HH prospect studies for CMS for the HL-LHC

HH Subgroup Meeting

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Di-Higgs Production

- One of the exciting prospects of HL-LHC
  - Cross section at √s=14 TeV is 40.2 fb [NNLO]
  - Challenging measurement
- Nominal performance for Phase II detector scenario and 3000fb^{-1}

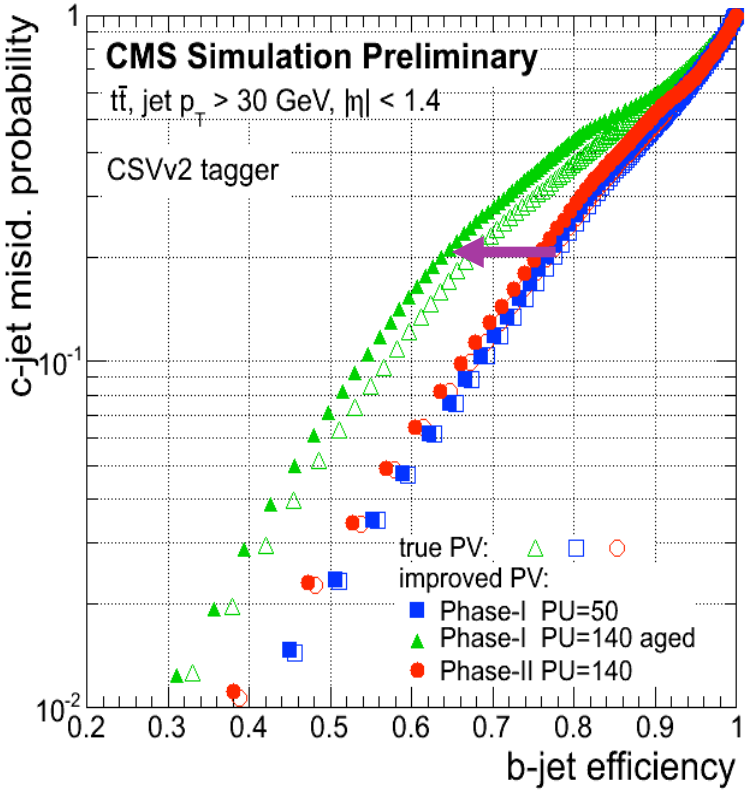
- Final states shown at ECFA
  - bbγγ [320 expected events at HL-LHC, 3000fb^{-1}]
    - But relatively clean signature
  - bbWW [31000 expected events at HL-LHC, 3000fb^{-1}]
    - But large backgrounds
- bbbb and bbττ final states under consideration

HH->bbγγ analysis description

- Event selection
  - 2 photons: p_T>40GeV and p_T>20GeV, |η|<2.5
  - 2 b-tagged jets, CSV medium WP, p_T>30GeV, |η|<2.4
- Kinematic selection
  - Additional lepton veto
  - Less than 4 jets with |η|<2.4 and p_T>30GeV
  - ΔR_{bb} and $\Delta R_{\gamma\gamma}$ less than 2.0, min of $\Delta R_{\gamma b}$>1.5
- Two categories considered
  1. Both photons in barrel
  2. At least one photon in endcap
- Likelihood fit signal extraction
  - 2D fit of M_{bb} and $M_{\gamma\gamma}$
  - Mass fit window of 100GeV<$M_{\gamma\gamma}$<150GeV and 70GeV<M_{bb}<200GeV is used

Phase II detector performance

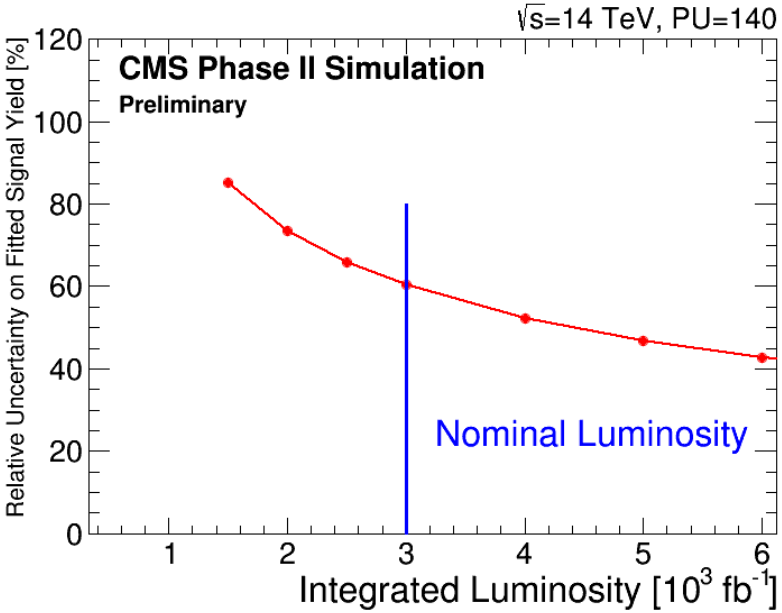
- Parameterized object performance
- Tuned to CMS Phase II detector at <PU>=140
- b-tagging performance
  - 75% b-tagging efficiency
  - 20% charm jet efficiency
  - 1% light jet efficiency
- 81% photon efficiency (barrel)
  - 1% electron->photon fake rate
  - (0.1-0.5)% jet->photon fake rate

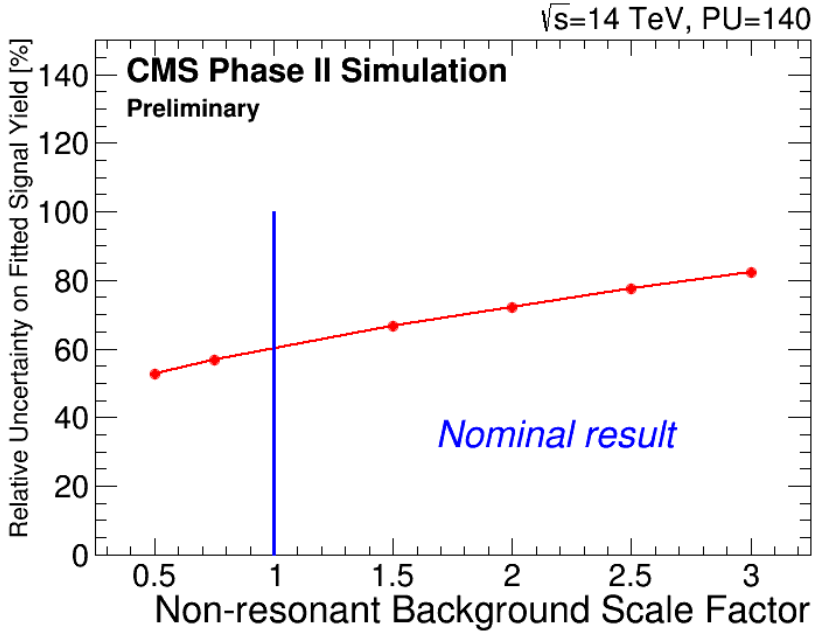


CMS results

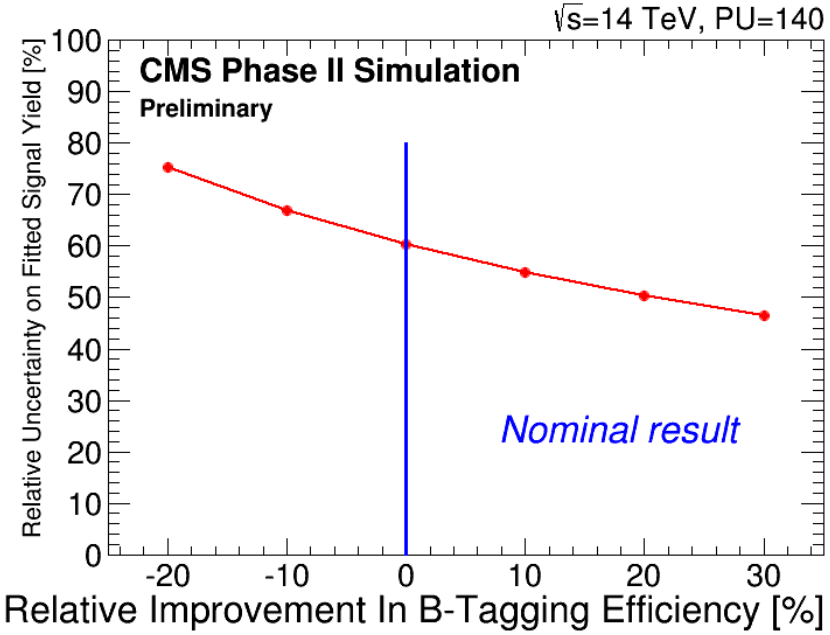
Process / Selection Stage	HH	ZH	$t\bar{t}H$	$b\bar{b}H$	$\gamma\gamma$+jets	γ+jets	jets	$t\bar{t}$
Object Selection & Fit Mass Window	22.8	29.6	178	6.3	2891	1616	292	113
Kinematic Selection	14.6	14.6	3.3	2.0	128	96.9	20	20
Mass Windows	9.9	3.3	1.5	0.8	8.5	6.3	1.1	1.1

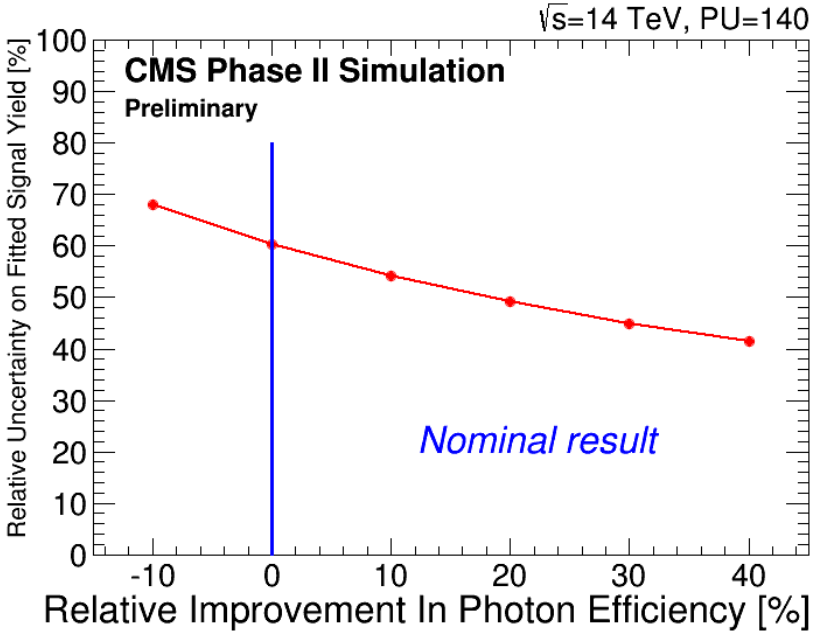
Table 3: The expected event yields of the signal and background processes for 3000 fb^{-1} of integrated luminosity are shown at various stages of the cut-based selection for the both photons in the barrel region. Mass window cuts are 120 GeV to 130 GeV for $M_{\gamma\gamma}$ and 105 GeV to 145 GeV for M_{bb}. A large fit mass window, 100 GeV to 150 GeV for $M_{\gamma\gamma}$ and 70 GeV to 200 GeV for M_{bb}, is used for the likelihood fit analysis. The statistical uncertainties on the yields are of the order of percent or smaller.





Upgrade effects





- The average expected relative uncertainty on the di-Higgs cross section measurement is shown as a function of the b-tagging efficiency (left) and the photon efficiency (right).

HH->bbWW analysis description

Search for HH → bbWW → bblvlv

Event pre-selection:

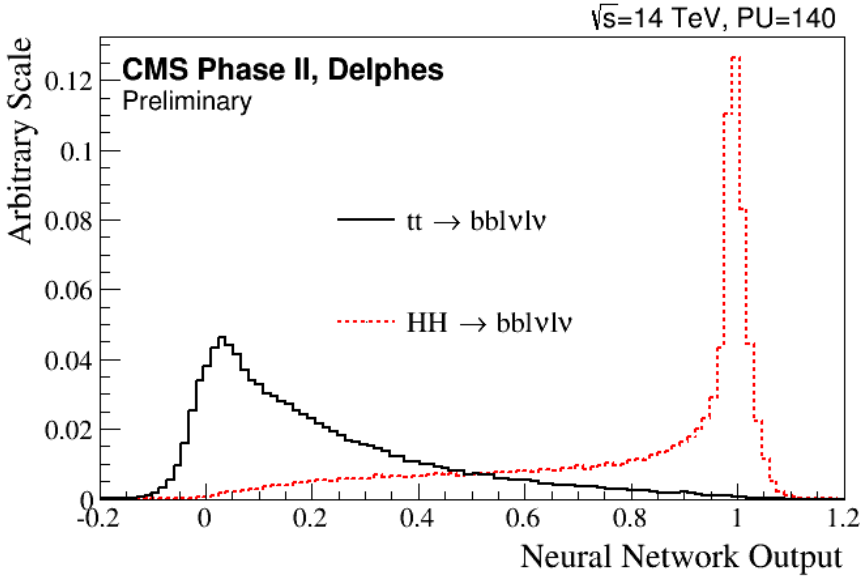
- 2 b-jets Medium WP, p_T > 30 GeV
  2 leptons, muons: p_T > 20 GeV, electrons: p_T > 25 GeV
- MET >20GeV
  Clean up cuts (m_{jj} , m_{ll} , ΔR_{jj} , ΔR_{ll} , $\Delta\phi_{jj,ll}$)

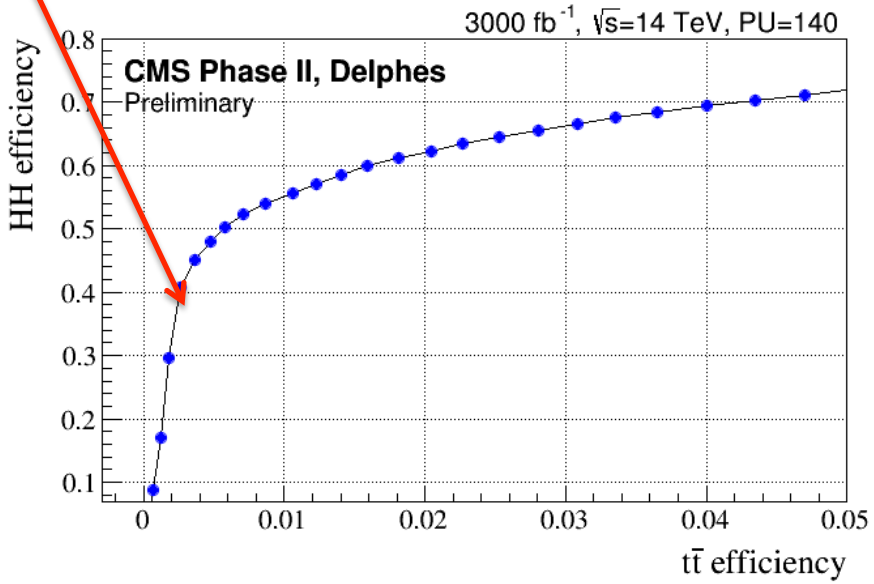
Analysis Optimization:

- Neural network discriminant from kinematic variables
- Variables: M_{ll}, M_{jj}, ΔR_{ll}, ΔR_{jj}, ΔR_{jl}, MET, $\Delta\phi_{ll,jj}$, p_{jj} , and M_T

HH->bbWW analysis

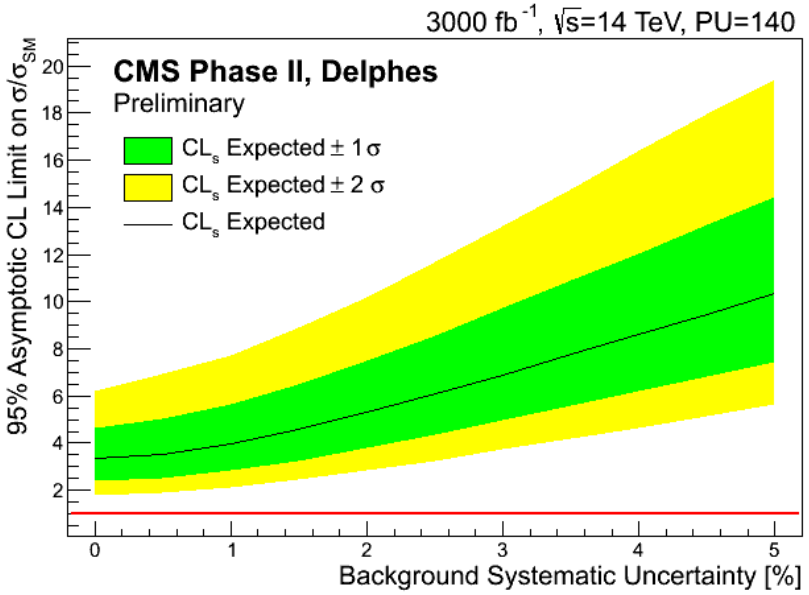
- Based on Delphes fast simulation tuned to CMS Phase II detector
- Considering only the main tt background
- The rest of the SM processes are negligible
- Neural Network discriminant to suppress tt
  - Signal region: Neural Network output > 0.97

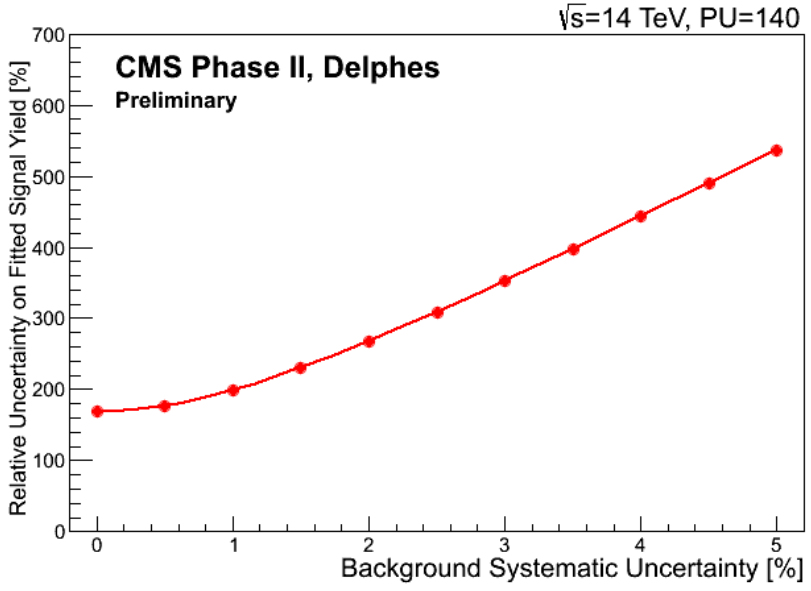




HH->bbWW results

- Results are quoted as a function of the background systematic uncertainty
  - Data driven techniques will likely constraint the uncertainties to the percent level



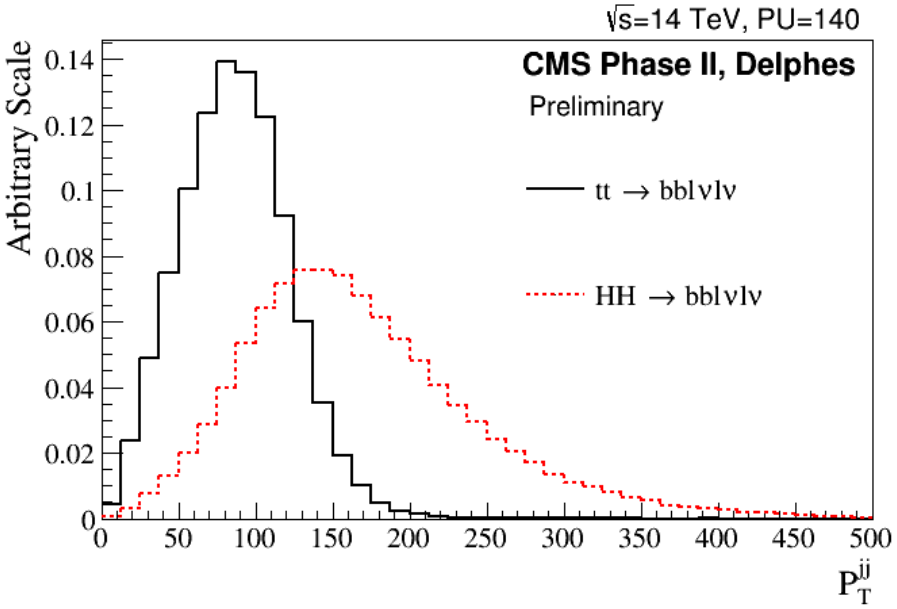


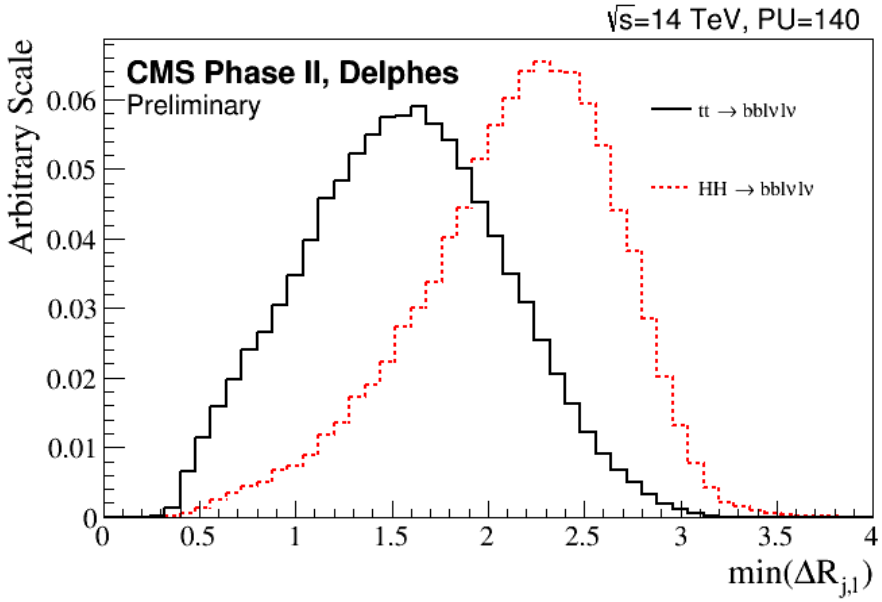
Summary

- Preliminary Higgs pair-production studies
  - Expected uncertainty of 60% on cross section for bbγγ at 3000fb^{-1}
    - Evaluating impact of end-cap calorimeters
  - Results for bbWW final state
    - Result quoted as a function of the background uncertainty
- Studies in other channels ongoing
  - bbbb and bbττ final states

BACKUP

Input variables to Neural Network





- (Left) p_{jj} distribution comparing the HH and tt shape differences. Variable used as input for the Neural Network discriminator.
- (Right) min(ΔR_{jl}) distribution comparing the HH and tt shape differences. Variable used as input for the Neural Network discriminator.