# O'Mega & WHIZARD: Monte Carlo Event Generator Generation For Future Colliders

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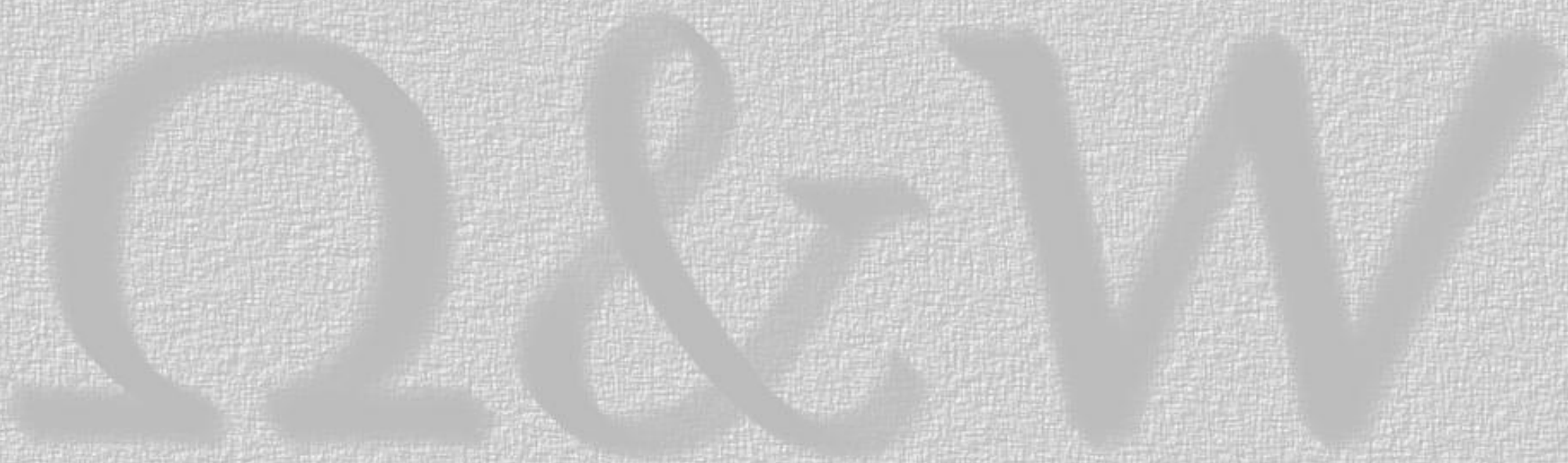
LCWS2000, Fermilab, October 2000


O&W

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  - the phase space also becomes much more intricate

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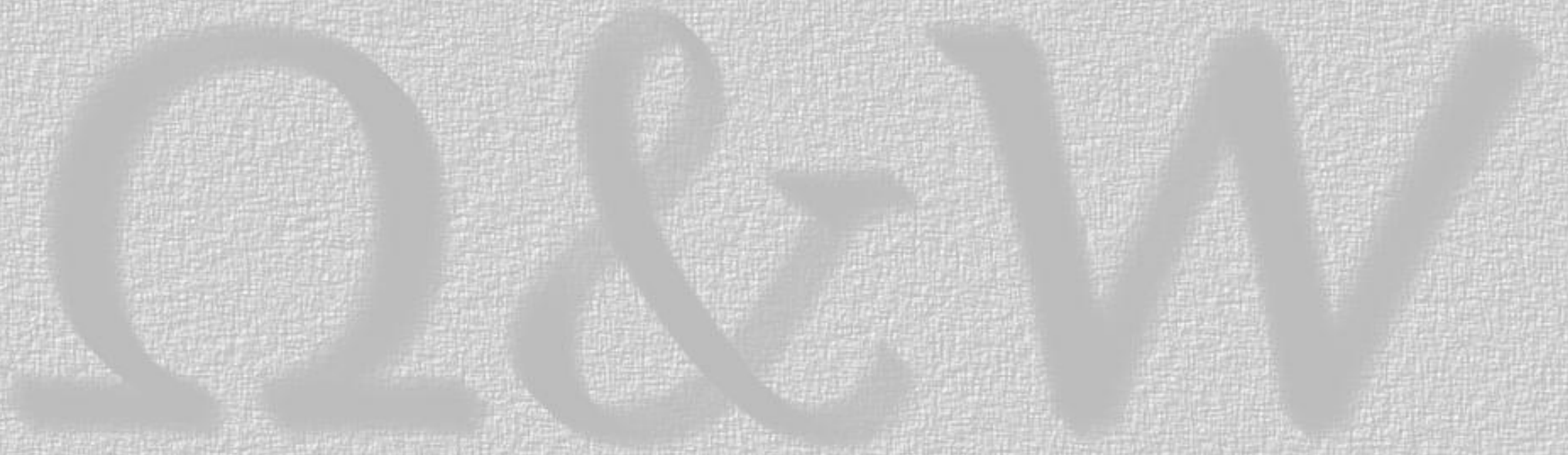

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- ☹ some essential parts will need a lot more work
  - loops for many particles
  - $\because$ complete one-loop calculations for $2 \to 4$ are the limit of our capabilities

The number of tree Feynman diagrams w/ $n$ legs in vanilla $\phi^3$-theory is

$$F(n) = (2n-5)!! = (2n-5)\cdot(2n-7)\cdot\ldots\cdot 3\cdot 1$$

| $n$ | | |
|---|---|---|
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☹ terms much too large to expect any help from common subexpression elimination by optimizing compilers that don't understand any physics!

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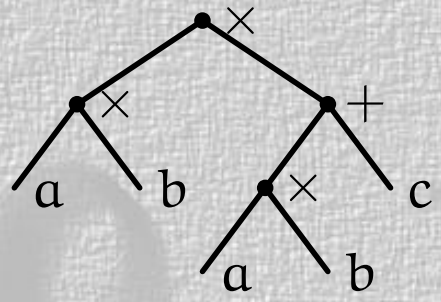

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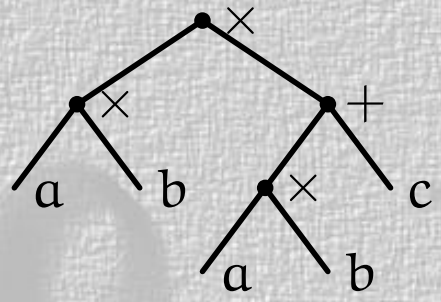


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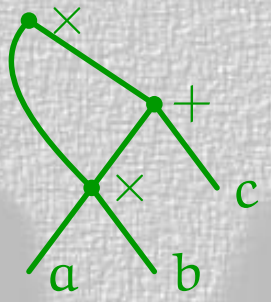

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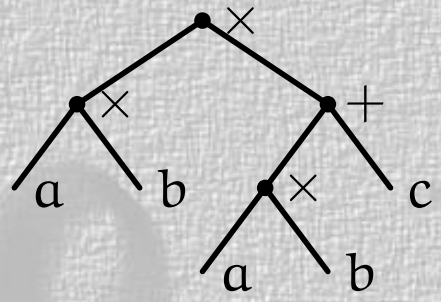
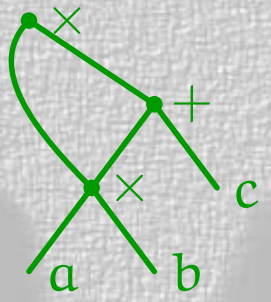
$$ab(ab+c) =$$  $=$ 

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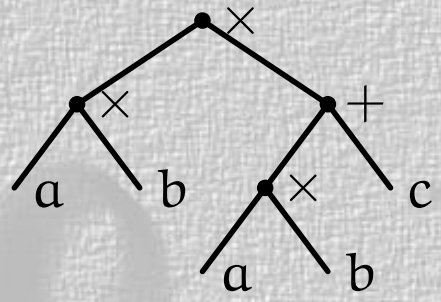


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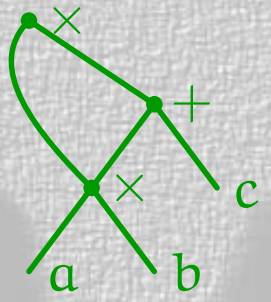


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One particle off-shell wave functions (1POWs) are obtained from Greensfunctions by applying the LSZ reduction formula to all but one line:

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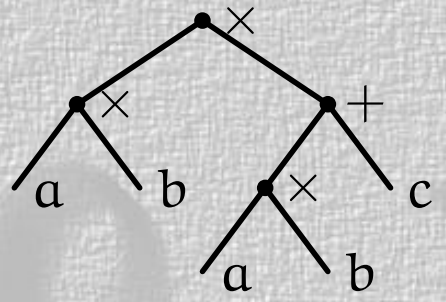


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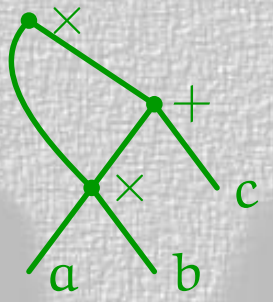


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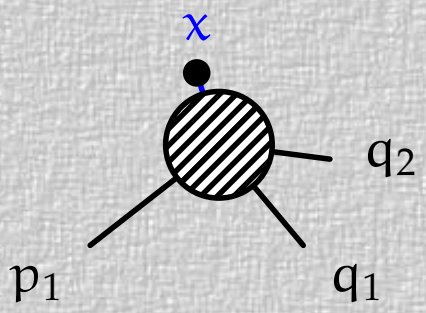

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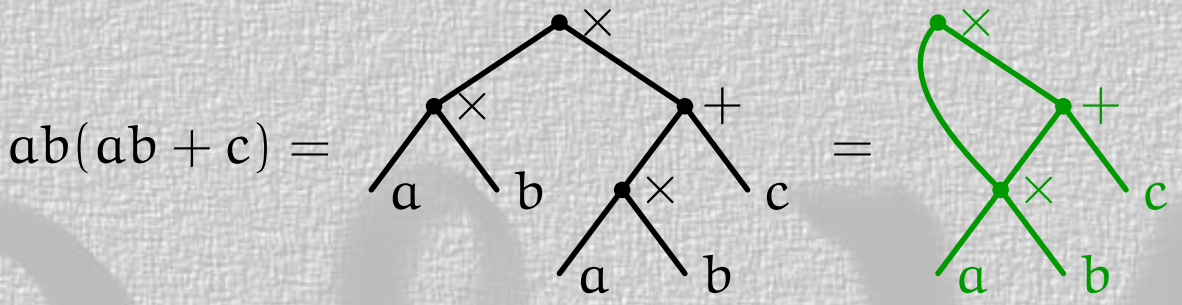


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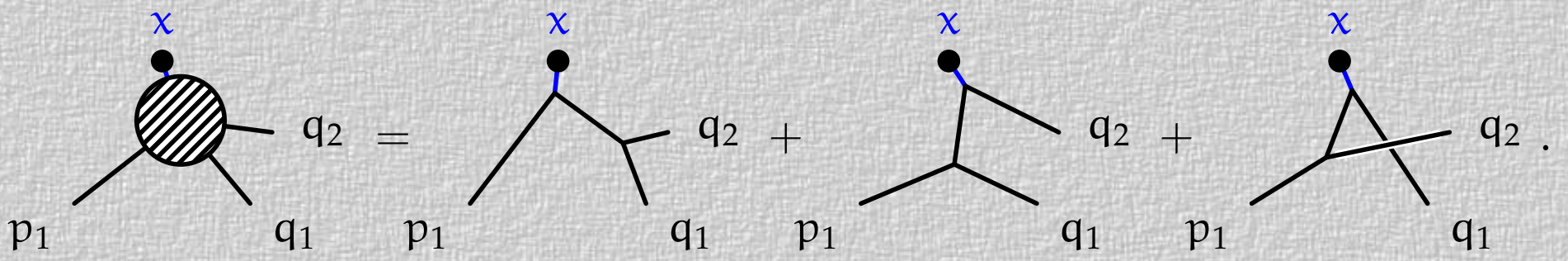

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☺ the symbolic algorithm contains the numerical methods of Alpha (Caravaglios/Moretti) and HELAC (Kanaki/Papadopoulos) as special cases.

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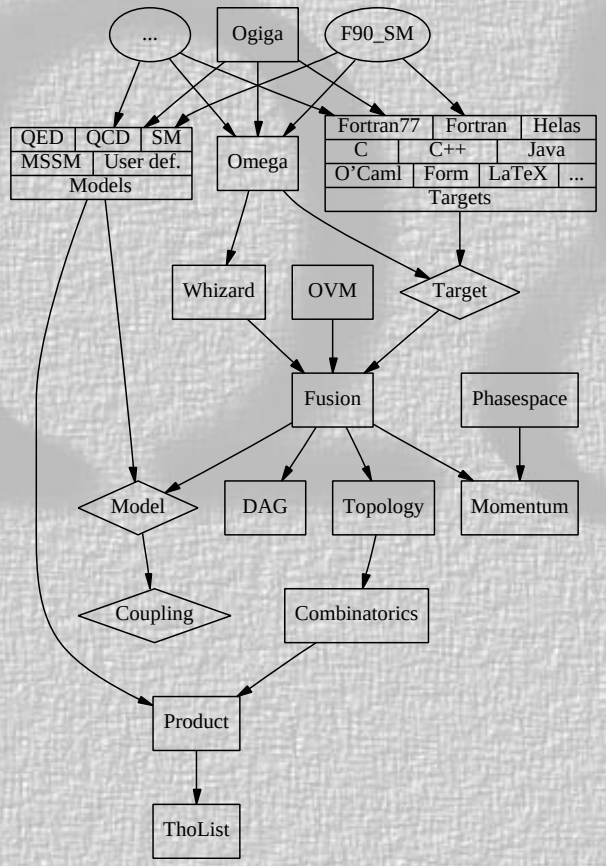

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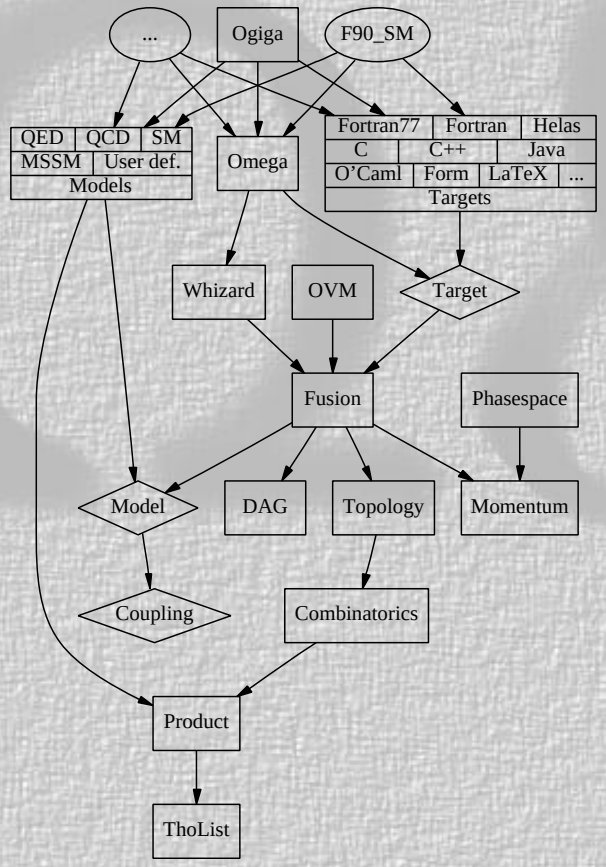

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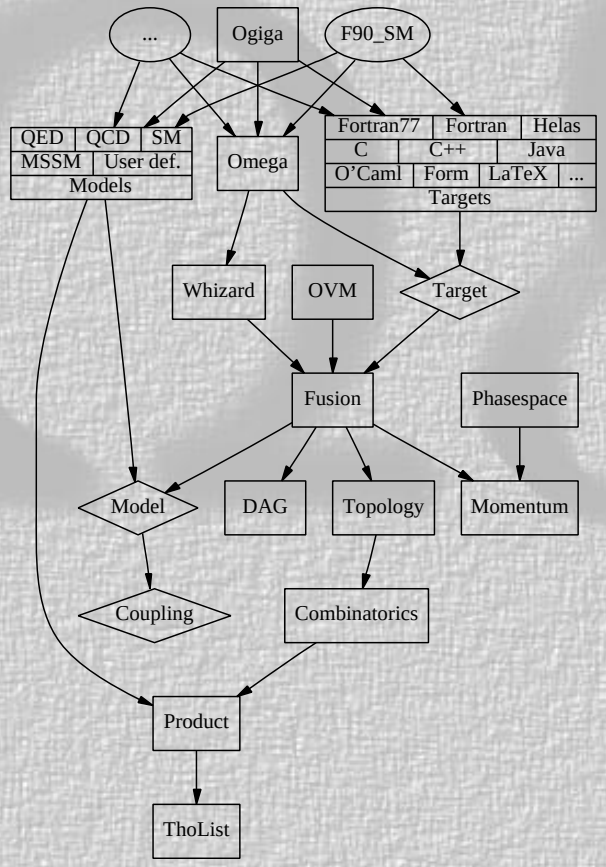


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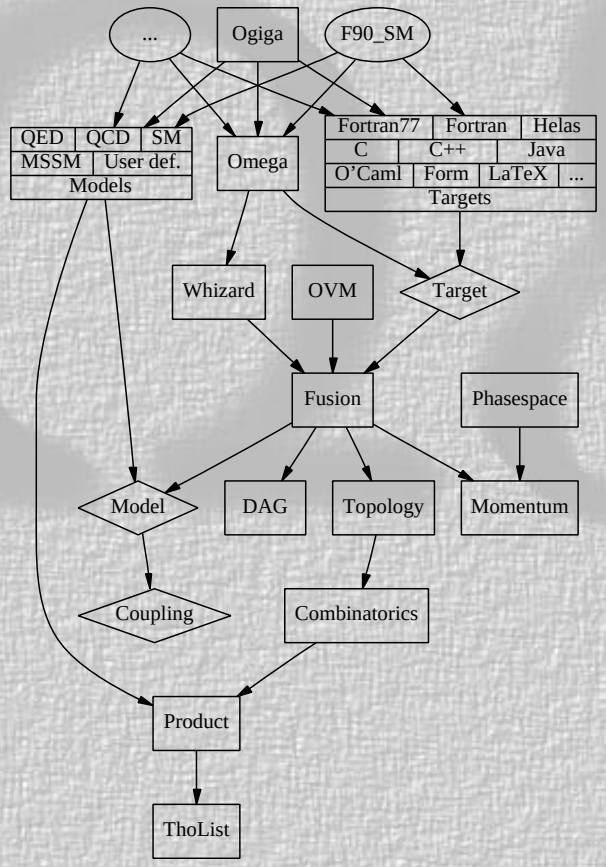


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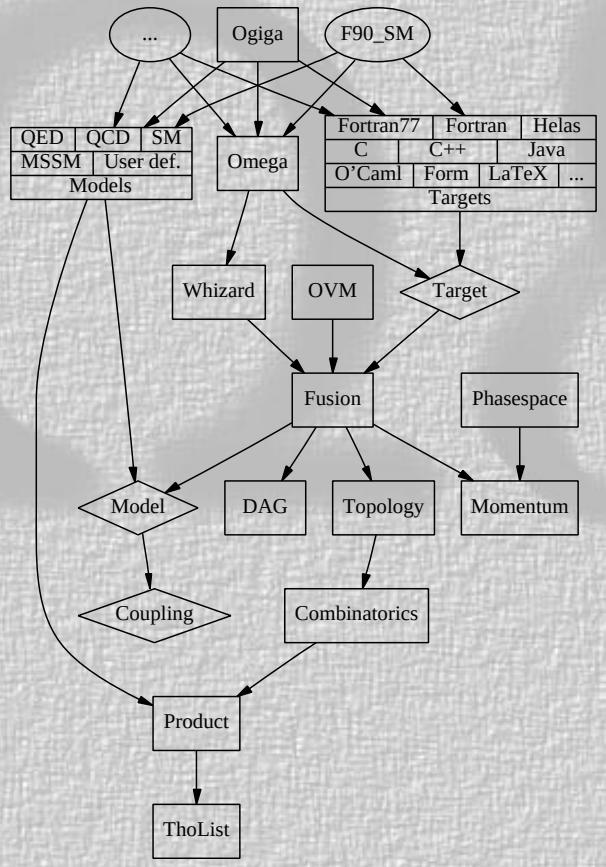
```
module O = Omega.Make
             (Fusion.Binary)
             (Targets.Fortran)
             (Models.SM)
let _ = O.main ()
```

Matrix element compiler O'Mega implemented in Objective Caml (INRIA, France). Its module system supports a flexible architecture with functors building applications from independent modules




The module `Targets` contains implementations of the signature `Target` for each target language and the module `Models` contains implementations of `Model` for each (class of) physics models. E. g. the application writing Fortran95 for the standard model is

```
module O = Omega.Make
             (Fusion.Binary)
             (Targets.Fortran)
             (Models.SM)
let _ = O.main ()
```

- any volunteers for Java and C++ targets?

Radiative corrections to four fermion production (standard model, unitarity gauge):

| process | Diagrams | | | |
|---|---|---|---|---|
| $e^+e^- \to$ | # | | | |
| $e^+\bar{\nu}_e d\bar{u}$ | | | | |
| $e^+\bar{\nu}_e d\bar{u}\gamma$ | | | | |
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Get it from `http://www.ikp.physik.tu-darmstadt.de/~ohl/omega/`.

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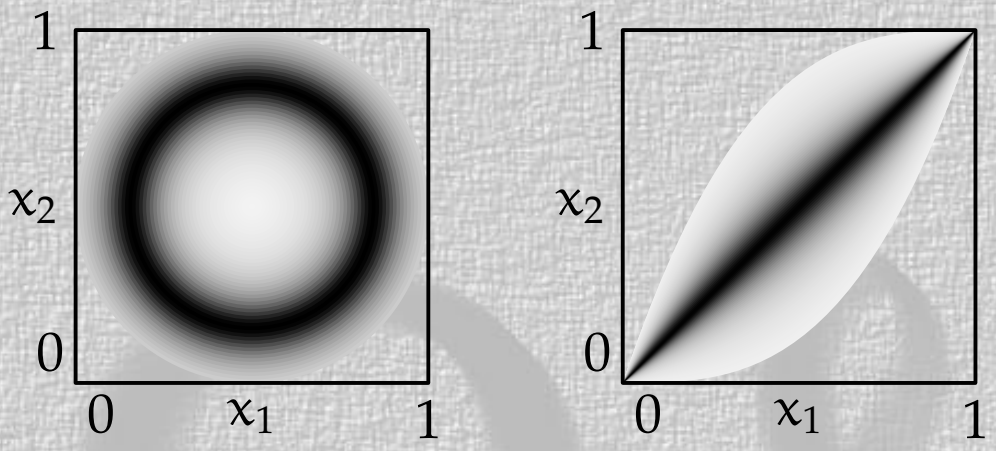
VEGAS' factorized ansatz can deal with




separately after appropriate mapping.

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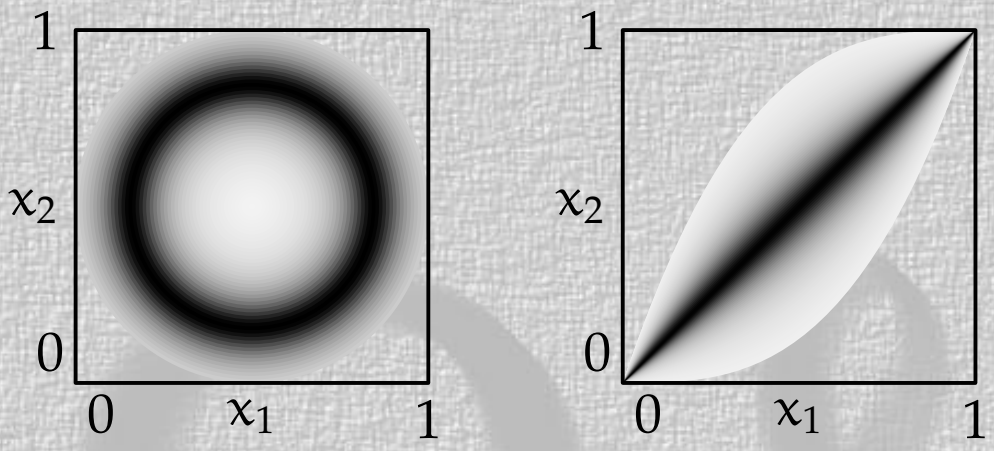


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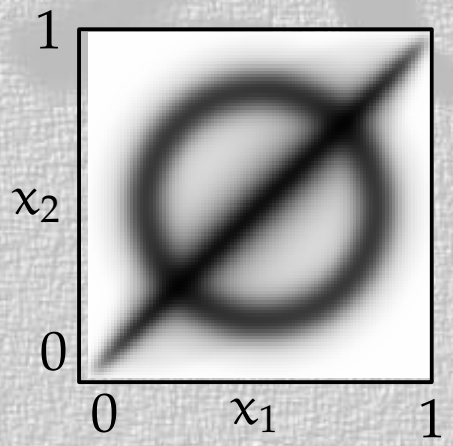
☹ fails for overlapping singularities



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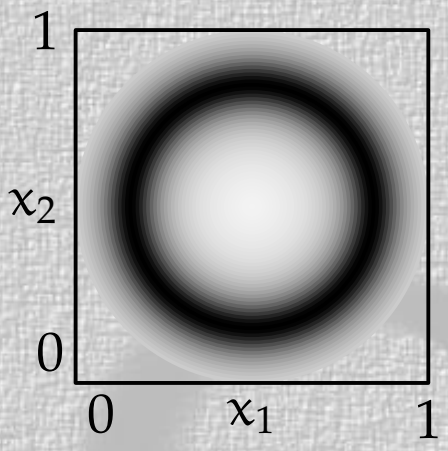


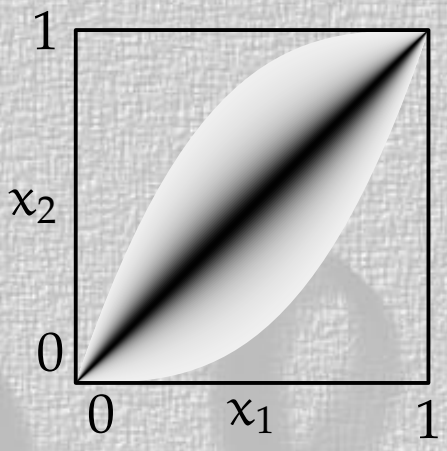


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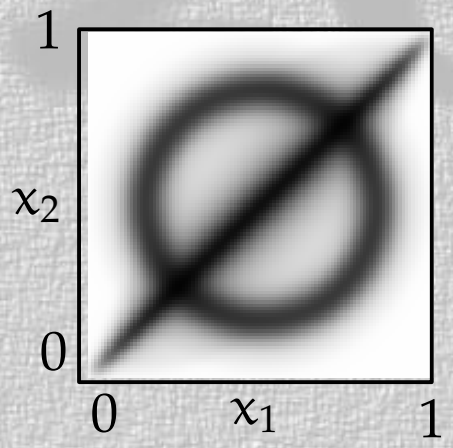


which is the common case (if more than one diagram contributes)

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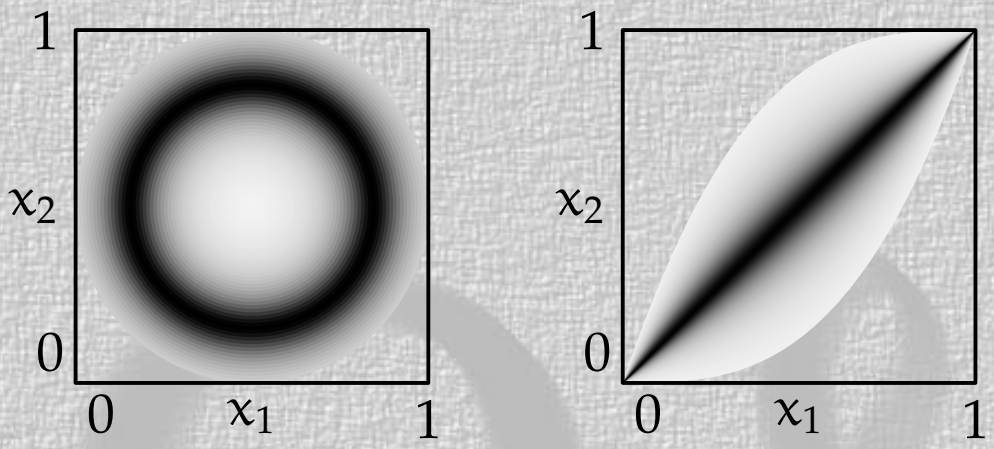


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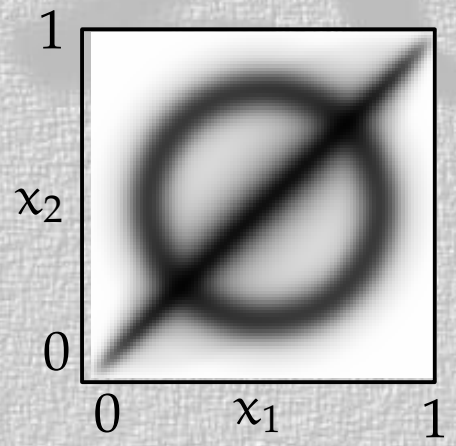


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$\therefore$ adaptive multichannel approach

$$I(f) = \int_M d\mu(p)\, f(p)$$

$$I(f) = \sum_{i=1}^{N_c} \alpha_i \int_0^1 g_i(x) d^n x \, \frac{f(\phi_i(x))}{g(\phi_i(x))}$$

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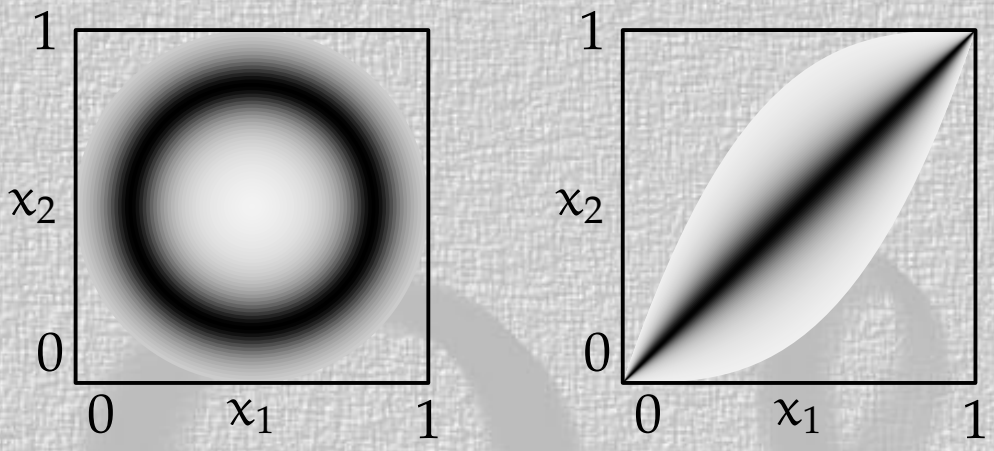


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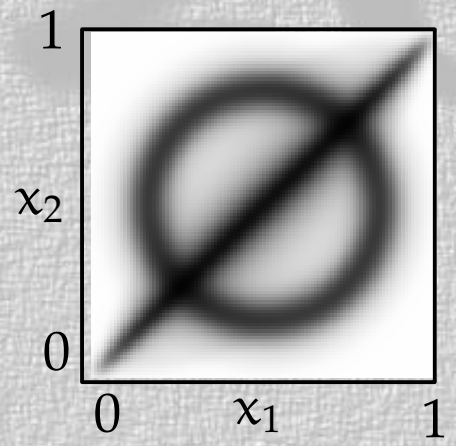


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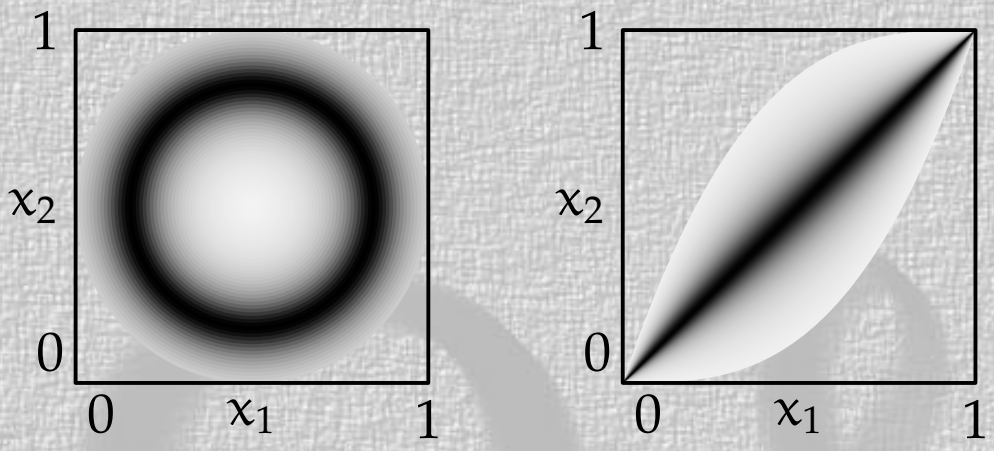


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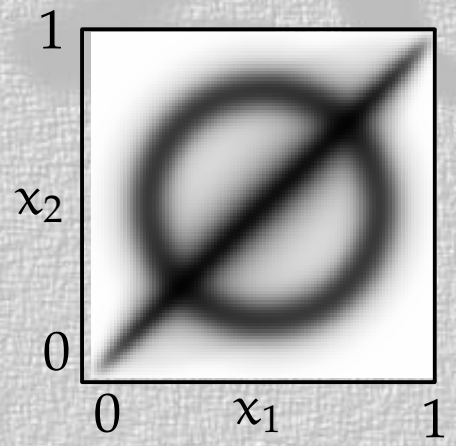


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☺ works with factorized $g_i$ adapted by VEGAS and $\alpha_i$ adapted by variance reduction.

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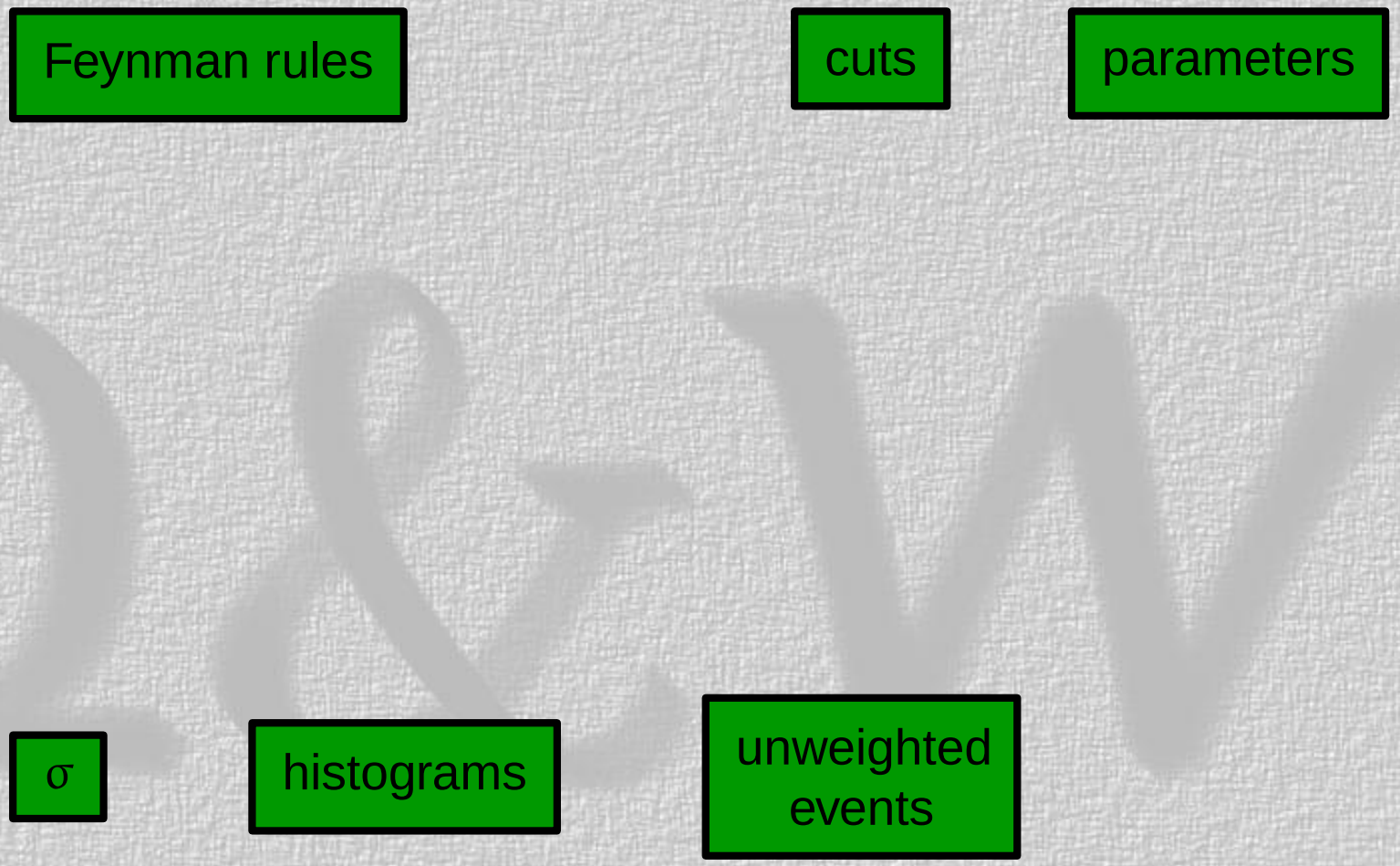
  - $s$-channel resonances
  - $1/t$-poles for massless particles

WHIZARD
*phase space & steering*

Feynman rules

cuts

parameters


Feynman rules
cuts
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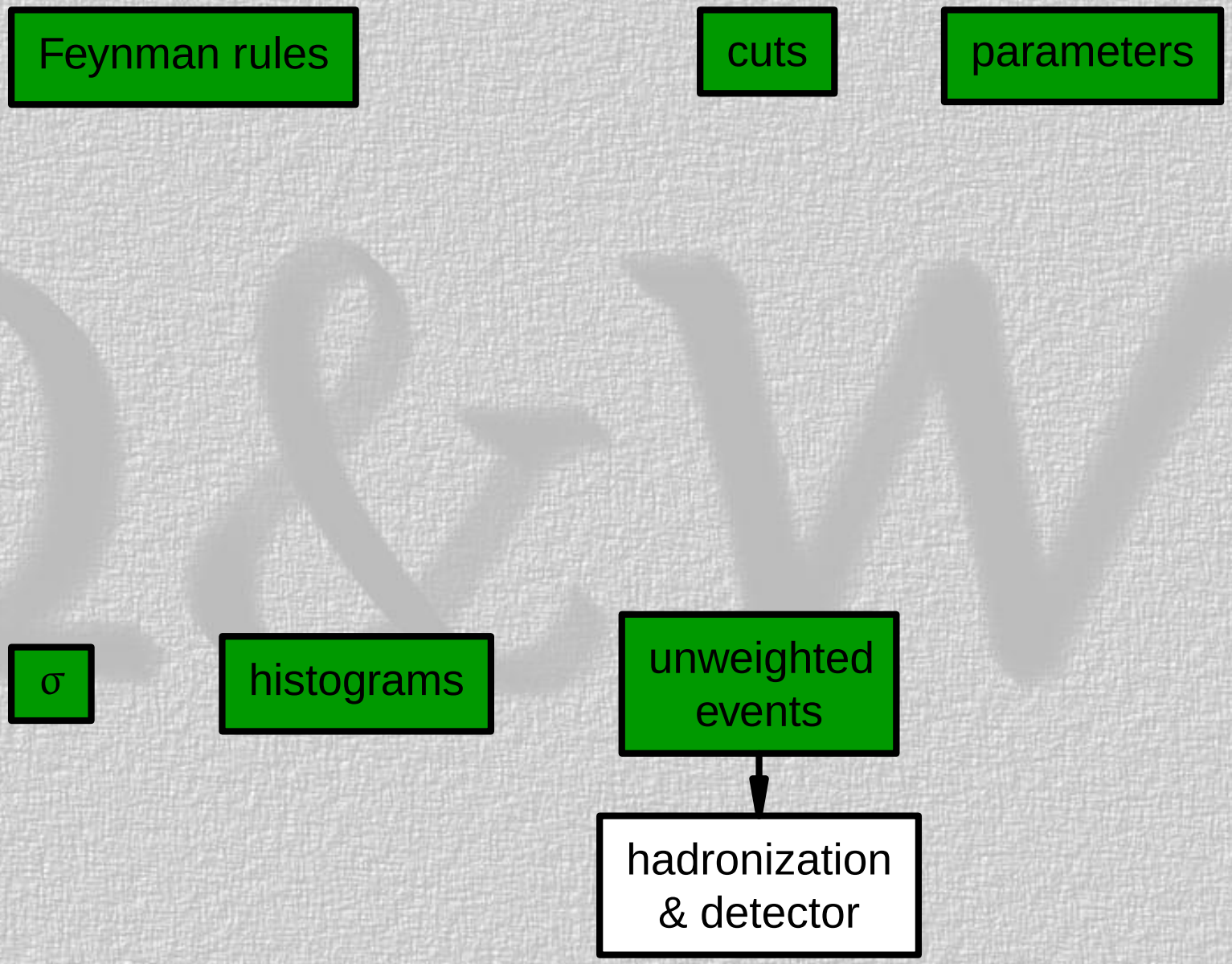
Feynman rules
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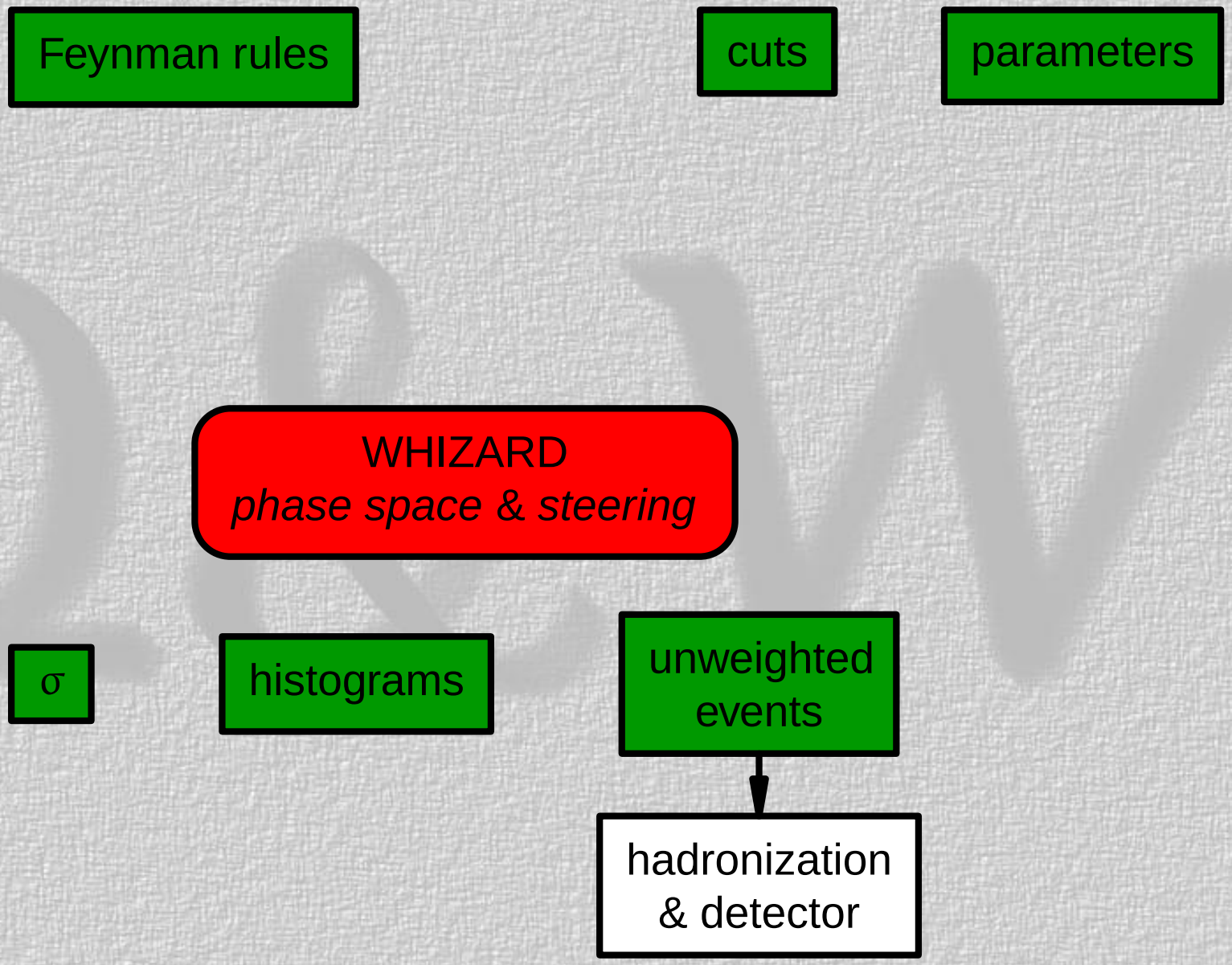
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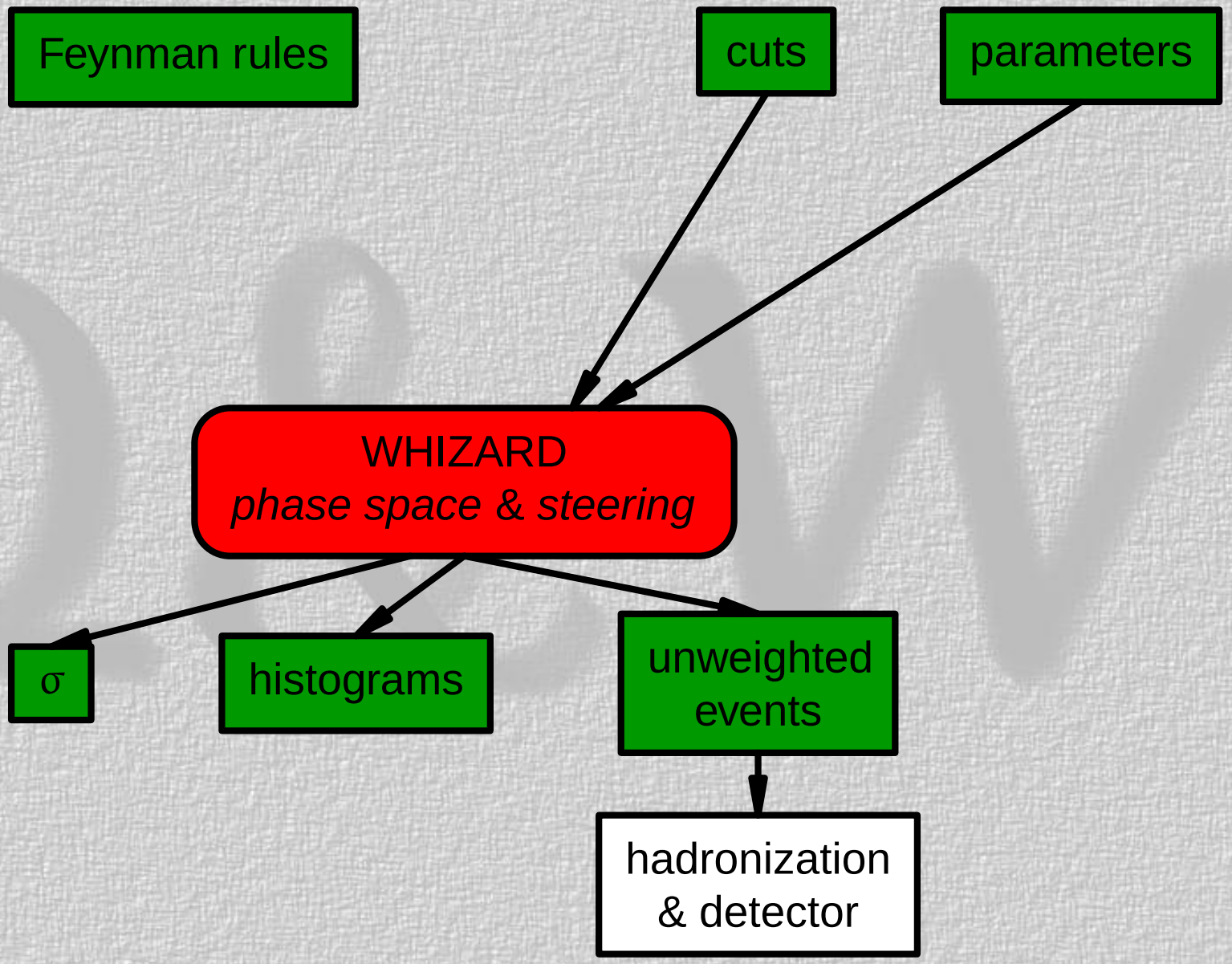
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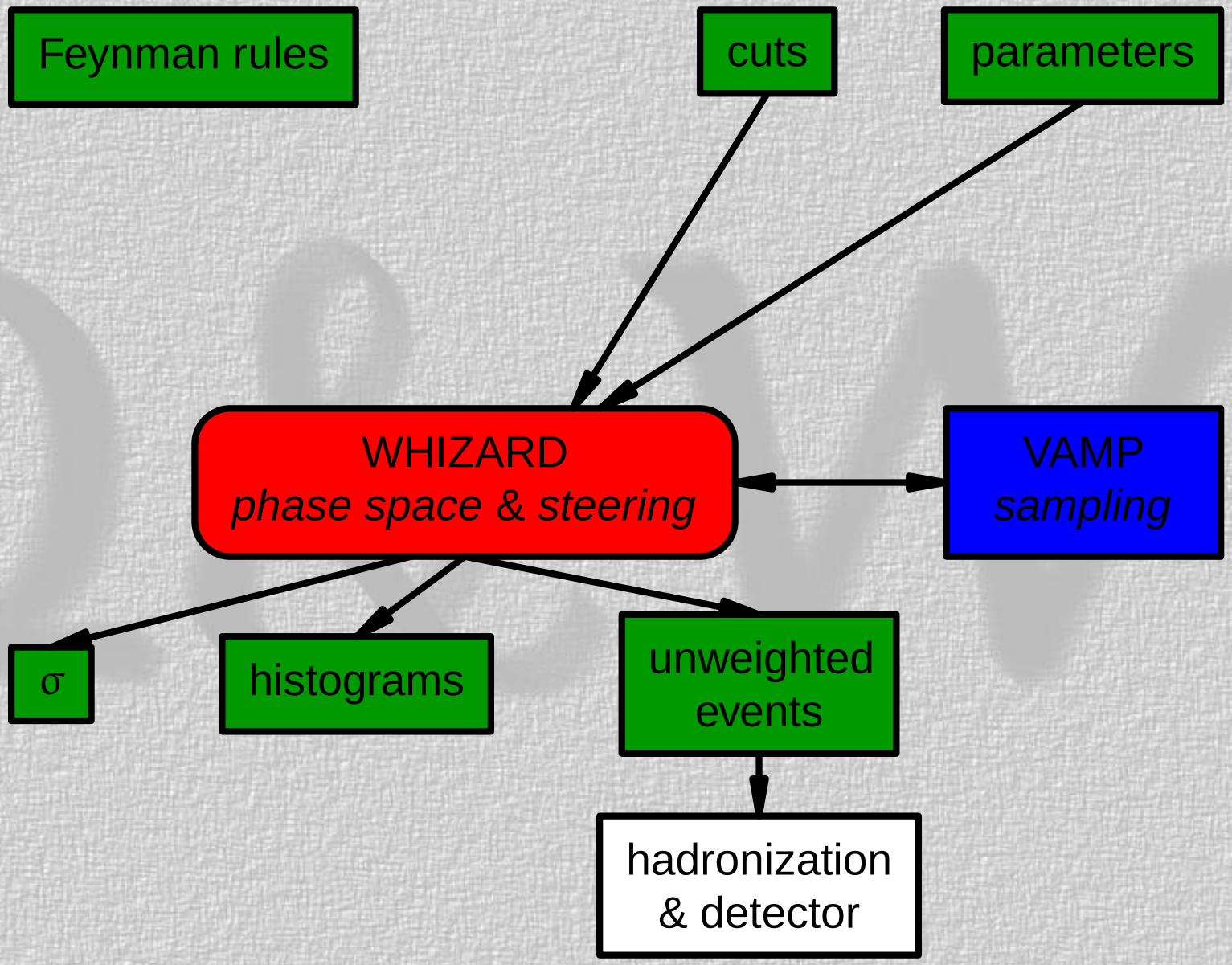
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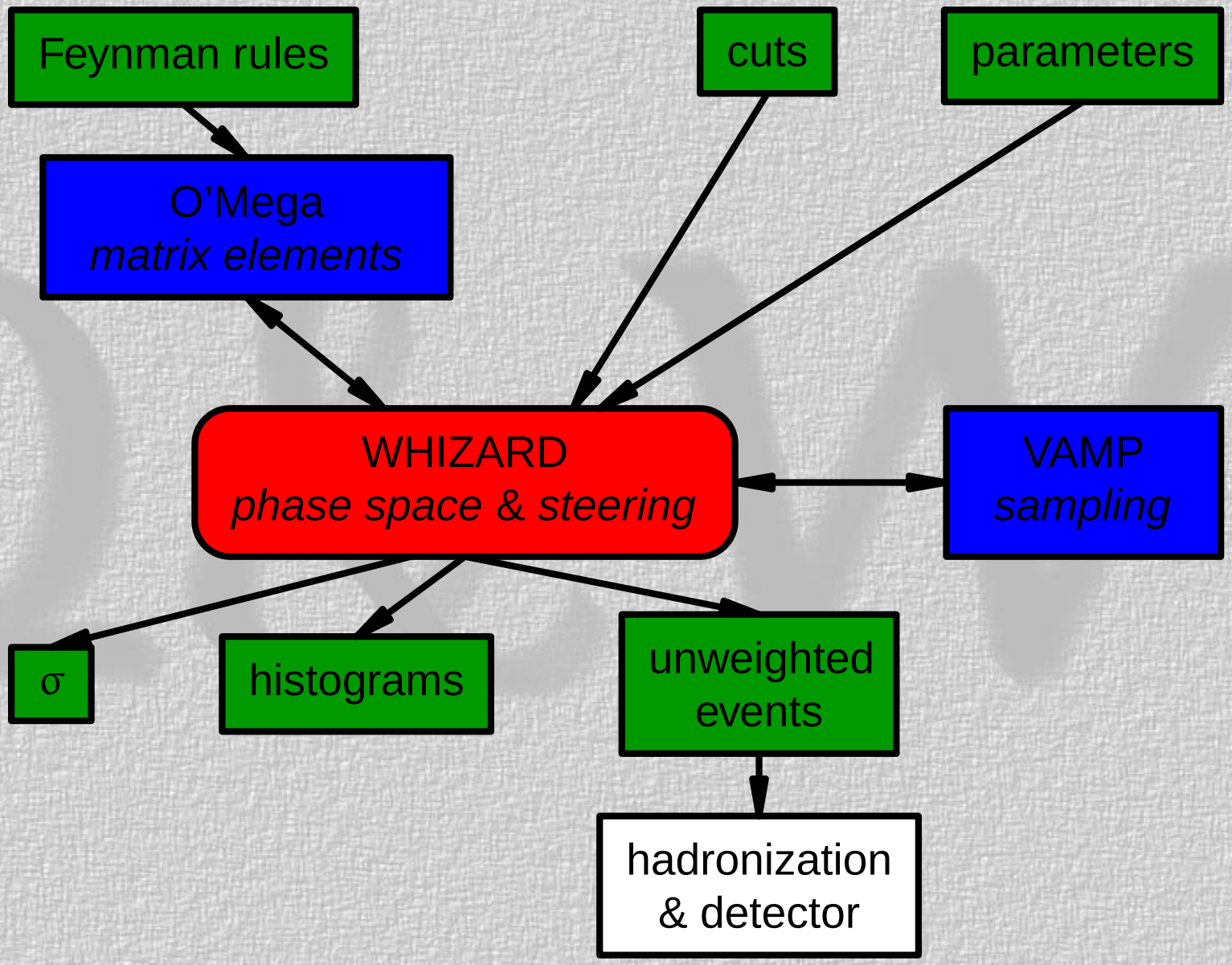
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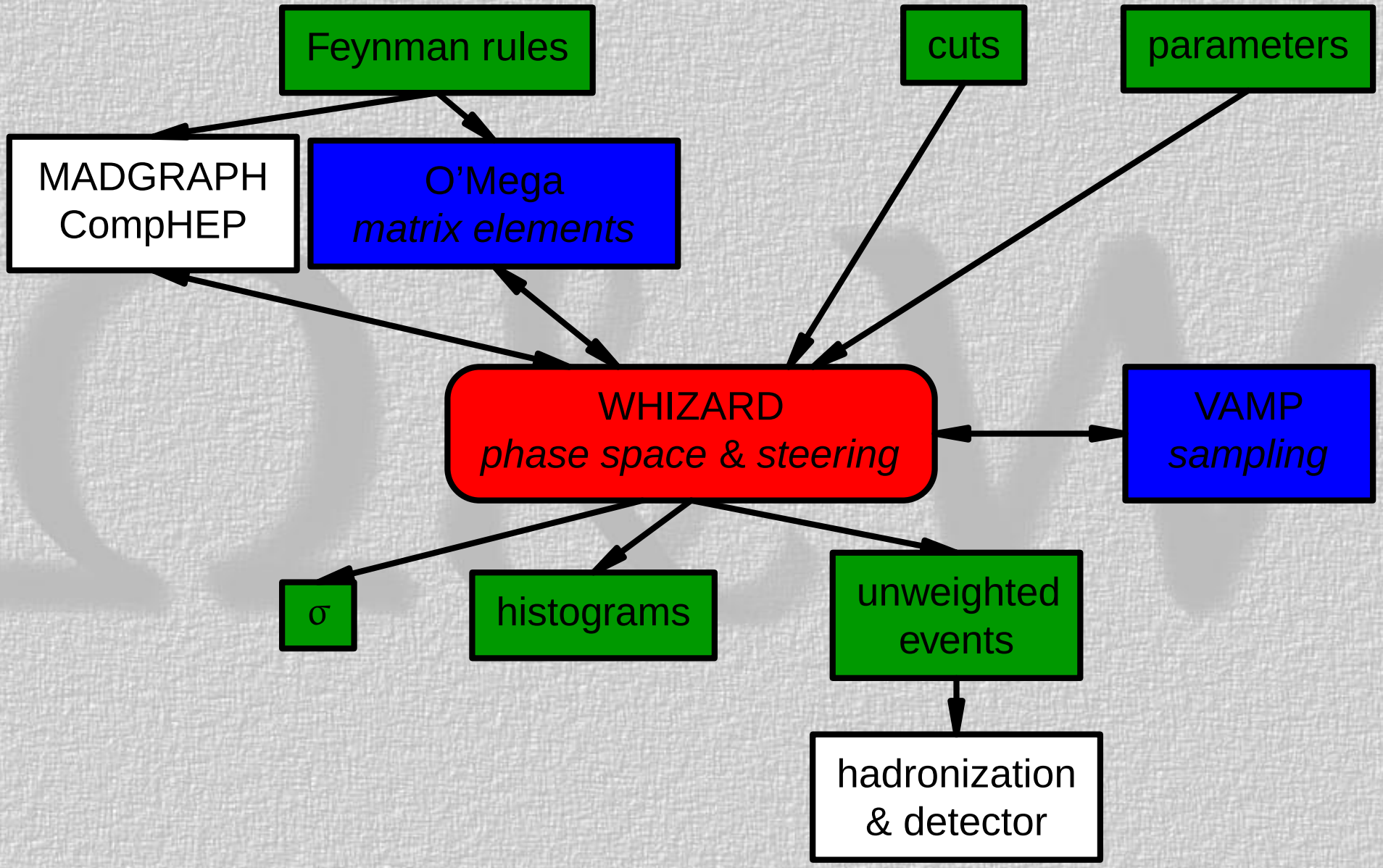
Feynman rules
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MADGRAPH
CompHEP
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ID       In      Out             Method
zh       e1,E1   Z,H             chep
zww      e1,E1   Z,W+,W-         chep
nnbb     e1,E1   n1,N1,b,B       mad
nnucsd   e1,E1   n1,N1,u,C,s,D   omega
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nnucsd   e1,E1   n1,N1,u,C,s,D   omega
```

**Compile:** `Makefile` performs all necessary steps

- 21 diagrams in 4 groves (gauge invariant subsets): Higgsstrahlung (5), *WW*-fusion (10), *ZZ* (4), *Z*-FSR (2)

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Event generation at $\sqrt{s} = 350\ \mathrm{GeV}$ for $m_H = 120\ \mathrm{GeV}$.

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   5      10000  5.8586436E+01  8.34E-01    1.42    1.42*  9.82
   6      10000  5.8997829E+01  6.89E-01    1.17    1.17* 12.18
   7      10000  5.8626448E+01  1.04E+00    1.78    1.78  10.78
   8      10000  5.7737567E+01  5.12E-01    0.89    0.89* 17.50
   9      10000  5.7693393E+01  4.75E-01    0.82    0.82* 19.50
  10      10000  5.8216141E+01  5.42E-01    0.93    0.93  14.60
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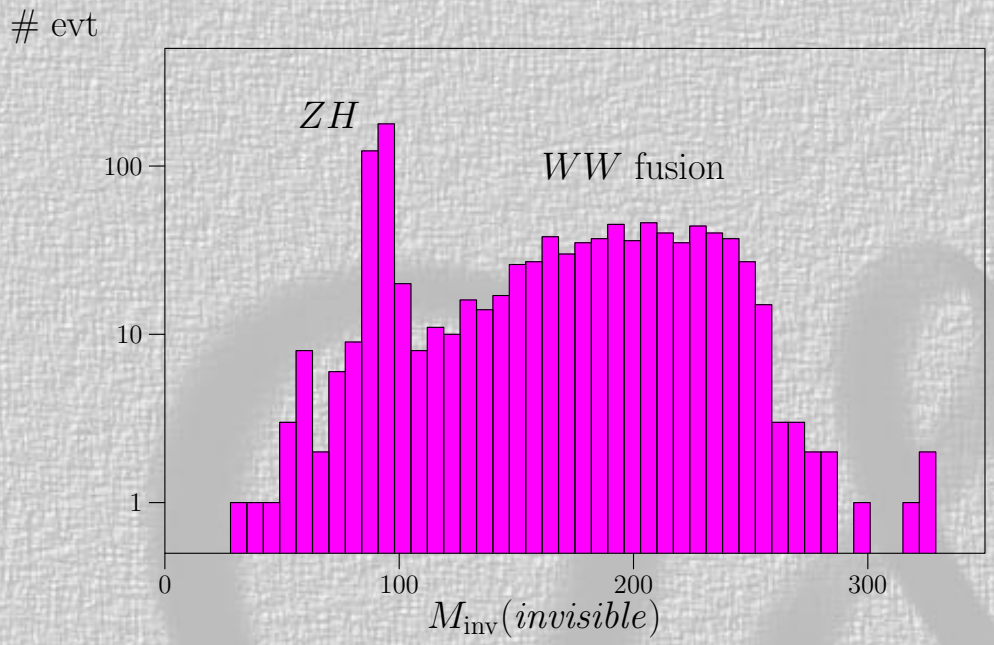
☺ 15 min for adaptation, 10 min for 10,000 unweighted events on a Pentium II 233 MHz.

## missing mass



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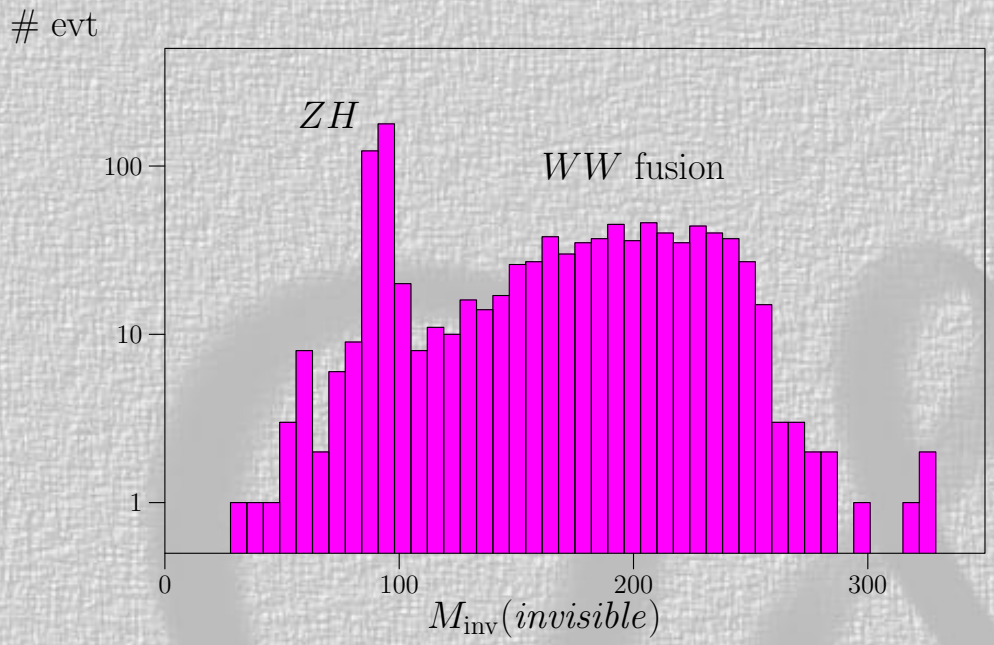
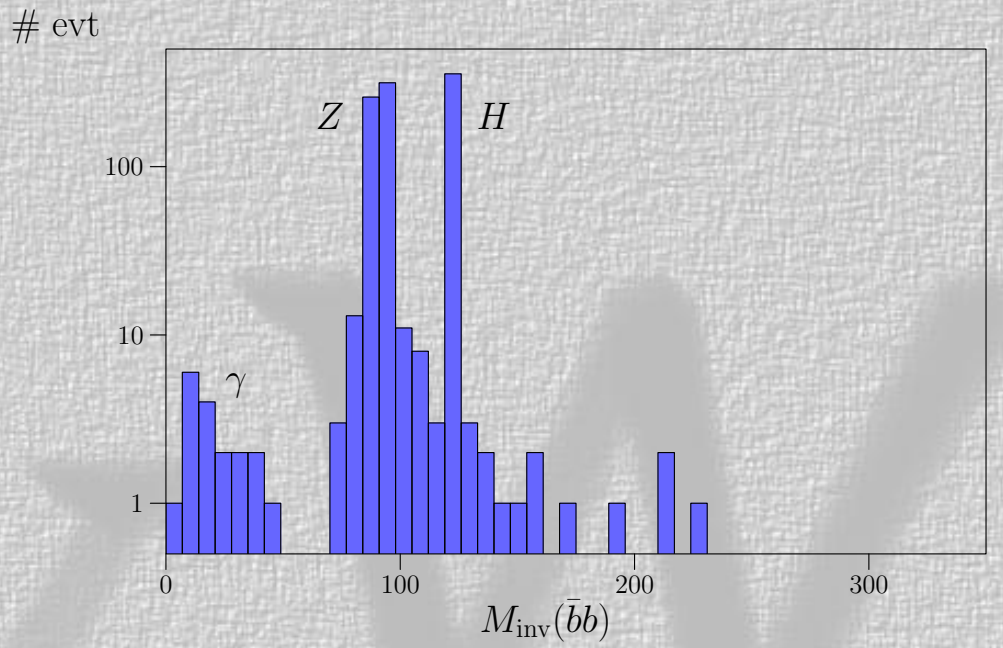



## invariant $b\bar{b}$-mass



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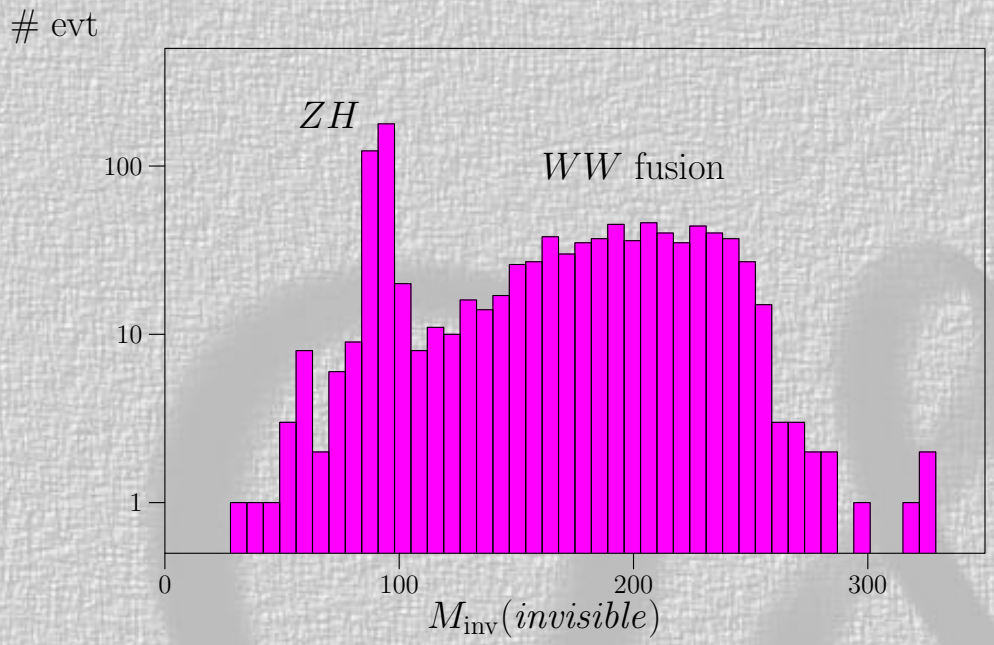


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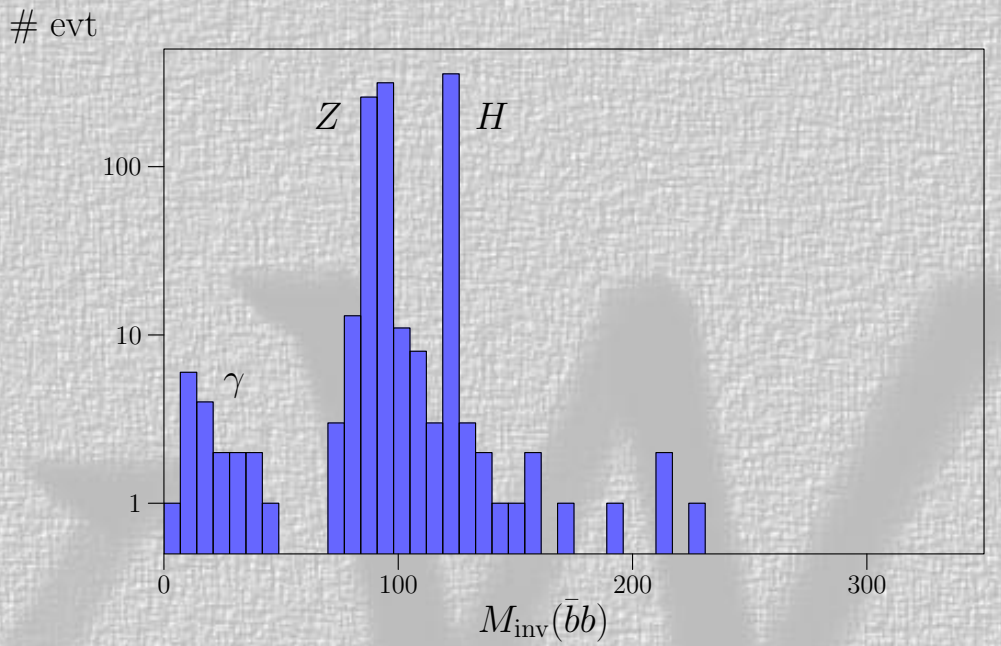


Observations:

- adaption typically takes a bit longer than event generation

# Example: $e^- e^+ \to \nu_e \bar{\nu}_e b\bar{b}$

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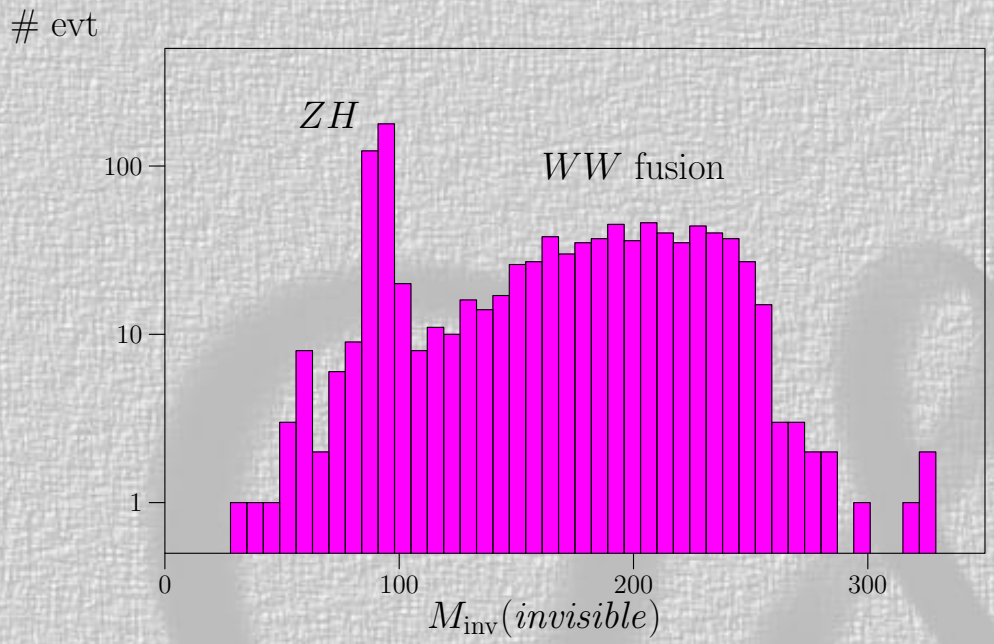


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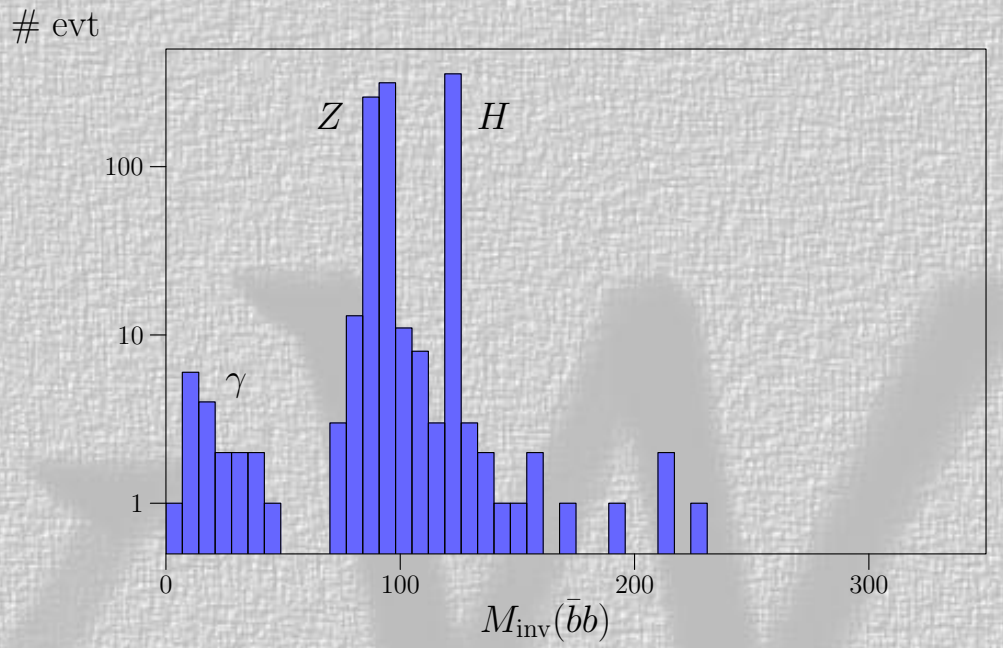


Observations:

- adaption typically takes a bit longer than event generation
- ☺ adapted grids and weights can be saved and reloaded if the cuts and parameters are changed only slightly

WHIZARD will be available from
`http://www-ttp.physik.uni-karlsruhe.de/~kilian/whizard/` soon.

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