Update: Trilinear Analysis

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Recap

- Generated LO and $\mathcal{O}(\lambda_3)$ events via madgraph. Can calculate C_1 in bins of kinematic distribution.
- Building up analysis: ZHLeptonic
  - Use ZHLeptonicTag on LHC MC samples
  - Dumper configured to output info of reconstructed + gen-level diphotons and leptons
  - End goal: fit for κ_λ using C_1 values determined from madgraph samples. Sensitivity at 3000 fb^{-1}?

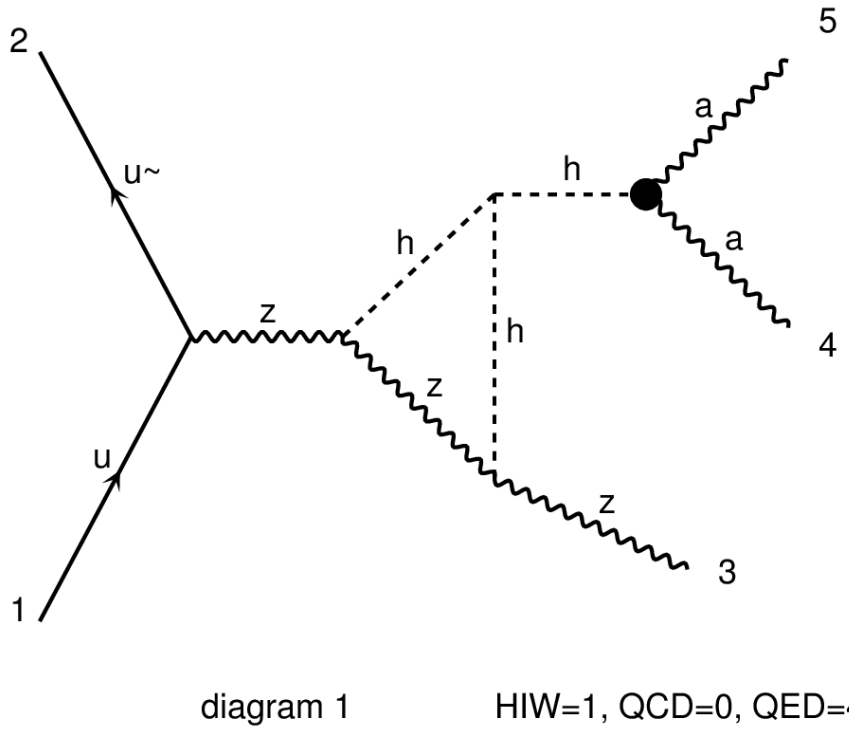
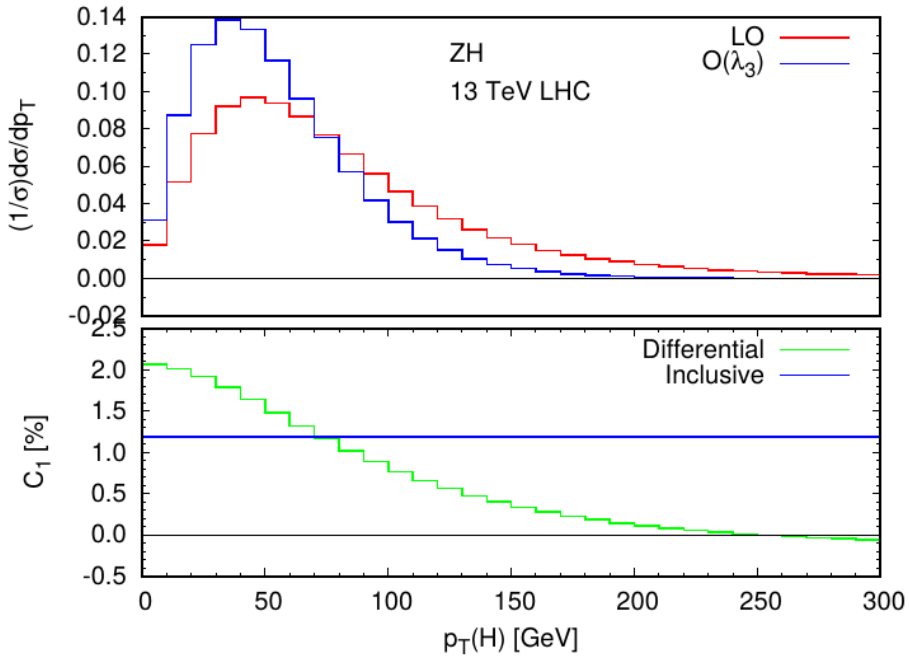
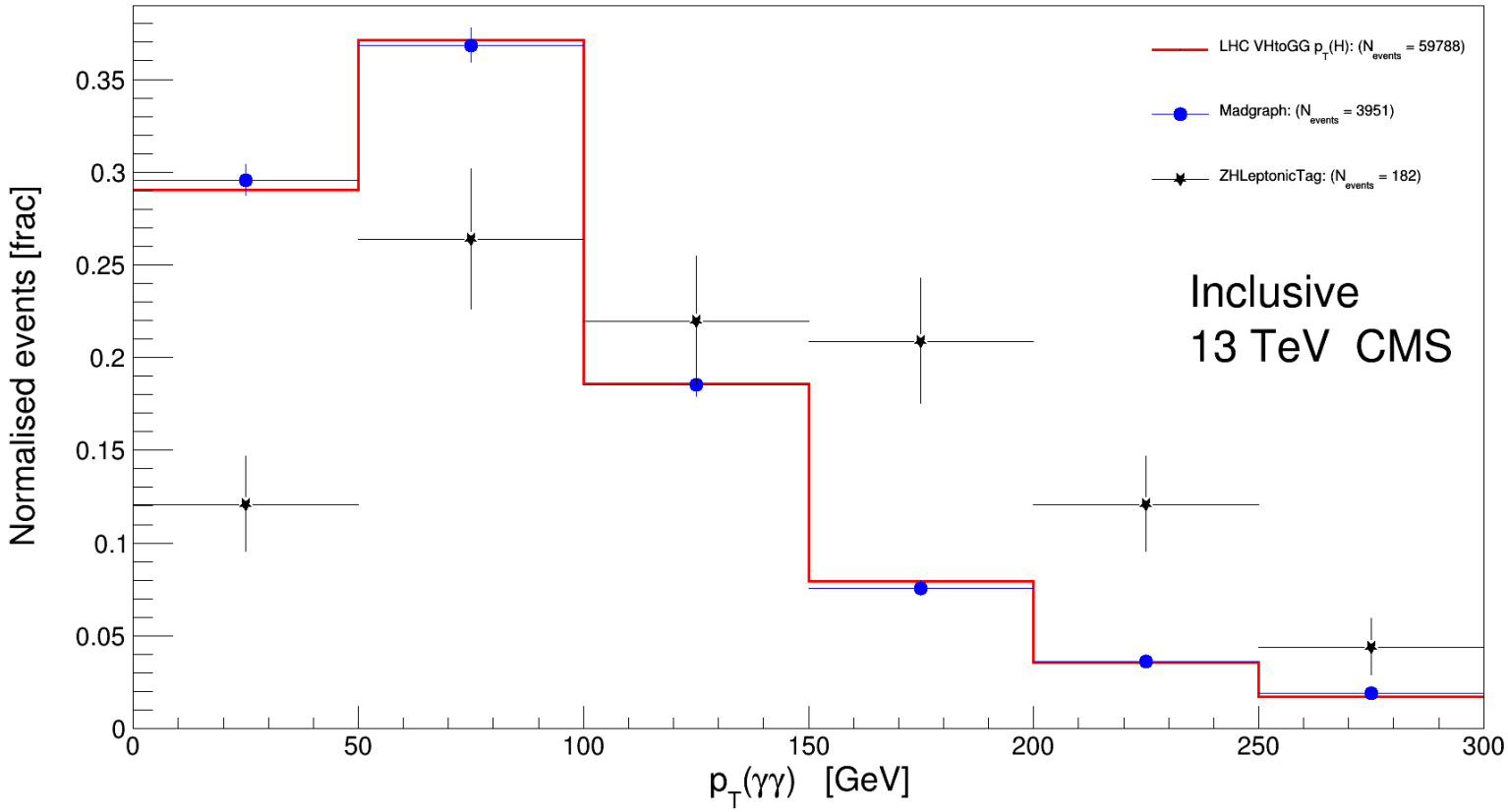


diagram 1 HIW=1, QCD=0, QED=4



Discrepancy at low $p_T(\gamma\gamma)$

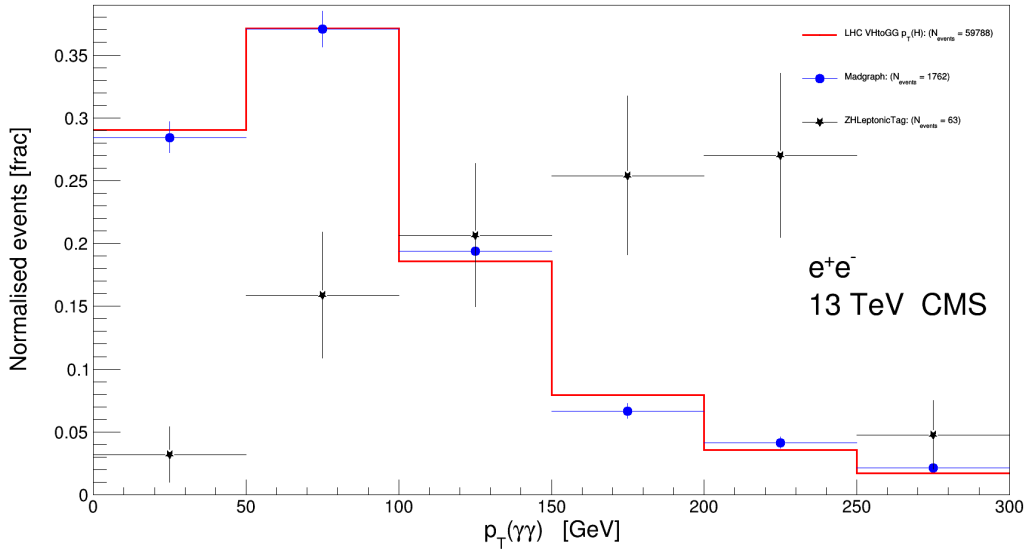
- $p_T(\gamma\gamma)$ spectrum of ZHLeptonicTag events (from LHC sample) has deficit at low $p_T(\gamma\gamma)$ compared to madgraph generated events.
- Inclusive LHC same shape as madgraph: **no significant different in intrinsic kinematics. Selection?**

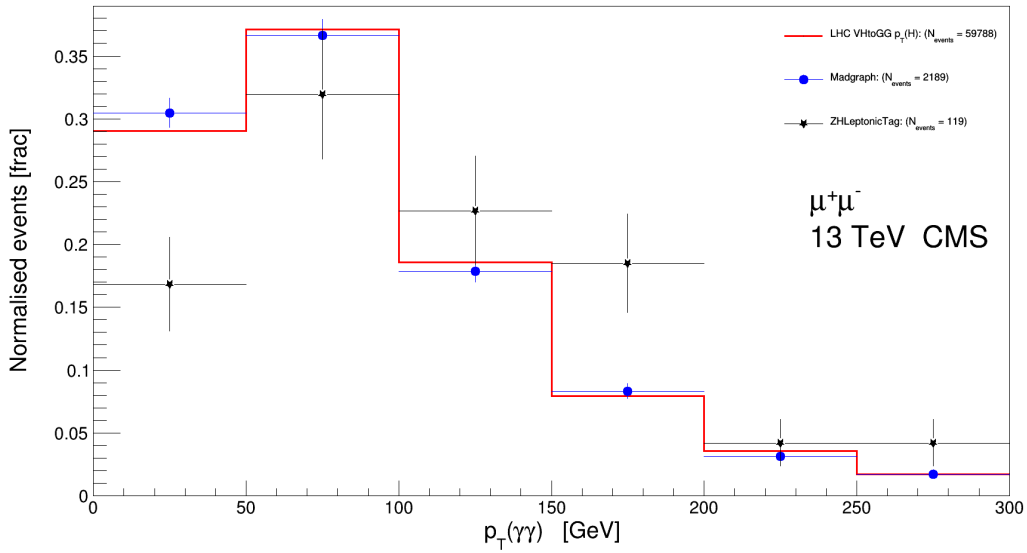


- Idea: Investigate selection with cut-flow output, # of events + mean pT at each stage of selection.

Discrepancy at low $p_T(\gamma\gamma)$

- Split into $Z \to e^+e^-$ (63) and $Z \to \mu^+\mu^-$ (119) and produced separate $p_T(\gamma\gamma)$ spectra.
- See larger deficit of low $p_T(\gamma\gamma)$ in e^+e^- events. Selection for electrons seems to be favouring high $p_T(\gamma\gamma)$.





Cut-flow

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############################################################
                    CUT COUNTERS

00) Total events: 59788
00) Total mean pT(H): 92.9647

01) (Vertex) Events: 29843
01) (Vertex) pT(H): 100.806

02) (LeadPhoPToverMass) Events: 29084
02) (LeadPhoPToverMass) pT(H): 102.344

03) (SubleadPhoPToverMass) Events: 25092
03) (SubleadPhoPToverMass) pT(H): 100.952

04) (Photon ID) Events: 25092
04) (Photon ID) pT(H): 100.952

05) (Diphoton MVA) Events: 23186
05) (Diphoton MVA) pT(H): 103.895

06a) (pT(l) > 20GeV: >=2 leptons passing) Events: 1915
06a) (pT(l) > 20GeV: >=2 leptons passing) pT(H): 122.295
      06a) Electron events: 1537
      06a) Electron pT(H): 116.311
      06a) Muon events: 391
      06a) Muon pT(H): 146.309

06b) (pT(l) > 10GeV: >=2 leptons passing) Events: 3009
06b) (pT(l) > 10GeV: >=2 leptons passing) pT(H): 121.196
      06b) Electron events: 2311
      06b) Electron pT(H): 115.383
      06b) Muon events: 755
      06b) Muon pT(H): 142.868

07a) (Lepton selection (pT20,eta,vtx,ID,dR)) Events: 188
07a) (Lepton selection (pT20,eta,vtx,ID,dR)) pT(H): 137
      07a) Electron events: 64
      07a) Electron pT(H): 174.159
      07a) Muon events: 124
      07a) Muon pT(H): 117.822

07b) (Lepton selection (pT10,eta,vtx,ID,dR)) Events: 214
07b) (Lepton selection (pT10,eta,vtx,ID,dR)) pT(H): 128.793
      07a) Electron events: 67
      07a) Electron pT(H): 169.704
      07a) Muon events: 147
      07a) Muon pT(H): 110.147

08) FINAL (inc (Zmass window)) Events: 182
08) FINAL (inc (Zmass window)) pT(H): 136.553
      08) Electron events: 63
      08) Electron pT(H): 172.739
      08) Muon events: 119
      08) Muon pT(H): 117.395
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Diphoton Selection

pT(l) selection:
a) pT(l) > 20 GeV
b) pT(l) > 10 GeV

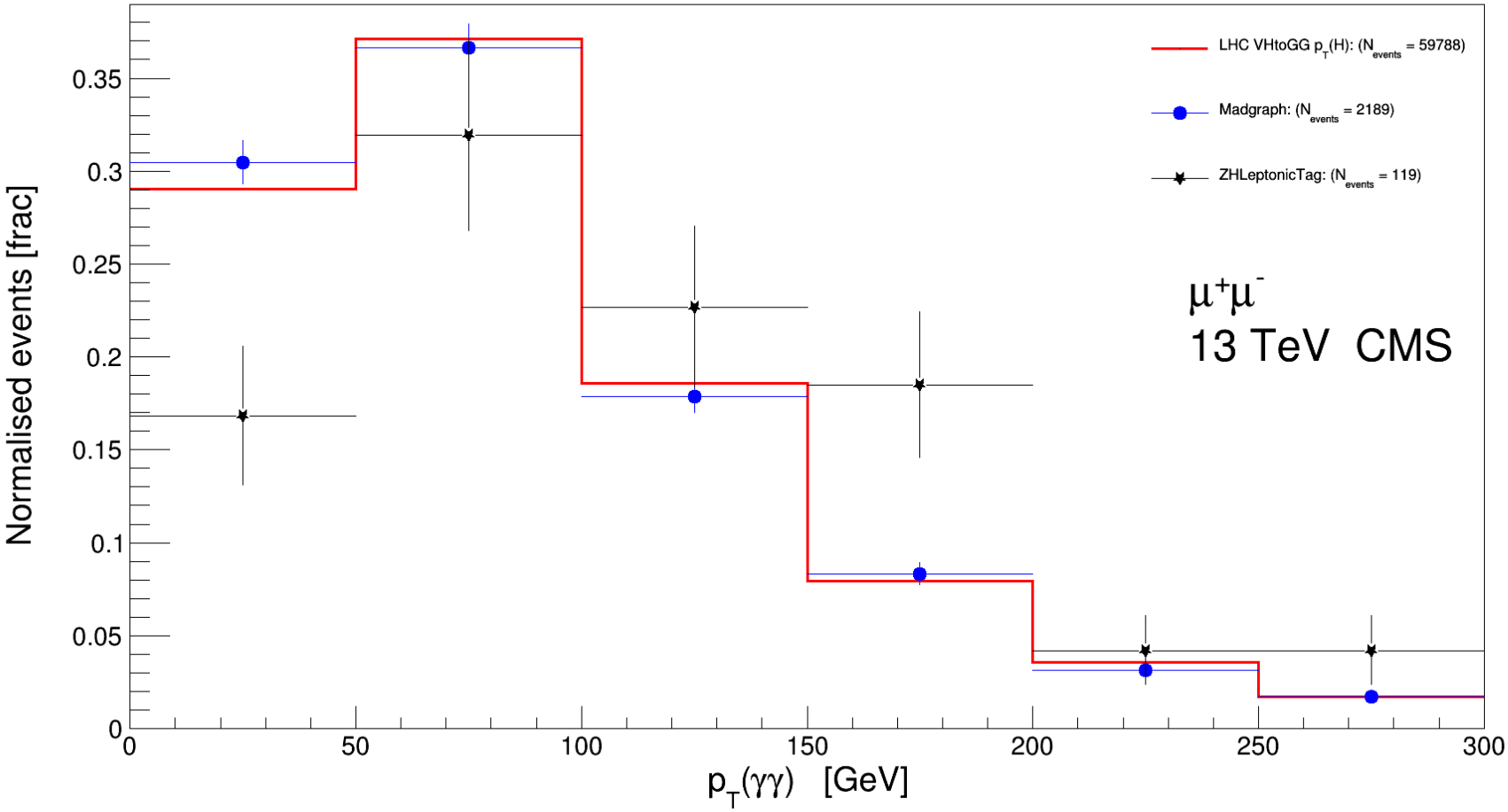
Main lepton selection (inc pT, eta, vtx, ID, dR(gamma):
a) pT(l) > 20 GeV
b) pT(l) > 10 GeV

Final Selection (inc Zmass window on lepton pair)

- Jump in mean $p_T(H)$ at **main lepton selection**.
- Extra: removed pT constraint entirely in lepton selection: N_{tot}=216, N_{ee}=67, $N_{\mu\mu}$=149. Negligible difference, therefore e^+e^- discrepancy **not** due to $p_T(l)$ selection. Lepton selection needs further investigation!

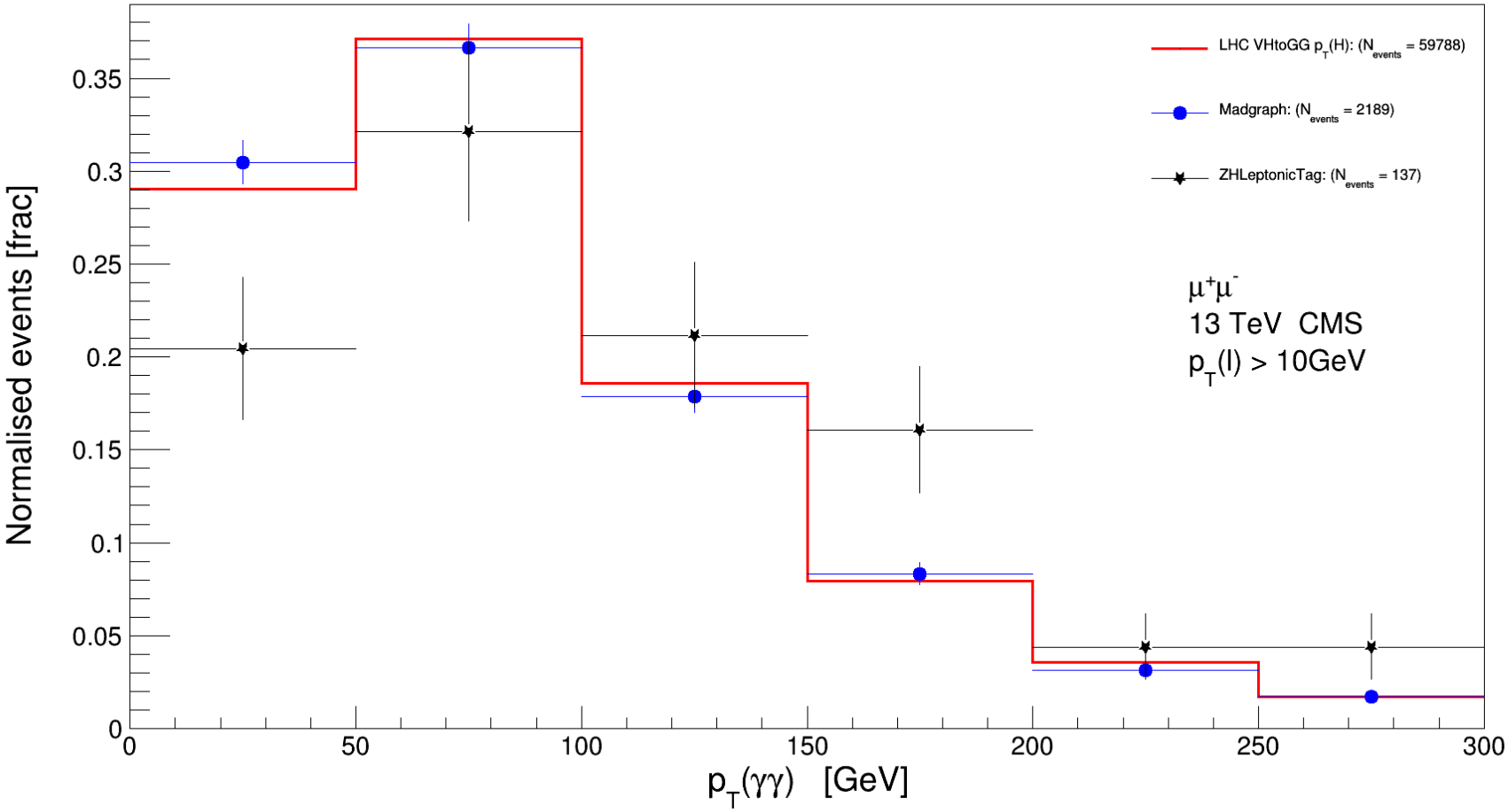
Result of relaxing $p_T(\ell)$ criteria

- $\mu\mu$: $p_T(\ell) > 20$ GeV, $N_{events} = 119$



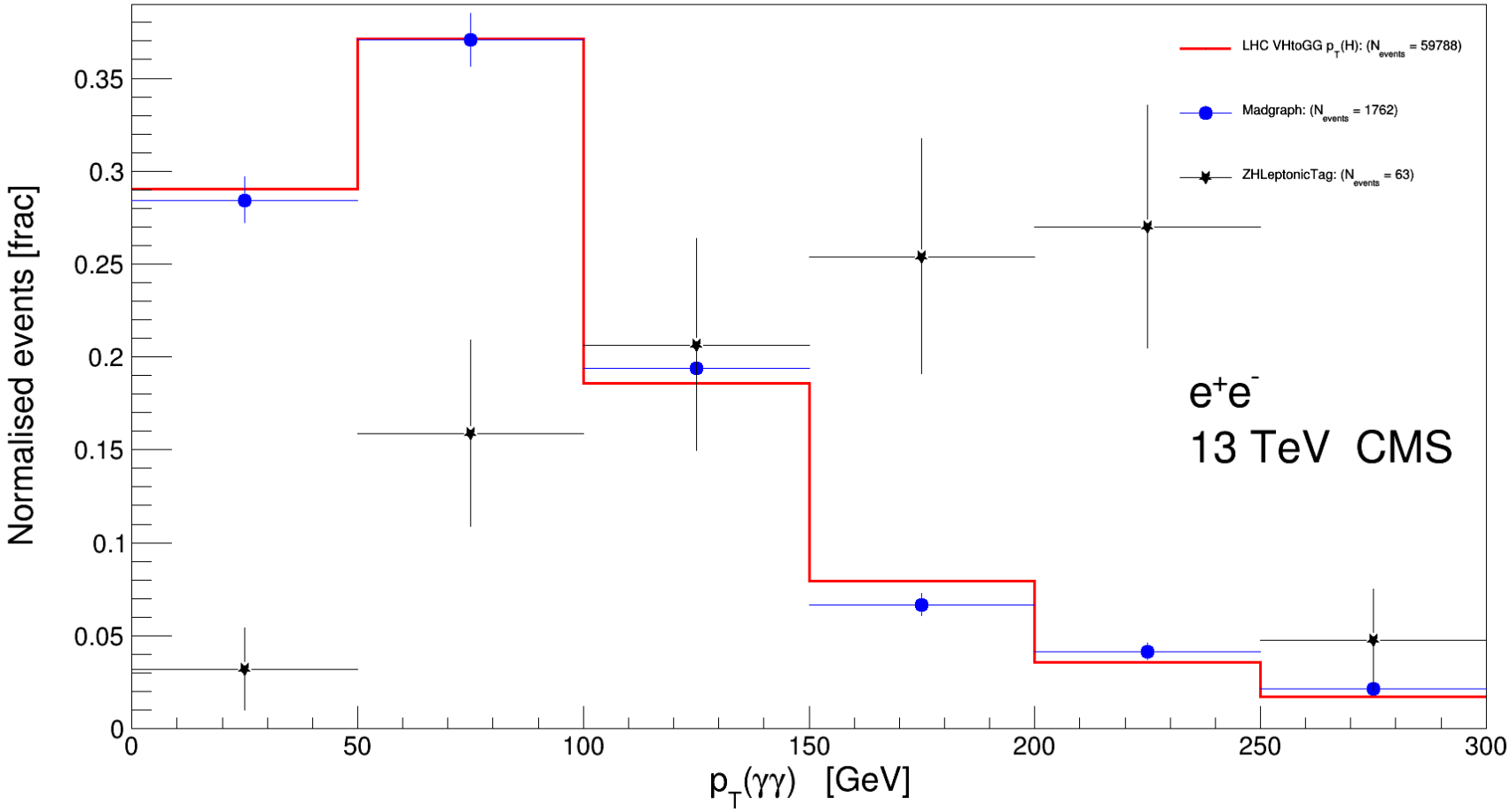
Result of relaxing $p_T(\ell)$ criteria

- $\mu\mu$: $p_T(\ell) > 10$ GeV, $N_{events} = 137$



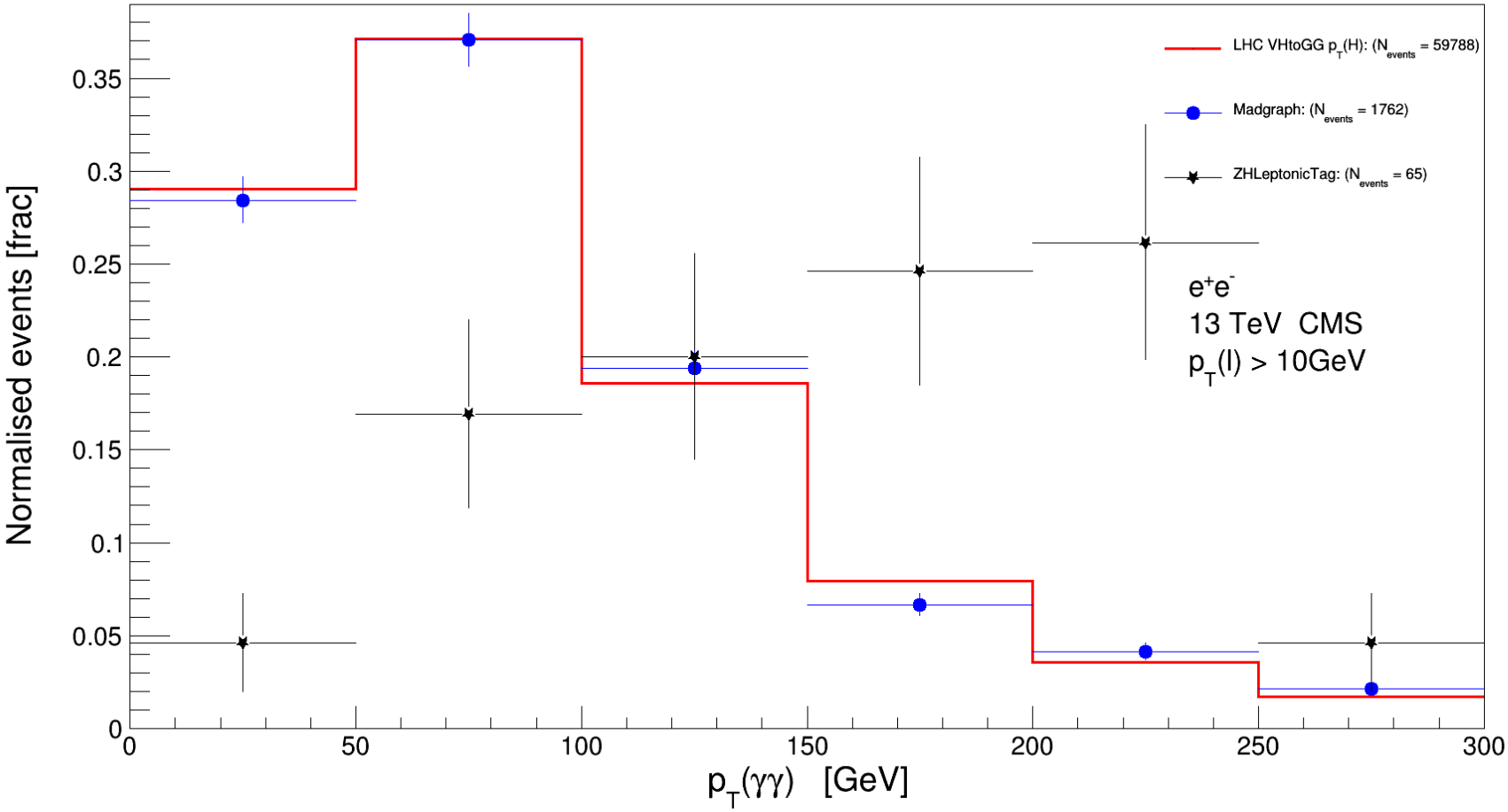
Result of relaxing $p_T(\ell)$ criteria

- ee: $p_T(\ell) > 20$ GeV, $N_{events} = 63$



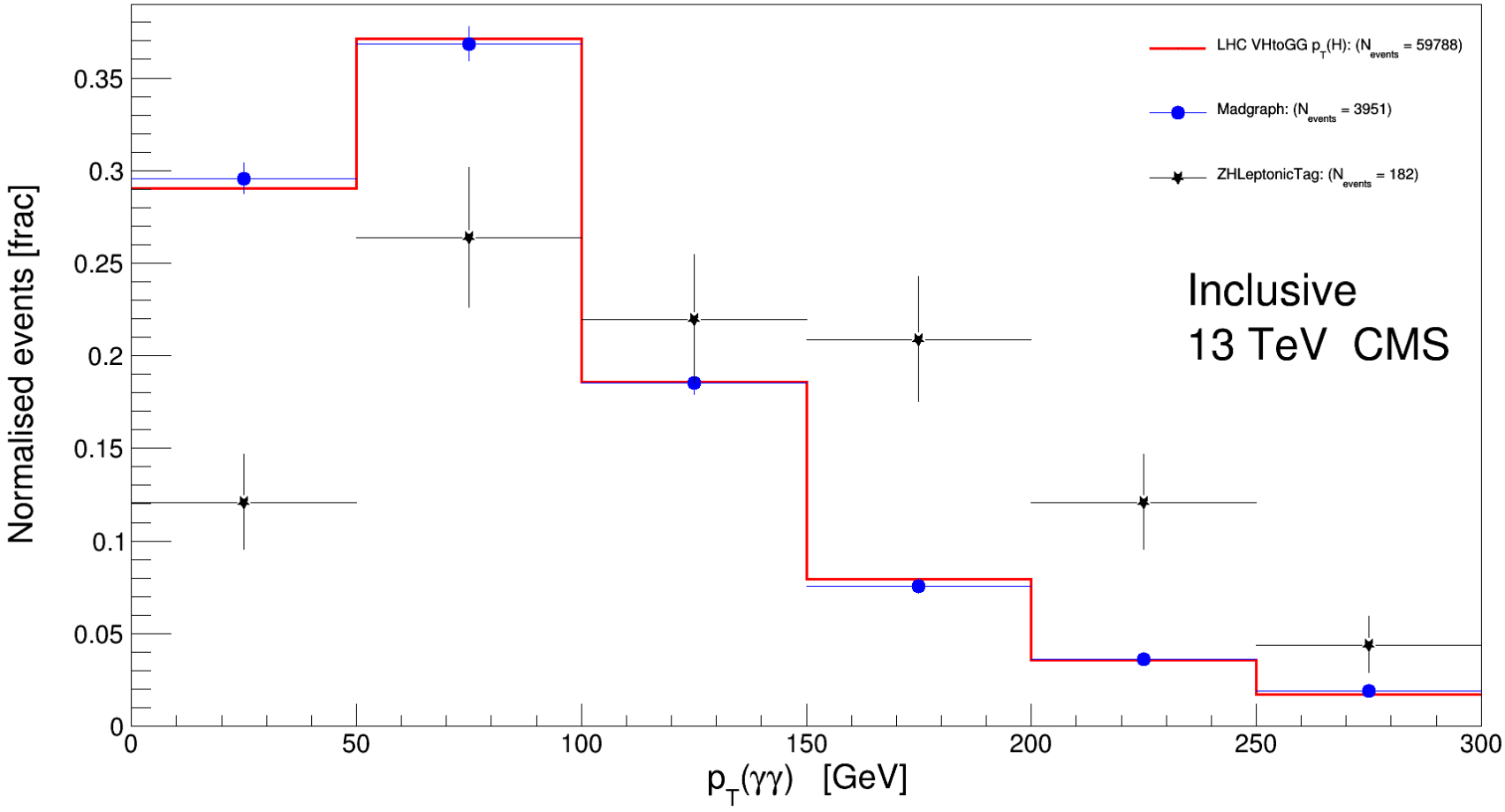
Result of relaxing $p_T(\ell)$ criteria

- ee: $p_T(\ell) > 10$ GeV, $N_{events} = 65$



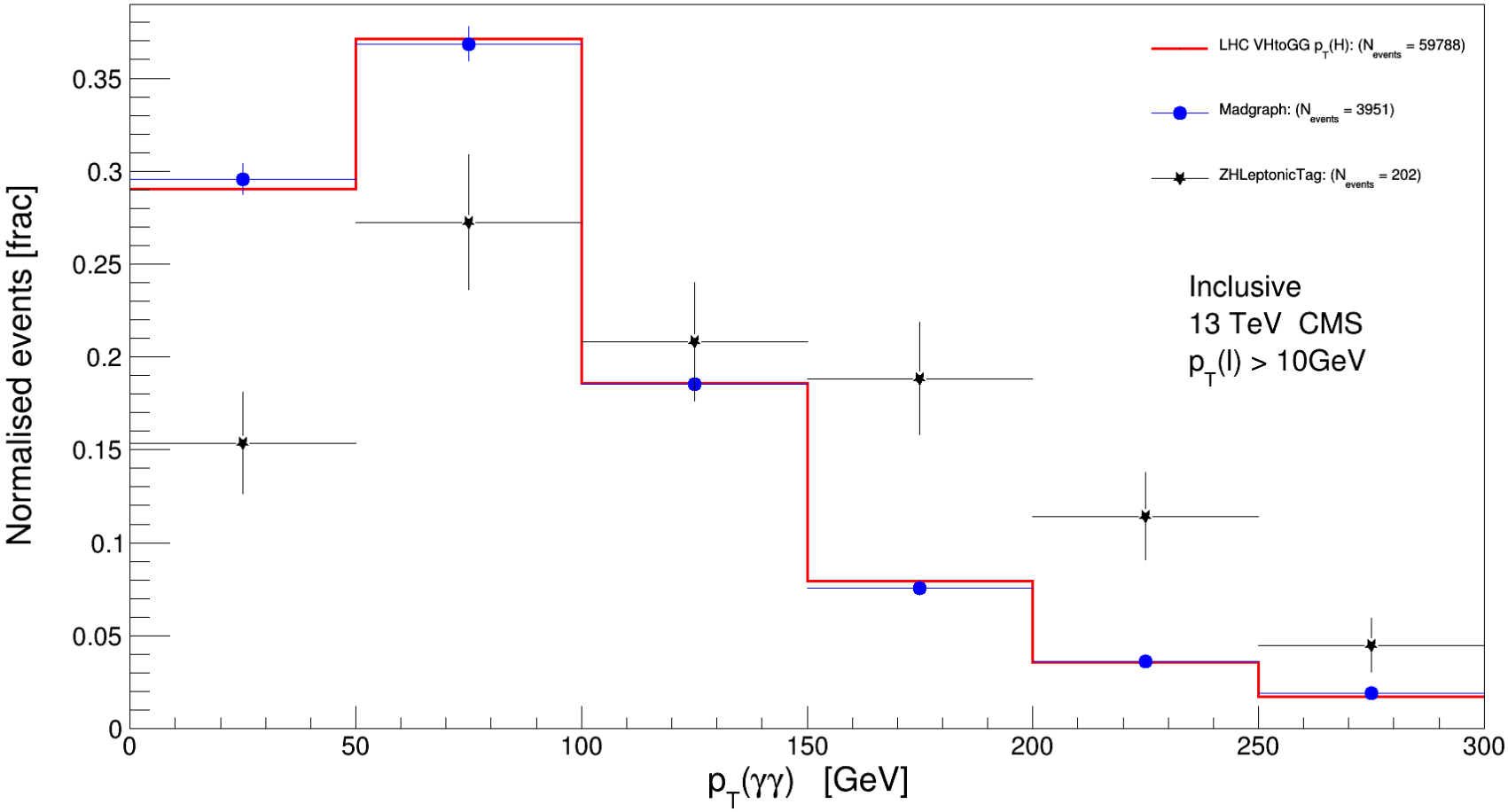
Result of relaxing $p_T(\ell)$ criteria

- Inclusive: $p_T(\ell) > 20$ GeV, $N_{events} = 182$



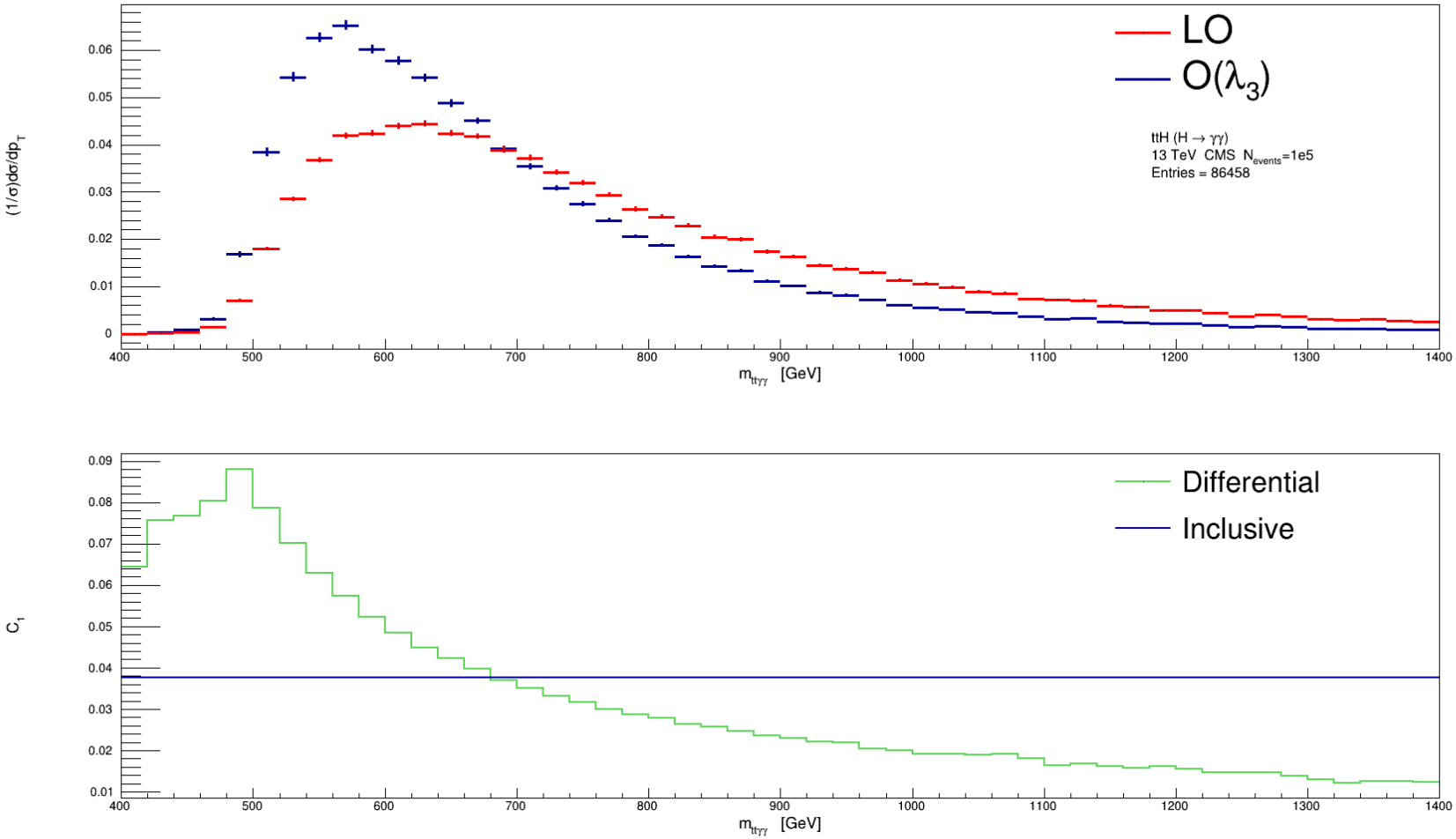
Result of relaxing $p_T(\ell)$ criteria

- Inclusive: $p_T(\ell) > 10$ GeV, $N_{events} = 202$

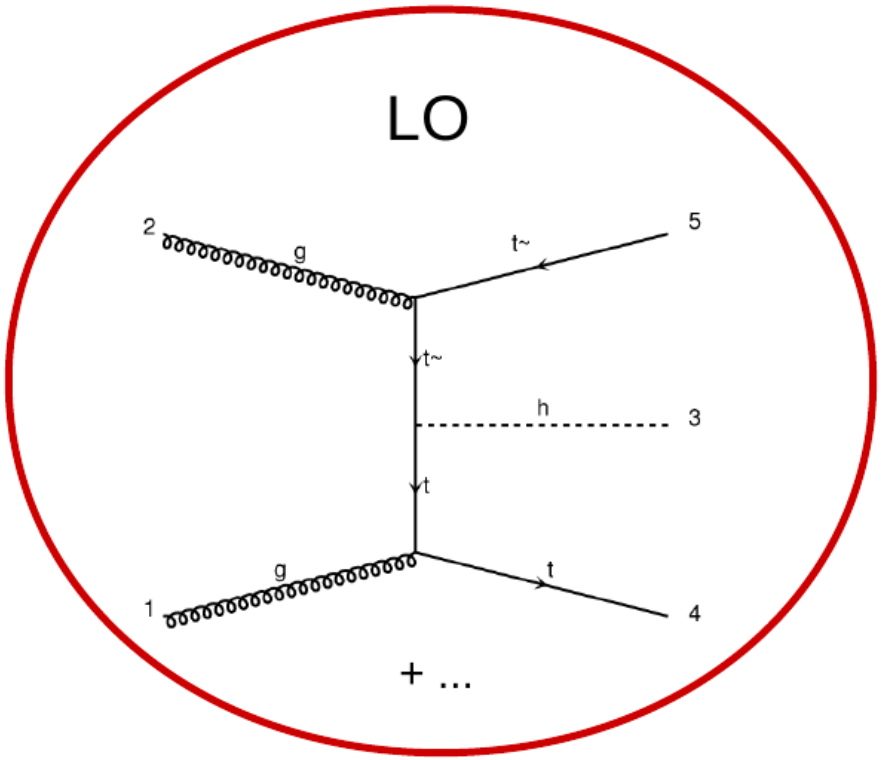


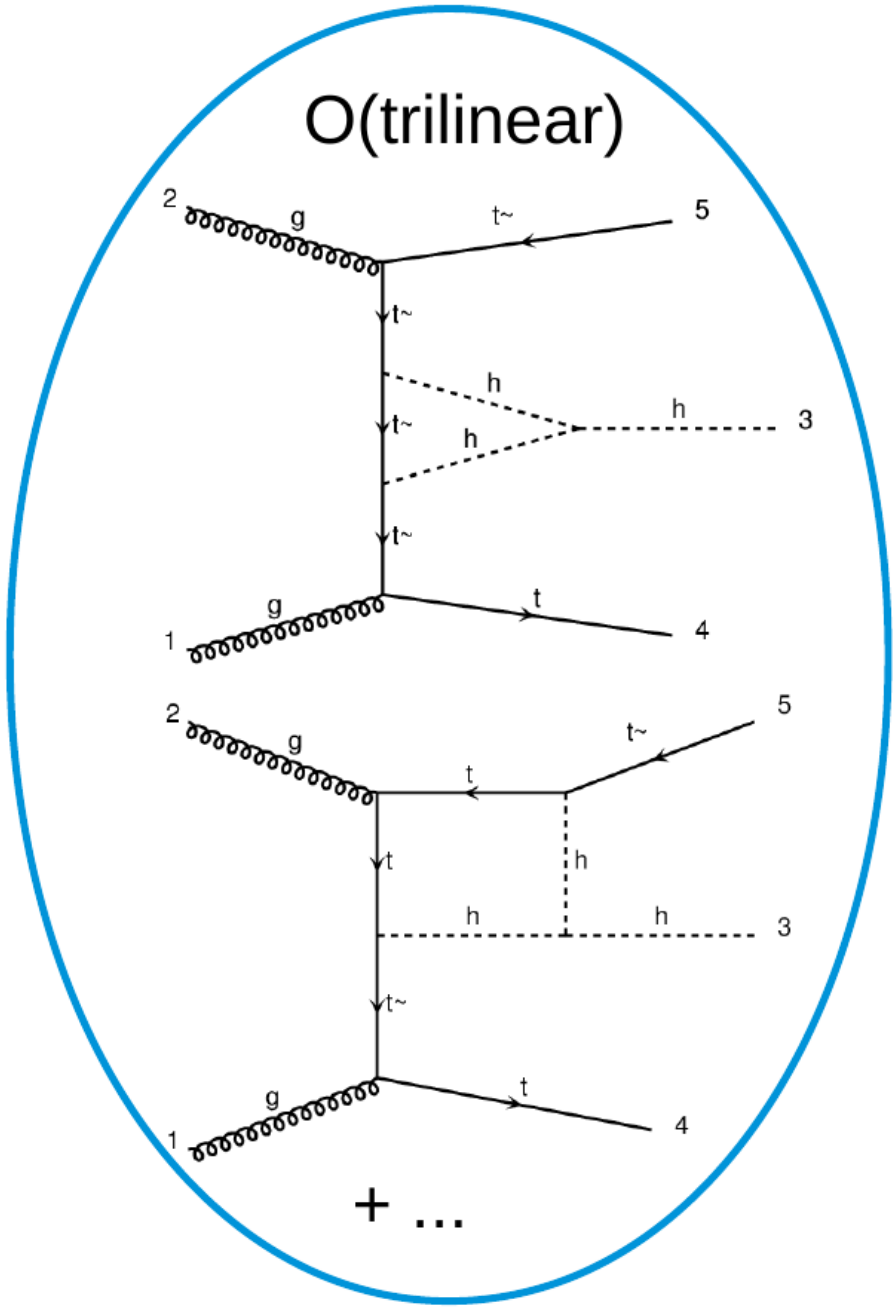
Good news...

- Successfully generated ttH LO and $\mathcal{O}(\lambda_3)$ events in Madgraph $\rightarrow$ Pythia $\rightarrow$ Delphes chain without segmentation fault (Authors updated code).
  - ttH shows largest intrinsic C_1 value of all significant Higgs production modes (3.5%): increased effect on differential distributions therefore increased sensitivity to κ_λ
  - Differential C_1 reaching as high as 9% in certain bins of kinematic distributions. Compared to max 5% in ZHLeptonic.



Example ttH diagrams





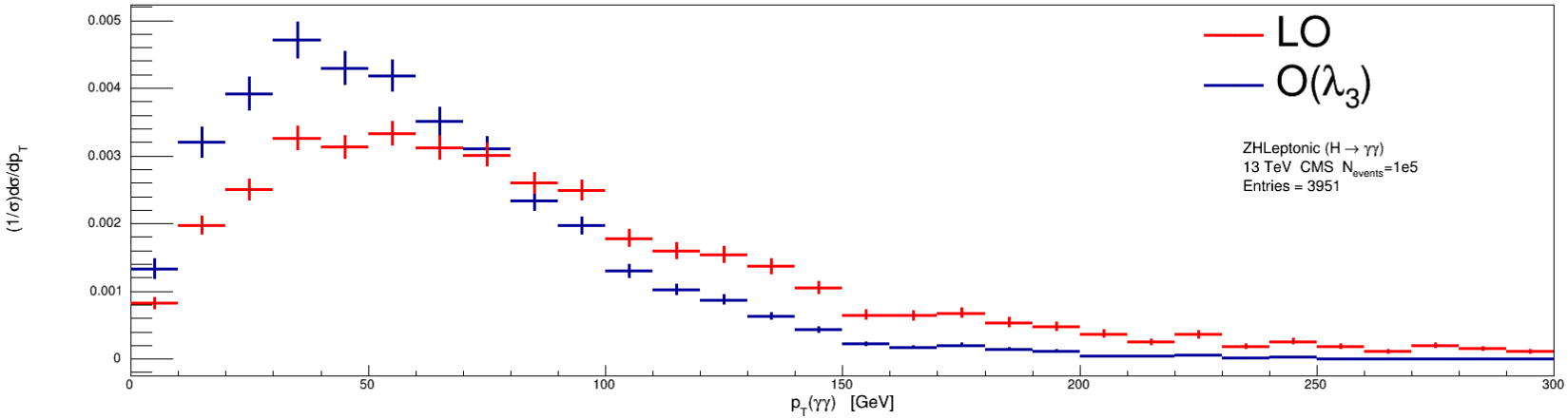
Plan

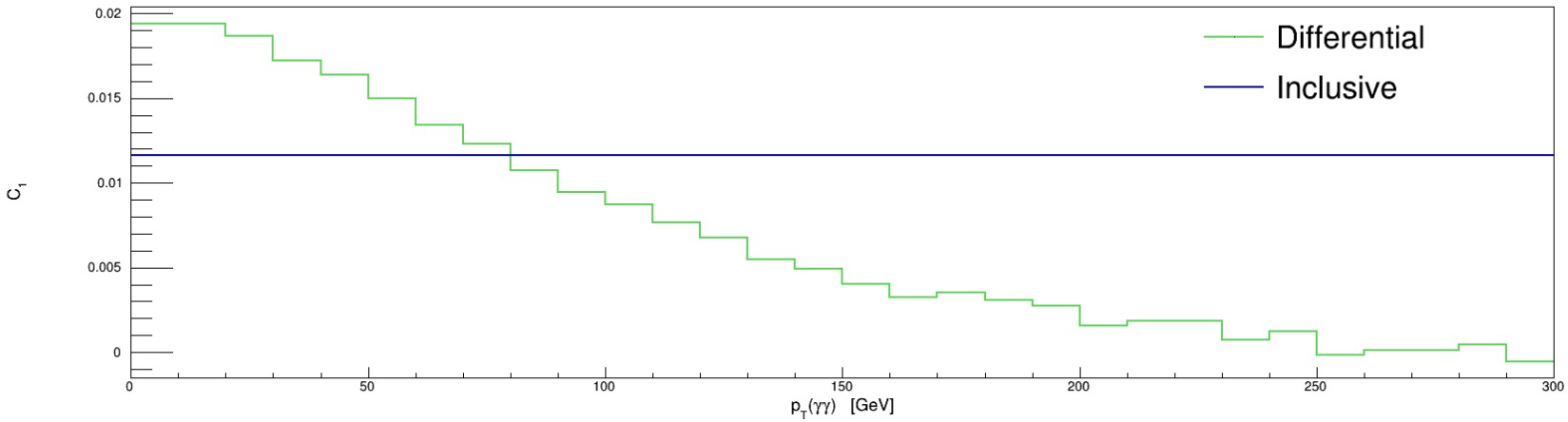
- Set up in analysis in ZHLeptonic and ttH(inclusive) channels.
  - Calculate C_1 in bins of kinematic distribution using madgraph samples. Optimize bin structure to be used throughout analysis.
  - Configure flashgg::TagDumper to extract required gen-level and reco-level info on LHC samples
  - Signal strength in bins of distribution: $\mu_i(C_{1i},\kappa_\lambda)$.
  - Create 3000 fb^{-1} asimov, and fit for κ_λ. Sensitivity?
- **ZHLeptonic**
  - Interesting variables: $p_T(\gamma\gamma)$, m_{ZH}. As in arXiv:1709.08649v1
  - Issue: Discrepancy at low $p_T(\gamma\gamma)$ in ZHLeptonicTag compared to Madgraph. Investigate lepton selection.
  - Also suffer from low MC statistics (but given eff$\times$acc and B.F is roughly as expect)
- **ttH(inclusive)**
  - Interesting variables: $p_T(\gamma\gamma)$, m_{ttH} + ...
  - How do we reconstruct top quarks in ttH Tag?
    - ttHHadronic: 6 jets, >=2 b-tagged. Choose 3-jets which give mass closest to m_t
    - ttHLeptonic: More difficult due to presence of ν. Use visible top mass, kinematic fitting methods.
    - Check: How is it currently done in flashgg::ttHTags (if at all)? Follow method of CMS top group differential cross section measurements?
  - Combine Hadronic and Leptonic at likelihood level.

- Set up working directory in vols to be used for event generation. Includes madgraph, pythia and delphes + ReadMe.txt on workflow for event gen.
  `/vols/cms/heptools/EventGen/CMSSW_7_4_4/src`

C_1 Kinematic Distributions: ZHLeptonic

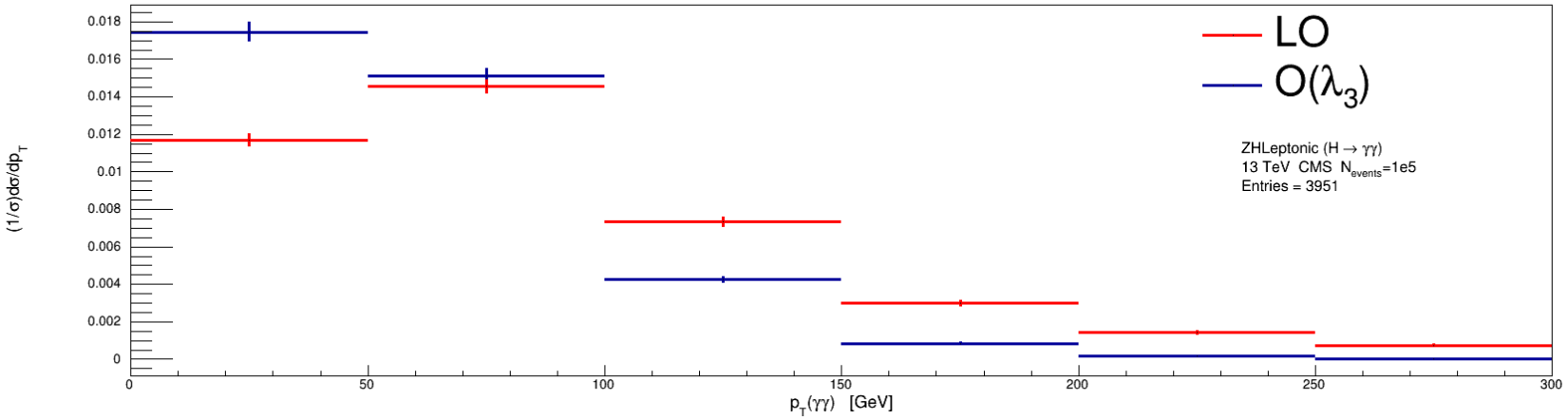
- $p_T(\gamma\gamma)$: fine binning

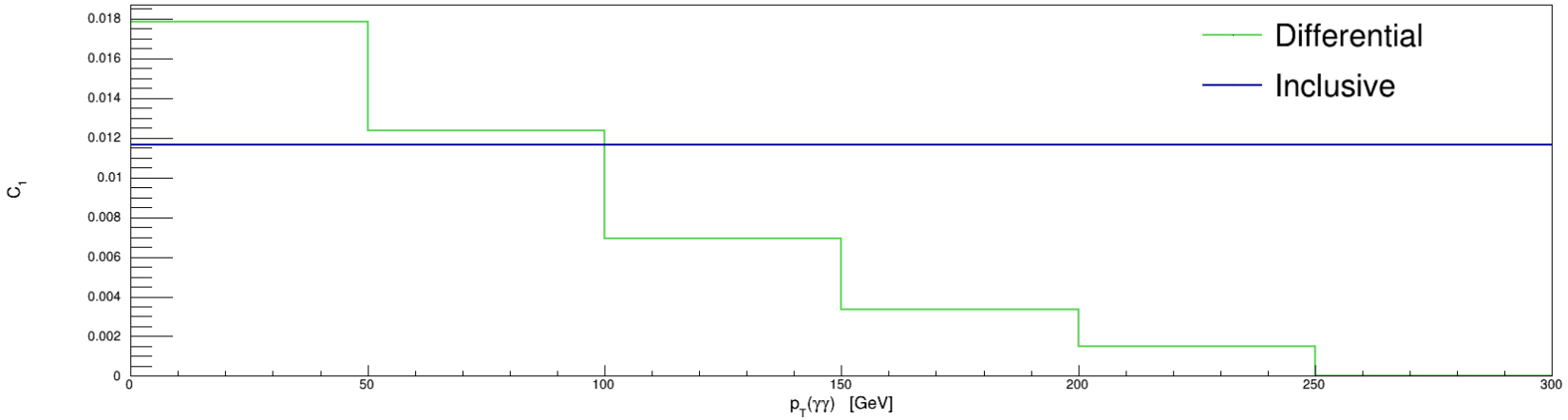




C_1 Kinematic Distributions: ZHLeptonic

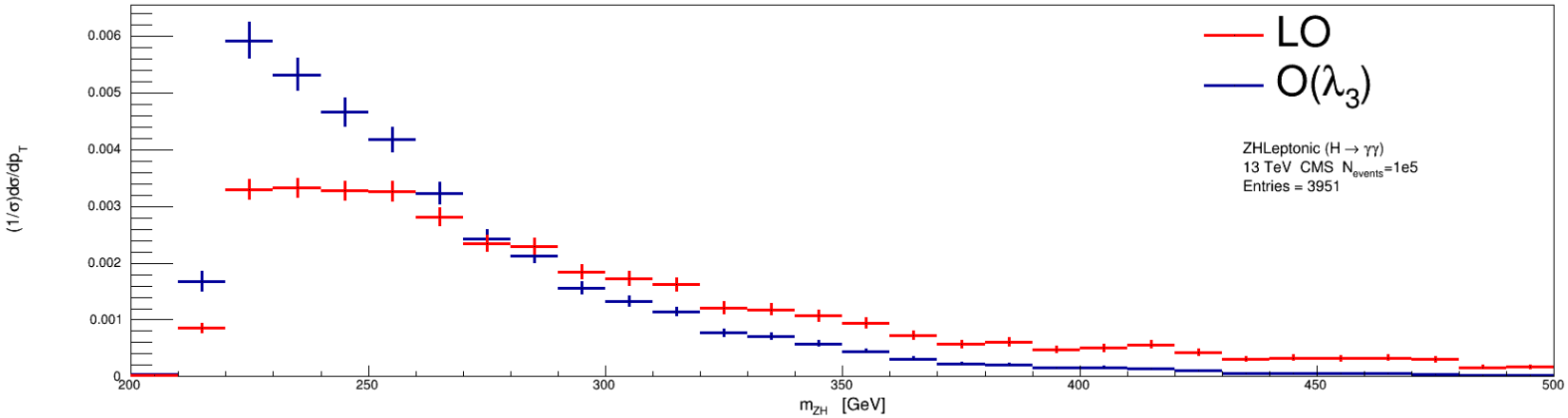
- $p_T(\gamma\gamma)$: coarse binning

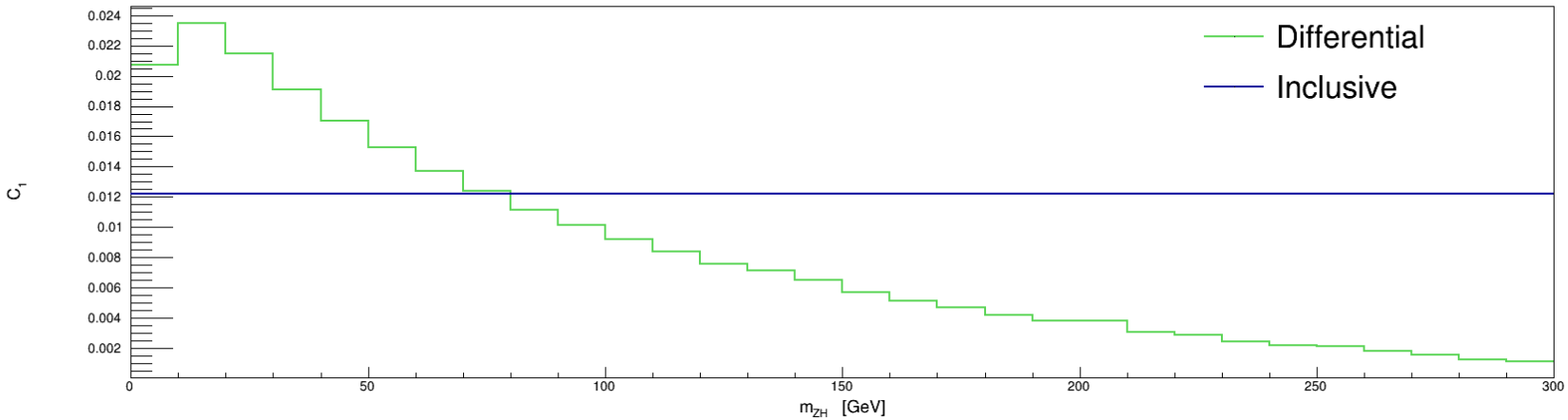




C_1 Kinematic Distributions: ZHLeptonic

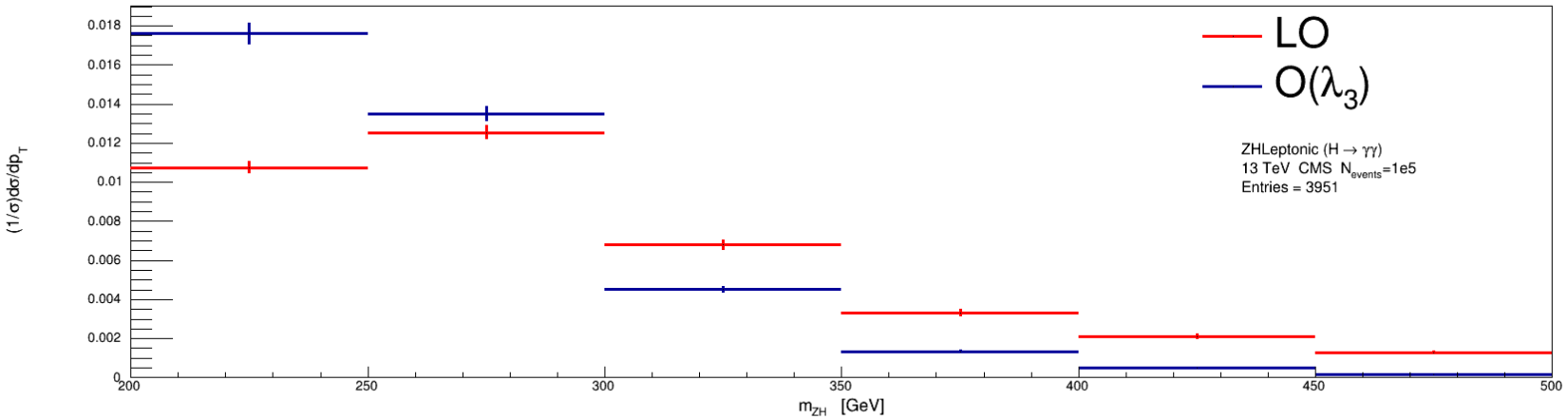
- m_{ZH}: fine binning

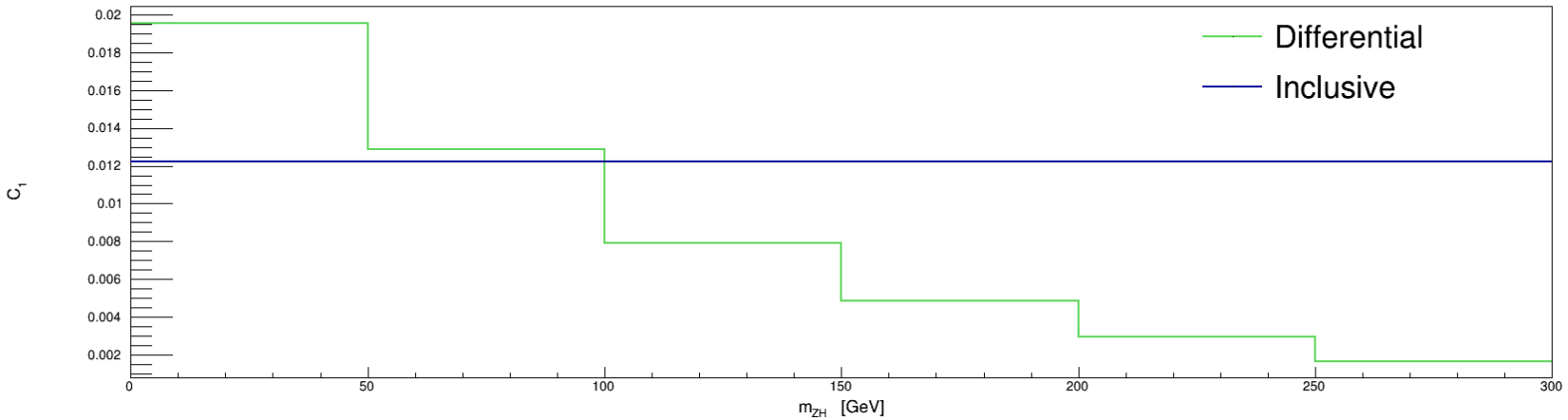




C_1 Kinematic Distributions: ZHLeptonic

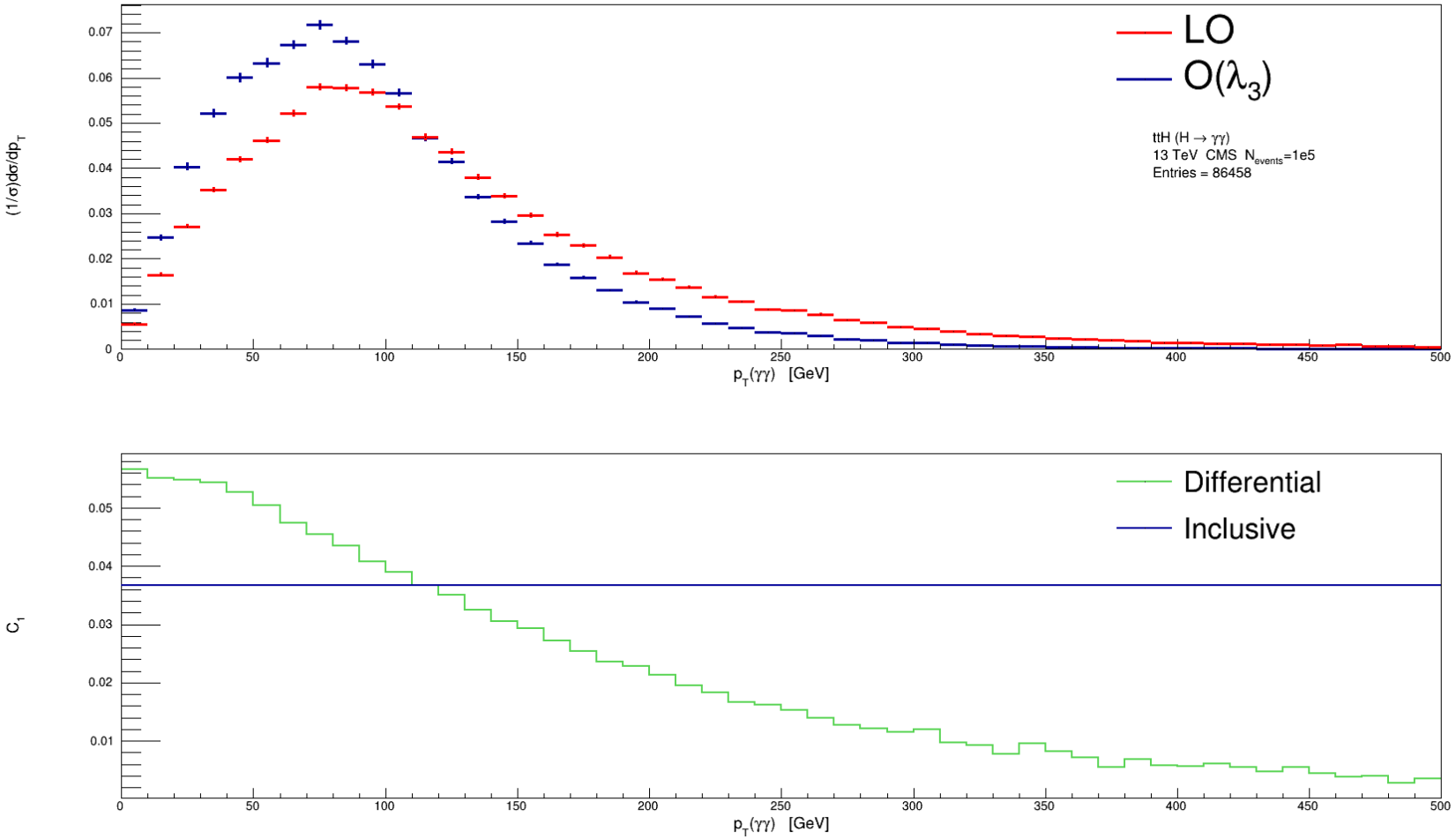
- m_{ZH}: coarse binning





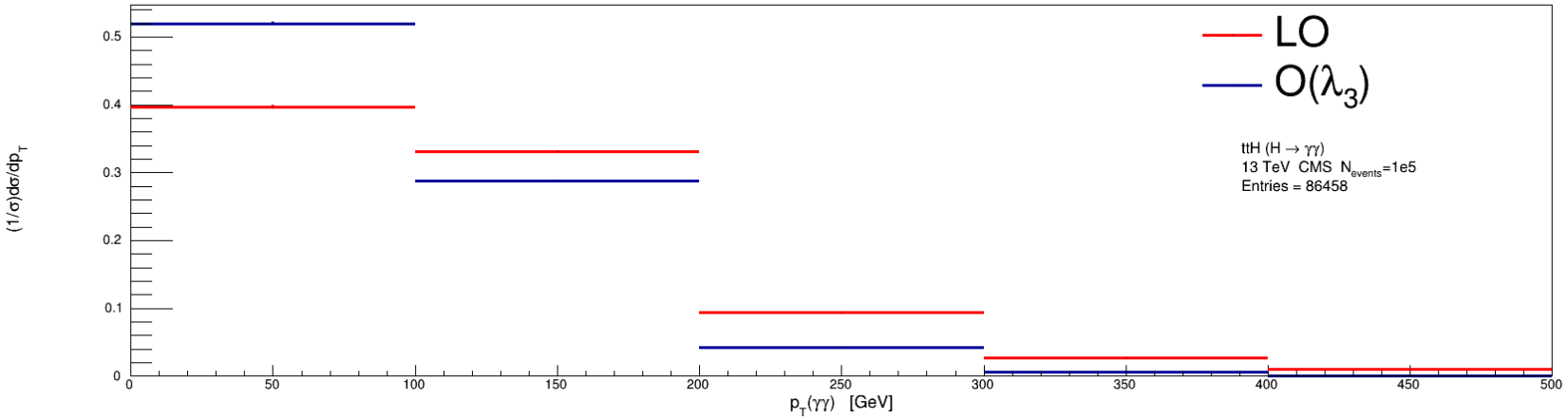
C_1 Kinematic Distributions: ttH(inclusive)

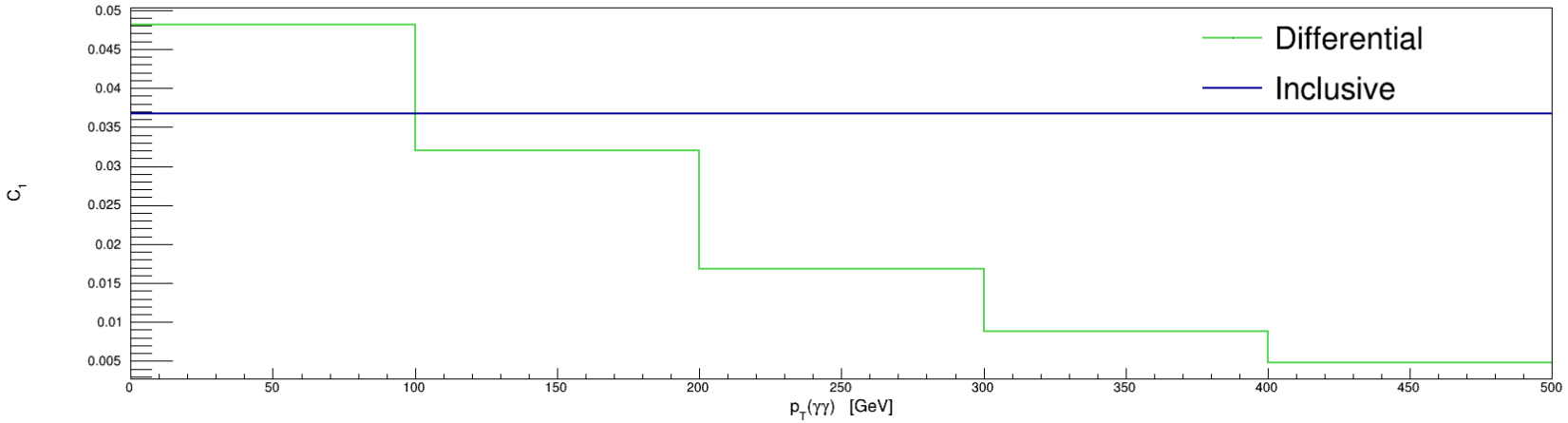
- $p_T(\gamma\gamma)$: fine binning



C_1 Kinematic Distributions: ttH(inclusive)

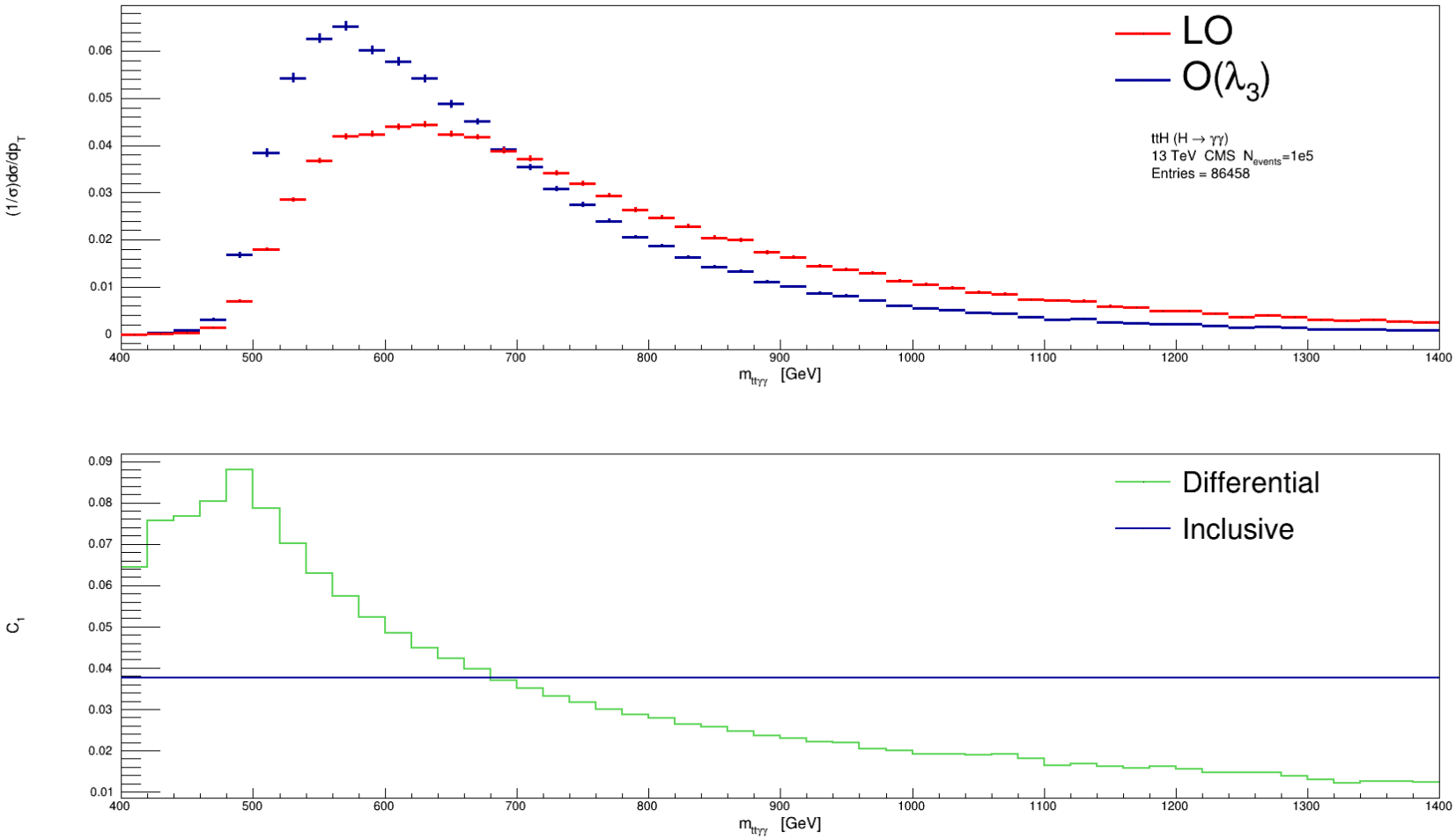
- $p_T(\gamma\gamma)$: coarse binning





C_1 Kinematic Distributions: ttH(inclusive)

- m_{ttH}: fine binning



C_1 Kinematic Distributions: ttH(inclusive)

- m_{ttH}: coarse binning