Displaced Leptons from Gauge Mediation and Beyond

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CMS 1409.4789
Evans, Shelton – to appear

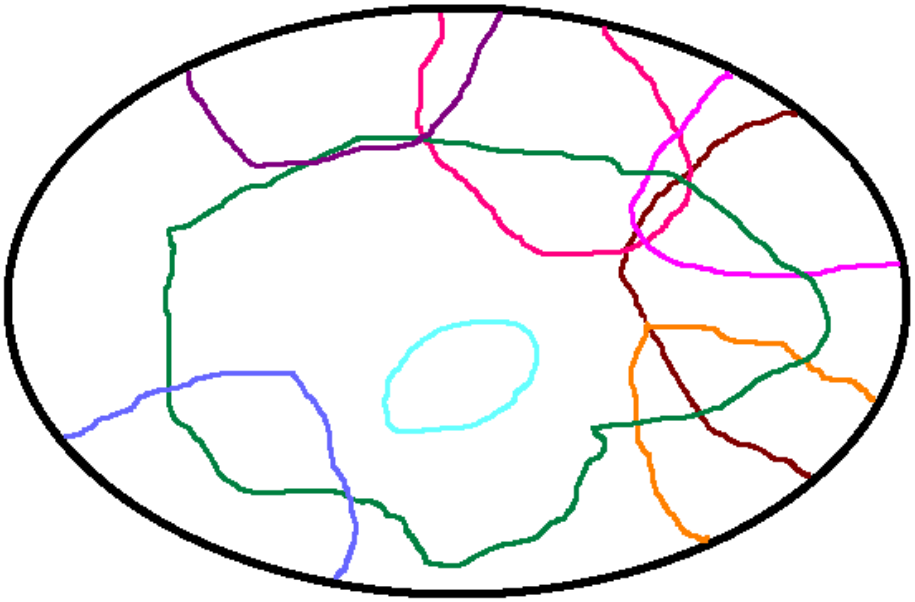
Outline

The LHC Program

The LHC has constrained many new particles in many models

- MSSM
- t'/b'
- UED
- GMSB
- RPV
- Stealth
- 2HDM
- ...

Signature Space



These searches cast a wide net

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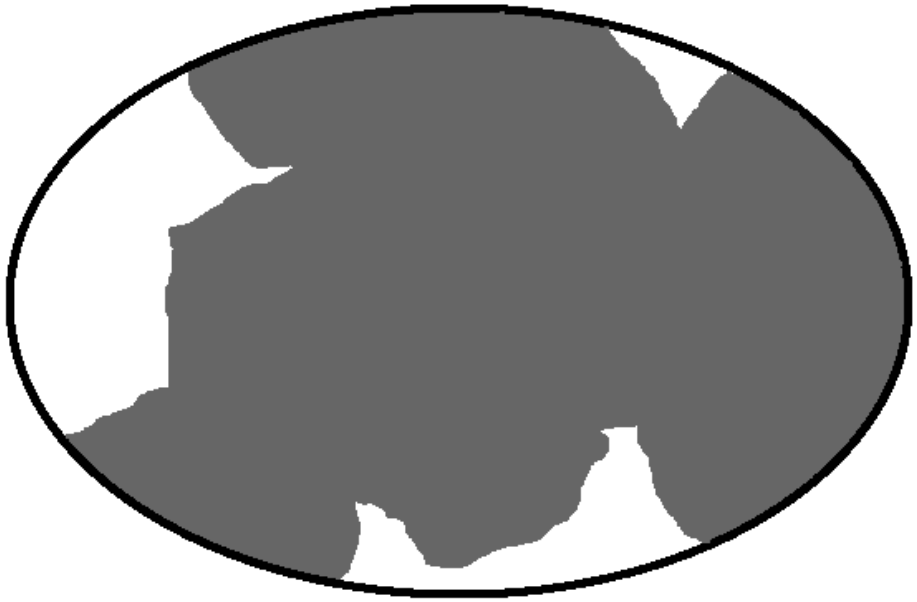

These searches cast a wide net – but there are gaps

Need comprehensive program that covers ALL new physics scenarios

Could be our FIRST pathway to BSM physics!

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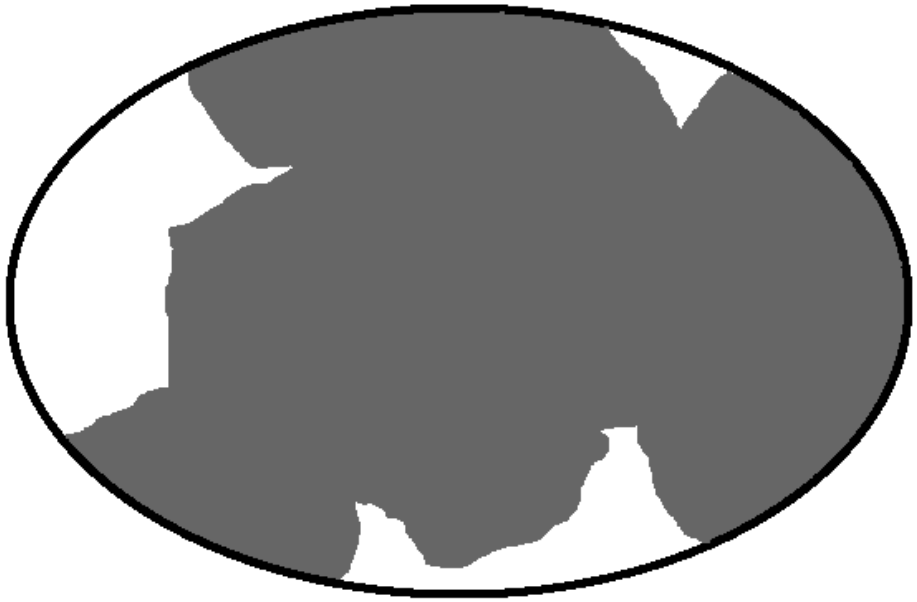

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Need comprehensive program that covers ALL new physics scenarios

Could be our ONLY pathway to BSM physics!!!

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j							
b	X						
γ	X	X					
e	X	X	X				
μ	X	X	X	X			
τ	X	X	X	X	X		

Search	arXiv	Symbol	Comments

- Focused on pair produced, heavy decays inside the detector
- Only a selection of searches used, but fairly representative
- Cavalier about lifetime ranges and triggers; ignoring tops
- **Bold** is where searches are really optimized

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	jj	jj	jj	jj	jj	jj	jj
b	X	jj	jj	jj	jj	jj	jj
γ	X	X					
e	X	X	X				
μ	X	X	X	X			
τ	X	X	X	X	X		

Search	arXiv	Symbol	Comments
CMS Displaced Dijets	1411.6530	jj	$m_X > 50$ GeV

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**jj**/**dv**	**jj**/**dv**	jj/dv	jj/**dv**	jj/**dv**	jj/dv	jj/**dv**
b	X	**jj**/**dv**	jj/dv	jj/**dv**	jj/**dv**	jj/dv	jj/**dv**
γ	X	X					
e	X	X	X	**dv**	**dv**	dv	
μ	X	X	X	X	**dv**	dv	
τ	X	X	X	X	X	dv	

Search	arXiv	Symbol	Comments
CMS Displaced Dijets	1411.6530	jj	$m_X > 50$ GeV
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$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**jj**/**dv**	**jj**/**dv**	jj/dv	jj/**dv**	jj/**dv**	jj/dv	jj/**dv**
b	X	**jj**/**dv**	jj/dv	jj/**dv**	jj/**dv**	jj/dv	jj/**dv**
γ	X	X					
e	X	X	X	**dv**/**ll**	**dv**	dv/ll	
μ	X	X	X	X	**dv**/**ll**	dv/ll	
τ	X	X	X	X	X	dv/ll	

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$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**jj**/**dv**	**jj**/**dv**	jj/dv/dA	jj/**dv**	jj/**dv**	jj/dv	jj/**dv**
b	X	**jj**/**dv**	jj/dv/dA	jj/**dv**	jj/**dv**	jj/dv	jj/**dv**
γ	X	X	dA	dA	dA	dA	**dA**
e	X	X	X	**dv**/**ll**	**dv**	dv/ll	
μ	X	X	X	X	**dv**/**ll**	dv/ll	
τ	X	X	X	X	X	dv/ll	

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ATLAS Delayed Photon	1409.5542	dA	$m_X \gtrsim 100$ GeV

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j	**jj**/**dv**	**jj**/**dv**	jj/dv/dA	jj/**dv**	jj/**dv**	jj/dv/em	jj/**dv**
b	X	**jj**/**dv**	jj/dv/dA	jj/**dv**	jj/**dv**	jj/dv/em	jj/**dv**
γ	X	X	dA	dA	dA	dA/em	**dA**
e	X	X	X	**dv**/**ll**	**dv**	dv/ll	
μ	X	X	X	X	**dv**/**ll**	dv/ll	
τ	X	X	X	X	X	dv/ll/em	em

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CMS Displaced $e\mu$	1409.4789	em	Best at LFU

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$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**jj**/**dv**	**jj**/**dv**	jj/dv/dA	jj/**dv**	jj/**dv**	jj/dv/em	jj/**dv**
b	X	**jj**/**dv**	jj/dv/dA	jj/**dv**	jj/**dv**	jj/dv/em	jj/**dv**
γ	X	X	dA	dA	dA	dA/em	**dA**
e	X	X	X	**dv**/**ll**	**dv**	dv/ll	
μ	X	X	X	X	**dv**/**ll**	dv/ll	
τ	X	X	X	X	X	dv/ll/em	em

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j							
b	X						
γ	X	X					
e	X	X	X				
μ	X	X	X	X			
τ	X	X	X	X	X		

Models	Symbol

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**						**M**
b	X	M					M
γ	X	X					
e	X	X	X				
μ	X	X	X	X			
τ	X	X	X	X	X		

Models	Symbol
Mini-Split	M

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**G						**M**G
b	X	MG					MG
γ	X	X					**G**
e	X	X	X	G			G
μ	X	X	X	X	G		G
τ	X	X	X	X	X	G	**G**

Models	Symbol
Mini-Split	M
GMSB	G

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**GR	**R**		R	R	R	**M**GR
b	X	MGR		R	R	**R**	MGR
γ	X	X					**G**
e	X	X	X	GR	R	R	GR
μ	X	X	X	X	GR	R	GR
τ	X	X	X	X	X	GR	**G**R

Models	Symbol
Mini-Split	M
GMSB	G
RPV/dRPV	R

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**GRS	**R**		R	R	R	**M**GR
b	X	MGR**S**		R	R	**R**	MGR
γ	X	X	S				**G**
e	X	X	X	GR	R	R	GR
μ	X	X	X	X	GR	R	GR
τ	X	X	X	X	X	GR	**G**R

Models	Symbol
Mini-Split	M
GMSB	G
RPV/dRPV	R
Stealth	S

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**GRS	**R**		R	R	R	**M**GR
b	X	MGR**S**H		R	R	**R**	MGR
γ	X	X	S				**G**
e	X	X	X	GR	R	R	GR
μ	X	X	X	X	GRH	R	GR
τ	X	X	X	X	X	GRH	**G**R

Models	Symbol
Mini-Split	M
GMSB	G
RPV/dRPV	R
Stealth	S
Higgs Mixed	H

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**GRSγ	**R**		R	R	R	**M**GR
b	X	MGR**S**Hγ		R	R	**R**	MGR
γ	X	X	S				**G**
e	X	X	X	GRγ	R	R	GR
μ	X	X	X	X	GRHγ	R	GR
τ	X	X	X	X	X	GRHγ	**G**R

Models	Symbol
Mini-Split	M
GMSB	G
RPV/dRPV	R
Stealth	S
Higgs Mixed	H
Dark Photon	γ

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**GRSγ	**R**		R	R	R	**M**GRD
b	X	MGR**S**Hγ		R	R	**R**	MGRD
γ	X	X	S				**G**
e	X	X	X	GRγ	R	R	GRD
μ	X	X	X	X	GRHγ	R	GRD
τ	X	X	X	X	X	GRHγ	**G**RD

Models	Symbol
Mini-Split	M
GMSB	G
RPV/dRPV	R
Stealth	S
Higgs Mixed	H
Dark Photon	γ
MD Freeze-In Dark Matter	D

Exotic Objects ($pp \to XX$, $X \to o_1 o_2$ or $X \to o_1 o_2 o_3$)

$o_2 o_1$	j	b	γ	e	μ	τ	$\not{E}_T$
j	**M**GRSγ	**R**		R	R	R	**M**GRD
b	X	MGR**S**Hγ		R	R	**R**	MGRD
γ	X	X	S				**G**
e	X	X	X	GRγ	R	R	GRD
μ	X	X	X	X	GRHγ	R	GRD
τ	X	X	X	X	X	GRHγ	**G**RD

Models	Symbol
Mini-Split	M
GMSB	G
RPV/dRPV	R
Stealth	S
Higgs Mixed	H
Dark Photon	γ
MD Freeze-In Dark Matter	D

Well-motivated Theoretically

Weak Coverage Experimentally

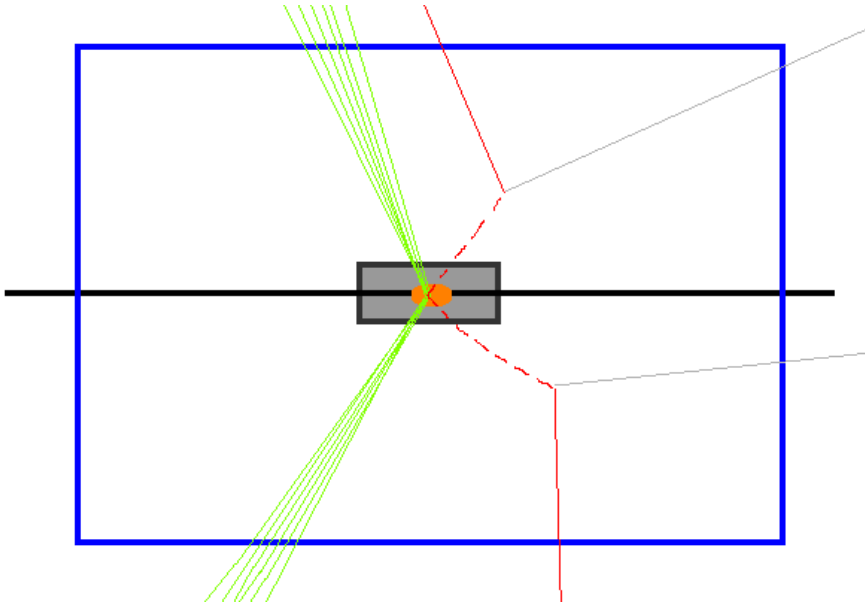
Displaced Leptons in Prompt Searches

Prompt lepton-based searches:

- Quality criteria drop displaced electrons
- Displaced muons veto events (cosmics)
- Vetoes range from 50 μm–1 mm

Prompt jets+$\not{E}_T$ searches:

- Veto events with leptons
- Definition not always transparent



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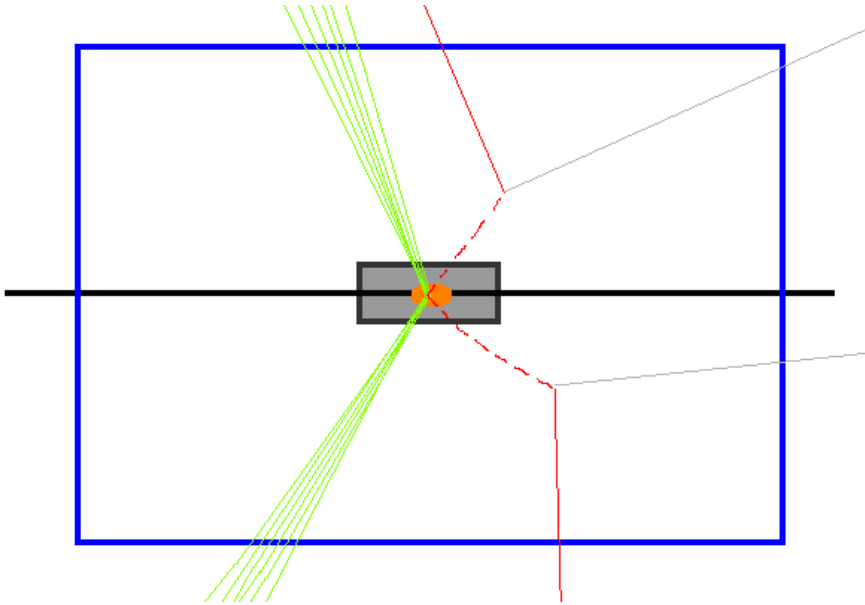


Prompt jets+$\not{E}_T$ searches:

- Veto events with leptons
- Definition not always transparent

Very dangerous region!

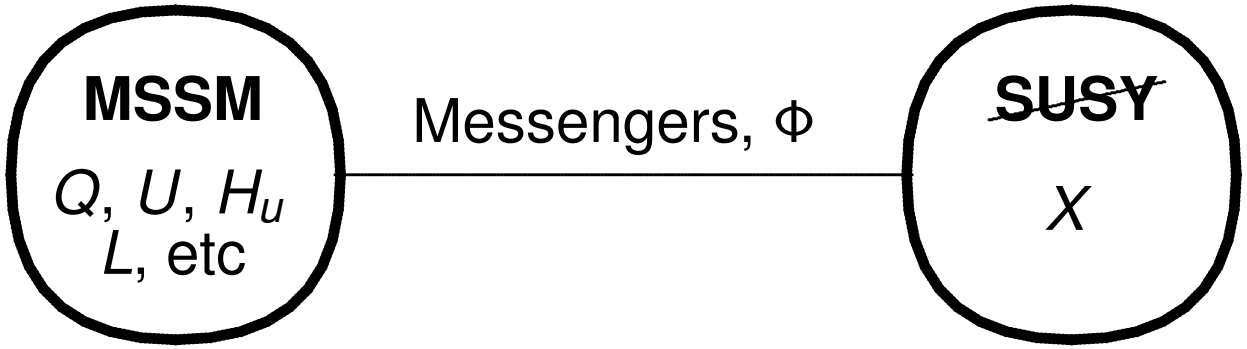
$$pp \to \tilde{\ell}^+\tilde{\ell}^- + X \to \{\text{displaced muons}\} + X$$

lives in a prompt search blind spot!

Displaced electrons and taus $\Rightarrow$ reduced efficiency

Gauge Mediation and $\tilde{\tau}_R$ NLSPs

Lightning Review of Minimal GMSB



$$W \sim X\Phi\tilde{\Phi} + \{\text{MSSM yukawas}\}$$

$$\langle X \rangle = M + \theta^2 F, \qquad \Lambda \equiv F/M, \qquad \tilde{\Lambda} \equiv \frac{\Lambda}{16\pi^2}$$

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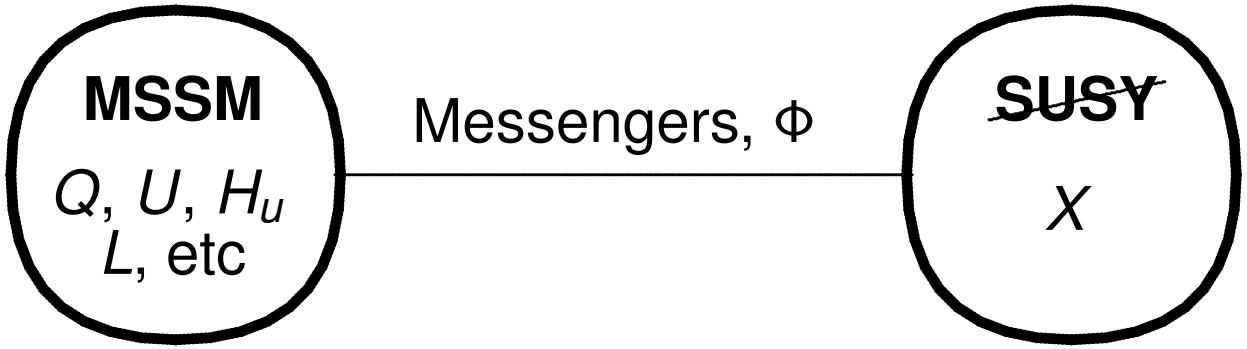

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$$\langle X \rangle = M + \theta^2 F, \qquad \Lambda \equiv F/M, \qquad \tilde{\Lambda} \equiv \frac{\Lambda}{16\pi^2}$$

$$M_r \sim N_{eff} g_r^2 \tilde{\Lambda} \qquad\qquad A\text{-terms} = 0$$

$$m_{soft}^2 \sim 2 N_{eff} C_r g_r^4 \tilde{\Lambda}^2 \qquad (C_r \text{ quadratic Casimirs } \mathcal{O}(1))$$

Gauge Mediation and $\tilde{\tau}_R$ NLSPs

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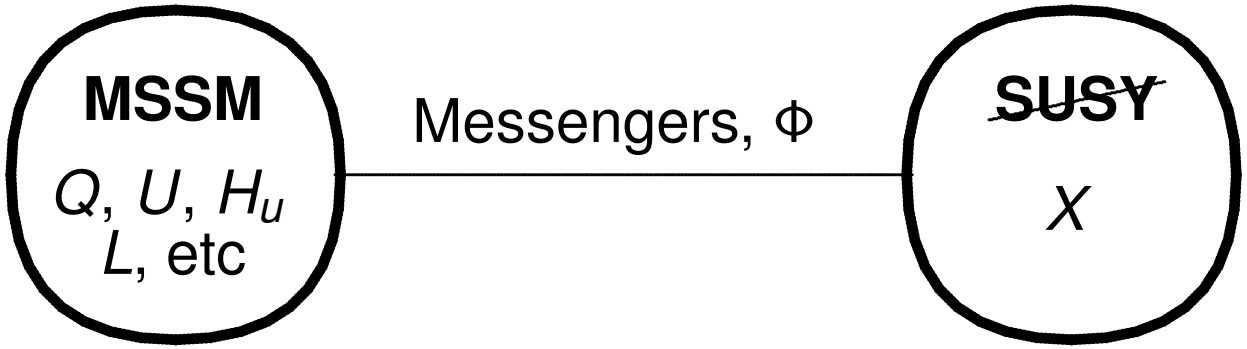

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Potential NLSP Masses: $\begin{cases} m_{\tilde{B}} = N_{eff} g_1^2 \tilde{\Lambda} \\ m_{\tilde{\ell}_R} = \sqrt{\frac{6 N_{eff}}{5}} g_1^2 \tilde{\Lambda} \end{cases}$ $\quad N_{eff} \geq 2 \Rightarrow \tilde{\tau}_R$ NLSP (or large running)

Gauge Mediation and $\tilde{\tau}_R$ NLSPs

Lifetimes

GMSB is a very well-motivated source of displaced particles

$$c\tau \approx 100\,\mu\text{m}\left(\frac{100\text{ GeV}}{m_{\tilde{\tau}}}\right)^5\left(\frac{\sqrt{F}}{100\text{ TeV}}\right)^4$$

What is $\sqrt{F}$?

Gauge Mediation and $\tilde{\tau}_R$ NLSPs

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What is $\sqrt{F}$?

$F < M^2$; otherwise arbitrary

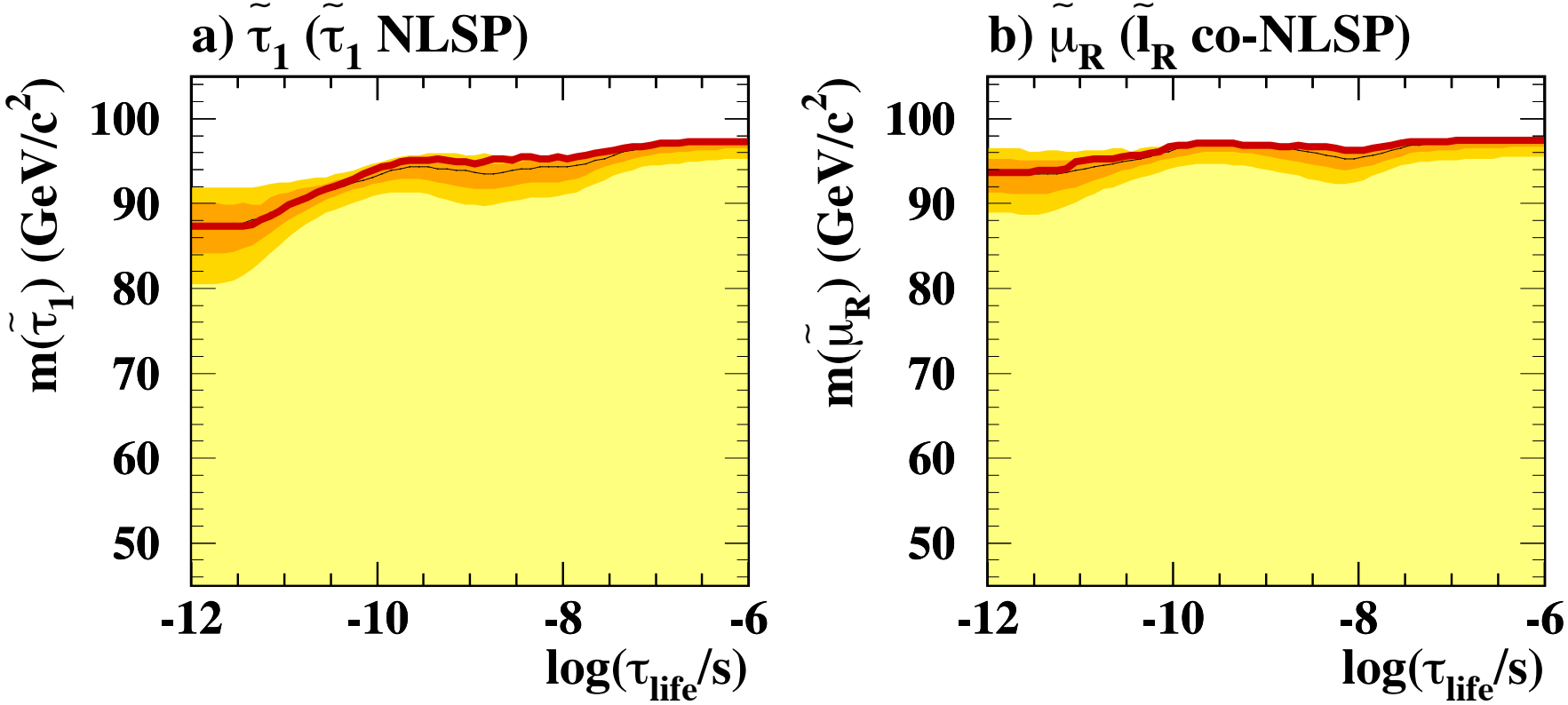
$$c\tau \sim 10\,\mu\text{m}\left(\frac{100\text{ GeV}}{m_{\tilde{\tau}}}\right)\left(\frac{M}{\sqrt{F}}\right)^4\frac{1}{N_{eff}^2} \qquad \text{(minimal GM only)}$$

LHC relevant range: $100\,\mu\text{m} \lesssim c\tau \lesssim 1$ m

Measuring $m_{\tilde{\tau}_R}$ & $c\tau_{\tilde{\tau}_R}$ probes SUSY breaking!

Gauge Mediation and $\tilde{\tau}_R$ NLSPs

LEP Limits on Slepton NLSPs



$m_{\tilde{\tau}} > 87$ GeV

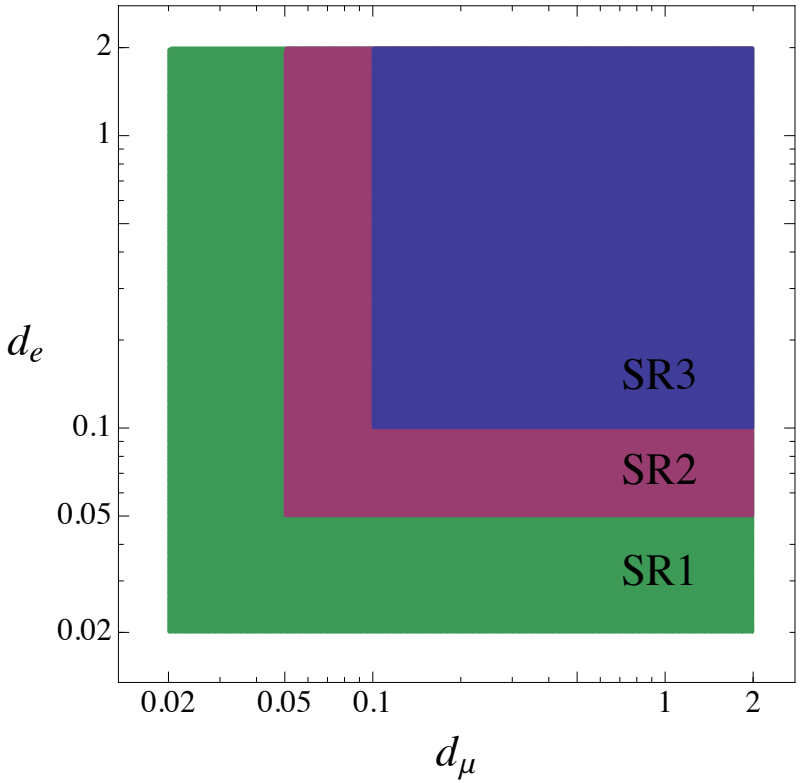
$m_{\tilde{\mu}} > 94$ GeV

OPAL placed the best limits on sleptons of all lifetimes

CMS Displaced Lepton Search

Cuts

Cut Summary of CMS $e\mu$
Preselection
1 OS $e^{\pm}\mu^{\mp}$ pair
$\rightarrow$ $d_\ell > 100\ \mu$m
$p_{T,\ell} > 25$ GeV, $\lvert\eta_\ell\rvert < 2.5$
Reject $1.44 < \lvert\eta_e\rvert < 1.56$
$I^{rel,e}_{\Delta R=0.3} < 0.10$, $I^{rel,\mu}_{\Delta R=0.4} < 0.12$
$\Delta R_{\ell j} > 0.5\ \forall$ jets with $p_T > 10$ GeV
$\Delta R_{e\mu} > 0.5$
Veto additional leptons



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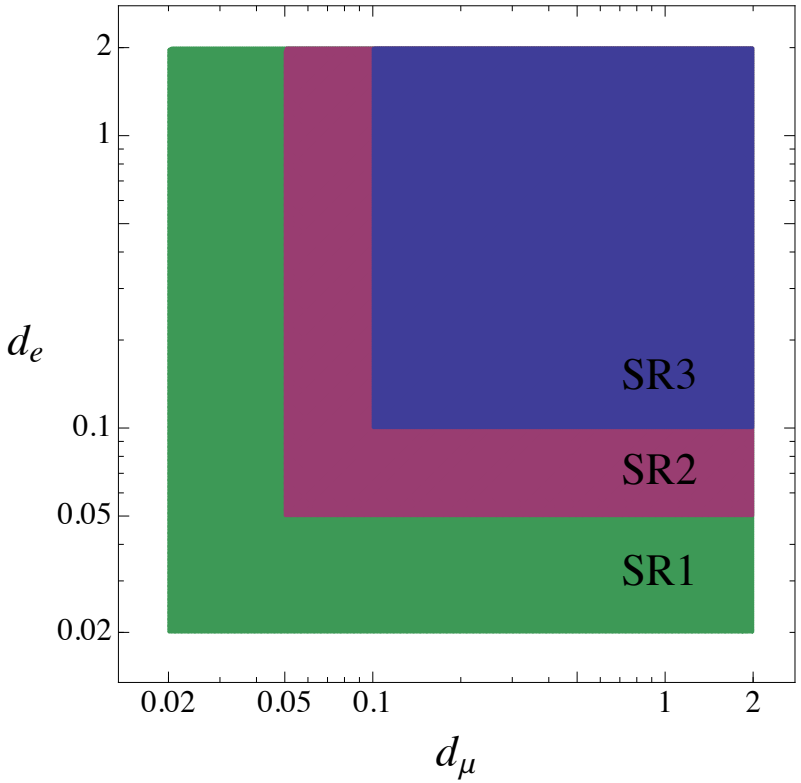

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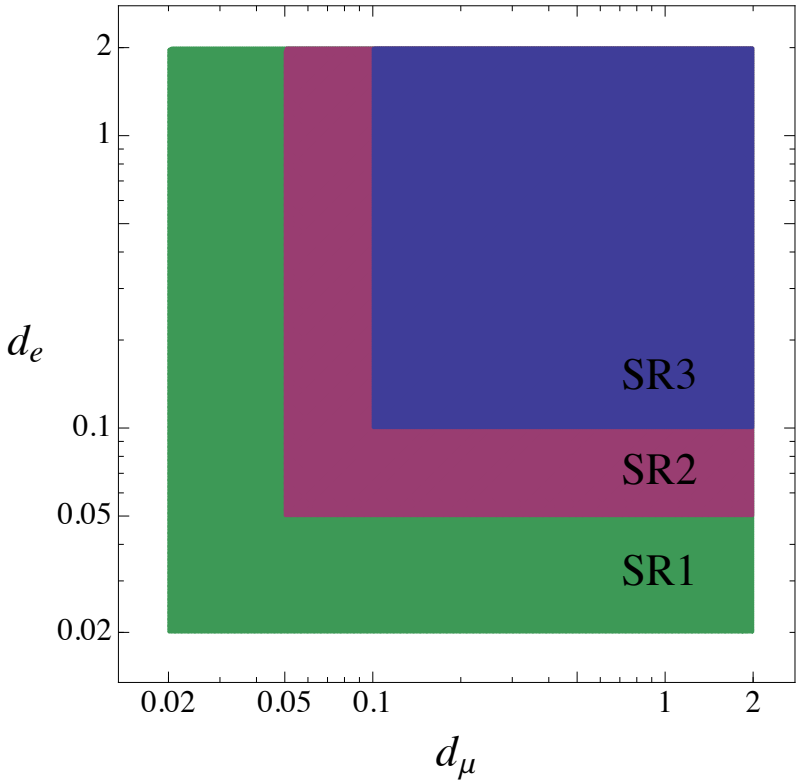

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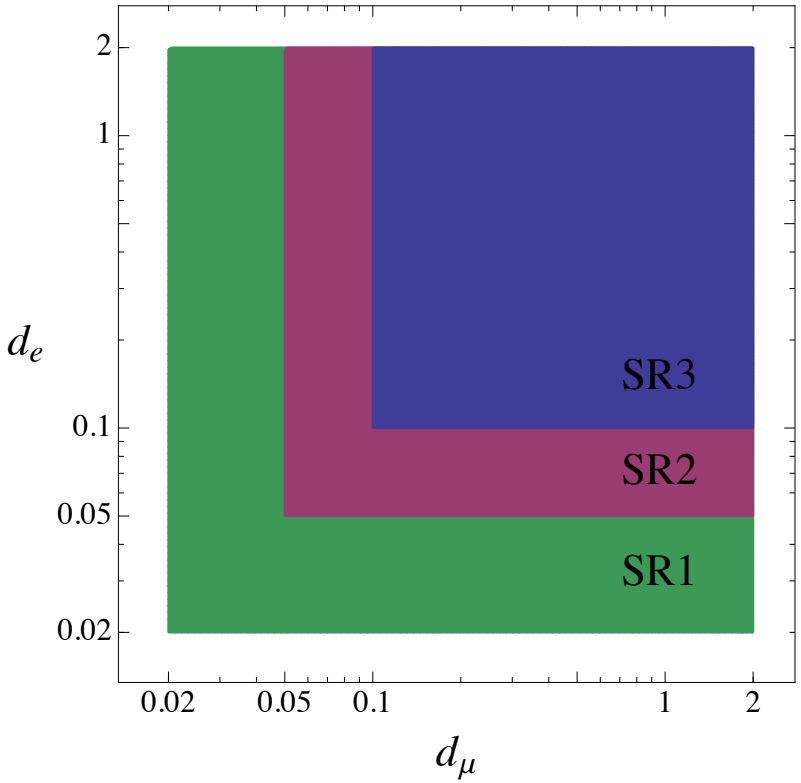
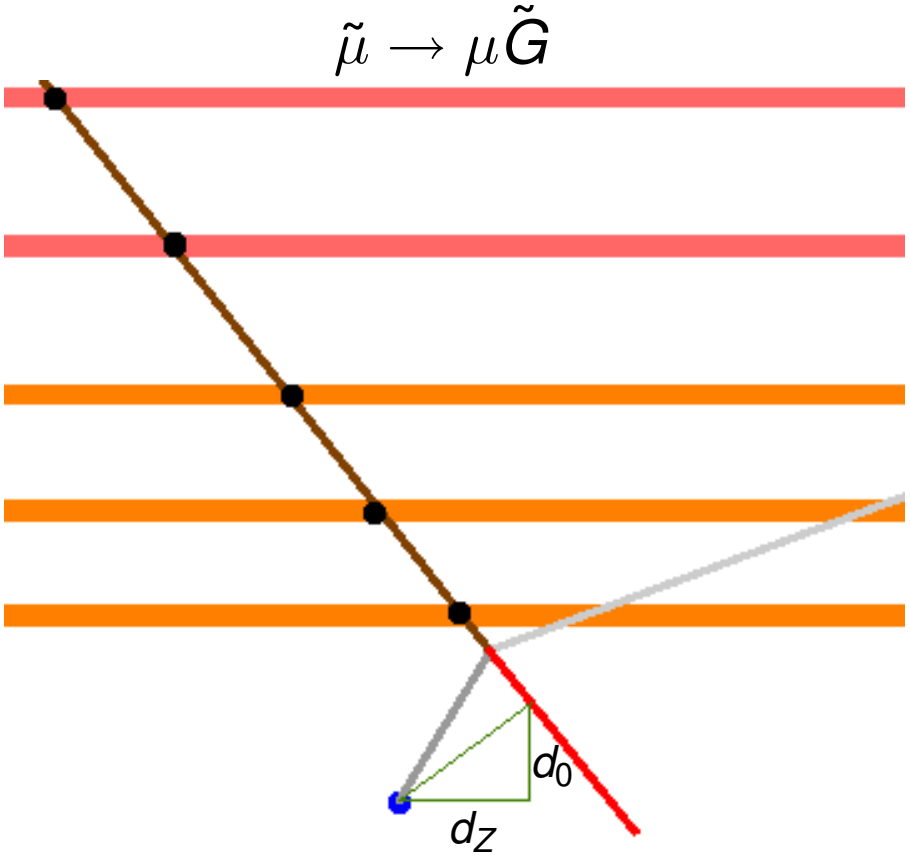
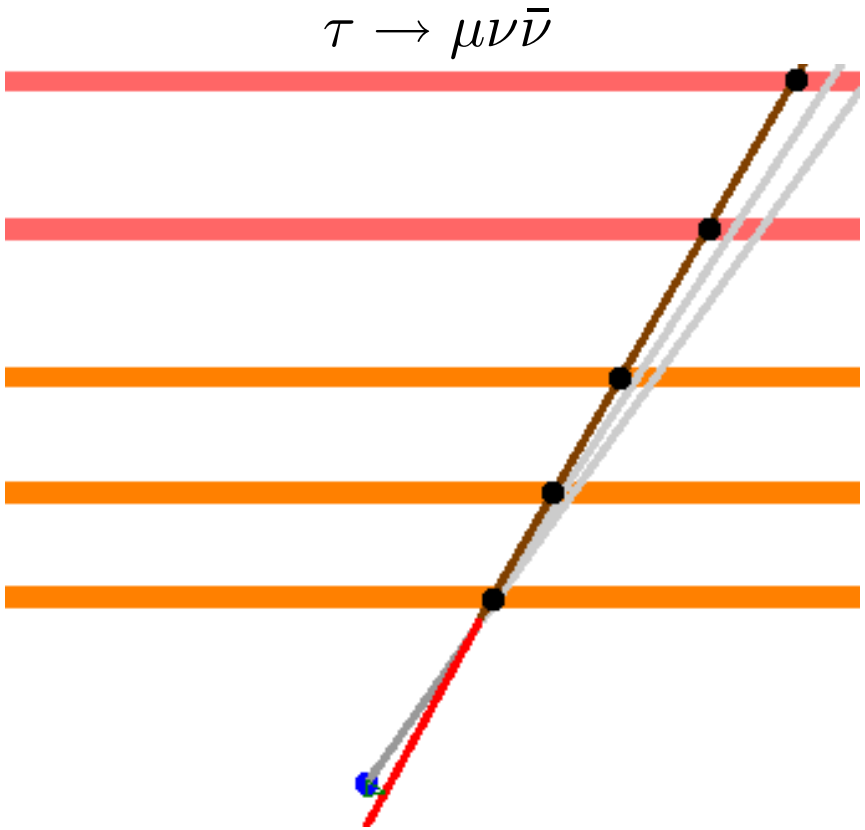
$\longrightarrow$ Veto additional leptons



CMS Displaced Lepton Search

Impact Parameter



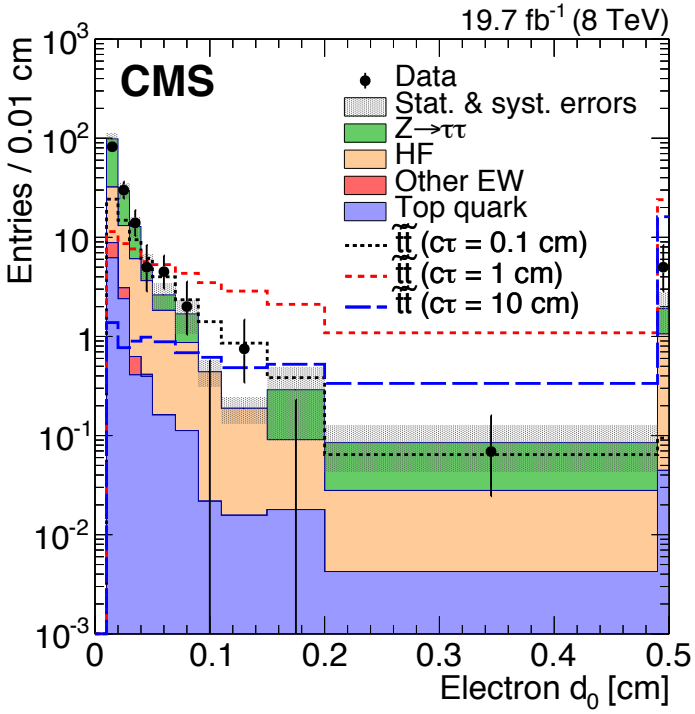


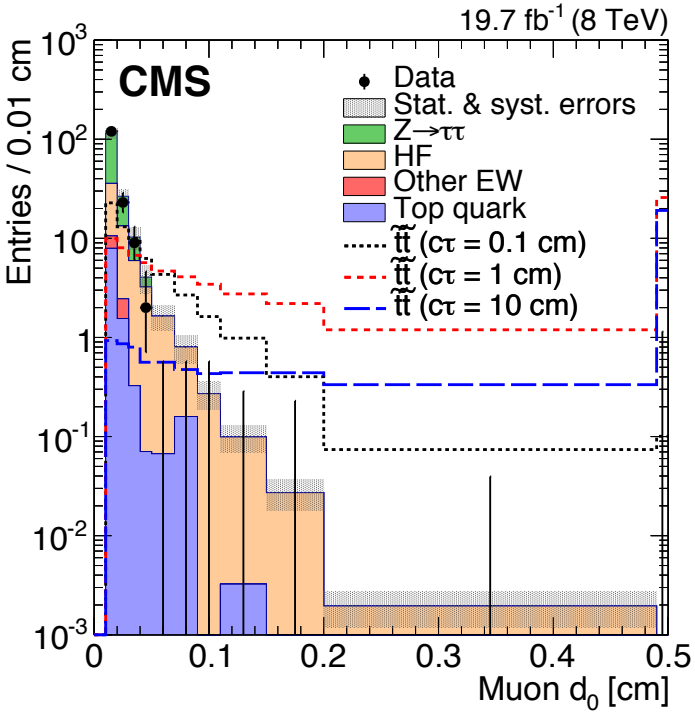
Impact Parameter is *not* the location of parent

b and τ decay products are more collimated

CMS Displaced Lepton Search

Backgrounds & Data





Event source	SR1	SR2	SR3
Other EW	$0.65 \pm 0.13 \pm 0.09$	$(0.89 \pm 0.53 \pm 0.12) \times 10^{-2}$	$<(89 \pm 53 \pm 12) \times 10^{-4}$
Top quark	$0.77 \pm 0.04 \pm 0.08$	$(1.25 \pm 0.26 \pm 0.12) \times 10^{-2}$	$(2.4 \pm 1.3 \pm 0.2) \times 10^{-4}$
$Z \to \tau\tau$	$3.93 \pm 0.42 \pm 0.39$	$(0.73 \pm 0.73 \pm 0.07) \times 10^{-2}$	$<(73 \pm 73 \pm 7) \times 10^{-4}$
HF	$12.7 \pm 0.2 \pm 3.8$	$(98 \pm 6 \pm 30) \times 10^{-2}$	$(340 \pm 110 \pm 100) \times 10^{-4}$
Total expected background	$18.0 \pm 0.5 \pm 3.8$	$1.01 \pm 0.06 \pm 0.30$	$0.051 \pm 0.015 \pm 0.010$
Observed	19	0	0

CMS Displaced Lepton Search

Recast Limits on $\tilde{\tau}_R$

No limits on direct $\tilde{\tau}_R$ production!

CMS Displaced Lepton Search

Recast Limits on $\tilde{\tau}_R$

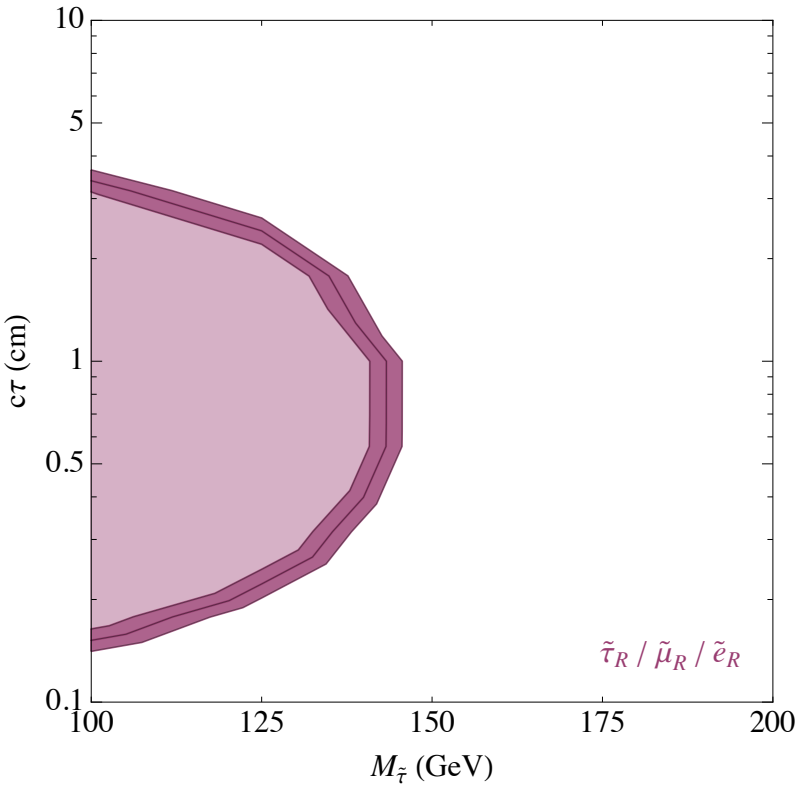
No limits on direct $\tilde{\tau}_R$ production!

But . . . a $\tilde{\tau}_R$ is not expected in isolation

Near degenerate slepton limits

$$m_{\tilde{e}_R} = m_{\tilde{\mu}_R} = m_{\tilde{\tau}_R} + 10 \text{ GeV}$$

$$\tilde{\ell}_R \to \tilde{\tau}_R + \{\text{soft}\}$$



CMS Displaced Lepton Search

Recast Limits on $\tilde{\tau}_R$

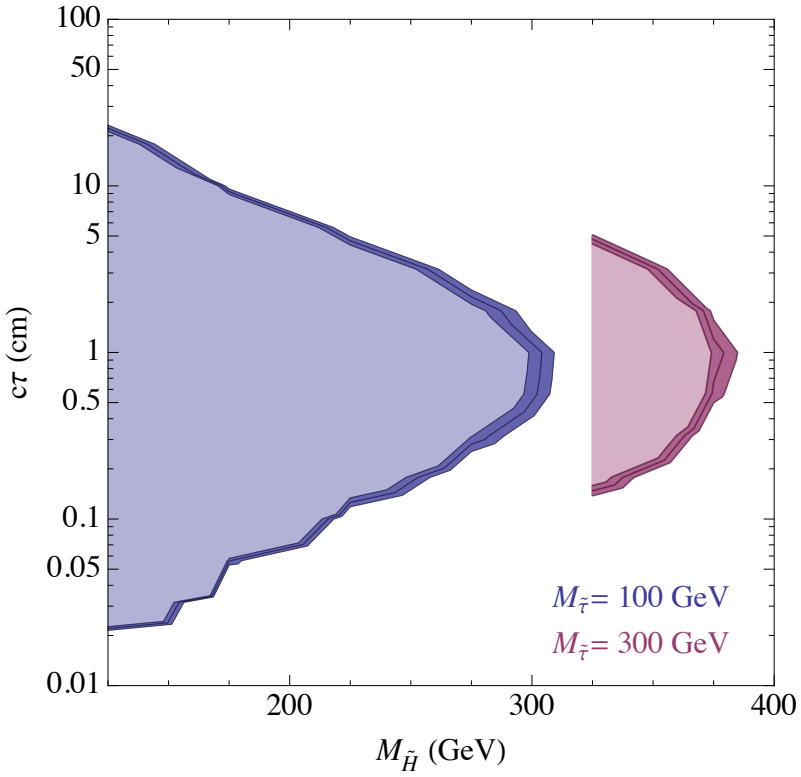
No limits on direct $\tilde{\tau}_R$ production!

But . . . a $\tilde{\tau}_R$ is not expected in isolation

Higgsino production limits

$$m_{\tilde{\chi}_1^0} = m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^+}$$

$$\tilde{\chi}_{1,2}^0 \to \tilde{\tau}_R^{\pm}\tau^{\mp}, \ \tilde{\chi}_1^{\pm} \to \tilde{\tau}_R^{\pm}\nu$$



Limits are very sensitive to $m_{\tilde{\tau}_R}$

CMS Displaced Lepton Search

Recast Limits on $\tilde{\tau}_R$

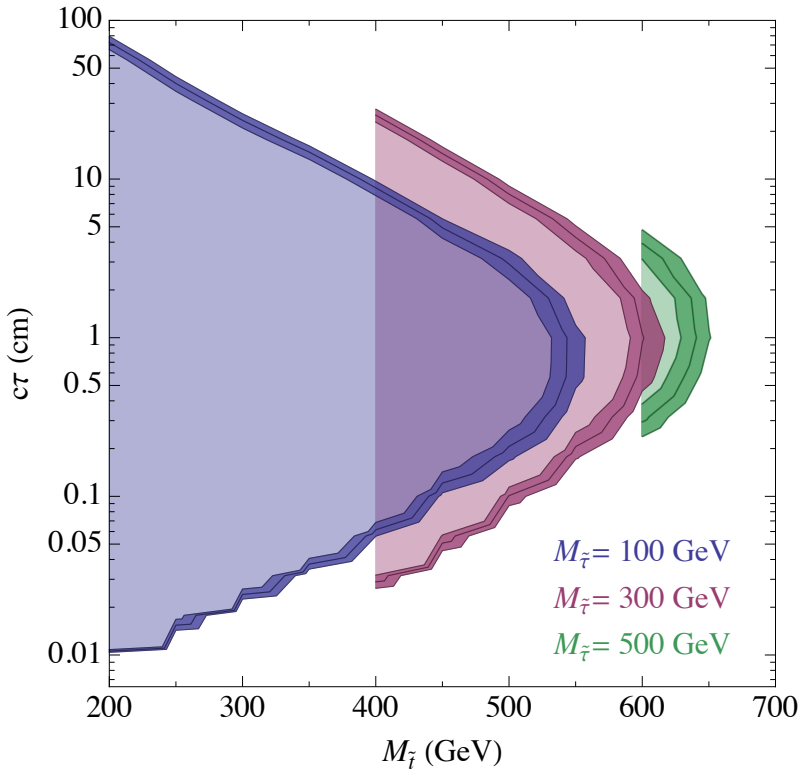
No limits on direct $\tilde{\tau}_R$ production!

But . . . a $\tilde{\tau}_R$ is not expected in isolation

Stop production limits

$$m_{\tilde{H}} = m_{\tilde{t}} - 50 \text{ GeV}$$

$$\tilde{t} \to b\tilde{H}^+ \to b\nu\tilde{\tau}_R^+$$



Limits are very sensitive to $m_{\tilde{\tau}_R}$

CMS Displaced Lepton Search

Recast Limits on $\tilde{\tau}_R$

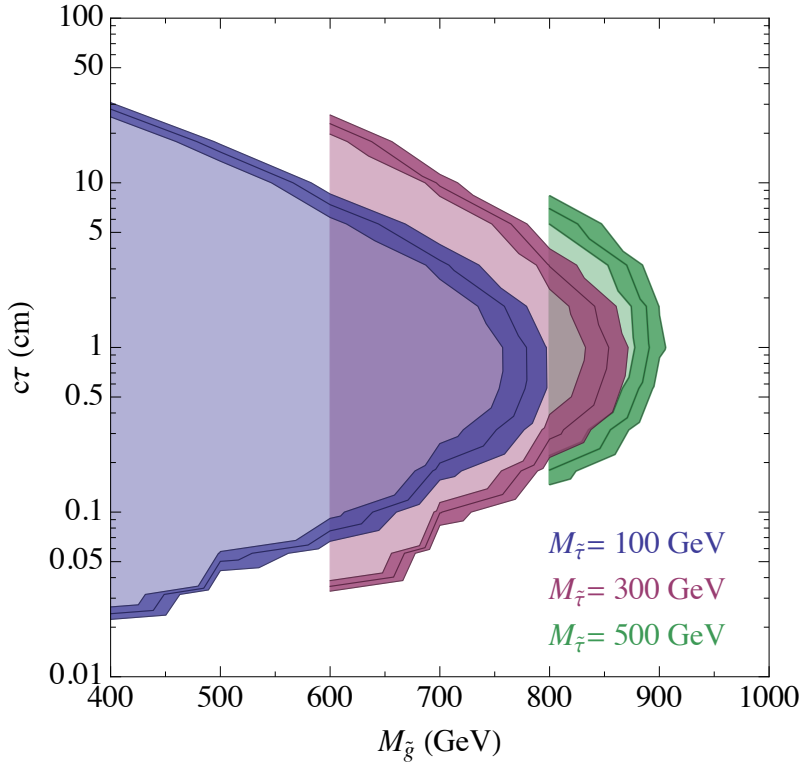
No limits on direct $\tilde{\tau}_R$ production!

But . . . a $\tilde{\tau}_R$ is not expected in isolation

Gluino production limits

$$m_{\tilde{t}} = m_{\tilde{g}} - 200 \text{ GeV}$$
$$m_{\tilde{H}} = m_{\tilde{t}} - 50 \text{ GeV}$$

$$\tilde{g} \to \tilde{t}\bar{t} \to \bar{t}b\tilde{H}^+ \to \bar{t}b\nu\tilde{\tau}_R^+$$
$$\tilde{g} \to \tilde{t}^* t \to t\bar{b}\tilde{H}^- \to t\bar{b}\bar{\nu}\tilde{\tau}_R^-$$



Limits are very sensitive to $m_{\tilde{\tau}_R}$

CMS Displaced Lepton Search

Potential Improvements?

There are several lessons from GMSB $\tilde{\tau}_R$s to improve sensitivity

$$BR(\tilde{\tau}^+\tilde{\tau}^- \rightarrow e^{\pm}\mu^{\mp} + X) = 6\%$$
$$BR(\tilde{\tau}^+\tilde{\tau}^- \rightarrow e^+e^- + X) = 3\%$$
$$BR(\tilde{\tau}^+\tilde{\tau}^- \rightarrow \mu^+\mu^- + X) = 3\%$$

1) Add same-flavor lepton channels

CMS Displaced Lepton Search

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1) Add same-flavor lepton channels

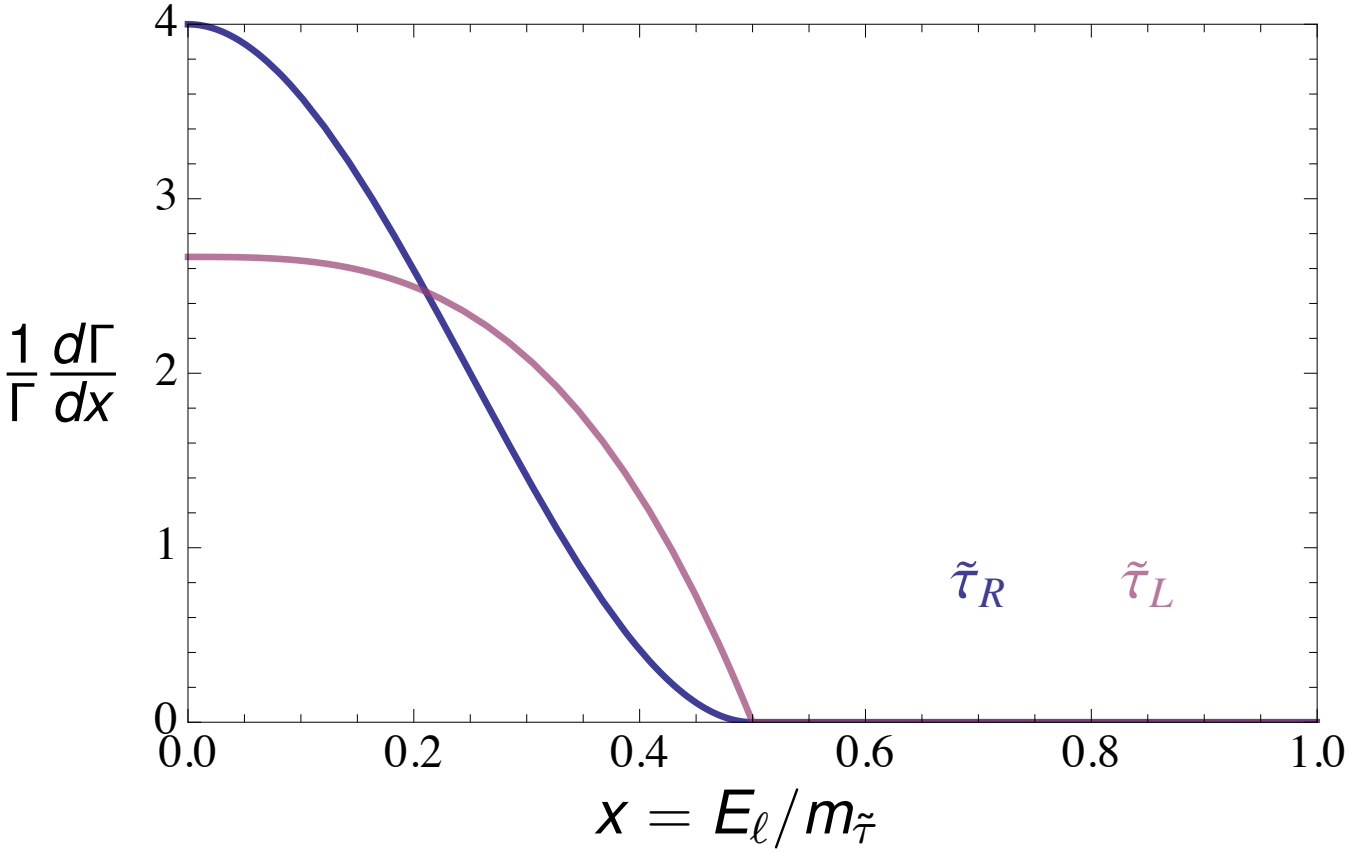
$$BR(\tilde{\tau}^+\tilde{\tau}^- \to e^\pm\tau_h^\mp + X) = 23\%$$
$$BR\tilde{\tau}^+\tilde{\tau}^- \to \mu^\pm\tau_h^\mp + X) = 23\%$$
$$BR(\tilde{\tau}^+\tilde{\tau}^- \to \tau_h^\pm\tau_h^\mp + X) = 42\%$$

2) Include hadronic τ_hs

Experimental feasibility of displaced τ_hs?

CMS Displaced Lepton Search

Potential Improvements?



Right-handed polarized τs from $\tilde{\tau}_R$ decays give softer leptons

3) Lower p_T thresholds can capture a lot more signal

Additional triggers – $\not{E}_T + \ell\ell$, $\not{E}_T$, $\ell\ell\ell$, etc

CMS Displaced Lepton Search

Potential Improvements?

Search vetoes additional leptons.

Why?

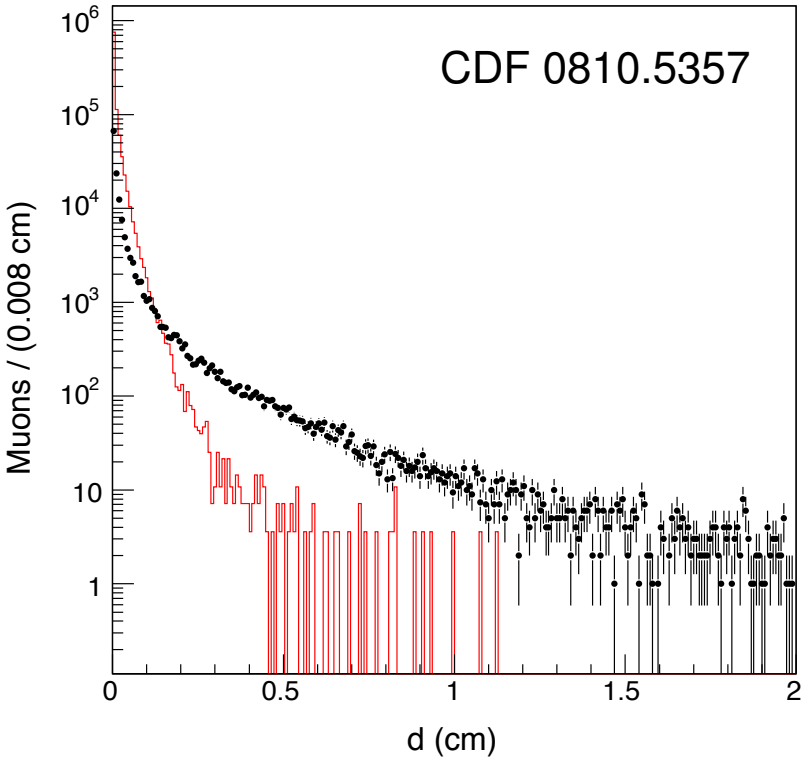
CMS Displaced Lepton Search

Potential Improvements?

Search vetoes additional leptons. Why?

Displaced multilepton background should be very small

(CDF ghost muons???)



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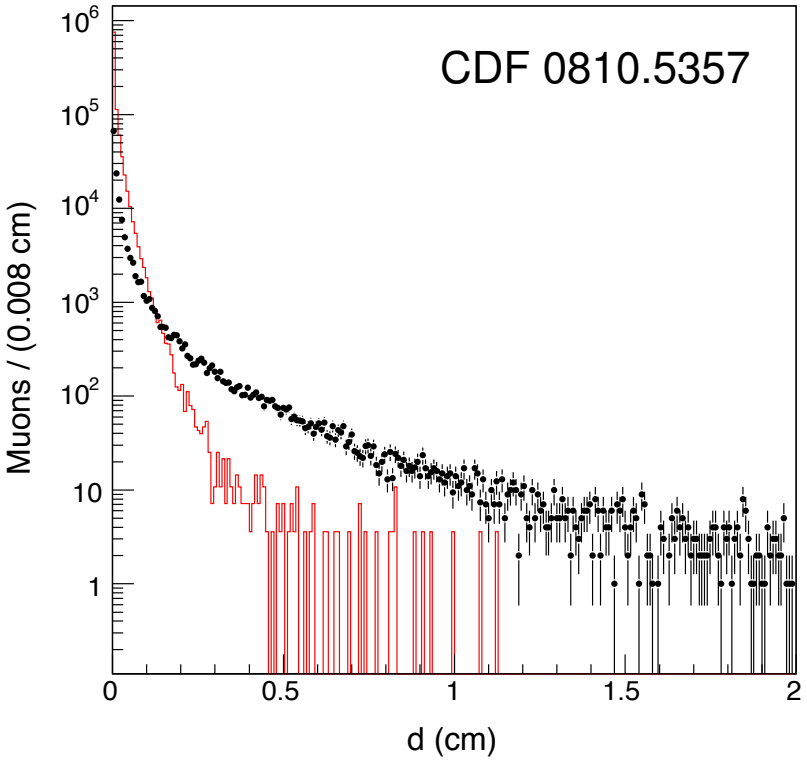


Gluino & Higgsino model have additional leptons often $\sim$(45%, 30%)

If pair-produced object is not charged under lepton number, additional leptons are generic

4) Don't veto additional leptons

CMS Displaced Lepton Search

Potential Improvements?

Gluino & Higgsino models have Majorana particles in chain

$\Rightarrow$ same-sign displaced leptons

5) Include same-sign displaced lepton signal regions

CMS Displaced Lepton Search

Potential Improvements?

Gluino & Higgsino models have Majorana particles in chain

$\Rightarrow$ same-sign displaced leptons

5) Include same-sign displaced lepton signal regions

5') Same-sign possibility fairly generic, be wary of CR contamination

SSℓ can appear in the $\tilde{t} \to \ell^+ b$ benchmark of CMS 1409.4789

Mesino oscillation allows up to 3/8 of events as SSℓ Sarid, Thomas – 9909349

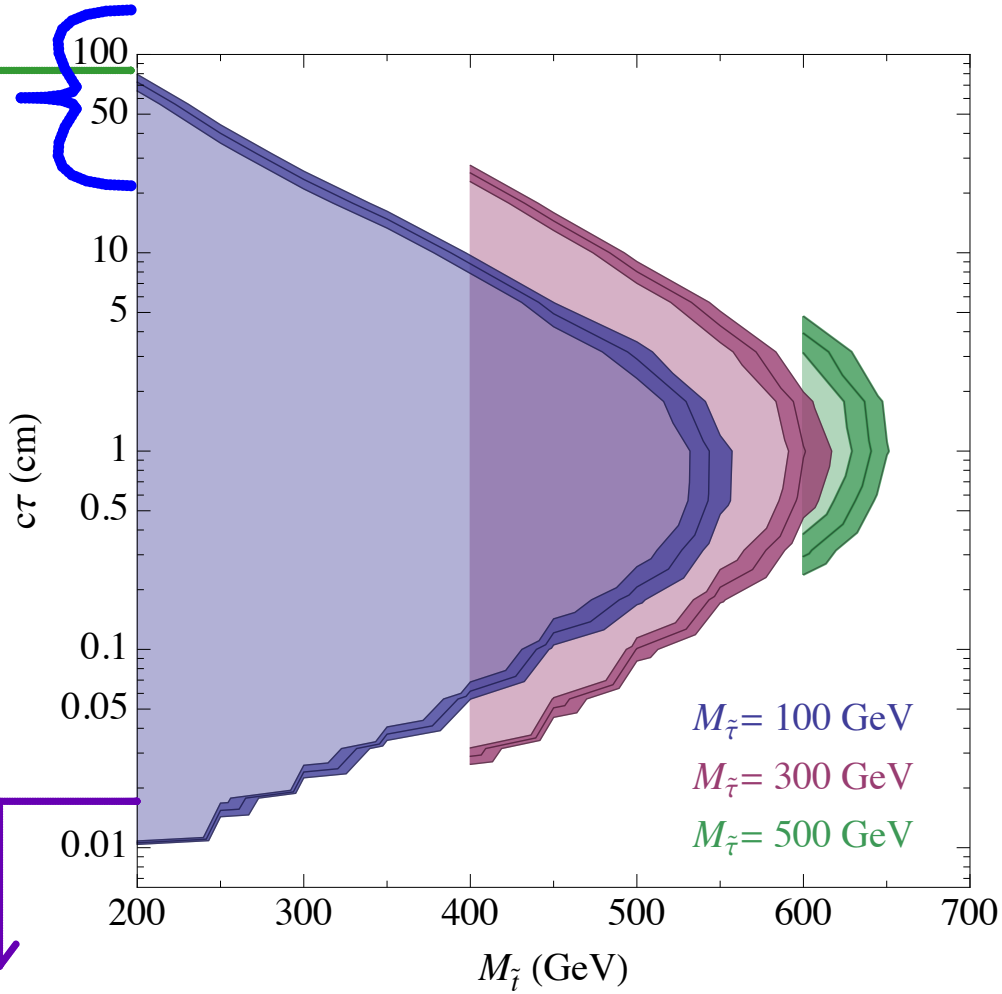
CMS Displaced Lepton Search

Potential Improvements?

HSCP

Disappearing Tracks*

Extend reach in $c\tau$?



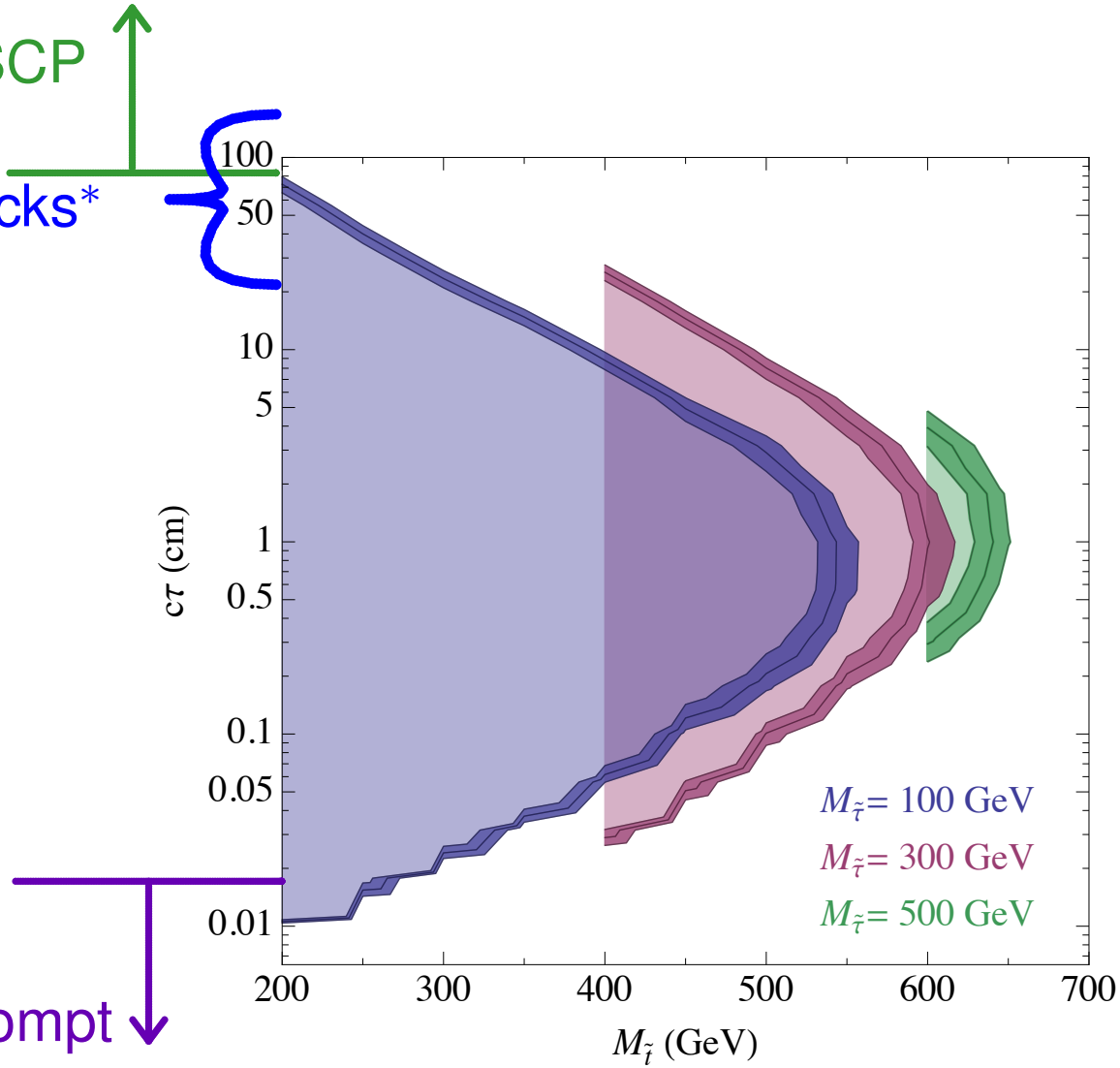
Prompt

CMS Displaced Lepton Search

Potential Improvements?

Extend reach in $c\tau$?

6) Allow d_0 above 2 cm
(Even just for muons)



CMS Displaced Lepton Search

Potential Improvements?

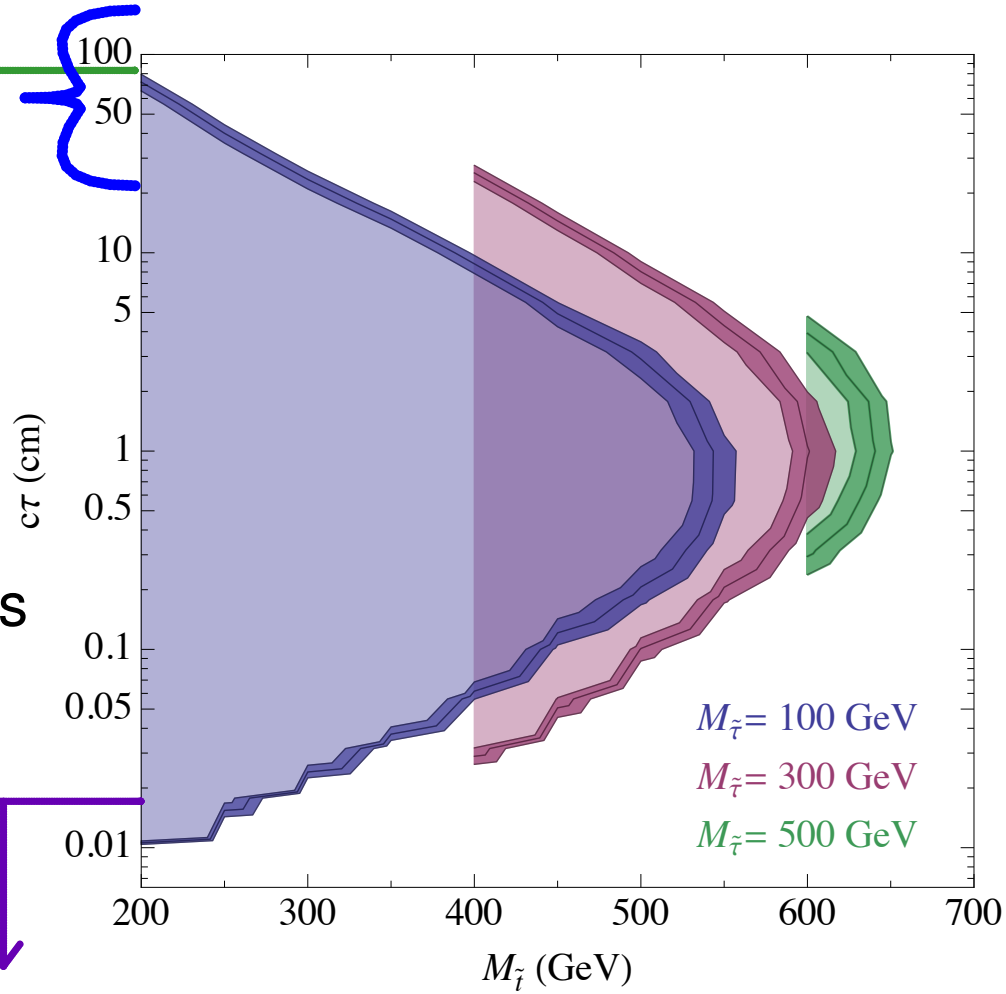
HSCP

Disappearing Tracks*

Extend reach in $c\tau$?

6) Allow d_0 above 2 cm
(Even just for muons)

7) Relax isolation in high d_0 bins
(Backgrounds are small there)



Prompt

Same-flavor Displaced Lepton Models

Slepton Co-NLSP in GGM

If $m_{\tilde{\ell}_R} - m_{\tilde{\tau}_R} \ll 10$ GeV **or** $m_{\tilde{B}} \gg m_{\tilde{\tau}_R}$,

then $\Gamma(\tilde{\ell}_R \to \ell\tau\tilde{\tau}_R) \ll \Gamma(\tilde{\ell}_R \to \ell\tilde{G}) \Rightarrow$ Slepton Co-NLSP

Events have displaced e^+e^-, $\mu^+\mu^-$, or $\tau^+\tau^-$

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Small splitting can happen for low $\tan\beta$

In GGM, M_1 and $m^2_{\tilde{E}_R}$ are independent

$\mu^+\mu^-$ and e^+e^- searches would be more sensitive to this model

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$\mu^+\mu^-$ and e^+e^- searches would be more sensitive to this model

Can get 100% e^+e^- or $\mu^+\mu^-$ from Extended GMSB: $W \supset \kappa_i E_i^c \Phi\tilde{\Phi}$

or Freeze-in of dark matter in matter dominated era: $\mathcal{L} \supset \lambda_{ij}\phi^+\ell_i\chi_j$

Same-flavor Displaced Lepton Models

$\tilde{\tau}_1$ with *LLE* RPV

RPV can do almost anything

Same-flavor Displaced Lepton Models

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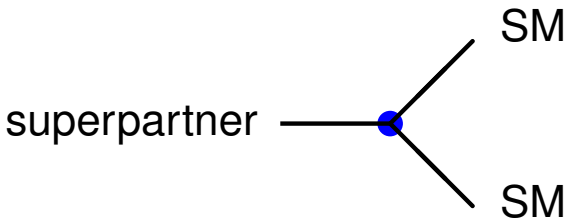
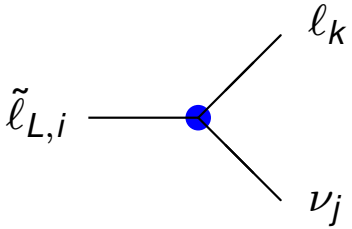
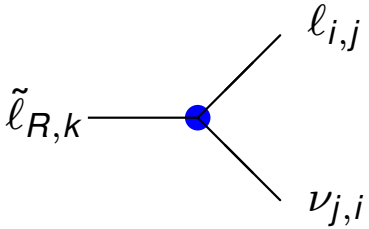


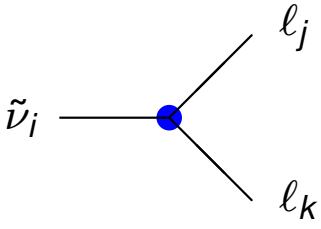
$$W = \frac{1}{2}\lambda_{ijk}\, L_i L_j E^c_k + \lambda'_{ijk}\, L_i Q_j D^c_k + \frac{1}{2}\lambda''_{ijk}\, U^c_i D^c_j D^c_k + \mu_i L_i H_u$$

i, j, k = generation indices

LLE



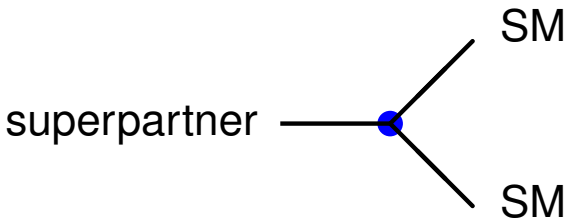




Same-flavor Displaced Lepton Models

$\tilde{\tau}_1$ with *LLE* RPV

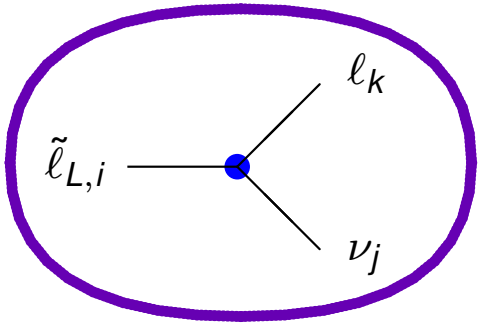
RPV can do almost anything

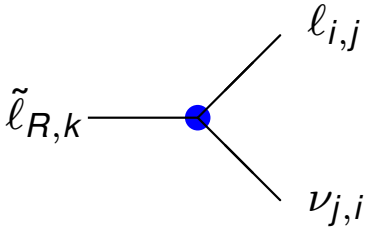


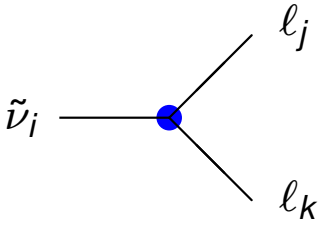
$$W = \frac{1}{2}\lambda_{ijk}\, L_i L_j E^c_k + \lambda'_{ijk}\, L_i Q_j D^c_k + \frac{1}{2}\lambda''_{ijk}\, U^c_i D^c_j D^c_k + \mu_i L_i H_u$$

i, j, k = generation indices

LLE







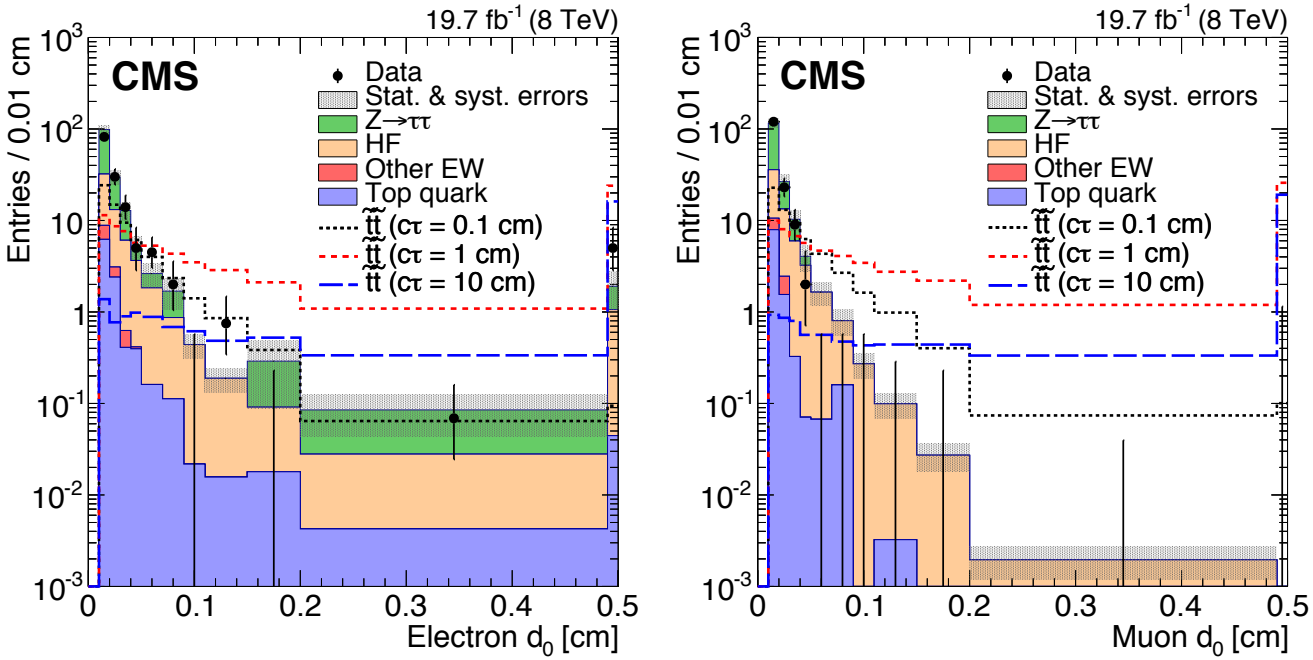
$$c\tau \approx 1\ \text{cm} \left(\frac{10^{-7}}{\lambda_{232}}\right)^2 \left(\frac{100\ \text{GeV}}{m_{\tilde{\tau}}}\right) \sec^2\theta_{\tilde{\tau}} \qquad (\theta_{\tilde{\tau}} = 0 \Rightarrow \tilde{\tau}_1 = \tilde{\tau}_L)$$

$$\lambda_{232}\cos\theta_{\tilde{\tau}} \gg \text{other RPV} \quad \Rightarrow \quad \text{BR}(\tilde{\tau}_1 \to \mu\nu) \approx 100\%$$

Same-Flavor Displaced Lepton Search

Backgrounds

How can we estimate 13 TeV backgrounds?



1. Use 8 TeV backgrounds to estimate 8 TeV SF backgrounds
2. Rescale backgrounds by $\frac{\sigma(13)}{\sigma(8)}$ (supported by HF MC)
3. Assume displaced $Z \to e^+e^-/\mu^+\mu^-$ is small or can be controlled

Same-Flavor Displaced Lepton Search

Backgrounds

How can we estimate 13 TeV backgrounds?

Sample	SR1	SR2	SR3
$e^{\pm}\mu^{\mp}$ 8 TeV (CMS actual)	18.0 ± 3.8	1.01 ± 0.31	0.051 ± 0.018
$e^{\pm}\mu^{\mp}$ 8 TeV (estimate)	19.8 ± 4.1	0.92 ± 0.28	0.055 ± 0.024
$e^{\pm}\mu^{\mp}$ 13 TeV (20 fb^{-1})	34.1 ± 6.5	1.49 ± 0.44	0.086 ± 0.038
$e^{+}e^{-}$ 13 TeV (20 fb^{-1})	25.2 ± 3.6	1.43 ± 0.33	0.31 ± 0.06
$\mu^{+}\mu^{-}$ 13 TeV (20 fb^{-1})	13.0 ± 3.1	0.50 ± 0.15	0.012 ± 0.006

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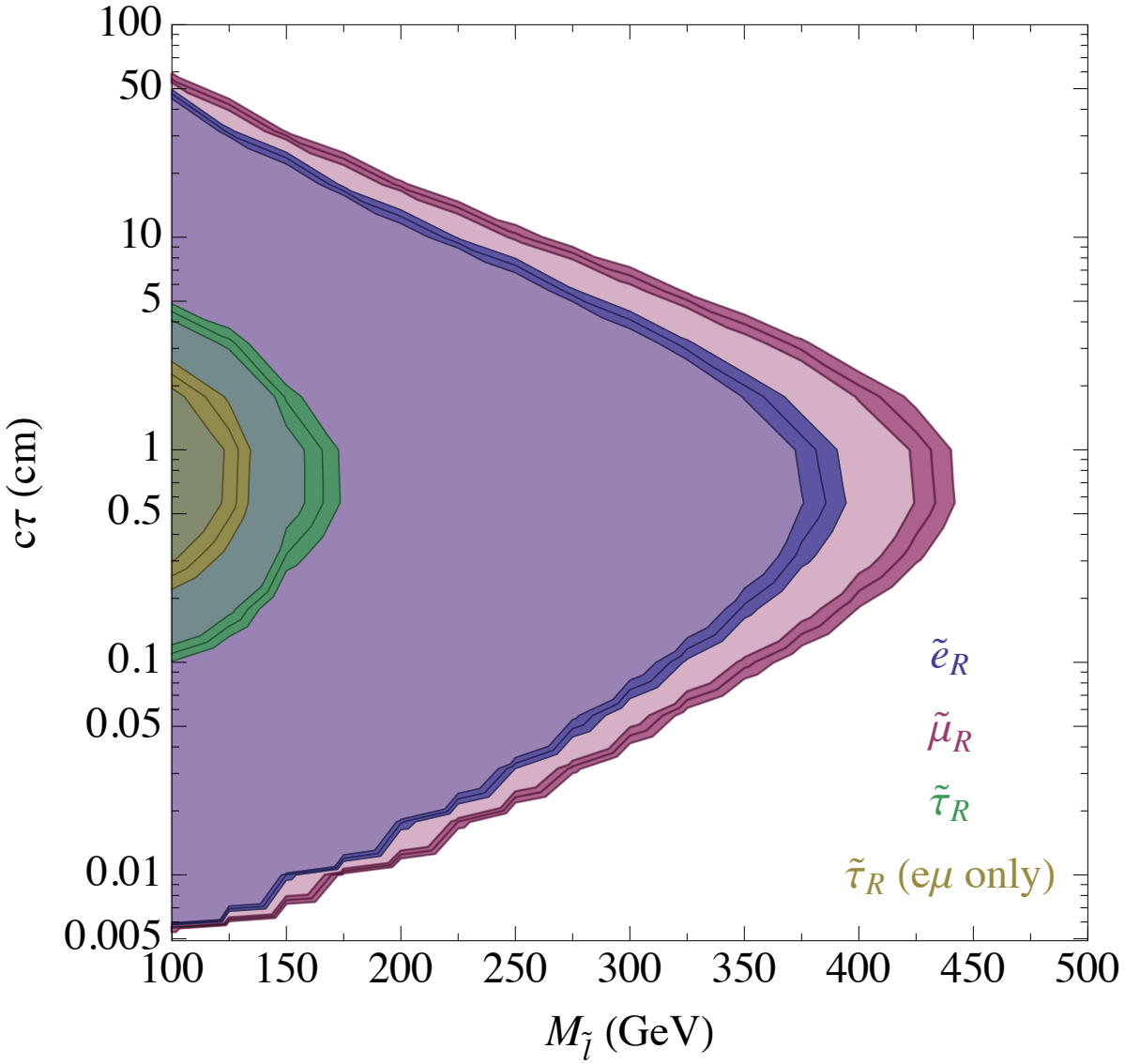
2. Rescale backgrounds by $\frac{\sigma(13)}{\sigma(8)}$ (supported by HF MC)
3. Assume displaced $Z \rightarrow e^{+}e^{-}/\mu^{+}\mu^{-}$ is small or can be controlled

Same-Flavor Displaced Lepton Search

13 TeV Same-Flavor Search



Same-Flavor Displaced Lepton Search

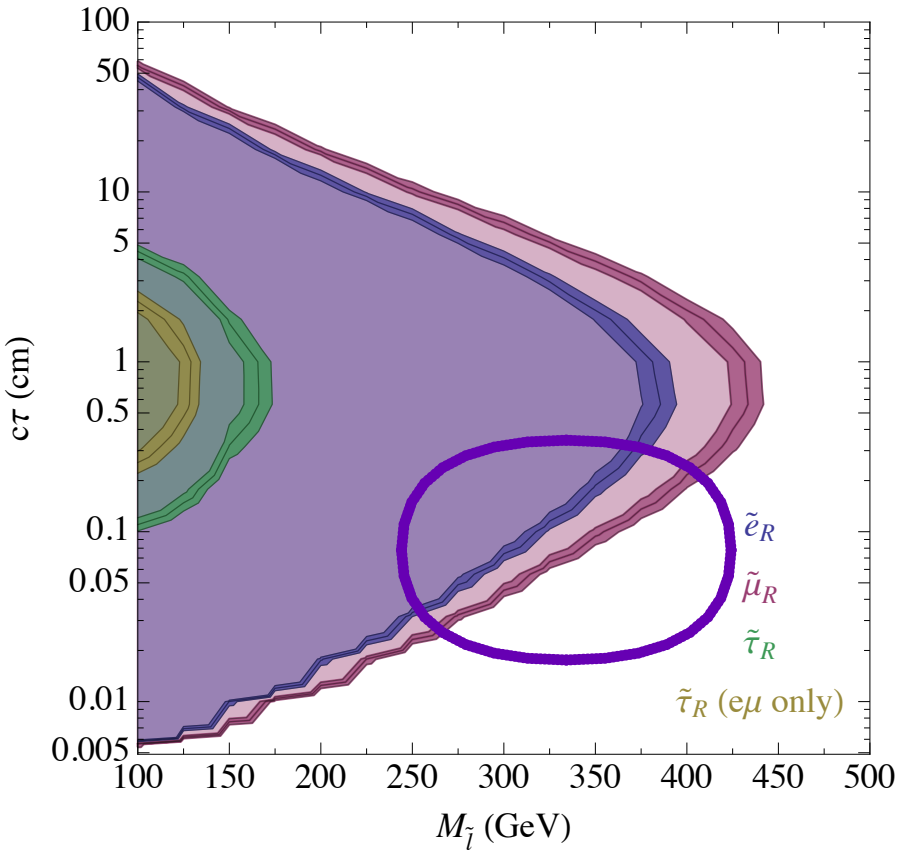
Improving a 13 TeV Same-Flavor Search

$\tilde{e}^+ \to e^+ \tilde{G} \Rightarrow$ hard leptons

$\tilde{\mu}^+ \to \mu^+ \tilde{G} \Rightarrow$ hard leptons

$\tilde{\tau}^+ \to \tau^+ \tilde{G} \Rightarrow$ soft leptons

8) SF search can be improved with higher $p_{T,\ell}$, lower background bins



Conclusions

- Displaced $\tilde{\tau}$s from GMSB: well-motivated and weakly constrained
- CMS large impact parameter $e^{\pm}\mu^{\mp}$ is not optimized for this signal
- Sensitivity to $\tilde{\tau}_R$ can be improved
  - Add SFℓ bins
  - Add τ_h bins
  - Lowered p_T thresholds
  - Extend $d_0 > 2$ cm
  - Add SSℓ bins (CR contamination)
  - Allow extra ℓs
  - Relax isolation in high d_0 bins
  - Add high $p_{T,\ell}$ bins
- Disappearing track searches should consider this benchmark
- Several models with displaced $ee/\mu\mu$ uncovered at LHC