Discovering New Physics With Non-Isolated Leptons

Chris Brust
Johns Hopkins University
University of Maryland
Perimeter Institute

arXiv:1409.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 Petar Maksimovic, Alice Sady, Prashant Saraswat, Matthew T. Walters, and Yongjie Xin

Sept. 15th
University of Toronto

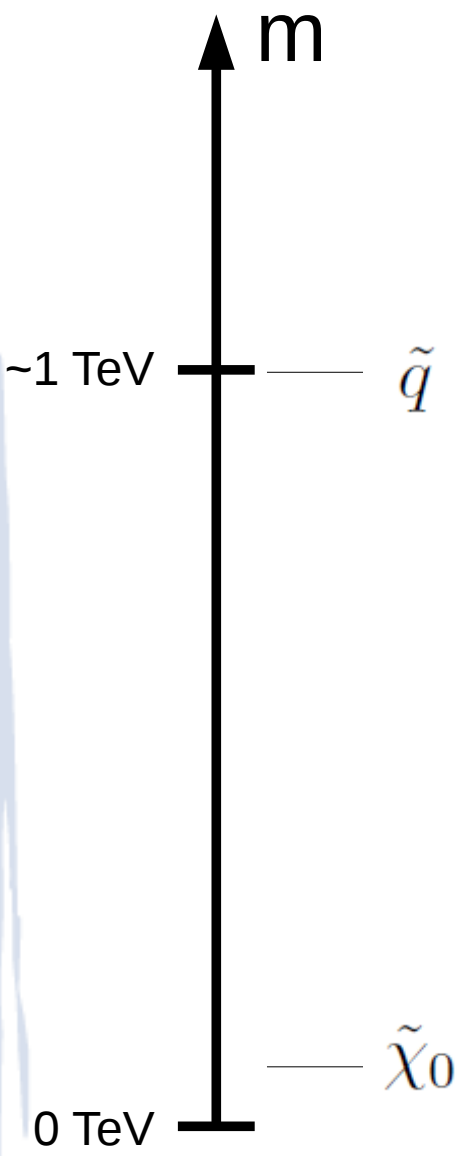
Relative Isolation

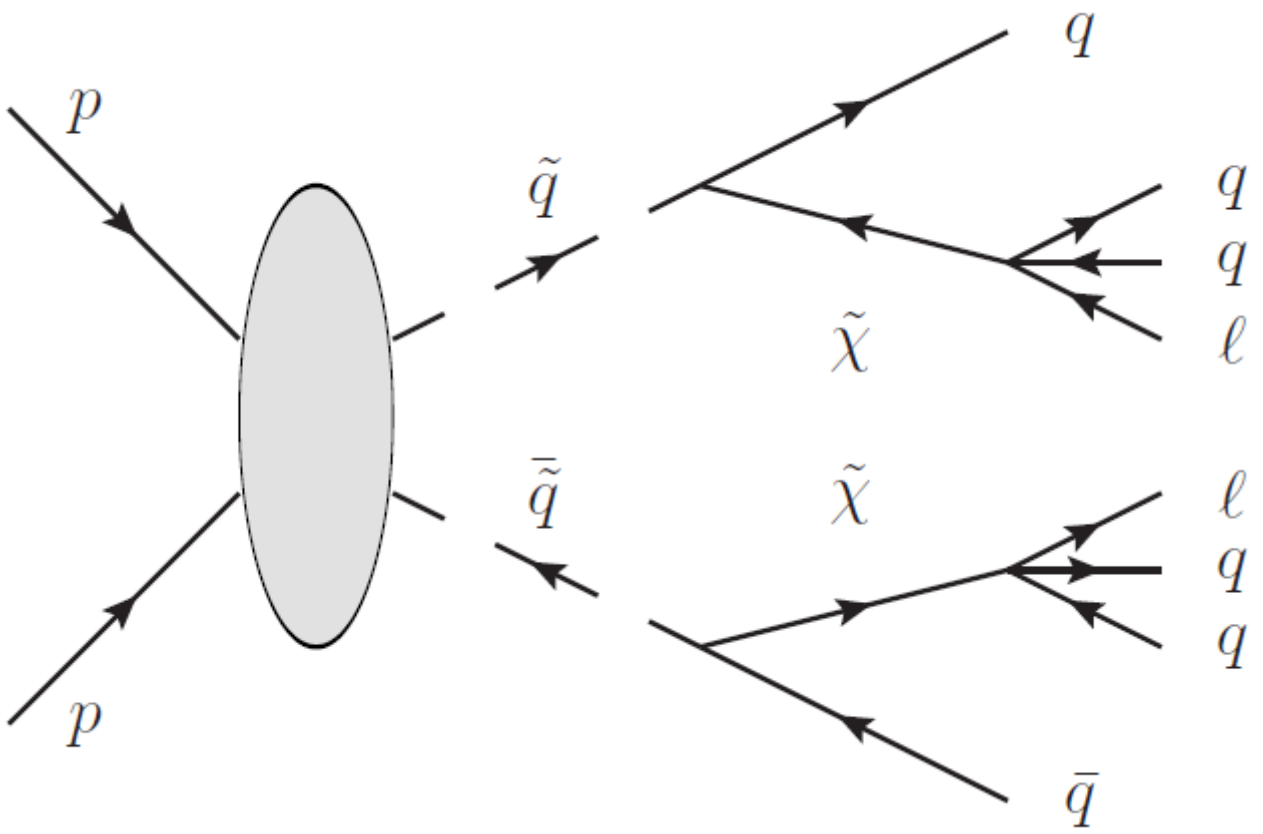
Sum over cone of radius R_{cone}

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

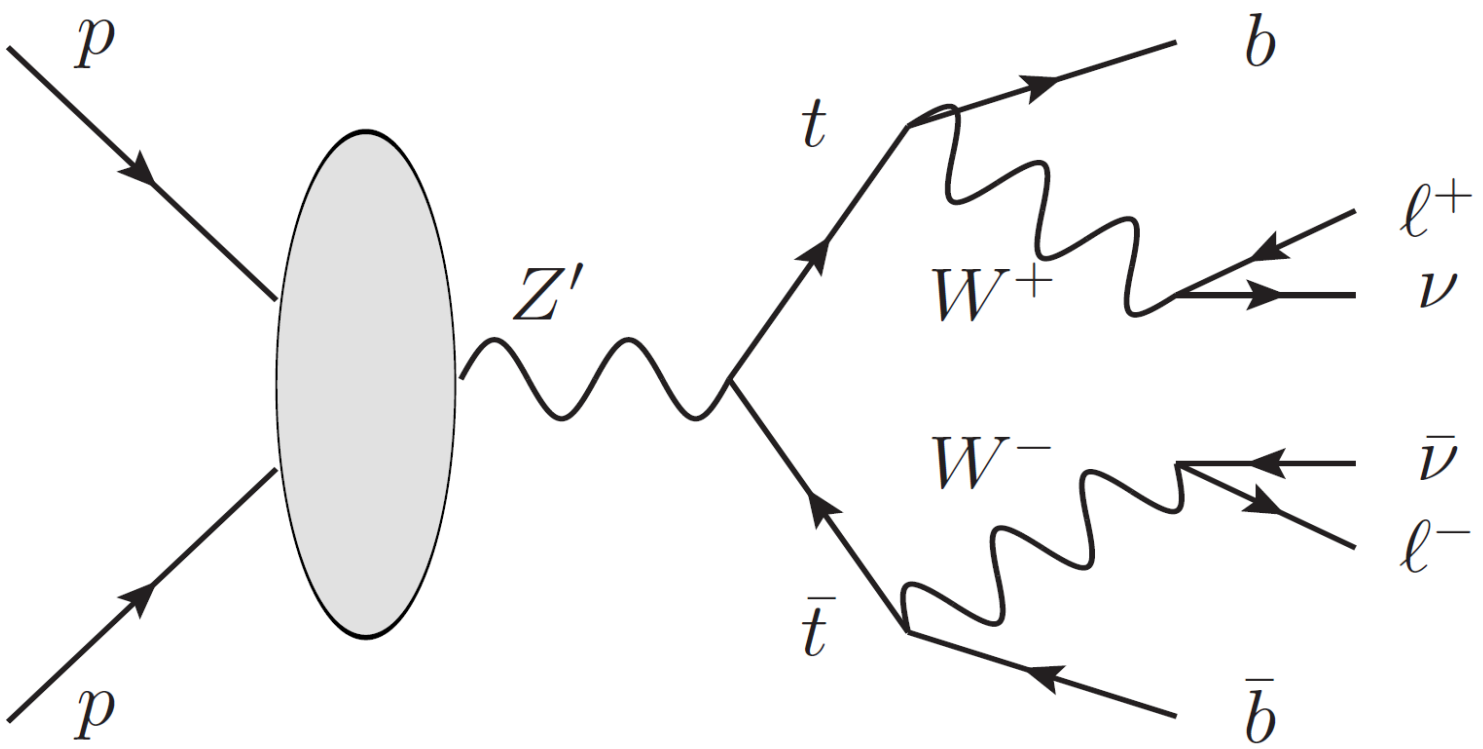
Discards non-isolated leptons

Example of Missed Signal

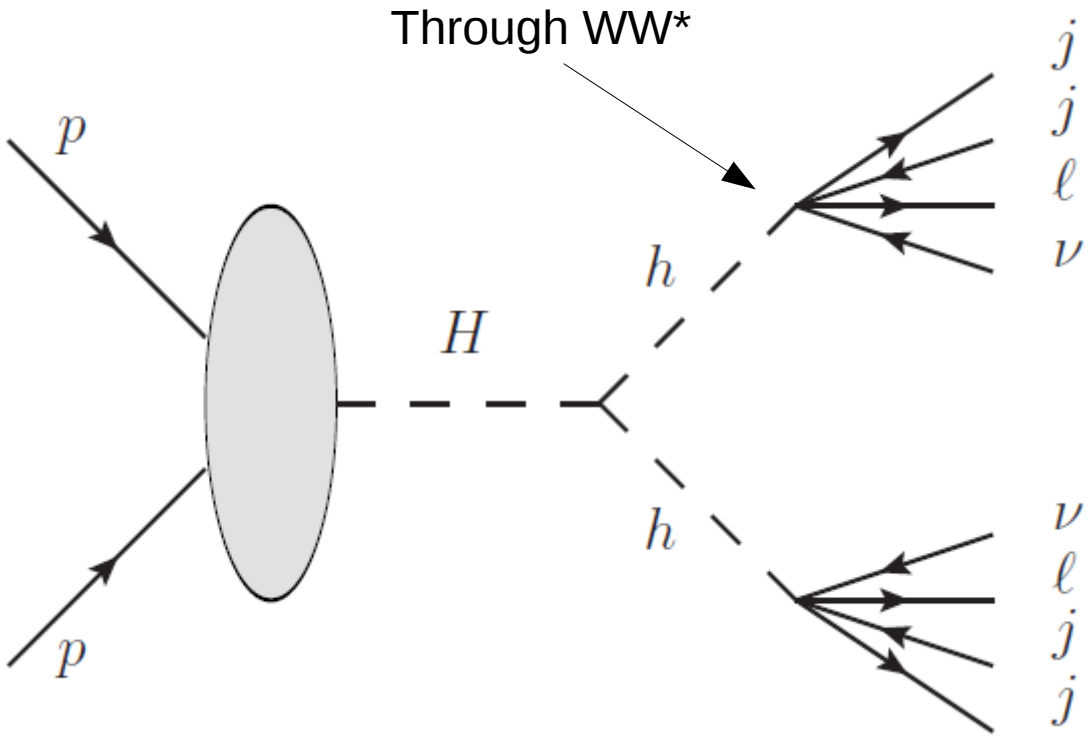




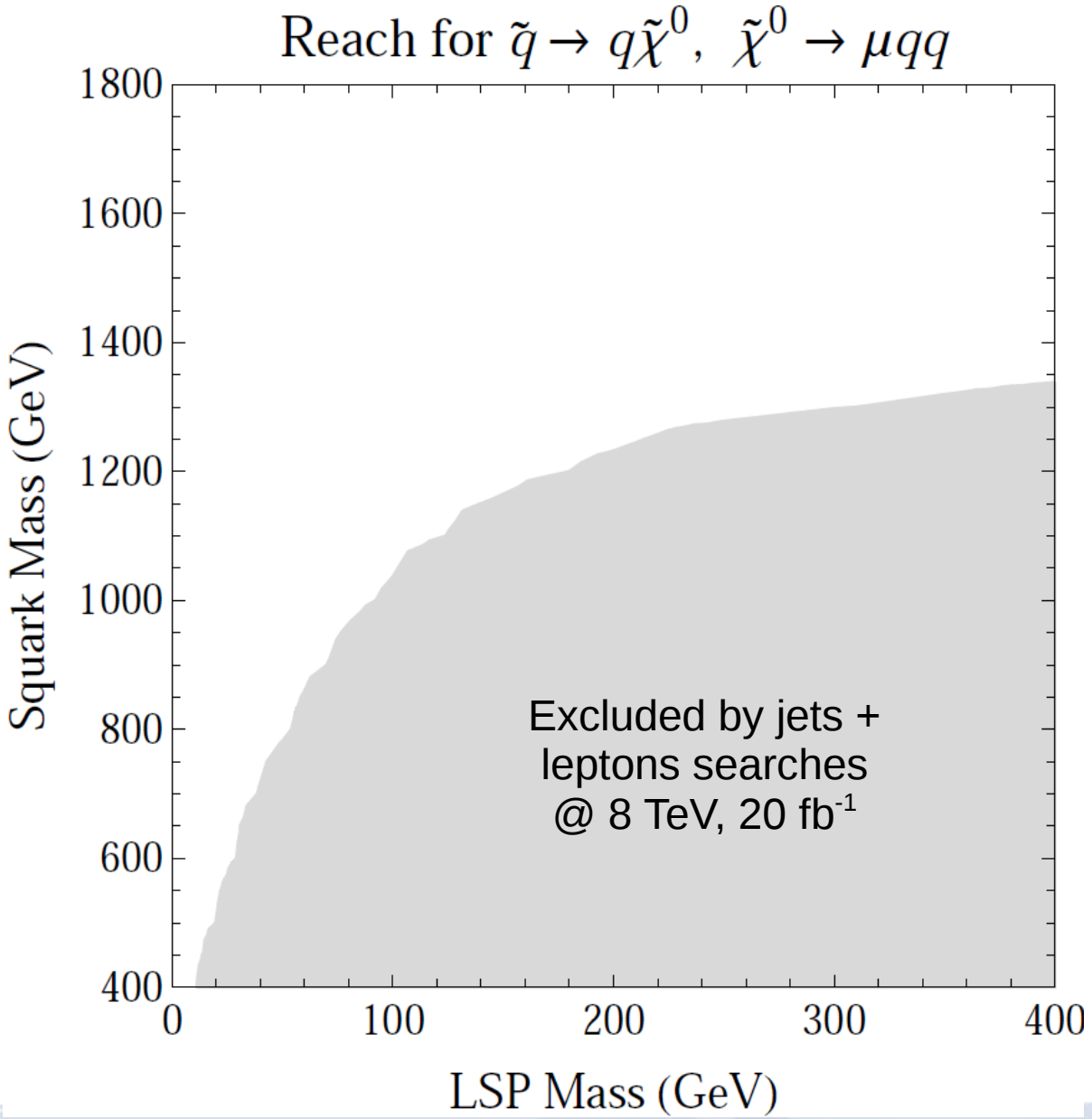
Other Topologies



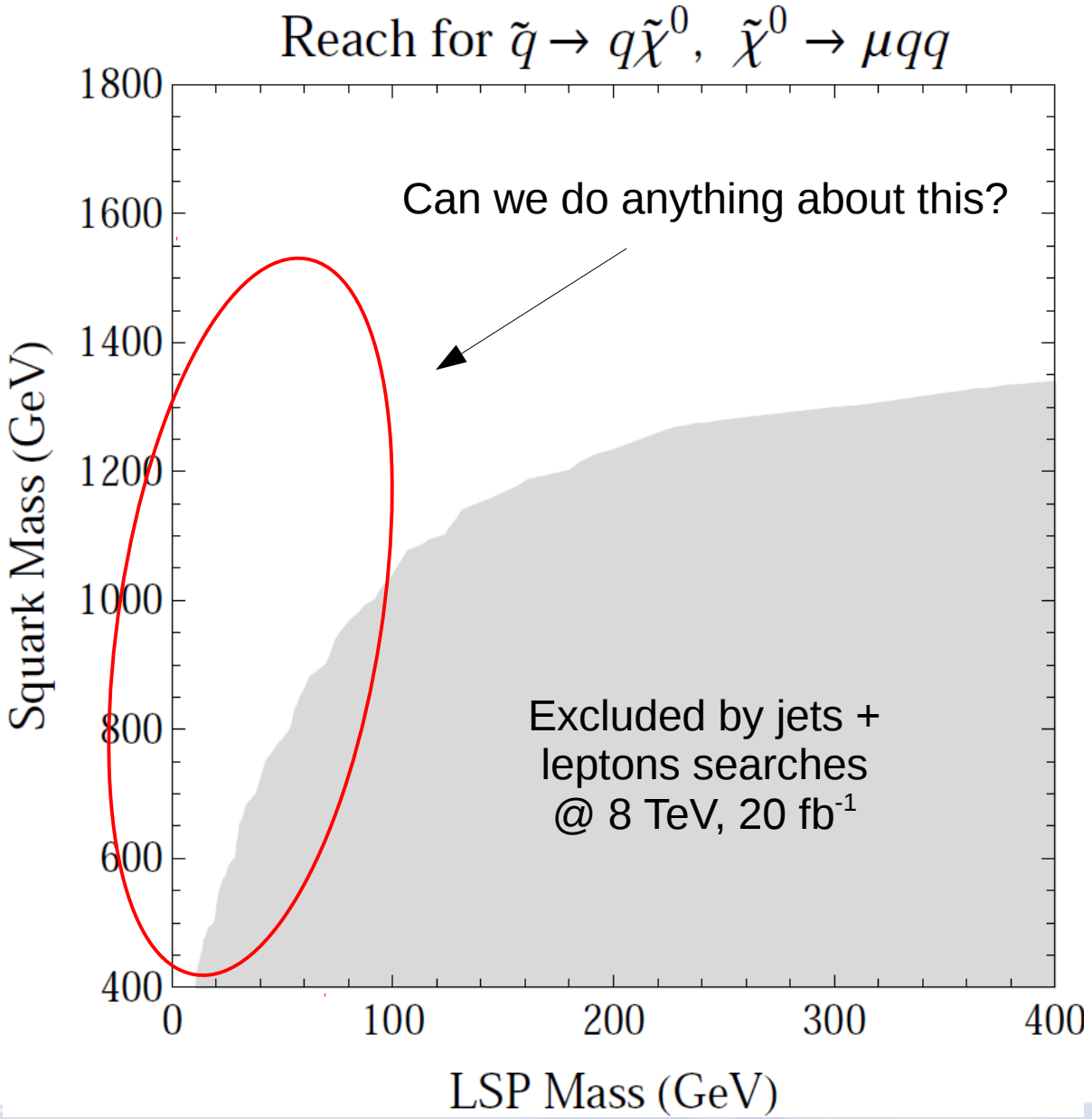
Other Topologies



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

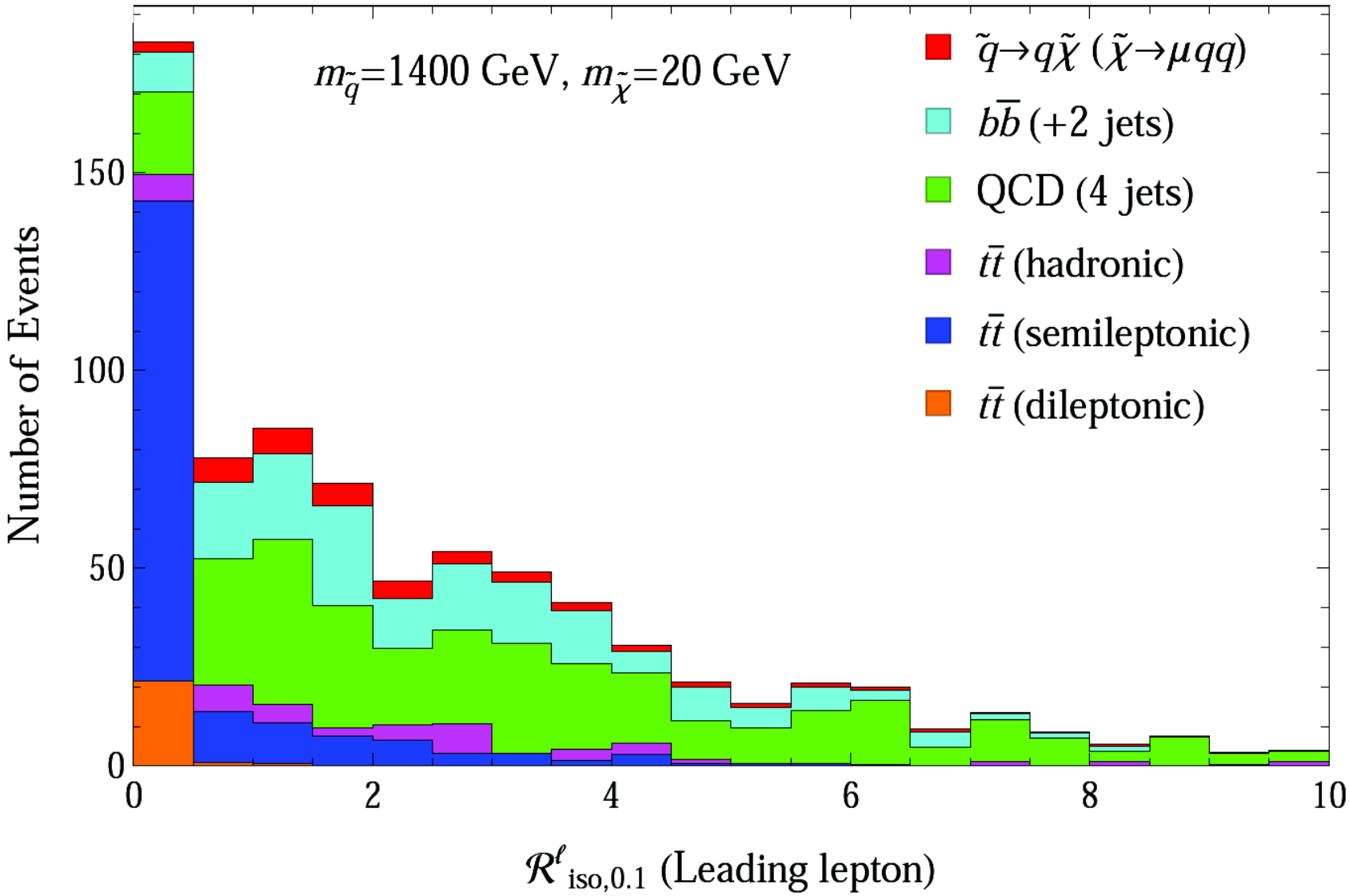
Our Goals

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

Cutting Hard on Hadronic Activity

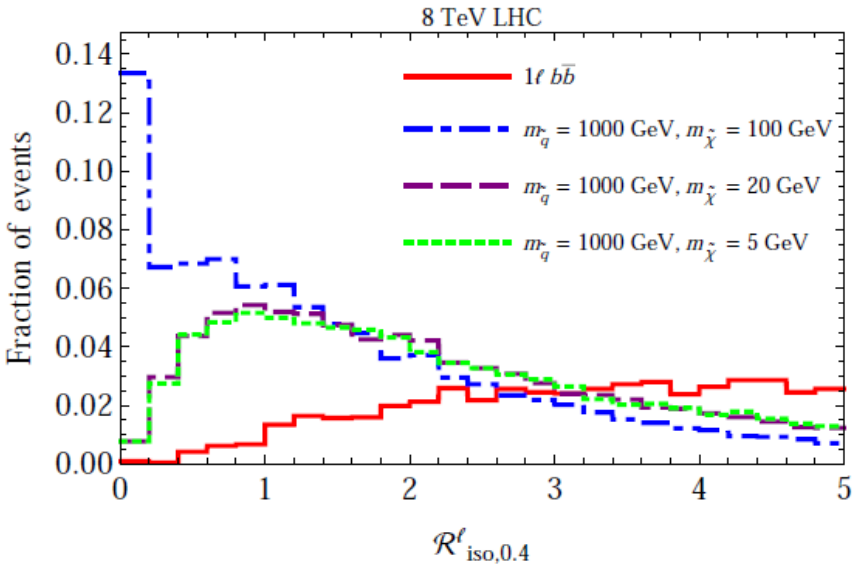
- 8 TeV relative isolation study
- Demand:
  - 4+ anti-k_T, R = 0.5 jets with p_T > 150 GeV
  - H_T > 850 GeV with $H_{\mathrm{T}} = \sum_j p_{\mathrm{T}}^j + \sum_\ell p_{\mathrm{T}}^\ell$
  - 2+ leptons with p_T > 40 GeV (no iso. req.!)

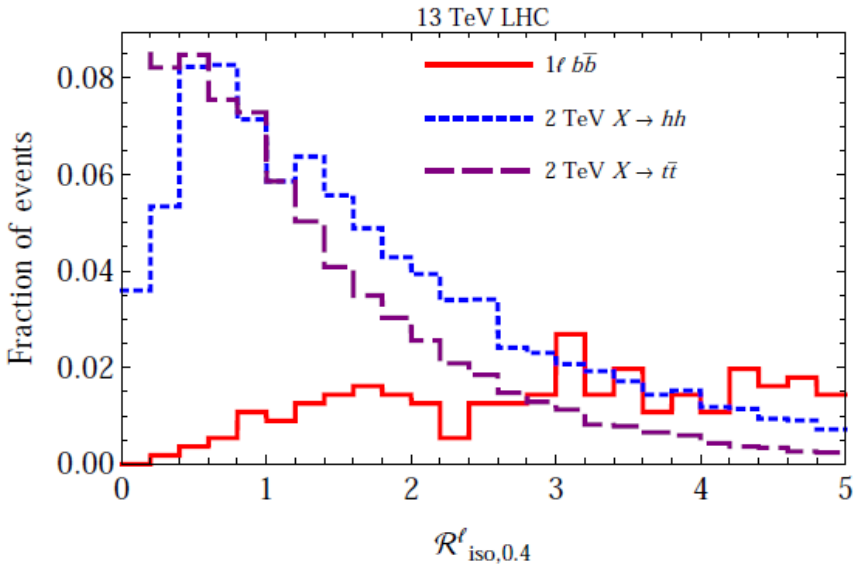
Relative Isolation of Hardest Lepton

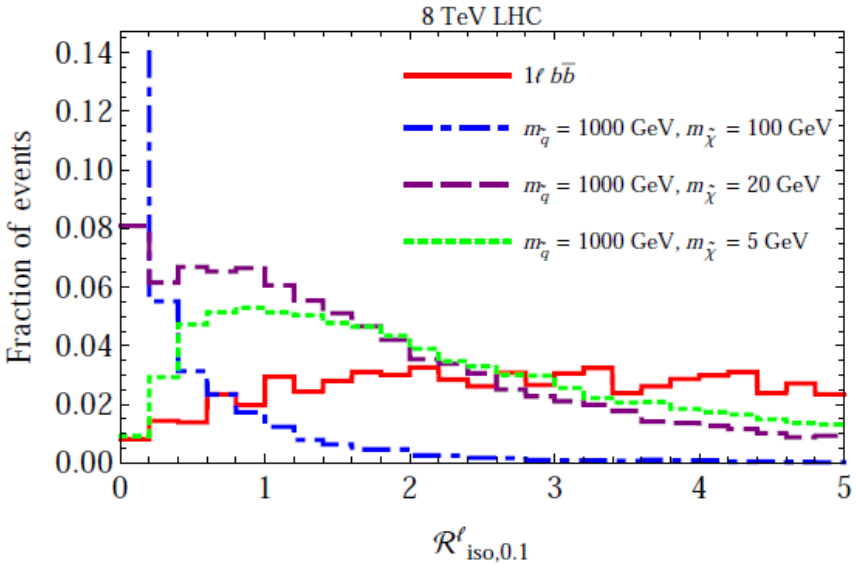


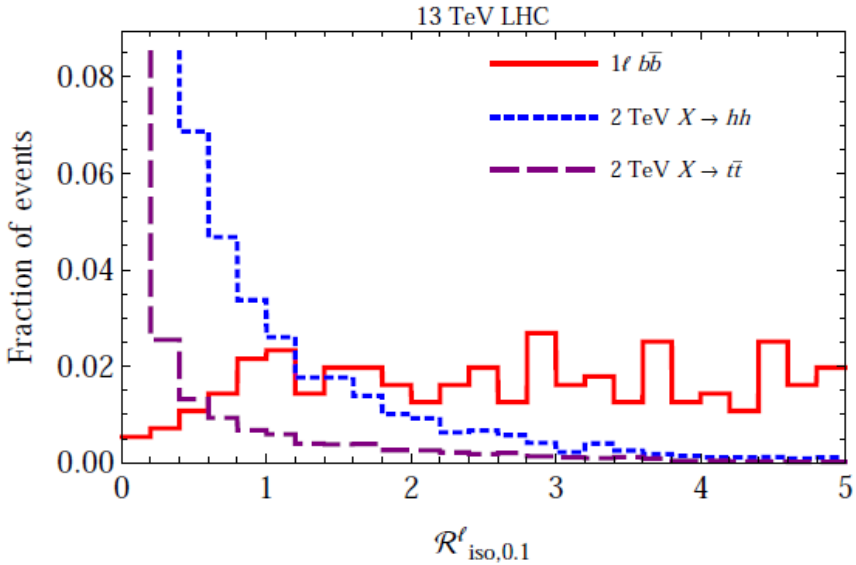
Plot is stacked

Relative Isolation in R_{cone} = 0.1, 0.4

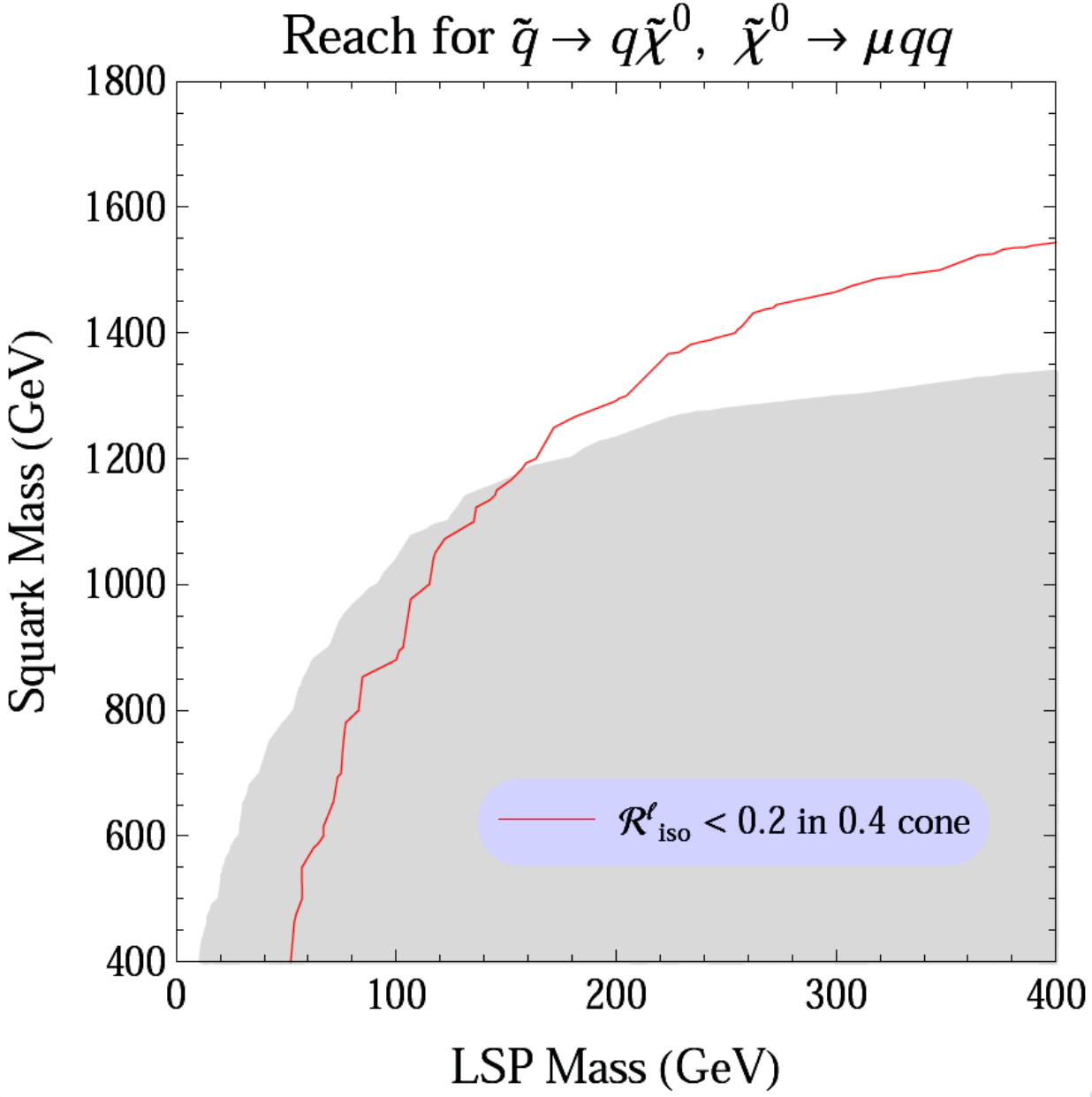






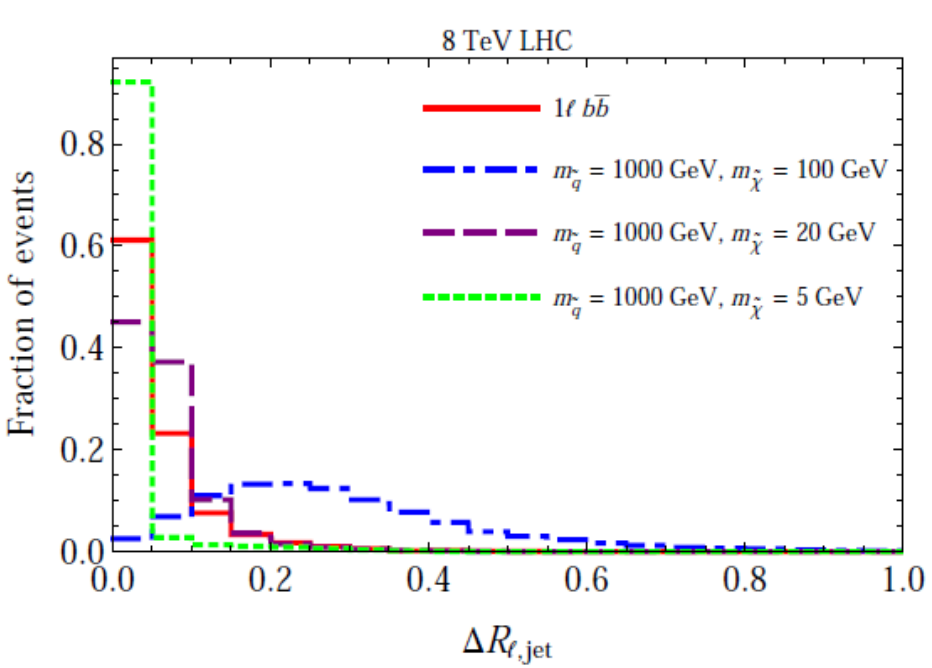


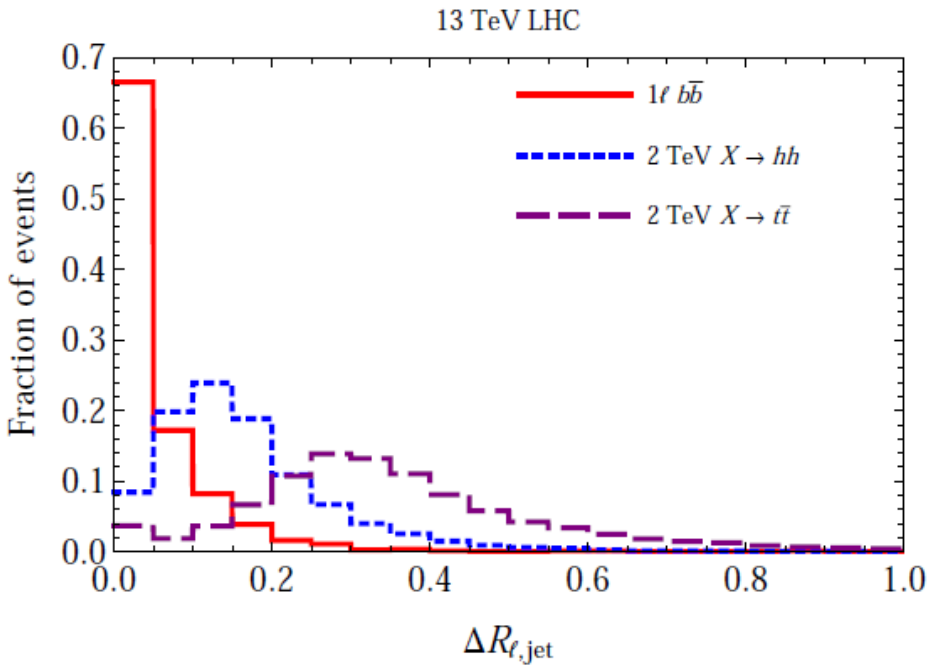
Optimizing Relative Isolation Cut?



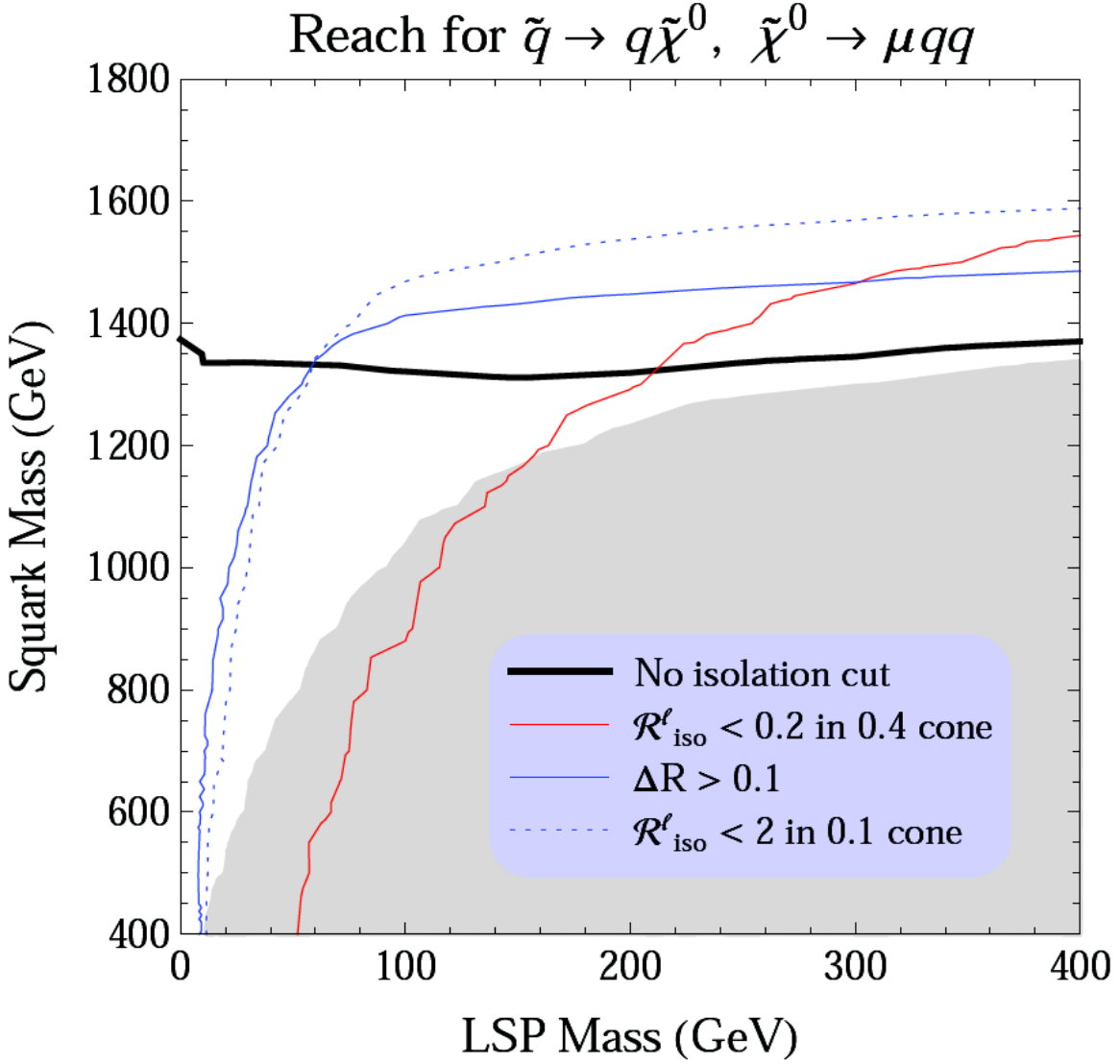
Clustering Jets Without Leptons

- Recluster event *without* clustering leptons that fail isolation
- R between hardest lepton and its nearest jet





Other Possibilities



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 $\mathrm{LSF} = \frac{p_{T,\ell}}{p_{T,subjet}}$

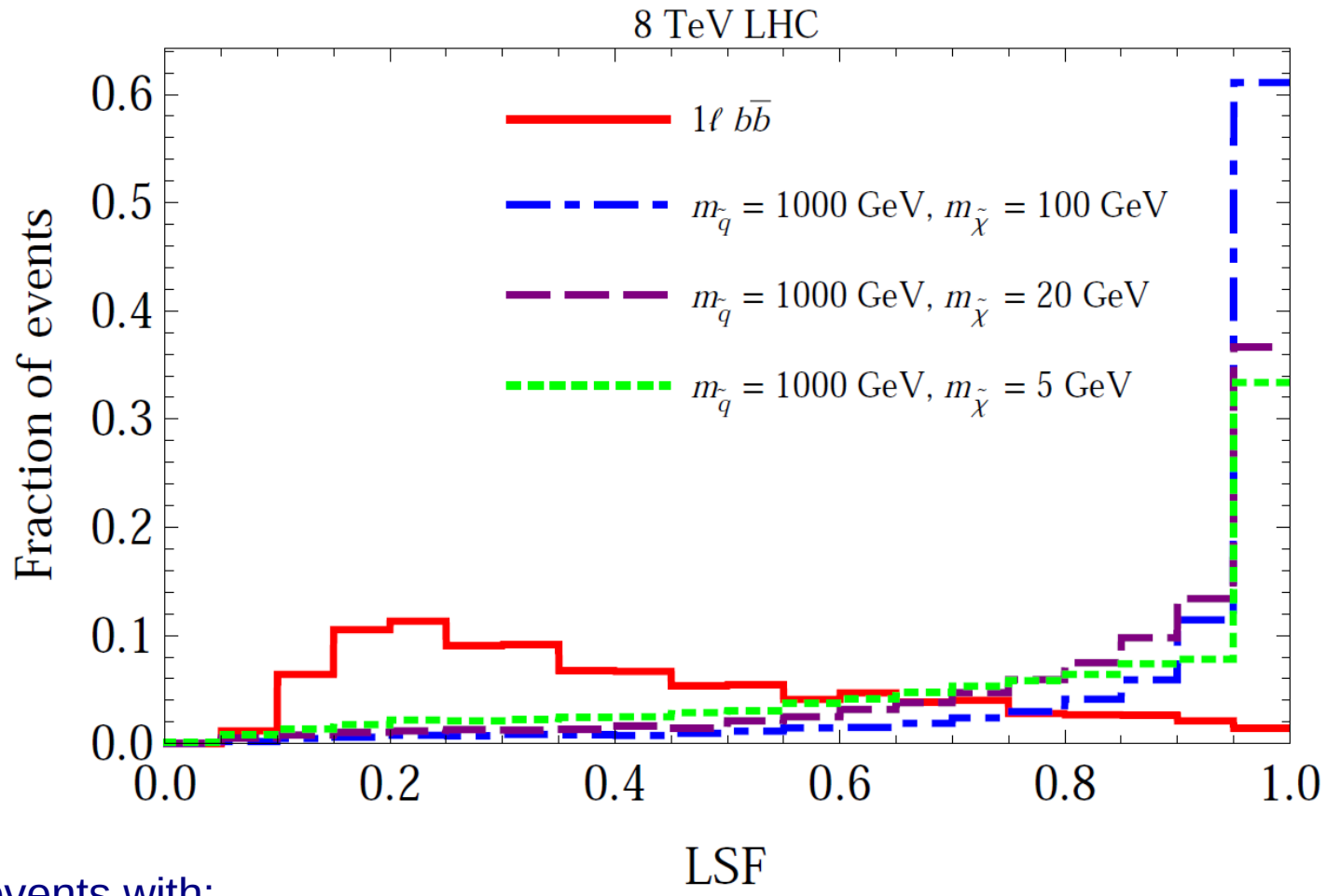
Exclusive k_T Clustering

- Cluster particles by beginning with pair with lowest distance:

$$d_{ij} = \min(p_{T,i}^2, p_{T,j}^2)\Delta R_{ij}$$

- Cluster until n pseudoparticles remain
- No intrinsic size parameter
- Tends to leave hard-process lepton in its own subjet

Lepton Subjet Fraction (n = 3)

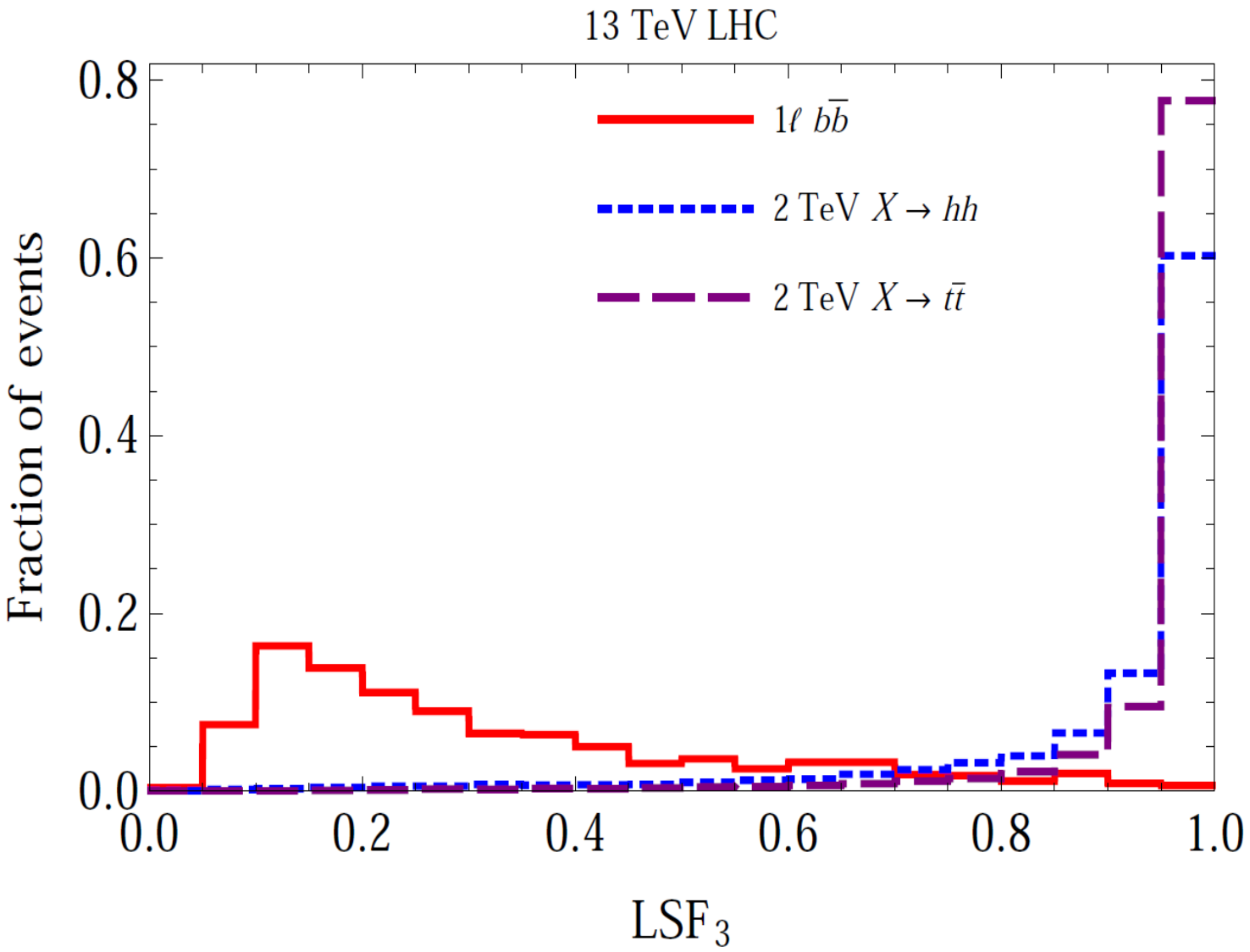


Select events with:

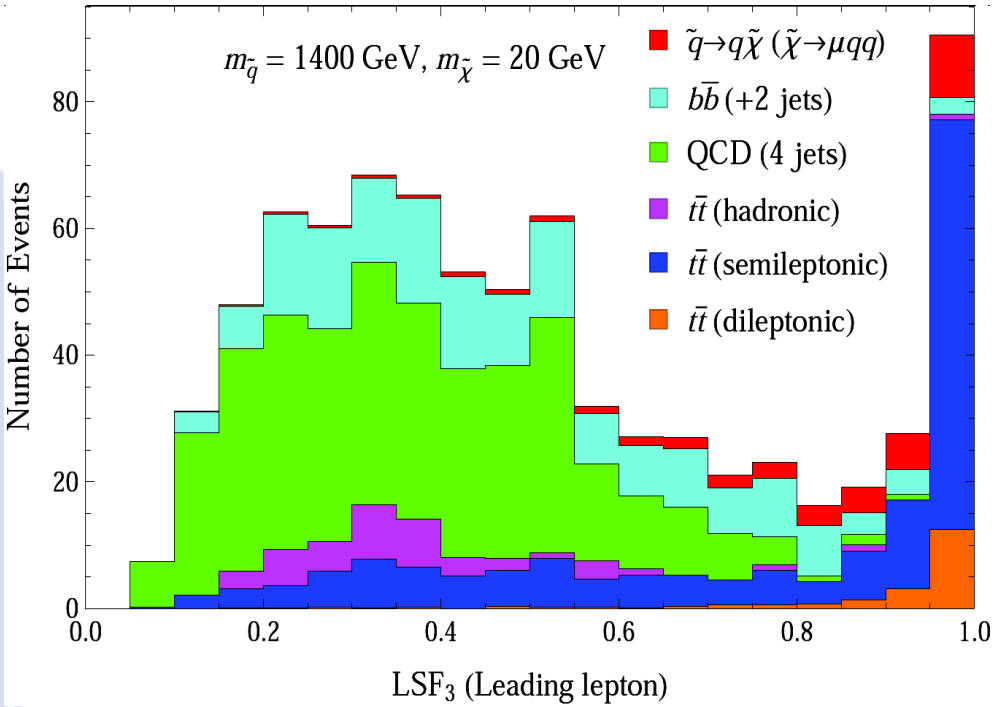
2+ jets, p_T > 150 GeV

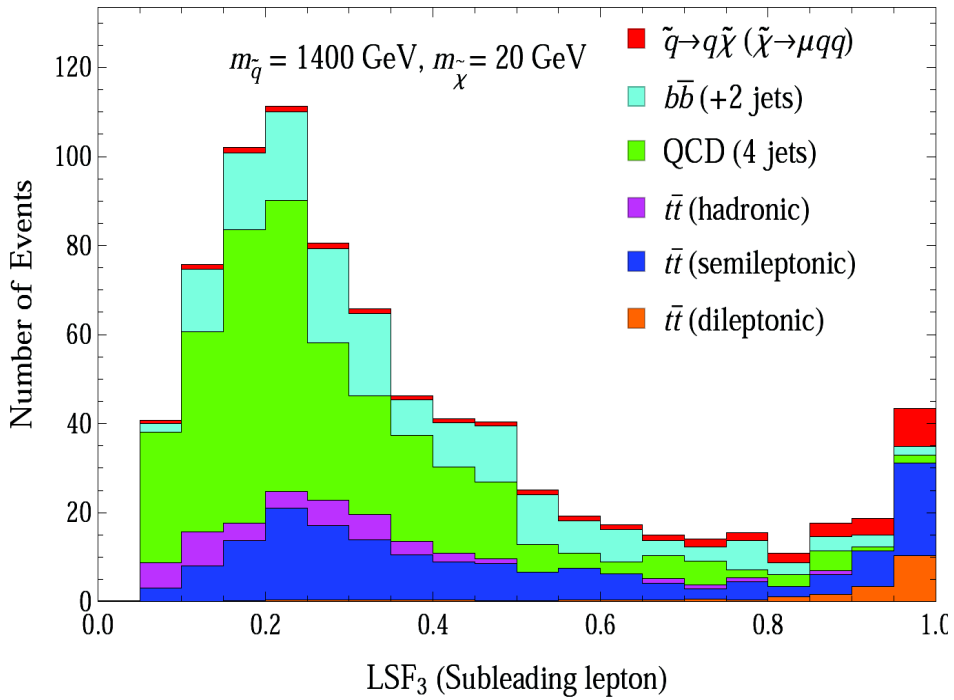
1+ lepton, p_T > 40 GeV

LSF for Other Models @ 13 TeV



LSF_3 of Hardest & 2nd Hardest Leptons





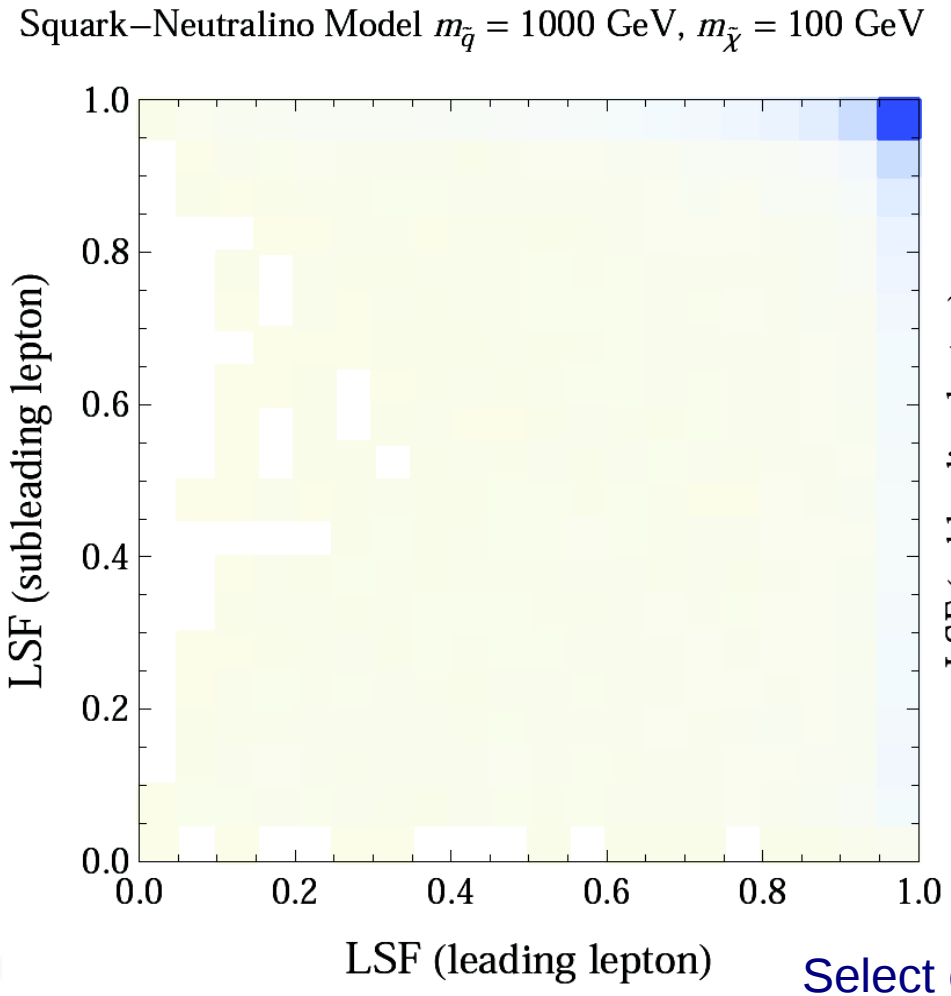
Select events with:

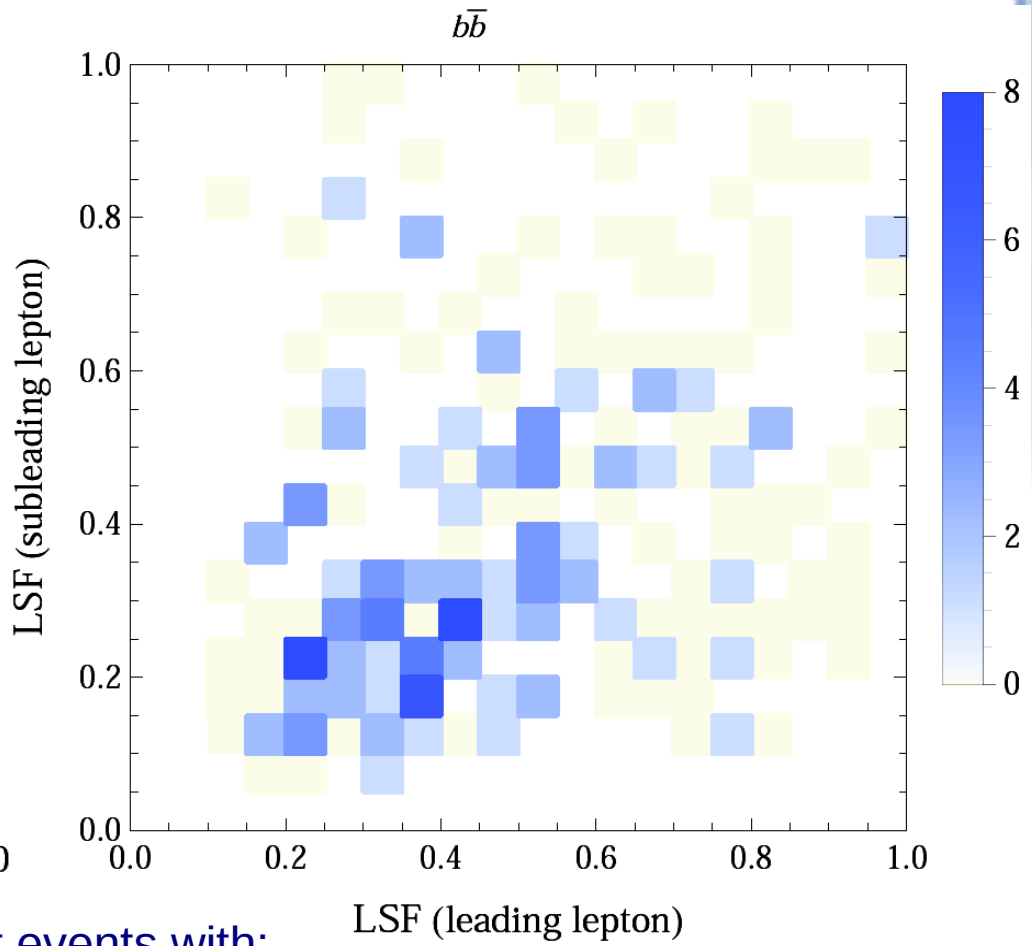
4+ jets, p_T > 150 GeV

2+ leptons, p_T > 40 GeV

H_T > 850 GeV

LSF_3 of Two Hardest Leptons





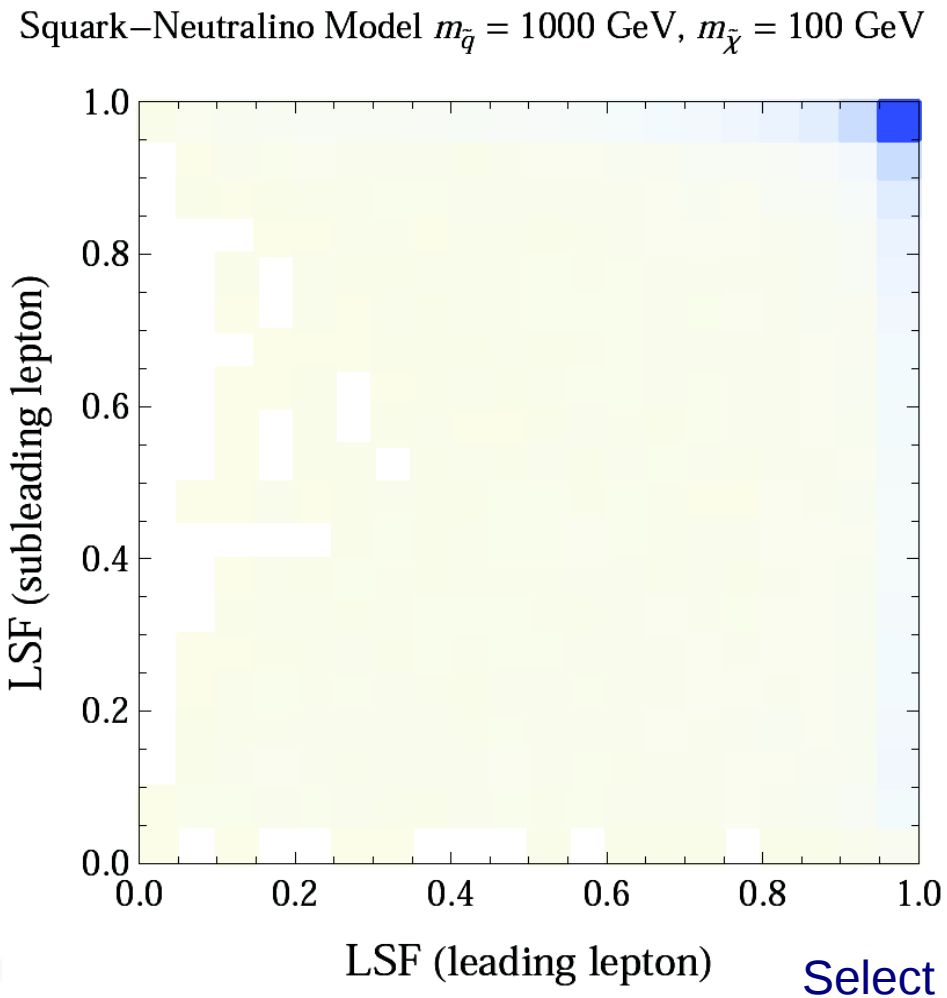
Select events with:

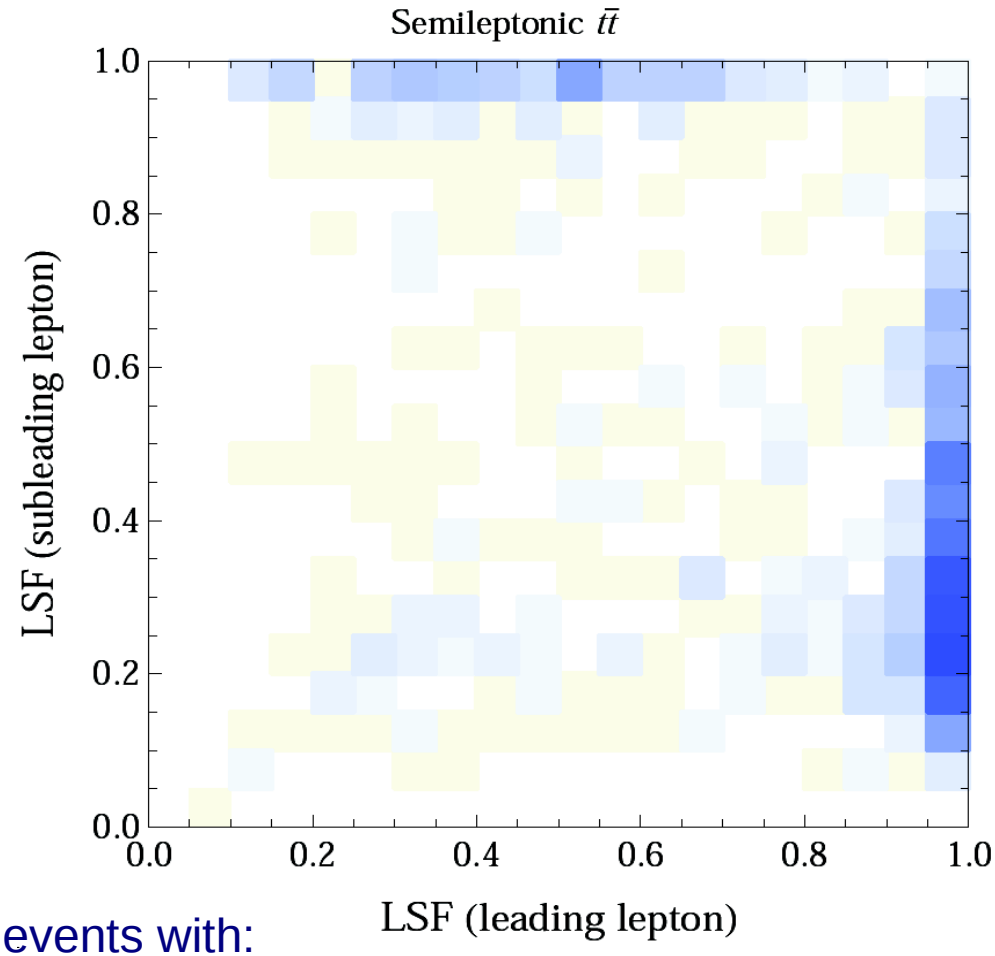
4+ jets, $p_T > 150$ GeV

2+ leptons, $p_T > 40$ GeV

$H_T > 850$ GeV

LSF_3 of Two Hardest Leptons





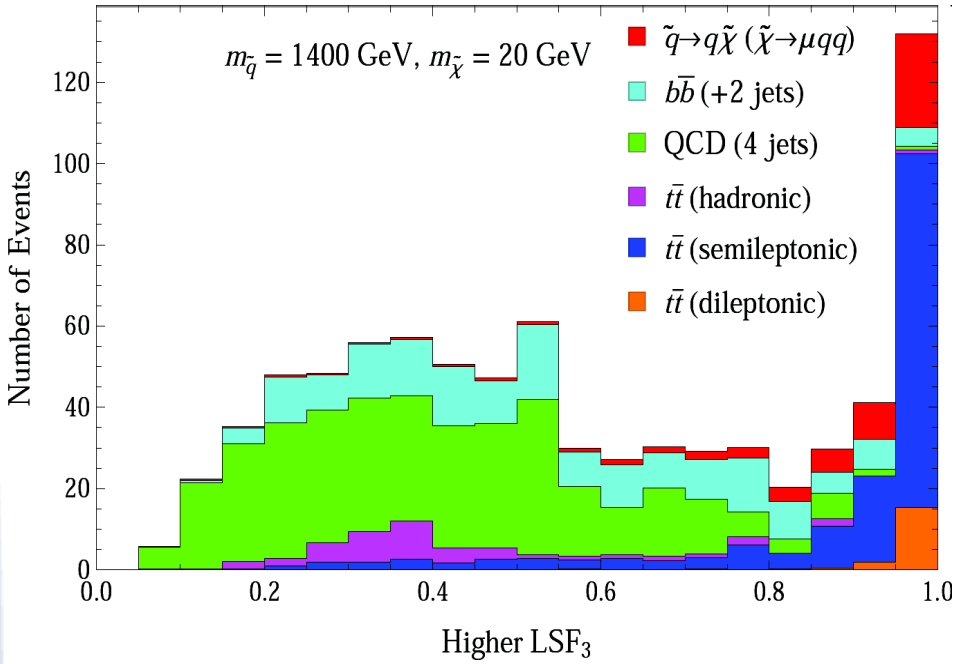
Select events with:

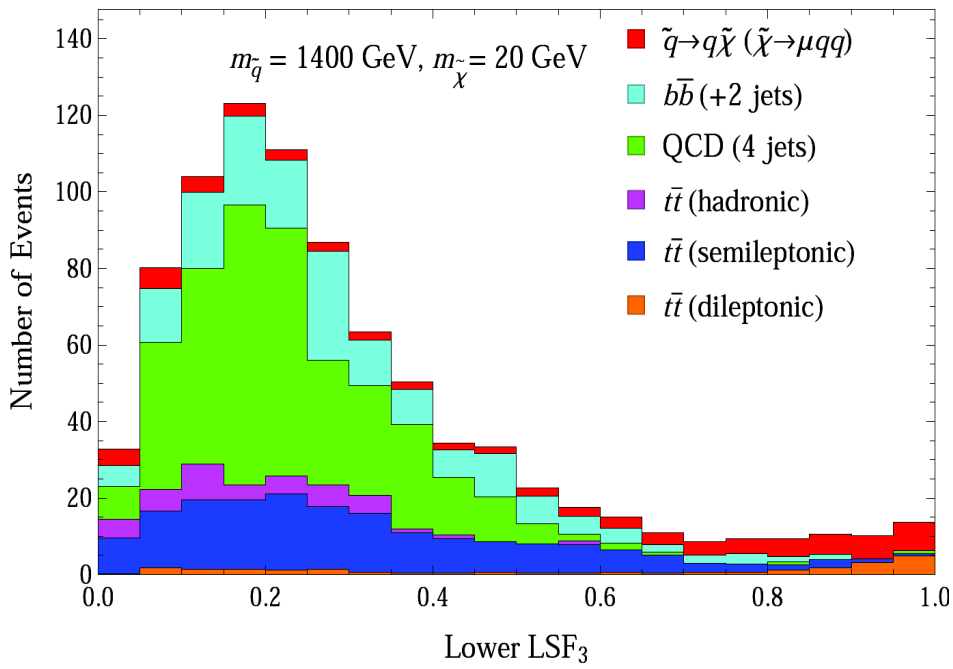
4+ jets, p_T > 150 GeV

2+ leptons, p_T > 40 GeV

H_T > 850 GeV

Highest LSF_3 vs 2nd Highest LSF_3

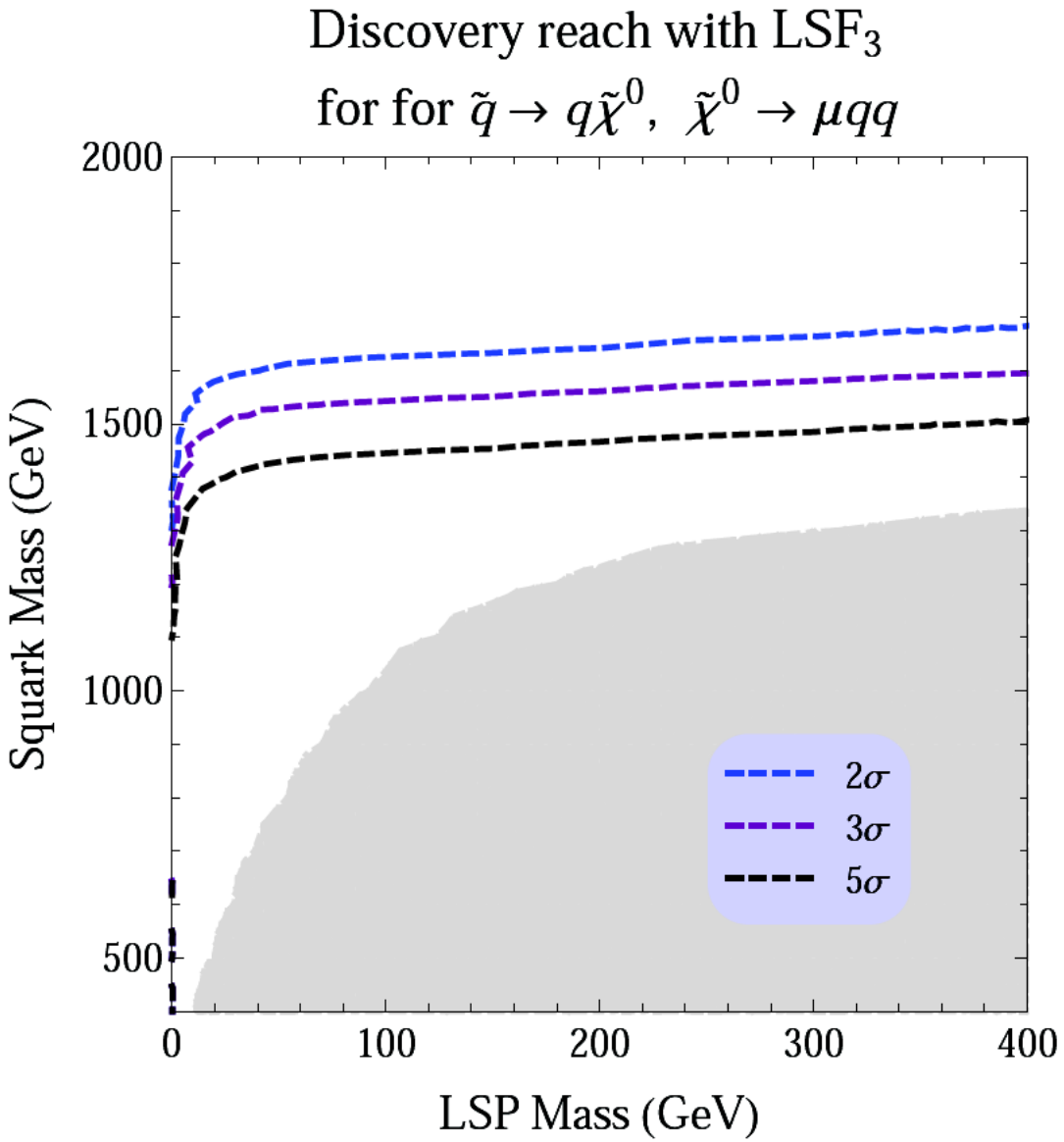




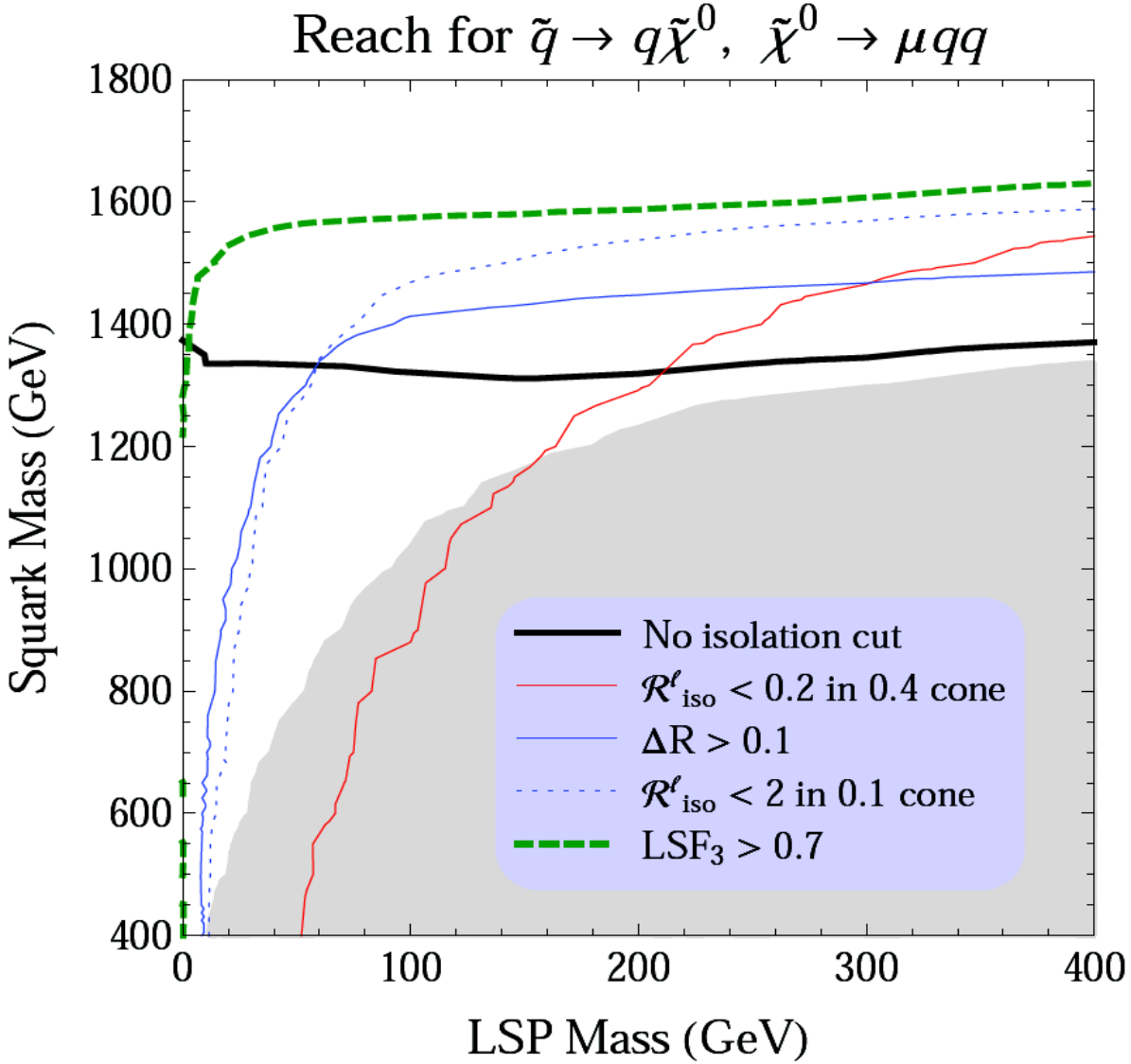
Our Proposed Search

- 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



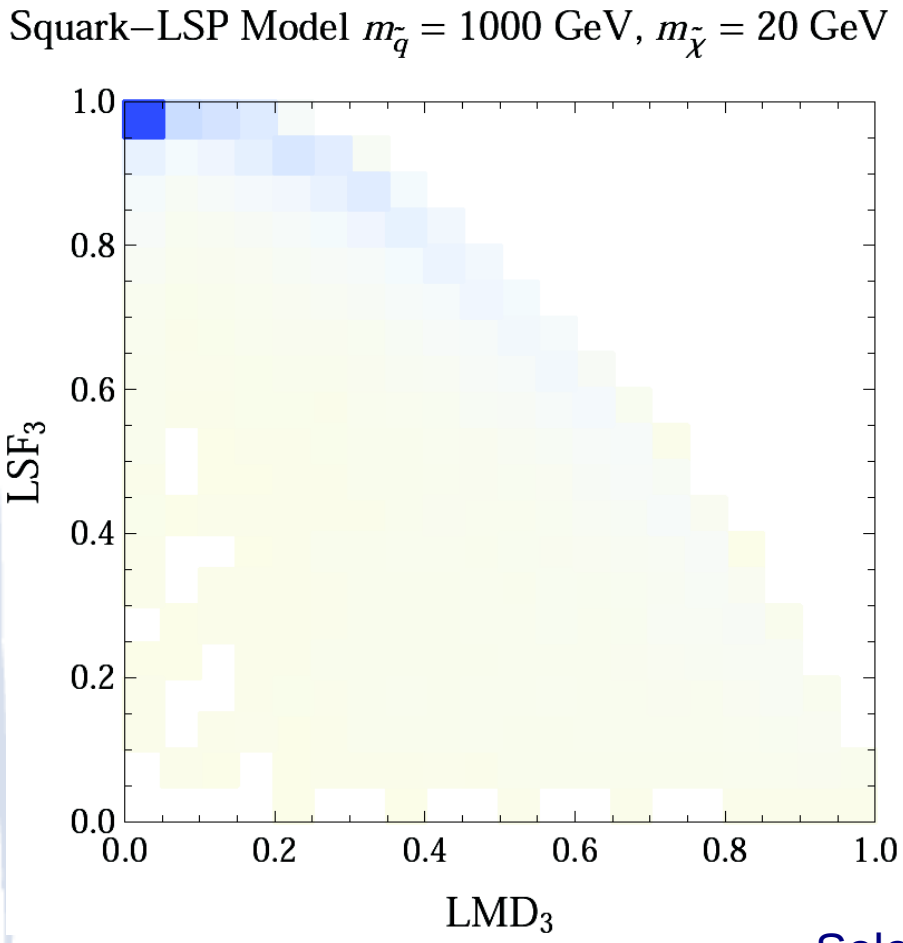
Lepton Mass Drop

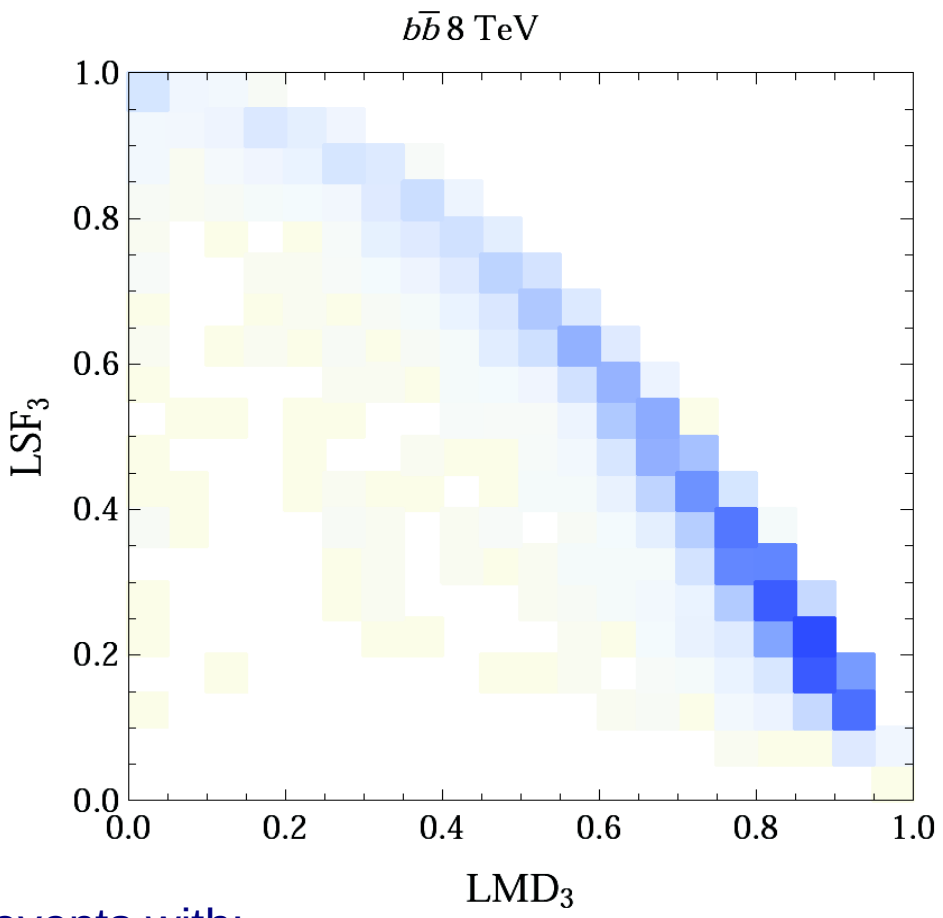
- Cluster into C/A R = 0.8 fat jets
- Recluster constituents with exclusive k_T into n subjets
- Lepton mass drop defined as mass of hadronic constituents of subjet over mass of entire subjet (including the hard lepton)

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

- Highly correlated with LSF in large-boost limit

LMD vs LSF_3





Select events with:

2+ jets, p_T > 150 GeV

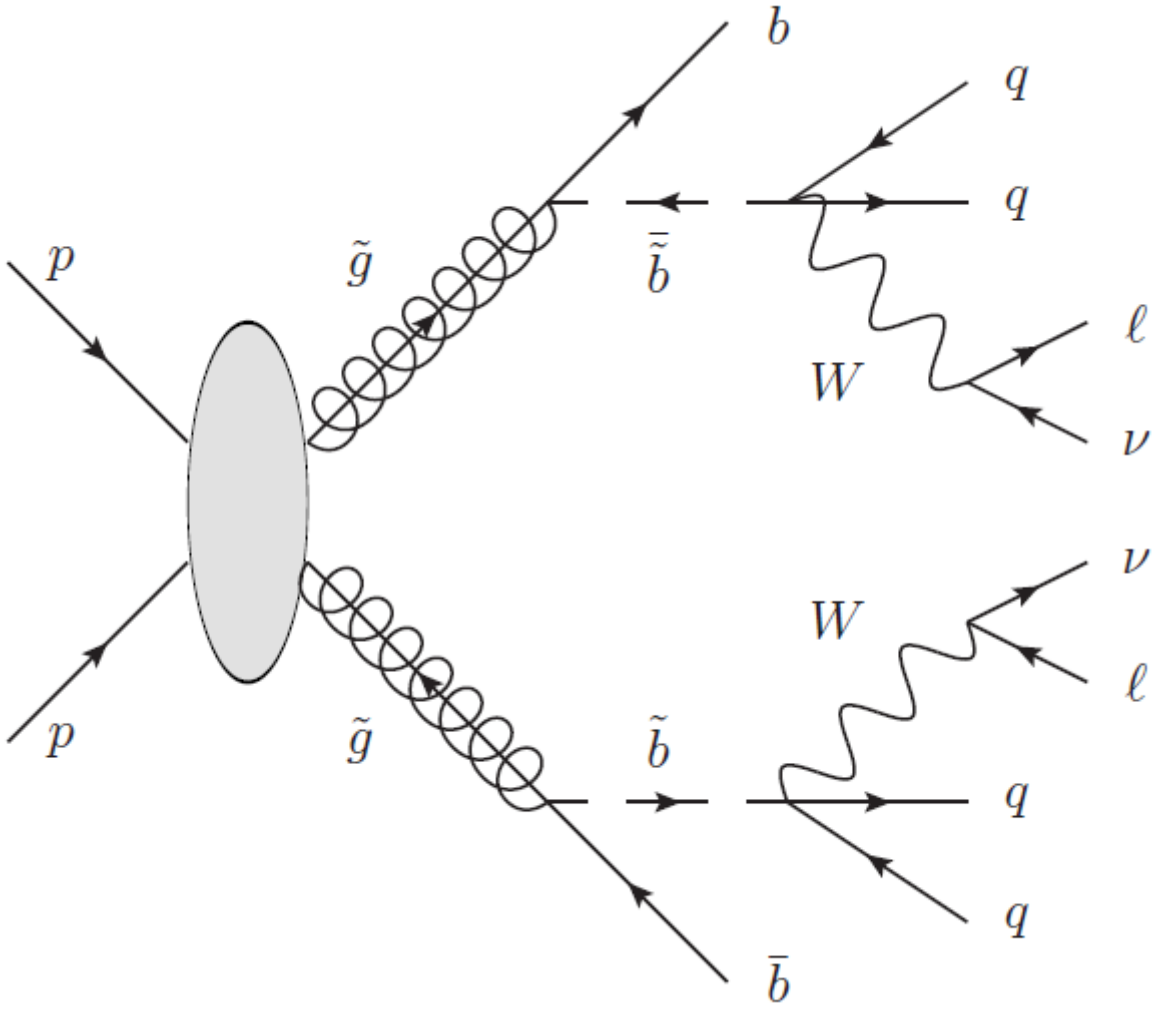
1+ lepton, p_T > 40 GeV

Looking Forward

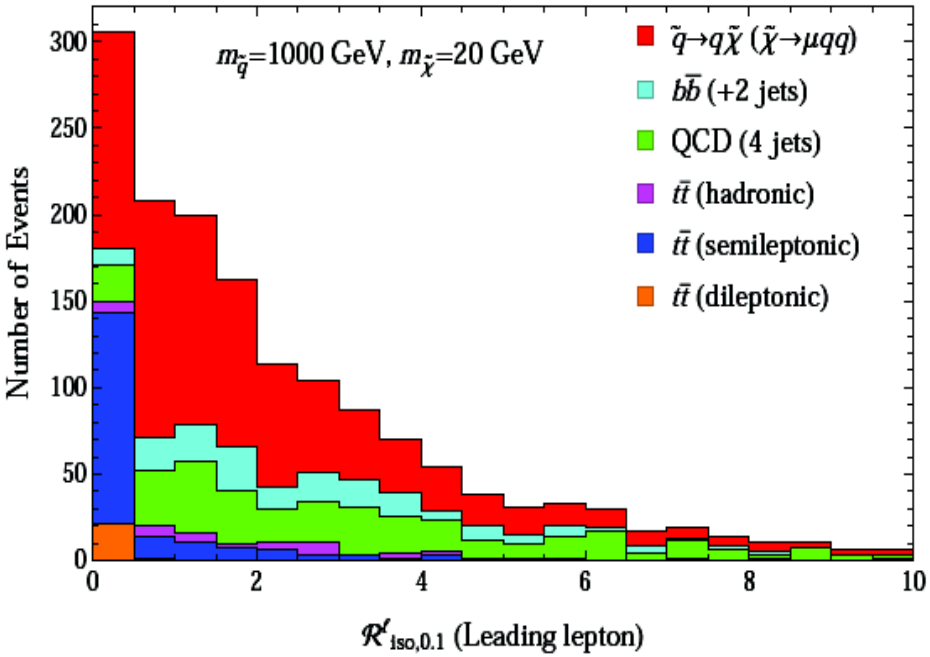
- Results very broad – not model-specific
- The community should:
  - Close gaps with 8 TeV data
  - Reconsider 13 TeV lepton triggers
  - Search for more refined discriminants of signal vs leptonic tops
  - Hope for the discovery of new physics!

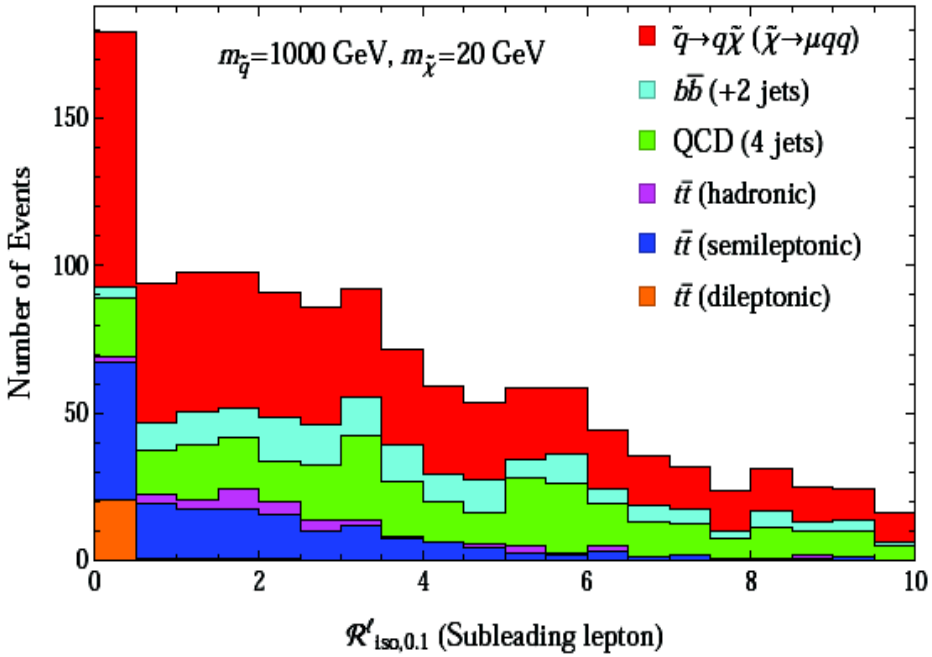
Backup Slides

Other Topologies

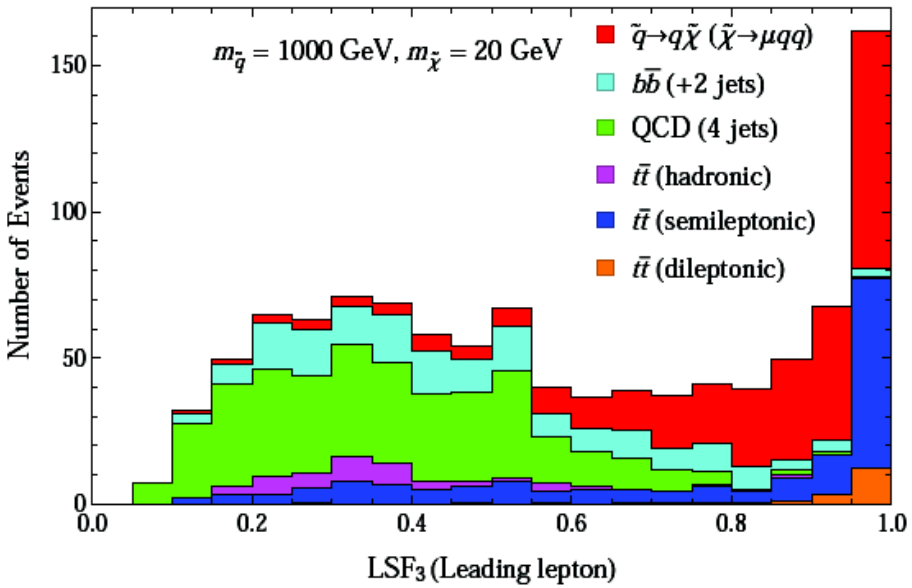


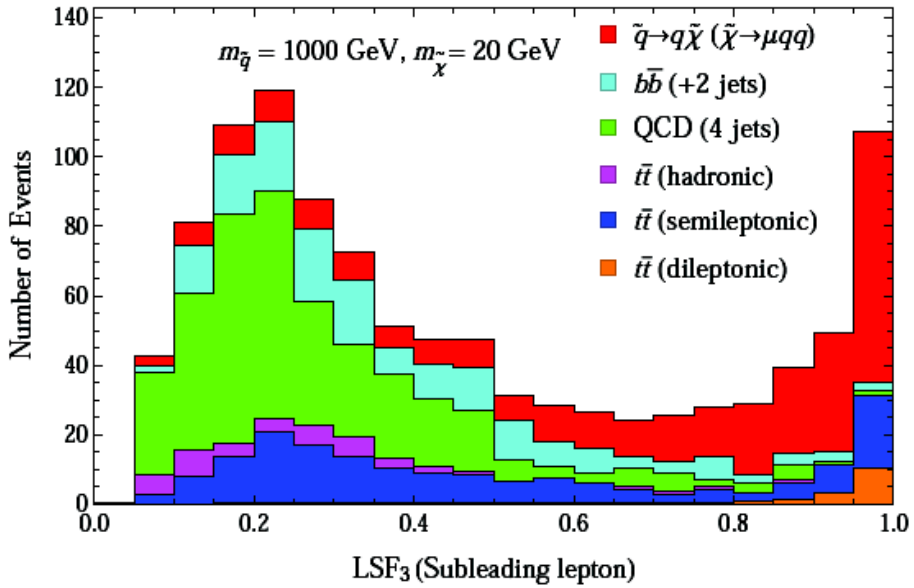
Relative Isolation with 1 TeV Squarks



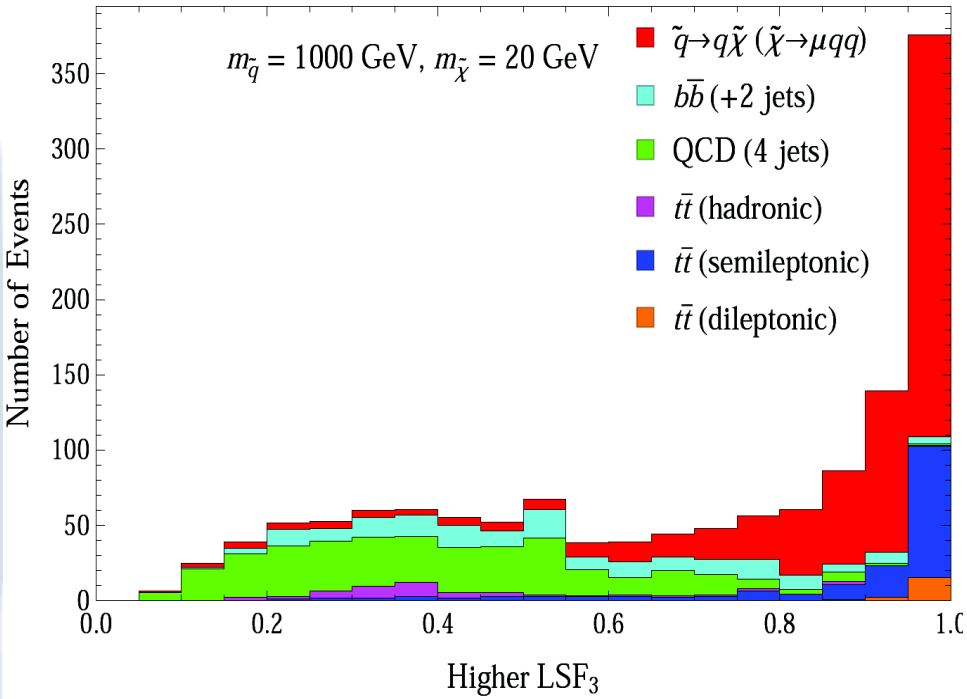


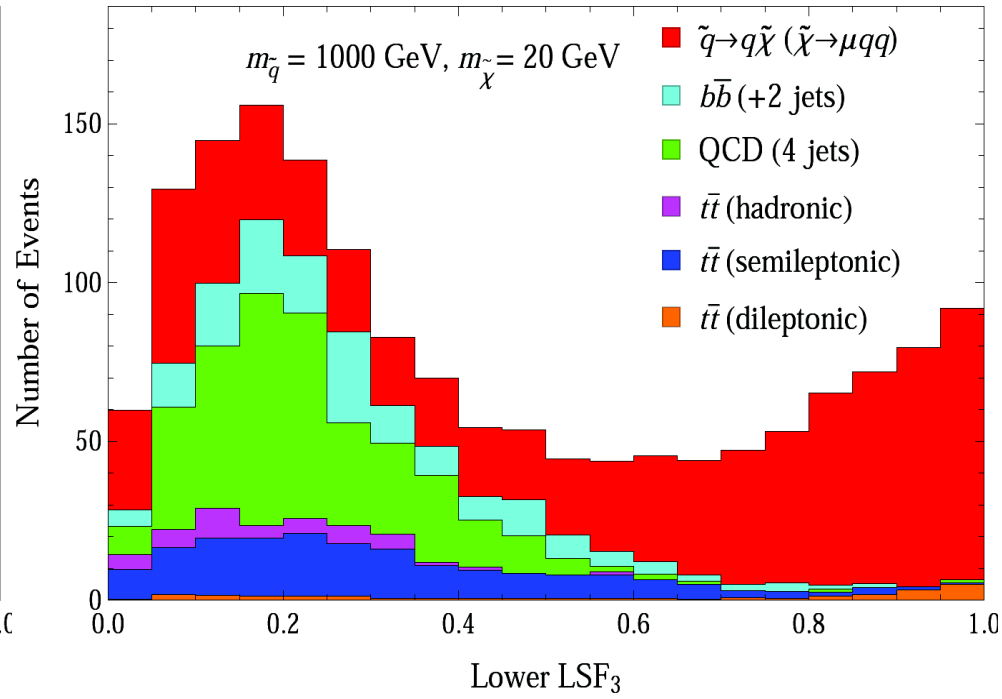
LSF_3 of Hardest & 2nd Hardest Leptons





Highest LSF_3 vs 2nd Highest LSF_3





Exclusion Reach With Mock Search