CMS in 2010: A Very Good Year

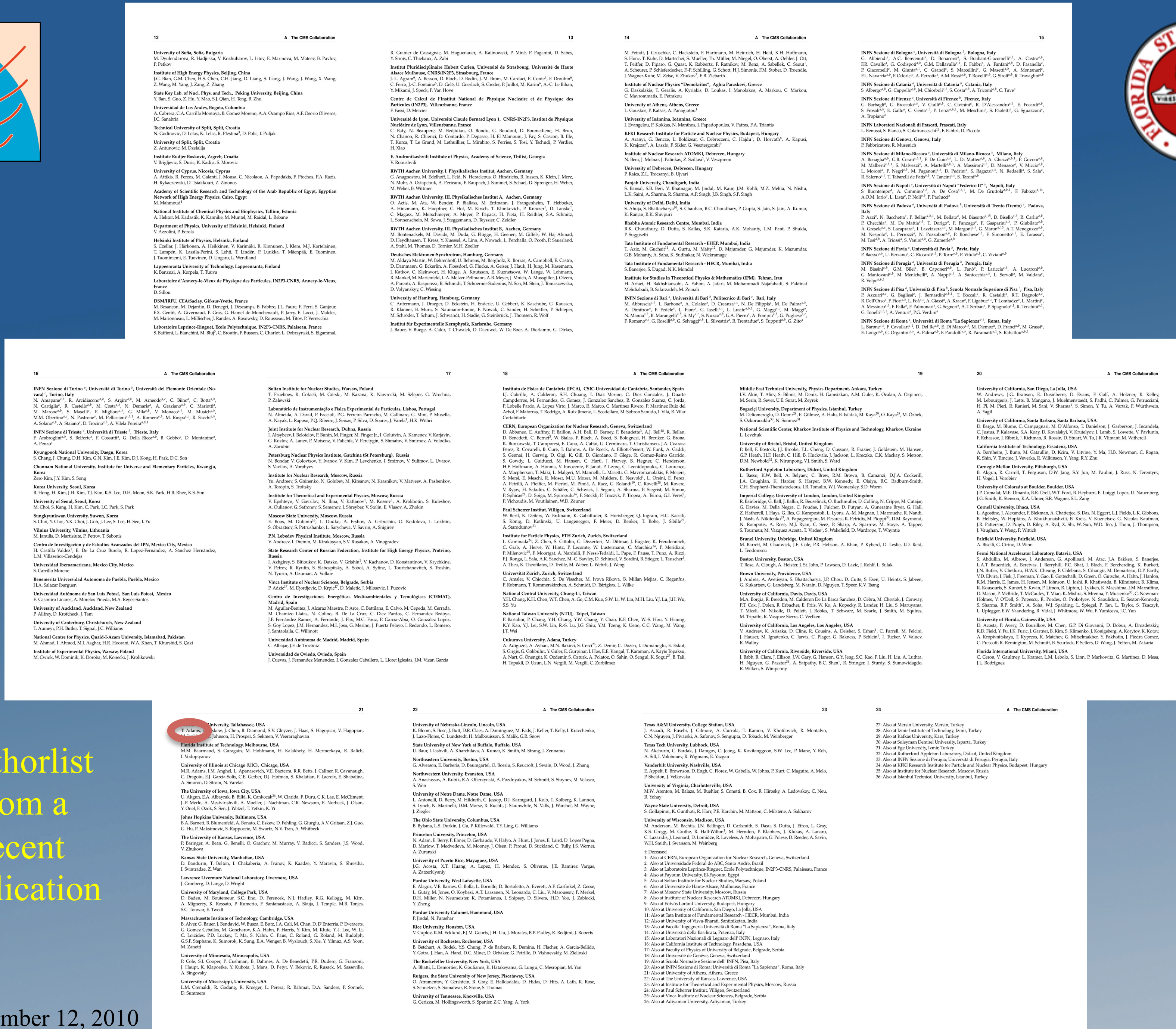
Conference on LHC First Data
December 12, 2010

Todd Adams
Florida State University

Outline

- Compact Muon Solenoid
- Detector/Object Performance
  - tracking, photons/electrons, jets, MET
- Physics
  - QCD, electroweak, top, searches, heavy ions
- Summary

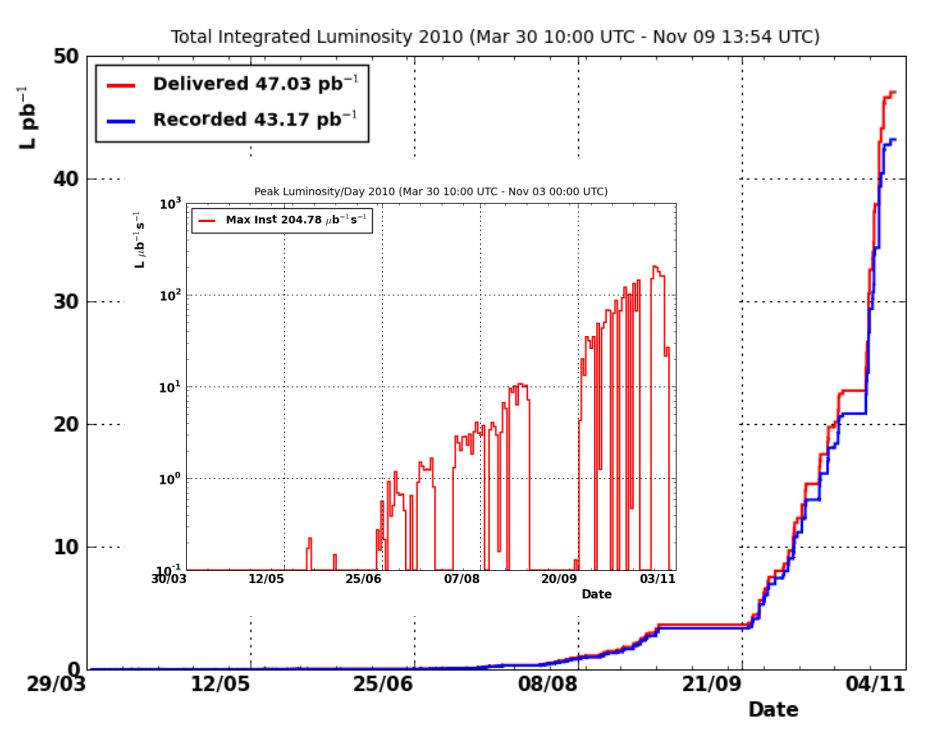
Authorlist from a recent publication



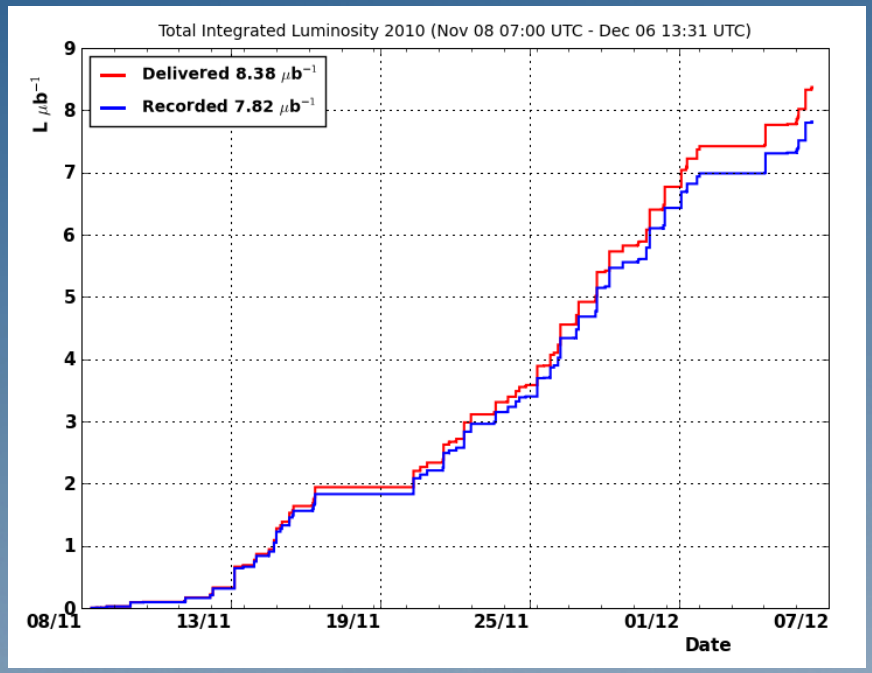
Authorlist from a recent publication

Luminosity

proton running

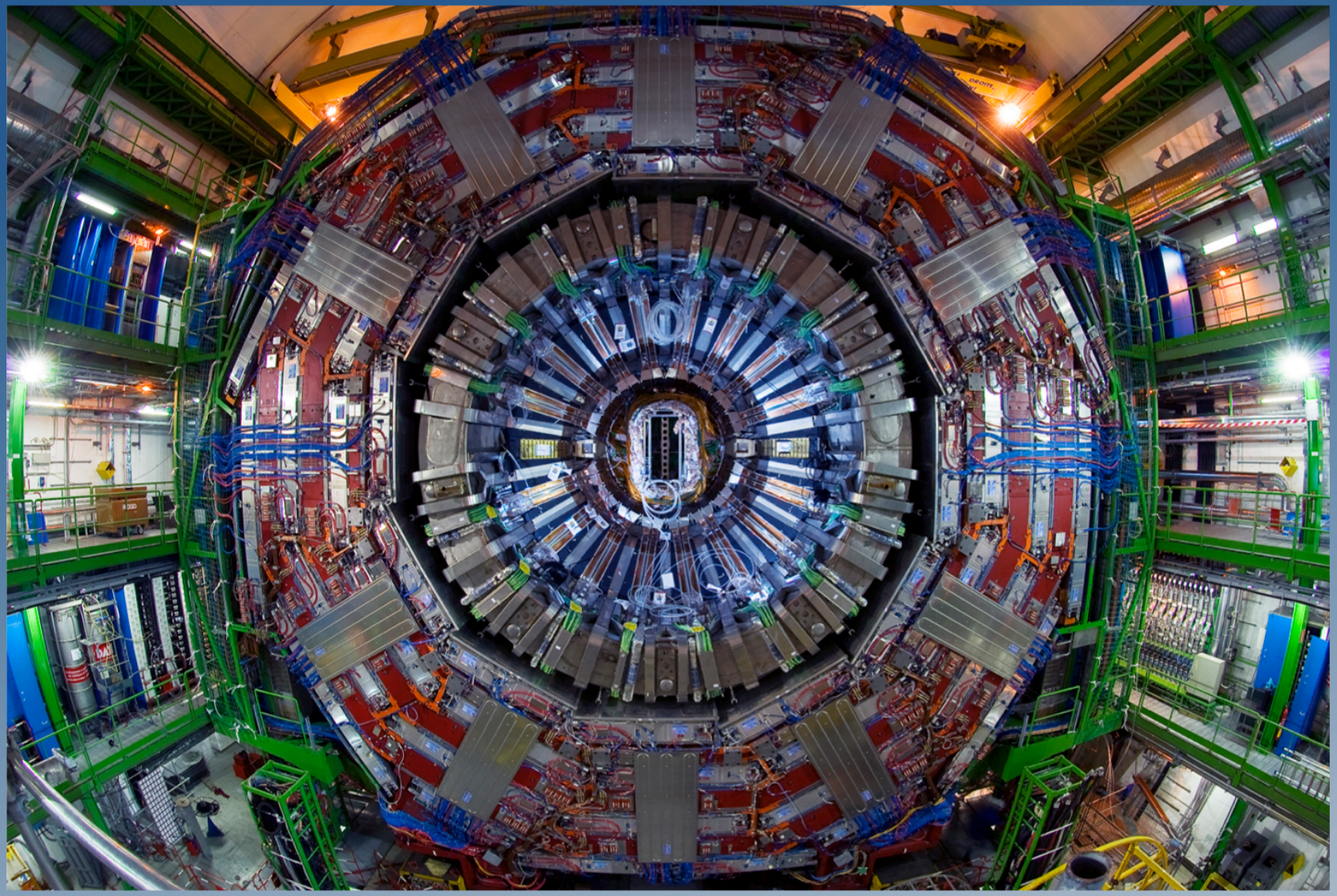


heavy ion running
Pb-Pb

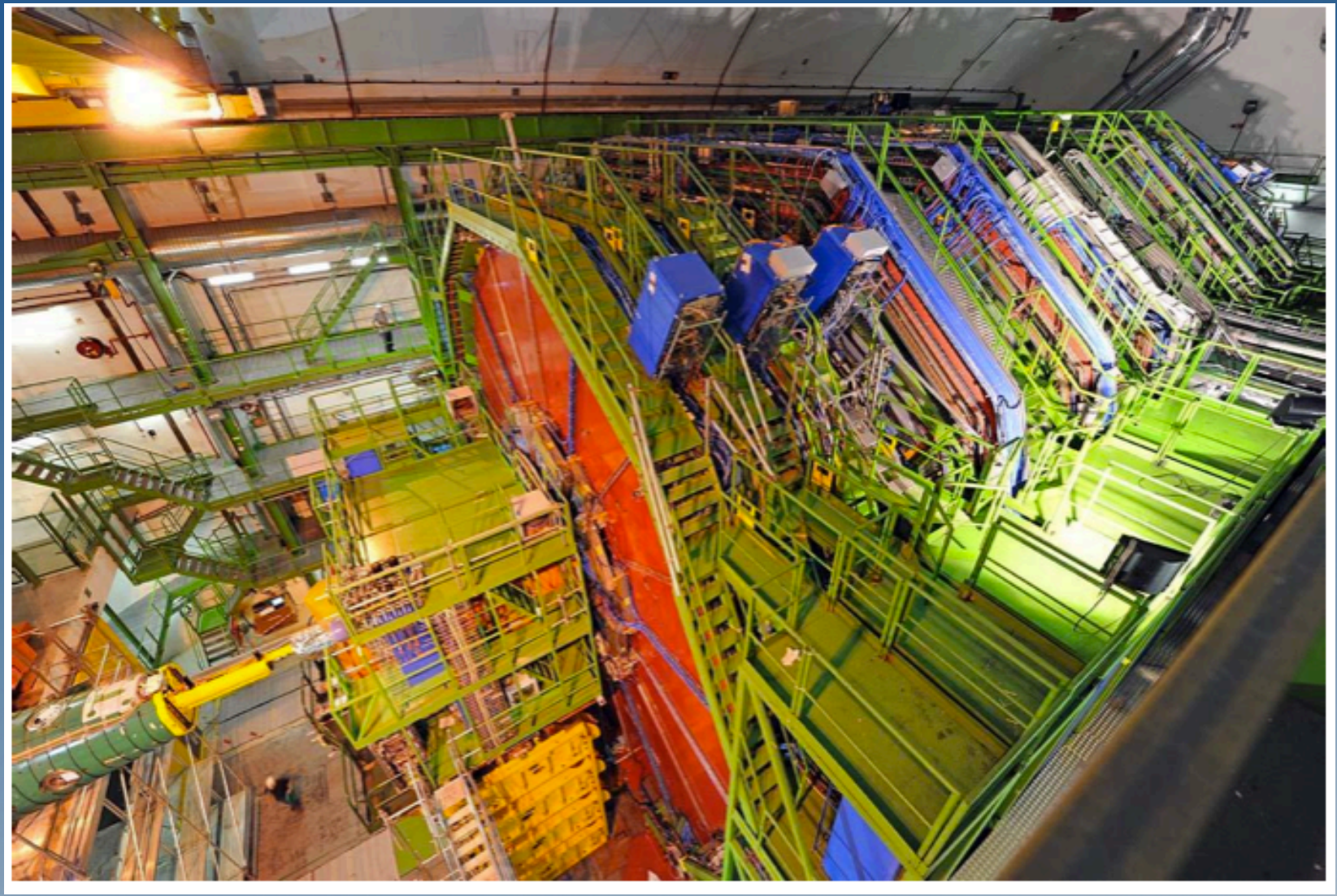


- significant increase in data from preliminary summer results

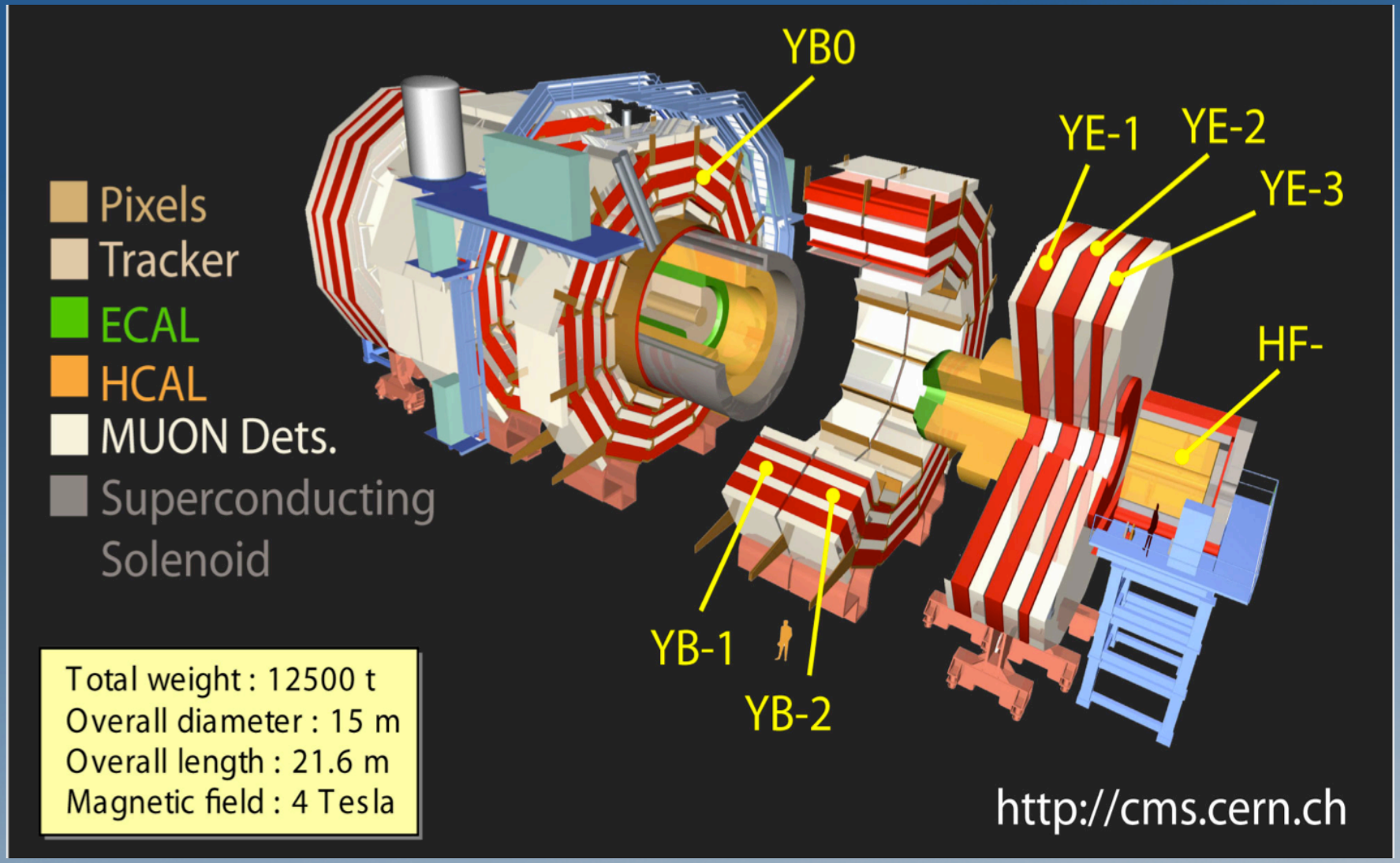
CMS Detector

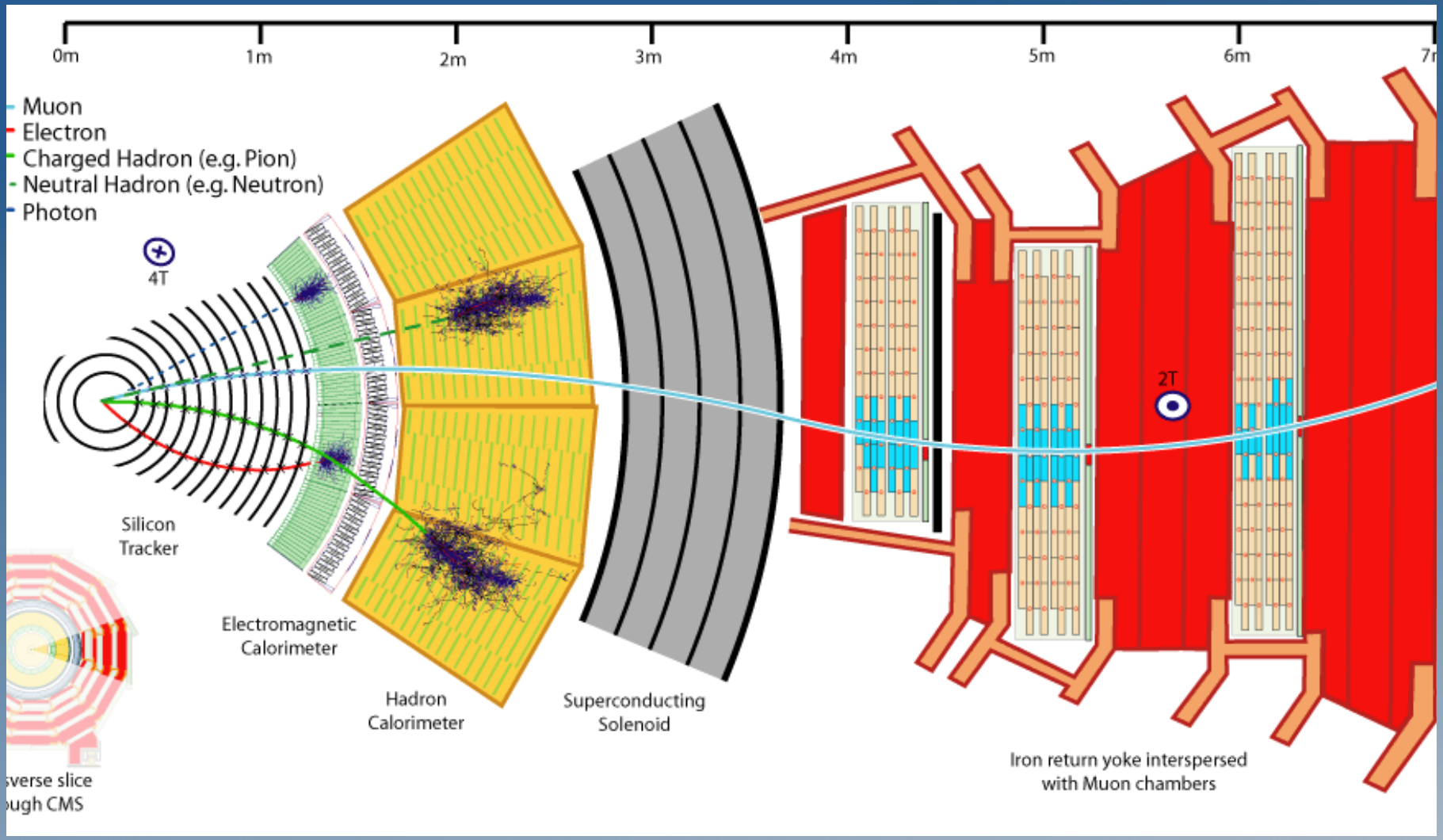


CMS Detector



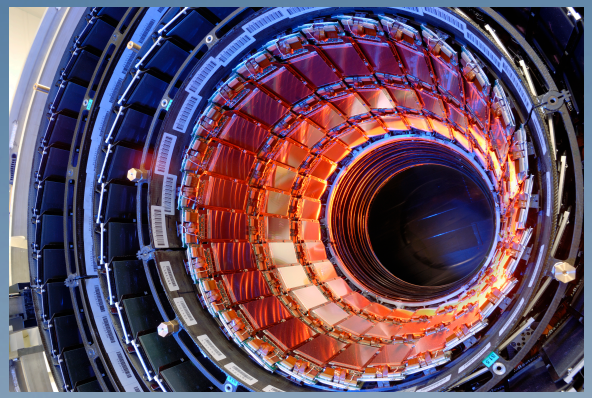
CMS Detector

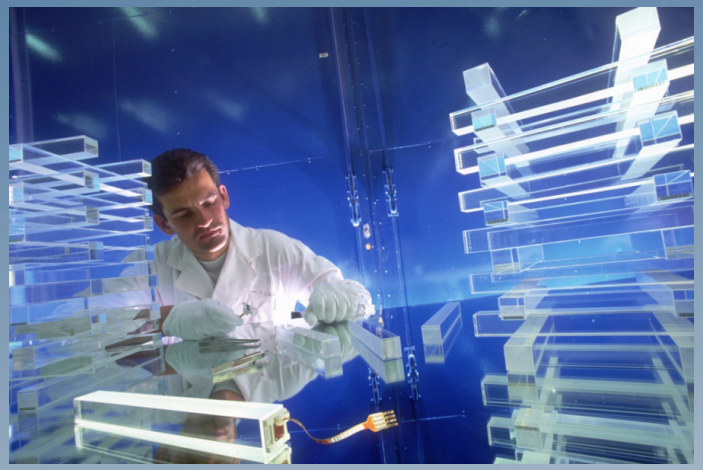



0m
1m
2m
3m
4m
5m
6m
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
sverse slice
ough CMS

Detector Performance

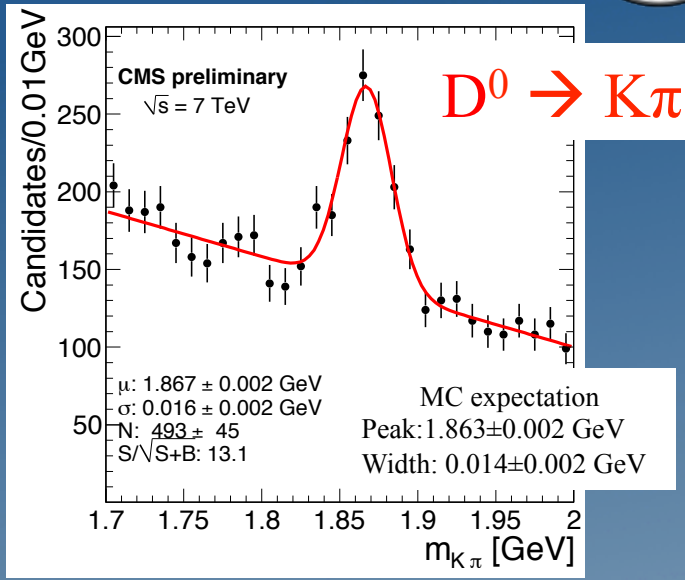
- Journal of Instrumentation, Volume 5, March 2010
  - 23 articles about CMS performance using cosmic rays
- "The CMS Experiment at the CERN LHC," J. Inst., Vol. 3 (2008) S08004
  - 300 page article describing detector
- "CMS Tracking Performance Results from Early LHC Operation," arXiv::1007.1988

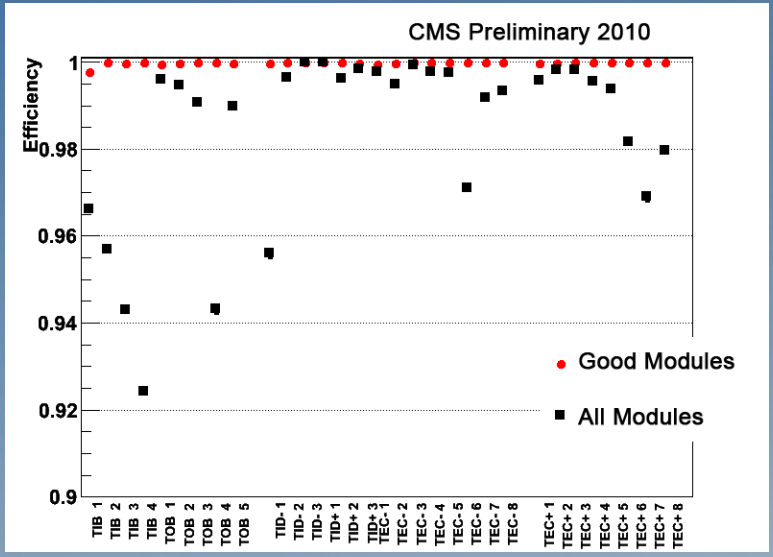


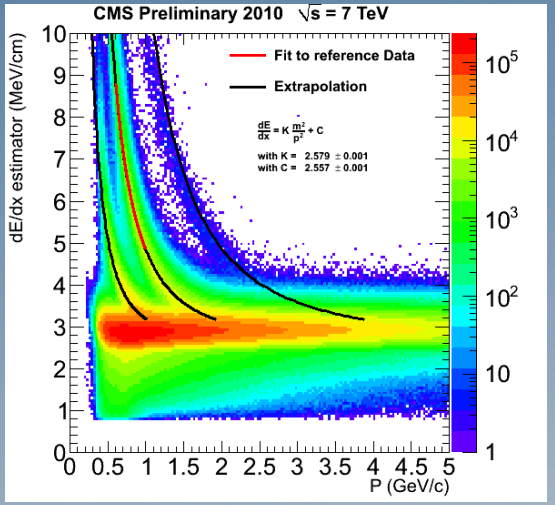


Tracking

- silicon tracker
  - 3 layers of pixels, 10 layers of strips (barrel)
- tracker operating at high efficiency
- tracking resolution similar to expectation

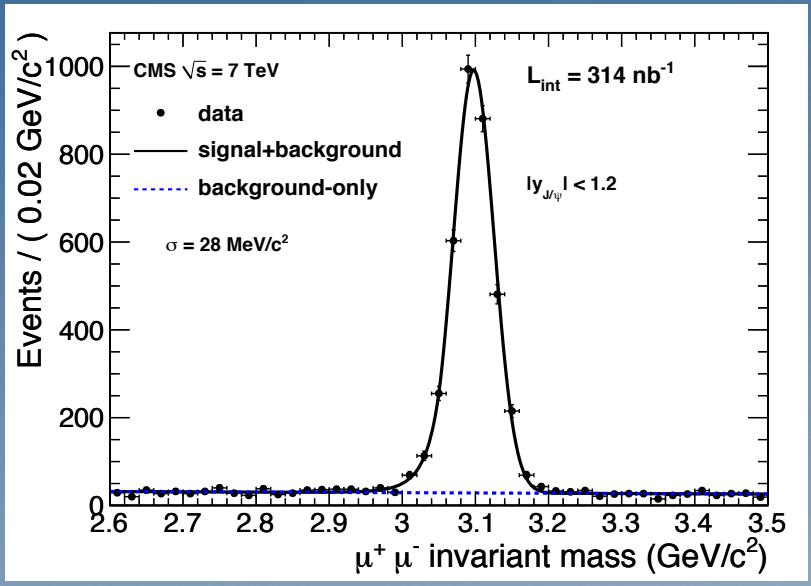


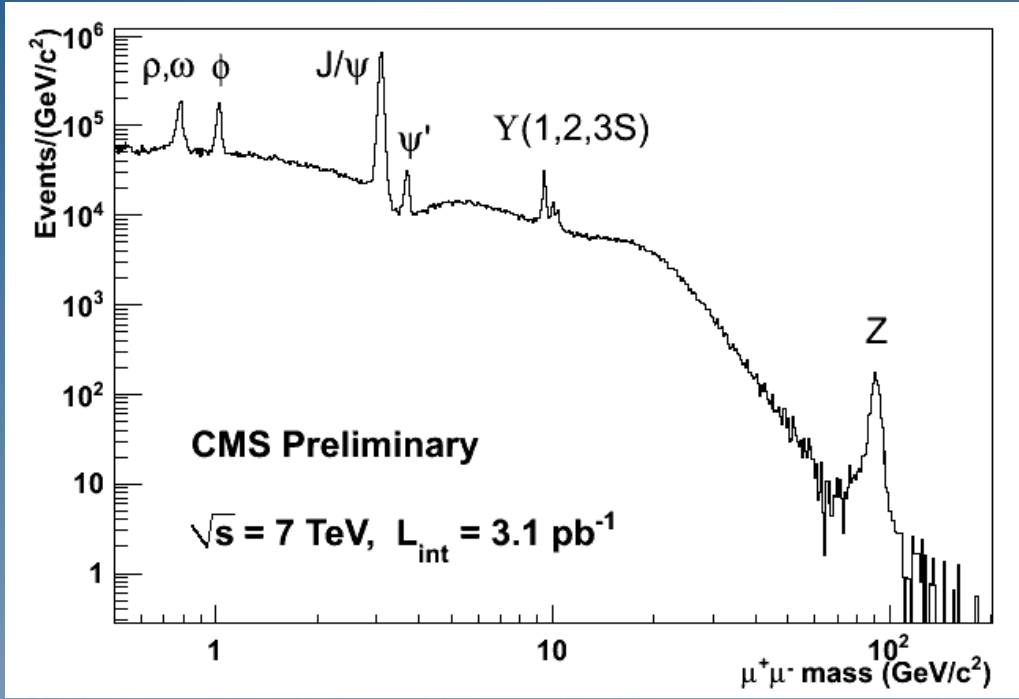




Tracking and Muons

- Dimuon resonances are excellent for
  - detector performance
  - efficiency/resolution
  - physics



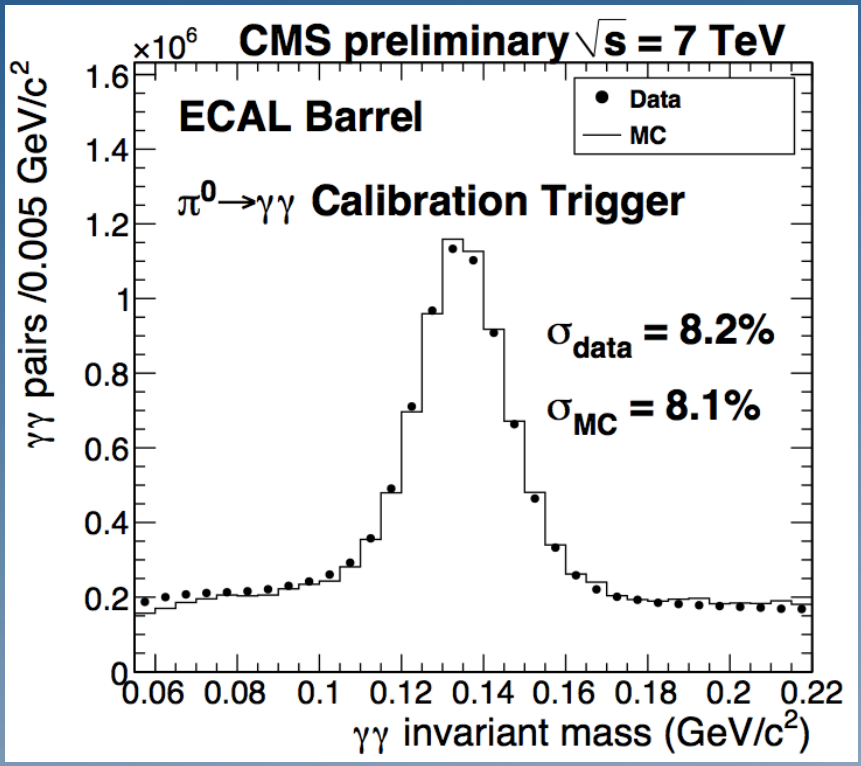


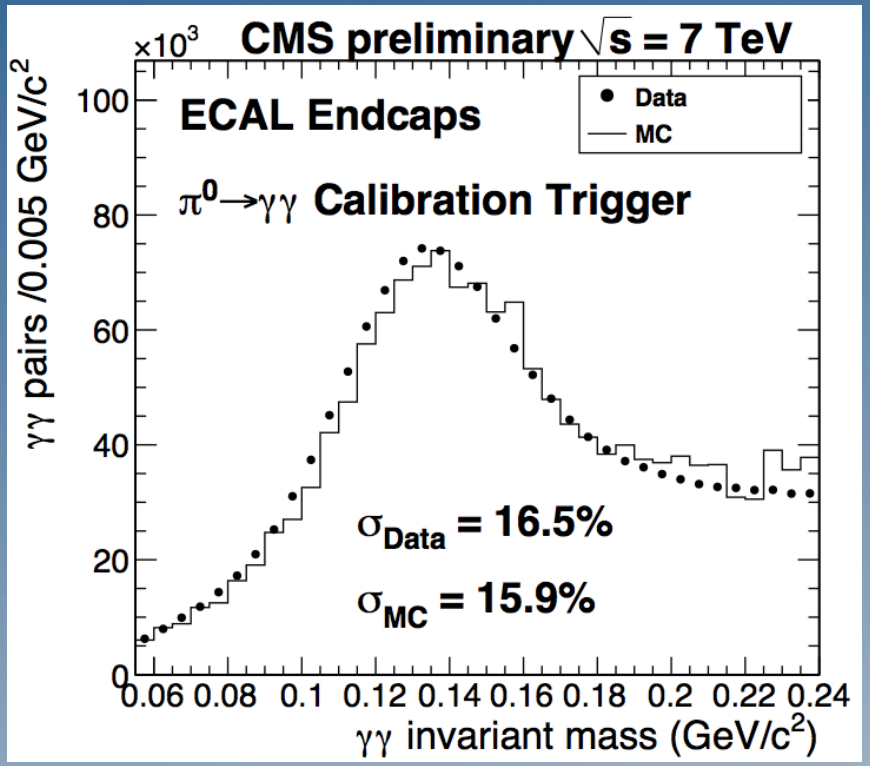
already resulted in submitted paper (J/ψ)

see talk by Giordano Cerizza on Monday

Electrons and Photons

- Calorimeter
  - EM: lead tungstate crystals
  - HAD: brass/steel and scintillator
- ECAL
  - excellent calibration important for physics, particularly H→γγ

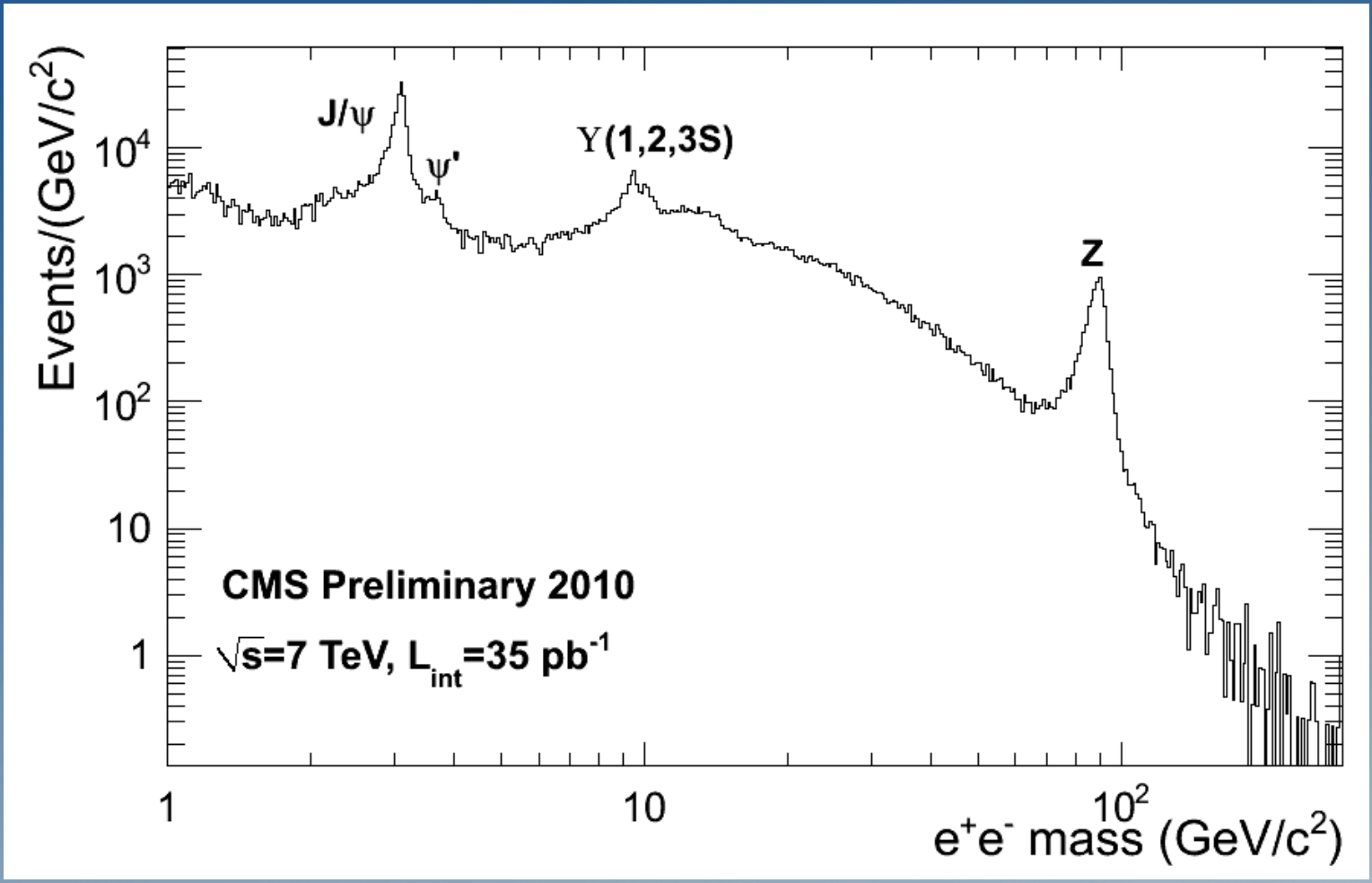




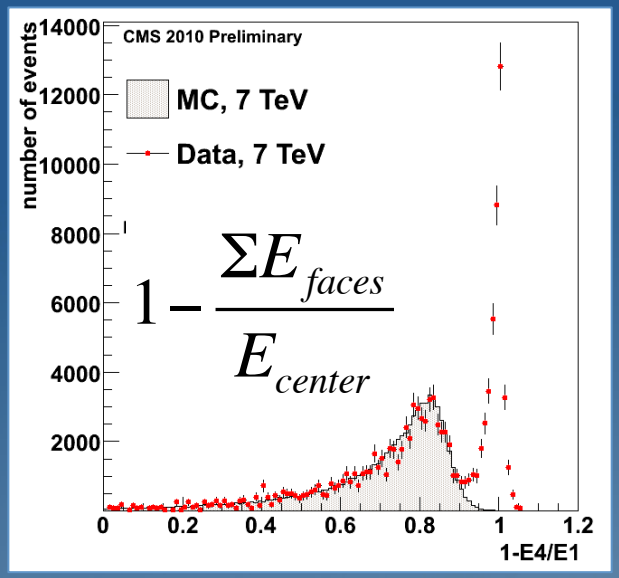
intercalibration with $\pi^0 \rightarrow \gamma\gamma$

Electrons and Photons

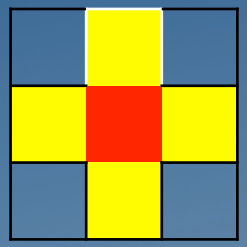
- Dielectron resonances (J/ψ and Z) are useful for energy scale



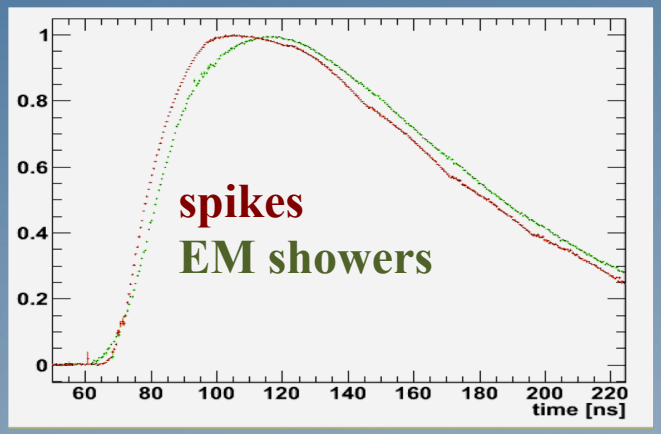
ECAL Spikes

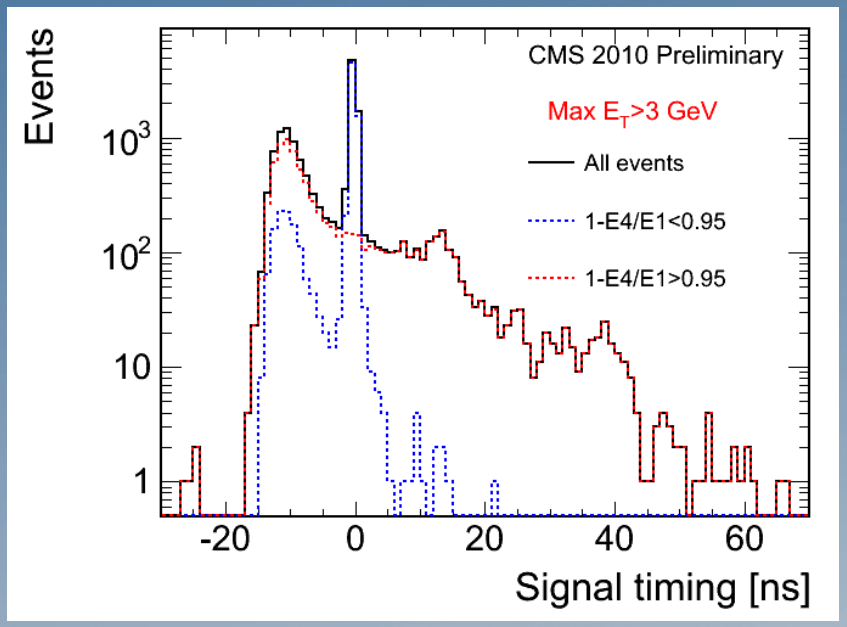


- anomalous signal observed in ECAL
  - large energy in single crystal
  - distorted time resolution
- direct energy deposition in photodiode



- use energy ratio/timing to clean ECAL hits

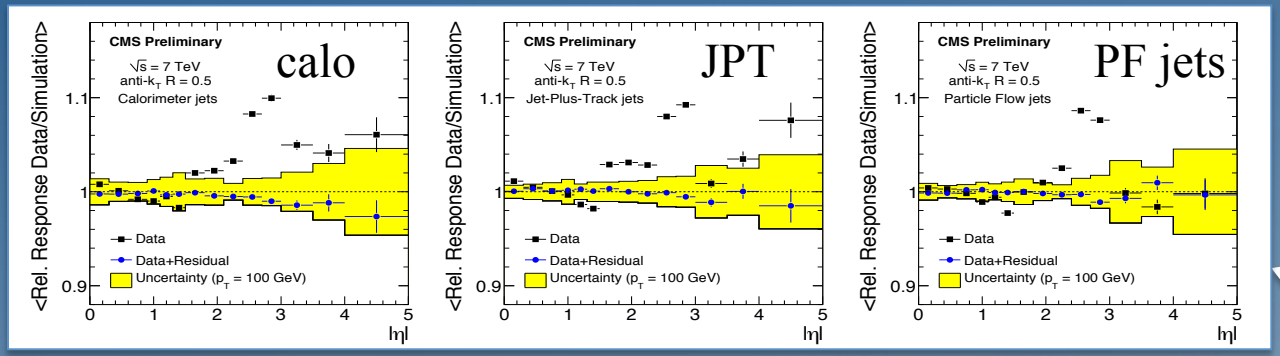




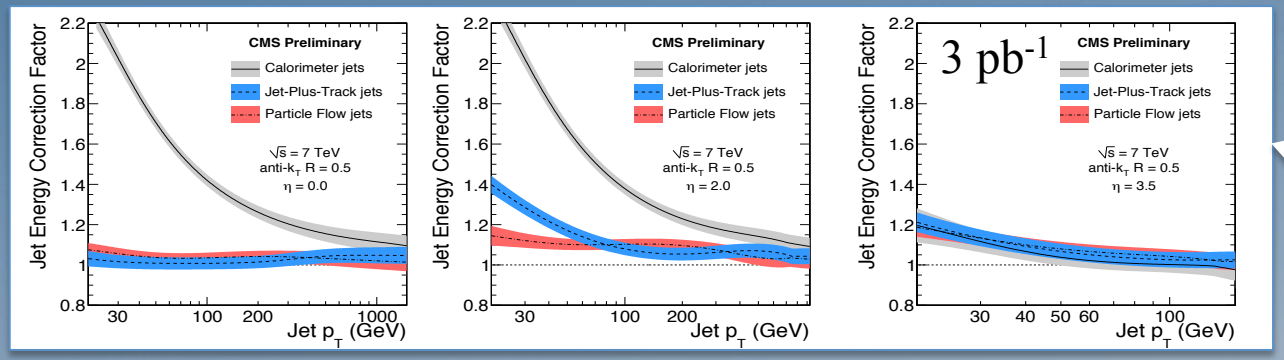
Jets

- Three methods of jet reconstruction
  - calo: calorimeter
  - JPT: calorimeter + tracker
  - PF jets: particle flow

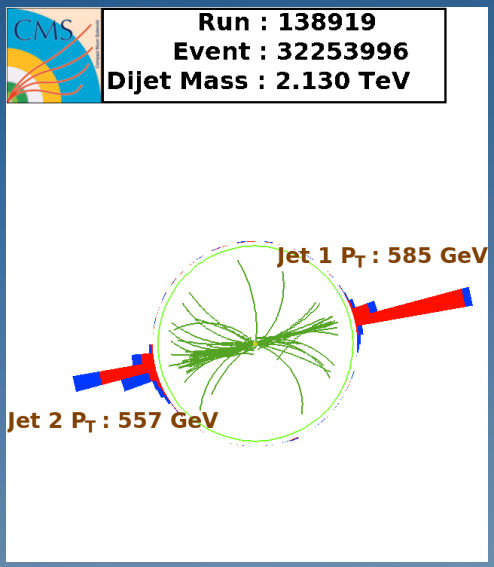
} smaller corrections



relative response (dijet pT balance)



absolute response (photon+jet pT balance)

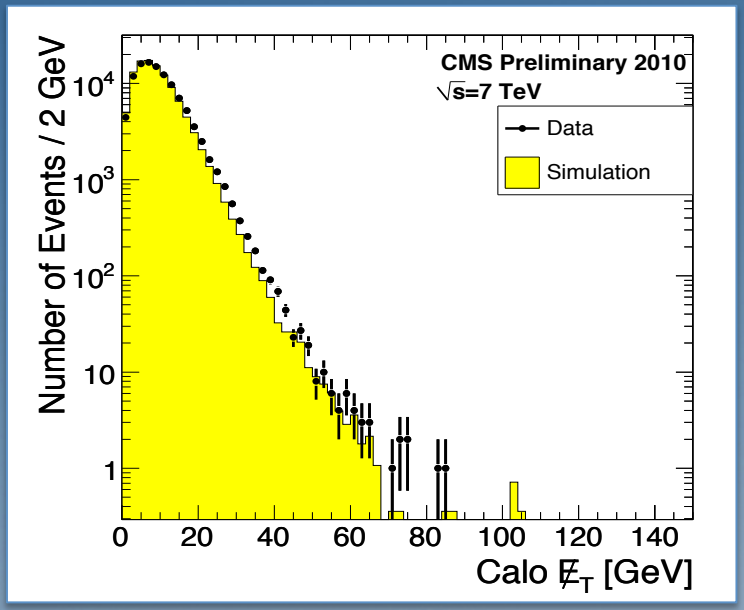


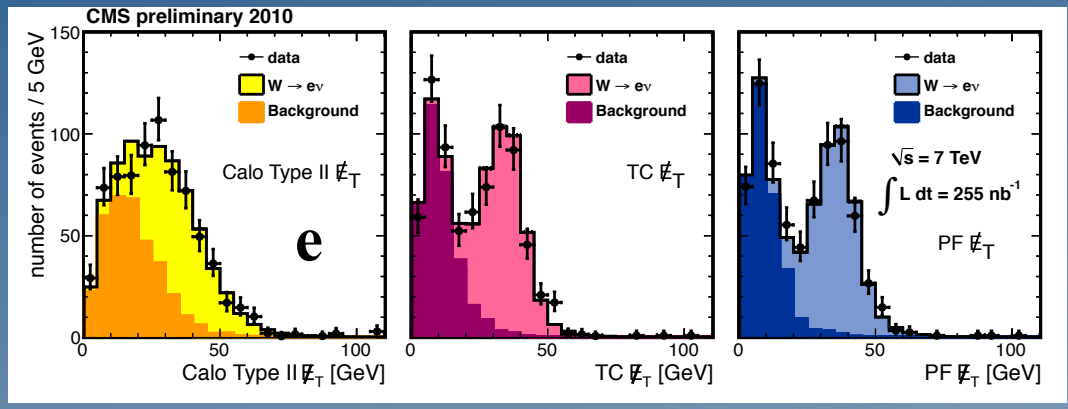
Missing Transverse Energy

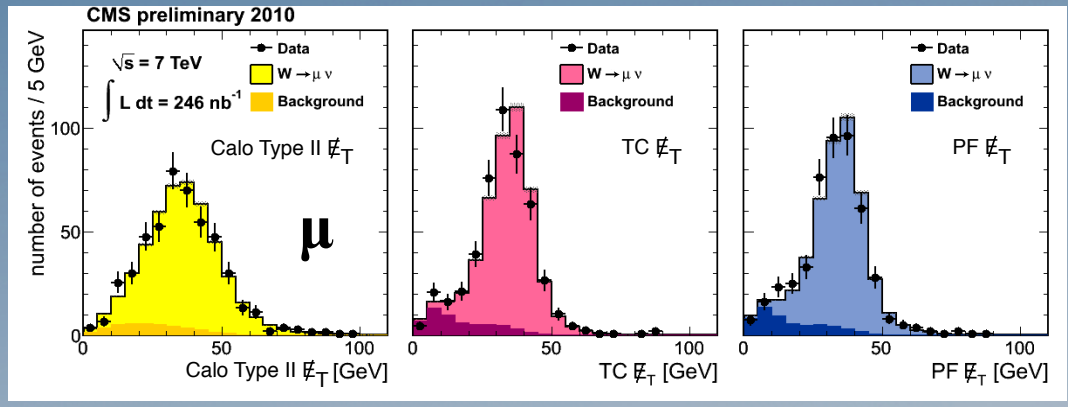
three methods of MET measurement

- calo MET: calorimeter + μ's
- tcMET: tracks + calorimeter + μ's
- pfMET: particle flow objects

MET in W candidate events

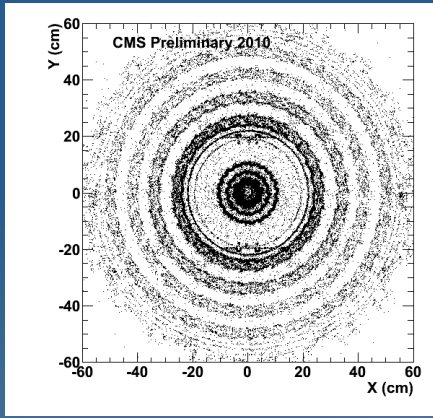




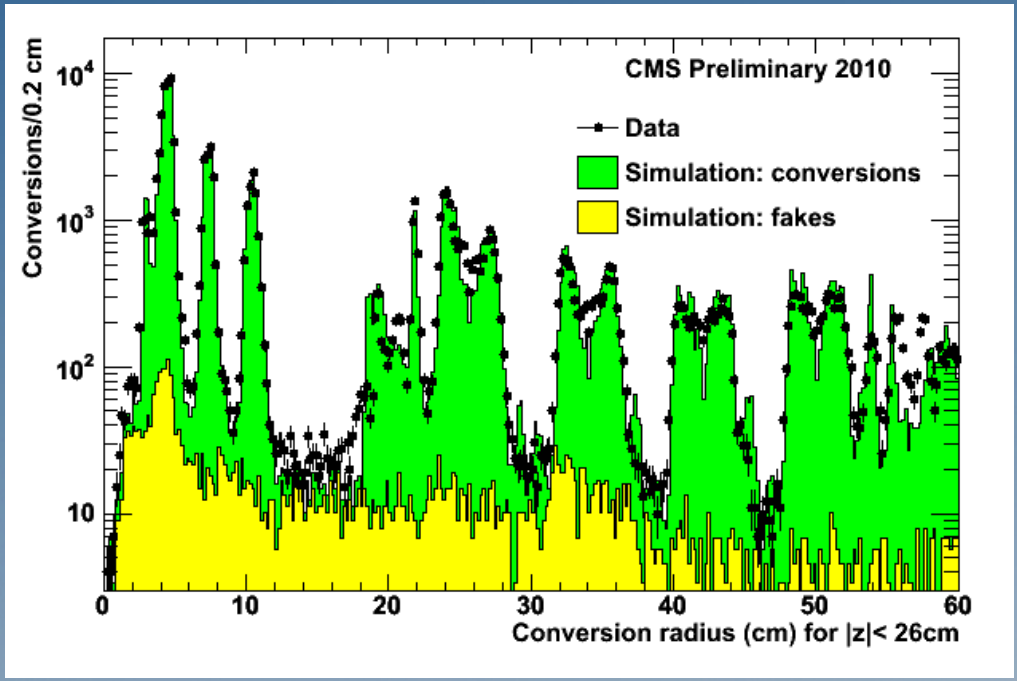


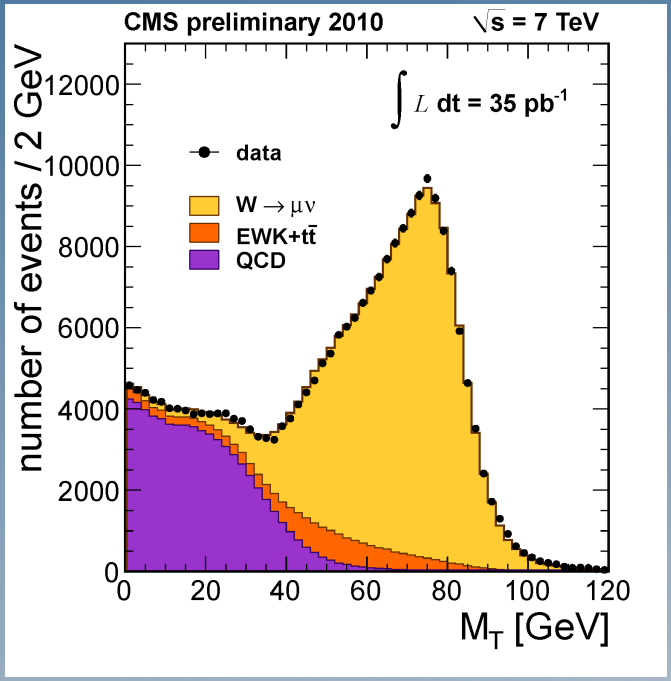
Data vs. Simulation

photon conversion in tracking detectors



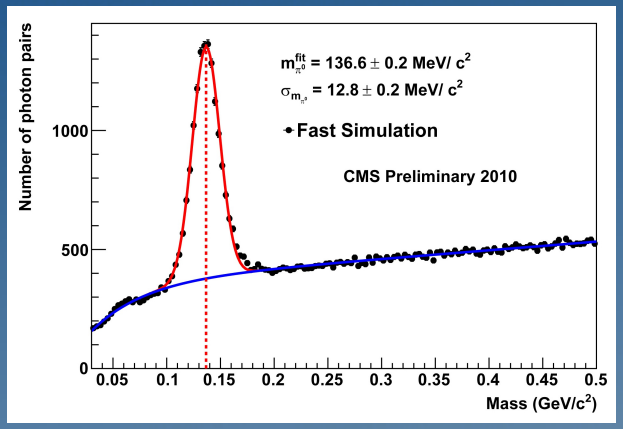
- Need simulation that properly models the detector
  - see previous plots
  - important for physics results

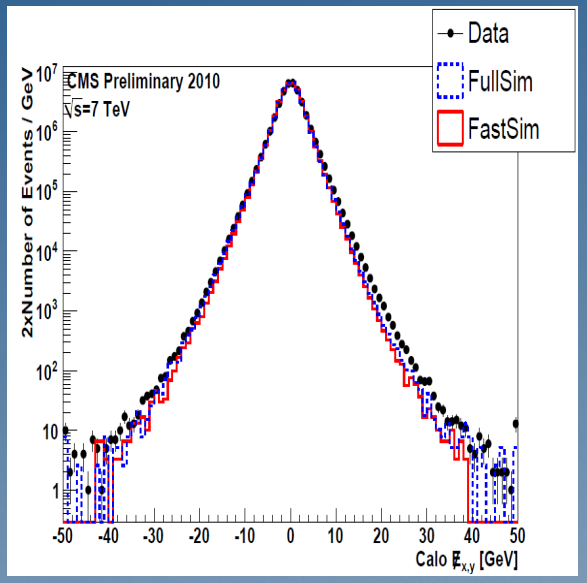


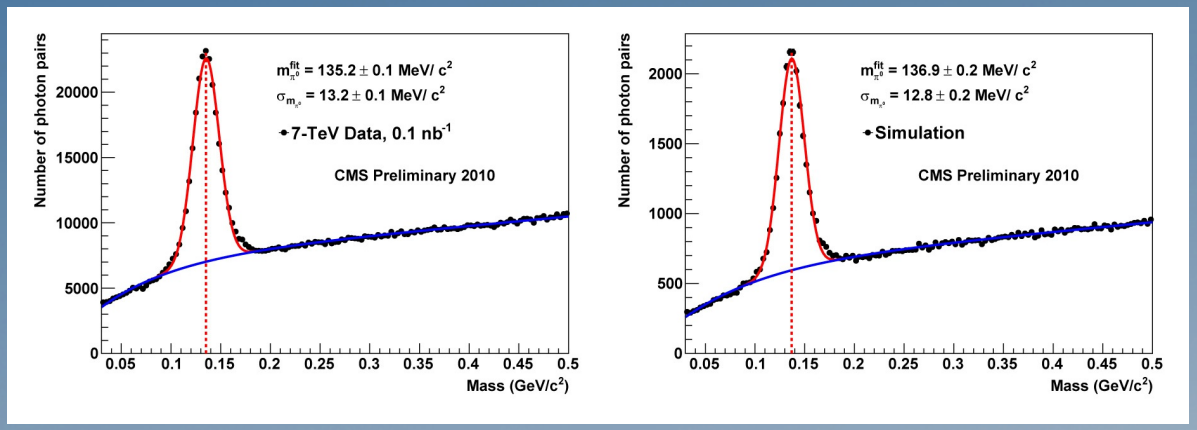


Data vs. Simulation

- fast simulation – parameterization of detector







good agreement with high level reconstructed objects

Climbing the Stairway to Knowledge

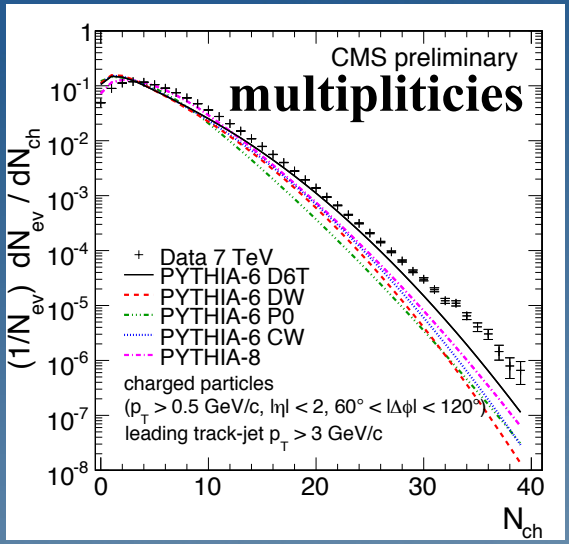
- Study those signals which have largest cross sections
  - strong force – jets
  - electroweak production – W and Z bosons
  - b physics (strong)
  - top pair production (strong)
  - diboson production (WW, WZ, ZZ)
  - Higgs production?
  - New physics???
- We have already observed several of these

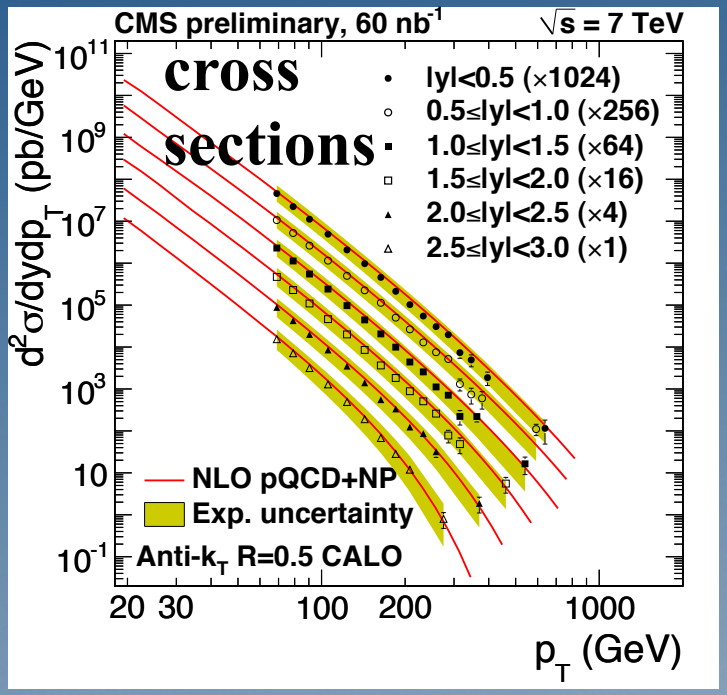
“Low Energy” Physics Results

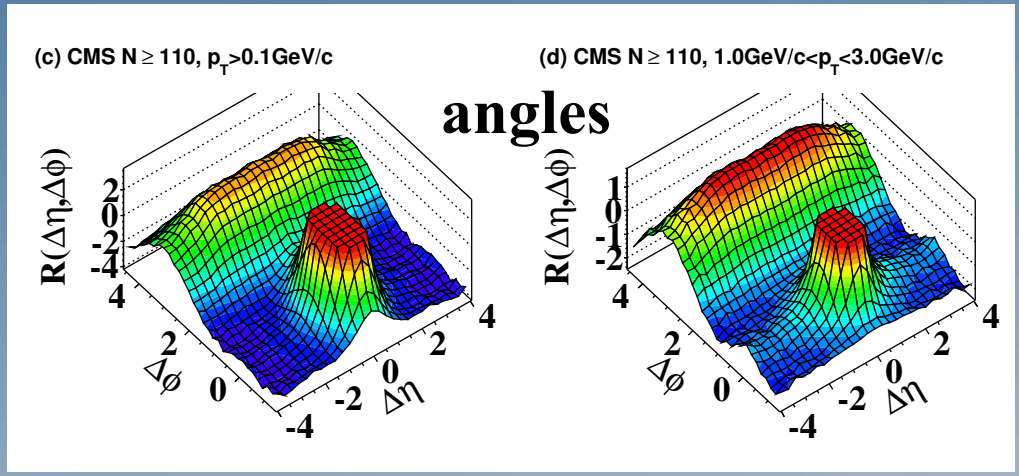
- “First Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 0.9$ TeV,” arXiv::1006.2083, submitted to Eur. Phys. J. C.
- “Transverse momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{s} = 0.9$ and 2.36 TeV,” J. of High Energy Physics, Vol. 2 (2010) 041
- “First Measurement of Bose-Einstein Correlations in proton-proton Collisions at $\sqrt{s} = 0.9$ and 2.36 TeV,” Phys. Rev. Lett., Vol. 105 (2010) 032001
- “Measurement of the charge ratio of atmospheric muons with the CMS detector,” Phys. Lett. B, Vol 692 (2010) 83

Strong Production

- largest cross section is strong production of light quarks and gluons



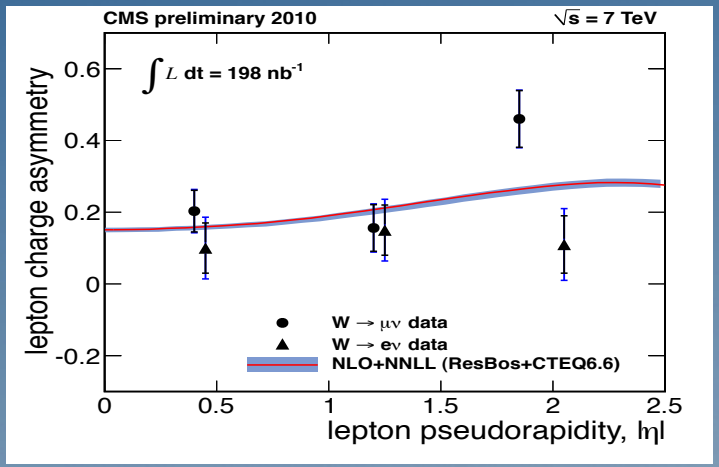


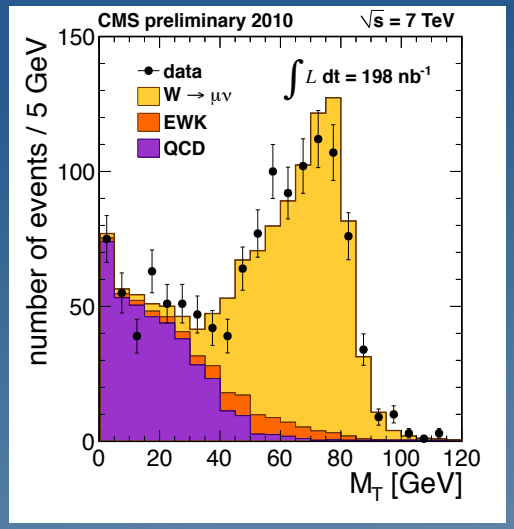


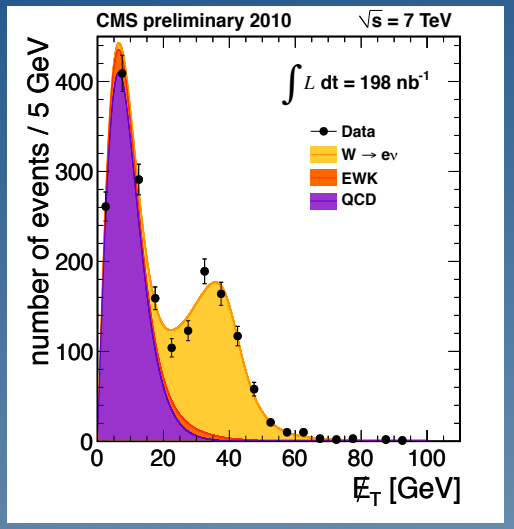
see talk by Colin Jessop today

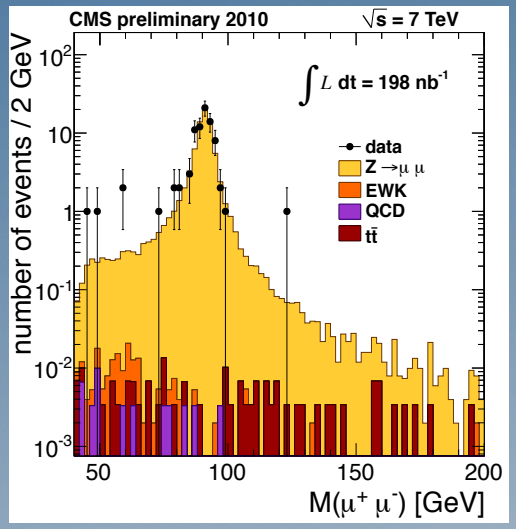
Electroweak Production

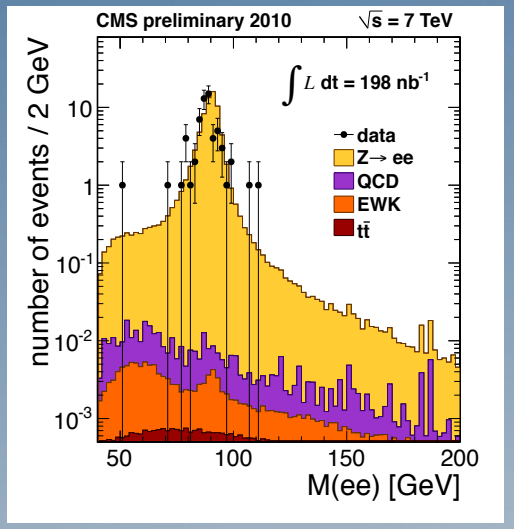
- electroweak production gives well-defined signals
  - W's and Z's
- excellent for studies and physics







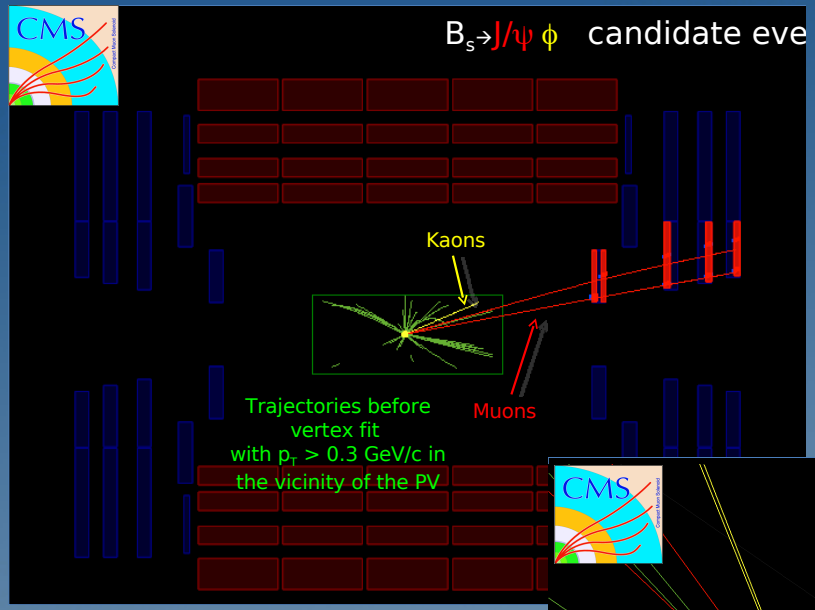


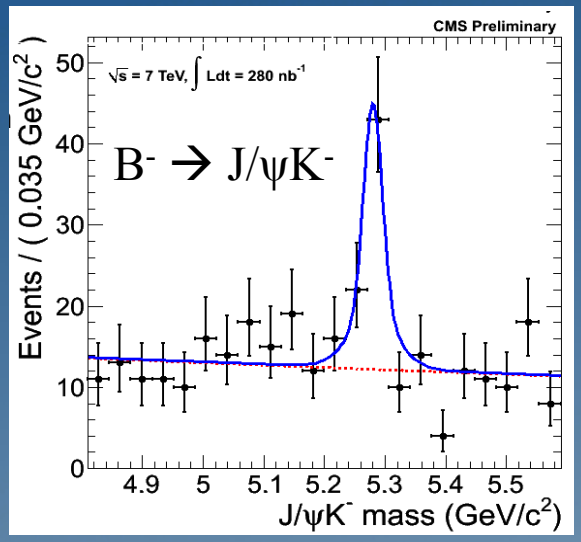


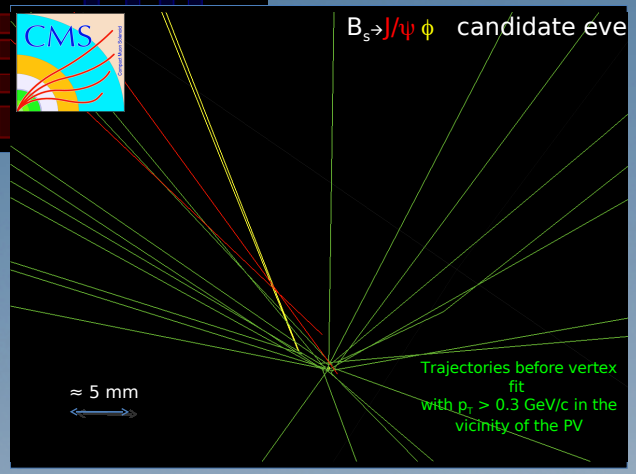
see talks by Jonathan Efron (today) and Kalanand Mishra (Monday)

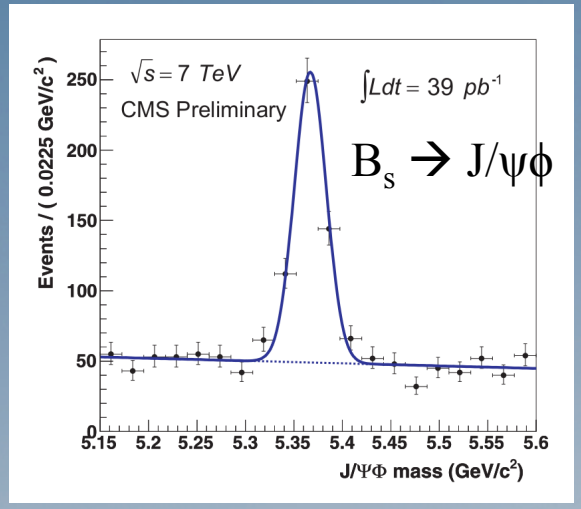
Bottom Physics

- heavy flavor in strong production





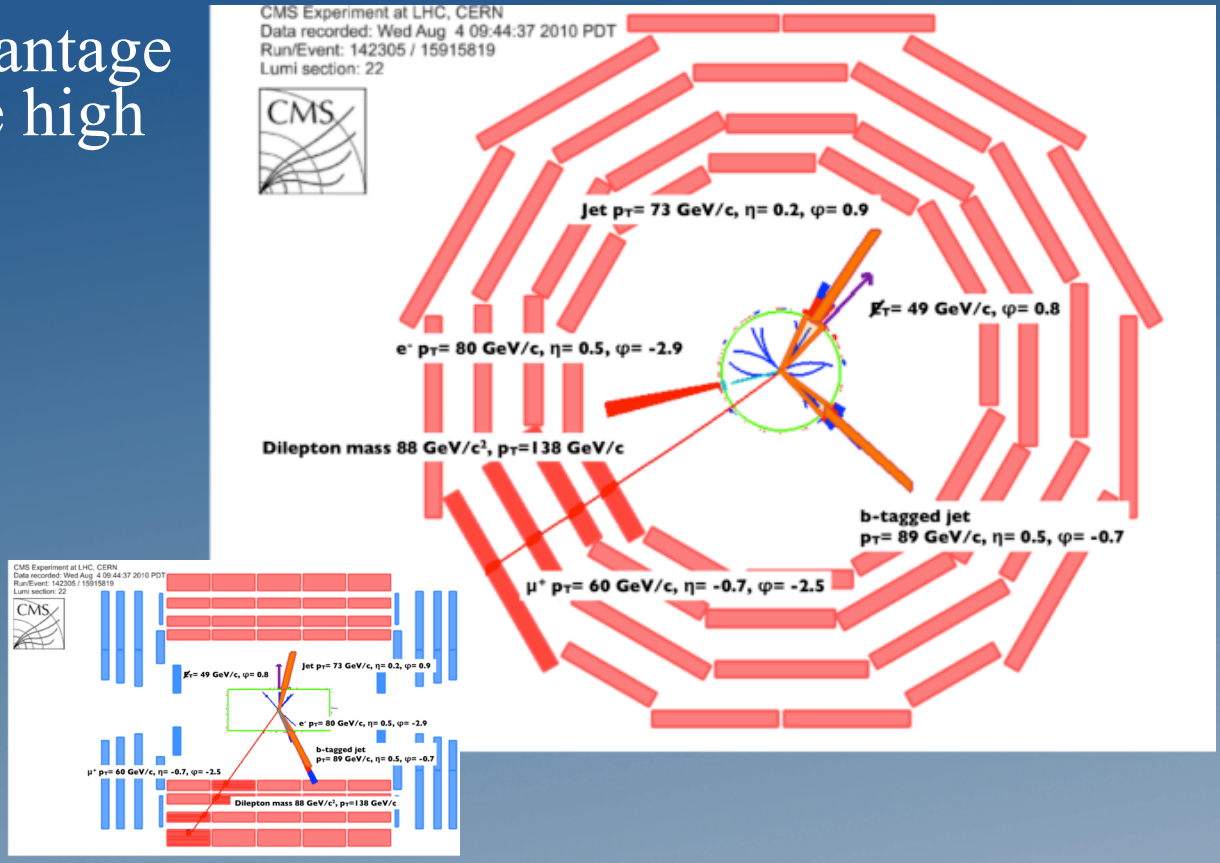




see talk by Giordano Cerizza on Monday

Top Quarks

- LHC's primary advantage is ability to produce high mass particles
- Top quark
  - Tevatron: ~8 pb
  - LHC: ~160 pb
- Final states
  - dilepton
  - l+jets
  - all jets
  - tau final states



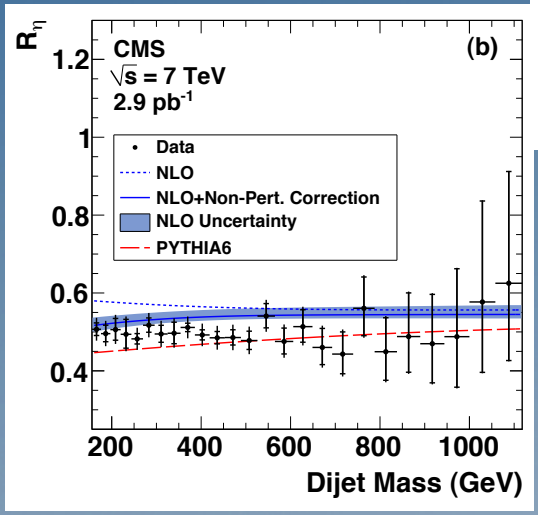
Tevatron is no longer the only place to study the top quark!

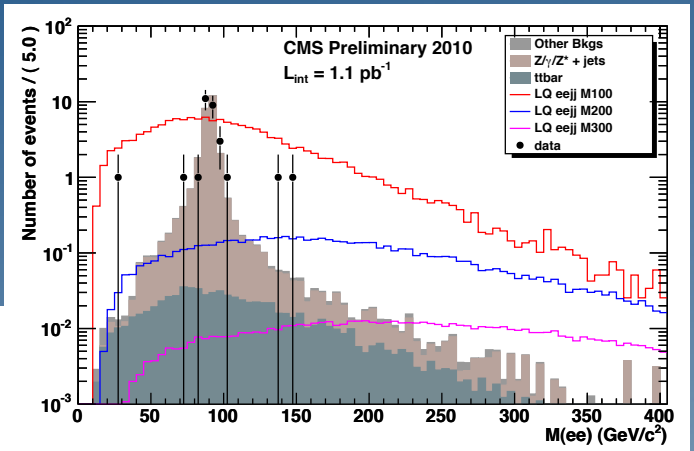
See talk by Kevin Lannon on Monday

Searches for New Physics

- LHC search most sensitive for high mass or under-explored channels
  - already breaking new ground in a number of searches

dijets

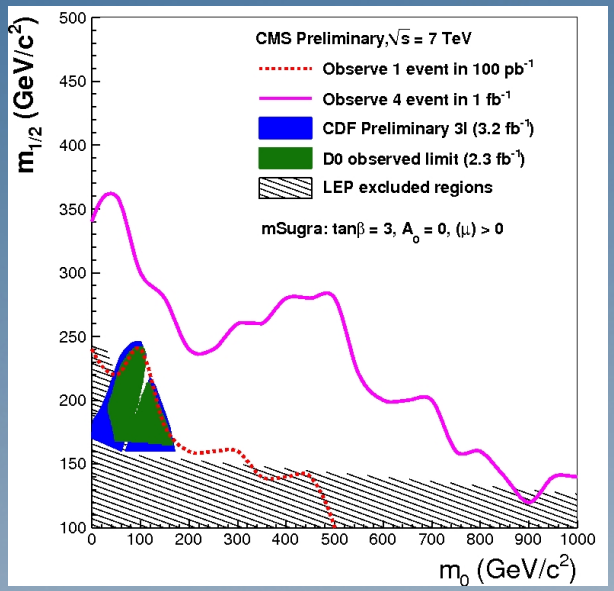




leptoquarks

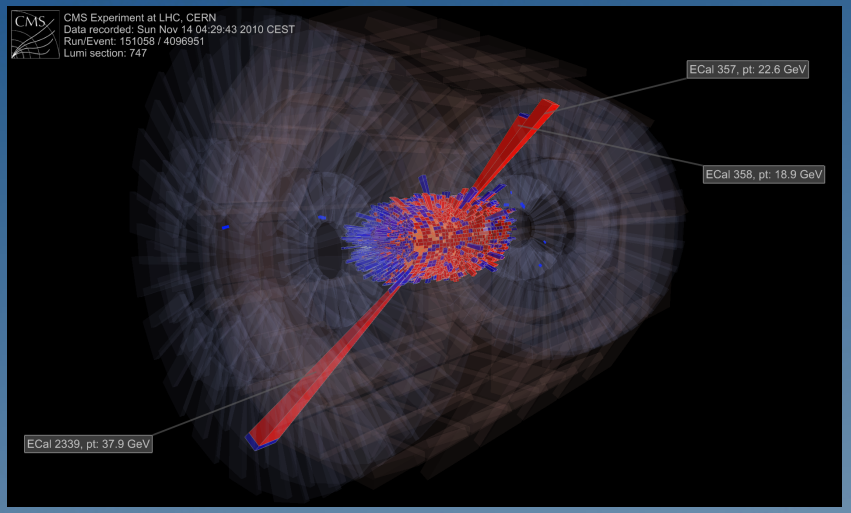
see talks by Jie Chen and Yousi Ma on Tuesday

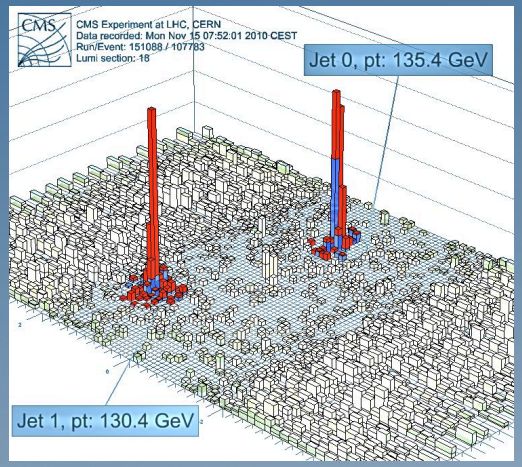
SUSY sensitivity



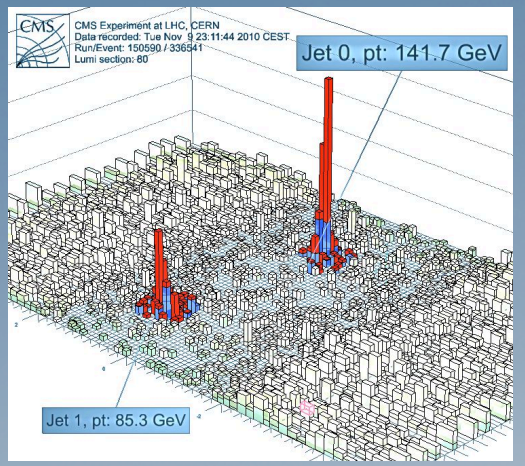
Heavy Ions

- CMS also studies heavy ions (Nov-Dec, 2010)
- first results (Dec. 2)
- first observation of Z in HI
- dijet energy asymmetry

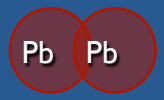




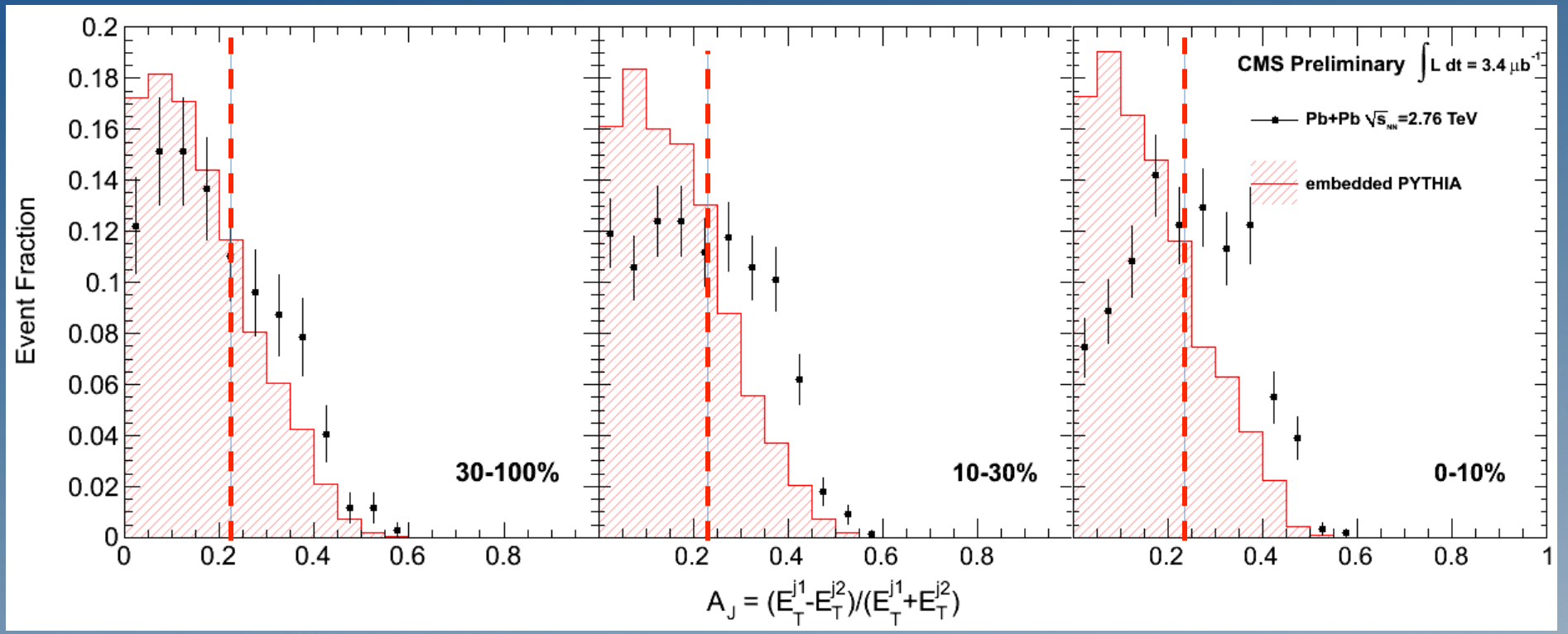
$$A_J = \frac{E_T^{j1} - E_T^{j2}}{E_T^{j1} + E_T^{j2}}$$



Heavy Ions

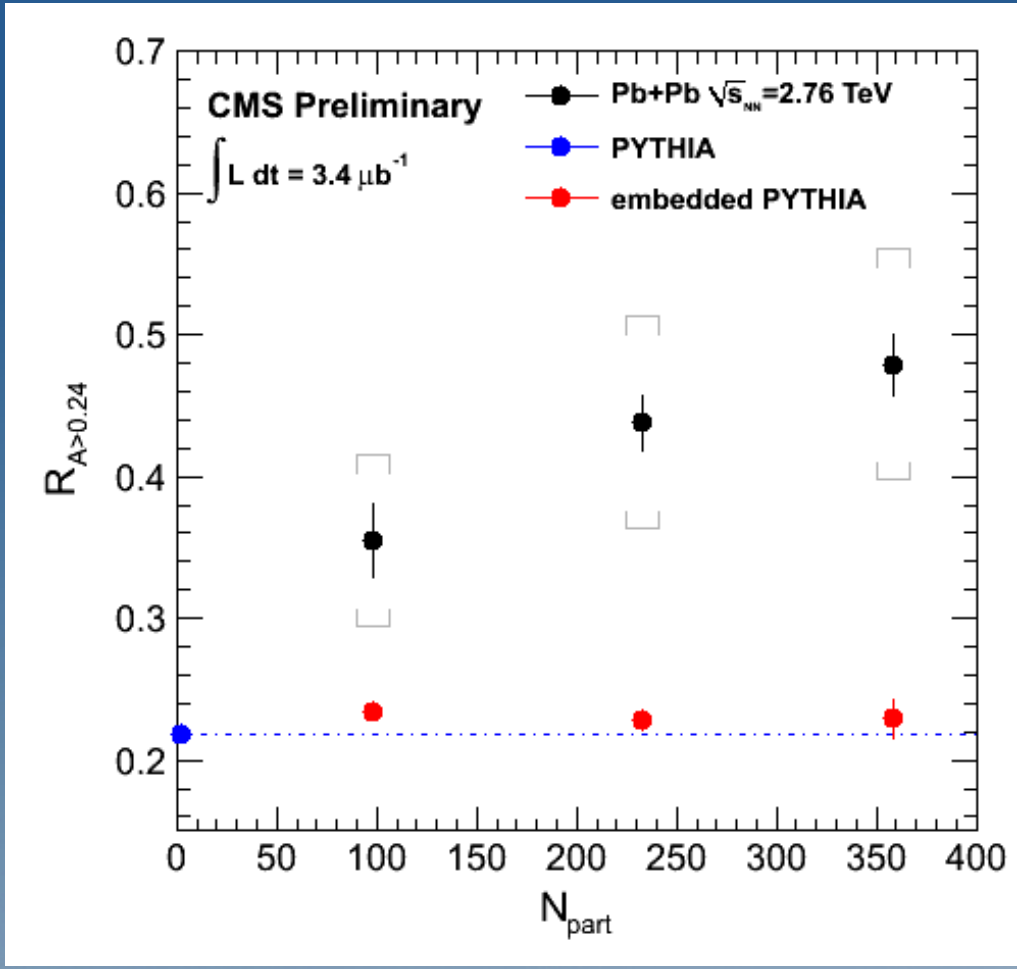


Semi-Peripheral **Semi-Central** **Central**



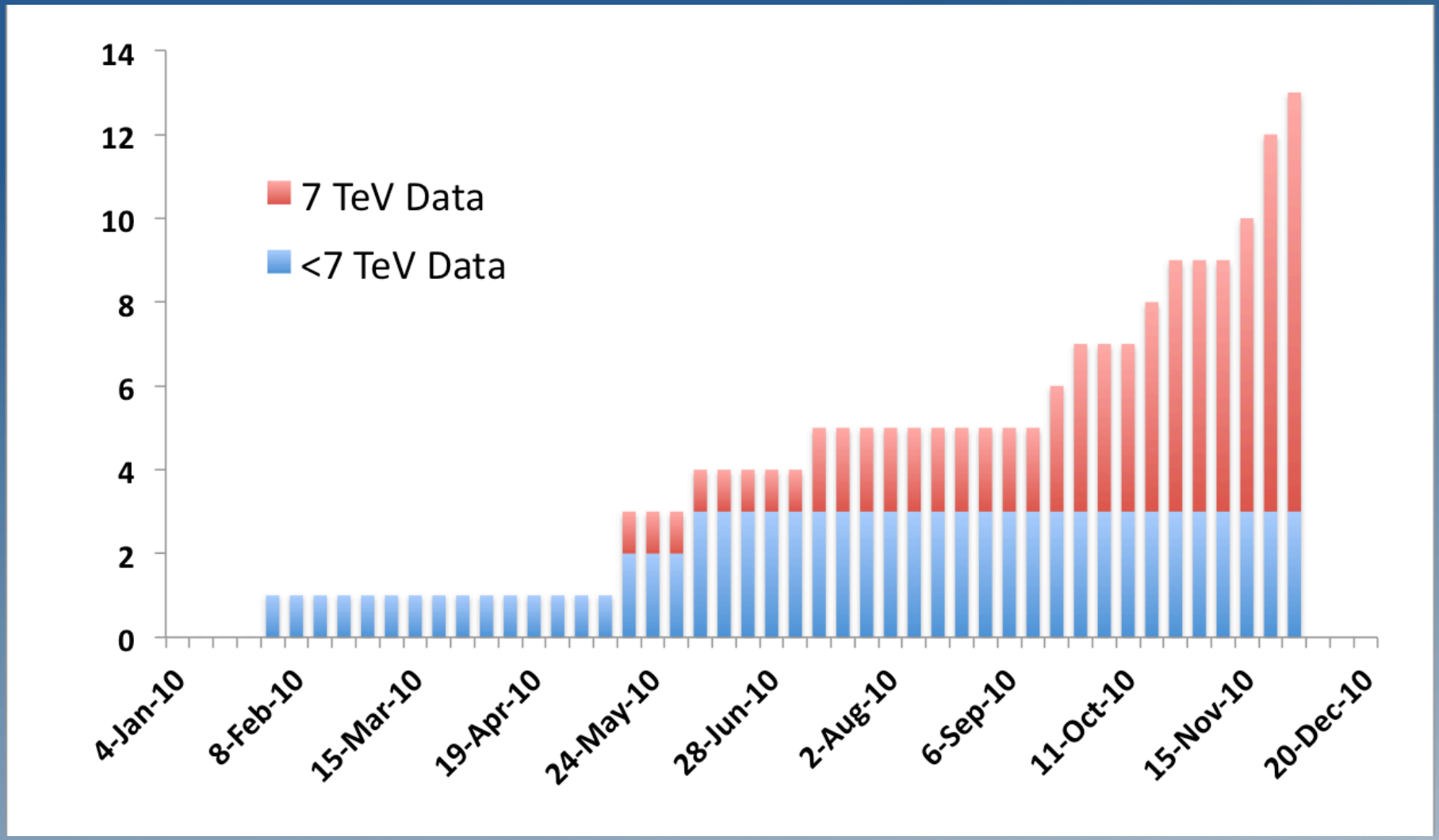
- **A significant dijet imbalance, well beyond that expected from unquenched MC, appears with increasing collision centrality**

Asymmetry Fraction (R)



- Fraction of jets with imbalance larger than 0.24
- Plot as a function of number of participating nucleons (volume) averaged over centrality bin

Paper Submissions



First Physics Publications

- "Measurement of the Isolated Photon Production Cross Section in pp Collisions at √s=7 TeV," arXiv::1012.0799 ← **last week**
- "Search for Stopped Gluinos ii pp Collisions at √s=7 TeV," arXiv::1011.5861.
- "Charged Particle Multiplicities in pp Interactions at √s=0.9, 2.36, and 7 TeV," arXiv::1011.5531.
- "Prompt and Non-prompt J/ψ Production in pp Collisions at √s=7 TeV," arXiv::1011.4193.
- "First Measurement of the Cross Section for Top-Quark Pair Production in Proton-Proton Collisions at √s=7 TeV," arXiv::1010.5994.
- "Search for Quark Compositeness with the Dijet Centrality Ratio in pp Collisions at √s=7 TeV," arXiv::1010.4439, submitted to Phys. Rev. Lett.
- "Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC," JHEP 09 (2010) 091.
- "Search for Dijet Resonances in 7 TeV pp Collisions at CMS", arXiv:: 1010.0203, submitted to Phys. Rev. Lett.
- "Transverse-momentum and pseudorapidity distributions of charged hadrons in *pp* collisions at √s = 7 TeV," Phys. Rev. Lett. 105 (2010) 022002.

Summary

- CMS has had a remarkable 2010
- First 7 TeV Collisions
- Excellent data acquisition efficiency and detector performance
- Many standard model processes observed
- Probing new regions of parameter space

This has been just an overview, the best parts will be presented in the following CMS talks…