Leptonic SUSY Searches at CMS

Workshop On Interpreting LHC Discoveries
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SUSY? What SUSY?

- Experimentalist view: search for new physics in events with lepton(s) and MET
  - Well motivated by dark matter, SUSY or not
  - CMS categories:
    - New Physics where MET really matters: SUSY
    - Other New Physics: EXOTICA
- Leptonic "SUSY" searches at CMS are <u>signature-based searches</u>
  - Strategies only loosely based on SUSY prejudices
    - <u>**Not**</u> optimized for the CMSSM at all
  - This is likely to change in 2012: we will have more searches targeted to specific final states

One Common Theme

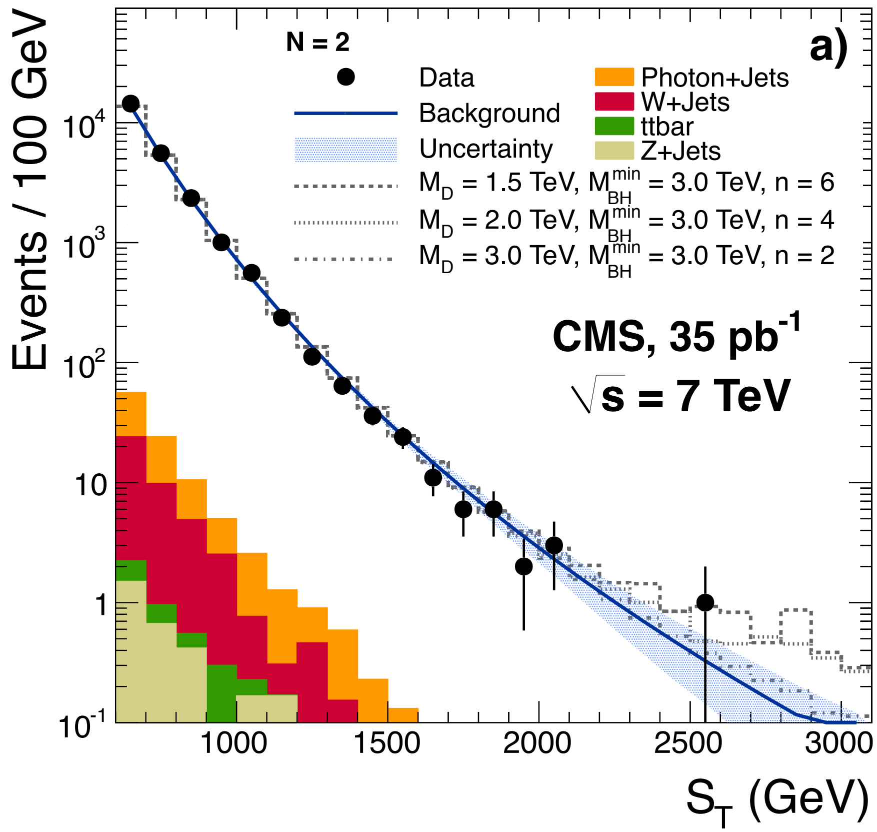
- Initial searches target high cross-section
- High cross-section means strong production
- Strong production means there must be jets in the final state

→ All searches require jets in addition to leptons and MET

- Also generally high H_T
  - Prejudice: New Physics at high mass → high HT
  - High H_T → Less SM background
- This is also likely to change in 2012, eg, EWK-ino searches

It’s the background, stupid!

- All the work goes in estimating the background
- “Instrumental backgrounds”, eg, fake leptons, are clearly data driven.
- CMS has gone to great lengths to minimize reliance on Monte Carlo also for “physics backgrounds”, ie, for tail of SM physics processes



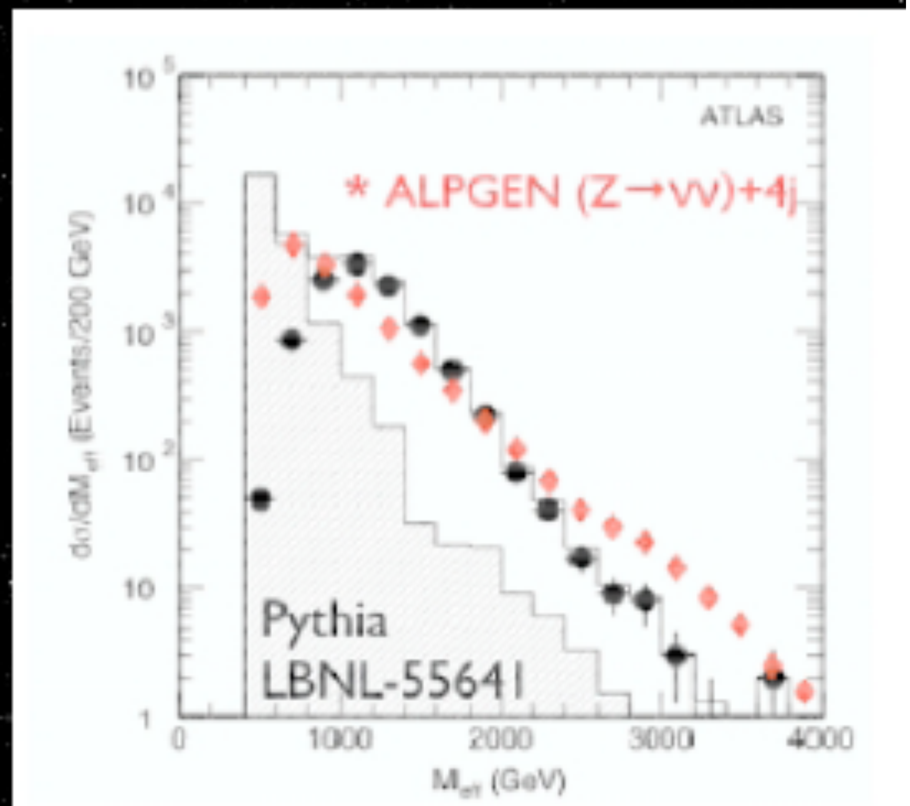
- "Tried and true" background estimation recipe:
  - Check SM MC prediction in a background control region
    - Maybe normalize to the control region
  - Use the SM MC tail prediction with uncertainties
- CMS "SUSY" leptonic analyses rely as little as possible on this procedure.

So what is done instead? Tricks!

- PROs:
  - Less reliance on modeling of SM tails…what if the tool that we use is wrong?
  - A good trick relies on well understood physics arguments
- CONs:
  - Hard
  - Most of these tricks are not perfect
    - Corrections, arguments, …..
  - A trick not well motivated and well understood can be a trap
- Important: does not mean you throw away the SM prediction.

(Extreme) Example

- at LHC, supersymmetry channels have large SM backgrounds from top, Z+jets, and W+jets
- showering Monte Carlos like Isajet and Pythia underestimate these backgrounds by up to a factor of ten in the signal region
- this was forgotten until recently, when better QCD theory tools became available



Multiple techniques

- In CMS a signature is often probed by multiple techniques, multiple overlapping signal regions
- What is then the "bottom line limit" for a given channel?
  - If more than 140 characters, it does not fit in a tweet

- Who cares, that is not the point
  - We want find "something new"
  - We do not know what the "something new" is
  - We must search broadly
  - Limit setting is not the goal
    - But it can be done anyway
    - Efficient communication of the information on what it is that we did not find is important
      - Some comments at the end of the talk

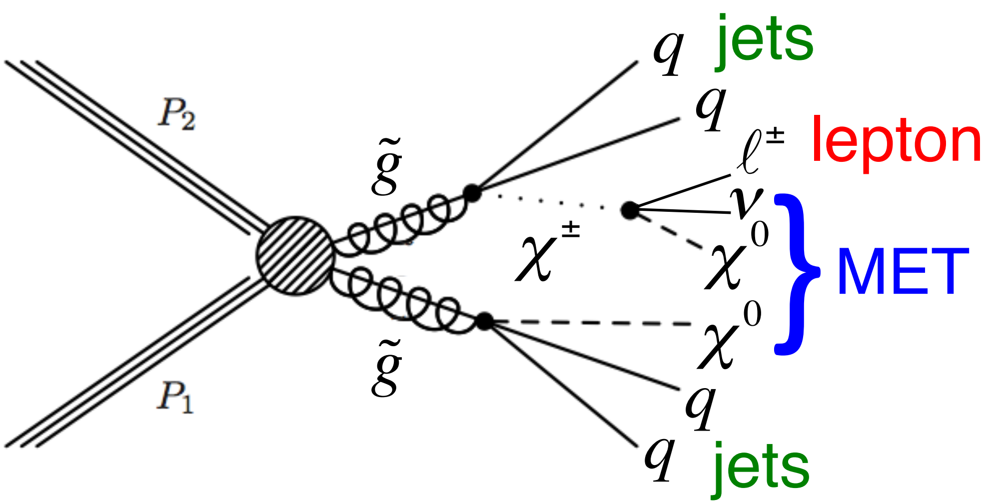
CMS "SUSY" searches

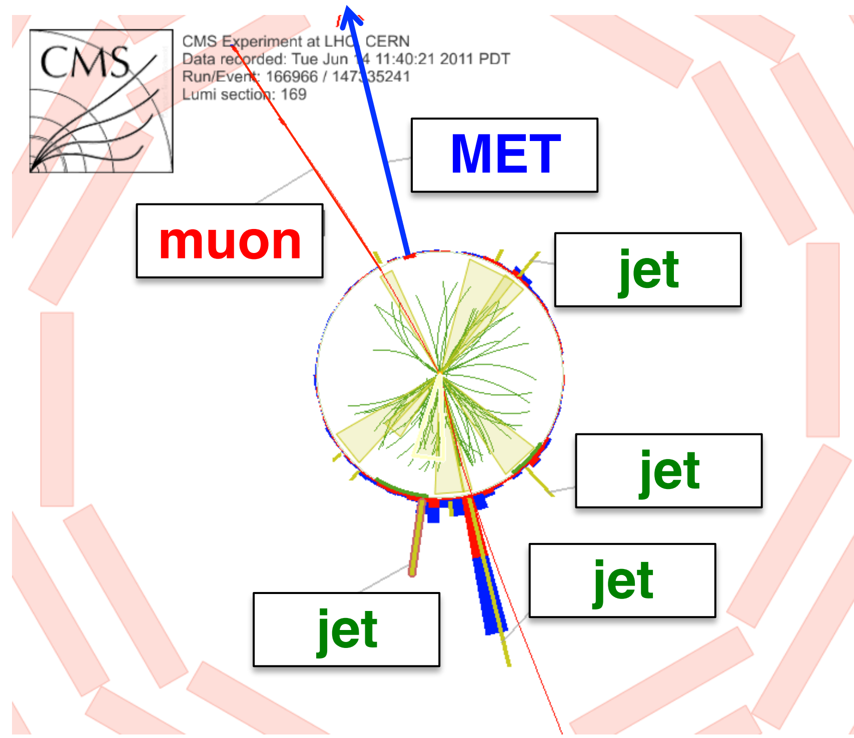
Channel	Signature	Documentation	Lumi
all-hadronic	inclusive jets+MHT	SUS-11-004	1.1 fb^{-1}
(0-leptons)	$\alpha_T + H_T$	arXiv:1109.2532	1.1 fb^{-1}
	MT2	SUS-11-005	1.1 fb^{-1}
	razor	arXiv:1107.1279	35 pb^{-1}
	b-jets + MET	SUS-11-006	1.1 fb^{-1}
single lepton	e/μ + jets + MET	SUS-11-015	1.1 fb^{-1}
di-lepton	opposite-sign (no Z)	SUS-11-011	0.98 fb^{-1}
	Z + (MET templates)	SUS-11-017	0.98 fb^{-1}
	Z + (JZB)	SUS-11-012	0.19 fb^{-1}
	same-sign	SUS-11-013	2.1 fb^{-1}
mullti-lepton	≥3 leptons	SUS-11-013	35 pb^{-1}
lepton+photon	e/μ + γ + MET	arXiv:1105.3152	35 pb^{-1}
photons	γ/γγ + jets + MET	SUS-11-009	1.1 fb^{-1}
long-lived	displaced fermions	EXO-11-004	1.1 fb^{-1}
particles	stopped gluinos	EXO-11-020	0.89 fb^{-1}
	R-hadrons	EXO-11-022	1.1 fb^{-1}

- Signatures with taus not well explored
- b-content (with <u>or</u> without) of lept. signatures not explored at all
- This is will improve in the future

Single Lepton Search

example signal:
SUSY with χ± decay





- Require isolated lepton ➞ suppress QCD
- **Signature: single lepton (e/μ) + jets + MET**
- Challenge: estimating "tails" of ttbar/W+jets MET, H_T distributions

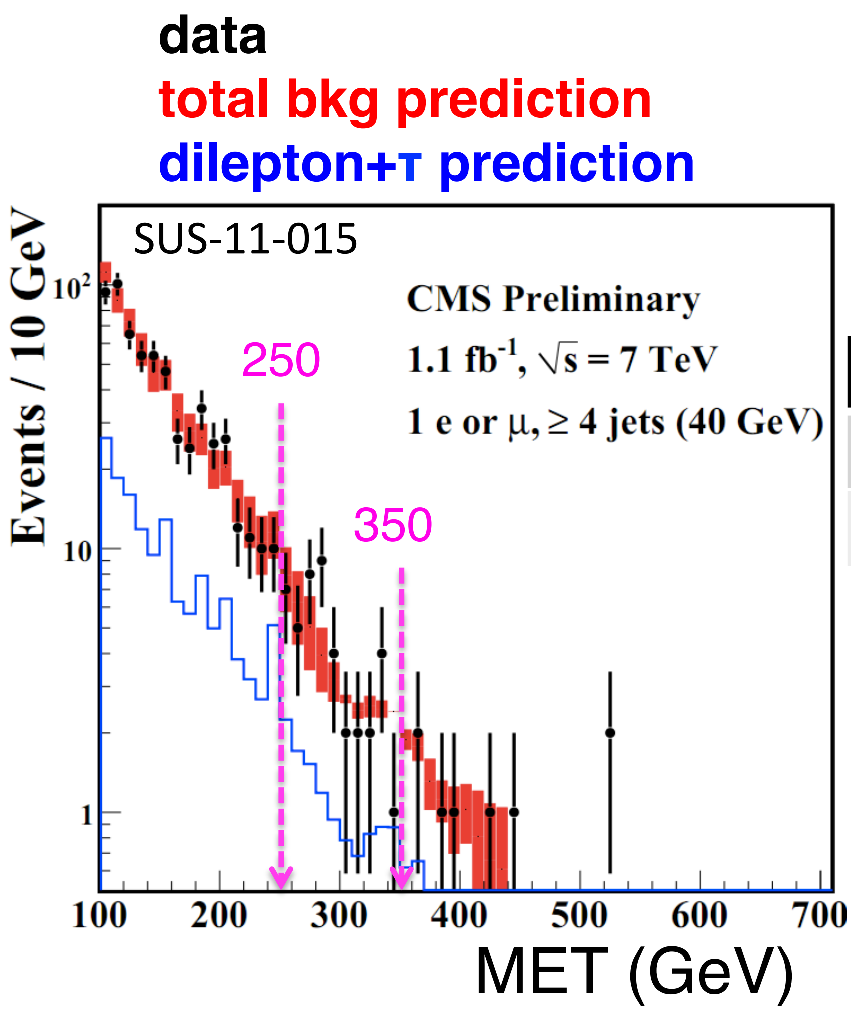
Single leptons: backgrounds

- W+jets and tt➞ℓ+jets (~75%)
  - **Challenge**: dominant bkg, don't want to rely solely on MC for tails of initial state radiation, large top boost
  - **Two tricks (see following)**
- tt➞ℓ⁺ℓ⁻ (~15%)
  - With lost lepton (not reconstructed/isolated, outside acceptance)
  - Estimate using dilepton data control sample, scale by probability to lose lepton
- W+jets/ttbar with W➞ τ ➞ e/μ decays (~10%)
  - Estimate using μ+jets data control sample, replace μ with expected τ response
- QCD bkg (~1%)
  - Small ➞ verify using data-driven technique, 2D extrapolation isolation vs. MET
- Other backgrounds (~1%)
  - DY, single top ➞ small, obtained from MC

Single lepton: first trick

- Signal: high MET
- In W+jets and $t\bar{t} \rightarrow \ell$+jets MET comes from ν in $W \rightarrow \ell\nu$
- Assumption: P_T spectrum of ν and ℓ are the same
- Not totally true, <u>need corrections</u>
  - ℓ can only be reconstructed in $|\eta|<2.4$
  - ν resolution, scale, not the same as ℓ
  - W-polarization introduces a difference in the P_T spectra in lab frame (<u>dominant effect</u>)

Can then use lepton P_T spectrum after full selection (no. of jets, HT, etc) to <u>predict</u> MET spectrum <u>without</u> using tt/W+jets MC



2 signal regions (defined a priori)

4 jets, HT>500 GEV

MET > 250 GeV (loose)

MET > 350 GeV (tight)

	MET > 250 GeV	MET > 350 GeV
predicted	49.8 ± 8.8 ± 10.8	12.1 ± 4.3 ± 3.6
observed	52	8

<u>**No excess.**</u>

Caveat: any NP with lept. spectrum = to MET spectrum would be calibrated away

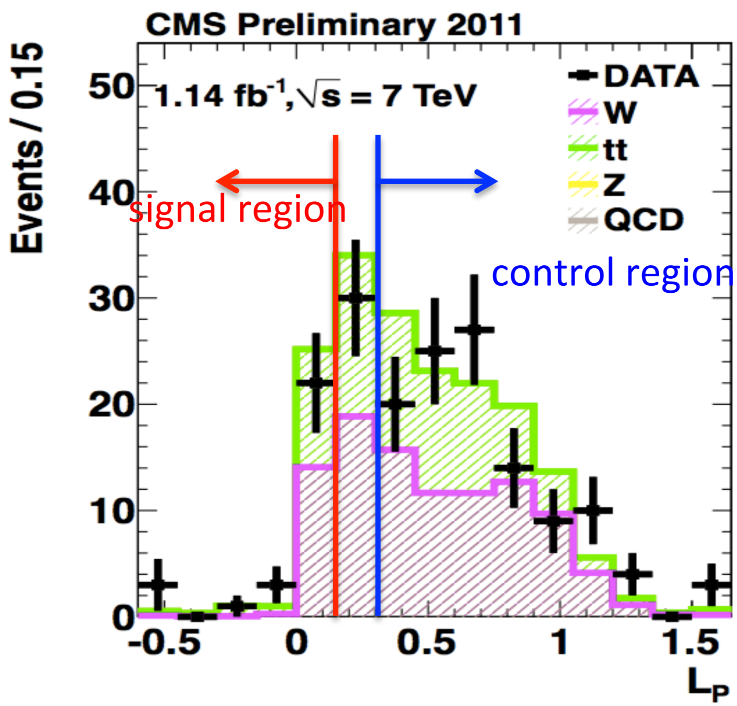
Single lepton: second trick

$$\mathrm{L_P} = \frac{\vec{p}_{\mathrm{T}}(\ell) \cdot \vec{p}_{\mathrm{T}}(\mathrm{W})}{|\vec{p}_{\mathrm{T}}(\mathrm{W})|^2}$$

- L_P tends to be small for SUSY and large for ttbar and Wjets
- L_P is related to the decay angle of the W in ttbar and Wjets. The decay angle depends on the W polarization, which is well known.

  → L_P is under control for SM

μ-channel, S_T^{lep} 250-350 GeV



- Analysis is performed by looking at L_P in bins of $S_T^{lep} = P_T(\ell) + MET$
- A signal would show up ay low L_P and high S_T^{lep}

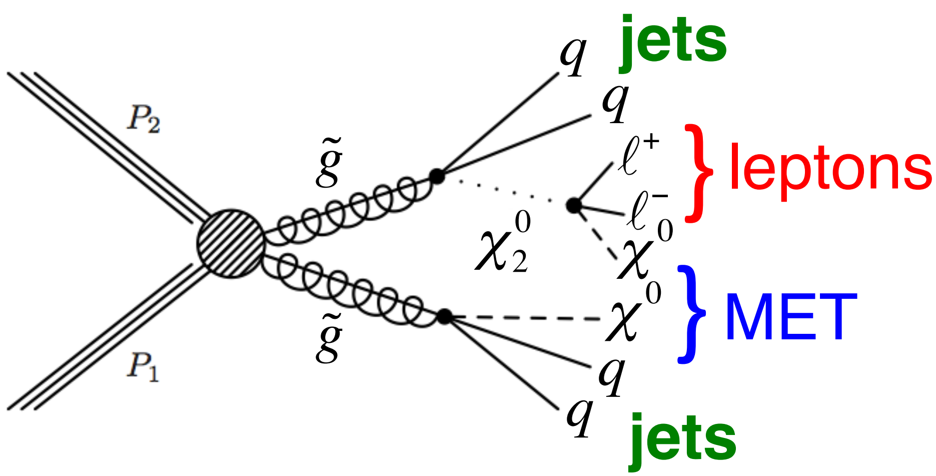
signal region: ≥3 jets + $H_T > 500$ GeV, 4 bins $S_T^{lep} = p_T(l) + MET$

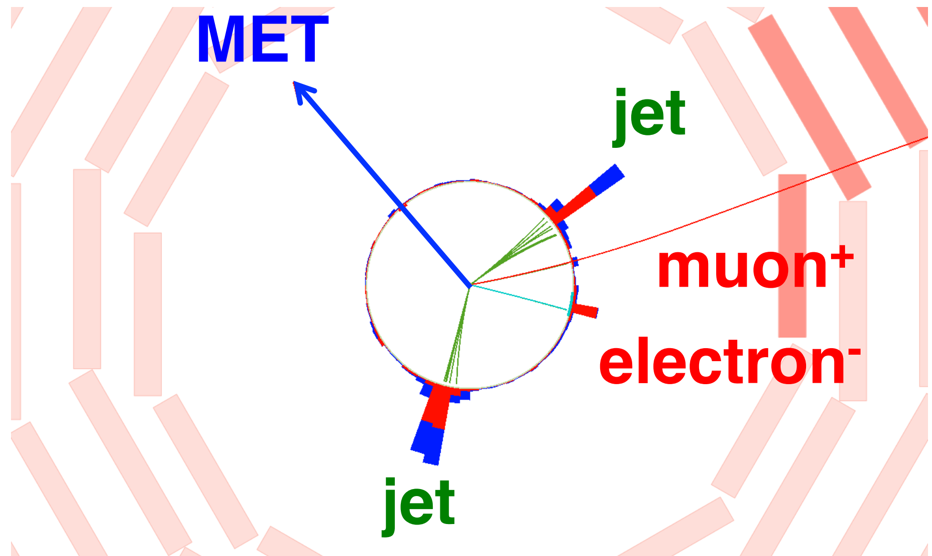
	Control Region (L_P >0.3)		Signal Region (L_P <0.15)		
S_T^{lep} Range (GeV)	Total MC	Data	Total MC	SM estimate	Data
[150-250]	385±7	368	73.9±3.0	70.6±11	84
[250-350]	116±2	112	28.1±1.1	27.2±4.6	29
[350-450]	43.4±2.	41	11.5±0.7	10.9± 2.3	9
> 450	18.4±0.8	15	6.5±0.4	5.3± 1.8	6

No excess

Opposite sign di-leptons (not from Z)

example signal:
SUSY with $\chi_2^0 \rightarrow \ell^+ \ell^- \chi^0$ decay



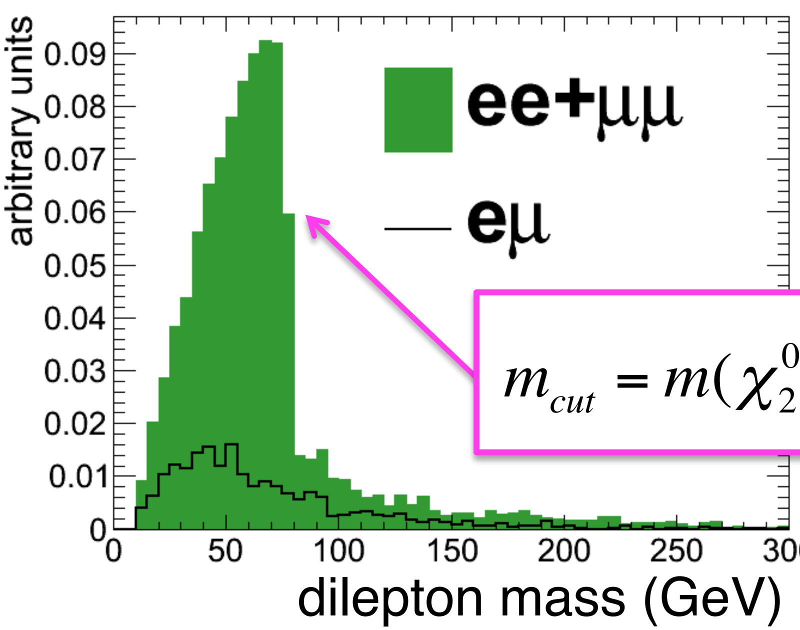


- **Signature: opposite-sign (OS) leptons (ee/eμ/eμ) + jets + MET**
- Search for "kinematic edge" in dilepton mass distribution
- Perform counting experiment in high MET vs. H_T signal region

OS Edge search

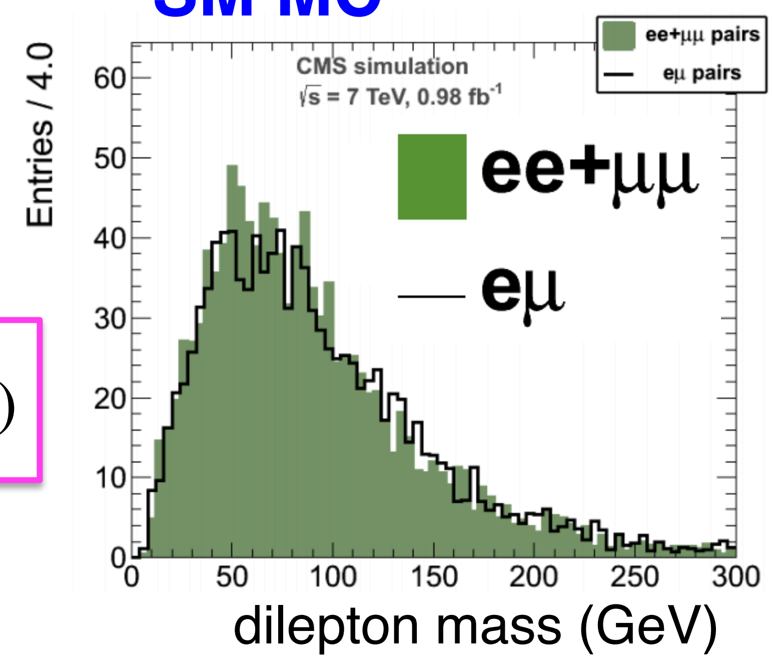
- $\chi_2^0 \rightarrow \ell^+\ell^-\chi_1^0$ kinematic endpoint produces "edge" in ee+μμ dilepton mass distribution
  - Potential "smoking gun" for new physics observation
  - Relax cuts, exploit shape info ➞ complementary to high MET, H_T searches
  - **Edge position (m_{cut})** ➞ precise measurement related to SUSY particle masses
- SM background: same yield/shape in opposite-flavor (eμ) vs. same-flavor (ee+μμ)
- **Search for edge in ee+μμ dilepton mass, take bkg shape from eμ sample**

SUSY with $\chi_2^0 \rightarrow \chi_1^0 \ell^+\ell^-$

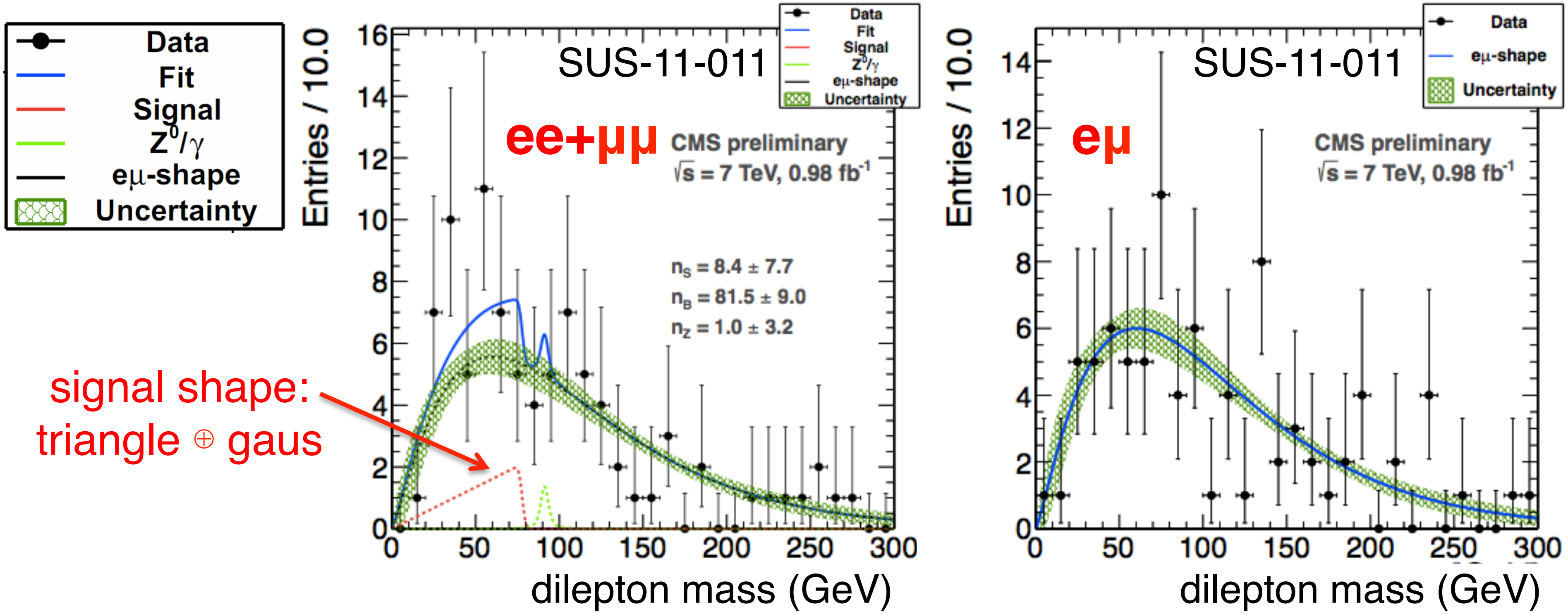


$$m_{cut} = m(\chi_2^0) - m(\chi_1^0)$$

SM MC



Edge search results (1.1/fb)



- **No edge observed** → extract signal yield UL using maximum likelihood fit
- Signal shape depends on 1 parameter only (edge position m_{cut}) → scan m_{cut} and extract signal yield, and upper limit, at each point
  - Signal yield consistent with 0 within ~2σ over full m_{cut} range (backup)
  - Example fit shown: m_{cut} ~ 80 GeV

OS counting experiment in tails of SM (1.1/fb)

Two leptons, PT>20,10 GeV, two jets (Pt>30 GeV)

Sample	σ [pb]	ee	$\mu\mu$	$e\mu$	total
$t\bar{t} \to \ell^+\ell^-$	17	412.8 ± 8.9	465.4 ± 9.0	1095.6 ± 14.2	$\boxed{1973.8 \pm 19.0}$
$t\bar{t} \to$ fake	141	12.6 ± 1.6	3.7 ± 0.8	22.7 ± 2.0	39.0 ± 2.7
DY$\to \ell^+\ell^-$	16677	18.6 ± 5.0	26.6 ± 6.0	37.6 ± 7.1	82.8 ± 10.6
W^+W^-	43	4.0 ± 0.5	4.3 ± 0.4	9.5 ± 0.7	17.7 ± 0.9
$W^\pm Z^0$	18	0.8 ± 0.1	1.0 ± 0.1	1.9 ± 0.1	3.8 ± 0.2
Z^0Z^0	5.9	0.3 ± 0.0	0.4 ± 0.0	0.4 ± 0.0	1.2 ± 0.1
single top	102	12.6 ± 0.6	14.0 ± 0.6	33.2 ± 1.0	59.9 ± 1.3
$W + $jets	96648	12.6 ± 5.4	0.0 ± 0.0	7.8 ± 4.6	20.5 ± 7.1
total SM MC		474.5 ± 11.7	515.4 ± 10.8	1208.6 ± 16.7	2198.5 ± 23.1
data		524	576	1381	2481
LM1	6.7	62.3 ± 1.6	69.5 ± 1.6	35.8 ± 1.2	167.5 ± 2.6
LM3	5.3	22.1 ± 0.8	26.9 ± 0.9	39.7 ± 1.1	88.6 ± 1.7
LM6	0.5	4.5 ± 0.1	5.0 ± 0.1	5.7 ± 0.1	15.3 ± 0.2

Sample is mostly ttbar

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Plausible SUSY signals are small compared to SM → search in the tails

OS counting experiment in tails of SM (1.1/fb)

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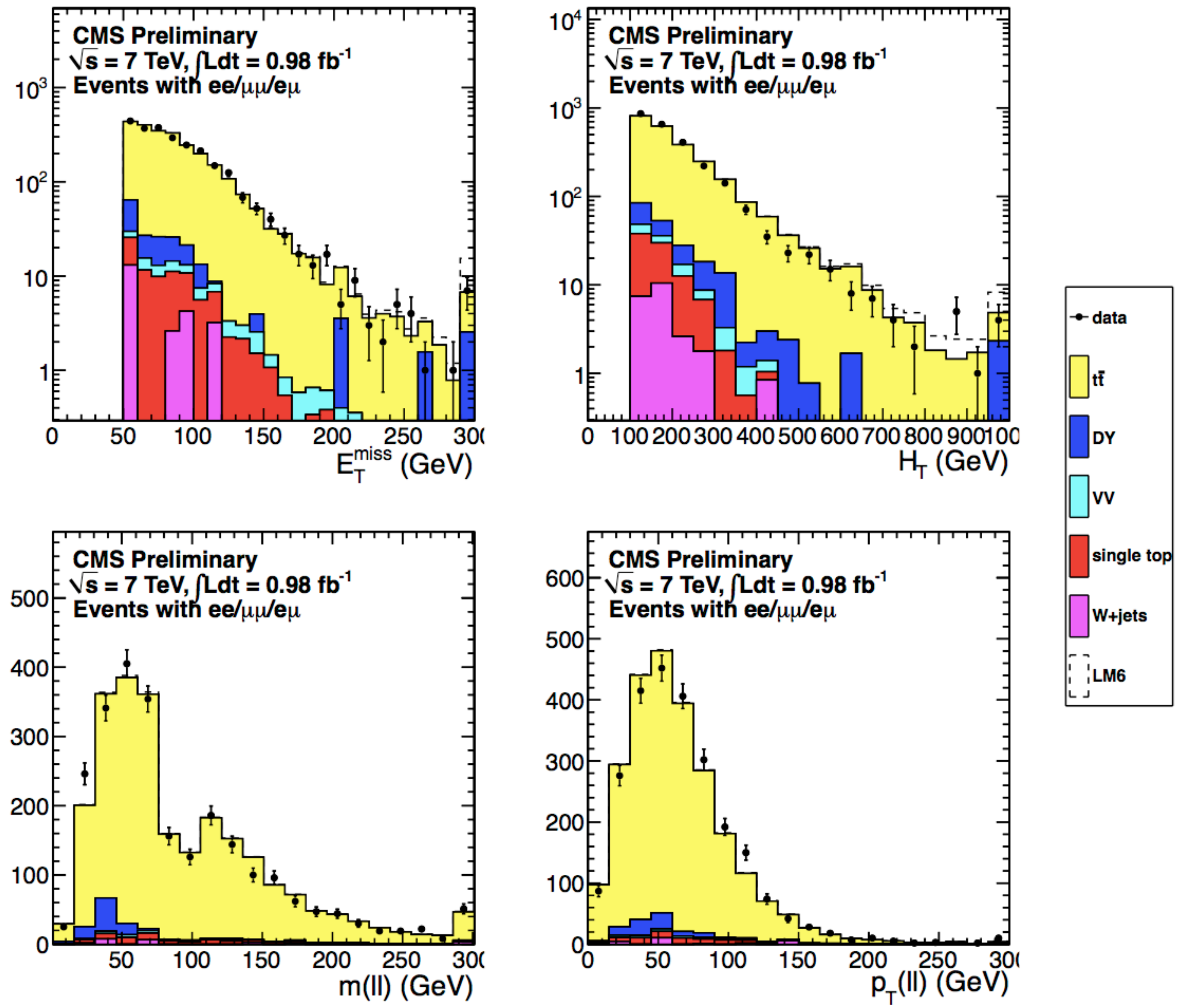
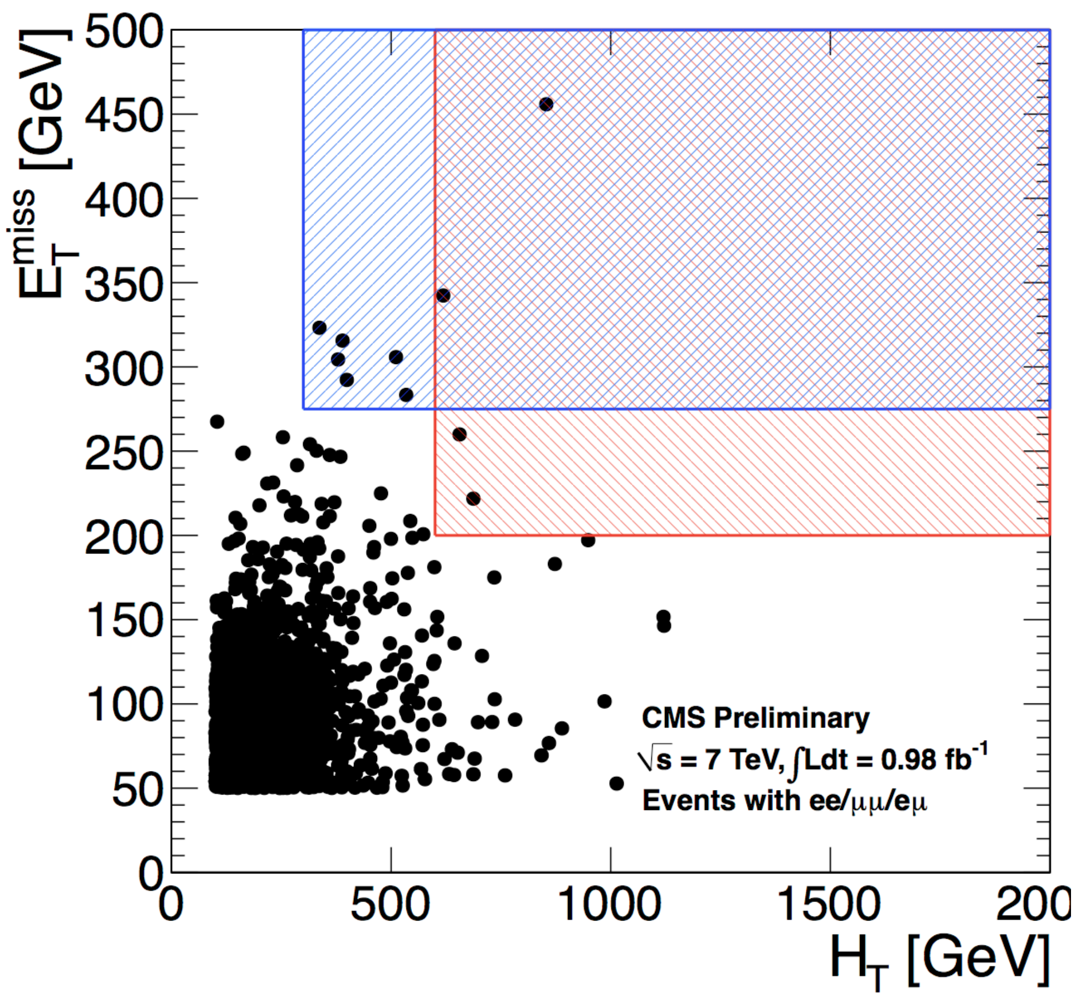
Many SUSY signals have more SameFlavor than OppositeFlavor pairs



Nothing too exciting in kinematical distributions

Counting experiment in tails of SM



- Define two signal regions in tails of HT and MET
- Tail = were expect "a few" SM events
- Counting experiment
- Compare OF vs SF yield

Tricks for counting experiment

1. Same P_T (ℓ) ≅ $P_T(\nu)$ method used in single lepton analysis
2. Extrapolate from low MET, low HT region under the assumption that HT and MET/sqrt(HT) are (almost) uncorrelated
   – This is an empirical observation in ttbar MC validated in bulk of ttbar data

Summary of counting expt results

	high E_T^{miss} signal region	high H_T signal region
observed yield	8	4
MC prediction	7.3 ± 2.2	7.1 ± 2.2
ABCD′ prediction	4.0 ± 1.0 (stat) ± 0.8 (syst)	4.5 ± 1.6 (stat) ± 0.9 (syst)
$p_T(\ell\ell)$ prediction	14.3 ± 6.3 (stat) ± 5.3 (syst)	10.1 ± 4.2 (stat) ± 3.5 (syst)
N_{bkg}	4.2 ± 1.3	5.1 ± 1.7
non-SM yield UL	10	5.3
LM1	49 ± 11	38 ± 12
LM3	18 ± 5.0	19 ± 6.2
LM6	8.1 ± 1.0	7.4 ± 1.2

Data yield agrees with MC prediction as well as the two data driven methods

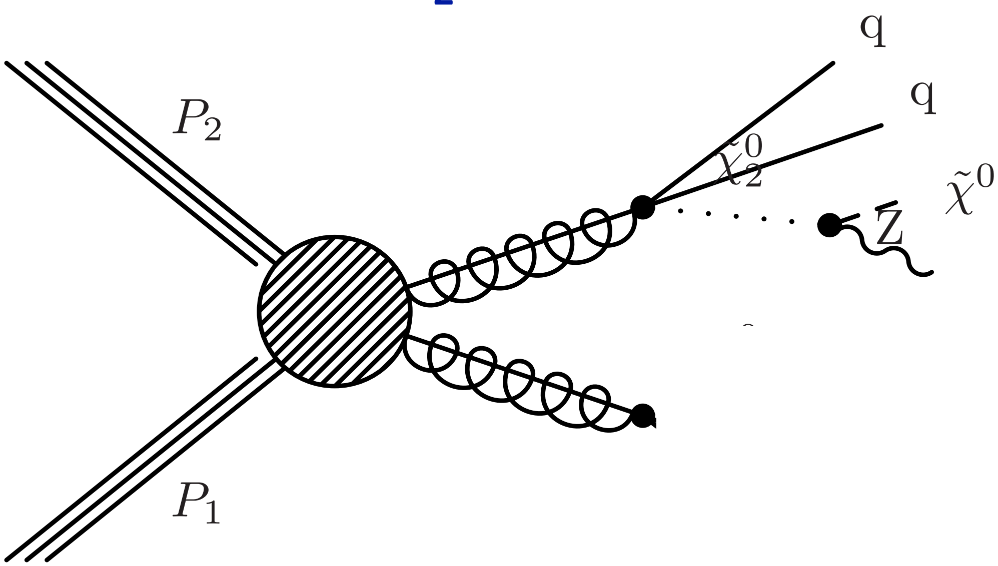
	high E_T^{miss} signal region	high H_T signal region
observed Δ	3.6 ± 2.9 (stat) ± 0.4 (syst)	-0.9 ± 1.8 (stat) ± 1.1 (syst)
UL	7.9	3.6
LM1	27 ± 6.0	24 ± 7.6
LM3	3.2 ± 0.9	3.3 ± 1.1
LM6	2.0 ± 0.2	1.9 ± 0.3

Δ = efficiency corrected excess of SF events over OF events

No excess of SF events as would be expected in some SUSY models

Opposite sign Z+MET

example signal:
SUSY with $\chi^0_2 \rightarrow Z\ \chi^0$ decay

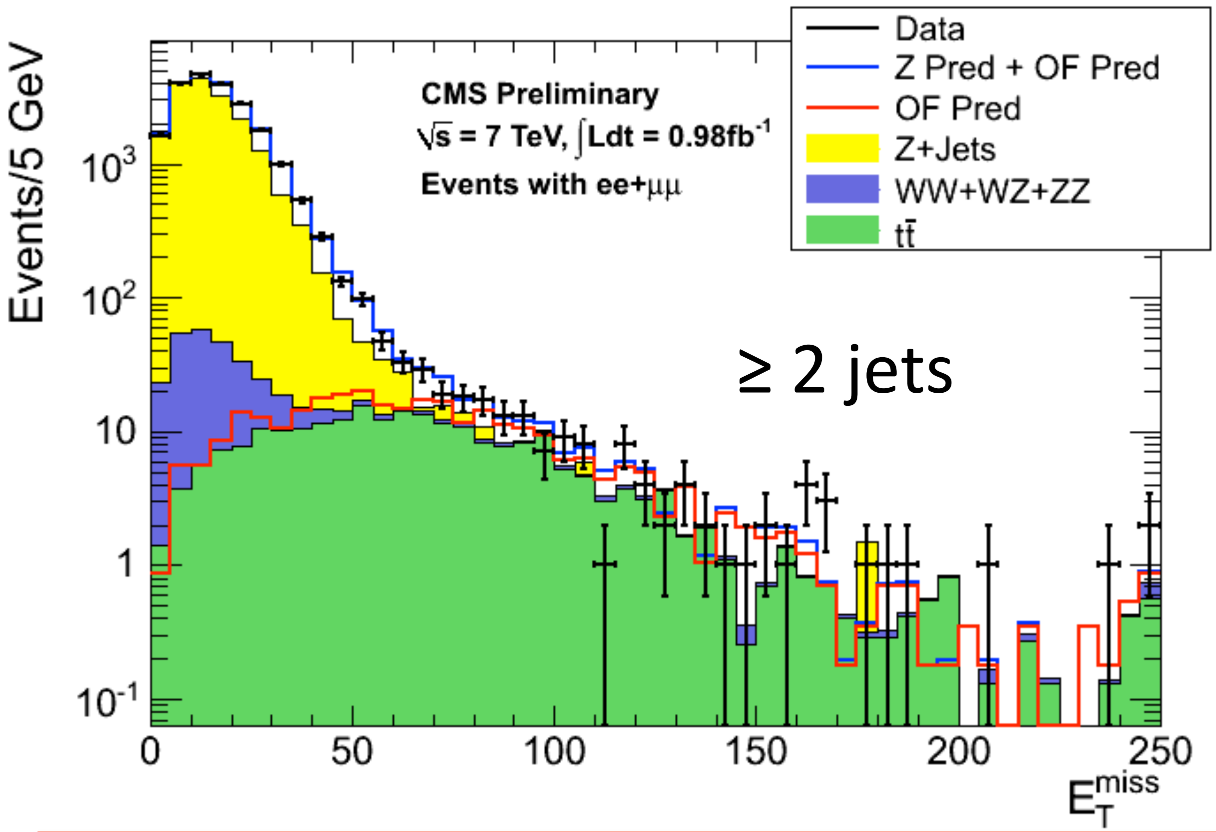


- **Signature: Z + jets + MET**
- **Backgrounds**
  - **Instrumental MET in pp→Z+jets**
    - **Data driven**
  - **tt→ e^+e^- or $\mu^+\mu^-$ where the dilepton mass is consistent with the Z**
    - **From MC or (better) fro eμ sample**

Two data driven methods for Z+jets

1. "Template" method
   - Use measured MET distributions in γ+jets and multijet events as a function of HT, N_{jets}, … to obtain a predicted MET distribution in the Z+jets sample
2. $JZB = \Sigma(p_T^i(jet)) - p_T(Z)$ method
   - Signal: large positive JZB
   - Z+jets background: symmetric (+ve or –ve) JZB
     - Use –ve JZB events to subtract off Z+jets in signal region

Z + Met template results

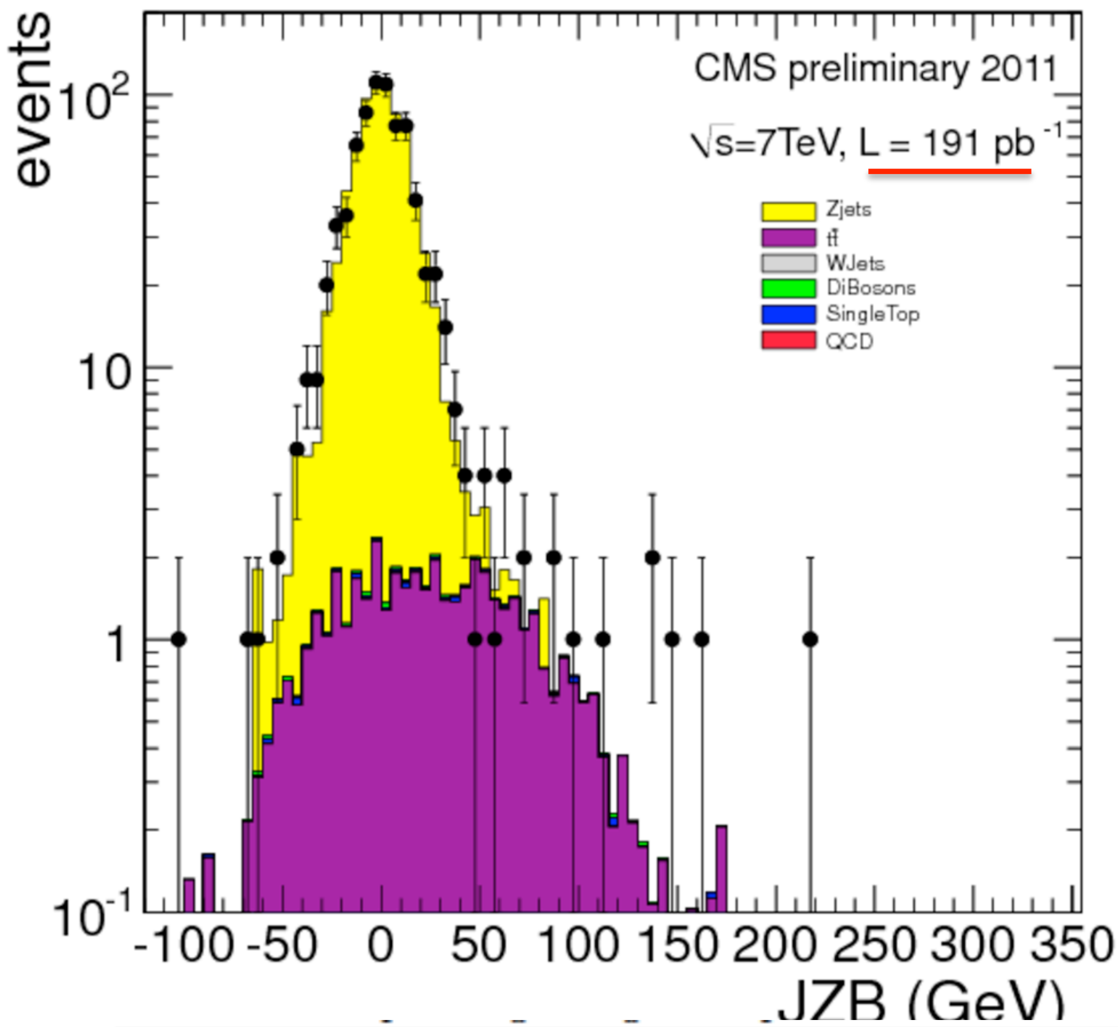


No excess of events

Note that at high MET the Z+jets BG becomes ~ irrelevant

	$E_T^{miss} > 30$ GeV	$E_T^{miss} > 60$ GeV	$E_T^{miss} > 100$ GeV	$E_T^{miss} > 200$ GeV
Z Pred	$2060.3 \pm 29.1 \pm 309.1$	$60.8 \pm 4.1 \pm 9.1$	$5.1 \pm 1.0 \pm 0.8$	$0.09 \pm 0.04 \pm 0.01$
$t\bar{t}$ Pred	$246.6 \pm 6.3 \pm 22.2$	$152.5 \pm 4.9 \pm 13.7$	$50.6 \pm 2.8 \pm 4.6$	$3.2 \pm 0.7 \pm 0.3$
Prediction	$2306.9 \pm 29.7 \pm 309.9$	$213.0 \pm 6.4 \pm 16.5$	$55.7 \pm 3.0 \pm 4.6$	$3.3 \pm 0.7 \pm 0.3$
Data	**2287 (1145,1142)**	**206 (114,92)**	**57 (25,32)**	**4 (1,3)**
UL	498	37	20	5.9
LM4	25.4 ± 1.9	22.9 ± 1.8	20.1 ± 1.7	12.3 ± 1.7
LM8	11.8 ± 0.9	10.7 ± 0.8	8.7 ± 0.8	5.0 ± 0.7

JZB results

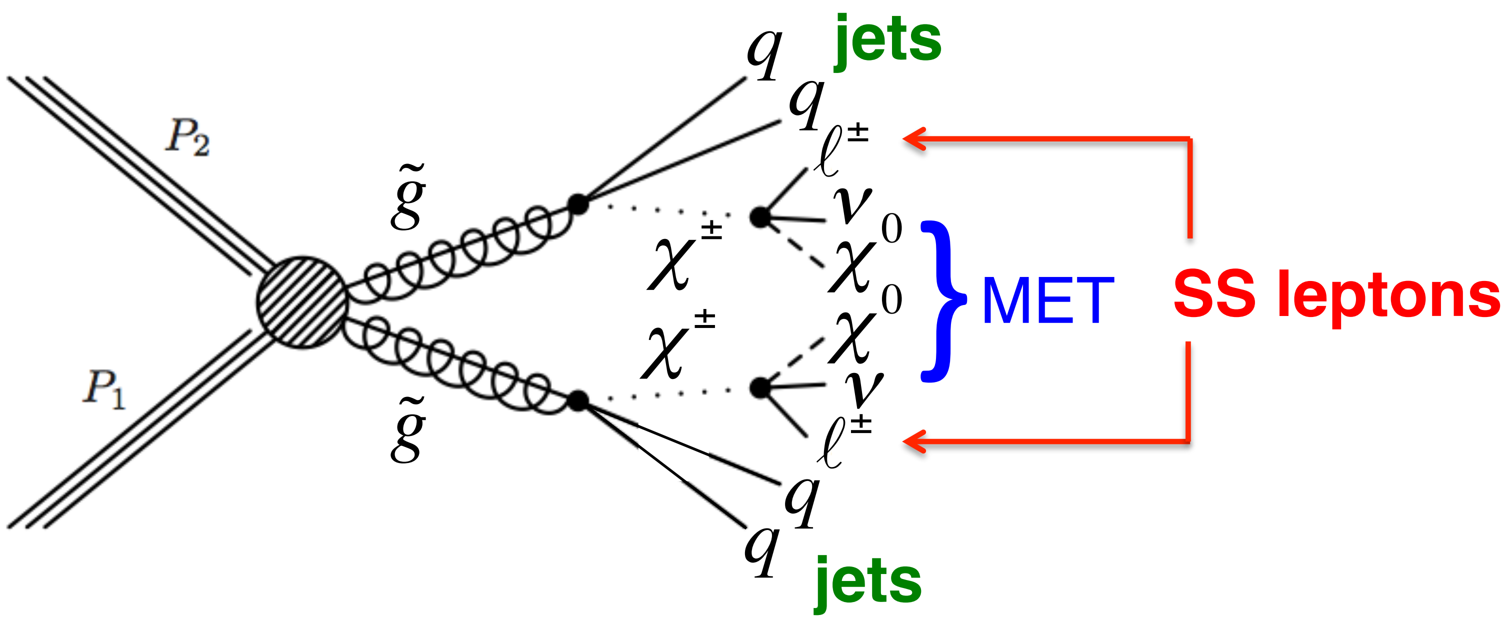


No excess of events

Region	Observed events	Background prediction	MC expectation
$JZB > 50\,\mathrm{GeV}$	20	$24 \pm 6(\mathrm{stat}) \pm 1.4(\mathrm{peak})^{+1.2}_{-2.4}(\mathrm{sys})$	16.0 ± 1.2 (MC stat)
$JZB > 100\,\mathrm{GeV}$	6	$8 \pm 4(\mathrm{stat}) \pm 0.1(\mathrm{peak})^{+0.4}_{-0.8}(\mathrm{sys})$	3.6 ± 0.4 (MC stat)

Same Sign Dileptons

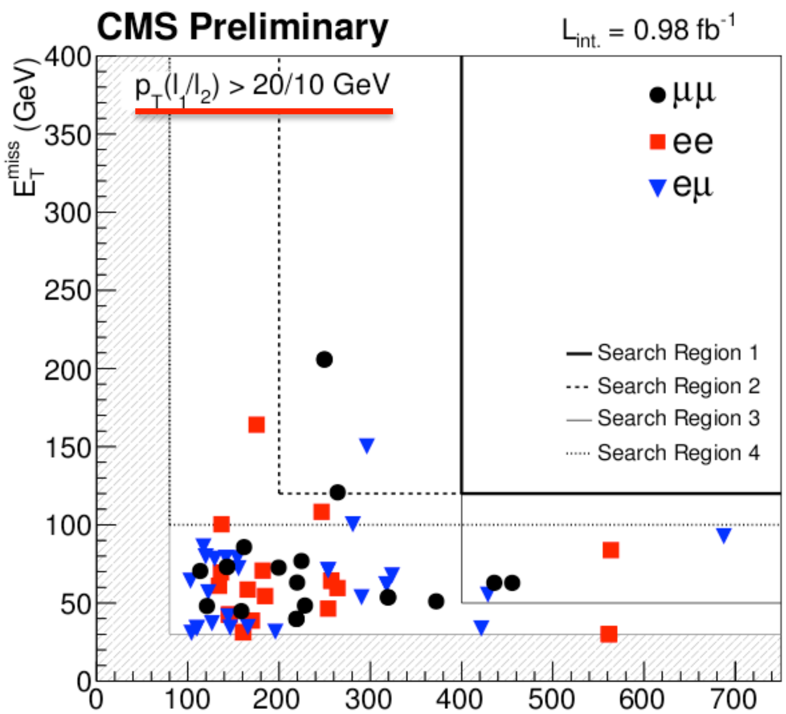
example signal:
SUSY with 2 $\chi^{\pm}$ decays

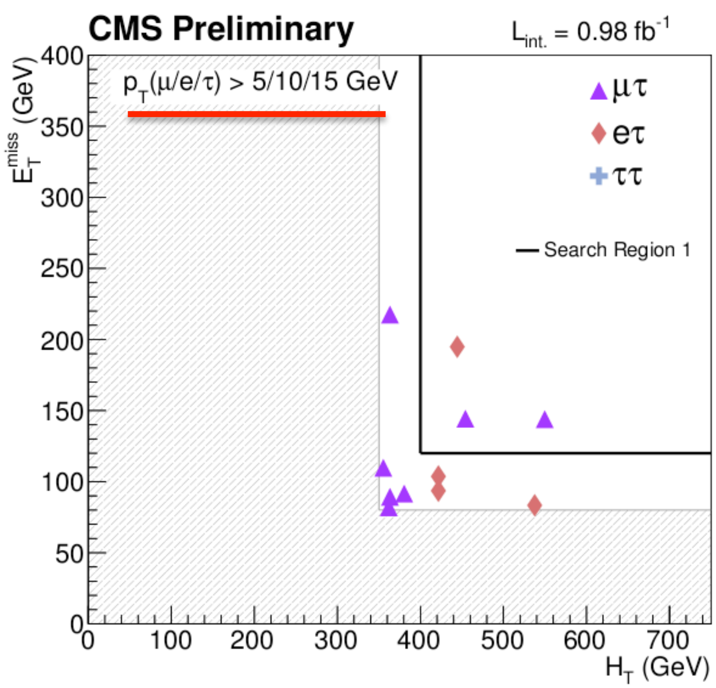


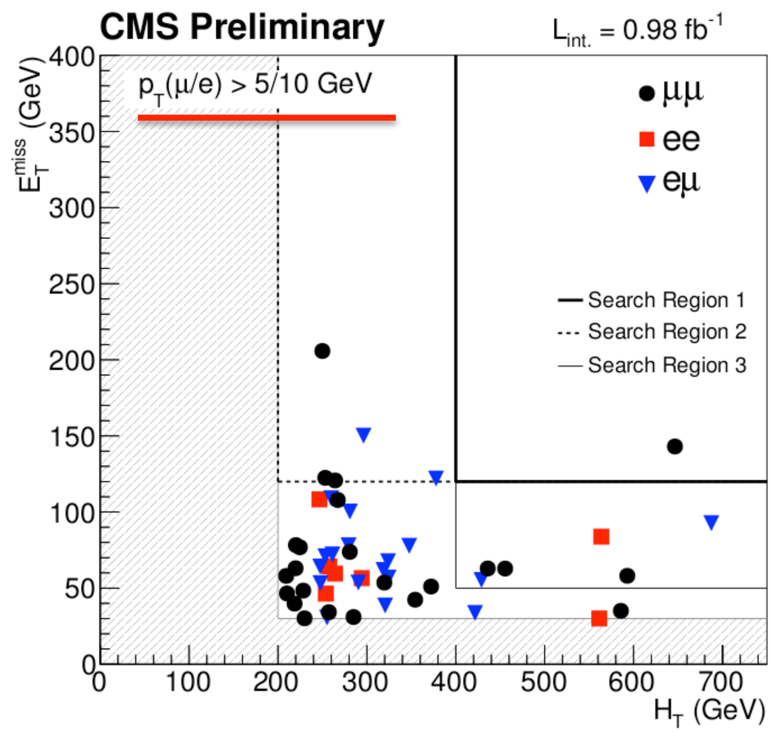
- Require 2nd same-sign lepton → **<u>suppress SM backgrounds</u>**
- **<u>Signature: sign-sign (SS) leptons + jets + MET</u>**
- **Challenge: estimating backgrounds from fake leptons**

SS search strategy

- Three complementary samples
  - ee, eμ, $\mu\mu$ high P_T (P_T>20,10 GeV)
  - ee, eμ, $\mu\mu$ low P_T (P_T>10 for e, P_T> 5 for μ)
    - More sensitive to compressed SUSY spectra, but higher BG
  - eτ, $\mu\tau$, $\tau\tau$ (P_T>15 for τ, P_T>10 for e, P_T> 5 for μ)
    - In case New Physics likes taus
- Several signal regions at high MET and HT
  - Where we expect only a few SM events
  - Chosen with an eye towards possible SUSY features

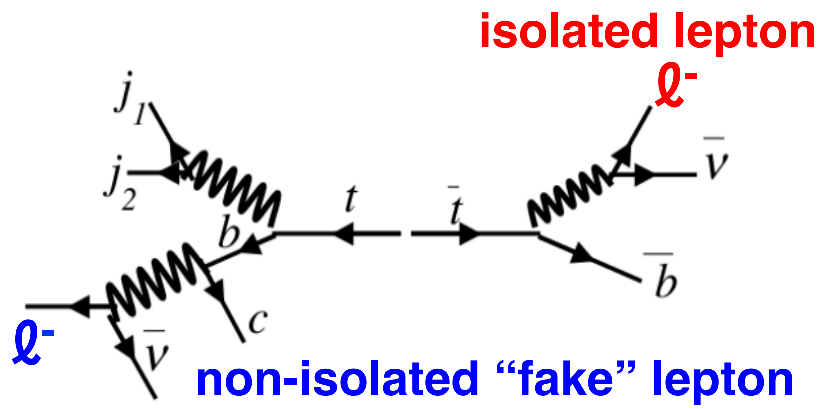

CMS Preliminary
$L_{int.}$ = 0.98 fb^{-1}
$p_T(l_1/l_2)$ > 20/10 GeV
μμ
ee
eμ
Search Region 1
Search Region 2
Search Region 3
Search Region 4
E_T^{miss} (GeV)


CMS Preliminary
$L_{int.}$ = 0.98 fb^{-1}
$p_T(\mu/e/\tau)$ > 5/10/15 GeV
μτ
eτ
ττ
Search Region 1
E_T^{miss} (GeV)
H_T (GeV)


CMS Preliminary
$L_{int.}$ = 0.98 fb^{-1}
$p_T(\mu/e)$ > 5/10 GeV
μμ
ee
eμ
Search Region 1
Search Region 2
Search Region 3
E_T^{miss} (GeV)
H_T (GeV)

Same Sign Backgrounds

dominant background: ttbar with “fake” lepton from b➞ℓ±



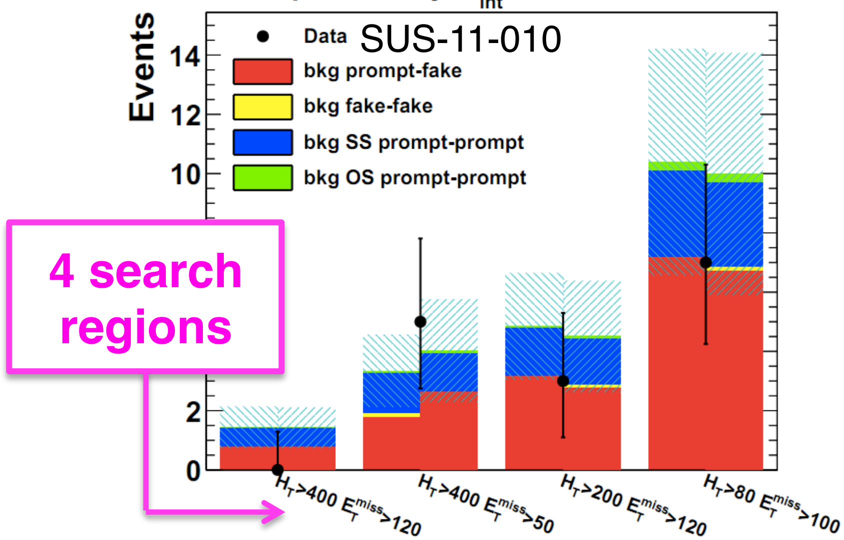
- Events with “fake” (non-W/Z) leptons (dominant)
  - **Must be a data driven BG estimate**
    - Fake rate method (same as discussed yesterday for Wjets BG in H→WW talk)
    - B tag-and-probe ➞ extract b➞ℓ± isolation distributions from b-enriched sample
  - Validated in lower MET, lower HT control region
- Rare SM processes with SS leptons
  - Estimate from MC
  - ttW, qq➞q’q’W±W±: never measured in pp collisions ➞ **measurement critical for future SS analysis**
- Opposite-sign leptons with charge mis-ID (~10%)
  - Charge mis-ID rate validated using same-sign Z sample in data

SS Results

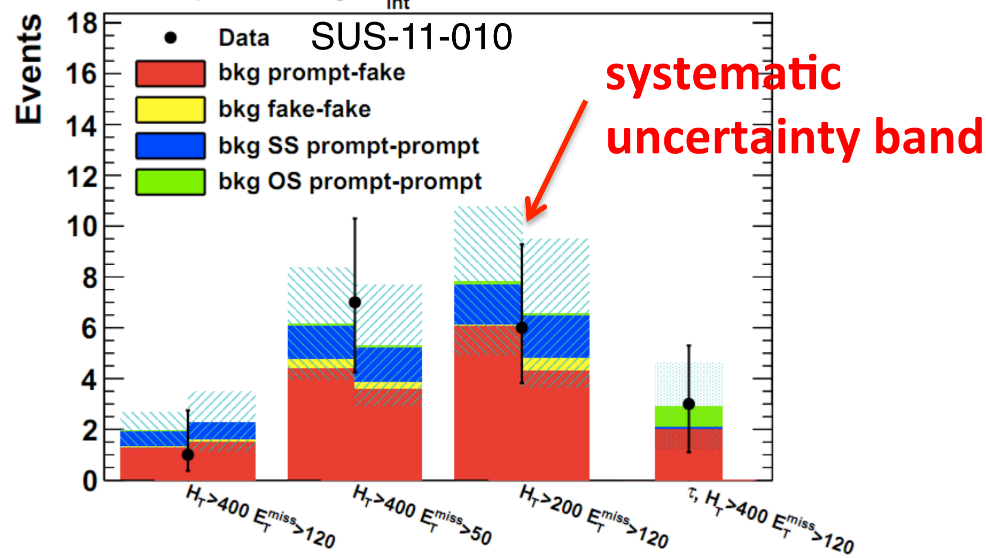
- single fake
- double fake
- SM SS processes
- charge mis-ID

Two alternative (but similar) fake estimates are shown

high P_T lepton sample

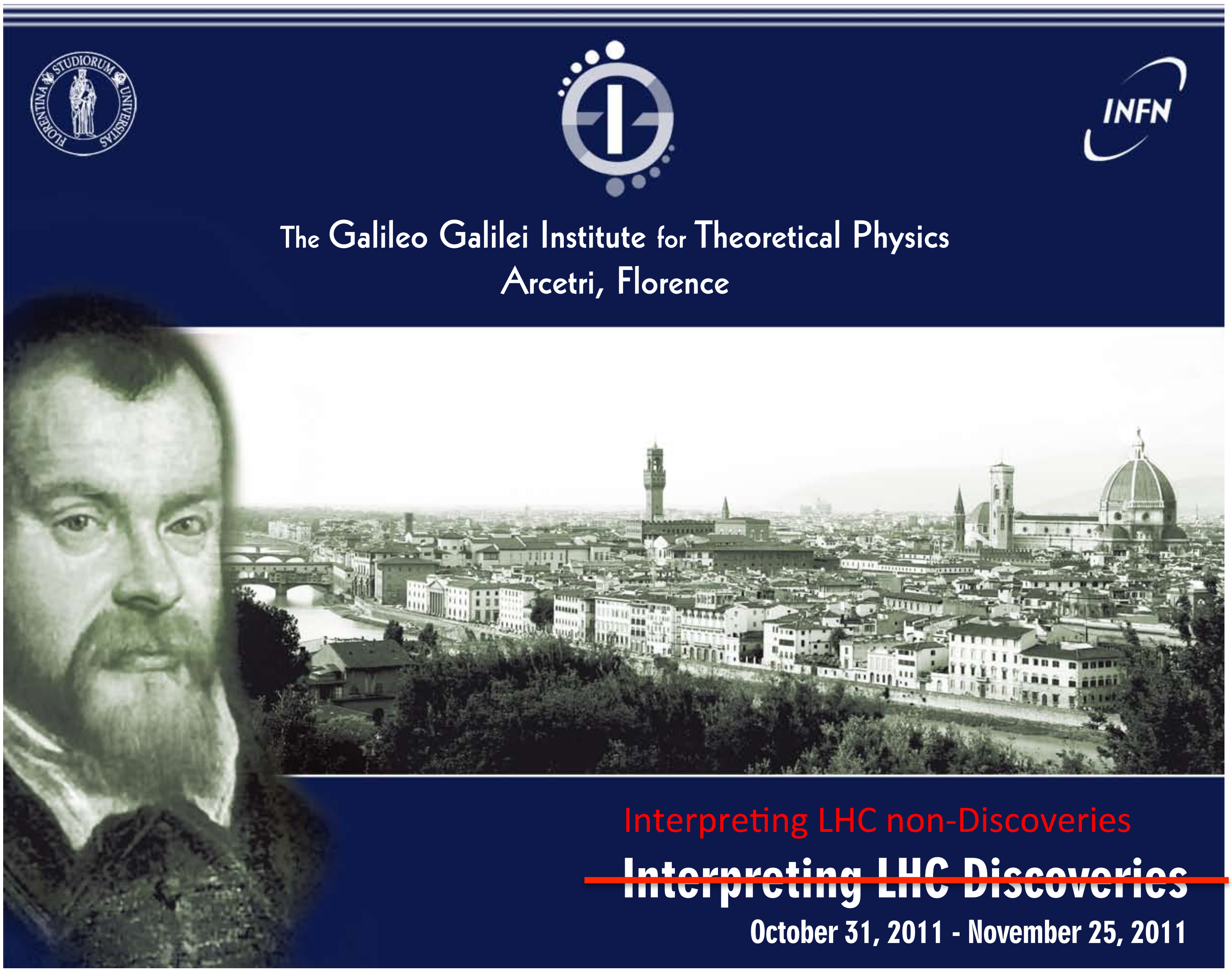


Low P_T lepton + $\tau \rightarrow$ hadrons sample



- Good agreement observed yields vs. both bkg predictions in all samples and signal regions → **no signs of new physics**
  - Note sizable contribution from **SM SS processes**

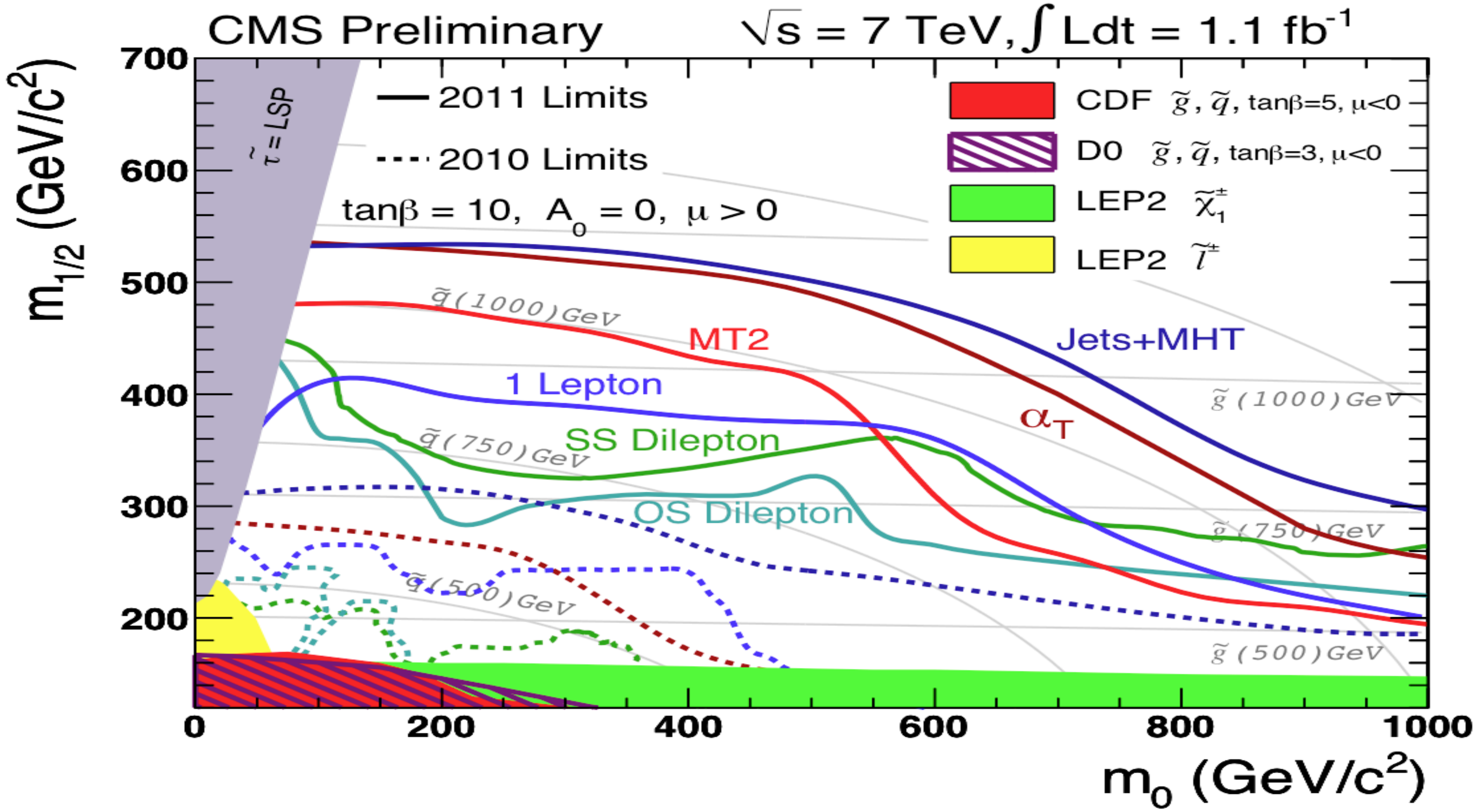
Interpretation



Three type of interpretation

- cMSSM
- Simplified Models
- “Outreach”

Disclaimer: opinions expressed are mine and not necessarily shared
By CMS. Although they should be.

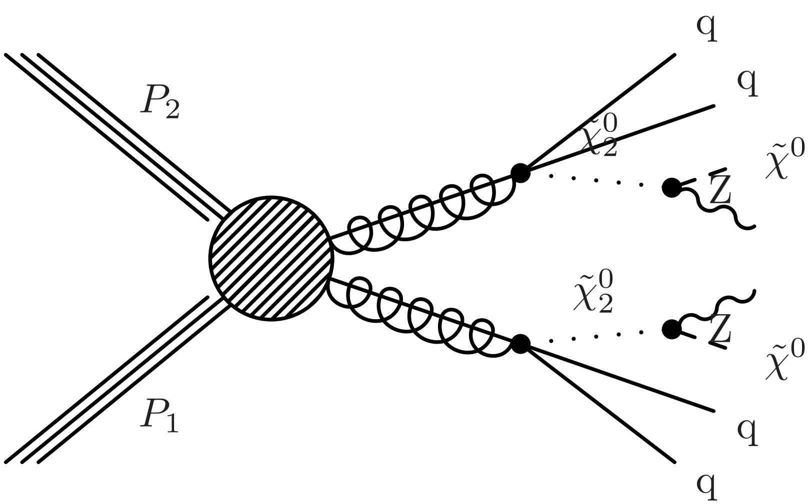


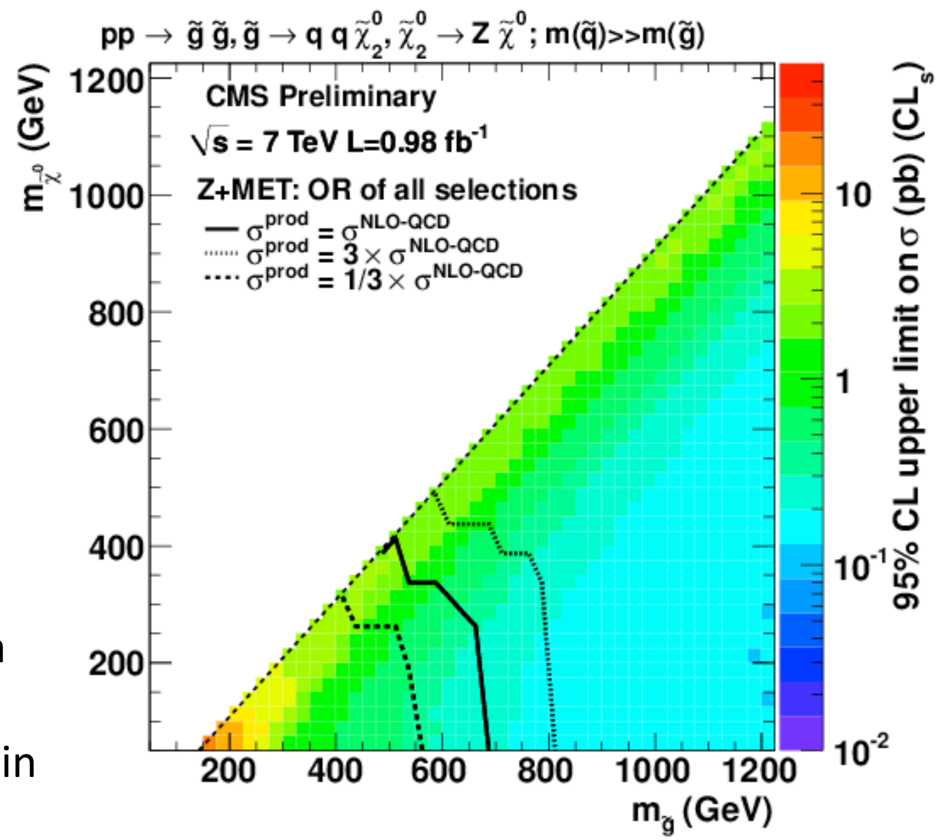
- The “currency” to communicate results.
- Or to show that “I am better than you”
- People have told me “this is the most useless plot ever”
- Others think it’s great
- Truth probably in the middle

Simplified models

- Many simplified models have been probed, more are added every week
- A nice industry
- I think that for leptonic final states it is difficult to make general use of the information presented this way
  - Because leptons in SUSY come at end of complicated decay chains
  - And there are two decay chains
  - May be more useful for hadronic final states?

Example of leptonic simplified model (T5zz)

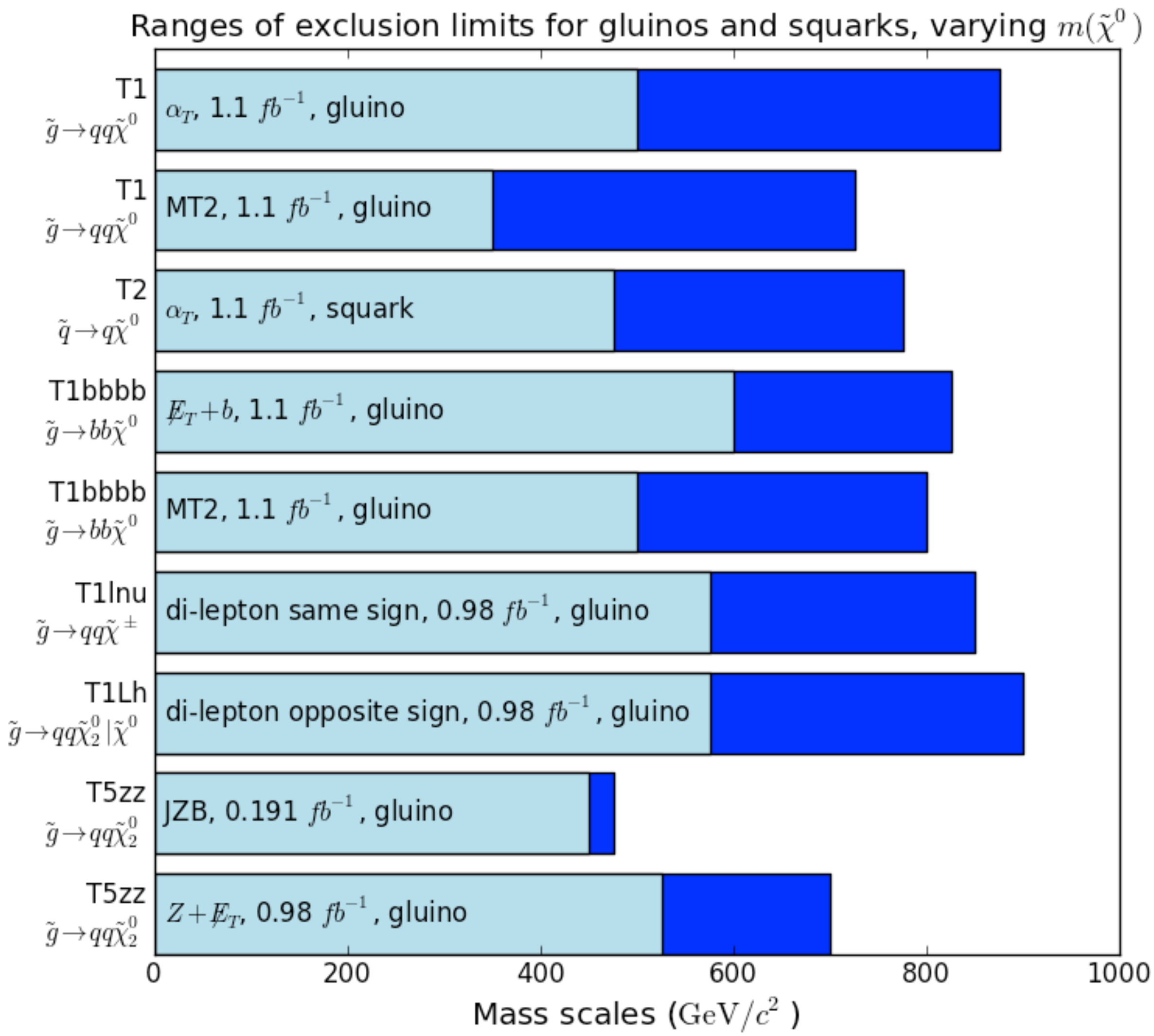




- Used to “interpret” Z+jets search
- Would like results to be applicable with a minimum of effort to similar processes
- Here we have 100% BR for the decay chain
  - Unrealistic

- You cannot simply rescale results based on branching ratios
  - Because efficiencies for various cuts depend on what happens on both sides

CMS preliminary



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).

Outreach

1. Present clear definitions of signal regions
2. Present event yields, background predictions with uncertainties
   – Possibly even recast as upper limits on number of events beyond the Standard Model
3. Present clear instructions on how to do an approximate detector simulation so that anybody can interpret the results for they favorite model
4. Sit back, relax, and let JoAnne et al. do their thing

- This approach has been taken by some analysis-authors at CMS, but there is still not full buy-in from the collaboration
  – Under discussion
- I think it makes sense

Outreach example (from 2010 Same Sign Dilepton Search)

JHEP 1106:077,2011

http://arxiv.org/abs/1104.3168

Abstract

The results of searches for new physics in events with two same-sign isolated leptons, hadronic jets, and missing transverse energy in the final state are presented. The searches use an integrated luminosity of 35 pb^{-1} of pp collision data at a centre-of-mass energy of 7 TeV collected by the CMS experiment at the LHC. The observed numbers of events agree with the standard model predictions, and no evidence for new physics is found. To facilitate the interpretation of our data in a broader range of new physics scenarios, information on our event selection, detector response, and efficiencies is provided.

It is in the abstract.
To emphasize that this is a major part of the scientific result in the paper

Search Region	ee	$\mu\mu$	$e\mu$	total	95% CL UL Yield
Lepton Trigger					
$E_T^{miss} > 80$ GeV					
MC	0.05	0.07	0.23	0.35	
predicted BG	$\mathbf{0.23^{+0.35}_{-0.23}}$	$\mathbf{0.23^{+0.26}_{-0.23}}$	$\mathbf{0.74 \pm 0.55}$	$\mathbf{1.2 \pm 0.8}$	
observed	**0**	**0**	**0**	**0**	**3.1**
$H_T > 200$ GeV					
MC	0.04	0.10	0.17	0.32	
predicted BG	$\mathbf{0.71 \pm 0.58}$	$\mathbf{0.01^{+0.24}_{-0.01}}$	$\mathbf{0.25^{+0.27}_{-0.25}}$	$\mathbf{0.97 \pm 0.74}$	
observed	**0**	**0**	**1**	**1**	**4.3**
H_T Trigger					
Low-p_T					
MC	0.05	0.16	0.21	0.41	
predicted BG	$\mathbf{0.10 \pm 0.07}$	$\mathbf{0.30 \pm 0.13}$	$\mathbf{0.40 \pm 0.18}$	$\mathbf{0.80 \pm 0.31}$	
observed	**1**	**0**	**0**	**1**	**4.4**
	$e\tau_h$	$\mu\tau_h$	$\tau_h\tau_h$	total	95% CL UL Yield
τ_h enriched					
MC	0.36	0.47	0.08	0.91	
predicted BG	$\mathbf{0.10 \pm 0.10}$	$\mathbf{0.17 \pm 0.14}$	$\mathbf{0.02 \pm 0.01}$	$\mathbf{0.29 \pm 0.17}$	
observed	**0**	**0**	**0**	**0**	**3.4**

Upper yields in number of events are given.
Any model that "predicts" more than this number of events after all cuts is excluded

8 Interpretation of Results

One of the challenges of signature-based searches is to convey information in a form that can be used to test a variety of specific physics models. In this section we present additional information that can be used to confront models of new physics in an approximate way by generator-level simulation studies that compare the expected number of events in 35 pb^{-1} with our upper limits shown in Table 2.

The kinematic requirements described in Section 4 are the first key ingredients of such studies. The H_T variable can be approximated by defining it as the scalar sum of the p_T of all final-state quarks (u, d, c, s, and b) and gluons with $p_T > 30$ GeV produced in the hard-scattering process. The E_T^{miss} can be defined as the magnitude of the vector sum of the transverse momentum over all non-interacting particles, *e.g.*, neutrinos and LSP. The ratio of the mean detector responses for H_T and E_T^{miss} as defined above, to their true values are 0.94 ± 0.05, and 0.95 ± 0.05, respectively, where the uncertainties are dominated by the jet energy scale uncertainty. The resolution on these two quantities differs for the different selections. In addition, the E_T^{miss} resolution depends on the total hadronic activity in the event. It ranges from about 7 to 25 GeV for events with H_T in the range of 60 to 350 GeV. The H_T resolution decreases from about 26% at 200 GeV to 19% for 300 GeV and to 18% for 350 GeV. The H_T resolution was measured in simulation using the LM0 reference model, while the E_T^{miss} resolution was measured in data.

Tells you how to calculate HT and MET from parton level
Tells you what the response and the resolution on these quantities is

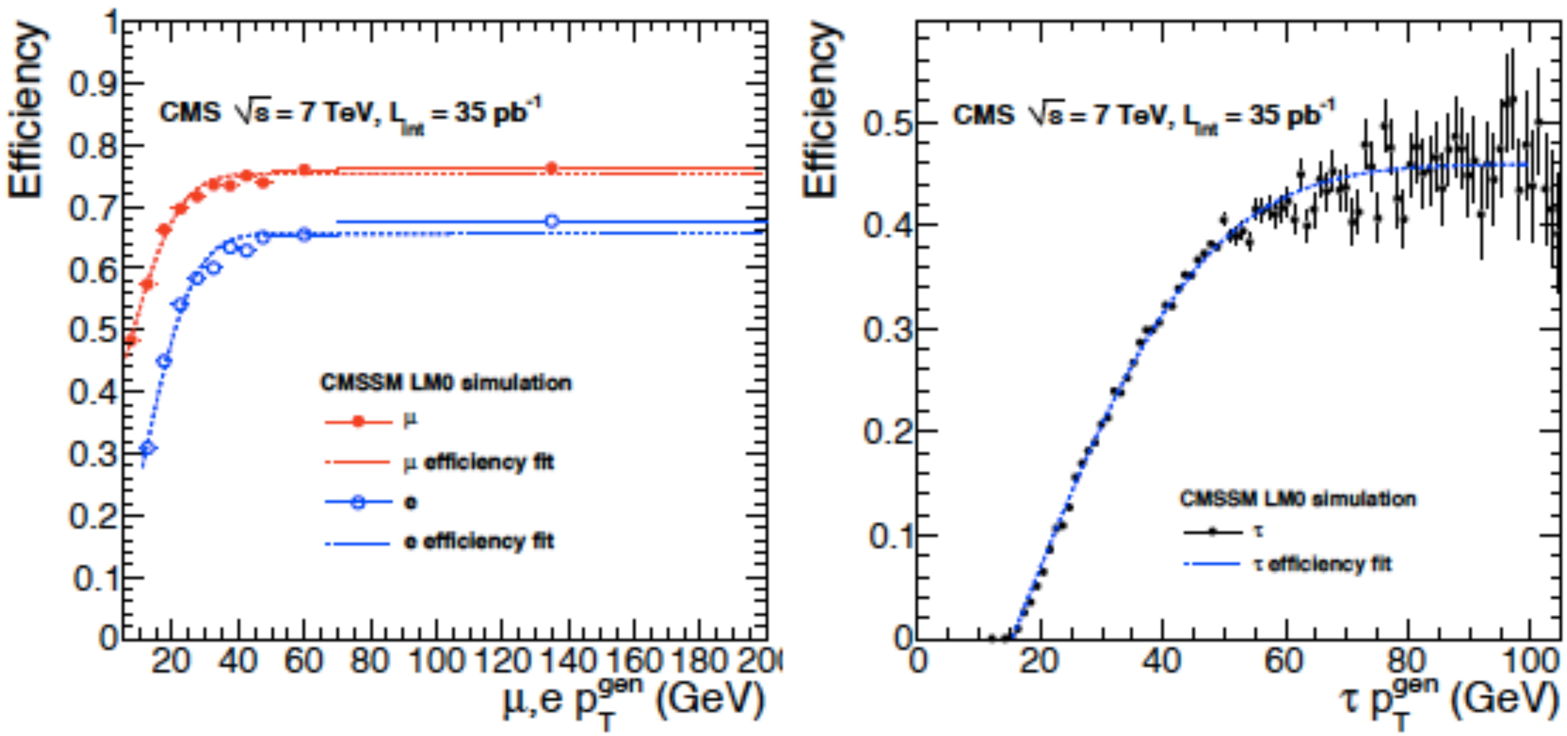


Figure 9: Electron, muon (left) and τ_h (right) selection efficiencies as a function of p_T. The results of the fits described in the text are shown by the dotted lines.

Gives you efficiency parametrizations

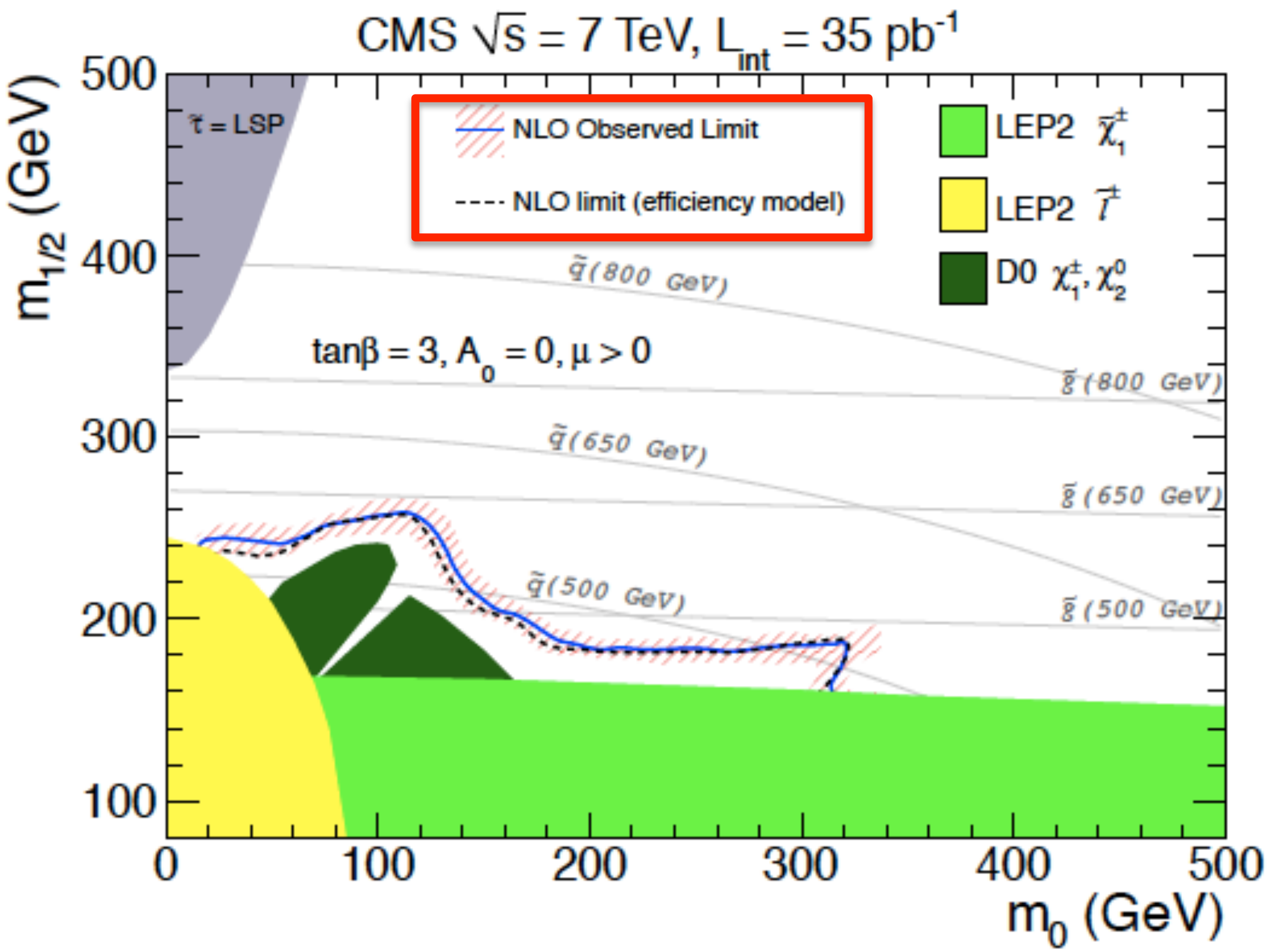


Figure 10: Exclusion contour in the m_0—$m_{1/2}$ plane for CMSSM as described in the text. Comparing the width of the red shaded band (theoretical uncertainty) around the blue curve with the difference between the solid blue and dashed black curves shows that the imperfections in the simple efficiency model described in the text are small compared to the theoretical uncertainties.

Demonstrates that if instead of the full CMS simulation you only had the efficiency model described in the paper, you would get ~ the same cMSSM limit

Conclusion

- No sign of new physics with ~ 1/fb
- Results with ~ 5/fb to come over the next few months
- How to best communicate our "zeroes" to the phenomenology community is an ongoing process
- Most of our searches have been general and signature based
  - But some signatures still not very explored (eg: events with leptons with and without b-quarks)
- In 2012 likely to add more targeted searches to more specific signatures

The End

Single lepton tables

Table 3: Predicted and observed yields in the signal regions for the loose selection ($H_T > 500$ GeV, $\not\!E_T > 250$ GeV) and the tight selection ($H_T > 500$, $\not\!E_T > 350$ GeV). The quoted uncertainties are statistical and systematic. All background contributions are determined from control samples in the data, except for the single-top and Z-plus-jets contributions, which are obtained from simulated event (MC) samples.

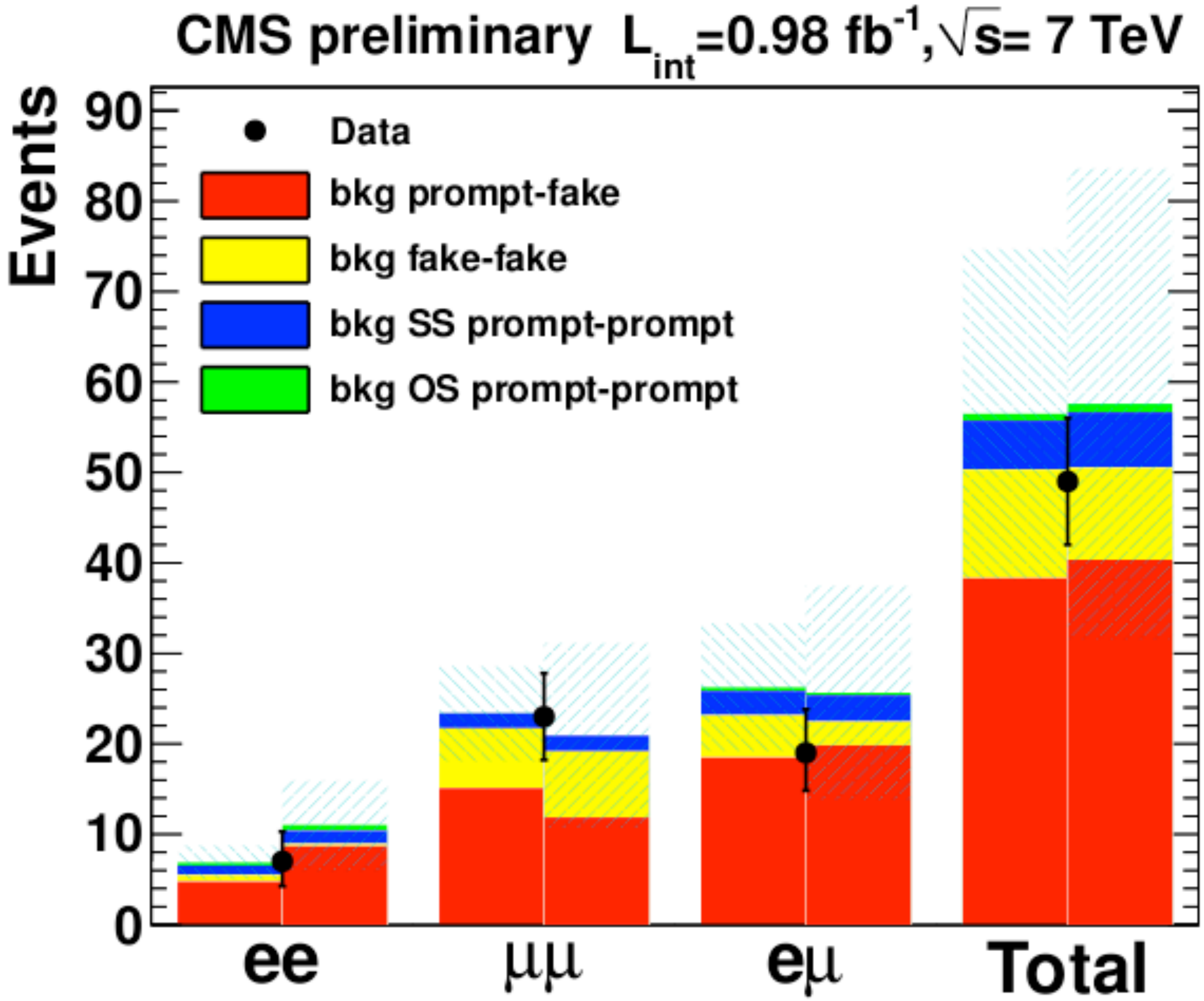
Sample	Loose Selection (e+μ)	Tight Selection (e+μ)
Predicted SM 1 ℓ	$34.6 \pm 7.7 \pm 10.8$	$8.8 \pm 3.7 \pm 3.4$
Predicted SM dilepton	$4.0 \pm 3.9 \pm 0.8$	$0.9 \pm 1.9 \pm 0.9$
Predicted single τ	$10.5 \pm 1.2 \pm 0.5$	$2.3 \pm 0.5 \pm 0.2$
Predicted QCD background	$0.0 \pm 1.2 \pm 0.3$	$0.0 \pm 1.0 \pm 0.3$
Single top (MC), Z+jets (MC)	$0.7 \pm 0.2 \pm 0.2$	$0.1 \pm 0.1 \pm 0.1$
Total predicted SM	$49.8 \pm 8.8 \pm 10.8$	$12.1 \pm 4.3 \pm 3.6$
Data	52	8

Table 4: Summary of systematic uncertainties for the subtraction of the backgound from single-lepton contributions using the lepton-spectrum method. The uncertainty from backgrounds in the control sample is associated primarily with contamination from Z + jets events and, to a lesser extent, from single-top processes.

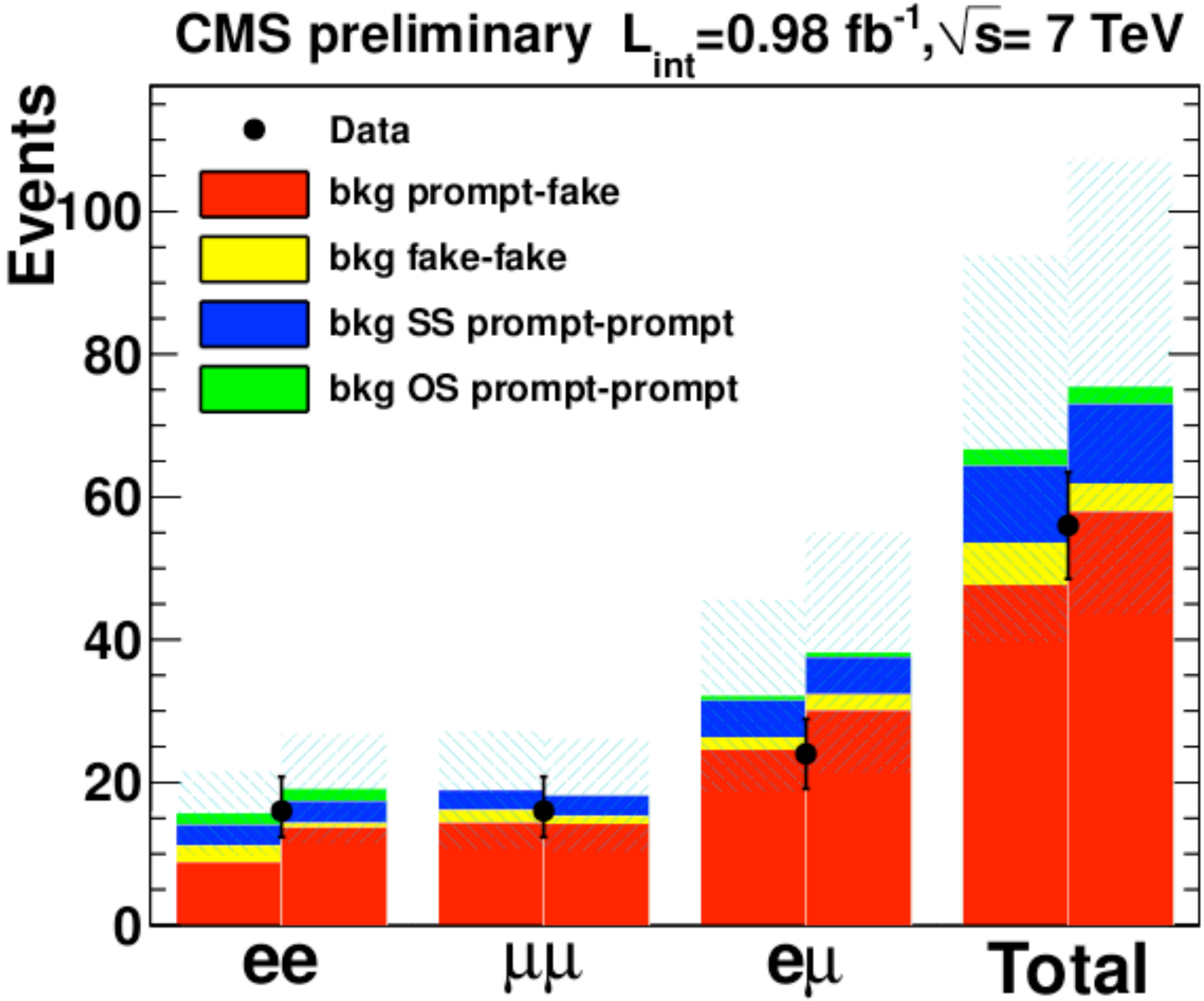
Source	$\Delta(N_{\text{predicted}}/N_{\text{true}})(\%)$ (Loose selection)	$\Delta(N_{\text{predicted}}/N_{\text{true}})(\%)$ (Tight selection)
$\not\!E_T$ and jet energy scale	23	31
W polarization in $t\bar{t}$	4	1.4
W polarization in W+jets	9	15
$\sigma(t\bar{t})$ and $\sigma(W)$	16	16
Lepton efficiency (μ) vs. p_T	4	4
Lepton efficiency (e) vs. p_T	4	4
Backgrounds in control sample	7	7
Total	31	39

Table 5: Expected event yields in the signal region, $L_P < 0.15$, with 1.14 fb^{-1} in the muon and electron channels. The MC values are only listed for illustration purposes, since the estimate of the number of SM events in the signal region uses the method described in the text. The contribution from QCD multijet production is expected to be negligible and is thus not included in the table.

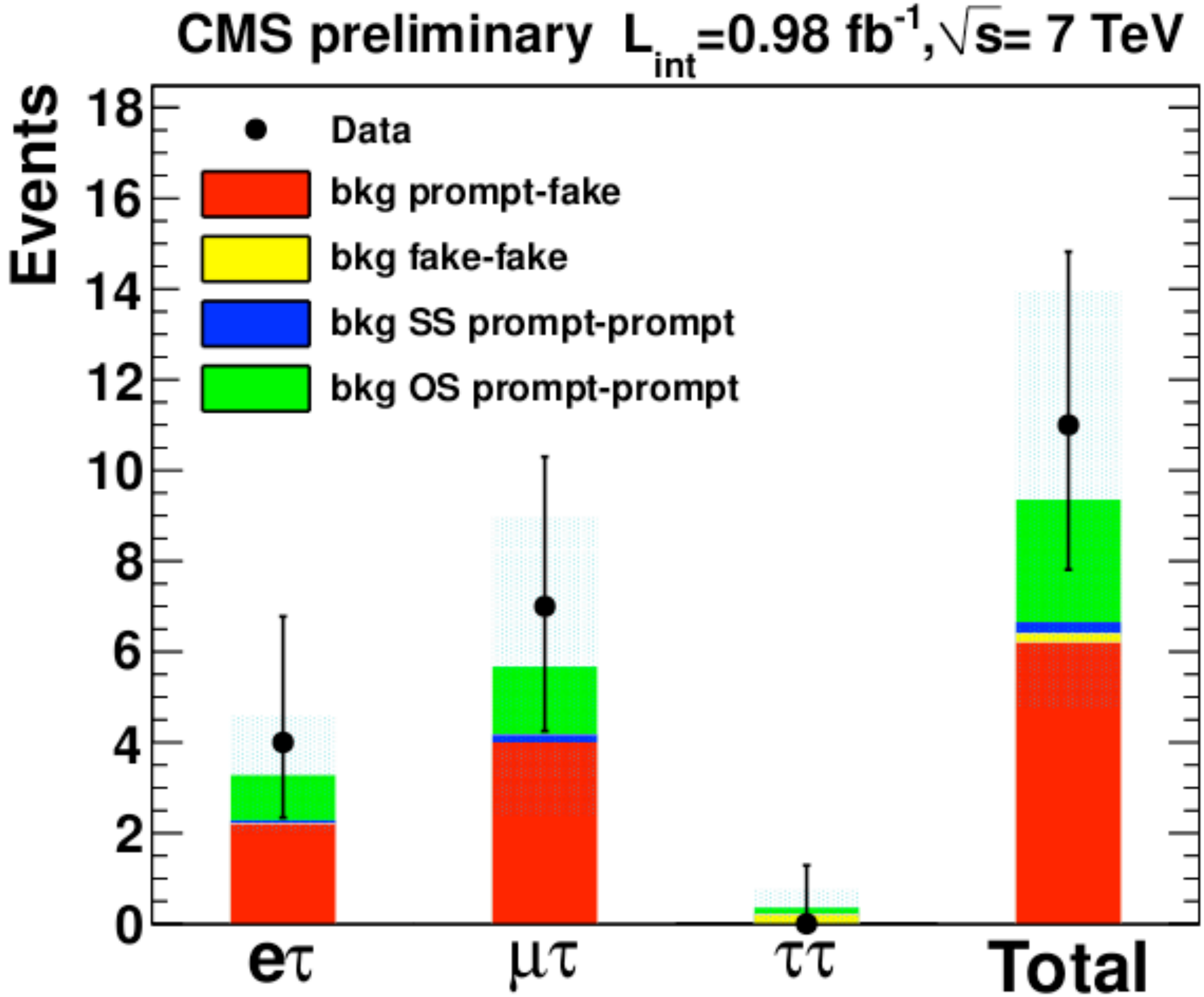
$L_P < 0.15$	Muons: S_T^{lep} range (GeV)			Electrons: S_T^{lep} range (GeV)		
Sample	[250-350]	[350-450]	[450-inf]	[250-350]	[350-450]	[450-inf]
$t\bar{t}$ (ℓ)	11.4±0.9	2.91±0.4	0.8±0.2	7.8±0.7	3.0±0.4	1.0±0.3
$t\bar{t}$ ($\ell\ell$)	2.2±0.4	0.6±0.2	0.1±0.1	2.4±0.4	0.7±0.2	0.4±0.2
W	14.5±0.6	8.0±0.5	5.6±0.4	10.5±0.5	5.2±0.4	4.7±0.3
Z	0±1.5	0±1.5	0±1.5	0±1.5	0±1.5	0±1.5
Total MC	28.1±1.1	11.5±0.7	6.5±0.4	20.8±1.0	8.8±0.6	6.1±0.5
LM1	24.2±0.9	23.1±0.9	16.2±0.7	22.9±0.9	20.8±0.8	14.7±0.7
LM3	24.8±0.8	16.7±0.6	9.7±0.5	22.8±0.7	14.8±0.6	9.7±0.5
LM6	1.9±0.0	2.5±0.1	5.9±0.1	1.7±0.0	2.3±0.1	5.3±0.1



Low pt control region



High Pt control region


CMS preliminary L_{int}=0.98 fb^{-1},$\sqrt{s}$= 7 TeV
Events
Data
bkg prompt-fake
bkg fake-fake
bkg SS prompt-prompt
bkg OS prompt-prompt
0
2
4
6
8
10
12
14
16
18
eτ
μτ
ττ
Total