Higgs decay to WW* in HZ at 500 GeV

Mila Pandurović

Vinca Institute of Nuclear Sciences

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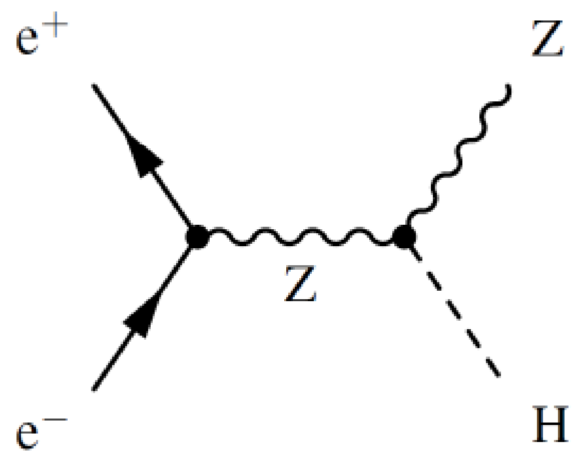
Overview

- Introduction
- The review of analysis results
- The comparison of the signal samples
- Summary

Introduction

- Analyzed HZ fully hadronic decay: $Z \rightarrow qq$, $H \rightarrow WW^* \rightarrow qqqq$
- $BF_{H\rightarrow WW}$~21.5% , $BF_{WW\rightarrow qqqq}$~45.4% $\Rightarrow$ ~ 10 % of Higgs decays
- HZ @500GeV $\sigma(e^+e^- \rightarrow HZ)$~114 fb including LR polarization
- $\sigma(e^+e^- \rightarrow HZ, Z\rightarrow qq , H\rightarrow WW^*\rightarrow qqqq)$~11.33fb

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



- Signal signature:

  6 central jets in the final state

Analysis strategy

- Analysis proceeds in several steps:

Fast Jet $\Leftarrow$ k_T exclusive, PandoraPFO's
Force events into 6 jets , R=1.5

$\Downarrow$

Lcfi Vertexing $\Leftarrow$ 6 jet hypothesis to apply btagging

$\Downarrow$

Preselection $\Leftarrow$ Reduction of large cross-section background

$\Downarrow$

MV selection $\Leftarrow$ BDT

$\Downarrow$

Relative statistical precision

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

Higgs, Z, W boson reconstruction

- The event is forced into 6 jets
- Obtained jets are grouped into pairs to form the Higgs, W, W* and Z bosons
- The combination which minimizes the χ^2 is chosen :

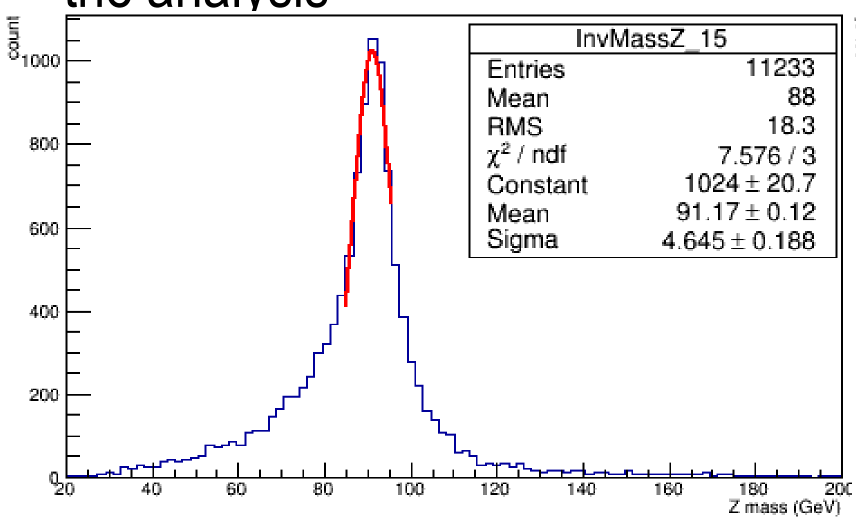
$$\chi^2 = \frac{(M_{ij} - M_W)^2}{\sigma^2_W} + \frac{(M_{kl} - M_Z)^2}{\sigma^2_Z} + \frac{(M_{ijmn} - M_H)^2}{\sigma^2_H}$$

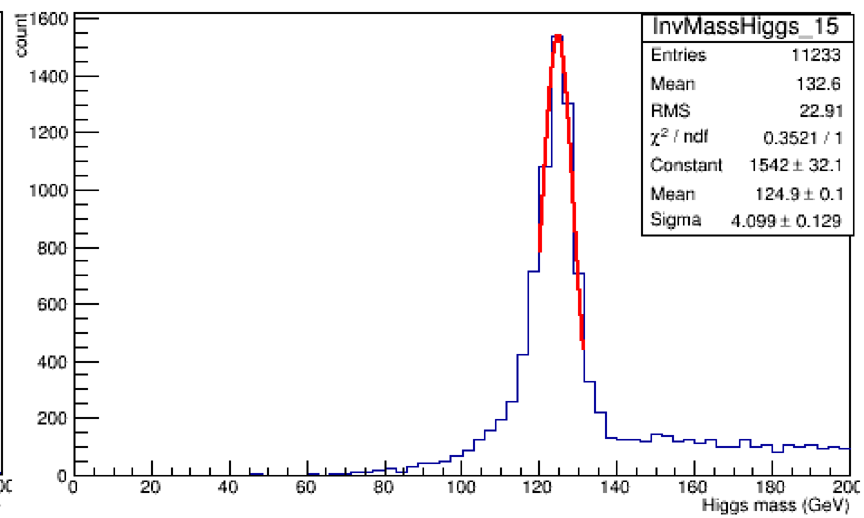
- For the $\sigma^2_{H,W,Z}$ - WA width

R parameter for jets

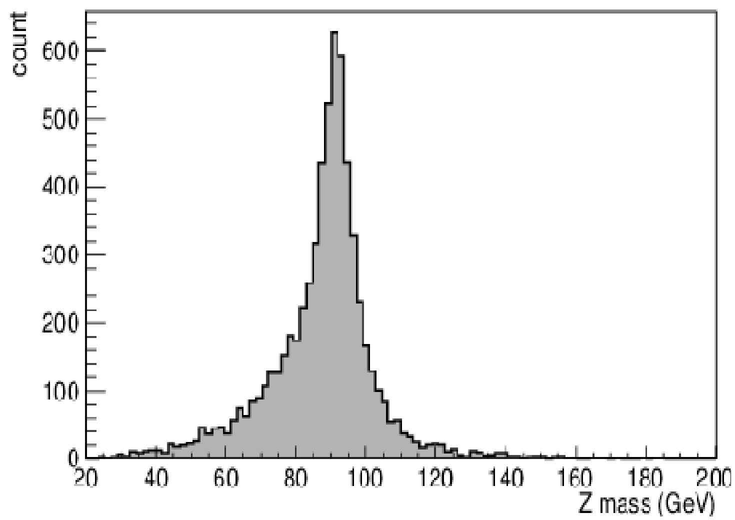
- Force event into 6 jets. R=0.6, 0.8, 1.0,1.1,1.2,1.3,1.4,1.5
- Jet Pairing to form Higgs, Z, W
- Fit of the invariant mass of the Z and Higgs boson in an interval s around the peak

  $85 < m_Z < 95 \qquad 120 < m_{Higgs} < 130$
- The best fit results are obtained for the R=1.5 which is further used in the analysis

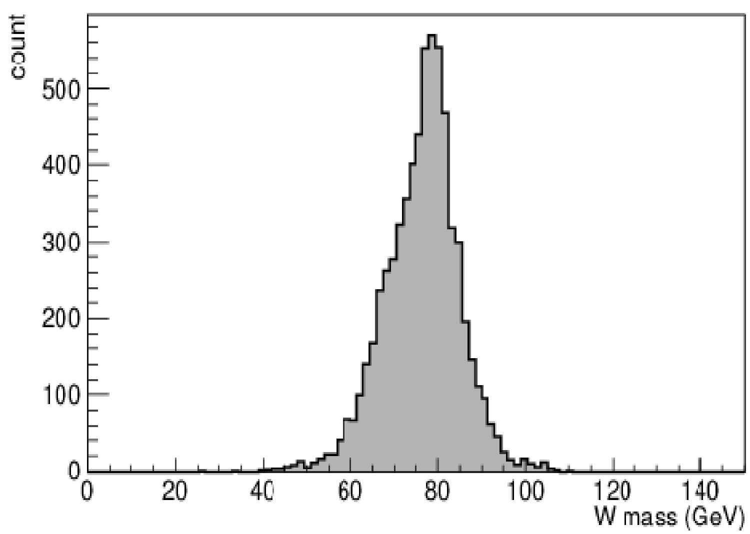


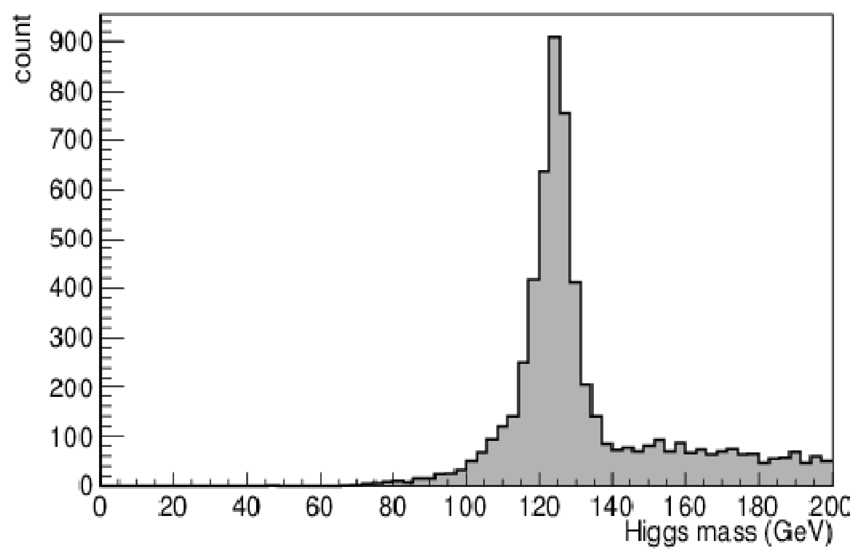


Reconstructed boson masses



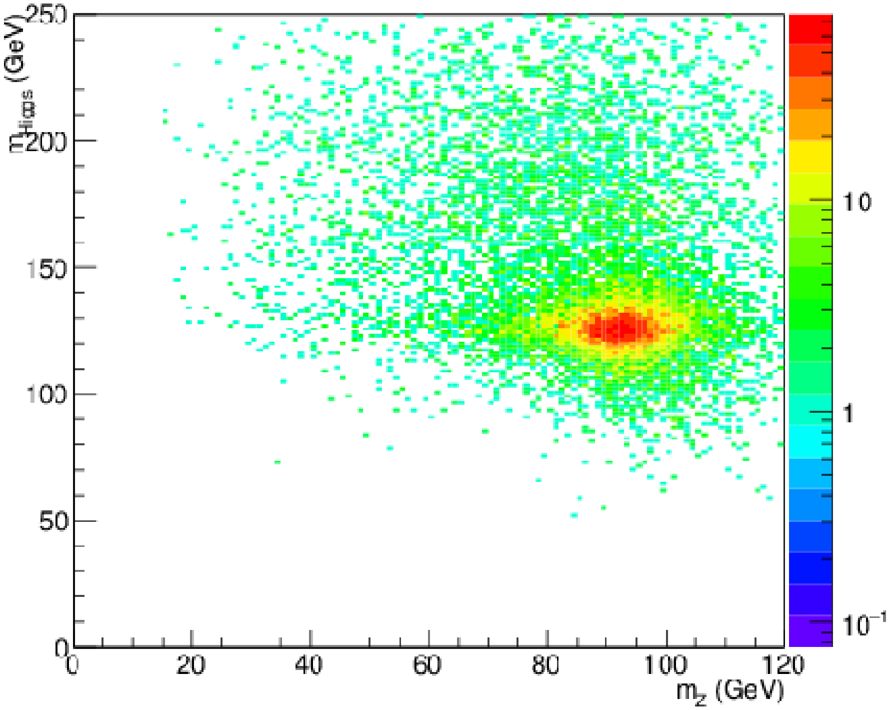
- The obtained invariant mass of the Z, Higgs, W real boson obtaided by the jet pairing

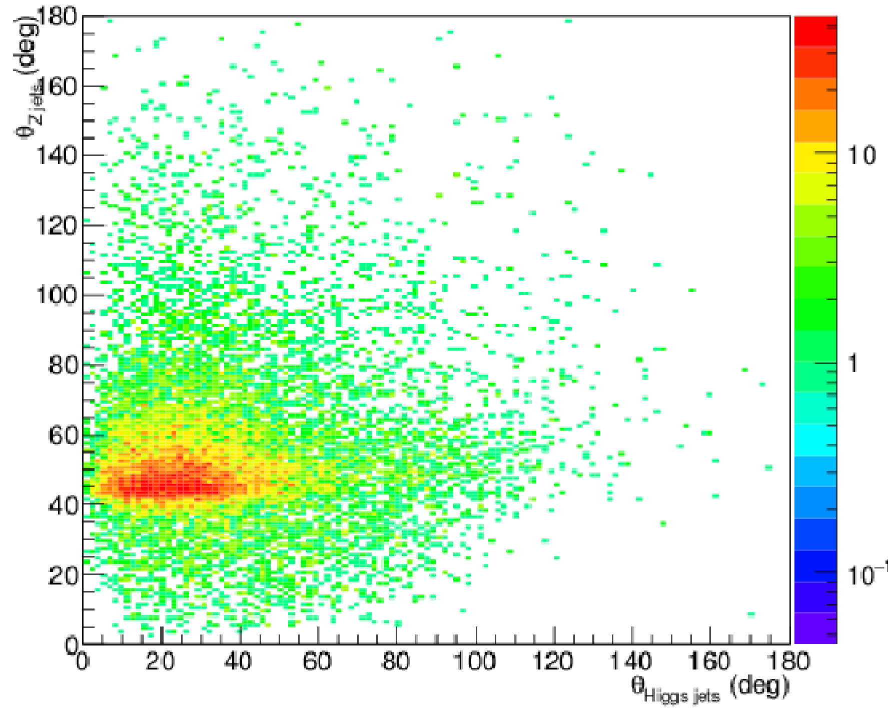




Signal reconstruction

- Higgs and Z boson invariant mass and angles between jets



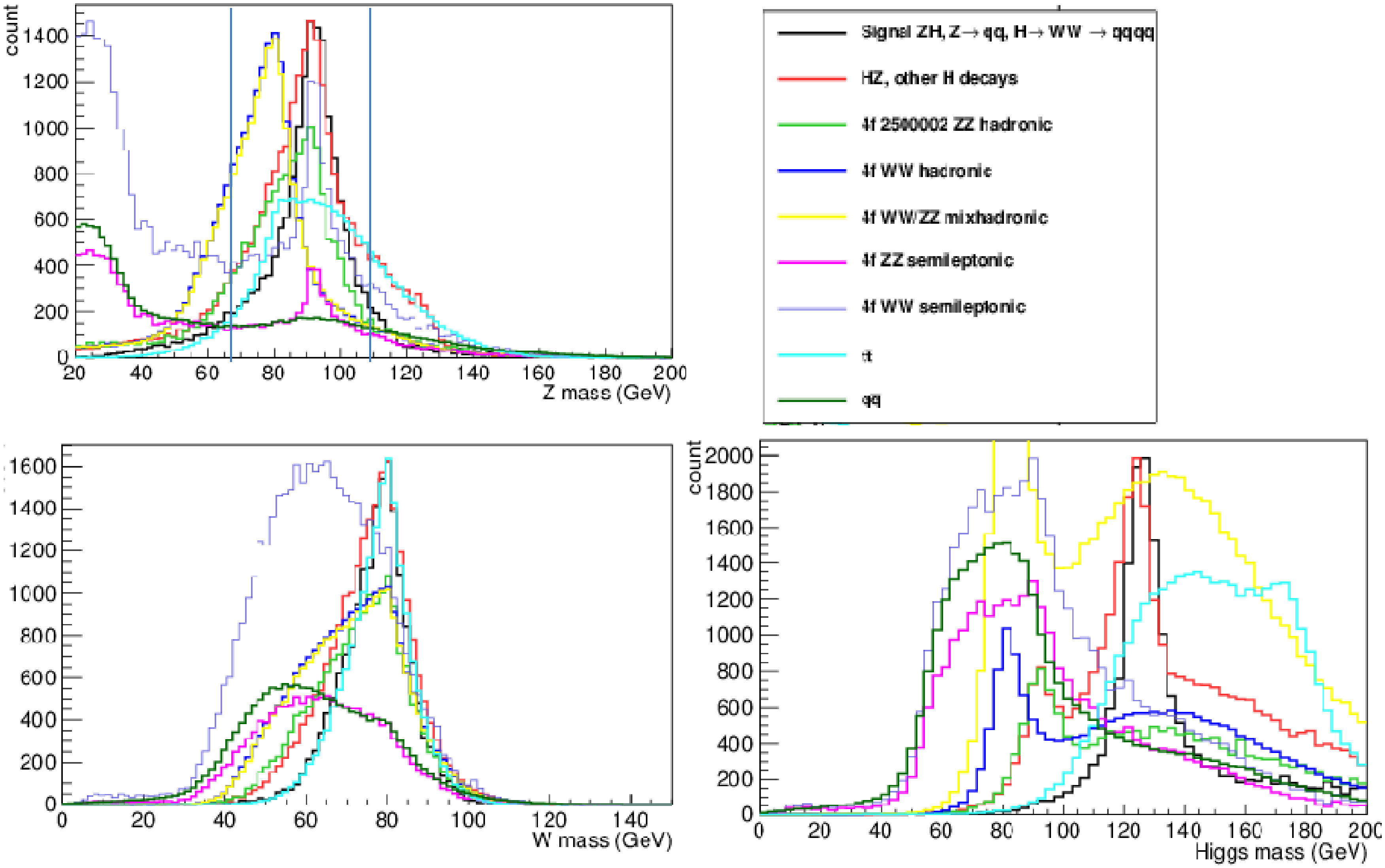


- Localised masses m_Z vs m_H
- $\theta_{HiggsJets}$ vs $\theta_{Z\ jets}$ angles between jets that are used to form Z and Higgs

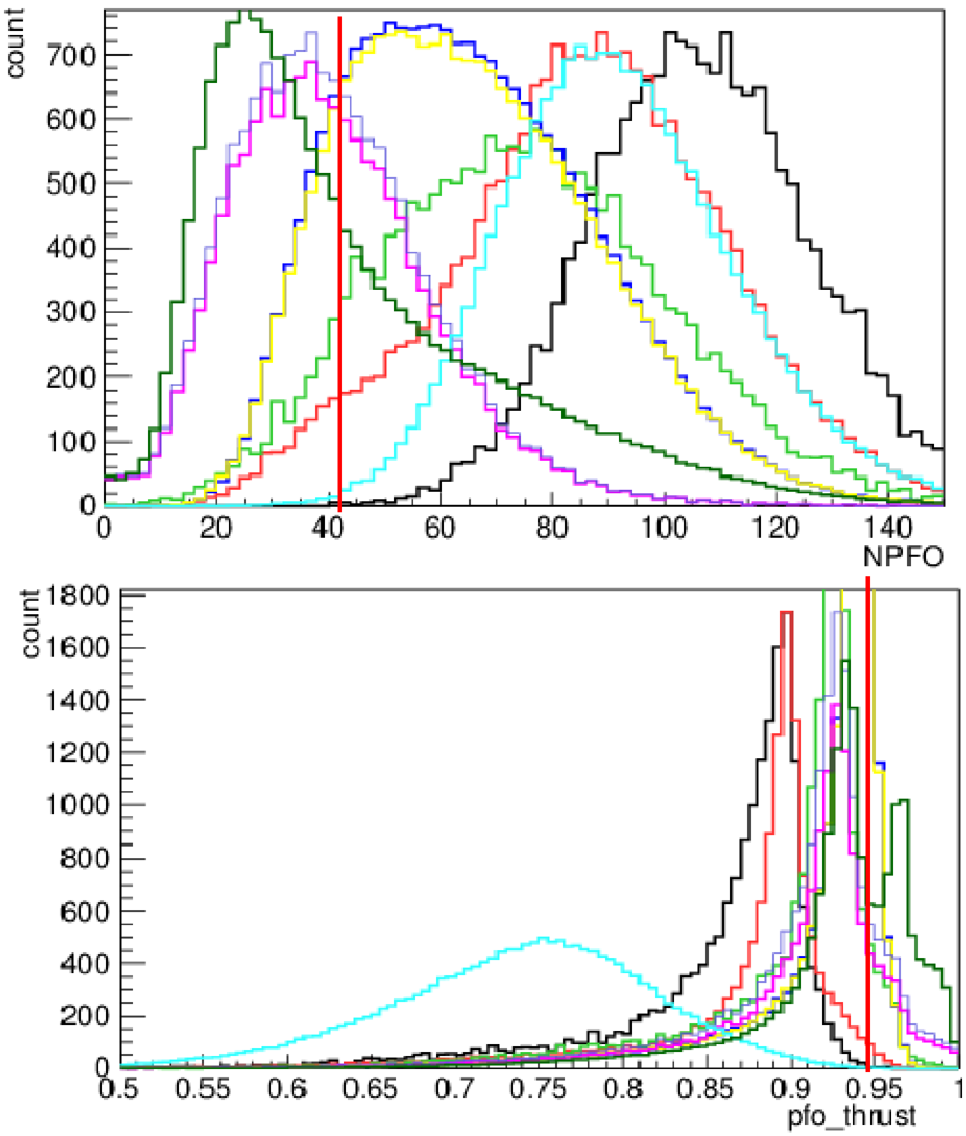
Signal and background samples

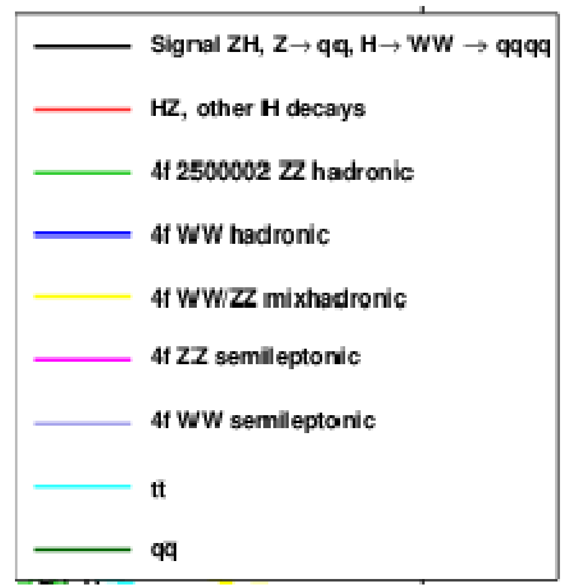
Process		σ[fb]	#evts/0.5ab⁻¹
signal	106730	11.33	5665
Other Higgs decays	106525	103.45	51725
$e^+e^- \rightarrow$ 4f_ZZ_hadronic	250002	680.23	340115
$e^+e^- \rightarrow$ 4f_WW_hadronic	250006	7680.69	3840345
$e^+e^- \rightarrow$ 4f WW/ZZ mix hadronic	250010	6400.11	3200055
$e^+e^- \rightarrow$ 4f_ZZ_semileptonic	250014	608.57	304285
$e^+e^- \rightarrow$ 4f_WW_semileptonic	250018	9521.45	4760725
$e^+e^- \rightarrow$ 2f hadronic	250114	32470.5	16235250
$e^+e^- \rightarrow$ 6f_$t\bar{t}$ yyxylv	108675	232.02	116740
$e^+e^- \rightarrow$ 6f_$t\bar{t}$ yyuyyc	108683	163.32	81160
$e^+e^- \rightarrow$ 6f_xxWW	37078	15.69	7845

Invariant masses m_Z m_H



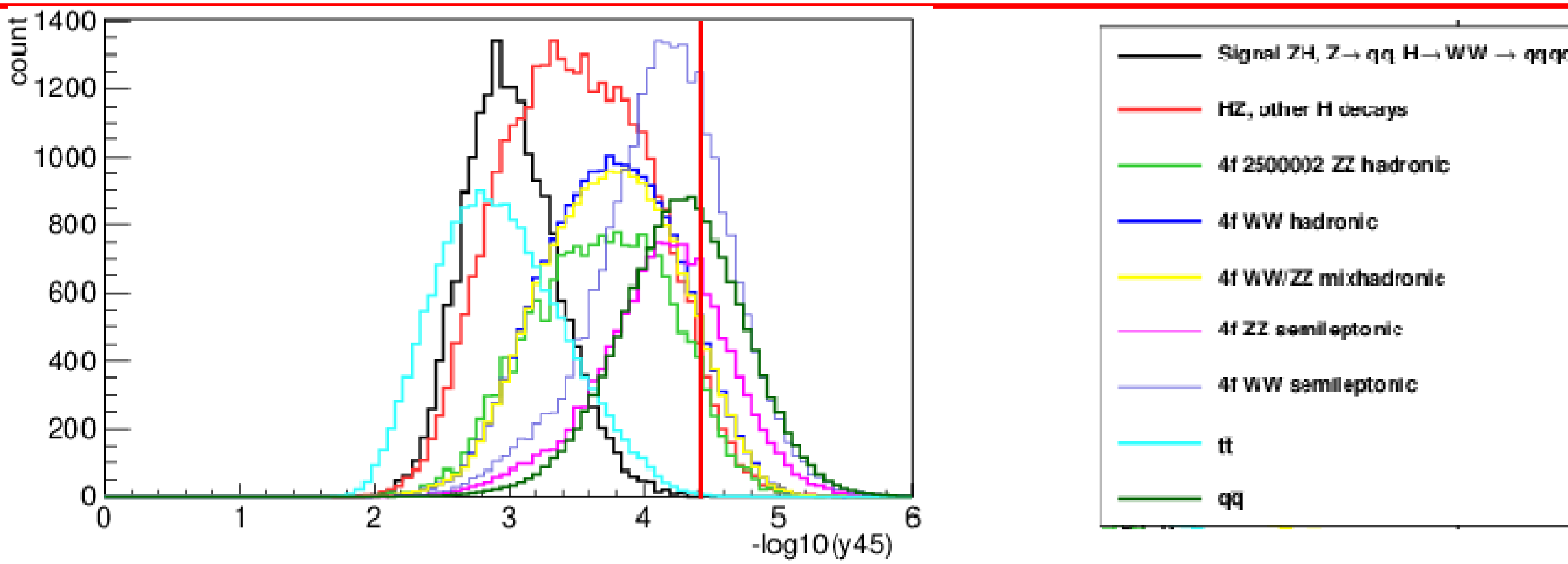
Input variables

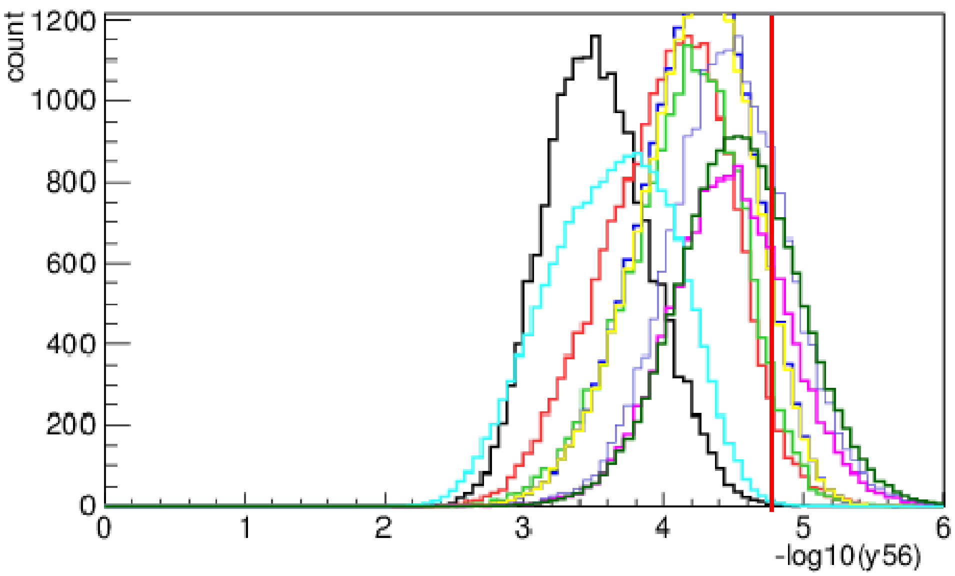




- Number of particle flow objects NPFO
- Event shape variable:thrust

Input variables





- Jet transition probabilities

  a kt value at which number of jets transits from i number of jets to j, y_{ij}

Preselection

- ε signal>99%: NPFO>40 thrust<0.95 y45<4.4 y56<4.8
- Additional cut – 70< m_z <110 $\Rightarrow$ ε_{signal}= 80.41%

Process		σ[fb]	#evts/0.5ab⁻¹	ε_{pres} [%]	#evts/0.5ab⁻¹ preselection
signal	106730	11.33	5665	80.0	4527
Other Higgs decays	106525	103.45	51725	61.3	31718
$e^+e^- \to$ 4f_ZZ_hadronic	250002	680.23	340115	58.3	191772
$e^+e^- \to$ 4f_WW_hadronic	250006	7680.69	3840345	45.7	1758779
$e^+e^- \to$ 4f WW/ZZ mix hadronic	250010	6400.11	3200055	46.1	1475371
$e^+e^- \to$ 4f_ZZ_semileptonic	250014	608.57	304285	11.3	34428
$e^+e^- \to$ 4f_WW_semileptonic	250018	9521.45	4760725	11.3	538652
$e^+e^- \to$ 2f hadronic	250114	32470.5	16235250	7.0	1143281
$e^+e^- \to$ 6f_$t\bar{t}$	108675	232.02	116740	59.0	68957
$e^+e^- \to$ 6f_$t\bar{t}$	108683	163.32	/	/	/
$e^+e^- \to$ 6f_WWZ	37078	/	/	/	/

TMVA

Input variables

- Invariant masses: m_Z m_{Higgs} m_W m_{w*}
- NPFO E_{vis} jetP_t
- Event shape variables: thrust, aplanarity, sphericity, oblateness
- Jet transitions: y_{12} y_{23} y_{34} y_{45} y_{56} y_{67}
- btag applied to all six jets, used the four highest btag values: btag1, btag2, btag3, btag4
- Angle between jets that comprise Z: ThetaPartZ
- Angle between jets that comprise W: ThetaPartW

Training was done on all backgrounds,

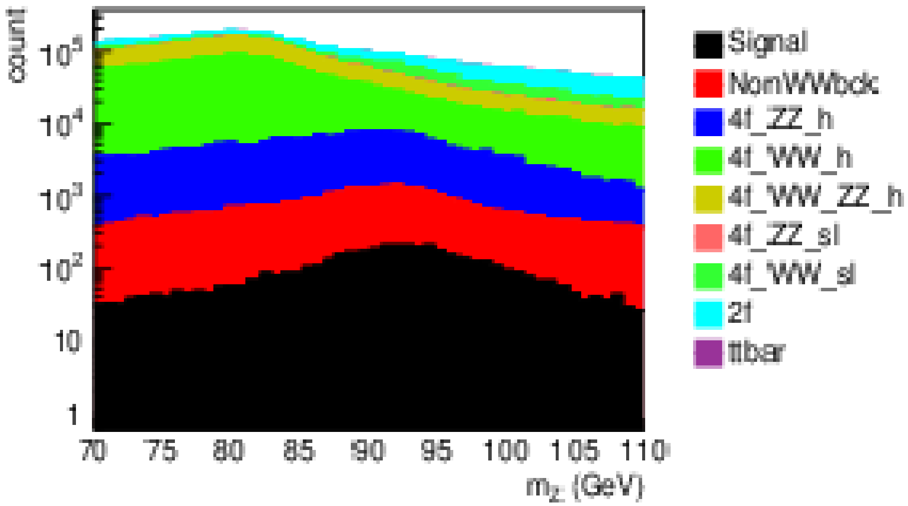
Reduction after tmva

Process		σ[fb]	#evts/0.5ab-1	#evts./0.5ab-1 pres	$\varepsilon_{tmva/pres}$ [%]	#evts/0.5ab-1 tmva
signal		11.33	5665	4527	30.0	1348
Other Higgs decays	106525	103.45	51725	31718	5.4	1713
$e^+e^- \rightarrow$ 4f_ZZ_hadronic	250002	680.23	340115	191772	0.17	331
$e^+e^- \rightarrow$ 4f_WW_hadronic	250006	7680.69	3840345	1758779	<0.05	733
$e^+e^- \rightarrow$ 4f WW/ZZ mix hadronic	250010	6400.11	3200055	1475371	<0.05	616
$e^+e^- \rightarrow$ 4f_ZZ_semileptonic	250014	608.57	304285	34428	<0.02	0
$e^+e^- \rightarrow$ 4f_WW_semileptonic	250018	9521.45	4760725	538652	$<10^{-4}$	0
$e^+e^- \rightarrow$ 2f hadronic	250114	32470.5	16235250	1143281	0.14	1617
$e^+e^- \rightarrow$ 6f_$t\bar{t}$	108675	232.02	116740	68957	0.11	79
$e^+e^- \rightarrow$ 6f_$t\bar{t}$	108683	163.32	/	/	/	/
$e^+e^- \rightarrow$ 6f_WWZ	37078	/	/	/	/	/

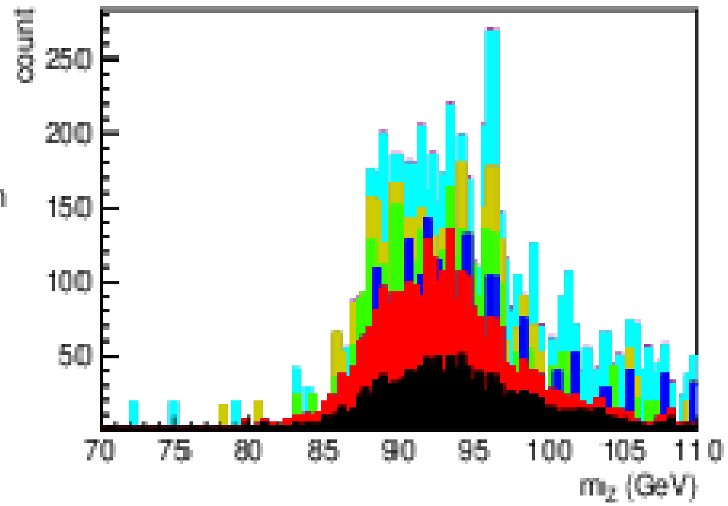
- Dominant background: other Higgs decays, qqqq, qq

Reduction after tmva

After preselection



After TMVA



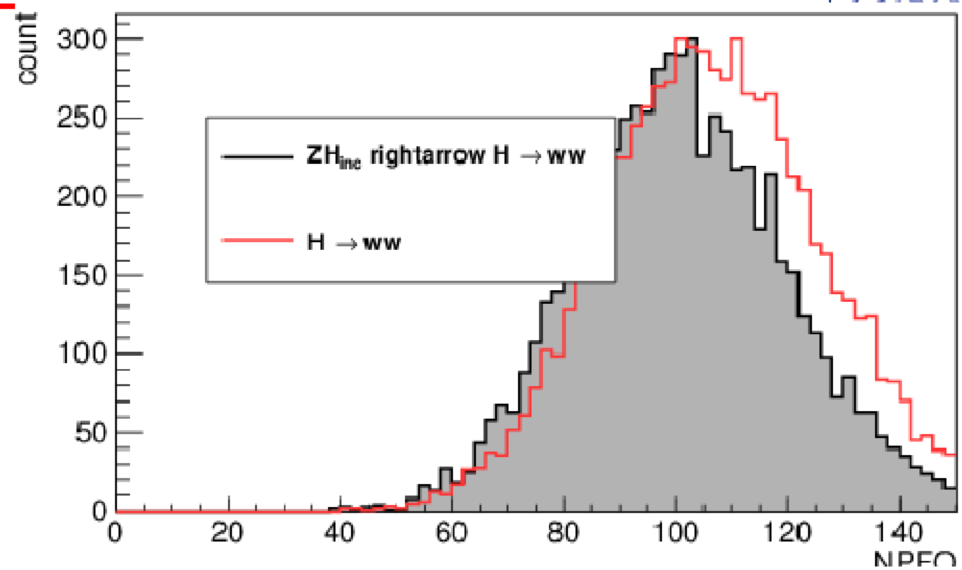
- The dominant background after mva is qqqq

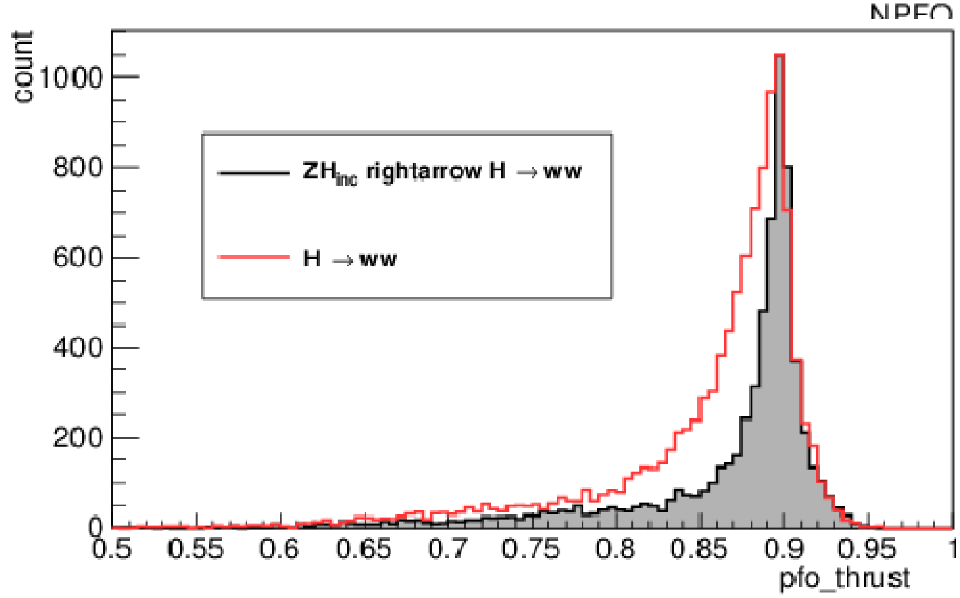
$$\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{S + B}}{S} \approx 6\,\%$$

Comparison of H→WW→qqqq samples

- HZ inclusive, extracting:H→WW* →4q (106525)
- Exclusive production of H→WW* →4q specific channel (106730)

- Higer number of particle flow objects NPFO’s
- Slighlty different event topology



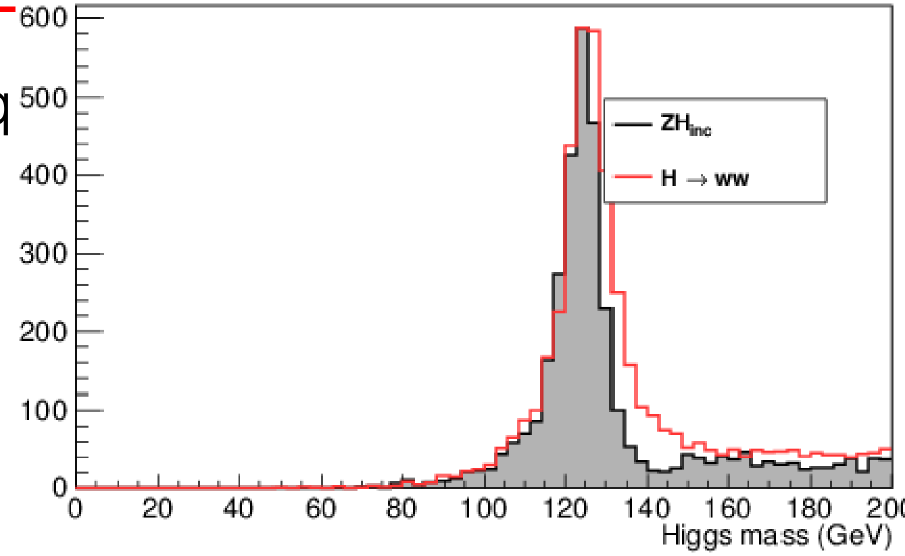


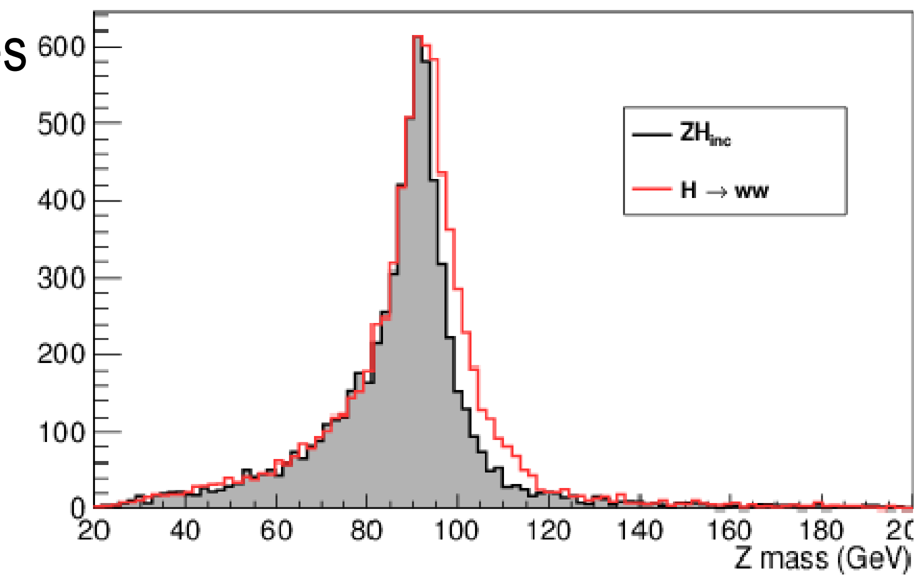
Signal samples

- HZ inclusive, extracting: H→WW* →4q
- Exclusive production of H→WW* →4q specific channel

- Higher NPFO's is resulting in slight discrepancy between Higgs and Z boson reconstructed invariant masses

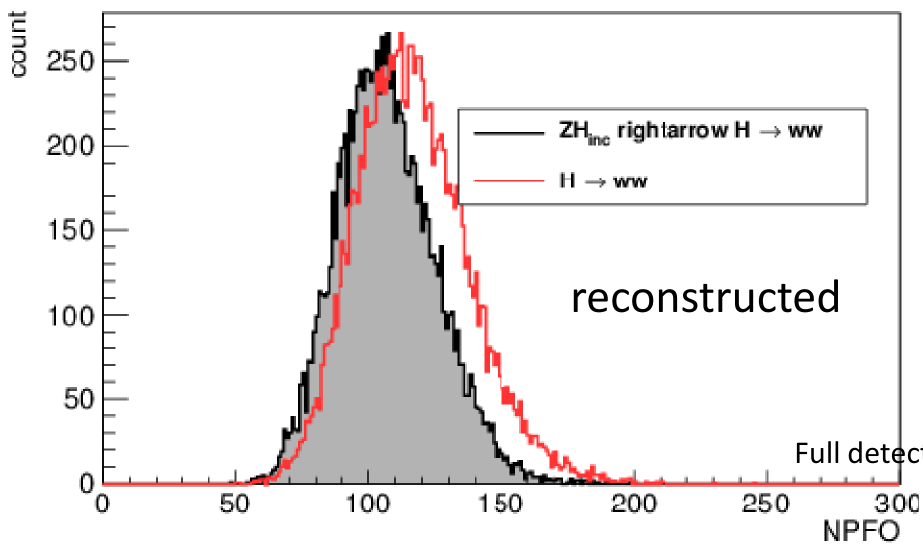
- All other distributions show no noticeable difference



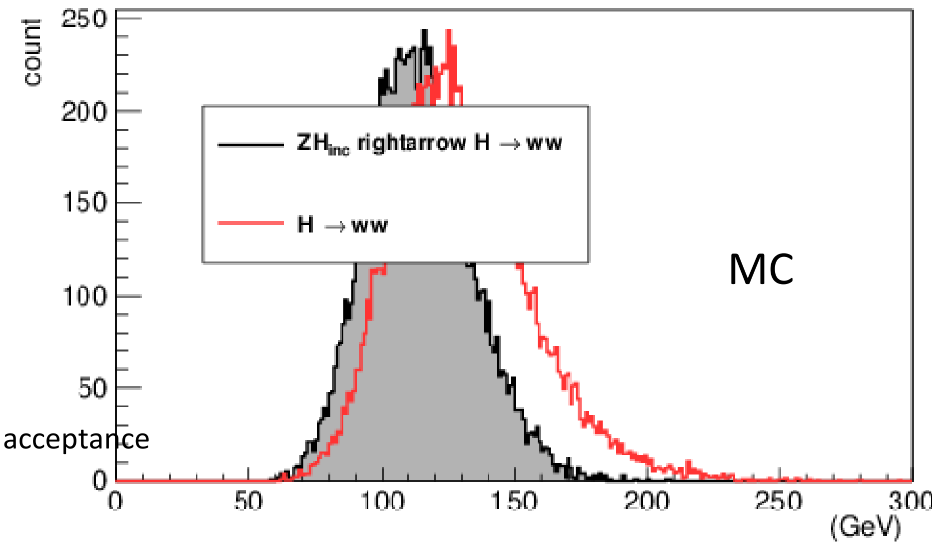


MonteCarlo

- The same difference is observed in Monte Carlo
- Used stable particles: Generator status==1
- When used getSimulatorStatus it has been found that the difference was in the overlaid particles , status=“o” , showing in exclusive 106730 , not present in inclusive sample 106525

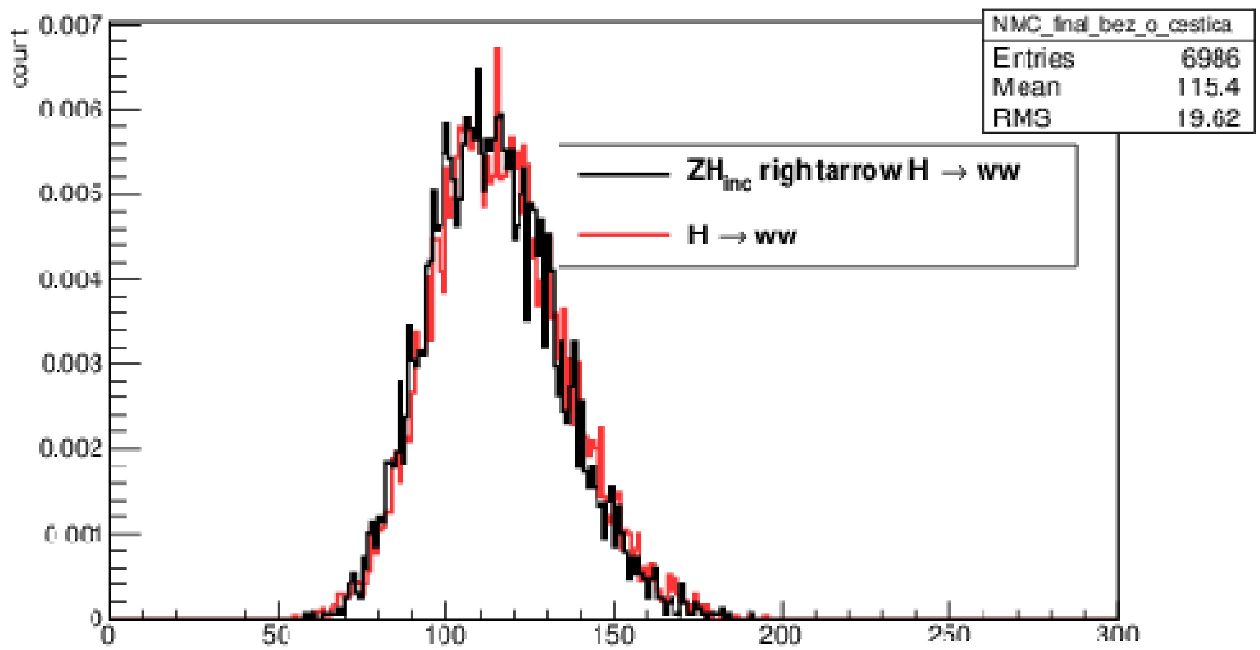


Full detector acceptance



Monte Carlo

- The distribution of stable particles (generator status=1)
- After removing the overlaid particles from 106730 we observe matching of that the number of final state particles with the106525 file



#stable partcles

Summary

- High cross-section backgrounds are included, plans include 6f final states
- The preliminary relative statistical uncertainty 6.0%
- Uncertainty of the measurement is dominated by qqqq, qq and other Higgs decays

- Difference between two signal sample is observed both in reconstructed and MC samples
- The main difference are overlaid particles, after removal of the overlaid particles the MC distributions of the stable particles are the same
- In the analysis for the obtained result the exclusive (106730) sample is used for signal and for other Higgs decays inclusive sample (106525): not consistent
- For consistency use HZ sample: only 10^4 events available

BACKUP

Backgrounds

Process		σ[fb]	#evts/0.5ab⁻¹
Other Higgs decays	106525	103.4	51725
$e^+e^- \rightarrow$ 4f_ZZ_hadronic	250002	680.2	340115
$e^+e^- \rightarrow$ 4f_WW_hadronic	250006	7680.7	3840345
$e^+e^- \rightarrow$ 4f WW/ZZ mix hadronic	250010	6400.1	3200055
$e^+e^- \rightarrow$ 4f_ZZ_semileptonic	250014	608.6	304285
$e^+e^- \rightarrow$ 4f_WW_semileptonic	250018	9521.4	4760725
$e^+e^- \rightarrow$ 2f hadronic	250114	32470.5	16235250
$e^+e^- \rightarrow$ 6f_tt_yyxyev	108670	116.9	58450
$e^+e^- \rightarrow$ 6f_tt_yyveyx	108668	117.1	58550
$e^+e^- \rightarrow$ 6f_tt_yyuyyc	108679	164.4	82200
$e^+e^- \rightarrow$ 6f_tt_yycyyu	108681	165.5	82750
$e^+e^- \rightarrow$ 6f_tt_yyxylv	108675	231.1	116500
$e^+e^- \rightarrow$ 6f_tt_yyvlyx	108673	231.6	115800
$e^+e^- \rightarrow$ 6f_tt_yycyyc	108683	163.3	81650
$e^+e^- \rightarrow$ 6f_tt_yyuyyu	108677	166.6	83300