Prelection for $H \rightarrow \gamma\gamma$ at 3 TeV

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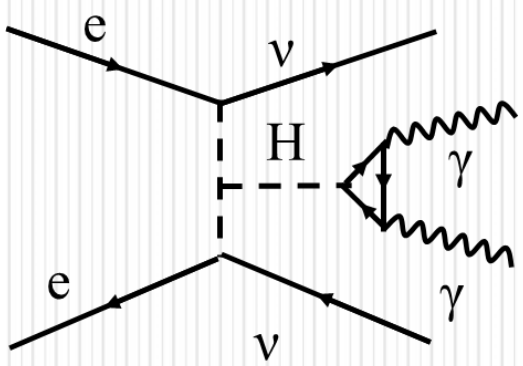
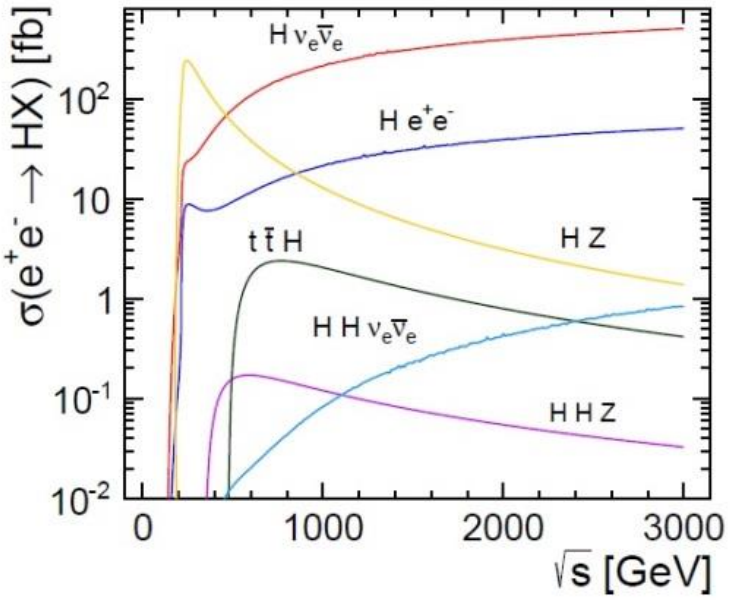
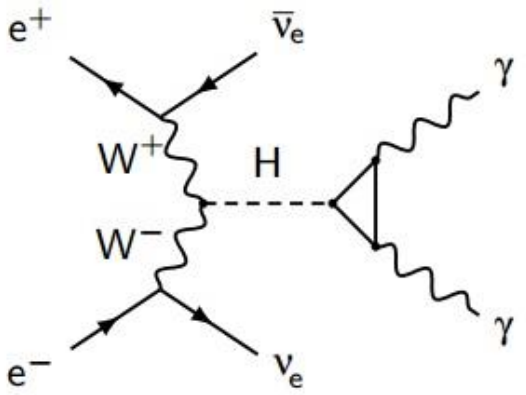


Higgs production at $\sqrt{s} = 3\ TeV$

- Assuming m_h = 126 GeV
- Using WHIZARD v1.95, including ISR and BS
- CLIC_ILD is fully simulated



- WW fusion dominant H production process
- σ (hνν) at 3 TeV is 415 fb
- BR(h→γγ) is 0.23%
- σ (hνν)*BR(h→γγ) ≈0.95 fb
- $N_{signal} \approx 1900evt/2\ ab^{-1}$



Analysis flow

- Preselection – reducing large cross-section backgrounds while conserving the signal.

  The idea is to benefit from the enlarged statistics w.r.t. 1.4 TeV.
- MVA – Signal vs. background separation based on the maximal significance (S).
- Extraction of the statistical uncertainty of the number of signal events – ToyMC or 1/S may be employed.

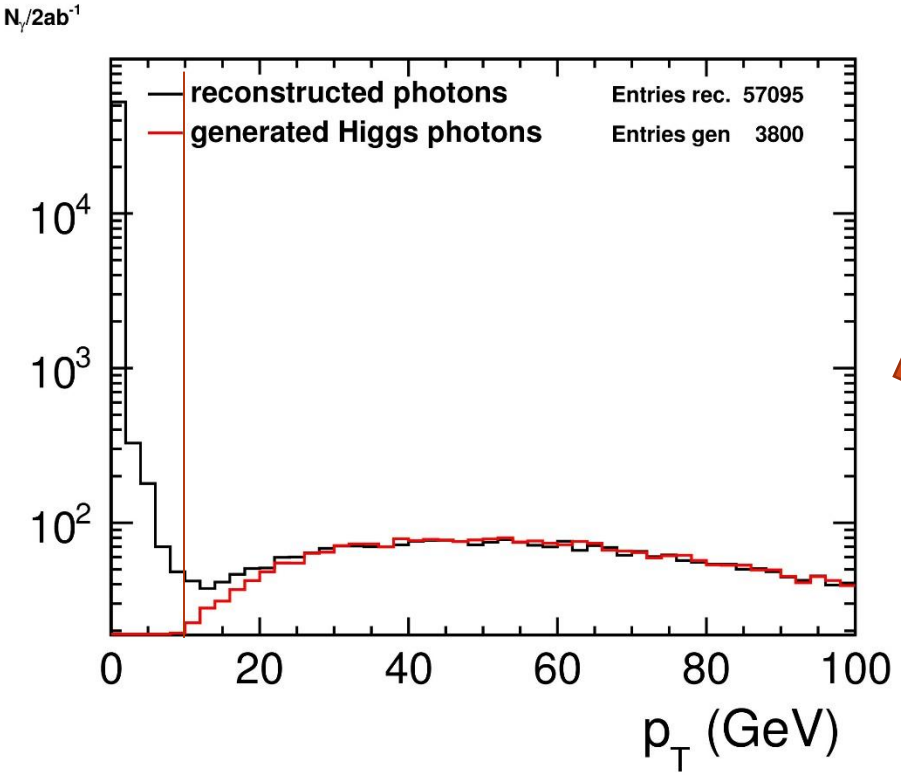
Simple Higgs candidate: Analyse only events with 2 photons

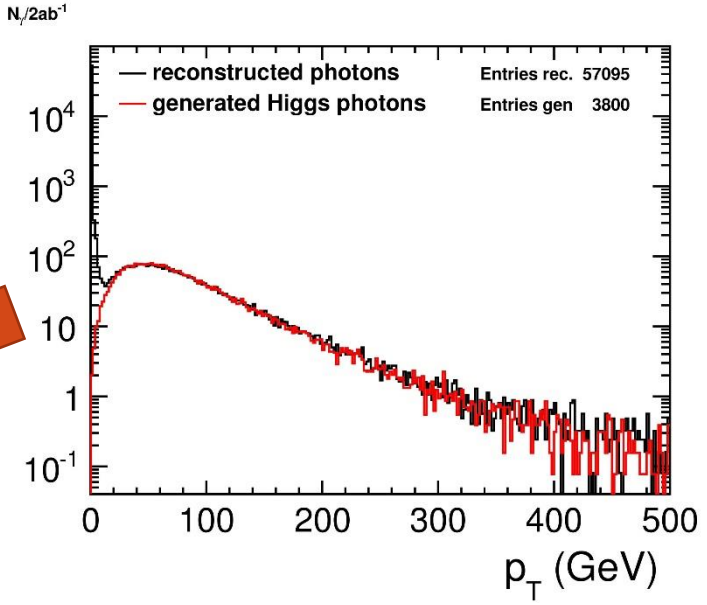
Comparing performances of old vs. new processor

(Pandora v00-11 in ILCSoft v01-17-05 vs. PandoraPFA v03-01-02)

(Improvement of photon reconstruction in PandoraPFA: https://arxiv.org/abs/1603.00013)

Signal: properties of photons - p_T

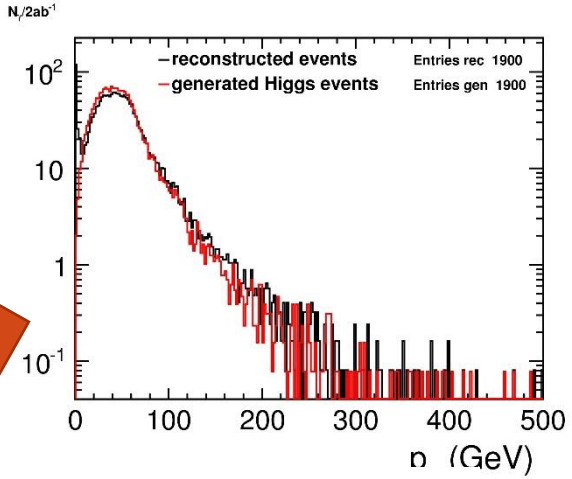


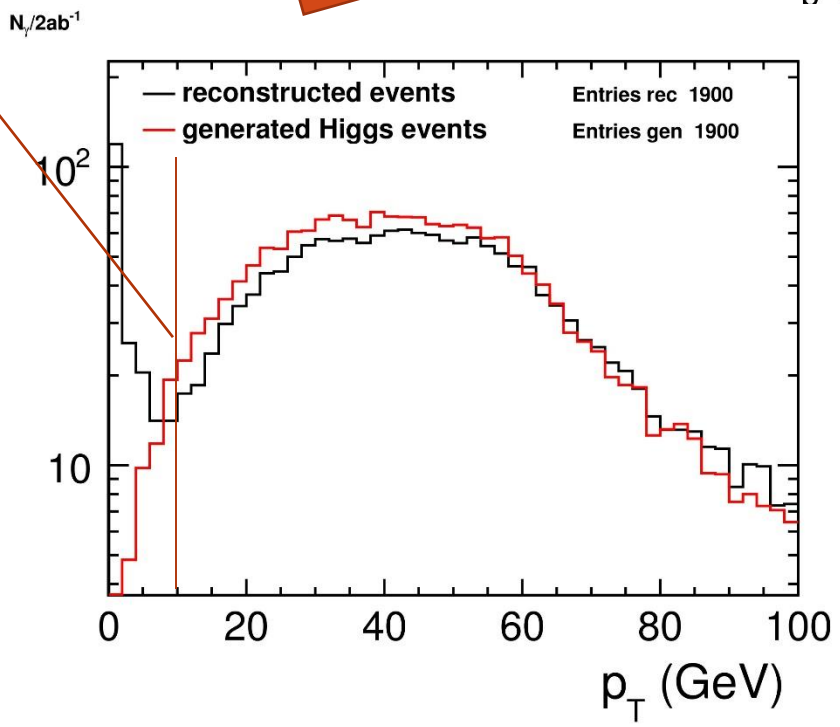


- In average: 30 reconstructed photons per Higgs event
- p_T provides reasonable separation of machine bck. photons from Higgs photons.
- Practically no signal loss

Signal: Photon with 2nd highest p_T

- In 10 % of signal events only 1 Higgs photon is reconstructed.
- Cut on 2nd highest p_T induces very little additional signal loss.
- Next: Photon isolation.
- Events with exactly 2 photons satisfying criteria above.

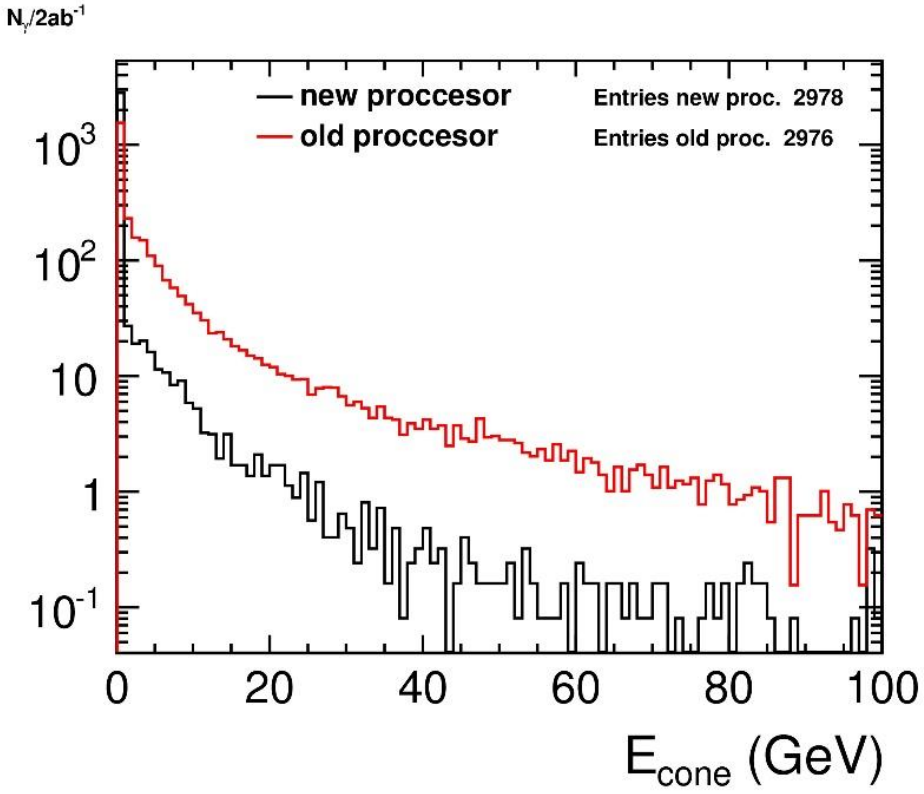




Higgs candidate – photon isolation

E_{PFO} < 20 GeV within 43 mrad (2.5 deg.) around the photon;

Photon isolation provides background reduction while signal is preserved within ≤1 %



- Photon isolation is much improved with the new photon processor in Pandora. Better efficiency of isolation criteria.
- Useful to remove bck. events with hadrons in the final state (eeγ, qqγ)

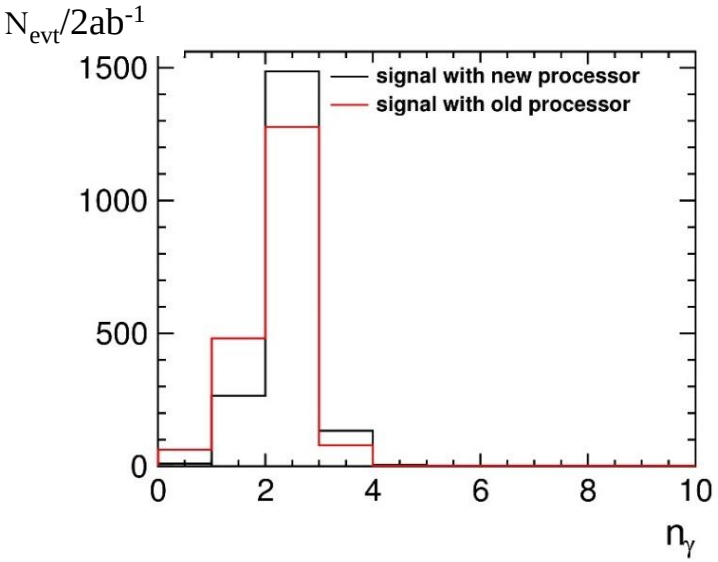
Higgs candidate - looking for events with 2 photons

- 22 % of signal events lost by requiring exactly 2 photons passing p_T and isolation criteria.
- In 10 % of events only one Higgs photon is reconstructed, cannot be recovered.
- ~10 % is in Higgs events with 3 or more selected photons - can try to recover.

No isolation, p_T > 10 GeV (1900 evt)		
Number of photons per event	Selected signal events (old) (%)	Selected signal events (new) (%)
0	0.6	0.5
1	14	10
2	78	78
3	6	11.5

Better performance of the new processor. Many events with only one-photon recovered.

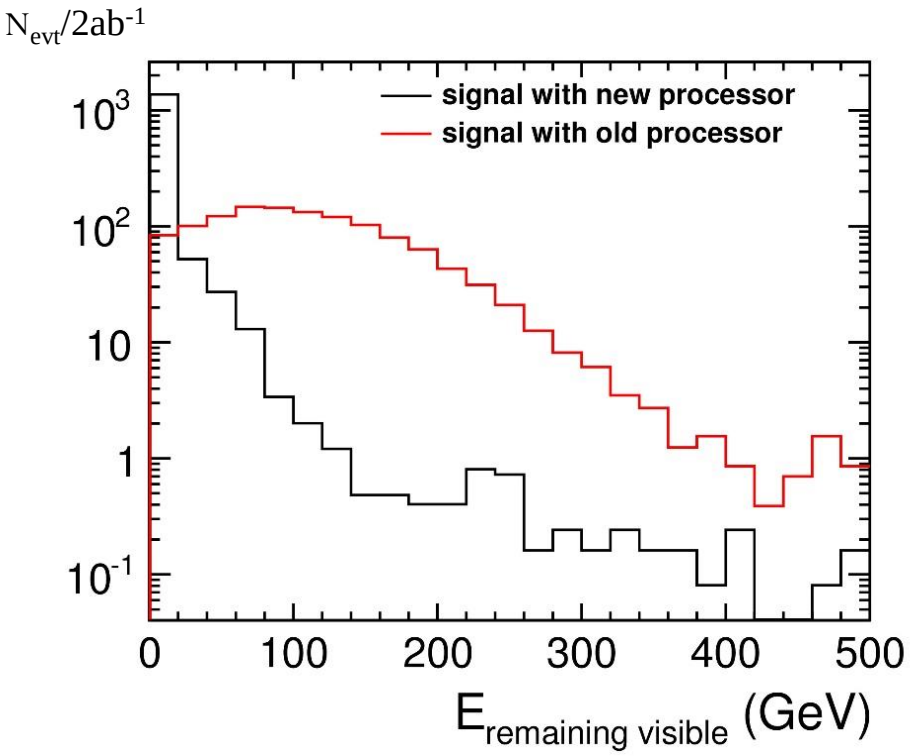
Number of photons passing the isolation and p_T criteria



Isolation, p_T > 10 GeV (1900 evt)		
Number of photons per event	Selected signal events (old) (%)	Selected signal events (new) (%)
0	3.5	0.5
1	25	13
2	67	78
3	4	7
4 or more	0.5	1.5

Comparison of new vs. old processor - remaining visible energy of Higgs candidate event

$$E_{rVis} = \sum E_{PFO} - \sum_{i=1}^{2} E_i$$



Due to better performance new processor finds very few Higgs candidates with E_{rVis} above 100 GeV.

Background

- Signal: 2 ab^{-1} , @ 3 TeV, BR(H→γγ) ~ 0.23 %, 1900 events
- Background: all relevant physics + ISR + FSR + γ_{BS}

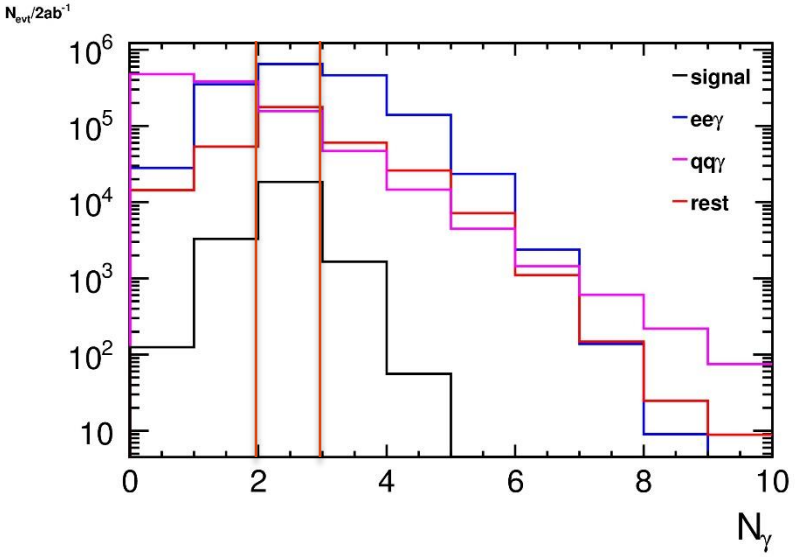
  * StdhepCut applied requesting di-photon events with:

  $p_T > 10$ GeV, $5° < \theta < 175°$, 100 GeV < $M_{\gamma\gamma}$ < 150 GeV

Process	σ (fb)	Expected events at 2ab^{-1}	Generated number of events
ee→γγ	19*	38 000	29 900
ee→eeγ	797*	1 600 000	3 029 000
ee→eeγγ	58*	116 000	144 900
ee→qqγ	583	1 160 000	1 198 600
ee→qqγγ	72	144 000	299 600
ee→νν̄γ	45*	90 000	194 900
ee→νν̄γγ	31*	62 000	155 500
σ(hνν̄) × BR(h→γγ)	0.95	1900	24 500

Background properties

Number of bck. photons per event with new processor



Large fraction of bck. events have more than two photons passing p_T and isolation criteria.

- Exactly two photons in event with $p_T > 10$ GeV
- Isolated photon within cone of 43 mrad with energy bellow 20 GeV

Process	Fake Higgs candidates (old) (%)	Fake Higgs candidates (new) (%)
ee→γγ	61	61
ee→eeγ	55	37
ee→eeγγ	42	26
ee→qqγ	15	4
ee→qqγγ	22	6
ee→νvγ	80	80
ee→νvγγ	73	73

Improvement with new processor in processes where photons are easily confused with other particles

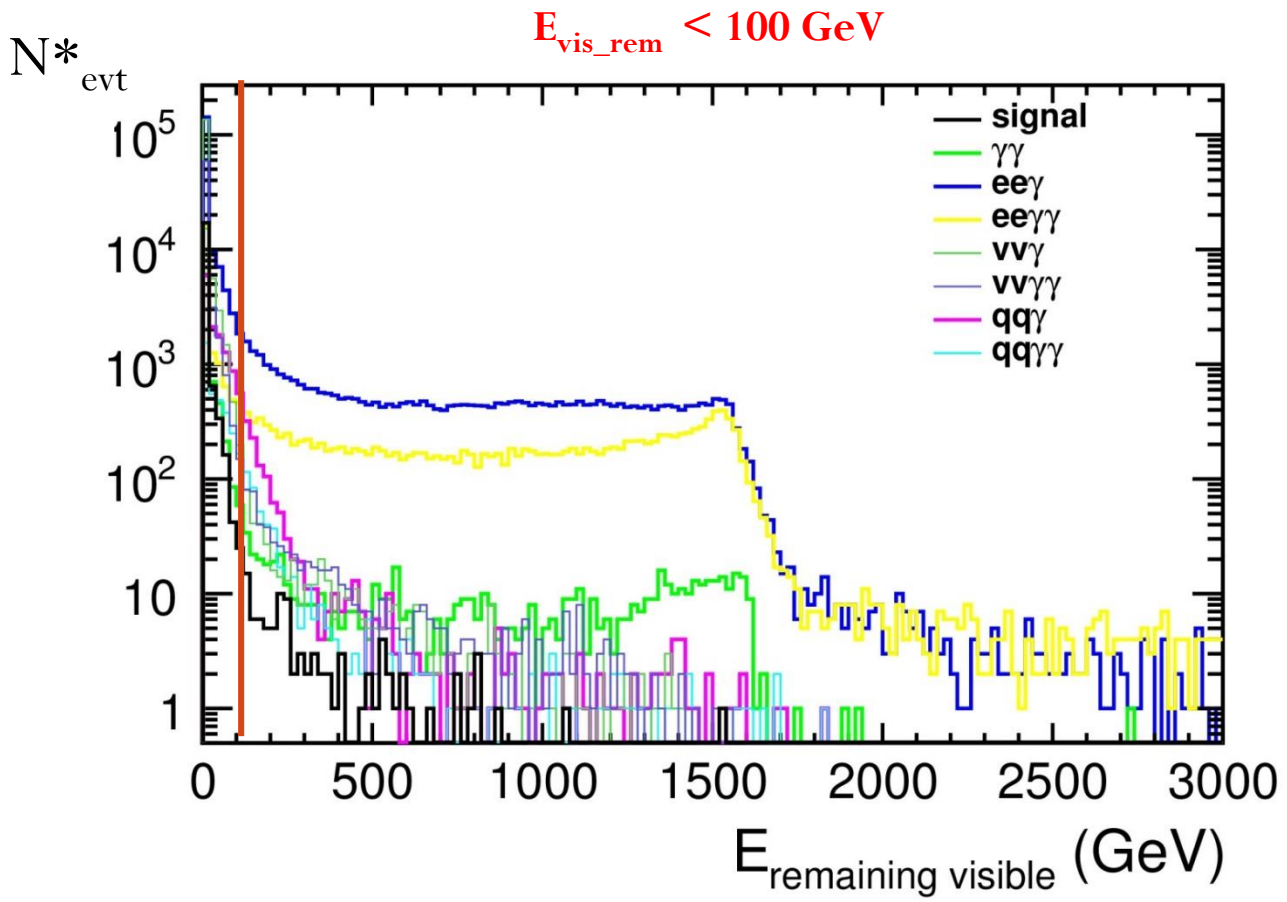
Preselection

- Save as much signal as possible to keep advantage of high Higgs production cross-section at 3 TeV
- Avoid making bias in $m_{\gamma\gamma}$ before TMVA
- Remove kinematically irrelevant background events

Preselection variables

- Exactly 2 photons in the event passing the p_T and isolation criteria
- Remaining visible energy ($E_{vis\_rem} < 100$ GeV)
- Higgs candidate invariant mass window ($110 \text{ GeV} < m_H < 140 \text{ GeV}$)
- Higgs candidate energy ($100 \text{ GeV} < E_H < 1000 \text{ GeV}$)
- Higgs candidate p_T ($p_T > 20$ GeV)

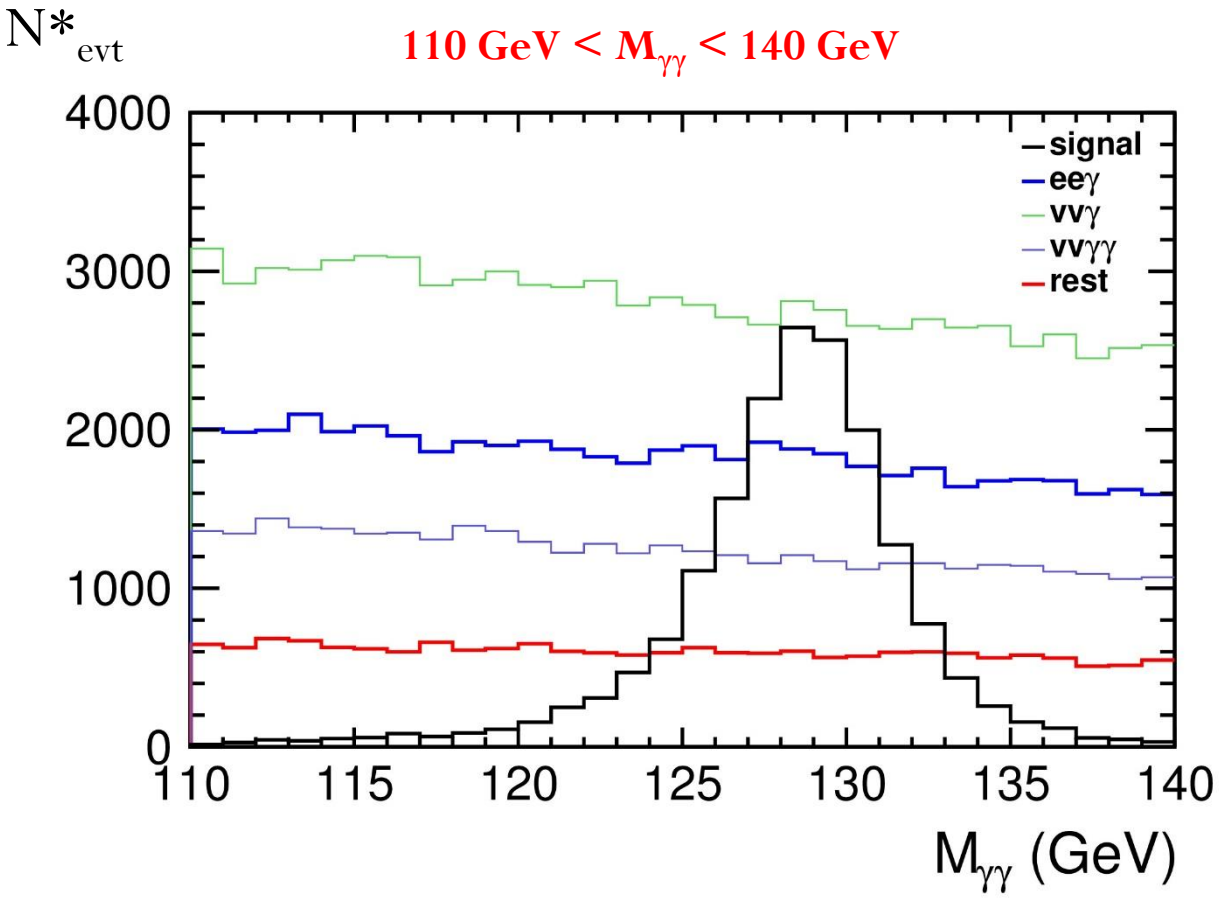
Remaining visible energy



-Most of bck. processes is characterized by significant amount of remaining visible energy

*Available events – not scaled to luminosity

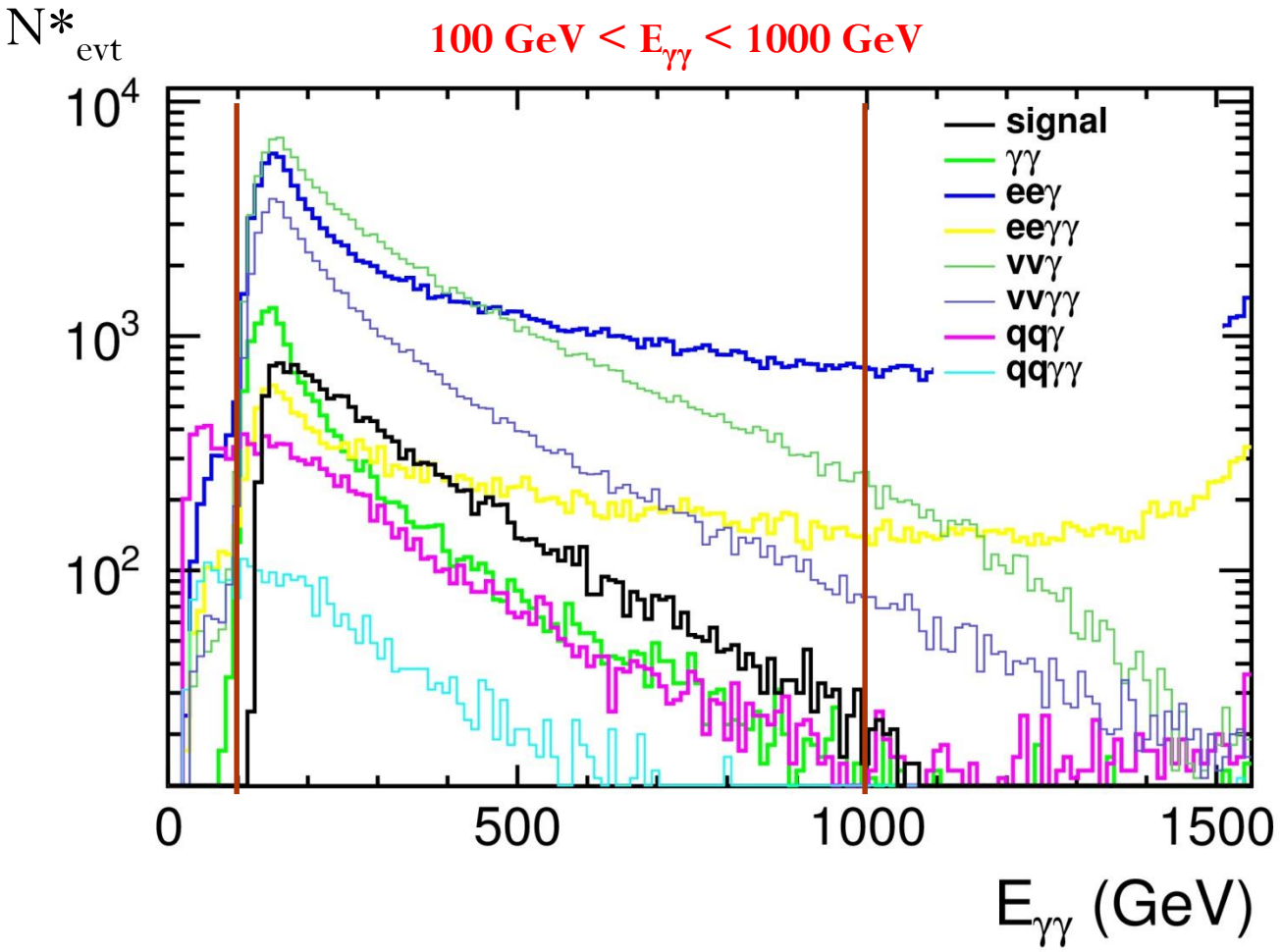
Candidate invariant mass



- Significant amount of bck. processes lay outside invariant mass window

*Available events – not scaled to luminosity

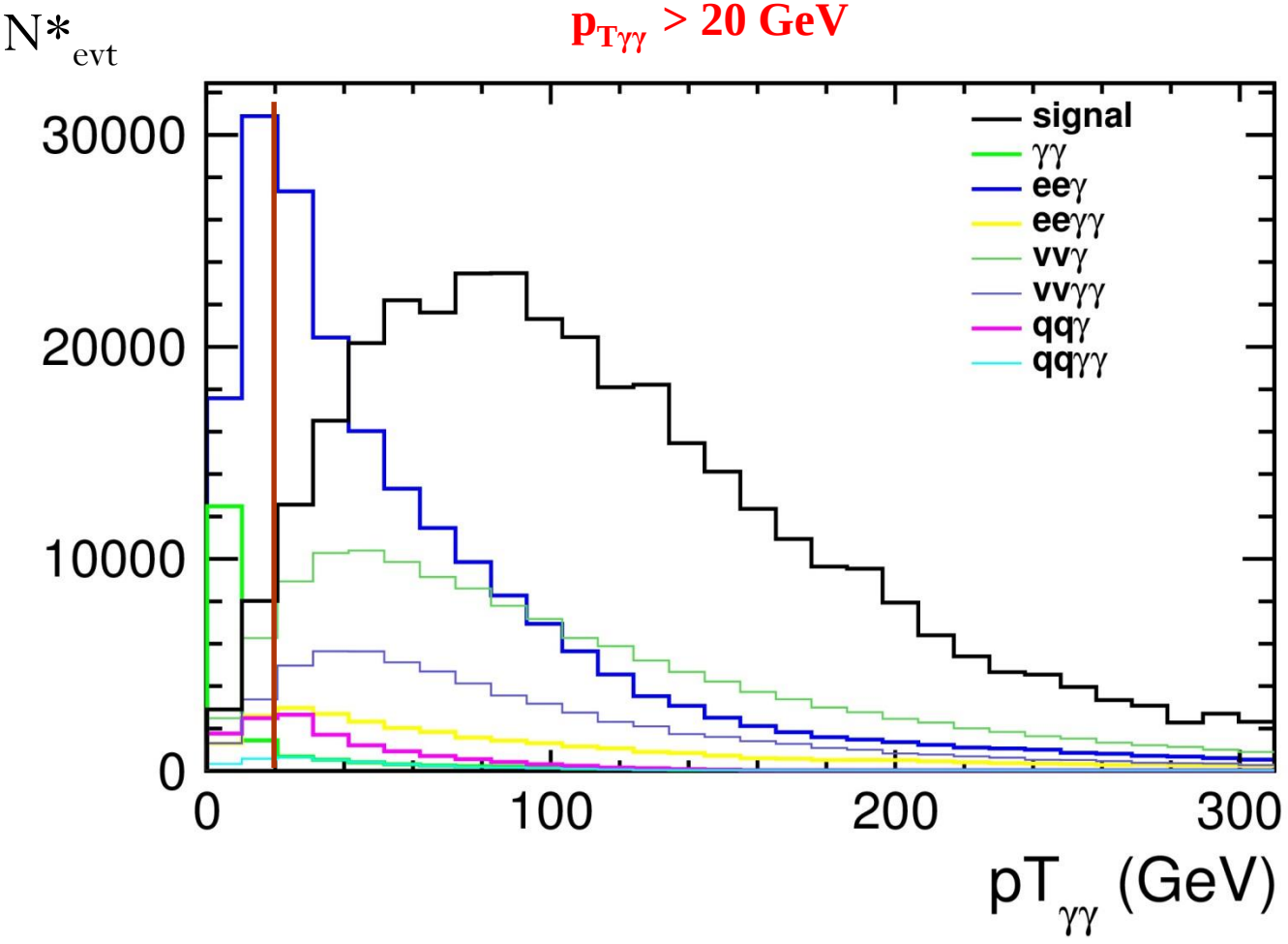
Higgs candidate energy



- Useful to reduce statistically dominant eeγ, qqγ backgrounds
- No impact on signal

*Available events – not scaled to luminosity

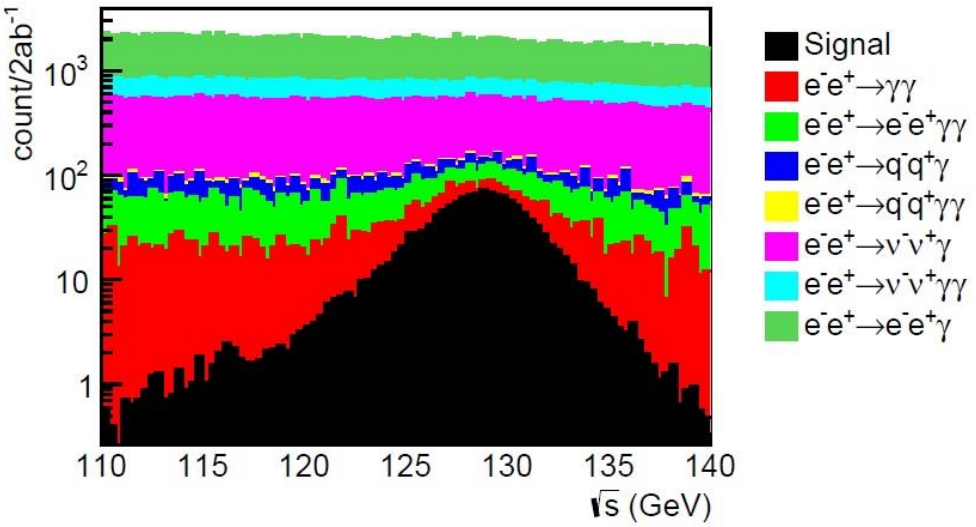
Higgs candidate p_T



- Additional rejection of high cross-section backgrounds (eeγ, qqγ)

Preselection results

Process	Preselection efficiency (%)
ee→γγ	4.6
ee→eeγ	6.9
ee→eeγγ	2.8
ee→qqγ	0.2
ee→qqγγ	0.3
ee→νν̄γ	42.1
ee→νν̄γγ	37.6
σ(hνν̄) × BR(h→γγ)	71.4



- Total signal efficiency is 71.4 %
- Total bck. rejection 94.5 %
- s/b = 6×10^{-4} before preselection
- Signal events after preselection: 1357
- s/b = 8×10^{-3} after preselection

Conclusions

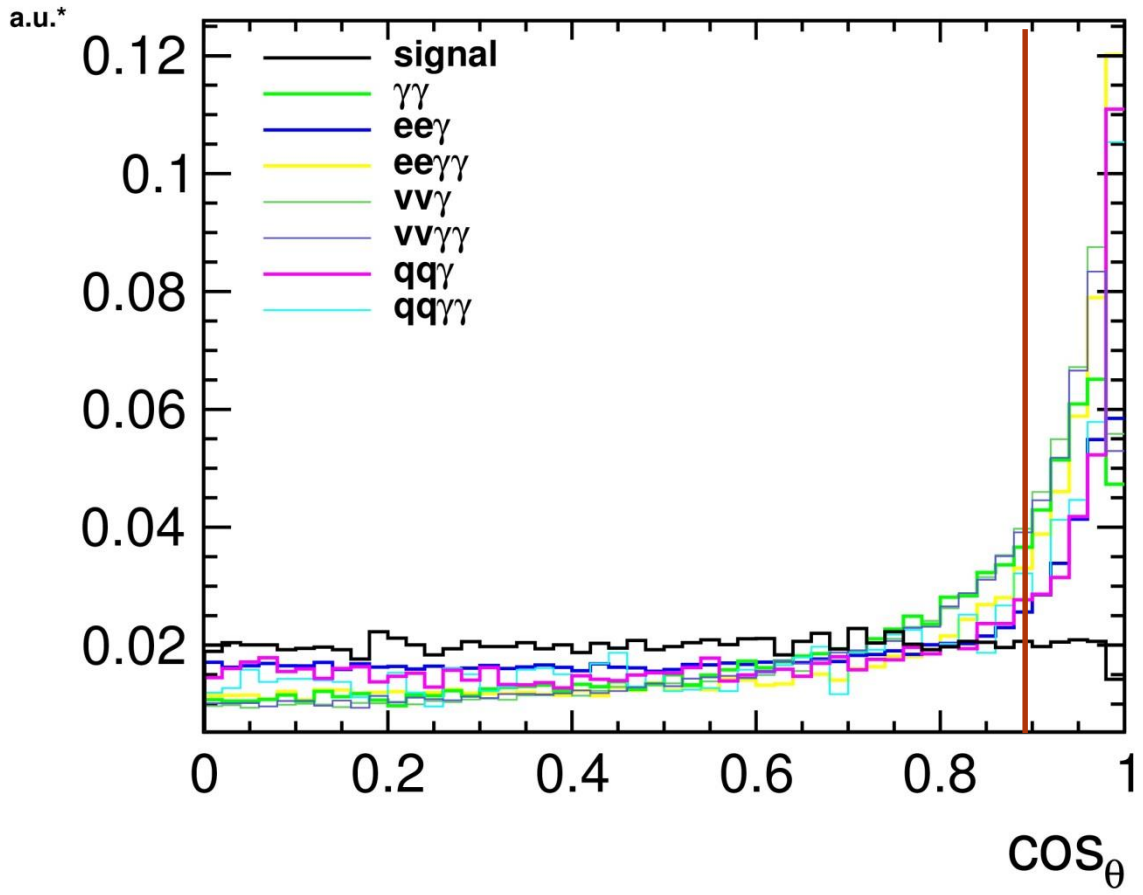
- Preselection for H $\rightarrow\gamma\gamma$ analysis at 3 TeV signal efficiency of 71.4 % and background rejection rate of 94.5 % in 2 ab^{-1} data.
- About 20 % of signal is lost by accepting only events with exactly 2 photons, while another ~10 % is lost by preselection variables.
- New photon reconstruction performs better in reconstruction of events with 2 photons, photon isolation and reconstruction of the remaining visible energy.

Thank you

Back up slides

Cosine of helicity angle

$\cos\theta_{hel} < 0.9$



Cosine of helicity angle for all bck. processes prefer values above 0,9

*arbitrary units – scaled to illustrate shapes of distributions