Higgs searches at the LHC

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On behalf of CMS and ATLAS collaborations

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ISMD 2010 @ Belgium
LHC operation

Recorded 4.0 pb\textsuperscript{-1} data in 7TeV

Expected o(100pb\textsuperscript{-1}) in 2010

1 fb\textsuperscript{-1} by the end of 2011

• 1 fb\textsuperscript{-1} Sensitivity prospect
  – Evaluated by cross section scaling from 10/14 TeV study with full simulation. Not optimized to 7 TeV.

• Background study with real data
  – Performance of final state particles and data driven background estimations are performed using current luminosity of data. Especially for the fake background.
Standard Model Higgs Boson

- $gg \rightarrow H$ production dominates for all Higgs masses.
  - 10 times larger cross section than Tevatron
  - Need clean final state i.e. photons/leptons($\gamma\gamma, WW, ZZ, \tau\tau$)
- VBF $qq \rightarrow qqH$ production is promising for the low mass region.
  - High $p_T$ forward jets can be tagged ($\gamma\gamma, \tau\tau$)
- Small WH/ZH cross section against background.
- Branching ratio:

![Graph showing branching ratios and Higgs mass spectrum for LHC 7TeV and Tevatron](image)
MSSM scenario

- Super symmetric models extend Higgs sector
  - $\phi=(H,A,h)$, and $H^\pm$
  - Two parameters at tree level ($\tan\beta,M_A$)
- Signature at LHC
  - production:
    - $gg\rightarrow\phi$, $bb\rightarrow bb\phi$ dominant
    - 10 times larger cross section than SM ($\tan\beta\sim40$)
  - Branching ratio:
    - 90% $bb$, 10% $\tau\tau$ -- enhanced
    - $WW$ and $\gamma\gamma$ are suppressed
    - $\mu\mu$ is also promising by clean signature and good mass resolution
  - need clean final state: i.e. $\tau\tau$
What can we see at a first $fb^{-1}$?
What can we see at a first fb$^{-1}$?

### Dilepton with large MET
- Main background is SM WW

#### Estimated number of events at 1fb$^{-1}$

<table>
<thead>
<tr>
<th>$M_H$ (GeV)</th>
<th>160</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM WW</td>
<td>55.2</td>
</tr>
<tr>
<td>top</td>
<td>14.0</td>
</tr>
<tr>
<td>$W$ + jets</td>
<td>5.6</td>
</tr>
<tr>
<td>Total background</td>
<td>74.8</td>
</tr>
<tr>
<td>Signal</td>
<td>39.5</td>
</tr>
</tbody>
</table>

- One fake lepton background is not negligible
- Need data-driven background estimation

### MSSM $H \rightarrow \tau \tau$
- Lepton + Tau + MET
- $\tau \tau \rightarrow$ lepton hadron is most sensitive

#### Estimated number of events at 1fb$^{-1}$

With B-tagging analysis: background is $t\bar{t}$ and $Z$+HF
- W/o B-tagging: $Z$+jets and fake($W$+jets,QCD)
- Need data-driven background estimation

LHC 1fb-1?
Di-lepton final state with large missing energy

CMS result
- using Neural Network for the event selection.
- Counting experiment on the high output region

ATLAS result
- Cut based counting experiment.
- estimated limit by 250pb⁻¹ Luminosity steps
Performance of $W$ + fake lepton will be estimated by data driven way. E.g. 
\[
\text{# of Fake bkg} = [W + \text{fake candidate}] \times [\text{Fake rate}]
\]
Fake rate should be calculated “IDed lepton” divided by “fake candidate” by jet data.

**Electron Fake rate**

\[
\text{Fake Rate} = \frac{\text{Identified electron candidate}}{\text{Reconstructed electron candidate}}
\]

**Muon Fake rate**

\[
\text{Fake Rate} = \frac{\text{Identified muon candidate}}{\text{Non-isolated muon candidate}}
\]
MSSM A/h/H $\rightarrow \tau\tau$

- Isolated pairs of ($\tau_{\text{had}}\tau_\mu$), ($\tau_{\text{had}}\tau_e$), ($\tau_\mu\tau_e$)
- With MET, 1 tagged bjet, veto extra jets
- Build $\tau\tau$-mass using collinear approx*
- Dominant background: $t\bar{t}$, $Z+bb$ & $Z+cc$

*direction of the $\tau$ approximated by direction of visible decay product

**Discovery:**

We have chance to discover MSSM Higgs, at the region not excluded by Tevatron!!

**Exclude:**

Can be excluded

- $\tan\beta > 18$ @ $M_A = 120$ GeV
- $\tan\beta > 40$ @ $M_A = 300$ GeV

Optimized analysis for 7TeV is on-going by ATLAS and CMS with real data.

Need to consider fake bkg by relaxed event selection.
Performancce Study for H→ ττ

- **Electromagnetic radius**: $E_T$ weighted shower width in EM calo
- **Track radius**: $p_T$ weighted track width
- **Leading track fraction**: Momentum fraction of leading track

- Cut based tau id uses three variables.
- Three selections according to signal efficiency. 
  - Tight: 30%, Medium: 50%, Loose: 60%
- Different cuts are applied for tau candidates with Ntrk=1 and Ntrk≥1.

Background Efficiency (fake rate) is estimated by data.
Other significant contributions and combination
$\gamma\gamma$ and $ZZ$ results from CMS

$H \rightarrow \gamma\gamma$

Conservative option:

- No reconstructed photon categories
- Simple counting events in mass window

Will be improved with photon category or MVA techniques.

$H \rightarrow ZZ \rightarrow llll$

4 lepton signature ($4e,4\mu,2e2\mu$)

$H \rightarrow WW$ and $H \rightarrow ZZ$ searches have similar sensitivities for $m_H \sim 200$ GeV.

Signal x-sec: NNLO

CMS Preliminary: projection for 7 TeV, 1 fb$^{-1}$

Mar 17 2010

$1 \text{ fb}^{-1}$ $H \rightarrow \gamma\gamma$ [no photon categories]

$4 \times \text{SM}$ $H \rightarrow ZZ$ [4e, 4\mu, 2e2\mu]

$2 \times \text{SM}$ 95% CL exclusion: mean

$95\% \text{ CL exclusion: 68\% band}$

$95\% \text{ CL exclusion: 95\% band}$

$95\% \text{ CL exclusion: mean (no sys)}$

Mar 17 2010

Higgs mass, $m_H$ [GeV/c$^2$]
γγ and ZZ results from ATLAS

**H → γγ**

Perform jet inclusive analysis for early data

**H → ZZ → llll**

4lepton signature (4e,4μ,2e2μ)

| M_H (GeV) | 120 |
| γγ | 5540 |
| γj | 2500 |
| j j | 360 |

Drell Yan: 90

Total background: 8490

Signal: 13.0

- Signal x-sec: NLO=0.7xNNLO

- 1 fb^{-1}

| M_H (GeV) | 190 |
| SM ZZ | 0.981 |
| top & Z+jets | 0.003 |

Total background: 0.984

Signal: 1.49

- 1 fb^{-1}

2.5 x SM

- 6 x SM
Combination (γγ, WW, ZZ)

H→WW→lνlν, ZZ→4l, γγ channels are combined

Expected 95% C.L. exclusion of SM Higgs is:
- ATLAS 135-188 GeV @ 1fb⁻¹
- CMS 145-190 GeV @ 1fb⁻¹

H→ττ and bb help to improve sensitivity in low mass region!!

Again, all results are scaled from 10/14 TeV study!!
Conclusion

• LHC accumulated 4.0 pb\(^{-1}\) of data already.
  – Certain performance and data driven background estimation studies are on-going.

• Sensitivity expectation scaled from 10/14 TeV results at 1 fb\(^{-1}\) was shown by CMS and ATLAS.

• 7TeV optimized analysis and low mass results improvement are on-going with real data.

• First physics impact from LHC Higgs search will be \(H \rightarrow WW\) and MSSM \(H \rightarrow \tau\tau\) (World best @<1fb\(^{-1}\))
Thank you!
backup
Sensitivity of $H \rightarrow WW \rightarrow l\nu l\nu$

![Graph showing the sensitivity of Higgs boson decays]

CMS Preliminary

Projection for $\sqrt{s} = 7$ TeV, $L = 1$ fb$^{-1}$

- Blue squares: Cut on Neural Network Output
- Red squares: Cut Based Analysis

Significance vs. Higgs mass, GeV/c

1 fb$^{-1}$
Difference between “Conservative” and “Optimistic” systematic uncertainties comes from background estimation uncertainty.