Searches for SUSY in All-Hadronic Events with Exclusive Jets

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Searches for SUSY in Exclusive Jet Final States:

- **Introduction**: SUSY in all-hadronic final states
- **\( \alpha_T \)** definition: di-jets and multi-jet final states
- **Validation**: the \( \alpha_T \) variable in the 7 TeV data
- **Background**: estimation from data using eta-uniformity
The CMS detector

Key:
- Blue: Muon
- Red: Electron
- Green: Charged Hadron (e.g. Pion)
- Green dashed: Neutral Hadron (e.g. Neutron)
- Blue dashed: Photon

lead tungstate scintillating crystals
sampling calorimeter alternating absorber & plastic scintillators

Calorimeter-jet resolution:
\[ \frac{\sigma_{p_T}}{p_T} \approx \frac{100\%}{\sqrt{p_T}} \]
SUSY topology: (example)

- Pair production of SUSY sParticles, e.g. $\tilde{q} \tilde{q}$, requires $m(\tilde{q}) < m(\tilde{g})$
- Assumed R-parity conservation leads to 2 jets + MET
- Squark and neutralino mass-measurements in this channel possible with high luminosity
- In general, longer cascades with more than one jet (+MET)

Analysis requirements: At least two jets.
Traditional SUSY searches require large MET and search for an excess over the SM in the tail → requires extraordinary good understanding of detector and SM-background → previous talk by C. Rogan

Alternative analysis not based on MET:
• Dimension-less variable $\alpha_T = \frac{p_{T2}}{M_T}$
• characterizes momentum balance in the event
• allows to suppress multi-jet QCD background


→ CMS follows both strategies
**Exclusive di-jet final state:**

$\alpha_T$ takes into account the jet momenta and angles, it makes no use of missing transverse momentum (MET). In QCD: $\alpha_T \leq 0.5$ since $p_T,j_2$ is by definition the lower momentum jet. Exception: A third jet is completely lost.
Suppressing QCD with $\alpha_T$

**Exclusive n-jet, $n \geq 3$ final state:**

$\alpha_T$ takes into account the jet momenta and angles, it makes no use of missing transverse momentum (MET)

\[ H_T = \sum_{\text{jets } j} p_{Tj}, \quad \text{MHT} \equiv |\sum_{\text{jets } j} -\vec{p}_{Tj}| \]
\[ \Delta H_T = p_{T\text{pseudojet 1}} - p_{T\text{pseudojet 2}} \]

\[ \alpha_T = \frac{1}{2} \frac{H_T - \Delta H_T}{M_T} \quad \rightarrow \quad \alpha_T = \frac{1}{2} \frac{H_T - \Delta H_T}{\sqrt{H_T^2 - (\text{MHT})^2}} \]

The two pseudo-jets are formed such that $\Delta H_T$ is minimal.

$\alpha_T < 0.55$ still holds for multi-jet QCD events
Validation of $\alpha_T$ in data (CaloJets)

$\int L \simeq 11 \text{ nb}^{-1}$

Very good agreement within statistical uncertainties!

- Trigger: jet 15 GeV (uncor)
- leading jet $p_T > 40$ GeV (corr)
- other jets $p_T > 20$ GeV (corr)
- all jets $|\eta| < 3$
- jet ID cuts

80 GeV $< HT < 120$ GeV

120 GeV $< HT$
Validation of $\alpha_T$ in data (Jet-plus-Track)

$\int L \approx 11 \text{ nb}^{-1}$

Very good agreement within statistical uncertainties!

- Trigger: jet 15 GeV (uncor)
- leading jet $p_T > 40$ GeV (corr)
- other jets $p_T > 20$ GeV (corr)
- all jets $|\eta| < 3$
- jet ID cuts

80 GeV $< HT < 120$ GeV

120 GeV $< HT$
Validation of $\alpha_T$ in data (Particle Flow)

\[ \int L \approx 11 \text{ nb}^{-1} \]

Very good agreement within statistical uncertainties!

- Trigger: jet 15 GeV (uncor)
- leading jet $p_T > 40$ GeV (corr)
- other jets $p_T > 20$ GeV (corr)
- all jets $|\eta| < 3$
- jet ID cuts

$\sqrt{s} = 7$ TeV
$L = 11$ nb$^{-1}$

80 GeV $< HT < 120$ GeV

120 GeV $< HT$
Background prediction using the eta-uniformity

- SUSY events tend to be more central compared to the SM-background (QCD multi-jet, $t\bar{t}$, $Z\rightarrow\nu\bar{\nu}$)

- The fraction of SM-events surviving the $\alpha_T > 0.55$ cut compared to the rejected is uncorrelated to $\eta$ of the leading jet

This allows to factorize the SM-background in the signal region:

Measure $f(\alpha_T > 0.55)$ at high eta and extrapolate to the central region.
Closure test: Comparing estimation with MC simulation.

Standard Model background only
(QCD multijet, $t\bar{t}$, $Z\rightarrow\nu\bar{\nu}$)

Standard Model + Low mass SUSY
(SUSY LM1, QCD multijet, $t\bar{t}$, $Z\rightarrow\nu\bar{\nu}$)
Validating eta uniformity of $f(\alpha_T > 0.55)$ in data

Even if randomly jets are removed (ID inefficiencies) the eta-uniformity of the fraction of QCD events that fail the $\alpha_T > 0.55$ cut is preserved.

Analysis requires $HT > 350$ GeV, but for the background-factorization, events with low HT could be used:

→ higher statistics, especially in region $\alpha_T > 0.55$, since the steepness of falloff of $\alpha_T$ depends on HT.

→ however, the failure-fraction $f(\alpha_T > 0.55)$ of QCD events must be a decreasing function of HT, so that the low HT control sample gives an upper bound on the background prediction.
An exponential decrease of $f(\alpha_T > 0.55)$ in dependence of $H_T$ is observed:

- The jet spectrum itself is exponential
- The jet-loss probability (which leads to $\alpha_T > 0.55$) decreases with $p_T$
- Perturbation of $\alpha_T$ by a lost jet of given $p_T$ decreases with $H_T$

→ Decrease of the failure fraction $f$ as a function of $H_T$ allows to obtain a strong upper limit on the background, from a lower $H_T$ (and therefore high statistic) control sample
Conclusion

- $\alpha_T$ is a powerful variable to suppress QCD multi-jet background to all-hadronic SUSY
- $\alpha_T$ behavior in data up to $HT<200$ GeV is as expected
- Failure fraction $f(\alpha_T>0.55)$ uniform in $\eta$, even when additional jet-failures are induced
- Background can be estimated and validated using data

Sensitivity to new physics beyond the Standard Model (and Tevatron) already with few 10 pb$^{-1}$ expected.

http://lpc.web.cern.ch/lpc/lumiplots.htm
CMS mSUGRA benchmark points