ATLAS W path

Instructions for tutors

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<u>Languages supported</u>: Czech, Danish, English, French, German, Greek, Italian, Polish, Portuguese, Slovak, Spanish, and Turkish

Content

1 Short description

- Students use the MINERVA event display.
- Students categorize events as W and WW candidate events or background events. Results are collected in an online spreadsheet, which is connected to a database.
- Students determine the electric charge in case of W candidate events. They count the number of events to calculate the W^+/W^- ratio. They discuss this result with regard to the inner structure of the proton.
- In case of WW candidate events, students measure the angle between electrically charged leptons in the transverse plane. They create histograms (plot distribution of angle between electrically charged leptons in the transverse plane) of "WW candidate events". They discuss the effect of a possible Higgs signal on the overall distribution, which is background-dominated (WW, ttbar and others).

2 Hardware/software requirements

- Reliable, high-speed internet connection
- Up-to-date version of Internet Explorer, Chrome, or Mozilla Firefox. Safari is not recommended.
- MINERVA event display (see Fig. 1) requires JAVA Runtime Environment
- You need to use the latest version of MINERVA. Remove older versions first and download latest one here: http://atlas.physicsmasterclasses.org/downloads/Minerva.zip

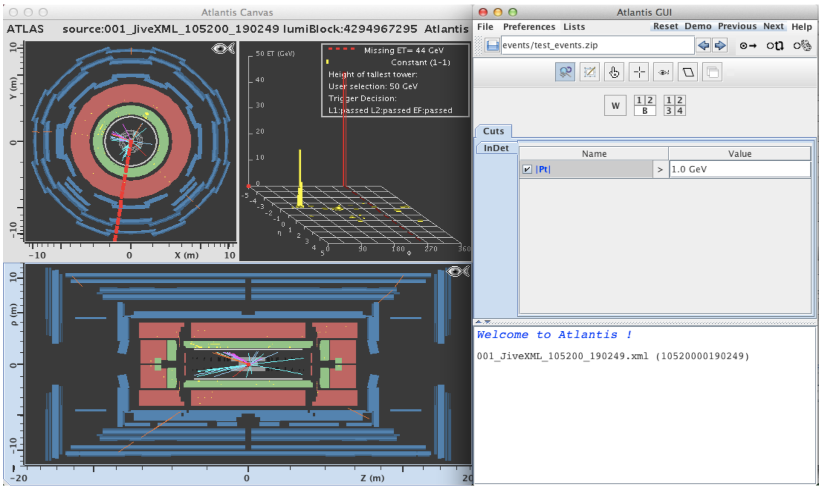


Figure 1: Event Display Programme MINERVA

3 Dataset

- The dataset consists of 12000 real data events from ATLAS, made up of W (6000), WW (1000) candidate events, and background events (5000).
- The dataset is split up into twelve data samples (labeled 1, 2, ...12), each containing 1000 events.
- All data samples are split into 20 sub-samples (labeled by a capital letter A, B, ... or T following the label of the data sample, e.g. 8 F). Each sub-sample contains 50 events.
- The institute´s dataset-number as well as the actual datasets are to be found at http://atlas.physicsmasterclasses.org/en/wpath_data.php

4 Schedule of the day

- Arrival/Registration
- Introductory lectures (~2 x 45 min)
  - presentation about research goals, open questions, fundamental methods (accelerators and detectors) and results of research in particle physics (brief, motivating, exciting)
  - presentation about W and Higgs bosons (short explanation of their role in particle physics, production processes at the LHC, decay channels ($W \to l\nu$ and $H \to WW \to ll\nu\nu$), signal vs. background)
- Lunch with physicists (~60 min)
- Analysis preparation (~60 min, including Q&A)
  - Guided practice with discussion (event display MINERVA, exercise 1 (identifying particles), exercise 2 (identifying events))
- Data Analysis (~60 min)
- Discussion of results on local level and preparation for the videoconference (~30 min)
- Videoconference (~60 min)

5 Student's tasks

5.1 Instructions for analysis, and download links

- Tally sheets, MINERVA, and datasets are to be found at this location: http://atlas.physicsmasterclasses.org/en/wpath_messung.htm
  - The tally sheet file includes 240 pages, labelled from 1A to 12T. Print out just the ones you need for your group and your datasets.

- Setup for the students´ PCs / desks:
  - MINERVA running
  - Tally sheet in front of students
  - Before analysis starts, assign each group of 2 students to a data group (identified by a letter and a number). This name will correspond to the file of events they will be analysing.
- Have opened the result submission page: http://atlas.physicsmasterclasses.org/results/wpath_auswertung.php?language=0 , "Combining results", >choose your institute (see Fig. 2). There is one separate online spreadsheet for each group, with 20 rows (labelled A-T) (see Fig. 3).

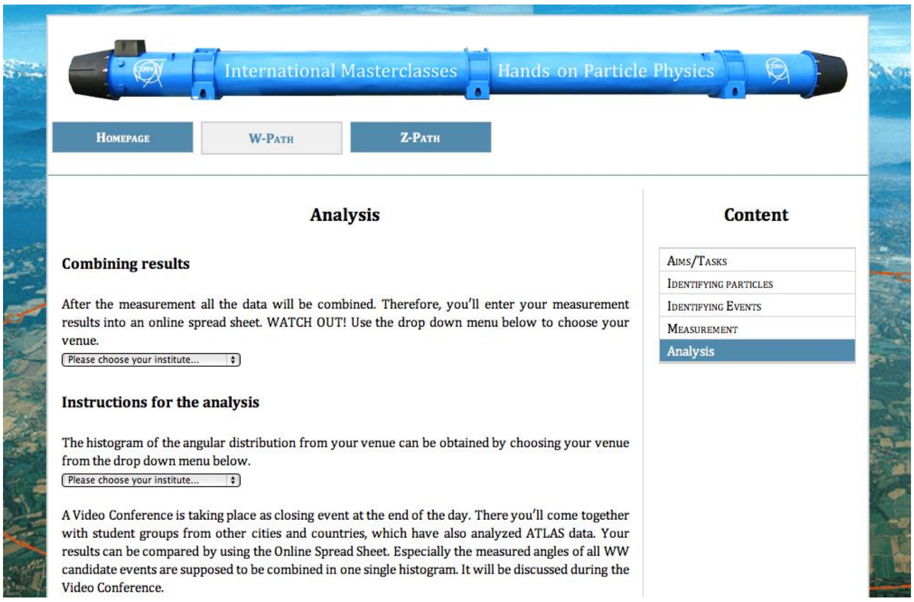
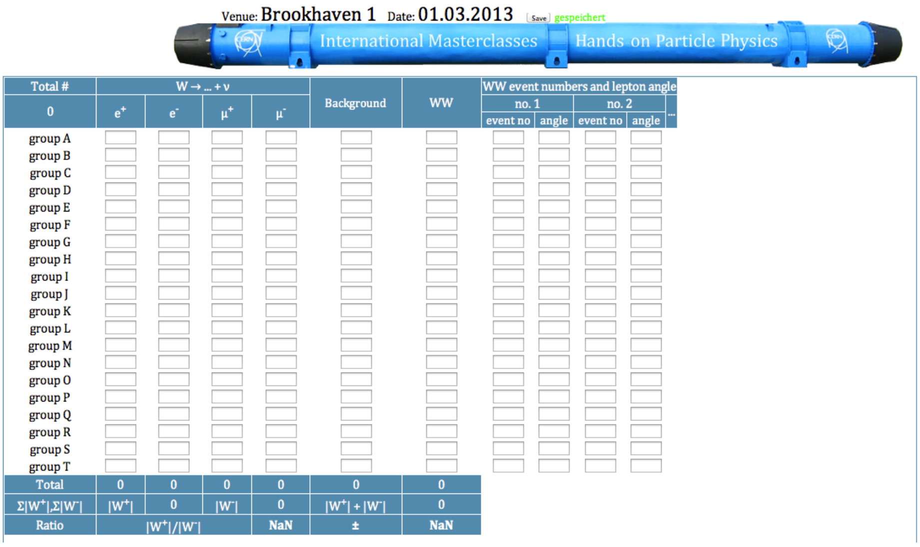


Figure 2: Webpage to access the online spreadsheet for results



Total #	W → ... + ν				Background	WW	WW event numbers and lepton angle				
							no. 1		no. 2		...
0	e^+	e^-	μ^+	μ^-			event no	angle	event no	angle	
group A											
group B											
group C											
group D											
group E											
group F											
group G											
group H											
group I											
group J											
group K											
group L											
group M											
group N											
group O											
group P											
group Q											
group R											
group S											
group T											
Total	0	0	0	0	0	0					
$\Sigma\|W^+\|,\Sigma\|W^-\|$	$\|W^+\|$	0	$\|W^-\|$	0	$\|W^+\| + \|W^-\|$	0					
Ratio	$\|W^+\|/\|W^-\|$			NaN	±	NaN					

Figure 3: online spreadsheet for results from 20 groups

5.2 How to start MINERVA

- MINERVA can be accessed from the W path: http://atlas.physicsmasterclasses.org/en/wpath_messung.htm
  1. Download
  2. Unzip it onto your Desktop
  3. To start MINERVA:
     a. Navigate to the unzipped MINERVA folder you downloaded
     b. Depending on your system:
        - Double click on either “MINERVA._Winows” or “MINERVA_Linux” or “MINERVA_Mac”

5.3 How they do it (step by step)

5.3.1 Procedure for Analysis preparation

- Teach them how to use the event display … or better, let them discover how the display works.
- Train them to identify particles. Make use of the following:
  - ATLAS animation on particle identification (ID) on http://atlas.physicsmasterclasses.org/en/wpath_teilchenid1.htm
  - Explanations on particle ID with MINERVA on http://atlas.physicsmasterclasses.org/en/wpath_teilchenid3.htm
  - Exercise 1: http://atlas.physicsmasterclasses.org/en/wpath_exercise1.htm
- Train them how to classify events
  - Introduce basic ideas of selecting events

- Explanations on Event ID with MINERVA on: http://atlas.physicsmasterclasses.org/en/wpath_lhcphysics3.htm
- Exercise 2: http://atlas.physicsmasterclasses.org/en/wpath_exercise2.htm (Here you need the current exercise2 data set – downloadable at http://atlas.physicsmasterclasses.org/downloads/exercise2-2014.zip)

5.3.2 Procedure for Data Analysis

- Each pair of students gets a set of 50 events. On the tally sheet handed out to them (upper left corner) they find the name of their dataset (e.g. 4B)
- They download their dataset from http://atlas.physicsmasterclasses.org/en/wpath_data.php.
- In the GUI window, they click on “File” and then on “Read events locally”. They navigate to their dataset, which they have downloaded before, and click on “open”. The first event is then loaded. With help of the arrow buttons in the GUI window, they can go to the next event.
- In MINERVA, for each event, they try to find signs of the existence of particles such as
  - a W boson, by hunting for a lepton plus neutrino,
  - a Higgs boson, by hunting for two W bosons with opposite electric charge (WW candidate events), or
  - background events (all other signatures).
- For each event students should draw their conclusions following the steps displayed by the flow chart (see Fig. 4)
- Students enter their results in the tally sheet in paper form in front of them. They add up the numbers in the different event categories in the end.
- The tutor or the students access the online spreadsheet (Fig. 3) and enter their results.
- Each row is for the results of one pair of students.
- They enter the number of W candidate events in the various decay channels, the number of background events, and for each WW candidate event the opening angle.
- Having entered their results they should press the “Save” button on top of the page (although automatic save process is enabled).
- The data is then automatically entered into a database hosted at the CERN web servers and both total numbers and histograms (find details about the histogram tool in the appendix C) will be calculated automatically.

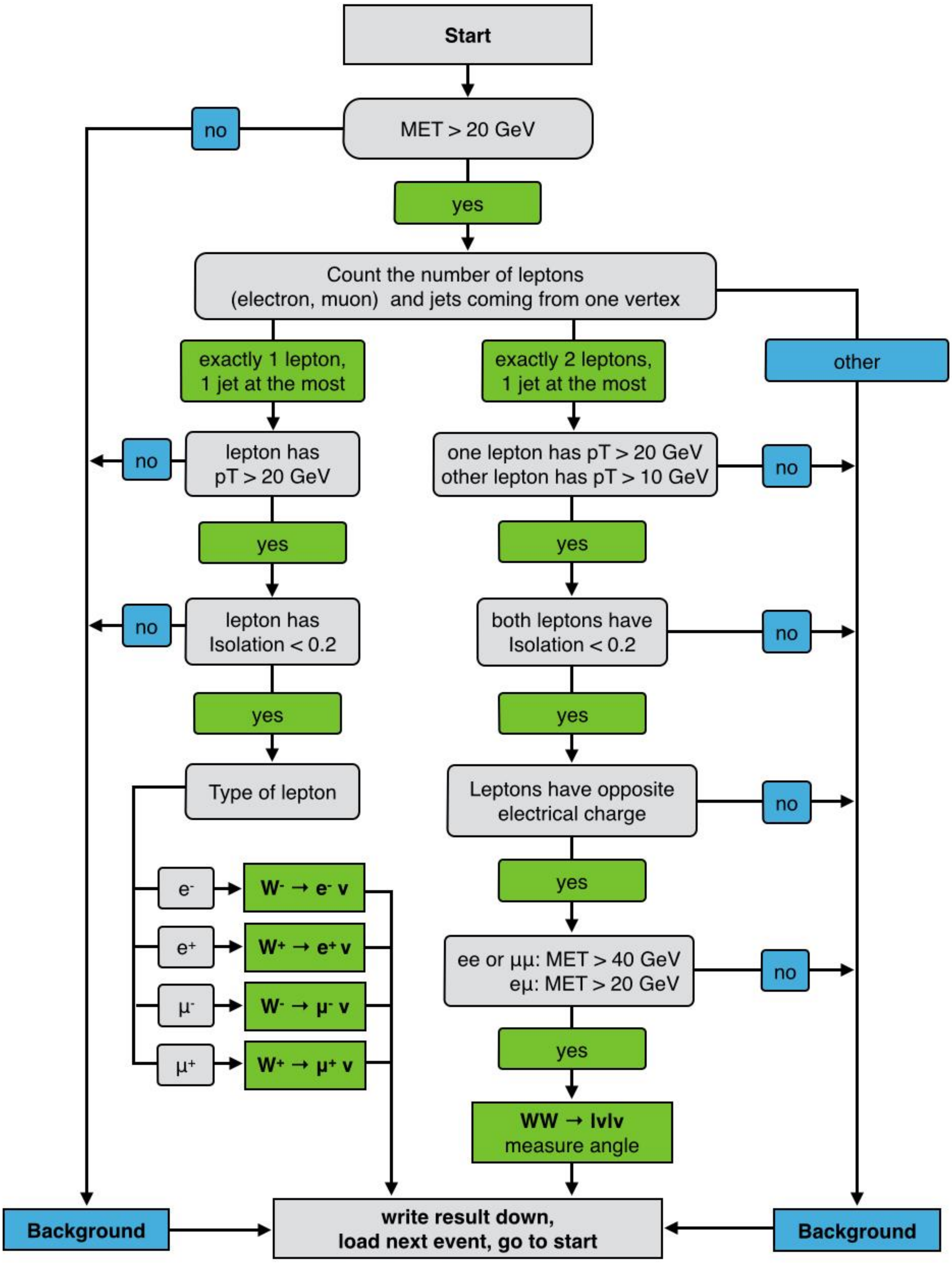
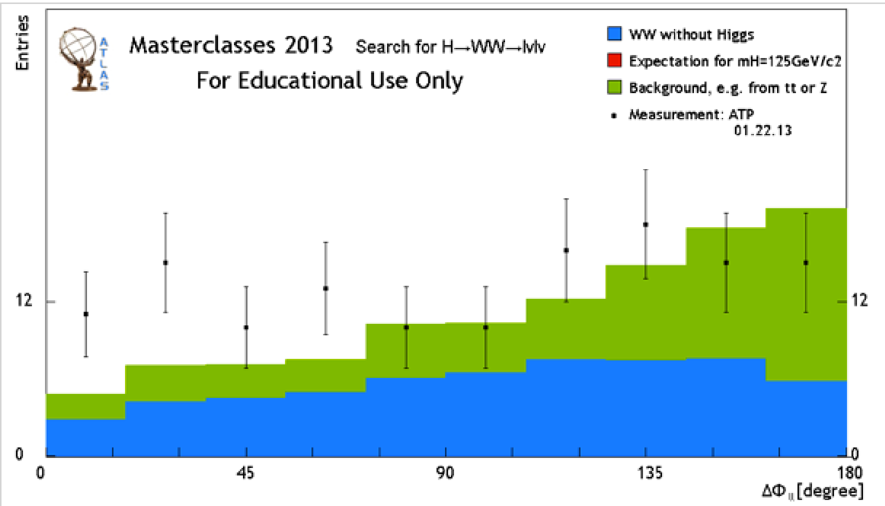


Figure 4: Flowchart for analysis in the ATLAS W path

6 Gaining and presentation of results

- Each institute discusses their results on a local level. Especially the meaning of the measured W+/W- ratio should be discussed and what one can learn from this about the inner structure of the proton.
- The online spreadsheet (Fig. 2) allows to compare the measurement with the result obtained by the ATLAS experiment (below).
- The histogram (Fig. 5, use second drop-down menu on http://atlas.physicsmasterclasses.org/results/wpath_auswertung.php?language=0) shows the distribution of opening angle for WW candidate events. Enable the Higgs contribution (in red) by checking into the appropriate checkbox (bottom left) and click on "submit" (bottom right).



	bin 1	bin 2	bin 3	bin 4	bin 5	bin 6	bin 7	bin 8	bin 9	bin 10	SUM
N	11	15	10	13	10	10	16	18	15	15	133
B	4.8	7	7.1	7.5	10.2	10.3	12.2	14.8	17.7	19.3	110.9
S	6.2	8	2.9	5.5	-0.2	-0.3	3.8	3.2	-2.7	-4.3	22.1
Z	2.8	3	1.1	2	-0.1	-0.1	1.1	0.8	-0.7	-1	2.1

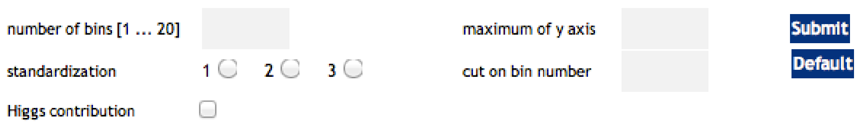


Figure 5: Histogram tool showing results of a Masterclass

- When a video conference is held (International Masterclasses), an additional discussion will be included there. Students can expect the following questions:
  - Results spreadsheet:
    - What was your result for R±? How did the combination with the other institutes change the total result?
    - Is the result compatible with the results measured in ATLAS?
  - Histogram:
    - You have measured the angle between two leptons. Let´s have a look at that. What exactly do the black data points mean?
    - How would you interpret the blue and green areas? What do they mean?
    - Can we claim a Higgs discovery? What would be necessary to claim a discovery?

7 Appendix

7.1 FAQ

"If I don't clearly see any yellow bar in the calorimeter view, is this event always a Background event?"

No, it could be that muons are in the event, which leave only little energy in the calorimeters. So one has to look for the signature of one or more muons in order to determine the event as signal or even background event.

"Why are some tracks visible in the side view and not in the cross-sectional view?"

Because of the overlaid detector parts. In cross-sectional view some parts of the forward (and backward) detectors are not displayed and with it possible entries of particles going through those parts.

“How can I be sure that a track is isolated from Jets?"

It’s complicated to tell if a track is isolated by using the view. Therefore an algorithm has been implemented to help. What the algorithm does is the following:

1. Collect all tracks that are closer than $\Delta R = 0.3$.
2. Sum all the transverse momenta of these tracks.
3. Divide this sum by the transverse momentum of the selected track.

We say that a track is well isolated when the isolation value is less than 0.2 which means that it has a transverse momentum 5 times than the combined transverse momentum of the tracks surrounding it.

"How can I be sure that two tracks are coming from the same vertex?"

Using the zoom option in side view you will see green circles indicating the vertices. If the tracks cross the green circle they probably originated from the same vertex. However, sometimes tracks stop shortly before the circle or end only after completely crossing the circle. In these cases the tracks can still be assigned to the tracks. Unfortunately, the algorithm sometimes fails in estimating the correct length of tracks.

"Sometimes there are tracks in the muon chambers, that can't be combined to tracks in the inner detector."

These could be cosmic muons.

7.2 Higgs → WW Selection at 7 TeV for the International Masterclasses

Higgs→WW Selection at 7 TeV for the international Masterclasses

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October 29, 2012

Contents

1

1 Introduction

In the Masterclasses 2013 Standard Model Higgs candidates (mass $m_H = 125\,\mathrm{GeV}$) recorded with ATLAS at the LHC at $\sqrt{s} = 7\,\mathrm{TeV}$ shall be used to be analysed by pupils. This documentation gives an overview of the event selection for which $1.154\,\mathrm{fb}^{-1}$ of data measured by ATLAS in 2011 at $\sqrt{s} = 7\,\mathrm{TeV}$ was used.
The process that was looked at is the production of Higgs bosons and their decay to W^+W^- boson pairs. The W^+W^- bosons themselves are deacaying as well before being detected. Concentrating on the leptonic decay the final state is a dilepton pair with opposite charge.

Chapter 2 describes how the cross section for the considered decay is calculated. Chapter 3 sums the selection criteria that the Higgs candidate events have to fulfill and shows the effects of these cuts. In chapter 4 the results of the selection and final distributions of various parameters are presented. The Appendix gives more detailed information on the selection was carried out. This chapter mainly refers to readers that would like to redo the selection.

2 Higgs cross section

Four processes contribute to the Higgs production: gluon fusion (gg→H), vector boson fusion (qq'→qq'H), Higgs radiation (WH/ZH) and top decays ($t\bar{t} \rightarrow b\bar{b}H$). The cross section of the Higgs production via gluon fusion is one order of magnitude bigger than the cross sections for the other processes. Therefore the other contributions to the production are negligible.
The following process shall be considered in our selection:

$$gg \rightarrow H \rightarrow W^+W^- \rightarrow l^+\nu l^-\overline{\nu} \tag{1}$$

Where l stands either for electrons, muons or taus.
The cross section σ_{tot} for this process is calculated as follows:

$$\sigma_{tot} = \sigma(gg \rightarrow H) \cdot BR(H \rightarrow W^+W^-) \cdot BR(W^+W^- \rightarrow l^+\nu l^-\overline{\nu}) \tag{2}$$

Figure 1 shows the Higgs production cross sections of the different processes over the Higgs mass. The values for the Higgs cross section and the Branching Ratios of its decay are listed in [3].

$$\sigma(gg \rightarrow H) = 15.31\,\mathrm{pb} \tag{3}$$
$$BR(H \rightarrow W^+W^-) = 0.216 \tag{4}$$

W bosons decay with 10.8 % to the leptonic channel. As there are three possible flavours and two W bosons decaying the Branching Ratio is:

$$BR(W^+W^- \rightarrow l^+\nu l^-\overline{\nu}) = (3 \cdot 0.108)^2 = 0.105 \tag{5}$$

Hence the total cross section is:

$$\underline{\underline{\Rightarrow \sigma_{tot} = 0.3472}} \tag{6}$$

3 Event Selection

The event selection of Higgs candidate events with $m_H = 125\,\mathrm{GeV}$ is done for measured events (referred to as data events in the following) as well as for simulated events (referred to as Monte Carlo events in the following). In order to estimate how many real Higgs events are among the selected ones the data is compared to the Simulation. If they are in good agreement the contribution of each background

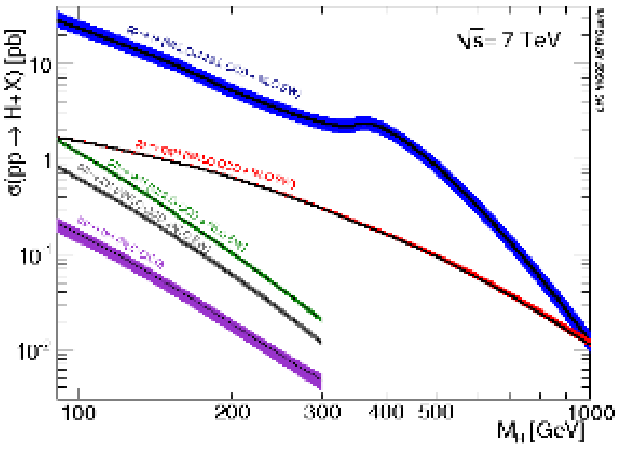


Figure 1: Dependance of the Higgs production cross sections on the Higgs mass at different center of mass energies

process and the real Higgs events (signal) can be seen. The final state that is detected is a dilepton pair with opposite charge and a high transverse momentum (p_T). The leptons can be electrons or muons. A tau will also be seen as an electron or muon as its lifetime is too short to be detected before decaying. Additionally a large missing transverse energy E_T^{miss} is seen and only few jets produced by strong interactions. Hence we consider only events where zero or one jets are within the acceptance (H0 and H1 bin). In each of the bins we have three different final states (channels): two electrons (ee), two muons (mm) or one electron and one muon (em).
The major background processes that can produce the same final states are:

- WW pairs coming from other standard model processes
- Z + jets (Drell Yan)
- $t\bar{t}$
- W + jets
- Single-top

In these processes it is either possible to produce two opposite signed leptons or leptons may be faked due to misidentification of photons or jets. With the selection the number of background events shall be reduced. The first cuts are the same for the H0 and the H1 bin. These cuts will be referred to as BaselineSelection in the following. It contains the following constraints:

- the primary vertex has a minimum of 3 tracks
- leading lepton (lepton with the higher p_T): $p_T^{lead} > 25\,\text{GeV}$, trailing lepton (lepton with the lower p_T): $p_T^{trail} > 15\,\text{GeV}$
- invariant mass of the leptonsystem: $m_{ll} > 15\,\text{GeV}$ in the ee or mm channel and $m_{ll} > 10\,\text{GeV}$ in the em channel
- $|m_Z - m_{ll}| > 15\,\text{GeV}$ in the ee and mm channel to reduce Z-events (Z-veto)
- $E_T^{miss} > 50\,\text{GeV}$ in the ee and mm channel and $E_T^{miss} > 25\,\text{GeV}$ in the em channel

The invariant mass of the lepton system m_{ll} is defined as $m_{ll} = \sqrt{(\mathbf{p}_\mathrm{T}^\mathrm{lead} + \mathbf{p}_\mathrm{T}^\mathrm{trail})^2}$ where $\mathbf{p}_\mathrm{T}^\mathrm{lead/trail}$ are Lorentzvectors. E_T^{miss} is the inbalance of the vectorial sum of all visible objects. Hence it is the energy that is carried away by nondetectable products like neutrinos.

To find and optimize good cuts one simple possibility is to look for a maximum of significance:

$$\frac{\text{Number of signal events}}{\sqrt{\text{Number of background events}}} = \frac{S}{\sqrt{B}} \tag{7}$$

The E_T^{miss}-cut for example was optimized using a simple tool that calculates the $S/\sqrt{B}$ for each hypothetical E_T^{miss} cut-value. The optimum cut is where $S/\sqrt{B}$ becomes maximal. This optimisation is performed in the step right before the E_T^{miss} cut.
Figure 2 shows the E_T^{miss} distribution in the ee and mm channel on the left and in the em channel on the right in the upper diagrams. The lower diagramm show the $S/\sqrt{B}$ for each cut-value

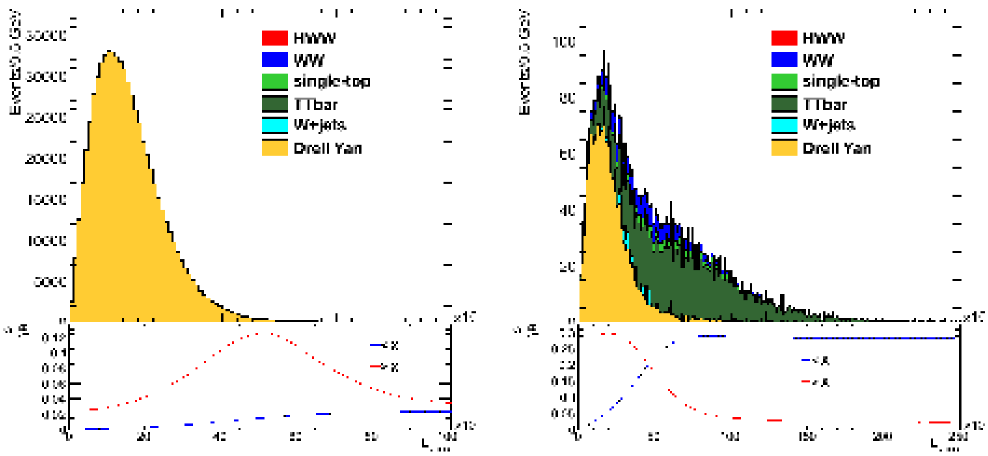


Figure 2: E_T^{miss} distribution after the Z veto cut for the ee and mm channel (left) and the em channel (right). The lower diagram shows the $S/\sqrt{B}$ over the E_T^{miss} cut value if cutting on bigger or smaller than this value.

Additionally the following cuts different for the H0 and H1 bins are applied:

H0-bin:

- no jet with $p_T > 25\,\mathrm{GeV}$ is allowed
- $p_T^{ll} \geq 30\,\mathrm{GeV}$

p_T^{ll} is the transverse momentum of the lepton system. It is defined as $p_T^{ll} = |\overrightarrow{p_T^{lepton1}} + \overrightarrow{p_T^{lepton2}}|$

H1-bin:

- exactly one jet with $p_T > 25\,\mathrm{GeV}$

- a b-jet veto is applied using a b-tagging algorithm. It calculates a so called b-tagging weight from a combination of variables suitable for discriminating between jets originating from b-quarks and jets from light quarks or gluons. A jet is considered as b-tagged if the b-tagging weight is greater than the algorithm depending value for an efficiency of 70% for b-jets in top Monte Carlo events.
- $p_T^{tot} < 30\,\text{GeV}$
- Z→ $\tau\tau$ veto: $|m_{\tau\tau} - m_Z| < 25\,\text{GeV}$

p_T^{tot} is the transverse momentum of the whole system consisting of the two leptons, one jet and missing energy. It is defined as $p_T^{tot} = |\overrightarrow{p_T^{lepton1}} + \overrightarrow{p_T^{lepton2}} + \overrightarrow{p_T^{jet}} + \overrightarrow{p_T^{miss}}|$.
As the neutrinos coming from τ-decays are not detected, the invariant mass of the hypothetical $\tau\tau$-system $m_{\tau\tau}$ is reconstructed using the collinear approximation. Hence the neutrinos are considered to be collinear with the lepton vectors possibly originating from τ decays. The calculation can be found in the appendix.

4 Results

4.1 Final numbers and $\Delta\Phi_{ll}$ distribution

The number of events left after all cuts are listed in the tables 1 and 2. The columns one to seven contain the numbers for simulated events.

Drell Yan	$t\bar{t}$	WW	W + jets	single-top	total Background	Signal	$S/\sqrt{B}$	Data
22.63	30.43	242.51	39.37	20.74	355.67	9.86	0.52	381

Table 1: Number of events left after all cuts in the **H0 bin**.

Drell Yan	$t\bar{t}$	WW	W + jets	single-top	total Background	Signal	$S/\sqrt{B}$	Data
94.36	64.16	101.37	12.65	31.93	304.47	4.85	0.28	312

Table 2: Number of events left after all cuts in the **H1 bin**.

Hence we expect to have 14.7 Higgs events in total among 660 Background events. In Data we found 693 events in total which is in good agreement with the Monte Carlo simulation.

The distribution of the angle between the two leptons $\Delta\Phi_{ll}$ is shown in Figure 3.
The leptons tend to have small opening angles when they come from a Higgs→WW decay. This can be explained by the parity violation of the W boson decay. By this characteristic the signal can be discerned from the background.

How do the pupils find the Higgs?
The task for the pupils is to look at the Event Displays of the selected Events. They should verify that the following criteria are fulfilled:

- two leptons with opposite charge are in the event
- $p_T^{lead} > 25\,\text{GeV}$ and $p_T^{trail} > 25\,\text{GeV}$
- $E_T^{miss} > 50\,\text{GeV}$ if there are two electrons or two muons in the event
- $E_T^{miss} > 25\,\text{GeV}$ if there is one electron and one muon in the event

If that is the case the angle between the two leptons has to be measured. In the end the distribution should be created and compared to the Monte Carlo simulation. If sufficiently many events are analysed the $\Delta\Phi_{ll}$-distribution should resemble Figure 3 and a small excess of data over the Monte Carlo background should be visible. This is due to Higgs events.

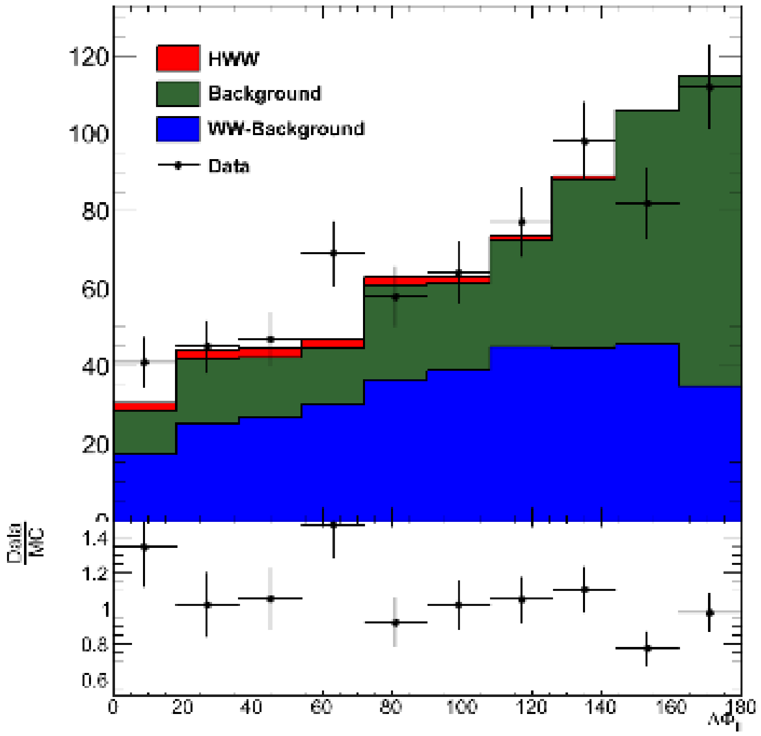


Figure 3: Distribution of the the angle between the two leptons $\Delta\Phi_{ll}$. The simulated background is divided into background due to WW pairs not coming from Higgs events and all other background processes.

4.2 Additional distributions

The Figures 4 to 6 show different distributions for the selected events. They are interesting to look at to verify the effects of certain cuts on these distributions.
The distribution of the invariant mass of the lepton system m_{ll} is shown in Figure 4 on the left. The effect of the Z-veto is reflected in the dip at around 90 GeV. The distribution of the transverse momentum of the lepton system is presented in Figure 4 on the right. The shape of the curve reflects the cuts $p_T^{trail} > 15$ GeV in the BaselineSelection and $p_T^{ll} > 30$ GeV for the H0 bin.

The distributions of the transverse momenta of the electrons and muons are shown in Figure 5. The electrons as well as the muons have a maximum at around 30GeV.

Figure 6 shows the distribution of the missing transverse energy. A maximum at around 50 GeV can be found and the cut $E_T^{miss} > 20$ GeV in the em channel is visible.

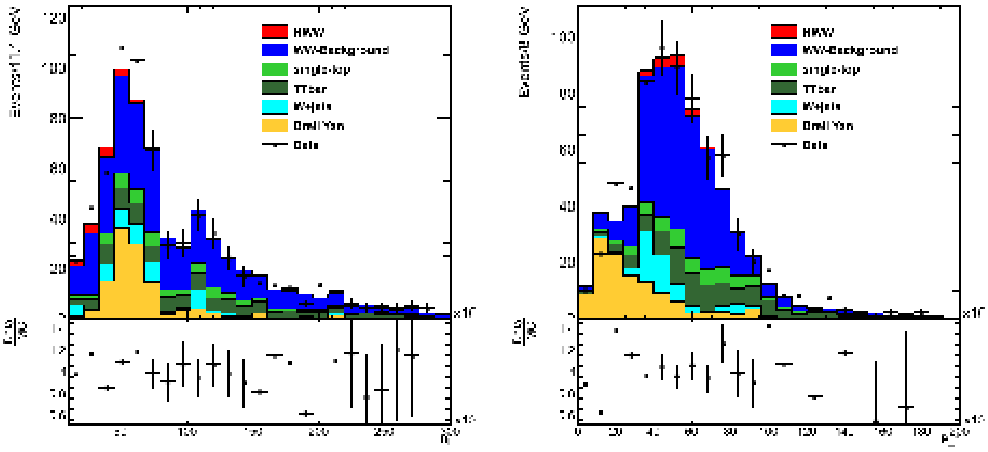


Figure 4: Distribution of m_{ll} (left) and p_T^{ll} (right) after all cuts

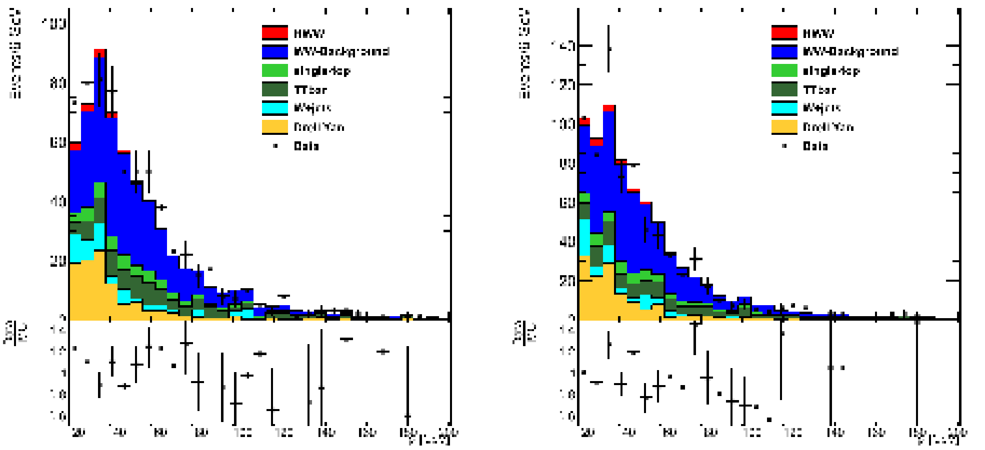


Figure 5: Distribution of the electron p_T^e (left) and muon p_T^μ (right) after all cuts

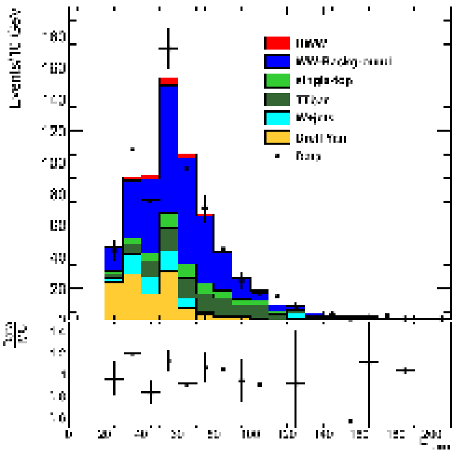


Figure 6: Distribution of the missing transverse energy after all cuts

5 Appendix

This sections contains additional information which can be useful to redo the analysis. As selection software SFrame was used. It is developped at CERN and verifys event by event, if all cuts are fulfilled. The SFrame code, used Macros and some output files can be checked out under:
https://svnweb.cern.ch/trac/atlasusr/browser/chastero/WWSelection
The event selection of the Higgs candidates was done following [1]. Only the cuts for the E_T^{miss} and p_T for the subleading lepton were changed to adopt it to our purpose.
The periods I, J and K recorded in 2011 at $\sqrt{s} = 7\,\text{TeV}$ were analysed. They contain a luminosity of $1.154\,\text{fb}^{-1}$ in total.

5.1 $m_{\tau\tau}$ reconstruction

The $m_{\tau\tau}$ reconstruction follows [4]:

$$m_{ll} = \sqrt{2p_{L1}p_{L2}} \tag{8}$$

$$x_1 = \frac{(p^x_{L1}p^y_{L2} - p^y_{L1} * p^x_{L2})}{(p^y_{L2}p^x_{miss} - p^x_{L2}p^x_{miss} + p^x_{L1}p^y_{L2} - p^y_{L1}p^x_{L2})} \tag{9}$$

$$x_2 = \frac{(p^x_{L1}p^y_{L2} - p^y_{L1} * p^x_{L2})}{(p^x_{L1} * p^y_{miss} - p^y_{L1} * p^x_{miss} + p^x_{L1} * p^y_{L2} - p^y_{L1} * p^x_{L2})} \tag{10}$$

$$m_{\tau\tau} = \frac{m_{ll}}{\sqrt{x1 \cdot x2}} \tag{11}$$

x1 and x2 are the energy fractions carried by the visible decay products. If they are positive and the $m_{\tau\tau}$ is within $|m_{\tau\tau} - m_Z| < 25\text{GeV}$ the event is rejected.

5.2 Cutflow

The cutflow is interesting to look at in order to find out which cut supresses which background best. One also sees how the significance $S/\sqrt{B}$ increases which means that the cuts reduce the background well. The uncertainties in the tables are calculated using poisson statistics.

5.2.1 BaselineSelection

The BaselineSelection is the same for the H+0 and H+1 jets bins.

Cut	Z+jets	TTbar	WW	Wjets	single-top	Signal	$S/\sqrt{B}$	Data
l^+l^-	726288.79	4482.06	1007.17	224.16	482.22	46.99	0.05	683612
	+/- 689.63	+/- 33.88	+/-7.45	+/- 24.64	+/- 5.84	+/-0.19		
$p_T^{lead} > 25\,\text{GeV}$,	683524.41	4382.19	976.02	206.71	473.60	42.41	0.05	639427
$p_T^{trail} > 15\,\text{GeV}$	+/- 587.95	+/- 33.51	+/-7.33	+/- 22.34	+/- 5.79	+/- 0.18		
$m_{ll} > 15/10\,\text{GeV}$	681708.34	4343.25	968.44	192.01	470.04	40.03	0.05	634063
	+/- 586.42	+/- 33.36	+/-7.31	+/- 19.66	+/- 5.77	+/- 0.18		
Z-veto	67748.02	3856.64	858.10	165.45	415.71	39.74	0.15	70023
	+/- 198.64	+/- 31.45	+/- 6.88	+/- 18.55	+/- 5.43	+/-0.18		
$E_T^{miss} > 50/25\,\text{GeV}$	910.31	3069.32	542.21	93.15	317.66	24.59	0.35	4803
	+/- 17.39	+/- 28.08	+/- 5.41	+/- 12.50	+/- 4.75	+/- 0.14		

5.2.2 H+0 jets

Cut	Z+jets	TTbar	WW	Wjets	single-top	Signal	$S/\sqrt{B}$	Data
$N_{jet} = 0$	373.20	31.86	290.18	60.62	23.27	10.99	0.39	835
	+/- 11.95	+/- 2.69	+/-4.14	+/- 11.72	+/- 1.28	+/- 0.09		
$p_T^{ll} > 30\text{GeV}$	22.63	30.43	242.51	39.37	20.75	9.86	0.52	381
	+/- 3.27	+/- 2.63	+/-3.79	+/- 9.25	+/- 1.21	+/- 0.09		

5.2.3 H+1 jets

Cut	DY	TTbar	WW	Wjets	single-top	Signal	$S/\sqrt{B}$	Data
$N_{jet} = 1$	287.95	379.23	149.78	19.66	138.29	7.85	0.25	976
+/- 9.83	+/- 9.22		+/- 2.84	+/- 3.47	+/- 3.14	+/- 0.08		
b-veto	281.98	131.02	146.75	19.11	55.28	7.65	0.30	655
	+/- 9.75	+/- 5.51	+/- 2.81	+/- 3.43	+/- 1.97	+/- 0.08		
$p_T^{tot} < 30\,\text{GeV}$	176.65	68.25	107.16	14.36	34.58	5.04	0.25	378
	+/- 7.06	+/- 3.93	+/- 2.42	+/- 3.04	+/- 1.56	+/- 0.06		
Z$\rightarrow \tau\tau$ veto	94.36	64.16	101.37	12.65	31.93	4.85	0.28	312
	+/- 5.50	+/- 3.81	+/-2.36	+/- 2.87	+/- 1.50	+/- 0.06		

5.3 Producing EventDisplays on the Grid

To produce the xml files of the selected events the run- and eventnumbers printed in the terminal for data samples should be tranfered to a .txt file. An instruction to create EventDisplays on the Grid using the txt file can be found on: /afs/cern.ch/user/j/jpthomas/public/AtlantisTutorial/README If the data is not on disk any more but only available on tape a request will be sent to Datri when excecuting the pathena command. The samples will be tranferred to the Grid. Then the EventDisplays can be produced in adding the flag –eventPickStagedDS=samplename/ to the previous comitted command.

References

[1] ATLAS-CONF-2011-134

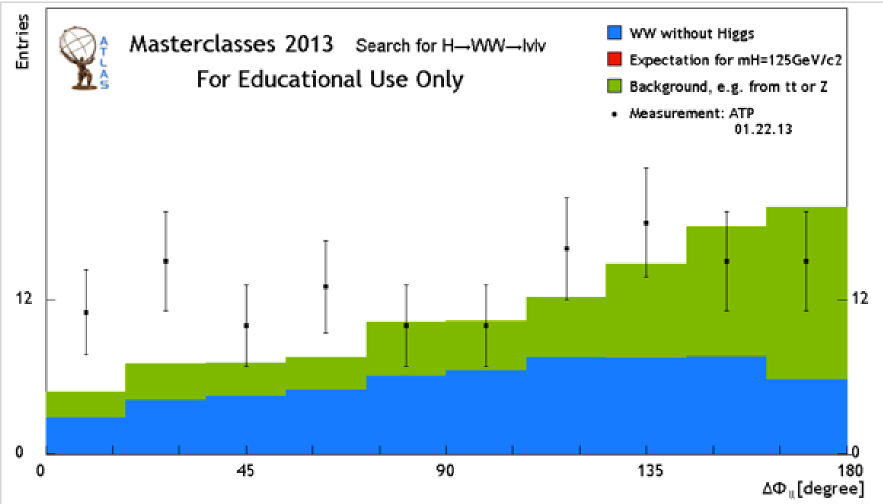
[2] CERN-PH-EP-2012-126 (http://arxiv.org/pdf/1206.0756v2.pdf)

[3] http://arxiv.org/pdf/1201.3084v1

[4] The Discovery Potential of Neutral Supersymmetric Higgs Bosons with Decay to Tau Pairs at the ATLAS Experiment: Dissertation Jana Schaarschmidt, TU Dresden

7.3 Histogram tool

The histogram tool is used to plot the distribution of the opening angle (angle between electrically charged leptons in transverse plane) in WW candidate events, which have been selected by the students. It is depicted in Fig. 6.



	bin 1	bin 2	bin 3	bin 4	bin 5	bin 6	bin 7	bin 8	bin 9	bin 10	SUM
N	11	15	10	13	10	10	16	18	15	15	133
B	4.8	7	7.1	7.5	10.2	10.3	12.2	14.8	17.7	19.3	110.9
S	6.2	8	2.9	5.5	-0.2	-0.3	3.8	3.2	-2.7	-4.3	22.1
Z	2.8	3	1.1	2	-0.1	-0.1	1.1	0.8	-0.7	-1	2.1

number of bins [1 … 20]
maximum of y axis
Submit
Default
standardization 1 2 3
cut on bin number
Higgs contribution

Figure 6: Histogram tool

It basically consists of three elements:

a) the actual histogram showing the distribution,

b) a table with numbers used in each bin of the histogram and

c) a simple user interface to change the appearance of the histogram.

a) Histogram

Student's measurements are displayed by black dots with uncertainty bars for the number of each bin. Theoretical expectations are plotted for each bin as rectangles in different colours, which correspond to a class of physics processes contributing to this decay channel. The legend in the upper right corner of the histogram also contains the institute's name and actual date.

b) Table

The table consists of five rows and a number of columns depending on the number of bins to be plotted. First row and column are headers. In the second row (N) you will see the numbers of WW candidate events found by the students of your institute (or Masterclasses day). The third row (B) displays the expected number of background events within the data sample depending on the chosen standardization (see User Interface). Row number four (S) shows the difference between the number of found WW candidate events and the number of expected background events. Finally, the statistical significance (Z) is displayed for each bin. The last column gives you the totals of N, B and S for all bins together and Z for the totals.

c) User Interface

The user interface allows to change the appearance of the distribution by:

i) changing the number of bins (*choose a value: "number of bins [1 ... 20]"; default is 10*),

ii) adapting the y-axis (*enter a value behind "maximum of y-axis"*),

iii) scaling the number of events theoretically predicted (*choose "1", "2" or "3" for "standardization"*),

iv) making cut on a particular bin number (*enter the bin number behind "cut on bin number", which you would like to see last in the histogram*) and

v) adding the theoretical predictions for the number of events of a 125 GeV decaying Standard Model Higgs in this channel as red coloured rectangles (*tick "Higgs contribution"*).

There are three options for standardization:

"1": Do you want to know how well your students found the hidden WW candidate events? Then you should click this option. It standardizes the expected number of events by taking both into account, the number of events analyzed by students and an equally distribution of all (693 pre-selected) WW candidate events over the dataset as well.

"2": This value standardizes the expected number of events by taking both into account, the number of WW candidate events found by the students and an equally distribution of all (693 pre-selected) WW candidate events over the dataset as well. So, if your students found 200 candidate events, the coloured histograms are calculated in a way that a total of 200 events are displayed over all bins.

"3" (default): Here, the expected number of background events are standardized differently: We calculate the total number of WW candidate events in all bins containing angles greater than 108 degrees. After standardization this number is equal to the number of expected background events in those bins following the distribution obtained by the pre-selection. With it and knowing the angular distribution obtained within the pre-selection, we also calculate the number of expected background events for all other bins.