CMS Status Report

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ETH Zürich

on behalf of the CMS collaboration

LHCC Open Session
March 23, 2011
Outline

Introduction
- Shutdown activities
- Commissioning, current status

Selected Physics results
- Heavy Ions
- Jet Production
- “Heavy Quark” production
- Vector Boson production
- Higgs searches
- Searches for Supersymmetry
- Exotic signatures
- Conclusions

Note 1: Most of the results shown based on full 2010 statistics

Note 2: Take-Home messages highlighted in this manner

- Reliable operations with 47 pb\(^{-1}\) delivered by LHC
- CMS recorded 43 pb\(^{-1}\). Overall data taking larger than 92%~85% recorded with all subdetectors in perfect conditions.
- All subdetectors have at least 98% of all channels operational.

- Improved evaluation of luminosity: syst. uncertainty reduced to 4%, central value shifted by 0.7% only
A long list of tasks, successfully carried out, such as

- Installation of TOTEM T1 telescope on both ends
- Filter farm cooling upgrade

21 Jan: All services restored
28 Jan: CMS closed, started to pump-down.
10 Feb: Pump-down complete.

B field 0T → 1T → 0T → 3.8T

18 Feb: Ready for beam (on schedule)

commissioning started with cosmics
taking collision data since March 13
~12 (10) pb⁻¹ delivered (recorded) so far
New events coming in...

The new challenge: Pile-Up!
CMS is prepared for it on all fronts: Trigger, Reconstruction, Analysis, Computing
List of physics analyses so far

In total: 83 physics analyses, based on 2010 data, approved so far
45 papers completed (published, submitted, or close to submission)
23 papers in preparation
24 analyses to be approved soon

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults
Heavy Ion Physics

jet quenching

the “ridge” : di-hadron correlations

Z production

Z → μμ

chg. particle multiplicity

CMS Preliminary PbPb / sNN=2.76 TeV

(dN_{ch}/dn)/(N_{part})^2

0-5% 30-35% 60-65% 85-90%
Jet Quenching

The phenomenon of jet quenching in Heavy-Ion collisions is now described in detail and well understood.

The di-jet momentum balance is fully recovered if we consider the low $p_T$ tracks distributed over a wider angular range wrt the jet axis.

The studies of Heavy-Ion collisions have already gone well beyond the mere observations of new effects!

Production of Jets

- Event shapes
- Azimuthal correlations
- Very forward jets

Graphs and data points illustrating the production of jets with emphasis on the ratio 3-jets / 2-jets rate.
Inclusive jet cross section

- From $p_T=18$ GeV to $p_T\sim1$ TeV!
- Extending to very low $p_T$ thanks to Particle Flow
- JES uncertainties: ~3-5 %
- Corrected to particle level
- Inclusive jet $p_T$ spectra are in good agreement with NLO QCD
- Consistent results obtained using calo-jets

$\sqrt{s} = 7$ TeV

$\frac{d^2\sigma}{dp_T dy}$ (pb/GeV)

CMS preliminary, 34 pb$^{-1}$

Data for:
- $|y|<0.5$ ($\times3125$)
- $0.5\leq|y|<1$ ($\times625$)
- $1\leq|y|<1.5$ ($\times125$)
- $1.5\leq|y|<2$ ($\times25$)
- $2\leq|y|<2.5$ ($\times5$)
- $2.5\leq|y|<3$

$N$ LO $\otimes$ NP theory

Exp. uncertainty

Anti-$k_T$ $R=0.5$
Inclusive jet cross section

- From $p_T=18$ GeV to $p_T\sim 1$ TeV!
- Extending to very low $p_T$ thanks to Particle Flow
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Further jet distributions

Di-jet mass distribution

CMS Preliminary

- $L_{\text{int}} = 36 \text{ pb}^{-1}$
- $\sqrt{s} = 7 \text{ TeV}$
- anti-$k_T$ $R = 0.7$

$|y|_{\text{max}} < 0.5$
$0.5 < |y|_{\text{max}} < 1.0 \times 10^1$
$1.0 < |y|_{\text{max}} < 1.5 \times 10^2$
$1.5 < |y|_{\text{max}} < 2.0 \times 10^3$
$2.0 < |y|_{\text{max}} < 2.5 \times 10^4$

$p\text{QCD at NLO + Non Pert. Corr.}$

PDF4LHC

$\mu_F = \mu_R = \left( p_{\text{T},1} + p_{\text{T},2} \right)/2$
Further jet distributions

Di-jet mass distribution

CMS Preliminary

- $|y|_{\text{max}} < 0.5$
- $0.5 < |y|_{\text{max}} < 1.0 \times 10^3$
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$L_{\text{int}} = 36 \text{ pb}^{-1}$

$\sqrt{s} = 7 \text{ TeV}$

anti-$k_T$ $R = 0.7$

$p\text{QCD at NLO + Non Pert. Corr.}$

$\mu_F = \mu_R = (p_{T,1} + p_{T,2})/2$

All distributions unfolded/corrected for detector effects

Achieved excellent understanding of jet production, over very wide phase space. Start to constrain Monte Carlo models.
Production of “heavy” quarks:

\[ s \rightarrow \text{Quarkonia} \rightarrow b \rightarrow \text{top} \]
Strangeness Production

Reconstruction of $K_s$, $\Lambda$, $\Xi^-$

Striking diff. Data-MC, increases with strangeness content
Extensive studies of b/B production. Consistent picture in all channels:
Data between predictions of MC@NLO and Pythia;
differences in shape, both for $p_T$ and rapidity distributions.
B-hadron angular correlations

New: Secondary vertex finder seeded with high IP tracks, jet independent
B-hadron angular correlations

- Sizable fraction of total BB cross section from collinear B-hadron pairs
- Fraction of collinear BB production increases with leading jet $p_T$

**New:** Secondary vertex finder seeded with high IP tracks, jet independent

Extremely important groundwork for upcoming searches with (boosted) bb final states. In particular: low-mass Higgs!
**TOP Cross section**

**New Analysis**: Lepton+jets, b-tagged

- divide sample into distinct categories: Nr. jets, Nr. of b-tags, electrons, muons
- fit the secondary vertex mass distribution, using templates, simultaneously in all categories
- let also data/MC scale factors (JES, b-tag eff, W+j $Q^2$-scale) float in the fit

**Result**:  
- top cross section, with overall 11% syst. uncert.
- scale factors consistent with 1, within the fit error

A fantastic proof of the excellent understanding of all relevant physics objects, and of their outstanding MC description
Top cross section and mass

CMS Preliminary, $\sqrt{s}=7$ TeV

- CMS combined (prel.)
  - TOP-11-001
  - CMS i+jets+btag (prel.)
    - TOP-10-003
  - CMS dilepton (prel.)
    - TOP-10-005
  - CMS i+jets (prel.)
    - TOP-10-002
  - ATLAS combined (prel.)
    - ATLAS-CONF-2011-040
  - ATLAS i+jets+btag (prel.)
    - ATLAS-CONF-2011-035
  - ATLAS dilepton (prel.)
    - ATLAS-CONF-2011-034
  - ATLAS i+jets (prel.)
    - ATLAS-CONF-2011-023
  - ATLAS dilepton+btag (prel.)
    - ATLAS-CONF-2011-034

Top Pair Production Cross Section [pb]

- CMS combined (36 pb$^{-1}$)
- ATLAS combined (35 pb$^{-1}$)
- CDF
- D0

MSTW 2008 NNLO PDF

TOP-11-001

CERN 23/3/11
Top cross section and mass

### CMS Preliminary, $\sqrt{s}=7$ TeV

<table>
<thead>
<tr>
<th>Method</th>
<th>$m_{top}$ (in GeV/$c^2$)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMWT</td>
<td>$175.8 \pm 4.9$(stat) $\pm 4.5$(syst)</td>
<td>0.65</td>
</tr>
<tr>
<td>KINb</td>
<td>$174.8 \pm 5.5$(stat) $^{+4.5}_{-5.0}$(syst)</td>
<td>0.35</td>
</tr>
<tr>
<td>combined</td>
<td>$175.5 \pm 4.6$(stat) $\pm 4.6$(syst) $\chi^2$/dof=0.040 (p-value=0.84)</td>
<td></td>
</tr>
</tbody>
</table>

Syst. uncertainty dominated by:

- JES (3.1 GeV)
- b-JES (2.5 GeV)
Single top production

Two methods employed:

- Cut based using angular info
- BDT, based on kinematic observables

An example of finding tiny signals with leptons, MET, b-tag & jets

Showing the readiness for challenging searches such as low-mass Higgs
Production of Vector Bosons

see also recent talk by
- P.C. Harris, Moriond EWK-11
Inclusive W and Z production

- 3 pb$^{-1}$ results published, JHEP01(2011)080
- New prelim. results for 36 pb$^{-1}$
- Z important tool: data-driven methods for controlling lepton eff, scale, resolution, $E_{T\text{miss}}$ (hadronic recoil).
- In general excellent data-MC agreement
Inclusive W and Z production

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Amazing precision reached (~1% experimental!) Start to put important constraints on theory (NNLO, PDFs)
Improvement in CMS Tau Identification Performance

due to reconstruction of individual decay modes
(vector meson resonances), **based on Particle Flow**

for same efficiency, fake rate reduced by factor of 3

**for the Z analysis included:**
- mu+had, e+had, e+mu, mu+mu (~55% of total BR)
- had-tau eff. constrained by ratio lept/semi-lept channels
**τ performance and Z → ττ**

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Tau established as an important tool for many analyses, in the SM sector and new physics searches
W properties, constraining PDFs

W asymmetry and $W^+$ over $W^-$ ratio:
Challenging PDF predictions!

 EWK-10-006

NNLO, FEWZ+MSTW08 prediction
(with PDF4LHC 68% CL uncertainty)

- $W \rightarrow e\nu$
  \[
  1.418 \pm 0.008_{\text{stat}} \pm 0.036_{\text{syst}}
  \]

- $W \rightarrow \mu\nu$
  \[
  1.423 \pm 0.008_{\text{stat}} \pm 0.036_{\text{syst}}
  \]

- $W \rightarrow l\nu$ (combined)
  \[
  1.421 \pm 0.006_{\text{stat}} \pm 0.033_{\text{syst}}
  \]

\[
R_{+/-} = \frac{\sigma \times B(W^+)}{\sigma \times B(W^-)}
\]
W properties, constraining PDFs

W asymmetry and $W^+$ over $W^-$ ratio: Challenging PDF predictions!

First measurement of W polarization: both $W^+$ and $W^-$ preferred left-handed
**W/Z+jets**

- **Simultaneous** extraction of W signal and top background
  - 2D fit to $M_\tau$ and $N_{\text{jets}}$ distributions
- Final distributions: **unfolded to particle level**
- Presented for experimental lepton and jet acceptance, eg. $p_{T\text{jet}} > 30 \text{ GeV}$
W/Z+jets

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  - 2D fit to $M_T$ and $N_{\text{bjets}}$ distributions
- final distributions: **unfolded to particle level**
- presented for experimental lepton and jet acceptance, eg. $p_{T\text{jet}} > 30$ GeV

Excellent agreement with ME+PS matched Monte Carlo model.
Also tested: Berends-Giele scaling
Di-Boson Production

**WW** (arXiv:1102.5429, subm. to PLB)

- same pre-selection as for HWW search, including a jet veto
- WW cross section and WW/W ratio in agreement with SM exp.
- limits on TGC from fit to leading lepton $p_T$
- consistent with LEP results and similar sensitivity as Tevatron
Di-Boson Production

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**$W\gamma$ and $Z\gamma$**

- cross sections measured for $E_{T\gamma} > 10$ GeV and $dR(\text{lept,}\gamma) > 0.7$
- cross sections in agreement with SM predictions
- first limits on $WW\gamma, ZZ\gamma, Z\gamma\gamma$ TGC at 7 TeV

Measurements of Di-Boson production established.
First limits on TGCs

Groundwork for HWW search!
### Summary of SM measurements

<table>
<thead>
<tr>
<th>Process</th>
<th>Ratio (CMS/Theory)</th>
<th>36 pb(^{-1}) at (\sqrt{s} = 7) TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\sigma \times B(W))</td>
<td>0.988 ± 0.009 (<em>{\text{exp}}) ± 0.050 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(W^+))</td>
<td>0.982 ± 0.010 (<em>{\text{exp}}) ± 0.047 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(W^-))</td>
<td>0.993 ± 0.010 (<em>{\text{exp}}) ± 0.054 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(Z))</td>
<td>1.003 ± 0.010 (<em>{\text{exp}}) ± 0.047 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(Z\rightarrow \tau\tau))</td>
<td>1.029 ± 0.097 (<em>{\text{exp}}) ± 0.043 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(W\gamma))</td>
<td>1.121 ± 0.177 (<em>{\text{exp}}) ± 0.077 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(Z\gamma))</td>
<td>0.969 ± 0.121 (<em>{\text{exp}}) ± 0.042 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(WW))</td>
<td>0.956 ± 0.381 (<em>{\text{exp}}) ± 0.007 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(t\bar{t}))</td>
<td>1.055 ± 0.236 (<em>{\text{exp}}) ± 0.079 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(t\bar{t}))</td>
<td>0.915 ± 0.117 (<em>{\text{exp}}) ± 0.079 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(t\bar{t}))</td>
<td>1.014 ± 0.138 (<em>{\text{exp}}) ± 0.079 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(t))</td>
<td>0.963 ± 0.115 (<em>{\text{exp}}) ± 0.079 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sigma \times B(t))</td>
<td>1.342 ± 0.478 (<em>{\text{exp}}) ± 0.039 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(R_{W/Z})</td>
<td>0.981 ± 0.010 (<em>{\text{exp}}) ± 0.015 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(R_{W/Z})</td>
<td>0.994 ± 0.011 (<em>{\text{exp}}) ± 0.035 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(Z_{\ell\ell}\rightarrow \mu\mu\alpha)</td>
<td>1.208 ± 0.280 (<em>{\text{exp}}) ± 0.021 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(Z_{\ell\ell}\rightarrow ee\alpha)</td>
<td>0.992 ± 0.199 (<em>{\text{exp}}) ± 0.020 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(W_{\ell\ell}\rightarrow \mu\nu\alpha)</td>
<td>0.833 ± 0.088 (<em>{\text{exp}}) ± 0.017 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(W_{\ell\ell}\rightarrow ev\alpha)</td>
<td>0.894 ± 0.097 (<em>{\text{exp}}) ± 0.017 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(\sin^{2}\theta_{W})</td>
<td>0.989 ± 0.037 (<em>{\text{exp}}) ± 0.001 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(M_{b})/World Average</td>
<td>1.014 ± 0.038 (<em>{\text{exp}}) ± 0.005 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(Z_{\ell\ell}\rightarrow \mu\mu\gamma)</td>
<td>1.000 ± 0.272 (<em>{\text{exp}}) ± 0.185 (</em>{\text{theo}})</td>
<td></td>
</tr>
<tr>
<td>(Z_{\ell}\rightarrow \ell\gamma)</td>
<td>1.059 ± 0.281 (<em>{\text{exp}}) ± 0.167 (</em>{\text{theo}})</td>
<td></td>
</tr>
</tbody>
</table>

from P.C.Harris, Moriond EWK 2011
Higgs searches

- Charged Higgs
- Doubly charged Higgs

see also recent talks by
- C. Veelken, Moriond EWK-11
- V. Sharma, Moriond EWK-11
- A. Tapper, CERN Seminar, March 15

HWW SM and SM4

MSSM $H \rightarrow \tau\tau$
H → WW → 2l 2v

( arXiv:1102.5429, subm. to PLB )

- same pre-selection as for WW analysis, including a jet veto
- Then: 2 analyses
  - cut-based (lepton $\Delta \Phi$, lepton mom.)
  - Boosted Decision Tree with 15% higher eff. for same bkgnd

Progression of Cuts: data vs MC

95% CL Limit for MH=160 GeV

<table>
<thead>
<tr>
<th></th>
<th>CMS (Bayesian)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected</td>
<td>3 x SM</td>
</tr>
<tr>
<td>Observed</td>
<td>2.1 x SM</td>
</tr>
</tbody>
</table>

SM-like Higgs in 4-gen model excluded for (144 < M_H < 207) GeV
$H \rightarrow \tau\tau$

- Channels used: e-mu, e-had, mu-had
- improved mass reconstruction (better resolution) using likelihood, based on tau decay kinematics of visible decay products and $E_{T\text{miss}}$
- first limits on MSSM Higgs production, already improving on the Tevatron results

The hunt for MSSM Higgs(es) is open. Tau channel will play prominent role.
Searches for Supersymmetry

- All hadronic, $\alpha_T$ based
- All hadronic, $\alpha_T$ + b-tag
- "The Razor" analysis

see also talks by
- C. Bernet, Moriond EWK-11
- A. Tapper, CERN, March 15

GGM : di-photons

lepton+jets+MET

multi-leptons
The strategy

Focus on signatures (topologies), use different approaches/observables
- $\alpha_T$, “Razor”, HT, MHT, ...

Established many different data-driven techniques to derive backgrounds
- jet smearing and re-balancing, ABCD, fakeable-object technique to estimate fake lepton rates, generic properties of lepton $p_T$ spectra, generic properties of falling SM spectra

Different trigger paths (all hadronic HT-based, leptonic)

Not necessarily optimized for best excl. limits, but sharpened tools for discovery!

cross check, cross check, cross check....
Example: Hadronic search with MET

- Analysis based on understanding the detector response in detail
- Complementary to kinematics-based searches
- Baseline selection
  - At least 3 jets with $E_T > 50$ GeV & $|\eta| < 2.5$
  - $H_T > 300$ GeV and MHT > 150 GeV
  - Veto isolated electrons and muons
- Backgrounds from
  - Multi-jet QCD, $Z(+\text{jets}) \rightarrow \nu\nu, W+\text{jets}, t\bar{t}$
  - All determined from data-driven techniques
Combined Exclusion plot

CMS preliminary \( L_{\text{int}} = 36 \text{ pb}^{-1}, \sqrt{s} = 7 \text{ TeV} \)

- LEP2 \( \tilde{\chi}_1^\pm \)
- LEP2 \( \tilde{\chi}_2^0 \)
- CDF $\tilde{g}, \tilde{q}$, $\tan\beta=5$, $\mu<0$
- D0 $\tilde{g}, \tilde{q}$, $\tan\beta=3$, $\mu<0$

**Tan\(\beta\) = 10, \(A_0 = 0, \mu > 0\)**

**Razor**

- **LM1**
- **OS Dilepton**
- **SS Dilepton**
- **$\alpha_T$** + b-tag
- **Lepton+MET**
- **Jets+MHT**

**Limits extended well beyond the Tevatron reach**
Simplified models

Models proposed at: http://www.lhcnewphysics.org

CMS Preliminary $\sqrt{s} = 7$ TeV $L_{int} = 35$ pb$^{-1}$

$\tilde{g}\tilde{g} \to 4$ jets + LSPs

$A \times \varepsilon$

High $H_T$ selection

Example:

Efficiency plot for MHT-based all-hadronic analysis

Shows complementarity of hadronic analyses.

CMS will provide these results electronically.

Feedback is welcome.
Exotic signatures

A W' → ev?
A Black Hole?
2 Leptoquarks?

A Di-jet Resonance?
A q* decay in qZ?

Run : 142528
Event : 201376378
Dijet Mass : 1636 GeV

see also talk by F. Santanastasio, Moriond EWK-11
Leptons (+ $E_{T\text{miss}}$)

Search for heavy resonances decaying to lepton pairs
- Bump hunt in $M(\mu\mu)$ spectrum
  - no deviations observed
- Bump hunt in $M_T(l\nu)$ spectrum
  - no deviations observed

Channel | $\mu\mu$ | $ee$ | Combined
---|---|---|---
$Z_{SSM}$ | 1027 GeV | 958 GeV | 1140 GeV
$Z_{\psi}$ | 792 GeV | 731 GeV | 887 GeV
$G_{KK}$, $k/M_{Pl} = 0.05$ | 778 GeV | 729 GeV | 855 GeV
$G_{KK}$, $k/M_{Pl} = 0.10$ | 987 GeV | 931 GeV | 1079 GeV

CMS limits (36 pb$^{-1}$)
- $e\nu$ | 1.36 TeV
- $\mu\nu$ | 1.4 TeV
- $e\nu + \mu\nu$ | 1.58 TeV

extending published CDF/D0 limits

arXiv:1103.0981, submitted to JHEP
arXiv:1012.5945, Accepted by PLB
arXiv:1103.0030, Submitted to PLB
Photons and Tops in the final state

- **Search for massive neutral bosons**
- Bump hunt in $M(t\bar{t})$ spectrum
- Lepton+jets channels (el and mu)
- No bump seen in data
- Limits set, competitive with Tevatron

![Graph showing CMS Preliminary results on the mass spectrum of Higgs bosons](image)

- CMS Preliminary
- 36 $fb^{-1}$ at $\sqrt{s} = 7$ TeV
- $\mu$, $\geq 4$ jets, $\geq 2$ b-tags

![Graph showing CMS Preliminary limits on the Higgs boson mass](image)

- CMS Preliminary
- 36 $fb^{-1}$ at $\sqrt{s} = 7$ TeV
- Upper Limit $\sigma_{Z} \times \text{BR}(Z \rightarrow t\bar{t}) [pb]$ vs $m_{Z} [\text{TeV}/c^{2}]$
Photons and Tops in the final state

Search for LED via

Virtual graviton exchange

G

Search for massive neutral bosons
- Bump hunt in $M(t\bar{t})$ spectrum
- Lepton+jets channels (el and mu)
- No bump seen in data
- Limits set, competitive with Tevatron

Photons in ECAL barrel, $E_T > 30$ GeV

Upper limit on $\sigma \times BR < 0.11$ pb for $M_{\gamma\gamma} > 500$ GeV

New lower limits on eff. Planck scale of 1.6 - 2.3 TeV!
And many, many more...
And many, many more...

As broad a spectrum as possible: new heavy resonances, leptoquarks, excited fermions, compositeness, extra dimensions, hidden valleys...

Big effort into development of data-driven background estimations: sharp tools established

~ 20 searches with 2010 data!

most of them published or submitted for publication; with few exceptions, all of them provide world’s best limits so far

CMS is well prepared for new data

<table>
<thead>
<tr>
<th>Mass Limits</th>
<th>CMS</th>
<th>Tevatron or ATLAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z'SSM II</td>
<td></td>
<td></td>
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<tr>
<td>Z'Ψ II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GKK II k/M = 0.1</td>
<td></td>
<td></td>
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<tr>
<td>W' lv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GKK γγ k/M = 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ms, γγ, GRW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ms, μμ, GRW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MD, monojet, nED = 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LQ1, β=0.5</td>
<td></td>
<td></td>
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<tr>
<td>LQ1, β=1.0</td>
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<tr>
<td>LQ2, β=1.0</td>
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<tr>
<td>Me* with Λ = 2 TeV</td>
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<tr>
<td>Mμ* with Λ = 2 TeV</td>
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<tr>
<td>Mq*, boosted Z</td>
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<tr>
<td>Mq*, jj mass (3 pb-1)</td>
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<tr>
<td>b' → tW</td>
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<tr>
<td>gluino mass (3 pb-1)</td>
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<tr>
<td>stopped gluino mass</td>
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</tbody>
</table>

**Summary of mass limits**

CMS

Tevatron or ATLAS
Conclusions

OH, I AM SORRY!

NO! MY FAULT ENTIRELY!

WHEN PROTONS COLLIDE
Summary

Our sincere thanks go to our colleagues from the machine

- The excellent LHC performance of last year is extremely promising for the upcoming year(s)

CMS is in excellent shape

- The complete chain of operation (from online data taking to final physics plots) has been stress-tested
- The often better-than-expected performance, and the high motivation of all involved, has allowed for the production of an impressive amount of physics results, on an unseen short time-scale
LHC

few TeV

O(100) GeV
CMS is ready for discoveries

LHC

few TeV

O(100) GeV
Thanks to...

... all my CMS colleagues who have helped me in preparing this talk!
Backup
1. Measurement of the Lepton Charge Asymmetry in Inclusive W Production in pp Collisions at sqrt(s) = 7 TeV
2. Search for Physics Beyond the Standard Model in Opposite-sign Dilepton Events in pp Collisions at sqrt(s) = 7 TeV
3. Search for Resonances in the Dilepton Mass Distribution in pp Collisions at sqrt(s) = 7 TeV
4. Search for Supersymmetry in pp Collisions at sqrt(s) = 7 TeV in Events with Two Photons and Missing Transverse Energy
5. Search for a W' boson decaying to a muon and a neutrino in pp collisions at sqrt(s) = 7 TeV
6. Study of Z boson production in PbPb collisions at sqrt(sNN) = 2.76 TeV
7. Measurement of W+W−Production and Search for the Higgs Boson in pp Collisions at sqrt(s) = 7 TeV
8. Search for Heavy Bottom-like Fourth Generation Quark in tW Final State at CMS in pp Collisions at sqrt(s) = 7 TeV.
9. Strange Particle Production in pp collisions at sqrt(s) = 0.9 and 7 TeV
10. Measurement of BB Angular Correlations based on Secondary Vertex Reconstruction at sqrt(s) = 7 TeV in CMS
11. Measurement of Dijet Angular Distributions and Search for Quark Compositeness in pp collisions at sqrt(s) = 7 TeV
12. Observation and studies of jet quenching in PbPb collisions sqrt(sNN) = 2.76 TeV
13. First Measurement of Hadronic Event Shapes in pp collisions at sqrt(s) = 7 TeV
14. Dijet Azimuthal Decorrelations in pp Collisions at sqrt(s) = 7 TeV
15. Measurement of Bose–Einstein Correlations in pp Collisions
16. Inclusive b-hadron production cross section with muons in pp collisions
17. Search for Heavy Stable Charged Particles in pp collisions
18. Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy
19. Measurement of the B+ Production Cross Section in pp Collisions at sqrt(s) = 7 TeV
20. Search for a heavy gauge boson W' in final states with electrons and large missing ET in pp collisions
21. Upsilon production cross section in pp collisions at sqrt(s) = 7 TeV
22. Search for Pair Production of Second-Generation Scalar Leptoquarks in pp Collisions at sqrt(s) = 7 TeV
23. Search for Pair Production of First-Generation Scalar Leptoquarks in pp Collisions at sqrt(s) = 7 TeV
24. Search for Microscopic Black Hole Signatures at the Large Hadron
25. Measurements of Inclusive W and Z Cross Sections in pp Collisions at sqrt(s) = 7 TeV
26. Measurement of the Isolated Prompt Photon Production Cross Section in pp Collisions at sqrt(s) = 7 TeV
27. Search for Stopped Gluinos in pp collisions at sqrt(s) = 7 TeV
28. Charged particle multiplicities in pp interactions at sqrt(s) = 0.9, 2.36, and 7 TeV
29. Prompt and non-prompt J/ψ production in pp collisions at sqrt(s) = 7 TeV
30. First Measurement of the Cross Section for Top-Quark Pair Production in Proton-Proton Collisions
31. Search for Quark Compositeness with the Dijet Centrality Ratio in pp Collisions at sqrt(s) = 7 TeV
32. Search for Dijet Resonances in 7 TeV pp Collisions at sqrt(s) = 7 TeV
33. Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC
34. CMS Tracking Performance Results from Early LHC Operation.
35. First Measurement of the Underlying Event Activity at the LHC with sqrt(s) = 0.9 TeV
36. Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at sqrt(s) = 7 TeV
37. First Measurement of Bose-Einstein Correlations in pp collisions at sqrt(s) = 0.9 and 2.36 TeV at the LHC
38. Transverse momentum and pseudorapidity distributions of charged hadrons at sqrt(s) = 0.9 and 2.36 TeV

+12 in CWR + many other analyses approved for the Winter Conferences.
Jet performance matches simulation very well, PF JEC uncertainties: 3-5%
Z production properties

EWK-10-010

EWK-10-007
Example SUSY search: same-sign dilepton

- Two different trigger approaches
  - HT or lepton $p_T$

- Baseline selection:
  - 2 same sign, isolated leptons (e or $\mu$)
  - $p_{T,1} > 20$, $p_{T,2} > 10$ GeV
  - $\geq 2$ jets: $p_T > 30$ GeV, $|\eta| < 2.5$
  - MET: $> 30$ GeV (ee and $\mu\mu$), $> 20$ GeV (e$\mu$)

- Main background: ttbar (lepton from b)
  - name of the game: jets faking leptons
  - data-driven fake-rate estimations

lepton efficiency parametrization agrees with full CMS simulation
Commissioning / Status

- Central DAQ upgraded to 64bit for better performance
- Global data taking started with cosmic data taking for alignment

Initial collisions have been used to re-commission the detector:
- Delay scans for timing with LHC beams – pixels and RPCs had moved by ½ bunch crossing with respect to the 2010 run
- HV scans
- Verification of trigger timing

The CMS detector operates with most subdetectors having over 98% of channels active

As the LHC has now started the intensity ramp-up, CMS is collecting data to perform high level validations
Highest MHT event in all hadronic jets+MET analysis
<table>
<thead>
<tr>
<th></th>
<th>CMS</th>
<th>Best Tevatron</th>
<th>ATLAS</th>
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</thead>
<tbody>
<tr>
<td><strong>Heavy Bosons</strong></td>
<td></td>
<td></td>
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<tr>
<td>$Z'_{SSM}$ ll</td>
<td>1.14</td>
<td>1.071</td>
<td>1.048</td>
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<tr>
<td>$Z'_{\psi}$ ll</td>
<td>0.887</td>
<td>0.738</td>
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<tr>
<td>$G_{KK}$ ll $k/M = 0.1$</td>
<td>1.079</td>
<td>1.050</td>
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<tr>
<td>$W'$ lv</td>
<td>1.58</td>
<td>1.10</td>
<td>1.40</td>
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<tr>
<td>$G_{KK}$ $\gamma\gamma$ $k/M = 0.1$</td>
<td>0.945</td>
<td>1.050</td>
<td>0.920</td>
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<tr>
<td><strong>Large Extra Dimensions</strong></td>
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<tr>
<td>$M_s$, $\gamma\gamma$, GRW</td>
<td>1.89</td>
<td>1.62</td>
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<tr>
<td>$M_s$, $\mu\mu$, GRW</td>
<td>1.75</td>
<td>1.62</td>
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<tr>
<td>$M_D$, monojet, $n_{ED} = 2$</td>
<td>2.16</td>
<td>1.6 (LEP)</td>
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<tr>
<td><strong>LeptoQuark</strong></td>
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<tr>
<td>LQ1, $\beta=0.5$</td>
<td>0.340</td>
<td>0.319</td>
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<tr>
<td>LQ1, $\beta=1.0$</td>
<td>0.384</td>
<td>0.376</td>
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<tr>
<td>LQ2, $\beta=1.0$</td>
<td>0.394</td>
<td>0.422</td>
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<tr>
<td><strong>Lepton Compositeness</strong></td>
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<tr>
<td>$M_{e^*}$ with $\Lambda = 2$ TeV</td>
<td>0.720</td>
<td>0.525</td>
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<tr>
<td>$M_{\mu^*}$ with $\Lambda = 2$ TeV</td>
<td>0.745</td>
<td>0.450</td>
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<td><strong>Contact Interactions</strong></td>
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<tr>
<td>$M_{q^*}$, boosted $Z$</td>
<td>1.17</td>
<td>0.252 (HERA)</td>
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<tr>
<td>$M_{q^*}$, jj mass (3 pb$^{-1}$)</td>
<td>1.58</td>
<td>2.15</td>
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<tr>
<td>C.I. $\Lambda$, jj mass (3 pb$^{-1}$)</td>
<td>4.0</td>
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<td>C.I. $\Lambda$, $X$ analysis</td>
<td>5.6</td>
<td>9.5</td>
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<td><strong>4th Generation</strong></td>
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<tr>
<td>$b' \rightarrow tW$</td>
<td>0.361</td>
<td>0.372</td>
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<tr>
<td><strong>Heavy Stable Charged Particle</strong></td>
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<tr>
<td>gluino mass (3 pb$^{-1}$)</td>
<td>0.398</td>
<td>0.397</td>
<td>0.586</td>
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<tr>
<td><strong>Stopped Gluino</strong></td>
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<tr>
<td>gluino mass</td>
<td>0.370</td>
<td>0.270</td>
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</tbody>
</table>
Intervals and Limits for a Physically Bounded $\mu$

- Prototype: measurement $x$ is unbiased Gaussian estimate of $\mu$. (Let $\sigma=1$.) What is 95% C.L. Upper Limit (UL)?
- 1986: Six methods for UL surveyed by V. Highland (VH) include U.L. $= \max(0, x + 1.64)$ and U.L. $= \max(0,x) + 1.64$.
- RPP 1986: Bayesian: uniform prior on the mean $\mu$ for $\mu \geq 0$, prior prob $= 0$ for $\mu < 0$. (VH’s other five not mentioned.)
- 1994,96: 3 ad-hoc frequentist recipes, one using $\max(x,0)$.
- 1998: Feldman & Cousins (FC) “Unified Approach” in (Kendall and Stuart) replaces ad hoc frequentist
- 2002: CLS from LEP added to Bayesian and FC.
- CMS Statistics Committee recommends using (at least) one of the three (red) methods in 2002-present PDG RPP.
- ATLAS SC method implies U.L. $= \max(0, x + 1.64)$ before power constraint (PC), U.L. $= \max(-1,x) + 1.64$ after PC.
Comparison of ATLAS PCL with the three methods in PDG

ATLAS PCL re-opens discussion on use of diagonal line along with ad hoc constraint, out of favor for many years, not recommended by CMS SC.

CMS and ATLAS SC’s are reviewing arguments and what has been learned in 25+ years. Academic statisticians have commented as well.

Just tip of iceberg: Poisson example brings in other issues. Nuisance parameters yet more. Choice of test statistic varies.