

# Multi-purpose Single Lepton Searches at the LHC

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# Roadmap

- A “Bright” Future for the LHC
- Unusual Signals: Single Lepton Channels
- An Application to Supersymmetry
- Results
- Conclusions & Outlook



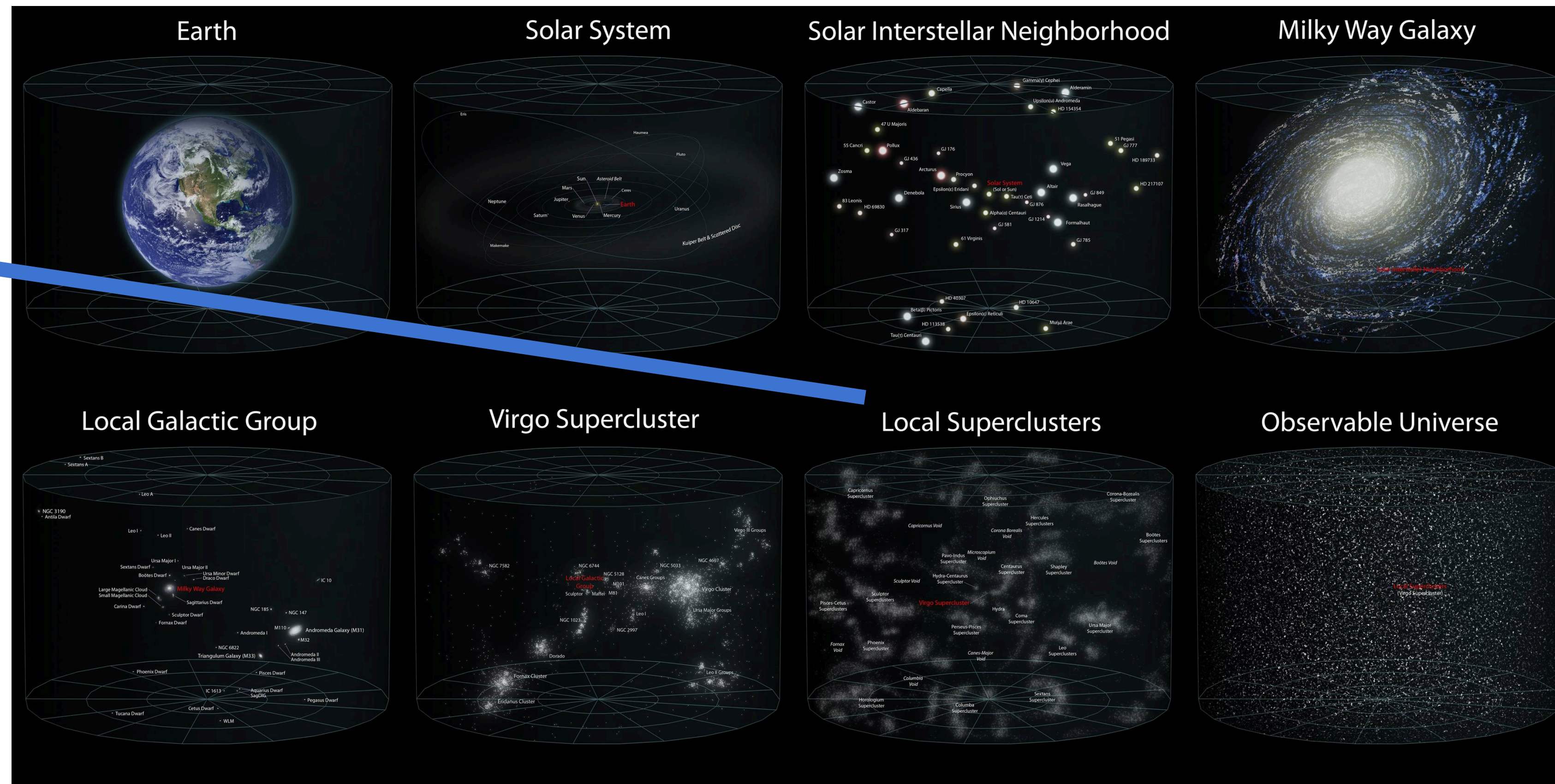
# A “Bright” Future for the LHC

- LHC’s next focus: Higher Energies -> Higher Luminosities (HL-LHC upgrade)

Currently  $200 \text{ fb}^{-1}$ :  
 $10^{16}$  p-p events

~ 100 times # of stars in here

- HL-LHC:  $250 \text{ fb}^{-1}$  per yr





# A “Bright” Future for the LHC

- What new physics will we find?  
...
- Where all can we look for new physics?
  - Ocean of data -> Probes rare, new mechanisms, signals
  - Worth revisiting! Can be surprisingly powerful

# Unusual Signals: Single Lepton Channels

**1 charged lepton + n jets + no MET**

- Interesting in 2 ways:

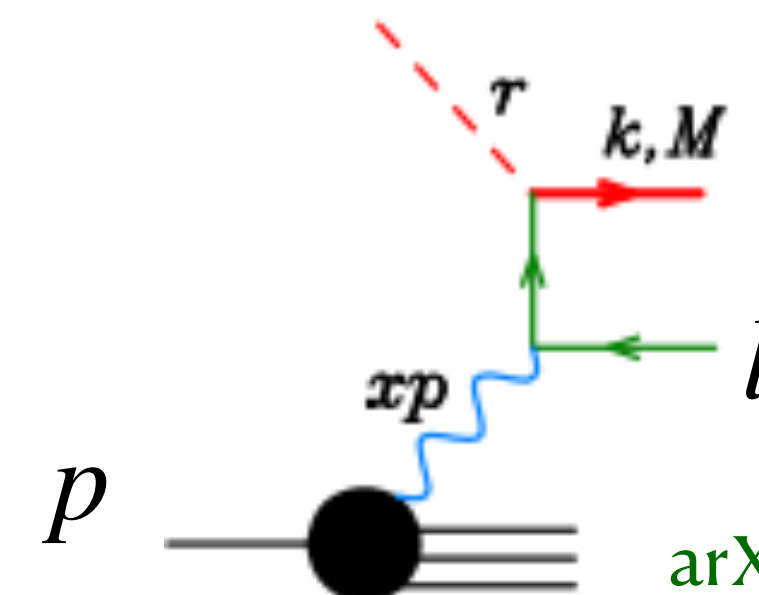
- No MET:

Unlike most SUSY, DM, LLPs, Axions, Heavy Neutrinos, etc. searches

- Odd in lepton number: Either LNV couplings, or lepton PDF initiated state!

SM low-energy bounds

2 powers of  $\alpha_{EM}$



# Unusual Signals: Single Lepton Channels

- ...but [arXiv: 1107.5055\[Lisanti et al.\]](#)) has shown that it was a real **gap** in LHC pair production searches for generic SUSY (& non-SUSY) scenario  
  
-> Recently ATLAS, CMS have started filling this gap: [arXiv: 2106.09609](#), [1704.08493](#), [1712.08920](#)
- [arXiv: 2005.06475\[Buonocore et al.\]](#)): Single lepton channel can probe single production to complement pair production for leptoquarks: **extension**
- Here: Study single lepton channel for single production in supersymmetry

# An Application to Supersymmetry

- Minimal particle content (as in MSSM):

$$W = W_{\text{MSSM}} + W_{\text{LNV}} + W_{\text{BNV}}$$

$$W_{\text{RPV}}$$

R-parity violating terms, usually set to zero -> arbitrary!

- How well is SUSY ruled out upto say squark/gluino masses  $\sim 1.5$  TeV?

Quite well if it is vanilla MSSM -> fixed large MET signal

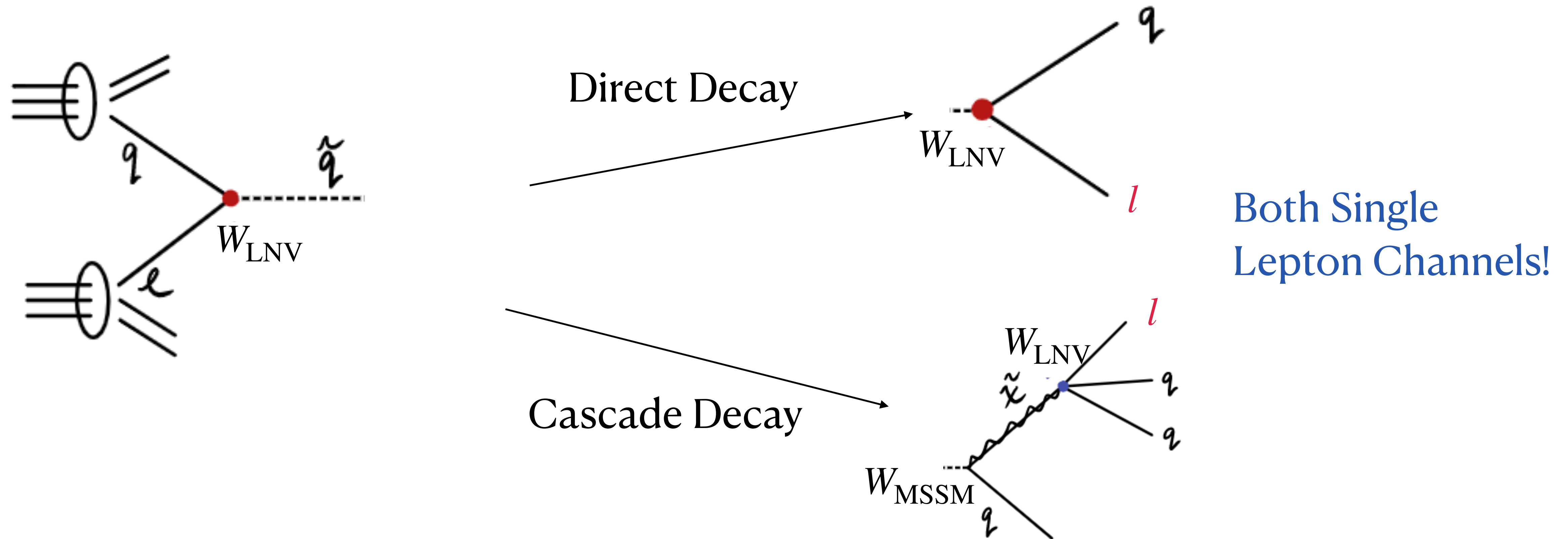
- But RPV MSSM can have gaps:

- Complex phenomenology: any particle can be LSP,  
and LSP is no longer stable

Ongoing efforts  
to fill these gaps

# An Application to Supersymmetry

- One striking, universal feature of all RPV models: single production possible! Example via lepton PDF





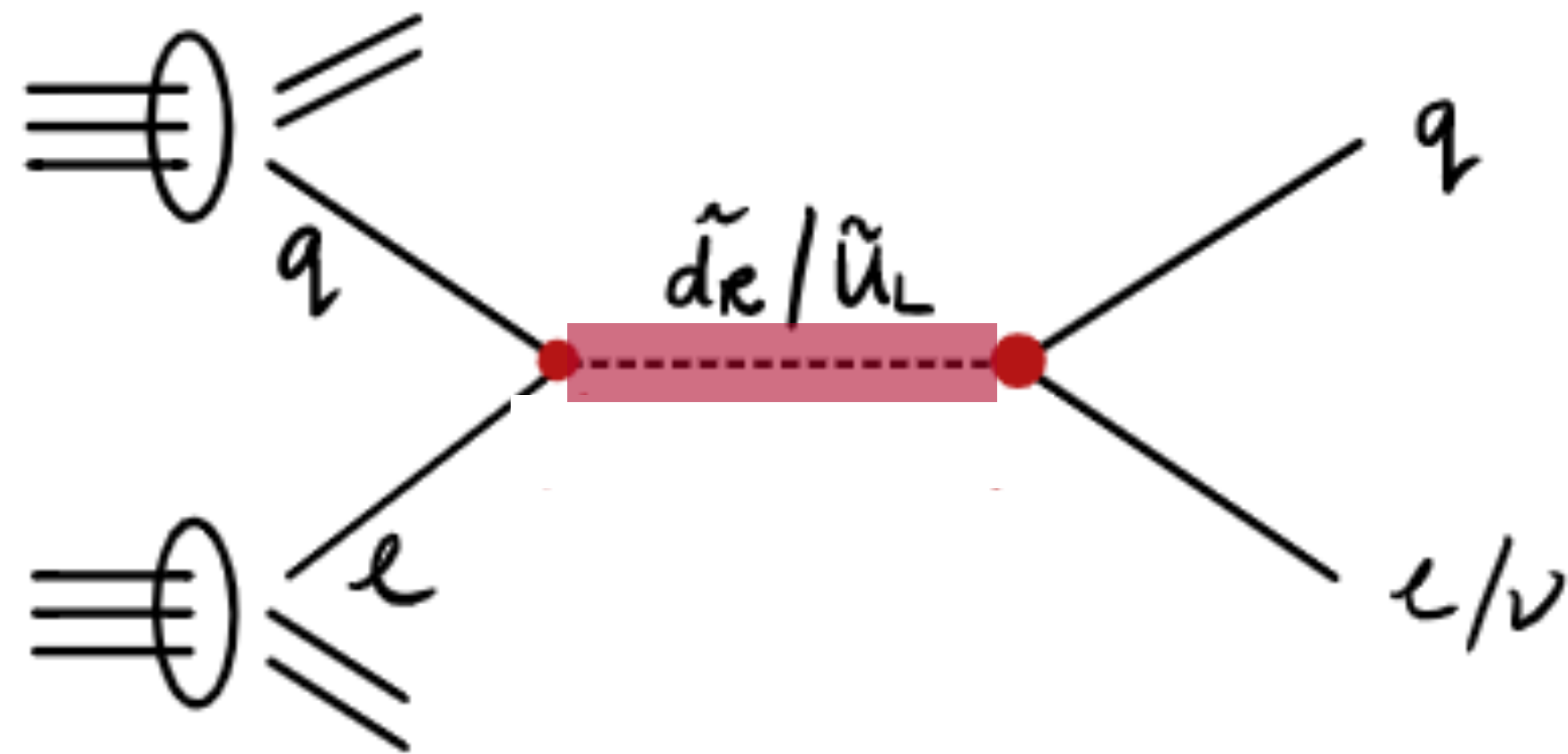
# An Application to Supersymmetry

- General trend
- Single lepton search can give us a quasi model-independent probe of RPV parameter space!

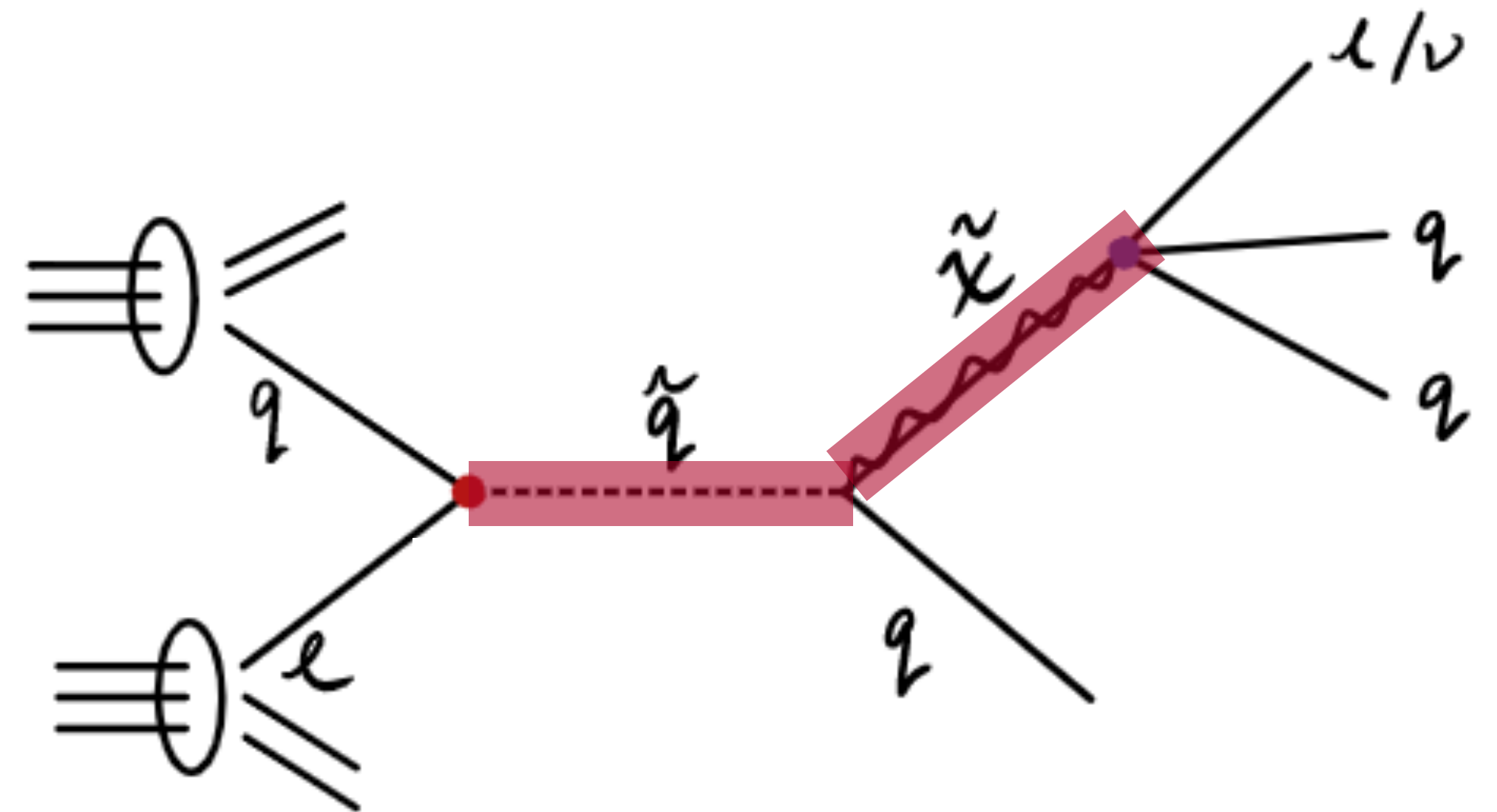
Cascade	End	Example	Signal
	$\tilde{B}$	$\tilde{d} \rightarrow \tilde{B} + 1j$	$1\ell + 3j$
	$\widetilde{W}$	$\tilde{d} \rightarrow \tilde{g} + 1j \rightarrow \tilde{q} + 2j \rightarrow \widetilde{W} + 3j$	$1\ell + 5j$
	$\tilde{g}$	$\tilde{d} \rightarrow \tilde{g} + 1j$	$1\ell + 3j$
	$\tilde{q}$	$\tilde{d} \rightarrow \tilde{g} + 1j \rightarrow \tilde{q} + 2j$	$1\ell + 3j$
	$\tilde{d}$	—	$1\ell + 1j$
	$\tilde{u}$	$\tilde{d} \rightarrow \tilde{g} + 1j \rightarrow \tilde{u} + 2j$	$1\ell + 5j$
	$\tilde{l}$	$\tilde{d} \rightarrow \tilde{g} + 1j \rightarrow \tilde{q} + 2j \rightarrow \widetilde{W}^0 + 3j \rightarrow \tilde{\ell} + 1\ell + 3j$	$1\ell + 5j$
	$\tilde{\nu}$	$\tilde{d} \rightarrow \tilde{g} + 1j \rightarrow \tilde{q} + 2j \rightarrow \widetilde{W}^{\pm} + 3j \rightarrow \tilde{\nu} + 1\ell + 3j$	$1\ell + 5j$
	$\tilde{e}$	$\tilde{d} \rightarrow \tilde{B} + 1j \rightarrow \tilde{e} + 1\ell + 1j$	$3\ell + 2j$

# An Application to Supersymmetry

- Search Strategy: 2 new resonance searches

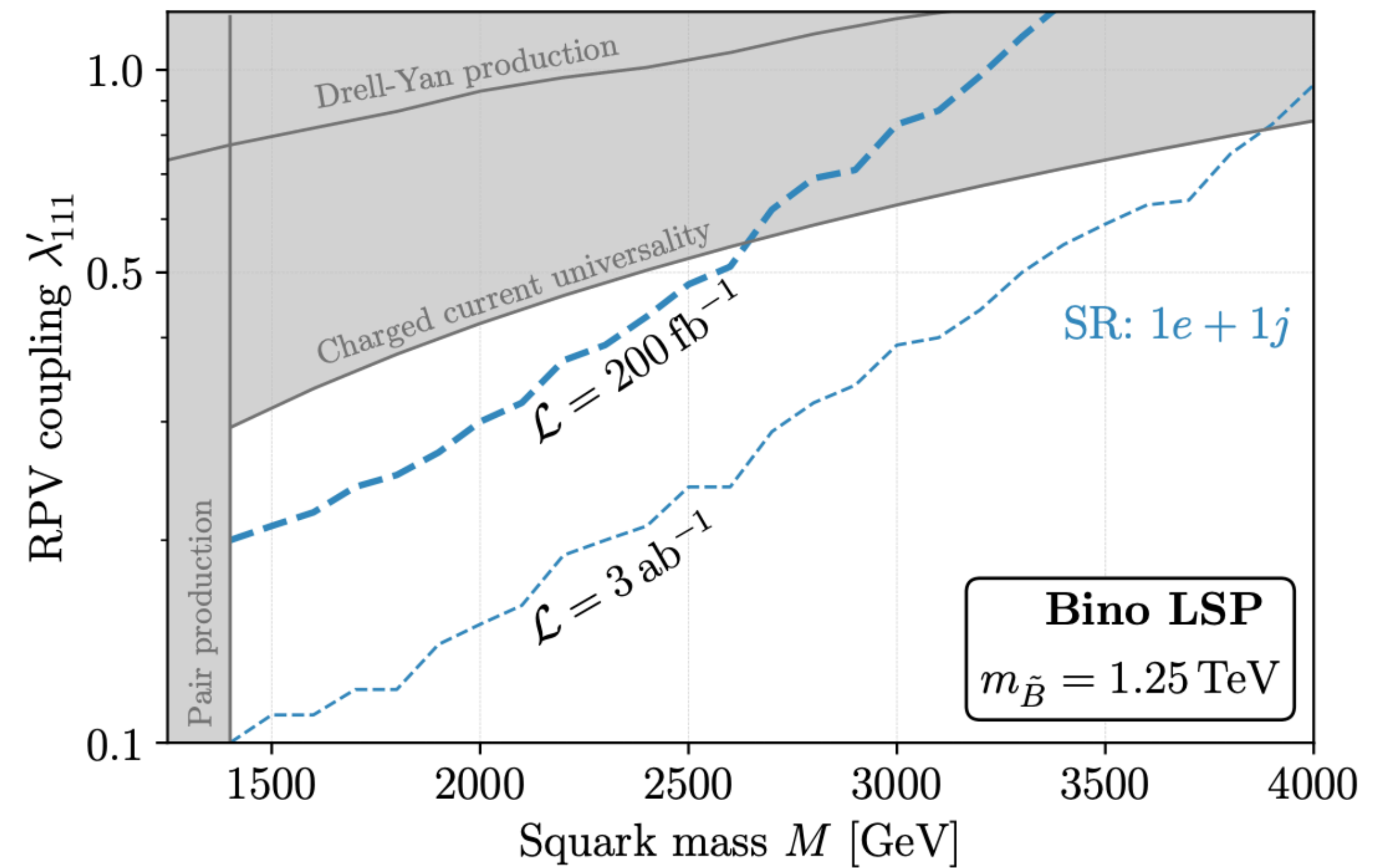
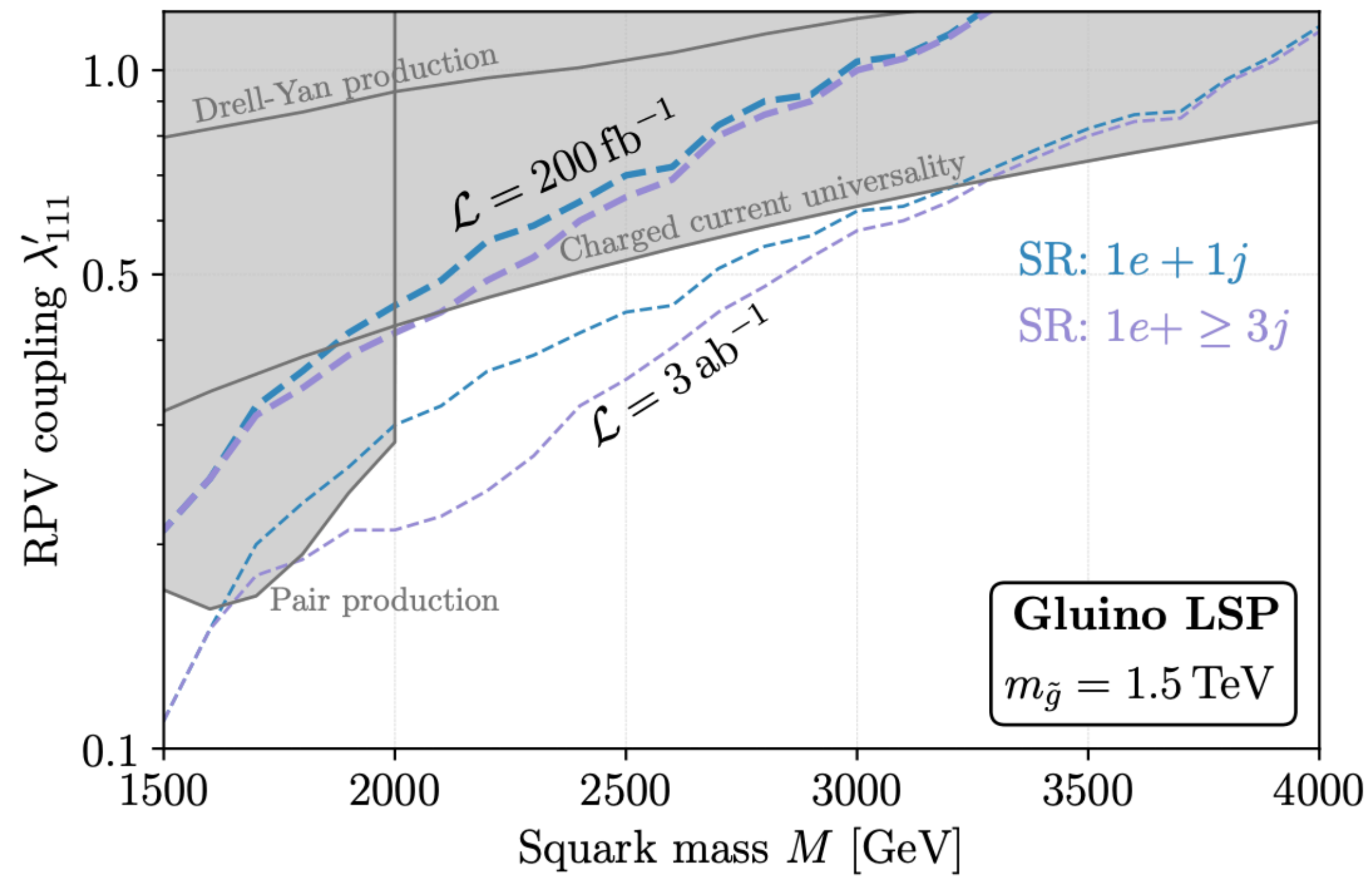


SR\_ej



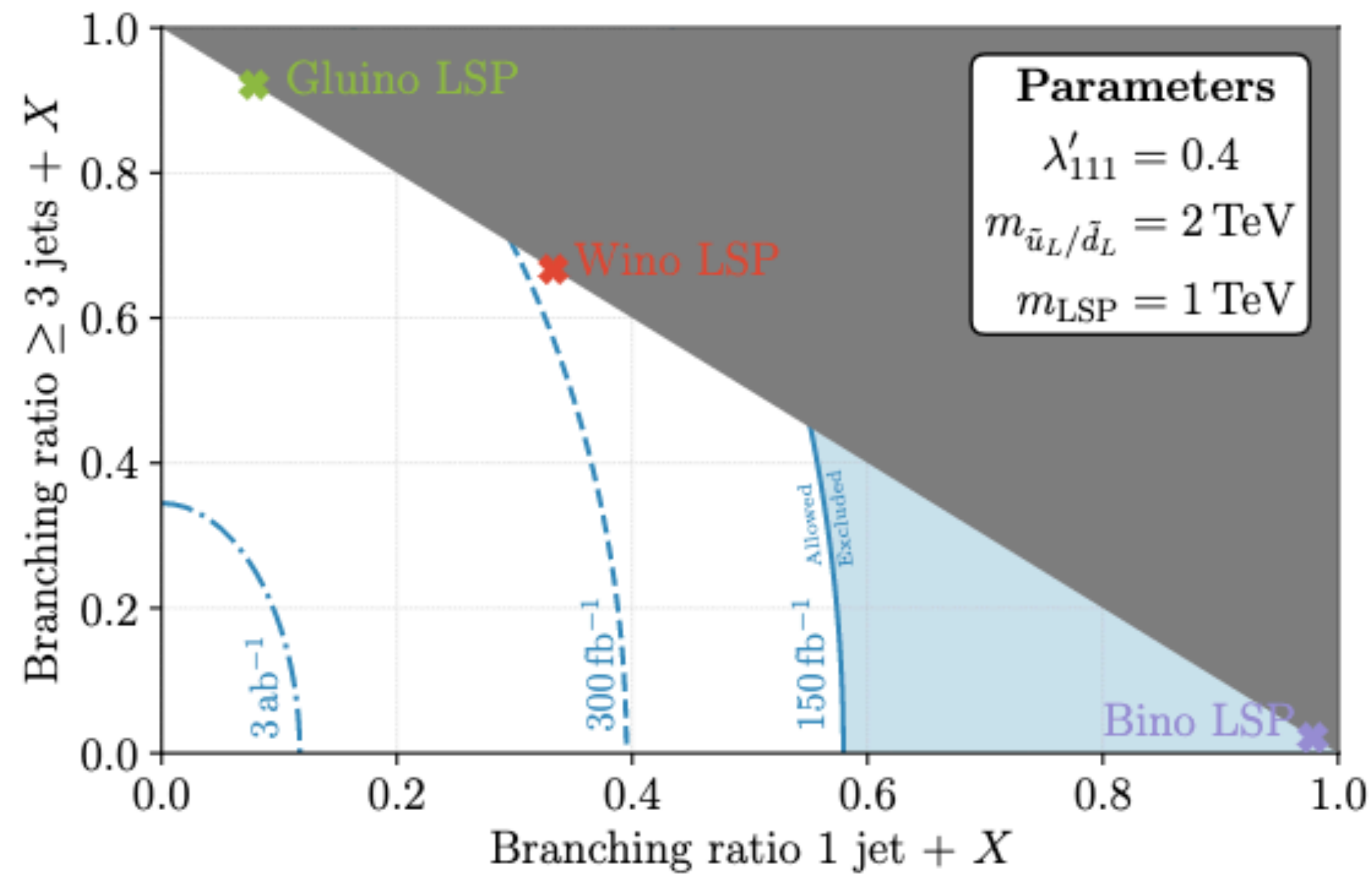
SR\_e3j

# Results



# Results

- $\text{BR}(1l + 1j) + \text{BR}(1l + \geq 3j) + \text{BR}(\text{other}) = 1$





# Conclusions & Outlook

- Single Lepton Channel + Lepton PDF  $\rightarrow$  unusual place to look but can probe large regions of the RPV parameter space
- Can achieve better limits than low-energy bounds!
- Can do so in a quasi model-independent way
- Why does it do well? Signal is rare but luminosity can overcome rare!
  - Resonance: 2 x Kinematical reach of pair production, dynamic boost, 2 powers less of coupling wrt DY
  - Uniqueness of final state
- Extend to 3rd generation fermions

**Thanks for your time!**

# Backup

Cuts	Signal	$W^-$ BG
Generator Level	91	11050
Leading lepton $p_T > 500$ GeV	37	3274
Leading jet $p_T > 500$ GeV	34	2183
$E_T^{\text{miss}} < 50$ GeV	21	750
Veto	10	278

Cuts	Signal	$W^-$ BG
Generator Level	130	9565
$b$ veto	118	8389
Leading lepton $p_T > 200$ GeV,		
Extra lepton veto	32	3787
$p_T^{\text{jet } 1,2,3} > 50$ GeV	29	2562
$H_T > 900$ GeV	25	1892
$S_T > 1500$ GeV	21	935
$E_T^{\text{miss}} < 50$ GeV	12	417

SR\_ej

SR\_e3j