Hadronic Search for SUSY with MT2 variable

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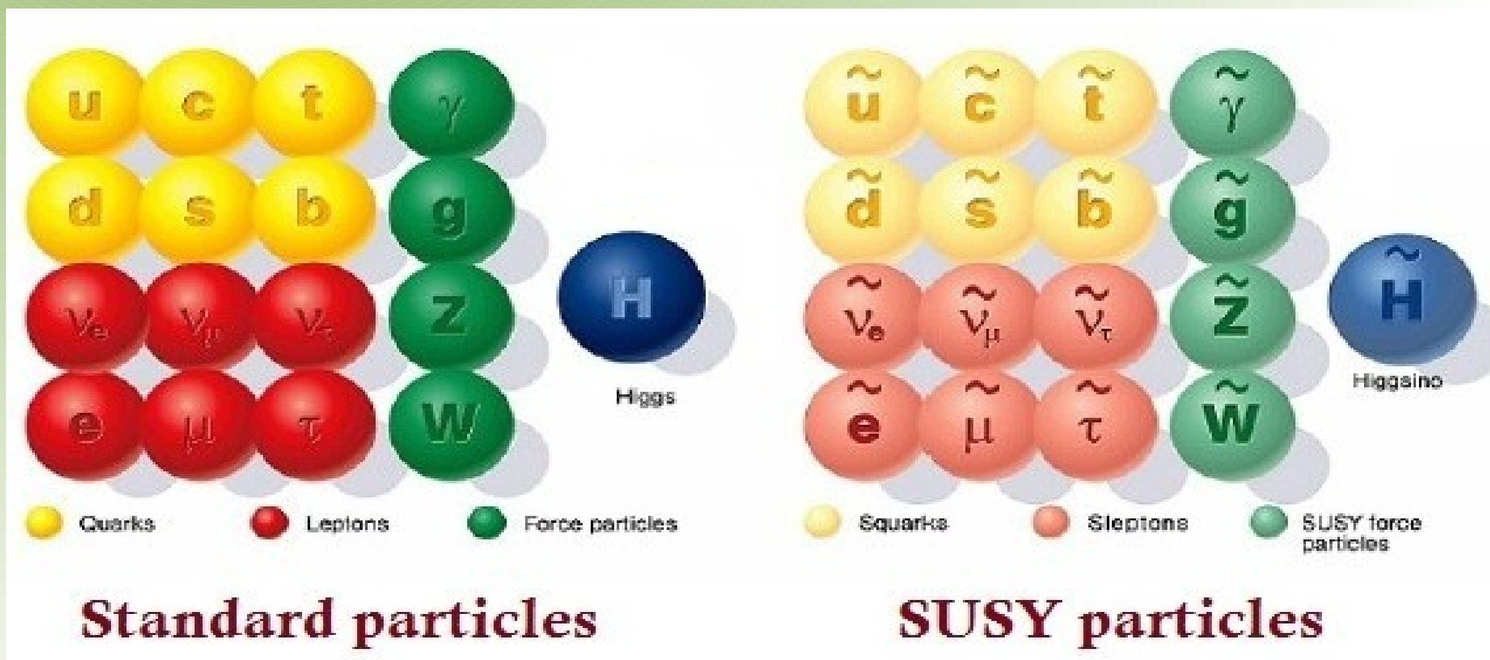
Outline

- Supersymmetry and Its Motivations
- Why Hadronic search? Why MT2?
- From MT to MT2
- Interpretation of MT2
- Search Sterategy
- Backgrounds Estimation
- Results
- Conclusion

Supersymmetry and Its Motivations

- SUperSYmmetry (SUSY) is a symmetry between fermions ⟷ bosons,
  Q |boson> = |fermion> , Q |fermion> = |boson>



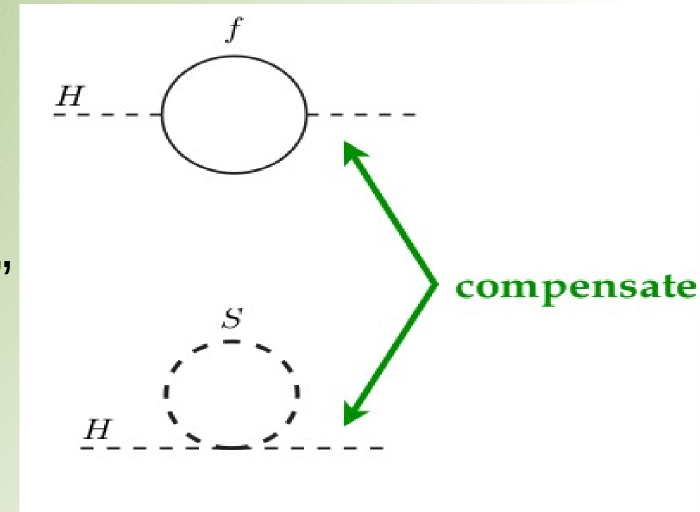
- SUSY: double number of particles (MSSM)
- Spin of SUSY particles differs by 1/2 a unit
- Must be broken, 105 free parameters due to SUSY breaking
- mSUGRA/cMSSM has 5 free parametes: A0, tanβ , sgn(μ), m0, m1/2.

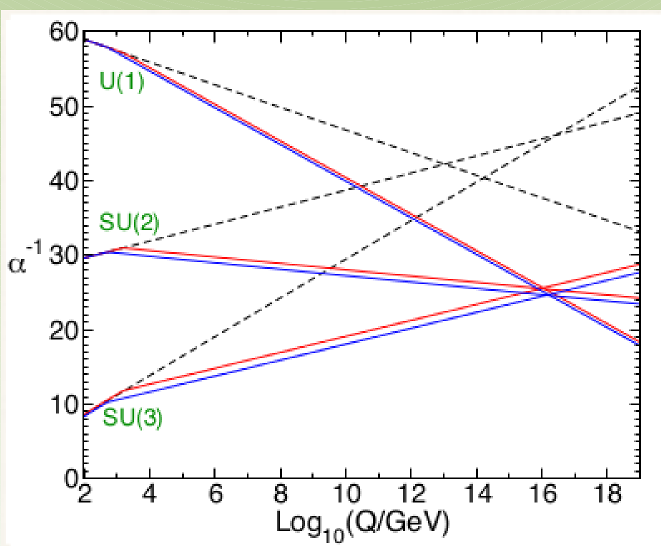
Supersymmetry and Its Motivations

- SUSY is very interesting, as it:

1. gives a

"Solution to the Hierarchy Problem"



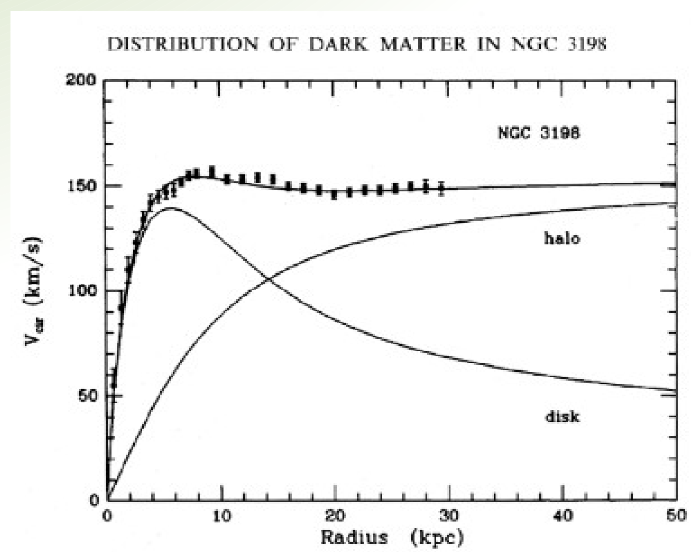


2. facilitates a

"Gauge Couplings Unification"

3. provides a

"Dark Matter candidate"



Astrophysical Journal, vol. 295, Aug. 15, 1985, p. 305-313.

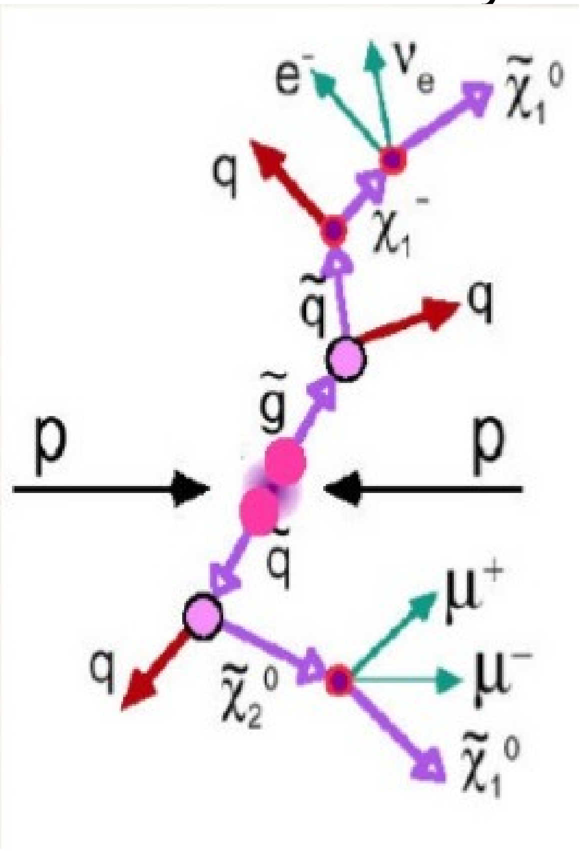
Why Hadronic search? Why MT2?

If SUSY ,conserving R-parity, comes with a Dark Matter candidate:

- SUSY particles must be produced in pairs and the lightest sparticle (LSP) as a Dark matter candidate is stable.
- Colored SUSY particles cascade down to LSP with emission of jets and sometimes leptons, therefore in search for SUSY, MET and HT are very useful variables:

$$H_T = \sum_{jets} |\vec{p}_T| \qquad E_T^{miss} = \left| - \sum_{particles} \vec{p}_T \right|$$

Hadronic activity — Missing transverse momentum



- Classical SUSY searches are based on these two variables but it can be defined a clever kinematical variable reflecting these properties which it is “MT2”.

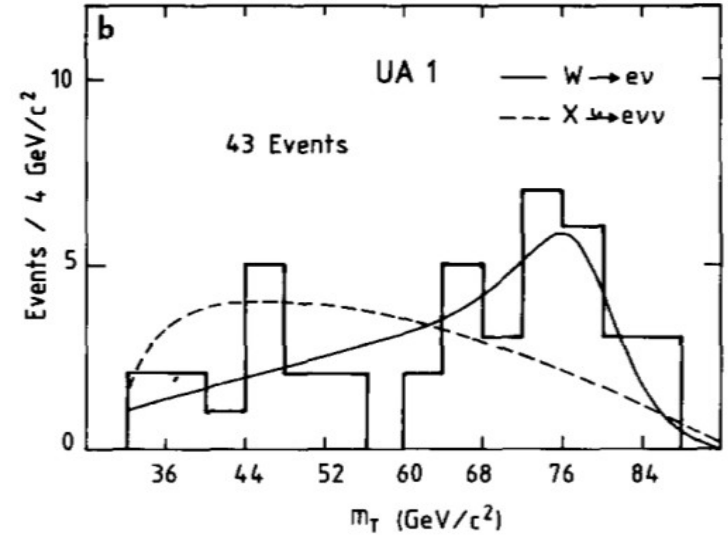
From MT to MT2

In W→eν decay, transverse mass MT has an endpoint at the true W-mass:

$$m_W^2 = \quad m_l^2 + m_\nu^2 + 2(E_T^l E_T^\nu \cosh \Delta\eta - \mathbf{p}_T^l \cdot \mathbf{p}_T^\nu) \geq$$

$$m_T^2 = m_l^2 + m_\nu^2 + 2(E_T^l E_T^\nu - \mathbf{p}_T^l \cdot \mathbf{p}_T^\nu)$$

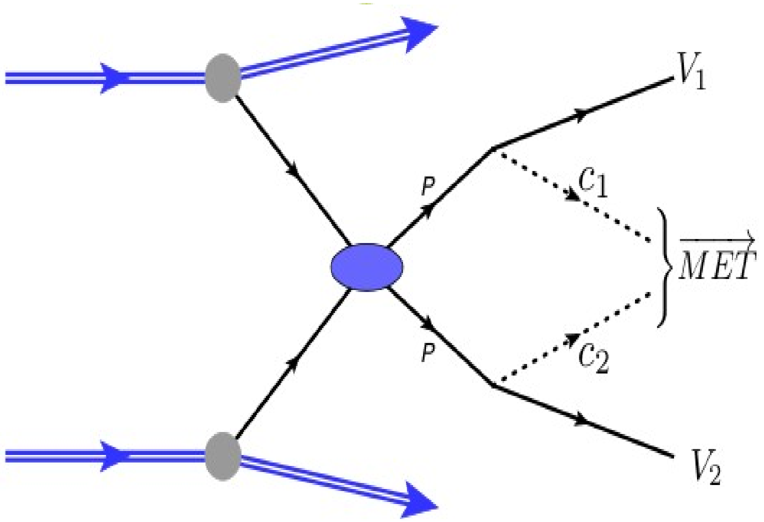
Phys. Lett. B 129 (1983) 273-282



At the LHC, assuming R-parity conservation, SUSY events give rise to two decay chains with an unobserved child (c1 and c2) at each end.

The "stransverse" mass MT2: extension of MT for the SUSY case of two unobserved particles:

$$M_{T2}(m_c) = \min_{p_T^{c(1)} + p_T^{c(2)} = p_T^{miss}} \left[\max\left(m_T^{(1)}, m_T^{(2)} \right) \right]$$



If Mc were known, the endpoint of MT2 would correspond to the parent mass Mp.

Interpretation of MT2

- In case of no initial state radiation (ISR) and zero masses:

$$M_{T2}^2 = 2 p_T^{(1)} p_T^{(2)} (1 + \cos\phi_{1,2})$$

  which pT(i) is the transverse momenta of the visible systems.

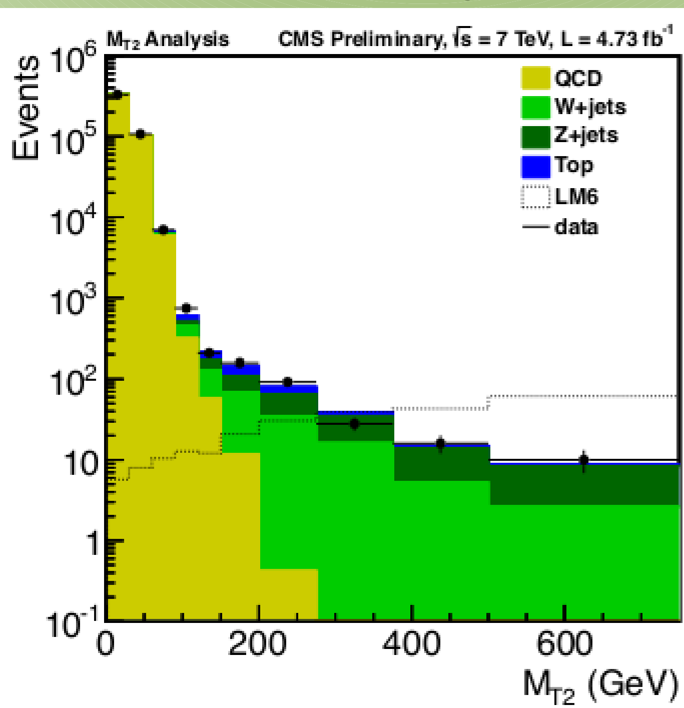
- MT2 = MET for symmetric systems, pT(1)=pT(2)

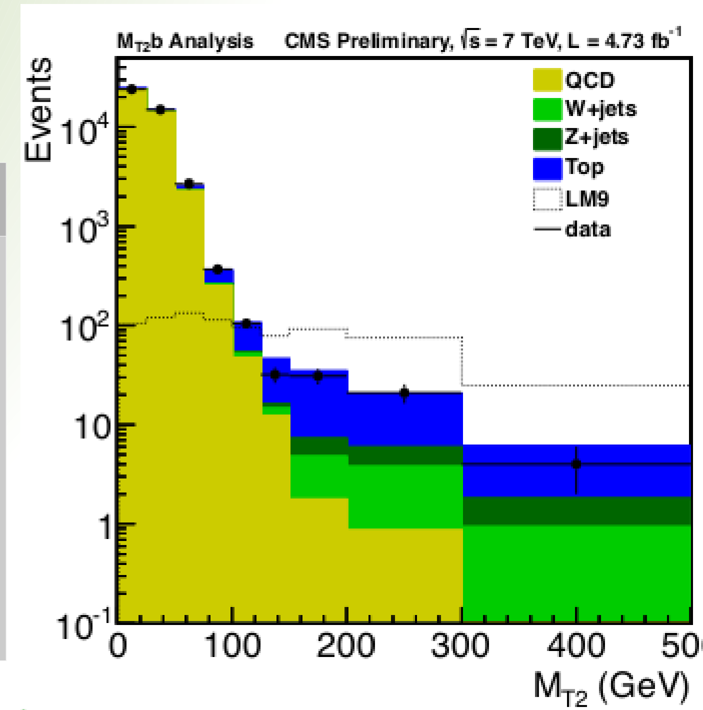
$$(E_T^{miss})^2 = (p_T^{(1)} - p_T^{(2)})^2 + 2 p_T^{(1)} p_T^{(2)} (1 + \cos\phi_{12})$$

- MT2 = 0 GeV for back-to-back systems, like QCD di-jets events.
- MT2 is similar to MET in signal region, but more robust against jet energy mismeasurements than MET. Therefore QCD multijet events accumulated at low MT2.
  Events with real MET can have large values in MT2.
- Multijet events are divided into a 2 pseudo-jets topology using a hemisphere algorithm.

Search Sterategy

- Search in fully hadronic final states with 2011 pp collision data at 7 TeV collected by the CMS detector, corresponding to 4.73 fb-1.





Baseline selection

HT ≥ 750 GeV

- electron and muon veto
- filters against detector noise

MT2 analysis

- At least 3 jets
- minΔφ(jets, MET) > 0.3
- MT2 > 150 GeV

sensitive to high/medium squark and gluino masses

sensitive to light gluinos with heavy squarks

MT2b analysis

- At least 4 jets
- At least one jet b-tagged
- minΔφ(j1-j4, MET) > 0.3
- MT2 > 125 GeV

Backgrounds Estimation

- QCD multijets have no genuine MET → small MT2. MC predicts that the signal regions are QCD free.
- Mismeasured jets can lead to larger MT2. These jets are aligned with MET. Use correlation of minΔφ(jets, MET) and MT2 to conservatively estimate the QCD contamination in the signal region from data.

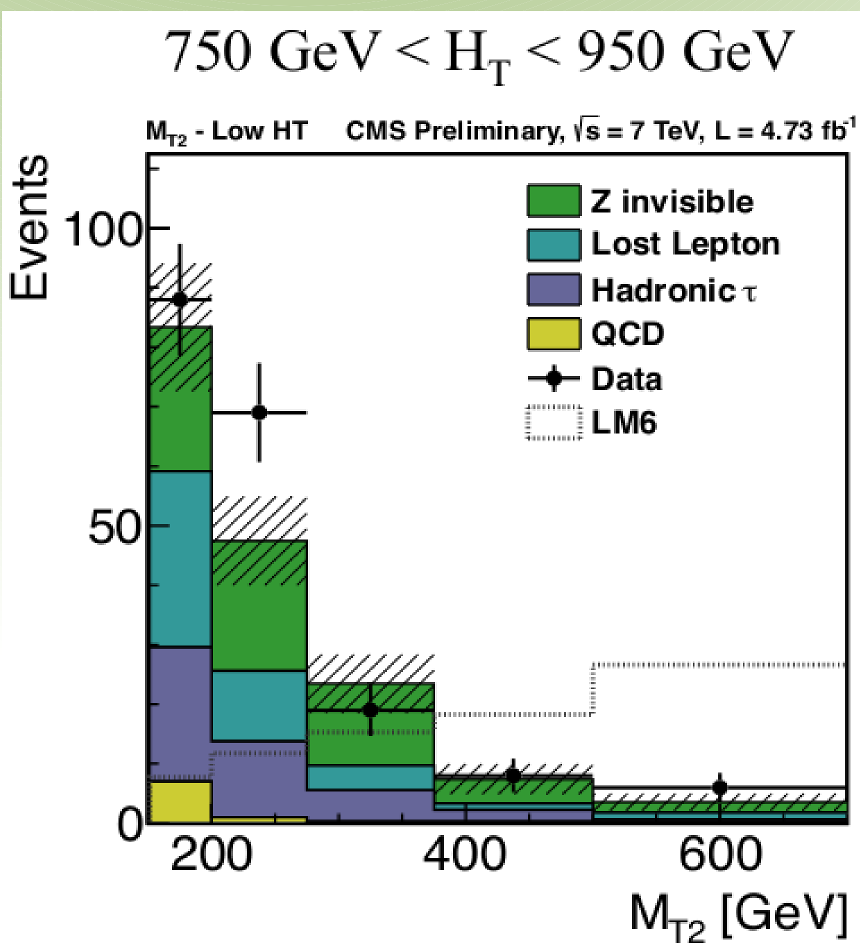
- Z bosons decaying into neutrinos are signal like with large MET.
- This background is predicted by using W(→μν)+jets and photon + jets events.
- In both cases the visible vector boson pT is added to the MET to mimic Z(→νν)+jets events.

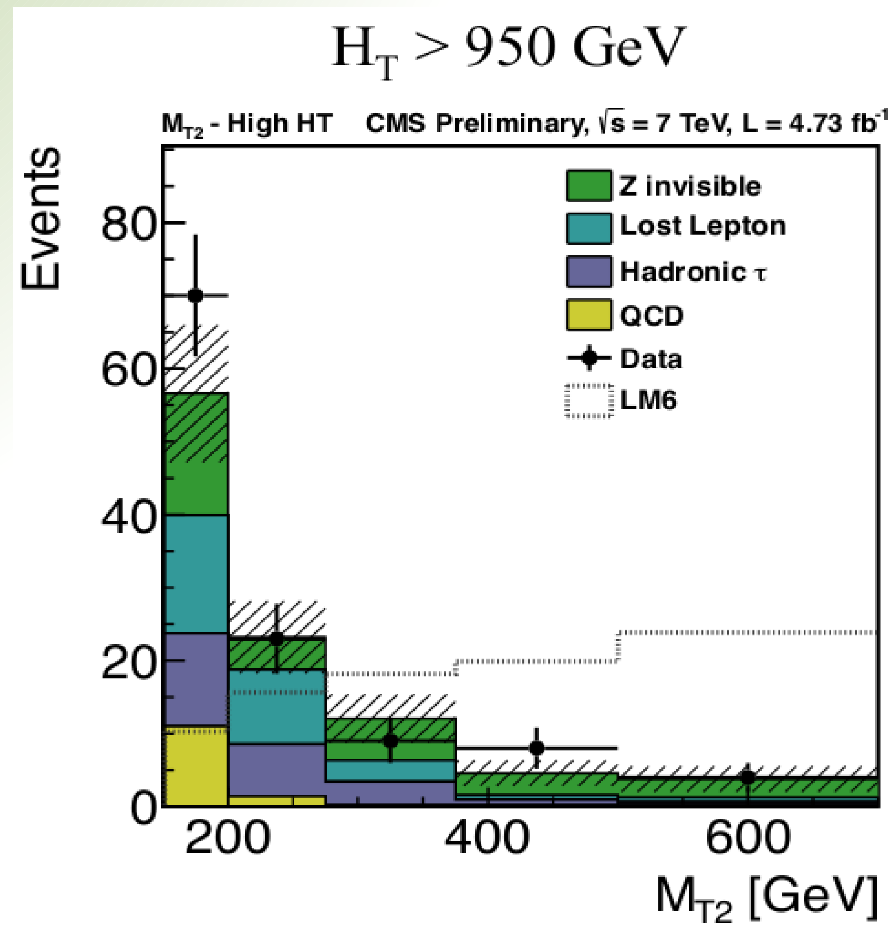
- Leptonic W+jets and Top+jets events have real MET. Largely reduced due to lepton veto.
- Enter to signal region if the charged lepton is not reconstructed or out of acceptance (= is lost).
- Remaining (lost lepton) background estimated in EWK control region from the number of events with a found lepton in data and corrected for the probability to lose a lepton.

Robust estimation of the SM backgrounds contribution to all signal bins.

Backgrounds Estimation

- The backgrounds estimation for the MT2 analysis are summarized here.
- Shaded region is uncertainty on the background estimation.
- The observed data are shown.
- A possible SUSY signal is overlaid to show sensitivity of search region.





Backgrounds Estimation

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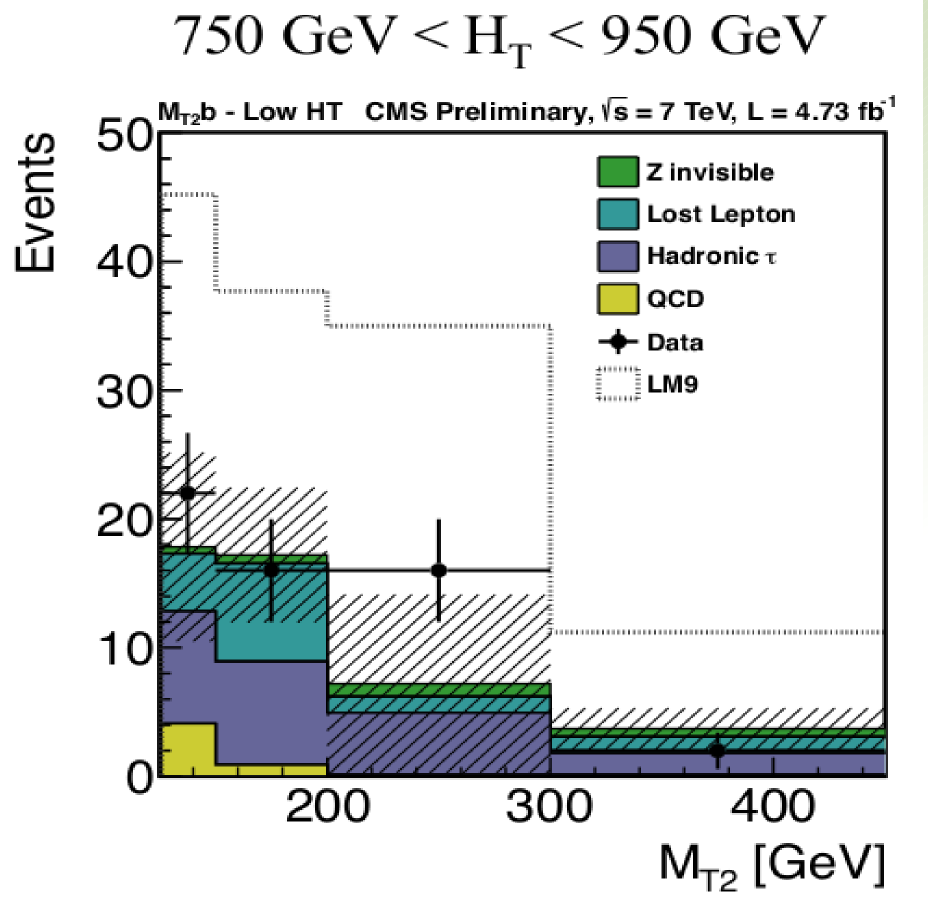
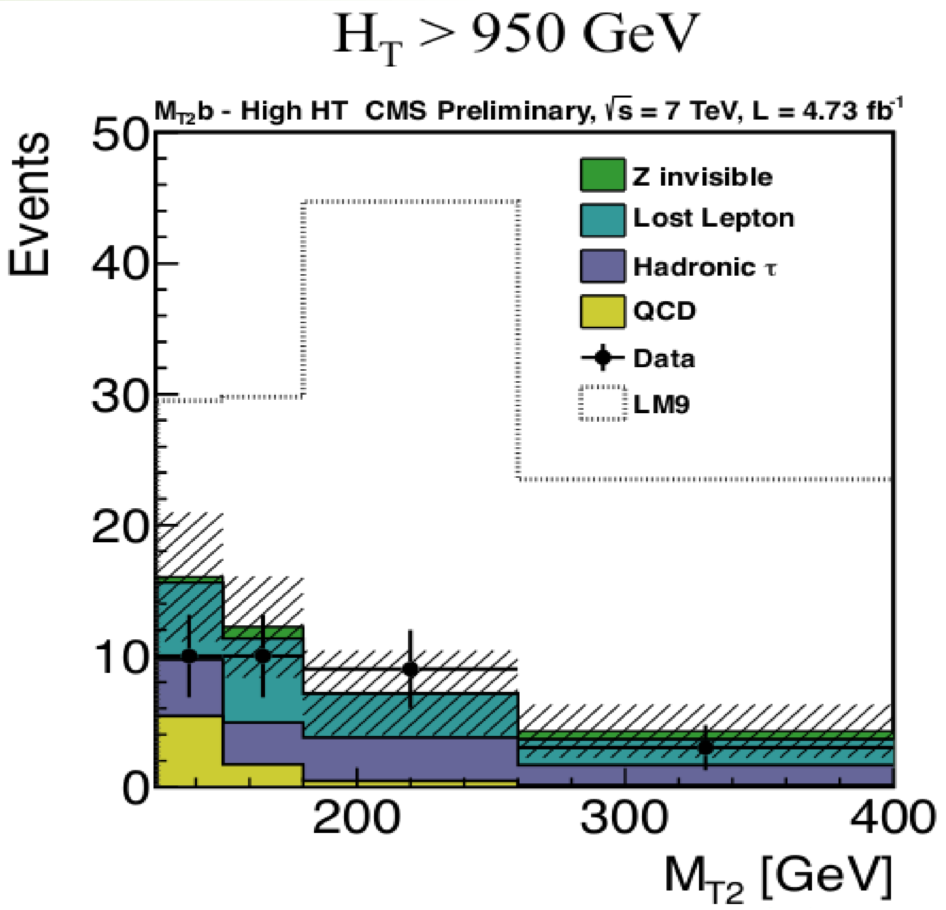
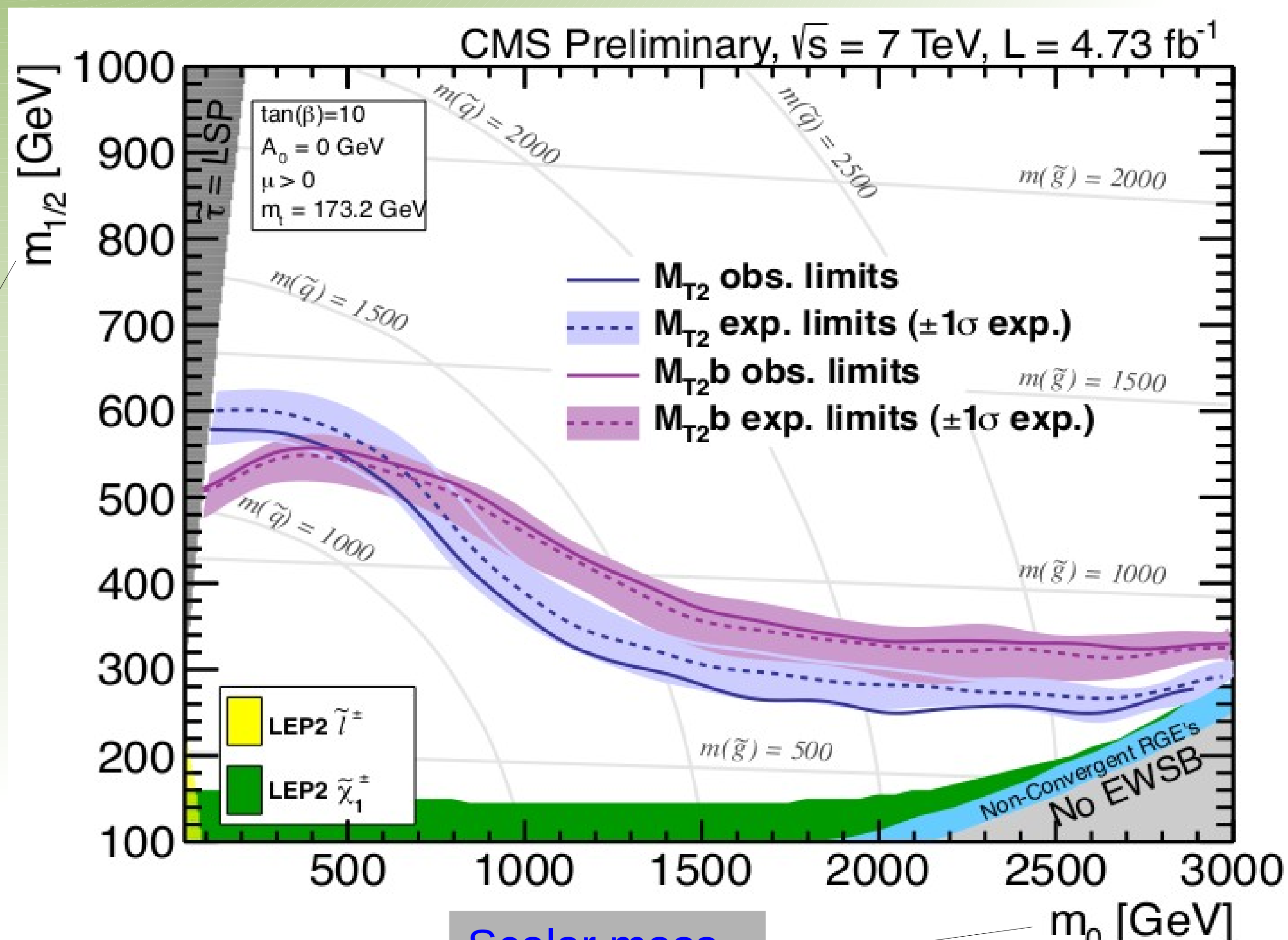




Results

- The results are interpreted in a full SUSY model constrained to five parameters (mSUGRA/cMSSM).
- In the plane below three of those parameters are fixed: A0 = 0, tanβ = 10, μ>0

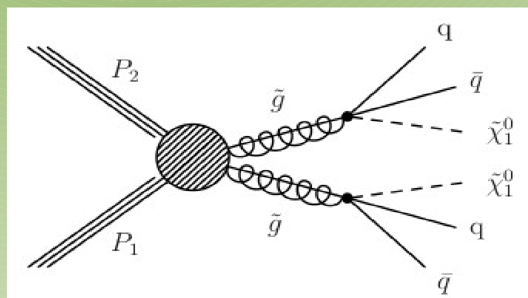


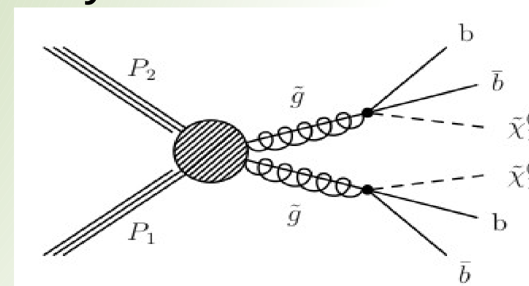
Gaugino mass parameter

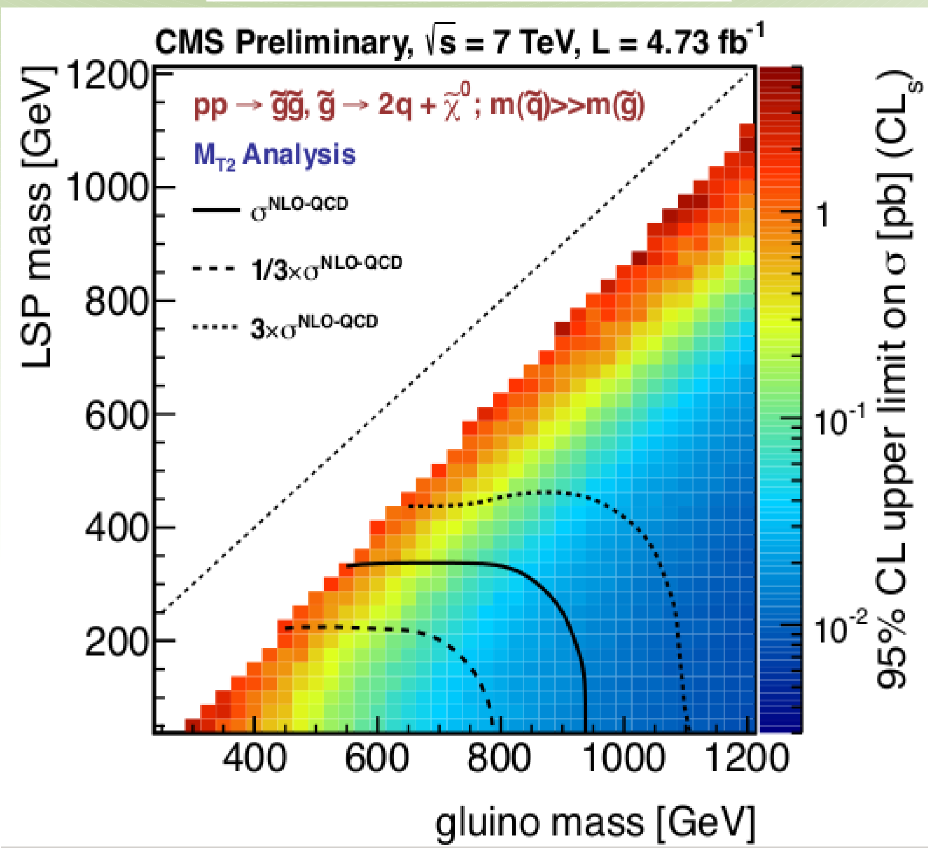
Scalar mass parameter

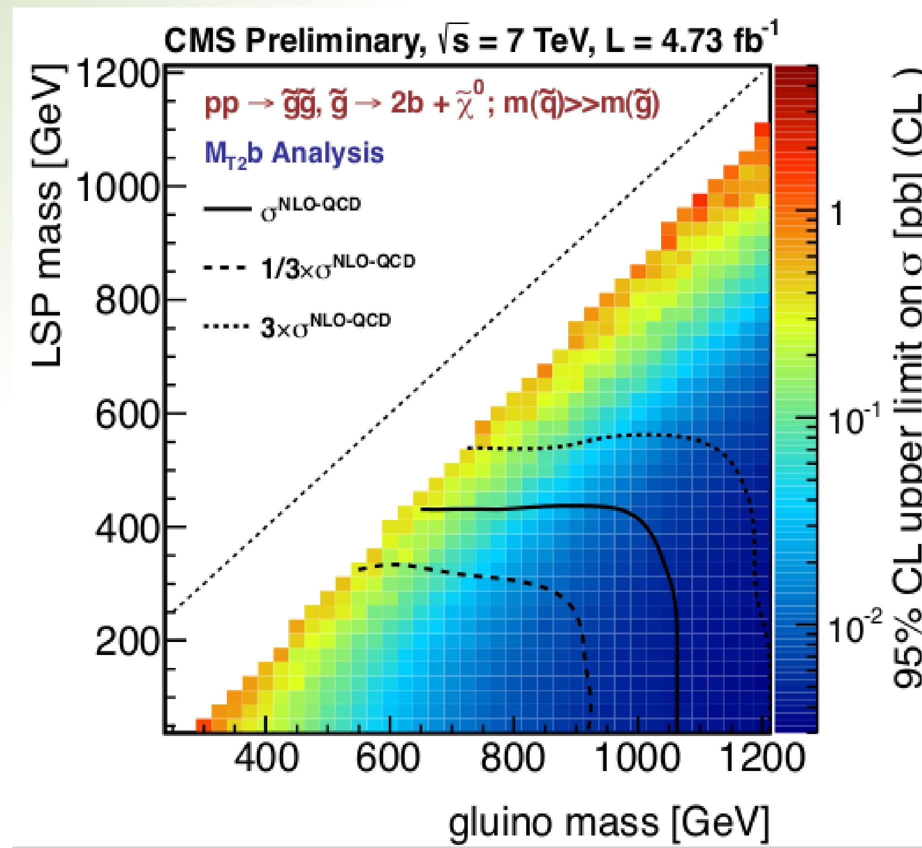
Results

- The analyses are also interpreted in simplified models.
- Models are reduced to one SUSY decay chain only.



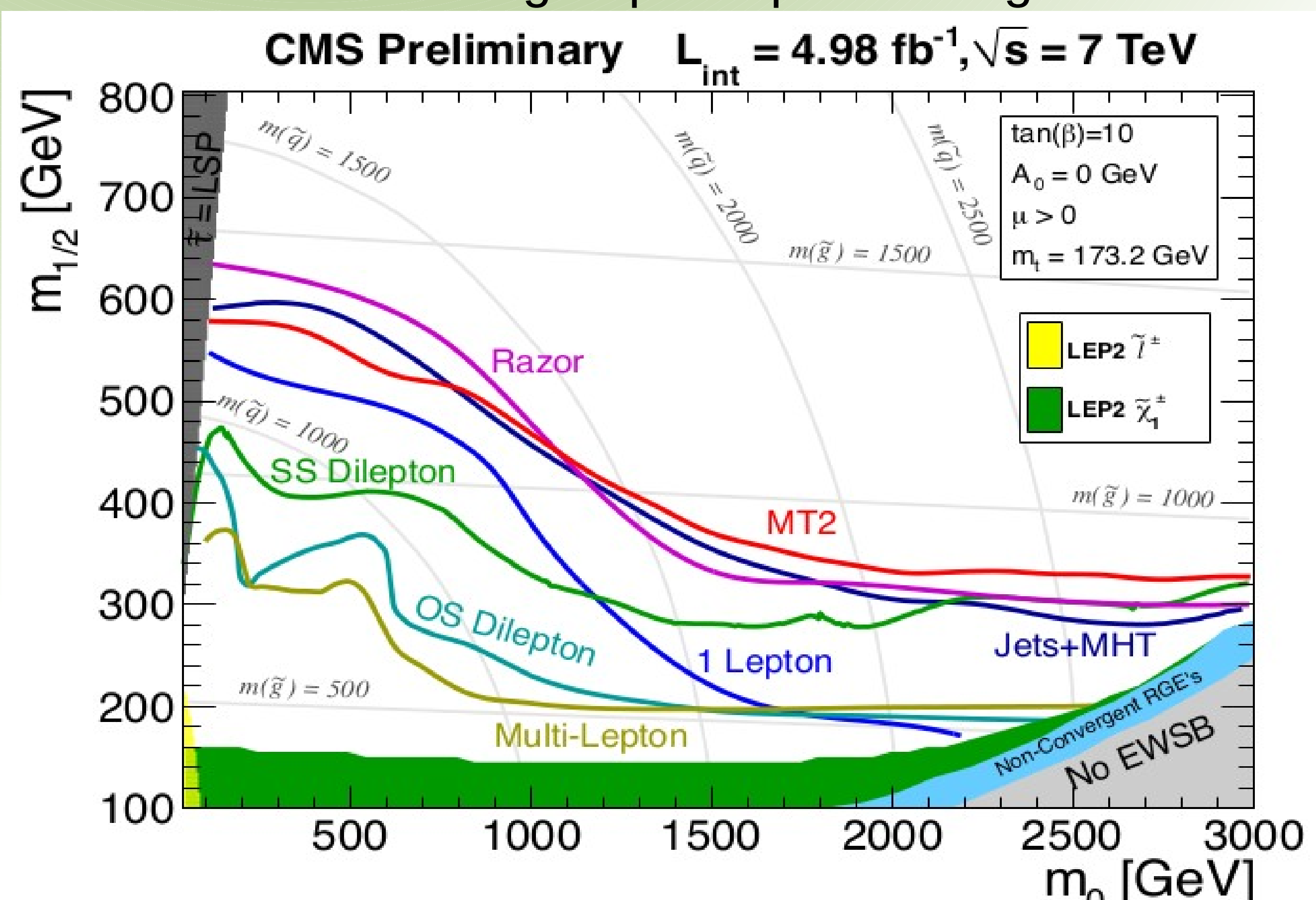






Conclusion

- A search for supersymmetry in fully hadronic final states with 2011 pp collision data collected by the CMS detector has been performed.
- No excess over the SM predicted background has been found.
- Limits in various signal model spaces have been set. Absolute mass limits in the mSUGRA/cMSSM scenario for A0 = 0, tanβ = 10, μ>0 are found to be m(squark) > 1160 GeV and m(gluino)> 860 GeV, and m(squark) = m(gluino) > 1200 GeV assuming equal squark and gluino masses.



For more details:

CMS-PAS SUS-12-002;
arXiv:1207.1798;
Published in :
J. High Energy Phys.
10 (2012) 018.

Thank you.

"One day, all of these will be supersymmetric phenomenology papers."