HIGGS and SUSY in ATLAS
- overview on physics prospects -

- Introduction, Detector Aspects
- Standard Model Higgs Search
- Determination of Higgs Parameters
- Higgs Search in the MSSM
- Search for SUSY signals
  - general SUSY signatures
  - Study of SUGRA models
  - Higgs in SUGRA

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55099 Mainz, Germany
The ATLAS Detector

ATLAS

S. C. Air Core Toroids
S. C. Solenoid
EM Calorimeters
Inner Detector
Hadron Calorimeters
Muon Detectors
Forward Calorimeters
### Important Detector Parameters

<table>
<thead>
<tr>
<th>Detector component</th>
<th>resolution, characteristics</th>
<th>$\eta$ coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Measurement</td>
</tr>
<tr>
<td>e.m. calorimetry</td>
<td>$10%/\sqrt{E} \oplus 0.7%$</td>
<td>±3</td>
</tr>
<tr>
<td>Preshower detection</td>
<td>Enhanced $\gamma-\pi^0$ and $\gamma$-jet separation, direction measurements, and b-tagging with electrons</td>
<td>±2.4</td>
</tr>
</tbody>
</table>
| Jet and missing $E_T$ Calorimetry | 50%/\sqrt{E} \oplus 3%  
100%/\sqrt{E} \oplus 10% | ±3  
3 < |$\eta$| < 5 | ±3  
3 < |$\eta$| < 5 |
| Inner detector     | 30% at $p_T = 500$ GeV  
Enhanced electron identification (TRT)  
b-tagging  
Secondary vertex detection | ±2.5  
±2.5  
±2.5 | ±2.5  
±2.5  
±2.5 |
| Muon detection     | 10% at $p_T = 1$ TeV  
in stand-alone mode at highest luminosity | ±3              | ±2.2        |
b-tagging performance:

Muon resolution, stand alone toroid:
**Running Scenarios and Luminosities**

starting date: $\sim 2005$  \hspace{1cm} $\sqrt{s} = 14$ TeV

**initial luminosity:** $\mathcal{L} = 1.0 \ 10^{33} \text{ cm}^{-2} \text{ sec}^{-1}$

\[
\int \mathcal{L} dt = 10 \ fb^{-1} \quad \text{per year}
\]

$\Rightarrow$ expected period of 3 years

**high luminosity:** $\mathcal{L} = 1.0 \ 10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$

\[
\int \mathcal{L} dt = 100 \ fb^{-1} \quad \text{per year}
\]

**ultimate reach:**

\[
\int \mathcal{L} dt = 300 \ fb^{-1} < 10 \text{ years}
\]
Simulation Framework

- **PYTHIA 5.7** Monte Carlo
  *SPYTHIA* and *ISAJET* for SUSY studies

- **K factors** not included
  
  K-factors are not known for many background processes, conservative, as long as \( \frac{K_{Signal}}{\sqrt{K_{Backgr.}}} > 1 \).

- **Higgs branching ratios**: HDECAY program

- **CTEQ-2 structure function** parametrizations

- **Detector Simulation**
  
  Many results based on fast detector simulation; Critical parameters (mass resolutions, background rejections) determined in full GEANT simulations

  Detector performance has been verified in many test-beam measurements with prototyp modules
Standard Model Higgs decays

Important channels at LHC:

- $H \rightarrow \gamma \gamma$
- $WH, t\bar{t}H$, $H \rightarrow \gamma \gamma, H \rightarrow b\bar{b}$
- $H \rightarrow Z Z^{(*)} \rightarrow l^+ l^- l^+ l^- \quad (*)$
- $H \rightarrow W W^* \rightarrow l^+ \nu l^- \bar{\nu}$
- $H \rightarrow Z Z \rightarrow l^+ l^- \nu \bar{\nu} \quad (**)$
- $H \rightarrow Z Z \rightarrow l^+ l^- \text{ jet jet}$
- $H \rightarrow W W \rightarrow l\nu \text{ jet jet}$

(*) see talk of Th. Trefzger (Tuesday 3:40 pm) for details
(**) see talk of D. Costanzo (Monday 4:20 pm) for details
Signal \[ \sigma \times B_r = 43 \text{ fb} \]
\[ (m_H = 100 \text{ GeV}) \]

\[ \gamma\gamma^- \text{ background (irreducible)} \quad \frac{d\sigma}{dm_{\gamma\gamma}} \sim 1200 \text{ fb/GeV} \]
\[ (m_{\gamma\gamma} = 100 \text{ GeV}) \]

\[ \text{QCD Jet background (reducible)} \quad \frac{\sigma_{\gamma\gamma}}{\sigma_{\gamma\gamma}} \sim 1000 \]
\[ \frac{\sigma_{\gamma\gamma}}{\sigma_{\gamma\gamma}} \sim 2 \cdot 10^6 \]

Background rejection study:
- based on $10^6$ fully simulated jet events
- $P_T > 20 \text{ GeV}$:
  jet rejection $\sim 10^3$
  (isolation, had. leakage, shower profile)
- add. $\pi^0$ rejection with first calo. sampling,
  fine $\eta$ segmentation

QCD background at the level of 10% of the $\gamma\gamma$ continuum background
\[ \frac{\sigma_M}{M} = \frac{1}{2} \left( \frac{\sigma_{E_1}}{E_1} \oplus \frac{\sigma_{E_2}}{E_2} \oplus \frac{\sigma_\theta}{\tan \theta/2} \right) \]

(ii) Degradation of performance due to detector material (conversions...)

<table>
<thead>
<tr>
<th>Energy resolution</th>
<th>low L</th>
<th>high L</th>
</tr>
</thead>
<tbody>
<tr>
<td>cluster size</td>
<td>10%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td>(\sqrt{E}) &amp; (\sqrt{E}) &amp; (\sqrt{E})</td>
<td></td>
</tr>
<tr>
<td>angular resolution</td>
<td>40 mrad / (\sqrt{E})</td>
<td></td>
</tr>
<tr>
<td>(\gamma) efficiency</td>
<td>80 %</td>
<td></td>
</tr>
<tr>
<td>incl. conversions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \chi^2/\text{ndf} \quad 22.21/23 \]

Constant 70.6
Mean 100.0
Sigma 1.306

mass resolution from full simulation:

\[ \sigma_m = 1.31 \text{ GeV} \]

for \(m_H = 100 \text{ GeV}\)

unconverted and converted (shaded) \(\gamma\)'s
**$H \rightarrow \gamma \gamma$ Signals**

**Analysis cuts:**

- **Two isolated photons**
  \[ P_T^1 > 40 \text{ GeV and } P_T^2 > 25 \text{ GeV} , \ |\eta| < 2.5 \]

- **exclude barrel - endcap transition region**
  \[ 1.42 < |\eta| < 1.57 \]

**Signal significance:** \(100 \text{ fb}^{-1}\)

<table>
<thead>
<tr>
<th>$m_H$ (GeV)</th>
<th>100</th>
<th>120</th>
<th>140</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal events</td>
<td>960</td>
<td>1200</td>
<td>930</td>
</tr>
<tr>
<td>$\gamma\gamma$ background</td>
<td>44700</td>
<td>30300</td>
<td>20800</td>
</tr>
<tr>
<td>$\gamma$-jet, jet-jet background</td>
<td>6700</td>
<td>4400</td>
<td>3900</td>
</tr>
</tbody>
</table>

| Stat. significance | 4.7 $\sigma$ | 6.9 $\sigma$ | 6.3 $\sigma$ |
Associated Production

\[ WH \rightarrow \gamma\gamma \, l \quad \text{and} \quad t\bar{t}H \rightarrow \gamma\gamma \, l \]

- additional lepton, \( \Rightarrow \) improved S/B ratio

- however low rates:
  Example: \( m_H = 100 \text{ GeV}, \int \mathcal{L} dt = 100 \text{ fb}^{-1} \)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected signal:</td>
<td>15.6 events</td>
</tr>
<tr>
<td>background:</td>
<td>6.6 events</td>
</tr>
<tr>
<td>Stat. significance (Poisson):</td>
<td>4.9 ( \sigma )</td>
</tr>
</tbody>
</table>

- irreducible background \((W\gamma\gamma, Z\gamma\gamma, t\bar{t}\gamma\gamma)\) dominant

\( \Rightarrow \) additional confirmation of a low mass Higgs signal

\[ \frac{S}{\sqrt{B}} \quad \text{versus} \quad \text{Higgs mass (GeV)} \]

- 100 fb\(^{-1}\)
- no K factors
Additional Channels for a low mass Higgs?

\[ t\bar{t}H, \ H \rightarrow b\bar{b} \]

\[ t\bar{t} \ H \rightarrow Wb \ W\bar{b} \ b\bar{b} \rightarrow l\nu b \ q\bar{q}\ b\bar{b} \]

- **Isolated Lepton:** (provides the trigger)
  - Electrons: \( P_T > 20 \text{ GeV}, \ |\eta| < 2.5 \)
  - Muon: \( P_T > 6 \text{ GeV}, \ |\eta| < 2.5 \)

- **Full reconstruction of the top quarks**
  
  require: 4 tagged b jets, \( P_T > 15 \text{GeV}, \ |\eta| < 2.5 \)
  2 non-b jets, \( P_T > 15 \text{GeV}, \ |\eta| < 2.5 \)

  reconstruct both W's from the \( q\bar{q} \) and \( l - P_T^{miss} \)-system, use W-mass constraint in case of neutrino

- **Pair two b-jets with the two W's**
  select that pairing that minimizes
  \[ \chi^2 = (M_{qqb} - M_{top})^2 + (M_{\nu b} - M_{top})^2 \]

- **require both rec. top masses to be in a window of**
  \( m_{top} \pm 2\sigma_m \)

![Graphs showing data for different values of \( \sigma \) and \( m_{jjb} \) or \( m_{\nu b} \)]

**top reconstruction efficiency:** \( \sim 50\% \)
Expected Rates for 30 $fb^{-1}$

<table>
<thead>
<tr>
<th>$m_H$ (GeV)</th>
<th>80</th>
<th>100</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal events</td>
<td>80</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>total background ($t\bar{t}jj$, ...)</td>
<td>145</td>
<td>150</td>
<td>130</td>
</tr>
<tr>
<td>Stat. sign. 30 $fb^{-1}$</td>
<td>6.7$\sigma$</td>
<td>5.0$\sigma$</td>
<td>3.6$\sigma$</td>
</tr>
<tr>
<td>Stat. sign. 100 $fb^{-1}$</td>
<td>7.2$\sigma$</td>
<td>6.4$\sigma$</td>
<td>3.1$\sigma$</td>
</tr>
</tbody>
</table>

Conclusion:

- Signal extraction in low mass region looks possible
- Good b-tagging is essential
- Knowledge of the background shape is important at low mass
  (dominant background is $t\bar{t}jj$ ← input from top analysis)
Scenario after 100 fb\(^{-1}\):

- ATLAS has a good sensitivity over the full mass range from 90 GeV to \(\sim 1\) TeV
- In most of the mass range two channels are available
Summary of the Standard Model Higgs Search

Scenario after 30 fb$^{-1}$:

- The full mass range can already be covered by ATLAS after running three years at low luminosity
Determination of Higgs Parameters

Mass, width, rates, branching ratios,......

- combine the information from the various channels
- errors considered:
  - statistical errors
  - errors on the background subtraction
  - systematic error on absolute energy scale,
    assumed uncertainty:
    $\pm 0.1\%$ for lepton/photon channels (conservative)
    $\pm 1.0\%$ for hadronic channels
  - systematic error on the momentum resolution
    (based on calibration with $Z$ events)
**Precision on the Higgs mass:**

- Higgs mass can be measured with a precision of 0.1% up to masses of \( \sim 400 \text{ GeV} \)
- still at the level of \( \pm 1\% \) at 700 GeV
- no theoretical errors taken into account (mass shifts due to interference effects between resonant and non-resonant production)
- uncertainty from structure functions is expected to be small
Precision on the Higgs width:

- exp. measurement of width of Higgs signal; unfold detector resolution \( \Rightarrow \Gamma_{Higgs} \pm \Delta \Gamma_{Higgs} \)
- measurement only possible if \( \Gamma_{Higgs} \sim \Gamma_{exp.} \), i.e. \( m_H > 200 \text{ GeV} \)

main uncertainties:

- energy/momentum resolution
- uncertainties due to radiative decays of the Z (calibration of the resolution function using Z decays, \( \pm 1.5\% \))
Higgs rates and branching ratios:

- deduce $\sigma \cdot Br$ from measured signal rates
- main uncertainty: absolute error on the luminosity LHC goal: $\pm 5\%$
- assume an add. uncertainty of $\pm 10\%$ on the background subtraction

- uncertainty on $\sigma \cdot Br$ is at the level of $\pm 7\%$ over a large mass range, if $5\%$ uncertainty on the luminosity can be achieved

work ongoing on: branching ratios, spin .....
The supersymmetric Higgs sector

5 Higgs particles: \( h, H, A \)
\( H^+, H^- \)

The MSSM Higgs sector is determined by two parameters: generally chosen to be: \( m_A, \tan \beta \)

tree level mass relations are significantly modified by radiative corrections

LEP/LHC interest: upper mass bound for the lightest SUSY higgs:
\[ m_h < 115 \text{ GeV} \quad \text{for } A_t = 0 \]

i.e. no mixing scenario, conservative assumption for LHC

dependence on \( m_A \) and \( \tan \beta \):

accessible at LHC through the \( \gamma \gamma \) and \( b \bar{b} \) (associated production) decay mode.
ATLAS studies of the MSSM Higgs sector concentrate on two scenarios:

1. SUSY particle masses are large, $m_{SUSY} = 1$ TeV, Higgs boson decays to SUSY particles are kinematically forbidden

2. Studies in the framework of SUGRA models
   - SUSY particles are light and appear in Higgs decays, competing with SM decay modes
   - Light Higgs particles appear in decays of SUSY particles
     Search for the $h \rightarrow b \bar{b}$ decay

later: after SUSY discussion
Important Channels in the MSSM Higgs search

• The Standard Model decay channels
  \- \ h \ \rightarrow \ \gamma \gamma
  \- \ h \ \rightarrow \ bb
  \- \ H \ \rightarrow \ ZZ^* \ \rightarrow \ l^+l^-l^+l^-

(\gamma \gamma \ \text{and} \ ZZ^* \ \text{decay modes are suppressed w.r.t. SM})

evaluation of performance based on SM results

• Modes strongly enhanced at large tan $\beta$:
  \- \ H/A \ \rightarrow \ \tau^+\tau^-
  \- \ H/A \ \rightarrow \ \mu^+\mu^-

• Other interesting channels:
  \- \ H/A \ \rightarrow \ t\bar{t}
  \- \ H/A \ \rightarrow \ Zh \ \rightarrow \ l^+l^- \ \gamma\gamma
  \hspace{1cm} \rightarrow \ l^+l^- \ \bar{b}b
  \- \ H \ \rightarrow \ hh
  \- \ t \ \rightarrow \ H^+b, \ \ H^+ \ \rightarrow \ \tau\nu

assume: \ \ m_{\text{SUSY}} = 1 \ \text{TeV}

\ \ m_{\text{top}} = 175 \ \text{GeV}

\ \ A_t = 0. \ \ (\text{pessimistic for LHC})

i.e. no mixing, SUSY particles do not appear in Higgs decays
The three main channels

$h \rightarrow \gamma \gamma$

$t\bar{t}h, h \rightarrow b\bar{b}$

$A, H \rightarrow \tau\tau$
after 3 years at low luminosity: ~80% of the parameter space can be covered
Summary of the MSSM Higgs Search

- Full parameter space covered, SM and MSSM can be distinguished for almost all cases

- Most part of the parameter space covered by at least two channels, except low $m_A$ region (covered by LEP200)

- If $h$ discovered at LEP200: $\Rightarrow$ heavy Higgs bosons ($A/H$) should be observable at LHC for $m_A < \sim 2 \ m_{top}$

- If $A,h$ discovered at LEP200: the charged Higgs should be seen at LHC

- Discovery of heavy Higgses ($m_A > 500$ GeV) seems to be difficult ($t\bar{t}$ decay mode)
The Search for SUSY

- If SUSY exists at the electroweak scale, a discovery at LHC should be easy

- Gluinos and squarks are strongly produced.

  They decay through cascades to the lightest SUSY particle $\tilde{\chi}_1^0$.

  $\Rightarrow$ combination of Jets, Leptons, $E_T^{miss}$

  ![Diagram of SUSY decay process]

  1. Step:
  Look for deviations from the Standard Model
  Example: Multijet $+$ $E_T^{miss}$-Signature

  2. Step:
  Establish SUSY mass scale, use inclusive variables
  Example: effective mass distribution

  3. Step:
  Determine Model parameters
Squarks and Gluinos

Experimental signature:
Several jets with large transv. momentum missing transverse energy

background:
top production
W + Jet-, Z + jet-production

| \( \int \mathcal{L} dt \) | \\
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( m_{\tilde{q}} = 2 m_{\tilde{g}} )</td>
<td>1050</td>
</tr>
<tr>
<td>( m_{\tilde{q}} \sim m_{\tilde{g}} )</td>
<td>1800</td>
</tr>
<tr>
<td>( m_{\tilde{q}} = m_{\tilde{g}} / 2 )</td>
<td>2600</td>
</tr>
</tbody>
</table>
SUSY Mass scale

Simple experimental cuts:

- $E_T^{miss} > \min(100 \text{ GeV}, 0.2 \ M_{eff})$
- At least 4 jets with $E_T > 50 \text{ GeV}$ and $P_T^1 > 100 \text{ GeV}$
- Transverse sphericity $S_T > 0.2$
- No $\mu$ or isolated $e$ with $P_T > 20 \text{ GeV}$ and $|\eta| < 2.5$

define effective mass:

$$M_{eff} = E_T^{miss} + P_T^1 + P_T^2 + P_T^3 + P_T^4$$

$$M_{SUSY} = \min (M_{\tilde{g}}, M_{\tilde{u}_R})$$

- good correlation between $M_{eff}$ and $M_{SUSY}$
  (spread is shown for 100 minimal SUGRA models
  selected at random, $m_0, m_{1/2}$ and $A_0$ varied)
Determination of Model Parameters

- Determination of model parameters is difficult (two missing $\tilde{\chi}_1^0$, not enough constraints to reconstruct mass peaks)

- Reconstruct partially the decay chain

  possible starting points:
  
  $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 h \rightarrow \tilde{\chi}_1^0 b\bar{b}$
  
  $\tilde{\chi}_2^0 \rightarrow \tilde{\ell}^\pm \ell^\mp \rightarrow \tilde{\chi}_1^0 l^+l^-$
  
  $\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 W \rightarrow \tilde{\chi}_1^0 q\bar{q}$

- start at the bottom of the decay chain, work backwards
  example: endpoint of $m(l^+l^-)$ determines $(m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$

- measure combinations of masses precisely

- global fit $\Rightarrow$ constrain model parameters

Which modes are available depends on the SUSY model and parameters.

ATLAS: discussed in framework of SUGRA models, LHCC studies, 1996
The LHCC SUGRA Points

![Graphs showing LHCC SUGRA points for different values of tanβ](image)

bricked and cross-hatched regions are excluded by theoretical constraints or by experimental data

**SUGRA parameters:**

- $m_0$: common scalar mass at GUT scale
- $m_{1/2}$: common gaugino mass at the GUT scale
- $\tan \beta$: common trilinear term
- $A_0$: common trilinear term
- $\text{sgn}(\mu)$: sign of Higgsino mass parameter

use point 5 to illustrate the methods
Point 5: Mass Spectrum and decay modes

**SUGRA Parameters**

- $m_0 = 100$ GeV
- $m_{1/2} = 300$ GeV
- $A_0 = 300$ GeV
- $\tan \beta = 2.1$
- $\text{sign}(\mu) = +$

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{g}$</td>
<td>770</td>
</tr>
<tr>
<td>$\tilde{q}_L$</td>
<td>690</td>
</tr>
<tr>
<td>$\tilde{q}_R$</td>
<td>660</td>
</tr>
<tr>
<td>$\tilde{t}_1$</td>
<td>490</td>
</tr>
<tr>
<td>$\tilde{\ell}_L$</td>
<td>240</td>
</tr>
<tr>
<td>$\tilde{\ell}_R$</td>
<td>157</td>
</tr>
<tr>
<td>$\chi_1^0$</td>
<td>121</td>
</tr>
<tr>
<td>$\chi_2$</td>
<td>232</td>
</tr>
<tr>
<td>$h$</td>
<td>93</td>
</tr>
<tr>
<td>$H$</td>
<td>640</td>
</tr>
</tbody>
</table>

The total cross section is dominated by $\tilde{q}\tilde{q}$, $\tilde{g}\tilde{g}$, and $\tilde{g}\tilde{g}$ -production; large SUSY cross section: $\sigma_{SU SY} = 20$ pb

**Decay modes of $\tilde{\chi}_2^0$:**

$\text{Br} \ (\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 h) = 70\%$

$\text{Br} \ (\tilde{\chi}_2^0 \rightarrow \tilde{\ell}_R l) = 10\%$ per lepton flavour
\[ pp \rightarrow \tilde{q}_L \tilde{q}_R : \quad \tilde{q}_R \rightarrow \tilde{\chi}_1^0 q \]
\[ \tilde{q}_L \rightarrow \tilde{\chi}_2^0 q \rightarrow \tilde{\chi}_1^0 h q \rightarrow \tilde{\chi}_1^0 b \bar{b} q \]

The \( h \rightarrow b \bar{b} \) is a clean signature/tag in SUSY events; \( E_T^{\text{miss}} \)-cut can be used to suppress the large SM background.

**Selection cuts:**
- 2 tagged b-jets, \( P_T > 50 \text{ GeV} \)
- veto 3. b-jet
- 2 non b-jets (jet\(_1\), jet\(_2\)) \( P_T > 100 \text{ GeV} \)
- \( E_T^{\text{miss}} > 300 \text{ GeV} \)
- veto isolated leptons

**Integrated Luminosity:** \( 30 \text{ fb}^{-1} \)

\begin{align*}
\text{1940 signal events} & \quad \Rightarrow m_h = 93 \pm 1 \text{ GeV} \\
\text{620 SUSY background} & \quad \text{75 SM background}
\end{align*}

**next steps:**
- select events in mass window around the \( h \)-mass pair b-jets with two other jets (veto add. jets \( \Rightarrow \tilde{q}_L \tilde{q}_R \) enriched):
  - \( m( bb, \text{jet}_2) \) is sensitive to \( \tilde{q}_L \) -mass
    \( \Delta m_{\tilde{q}_L} = \pm 1.5\% \)
  - \( P_T(\text{jet}_1) \) (hardest jet) is sensitive to \( \tilde{q}_R \)-mass
    \( \Delta m_{\tilde{q}_R} = \pm 20 \text{ GeV} \)
\[ \tilde{\chi}_2^0 \rightarrow \tilde{l}_R \rightarrow \tilde{\chi}_1^0 l l \]

**Selection cuts:**
- 2 leptons, same flavour, opp. charge
- large jet multiplicity
- \( E_T^{miss} > 300 \, \text{GeV} \)

very sharp edge on invariant mass of two leptons:

\[ m_{l+l^-}^{max} = m_{\tilde{\chi}_2^0} \sqrt{1 + \frac{m_{lR}^2}{m_{\tilde{\chi}_2^0}^2}} \sqrt{1 + \frac{m_{\tilde{\chi}_1^0}^2}{m_{lR}^2}} \]

- endpoint can be measured with a precision of \( \pm 500 \, \text{MeV} \)
  \( \Rightarrow \) provides constraint in global fit \( (m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{l}_R}) \)

- ratio of \( P_T \) of the two leptons is sensitive to the \( \tilde{l}_R \) mass
Top production in decays of $\tilde{g}, \tilde{t}, \tilde{b}$

Select inclusive $t\bar{t} \rightarrow WWb\bar{b} \rightarrow q\bar{q} q\bar{q} b\bar{b}$ signal:
(two tagged b-jets, four add. jets, consistent with WW mass hypothesis, $E_T^{\text{miss}}$ cut)

use sidebands of the W-mass spectrum to subtract the combinatorial background

Examples:

1. $\tilde{t}_1 \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0 t\tilde{\chi}_1^0$

$P_T$(top) is sensitive to $m_{\tilde{t}_1}$
(needs high luminosity)

2. $\tilde{q}_R \tilde{g}, \quad \tilde{g} \rightarrow \tilde{t} t \rightarrow tt\tilde{\chi}_1^0$

$m_{tt}$ is sensitive to $m_{\tilde{g}}$
Summary of Measurements in Point 5

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Expected value (GeV)</th>
<th>Error for 30 fb⁻¹ (GeV)</th>
<th>Error for 300 fb⁻¹ (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_h$</td>
<td>93</td>
<td>±1.0</td>
<td>±0.2</td>
</tr>
<tr>
<td>$m_{\ell^+\ell^-}$ edge</td>
<td>109</td>
<td>±0.5</td>
<td>±0.2</td>
</tr>
<tr>
<td>$m_{\ell_R}$</td>
<td>157</td>
<td>±1.9</td>
<td>±0.5</td>
</tr>
<tr>
<td>$m_{\ell_L}$</td>
<td>240</td>
<td>±10</td>
<td>±3</td>
</tr>
<tr>
<td>$m_{\tilde{q}_L}$</td>
<td>690</td>
<td>±12</td>
<td>±7</td>
</tr>
<tr>
<td>$m_{\tilde{q}_R}$</td>
<td>660</td>
<td>±20</td>
<td>±10</td>
</tr>
<tr>
<td>$m_{\tilde{g}}$</td>
<td>770</td>
<td>±20</td>
<td>±11</td>
</tr>
<tr>
<td>$m_{\tilde{t}_1}$</td>
<td>490</td>
<td></td>
<td>±50</td>
</tr>
</tbody>
</table>

Results of final parameter fit:

<table>
<thead>
<tr>
<th>SUGRA parameter</th>
<th>Error for 30 fb⁻¹</th>
<th>Error for 300 fb⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_0 = 100$ GeV</td>
<td>±5 GeV</td>
<td>±3 GeV</td>
</tr>
<tr>
<td>$m_{1/2} = 300$ GeV</td>
<td>±8 GeV</td>
<td>±4 GeV</td>
</tr>
<tr>
<td>$\tan\beta = 2.1$</td>
<td>±0.11</td>
<td>±0.02</td>
</tr>
</tbody>
</table>

- $m_0$, $m_{1/2}$ and $\tan\beta$ can be determined with a precision at the percent level

- $sgn \mu$ unambiguously determined

($BR(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 h)$)

- $A_0$ remains unconstraint, due to small influence on the phenomenology at the el.weak scale
Similar results have been obtained for the other points:

I. Hinchliffe et al., Phys. Rev. D55, 5520

ultimate fit:
D. Froidevaux et al., LHCC workshop, Okt. 1996

More on ATLAS SUSY:
I. Hinchliffe, Gauge Mediated SUSY Breaking,
Tuesday 4:15 pm

F. Paige, More on SUGRA signatures, 
Thursday 9:35 am
Lightest Higgs $h$:

- Decay of $h \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0$ is kinematically closed in the allowed SUGRA parameter space

- SUSY particles in loops affect the production and decays

$\sigma \cdot Br(h \rightarrow \gamma\gamma)$ is found to be in the range of $\pm10\%$ of the SM value

Observation of $h$ in the SM channels is preserved
$h \rightarrow \gamma \gamma$

$t\bar{t}h, h \rightarrow b\bar{b}$
* Use $h \rightarrow b\bar{b}$ decay mode in SUSY events to discover the $h$

* Analysis as described above for SUGRA point 5

excluded regions in the SUGRA parameter space

$tan\beta = 10, \mu > 0$
Heavy Higgses $H/A$:

* H and A Higgs bosons are heavy in many SUGRA models

* Decay modes are strongly affected by SUSY particles

* $H, A \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0, \tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$ decay channels are open over a significant fraction of the SUGRA parameter space
Decay mode: $H, A \rightarrow \tilde{\chi}^0_2 \tilde{\chi}^0_2 \rightarrow \tilde{\chi}^0_1 l^+ l^- \tilde{\chi}^0_1 l^+ l^-$

* Search for four leptons, 2 pairs SF,OS ($P_T > 20$ GeV (1.,2.lepton), $P_T > 7$ GeV (3.,4.lepton))

* tight jet veto to suppress SUSY background

* $E_T^{miss}$ cut to suppress SM background

excluded regions in the SUGRA parameter space
Conclusions

The ATLAS experiment at the LHC can make substantial contributions in the Search for Higgs and SUSY:

* The discovery of a SM Higgs is possible over the full mass range \(90 \text{ GeV} < m_H < 1 \text{ TeV}\) after a few years of running

* The MSSM Higgs sector is challenging for LHC experiments (em calorimetry, b-tagging, \(\tau\)-identification, \(E_T^{\text{miss}}\)-resolution and jet-spectroscopy)

  - With moderate luminosity \(30 fb^{-1}\) about 80% of the \((m_A, \tan \beta)\) plane can be covered.
  - Full coverage at high luminosity

* ATLAS has a large potential to discover SUSY particles and to measure their masses

* The Parameters of the SUSY model can be determined or largely constraint by many measurements