CMS Status Report

Anders Ryd
Cornell University
On behalf of the CMS Collaboration

Dec. 7, 2011
Outline

Detector performance when integrating from 2 to 5 fb-1
Lessons learnt from the high mu operation
Updates on calorimeter and tracking performance
Many (less mundane) physics channels updates
lessons from high beta running
pA and AA running experience and plans
Possibly new insights and wishes for the 2012 running of the LHC
Plans and progress for the upgrades
The 2011 Proton Run

Delivered and Recorded Luminosity

- Delivered 5.72 fb^{-1}
- Recorded 5.20 fb^{-1}

Peak Luminosity

- Max Inst 3.54 nb^{-1}s^{-1}

Integrated Luminosity per day

- Delivered Max 138.91 pb^{-1}
- Recorded Max 132.48 pb^{-1}

- A very successful run
- We thank the LHC for their excellent performance!
Most detectors over 97% live – and stable in time
CMS Data Taking Efficiency

LHC delivered 5.72 fb\(^{-1}\)
Lost due to deadtime: 176 pb\(^{-1}\)
Lost due to downtime: 325 pb\(^{-1}\)

Sources of downtime:
- Trigger rules (~0.7%)
- Partition control (sub detectors ~0.5%)
- HLT at start of runs (~0.5%)
- Short stops that don't count as downtime.

Sources of downtime:

- Largest single source of downtime was a cooling failure affecting two fills.
- SEUs affecting several subsystems (Pixel, ECAL, CSC, HCAL) has contributed to the downtime.
Tracking Challenges with High PU

Tracking threshold in $p_T \sim 100$ MeV. Fake rate $< 1%$

Keeping essentially the same performance

Event with 40 reconstructed vertices from high PU fill
**DAQ Bandwidth Studies**

- The CMS DAQ was designed to operate at 100 kHz L1 trigger rate with 25 ns bunch spacing at 1e34 Hz/cm² with a PU of about 20.
  - With higher PU in 50 ns operation the design bandwidth guaranteed by the DAQ would be exceeded at ~4.5e33 Hz/cm² – what is the limit?
  - Using the high pileup fill with 10 colliding bunches we can trigger at up to 110 kHz and read out high PU collisions.

  ![Fill 2252 CMS Pileup Monitor](image1)
  ![Fill 2252 L1 Trigger](image2)

- With a PU of >30 at the start of the fill we ran at 110 kHz L1 trigger rate – no limitation seen by the DAQ bandwidth.
- Without modifications to the readout we can operate at 7e33 Hz/cm² with 50 ns bunch spacing.
Progress in ECAL calibration

Stable energy scale throughout 2011 run after applying laser corrections:
- Barrel: average loss ~ 2.5%, RMS stability after corrections 0.14%
- Endcap: average loss ~ 10%, RMS stability after corrections 0.5%

Good energy resolution with preliminary energy calibration for 2011:
- Invariant mass resolution on Z → e+e- events: 1.0 GeV in ECAL Barrel (**)
JET Calibration at High Pile-Up

CMS Simulation

Pile up 15-25

1-2% residual effects in the energy scale

Data MC comparison $\gamma$+jet

Also the jet composition is very well simulated
Physics Updates

- At the last LHCC on Sept. 21 Darin Acosta gave a detailed overview of many analysis.
- In the next few slides some updates on recent results are given.

1109.2352  36 citations
1101.1628  141 citations

Most cited LHC paper on collision data
Single Top+W

\[ \sigma(tW) = 21^{+9}_{-7} \text{ pb} \]

Consistent with the SM with a significance of 2.7\( \sigma \)
Top Pair Cross-Section

New result for HCP 2011

8% precision – systematics limited

Start to be sensitive to different NNLO approximations

<table>
<thead>
<tr>
<th>systematic source</th>
<th>single lepton</th>
<th>ee</th>
<th>μμ</th>
<th>eμ</th>
<th>μτ</th>
<th>hadronic</th>
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CMS Preliminary, $\sqrt{s}=7$ TeV
Top Mass From Cross-Section

CMS Preliminary, \( \sqrt{s}=7 \text{ TeV}, \ L=1.14 \text{ fb}^{-1} \)

approx. NNLO \times \text{HERAPDF15NNLO}

errors: scale variations \times 68\% \text{ CL PDF}_{\text{exp}} \times \alpha_{s}(M_Z)

- Langenfeld et al.
- Ahrens et al.

Measured cross section dependence on \( m_{\text{MC}}^t \)

Cross section corrected for \( m_{\text{pole}}^t \) (Langenfeld et al.)

Value ± theory ± experiment ± \( \alpha_{s}(m_t) \)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Value (GeV)</th>
<th>Error (GeV)</th>
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<tbody>
<tr>
<td>CMS (Prel., ( L=1.14 \text{ fb}^{-1} )) approx. NNLO \times MSTW08NNLO</td>
<td>170.3</td>
<td>6.2 ± 3.8</td>
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<td>170.0</td>
<td>6.6 ± 3.7</td>
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<td>167.6</td>
<td>6.8 ± 3.3</td>
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<td>166.4</td>
<td>7.8 ± 7.4</td>
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<td>166.2</td>
<td>7.8 ± 7.4</td>
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<tr>
<td></td>
<td>162.2</td>
<td>8.0 ± 7.6</td>
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</table>

ATLAS (Prel., \( L=35 \text{ pb}^{-1} \)) approx. NNLO \times MSTW08NNLO

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<tr>
<td>Langenfeld et al.</td>
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<td>Kidonakis</td>
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<tr>
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<td>162.2</td>
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D0 (\( L=5.3 \text{ fb}^{-1} \)) approx. NNLO \times MSTW08NNLO

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<tr>
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<td>Kidonakis</td>
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<td>5.2 ± 4.5</td>
</tr>
<tr>
<td>Ahrens et al.</td>
<td>163</td>
<td>5.1 ± 4.6</td>
</tr>
<tr>
<td>Tevatron direct measurement (July 2011)</td>
<td>173.2</td>
<td>0.9 ± 0.9</td>
</tr>
</tbody>
</table>
SUSY - Razor

$M_R$ – Estimate of the heavy particle scale

$R^2$ – Related to the event MET

Perform fits to the $M_R$ vs $R^2$ distributions

Powerful search based on kinematics
Jet-Z Balance: Jets+Z+MET

$$JZB = \left| \sum_{jets} \vec{p}_{T}^{} \right| - \left| \vec{p}_{T}^{Z} \right|$$

Method allows a very robust prediction for Z+jets background.
Multilepton SUSY Searches

- At least 3 leptons
- Require MET and veto Z
- Need to understanding backgrounds from internal conversions
Many different search strategies
Simplified Models

The dark blue range corresponds to a range of neutralino masses down to 200 GeV below the gluino mass.
SUSY: MET + jets + b-tags

- At least 3 jets + MET
- Greater than 1 or 2 b-tags

Simplified Model: T1bbbb

![Graph showing event distribution and cross-section limits](image)

- At least 1 b-tag
- At least 2 b-tags
Longlived Particle Decays to Photon+MET

Reconstruct photon conversion to determine impact parameter of photon
Summary of CMS Exotica Searches

- Heavy Resonances
  - Z' SSM II
  - Z'ψ II
  - GKK II k/M = 0.1
  - GKK γγ k/M = 0.1
  - GKK II k/M = 0.05
  - GKK γγ k/M = 0.05
  - W' lv
  - W' dijet
  - WR, MNR < 1.0 TeV
  - W' → WZ
  - gTC

- 4th Generation
  - Mb', b' → tW, l+jets
  - Mt', t' → tZ (100%)
  - Mt', t' → bW (100%), l+jets
  - Mt', t' → bW (100%), l+l

- Heavy Long-Lived
  - gluino, HSCP
  - gluino, Stopped Gluino
  - stop, HSCP
  - stop, Stopped Gluino
  - stau, HSCP

- Extra Dimension
  - MBH, rotating, MD=3.5 TeV, nED = 2
  - MBH, non-rot, MD=1.5 TeV, nED = 6
  - String Ball M, MD=2.1, Ms=1.7, gs=0.4
  - String Resonances
    - E6 diquarks
    - Axigluon/Coloron
    - q*, dijet
    - q*, boosted Z
    - e*, λ = 2 TeV
    - μ*, λ = 2 TeV
    - C.L. λ, dijet mass (3 pb⁻¹)
    - C.L. λ, X analysis

95% C.L. Exclusion Limits on Masses
CMS-ATLAS Combined Higgs

Combine results from:
H -> gg
H -> bb
H -> WW(lνlν)
H -> ττ
H -> ZZ(4l,2l2n,2l2q,2l2τ)

Exclude 141 to 476 GeV at 95% C.L.
Most of this range excluded at 99% C.L.

Updates to the Higgs searches with more data on Dec. 13
Pb-Pb Data Taking in 2011

CMS was reconfigured for Pb-Pb data taking in the last Technical Stop
- Non-zero suppressed readout of the strip tracker
- New trigger/HLT configuration
Running with \( \sim 2.5 \) kHz L1 rate has been very smooth
Recorded a factor of 15 more data in 2011 than in 2010
Pb-Pb from the Most Complicated...

Typical HI Collision
...to the Simplest Final States at the LHC: J/Ψ in an Ultra-Peripheral Event

Only two tracks in the event (the two muons), virtually no energy in the Calorimeters, and classified in the 2.5% most peripheral collision bin for heavy ions
Gains in Statistics

The higher statistics in 2011 allows probing higher energies

- **Tracks**
  - Tracks above 4 GeV/c in events with jets (jet $p_T > 90$ GeV/c and $|\eta| < 2$)

- **Jets**
  - CMS Preliminary
  - icPu5 $|\eta| < 2.0$
  - PbPb 2011, 84 $\mu$b$^{-1}$
  - PbPb 2010, 6.8 $\mu$b$^{-1}$
  - $2010$ PbPb, 6.8 $\mu$b$^{-1}$
  - $2011$ PbPb, 84 $\mu$b$^{-1}$

- **Photons**
  - CMS Preliminary
  - H/E $< 0.2$
  - Sum ISO $< 5$ GeV
  - $\alpha_{\mu} < 0.011$
Gamma-jet Event
centrality bin 30-40%

Photon
$E_T$ 402 GeV
eta 0.45
Phi -1.90

Jet
$E_T$ 252 GeV
eta -0.68
phi 1.7
Dimuons in Pb-Pb Collisions
$Z \rightarrow e^+e^-$

CMS Preliminary
PbPb $\sqrt{s_{NN}} = 2.76$ TeV
$p_T^e > 20$ GeV/c, $|\eta^e| < 2.4$

- opposite-sign pairs
- same-sign pairs

$L_{int} = 45 \mu b^{-1}$
The 2012 Proton Run

- CMS strongly supports 4 TeV in 2012 - enhances discovery potential:
  - Overhead in machine commissioning small
  - Higher luminosity (allows smaller $\beta^*$)
  - Larger cross-section (gluon-gluon luminosity)
  - MC tuning and production not an issue
- We want the largest usable luminosity possible:
  - Detector and readout OK for both 25 and 50 ns
  - Challenges with physics and trigger for high PU (50 ns)
    - These effects are now being quantified

![Graph showing ratios of luminosities](image_url)

(i.e. increase in production rate)
CMS Upgrade Scope

System
- 2010-2020
- 2020-2030

Pixel
- New Pixel Detector

Tracker
- New Tracking System (incl Pixel)

HCAL
- Back End Electronics + PD replacement
- HF/HE?

ECAL
- Trigger Primitive Transmission
- EE?

Muons
- ME4/2, ME1/1, RPC endcap, Minicrate spares, some CSC Electronics
- Electronics replacement

Trigger
- HCAL/RCT/GCT to μTCA
- Complete replacement
CSC Factory

- Gluing
- Winding
- Component soldering
- Wire soldering
- CSC assembly
New Pixel Detector

- It will have the following features
  - 4 barrel and 3 endcap layers (current has 3 barrel 2 ec)
    - Barrel Inner layer closer to the beam
  - Less material in the tracking volume!
  - Capable of handling more hits (Required for luminosity beyond $1 \times 10^{34}$)

- 100 bar pressure tested
  - Tubes, 50µm wall thickness

<table>
<thead>
<tr>
<th>Layer #</th>
<th>Radius</th>
<th># of faces</th>
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<tr>
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<td>160</td>
<td>64</td>
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<tr>
<td>3</td>
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<td>1</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>1*</td>
<td>39</td>
<td>16</td>
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</table>

Baseline: 45 mm Ø beampipe
30 mm radius L1
tight installation tolerances → adjustable wheels
1* = backup solution for old beampipe
Tracking Trigger Simulations

Need to build candidate layouts to study how much information is needed from the tracker to get reliable trigger information as well as keeping the tracking performance.

Long Barrel (LB) Simulation

- Stack separation: 1mm
- Pixel size: 1mm (z) x 100um (phi)
- Module area: ~100 cm²
- Available alternative: swap SuperLayer 2 and 3 (not covered in this talk)
- Sim hits → **digi hits** → **clusters** → **stubs**

E. Salvati
Conclusions

- The 2011 run has been a great success:
  - We thank LHC for the excellent performance!
  - The CMS detector performance has been outstanding
  - Many physics results on 1 to 2 fb\(^{-1}\) of data ready
  - Ion run was also very successful
- LHC has provided test fills with high PU and 25 ns has
  - Detectors+DAQ OK for both conditions
  - Trigger and Physics more challenging with PU of around 30
    - We are still working on quantifying the effects of high PU on trigger and physics
- For the 2012 run CMS wishes are:
  - Running at 4 TeV beam energy from the start
    - MC tuning and production for 4 TeV is not an issue for us
  - Record the largest possible data sample before the long shutdown
- Upgrades for the long shutdown progressing well