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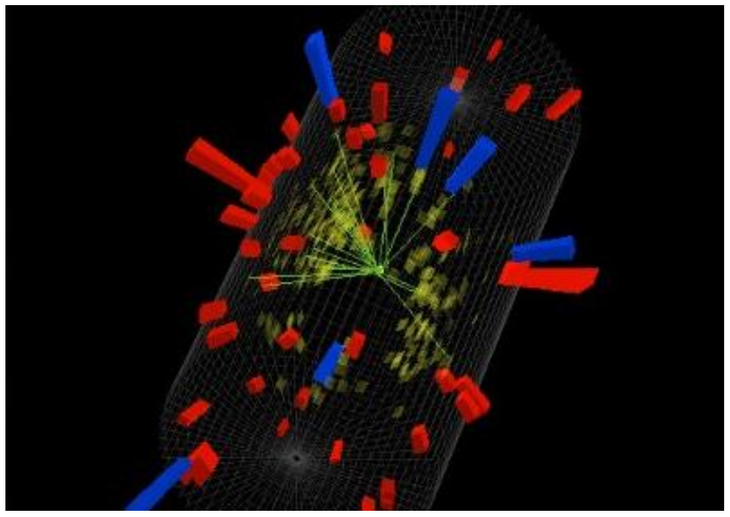
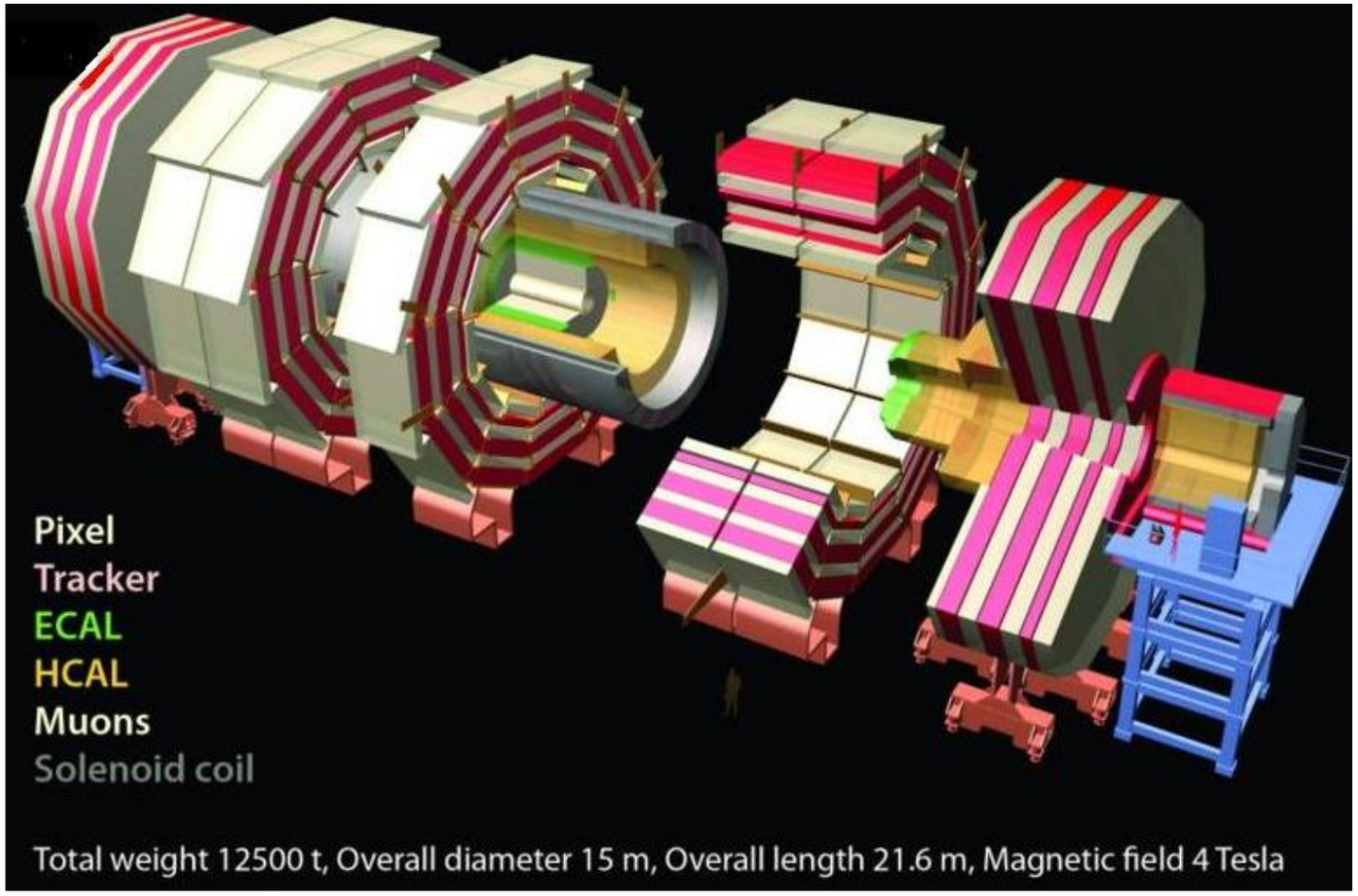
CMS Masterclass 2012





EPPOG

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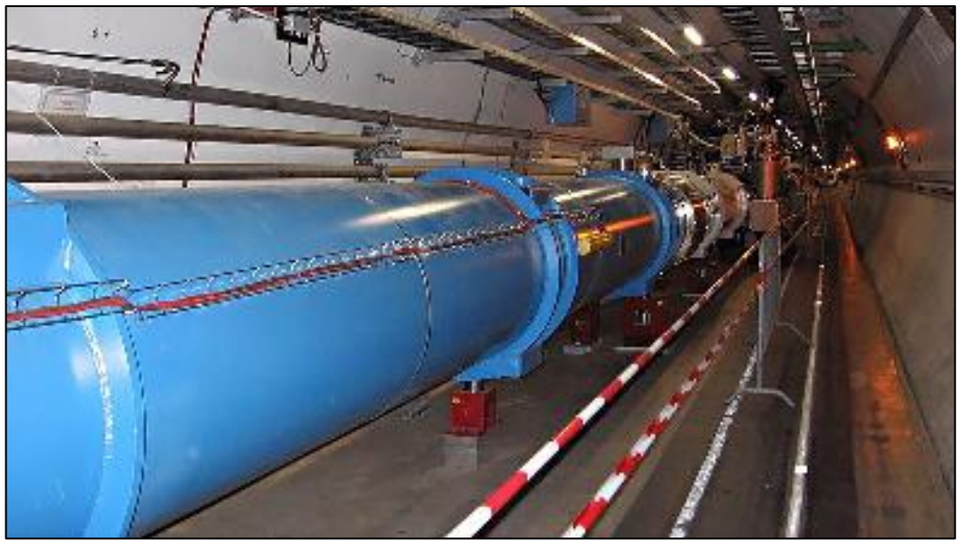
The LHC and New Physics

It's the dawn of an exciting age of new discovery in particle physics!

At CERN, the LHC and its experiments are underway.

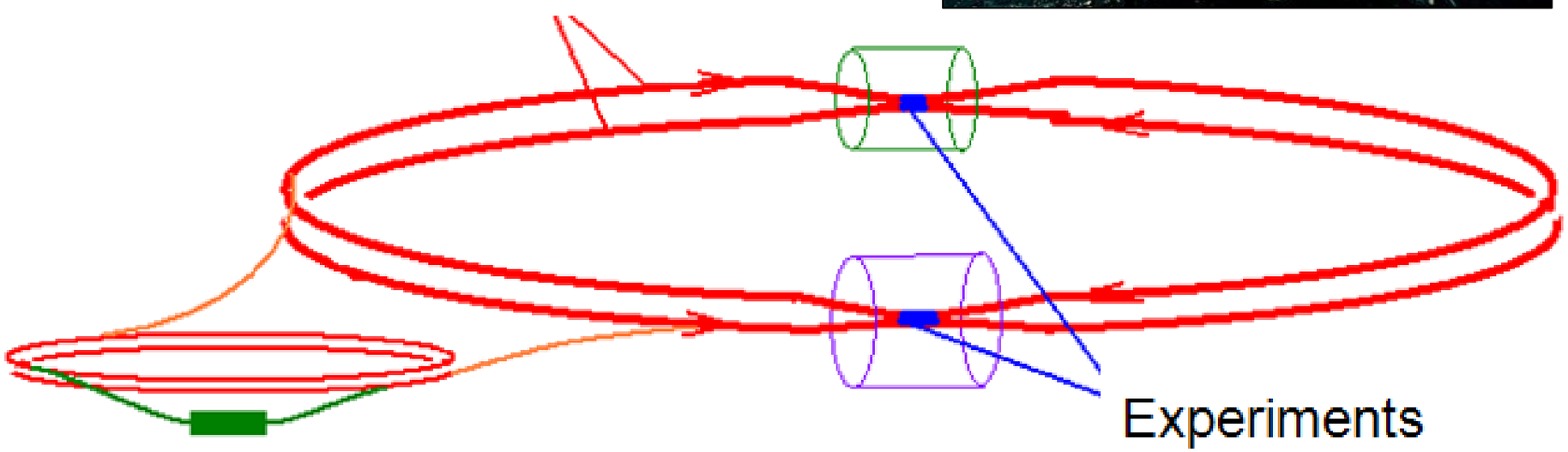


ATLAS and CMS, the Compact Muon Solenoid, have been taking data. The first job is to confirm how the detector data corresponds to our understanding we call the ***Standard Model****. Secondly, the task is to look for new phenomena.*

The LHC and New Physics

The LHC is buried ~100 m below the surface near the Swiss-French border.

beams accelerated in large rings
(27 km circumference at CERN)



particle source
(injector)

Experiments
where beams cross and
some particles collide

Detector Design

Generic Design

Cylinders wrapped around the beam pipe

From inner to outer . . .

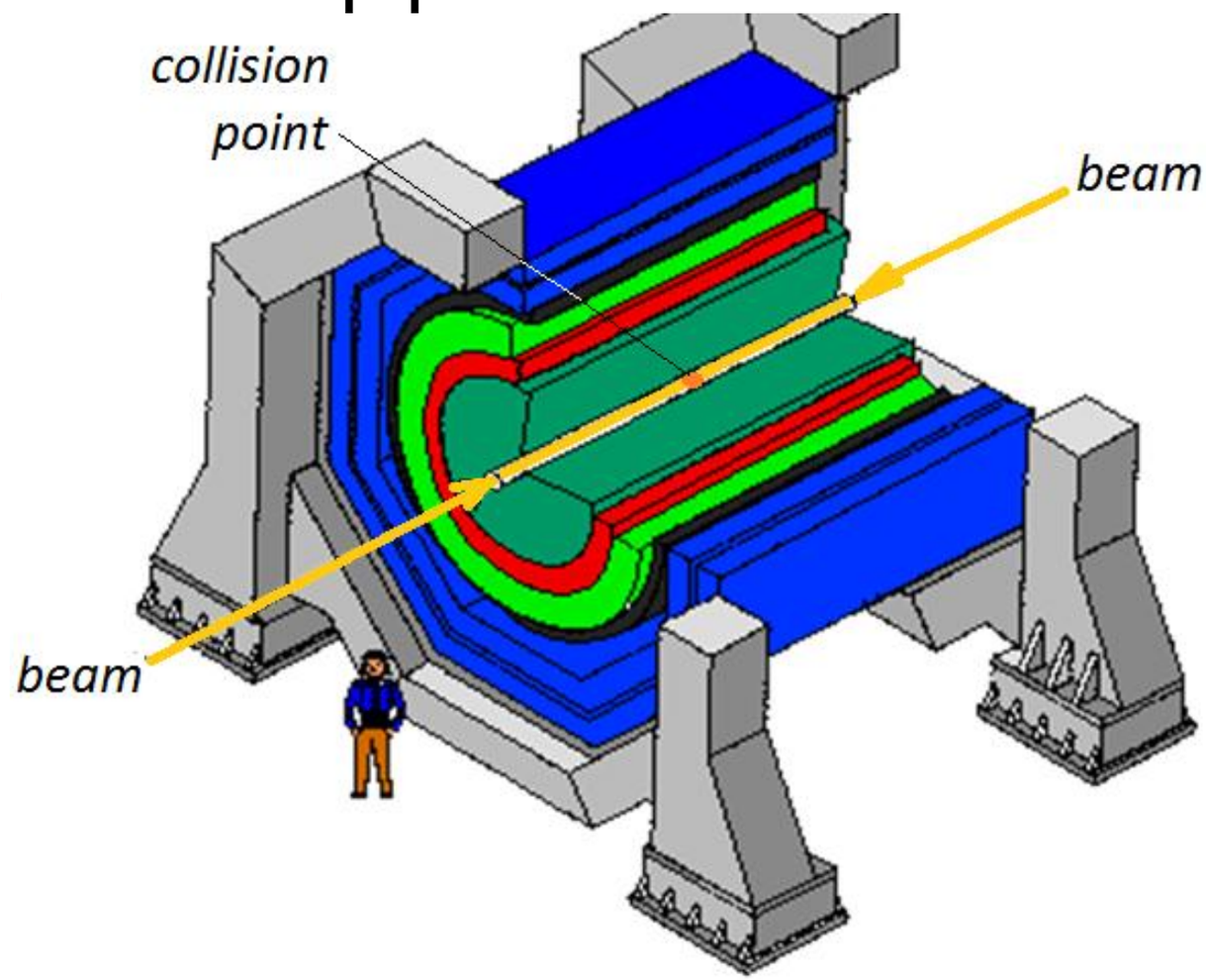
Tracking

Electromagnetic calorimeter

Hadronic calorimeter

Magnet*

Muon chamber



* *location of magnet depends on specific detector design*

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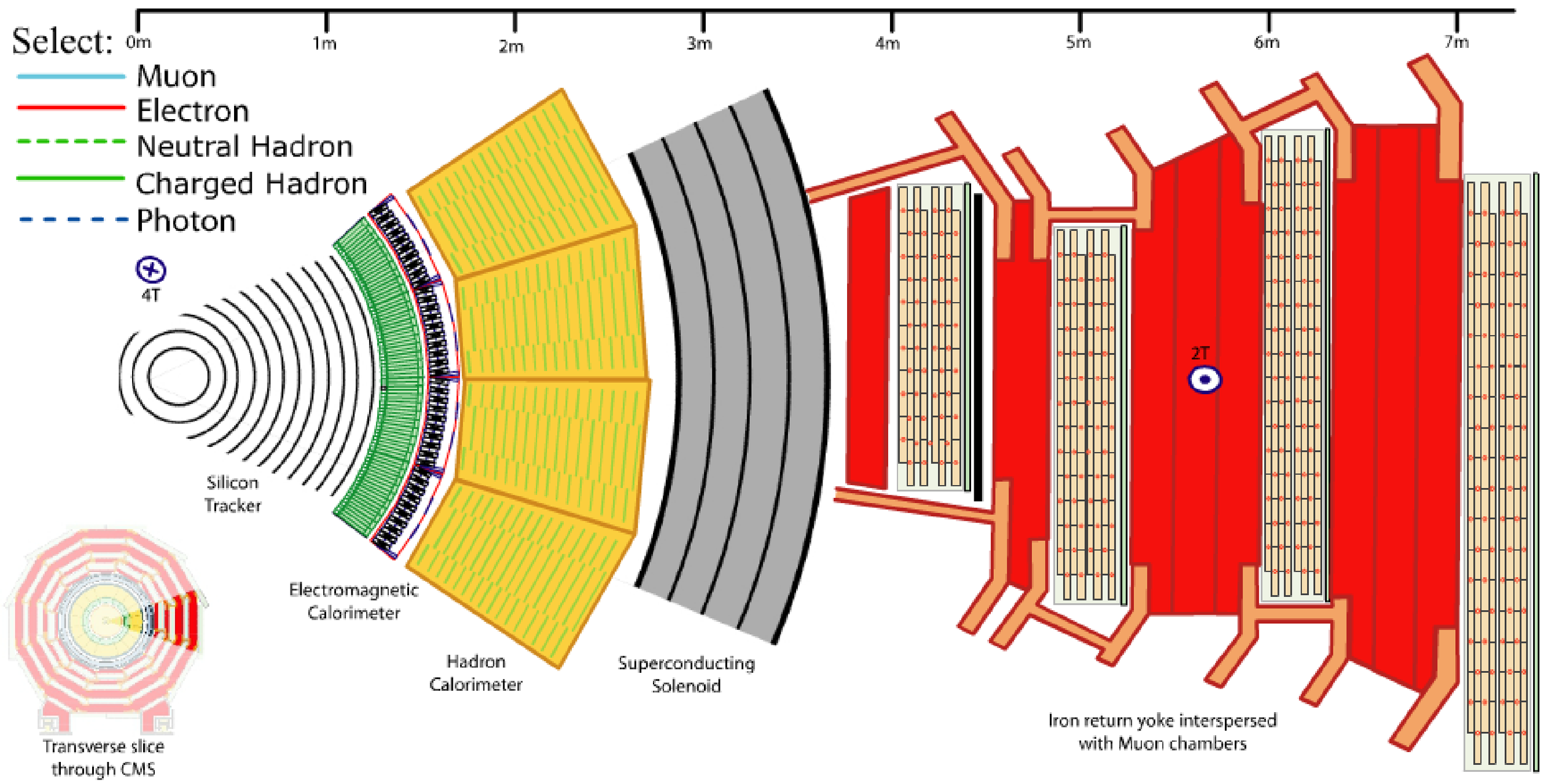
Detector Tracks

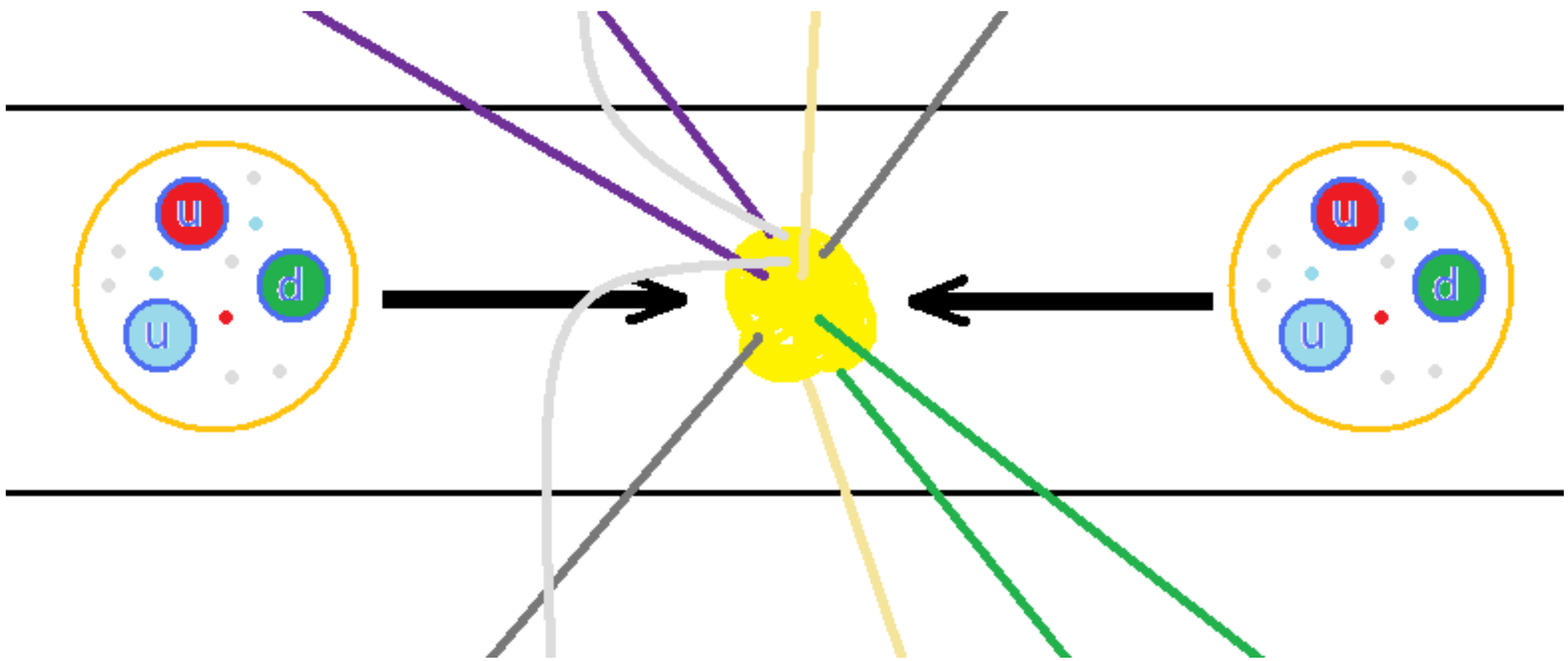
Web Version



Energy & Particle Mass

If each beam proton has energy 3.5 TeV....

- The total collision energy is 2 x 3.5 TeV = 7 TeV.
- But each particle inside a proton shares only a portion.
- So a newly created particle's mass ***must be*** smaller than the total energy.

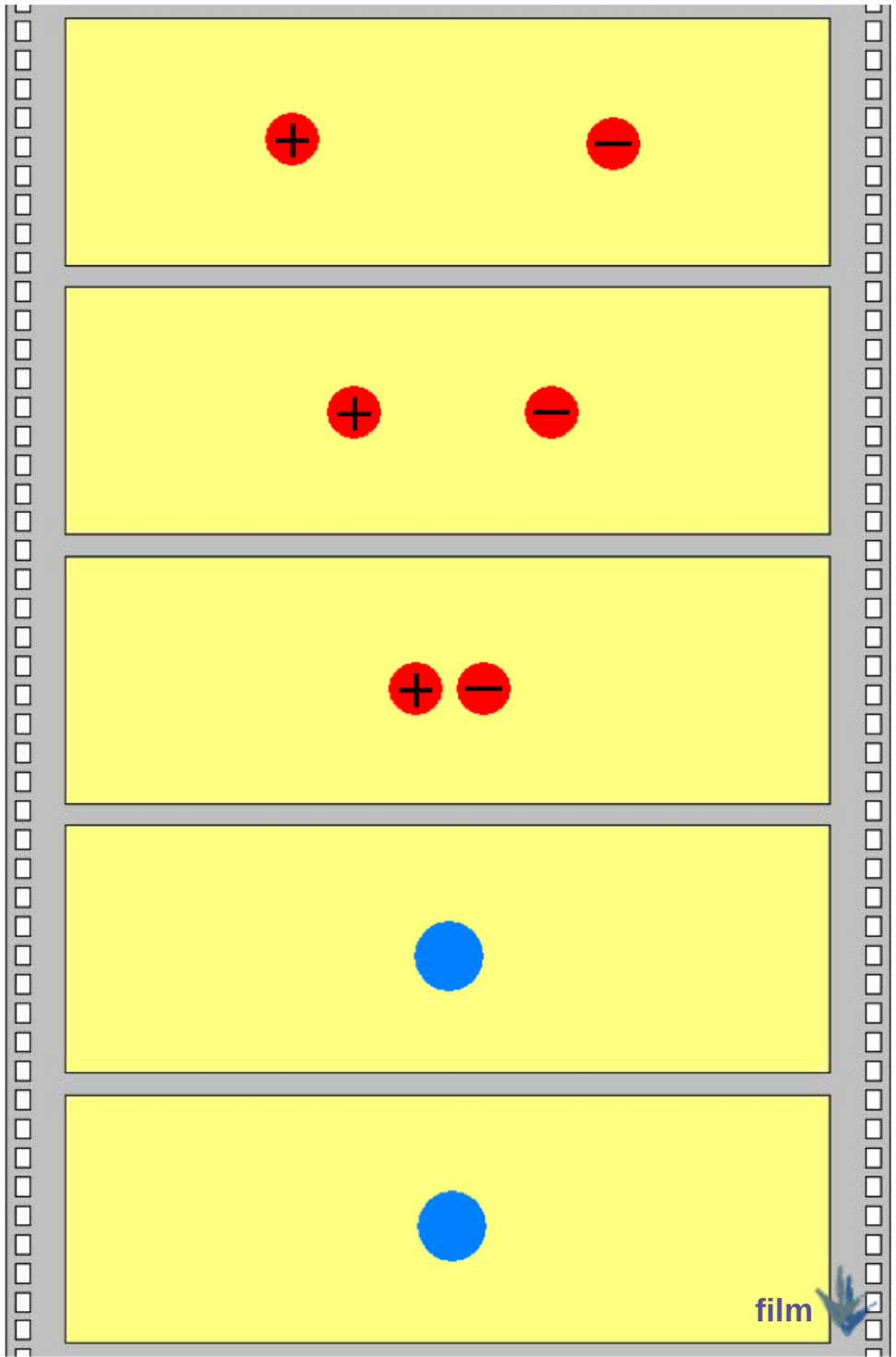


Particle Decays

The collisions create new particles that promptly decay. Decaying particles *always* produce lighter particles.

Conservation laws allow us to see patterns in the decays.

Try to name some of these conservation laws.

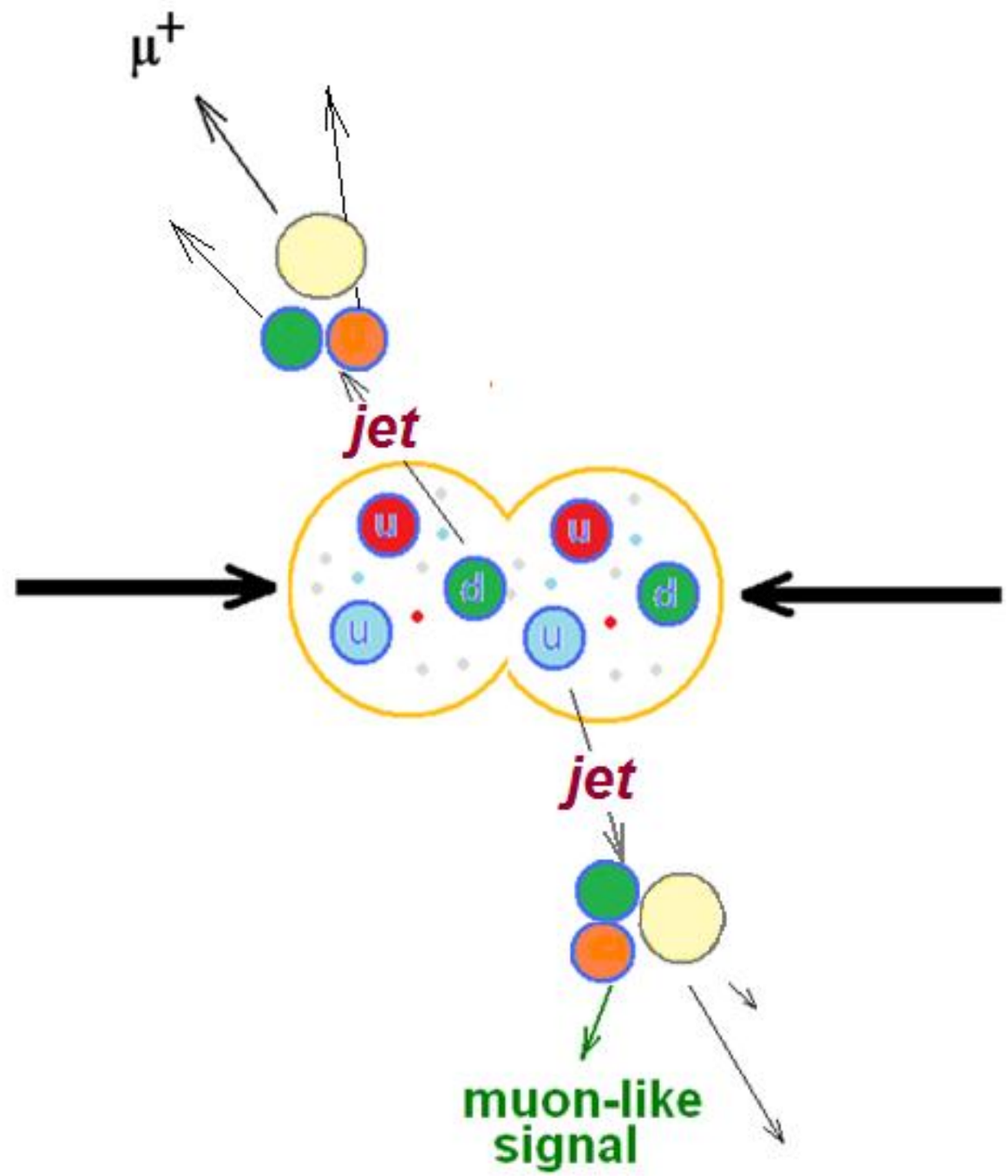


Background Events

Often, quarks are scattered by proton collisions.

As they separate, the binding energy between them converts to sprays of new particles called ***jets.*** Electrons and muons may be included in jets.

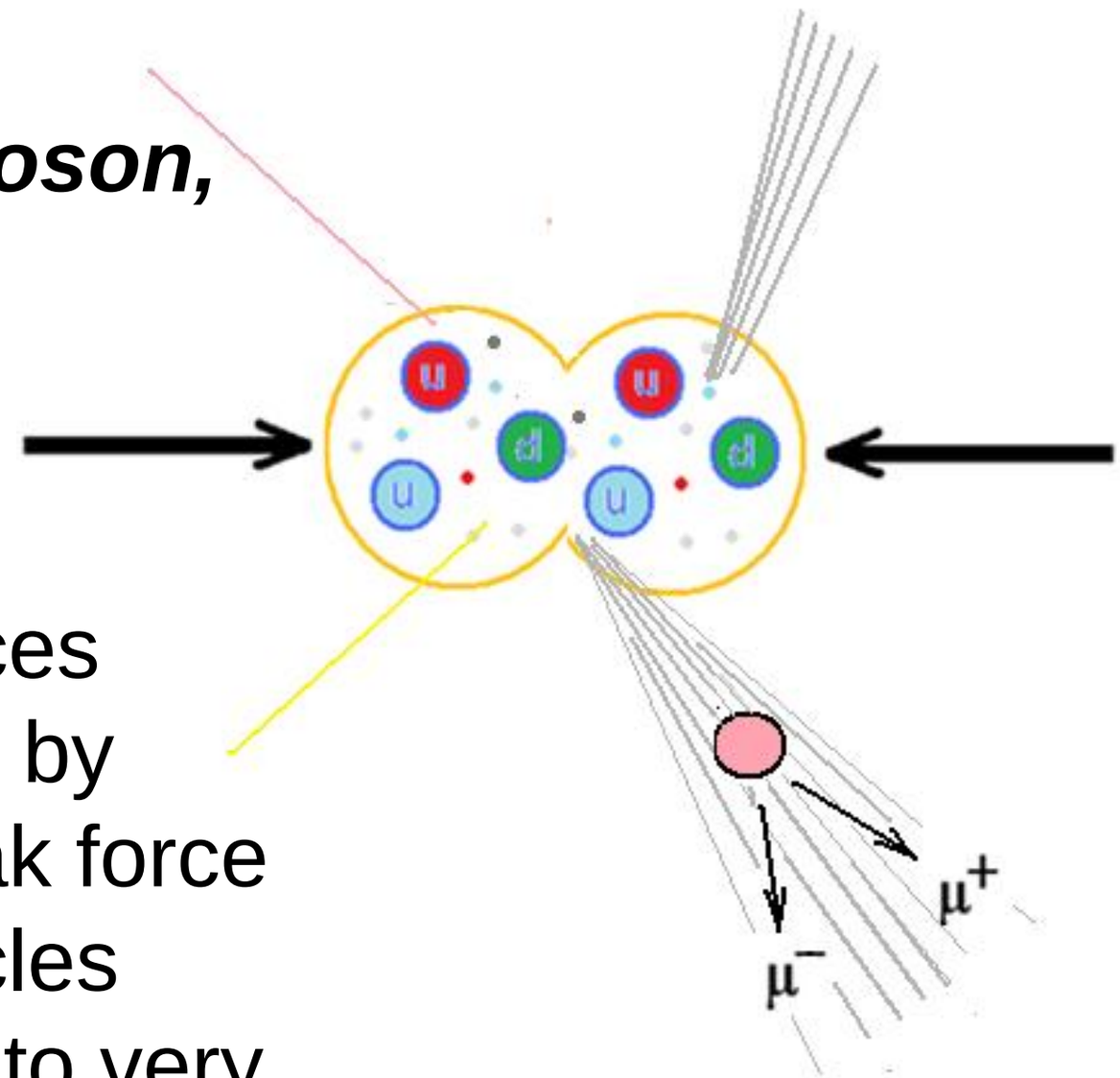
Software can filter out events with jets beyond our current interest.



W and Z Particles

We are looking for the mediators of the ***weak interaction:***

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



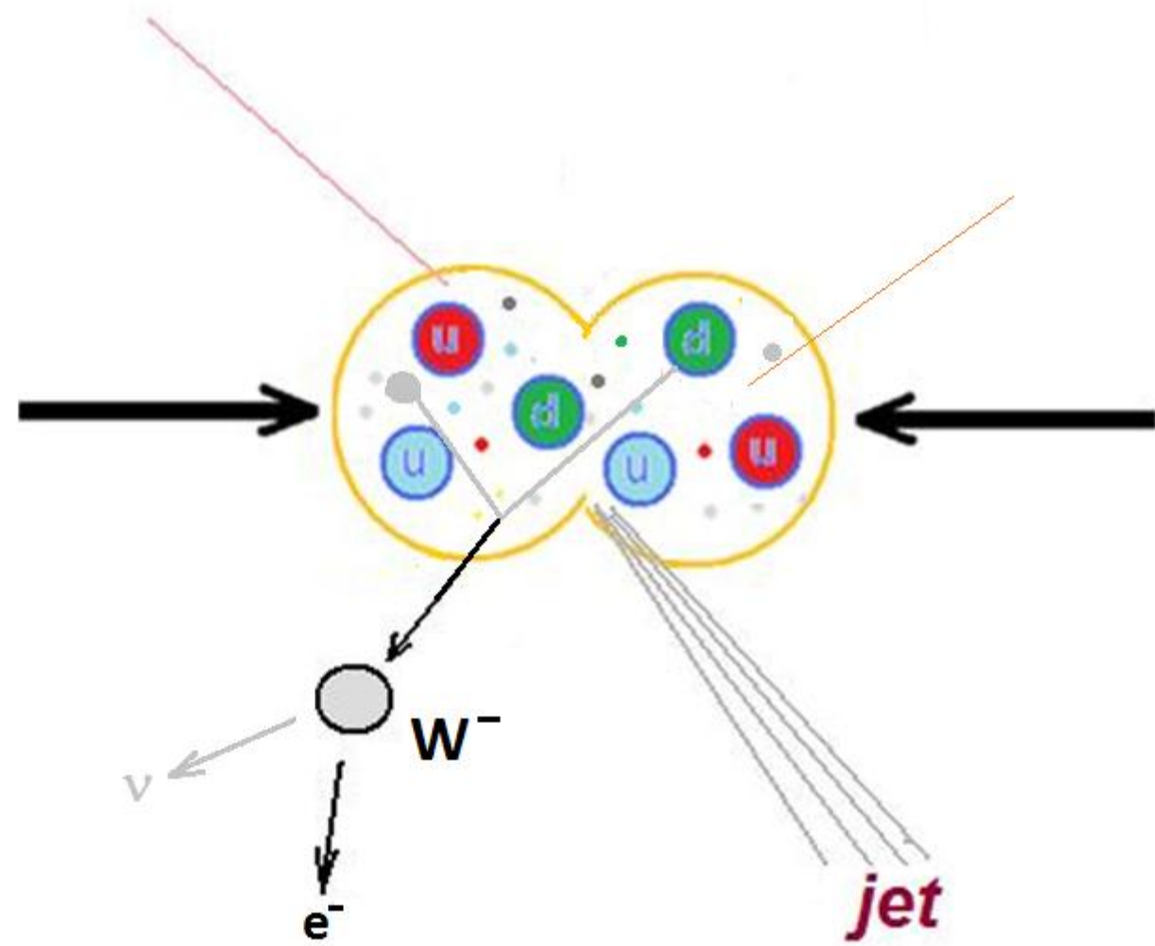
Unlike electromagnetic forces carried over long distances by massless photons, the weak force is carried by massive particles which restricts interactions to very tiny distances.

W and Z Particles

The W bosons are responsible for radioactivity by transforming a proton into a neutron, or the reverse.

Z bosons are similarly exchanged but do not change electric charge.

Collisions of sufficient energy can create W and Z or other particles.



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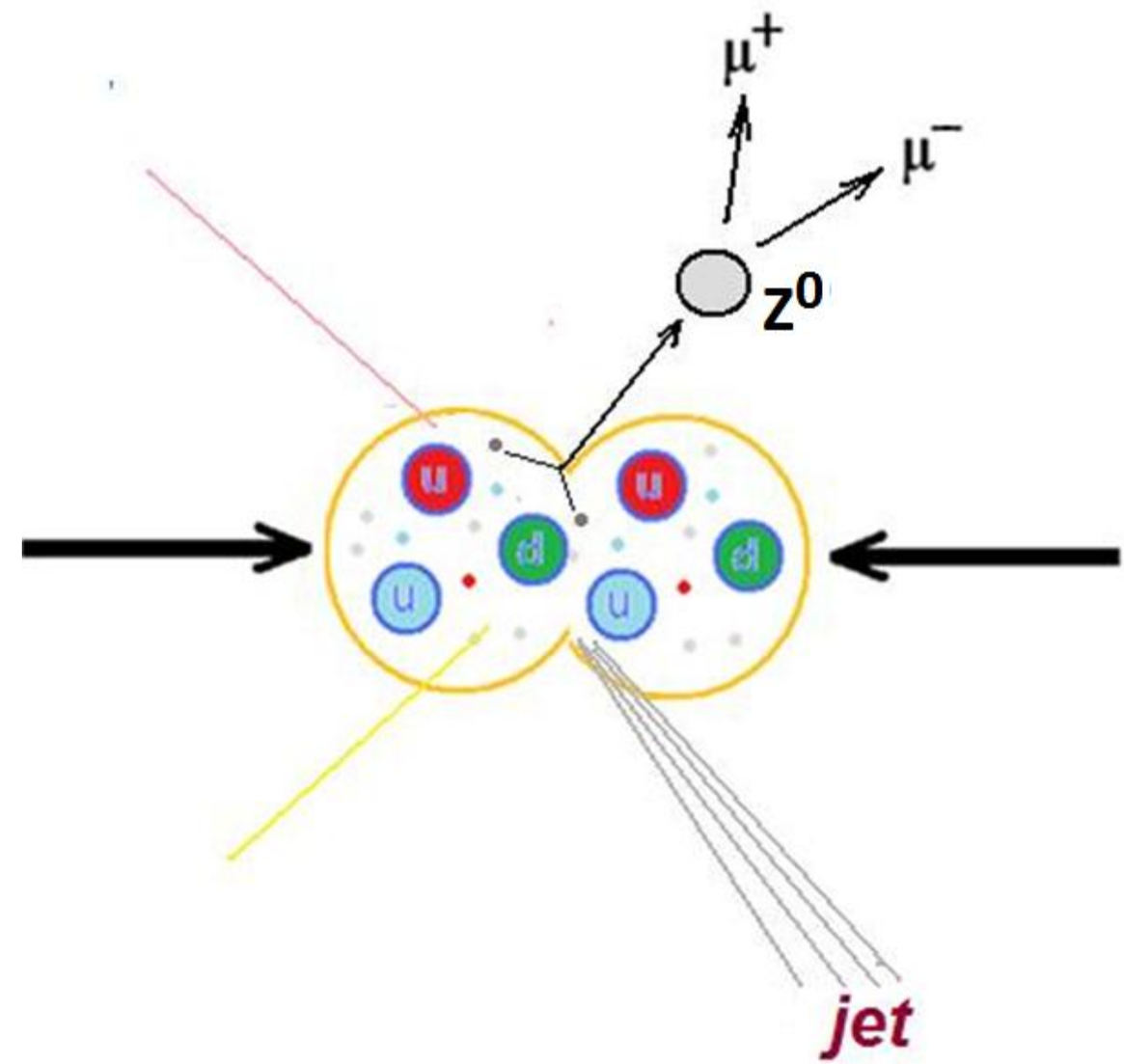

W and Z Decays

Because W and Z only travel a tiny distance before decaying, CMS does not "see" W or Z bosons directly.

CMS *can* detect :

- electrons
- muons

CMS can infer:

- neutrinos from "missing energy"

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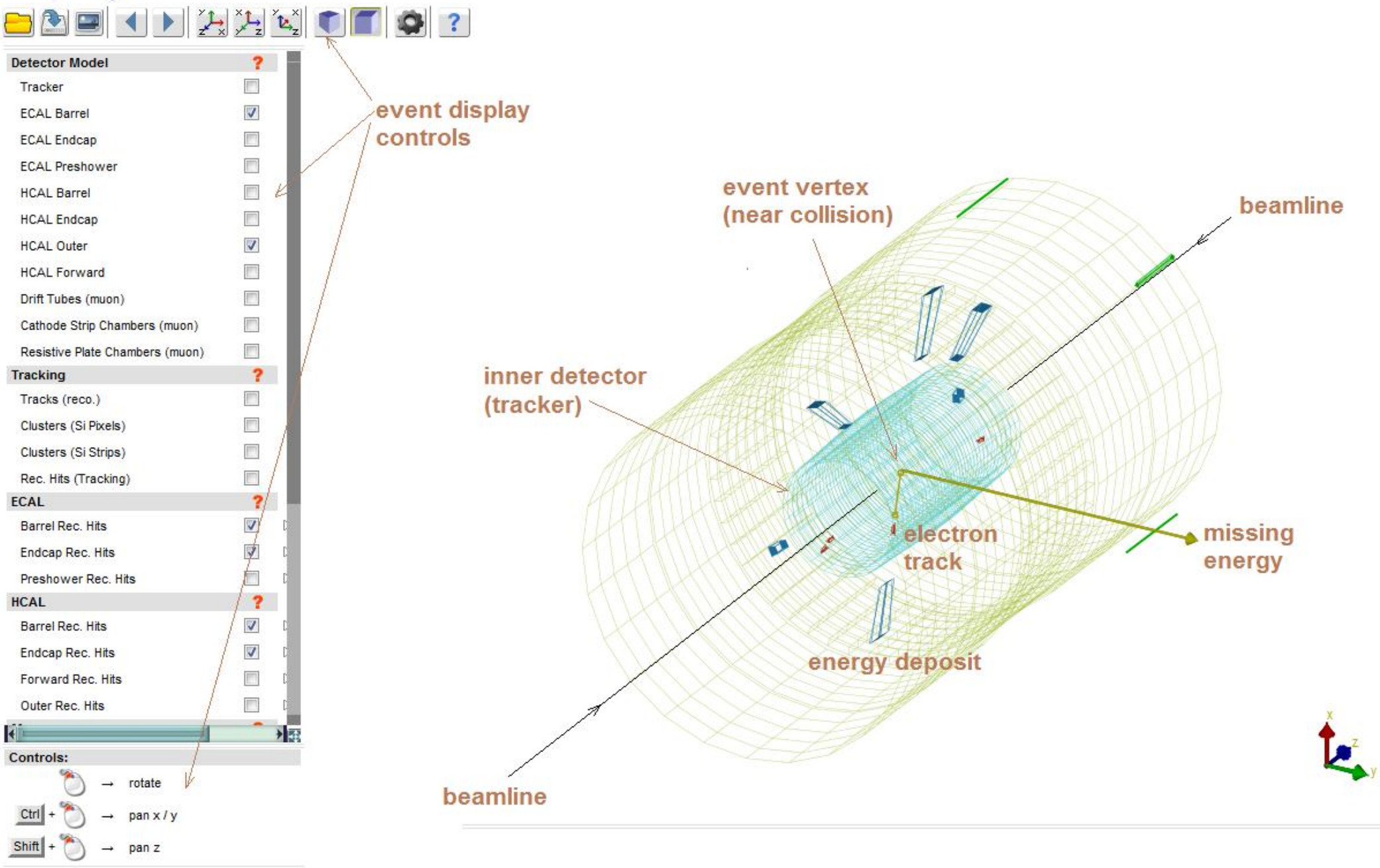
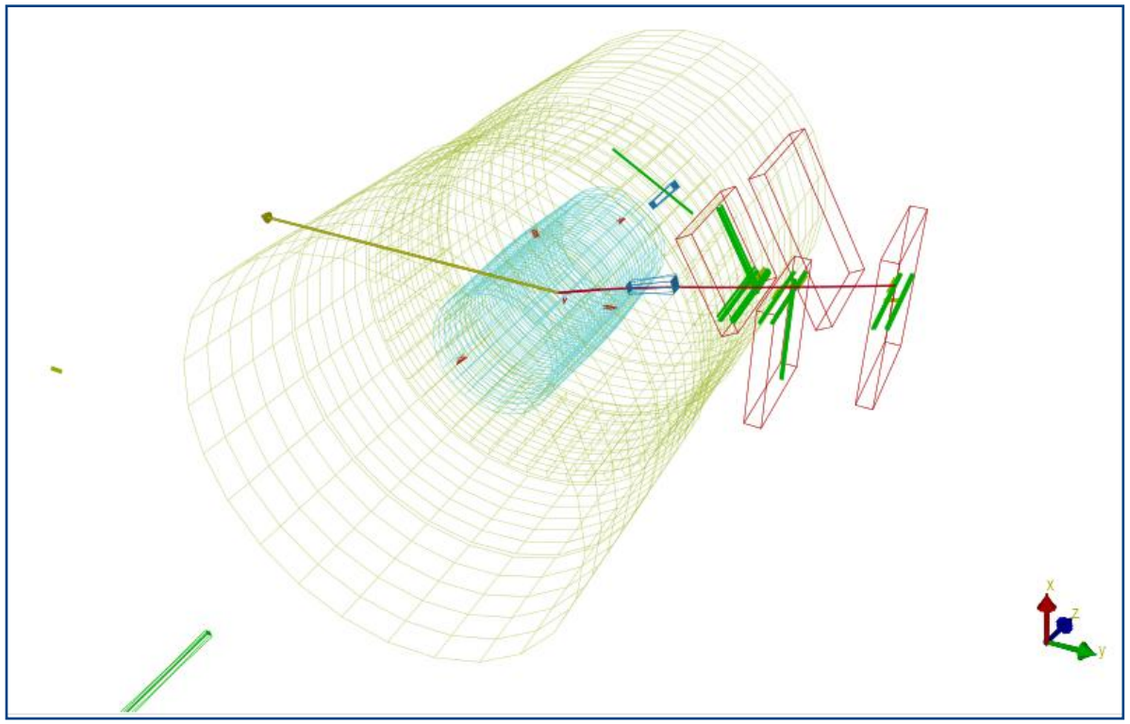
iSpy-online

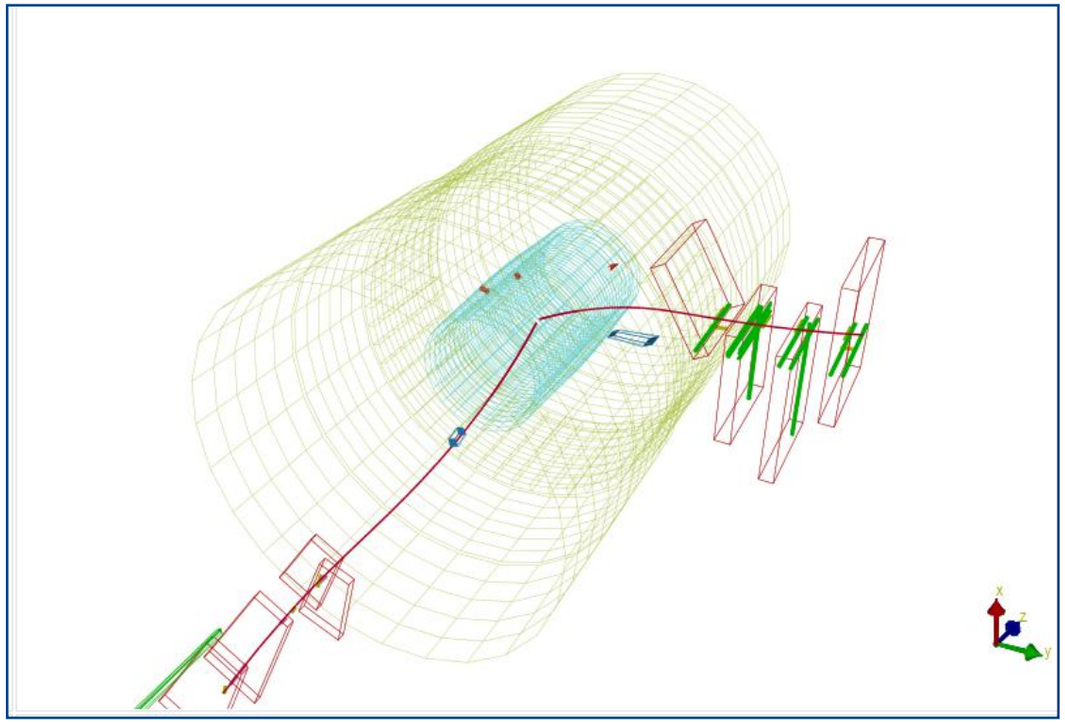


Today's Task

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

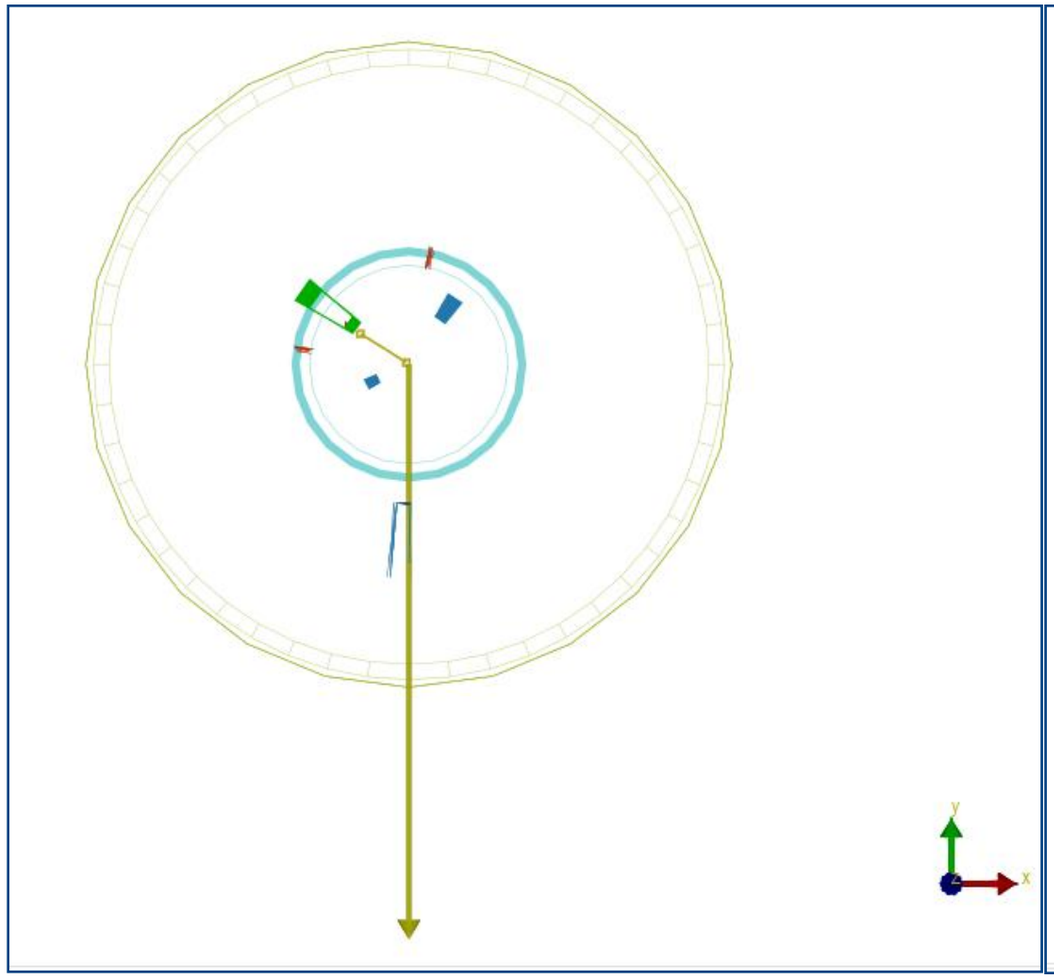
- Can we distinguish W from Z candidates?

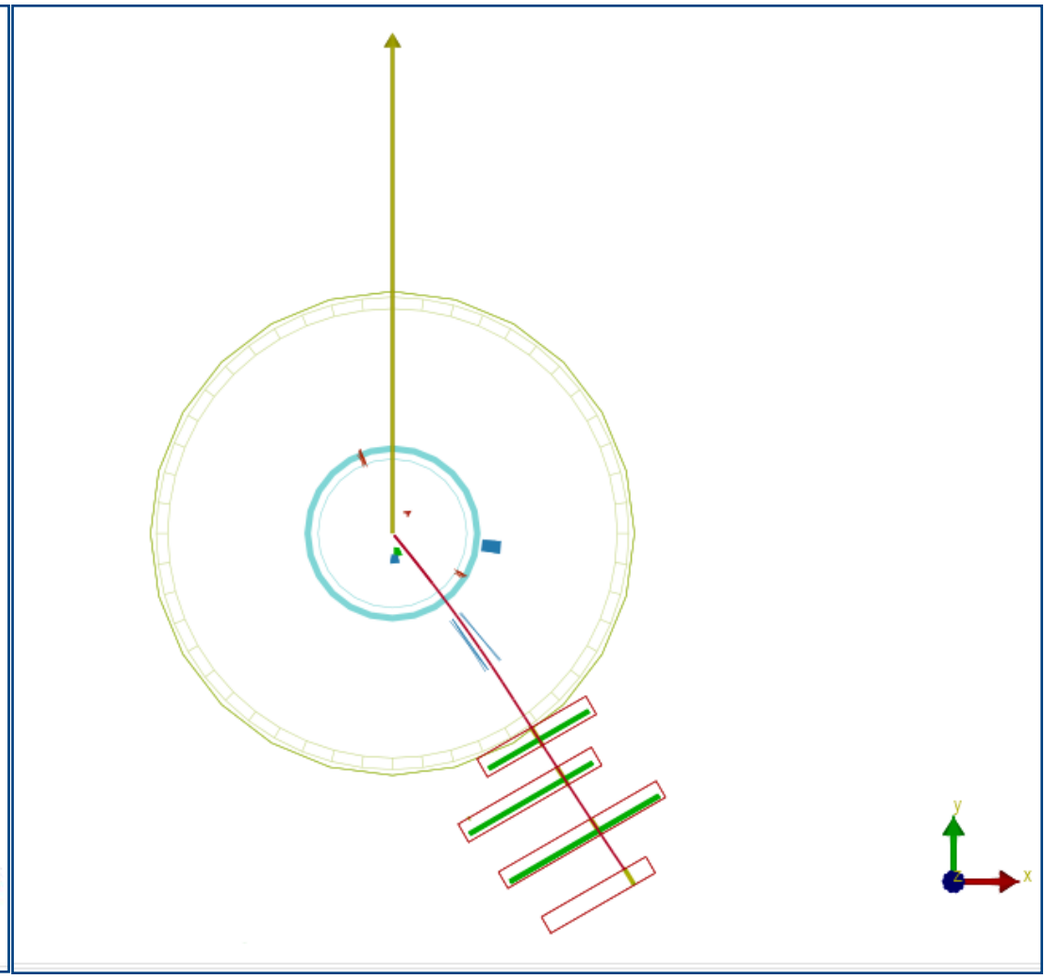




Today's Task

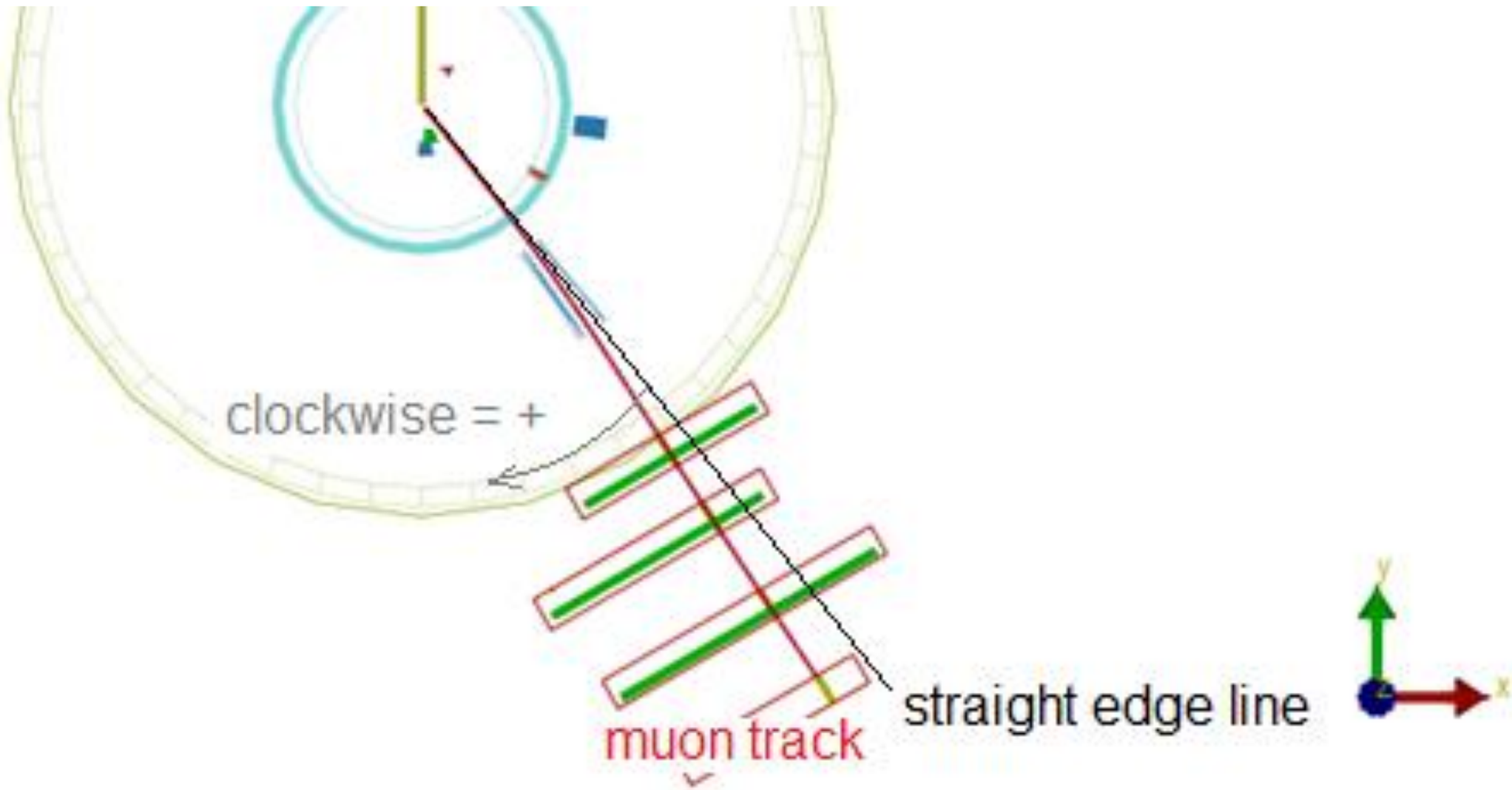
- Can we calculate the e/μ ratio?





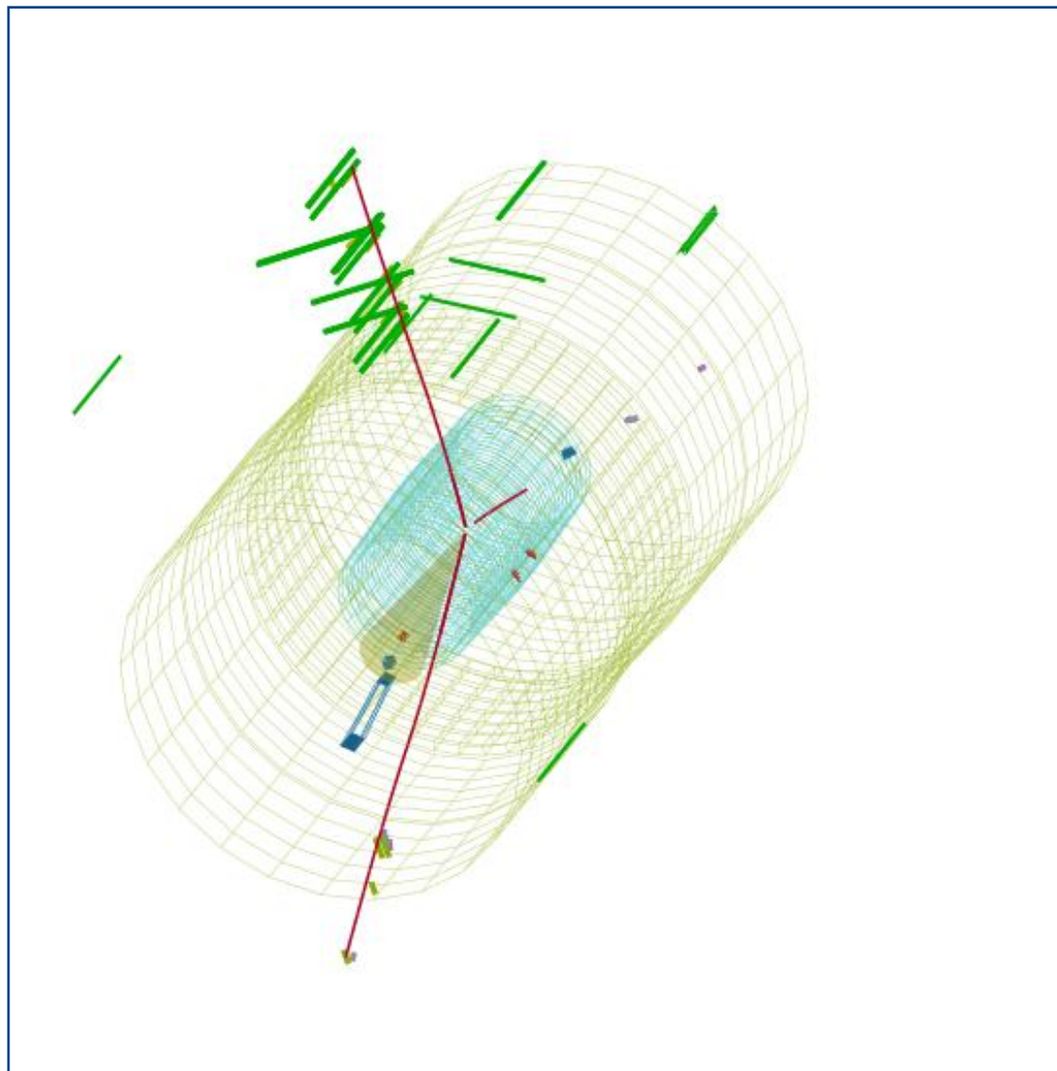
Today's Task

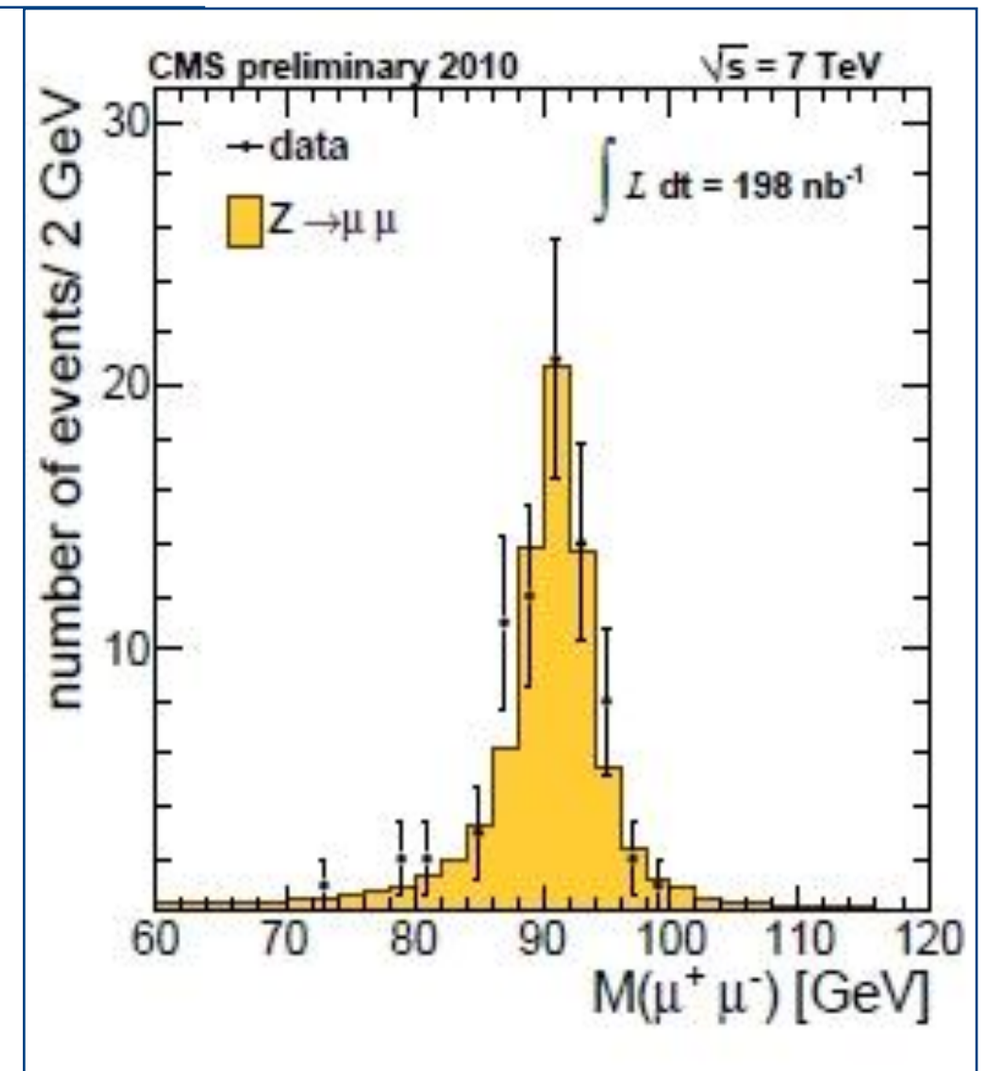
- Can we calculate a W+/W- ratio for CMS?



Today's 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

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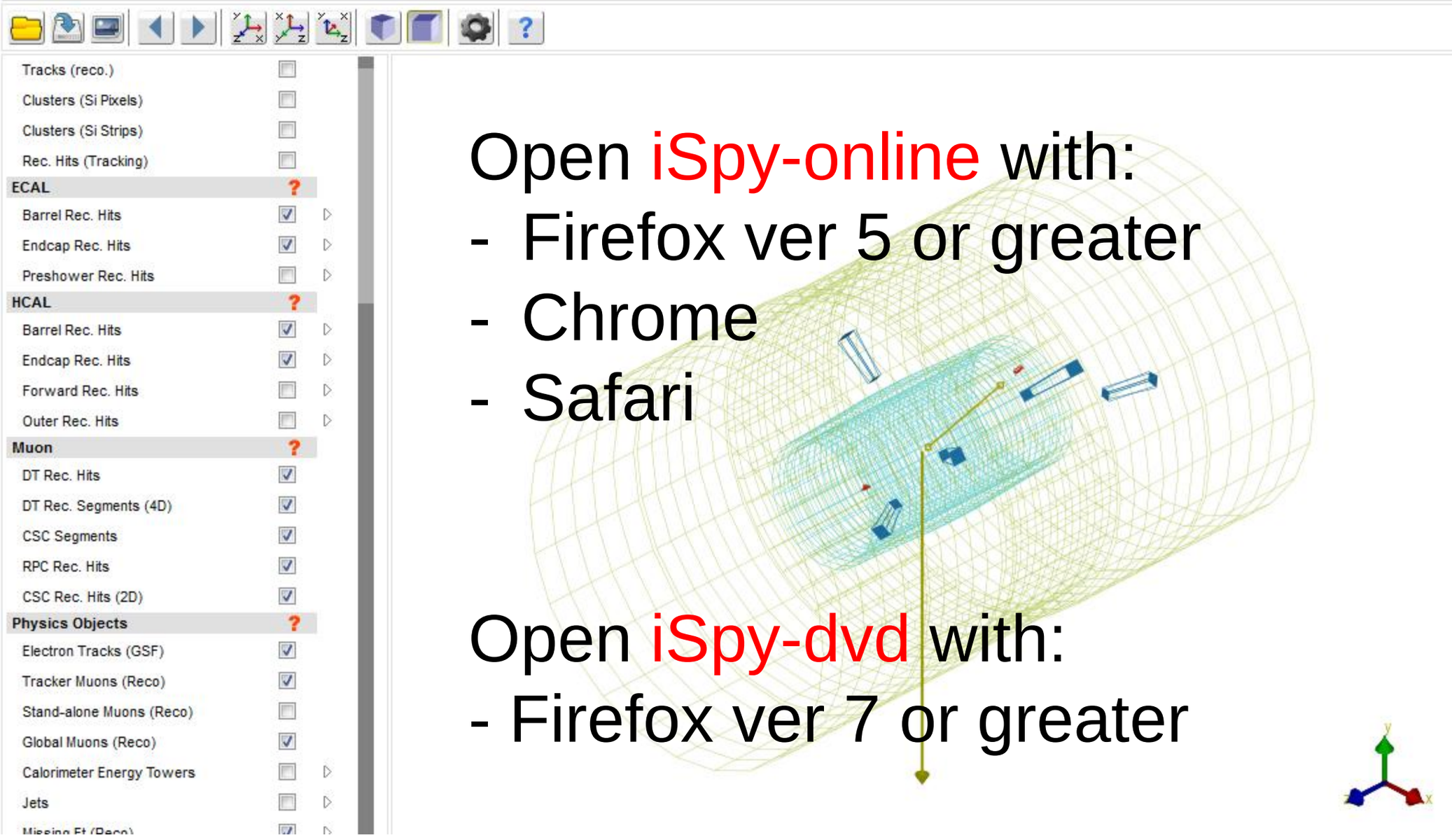
Try some real events



Open iSpy-online with:

- Firefox ver 5 or greater
- Chrome
- Safari

Open iSpy-dvd with:

- Firefox ver 7 or greater

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Recording event data

cms_mc_data_25jan2012.xls [Compatibility Mode] - Microsoft Excel

C102 = SUM(C2:C101)

	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		Student Instructions
2	X .01	X X X X X	1									1	Find the file in iSpy_online or iSpy_dvd that corresponds to this tab.
3	X .02	X X X X X		1	1							2	Start with the first event.
4	X .03	X X X X X		1	1							3	Make sure Event Nos. match on the display and in the spreadsheet row.
5	X .04	X X X X X	1						1			4	Determine if the tracks are electron or muon.
6	X .05	X X X X X		1	1							5	Put a 1 under **electron** or **muon**.
7	X .06	X X X X X	1			1						6	If the event is a W candidate, determine if it is W+ or W-.
8	X .07	X X X X X	1					1		80.55	80.55	7	Put a 1 under **W+ cand**, **W- cand**, or (if you cannot tell charge) **W cand**.
9	X .08	X X X X X		1		1						8	If the event is a Z candidate, put a 1 under **Z cand** instead.
10	X .09	X X X X X		1	1							9	If you indicate Z cand, a mass will appear in green under Z mass.
11	X .10	X X X X X	1						1			10	If you cannot tell what the particle is, put a 1 under **"zoo"**.
12	X .11	X X X X X	1						1			11	Go to the next event. Repeat Instructions 3-10 until this tab is done.
13	X .12	X X X X X	1		1							12	You will find the sums in line 102 in blue.
14	X .13	X X X X X	1			1						13	Find your row on the Results page (your tab number under **mc_no**).
15	X .14	X X X X X		1	1							14	Copy the sums onto the Results page under **electron-->"zoo"** in your row.
16	X .15	X X X X X		1	1							15	Totals for your Institute will update in purple on Results line 21.
17	X .16	X X X X X		1	1							16	Return to your mc_xx tab.
18	X .17	X X X X X	1			1						17	*Manually* copy numbers under **Z mass** to under **Zmass list** w/no spaces.
19	X .18	X X X X X		1	1							18	Copy your Zmass list (numbers only).
20	X .19	X X X X X		1	1							19	Go to Results tab. Find **Z cand masses** (line 21, left).
21	X .20	X X X X X	1				1					20	Find the last number entered in the column under **Z cand masses**.
22	X .21	X X X X X							1			21	Paste your list under that last number.
23	X .22	X X X X X	1		1							22	Go back and check your own totals in blue and the ratios below in red.
24	X .23	X X X X X		1	1							23	Discuss with others - create a buzz.
102		Sums -->	48.00	52.00	38.00	24.00	10.00	11.00	16.00	74.96			
103													
104			e/mu	W+/W-									
105		Ratios -->	0.923077	1.583333									

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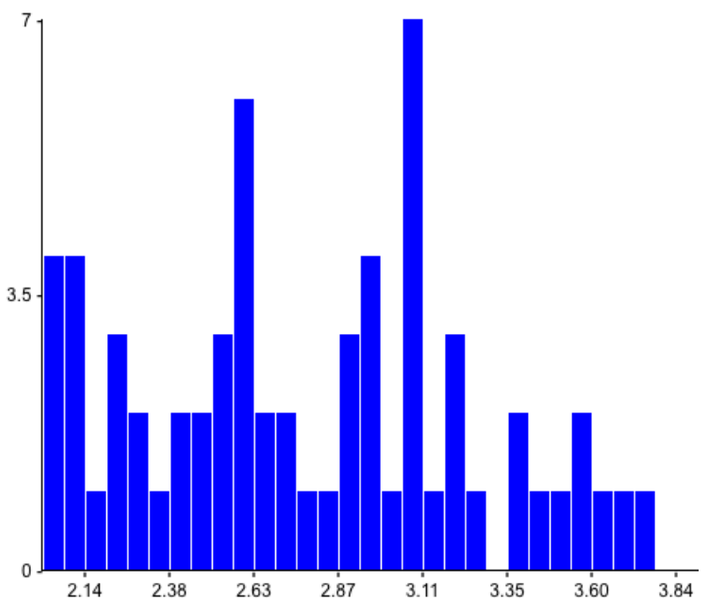
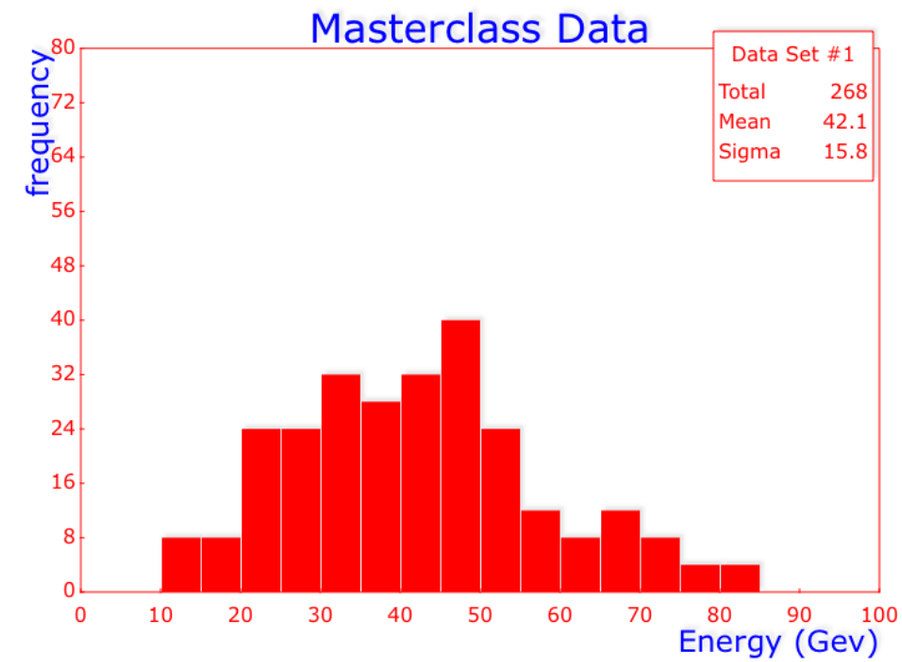
Histogram Review

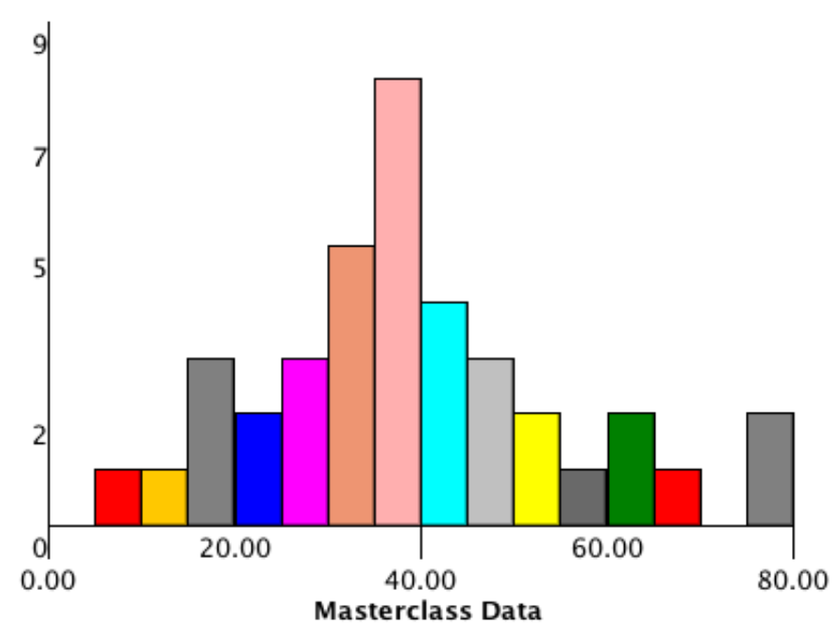




What do these histograms tell us?

Turn data into a histogram:

- http://folk.uio.no/frankol/masterclass/
- http://freyr.phys.nd.edu/~karmgard/histogram/
- http://www.shodor.org/interactivate/activities/Histogram/
- Spreadsheet
- Paper, chalkboard, or whiteboard



Keep in Mind . . .

"Science is nothing but developed perception, interpreted intent, common sense rounded out and minutely articulated." *George Santayana*

- Indirect observations and imaginative, critical, logical thinking can lead to reliable and valid inferences.
- Therefore: work together, think (sometimes outside the box), and be critical of each other's results to figure out what is happening.

Form teams of two. Each team analyzes 100 events.

Talk with physicists about interpreting events. Pool results.