Measurement of the ZH cross section using Z->qq in ILD

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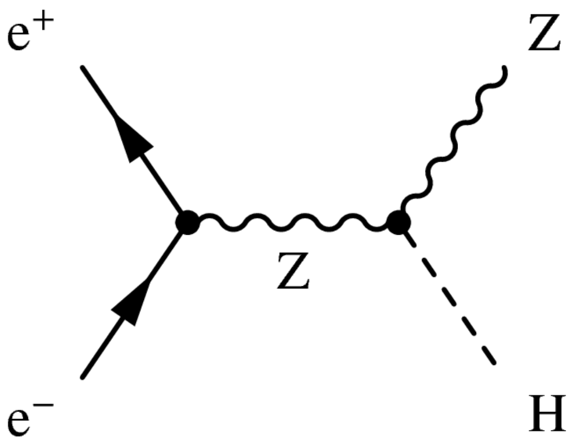
- At $\sqrt{s}$ = 250 GeV , the higgsstrahlung process is the dominant higgs production channel

- It is usually considered for $Z \rightarrow \mu\mu$ and Z->ee decays as it provides clear event topology

- It is however limited by the small branching ratio of $Z \rightarrow ll$ (~3 % for each lepton)

- On the opposite, the $Z \rightarrow qq$ provides a lot more statistics (br ~ 70%), but the event topology is not as clean as for Z leptonic decays



- Event sample :
  - DBD samples
  - ILCSoft : v02-00
  - ILD Model : **ILD_l5_o2_v02** (**SDHCAL** option)
    - See Bo Li's talk on Thursday for ILD_l5_o2_v02 performances
  - Signal :
    - qqH
  - Backgrounds :
    - Z->qq
    - WW->qqqq
    - WW->qqlv (l = μ / τ)
    - ZZ->qqqq
    - ZZ->qqll (l = μ / τ)
    - ZZ->qqvv (μ / τ only but does not really matter here...)
    - qqee and qqev events not processed yet
  - No background overlay

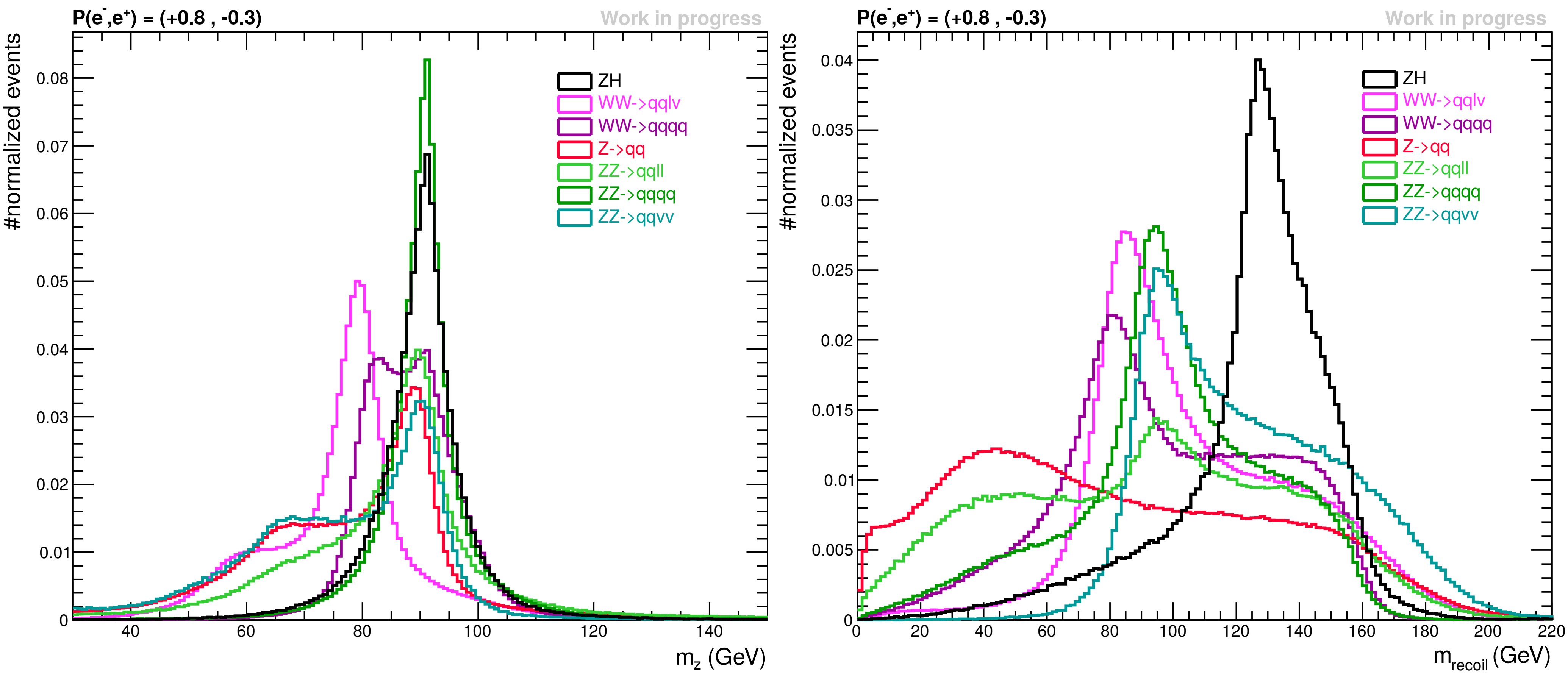
- Depending on the higgs decay channel, the events can have different topologies :
  - For example $H \to b\bar{b}$ will give a 4-jet final state ,
    $H \to WW \to q\bar{q}\tau\nu$ 5-jet final state ,
    $H \to WW \to q\bar{q}q\bar{q}$ and $H \to ZZ \to q\bar{q}q\bar{q}$ 6-jet final state

- Jet clustering is performed using Durham algorithm with a fixed y_{cut} =0.003 in order to not constrain the number of jets

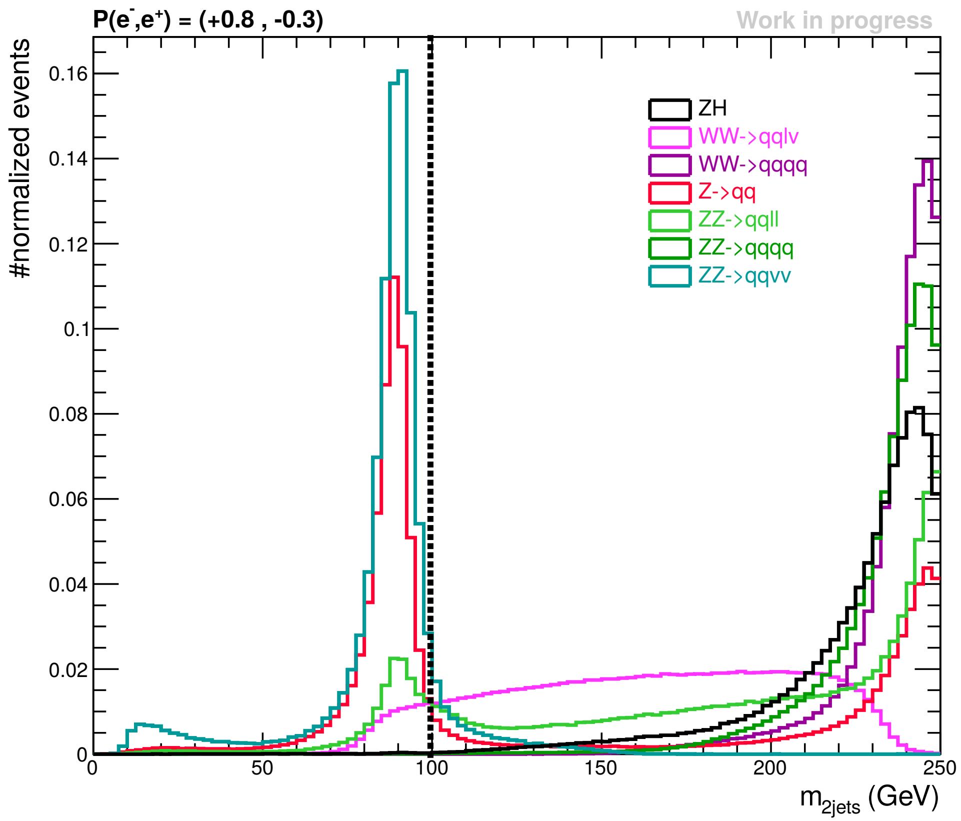
$$y_{ij} = \frac{2\min\{E_i^2, E_j^2\}}{E_{vis}^2}(1 - cos\theta_{ij})$$

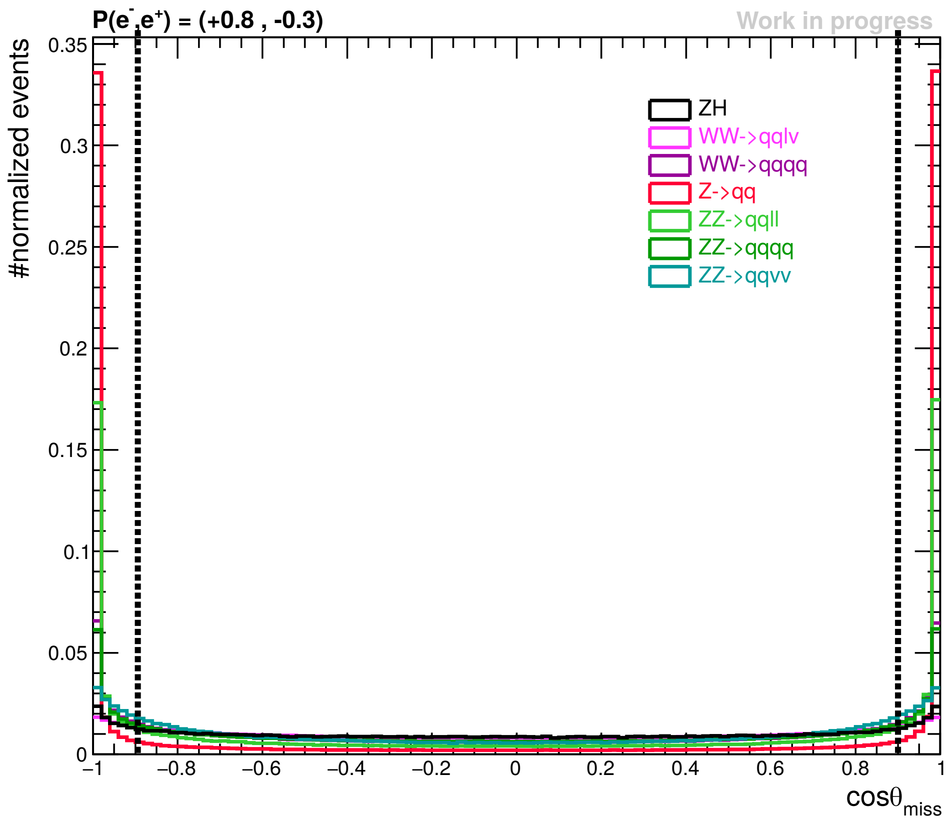
- The jet pair with invariant mass closest to m_Z is identified as the Z

- The recoil mass is calculated using the Z jet pair : $m_{rec}^2 = (\sqrt{s} - E_{Dijet})^2 - p_{Dijet}^2$

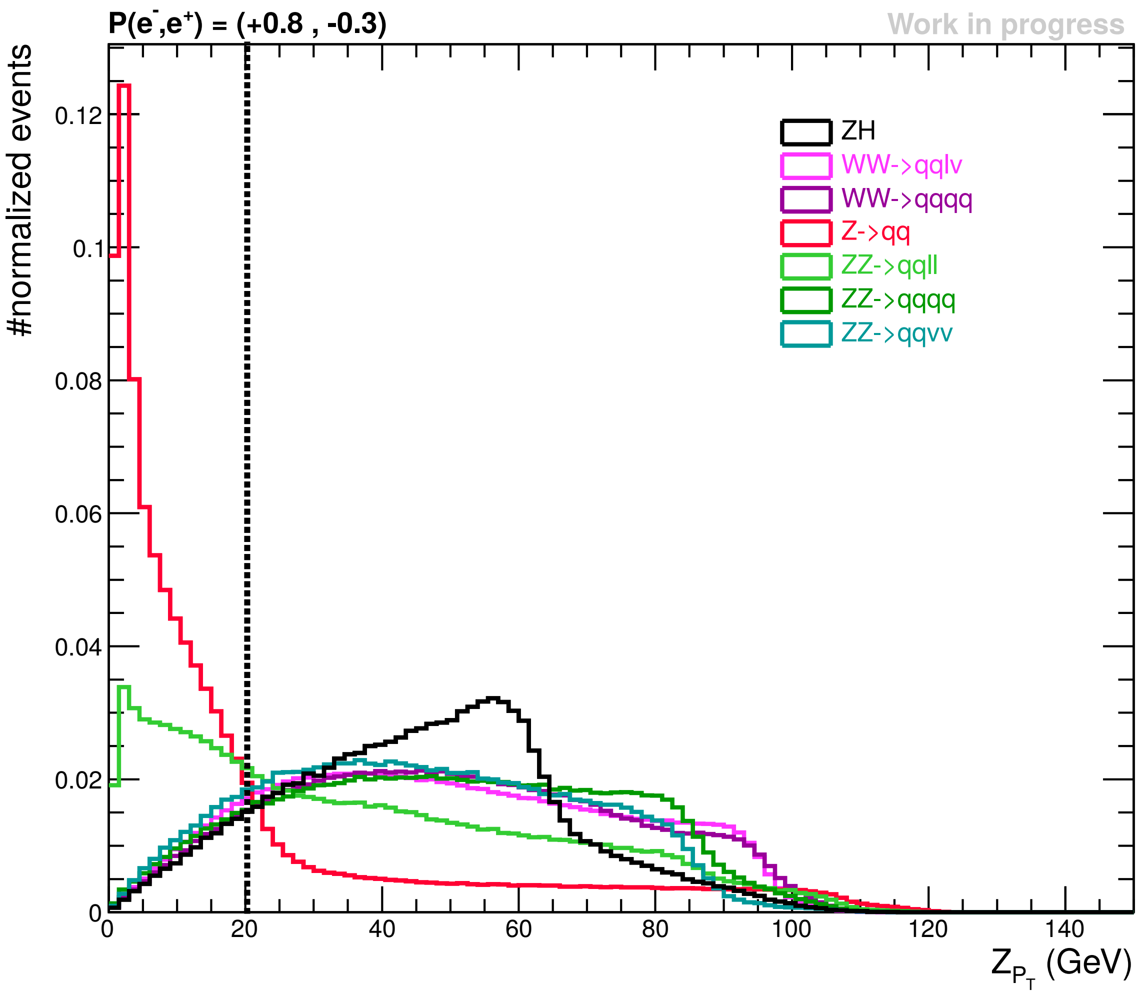

P(e-,e+) = (+0.8 , -0.3)
Work in progress
#normalized events
ZH
WW->qqlv
WW->qqqq
Z->qq
ZZ->qqll
ZZ->qqqq
ZZ->qqvv
m_z (GeV)
P(e-,e+) = (+0.8 , -0.3)
Work in progress
#normalized events
ZH
WW->qqlv
WW->qqqq
Z->qq
ZZ->qqll
ZZ->qqqq
ZZ->qqvv
m_{recoil} (GeV)

- Preselection cuts :
  - Event forced in 2 jets
  - Reject event if M_{2jet} <100 GeV
  - Reject if $|\cos\theta_{miss}| > 0.9$

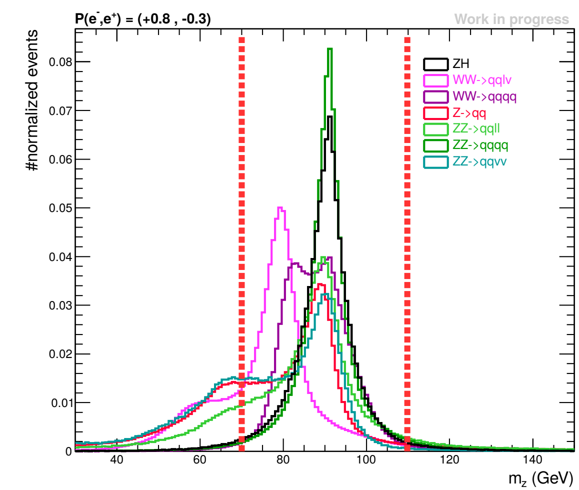


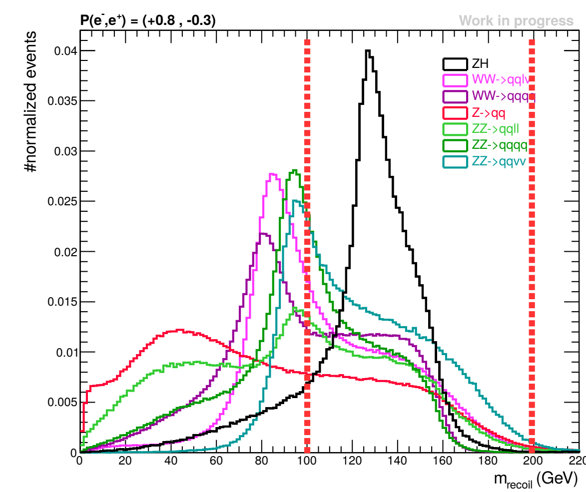


- Preselection cuts :
  - Reject events with :
    - P_T of selected Z diJet < 20 GeV



- Preselection cuts :
  - Event forced in 4 jets
  - Find the jet combination that minimises :
    - $X^2 = (m_{12} - m_W)^2 + (m_{34} - m_W)^2$
  - Reject event if :
    - 70 GeV < m_{12} < 90 GeV and
    - 70 GeV < m_{34} < 90 GeV
  - Find the jet combination that minimises :
    - $X^2 = (m_{12} - m_Z)^2 + (m_{34} - m_Z)^2$
  - Reject event if :
    - 80 GeV < m_{12} < 100 GeV and
    - 80 GeV < m_{34} < 100 GeV
  - Accept event if :
    - 70 GeV < m_Z < 110 GeV and
    - 100 GeV < m_{rec} < 200 GeV



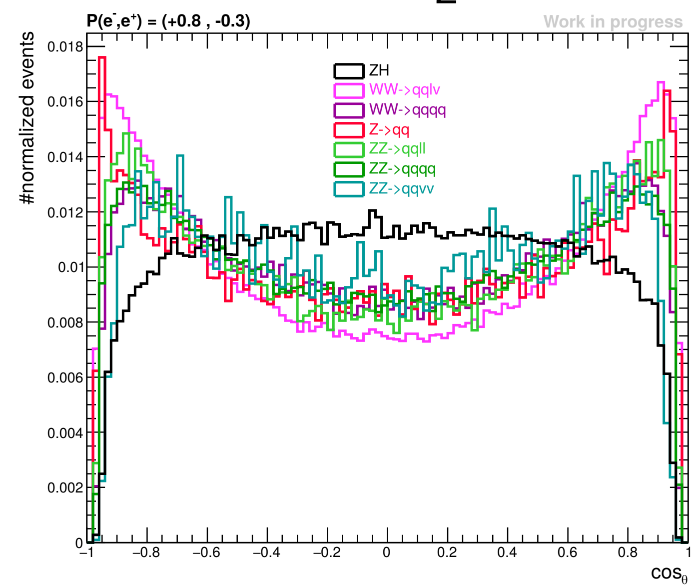


- BDT training :

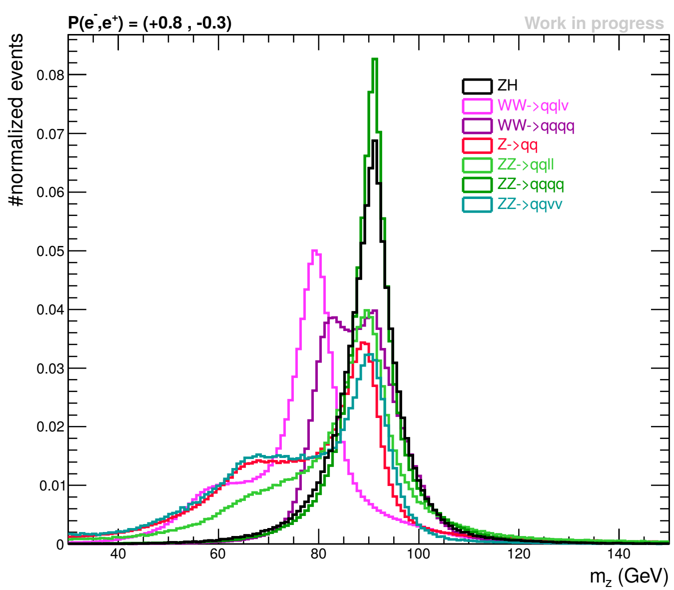
$\cos\theta_Z$: production angle of the selected Z di-jet system

θ_{Z12} : angle between the two jets of the selected Z di-jet system

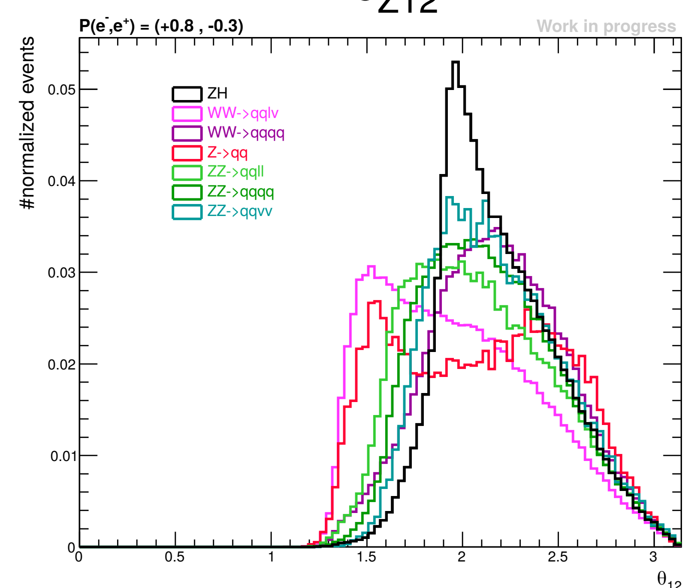
- $\cos\theta_Z$



- zMass



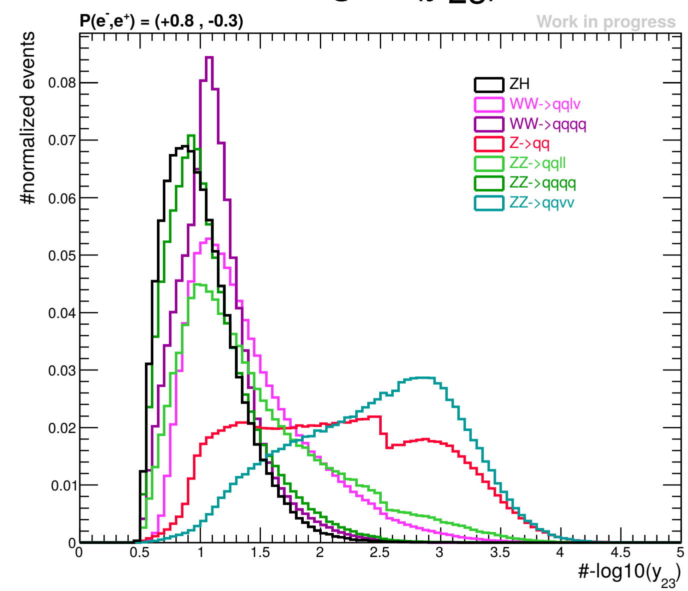
- θ_{Z12}



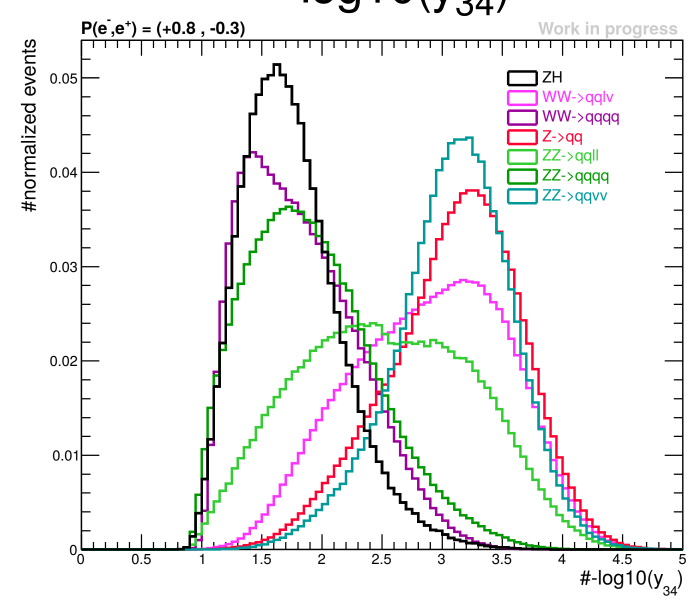
- BDT training :

$-\log10(y_{23})$, $-\log10(y_{34})$: Durham jet resolution parameters

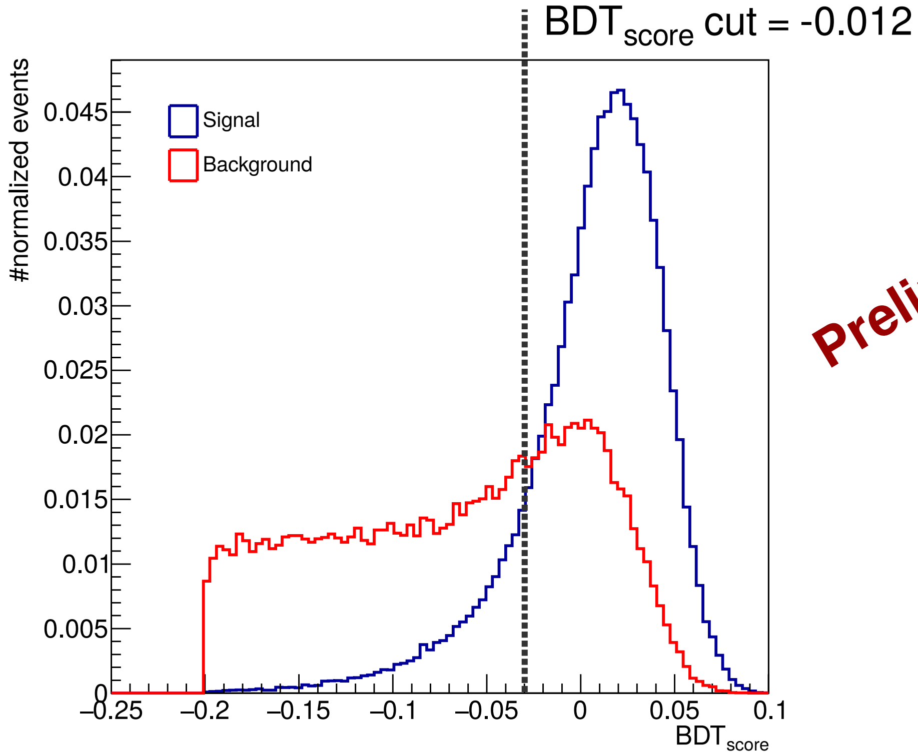
- $-\log10(y_{23})$



- $-\log10(y_{34})$



- BDT Training :
  - Variables used :
    - Zmass
    - $\cos\theta_Z$
    - θ_{Z12}
    - $-\log10(y_{23})$
    - $-\log10(y_{34})$



- $P(e^-,e^+) = (+80\ \%,-30\%)$

Preliminary

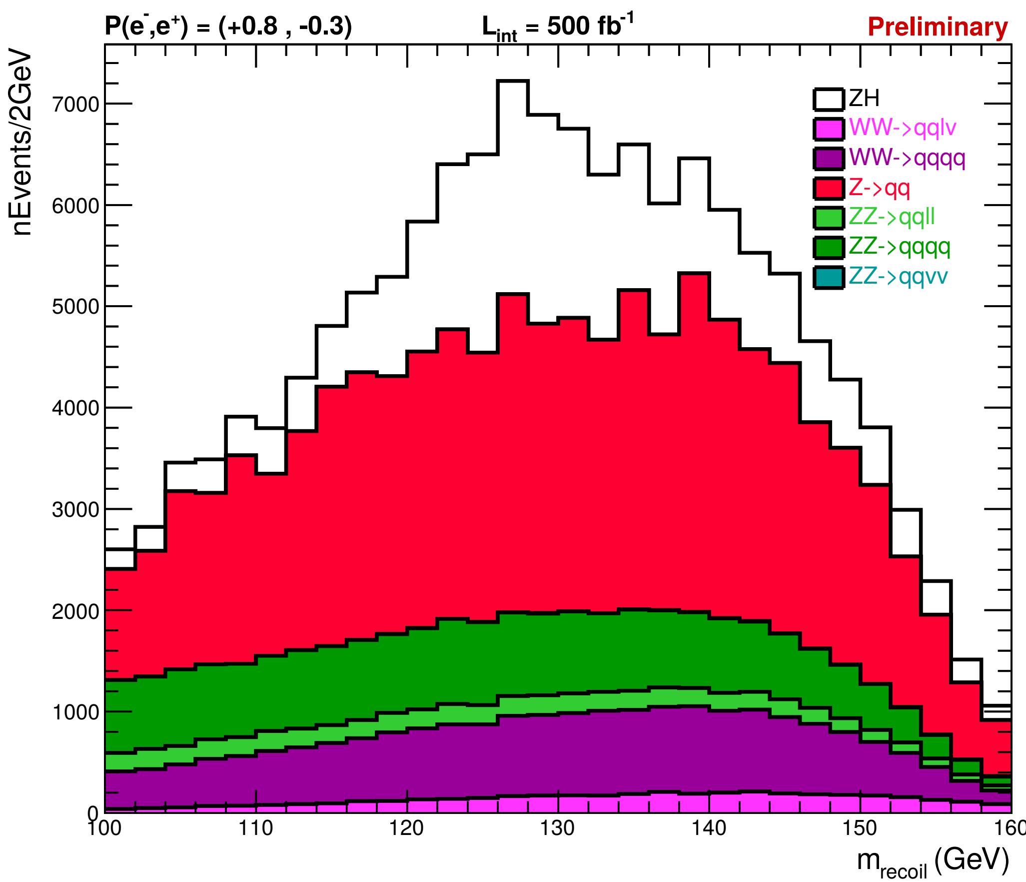
Channel	ε_{presel}	ε_{BDT}
ZH	50,11%	38,46%
WW->qqlv	17,29%	1,07%
WW->qqqq	9,71%	6,12%
Z->qq	1,40%	0,29%
ZZ->qqll	9,63%	3,43%
ZZ->qqqq	15,61%	9,90%
ZZ->qqvv	3,86%	0,07%

- $P(e^-,e^+) = (-80\ \%,+30\%)$

Preliminary

Channel	ε_{presel}	ε_{BDT}
ZH	50,06%	38,35%
WW->qqlv	16,89%	1,03%
WW->qqqq	9,47%	5,62%
Z->qq	1,88%	0,45%
ZZ->qqll	11,47%	4,35%
ZZ->qqqq	17,24%	11,33%
ZZ->qqvv	4,80%	0,08%

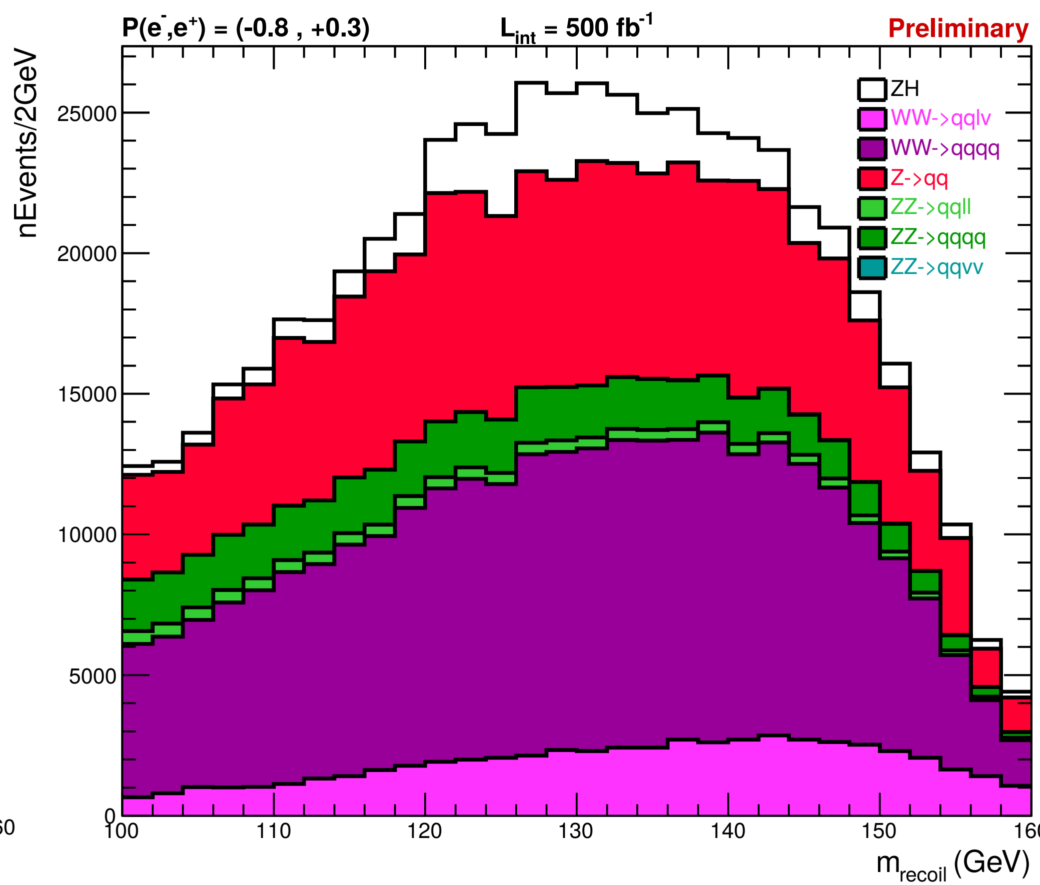
- $P(e^-,e^+) = (+80\ \%,-30\%)$



$N_S / \sqrt{N_S+N_B} = 72.45$

$\Delta\sigma/\sigma = 1.4\ \%$

- $P(e^-,e^+) = (-80\ \%,+30\%)$



$N_S / \sqrt{N_S+N_B} = 59.84$

$\Delta\sigma/\sigma = 1.9\ \%$

Preliminary

- $P(e^-,e^+) = (+80\ \%,-30\%)$

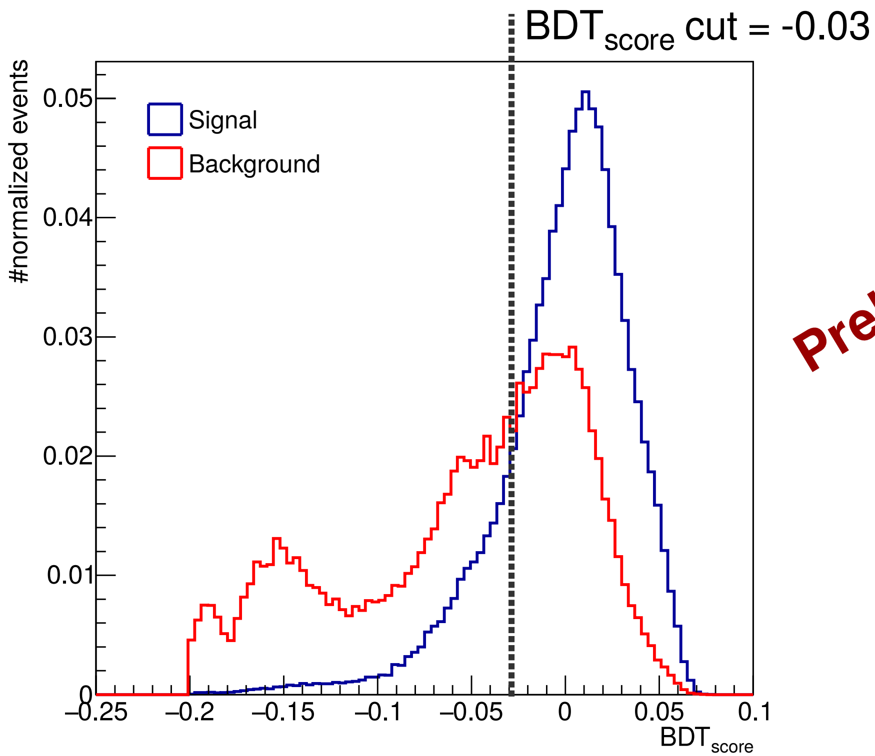
Channel	e_{presel}	e_{BDT}	Δe/e
H->ss	49,2%	36,7%	-4,6%
H->cc	49,0%	38,6%	0,2%
H->bb	49,2%	38,3%	-0,5%
H->μμ	49,3%	24,6%	-36,0%
H->ττ	48,5%	24,6%	-36,1%
H ->gg	51,6%	42,1%	9,4%
H->γγ	50,8%	35,6%	-7,3%
H->ZZ	49,3%	35,5%	-7,8%
H->WW	52,5%	37,5%	-2,5%
WW->qqqq	52,8%	44,6%	16,0%
WW->qqlv	50,4%	34,2%	-11,1%
WW->lvlv	60,2%	20,6%	-46,5%
H->Zγ	55,2%	36,7%	-4,5%

- $P(e^-,e^+) = (-80\ \%,+30\%)$

Channel	e_{presel}	e_{BDT}	Δe/e
H->ss	44,0%	35,5%	-7,5%
H->cc	50,5%	41,1%	7,2%
H->bb	49,2%	39,4%	2,8%
H->μμ	43,2%	28,8%	-24,8%
H->ττ	48,3%	26,3%	-31,5%
H ->gg	50,8%	42,2%	10,2%
H->γγ	49,1%	36,3%	-5,4%
H->ZZ	49,5%	35,6%	-7,2%
H->WW	52,7%	39,1%	2,1%
WW->qqqq	53,2%	46,0%	19,8%
WW->qqlv	50,3%	35,8%	-6,8%
WW->lvlv	60,5%	23,4%	-39,0%
H->Zγ	52,9%	34,9%	-9,1%

- Huge inconsistency for selection efficiency of H->μμ and H->ττ
  - Not seen in previous ZH (Z->qq) studies
  - Maybe related to a issue with treatment of lepton pairs in DD4hep
- Inconsitency of H->WW different decay modes due to the inclusion of $-\log10(y_{23})$ and $-\log10(y_{34})$ parameters

- Reduced training :
  - Variables used :
    - Zmass
    - $\cos\theta_Z$
    - θ_{Z12}



- $P(e^-,e^+) = (+80\ \%,-30\%)$

Preliminary

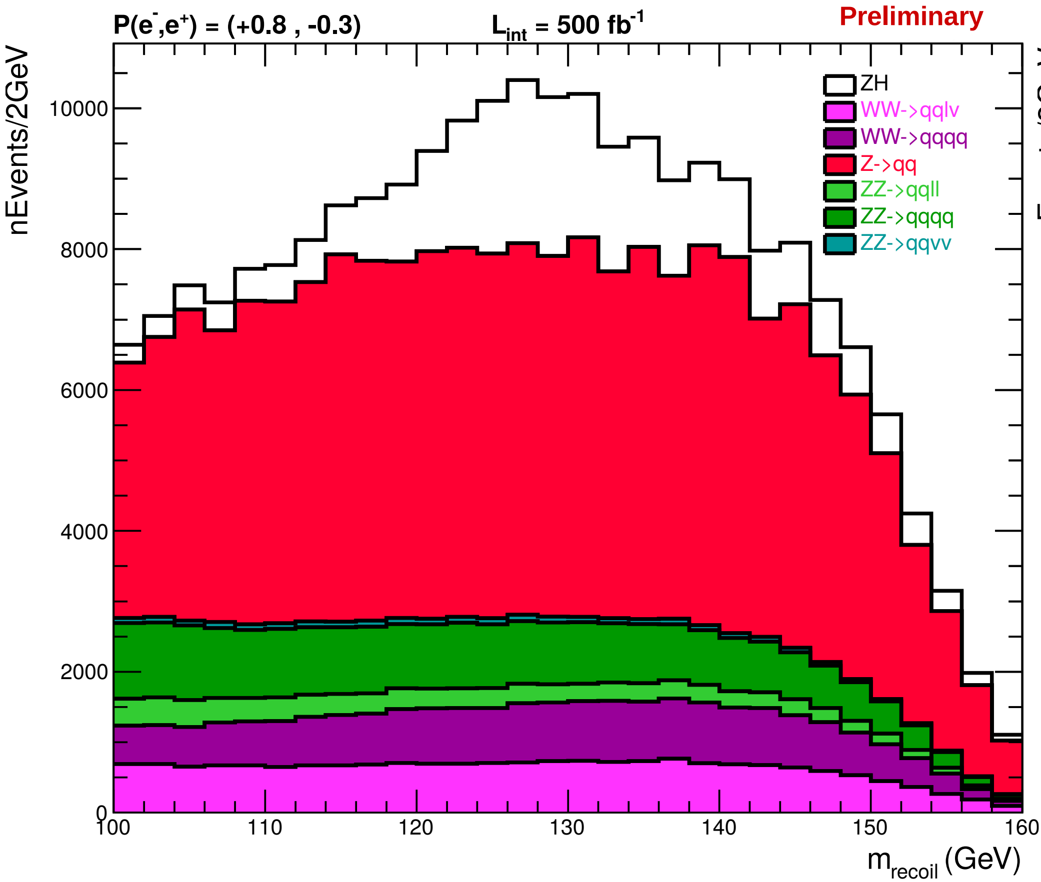
Channel	ε_{presel}	ε_{BDT}
ZH	50,11%	41,36%
WW->qqlv	17,29%	4,86%
WW->qqqq	9,71%	6,61%
Z->qq	1,40%	0,57%
ZZ->qqll	9,63%	5,11%
ZZ->qqqq	15,61%	11,42%
ZZ->qqvv	3,86%	2,32%

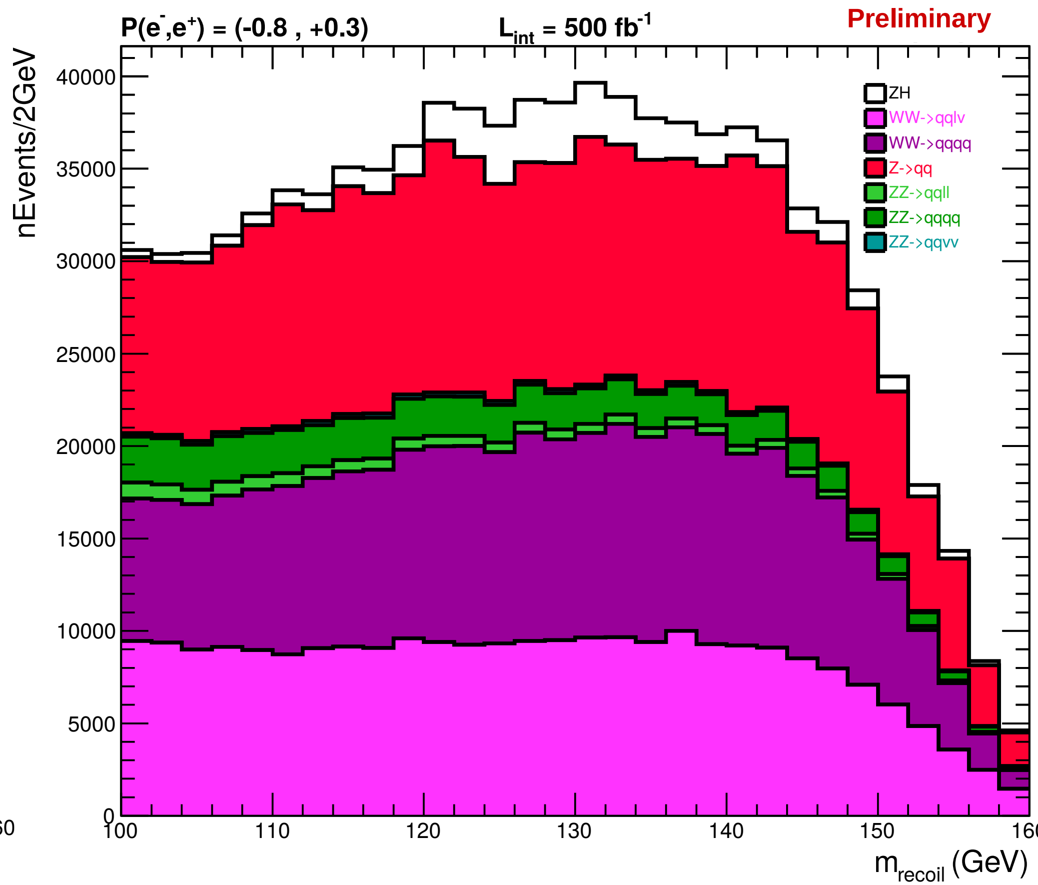
- $P(e^-,e^+) = (-80\ \%,+30\%)$

Preliminary

Channel	ε_{presel}	ε_{BDT}
ZH	50,06%	40,38%
WW->qqlv	16,89%	4,49%
WW->qqqq	9,47%	6,07%
Z->qq	1,88%	0,82%
ZZ->qqll	11,47%	6,06%
ZZ->qqqq	17,24%	12,54%
ZZ->qqvv	4,80%	2,83%

- Reduced training :
  - $P(e^-,e^+) = (+80\ \%,-30\%)$
  - $P(e^-,e^+) = (-80\ \%,+30\%)$





$N_S / \sqrt{N_S+N_B} = 61.1$

$\Delta\sigma/\sigma = 1.6\ \%$

$N_S / \sqrt{N_S+N_B} = 43.60$

$\Delta\sigma/\sigma = 2.3\ \%$

- Reduced training :

- $P(e^-,e^+) = (+80\ \%,-30\%)$

Preliminary

Channel	e_{presel}	e_{BDT}	Δe/e
H->ss	49,2%	41,0%	-0,9%
H->cc	49,0%	41,3%	-0,1%
H->bb	49,2%	41,3%	-0,2%
H->μμ	49,3%	30,5%	-26,2%
H->ττ	48,5%	35,8%	-13,4%
H ->gg	51,6%	44,4%	7,4%
H->γγ	50,8%	37,9%	-8,3%
H->ZZ	49,3%	40,3%	-2,7%
H->WW	52,5%	42,1%	1,9%
WW->qqqq	52,8%	45,2%	9,4%
WW->qqlv	50,4%	38,7%	-6,4%
WW->lvlv	60,2%	43,0%	3,9%
H->Zγ	55,2%	47,7%	15,3%

- $P(e^-,e^+) = (-80\ \%,+30\%)$

Channel	e_{presel}	e_{BDT}	Δe/e
H->ss	44,0%	36,2%	-10,4%
H->cc	50,5%	42,9%	6,3%
H->bb	49,2%	41,2%	2,0%
H->μμ	43,2%	31,0%	-23,3%
H->ττ	48,3%	35,8%	-11,4%
H ->gg	50,8%	43,3%	7,2%
H->γγ	49,1%	37,6%	-7,0%
H->ZZ	49,5%	40,2%	-0,4%
H->WW	52,7%	42,3%	4,8%
WW->qqqq	53,2%	45,6%	12,9%
WW->qqlv	50,3%	38,7%	-4,0%
WW->lvlv	60,5%	43,2%	6,9%
H->Zγ	52,9%	43,8%	8,4%

- Inconsitency of H->WW different decay modes greatly reduced

- Study of higgs recoil mass in HZ (Z->qq) with ILD_l5_o2_v02 model has started
- At $\sqrt{s}$ = 250 GeV and 500fb^{-1} integrated luminosity, the statistical error on the σ_{ZH} cross section reaches ~1.6 % using $P(e^-,e^+)$ = (+80 %,-30%) polarization
- However, the selection efficiency is not consistent with respect to higgs decay mode
  - Inconsistencies up to ~15% (H->Zγ)
  - Difficult to conclude on the H->μμ case due to very low statistics and ILCSoft issue
    - Need to process a dedicated H->μμ sample with more statistics

- Plans :
  - Add qqeν and qqee background
  - Reprocess events with patched ILCSoft to investigate the H->ττ / H->μμ cases
  - Improve on systematics uncertainty by applying categorization / optimizing cuts