Search for Anomalous Production of Multileptons at CMS using 4.98 fb^{-1}

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Chicago 2012 Workshop on LHC Physics

Outline

- Intro: Three or more leptons (incl hadronic tau's)
- Unified /Ambiguous "Signal" and "Control" Regions
- Multi-binned Search for Anomalous Production
- Interpretations
- Conclusion

A bit of recent "history"

- Since 35 ipb data (2010):

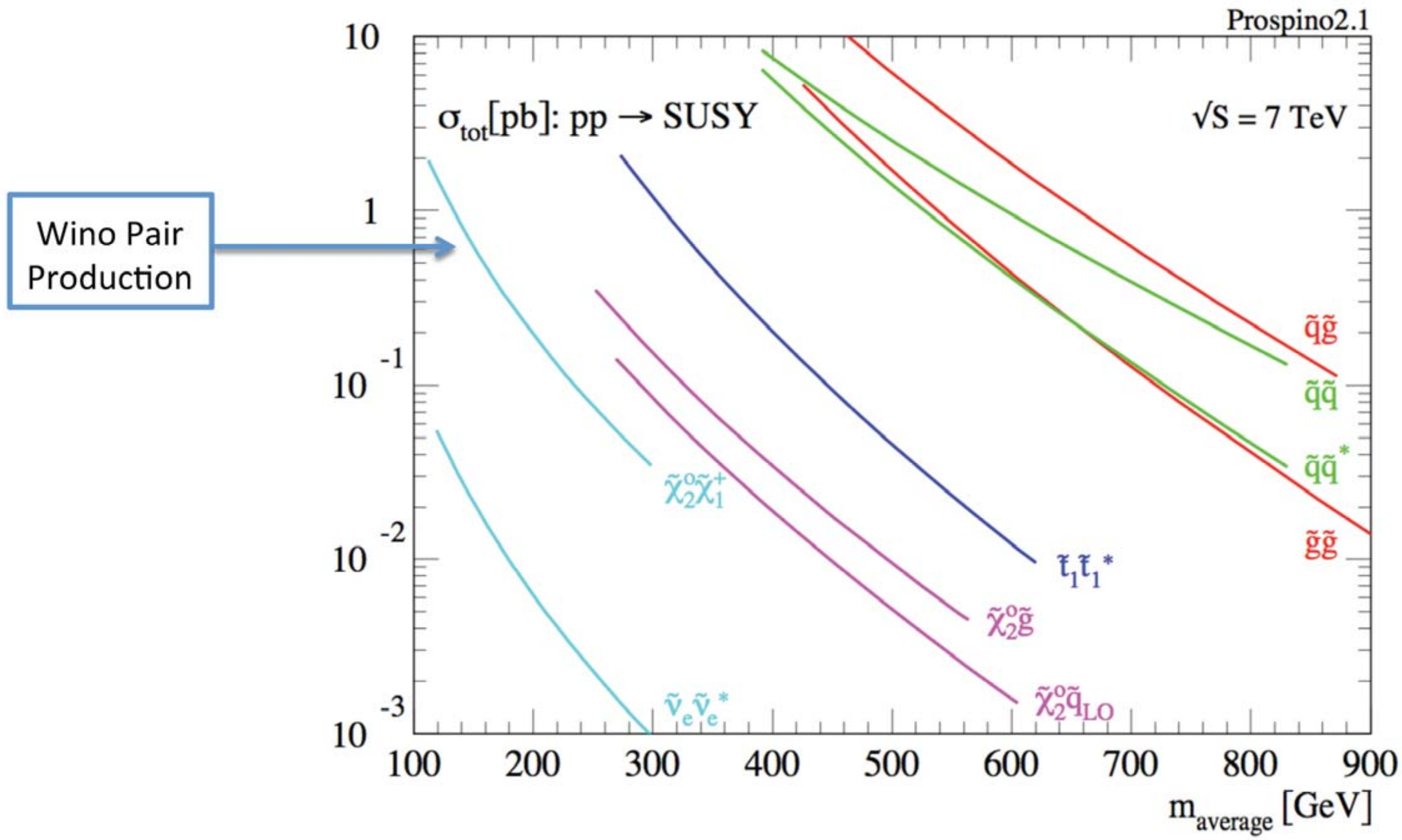
  Great expectations from Jet/met/α_T

  (Strong production: How hot is the beam pipe?)
- Now three possibilities nearby the lamp-post:
  - Strong production with even higher mass scales
  - Strong production but topological accidents
  - Weak production (etc).
- Search axes:

  a) jets,b-tags b) MET/HT c) Leptons, photons

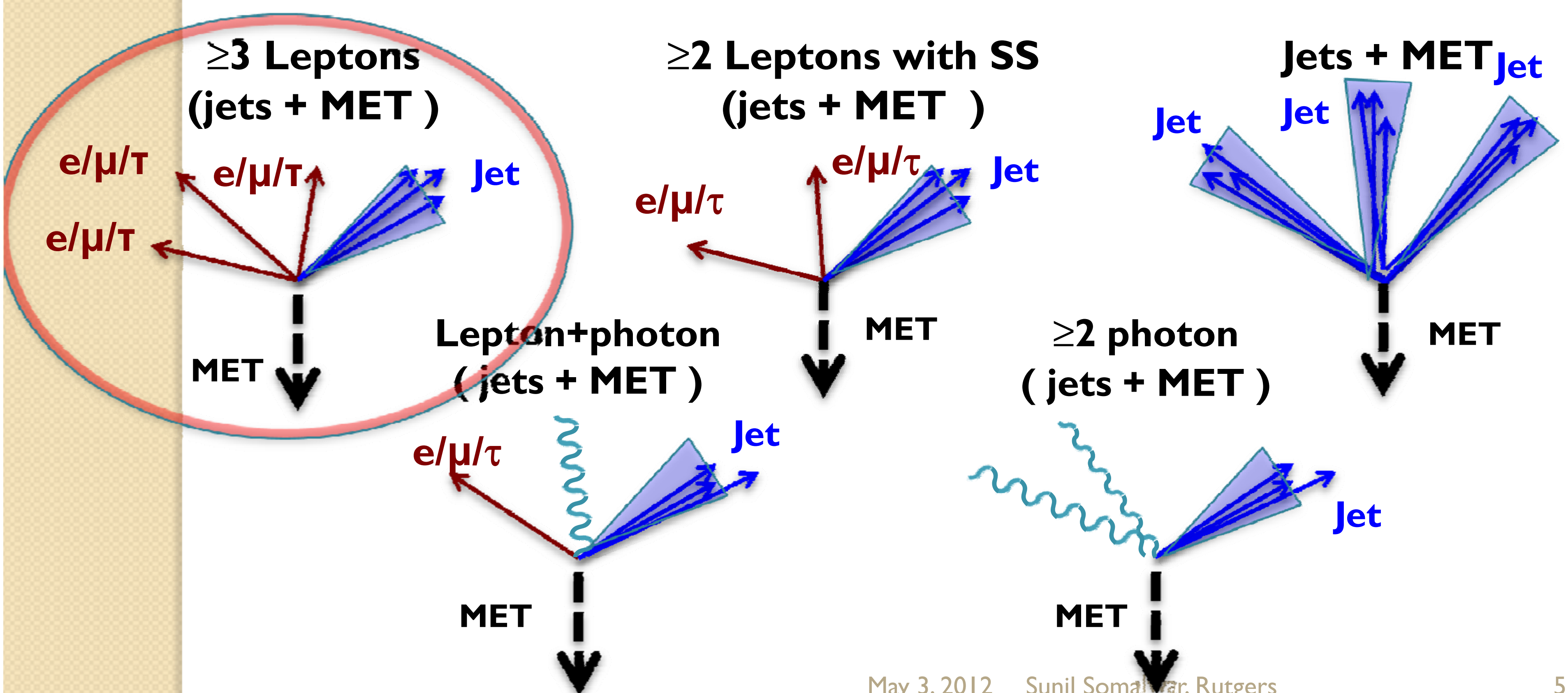
  (New physics potential for each even with 35 ipb).

Strong vs Weak Super-Partner Production



New Physics Search Axes

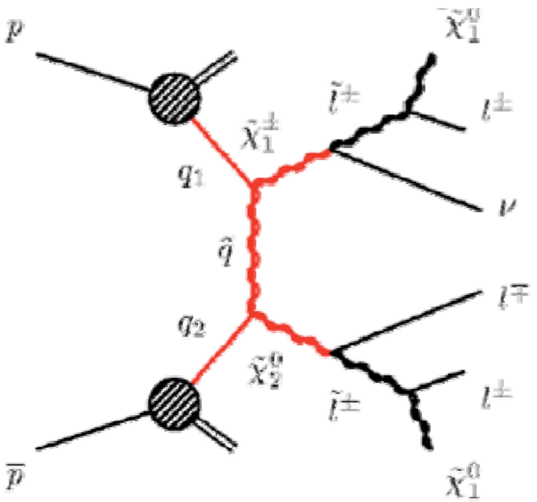
MET or jets/HT not guaranteed



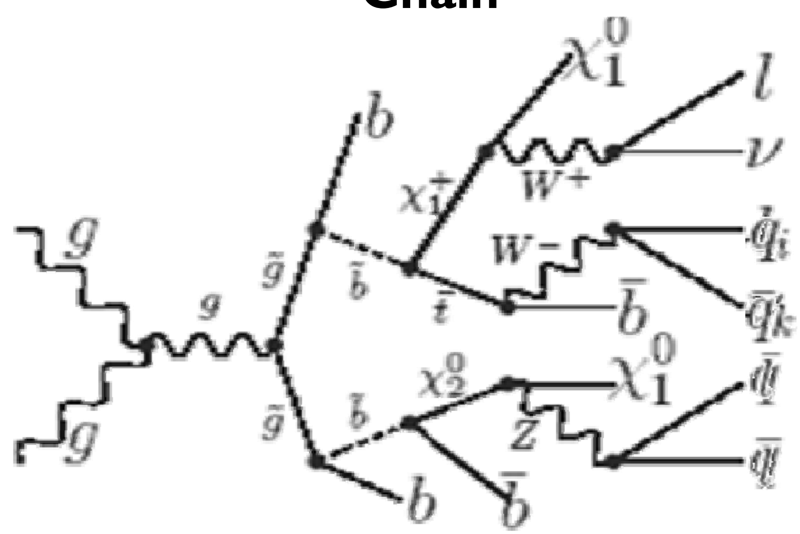
MultiLepton Production at LHC

- **Leptons produced directly from heavy parents or in a long chain of decays**

Leptons Directly from Parent Particles



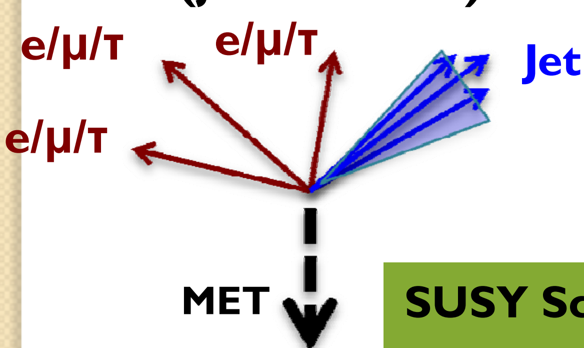
Leptons from Complicated Chain



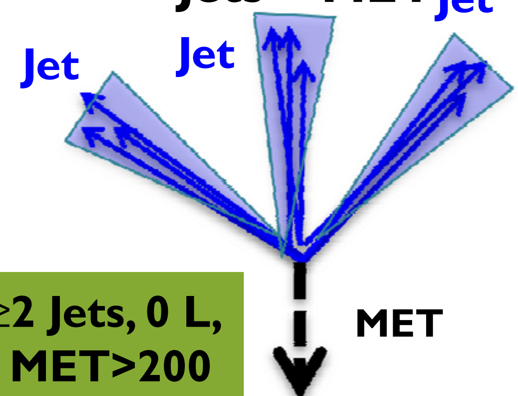
Multileptons vs Jet-MET

- Branching fraction to different final states dependant on mass spectra in model.
  - Below are branching fractions for different SUSY scenarios.

≥3 Leptons
(jets + MET)



Jets + MET



SUSY Scenario Examples	≥3L	≥2 Jets, 0 L, MET>200
Slepton co-NLSP (GMSB)	~100%	0%
Leptonic R-parity violating	~100%	0%
mSUGRA (Mo=60, M1/2=190)	~23%	11.4%
mSUGRA (Mo=200, M1/2=250)	~1.8%	35%

Search Strategy: Multileptons + MET or HT?

H_T is the scalar sum of jet E_T

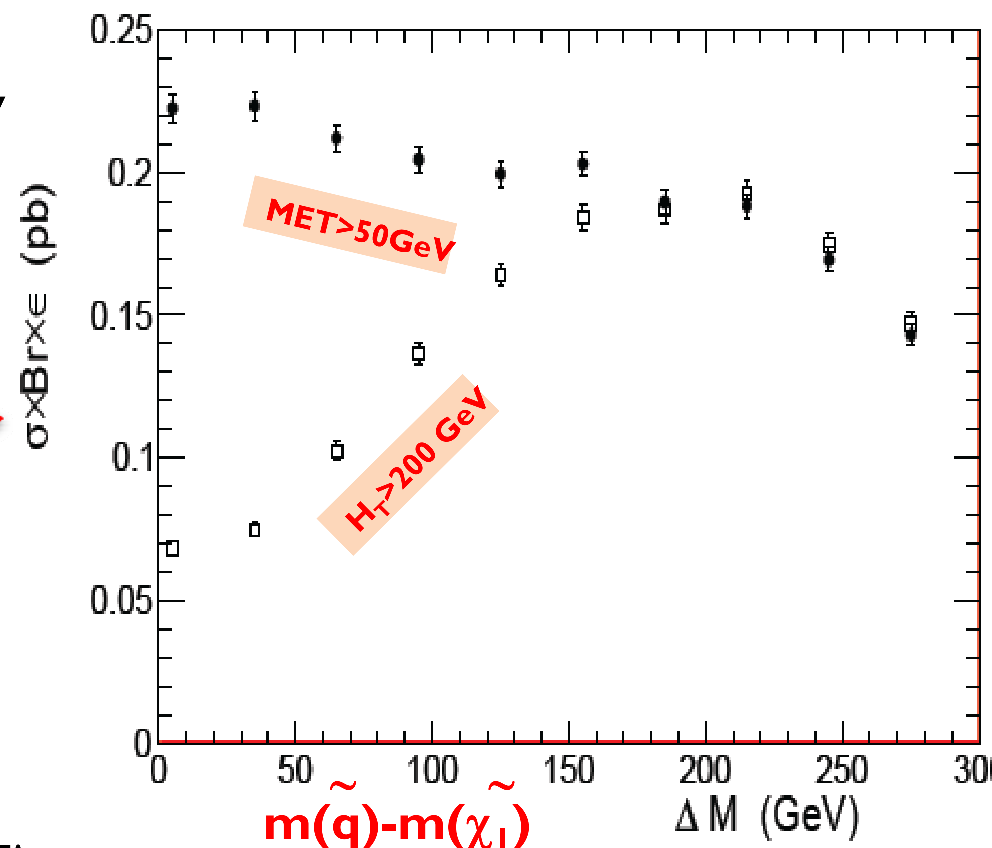
$$H_T = \sum_i E_T(\text{Jet}_i)$$

MET is Missing Transverse Momentum

$$\text{MET} = \left|\sum_i \vec{p}_T(i)\right|$$

WARNING: Some models have both H_T and MET, but some only have H_T or MET. Cannot rely on just one of these variables.

Example:
slepton co-NLSP GMSB scenario m(q)=500. Small mass difference can cut off jet production.



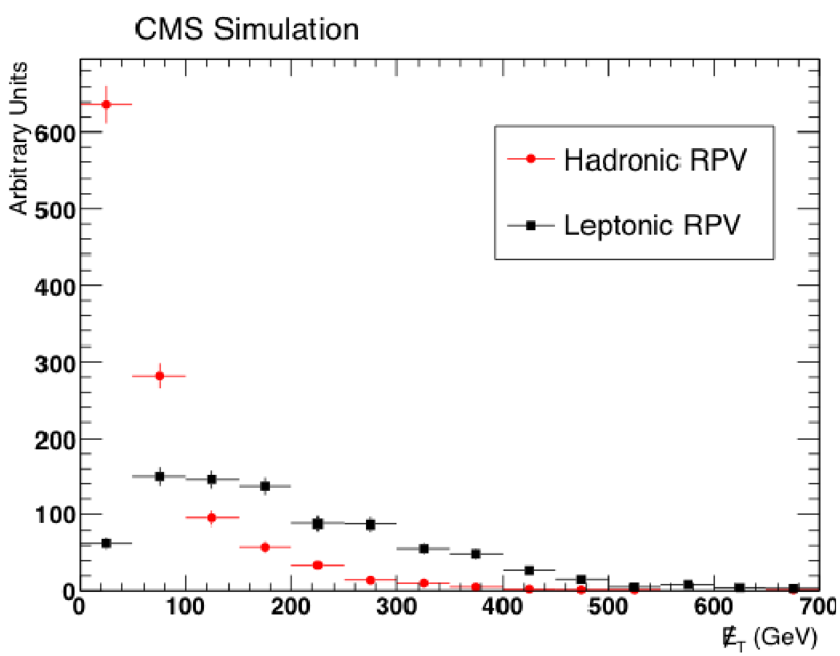
THIS IS *NOT* WEAK PRODUCTION!!

"Weakinos" come with small HT!

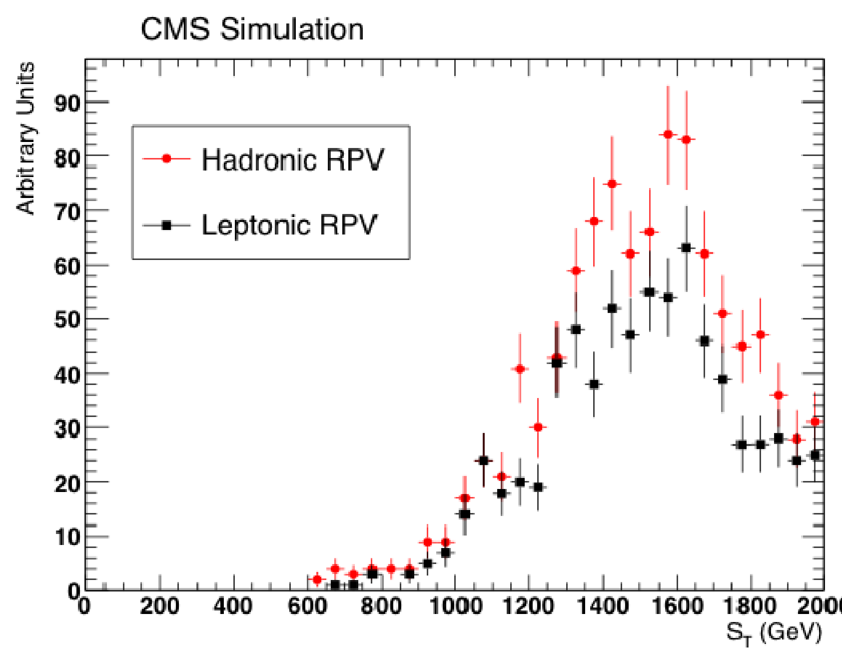
S_T versus MET/H_T Binning

- S_T=MET+H_T+Σp_T(iso-leptons) (ATLAS:"Effective Mass".)
- S_T ~insensitive to how parent decays.
  - Consider two types of RPV SUSY: Leptonic and Hadronic
    - MET distributions are very different, but S_T is almost the same.
  - S_T Analysis can be sensitive to a wider range of models
    - S_T gives information about mass scale of the new physics.
    - Peak is ~ M(parents) - < M(invisible daughters) >

MET misses Hadronic RPV



S_T Distributions same



Ambiguous Search/Control Regions

- We know that we don't know → cast a wide net
- Cover a wide range of scenarios
  - SUSY models only as vague guides
    - (CMSSM, GMSB, R-parity violating)
  - Selections based on SM background considerations.
  - Anomalous (nonSM) production in numerous channels.
- Highlights observed on the way:
  - First $ZZ \rightarrow 4\mu$ event
    - (animation available on youtube), Oct 10, 2010 (10/10/2010).
  - Hit a forgotten Standard Model background in the Higgs→WW searches.
    - $W\gamma^*$ was left out of searches in both ATLAS and CMS
    - Prompted changes to CMS/ATLAS H→WW searches.
    - Interesting story, more later.

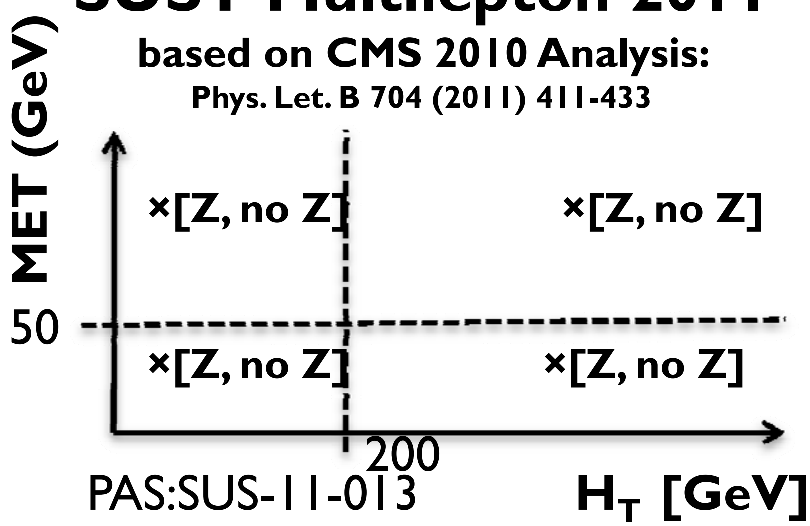
CMS 2011 4.98 fb^{-1} Multileptons
(SUBMITTED TO JHEP)

- Two sub-analyses to cover wide range of scenarios.
  - Same lepton selection, backgrounds, triggers, code
  - ~50 bins in each analysis
  - 3 or ≥4 leptons (e, μ, and τ), bin in M(l+l-) and number OSSF pairs
  - Different strategies for isolating new physics from SM.
    - MET=Missing Transverse Momentum
    - $H_T = \Sigma p_T$(jets) , $|\eta| < 2.5$ and $p_T > 40$ GeV
    - S_T=MET+H_T+Σp_T(iso-leptons) (ATLAS:"Effective Mass".)

SUSY Multilepton 2011

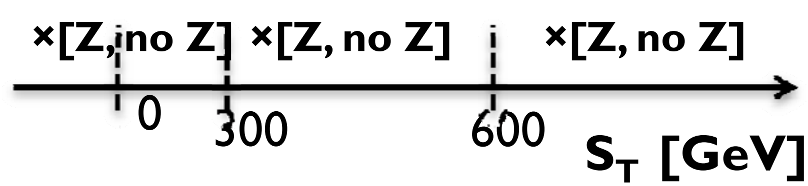
based on CMS 2010 Analysis:

Phys. Let. B 704 (2011) 411-433



PAS:SUS-11-013

RPV/Exotic Multilepton 2011



PAS:EXO-11-045

Event Selection

- 3 and $\geq$4 lepton combinations with e, μ, and ≤ 2 τ's
  - Select on single and dilepton triggers.
  - Cut events if M(l+l-) < 12 GeV (J/ψ, Upsilon, γ*)
  - In low S_T (or low MET&HT) cut events where M(ll) off Z and M(lll) on Z

- Bin instead of cut! Poor S/B bins act as control channels.
  - # Drell Yan candidates (e+e−, μ+μ-): 4 leptons can be DY=0,1,2
  - Is there a Z candidate? M(l+l-) 75-105 GeV

nDY = number of Drell-Yan (OSSF) pairs

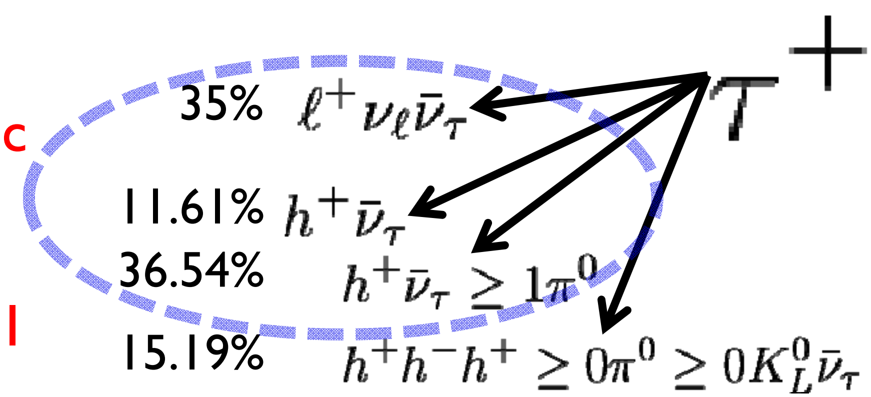
Lepton Selection: (e, μ, τ)

- Electrons and Muons:
  - $p_T > 8$ GeV, $|\eta| < 2.1$
  - Require Relative isolation < 15% and total isolation < 10 GeV
    - Isolation for μ(e) is sum of tracker, calo transverse energy in $\Delta R < 0.3(0.4)$
    - Relative isolation is total isolation divided by lepton p_T

Lepton\Trigger Type	μ	e	μμ	ee	e μ
Leading e/μ	> 35	> 85	>20	>20	>20
Next-to-leading e/μ	NA	NA	>10	>10	>10

Primary Triggers

- Tau Leptons:
  - Leptonic decays fall under e/μ
  - Accept "single prong" hadronic
    - Isolated track (no π^0)
    - HPS Algorithm (with π^0)
  - Visible p_T > 8/15 GeV, $|\eta| < 2.1$



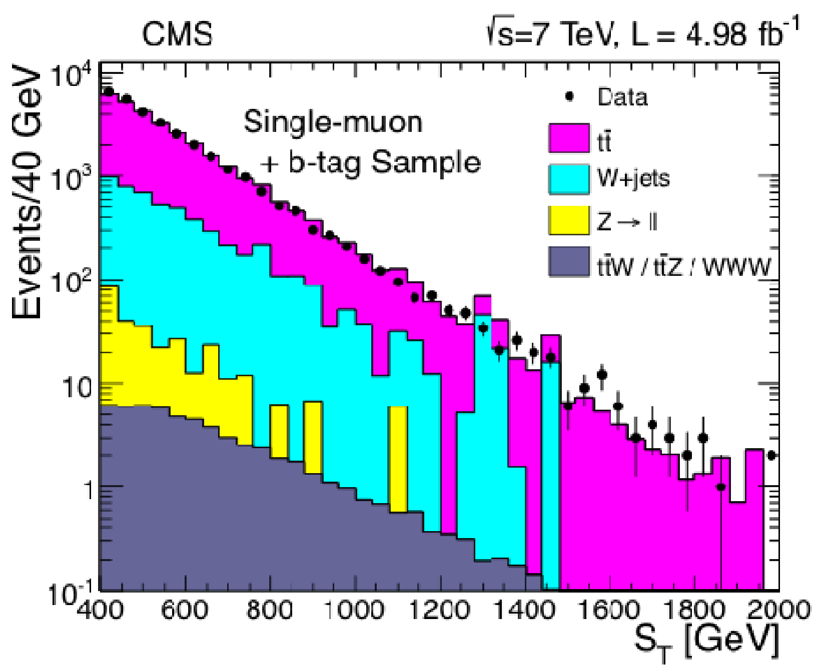
Background Predictions

- Uniform background treatment of all channels.
- Monte Carlo Predictions (MC)
  - TTbar and Irreducible backgrounds: WZ+Jets, ZZ+Jets
    - Corrected to match efficiency measurements.
    - Systematic for kinematics as well as "fake rates" for ttbar.
- Other backgrounds are "Data Driven"
  - Z+Jets, WW+Jets, W+Jets, QCD
    - No MC. Use dilepton data, estimate number of 3rd and 4th lepton candidates from jets.
  - Z+γ Asymmetric Conversion γ→e+e- or γ→μ+μ-
    - Estimate number dileptons+photon conversion from data.

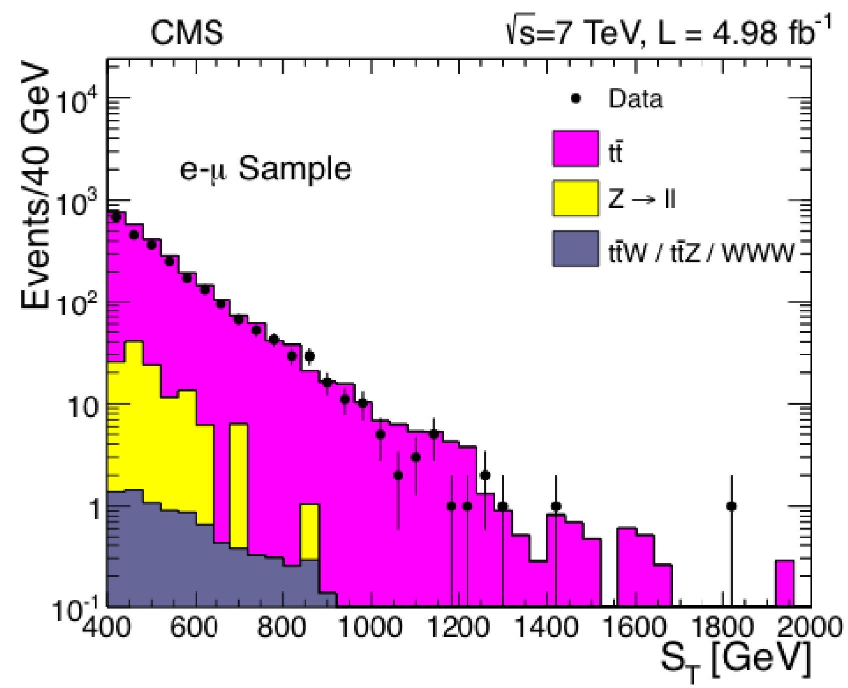
Data vs Monte Carlo

TTbar Control Regions (*not* 3-leptons)

- Example: TTbar in following control data sets
  - One lepton ($p_T > 30$) + ≥3 jets (≥1 b-jet), or dilepton 1 e + 1 μ
  - $S_T > 400$ GeV
  - Test the overall number of TTbar as well as S_T tails.



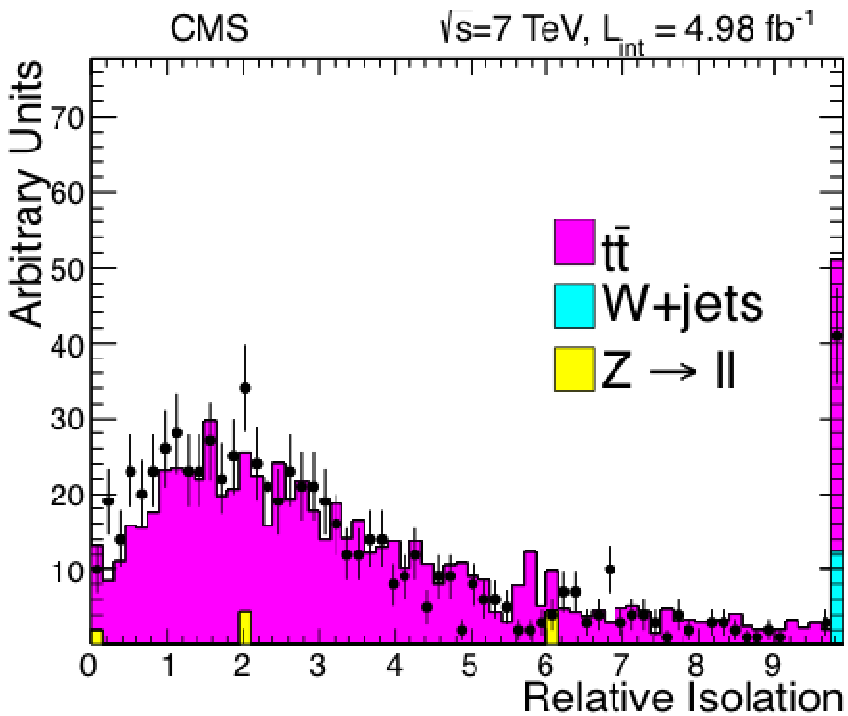
S_T for single-lepton sample.



S_T for dilepton e+μ- sample.

TTbar MC Validation with Data (cont..)

- TTbar has known jet composition (mostly b-jets)
  - MC ok for this purpose.
  - Semileptonic decays of heavy flavor measured at B-factories.
- Isolation of leptons from jets in TTbar
  - 1 lepton + ≥3 jets (≥1 b-jet), test μ with large impact parameter.
    - Require test μ far from leading tagged b-jet. ($\Delta R > 0.6$)



Integrals from Isolation plot:

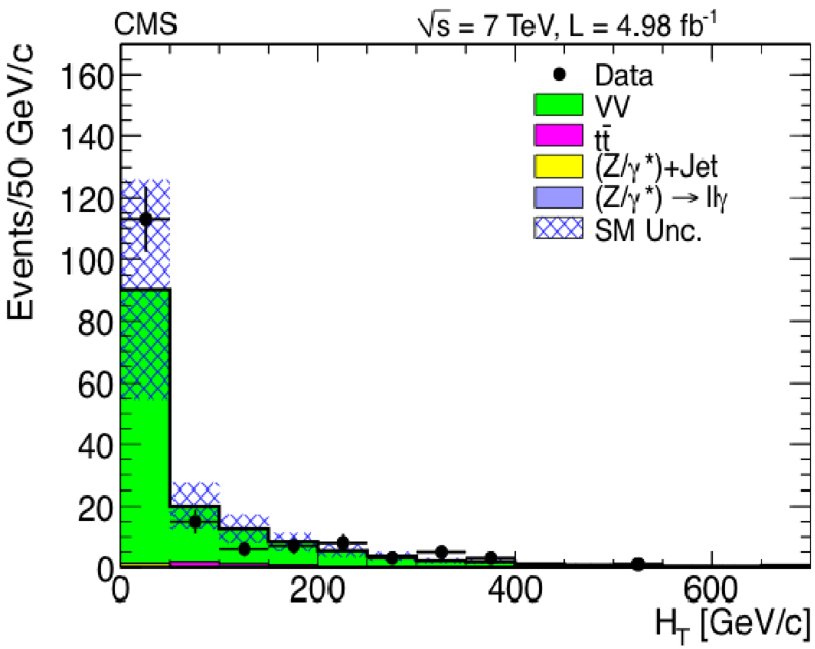
Isolation Range	Data	MC
0.0-0.15	10	13
0.0-inf	733	745

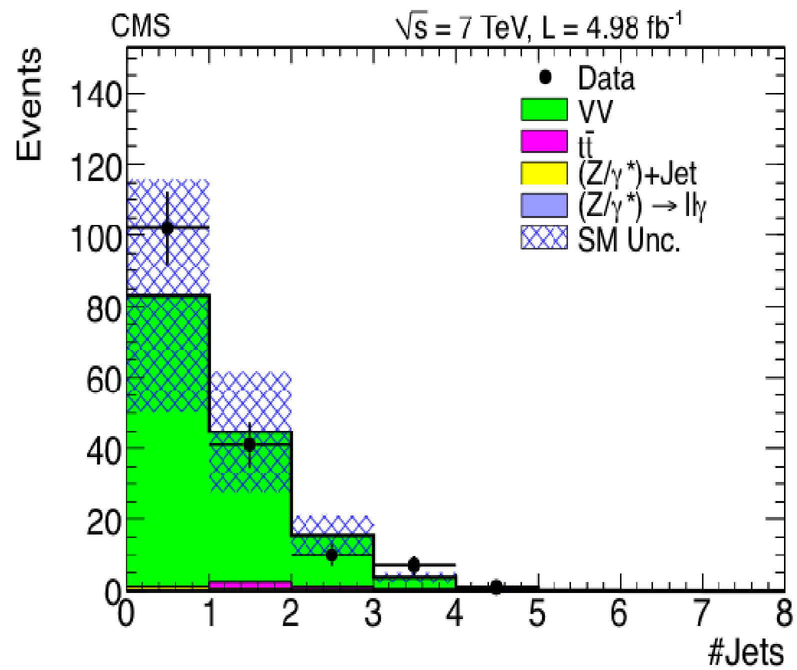
Isolated Bin (Most important!)

Cross check heavy flavor semileptonic branching fractions

W±Z MC versus Data

3 e/μ, Z candidate, and MET > 50 GeV





H_T distribution of WZ **Number of jets in WZ**

Blue hash bands are uncertainties (syst+stat) on background.

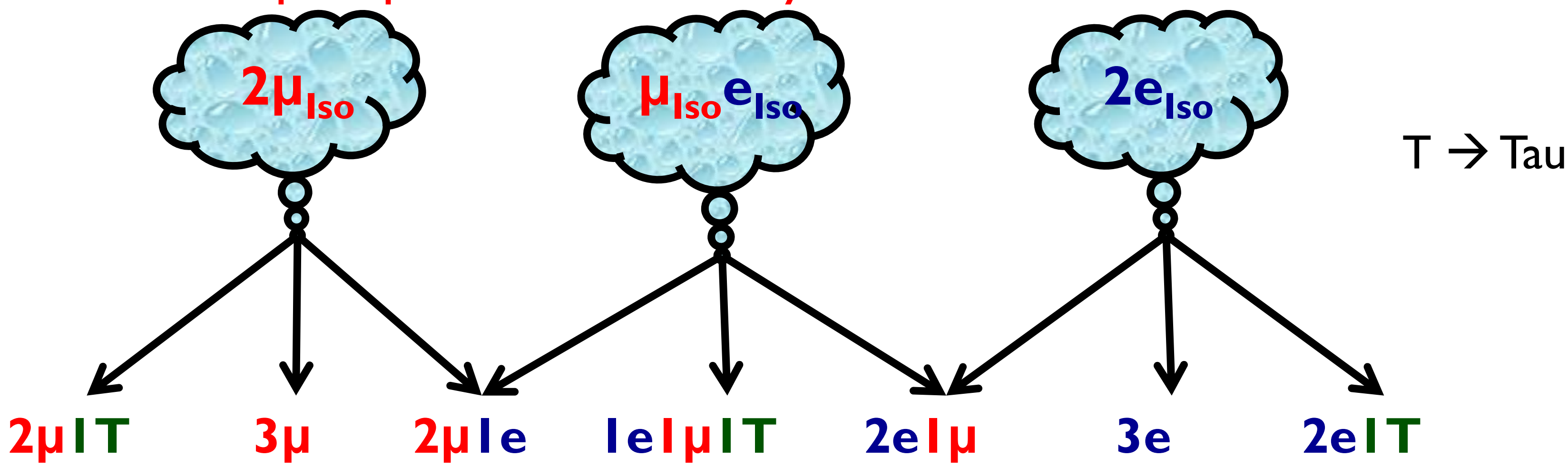
Fully Data Driven Backgrounds

Basics of (Legitimate) "Data-Driven" Predictions

- Pick a proxy object to treat like a lepton
  - Example: track, non-isolated lepton, loosened ID, etc.
- In control data measure Proxy→ Fake factor
  - Proxy→Fake factor has many aliases "fake rate", "Tight Loose Ratio", "conversion factor"….
    - Depends on spectra, flavor, resolution, branching fraction….
  - Test in 2nd control set for "closure test"
  - Apply to a "seed" data set to get prediction in signal region.
- Systematics: Do key features in control data match seed?
  - Primary source of systematic uncertainty.
  - Especially important for this analysis!

Data Driven Predictions

- Use 2L data as a seed to predict ≥3L background
  - Example: 2e to predict 2e1μ background
  - Effects like pileup are automatically included.



- Apply background estimation procedures to seeds.
  - Predict fake Tau using isolation side band. (~25% systematic)
    - Systematic from how well we understand isolation distribution.
  - Predict e or μ from jet using isolated tracks (~15% systematic)
    - Systematic from how well you understand types of jets in data set.
  - Predict asymmetric conversions using photons. (~100% systematic)
    - Large systematic due to difficulty in testing method beyond control.

Isolated Track→e/μ Scale Factor

- Isolated tracks ($\pi^{\pm}$) as proxy for e/μ from jets
  - Isolation related systematics are ~same as e/μ
  - However! Track→e/μ sensitive to average jet flavor

$$f_\mu = \frac{N_\mu^{Iso}}{N_T^{Iso}} = \frac{N_\mu}{N_T} \times \frac{\epsilon_{Iso}^{\mu}}{\epsilon_{Iso}^{T}}$$

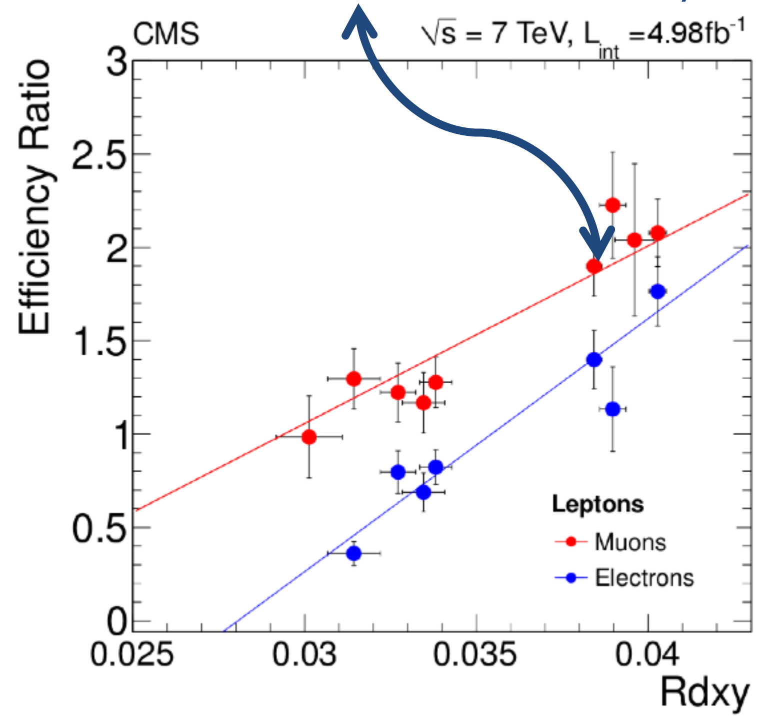
Ratio of lepton to track isolation efficiencies. Parameterize in di-jet data as a function of R_{dxy}

Non isolated leptons and tracks measured in seed to reduce dependence on control data.

Heavy Flavor produces displaced vertices and non-isolated tracks with large dxy

R_{dxy}=N(|dxy|>0.02cm)/N(|dxy|<0.02cm)

A sample of pure b-jets has Rdxy~30%
A sample of pure uds jets has Rdxy~3%

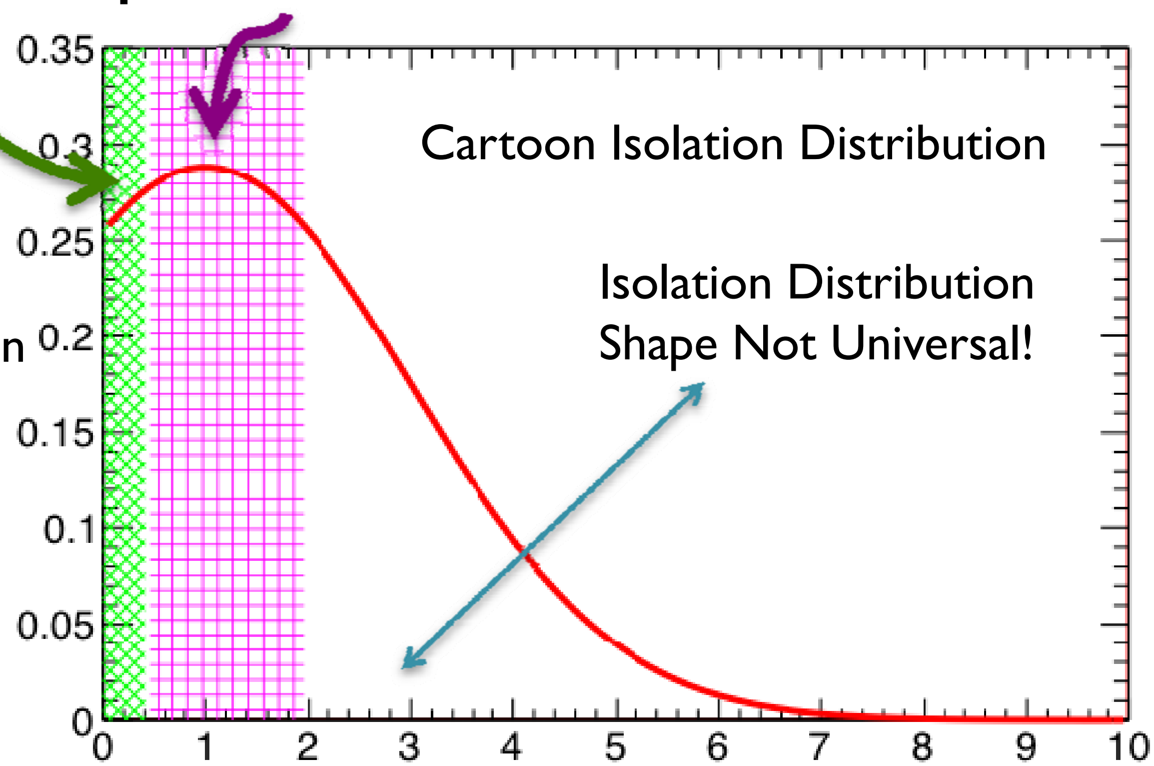


Tau Background

- Use isolation side band to predict Fakes
  - Define f_T to convert sideband to isolated

#ISO = f_T x #SB

We measure f_T in dijet data and apply it to nonisolated τ candidates in l^+l^- data.



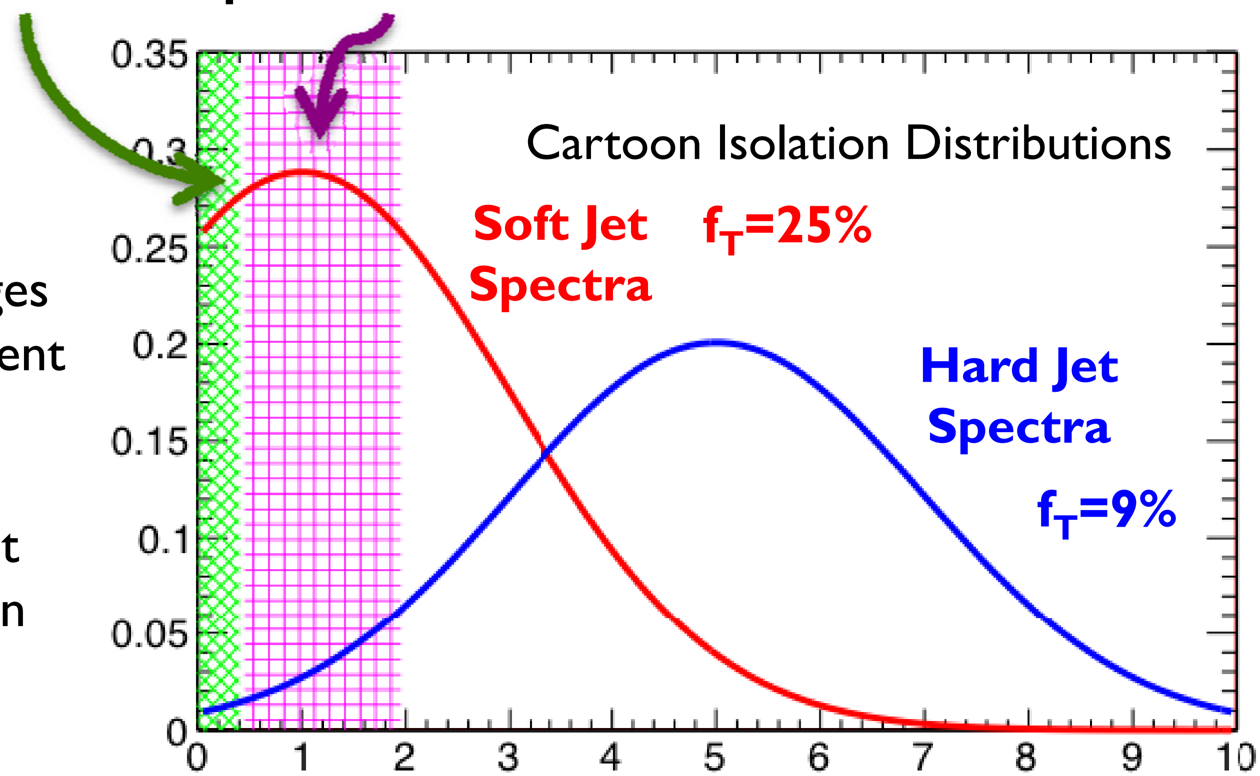
Tau Background Problem

- Isolation shape can change drastically.
  - f_T changes between dijet and dilepton data!!

#ISO = f_T x #SB

We need a way to parameterize changes in f_T between different data sets.

Need to match dijet data to conditions in dilepton data.

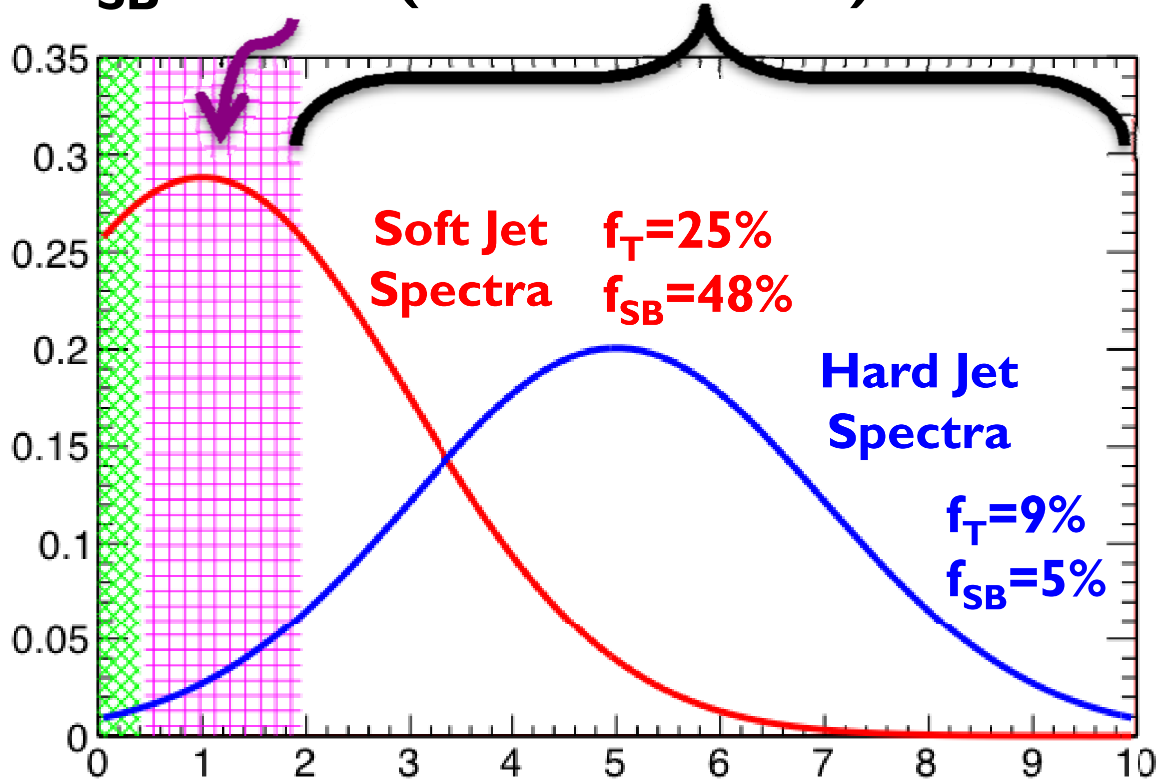


Tau Background by Parametrization

- f_{SB} - Control parameter for isolation shape
  - f_{SB} approaches zero as jets become harder

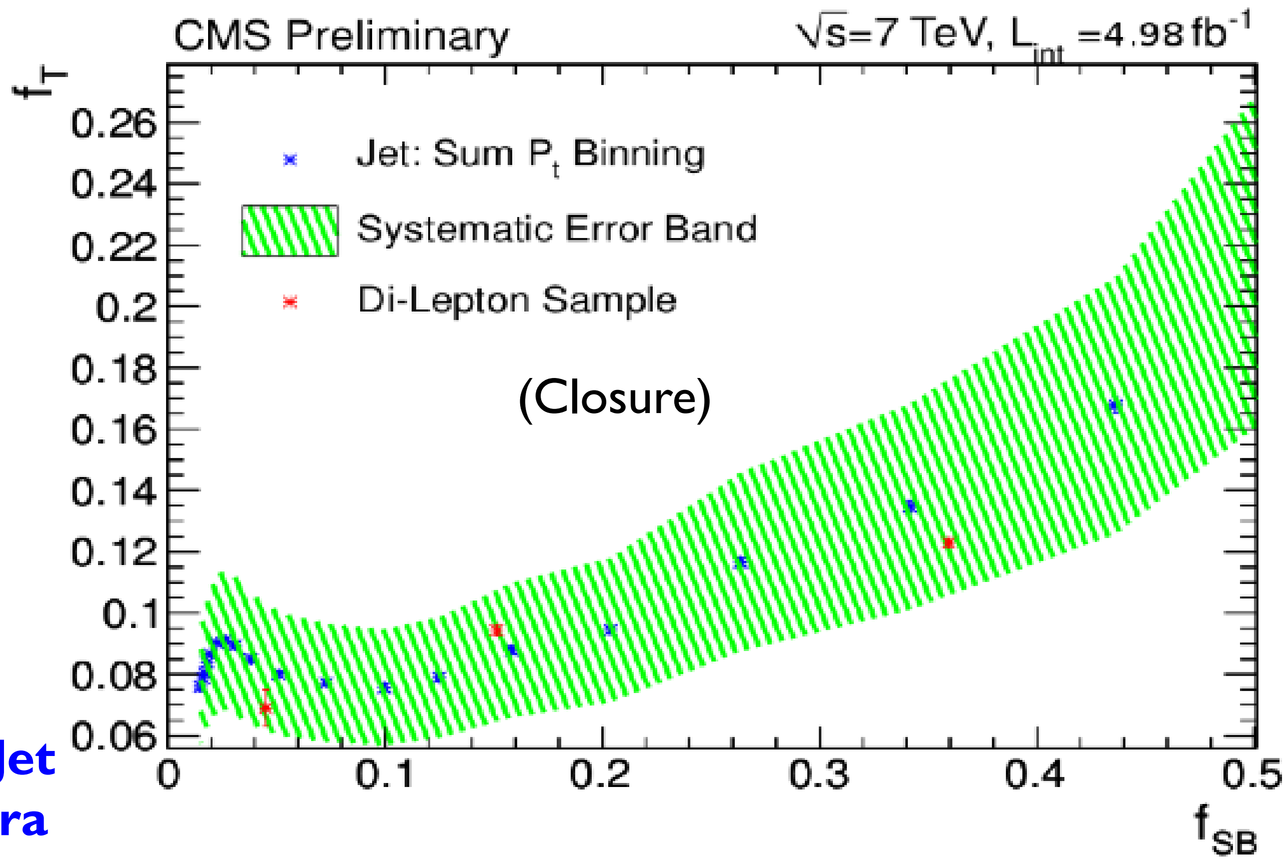
$$f_{SB} = \#SB/(\#SB+\#OTHER)$$

Use f_{SB} to check for changes in the shape of the fake τ isolation distribution.



Tau: f_T vs f_{SB} (Data)

- Bin dijet data and plot f_T vs f_{SB}
- In dilepton use f_{SB} to predict f_T



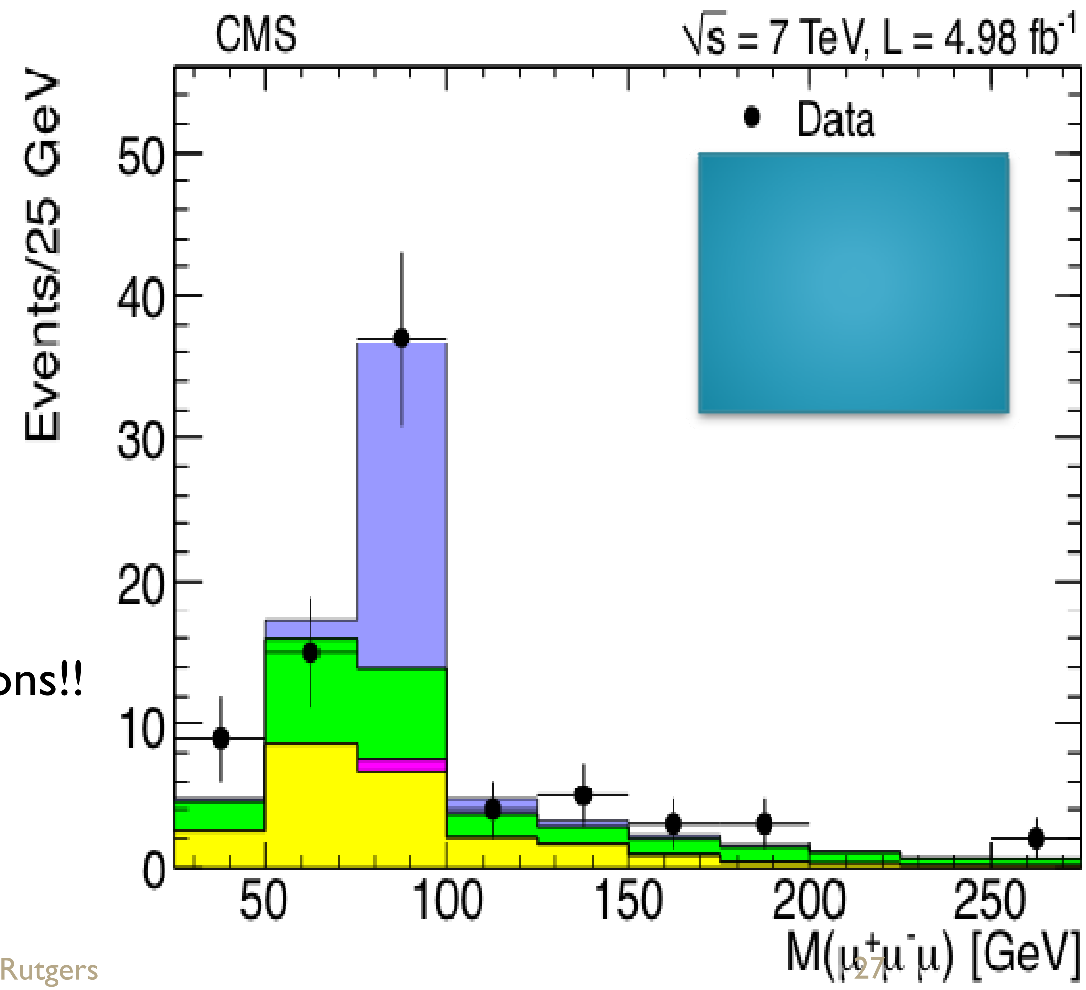
Hard Jet Spectra

Soft Jet Spectra

Photon Conversions

External conversions (in material) removed with the usual tools.

But then something happened on the way to the forum….

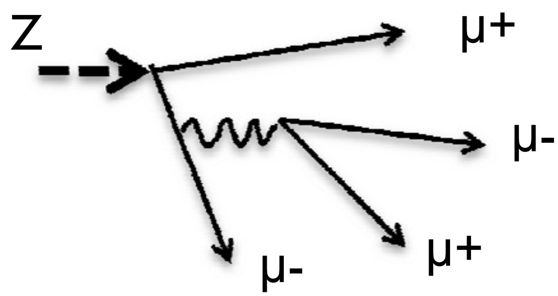


Note: Muons!

Note Again: 3 muons!!

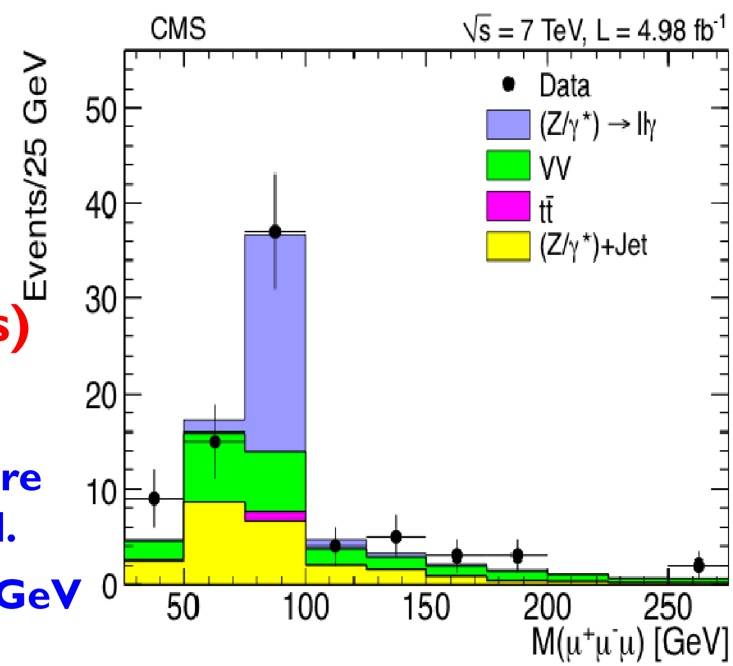
Asymmetric Photon Conversions to $\mu^+\mu^-$

- Two types of asymmetric photon conversions:
  - External: Due to interactions in material, gives only e+e-
  - Internal (Dalitz): Feynman level (γ^*) gives e+e- and μ+μ-



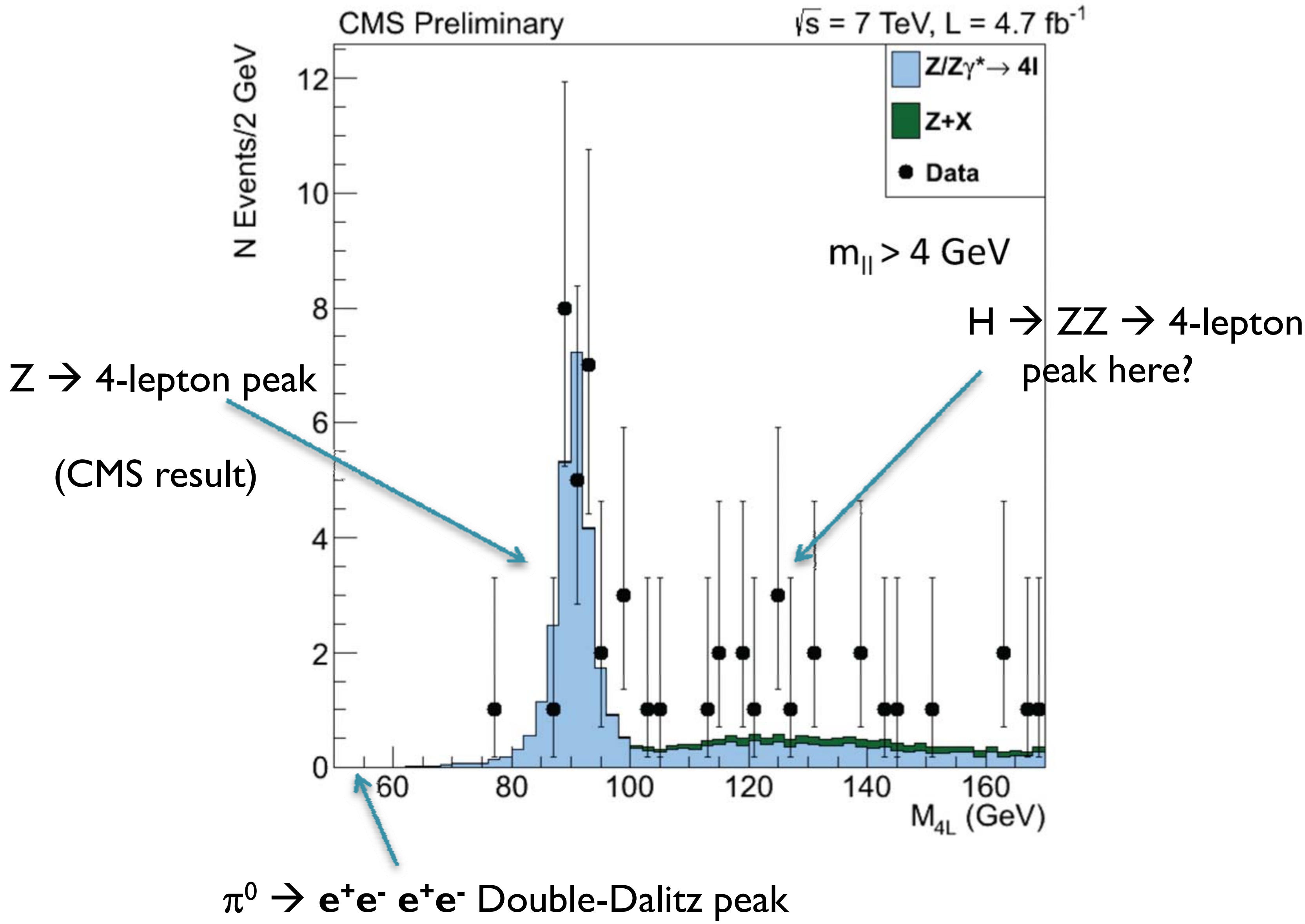
In asymmetric conversion only 3 of 4μ are reconstructed

- 2011 Observation of Z→(3)4μ
  - Analogous to π^0 → e+e-γ
  - Observe 3μ Z peak (4^{th} μ failed cuts)
  - Also W→2μ (+neutrino) (Higgs!)
    - Wg* ignored in Higgs WW search before this. arXiv:1110.1368 R. C. Gray et. al.
    - Important background for Higgs ~125 GeV
    - Searches modified accordingly.



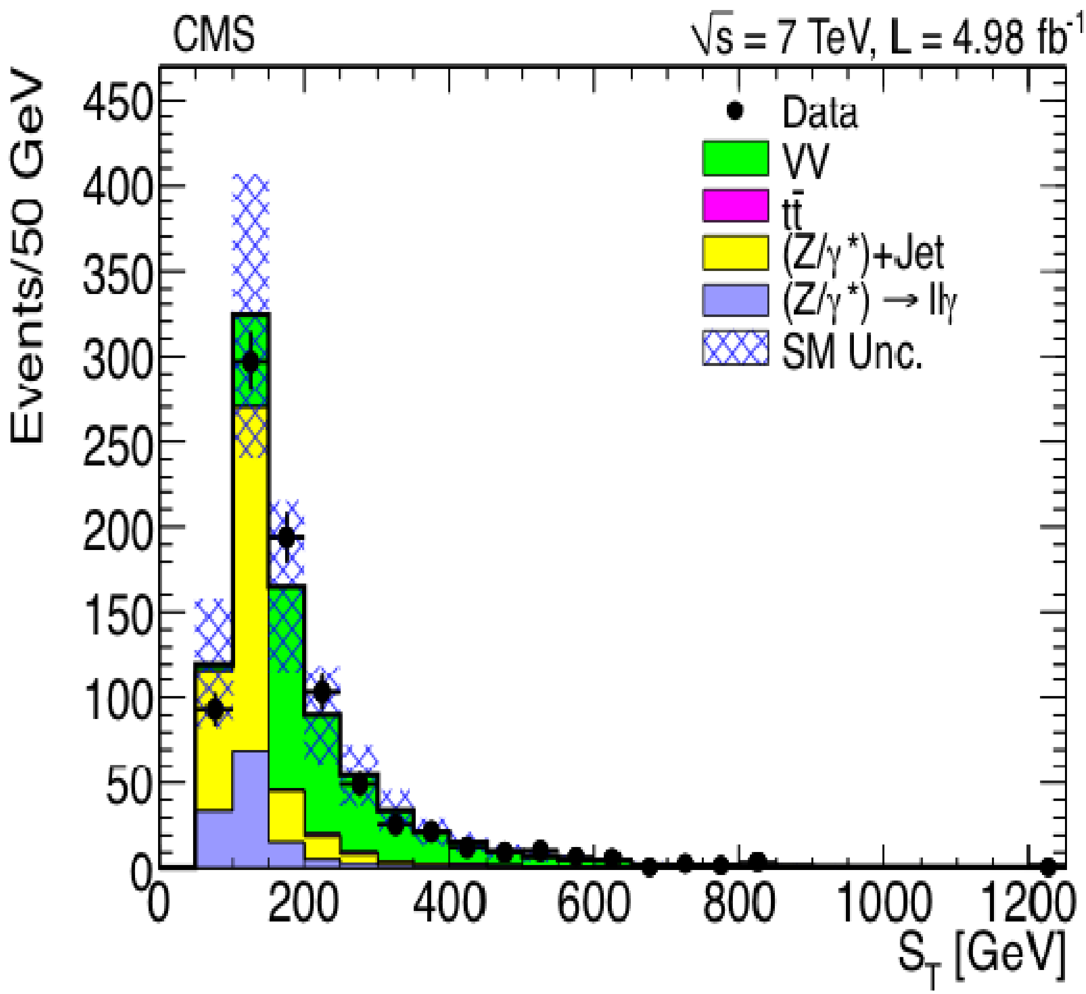
Internal Conversion shape obtained from μ+μ-γ

A textbook plot of tomorrow



L=4.98 fb^{-1} 7 TeV CMS Results

Three Lepton S_T Distributions with l^+l^- on Z (Sort of "Control")



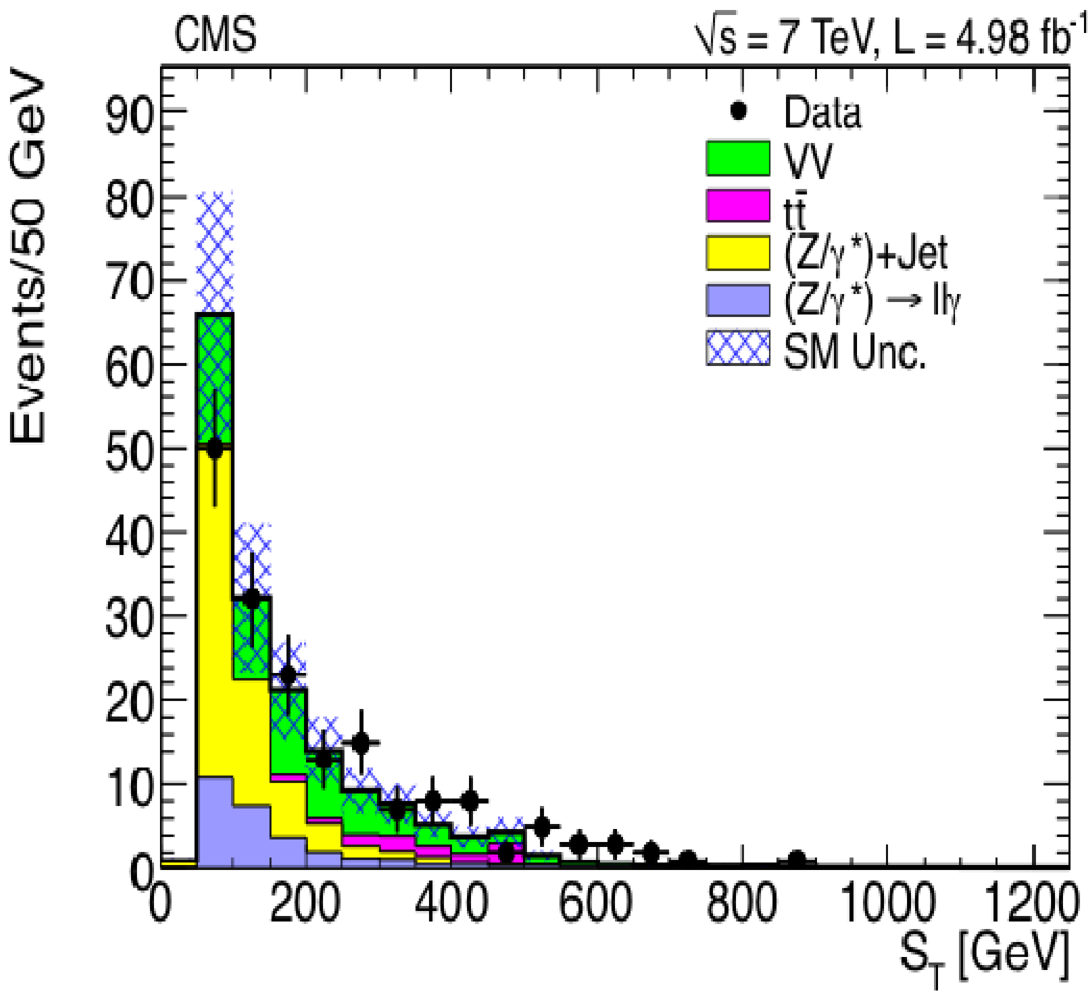
S_T distribution of three lepton events that have a Z candidate.

If we assume new physics does not come with Z's, this is a good test of SM predictions.

Yellow: data-driven

Blue bands: Background uncertainties (syst+stat).

Three Lepton S_T Distributions with l^+l^- off Z (Signal Channel)



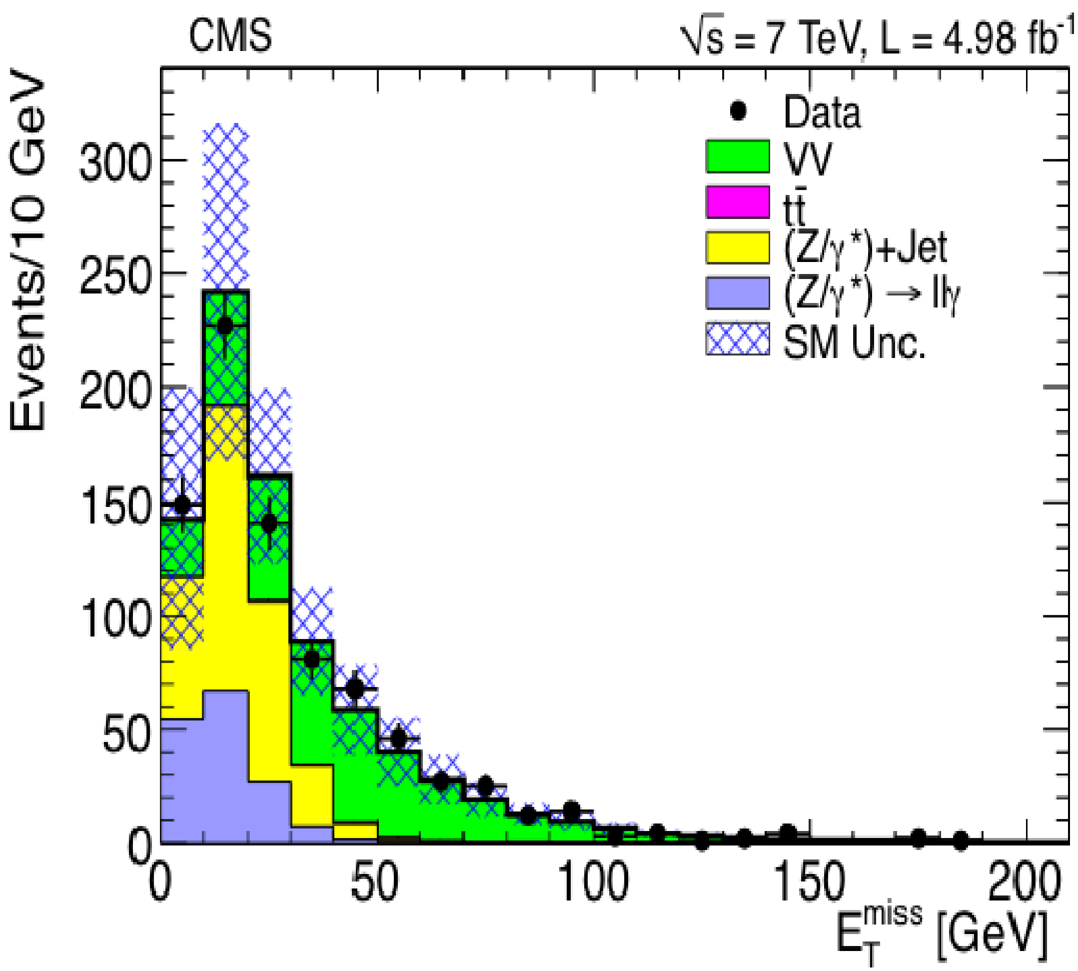
S_T distribution of three lepton events that have a an l+l- pair, but does not make a Z.

One of our signal channels. New physics would be seen as an excess of events at large S_T

The yellow histograms are data driven predictions.

Blue bands are background uncertainties.

Three Lepton MET Dist with l^+l^- on Z (H_T<200 Control Channel)



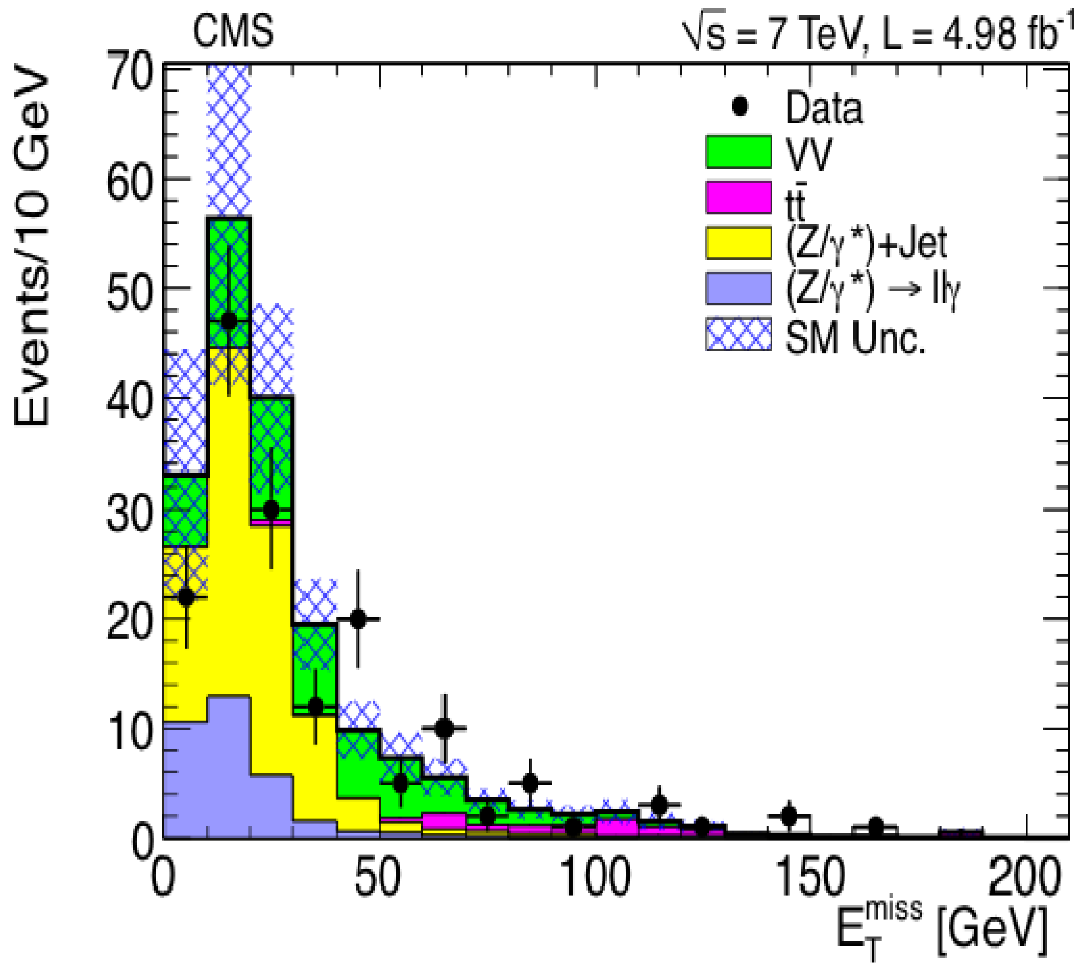
MET distribution of three lepton events that have a l+l- pair that makes a Z.

The yellow and light blue histograms are data driven predictions.

Blue bands are background uncertainties (syst+stat)

Three Lepton MET Dist with l^+l^- off Z (H_T<200 Signal Channel)

Sensitive to EWK SUSY (ElectroWeakino)



MET for 3-lepton events that have a l+l- pair that does not make a Z.

The yellow and light blue histograms are data driven predictions.

Blue bands are background uncertainties (syst+stat)

ST-binned Results (54 channels)

$(N_{DY})x(S_T)x(llll, lll\tau, ll\tau\tau, lll, ll\tau, l\tau\tau)$

Number of Tau candidates (0,1,2) →

≥4 Leptons

Selection			4(e/μ)		3(e/μ)+T		2(e/μ)+2T	
ST	DYpairs	Z?	SM	Obs	SM	Obs	SM	Obs
> 600	DY0		0.0009 ± 0.0009	0	0.01 ± 0.09	0	0.17 ± 0.07	0
300-600	DY0		0.004 ± 0.002	0	0.27 ± 0.10	0	2.5 ± 1.1	2
0-300	DY0		0.04 ± 0.02	0	2.98 ± 0.48	0	3.4 ± 1.0	4
> 600	DY1		0.009 ± 0.004	1	0.09 ± 0.07	0	0.11 ± 0.05	0
>600	DY1	Z	0.09 ± 0.01	1	0.48 ± 0.14	0	0.42 ± 0.15	0
300-600	DY1		0.06 ± 0.02	0	0.83 ± 0.24	1	0.92 ± 0.29	1
300-600	DY1	Z	0.42 ± 0.10	0	3.9 ± 1.1	5	3.4 ± 0.9	3
0-300	DY1		0.08 ± 0.04	0	5.4 ± 2.2	7	13.6 ± 6.4	19
0-300	DY1	Z	0.75 ± 0.32	2	16.9 ± 4.6	19	60 ± 31	95
>600	DY2		0.02 ± 0.01	0	--	--	--	--
>600	DY2	Z	0.34 ± 0.32	0	--	--	--	--
300-600	DY2		0.19 ± 0.08	0	--	--	--	--
300-600	DY2	Z	7.4 ± 3.0	3	--	--	--	--
0-300	DY2		2.3 ± 1.0	1	--	--	--	--
0-300	DY2	Z	27 ± 11	29	--	--	--	--
4-body			39 ± 12	37	30.8 ± 5.2	32	84 ± 32	124

3 Leptons

Selection			3(e/μ)		2(e/μ)+T		1(e/μ)+2T	
ST	DYpairs	Z?	SM	Obs	SM	Obs	SM	Obs
>600	DY0		1.12 ± 0.43	2	11.0 ± 3.2	17	22.3 ± 6.0	20
300-600	DY0		7.3 ± 3.0	5	96 ± 31	113	181 ± 24	157
0-300	DY0		13.3 ± 4.1	17	413 ± 63	522	2016 ± 253	1631
>600	DY1		3.3 ± 0.9	6	13.0 ± 2.3	10	--	--
>600	DY1	Z	17.6 ± 5.6	17	39.0 ± 4.7	35	--	--
300-600	DY1		24.6 ± 6.4	32	141 ± 27	159	--	--
300-600	DY1	Z	97 ± 29	89	462 ± 41	441	--	--
0-300	DY1		147 ± 36	126	2981 ± 418	3721	--	--
0-300	DY1	Z	797 ± 189	727	15751 ± 2452	17631	--	--
3-body			1108 ± 195	1021	19906 ± 2489	22649	2220 ± 255	1808

Exclusion contours from a multichannel likelihood from the 54 channels shown here.

The signal model defines which bins are signal bins and which are control bins.

The same background estimation techniques are applied to all bins.

MET vs H_T tables later in talk.

4 Lepton (e/μ/τ) S_T

Selection			4(e/μ)		3(e/μ)+T		2(e/μ)+2T	
ST	DYpairs	Z?	SM	Obs	SM	Obs	SM	Obs
> 600	DY0		0.0009 ± 0.0009	0	0.01 ± 0.09	0	0.17 ± 0.07	0
300-600	DY0		0.004 ± 0.002	0	0.27 ± 0.10	0	2.5 ± 1.1	2
0-300	DY0		0.04 ± 0.02	0	2.98 ± 0.48	0	3.4 ± 1.0	4
> 600	DY1		0.009 ± 0.004	1	0.09 ± 0.07	0	0.11 ± 0.05	0
>600	DY1	Z	0.09 ± 0.01	1	0.48 ± 0.14	0	0.42 ± 0.15	0
300-600	DY1		0.06 ± 0.02	0	0.83 ± 0.24	1	0.92 ± 0.29	1
300-600	DY1	Z	0.42 ± 0.10	0	3.9 ± 1.1	5	3.4 ± 0.9	3
0-300	DY1		0.08 ± 0.04	0	5.4 ± 2.2	7	13.6 ± 6.4	19
0-300	DY1	Z	0.75 ± 0.32	2	16.9 ± 4.6	19	60 ± 31	95
>600	DY2		0.02 ± 0.01	0	--	--	--	--
>600	DY2	Z	0.84 ± 0.32	0	--	--	--	--
300-600	DY2		0.19 ± 0.08	0	--	--	--	--
300-600	DY2	Z	7.4 ± 3.0	3	--	--	--	--
0-300	DY2		2.3 ± 1.0	1	--	--	--	--
0-300	DY2	Z	27 ± 11	29	--	--	--	--
4-body			39 ± 12	37	30.8 ± 5.2	32	84 ± 32	124

DPS issues in SUSY searches?

A quick digression due to the Double parton scattering (DPS) discussion yesterday:

$\sigma(AB)_{\mathbf{DPS}} \sim 100(\sigma_{\mathbf{A}})(\sigma_{\mathbf{B}}/\text{barn})$ @7TeV

$\sigma(\text{ttbar}) \sim 160\text{pb}$, $\sigma(W) \sim 30\text{nb}$

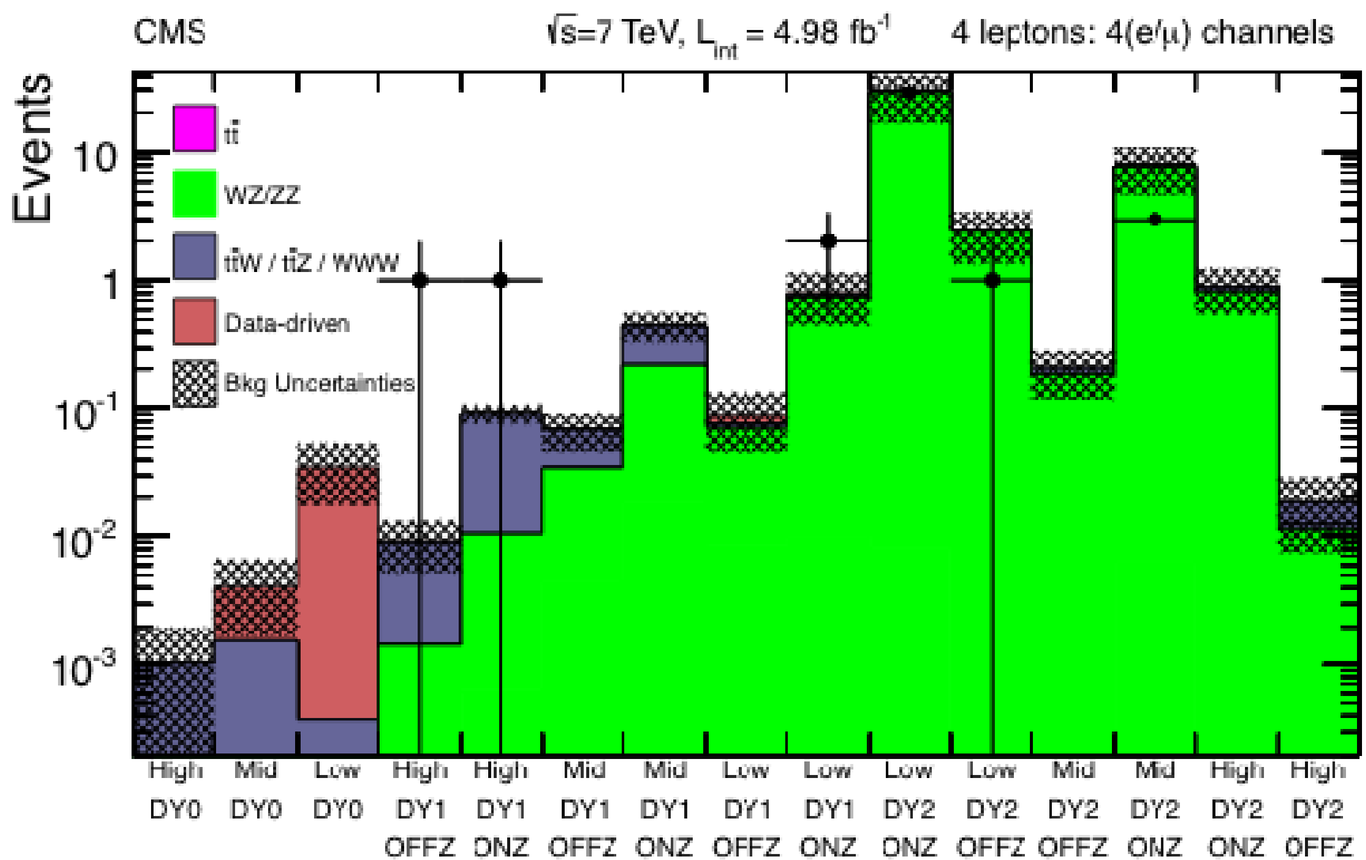
$\sigma(\text{ttW})_{\mathbf{DPS}} \sim 0.5\text{fb}$ vs $\sigma(\text{ttW}) \sim 150\text{fb}$

(kinematic dependence caveats?)

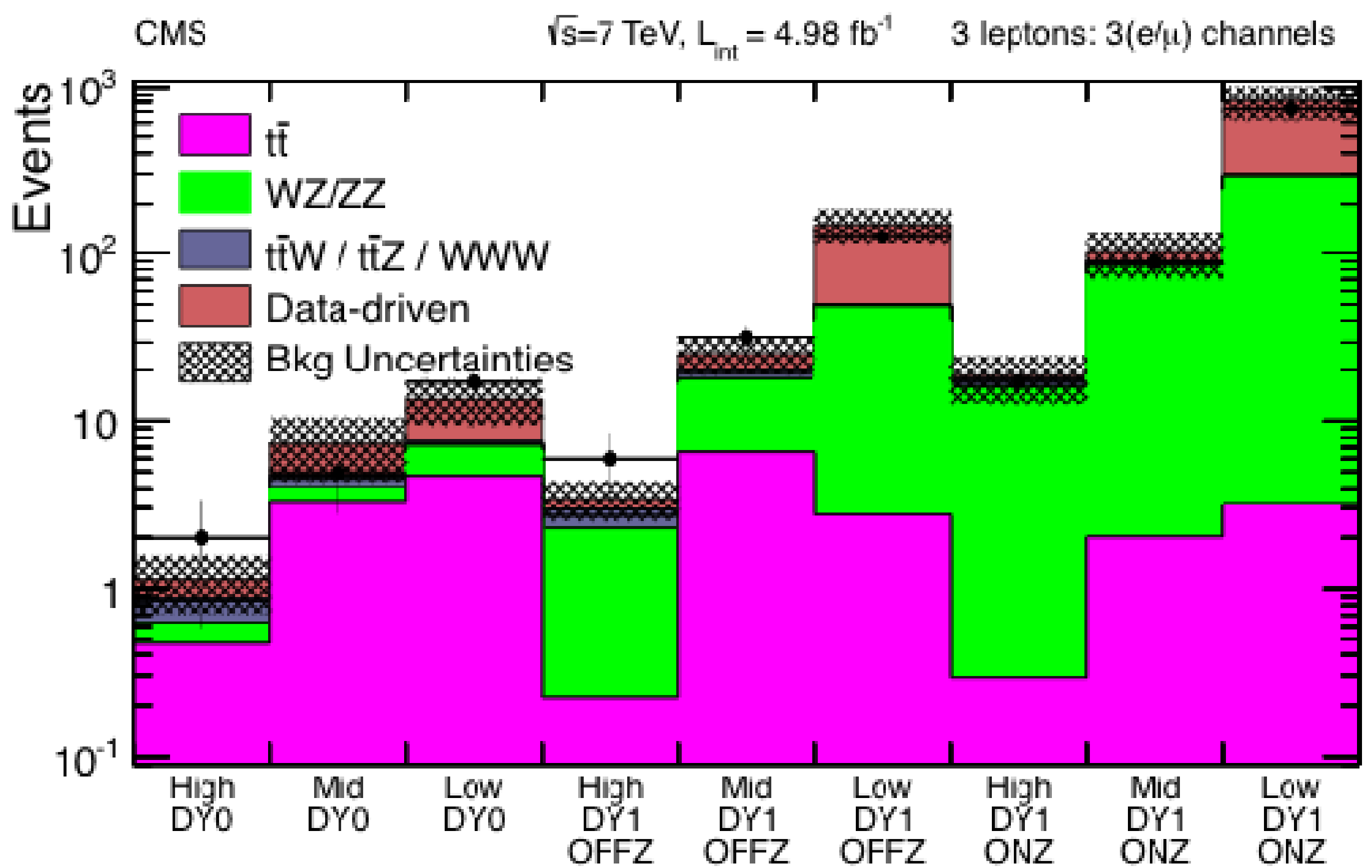
3 Lepton (e/μ/τ) S_T

Selection			3(e/μ)		2(e/μ)+T		1(e/μ)+2T	
ST	DYpairs	Z?	SM	Obs	SM	Obs	SM	Obs
>600	DY0		1.12 ± 0.43	2	11.0 ± 3.2	17	22.3 ± 6.0	20
300-600	DY0		7.3 ± 3.0	3	96 ± 31	113	181 ± 24	137
0-300	DY0		13.3 ± 4.1	17	413 ± 63	522	2016 ± 253	1631
>600	DY1		3.3 ± 0.9	6	13.0 ± 2.3	10	--	--
>600	DY1	Z	17.6 ± 5.6	17	39.0 ± 4.7	35	--	--
300-600	DY1		24.6 ± 6.4	32	141 ± 27	159	--	--
300-600	DY1	Z	97 ± 29	89	462 ± 41	441	--	--
0-300	DY1		147 ± 36	126	2981 ± 418	3721	--	--
0-300	DY1	Z	797 ± 189	727	15751 ± 2452	17631	--	--
3-body			1106 ± 195	1021	19906 ± 2489	22649	2220 ± 255	1808

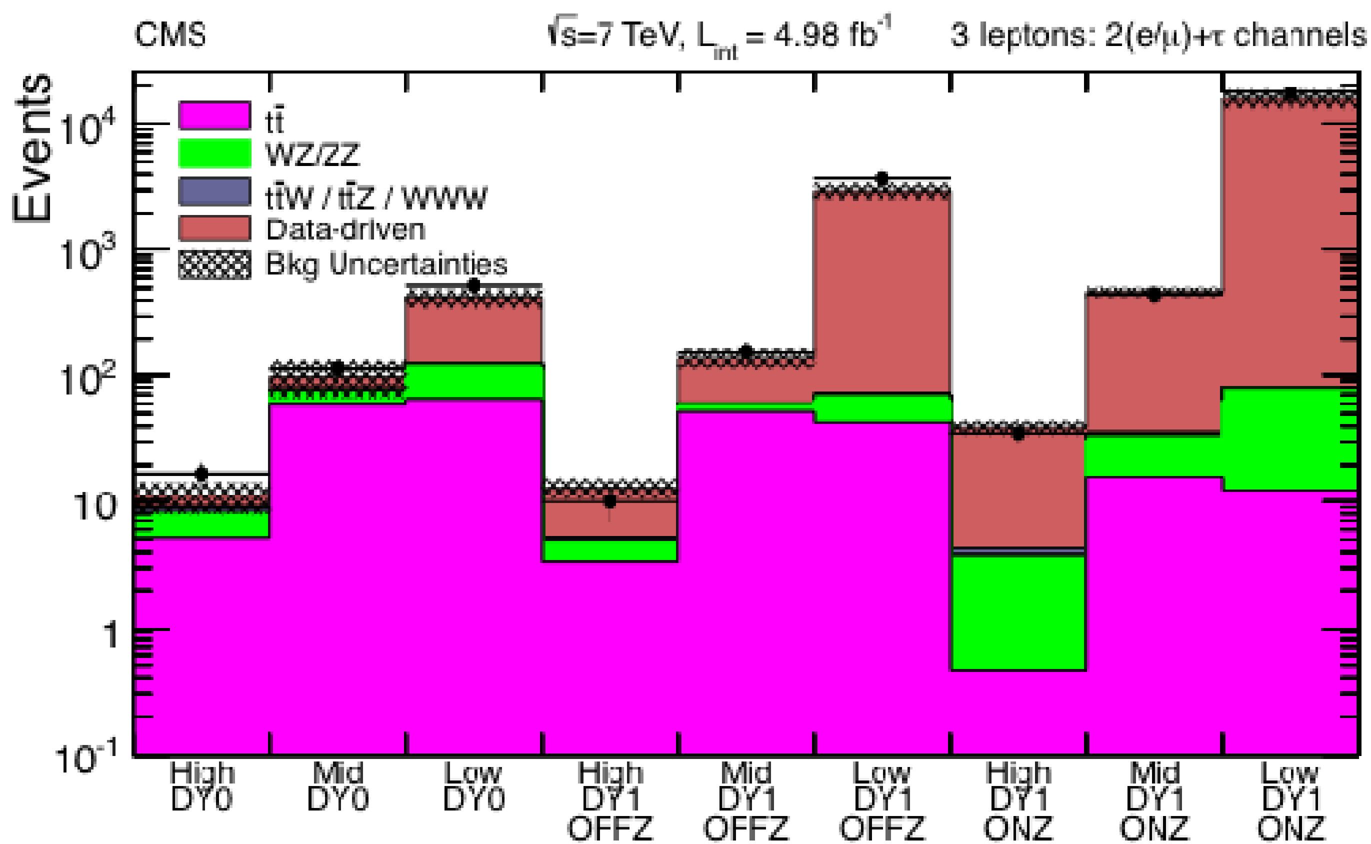
4(e/μ) S_T Channels: Backgrounds



3(e/μ) S_T Channels: Backgrounds



2(e/μ)+ OneTau S_T Analysis



MET/HT "SUSY" Results: 52 Channels

(MET)x(H_T)x(llll, lllτ, llττ, lll, llτ, lττ)

Number of Tau candidates (0,1,2) →

≥4 Leptons

Selection (MET? HT? Z?)	4(e/μ) SM	4(e/μ) Obs	3(e/μ)+T SM	3(e/μ)+T Obs	2(e/μ)+2T SM	2(e/μ)+2T Obs
MET>50 HT>200 NoZ	0.017 ± 0.005	0	0.08 ± 0.06	0	0.6 ± 0.6	0
MET>50 HT>200 Z	0.20 ± 0.04	0	0.25 ± 0.11	0	0.7 ± 1.0	0
MET>50 HT<200 NoZ	0.19 ± 0.07	1	0.56 ± 0.16	3	1.4 ± 0.6	1
MET>50 HT<200 Z	0.74 ± 0.20	1	2.2 ± 0.6	4	1.1 ± 0.7	0
MET<50 HT>200 noZ	0.006 ± 0.001	0	0.13 ± 0.08	0	0.25 ± 0.07	0
MET<50 HT>200 Z	0.78 ± 0.31	1	0.52 ± 0.20	0	1.13 ± 0.42	0
MET<50 HT<200 NoZ	2.4 ± 1.0	1	3.7 ± 1.2	5	10.5 ± 3.2	17
MET<50 HT<200 Z	35 ± 14	33	16.1 ± 4.9	20	42 ± 16	62
SUM 4-body	39 ± 15	37	23.6 ± 5.1	32	58 ± 16	80

3 Leptons

Selection (MET? HT? Z?)	3(e/μ) SM	3(e/μ) Obs	2(e/μ)+T SM	2(e/μ)+T Obs	1(e/μ)+2T SM	1(e/μ)+2T Obs
MET>50 HT>200 n/a	1.5 ± 0.5	2	30.3 ± 9.4	38	13.5 ± 2.6	15
MET>50 HT<200 n/a	6.5 ± 2.3	7	140 ± 37	159	106 ± 16	82
MET<50 HT>200 n/a	1.2 ± 0.7	1	16.5 ± 4.5	16	31.9 ± 4.8	18
MET<50 HT<200 n/a	11.6 ± 3.6	14	354 ± 55	446	1025 ± 171	1006
MET>50 HT>200 noZ	4.8 ± 1.3	8	31.0 ± 9.5	16	--	--
MET>50 HT>200 Z	17.8 ± 6.0	20	24.0 ± 4.9	13	--	--
MET>50 HT<200 noZ	25.9 ± 7.3	30	106 ± 27	114	--	--
MET<50 HT>200 noZ	4.4 ± 1.5	11	51.8 ± 6.2	45	--	--
MET>50 HT<200 Z	126 ± 47	141	115 ± 16	107	--	--
MET<50 HT>200 Z	18.4 ± 4.5	15	244 ± 24	166	--	--
MET<50 HT<200 noZ	142 ± 36	123	2906 ± 412	3721	--	--
MET<50 HT<200 Z	749 ± 181	657	15516 ± 2421	17857	--	--
SUM 3-body	1109 ± 191	1029	19523 ± 2457	22681	1177 ± 172	1121

Exclusion contours from a multichannel likelihood from the 52 channels shown here.

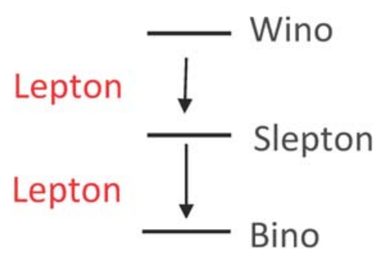
The signal model defines which bins are signal bins and which are control bins.

The same background estimation techniques are applied to all bins.

Produced from same package as EXO-11-045

Multilepton MET/HT SUSY Signals

Tri-Lepton + MET Signatures



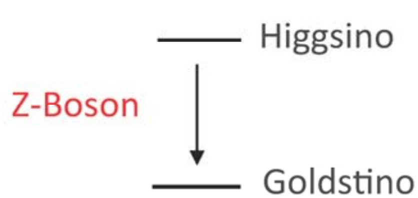
Tri-Lepton + MET

Di-Lepton + Tau + MET

Tri-Tau + MET

Sensitivity Ranges from
Just Beginning to m_{Wino} 500+ GeV

Di-Z-Boson + MET Signatures



Quad-Lepton + MET

Sensitivity Just Beginning

4 Lepton (e/μ/τ) MET vs H_T

Selection	4(e/μ)		3(e/μ)+T		2(e/μ)+2T	
MET? HT? Z?	SM	Obs	SM	Obs	SM	Obs
MET>50 HT>200 NoZ	0.017 ± 0.005	0	0.08 ± 0.06	0	0.6 ± 0.6	0
MET>50 HT>200 Z	0.20 ± 0.04	0	0.25 ± 0.11	0	0.7 ± 1.0	0
MET>50 HT<200 NoZ	0.19 ± 0.07	1	0.56 ± 0.16	3	1.4 ± 0.6	1
MET>50 HT<200 Z	0.74 ± 0.20	1	2.2 ± 0.6	4	1.1 ± 0.7	0
MET<50 HT>200 noZ	0.006 ± 0.001	0	0.13 ± 0.08	0	0.25 ± 0.07	0
MET<50 HT>200 Z	0.78 ± 0.31	1	0.52 ± 0.20	0	1.13 ± 0.42	0
MET<50 HT<200 NoZ	2.4 ± 1.0	1	3.7 ± 1.2	5	10.5 ± 3.2	17
MET<50 HT<200 Z	35 ± 14	33	16.1 ± 4.9	20	42 ± 16	62
SUM 4-body	39 ± 15	37	23.6 ± 5.1	32	58 ± 16	80

Higgsino → Z + Goldstino (diZ + MET signature)

3 Lepton (e/μ/τ) MET vs H_T

Increasing tan(β)

EWKino

Selection			3(e/μ)		2(e/μ)+T		1(e/μ)+2T	
MET?	HT?	Z?	SM	Obs	SM	Obs	SM	Obs
MET>50	HT>200	n/a	1.5 ± 0.5	2	30.3 ± 9.6	33	13.5 ± 2.6	15
MET>50	HT<200	n/a	6.5 ± 2.3	7	140 ± 37	159	106 ± 16	82
MET<50	HT>200	n/a	1.2 ± 0.7	1	16.5 ± 4.5	16	31.9 ± 4.8	18
MET<50	HT<200	n/a	11.6 ± 3.6	14	354 ± 55	446	1025 ± 171	1006
MET>50	HT>200	noZ	4.8 ± 1.3	8	31.0 ± 9.5	16	--	--
MET>50	HT>200	Z	17.8 ± 6.0	20	24.0 ± 4.9	13	--	--
MET>50	HT<200	noZ	25.9 ± 7.3	30	106 ± 27	114	--	--
MET<50	HT>200	noZ	4.4 ± 1.5	11	51.8 ± 6.2	45	--	--
MET>50	HT<200	Z	126 ± 47	141	115 ± 16	107	--	--
MET<50	HT>200	Z	18.4 ± 4.5	15	244 ± 24	166	--	--
MET<50	HT<200	noZ	142 ± 36	123	2906 ± 412	3721	--	--
MET<50	HT<200	Z	749 ± 181	657	15516 ± 2421	17857	--	--
SUM	3-body		1109 ± 191	1029	19533 ± 2457	22693	1177 ± 172	1121

Higgs background: Spread around.

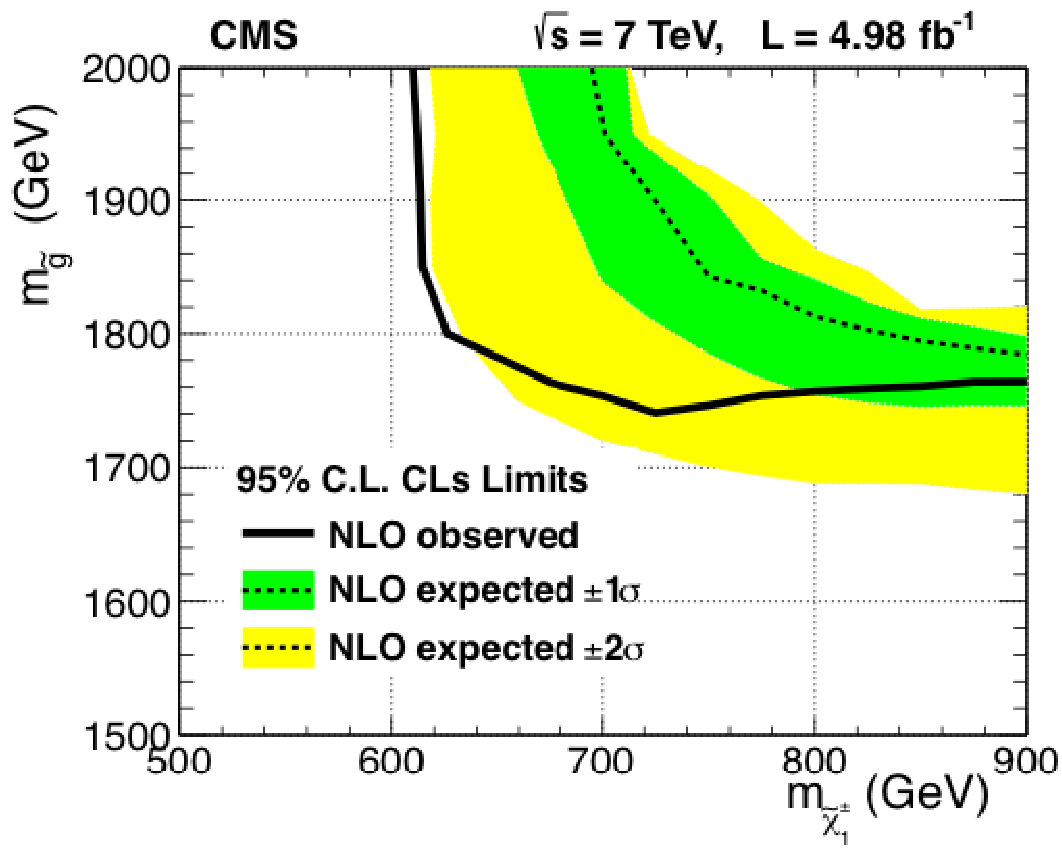
Interpretations

GMSB Slepton CO-NLSP Exclusion

Sleptons share the role of Next to lightest super partner (NLSP) above the gravitino. This results in a multilepton signal.

Strong production dominates

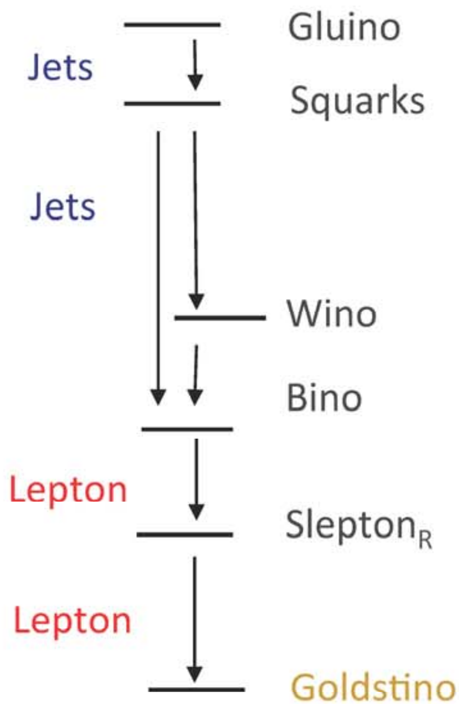
Contours made using MET vs HT table

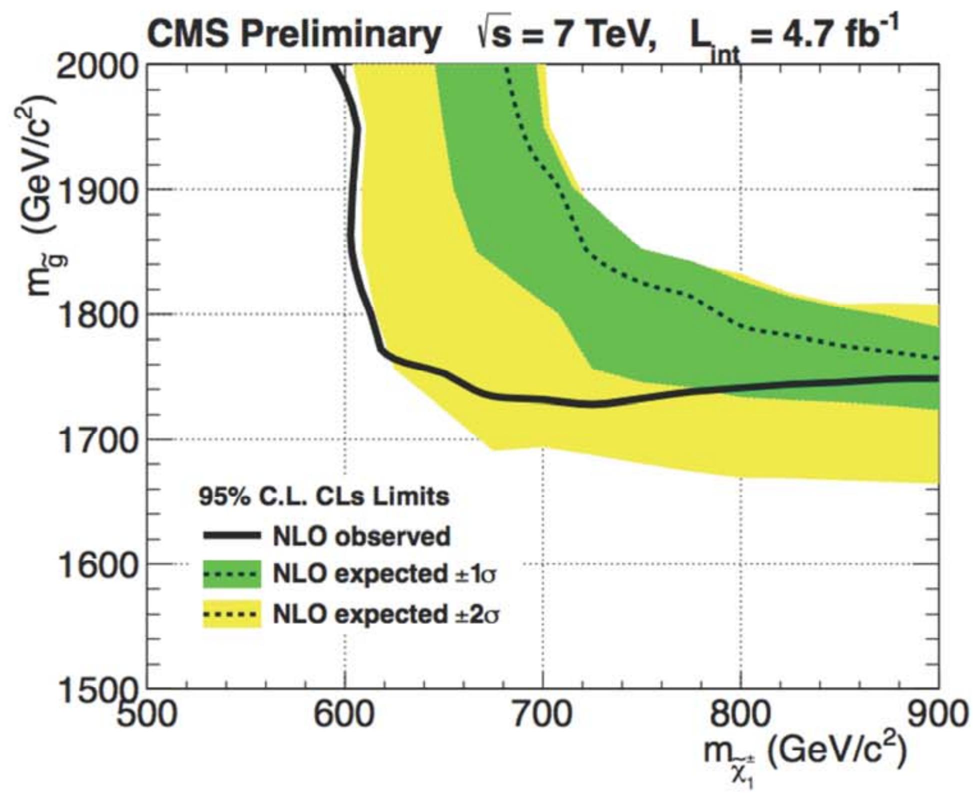


See model description http://lhcnewphysics.org/web/Topology_Sets.html under GMSB slepton co-NLSP

GMSB Slepton CO-NLSP Exclusion

Slepton Co-NLSP - Prompt Decay to Goldstino
with Strong Production





$m_q = 0.8\ m_g$, $m_{lR} = 0.3\ m_C$, $m_N = 0.5\ m_C$

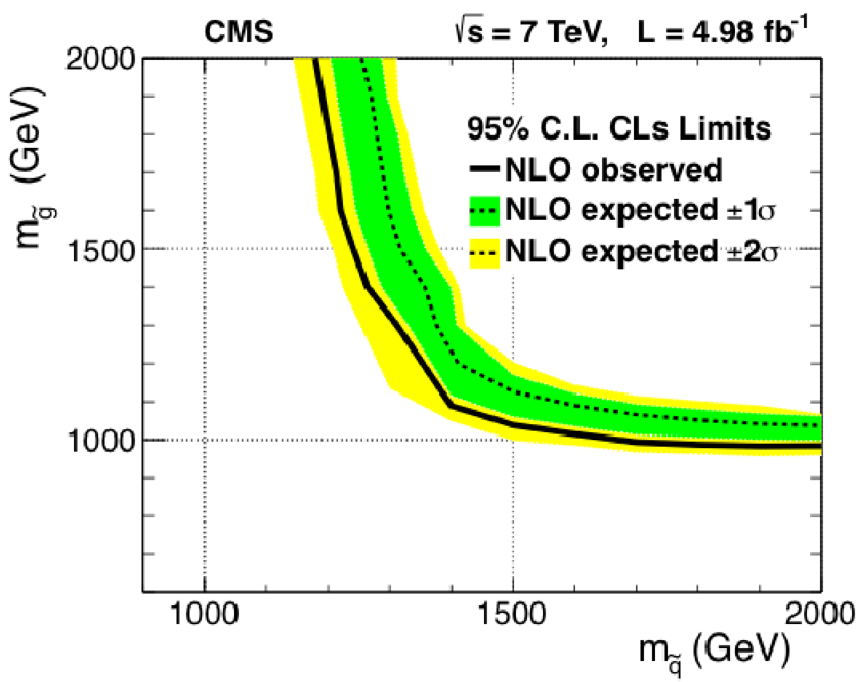
Stau NLSP,
Leptonic RPV and
No-MET Hadronic RPV
Topologies also …

Strong vs Weak Production

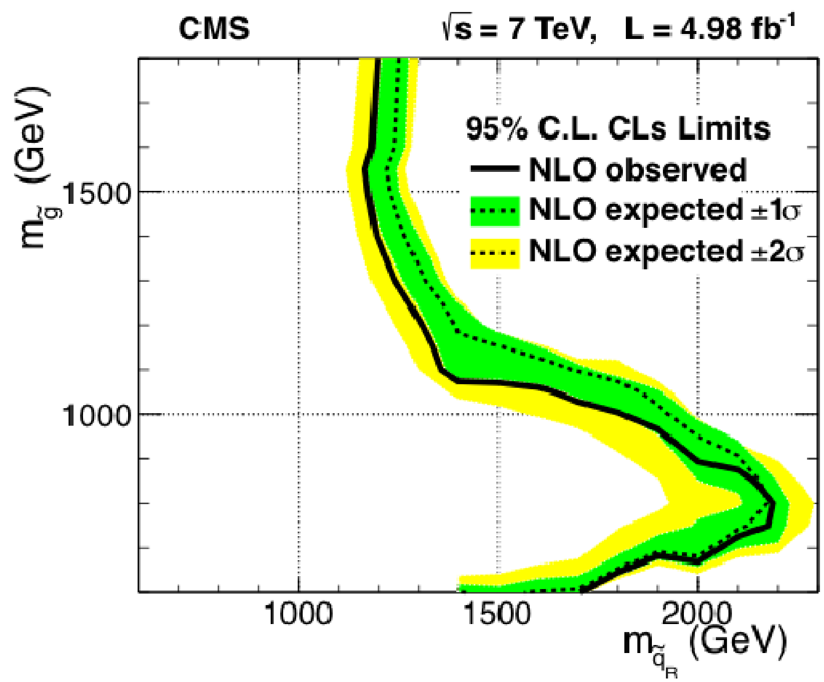
Leptonic and Hadronic RPV

Exclusion using S_T - binned Results (MET can be small)

Leptonic RPV



Hadronic RPV



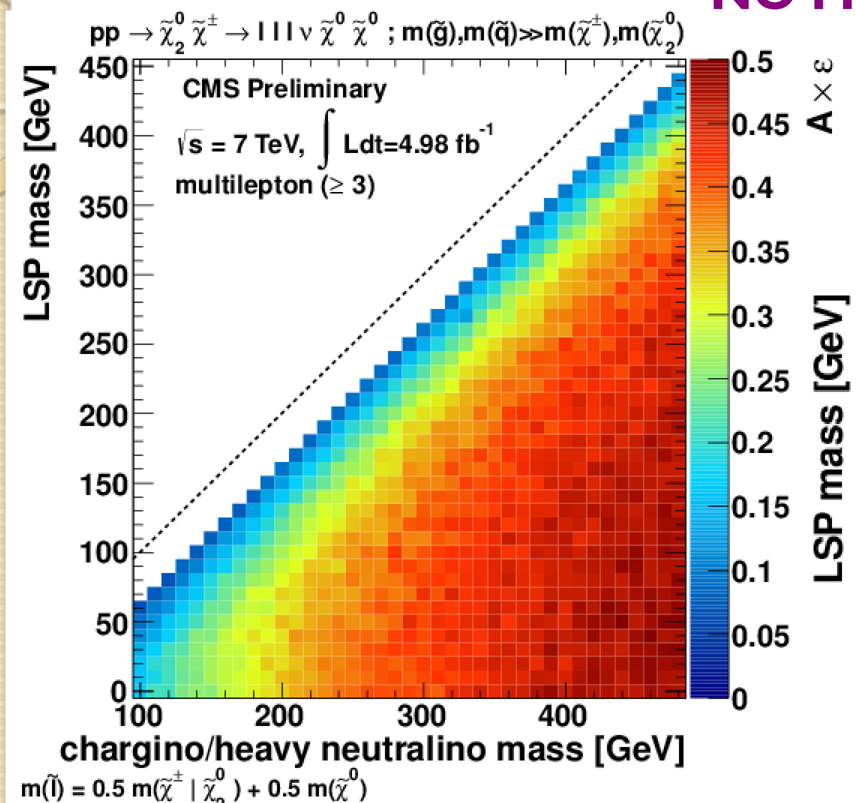
$\lambda_{e\mu\tau}$ L-RPV

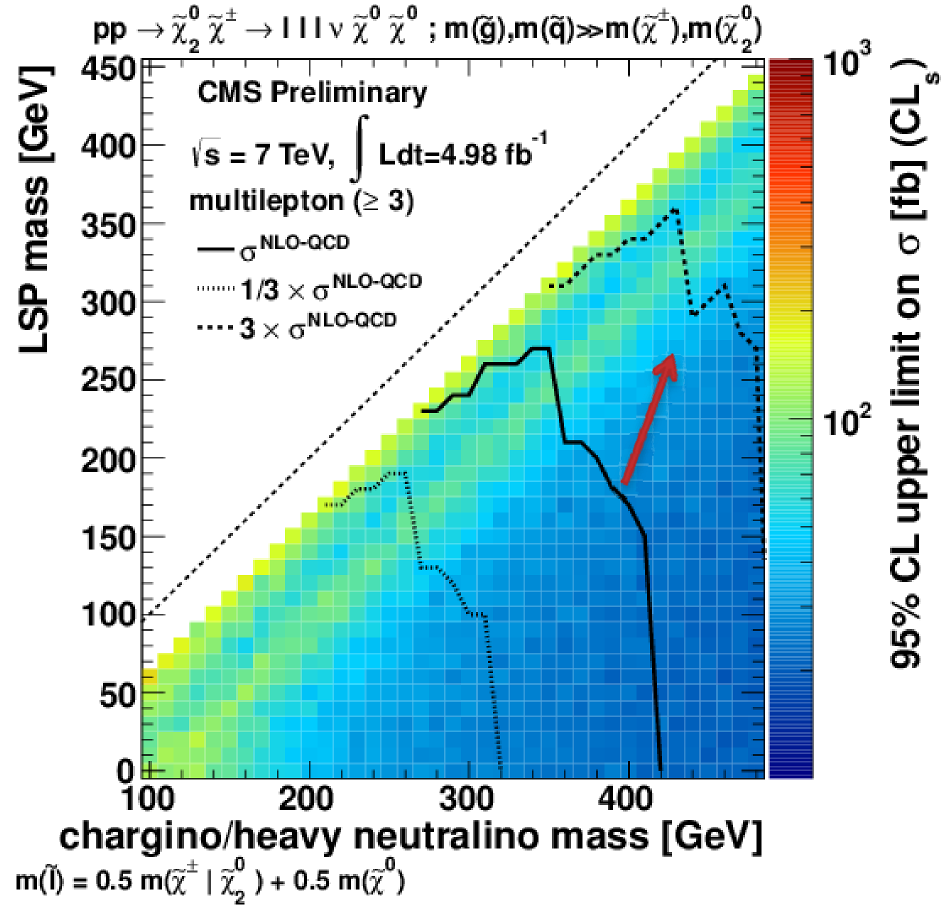
λ_{uds} H-RPV

EWK production: new result

Contours made using met/ht search channel counts

NO MET SHAPE INFO YET





Red arrow: MET shape info lifts up the curve.

Conclusions

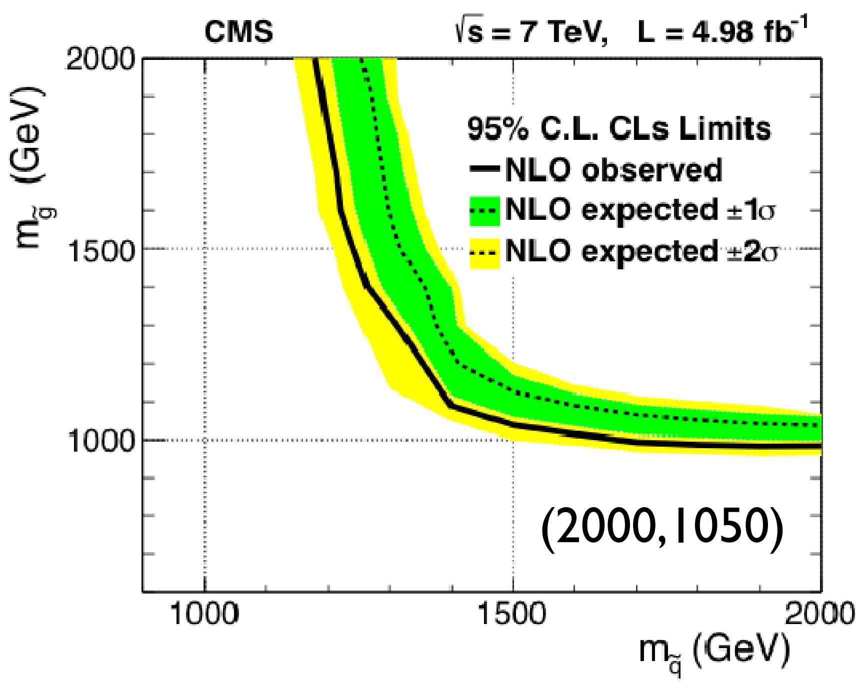
- ≥3 lepton e/μ/τ) search with 4.98 fb-1
  - Combination of MC and data-driven SM backgrounds. Uniform methods/MC are used in each channel.
  - Data binned in number DY candidates, on/off Z.
  - Two types of binning explored: MET/H_T or S_T
  - Background and signal channels are simultaneously examined, a total of 52+54 = 106 channels.
  - Observed Z→3L (4L, really), but not SUSY…
  - Limits on SUSY R-parity conserving and R-parity violating models.
- More than 1 fb^{-1} of 8 TeV 2012 data on disk! Backgrounds methods ok with pileup.

Icing

A comparison (Expected vs Expected)

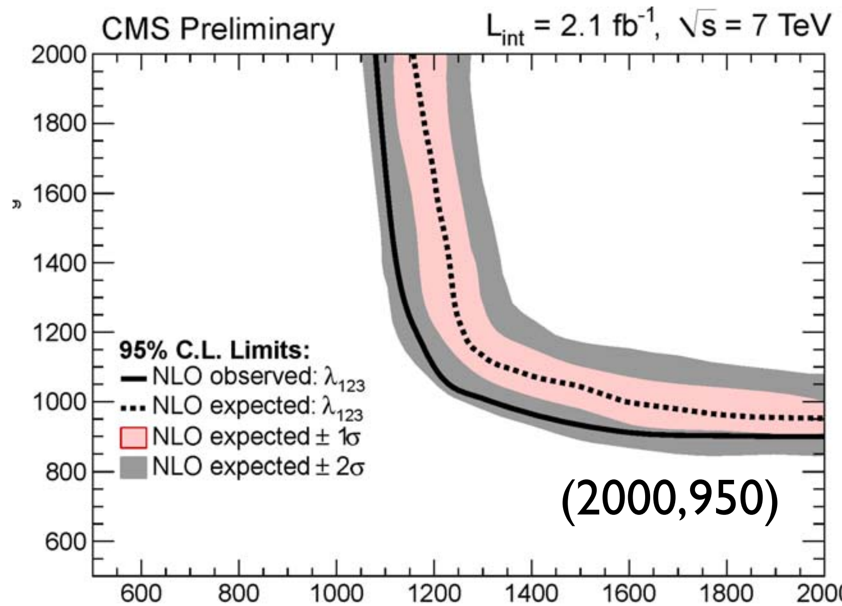
$\lambda_{e\mu\tau}$ L-RPV 5/fb vs 2/fb (prelim)

(1275,2000)



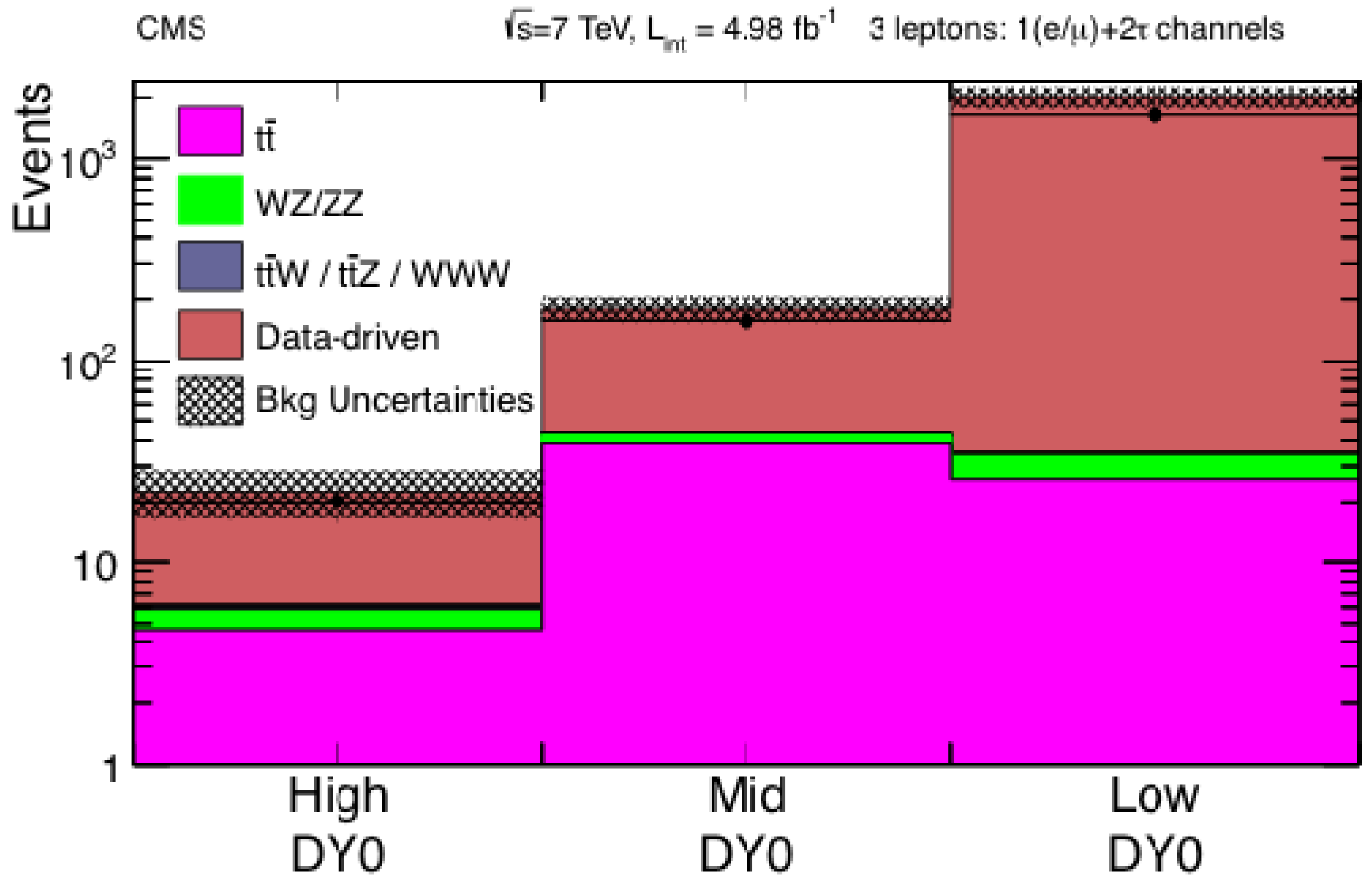
5/fb

(1150,2000)

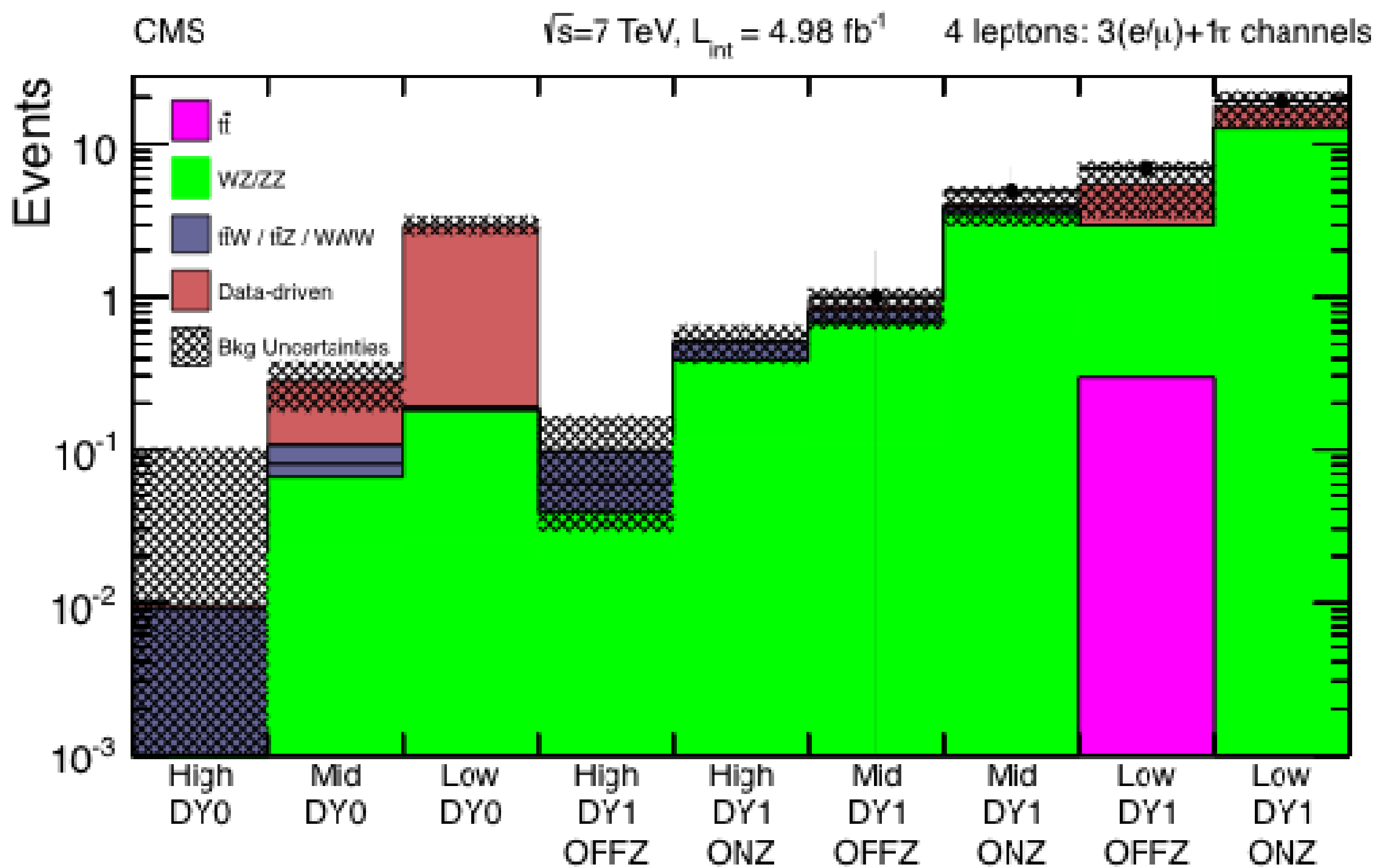


2/fb

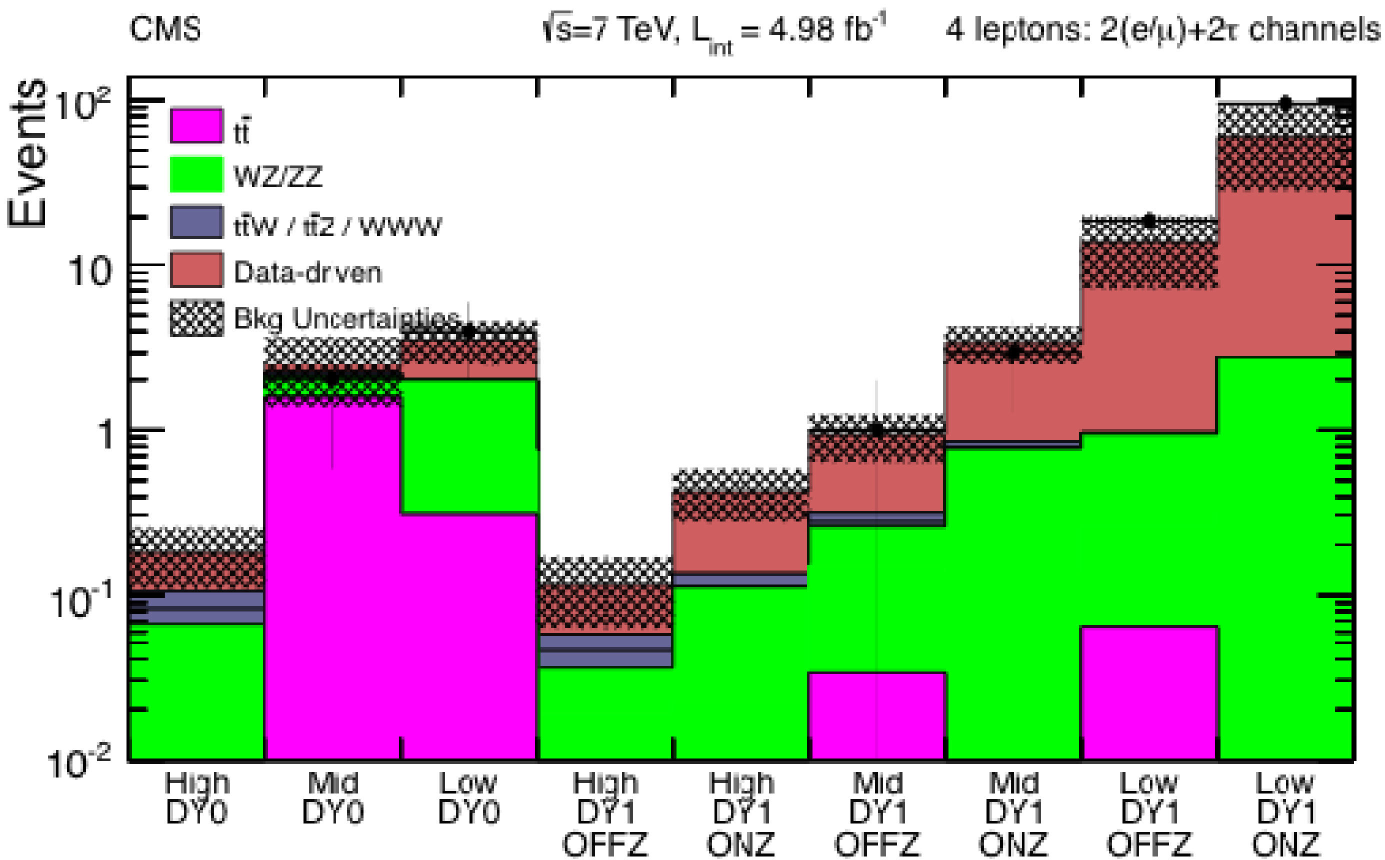
1(e/μ)+2Tau S_T Analysis



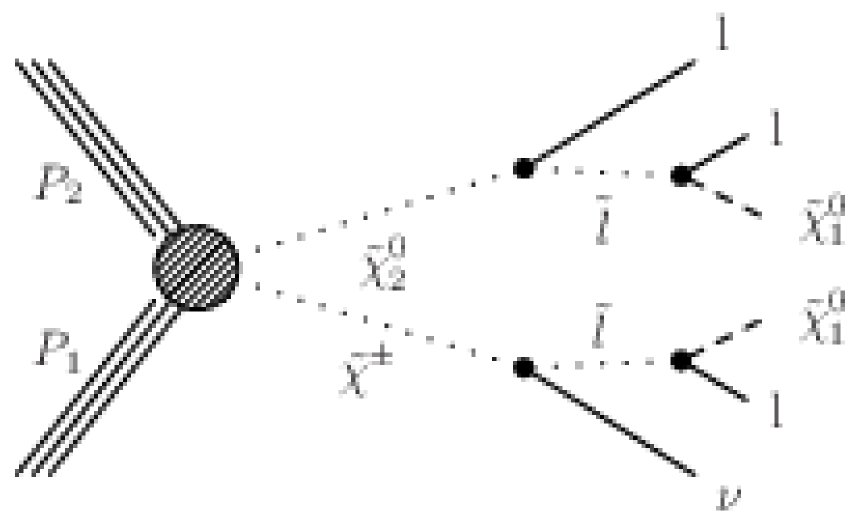
$3(e/\mu)+1$ Tau S_T Analysis



2(e/μ)+2Tau S_T Analysis



Electroweakino Simple topology



GMSB co-NLSP

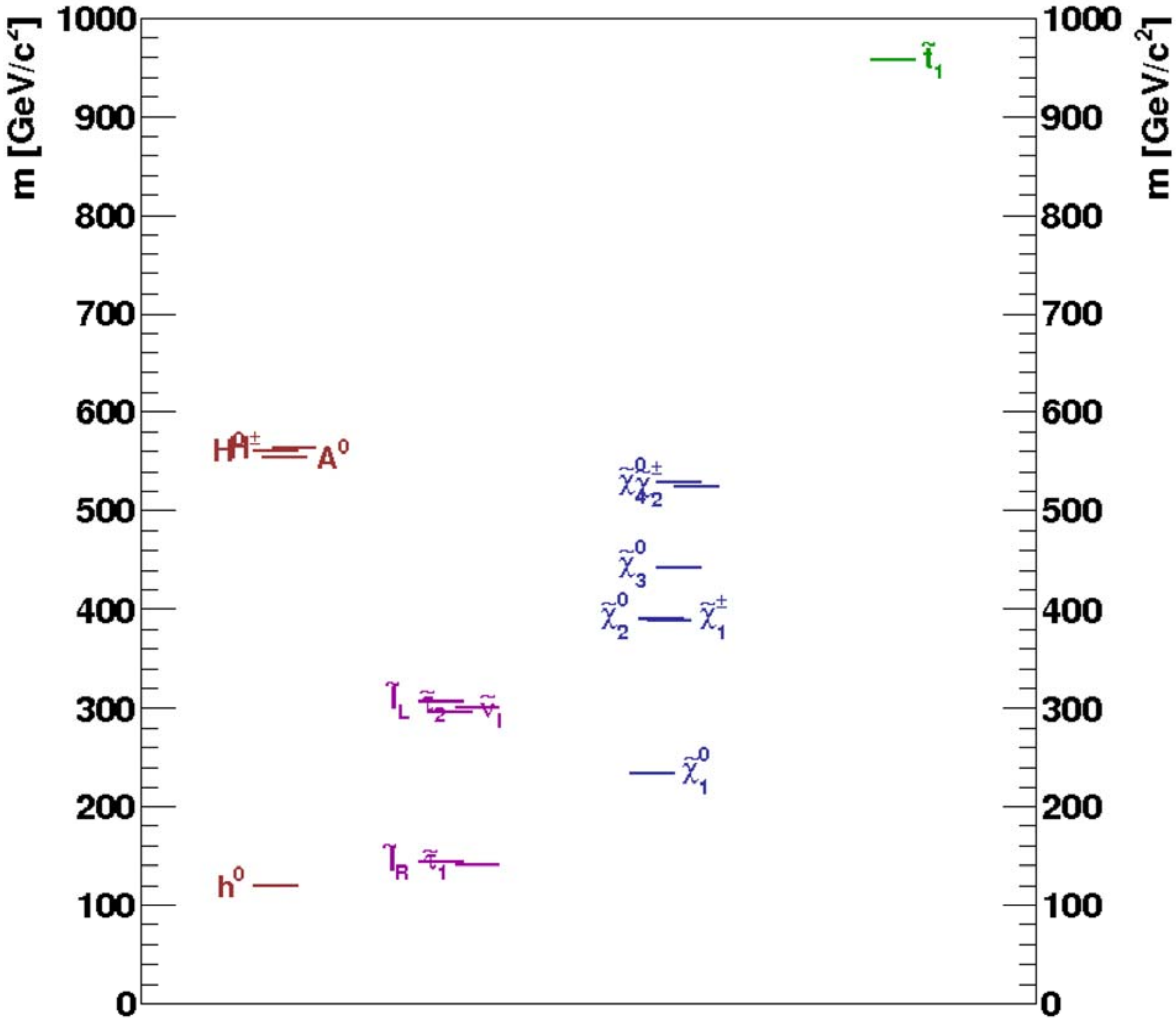


Figure 1: MGM slepton Co-NLSP spectrum with $\Lambda = \Lambda_L = \Lambda_d = 35$ TeV, $N_5 = 5$, $\tan\beta = 3$,$M/\Lambda = 3$, $\mathrm{sgn}(\mu) = +$, and $\mu/m_2 = 0.95$. All strongly interacting superpartners except for the lightest stop are heavier than 1 TeV. The essentially massless Goldstino is not shown. This plot was produced with the spectrum.py script from

Simulation for the co-NLSP scenario is generated on a grid in the chargino-gluino mass plane. The other super partner masses are related to these by $m_{\tilde{\ell}_R} = 0.3 m_{\chi^\pm}$, $m_{\tilde{\chi}_1^0} = 0.5 m_{\chi^\pm}$, $m_{\tilde{\ell}_L} = 0.8 m_{\chi^\pm}$, and $m_{\tilde{q}} = 0.8 m_{\tilde{g}}$. Flavor universality and vanishing left-right mixing for squarks and sleptons are enforced. Simulations for three separate L-RPV models and the H-RPV model, described below, are generated on a grid in the squark–gluino mass plane. To determine the

In the specific slepton co-NLSP L-RPV SUSY topology described in Ref. [1] and references therein, the bino is the lightest superpartner with a fixed mass of 300 GeV. The gluino and degenerate squark masses, $m_{\tilde{g}}$ and $m_{\tilde{q}}$, are variable and define the parameter space for our search. All other superpartners are decoupled, holding the bino RPV decay width fixed.

The superpartner spectrum for the H-RPV SUSY topology used here consists of a wino, right-handed sleptons, and bino, with fixed masses of 150, 300, and 500 GeV, respectively, and varying gluino and right-handed squark masses larger than 500 GeV. The left-handed squark masses and higgsino mass parameter are fixed at 5000 and 3000 GeV, respectively. Flavor universality and vanishing left-right mixing for squarks and sleptons are enforced.

In this topology, the right-handed squarks decay to the bino and the gluino decays predominantly to the bino except for relatively small values of the gluino–bino mass splitting. The bino decays to a right-handed slepton, which in turn decays to the wino neutralino. Starting from strongly-interacting superpartner pair production, all cascade decays that produce the bino therefore yield either four leptons, of which zero, two, or four can be taus. The wino lightest superpartner decays to three jets through hadronic R-parity violating couplings. This topology yields events with jets and multiple charged leptons, with no particles emitted directly from the supersymmetric cascade that carry missing energy.

In the H-RPV case, gluino masses below 500 GeV are not excluded even though the production cross section in this region can be large. This is due to the low gluino branching fraction to the bino and subsequently to leptons. The non-zero coupling is λ_{uds} in our H-RPV model.