Minimum bias ZH, $\mathrm{Z} \to \mathrm{q\bar{q}}$ @ 250 GeV

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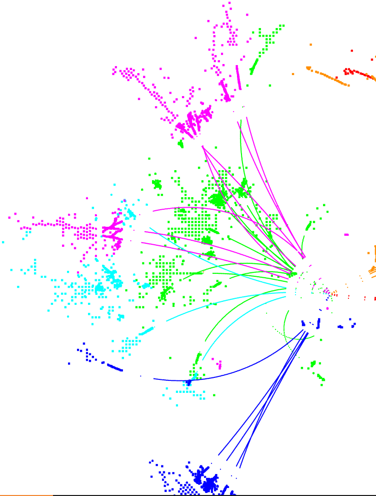
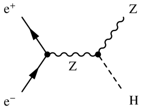
Outline

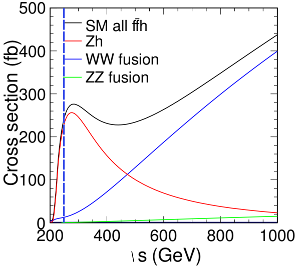


Motivation

- ZH is the dominant Higgs prodcution process @ 250 GeV
- Signal: $e^+e^- \rightarrow Z^* \rightarrow ZH \rightarrow 2j + X$



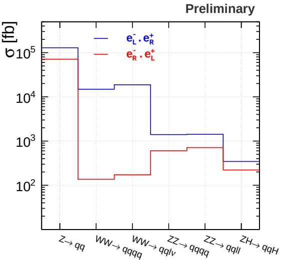
- $M_H^2 = M_{jj}^{recoil} = (\sqrt{s} - E_Z)^2 - P_Z^2$
  $\Rightarrow g_{ZZH} \propto \sigma = N/(L \cdot \epsilon)$
- Reconstruct the M_{jj}^{recoil} from the Z dijet only, without measuring the Higgs products.
  - Increase the Higgs statistics $\rightarrow 70\%$ Z BR ($\sim 6\%$ for (ll)recoil)
  - Almost model independent.
- Very difficult @250 GeV (ZZ/WW background)



MC Samples

- Main processes at $250\ GeV$: ZH, W^+W^-, Z^0Z^0, $Z \to q\bar{q}$
- For qq(Recoil) analysis $\to$ the main background : $WW \to 2j + X$, $ZZ \to 2j + X$
- 2012 DBD MC Generator samples (`WHIZARD-v1.95` Generator)

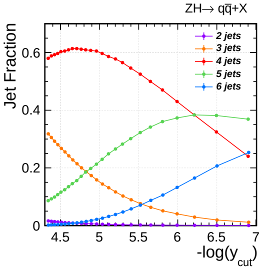
	$N_{jet} \geq 2$	N_{events}	$\sigma\ [fb]$	weight ($L = 500\ fb^{-1}$)
$e^-_L e^+_R$	$ZH(qq+X)$	346.013	437368	0.395563
	$WW(qqqq)$	14874.3	1074111	6.92401
	$WW(ql\nu)$	18781	1753663	5.35479
	$ZZ(qqqq)$	1402.06	1004632	0.697798
	$ZZ(qqll)$	1422.14	1299591	0.547149
	$Z(qq)$	129149	1629438	39.6299
$e^-_R e^+_L$	$ZH(qq+X)$	221.952	267357	0.415085
	$WW(qqqq)$	136.357	136325	0.500117
	$WW(ql\nu)$	172.733	158021	0.546551
	$ZZ(qqqq)$	604.971	603931	0.500861
	$ZZ(qqll)$	713.526	637256	0.559843
	$Z(qq)$	71272.8	1676503	21.2564

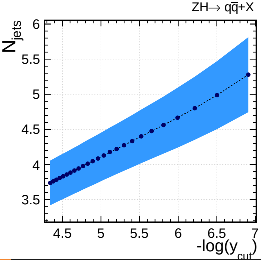


- Event weighting calculated for a processus "i" by $w_i = L \cdot \sigma_i / N_i$

Fast Simulation & Jet Clustering

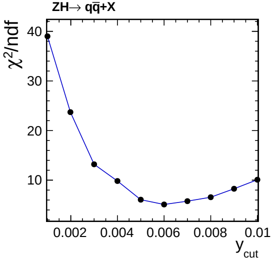
- Reconstruct only the stable `MCParticle` in generator level
- Jet clustering :
  - Durham algorithm implemented in `FastJet-v3.04`.
    $y_{ij} = \frac{2\min\{E_i^2, E_j^2\}}{Q}(1-\cos\theta_{ij})$
  - Exclusive jet clustering with fixed-y_{cut}
- Smearing of the jet
  - Energy : $\sigma(E_j)/E_j = \alpha$
  - $\Rightarrow$ Momentum : $\sigma(p_j) = \left(\frac{E_j}{P_j}\right)\sigma(E_j) = \left(\frac{E_j^2}{P_j}\right)\alpha$
- A $\alpha = 3\%$ is chosen for this analysis
- For $ZH \rightarrow q\bar{q} + Z$: Jet Fraction vs y_{cut}
- Z boson di-jet $\rightarrow$ the jet pair minimizing $D = |m_{jj} - m_Z|$
- The number of Jet in final stat $n_{jet} = n_{q\bar{q}} + n_X$
- The $n_{q\bar{q}} \sim 2$ ($\geq 2 \rightarrow$ Gluon radiation)
- $n_X \sim [0, 4]$ depends on how the Higgs decays

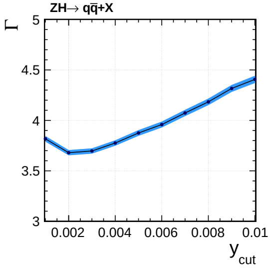




Jet Clustering Optimization

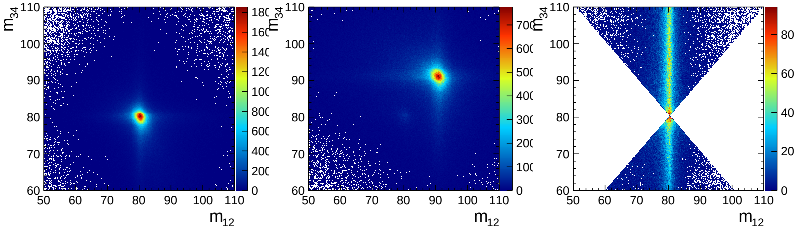
- The Selected di-jet mass is fitted by a Voigtian p.d.f (Breit-Wigner⊗Gauss)
  - The $\chi 2$ vs $y_{cut} \rightarrow$ min at $y_{cut} = 0.006$
  - The Γ vs $y_{cut} \rightarrow$ min at $y_{cut} = 0.002$
- The $y_{cut} = 0.006$ is chosen for the further analysis.
- Next step :
  - Measurement of the MC-Matching efficiency of the Z
  - The best y_{cut} table for each Higgs decay as





Preselection

- ZZ/WW Background rejection method (a la Thomson):
  - ZZ lead in 4-Jet final state (all-hadronic decays) or $2jet + 2l$
    - Force jet-clustering into 4-Jet and select the best two pairs loseset to Z mass
  - ZZ lead in 4-Jet in the final state (all-hadronic decays) or $2jet + 1l = 3 - jet$
    - Force jet-clustering into 4-Jet and select the best two pairs closest to W mass
    - Force jet-clustering into 3-Jet select the best par clostest to W best
  - A rejection box is applied to remove to ZZ/WW contribution
  - The forced jet clustering is used only for the background rejection:
    The di-jet with fixed y_{cut} is used for the measurement.



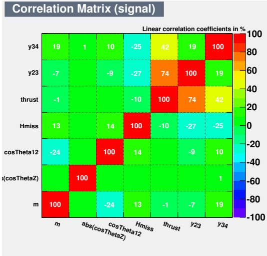
Preselection

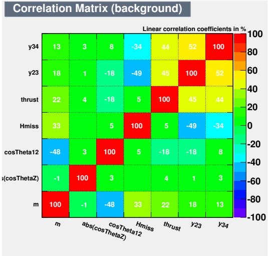
- First selection (preselection) on the forced-jet variables
  - for $WW \rightarrow q\bar{q}q\bar{q}$ reject event with :
    $(90 > m12 > 70 \text{ GeV})$ and $(90 > m_{34} > 70 \text{ GeV})$
  - for $ZZ \rightarrow q\bar{q} + (q\bar{q}|l^- l^+)$ reject event with :
    $(100 > m12 > 80 \text{ GeV})$ and $(100 > m34 > 80 \text{ GeV})$
  - Very loose cut on the recoil mass : $200 > m_{rec} > 50$ GeV

	Process	N_{tot}	N_{pres}	ε_{pres}
$e^-_L e^+_R$	$Z \rightarrow qq$	1.62944e+06	681176	0.418044
	$WW \rightarrow qqqq$	1.07411e+06	309080	0.287754
	$WW \rightarrow qql\nu$	1.75366e+06	1.43914e+06	0.82065
	$ZZ \rightarrow qqqq$	1.00463e+06	393609	0.391794
	$ZZ \rightarrow qqll$	1.29959e+06	925202	0.711918
	$ZH \rightarrow qqH$	437368	325021	0.743129
$e^-_R e^+_L$	$Z \rightarrow qq$	1.6765e+06	763544	0.455438
	$WW \rightarrow qqqq$	136325	34991	0.256673
	$WW \rightarrow qql\nu$	158021	128520	0.81331
	$ZZ \rightarrow qqqq$	603931	238576	0.395039
	$ZZ \rightarrow qqll$	637256	434858	0.682391
	$ZH \rightarrow qqH$	267357	199170	0.744959

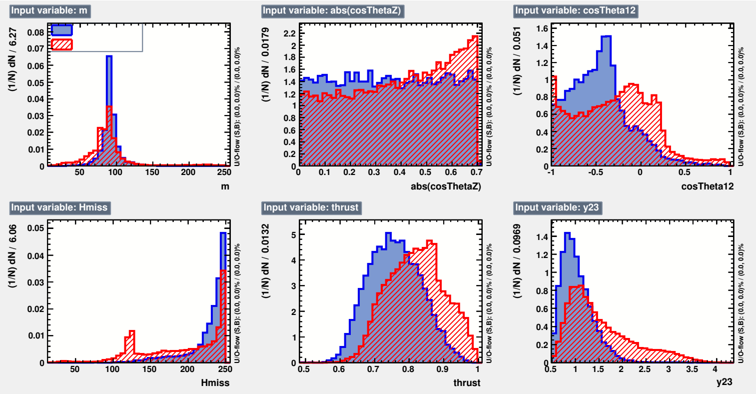
BDT based selection

- Use of ROOT TMVA package → Boosted Decision Tree (BDT)
- The input variables are;
  - m_{jj}: The invariant mass of the di-jet system
  - $\cos\theta_Z$: Production angle of the di-jet system
  - $\cos\theta_{12}$: Angle between two selected jets
  - Thrust
  - y_{23}, y_{34} ($y_{ab} = \min\{y_{cut} | a\ jets \leftarrow b\ jets\}$)
  - $H_{miss} = \sum_{i \in Event} \parallel \vec{p}_i \parallel$
- Train the BDT for combined backgrounds
- One BDT of each polarization ($e^-_R e^+_L$ or $e^-_L e^+_R$)
  - The Gradient BDT (BDTG) is chosen, more powerful than the standard BDT.

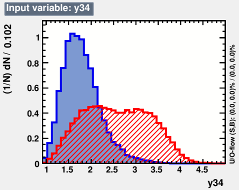




MVA based selection

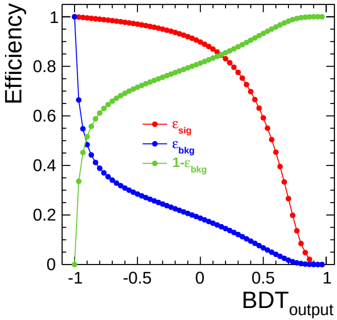


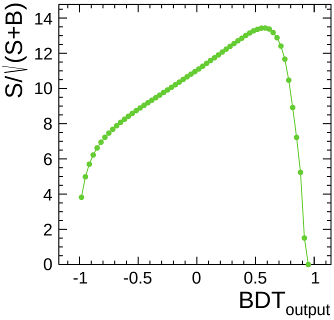
MVA based selection



MVA results

- Signal and background efficiency are calculated ($\varepsilon_i = N_i/N_{tot}$).
- The significance defined as $S/\sqrt{S+B}$ shows a maximum at
- for $e^-_L.e^+_R$





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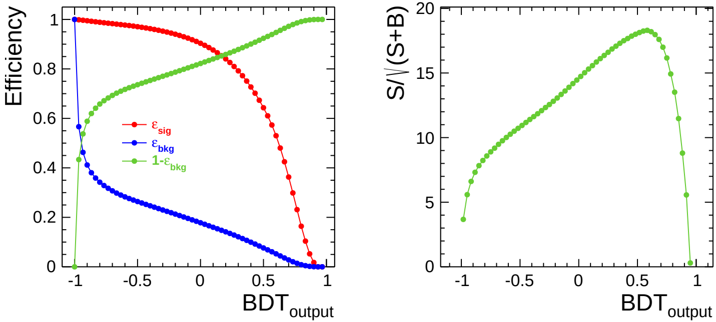
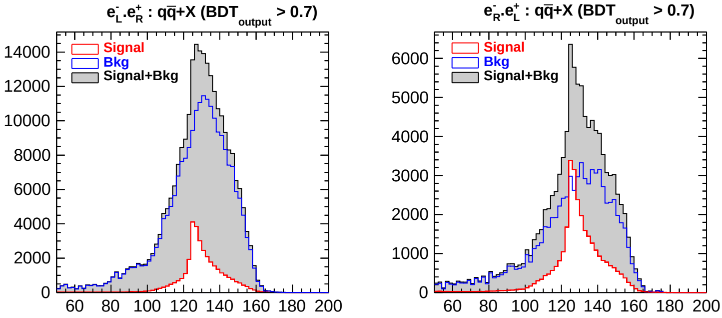


- Optimal cut at $\mathrm{BDT_{output}} > 0.7$ for both polarizations

MVA results

- Signal and background efficiency are calculated ($\varepsilon_i = N_i/N_{tot}$).
- The significance defined as $S/\sqrt{S+B}$ shows a maximum at
- for the recoil mass



MVA results for both polarizations

Process $(e^-_L e^+_R)$	σ[fb]	N_{tot}	Weight	$N_{BDT>0.7}$	$\varepsilon_{BDT>0.7}$
$Z \to qq$	129149	681176	94.8	1831	0.00268
$WW \to qqqq$	14874.3	309080	24.1	15499	0.05014
$WW \to qql\nu$	18781	$1.44\ 10^6$	6.5	1325	0.00092
$ZZ \to qqqq$	1402.06	393609	1.8	40261	0.10228
$ZZ \to qqll$	1422.14	925202	0.8	7290	0.00788
$ZH \to qqH$	346.013	325021	0.5	86463	0.26602

Process $(e^-_R e^+_L)$	σ[fb]	N_{tot}	Weight	$N_{BDT>0.7}$	$\varepsilon_{BDT>0.7}$
$Z \to qq$	71272.8	763544	46.7	2467	0.00323
$WW \to qqqq$	136.357	34991	1.9	3272	0.09350
$WW \to qql\nu$	172.733	128520	0.7	183	0.00142
$ZZ \to qqqq$	604.971	238576	1.8	33341	0.13975
$ZZ \to qqll$	713.526	434858	0.8	5368	0.01234
$ZH \to qqH$	221.952	199170	0.5	72288	0.36294

Conclusion & Outlook

- Clear Higgs peak with good significance in $e^-_R.e^+_L$ polarization.
- Still improvement are needed:
  - Include a realistic beam polarization.
  - Optimization of the selection $\rightarrow$ investigation of more discriminant variables.
- Next :
  - Extraction of the cross section of ZH process
  - Measurement of the selection efficiency for each Higgs boson decay mode.
  - Full simulation undergoing.