Projections for Non-SUSY Searches at the LHC for 200pb\(^{-1}\) and 1fb\(^{-1}\)

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On behalf of the ATLAS and CMS Collaboration
Brief Description of The Detectors.
(Details were given in plenary talks by L. Rossi, M. Shapiro and A. De Roeck.)

LHC sensitive to a broad array of new physics.

Discovery potential of some of these new physics final states.

Give a general feeling of what LHC groups are doing.

Selection of few benchmark analyses.

Will try to cover topics involving different experimental challenges.
ATLAS

Tracker\cite{1}
Si pixels, strips + TRT (pid)
\[ \sigma(1/p_t) \approx 0.34(1 \oplus 0.44 \text{ TeV}/p_t)\text{TeV}^{-1} \]

EM Calorimeter\cite{3}
Pb + Lar
\[ \sigma/E \approx 10\% \text{ GeV}^{1/2}/\sqrt{E} \oplus 0.2 \]

Had. Calorimeter\cite{1}
Fe+scintillator / Cu + Lar
\[ \sigma/E \approx 60\%/\sqrt{E} \oplus 0.03 \]

Combined Muons\cite{1,2}
2\%@50\text{GeV} to 10\%@1\text{TeV}
<table>
<thead>
<tr>
<th><strong>CMS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tracker</strong>&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>Si Pixels, strips</td>
</tr>
<tr>
<td>$\sigma(p_T)/p_T \approx 0.17 p_T \oplus 0.05(p_T\text{ in GeV/c})$</td>
</tr>
<tr>
<td><strong>EM Calorimeter</strong>&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>PbWO&lt;sub&gt;4&lt;/sub&gt; crystals</td>
</tr>
<tr>
<td>$\sigma/E \approx 2.8%/\sqrt{E} \oplus 125\text{ MeV/E} \oplus 0.3%$</td>
</tr>
<tr>
<td><strong>Had. Calorimeter</strong>&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cu+scintillator</td>
</tr>
<tr>
<td>$\sigma/E \approx 100%/\sqrt{E}$</td>
</tr>
<tr>
<td><strong>Combined Muons</strong>&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>1%@50GeV to 5%@1TeV</td>
</tr>
</tbody>
</table>
Selection of few benchmark analyses

- Lepton Plus Missing Energy Final States

- Di-lepton Final States

- Lepton Plus Jets Final States.
Lepton+MET final states
W’ in the Sequential Standard Model:

- Lower bound on W’ mass (direct searches): ~1 TeV

\(\sqrt{s}=14\) TeV

CMS Preliminary

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Discovery Potential for W’

ATLAS Preliminary Simulation

\[ \sqrt{s} = 7 \text{ TeV} \]

\[ M(W') \text{ [TeV]} \]

\[ \text{Luminosity [pb]} \]

\[ 10^3 \]

\[ 10^2 \]

\[ 10^1 \]

\[ W' \rightarrow e\nu \text{ 10 Events} \]

\[ W' \rightarrow e\nu \text{ 5}\sigma \text{ Evidence} \]

\[ W' \rightarrow \mu\nu \text{ 10 Events} \]

\[ W' \rightarrow \mu\nu \text{ 5}\sigma \text{ Evidence} \]
Exclusion Limits for $W'$

- Exclusion
- $O(200 \text{pb}^{-1})$ up to ~1.8 TeV.
- $O(1 \text{fb}^{-1})$ up to ~2.5 TeV.
Narrow Resonances in Di-lepton final states
Z’
(mentioned by Yuri Gershtein in today’s plenary talks)

Z’ in some representative models:

<table>
<thead>
<tr>
<th>Z’ Model</th>
<th>Indirect Searches (GeV)</th>
<th>Direct Searches (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electroweak</td>
<td>LEP</td>
</tr>
<tr>
<td>Z'χ</td>
<td>680</td>
<td>781</td>
</tr>
<tr>
<td>Z'ψ</td>
<td>137</td>
<td>481</td>
</tr>
<tr>
<td>Z'η</td>
<td>619</td>
<td>515</td>
</tr>
<tr>
<td>Z'L_{LRSM}</td>
<td>860</td>
<td>804</td>
</tr>
<tr>
<td>Z'S_{SSM}</td>
<td>1500</td>
<td>1787</td>
</tr>
</tbody>
</table>

- Standard Model backgrounds
- For $Z' \rightarrow e e, \mu \mu$
  - Drell-Yan
- For $Z' \rightarrow \tau \tau$
  - ttbar
  - QCD
  - W+jets
Two well reconstructed muons
- Tracking Normalized Isolation < 5% (ATLAS)
- Opposite charged (CMS)

Z’ → ee
- 2 well reconstructed electrons
- p_T > 20 GeV (ATLAS)
- Tracking Normalized Isolation < 5% (<2% CMS)

Z’ → μ μ
- Two well reconstructed muons
- Tracking Normalized Isolation < 5% (ATLAS)
- Opposite charged (CMS)
$Z'$

**(CERN-OPEN-2008-02)**

- $Z' \rightarrow \tau\tau$
- $\tau$ selection
- Opposite charge
- $E_{t,\text{miss}}>30\text{GeV}$
- $m_{\tau}>300\text{GeV}$
- $p_{T,\text{tot}}<70\text{GeV}$
- $m_{\text{vis}}<300\text{GeV}$
- $\cos \Delta \phi_{lh}<-0.99$

*($\sqrt{s}=14\text{ TeV}$)*

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(Images of figures and histograms are not transcribed.)
Discovery Potential

$Z'_\text{SSM}$

- $O(200 \text{ pb}^{-1})$
  - $Z'$ at $\sim 1.2$ TeV.
- $O(1 \text{ fb}^{-1})$
  - $Z'$ at $\sim 1.55$ TeV.
Exclusion Potential $Z'$

- $O(200 \text{pb}^{-1})$
  - $Z'$ at ~ 1.2 TeV.
- $O(1 \text{fb}^{-1})$
  - $Z'$ at ~ 1.55 TeV.
The “Technicolor Strawman Model” or TCSM is used as a benchmark model for generic strongly interacting theories.

<table>
<thead>
<tr>
<th>$m_{\rho_{TC},\omega_{TC}}$</th>
<th>400</th>
<th>600</th>
<th>800</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak mass (GeV)</td>
<td>403</td>
<td>603</td>
<td>804</td>
<td>1004</td>
</tr>
<tr>
<td>$\sigma(m)$ (GeV)</td>
<td>13</td>
<td>22</td>
<td>34</td>
<td>46</td>
</tr>
</tbody>
</table>

• Current Limit $\rho_{TC}$ and $\omega_{TC}$ masses below 280 GeV [10]
$\rho_{TC}$ and $\omega_{TC}$

$\sqrt{s}=14$ TeV

ATL-PHYS-CONF-2008-004

CMS-PAS-EXO-09-007

$\sqrt{s}=14$ TeV
Discovery Potential ($\sqrt{s}=14$ TeV)

$\rho_{TC}$ and $\omega_{TC}$

- $1$ fb$^{-1}$ -> world without Higgs.

(Considering the scaling of the production cross section for $\sqrt{s}=7$ TeV)

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Exclusion Limits $\rho_{TC}$ and $\omega_{TC}$

$\sqrt{s} = 10$ TeV

- $1$ fb$^{-1}$ would allow to go beyond Tevatron Limits
  (Considering the scaling of the production cross section for $\sqrt{s} = 7$ TeV)
Randall-Sundrum model addresses the hierarchy problem by adding one extra-dimension. It predicts the existence of a tower of Kaluza-Klein excitations of the graviton.

\[ E^2 = \vec{p}^2 + p^2_{\text{extra}} + m^2 \]

\textbf{Graviton}

(Some description given in Carlos Wagner talk, and Yuri Gershtein)
Graviton

<table>
<thead>
<tr>
<th>Model Parameters</th>
<th>$\Gamma_G$ [GeV]</th>
<th>$\sigma_m$ [GeV]</th>
<th>$\sigma \cdot BR(G \rightarrow e^+e^-)$ [fb]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_G$</td>
<td>$k/\tilde{M}_{pl}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 GeV</td>
<td>0.01</td>
<td>0.08</td>
<td>4.6</td>
</tr>
<tr>
<td>750 GeV</td>
<td>0.01</td>
<td>0.10</td>
<td>6.4</td>
</tr>
<tr>
<td>1.0 TeV</td>
<td>0.02</td>
<td>0.57</td>
<td>7.9</td>
</tr>
<tr>
<td>1.2 TeV</td>
<td>0.03</td>
<td>1.62</td>
<td>10.3</td>
</tr>
<tr>
<td>1.3 TeV</td>
<td>0.04</td>
<td>2.98</td>
<td>11.4</td>
</tr>
<tr>
<td>1.4 TeV</td>
<td>0.05</td>
<td>5.02</td>
<td>13.1</td>
</tr>
</tbody>
</table>

- Standard Model backgrounds
- For $G \rightarrow ee$
  - Drell-Yan
  - All other backgrounds are expected to be small.
Two electrons
$p_T \geq 65$ GeV
$\cos \Delta \phi_{ee}<0$

The observed distribution includes a graviton with mass 1 TeV and coupling $\kappa / \mathcal{M}_{pl}=0.02$.

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$\sqrt{s}=14$ TeV

ATLAS
Discovery Potential
$G \rightarrow \mu \mu$

- 200 pb$^{-1}$ -> Graviton with a mass up to 1.1 TeV,
- 1 fb$^{-1}$ up to 1.35 TeV.

CMS Preliminary
SBM-07-002, scaled to $\sqrt{s} = 7$ TeV

CMS-NOTE-2010-008
Leptons + Jets final states

Leptoquarks

<table>
<thead>
<tr>
<th>LIMITE$^{[8]}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Generation</td>
</tr>
<tr>
<td>Second Generation</td>
</tr>
<tr>
<td>Third Generation</td>
</tr>
</tbody>
</table>

- Standard model background
  - Drell-Yan
  - ttbar
  - DiJets
Leptoquarks

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$\sqrt{s}=14$ TeV
Leptoquarks

Exclusion and discovery potential /100pb$^{-1}$ for the first generation.

With 200pb$^{-1}$ would be possible to go well beyond the Tevatron limits.
Right-handed Majorana neutrinos would required the existence of a right-handed new heavy gauge bosons.

The current limit for the mass of the $W_R$ is 715[8]

- Standard model background
  - Drell-Yan
  - $t\bar{t}$bar
  - VB pair
Left-Right Symmetric Models

• The observed correspond to the invariant mass for the $W_R \rightarrow e\nu$ and $W_R \rightarrow \mu \nu$

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At 200 pb$^{-1}$, the sensitivity with $\sqrt{s}$=7 TeV will be enough to go beyond the current limits.
Conclusions

A selection of analyses on new predicted particles with Di-lepton, Lepton+MET and Leptons+Jets final states was presented.

LHC detectors constitute a powerful tool to discover or exclude new particles.

7 TeV studies have shown that the existence of a $W'$ and $Z'$ could be established at the 5 sigma level even with $O(100\text{pb}^{-1})$ of integrated luminosity.

The initial run of few tens of $\text{pb}^{-1}$ at 7TeV would be enough to go beyond Tevatron limits in most of these models.
BACKUP
<table>
<thead>
<tr>
<th></th>
<th>ATLAS</th>
<th>CMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight</strong></td>
<td>7000 tons</td>
<td>12,500 tons</td>
</tr>
<tr>
<td><strong>Diameter</strong></td>
<td>22 m</td>
<td>15 m</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>46 m</td>
<td>22 m</td>
</tr>
<tr>
<td><strong>Peak B Field</strong></td>
<td>2T solenoid, 3.9T (peak) BA toroid, 4.1T (peak) EC toroids</td>
<td>4T solenoid</td>
</tr>
</tbody>
</table>
The QCD cross sections at LHC are 10 to 100 times higher than at the Tevatron.
Muons

![Graph showing contribution to resolution vs. Pt (GeV/c)]

- Total
- Spectrometer entrance
- Multiple scattering
- Chamber Alignment
- Tube resolution and auto-calibration (stochastic)
- Energy loss fluctuations

![ATLAS plot showing efficiency vs. p_T (GeV)]

Efficiency vs. p_T (GeV)
With 100 pb-1, clear signals for W and Z in τ channels.

Z→ ττ can then be used to set the ET miss scale to a few %.

τ reconstruction is tricky and relies (not for very first data but soon after) on multivariate techniques.
REFERENCES

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2. ATL-PHYS-PUB-2010-007
3. ATL-PHYS-PROC-2009-014
5. CMS-NOTE2006-026
6. CERN-LHCC-2006-001
7. ALEPH, DELPHI and L3 Collaborations, arxiv:hep-ex/0612034
9. CDF/PHYS/EXO/PUBLIC/10165