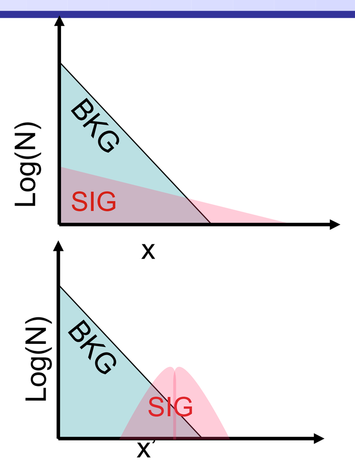
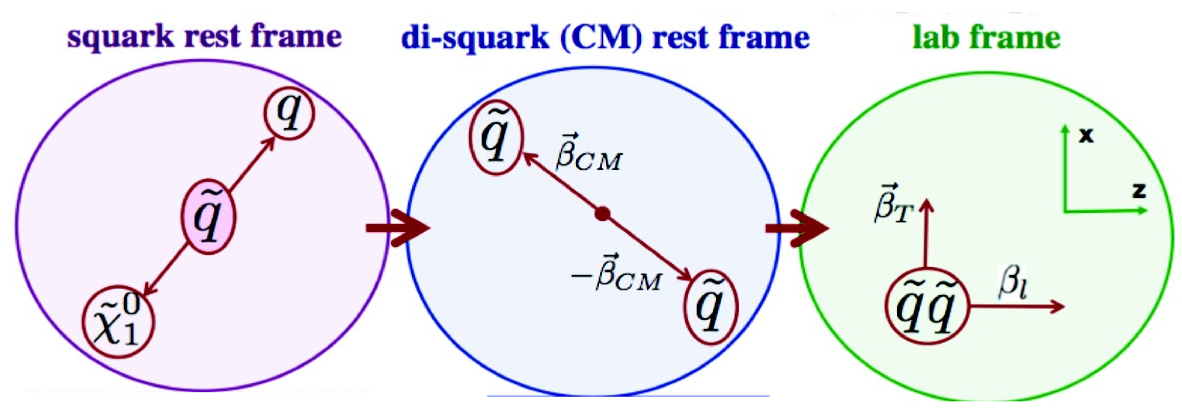
Inclusive Search for Squarks and Gluinos using the Razor Kinematic Variable

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

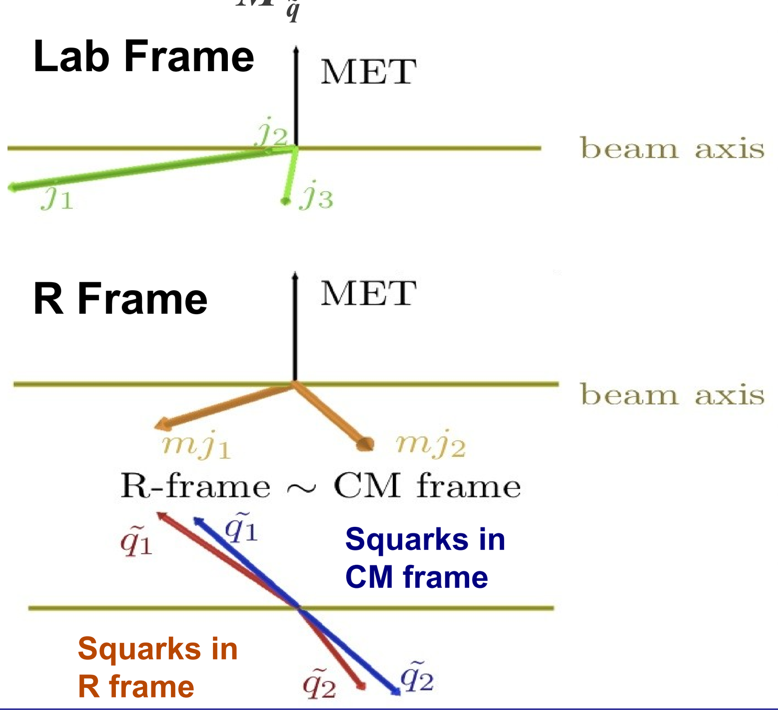


The Razor Variables



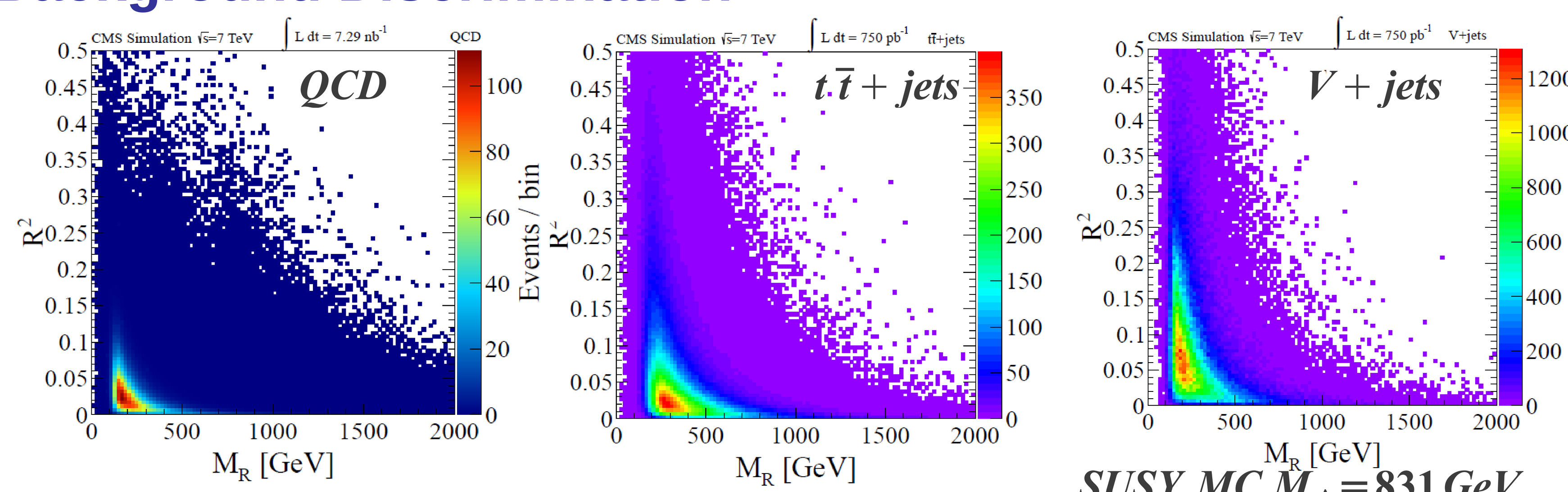
R-frame: Longitudinally boosted frame in which the energies of the two jets are equal

$M_\Delta = \frac{M_{\tilde{q}}^2 - M_{\chi}^2}{M_{\tilde{q}}}$ $\quad 2\gamma_{CM} M_\Delta = \sqrt{\hat{s}}$ $\quad |\vec{\beta}_T| \ll 1$

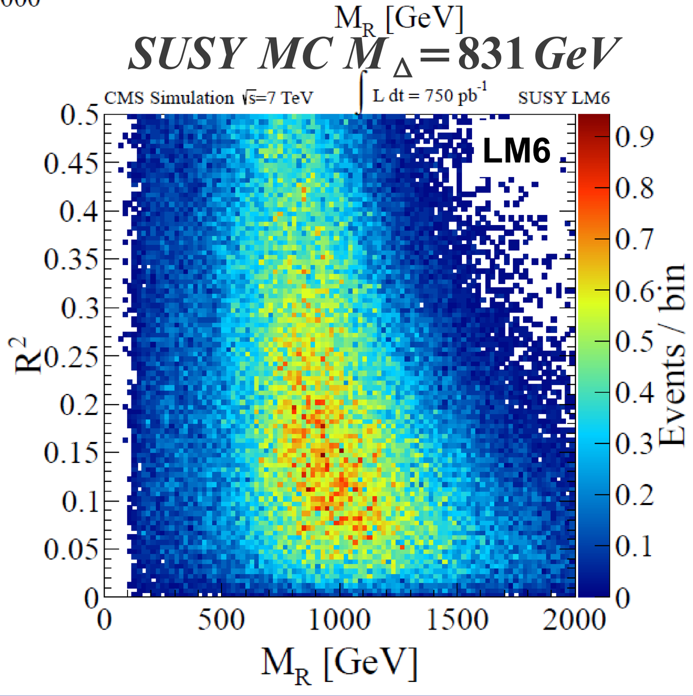


- M_R is defined as twice the jet energy in the R frame
- For events with a heavy scale, M_R peaks at $\gamma_{CM} M_\Delta$
- Define another variable M_T^R, which acts like the transverse mass
- M_T^R has a kinematic edge at $\gamma_{CM} M_\Delta$
- Define the razor R as the ratio: $R \equiv \frac{M_T^R}{M_R}$
- R peaks near 0.5 for signal events, but around zero for events without a heavy scale (e.g. QCD).

Background Discrimination

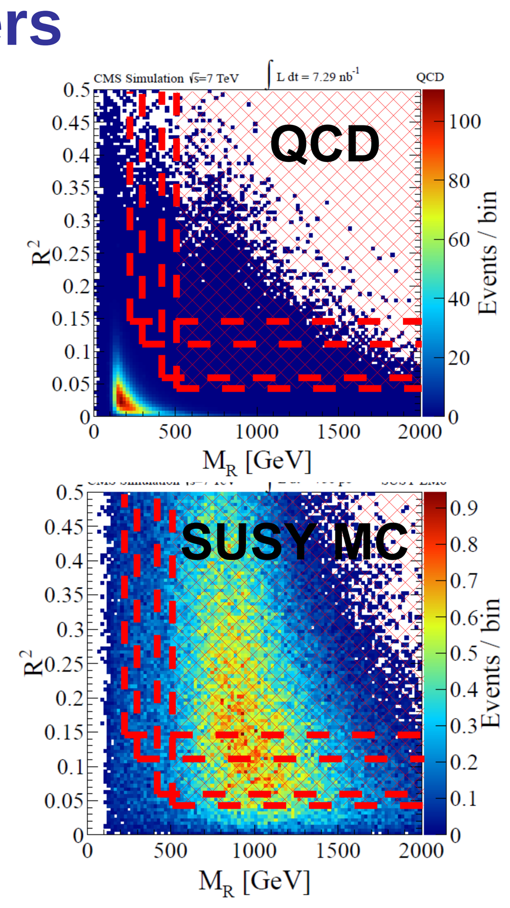


- The primary backgrounds for the come from QCD, ttbar and V+jets
- For QCD, with no heavy scale, the M_R distribution is steeply falling
- For events with a heavy scale, the M_R distribution peaks around the mass of the heavy particle
- SUSY-like MC is clustered at high M_R, because of the heavy scale, and high R because of the large missing energy



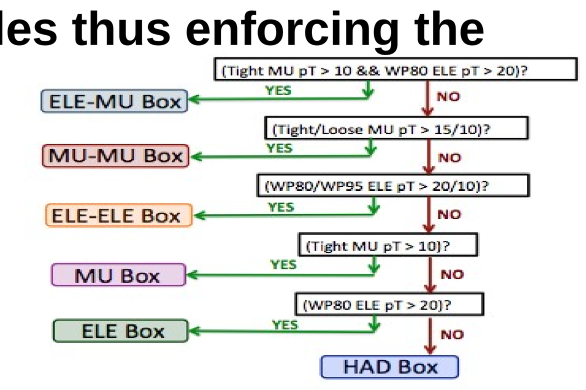
Online Event Selection with Razor Triggers

- In order to select events online with maximal range in R and M_R, dedicated triggers are used
- These triggers compute the variables R and M_R in the online farm, allowing much further reach for this analysis than traditional trigger variables
- In order to fully cover the signal and sideband regions, while cutting as much QCD as possible to keep the trigger rates down, a suite of razor triggers are deployed in the high-level trigger menu
- A set of cross-triggers, pairing muons and electrons with the razor variables, is also used to provide further reach in the leptonic and double leptonic boxes

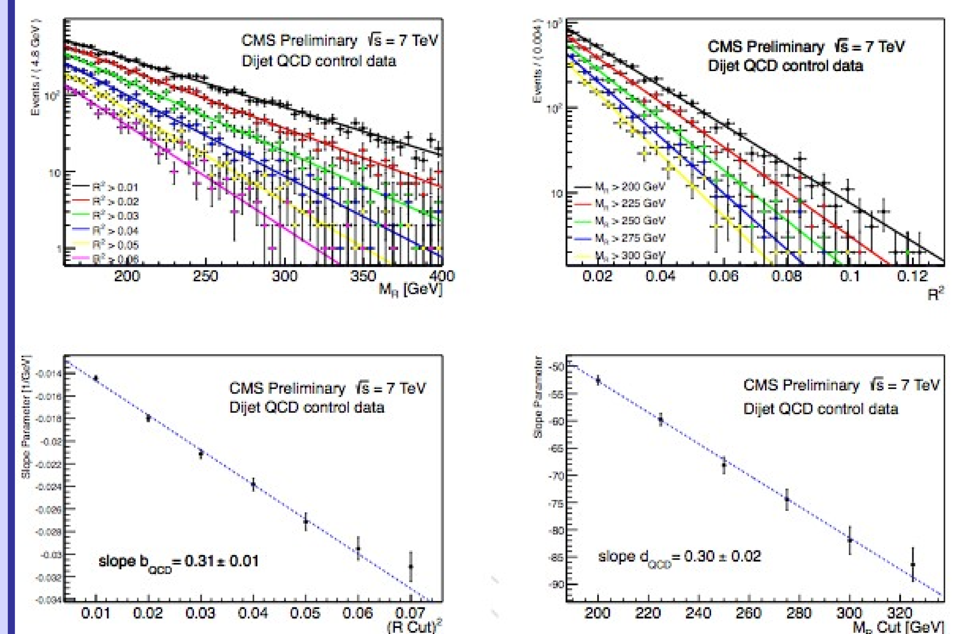


Analysis Overview:

- 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 "megajets" in the computation of the razor variables thus enforcing the dijet-like topology
- We separate events into disjoint boxes based on their lepton content
- Each box has different dominant backgrounds, allowing us to get data-driven estimates of the different background contributions



Background Scaling



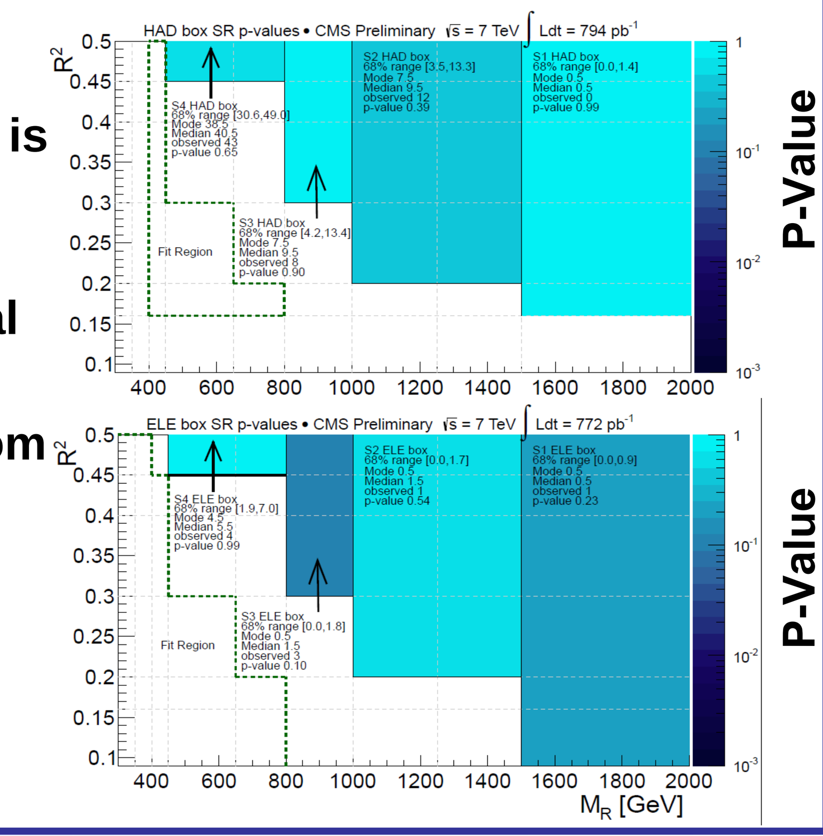
- On a data control sample, we see that the distributions in R^2 and M_R are exponentially falling
- The slope of the exponential scale as a function of the cut applied to the other variable
- In fact, in both cases we observe a linear scaling of the slope parameters with respect to the cut on the other variable
- The slope of the scaling in R^2 is the same as that for the scaling in M_R
- We observe that the same type scaling occurs for each SM process with different parameters dependent on the process
- The equivalence of the slope parameters is observed for all processes
- We use this to construct a 2D function that analytically describes the full R^2-M_R distribution and recovers the 1 dimensional scaling after integration

Background Fit

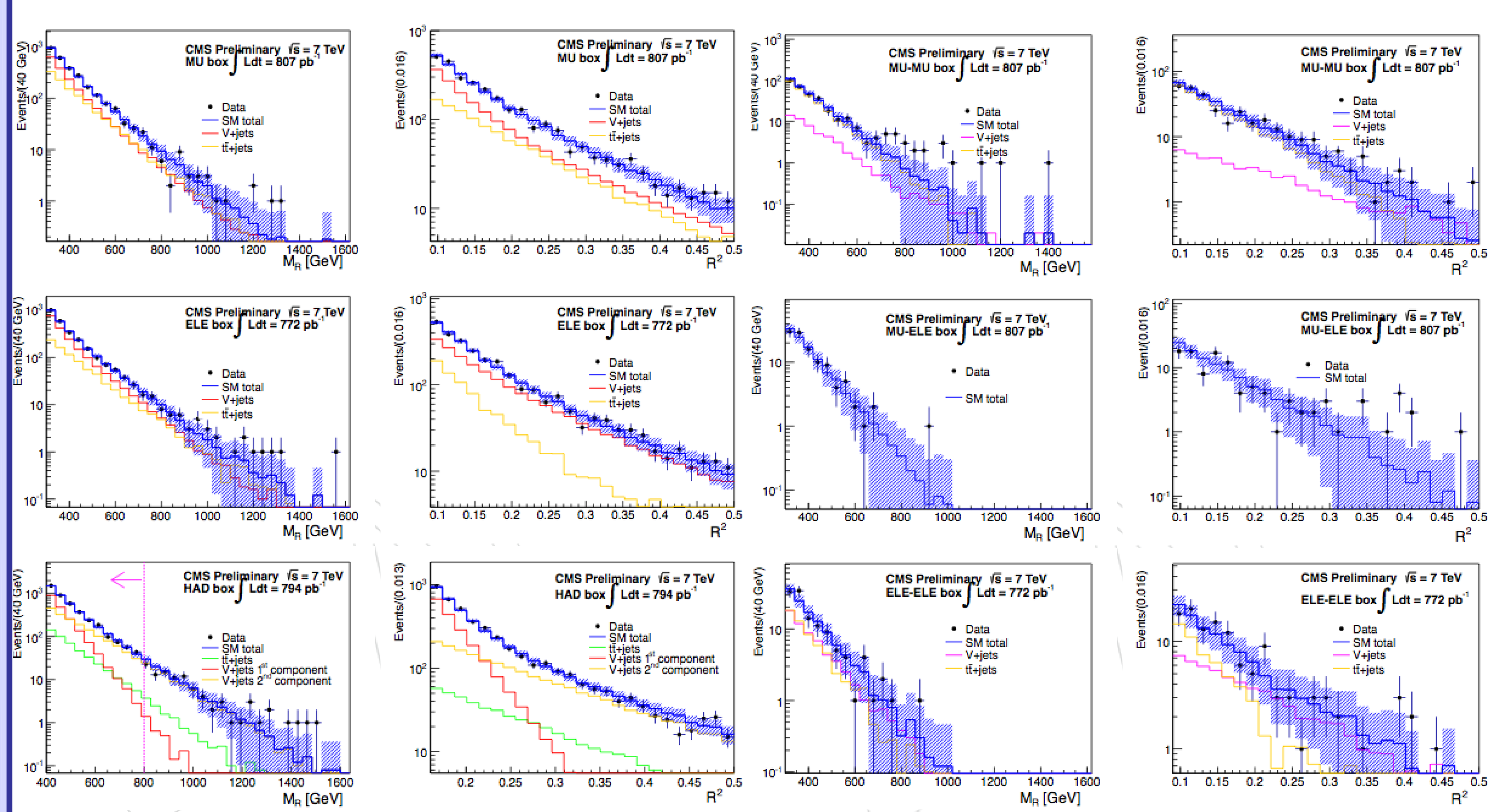
- We perform an extended and unbinned maximum likelihood fit in the fit region of the R^2-M_R plane in each box with two-components of the form:

$$F(R^2, M_R) = [k(M_R - M_R^0)(R^2 - R_0^2) - 1]\, e^{-k(M_R - M_{R,i}^0)(R^2 - R_{0,i}^2)}$$

- The shape of the first component is found to be box dependent, i.e. it depends on the particular process dominant in each box
- The shape of the second component is found, though not constrained, to be universal in both simulation and data, and is associated with large amounts of ISR
- The background shapes found on data control samples are then used as the initial values for the 2D fits
- The shape parameters k, R_0^2, M_R^0 taken from the fits are then used to define the background model and uncertainty
  - The fits are continued into the signal region to estimate the total SM background yield in the region where a SUSY signal would be visible



Fit Results and Background Estimation

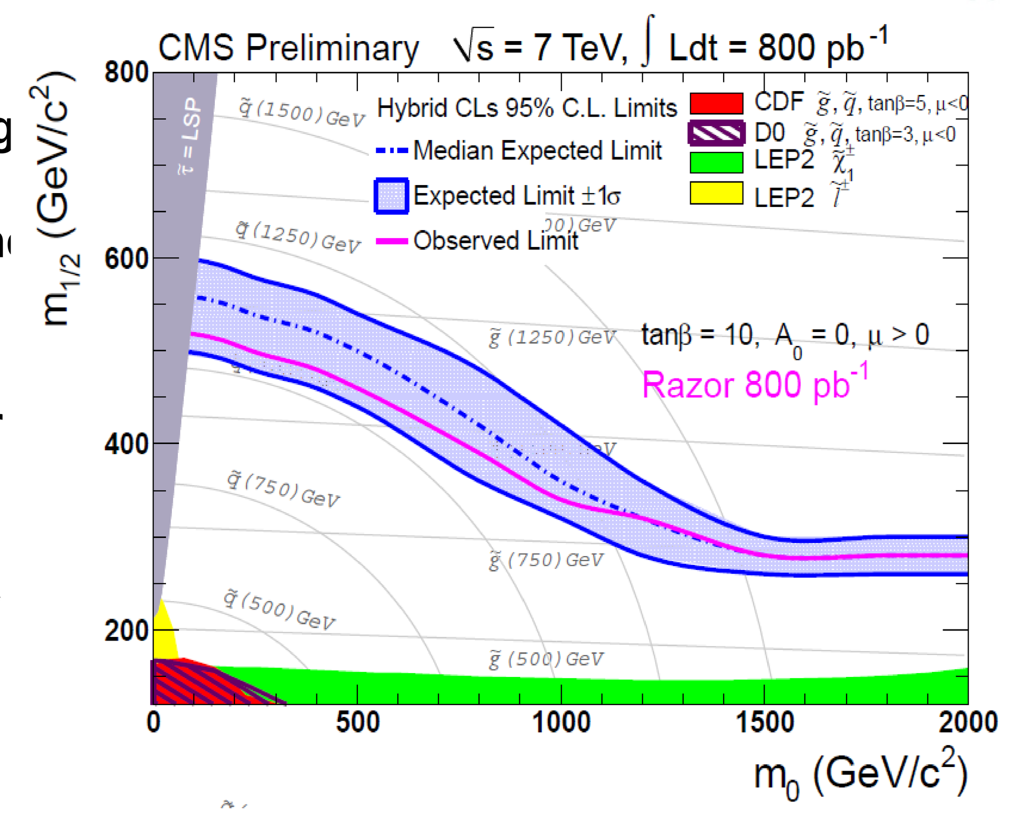


- No significant excess over the Standard Model background is observed

Model-Dependent Limits

$$\mathcal{L}_b = \frac{e^{-(\sum_{j\in SM} N_j)}}{N!} \prod_{i=1}^{N} \Big(\sum_{j\in SM} N_j P_j(M_{R,i}, R_i^2) \Big) \qquad \mathcal{L}_{s+b} = \frac{e^{-N_S-(\sum_{j\in SM} N_j)}}{N!} \prod_{i=1}^{N} \Big(N_S P_S(M_{R,i}, R_i^2) + \sum_{j\in SM} N_j P_j(M_{R,i}, R_i^2) \Big)$$

- We use the extended unbinned full shape fit to compute the log likelihood of the signal plus background hypothesis over th background hypothesis
- We set limits in the $(m_0, m_{1/2})$ plane for the CMSSM model for $\tan(\beta) = 10$
- These results extended the current LHC limits significantly



https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS11008

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