Searches for Supersymmetry in Final States with Leptons or photons and missing energy

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On behalf of the CMS collaboration

Introduction

0-leptons	1-lepton	OSDL	SSDL	≥3 leptons	2-photons	γ+lepton
Jets + MET	Single lepton + Jets + MET	Opposite-sign di-lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET

SUSY has many properties:

- Provides dark matter candidates, solves the hierarchy problem, better unification of couplings etc.
- We do not know where it is, so we look generically everywhere.

Inclusive searches are defined:

- Categorized by the number of leptons in final state
- Generic missing energy signatures
- Many include jet requirements to be sensitive to strong production

Results of the studies not covered in this talk (including b-jets), can be found at:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Outline

In this talk, recent results from CMS using ~1 fb^{-1} of 2011 data are summarized:

- **Inclusive Searches with data driven background predictions**
  - **Opposite sign dileptons with Z veto**
  - **Opposite sign dileptons with Z in the final states**
  - **Same sign dilepton searches**
- **Exclusion limits/Interpretation of results**
  - Limits using CMSSM framework
  - Information to test variety of specific physics models
- **Summary and Conclusion**

Inclusive searches with data driven background predictions

- Opposite sign di-leptons studies with Z veto

- Counting experiment in signal region with large MET and H_T

- Search for kinematic edge in dilepton mass distribution

[CMS PAS SUS-11-011]

**H_T* is defined as the scale sum p_T of the hadronic jets*

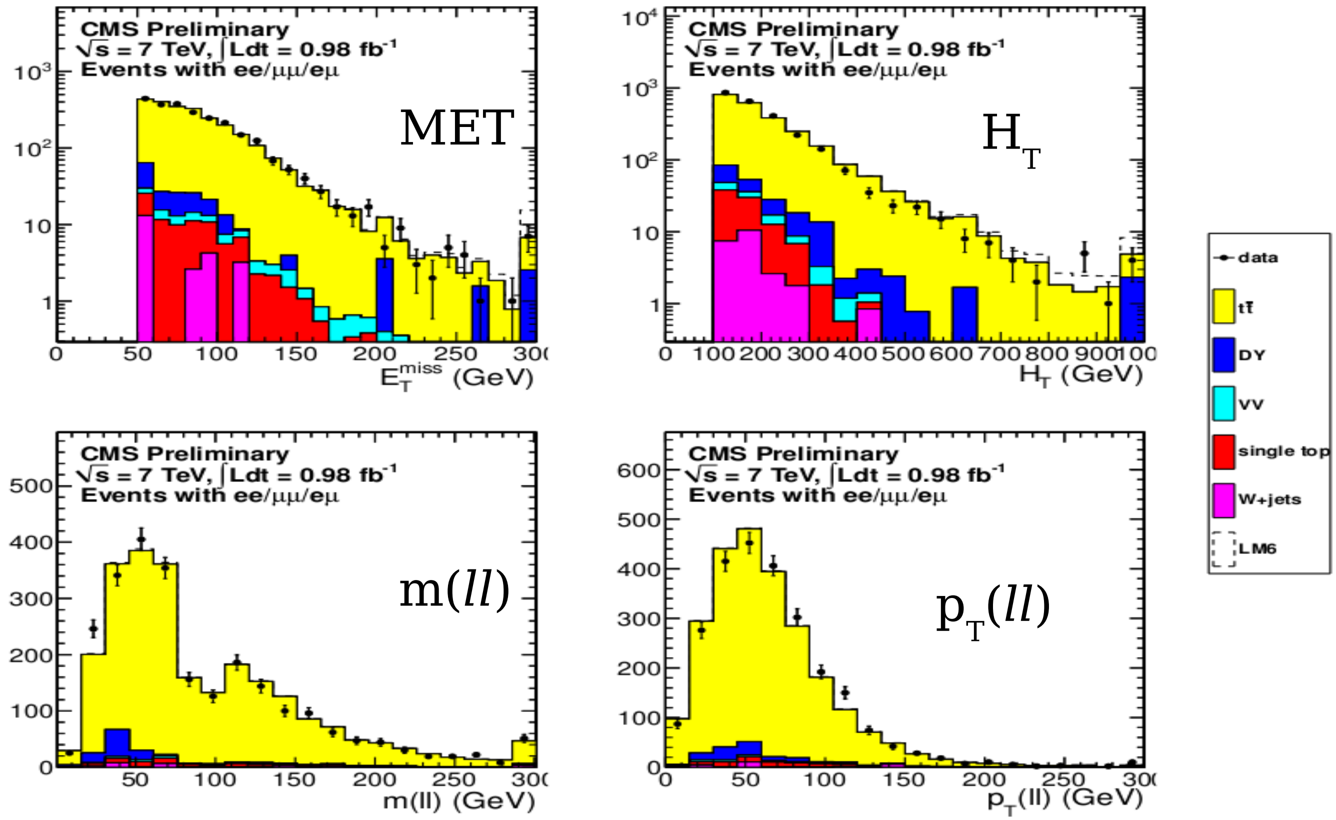
Opposite sign dilepton search

Requirement of di-leptons reduces W+Jets & QCD drastically, leaving mostly top

Use data driven techniques to predict bkg in tails of H_T and MET distribution

<u>Baseline selection:</u>

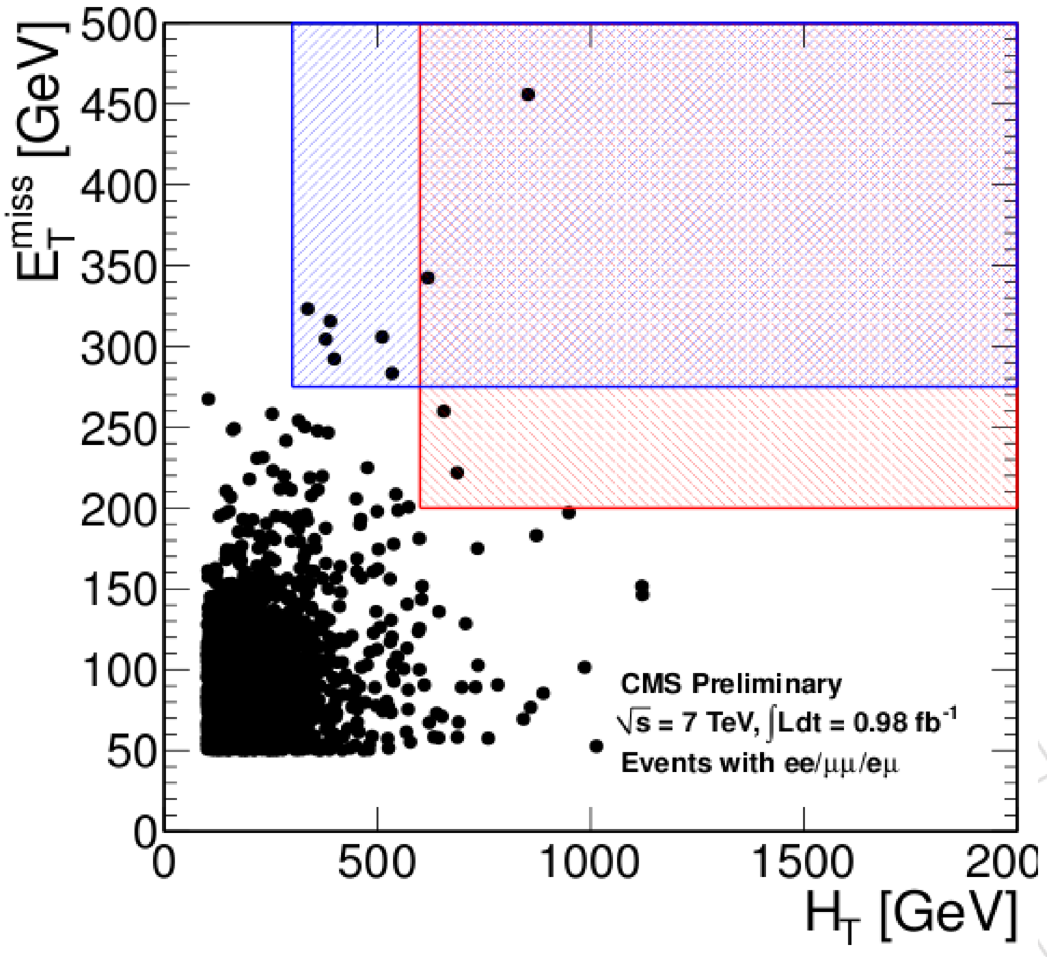
- Two isolated leptons (e, μ): one with p_T > 20 GeV, other with p_T > 10 GeV
- At least 2 jets with p_T > 30 and $|\eta|$ < 3.0, MET > 30 GeV, H_T > 100 GeV
- Veto same-flavor pairs in Z mass window (76, 106) and m_{ll} < 12 GeV



Simulation shape (scale x 1.13) agrees with the data in various distributions

Opposite sign dilepton search regions

Define signal regions in tails of MET and H_T



Derive data driven background Estimations ⇒ See Next

High MET signal region (MET > 275 GeV, H_T > 300 GeV)

High H_T signal region (MET > 200 GeV, H_T > 600 GeV)

Opposite sign dilepton search (Lepton spectrum method)

Two data driven methods used in this search:

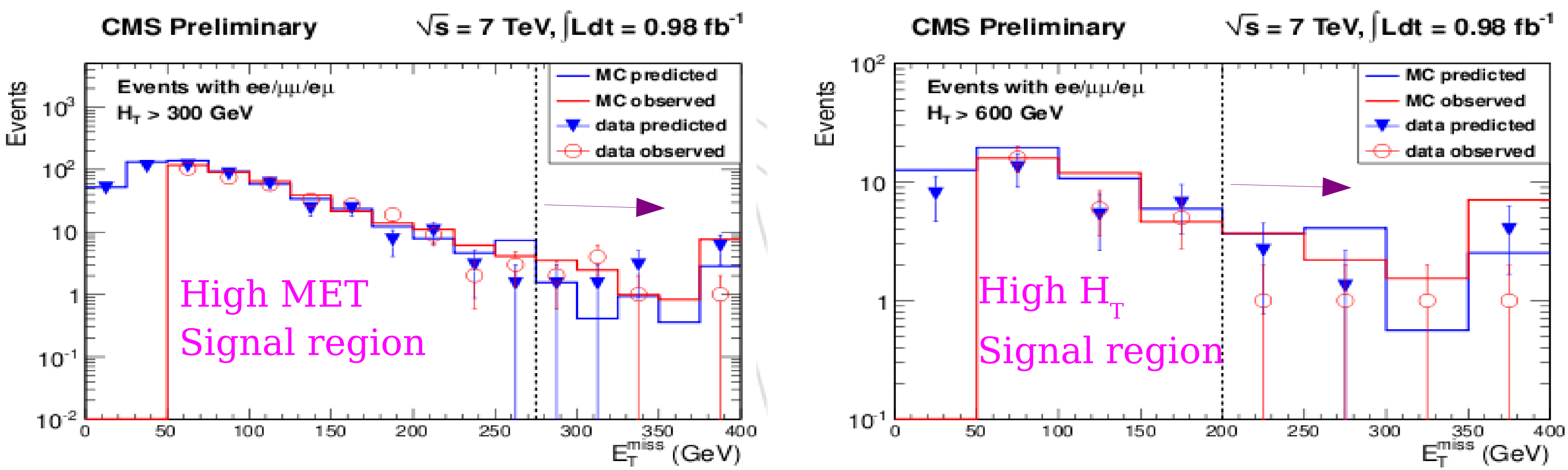
a) Lepton spectrum method ($p_T(ll)$) [V. Pavlunin, PRD 81, 035005 (2010)

This method relies on the $p_T(ll)$ distribution to get $p_T(\nu\nu)$

In SM, the neutrino and the lepton p_T are anti-correlated in an given event

- Overall spectra are similar

Corrections are needed to account for cuts on MET, polarization effects due to Ws. Both of these are well modeled in MC.



	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)

The observation is consistent with the prediction

Opposite sign dilepton search (ABCD' method)

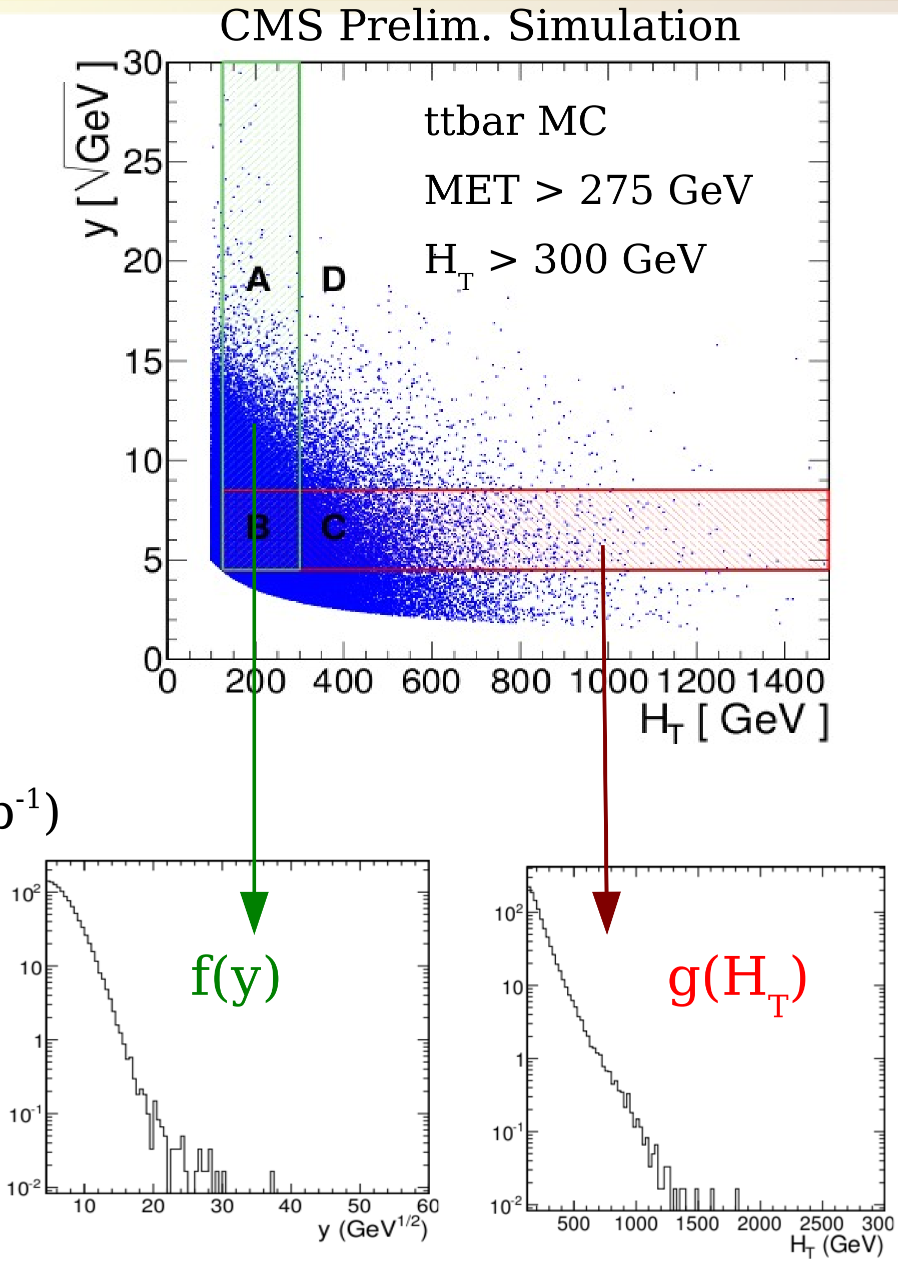
b) ABCD' method (Use weakly correlated variables, H_T & y)

- Measure in data the H_T & $y = MET/\sqrt{H_T}$ distributions $f(y)$, $g(H_T)$.
- Predict yields in a given region using:

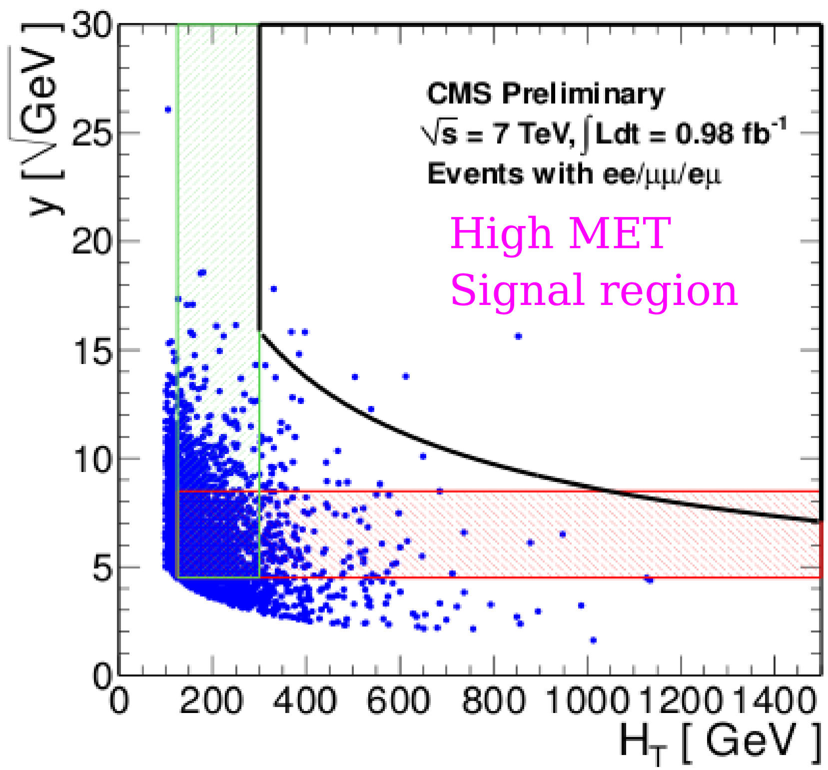
$$\frac{\partial^2 N}{\partial y \partial H_T} = f(y)g(H_T)$$

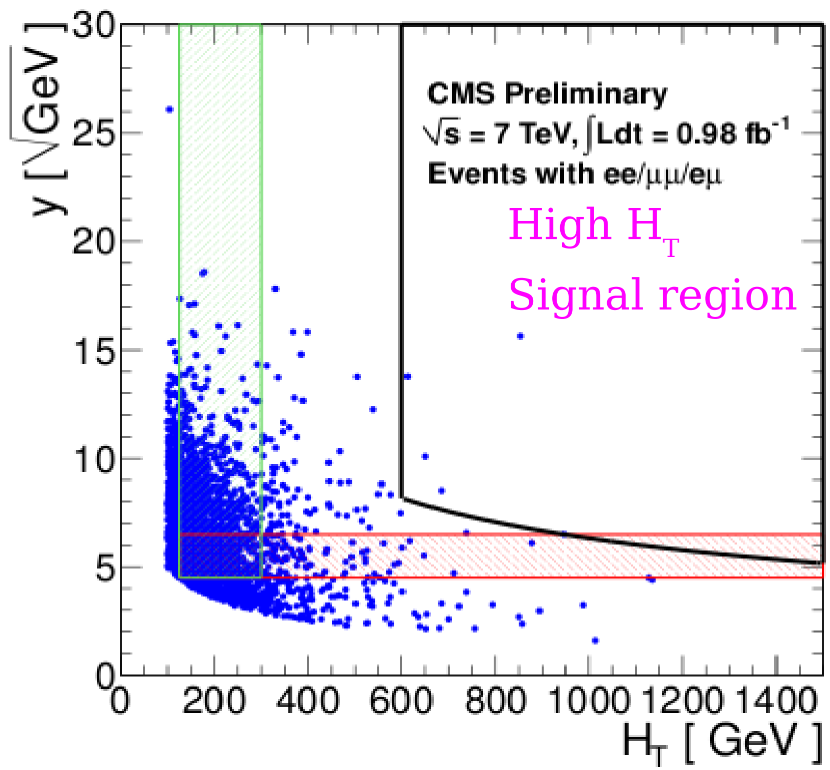
- Method validated using toy MC studies (~1fb^{-1})

Bin contents of f(y) and f(H_T) are smeared according to their poisson uncertainties for stat uncert. in the bkg prediction.



b) ABCD' method





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$p_T(\ell\ell)$ prediction	14.3 ± 6.3 (stat) ± 5.3 (syst)	10.1 ± 4.2 (stat) ± 3.5 (syst)

Prediction yields are consistent with MC and the observation

Opposite sign dileptons – Opposite flavour Subtraction

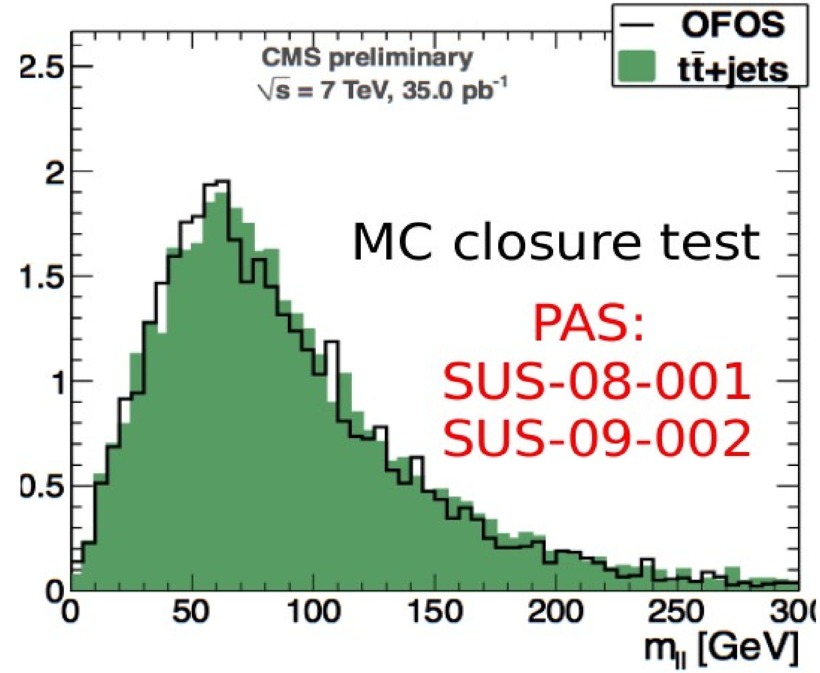
- Predict number of ttbar from dileptons μμ and ee from eμ events

$$n_{ee} = \frac{1}{2} n_{e\mu} r_{\mu e}, \quad n_{\mu\mu} = \frac{1}{2} \frac{n_{e\mu}}{r_{\mu e}}$$

- Lepton p_T > 10 GeV

Relies on $r_{\mu e}$ = N(Z→ee)/N(Z→μμ)

- Known within 2% syst.



Quantify the excess of SF Vs OF events using:

$$\Delta = 1/r_{\mu e} N(ee) + r_{\mu e} N(\mu\mu) - N(e\mu)$$

Note: $\Delta = 0$ for dominant SM bkg's (ttbar, WW, DY $\to \tau\tau$)

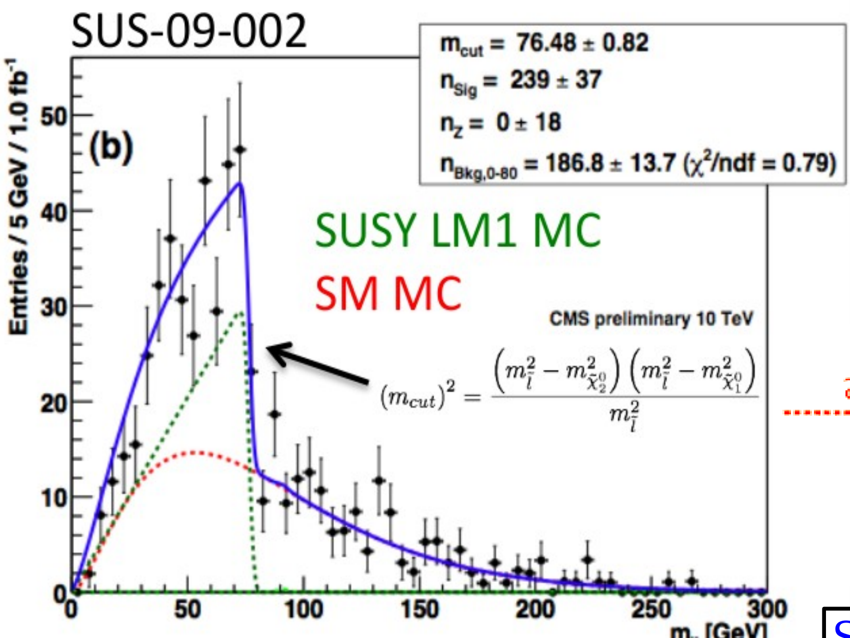
	high E_T^{miss} signal region	high H_T signal region
observed Δ	3.6 ± 2.9 (stat) ± 0.4 (syst)	-0.9 ± 1.8 (stat) ± 1.1 (syst)

No evidence of any excess

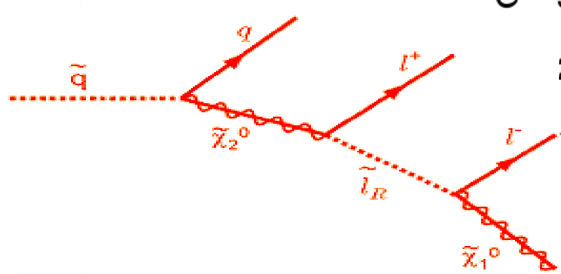
Search for kinematic edge in m(*ll*) distribution

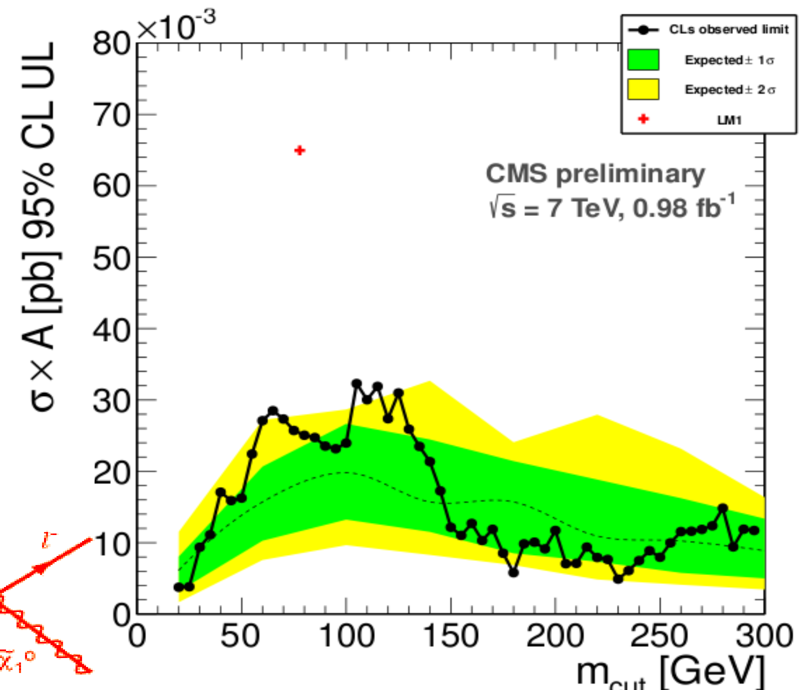
- Perform extended maximum likelihood fit simultaneously to ee, μμ, eμ events
  - ee/μμ with signal + Z + bkg
  - em: bkg only
- Validate fit in control region dominated by ttbar (MET > 100 GeV, 100 < H_T < 300)
- Search for NP in signal region (MET > 100 GeV, H_T > 300 GeV)
- Observe no evidence for kinematic edge ⇒ Set upper limit on the signal

$$\chi_2^0 \to \ell\tilde{\ell} \to \chi_1^0 \ell^+ \ell^-$$



$$T(m_{ll}) = \frac{1}{\sqrt{2\pi}\sigma} \int_0^{\boxed{m_{cut}}} dy \cdot y e^{\frac{-(m_{ll}-y)^2}{2\sigma^2}}$$





Shape depends on 1 parameter (position of the edge)

- Perform fit to m_{cut} for LM1 benchmark point
- Scan edge position and extract Upper limit

Upper Limits from Opposite sign dilepton studies

- Extract model independent limits on non-SM contributions to yields
- For generic search, use error-weighted average of 2 data-driven estimates
- Compute 95% CL UL, compare to the NLO yields from benchmark points*

Generic results ►

	high $E_{\mathrm{T}}^{\mathrm{miss}}$ signal region	high H_T signal region
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$p_T(\ell\ell)$ 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

correlated flavor results ►

	high $E_{\mathrm{T}}^{\mathrm{miss}}$ 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

**benchmark points are defined in backup slides*

Inclusive Searches with data driven background predictions

Opposite sign di-leptons with Z

- *Jet-Z* balance method (CMS SUS-11-012)

- MET template method (CMS SUS-11-017)

Opposite sign di-leptons with Z (*Jet-Z* balance method)

Search for SUSY in Z + Jets + MET final state (e.g $\chi^2_0 \rightarrow Z\,\chi^1_0$)

- Two isolated leptons (e, μ): $p_T > 20$ GeV
- At least 3 jets with $p_T > 30$ and $|\eta| < 3.0$, MET > 30 GeV
- Require same-flavor pairs in Z mass window $|m_{ll} - Z| < 20$ GeV

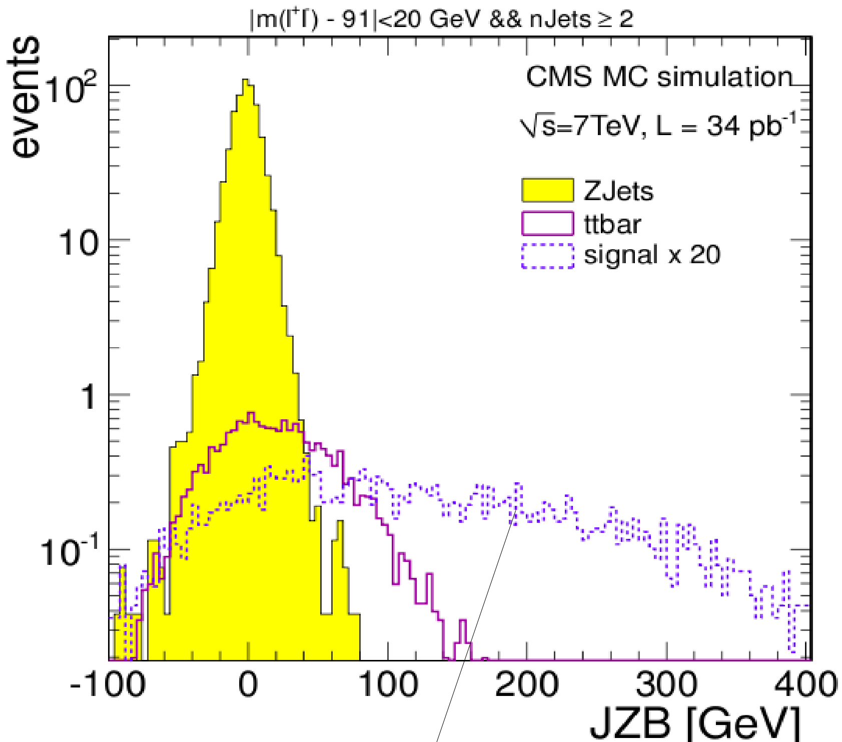
Backgrounds:

- Z + Jets + instrumental MET
- OSSF dileptons from ttbar
  (Predict using OSOF subtraction method)

Define:

$$\mathrm{JZB} = \left|\sum_{\mathrm{jets}} \vec{p}_T\right| - \left|\vec{p}_T^{\,Z}\right|$$

JZB < 0: Control region

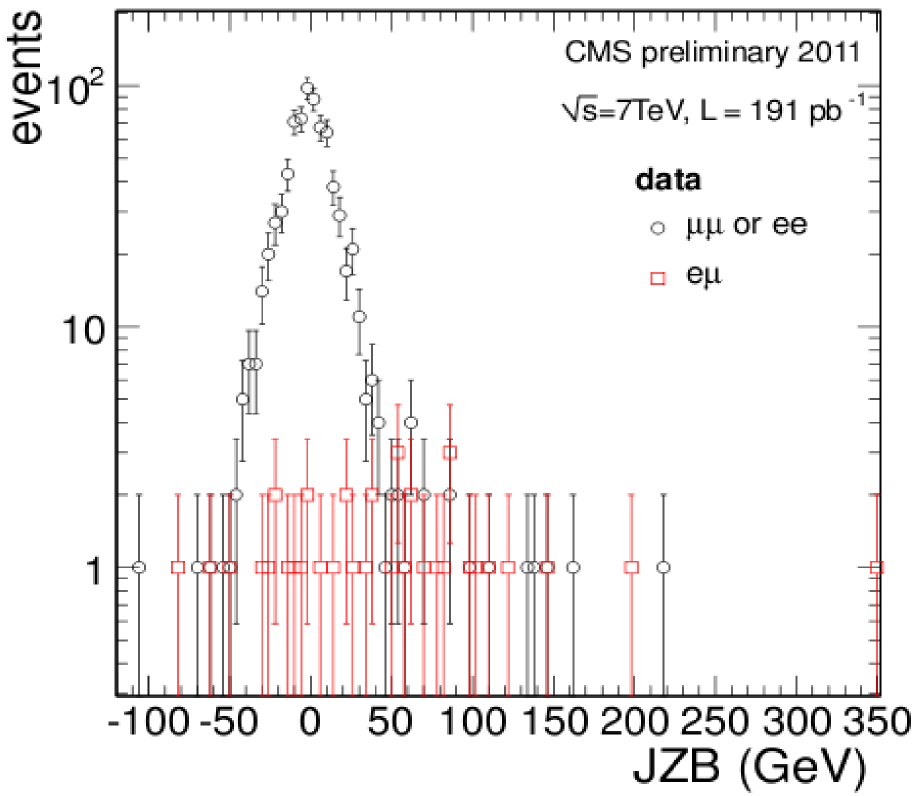


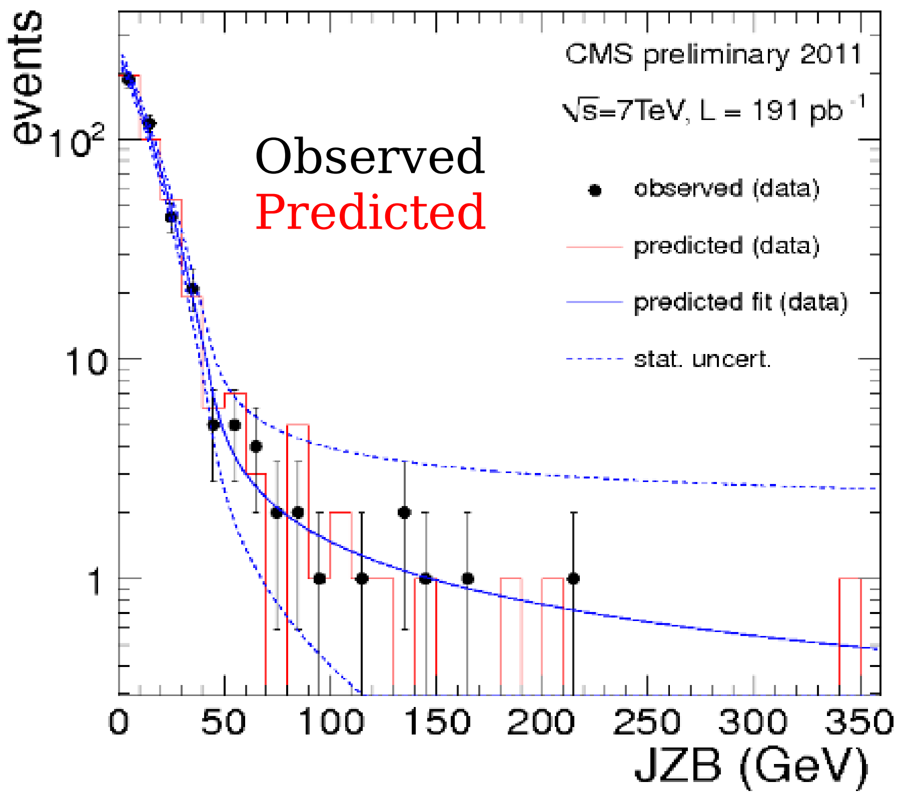
Substantial tail for SUSY in JZB > 0 events

Use JZB (<0) peak events to predict
JZB (>0) peak events after the eμ subtraction

Opposite sign di-leptons with Z (*Jet-Z* balance method)

Two regions defined: JZB > 50 GeV (reference region); JZB > 100 GeV (search region)





The background prediction has been fitted to ±σ display uncert. band

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)

Prediction agrees well with the observation in both regions

Opposite sign di-leptons with Z (MET template method)

New physics search similar to previously outlined:

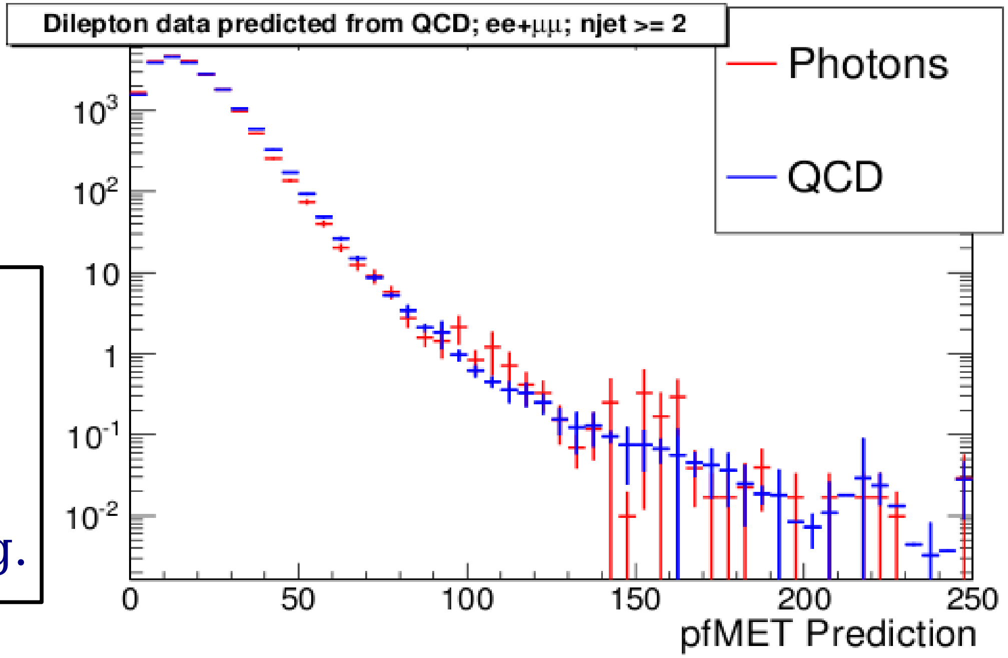
- It uses MET as the major discriminant
  - Two isolated leptons (e, μ): $p_T > 20$ GeV
  - At least 2 jets with $p_T > 30$ and $|\eta| < 3.0$
  - Require same-flavor pairs in Z mass window (81 – 101) GeV

Predicted MET in Z events from 2 complementary control samples are consistent within uncertainties

Two signal regions:

Loose region: MET > 100 GeV

Tight region: MET > 200 GeV



Dominant bkg from: Z + Jets & ttbar.

Use data-driven bkg estimation:

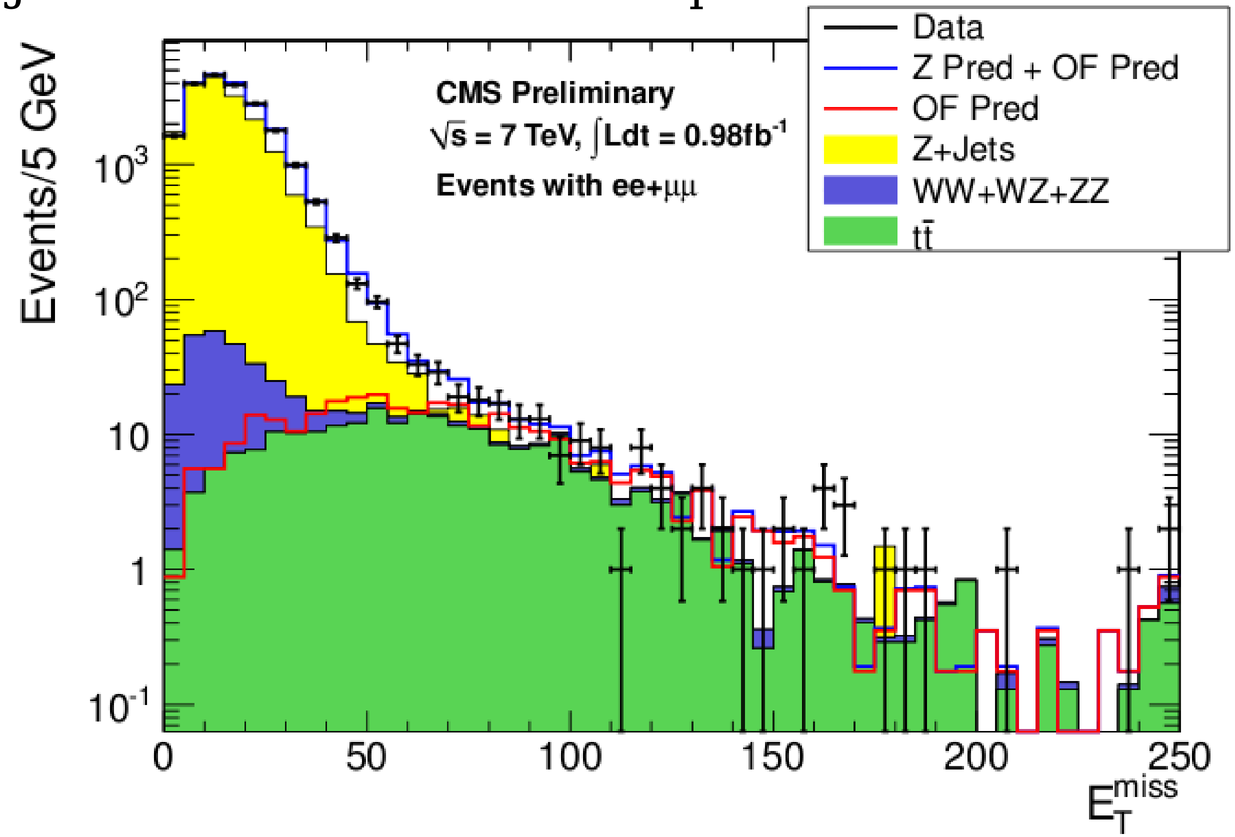
- MET template to model Z + Jets
- Flavor subtraction to model ttbar bkg.

Construct MET templates by studying MET in control samples (QCD & photon +Jets)

- Bin in Scalar sum p_T and njets
- Binning accounts for MET dependence on these two variables
- Form prediction by summing templates corresponding to sum jet P_T and njet of each Z event passing pre selection (Verified the prediction using MC)

Opposite sign di-leptons with Z (MET template method)

Use photon + Jets events for the MET template



	$E_T^{miss} > 30$ 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

No excess of data over prediction in signal regions ⇒ Upper limit

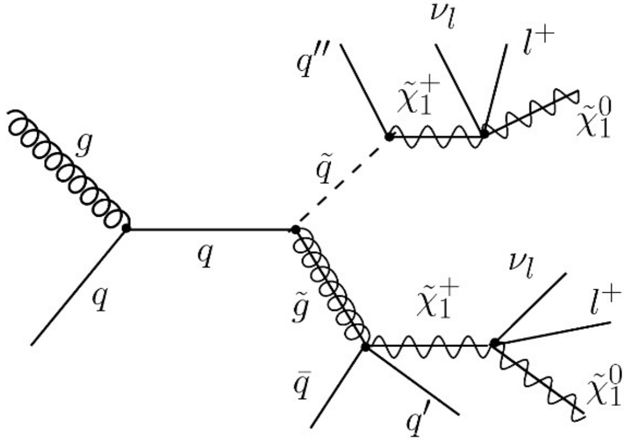
Inclusive Searches with data driven background predictions

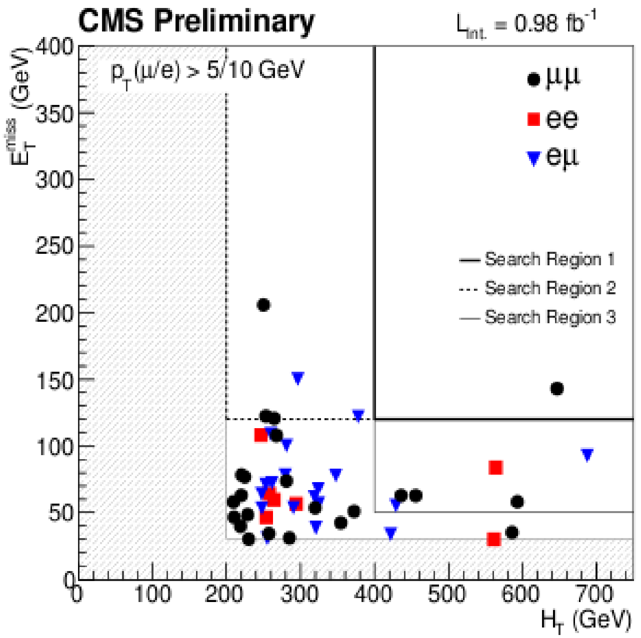
- Same sign di-leptons searches (CMS SUS-11-010)

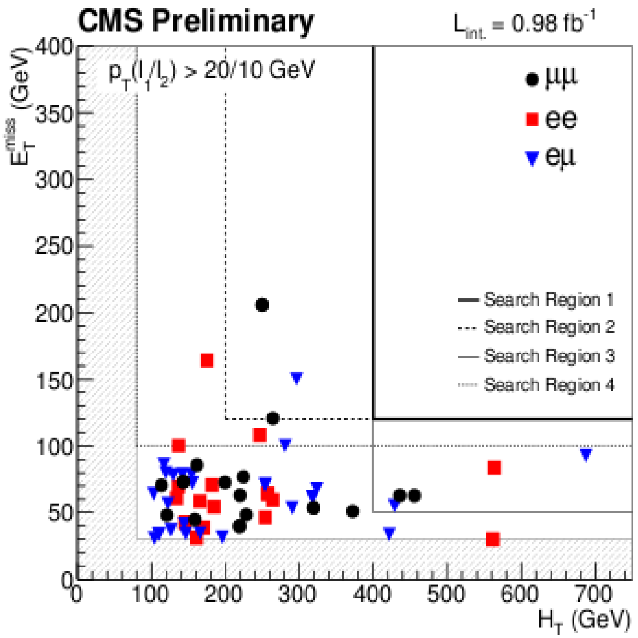
Same sign dilepton search

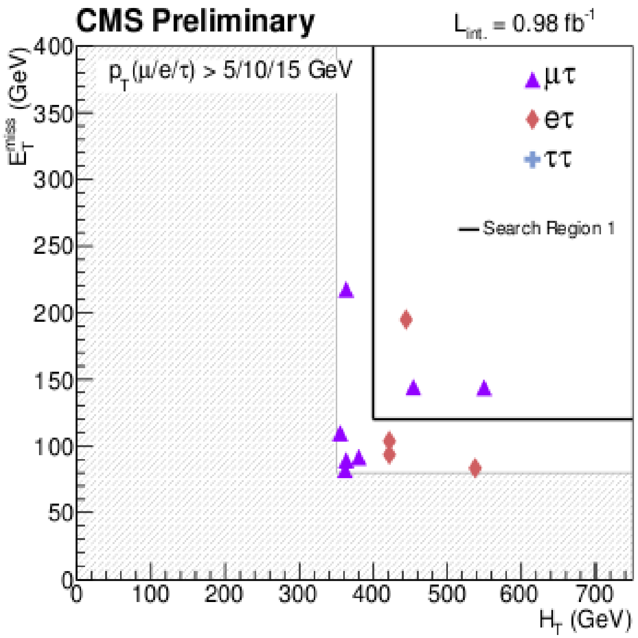
- Isolated same sign dileptons (SS) are very rare in the SM
- Several search regions with three lepton flavors (e, μ, τ) are studied
- A natural SUSY signature
- All cross channels are included in

three lepton flavors :







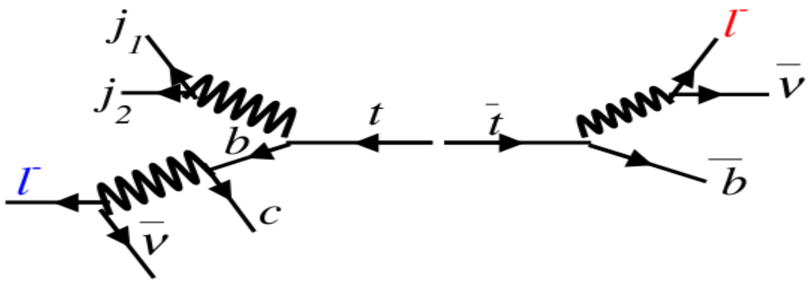


Same sign dilepton search

Major Backgrounds:

- "~Fake" leptons from ttbar (b/c → e,μ)
- Charge Mis-reconstruction
- QCD fakes in case of tau final states

Isolated lepton



Non-isolated lepton = "fake" lepton

- **We use data-driven methods based upon an extrapolation from the analysis selection to a region defined by looser lepton requirements.**

- Two distinct methods for both electrons and muons
  - **Method A**
    - Method A1 (applied to inclusive and high-p_T leptons)
    - Method A2 (applied to high-p_T leptons)
  - **Method B** (applied to inclusive leptons)
    - Assumes that single fakes come from b-decays in ttbar events
    - Uses different methods to estimate single and double fakes.

- **For τaus:**
  - Loose τau selection relaxes isolation and requirement that the τau pass the hadronic decay mode reconstruction.

SS Background estimation – Method A

Define a "Tight" and a "Loose" lepton selection:

- "Loose" is essentially extrapolation in isolation

Measure "Tight-to-Loose Ratio" a.k.a "Fake Rate" in an unbiased sample

FR = (# evts passing tight)/ (# evts passing loose)

Measure this as a function of f(p_T, η).

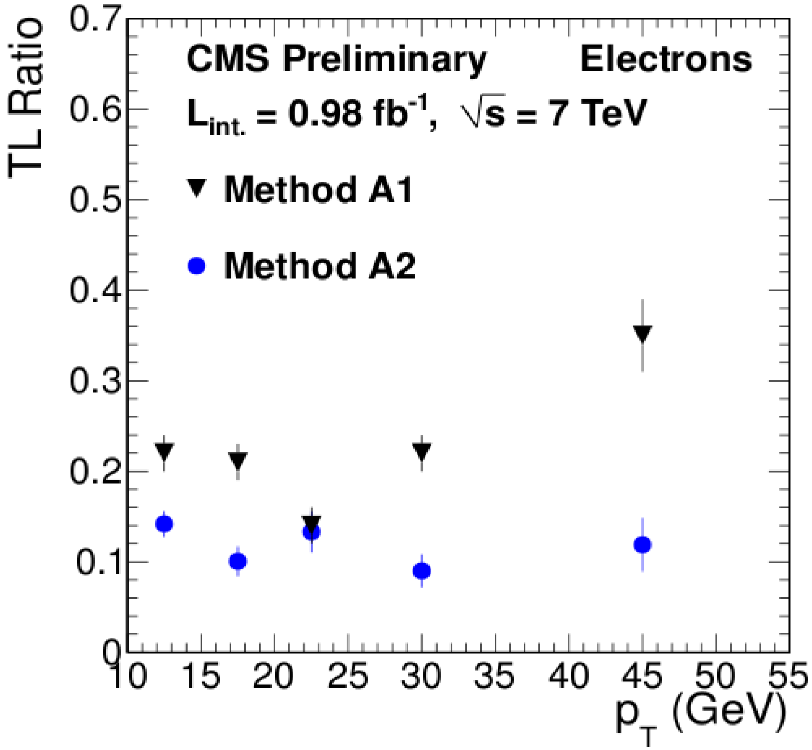
Apply to f(p_T, η) sample with:

- Two loose to estimate double fake (QCD)
- One tight one loose to estimate single fakes
- Total = Combination of the above two estimates

Methods A1(A2) use different extrapolations.

- A1 uses extrapolation in lepton isolation
- A2 uses extrapolation in ID and Isolation

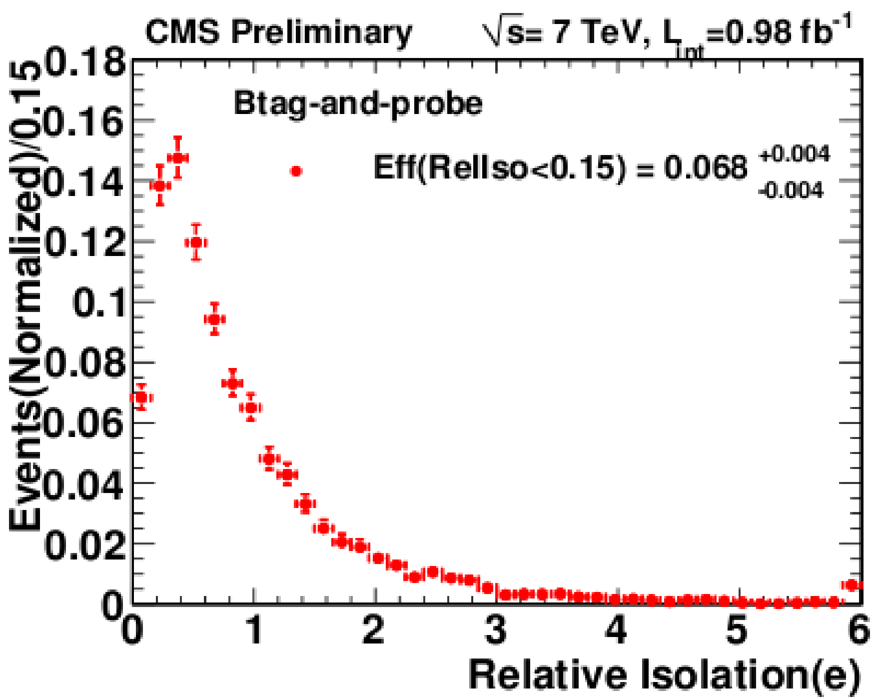
Muons similar, see backup

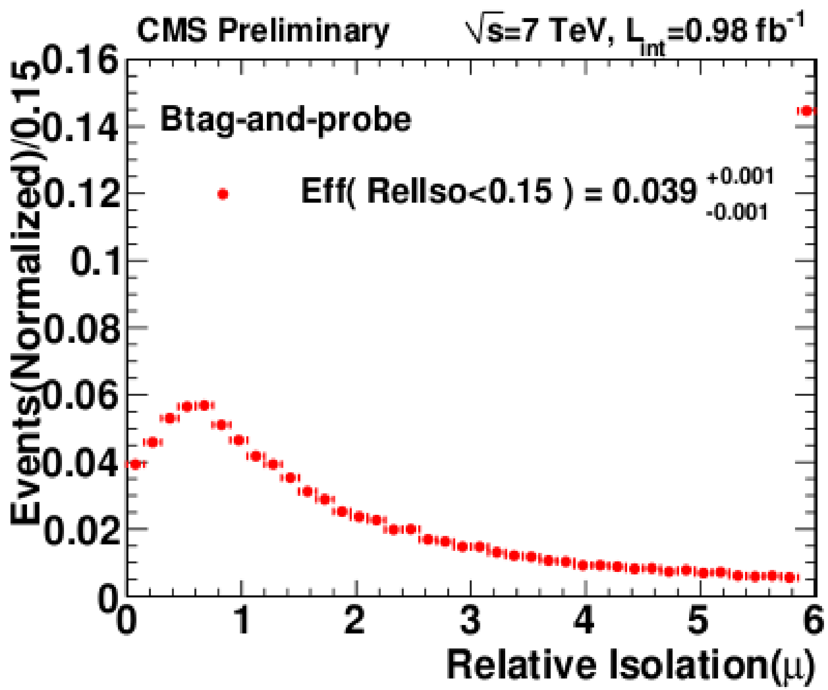


The systematic uncert. is evaluated based on closure tests and dependence of the TL ratio on the away jet p_T and the sample composition

SS Background estimation – (Method B)

Measure background from b/c → e,μ





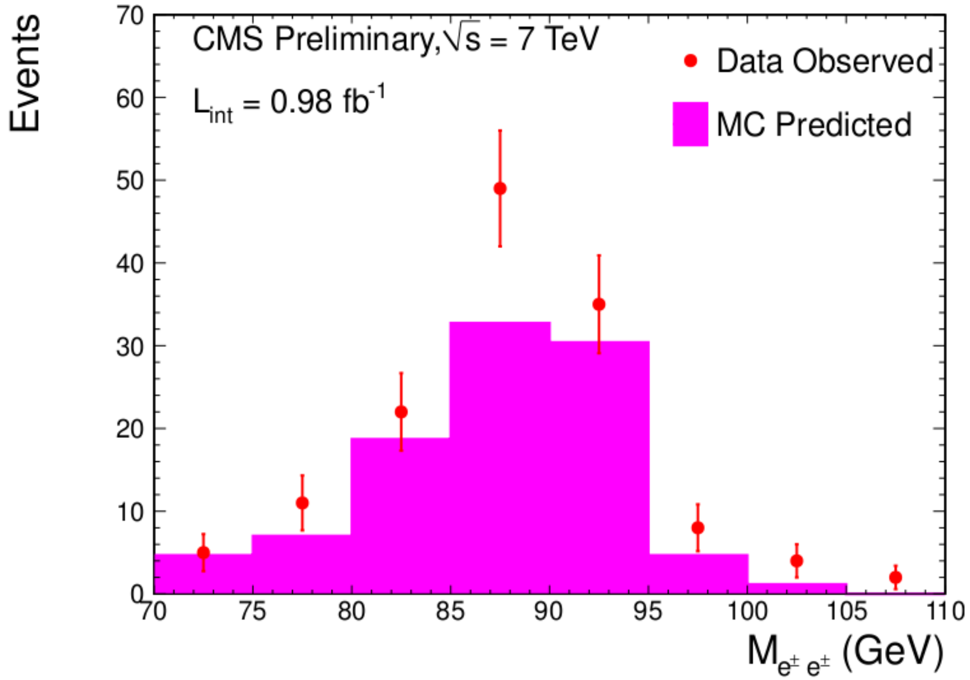
- Use tag and probe in bbbar (QCD) events to measure isolation efficiency
- Re-weight this distribution to reflect lepton p_T and Njets in ttbar expectation
- Use this isolation efficiency to determine background

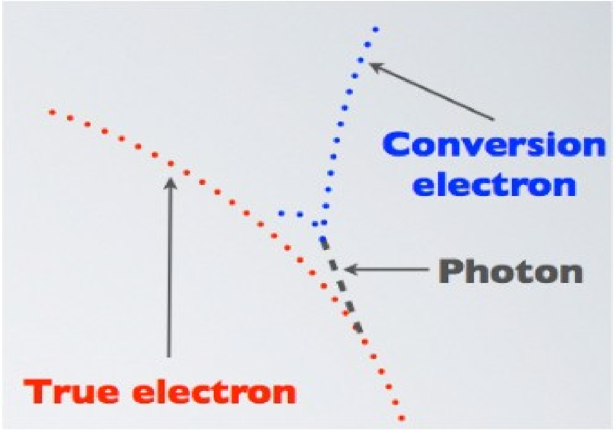
SS Background estimation – Charge Mis-reconstruction

Electron momentum is measured (mostly) by ECAL

Electron charge is measured (mostly) by tracker

- Charge mis-measurement leaves the momentum unchanged





Hard brems followed by conversion can lead to Charge mismeasurement

Same sign Z to ee in data and MC (veto W using MET < 20 and M_T < 25 GeV requirements)

Measure the mis-measurement rates in data Or MC [e.g: SS/(OS + SS) Z bosons]

- Mis-Charge Rate $\sim 10^{-4}$ in barrel, and $\sim 10^{-3}$ at $|\eta| \sim 1.5$.

Apply the rate to OS dilepton sample with exact same selections to get a prediction:

Control region: N(Observed) = 129, N(Predicted) = 100 ± 0.3, Expect 8 ± 4 from fake electrons

Results with High-p_T dileptons

Search Region (minimum H_T / E_T^{miss})	ee	$\mu\mu$	$e\mu$	Total	95% CL UL yield
Region 1 (400 / 120)					
Predicted background by (A1)	0.4 ± 0.3	0.4 ± 0.3	0.7 ± 0.4	1.4 ± 0.7	
Predicted background by (A2)	0.7 ± 0.5	0.4 ± 0.3	0.4 ± 0.3	1.4 ± 0.7	
Observed	0	0	0	0	3.0
Region 2 (400 / 50)					
Predicted background by (A1)	1.4 ± 0.8	1.3 ± 0.8	1.3 ± 0.6	4.0 ± 1.7	
Predicted background by (A2)	1.5 ± 0.8	0.8 ± 0.4	1.0 ± 0.5	3.3 ± 1.2	
Observed	1	2	2	5	7.5
Region 3 (200 / 120)					
Predicted background by (A1)	1.2 ± 0.7	1.5 ± 0.8	1.8 ± 0.8	4.5 ± 1.9	
Predicted background by (A2)	1.3 ± 0.7	1.8 ± 0.8	1.8 ± 0.7	4.9 ± 1.8	
Observed	0	2	1	3	5.2
Region 4 (80 / 100)					
Predicted background by (A1)	2.5 ± 1.2	2.6 ± 1.2	4.9 ± 2.2	10 ± 4	
Predicted background by (A2)	2.4 ± 1.0	3.6 ± 1.6	4.4 ± 1.6	10 ± 4	
Observed	3	2	2	7	6.0

No sign of any new physics anywhere

Same Sign dilepton search

Results with inclusive dileptons with H_T trigger

Search region (minimum H_T / E_T^{miss})	ee	$\mu\mu$	$e\mu$	Total	95% CL UL yield
Region 1 (400/120)					
Predicted background by (B)	0.2 ± 0.1	0.9 ± 0.3	0.9 ± 0.3	2.0 ± 0.7	
Predicted background by (A1)	0.4 ± 0.4	1.2 ± 0.8	0.7 ± 0.4	2.3 ± 1.2	
Observed	0	1	0	1	3.7
Region 2 (400/50)					
Predicted background by (B)	1.0 ± 0.4	2.3 ± 0.7	3.0 ± 1.0	6.2 ± 2.2	
Predicted background by (A1)	1.3 ± 0.7	2.5 ± 1.5	1.4 ± 0.7	5.3 ± 2.4	
Observed	1	4	2	7	8.9
Region 3 (200/120)					
Predicted background by (B)	0.8 ± 0.4	3.6 ± 1.3	3.4 ± 1.3	7.8 ± 2.9	
Predicted background by (A1)	1.5 ± 0.9	3.0 ± 1.6	2.1 ± 1.0	6.6 ± 2.9	
Observed	0	4	2	6	7.3

Include hadronic τ channels: $e\tau$, $\mu\tau$ and $\tau\tau$

- Backgrounds from QCD jets faking hadronic τ's
- Use similar tight to loose probability to predict the background

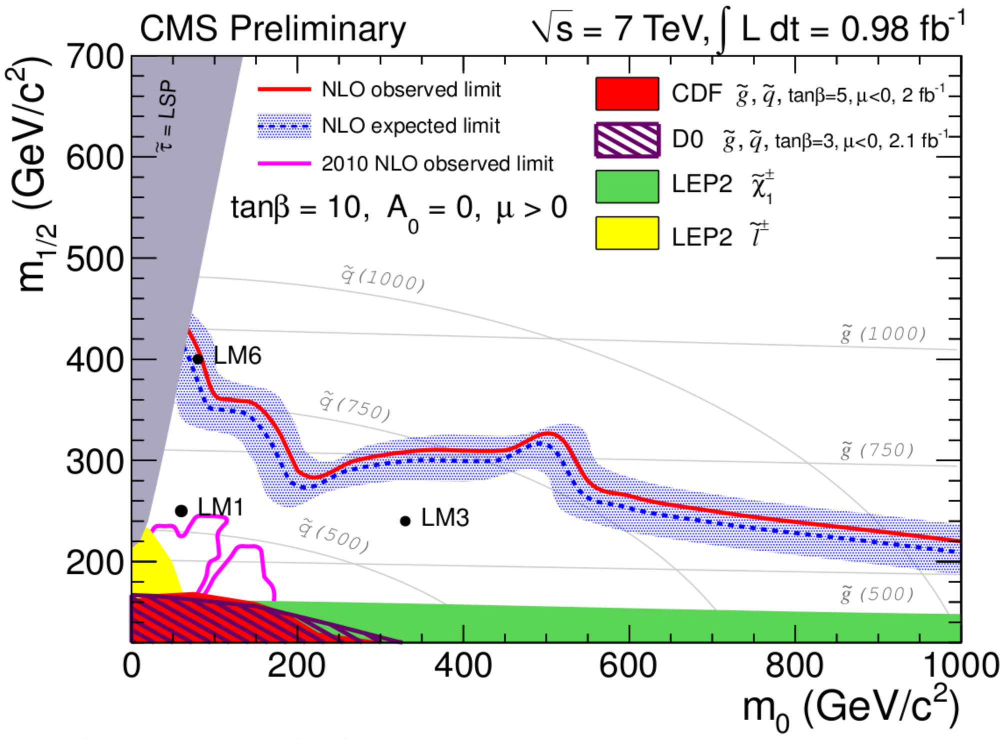
Search Region (minimum H_T / E_T^{miss})	$e\tau$	$\mu\tau$	$\tau\tau$	Total	95% CL UL yield
Region 1 (400/120)					
Predicted background	1.1 ± 0.4	1.8 ± 1.4	0.0 ± 0.2	2.9 ± 1.7	
Observed	1	2	0	3	5.8

No sign of any new physics anywhere

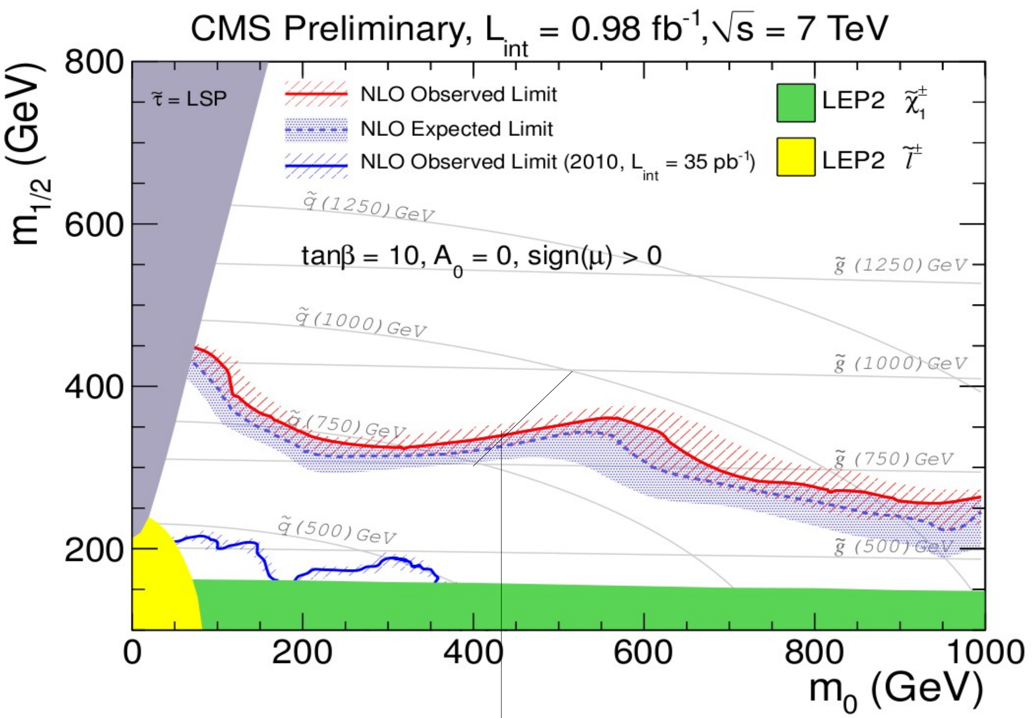
Exclusion limits/Interpretation of results

Limits using CMSSM framework

OS dileptons study



SS dileptons study

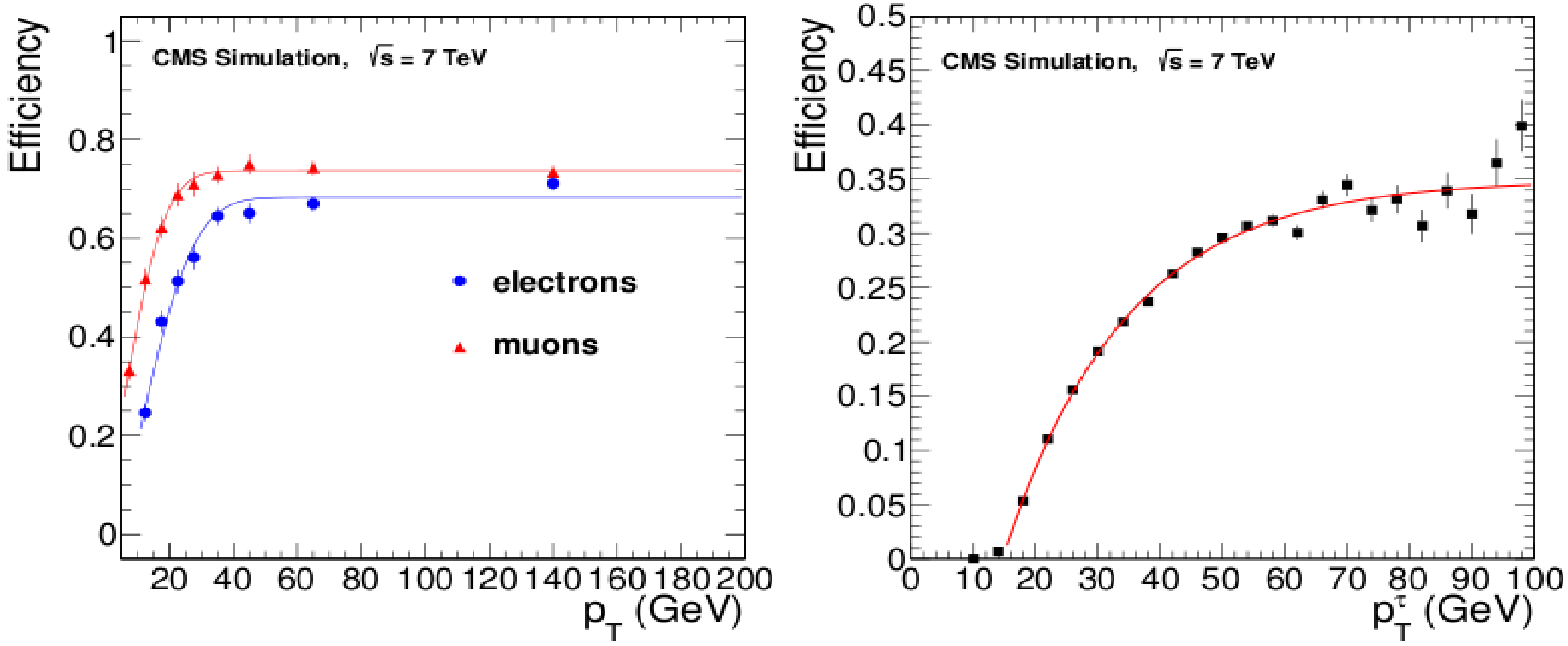


- CMS exclusion reach is well beyond previous Tevatron limits
- **Assuming same squarks and gluino masses**

CMS using 0.98 fb^{-1} excludes @ 95% CL., M_{SUSY} ~ 825 GeV

Information to test variety of specific physics models

We provide additional information needed for Model Testing



1. Different lepton efficiencies and Jet/MET response parameterizations are provided in order to test specific models

2. Upper limit on (σ x BR x Acceptance) is provided for all presented analyses

   (See details in the references)

Summary and Conclusion

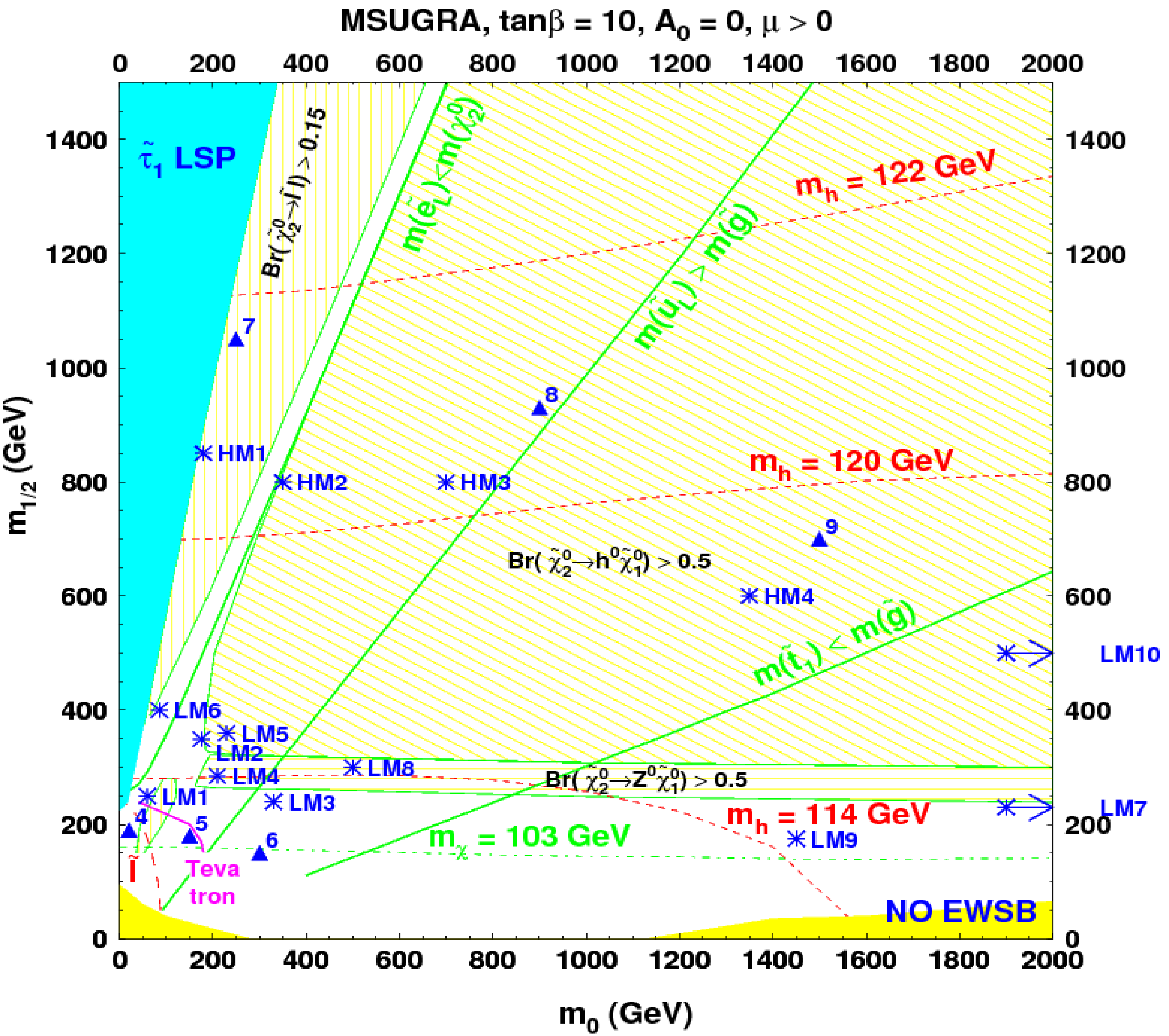
- Presented new SUSY searches with di-leptons, including opposite and same-sign dileptons
- In all cases, dominant backgrounds are estimated from the data itself with minimal reliance on Monte Carlo
- Unfortunately using ~ 0.98 fb^{-1} no new physics was found

  ⇒ We set limits using different SUSY frameworks
- CMS experimental exclusions covers a new territory in the (m_0 & $m_{1/2}$) squark and gluino mass regime

  ⇒ Extended the limits significantly

Backup Slides

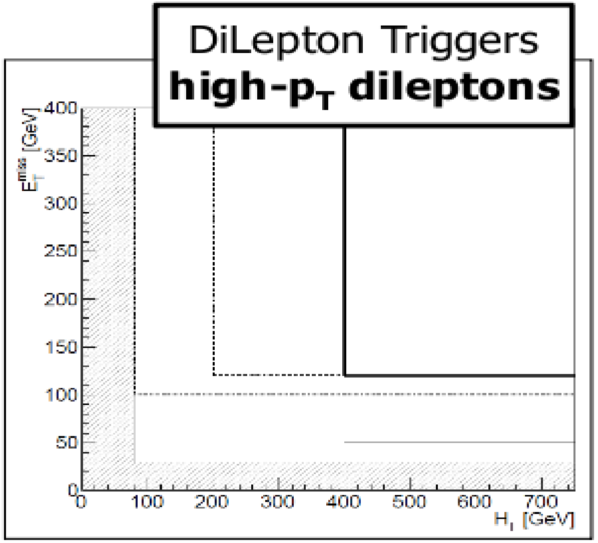
CMS benchmark points

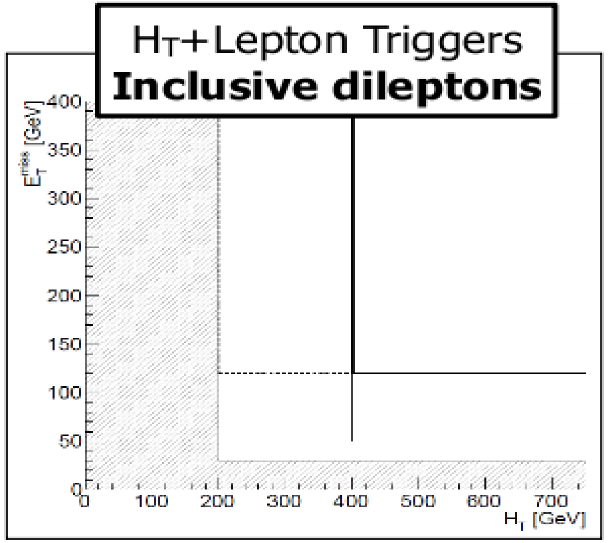


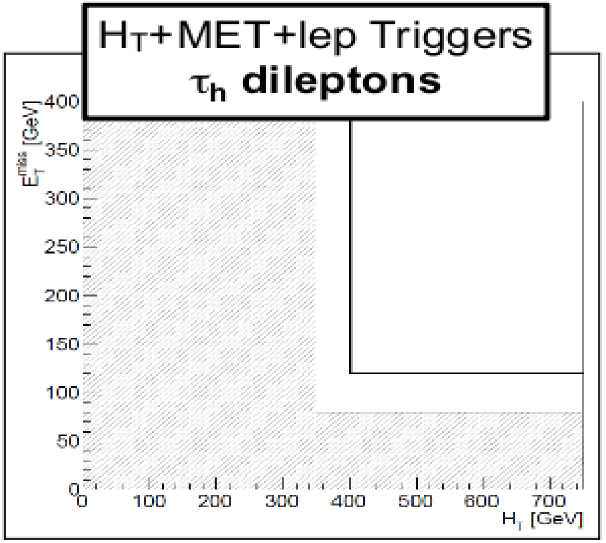
Same sign dilepton search

Isolated same sign dileptons (SS) are very rare in the SM

Several search regions with three lepton flavors (e, μ, τ) are studied

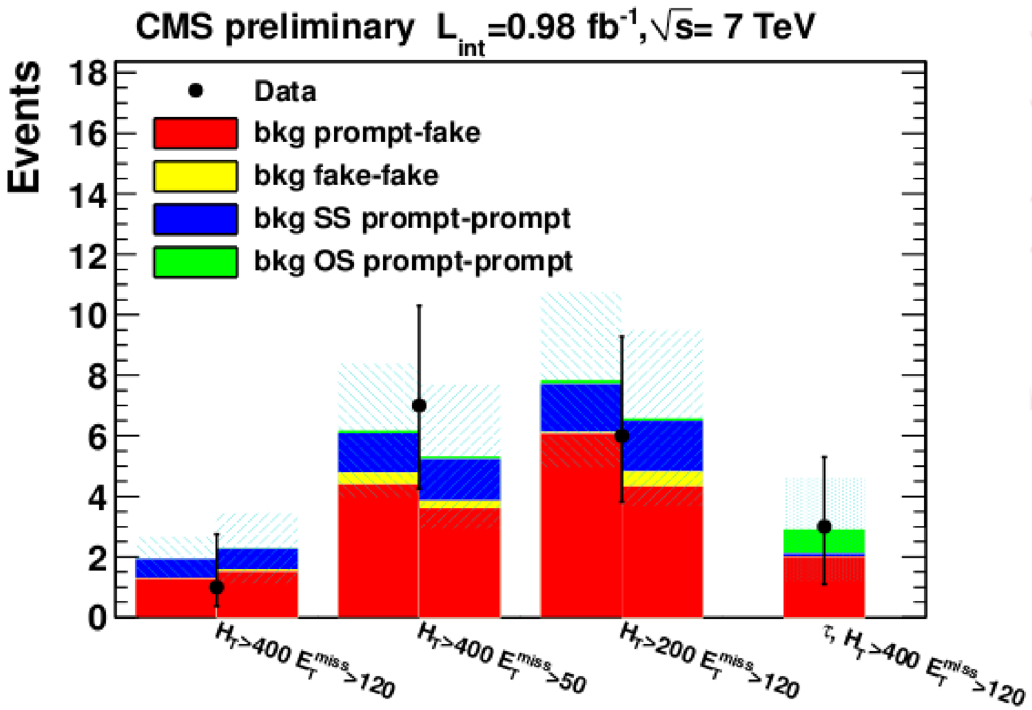


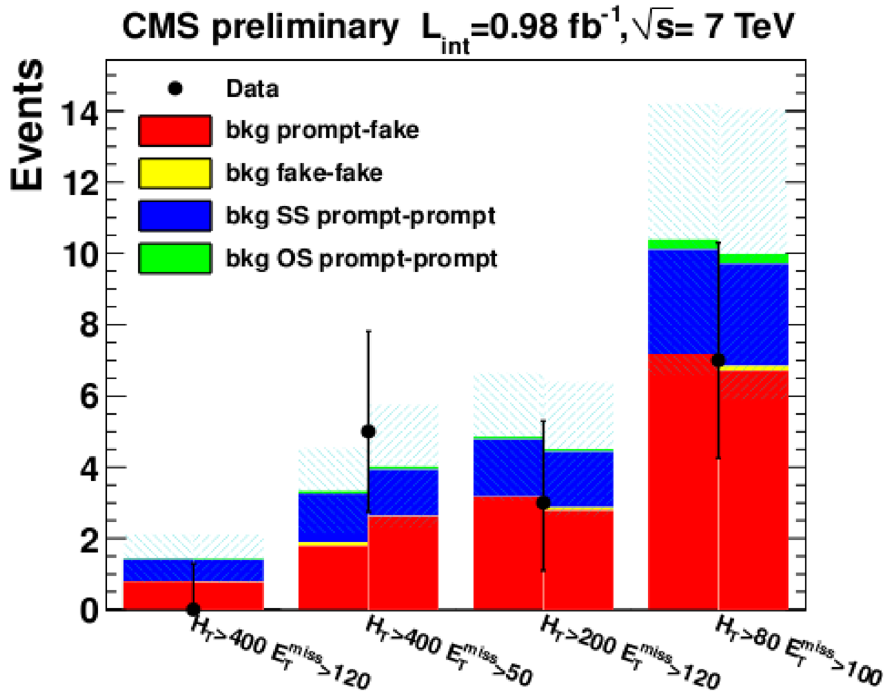




Region 1 $(ee, \mu\mu, e\mu)$: **leptons p_T > 20/10** **H_T > 400 MET > 120**	**Region 1** $(ee, \mu\mu, e\mu)$: **mu p_T > 5, ele p_T>10** **H_T > 400 MET > 120**	**Region 1** $(e\tau, \mu\tau, \tau\tau)$: **mu p_T > 5, ele p_T > 10, tau p_T> 15** **H_T > 400 MET > 120**
Region 2 $(ee, \mu\mu, e\mu)$: **leptons p_T > 20/10** **H_T > 200 MET > 120**	**Region 2** $(ee, \mu\mu, e\mu)$: **mu p_T > 5, ele p_T>10** **H_T > 200 MET > 120**	
Region 3 $(ee, \mu\mu, e\mu)$: **leptons p_T > 20/10** **H_T > 400 MET > 50**	**Region 3** $(ee, \mu\mu, e\mu)$: **mu p_T > 5, ele p_T>10** **H_T > 400 MET > 50**	
Region 4 $(ee, \mu\mu, e\mu)$: **leptons p_T > 20/10** **H_T > 80 MET > 100**		

SS Yields -signal regions





Trigger Rates in Hz

Hadronic triggers (a few examples from recent runs):

Path	Rate @ 2.3e32	Rate @ 5e32	Estimate @ 5e32
HT250_MHT60	6.5	14.1	14.0
HT300_MHT75	1.8	3.9	3.8
Meff440	6	13.0	
Meff520	2.8	6.1	9.4*

Leptonic triggers (a few examples from recent runs):

Path	Rate @ 2.3e32	Rate @ 5e32	Estimate @ 5e32
DoubleMu6	4.2	9.1	
DoubleMu7	2.2	4.8	5.9
Ele17_CaloIdL_CaloIsoVL_Ele8_CaloIdL_CaloIsoVL	3	6.5	11
Mu17_Ele8_CaloIdL	0.8	1.7	2
Mu8_Ele17_CaloIdL	2	4.3	7

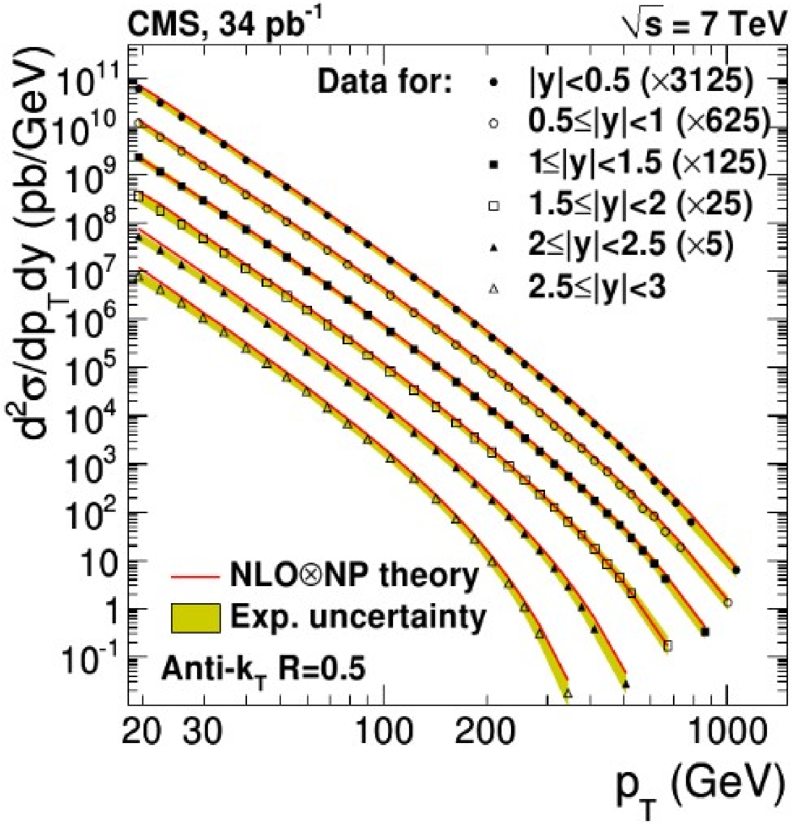
Trigger Rates in Hz

Cross triggers (a few examples from recent runs):

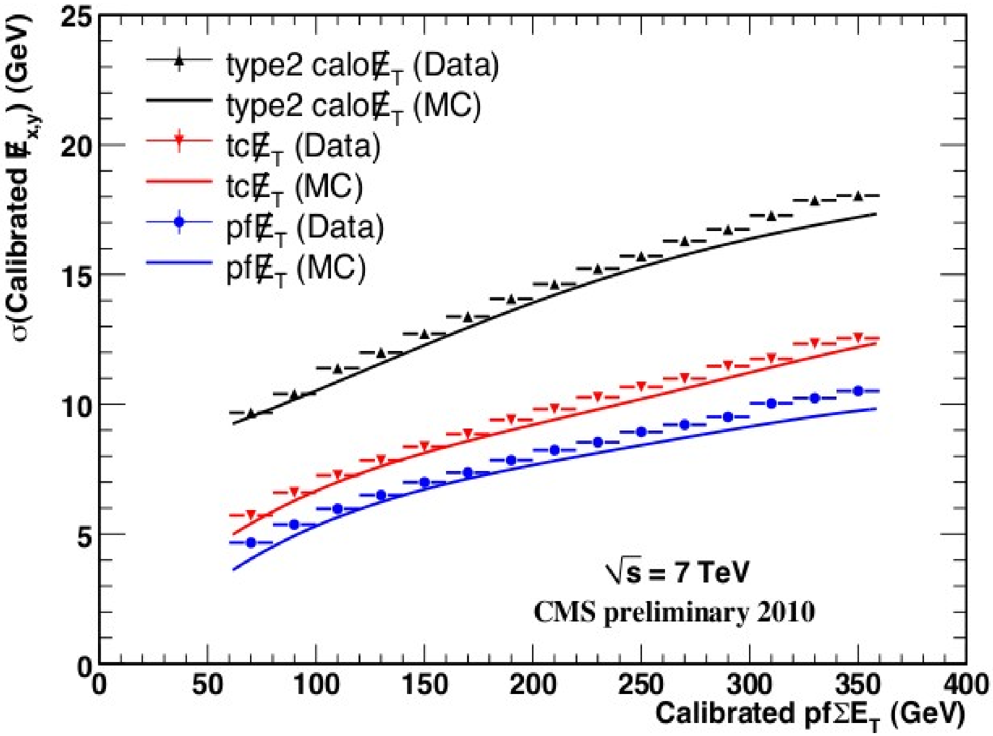
Path	Rate @ 2.3e32	Rate @ 5e32	Estimate @ 5e32
Ele10_CaloIdL_CaloIsoVL_TrkIdVL_TrkIsoVL_HT20	2.6	5.7	~7 Hz
Ele10_CaloIdT_CaloIsoVL_TrkIdT_TrkIsoVL_HT200	1.1	2.4	
Mu5_HT200	5	10.9	
Mu8_HT200	2.5	5.4	5.5
DoubleMu3_HT160	0.4	0.9	2.0
DoubleMu3_HT200	0.25	0.5	1.0
Mu3_Ele8_CaloIdL_TrkIdVL_HT160	1.3	2.8	3
Mu3_Ele8_CaloIdLT_TrkIdVL_HT160	0.5	1.1	1.5
DoubleEle8_CaloIdL_TrkIdVL_HT160	1.2	2.6	2
DoubleEle8_CaloIdT_TrkIdVL_HT160	0.3	0.7	1

Performance of Jets and MET

CMS-QCD-10-011



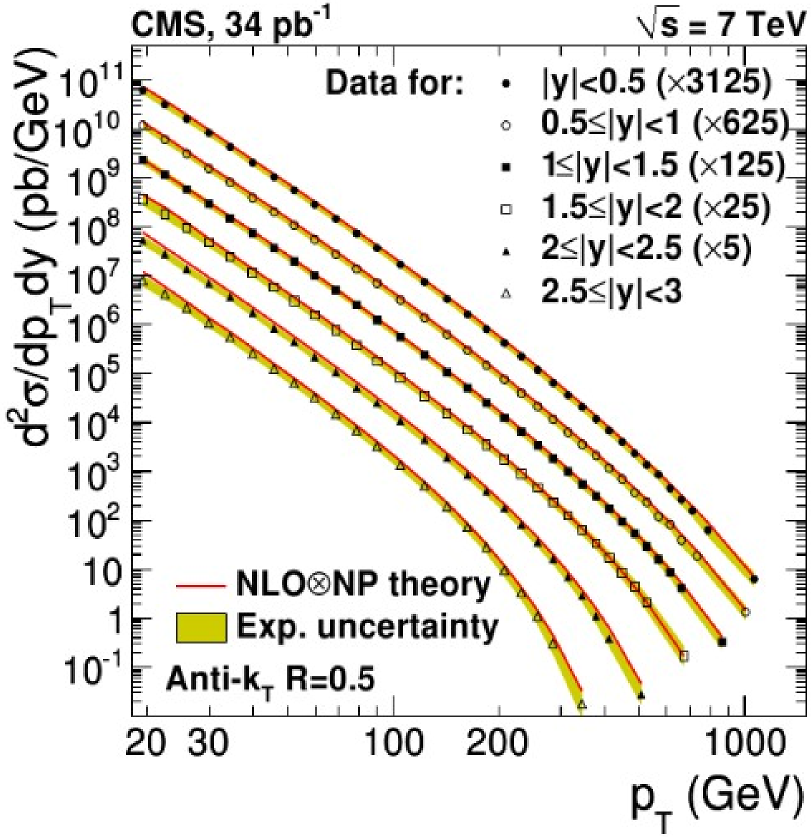
CMS-PAS-JME-10-004



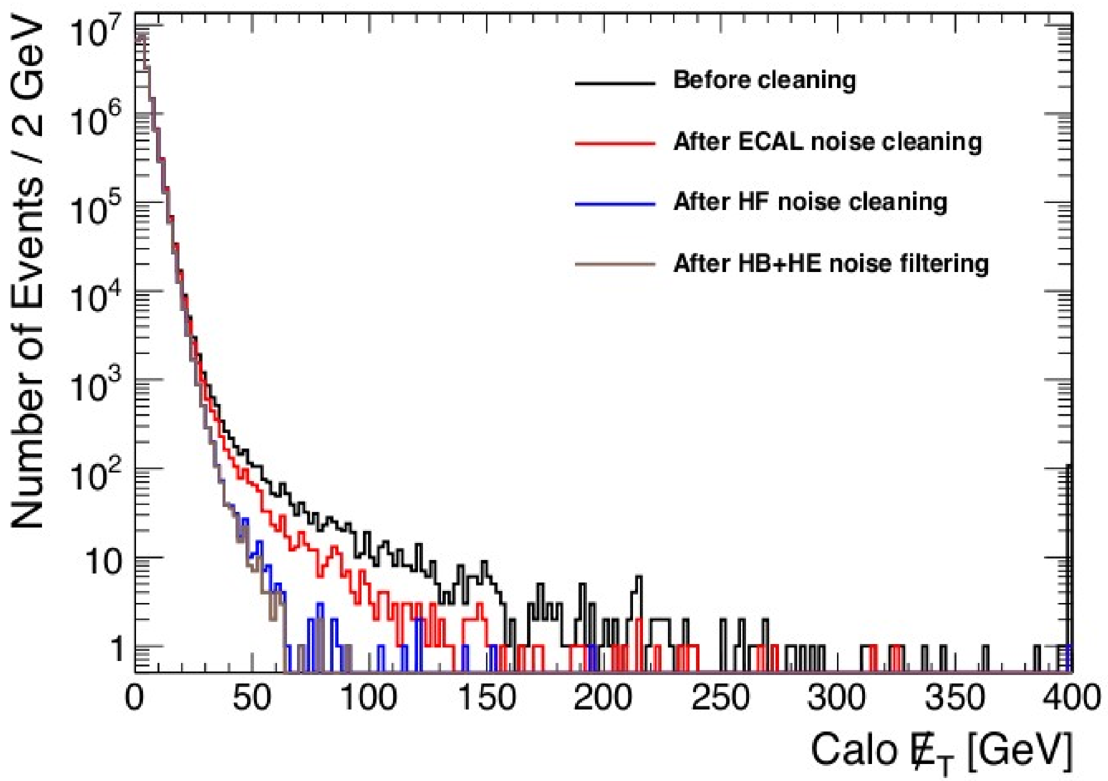
- Measurements of jet cross sections and MET resolution
- Jets and MET in good shape

Performance of Jets and MET

CMS-QCD-10-011



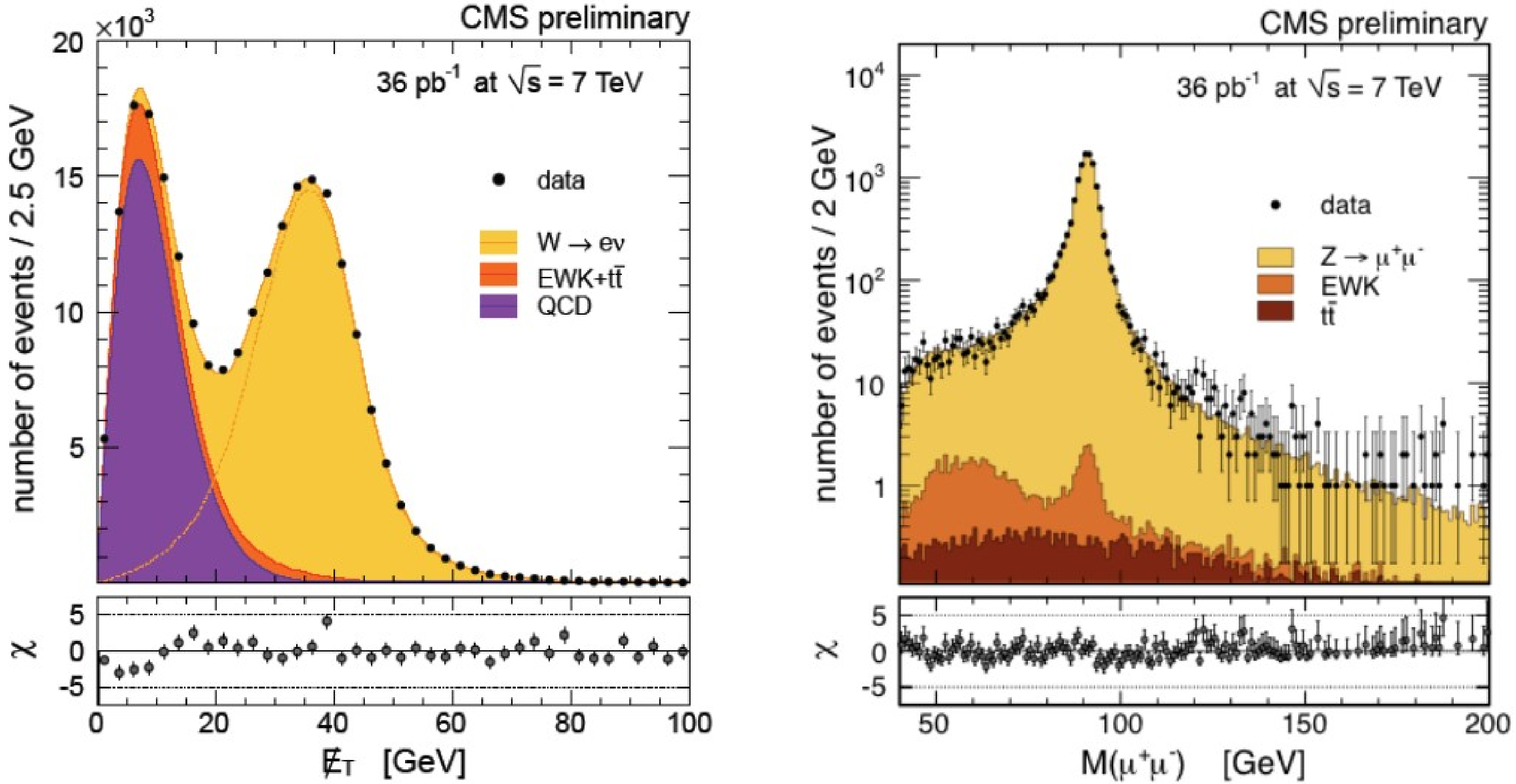
CMS-PAS-JME-10-004



- Measurements of jet cross sections and MET resolution
- Jets and MET in good shape

Lepton Performance

CMS-EWK-10-005

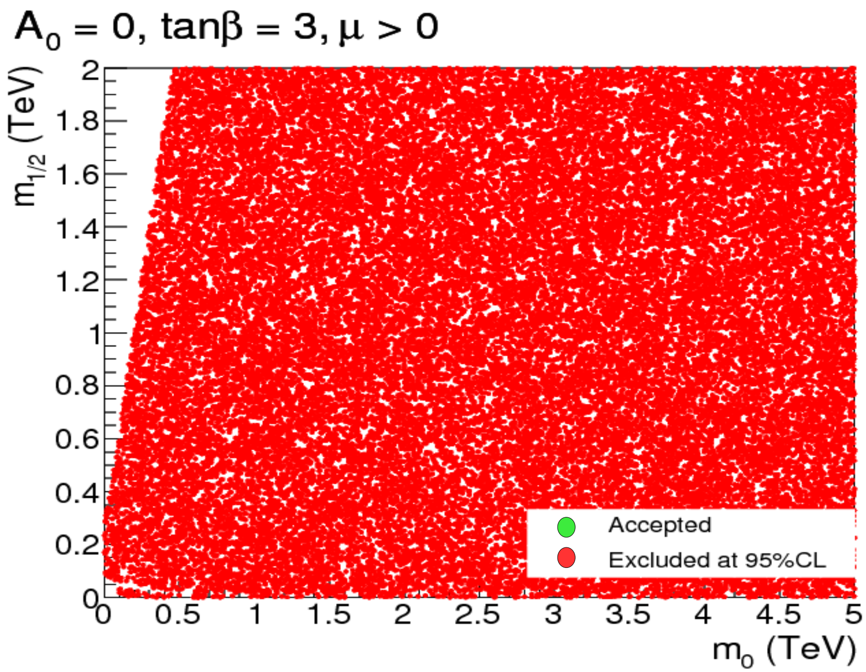


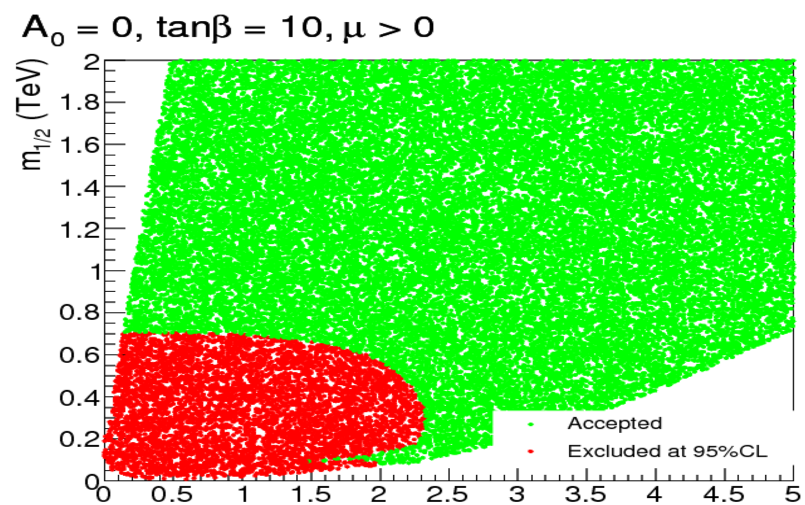
- Beautiful reconstruction of W and Z bosons
- Leptons and MET reconstruction performing well

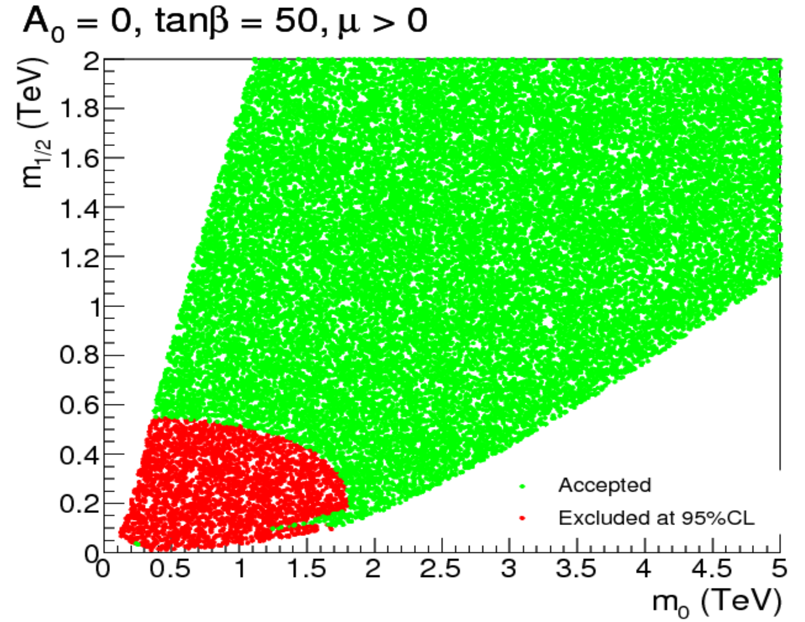
Limits using CMSSM framework

Consider Higgs mass limits from LEP (without uncert.)

Using Softsusy + Higgsbounds (SLHA interface via SuperIso 3.0): Plots by Sezen Sekmen







Results from hadron colliders (Tevatron, LHC) can probe direct squarks/gluino production to the highest scales in the world.

Major region of phase space is already excluded based on LEP higgs mass limit with this “EXACT” choice of parameters in the model

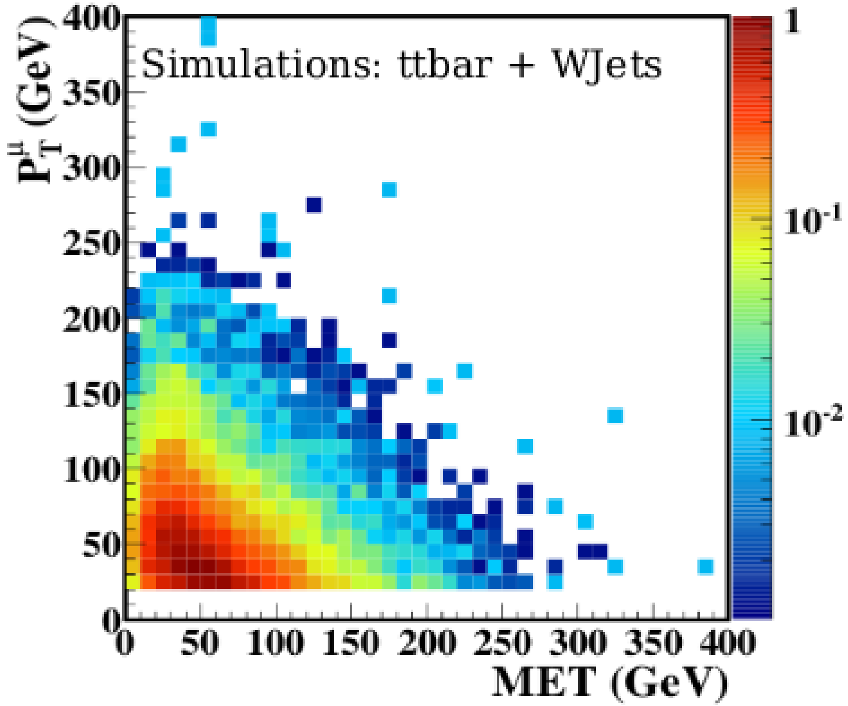
We use them in order to compare with previous LEP/Tevatron results

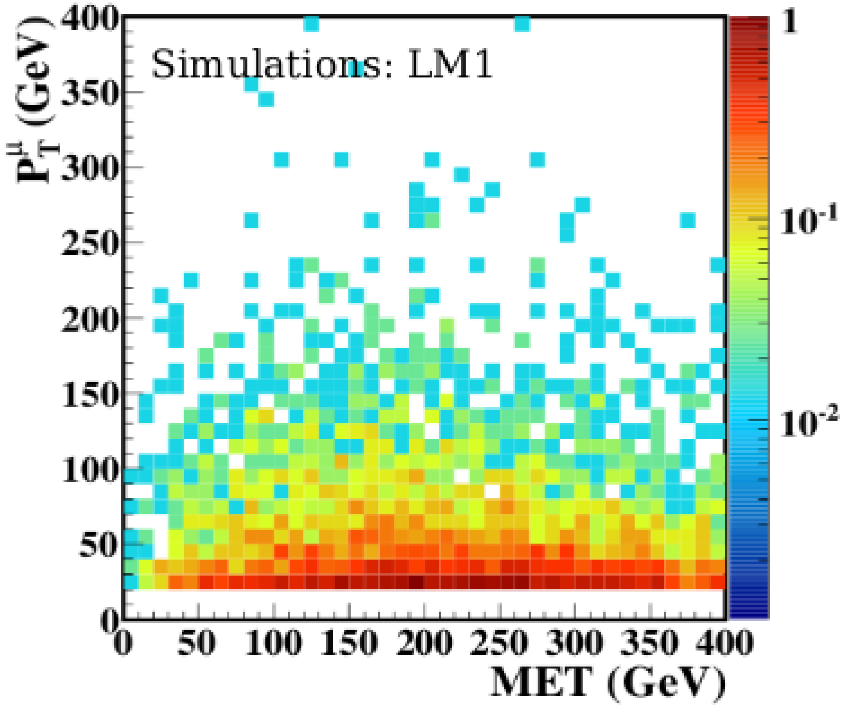
Lepton spectrum method

In SM events, the neutrino and lepton p_T are anti-correlated in a given event

$\Rightarrow$ Overall spectra are similar

In SUSY event, the correlation between MET and lepton p_T is very different.





- Main backgrounds: ttbar, W + Jets
- Use the muon p_T spectrum to predict the MET spectrum
- MET resolutions and W polarization effects are accounted for

Lepton spectrum method

- While lepton and neutrino p_T spectra are different in a given event, their spectra are very similar in SM processes
- Strong physics foundation for method but many details to check before lepton spectrum can be used to quantitatively predict the MET for SM
  - <u>MET resolution/scale</u>: Resolution of MET and lepton p_T are quite different and energy scale uncertainty on MET much be taken into account
  - <u>W polarization</u>: Due to V-A effects, W polarization of the W boson, in either Wjets or ttbar can lead to different angular distributions for the lepton and neutrino in the W rest frame. This can produce differences in lepton, neutrino p_T in lab frame
  - <u>Non single lepton background</u>: Lepton spectrum method predicts single lepton events but not tau→μ,e background and feed down from dilepton ttbar events
  - <u>Threshold on lepton p_T</u>: not applied to neutrino

Have investigated all these points and many more

Lepton spectrum method

Helicity fractions of W bosons from top quark decays at NNLO in QCD

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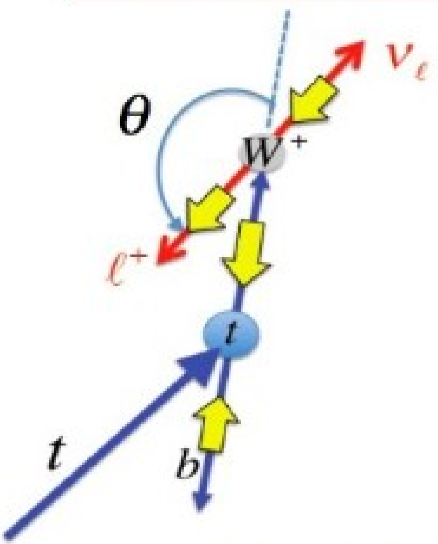
Department of Physics, University of Alberta, Edmonton, Alberta T6G 2G7, Canada
(Dated: May 18, 2010)

Decay rates of unpolarized top quarks into longitudinally and transversally polarized W bosons are calculated to second order in the strong coupling constant α_s. Including the finite bottom quark mass and electroweak effects, the Standard Model predictions for the W boson helicity fractions are $\mathcal{F}_L = 0.687(5)$, $\mathcal{F}_+ = 0.0017(1)$, and $\mathcal{F}_- = 0.311(5)$.



$\lambda(W) = -1$ (30%)
$\lambda(W) = \;\;0$ (70%)

- Helicity fractions are very precise prediction in SM theory, have been calculated with QCD corrections to NNLO.
- Errors on F_L and F_- are O(1%); due to m(top) uncertainty
- Reduces uncertainties due to W polarization in top events to very low level
- The boost is the same for lepton, neutrino
- Lepton, neutrino spectra are result of polarizations
- In ttbar understand fully where any differences in lepton, neutrino spectrum come from