Probing Light Stops with Stoponium

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2016 High1 Workshop

1504.01740 with Brian Batell

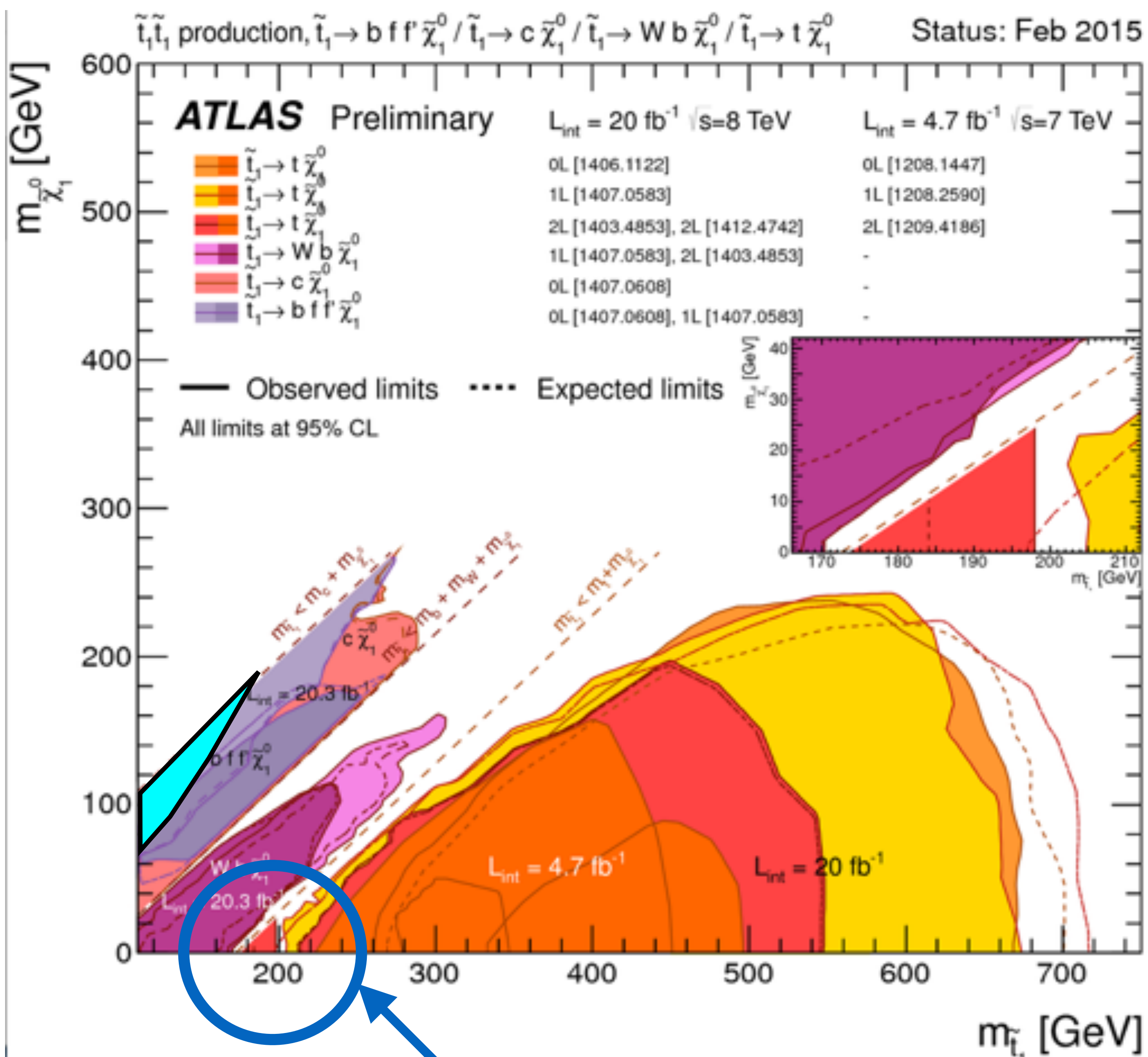
Stop Searches & Blind Spots

1. Direct searches at the LHC

2. Indirect constraints

Stop Searches & Blind Spots

1. Direct searches at the LHC



stop NLSP, Bino LSP

aka. stealth stop

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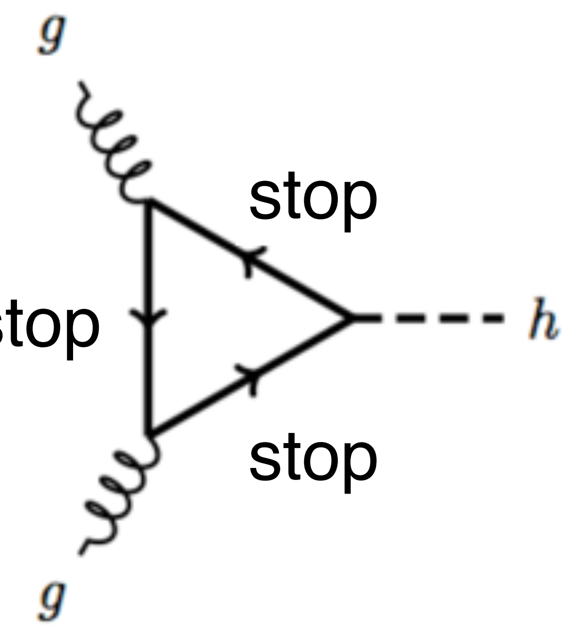
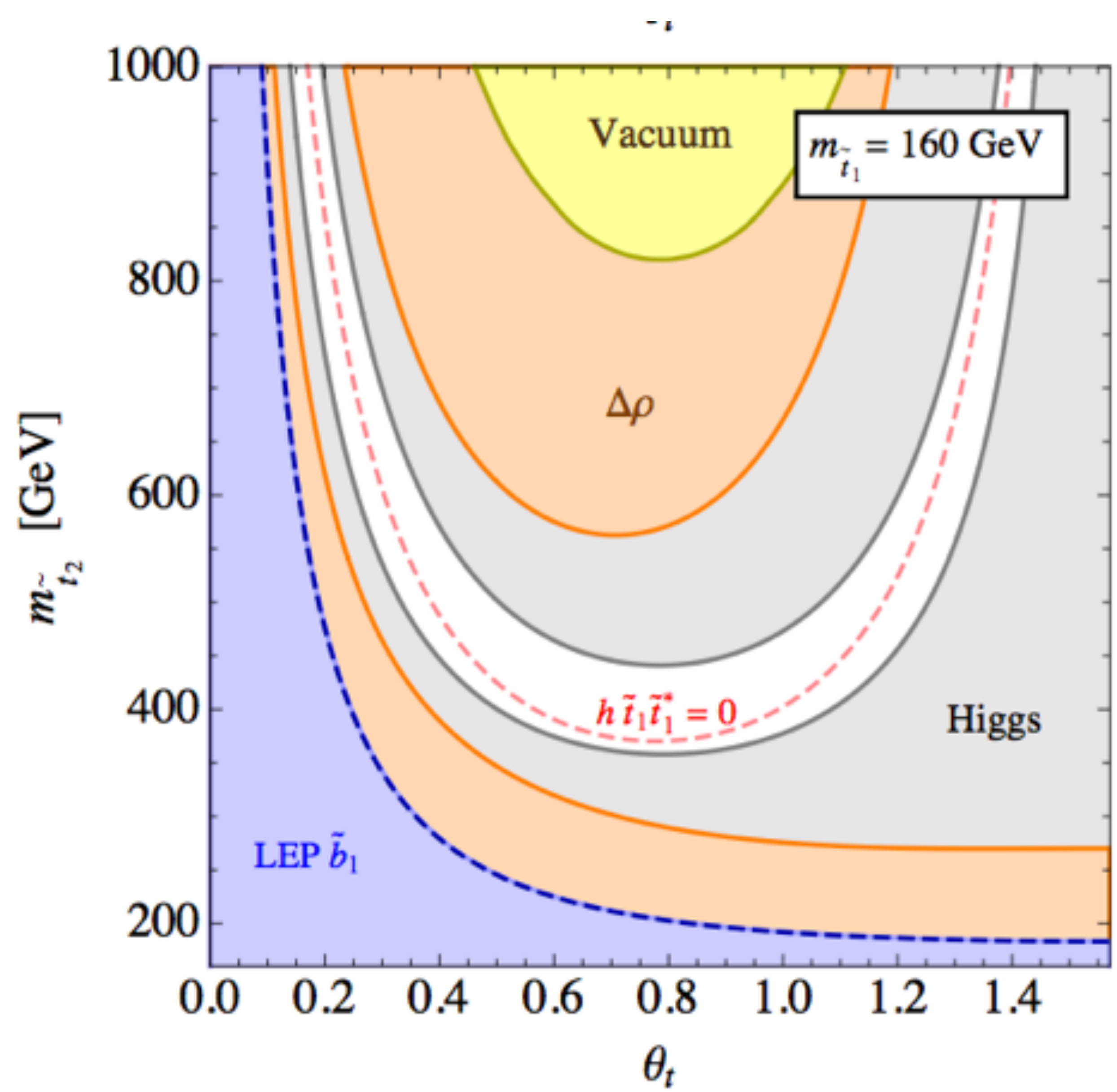
Stop Searches & Blind Spots

2. Indirect constraints

Higgs signal precision





EWPT (delta rho)

$$\begin{pmatrix} \tilde{t}_1 \\ \tilde{b}_1 \end{pmatrix}$$

Vacuum stability

$$V \ni \frac{y_t X_t}{\sqrt{2}} h \tilde{t}_L \tilde{t}_R$$

After all, no indirect constraints when the coupling vanishes.

Stoponium can cover both

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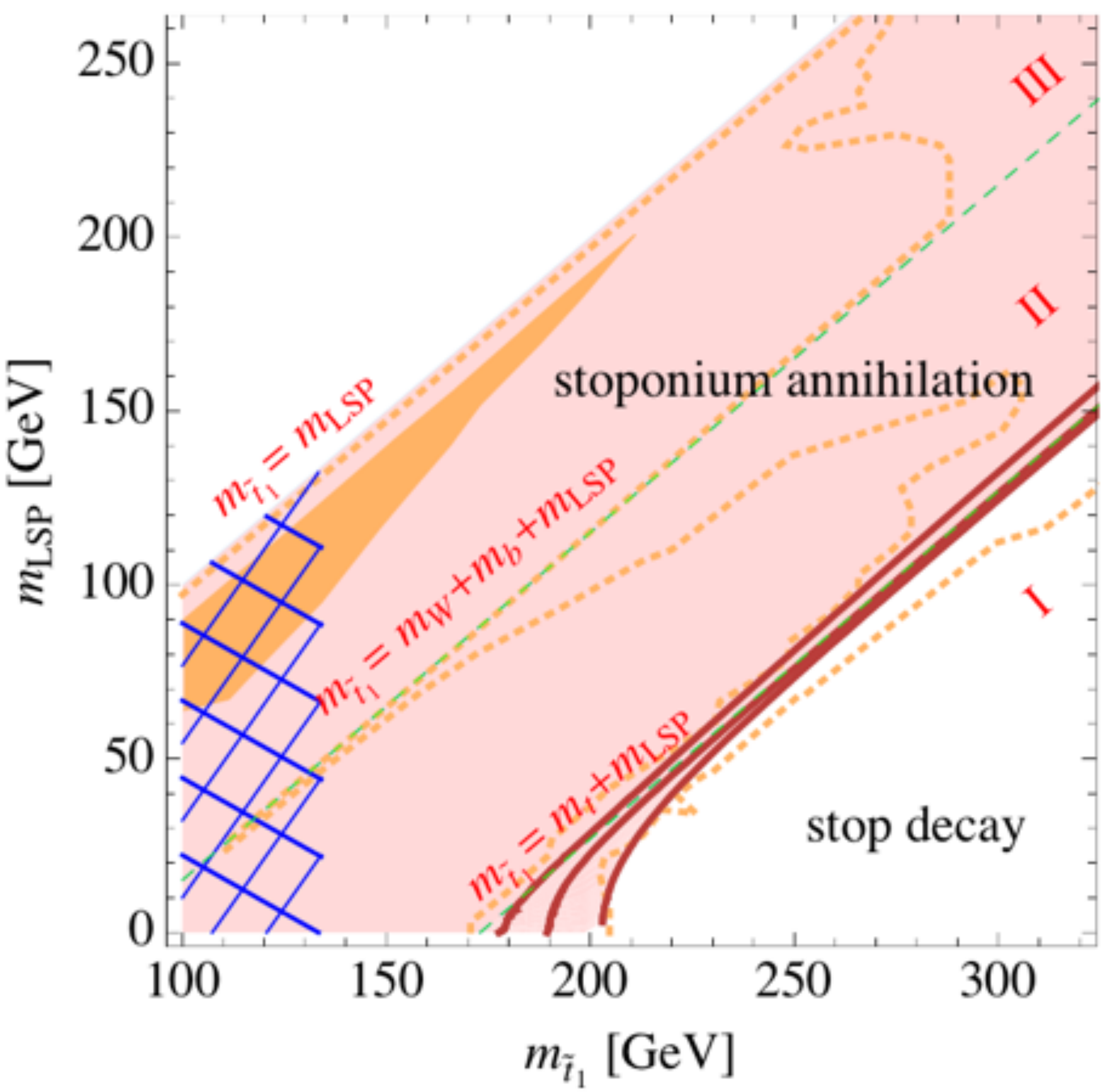

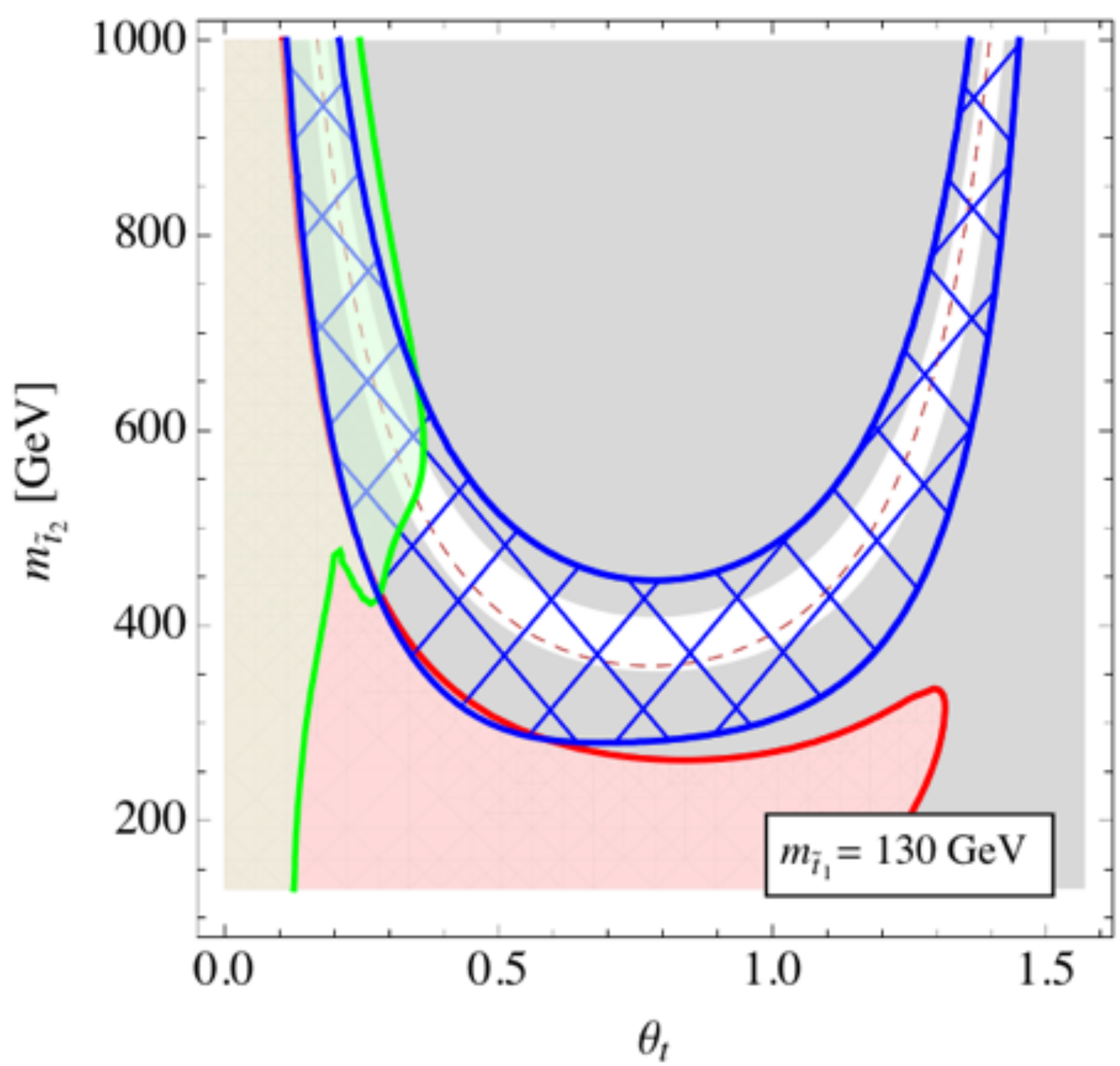

Highly complementary to both direct and indirect constraints.

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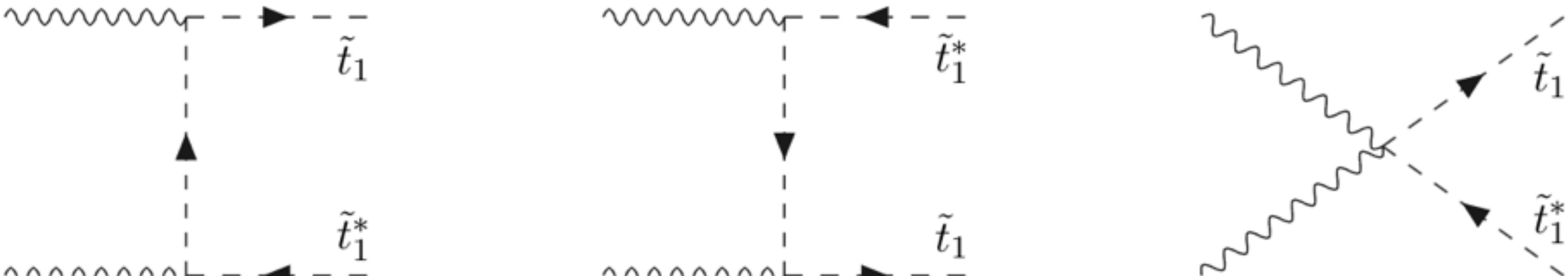
Stoponium

Stoponium: The stop—anti-stop QCD bound state.
(1S0 quantum number equals to SM Higgs'.)



Produced just below the stop-pair threshold.

$$\sigma(pp \to \eta_{\tilde{t}_1}) \propto \alpha_S^5$$

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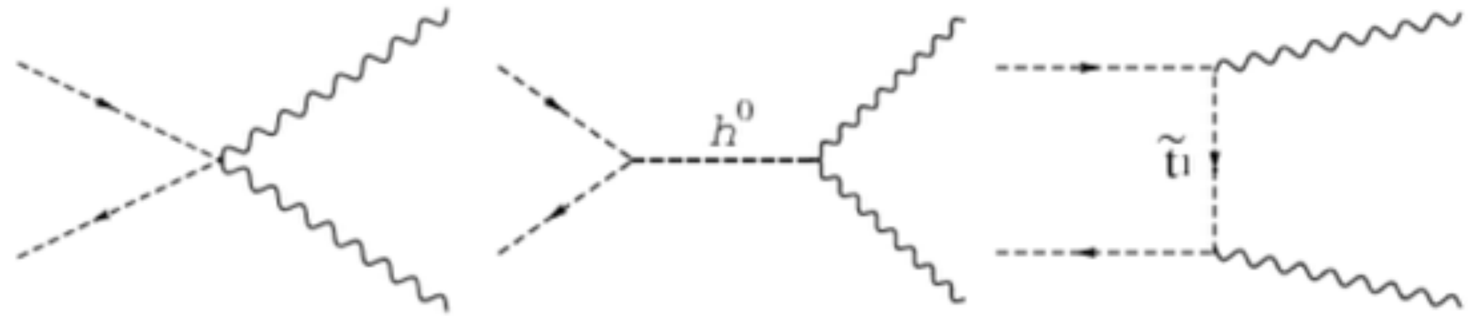
Annihilation makes it special

$$\eta_{\tilde{t}} \to \gamma\gamma, Z\gamma, WW, ZZ, hh, \cdots$$



- Clean resonance signal.
  (high sensitivity, mass measurable)

- Independent on stop decay modes.
  (but depends on different parameters and assumptions)

- Another remarkable property that makes it highly complementary to existing searches…

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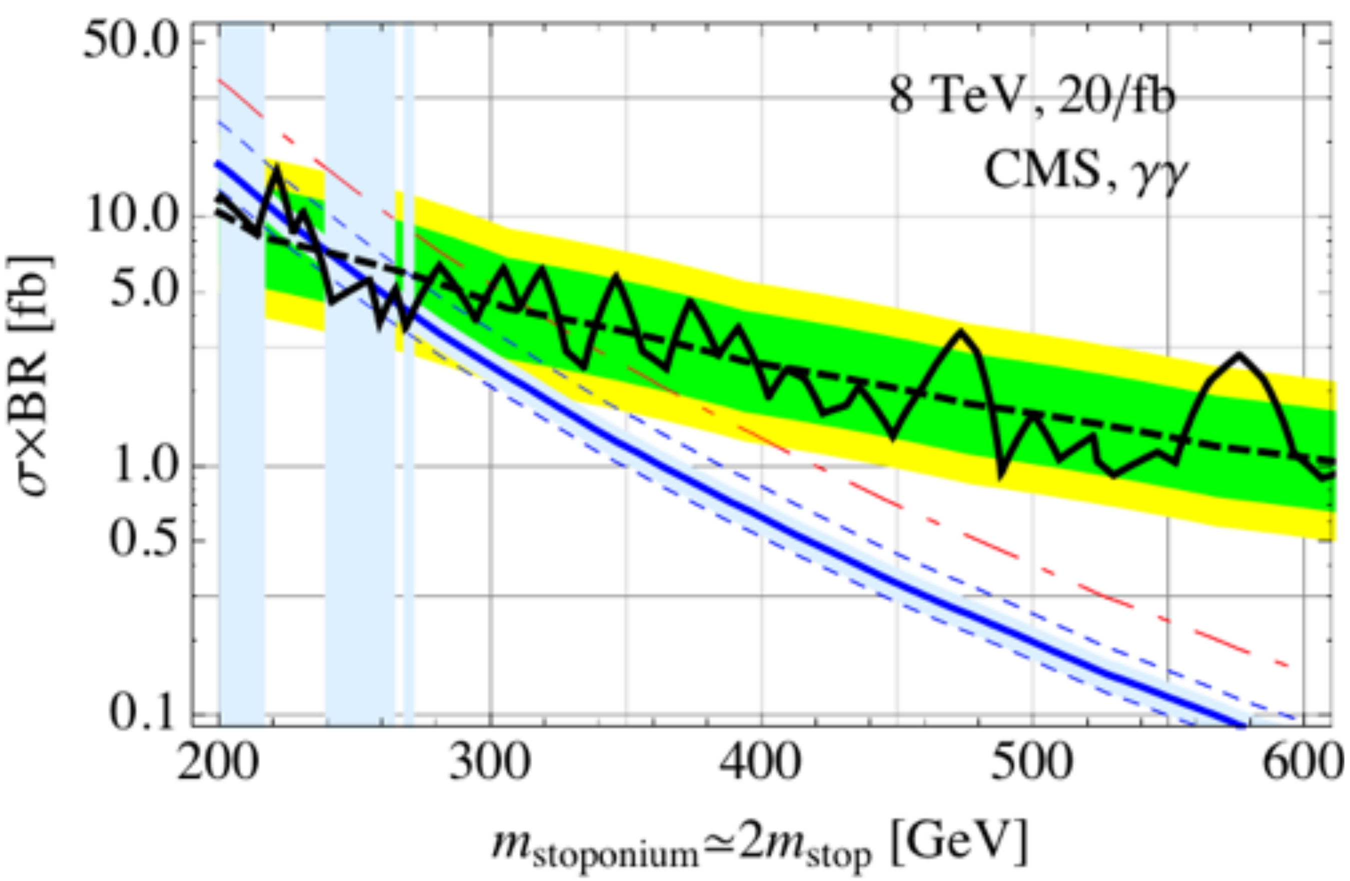
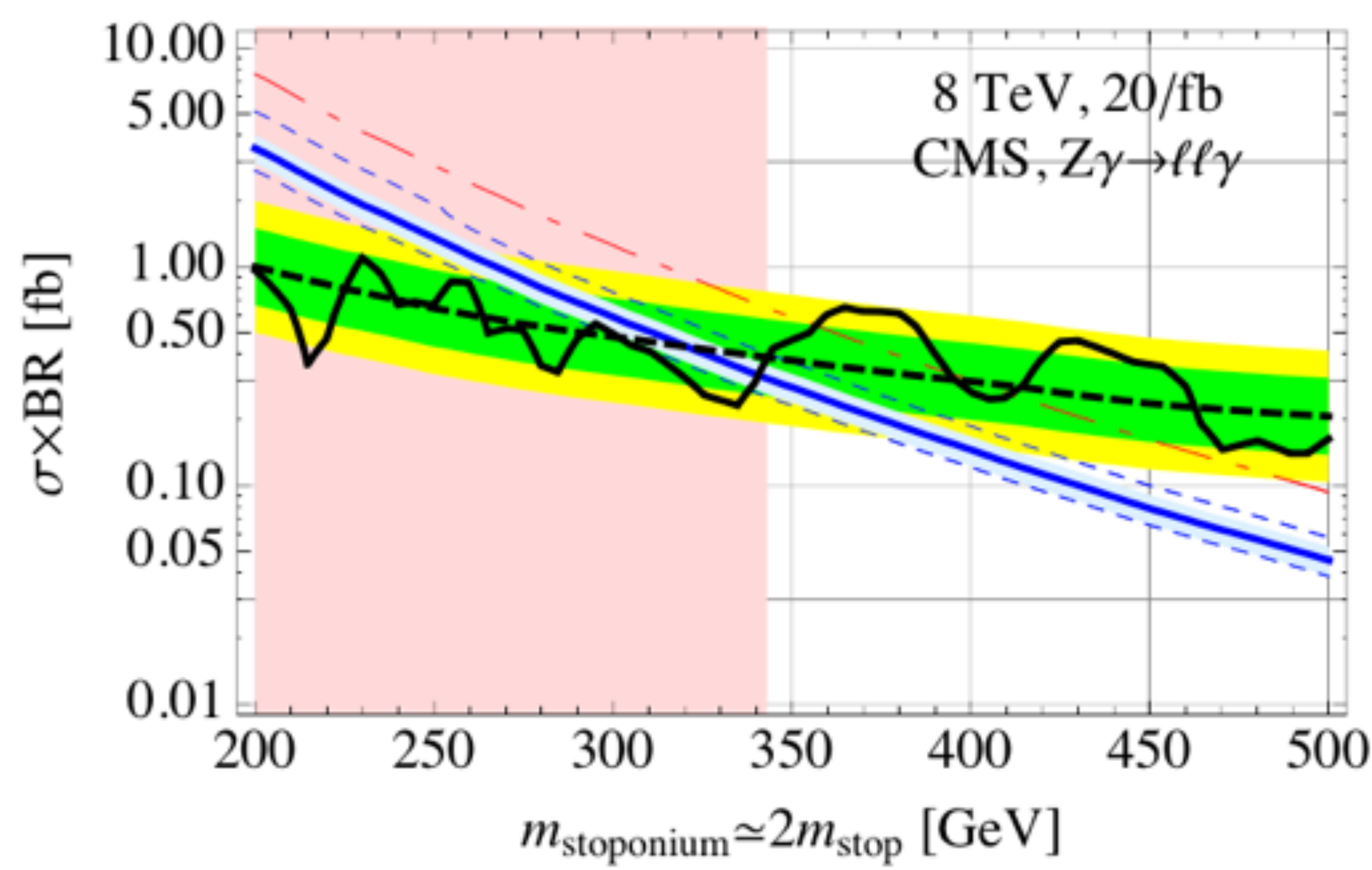
Diphoton and Zgamma

Assuming the stoponium forms and annihilates…





ideal(maximal) BRs ~ 0.4%, 1%

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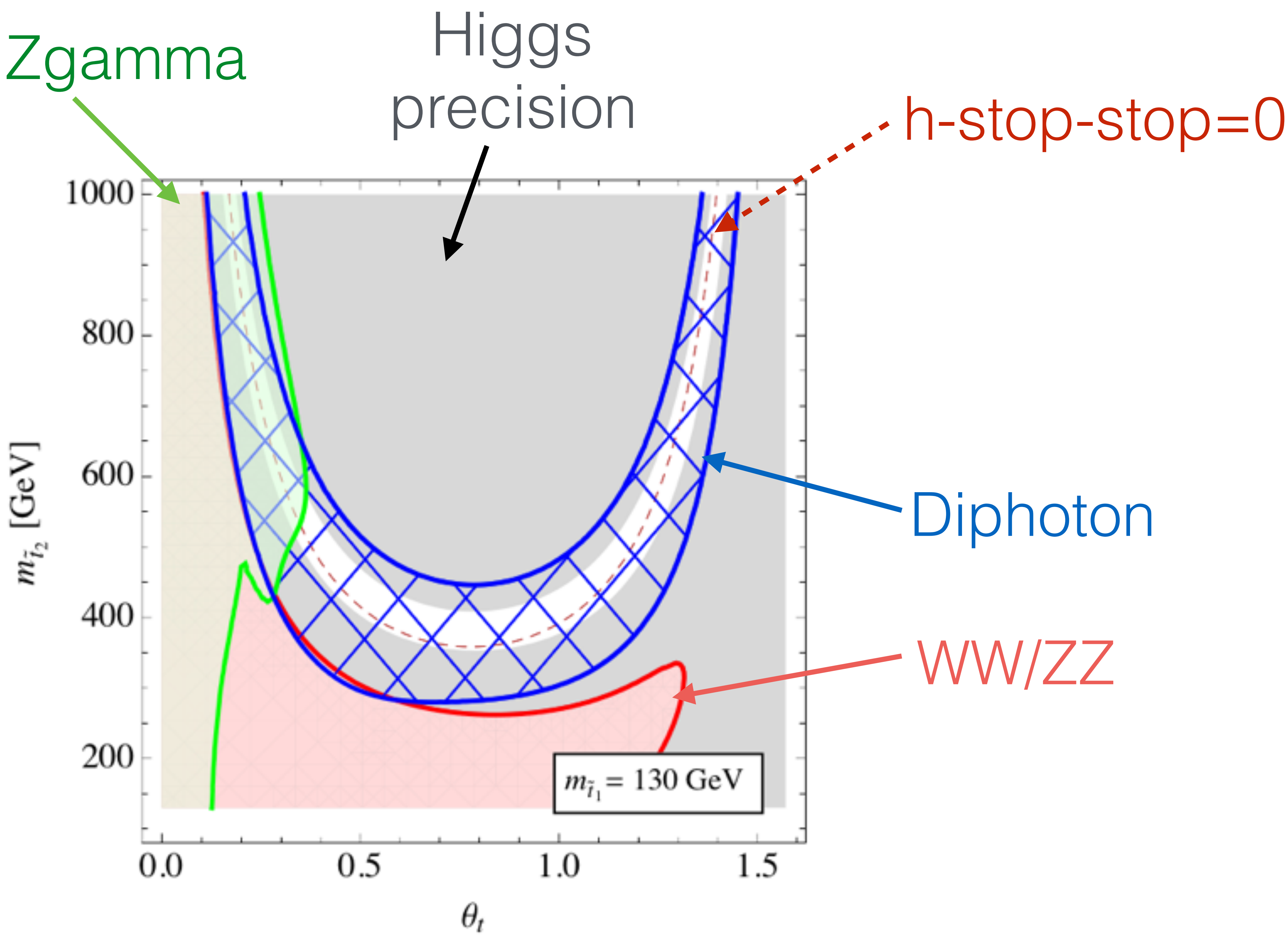
Indirect + stoponium



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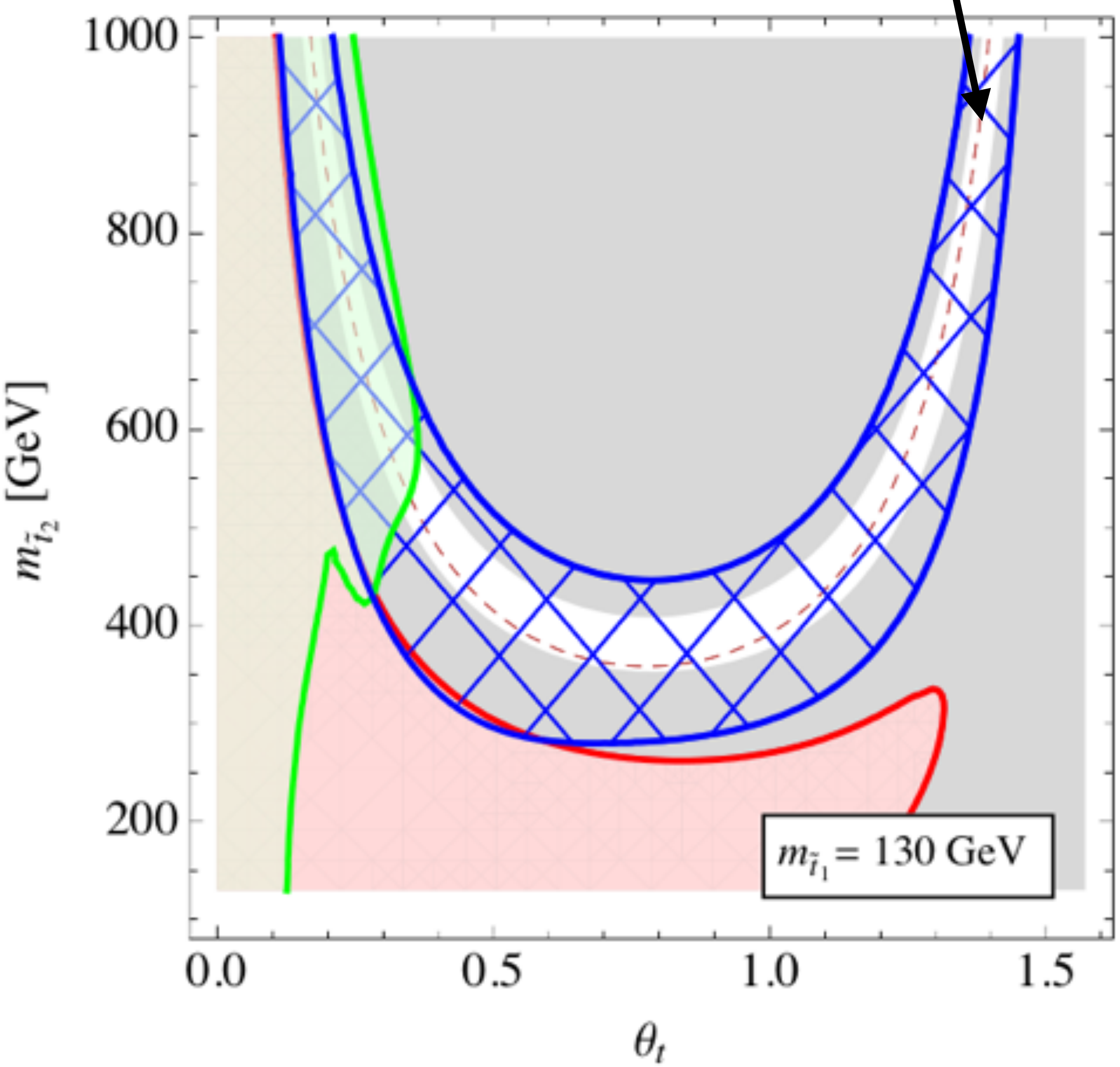
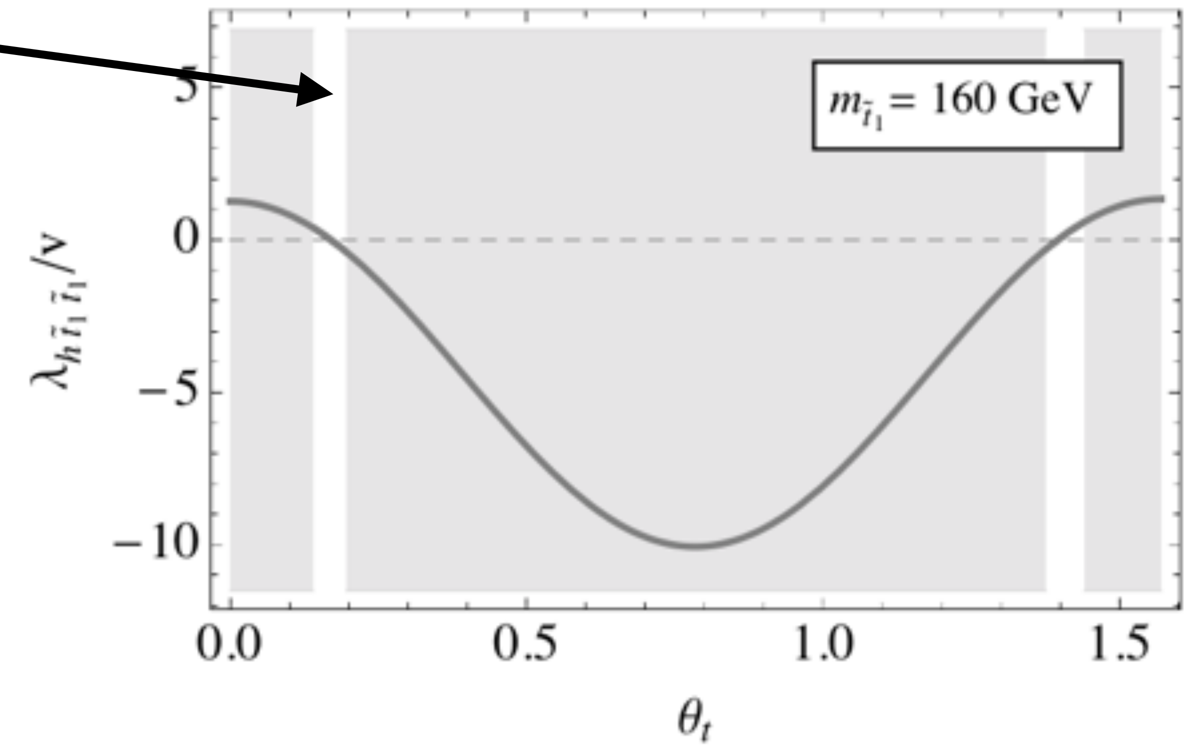
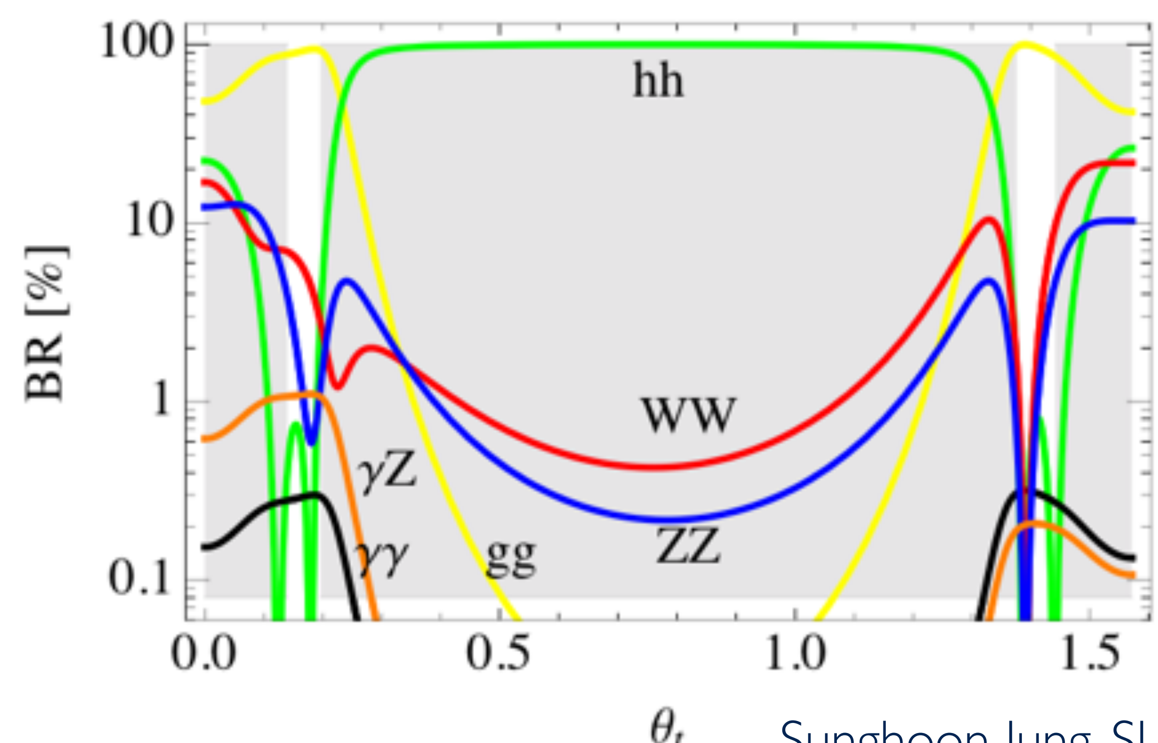
Complementarity!

Blind spots







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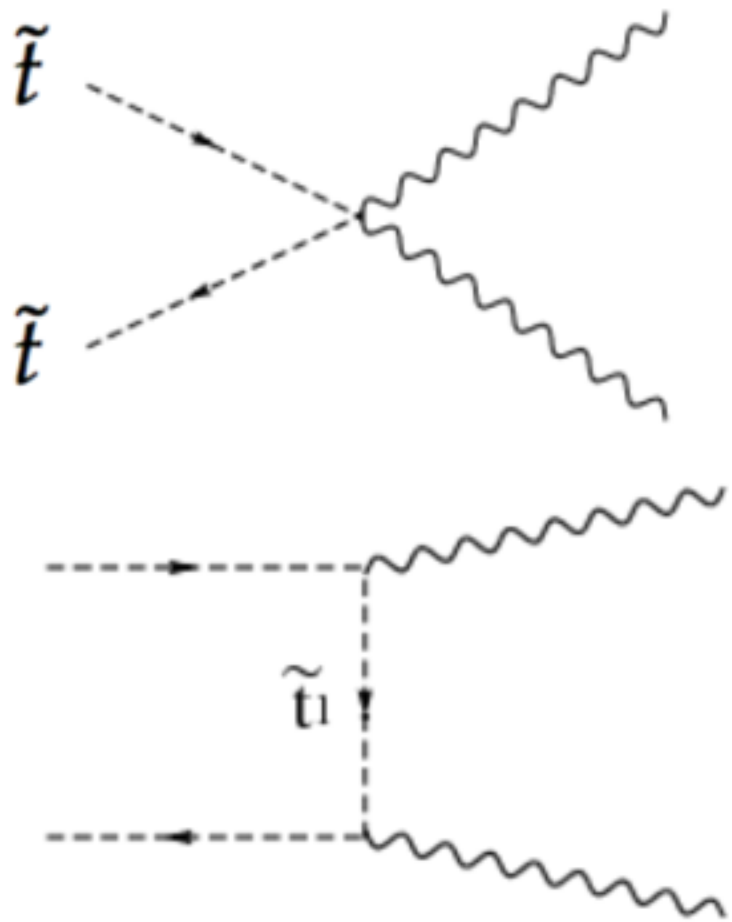
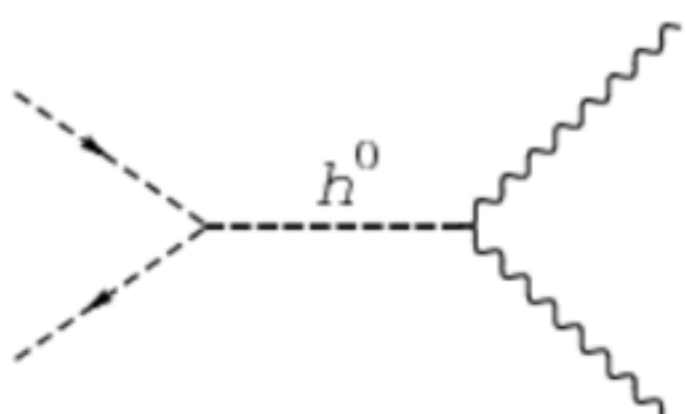
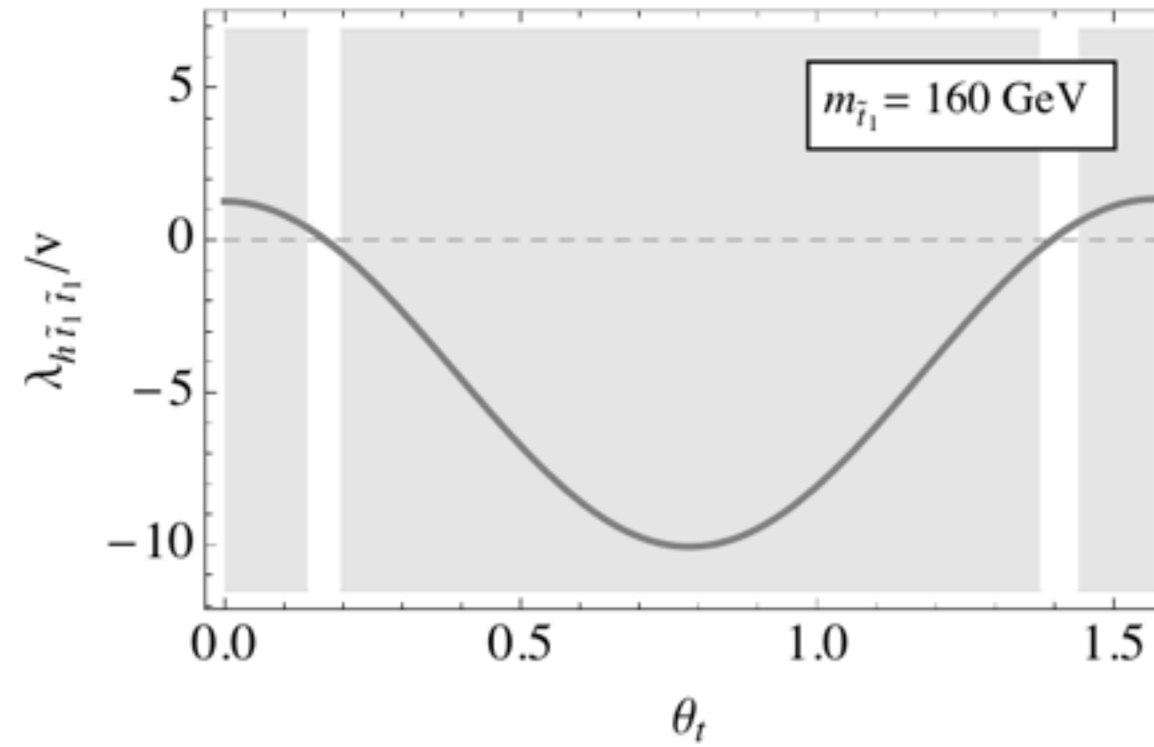
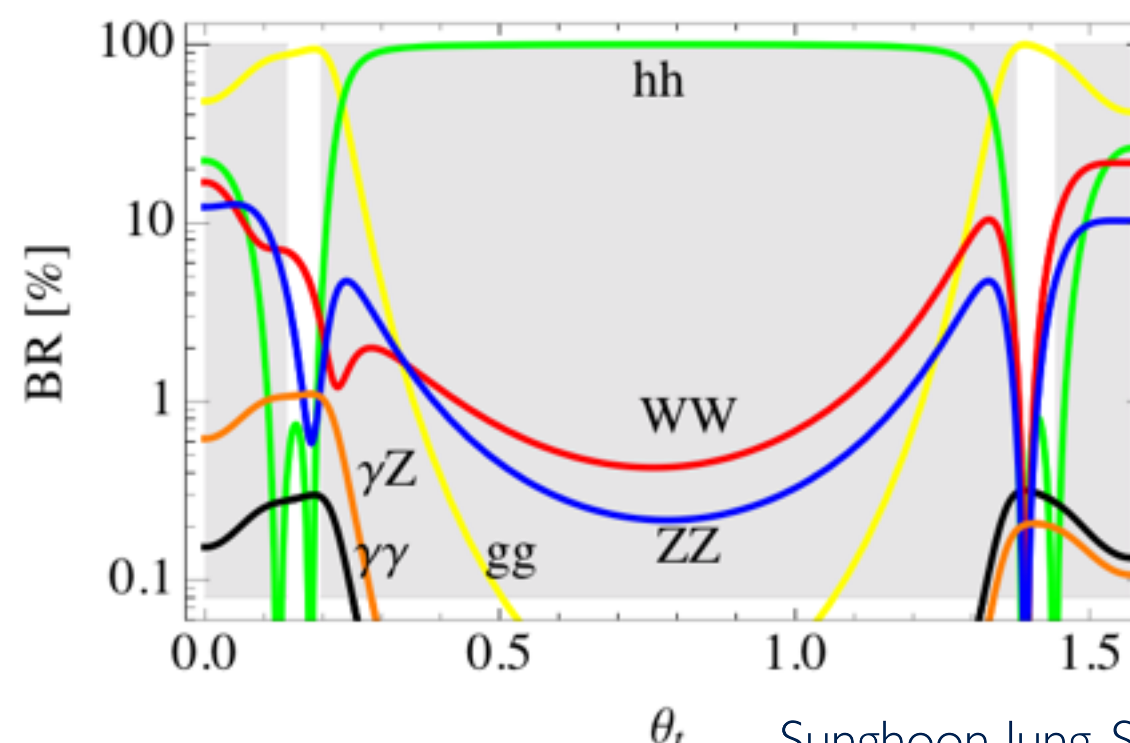
Complementarity!



vs.







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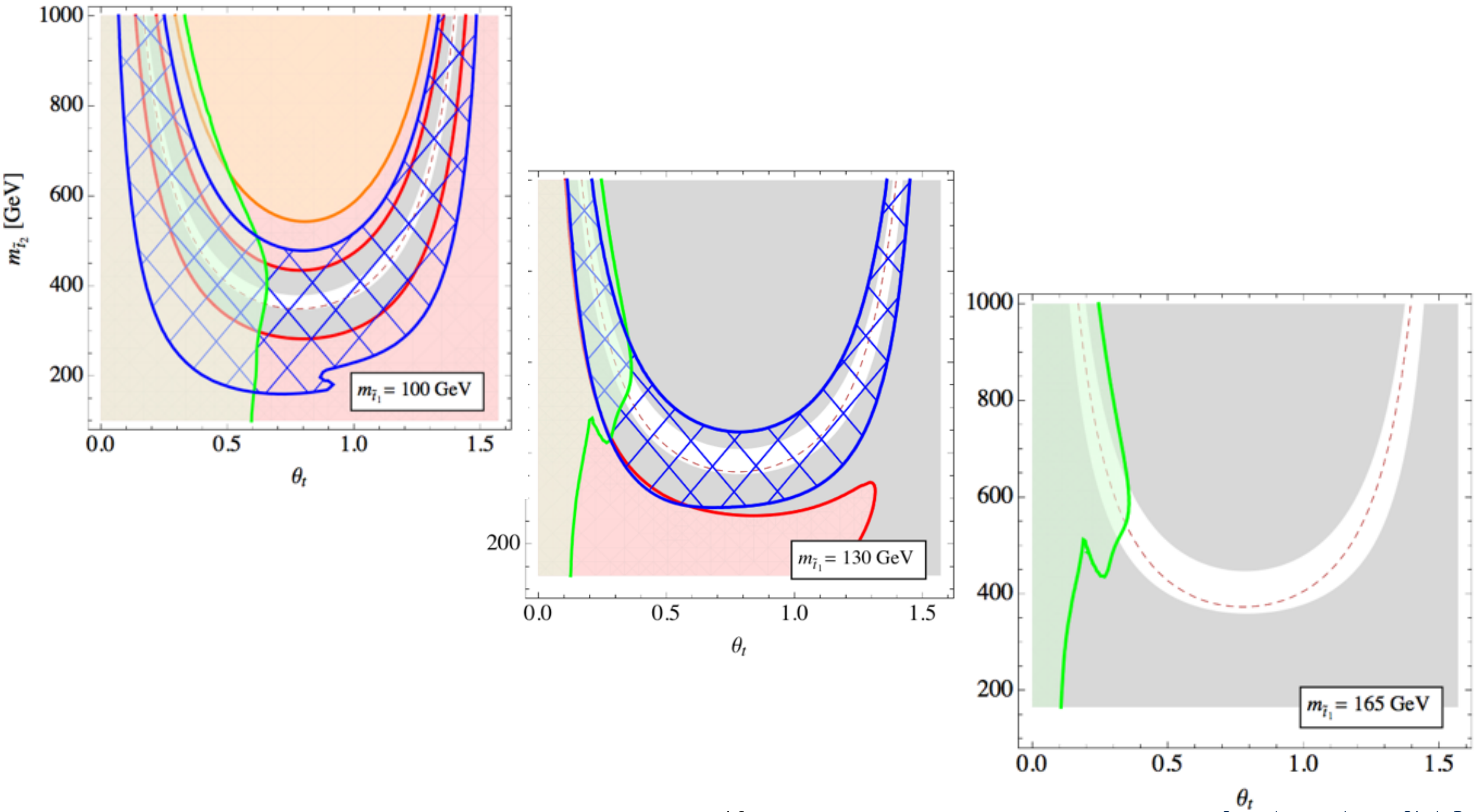
Indirect + stoponium



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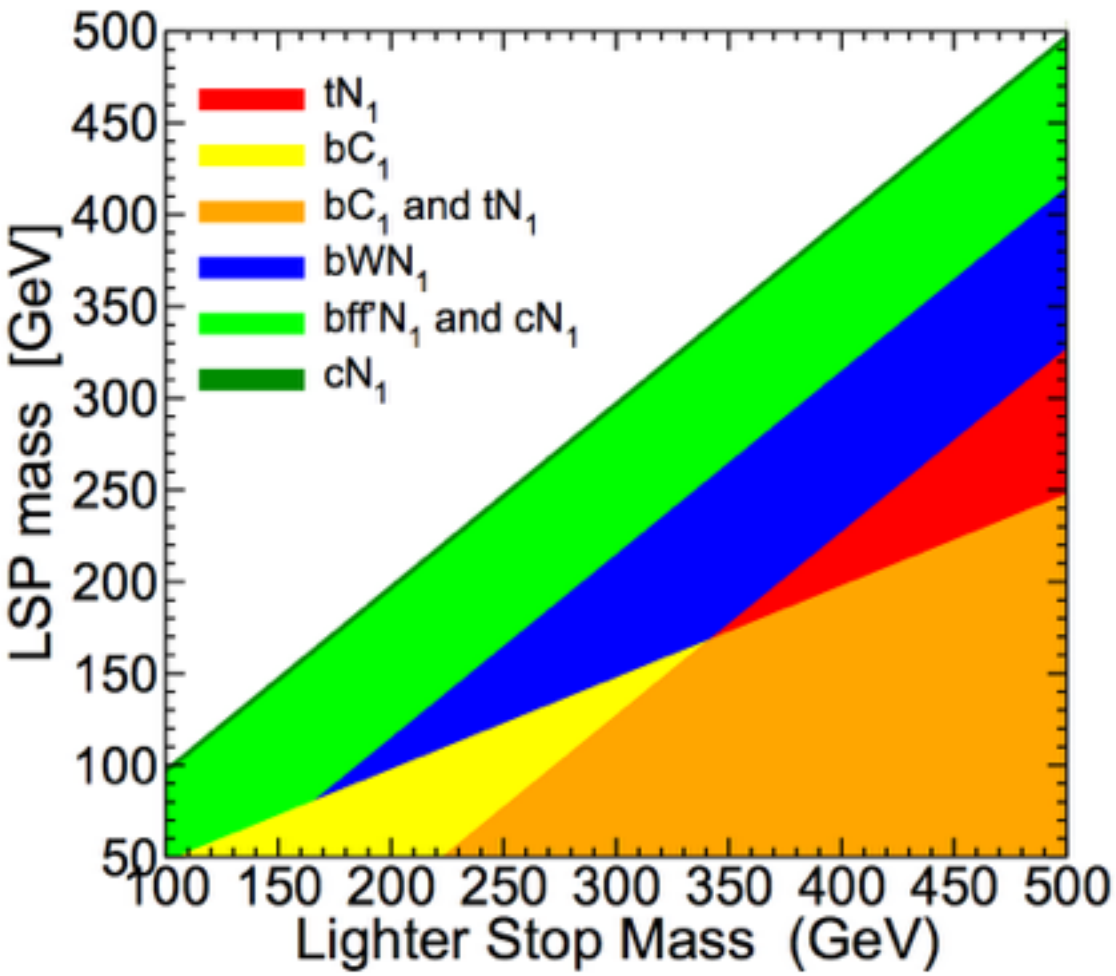
Common lore

- Relevant when no unsurpassed 2-body stop decays…

In green and blue regions, the top squark hadronizes before it decays.



Red, yellow, orange = 2-body

Blue = 3-body

Green = competition between 2-body flavor violating, 4-body decays

from S.Martin's slide

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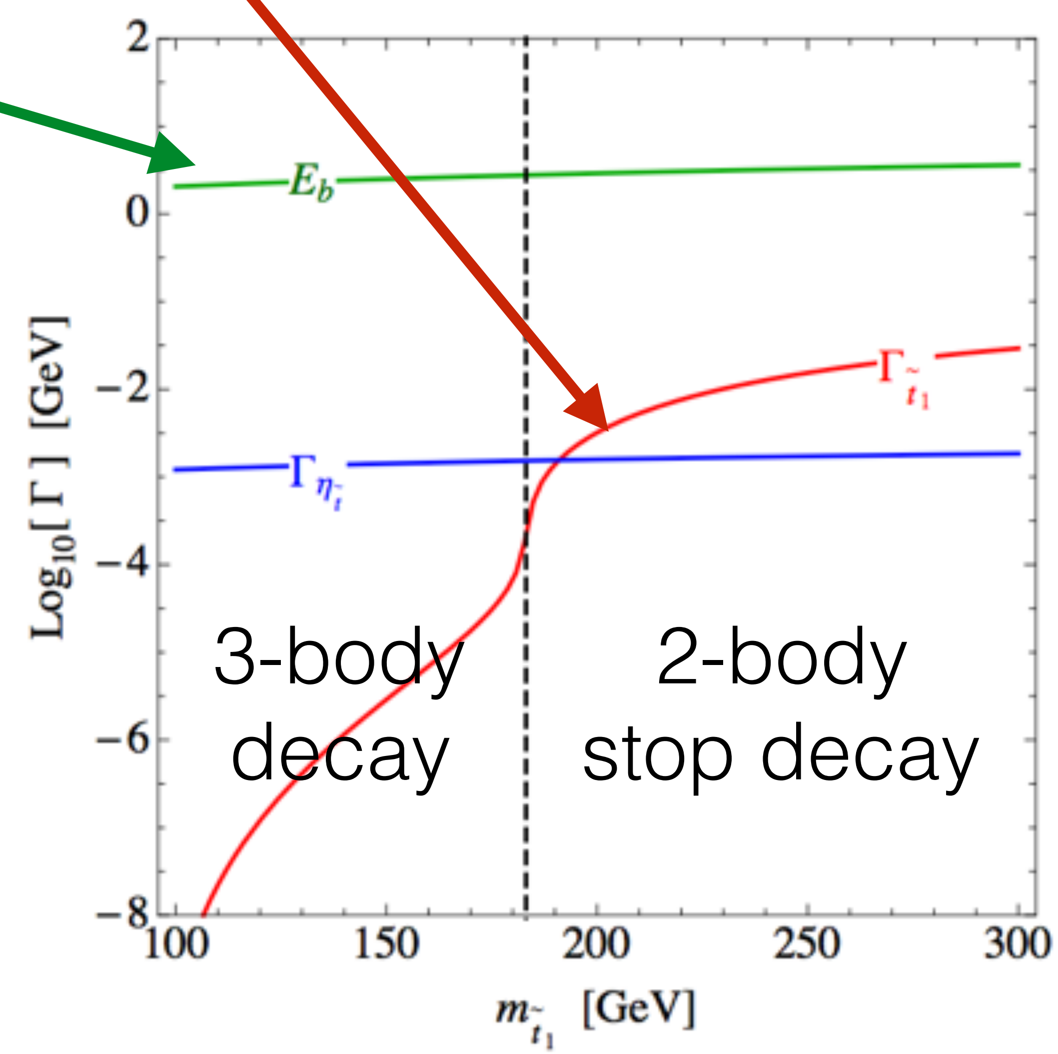
Formation condition

- If the stop decay is slow enough compared to the binding time scale.

stop NLSP, Bino LSP



(NB: the toponium has not been observed!)

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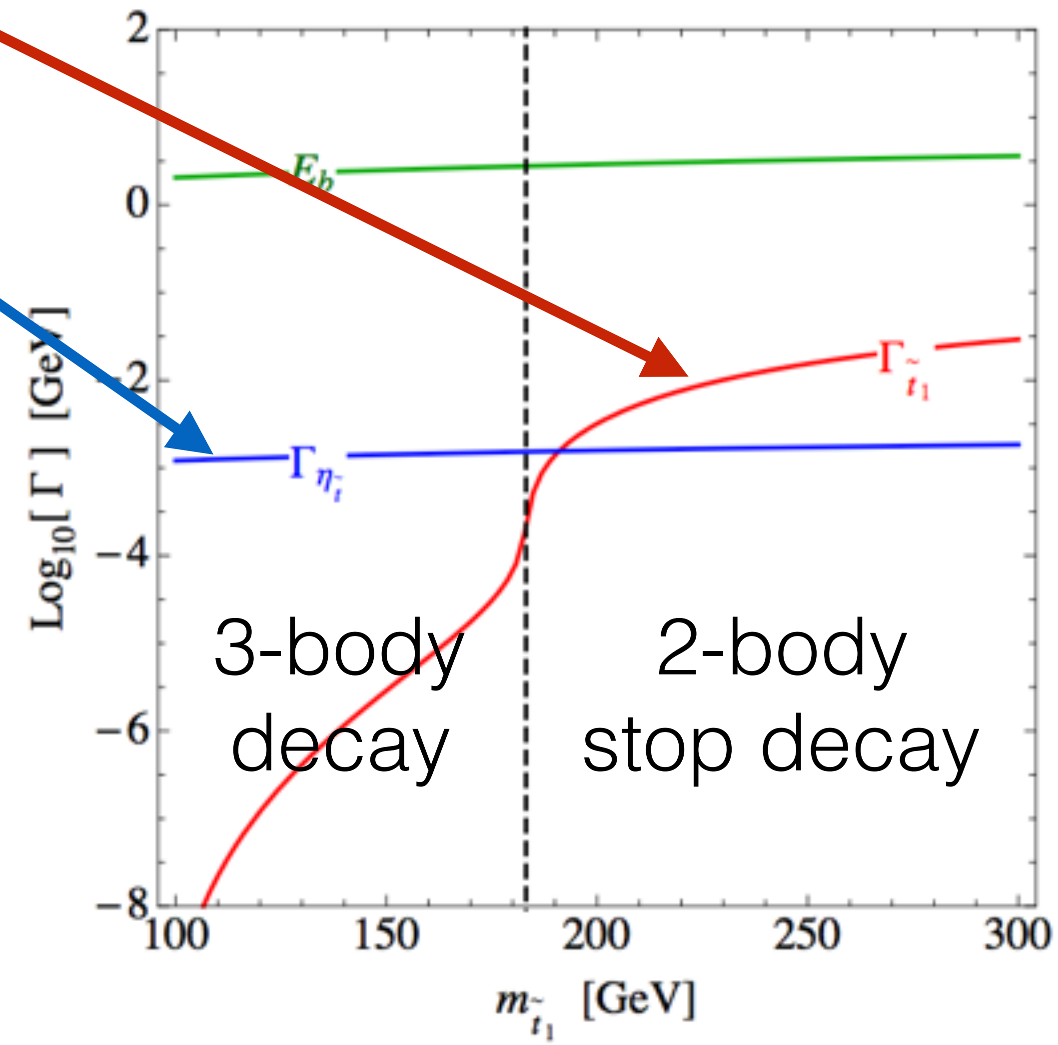
Annihilation condition

- Annihilation is what makes it a resonance peak.
- Individual stop decay should be slower than stoponium annihilation.

stop NLSP, Bino LSP



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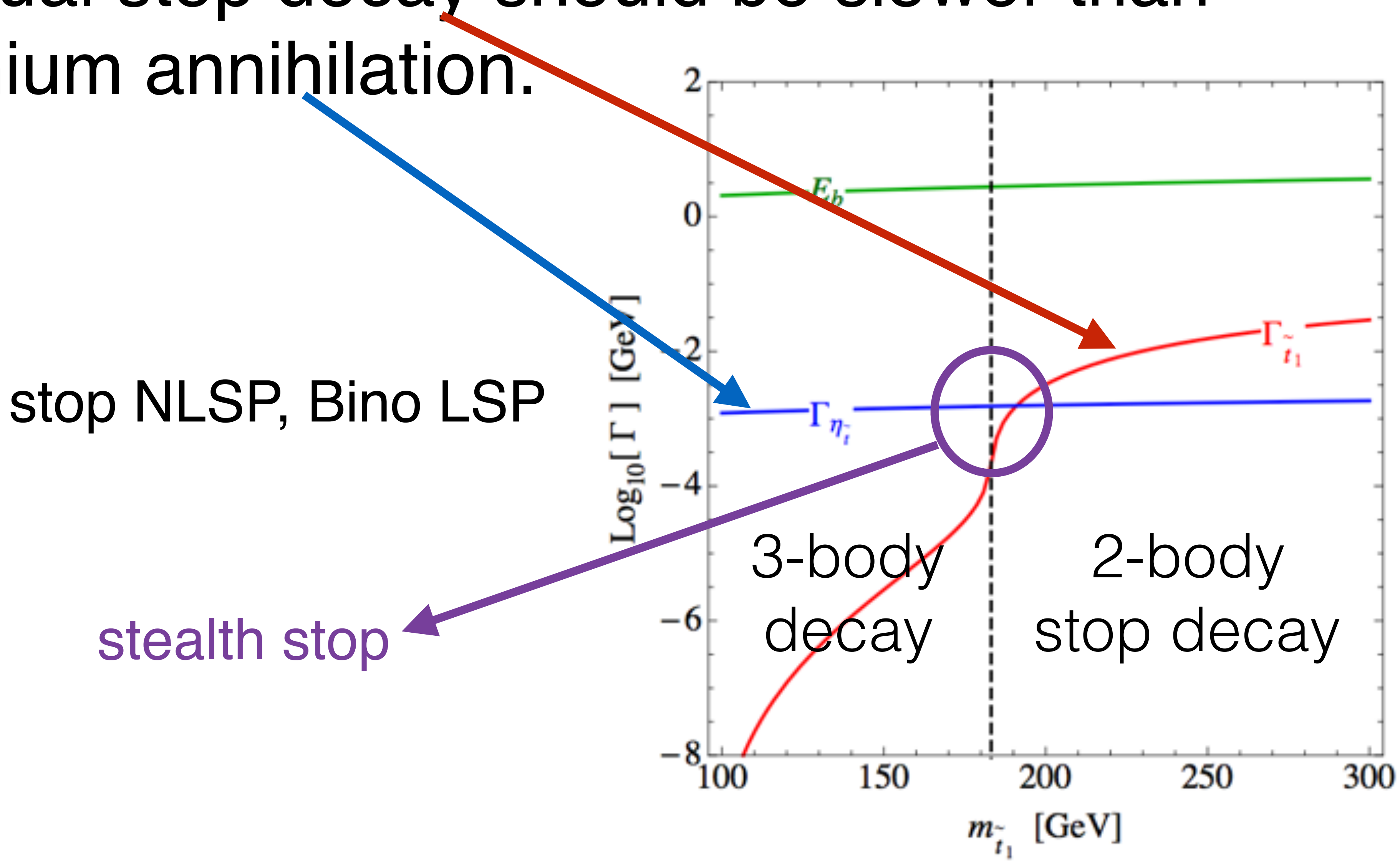

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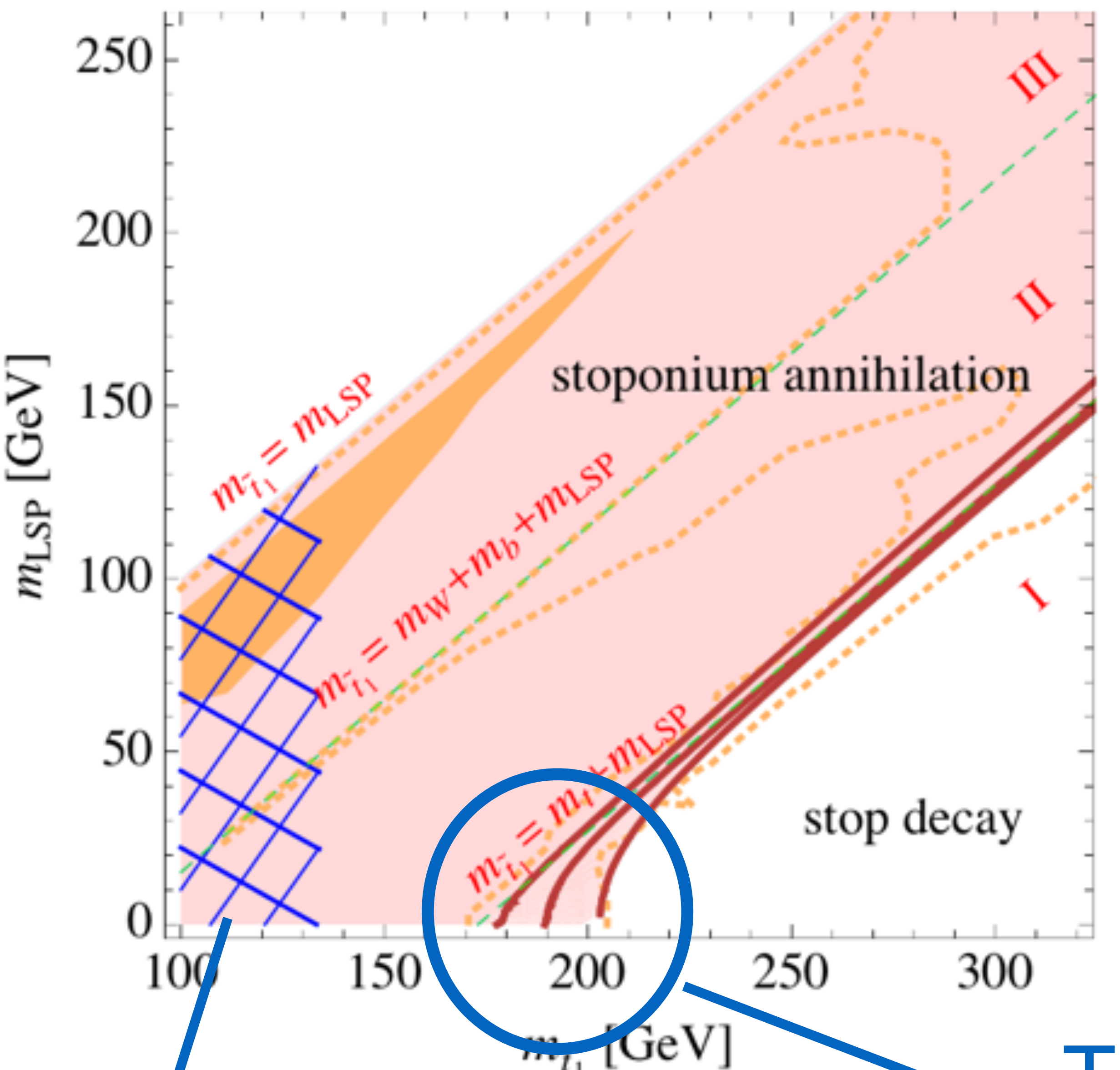
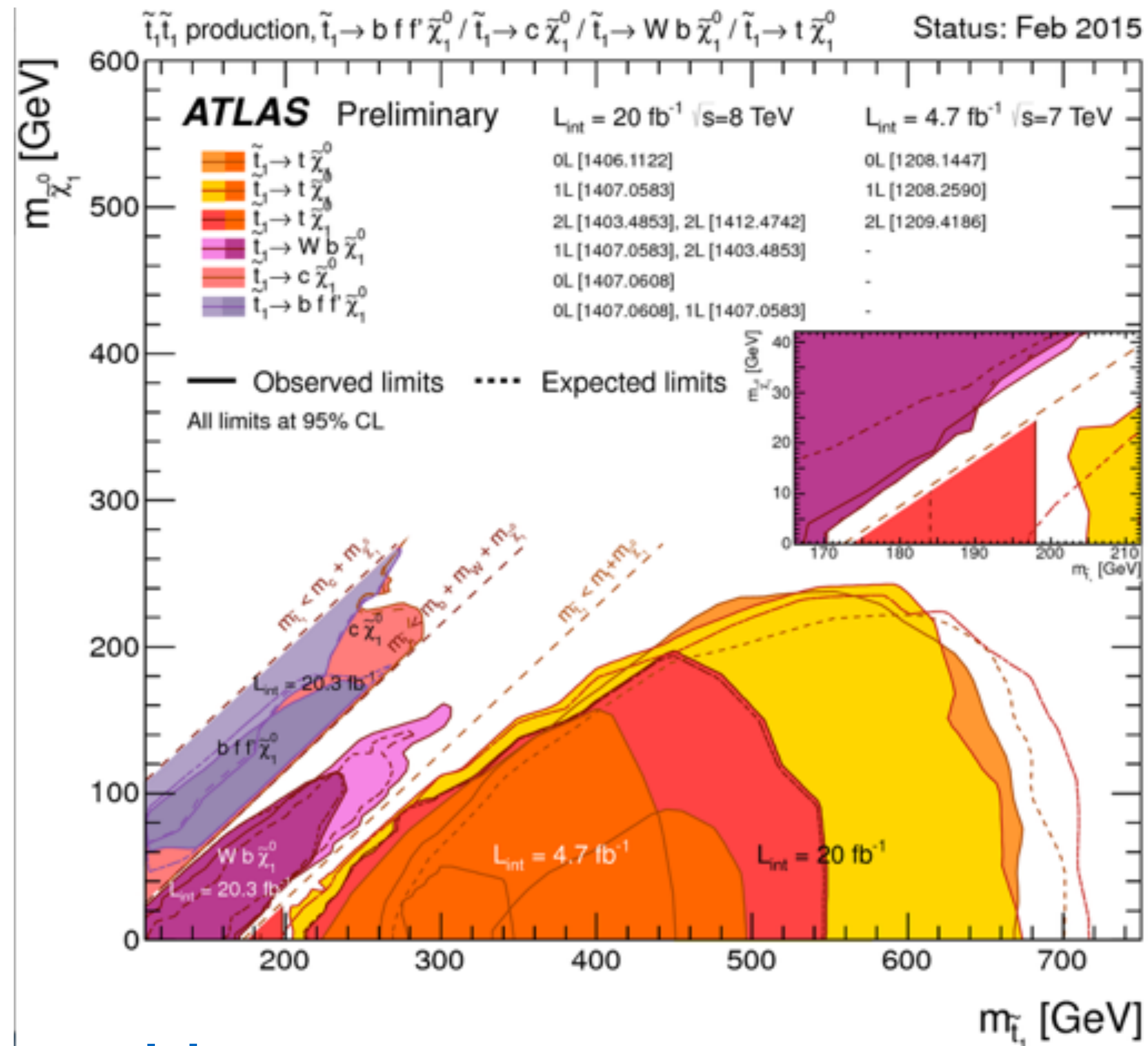
New combined limits – RPC stop-bino





new combined bounds

The stealth stop can also be probed!

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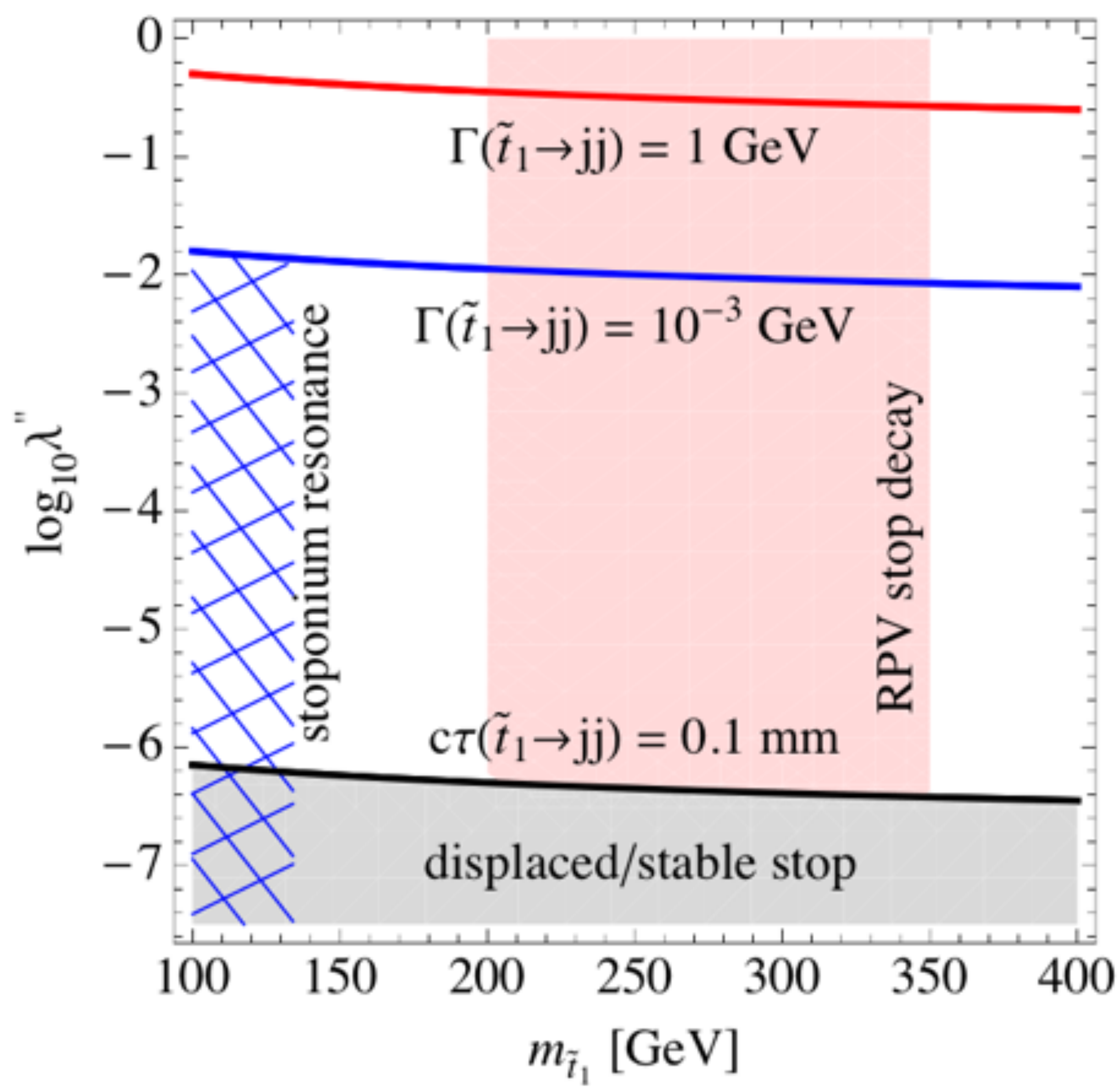
New combined limits - RPV stop-UDD



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Uncertainties

~4.0 factor uncertainty from:

Non-perturbative potential models:
Coulomb vs. charmonium-inspired (vs. lattice)

~1.5 factor uncertainty from:

Not only ground state, but excited S-wave states
can also contribute.

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Summary

- Highly complementary to existing probes of direct collider and indirect Higgs precision.
- Clean/unambiguous resonance searches: diphoton, Zgamma, ZZ, hh, ttbar…
- Applicable to various models.
- Uncertainties from potential models and excited states shall be improved (lattice did some).

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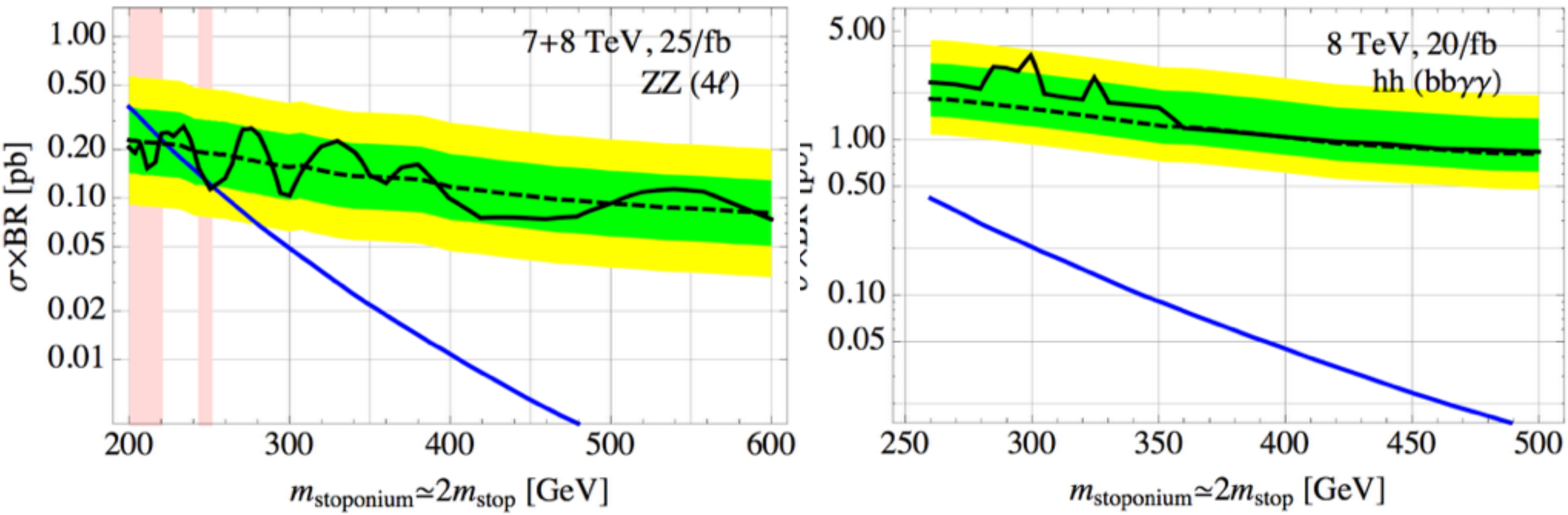
ZZ, WW, hh are weaker

Assuming the stoponium forms and annihilates…



ideal(maximal) BRs

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