Discovering New Physics With Non-Isolated Leptons

Chris Brust
Johns Hopkins University
University of Maryland
Perimeter Institute

arXiv:1408.XXXX

- Leptons which are decay products of boosted objects fail isolation criteria
- Jets with hard leptons from boosted processes distinct from QCD
- Can we model-independently discriminate non-isolated leptons in signal vs background?

Also with Ian Anderson, Petar Maksimovic, Alice Sady, Prashant Saraswat, Matthew T. Walters, and Yongjie Xin

Boost 2014 – Aug. 19th
University College London

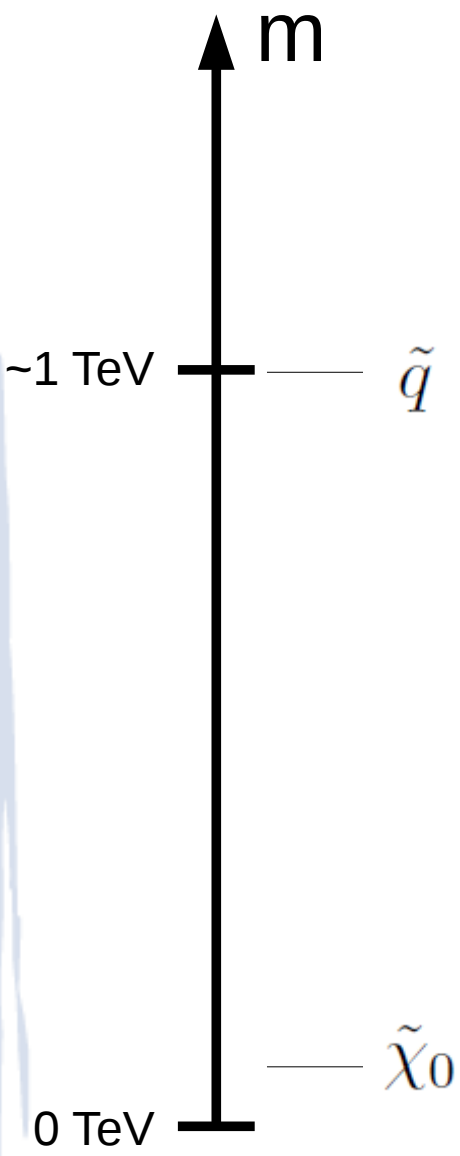
Relative Isolation

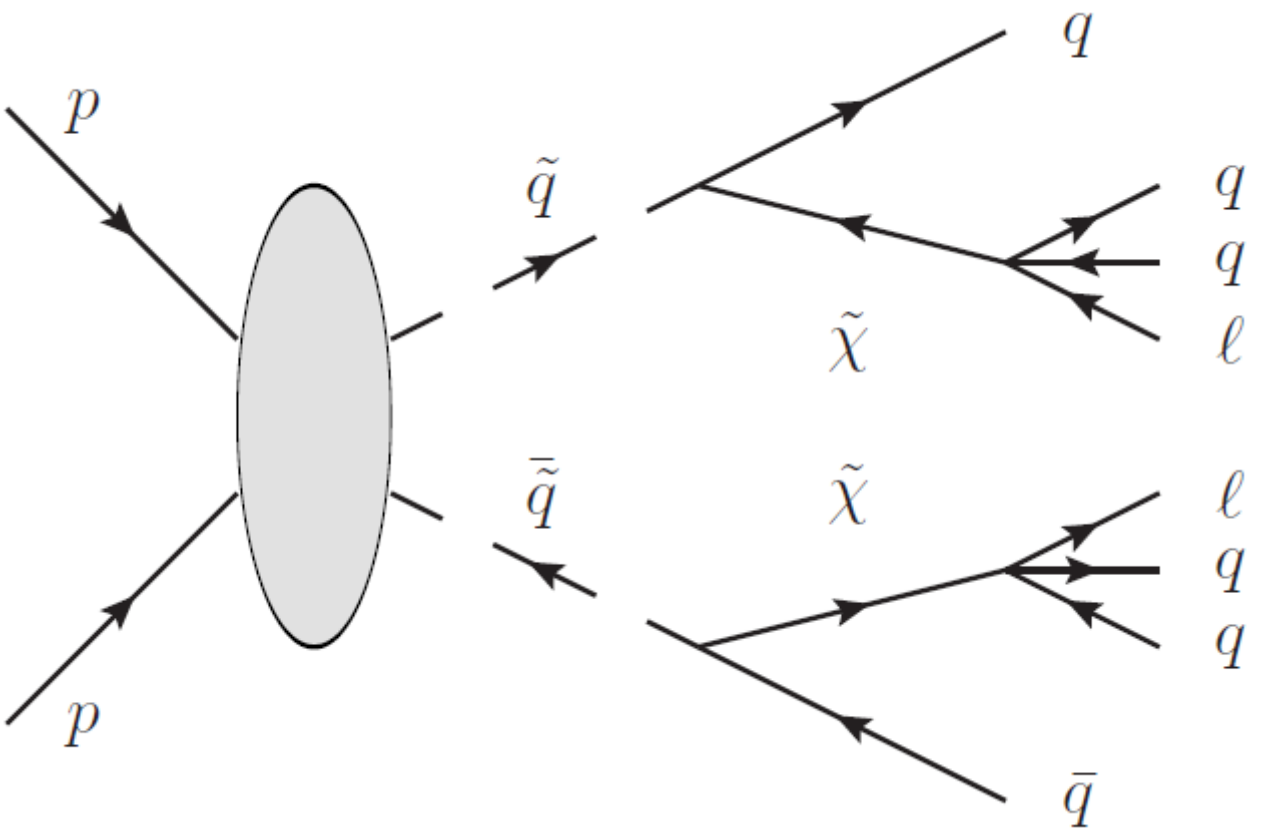
Sum over cone of radius R_{cone}

- Standard relative isolation: $\mathcal{R}^{\ell}_{\rm Iso} = \dfrac{\sum_i p^i_{\rm T}}{p^{\ell}_{\rm T}}$
- Typically $\mathcal{R}^{\ell}_{\rm Iso} \lesssim 0.2\,, \quad R_{\rm cone} \gtrsim 0.3$

Discards non-isolated leptons

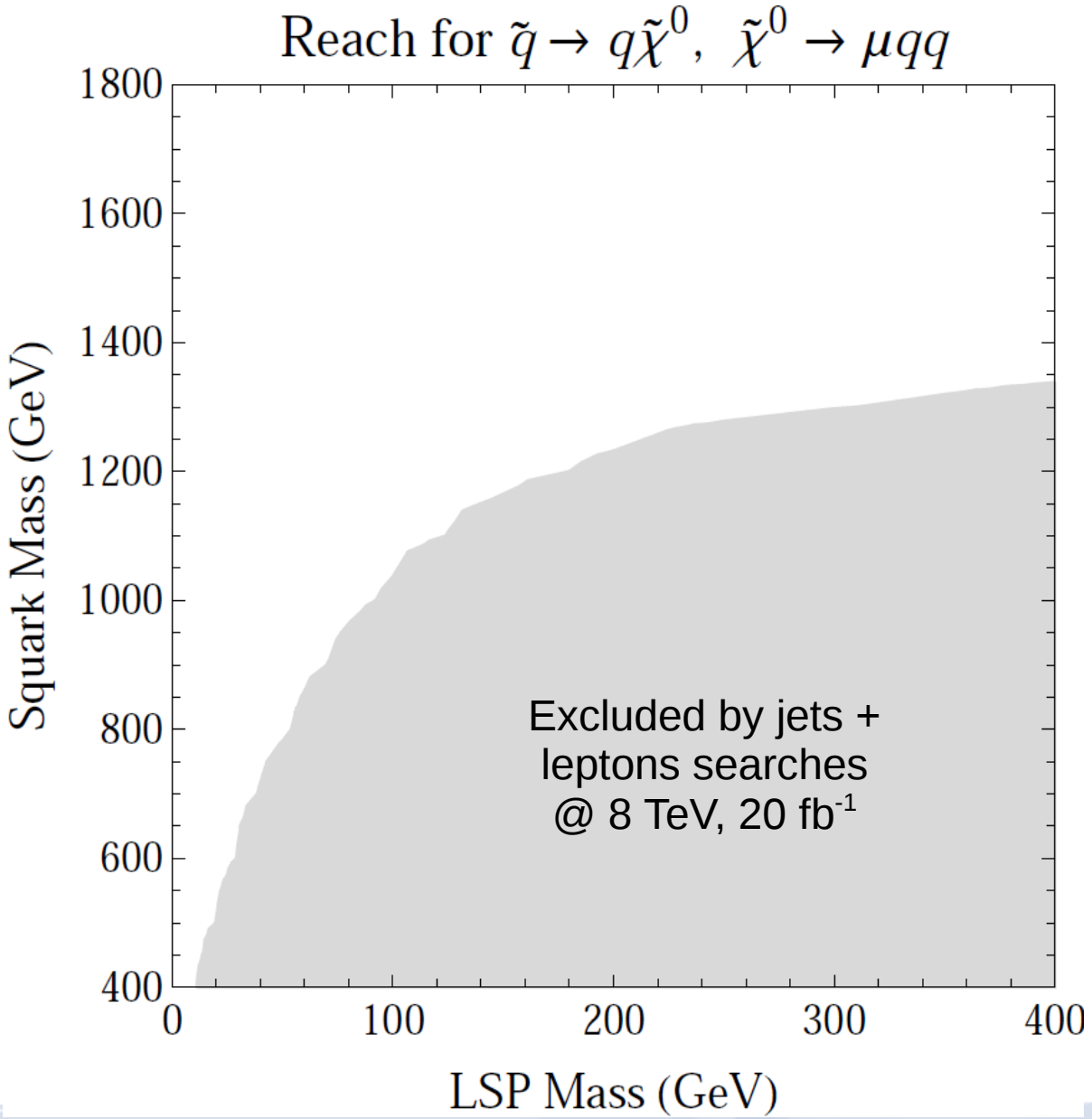
Example of Missed Signal



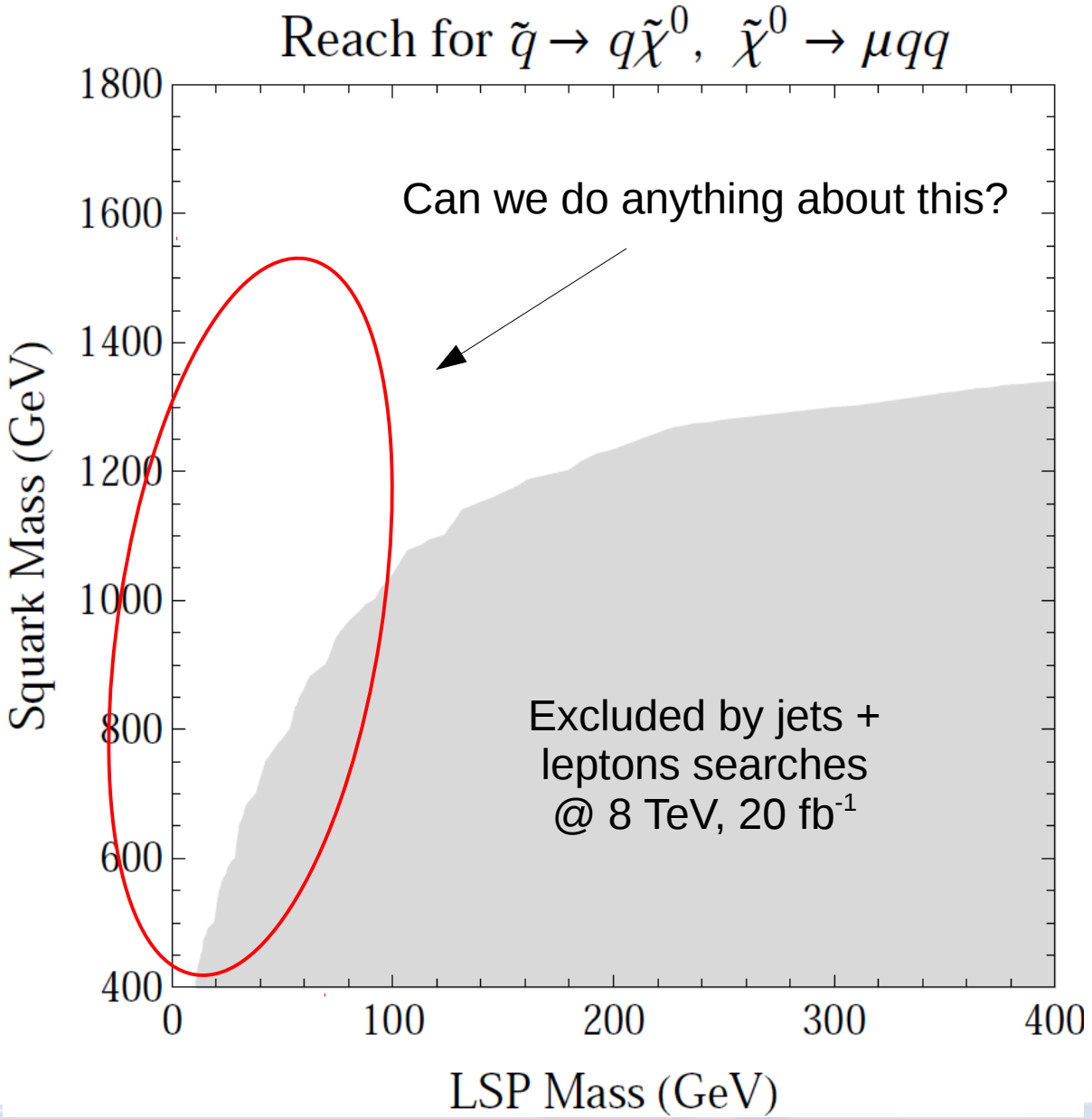


Many other models, too!

Current Squark Exclusion Plot



Current Squark Exclusion Plot



Takeaway Message

- Non-isolated leptons are useful discriminants for new physics if...
  - ...we loosen or eliminate isolation criteria
  - ...we minimize background with cuts on hadronic activity
- Existence of a size parameter (e.g. isolation cone size) equals restricting range of boosts

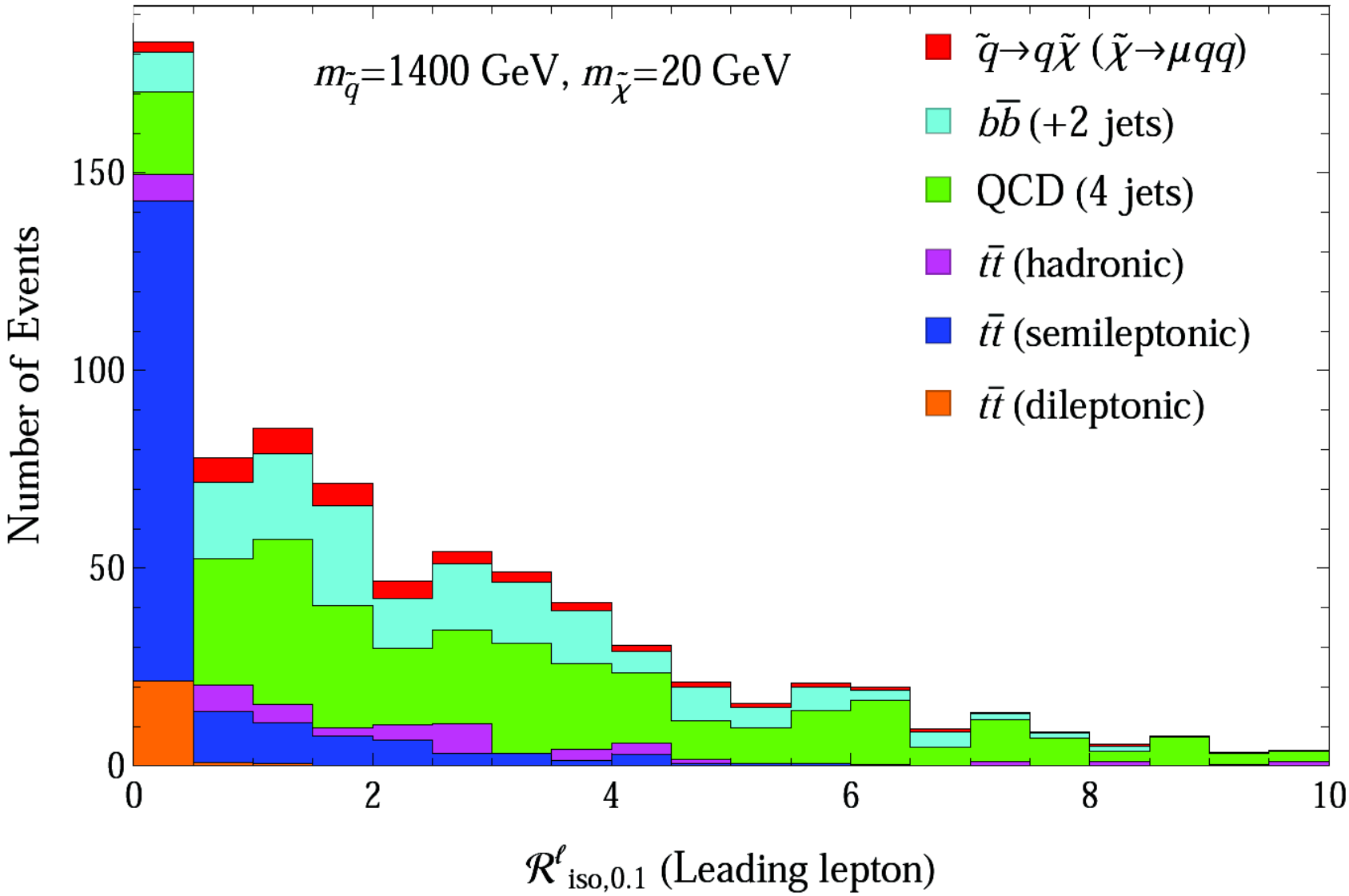
Our Goals

- Develop and cut on *model-independent* observables
- They should distinguish hard-process leptons from leptons produced in QCD jets

Cutting Hard on Hadronic Activity

- 8 TeV relative isolation study
- Demand:
  - 4+ anti-k_T, R = 0.5 jets with p_T > 150 GeV
  - H_T > 850 GeV with $H_{\mathrm{T}} = \sum_j p_{\mathrm{T}}^j + \sum_\ell p_{\mathrm{T}}^\ell$
  - 2+ leptons with p_T > 40 GeV (no iso. req.!)

Relative Isolation of Hardest Lepton



Plot is stacked

Our Strategy

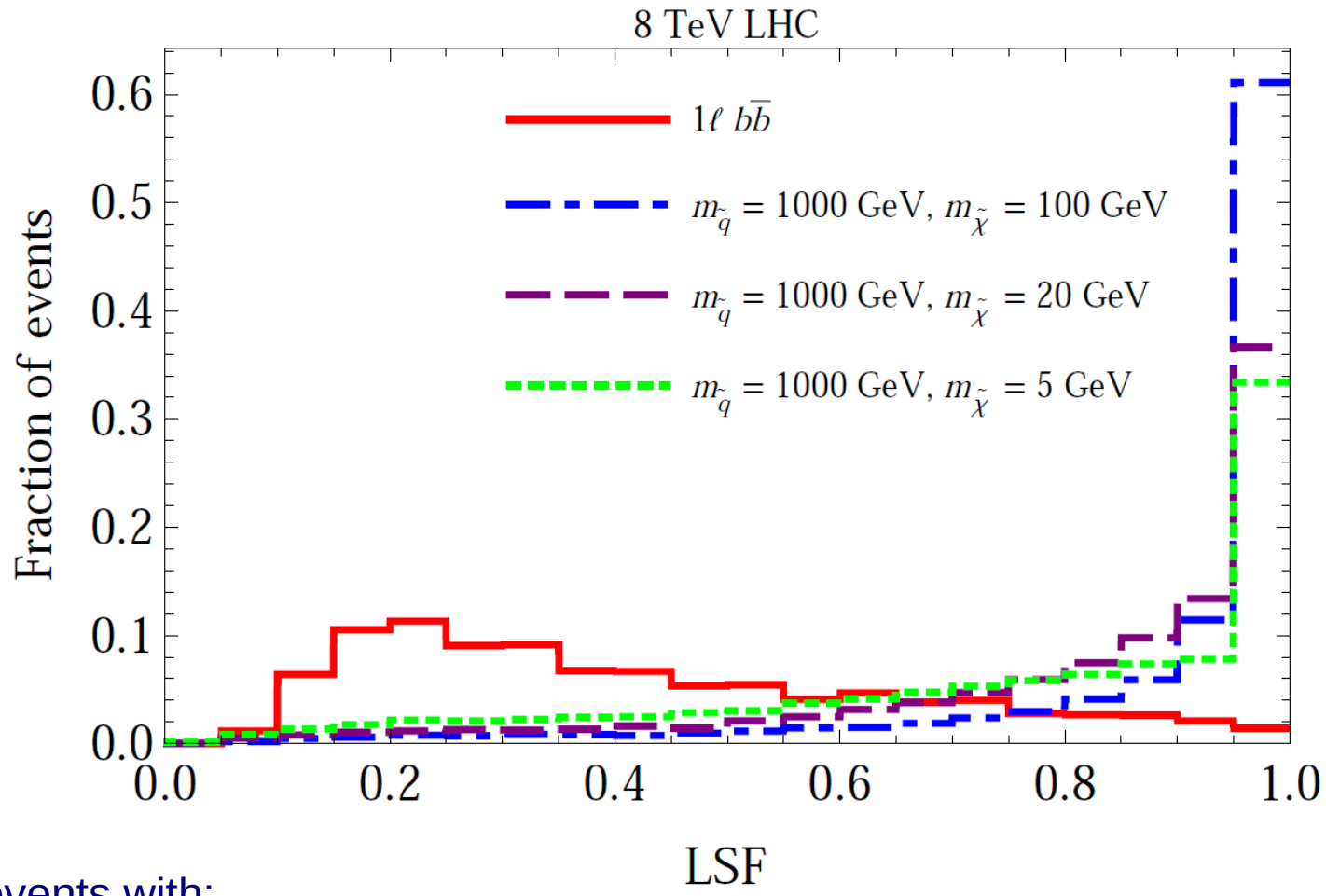
- Unlike relative isolation, they should exploit properties of *all* leptons, regardless of how boosted an object they came from

Our solution:
Substructure with no built-in size parameter

Lepton Subjet Fraction

- Cluster *every* hadron and lepton in event into "fat jets" with C/A, R = 0.8
- For each fat jet, recluster constituents into n subjets with exclusive k_T – no size parameter!
- For each lepton, define $\mathrm{LSF} = \frac{p_{T,\ell}}{p_{T,subjet}}$

Lepton Subjet Fraction (n = 3)

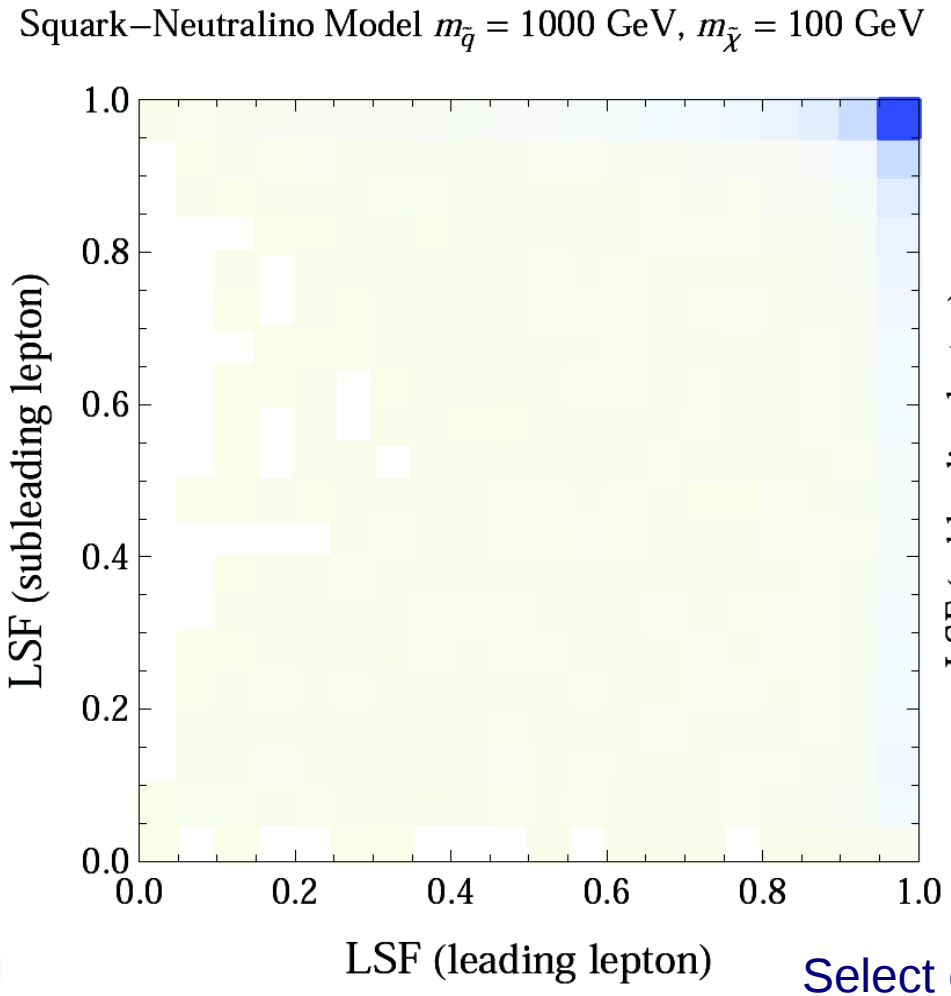


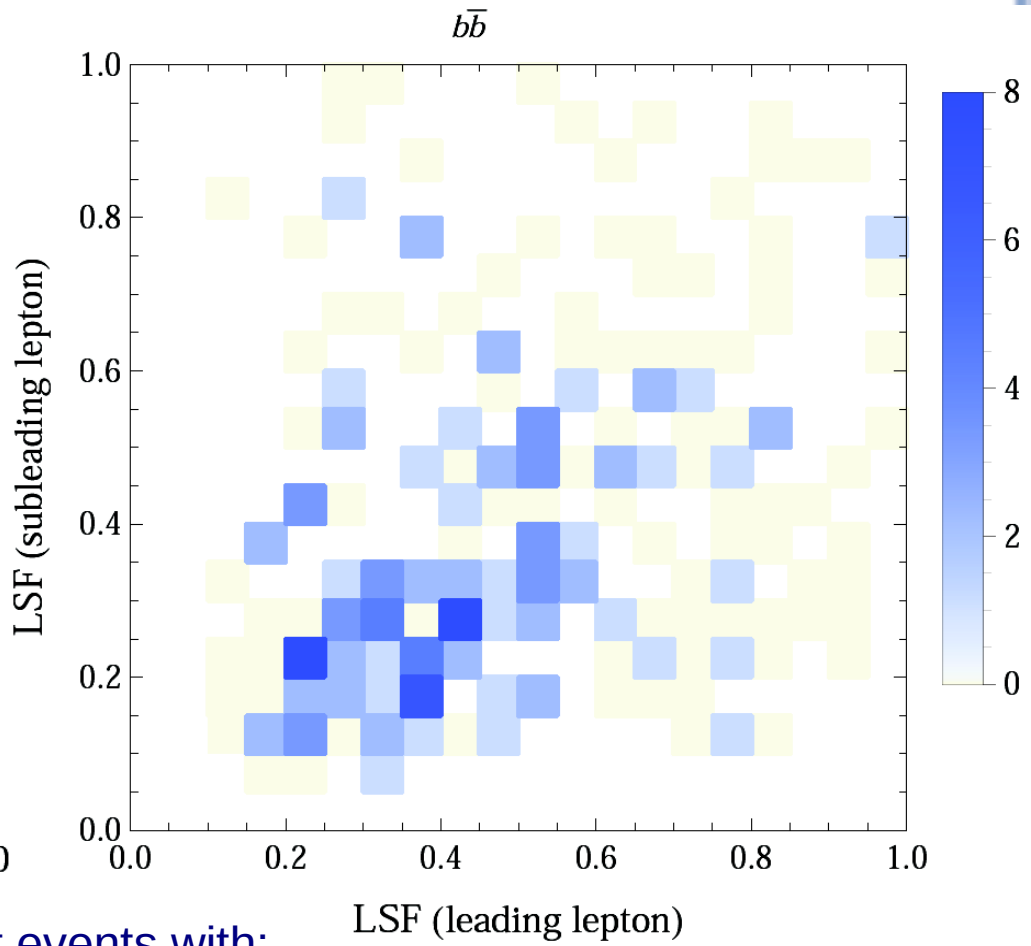
Select events with:

2+ jets, p_T > 150 GeV

1+ lepton, p_T > 40 GeV

LSF_3 of Two Hardest Leptons





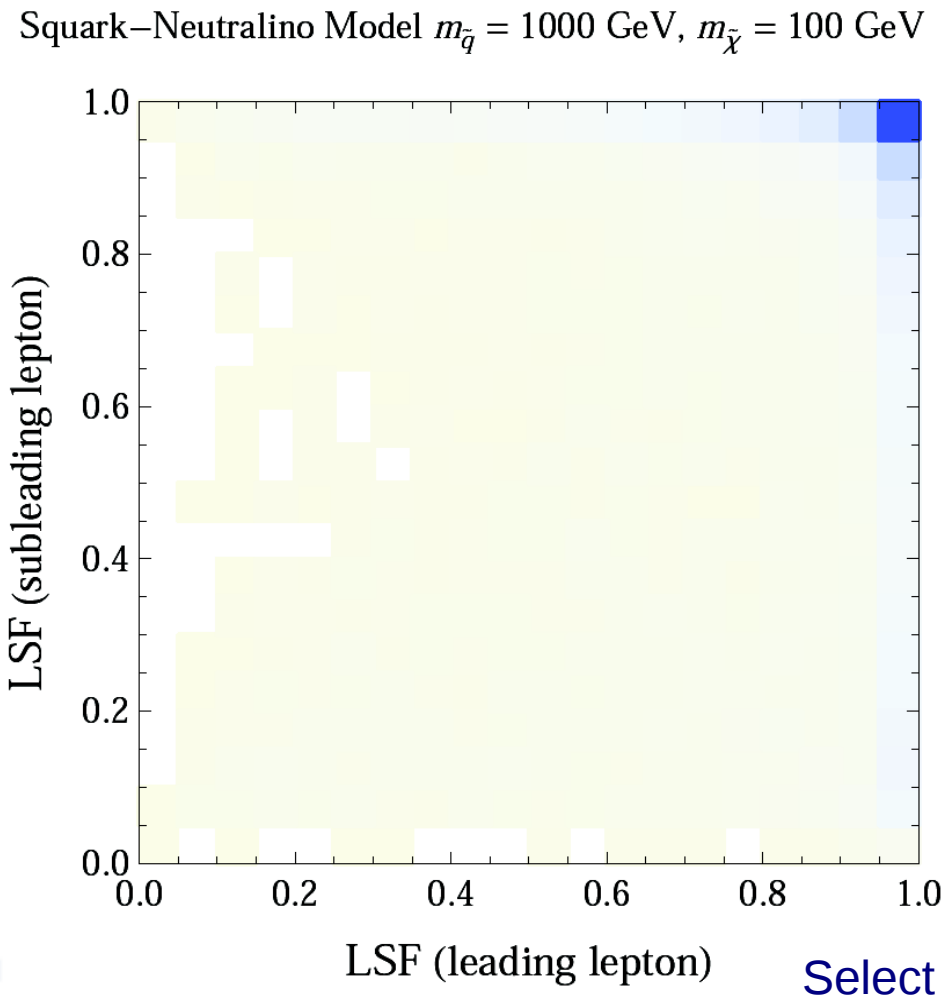
Select events with:

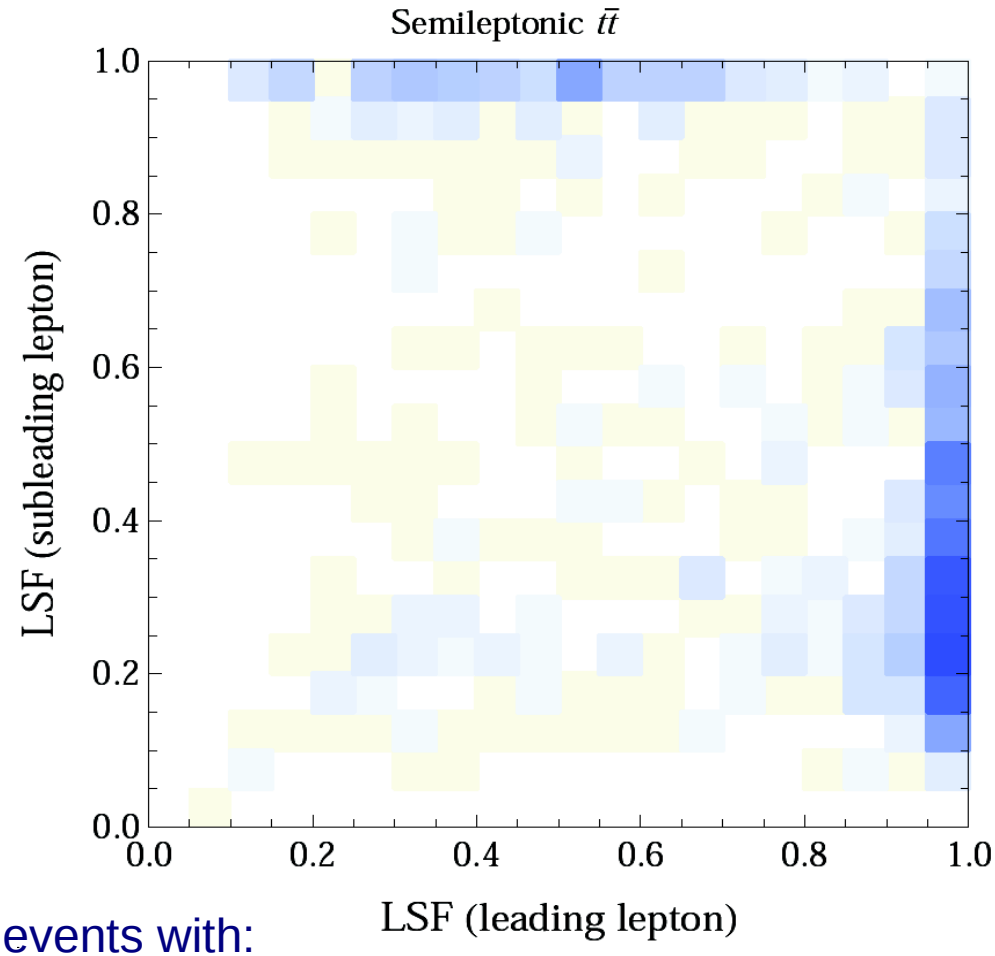
4+ jets, $p_T > 150$ GeV

2+ leptons, $p_T > 40$ GeV

$H_T > 850$ GeV

LSF_3 of Two Hardest Leptons





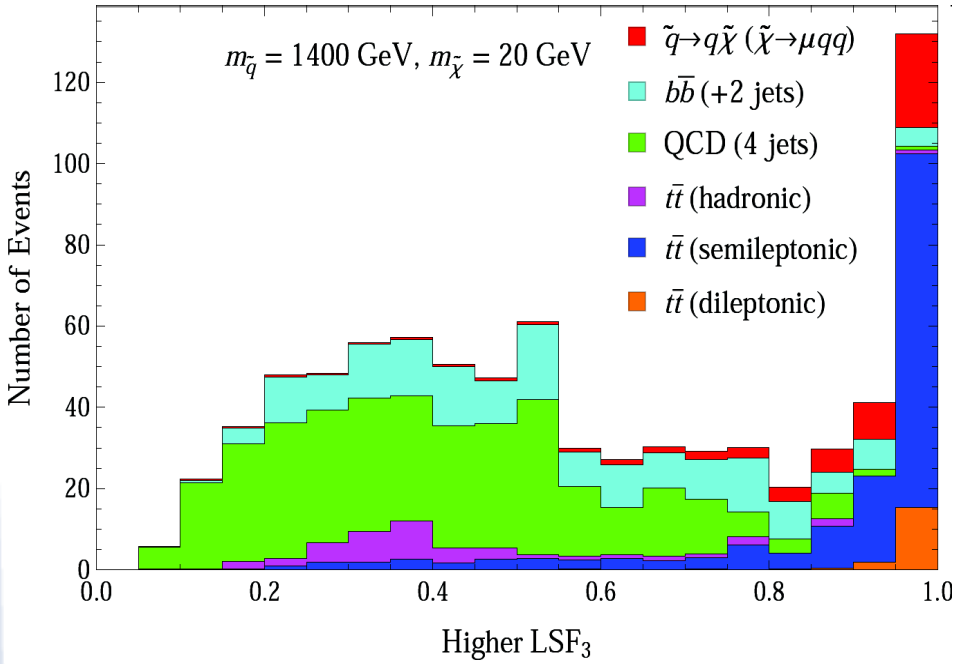
Select events with:

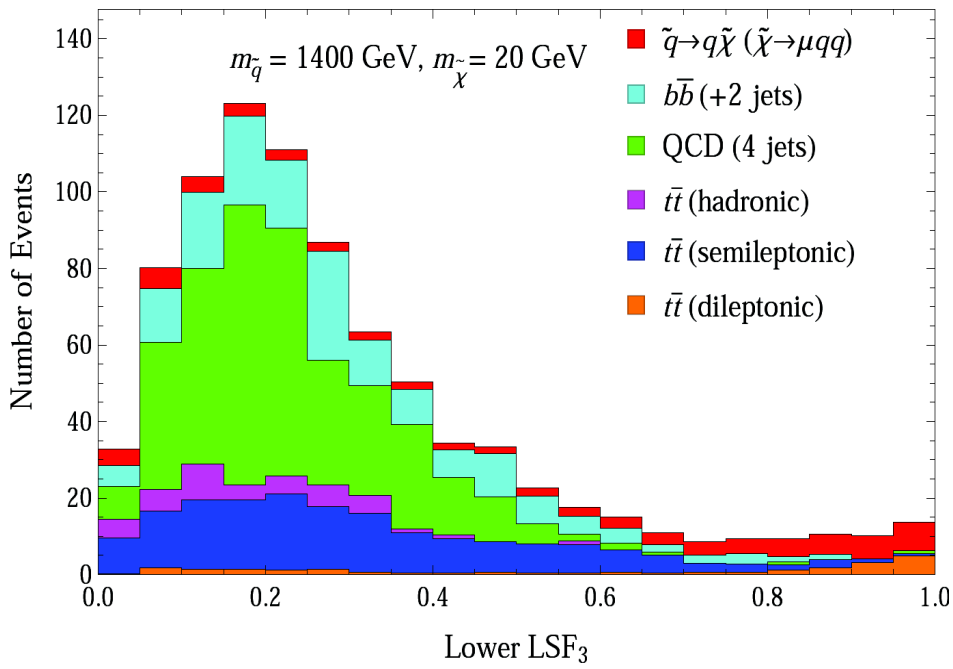
4+ jets, p_T > 150 GeV

2+ leptons, p_T > 40 GeV

H_T > 850 GeV

Highest LSF_3 vs 2nd Highest LSF_3

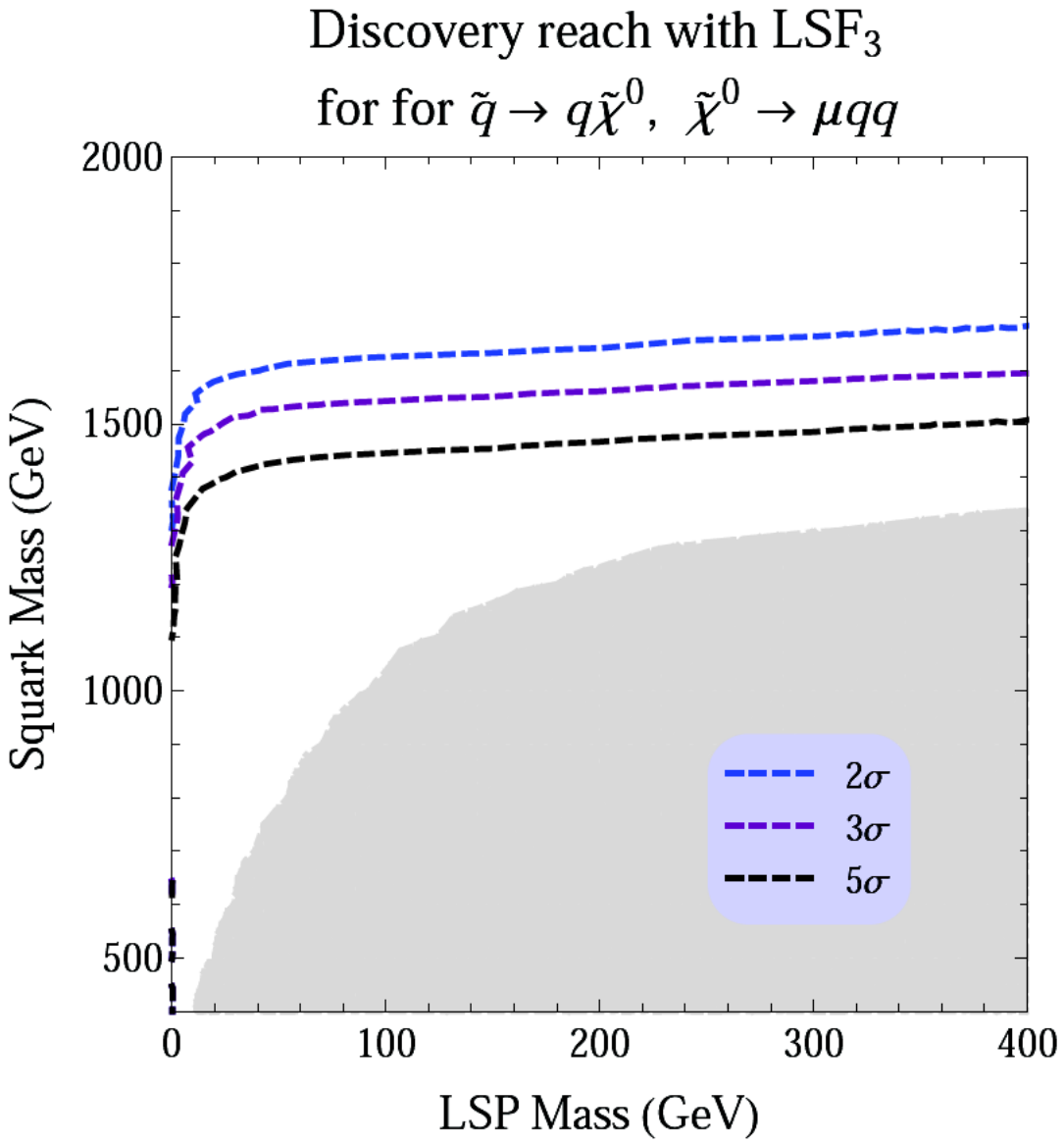




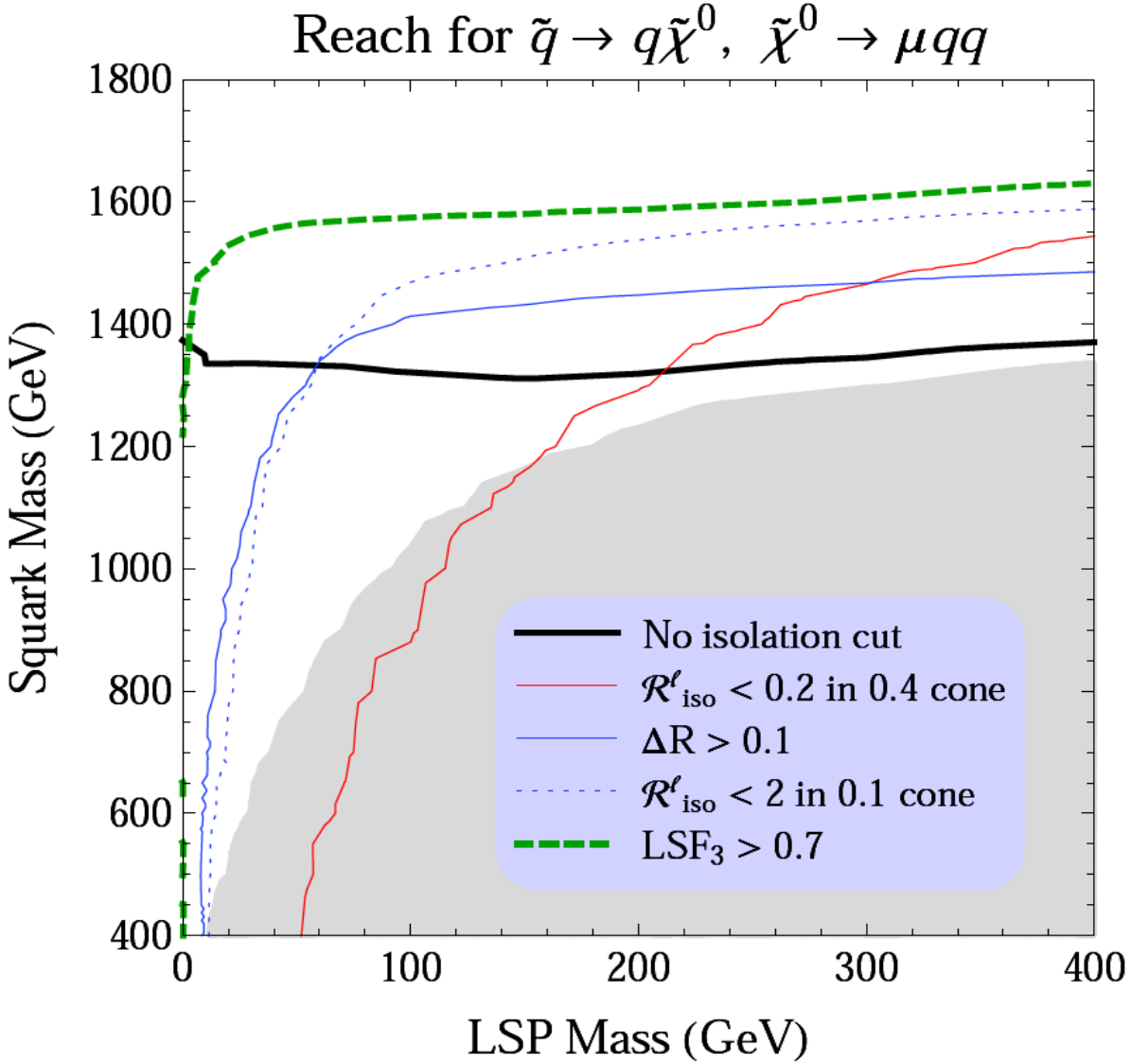
Our Proposed Search

- Cut on:
  - Two hardest leptons: $LSF_3 > 0.7$
- ...in addition to...
  - 4+ anti-k_T, R = 0.5 jets with $p_T > 150$ GeV
  - 2+ leptons with $p_T > 40$ GeV (no iso. req.!)
  - $H_T > 850$ GeV with $H_{\mathrm{T}} = \sum_j p_{\mathrm{T}}^j + \sum_\ell p_{\mathrm{T}}^\ell$

Results of Monte Carlo Study



Our Mock Search Compared



Looking Forward

- Results very broad – not model-specific
- The community should:
  - Close gaps with 8 TeV data
  - Reconsider 13 TeV lepton triggers
  - Search for more refined discriminants of signal vs leptonic tops
  - Hope for the discovery of new physics!

Backup Slides

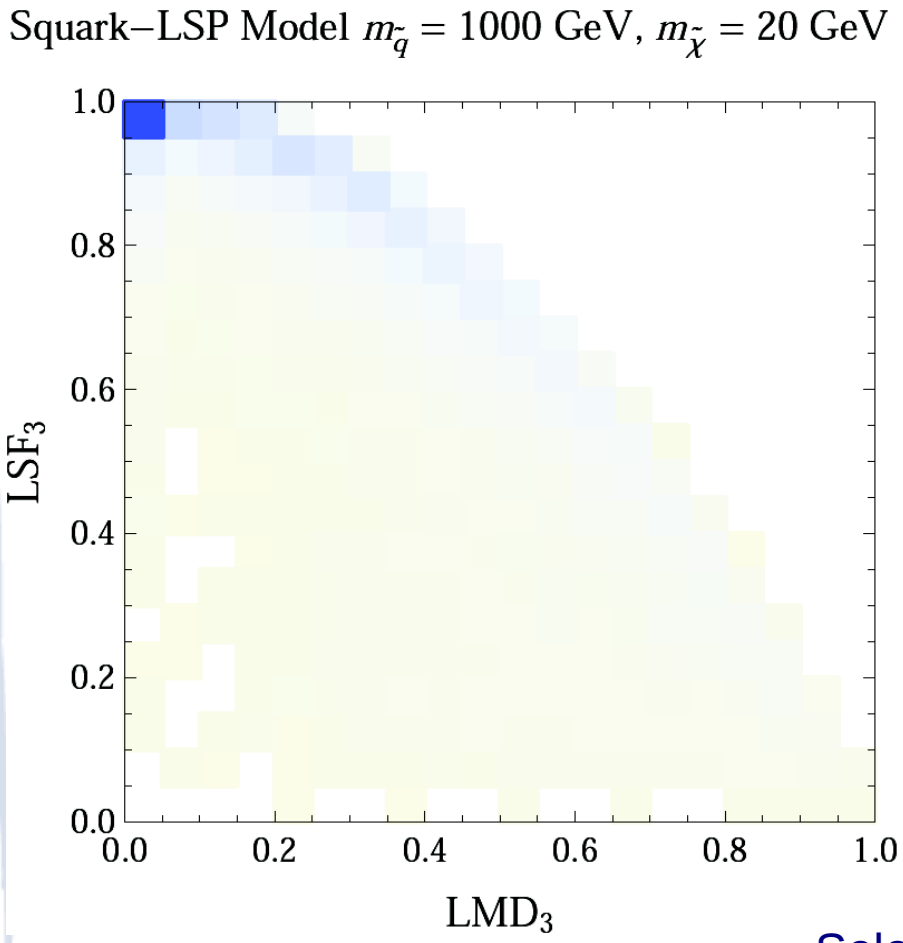
Lepton Mass Drop

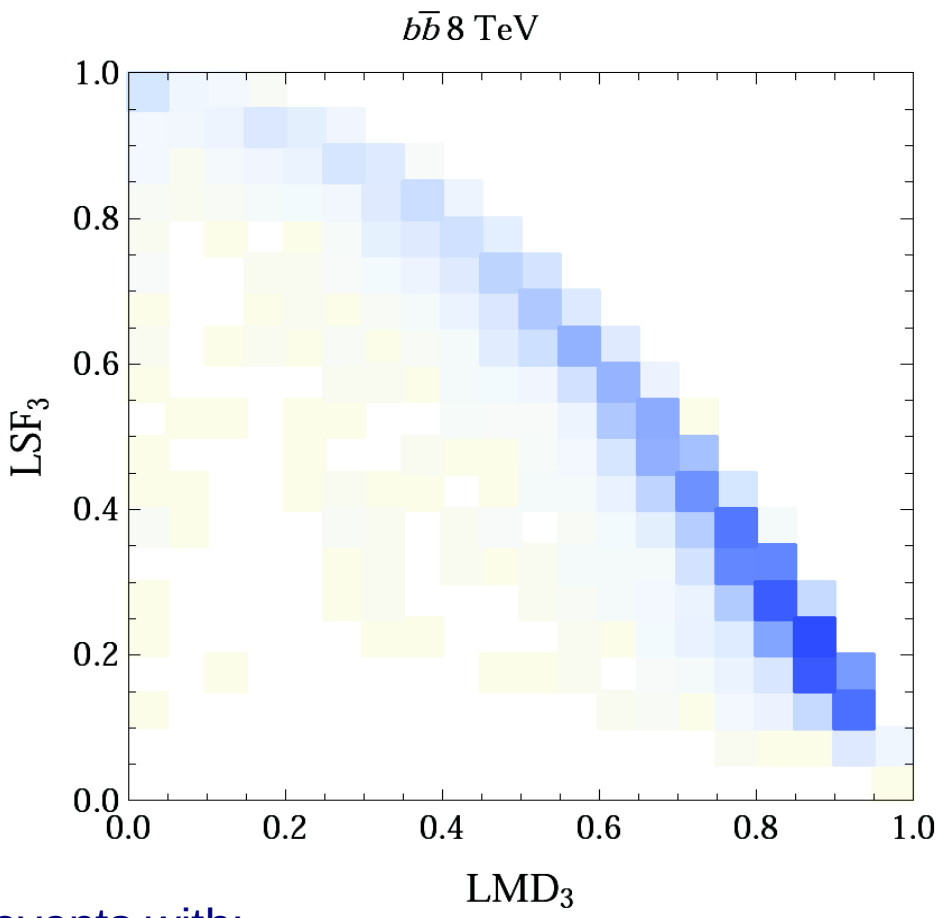
- Cluster into C/A R = 0.8 fat jets
- Recluster constituents with exclusive k_T into n subjets
- Lepton mass drop defined as mass of hadronic constituents of subjet over mass of entire subjet (including the hard lepton)

$$\mathrm{LMD} = \frac{m_{sj-\ell}}{m_{sj}}$$

- Highly correlated with LSF in large-boost limit

LMD vs LSF_3



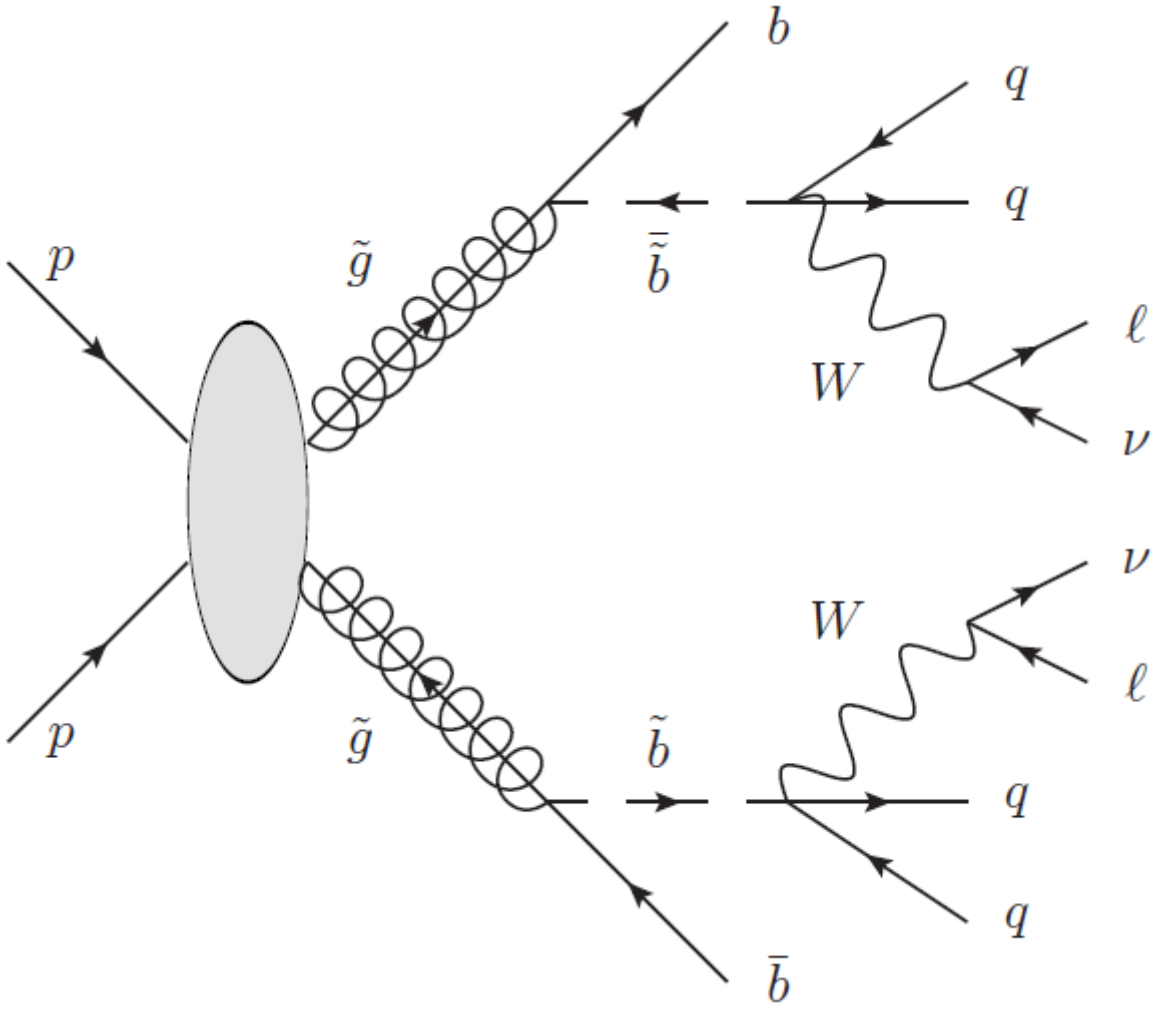


Select events with:

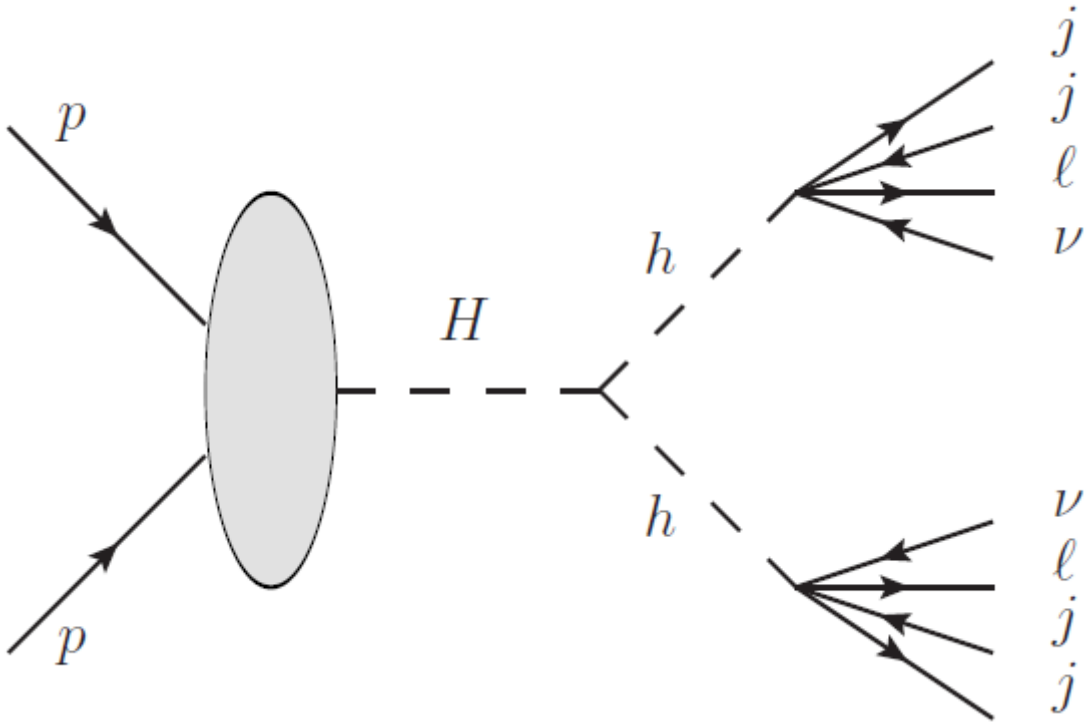
2+ jets, p_T > 150 GeV

1+ lepton, p_T > 40 GeV

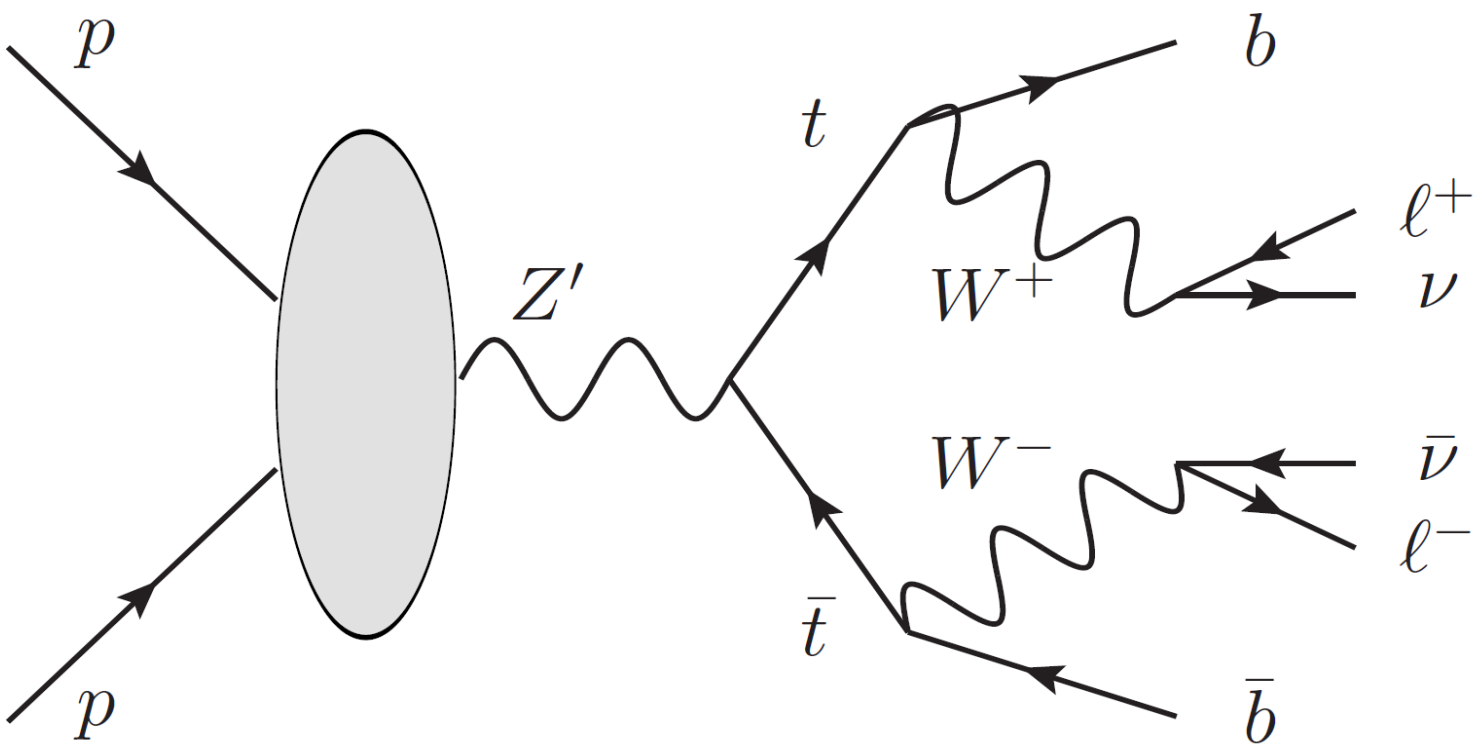
Other Topologies



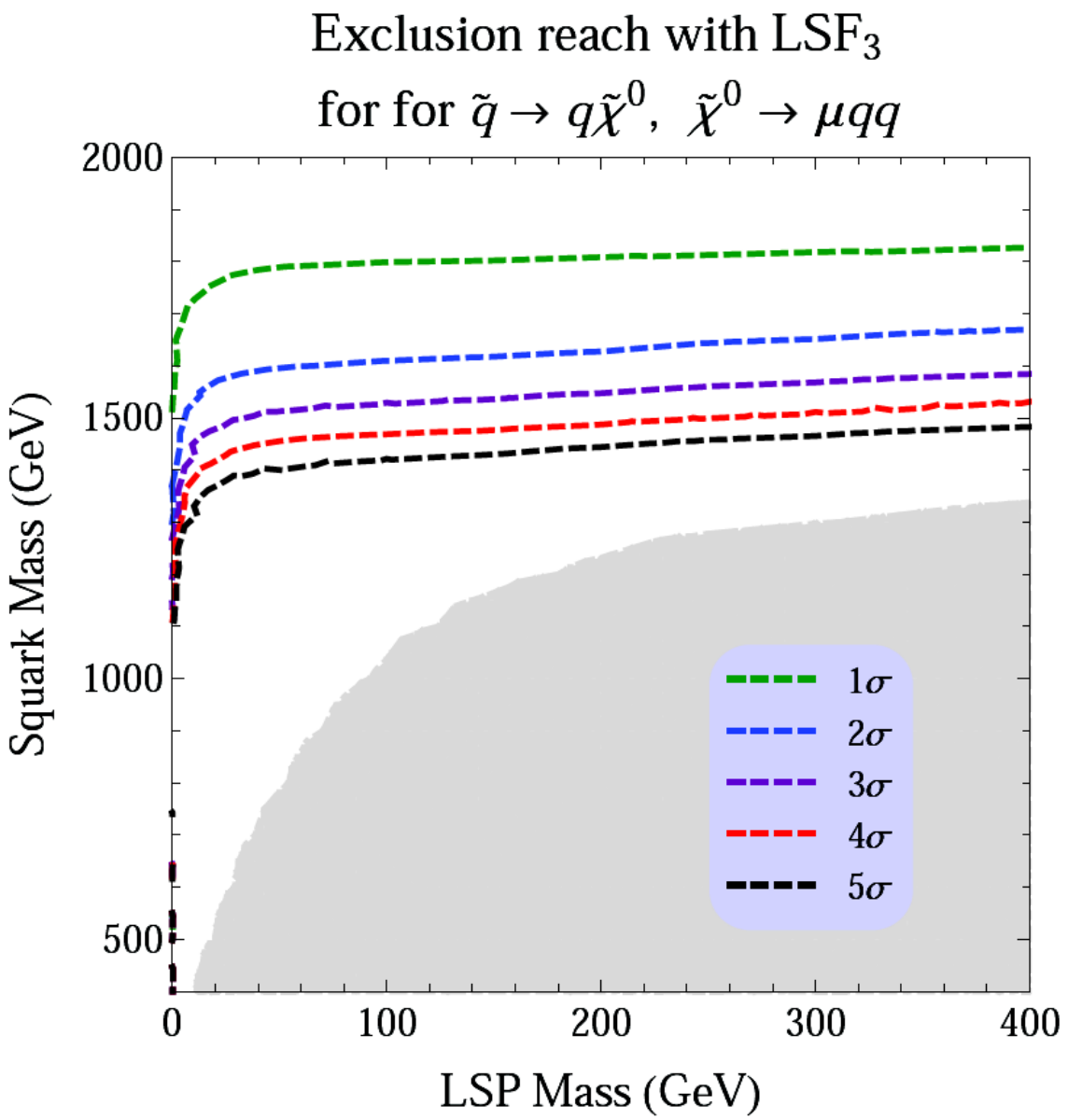
Other Topologies



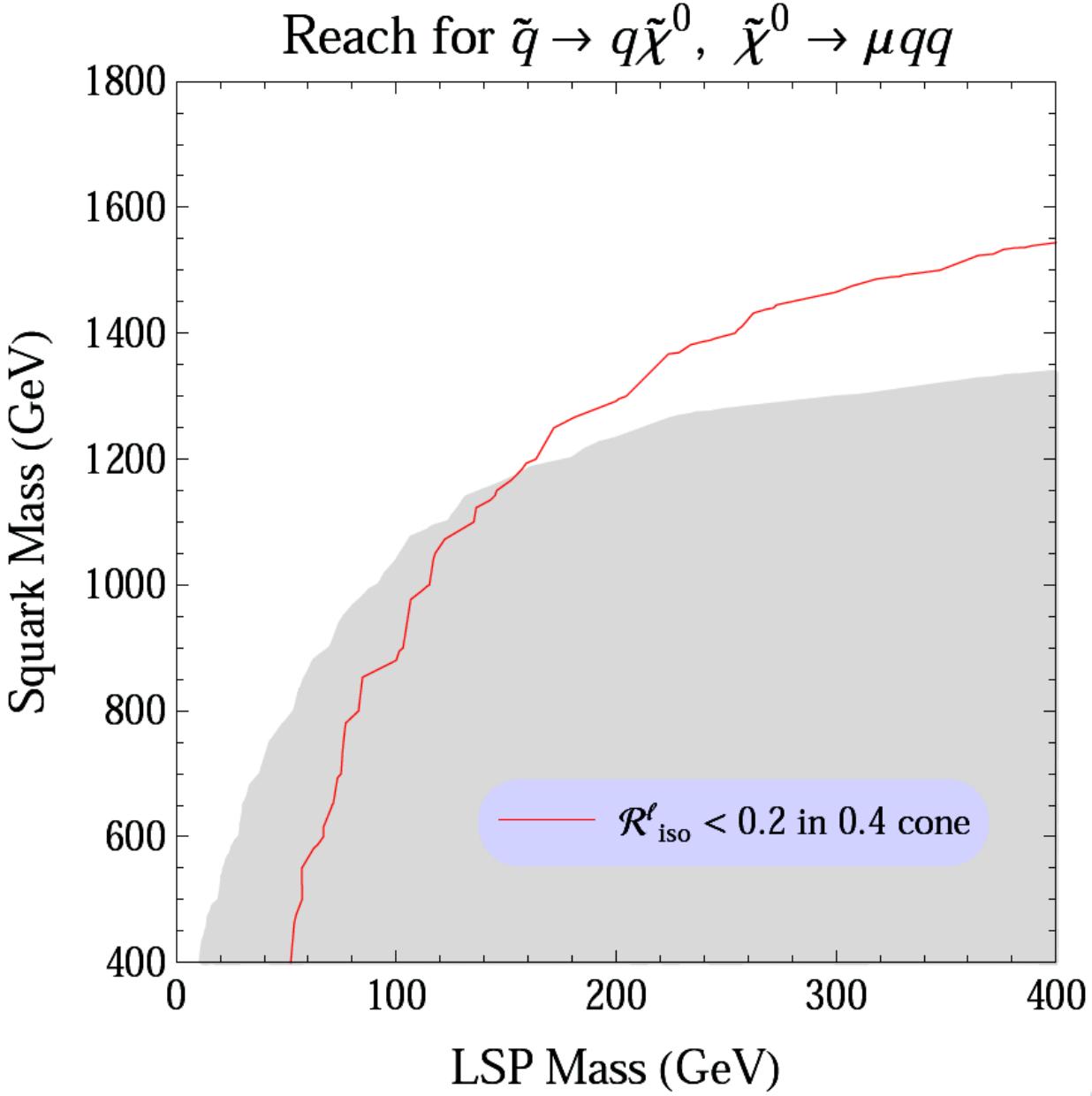
Other Topologies



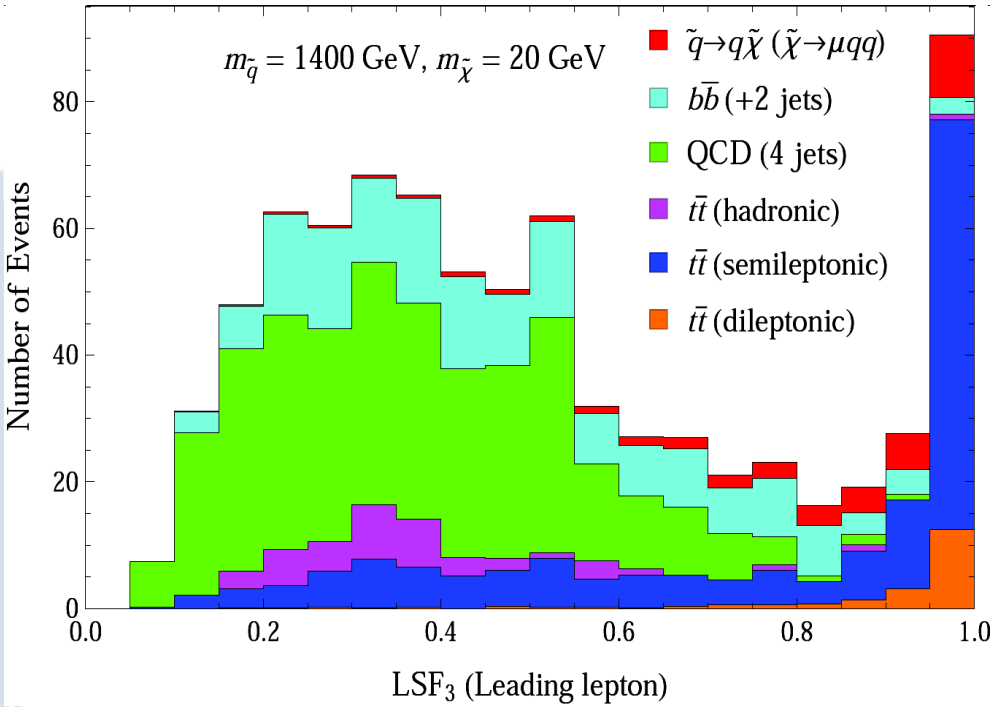
Exclusion Reach With Mock Search

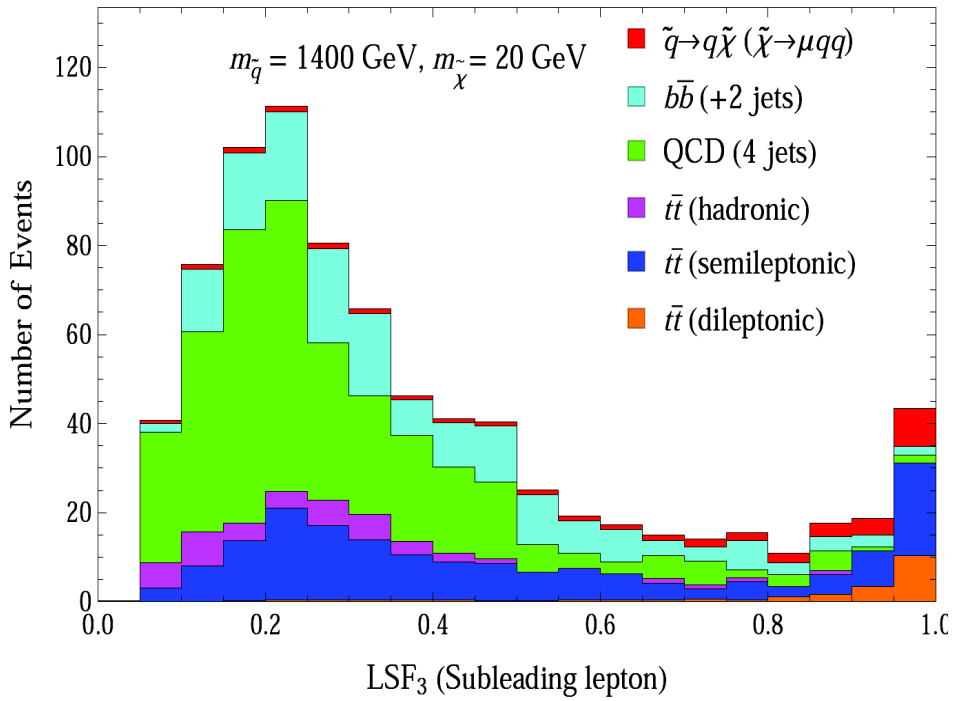


Optimizing Relative Isolation Cut?

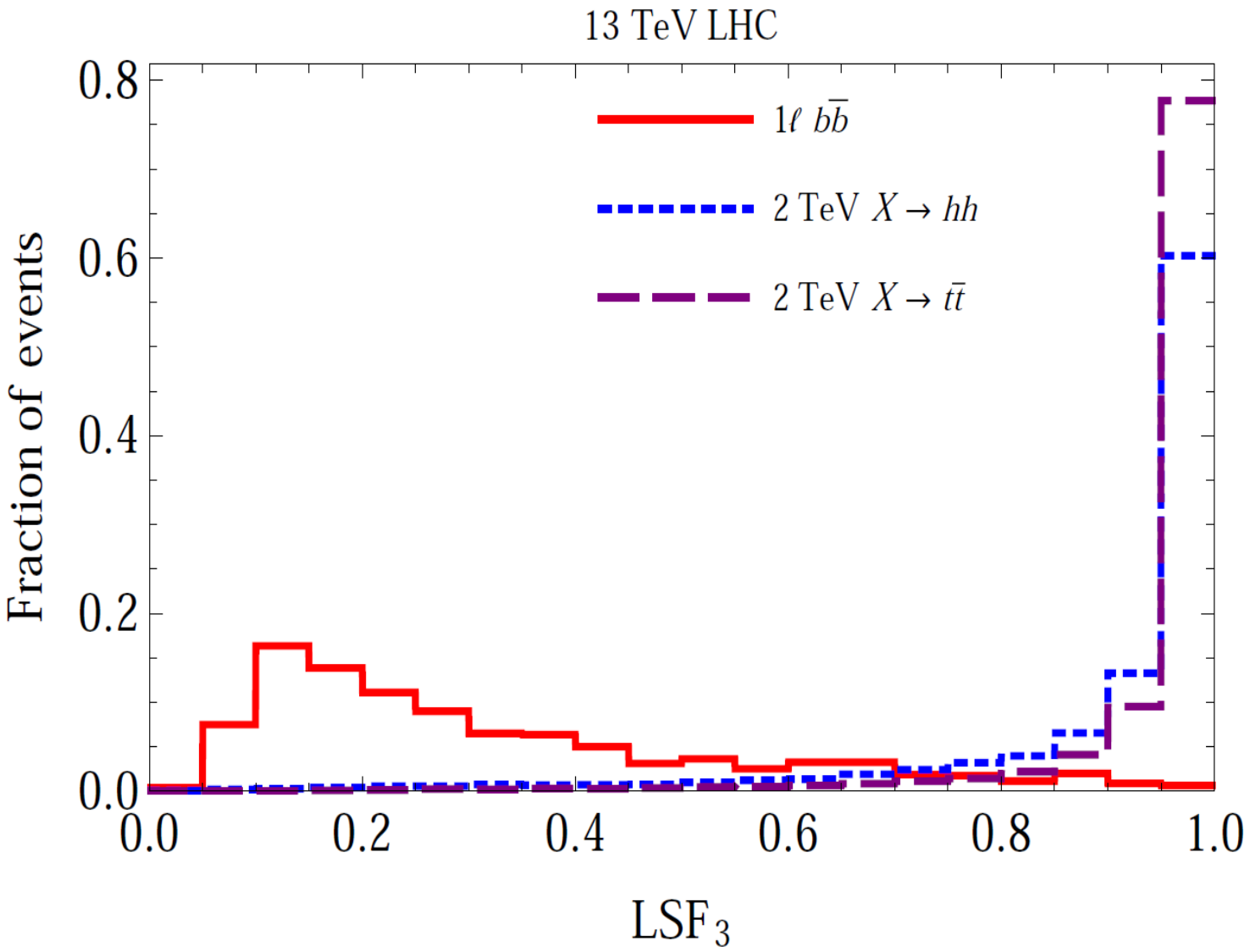


LSF_3 of Hardest & 2nd Hardest Leptons

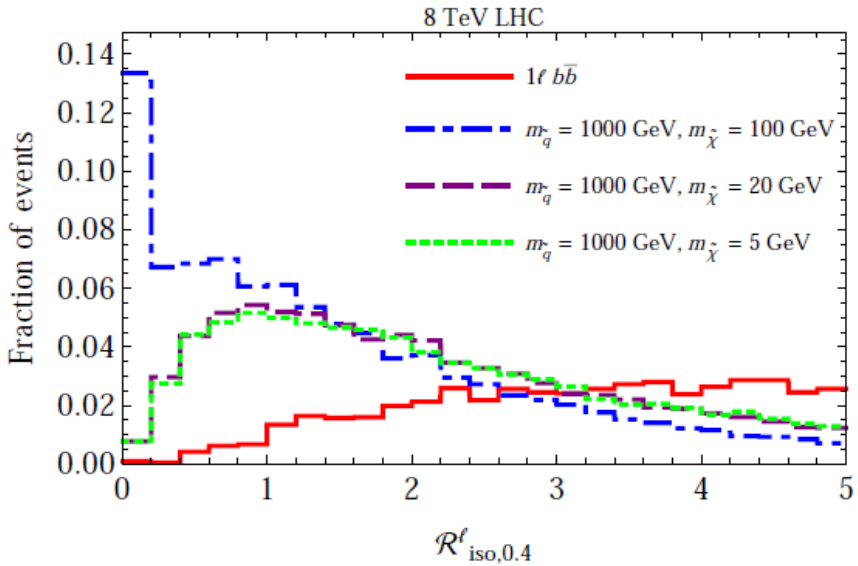


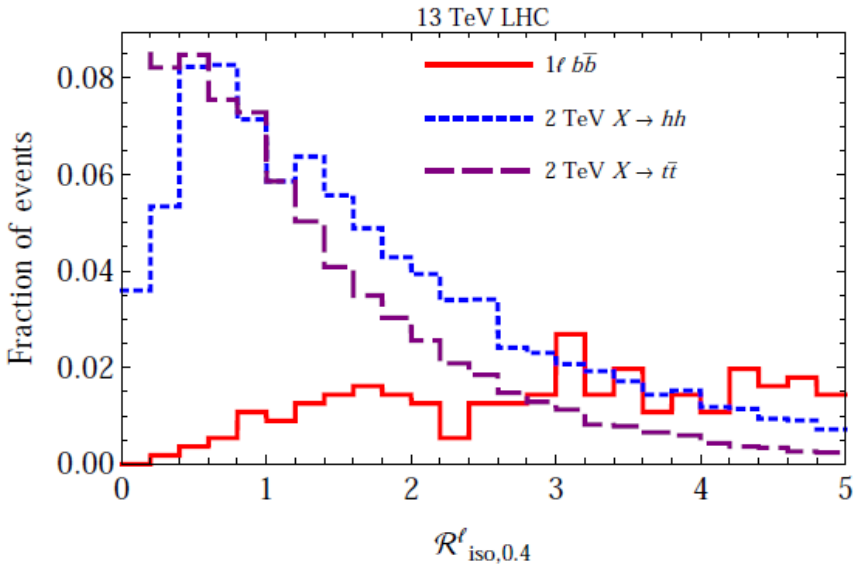


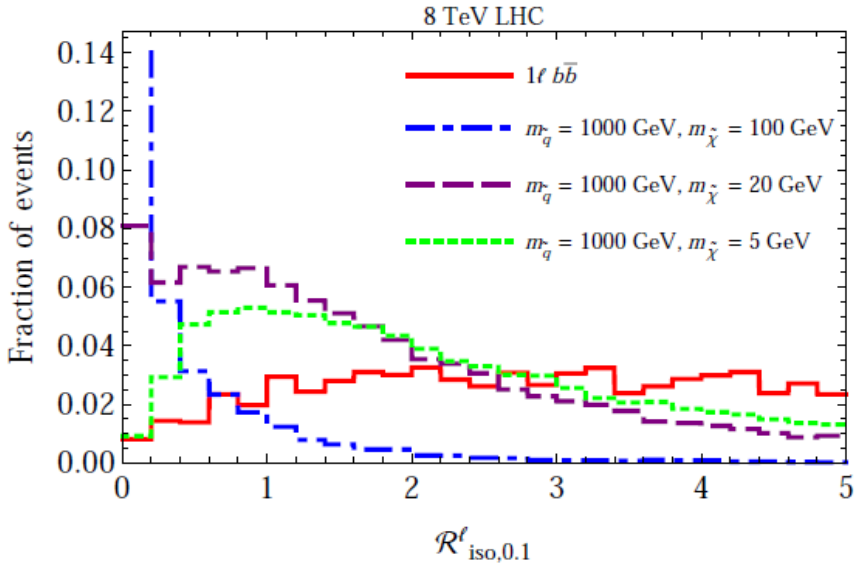
LSF for Other Models @ 13 TeV

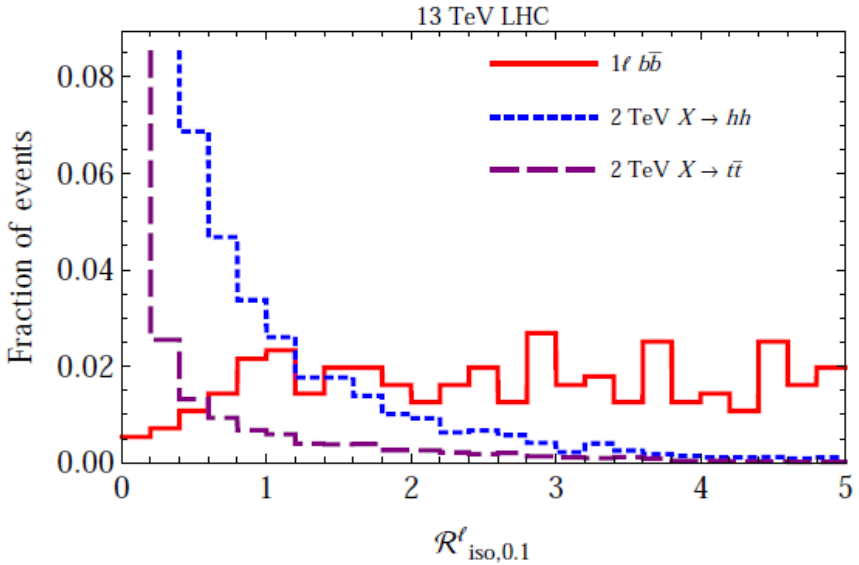


Relative Isolation in $R_{cone} = 0.1$

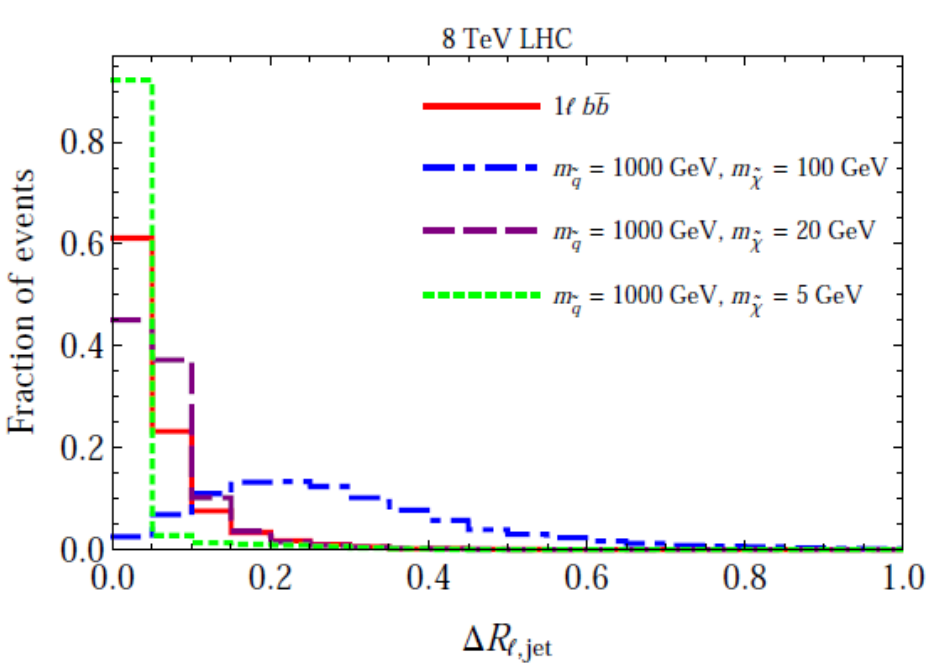


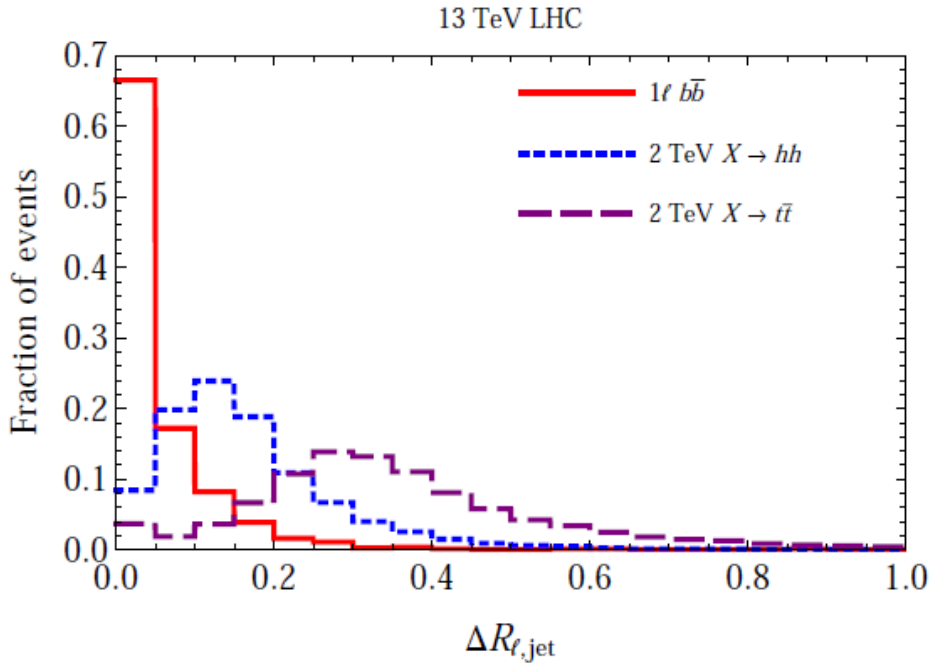




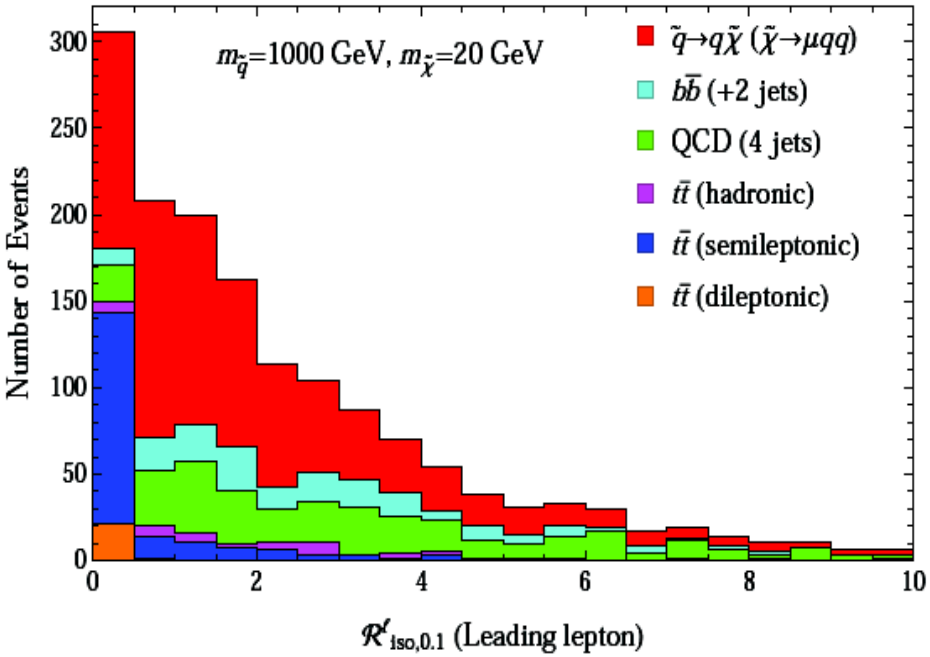


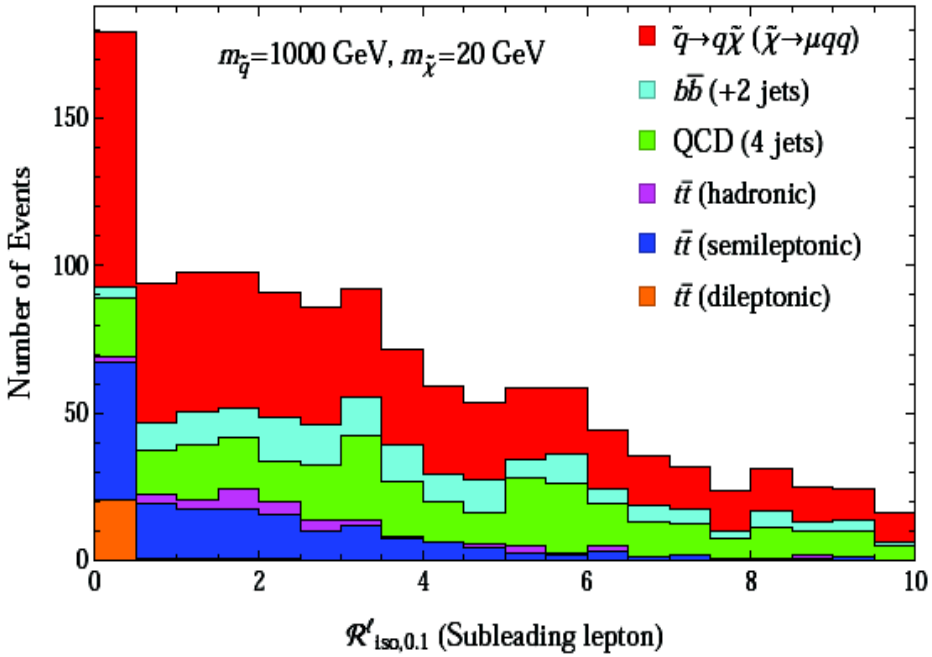
Clustering Jets Without Leptons



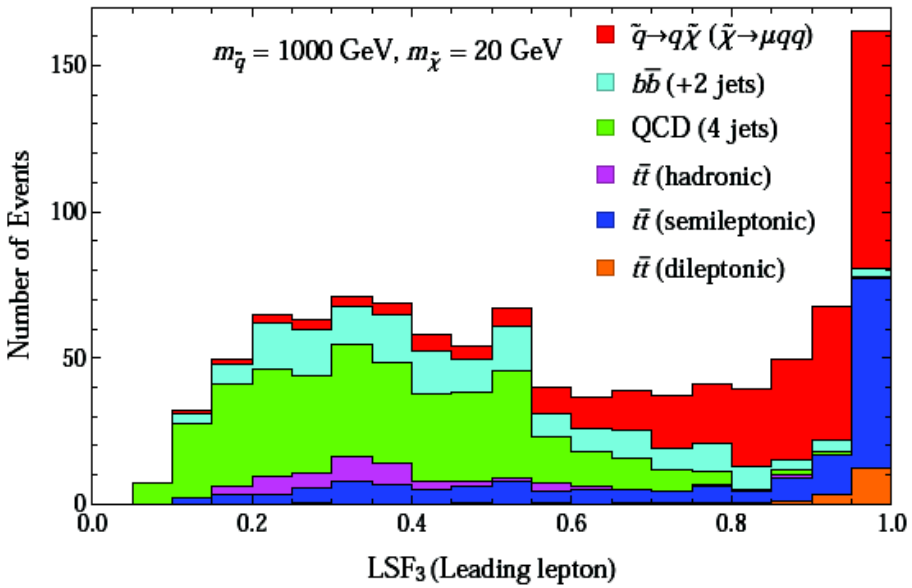


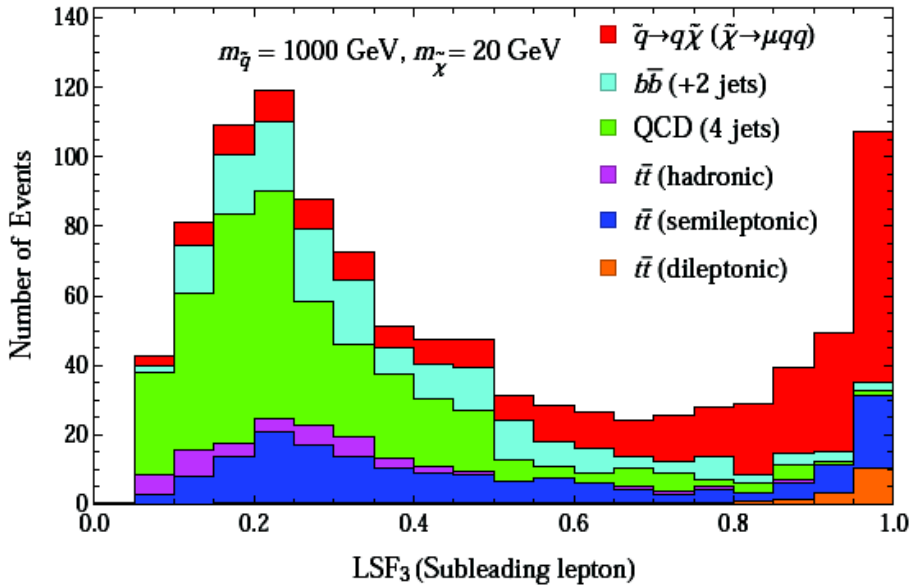
Relative Isolation with 1 TeV Squarks





LSF_3 of Hardest & 2nd Hardest Leptons





Highest LSF_3 vs 2nd Highest LSF_3