

## CMS Presents First 13 TeV Results

The European Physical Society Conference on High Energy Physics (EPS-HEP) begins today in Vienna, where the CMS Collaboration will present a first look at the new proton collision data collected within the last two months at 13 TeV, as well as more than 30 new results on the Run 1 data collected at 7 and 8 TeV.

The highlight of the conference for CMS is the first physics result using 13 TeV data: the measurement of charged hadron multiplicity ( $dN/d\eta$ ). This paper reports the differential multiplicity distribution for pseudorapidity less than 2, and the measured density for central charged hadrons ( $|\eta| < 0.5$ ) of  $5.49 \pm 0.01$  (stat)  $\pm 0.17$  (syst). Figure 1 shows the differential distribution and the energy dependence of the CMS result compared to earlier data at lower energies. The paper was submitted to PLB on July 21, and is the first result from the LHC on 13 TeV data submitted for publication.

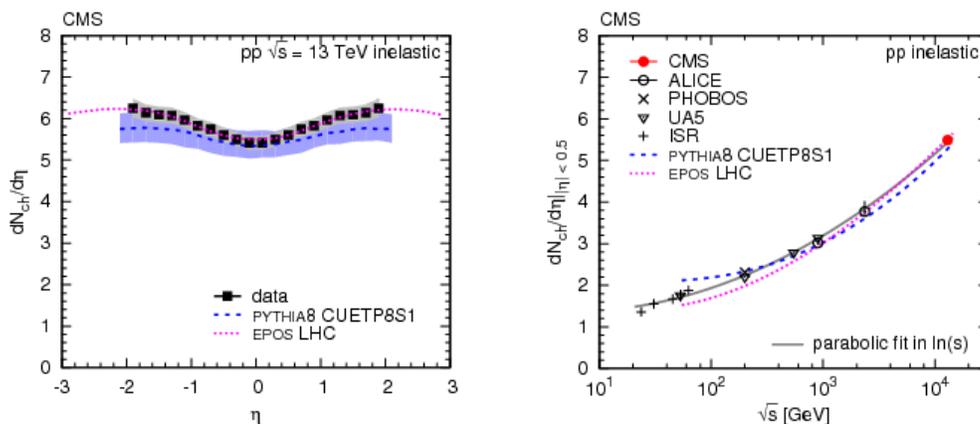


Figure 1: Measured charged hadron production as a function of pseudorapidity (left), and the multiplicity in the central region compared to previous measurements at lower energies.

In addition to the  $dN/d\eta$  result, CMS produced a full suite of performance plots covering a wide range of physics objects and final states using up to 43/pb of 13 TeV data. (Details on the Run 2 performance studies can be found [here](#)). Figure 2 shows the dimuon mass spectrum obtained from multiple trigger paths, where several known resonances from the omega meson to the Z boson can be clearly seen. The B physics (BPH) group has studied this spectrum in detail from  $J/\psi$  to Upsilon masses, and also the decay time distributions for events with  $J/\psi$  or  $B^+$  mesons. Dedicated performance plots are presented for various muon, electron, and photon kinematic and identification variables, as well as their measured reconstruction and identification efficiencies. The performance of the CMS Tracker is further demonstrated by the reconstruction of several low-mass states, including Ks, Lambda,  $D^0$ ,  $D^*$ ,  $B^+$ ,  $B^0$ , and  $B_s$ , and the beam spot position has been measured in all three dimensions. Simulation is found to reproduce physics object data very well at this early stage.

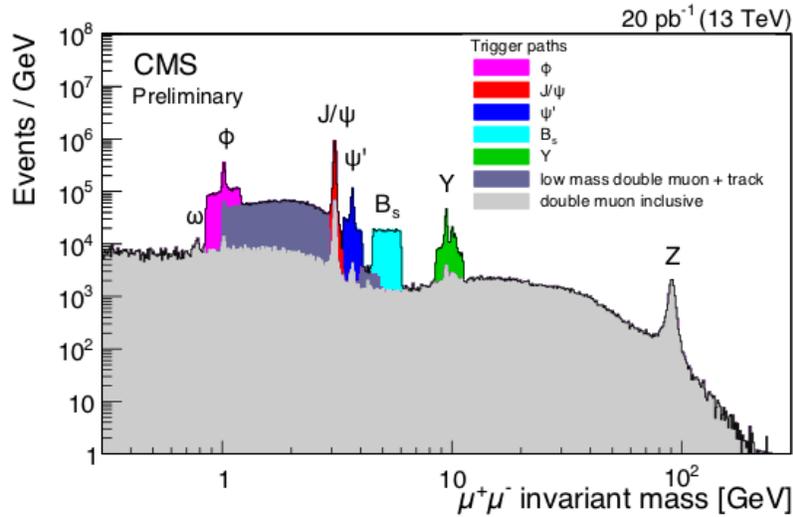


Figure 2: Dimuon invariant mass spectrum from several different trigger paths.

The physics groups have also been active in analysing the 13 TeV data, with several processes having been studied in some detail. One highlight of this effort is a first look at the dijet invariant mass spectrum up to approximately 5 TeV (Fig. 3), demonstrating the readiness of CMS for discovery physics in this new energy regime. The TOP group has studied  $t\bar{t}$  events in the dilepton and lepton+jet channels, as well having a first look at events consistent with production of single top quarks.

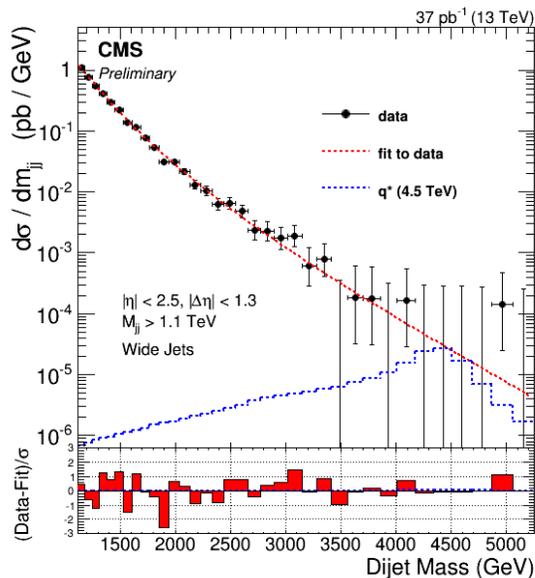


Figure 3: Dijet invariant mass spectrum, showing the expected signal distribution from a hypothetical particle with a mass of 4.5 TeV decaying into two jets.

While eagerly jumping on the new data, CMS continues to produce world-class physics results on the Run 1 data collected at 7 and 8 TeV. More than 30 new results have been approved recently and will be

shown in Vienna. These results include both searches for new physics and precision Standard Model measurements.

In addition to the charged hadron spectrum, the Forward and Small-x QCD (FSQ) group has presented new measurements of dijet production with large rapidity gaps and two-photon production of W boson pairs. The B physics (BPH) group extended their study of the  $B \rightarrow K^* \mu \mu$  process, including a full angular analysis, and has also measured the CP-violating angle  $\phi_s$  and the decay width difference  $\Delta\Gamma_s$  from  $B_s \rightarrow \phi K_s$  decays. The Standard Model (SMP) group reports four new measurements for EPS-HEP, including cross sections for inclusive jets at 2.76 TeV compared to 8 TeV, two-photon production of jets, and electroweak production of W + 2 jets. A measurement of the cross section for the  $Z\gamma \rightarrow \nu\nu\gamma$  process and limits on anomalous triple gauge couplings are also reported.

The top quark (TOP) group has approved eight new results recently, including measurements of the differential  $t\bar{t}$  cross section in the fully hadronic sample, and measurements of the cross sections for the  $t\bar{t} + b\bar{b}$  and  $t\bar{t} + V$  processes. New measurements of top properties such as spin correlations, W helicity, and charge asymmetry are also being reported. In addition, the TOP group continues to search for signs of new physics, most recently in the flavour-changing process  $t \rightarrow ch$  where the Higgs boson decays to photons.

The Higgs boson (HIG) group continues to search for non-SM Higgs bosons using the Run 1 data, approving three new results for EPS-HEP focused on final states including tau leptons, as well as a first limit on the Higgs boson lifetime. Searches have been conducted for neutral MSSM and low-mass pseudoscalar Higgs bosons decaying directly to tau pairs, and for the MSSM process H to hh and A to Zh, where h is the 125 GeV Higgs boson and H/A are neutral scalar and pseudoscalar bosons in the MSSM model.

The Exotica (EXO), Supersymmetry (SUS), and Beyond 2 Generations (B2G) groups have together produced seven new results, including searches for Dark Matter, unparticles, top squarks, vector-like quarks, and R-parity violating SUSY particles in multilepton final states. While no significant signals have been observed in the Run 1 data, these groups are actively searching the new data at higher energy with the hopes of finding the first signs of new physics beyond the Standard Model at the LHC.

Finally, while awaiting the Heavy Ion (HIN) run scheduled to begin in November, the HIN group has produced five new results from the Run 1 pp, pPb, and PbPb data. These include Upsilon polarization as a function of charged particle multiplicity in pp collisions; Z boson production, prompt and non-prompt J/psi production, and jet fragmentation functions in pPb collisions; and nuclear modification of Upsilon states in PbPb collisions.

## List of New Results from CMS for the EPS-HEP Conference:

[FSQ-12-001](#): Dijet production with a large rapidity gap between jets

[FSQ-13-008](#): Study of gamma-gamma -> W W at 8 TeV

[FSQ-15-001](#): Pseudorapidity distributions of charged hadrons in proton-proton collisions at  $\sqrt{s}$  TeV

[BPH-13-010](#): Angular analysis of the decay  $B_0 \rightarrow K^* \mu \mu$  with full data set

[BPH-13-012](#):  $\phi_s$  and  $\Delta\Gamma_s$  from  $B_s \rightarrow J/\psi \phi$

[SMP-13-012](#): EW production of  $W + 2$  jets

[SMP-14-017](#): Inclusive jets cross section at 2.76 TeV and ratio to 8 TeV

[SMP-14-019](#):  $Z \rightarrow \nu\bar{\nu} \gamma$  and aTGC at 8 TeV

[SMP-14-021](#):  $\gamma\gamma +$  jets at 7 TeV

[TOP-12-033](#): Measurement of the  $t\bar{t}$  charge asymmetry with lepton+jets events at 8 TeV

TOP-13-013 (to be submitted): Measurement of the charge asymmetry in top quark pair production in pp collisions at  $\sqrt{s} = 8$  TeV using a template method

[TOP-13-015](#): Measurement of spin correlations in top pair events with the matrix element method

TOP-13-016: Measurement of  $t\bar{t}b\bar{b}$  production at 8 TeV in the  $l$ +jets channel

[TOP-14-017](#):  $W$  helicity in  $t\bar{t}$  (dileptons) at 8 TeV

TOP-14-018 (to be submitted): Differential  $t\bar{t}$  cross section in the fully hadronic channel at 8 TeV

[TOP-14-019](#): Search for flavour-changing top-quark decays ( $t \rightarrow cH$ ) with  $H \rightarrow \gamma\gamma$

[TOP-14-021](#): Measurement of top quark pair production in association with a  $W$  or  $Z$  boson at the LHC

HIG-14-029 (to be submitted): MSSM  $H \rightarrow \tau\tau$  search using a new tau identification selection

HIG-14-033 (to be submitted): Low Mass Pseudoscalar Higgs boson to  $\tau\tau$

HIG-14-034 (to be submitted): MSSM  $H \rightarrow hh/A \rightarrow Zh$  in tau channels

[HIG-14-036](#): Lifetime analysis using Higgs to  $4l$  events

[EXO-12-054](#): DM and unparticles from  $Z$ +MET

[EXO-12-055](#): DM from boosted  $V$ +MET

[EXO-14-013](#): RPV stops,  $ll$  plus 6jets

SUS-13-023 (to be submitted): all hadronic stop MVA

SUS-14-003: RPV SUSY Searches with 0,1,2,3, and 4 leptons

SUS-14-015: Search for direct stop pair production in single and double lepton channels at  $\sqrt{s} = 8$  TeV

B2G-13-006 (to be submitted): Search for Vector-like  $B_{1/3}$  Quarks

HIN-14-009: Measurement of prompt and non-prompt  $J/\psi$  in pPb collisions

[HIN-15-001](#): Nuclear modification of  $Y$  states in PbPb

[HIN-15-002](#):  $Z$  boson production in pPb collisions

[HIN-15-003](#): Upsilon(nS) polarizations vs. charged particle multiplicity

[HIN-15-004](#): Jet Fragmentation Function in pPb collisions