Part II – simulations

Start the Virtual Machine

- **important!**
```
sudo apt-get update
sudo apt-get install python-dev
```
  sudo password is `delphes`

- cd in `MG5_aMC_v2_7_0/models/`

  download the SMEFTsim UFO with:
```
wget https://www.dropbox.com/s/ht5pxncemz35aig/SMEFTsim_A_MwScheme_UFO_int_orders.tar
```
  and untar it with
```
tar -xvf SMEFTsim_A_MwScheme_UFO_int_orders.tar
```

- cd back into your working directory, download the `SMEFT_HandsOn_pt2.tar` material
```
wget https://twiki.cern.ch/twiki/pub/VBSCan/PREFIT20/SMEFT_HandsOn_pt2.tar
```
  and **untar** it

$$h \to b\bar{b}$$

$h \to bb$ in the SMEFT with MG: scan

in the working dir, open MadGraph with `../MG5_aMC_v2_7_0/bin/mg5_aMC`

- import SMEFTsim with

```
import model SMEFTsim_A_MwScheme_UFO_int_orders-massless
```

- generate diagrams for the full EFT:

```
generate h > b b~ NP=1
output h_bb_all
quit
```

- `cp param_card_SMEFT.dat h_bb_all/Cards/param_card.dat`

  sets to 0 all the Wilson coefficients

- run the `hbb_all_scan.dat` script with

```
../MG5_aMC_v2_7_0/bin/mg5_aMC hbb_all_scan.dat
```

  this runs over all coefficients, scans 6 values for each and writes a result file called `results_h_bb_all.dat` (this is also given as a solution)

$h \to bb$ in the SMEFT with MG: interpolation

- to extract the **polynomials**: run in the VM

```
python interpolation.py results_h_bb_all.dat
```

- to make **plots**: if you can, drag and drop the `results_h_bb_all.dat` file to your laptop, in the same directory of the `SMEFT_HandsOn_2.nb` notebook. Alternatively, use the solutions file given.

  Use the predefined functions to import the results and fit the dependence for each coefficient.

- check that, after reabsorbing (v^2/Λ^2) in the C_i, the result is the same we found in the theory part.

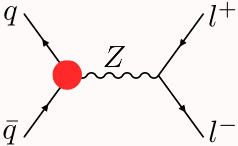
$$pp \rightarrow e^+e^-$$

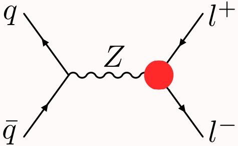
$pp \to e^+e^-$ in the SMEFT ($U(3)^5$ symmetry)

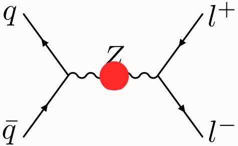
$C_{uW}, C_{uB}, C_{dW}, C_{dB},$
$C_{Hu}, C_{Hd}, C_{Hq}^{(1)}, C_{Hq}^{(3)},$
C_{HD}, C_{HWB}, C'_{ll}

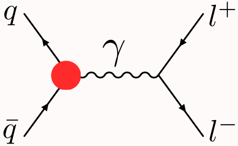
$C_{eW}, C_{eB},$
$C_{He}, C_{Hl}^{(1)}, C_{Hl}^{(3)},$
C_{HD}, C_{HWB}, C'_{ll}

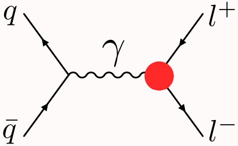
$\delta\Gamma_Z$

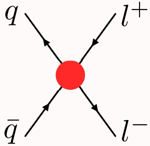












δe

δe

$C_{lq}^{(1)}, C_{lq}^{(3)}, C_{eu}, C_{ed},$
$C_{qe}, C_{lu}, C_{ld},$
$C_{ledq}, C_{lequ}^{(1)}, C_{lequ}^{(3)}$

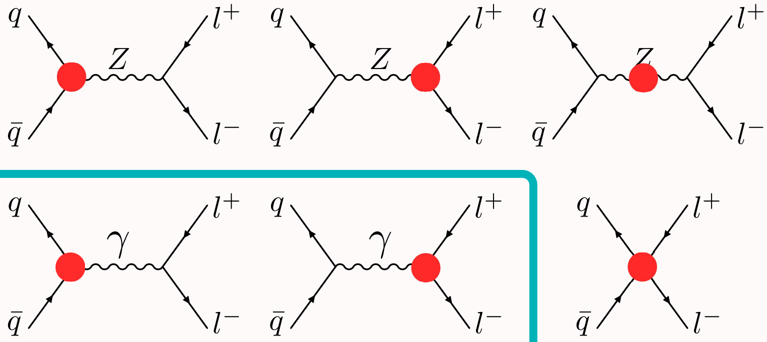
$$\delta e = v^2 \left[-C_{Hl}^{(3)} + \frac{C'_{ll}}{2} - \frac{C_{HD}}{4t_\theta^2} - \frac{C_{HWB}}{t_\theta} \right]$$

$pp \to e^+e^-$ in the SMEFT ($U(3)^5$ symmetry)

$C_{uW}, C_{uB}, C_{dW}, C_{dB}, C_{Hu}, C_{Hd}, C_{Hq}^{(1)}, C_{Hq}^{(3)}, C_{HD}, C_{HWB}, C'_{ll}$

$C_{eW}, C_{eB}, C_{He}, C_{Hl}^{(1)}, C_{Hl}^{(3)}, C_{HD}, C_{HWB}, C'_{ll}$

$\delta\Gamma_Z$



δe δe

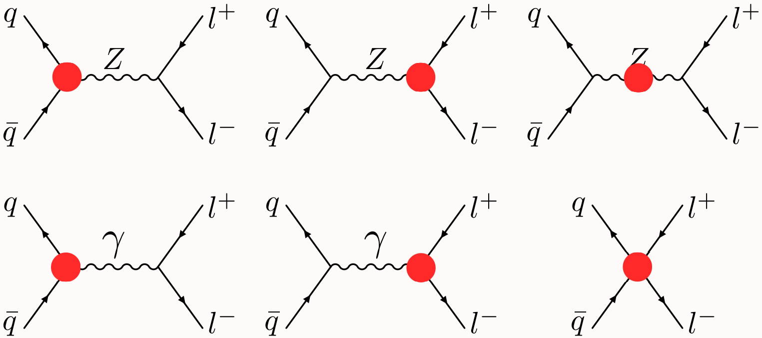
only in m_W scheme!

$C_{lq}^{(1)}, C_{lq}^{(3)}, C_{eu}, C_{ed}, C_{qe}, C_{lu}, C_{ld}, C_{ledq}, C_{lequ}^{(1)}, C_{lequ}^{(3)}$

$C_{uW}, C_{uB}, C_{dW}, C_{dB},$
$C_{Hu}, C_{Hd}, C_{Hq}^{(1)}, C_{Hq}^{(3)},$
C_{HD}, C_{HWB}, C'_{ll}

$C_{eW}, C_{eB},$
$C_{He}, C_{Hl}^{(1)}, C_{Hl}^{(3)},$
C_{HD}, C_{HWB}, C'_{ll}

$\delta\Gamma_Z$



δe

δe

$C_{lq}^{(1)}, C_{lq}^{(3)}, C_{eu}, C_{ed},$
$C_{qe}, C_{lu}, C_{ld},$
$C_{ledq}, C_{lequ}^{(1)}, C_{lequ}^{(3)}$

$$\delta e = v^2 \left[-C_{Hl}^{(3)} + \frac{C'_{ll}}{2} - \frac{C_{HD}}{4t_\theta^2} - \frac{C_{HWB}}{t_\theta} \right]$$

$pp \to e^+e^-$ in the SMEFT with MG : set up

start MadGraph

- import SMEFTsim with

```
import model SMEFTsim_A_MwScheme_UFO_int_orders-massless
```

- generate diagrams for SM + interference:

```
generate p p > e+ e- SMHLOOP=0 NP<=1 NP^2<=1
output pp_ee_SM+int
quit
```

- copy the cards: (set SM limit and cut on the Z peak)

```
cp param_card_SMEFT.dat h_bb_all/Cards/param_card.dat
cp run_card_Zpole.dat h_bb_all/Cards/run_card.dat
cp madanalysis5_parton_card_Zpole.dat
            h_bb_all/Cards/madanalysis5_parton_card.dat
```

- generate events in SM: `./pp_ee_SM+int/bin/generate_events`

$pp \to e^+e^-$ in the SMEFT with MG: reweighting

- copy the reweight card

```
cp reweight_card_ppee.dat pp_ee_SM+int/Cards/reweight_card.dat
```

  this reweights the events for 8 different configurations, with
  {`cHe, cHl1, cHu, cHd, cHq1, cqe, clq1, cHDD`}=1

- start the reweighting with

```
./pp_ee_SM+int/bin/madevent reweight run_01 -f
```

- analyze the events with

```
gunzip pp_ee_SM+int/Events/run_01/unweighted_events.lhe.gz
python lhe_analyzer_rwgt.py pp_ee_SM+int/Events/run_01/unweighted_events.lhe events_ee.root
```

- open `plot_histos_rwgt.dat`, **adjust the path and file name**, then run

```
python plot_histos_rwgt.py
```

$pp \to e^+e^-$ in the SMEFT: results

the script produces 3 plots:

- `plot_ll_mass_rwgt.pdf` : invariant mass of (e^+e^-)

  $\to$ at $\sqrt{s} \simeq m_Z$ the size is consistent with Z coupling scalings:

$$\frac{\sigma_{int.}(m_Z)}{\sigma_{SM}(m_Z)} = 2\,\frac{g_{eR}^{SM}\,\delta g_{eR} + g_{eL}^{SM}\,\delta g_{eL}}{(g_{eR}^{SM})^2 + (g_{eL}^{SM})^2}$$

  $\to$ 4fermion operators suppressed: not resonant

- `plot_lm_y_rwgt.pdf` : rapidity of the e^-: y_{e^-}

  $\to$ angular sensitivity: discriminates operator **chirality**

$$y_{e^-} \simeq \frac{1}{2}\ln\left[\frac{1+\cos\theta}{1-\cos\theta}\right], \qquad \theta = \text{angle}\,(\vec{p}_q, \vec{p}_{e^-})$$

and

$$\frac{d\sigma}{d\cos\theta_{e^-}} \propto \quad A\left(g_{eL}^2 + g_{eR}^2\right)(1+\cos^2\theta) + B\left(g_{eL}^2 - g_{eR}^2\right)\cos\theta$$

- `plot_lp_y_rwgt.pdf`: same for the e^+

Backup slides