Latest Public Results for SUSY Searches with the CMS Experiment

LHC Physics Discussion

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CMS-SUSY
DESY, 14 May 2012

HELMHOLTZ ASSOCIATION

DESY

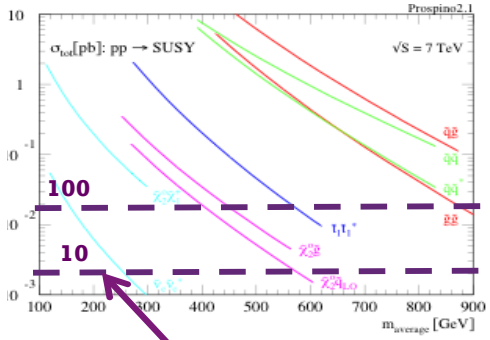
CMS Supersymmetry Searches

Explore previously inaccessible phase space
➔ unlocked with 7 TeV pp collisions at the LHC

Look for deviations from Standard Model expectations
➔ can make inferences about SUSY and other BSM physics

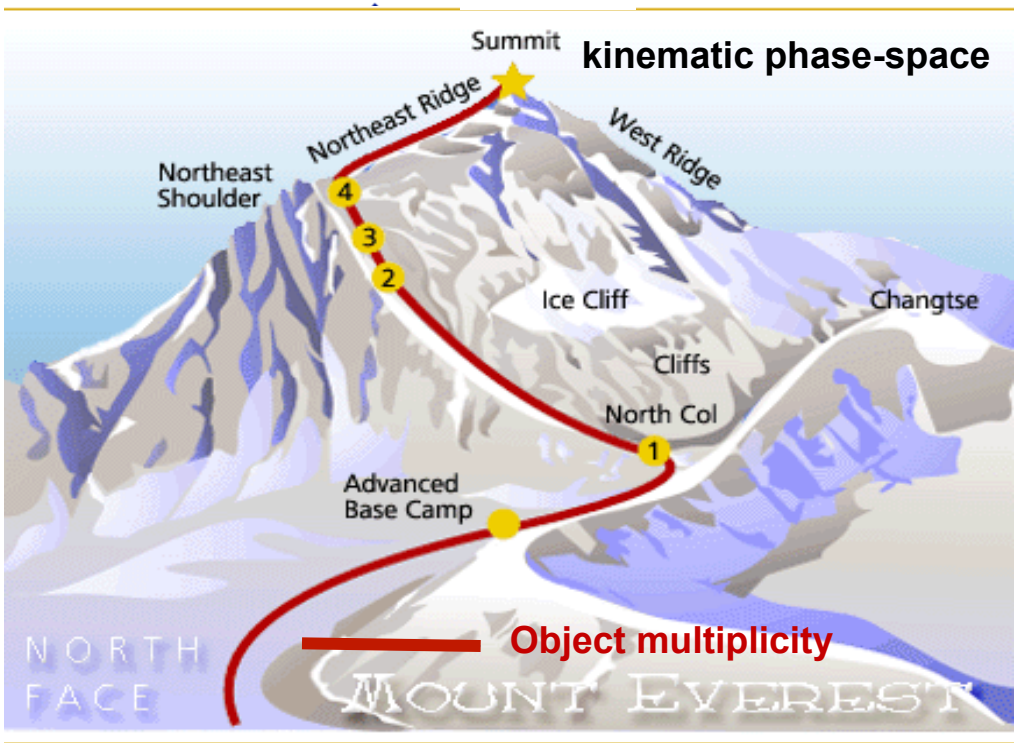
The Intensity Frontier:

- Integrated luminosity dictates how much phase space we can explore – trigger-rate limitations lead to selected phase-space trade-offs



7 TeV LHC Phase Space @ 5 fb^{-1}

- Production of 3rd generation super-partners can result in final states with tops and b-jets
- Sparticles decaying to W/Z/ γ /leptons
- Cascading decays through SUSY and SM spectrum can lead to high object multiplicities

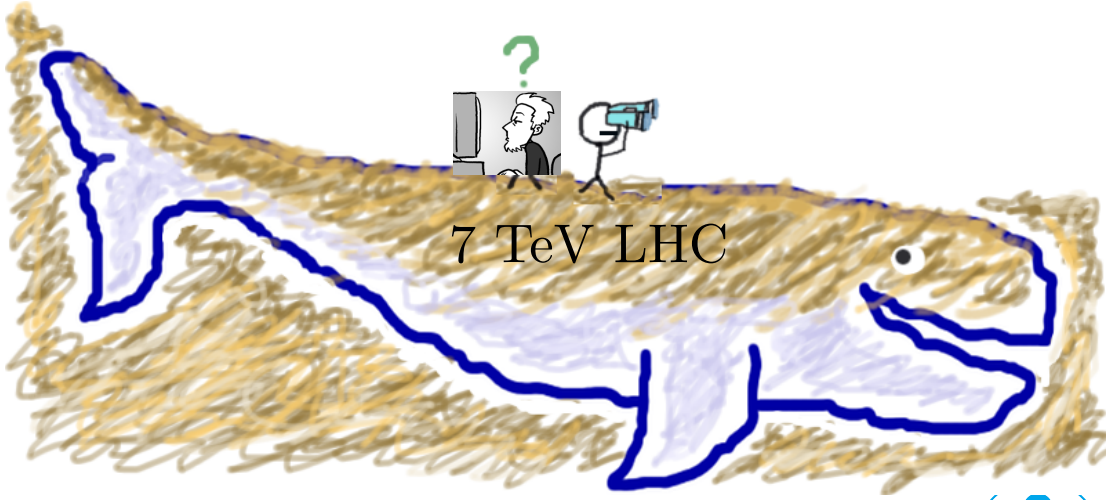


- Heavy sparticles decaying to SM particles ➔ large visible momenta
- R-parity conservation ➔ large missing momenta

Resonances, kinematic edges, mass sensitive variables…

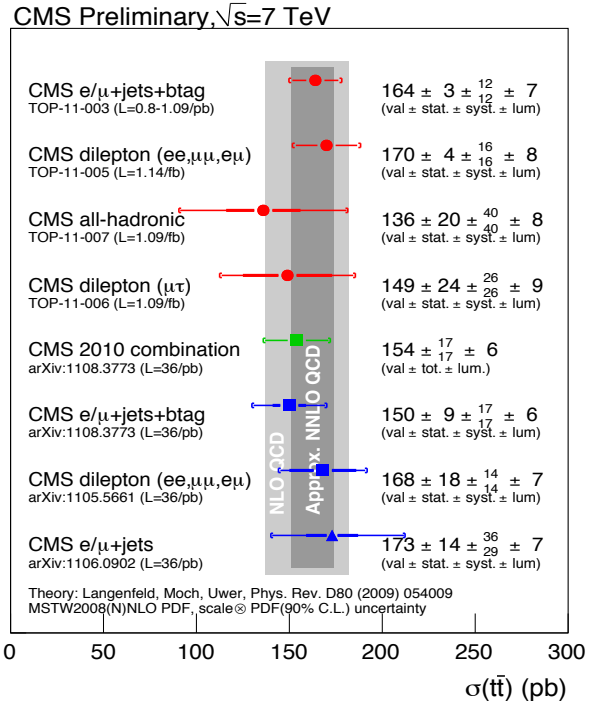
Searching for general excesses

- Nearby regions of phase space are often necessary to contextualize our observations in signal sensitive regions – sidebands, control regions, …
- Many different ways to constrain our SM expectations:
  - sidebands in kinematic variables
  - inversion/loosening of object ID requirements
  - exploiting symmetries of the SM [ex. γ +jets ➔ Z+jets]
  - control samples of leptons/b+jets/photons and even particular kinematic configurations

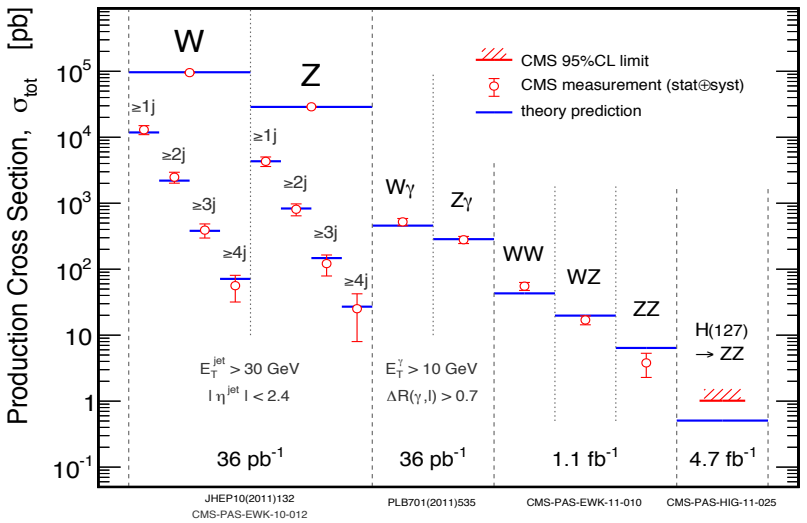


The view from North Cole

- **SUSY searches begin at** the NC (see prev. pic): bosons, tops and Onia SM candles
- **Used to:** select control samples of leptons, photons, b-jets, …
  calibrate/measure object reconstruction performance, fake-rates, energy scales
  validate our understanding of the SM

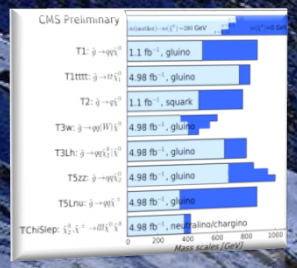


https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults



CMS SUSY @ 5 fb^{-1} 7 TeV LHC

The analyses described in this talk:



Interpretation of Searches for Supersymmetry with SMS – SUSY-12-005

Hadronic Razor + MET – SUSY-12-005

Single Lepton+ b + MET – SUSY-11-028

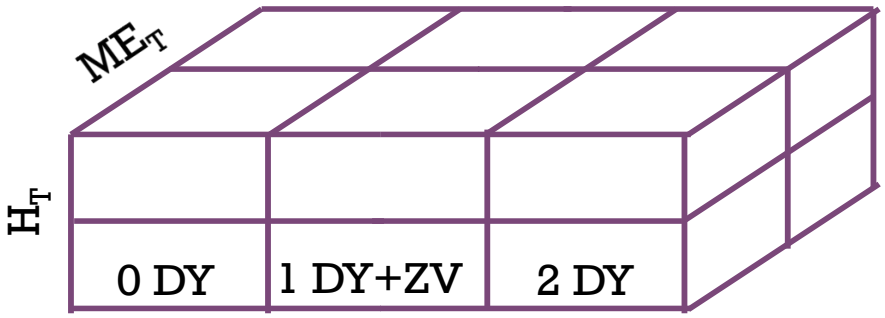
Multilepton Searches– SUSY-11-013/ EXO-11-045

Multi-Lepton Search

CMS-SUS-11-013
CMS-EXO-11-045

Selection

- Look for deviations from SM in final states with 3 or 4 isolated leptons (e, μ , τ_h)



- Look in a 'matrix' of phase-space:
  - low vs. high H_T
  - low vs. high ME_T
  - presence of opposite-sign (OS) same flavor (SF) lepton pairs (DY)
  - OSSF pairs in / out Z mass window

52 different regions

Backgrounds

- SM sources of 3 or 4 prompt, isolated leptons:

$$t\bar{t}, WZ, ZZ, t\bar{t}Z, t\bar{t}W$$

  - Contribution predicted from simulation – control region validations

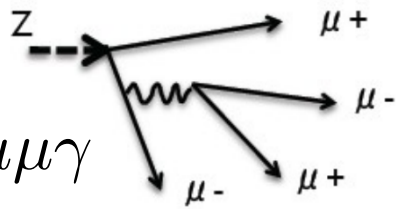
- Z+jets with lepton(s) from jet(s)
  - rate of reconstructed leptons coming from jets inferred from data

- Drell-Yan ➔ 4 leptons
  - internal and external photon conversions yield leptons – estimate rate from data

Multi-Lepton Search

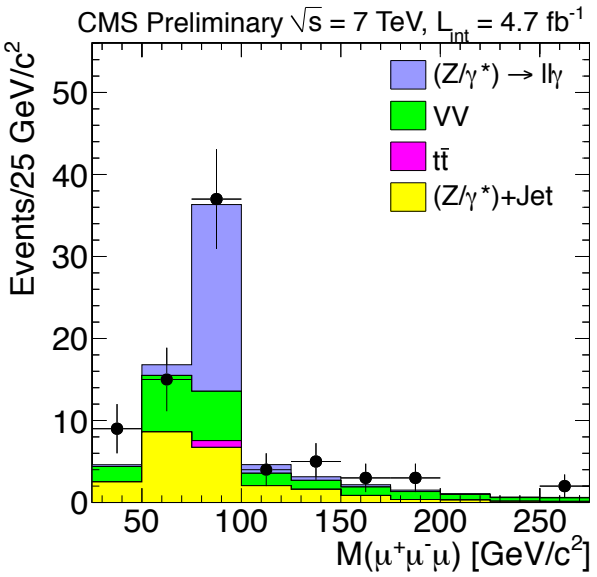
Asymmetric Conversions

- Use the 'Z pole':



- measure the ratio of $\mu\mu\gamma$ to $\mu\mu e/\mu$ at the Z pole

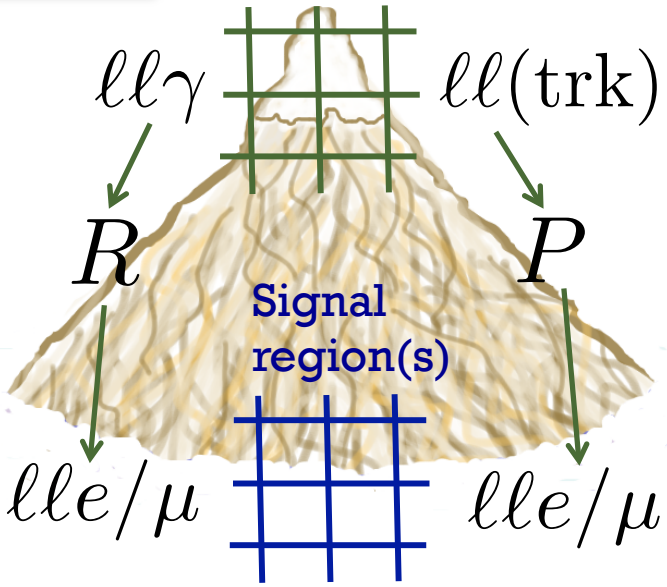
$$R = \frac{N_{\mu\mu\ell}(m_{\mu\mu\ell} \in [75,105])}{N_{\mu\mu\gamma}(m_{\mu\mu\gamma} \in [75,105])}$$



Z+jets x (jet ➔ lepton)

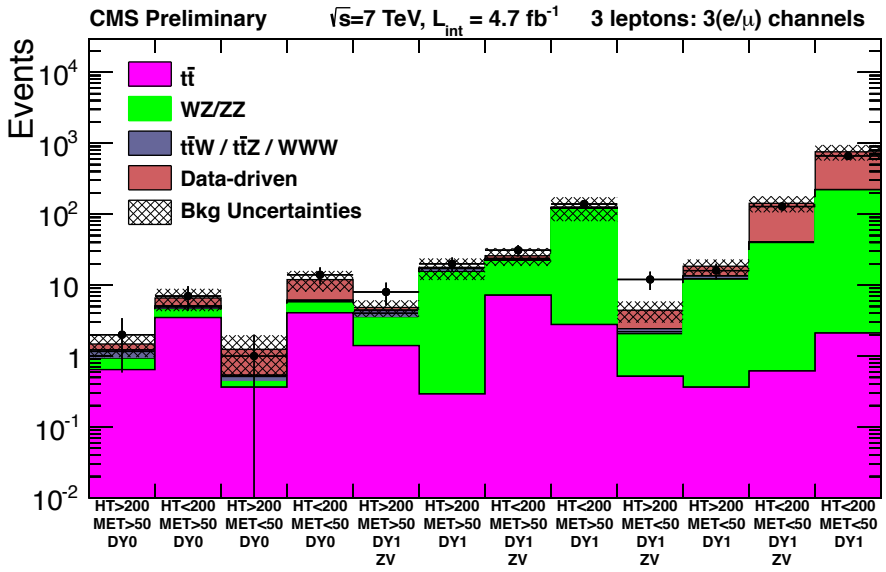
- Use 'the rate peak' - multijets
- measure the probability that isolated track (trk) ➔ lepton in jet triggered events

$$P(\mathrm{trk} \to e/\mu)$$



Use these factors to extrapolate from one grid of phase space to another

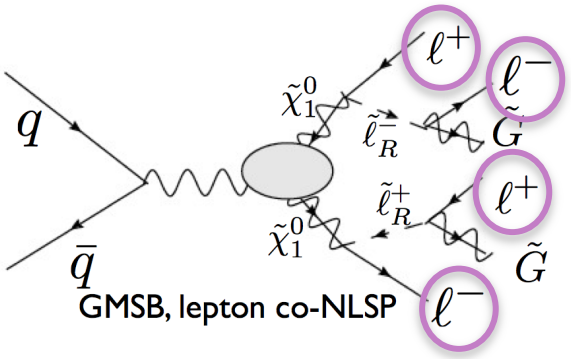
Multi-Lepton Search:



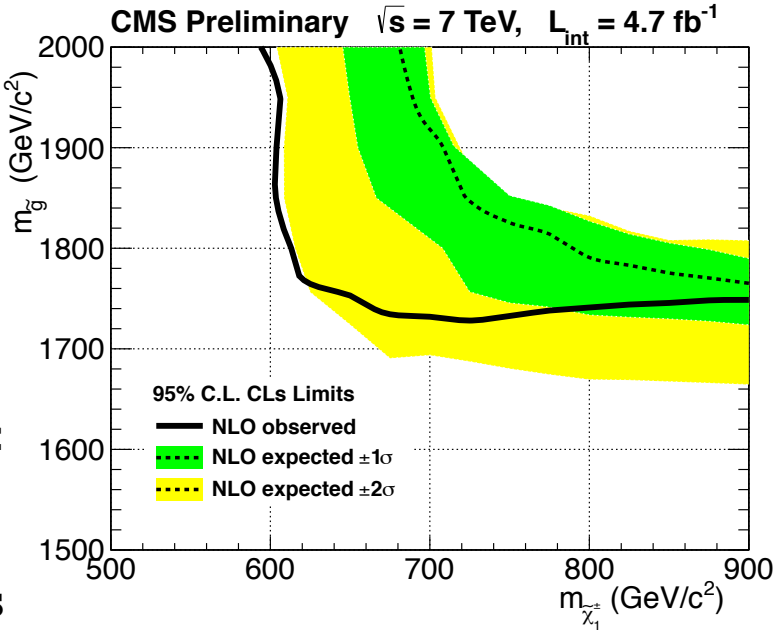
Submitted to JHEP:
arXiv:1204.5341

Yields are consistent with SM expectations –
see backup for more results

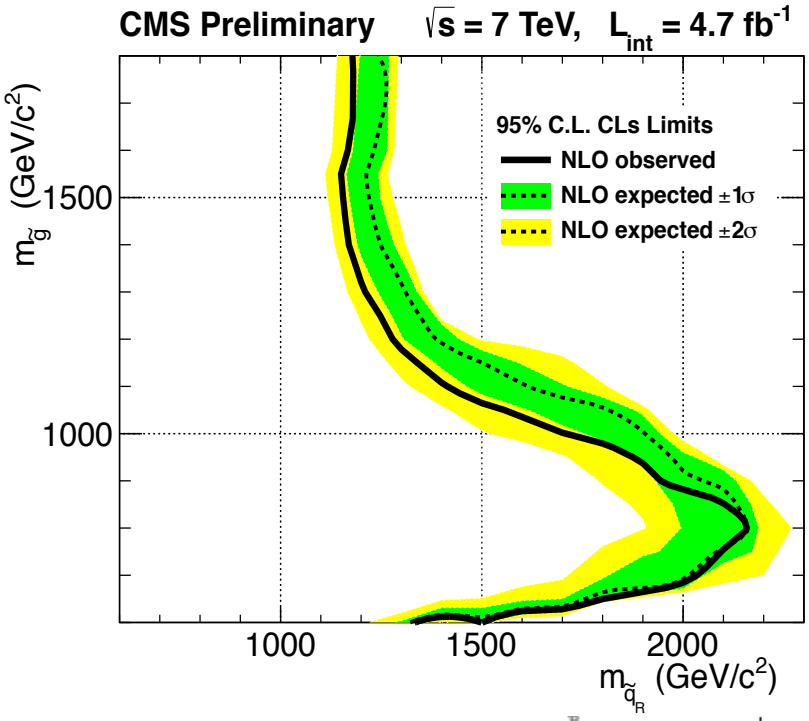
Null result interpreted as constraint on new physics

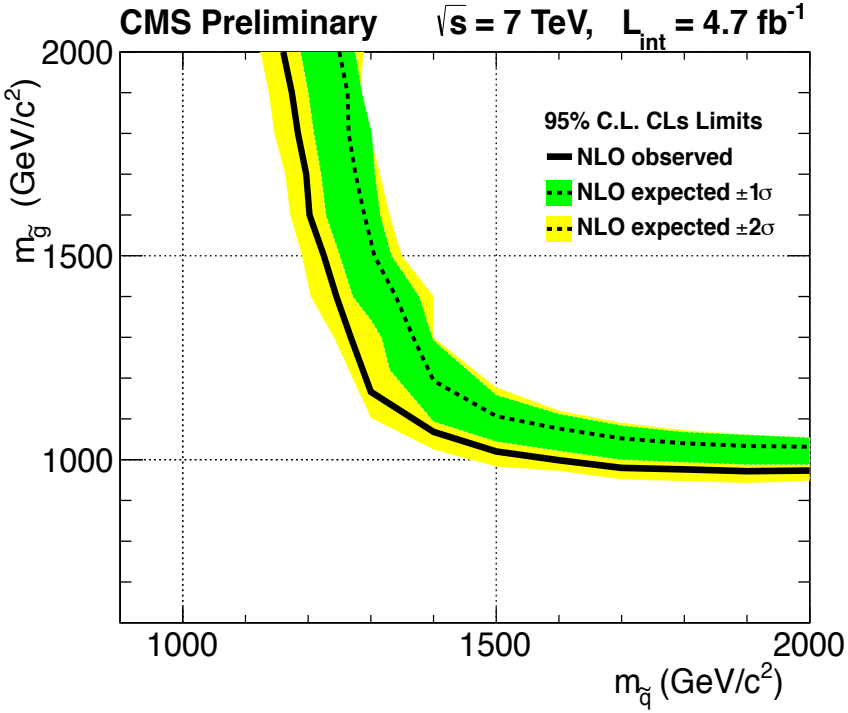


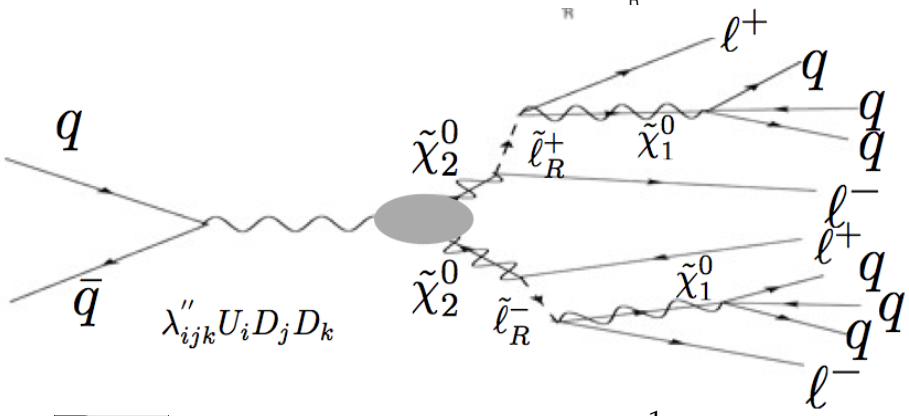
Here, GMSB model:
gravitino LSP
degenerate sleptons:
co-NLSP
neutralino is bino
and next in mass

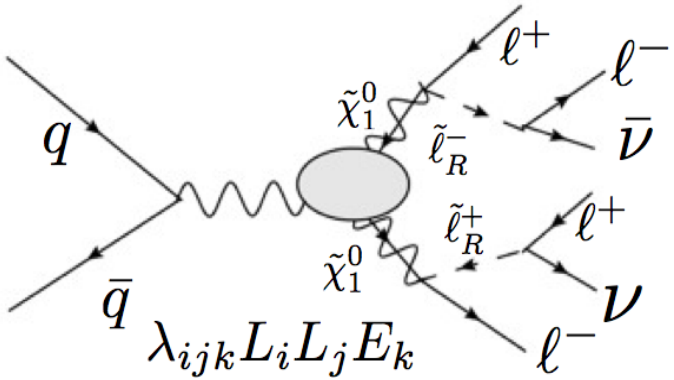


Results





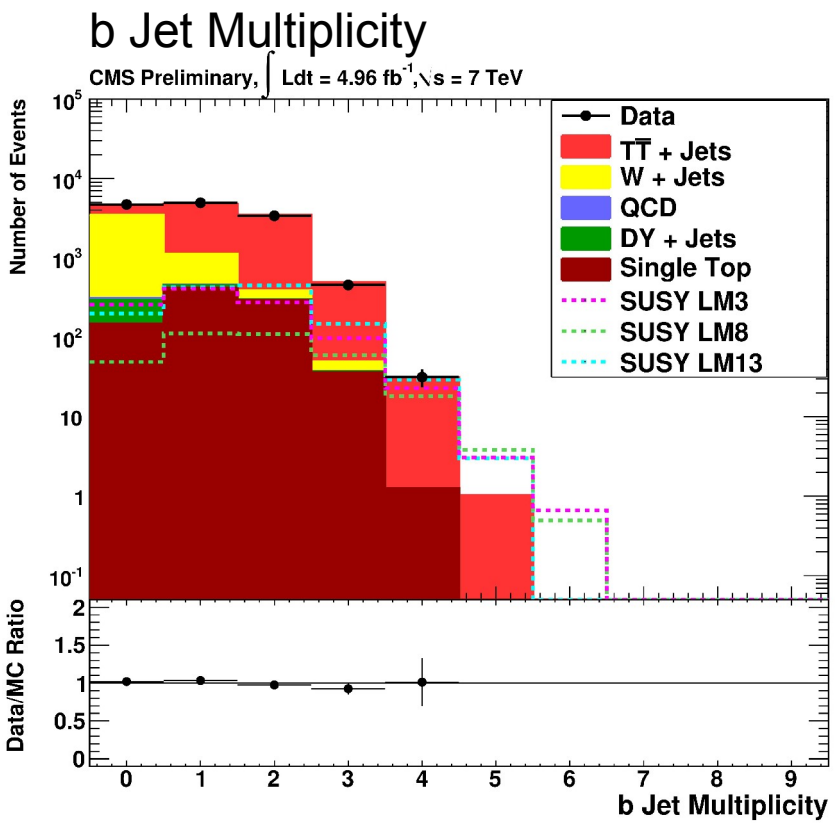




$$W_{\not R_p} = \frac{1}{2}\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{1}{2}\lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k,$$

Single lepton, b-jets and Missing Transverse Energy

CMS-SUSY-11-028



Selection:

- Event selection based on ***1 lepton*** **+** ***MET search*** with few changes to optimize for ***b-rich*** **SUSY** models.
- **Hadronic activity:**

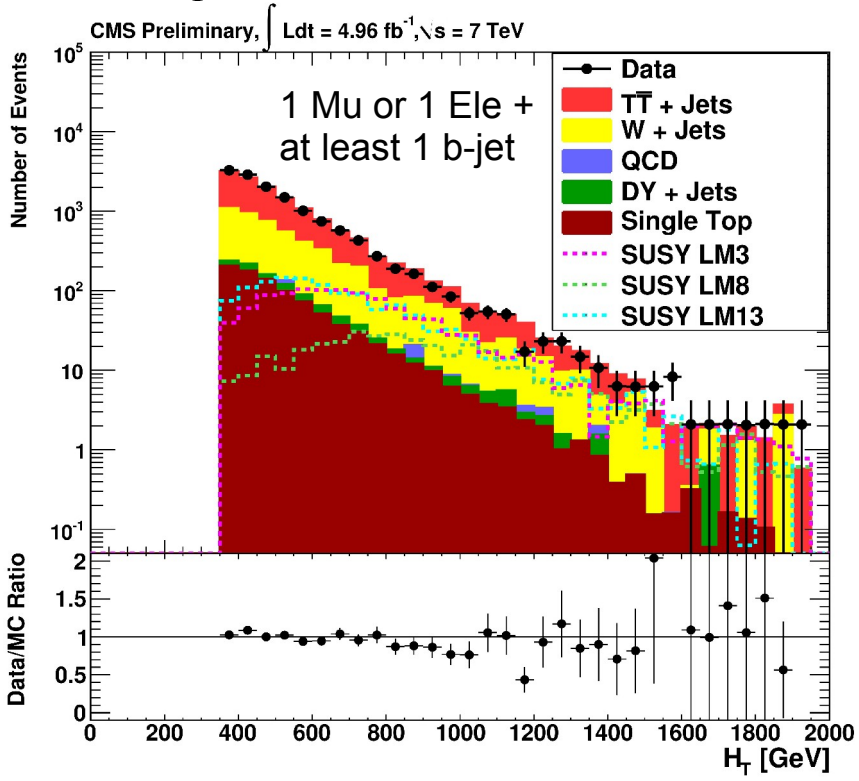
$$H_T = \sum_{jets} p_t > 375\,GeV$$

- **Four Jets** (ak5PF) each with E_T> 40 GeV
- **B-tags***: 0,1,2,3 or 4 more (TCHEM)
- Exactly **one isolated electron** and **muon** with P_T > 20 GeV
- **MET** > 60 GeV

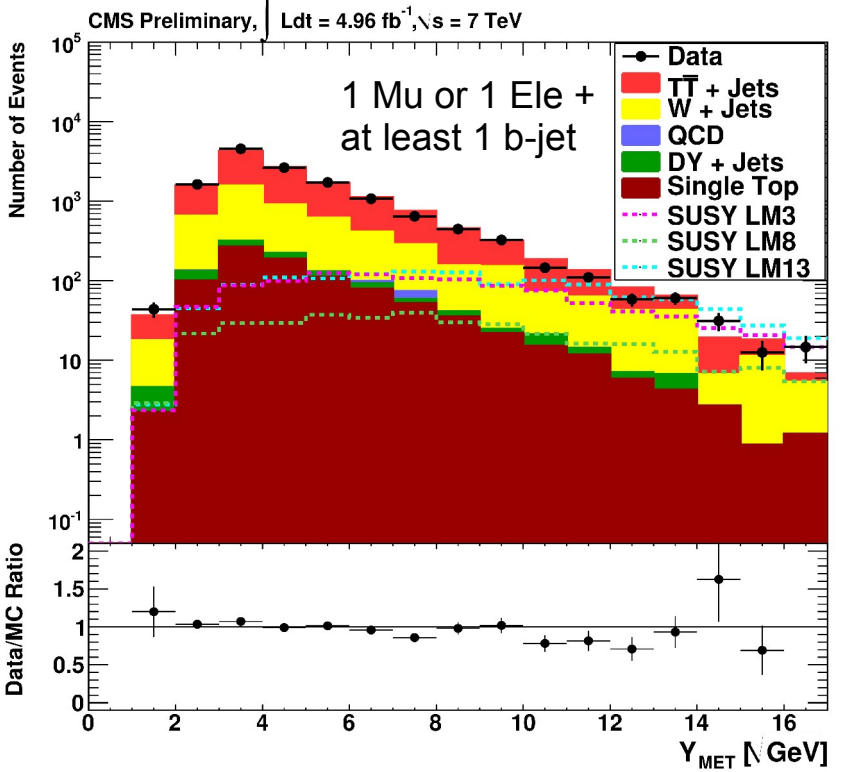
***CMS Collaboration**, **"Performance of the b-jet identification in CMS"**, CMS-PAS-BTV-11-001

Single lepton, b-jets and Missing Transverse Energy

H_T



$Y_{MET} = MET / \sqrt{H_T}$



SUSY benchmark points in

cMSSM →	m_0	$m_{1/2}$	A_0	tanβ	σ (LO *K factor)
LM3 →	330	240	0	20	3.438 * 1.4 pb
LM8 →	500	300	-300	10	0.73 * 1.41 pb
LM13 →	270	218	-553	40	6.899 * 1.42 pb

Background Estimation (Factorization Method)

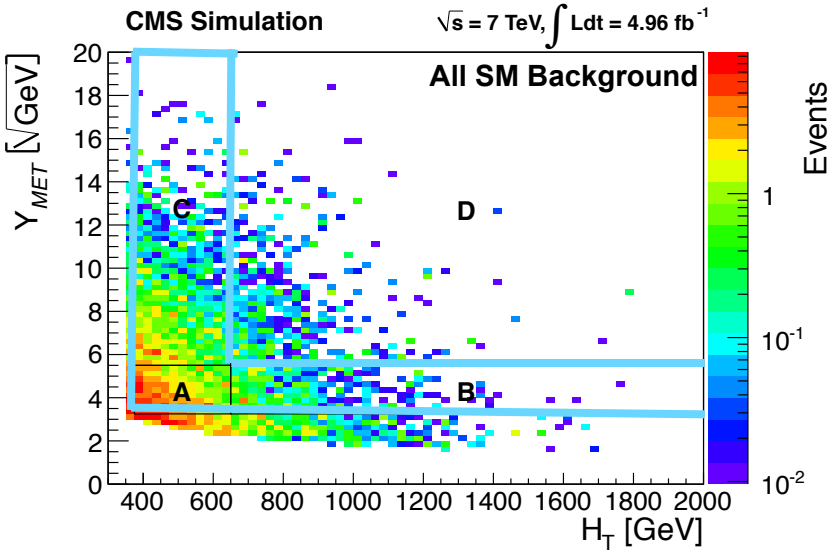
Hypothesis: H_T and Y_{MET} are **not strongly correlated**

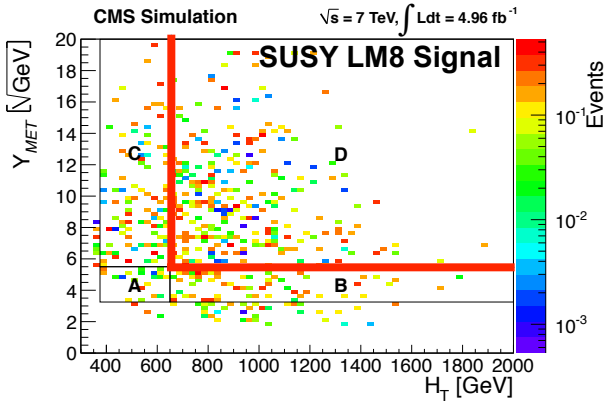
$$k := \frac{N_A \times N_D}{N_B \times N_C} \qquad \hat{N}_D := k \frac{N_B \times N_C}{N_A}$$

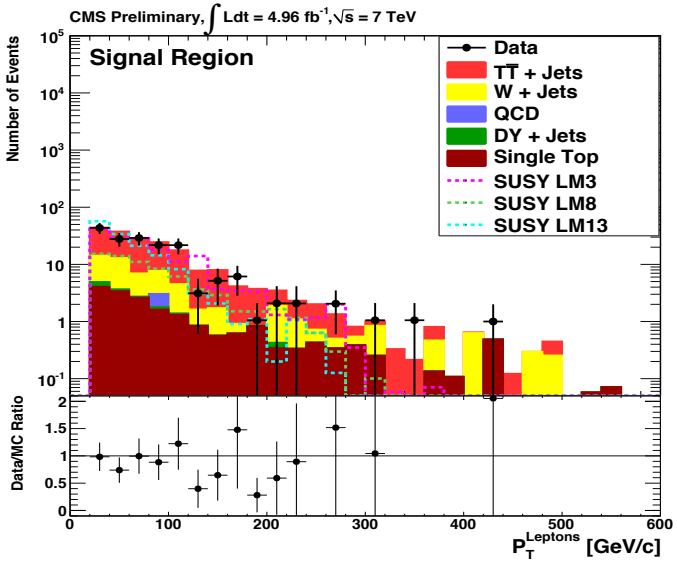
K≠1 to account for correlation where K is taken from MC

K=1.20 ± 0.04

Regions Boundaries	H_T	Y_{MET}
Control regions	A: 375 < H_T < 650	3.25 < Y_{MET} < 5.5
	B: 650 < H_T	3.25 < Y_{MET} < 5.5
	C: 375 < H_T < 650	5.5 < Y_{MET}
Signal region	D: 650 < H_T	5.5 < Y_{MET}

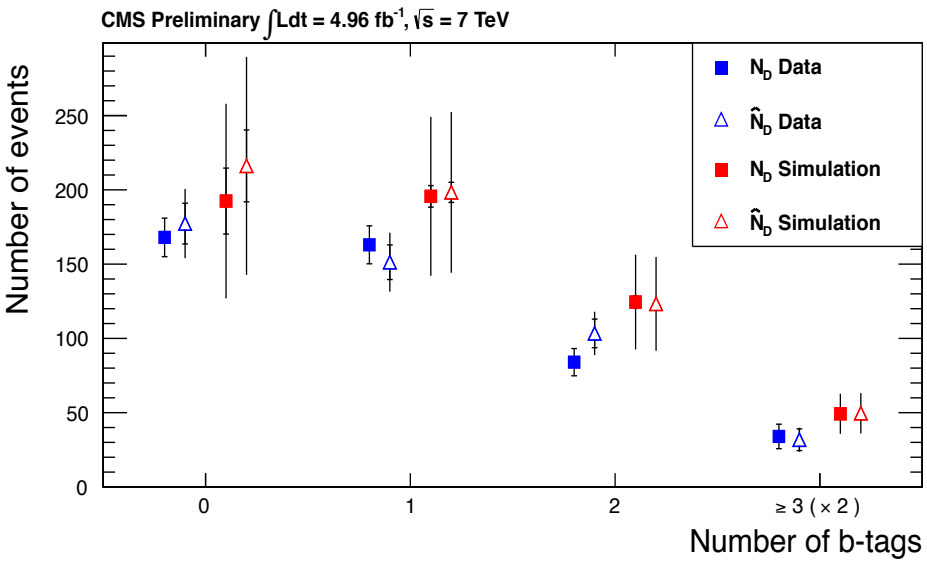






Results

CMS-SUSY-11-028

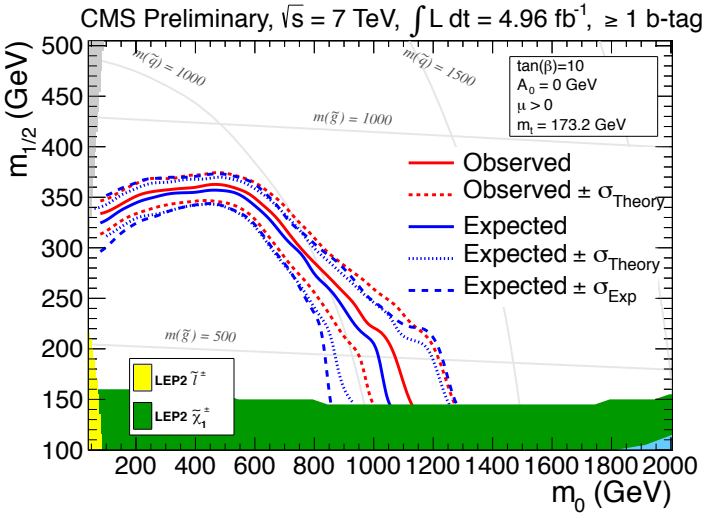


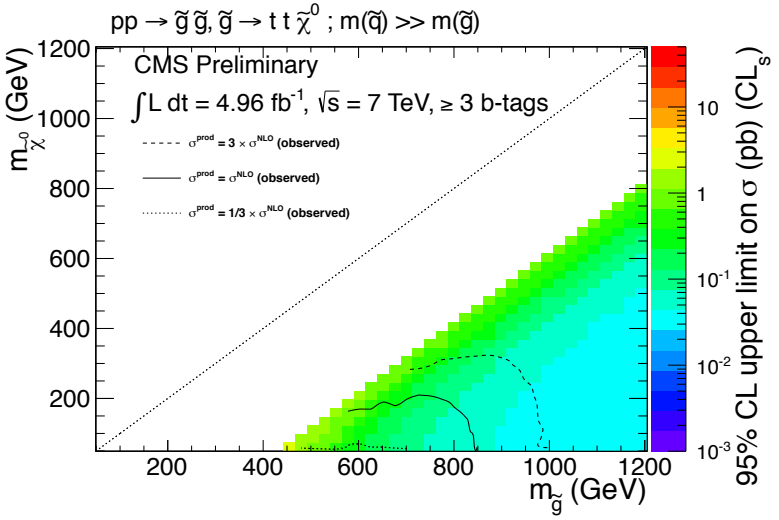
Data and prediction agree well → No Signal

MC Closure → Factorization Method works

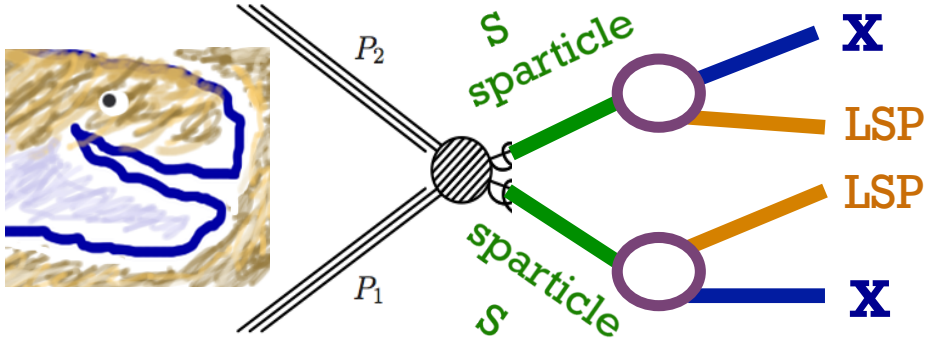
Small sys uncertainties in data

Large sys uncertainties in MC (scale factors)



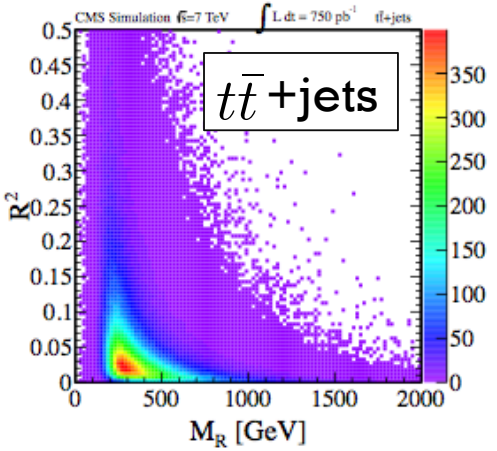


Inclusive final state search: Razor Analysis



CMS-SUSY-12-005

General final state topology characteristic of R-parity SUSY



Selection:

Group all final state objects (jets, leptons) into two mega-jets

Calculate Razor variables R/M_R designed for this topology

In simple case:
S = squark
X = jet

$$M_R = \sqrt{(|\vec{p}_{j_1}| + |\vec{p}_{j_2}|)^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

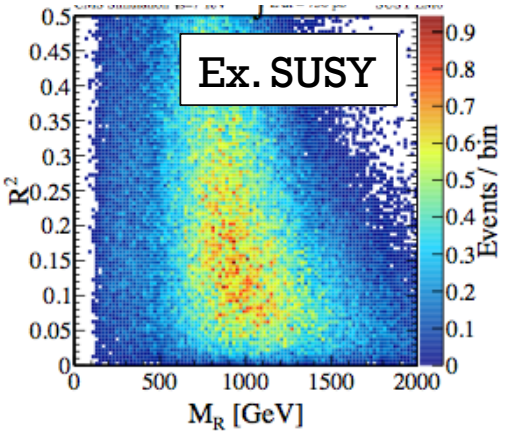
$$M_T^R = \sqrt{\frac{E_T^{miss}(p_T^{j_1} + p_T^{j_2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{\,j_1} + \vec{p}_T^{\,j_2})}{2}}$$

Peaks at $M_\Delta = \dfrac{M_S^2 - M_{\mathrm{LSP}}^2}{M_S}$

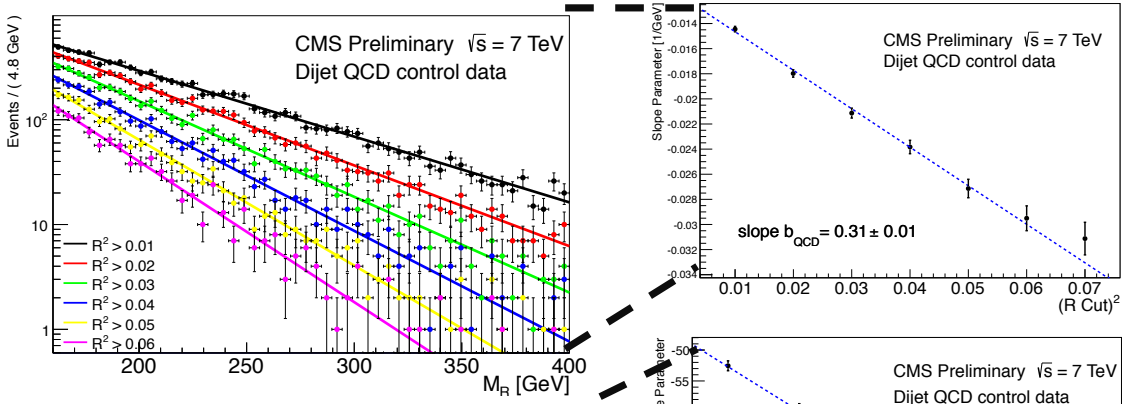
Edge at M_Δ

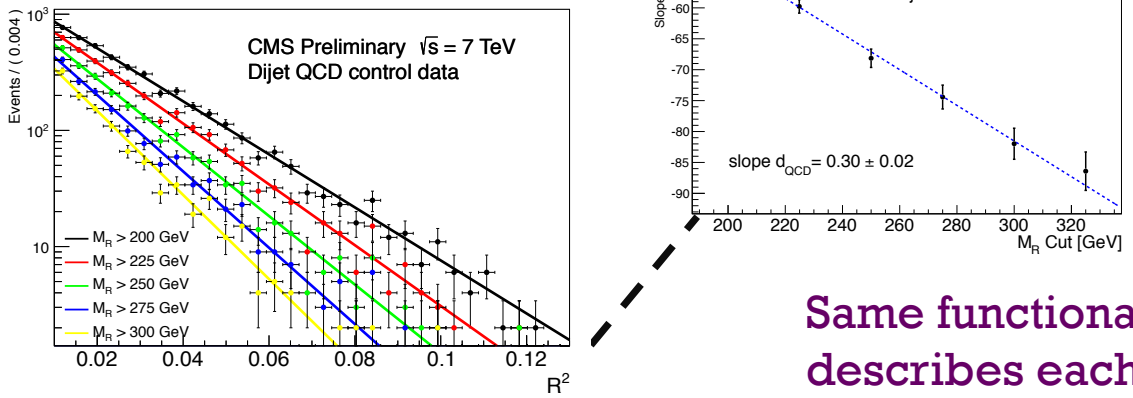
$$R = \frac{M_T^R}{M_R}$$

Ratio of two estimators of SUSY scale – describes transverse shape of event



Inclusive Razor





$$f(M_R) \propto e^{-SM_R}$$

$$S = a + b(R\ \text{cut})^2$$

$$f(R^2) \propto e^{-SR^2}$$

$$S = c + d(M_R\ \text{cut})$$

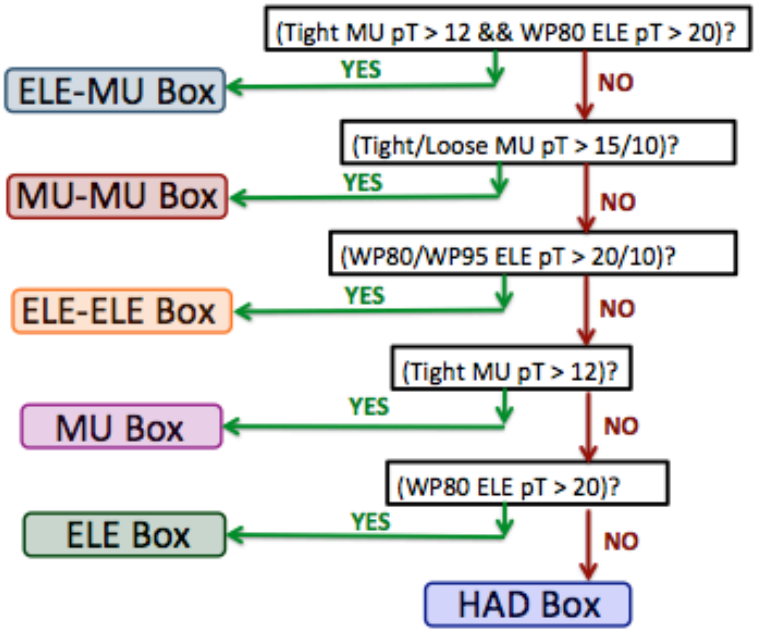
Same functional phenomenology describes each SM bkg

$$f(R^2, M_R) \propto \left[k(M_R - M_R^0)(R^2 - R_0^2) - 1\right] e^{-k(M_R - M_R^0)(R^2 - R_0^2)}$$

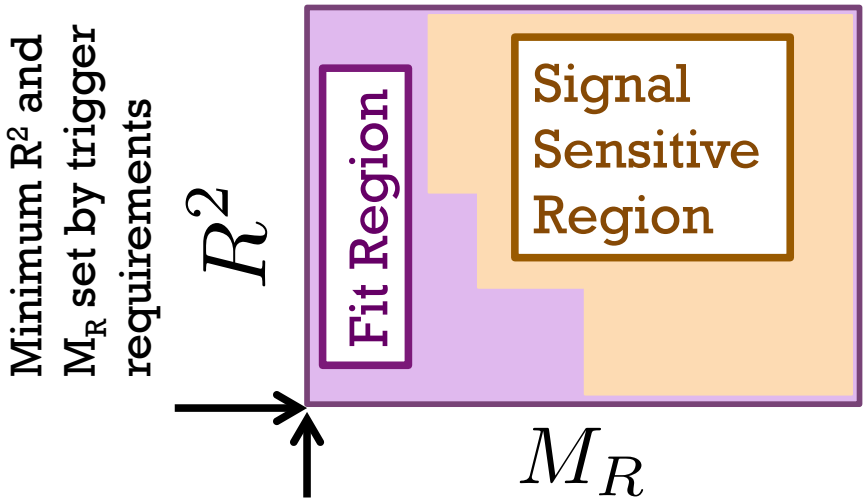
With:

$$b\ (\text{from}\ M_R\ \text{view}) = d\ (\text{from}\ R^2\ \text{view}) = k\ (\text{from 2D view})$$

Inclusive Razor



Final state BOX classification based on lepton ID



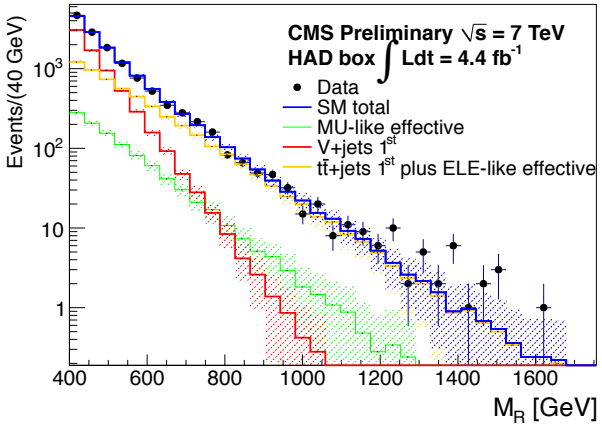
$$\mathcal{L}_b = \frac{e^{-(\sum_{j\in SM} N_j)}}{N!} \prod_{i=1}^{N} \left(\sum_{j\in SM} N_j P_j(M_{R,i}, R_i^2) \right)$$

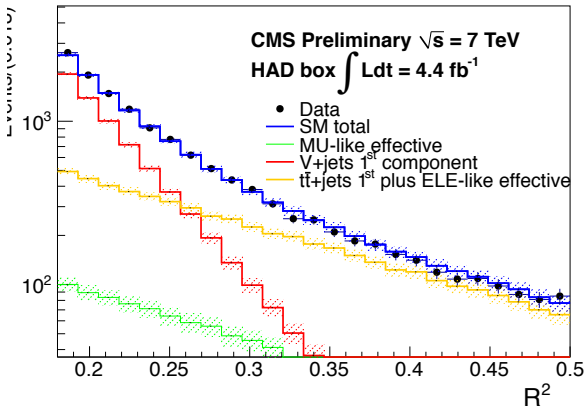
Extended and unbinned maximum likelihood fit performed in 2D R^2-M_R plane independently in each BOX

background functionally extrapolated to signal region –
Exclusively a kinematic extrapolation – not object based

Inclusive Razor: Results

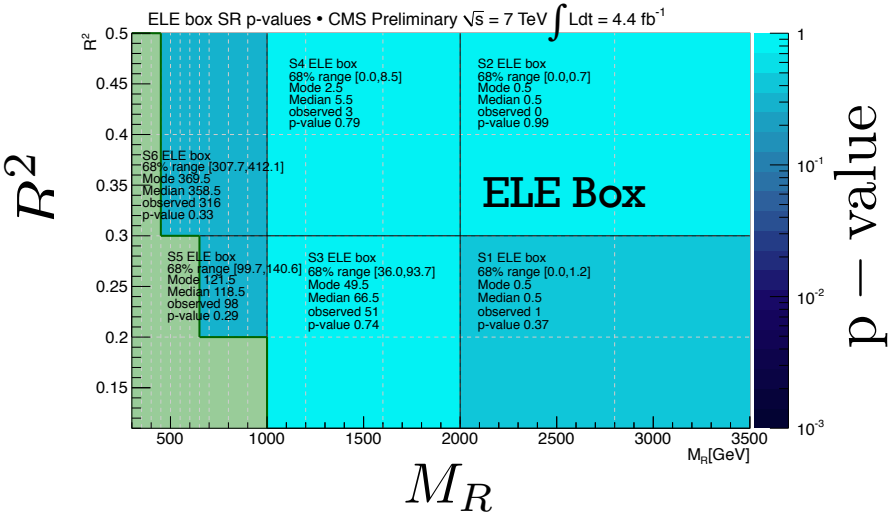
1D projections of 2D ML Fit – HAD Box



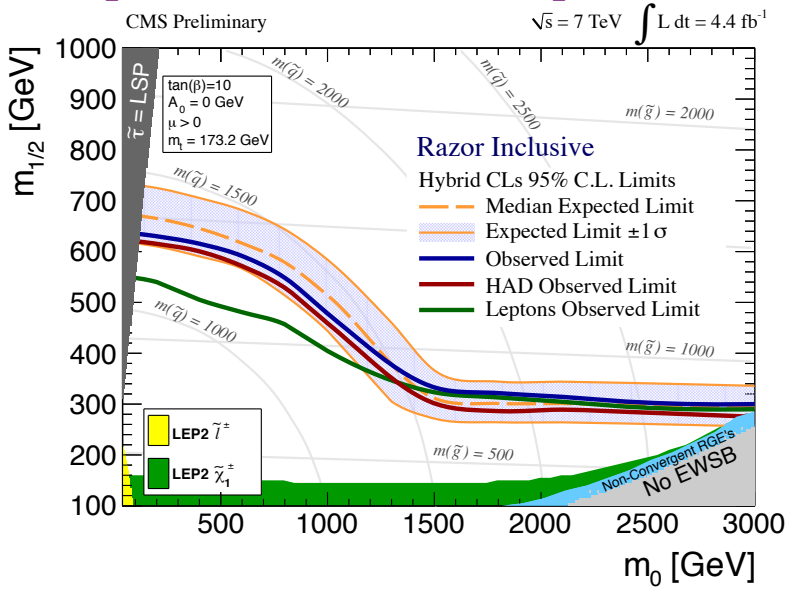


Observations consistent with SM expectations

Model independent results showing data/prediction compatibility



Model dependent CMSSM interpretation



Interpretation of Searches for Supersymmetry with SMS

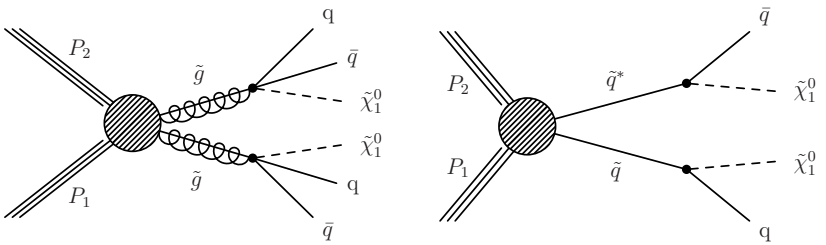


Figure 1: Diagrams of the hadronic models: gluino pair production (T1,left) and squark anti-squark production (T2,right).

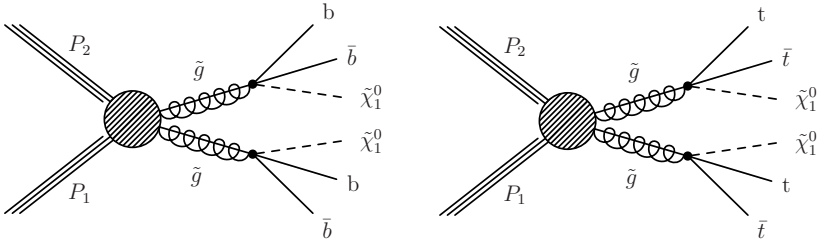


Figure 2: Diagrams of the heavy flavor models: T1bbbb (left), T1tttt (right).

name	prod. mode	decay	visibility
T1	$\tilde{g}\tilde{g}$	$\tilde{g} \to qq\tilde{\chi}^0$	hadronic
T2	$\tilde{q}\tilde{q}$	$\tilde{q} \to q\tilde{\chi}^0$	hadronic
T5zz	$\tilde{g}\tilde{g}$	$\tilde{g} \to qqZ\tilde{\chi}^0$	hadronic di-leptons
T3w	$\tilde{g}\tilde{g}$	$\tilde{g} \to qq\tilde{\chi}^0$ $\tilde{g} \to qq\tilde{\chi}^\pm$, $\tilde{\chi}^\pm \to W^\pm\tilde{\chi}^0$	single lepton
T5lnu	$\tilde{g}\tilde{g}$	$\tilde{g} \to qq\tilde{\chi}^\pm\,\tilde{\chi}^\pm \to l\nu\tilde{\chi}^0$	di-leptons
T3lh	$\tilde{g}\tilde{g}$	$\tilde{g} \to qq\tilde{\chi}^0$ $\tilde{g} \to qqll\tilde{\chi}^0$	di-leptons
T1bbbb	$\tilde{g}\tilde{g}$	$\tilde{g} \to bb\tilde{\chi}^0$	hadronic
T1tttt	$\tilde{g}\tilde{g}$	$\tilde{g} \to tt\tilde{\chi}^0$	hadronic di-leptons(b)
TChiSlepSlep	$\tilde{\chi}^\pm\tilde{\chi}^0_2$	$\tilde{\chi}^0_2 \to l\tilde{l}$, $\tilde{l} \to l\tilde{\chi}^0$ $\tilde{\chi}^\pm \to \nu\tilde{l}$, $\tilde{l} \to l\tilde{\chi}^0$	multi-leptons
TChiwz	$\tilde{\chi}^\pm\tilde{\chi}^0_2$	$\tilde{\chi}^\pm \to W^\pm\tilde{\chi}^0$, $\tilde{\chi}^0_2 \to Z\tilde{\chi}^0$	multi-leptons
TChizz	$\tilde{\chi}^0_2\tilde{\chi}^0_3$	$\tilde{\chi}^0_2, \tilde{\chi}^0_3 \to Z\tilde{\chi}^0$	multi-leptons

CMS-SUSY-11-016

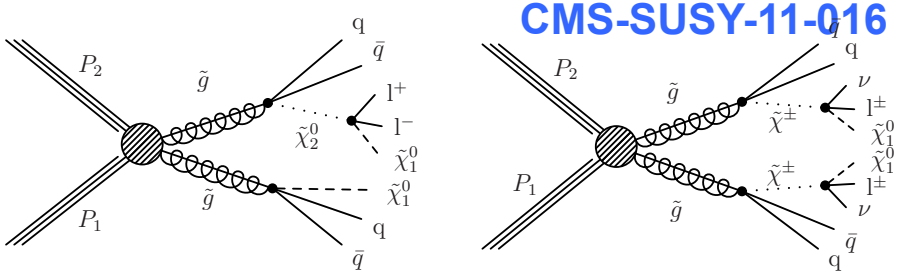


Figure 3: Diagrams of the dilepton models: T3lh (left), T5lnu (right).

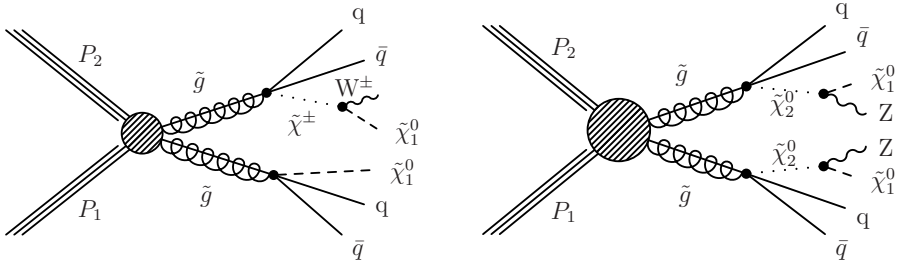
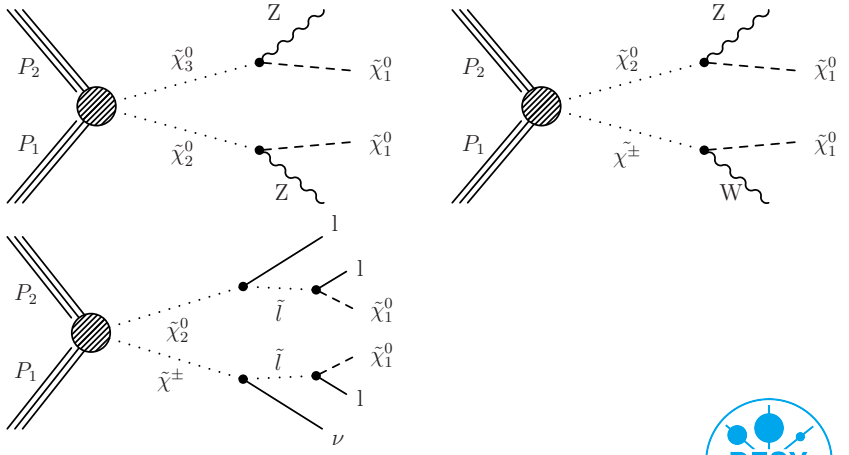
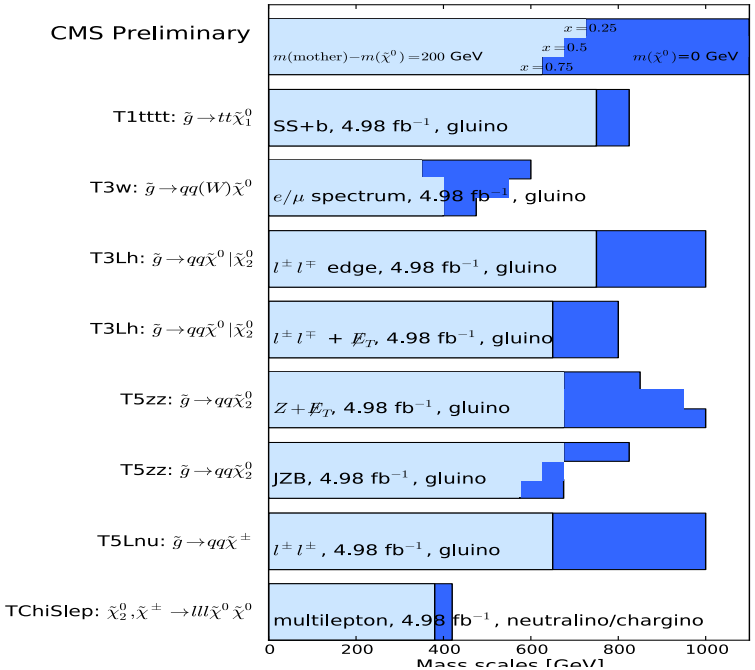
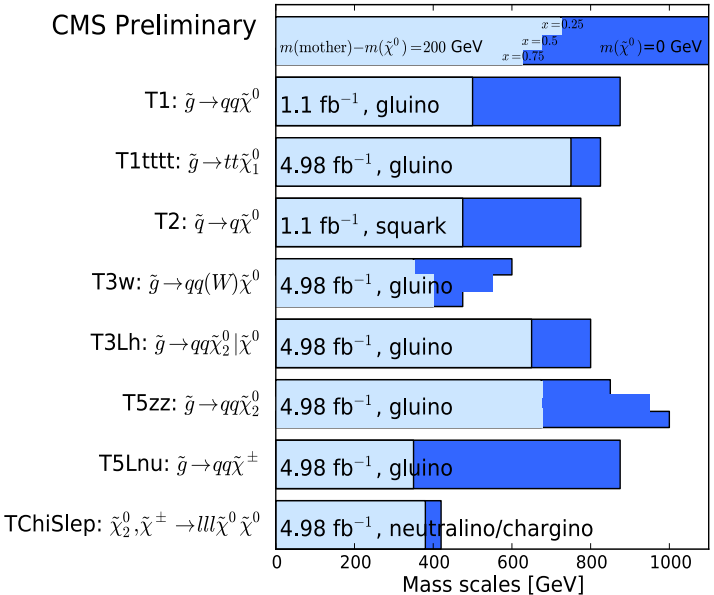


Figure 4: Diagrams of T3w (left), T5zz (right).



Summary





- ~5 fb^{-1} of data analyzed by the CMS Collaboration
  - Unfortunately no evidence of Supersymmetry
  - Extended previously explored range of model parameters
  - Results are presented in the cMSSM and SMS models
- Prospects for 2012: expected 5 (10) fb^{-1} data at 8 TeV center of mass energy up to end of this year .

DESY