SUSY searches in leptons + MET final states

LPCC BSM Jamboree: Status of Higgs and BSM searches at the LHC

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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
- All are counting experiments during 2010 phase

Outline

In this talk, results from CMS using ~35 pb^{-1} of data are summarized:

- **Inclusive Searches with data driven background predictions**
- **Exclusion limits/Interpretation of results**
  - Limits using CMSSM framework
  - Information to test variety of specific physics models
- **Generic topology based results**
  - Gauge mediation with slepton co-NLSP
  - Sneutrino LSP, slepton NLSP using dileptons
- **Summary and Conclusion**

R-Parity Violating studies are not covered in this talk. For details see:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Inclusive searches with data driven background predictions

- Single lepton studies [CMS PAS SUS-10-006]

- Opposite sign dileptons studies [arXiv: 1103.1348]

- Same sign dileptons studies [CERN-PH-EP-2011-033]

- Multi-lepton studies [CERN-PH-EP-2011-046]

Search Strategy for single-lepton and OS dilepton studies

- define baseline selection at moderate H_T (Sum Jet p_T) and MET
- show that data and MC expectations agree in baseline region

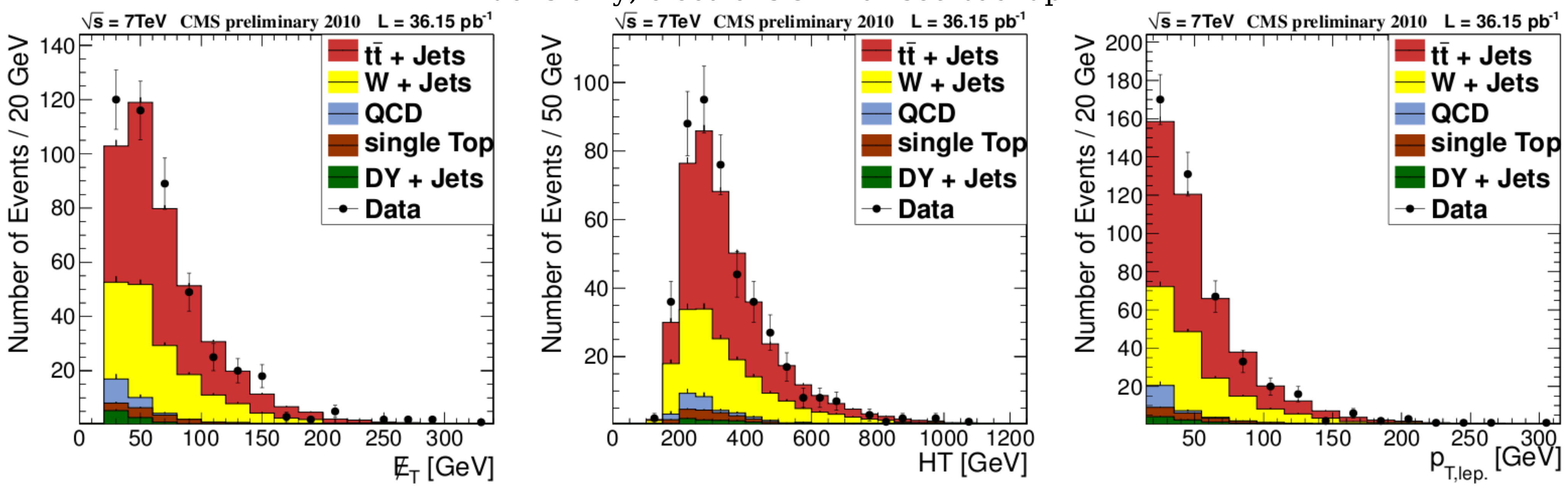
  ⇒ no massive new physics signals are present
- define signal region in tails of H_T and MET
- define two or more complementary data-driven prediction of SM background in signal region
- open the box, and look what's there.

Search in Single lepton events

Baseline selection:

- Require exactly one isolated electron or muon, $p_T > 20$ GeV
- At least 4 Particle Flow Jets with $P_T > 30$ GeV, $|\eta| < 2.4$
- Use MET (Particle Flow) > 25 GeV for baseline only.
- $H_T = \sum_{\text{jets}>20\text{ GeV}} p_T$ and $S_{MET} = \text{MET}/\sqrt{H_T}$ are used for Signal/Control regions

Muons only, electrons similar see backup



- SM simulations agrees well with the data
- Dominant contributions are from ttbar+Jets & W+Jets (~90%)
- Determine backgrounds from data ⇒

Search in Single lepton events – ABCD method

Use two different data driven methods for background estimation.

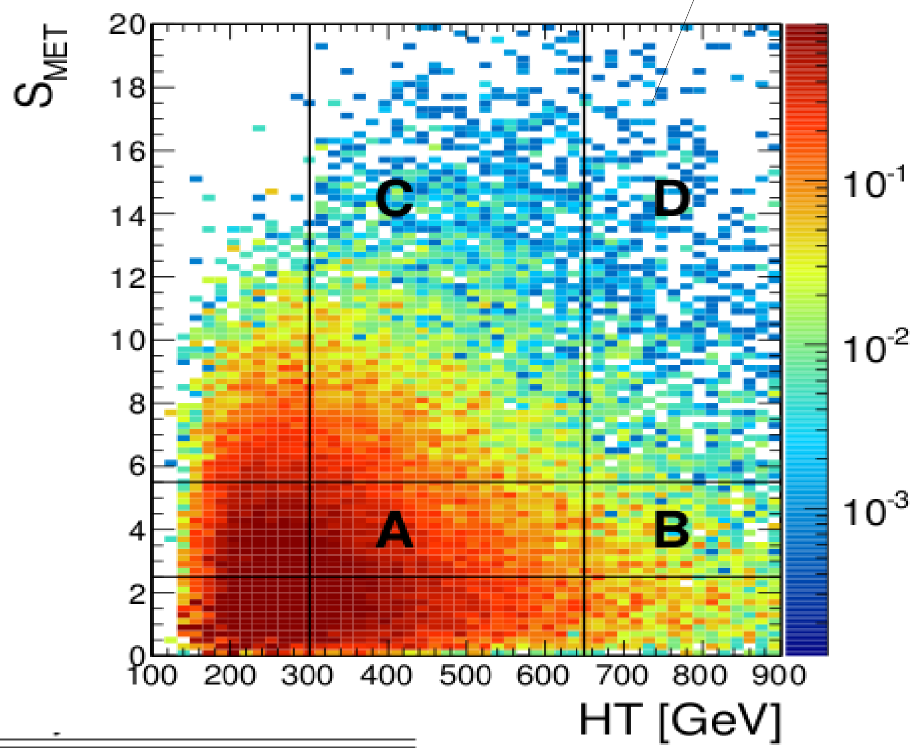
a) **ABCD (matrix method) using un-correlated variables**

b) Lepton spectrum method [Ref. 5]

Region	Tight selection	
	H_T	$\mathcal{S}_{\mathrm{MET}}$
A	$300 < H_T < 650$	$2.5 < \mathcal{S}_{\mathrm{MET}} < 5.5$
B	$650 < H_T$	$2.5 < \mathcal{S}_{\mathrm{MET}} < 5.5$
C	$300 < H_T < 650$	$5.5 < \mathcal{S}_{\mathrm{MET}}$
D	$650 < H_T$	$5.5 < \mathcal{S}_{\mathrm{MET}}$

$$N(D)_{\mathrm{pred}} = [N(C)/N(A)]\, N(B)$$

Signal region



sample	$N(A)$	$N(B)$	$N(C)$	$N(D)$	$N(D)_{\mathrm{pred}}$
μ channel: total SM MC	93.1 ± 1.1	8.7 ± 0.4	37.6 ± 0.7	3.4 ± 0.2	3.5 ± 0.2
μ channel: data	98.0 ± 9.9	4.0 ± 2.0	41.0 ± 6.4	5.0 ± 2.2	1.7 ± 0.9
e channel: total SM MC	76.8 ± 1.5	6.5 ± 0.3	29.5 ± 0.7	2.9 ± 0.2	2.5 ± 0.1
e channel: data	80.0 ± 8.9	4.0 ± 2.0	30.0 ± 5.5	2.0 ± 1.4	1.5 ± 0.8

SM in μ channel

$\pm$ 0.3 (syst.)

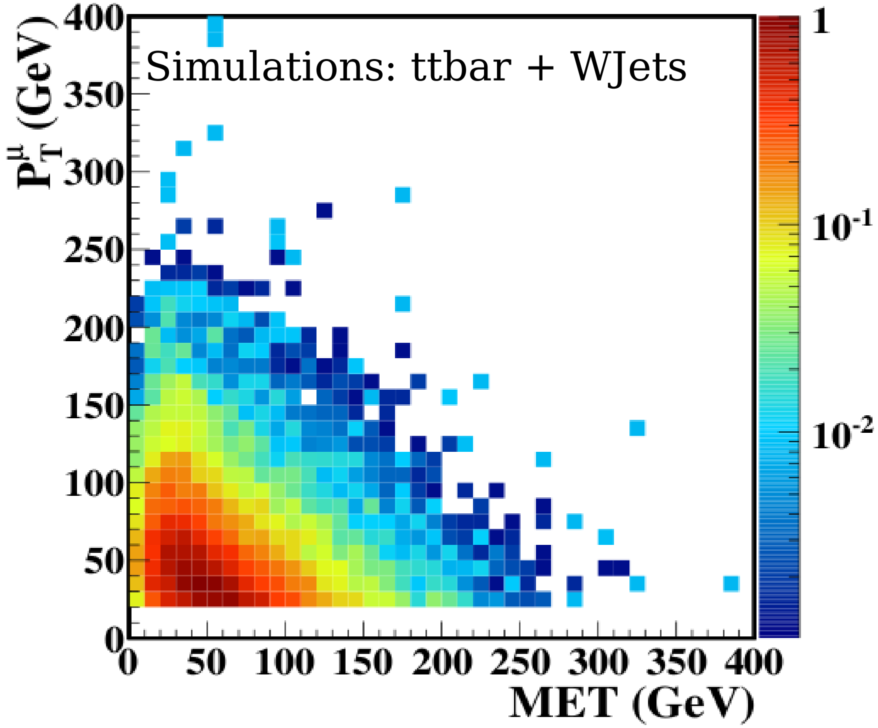
Observed: N(μ) = 5, N(e) = 2 ⇒ **Prediction agree with observation**

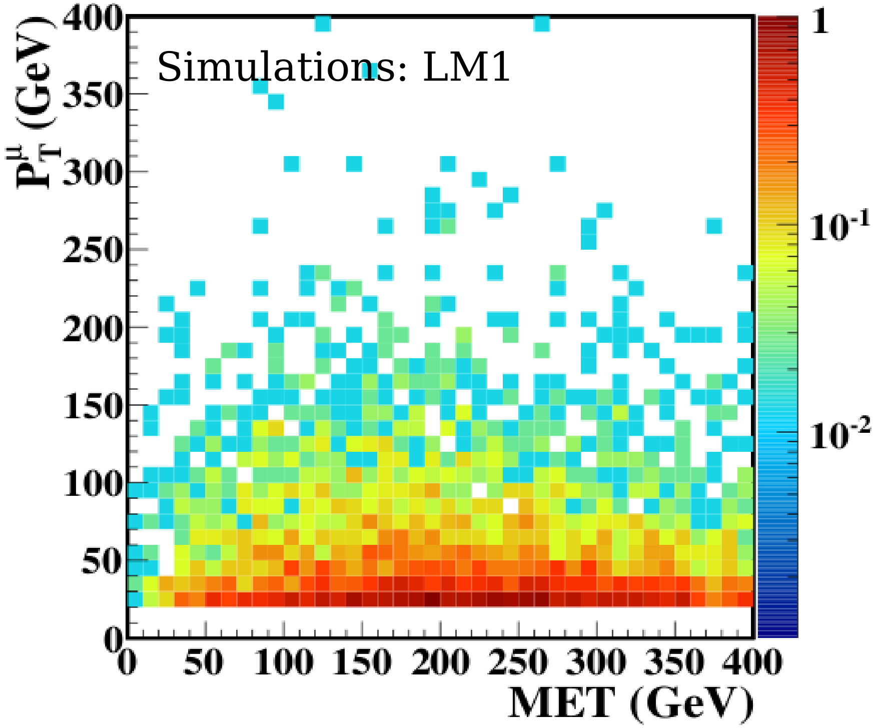
Search in Single lepton events – Lepton spectrum method

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

⇒ Overall spectra are similar

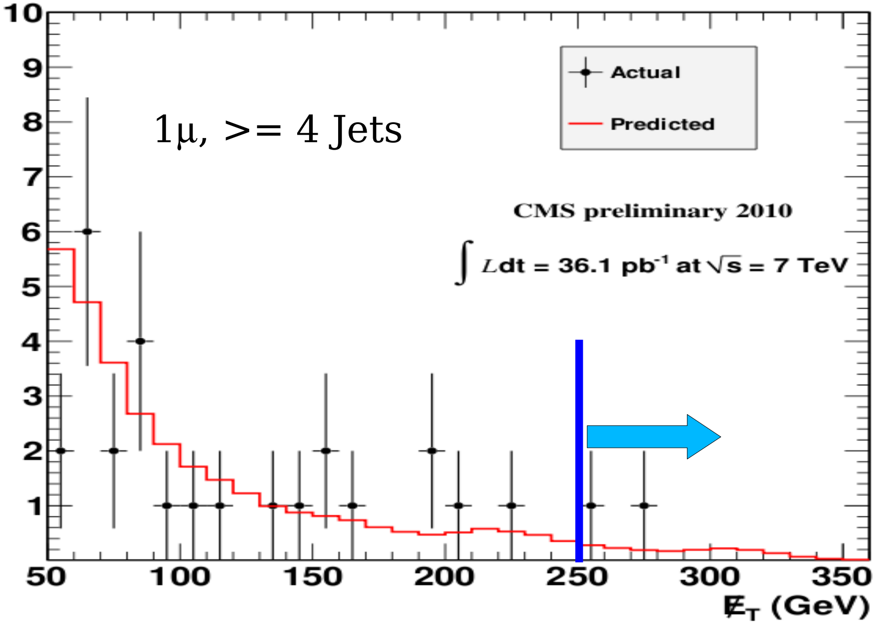
In SUSY event, the correlation between MET and lepton p_T is very different.

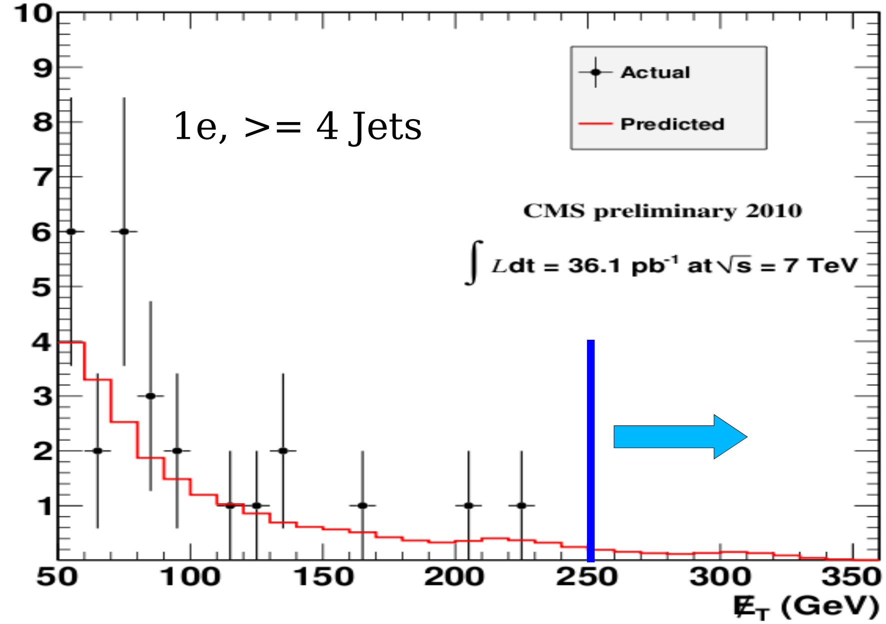




- Main backgrounds: ttbar, W + Jets
- Use the muon p_T spectrum to predict the MET spectrum
- MET resolutions and W polarization effects are accounted for [See backup]

Search in Single lepton events – Lepton spectrum method





Signal region: MET > 250 GeV, H_T > 500 GeV

Sample	$\ell = \mu$	$\ell = e$
Predicted SM 1 ℓ	1.7 ± 1.4	1.2 ± 1.0
Predicted SM dilepton	$0.0^{+0.8}_{-0.0}$	$0.0^{+0.6}_{-0.0}$
Predicted single τ	0.29 ± 0.22	$0.32^{+0.38}_{-0.32}$
Predicted QCD background	0.09 ± 0.09	$0.0^{+0.16}_{-0.0}$
Total predicted SM	2.1 ± 1.5	1.5 ± 1.2
Observed signal region	2	0

The observation is consistent with the background predictions

Opposite sign dilepton search

Adding a second lepton reduces W+Jets drastically, leaving mostly top

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

Baseline selection:

- 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 |η| < 2.5
- Veto same-flavor pairs in Z mass window (76, 106) and m_{ll} < 10 GeV

Sample	σ (pb)	ee	$\mu\mu$	$e\mu$	Total
$t\bar{t} \to \ell^+\ell^-$	16.9	14.50 ± 0.24	17.52 ± 0.26	41.34 ± 0.40	73.36 ± 0.53
$t\bar{t} \to$ other	140.6	0.49 ± 0.04	0.21 ± 0.03	1.02 ± 0.06	1.72 ± 0.08
Drell–Yan	18417	1.02 ± 0.21	1.16 ± 0.22	1.20 ± 0.22	3.38 ± 0.37
$W^{\pm}$ + jets	28049	0.19 ± 0.13	0.00 ± 0.00	0.09 ± 0.09	0.28 ± 0.16
W^+W^-	2.9	0.15 ± 0.01	0.16 ± 0.01	0.37 ± 0.02	0.68 ± 0.03
$W^{\pm}Z$	0.3	0.02 ± 0.00	0.02 ± 0.00	0.04 ± 0.00	0.09 ± 0.00
ZZ	4.3	0.01 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.05 ± 0.00
Single top	33.0	0.46 ± 0.02	0.55 ± 0.02	1.24 ± 0.03	2.25 ± 0.04
Total SM MC		16.85 ± 0.34	19.63 ± 0.34	45.33 ± 0.47	81.81 ± 0.67
Data		15	22	45	82

- Simulations agrees with the data [General event properties are well understood]

Use data driven backgrounds ⇒

Opposite sign dilepton search

Two data driven methods used in this search:

a) ABCD (matrix) method using un-correlated variables

b) Lepton spectrum method (described earlier)

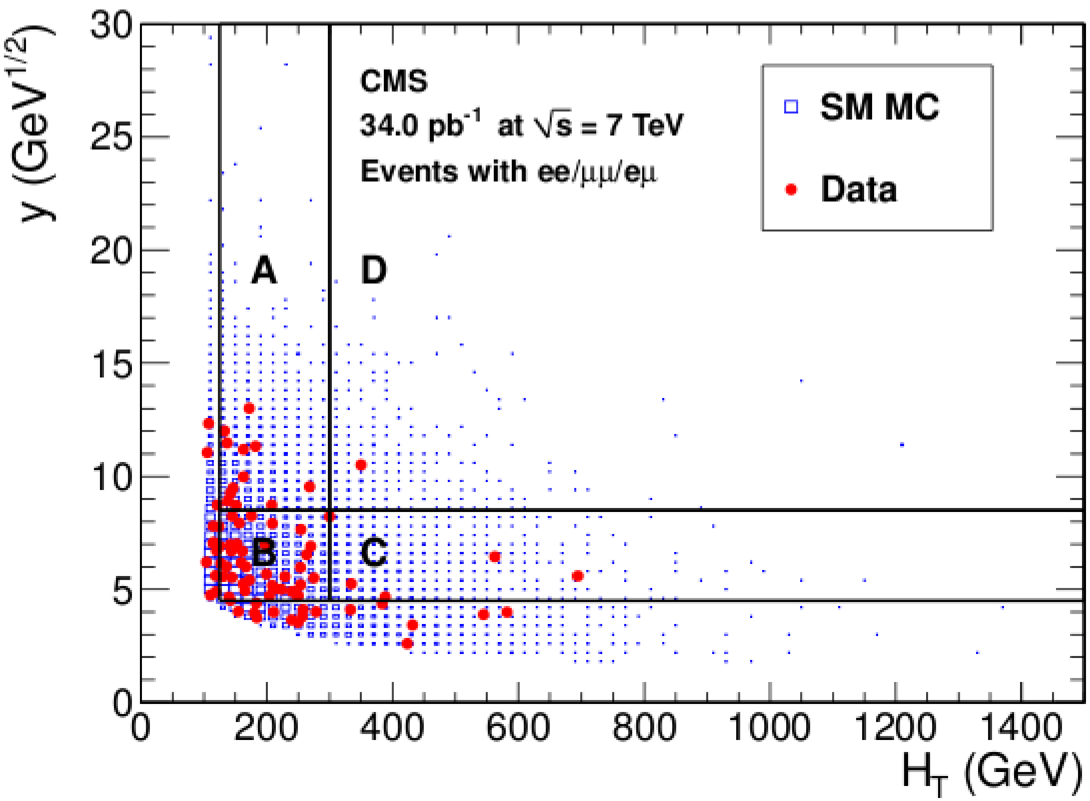
Signal region:

$H_T = \sum_{jets>30\ GeV} p_T > 300$ GeV

$y = MET/\sqrt{H_T} > 8.5\ \sqrt{GeV}$

- Region D (Observed) = 1
- Region D (Predicted):

$1.3 \pm 0.8 \pm 0.3$



Prediction using Lepton spectrum method: $2.1 \pm 2.1 \pm 0.6$

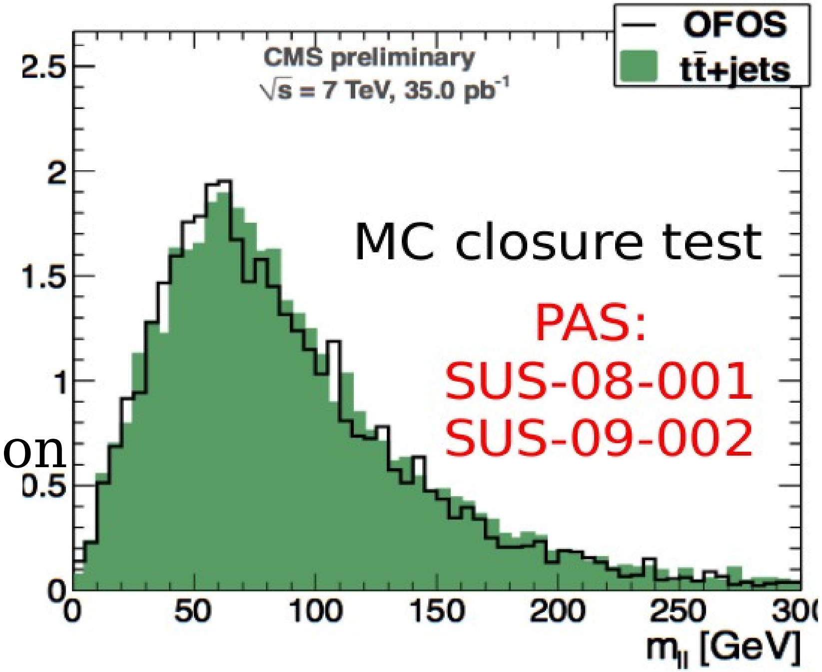
The observation is consistent with the prediction

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 efficiency $r_{\mu e}$ = eff (e)/ eff(μ) ~1.07
  - Use Tag & Probe on the Z events
  - Known within 2% syst.
- Rest of W+Jets, QCD bkg from fit to the lepton isolation distribution with relaxed isolation



$100 < H_T = \Sigma_{jets>30\ GeV}\ p_T < 350$, MET > 80

	Control Region	
Process	ee	$\mu\mu$
$t\bar{t}$ from $e\mu$	11.7 ± 2.4	13.4 ± 2.8
Non-W/Z leptons	0.5 ± 0.3	0.4 ± 0.2
Total predicted	12.2 ± 2.4	13.8 ± 2.8
Total observed	10	15
SM MC	8.4 ± 0.2	10.5 ± 0.3

H_T > 350, MET > 150

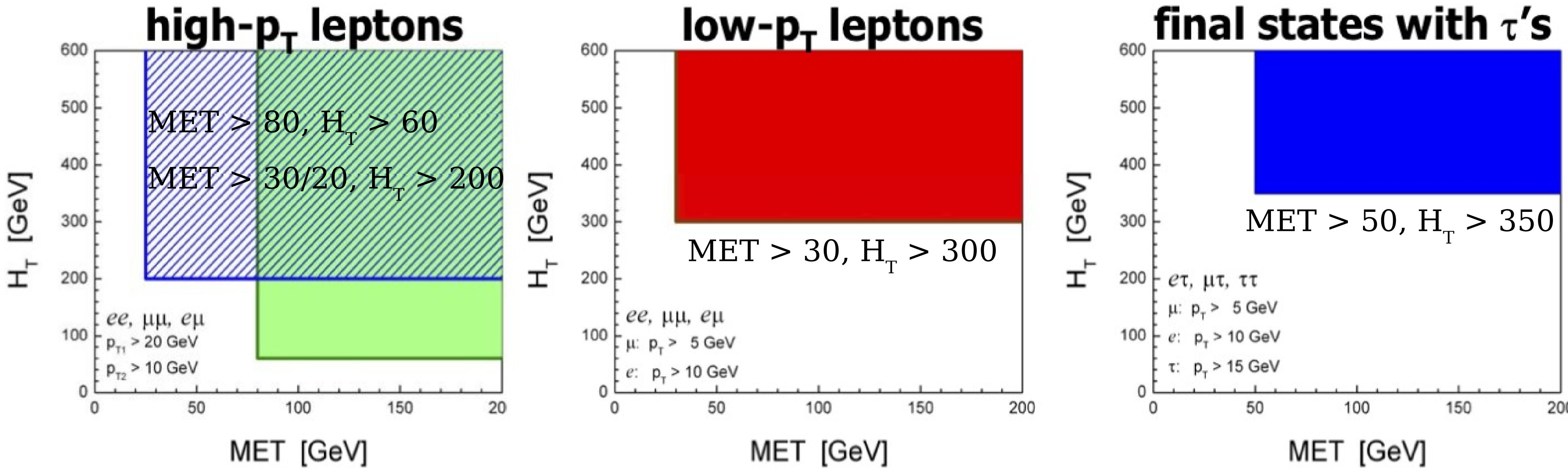
	Signal Region	
Process	ee	$\mu\mu$
$t\bar{t}$ from $e\mu$	$0.4^{+1.0}_{-0.4}$	$0.5^{+1.2}_{-0.4}$
Non-W/Z	0	0
Total predicted	$0.4^{+1.0}_{-0.4}$	$0.5^{+1.2}_{-0.4}$
Total observed	0	0
SM MC	0.38 ± 0.08	0.56 ± 0.07

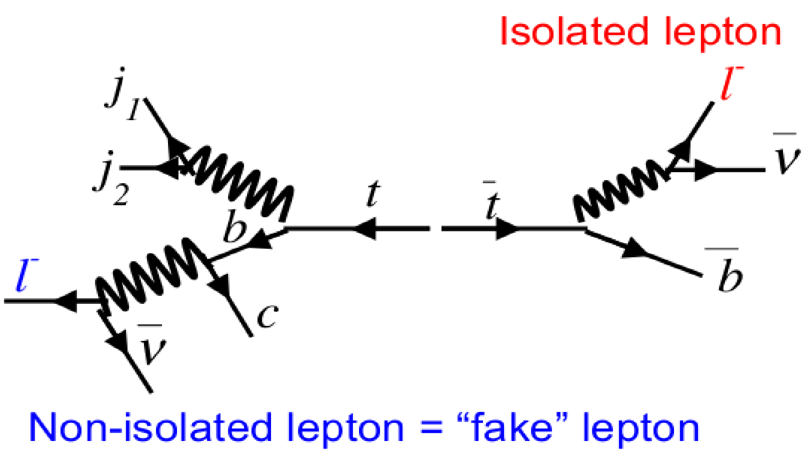
Prediction agrees well with the observation

Same sign dilepton search

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

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





<u>Major Backgrounds:</u>

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

Use data driven background estimation ⇒

SS Background estimation – Tight-to-loose Technique

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

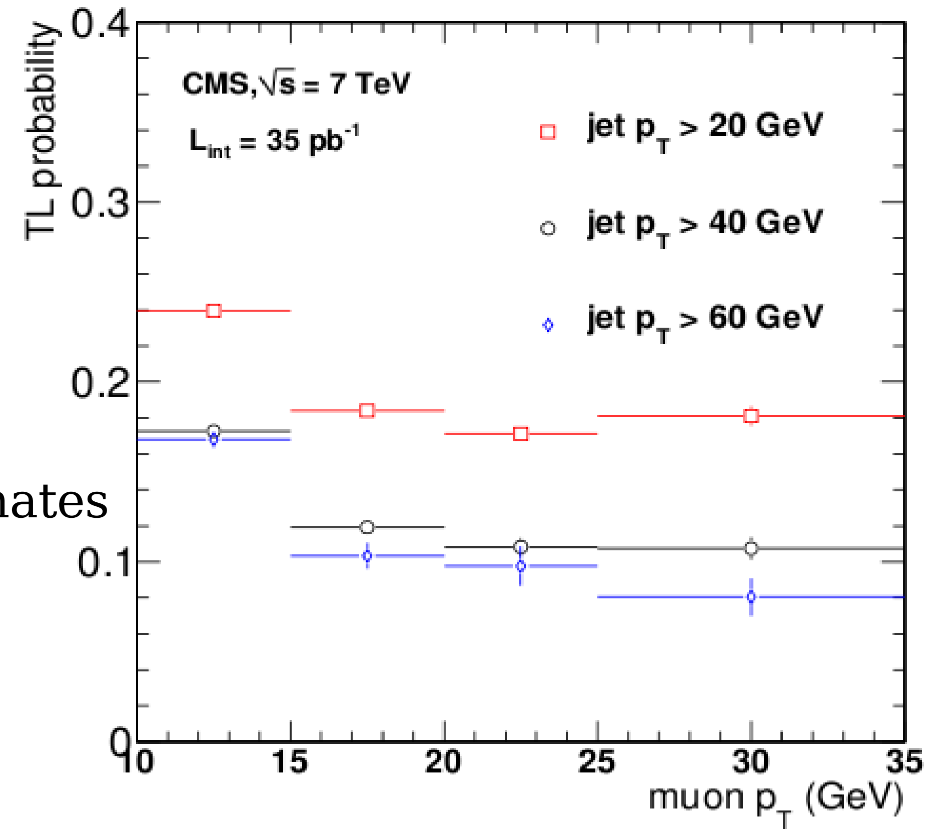
FR = (# evts passing tight)/ (# evts passing loose)

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

Muon fake rate, Electrons similar



For a baseline selection with:

$N_{jet} > 1$, $pT_{Jet} > 30$ GeV, $|\eta| < 2.5$

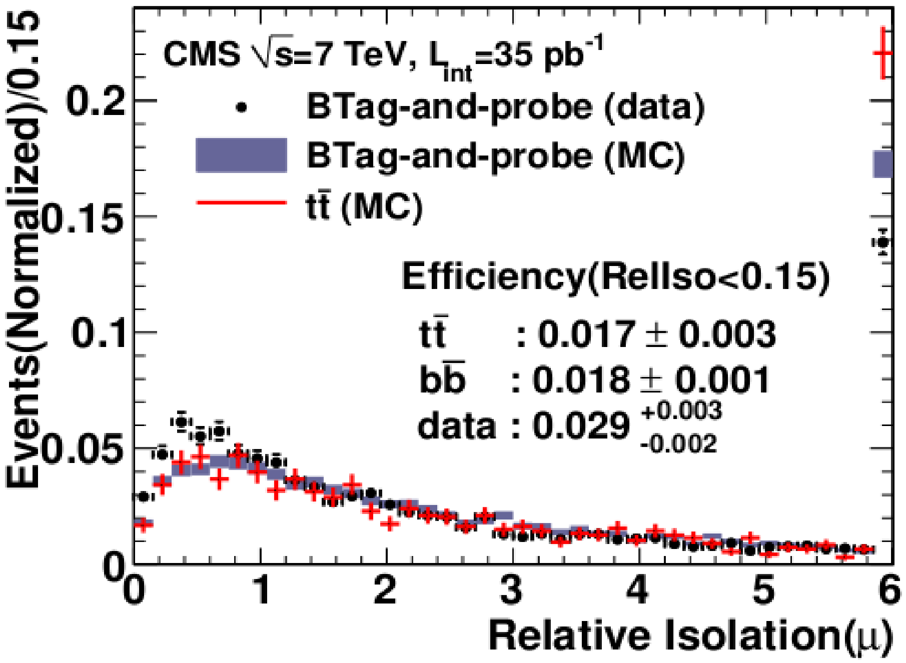
MET > 30(ee/μμ)/20(eμ) GeV

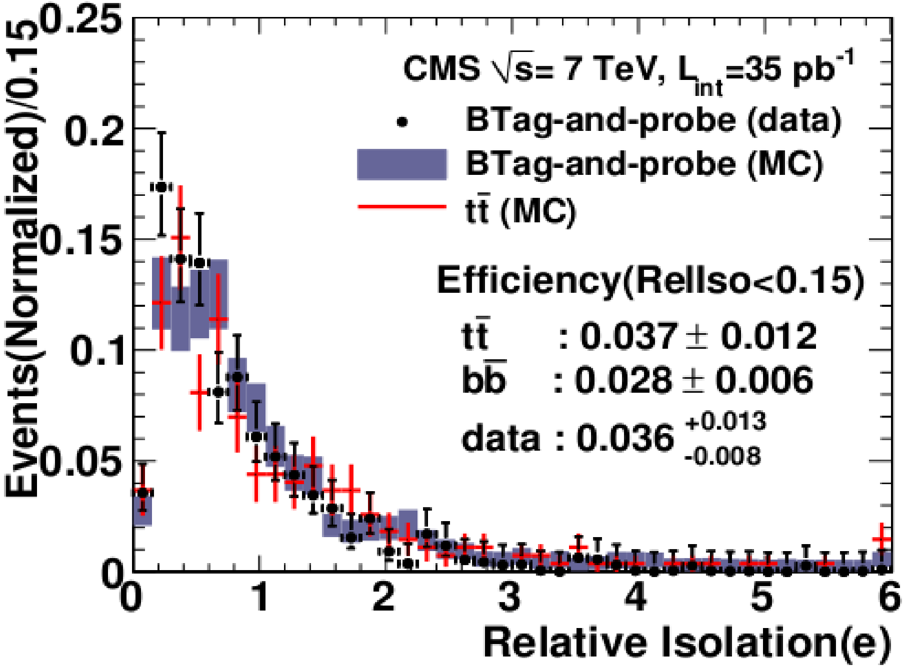
Same sign di-leptons with Pt(e,μ) > 20/10

$N_{Observed} = 3$; $N_{Predicted} = 3.2 \pm 0.9 \pm 1.6$

SS Background estimation - Btag and probe method

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

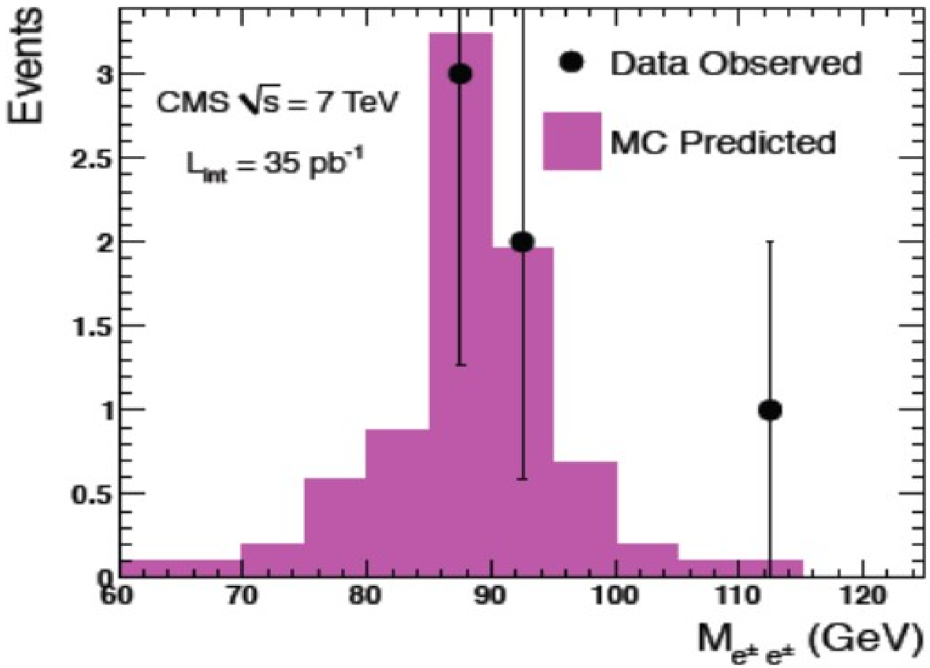
  ttbar expectation
- Use this isolation efficiency to determine background

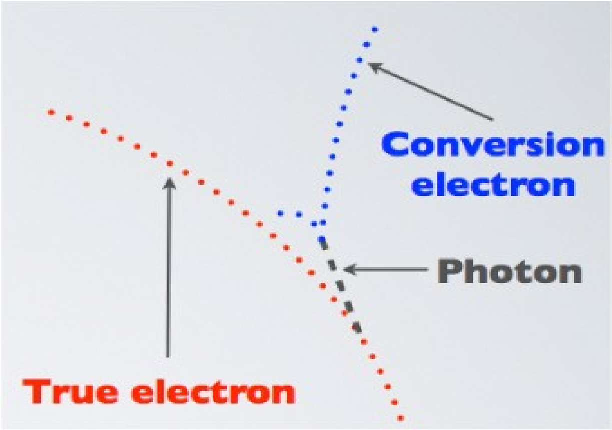
SS Background estimation – Charge Mis-reconstruction

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 ~10^{-4} in barrel, and ~10^{-3} at |η| ~1.5.

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

Control region: N(Observed) = 5, N(Predicted) = 4.9 ± 0.1

Same Sign dilepton search

Include hadronic τ channels: eτ, μτ and ττ

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

Results:

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

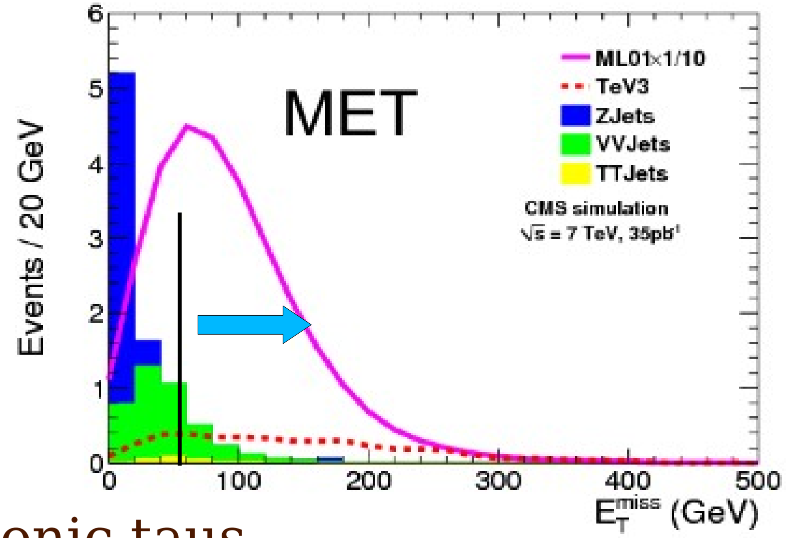
No sign of any new physics anywhere

Multi-lepton search (≥3 leptons)

Search in events with at least three isolated leptons

- Large suppression of backgrounds

- Very inclusive search with wide phase space



Baseline selection:

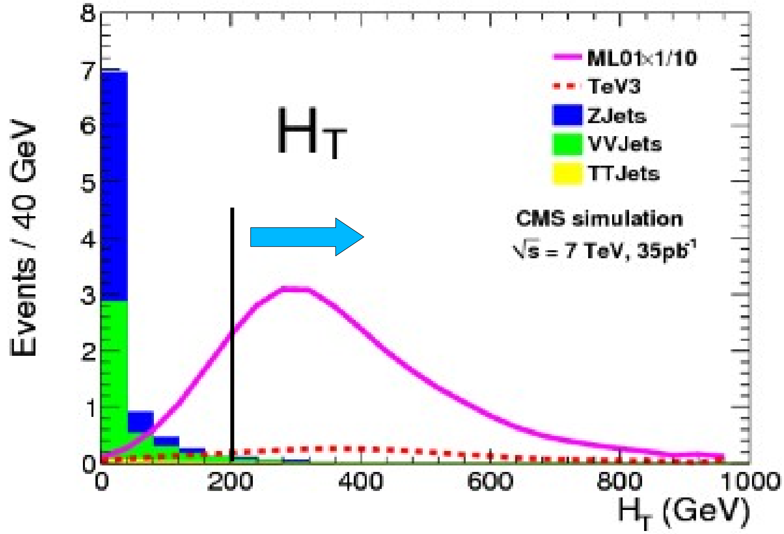
- At least three isolated leptons (e,μ,τ) with pT from 8 GeV
- Use isolated tracks (T) and τ ID for fully hadronic taus
- Require one non-τ lepton trigger.

Signal region:

- MET > 50 GeV

  Or

- H_T > 200 GeV



Above two selection with ≥3 leptons probes complementary phase space

Multi-lepton search

Backgrounds:

- Z+Jets, WW+Jets, W+Jets, QCD

  – determined using similar fake rate method discussed earlier

- Irreducible: WZ +Jets, ZZ +Jets and ttbar are from simulations

Very complex analysis with 55 exclusive channels:

- Opposite-sign/Same-sign/Z peak/Off peak/MET/H_T ...

An example of the prediction/observation of the modes after the lepton ID

	After Lepton ID Requirement				
	Z +jets	$t\bar{t}$	V V +jets	ΣSM	Data
Channel					
ll(OS)e	1.7	0.1	1.2	4.4 ± 1.5	6
ll(OS)μ	2.83	0.2	1.7	4.7 ± 0.5	6
ll(OS)T	121.5	0.5	0.7	123 ± 16	127
ll(OS)τ	476	2.7	3.9	484 ± 77	442

Expectation agrees with the observation in multi-lepton channels as well

Exclusion limits/Interpretation of results

We use either of the following statistical methods to set limits, as recommended by CMS statistics committee and outlined by Particle Data Group

- Bayesian method with a flat prior

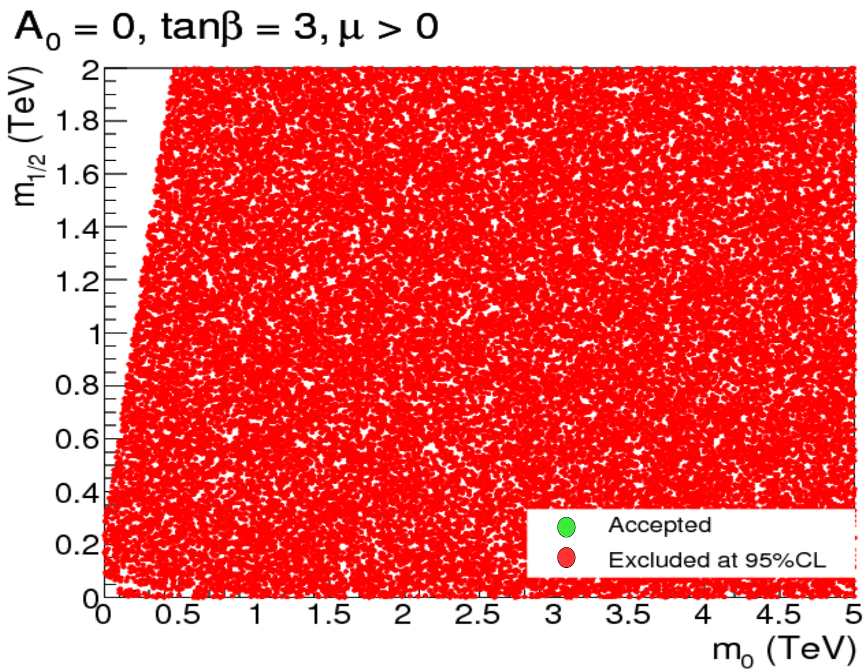
- LEP CLs frequentist method

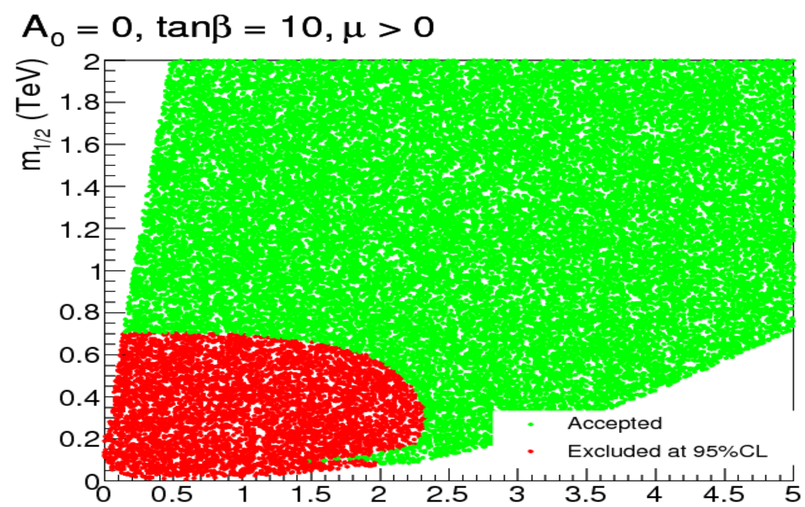
[See details in the backup]

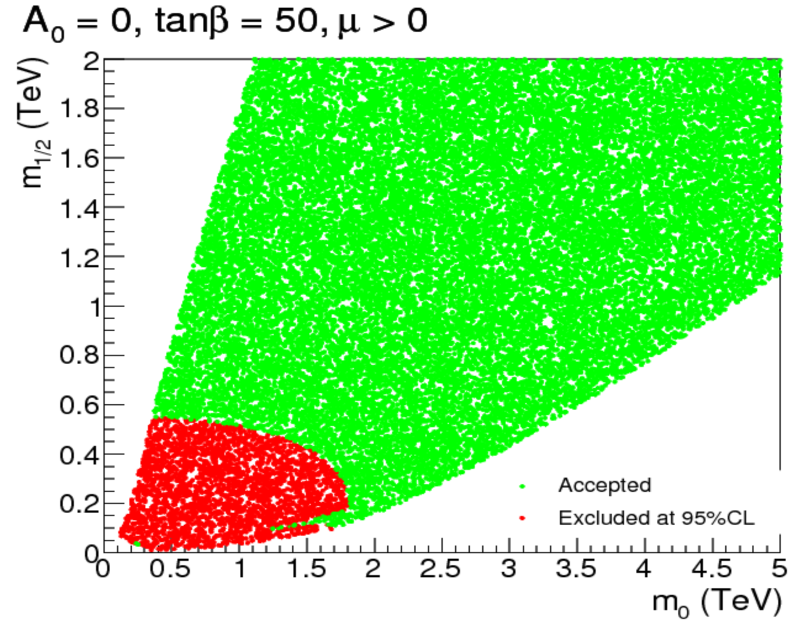
Limits using CMSSM framework

Consider Higgs mass limits from LEP (without uncert.)

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





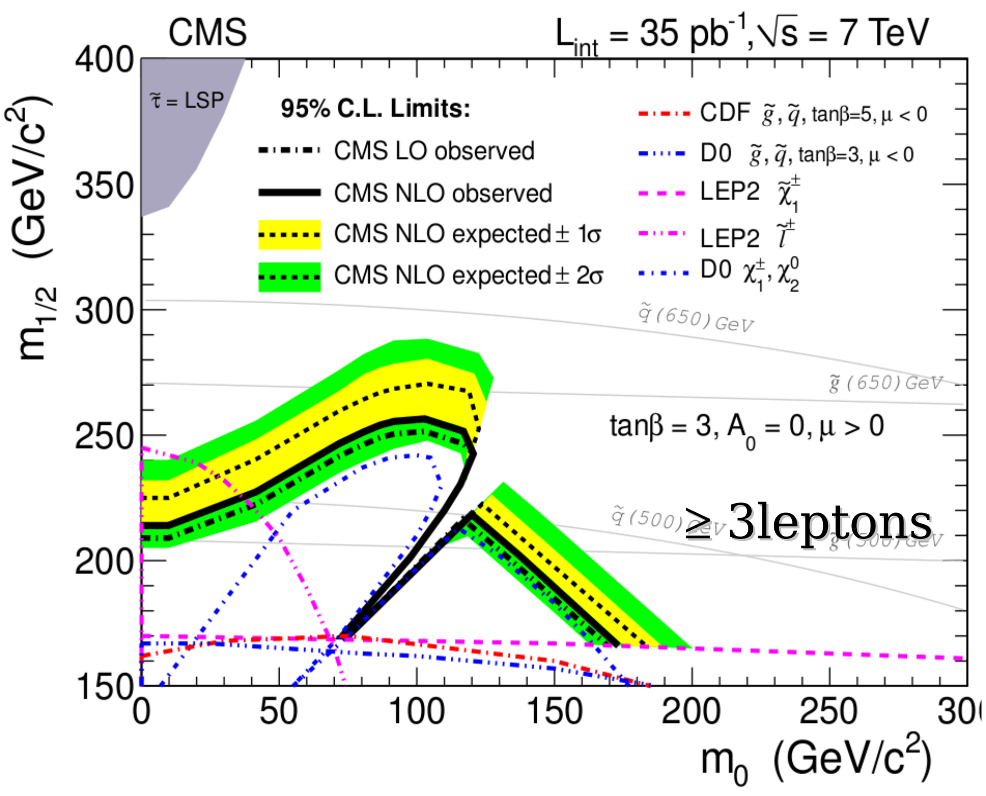


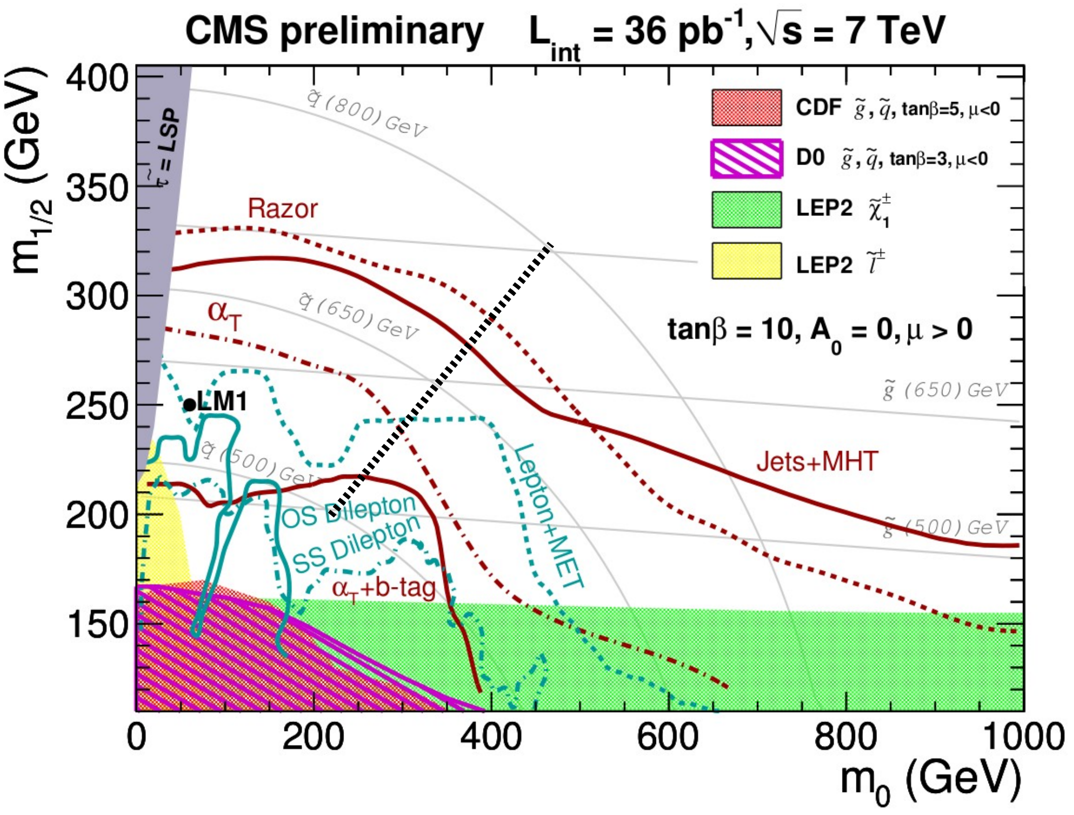
Results from hadron colliders (Tevatron, LHC) can probe direct squarks/gluino production to the highest scales in the world.

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

Limits using CMSSM framework



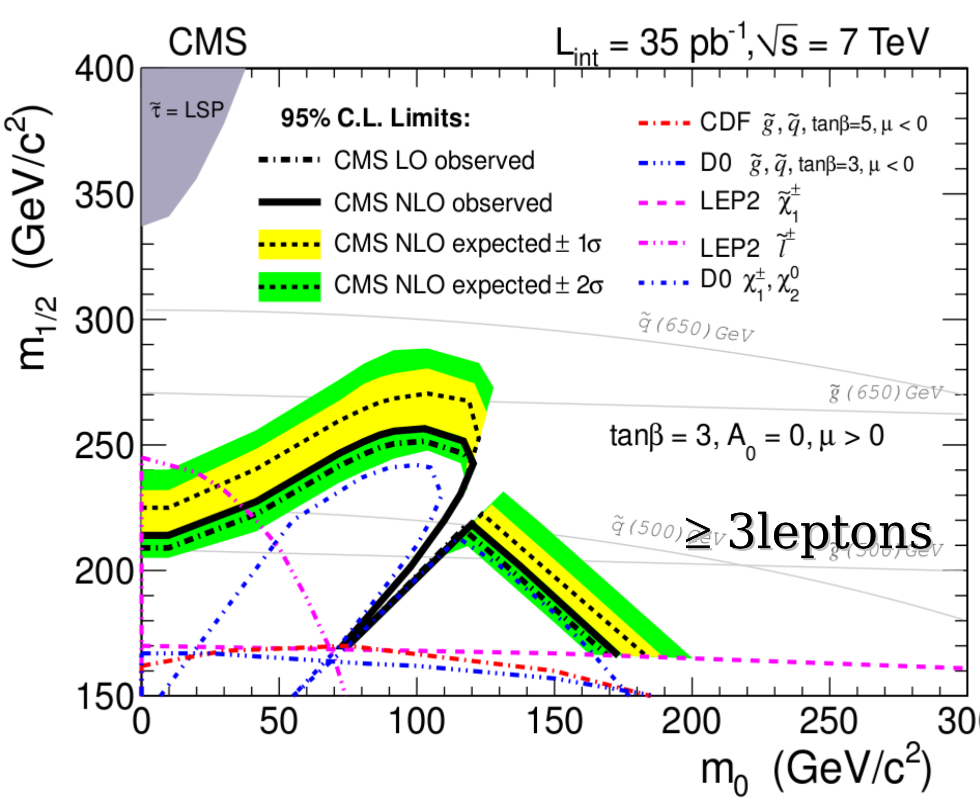


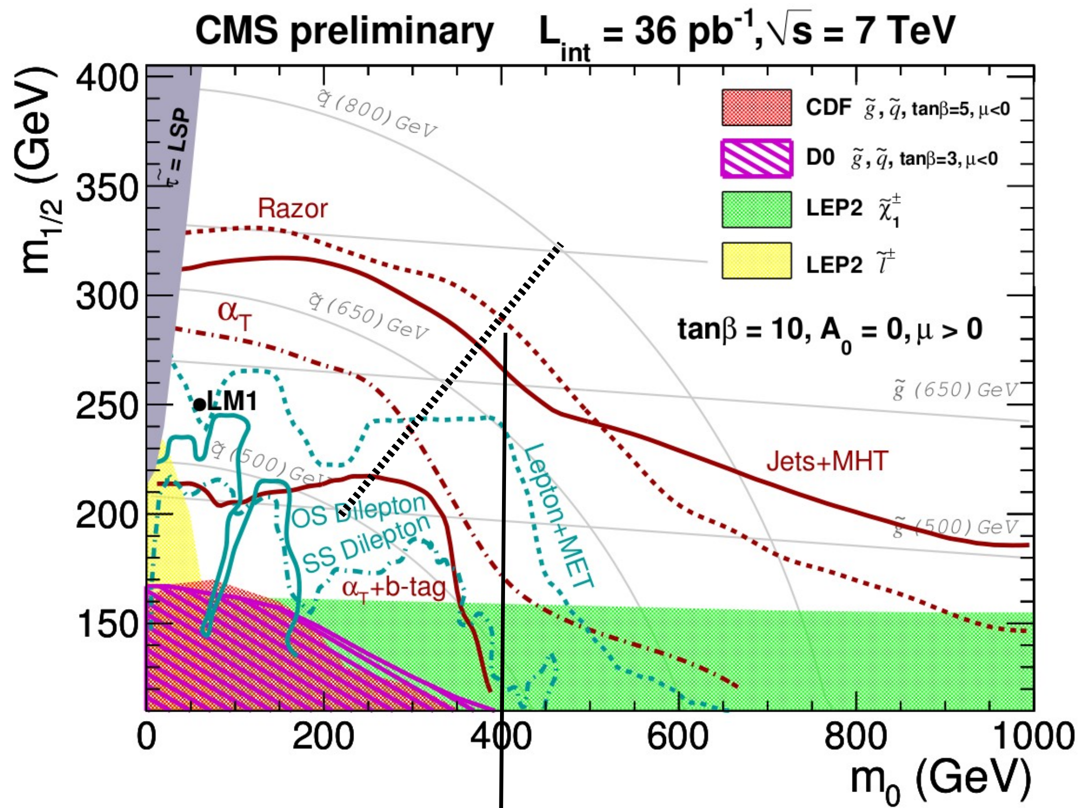
- CMS (ATLAS as well) exceeds previous Tevatron limits in the chosen parameter space (tanβ = 3, A_0 =0, sign(μ) > 0).
- **Assuming same squarks and gluino masses (dotted line above)**

  CMS using 35 pb^{-1} excludes @ 95% CL., M_{SUSY} ~ 730 GeV

  ATLAS similar M_{SUSY} ~ 700 (arXiv:1102.2357)/775 GeV (arXiv:1102.5290)

Limits using CMSSM framework





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  CMS using 35 pb^{-1} excludes @ 95% CL., M_{SUSY} ~ 730 GeV

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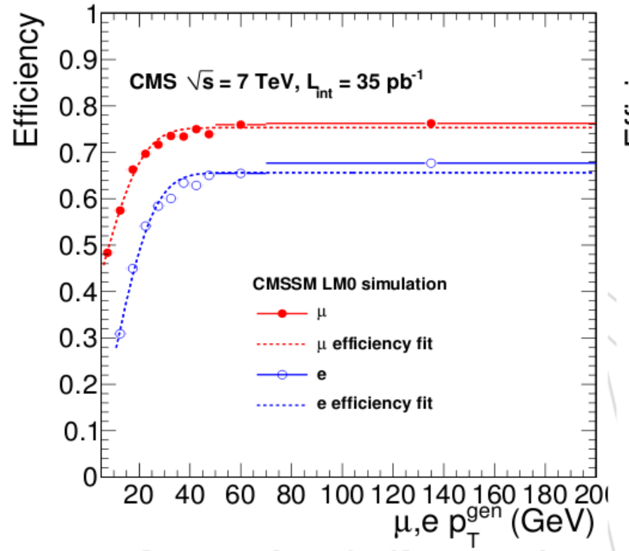
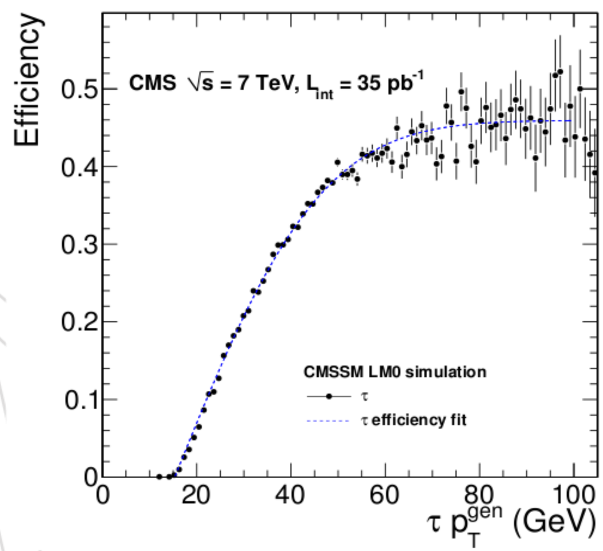
Information to test variety of specific physics models

We provide additional information needed for Model Testing

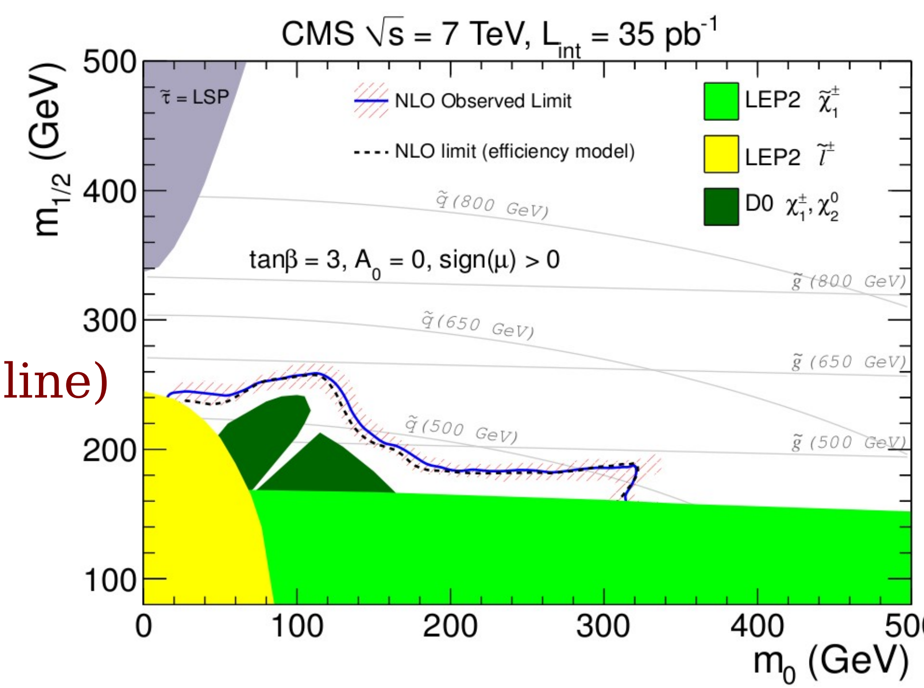




Same-Sign dileptons

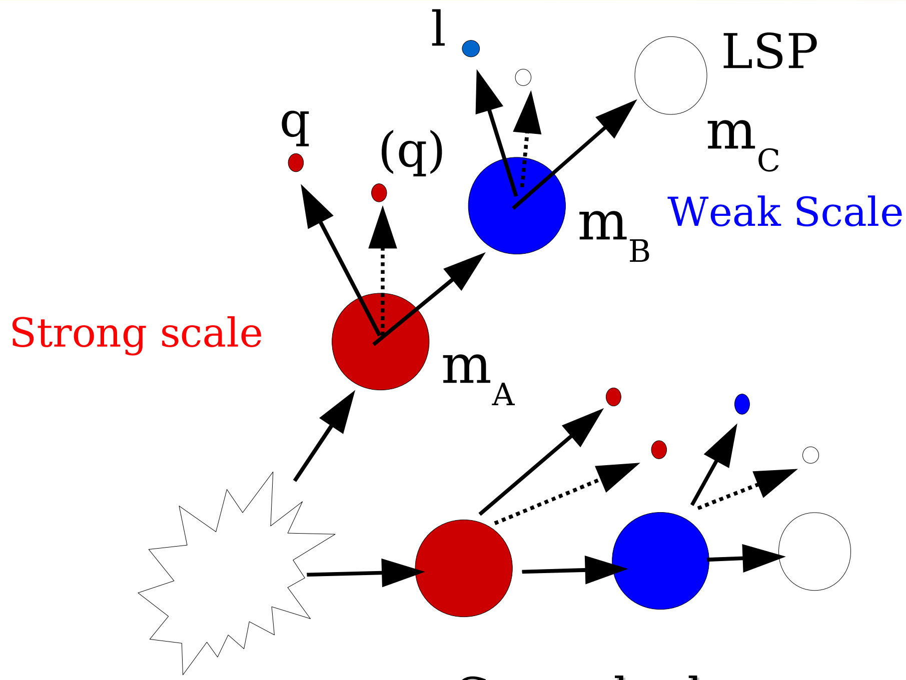
Different lepton efficiency and Jet/MET response parameterizations are provided in order to test specific models

The simple efficiency parametrization (dotted line) reproduces the result from CMS simulation to better than the theoretical uncertainties on the cross section



Generic topology based results

Simplified Topology



Cascade decays

assume LSP

- LSP (m_C): 1st mass scale (expect MET)

assume production via QCD

- squarks/gluinos (m_A): 2nd mass scale
- large cross sections

assume charged EWK particle coupling to quarks/squarks

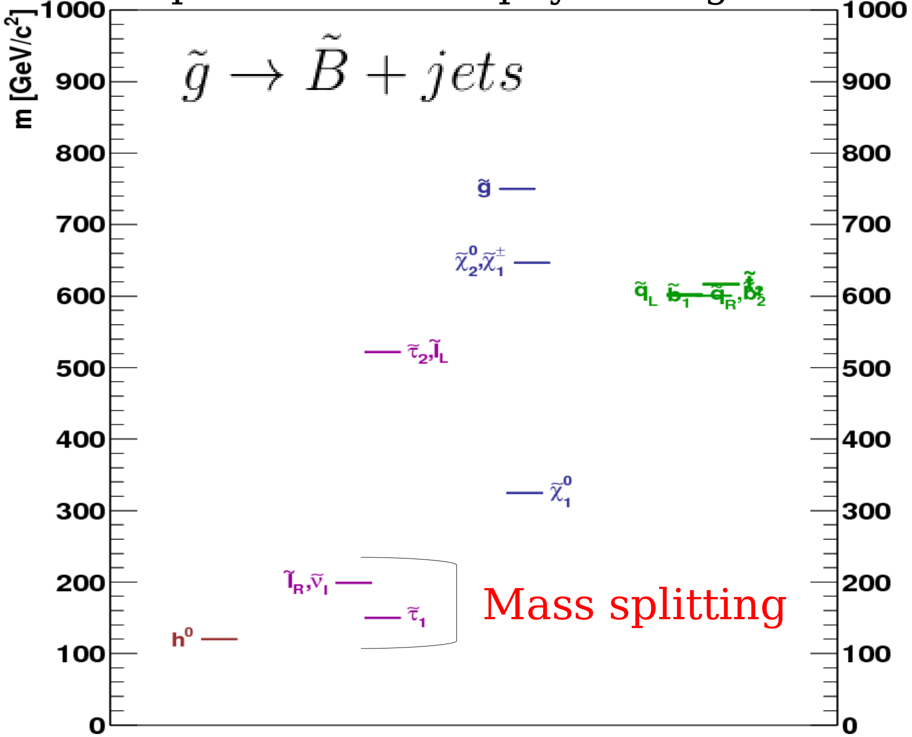
- if chargino mass is in between gluino/squarks & LSP (m_B): 3rd mass scale

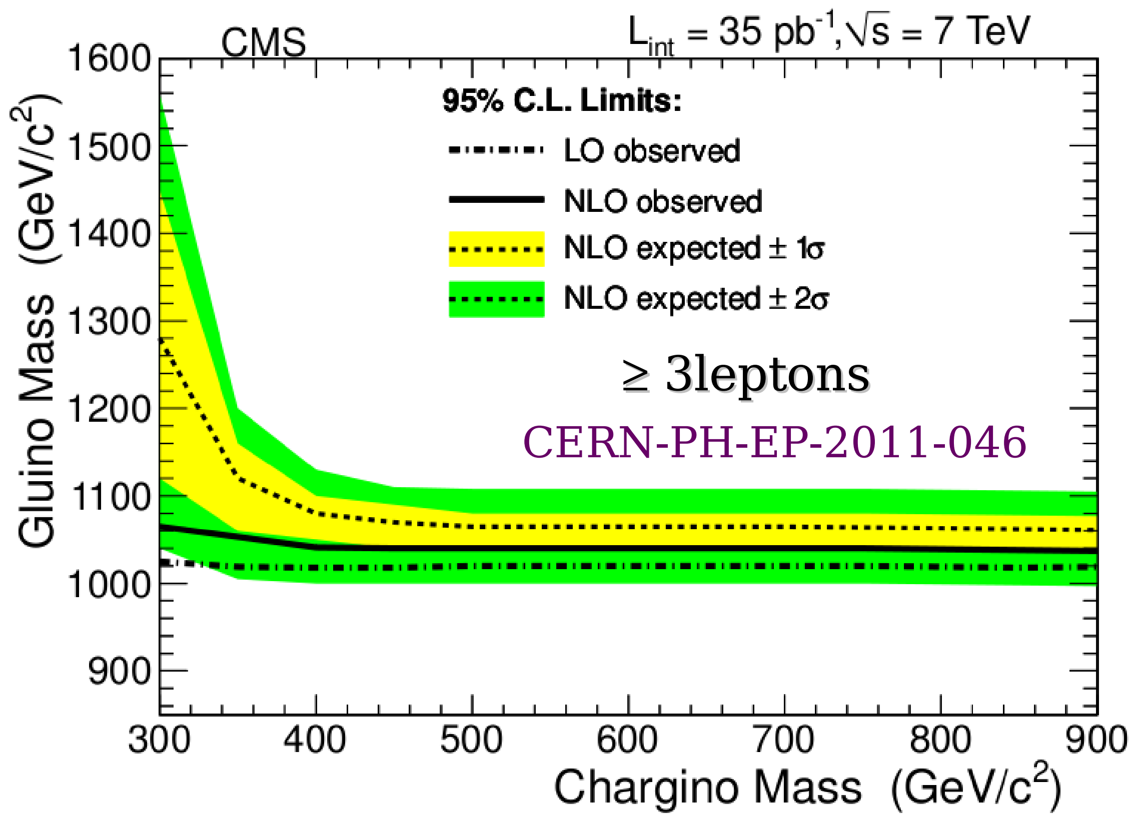
→ Two mass scales for direct production with 2 or 3 body decays

Gauge mediation with slepton co-NLSP

Spectra with GGM/GMSB: *Scott Thomas et. al.*

http://www.lhcnewphysics.org/





$$\tilde{B} \rightarrow (\tilde{e}_R^{\pm}, e^{\mp}),\ (\tilde{\mu}_R^{\pm}, \mu^{\mp}),\ (\tilde{\tau}_1^{\pm}, \tau^{\mp}) \quad ; \quad \tilde{\ell}_R^{\pm} \rightarrow \ell^{\pm} + \tilde{G}$$

Bino decays with equal branching ratio per family to the leptons

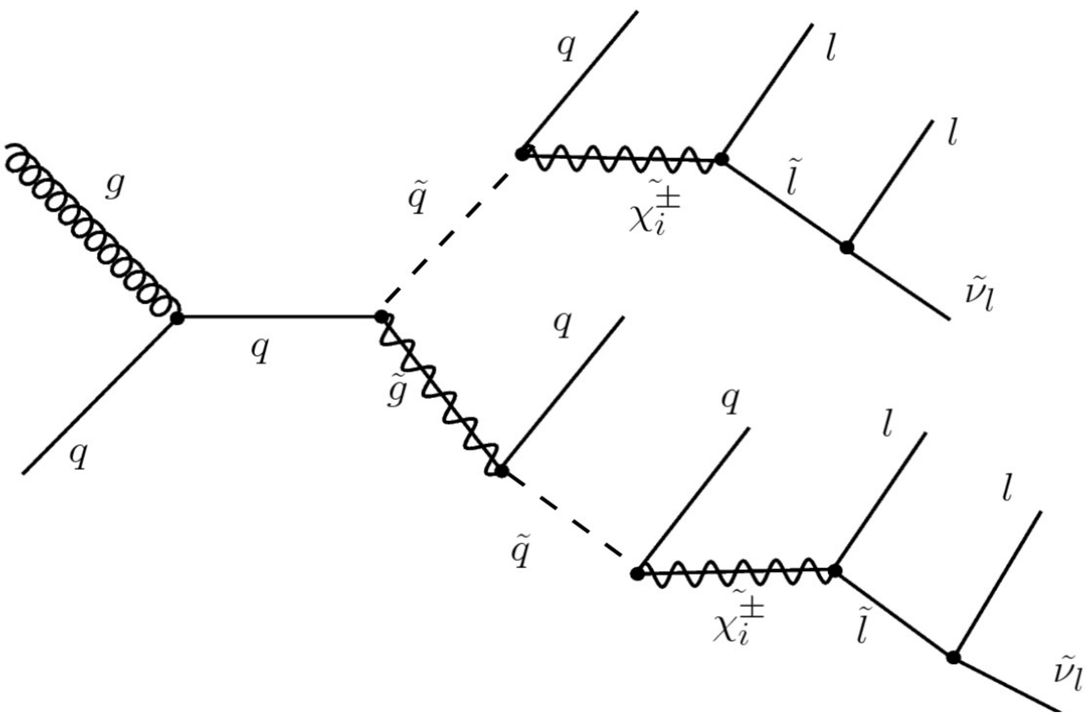
This gives rise to : Multilepton signature

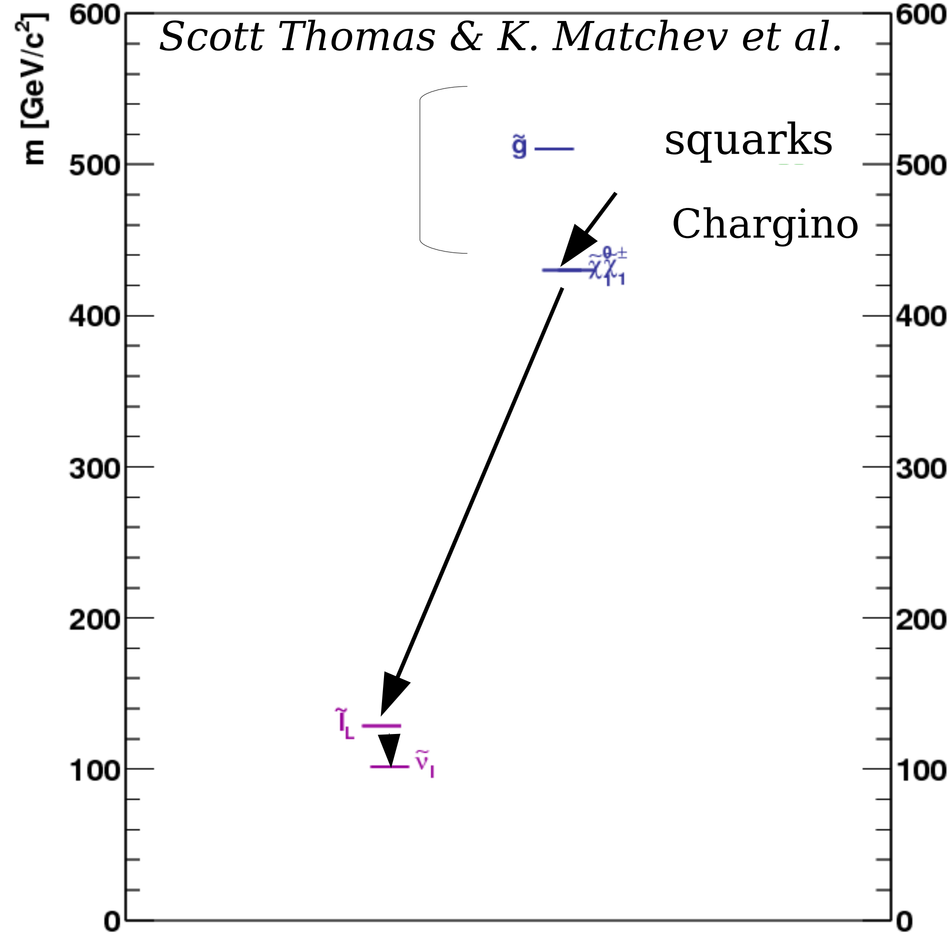
Note: If mass splitting between staus and sleptons = 0; slepton co-NLSP

SUSY with sneutrino LSP, sleptons NLSP

Sneutrino LSP by definition is a classic source with leptonic final states

Topology inspired due to the latest developments in the field [Ref. 6,7,8]

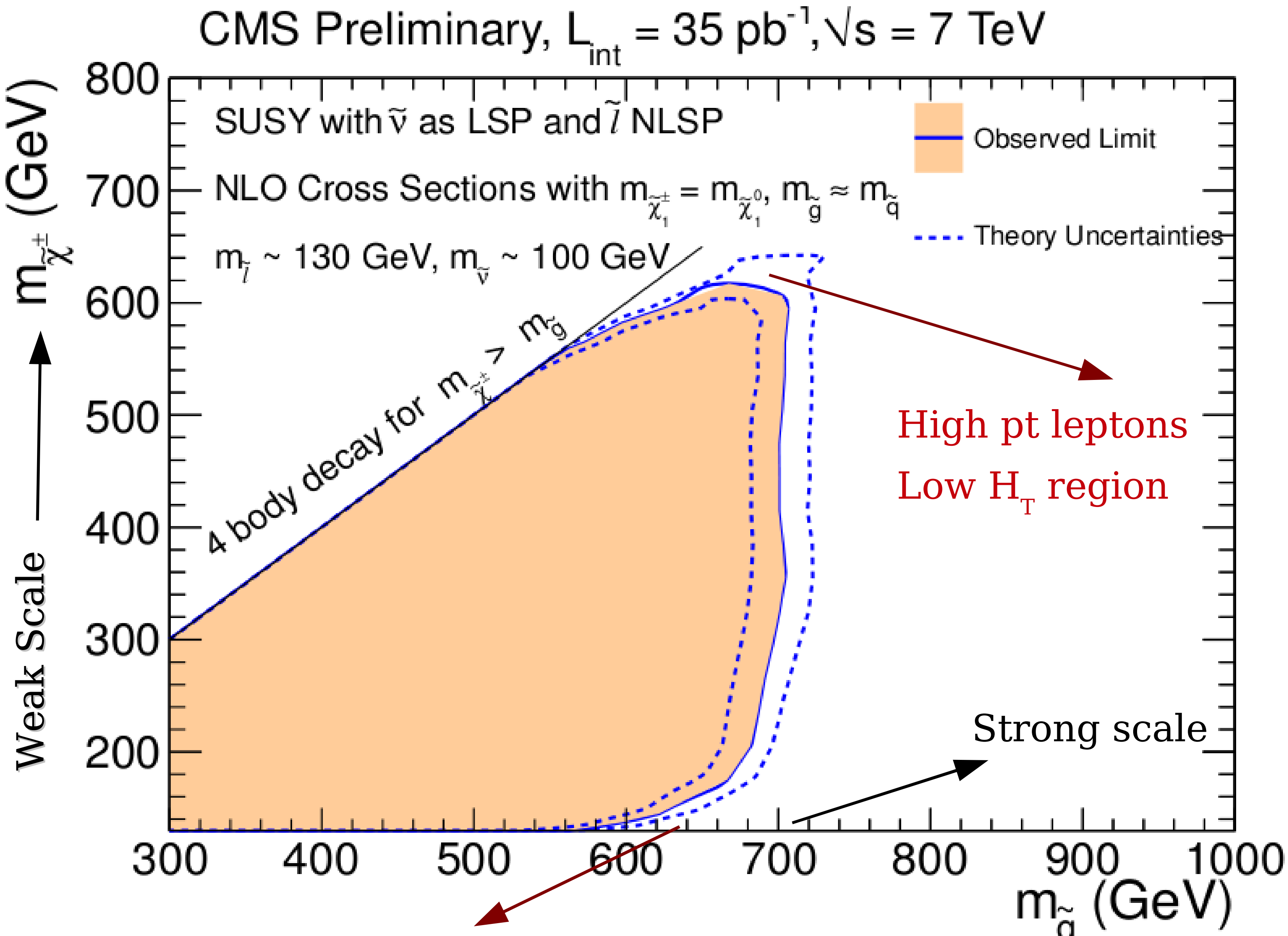




- $M_{\tilde{g}} \sim M_{\tilde{q}}$; M_{LSP} ~ 100 GeV ; M (Chargino) ~ M (Neutralino), tanβ = 10.
- Squarks/gluino lead to jets, thus
- Mass difference between $M\tilde{g}/\tilde{q}$ and Chargino is a measure of H_T

Same Sign dilepton interpretation of the results

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS10004_sneutrino



Low pt leptons and high H_T area

Summary and Conclusion

- Presented SUSY searches with 1, 2, ≥ 3 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 ~ 35 pb^{-1} no new physics was found

  ⇒ We set limits using different SUSY frameworks
- CMS (ATLAS as well) exceeds previous Tevatron limits in the common parameter space
- Commissioned all our tools for new physics searches

We are prepared to go for discovery in 2011/12

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5. V. Pavlunin, arXiv:0906.5016.

6. Nima Arkani-Hamed et al. Phys. Rev. D64:115011,2001.

7. Zachary Thomas et. al. Phys.Rev.D77:115015,2008

8. A. Katz et. al. Phys. Rev. D 81, 035012 (2010)

9. https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

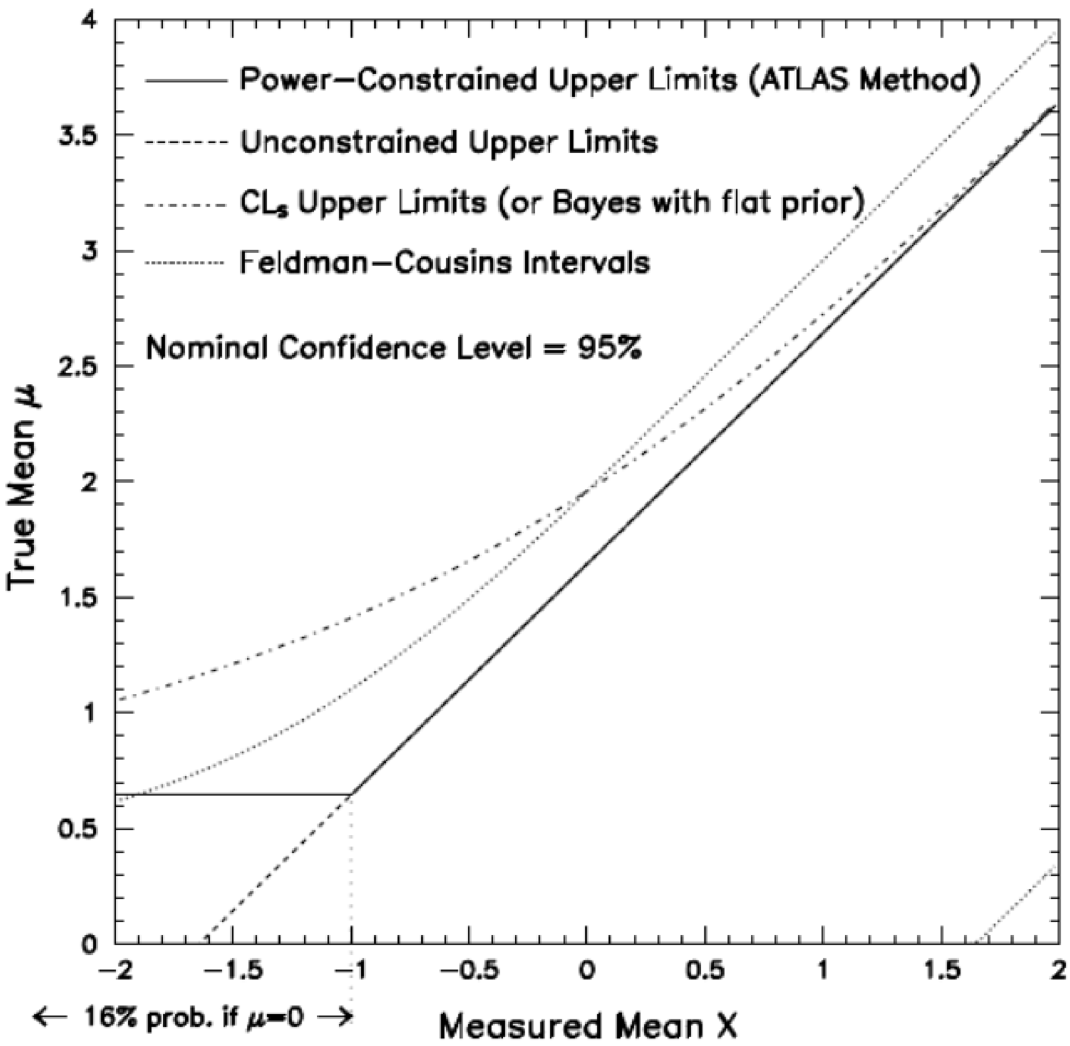
10. https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS10004_sneutrino

Backup Slides

Intervals and Limits for a Physically Bounded μ

- Prototype: measurement x is unbiased Gaussian estimate of μ. (Let $\sigma=1$.) What is 95% C.L. Upper Limit (UL)?
- 1986: Six methods for UL surveyed by V. Highland (VH) include U.L. = max(0, x + 1.64) and U.L. = max(0,x) + 1.64.
- RPP 1986: Bayesian: uniform prior on the mean μ for $\mu \geq 0$, prior prob = 0 for $\mu < 0$. (VH's other five not mentioned.)
- 1994,96: 3 ad-hoc frequentist recipes, one using max(x,0).
- 1998: Feldman & Cousins (FC) "Unified Approach" in (Kendall and Stuart) replaces ad hoc frequentist
- 2002: CL_S from LEP added to Bayesian and FC.
- CMS Statistics Committee recommends using (at least) one of the three (red) methods in 2002-present PDG RPP.
- ATLAS SC method implies U.L. = max(0, x + 1.64) before power constraint (PC), U.L. = max(-1,x) + 1.64 after PC.

Comparison of ATLAS PCL with the three methods in PDG



(Atlas unconstrained U.L. is zero, not null, for x < -1.64)

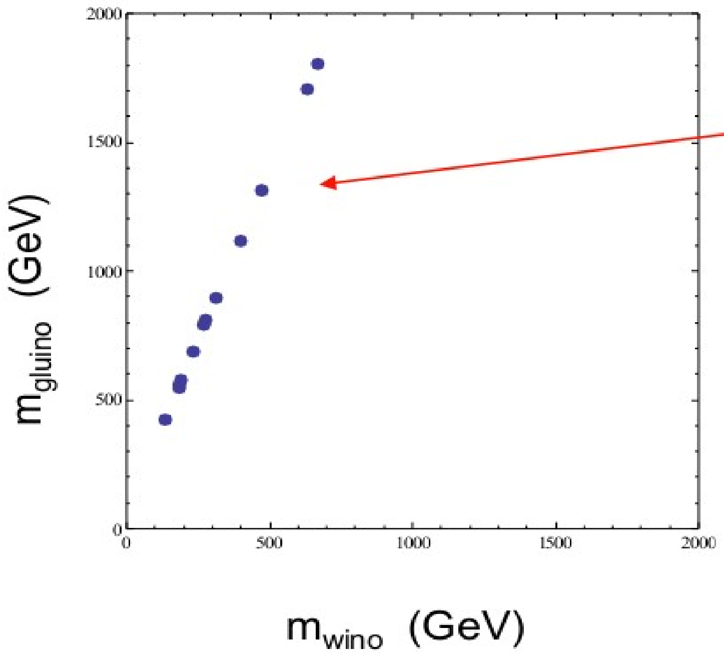
ATLAS PCL re-opens discussion on use of diagonal line along with ad hoc constraint, out of favor for many years, not recommended by CMS SC.

CMS and ATLAS SC's are reviewing arguments and what has been learned in 25+ years. Academic statisticians have commented as well.

Just tip of iceberg: Poisson example brings in other issues. Nuisance parameters yet more. Choice of test statistic varies.

cMSSM/mSUGRA

CMS (Public) SUSY Benchmarks - TDR (Atlas Similar)



Stretched Gauge Ordered Spectra

Relatively Low σ

Led to Expectation that Need O(100's) pb^{-1} to go Beyond Tevatron

(Gaugino Unification)

Most mSUGRA cases CMS has studied so far:

- is a search along this line on the plane of Chargino Vs Gluino mass

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

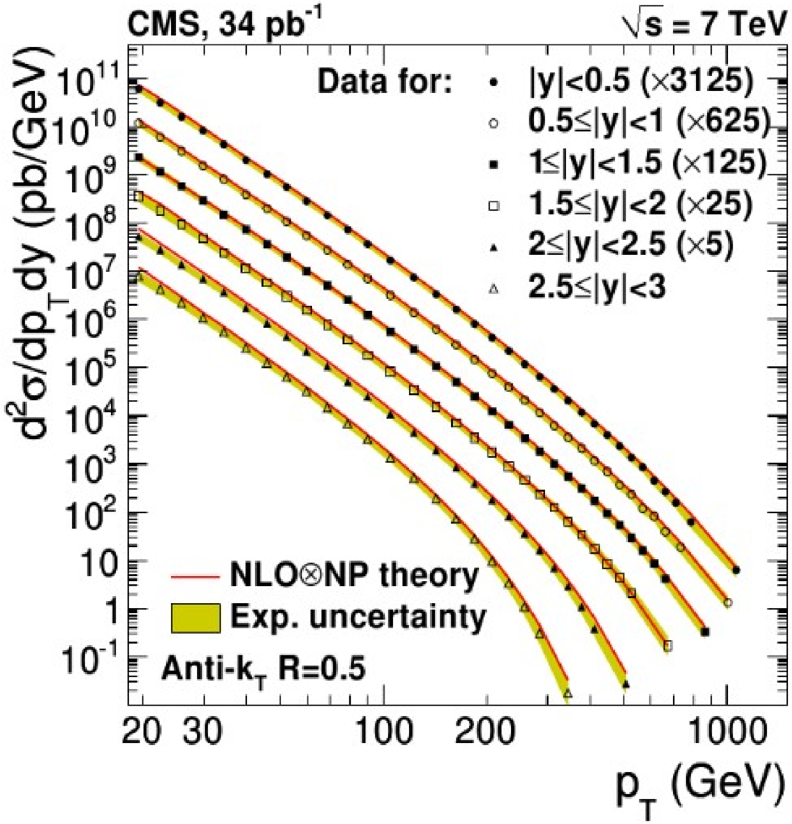
Trigger Rates in Hz

Cross triggers (a few examples from recent runs):

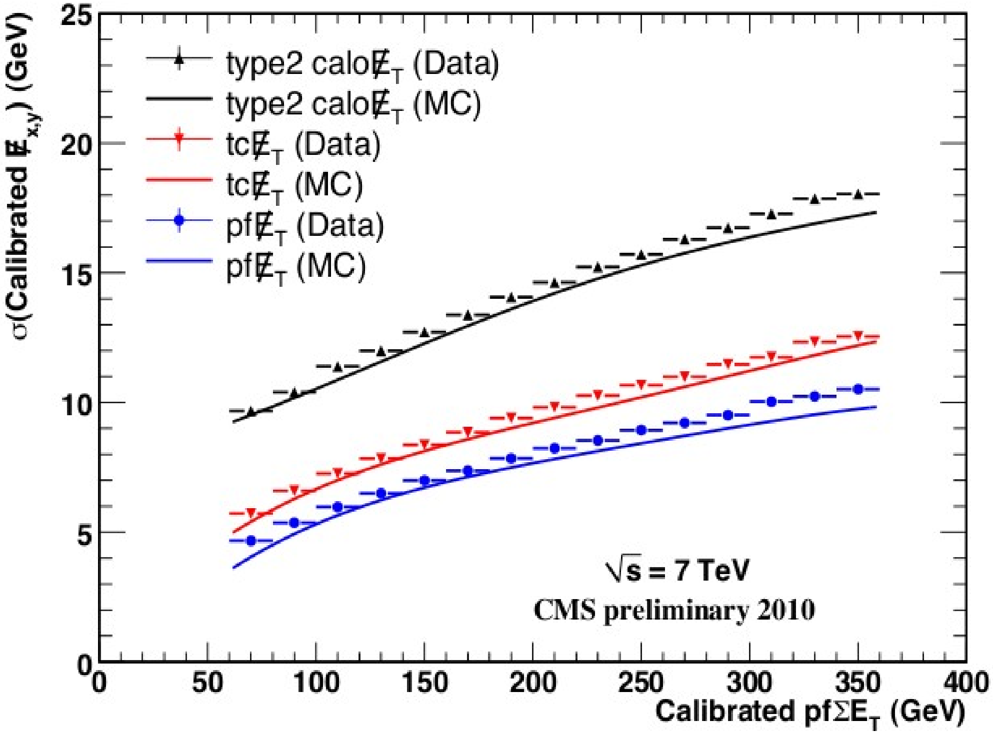
Path	Rate @ 2.3e32	Rate @ 5e32	Estimate @ 5e32
Ele10_CaloIdL_CaloIsoVL_TrkIdVL_TrkIsoVL_HT20	2.6	5.7	~7 Hz
Ele10_CaloIdT_CaloIsoVL_TrkIdT_TrkIsoVL_HT200	1.1	2.4	
Mu5_HT200	5	10.9	
Mu8_HT200	2.5	5.4	5.5
DoubleMu3_HT160	0.4	0.9	2.0
DoubleMu3_HT200	0.25	0.5	1.0
Mu3_Ele8_CaloIdL_TrkIdVL_HT160	1.3	2.8	3
Mu3_Ele8_CaloIdLT_TrkIdVL_HT160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



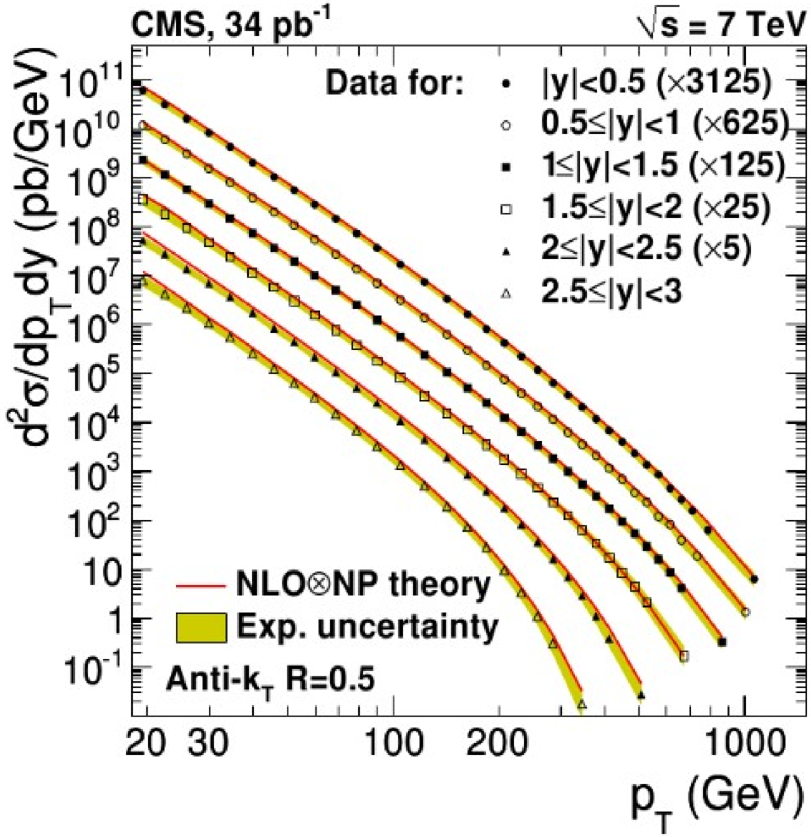
CMS-PAS-JME-10-004



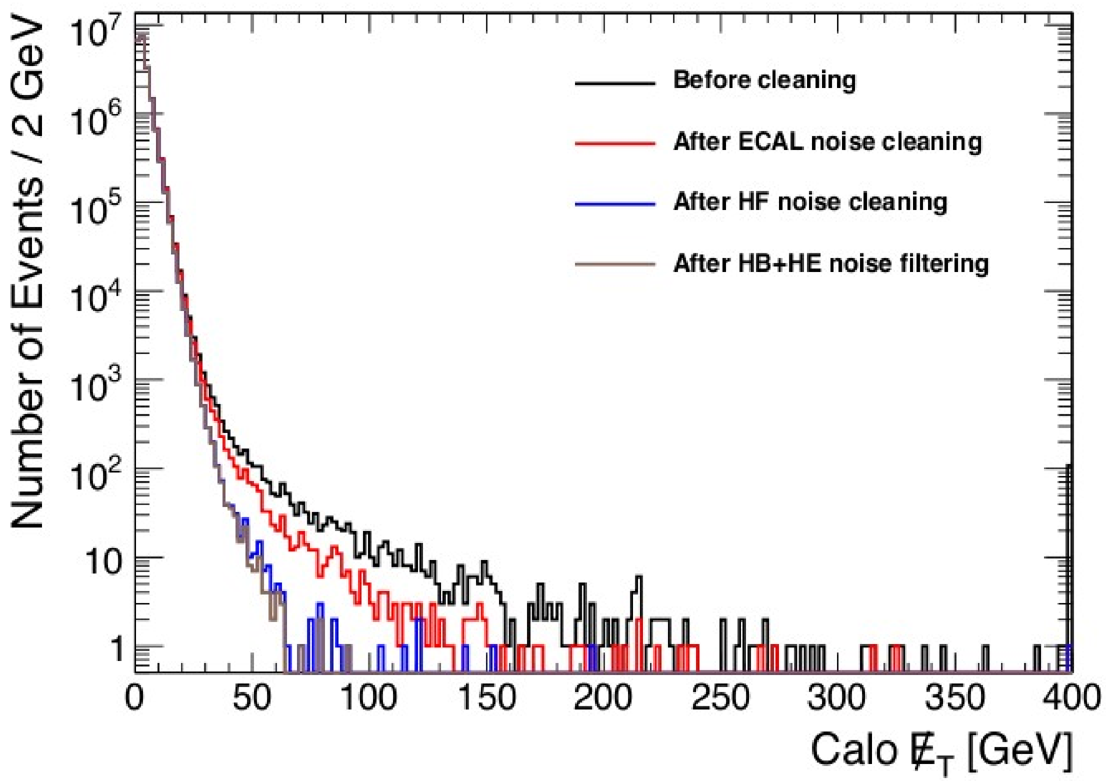
- Measurements of jet cross sections and MET resolution
- Jets and MET in good shape

Performance of Jets and MET

CMS-QCD-10-011



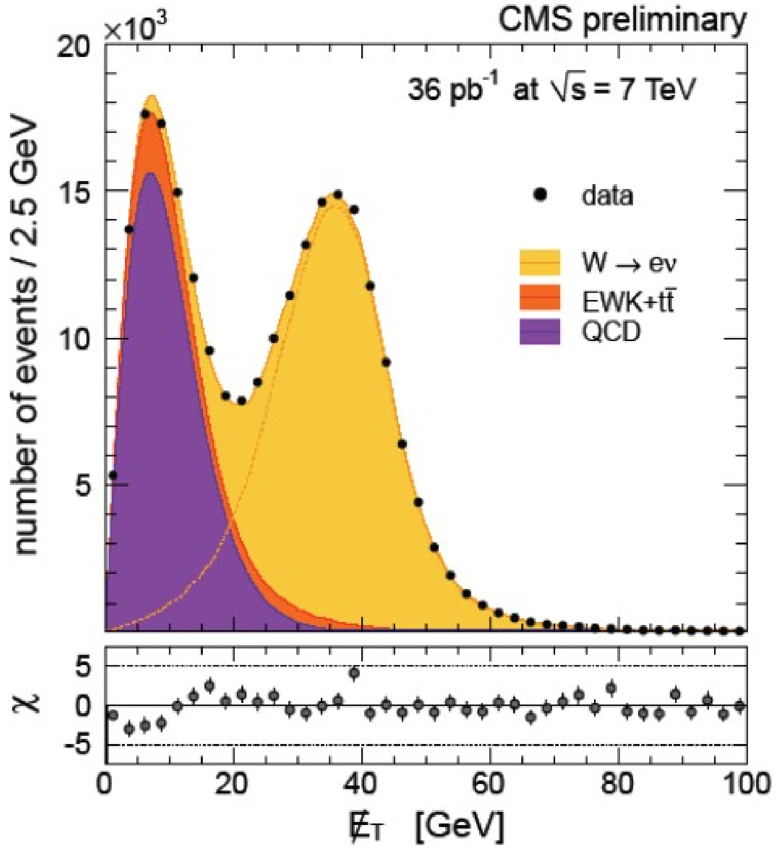
CMS-PAS-JME-10-004

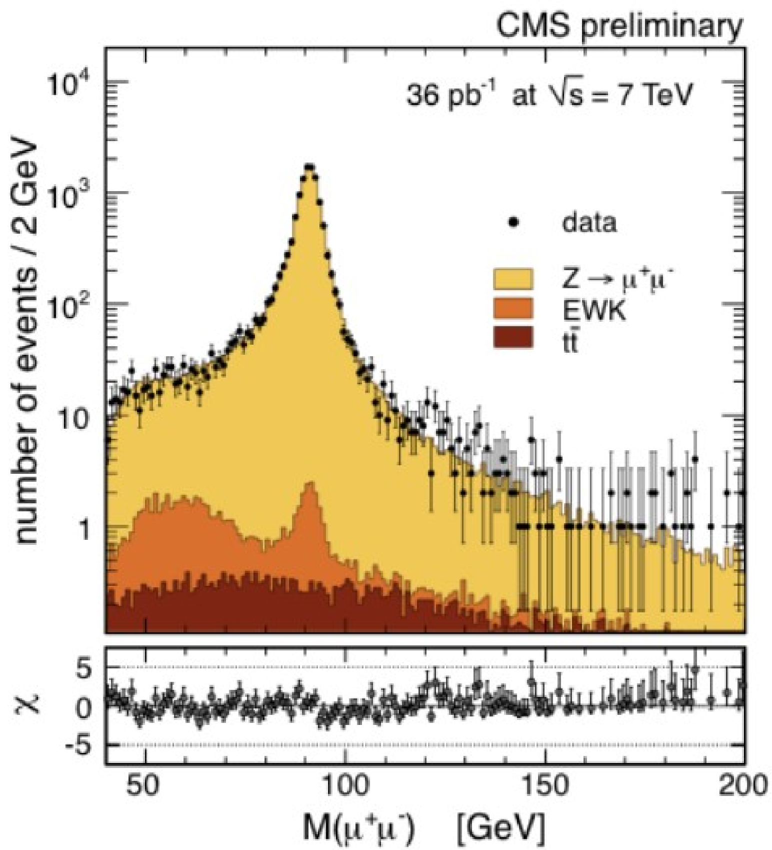


- Measurements of jet cross sections and MET resolution
- Jets and MET in good shape

Lepton Performance

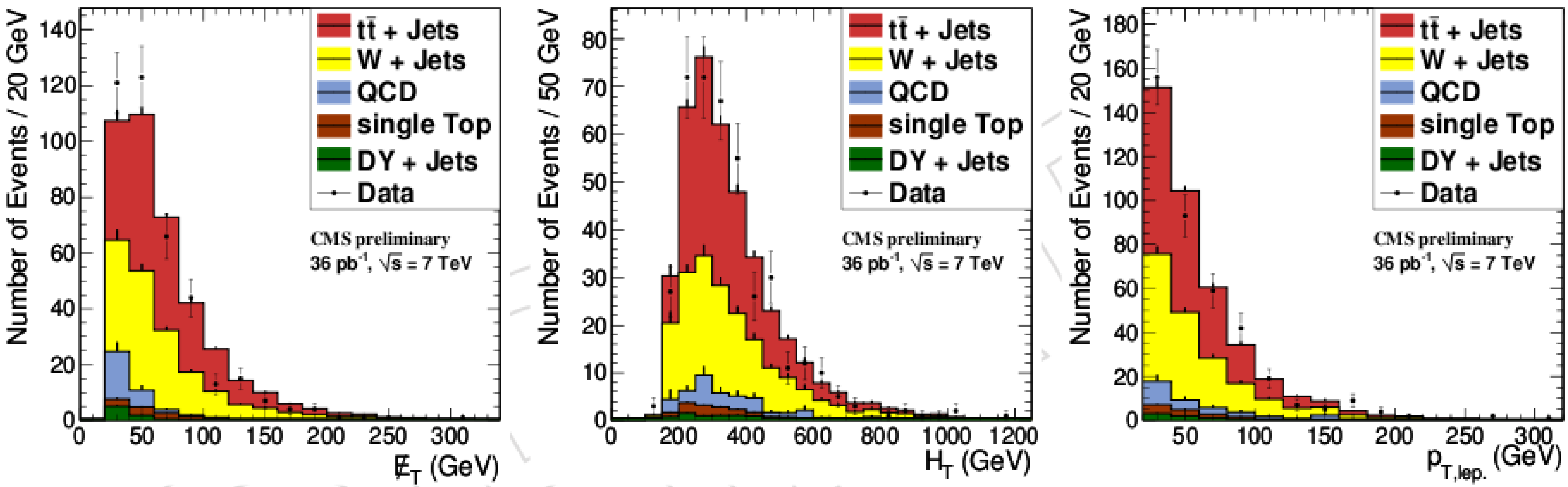
CMS-EWK-10-005





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

Single lepton analysis



(a) $\not{E}_T$ (e channel) (b) H_T (e channel) (c) Lepton p_T (e channel)

Single lepton analysis

- 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
  - MET resolution/scale: Resolution of MET and lepton p_T are quite different and energy scale uncertainty on MET much be taken into account
  - W polarization: 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
  - Non single lepton background: Lepton spectrum method predicts single lepton events but not tau→μ,e background and feed down from dilepton ttbar events
  - Threshold on lepton p_T: not applied to neutrino

Have investigated all these points and many more

Single lepton analysis

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

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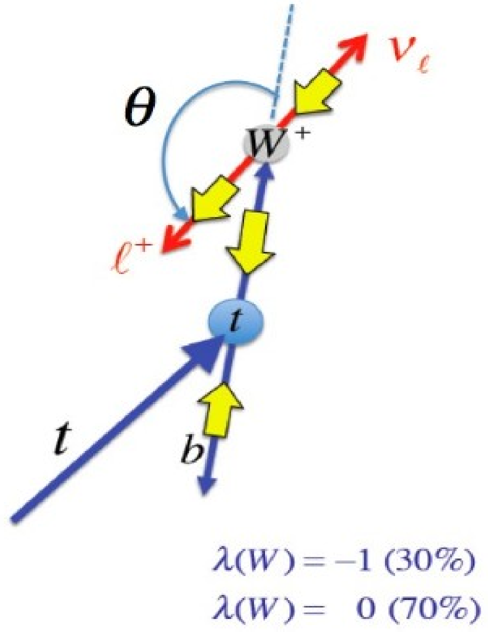
Jan H. Piclum‡
Department of Physics, University of Alberta, Edmonton, Alberta T6G 2G7, Canada
(Dated: May 18, 2010)

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 $\mathcal{F}_- = 0.311(5)$.



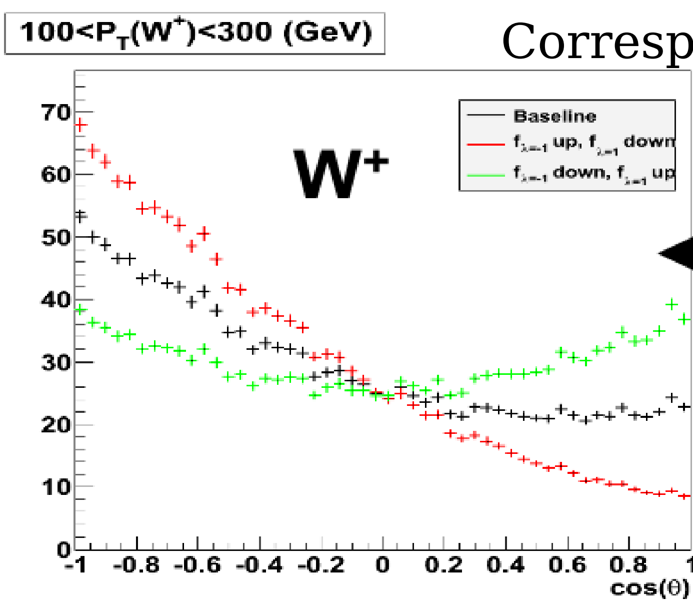
- Helicity fractions are very precise prediction in SM theory, have been calculated with QCD corrections to NNLO.
- Errors on F_L and F_- are O(1%); due to m(top) uncertainty
- Reduces uncertainties due to W polarization in top events to very low level
- The boost is the same for lepton, neutrino
- Lepton,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

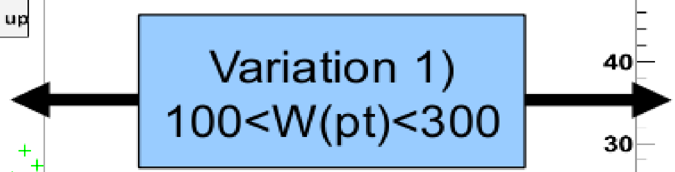
Single lepton analysis

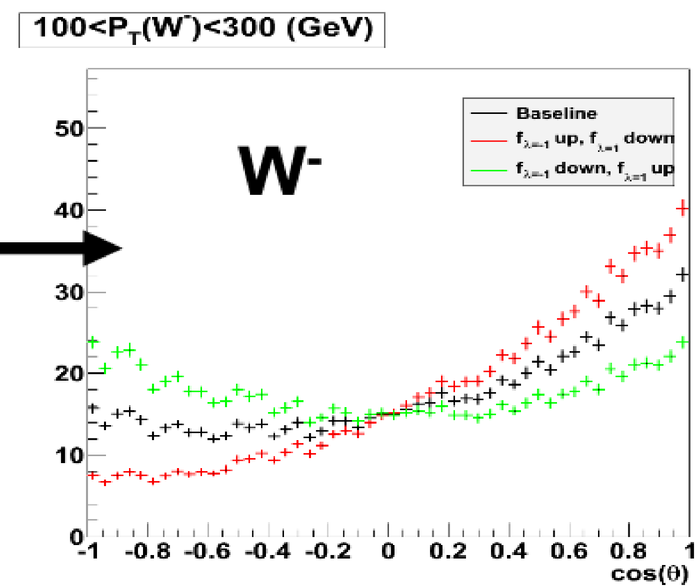
- Used Wjets polarization measurement at CMS as starting point for studies
- W polarization in Wjets is p_T dependant; somewhat different for W+ and W-. Also, W+ cross section higher than W- by ~40%
- Agreement between lepton and neutrino p_T dependent on polarization
- To account for W polarization uncertainties chosen variations that are conservative;

- Applied 3 different variations of the polarization fractions. Applied the same variation in 3 different bins of W pt, 50-100 GeV, 100-300 GeV, 300+ GeV
  1) ~30% variation to left-handed, right-handed fractions in W+ and W- simultaneously
  2) ~10% variation to left-handed, right-handed fractions in only W+ or only W-
  3) 100% variation to longitudinal fraction in both W+ and W-

Corresponds to 14% uncert.

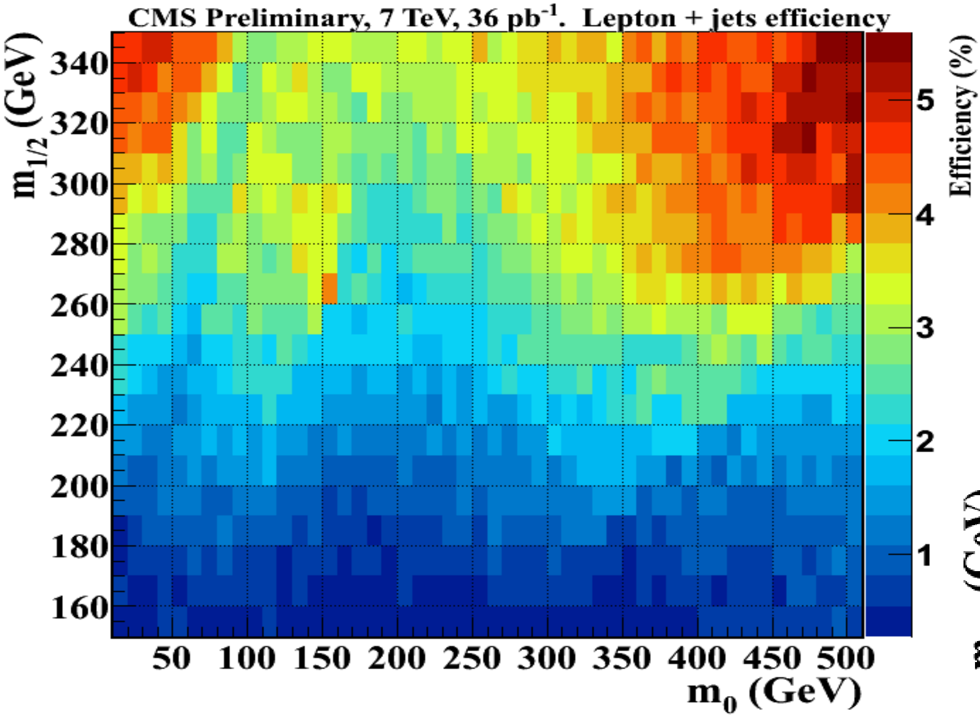




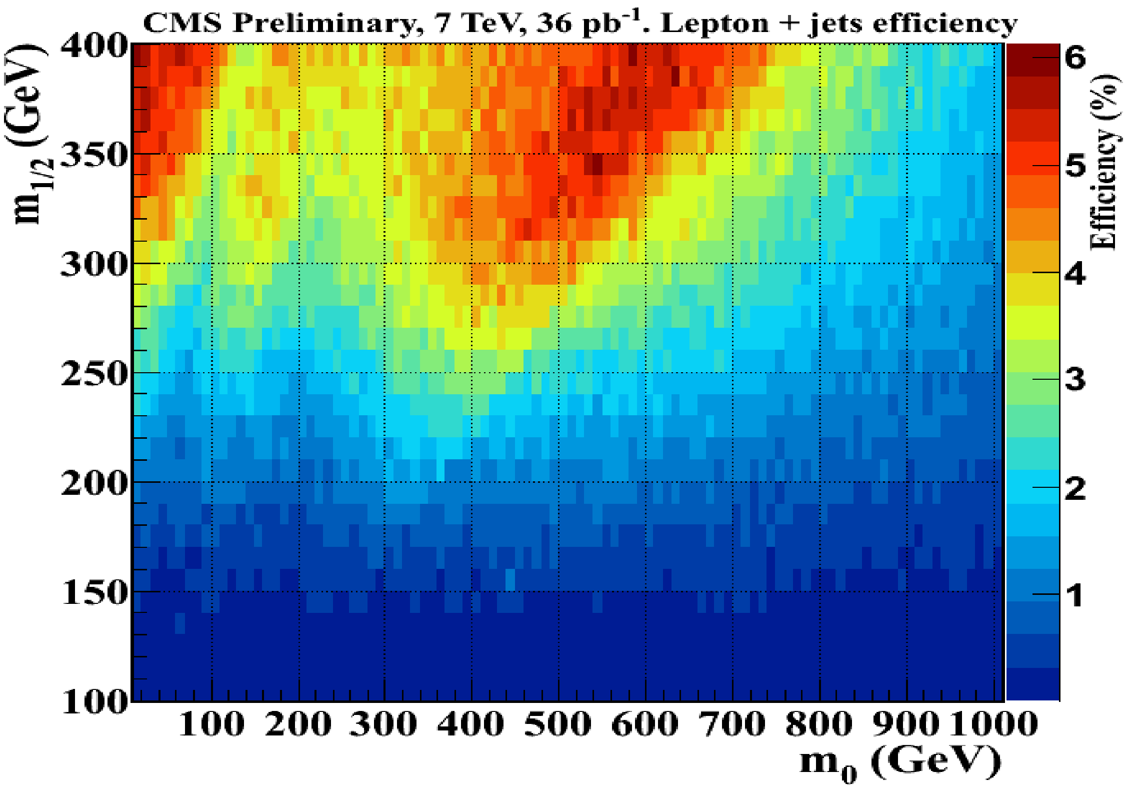


Efficiencies for Single lepton analysis

(tanβ = 3, A_0 =0, sign(μ) > 0)



(tanβ = 10, A_0 =0, sign(μ) > 0)



Motivation: Issues with sneutrino dark matter

Sneutrinos annihilate rapidly in the early universe

To get interesting abundance we need:

snutrino mass < few GeV or > 600 GeV

Z-width constraint rules out sneutrino mass < 45 GeV

PDG expects (Eur. Phys. J C3 (1998)) sneutrino mass > 44.6 GeV

Motivation: Issues with sneutrino dark matter

The picture is improved inorder to keep sneutrino LSP:

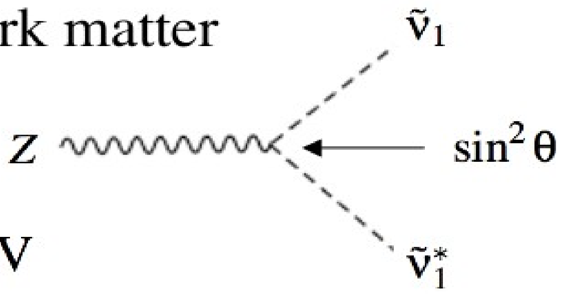
• Introduce right-handed neutrinos with vanishing or small Majorana masses

Arkani-Hamed, Hall, Murayama, Smith, Weiner (See references)

Implications of mixings for dark matter

- Z-width constraint:

$$\delta\Gamma = \frac{\sin^4\theta}{2}[1-(2m_{\tilde{\nu}_1}/m_z)^2]^{3/2}\Gamma_\nu < 2 \text{ MeV}$$



- If $\sin\theta < 0.4$ no constraint on mass -- light sneutrino dark matter opens up as possibility.

Other justifications that use sneutrinos as dark matter candidates

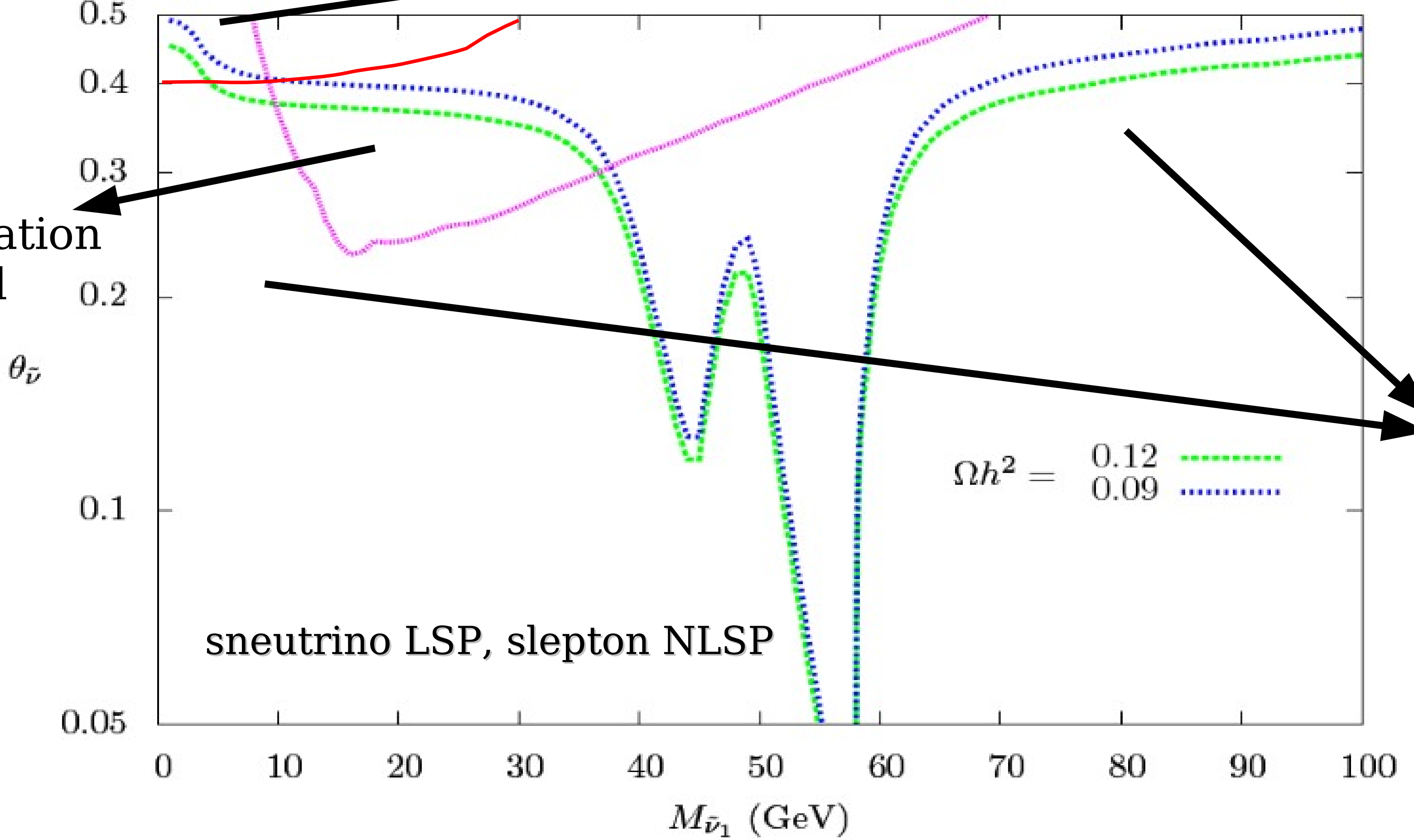
(using small weak-scale coupling term):

- Asaka, Ishiwata and Moroi
- Gopalakrishna, de Gouvea and Porod
- Lee, Matchev, Nasri .. etc

Motivation: Issues with sneutrino dark matter

Inspired by the characteristics and topology

*[Zachary Thomas, David Tucker-Smith, (Williams Coll.) , Neal Weiner](See references)



Although we have allowed regions: do we care if sneutrino can solve all the dark matter problems ?

Most interesting aspect is in its topology

Exclusive combinations - Multileptons

Each of the sources of the systematics is presented in the Likelihood as a truncated Gaussian distribution with variance σ for the corresponding nuisance parameter δ. In case of only leptonic selection there are overall N_{ch} nuisance parameters for the backgrounds, three nuisance parameters for the lepton identification and one for the luminosity. The combined Likelihood for N_{ch} exclusive channels can be written as a product of the individual ones:

$$
\begin{aligned}
L_{s+b} =& \prod_{k}^{Nch} Poisson(n_k|\mu_k) \cdot Gauss(\sigma_{b_k}, \delta_{b_k})\, Gauss(\sigma_\mu, \delta_\mu)\, Gauss(\sigma_e, \delta_e)\, Gauss(\sigma_\tau, \delta_\tau) \cdot \\
& Gauss(\sigma_{lumi}, \delta_l)\, Gauss(\sigma_{MC}, \delta_{MC})\, Gauss(\sigma_{Trigger}, \delta_{Trigger})\, Gauss(\sigma_{JES}, \delta_{JES}) \qquad (1) \\
\mu_k =& b_k(1+\delta_{bk}) + S \cdot \epsilon_k \prod_{l}^{n_l} (1+\delta_l) \cdot lumi \cdot (1+\delta_{lumi})(1+\delta_{MC})(1+\delta_{Trigger})(1+\delta_{JES})
\end{aligned}
$$

The common signal $S = \sum_k^{Nch} s_k$ is contributing to the k-search via the susy-fractions ϵ_k given in Table 1. The uncertainty in this fraction is defined by the uncertainties in lepton identification δ_l where $l = \mu, \tau, e$ and n_l -number of leptons in the final state. Here δ are Gaussian distributed nuisance factors with mean zero and variance σ. For equal leptons the correlation is taken into account by using the same random number for generating the fluctuation. All search channels, as described in Table 1, have been implemented in the statistical model using the RooFit framework [27].

The calculated 95% CL_s limit corresponds to a common signal S_u=5.0 which has been used to draw the 95%CL exclusion limits, see Fig. 8. The coverage properties of the Hybrid method have been verified by simulating toy experiments in the described statistical model and counting the fraction where the calculated limit is bigger than the true signal value. No undercoverage has been observed in the whole range of parameters, but some overcoverage especially at low n_{obs} values. Instead of truncated Gaussian distributions for the nuisance parameters also log-normal and gamma distributions have been used. The longer tails allow for a higher upward fluctuation of the background and hence decrease the upper limit on the signal. Therefore we use the Gaussian distribution, which yields the most conservative result.

DRAFT