Weekly Updates

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01/09/2020

Items

・Check the effect of update about the selection of “isolated electron” candidate

-- the setting at “IsolatedLeptonFInderProcessor” roughly find the electron with “isolated” status, ~50% . (It depends on the energy of electron as well as the analysis channel)

・Separately analyze Z(->νν)H(Z->μμ, Z*->qq) / Z(->νν)H(Z->qq, Z*->μμ)

-- both regions are combined so far.

Parameters for lepton isolation

Settings (for “IsolatedLeptonFinder”) in template_jobfile.xml

```
<parameter name="IsolationMinimumTrackEnergy" type="float">3 </parameter>
  <!--Polynomial cut (A) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="IsolationPolynomialCutA" type="float">0.01 </parameter>
  <!--Polynomial cut (B) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="IsolationPolynomialCutB" type="float">0 </parameter>
  <!--Polynomial cut (C) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="IsolationPolynomialCutC" type="float">0 </parameter>
```

➡ Finding the isolated muon candidates is fine.

➡ Prepare parameters for muon&electron separately

Muon : IsolationPolynomialCutA = 0.01, IsolationMinimumTrackEnergy = 3 GeV

Electron : IsolationPolynomialCutA = 0.49, IsolationMinimumTrackEnergy = 10 GeV

and, one more, the cone protection (introduced in the past slide)

Ref.)

Modified template file (test version)

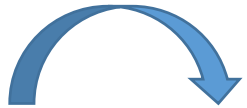
will soon update on the github

```
<!-- Electron: Maximum cone energy for isolation requirement-->
  <parameter name="ElectronIsolationMaximumConeEnergy" type="float">1e+20 </parameter>
  <!-- Electron: Maximum track energy for isolation requirement-->
  <parameter name="ElectronIsolationMaximumTrackEnergy" type="float">1e+20 </parameter>
  <!-- Electron: Minimum cone energy for isolation requirement-->
  <parameter name="ElectronIsolationMinimumConeEnergy" type="float">0 </parameter>
  <!-- Electron: Minimum track energy for isolation requirement-->
  <parameter name="ElectronIsolationMinimumTrackEnergy" type="float">10 </parameter>
  <!-- Electron: Polynomial cut (A) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="ElectronIsolationPolynomialCutA" type="float">0.49 </parameter>
  <!-- Electron: Polynomial cut (B) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="ElectronIsolationPolynomialCutB" type="float">0 </parameter>
  <!-- Electron: Polynomial cut (C) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="ElectronIsolationPolynomialCutC" type="float">0 </parameter>

  <!-- Muon: Maximum cone energy for isolation requirement-->
  <parameter name="MuonIsolationMaximumConeEnergy" type="float">1e+20 </parameter>
  <!-- Muon: Maximum track energy for isolation requirement-->
  <parameter name="MuonIsolationMaximumTrackEnergy" type="float">1e+20 </parameter>
  <!-- Muon: Minimum cone energy for isolation requirement-->
  <parameter name="MuonIsolationMinimumConeEnergy" type="float">0 </parameter>
  <!-- Muon: Minimum track energy for isolation requirement-->
  <parameter name="MuonIsolationMinimumTrackEnergy" type="float">3 </parameter>
  <!-- Muon: Polynomial cut (A) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="MuonIsolationPolynomialCutA" type="float">0.01 </parameter>
  <!-- Muon: Polynomial cut (B) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="MuonIsolationPolynomialCutB" type="float">0 </parameter>
  <!-- Muon: Polynomial cut (C) on track energy and cone energy: Econe^2 < A*Etrk^2+B*Etrk+C-->
  <parameter name="MuonIsolationPolynomialCutC" type="float">0 </parameter>

                                                    ...

<!--Use lepton cone protection for neutral particles inside the cone -->
  <parameter name="UseLeptonConeProtection" type="bool"> true </parameter>
  <!--Cosine of the half-angle of the cone used in lepton associated particle identification criteria-->
  <parameter name="CosLeptonAssociatedConeAngle" type="float">0.998 </parameter>
```

[μμHννqq channel] Comparison of numbers

Just run the entire process, following the submit.sh

With original IsolatedLeptonFinder



With modified IsolatedLeptonFinder

```
-bash-4.1$ ./submit.sh  1.4.2
run mumuHzz
plot pictures and save results
Plot information...
scale for signal is 0.010008768
name                    scale                   final
e2e2h_az                0.0005824               0.0005824
e2e2h_e3e3              0.023968                1.07856
e2e2h_ww                0.08176                 9.97472
e2e2h_zz                0.010024                0.160384
e3e3h_ww                0.0812                  0.3248
e3e3h_zz                0.009968099681          0.079744797448
nnh_zz                  0.06832                 11.34112
zz_sl0tau_up            1.10880522921           1.10880522921
zz_l0taumu              1.0404004004            2.0808008008


cut                     llhzz         zh            2f            4f
Raw events              1000          1140511       801811977     107203890
Pre-selection           616           30494         480828        515450
Signal or not           211           30282         480828        515450
missingM > M(dijet)     107           1608          115062        28809
M(dimuon)               95            725           73741         6830
RecM(dimuon)            93            671           4911          1032
N(pfo)                  89            253           1396          324
Pt(total visible)       85            235           261           77
Min angle               81            225           216           64
Missing Mass & M(dijets) 63           65            0             6
Single jet              56            56            0             3
RecM(dijet) not qqhzz   56            56            0             3
VisM not vvhzz          47            22            0             3
-bash-4.1$
```

```
-bash-4.1$ ./submit.sh 1.4.2
run mumuHzz
plot pictures and save results
Plot information...
scale for signal is 0.010008768
name                    scale                   final
e2e2h_az                0.0005824               0.0005824
e2e2h_e3e3              0.023968                1.102528
e2e2h_ww                0.08176                 10.87408
e2e2h_zz                0.010024                0.180432
e3e3h_ww                0.0812                  0.3248
e3e3h_zz                0.009968099681          0.089712897129
nnh_zz                  0.06832                 11.54608
zz_sl0tau_up            1.10880522921           1.10880522921
zz_l0taumu              1.0404004004            2.0808008008


cut                     llhzz         zh            2f            4f
Raw events              1000          1140511       801811977     107203890
Pre-selection           619           30394         384591        443299
Signal or not           213           30180         384591        443299
missingM > M(dijet)     109           1628          106183        27075
M(dimuon)               97            741           68851         6800
RecM(dimuon)            95            686           4295          925
N(pfo)                  91            264           1418          314
Pt(total visible)       86            246           276           80
Min angle               82            235           261           66
Missing Mass & M(dijets) 64           67            0             6
Single jet              57            58            0             3
RecM(dijet) not qqhzz   57            58            0             3
VisM not vvhzz          48            24            0             3
-bash-4.1$
```

Just after the pre-selection, 2f/4f backgrounds reduce the number, by tagging more electrons, however, the final result remain almost the same

[μμHqqνν channel] Comparison of numbers

With original IsolatedLeptonFinder

```
-bash-4.1$ ./submit.sh  1.4.2
run mumuHzz
plot pictures and save results
Plot information...
scale for signal is 0.010008768
name                    scale                   final
e2e2h_az                0.0005824               0.0821184
e2e2h_bb                0.21896                 297.56664
e2e2h_cc                0.011032                3.552304
e2e2h_e3e3              0.023968                4.242336
e2e2h_gg                0.0326888819557         0.653777639114
e2e2h_ww                0.08176                 180.44432
e2e2h_zz                0.010024                4.079768
e3e3h_az                0.0005768               0.0011536
e3e3h_ww                0.0812                  0.0812
e3e3h_zz                0.009968099681          1.35566155662
qqh_az                  0.0117041170412         0.0234082340823
qqh_e2e2                0.00168                 0.0084
qqh_e3e3                0.4844                  3.3908
qqh_ww                  1.6464                  1.6464
qqh_zz                  0.20216                 13.34256
zz_sl0mu_up             1.09032214858           33.7999866059
zz_sl0mu_down           1.08025726079           137.19267212
zz_sl0tau_down          1.10887174477           3.3266152343
ww_sl0muq               1.2235862395            1.2235862395


cut                     llhzz       zh          2f          4f
Raw events              1000        1140511     801811977   107203890
Pre-selection           616         30494       480828      515450
Signal or not           211         30282       480828      515450
M(dijet) > missingM     103         28674       365766      486640
M(dimuon)               92          22473       215445      239022
RecM(dimuon)            90          21802       13226       17787
N(pfo)                  87          16327       186         14406
Pt(total visible)       66          3423        0           744
Min angle               64          3294        0           711
Missing Mass & M(dijets) 43         703         0           200
Single jet              38          589         0           189
RecM(dijet) not qqhzz   35          510         0           175
VisM not vvhzz          35          510         0           175
-bash-4.1$
```

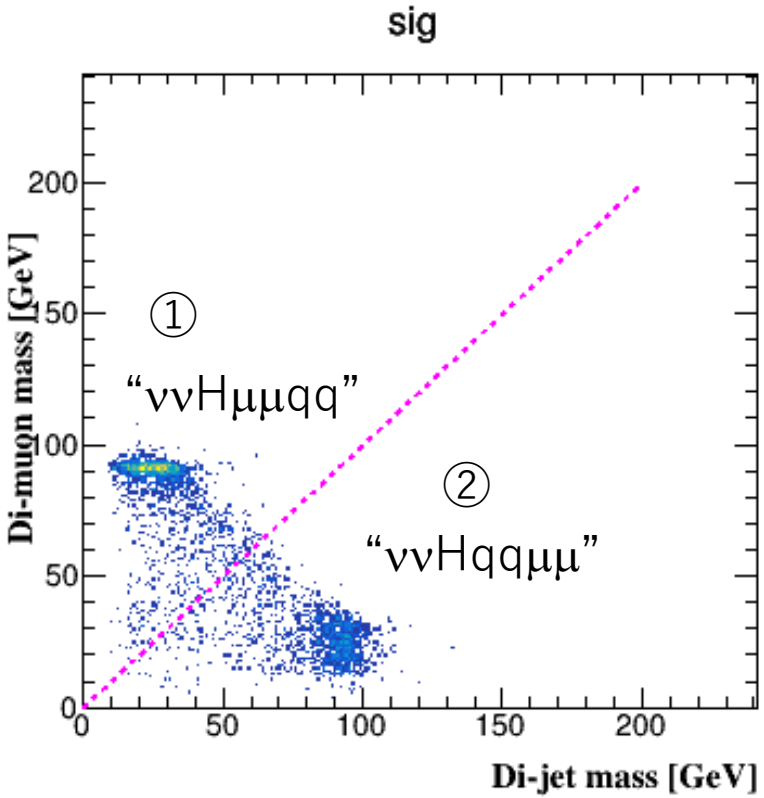
With modified IsolatedLeptonFinder

```
-bash-4.1$ ./submit.sh 1.4.2
run mumuHzz
plot pictures and save results
Plot information...
scale for signal is 0.010008768
name                    scale                   final
e2e2h_az                0.0005824               0.0861952
e2e2h_bb                0.21896                 302.82168
e2e2h_cc                0.011032                3.662624
e2e2h_e3e3              0.023968                4.242336
e2e2h_gg                0.0326888819557         0.653777639114
e2e2h_ww                0.08176                 186.98512
e2e2h_zz                0.010024                4.370464
e3e3h_az                0.0005768               0.0005768
e3e3h_ww                0.0812                  0.0812
e3e3h_zz                0.009968099681          1.39553395534
qqh_az                  0.0117041170412         0.0351123511235
qqh_e2e2                0.00168                 0.0084
qqh_e3e3                0.4844                  3.3908
qqh_ww                  1.6464                  1.6464
qqh_zz                  0.20216                 13.94904
zz_sl0mu_up             1.09032214858           32.7096644573
zz_sl0mu_down           1.08025726079           117.748041426
zz_sl0tau_down          1.10887174477           3.3266152343
ww_sl0muq               1.2235862395            1.2235862395


cut                     llhzz       zh          2f          4f
Raw events              1000        1140511     801811977   107203890
Pre-selection           619         30394       384591      443299
Signal or not           213         30180       384591      443299
M(dijet) > missingM     104         28552       278408      416224
M(dimuon)               93          22401       164401      228082
RecM(dimuon)            91          21731       10643       15742
N(pfo)                  88          16279       179         14063
Pt(total visible)       67          3341        0           725
Min angle               64          3220        0           696
Missing Mass & M(dijets) 43         719         0           180
Single jet              39          603         0           167
RecM(dijet) not qqhzz   35          523         0           155
VisM not vvhzz          35          523         0           155
-bash-4.1$
```

Z(->νν)H(ZZ*->μμ,qq)

・ Like the other channels, 2D map , M(di-jet) vs M(di-muon) (or M(di-jet) vs M^{rec}(di-muon) … what ever we want) show the two bumps

・ The very first cut is set as “M(di-muon) > M(di-jet) “ or vice verse and later on, confine the region more compact



Analysis cut order

cut order, variables are changed . Intended for applying the similar cut chain used in mmHZZ . ⟹ If we could use very identical one, it suggest some topology as well as possibility of simultaneous analysis

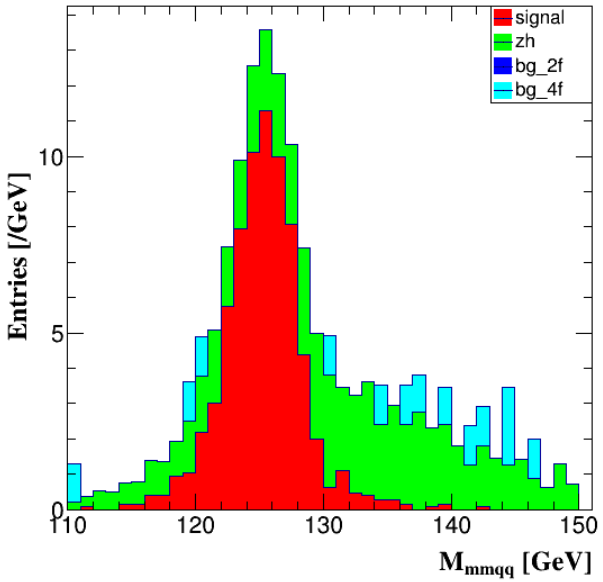
Original	Try
$20 < N(pfo) < 73$	$M(dimuon) > M(dijet)$
$115\ GeV < M(vis\_all) < 135\ GeV$	$100\ GeV < M(vis\_all) \sim M(Higgs) < 150\ GeV$
$-0.9 < cos < 0.9$ <-- this cos is ??	$70\ GeV < M_{recoil}(vis\_all) < 120\ GeV$
$104 < M_{recoil}(dimuon) < 162$ && $190 < M < 214$	$20 < N(pfo) < 73$
$43\ GeV < P(vis\_all) < 60\ GeV$	$-0.95 < Cos_{vis\_all}(polar\ angle) < 0.95$
$14 < M(dijet) < 55$ && $81 < M < 99$	$30\ GeV < P(vis\_all) < 70\ GeV$
$69GeV > E(leading\ jet) > 14\ GeV$	Angle between Z<->Z* <142 degree
$49GeV > E(sub\ leading\ jet) > 3\ GeV$	$M(dimuon) > 80\ GeV$ && $M(dijet) < 40\ GeV$
Angle between Z<->Z* <142 degree	$69GeV > E(leading\ jet) > 14\ GeV$
$-0.9 < Cos_{vis\_all}(polar\ angle) < 0.9$	$49GeV > E(sub\ leading\ jet) > 3\ GeV$
$78\ GeV < M_{recoil}(vis\_all) < 100\ GeV$	*Jet selection (E(jet)) could be set earlier even for mmHZZ .*
Not . $122 < M_{recoil}(dimuon) < 128$	
Not . $122 < M_{recoil}(dijet) < 128$	

① Z(->νν)H(Z->μμ, Z*->qq)

- Very temporal result is $\frac{\sqrt{S+B}}{S} = \frac{\sqrt{71+68+14}}{71} = 17.2\%$

- Probably, we could reduce the background around M~135-150GeV (plus, “RecM(dimuon) not mmHzz” could reduce more to be consistent procedure)

→ 14~15 % is expected, at least. (may close to 13%)




```
-bash-4.1$
-bash-4.1$ ./submit.sh 2.4.2
run nnHzz
plot pictures and save results
Plot information...
scale for signal is 0.06844992
name                    scale                   final
e2e2h_az                0.0005824               0.0011648
e2e2h_e3e3              0.023968                1.462048
e2e2h_ww                0.08176                 20.60352
e2e2h_zz                0.010024                45.789632
e3e3h_e2e2              8.288e-05               0.00024864
e3e3h_e3e3              0.023912                0.023912
e3e3h_ww                0.0812                  0.6496
e3e3h_zz                0.009968099681          0.109649096491
nnh_zz                  0.06832                 0.06832
zz_sl0tau_up            1.10880522921           2.21761045841
zz_sl0tau_down          1.10887174477           1.10887174477
zz_l0taumu              1.0404004004            2.0808008008
ww_sl0muq               1.10890944134           1.10890944134
ww_sl0tauq              1.10899434445           4.43597737778
zzorww_l0mumu           1.10891486372           3.32674459116


cut                     nnhzz       zh          2f          4f
Raw events              6844        1140511     801811977   107203890
Pre-selection           238         30494       480828      515426
Signal or not           226         30268       480828      515426
M(dimuon)>M(dijet)      125         2832        421952      156993
Vis_mass                121         495         75645       12228
M(missing)              114         371         5792        2651
Npfo                    110         145         2015        701
Polar Angle             104         137         272         212
vis_all_p               101         115         27          114
Z-Z* angle              96          100         20          76
M(dimuon),M(dijet)      73          71          14          36
jet_lead_e              71          69          0           15
jet_sub_e               71          68          0           14
                        0           0           0           0
                        0           0           0           0
RecM(dimuon) not mmHzz  0           0           0           0
RecM(dijet) not qqHzz   0           0           0           0
-bash-4.1$
```

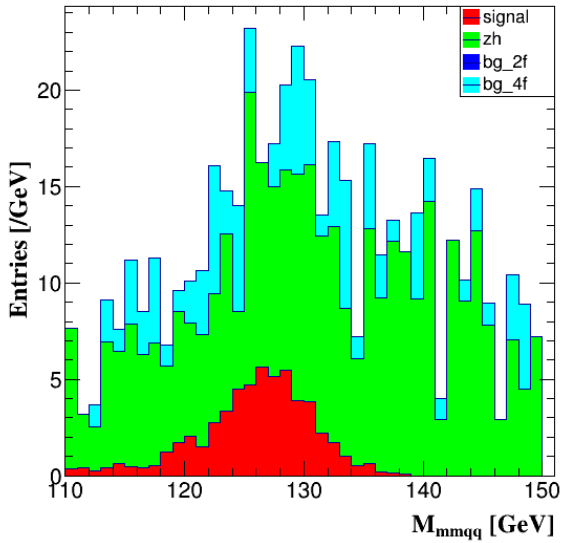
② Z(->νν)H(Z->qq, Z*->μμ)

- Much more background

noticed that the cut is looser than the original

However, tighter cuts like the original , can reduce the signal events a lot.
It is a bit early to mention the numbers, but
possibly, this region ② has factor worse precision

So far, the number of ννHZZ is determined by region ①




```
-bash-4.1$ ./submit.sh 2.4.2
run nnHzz
plot pictures and save results
Plot information...
scale for signal is 0.06844992
name                    scale                   final
e2e2h_az                0.0005824               0.0069888
e2e2h_bb                0.21896                 16.422
e2e2h_cc                0.011032                0.187544
e2e2h_e3e3              0.023968                0.143808
e2e2h_gg                0.0326888819557         0.0980666458671
e2e2h_ww                0.08176                 10.13824
e2e2h_zz                0.010024                1.30312
e3e3h_az                0.0005768               0.002884
e3e3h_bb                0.21784                 4.79248
e3e3h_cc                0.010976                0.098784
e3e3h_e2e2              8.288e-05               0.00016576
e3e3h_e3e3              0.023912                0.167384
e3e3h_gg                0.0326221263644         0.0978663790931
e3e3h_ww                0.0812                  15.1844
e3e3h_zz                0.009968099681          0.637958379584
nnh_ww                  0.5572                  3.3432
qqh_az                  0.0117041170412         0.0117041170412
qqh_e2e2                0.00168                 0.08232
qqh_e3e3                0.4844                  112.3808
qqh_ww                  1.6464                  144.8832
qqh_zz                  0.20216                 36.3888
zz_sl0mu_down           1.08025726079           9.72231534709
zz_sl0tau_up            1.10880522921           21.0672993549
zz_sl0tau_down          1.10887174477           53.2258437489
zz_l04tau               0.258421381722          0.258421381722
ww_sl0muq               1.10890944134           4.43563776534
ww_sl0tauq              1.10899434445           5.54497172223
sze_l0mu                1.10916641266           7.7641648886


cut                     nnhzz       zh          2f          4f
Raw events              6844        1140511     801811977   107203890
Pre-selection           238         30494       480828      515426
Signal or not           226         30268       480828      515426
M(dimuon)>M(dijet)      101         27436       58876       358433
Vis_mass                100         1574        2759        27121
M(missing)              94          1117        725         5872
Npfo                    90          958         37          3348
Polar Angle             86          917         0           1103
vis_all_p               84          847         0           829
Z-Z* angle              80          602         0           242
M(dimuon),M(dijet)      63          382         0           134
jet_lead_e              58          349         0           106
jet_sub_e               57          346         0           102
                        0           0           0           0
                        0           0           0           0
RecM(dimuon) not mmHzz  0           0           0           0
RecM(dijet) not qqHzz   0           0           0           0
-bash-4.1$
```

Summary

・ Update of the electron finder in the IsolatedLeptonfinder, does not affect our final results

==> No need to run it again right now.
We could update the result next time, when we need to run the analysis from the beginning. (of course, final version of the CEPC memo and/or the draft should contain the result with this update)

・ $\nu\nu$HZZ can be divided into two regions. It seems,,, one of region, namely, Z(->$\nu\nu$)H(Z->$\mu\mu$, Z*->qq) has better precision than the other.

Comment/idea

・ Can we arrange the cut chain , somehow , in a similar way ？ At least , ννHZZ shows that potential .

・ Can we think 3D map like the right figure ?

- In fact, the main cut flow is to confine each region in 3D-like space. (of course, actual dimension is more)

- We have 6 channels, but they can be classified into 3 regions, in 3D map like that.
- For example, μμHννqq and ννHμμqq has similar precision (= similar background level) and has certain overlap each other. worth to display it on the 3D map.

- If we can treat the signal as "μμHZZ+ννHZZ+qqHZZ" and then, separate the analysis regions into 3, what happens ?