Overview of Activities / Recent Results: $H \to bb$, $H \to \tau\tau$, $H \to 4\ell$, $A \to \mu\mu$, $A \to \tau\tau$ / To Do
Overview of the Higgs searches at MPI

**SM Higgs:**

Motivation: cover the whole allowed mass region.

- $(tt, W, VBF) \ H \rightarrow b\bar{b}$
- $VBF \ H \rightarrow \tau\tau \rightarrow (\ell\nu\nu)(\text{anything})$
- $VBF \ H \rightarrow WW \rightarrow (\ell\nu)(\text{anything})$
- $H \rightarrow ZZ^{(*)} \rightarrow (\ell^{+}\ell^{-})(\ell^{+}\ell^{-})$

**Neutral MSSM Higgs:**

Motivation: expertise in $\mu$- (and $\tau$-) reconstruction.

- $A/H \rightarrow \mu^{+}\mu^{-}$
- $A/H \rightarrow \tau^{+}\tau^{-} \rightarrow (\ell\nu\nu)(\text{anything})$

**Related software development:**

- b-jet reconstruction, b-tagging: Neural-Net Tag Combiner
- $\tau$-identification (using TopoClusters): first preliminary results
- forward jet reconstruction (VBF channels): just starting
- jet reconstruction with the first data: to start in Jan 2007
### Current status of analyses

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>PEOPLE</th>
<th>STATUS</th>
<th>DATA USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM $(tt, W, VBF)H \rightarrow bb$</td>
<td>S.Kotov, J.Yuan</td>
<td>optimized</td>
<td>FULL/FAST</td>
</tr>
<tr>
<td>SM $(VBF)H \rightarrow \tau\tau \rightarrow (\ell\nu)(\ell\nu)$</td>
<td>S.Horvat, S.M-Möck, C.Valderanis</td>
<td>optimized</td>
<td>FAST</td>
</tr>
<tr>
<td>SM $(VBF)H \rightarrow \tau\tau \rightarrow (\ell\nu)(h\nu)$</td>
<td>M.Groh, S.Horvat</td>
<td>first data</td>
<td></td>
</tr>
<tr>
<td>SM $(VBF)H \rightarrow WW \rightarrow (\ell\nu)(\ell\nu, h\nu)$</td>
<td>S.Horvat, S.Kaiser, O.Kortner</td>
<td>first data</td>
<td></td>
</tr>
<tr>
<td>SM $H \rightarrow ZZ^{(*)} \rightarrow (\ell^+\ell^-)(\ell^+\ell^-)$</td>
<td>N.Benekos, S.Horvat, O.Kortner</td>
<td>optimized</td>
<td>FULL</td>
</tr>
<tr>
<td>MSSM $(bb)A/H \rightarrow \mu^+\mu^-$</td>
<td>G.Dedes, S.Horvat</td>
<td>optimized</td>
<td>FULL/FAST</td>
</tr>
<tr>
<td>MSSM $(bb)A/H \rightarrow \tau^+\tau^-$</td>
<td>G.Dedes, S.Horvat</td>
<td>first data</td>
<td></td>
</tr>
</tbody>
</table>

**Optimized analyses:**

- Cuts optimized for the low-luminosity up to $\mathcal{L}=30$ fb$^{-1}$.
- Using FAST (Atlfast) and/or FULL (V10.0.4, ”Rome-Layout”) detector simulation.
- All data (before the CSC era) produced privately at MPI and FZK.
- Pile-up, cavern background and misalignment effects still missing, to be done with the CSC data (Dec 2006).

**First data:**

- Preparation for the studies on the CSC data (V11.0.42, V12.0.2).
Neural-Network based analysis (S.Kotov):

- analysis results strongly depend on the jet reconstruction performance ⇒ using recalibrated Cone4-jets
- NN trained with ATLFAST or FULLY SIM. data, then applied on FULLY SIM. data
- selects the best combination of reconstr. $W_{lep}$, $W_{had}$ and 4 b-jets

Performance of different jet reconstruction algorithms:

<table>
<thead>
<tr>
<th>Rec. efficiency, %</th>
<th>$t\bar{t}H$</th>
<th>$t\bar{t}bb$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cone4</td>
<td>Cone7</td>
</tr>
<tr>
<td>b-jet</td>
<td>52.2</td>
<td>42.9</td>
</tr>
<tr>
<td>light jet</td>
<td>72.9</td>
<td>54.4</td>
</tr>
<tr>
<td>Mean $\Delta p_t/p_t$ shift, %</td>
<td>$t\bar{t}H$</td>
<td>$t\bar{t}bb$</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td>Cone4</td>
<td>Cone7</td>
</tr>
<tr>
<td>b-jet</td>
<td>-10.5</td>
<td>0.4</td>
</tr>
<tr>
<td>light jet</td>
<td>-8.2</td>
<td>3.4</td>
</tr>
</tbody>
</table>
**Overview of Activities / Recent Results:**

- **Recent Improvement:** NN training on the fully simulated data

**A)** Using NN-training on ATLFAST data (1M $t\bar{t}H$, 1.8M $t\bar{t}b\bar{b}$)

**B)** Using NN-training on FULLY SIM. data (50k $t\bar{t}H$, 150k $t\bar{t}b\bar{b}$)

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**Analysis Results**

Recent improvement: NN training on the fully simulated data

### Overview of Activities

- $H \rightarrow b\bar{b}$, $H \rightarrow \tau\tau$, $H \rightarrow 4\ell$, $A \rightarrow \mu\mu$, $A \rightarrow \tau\tau$ / To Do

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**Recent Results:**

- $H \rightarrow b\bar{b}$
- $H \rightarrow \tau\tau$
- $H \rightarrow 4\ell$
- $A \rightarrow \mu\mu$
- $A \rightarrow \tau\tau$
(W, VBF)H, H → b¯b

ATLFAST studies exploring the feasibility of these searches (J. Yuan).

**WH channel:**
- Dominant bckgr.: W + jets
- More realistic b-tagging compared to TDR ⇒
  - TDR significance: 2.4
  - New result: 1.1

**VBF H channel:**
- Without the b¯b:
  Significance ≈ 3-4
- b¯b-contribution hard to estimate, large statistics needed
**VBF** $H \rightarrow \tau^+\tau^- \rightarrow (l\nu
u)(l\nu\nu)$: Analysis results

**ATLFAST study** (M. Groh, C. Valderanis):

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**Number of events at 30 fb**

<table>
<thead>
<tr>
<th>cut number</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>events</td>
<td>10^8</td>
<td>10^7</td>
<td>10^6</td>
<td>10^5</td>
<td>10^4</td>
<td>10^3</td>
<td>10^2</td>
<td>10</td>
<td>1</td>
<td>10^-1</td>
<td>10^-2</td>
<td>10^-3</td>
<td>10^-4</td>
</tr>
</tbody>
</table>

**Lepton-Cuts**

- $n_\ell > 1$
- $n_{\text{jet}} > 1$
- $\Delta \phi (2\ell) > 152.0$ GeV
- $\Delta R (2\ell) > 8.384$
- $m_{\ell\ell} > 210.000$

**Jet-Cuts**

- $E_T^{\text{miss}} > 37.0$ M GeV
- $x_l > 0.122$
- $\Delta \eta (2\ell) > 1.582$
- $m_{jj} > 103.950$

**Central jet veto**

- $\Delta \eta (2\ell) > 1.582$
- $m_{jj} > 103.950$

**Significance** = 4.3

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**Plans:**

- extend to the lepton-hadron channel
- perform the analysis with the CSC data
**VBF $H \rightarrow \tau^+\tau^- \rightarrow (\ell\nu\nu)(\ell\nu\nu)$: First CSC data**

Contribution to the CSC data production (full sim. with 11.0.42):
- 8138-8141: $Z \rightarrow e^+e^- + n$ jets, $\sim 160k$ events
- 8150-8153: $Z \rightarrow \mu^+\mu^- + n$ jets, $\sim 160k$ events
- 8162: $Z \rightarrow \tau^+\tau^- + 2$ jets, $\sim 30k$ events (4M ATLFAST)

First look at the data (8162), very preliminary:

- good agreement for lepton distributions
- discrepancies for the jets
Analysis of $H \to ZZ^{(*)} \to (\ell^+\ell^-)(\ell^+\ell^-)$: Analysis results

Analysis optimized with 10.0.4 data (S. Horvat, O. Kortner):
(afterwards well reproduced on the 11.0.42 CSC data: 5300, 5200, 5176, 5980).

<table>
<thead>
<tr>
<th>$m_H$ (GeV/c$^2$)</th>
<th>$m_H = 130$ GeV</th>
<th>$m_H = 160$ GeV</th>
<th>$m_H = 180$ GeV</th>
<th>$m_H = 280$ GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta m = \pm 5$ GeV</td>
<td>$N_{signal}$</td>
<td>17.2$\pm$0.1</td>
<td>20$\pm$1</td>
<td>21.4$\pm$0.3</td>
</tr>
<tr>
<td>$\delta m = \pm 6$ GeV</td>
<td></td>
<td>8.7$\pm$0.3</td>
<td>8.8$\pm$0.3</td>
<td>21.0$\pm$0.5</td>
</tr>
<tr>
<td>$\delta m = \pm 7$ GeV</td>
<td></td>
<td>2$\pm$2</td>
<td>2$\pm$2</td>
<td>1$\pm$1</td>
</tr>
<tr>
<td>$\delta m = \pm 20$ GeV</td>
<td></td>
<td>0$\pm$0.4</td>
<td>0$\pm$0.4</td>
<td>0.5$\pm$0.4</td>
</tr>
<tr>
<td>Signif. (no K-fact)</td>
<td>5.0$\pm$0.3</td>
<td>5.5$\pm$0.5</td>
<td>4.5$\pm$0.2</td>
<td>8.7$\pm$0.4</td>
</tr>
</tbody>
</table>
$H \rightarrow ZZ^{(*)} \rightarrow (\mu^+\mu^-)(\mu^+\mu^-)$: Pile-Up Studies

Influence of the pile-up at $L=10^{33}$ (N. Benekos in collaboration with Saclay)

- suppression of the $t\bar{t}$ and $Zb\bar{b}$ background might be affected

**Total number of ID-tracks**

**Impact parameter of ID-tracks**

without pile-up

with pile-up

- no influence on the muon reconstruction

**Number of combined muons (STACO+ID)**

**$m_H$ (4 mu)/ GeV, Muonboy**

without pile-up

with pile-up

**Plans:**
develop the tools to identify the tracks from secondary pp-collisions.

**Overview of Activities / Recent Results:** $H \rightarrow bb$, $H \rightarrow \tau\tau$, $H \rightarrow 4\ell$, $A \rightarrow \mu\mu$, $A \rightarrow \tau\tau$ / To Do
(bb)A/H → μ⁺μ⁻: Analysis results

Analysis with ATLFAST and FULL SIM (10.0.4) (G.Dedes, S.Horvat):

Cuts optimized separately for the FAST and the FULL simulation:

<table>
<thead>
<tr>
<th></th>
<th>TDR cut</th>
<th>ATLFAST</th>
<th>FULL</th>
</tr>
</thead>
<tbody>
<tr>
<td>E^{miss}_{T}</td>
<td>20</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>p_{T}^{b}</td>
<td>–</td>
<td>35</td>
<td>48</td>
</tr>
</tbody>
</table>

Significance

<table>
<thead>
<tr>
<th></th>
<th>200 GeV</th>
<th>300 GeV</th>
<th>350 GeV</th>
<th>450 GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLFAST</td>
<td>6.5</td>
<td>1.9</td>
<td>1.5</td>
<td>0.7</td>
</tr>
<tr>
<td>FULL</td>
<td>5.4</td>
<td>1.7</td>
<td>–</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Plans:

- CSC analysis, combined with the low-mass region (m_A < 150 GeV)
- extend to the A → ττ channel
(bb)A/H \rightarrow \tau^+\tau^-: First data

Performance plots, CSC samples 5352, 5200, 5149 (G.Dedes):

Discriminating variables, invariant mass m_{\tau\tau}:

Overview of Activities / Recent Results: H \rightarrow bb, H \rightarrow \tau\tau, H \rightarrow 4\ell, A \rightarrow \mu\mu, A \rightarrow \tau\tau / To Do
Related software: $\tau$-identification

Exploring TopoClusters as the seeds for $\tau$-reconstruction (M. Groh, S. Horvat):

- work started in collaboration with Freiburg

TopoClusters: possible improvements at low $p_T$. 

Overview of Activities / Recent Results: $H \rightarrow bb$, $H \rightarrow \tau\tau$, $H \rightarrow 4\ell$, $A \rightarrow \mu\mu$, $A \rightarrow \tau\tau$ / To Do
To Do List

Commitments to the Higgs Working Group:

Contributions to 6 Higgs CSC notes (editing of the $A/H \rightarrow \mu\mu$ note).

- Validation and development of the reconstruction algorithms. (Possible field for the common work within ATLAS-D: organized, systematic evaluation of the reconstruction perform.)

- Preparation of analyses for the CSC data, CSC data production.

- Trigger studies.

- Include more realistic detector effects:
  - Pile-up (VBF channels): development of the handling tools.
  - Misalignment, cavern background (particularly for the muons).

- Priority: determination of the background from real data.
Extracting information from real data

Methods for evaluating the lepton and jet reconstruction performances from the data, using standard candles like $t\bar{t}$ and $Z \rightarrow ee, \mu\mu, \tau\tau, b\bar{b}$.

Measurement of background shapes by means of control samples:
- Control sample selected by relaxing the cuts on certain variables. such to obtain a large background sample
- Ideally, the background shape should not be correlated with the particular variable for which the cut was relaxed.

Calibration with related reference processes.
Example $Z + jets$:
- Information on the pile-up effects contained in angular and rapidity gap distributions of forward jets.
- Reference for the cross-section of the VBF Higgs production (same dependence on the $p_T^{jet}$-cuts). V.A.Khoze et al., hep-ph/0207365v3