Breakdown of the Narrow Width Approximation in BSM Physics

- Assumptions and Definition
- Effective Branching Ratio
- Cascade ‘Super - Enhancement’
- Left-Right Asymmetry
- Conclusions

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Narrow Width Approximation

- Assumptions:
  - Separability of the Propagator
    - → Resonant Diagrams Only
  - Massless Final State $m \ll M$
  - $\sqrt{\hat{s}} - m \gg \Gamma$
  - $\Gamma \ll M$
- $R = \frac{\sigma_{OFS}}{\sigma_{NWA}} \sim \log(s), \log(m)$
- Violations typically vary with $\frac{m}{M}$
- $(R-1) \sim \mathcal{O}\left(many \times \frac{\Gamma}{M}\right)$ even for moderate

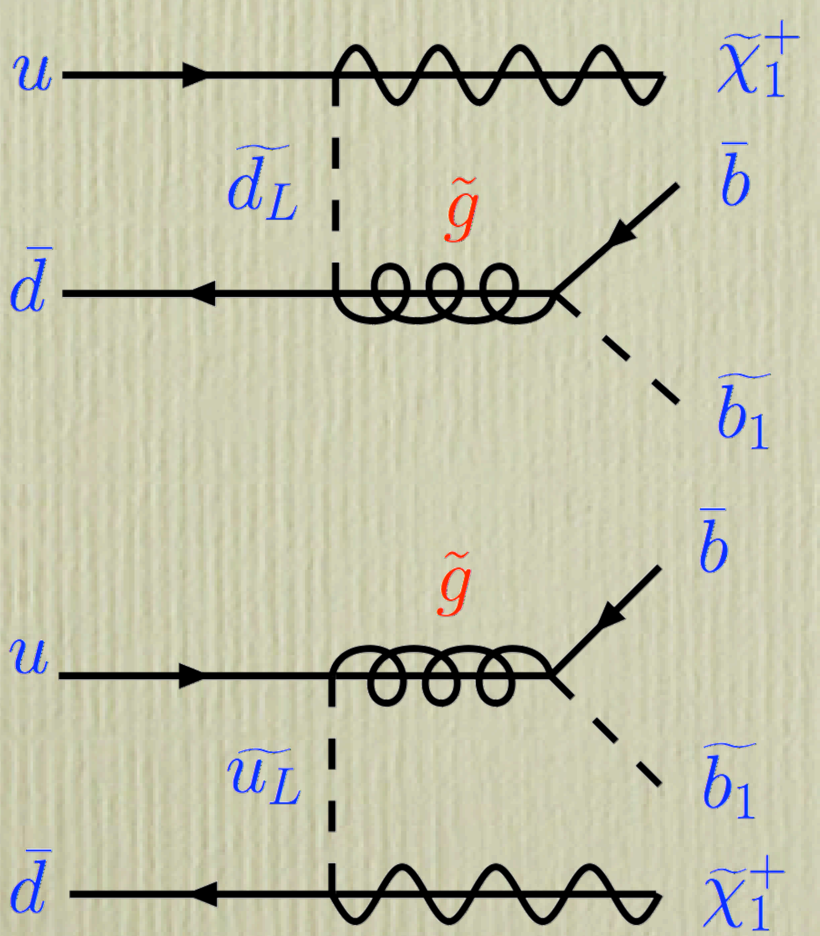
$$\int_{q^2_{\mathrm{min}}}^{q^2_{\mathrm{max}}} dq^2 \left| \frac{1}{q^2 - m^2 + im\Gamma} \right|^2$$

$$= \int_{q^2_{\mathrm{min}}-m^2}^{q^2_{\mathrm{max}}-m^2} \left\{ \frac{dx}{x^2 + (m\Gamma)^2} \right\}$$

$$\cong \int_{-m^2}^{s-m^2} \left\{ \right\} \begin{matrix} q^2_{max} \to s \\ q^2_{min} \to 0 \end{matrix}$$

$$\approx \int_{-\infty}^{\infty} \left\{ \right\} \begin{matrix} s \to \infty \\ m^2 \to \infty \end{matrix} = \frac{\pi}{m\Gamma}$$

Effective Branching Ratio



$$BR = \frac{\sigma_{NWA}}{\sigma_{2\to 2}} \to BR_{naive} = \frac{\sigma_{OFS}}{\sigma_{2\to 2}}$$

- Proper: $BR_{eff} = \frac{\sigma_{OFS}}{\sigma_{Tot}}$
- Assume only 1 decay violates NWA

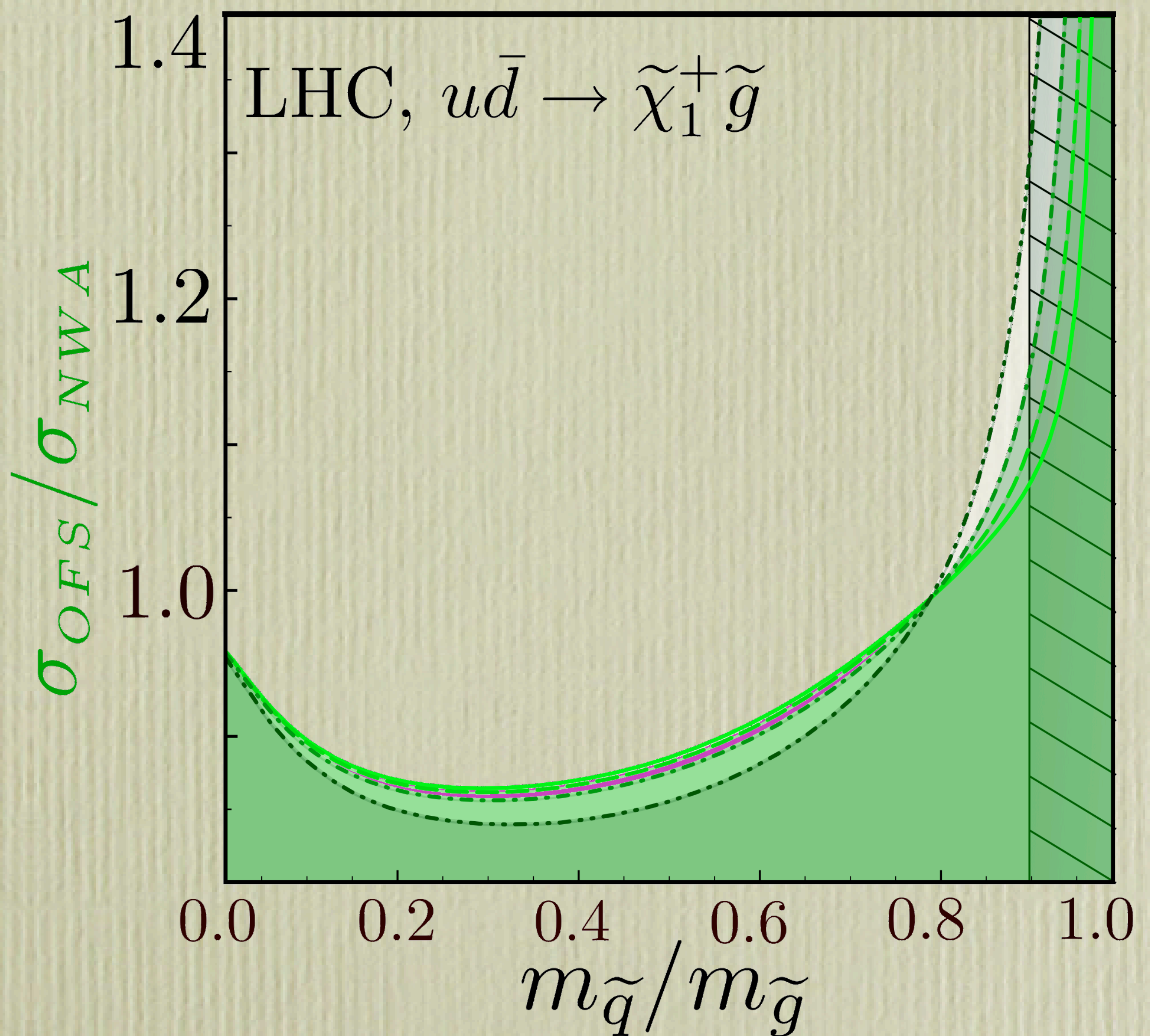
$$BR_{eff} = \frac{\sigma_{OFS}}{\sigma_{OFS} + \left(\frac{\Gamma_i}{\Gamma_i + \Gamma_b} \times \sigma_{2\to 2}\right)}$$

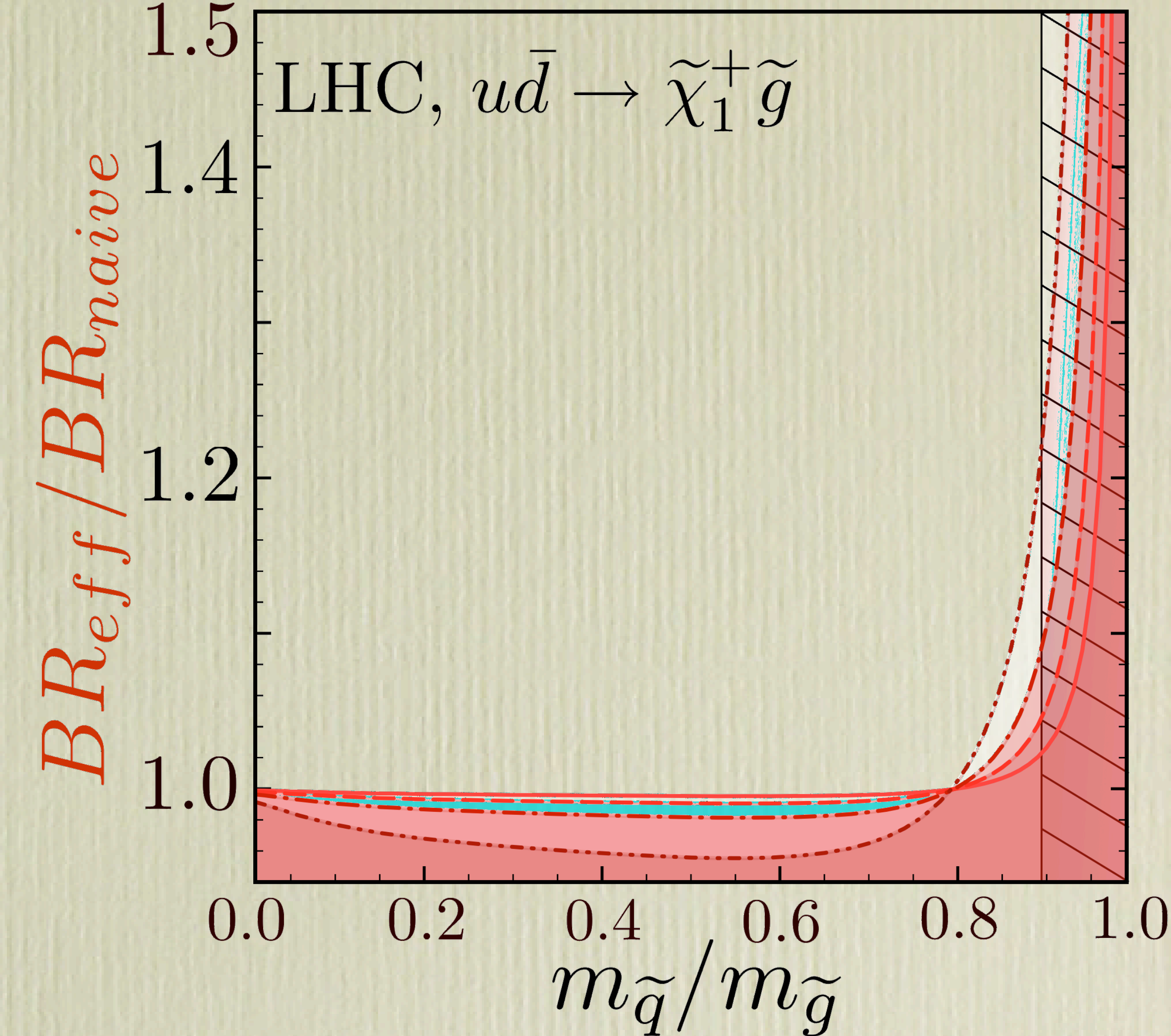
- If R ~1, $BR_{eff} \approx BR_{naive}$

$\frac{BR_{eff}}{BR_{naive}}$ near 1 if:

  - A rare decay mode has $\frac{m}{M}$ ~1
- Common b.c. PS suppresses $\frac{m}{M}$ ~1 modes

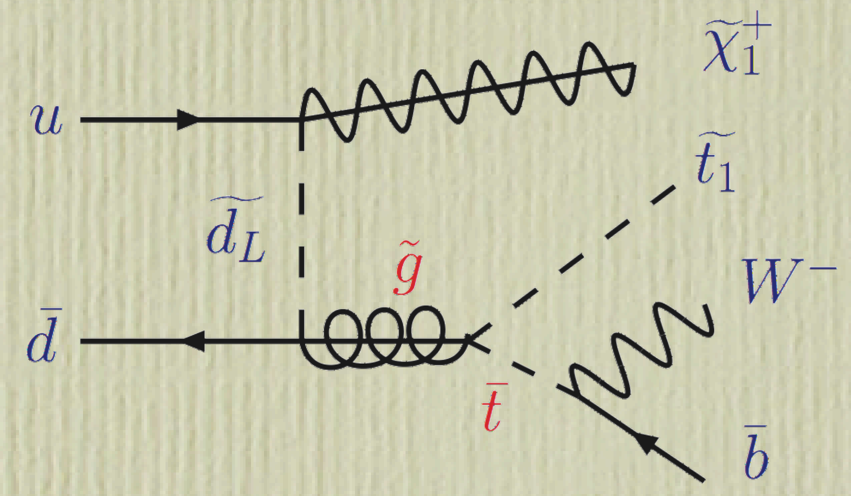
- Scan over $\frac{m}{M}$ Compare w/ R
- Assume 1st 2 generations of squark degenerate



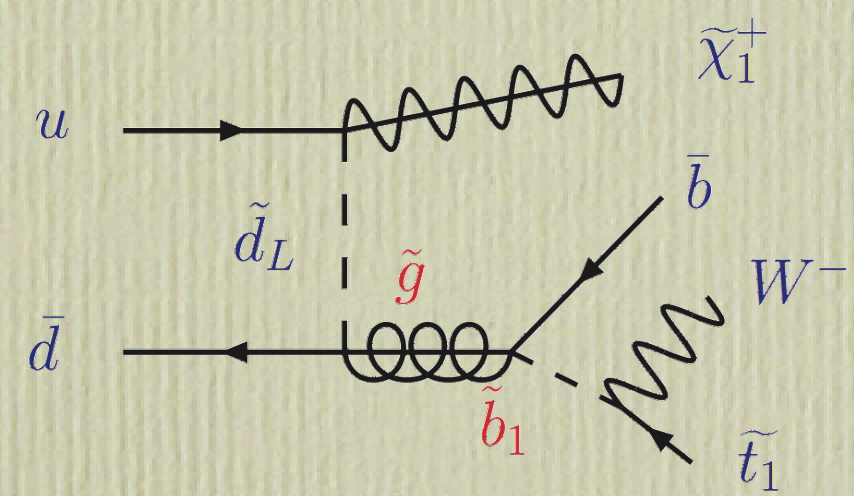


- Shaded region = SPS points
- Decay/Cascade Tools (e.g. SDECAY, PYTHIA..) ignore this

Multiple Successive Decays

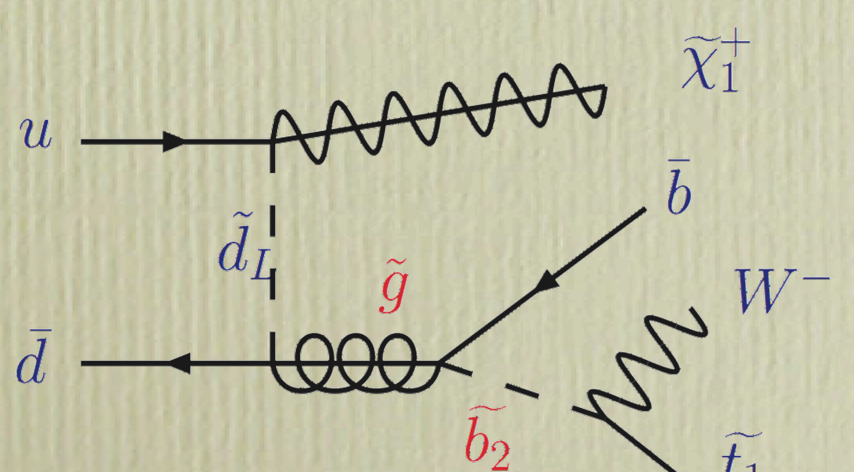


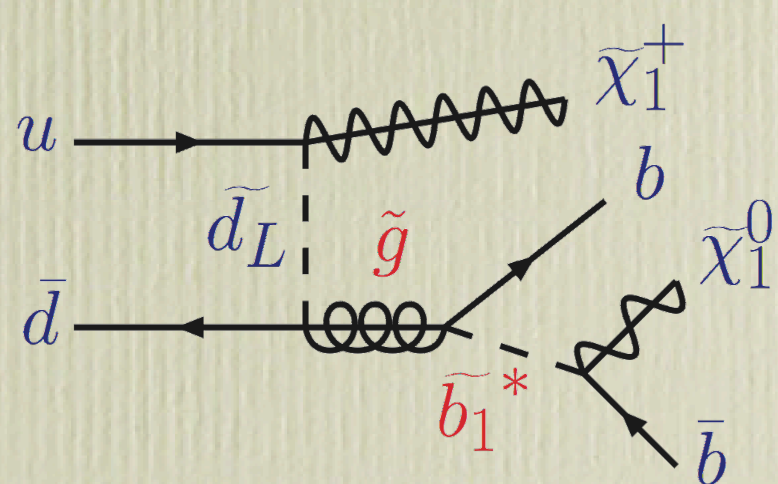
- Real processes cascade
- Multiple Breit-Wigners
- How does this change things?
- When? Need multiple degeneracies?

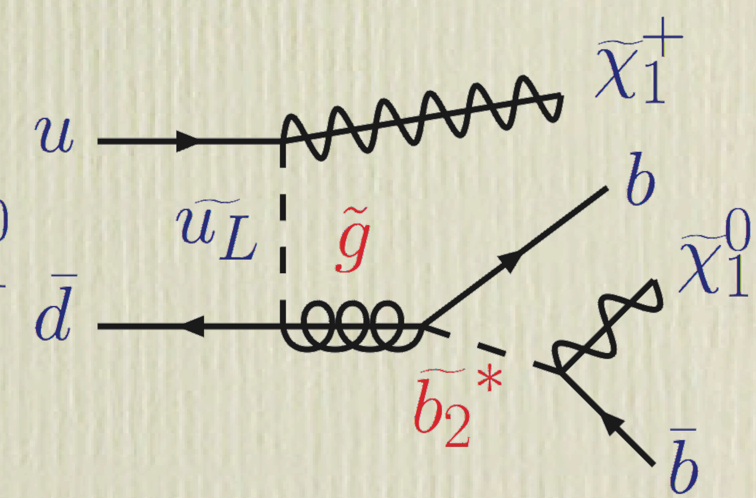


SSV

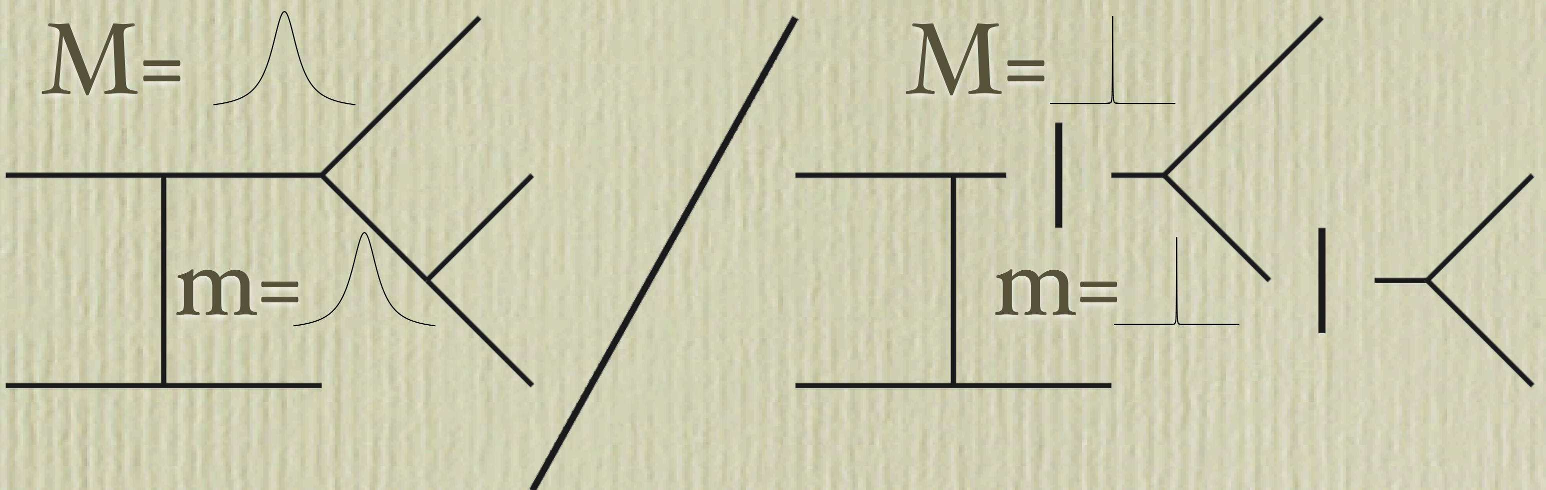
SFF



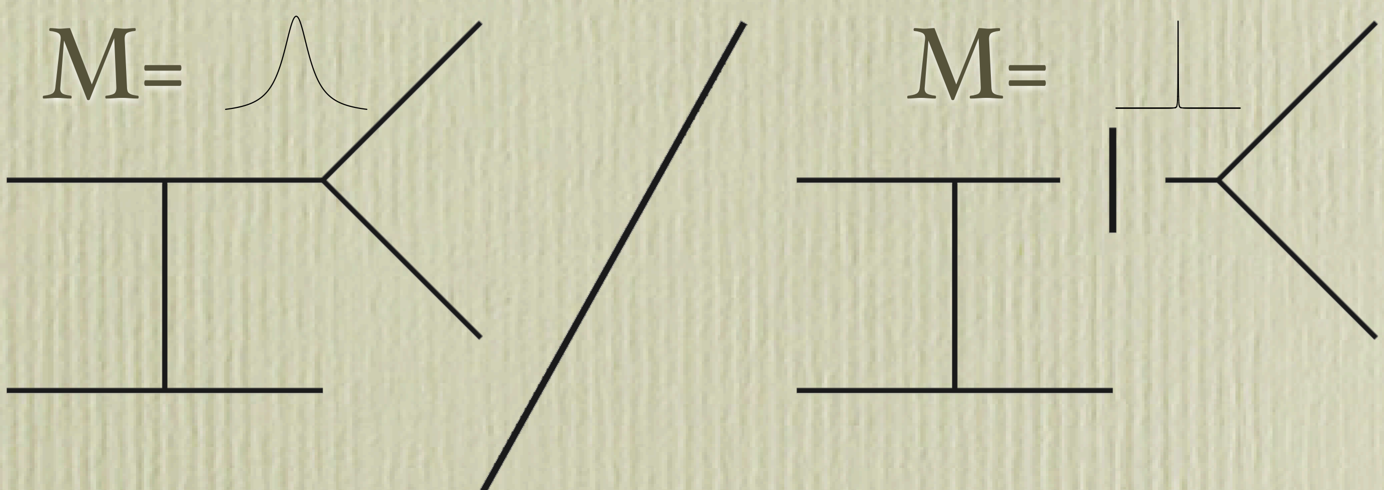




"Super-Enhancement": Origin



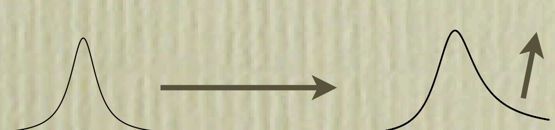
= R2



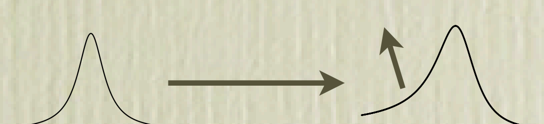
= R1

RR

If R1 > 1 and m can vary:



If $\frac{m}{M} \to 1$ and m can vary,

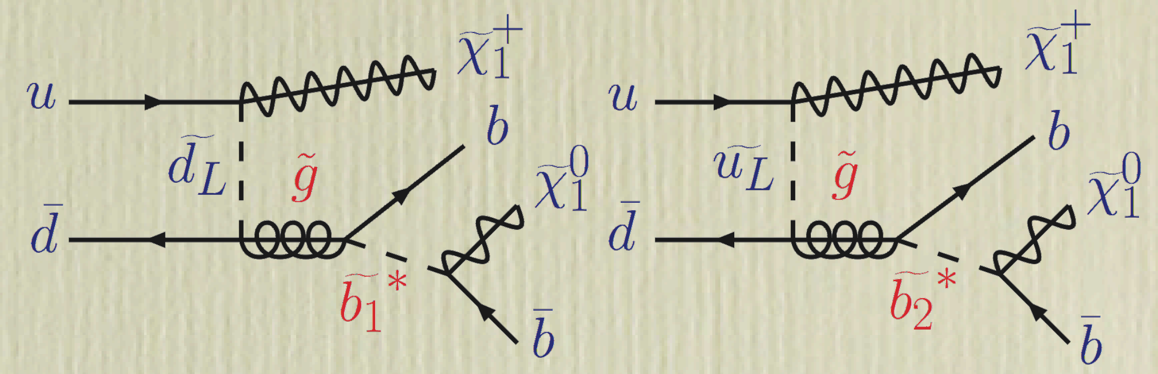


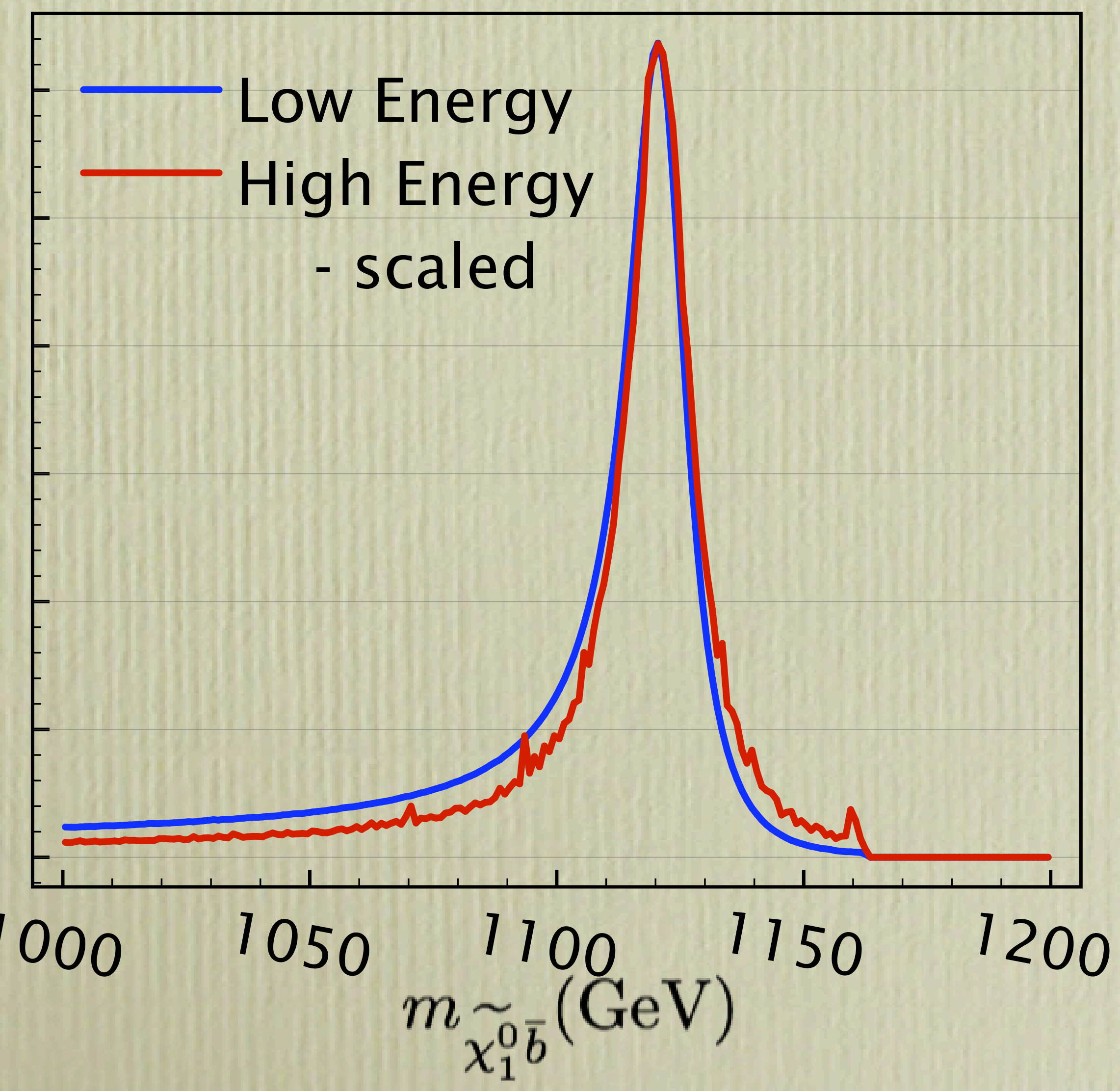
- OFS enhancement enhances high tail, PS suppression kills it

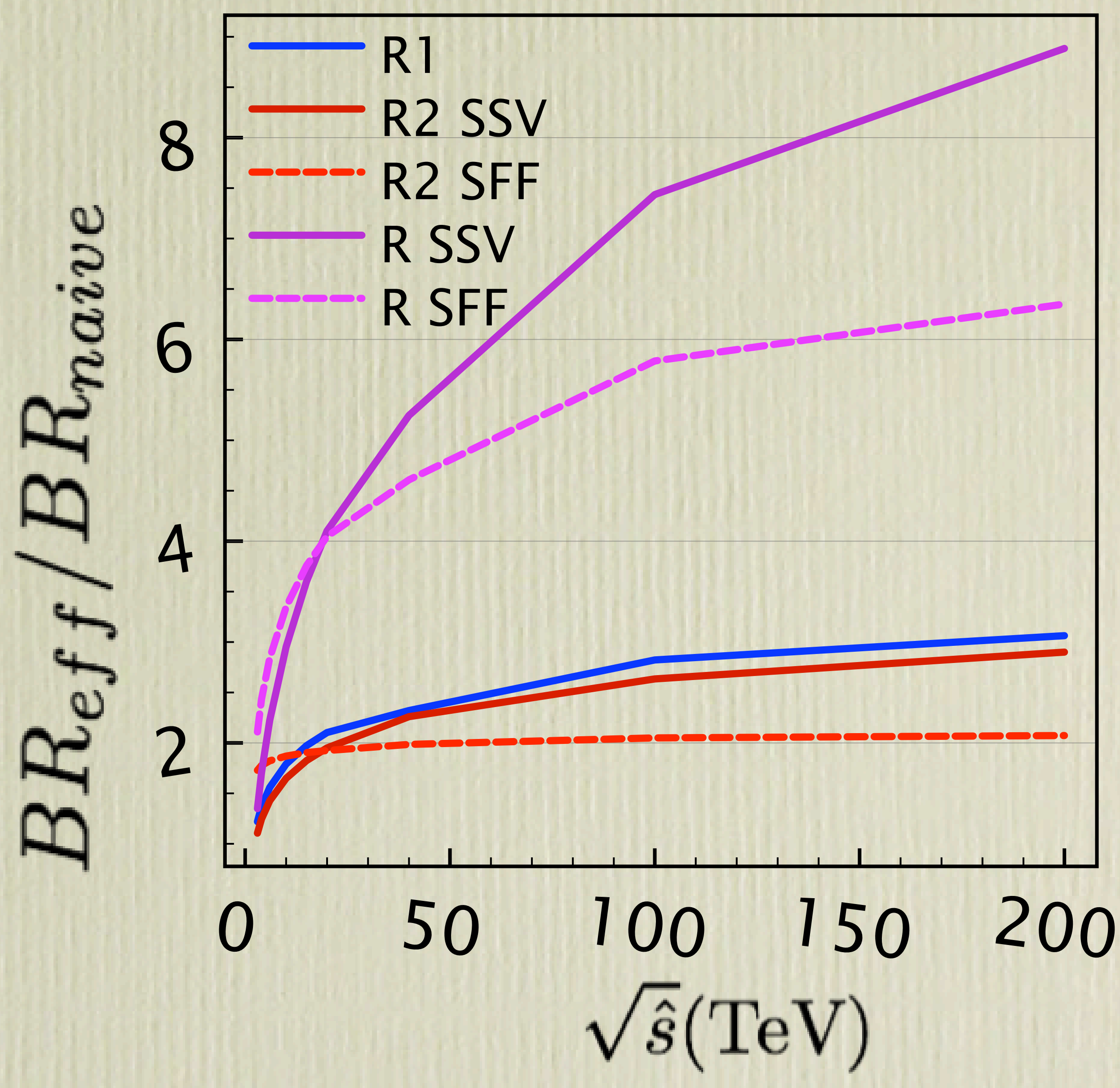
Energy Dependance

PRELIMINARY

Process@LHC		*R*	$\frac{BR_{eff}}{BR_{naive}}$
	1-level	1.16	1.16
SSV	2-level	3.36	3.37
SFF	2-level	1.04	1.06

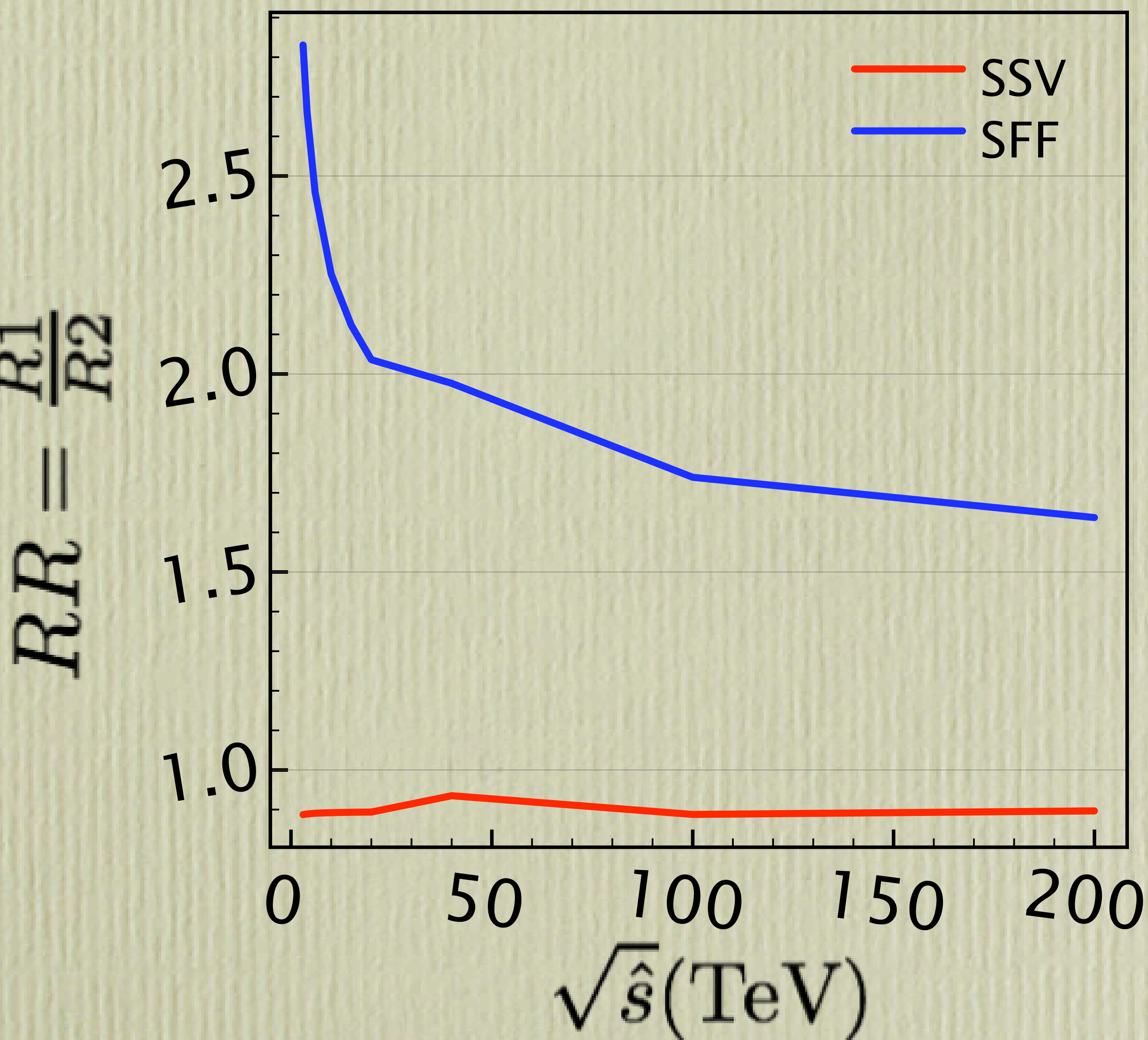


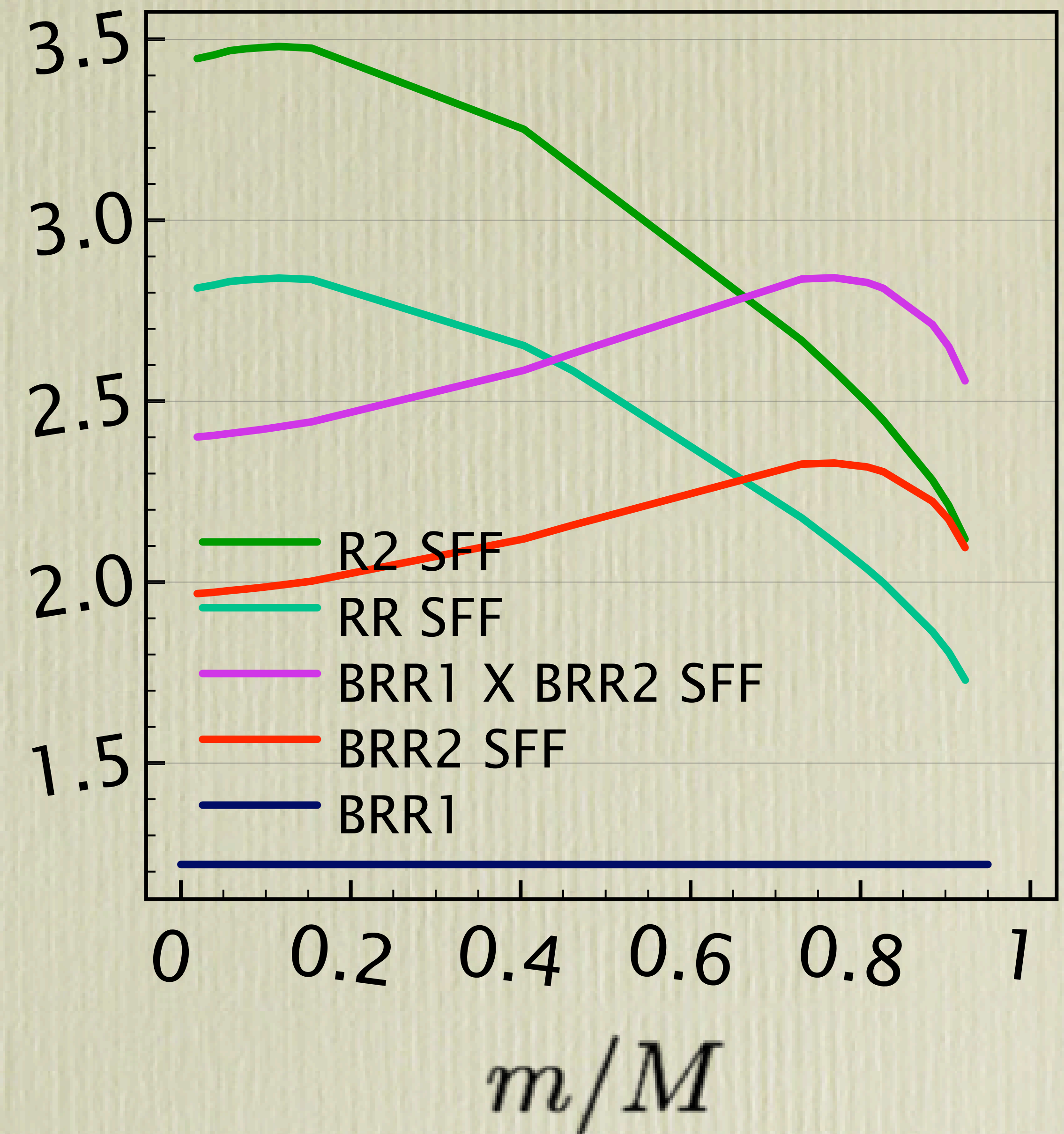




"Super-Enhancement": Behavior

PRELIMINARY

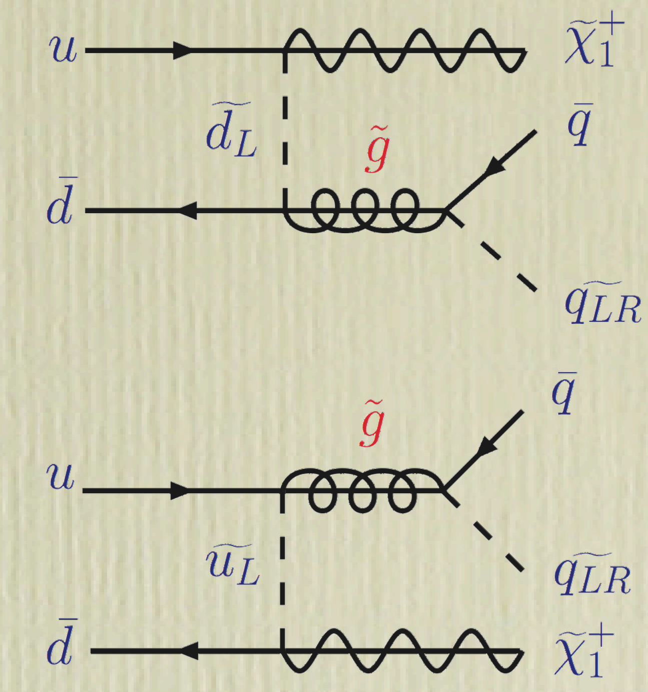




$$\text{BRR} = \frac{BR_{eff}}{BR_{naive}}$$

- For large $\frac{m}{M}$, 2nd decay suppresses R

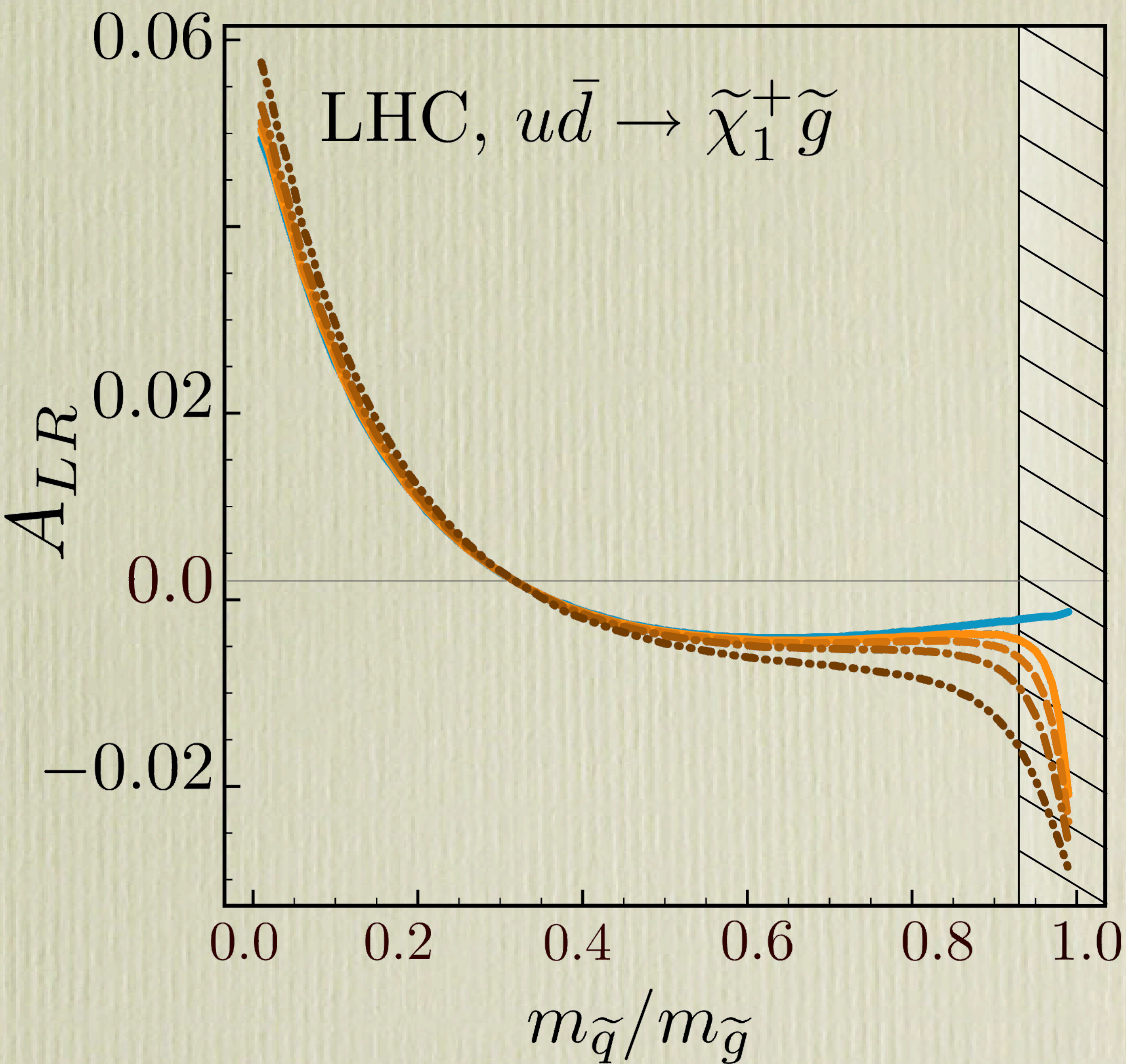
Left-Right Asymmetry



- $\sigma_{2\to 2} \times BR$ is helicity-neutral
- Chargino choses left coupling
- Helicity pref carried through
- Gluino mass can flip, but doesn't equalize

$$A_{LR} = \frac{\sigma_{\tilde{q}_L} - \sigma_{\tilde{q}_R}}{\sigma_{\tilde{q}_L} + \sigma_{\tilde{q}_R}}$$

- $\frac{m}{M}$ <.3 (light squark) disfavored
- $\frac{m}{M}$ >.8 effect may be observable



Conclusions

- NWA often dramatically invalid in BSM physics
- Modified BRs could confuse Model ID
- Large effects from successive decays
- Cannot parametrize effect of addition decays
- Left-Right Asymmetry could confuse coupling measurement / Model ID
- Cannot trust NWA with massive spectra.