H⟶ WW* fully hadronic in HZ at CLIC at 350 GeV

status report

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Analysis recap

- Measure the statistical uncertainty of the couplings
- Considering only fully hadronic H→WW*→qqqq decays
  ⇒ complete reconstruction of Higgs invariant mass
- BF (H→WW→qqqq)~10%

$$\frac{g^2_{HZZ} \cdot g^2_{HWW}}{\Gamma_H}$$

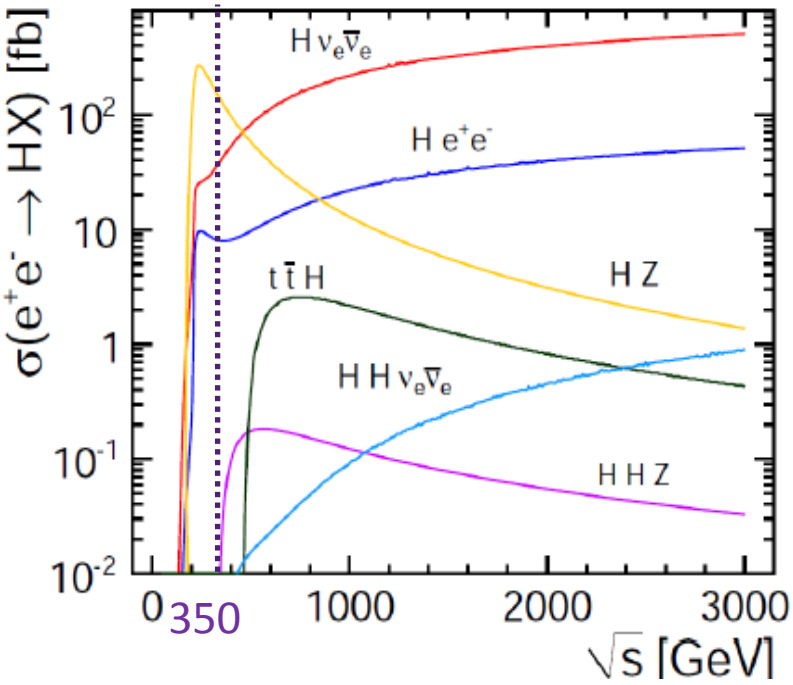
This talk:

6 jets

- Applied b-tag/c-tag to 6 jet hypothesis aiming to furhter reduce ttbar

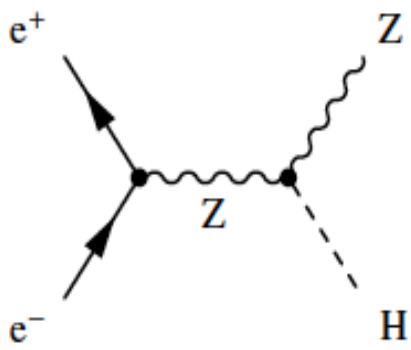
4 jets

- redid both channels



Signal

- Considering **two types of final states: 4jets +2 leptons**
  6 jets
- Central signature for jets and leptons



Process	BF [%]	σ[fb]	Events in 0.5 fb^{-1}	Events generated
$e^+e^- \to HZ$		134	68.000	
$H \to WW \to qqqq$	9.800			
$Z \to e^+e^-$	3.363	0.453	226	50873
$Z \to \mu^+\mu^-$	3.366	0.454	227	66377
$Z \to qq$	69.910	9.161	4580	61178

Backgrounds

Process	σ[fb]	Events in 0.5 fb^{-1}	Events generated
Other Higgs decays	93	46311	1.397.072
$e^+e^- \to qqqq$	5847	2.923.500	1.440.500
$e^+e^- \to qqll$	1704	852.000	488.500
$e^+e^- \to qql\nu$	5914	2.957.000	1.437.500
$e^+e^- \to qq\nu\nu$	325	162.300	306.500
$e^+e^- \to H\nu\nu$	52	26.700	500.000
$e^+e^- \to t\bar{t}$	450	225.000	20979+196911
$e^+e^- \to WWZ$	10	5.000	39880

- Events are generated using WHIZARD v1.95 (ISR and CLIC beam spectrum)
- Assuming m_H=126 GeV
- Full simulation using CLIC_ILD detector model

Analysis strategy

- Lepton isolation
- Jet clustering: forcing event into 4/6 jets
- Vertex finding: primary and secondary
- Flavor tagging
- Preselection
- MVA classification

Kinematical variables

- Invariant masses of Higgs, Z and W bosons: $\mathbf{m_H}$, $\mathbf{m_Z}$, $\mathbf{m_W}$, $\mathbf{m_{W^*}}$.
- Event shape variables: **thrust, sphericty, aplanarity, oblateness.**
- Jet transitions: $\mathbf{-\log_{10}(y_{12})}$ ($\mathbf{y_{23}}$,$\mathbf{y_{34}}$, $\mathbf{y_{45}}$,$\mathbf{y_{56}}$, $\mathbf{y_{67}}$)
- Angle between the jets that comprise: real W, Z : θ_{partW} , θ_{partZ}
- Number of PFO's: **NPFO** ,θ_{lept}
- Visible energy: $\mathbf{E_{vis}}$,
- Transverse momentum of jets that comprise Higgs $\mathbf{P_{tHiggsJets}}$
- b/c tag probablity for 2 jet hypothesis: **btag, ctag**
- **Multijet tagging: $btag_i$, $ctag_i$ values i=1,6**

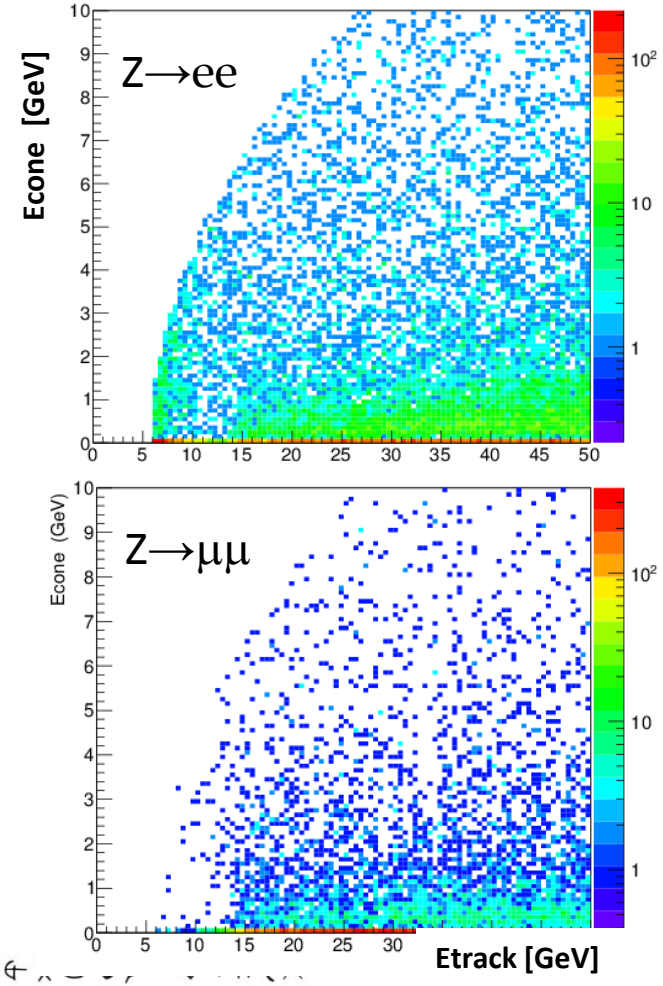
Lepton isolation

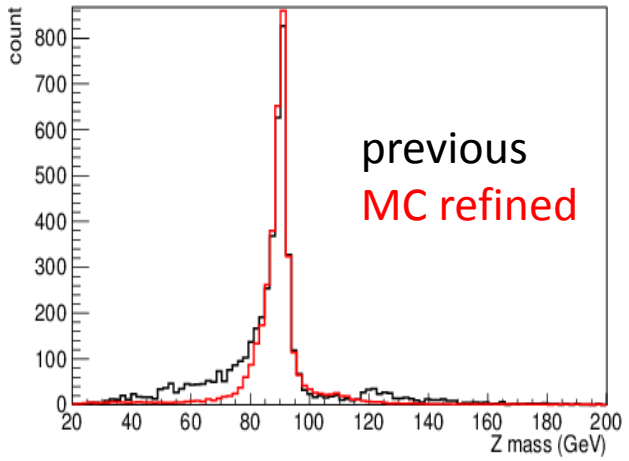
- Isolation based on energy of a lepton track, and energy contained in a cone around the track- refined with MC truth matching
- For electron/muon separation: ratio of the energy deposited in the HCAL and ECAL

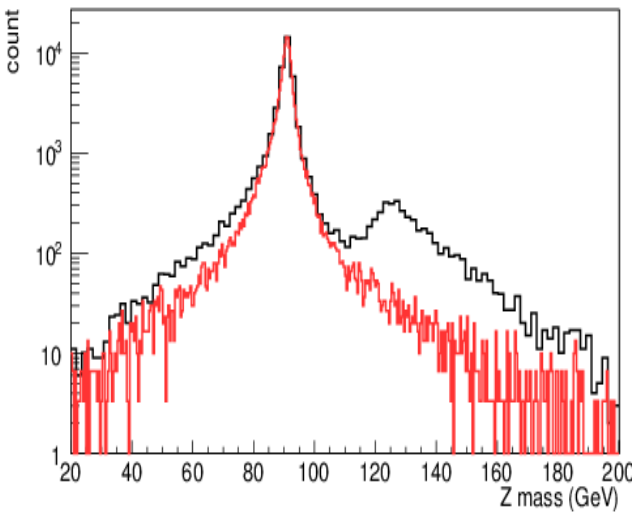
	Lepton Isolation	
Cosine Cone Isolation angle	0.995	
Polynomial isolation	$E_{cone} < \mathbf{-0.005}\ E_{tr}^2 + \mathbf{5.0}\ E_{tr} - \mathbf{30.0}$	
	electrons	muons
ECAL/(HCAL+ECAL)	0.9	0.5
Etot/P min	0.7	0.4
Etot/P max	1.2	0.7

4 jet final state

- Lepton isolation $N_{lept}=2$
- Force event into four jets which are grouped into pairs $\mathbf{d_{ij} = min\ |M_{ij} - M_W|}$







Preselection

4 jet Z→ee final state

	Process	σ[fb]	Efficiency [%]	σ_{pres} [fb]
80 GeV<m_Z< 110 GeV	signal	0.453	48.4	0.22
45 GeV < m_W < 95GeV	HZ back.	4.13	5.95	0.25
100 GeV< m_H <140 GeV	$e^+e^- \to qqqq$	5847	<10^{-4}	/
-log(y45)<4.0	$e^+e^- \to qqll$	1704	0.246	4.19
-log(y23)<3.0	$e^+e^- \to qql\nu$	5914	1.2 10^{-3}	0.07
jetPt > 20 GeV NPFO>20	$e^+e^- \to qq\nu\nu$	325	<10^{-3}	/
100 < E_{vis} < 300 GeV	$e^+e^- \to H\nu\nu$	52	<10^{-3}	/
btag <0.9	$e^+e^- \to t\bar{t}$	450	0.012	0.06
Thrust <0.9	$e^+e^- \to WWZ$	10	0.3	0.03
100 <E_{vis} <200 GeV				

Minimal set to completely remove high cross-section backgrounds (qqqq,qq$\nu\nu$)

MVA analysis

4 jet Z→ee final state

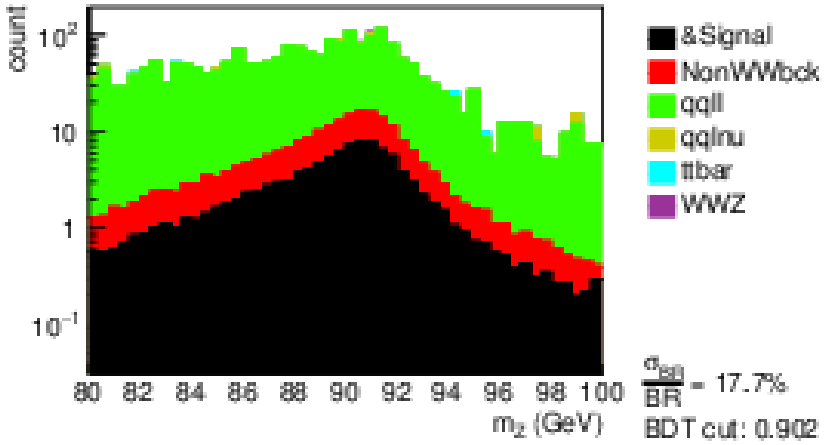
- After the preselection the most difficult backgrounds
  other Higgs decays, qqll

- **BDT input variables:**

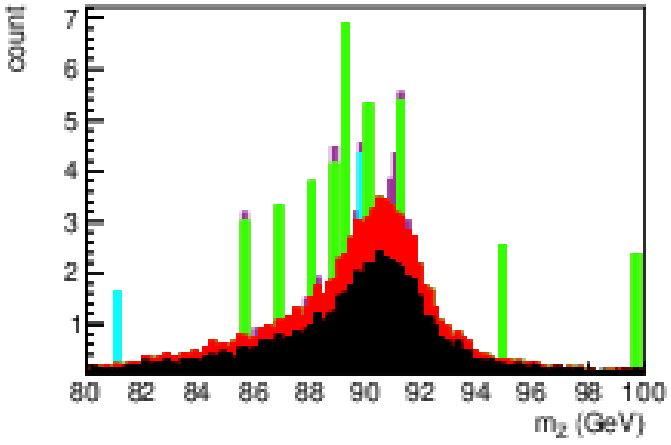
- m_H, m_Z, m_W, m_{W^*}
- thrust, sphericty, aplanarity, oblatness
- NPFO, Evis, PtOfHiggsJets
- $-\log_{10}(y_{12})$ (y_{23} ,y_{34}, y_{45} ,y_{56}, y_{67})
- θ_{partW} , θ_{el}
- btag, ctag variables

Results

4 jet Z→ee final state



After preselection



After final selection

RESULTS	
Total signal efficiency	**27.9 %**
Number of events final	63
$\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S+B}}{S}$	**17.7%**

Uncertainty is dominated by small signal cross-section

Preselection

4 jet Z→μμ final state

	Process	σ[fb]	Efficiency [%]	σ_{pres} [fb]
70 GeV<m_Z< 110 GeV	signal	0.454	86.8	0.394
	HZ back.	4.13	78.4	3.24
	$e^+e^- \to qqqq$	5847	$1.5\ 10^{-4}$	/
	$e^+e^- \to qqll$	1704	1.96	33.46
	$e^+e^- \to qql\nu$	5914	0.14	0.81
	$e^+e^- \to qq\nu\nu$	325	$<10^{-5}$	/
	$e^+e^- \to H\nu\nu$	52	0.1	/
	$e^+e^- \to t\bar{t}$	450	0.44	1.98
	$e^+e^- \to WWZ$	10	2.9	0.29

Preselection set targeted to completely remove high cross-section backgrounds

MVA analysis

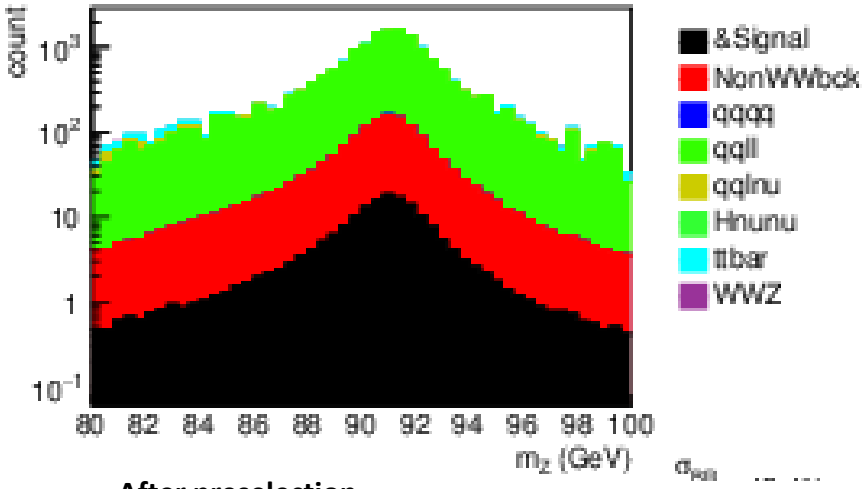
4 jet $Z \rightarrow \mu\mu$ final state

- After the preselection the most difficult backgrounds
  other Higgs decays, qqll

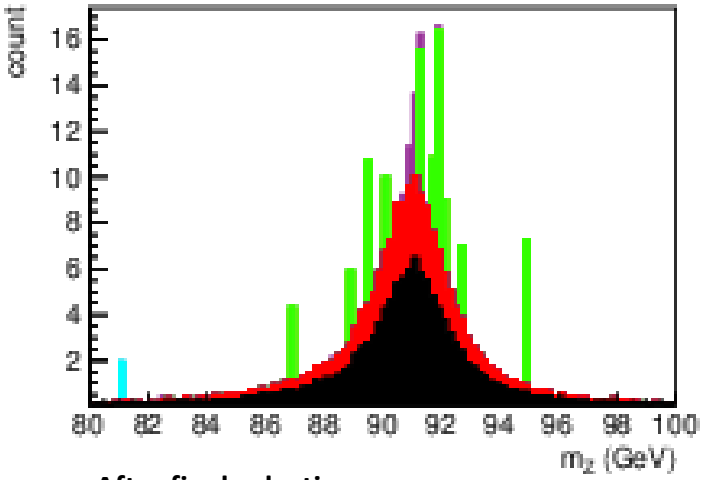
- m_H, m_Z, m_W, m_{W^*}
- thrust, sphericty, aplanarity, oblatness
- NPFO, Evis, PtOfHiggsJets
- $-\log_{10}(y_{12})$ (y_{23} ,y_{34}, y_{45} ,y_{56}, y_{67})
- θ_{partW} , θ_{el}
- btag, ctag variables

Results

4 jet Z→μμ final state



After preselection



After final selection

RESULTS	
Total signal efficiency	**0.55%**
Number of events final	125
$\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S+B}}{S}$	**13.1%**

Uncertainty is dominated by small signal cross-section

6 jet final state

- Lepton isolation $N_{lept}=0$
- After the lepton isolation we force event into six jets which are grouped into pairs to form H, W, Z.
- The combination which minimizes the chi2 is chosen:

$$\chi^2 = \frac{\left(M_{ij} - M_W\right)^2}{\sigma^2_W} + \frac{\left(M_{kl} - M_Z\right)^2}{\sigma^2_Z} + \frac{\left(M_{ijmn} - M_H\right)^2}{\sigma^2_H}$$

Preselection

6 jet final state

	Process	σ[fb]	Efficiency [%]	σ_{pres} [fb]
40 GeV< m_z	signal	9.16	70.9	6.5
Evis>250.	HZ back.	84.23	16.5	13.9
NPFO>50	$e^+e^- \to qqqq$	5847	18	1056.9
y12<2.0 y23<2.6	$e^+e^- \to qqll$	1704	0.046	/
y34<3.0 y45<3.5	$e^+e^- \to qql\nu$	5914	0.01	/
y56<4.0	$e^+e^- \to qq\nu\nu$	325	0.001	/
pfo_thrust<0.9	$e^+e^- \to H\nu\nu$	52	0.0001	/
btag2 < 0.9	$e^+e^- \to t\bar{t}$	450	18.9	85.5
	$e^+e^- \to WWZ$	10	19.7	2.0

Minimal set to completely remove high cross-section backgrounds (qqll qqlν)

MVA analysis

6 jet final state

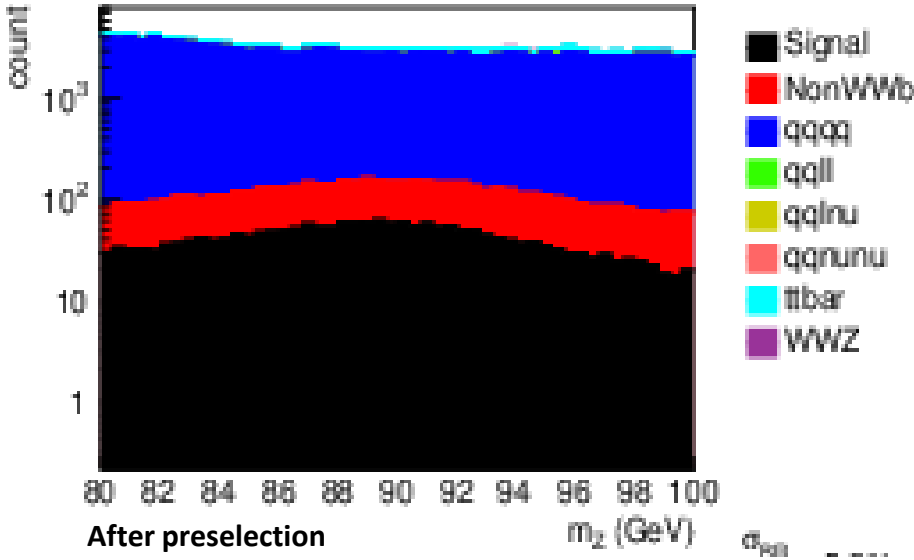
- After the preselection the most difficult backgrounds

  ttbar, other Higgs decays,qqqq

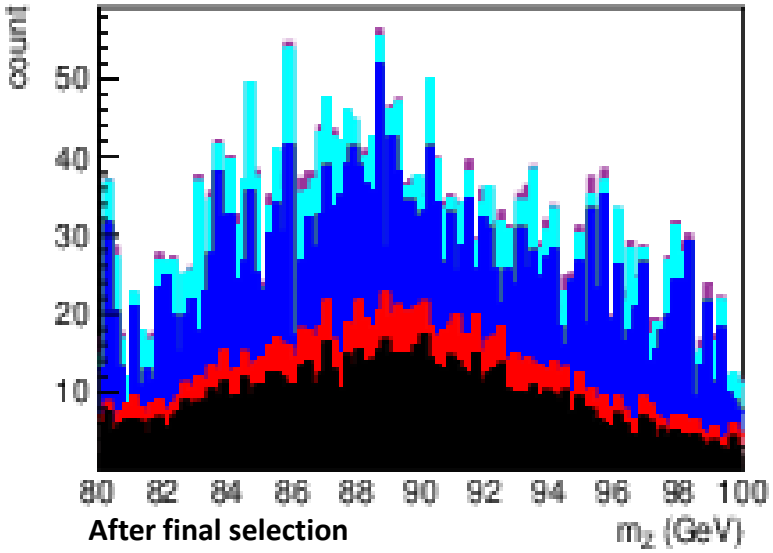
- Optimizing set of the input variables from 32 → 26 final ones
- **m_H, m_Z, m_W, m_{W^*}**
- **thrust, sphericty, aplanarity**
- **NPFO, Evis, PtOfHiggsJets**
- **$-\log_{10}(y_{12})$ (y_{23} ,y_{34}, y_{45} ,y_{56}, y_{67})**
- **θ_{partW} , θ_{partZ}**
- **$btag_i$, i=1,2,3,6 $ctag_i$ i=1,3,6 (tagging of 6 jets)**

Results

6 jet final state



After preselection



After final selection

RESULTS	
Total signal efficiency	**29.0 %**
Number of events final	1328
$\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S+B}}{S}$	5.9%

Uncertainty is dominated by high cross-section backgrounds (qqqq, tt)

Summary

Steps added:

MC truth matching done: refined lepton isolation

ttbar and WWZ background added

multijet hypothesis (6) b/c tagging

- Semileptonic channels:

  Electron channel : 17.7 %

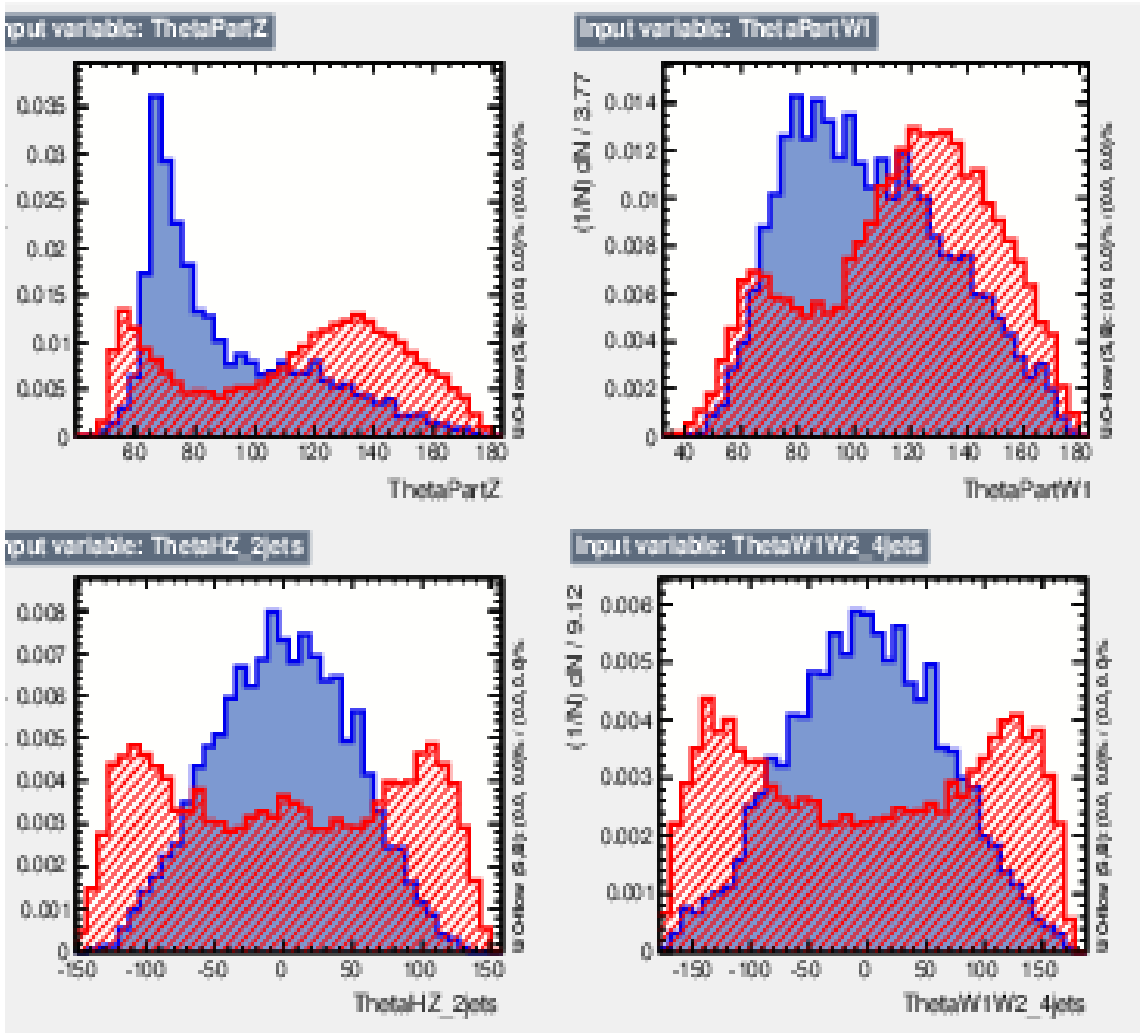
  Muon channel : 13.1 %

- Hadronic decay channel:

  Hadronic channel : 5.9 % (30 % signal efficiency)

END

Variables ANGLES 6 jets FS



Variables ANGLES

1. ThetaPartW1
   FORCE EVENTS INTO 6 jets
   the angle between two jets
   that consitute W real

2. ThetaHZ_2jets
   FORCE EVENTS INTO 2 jets
   the angle between H and Z