FCC-hh: HH Acceptance Studies

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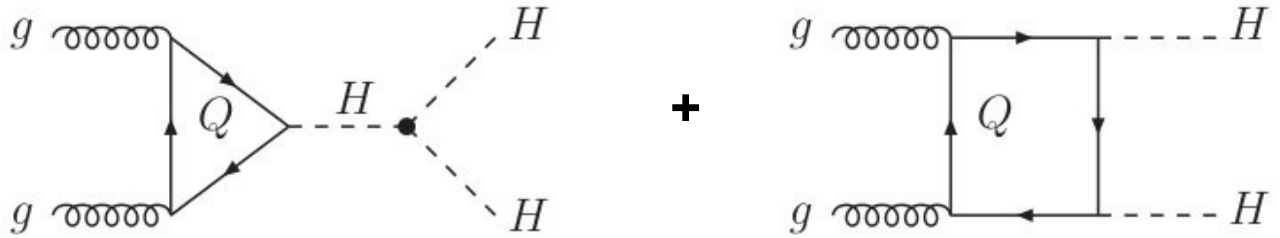
Physics benchmark: gg → HH

- **Physics benchmark channel: HH production through gluon-gluon fusion**



  - **Studied H (125GeV) decay channels:**
    - $H \to b\bar{b}$, $H \to \gamma\gamma$
    - $H \to b\bar{b}$, $H \to WW^*$ ($W \to e, \mu$)
    - $H \to bb$, $H \to \tau^+\tau^-$
    - NLO production cross section @100TeV = 1.4 pb (**arXiv 1212.5581v2**) (cross section @14TeV = 0.03 pb)
    - Studied SM physics → $\lambda_{HH} = 1$

Strategy

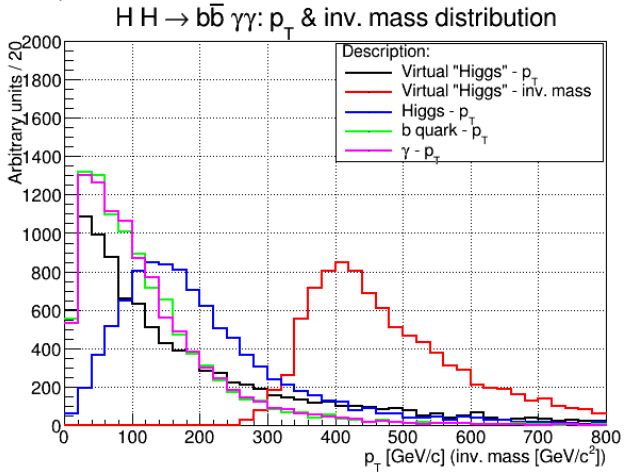
- **Strategy for physics driven FCC-hh detector studies:**
  - Use Madgraph (C.Helsens) → Add MPI, ISR, FSR & decay in Pythia (Z.Drasal)
    → Madgraph files @ https://test-fcc.web.cern.ch/test-FCC/LHEevents.php
  - Start with Pythia true information → study kinematics & invariant mass resolution versus applied p_T cuts, geometric acceptance (eta coverage), E cuts, (reconstructed missing E_T)

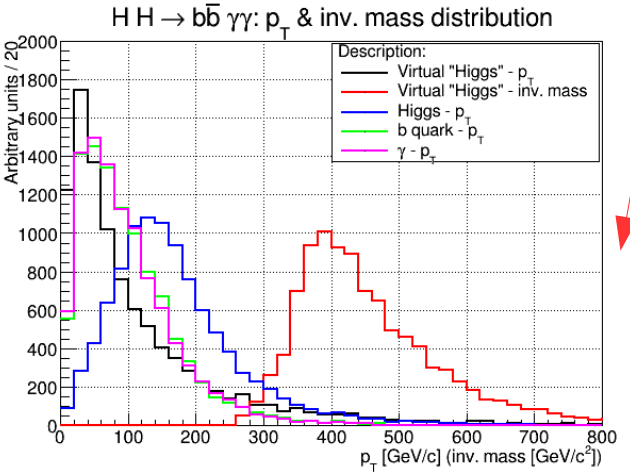
    → A natural starting point to understand the basic constraints on FCC-hh detector design

    → The idea is to avoid too many assumptions on detection efficiencies, reconstruction algorithms, etc. (which are detector dependent!)
  - Continue with DELPHES and study impact of other various detector technology-dependent effects: tracking resolution, detection efficiencies, b-tagging, τ-reconstruction …
  - Crosscheck results with LHC @ 13TeV versus FCC-hh @ 100 TeV

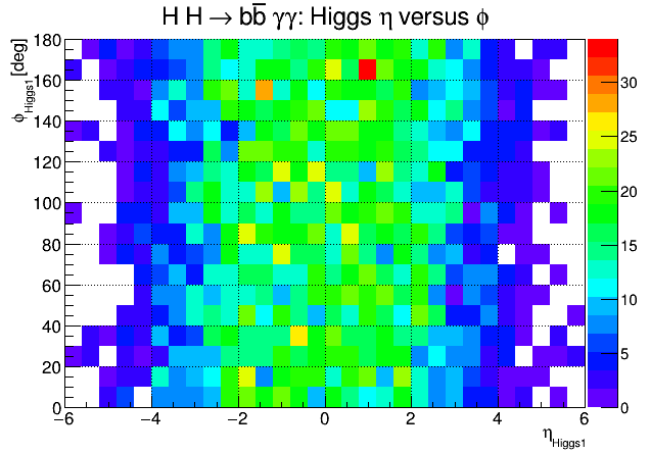
Results for decay mode: $H \to b\bar{b}$ + $H \to \gamma\gamma$

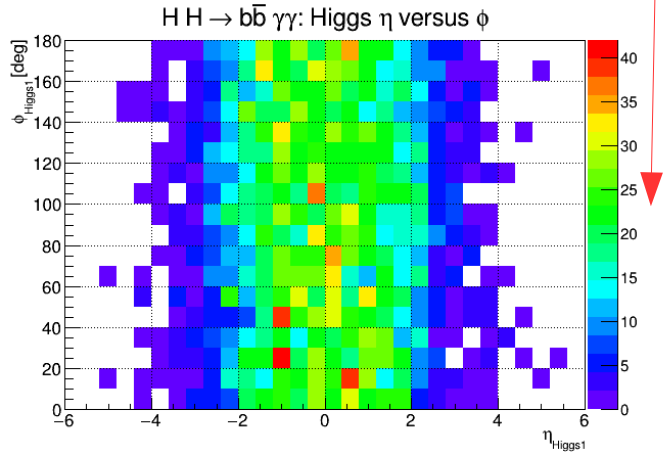
- **P_T spectrum & Higgs invariant mass for 100TeV versus 13TeV machine**





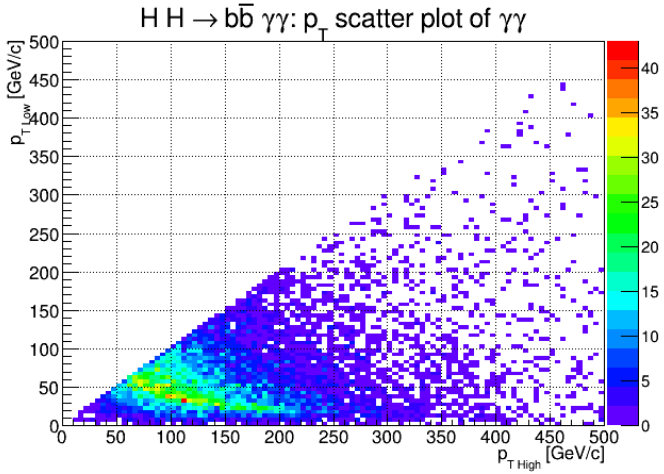
- **Required geometric acceptance for Higgs particles:**

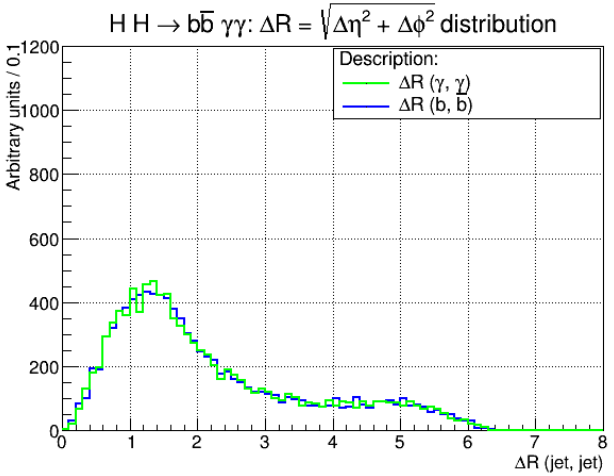


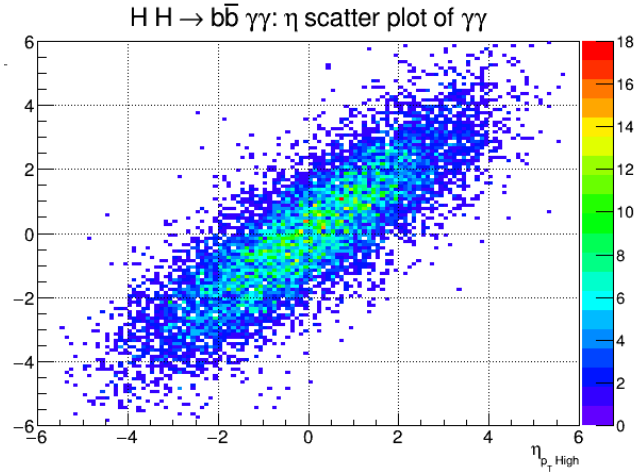


Results for decay mode: $H \to b\bar{b}$ + $H \to \gamma\gamma$

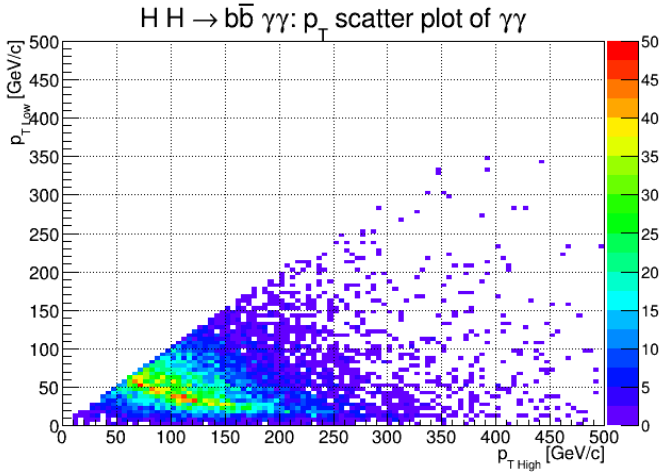
- P_T spectrum, jet isolation & eta spectrum for 100 TeV machine

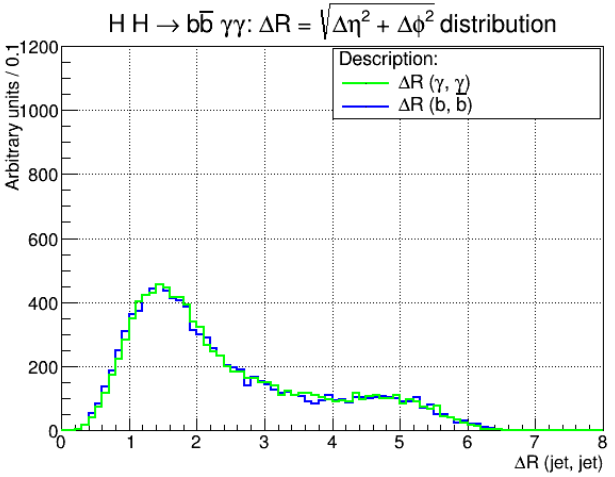


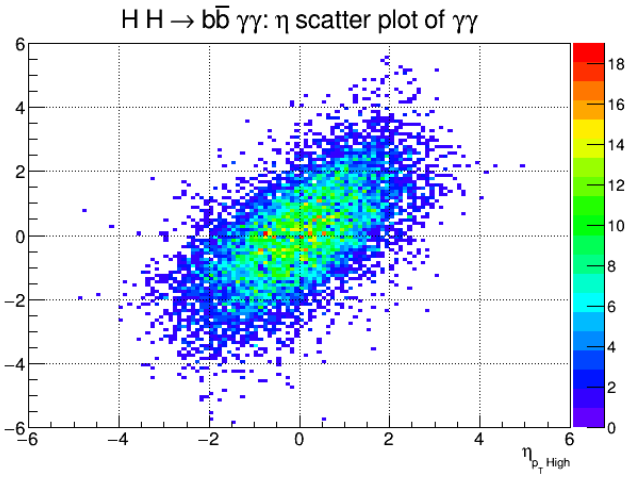




- For 13 TeV machine:

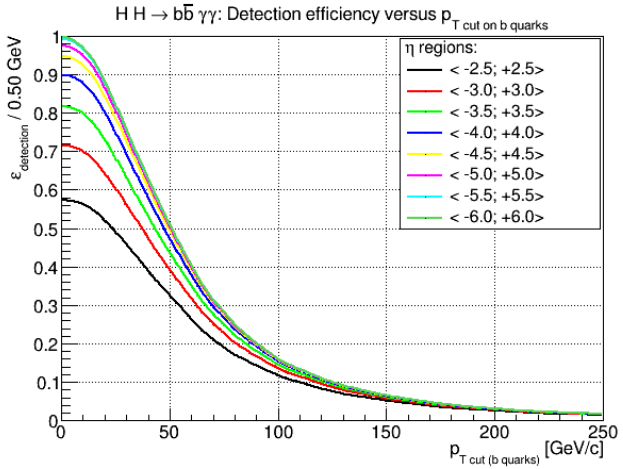


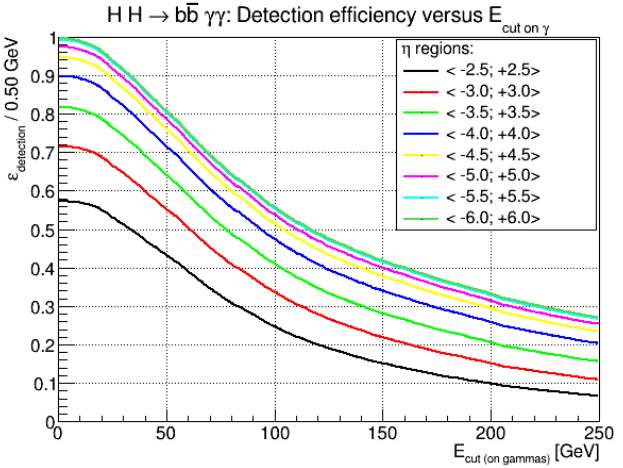




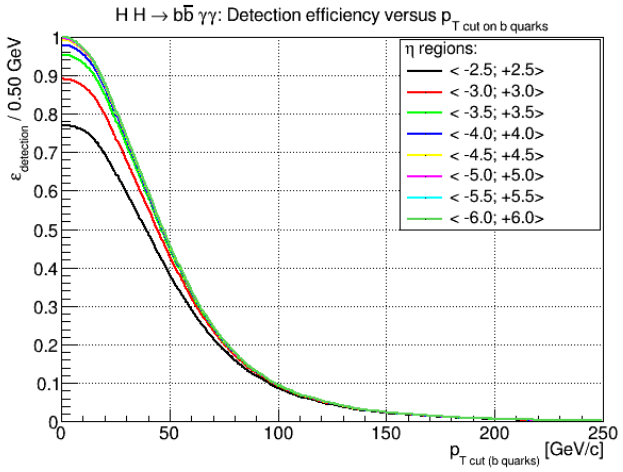
Results for decay mode: $H \to b\bar{b}$ + $H \to \gamma\gamma$

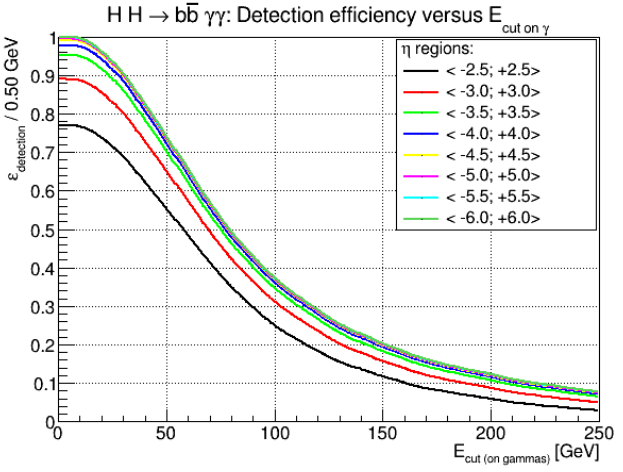
- **Apply $P_T(b\bar{b})$, E ($\gamma\gamma$) cuts versus eta acceptance for 100 TeV machine**





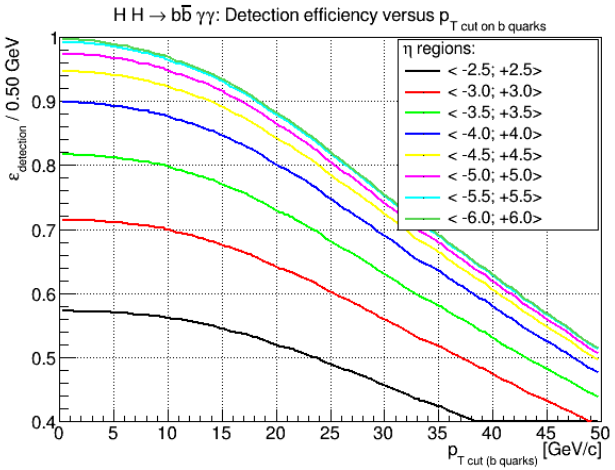
- **For 13 TeV machine:**

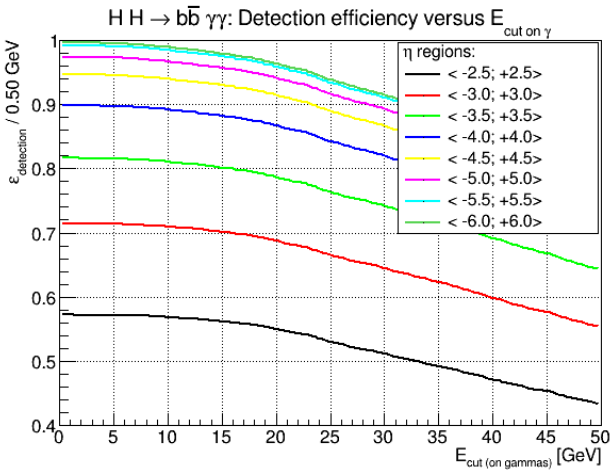




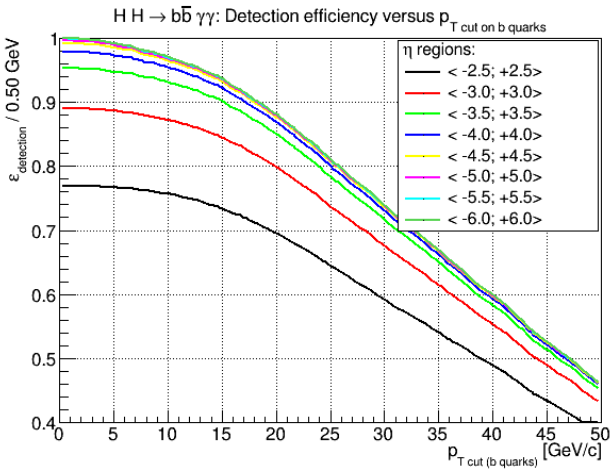
Zoomed-In Results for: $H \to b\bar{b}$ + $H \to \gamma\gamma$

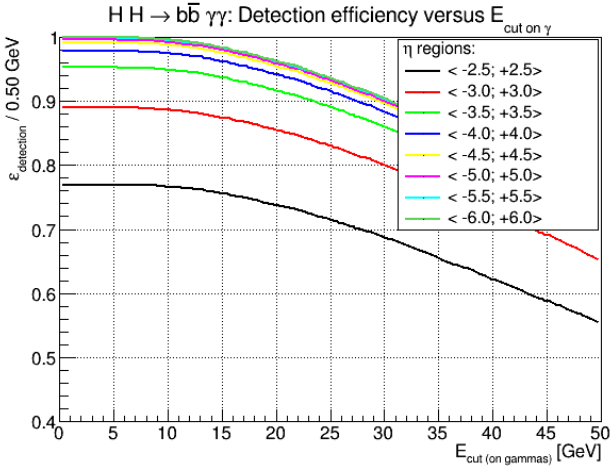
- **Cuts in detail & numbers for 100 TeV machine**





- **For 13 TeV machine:**





Efficiency (b quarks) [%]

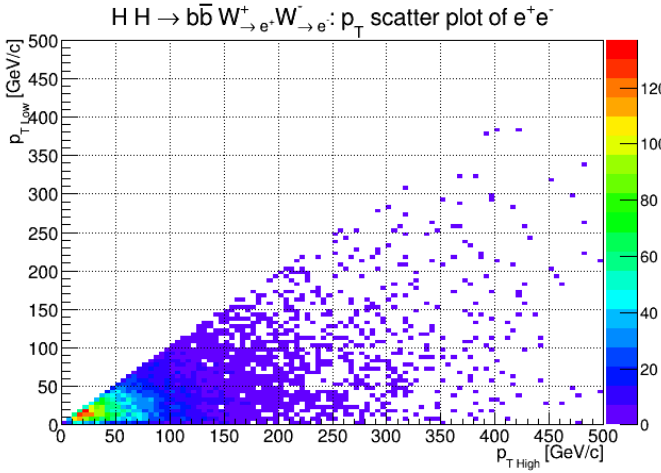
p_T(b)[GeV] ≥	0.0	5.0	10.0
<-4.5;+4.5>	94.6	94.0	92.2
<-5.0;+5.0>	97.4	96.8	94.8
<-6.0;+6.0>	99.6	98.8	96.8

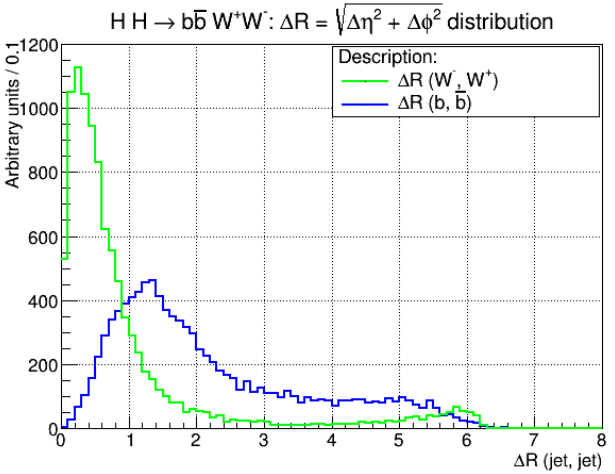
Efficiency (gammas) [%]

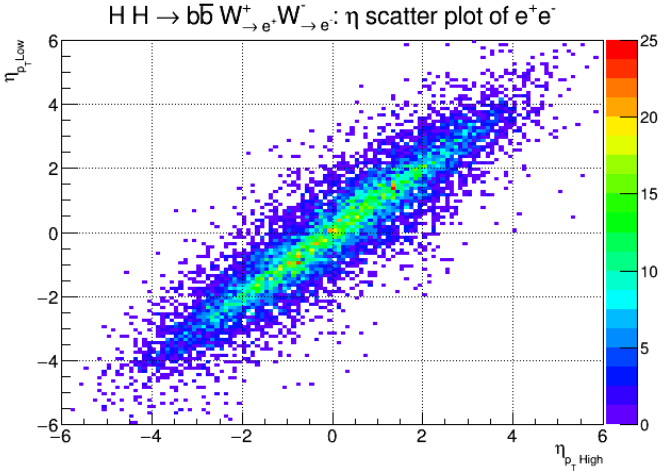
E(γ)[GeV] ≥	0.0	5.0	10.0
<-4.5;+4.5>	94.6	94.6	94.0
<-5.0;+5.0>	97.4	97.3	96.6
<-6.0;+6.0>	99.6	99.5	98.8

Results for decay modes: $H \to b\bar{b}$ + $H \to W^+W^-$

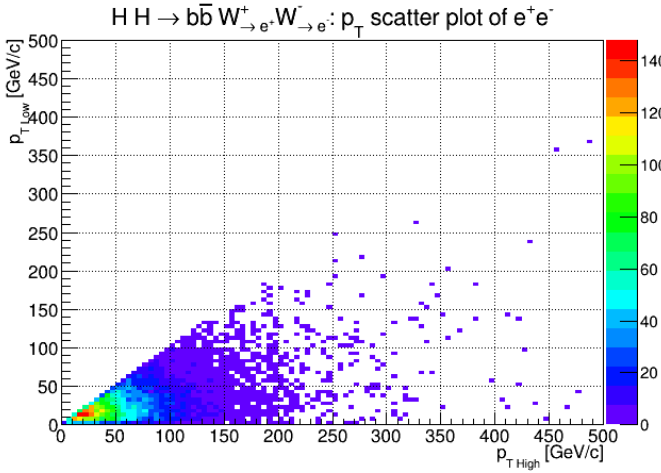
- **WW → ee ; P_T spectrum, jet isolation & eta spectrum for 100 TeV machine**

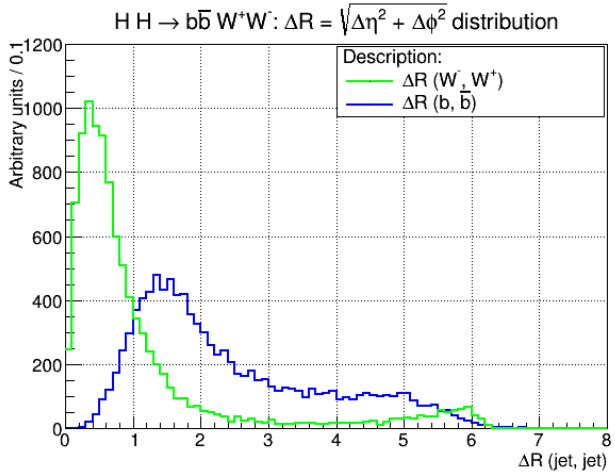


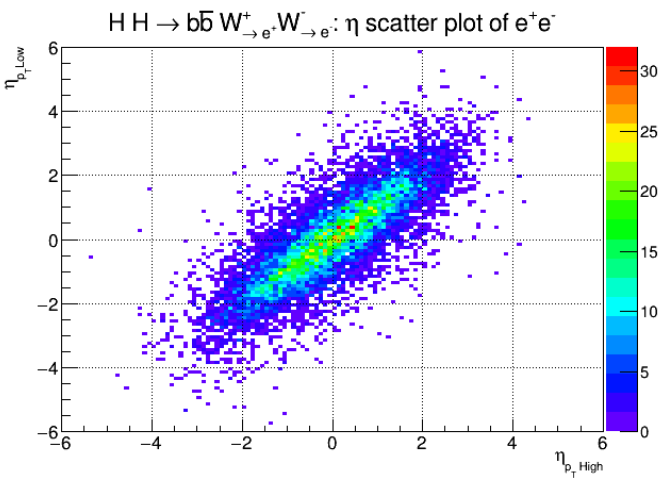




- **For 13 TeV machine**

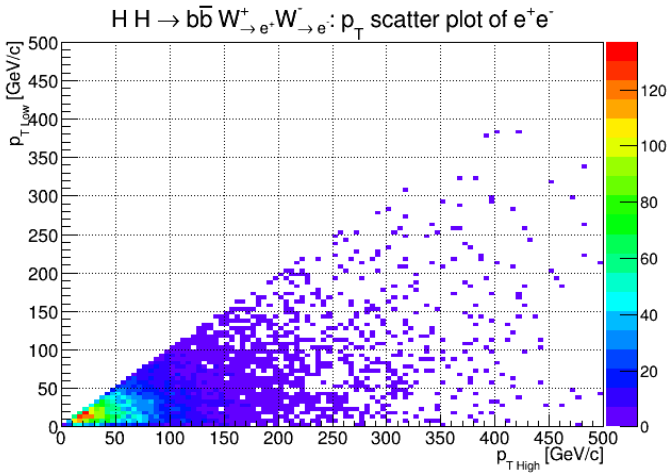


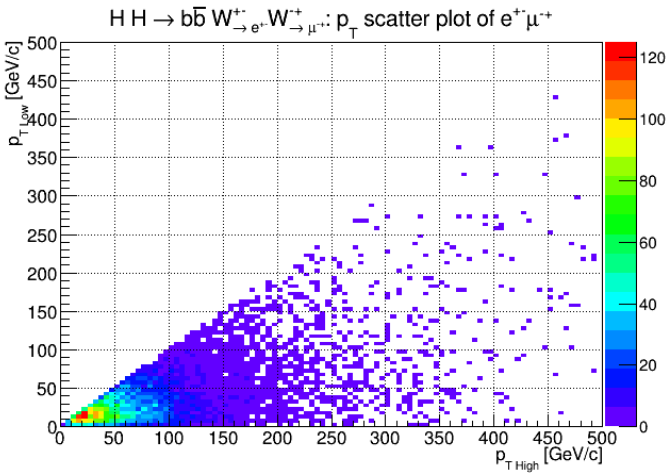


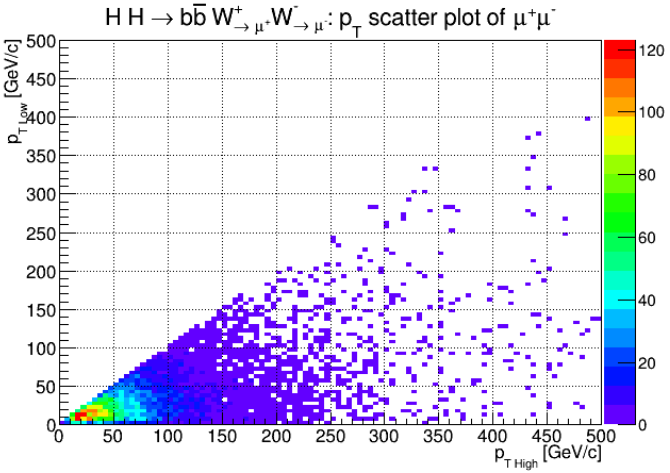


Results for decay modes: H→bb̄ + H→W⁺W⁻

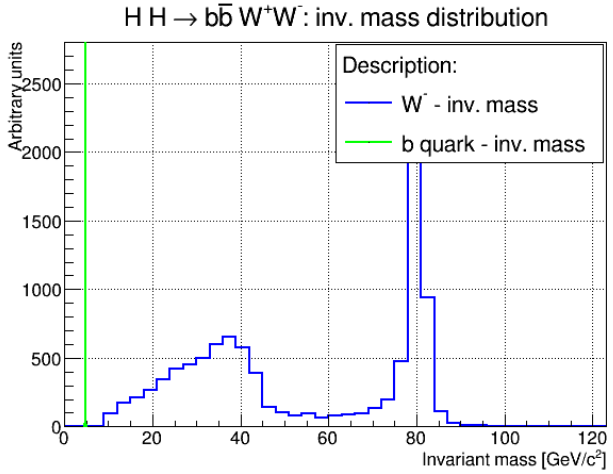
- **WW → ee x WW → eμ x WW → μμ → very similar results (100 TeV machine)**





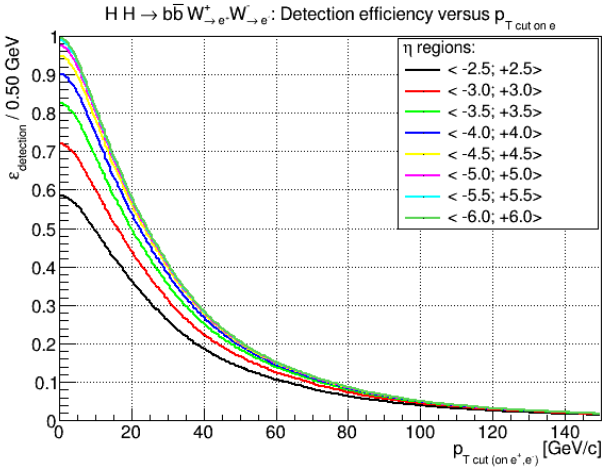


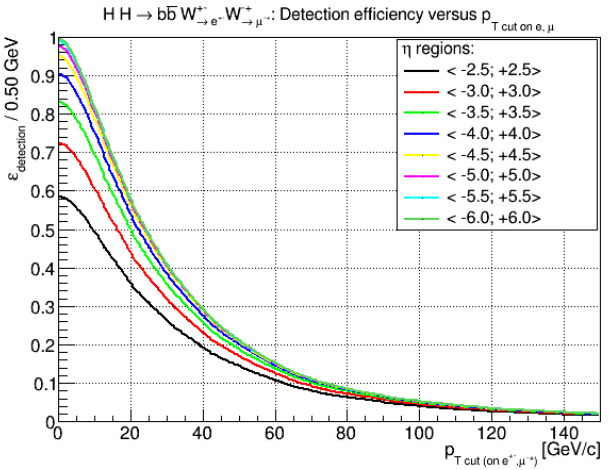
- **W invariant mass → one W virtual (off-shell):**

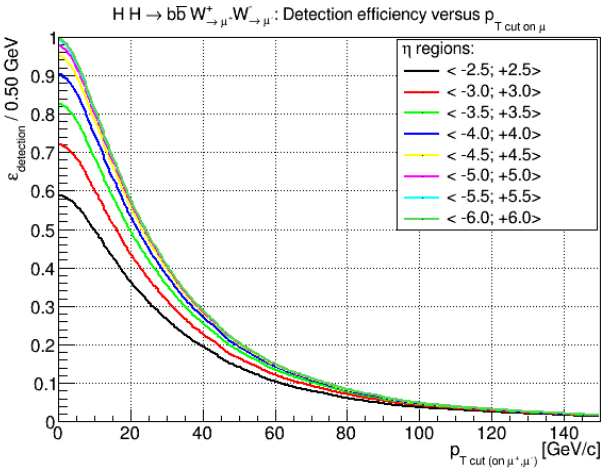


Results for decay modes: $H \to b\bar{b}$ + $H \to W^+W^-$

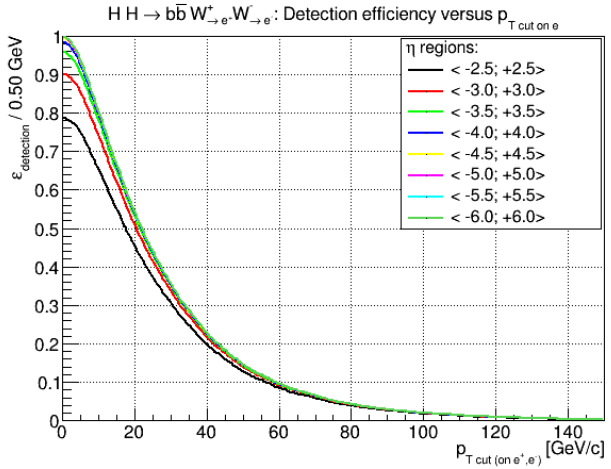
- **WW → ee,eμ,μμ ; Apply P_T cuts versus eta acceptance for 100 TeV machine**





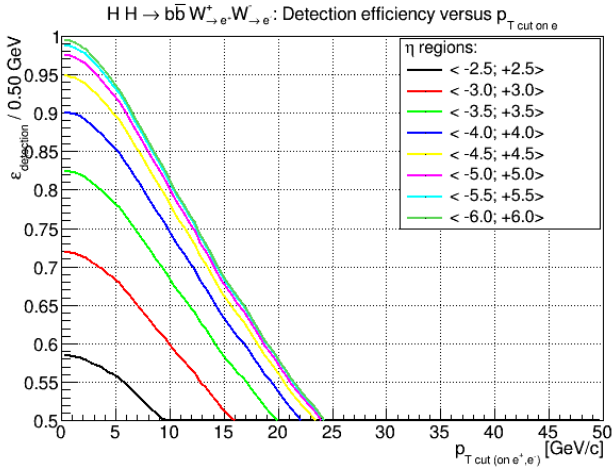


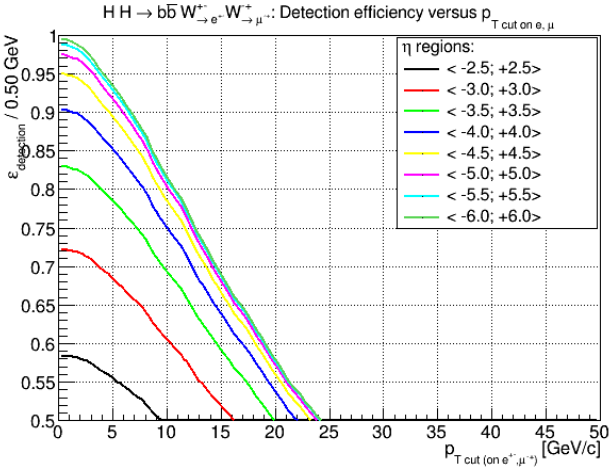
- **For 13 TeV machine**

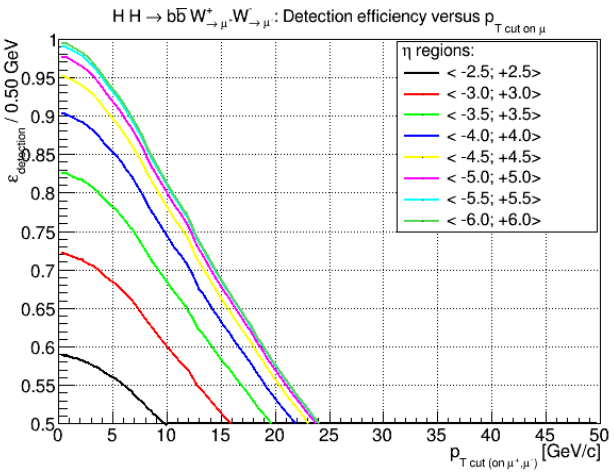


Zoomed-In Results for: $H \to b\bar{b}$ + $H \to W^+W^-$

- **WW → ee,eμ,μμ ; Cuts in detail & numbers for 100 TeV machine**





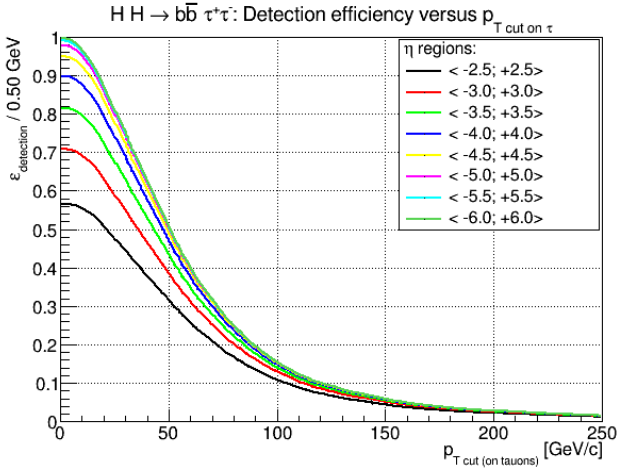


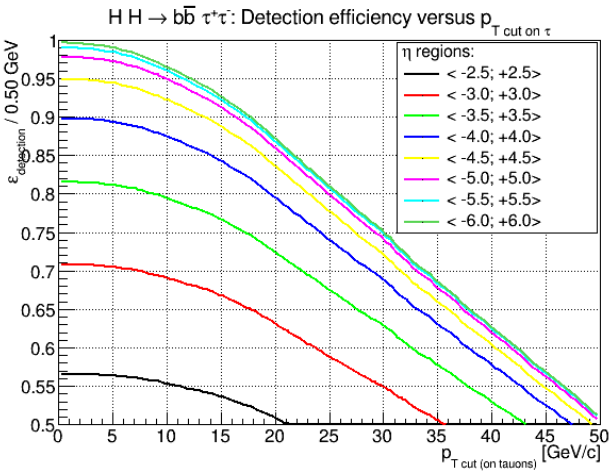
Efficiency (e,μ) [%] → very similar for all three leptonic decay channels

pT[GeV] ≥	0.0	5.0	10.0
<-4.5;+4.5>	94.9	89.2	77.6
<-5.0;+5.0>	97.6	91.6	79.6
<-6.0;+6.0>	99.6	93.2	80.8

Results for decay mode: $H \to b\bar{b}$ + $H \to \tau^+\tau^-$

- Very similar topology as in previous decay channels, but still missing tau lepton decayed to the final states: e,μ
- For demonstration: **Apply P_T cuts versus eta acceptance (100 TeV)**





gg → HH studies: Summary & Outlook

- **Summary**:
  - The study is far from being complete:
    - b-tagging effects not yet implemented
    - tau reconstruction missing (in progress)
    - E_T reconstruction for W decay channel missing (in progress)
    - but the following can be stated:
  - gg → HH represents a "low" pT physics compared to FCC-hh TeV scale in terms of detector design! So, various channels "in other corners" of TeV scale spectra needs to be addressed to have a realistic picture of our detector
  - Rather than $\eta_{coverage}$ = <-6.0;+6.0>, $\eta_{coverage}$ = <-5.0;+5.0> or even $\eta_{coverage}$ = <-4.5;+4.5> seems to be sufficient
  - More crucial are the applied p_T (E) cuts on final leptons (gammas), i.e. detector resolution rather than eta → the degradation in terms of efficiency is very steep!
- **Outlook**: Add study with DELPHES to understand other detector effects