

# International Masterclasses

## CERN video conference manual

### for local organizers

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## Technical details (Zoom)

The official video conference service is Zoom. Video conferences will be “meeting” style, so connecting groups are supposed to share video and audio.

The links to the Zoom video conferences will be sent to you 2-3 days ahead of your Masterclass.

Most video conferences are from 16:00 – 17:00 CET, a few exceptions start at 13 or 14 CET.

## Key points

To make the video conference enjoyable for both moderators and students and to ensure a smooth flow of information:



The VC starts at 4:00 pm CET sharp (few exceptions start at 2 or 3 pm CET).



Stay muted unless you are supposed to talk.



Select students as speakers of the group beforehand (for answering moderators' questions on results).



Ask students to have some questions ready for the moderators (Q&A session).



For the quiz, students need answer sheets (download from <https://physicsmasterclasses.org/downloads/answersheet-2026.pdf>)

## Elements of the Videoconference

### 1. Overview & Timing

Welcome & Icebreaker \_\_\_\_\_ 10' (16:00 – 16:10)

Combination & Discussion of Measurement \_\_\_\_\_ 20' (16:10 – 16:30)

Open Discussion \_\_\_\_\_ 19' (16:30 – 16:49)

Quiz \_\_\_\_\_ 10' (16:49 – 16:59)

Good Bye \_\_\_\_\_ 01' (16:59 – 17:00)

## 2. Welcome & Icebreaker (10')

Moderators will welcome participants and ask each group one short question. They will introduce themselves, explain the timeline of the videoconference and display a map showing all connecting sites. Example:



## 3. Combination & Discussion of Measurements (20')

Moderators show combined results. They will ask one question to each group, on the measurements and the results.

- Select students to answer the question already before the VC starts!
- To prepare your students, we recommend to use the information given in *Scenarios for Discussion of Measurements*, p. 4 ff.

It is **not** intended that institutes present reports.

## 4. Open Discussion (19')

After the specific discussion of the measurement, the discussion can expand to more open and general questions. The students should be prepared by you, in order to have some questions ready.

## 5. Quiz (10')

The quiz will be presented by moderators as ppt slideshow. Students need answer sheets (download from <https://physicsmasterclasses.org/downloads/answersheet-2026.pdf>)

The quiz includes 7 multiple choice questions (4 answers each). Every student plays on their own. The correct answer will be revealed by the moderators immediately after each question.

You can download the quiz from <https://physicsmasterclasses.org/downloads/quiz-2026-en.pptx>.

## 6. Common Good Bye (01')

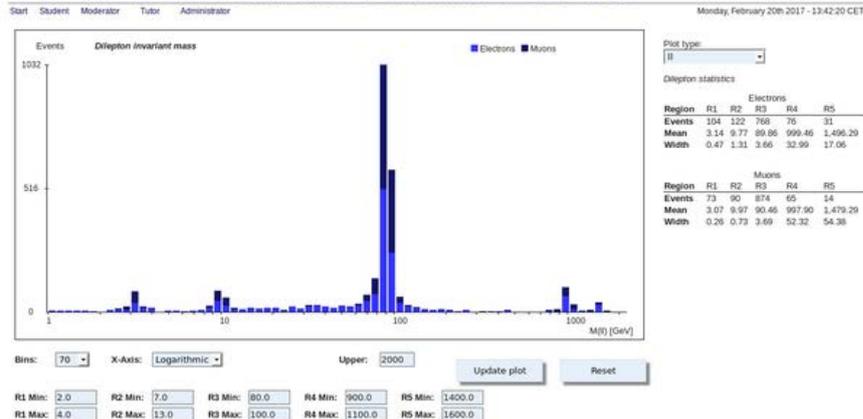
Moderators are supposed to close the session after 60 minutes, also in the case of very lively discussions.

## 7. Scenarios for Discussion of Measurements

To streamline the discussion of measurements, sets of questions (scenarios) have been developed which will be used by the moderators. Each scenario consists of a plot/histogram/table/etc. and 1-2 relevant question(s) that students are supposed to answer. These scenarios will help moderators and institutes to go through the results and the physics discussion in an efficient way.

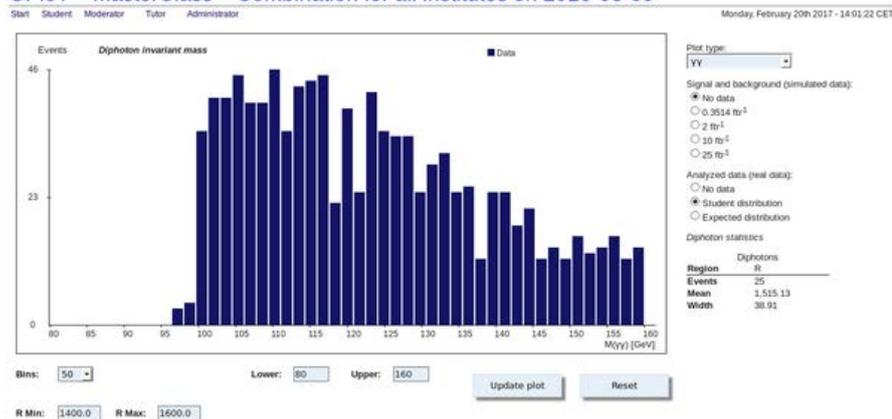
### a) ATLAS Z path

#### OPlot – MasterClass – Combination for all institutes on 2016-03-09



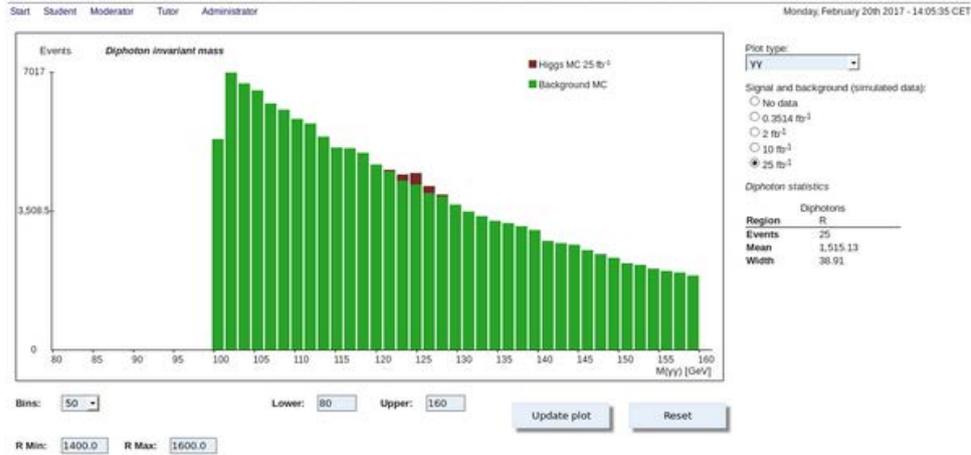
- Question 1: What does it mean when we see a peak in the distribution? Do you see any peaks that you did not expect?

#### OPlot – MasterClass – Combination for all institutes on 2016-03-09



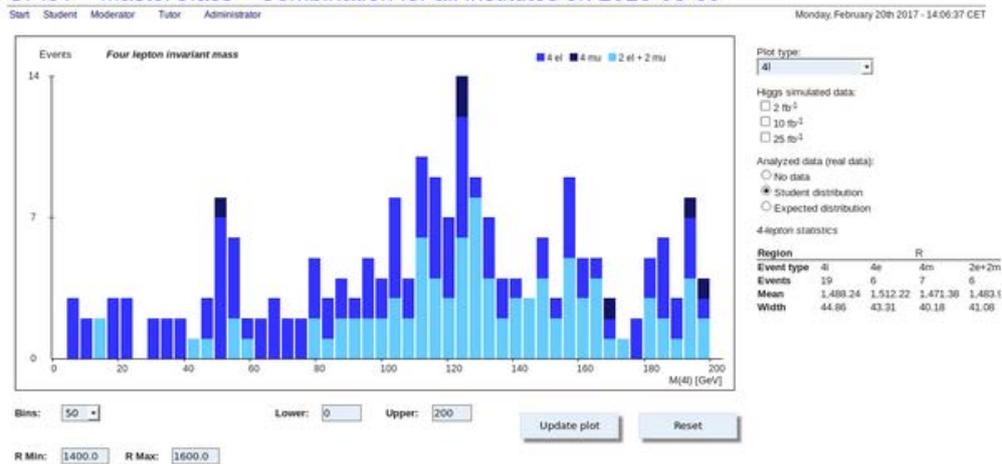
- Question 2: Do you see a peak corresponding to the Higgs boson? Why not? (Hopefully students are aware of statistics limitations from local institute discussions.)

## OPlot – MasterClass – Combination for all institutes on 2016-03-09

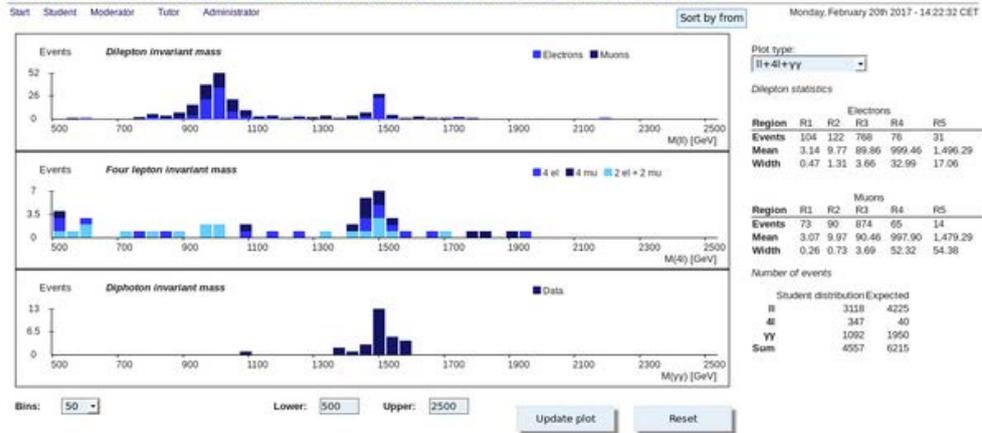


- Question 3: Do you think we could see the peak here even if it had the same color as the background? Why does it help to collect more data?

## OPlot – MasterClass – Combination for all institutes on 2016-03-09



- Question 4: Why are there many more 4-lepton events than expected? (Here you can compare to the table in the summary screen or to the expected distribution.) What can you say about the composition in terms of  $4e$ ,  $2e2\mu$ , and  $4\mu$ ?



- Question 5: What does it tell us that the particle at 1000 GeV is not seen in the 4-lepton and diphoton distributions, while the particle at 1500 GeV is seen in all distributions?

b) ATLAS W path

Moderators show combined online spreadsheet.

Analysis

Total #	W → $\mu\mu + \nu$				Background	WW
	e <sup>+</sup>	e <sup>-</sup>	$\mu^+$	$\mu^-$		
1615						
ATP	56	56	56	56	343	133
Bonn-NTW						
BSZ Riesa	18	27	22	16	86	21
Hamburg-NTW-1	25	17	19	14	149	20
R-Hildebrand-Gym. Ma	0	0	0	0	390	91
<b>Total</b>	<b>99</b>	<b>100</b>	<b>97</b>	<b>86</b>	<b>968</b>	<b>265</b>
$\Sigma W^+ , \Sigma W^- $	$ W^+ $	196	$ W^- $	186	$ W^+  +  W^- $	382
Ratio	$ W^+ / W^- $		1.0538	$\pm$	0	

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

Measurement of the W →  $\mu\mu$  and Z/ $\gamma$  →  $\mu\mu$  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  $ll \rightarrow WW^{(*)} \rightarrow l\nu l\nu$  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>

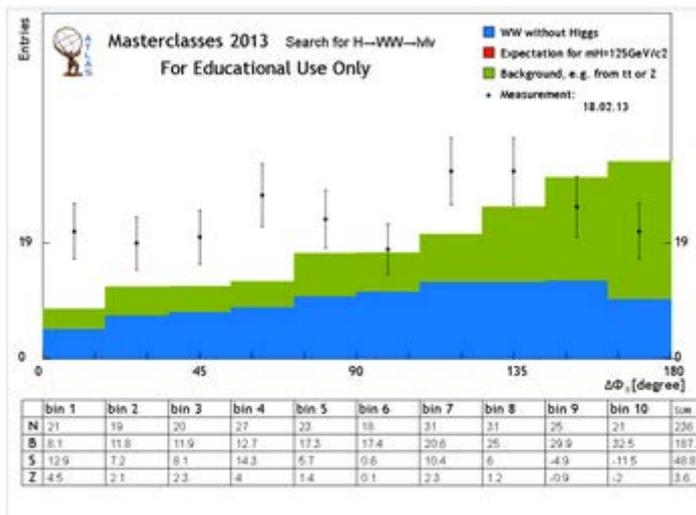
\*\*\*) Authors: The ATLAS Collaboration [24 Aug 2011]: ATLAS-CONF-2011-134

	W → $\mu\mu + \nu$				Background	WW cand.
	e <sup>+</sup>	e <sup>-</sup>	$\mu^+$	$\mu^-$		
Total	77885	52856	84514	55234	21930	469
$\Sigma W^+ , \Sigma W^- $	$ W^+ $	162399	$ W^- $	108090	$ W^+  +  W^- $	270489
Ratio	$ W^+ / W^- $		1.50	$\pm$	0.01	

- Question 1: What was your result for R $\pm$ ? How did the combination with the other institutes change the total result?
- Question 2: Is the result compatible with the results measured in ATLAS?

Then moderators show combined histogram.

## WW-Histogramme



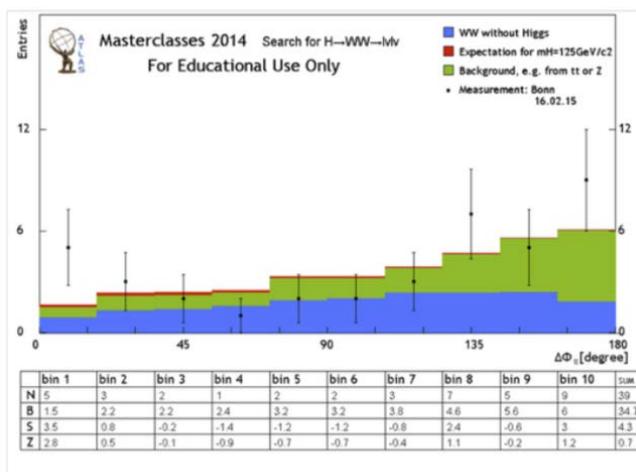
number of bins [1 ... 20]  maximum of y axis

standardization  1  2  3  cut on bin number

Higgs contribution

- Question 3: You have measured the angle between two leptons. Let's have a look at that. What exactly do the black data points mean?
- Question 4: How would you interpret the blue and green areas? What do they mean?

Then moderators show the Higgs contribution (in red).



number of bins [1 ... 20]  maximum of y axis

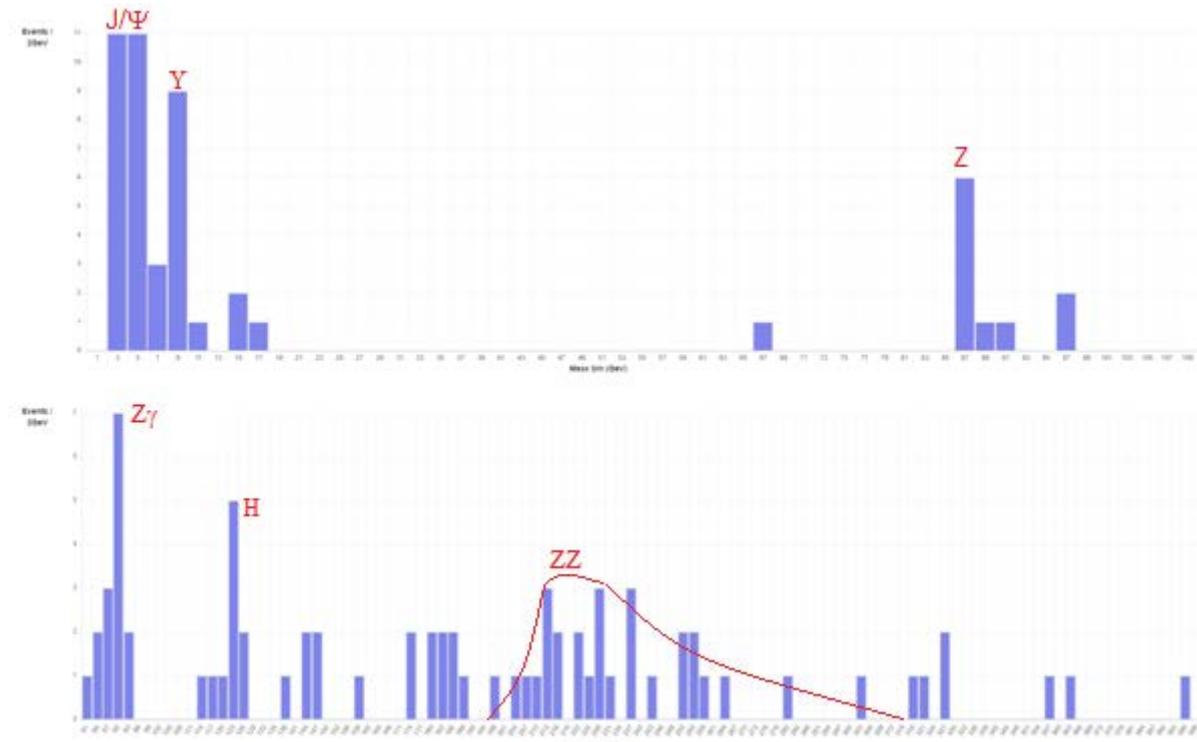
standardization  1  2  3  cut on bin number

Higgs contribution

- Question 5: Can we claim a Higgs discovery? What would be necessary to claim a discovery?

c) CMS

Moderators share overall 2- and 4-lepton mass plots. The mass plots appear together in CIMA in the Mass Histogram tab with the 2-lepton plot at the top and the 4-lepton plot at the bottom. Expected peaks are marked here in red.



The above plots were made with limited data. The full masterclass plots may look different and the relative heights of peaks may appear to be different.

- Question 1: Where are the peaks in the Mass Histograms? What do they represent?
- Question 2: Where is Z boson in the 2-lepton plot? What are the other peaks, then?
- Question 3: Do you have possible Higgs events in the 4-lepton plot? Where? Can we claim discovery?
- Question 4: Why does there appear to be a Z peak in the 4-lepton plot as well? Since the Z does not directly decay to 4 leptons, how do we explain this?
- Question 5: Is there anything else significant in the 4-lepton plot?

Moderators share key ratios. The key ratios,  $e/\mu$  and  $W^+/W^-$  are in the Results tab toward the bottom, isolated here in red.

Group	e	$\mu$	$W^+$	$W^-$	$W_s$	Neutral	Zoo	Total
	0	0	0	0	0	0	0	0
5.1	4	7	1	0	0	7	1	9
5.2	11	14	6	2	1	13	1	23
5.3	0	0	0	0	0	0	0	0
5.4	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0
10.1	7	6	1	1	0	5	7	14
10.2	6	5	2	2	0	5	0	9
10.3	13	22	9	5	2	13	1	30
10.4	33	43	17	16	0	33	1	67
10.5	17	18	11	8	0	13	0	32
10.6	46	59	31	17	0	44	6	100
10.7	12	18	6	10	1	6	12	35
10.8	2	6	1	0	1	6	0	8
10.9	21	24	10	5	5	19	4	43
Total:								
Group	e	$\mu$	$W^+$	$W^-$	$W_s$	Neutral	Zoo	Total
All	172	222	95	66	10	164	35	370

Ratios:	
$e/\mu$	$W^+/W^-$
0.73	1.44

The expected values are  $e/\mu = 1.0$  and  $W^+/W^- = 1.4$ , though results will vary.

- Question 6: What do you expect the ratio of electron events to muon events to be? Is your result consistent with this?
- Question 7: What is the ratio of  $W^+$  to  $W^-$  bosons? What does this ratio tell us about protons?

#### d) ALICE – Looking for strange particles

Why are the two tracks of each V0 curved in opposite directions?

Why is the radius of curvature of the proton bigger than that of the pion in  $\Lambda$  decays?

Why don't you see the  $\Lambda$  or the  $K^0$  before their decay?

Why does the  $\Lambda$  not decay to two pions, like the  $K^0$ ?

Why does the invariant mass have a width and is not a delta-function?

*e) ALICE – R\_AA*

Visual analysis: where do the clusters come from that are not associated with a reconstructed track?

Visual analysis: did you observe more positively or negatively charged particle tracks? Why is this so?

Visual analysis: why do most of the produced particles have low momenta?

What is a reconstruction efficiency and why is it important?

What is the difference between R\_CP and R\_AA?

Why is  $R_{AA} < 1$  consistent with energy loss in a quark-gluon plasma?

*f) LHCb*

Moderators introduce measurement, say now we merge data from all groups and show the combined plot of D0 invariant mass distribution

- Question 1: How did the D0 mass distribution change with more data?

Moderators discuss statistics and importance of collecting large datasets

- Question 2: What can cause the background in the invariant mass distributions?

Moderators show the lifetime plot

- Question 3: Did your result of lifetime agree with the world average value listed in PDG tables?

Usually, students measure larger lifetime than PDG. Moderators can discuss the sources of bias, using more cuts and better selection in real analyses etc.

- Question 4: How much data would you need to be as precise as the current world average? As example take your error  $\sim 5$  fs, PDG world average error  $\sim 1$  fs.

Moderators can discuss statistics, future experiments etc.

- Question 5: Is it a good idea to measure D0 lifetime by more than one experiment?
- Question 6: What experimental effects might cause a difference between the measured lifetime and the world average?