Search for supersymmetry with jets and missing $E_T$ and no leptons at CMS

Gheorghe Lungu
The Rockefeller University
Outline

• Introduction to SUSY
• LHC and CMS detector
• Standard Model background methods
• Results in 2011 with 1.1 fb\(^{-1}\)
• Summary and outlook
Introduction to SUSY

- SUSY = symmetry between fermions and bosons ⇒ new particles
- Solves the hierarchy problem in SM
- Unification of forces is realized
- R-parity conservation results in a dark matter candidate
- No new forces ⇒ hadronic channels the most sensitive

Higgs mass corrections

Coupling unification

Dark matter in the Bullet cluster
LHC in 2011

- Delivered > 5 fb\(^{-1}\) pp data in 2011
- Max. inst. lumi. \(\sim 3.7 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}\)
- The analysis to be presented is based on 1.1 fb\(^{-1}\) of data
The CMS detector

- Each subdetector >99% operational
- Data taking efficiency ~91%
- Uncertainty on the luminosity measurement ~4.5%
- Detector performance approaching expectation
Multiple interactions effects

- High instantaneous luminosity results in more multiple interactions (pile-up)
- Use jet-area based technique to subtract the pile-up from jets
  - areas determined for each jet
  - pile-up density determined for each event
- Jet resolutions are not significantly affected
- Details in hep-ph arXiv: 0707.1378v2, 0802.1188v2

\[
\rho_{\text{subtracted}} = p_{t,\text{jet}} - \rho \times A_{\text{jet}}
\]

\[
A_{\text{jet}} = \text{jet area}
\]

\[
\rho = p_t \text{ per unit area from pileup}
\]

\[
\rho \approx \text{median}_{\{\text{jets}\}} \left( \frac{p_{t,\text{jet}}}{A_{\text{jet}}} \right)
\]
Hadronic search

• Describe the analysis documented in **CMS-PAS-SUS-11-004**
  
  • https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS11004

• Focus on final states containing many jets and large energy imbalance

• Reject events with good, isolated lepton

• **Main SUSY signals**
  
  • strong production of *squark pairs, gluino pairs and squark-gluino*

• **Main SM backgrounds**
  
  • QCD multijet production
  
  • \(Z(\rightarrow\nu\bar{\nu})+\text{jets} \) production
  
  • \(W+\text{jets} \) production
  
  • \(tt+\text{jets} \) production
Event selection

- \( N_{\text{jets}} \geq 3 \) (\( P_T > 50 \text{ GeV}, |\eta| < 2.5 \))
- HT computed from these jets
- MHT computed from jets with \( P_T > 30, |\eta| < 5 \)
- \( \Delta \varphi (\text{jets}[1,2,3], \text{MHT}) > [0.5,0.5,0.3] \)
- Data described well by the simulation

\[
H_T = \sum_{i} |p_T, i|, \quad \tilde{H}_T = -\sum_{i} p_T, i
\]

Search regions:
- HT>800,MHT>200
- HT>800,MHT>500
QCD background: Rebalance & Smear

- QCD multijet events are balanced at the parton level
- The imbalance appears due to fluctuations in response of detector, malfunctions or semileptonic decays
- **Rebalance**: restore particle level jet $P_T$ from detector level using inclusive multijet data via kinematic fit using jet resolution functions measured in data
- **Smear**: the rebalanced events are smeared using the measured jet resolution functions
Invisible Z from photon+jets

- At high $P_T$ (~200 GeV) photon+jets kinematics are similar to Z+jets
- Ignore photons, account for its reconstruction efficiency, ratio of cross-sections from theory
- High statistics sample, large systematics on theoretical factors
W/\tt+jets background (I)

- **W\rightarrow e/\mu events with the lepton failing the lepton veto**

- lepton is not reconstructed or not isolated
- start from a leptonic sample with inverted veto
- normalize yields with inverse of lepton efficiency

CMS Preliminary, L = 1.1 fb$^1$, \( \sqrt{s} = 7 \) TeV

![Graph](image)
W/\tau+\text{jets} background (2)

- $W \rightarrow \tau \rightarrow \text{hadronic decay}$

- Use a leptonic sample and replace the lepton with $\tau$ via $\tau$ jet response template from simulation

- Account for lepton efficiencies, acceptance, branching ratios
Results

No excess over SM found in the data ⇒ set limits
Efficiency calculated for mSUGRA SUSY model with $A_0=0$, $\mu>0$, $\tan B=10$

- white cells correspond to missing official CMS SUSY samples

Main systematic uncertainties
- luminosity measurement: 4.5%
- jet energy scale and jet resolution: 2.5%
- NLO cross-section and proton PDF choice: 10%
- modeling of lepton veto: 2.5%
- ECAL masked region: 3%
95% CL excluded cMSSM region with 1.1 fb⁻¹

- New results extend dramatically the previous exclusion regions set with 2010 dataset
- cMSSM exclusion region
  - $m_0=100$ GeV, $m_{1/2}>530$ GeV
  - $m_0=1500$ GeV, $m_{1/2}>230$ GeV
• “Simplified models” = one topology models
  - Gluino pair production decaying to squarks ⇒ exclude gluino masses up to 850 GeV
  - Squark pair production ⇒ exclude squark masses up to 650 GeV
All SUSY searches with 1.1 fb^{-1} at CMS

This analysis

CMS Preliminary

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

Ranges of exclusion limits for gluinos and squarks, varying $m(\tilde{\chi}^0)$

<table>
<thead>
<tr>
<th>Process</th>
<th>$m(\tilde{\chi}^0)$</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1: \tilde{g} \rightarrow q\tilde{\chi}^0$</td>
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For limits on $m(\tilde{g}), m(\tilde{q}) > m(\tilde{\chi})$ (and vice versa), $\sigma_{\text{prod}} \approx \sigma_{\text{NLO-QCD}}$.

$m(\tilde{\chi}^0), m(\tilde{\chi}^0) = m(\tilde{g}) + m(\tilde{q})$.

$m(\tilde{\chi}^0)$ is varied from 0 GeV/c^{2} (dark blue) to 200 GeV/c^{2} (light blue).
Summary

- Presented the search for SUSY in the hadronic channel with $1.1 \text{ fb}^{-1}$
- No excess found over the SM predictions
- Extended greatly previous exclusion regions
- Currently working on making public the analysis of the total 2011 dataset ($\sim 4.7 \text{ fb}^{-1}$)
BACK-UP
Event reconstruction

- Events reconstructed with Particle Flow algorithm
  - combines information from tracker, ECAL, HCAL and muon detectors
  - obtain energy, direction and identity of particles
    - jets, photons, electrons, muons
  - jets are typically clustered with antiKT05 algorithm
Standard sample cleaning

- ≥1 well-defined primary vertex (|z| < 24 cm, r < 2 cm, N_{dof} > 4)
- reject events with small fraction of high quality tracks
- require ΣP_T^{tracks} > 0.1 ΣP_T^{jets}
- reject beam halo events
- reject events with jets pointing to > 1% of the masked ECAL cells
- reject events with calorimeter noise (HCAL & ECAL)