

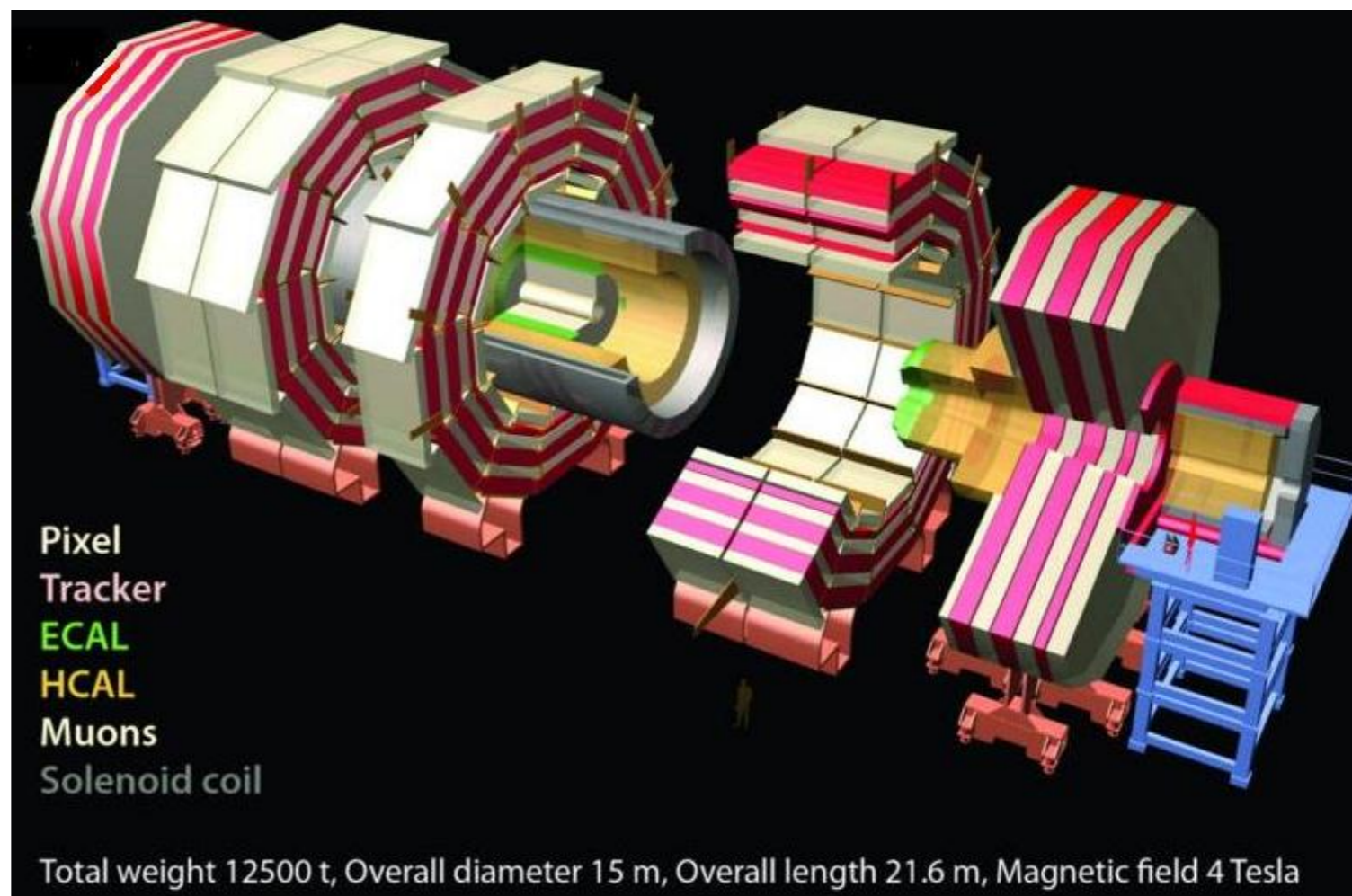
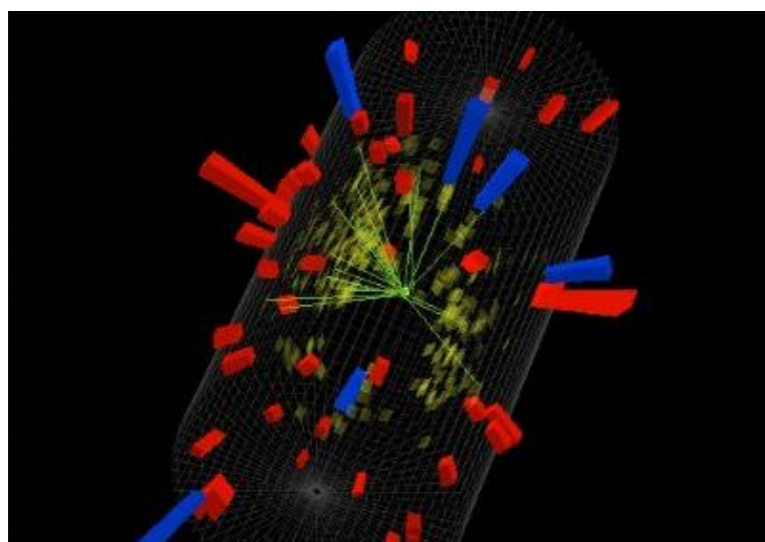
# INTERNATIONAL MASTERCLASSES

hands on particle physics

QuarkNet



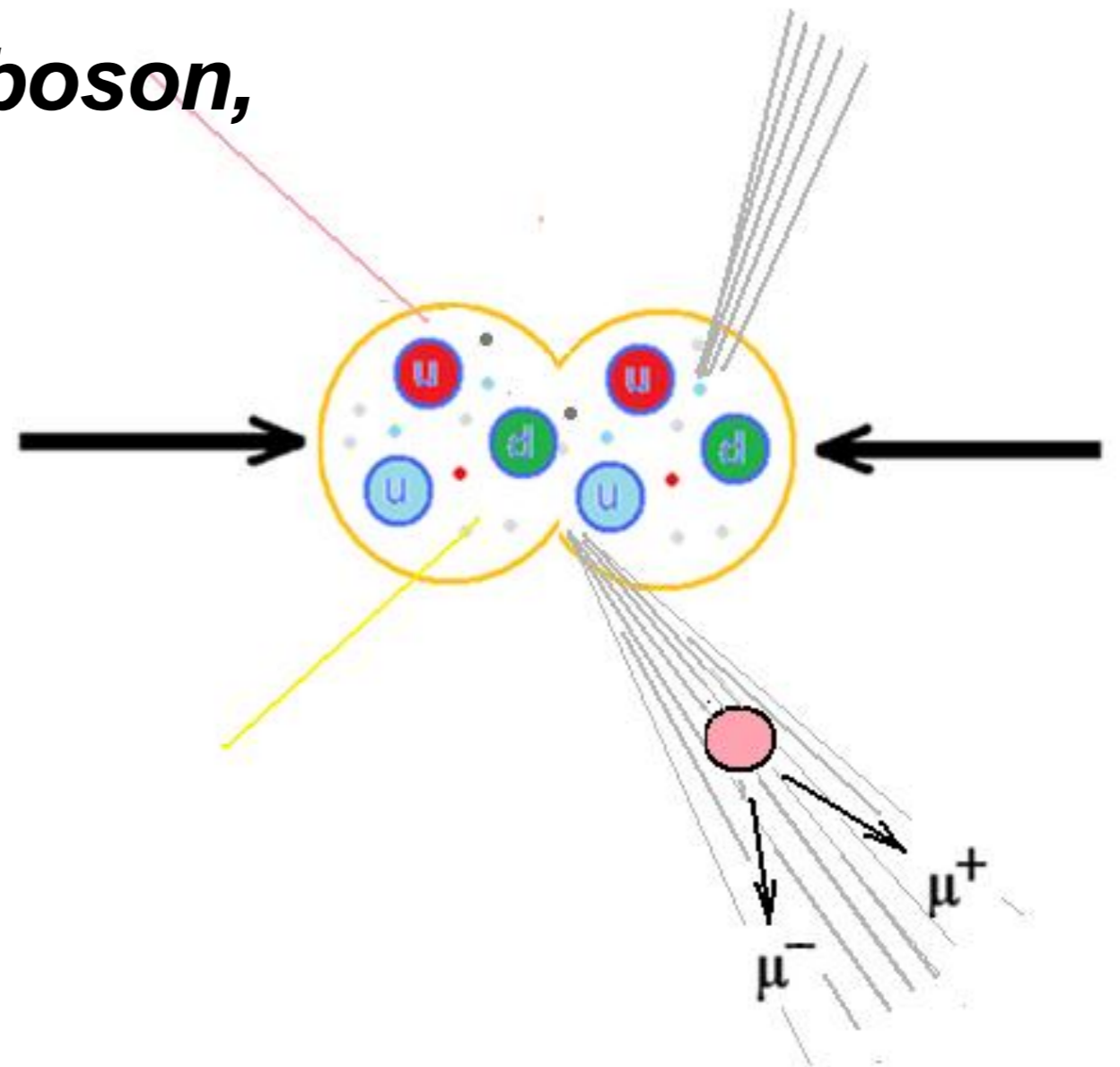
# CMS Masterclass 2012



# W and Z Particles

Looking for the mediators of the *weak interaction*:

- electrically charged  $W^+$  boson,
- the negative  $W^-$  boson,
- the neutral  $Z$  boson.

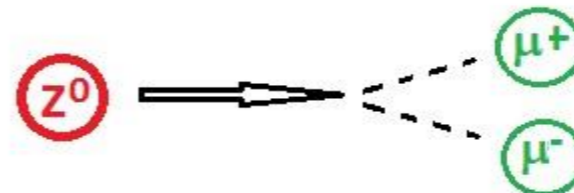
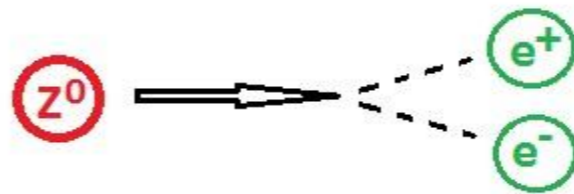


# W and Z Decays

W and Z travel only a tiny distance before decaying, so CMS does not “see” W or Z bosons directly.

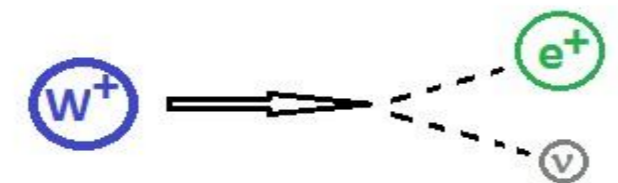
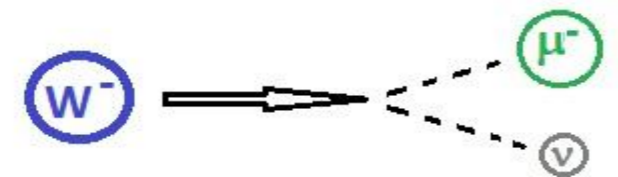
CMS can detect

- electrons
- muons



CMS can infer

- neutrinos from “missing energy”



# iSpy-online

**Detector Model** ?

- Tracker
- ECAL Barrel
- ECAL Endcap
- ECAL Preshower
- HCAL Barrel
- HCAL Endcap
- HCAL Outer
- HCAL Forward
- Drift Tubes (muon)
- Cathode Strip Chambers (muon)
- Resistive Plate Chambers (muon)

**Tracking** ?

- Tracks (reco.)
- Clusters (Si Pixels)
- Clusters (Si Strips)
- Rec. Hits (Tracking)

**ECAL** ?

- Barrel Rec. Hits
- Endcap Rec. Hits
- Preshower Rec. Hits

**HCAL** ?

- Barrel Rec. Hits
- Endcap Rec. Hits
- Forward Rec. Hits
- Outer Rec. Hits

**Controls:**

- rotate
- Ctrl + pan x / y
- Shift + pan z

event display controls

inner detector (tracker)

event vertex (near collision)

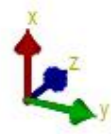
beamline

electron track

missing energy

energy deposit

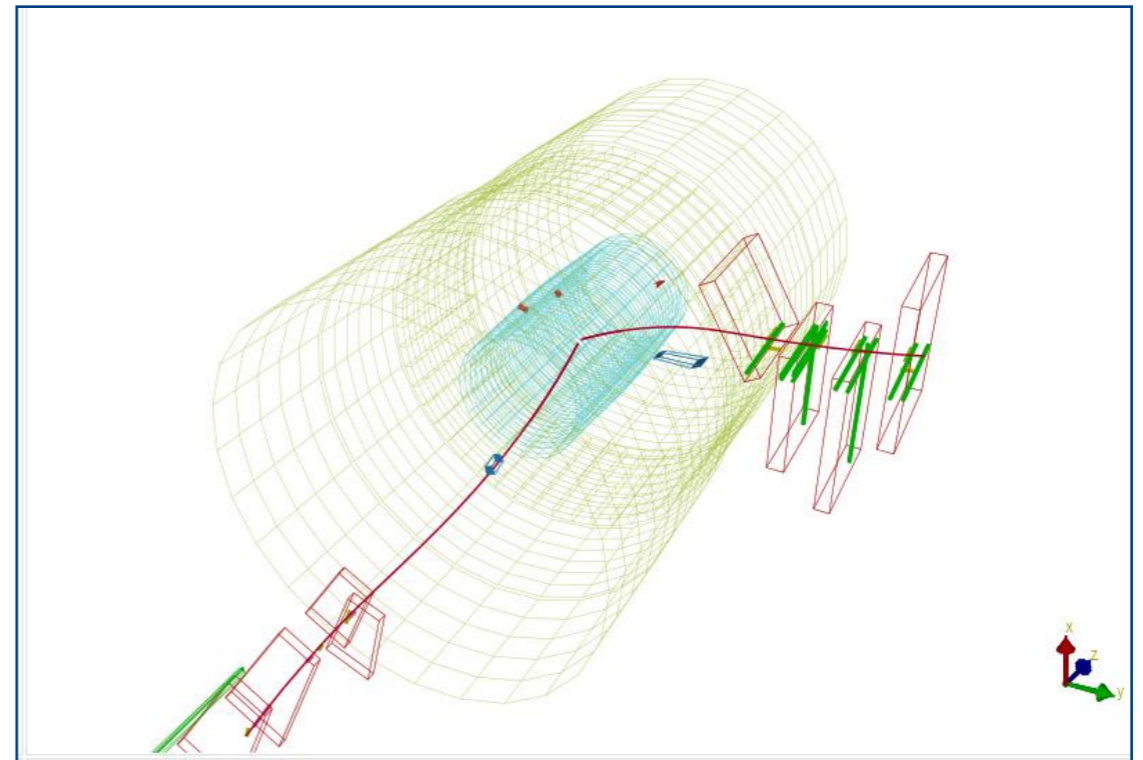
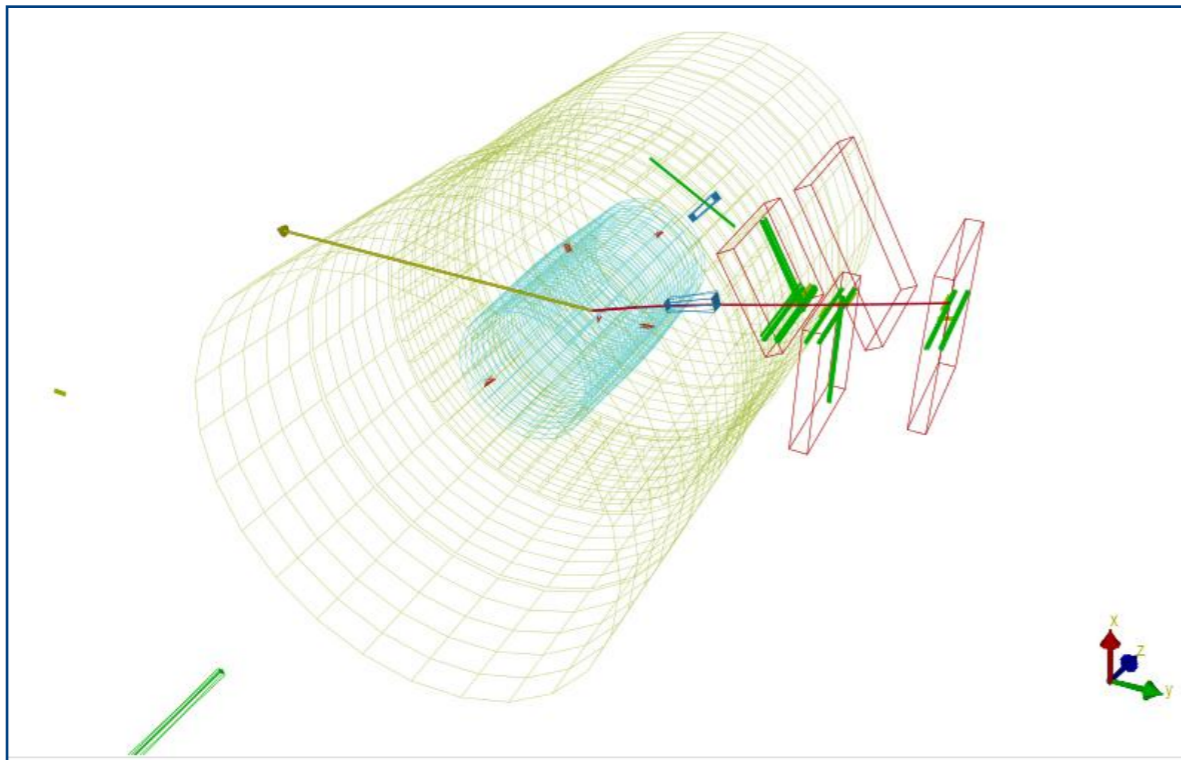
beamline



# The Task

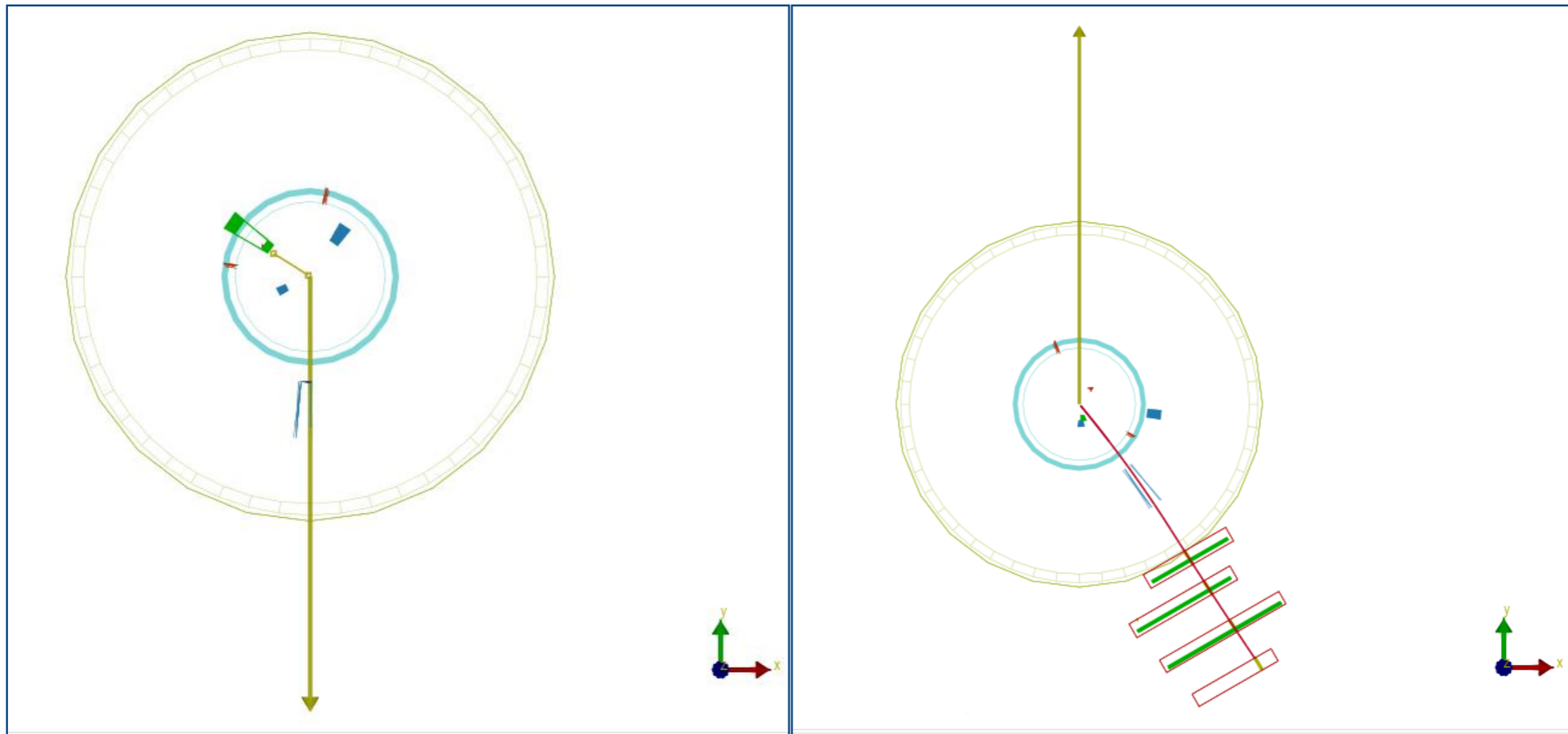
Use new data from the LHC in iSpy to test CMS performance.

Can we distinguish W from Z candidates?



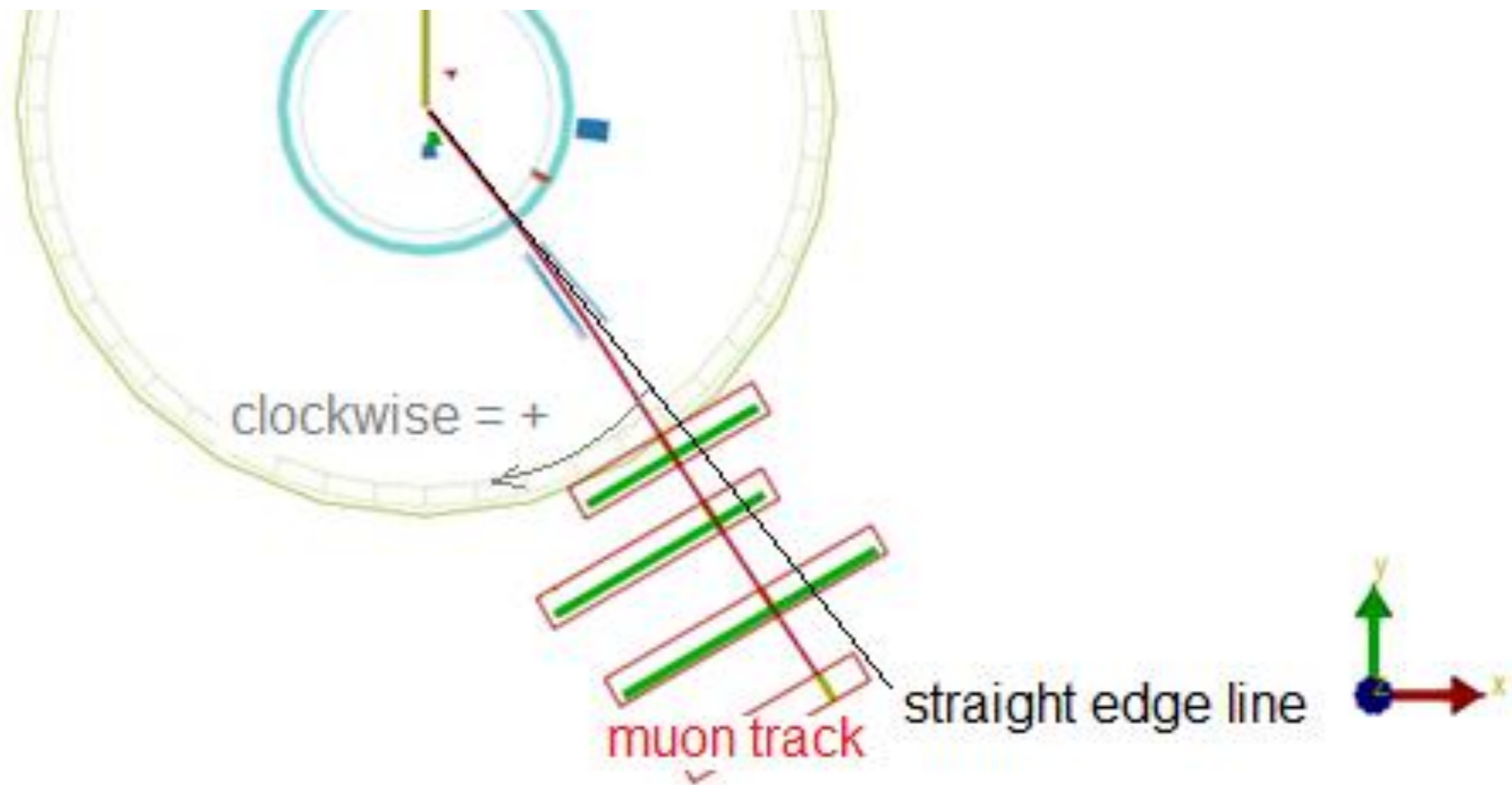
# The Task

Can we calculate the  $e/\mu$  ratio?



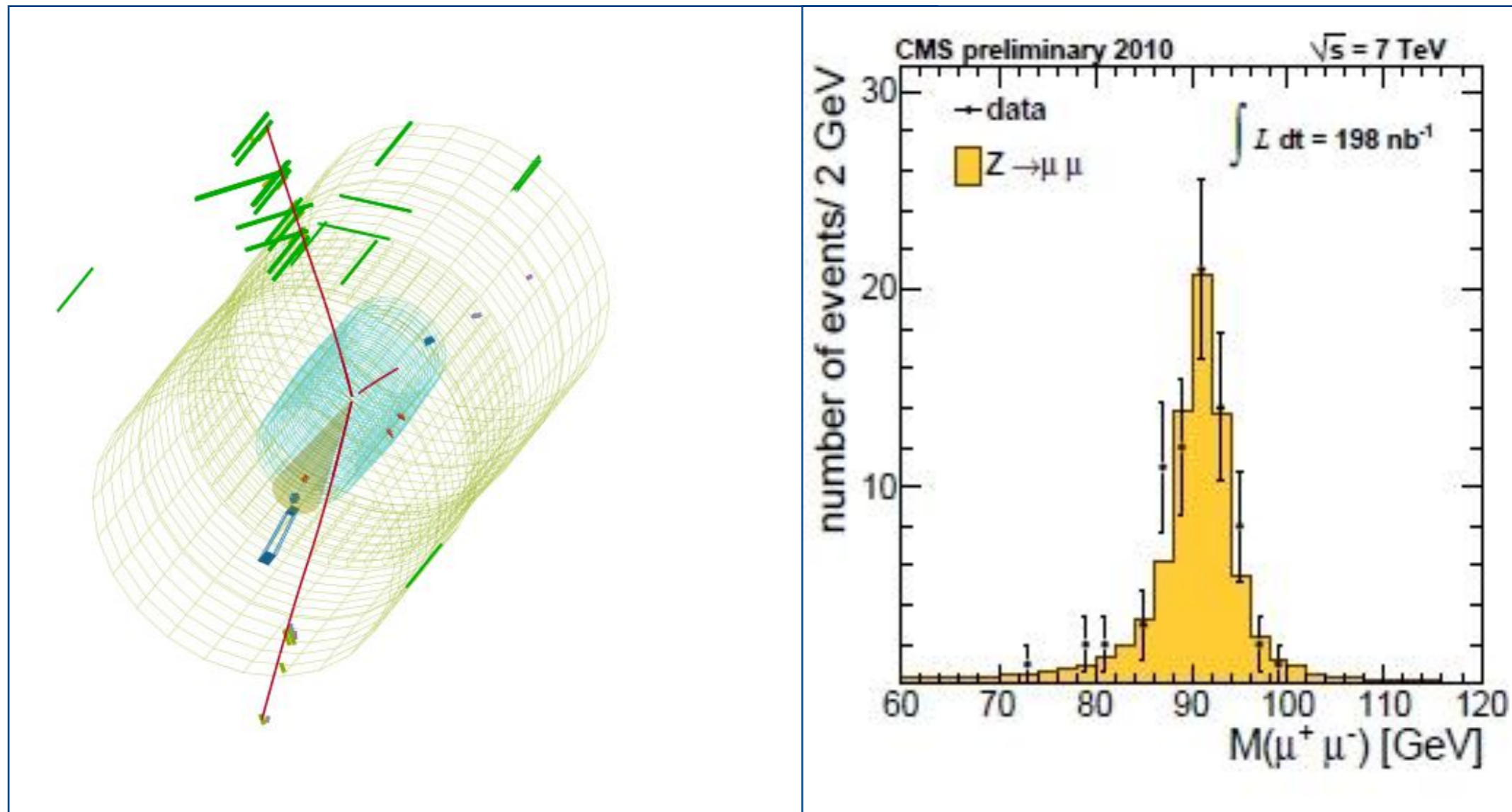
# The Task

Can we calculate a  $W^+/W^-$  ratio for CMS?



# The Task

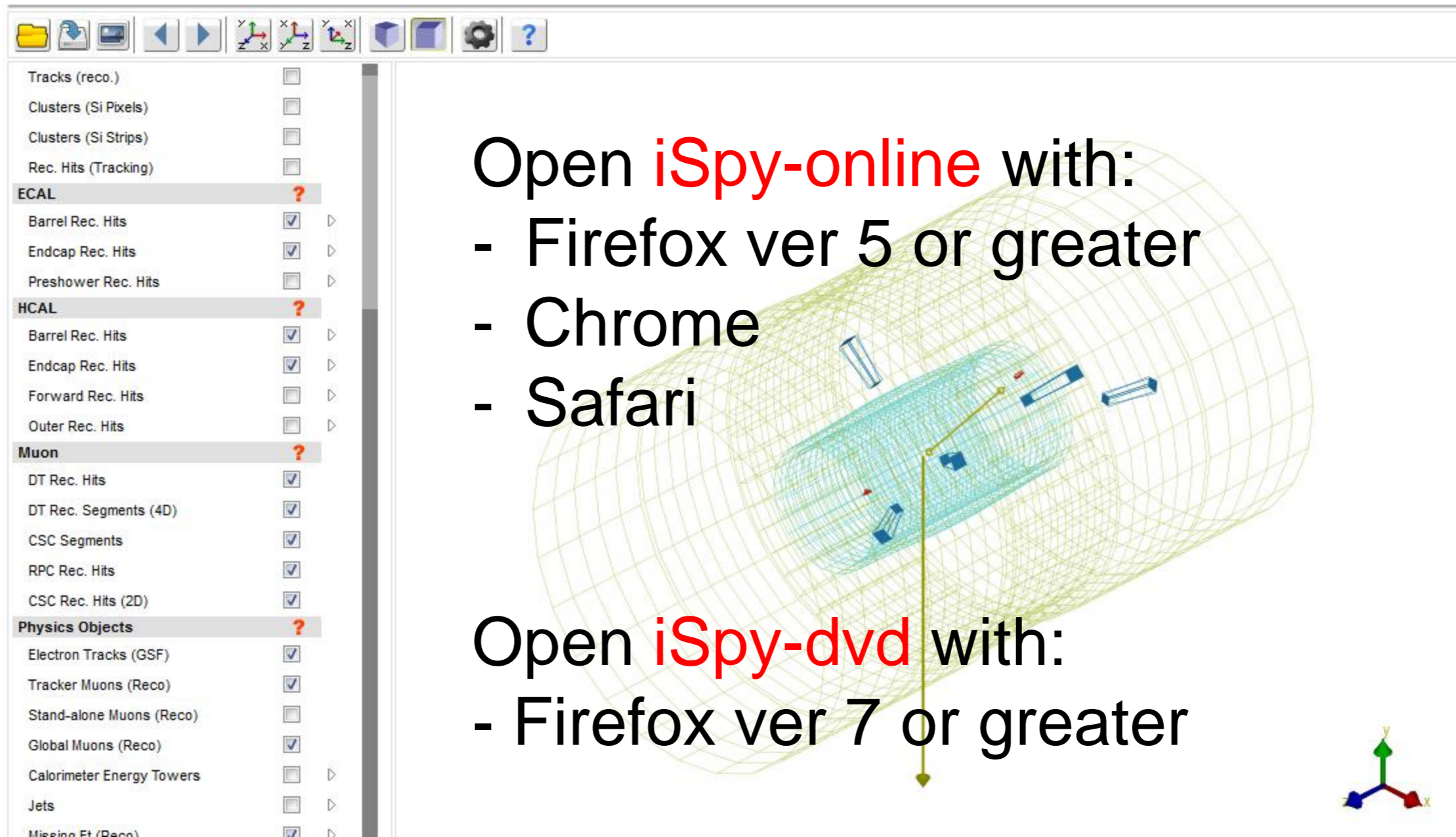
Can we make mass plot of Z candidates?



EvNo	E1	px1	py1	pz1	pt1	eta1	phi1	Q1	E2	px2	py2	pz2	pt2	eta2	phi2	Q2	M
128943239	72.89895	13.36098	-26.087	66.74727	29.3095	1.5612	-1.09746	1	37.6277	-10.9181	35.80517	-3.82334	37.3966	-0.10197	1.86677	-1	90.31227



# Try Real Events



The screenshot shows the iSpy-online interface. On the left is a list of data layers with checkboxes and expand/collapse icons. The main area displays a 3D visualization of a particle detector, likely the ATLAS detector, with a green wireframe grid and various components highlighted in blue and red. A yellow line with a downward arrow points from the text below to the detector visualization.

Layer Name	Checked	Expandable
Tracks (reco.)	<input type="checkbox"/>	
Clusters (Si Pixels)	<input type="checkbox"/>	
Clusters (Si Strips)	<input type="checkbox"/>	
Rec. Hits (Tracking)	<input type="checkbox"/>	
<b>ECAL</b>	<input type="checkbox"/>	<input type="checkbox"/>
Barrel Rec. Hits	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Endcap Rec. Hits	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Preshower Rec. Hits	<input type="checkbox"/>	<input type="checkbox"/>
<b>HCAL</b>	<input type="checkbox"/>	<input type="checkbox"/>
Barrel Rec. Hits	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Endcap Rec. Hits	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Forward Rec. Hits	<input type="checkbox"/>	<input type="checkbox"/>
Outer Rec. Hits	<input type="checkbox"/>	<input type="checkbox"/>
<b>Muon</b>	<input type="checkbox"/>	<input type="checkbox"/>
DT Rec. Hits	<input checked="" type="checkbox"/>	
DT Rec. Segments (4D)	<input checked="" type="checkbox"/>	
CSC Segments	<input checked="" type="checkbox"/>	
RPC Rec. Hits	<input checked="" type="checkbox"/>	
CSC Rec. Hits (2D)	<input checked="" type="checkbox"/>	
<b>Physics Objects</b>	<input type="checkbox"/>	<input type="checkbox"/>
Electron Tracks (GSF)	<input checked="" type="checkbox"/>	
Tracker Muons (Reco)	<input checked="" type="checkbox"/>	
Stand-alone Muons (Reco)	<input type="checkbox"/>	
Global Muons (Reco)	<input checked="" type="checkbox"/>	
Calorimeter Energy Towers	<input type="checkbox"/>	<input type="checkbox"/>
Jets	<input type="checkbox"/>	<input type="checkbox"/>
Missing Et (Deno)	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Open **iSpy-online** with:

- Firefox ver 5 or greater
- Chrome
- Safari

Open **iSpy-dvd** with:

- Firefox ver 7 or greater

# Recording Event Data

https://www.editgrid.com/qn-nd/qnmasterclasses/CMS\_WZ\_cohoes

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Spreadsheet / qnmasterclasses / CMS WZ cohoes Comments (0)

File Edit View Format Insert Data Share Publish Collaborate Macro Help Auto Saved Close

A1  $f_{\omega}$  MC No

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	MC No	Ev No	electron	muon	W+ cand	W- cand	W cand	Z cand	"zoo"	Z mass	Zmass list		
2	201	110239978			1	1							
3	202	112324546	1					1					
4	203	112536826	1						1	23.44	23.44		
5	204	115180352			1		1					86.23	
6	205	118510854			1		1					86.56	
7	206	120218778	1						1	86.23	29.41		
8	207	120706369	1					1				9.42	
9	208	127095686	1			1						9.08	
10	209	130593477	1				1					10.33	
11	210	130601256		1	1							5.85	
12	211	139591470	1		1							24.03	
13	212	139984297	1				1					24.57	
14	213	140664090	1		1							2.97	
15	214	141933955	1				1					63.88	
16	215	142471053	1				1					49.58	
17	216	142715334	1				1					85.97	
18	217	147313218	1				1					68.3	
19	218	15395536	1						1	86.56	90.39		
20	219	156900355	1			1						70.37	
21	220	164518991		1	1							86.75	
22	221	173183638		1	1							64.67	
23	222	188499351	1		1								
24	223	207058976	1		1								
97	296	658338706		1					1	64.67			
98	297	664543623		1	1								
99	298	667373800		1			1						
100	299	96499840	1		1								
101	300	96771000	1				1						
102		Sums -->	41	53	43	28	2	19	8	46.94	<--Averages		
103													
104			e/mu	W+/W-									
105		Ratios -->	0.773584905	1.53571428571429									
106													

# Recording Event Data

https://www.editgrid.com/qn-nd/qnmasterclasses/CMS\_WZ\_cohoes

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Spreadsheet / qnmasterclasses / CMS WZ cohoes Comments (0)

File Edit View Format Insert Data Share Publish Collaborate Macro Help Auto Saved Close

A1	mc_no.	electron	muon	W+ cand	W- cand	W cand	Z cand	"zoo"
1	1	49	49	40	45	0	8	6
2	2	56	57	39	35	7	13	5
3	3	41	53	43	28	2	19	8
4	4	0	0	34	17	0	11	3
5	5	59	45	48	41	0	10	0
6	6							
7	7							
8	8							
9	9							
10	10							
11	11							
12	12							
13	13							
14	14							
15	15							
16	16							
17	17							
18	18							
19	19							
20	20							
21	21	205	204	204	166	9	61	22 <-- Institute Totals
22	22							
23	23							
24	24	Z cand masses	<-- make one contiguous list below A24					
25	25	3.03						
26	26	11.18						
27	27	8.25						
28	28	11.1						
29	29	17.01						
30	30	94.57						

W+/W- = 1.2289156626506

e/m = 1.00490196078431

mc\_7 / mc\_8 / mc\_9 / mc\_10 / mc\_11 / mc\_12 / mc\_13 / mc\_14 / mc\_15 / mc\_16 / mc\_17 / mc\_18 / mc\_19 Result

# Upload Institute Results

quarknet.us/library/index.php/CMS\_Combination\_of\_Results\_2012#Moderator\_Level

5. Find your data upload spreadsheet for:
  1. [CERN-moderated video conferences](#)
  2. [Fermilab-moderated video conferences](#) (or use Indico page)
6. Send the following to moderators at least 30 minutes prior to video conference:
  1. final tally of e, mu, W+, W-, Z, and zoo
  2. list of all Z candidate masses (including events which are not near Z mass)
7. Share mass plot on Vidyo and/or transmit to moderators (U.S. Masterclass can upload to Indico page)

## Moderator Level

[edit]

Find your data upload spreadsheet for

- [CERN-moderated video conferences](#)
- [Fermilab-moderated video conferences](#) (or use Indico page)

Moderators should show and discuss the following results with students:

- e/ $\mu$  ratio
- W+/W- ratio
- Z candidate mass plot (including "surprises") for all Institutes that day.

### Optional:

The second and third tabs of the data upload spreadsheet each have moment measurement. Moderators may use this to create a unique plot of their own (

quarknet.us/library/index.php/Spreadsheets\_2012#CERN

## CERN

Date (2012)	Time (CET)	Results upload	Data analysis spreadsheets
Tue 28 Feb	16:00	<a href="#">CERN 1</a>	<a href="#">Roma Sapienzia</a> - <a href="#">Notre Dame 1</a> - <a href="#">Cohoes</a>
Thu 08 Mar	16:00	<a href="#">CERN 2</a>	<a href="#">Paliaseau 1</a> - <a href="#">Notre Dame 2</a> - <a href="#">Zagreb</a>
Fri 09 Mar	16:00	<a href="#">CERN 3</a>	<a href="#">Santander</a> - <a href="#">Perugia</a> - <a href="#">Wien HEPHY</a>
Sat 10 Mar	16:00	<a href="#">CERN 4</a>	<a href="#">Antwerp</a> - <a href="#">Warszawa</a> - <a href="#">Ghent</a>
Mon 12 Mar	16:00	<a href="#">CERN 5</a>	<a href="#">Padova 1</a> - <a href="#">Split</a> - <a href="#">Trieste</a> - <a href="#">Łódz</a> - <a href="#">Genève CERN</a>
Tue 13 Mar	16:00	<a href="#">CERN 6</a>	<a href="#">Padova 2</a> - <a href="#">Obuda</a> - <a href="#">Debrecen</a>
Wed 14 Mar	16:00	<a href="#">CERN 7</a>	<a href="#">Padova 3</a> - <a href="#">Jerusalem</a> - <a href="#">Mons</a> - <a href="#">Athena, Demokritos</a>
Thu 15 Mar	16:00	<a href="#">CERN 8</a>	<a href="#">Palaiseau 2</a> - <a href="#">Lyons</a> - <a href="#">Rio de Janeiro</a>
Thu 22 Mar	16:00	<a href="#">CERN 9</a>	<a href="#">Strasbourg 1</a> - <a href="#">Palaiseau 3</a> - <a href="#">Madrid CIEMAT</a> - <a href="#">Budapest KFKI</a> - <a href="#">Bragança</a>
Fri 23 Mar	16:00	<a href="#">CERN 10</a>	<a href="#">Strasbourg 2</a> - <a href="#">Torino</a>

Combination of Results pages  
linked from  
<http://physicsmasterclasses.org>

# Upload Institute Results

Browser address: [https://www.editgrid.com/qn-nd/qnmasterclasses/CMS\\_WZ\\_Combined\\_28\\_Feb2012\\_CERN](https://www.editgrid.com/qn-nd/qnmasterclasses/CMS_WZ_Combined_28_Feb2012_CERN)

EditGrid Welcome, qnmasterclasses  
 Preferences | [Verify Email](#) | [Logout](#)

Home | Spreadsheets | Organisation | Data | **Important**

Spreadsheet / qnmasterclasses / CMS WZ Combined 28 Feb2012 CERN Comments (0)

File Edit View Format Insert Data Share Publish Collaborate Macro Help Auto Saved Close

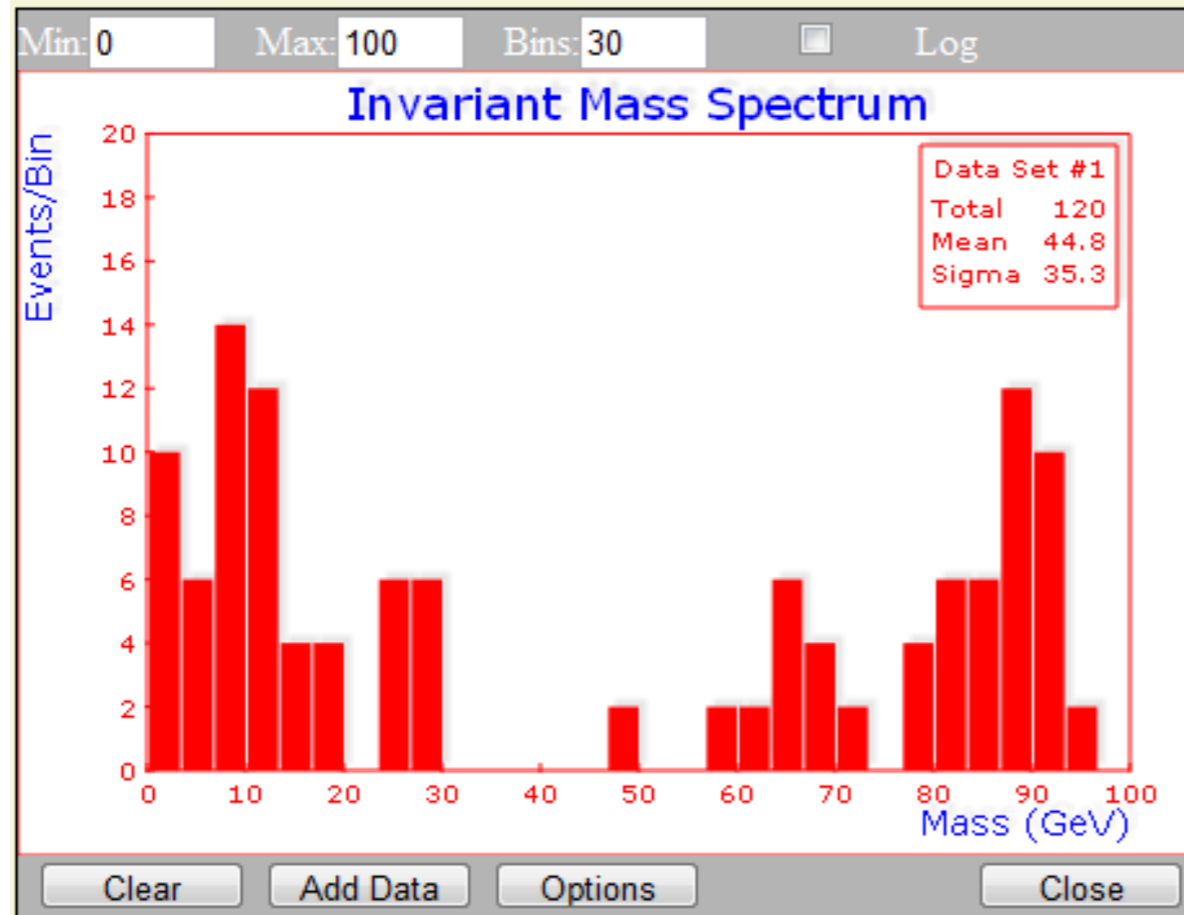
Font: Arial 11 pt | Bold | Italic | Underline | Text Color | Background Color | Merge | Unmerge | Sort Ascending | Sort Descending | Filter | Print | Refresh | Undo | Redo

	A	B	C	D	E	F	G	H	I	J
1	<b>CMS W/Z Measurement Results</b>				Date:					
2										
3	<b>Institute</b>	<b>electron</b>	<b>muon</b>	<b>W+ cand</b>	<b>W- cand</b>	<b>W cand</b>	<b>Z cand</b>	<b>"zoo"</b>	<b>e/mu</b>	<b>W+/W-</b>
4	Roma Sapienza									
5	Notre Dame									
6	Cohoes	205	204	204	166	9	61	22		
7										
8										
9		205	204	204	166	9	61	22	1.0049019	1.228915
10										
11										
12	<b>Z cand masses</b>									
13	3.03	<-- make one contiguous list below A10								
14	11.18									
15	8.25									
16	11.1									
17	17.01									
18	94.57									
19	89.96									
20	90.21									
21	23.44									
22	86.23									

Sheet tabs: Results | Inu\_ext\_data | ll\_ext\_data

# Masterclass Results

Make mass plot for all Institutes



Optional scatter plot (example):

