Feasability of a minimum bias analysis of $e^+e^- \to ZH \to q\bar{q} + X$ at 250 GeV

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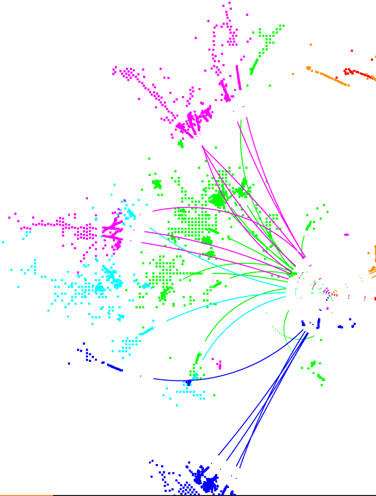
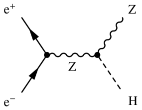
Outline

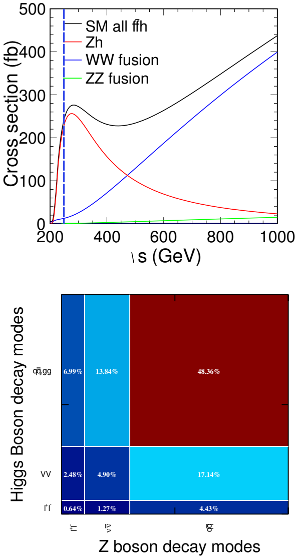


Motivation

- ZH is the dominant Higgs prodcution process @ 250 GeV
- Signal : $e^+e^- \to Z^* \to ZH \to 2j + X$ is used for this analysis



- Reconstruct the M_{jj}^{recoil} from the Z dijet only, without measuring the Higgs products.
  - Increase the Higgs statitics $\to$ 70% Z BR ($\sim 6\%$ for (ll)recoil)
  - Model independent of Higgs measurement.
- Very difficult @250 GeV (ZZ/WW background)



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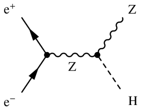

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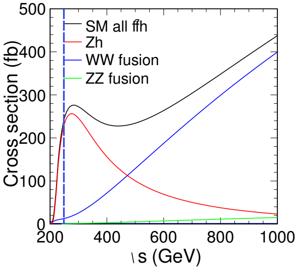
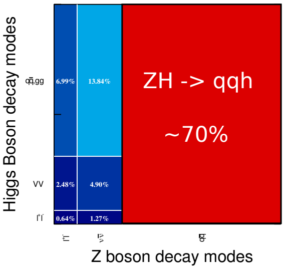
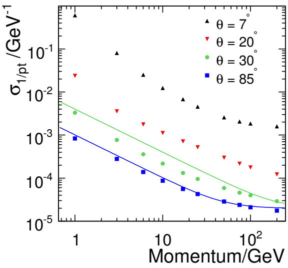
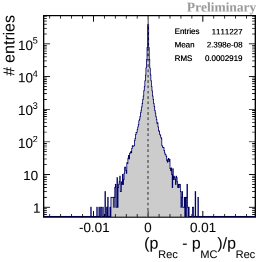




Fast Simulation

- Reconstruct only the MCparticles stable @ the generator level.
- Particle 4-Momentum is smeared following the ILD performance benchmarks :
  - Expected tracking performance (for $\mathbf{P}$ smearing) : $\sigma_{1/p_T} \approx 2 \times 10^{-5}$ GeV^{-1}
  - Expected calorimetry (for E smearing) :
    - $h^0 \to \sigma_E/E \sim 0.1 + 0.5\sqrt{(E)}$
    - $\gamma \to \sigma_E/E \sim 0.01 + 0.1\sqrt{(E)}$
- Reconstructed particle $\to$ PFO
- Only PFO with $|\eta| < 2.66$ and $p_t > 0.5$ GeV are reconstructed.





MC Samples

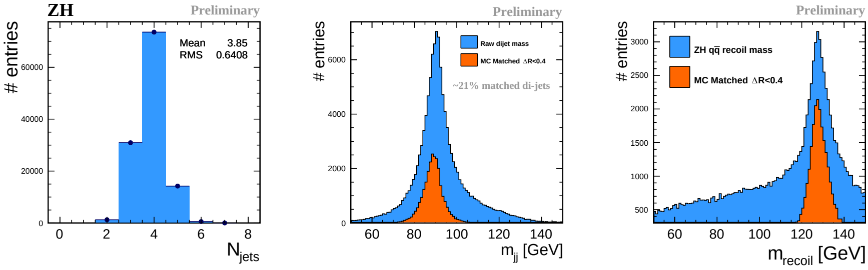
- Main processes at $250\ GeV$: ZH, W^+W^-, Z^0Z^0
- For qq(Recoil) analysis $\rightarrow$ the main background : $W^+W^- \rightarrow 2j + X$, $Z^0Z^0 - \rightarrow 2j + X$
- 2012 DBD MC Generator samples (WHIZARD Generator)

$N_{jet} \geq 2$	N_{events}	$\sigma\ (fb)$ $e^-_L e^+_R$	weight ($L = 500\ fb^{-1}$)
$ZH \rightarrow 2j + X$	120409	346.01	1.41
$WW(4j)$	321376	18781.00	60.48
$WW(sl)$	181533	14874.30	52.30
$ZZ(4j)$	120088	1422.14	4.45
$ZZ(sl)$	178900	1402.06	6.46

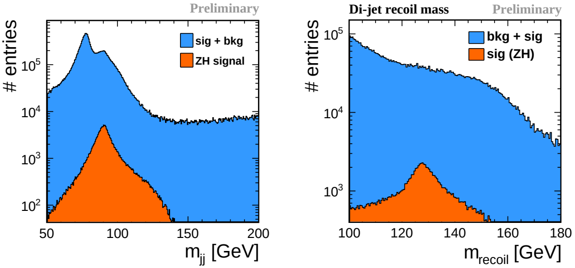
- Considering (now) only $e^-_L e^+_R$ (Signal & background cross section are larger)
- Ask for at least 2 jets in the final stat.

Jet reconstruction & Jet pairing

- Durham jet clustering with fixed y_{cut} ; $y_{ij} = 2\min(E_i^2, E_j^2)\frac{(1-\cos\theta_{ij})}{Q^2}$
- The y_{cut} is fixed to 0.01, with E recombination scheme.
- Z boson di-jet → the jet pair which minimize $\chi 2 = (m_{jj} - m_z)^2/\sigma_z^2$
- The jets are matched from the Z boson quarks (Gen level) → Test the Jet pairing efficiency.
  - Only $\sim 20\%$ of di-jets are matched in $\Delta R < 0.4$
  - Highly depend in the jet clustering performance → Should be optimized ! !
- The recoil mass defined by ; $m_{recoil}^2 = s + m_{jj}^2 - 2p_z\sqrt{s}$



- The raw signal + background → no cut applied.

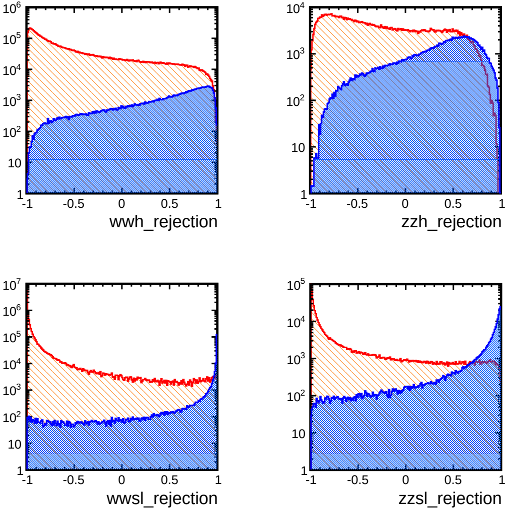


- Only di-jet variables are not enought for a good background rejection → use some Event Shape Variables ! !
  - Thrust : $\tau \equiv 1 - \max_{\vec{n}}(\sum_i |\vec{p}_i \cdot \vec{n}| / \sum |\vec{p}_i|)$
  - Sphericity $\equiv (3/2)\min(\sum \mathbf{p}_L^2 / \sum \mathbf{p}^2)$
  - Acollinearity $\equiv \cos^{-1}(\mathbf{p_1} \cdot \mathbf{p_2} / |\mathbf{p_1}||\mathbf{p_2}|)$, Acoplanarity $\equiv |\phi_1 - \phi_2|$

MVA based selection

- Use of ROOT TMVA package → Boosted Decision Tree (BDT)
- The input variables are ;
    - N_{jet}, $\cos\theta_{jj}$, E, $E_{visible}$, χ^2(from di-jet pairing)
    - Sphericity, thrust, $\cos\theta_{thrust}$
    - Y_{23}, Y_{34}, Y_{45} ($Y_{ab} = \min\{y_{cut}|a\ jets \leftarrow b\ jets\}$)
    - Acollinearity, Acoplanarity.
- Train the MVA for each background category → 4 BDT output variables.

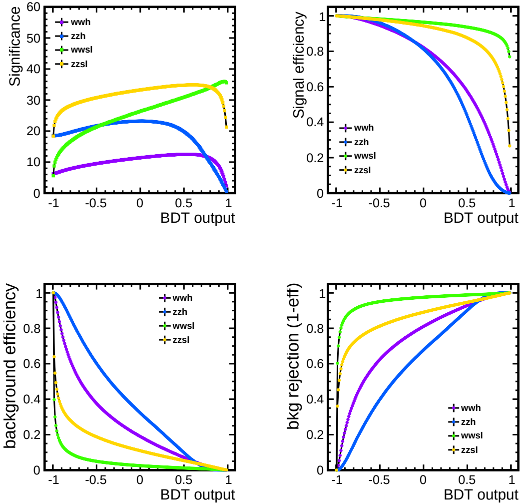
MVA results


10^6
10^5
10^4
10^3
10^2
10
1
-1
-0.5
0
0.5
1
wwh_rejection
10^4
10^3
10^2
10
1
-1
-0.5
0
0.5
1
zzh_rejection
10^7
10^6
10^5
10^4
10^3
10^2
10
1
-1
-0.5
0
0.5
1
wwsl_rejection
10^5
10^4
10^3
10^2
10
1
-1
-0.5
0
0.5
1
zzsl_rejection

Results (Very preliminary)

- The exlusive significance $(S/\sqrt{S+B})$ for each rejection variable.
- A naive cut on the BDT output variables only (not optimized yet !) :

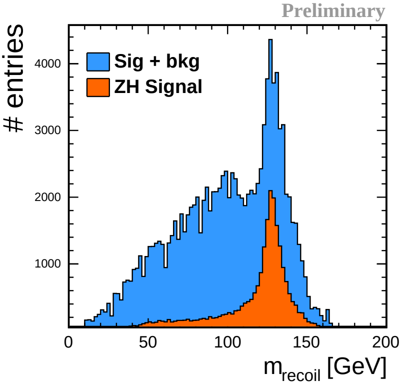
category	BDT cut	ε_{sig}	$(1-\varepsilon_{bkg})$
$ww \rightarrow h$	> 0.8	58%	98.2%
$ww \rightarrow sl$	> -0.5	96%	95%
$zz \rightarrow h$	> 0.6	44%	94%
$zz \rightarrow sl$	> 0.6	88%	94.5%



Results (Very preliminary)

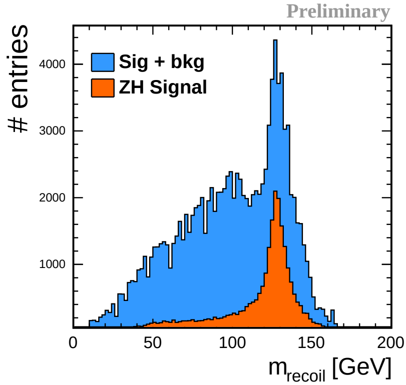
- Results :
  - Combine the previous cuts ⇒ Clear peak @ Higgs mass :
  - Significance ($S/\sqrt{S+B} = 101.44$)
  - Signal efficiency after cuts : $\sim 13\%$
  - Over 98% of background rejection.

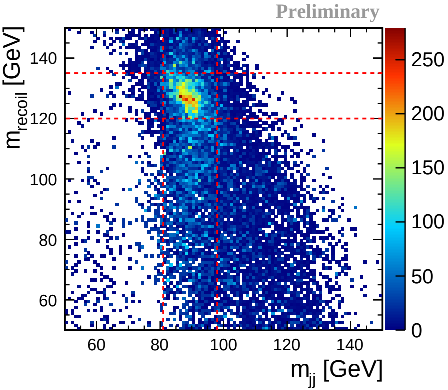
sample	before cuts	after cuts	efficiency
ZH	120409	16613	13.8%
$\mathrm{ww} \to \mathrm{h}$	321376	2225	0.6%
$\mathrm{ww} \to \mathrm{sl}$	120088	246	0.1%
$\mathrm{zz} \to \mathrm{h}$	120088	3085	2.5%
$\mathrm{zz} \to \mathrm{sl}$	178900	967	0.5%



Results (Very preliminary)

A selection in m_{recoil} can provide an unbiased (or minimum bias) sample of Higgs





Higgs measurements (BR ...) → To be done ! !

Conclusion & Outlook

- Clear Higgs peak with good significance
- Still some improuvements are needed :
  - Jet clustering & jet pairing algorithms
  - Optimize the MVA cuts (use additional variables ...)
- Very reliminary results BUT Very encouraging ! !

- NEXT STEP :
  - Results from a fast simulation → Do it in Full Simulation ! !