CMS RUN2: PRIMI RISULTATI E PROSPETTIVE

F. Cossutti, INFN Trieste
per la Collaborazione CMS

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Università di Roma “La Sapienza”, Roma, 22/9/2015
RUN1: ANALYSIS STATUS

- 426 papers on collisions studies
- 24 papers on detector performances with data taking from cosmic rays
- Rich program of measurements of electroweak, QCD, top and bottom physics is continuing and producing results
Run 1 Results Summary

July 2015

- Studied processes with cross sections spanning 8 orders of magnitude
- No surprise from the Higgs boson, for the time being…
RUN1: NEW PHYSICS SEARCH

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined

- Wide spectrum of physics processes examined

No evidence of new physics signals
Parton luminosities significantly increase with the change in energy.

- besides wider phase space accessible, higher statistics available than in Run1, for the same integrated luminosity.
RUN2: WHAT’S NEW IN CMS

CMS DETECTOR
- Total weight: 14,000 tonnes
- Overall diameter: 15.0 m
- Overall length: 28.7 m
- Magnetic field: 3.8 T

STEEL RETURN YOKE
- 12,500 tonnes

SILICON TRACKER
- Pixel (100x150 μm) ~ 16 m² ~ 66M channels
- Microstrips (80x180 μm) ~ 200 m² ~ 9.6M channels

SUPERCONDUCTING SOLENOID
- Niobium titanium coil carrying ~ 18,000 A

MUON CHAMBERS
- Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
- Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

PRESHOWER
- Silicon strips ~ 16 m² ~ 137,000 channels

FORWARD CALORIMETER
- Steel + Quartz fibres ~ 2,000 Channels

CRYSTAL
- ELECTROMAGNETIC CALORIMETER (ECAL)

HADRON CALORIMETER (HCAL)
- Brass + Plastic scintillator ~ 7,000 channels

New DAQ2
- New CPUs for HLT
- Multi-threading computing/multi-core queues

New beampipe

Muon chambers
- 4th station

Additional luminometers

Low temperature tracker operations
- Pixel inactive channels recovered

First stage of L1 trigger upgrade
- (to be completed in 2016)
Detector status

Several recovery campaigns have re-established an almost perfect status.

➡ Please note that the scale starts at 90%!

**RUN2: CMS STATUS**

22/9/2015

F. Cossutti

All subdetectors are working, with an active channel fraction better than at the Run1 end.

New luminometers are operative.

This plot is a qualitative comparison between the luminosities measured by Hadron Forward Calorimeter (HF), the Beam Conditions Monitors (BCM), and the triple coincidence count rate of Pixel Luminosity Telescope (PLT).

A triple coincidence in a single PLT telescope is produced, when all three planes register one or multiple hits during the same bunch crossing of 25ns.

A clear correlation between the measured rates of the PLT and the already established luminometers can be seen during the time of the luminosity scan in LHC fill 3679.

New luminometers are operative
Problems with the solenoid cold box forced part of the data taking at B=0T

At B=3.8T:
- LHC delivered 0.19 fb\(^{-1}\)
- CMS recorded 0.17 fb\(^{-1}\)
  - efficiency 89%
- Analysis certification:
  - processed 97.30 pb\(^{-1}\)
  - validated for analysis 84.56 pb\(^{-1}\)
  - efficiency 87%
**RUN2: GEOMETRY AND ALIGNEMENT**

Beampipe and first pixel layer “radiography” with reconstructed nuclear interactions

**CMS-DP-2015-024/CDS:2039957**

Alignment with cosmic rays
New geometry with recentered pixels
Close to ideal geometry

**CMS-DP-2015-029/CDS:2041841**

Alignment: cosmic rays
aligned tracker $r_m=0.0127$
Run I geometry $r_m=0.8924$
MC (no misalignment) $r_m=0.0120$

The normalized differences between two halves of a cosmic track, split at the point of closest approach to the interaction region, in the track’s transverse momentum $p_T$. The observed precision in the alignment (green circles) produced with the Millepede-II and HIP algorithms using cosmic ray data at 0 and 3.8 T, is a major improvement over the Run I geometry (blue empty squares) which is no longer valid for Run II data, primarily because of temperature changes and pixel re-centering and repair. The precision comes close to that of the ideal Monte Carlo, illustrating that the tracker has almost reached its design momentum resolution.

The CMS Collaboration (cms-dpg-conveners-tracker@cern.ch)
RUN2: ELECTRONS AND PHOTONS

- Electron identification validated
- Energy scale derived from Run1 already good

CMS Preliminary, $\sqrt{s} = 13$ TeV
$\int L dt = 21.3$ pb$^{-1}$

CMS Preliminary

Di-Electron Spectrum

Dielectron mass spectrum for electrons in the DoubleEG dataset with $p_T > 10$ and $|\eta| < 2.5$ which pass the cut-based Electron ID Veto working point.


Using photons from $Z \to \mu\mu\gamma$
RUN2: MUONS

**Dimuon invariant mass spectrum**

- **J/ψ**
  - $27$ MeV
  - $p_T > 10$ GeV
  - $|y| < 1.25$
  - $20$ pb$^{-1}$ (13 TeV)

- **Y(nS)**
  - $65$ MeV
  - $p_T > 8$ GeV
  - $|y| < 0.9$
  - $20$ pb$^{-1}$ (13 TeV)

- **Φ(1020)**
  - $15$ MeV
  - $|y| < 1.25$
  - $20$ pb$^{-1}$ (13 TeV)

**Trigger paths**
- $\phi$
- $J/\psi$
- $\psi'$
- $B_s$
- $Y$
- low mass double muon + track
- double muon inclusive

**Events**

- All standard candles are under control
RUN2: MISSING ENERGY AND PILEUP

With the anticipated pileup increase in Run2 it becomes essential to improve the jet energy and missing energy correction, besides traditional Particle Flow (PF) PUPPI: Pile Up Per Particle identification

arXiv.1407.6013
CMS-PAS-JME-14-001
FIRST PUBLICATION AT 13 TEV: $dN_{ch}/d\eta$

- Charged particle multiplicity measurement
  - $\sqrt{s}$ dependence is important to discriminate the soft and hard collision components
  - Special run at low PU (0.2%-5%), 11.5M event
  - at B=0T
- combined use of pixel hits from different layers
  - “tracklet” (hit pixel pairs)
  - tracks (hit pixel triplets)
- different background contamination
  - consistent within 2-3%
  - combination as average

\hspace{1cm}

arXiv.1507.05915
Submitted to PLB
FIRST PUBLICATION AT 13 TEV: $dN_{\text{ch}}/d\eta$

\[
\frac{dN_{\text{ch}}}{d|\eta|(|\eta|<0.5)} = 5.49 \pm 0.01 \text{ (stat)} \pm 0.17 \text{ (syst)}
\]

- Consistent with Pythia8 (CUETP8S1/CUETP8M1) and EPOS LHC predictions
- Rapidity distribution better described by EPOS
σ(tt) WITH DILEPTON RECONSTRUCTION: INCLUSIVE CROSS SECTION

- Measurement based on 42 pb⁻¹
- events with eµ lepton pairs
  - p_T(l) > 20 GeV, |η(l)|< 2.4
  - M_{eµ} >20 GeV
- at least 2 jet anti-k_T R=0.4
  - p_T(j)>30 GeV, |η(j)|<2.4

Data statistics 60 7.7
Trigger efficiencies 39 5.0
Lepton efficiencies 33 4.3
Lepton energy scale < 1 0.1
Jet energy scale 20 2.6
Jet energy resolution < 1 0.1
Pileup 2.8 0.4
Scale (µ_F and µ_R) 1.5 0.2
tt NLO generator 15 1.9
tt hadronization 14 1.8
PDF 12 1.5
Single top quark 14 1.8
VV (V = W or Z) 3.5 0.5
Drell–Yan 3.9 0.5
Non-W/Z leptons 8 1.0
Total systematic (no integrated luminosity) 62 8.0
Integrated luminosity 93 12
Total 126 16.4

• preliminary uncertainty on luminosity: 12%
• Vdm scan analysis ongoing…

σ_{tt}(13 TeV)=772 ± 60 (stat) ± 62 (syst) ± 93 (lumi) pb
σ(NNLO+NNLL, m_t=172.5 GeV) = 832^{+40}_{-46} pb
σ(tt) WITH DILEPTON RECONSTRUCTION:
DIFFERENTIAL DISTRIBUTIONS

CMS-PAS-TOP-15-010

using every ee/µµ/µ combination
σ(tt) WITH SEMILEPTONIC RECONSTRUCTION

CMS-PAS-TOP-15-005

σ_{tt}(13 TeV) = 836 ± 27 (stat) ± 84 (syst) ± 100 (lumi) pb

σ(NNLO+NNLL, m_t=172.5 GeV) = 832^{+20}_{-29} (scale) ± 35 (PDF) pb

p_T(tt) well reproduced by POWHEG
SINGLE TOP QUARK IN T CHANNEL

- Based on 42 pb$^{-1}$
- 1 µ, $p_T > 22$ GeV, $|\eta| < 2.1$
- jets anti-$k_T$ R=0.4
  - $p_T > 40$ GeV, $|\eta| < 4.7$
  - b-tagged jet multiplicity discriminates signal and background
- $\Delta R(\mu, j) > 0.3$, $m_T > 50$ GeV

$\sigma_{t\bar{t}}(13\text{ TeV}) = 274 \pm 98$ (stat) ± 52 (syst) ± 33 (lumi) pb

$\sigma$(NLO) = 216.99$^{+6.62}_{-4.64}$ (scale) ± 6.16 (PDF) pb

CMS-PAS-TOP-15-004

- 2-jet 1-tag (SR)
- 3-jet 2-tag

CMS Preliminary
RUN2: NEW PHYSICS PERSPECTIVES

Run1 equivalent limit

Cross section ratios: 14 (13) TeV / 8 TeV

And: pp → H⁺(500) + X: 14 TeV/8 TeV ~ 7
DIJET RESONANCES SEARCH

- jets anti-$k_T$, R=0.4
- combined into two wide jets
- $|\Delta\eta_{jj}|<1.3$, $|\eta|<2.5$

CMS Preliminary

\[
\frac{d\sigma}{dm_{jj}} = p_0 \left( \frac{1-x}{x^2} \right)^\delta, \quad x = \frac{m_{jj}}{\sqrt{s}}
\]

42 pb$^{-1}$ (13 TeV)

CMS-PAS-EXO-15-001

$M_{jj} = 5.4$ TeV
DIJET RESONANCES SEARCH

- Observed limits at 95% CL
- Separated according to final state: qq, qg, gg

- Final state gluons: more radiation
  - Worst resolution

- Sensitivity larger than at 8 TeV for masses beyond 5 TeV

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<tr>
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<tr>
<td>String Resonance (S)</td>
<td>qq</td>
<td>5.1</td>
<td>5.2</td>
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<tr>
<td>Excited Quark (q^*)</td>
<td>qg</td>
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<td>2.9</td>
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<td>Scalar Diquark (D)</td>
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<td>3.3</td>
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<td>Axigluon (A)/Coloron (C)</td>
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<td>2.9</td>
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<tr>
<td>Color Octet Scalar (s8)</td>
<td>gg</td>
<td>2.3</td>
<td>2.0</td>
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LEPTONIC RESONANCES SEARCH

Dielectrons

- Electrons: $E_T > 35$ GeV, $|\eta| < 2.5$
- Predictions normalize to data in $60 < m_{ee} < 120$ GeV

Dimuons

- Muons: $p_T > 48$ GeV, $|\eta| < 2.4$
- opposite sign

Muon + $E_T^{miss}$

- Muon: $p_T > 55$ GeV, $|\eta| < 2.4$
- veto second muon with $p_T > 25$ GeV
- $0.4 < p_T(\mu)/E_T^{miss} < 1.5$
- $\Delta \phi(\mu, E_T^{miss}) > 2.5$

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CMS-DP-2015-037/CDS:2048094
DIELECTRON RESONANCE SEARCH

- negative $\cos\theta_C$
- Drell-Yan background mostly positive
- $\sim 0.002$ expected background events above 2.5 TeV
- not excluded by Run1 search

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<thead>
<tr>
<th></th>
<th>electron 0</th>
<th>electron 1</th>
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<tr>
<td>$E_T$</td>
<td>1260 GeV</td>
<td>1280 GeV</td>
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<tr>
<td>$\eta$</td>
<td>-0.24</td>
<td>-1.31</td>
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<tr>
<td>$\phi$</td>
<td>-2.74 rad</td>
<td>0.42 rad</td>
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<tr>
<td>charge</td>
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<td>+1</td>
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<tr>
<td>mass</td>
<td>2.91 TeV</td>
<td></td>
</tr>
<tr>
<td>$\cos \theta_C^*</td>
<td>$ -0.49</td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>-0.78</td>
<td></td>
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$\mathbf{m_{ee} = 2.9 \text{ TeV}}$
After a 2 years shutdown and upgrade CMS is operative
First results produced, one paper already submitted, more coming
First extension of new physics reach
Ready for some surprise…
BACKUP MATERIAL
RUN1: NEW PHYSICS SEARCH

Summary of CMS SUSY Results* in SMS framework

ICHEP 2014

For decays with intermediate mass, $m_{\text{intermediate}} = x m_{\text{mother}} + (1-x) m_{\text{LSP}}$

*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe "up to" the quoted mass limit

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined

CMS Preliminary
HIGHEST MASS DIPHOTON CANDIDATE

3D event display of the highest-mass diphoton candidate passing the event selection. The diphoton invariant mass is 730 GeV.

**CMS-DP-2015-037/CDS:2048094**