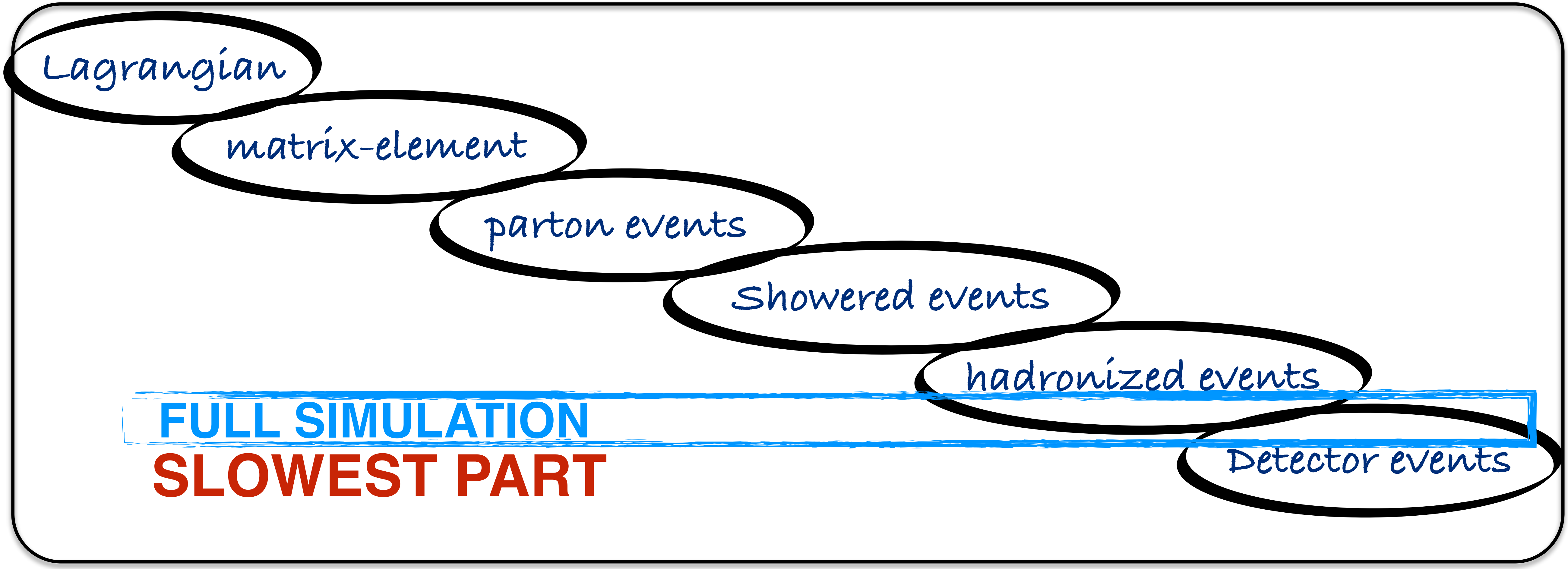
UCLouvain
Institut de recherche en mathématique et physique
Centre de Cosmologie, Physique des Particules et Phénoménologie
MCnet

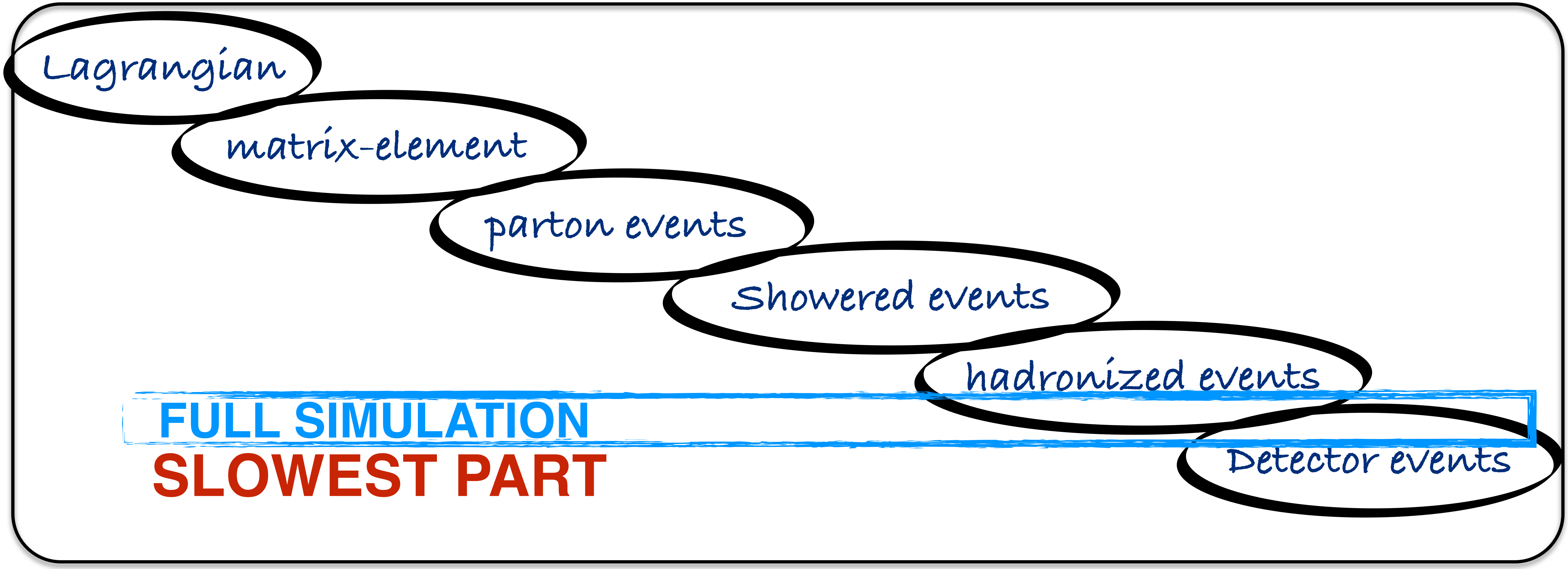
Reweighting of MC sample

Olivier Mattelaer

Motivation


Lagrangian
matrix-element
parton events
Showered events
hadronized events
Detector events
FULL SIMULATION
SLOWEST PART

Motivation



Re-Weighting

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

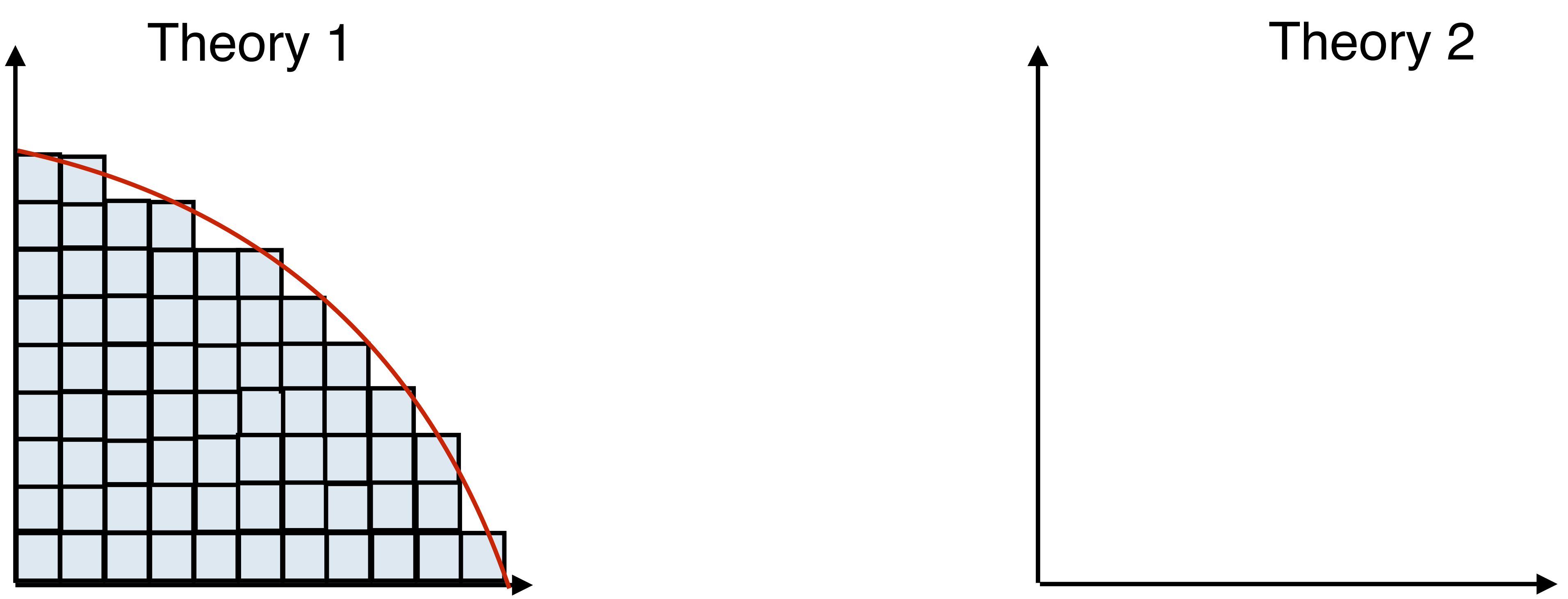
$$W_{new} = \frac{|M_{new}|^2}{|M_{old}|^2} * W_{old}$$

1405.0301
1404.7129

Scan

LHE Events

- Is nothing else than a (efficient) probing of the phase-space



- Fully differential method (not one dimension)

Scan

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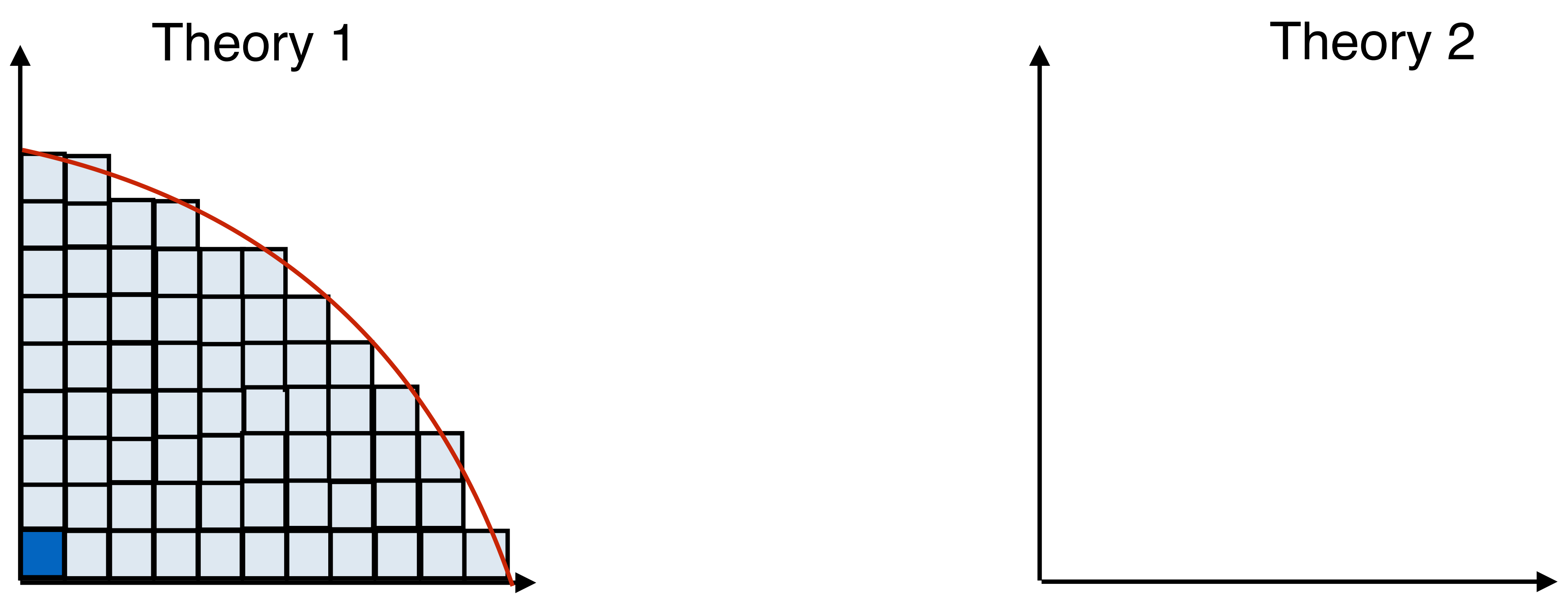

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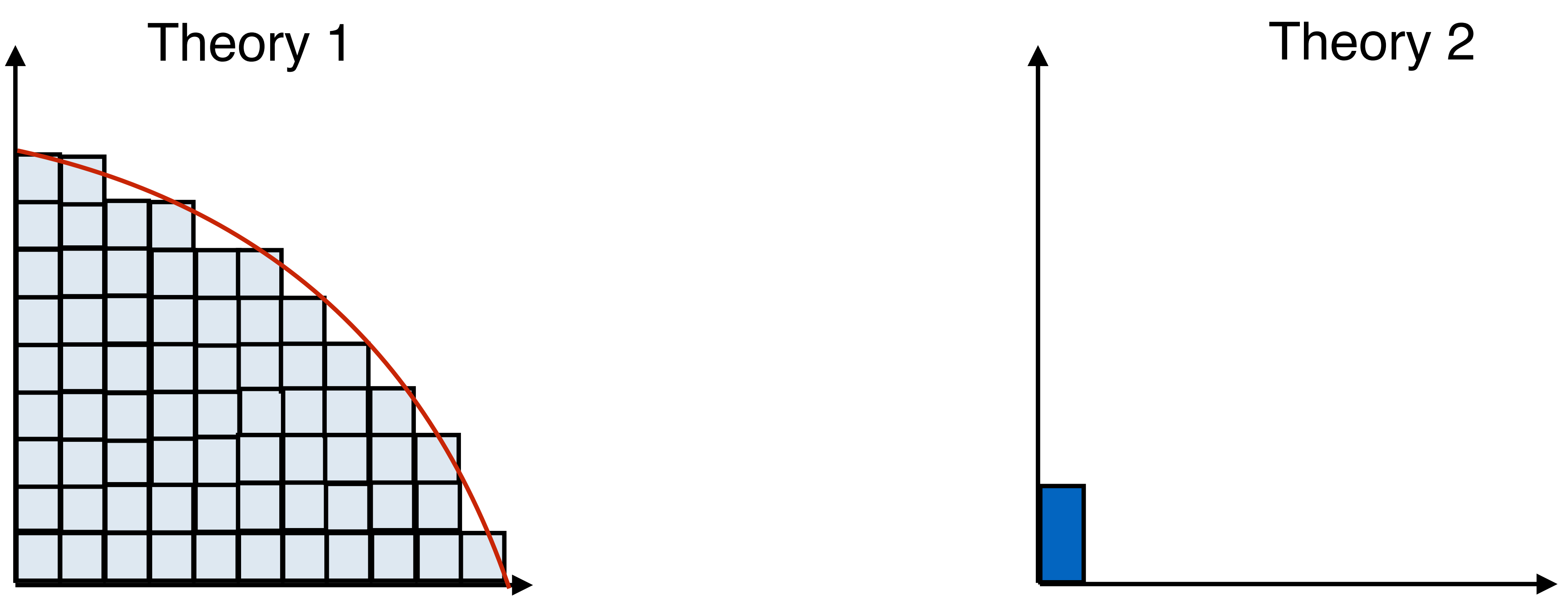

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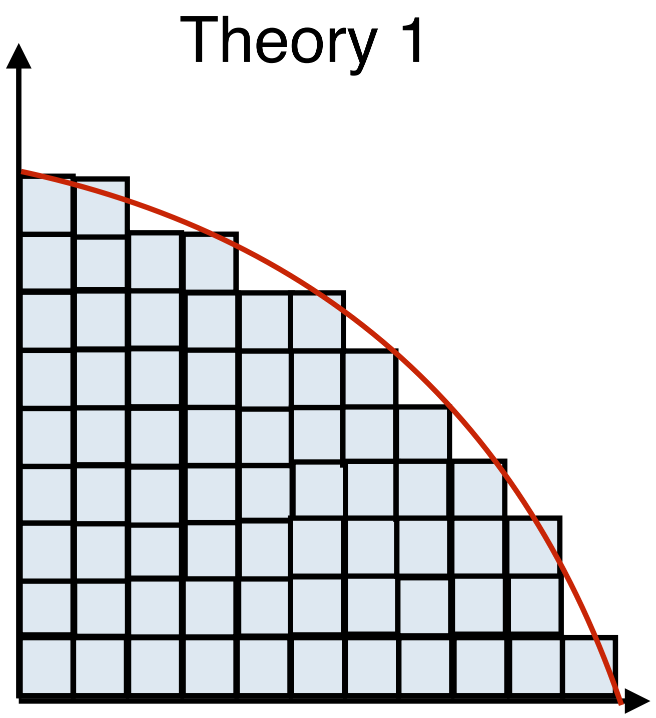
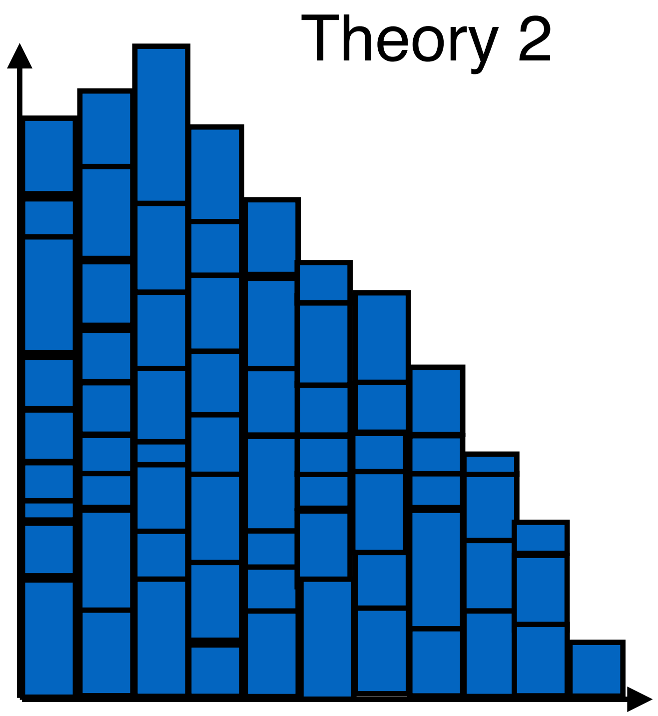




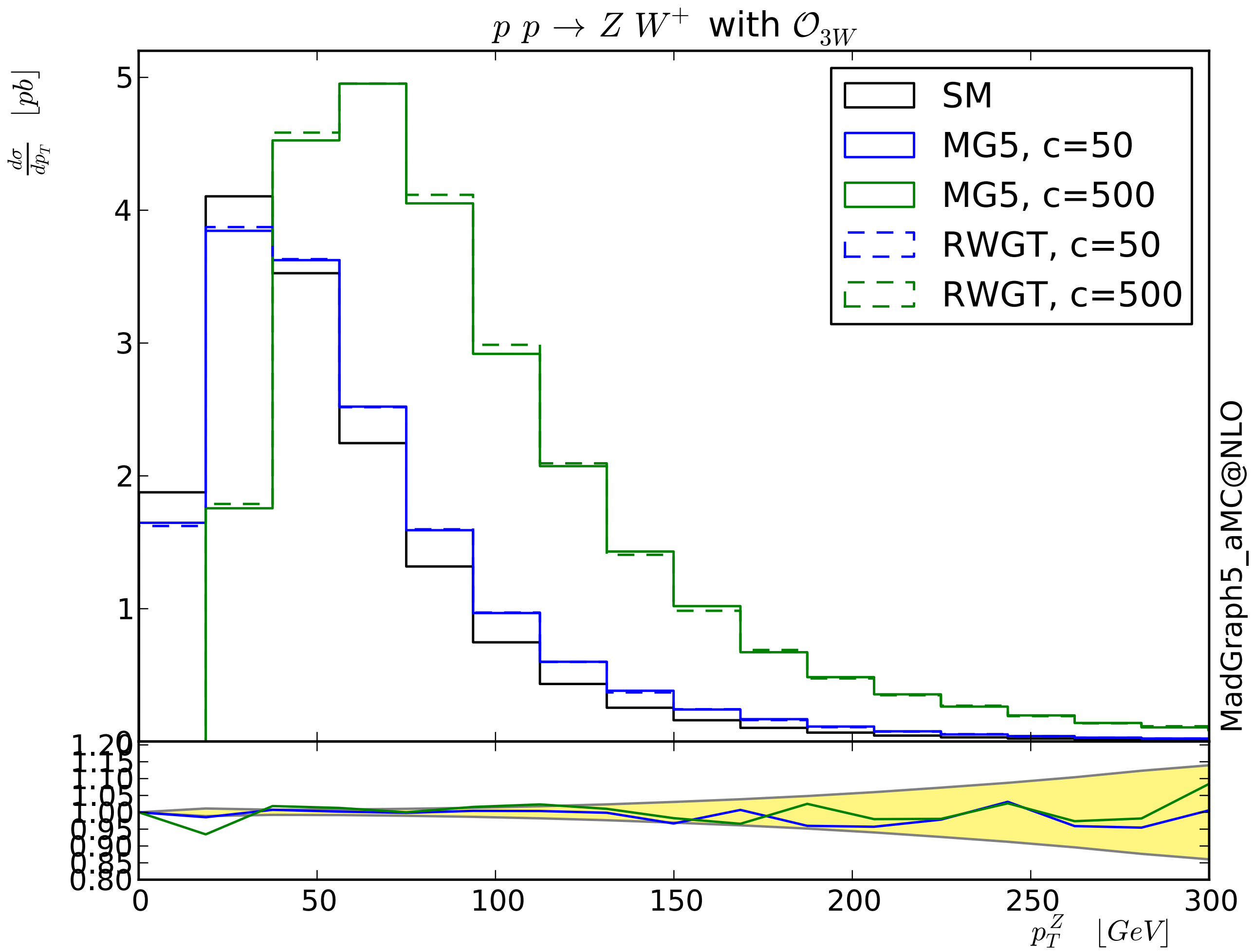
- Fully differential method (not one dimension)

Re-Weighting usage

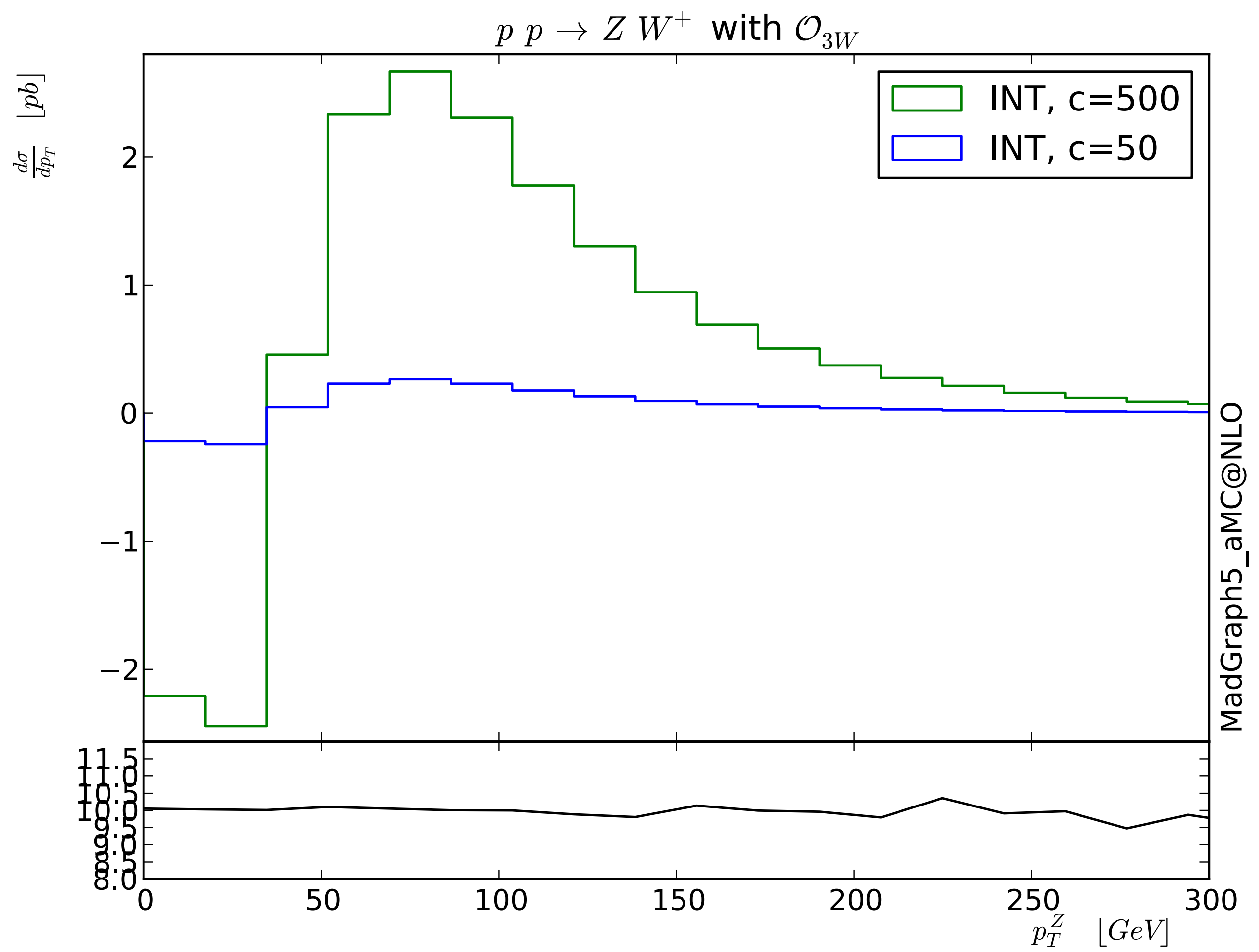
- scale and pdf uncertainties (available both for LO and NLO computation)
- re-introduce top mass effect for Higgs processes
- EFT scan
- Many other application

Examples EFT

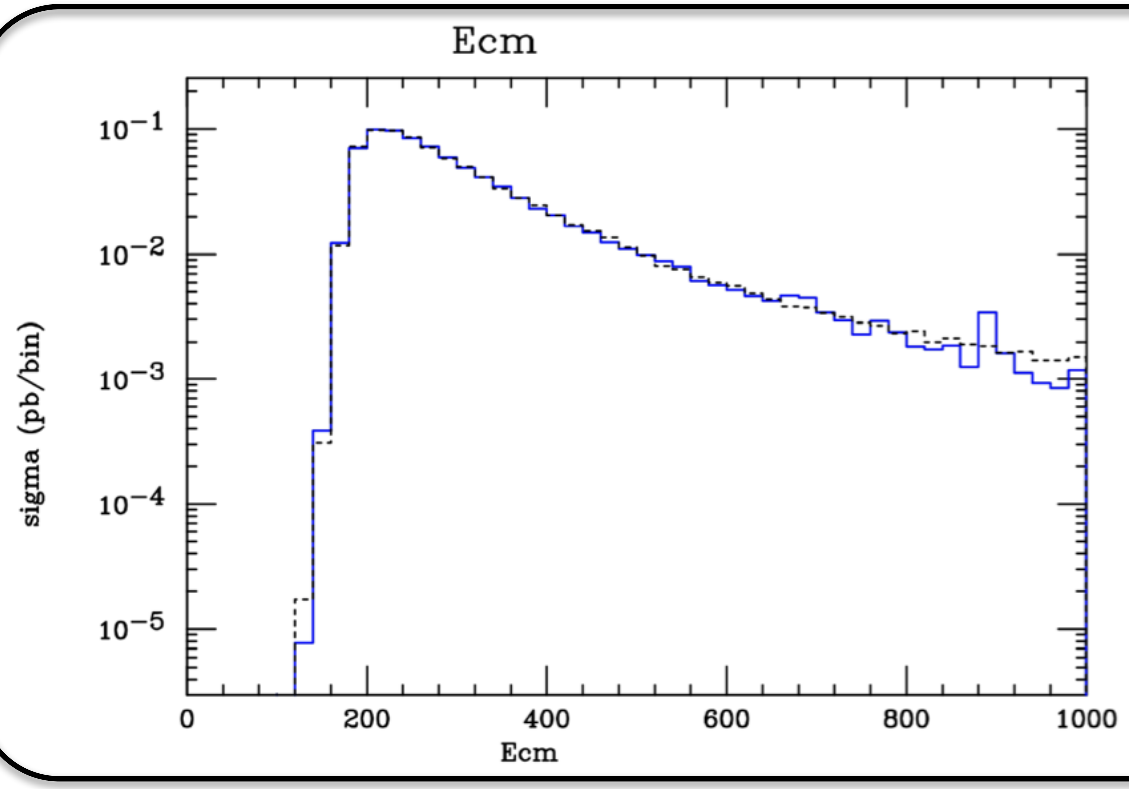
Re-Weighting (by SM+Interference)



Interference contribution

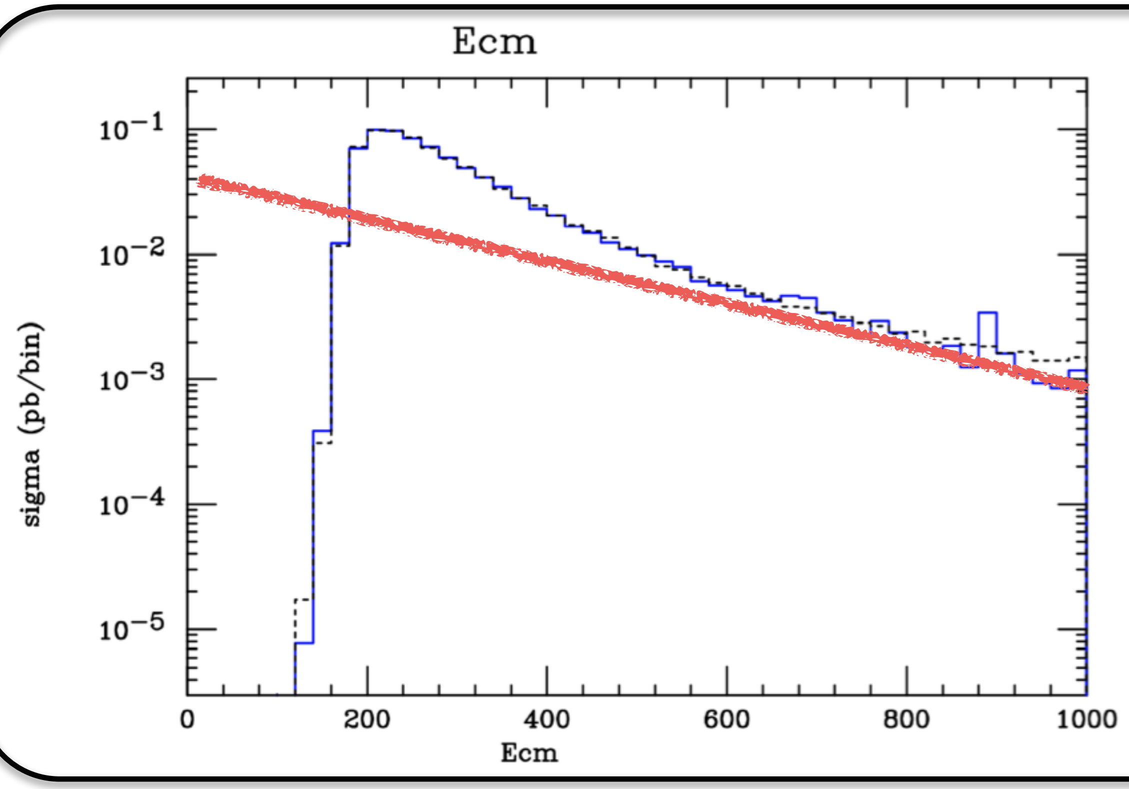


Re-Weighting Limitation



- statistical uncertainty are enhanced by the re-weighting
- better to have wgt<1and small variance

Re-Weighting Limitation



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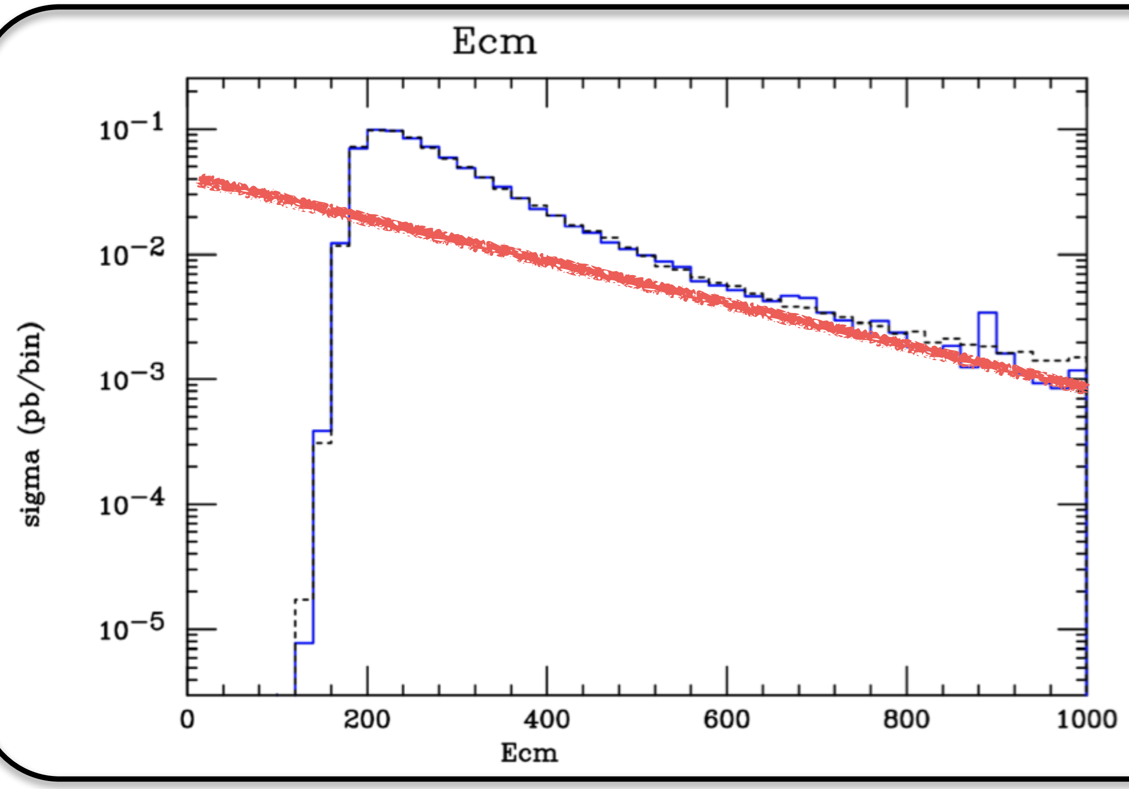
Re-Weighting Limitation



- statistical uncertainty are enhanced by the re-weighting
- better to have wgt<1and small variance

- You need to have the same phase-space (more exactly a subset)

Caution

LHE Additional information

Helicity

Leading color information

Intermediate particle

Caution

LHE Additional information

Helicity

- Partial helicity distribution are not correct with the full re-weighting
- Solution $$W_{new} = \frac{|M^h_{new}|^2}{|M^h_{orig}|^2} W_{orig},$$
- This is done by default !

Leading color information

Intermediate particle

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Leading color information

- modify the parton-shower so not suitable.

Intermediate particle

- modify the parton-shower so not suitable.

GPU

- Reweighting are massively repetitive task
- Ideal for GPU
  - ➡Zenny Wettersten
- We are in need of real experimental test case
  - ➡ Number of event in sample
  - ➡ Number of benchmark

NLO Re-Weighting

NLO method

- tracks the dependencies in the various matrix-elements (born, virtual, real)

$$d\sigma^\alpha = f_1(x_1,\mu_F) f_2(x_2,\mu_F) \Big[\mathcal{W}_0^\alpha + \mathcal{W}_F^\alpha \log\left(\mu_F/Q\right)^2 + \mathcal{W}_R^\alpha \log\left(\mu_R/Q\right)^2\Big]\, d\chi^\alpha,$$

$$\mathcal{W}_\beta^\alpha = \quad \mathcal{B} * \mathcal{C}_{\beta,B}^\alpha + \mathcal{B}_{CC} * \mathcal{C}_{\beta,B_{CC}}^\alpha + \mathcal{V} * \mathcal{C}_{\beta,V}^\alpha + \mathcal{R} * \mathcal{C}_{\beta,R}^\alpha$$

- re-weight each part according to the associated matrix-element

$$\mathcal{W}_{\beta,B}^{\alpha,new} = \frac{\mathcal{B}^{new}}{\mathcal{B}^{old}} * \mathcal{W}_{\beta,B}^{\alpha,old},$$
$$\mathcal{W}_{\beta,V}^{\alpha,new} = \frac{\mathcal{V}^{new}}{\mathcal{V}^{old}} * \mathcal{W}_{\beta,V}^{\alpha,old},$$
$$\mathcal{W}_{\beta,R}^{\alpha,new} = \frac{\mathcal{R}^{new}}{\mathcal{R}^{old}} * \mathcal{W}_{\beta,R}^{\alpha,old}.$$

NLO ISSUE

- MadGraph use some phase-space trick to avoid to compute the loop as much as possible (and replace it by the born)
  - ➡ Need smarter/complex re-weighting

$$\mathcal{W}^{\alpha,new}_{\beta,B} = \frac{\mathcal{B}^{new}}{\mathcal{B}^{old}} * \mathcal{W}^{\alpha,old}_{\beta,B},$$
$$\mathcal{W}^{\alpha,new}_{\beta,V} = \frac{\mathcal{V}^{new}}{\mathcal{V}^{old}} * \mathcal{W}^{\alpha,old}_{\beta,V},$$
$$\mathcal{W}^{\alpha,new}_{\beta,R} = \frac{\mathcal{R}^{new}}{\mathcal{R}^{old}} * \mathcal{W}^{\alpha,old}_{\beta,R}.$$

→

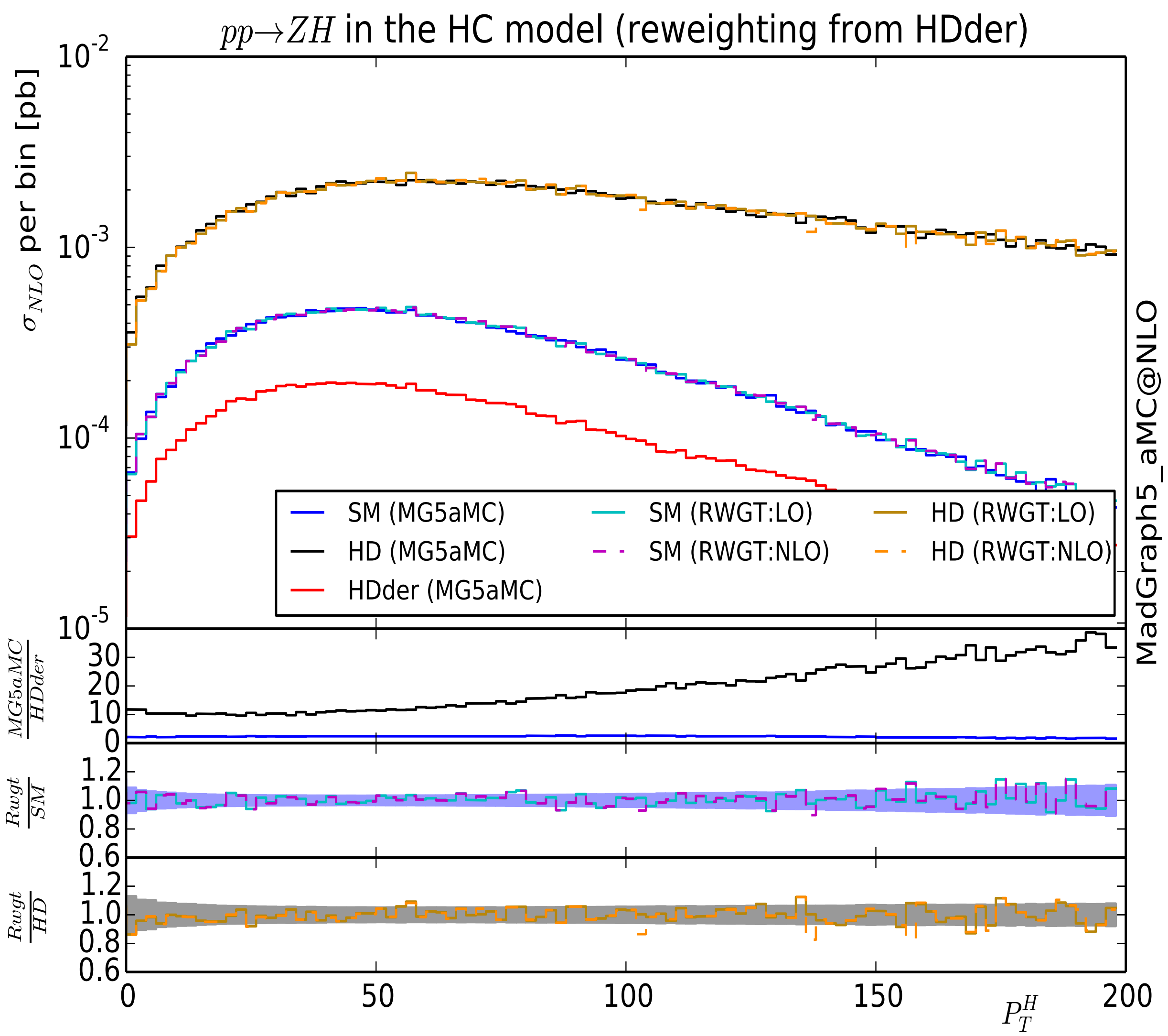
$$\mathcal{W}^{\alpha,new}_{\beta,BB} = \frac{(\mathcal{B}^{new} + \mathcal{V}^{new})}{(\mathcal{B}^{old} + \mathcal{V}^{old})} * \mathcal{W}^{\alpha,old}_{\beta,BB}$$
$$\mathcal{W}^{\alpha,new}_{\beta,BC} = \frac{\mathcal{B}^{new}}{\mathcal{B}^{old}} * \mathcal{W}^{\alpha,old}_{\beta,BC}$$
$$\mathcal{W}^{\alpha,new}_{\beta,V} = \frac{(\mathcal{B}^{new} + \mathcal{V}^{new})}{(\mathcal{B}^{old} + \mathcal{V}^{old})} * \mathcal{W}^{\alpha,old}_{\beta,V}$$
$$\mathcal{W}^{\alpha,new}_{\beta,R} = \frac{\mathcal{R}^{new}}{\mathcal{R}^{old}} * \mathcal{W}_{\beta,R},^{\alpha,old}$$

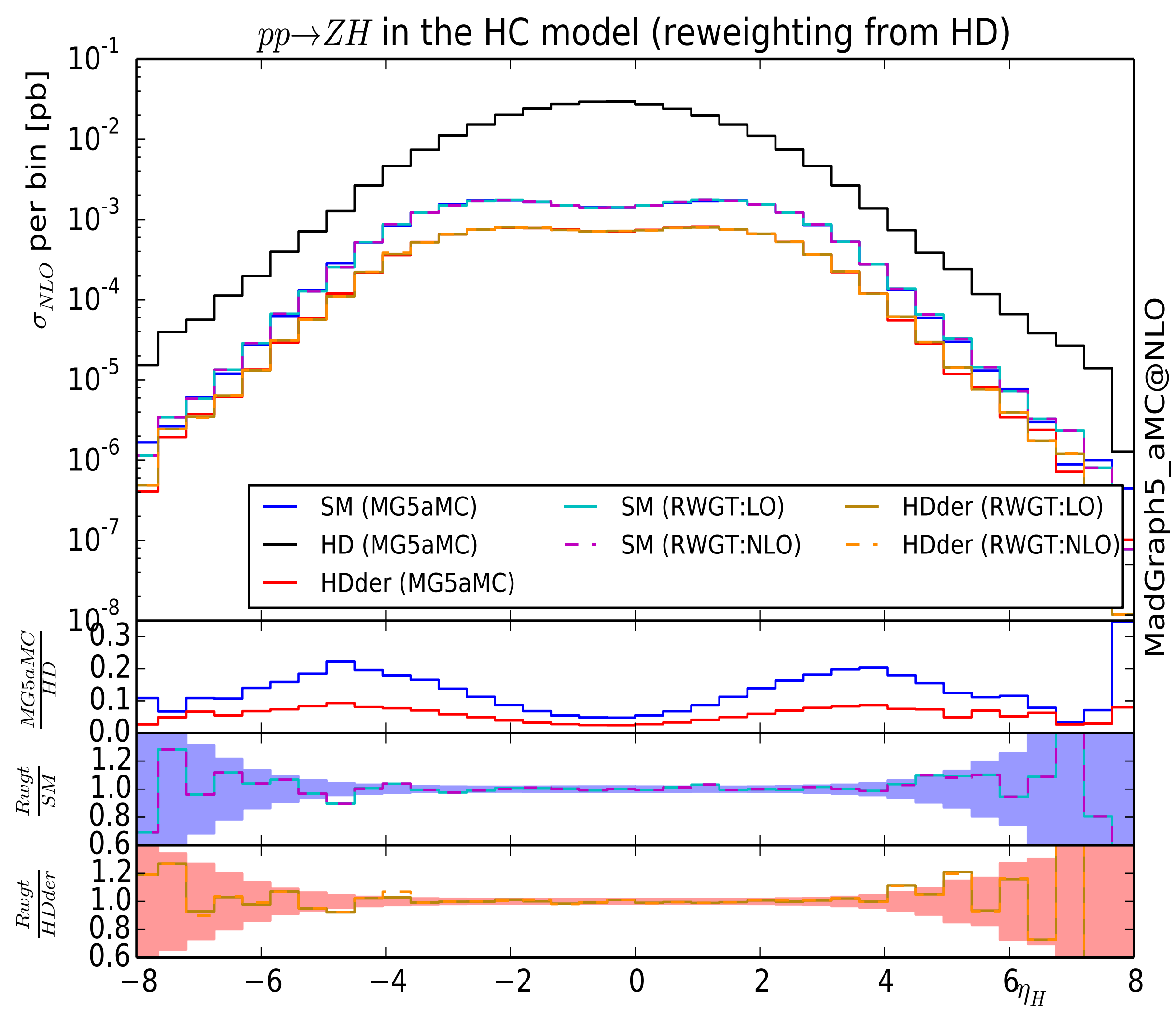
NLO Re-Weighting

EFT Example

$$\mathcal{L}_{HD} = -\frac{1}{4}\frac{1}{\Lambda}\kappa_{HWW} Z_{\mu\nu} Z^{\mu\nu} H$$

$$\mathcal{L}_{HDder} = -\frac{1}{\Lambda}\kappa_{H\partial Z} Z_{\nu}\partial_{\mu} Z^{\mu\nu} H + \left(-\frac{1}{\Lambda}\kappa_{H\partial W} W^{+}_{\nu}\partial_{\mu} W^{-\mu\nu} H + h.c.\right),$$





Conclusion

- Re-using previous generation/computation is always a smart move.
- This methods is fully exact but not bullet proof
  - Need to check overlap of phase-space/helicity
  - not (really) suitable for mass scanning
  - helicity (need to be careful)
  - leading color information
  - intermediate particle
- NLO is ready
  - Same limitation
  - Issue with numerical precision

Why it works

without un-weighting

$$\sigma_{orig} = \sum_{i=1}^{N} W^i_{orig},$$
$$= \sum_{i=1}^{N} f_1(x^i_1) \cdot f_2(x^i_2) \cdot |M^i_{orig}|^2 \cdot d\Omega$$

$$\sigma_{new} = \sum_{i=1}^{N} W^i_{new}$$
$$= \sum_{i=1}^{N} f_1(x^i_1) \cdot f_2(x^i_2) \cdot |M^i_{new}|^2 \cdot d\Omega$$

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$$= \sum_{i=1}^{N} f_1(x^i_1) \cdot f_2(x^i_2) \cdot |M^i_{new}|^2 \cdot d\Omega$$
$$= \sum_{i=1}^{N} W^i_{orig} \cdot \frac{|M^i_{new}|^2}{|M^i_{orig}|^2}$$

unweighting case

unweighted sample

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

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

helicity case

$$\sigma_{orig} = \sum_{i=1}^{N} W^i_{orig} P^i_{h,orig},$$
$$= \sum_{i=1}^{N} W^i_{orig} \frac{|M^h_{orig}|^2}{\sum_{\tilde{h}} |M^{\tilde{h}}_{orig}|^2},$$

$$\sigma_{new} = \sum_{i=1}^{N} W^i_{new} P^i_{h,new},$$
$$= \sum_{i=1}^{N} W^i_{new} \frac{|M^h_{new}|^2}{\sum_{\tilde{h}} |M^{\tilde{h}}_{new}|^2},$$
$$= \sum_{i=1}^{N} W^i_{orig} \frac{\sum_{\tilde{h}} |M^{\tilde{h}}_{new}|^2}{\sum_{h'} |M^{h'}_{orig}|^2} \frac{|M^h_{new}|^2}{\sum_{\tilde{h}} |M^{\tilde{h}}_{new}|^2},$$
$$= \sum_{i=1}^{N} W^i_{orig} \frac{1}{\sum_{h'} |M^{h'}_{orig}|^2} \frac{|M^h_{new}|^2}{1},$$
$$= \sum_{i=1}^{N} W^i_{orig} \frac{|M^h_{orig}|^2}{\sum_{h'} |M^{h'}_{orig}|^2} \frac{|M^h_{new}|^2}{|M^h_{orig}|^2},$$
$$= \sum_{i=1}^{N} W^i_{orig} P^i_{h,orig} \frac{|M^h_{new}|^2}{|M^h_{orig}|^2}.$$