model:fudged_width use fudge factor for charge particle width
-model:.....................
-warning: check arguments and print warning on error
-error: check arguments and terminate on error
-...............................
-scatter in1 in2 -> out1 out2 ...
-scatter_list proc1 ;; proc2 ;; proc3 ;;  ...
-decay in -> out1 out2 ...
-decay_list in -> out1 ;; in -> out2 ;; in -> out3
-cascade select certain cascade channels
-forest symbolic output of all Feynman diagrams
-feynmf LaTeX output of all Feynman diagrams (for feynmp.sty)
-revision print revision control information
-summary print only a summary
-poles print the Monte Carlo poles
-dag print minimal DAG
-full_dag print complete DAG
-help  Display this list of options
--help  Display this list of options
```

# WHiZard installation

- Create a directory `[whizard_dir]` and unpack the WHiZard tarball therein
- Edit the file `config.site` and insert the locations of

  `OMEGA_DIR=$ HOME/[omega_dir]`

  `CERNLIB_DIR=[cernlib_dir]` (optional)

  LHAPDF will be available in release 2.0

  `STDHEP_DIR=[stdhep_dir]` (optional)
- from the top directory do:

  `./configure`

  `—disable-mad —disable-chep`, since (old) Madgraph and Comphep mainly for internal sanity checks

  will be standard in new version anyhow

  `make man`: creates the manual `manual.ps` in `doc/`

  `make doc`: creates docu. source code `whizard.ps` (if `noweave` present)
- Now, you can already specify a process in file `conf/whizard.prc`
- from the top directory do:

  `make prg install`

# `configure` status

```
...................
config.status: creating Makefile
config.status: executing default-1 commands
config.status: executing default-2 commands
config.status: executing default-3 commands

--- Configure summary: ---
--- Enabled features: ---
CompHEP    (Matrix elements)     chep-src/setup/
Madgraph   (Matrix elements)     mad-src/
O'Mega     (Matrix elements)     /home/jr/Physik/progs/omega/omega-2006
Autoconf   (Restricted bundle)   autoconf
CIRCE      (Beamstrahlung)       circe-src/
CIRCE2     (Beamstrahlung)       circe2-src/
PDFLIB     (Structure functions) /usr/local/cernlib/pro/lib/libpdflib80
PYTHIA     (Fragmentation)       /usr/local/cernlib/pro/lib/libpythia62
LaTeX/Metapost  (Histograms)     /usr/bin/mpost

--- Disabled or absent features: ---
STDHEP     (Binary event files)

--- Configuration complete. --
```

# Models currently supported by `WHiZard/O'Mega`

| Model type | with CKM matrix | trivial CKM |
|---|---|---|
| QED with $e, \mu, \tau, \gamma$ | – | `QED` |
| QCD with $d, u, s, c, b, t, g$ | – | `QCD` |
| Standard Model | `SM_CKM` | `SM` |
| SM with anomalous couplings | `SM_ac_CKM` | `SM_ac` |
| MSSM | `MSSM_CKM` | `MSSM` |
| Littlest Higgs | — | `Littlest` |
| Littlest Higgs with ungauged $U(1)$ | — | `Littlest_Eta` |
| Simplest Little Higgs (anomaly-free) | — | `Simplest` |
| Simplest Little Higgs (universal) | — | `Simplest_univ` |
| SM with spin-2 graviton | — | `Xdim` |
| SM with gravitino and photino | — | `GravTest` |
| Augmentable SM template | — | `Template` |

New version: LH with $T$ parity, NMSSM, SUSY exotics like ESSM/PSSSM, NCSM, UED, maybe NLO SUSY stuff

# Process file: `conf/whizard.prc`

**Model selection:** we already had that

**Particles names:** look in `conf/whizard.prc.XXX` or `conf/models/Model.mdl`

`test`: Constant matrix elements for testing, e.g. structure function

```
# WHIZARD configuration file

# The selected model
model   SM

alias q u:d:s:c
alias Q U:D:S:C

# Processes
#  Methods: ....., omega=O'Mega, test=trivial)
#  Options: r      restricted intermediate state (O'Mega)
#           c      apply exact color algebra (O'Mega)
#           w:XXX  width scheme (O'Mega)
#           u      unit matrix element (test)
#
# Tag            In       Out              Method  Option
#======================================================
em               e1,E1    e2,E2            omega
em_test          e1,E1    e2,E2            test
em_test          e1,E1    e2,E2            test    u
eeqq             e1,E1    u:d:s,U:D:S      omega
uudd_nc          u,U      d,D              omega
uudd             u,U      d,D              omega   c
qqwz             q,Q      W,Z              omega
ee_z_only        e1,E1    e1,E1            omega   r:3+4~Z
```

Options available:

- `u (test)`: unit matrix element
- `c (omega)`: exact color amplitudes and full color flow information
- `r: (omega)`: restricted diagrams (cascading)
- `w: (omega)`: different width schemes (fudge, fixed, . . .

After changes in `whizard.prc` do `make prg install`

# Input file: `results/whizard.in` (`NAMELIST` fmt)

Let's just do a simple example (better than audience buffer overflow): $e^+e^- \to \mu^-\bar{\nu}_\mu u\bar{d}$

- `conf/whizard.prc`:

```
# The selected model
model    SM
# Tag    In        Out           Method   Option
#==========================================
cc10     e1,E1     e2,N2,u,D     omega
```

- `make prg install`
- edit `results/whizard.in`

```
&process_input
process_id = "cc10"
sqrts = 500
/
&integration_input
/
&simulation_input
/
&diagnostics_input
/
&parameter_input
Mmu = 0
/
&beam_input
/
&beam_input
/
```

- `whizard` executable in `results` is MC generator for process cc10, to run do
  - a) Execute `./whizard` in `results` with command line options (cf. `./whizard --help`)
  - b) `make run`, either in `results` or the top directory

```
! WHIZARD 1.51 (Jun 15 2005)
! Reading process data from file whizard.in
! Wrote whizard.out
!
! Process cc10:
!    e a-e ->  mu a-nu_mu   u a-d
!   32  16 ->   1        2   4   8
! Process energy set to     500.00     GeV
! Reading vertices from file whizard.mdl ...
! Model file:        54 trilinear vertices found.
! Model file:        54 vertices usable for phase space setup.
! Generating phase space channels for process cc10...
! Phase space:        8 phase space channels generated.
! Scanning phase space channels for equivalences ...
! Phase space:        8 equivalence relations found.
! Note: This cross section may be infinite without cuts.
! Wrote default cut configuration file whizard.cc10.cut0
! Wrote phase space configurations to file whizard.phx
!
! Created grids:      8 channels,  8 dimensions with 20 bins
```

```
! WHIZARD run for process cc10:
!=============================================================================
! 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 cc10
! Using default cuts.
cut M of   12      within  1.00000E+01  1.00000E+99
! Preparing (fixed weights):   1 sample of      20000 calls ...
   1      20000  2.6806323E+02  1.01E+01    3.76    5.31*  1.66    0.00   1
!-----------------------------------------------------------------------------
! Adapting (variable wgts.):  10 samples of      20000 calls ...
   2      20000  2.7592027E+02  1.05E+01    3.81    5.38   1.50
   3      20000  2.7127725E+02  1.96E+00    0.72    1.02* 10.69
   4      20000  2.7123539E+02  1.51E+00    0.56    0.79* 11.73
   5      20000  2.7016999E+02  1.36E+00    0.50    0.71* 15.36
   6      20000  2.7204042E+02  1.32E+00    0.49    0.69* 16.44
   7      20000  2.7265921E+02  1.30E+00    0.47    0.67* 16.40
   8      20000  2.7105262E+02  1.28E+00    0.47    0.67* 13.70
   9      20000  2.7154268E+02  1.27E+00    0.47    0.66* 15.15
  10      20000  2.7265788E+02  1.33E+00    0.49    0.69  11.91
  11      20000  2.7105441E+02  1.32E+00    0.49    0.69  12.45
!-----------------------------------------------------------------------------
! Integrating (fixed wgts.):   3 samples of      20000 calls ...
  12      60000  2.7196199E+02  7.48E-01    0.27    0.67  10.72    1.39   3
!-----------------------------------------------------------------------------
!
! Time estimate for generating 10000 unweighted events:    0h 00m 03s
!=============================================================================
! Summary (all processes):
!-----------------------------------------------------------------------------
! Process ID     Integral[fb]  Error[fb]   Err[%]        Frac[%]
!-----------------------------------------------------------------------------
  cc10           2.7196199E+02  7.48E-01    0.27         100.00
!-----------------------------------------------------------------------------
  sum            2.7196199E+02  7.48E-01    0.27         100.00
!=============================================================================
! Wrote whizard.out
! Integration complete.
! No event generation requested
! WHIZARD run finished.
```

# Further steps: Event Generation

whizard.in:

```
&process_input
process_id = "cc10"
sqrts = 500
luminosity = 10
/
&integration_input
read_grids = T
/
&simulation_input /
&diagnostics_input /
&parameter_input
Mmu = 0
/
&beam_input /
&beam_input /
```

Screen output:

```
! Using grids and results from file:
! Reading analysis configuration data from file whizard.cut5
! No analysis data found for process cc10
! Event sample corresponds to luminosity [fb-1] =   9.999
! Event sample corresponds to       22665  weighted events
! Generating       2717 unweighted events ...
!=============================================================================
! Analysis results for process cc10:
! It      Events Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
!-----------------------------------------------------------------------------
  13       2717  2.7173259E+02  5.21E+00    1.92    1.00 100.00
!-----------------------------------------------------------------------------
! Warning: Excess events:    1.2        (    0.04% )  | Maximal weight:  1.04
! There were no errors and  2 warning(s).
! WHIZARD run finished.
```

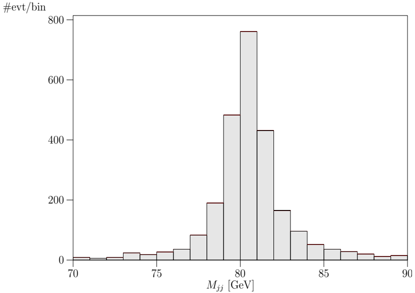
# Further steps: Event Generation

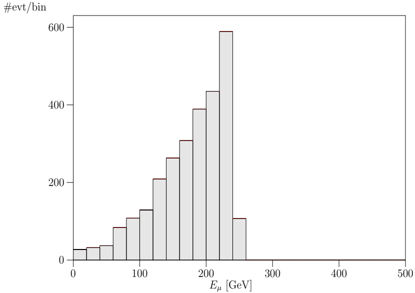
whizard.in:

```
&process_input
process_id = "cc10"
sqrts = 500
luminosity = 10
/
&integration_input
read_grids = T
/
&simulation_input /
&diagnostics_input /
&parameter_input
Mmu = 0
/
&beam_input /
&beam_input /
```

Screen output:

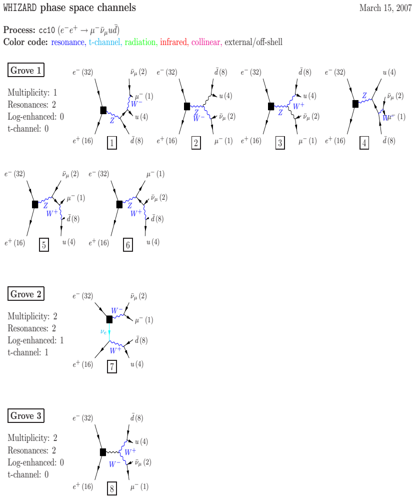
```
! Using grids and results from file:
! Reading analysis configuration data from file whizard.cut5
! No analysis data found for process cc10
! Event sample corresponds to luminosity [fb-1] =   9.999
! Event sample corresponds to       22665  weighted events
! Generating       2717 unweighted events ...
!=============================================================================
! Analysis results for process cc10:
! It       Events Integral[fb]  Error[fb]   Err[%]    Acc  Eff[%]   Chi2 N[It]
!-----------------------------------------------------------------------------
  13        2717  2.7173259E+02  5.21E+00    1.92    1.00 100.00
!-----------------------------------------------------------------------------
! Warning: Excess events:    1.2        (    0.04% )  | Maximal weight:  1.04
! There were no errors and  2 warning(s).
! WHIZARD run finished.
```



# Useful: `results/make graphs`

make graphs in `results/` produces most important Feynman diagrams with phase space information:



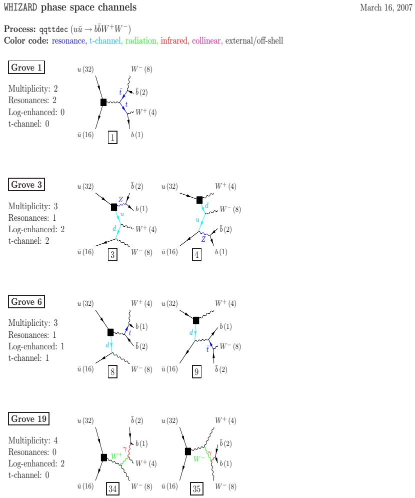
WHIZARD phase space channels — March 15, 2007

**Process:** cc10 ($e^-e^+ \to \mu^-\bar{\nu}_\mu u\bar{d}$)
**Color code:** resonance, t-channel, radiation, infrared, collinear, external/off-shell

**Grove 1**
Multiplicity: 1
Resonances: 2
Log-enhanced: 0
t-channel: 0

**Grove 2**
Multiplicity: 2
Resonances: 2
Log-enhanced: 1
t-channel: 1

**Grove 3**
Multiplicity: 2
Resonances: 2
Log-enhanced: 0
t-channel: 0



WHIZARD phase space channels — March 16, 2007

**Process:** qqttdec ($u\bar{u} \to b\bar{b}W^+W^-$)
**Color code:** resonance, t-channel, radiation, infrared, collinear, external/off-shell

**Grove 1**
Multiplicity: 2
Resonances: 2
Log-enhanced: 0
t-channel: 0

**Grove 3**
Multiplicity: 3
Resonances: 1
Log-enhanced: 2
t-channel: 2

**Grove 6**
Multiplicity: 3
Resonances: 1
Log-enhanced: 1
t-channel: 1

**Grove 19**
Multiplicity: 4
Resonances: 0
Log-enhanced: 2
t-channel: 0

# Input blocks in `results/whizard.in`

**&process_input**

```
process_id = ""            ! Process Name

sqrts = 0                  ! CM energy
luminosity = 0             ! [fb^-1]

structured_beams = F       ! structur f.

input_file = ""            ! appends .in
input_slha_format = F       ! SLHA format
```

**&integration_input**

```
calls = 1 10000 3 10000 ! process dep.

read_grids = F             ! avoids adap.
```

**&simulation input**

```
n_events = 0               ! N_unweighted
n_calls = 0                ! ME calls (weighted)

unweighted = T             ! unweighted samples

write_events = F           ! whizard.evt (ext. use)
write_events_format = 1    ! Event format
several_file_opt. = ""     ! user-def. files
write_events_raw = T       ! whizard.evx
```

**&diagnostics_input**

**&parameters_input**

```
depends on used model,      e.g. gg = 1.218 ! g_s
```

**&beam_input**

```
polarization = 0 0 0       ! fraction of pols.
```

# Input blocks in results/whizard.in

**&process_input**

```
process_id = ""              ! Process Name
cm_frame = T                 ! CM frame
sqrts = 0                    ! CM energy
luminosity = 0               ! [fb^-1]
polarized_beams = F          ! Polarization
structured_beams = F         ! structur f.
beam_recoil = F              ! Beam recoil
recoil_cons._mom. = F        ! p, not E cons.
filename = ""                ! instead of W
directory = ""               ! dir. for I/O
input_file = ""              ! appends .in
input_slha_format = F         ! SLHA format
```

**&integration_input**

```
calls = 1 10000 3 10000 ! process dep.
seed = undef.                ! random seed
reset_seed_each_process = F
accuracy_goal = 0            ! stops grid adap.
efficiency_goal = 100        ! stops grid adap.
time_limit_adaption = 0 ! time limit
stratified = T               ! srat. vs. import.
use_efficiency = F           ! eff. vs. acc.
weights_power = 0.25         ! Channel adap.
min_bins = 3                 ! bins per dim.
max_bins = 20                ! bins per dim.
min_calls_per_bin = 10       ! calls per bin
min_calls_per_channel = 0
write_grids = T              ! Grid output
write_grids_raw = F          ! grid raw fmt
write_all_grids = F          ! all grid adap.
read_grids = F               ! avoids adap.
read_grids_raw = F           !
read_grids_force = F         ! forces reading
generate_phase_space = T ! whizard.phx
read_phase_space = T         ! read whizard.phs
several_file_opt. = ""       ! user-def. files
phase_space_only = F         ! stop after PS gen.
use_equivalences = T         ! use permut. symm.
azimuthal_dependece = F ! no azimuth info.
phase_space_setup_opt.       ! detailed PS setup
```

**&simulation input**

```
n_events = 0                 ! N_unweighted
n_calls = 0                  ! ME calls (weighted)
N_events_warmup = 0          ! xtra warmup events
unweighted = T               ! unweighted samples
normalize_weight = T         ! norm. to 1 vs. sigma
write_weights = F            ! write weights
write_events = F             ! whizard.evt (ext. use)
write_events_format = 1 ! Event format
several_file_opt. = ""       ! user-def. files
write_events_raw = T         ! whizard.evx
read_events[_force] = F ! read whizard.evx
keep_xxx = F                 ! record remnants/beam
guess_color_flow = F         ! for non-ex. flow info
recalculate = F              ! reeval. ME
fragment = F                 ! fragmentation on/off
fragmentation_method = 0 ! PYTHIA/Jetset
user_fragmentation_method = 0
pythia_parameters = ""       ! PYTHIA frag. params.
```

**&diagnostics_input**

```
chattiness = 4               ! Message level
catch_signals = T            ! catch ext. sign.
time_limit = F               ! see manual
warn_empty_channel = F       !    dto.
screen_xxx = F               ! show on screen
show_pythia_xxx = T          ! Pythia output
write_logfile = T            ! whizard.xxx.out
show_input = T               ! see manual
show_results = T             ! integr. results
show_phase_space = F         ! PS config.
show_cuts = T                ! cuts in log file
show_histories = F           ! detailed VAMP history
show_history = T             ! VAMP summary
```

**&parameters_input**

```
depends on used model,      e.g. gg = 1.218 ! g_s
```

**&beam_input**

```
energy = 0                   ! E of beam
angle = 0                    ! angle of beams
direction = 0 0 0            ! beam direction in LAB
vector_polarization = F ! long./transv. vs. hel.
polarization = 0 0 0         ! fraction of pols.
```

# Output files, Cuts and Histograms

When you run a process, then the following files are written in `results/`:

- `whizard.out`: generic output summary
- `whizard.XXX.out`: process specific output
- `whizard.XXX.grc`, `whizard.XXX.grb[grc]`: best [current] grid for process XXX
- `whizard.phx`: phase space for current process

```
! e-   e+   ->  e-   e+   gamma
! 16    8        1    2     4
process eeg
  cut Q of 10 within -99999 -1
  cut Q of 17 within -99999 -1
  cut M of  3 within 10 99999
  cut E of  4 within  5 99999
  cut PT of 4 within 19 99999
  cut THETA(DEG) of  4 1 within 5 180
  cut THETA(DEG) of  4 2 within 5 180
```

## Cuts and Histograms:

- File `results/whizard.cut1` Real kinematic cuts, taken into account for phase space int.
- File `results/whizard.cut5` Cuts for histogramming, declaration of desired histograms
- **Events needed for plots!**
- `make plots` produces `whizard-plots.ps`

```
! e-   e+   ->  e-   e+   gamma
! 16    8        1    2     4
process eeg
  cut M of 3 within  80 100
and
  cut M  of 3 within 180 200
  cut PT of 4 within 100 99999
and
  cut E of 4 within 0 100
  histogram PT of 1 within 0 500
histogram PT of 1 within 0 500
histogram PT of 1 within 0 500
```

# Overview over allowed cuts and Histogram syntax

| Code | Alternative code(s) | # Args | Description |
|---|---|---|---|
| - | | 0 — 2 | No cut |
| M | Q | 1 | (Signed) invariant mass $M = \text{sgn}(p^2)\sqrt{\|p^2\|}$ |
| LM | LQ | 1 | $\log_{10} \|M\|$ |
| MSQ | QSQ S T U | 1 | Squared invariant mass $M^2 = p^2$ |
| E | | 1 | Energy in the lab frame |
| LE | | 1 | $\log_{10} E$ |
| PT | | 1 | Transverse momentum $p_\perp$ |
| LPT | | 1 | $\log_{10} p_\perp$ |
| PL | | 1 | Longitudinal momentum $p_L$ |
| P | | 1 | Absolute value of momentum $\|\vec{p}\|$ |
| Y | RAP RAPIDITY | 1 | Rapidity $y$ |
| ETA | | 1 | Pseudorapidity $\eta$ |
| DETA | DELTA-ETA | 2 | Pseudorapidity distance $\Delta\eta$ |
| PH | PHI | 1 | Azimuthal angle $\phi$ (lab frame) in radians |
| PHD | PHID PHI(DEG) | 1 | Azimuthal angle $\phi$ (lab frame) in degrees |
| DPH | DPHI DELTA-PHI | 2 | Azimuthal distance $\Delta\phi$ (lab frame) in radians |
| DPHD | DPHID DELTA-PHI(DEG) | 2 | Azimuthal distance $\Delta\phi$ (lab frame) in degrees |
| AA | ANGLE-ABS TH-ABS THETA-ABS | 1 | Absolute polar angle $\theta_{\text{abs}}$ (lab frame) in radians. Reference axis is the $z$-axis. |
| AAD | ANGLE(DEG) | | |
| | TH-ABS(DEG) THETA-ABS(DEG) | 1 | Absolute polar angle $\theta_{\text{abs}}$ (lab frame) in degrees |
| CTA | COS(TH-ABS) COS(THETA-ABS) | 1 | $\cos\theta_{\text{abs}}$ |
| A | ANGLE TH THETA | 2 | Relative polar angle $\theta$ (lab frame) in radians |
| AD | ANGLE(DEG) | | |
| | TH(DEG) THETA(DEG) | 2 | Relative polar angle $\theta$ (lab frame) in degrees |
| CT | COS(TH) COS(THETA) | 2 | $\cos\theta$ |
| A* | ANGLE* TH* THETA* | 2 | Relative polar angle $\theta^*$ (rest frame of part.#2) in radians |
| AD* | ANGLE*(DEG) | | |
| | TH*(DEG) THETA*(DEG) | 2 | Relative polar angle $\theta^*$ (rest frame of part.#2) in degrees |
| CT* | COS(TH*) COS(THETA*) | 2 | $\cos\theta^*$ |
| DR | DELTA-R CONE | 2 | Distance in $\eta$-$\phi$ space, i.e. $\sqrt{\Delta\eta^2 + \Delta\phi^2}$ |
| LDR | LOG-DELTA-R LOG-CONE | 2 | $\log_{10}\sqrt{\Delta\eta^2 + \Delta\phi^2}$ |

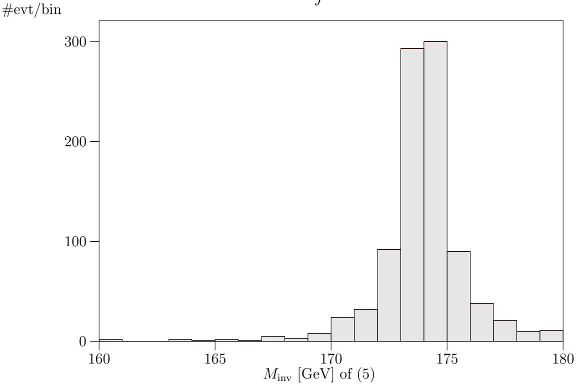
# WHiZard histograms

## New completely general cut syntax in W 2.0/O 1.0

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

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

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




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

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

# Examples for structured beams

```
&beam_input
 particle_name = "p"
 PDF_on = T
 PDF_ngroup = 4
 PDF_nset = 46
 PDF_scale = 1000
! PDF_running_scale = T
 /

 &beam_input
 particle_name = "p"
 PDF_on = T
 PDF_ngroup = 4
 PDF_nset = 46
 PDF_scale = 1000
! PDF_running_scale = T
```

```
 &beam_input
 particle_name = "A"
 CIRCE2_on = T
 CIRCE2_file = "teslagg_500_rr.circe"
 CIRCE2_polarized = T
 /

 &beam_input
 particle_name = "A"
 CIRCE2_on = T
 CIRCE2_file = "teslagg_500_rr.circe"
 CIRCE2_polarized = T
/
```

```
 &beam_input
 USER_strfun_on = T /
 &beam_input
 USER_strfun_on = T /
```

```
&beam_input
 particle_name = "e-"
 polarization = 0.80 0
 CIRCE_on = T
 CIRCE_acc = 2
 ISR_on = T
 ISR_alpha = 0.0072993
 ISR_m_in = 0.000511
 /

 &beam_input
 particle_name = "e+"
 polarization = 0 0.40
 CIRCE_on = T
 CIRCE_acc = 2
 ISR_on = T
 ISR_alpha = 0.0072993
 ISR_m_in = 0.000511
```

```
! WHIZARD 1.51 (Jun 15 2005)
! Reading process data from file whizard.in
! Reading process data from file sps1a.in
! Reading SUSY Les Houches Accord (SLHA) data
! SLHA: Spectrum calculator name:    SOFTSUSY
! SLHA: Spectrum calculator version: 1.9
! Wrote whizard.out
! Reading phase space configurations from file whizard.phx
!
! Process qqttdec:
!    u a-u ->   b a-b  W+ a-W+
!   32  16 ->   1   2   4    8
! Process energy set to     14000.     GeV

 *****  CERN Computer Program Library     -     Reference:  W5051  *****
 *****  PDFLIB Version:  8.04  Released on  2000-04-17  at  12.24  *****
 PDFLIB  : TMAS value
 Warning : NON standard settings, TMAS value =   174.  set by user !!
```

# The Phantom Menace – the MSSM

- 5318 couplings (with Goldstone/4-point)
- negative neutralino matrices: explicit factor of $i$
- Fully implemented, fully tested and fully functional
- Model `MSSM`
- Recommended usage: SUSY Les Houches Accord (SLHA)

```
&process_input
 process_id ``your_susy_proc''
 .....................
 input_file = "sps1a"
 input_slha_format = T
```

**What about tests? Have we checked?**


- 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://www.physics.carleton.ca/~reuter/susy_comparison.html`

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

| Process | status | Madgraph/Helas 0.5 TeV | Madgraph/Helas 2 TeV | Whizard/O'Mega 0.5 TeV | Whizard/O'Mega 2 TeV | Sherpa/A'Megic 0.5 TeV | Sherpa/A'Megic 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) |

# How to add a new model?

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

Version WHiZard 2.0/O'Mega 1.0 brings major improvement:
CompHep-style model declarations possible within O'Mega (this sacrifices fully functionality and object-orientedness of O'Caml)

Until then (if you dare to go the high road):
Works only with the version on my homepage

- Add your new particles and couplings in `omega/src/models3.ml` in the `template[_Col]`
- Declare the couplings in `omega/src/omega_parameters_template.nw`
- Add the new particles and (trilinear) vertices to `whizard/conf/models/Template.mdl`
- Add the couplings constants (with their names declared in `omega/src/omega_parameters_template.nw`) to `whizard/conf/models/parameters.Template.omega.f90`
- Do the debugging by yourself, no responsibility from the authors!

# Final Remarks

**Left out:**

- Details about phase space generation and integration

  We don't use black boxes, we write them!
- Fragmentation, hadronization, showers, underlying event (stay tuned!)
- No Advanced WHiZard spells: grid adaptation, dirty tricks, failures
- Implementation of NLO calculations
  (come to my talk at LoopFest/Fermilab)

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# Upgrade '07

# Upgrade '07