# Physics of the W path

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**TECHNISCHE UNIVERSITÄT DRESDEN**

# Introduction

- W-path consists of two measurements:
  - $W^+/W^-$ ratio from single W events → determines the composition of the proton
  - search for the Higgs in WW → $\ell\nu\ell\nu$ 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 the composition of the proton
  - H → WW candidates: how significant is the measurement

# What the students do:



InDetTrack index: 28
PT=36,730 GeV
η = 0,515
Φ = 286,005°
Px=10,127 GeV
Py=-35,307 GeV
Pz=19,771 GeV
Charge = -1
Isolation: 0,03
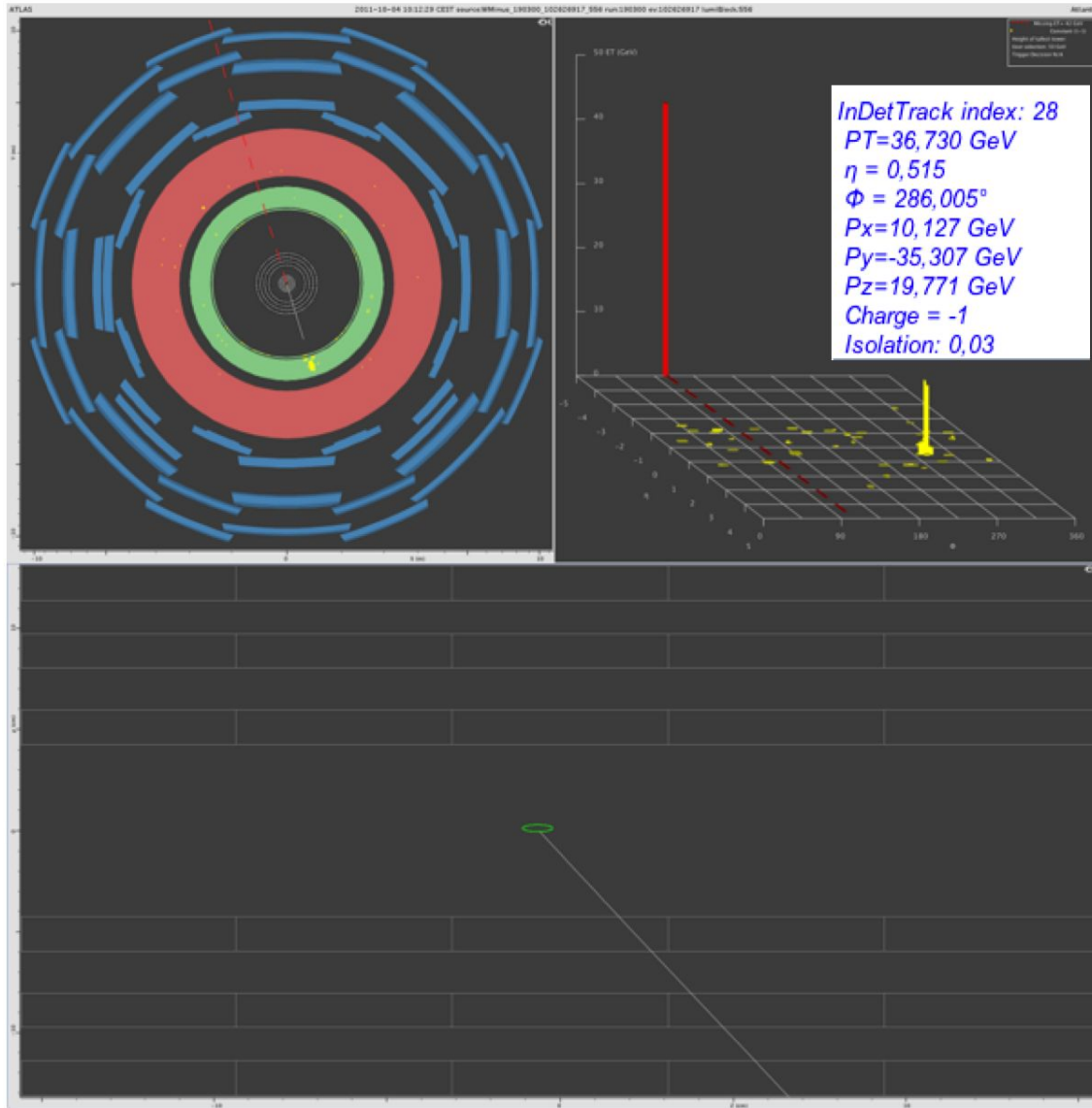
- The students analyze event displays like the one on the left

- the events are categorized using a flowchart

# What the students do:
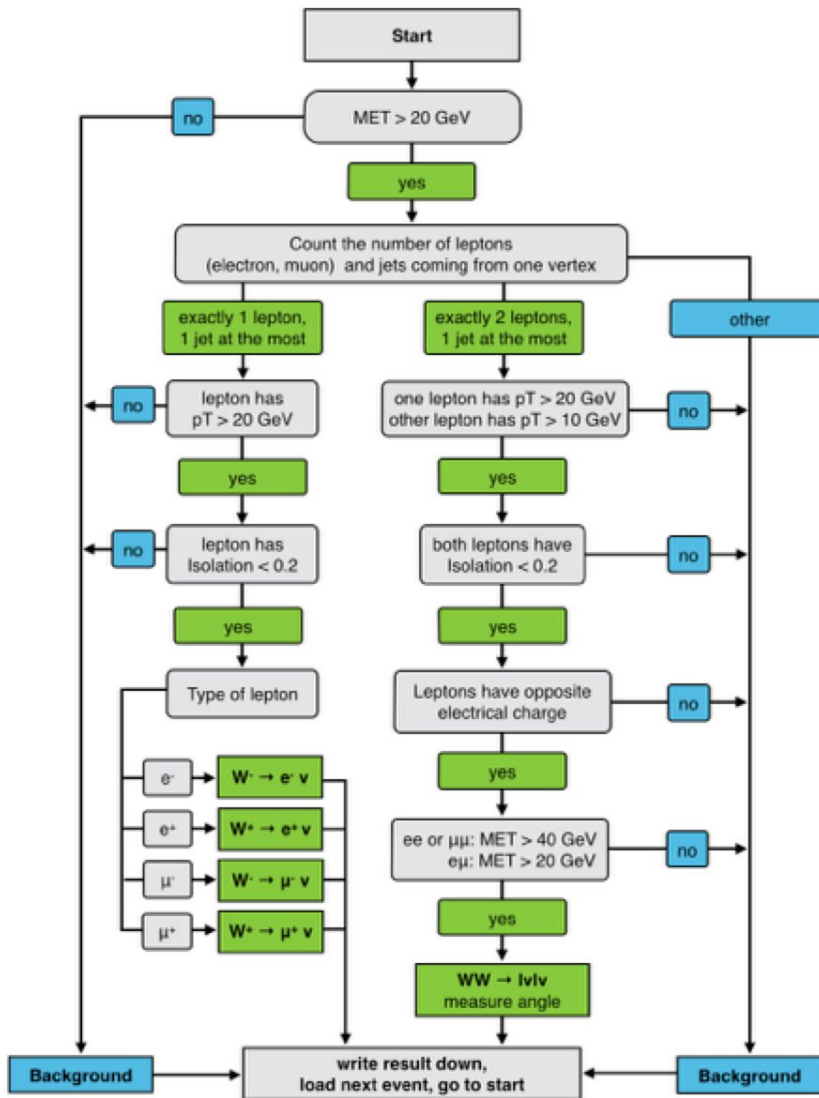


- categorize each event as
  - a single W event
  - a WW event
  - background

- if the event is a single W event:
  - determine the type and charge of the lepton

- if the event is a WW candidate
  - measure the azimuthal opening angle $\Delta\phi_{\ell\ell}$

- if the event is background
  - discard

# Results: General

- go to: https://atlas.physicsmasterclasses.org/results/wpath_moderator.php
- this site can be reached from https://atlas.physicsmasterclasses.org/en/index.htm

- there are two parts:
  - inner structure of the proton
  - search for the Higgs

- the drop down menus contain the dates of masterclasses, choose the date of the masterclass you are moderating:



| Analysis | Content |
|---|---|

**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→WW→l$^+$l$^-$νν decay channel: angular distribution**

Please choose the date... ⬍

| Content |
|---|
| Aims/Tasks |
| Identifying particles |
| Identifying Events |
| Measurement |
| Analysis |
| For moderators |
| Supporting material |

# Results: W⁺ / W⁻ ratio

## Analysis

| Total # | W → ... + ν | | | | Background | WW |
|---|---|---|---|---|---|---|
| 4354 | $e^+$ | $e^-$ | $\mu^+$ | $\mu^-$ | | |
| 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 |
| Total | 738 | 566 | 712 | 535 | 1517 | 286 |
| $\Sigma|W^+|,\Sigma|W^-|$ | $|W^+|$ | 1450 | $|W^-|$ | 1101 | $|W^+| + |W^-|$ | 2551 |
| Ratio | $|W^+|/|W^-|$ | | | 1.32 | ± | 0.05 |

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

Measurement of the W -> lnu and Z/gamma* -> 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→ WW(*)→ lvlv decay mode using 1.7 fb−1 of data collected with the ATLAS detector at √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 → ... + ν | | | | 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 |
| Ratio | $|W^+|/|W^-|$ | | | 1.50 | ± | 0.03 |

- 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/wpath_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

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| Ratio | \|W$^+$\|/\|W$^-$\| | | **1.50** | ± | | **0.03** |

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 → WW



WW-Histogramme
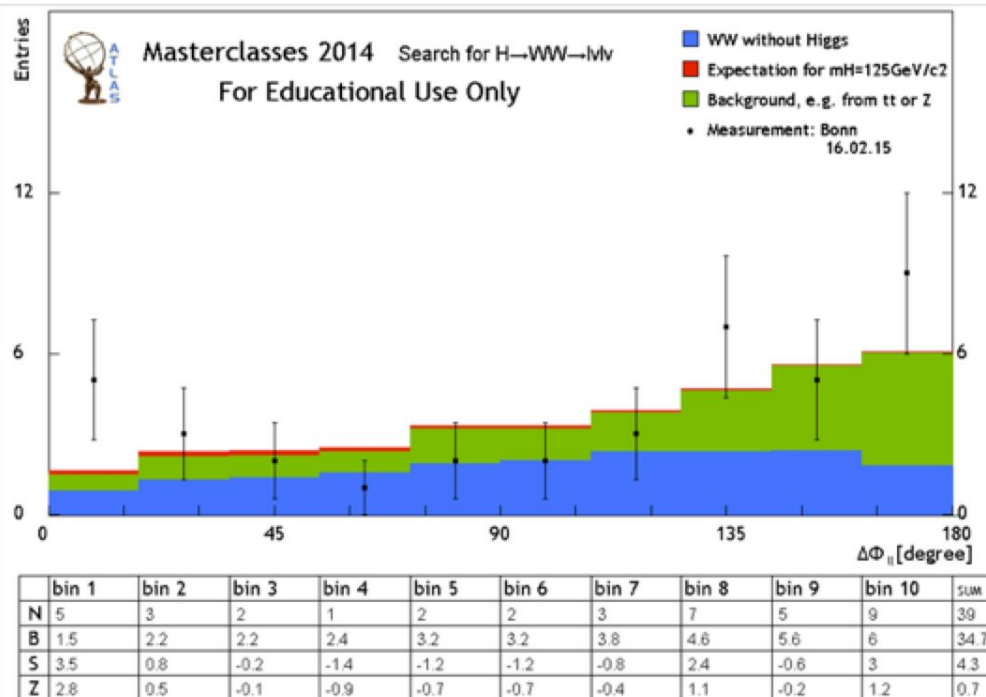
- the results for H → WW are discussed via this histogram

- **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 $\Delta\phi_{\ell\ell} \geq 115°$

# Results: H → WW



WW-Histogramme

**Moderation scenario questions:**

All questions can be found at

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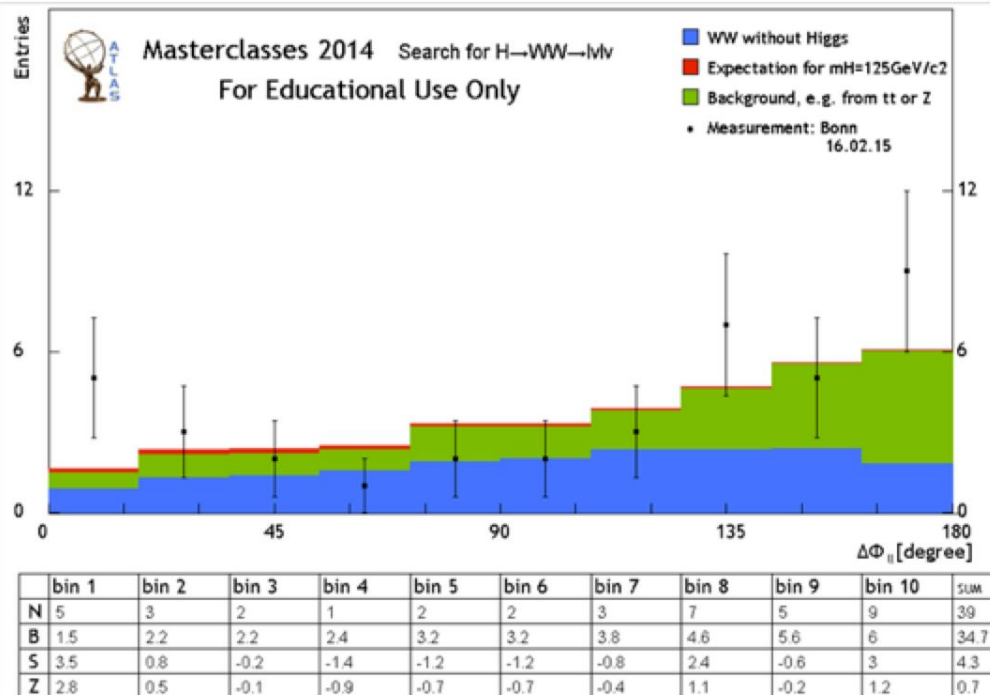
- Q3: What do the blue and green areas mean?

After turning on the Higgs contribution:

- Q4: Can we claim a Higgs discovery?
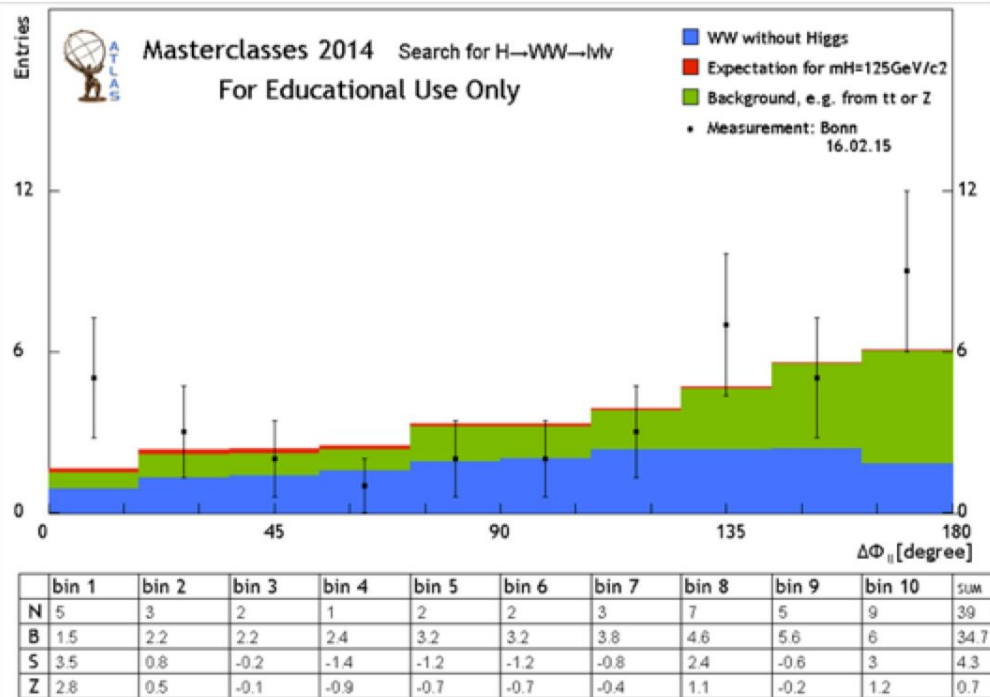
Further things to discuss:

- 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

backup

# Composition of the datasets

| | Bkg | Wplus | Wminus | WW | Total | W+/W- |
|---|---|---|---|---|---|---|
| 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 |
| | | | | | | |
| Sum Events | 5000 | 3600 | 2400 | 1000 | 12000 | |

# Composition of the datasets