

CMS in 2010:A Very Good Year

Conference on LHC First Data December 12, 2010

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Outline



- Compact Muon Solenoid
- Detector/Object Performance
 - tracking, photons/electrons, jets, MET
- Physics

- QCD, electroweak, top, searches, heavy ions

• Summary





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proton running

heavy ion running Pb-Pb





• significant increase in data from preliminary summer results



CMS Detector







CMS Detector







CMS Detector













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







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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 $H \rightarrow \gamma \gamma$





Electrons and Photons



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





ECAL Spikes

•

•







• use energy ratio/timing to clean ECAL hits

anomalous signal observed in ECAL

direct energy deposition in photodiode

- large energy in single crystal

- distorted time resolution



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Missing Transverse Energy



three methods of MET measurement

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



CMS preliminary 2010 number of events / 5 GeV 🔶 data 🔶 data + data $W \rightarrow e_V$ W → e_V W → ev Background Background Background √s = 7 TeV тс ∉⊤ Calo Type II ∉_T L dt = 255 nb e PF ∉_∓ 0 50 100 50 50 100 0 100 TC ₽_T [GeV] Calo Type II ₽_T [GeV] PF **∉**_⊤ [GeV] CMS preliminary 2010 number of events / 5 GeV 6 00 - Data 🗕 Data Data √s = 7 TeV $W \rightarrow \mu v$ $W \rightarrow \mu \nu$ $W \rightarrow \mu \nu$ L dt = 246 nb⁻¹ Background Background Background ТС ⊭⊤ PF ∉_⊤ Calo Type II ∉_T μ

50

100

TC ∉_τ [GeV]

0

MET in W candidate events

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50

Calo Type II ∉_T [GeV]

100 0

50

100

PF ∉_⊤ [GeV]



Data vs. Simulation







- 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







- "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 protonproton 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



CMS Preliminary

 $\int Ldt = 39 \ pb^{-1}$

J/ΨΦ mass (GeV/c²)

 $B_{s} \rightarrow J/\psi \phi$

heavy flavor in strong production





50

40

√s = 7 TeV, Ldt = 280 nb⁻¹

see talk by Giordano Cerizza on Monday

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≈ 5 mm



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

CMS



Searches for New Physics



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





leptoquarks

see talks by Jie Chen and Yousi Ma on Tuesday





Heavy lons

Data recorded: Sun Nov 14 04:29:43 2010 CEST Run/Event: 151058 / 4096951



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



$$A_{J} = \frac{E_{T}^{j1} - E_{T}^{j2}}{E_{T}^{j1} + E_{T}^{j2}}$$





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

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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

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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 $\sqrt{s}=7$ TeV," arXiv::1011.5861.
- "Charged Particle Multiplicities in pp Interactions at $\sqrt{s}=0.9$, 2.36, and 7 TeV," arXiv::1011.5531.
- "Prompt and Non-prompt J/ ψ Production in pp Collisions at $\sqrt{s}=7$ TeV," arXiv::1011.4193.
- "First Measurement of the Cross Section for Top-Quark Pair Production in Proton-Proton Collisions at $\sqrt{s}=7$ TeV," arXiv::1010.5994.
- "Search for Quark Compositeness with the Dijet Centrality Ratio in pp Collisions at $\sqrt{s}=7$ 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 $\sqrt{s} = 7$ TeV," Phys. Rev. Lett. 105 (2010) 022002.







- 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...