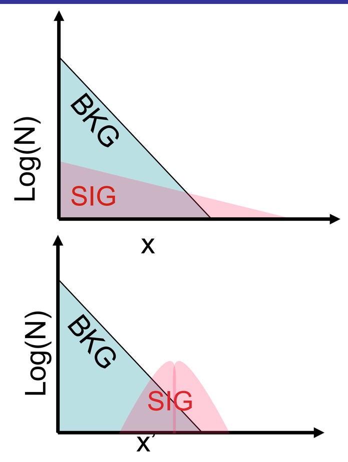
Inclusive Search for Squarks and Gluinos using the Razor Kinematic Variable

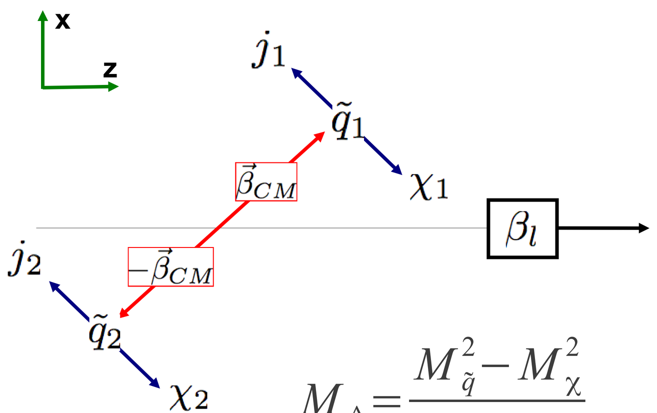
Overview

- SUSY searches using traditional variables involve searching for an exponentially falling signal on exponential background
- The razor variables separates the signal region from the background region turning the search into a bump hunt



The Razor Variables

- Consider a topology where two heavy squarks $\tilde{q}_1 \tilde{q}_2$ each decay into a visible product and an LSP: $\tilde{q}_i \rightarrow j_i \chi_1$
- In the CM frame of this system, the energy of the jets is given by M_Δ /2 the scale of the heavy process



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

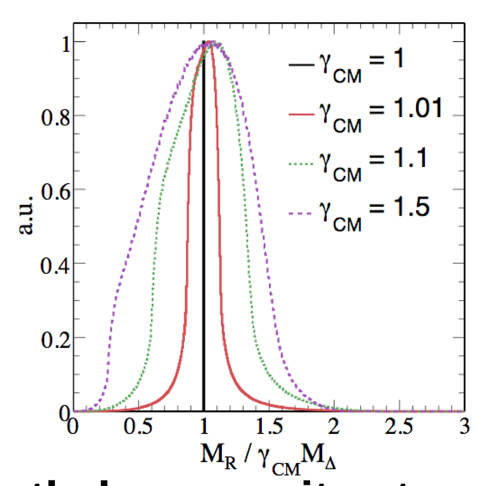
- An event-by-event approximation of the CM frame, the "R frame," is constructed with the approximation that the system has no transverse momentum from ISR
- The R frame is found by computing the longitudinal boost that equalizes the magnitude of the 3-momenta of the jets $\beta_R = \frac{E^{j1} - E^{j2}}{p_z^{j1} - p_z^{j2}}$
- When the R frame matches the CM frame we find that, in this frame $2|\vec{p}_{j1}| = 2|\vec{p}_{j2}| = M_\Delta$ so we define the variable $M_R = 2|\vec{p}_{j1}|$ as an estimator of M_Δ
- For events where the R frame does not match the CM frame, we expect M_R to approximate M_Δ and to peak there for signal events
- For background events, especially QCD multijets, the only relevant scale is $\sqrt{\hat{s}}$ so we expect background to have a steeply falling distribution in M_R
- We also note that, M_Δ is a kinematic end point for $p_T^{j1} + p_T^{j2}$ and E_T^{miss}
- We construct another variable that also has M_Δ as an endpoint:

$$M_T^R = \sqrt{\frac{|E_T^M|(p_T^{j1} + p_T^{j2}) - \vec{E}_T^M \cdot (\vec{p}_T^{j1} + \vec{p}_T^{j2})}{2}}$$

- This variable contains information about the angle between the missing energy and dijets
- To select the signal we use the "razor" discriminator: $R = \frac{M_T^R}{M_R}$
- For signal, R has a maximum value of approximately 1 and a peak value ~0.5
- While both M_T^R and M_R measure the scale M_Δ they are largely uncorrelated for signal events

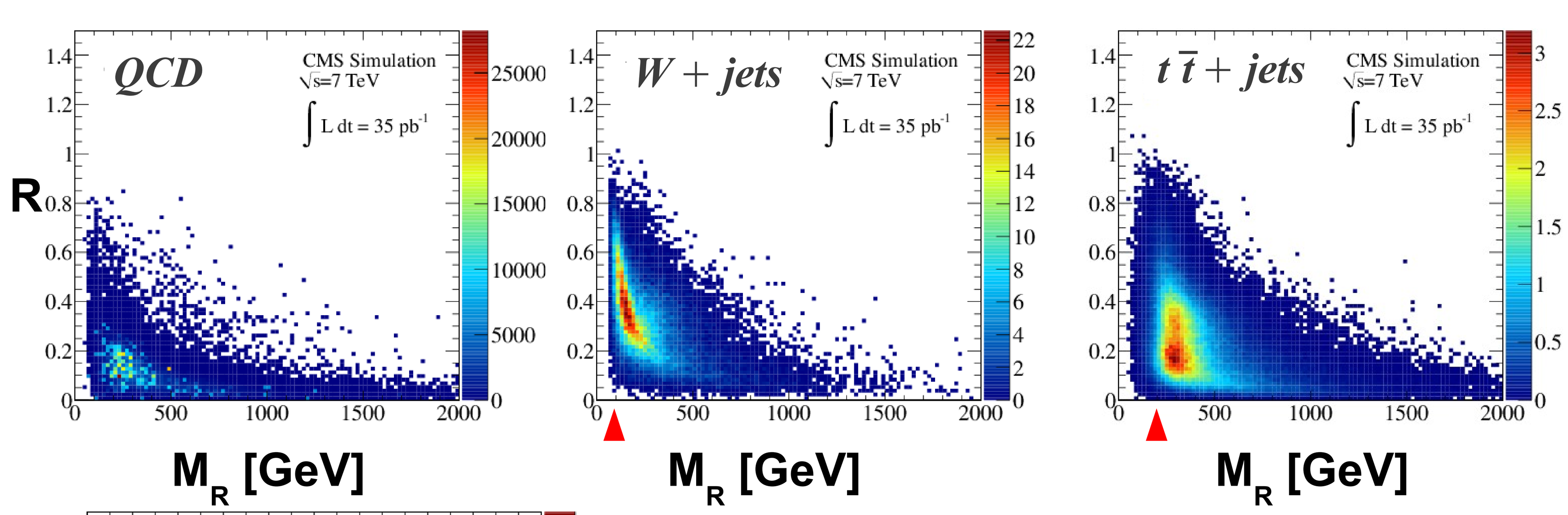
Properties of the razor variables

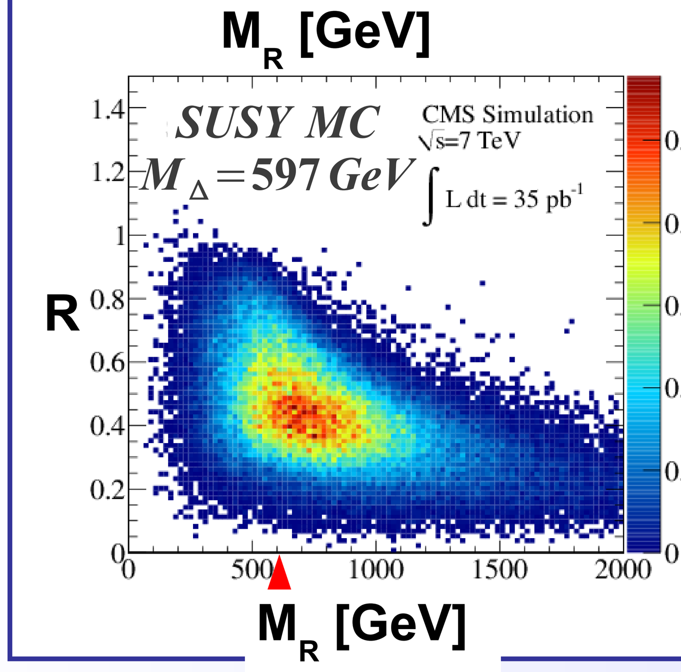
- Squarks produced exactly at threshold ($\gamma_{CM} = 1$) will have $M_R = M_\Delta$
- Even when $\gamma_{CM} > 1$ we still find that M_R has a peak related to the value of the heavy scale
- As long as this remains true casting the search in this variable will produce a peaking signal because of the heavy scale, on falling background



- M_R is robust against jet energy mis-measurements partly because it acts like a geometric average of two jets
- Large transverse momentum imbalances created by jet mis-measurement or jets falling out of acceptance are protected against by the razor: Since M_T^R and M_R measure the same scale in an uncorrelated way the razor is largely unaffected by such imbalances

Background discrimination using razor variables





- We see in the QCD exponential fall-off in R and M_R and no strong peak, reflecting the lack of a heavy scale
- In W+jets and tt+jets we see the massive particle sets the scale in M_R and exponential fall-off above this scale
- For SUSY MC the peak is set by M_Δ in M_R and the large amount of missing energy in R

Analysis Overview:

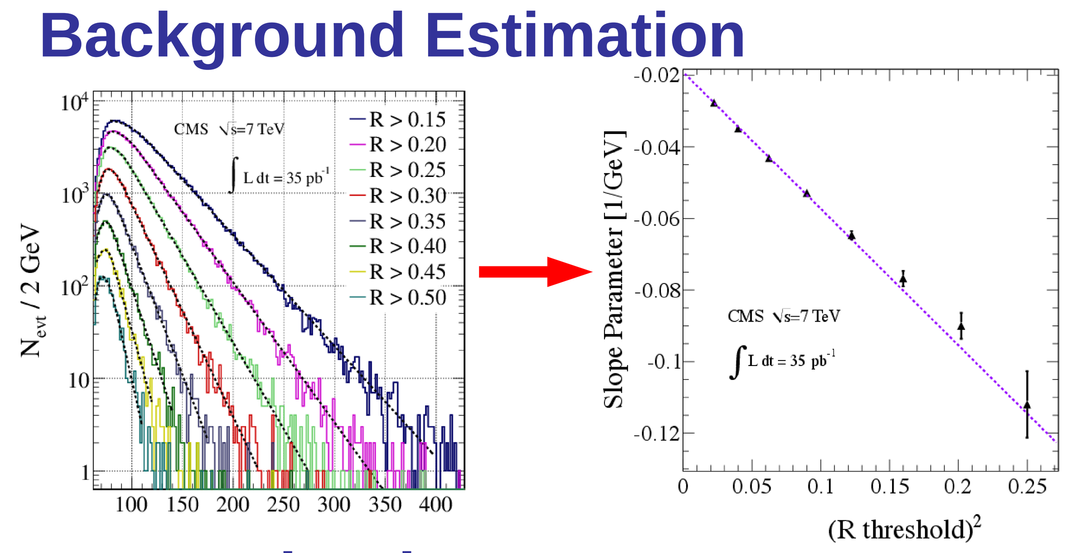
- The razor variables are designed with dijet final states in mind, thus we cast multijet final states into a dijet topology
- All jet-like objects are grouped into 2 hemispheres which are used at "mega"-jets in the computation of the razor variables thus enforcing the dijet-like topology
- These hemispheres are computed by looking at all possible assignments of the jets between the two and finding the one minimizing the transverse mass of the hemisphere system
- Use data-driven corrections to MC for background estimation
- Separate the data into disjoint boxes each with different background
- Use the region dominated by background in each box to get data-driven estimates of the contribution from that source of background and treat this as a correction to the Monte Carlo

Muon Box	Electron Box	Hadronic Box
> 0 good muons	0 good muons >0 good electrons	0 good muons 0 good electrons
W+jets, Z+jets t+X	W+jets, Z+jets t+X	QCD, Z→νν W,Z,t w/ bad lepton

Event Selection

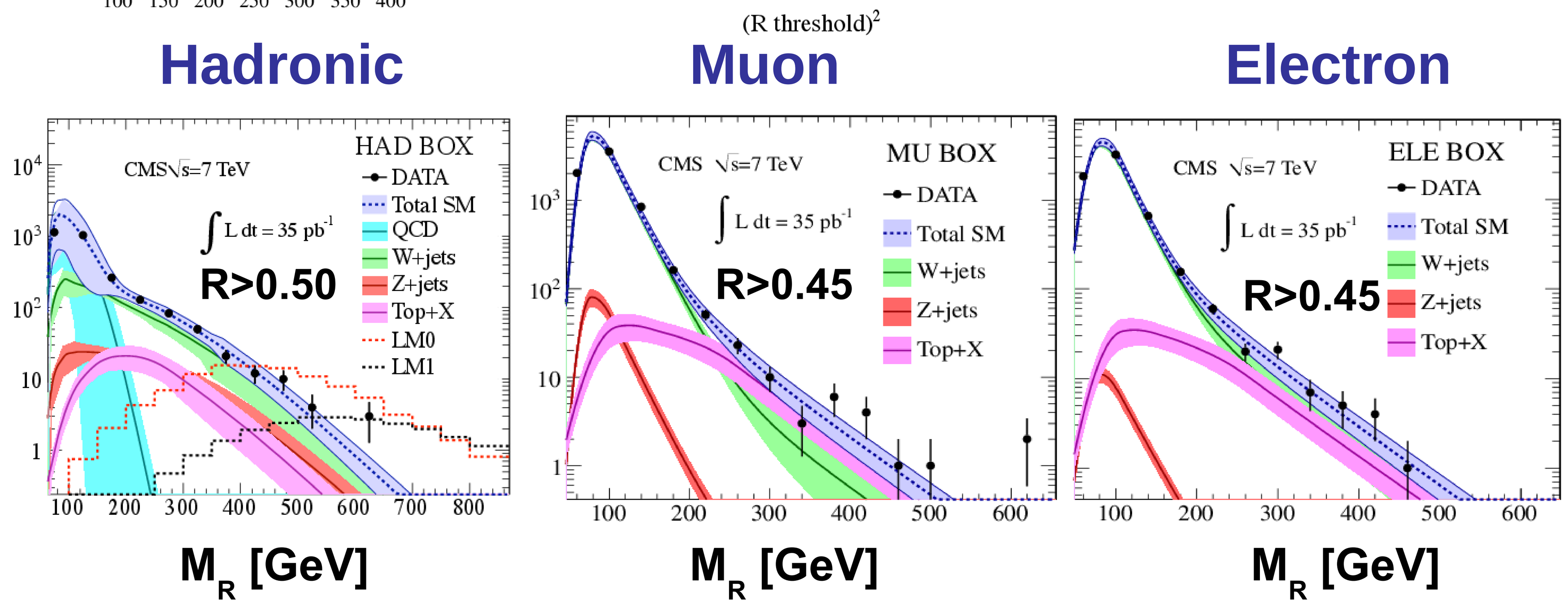
- Data is selected using triggers for Electrons, Muons and H_T (the uncorrected scalar sum of the E_T of trigger lever jets)
- 2 Energy corrected jets with p_T > 30 GeV and $|\eta| < 3$ are required for hemisphere reconstruction, hemispheres are made from all jets passing these requirements
- CMS particle flow algorithms are used to reconstruct the E_T^{miss}
- Once the hemispheres are constructed the boost variable β_R is computed. Events with non-physical β_R>1 are excluded (possible because of the approximations used). Furthermore, events with β_R=1 are excluded to avoid singularities in razor computation
- Events where the the best hemispheres have an azimuthal angular difference > 2.8 radians are excluded to suppress back-to-back QCD events
- Electrons and Muons are selected passing quality requirements and with p_T > 20 GeV

Background Estimation



For each box:

- Measure slope vs R cut
- Fit slope vs (R cut)^2
- Compare with MC and use to correct MC distributions in all boxes

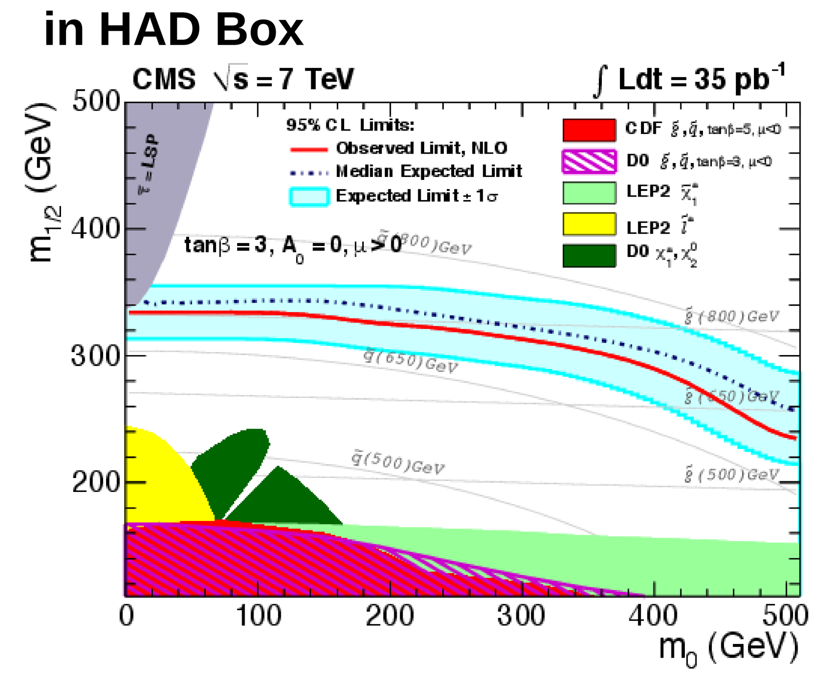


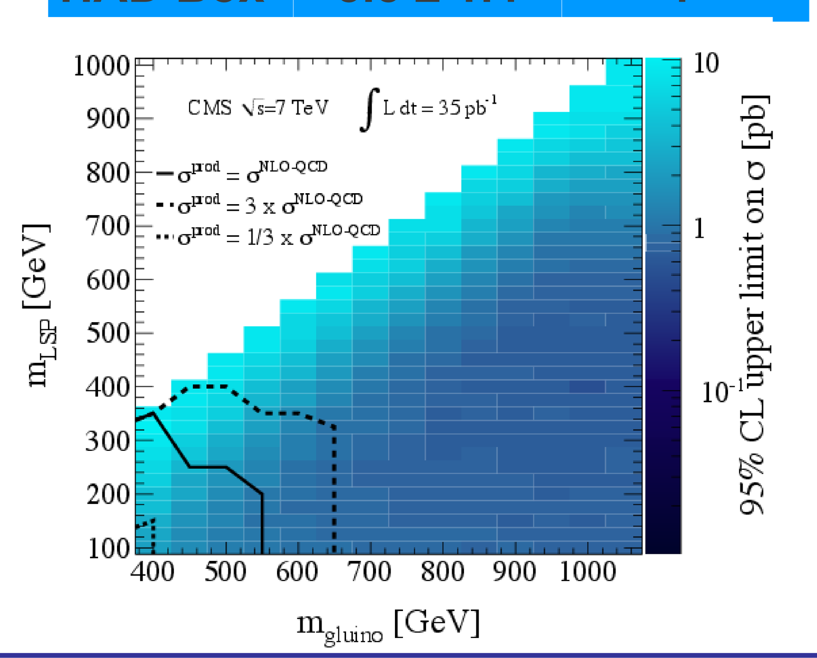
- W+jets: first component in mu and electron boxes box
- t+X: second component in mu and electron boxes
- QCD: QCD control box (dijet triggered sample in low MR region)

Results and Limits

- Look at events with R > 0.45 M_R > 500 in MU and ELE Boxes
- Look at events with R > 0.50 M_R > 500 in HAD Box

	Expected	Observed
MU Box	0.51 ± 0.20	3
ELE Box	0.63 ± 0.23	0
HAD Box	5.5 ± 1.4	7





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