Feasibility Study of Measuring the Higgs Self-coupling Using the Muon Collider

Kenny Jia

Feb 4th, 2022

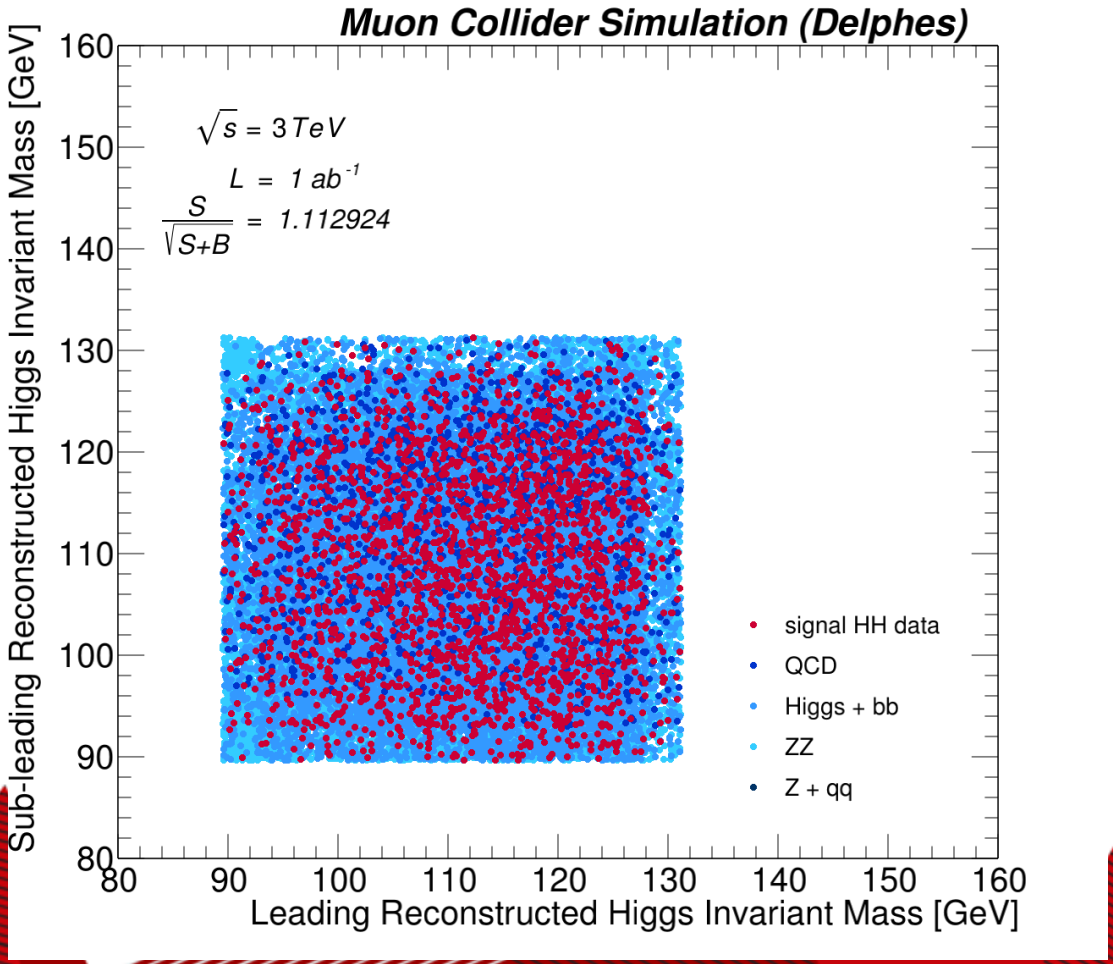
- Signal: $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + H + H$ (0.0008182 pb)
- Background:
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + \boldsymbol{q} + \boldsymbol{\bar{q}} + Z$ (0.05685 pb)
  - $\boldsymbol{\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + Z + Z}$ **(0.081 pb)**
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + H$ (0.003771 pb)
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + b + \bar{b}$ (0.0009237 pb)

100k for each

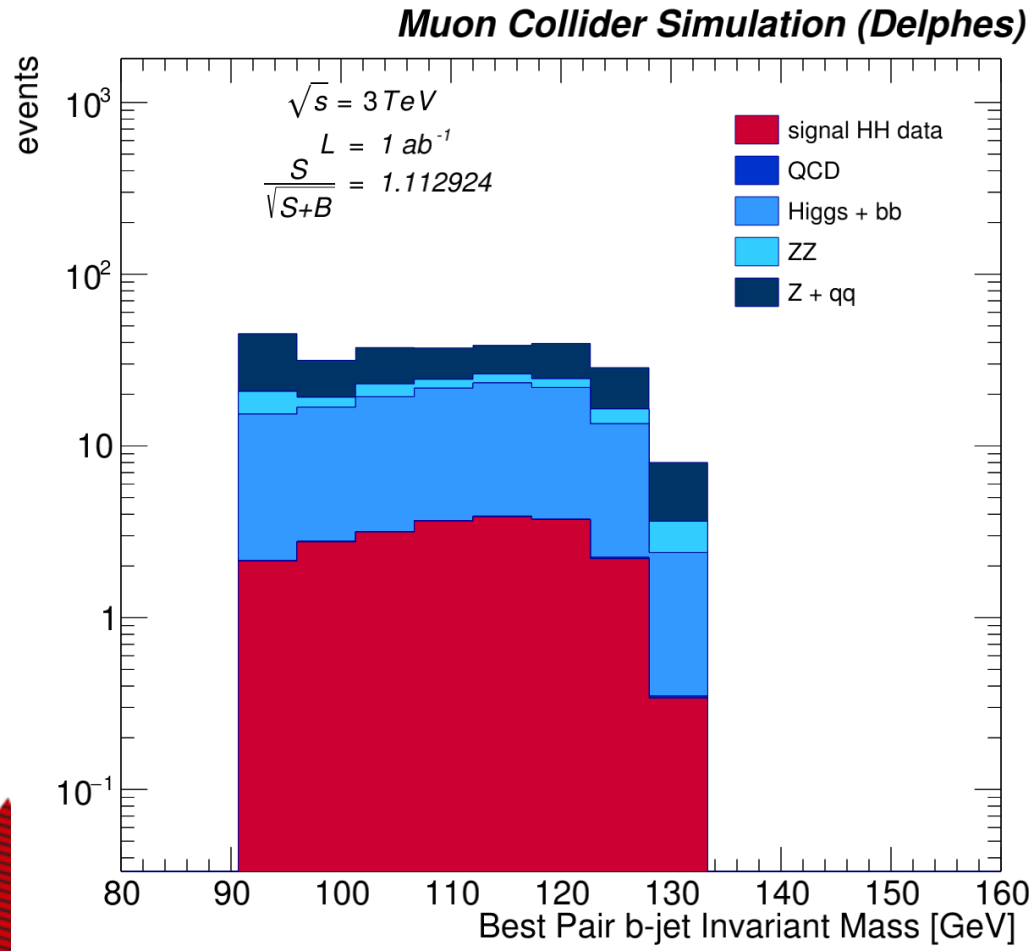
3 TeV

- Make really tight cut on reco-higgs mass [91-130] in order to improve the signal strength

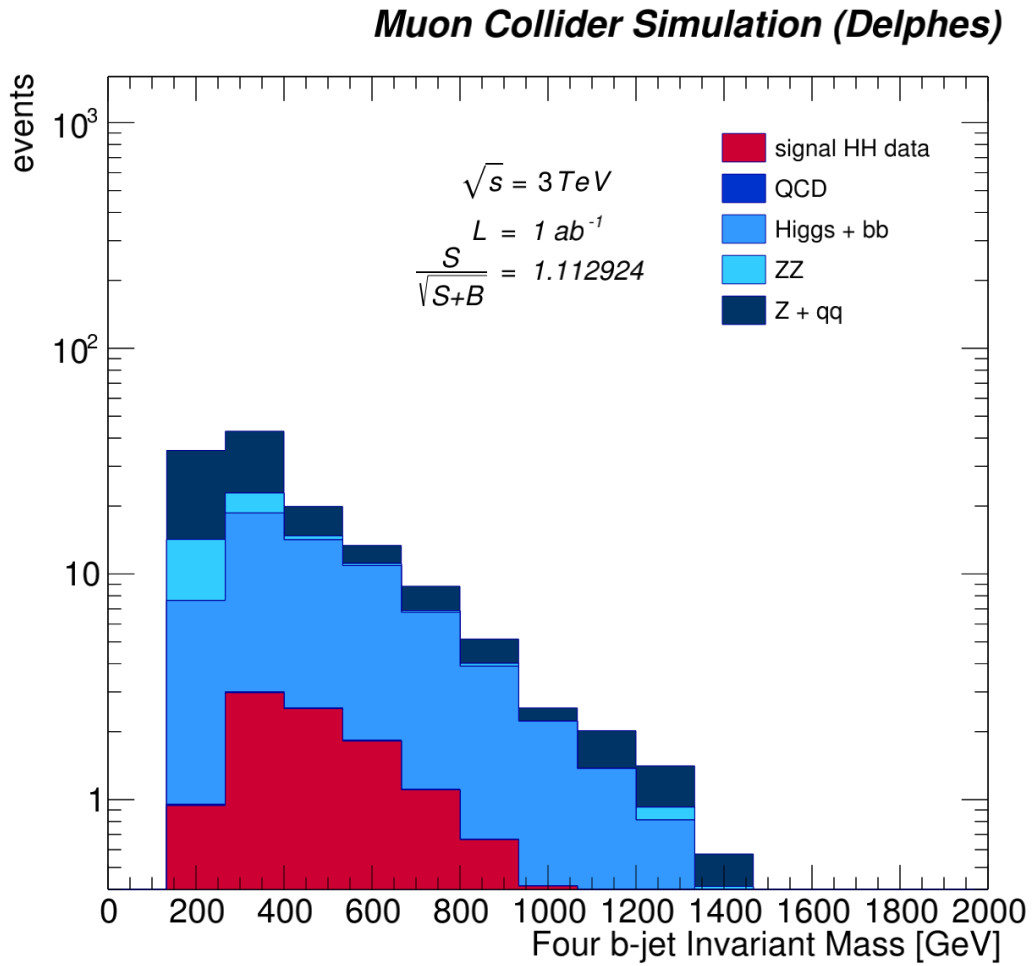
Requiring 3 tight B-Tag



Requiring 3 tight B-Tag



Requiring 3 tight B-Tag



MVA

- When we cut this tight, the H+bb process becomes the dominant background, but at that stage it become almost indistinguishable with the signal.
- But the BDT model training respect to the qqZ background still have auc score 0.866794.

10TeV and 30TeV generation

hjia38@login02:~/MG5_aMC_v2_7_2

```
INFO: Generating 100000.0 unweighted events.
INFO: Effective Luminosity 94844446.5013 pb^-1
INFO: need to improve 3 channels
Current estimate of cross-section: 0.00126522958831 +- 1.05533697678e-06
    P1_ll_vlvlbbxbbx
INFO:  Idle: 1,  Running: 19,  Completed: 0 [ current time: 02h32 ]
INFO:  Idle: 0,  Running: 20,  Completed: 0 [  5m 0s  ]
INFO:  Idle: 0,  Running: 19,  Completed: 1 [  39m 25s  ]
INFO:  Idle: 0,  Running: 17,  Completed: 3 [  53m 23s  ]
INFO:  Idle: 0,  Running: 16,  Completed: 4 [  1h 41m  ]
INFO:  Idle: 0,  Running: 15,  Completed: 5 [  1h 46m  ]
INFO:  Idle: 0,  Running: 14,  Completed: 6 [  2h 13m  ]
INFO:  Idle: 0,  Running: 13,  Completed: 7 [  2h 22m  ]
INFO:  Idle: 0,  Running: 10,  Completed: 10 [  2h 31m  ]
INFO:  Idle: 0,  Running: 7,  Completed: 13 [  2h 34m  ]
INFO:  Idle: 0,  Running: 1,  Completed: 19 [  2h 37m  ]
INFO:  Idle: 0,  Running: 0,  Completed: 20 [  2h 43m  ]
INFO:  Idle: 0,  Running: 0,  Completed: 20 [  2h 43m  ]
INFO: Combining runs
INFO: finish refine
INFO: Combining Events
INFO: fail to reach target 100000
  === Results Summary for run: run_01 tag: tag_1 ===

     Cross-section :   0.001264 +- 3.763e-06 pb
     Nb of events :  59662
```

“Fail to reach the target”

- No certain solution or reason is given:
- not having the correct number of events is a sign of difficulty of the phase-space integrator
- Some people mention update version of MG5, tried the newest version 3.3.1, failed.
- Surprisingly, HH, ZZ, and HZ works, but all the rest with five or more QED+QCD vertex have this problem.
- Any suggestion/solution/idea?