CMS Data Analysis

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Available Data Sets

- 2000 di-muon events around the J/ψ
- 2000 di-electron events around the J/ψ
- 2000 di-electron events around the Y
- 100,000 di-muon events in the invariant mass range 2-110 GeV
- 100,000 di-electron events in the invariant mass range 2-110 GeV
- 500 di-electron events around the Z boson
- 500 di-muon events around the Z boson
- 500 events of W to eν
- 500 events of W to μν
- 13 Higgs candidate events: H to γγ, 4e, 2e2μ, 4μ
- ~50 1/pb single muons for top quark analysis (508,561 events)

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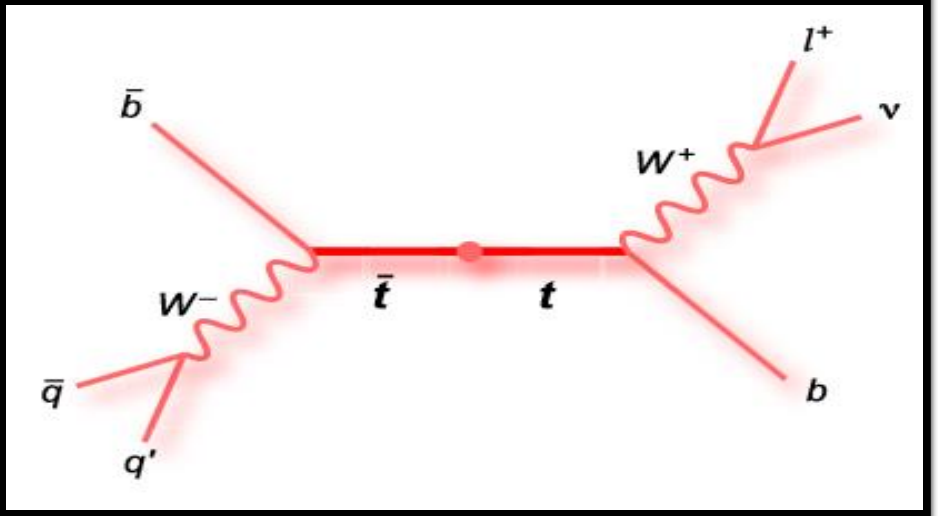
Why the $t\bar{t}$ Data Set?

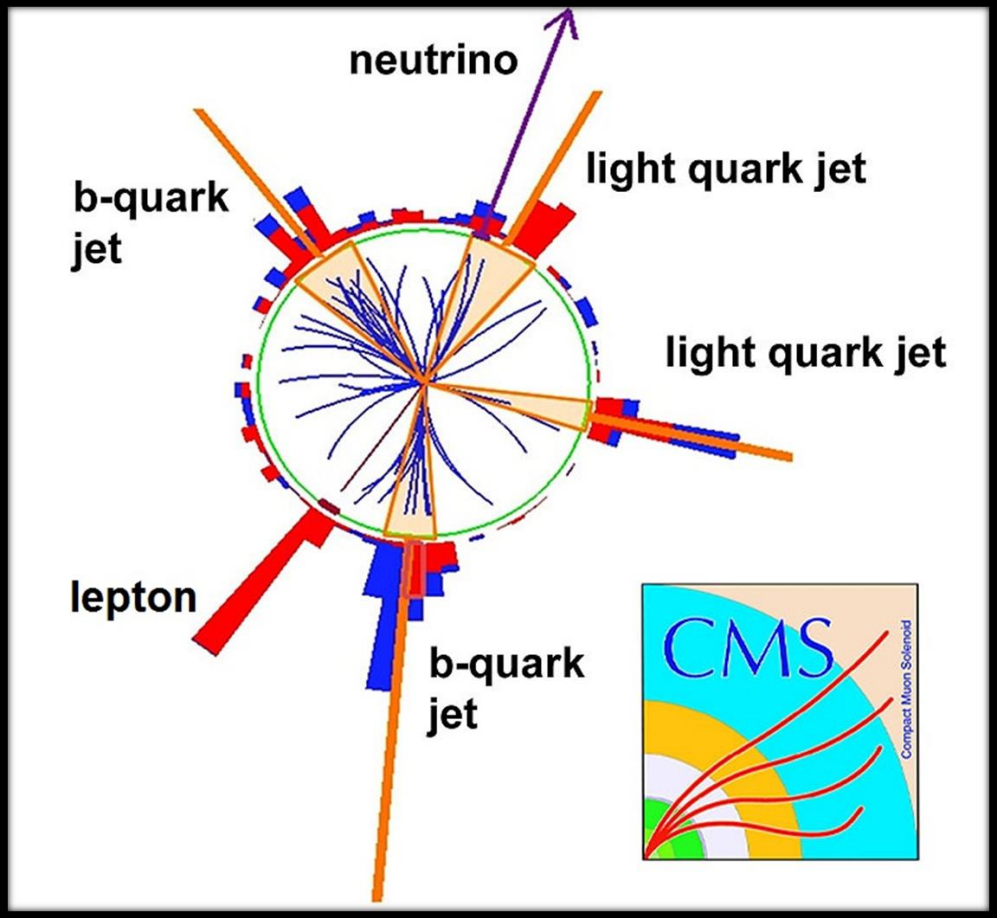
- Reasons for chosing the $t\bar{t}$ data set:
  - well-designed accompanying activity
  - activity requires use of simulated data to determine cuts and efficiencies
  - provides an opportunity to learn Linux, C++, and ROOT

Preparatory Activity

- We downloaded data and several example programs to our local Linux machine
  - created individual accounts for each member of the group
- We used MobaXterm to give us virtual terminals on that machine to access the data
- We studied C++ for two weeks before starting work with ROOT

$t\bar{t}$ Events

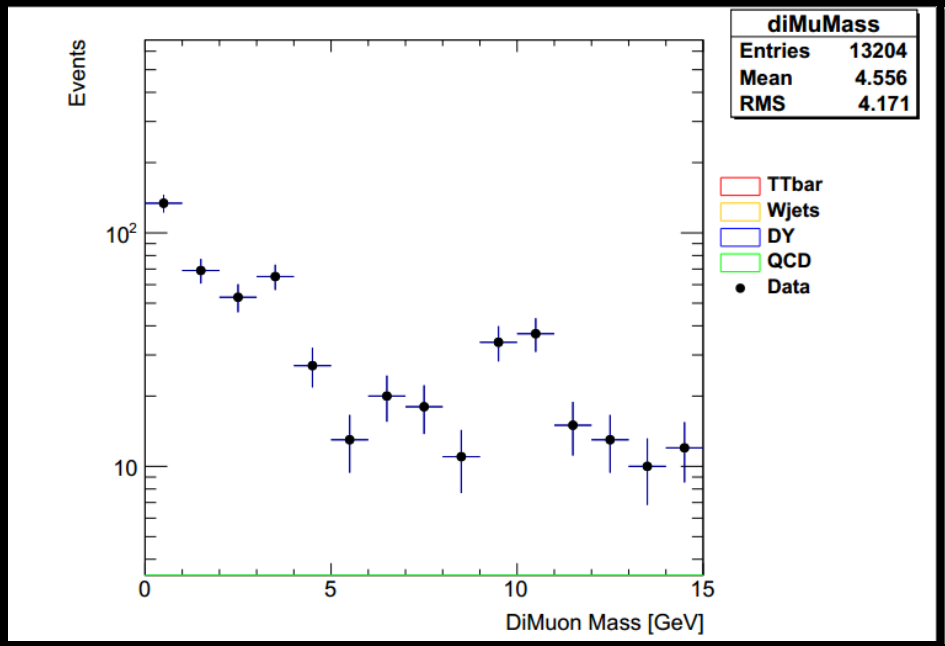


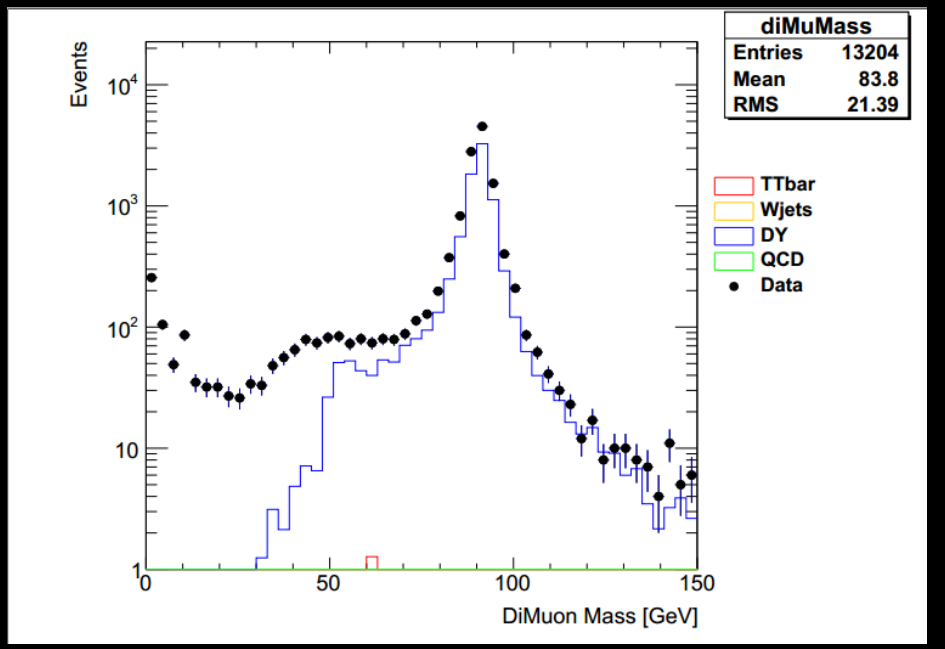


Preliminary Plots

1. Diagnostic Plots

2. DiMuon Mass Plots





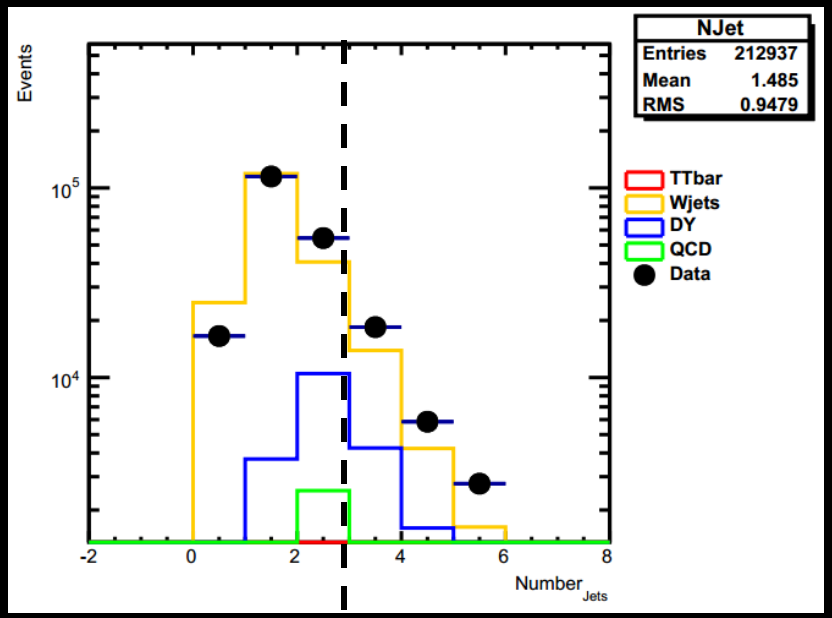
Enriching the Top Content of the Data Sample: Strategy

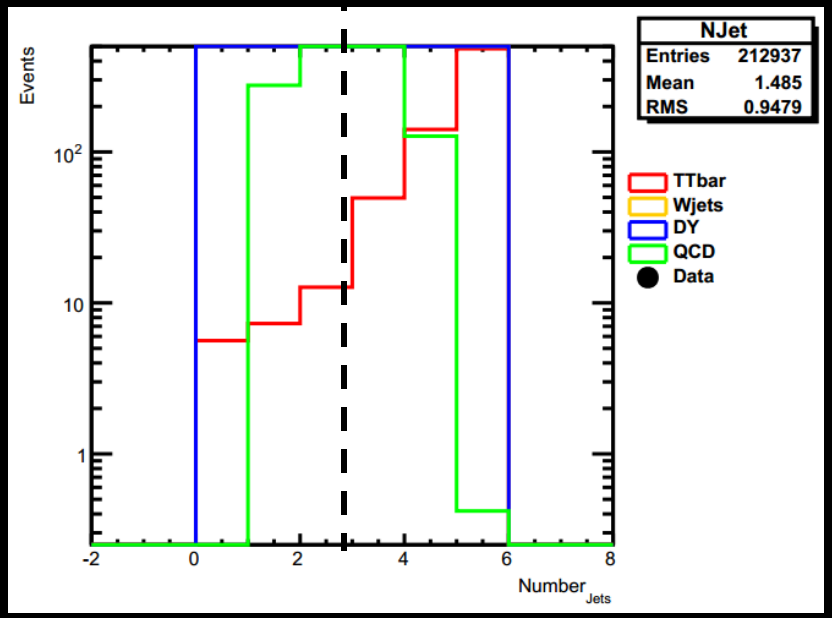
- Identify measured quantities that allow us to distinguish between $t\bar{t}$ events and expected background
- Number of simulated events
  - $t\bar{t}$: 383,167 (signal)
  - Drell-Yan: 109,656 (background)
  - W + Jets: 76,196 (background)
  - QCD: 137 (background)

  total: 569,156

Enriching the Top Content of the Data Sample

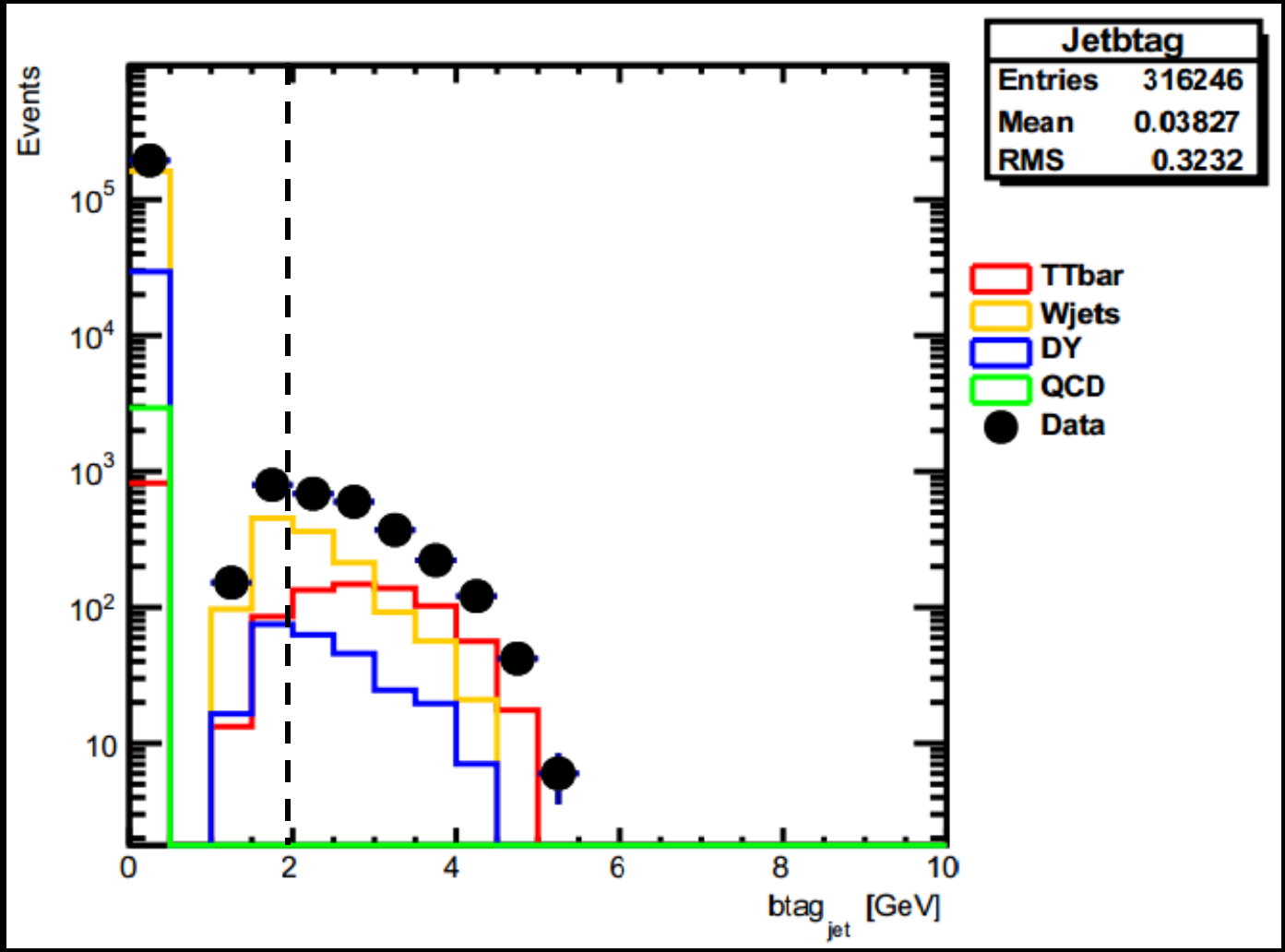
- NJets





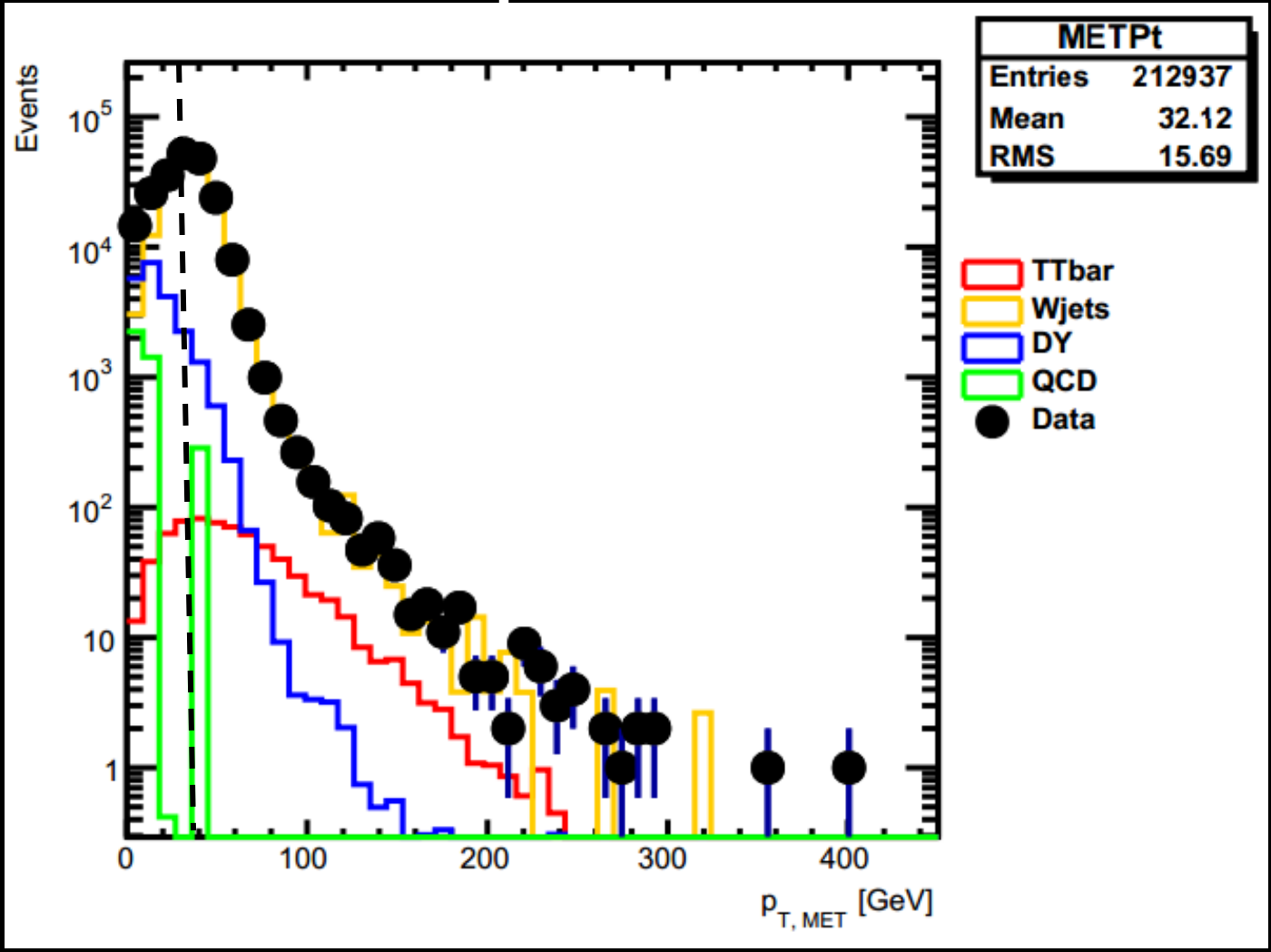
Enriching the Top Content of the Data Sample

- bTags



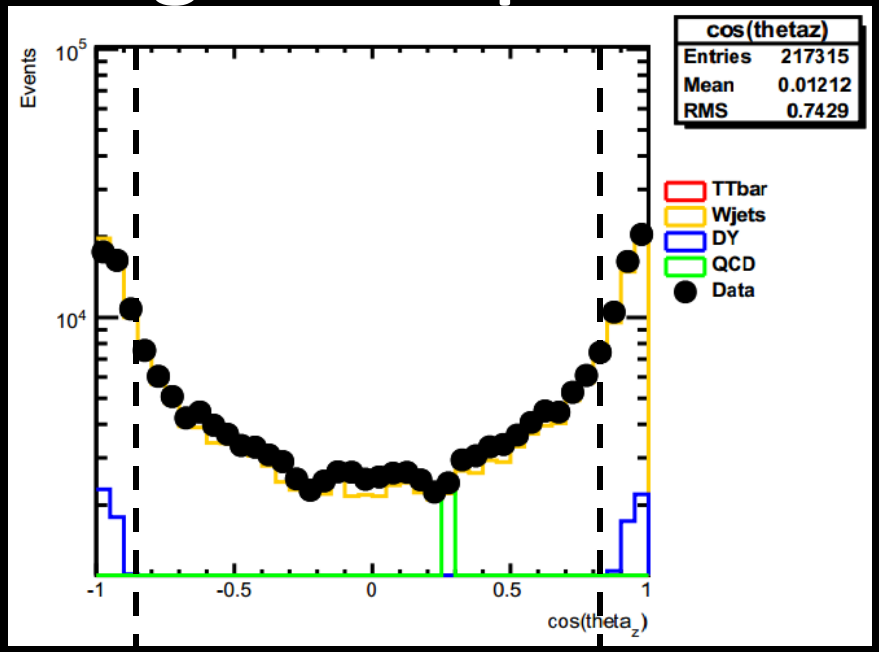
Enriching the Top Content of the Data Sample

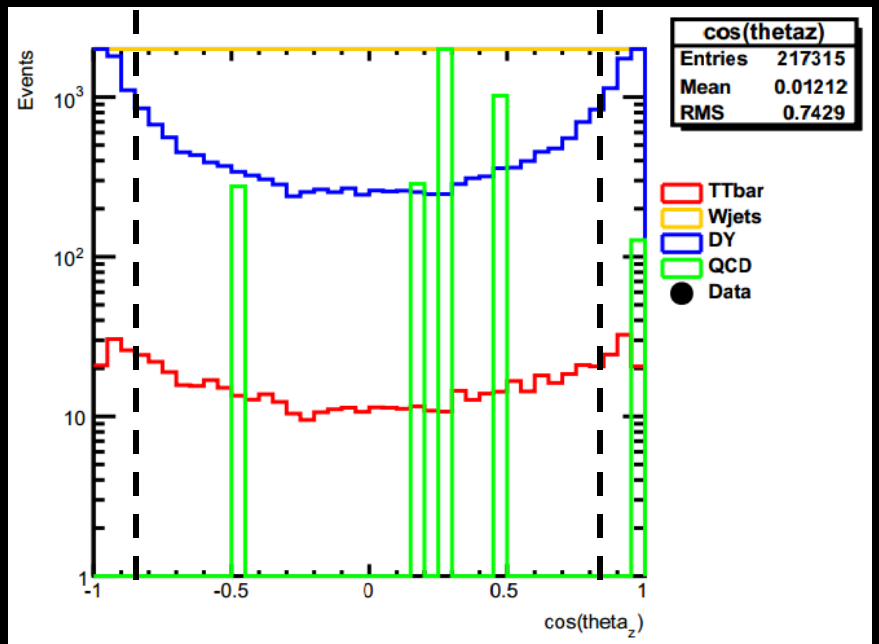
- MET



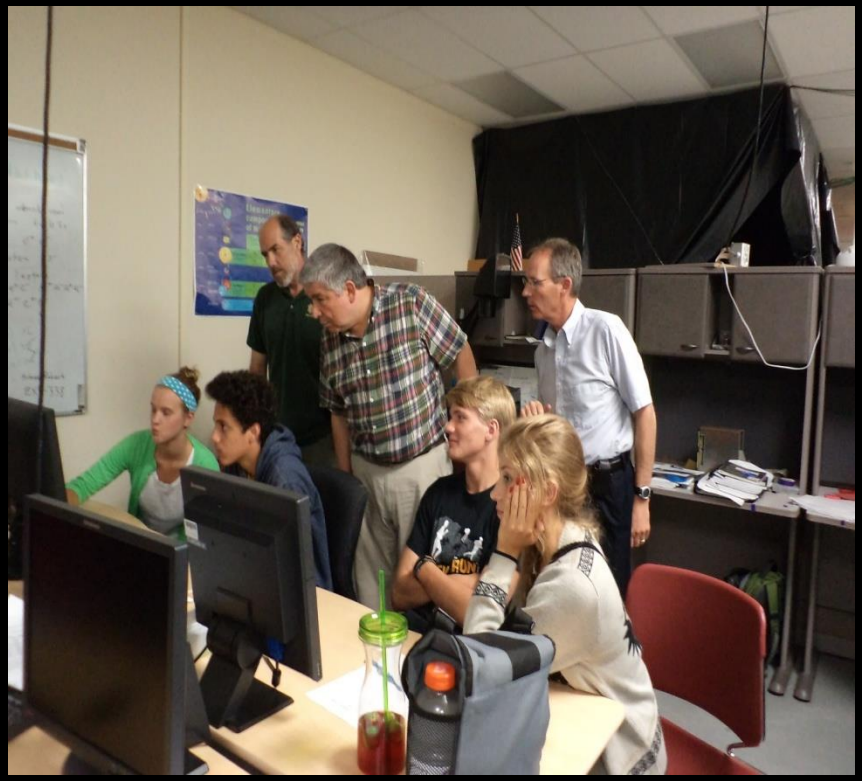
Enriching the Top Content

- Angular Distribution





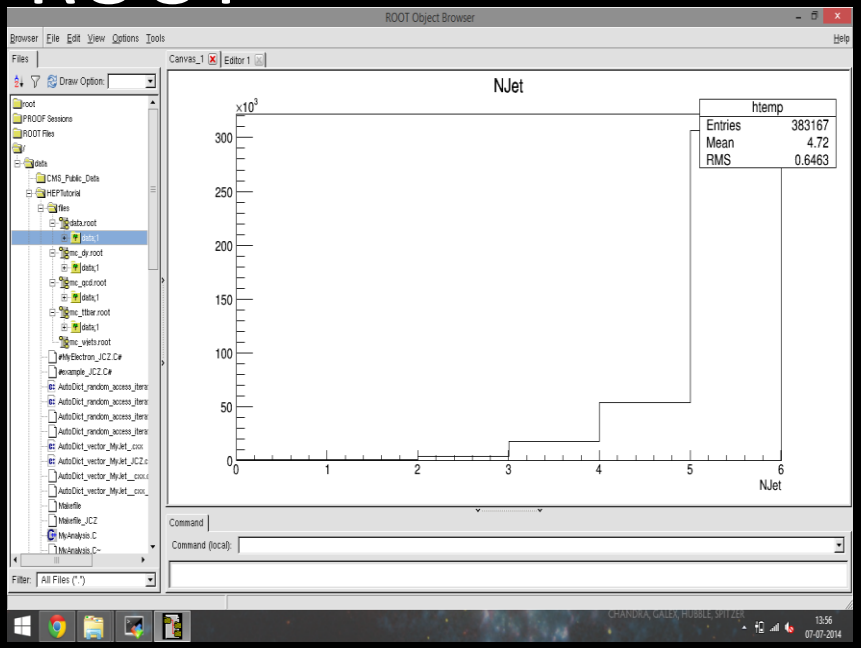
Quarknet



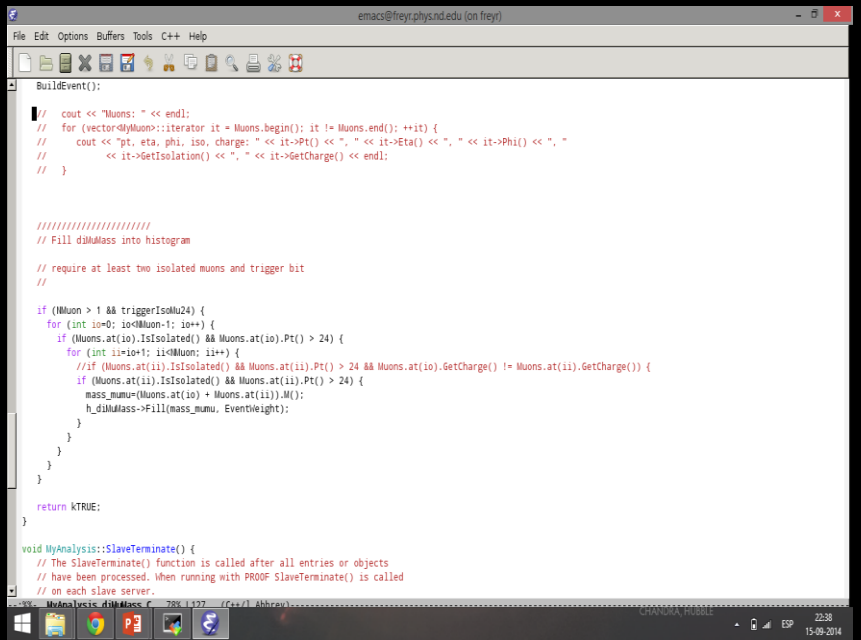
Quarknet

CMS Data Group

ROOT



C++



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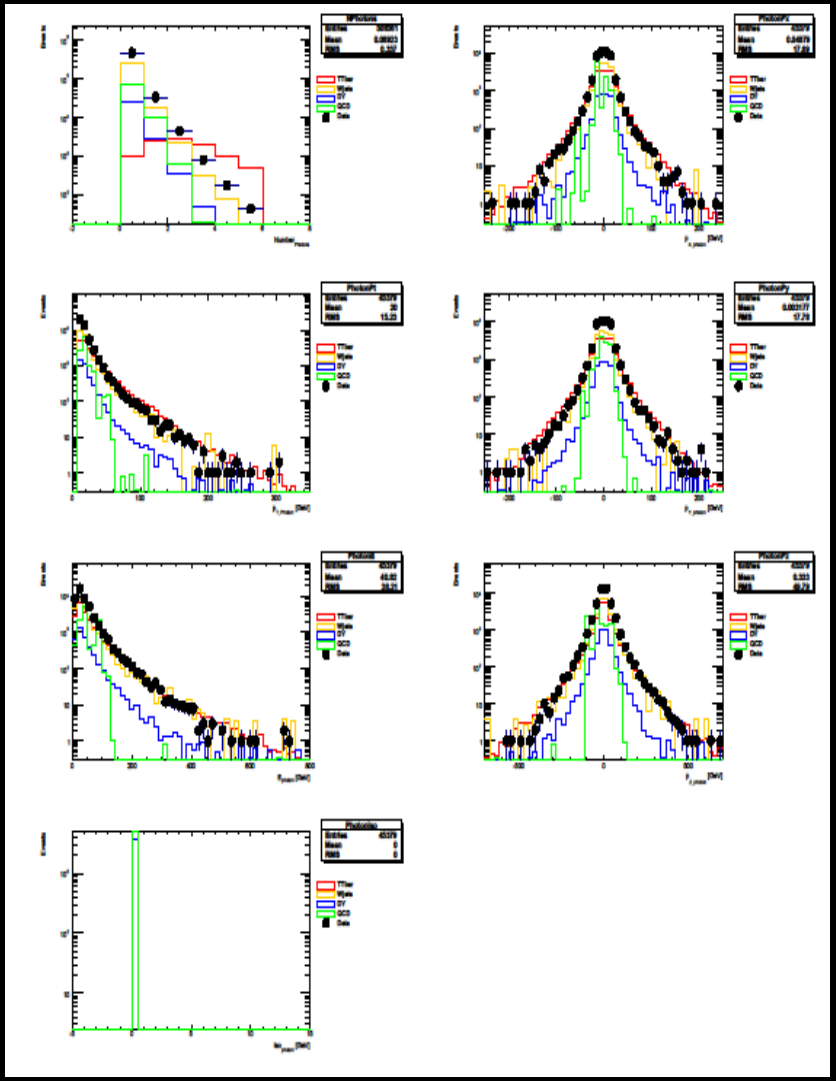
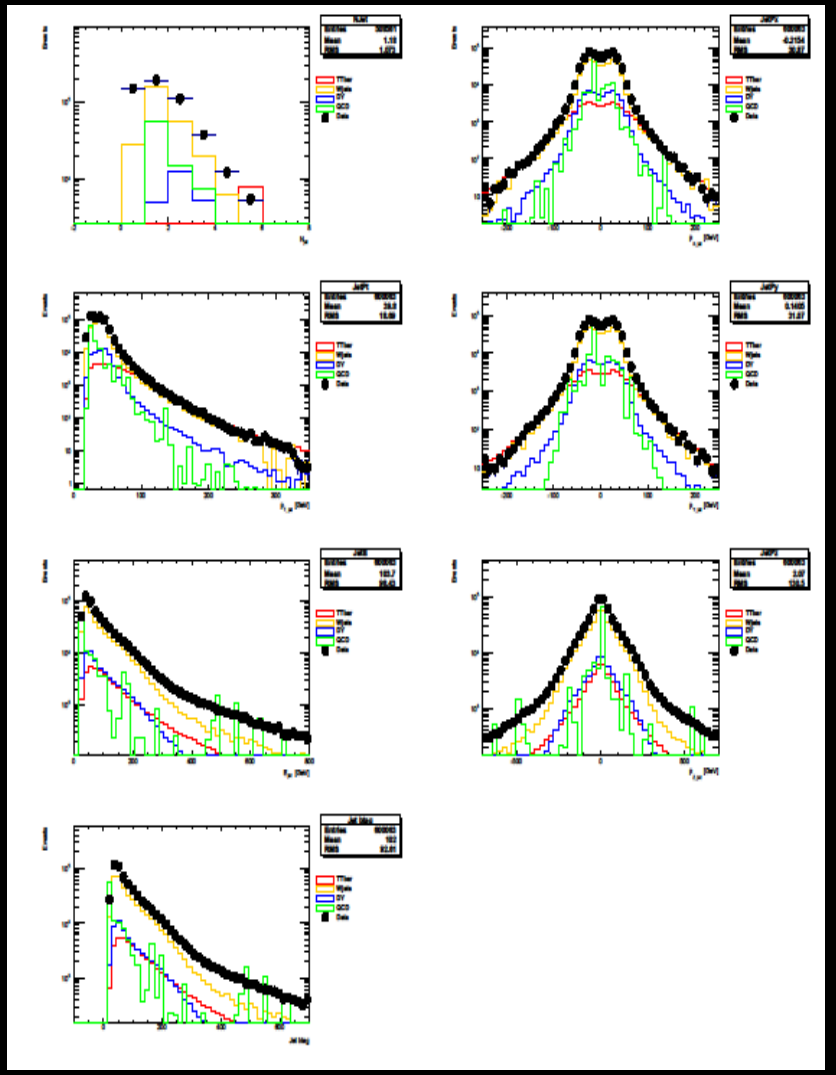
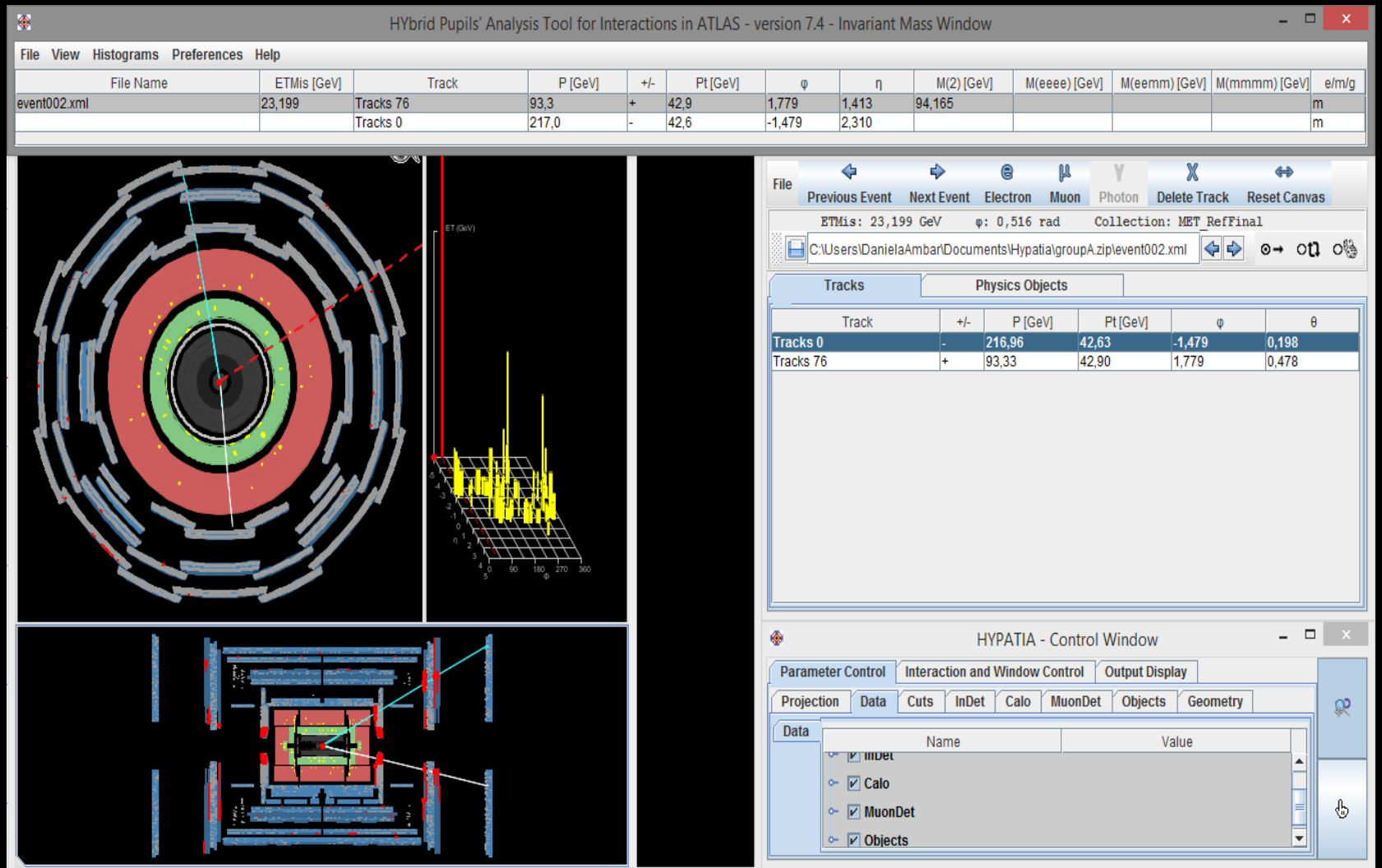
Photons





Quarknet

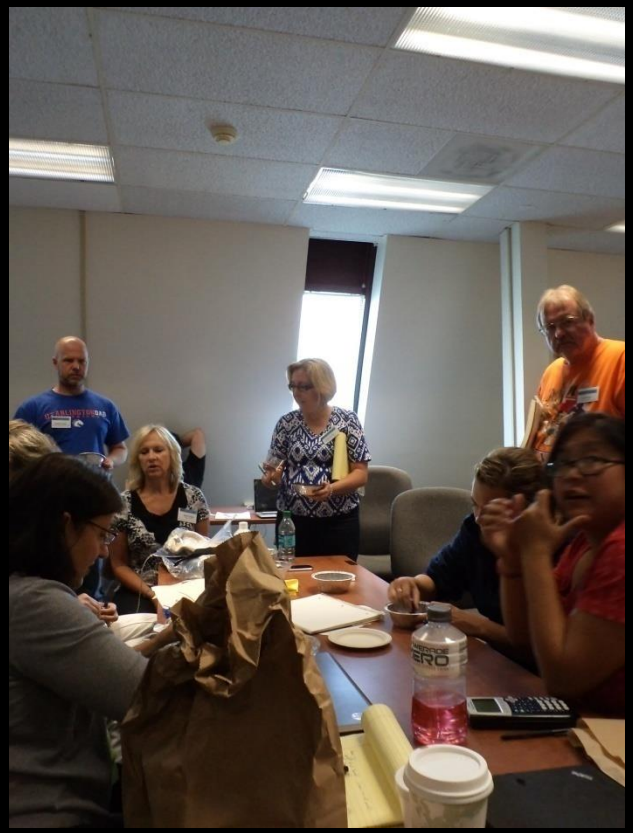
Masterclass Hypatia



Fermilab

FERMILAB

Activities



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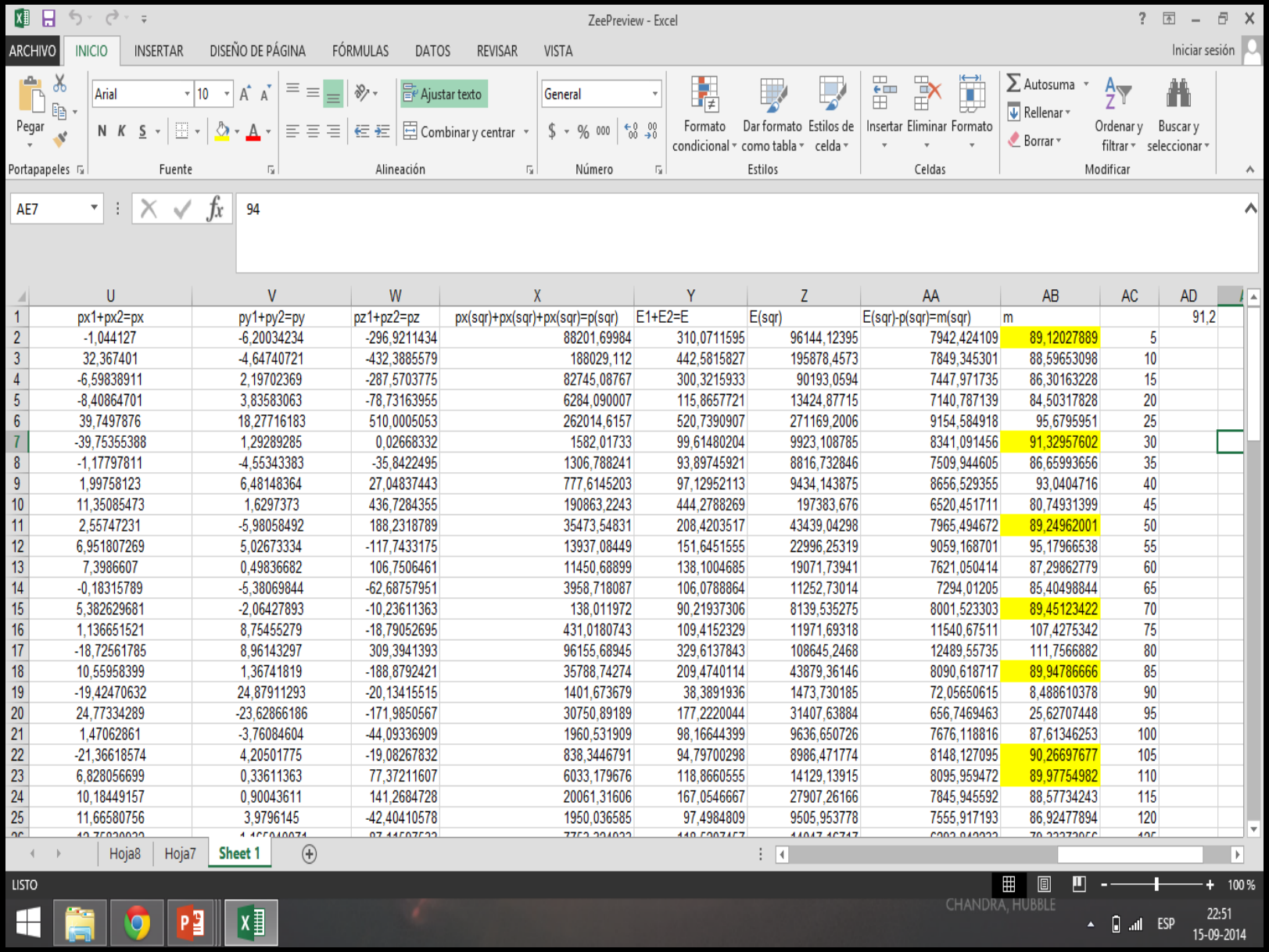
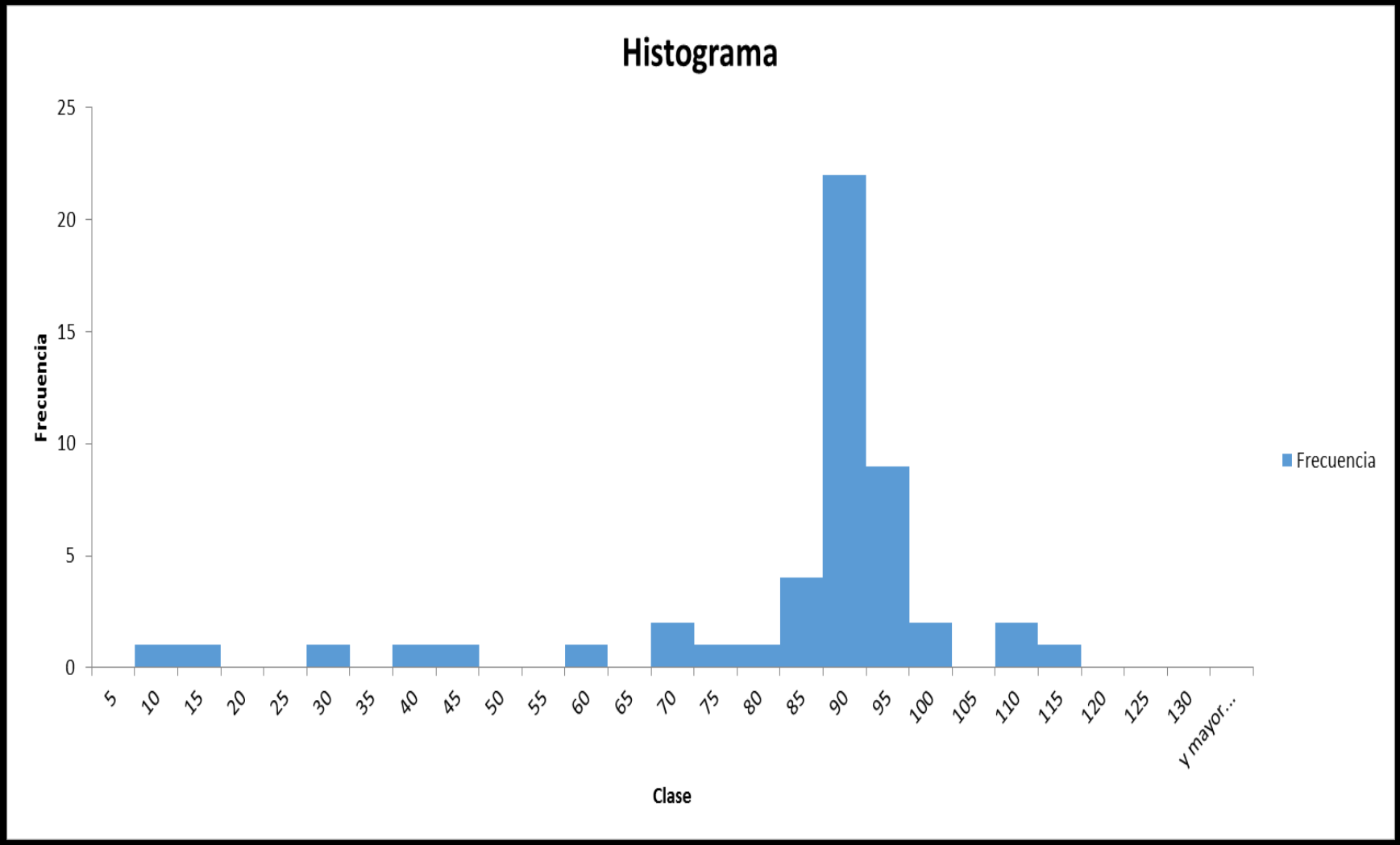


	U	V	W	X	Y	Z	AA	AB	AC	AD
1	px1+px2=px	py1+py2=py	pz1+pz2=pz	px(sqr)+px(sqr)+px(sqr)=p(sqr)	E1+E2=E	E(sqr)	E(sqr)-p(sqr)=m(sqr)	m		91,2
2	-1,044127	-6,20034234	-296,9211434	88201,69984	310,0711595	96144,12395	7942,424109	89,12027889	5	
3	32,367401	-4,64740721	-432,3885579	188029,112	442,5815827	195878,4573	7849,345301	88,59653098	10	
4	-6,59838911	2,19702369	-287,5703775	82745,08767	300,3215933	90193,0594	7447,971735	86,30163228	15	
5	-8,40864701	3,83583063	-78,73163955	6284,090007	115,8657721	13424,87715	7140,787139	84,50317828	20	
6	39,7497876	18,27716183	510,0005053	262014,6157	520,7390907	271169,2006	9154,584918	95,6795951	25	
7	-39,75355388	1,29289285	0,02668332	1582,01733	99,61480204	9923,108785	8341,091456	91,32957602	30	
8	-1,17797811	-4,55343383	-35,8422495	1306,788241	93,89745921	8816,732846	7509,944605	86,65993656	35	
9	1,99758123	6,48148364	27,04837443	777,6145203	97,12952113	9434,143875	8656,529355	93,0404716	40	
10	11,35085473	1,6297373	436,7284355	190863,2243	444,2788269	197383,676	6520,451711	80,74931399	45	
11	2,55747231	-5,98058492	188,2318789	35473,54831	208,4203517	43439,04298	7965,494672	89,24962001	50	
12	6,951807269	5,02673334	-117,7433175	13937,08449	151,6451555	22996,25319	9059,168701	95,17966538	55	
13	7,3986607	0,49836682	106,7506461	11450,68899	138,1004685	19071,73941	7621,050414	87,29862779	60	
14	-0,18315789	-5,38069844	-62,68757951	3958,718087	106,0788864	11252,73014	7294,01205	85,40498844	65	
15	5,382629681	-2,06427893	-10,23611363	138,011972	90,21937306	8139,535275	8001,523303	89,45123422	70	
16	1,136651521	8,75455279	-18,79052695	431,0180743	109,4152329	11971,69318	11540,67511	107,4275342	75	
17	-18,72561785	8,96143297	309,3941393	96155,68945	329,6137843	108645,2468	12489,55735	111,7566882	80	
18	10,55958399	1,36741819	-188,8792421	35788,74274	209,4740114	43879,36146	8090,618717	89,94786666	85	
19	-19,42470632	24,87911293	-20,13415515	1401,673679	38,3891936	1473,730185	72,05650615	8,488610378	90	
20	24,77334289	-23,62866186	-171,9850567	30750,89189	177,2220044	31407,63884	656,7469463	25,62707448	95	
21	1,47062861	-3,76084604	-44,09336909	1960,531909	98,16644399	9636,650726	7676,118816	87,61346253	100	
22	-21,36618574	4,20501775	-19,08267832	838,3446791	94,79700298	8986,471774	8148,127095	90,26697677	105	
23	6,828056699	0,33611363	77,37211607	6033,179676	118,8660555	14129,13915	8095,959472	89,97754982	110	
24	10,18449157	0,90043611	141,2684728	20061,31606	167,0546667	27907,26166	7845,945592	88,57734243	115	
25	11,66580756	3,9796145	-42,40410578	1950,036585	97,4984809	9505,953778	7555,917193	86,92477894	120	

FERMILAB


Histograma
Frecuencia
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130
y mayor...
Clase
Frecuencia

How about in Chile?

- Classes to learn about Hadronic structure and Collider and particle physics.
- Classes using software hypatia.
- Connect relativity with particle physics through calculations of Z mass.
- Make videos about Quark Workbench.
- Watch and discussed movies about relativity and particle physics, for example Interstellar.

Plans for Next Summer

- Continue $t\bar{t}$ analysis
  - Develop a set of cuts
  - Determine efficiencies
  - Create $t\bar{t}$ mass plots
  - Calculate $t\bar{t}$ cross-section and mass

Conclusions

- We've made substantial progress toward analyzing CMS data in its native format
- We are in a good position to finish the $t\bar{t}$ analysis by the end of next summer
- We are better poised to access and analyze CMS data in general

- In October 2014 LHC Collaborations released portions of their datasets for education and research purposes at: http://opendata.cern.ch/