Search for SUSY signatures with the CMS detector in events with electron(s), jets and missing energy

Handling of QCD background

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Motivation

- Theories with supersymmetry are promising candidates for BSM physics
- Motivation to base a SUSY search on events with one isolated lepton or two isolated same-sign (SS) leptons at the LHC
  - Leptons are in general very well reconstructed by the CMS detector (electrons need more attention regarding fakes than muons),
  - Production of SS di-leptons is in many scenarios comparable with OS di-leptons (gluino-gluino, squark-gluino, same-sign squark-squark),
  - The SM produces a low background which can be significantly reduced with dedicated cuts
    e.g. lepton isolation, jet multiplicity, jet Pt, missing transverse energy (MET)
    (more backgrounds exist with significant cross-sections for OS searches)
- The goal of this talk is to present a new possibility for controlling the QCD background.

Production channels

- Several ways to produce isolated leptons at the LHC if SUSY exists
  - Direct chargino or neutralino production (low σ)
  - Direct squark or gluino production (with subsequent decays to charginos/neutralinos)

Main channels for leptonic SUSY signatures:

$\tilde{\chi}_2^{\,o} \to \tilde{\ell}\ell$ $\quad$ $\tilde{\chi}_1^{\,\pm} \to \tilde{\ell}\nu / \tilde{\nu}\ell$

$\tilde{\chi}_2^{\,o} \to h^o \tilde{\chi}_1^{\,o}$ $\quad$ $\tilde{\chi}_1^{\,\pm} \to H^{\pm} \tilde{\chi}_1^{\,o}$

$\tilde{\chi}_2^{\,o} \to Z^o \tilde{\chi}_1^{\,o}$ $\quad$ $\tilde{\chi}_1^{\,\pm} \to W^{\pm} \tilde{\chi}_1^{\,o}$

$\tilde{\chi}_2^{\,o} \to \ell^{\pm}\ell^{\mp}\tilde{\chi}_1^{\,o}$ $\quad$ $\tilde{\chi}_1^{\,o} \to \ell^{\pm}\nu\tilde{\chi}_1^{\,o}$

- Some channels lead to OS di-lepton, some to SS di-lepton production
  - The OS/SS fraction will depend on the actual realisation of SUSY and the way in which squarks and gluinos are produced
    e.g. on the SUSY mass spectrum and the relation between M_{gluino} and M_{squark}

    Note: Because the LHC is a pp collider and runs at higher energies, the SS final state configurations can be more probable than at Tevatron

Example backgrounds for SS signatures

- W + jets (production cross-section @ 10 TeV: 4×10^4 pb)
  - Discriminating variable(s): isolation of second lepton (from b-jet), jet multiplicity
- Z + jets (production cross-section @ 10 TeV: 3.7×10^3 pb)
  - Discriminating variable(s): isolation of second lepton (from b-jet), jet multiplicity, invariant mass cut, MET (issue: charge misidentification)
- TTbar + jets (production cross-section @ 10 TeV: 317 pb)
  - Discriminating variable(s): isolation of second lepton (from b-jet), tight vertex requirement (issue: charge misidentification)
- QCD jets (di-jets production cross-section @ 10 TeV: $> 7 \times 10^5$ pb)
  - Discriminating variable(s): isolation of both leptons, jet multiplicity, MET

➡ Enormous cross-section and large uncertainties from MC (PDFs, UE, JES etc.)

QCD background

- Non-physical MET
  comes from finite e/jets resolutions, mis- or non-reconstructed objects etc.
- Non-prompt and fake isolated electron(s)
  reconstructed electrons not from the primary decay and mis-identified jets
- Origins of non-prompt and fake electrons:
  - Decays of mesons within jets (heavy-flavour decays, Dalitz decays etc.)
  - Photon conversions (asymmetric)
  - Jets depositing large amount of energy in the ECAL that is matched to a single high-p_T track
    e.g., jet with leading π^0 (ECAL deposit) and charged pion (track)
- Fake electrons can be reduced by simple kinematics cuts (e.g., p_T and $|\eta|$), identification (e.g., *robust*, *tight*) and isolation

➡ How much of this QCD background have we actually removed?

Proposal for exclusive di-jet SUSY search

- Idea by L.Randall & D.Tucker-Smith (doi:10.1103/PhysRevLett.101.221803)
- Explore different topologies:
  - SUSY: two jets + MET.
  - QCD: two jets, no MET.
- Use of kinematic properties which are not directly dependent on MET!
  ➡ Good potential for robust search

Variable α

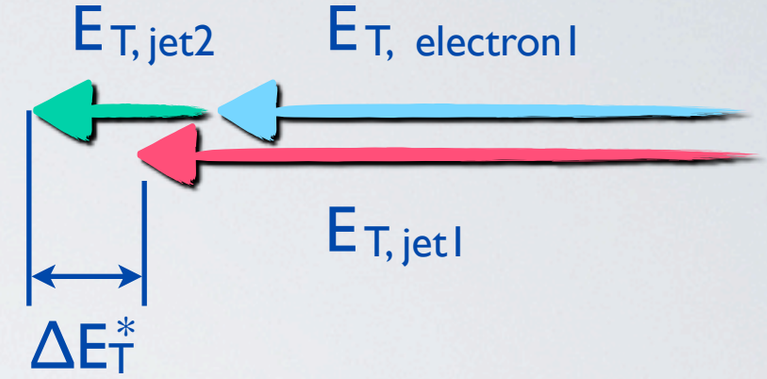
$$\alpha \equiv \frac{E_T^{j2}}{M_{inv}^{j1,j2}} \equiv \frac{E_T^{j2}}{\sqrt{2E^{j1}E^{j2}(1-\cos\Theta)}}$$

- Variable α : full jet kinematics, ≲ 0.5 for perfectly measured QCD event
- Variable α_T : only transverse kinematics, exactly 0.5 for perfectly measured QCD event

  ➡ Can we extend the α_T and use it with signatures that include leptons?

Extension of the idea for leptonic searches

- Treat electrons as jets and form "pseudo jet objects" out of *n* jets and *k* electron(s) in such a way that they balance each other as well as possible.



Modified variable α_T* - "leptonic α_T"

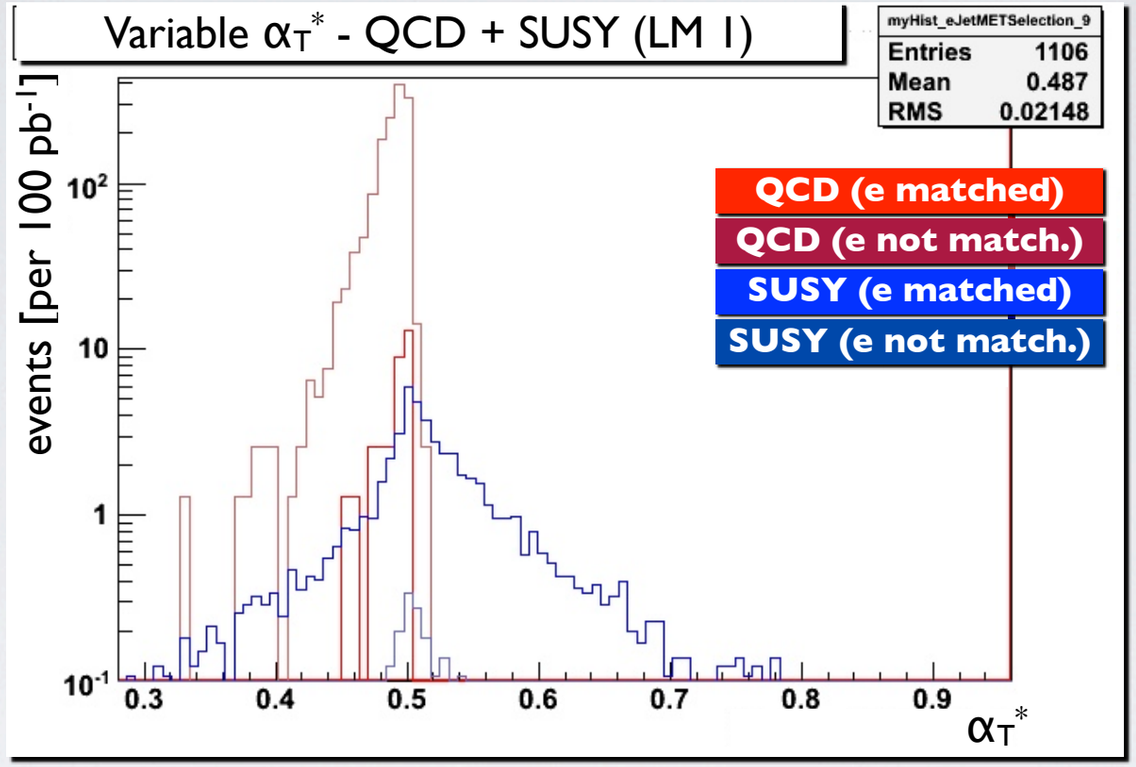
$$\alpha_T^* \equiv \frac{E_T^{(J2)}}{M_T^{(J1),(J2)}} \equiv \frac{1}{2} \frac{(\sum_{i=1}^{n+k} E_{T,i}) - \Delta E_T^*}{\sqrt{(\sum_{i=1}^{n+k} E_{T,i})^2 - (\sum_{i=1}^{n+k} p_{x,i})^2 - (\sum_{i=1}^{n+k} p_{y,i})^2}}$$

- ΔE_T^* is small for balanced QCD events. - $(missing\text{-}H_T^*)^2$
- ΔE_T^* and $missing\text{-}H_T^*$ are correlated for QCD events with mismeasured jets, but not for SUSY events.
- Similar properties as in the real QCD di-jet system

Event selection

- Electrons:
  - cut based ID: "tight" (according to set of cuts propsed by dedicated group),
  - acceptance: $p_T > 20$ *GeV*, $|eta| < 2.4$,
  - additional cuts: $|d_0| < 0.2$ *cm*, combined relative isolation < 1.0
- Muons (needed for vetoing prompt muons from the event):
  - acceptance: $p_T > 20$ *GeV*, $|eta| < 2.1$,
  - quality cuts: $\chi^2 < 10$, number of hits > 11,
  - additional cuts: $|d_0| < 0.2$ *cm*, isolation < 0.1
- Jets:
  - ID/reco: S.C. 0.5 jets, corrected for relative response in *eta* and p_T
  - acceptance: $p_T > 30$ *GeV*, $|eta| < 3.0$,
  - additional cuts: $E.M._{fract} > 0.1$, distance(jets,electrons) > 0.4
- Single electron events: *N(elec) = 1, N(muons) = 0, N(jets) ≥ 2, no MET cut*
- SS di-electron events: *N(elec) = 2 SS, N(muons) = 0, N(jets) ≥ 2, no MET cut*

Distribution of leptonic α_T



- **Leptonic α_T** distribution for QCD shows sharp edge around ~0.5 value
- Has virtually no events above ~0.55 if it includes all objects originating from QCD
- Good potential to be:
  - insensitive to "definition" of the jet energy scale
  - insensitive to jet mis-measurements

Event numbers @ 10 TeV and for 100 pb^{-1}

	QCD	LM 0	LM 1
selection	1517.2	505.8	57.4
selection and $\alpha_T > 0.55$	0	121.8	30.2

Conclusion and outlook

- We have presented a modified α_T variable
  a possible new way to handle QCD background in leptonic SUSY searches
- Leptonic α_T variable is based on kinematic properties which are not directly dependent on MET
  good potential for robust searches
- Possible applications:
  - Estimation of QCD background
    (in combination with variables which have low inter-dependence with leptonic α_T)
  - Measurements of QCD fake rates
    (selection of a QCD-enriched sample by inverting cut on leptonic α_T)