CMS Highlights from Spring 2013

LHCC open session
June 12, 2013
Jeffrey Berryhill (Fermilab)
On behalf of the CMS collaboration

Digital art courtesy of Xavier Cortada (with the participation of physicist Pete Markowitz) "In search of the Higgs boson: H -> ZZ"
CMS Collaboration status

• 241+ physics publications with collision data; Higgs discovery paper has nearly 1200 citations

• 33 new physics results since Moriond 2013, including new Higgs combination

• Manpower shifting to upgrades/LS1 activities as Run 1 analysis is completed

• Welcoming new spokesperson-elect Tiziano Camporesi in 2014.
2012 data and MC reprocessing with final calibrations and alignments is complete!
- (Core + Parked) with improved conditions has been delivered!
- This is the legacy 2012 dataset

And fully certified!
- Golden: 19.79 /fb (91% of recorded)
- Muon: 20.65 /fb (95% of recorded)
  - Jet Energy Corrections and Btag scale factors based on new reprocessing signed off and available to analyzers since June 7th
  - Improved MC for H->\gamma\gamma (with run dependent ECAL conditions)
Digital art courtesy of Xavier Cortada (with the participation of physicist Pete Markowitz) "In search of the Higgs boson: H -> taunu"
31/nb of 2013 pPb collisions, a comprehensive follow-up on 1/μb 2012 observation of near-side long-range correlations in pPb.

Ridge phenomena can now be compared with PbPb at similar multiplicity (> 200), as well as 4-particle correlations and multipole harmonics (v2, v3).
p-Pb results: 2013 ridge analysis

Submitted to PLB
arXiv:1305.0609

31/nb of 2013 pPb collisions, a comprehensive follow-up on 1/µb 2012 observation of near-side long-range correlations in pPb

Hydrodynamic expansion of a strongly coupled medium presently the only theory that explains all CMS observations

Ridge phenomena can now be compared with PbPb at similar multiplicity (> 200), as well as 4-particle correlations and multipole harmonics (v2, v3)
Standard Model: 8 TeV inclusive jets

Double-differential inclusive jet cross section obtained with 11/fb at 8 TeV

Agreement with NLO QCD over 11 orders of magnitude, with sensitivity beyond 2 TeV

- 2-5% jet energy scale uncertainty for PF jets
- 4-8% jet energy resolution
- 10-30% cross section uncertainty per bin
- Improvement to high $x$ q/g PDF expected
Standard Model: W+heavy flavor studies

**CMS-PAS-SMP-12-002**

Large W+c rate exploited for a high-purity W+c cross section measurement at 7 TeV.

Sensitivity to strange PDF now an interesting alternative to fixed target neutrino data.

**CMS-PAS-SMP-12-026**

W+bb exclusive final state extracted for the first time at 7 TeV

Rate and production dynamics consistent with MadGraph and NLO QCD (MCFM) within errors (22%)
Comprehensive study of Z+forward dijet production at 7 TeV.

VBF Z one of the interfering amplitudes

Submitted to JHEP, arXiv:1305.5596

• First search for photon-photon scattering production of WW

• WW$\gamma\gamma$ quartic gauge coupling one of the amplitudes

Submitted to JHEP, arXiv:1305.7389
Comprehensive study of Z+forward dijet production at 7 TeV. Electroweak component has 2.6 sigma significance. Forward dijet dynamics in agreement with MadGraph.

Submitted to JHEP, arXiv:1305.5596

- Two $e\mu$ events observed with no UE present
- First quartic gauge coupling limits at LHC; $WW\gamma\gamma$ limit two orders better than LEP or Tevatron!
Higgs Results

Digital art courtesy of Xavier Cortada (with the participation of physicist Pete Markowitz) "In search of the Higgs boson: H -> bottom bottom"
H → γγ : Full Run 1 result

CMS-PAS-HIG-13-001

- Most sensitive MVA-based analysis finds an excess with local significance of 3.2 σ at 125 GeV mass (4.2 σ expected).
- Signal strength μ = 0.78 ± 0.27 consistent with SM Higgs and consistent across categories.
- Alternative cut-based analysis has significance of 3.9 σ (3.5 expected).
- Different analyses compatible with each other at 1.5 σ level, including correlations.
Moriond 2013 combination

CMS-PAS-HIG-13-005

A consistent mass is measured for ZZ* and $\gamma\gamma$: 125.7±0.3±0.3 GeV

A consistent signal strength is measured for 5 decay modes $\mu = 0.80\pm0.14$

• A consistent signal strength is measured w.r.t production mode, fermion vs. boson couplings, and custodial symmetry

• JCP 2++/0- disfavored at 2.8/3.3 $\sigma$ level
V+H, H→bb: Full Run 1 result

- BDT shape-based analysis finds an excess with local significance of $2.1 \sigma$ at 125 GeV mass ($2.1 \sigma$ expected).
- VZ diboson peak clearly visible ($7.5\sigma$), consistent with SM rate.
- Signal strength $\mu = 1.0 \pm 0.50$ consistent with SM Higgs and consistent across V modes.
Higgs newcomers since Moriond:

CMS-PAS-HIG-13-011

- First search for VBF $H \rightarrow bb$.
- $Z \rightarrow bb$ peak clearly visible (8 $\sigma$, 6.8 $\sigma$ exp.)
- $bb$ Mass fit in MVA categories
- At 125 GeV $\mu = 0.7 \pm 1.4$, 95% CL UL of 3.6 (3.0 exp.)

CMS-PAS-HIG-13-015, HIG-13-008

- $ttH$ now extended to $\gamma\gamma$ decay mode. At 125 GeV, $\mu < 5.4$ (95% CL, 5.3 expected)
- $H \rightarrow WW \rightarrow l\nu J$ search. First Higgs search to include merged dijet W-tagging (pruned CA8 with n-subjettiness cut).
Beyond Standard Model Search Results

Digital art courtesy of Xavier Cortada (with the participation of physicist Pete Markowitz) "In search of the Higgs boson: H -> gamma gamma"
SUSY: Remaining strategies for Run 1

- Natural R-parity-conserving SUSY offered possibility of light squark/gluino discovery. Exclusions up to 800-1300 GeV mass complete.

- Now searching for more general realizations of natural SUSY:
  - R-parity violation
  - Electroweak gaugino production
  - Light stop/sbottom
  - Compressed spectra
SUSY: stop search in lepton+jets

Stop pair search in stop → top + LSP and b+W+LSP decays. Signature is semileptonic tt candidates with large MET. Kinematic BDT identifies loose (tight) selection for light (heavy) stop.

Stop mass limits obtained 150-650 GeV in mass, including the off-shell top sector.
BSM: bb resonances

CMS-PAS-EXO-12-023

• bb and bg resonance search

• Wide central ($\eta < 2.5$) jets of radius 1.1 reconstructed from anti-kt jets of radius 0.5, $|\Delta \eta| < 1.3$

• 0, 1, and 2 b-tagged jet categories analyzed to maximize efficiency at high mass

• Data consistent with smooth background

• RS graviton bounds
  > 1.42-1.57 TeV

• Narrow topcolor $Z'$
  > 1.20-1.68 TeV

• Excited $b^* \rightarrow bg$
  > 1.34-1.54 TeV
BSM: tt resonances

CMS-PAS-B2G-12-005

- tt resonance search in the all-hadronic state
- 400 GeV CA8 dijets selected for 3-jet, top-like substructure (JHUTopTagger)
- Top tagger performance calibrated with tt control samples
- RS KK gluon bounds > 1.8 TeV
- Narrow topcolor Z' > 1.65 TeV

CMS-PAS-B2G-12-006

- tt resonance search in the lepton+jets state
- Threshold, low mass selection: isolated lepton + 4 jets
- Boosted, high mass selection: non- or isolated lepton + 2 jets
- Both 0 and 1 b-tagged categories examined
- RS KK gluon bounds > 2.5 TeV
- Narrow topcolor Z' > 2.1 TeV
BSM: black holes

Submitted to JHEP, arXiv:1303.5338

- Microscopic black hole or string-ball production results in high-multiplicity, high sum-ET events
- Select 2 jets + X events, count N physics objects with ET > 50 GeV and compute their scalar sum-ET, ST for N=2-10
- N=2 control sample for ST background shape
- ST 1.9-2.3 TeV sideband for background norm vs. N
- Semi-classical BH bounds from 4.3-6.2 TeV
- Minimum string ball bounds ~5.5 TeV
- +model-independent xsec limits
- Final result for Run 1
Shutdown and Upgrade Activities

Digital art courtesy of Xavier Cortada (with the participation of physicist Pete Markowitz) "In search of the Higgs boson: H -> WW"
Current CMS detector status

- Beam pipe HF/CT2, and endcap sections removed at both ends
- Barrel and forward pixels have been removed to cold lab
- ME1/1 chamber removal begun
- Water cooling has returned, power to racks soon to follow
Near term plans for LS1

• Full ME1/1 chamber removal to surface for electronics refurbishing
• HO SiPM, HF PMT testing and installation at Pt 5 test-stand
• Strip tracker "Going Cold" activities in full swing; recommissioning cold in September
• CSC and RPC chambers in layer 4, installation in Oct. and Feb.
• Global run planned for end October
LS1: Surface Facilities

- Pixel cold lab
- Sensor repair lab
- RP workshop
- Beampipe
- ME1/1 revision
- Drift tube active storage
- Shielding/T1 bunker
- CASTOR bunker
**Longer term**

- **LHCC this week:** **L1 Trigger Upgrade TDR**
  - Asking for approval at this meeting
- **With approval this joins the Pixel and HCAL Upgrade TDRs** for Phase 1
- **CMS held an upgrade workshop last week at DESY**, focused on the upgrade scenarios and R&D for Phase 2
- **Preparing for Snowmass**, End of June (Seattle), Start of August (Minneapolis): Variety of physics studies for HL-LHC
- **And for ECFA HL-LHC Workshop, Oct 1-3**
- Developing upgrade scenarios with cost scale for Phase 2 (HL-LHC) based on physics performance and detector longevity requirements – by October
- **Phase 2 Technical Proposal** planned in 2014
Summary

• Run 1 pp, pPb, PbPb data being successfully exploited for novel insights into heavy ion and SM physics.

• 2013 Run 1 Higgs results validate and improve upon the 2012 Higgs-like boson discovery. SM Higgs hypothesis is holding up well; now on the offensive in new SM and BSM modes.

• BSM search data continue to confront TeV scale physics (and beyond). New avenues in natural SUSY under exploration.

• LS1 improvements proceed on schedule. Phase 1 projects are underway. Converging on plans for Phase 2 Technical Proposal.
Backups
**H → γγ: Full Run 1 result**

Signal strength by analysis and year

<table>
<thead>
<tr>
<th></th>
<th>MVA analysis (at $m_H=125$ GeV)</th>
<th>cut-based analysis (at $m_H=124.5$ GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 TeV</td>
<td>$1.69^{+0.65}_{-0.59}$</td>
<td>$2.27^{+0.80}_{-0.74}$</td>
</tr>
<tr>
<td>8 TeV</td>
<td>$0.55^{+0.29}_{-0.27}$</td>
<td>$0.93^{+0.34}_{-0.32}$</td>
</tr>
<tr>
<td>7 + 8 TeV</td>
<td>$0.78^{+0.28}_{-0.26}$</td>
<td>$1.11^{+0.32}_{-0.30}$</td>
</tr>
</tbody>
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![Graphs showing signal strength for 7 TeV and 8 TeV]
H → γγ : Full Run 1 result

The correlation coefficient between the MVA and cut-based signal strength measurements is found to be $r=0.76$ (estimated using jackknife techniques). Taking account of the correlation, the compatibility between the MVA and cut-based analysis measurements of the signal strength is found to be within 1.5σ for the combined 7 and 8 TeV measurement, and within 1.8σ for the 8 TeV measurement alone.
EM and muon object isolation using calorimeter energy with pile-up subtraction.

Improved jet finding with pile-up subtraction.

Improved hadronic tau ID with a much narrower cone.

Improved muon pT resolution.

Improved global Level-1 trigger menu with larger capacity and more complex object combination.

Realized with new high-bandwidth optical links (μTCA) and large FPGAs (Xilinx Virtex 7)

Commissioning system in 2015
Complete system ready for physics in 2016