

# Re-Weighting in MG5\_aMC

Olivier Mattelaer  
IPPP/Durham

## Reweightings are everywhere

- scale and pdf uncertainties (available both for LO and NLO computation)
- re-introduce top mass effect for Higgs processes
  - ➔ Higgs production [1110.1728]
  - ➔ Higgs pair mechanism [1401.7340]
  - ➔ ZH associated production [1503.01656]
- parameter scan (for coupling/lorentz)

Lagrangian

matrix-element

parton events

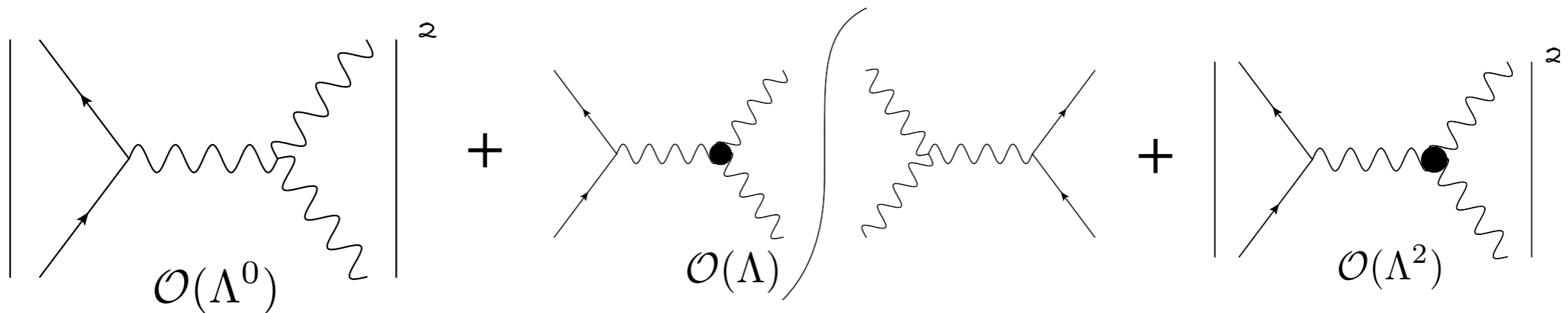
Showered events

hadronized events

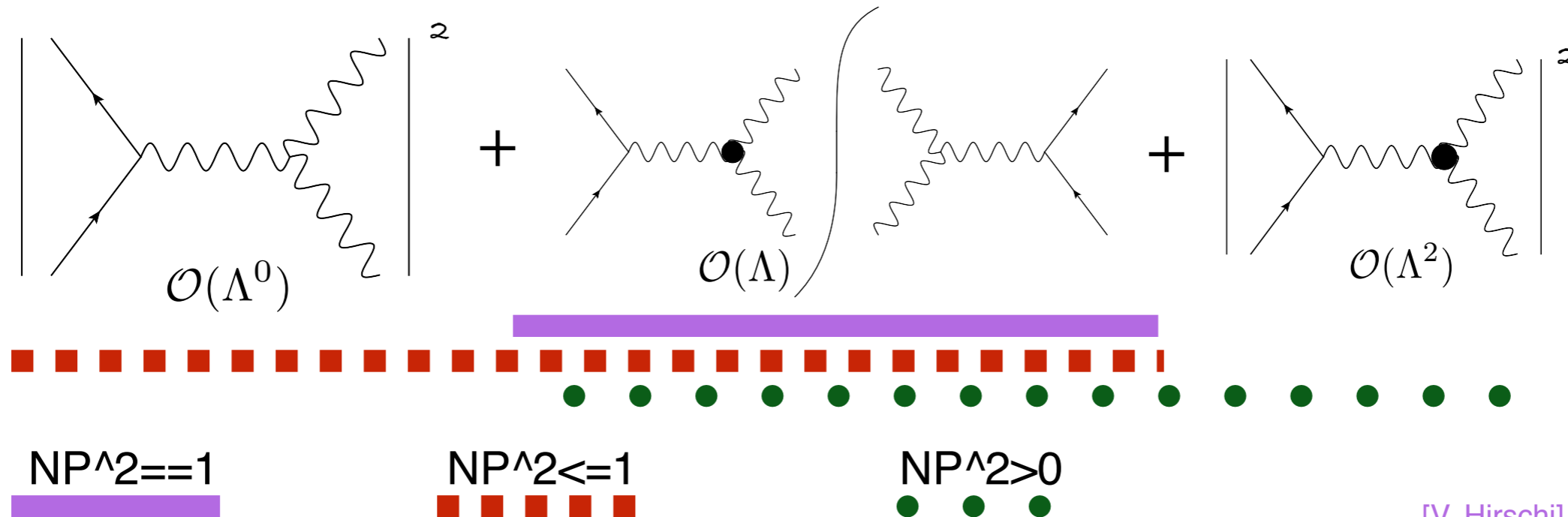
Detector events

**FULL SIMULATION**  
**SLOWEST PART**

- Critical when interference are relevant



## Interference alone



[V. Hirschi]

## EFT Case

- The interference is the important part
- The **difference** between the full matrix-element and the SM plus interference is an estimation of one **theoretical uncertainty**
- We should report this error!

## Re-Weighting

- Reuse the sample (Only one Full Sim)
- Change the weight of the events

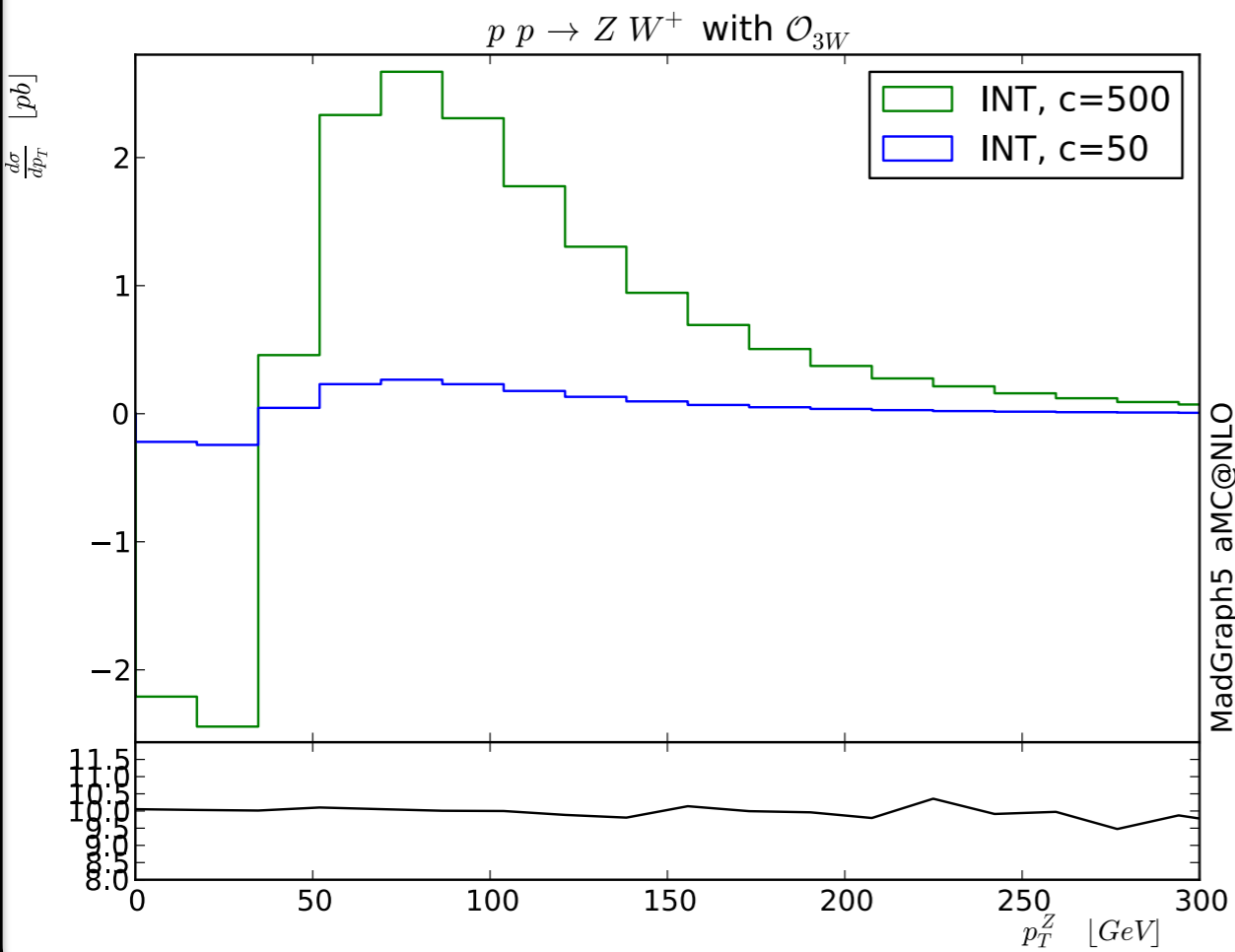
$$W_{new} = \frac{|M_{new}|^2}{|M_{old}|^2} * W_{old}$$

1405.0301  
1404.7129

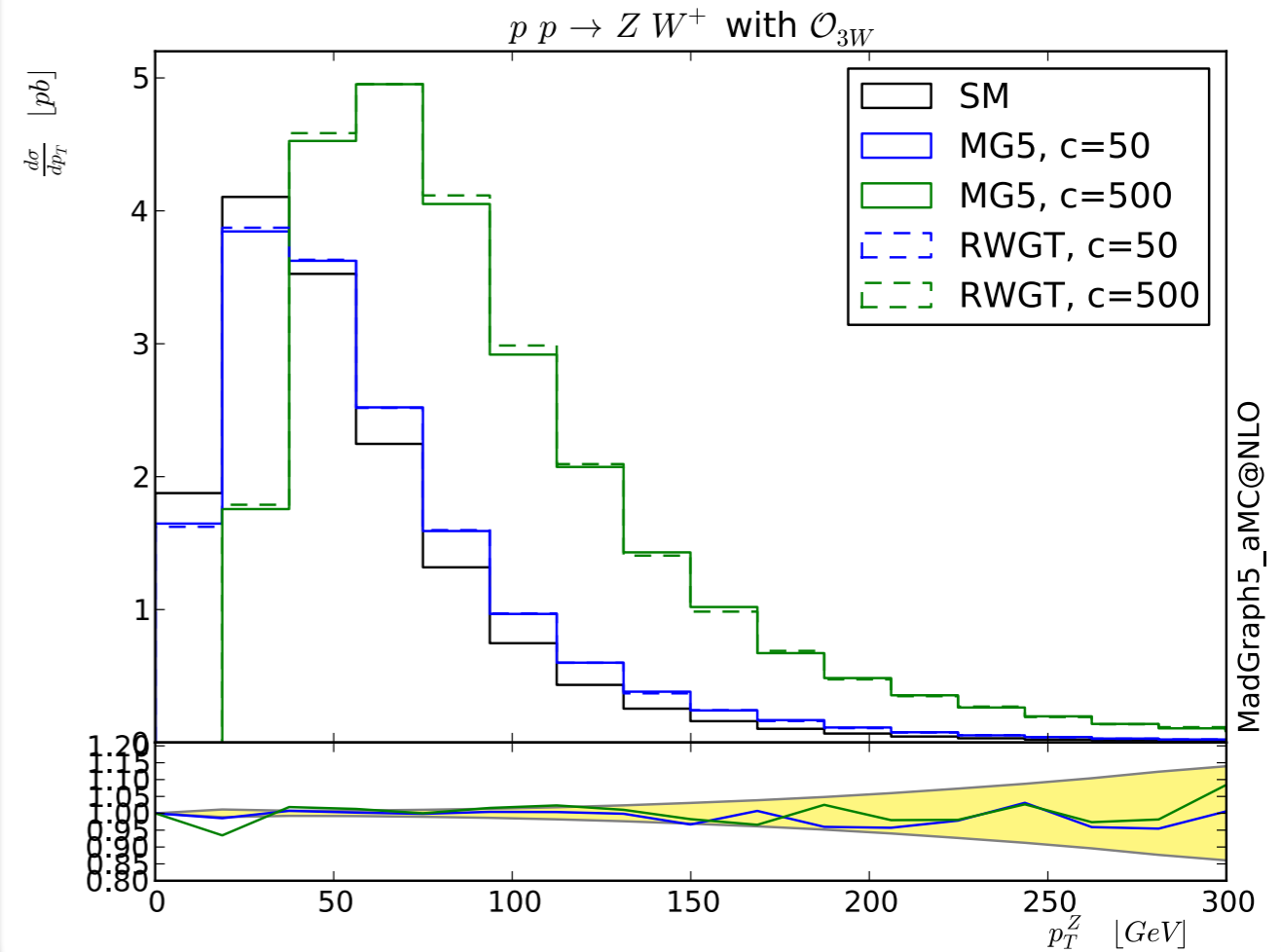
## EFT case

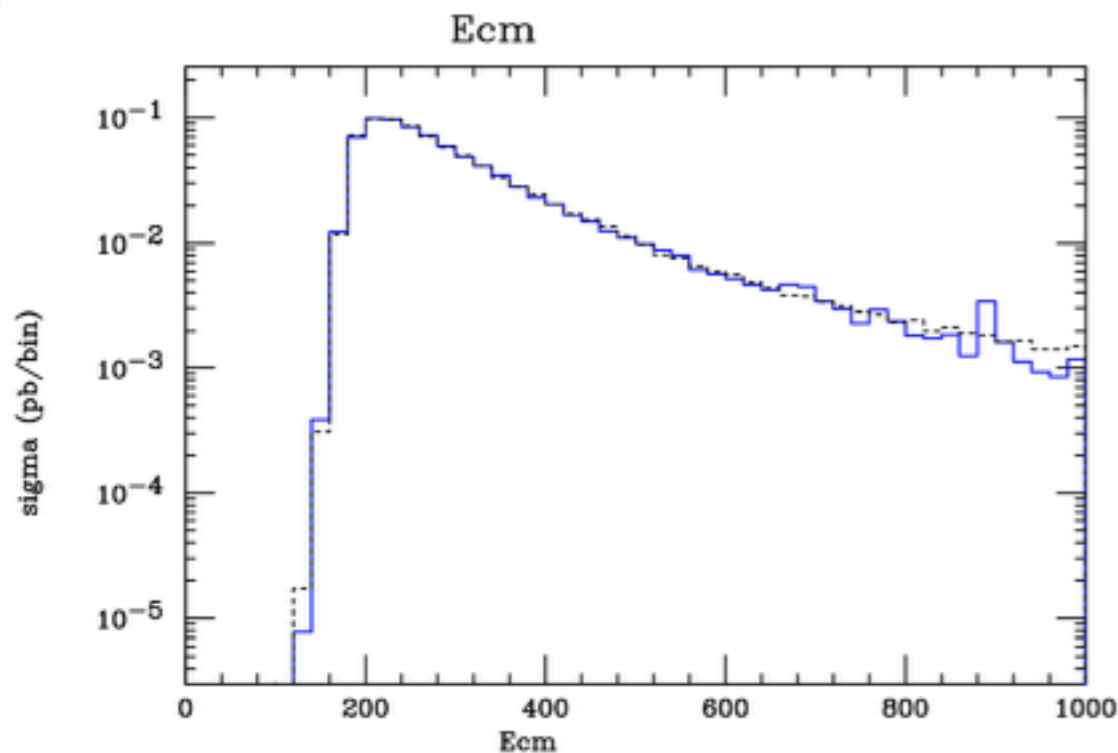
- The numerator should not be positive definite
  - can be SM + interference
  - so easy to estimate that theoretical uncertainty
  - NLO is tricky (See second part of the talk)

## Interference contribution



## Re-Weighting (by SM+Interference)





$$\Delta\sigma_{new} = \frac{\sigma_{new}}{\sigma_{old}} \Delta\sigma_{new} + \text{Var}_{wgt} \sigma_{old}$$

- statistical uncertainty can be enhanced by the re-weighting
- better to have  $wgt < 1$

- You need to have the same phase-space (more exactly a subset)
- Mass scan are possible only in special case
  - only for internal propagator
  - for small mass variation (order of the width)

## LHE Additional information

### Helicity

- Partial helicity distribution are not correct with the full re-weighting

- Solution 
$$W_{new} = \frac{|M_{new}^h|^2}{|M_{orig}^h|^2} W_{orig},$$

Now the default (@LO)

### Leading color information

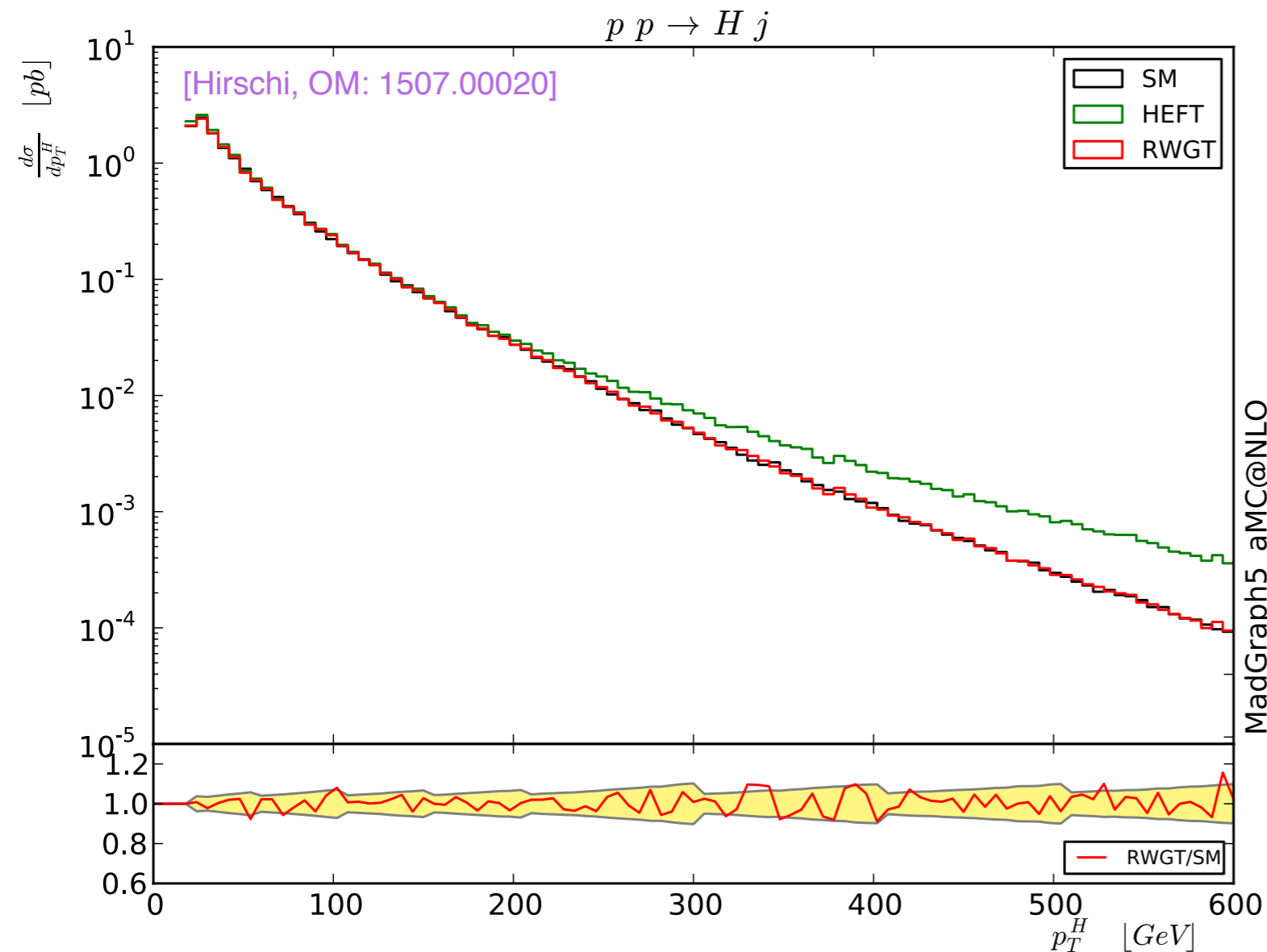
- modify the shower so not suitable.

### Intermediate particle

- modify the shower so not suitable.



1. Include the re-weighting by a given helicity (as default)
2. Allow to change model
  - ➔ “change model NAME”
3. Allow to change process
  - ➔ change process XXX [—add]
  - ➔ allow loop-induced re-weighting
4. easier syntax for scan in re-weighting
  - ➔ set mt scan:[100,200,300]



## proc\_card

```
import model heft
generate p p > h j
output
launch
```

## reweight\_card

```
change model loop_sm
change process g g > H g [sqrvirt=QCD]
change process g u > H u [sqrvirt=QCD] —add
change process g u~ > H u~ [sqrvirt=QCD] —add
change process g d~ > H d~ [sqrvirt=QCD] —add
change process g c > H c [sqrvirt=QCD] —add
change process g c~ > H c~ [sqrvirt=QCD] —add
change process g s > H s [sqrvirt=QCD] —add
change process g s~ > H s~ [sqrvirt=QCD] —add
launch
~/Cards/param_card_loop_sm.dat
```

## MC@NLO

$$\frac{d\sigma_{\text{NLOwPS}}}{dO} = \left[ d\Phi_m (B + \int_{\text{loop}} V + \int d\Phi_1 MC) \right] I_{\text{MC}}^{(m)}(O) \\ + \left[ d\Phi_{m+1} (R - MC) \right] I_{\text{MC}}^{(m+1)}(O)$$

## LHE

- “S-events” (which have  $m$  body kinematics)
- “H-events” (which have  $m+1$  body kinematics)

## Re-Weighting

- “S-events” need to be re-weight by the born/virtual + counter-term
- “H-events” need to be re-weight by the real + counter-term
- The counter-term might not have the same kinematic

## LO/Kamikaze Reweighting

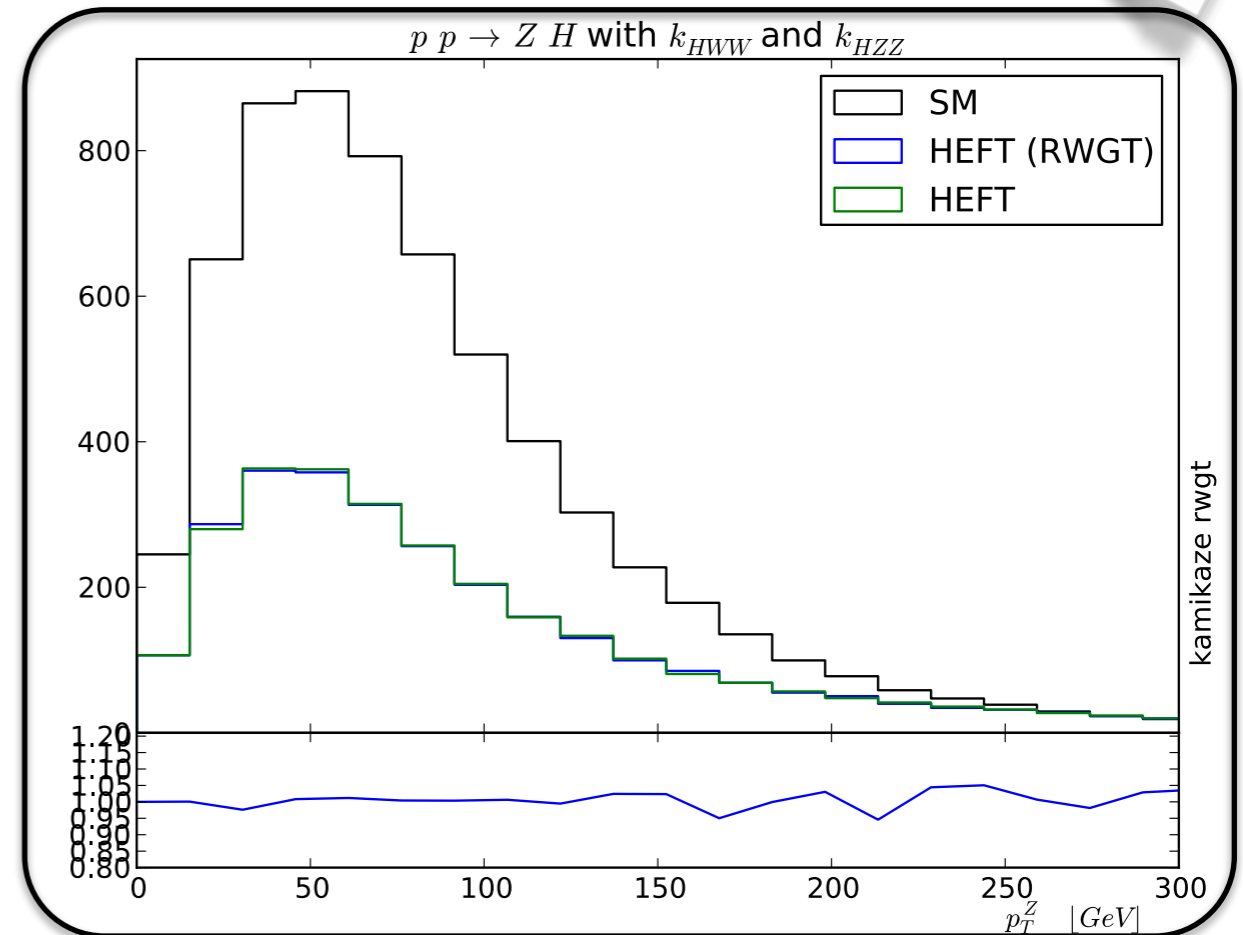
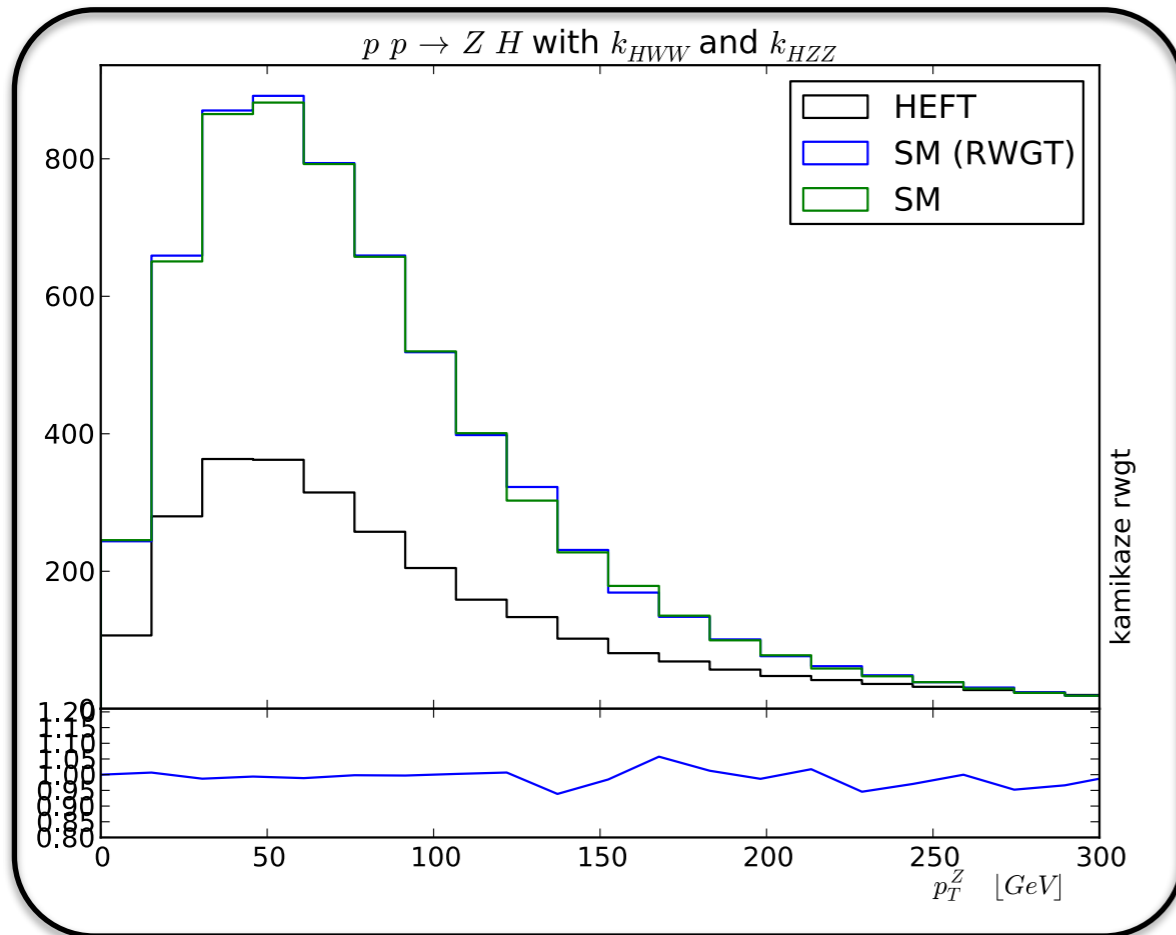
- Reweight the S event by the born
- Reweight the H event by the real
- No guarantee of NLO accurate
- available in re polo and MG5\_aMC

## NLO Reweighting

- Keep the kinematics of each counter event
- Reweight each piece accordingly (including the virtual reweighting)
- Recombine to give the weight
- not yet released in MG5\_aMC

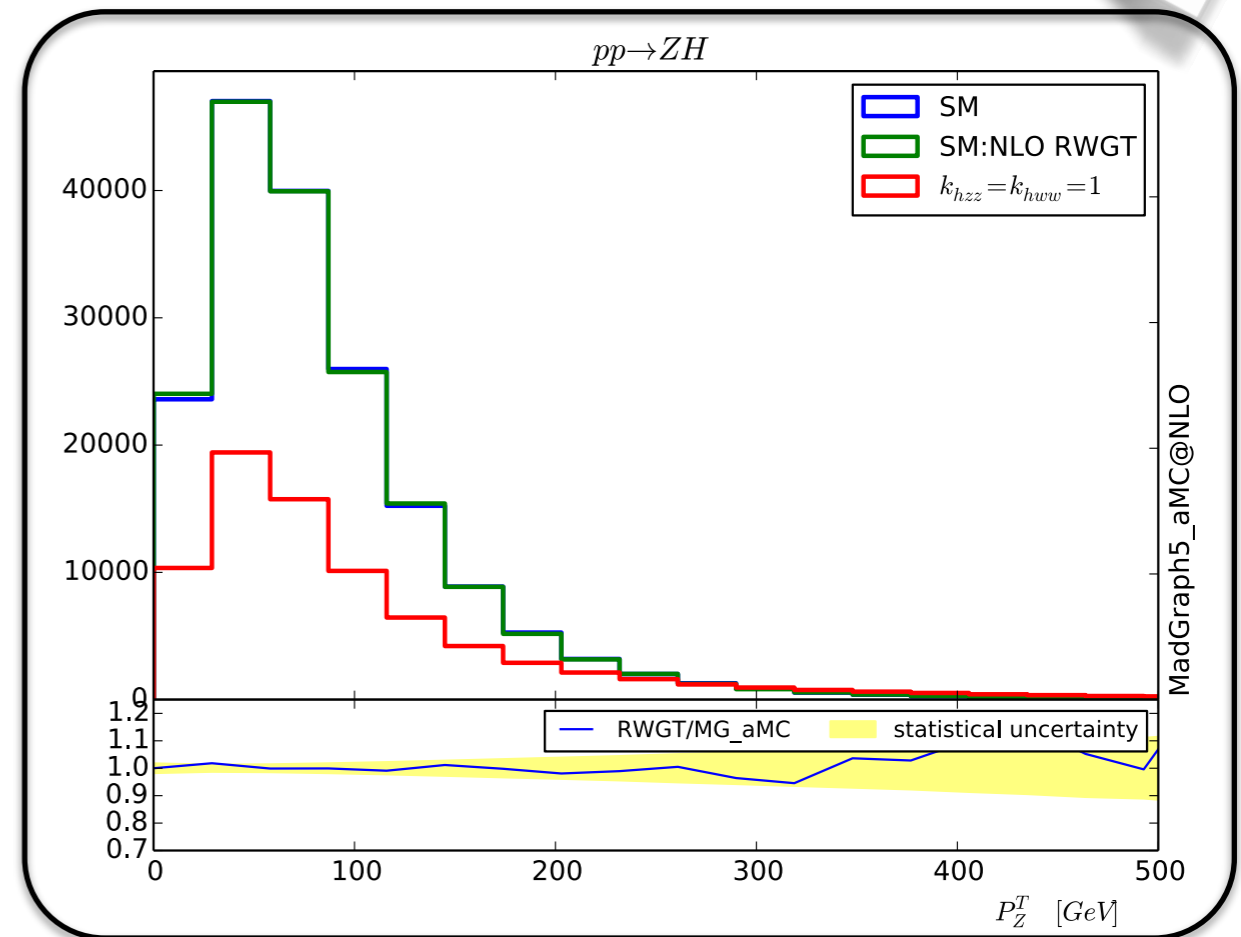
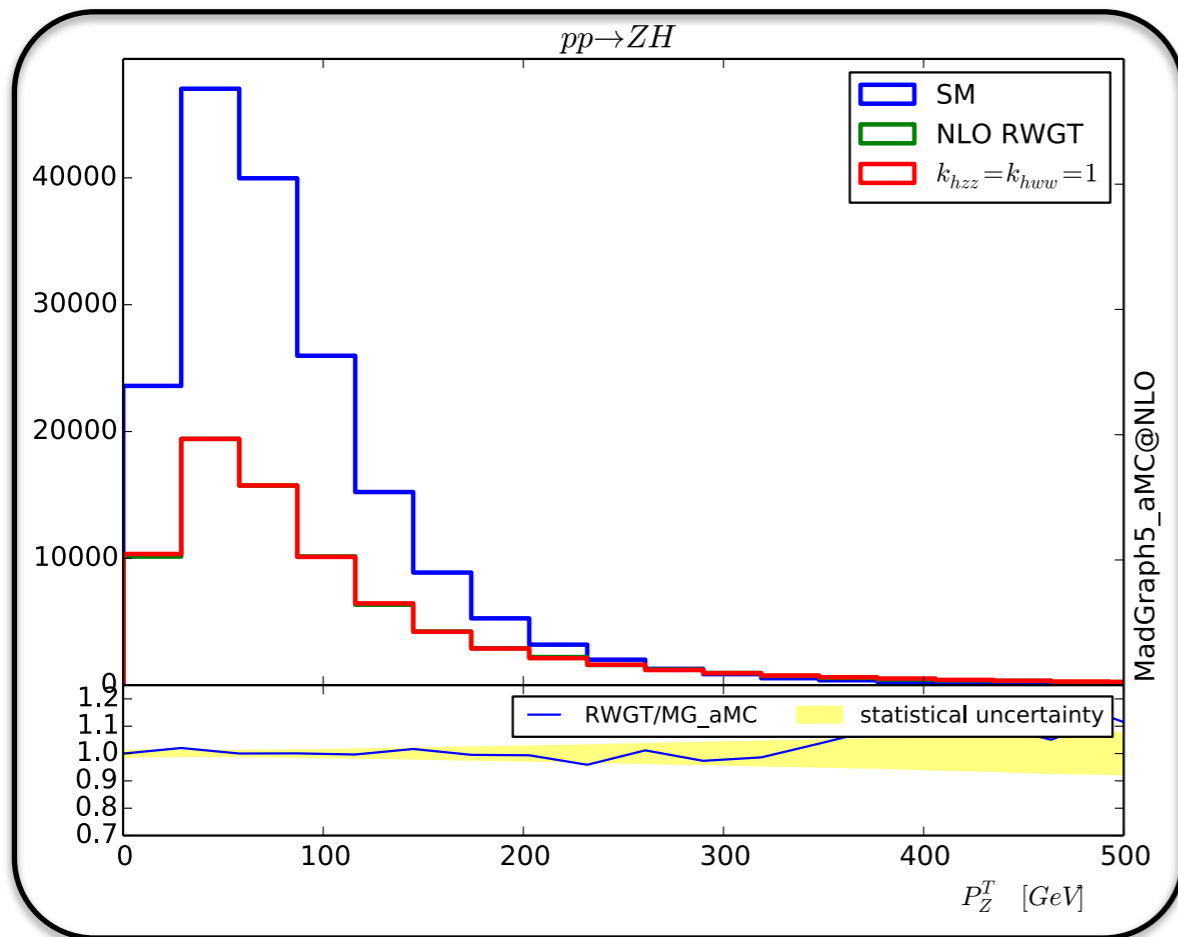
## MCFM method

## LO/Kamikaze re-weighting



- Works very well for EW EFT
  - Since the QCD/EW effect are factories
  - Same principle as for MadSpin

## Correct NLO re-weighting



- Works as well
- Ensure NLO accuracy
  - Usual comment on Reweighting error

## Naively

$$\Delta\sigma_{new} = \frac{\sigma_{new}}{\sigma_{old}} \Delta\sigma_{new} + \text{Var}_{wgt} \sigma_{old}$$

## Problem

- How to evaluate the variance?
  - ➔ Use the global weight
  - ➔ Make one variance for the each pieces?  
and multiply by the relative contribution
- Virt-tricks handling
  - ➔ MG5\_aMC uses sometimes an approximate to the loop
  - ➔ We correct that by a specific reweighting (B+V) but induces an additional error

- **Both works well** for EFT
- NLO ReWeighting is
  - Theoretical **NLO accurate**
  - Requires **larger file** (need the additional information)
  - **Much slower** to run. ~10 times slower than generating the dedicated sample
- LO/Kamikaze Reweighting is
  - **Not NLO** accurate (in general)
  - **Compatible** with **old production** (no need of extra information)
  - **Easier error estimate**

• I Recommend LO/Kamikaze for EFT



- allows to **reuse** the same shower / event reconstruction -> huge gain in efficiency
- are **no bullet proof**
  - ➔ additional error
  - ➔ need the same phase-space
  - ➔ some shower related information
- **available** both for LO and NLO generation
  - ➔ correct NLO reweighting works!
  - ➔ LO reweighting for NLO sample still recommended

without un-weighting

$$\begin{aligned}\sigma_{orig} &= \sum_{i=1}^N W_{orig}^i \\ &= \sum_{i=1}^N f_1(x_1^i) \cdot f_2(x_2^i) \cdot |M_{orig}^i|^2 \cdot d\Omega\end{aligned}$$

$$\begin{aligned}\sigma_{new} &= \sum_{i=1}^N W_{new}^i \\ &= \sum_{i=1}^N f_1(x_1^i) \cdot f_2(x_2^i) \cdot |M_{new}^i|^2 \cdot d\Omega \\ &= \sum_{i=1}^N W_{orig}^i \cdot \frac{|M_{new}^i|^2}{|M_{orig}^i|^2}\end{aligned}$$

## unweighted sample

$$\begin{aligned}
 \sigma_{orig} &= \sum_{i=1}^N W_{orig}^i, \\
 &= \max_i(W_{orig}^i) \sum_{i=1}^N \frac{W_{orig}^i}{\max_i(W_{orig}^i)}, \\
 &\approx \sum_{i=1}^N \max_i(W_{orig}^i) Acc_i
 \end{aligned}$$

$$\begin{aligned}
 \sigma_{new} &= \sum_{i=1}^N W_{new}^i, \\
 &= \max_i(W_{orig}^i) \sum_{i=1}^N \frac{W_{new}^i}{\max_i(W_{orig}^i)}, \\
 &= \max_i(W_{orig}^i) \sum_{i=1}^N \frac{W_{new}^i}{W_{orig}^i} \frac{W_{orig}^i}{\max_i(W_{orig}^i)}, \\
 &\approx \sum_{i=1}^N \max_i(W_{orig}^i) Acc_i \cdot \frac{|M_{new}|^2}{|M_{orig}|^2}
 \end{aligned}$$

$$\begin{aligned}\sigma_{orig}^h &= \sum_{i=1}^N W_{orig}^i P_{h,orig}^i \\ &= \sum_{i=1}^N W_{orig}^i \frac{|M_{orig}^h|^2}{\sum_{\tilde{h}} |M_{orig}^{\tilde{h}}|^2},\end{aligned}$$

$$\begin{aligned}\sigma_{new}^h &= \sum_{i=1}^N W_{new}^i P_{h,new}^i \\ &= \sum_{i=1}^N W_{new}^i \frac{|M_{new}^h|^2}{\sum_{\tilde{h}} |M_{new}^{\tilde{h}}|^2}, \\ &= \sum_{i=1}^N W_{orig}^i \frac{\sum_{\tilde{h}} |M_{new}^{\tilde{h}}|^2}{\sum_{h'} |M_{orig}^{h'}|^2} \frac{|M_{new}^h|^2}{\sum_{\tilde{h}} |M_{new}^{\tilde{h}}|^2}, \\ &= \sum_{i=1}^N W_{orig}^i \frac{1}{\sum_{h'} |M_{orig}^{h'}|^2} \frac{|M_{new}^h|^2}{1}, \\ &= \sum_{i=1}^N W_{orig}^i \frac{|M_{orig}^h|^2}{\sum_{h'} |M_{orig}^{h'}|^2} \frac{|M_{new}^h|^2}{|M_{orig}^h|^2}, \\ &= \sum_{i=1}^N W_{orig}^i P_{h,orig}^i \frac{|M_{new}^h|^2}{|M_{orig}^h|^2}.\end{aligned}$$