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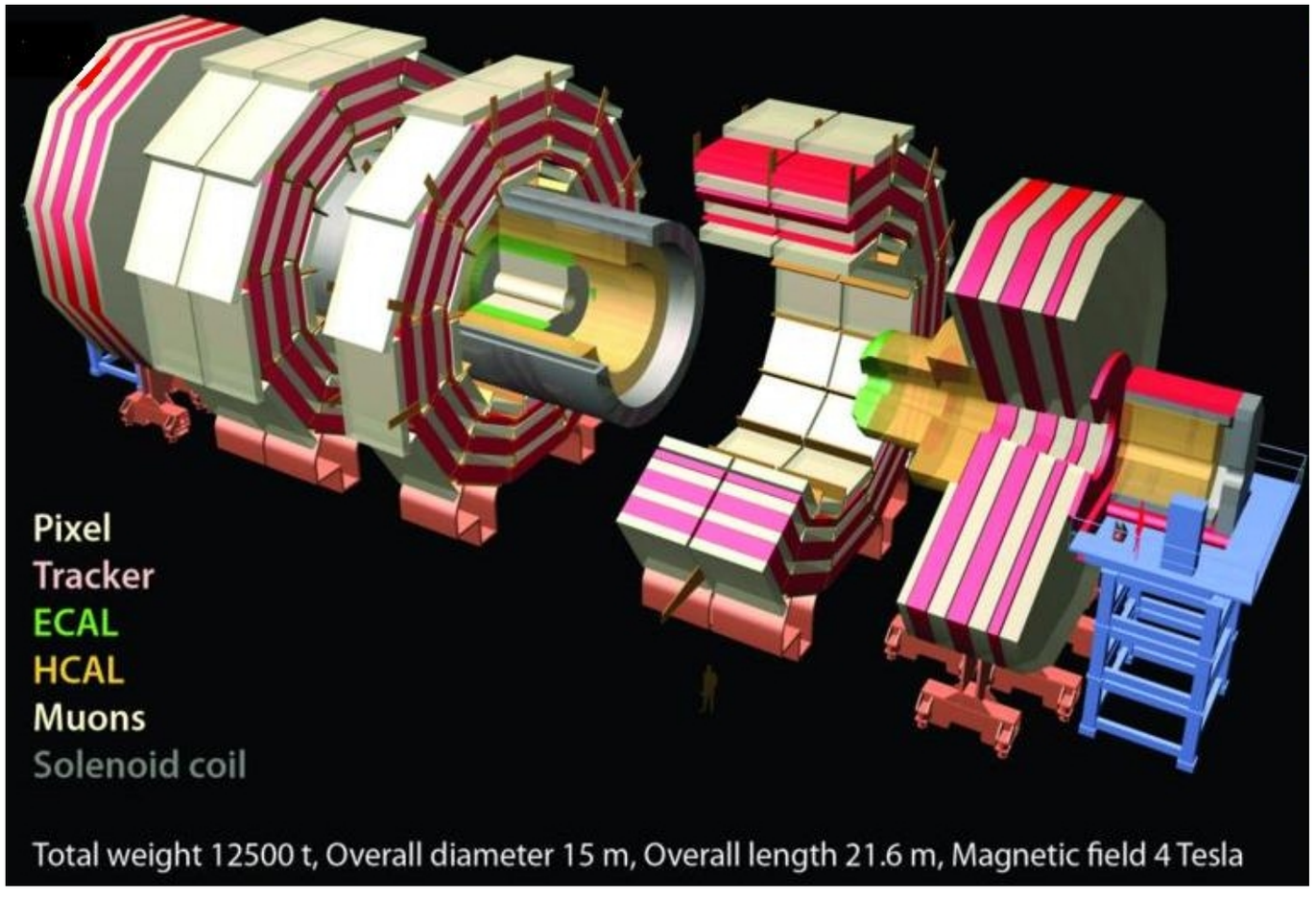
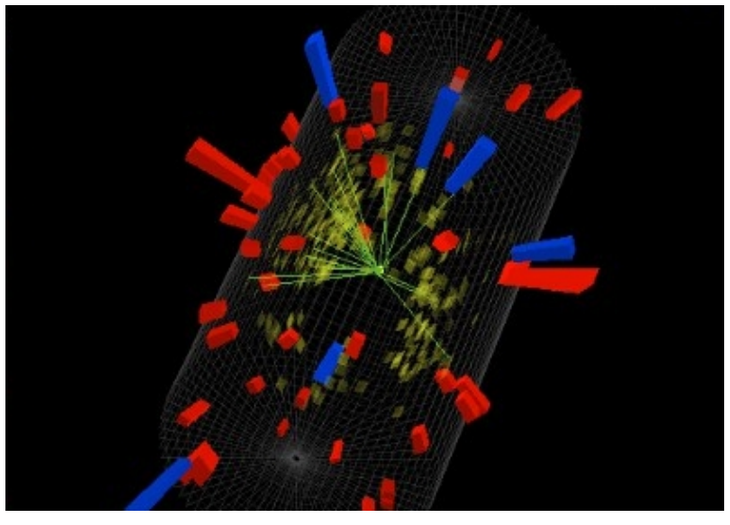
INTERNATIONAL MASTERCLASSES
hands on particle physics

CMS Masterclass 2015





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Detector Design

Generic Design

Cylinders wrapped around the beam pipe

From inner to outer . . .

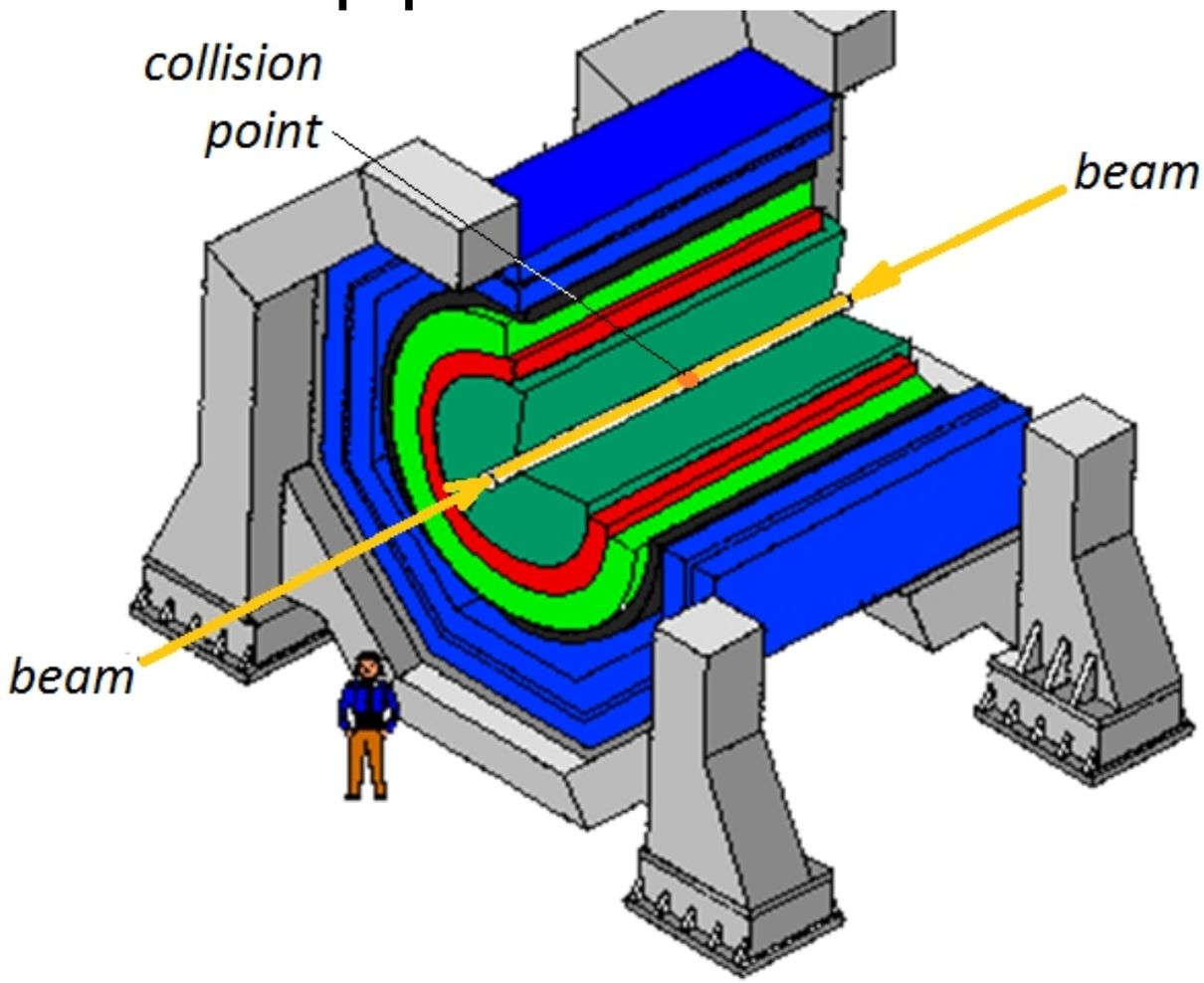
Tracking

Electromagnetic calorimeter

Hadronic calorimeter

Magnet*

Muon chamber



* *location of magnet depends on specific detector design*

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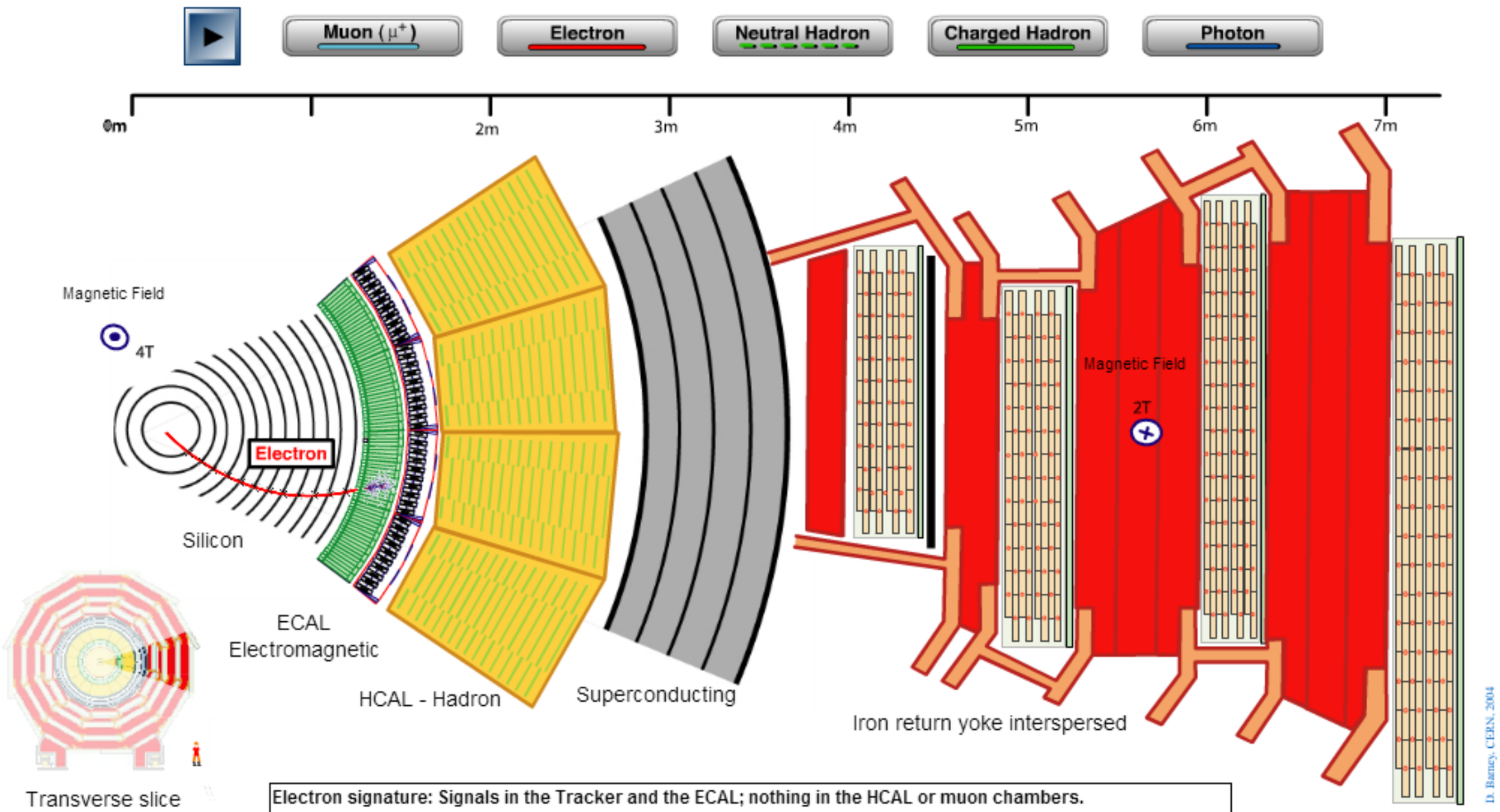
Detector Tracks

Web Vers

Transverse Slice of the Compact Muon Solenoid (CMS) Detector



Transverse slice through CMS

Electron signature: Signals in the Tracker and the ECAL; nothing in the HCAL or muon chambers.
These electrically charged particles bend in the field and leave signals in the Tracker, enabling their paths to be reconstructed. The amount of bend depends on the momentum they carry, with the radius of curvature, r, being given by the momentum, p, divided by 0.3xB, where B is the magnetic field strength (3.8T in CMS). Electrons are slowed to a stop in the transparent lead tungstate crystals of the ECAL, producing a **shower** of electrons, photons and positrons along the way and depositing their energy in the form of light, which is detected. The amount of light is proportional to the electron energy.

Derived from CMS Detector Slice from CERN

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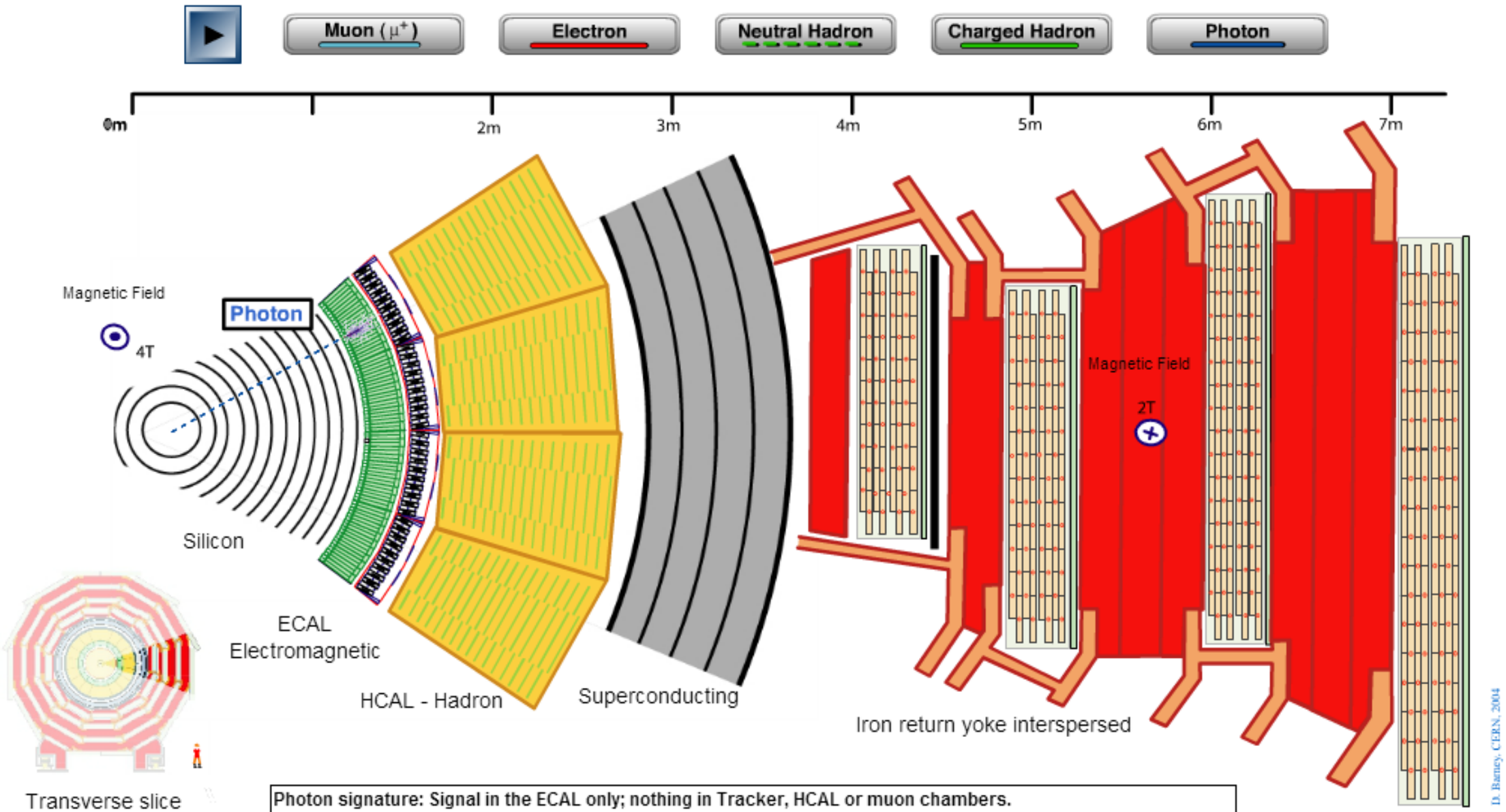
Detector Tracks

Web Vers

Transverse Slice of the Compact Muon Solenoid (CMS) Detector

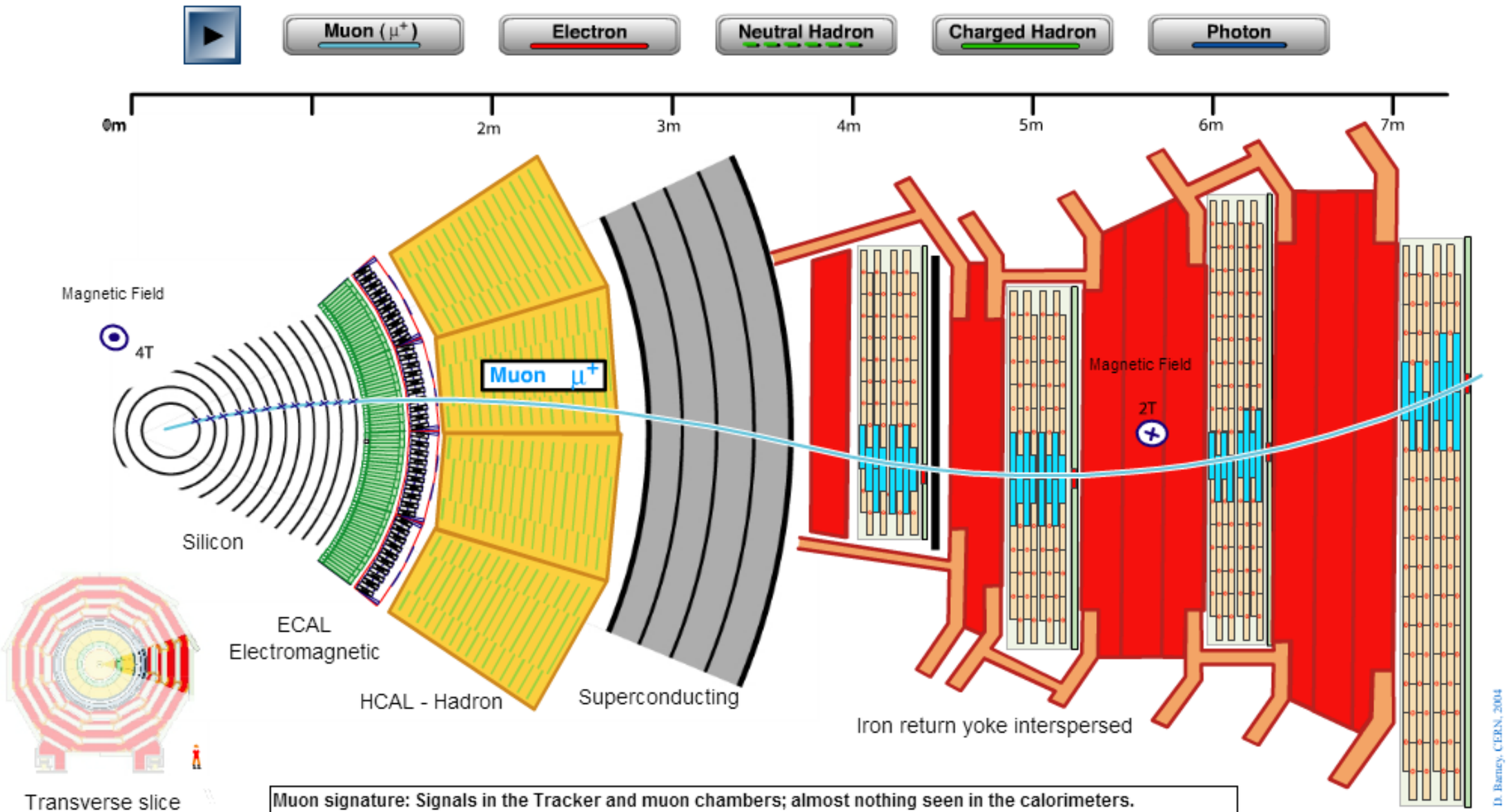


Transverse slice through CMS

Photon signature: Signal in the ECAL only; nothing in Tracker, HCAL or muon chambers.
Being electrically neutral, photons pass through the Tracker undetected and not bent by the magnetic field. They interact in the ECAL in a similar way to electrons, producing electromagnetic showers that leave their energies in the form of light that is detected.

Derived from CMS Detector Slice from CERN

Transverse Slice of the Compact Muon Solenoid (CMS) Detector



Transverse slice through CMS

Muon signature: Signals in the Tracker and muon chambers; almost nothing seen in the calorimeters.
Muons are perhaps the easiest particles to identify in CMS: no other charged particle traverses the whole detector. Being charged, they are bent by the field in one direction inside the solenoid and in the opposite direction outside. As muons can only arise from the decay of something heavier their presence signifies that something potentially interesting has happened.

Derived from CMS Detector Slice from CERN

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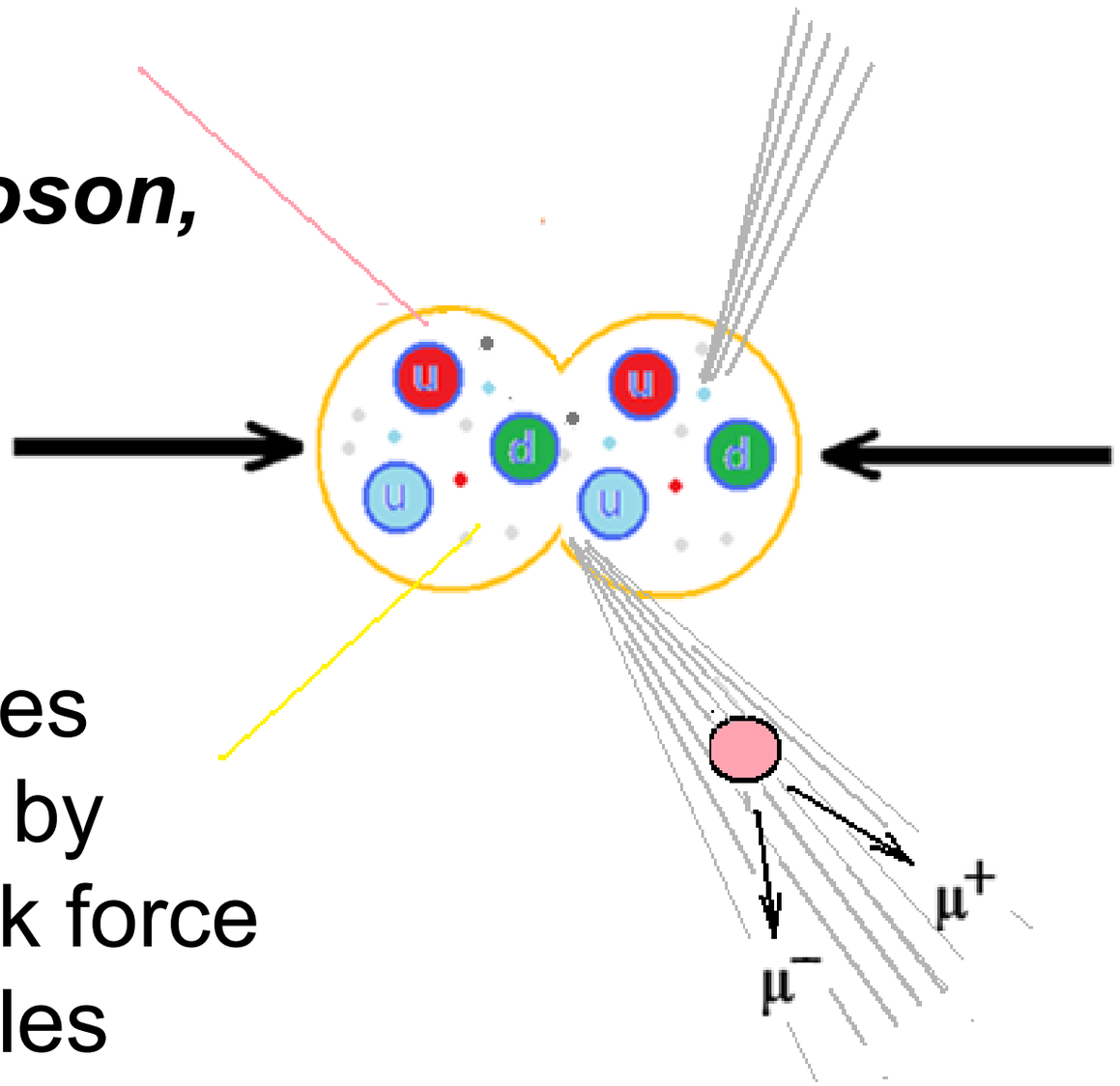
W and Z Particles

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.

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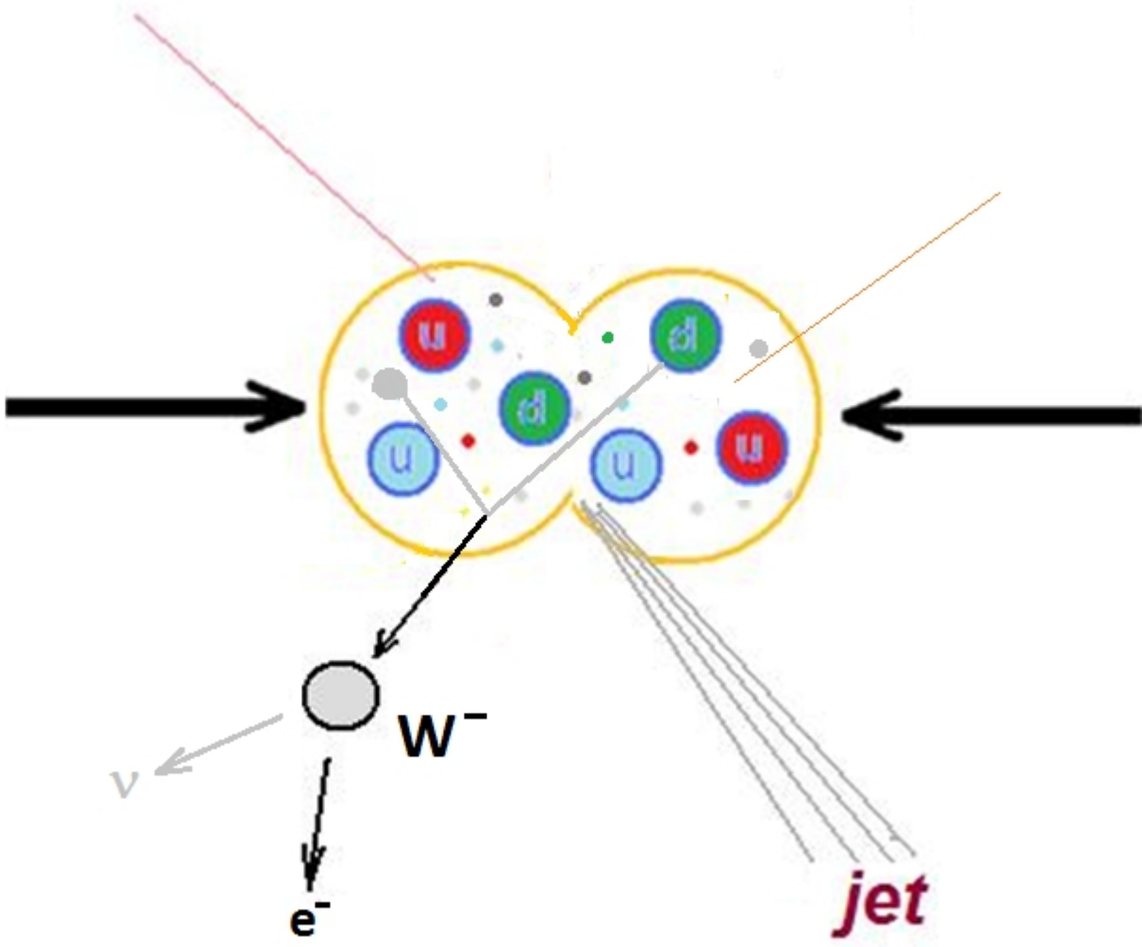
W and Z Particles

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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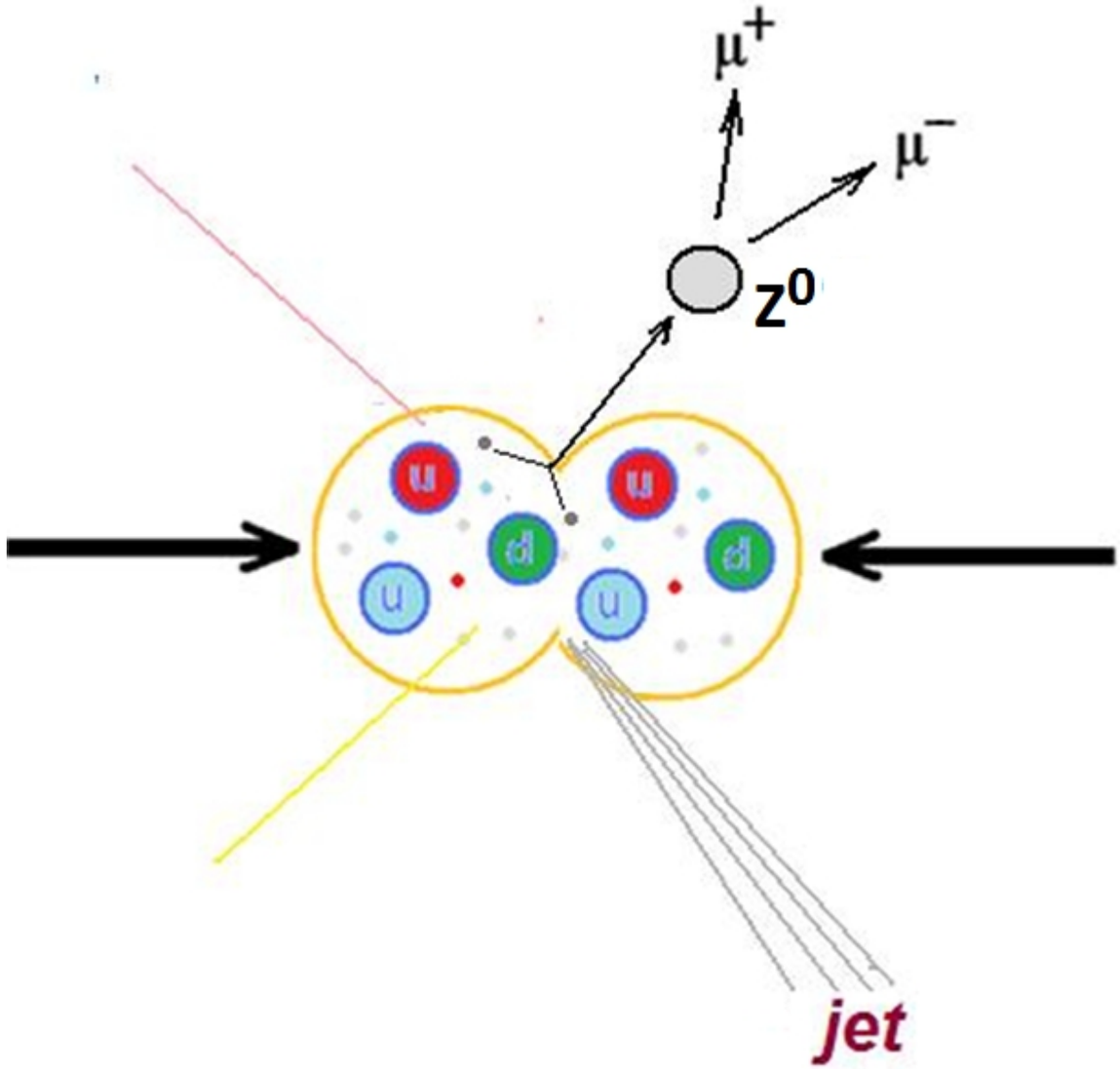

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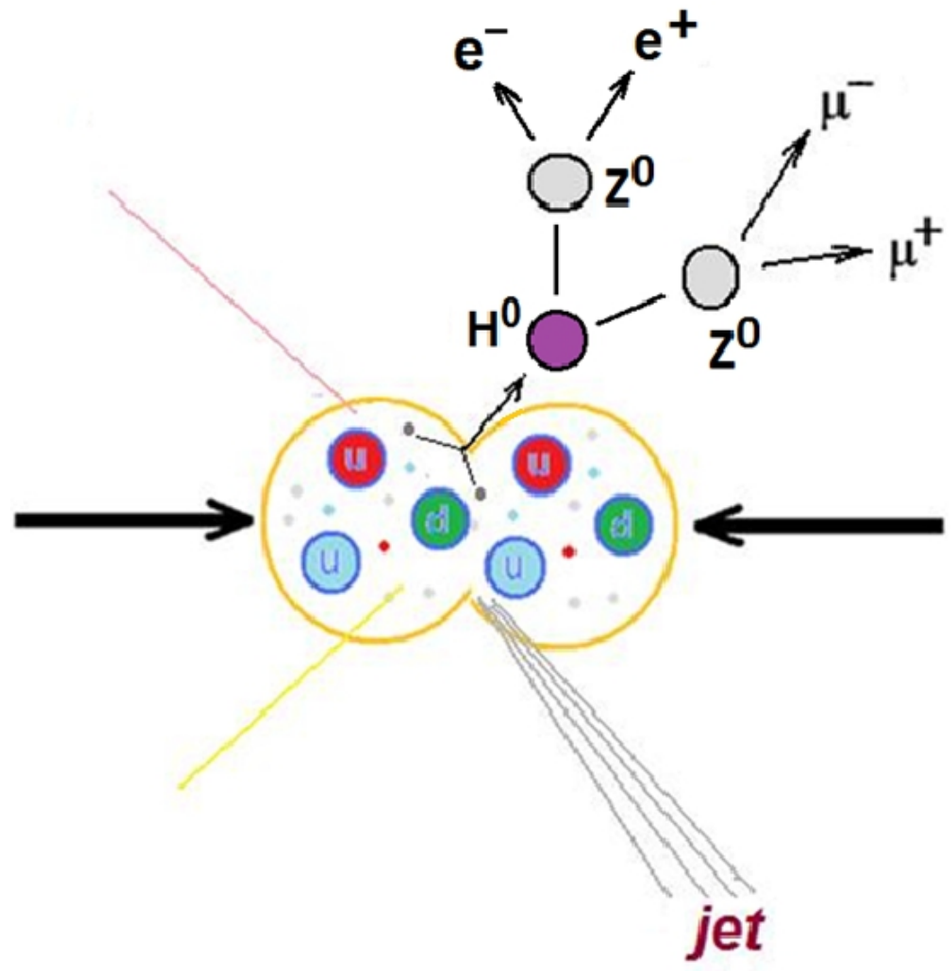
Higgs Particles

The Higgs boson was discovered by CMS and ATLAS and announced on July 4, 2012.

This long-sought particle is part of the "Higgs mechanism" that accounts for other particle having mass.



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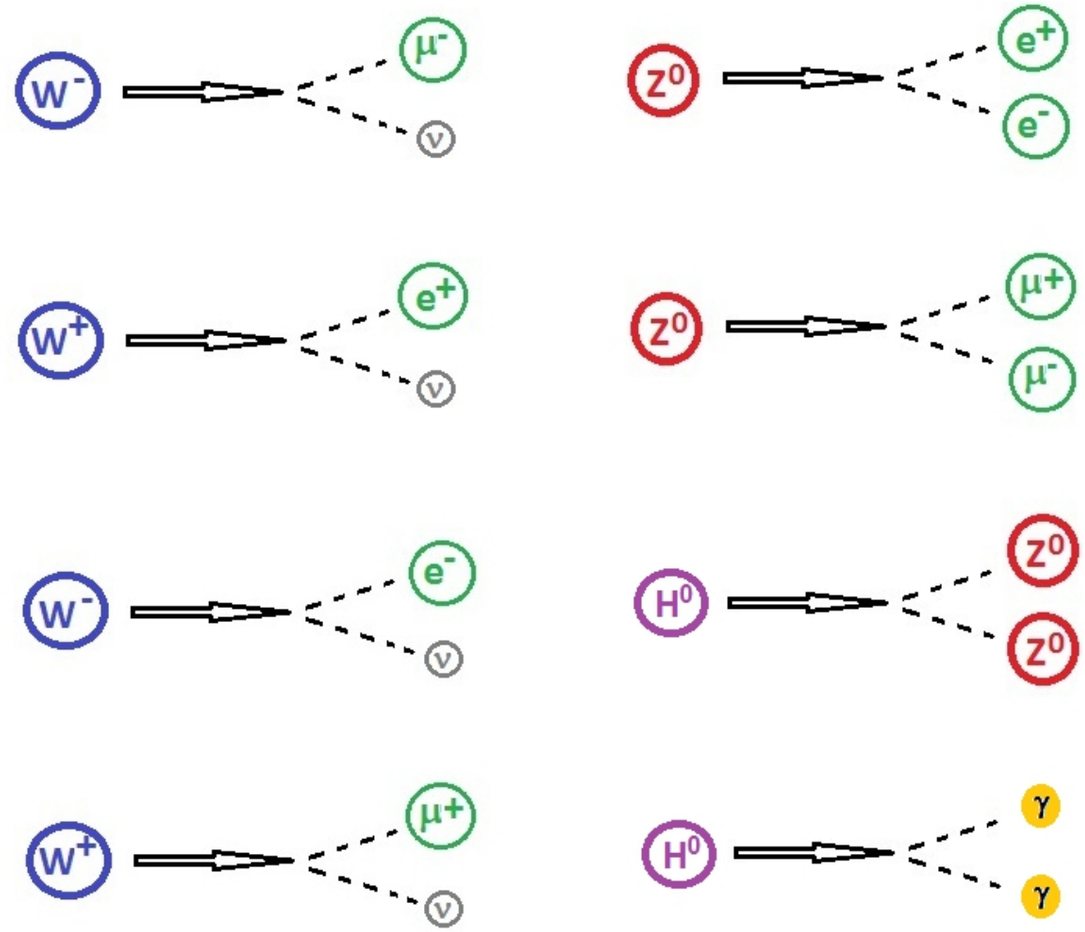
W and Z Decays

Because bosons only travel a tiny distance before decaying, CMS does not "see" them directly.

CMS *can* detect :

- electrons
- muons
- photons



CMS can infer:

- neutrinos from "missing energy"

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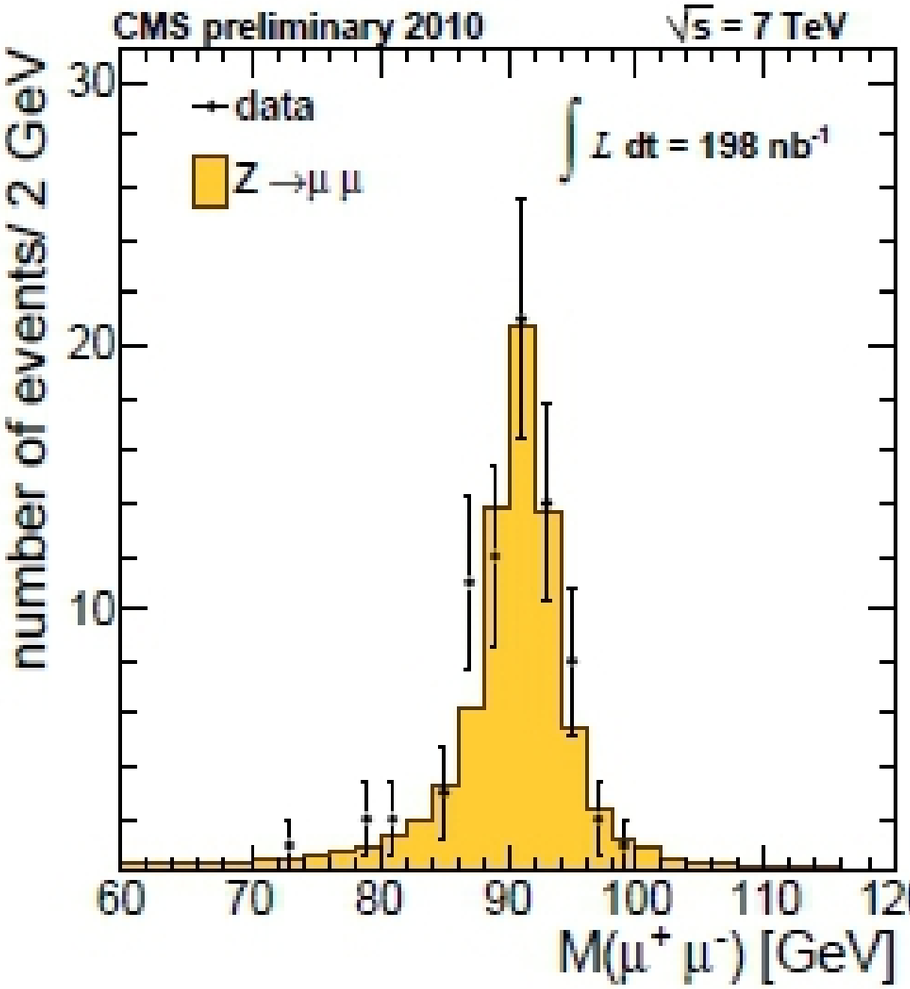
W and Z Decays

Goal for today's exercise:

Look through event displays to classify whether events came from a W,Z, or H boson and the final state (e.g., muons)

Attempt to 'see' the Z, H bosons by making a mass histogram

Bonus: Measure the universality of leptons: do we make more electrons than muons?



W and Z Decays

BACKUP

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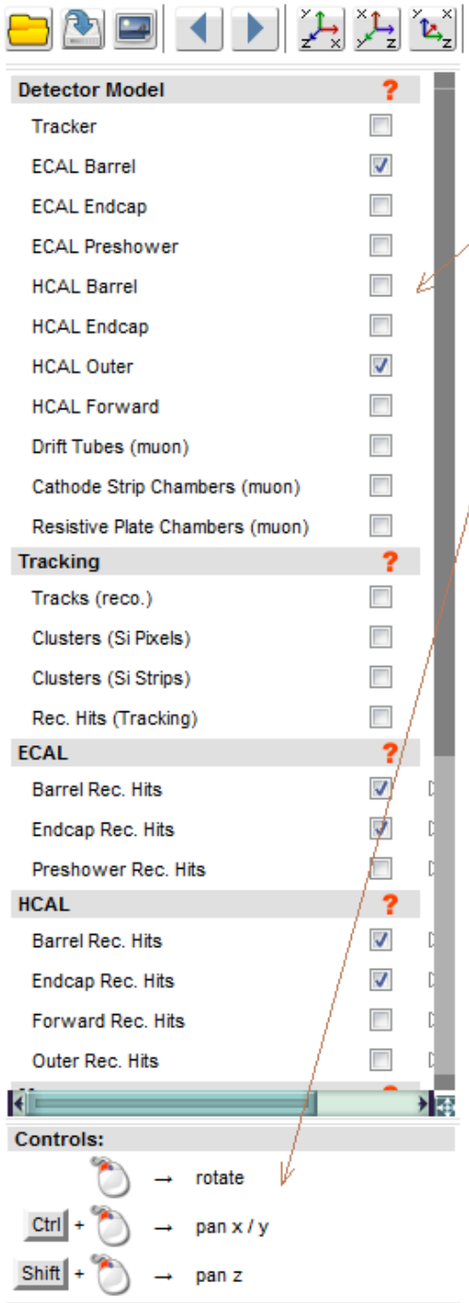
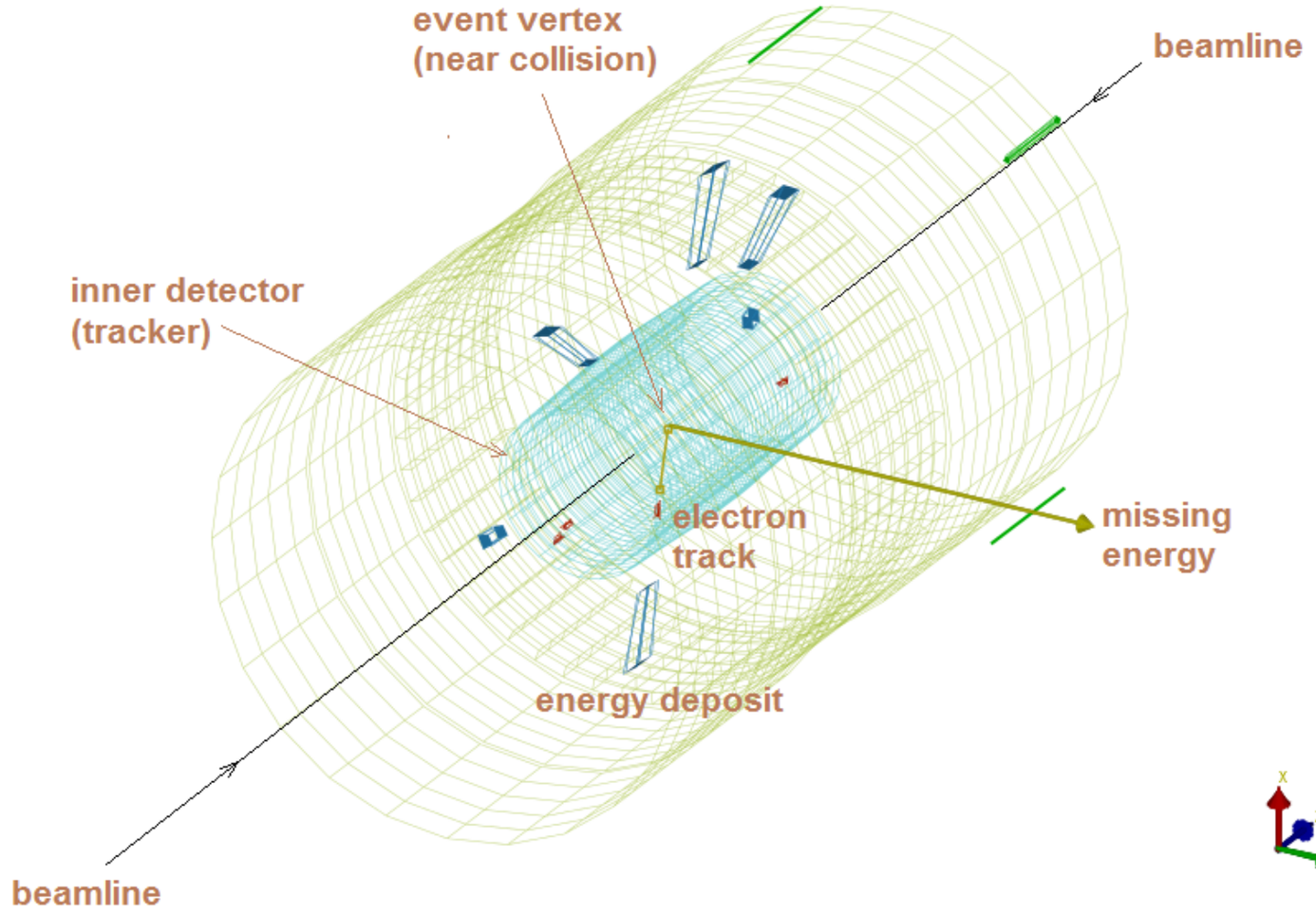
iSpy-online



event display controls



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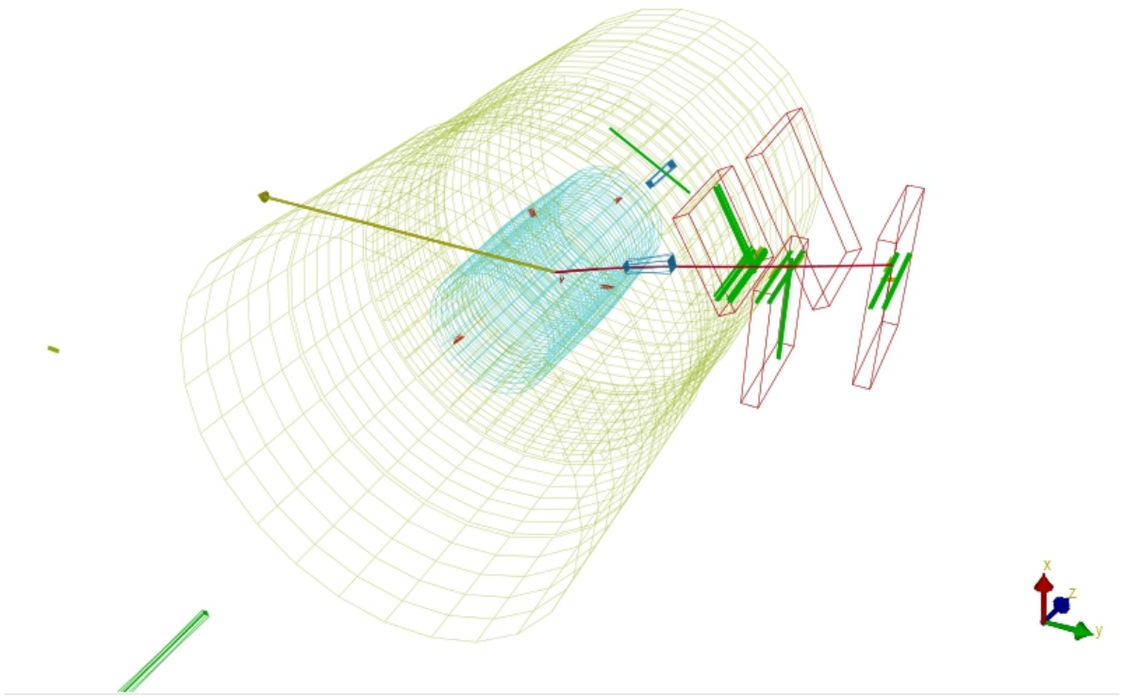
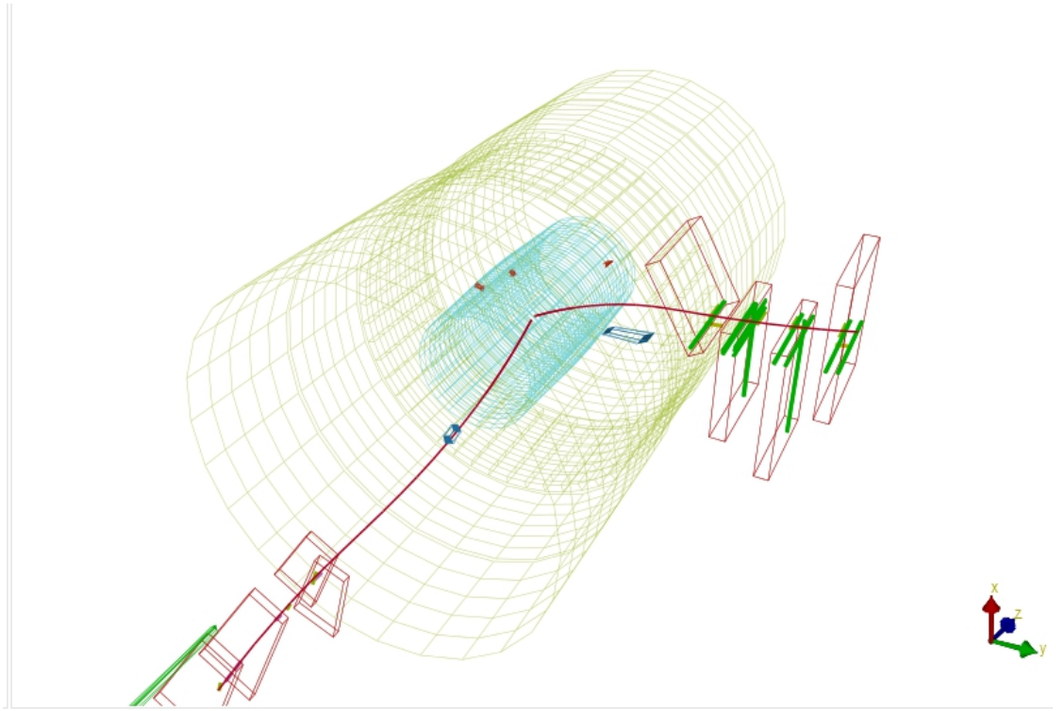
Today's Task

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

- Can we distinguish W from Z candidates?





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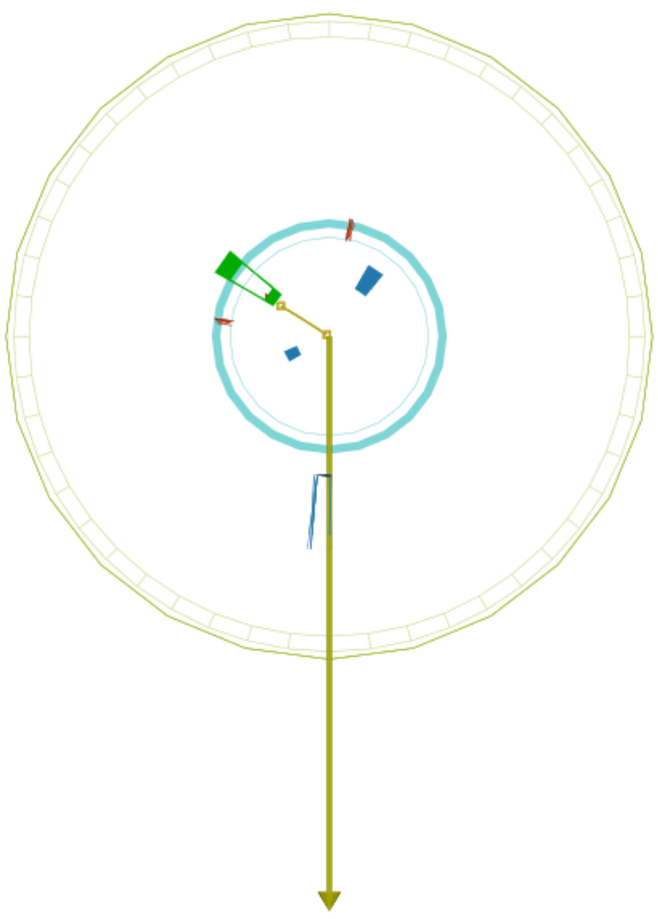
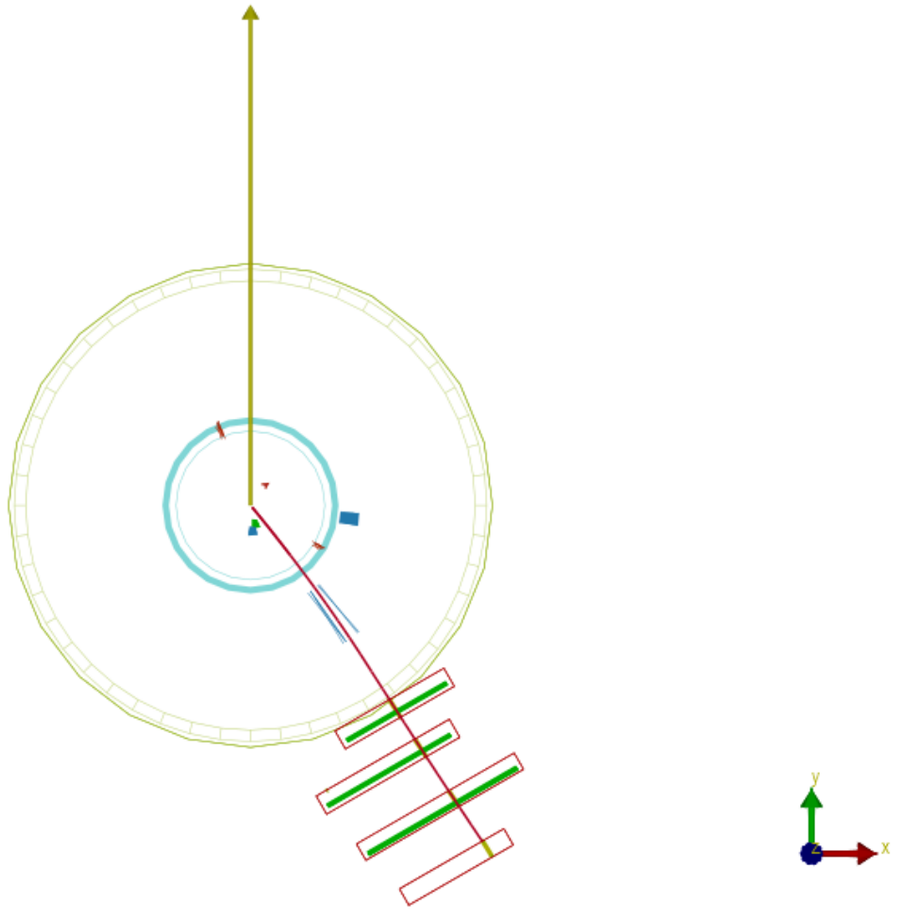
Today's Task

- Can we calculate the e/⌈ ratio?





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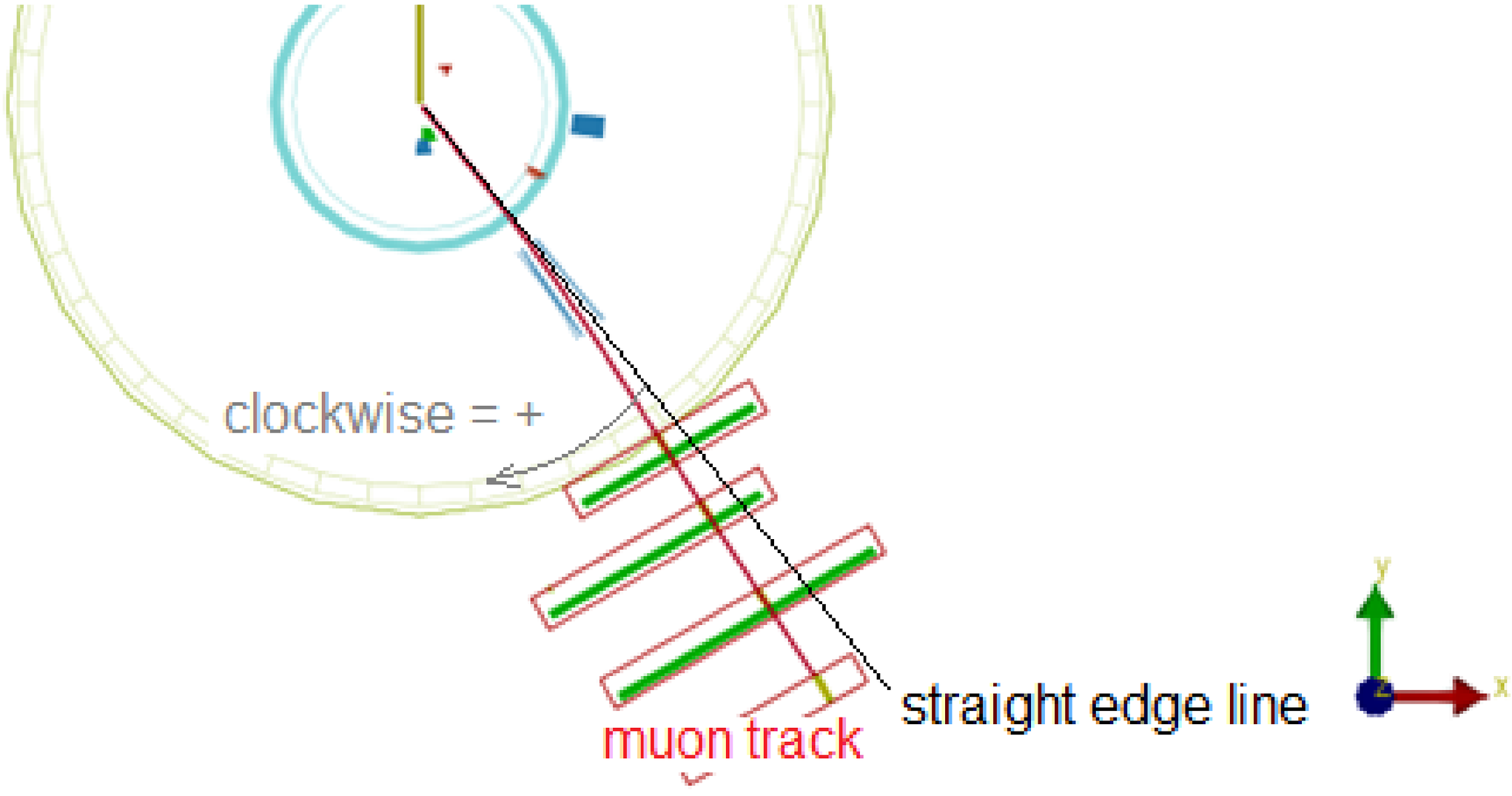
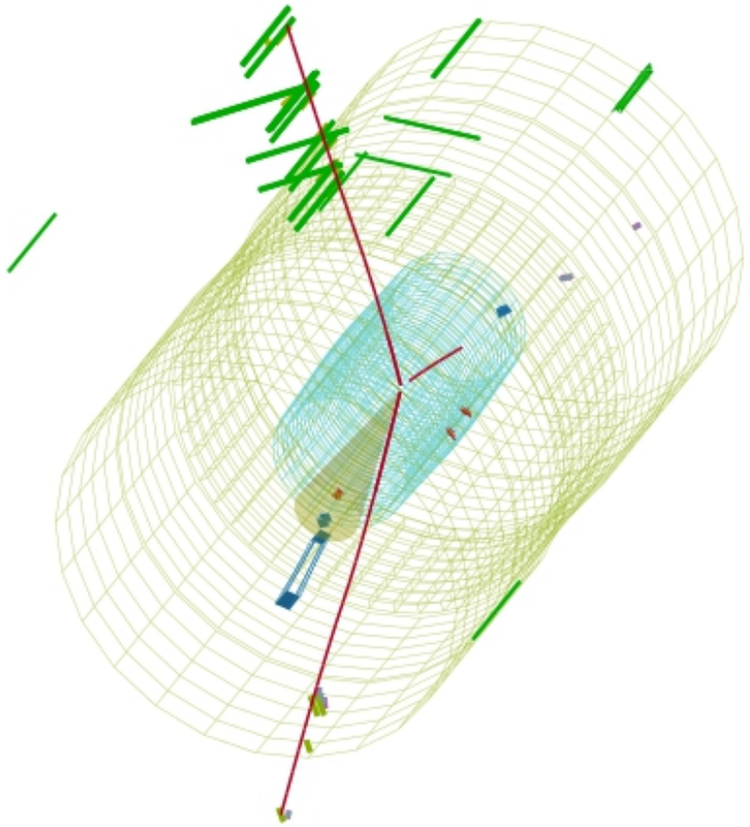
Today's Task

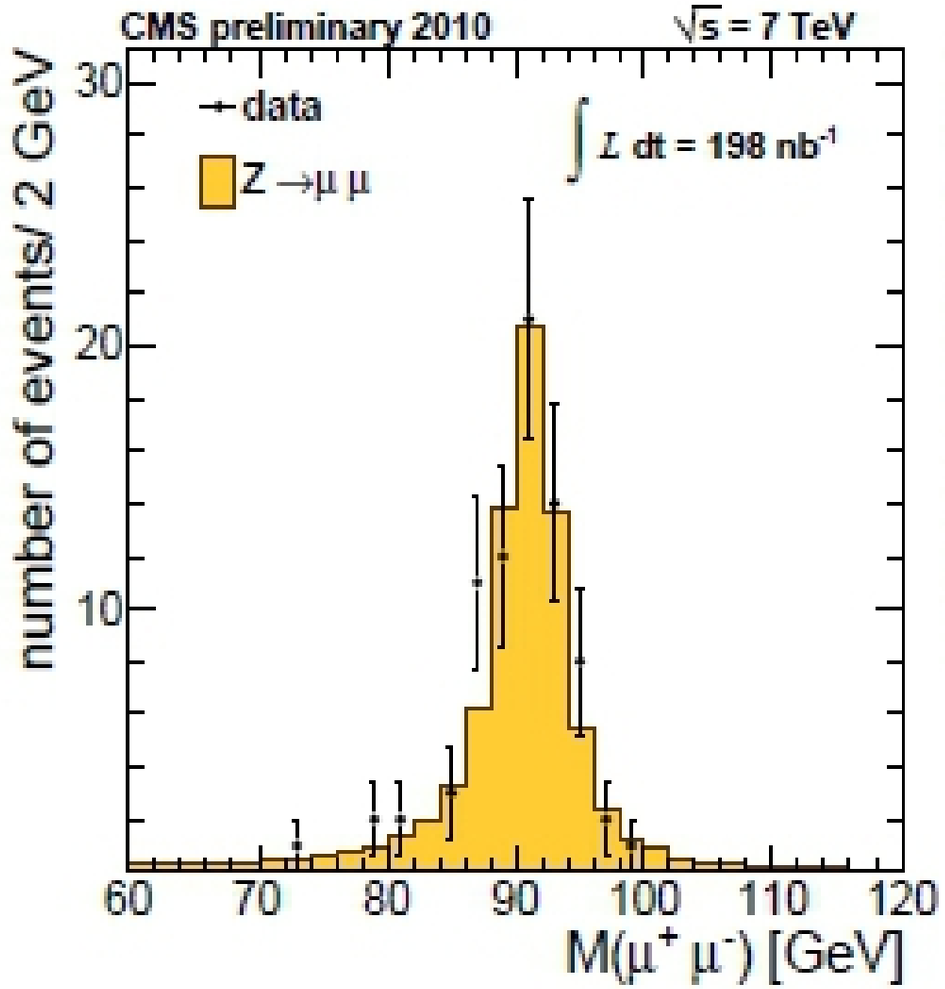
- Can we calculate a W+/W- ratio for CMS?



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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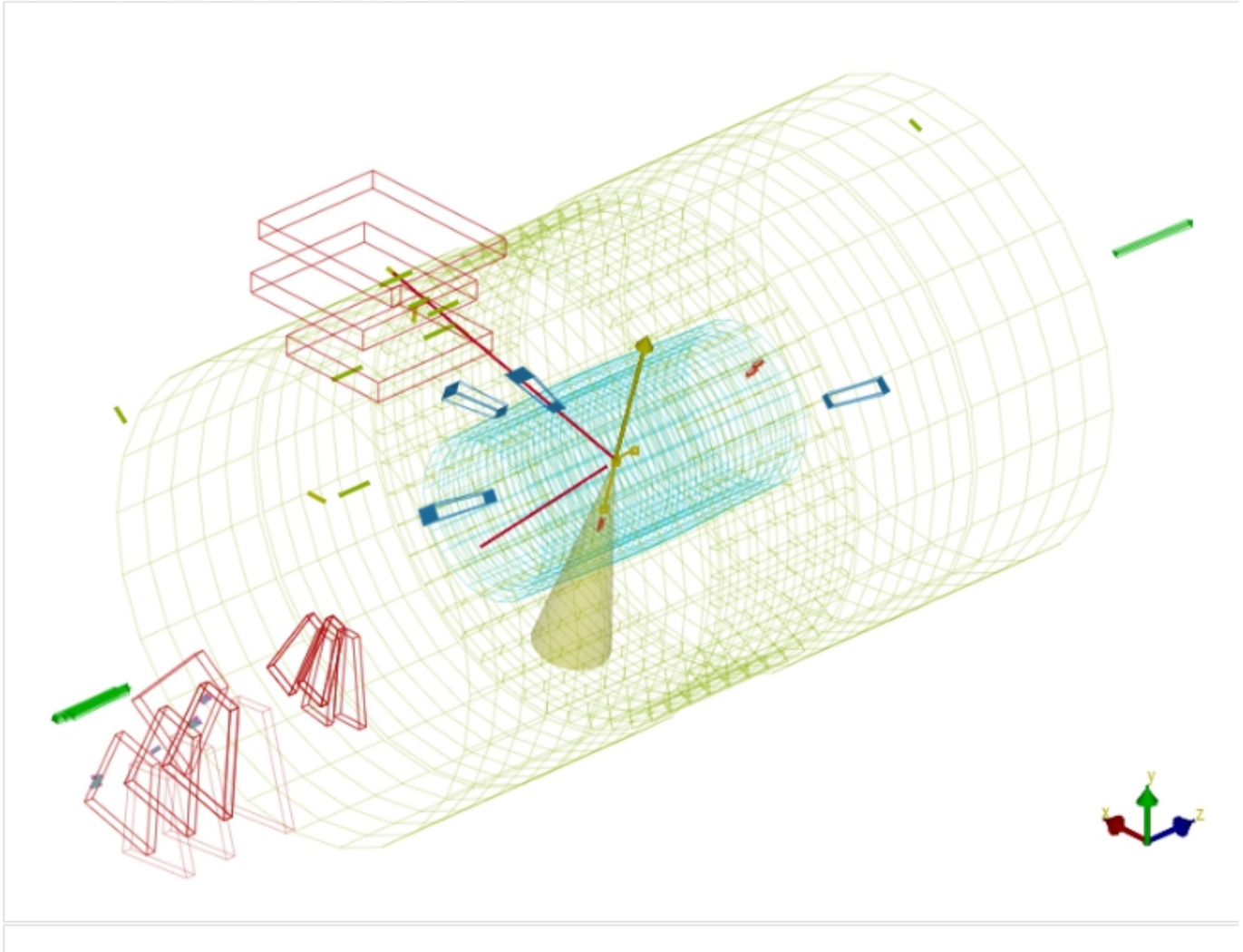
Today's Task

- Can we find rare H→ZZ events?
  - Z → e+e-
  - Z → ⌈ +⌈ -

Can we pick out electrons and/or muons?

How should an event be filtered so we can recognize the correct tracks?



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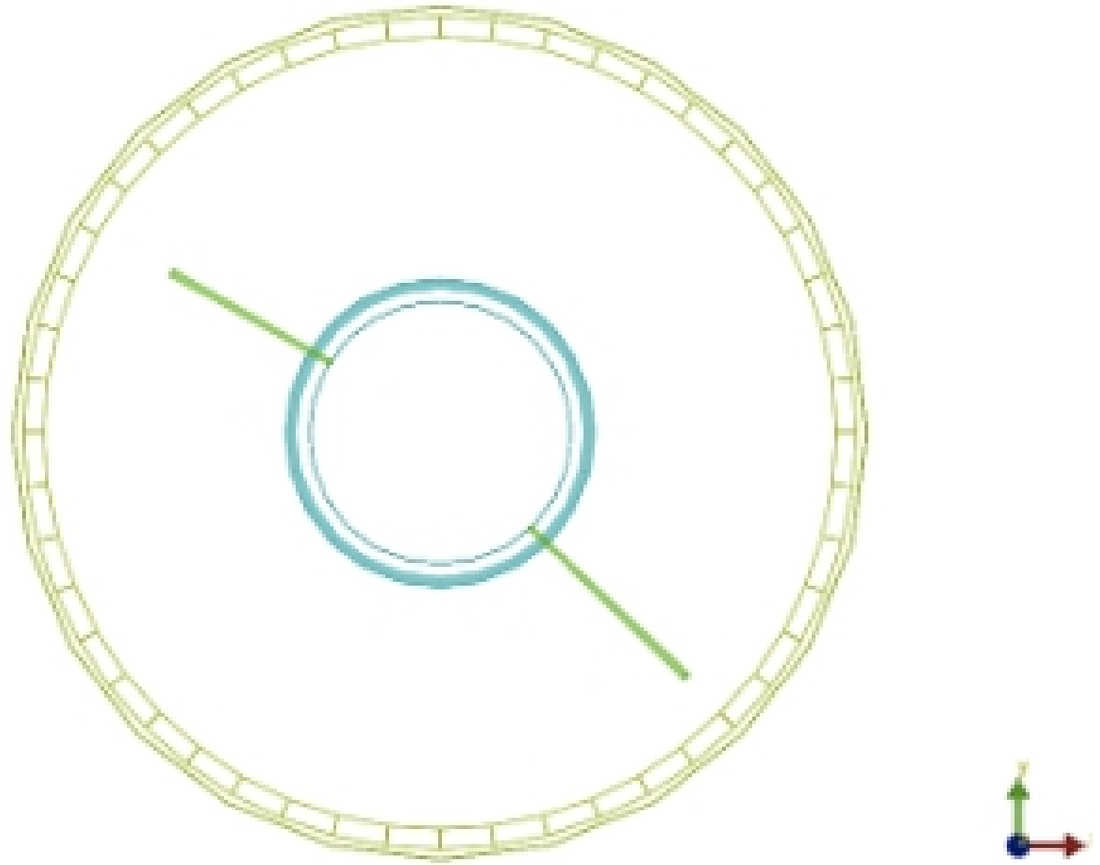
Today's Task

- Can we find some H→⌈ ⌈ events?



How do we spot photons that leave no track?

Where should we look? What should we see – and not see?

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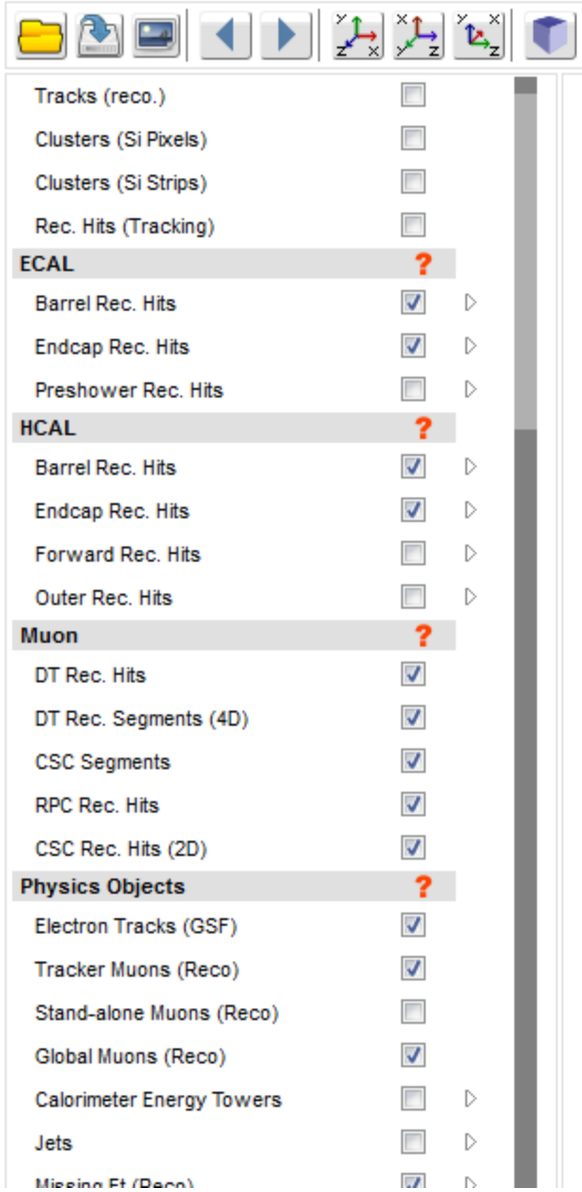
Try some real events



Open iSpy-online with:

- Firefox ver 5 or greater
- Chrome
- Safari

Open iSpy-dvd with:

- Firefox ver 7 or greater

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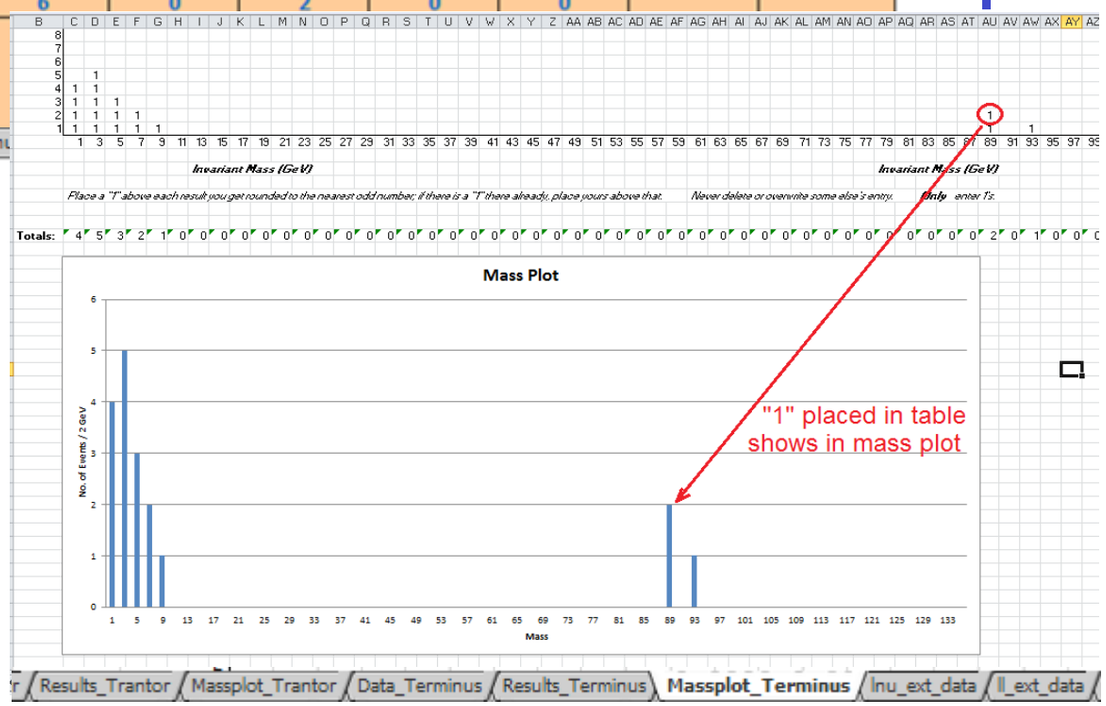
Recording event data

Dataset	Ord No	Ev No	electron	muon	W+ cand	W- cand	W cand	Z cand	"zoo"	H cand	Mass	Mass-->odd
masterclass_1	1	104488192	1			1						
masterclass_1	2	104883322	1		1							
masterclass_1	3	106817913	1			1						
masterclass_1	4	109019570		1		1						
masterclass_1	5	110202776	1		1							
masterclass_1	6	111147144	1			1						
masterclass_1	7	143928422	1			1						
masterclass_1	8	145942990	1					1			89.40	89
masterclass_1	9	149498854	1					1			93.61	93
masterclass_1	10	150447432		1		1						
masterclass_1	11	151909513										
masterclass_1	12	152676268										
masterclass_1	13	155762440										
masterclass_1	14	157942843										
masterclass_1	99	95617291										
masterclass_1	100	96831177										
		Sums -->	8	2	2	6	0	2	0	0		
						e/mu	W+/W-					
		Ratios -->				4	0.33333333					

Results_Trantor | Massplot_Trantor | Data_Terminus | Results_Terminus | Massplot_Terminu



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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.