Signatures of lepton-jet production at the LHC

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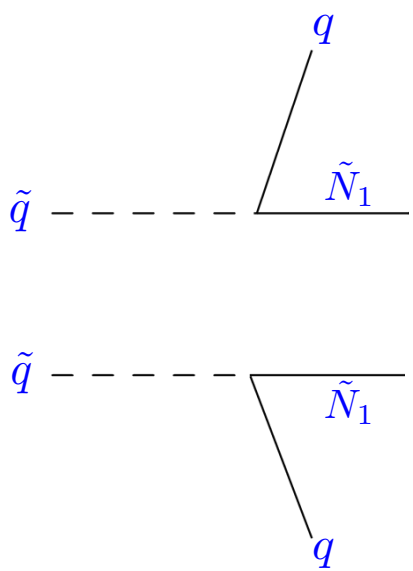
Motivation

- Hidden valley models give rise to hidden sector
  - Weakly couple to SM particles
  - New physics could escape detection
  - Source of dark matter?
- Could SUSY also be hidden?
  - If so, is it still possible to search for it at the LHC?
- Investigate case when lightest *visible* neutralino is allowed to cascade into the hidden sector
  - This SUSY cascade produces a signature of lepton jet production
    - Clusters of collimated leptons
    - Individual leptons in the lepton jets can be quite soft and not isolated
    - Large multiplicity of lepton jets
    - Large missing energy

Lepton Jets Production Example

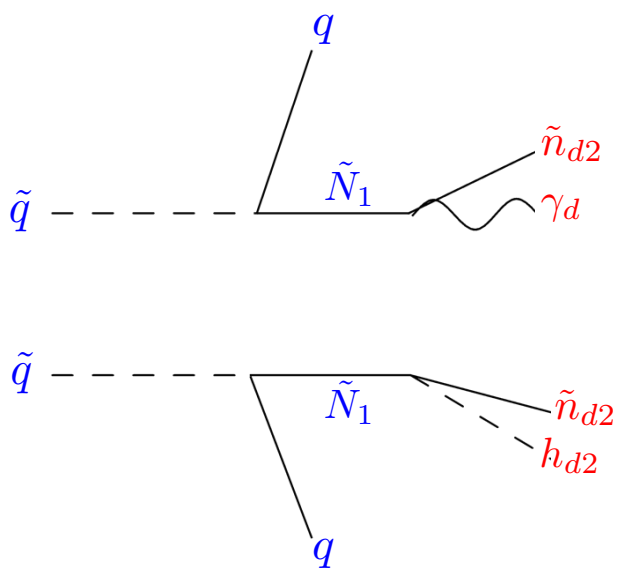
Squark pair production to quark and neutralino
(only last step in visible sector cascade shown)



Lepton Jets Production Example

Neutralino decay to hidden sector

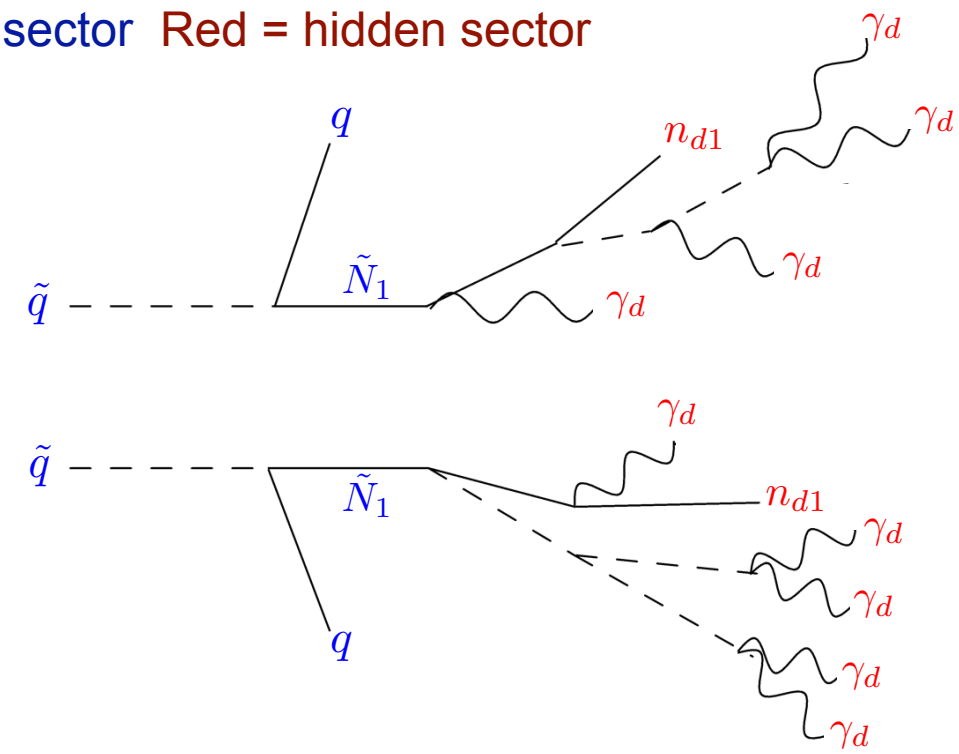
Blue = visible sector Red = hidden sector



Lepton Jets Production Example

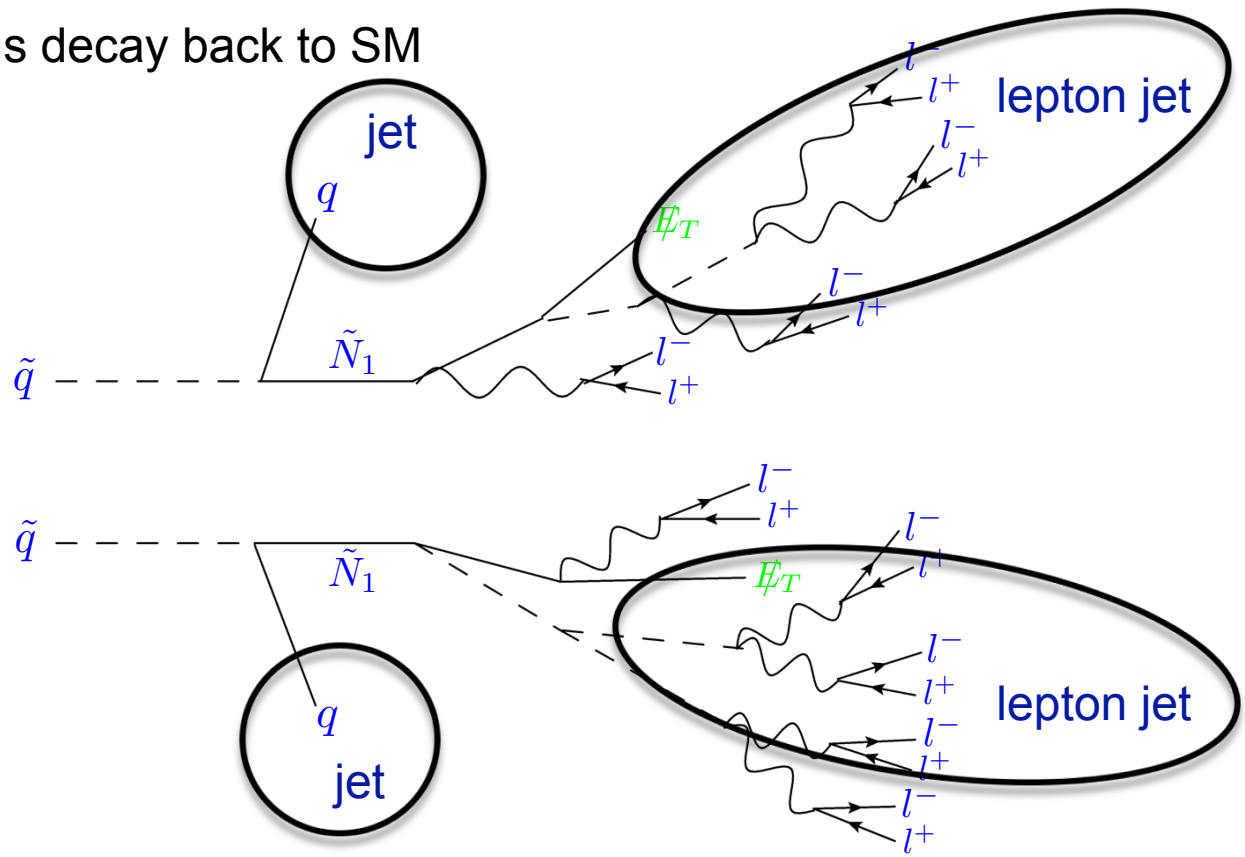
Cascade into hidden sector

Blue = visible sector Red = hidden sector



Lepton Jets Production Example

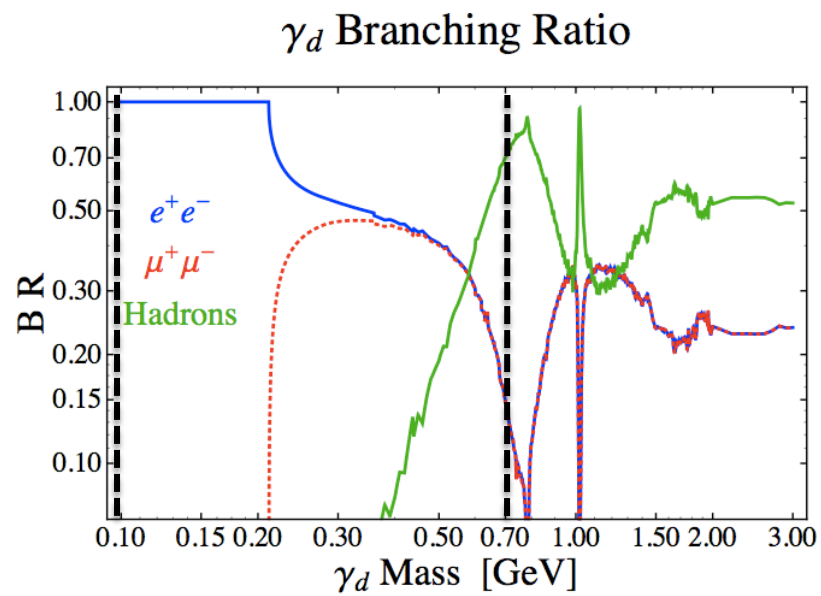
Hidden photons decay back to SM



Signature we are considering here: 2 regular jets, plus 2 lepton jets, plus MET

Signal & Background

- Signal @ 7 TeV
  - gg ➔squark squark ➔ q q N_1 N_1 generated with Madgraph
    - ~0.7 pb cross section
    - M_{squark} = 400 GeV, M_{n1} = 5 GeV
      - $M_{\gamma d}$ = 700 MeV mostly decays to hadron
        - Today's talk primarily focuses on this
      - $M_{\gamma d}$ = 100 MeV decays to e+e-
- Background @ 7 TeV
  - N-jet (2, 3, 4+) QCD generated with Madgraph
    - Binned in H_T
      - 100-250 GeV, 250-500 GeV, 500-1000GeV, 1000-inf GeV
    - MLM matching used
- Analysis
  - PGS 4
    - http://www.physics.ucdavis.edu/~conway/research/software/pgs/pgs4-general.htm



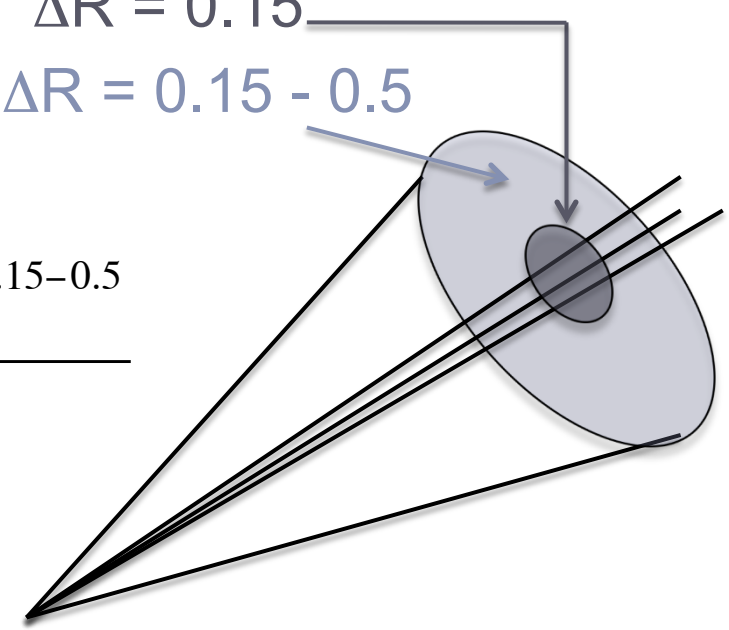
http://arxiv.org/abs/1002.2952

Falkowski, Ruderman, Volansky, Zupan

Event Selection

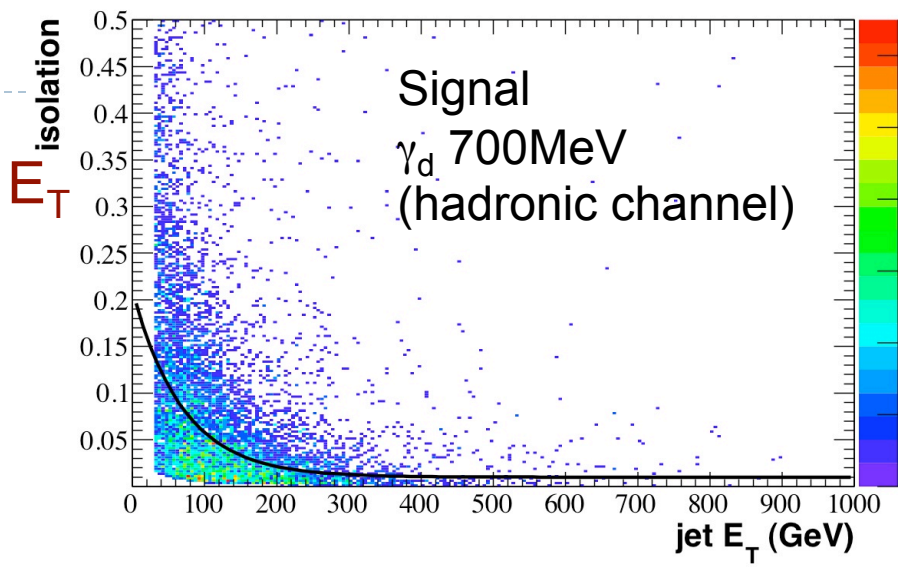
- Use k_T jet clustering algorithm with cone 0.5
- Select ≥ 4 jets with p_T > 40 GeV
- Jet $|\eta|$ < 5 (PGS default)
- At least one *isolated* lepton jet
  - Define a narrow lepton jet cone of $\Delta R = 0.15$
  - Define an isolation cone between $\Delta R = 0.15 - 0.5$

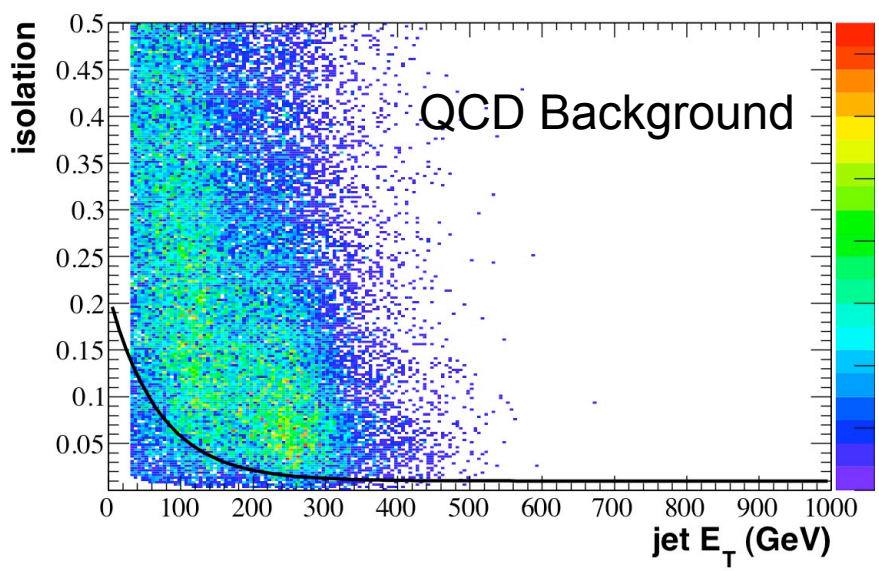
$$Iso = \frac{\sum E_T^{calo,\Delta R=0.15-0.5} + \sum p_T^{tracks,\Delta R=0.15-0.5}}{\sum E_T^{calo,\Delta R=0.15}}$$

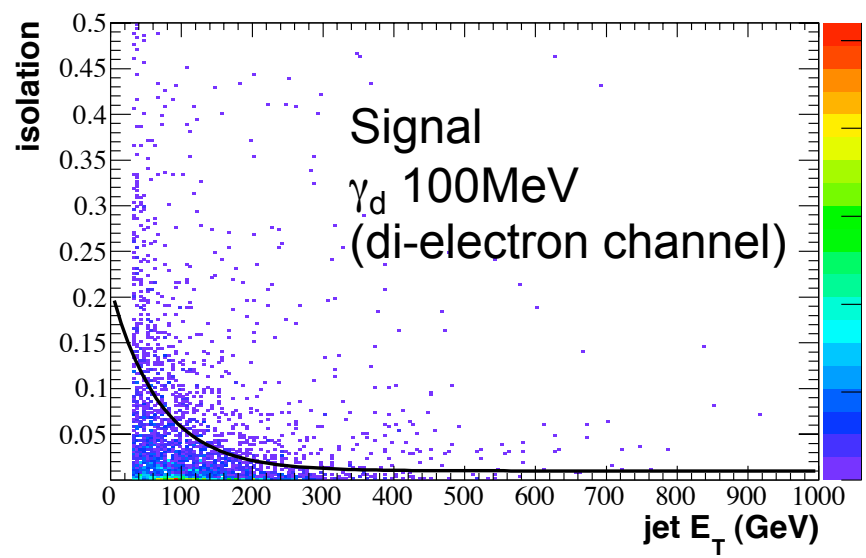


Lepton Jet Isolation

- Isolation has a dependence on Jet E_T
- Cut on:
  Iso < 0.2 • exp(-E_T^{Jet}/ 70)+0.01

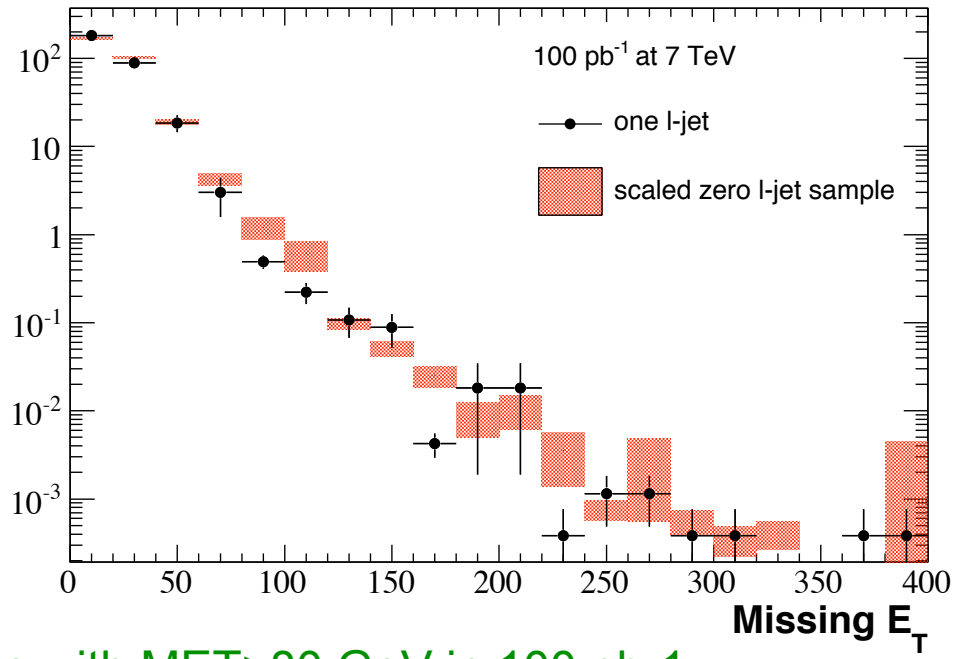






Missing E_T for QCD Events

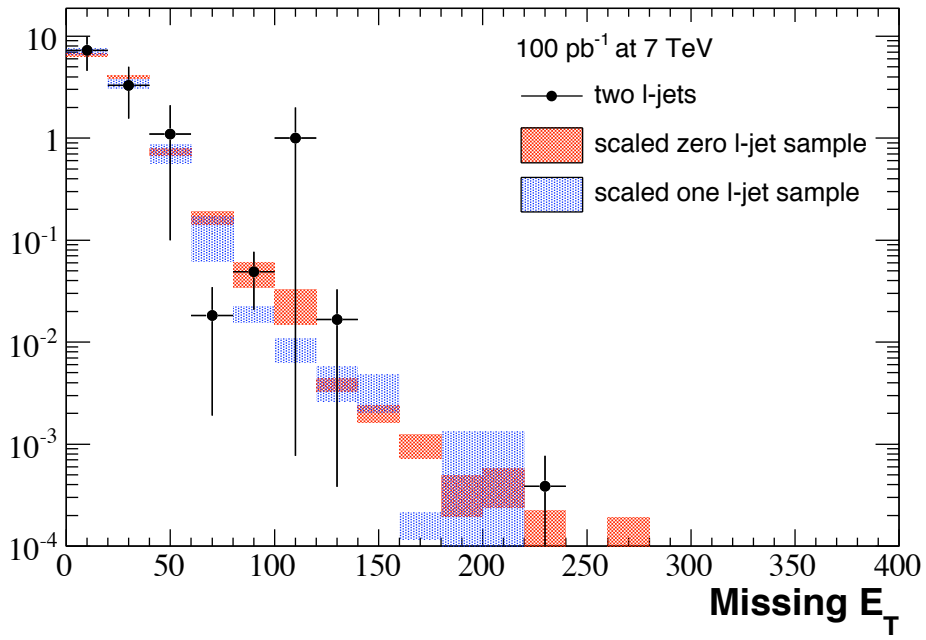
- Signal expected to have large MET and point in direction of lepton jet
  - Can we use MET as a handle?
- Use MET distribution in QCD events selected with no lepton jets to predict events with exactly one lepton jet
  - Similar shapes



  - Number of events with MET>80 GeV in 100 pb-1
    - **Predicted (zero lepton-jet): 2.03 ± 0.40**
    - **Observed (one lepton-jet): 0.96 ± 0.12**

Missing E_T for QCD Events

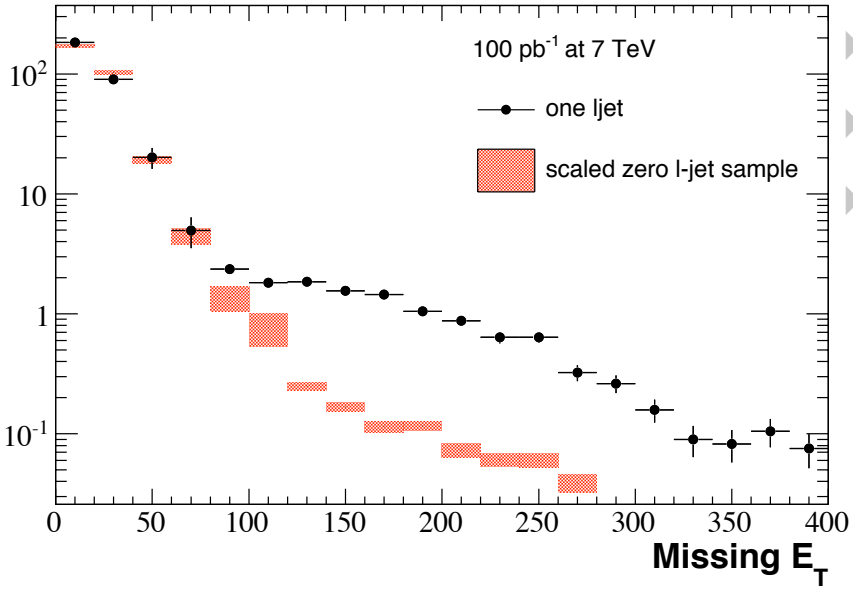
- Similarly, use MET distribution in QCD events selected with one or no lepton jets to predict events with exactly two lepton jet
  - Again, similar shapes



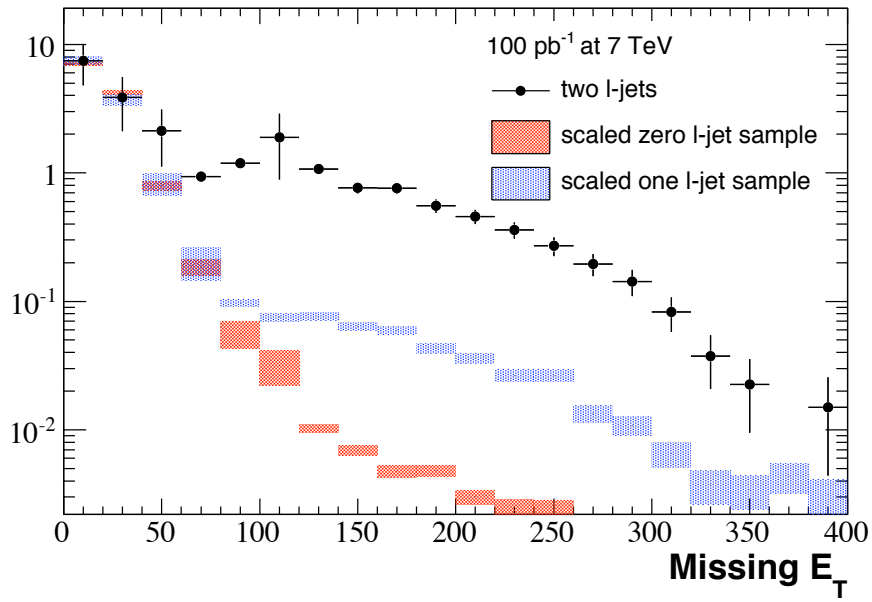
- Number of events with MET>80 GeV in 100 pb-1
  - **Predicted (zero lepton-jet): 0.079 ± 0.016**
  - **Predicted (one lepton-jet): 0.037 ± 0.005**
  - **Observed (two lepton-jets): 1.1 ± 1.0**

Missing E_T with Signal Events

- Now adding hadronic channel signal events:



- **Predicted (zero lepton-jet): 0.13 ± 0.02**
- **Predicted (one lepton-jet): 0.56 ± 0.01**
- **Observed (two lepton-jets): 7.9 ± 0.4**

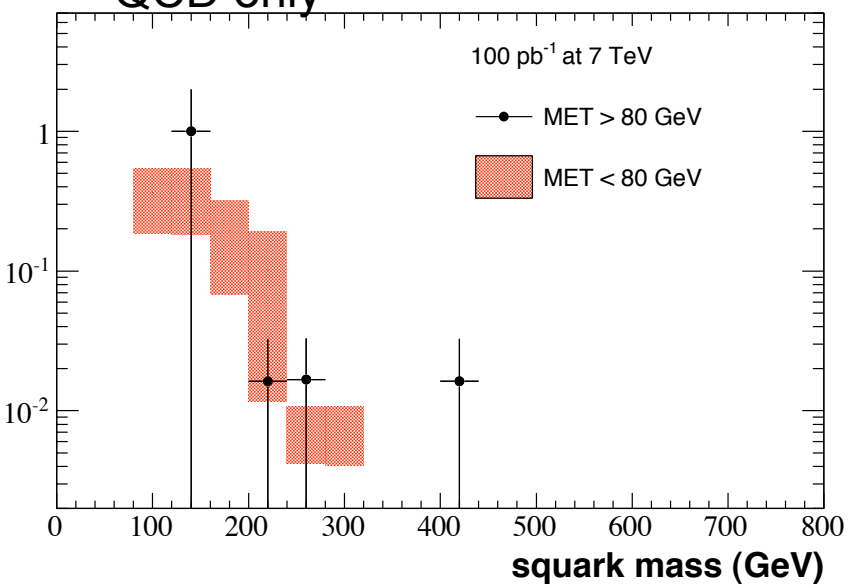


- **Predicted (zero lepton-jet): 3.1 ± 0.4**
- **Observed (one lepton-jet): 13.5 ± 0.3**

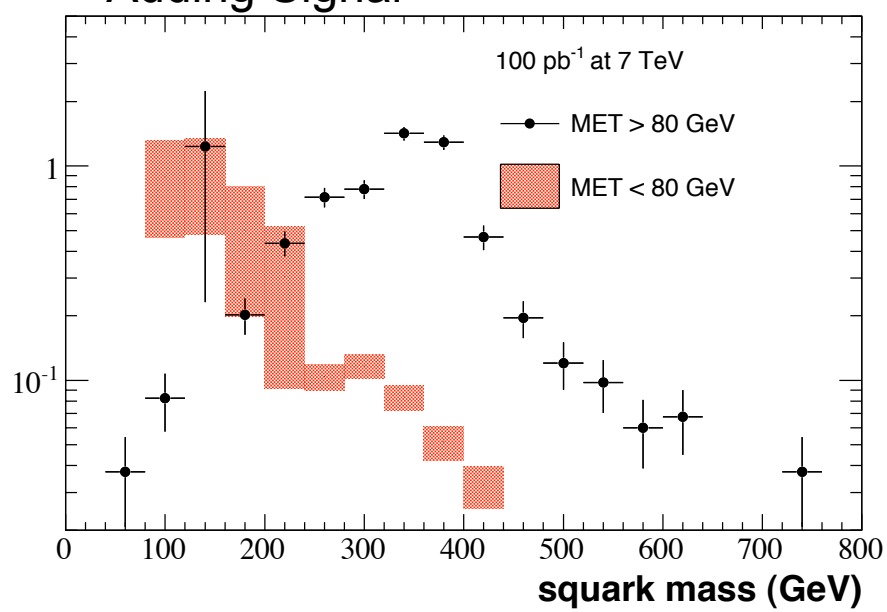
Invariant Mass

- Reconstruct invariant mass
  - Assume MET is in direction of lepton jet
  - Two possible pairs of jet+lepton jet
    - Chose pair that gives closest masses
    - Plot the average of the two masses

QCD only



Adding Signal



Conclusions & Future Prospects

- Investigating signatures of lepton jet production in SUSY cascades at the LHC
- Initial studies assuming 100 pb^{-1} seem promising
  - Lepton jet isolation dependence on jet E_T as a distinguishing variable
    - Potential gain: use of "shrinking cone" as is done for tau ID at the Tevatron
  - Studied MET and invariant mass of jet + lepton jet
- Further study
  - Two extreme cases of γ_d decays into mostly pions or into only electrons.