
SUSY Results from CMS
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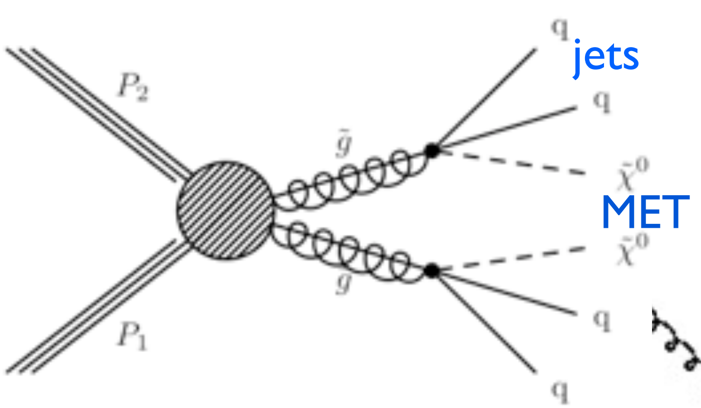
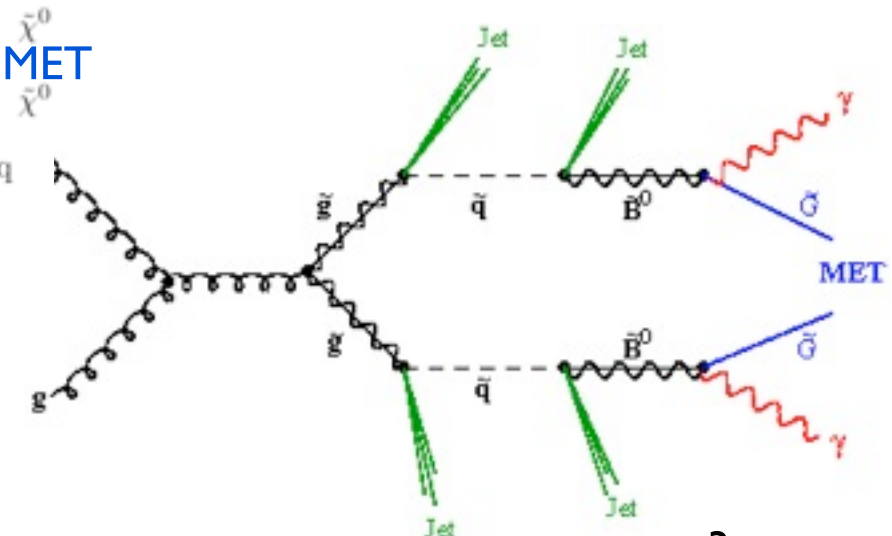
We'll be talking about...

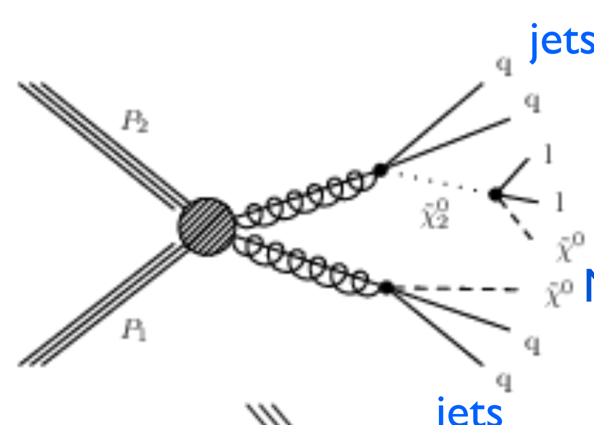
- SUSY in the context of CMS
- Walk (run?) through the long list of CMS SUSY results
  - Simple physics object + missing energy searches
  - Searches with kinematic tools designed to improve sensitivity
  - Third generation searches
  - All results (and future ones) may be found at: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
- Combined interpretation
- Summary/discussion

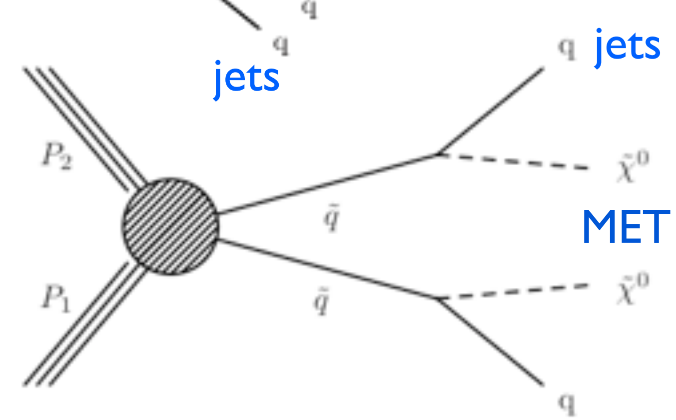
SUSY and how it might manifest...

- Typically frame searches around Minimal SuperSymmetric Model (MSSM) or more constrained relatives (cMSSM/mSUGRA, GMSB,...)
- R (matter) parity conservation -- SUSY particles produced in pairs, lightest (LSP) can't decay -- stable dark matter candidate.
- Stable LSP not detected -- manifests in an apparent nonconservation of momentum in an event -- Missing E_T or "MET"
- Produced particles can have long decay chains emitting jets and SM particles along the way
- Choice of LSP and "Next to" LSP (NLSP) defines the topology one looks for in the detector.



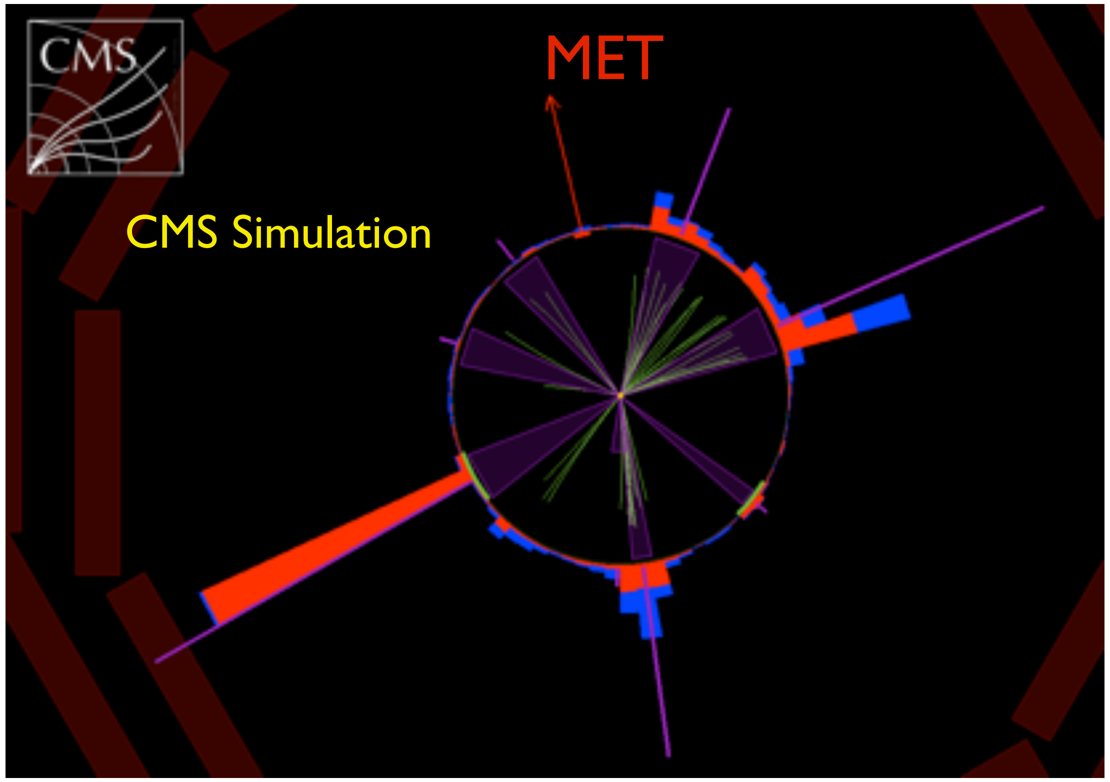






Commonalities in the analyses that follow

- In the measurements we march through next, jet activity and MET are used to separate potential signal from standard model backgrounds
  - i.e. large QCD backgrounds don't have MET on their own but can aquire it through detector resolution effects and mis-measurements
  - backgrounds from EW processes can make real MET through undetected neutrinos
  - Dominant backgrounds estimated from the data, via templates, sidebands
  - Less significant backgrounds estimated from MC, sometimes MC estimates used overall as cross check of data driven methods



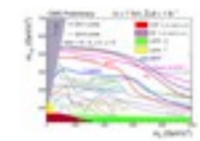
- Signal search regions usually involve jet activity requirements in the form of jet multiplicity or scalar sum of jet p_T (H_T)
- MET or variables emphasizing momentum imbalance
- Requirements on additional particles depending on NLSP of the particular model

2011 Results (so far)

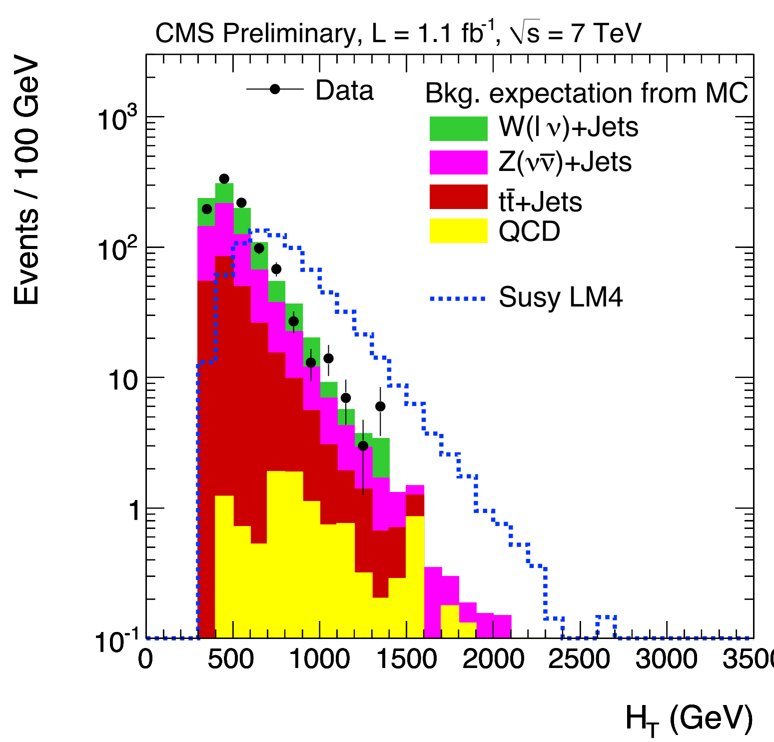
- All but the last include 0.98 - 2.1 fb^{-1} of luminosity
- Physics Objects + Missing Energy
  - hadronic activity + MET *
  - leptons + jets + MET *
  - photons + jets + MET
- Kinematic quantities designed to enhance sensitivity
  - alphaT *
  - MT2 *
  - RAZOR *
- Picking on the 3rd generation
  - hadronic activity with b jets + MET
  - hadronic tau + MET
- Z + jets + MET -- first on full 2011 dataset -- 4.7 fb^{-1}

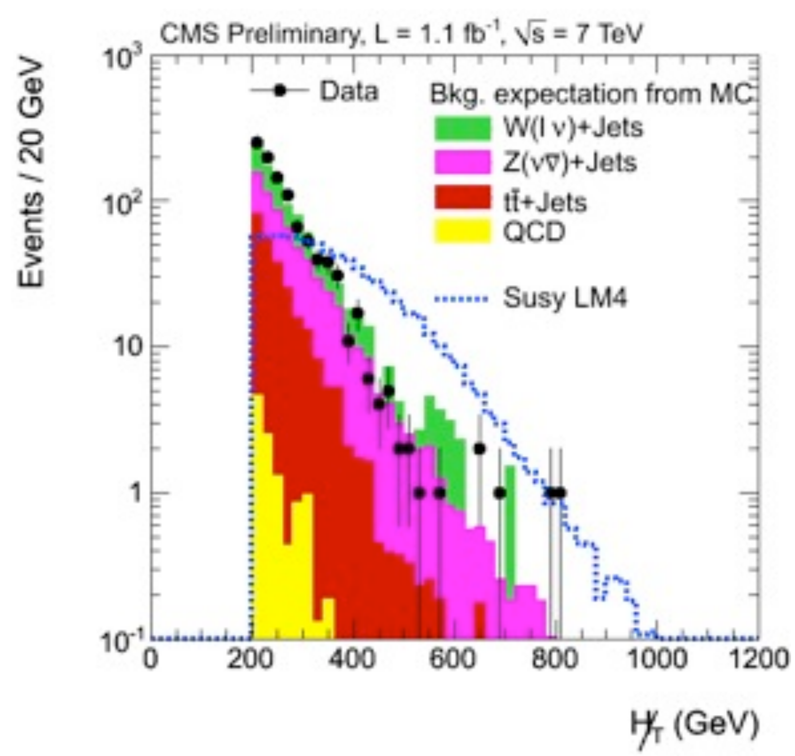
* Included in combined limit plots at end, so won't show interpretation limits with these guys

Inclusive Jets + MET analysis



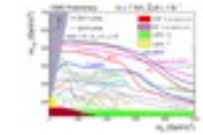
- http://cdsweb.cern.ch/record/1378478 (SUS-11-004)
- Requires 3 jets with p_T > 50 GeV and within barrel region ($|\eta|$ < 2.5)
- H_T, or the scalar sum of jet p_T's, must be > 350 GeV
- Missing H_T (MH_T), the negative vector sum of jet p_T's must be > 200 GeV
- Topological requirement -- veto on any of the 3 jets w.r.t. plane of MH_T
  - Removes bulk of QCD background events with mismeasured jets
- Veto on isolated muon and electrons
  - Removes leptonic final state ttbar, W & Z events





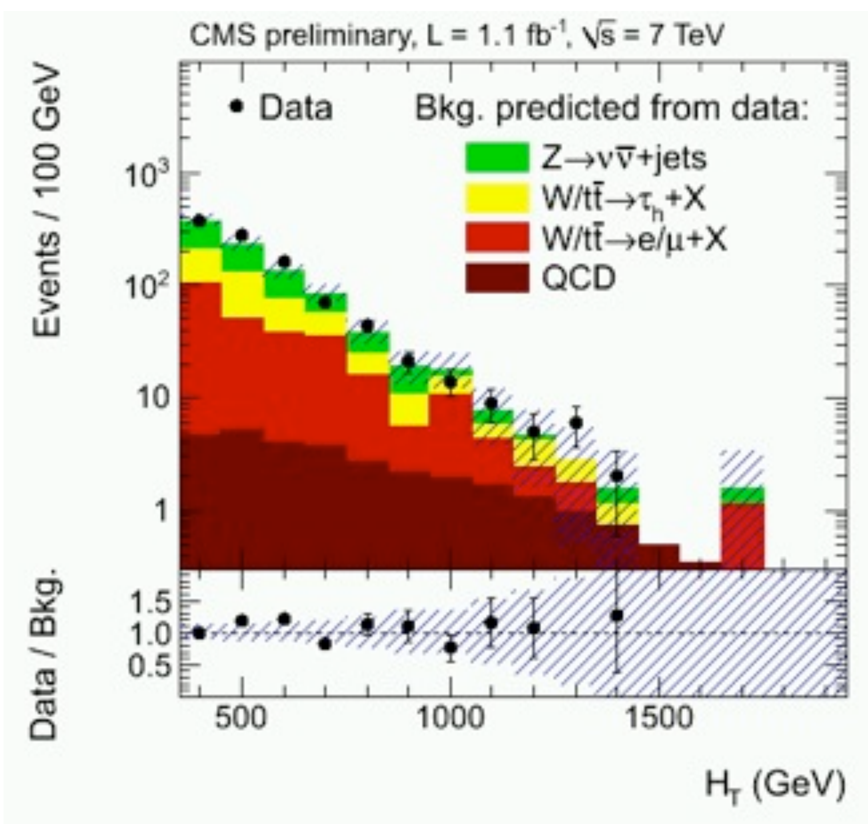
- H_T and MH_T data distributions with MC estimated backgrounds and example SUSY model point (blue)

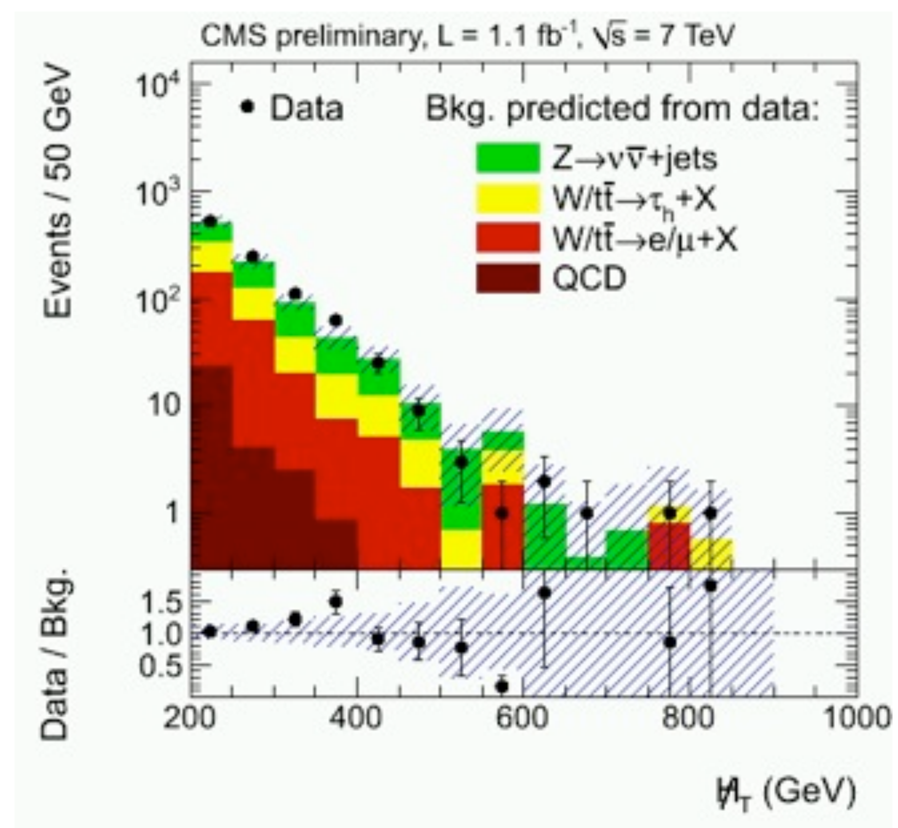
Inclusive Jets + MET analysis II



- Event yields and distributions from data driven background estimates

	Baseline (H_T >350 GeV) ($\not{H}_T$ >200 GeV)	Medium (H_T >500 GeV) ($\not{H}_T$ >350 GeV)	High H_T (H_T >800 GeV) ($\not{H}_T$ >200 GeV)	High $\not{H}_T$ (H_T >800 GeV) ($\not{H}_T$ >500 GeV)
$Z \to \nu\bar{\nu}$ from γ+jets	$376 \pm 12 \pm 79$	$42.6 \pm 4.4 \pm 8.9$	$24.9 \pm 3.5 \pm 5.2$	$2.4 \pm 1.1 \pm 0.5$
$t\bar{t}/W \to e, \mu$+X	$244 \pm 20^{+30}_{-31}$	$12.7 \pm 3.3 \pm 1.5$	$22.5 \pm 6.7^{+3.0}_{-3.1}$	$0.8 \pm 0.8 \pm 0.1$
$t\bar{t}/W \to \tau_h$+X	$263 \pm 8 \pm 7$	$17 \pm 2 \pm 0.7$	$18 \pm 2 \pm 0.5$	$0.73 \pm 0.73 \pm 0.04$
QCD	$31 \pm 35^{+17}_{-6}$	$1.3 \pm 1.3^{+0.6}_{-0.4}$	$13.5 \pm 4.1^{+7.3}_{-4.3}$	$0.09 \pm 0.31^{+0.05}_{-0.04}$
Total background	928 ± 103	73.9 ± 11.9	79.4 ± 12.2	4.6 ± 1.5
Observed in data	986	78	70	3



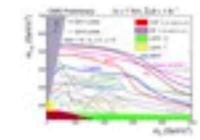


- Only showing observed results -- will show the resulting limits in a bit...

leptons + MET

- Four analyses here:
- Single lepton + jets + MET http://cdsweb.cern.ch/record/1380922 (SUS-11-015)
- Opposite signed leptons + MET http://cdsweb.cern.ch/record/1370065 (SUS-11-018)
- Same signed lepton + MET http://cdsweb.cern.ch/record/1370064 (SUS-11-020)
- Multi-leptons + MET http://cdsweb.cern.ch/record/1393719 (SUS-11-025)

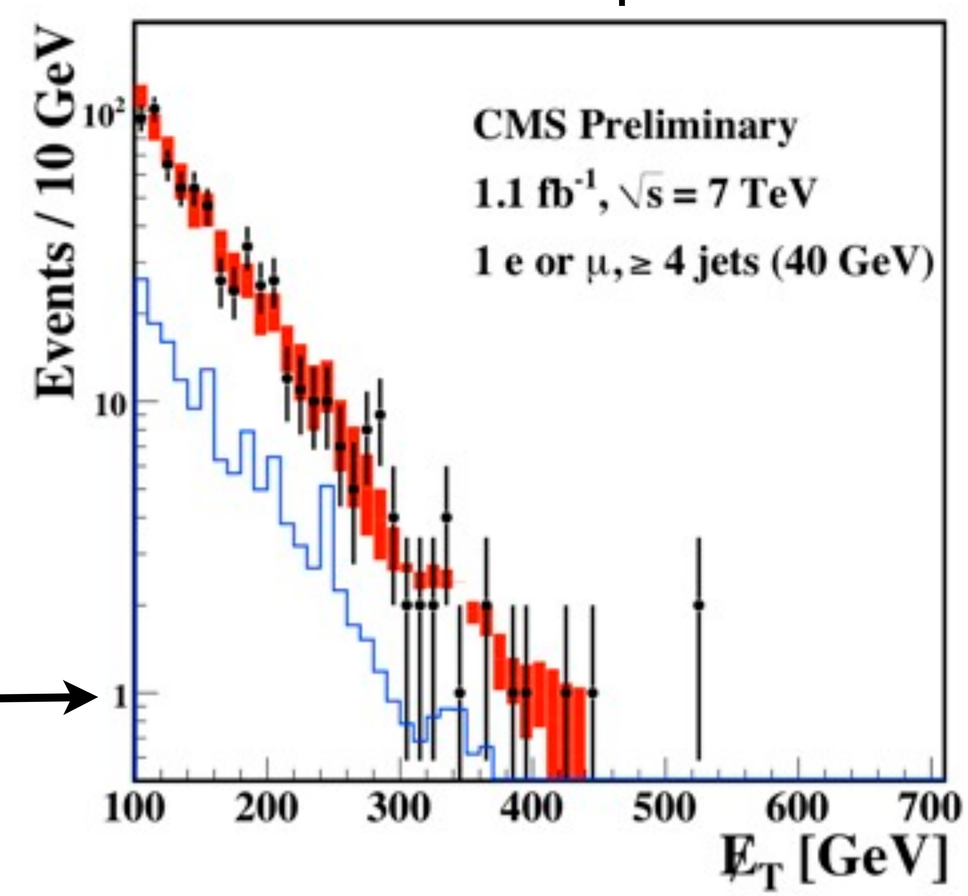
Single lepton



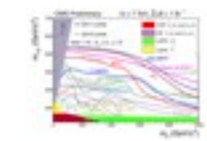
- Two complementary analysis methods employed, first on this slide, next on the next one:
  - "Lepton Spectrum Method" where the relationship between the lepton p_T and the MET (Think lepton back to back with neutrino) is used to turn the lepton p_T distribution into a MET estimate.
  - MET from SUSY would not necessarily be correlated with the lepton, and should be larger.
  - Corrections applied for W polarization, lepton p_T threshold, differences in MET resolution between the measured MET and lepton p_T, as well as backgrounds from dileptons, leptonic taus.
  - Combined MET distribution and background estimate →

Quantity	Requirement
Jet p_T threshold	> 40 GeV
Jet η range	$\|\eta\| < 2.4$
Number of jets	≥ 3 (LP Variable method),
	≥ 4 (Lepton Spectrum method)
Lepton p_T threshold	> 20 GeV
Muon η range	$\|\eta\| < 2.1$
Muon isolation (relative)	< 0.10
Electron isolation (relative)	< 0.07 (barrel), < 0.06 (endcaps)
Electron η range	$\|\eta\| < 1.4, 1.6 < \|\eta\| < 2.4$
Lepton p_T threshold for veto	> 15 GeV

Combined leptons



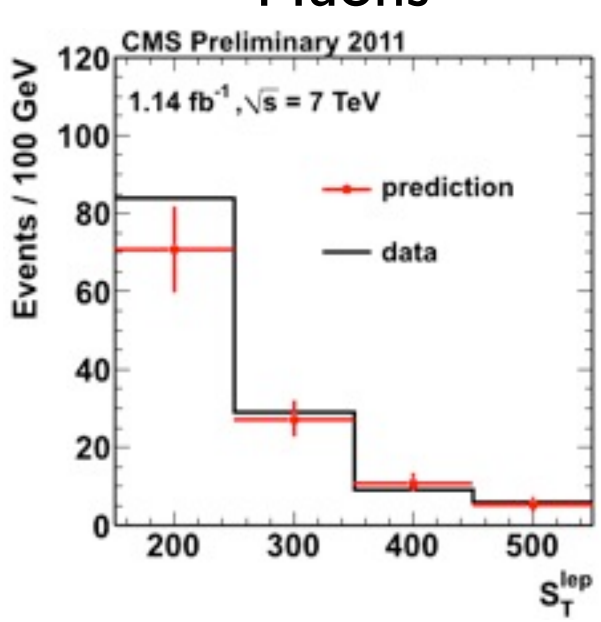
More Single Lepton



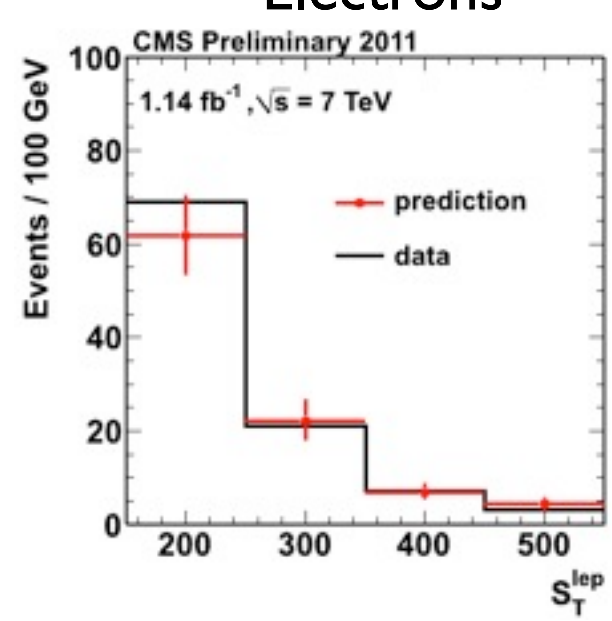
- Second analysis method -- “Lepton Projection Method”
- Categorizes events by “Lepton Projection Variable”: $\mathrm{L_P} = \frac{\vec{P}_T(\ell) \cdot \vec{P}_T(W)}{|\vec{P}_T(W)|^2}$ correlated with cos θ*
- For SUSY $\mathrm{L_P}$ peaks near zero, for W’s away from zero.
- Define signal region with $\mathrm{L_P} < 0.15$, and control region > 0.30. to estimate background.
    - Values chosen from MC studies
- Divide data into bins in $\mathrm{S_T^{lep}} = p_T(\ell) + \not{E}_\mathrm{T}$

	Control Region (L_P >0.3)		Signal Region (L_P <0.15)		
$\mathrm{S_T^{lep}}$ Range (GeV)	Total MC	Data	Total MC	SM estimate	Data
[150-250]	385±7	368	73.9±3.0	70.6±11	84
[250-350]	116±2	112	28.1±1.1	27.2±4.6	29
[350-450]	43.4±2.	41	11.5±0.7	10.9± 2.3	9
> 450	18.4±0.8	15	6.5±0.4	5.3± 1.8	6

Muons

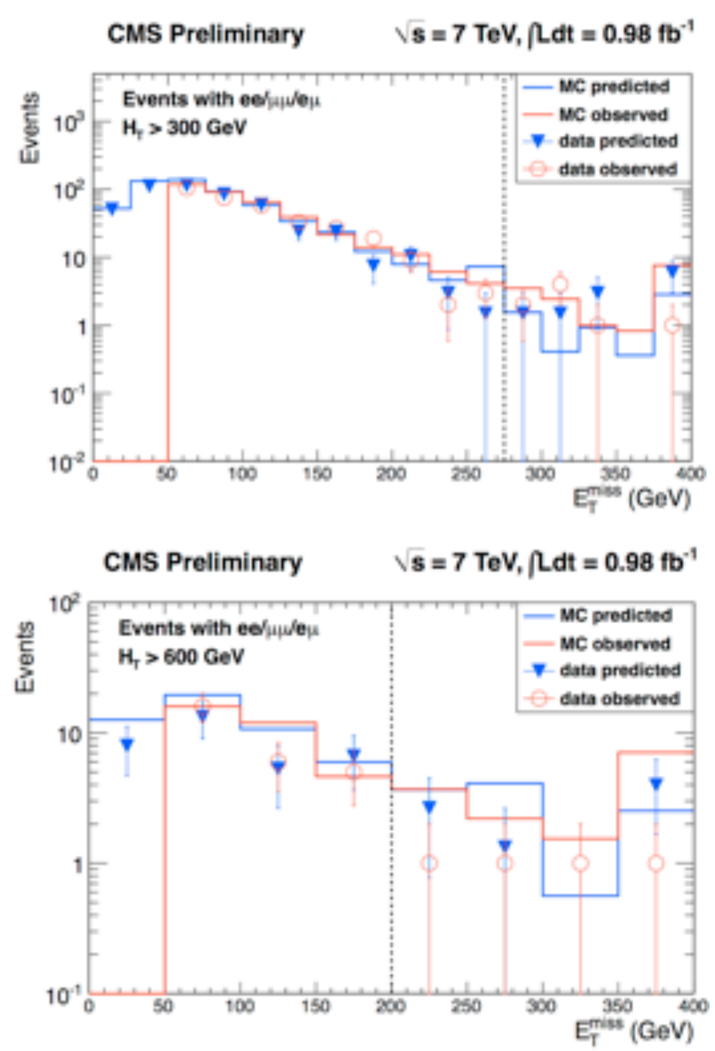


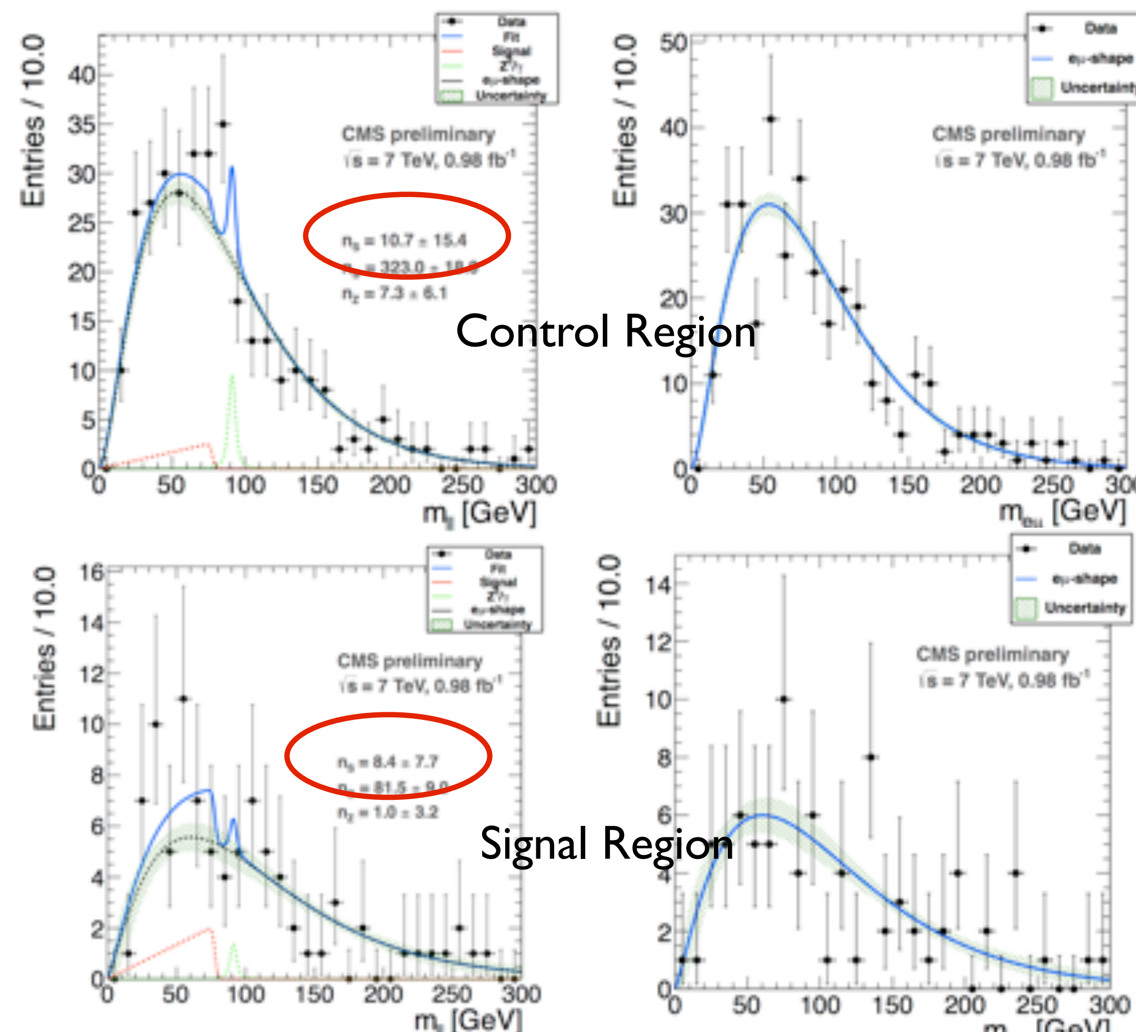
Electrons



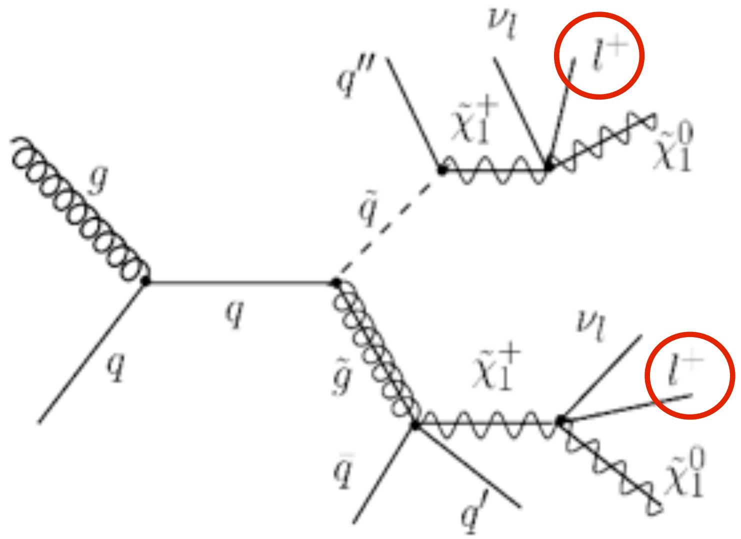
Opposite signed dileptons + jets + MET

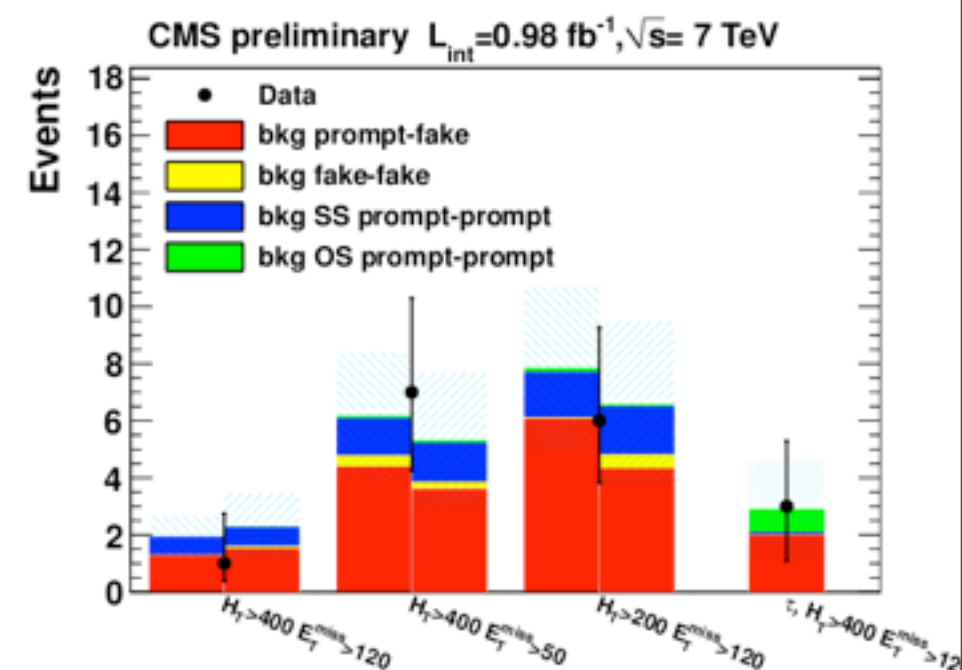
- Assuming R parity and lepton flavor conservation, SUSY with leptons in the decay chain would produce opposite signed, same flavor leptons along with jets and MET.
- Treats opposite signed sample as candidates, same signed events used for background estimate.
- We perform counting experiments (left) or look for kinematic edges in invariant mass distributions (right)

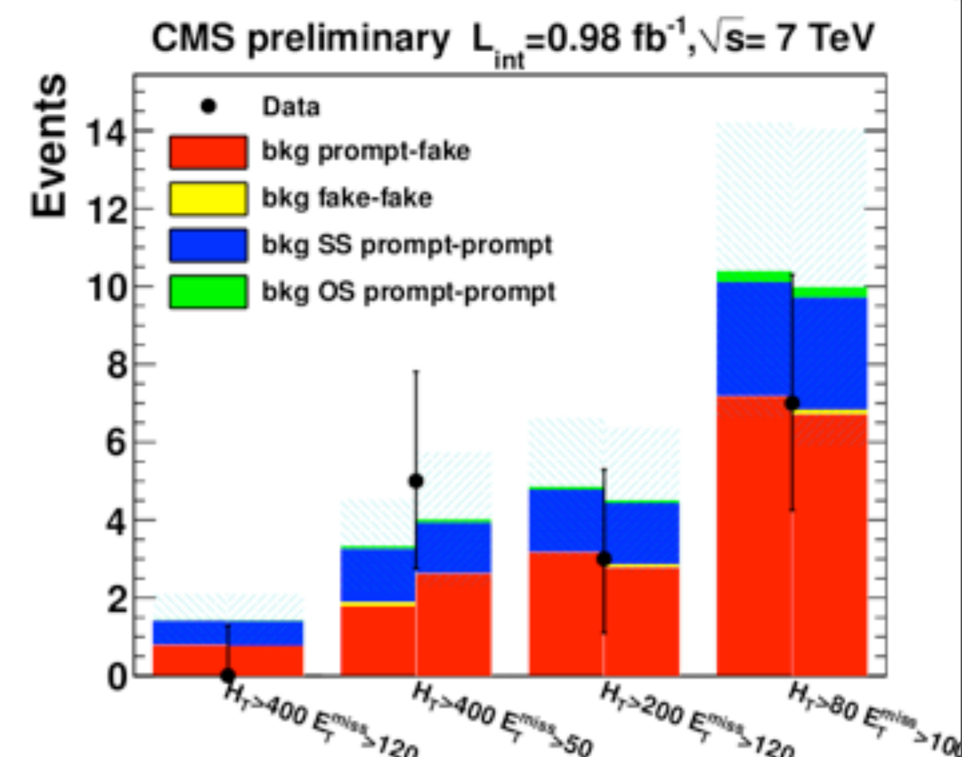




Same signed dileptons

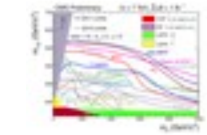




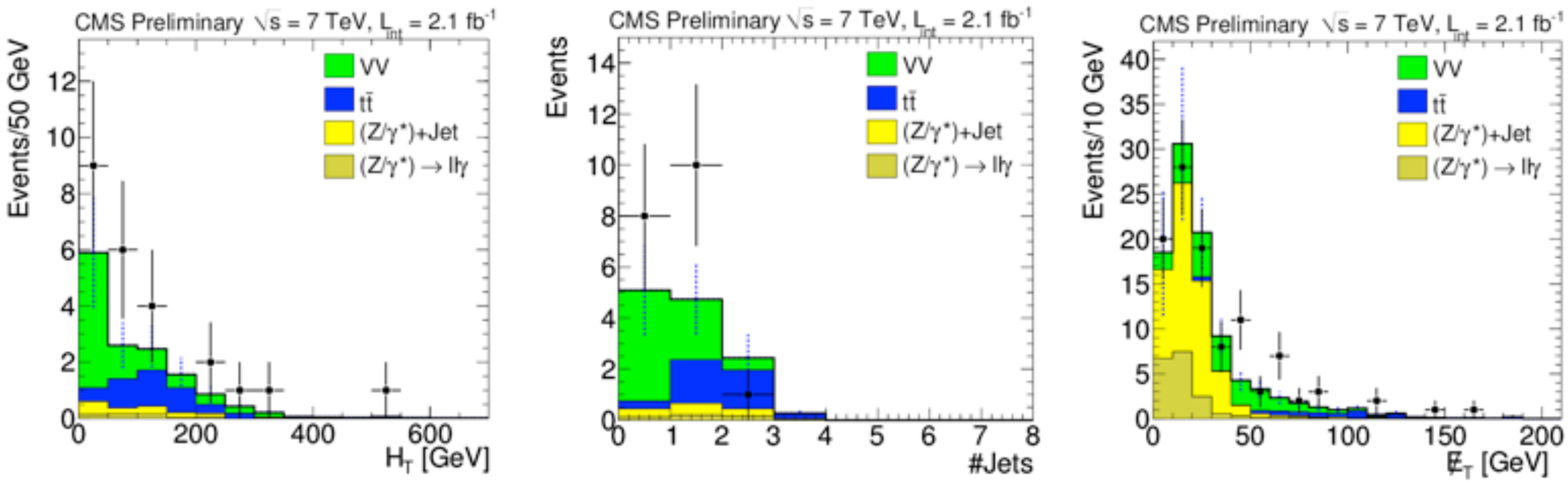


- Look for two same sign leptons, 2 jets and MET
- Yields for inclusive dileptons (H_T > 200 GeV), high p_T dileptons (both p_T>10 GeV, one > 20 GeV, H_T>80 GeV) and dileptons with taus (H_T>350 GeV, MET>80 GeV)
- In the non tau cases two different methods of estimating the backgrounds are shown
  - Leptons passing looser cuts and failing tight cuts to estimate probability of jets faking leptons
  - Assuming factorization of passing MET and H_T requirements to estimate the probability of passing both

Multileptons



- Analysis requires several variations of at least 3 leptons



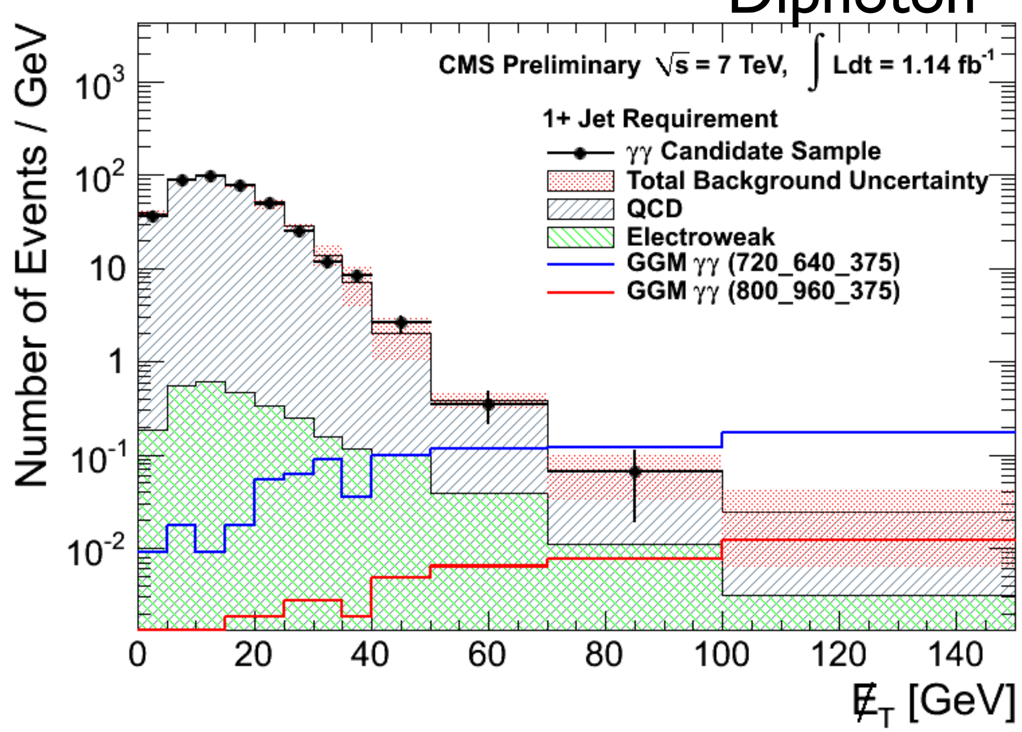
See Sunil's Talk This Afternoon!

Photons

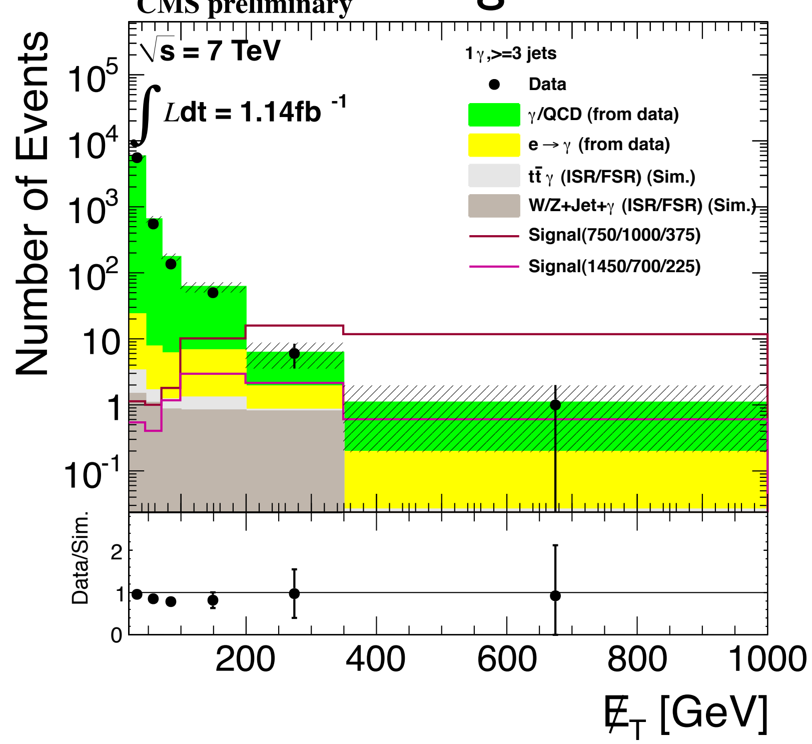
Photons+Jets+MET

- http://cdsweb.cern.ch/record/1377324 (SUS-11-009)
- Two analyses: diphoton + jet(s) + MET and single photon + 3 jets + MET
- Photons required to be isolated, pass p_T requirements
  - A 40 GeV and a 25 GeV photon in the diphoton case, a 70 GeV photon in the single photon case
- Jets separated from the photons (at least one 30 GeV jet in the diphoton case, 3 jets and H_T>400 GeV -- H_T here includes the photon)
- Backgrounds dominated by QCD -- obtained in sidebands from less isolated photons. EW backgrounds from the data in the diphoton analysis, both data and MC in the single photon case.

Diphoton



Single Photon

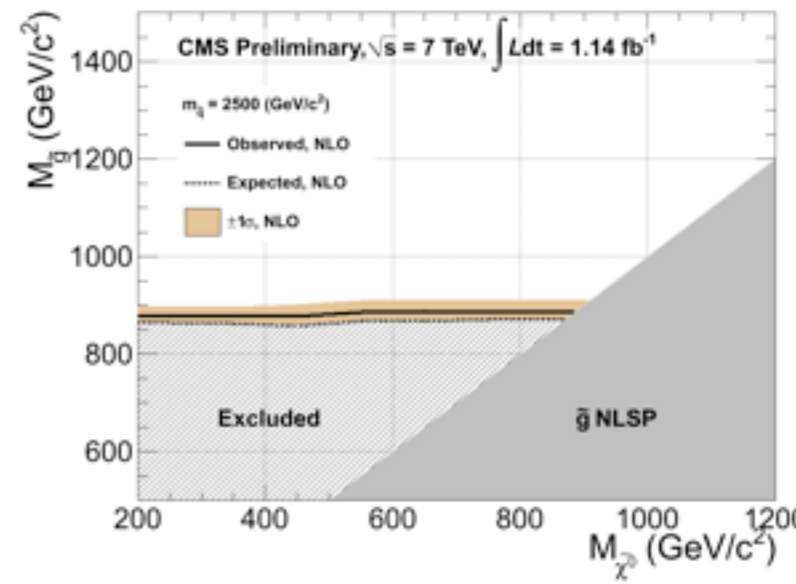


Observed events and interpretation

- Interpretation from GMSB, bino or wino-like neutralino NLSP, gravitino as LSP

Diphoton

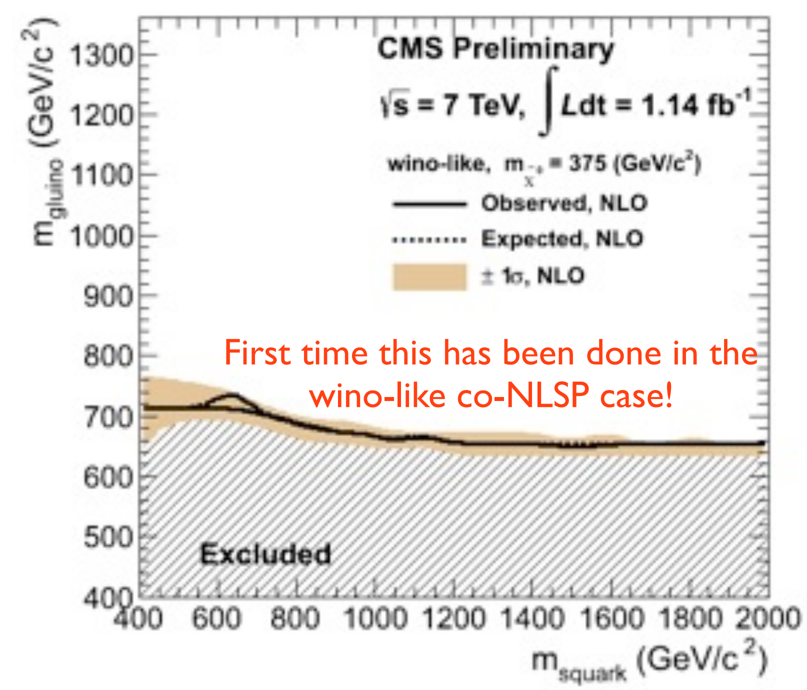
Type	Events	stat. error	scal. error	norm. error
$\gamma\gamma$ candidates	0			
ff QCD background	2.3 ± 2.2	± 2.19	± 0.13	± 0.10
ee QCD background	1.0 ± 0.8	± 0.82	± 0.02	± 0.03
EWK background	0.3 ± 0.1	± 0.06	± 0.0	± 0.03
Total background (ff)	2.5 ± 2.2			
Total background (ee)	1.3 ± 0.8			



Single Photon

Sample	Event yield		
		(stat.)	(syst.)
Data	7		
QCD (est. from data)	5.16	± 2.58	± 0.62
EWK $e \to \gamma$ (est. from data)	1.22	± 0.13	± 0.04
FSR/ISR ($W \to \mu/\tau\nu, Z \to \nu\nu$) (Sim.)	0.80	± 0.31	± 0.80
FSR/ISR ($t\bar{t} \to \mu/\tau\nu + X$) (Sim.)	0.07	± 0.05	± 0.07
Total SM background estimate	7.24	± 2.6	± 1.53

1γ, >=3 jets, MET> 200 GeV



Working with kinematics...

- 3 Analyses -- technically all inclusive hadronic analyses
- M_{T2} -- all hadronic: http://cdsweb.cern.ch/record/1377032 (SUS-11-005)
- α_T -- also all hadronic http://cdsweb.cern.ch/record/1370596 (SUS-11-003)
- RAZOR: http://cdsweb.cern.ch/record/1404167 (SUS-11-008)

All Hadronic Events with M_{T2}

- Takes advantage of R parity conservation -- relies on production of pair of particles that generate MET
- "Stransverse Mass": $M_{T2}(m_\chi) = \min_{p_T^{\chi(1)} + p_T^{\chi(2)} = p_T^{miss}} \left[\max\left(m_T^{(1)}, m_T^{(2)} \right) \right]$
- The m_T's come from $(m_T^{(i)})^2 = (m^{vis(i)})^2 + m_\chi^2 + 2\left(E_T^{vis(i)} E_T^{\chi(i)} - \vec{p}_T^{\,vis(i)} \cdot \vec{p}_T^{\,\chi(i)} \right)$
- "axes" defined initially by two highest inv. mass jets
- Associate multiple jets into hemispheres with an iterative procedure where jet "k" is associated with axis i or j according to:

$$(E_i - p_i cos\theta_{ik}) \frac{E_i}{(E_i + E_k)^2} \leq (E_j - p_j cos\theta_{jk}) \frac{E_j}{(E_j + E_k)^2}.$$

- Axes are recalculated with the newly associated jets, iterate.
- Once stable with no jets swapping, with two final axes, M_{T2} is calculated
- Signal SUSY events will in general have high M_{T2} --look for an excess

M_{T2} Results

- High M_{T2} analysis: counting experiment with M_{T2}> 400 GeV, HT>600 GeV.
- Table shows observed events for ranges of M_{T2} cuts, plot M_{T2} distribution with a potential signal

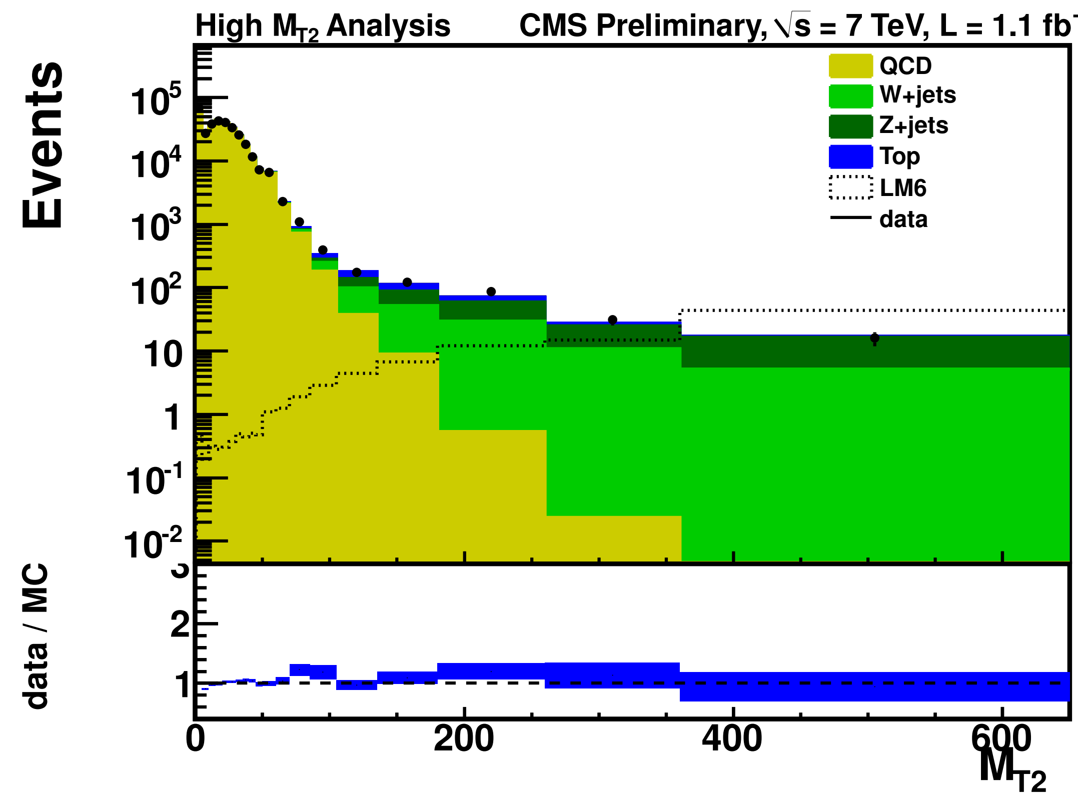
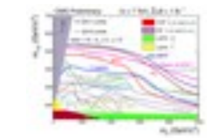


Table 2: Expected background event yields and observed number of events in data after various M_{T2} cuts for events with ≥ 3 jets. "Other" backgrounds are mostly γ + jets.

Process	QCD	W+jets	Z+jets	Top	Other	Total Bkg.	data
After full selection	322001	869.4	409.2	1090.1	995.8	325365	325365
MT2 > 100 GeV	61.4	162.2	138.7	88.2	2.4	452.9	482
MT2 > 150 GeV	4.0	69.0	75.8	27.7	1.2	177.6	208
MT2 > 200 GeV	0.1	33.7	45.5	9.6	0.8	89.8	105
MT2 > 250 GeV	0.0	17.7	27.7	4.1	0.1	49.6	58
MT2 > 300 GeV	0.0	9.9	19.0	1.2	0.0	30.1	30
MT2 > 350 GeV	0.0	5.8	11.9	0.5	0.0	18.2	17
MT2 > 400 GeV	0.0	3.5	7.3	0.2	0.0	11.0	12
MT2 > 450 GeV	0.0	1.9	4.7	0.2	0.0	6.8	9
MT2 > 500 GeV	0.0	1.2	3.5	0.0	0.0	4.6	7

α_T all hadronic search



- α_T is a similar idea with M_{T2}:

$$\alpha_T = \frac{E_T^{\text{jet}_2}}{M_T} = \frac{E_T^{\text{jet}_2}}{\sqrt{\left(\sum_{i=1}^{2} E_T^{\text{jet}_i}\right)^2 - \left(\sum_{i=1}^{2} p_x^{\text{jet}_i}\right)^2 - \left(\sum_{i=1}^{2} p_y^{\text{jet}_i}\right)^2}},$$

in general this is defined for a di-jet system -- for multiple jets an iterative procedure as with the M_{T2} analysis is followed to produce a pair of combined jets

- Used to differentiate between events with real or instrumental MET (QCD)
- α_T>0.55 defines signal region, binned in H_T bins:

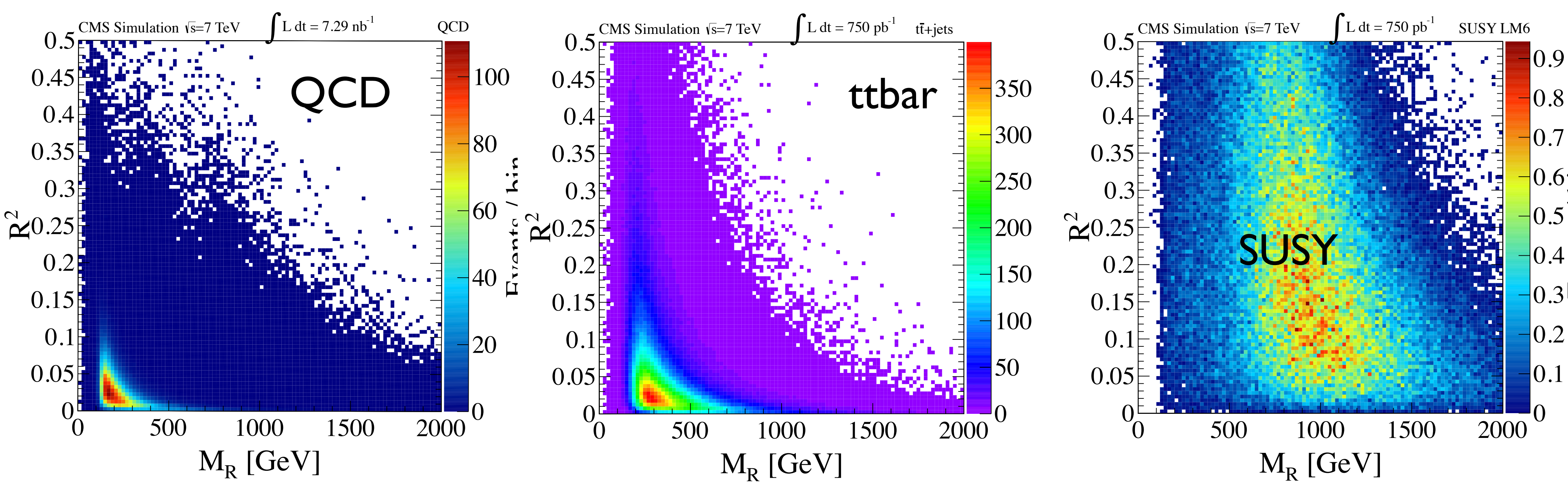
H_T Bin (GeV)	275–325	325–375	375–475	475–575
W + $t\bar{t}$ background	363.7	152.2	88.9	28.8
$Z \to \nu\bar{\nu}$ background	251.4	103.1	86.4	26.6
QCD background	172.4	55.1	26.9	5.0
Total Background	787.4	310.4	202.1	60.4
Data	782	321	196	62
H_T Bin (GeV)	575–675	675–775	775–875	875–∞
W + $t\bar{t}$ background	10.6	3.1	0.6	0.6
$Z \to \nu\bar{\nu}$ background	8.7	4.3	2.5	2.2
QCD background	1.0	0.2	0.1	0.0
Total Background	20.3	7.7	3.2	2.9
Data	21	6	3	1

RAZOR

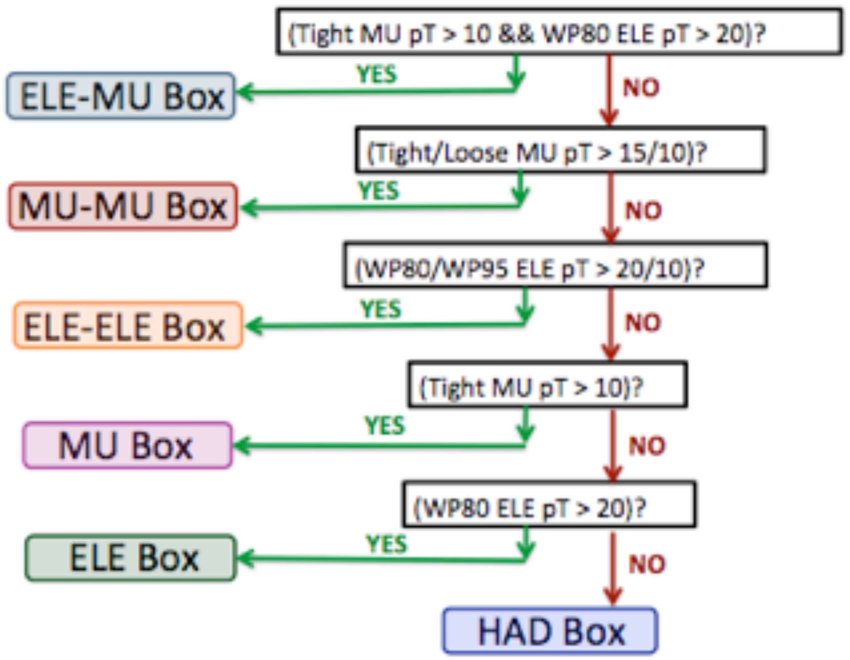
- Again relying on there having been two SUSY particles produced, tries to approximate the CM frame of the two heavy particles (whose decay products, jets, etc are measured.)
- Clusters jets together in a similar way to the previous two analyses, then the RAZOR ratio is defined as:

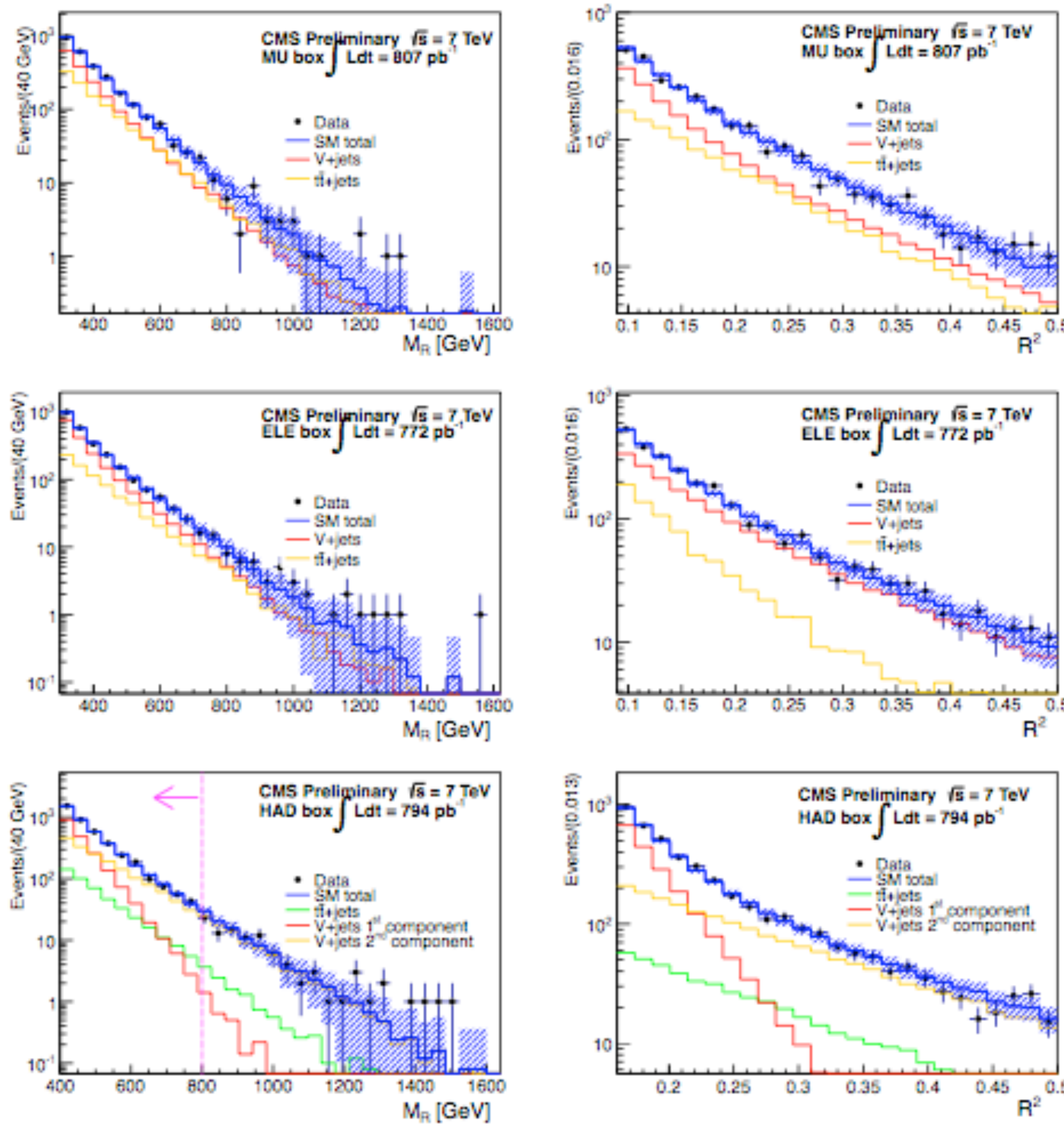
$R \equiv \frac{M_T^R}{M_R}$ where $M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$ and $M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$

- The jet for momenta are evaluated in this RAZOR prospective CM frame
- Examples of how backgrounds and potential signal would manifest in these variables:



Categorization and Results



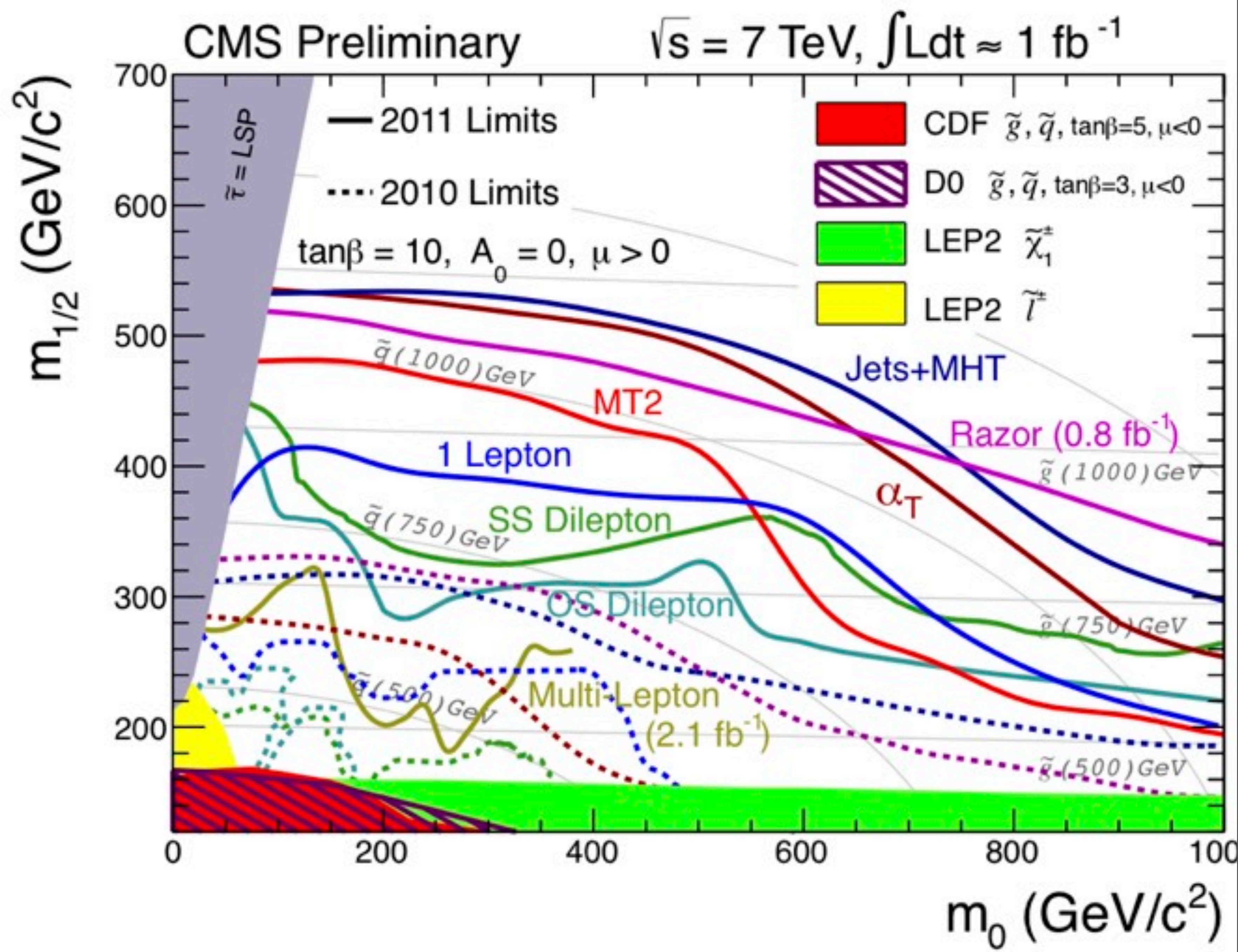


- Events are categorized into 21 signal regions depending on the presence and combination of electrons, muons
- Improved sensitivity in some regions, but no excess seen

Combined interpretation
(part 1)

Pasta con CMSSM

- Constrained Minimal SuperSymmetric Model
- Primarily an illustration of the variety of limits and many corners in SUSY model space CMS has searched
- This is though specific to this particular model.
- A more general way to represent our results (and more importantly be able to compare with others) a bit later -- after we run through just a few more analyses

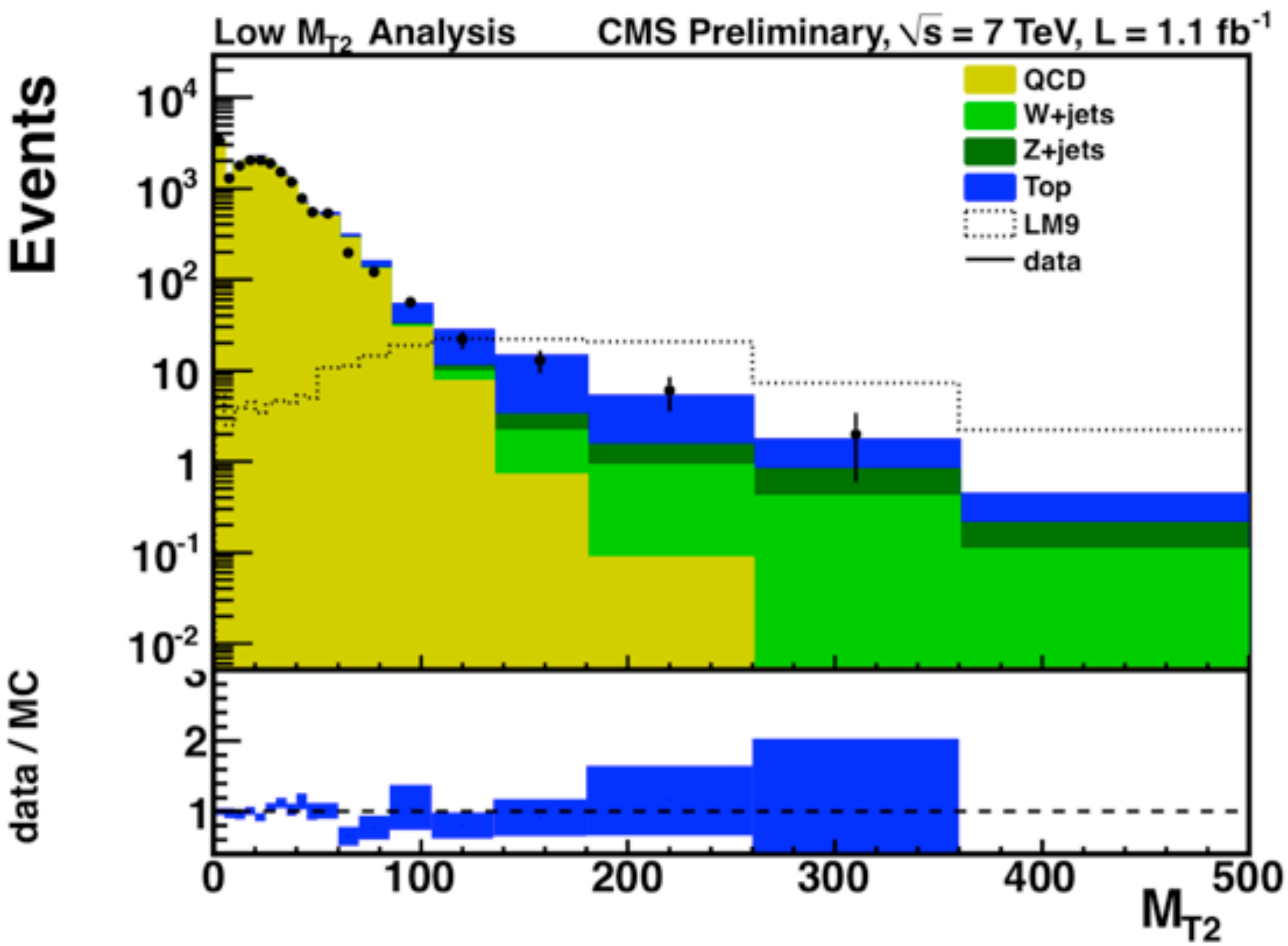


Reaching into the 3rd generation

- Adding selections on 3rd generation particles to "standard" analyses can allow better discrimination from backgrounds -- sometimes even reduction of cut thresholds
- Have 3 analyses:
- M_{T2} with a B tag http://cdsweb.cern.ch/record/1377032/ (SUS-11-005)
- Hadronic events with b jets http://cdsweb.cern.ch/record/1390493 (SUS-11-006)
- All hadronic events with taus http://cdsweb.cern.ch/record/1401920 (SUS-11-007)

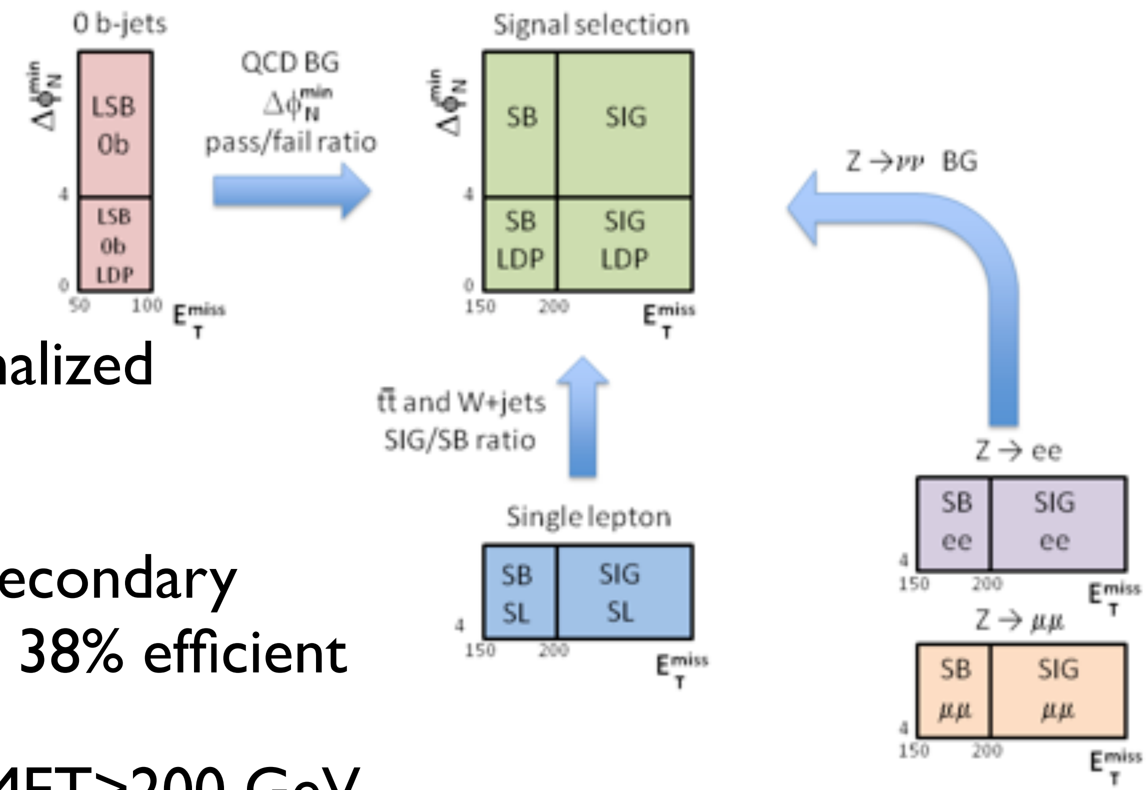
M_{T2} B

- Just like the standard M_{T2} analysis, but requiring a B tagged jet.
- Allows bringing down M_{T2} threshold from 400 to 150 GeV (though H_T moves up from 600 to 650 GeV to reduce some of the QCD backgrounds as well)

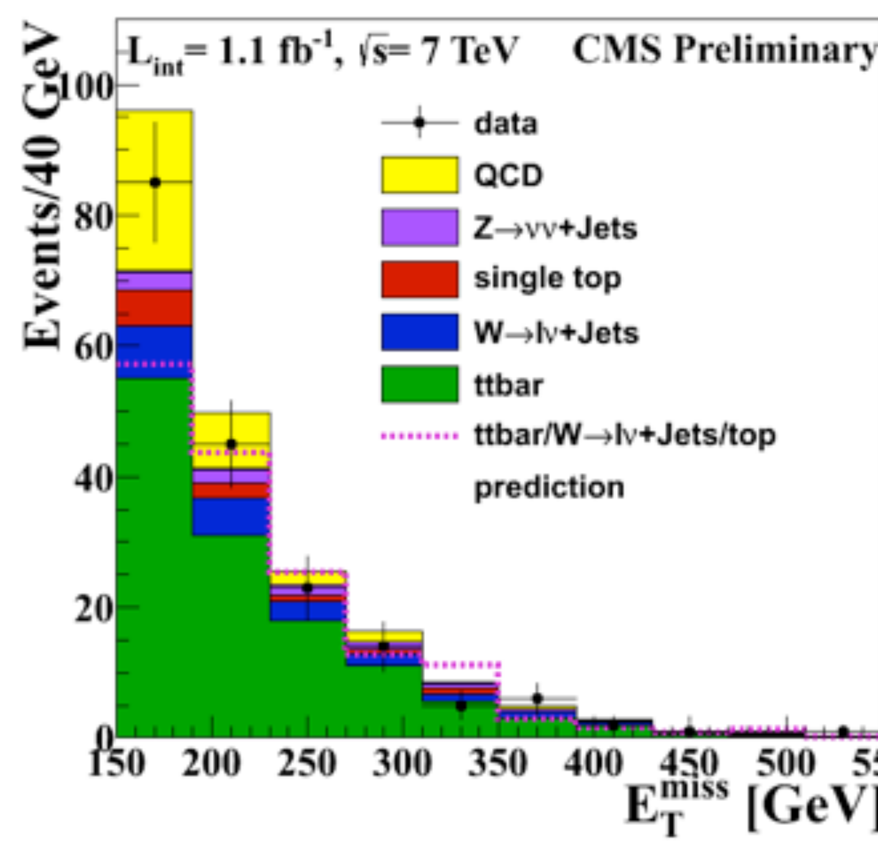


Hadronic events with b jets + MET

- 3 jets, no leptons, at least one b tagged jet, and MET
- Uses $\Delta\Phi_N^{min}$, the minimum opening angle between any of the 3 highest p_T jets, normalized by resolution.
- B jets identified by trying to reconstruct secondary vertex from 3 charged tracks within a jet. 38% efficient
- Two search regions, loose: HT>350 GeV, MET>200 GeV, tight: HT>500 GeV, MET>300 GeV



	Loose search region		Tight search region	
	≥ 1 b	≥ 2 b	≥ 1 b	≥ 2 b
QCD	$9.7^{+10.1}_{-8.4}$	$0.0^{+3.7}_{-0.0}$	$0.2^{+0.8}_{-0.2}$	$0.1^{+0.6}_{-0.1}$
top and W+jets	115 ± 15	24.5 ± 5.5	$13.9^{+4.6}_{-4.3}$	$5.0^{+2.4}_{-1.9}$
$Z \to \nu\bar{\nu}$	29^{+14}_{-11}	$5.2^{+4.6}_{-2.9}$	$5.3^{+3.6}_{-2.7}$	$0.6^{+0.9}_{-0.6}$
Total SM (LH)	152.8	29.7	19.5	5.7
Data	155	30	20	5
LM9 95% CL upper limit	91	21	20	7.3
LM9 MC	145	58	27	9.3

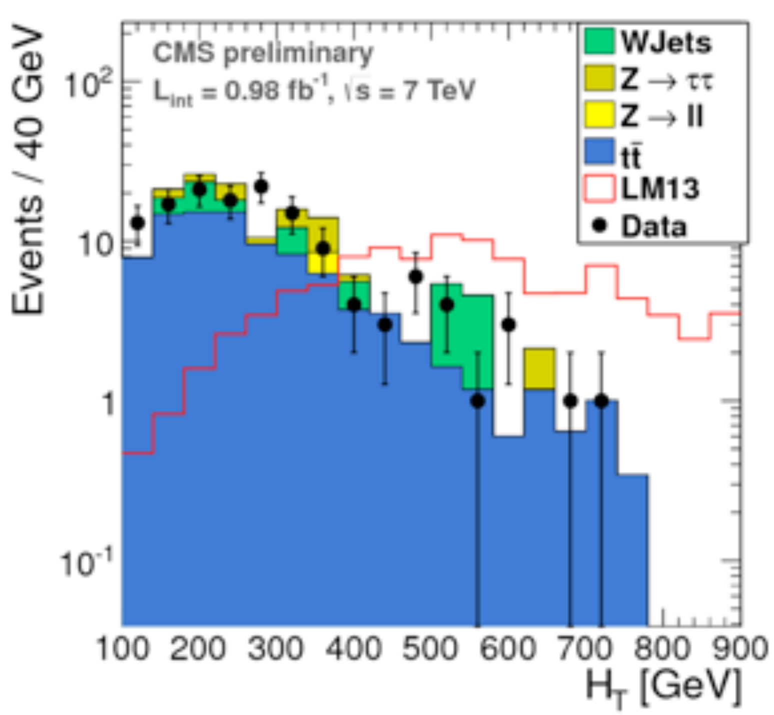


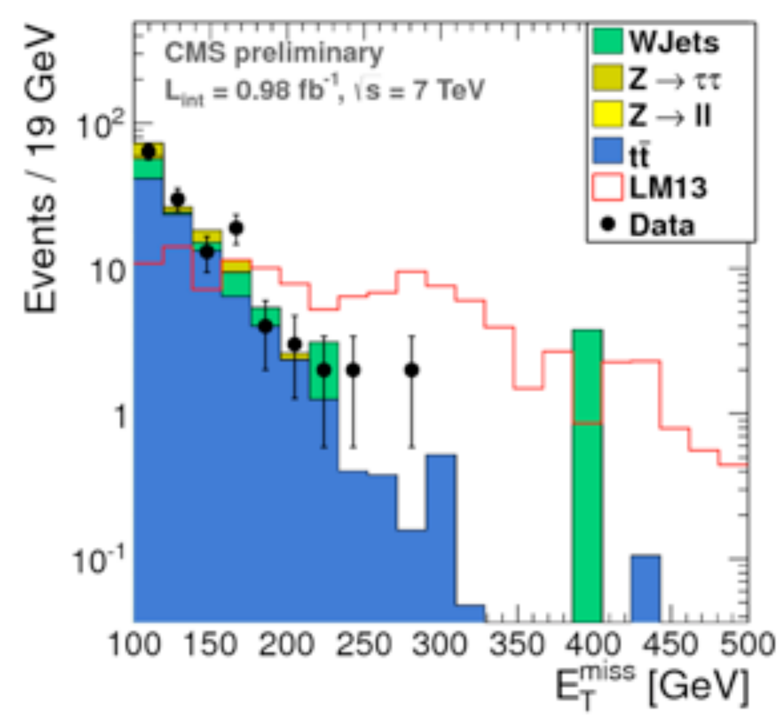
All hadronic with opposite signed taus

- Look for events with either large H_T or large MET with opposite signed taus, such that at least one of them decayed hadronically
    - leptonic decay modes covered in dilepton analysis, i.e. slide ~11

Table 1: Summary of the selections and signal region definitions.

Property	$e/\mu\tau_h$ high E_T^{miss}	$e/\mu\tau_h$ high H_T	$\tau_h\tau_h$
Geom. Acceptance	$\|\eta^{e,\mu,\tau_h}\| < 2.1$		
Charge	opposite-sign		
Trigger	$e/\mu + \tau_h$		$\|\overrightarrow{H\!\!\!/_T}\|$
Momentum	$p_T^{e,\mu,\tau_h} > 20$ GeV		$p_T^{\tau_h} > 15$ GeV
N_{jets}	2 jets ($p_T > 30$ GeV)		2 jets ($p_T > 100$ GeV)
Transverse Energy imbalance	$E_T^{miss} > 200$ GeV	$E_T^{miss} > 150$ GeV	$\|\overrightarrow{H\!\!\!/_T}\| > 200$ GeV
Hadronic activity	$H_T > 300$ GeV	$H_T > 400$ GeV	—

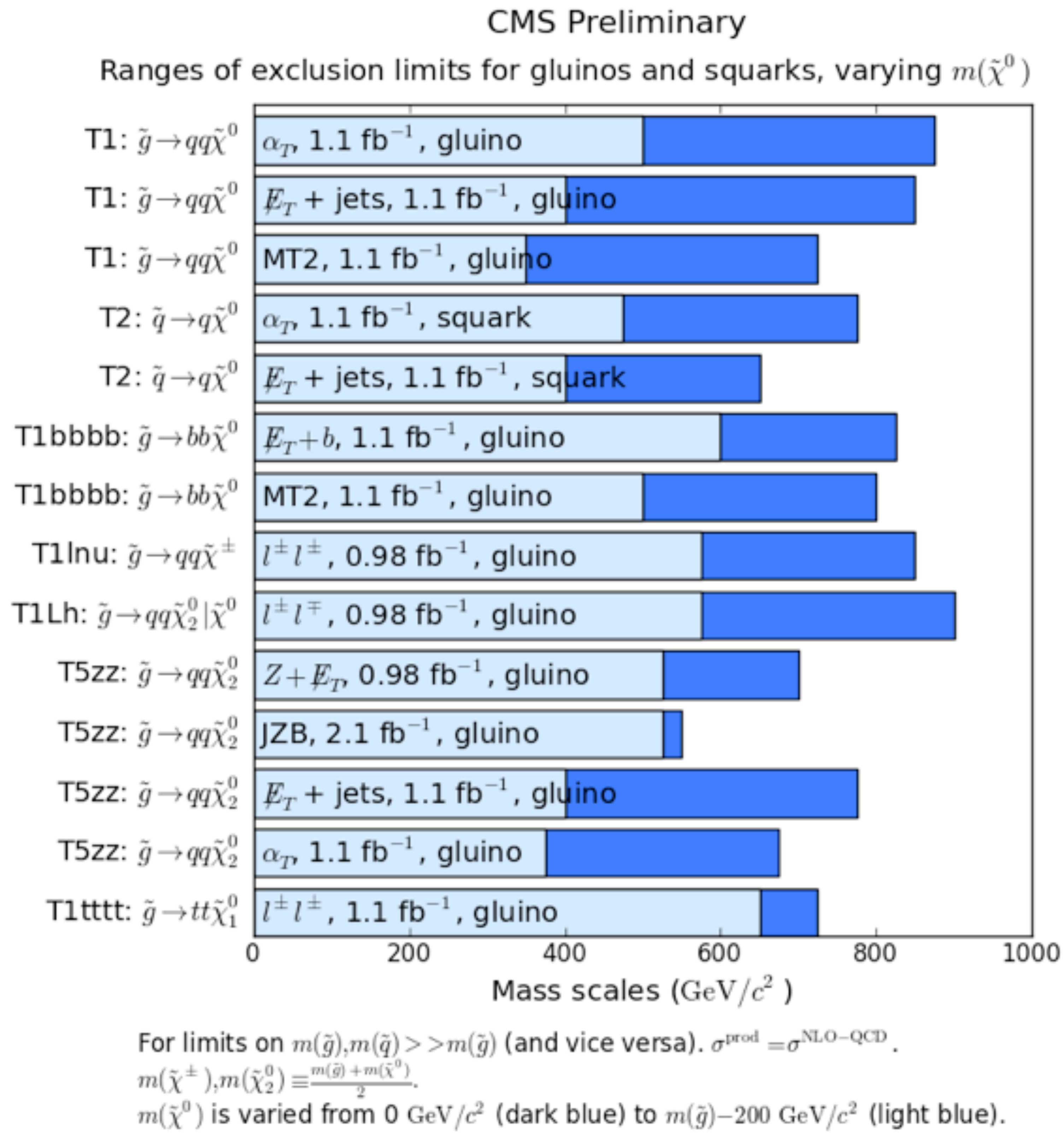




Combined interpretation (part 2)

Simplified Model Scans

- Common effort between experiments to aid comparison of the different measurements
- Concentrate on initial production and final state, to first order don't care by what path you get there.
- Shown at right current limits from summer results
- Range in dark blue due to varying LSP mass (zero at high end, heavier at low end)
- Inching towards 1 TeV



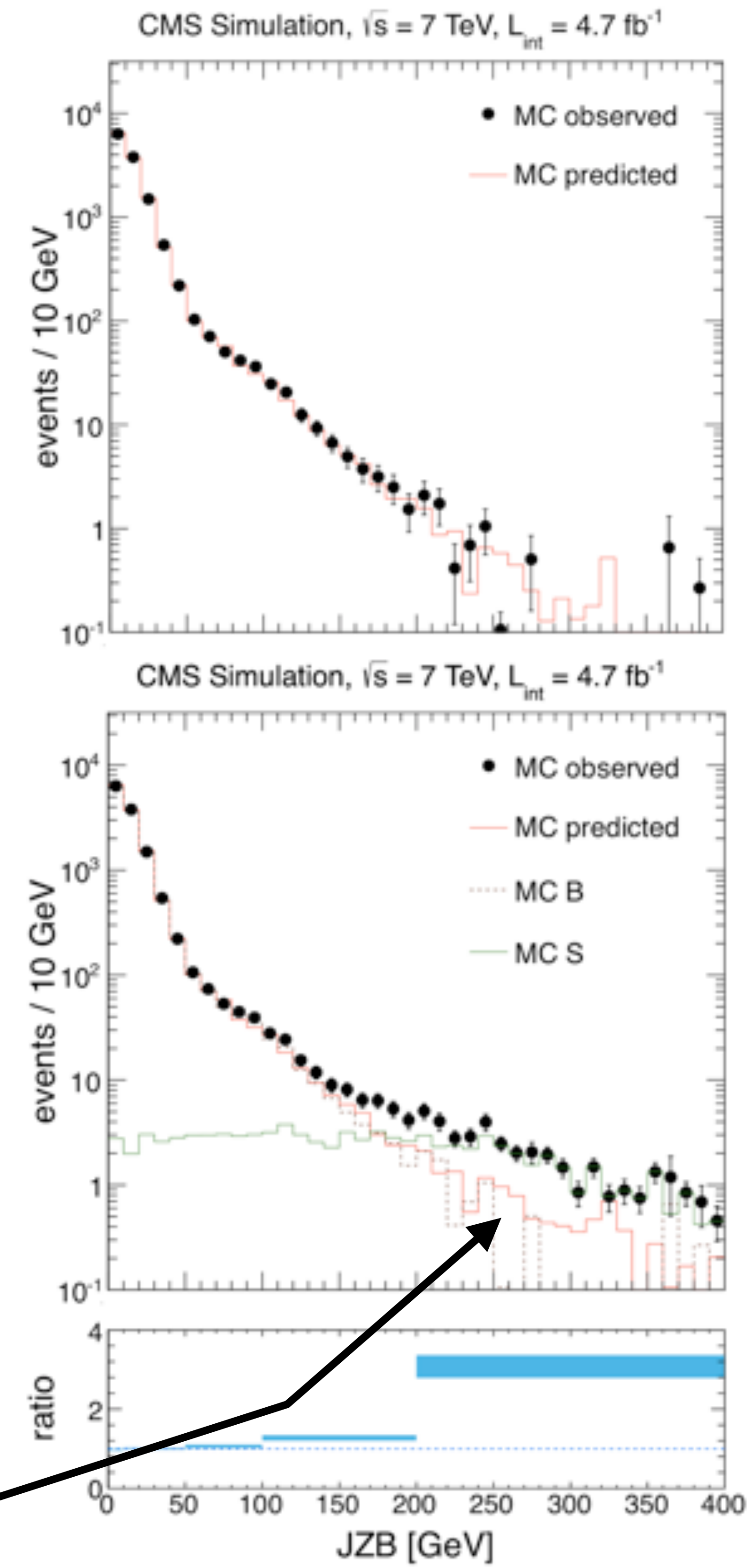
Z+jets+MET

Z + Jets + MET

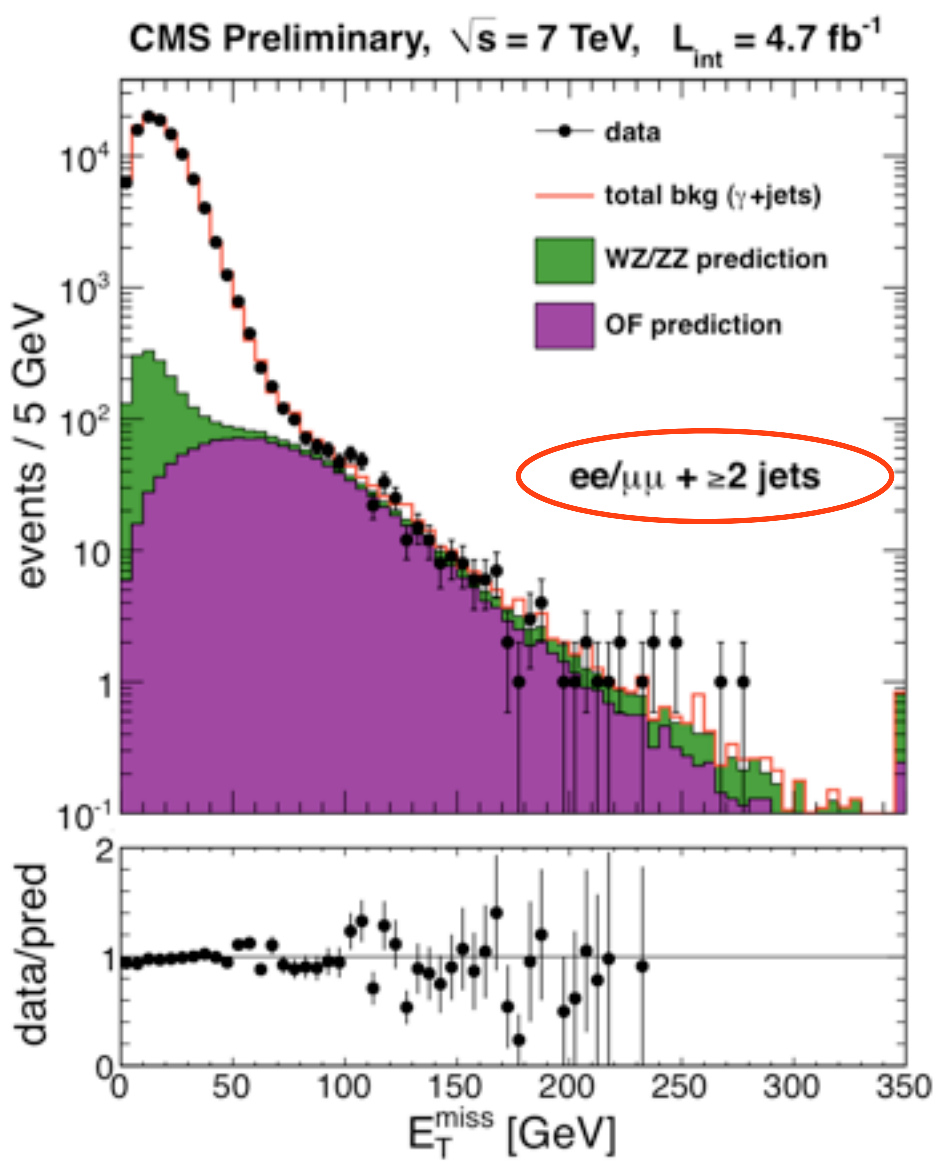
- Paper to be submitted shortly, plots and documentation at
  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS11021
- Two complementary search methods (SUS-11-021)
  - Look for excess in MET distribution in Z + jet events
  - Use "Jet-Z" balance distribution (JZB)

$$\mathrm{JZB} = \left| -\vec{E}_{\mathrm{T}}^{\mathrm{miss}} - \vec{p}_T^{(\mathrm{Z})} \right| - \left| \vec{p}_T^{(\mathrm{Z})} \right|$$

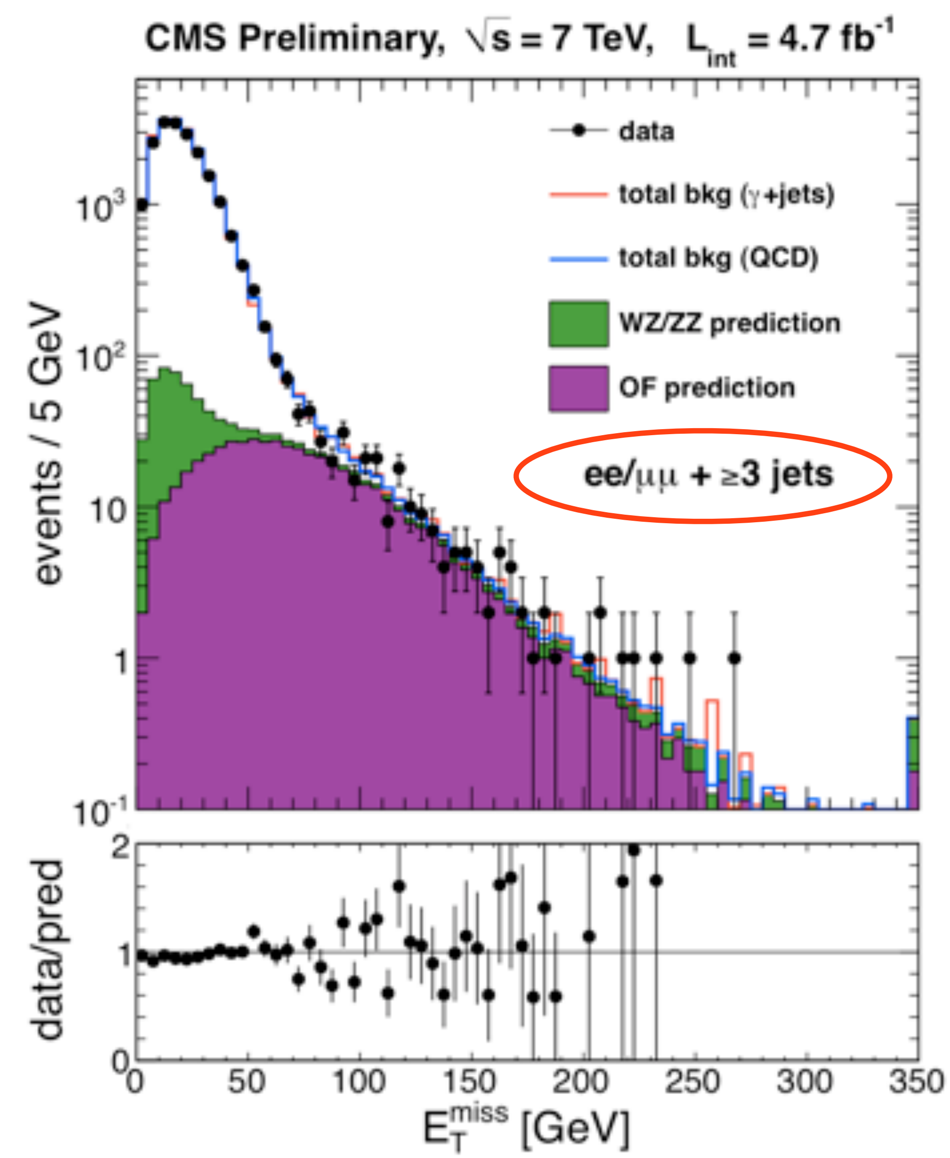
  - Centered on zero, fold in half, fit, using negative half to predict background for positive half (where excess MET manifests)
  - On right -- two examples in MC, top is without a signal, bottom is with signal MC added -- SUSY would manifest as an excess at high JZB:



Z+Jet+MET Results

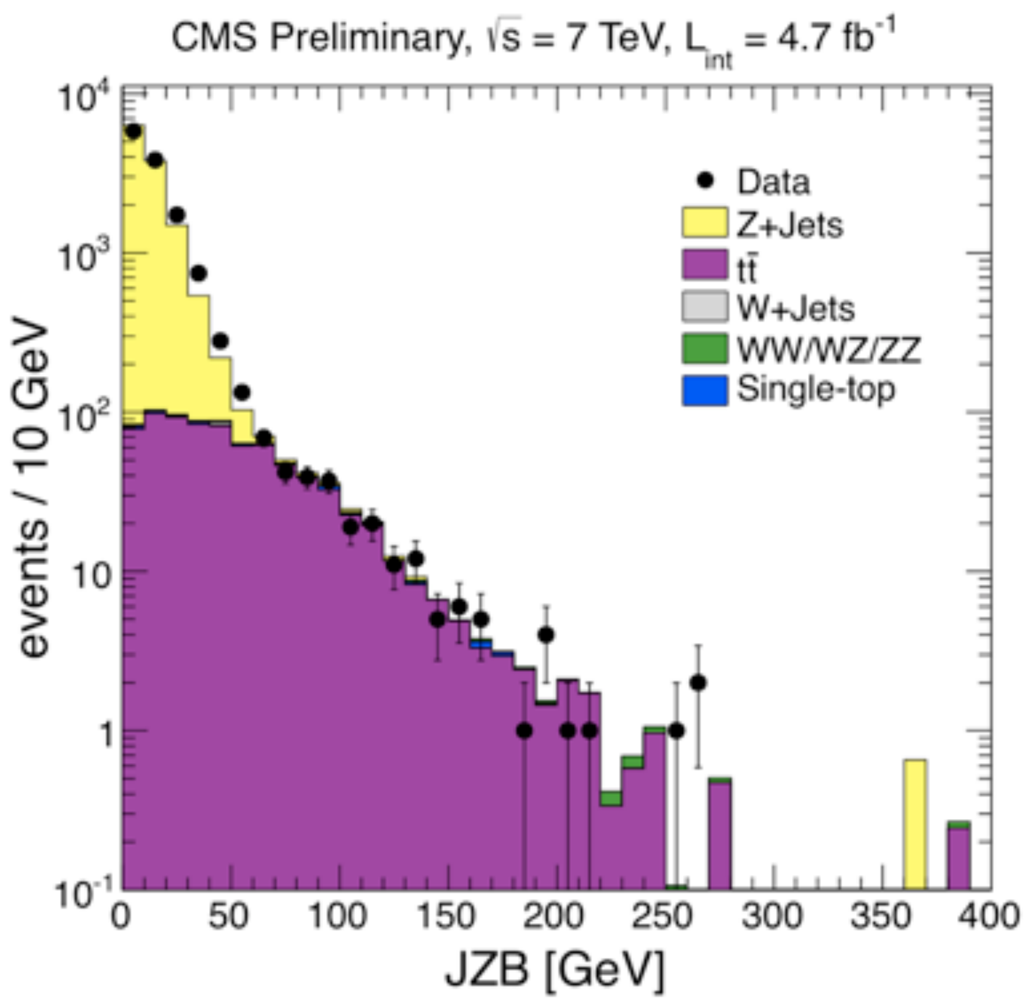


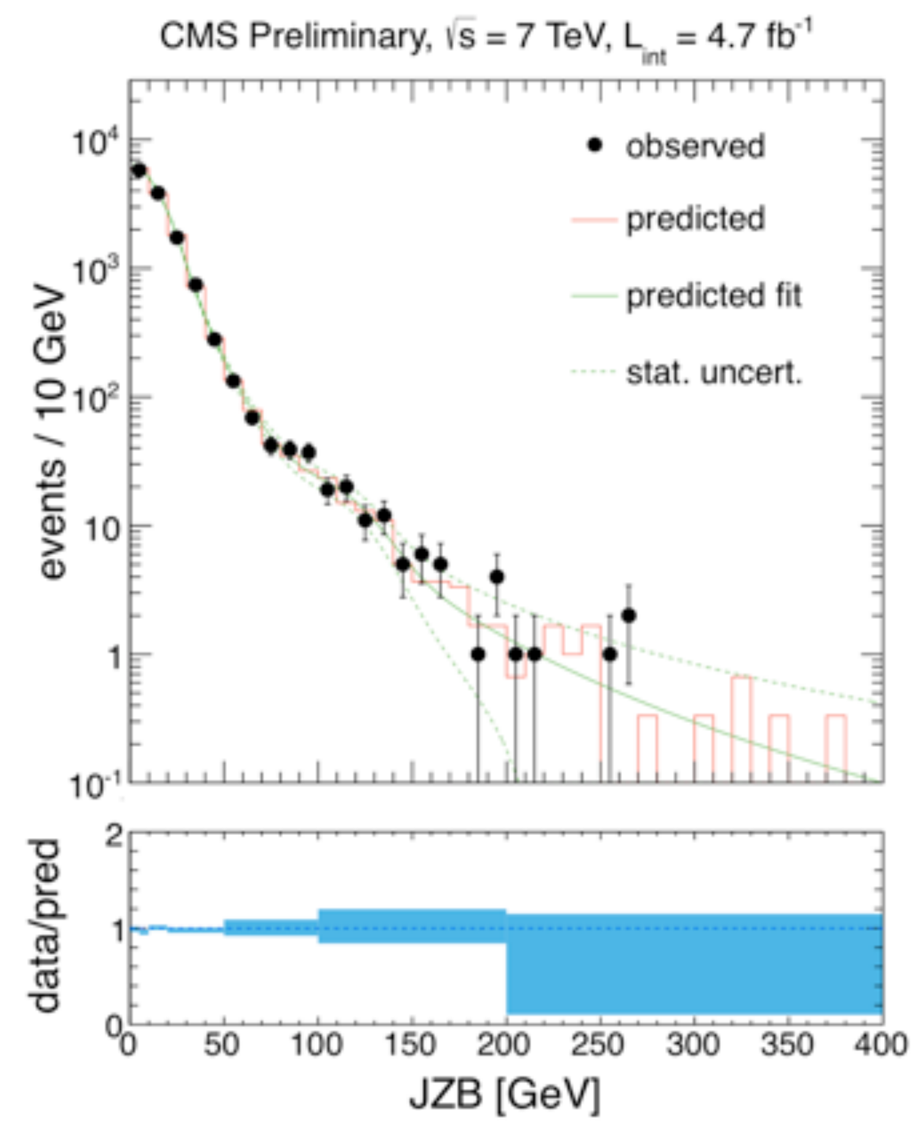
	$E_T^{miss} > 30$ GeV	$E_T^{miss} > 60$ GeV	$E_T^{miss} > 100$ GeV	$E_T^{miss} > 200$ GeV	$E_T^{miss} > 300$ GeV
Z bkg	15070 ± 4825	484 ± 156	36 ± 12	2.4 ± 0.9	0.4 ± 0.3
OF bkg	1116 ± 101	680 ± 62	227 ± 21	11.4 ± 3.2	1.6 ± 0.6
VZ bkg	252 ± 126	79 ± 39	32 ± 16	5.0 ± 2.5	1.1 ± 0.7
total bkg	**16438 ± 4828**	**1243 ± 173**	**295 ± 29**	**18.8 ± 4.2**	**3.1 ± 1.0**
data	**16483 (8243,8240)**	**1169 (615,554)**	**290 (142,148)**	**14 (8,6)**	**0**
upper limit	6389	239	57	8.3	2.9
LM4	113 ± 9.1	102 ± 8.5	88 ± 7.9	50 ± 7.4	22 ± 6.0
LM8	49 ± 4.1	43 ± 3.7	35 ± 3.2	19 ± 2.9	9 ± 2.2



	$E_T^{miss} > 30$ GeV	$E_T^{miss} > 60$ GeV	$E_T^{miss} > 100$ GeV	$E_T^{miss} > 200$ GeV	$E_T^{miss} > 300$ GeV
Z bkg (QCD)	4010 ± 802	191 ± 57	11 ± 11	0.7 ± 0.7	0.1 ± 0.1
Z bkg (γ + jets)	3906 ± 1252	187 ± 61	14 ± 5	1.7 ± 0.7	0.3 ± 0.2
OF bkg	442 ± 41	284 ± 26	107 ± 10	7.5 ± 2.2	1.1 ± 0.5
VZ bkg	80 ± 40	24 ± 12	10 ± 5	1.8 ± 0.9	0.4 ± 0.3
total bkg (QCD)	4533 ± 804	500 ± 64	128 ± 16	10 ± 2.5	1.6 ± 0.6
total bkg (γ + jets)	4429 ± 1253	496 ± 67	131 ± 13	11 ± 2.5	1.9 ± 0.6
total bkg (average)	**4481 ± 1034**	**498 ± 66**	**129 ± 15**	**11 ± 2.7**	**1.8 ± 0.6**
data	**4501 (2272,2229)**	**479 (267,212)**	**137 (73,64)**	**8 (3,5)**	**0**
upper limit	1513	121	42	6.9	2.9
LM4	91 ± 7.7	85 ± 7.5	75 ± 7.5	42 ± 7.1	18 ± 5.2
LM8	40 ± 3.3	37 ± 3.1	31 ± 2.9	18 ± 2.7	8 ± 2.1

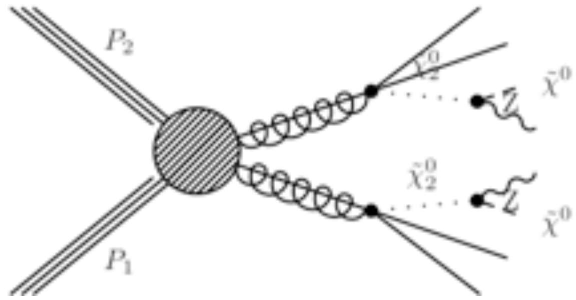
JZB Results



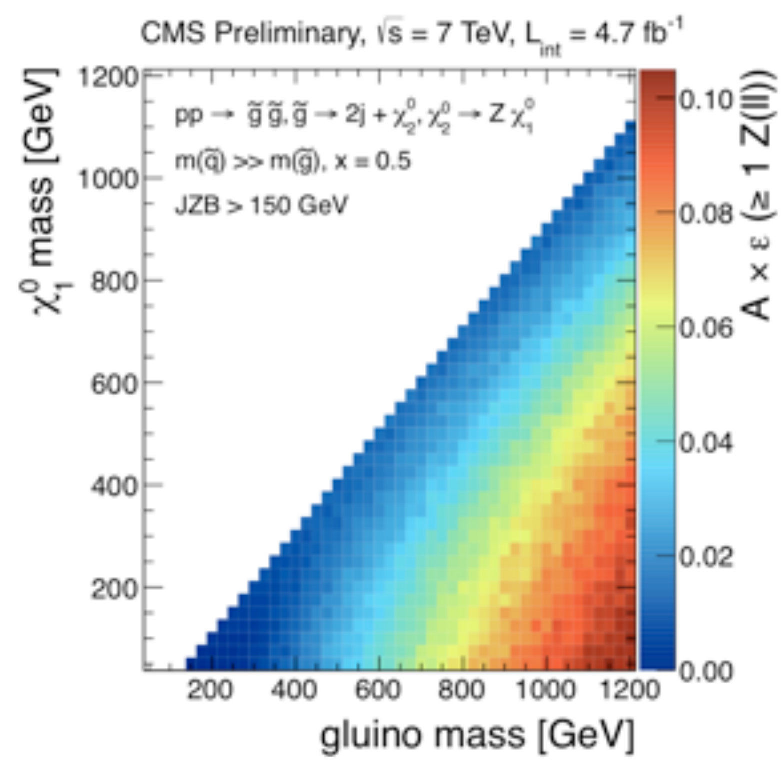


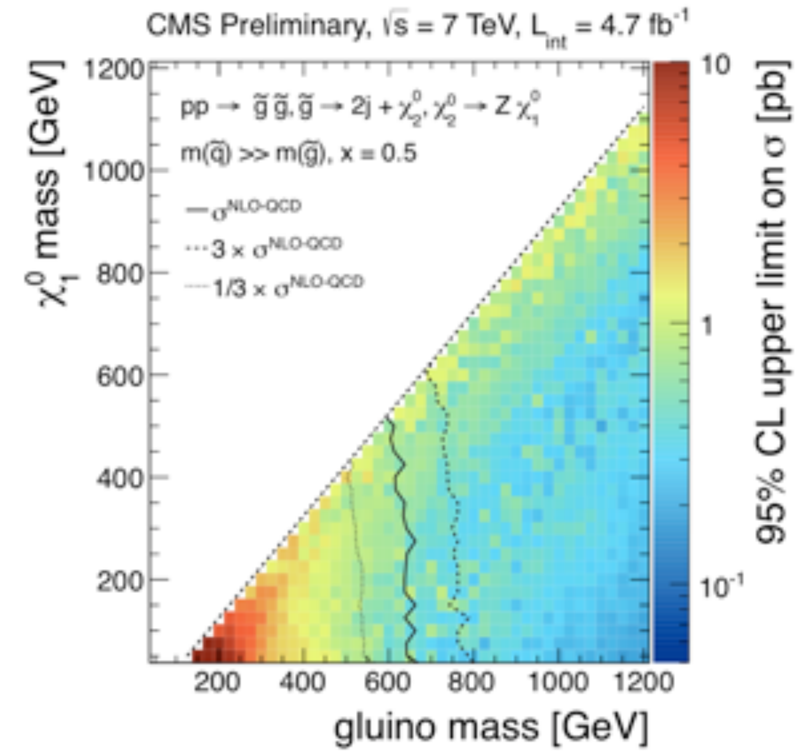
	JZB > 50 GeV	100 GeV	150 GeV	200 GeV	250 GeV
Z bkg	$97 \pm 13 \pm 38$	$8 \pm 3 \pm 3$	$2.7 \pm 1.8 \pm 0.8$	$1.0 \pm 1.0 \pm 0.25$	0
flavor-symmetric	$311 \pm 10 \pm 45$	$81 \pm 5 \pm 12$	$19 \pm 3 \pm 3$	$7 \pm 2 \pm 1$	$2.0 \pm 0.8 \pm 0.3$
total bkg	$408 \pm 16 \pm 59$	$89 \pm 6 \pm 12$	$22 \pm 3 \pm 3$	$8 \pm 2 \pm 1$	$2.0 \pm 0.8 \pm 0.3$
data	**408 (203,205)**	**88 (52,36)**	**21 (13,8)**	**5 (3,2)**	**3 (2,1)**
upper limit	114	32	14	6	6
LM4	57 ± 2	48 ± 2	38 ± 1	27 ± 1	17 ± 1
LM8	21 ± 1	18 ± 1	15 ± 1	11.0 ± 0.5	7.0 ± 0.4

Limits

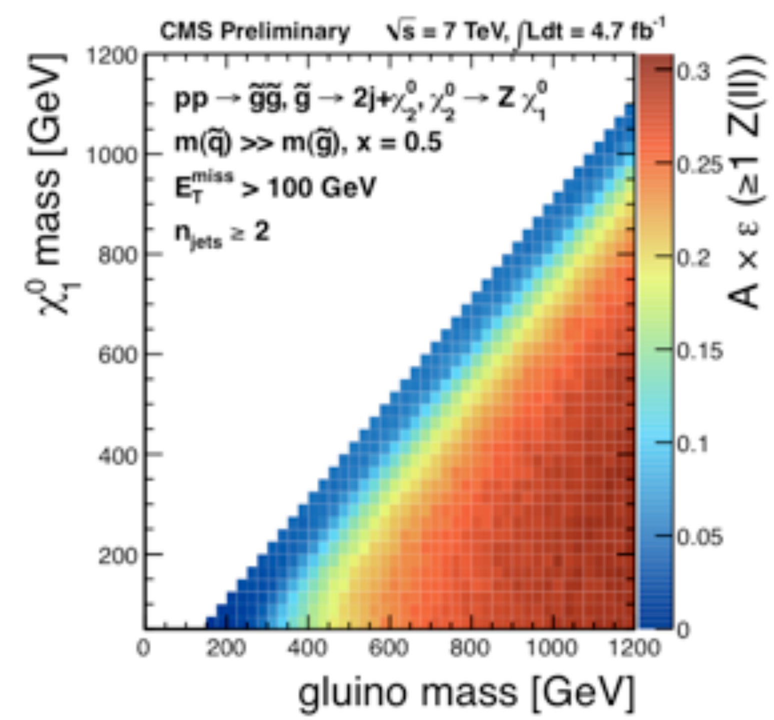


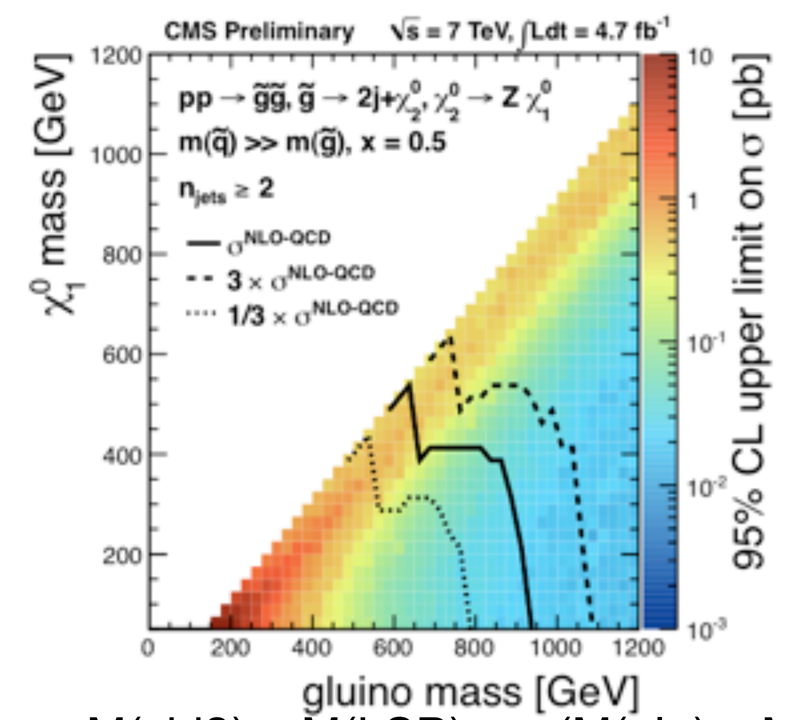
JZB Method





MET Method

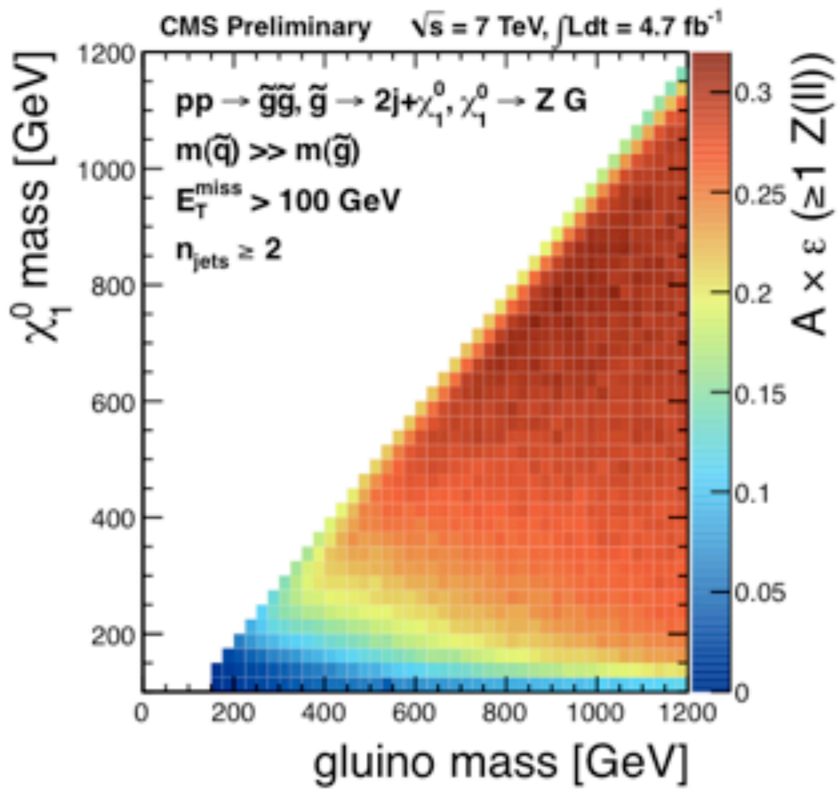


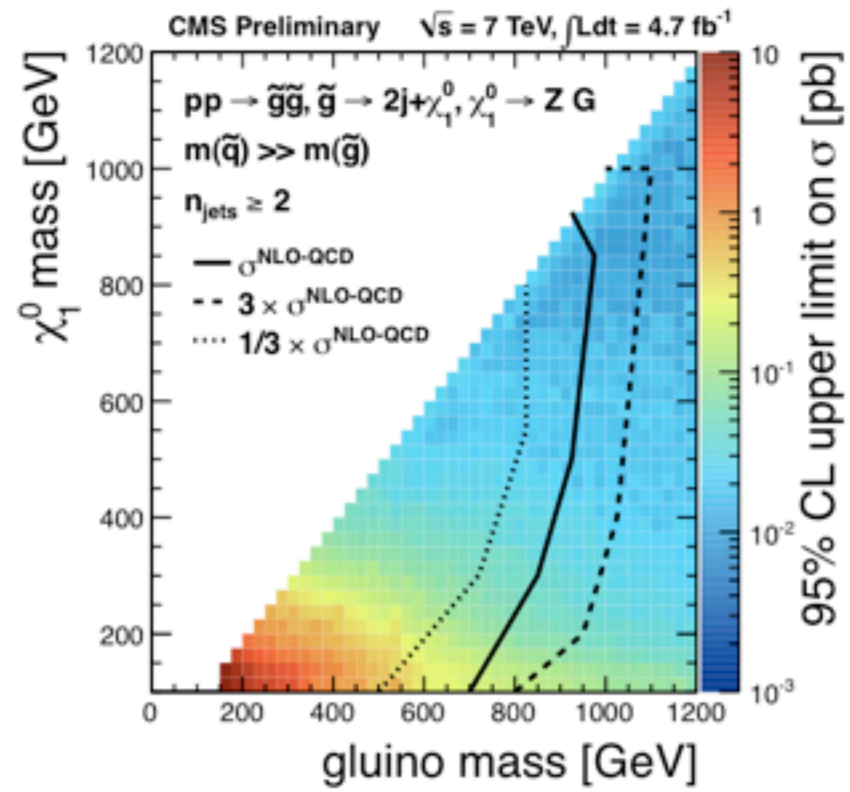


M(chi2) = M(LSP) + x (M(glu) – M(LSP))

We provide generator level efficiencies vs JZB and MET!

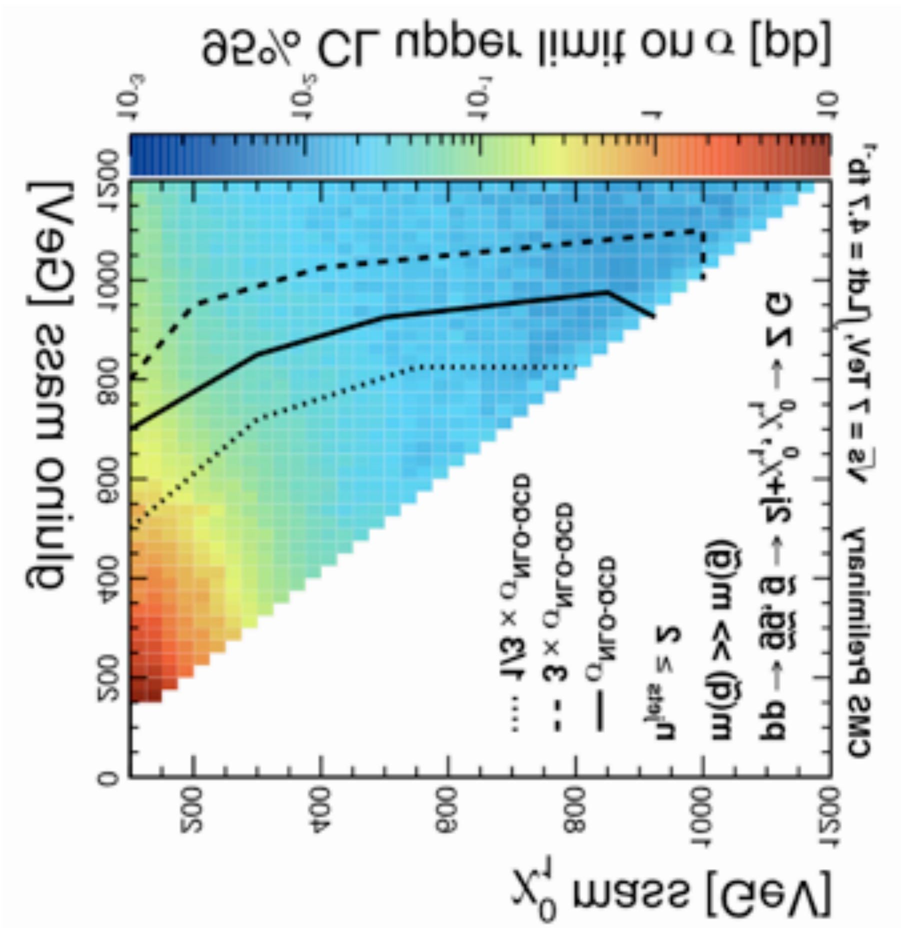
GMSB interpretation

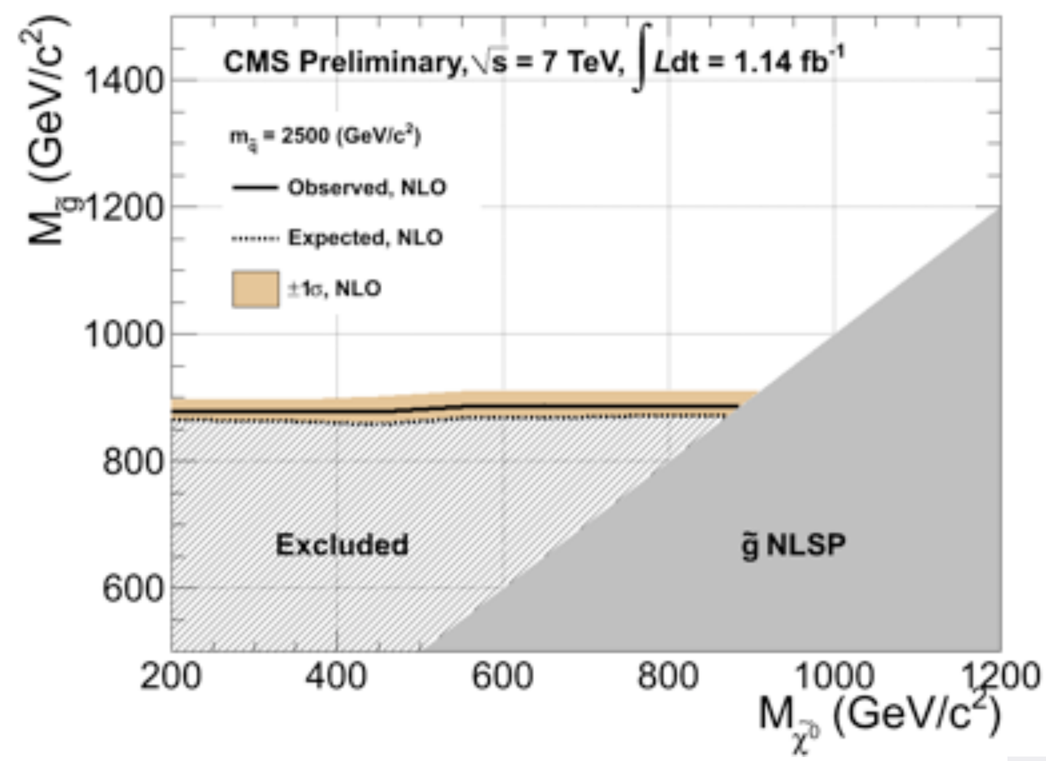




- Z+Jets + MET limit with gravitino LSP (before was neutralino LSP)
- This is GMSB, so we can try to put this together with the diphoton result with a bit of gymnastics (keynote physics?)

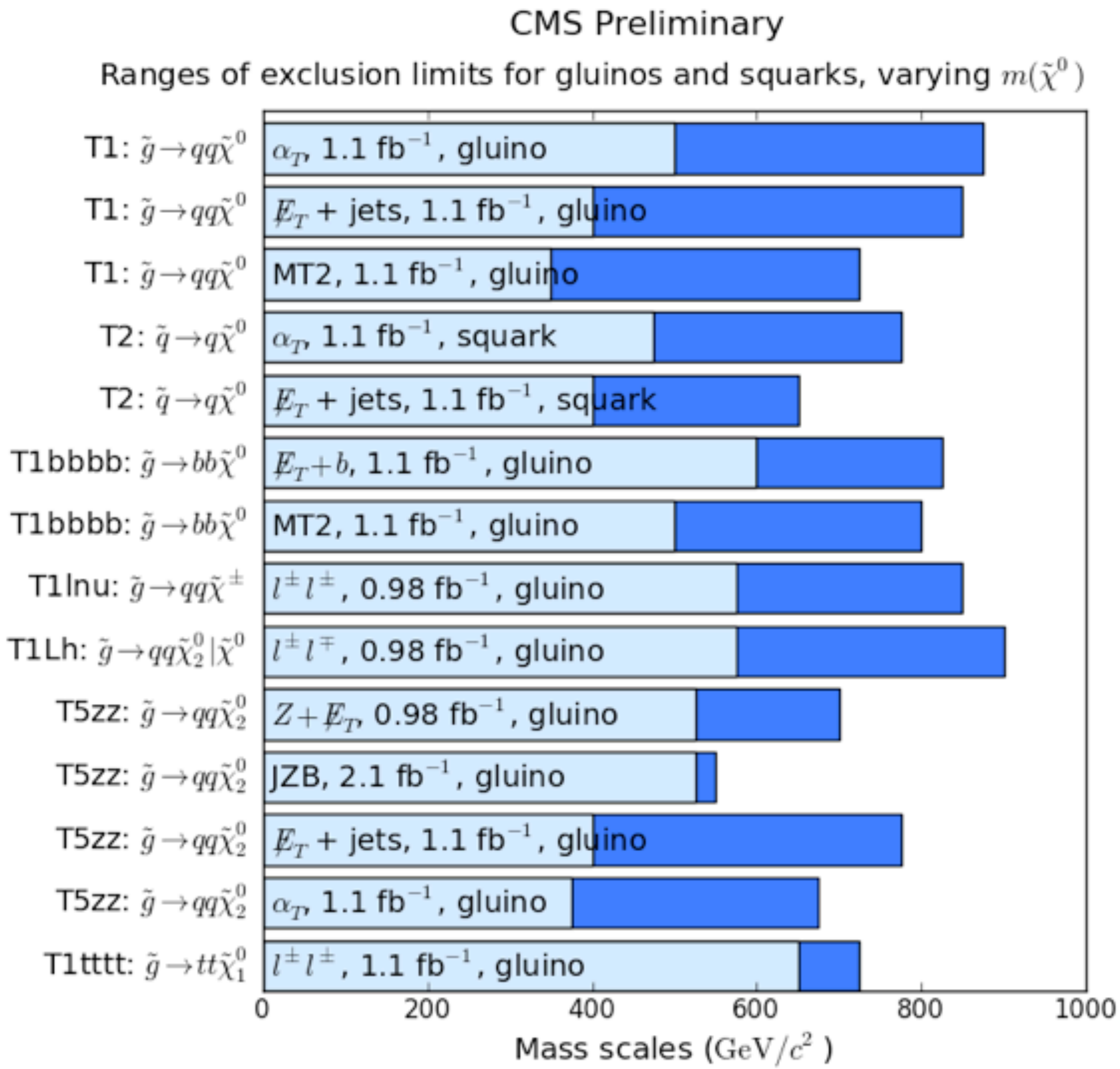
Single McTwist 1260 Limit





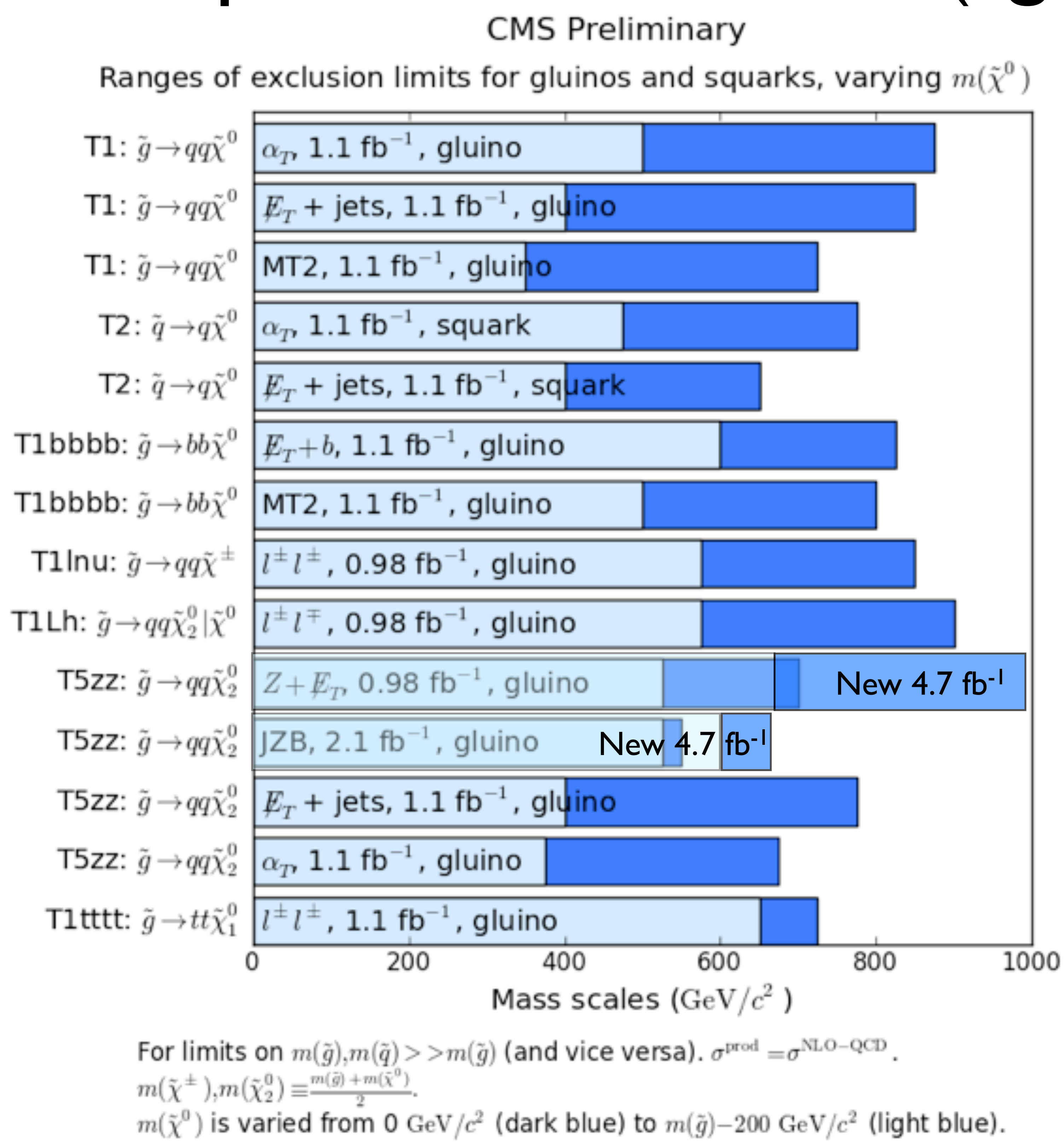
- Twisting and rotating the Z plot to compare to the diphoton result
- Caveat -- luminosity different between the two -- not apples to apples
- More of an illustration of two complementary measurements -- one sensitive to bino like NLSP, the other wino-like.

Simplified Model Scans (again)



For limits on $m(\tilde{g}),m(\tilde{q}) >> m(\tilde{g})$ (and vice versa). $\sigma^{\mathrm{prod}} = \sigma^{\mathrm{NLO-QCD}}$.
$m(\tilde{\chi}^{\pm}),m(\tilde{\chi}^0_2) \equiv \frac{m(\tilde{g})+m(\tilde{\chi}^0)}{2}$.
$m(\tilde{\chi}^0)$ is varied from 0 GeV/c^2 (dark blue) to $m(\tilde{g})-200$ GeV/c^2 (light blue).

Simplified Model Scans (again)

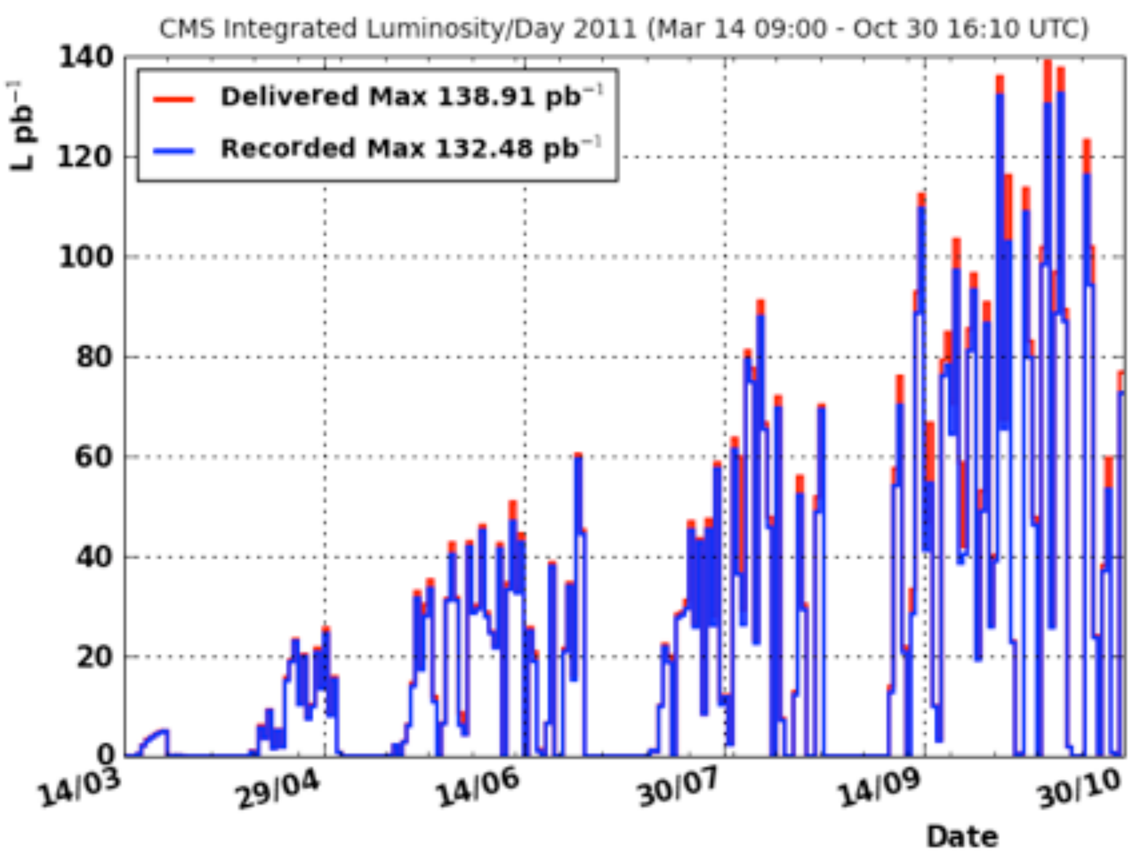


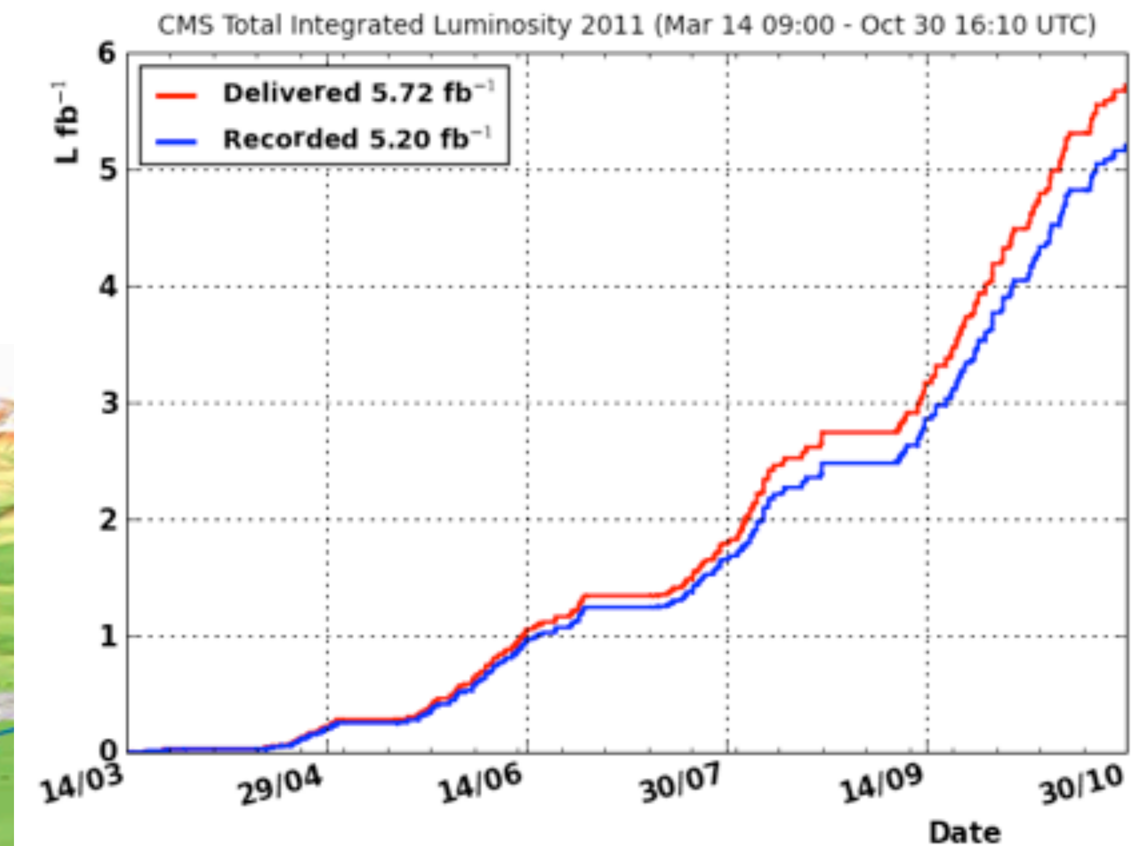
Summary

- CMS has a wide ranging (and growing) SUSY search program!
- SUSY signals expected to have significant jet activity, large missing energy, this has been reflected in search criteria
- Have begun to refine initial "low berries" searches
  - with more sophisticated ways of identifying missing energy
  - more exclusive states (3rd generation) can buy peeks into phase space impossible in the inclusive measurements
- No excesses observed in the early 2011 data, -- limits reaching to 1 TeV
- Only a few more weeks to see what the rest of the 5/fb bring!

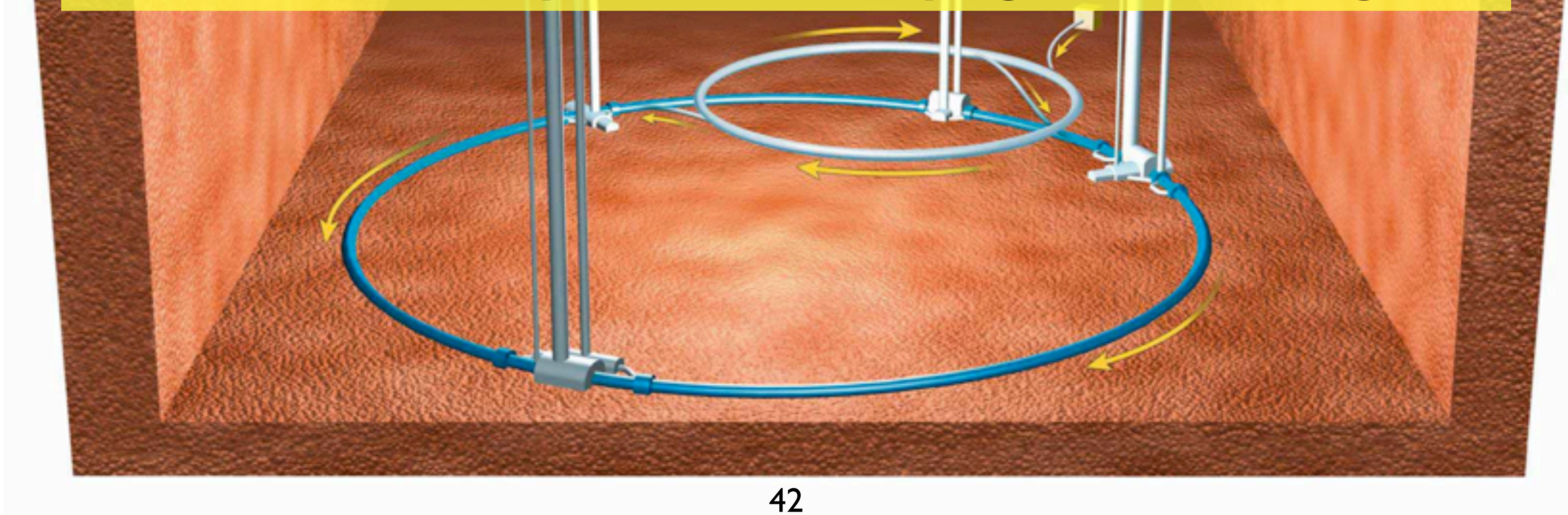
Backups

LHC 2011

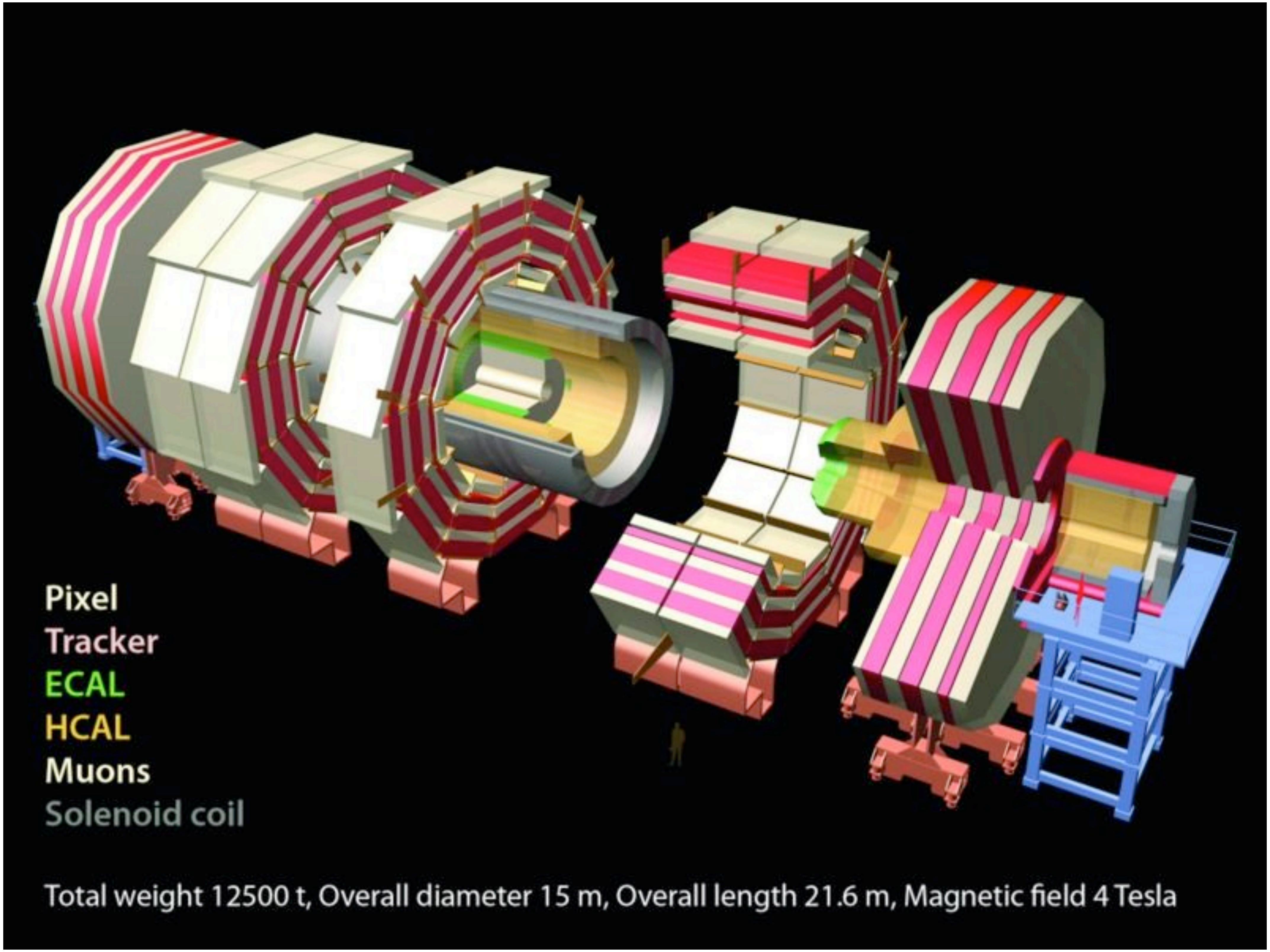




- **This time last year we were hoping for 1/fb. We got 5!**



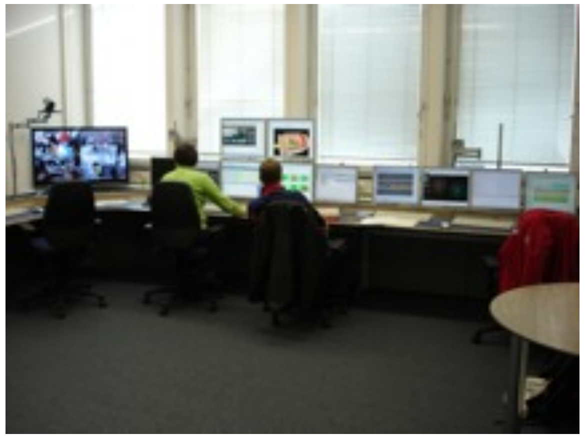
Compact Muon Solenoid



Realtime Computing and DQM

- To minimize the chance that MET results from problems with our detector:
  - Reconstruct the data right away -- a subset in less than an hour from when it was taken, the rest within days
  - While running have an army of shifters, 24/7 & around the world scrutinizing histograms to certify our data is of physics analysis quality



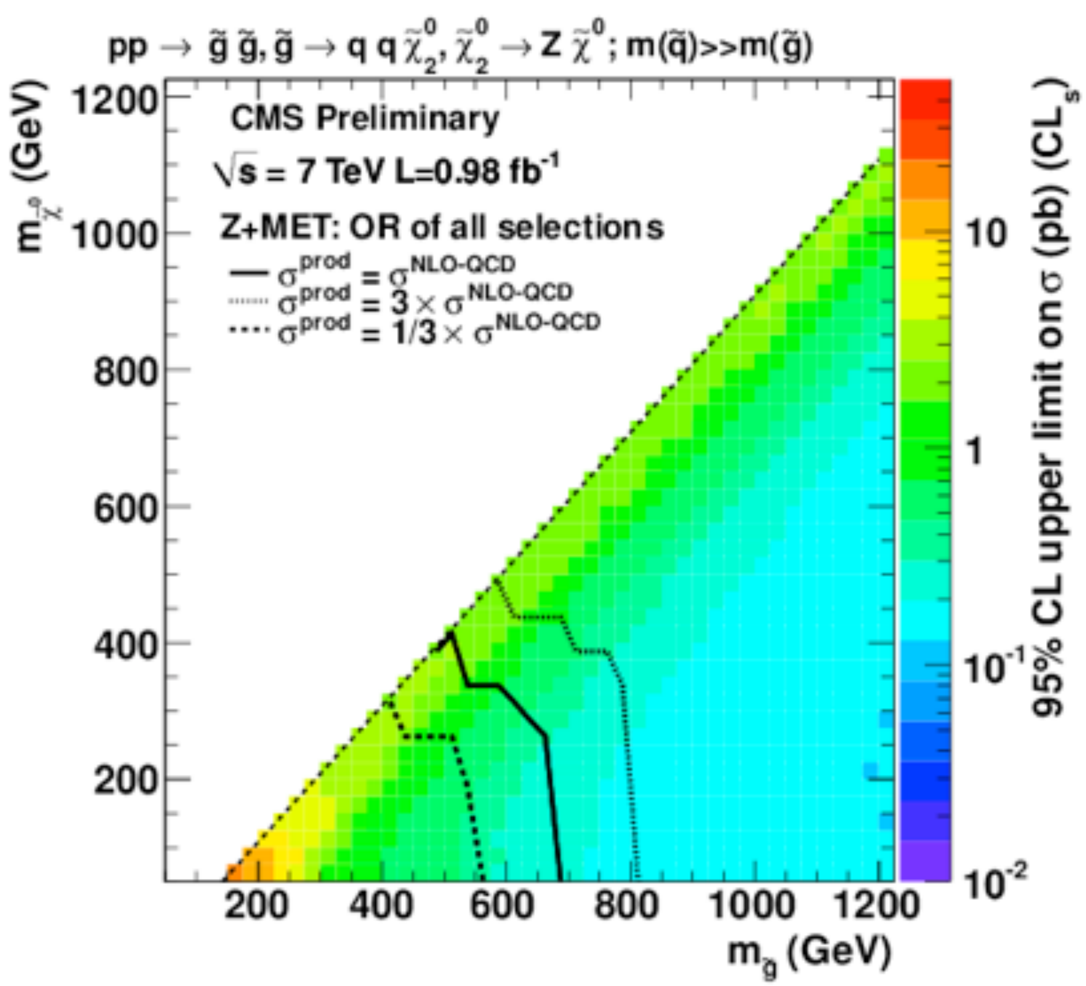



  - Roughly 85% of the data found to be good for physics in 2011

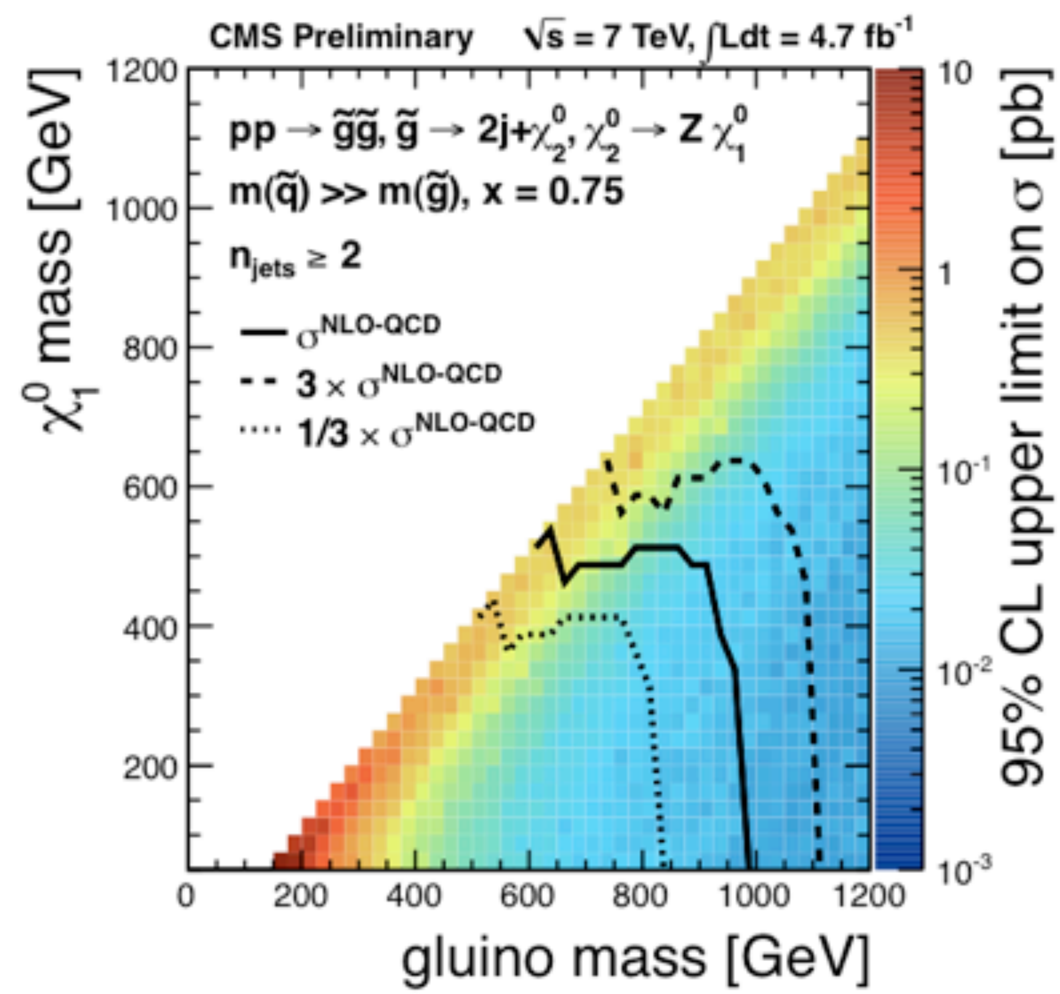
Showing what x5 Lumi does for you

- Quick comparison of summer limit Z + Jets + MET result to now full 2011 dataset:

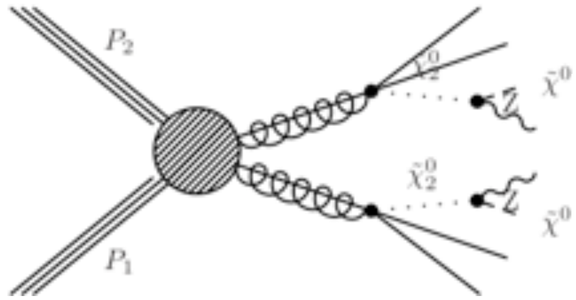
0.98 fb^{-1}



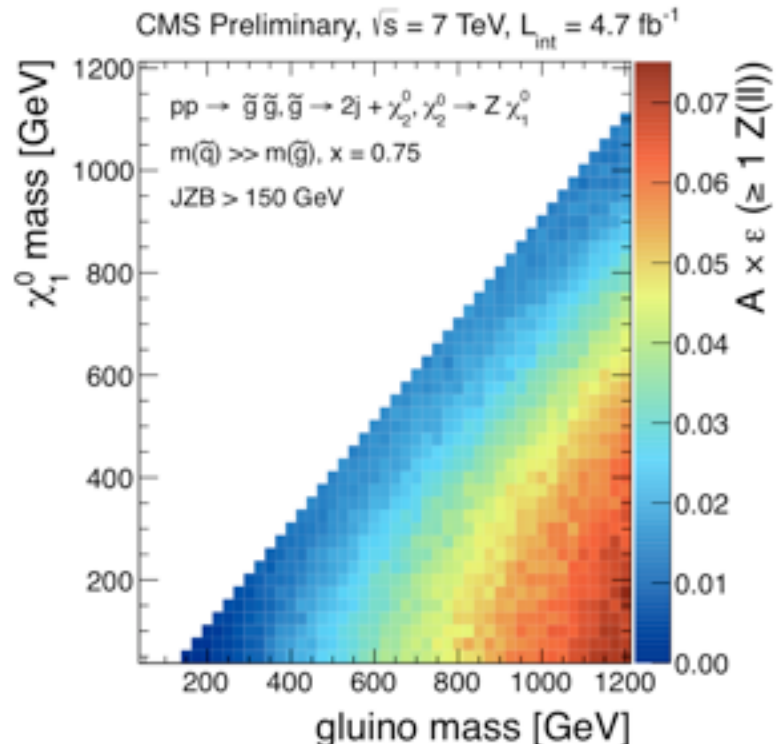
4.7 fb^{-1}

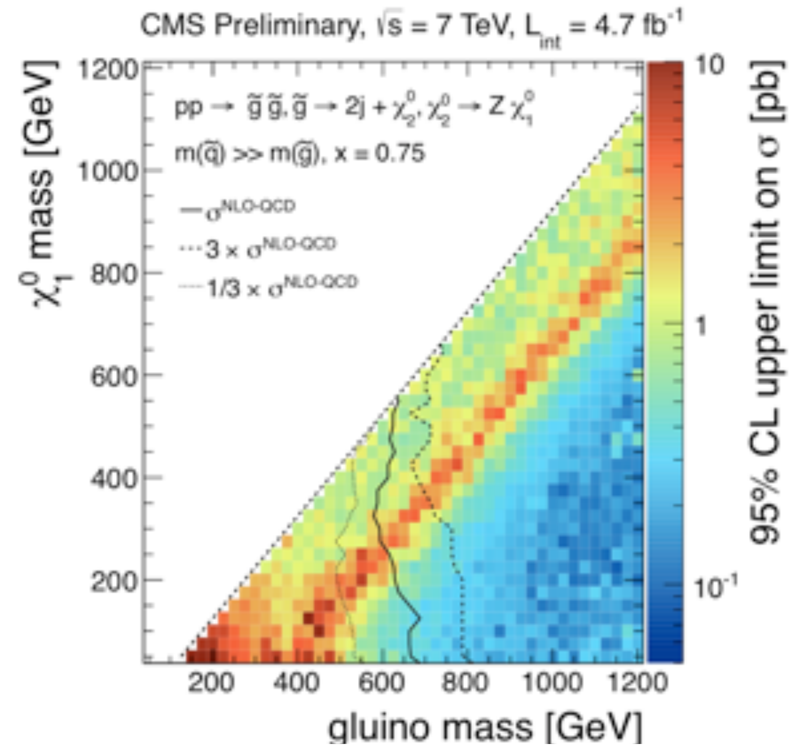


Limits

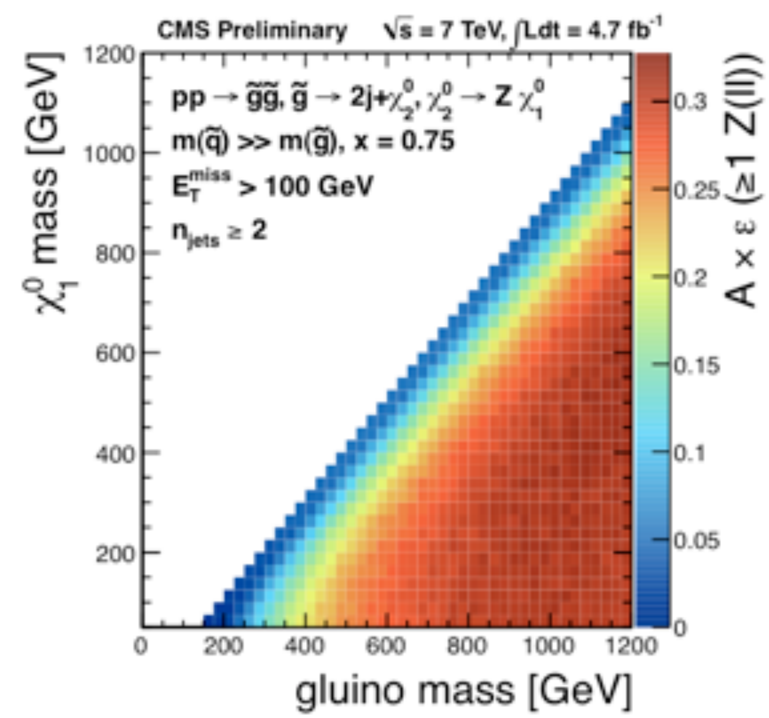


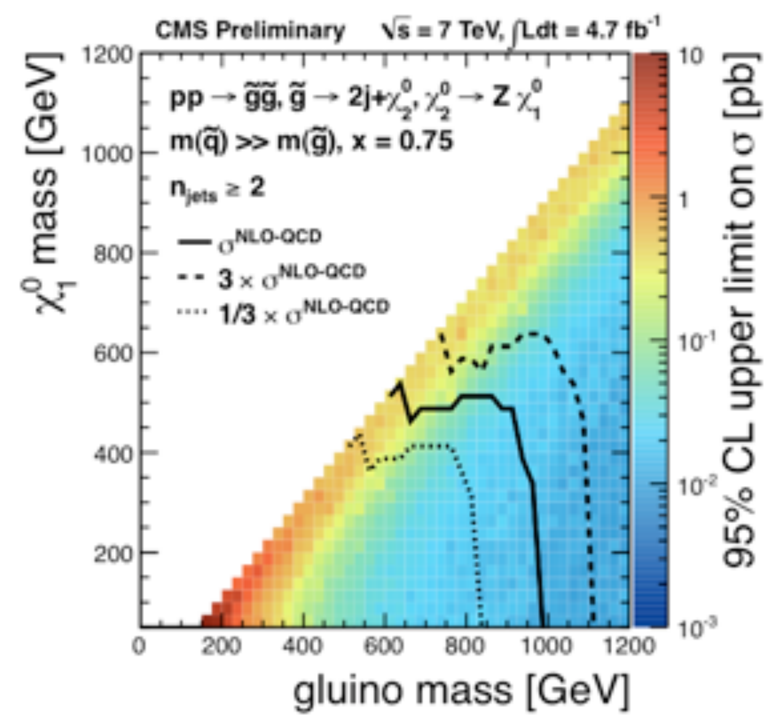
JZB Method





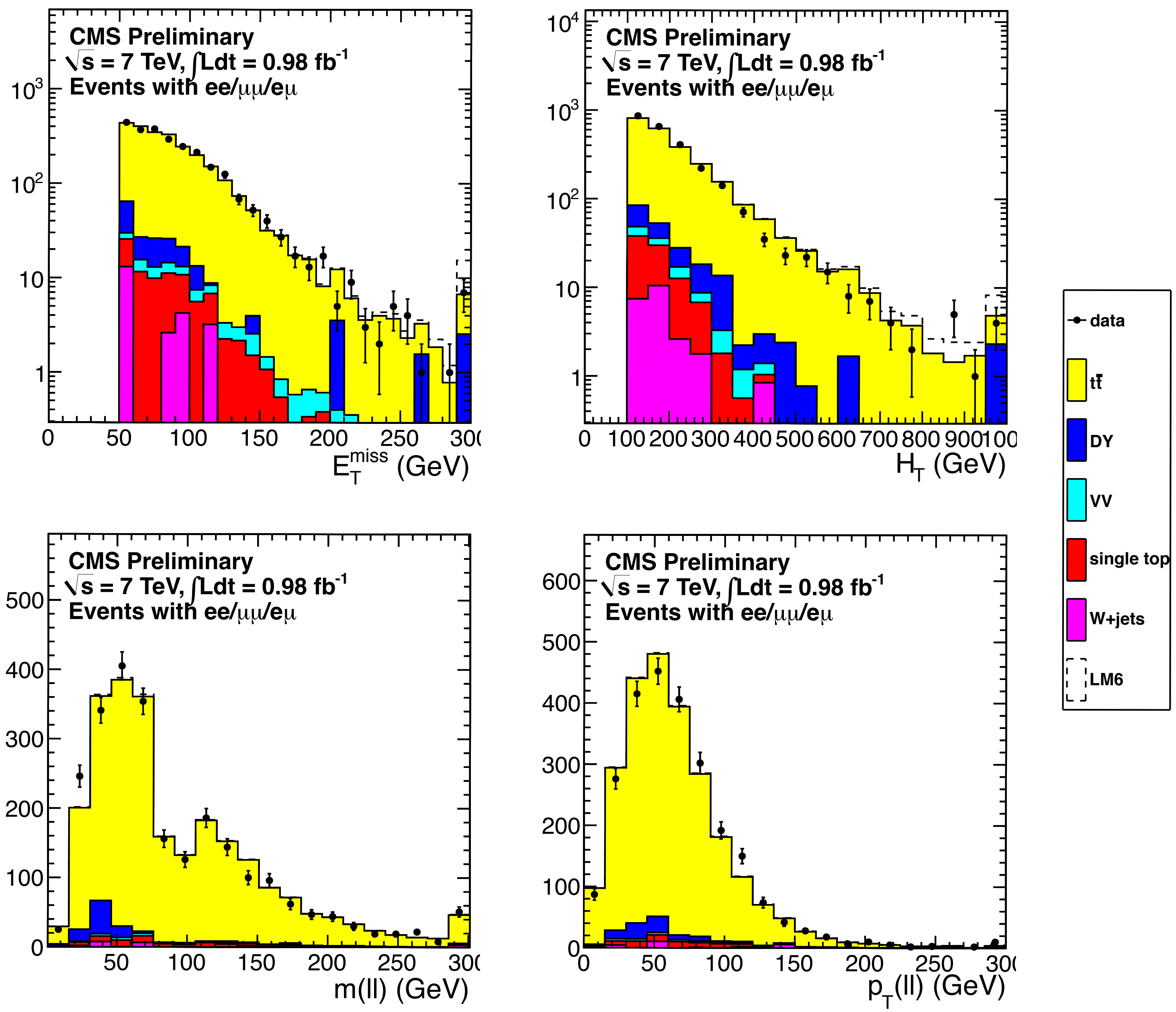
MET Method





M(chi2) = M(LSP) + x (M(glu) – M(LSP))

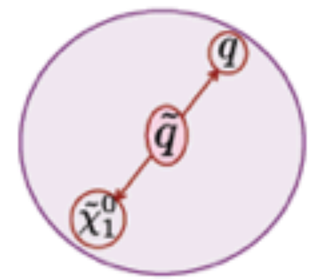
Opposite sign lepton candidates & backgrounds



CMS PAS-SUS-11-008

Search for SUSY using Razor variables ~1 fb^{-1}

- Search for pair production heavy particles
  - squarks and gluinos



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

- Objects grouped into two "megajets"
  - perform event-by-event test that they represent visible portion of decays
- Use two kinematic variables: M_R and R
  - Evaluated in *razor* frame:

    M_R is invariant under this longitudinal boost

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}\,.$$ ← M_R peaks at M_Δ

$$M_T^R \equiv \sqrt{\frac{E\!\!\!/_T(p_T^{j1} + p_T^{j2}) - \vec{E\!\!\!/}_T \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$$ ← M_Δ edge in M_T^R

$$R \equiv \frac{M_T^R}{M_R}$$ ← R is ratio of the two and related to MET