Kinematical variables towards new dynamics at the LHC

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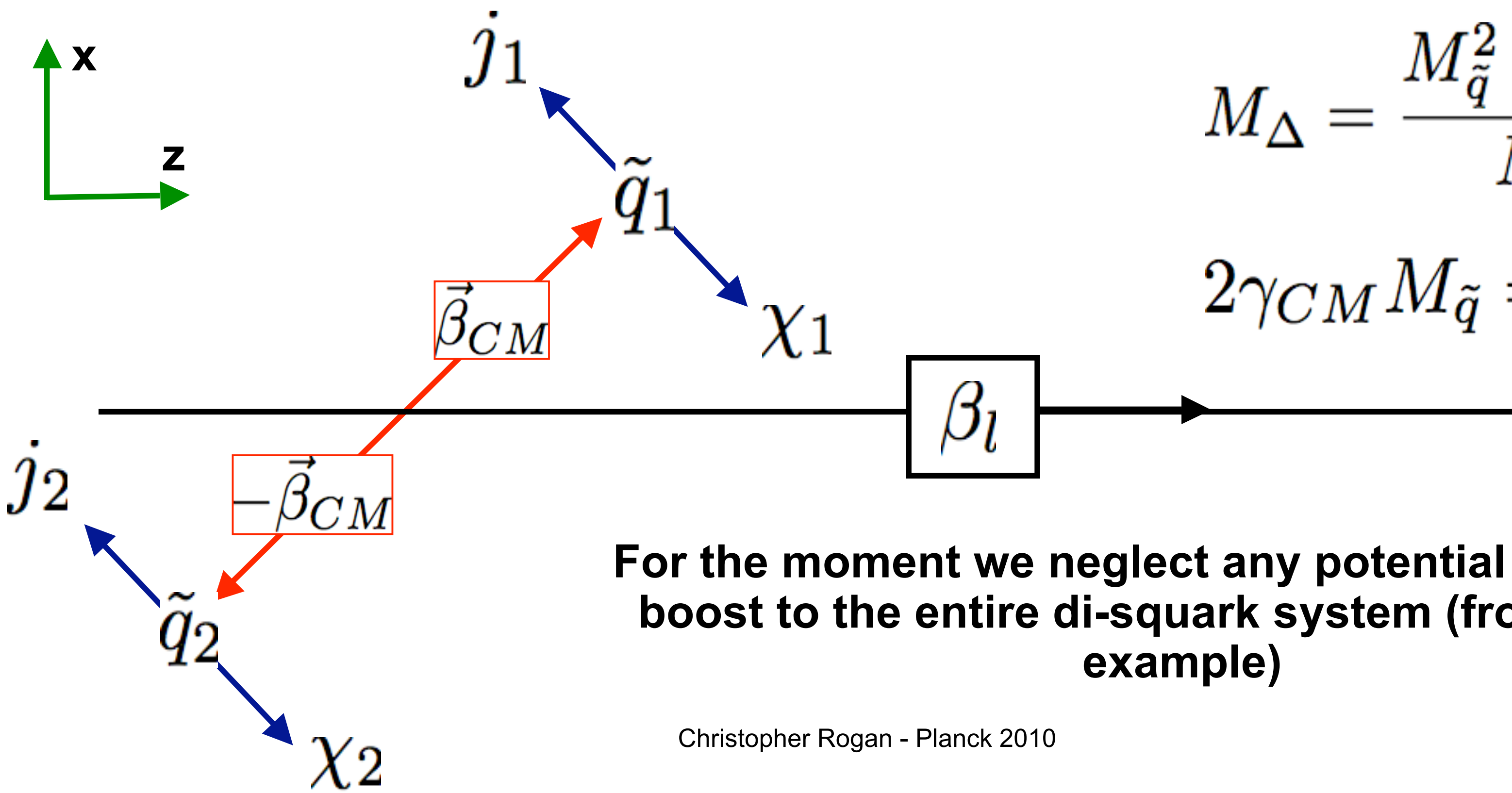
Introduction

- In the past years there has been a lot of suggestions for variables intended to study new physics processes with ≥ 2 weakly interacting particles in the final state (ex. DM candidates)

- Here, we introduce a new set of kinematic variables designed for
  - Discovery of processes of this type
  - Characterization of underlying dynamics

SUSY di-jets

- Examples: Let's consider a SUSY di-jet final state topology where two squarks are produced and each decay to a quark and an LSP



$$M_\Delta = \frac{M_{\tilde{q}}^2 - M_\chi^2}{M_{\tilde{q}}}$$

$$2\gamma_{CM} M_{\tilde{q}} = \sqrt{\hat{s}}$$

For the moment we neglect any potential transverse boost to the entire di-squark system (from ISR for example)

M_R

- Let's assume that $\gamma_{CM} = 1$, such that $\sqrt{\hat{s}} = 2M_{\tilde{q}}$ and both squarks are at rest in the di-squark rest-frame

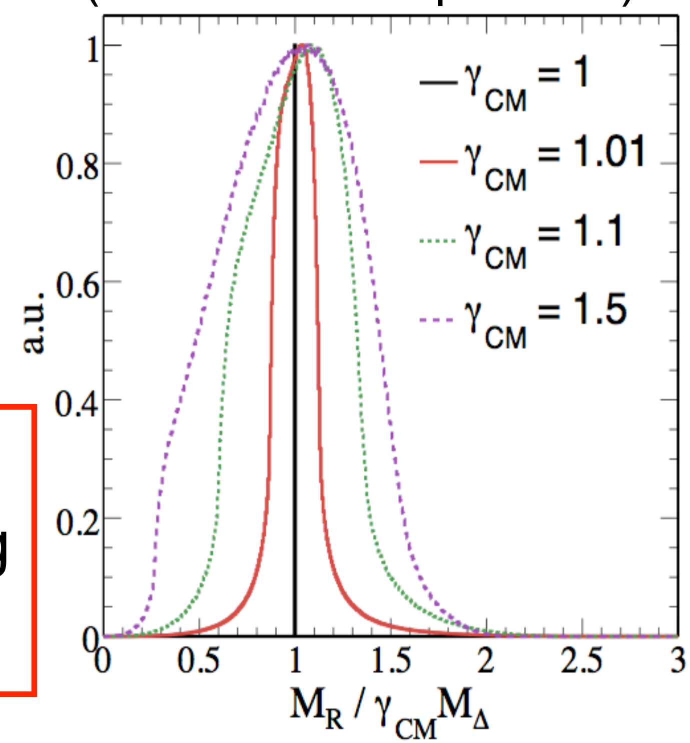
- Even without observing the two LSP's directly, we can move from the laboratory frame to the di-squarks rest frame through a longitudinal boost that takes us to a reference frame where the magnitude of the two jets' momenta is equal - we will call this reference frame the "rough-approximation"-frame or R-frame

- We denote the magnitude of the jets' momenta in the R-frame as M_R and the boost moving from the lab frame to the R-frame as β_R:

$$M_R = 2\sqrt{\frac{(E^{j1}p_z^{j2} - E^{j2}p_z^{j1})^2}{(p_z^{j1} - p_z^{j2})^2 - (E^{j1} - E^{j2})^2}} \qquad \beta_R = \frac{E^{j1} - E^{j2}}{p_z^{j1} - p_z^{j2}}$$

Properties of M_R

- Returning to the di-squark example:
  - M_R is invariant under longitudinal boosts (independent of β_l)
  - If $\gamma_{CM} = 1$ then $M_R = M_\Delta = \dfrac{M_{\tilde{q}}^2 - M_\chi^2}{M_{\tilde{q}}}$
- We find that, even if γ_{CM} deviates from 1 (which it will in practice) that M_R still peaks
- For QCD di-jets (assuming no mis-measurements, no p_T to dijet system etc.) $M_R = \sqrt{\hat{s}}$



Conceptually, we expect to see a peaking signal over a steeply falling background

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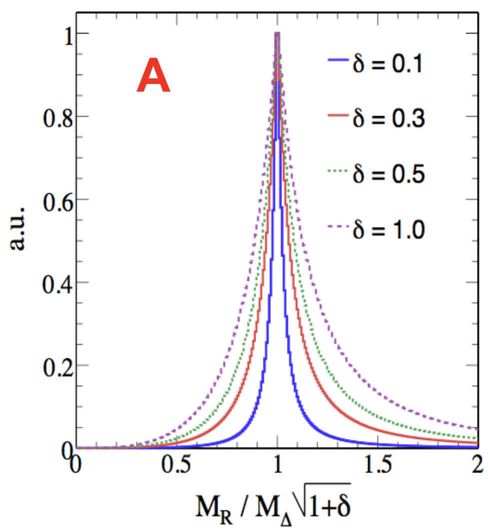
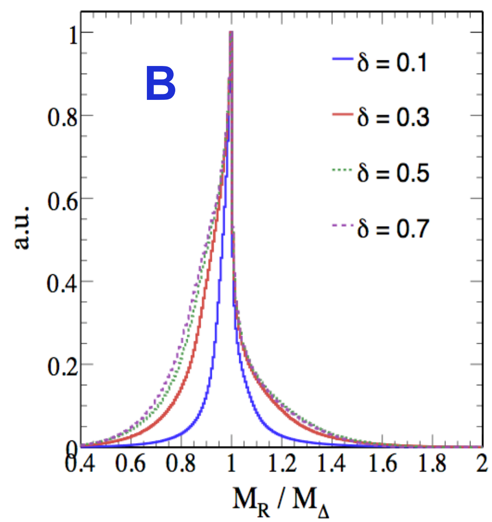
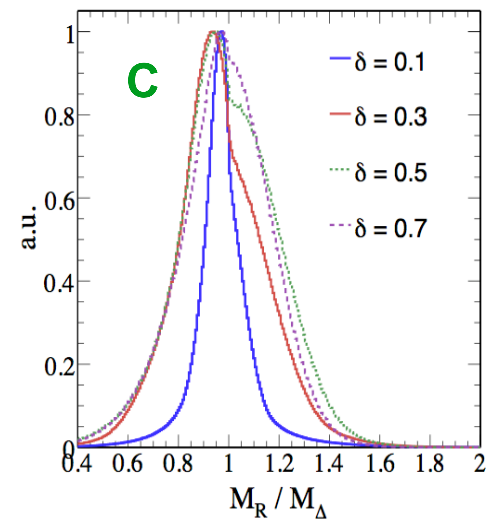
- In the following examples, we do this my minimizing the invariant masses of the two hemispheres (we have studied other hemisphere algorithms and find that these results are not sensitive to this choice)

Toy examples

- What were our two jets are now two hemispheres, and M_R is defined as before with this substitution (hemisphere masses set to zero, like jets)
- To understand what should happen to M_R in a more general class of scenarios, we consider 3 toy examples:
  - (A) production of two different heavy particles with $M_\Delta^1 = M_\Delta^2(1+\delta)$
  - (B) production of two identical heavy particles, with one decaying through the lighter massive particle and then to jet+LSP
  - (C) Both identical heavy particles decaying as in (B)







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- Such a variable is the Razor, denoted R and defined as:($\vec{M} = M\vec{E}T$)

$$M_T^R = \sqrt{\frac{|\vec{M}|(|\vec{p}_T^{j1}| + |\vec{p}_T^{j2}|) - \vec{M} \cdot (\vec{p}_T^{j1} + \vec{p}_T^{j2})}{2}} \qquad R \equiv \frac{M_T^R}{M_R}$$

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- M_T^R behaves similarly to the stransverse mass or M_{T2}, such that if $\gamma_{CM} = 1$ then M_T^R has a kinematic endpoint at

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- Hence, we take the ratio of two variables with dimension mass (or energy if you prefer) and cut on a scale-less variable - two variables in ratio measure similar quantity, using different sets of information

Example: Inclusive SUSY search

- As an example, we consider an inclusive SUSY search
  - As signal benchmark we consider mSUGRA scenario w/

$$M_0 = 60 \text{ GeV}, \quad M_{1/2} = 250 \text{ GeV}, \quad \tan\beta = 10, \quad \text{sgn}(\mu) = +, \quad A_0 = 0$$

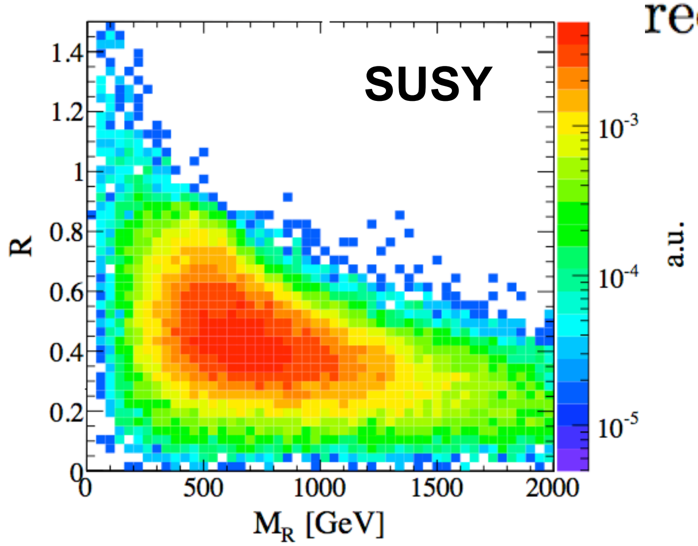
  - backgrounds generated w/ ALPGEN

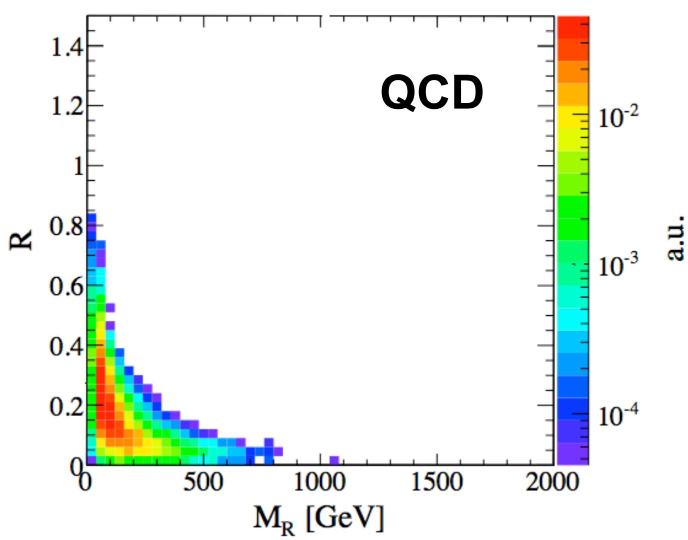
- Use a PGS-like detector simulation
  - "jets" clustered from simulated calorimeter depositions

- Only selection requirements we will apply are:
  - $H_T = \sum_i^{jets} E_T^i > 200\text{GeV}$ (trigger-like requirement)
  - R > 0.4

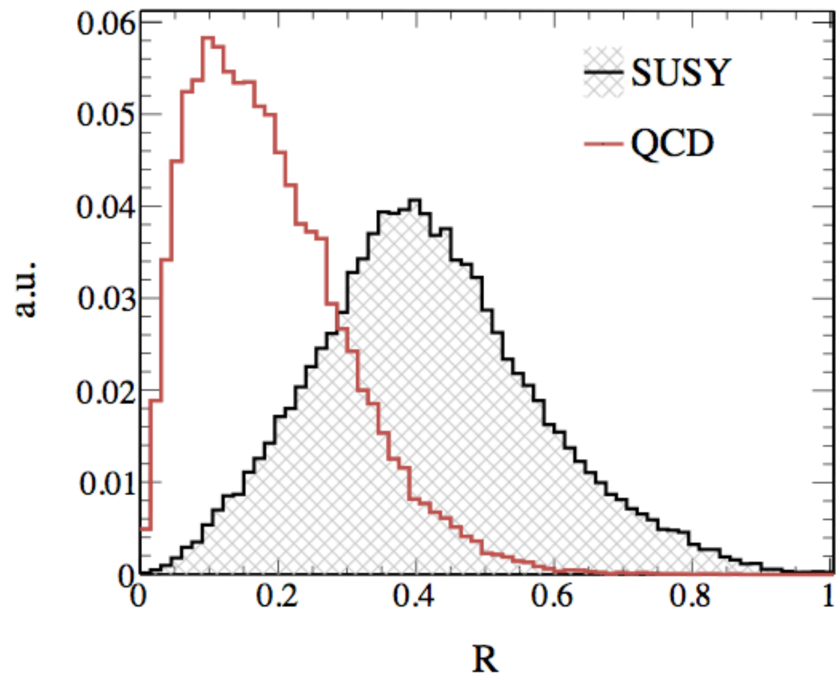
The Razor in practice

$\sqrt{s} = 14$ TeV





requiring $H_T > 200\text{GeV}$



- Razor cut reduces QCD bkg rate w.r.t. SUSY signal
- More importantly, changes bkg shape

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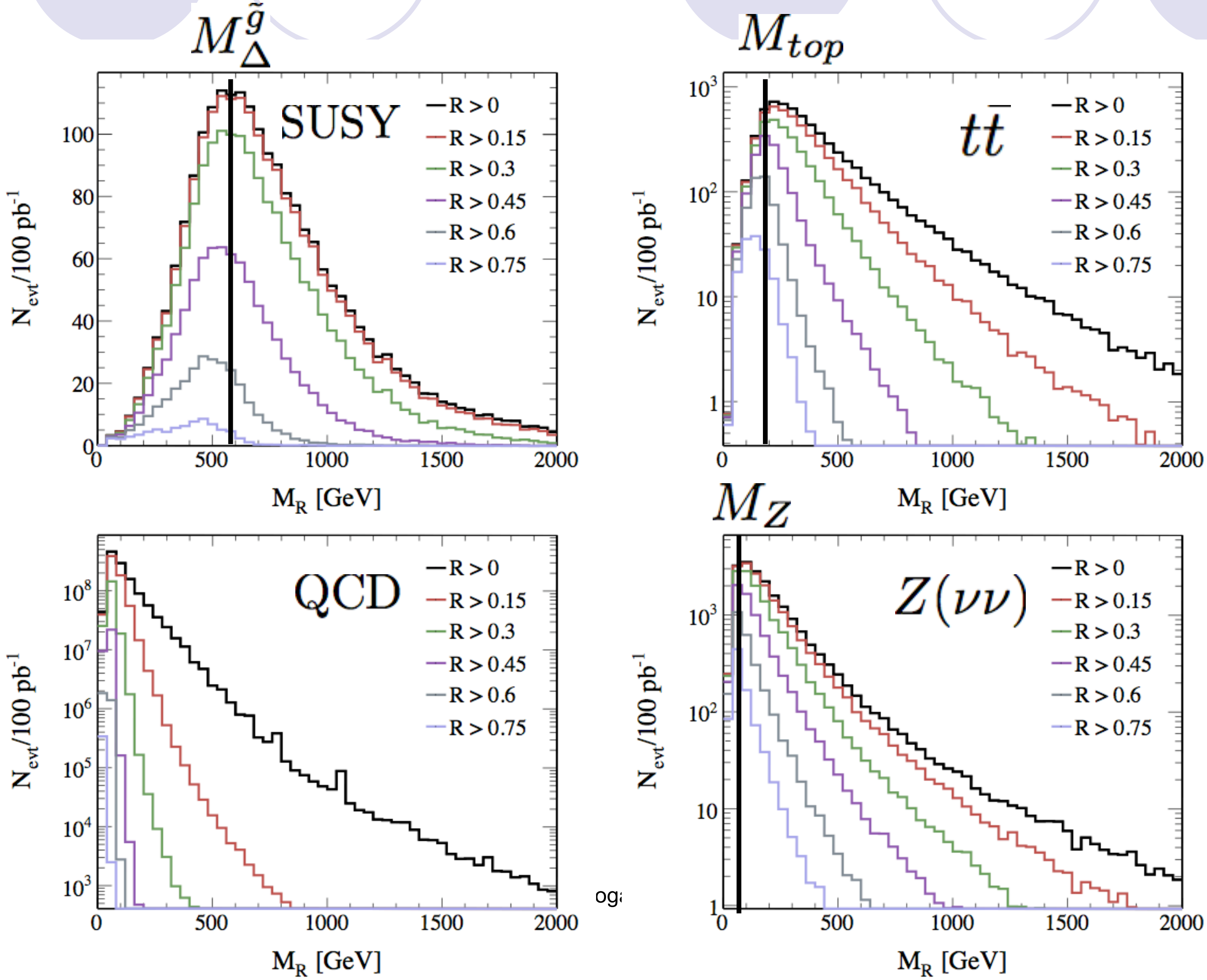

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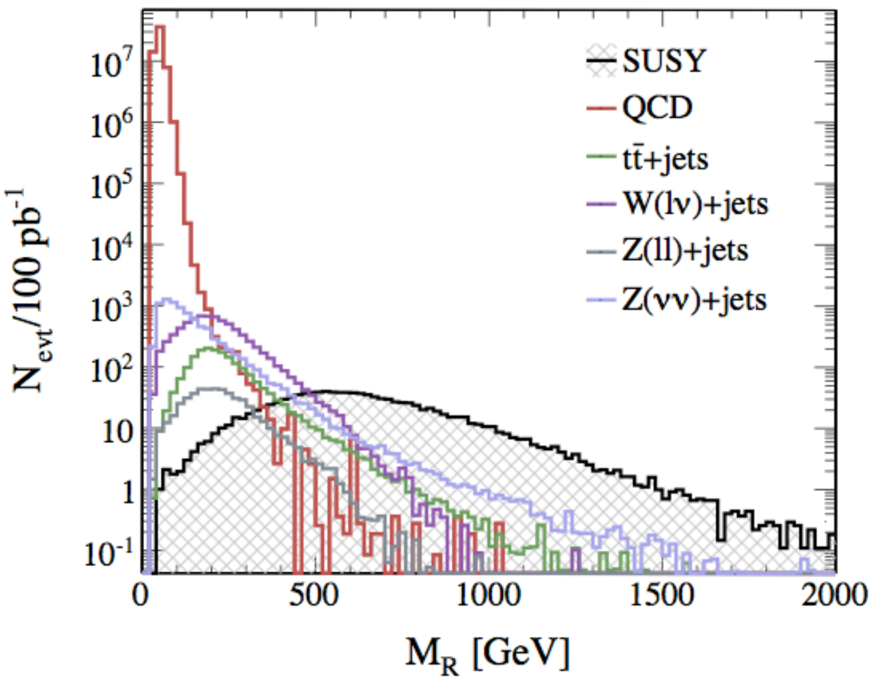
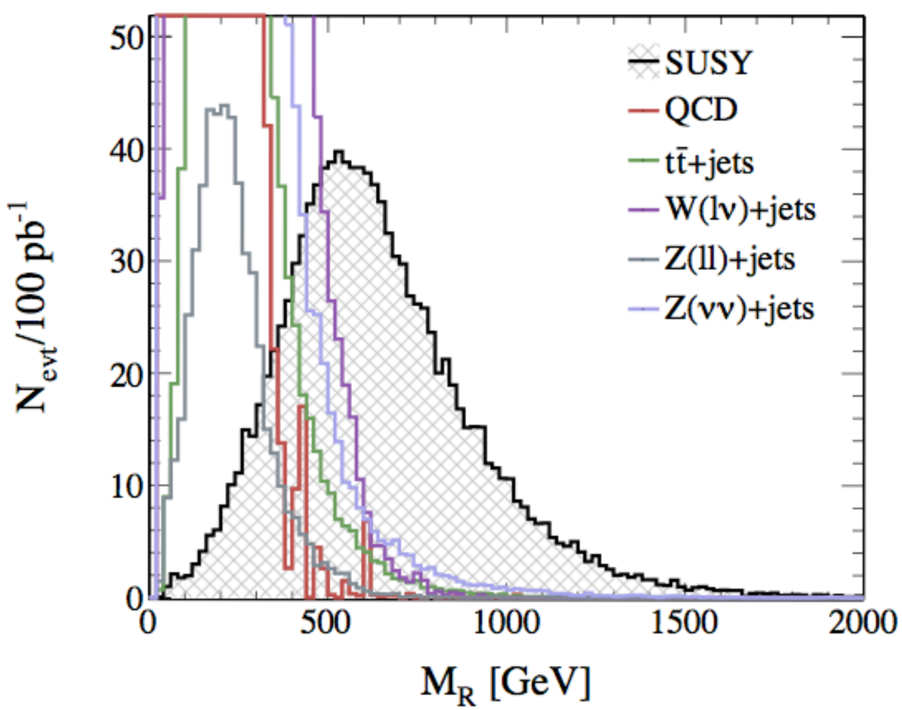
Example results

$\sqrt{s} = 14$ TeV

- Selection:
  - trigger requirement
  - R > 0.4
  - No lepton reco or ID

~30% signal efficiency w.r.t. inclusive SUSY x-section



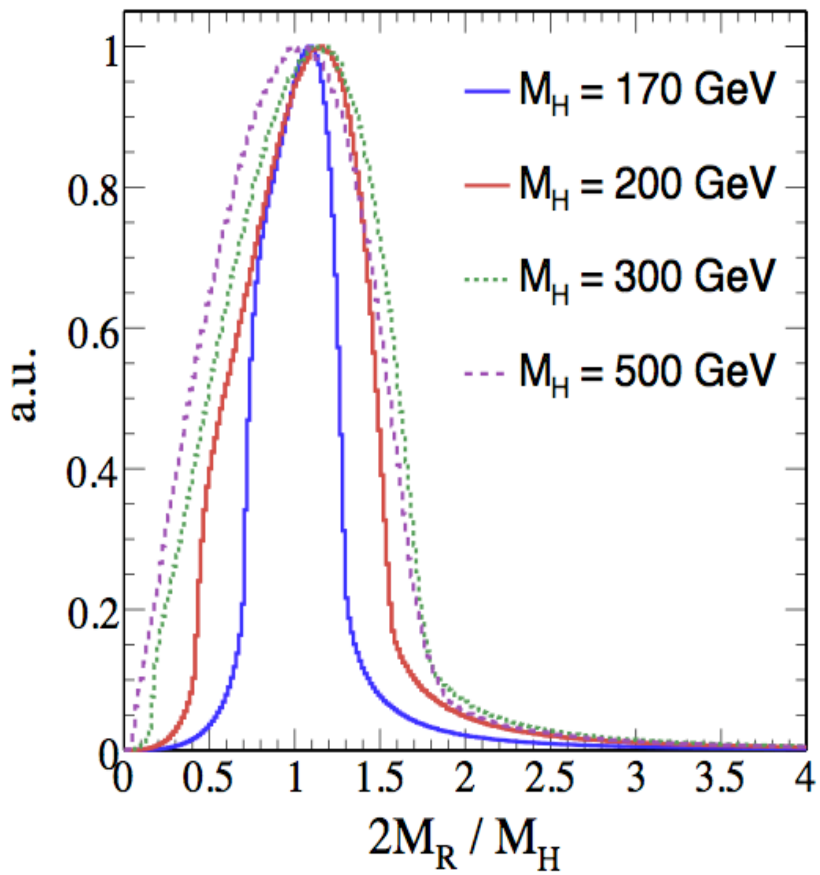


Outlook

- We have introduced new variables that are potentially useful for discovery and characterization of new physics with weakly interacting particles in the final state
- As an example, we observe that these variables can be used in a high-efficiency, fully inclusive SUSY search
- Potentially useful in a variety of final states
  - For example, MR will peak at the Higgs mass for $H \rightarrow WW \rightarrow \ell\nu\ell\nu$
- More details can be found in (to be posted to arXiv.org this week):

  http://www.hep.caltech.edu/~crogan/files/MR_Rogan.pdf

M_R Toys $H \to WW \to \ell\nu\ell\nu$



- Here, we consider a toy Monte Carlo with the following prescription:
  - Uniform 4π detector acceptance
  - Perfect resolution
  - No Higgs transverse mass
- We find that, regardless of the Higgs mass, that two times M_R will peak at ~the Higgs mass

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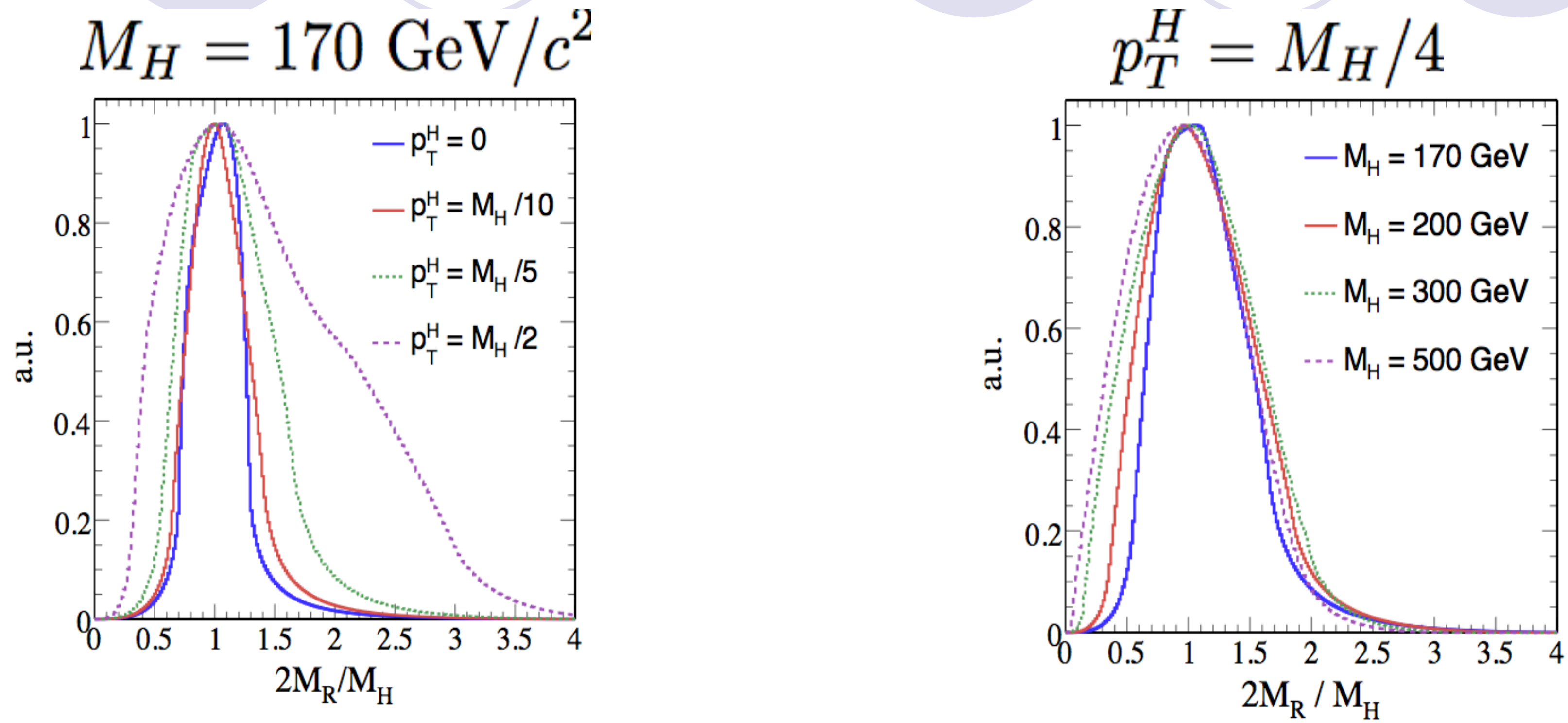

- Here, we use the same toy Monte Carlo, accept we now allow for non-zero Higgs transverse mass

- M_R still peaks at one half the Higgs mass (although peak width will increase with Higgs p_T)