Measurement of H→WW* in HZ events at 350 GeV

status report

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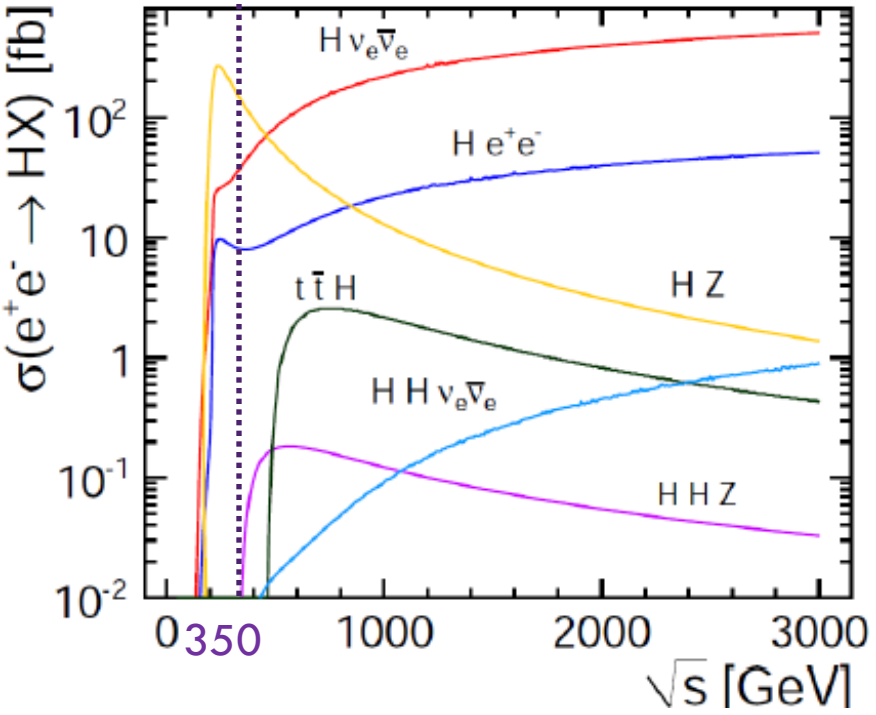
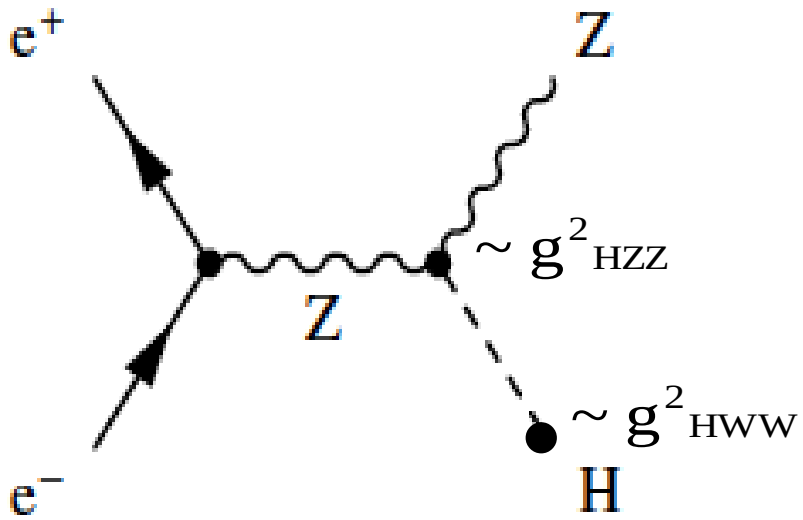
Outline

- Introduction
- Signal characterization
- Backgrounds
- Analysis strategy
- Status of semileptonic final states
- Update on hadronic final state
- Summary and outlook

Introduction





- Higgsstrahlung is the leading Higgs production process at 350 GeV
- Subleading Higgs decay mode $BR_{H\rightarrow WW} = 0.215$
- Complete reconstruction of Higgs invariant mass possible only when both W bosons decay hadronically $BR_{WW\rightarrow qqqq} = 0.457$

Signal

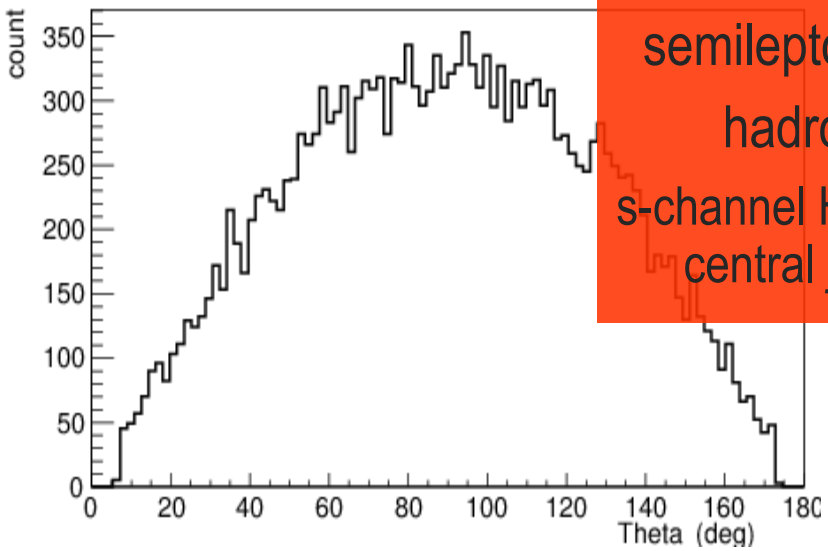
Process	BF [%]	σ[fb]	Events in 0.5 fb^{-1}	Events generated
$e^+e^- \rightarrow HZ$		134	68.000	
$H \rightarrow WW \rightarrow qqqq$	9.800			
$Z \rightarrow e^+e^-$	3.363	0.453	226	50873
$Z \rightarrow \mu^+\mu^-$	3.366	0.454	227	66377
$Z \rightarrow qq$	69.910	9.161	4580	61178

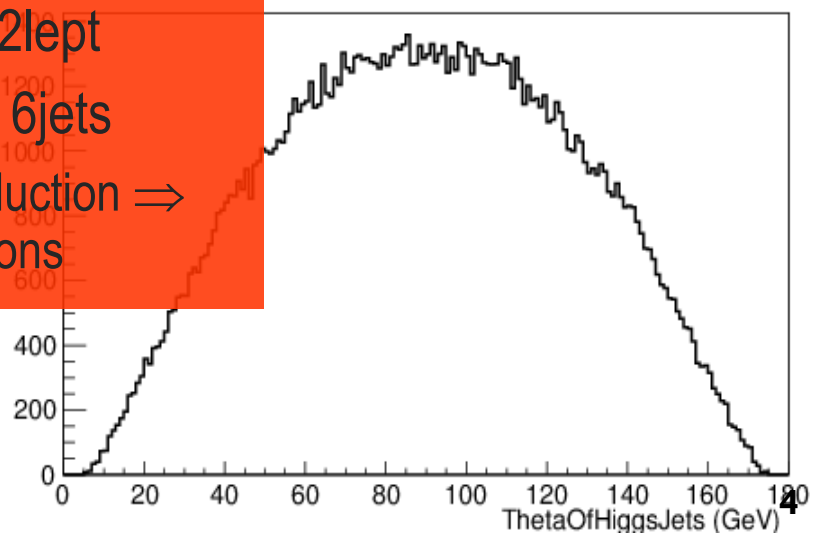
Final states:

semileptonic: 4jets+2lept

hadronic: 6jets

s-channel H and Z production ⇒ central jets and leptons





Relevant backgrounds

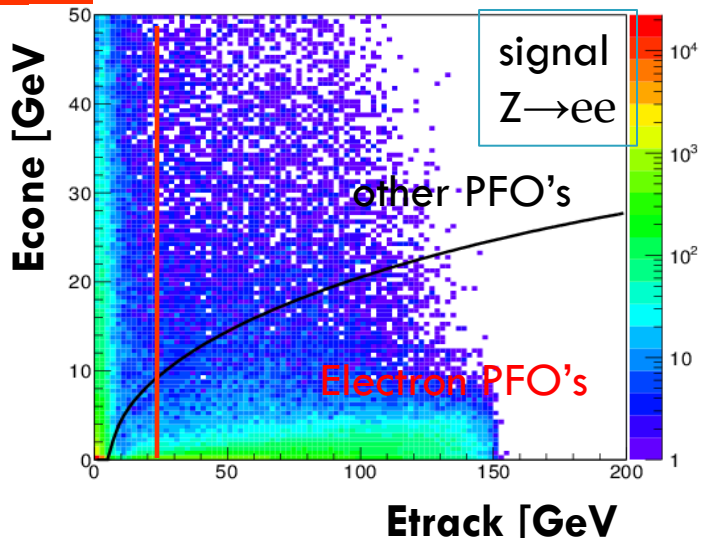
Process	σ[fb]	Events in 0.5 fb^{-1}	Events generated
Other Higgs decays	93	46311	1.397.072
$e^+e^- \to qqqq$	5847	2.923.500	1.440.500
$e^+e^- \to qqll$	1704	852.000	488.500
$e^+e^- \to qql\nu$	5914	2.957.000	1.437.500
$e^+e^- \to qq\nu\nu$	325	162.300	306.500
$e^+e^- \to H\nu\nu$	52	26.700	500.000
$e^+e^- \to t\bar{t}$	450	225.000	42000+440000
$e^+e^- \to WWZ$	10	5.000	29785+ ~50000

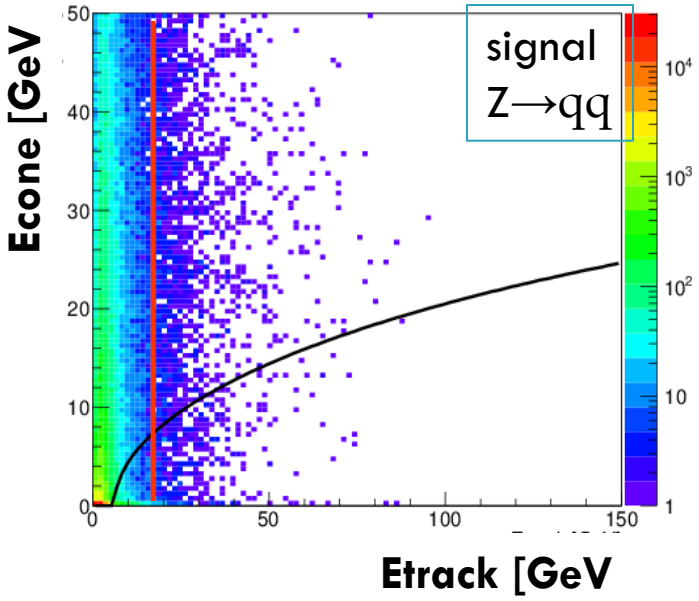
- Events are generated using WHIZARD v1.95 (ISR and CLIC beam spectrum)
- Assuming m_H=126 GeV
- Full simulation using CLIC_ILD detector model

Analysis strategy

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

Lepton isolation and jet formation





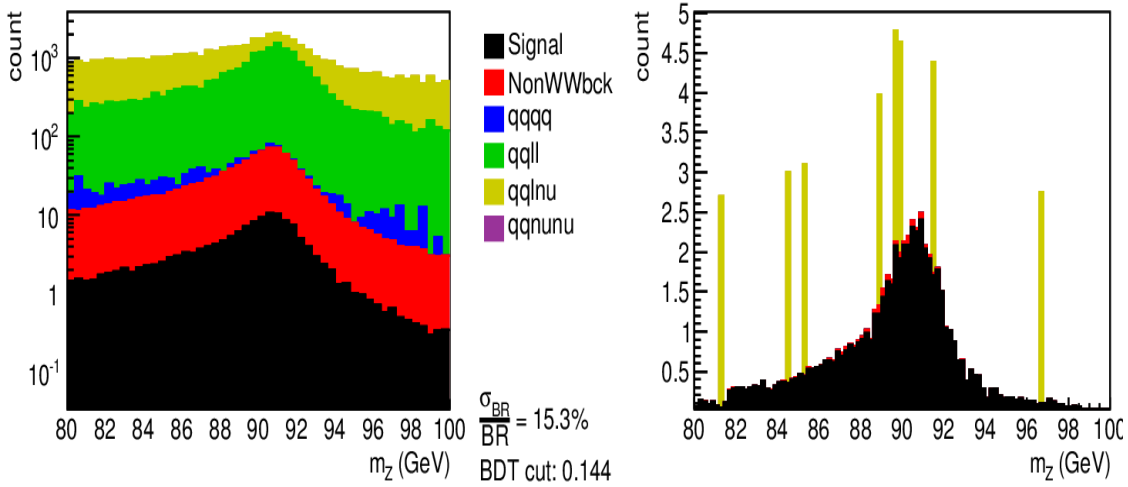
- Semileptonic events are clustered into 4 jets
- Jet are grouped into W, W*

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

- Hadronic events are clustered into 6 jets
- Jet are grouped into W, Z, H

Semileptonic final states - reminder

- Isolated lepton finder: $N_{lept}=2$, which form Z boson
- The event is forced into 4 jets
- Jet are grouped into pairs to form W , W* to minimize: min $|M_{ij} - M_W|$
- Results before MC refinement of the lepton isolation and addition of ttbar and WWZ backgrounds:



$$\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S+B}}{S} = 15.3\%$$

Eff~30%

Apply new lepton isolation tbd and include ttbar and WWZ background

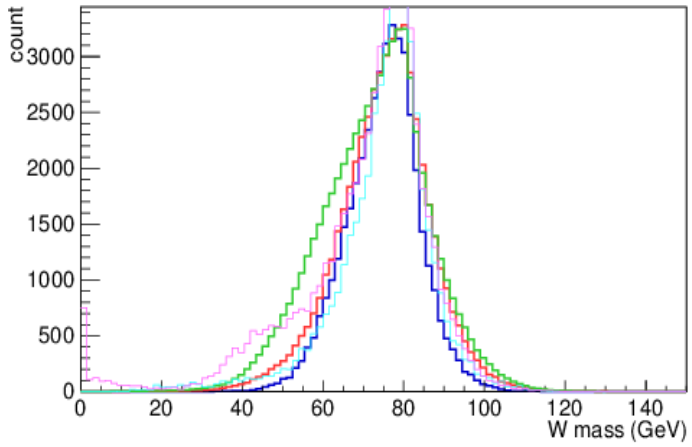
Fully hadronic final state

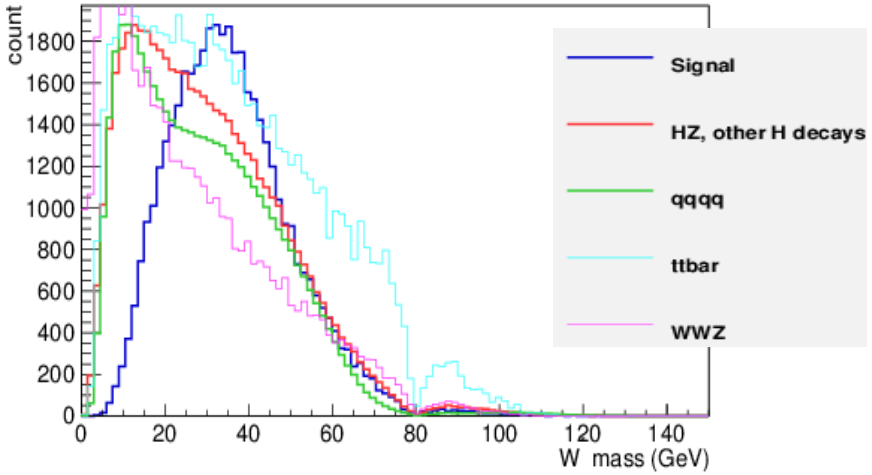
- Employed refined lepton isolation and added new backgrounds ttbar and WWZ
- Isolated lepton finder: $N_{lept}=0$
- The event is forced into 6 jets
- Obtained jets are grouped into pairs to form W, W* and Z
- The combination which minimizes the χ^2 is chosen :

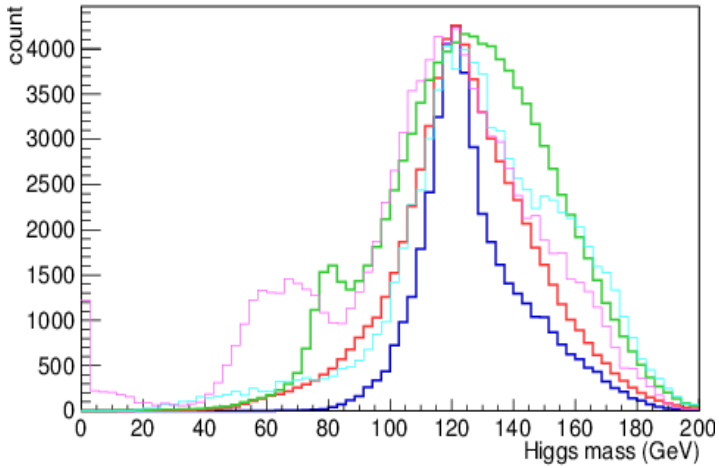
$$\chi^2 = \frac{\left(M_{ij} - M_W\right)^2}{\sigma^2_W} + \frac{\left(M_{kl} - M_Z\right)^2}{\sigma^2_Z} + \frac{\left(M_{ijmn} - M_H\right)^2}{\sigma^2_H}$$

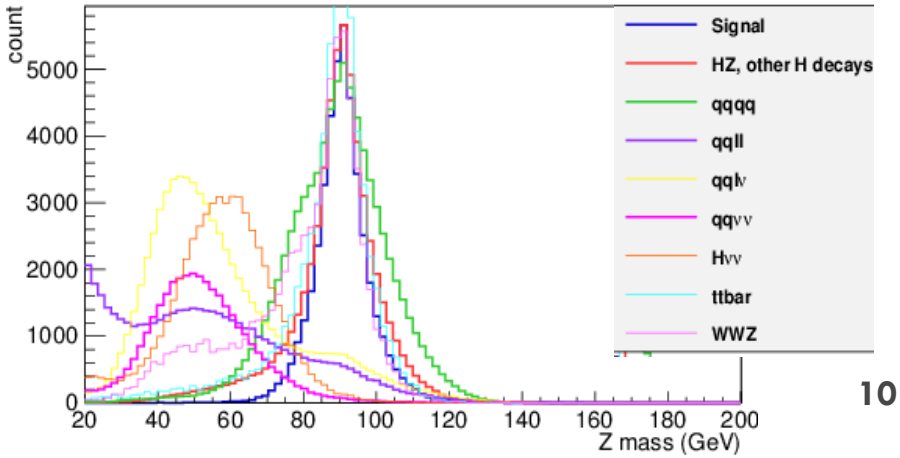
Invariant masses reconstruction

- For the background qqqq, ttbar, other Higgs decays and WWZ invariant masses distributions are quite similar.
- The semileptonic backgrounds are suppressed to large extend only by using m_Z





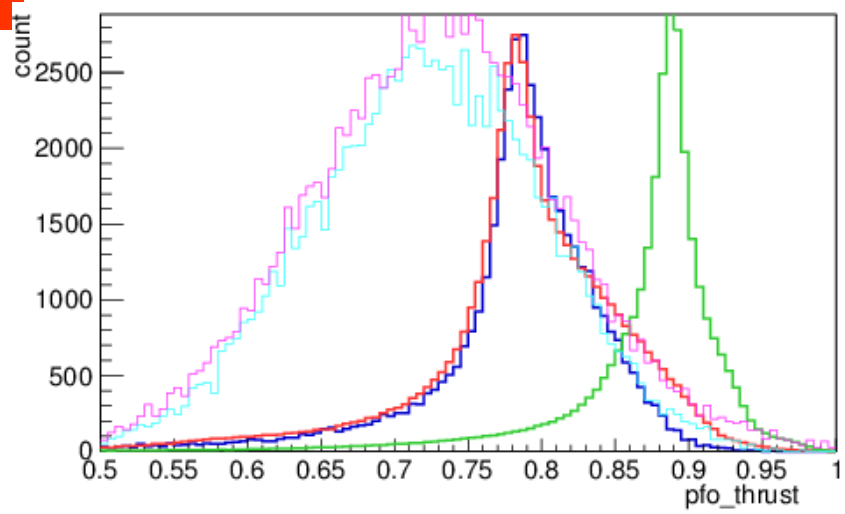


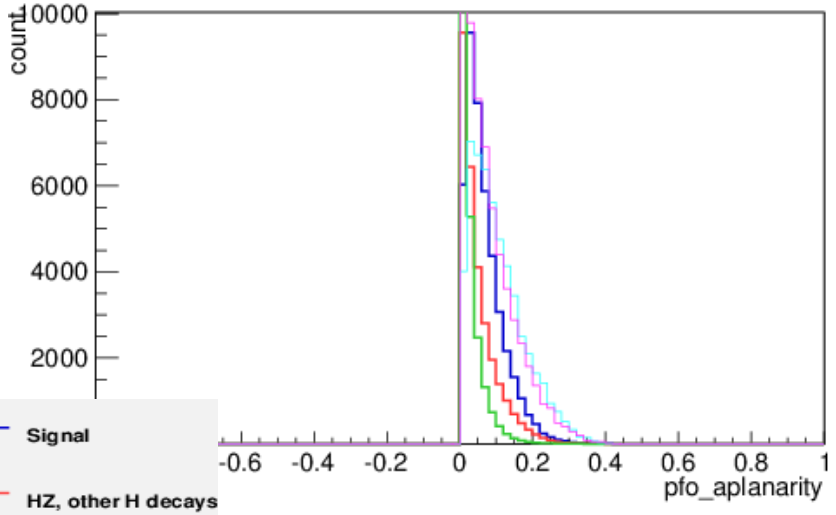


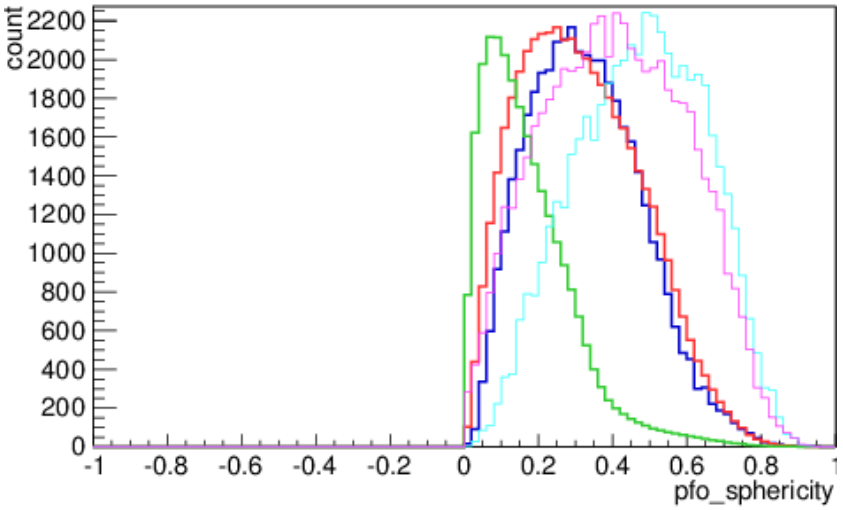
Kinematic variables

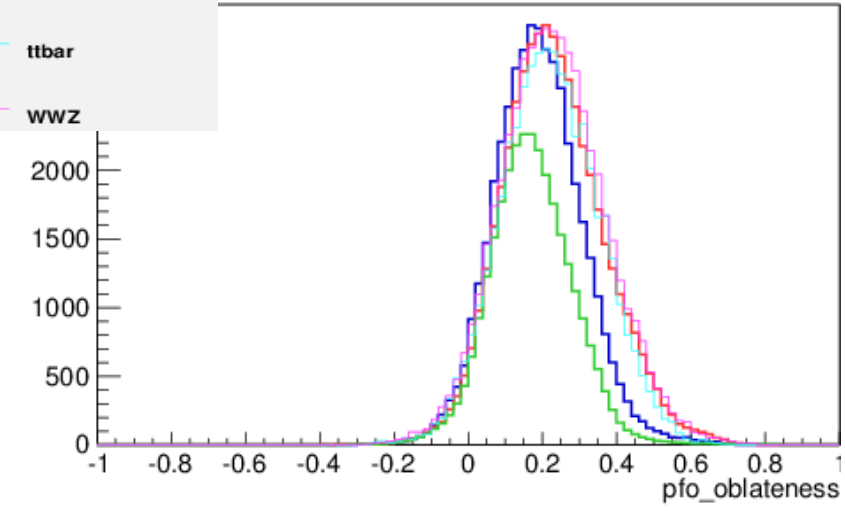
- Invariant masses of Higgs, Z and W bosons: $\mathbf{m_H}$, $\mathbf{m_Z}$, $\mathbf{m_W}$, $\mathbf{m_{W^*}}$.
- Event shape variables: **thrust, sphericity, aplanarity, oblateness.**
- Jet transitions: $-\mathbf{log_{10}}(\mathbf{y_{12}})$ ($\mathbf{y_{23}}$,$\mathbf{y_{34}}$, $\mathbf{y_{45}}$,$\mathbf{y_{56}}$, $\mathbf{y_{67}}$)
- Angle between the jets that comprise real W: θ_{partW}
- Angle between the jets that comprise Z: θ_{partZ}
- Number of PFO's: **NPFO**
- Visible energy: $\mathbf{E_{vis}}$
- transverse momentum of jets that comprise Higgs $\mathbf{P_{tHiggsJets}}$
- **btag, ctag**

Event shape variables

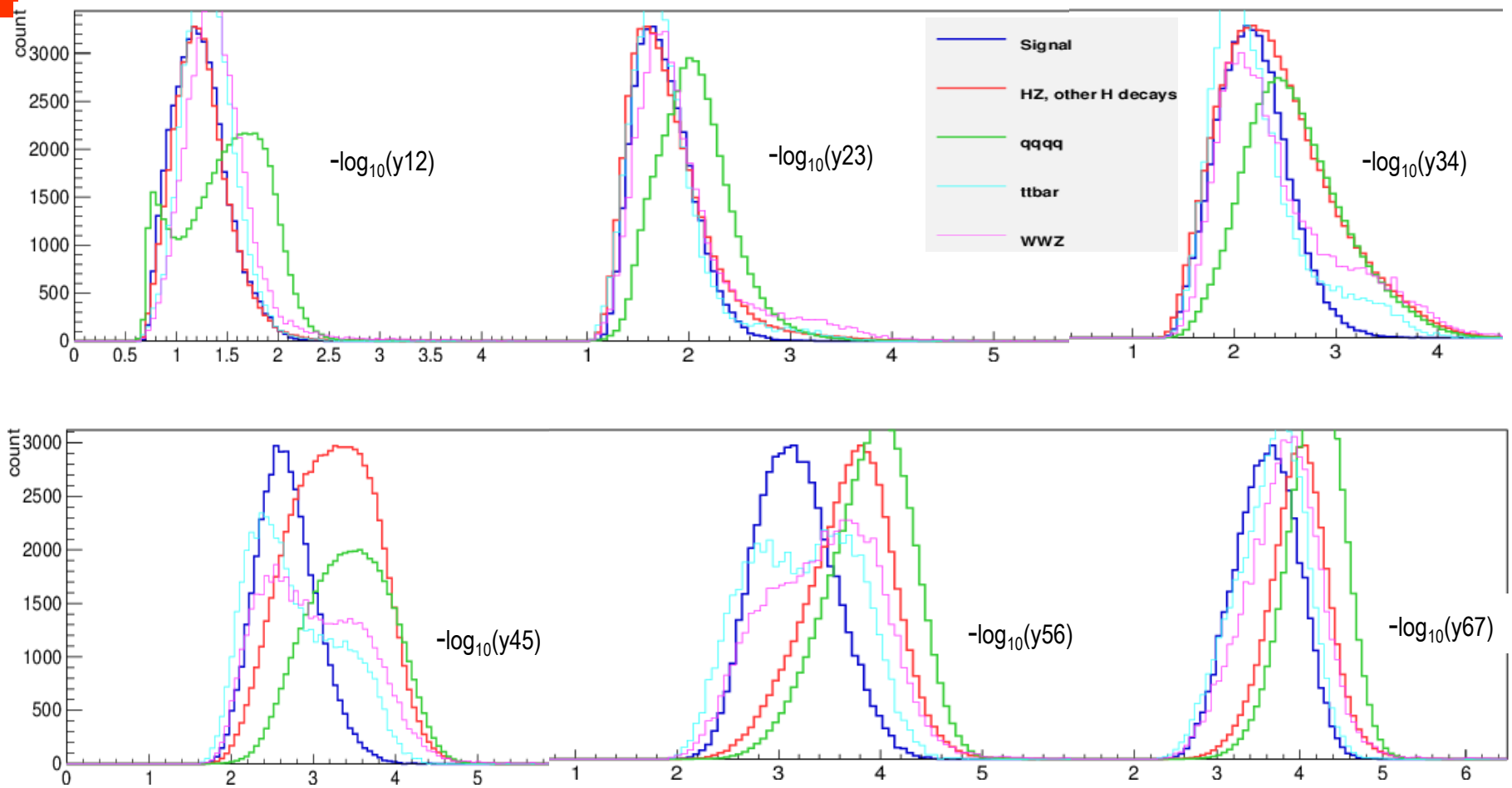






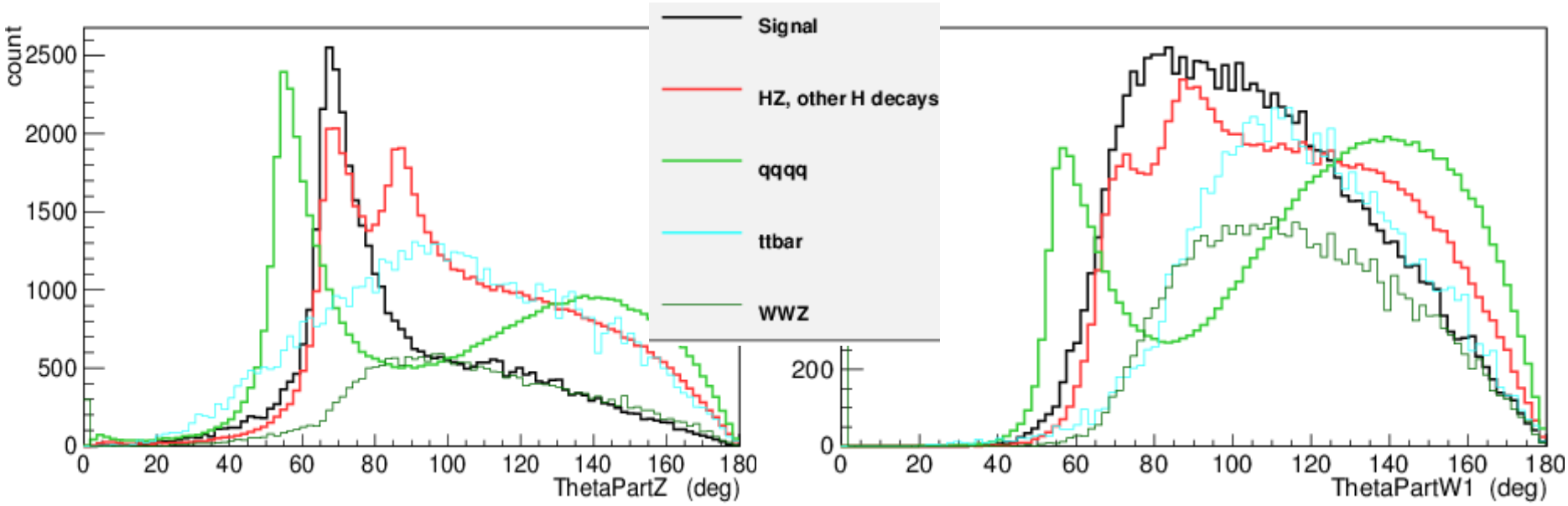


Jet transitions



Angular distributions

- ThetaPartZ: the angle between two jets that constitute Z
- ThetaPartW1: the angle between two jets that constitute W



Preselection

Preselection
NPFO >40
m_Z> 70 GeV
45 GeV < m_W < 95GeV
-log(y12)<2.0
-log(y23)<2.6
-log(y34)<3.0
-log(y45)< 4.2
jetPt < 20 GeV
E_{vis} > 250 GeV
PtOfHiggJets>60 GeV
btag <0.95

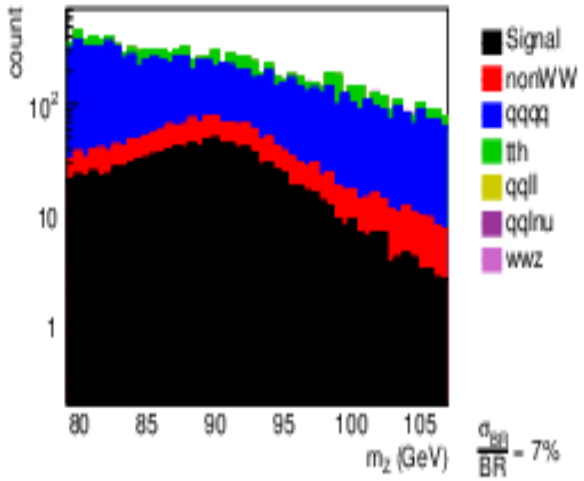
Process	σ[fb]	Efficiency	σ_{pres} [fb]
signal	9.16	40%	3.88
HZ back.	84.23	6.4%	5.35
$e^+e^- \rightarrow qqqq$	5847	3.3%	200
$e^+e^- \rightarrow qqll$	1704	$< 10^{-5}$	/
$e^+e^- \rightarrow qql\nu$	5914	$< 10^{-5}$	/
$e^+e^- \rightarrow qq\nu\nu$	325	$< 10^{-5}$	/
$e^+e^- \rightarrow H\nu\nu$	52	$< 10^{-5}$	/
$e^+e^- \rightarrow t\bar{t}$	450	6.1 %	27.5
$e^+e^- \rightarrow WWZ$	10	8.9%	0.9

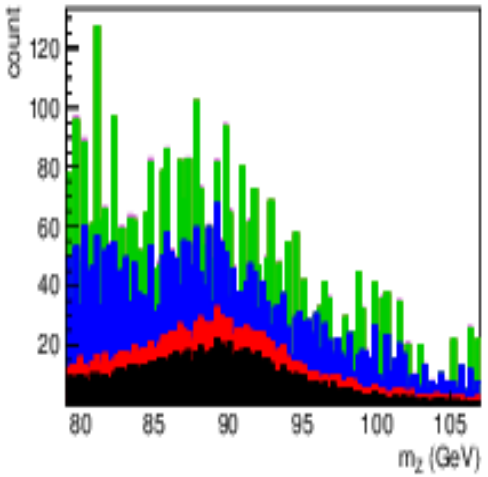
- Due to the relative similarity in the most of the distributions of the kinematic variables the preselection was optimized to completely remove ‘semileptonic background’ and mostly to cut off ttbar and qqqq background.

BDT classification

- After the preselection the most difficult background to reduce are used to train the BDT classfier: **other Higgs decays, qqqq, ttbar**

BDT input variables
NPFO E_{vis} P_tOf HiggsJets
-log(y12), -log(y23), -log(y34),
-log(y45), -log(y56), -log(y67)
m_z m_H m_w m_{W^*}
btag ctag
thrust, aplanarity, oblatness, sphericity



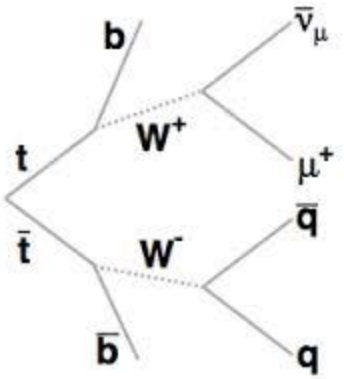


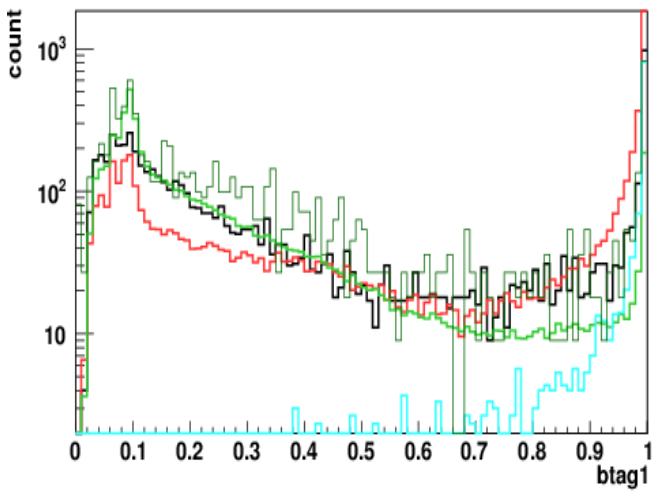
$$\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S+B}}{S} = 7\%$$

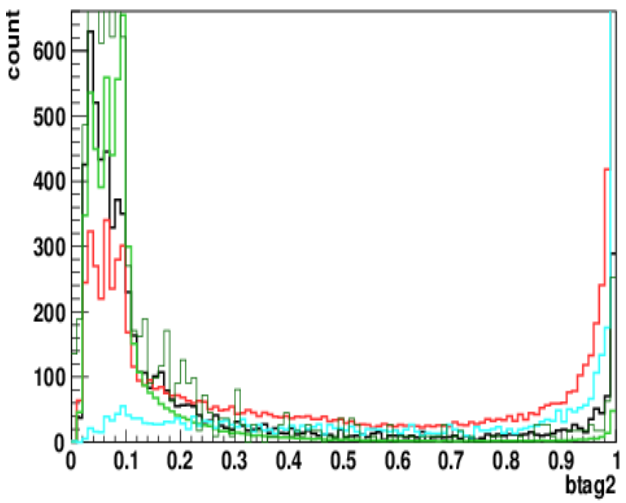
Eff~30%

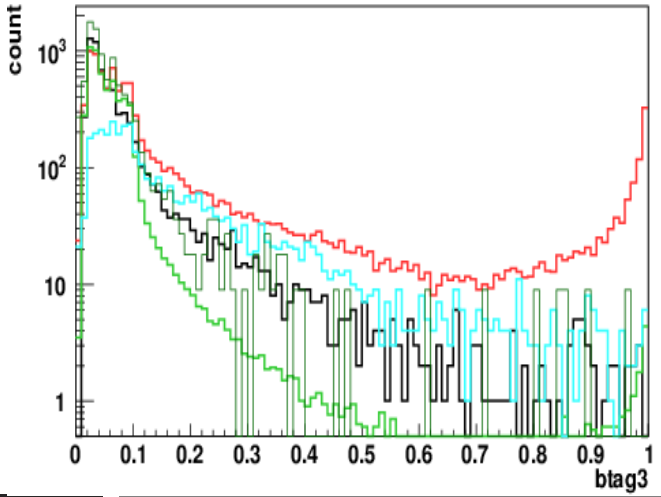
B tagging

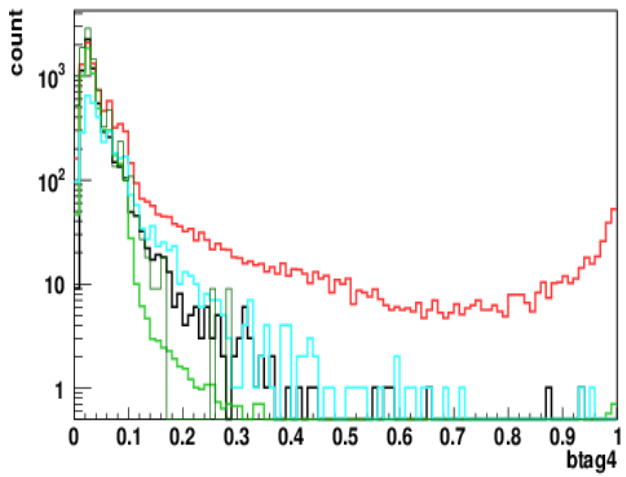
- Use LCFI to assign the btag probability to each of the 6 jets
- The leading background contains two b jets











Summary

- Lepton isolation is refined using MC Truth information
- Hadronic channel: ttbar and WWZ background included and new lepton isolation applied.
- For the hadronic final state ttbar and qqqq are leading backgrounds.
- Obtained statistical uncertainty in this channel is: $\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S+B}}{S} = 7\%$
- Signal efficiency is: 30% .

Plans:

- priority is hadronic channel: use multiple jet tagging to suppress ttbar background, use complete ttbar statistics
- semileptonic channel: lepton isolation and include new backgrounds