

Support for EFT at LO  
In MadGraph5\_aMC@NLO

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# Plan of the talk

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- Re-Weighting
- Polarisation
- Issue with EFT
  - Version 2.9.0 (January 2021)
- Future Development (under validation)
  - EFT Running
  - SMEFTNLO

# Reweighting@LO

## Re-Weighting

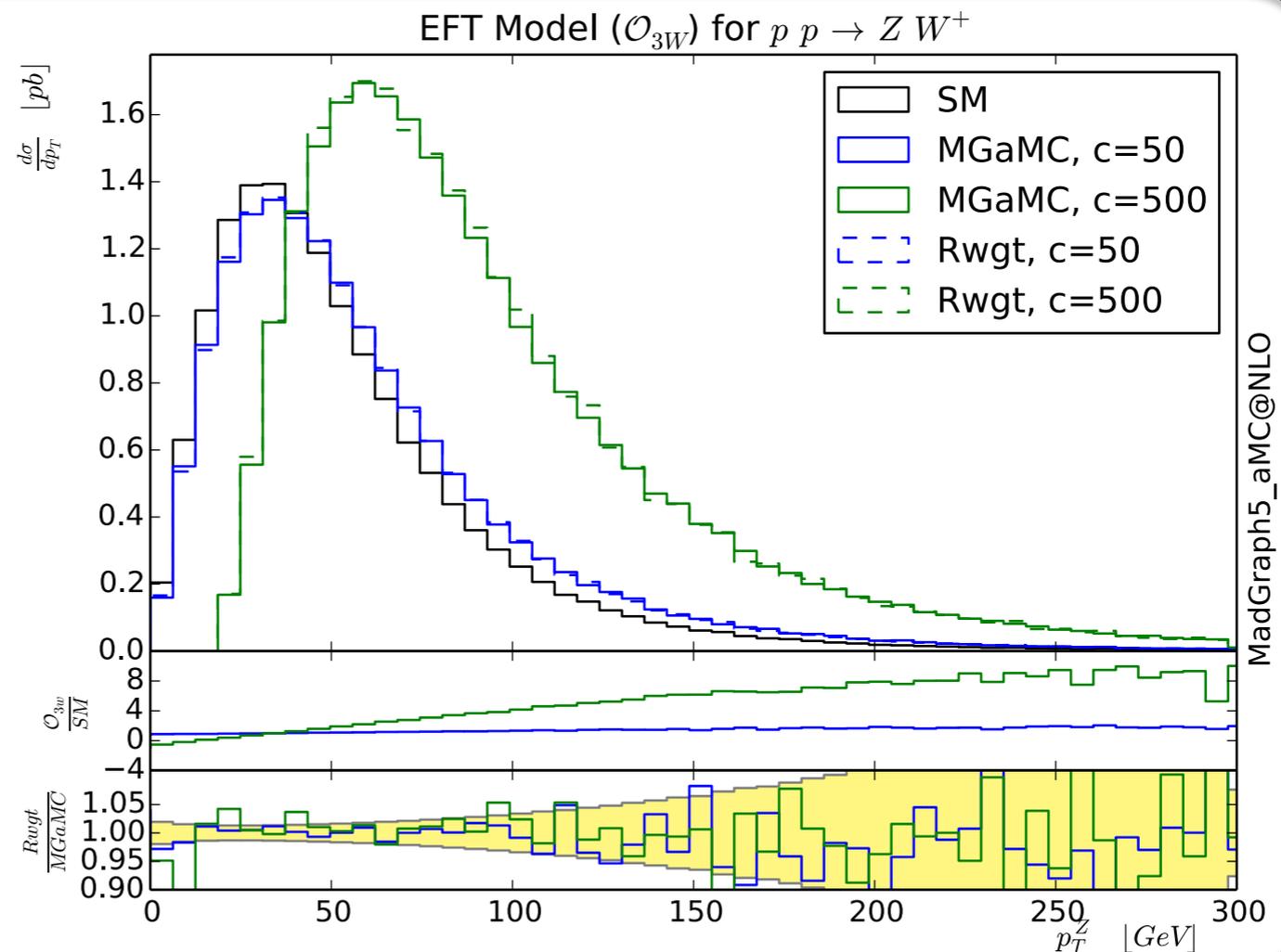
- Change the weight of the events

1404.7129  
1607.00763

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

## EFT Case

$$\mathcal{O}_{3W} = Tr [W_{\mu\nu} W^{\nu\rho} W_{\rho}{}^{\mu}]$$



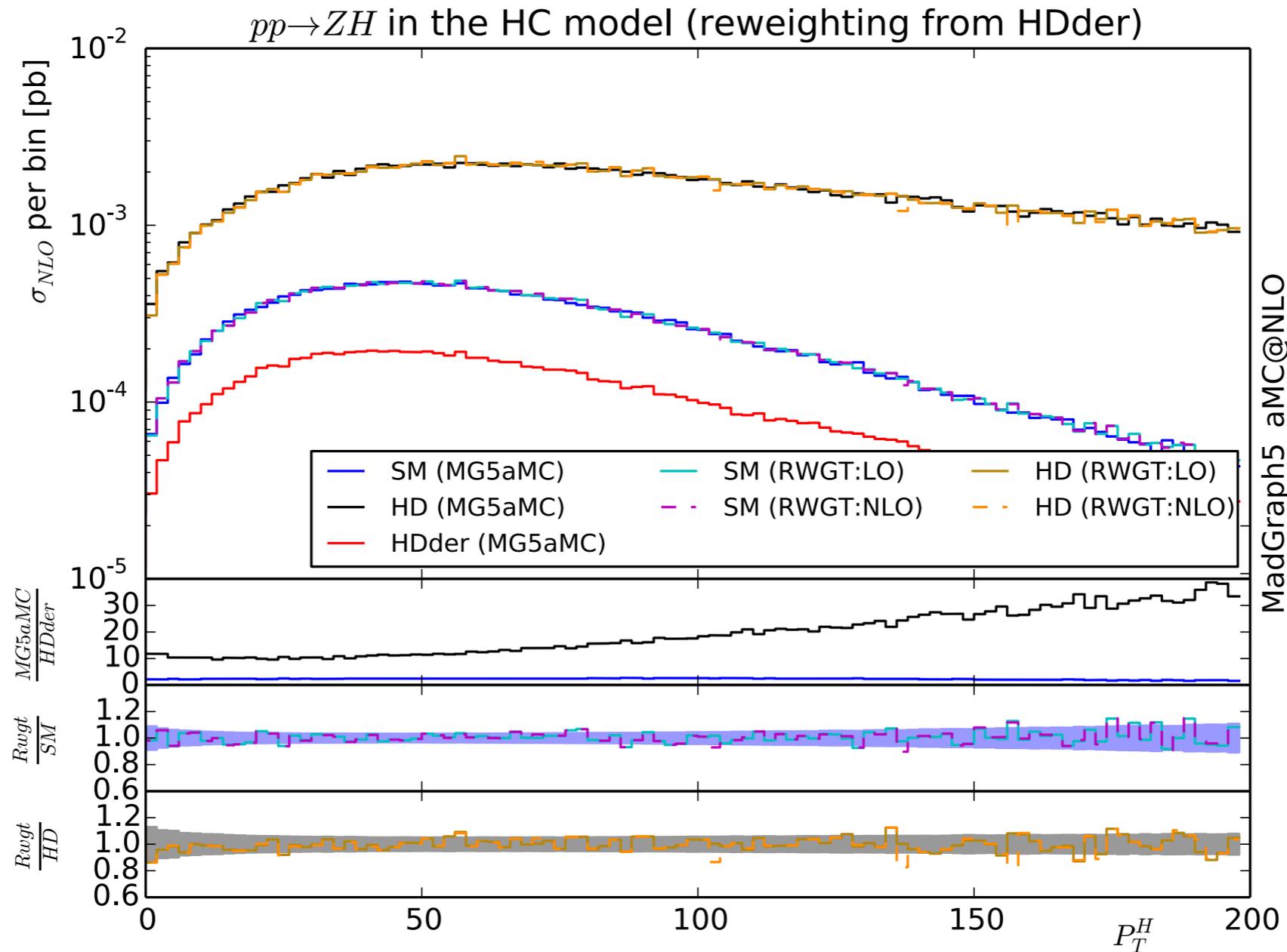
## NLO method

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

$$d\sigma^\alpha = f_1(x_1^\alpha, \mu_F) f_2(x_2^\alpha, \mu_F) \left[ \mathcal{W}_0^\alpha + \mathcal{W}_F^\alpha \log(\mu_F/Q)^2 + \mathcal{W}_R^\alpha \log(\mu_R/Q)^2 \right] d\chi^\alpha, \quad (9)$$

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

- re-weight each part according to the associated matrix-element
  - MG5aMC optimisation degrades efficiency



# Polarisation

## New in 2.7.0 (LO only)

- Generate  $p p \rightarrow t\{R\} t\sim W_+\{0\} W_-\{T\}$

## What is the meaning of polarization?

- Longitudinal/Transverse are **NOT** lorentz invariant
- New option in the run\_card

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*****
# Frame where to evaluate the matrix-element (not the cut!) for polarization
*****
1, 2 = me_frame ! list of particles to sum-up to define the rest-frame
                ! in which to evaluate the matrix-element
                ! [1,2] means the partonic center of mass
    
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Process	p-CM SM ( $a = 1$ )		WW-CM SM ( $a = 1$ )	
	$\sigma$ [fb]	$f_{\lambda\lambda'}$	$\sigma$ [fb]	$f_{\lambda\lambda'}$
$jjW^+W^-$	171	...	171	...
$jjW_T^+W_T^-$	119	70%	118	69%
$jjW_0^+W_T^-$	20.6	12%	22.2	13%
$jjW_T^+W_0^-$	23.8	14%	24.1	14%
$jjW_0^+W_0^-$	5.45	3%	6.93	4%

# Decay of polarised particles

## Objective

- Generate  $p p > W_{+}\{0\} W_{-}\{T\}, w_{+} > e_{+} \nu_{e}$

## What is the meaning?

- **NOT** lorentz invariant
- You have four polarization (not three!!)  $\{A\}$
- You have interference between polarization
  - Cancels if you integrate over the full decay
  - No support for interference within MG5aMC

$$\Pi_{\mu\nu}(q, M_V, \Gamma_V) = \frac{-i \left[ g_{\mu\nu} - \frac{q_\mu q_\nu}{M_V^2} \right]}{q^2 - M_V^2 + iM_V \Gamma_V} \approx \sum_{\lambda \in \{0, \pm 1, A\}} \Pi_{\mu\nu}^\lambda(q, M_V, \Gamma_V).$$

$$\Pi_{\mu\nu}^\lambda(q, M_V, \Gamma_V) = \frac{-i \varepsilon(q, \lambda) \varepsilon^*(q, \lambda)}{q^2 - M_V^2 + iM_V \Gamma_V}.$$

# Issue With Eft

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- A lot of Feynman Diagram
  - ➔ But a lot of them have zero coupling
- Phase-Space Integration problem
  - ➔ for VBF processes
  - ➔ For interference

# New flow for the amplitude

- 2.9.0 introduces on the flight optimiser of the code evaluation the matrix-element
  - ➔ Trim all irrelevant computation
  - ➔ Allow to use better algorithm

process	zeroamp	speed-up
VBF like processes		
$pp \rightarrow W^- W^+ jj$ QCD=0	0/774	1.5x
$pp \rightarrow W^- W^- jj$ QCD=0, $w \rightarrow lvl$ [13TeV]	→296/612	1.27x
$pp \rightarrow W^- W^- jj$ QCD=0, $w \rightarrow lvl$ [100TeV]	→296/612	1.05x
$u\bar{d} \rightarrow W_L^+ W_L^- u\bar{d}$ QCD=0	151/344	3.2x
$u\bar{d} \rightarrow W_L^+ W_L^- u\bar{d}$ QCD=0, $W^+ \rightarrow d\bar{u}$ , $W^- \rightarrow \tau^+ \nu_\tau$	302/688	2.5x
$u\bar{d} \rightarrow w_T^+ w_T^- u\bar{d}$ QCD=0, $w^+ \rightarrow d\bar{u}$ , $w^- \rightarrow \tau^+ \nu_\tau$	302/688	1.13x
$\mu^+ e^- \rightarrow hhh \bar{\nu}_\mu \nu_e$ [14TeV]	0/25	1x
$\mu^+ \mu^- \rightarrow t\bar{t} \mu^+ \mu^- / hZ$ [13TeV]	0/3072	4x
$\mu^+ \mu^- \rightarrow W^+ W^- \mu^+ \mu^-$ [4TeV]	1311/22k	4.3x
other processes		
$pp \rightarrow W^- [0 - 4]j$	→1728/25k	1.8x
$pp \rightarrow t\bar{t} [0 - 2]j$	→800/10k	2.6x
$pp \rightarrow 4j$	→2016/25k	1.8x
$pp \rightarrow t\bar{t} 3j$	→15k/240k	1.28x
$pp \rightarrow W^- Z$	0/27	~1x
$pp \rightarrow t\bar{t} h$	→16/128	1.4x
$pp \rightarrow t\bar{t} h j$	→160/1728	2x
$pp \rightarrow t\bar{t} Z$	→48/384	1.7x
$pp \rightarrow W^- W^- jj$ QED=0	→738/2232	3x

➔ In the SM:

➔ Up to 4x speed-up

➔ In general ~2x

# New T-channel/Multi-channel

- Redesign phase-space integrator for QED processes (designed for VBF)
- Would be interesting for interference

process	2.8.1		2.9.0		speed-up
	survey	refine	survey	refine	
VBF like processes					
$\mu^+ e^- \rightarrow h h h \nu_m \nu_e$ [14TeV]	2.7s	<b>4d 10h/43</b>	3.9	13.3s	22000×
$u\bar{d} \rightarrow w_L^+ w_L^- u\bar{d}$ QCD=0, $w^+ \rightarrow d\bar{u}$ , $w^- \rightarrow \tau^+ \nu_\tau$	1m48s	<b>4h 56m/3120</b>	2m5s	9m11	26×
$\mu^+ \mu^- \rightarrow t\bar{t} \mu^+ \mu^- / h \gamma z$ [13TeV]	53.3s	<b>1h25m/6401</b>	7.2s	23.9s	163×
$p p \rightarrow w^+ w^+ j j$ QCD=0	15.8s	16m40s	18.8s	6m15s	2.5×
$u\bar{d} \rightarrow w_T^+ w_T^- u\bar{d}$ QCD=0, $w^+ \rightarrow d\bar{u}$ , $w^- \rightarrow \tau^+ \nu_\tau$	43	8m36	56s	3m52s	1.9×
$pp \rightarrow w^+ w^- j j$ QCD = 0, $w \rightarrow l\nu_l$ [13TeV]	18m24s	22m54s	20m14	3m15	1.9×
$pp \rightarrow w^+ w^- j j$ QCD = 0, $w \rightarrow l\nu_l$ [100TeV]	8m0s	<b>11h20/1398</b>	9m12s	55m4s	10×
$\mu^+ \mu^- \rightarrow w^+ w^- \mu^+ \mu^-$ [4TeV]	10m	1h55	1m26s	1m27s	41×
$u\bar{d} \rightarrow w_L^+ w_L^- u\bar{d}$ QCD=0	21.7s	<b>3h 54/1497</b>	19.7s	2m36	80×

- Huge speed-up observed (up to 20k faster)
  - 10x faster for VBF at 100TeV
  - Huge progress for polarised quantity
- 2.8.1 is also ~4 times faster than 2.7.x

Kiran Ostrelenk/OM

# EFT Running

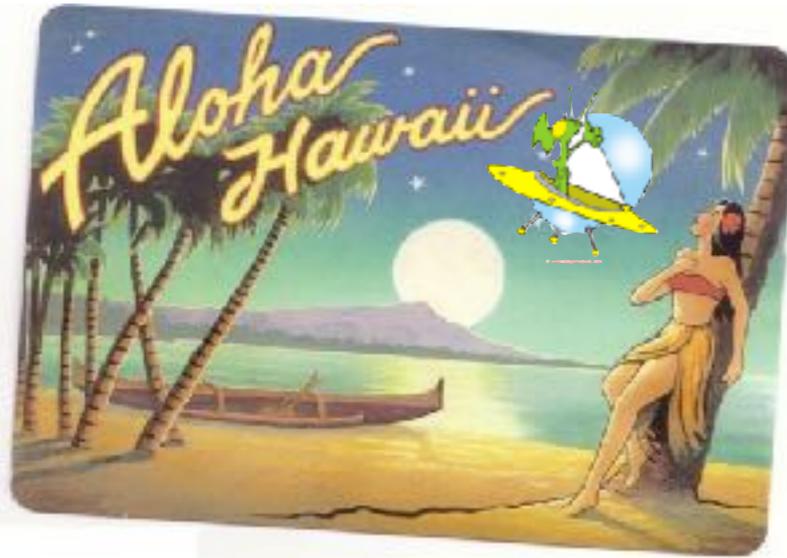


- UFO extension for running parameter is designed
- Pyrate will generate such format (NO EFT)

$$\frac{dC}{d\log(\mu)} = (g_s\gamma_1 + \alpha_s\gamma_2)C$$

- For the above expression (EFT style), MG5aMC will use analytical solution for the running
  - Working both at LO and NLO
  - Under-validation

# Conclusion



- BSM is one of the core feature of MG5aMC
  - Many of our last 10 years of development was partly motivated by EFT
- A lot of exiting feature are coming
  - Huge speed improvement (soon)
  - EFT Running
  - SMETNLO