$H \to \gamma\gamma$ progress

CEPC Physics Performance Wednesday Working Meeting

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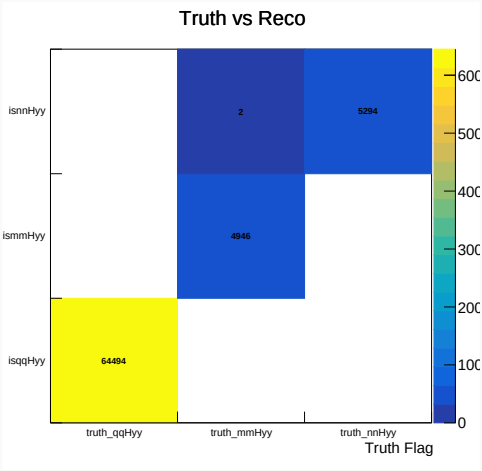
Additional selections

In analysis package, all signal/bkgs mixed and developing an event discriminator with flags for each signal/bkg:

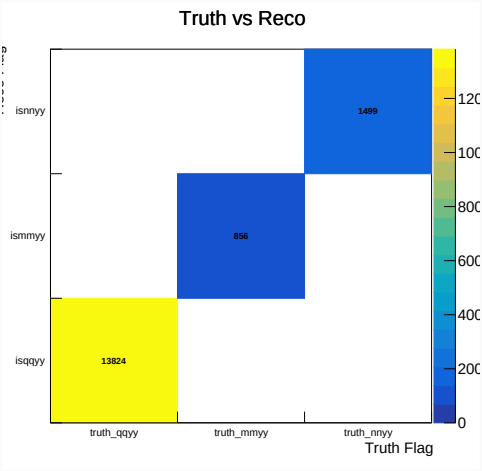
- $\mu^+\mu^-\gamma\gamma$ sub-channel:
  jet-veto: $N_{PFO} < 20$
  2 muons: 2 leading energy charged PFOs (exactly 2 charged PFOs to veto all other charged particles) & $|m_{\mu\mu} - m_Z| < 10$ GeV
  neutrino veto: ($|E_{missing}| < 10$ GeV & $|M_{missing}| < 10$ GeV)
- $\nu\bar{\nu}\gamma\gamma$ sub-channel:
  jet-veto: $N_{PFO} < 20$
  0 charged particle required to get rid of all tracks (selections on missing energy/mass in cutflow)
- $q\bar{q}\gamma\gamma$ sub-channel:
  $N_{PFO} > 20$

Contamination matrix for signal



Little to no contamination between channels after selections

Contamination matrix for background



Little to no contamination between channels after selections

Cutflow

- Keeping the same cutflow as previously with some selections to consider depending on background efficiency ($M^{\gamma\gamma}_{recoil}$ in $\mu^+\mu^-$ channel for example)
- For signal, all channels with practically same number of Final selected events except $\mu^+\mu^-$ as the new flag for our two muons has an efficiency of 67.73 % (vs. previously Exclusive 2 photons & 2 muons: 72.01 % (7201 events)
- After running on background awhile using new flags for sub-channels (Different package: FastSim Delphes file structure different than CEPCSW reco files) $\rightarrow$ better rejection as expected especially for $q\bar{q}$ & $\mu^+\mu^-$ channels

Cutflow comparison: qq signal

Most recent result:

```
===== Event Selection Summary (qq channel) =====
Total events processed: 99800
Exclusive 2 jets and 2 photons: 99795 (99.995%)
E_y1 > 20 GeV: 90686 (90.8723%)
30 GeV < E_y2 < 100 GeV: 82246 (90.6932%)
cos(theta_yy) > -0.95: 80516 (97.8966%)
cos(theta_jj) > -0.95: 78804 (97.8737%)
pT_y1 > 20 GeV: 72114 (91.5106%)
pT_y2 > 30 GeV: 68233 (94.6182%)
110 GeV <m_yy < 140 GeV: 64494 (94.5202%)
E_yy > 110 GeV: 64494 (100%)
min|cos(theta_yj)| < 0.9: 64494 (100%)
Final selected events:       64494 (64.6232%)
Expected yield at 20ab^-1: 4013.86 events
```

Signal events

Selection Step	Events (Efficiency)
Total events generated	99800
Exclusive 2 jets and 2 photons	99800 (100%)
$E_{\gamma 1} > 20$ GeV	90691 (90.87%)
30 GeV $< E_{\gamma 2} <$ 100 GeV	82251 (90.69%)
$\cos\theta_{\gamma\gamma} > -0.95$	80521 (97.90%)
$\cos\theta_{jj} > -0.95$	78808 (97.87%)
$p_{T,\gamma 1} > 20$ GeV	72117 (91.51%)
$p_{T,\gamma 2} > 30$ GeV	68236 (94.62%)
$110 < m_{\gamma\gamma} <$ 140 GeV	64496 (94.52%)
$E_{\gamma\gamma} > 110 GeV$	64496 (100%)
$\min\lvert\cos_{\gamma j}\rvert >$ 0.9 GeV	64496 (100%)
Final selected events	64496 (64.63%)
Expected yield at 20 ab^{-1}	4013.99 events

Cutflow comparison: qq background

Most recent result:

```
===== Event Selection Summary (qq channel) =====
Total events processed: 440203
Exclusive 2 jets and 2 photons: 391674 (88.9758%)
E_y1 > 20 GeV: 387178 (98.8521%)
30 GeV < E_y2 < 100 GeV: 102068 (26.362%)
cos(theta_yy) > -0.95: 91484 (89.6304%)
cos(theta_jj) > -0.95: 81971 (89.6015%)
pT_y1 > 20 GeV: 42114 (51.3767%)
pT_y2 > 30 GeV: 31246 (74.1939%)
110 GeV <m_yy < 140 GeV: 13824 (44.2425%)
E_yy > 110 GeV: 13824 (100%)
min|cos(theta_yj)| < 0.9: 13824 (100%)
Final selected events:       13824 (0.0558785%)
Expected yield at 20ab^-1: 604682 events
```

Background events

Selection Step	Events (Efficiency)
Total events generated	24739403 (100%)
Gen Filter ($m_{\gamma\gamma} \geq 90$)	3375000 (13.64%)
Delphes fast sim ($m_{\gamma\gamma} \geq 90$)	440203 (13.04%)
$E_{\gamma 1} > 20$ GeV	433340 (98.44%)
30 GeV $< E_{\gamma 2} <$ 100 GeV	109508 (25.27%)
$\cos\theta_{\gamma\gamma} > -0.95$	98097 (89.58%)
$\cos\theta_{jj} > -0.95$	87978 (89.68%)
$p_{T,\gamma 1} > 20$ GeV	45863 (52.13%)
$p_{T,\gamma 2} > 30$ GeV	34073 (74.29%)
$110 < m_{\gamma\gamma} <$ 140 GeV	15069 (44.23%)
$E_{\gamma\gamma} >$ 110 GeV	15069 (100%)
$\min\lvert\cos_{\gamma j}\rvert >$ 0.9 GeV	15034 (99.77%)
Final selected events	15034 (0.0607%)
Expected yield at 20 ab^{-1}	657525.5 events

More than 50k events rejected in this background, will definitely improve our precision

Cutflow comparison: mm signal

Most recent result:

```
===== Event Selection Summary (mm channel) =====
Total events processed: 9898
Exclusive 2 muons and 2 photons: 6704 (67.7309%)
E_y > 35 GeV: 6645 (99.1199%)
|cos(theta_y)| < 0.9: 5661 (85.1919%)
10 GeV < pT_y1 < 70 GeV: 5659 (99.9647%)
30 GeV < pT_y2 < 100 GeV: 5648 (99.8056%)
110 GeV <m_yy < 140 GeV: 5572 (98.6544%)
85 GeV < m^recoil_yy < 105 GeV: 4954 (88.9088%)
125 GeV < E_yy < 145 GeV: 4946 (99.8385%)
Final selected events:       4946 (49.9697%)
Expected yield at 20ab^-1: 153.586 events
```

Signal events

Selection Step	Events (Efficiency)
Total events generated	10000
Exclusive 2 photons & 2 muons	7201 (72.01%)
$E_\gamma > 35$ GeV	6777 (94.11%)
$\lvert\cos(\theta_\gamma)\rvert < 0.9$	5771 (85.16%)
$10\ GeV < p_T^{\gamma 1} < 70\ GeV$	5769 (99.97%)
$30\ GeV < p_T^{\gamma 2} < 100\ GeV$	5758 (99.81%)
$110\ GeV < m_{\gamma\gamma} < 140\ GeV$	5672 (98.51%)
$85\ \text{GeV} < m_{\gamma\gamma}^{recoil} < 105\ \text{GeV}$	5044 (88.92%)
$125\ \text{GeV} < E_{\gamma\gamma} < 145\ \text{GeV}$	5036 (99.84%)
Final selected events	5036 (50.36%)
Expected yield at 20 ab^{-1}	154.79 events

Cutflow comparison: mm background

Most recent result:

```
===== Event Selection Summary (mm channel) =====
Total events processed: 64029
Exclusive 2 muons and 2 photons: 11829 (18.4744%)
E_y > 35 GeV: 7848 (66.3454%)
|cos(theta_y)| < 0.9: 1640 (20.897%)
10 GeV < pT_y1 < 70 GeV: 1635 (99.6951%)
30 GeV < pT_y2 < 100 GeV: 1627 (99.5107%)
110 GeV <m_yy < 140 GeV: 943 (57.9594%)
85 GeV < m^recoil_yy < 105 GeV: 863 (91.5164%)
125 GeV < E_yy < 145 GeV: 856 (99.1889%)
Final selected events:       856 (0.00794183%)
Expected yield at 20ab^-1: 8470.3 events
```

Background events

Selection Step	Events (Efficiency)
Total events generated	10778370 (100%)
Gen Filter ($M_{\gamma\gamma} \geq 90$)	882451 (8.19%)
Delphes fast sim ($M_{\gamma\gamma} \geq 90$)	64029 (7.26%)
$E_\gamma > 35$ GeV	39609 (61.86%)
$\lvert\cos\theta_\gamma\rvert < 0.9$	14208 (35.87%)
$10GeV < p_T^{\gamma 1} < 70GeV$	13192 (92.85%)
$30GeV < p_T^{\gamma 2} < 100GeV$	11502 (87.19%)
$110GeV < m_{\gamma\gamma} > 140GeV$	5574 (48.46%)
85 GeV $< m_{\gamma\gamma}^{recoil} <$ 105 GeV	1198 (21.49%)
125 GeV $< E_{\gamma\gamma} <$ 145 GeV	1176 (98.16%)
Final selected events	1176 (0.01 %)
Expected yield at 20 ab^{-1}	12050.9 events

Almost 4k more events rejected with new selections/flags -> expecting improvement in precision

Cutflow comparison: nn signal

Most recent result:

```
===== Event Selection Summary (nn channel)=====
Total events processed: 8930
Inclusive 2 photons: 7928 (88.7794%)
E_y > 30 GeV: 6645 (98.7639%)
|cos(theta_y)| < 0.8: 5626 (71.8519%)
pT_y > 20 GeV: 5626 (100%)
M_missing > 60 GeV: 5406 (96.0896%)
110 GeV < m_yy < 140 GeV: 5324 (98.4832%)
120 GeV < E_yy < 150 GeV: 5296 (99.4741%)
Final selected events:       5296 (59.3057%)
Expected yield at 20ab^-1: 1246.35 events
Execution time: 236.537 seconds
```

Signal events

Selection Step	Events (Efficiency)
Total events generated	9019
Inclusive 2 photons	8930 (99.01%)
$E_\gamma > 30$ GeV	8013 (89.73%)
$\lvert\cos(\theta_\gamma)\rvert < 0.8$	5740 (71.63%)
$p_{T,\gamma} > 20$ GeV	5730 (100%)
$M_{\text{missing}} > 60$ GeV	5489 (95.63%)
110 GeV $< m_{\gamma\gamma} <$ 140 GeV	5351 (97.49%)
120 GeV $< E_{\gamma\gamma} <$ 150 GeV	5322 (99.46%)
Final selected events	5322 (59.01%)
Expected yield at 20 ab^{-1}	1254.86 events

Cutflow comparison: nn background

Most recent result:

```
===== Event Selection Summary (nn channel)=====
Total events processed: 50138
Inclusive 2 photons: 50502 (100.726%)
E_y > 30 GeV: 7848 (83.4363%)
|cos(theta_y)| < 0.8: 3120 (7.40442%)
pT_y > 20 GeV: 3105 (99.5192%)
M_missing > 60 GeV: 3086 (99.3881%)
110 GeV < m_yy < 140 GeV: 1505 (48.7686%)
120 GeV < E_yy < 150 GeV: 1499 (99.6013%)
Final selected events:       1499 (0.00181029%)
Expected yield at 20ab^-1: 19587.2 events
```

Background events

Selection Step	Events (Efficiency)
Total events generated	82804236 (100%)
Gen Filter ($M_{\gamma\gamma} \geq 90$)	1491000 (1.80%)
Delphes fast sim ($M_{\gamma\gamma} \geq 90$)	50138 (3.36%)
$E_\gamma > 30$ GeV	41930 (83.63%)
$\lvert\cos\theta_\gamma\rvert < 0.8$	3114 (7.43%)
$p_{T,\gamma} > 20$ GeV	3099 (99.52%)
$M_{\text{missing}} > 60$ GeV	3086 (99.58%)
110 GeV $< m_{\gamma\gamma} <$ 140 GeV	1505 (48.77%)
120 GeV $< E_{\gamma\gamma} <$ 150 GeV	1499 (99.60%)
Final selected events	1499 (0.0018 %)
Expected yield at 20 ab^{-1}	19655.5 events

Not much change in this channel whether for signal or background

Thank you!

Back-up

Back-up