

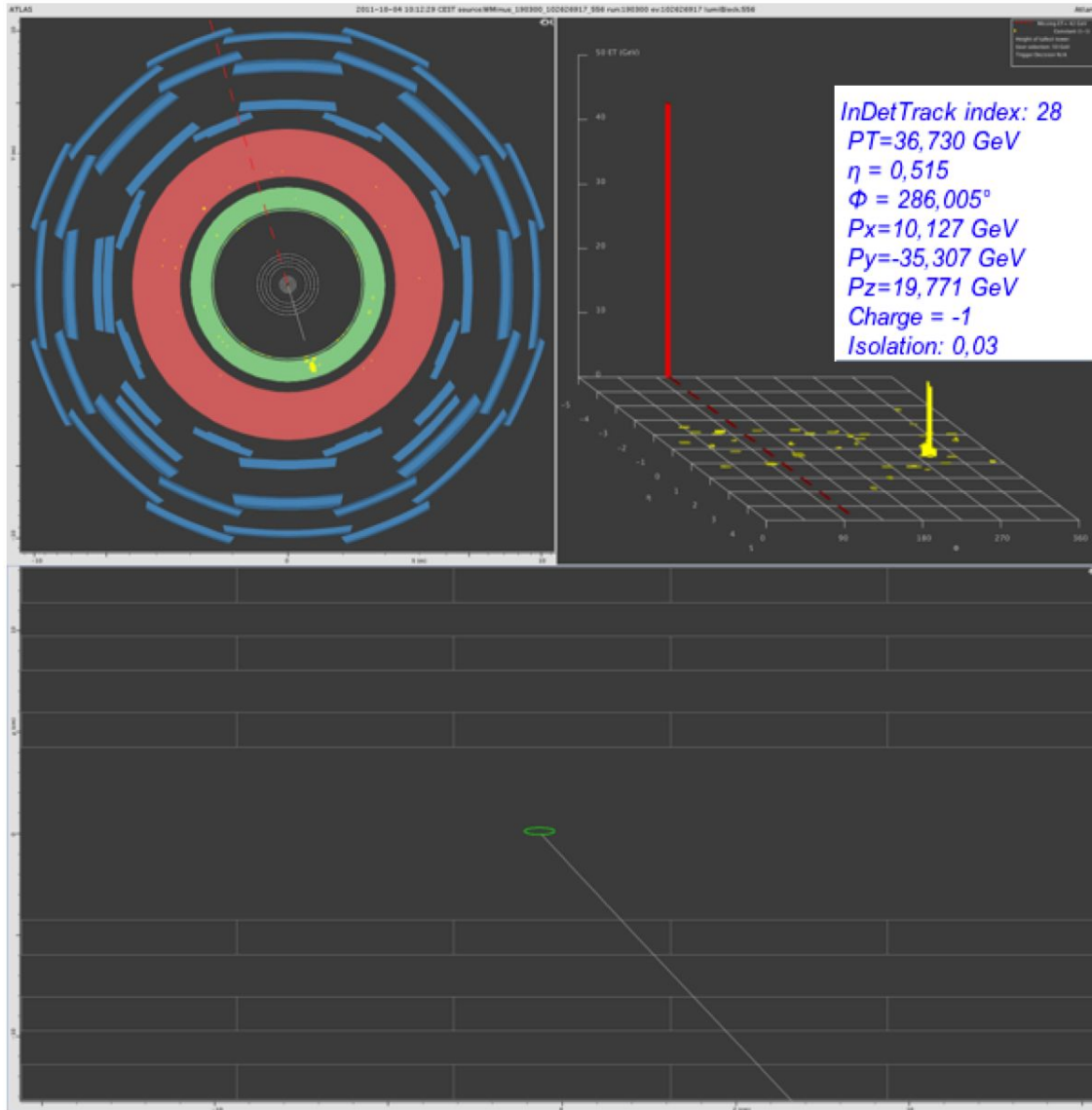
# Physics of the W path

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M. Stange

06.02.2023

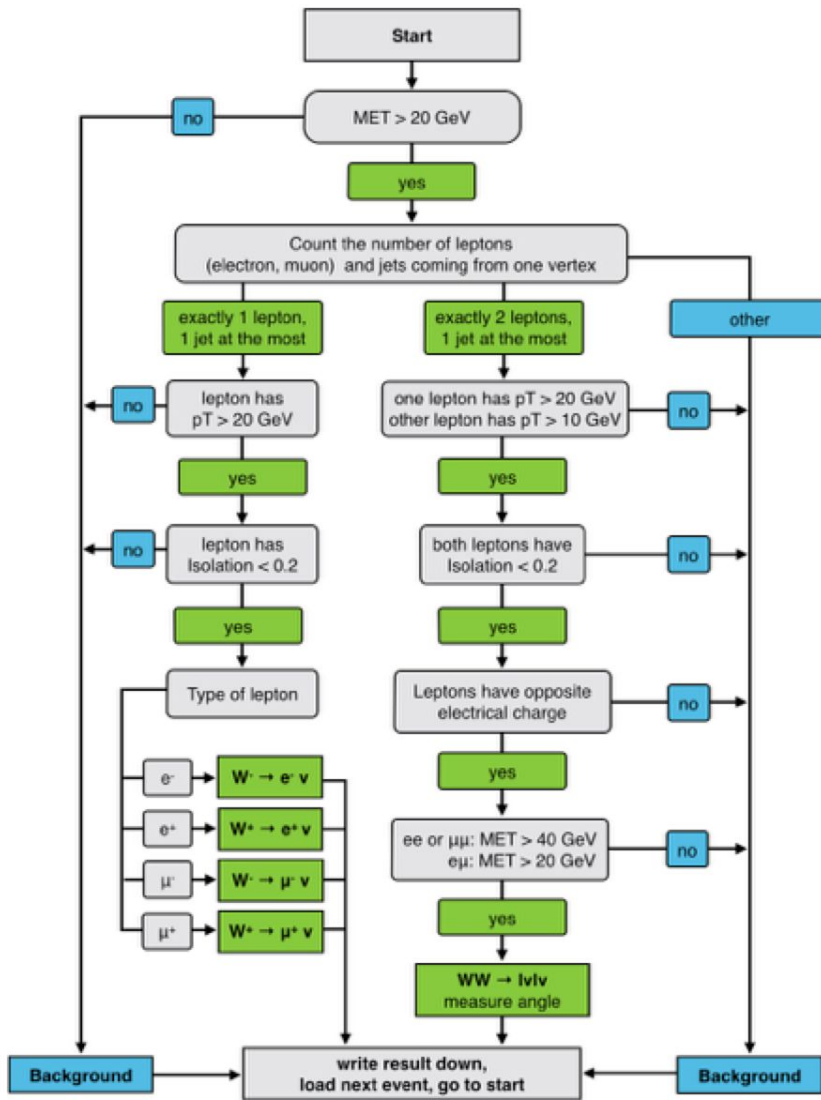
- W-path consists of two measurements:
  - $W^+/W^-$  ratio from single W events
  - Search for the Higgs in  $WW \rightarrow \ell\nu\ell\nu$  events
- Instructions for the students:  
<https://atlas.physicsmasterclasses.org/en/wpath.htm>
- Recommended moderation scenarios at:  
<https://twiki.cern.ch/twiki/bin/viewauth/Main/InternationalMasterclassesModeratorManual>
- Two aspects will be discussed:
  - $W^+/W^-$  ratio: how to get from the measured ratio to composition of the proton
  - $H \rightarrow WW$  candidates: how significant is the measurement

# What the students do:



- The students analyze event displays like the one on the left
- The events are categorized using a flowchart

# What the students do:



- Categorize each event as
  - Single W event
  - WW event
  - Background
- If the event is a single W event:
  - Determine type and charge of the lepton
- If the event is a WW candidate
  - Measure azimuthal opening angle  $\Delta\phi_{\ell\ell}$
- If the event is background
  - Discard

# Results: General

- Combine the results: [https://atlas.physicsmasterclasses.org/results/wpath\\_auswertung.php](https://atlas.physicsmasterclasses.org/results/wpath_auswertung.php)
- Final Moderation: [https://atlas.physicsmasterclasses.org/results/wpath\\_moderator.php](https://atlas.physicsmasterclasses.org/results/wpath_moderator.php)
- There are two parts:
  - Inner structure of the proton
  - Search for the Higgs
- Drop down menus contain the dates of masterclasses, choose the date of the masterclass you are moderating:

## Analysis

**Inner structure of the proton: Measurement of  $|W^+|/|W^-|$**

✓ Please choose the date...  
01/02/2018  
01/24/2018  
02/01/2018

**Search for the Higgs in the  $H \rightarrow WW \rightarrow l^+ l^- \nu \nu$  decay channel: angular distribution**

Please choose the date... ▾

## Content

Aims/Tasks
Identifying particles
Identifying Events
Measurement
Analysis
<b>For moderators</b>
Supporting material

# Results: $W^+ / W^-$ ratio

## Analysis

Total #	$W \rightarrow \dots + \nu$				Background	WW
	$e^+$	$e^-$	$\mu^+$	$\mu^-$		
4354						
Braganca	239	207	208	175	345	145
Cosenza	127	76	147	106	481	64
Erlangen	130	107	128	92	482	41
Mainz	136	103	153	110	0	0
Nitra	106	73	76	52	209	36
<b>Total</b>	<b>738</b>	<b>566</b>	<b>712</b>	<b>535</b>	<b>1517</b>	<b>286</b>
$\Sigma W^+ , \Sigma W^- $	$ W^+ $	1450	$ W^- $	1101	$ W^+  +  W^- $	2551
<b>Ratio</b>	$ W^+ / W^- $			<b>1.32</b>	$\pm$	<b>0.05</b>

Comparison with results of the ATLAS collaboration (from 2011):

Measurement of the  $W \rightarrow l\nu$  and  $Z/\gamma^* \rightarrow ll$  production cross sections in proton-proton collisions at  $\sqrt{s} = 7$  TeV with the ATLAS detector\*) and Search for the Standard Model Higgs boson in the  $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$  decay mode using 1.7 fb<sup>-1</sup> of data collected with the ATLAS detector at  $\sqrt{s} = 7$  TeV \*\*)

\*) Authors: The ATLAS Collaboration (Submitted on 5 Dec 2011): <http://arxiv.org/abs/1109.5141.pdf>

\*\*) Authors: The ATLAS Collaboration (24 Aug 2011): ATLAS-CONF-2011-134

	$W \rightarrow \dots + \nu$				Background	WW cand.
	$e^+$	$e^-$	$\mu^+$	$\mu^-$		
Total	77885	52856	84514	55234	21930	469
$\Sigma W^+ , \Sigma W^- $	$ W^+ $	162399	$ W^- $	108090	$ W^+  +  W^- $	270489
<b>Ratio</b>	$ W^+ / W^- $			<b>1.50</b>	$\pm$	<b>0.03</b>

- The page will show the tables on the left
- Red table shows results combined from all institutes
- Blue table shows results from ATLAS
- Main result in table is  $W^+/W^-$  ratio
- Structure of the proton should already have been discussed in each institute individually
- Step from ratio to composition of the proton is described here: [https://atlas.physicsmasterclasses.org/en/w/path\\_auswertung.htm](https://atlas.physicsmasterclasses.org/en/w/path_auswertung.htm)

# Results: $W^+ / W^-$ ratio

## Analysis

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## Moderation scenario questions:

All questions can be found at

<https://twiki.cern.ch/twiki/bin/viewauth/Main/InternationalMasterclassesModeratorManual>

- Q1: How did the final result change when we did the combination?
- Q2: Is our result compatible with the results measured at ATLAS?

# Results: $W^+ / W^-$ ratio

## Analysis

Total #	W → ... + ν				Background	WW
	e <sup>+</sup>	e <sup>-</sup>	μ <sup>+</sup>	μ <sup>-</sup>		
4354						
Braganca	239	207	208	175	345	145
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	e <sup>+</sup>	e <sup>-</sup>	μ <sup>+</sup>	μ <sup>-</sup>		
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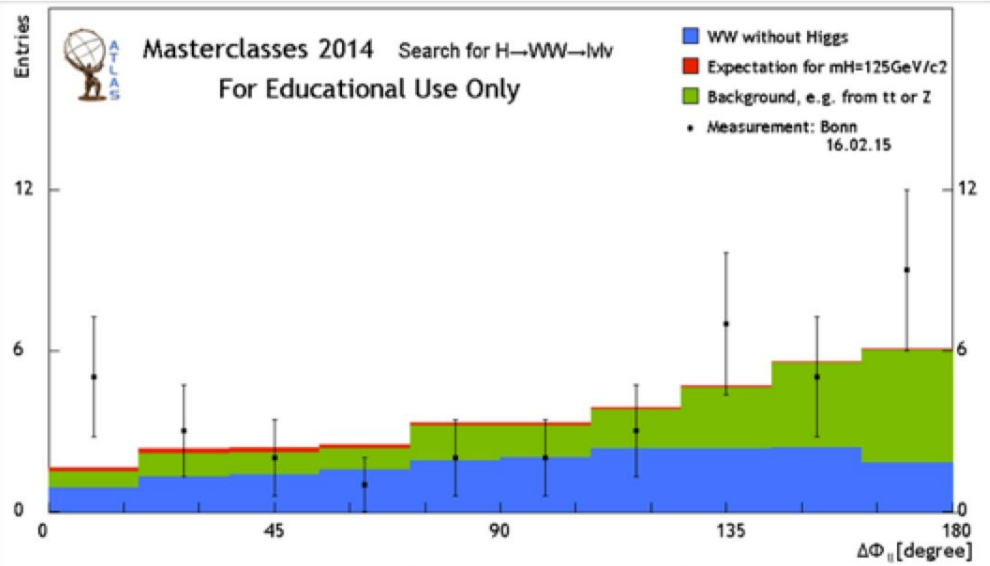
Further things to discuss:

- The datasets contain 50% single W events and 42% background, ratio is about 1.2
- The  $W^+/W^-$  ratio should be compatible with 1.5 within statistical uncertainty  
→ structure of the proton
- Compare to ATLAS measurement  
→ larger statistics, smaller uncertainty



# Results: $H \rightarrow WW$

## WW-Histogramme



	bin 1	bin 2	bin 3	bin 4	bin 5	bin 6	bin 7	bin 8	bin 9	bin 10	SUM
<b>N</b>	5	3	2	1	2	2	3	7	5	9	39
<b>B</b>	1.5	2.2	2.2	2.4	3.2	3.2	3.8	4.6	5.6	6	34.7
<b>S</b>	3.5	0.8	-0.2	-1.4	-1.2	-1.2	-0.8	2.4	-0.6	3	4.3
<b>Z</b>	2.8	0.5	-0.1	-0.9	-0.7	-0.7	-0.4	1.1	-0.2	1.2	0.7

number of bins [1 ... ]

standardization  1  2  3

Higgs contribution

maximum of y axis

cut on bin number

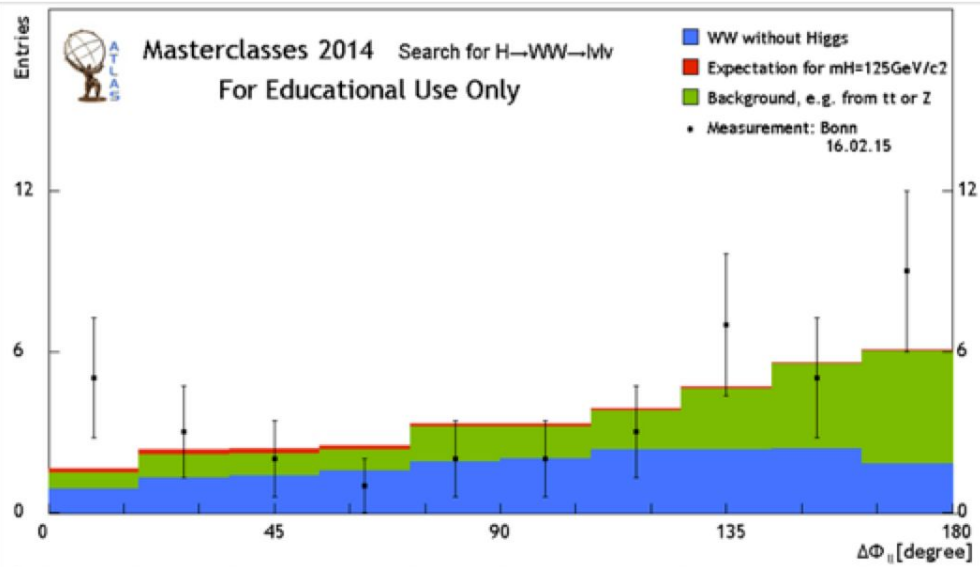
- Results for  $H \rightarrow WW$  are discussed via this histogram
- **Higgs contribution must be toggled on!**

### Options:

- number of bins can be set
- histogram normalization (standardization)
  - 1: normalized to expected number of WW candidates in analyzed data
  - 2: normalized to number of found WW candidates
  - 3: normalized to number of WW candidates found with  $\Delta\phi_{ll} \geq 115^\circ$

# Results: H $\rightarrow$ WW

## WW-Histogramme



	bin 1	bin 2	bin 3	bin 4	bin 5	bin 6	bin 7	bin 8	bin 9	bin 10	SUM
N	5	3	2	1	2	2	3	7	5	9	39
B	1.5	2.2	2.2	2.4	3.2	3.2	3.8	4.6	5.6	6	34.7
S	3.5	0.8	-0.2	-1.4	-1.2	-1.2	-0.8	2.4	-0.6	3	4.3
Z	2.8	0.5	-0.1	-0.9	-0.7	-0.7	-0.4	1.1	-0.2	1.2	0.7

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- Q3: What do the blue and green areas mean?

After turning on the Higgs contribution:

- Q4: Can we claim a Higgs discovery?

number of bins [1 ...  20]

standardization  1  2  3

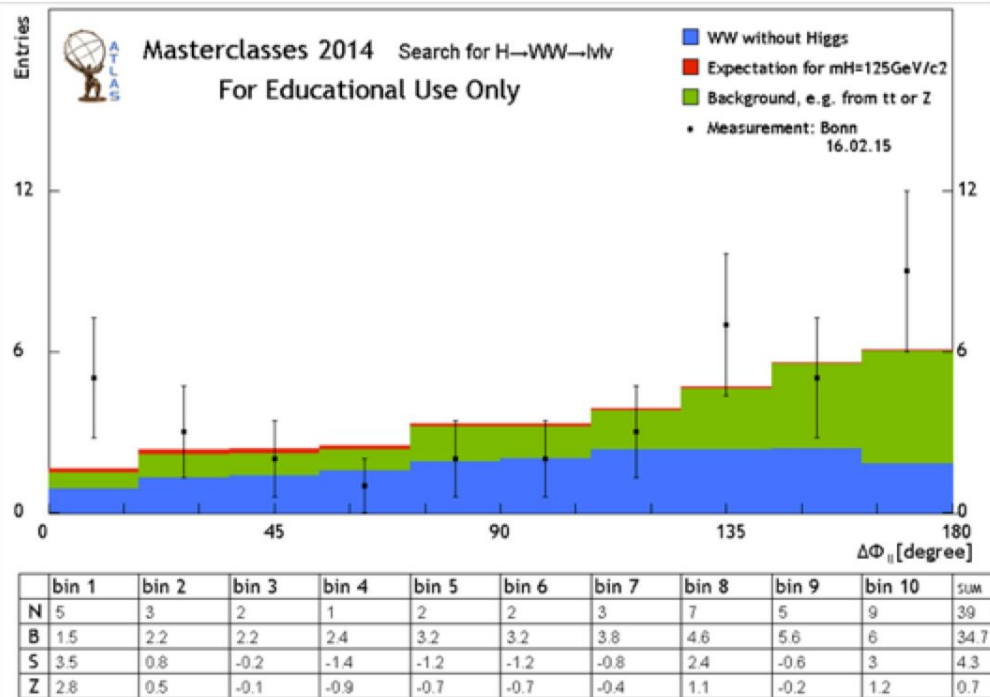
Higgs contribution

maximum of y axis

cut on bin number

# Results: $H \rightarrow WW$

## WW-Histogramme



Further things to discuss:

- Significance of measurement
- Need for large statistics for Higgs hunt
- Compare to ATLAS measurement  
→ animations:

<https://twiki.cern.ch/twiki/pub/AtlasPublic/HiggsPublicResults/WW-FixedScale.gif>

number of bins [1 ...  20]

standardization  1  2  3

Higgs contribution

maximum of y axis

cut on bin number

**Submit** **Default**

backup

# Composition of the datasets

	<b>Bkg</b>	<b>Wplus</b>	<b>Wminus</b>	<b>WW</b>	<b>Total</b>	<b>W+/W-</b>
Dataset1	433	294	197	76	1000	1.492
Dataset2	415	305	197	83	1000	1.548
Dataset3	414	306	198	82	1000	1.545
Dataset4	420	304	196	80	1000	1.551
Dataset5	420	293	198	89	1000	1.480
Dataset6	414	303	199	84	1000	1.523
Dataset7	412	298	207	83	1000	1.440
Dataset8	418	315	187	80	1000	1.684
Dataset9	419	293	210	78	1000	1.395
Dataset10	421	292	201	86	1000	1.453
Dataset11	401	296	214	89	1000	1.383
Dataset12	413	301	196	90	1000	1.536
<b>Sum Events</b>	<b>5000</b>	<b>3600</b>	<b>2400</b>	<b>1000</b>	<b>12000</b>	

# Composition of the datasets

