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

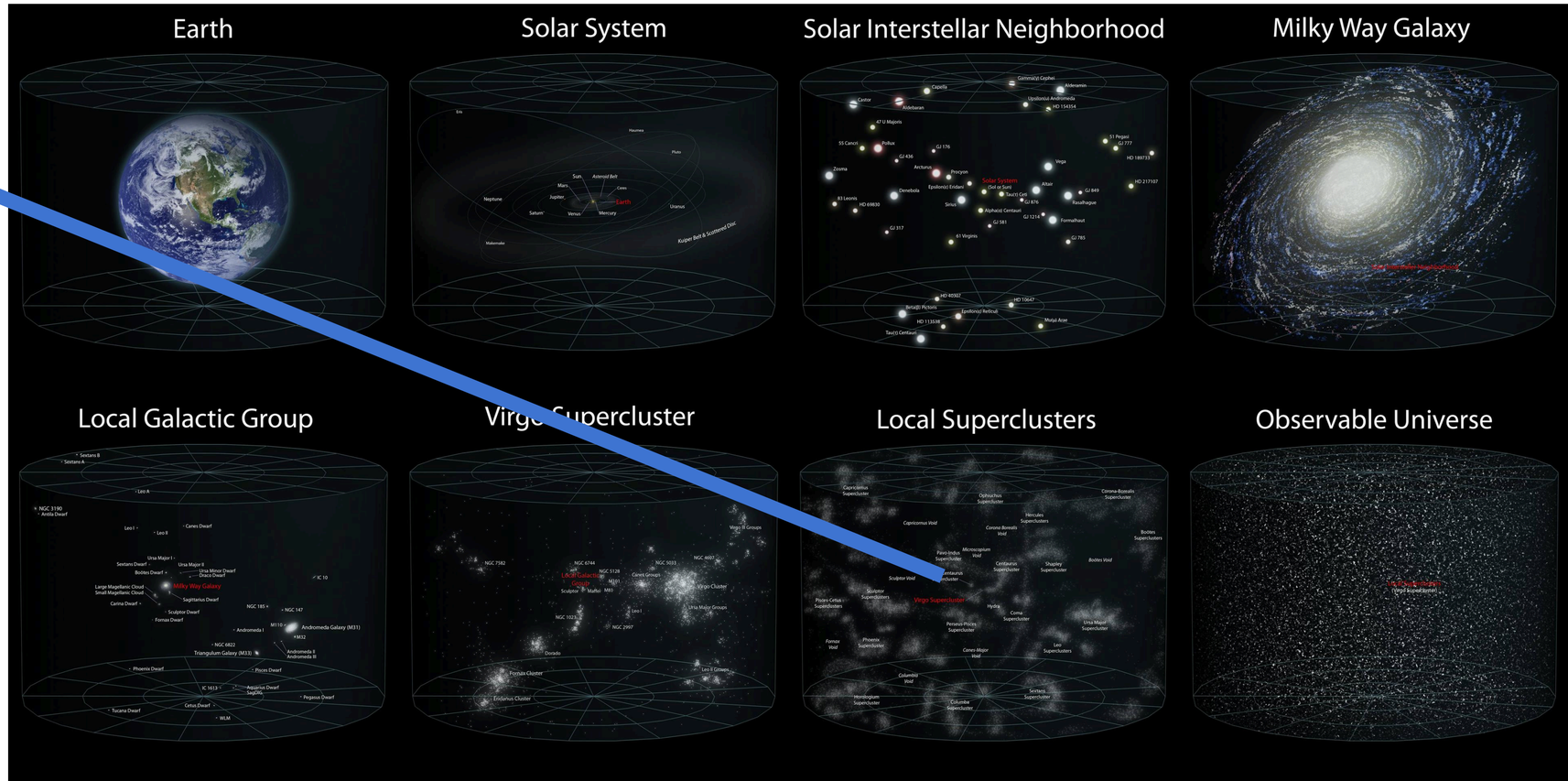
A “Bright” Future for the LHC

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

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

~ 100 times # of stars in here

- HL-LHC: 250 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

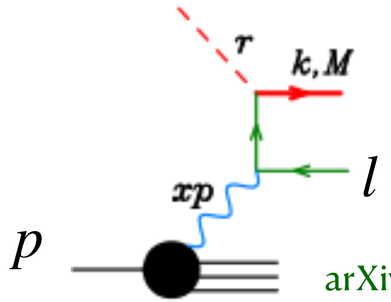
- 1 charged lepton + n jets + 0 MET
- Interesting in 2 ways:

  - 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 α_{EM}



- Channel seems unusual & suppressed...

arXiv: 2005.06477 [Buonocore et al.]

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) scenarios
  - Recently ATLAS has started filling this gap: arXiv: 2106.09609, 1704.08493

- 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_{RPV}

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

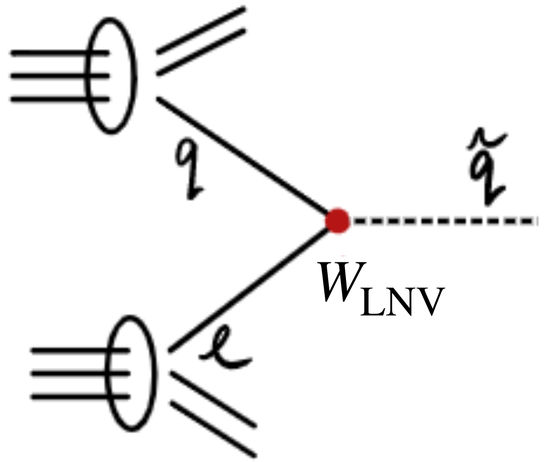
- How well is SUSY ruled out upto say squark/gluino masses ~ 1.5 TeV?
  Quite well if it is vanilla MSSM -> fixed large MET signal

- But RPV MSSM can have gaps:
  - Complex phenomenology: any particle can be LSP, and LSP is no longer stable

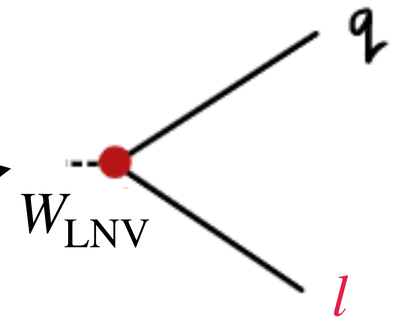
Ongoing efforts to fill these gaps

An Application to Supersymmetry

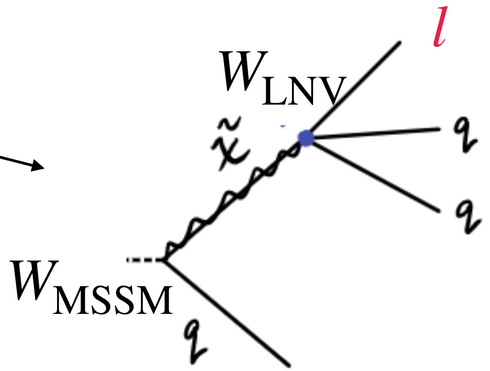
- One striking, universal feature of all RPV models: single production possible! Example via lepton PDF



Direct Decay



Cascade Decay



Both Single Lepton Channels!

An Application to Supersymmetry

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

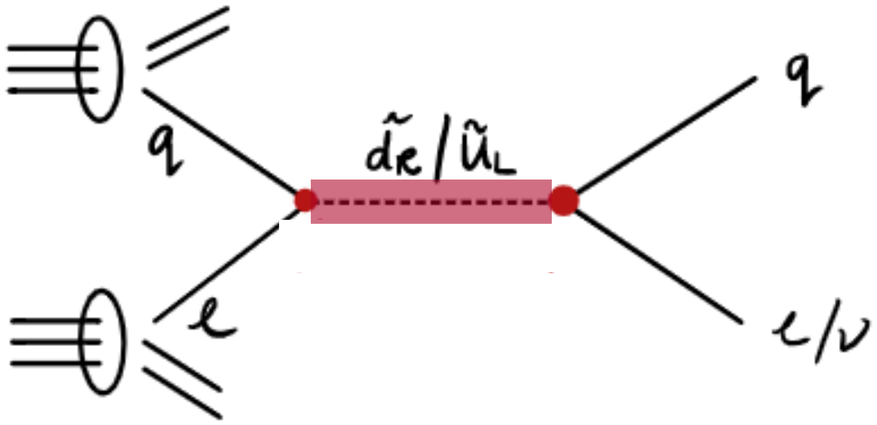
Cascade End	Example	Signal
$\widetilde{B}$	$\tilde{d} \to \tilde{B} + 1j$	$1\ell + 3j$
$\widetilde{W}$	$\tilde{d} \to \tilde{g} + 1j \to \tilde{q} + 2j \to \widetilde{W} + 3j$	$1\ell + 5j$
$\tilde{g}$	$\tilde{d} \to \tilde{g} + 1j$	$1\ell + 3j$
$\tilde{q}$	$\tilde{d} \to \tilde{g} + 1j \to \tilde{q}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

An Application to Supersymmetry

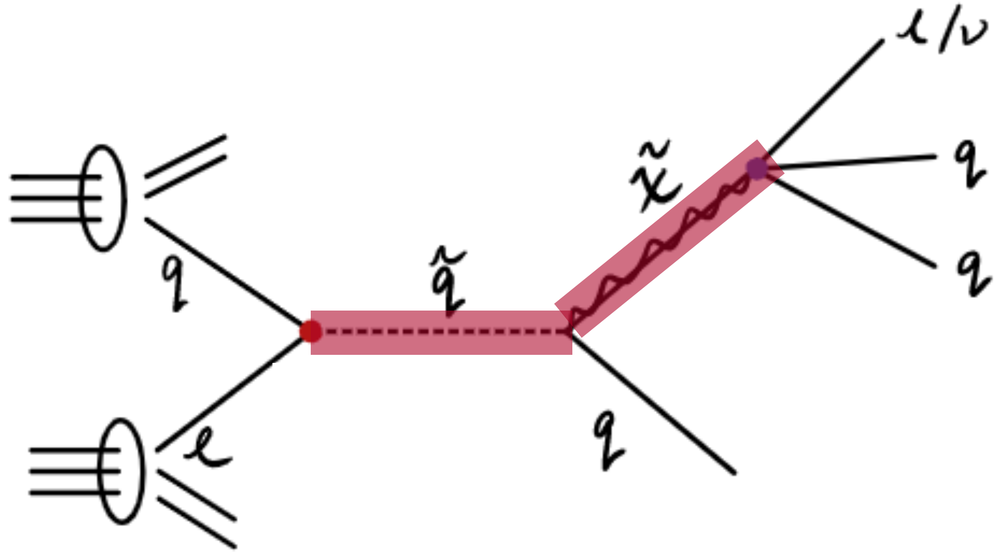
- $\mathrm{BR}\left(1l + 1j\right) + \mathrm{BR}\left(1l + \geq 3j\right) + \mathrm{BR}\left(\mathrm{other}\right) = 1$

  Both single lepton channels!

- Search Strategy: 2 new resonance searches



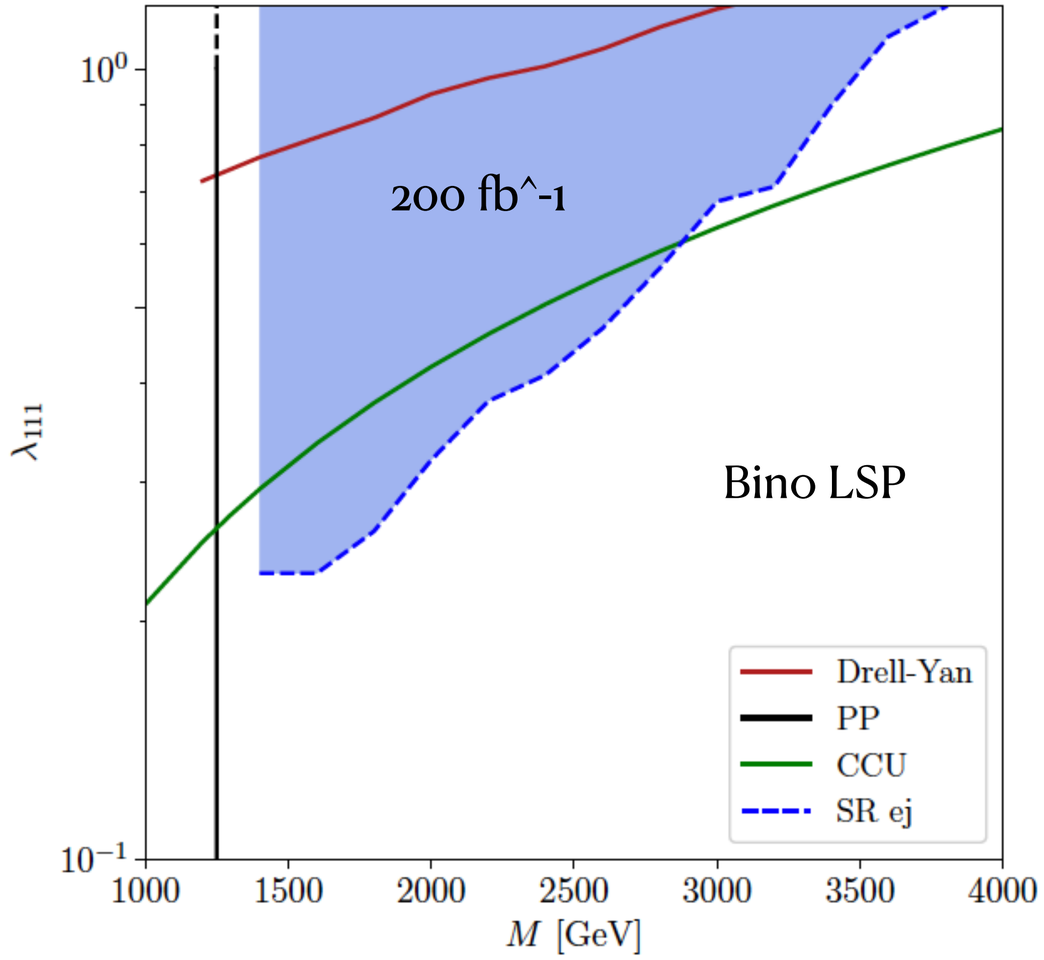
SR_ej

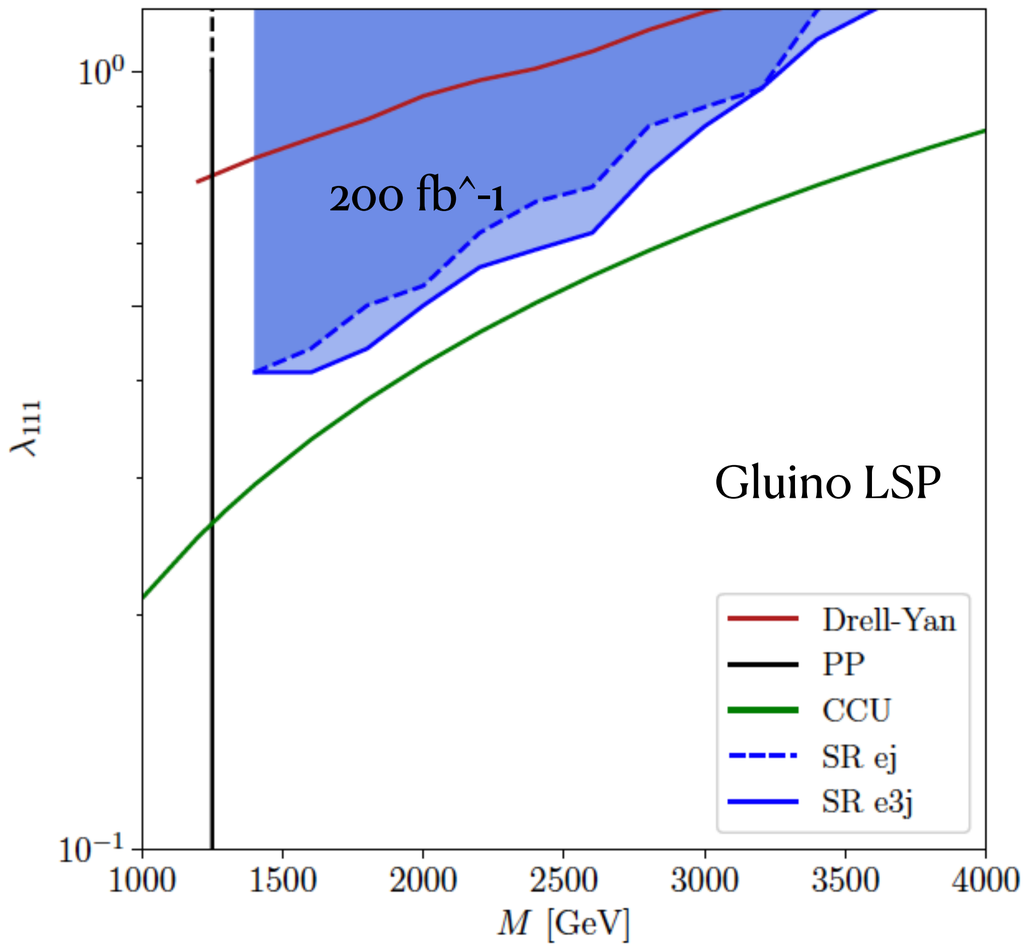


SR_e3j

Results

- Using CheckMATE arXiv: 1312.2591





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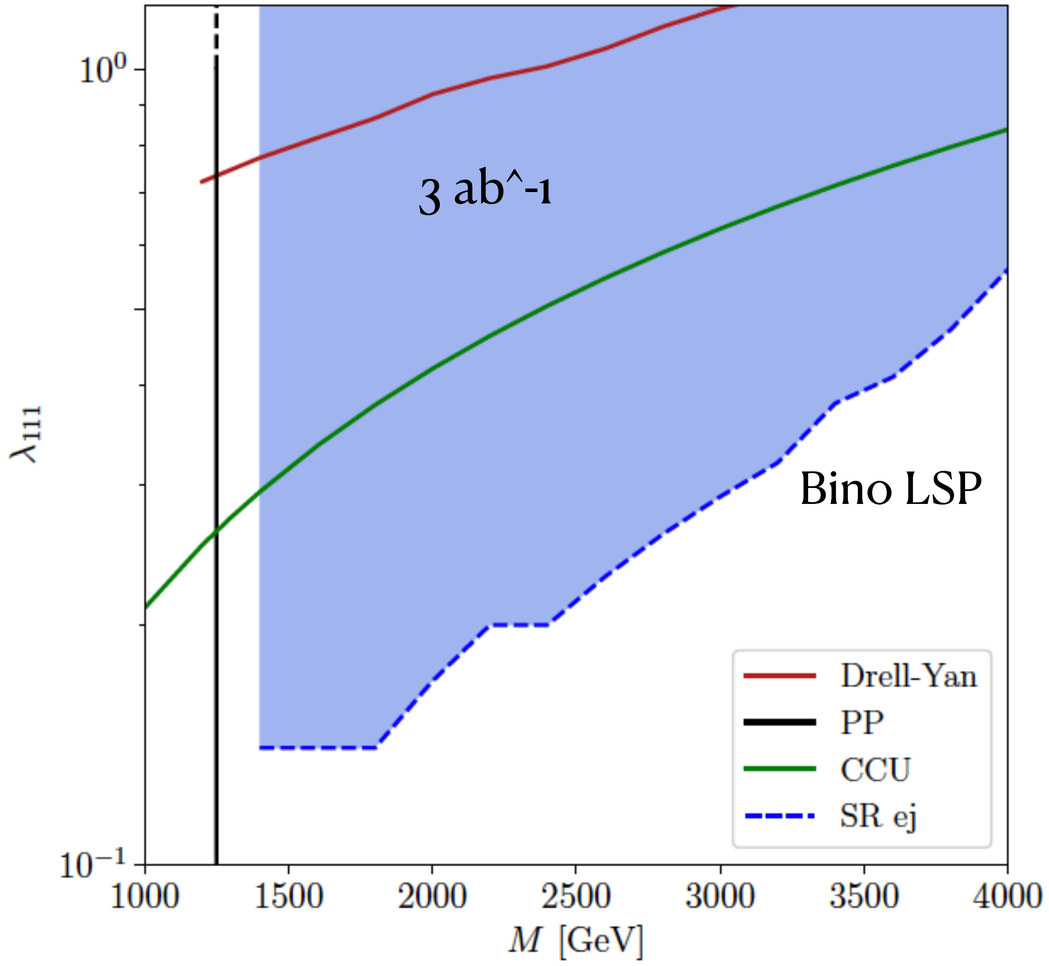

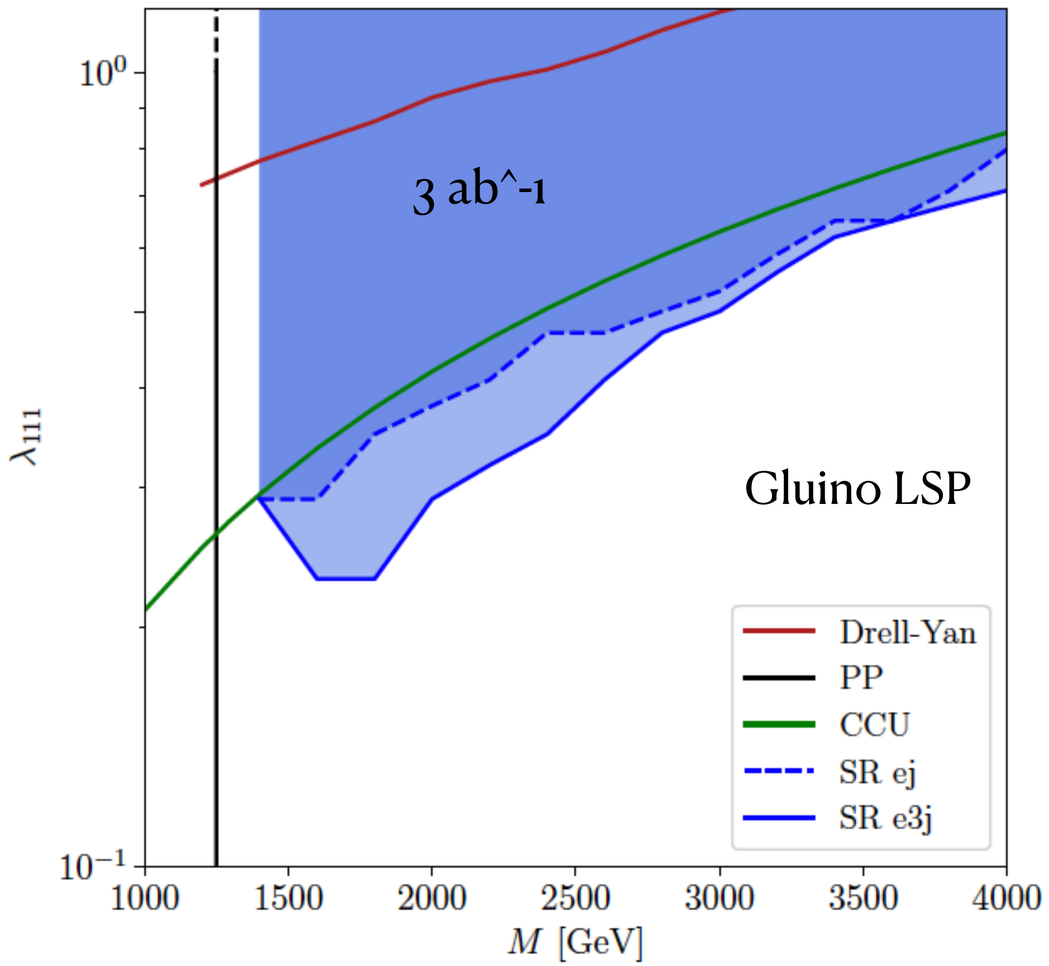

Results

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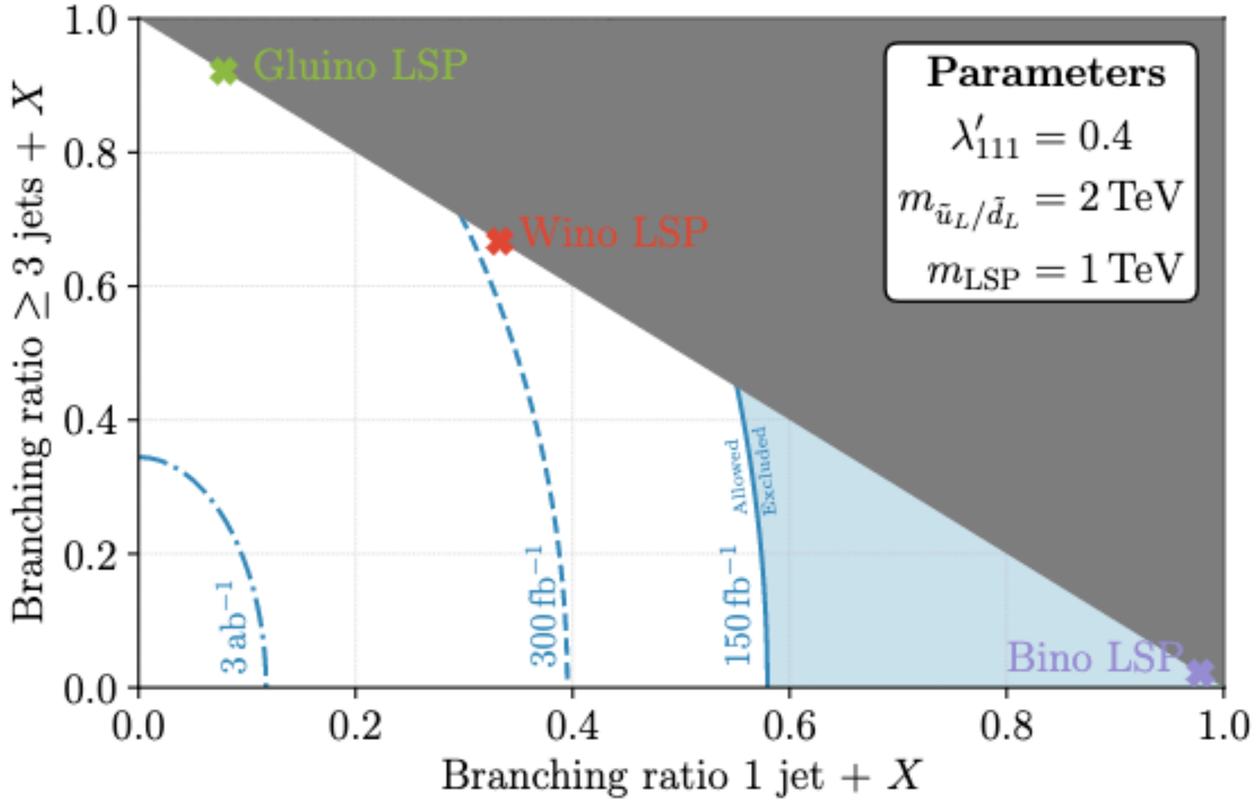

Conclusions & Outlook

- Single Lepton Channel + Lepton PDF -> unusual place to look but can probe large regions of the RPV parameter space
- Can achieve better limits than low-energy bounds already!
- 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!