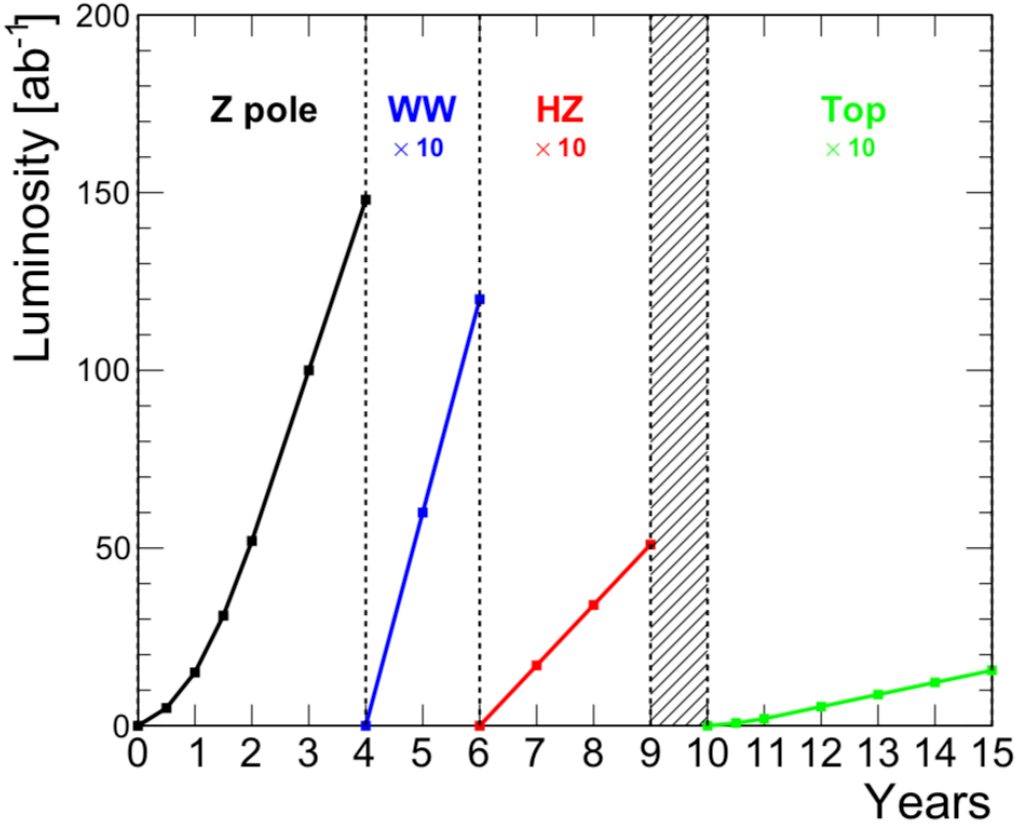
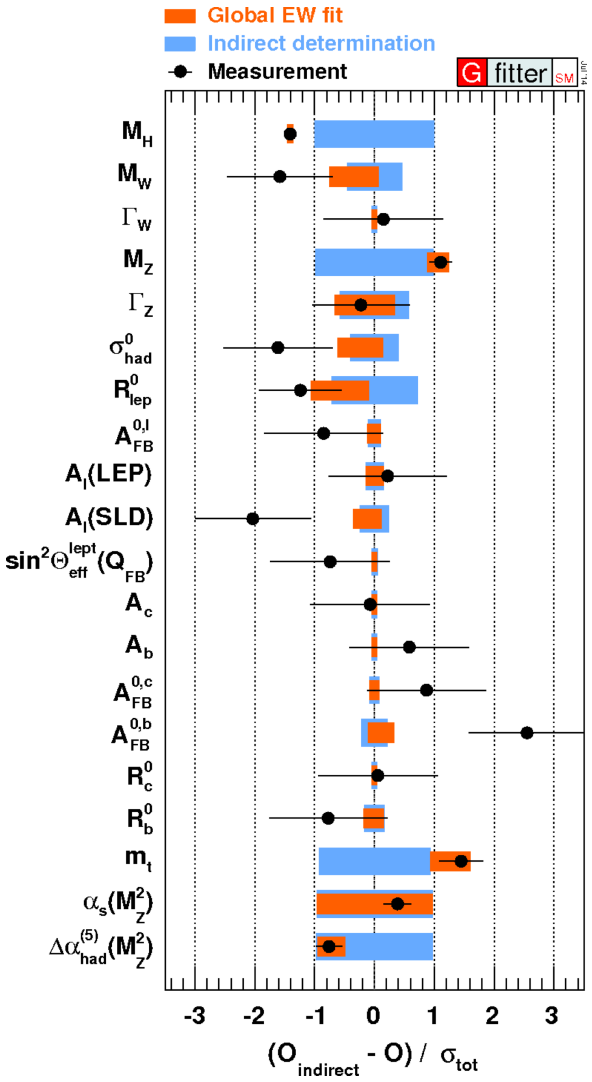
Hands on ee→WWZ / ZZZ

FCCee Pisa - 13 Luglio 2021

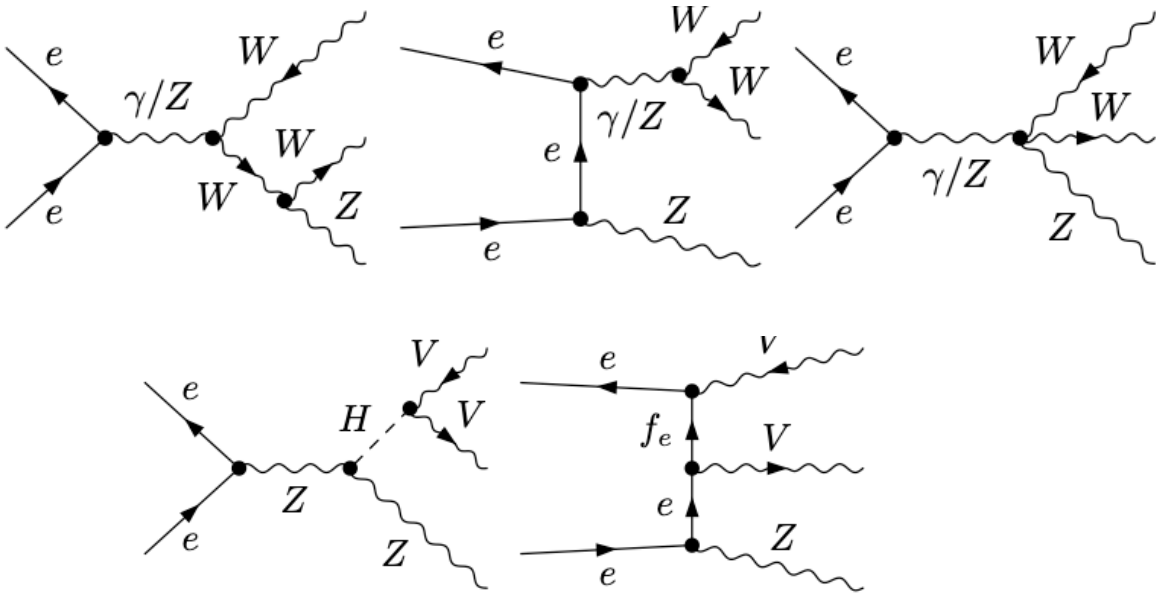
FCCee Physics program





6-fermion processes : tri-bosons

On shell production at E_{CM} =350-365 GeV : e+e- → WWZ (~10 fb) , ZZZ (~0.5 fb)
Similar x-sections and luminosity wrt HL-LHC, but much better acceptance & purity



No studies yet

Potential of stringent TGC/QGC (EFT dim6 & dim8) explorations

Getting started with Madgraph

Tutorial slides example here
https://cp3.irmp.ucl.ac.be/projects/madgraph/raw-attachment/wiki/MCNET2017/17_06_02_tuto_mcnet.pdf

https://launchpad.net/madgraph5
untar it (tar -xzpvf MG5_XXX.tgz)
launch it ($ ./bin/mg5_amc)

Type tutorial and follow instructions

install external package
install pythia8
Intall Delphes

Generate tribosons

```
MG5_aMC>generate e+ e- > W+ W- Z
INFO: Checking for minimal orders which gives processes.
INFO: Please specify coupling orders to bypass this step.
INFO: Trying process: e+ e- > w+ w- z WEIGHTED<=6 @1
INFO: Process has 16 diagrams
1 processes with 16 diagrams generated in 0.059 s
Total: 1 processes with 16 diagrams
MG5_aMC>output eeWWZ
…
MG5_aMC>launch
…
/============================================================================\
| 1. Choose the shower/hadronization program     shower = OFF                |
| 2. Choose the detector simulation program    detector = OFF                |
| 3. Choose an analysis package (plot/convert) analysis = ExRoot             |
| 4. Decay onshell particles                    madspin = OFF                |
| 5. Add weights to events for new hypp.       reweight = OFF                |
\============================================================================/
```

Generate tribosons

```
Edit :
2. run   : run_card.dat

 182.5     = ebeam1  ! beam 1 total energy in GeV
 182.5     = ebeam2  ! beam 2 total energy in GeV
..

=== Results Summary for run: run_01 tag: tag_1 ===

     Cross-section :   0.01589 +- 2.211e-05 pb
     Nb of events :  10000
```

Output LHE and root files in the launch directory eeWWZ/Events/Run01/

WWZ cross sections

Numbers to be x-checked

WWZ	σ/fb	N/1.65 ab-1	
Total	15.9	26 235	
$\ell\nu\ell\nu\ell\ell$	0.18	292	4ℓ(1Z) + p_{miss}
qq$\ell\nu\ell\ell$	0.71	1170	2ℓ(1Z) + 2jets + p_{miss}
qqqq$\ell\ell$	0.71	1170	2ℓ(1Z) + 4jets
$\ell\nu\ell\nu$qq	0.97	1600	2ℓ + 2jets(1Z) + p_{miss}
$\ell\nu\ell\nu$bb	0.26	437	2ℓ + 2b-jets(1Z) + p_{miss}
$\ell\nu$qqqq	3.89	6410	1ℓ + 4jets(1Z) + p_{miss}
$\ell\nu$qqbb	1.06	1750	1ℓ + 2jets + 2b-jets(1Z) + p_{miss}
$\ell\nu\ell\nu\nu\nu$	0.35	580	2ℓ + p_{miss}
qq$\ell\nu\nu\nu$	1.41	2330	1ℓ + 2jets + p_{miss}
qqqq$\nu\nu$	1.41	2330	4jets + p_{miss}
qqqqqq	3.89	6410	6jets(1Z)
qqqqbb	1.06	1750	4jets + 2b-jets(1Z)

ZZZ cross sections

Numbers to be x-checked

ZZZ	σ/fb	N/1.65 ab-1	
Total	0.76	1250	
$\ell\ell\ell\ell\ell\ell$	0.00076	1	6ℓ(3Z)
qq$\ell\ell\ell\ell$	0.013	21	4ℓ(2Z) + 2jets(1Z)
bb$\ell\ell\ell\ell$	0.0034	6	4ℓ(2Z) + 2b-jets(1Z)
qqqq$\ell\ell$	0.069	115	2ℓ(1Z) + 4jets(2Z)
bbqq$\ell\ell$	0.018	62	2ℓ(1Z) + 2b-jets(1Z) +2jets(1Z)
bbbb$\ell\ell$	0.0051	8	2ℓ(1Z) + 4b-jets(2Z)
qqqqqq	0.126	210	6jets(3Z)
bbqqqq	0.103	170	4jets(2Z) +2b-jets(1Z)
bbbbqq	0.028	47	2jets(1Z)+4b-jets(2Z)
bbbbbb	0.0026	4	6b-jets(3Z)

ZZZ cross sections (cont...) Numbers to be x-checked

ZZZ	σ/fb	N/1.65 ab-1	
Total	0.76	1250	
vv$\ell\ell\ell\ell$	0.0045	8	4ℓ(2Z) + p_{miss}
vvvv$\ell\ell$	0.0091	15	2ℓ(1Z) + p_{miss}
vvqqqq	0.069	115	4jets(2Z) + p_{miss}
vvbbqq	0.018	62	2b-jets(1Z) +2jets(1Z) + p_{miss}
vvbbbb	0.0051	8	4b-jets(2Z) + p_{miss}
vvvvqq	0.050	83	2jets(1Z) + p_{miss}
vvvvbb	0.014	23	2b-jets(1Z) + p_{miss}
vvvvvv	0.0061	10	p_{miss}
vv$\ell\ell$qq	0.050	83	2ℓ(1Z) + 2jets(1Z) + p_{miss}
vv$\ell\ell$bb	0.014	23	2ℓ(1Z) + 2b-jets(1Z) + p_{miss}

WWZ / ZZZ backgrounds

```
MG5_aMC>generate e+ e- > t t~
```
- tt(→WWbb) 487 fb

```
MG5_aMC>generate e+ e- > W+ W-
```
- WW 11.46 pb ⇒ WW+jj ~100fb

```
MG5_aMC>generate e+ e- > Z Z
```
- ZZ 635 fb ⇒ ZZ+jj ~10fb

```
MG5_aMC>generate e+ e- > Z H
```
- ZH 100 fb ⇒ ZH+jj ~fb

```
MG5_aMC>generate e+ e- > j j
```
- qq 4.1 pb ⇒ 6jet ~fb

Presumably negligible
Single-V (Wev, Zee)
Diphoton interactions
Other 4f sources

Could be interesting to check possible 6f interference effects, for example between WWZ and ditop

Possible next steps

Everyone/anyone

- Install and run MG5, generate small samples (1K is default)
- Open output root files and make Gen-level plots
- Process/generate events also with Delphes, make plots
- Plan desired analyses and studies at next meetings (include SMEFT ?)

Coordinate “central” event productions

- Produce and store event samples on common & accessible resources in Pisa : where ?
- Github repository for common code ?
- Overleaf repository for documentation (paper draft)