Higgs expectations and status of $Z$ and $Z+\text{jets}$ at $\sqrt{s} = 7$ TeV with the ATLAS detector

G. Carrillo-Montoya
U. of Wisconsin, EPFL

LPHE Seminar

October - 4th - 2010
A Toroidal LHC Apparatus

Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t

- Muon Detectors
- Electromagnetic Calorimeters
- Solenoid
- Forward Calorimeters
- End Cap Toroid
- Barrel Toroid
- Inner Detector
- Hadronic Calorimeters
- Shielding
A Toroidal LHC Aparatus

- ID: $|\eta| < 2.5$ (TRT up to 2.0)
- EM: $|\eta| < 3.0$ (Transition region 1.36-1.52)
- HCAL: $|\eta| < 4.8$ (Endcap $\rightarrow$ 3.0)
- MS: $|\eta| < 2.7$ (Hole close to 0)
### A Toroidal LHC Apparatus

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Number of Channels</th>
<th>Approximate Operational Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixels</td>
<td>80 M</td>
<td>97.3%</td>
</tr>
<tr>
<td>SCT Silicon Strips</td>
<td>6.3 M</td>
<td>99.2%</td>
</tr>
<tr>
<td>TRT Transition Radiation Tracker</td>
<td>350 k</td>
<td>97.1%</td>
</tr>
<tr>
<td>LAr EM Calorimeter</td>
<td>170 k</td>
<td>98.1%</td>
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<tr>
<td>Tile calorimeter</td>
<td>9800</td>
<td>96.9%</td>
</tr>
<tr>
<td>Hadronic endcap LAr calorimeter</td>
<td>5600</td>
<td>99.9%</td>
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<tr>
<td>Forward LAr calorimeter</td>
<td>3500</td>
<td>100%</td>
</tr>
<tr>
<td>LVL1 Calo trigger</td>
<td>7160</td>
<td>99.9%</td>
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<tr>
<td>LVL1 Muon RPC trigger</td>
<td>370 k</td>
<td>99.5%</td>
</tr>
<tr>
<td>LVL1 Muon TGC trigger</td>
<td>320 k</td>
<td>100%</td>
</tr>
<tr>
<td>MDT Muon Drift Tubes</td>
<td>350 k</td>
<td>99.7%</td>
</tr>
<tr>
<td>CSC Cathode Strip Chambers</td>
<td>31 k</td>
<td>98.5%</td>
</tr>
<tr>
<td>RPC Barrel Muon Chambers</td>
<td>370 k</td>
<td>97.0%</td>
</tr>
<tr>
<td>TGC Endcap Muon Chambers</td>
<td>320 k</td>
<td>98.6%</td>
</tr>
</tbody>
</table>
Content

1. **Z and Z + jets**
   - Z Cross section measurement
   - Z + jets Exclusive/Inclusive ratios
   - Z Background Normalization

2. **Resolution Studies with Z → \( \mu \mu \)**

3. **Higgs searches**
   - \( H \rightarrow WW \) (Highest sensitivity)
   - \( H \rightarrow ZZ \rightarrow 4\ell \) (The Golden Channel)
   - ATLAS Higgs expectations
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- U. of Wisconsin, EPFL, German Carrillo-Montoya: LPHE Seminar Oct 2010 7/52
Z and Z + jets
Resolution Studies with Z → µµ
Higgs searches

Z Cross section measurement
Z + jets Exclusive/Inclusive ratios
Z Background Normalization

Electrons
- Trigger: L1_EM14 (→ 14 GeV)
- ETCluster > 20 GeV, |η_{Cluster}| < 2.47, no in crack.
- OTX Cleaning: 2D Map to remove problematic sectors
- Electron Shower Shape ID: robust Medium

Muons
- Trigger L1_MU10 (→ 10 GeV)
- P_T > 20 GeV, and |η| < 2.4
- Hits in ID: Pixel > 1, SCT > 5 and TRT > 0 (if |η| < 2.0)
- |z_0 - z_{pv}| < 10 mm, and |d_0| < 0.1 mm (wrt primary vertex)
- P_{T_{MS}} > 10 GeV and |P_{T_{ID}} - P_{T_{MS}}| / P_{T_{ID}} < 0.5
- Track isolation: \sum_{cone20} P_{T_{track}} < 1.8 GeV
- Combined (ID+MS tracks) using the STACO chain (refit of tracks)

Jets: AntiKt4Topo
- P_T > 20 GeV with EMJES correction, |η| 2.8 (4.5)
- Jet Vertex Fraction < 0.75 (wrt tagged vertex), and Jet Cleaning (Noisy Cells)

Overlap removal: Remove jets in ΔR cone = 0.5 (e/µ)
- Vertex: at least 3 tracks, compatible with beam spot and |z_{vtx}| < 150 mm
- Exactly 2 same flavor leptons with opposite charge
Lepton $P_T$

Very low background rate is expected.

MC with Pileup (5 interaction per BC) is weighted to match data Pileup conditions.
Resolution Studies with $Z \rightarrow \mu \mu$

Higgs searches

$Z$ Cross section measurement

$Z +$ jets Exclusive/Inclusive ratios

$Z$ Background Normalization

$\int L \, dt = 316 \text{ nb}^{-1}$

$\int L \, dt = 331 \text{ nb}^{-1}$
Cross Section with $Z \rightarrow \mu\mu$ 

Cross section measurement $Z + jets$ Exclusive/Inclusive ratios

$Z$ Background Normalization

Resolution Studies with $Z \rightarrow \mu\mu$

Higgs searches

$\sigma_{pp \rightarrow Z/\gamma^* \rightarrow ll}$

$\int L \, dt = 316-331 \text{ nb}^{-1}$

Data 2010 $\sqrt{s} = 7 \text{ TeV}$

Systematic uncertainties:

$\delta C_Z/C_Z$: $\epsilon[\%]$ $\mu[\%]$

<table>
<thead>
<tr>
<th></th>
<th>$\epsilon$</th>
<th>$\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger</td>
<td>$&lt;0.2$</td>
<td>0.7</td>
</tr>
<tr>
<td>Reconstruction</td>
<td>8.8</td>
<td>5.0</td>
</tr>
<tr>
<td>$P_T$ Scale</td>
<td>1.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Resolution</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Calorimeter reg</td>
<td>1.4</td>
<td>-</td>
</tr>
<tr>
<td>Theoretical(PDF)</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Total</td>
<td>9.4</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Statistical (10%)

Luminosity (11%)

$\sigma_{Z/\gamma^*}^{tot} = \frac{N_{Z}^{sig}}{A_{Z} \cdot C_{Z} \cdot \mathcal{L}_{int}}$

where $ll$ are $e, \mu$
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Resolution Studies with $Z \rightarrow \mu\mu$ 
Higgs searches

$Z$ and $Z + jets$

$Z + jets$ Exclusive/Inclusive ratios

$Z$ Cross section measurement

Background Normalization

- U. of Wisconsin, EPFL, German Carrillo-Montoya:
Resolution Studies with $Z \rightarrow \mu\mu$

Higgs searches

$Z$ Cross section measurement

$Z + jets$ Exclusive/Inclusive ratios

$Z$ Background Normalization
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QCD bckg check, **caveat → signal contamination**

- With low luminosity background taken from MC, but we proved it is SMALL
- **Backup**: 100% data driven method using control regions populated with opposite flavor leptons in a 2D sideband. *(few pb$^{-1}$ of luminosity needed)*
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Fit models

- Signal Model:
  
  Breit-Wigner ($Z$) $\otimes$ Gaussian(Resolution) + Exponential(Low Drell-Yan)

  \[
  \frac{1}{(x - M_Z)^2 + \frac{1}{4} \Gamma^2} \otimes \exp \left( -\frac{(x - M_Z)^2}{2\sigma^2} \right) + e^{a \cdot x}
  \]

  $\Gamma$ is allowed to float in a very limited range in order constraint the $Z$ width.

  It is known that this model does not described 100% the tails of the $Z$ peak. A fit using MC shape before reconstruction could be more accurate (generator dependent). In any case it is not relevant for this studies.

- Binned vs Unbinned:
  
  - Data is adjusted using unbinned fits (bin-size could bias parameter values)
  - Monte Carlo is fitted from histograms (binned)
  
    $\rightarrow$ small bin-sizes and very large statistics
$Z \rightarrow \mu\mu$ with 2.3 pb$^{-1}$
$\sigma$ from Gaussian contribution [GeV], $2.3 \text{ pb}^{-1}$

<table>
<thead>
<tr>
<th></th>
<th>STACO</th>
<th>MuID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DATA</td>
<td>MC</td>
</tr>
<tr>
<td><strong>Combined $P_{\mu T}$</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALL</td>
<td>3.04 ± 0.22</td>
<td>1.85 ± 0.01</td>
</tr>
<tr>
<td>Muon Spect. $P_{\mu T}$</td>
<td>4.88 ± 0.30</td>
<td>3.39 ± 0.02</td>
</tr>
<tr>
<td>Inner Track $P_{\mu T}$</td>
<td>3.94 ± 0.26</td>
<td>2.37 ± 0.01</td>
</tr>
<tr>
<td>**$</td>
<td>\eta</td>
<td>&lt; 2$**</td>
</tr>
<tr>
<td>Combined $P_{\mu T}$</td>
<td>2.69 ± 0.23</td>
<td>1.81 ± 0.01</td>
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<tr>
<td>Muon Spect. $P_{\mu T}$</td>
<td>4.37 ± 0.33</td>
<td>3.43 ± 0.02</td>
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<tr>
<td>Inner Track $P_{\mu T}$</td>
<td>3.32 ± 0.24</td>
<td>2.09 ± 0.02</td>
</tr>
<tr>
<td><strong>Barrel-Barrel</strong></td>
<td></td>
<td></td>
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<tr>
<td>Combined $P_{\mu T}$</td>
<td>2.25 ± 0.41</td>
<td>1.61 ± 0.02</td>
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<tr>
<td>Muon Spect. $P_{\mu T}$</td>
<td>4.03 ± 0.58</td>
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<td>Inner Track $P_{\mu T}$</td>
<td>3.07 ± 0.42</td>
<td>1.84 ± 0.02</td>
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<tr>
<td><strong>Barrel-Endcap</strong></td>
<td></td>
<td></td>
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<tr>
<td>Combined $P_{\mu T}$</td>
<td>2.83 ± 0.25</td>
<td>1.85 ± 0.02</td>
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<tr>
<td>Muon Spect. $P_{\mu T}$</td>
<td>4.92 ± 0.41</td>
<td>3.48 ± 0.03</td>
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<tr>
<td>Inner Track $P_{\mu T}$</td>
<td>3.78 ± 0.30</td>
<td>2.38 ± 0.00</td>
</tr>
<tr>
<td><strong>Endcap-Endcap</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined $P_{\mu T}$</td>
<td>4.06 ± 0.44</td>
<td>2.17 ± 0.03</td>
</tr>
<tr>
<td>Muon Spect. $P_{\mu T}$</td>
<td>5.52 ± 0.70</td>
<td>4.29 ± 0.05</td>
</tr>
<tr>
<td>Inner Track $P_{\mu T}$</td>
<td>6.35 ± 0.49</td>
<td>3.18 ± 0.04</td>
</tr>
</tbody>
</table>
Resolution Studies with $Z \rightarrow \mu\mu$

Higgs searches
Resolution as function of $|\eta|$, 3.4 pb$^{-1}$

- 1091 (STACO) and 1129 (MuID) candidates
- Similar behavior for candidates from STACO chain
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Higgs Production Processes

- At the LHC gluon-gluon fusion is the dominant production process for a SM Higgs
- Vector Boson Fusion signatures can be relevant for some Higgs decay modes
- Associated productions become relevant in the case of a low \( m_H \)

- Inclusive cross-section estimates with high order (NNLO, NNLL) and electroweak corrections with most recent PDFs

On going: Exclusive estimates and specific kinematic regions together with a comprehensive agreement on scale and uncertainties choices
Higgs Production cross sections @ $\sqrt{s} = 7$ TeV

$\sigma(\text{pp} \to H \rightarrow \mu\mu)$

$\sigma(\text{pp} \to H \rightarrow WW \text{ (Highest sensitivity)})$

$\sigma(\text{pp} \to H \rightarrow ZZ \rightarrow 4\ell \text{ (The Golden Channel)})$

$\sigma(\text{pp} \to H \rightarrow ggqH \text{ (NLO)})$

$\sigma(\text{pp} \to H \rightarrow ggqH \text{ (NNLO+NNLL)})$

$\sigma(\text{pp} \to H \rightarrow ttH \text{ (NLO)})$
**Content**

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Z and Z + jets
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ATLAS Higgs expectations
Higgs to $WW$

- This analysis is divided in different analysis for different jet multiplicities:
  - Then systematic uncertainties can be treated differently
  - Some of the features of this channel:
    - Signal / Irreducible bkg discrimination $\rightarrow \Delta \phi_{\ell\ell}$ (Spin correlations)
    - Missing energy as part of the signature.
    - Jet discriminators are needed
    - Backgrounds with cross sections many orders of magnitude bigger than signal need to be reduced.
    - Will be affected by large theoretical and detector uncertainties.
    - Systematics MUST be under control
$H \rightarrow WW \rightarrow \ell\nu\ell\nu$, and strategy for early data

- A cut-based analysis was proposed for the early data
  Have in mind that **statistical uncertainties** are going to be dominant.
- The relevant backgrounds for this analysis:
  - QCD $WW$ (dominant in 0 and 1 jet)
  - $t\bar{t}$ and single top (dominant in 2 jets)
  - $WZ$
  - $Z$+jets (same flavor channels)
  - $W$+jets
    (cross sections many orders of magnitude bigger than Higgs production)
  - QCD di-jets
  - $b\bar{b}$ (some predictions of underestimation and an enormous cross section)

- For different jet multiplicities the impact of the different backgrounds is different
In order to estimate the impact of the main backgrounds, different control regions can be defined reversing or changing some cuts from the signal-like region.

\[ \sigma_{\text{data}}^{\text{CR}} \rightarrow \sigma_{\text{bkgr}}^{\text{SR}} = \sigma_{\text{data}}^{\text{CR}} \cdot \alpha_{\text{MC}}^{\text{SR}/\text{CR}} \]

Different jet multiplicity → different systematic errors on the extrapolation ratios

<table>
<thead>
<tr>
<th>S.R.</th>
<th>C.R.(WW)</th>
<th>C.R.(Top)</th>
<th>C.R.(W+jets)</th>
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</thead>
<tbody>
<tr>
<td>WW</td>
<td>WW</td>
<td>Top</td>
<td>Top</td>
</tr>
<tr>
<td>Top</td>
<td>Top</td>
<td></td>
<td>W+jets</td>
</tr>
<tr>
<td>W+jets</td>
<td>W+jets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Some other regions are also studied to make sure backgrounds like $b\bar{b}$ can be neglected.
$H \rightarrow WW \rightarrow \ell\nu\ell\nu$ - exclusion

- Independent uncertainty for each extrapolation ratio:
  - $Q^2$, jet energy scale/resolution, $b$-tagging
- Dominated by MC statistics
- Also signal uncertainties: lepton efficiency and luminosity.

### ATLAS Preliminary

<table>
<thead>
<tr>
<th>$M_H$ (GeV)</th>
<th>120</th>
<th>140</th>
<th>160</th>
<th>180</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM WW</td>
<td>26.3</td>
<td>43.8</td>
<td>55.2</td>
<td>60.6</td>
<td>62.4</td>
</tr>
<tr>
<td>top</td>
<td>4.9</td>
<td>9.1</td>
<td>14.0</td>
<td>17.2</td>
<td>18.2</td>
</tr>
<tr>
<td>$W^+\text{jets}$</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Signal</td>
<td>4.1</td>
<td>18.5</td>
<td>39.5</td>
<td>26.2</td>
<td>11.0</td>
</tr>
</tbody>
</table>
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The “Golden” Channel

- It is one of the cleanest signatures
  - 4 Isolated leptons ($\mu, e$) coming from Z decays (on shell or off shell in the case of low $m_H$)
  - Main discriminators: track and calorimeter isolation, impact parameter significance.

†Irreducible background: direct production of $ZZ$
†Reducible backgrounds: $tt$, $Zb\bar{b}$, $Z/\gamma +$jets

STATISTICAL ERROR WILL BE DOMINANT, SMALLER IMPACT FROM OTHER SOURCES OF UNCERTAINTIES.
**H → ZZ → 4ℓ**

**Resolution Studies with Z → μμ**

**Higgs searches**

**H → WW (Highest sensitivity)**

**H → ZZ → 4ℓ (The Golden Channel)**

**ATLAS Higgs expectations**

### Resolution Studies with Z → μμ

<table>
<thead>
<tr>
<th>MH (GeV)</th>
<th>120</th>
<th>130</th>
<th>150</th>
<th>170</th>
<th>200</th>
<th>260</th>
<th>400</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZZ</td>
<td>0.090</td>
<td>0.094</td>
<td>0.083</td>
<td>0.147</td>
<td>1.29</td>
<td>0.89</td>
<td>0.48</td>
<td>0.39</td>
</tr>
<tr>
<td>top and Z+jets</td>
<td>0.005</td>
<td>0.004</td>
<td>0.005</td>
<td>0.005</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Signal</td>
<td>0.105</td>
<td>0.595</td>
<td>0.713</td>
<td>0.192</td>
<td>1.60</td>
<td>1.08</td>
<td>0.67</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**ATLAS Preliminary (Simulation)**

**Selection Step**

- Preselection
  - Z
  - M
  - Track Isol. Calo Isol. IP Sign.

**Signal Efficiency**

- 0.25
- 0.30
- 0.35
- 0.40
- 0.45
- 0.50
- 0.55
- 0.60
- 0.65
- 0.70

**No Pile-Up**

- Pile-Up / Si Hits + PT > 1 GeV
- Pile-Up / Si Hits + z < 10 mm

**ATLAS Preliminary (Simulation)**

**H → ZZ(*) → 4μ**

- No Mz Constraint
- With Mz Constraint

**MH (GeV)**

- 120
- 130
- 150
- 170
- 200
- 260
- 400
- 600
$H \rightarrow ZZ \rightarrow 4\ell$ - exclusion (CLs $\rightarrow$ LEP)

- $M_H$ about 200 GeV $\rightarrow$ exclusion of $2.5 \times (\sigma_{SM} \times BR_{H \rightarrow 4\ell})$.
- In the “SM”, a Higgs with mass larger than 200 GeV would have a natural width larger than the experimental resolution.
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Higgs Exclusion - all $m_H$ range (No public yet)

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

ATLAS Preliminary
(Simulation)

\[ \int L \, dt = 1 \text{ fb}^{-1} \]

$95\%$ CL Upper Bound on $\sigma/\sigma_{SM}^{\text{NNLO}}$

- $H \to WW$
- $H \to 4l$
- $H \to ZZ \to 4\ell$ (no syst.)
- $H \to \gamma\gamma$
- $H \to \tau\tau$
- $H \to VH, H \to b\bar{b}$
- Combined

$\pm 1\sigma$
$\pm 2\sigma$

$M_H [\text{GeV}]$

100 200 300 400 500 600
Higgs Exclusion - medium $m_H$ range (No public yet)

$\sigma/\sigma_{SM}$

$\int L \, dt = 1 \text{ fb}$

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

$Z$ and $Z + \text{jets}$

$H \rightarrow WW$ (Highest sensitivity)

Resolution Studies with $Z \rightarrow \mu\mu$

$H \rightarrow ZZ \rightarrow 4\ell$ (The Golden Channel)

Higgs searches

ATLAS Higgs expectations

Higgs Exclusion - medium $m_H$ range (No public yet)

$\sigma_{NNLO}$

$95\% \text{ CL Upper Bound on } \sigma_{NNLO}/\sigma_{SM}$

$H \rightarrow WW$

$H \rightarrow 4\ell$

$H \rightarrow ZZ \rightarrow llvllbb$ (no syst.)

$H \rightarrow \gamma\gamma$

$VH, H \rightarrow b\overline{b}$

$H \rightarrow \tau\tau$

Combined

$\pm 1\sigma$

$\pm 2\sigma$

$M_H[\text{GeV}]$

100 120 140 160 180 200

- U. of Wisconsin, EPFL, German Carrillo-Montoya:
Higgs Observation - all $m_H$ range (No public yet)

$Z$ and $Z + jets$
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Higgs Observation - all $m_H$ range (No public yet)
Higgs Observation - medium $m_H$ range (No public yet)

Resolution Studies with $Z \rightarrow \mu \mu$

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ATLAS Higgs expectations

**Expected, $\sqrt{s} = 7$ TeV**

<table>
<thead>
<tr>
<th>TeVatron</th>
<th>LEP</th>
<th>ATLAS Preliminary (Simulation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 fb^{-1}</td>
<td>1 fb^{-1}</td>
<td>2 fb^{-1}</td>
</tr>
<tr>
<td>TeVatron</td>
<td>LEP</td>
<td>ATLAS Preliminary (Simulation)</td>
</tr>
<tr>
<td>100</td>
<td>110</td>
<td>120</td>
</tr>
<tr>
<td>$\sigma/\sigma_{SM}$</td>
<td>$95%$ CL Limit on $\sigma/\sigma_{SM}$</td>
<td>0.5 fb^{-1}</td>
</tr>
<tr>
<td>10^{-1}</td>
<td>1</td>
<td>Expected, $\sqrt{s} = 7$ TeV</td>
</tr>
</tbody>
</table>
Outlook

- **Z Cross section in both ee and $\mu\mu$ channels** with 316 and 331 nb$^{-1}$ of integrated luminosity
- **Z + jets** distributions: jet multiplicity, and $P_T$ spectrums of jets
- Resolution using $Z \rightarrow \mu\mu$ candidates using an unbinned fit separating in regions of $\eta$
- Description of 2 of the most important SM Higgs analyzes: $H \rightarrow WW \rightarrow \ell\nu\ell\nu$ and $H \rightarrow ZZ \rightarrow 4\ell$ where $\ell : e, \mu$
- **ATLAS Expectation of SM Higgs sensitivity combining** $WW \rightarrow \ell\nu\ell\nu$, $ZZ \rightarrow 4\ell$, $ZZ \rightarrow \ell\ell\nu\nu$, $ZZ \rightarrow \ell\ell\bb$, $H \rightarrow \gamma\gamma$, $VBF : H \rightarrow \tau\tau$ and $VH : H \rightarrow \bb$.
- With 1 fb$^{-1}$ of integrated luminosity ATLAS would exclude a range between 128 and 460 GeV at $\sqrt{s}$ of 7 TeV
- On the hypothetical case of expected and planned improvements in the diffreren analyzes and an increment in $\sqrt{s}$ from 7 to 8 TeV, the LHC with 1+1 fb$^{-1}$ (1 in ATLAS + 1 in CMS) could exclude the SM Higgs (114 to 500 GeV) - see backup slides.
Z and $Z + \text{jets}$
Resolution Studies with $Z \rightarrow \mu\mu$
Higgs searches

$H \rightarrow WW$ (Highest sensitivity)
$H \rightarrow ZZ \rightarrow 4\ell$ (The Golden Channel)

ATLAS Higgs expectations

EXITING TIMES AHEAD OF US

THANKS
BACKUP SLIDES ...
Toroidal Magnetic Field

Resolution Studies with $Z \rightarrow \mu\mu$

Higgs searches

$Z$ and $Z$ + jets

$H \rightarrow WW$ (Highest sensitivity)

$H \rightarrow ZZ \rightarrow 4\ell$ (The Golden Channel)

ATLAS Higgs expectations
Resolution Studies with $Z \to \mu\mu$

Higgs searches

ATLAS Higgs expectations

Possibilities: IP significance or Relative isolation

Signal Region = A:
- Same Flavor
- $66 \text{ GeV} < M_{\ell\ell} < 116 \text{ GeV}$
- $\frac{D_0}{\sigma D_0} < 6$ or $\frac{\text{TrackIso}}{P_T} < 0.2$

Control Region B:
- Same Flavor
- $30 \text{ GeV} < M_{\ell\ell} < 66 \text{ GeV}$
- $\frac{D_0}{\sigma D_0} > 6$ or $\frac{\text{TrackIso}}{P_T} > 0.2$

Control Region C:
- Different Flavor
- $66 \text{ GeV} < M_{\ell\ell} < 116 \text{ GeV}$
- $\frac{D_0}{\sigma D_0} < 6$ or $\frac{\text{TrackIso}}{P_T} < 0.2$

Control Region D:
- Different Flavor
- $30 \text{ GeV} < M_{\ell\ell} < 66 \text{ GeV}$
- $\frac{D_0}{\sigma D_0} > 6$ or $\frac{\text{TrackIso}}{P_T^3} > 0.2$

\[
\left(\frac{A}{B}\right) = \left(\frac{C}{D}\right) \Rightarrow A \approx \frac{C \cdot B}{D}
\]
Z and $Z + \text{jets}$ Resolution Studies with $Z \rightarrow \mu\mu$

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ATLAS Higgs expectations

Di-lepton mass in control regions (75.9 nb$^{-1}$ only)
Branching Ratios

![Branching Ratios Graph](image)

Prophecy4f and HDEACY ±1%
\( H \rightarrow WW \rightarrow \ell\nu\ell\nu \) - Loose lepton for \( W+\text{jets} \) bkg

- \( W+\text{jets} \) is an important background for \( WW \) searches
- Using a **GOOD lepton + a LOOSE lepton** it is possible estimate its contribution in signal region.
  - For LOOSE lepton definition: \( P_T > 10 \) GeV:
    - for \( e \): Loose isEM ID
    - for \( \mu \): no isolation applied.
  - QCD contamination can be subtracted using MET
- Fake lepton rates extracted from di-jet and \( \gamma \)-jet
- Rejection of \( Z \) like events (\( M_{\ell\ell} \) and \( E_T^{\text{miss}} > 25 \) GeV)
- Jet veto \( \rightarrow 2 \) jets (AntiKt of 20 GeV and \( |\eta| < 3.0 \))
Resolution Studies with $Z \rightarrow \mu \mu$

Higgs searches

$H \rightarrow WW$ (Highest sensitivity)

$H \rightarrow ZZ \rightarrow 4 \ell$ (The Golden Channel)

ATLAS Higgs expectations

$H \rightarrow WW \rightarrow \ell \nu \ell \nu$ - Loose lepton for $W+\text{jets}$ bkg
Higgs Exclusion @ different $\sqrt{s}$ (No public yet)

- $Z$ and $Z + \text{jets}$ resolution studies
- $H \rightarrow WW$ (Highest sensitivity)
- $H \rightarrow ZZ \rightarrow 4\ell$ (The Golden Channel)

ATLAS Higgs expectations

ATLAS Preliminary (Simulation)
Higgs Exclusion @ different $\sqrt{s}$ (No public yet)
Higgs Exclusion @ different $\sqrt{s}$ (No public yet)

$\sigma/\sigma_{SM}$ vs. $M_H$ [GeV]

- 7 TeV
- 8 TeV
- 9 TeV

Expected, 1 fb$^{-1}$

ATLAS Preliminary (Simulation)

UT of Wisconsin, EPFL, German Carrillo-Montoya:

- U. of Wisconsin, EPFL, German Carrillo-Montoya:
Luminosity $\sqrt{s} = 8$ TeV to match $\sqrt{s} = 7$ TeV

\[ \int L \, \text{(pb)} \]

\[ \int \text{Matching 1fb}^{-1} \, @ \sqrt{s}=7 \text{ TeV} \]

$H \rightarrow WW$ (Highest sensitivity)

$H \rightarrow ZZ \rightarrow 4\ell$ (The Golden Channel)

ATLAS Higgs expectations

$Z$ and $Z +$ jets

Resolution Studies with $Z \rightarrow \mu\mu$

Higgs searches

ATLAS Preliminary (Simulation)
Higgs cross sections ratio

\[ \frac{\text{gg} \rightarrow H \ (\text{NNLO+NNLL})}{\text{qq} \rightarrow qqH \ (\text{NLO})} = \frac{\text{q\overline{q}} \rightarrow WH \ (\text{NNLO})}{\text{q\overline{q}}/gg \rightarrow ZH \ (\text{NNLO})} \]

9TeV/7TeV
8TeV/7TeV

Cross Section Ratio

M_H [GeV]

100 200 300 400 500 600

1 1.5 2 2.5

H (NNLO+NNLL) → gg
qqH (NLO) → qq
WH (NNLO) → qq
ZH (NNLO) → gg/qq

Higgs searches
Z and Z + jets
Resolution Studies with \( Z \rightarrow \mu\mu \)
H → WW (Highest sensitivity)
H → ZZ → 4\ell (The Golden Channel)
ATLAS Higgs expectations