Search for Groups of Nearby Muons at CMS ("Muon Jets")

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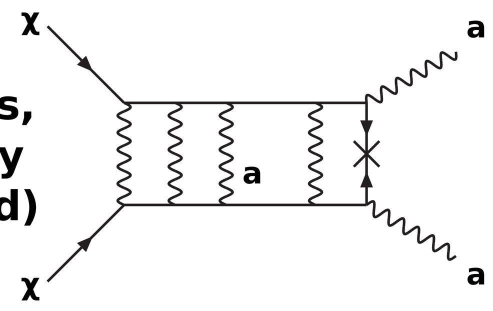
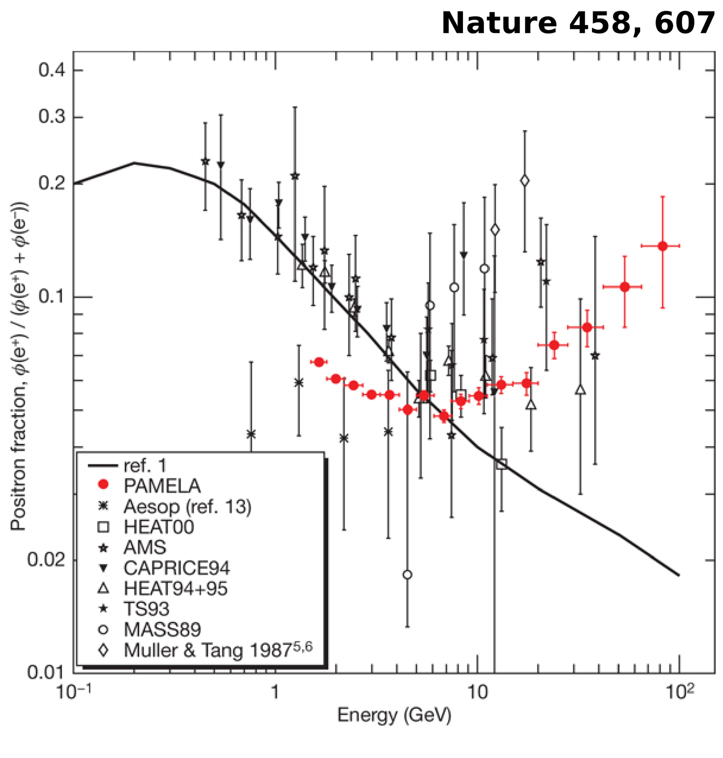
(for other lepton-jet related work at CMS, see Princeton, Florida State, Rice, and Rutgers)

MOTIVATION

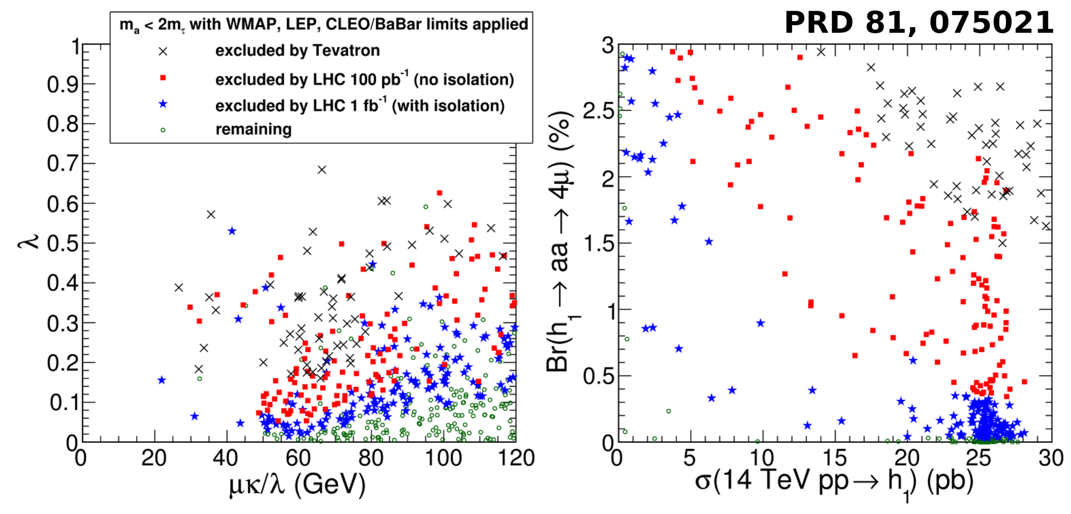
1. PAMELA positron excess might be due to dark matter, but only if WIMP annihilation rate is much higher than expected
→ adding an O(1 GeV/c^2) boson to the dark sector would enhance present-day WIMP annihilation without upsetting freeze-out constraints, and also kinematically forbid an (unobserved) antiproton excess
(see e.g. PRD 79, 015014)



Nature 458, 607



PRD 81, 075021



2. NMSSM could hide Higgs in Higgs-to-Higgs decays such as $h \to aa \to 4\mu$ if CP-odd "a" is O(few GeV)
→ regions of parameter space survive current experimental constraints

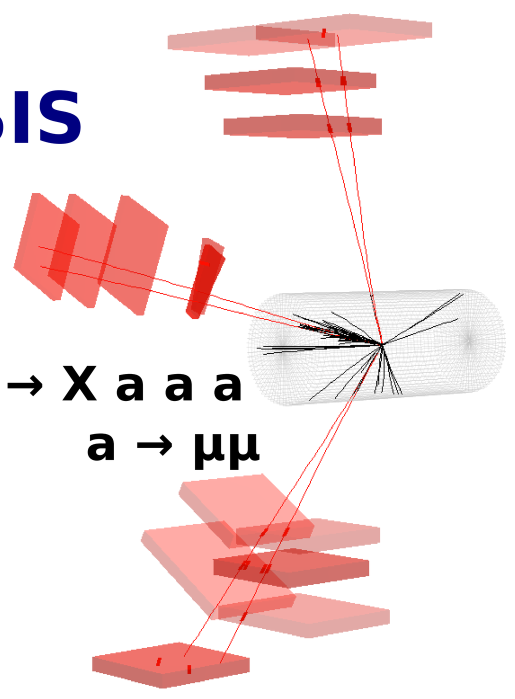
3. General "hidden valley" phenomenon predicts new low-mass particles produced at high energies, kinematically forced to decay to light fermions

GENERAL SIGNATURE

- low-mass, high-momentum neutral resonances from top-down decays
- unknown number of fermion pairs at the end of the cascade

RESTRICTION FOR THIS ANALYSIS

- muon-only final states
- ≥ 2 groups ("muon jets")



$pp \to X\,a\,a\,a$
$a \to \mu\mu$

Similarity to jets: we don't know how many particles to expect

Similarity to tau-jets: we want to accept a well-defined mass range (like "shrinking cone" analysis)

Similarity to dimuons: we can fully reconstruct the final state, hunt for mass-peaks

MUON-JET DEFINITION

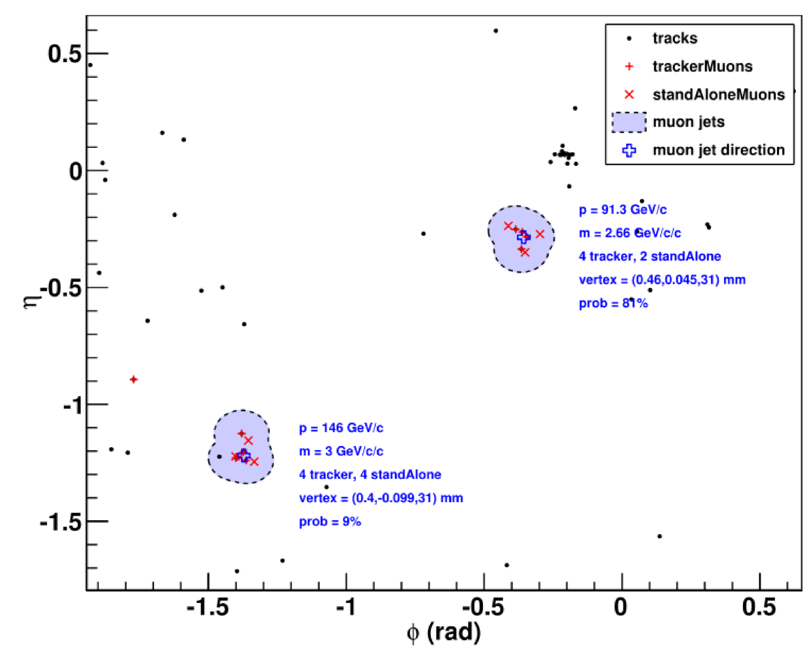
→ Recursively group pairs of "nearby" muons

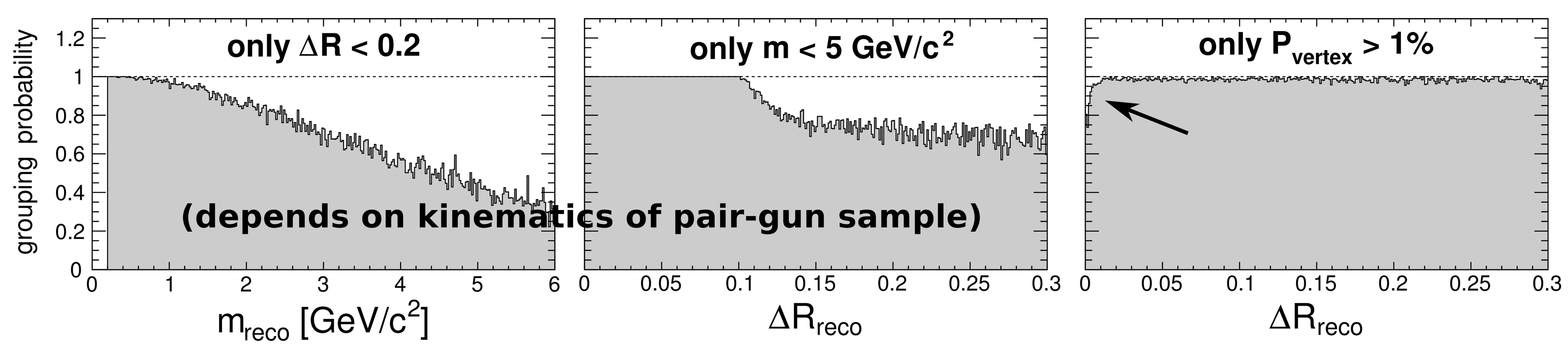
→ "Nearby" means:

$(m_{\mathrm{inv}} < 5$ GeV$/c$ and $P_{\mathrm{vertex}} > 1\%)$

or $\Delta R < 0.1$

for oppositely charged muons





ANALYSIS STRATEGY

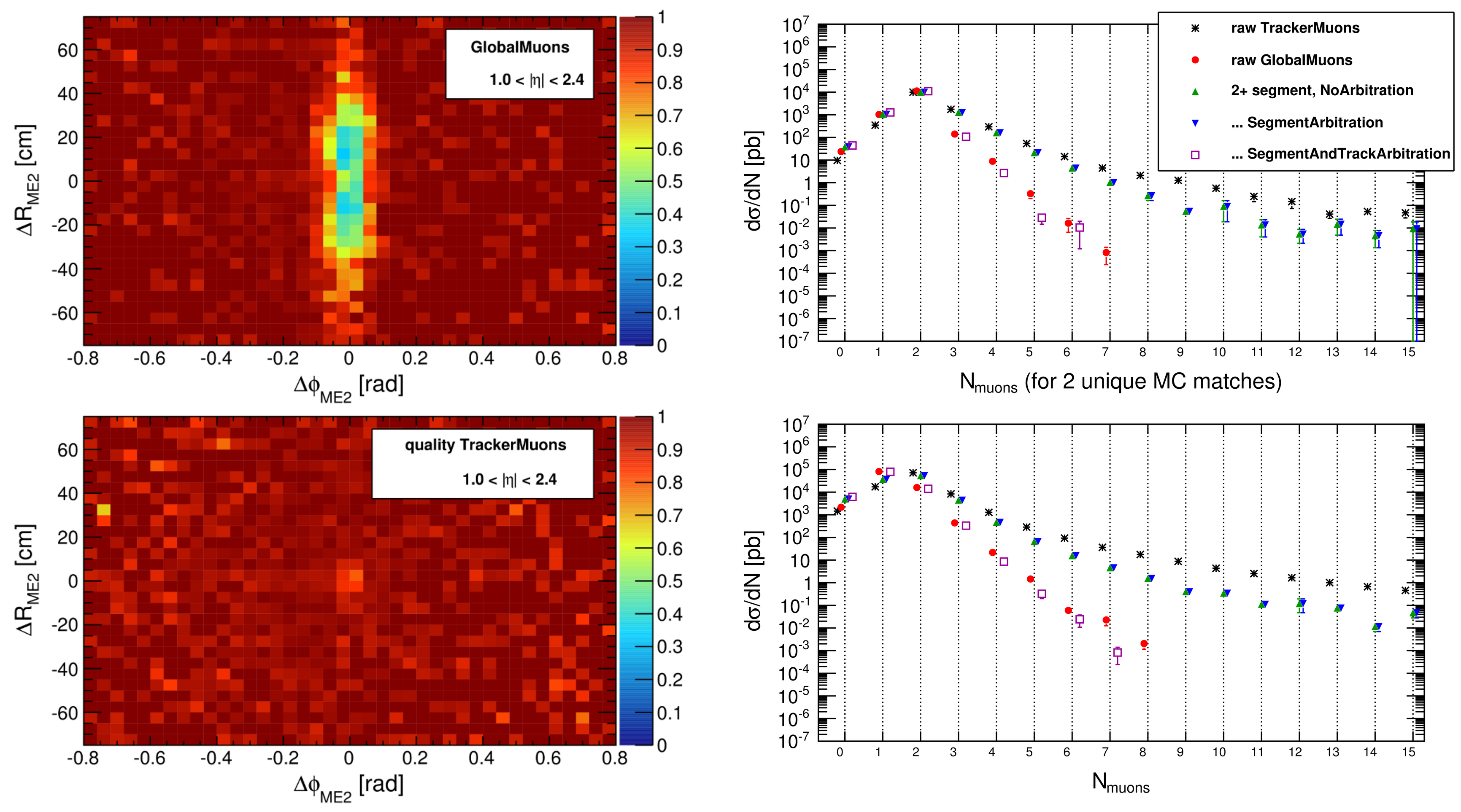
1. Optimize detector sensitivity and define selections from MC (done)
2. Identify single muon-jet background (a.k.a. the SM dimuon spectrum)
3. Estimate two-or-more muon-jet backgrounds from data
4. Understand trigger efficiency for nearby muons
5. Search for events with at least two clean muon-jets (a) by counting above background estimate and (b) with a double-mass peak fit

DETECTOR AND RECONSTRUCTION

- **GlobalMuons:** low fake rate, but StandAloneMuon reconstruction (a prerequisite) is inefficient *when muons cross in the muon system*
- **TrackerMuons:** efficiency is independent of crossing but fake rates are high in jets, where many tracks point to the same muon segments
- **TrackerMuons with number of arbitrated segments ≥ 2:** provides both high, well-understood efficiency and a fake rate as low as GlobalMuons

efficiency (color scale) vs. difference in track positions evaluated at ME2 plane

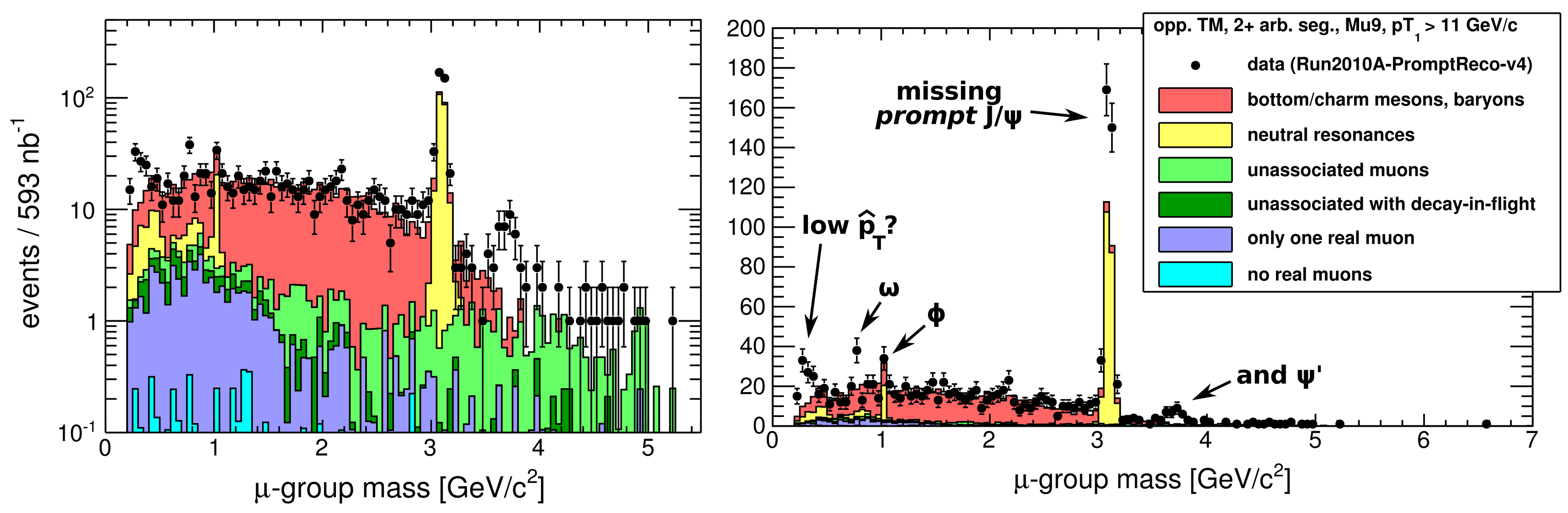
number of reconstructed tracks for a given number of generator-level muons



Note: HLT relies on StandAloneMuon identification, so trigger efficiency for nearby muons is still an issue (trigger only needs to find one, though)

BACKGROUNDS

Overlay of single muon-jets from $\hat{p}_T > 30$ GeV/c QCD Monte Carlo and 0.6 pb^{-1} of data shown below (more complete MC and data in progress)



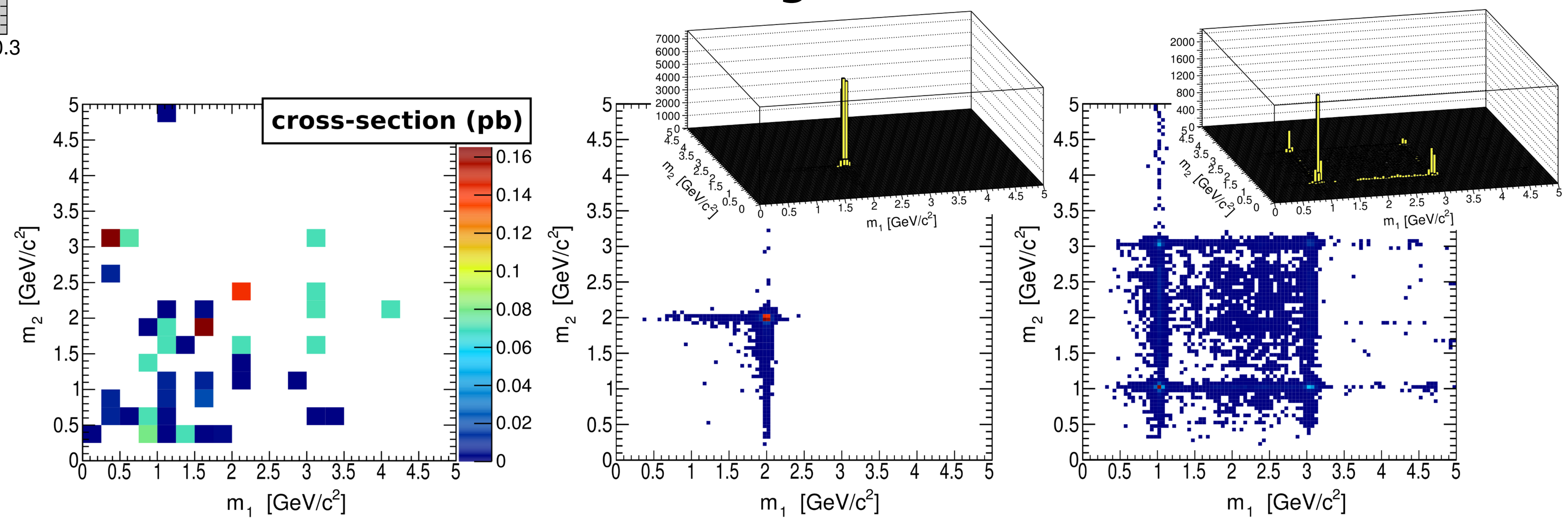
ESTIMATING BACKGROUNDS FROM DATA

- **Decay method:** assume decay chain for each jet is independent; measure P(≥2 muons | 1 muon) in single muon/muon-jet, apply it to ≥2 jet events
- **Isolation method:** assume kinematics and isolation are independent; extrapolate from anti-cut
- **Fitting method:** assume background shape, fit for 2-D peaks plus background in m_1, m_2 plane

Each method will need to be tested in Monte Carlo (fitting method was demonstrated for a simplified detector in PRD 81, 075021)

DOUBLE-MASS PEAKS

In signal events with at least two muon-jets, the muon-jet masses are correlated; backgrounds are not



QCD backgrounds

NMSSM point ($m_a = 2$ GeV/c^2)

Extra U(1) in dark sector ($m_a = 1$ GeV/c^2, $m_h = 3$ GeV/c^2, both $a \to 2\mu$ and $h \to aa \to 4\mu$)