# Photon interactions in MadGraph/MadEvent v4

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& the MG/ME development team

# An indisputable reason to study photons interactions ?

**AND GOD SAID, "LET THERE BE LIGHT," AND THERE WAS LIGHT. GOD SAW THAT THE LIGHT WAS GOOD, AND HE SEPARATED THE LIGHT FROM THE DARKNESS.**

*GENESIS 1:3-4*

# Outline

* MadGraph/MadEvent v4
* Photons interactions
* Going beyond the Standard Model

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# Why tree-level?

- Most of the current collider pheno is done at tree-level both at the theoretical and (even more) at experimental level.
- Experiments may need fully exclusive descriptions.
- MC at NLO are very recent (and impressive) achievements, but currently limited to a small set of key SM processes.

# Why tree-level?

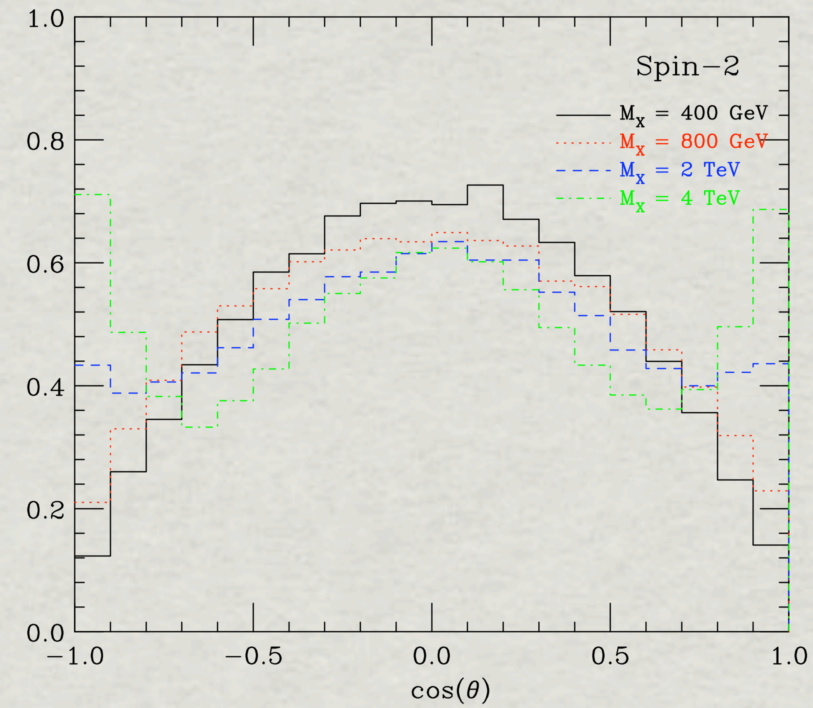
Always the fastest way,

very often the most accurate way,

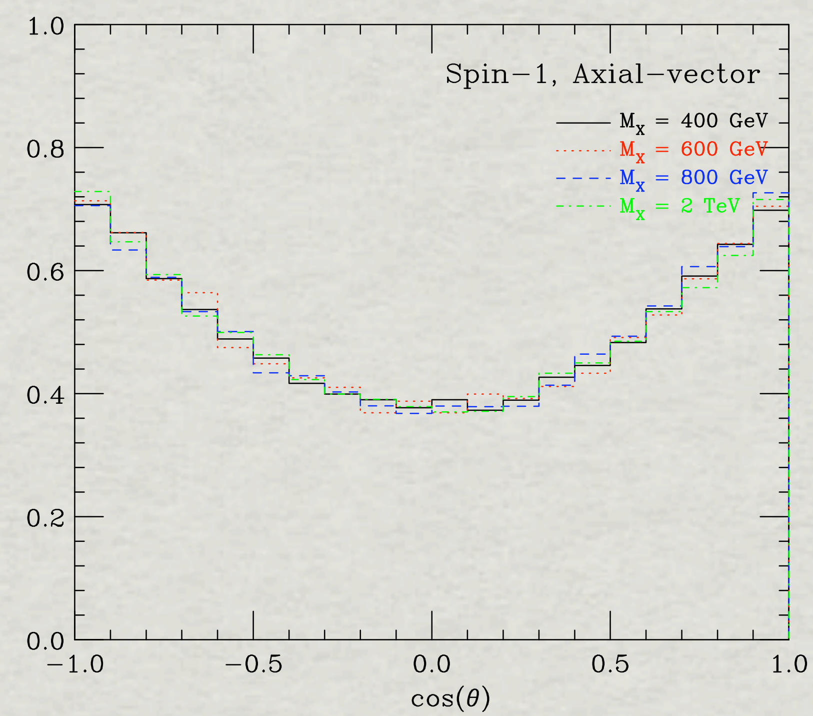
sometimes the only way to bring ideas to life and test them in the experiments!

# Why Matrix Elements ?

- “Natural” approach for phase space regions where perturbative expansion is effective (hard, high angle, ...)
- Take into account all possible interferences
- Simulate correctly spin correlations
- Can be used for new analysis techniques

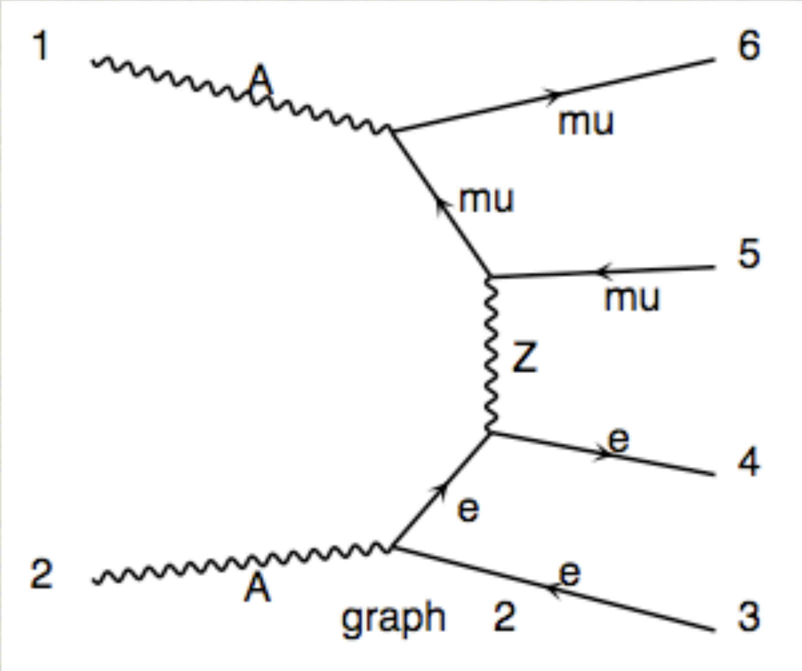



(b)



# MadGraph

- Basic building blocks : Feynman diagrams
- Generates “empty” topologies for m>n diagrams and “fill” them using valid interaction vertices
- Knowing particles properties, produces Feynman diagrams and suitable calls to the HELAS library



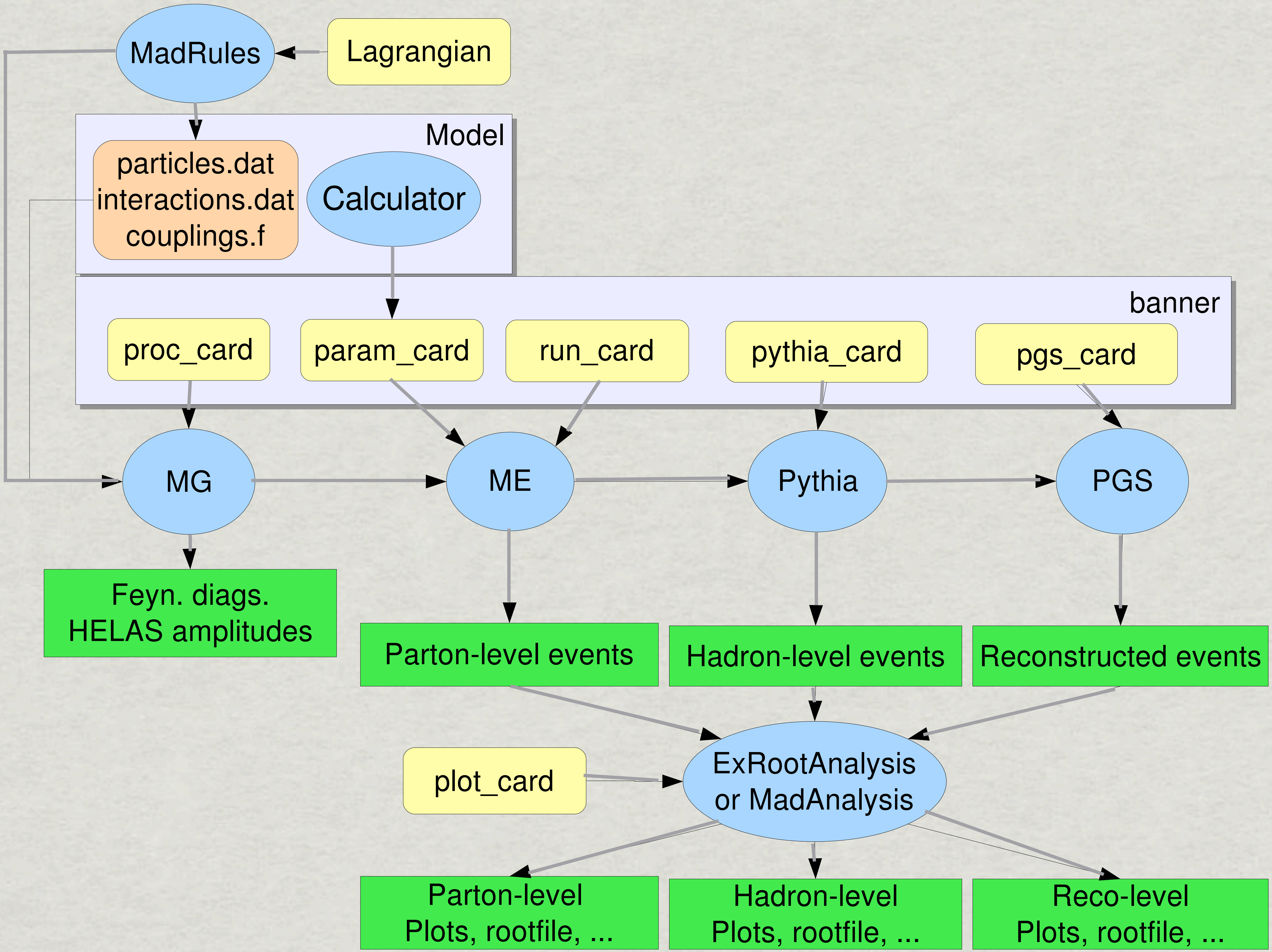
# MadEvent

- Integrates the MEs from MadGraph to generate events. Uses adaptive methods like VEGAS to adjust a “grid” to numerically flatten peaks
  - But : time expensive, peaks must lie on integration variables
- Solutions exist : Multi-Channel Integration (Amegic, Nextcalibur, Whizard), **Single Diagram Enhanced MCI** (MadEvent) :

$$|\sum_i A_i|^2 = \sum_i \left( \frac{|A_i|^2}{\sum_j |A_j|^2} |\sum_k A_k|^2 \right)$$

  - One peaked function per diagram
  - Parallel in nature

# MadGraph/MadEvent Flow



# New web generation

- The new web generation:
  - User inputs model/parameters/cuts.
  - Code runs in parallel on one of our farms (UCL, UIUC, Roma)
  - Returns cross section, plots, parton-level events.
  - Returns also Pythia and PGS events if needed
- Advantages:
  - Reduces overhead to getting results
  - Events can easily be shared/temporarily stored

# MG/ME v4 features

- Helicity amplitudes, based on HELAS
- Parallel phase space integration (up to 10 external particles)
- Les Houches Accord standards for model parameters (LHA) and for the parton-level event files (LHEF)
- CKKW and kt-MLM matching methods
- Interfaces for Pythia, Sherpa (and Herwig)
- Analysis platforms: ExRootAnalysis and MadAnalysis
- "Decay chains" syntax for diagram generation

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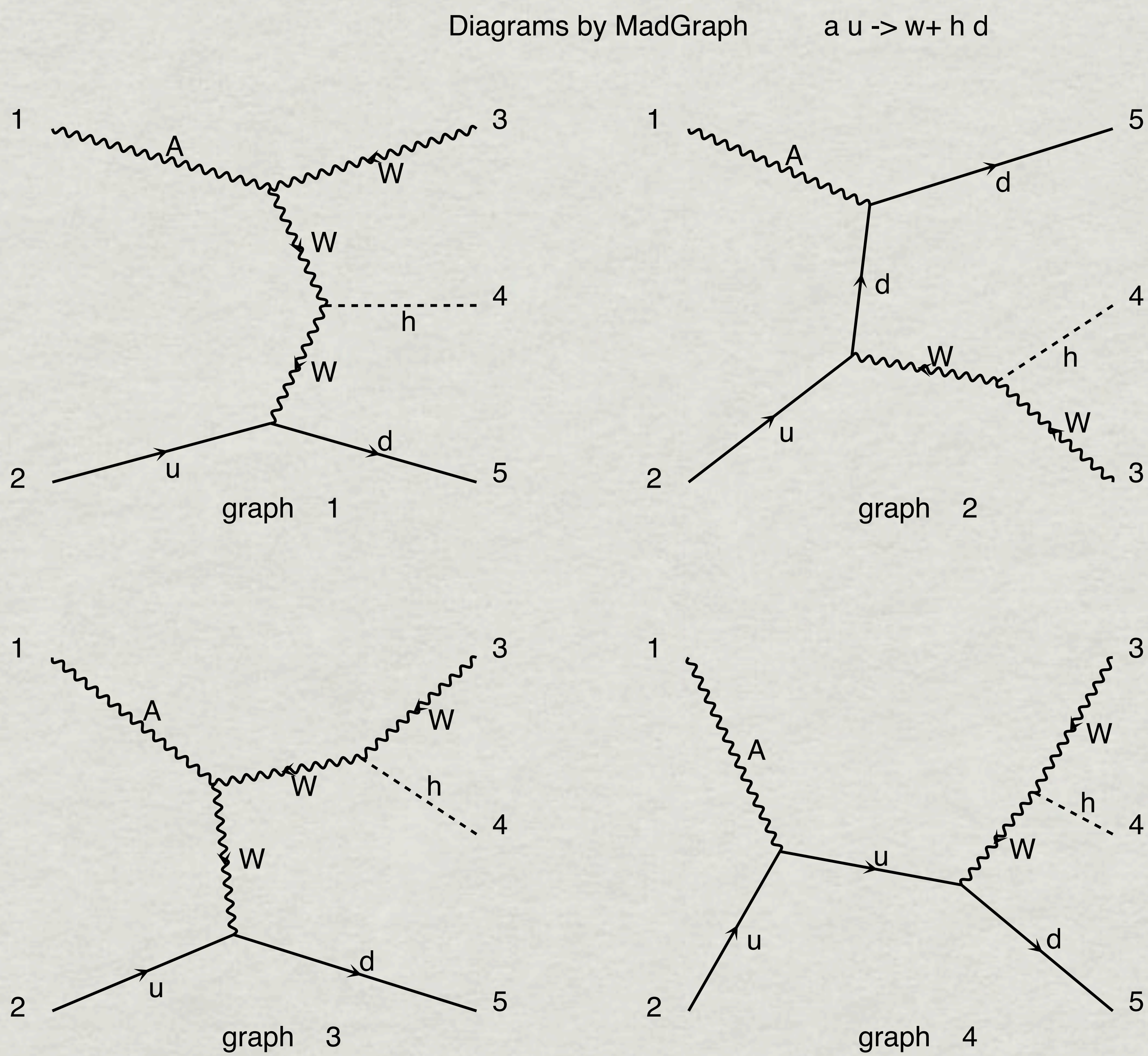
# Basic principle...

If MG/ME can do the job for ee, ep and pp collisions ...

... it can do it as well for collisions involving photon(s)

# Matrix elements for photon physics

- MadGraph can generate diagrams for any hard scattering process with γγ, γe and γp as initial states
- At this stage, no assumption is made on photon exact origin
- E.g. Associated WH production at the LHC



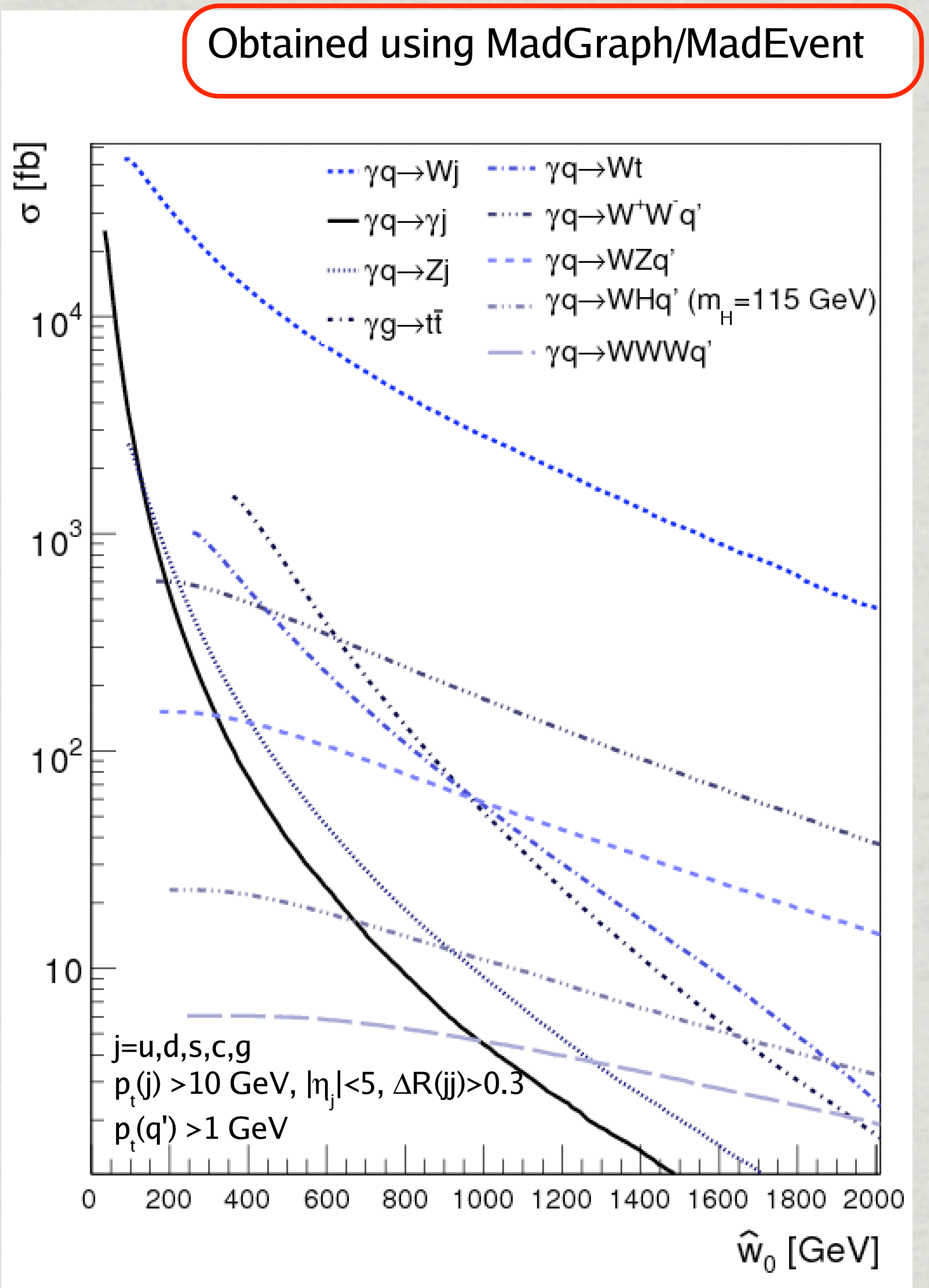
# Events production for photon physics

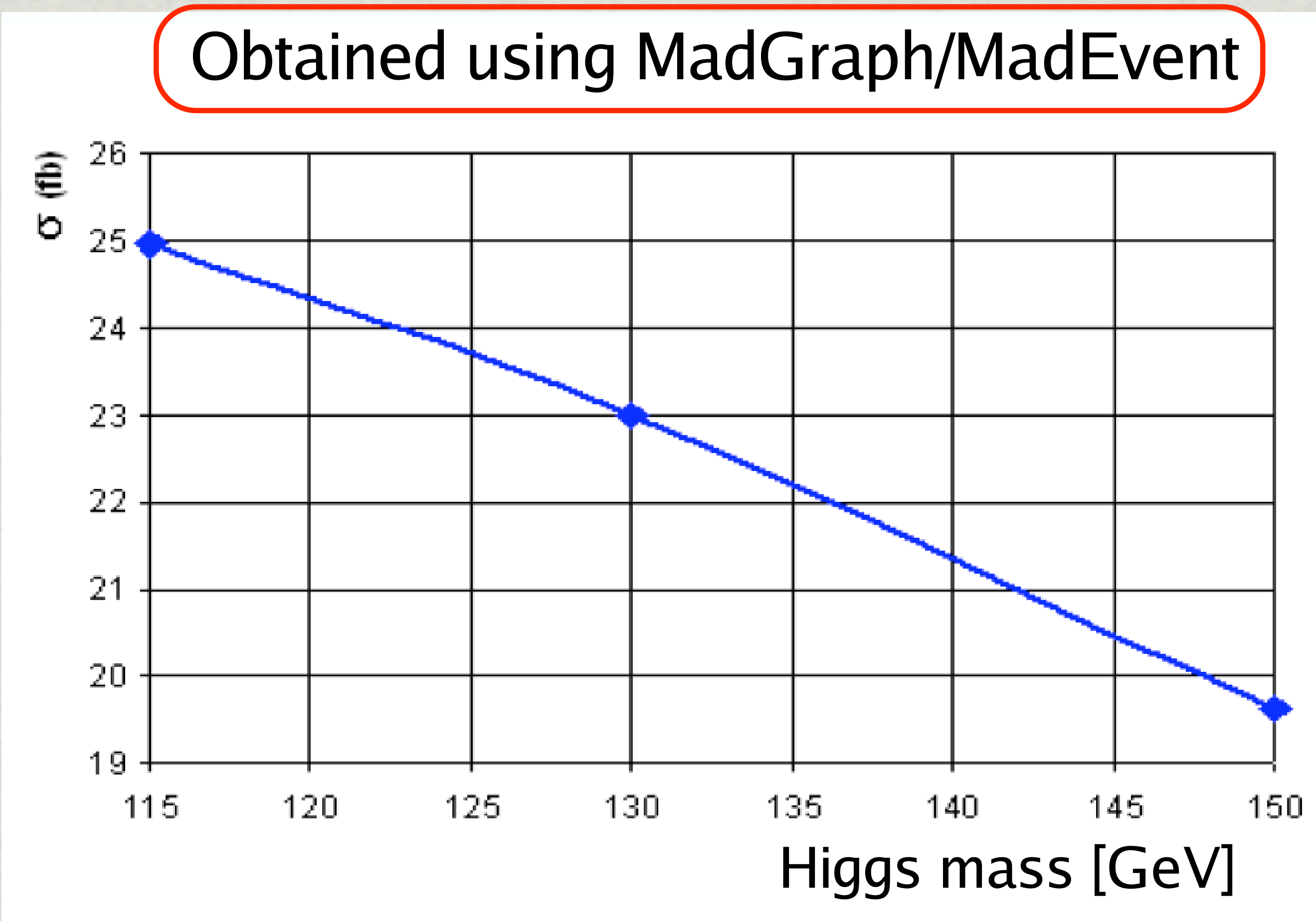
- Both electron and proton (no breaking) beams have been implemented as photon sources in MadEvent (status 2 and 3 for the photon beam) by members of the UCL-CP3 photon group (Thanks!).
- Electron: Weizsaecker-Williams EPA formula (very basic)

$$f_\gamma(z) = \frac{\alpha}{2\pi} \log \frac{s}{m_e^2} \left[ \frac{1 + (1-z)^2}{z} \right]$$

- Proton: more model dependent since the proton is not an elementary particle (V.M.Budnev et al., Phys.Rep. 15C (1975) 181)
- No polarized γ beams yet, but trivial to implement (already there for electrons)

# Real-life applications




S. OVYN, SEE SEVERINE'S PRESENTATION

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# New models

- MG/ME deals with different physical models as directories containing:
  - particles.dat : particle list with name, PDG codes, properties, ...
  - interactions.dat : list of all possible 3- and 4-vertices
  - couplings.f : analytic expressions for Feynman rule couplings
- MG/ME comes with several predefined models: MSSM, 2HDM, HEFT, BSM top, ...

# New models (2)

- Calculators: generic name for tools generating param_card.dat files (text files with all model parameters compliant with the Les Houches Accord format). Exist for MSSM, 2HDM, ...
- USRMOD: script allowing users to implement their own models by modifying the SM default
- Limitation: computing Feynman rules by hand is a hard task...

# FeynRules

- New package to compute Feynman rules from Lagrangian
- Theorist friendly Mathematica package
- Completely generic, zeroth level output is TeX!
- Interfaces for MG/ME, but also for FeynArts, Sherpa and CalcHEP
- Standard Model and simple models implemented and tested, MSSM on its way

# FeynRules (example)

**SM SCALAR AND EXTRA SINGLET(S)**

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[arXiv:0707.0359]

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$$L = -\frac{1}{2}(D_\mu \Phi)^\dagger (D_\mu \Phi) \;\; - \frac{\lambda_0}{8}(\Phi^\dagger \Phi - f_0^2)^2$$
$$- \frac{1}{2}(\partial_\mu H)^2 \;\; - \frac{\lambda_1}{8}(2 f_1 H - \Phi^\dagger \Phi)^2$$

FROM CLAUDE DUHR'S PRESENTATION AT MC4BSM08

# FeynRules (example)

```
Φ = {0, h + f0}

LHill = -1 / 2 del[H, mu] ^2 -
  l1 / 8 (2 f1 H - HC[Φ].Φ) ^2
```

$$-\frac{1}{2}\,\partial_{\mathrm{mu}}(H)^2 - \frac{1}{8}\,\mathrm{l1}\left(2\,\mathrm{f1}\,H - \Phi^{\dagger}.\Phi\right)^2$$

$$L = -\frac{1}{2}(D_\mu\Phi)^\dagger(D_\mu\Phi)$$

$$-\frac{\lambda_0}{8}(\Phi^\dagger\Phi - f_0^2)^2$$

$$-\frac{1}{2}(\partial_\mu H)^2$$

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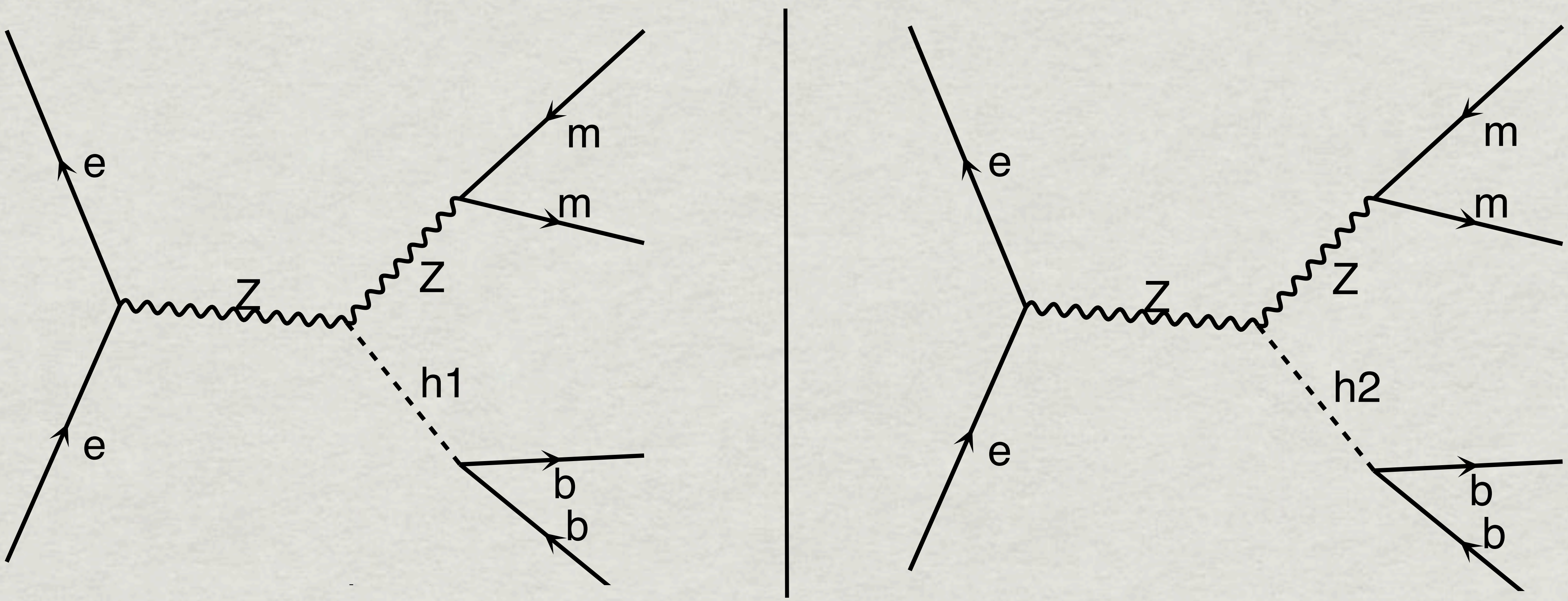
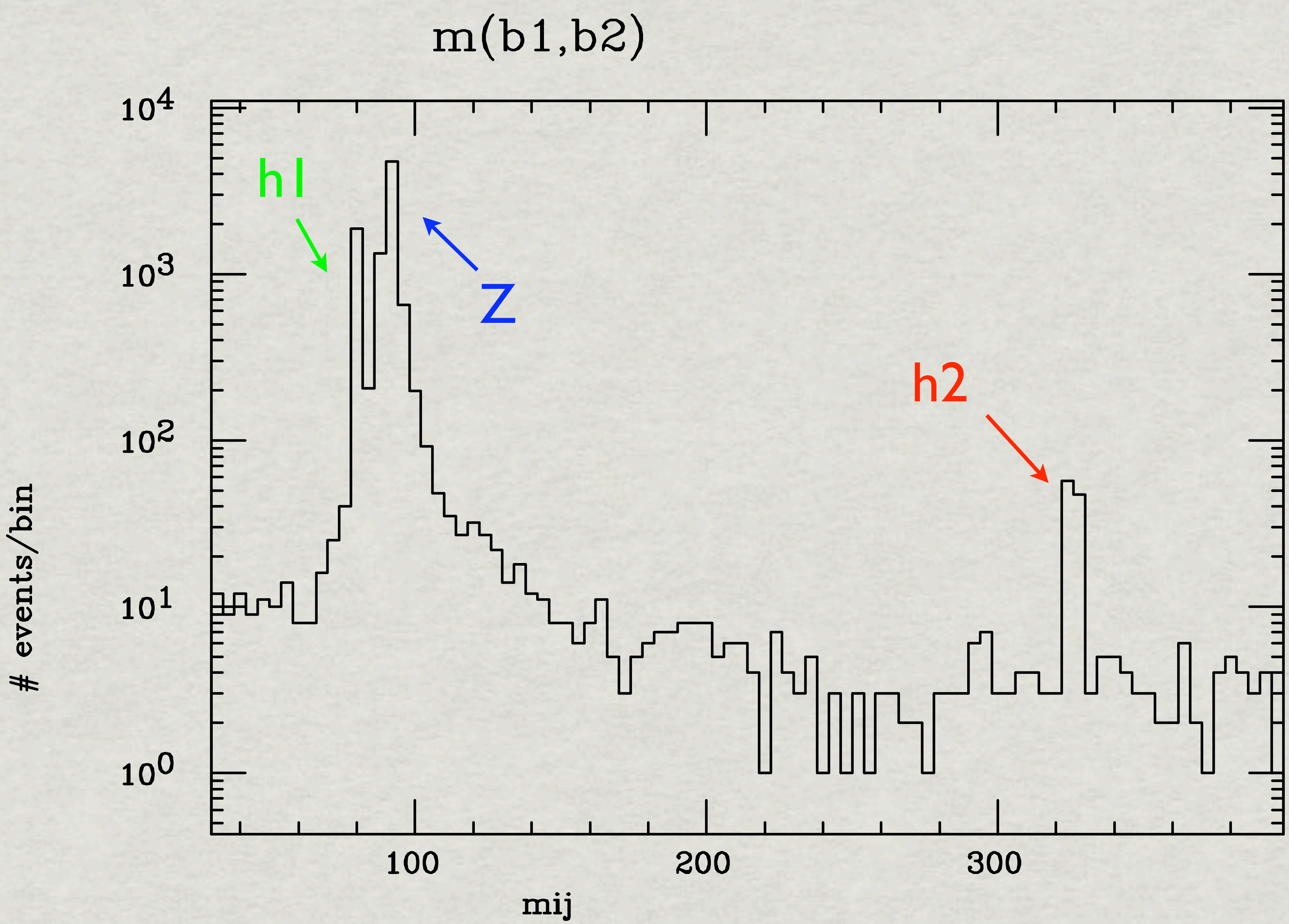
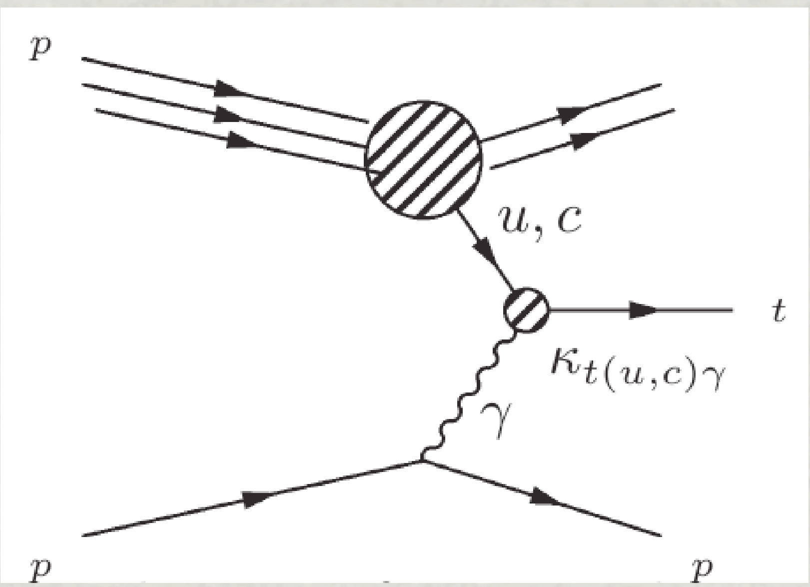


# FeynRules (example)



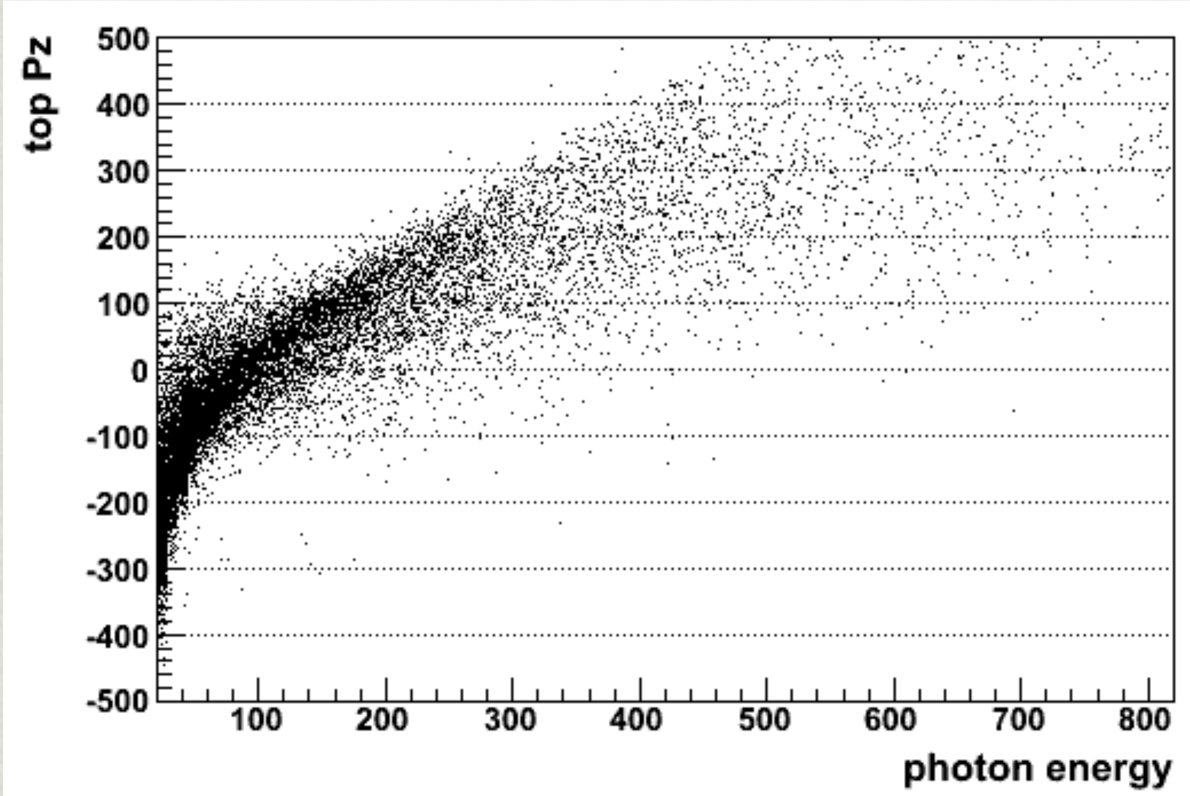
# BSM with photons

- Example: effect of an anomalous γtu,c coupling for single top production in γp interactions at the LHC




$$iee_t\bar{t}\frac{\sigma_{\mu\nu}q^{\nu}}{\Lambda}k_{tu\gamma}uA^{\mu}$$

MG/ME
USRMOD




J. DE FAVEREAU, SEE JEROME'S TALK

# Conclusion

- MadGraph/MadEvent v4 is a multi-purpose, user-friendly event generation package based on exact matrix element calculations. It has been designed for both signal and complex background studies.
- It can deal with initial state photons, either as real beams or coming from e and p, using EPA
- Various BSM models are now available, and new ones have never been so easy to implement

# Thanks for your attention!