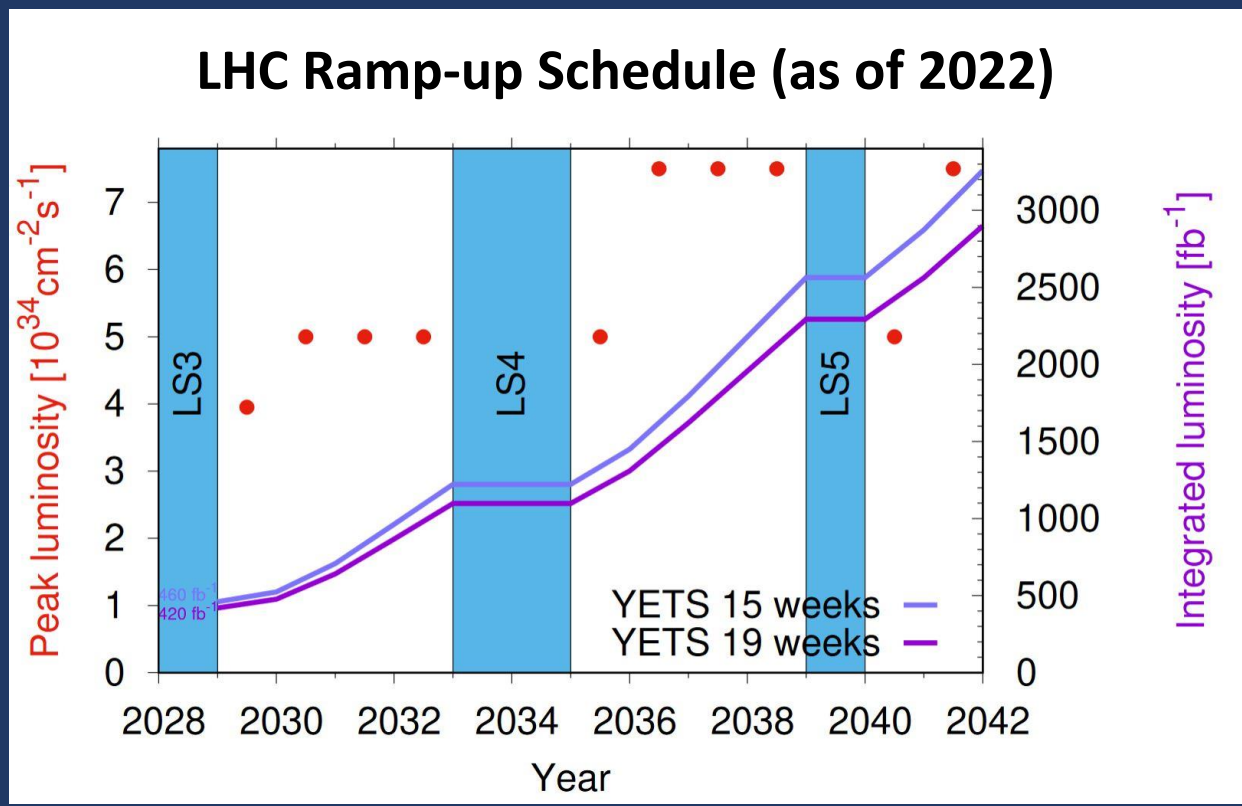


Quirky Signals at Colliders

Joshua Forsyth
with Chris Verhaaren

Phenomenology 2023 Symposium | 9 May 2023

LHC Search Potential

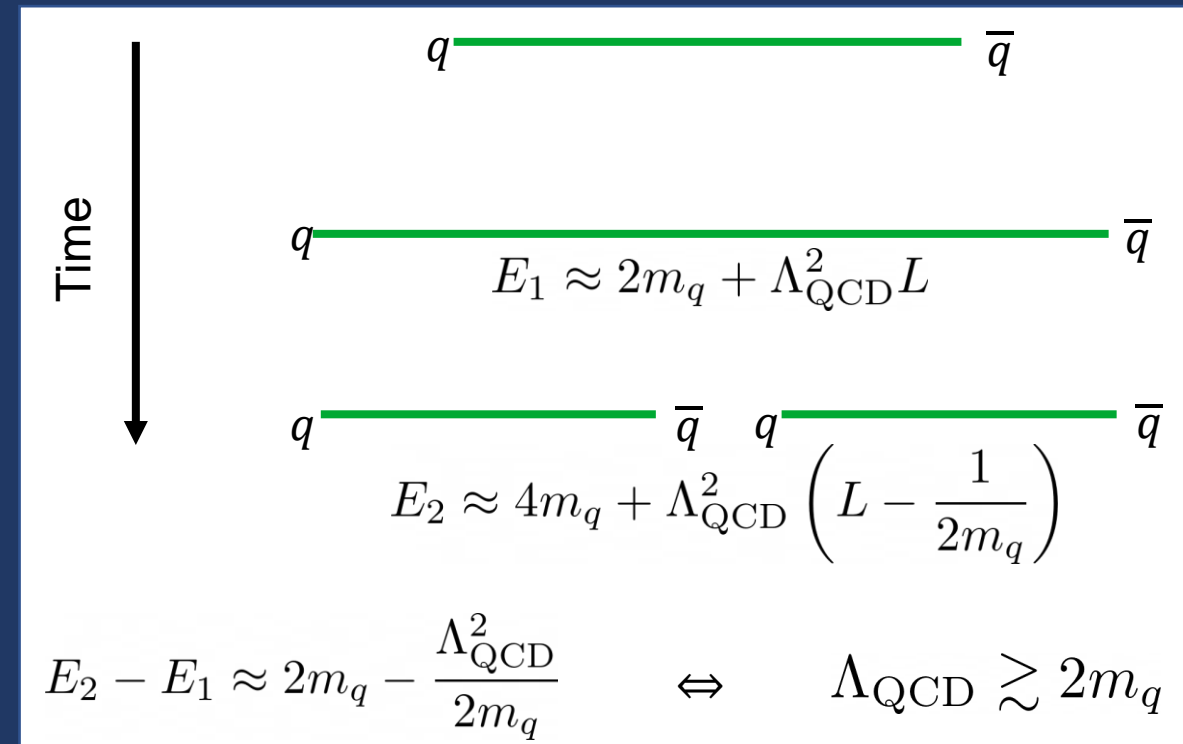
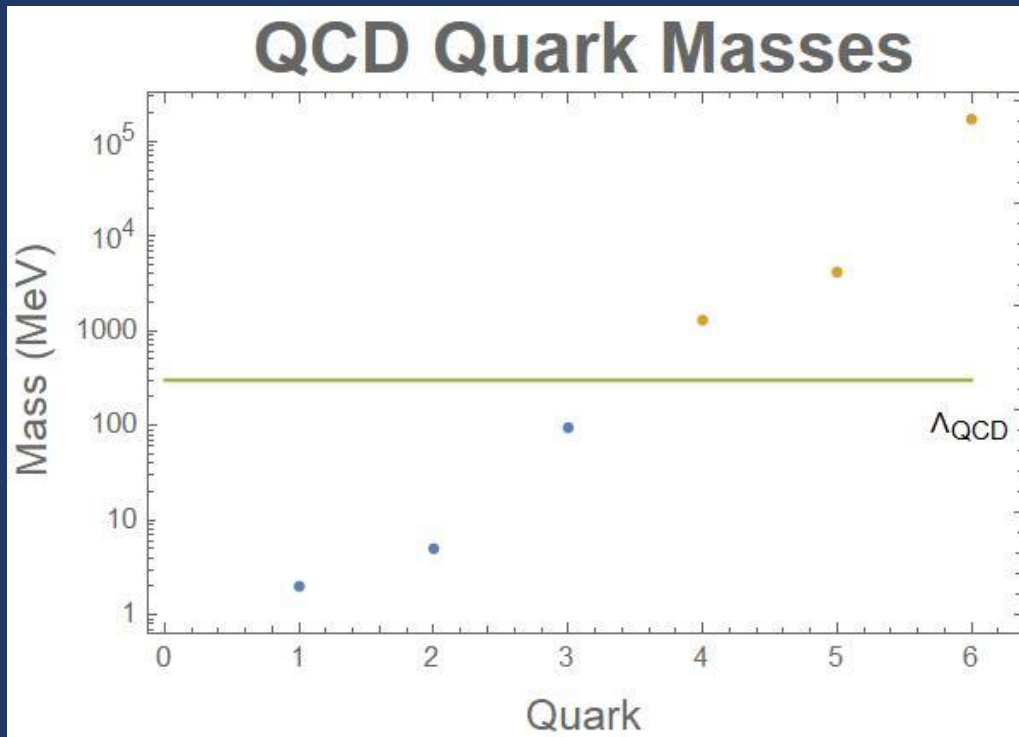


- Run 3 underway, HL-LHC on the horizon [1]
 - Directly probes electroweak scale
- Want to optimize its search potential
 - New signals could help us in our searching

[1] <https://lhc-commissioning.web.cern.ch/schedule/LHC-long-term.htm>

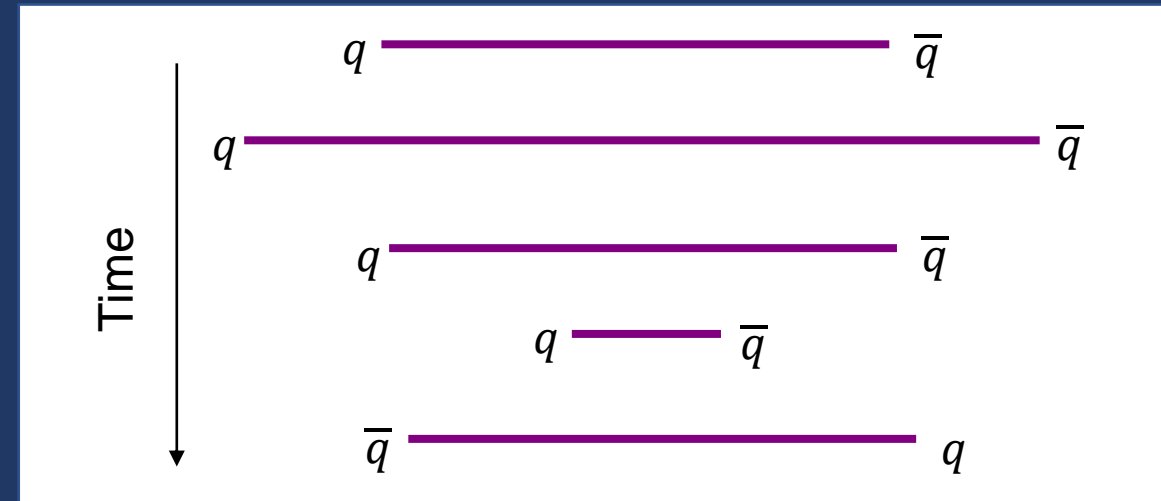
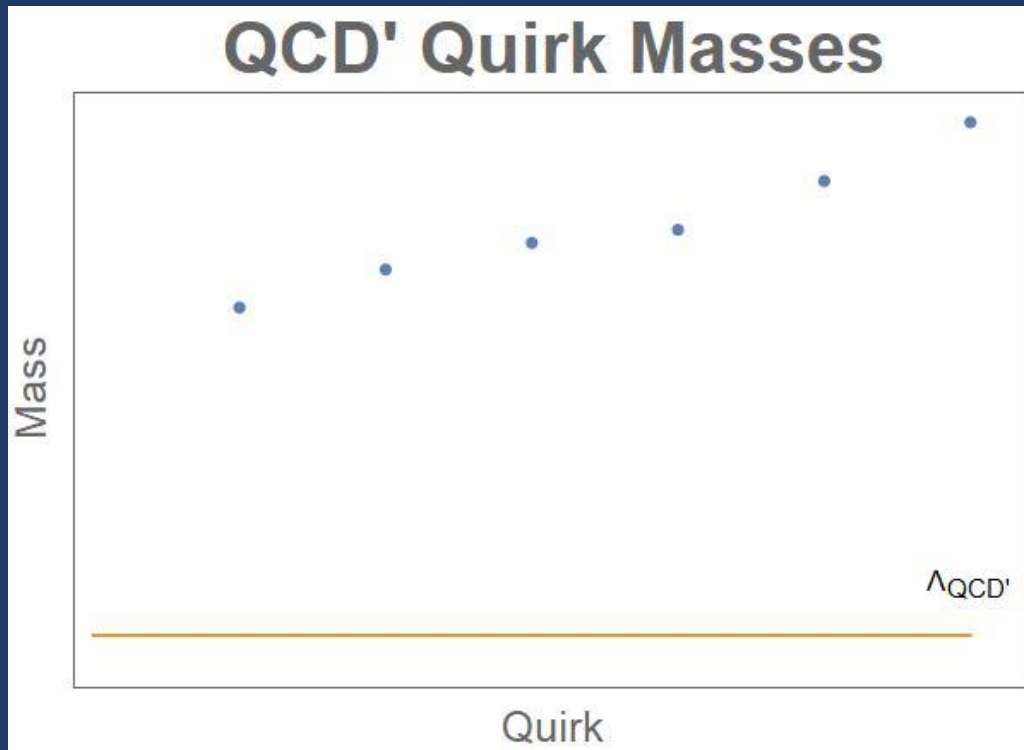
Quirks: What are they?

- Different gauge group than SM $SU(3)$ color
- SM QCD has a confining scale $\Lambda_{QCD} \approx 300$ MeV



Quirks (cont.)

- Quirks have large masses, compared to confinement scale
 - String cannot fragment \Rightarrow annihilate as a bound pair
 - Decay in low angular momentum bound state [2]
 - No pair production = qualitatively different signals than SM jets



[2] Kang, Luty arXiv:[0805.4642v3](https://arxiv.org/abs/0805.4642v3)

Quirks (cont.)

- Kinetic energy of quirks and their mass set length [2]

$$L = \frac{KE}{\Lambda^2} \sim \frac{m}{\Lambda^2} \sim 10 \text{ m} \left(\frac{m}{\text{TeV}} \right) \left(\frac{\Lambda}{100 \text{ eV}} \right)^{-2}$$

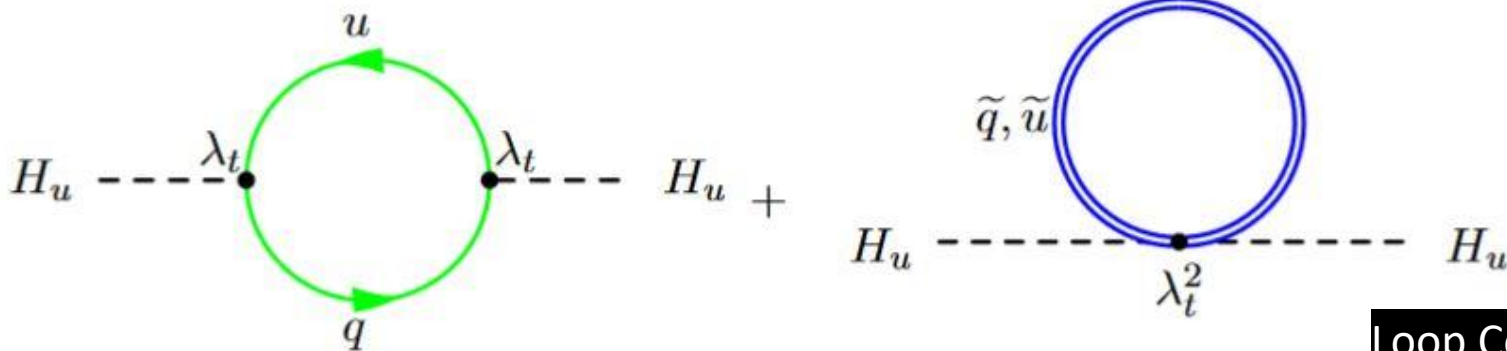
$$\begin{aligned} m &\sim 1 \text{ TeV} \\ \Lambda &\sim 1 \text{ GeV} \end{aligned} \Rightarrow L \sim 10^{-7} \text{ m}$$

- Different lengths \Rightarrow interesting possibilities
- Charged squirks de-excite and decay quickly

[2] Kang, Luty arXiv:[0805.4642v3](https://arxiv.org/abs/0805.4642v3)

Electroweak Hierarchy

- Higgs mass value is puzzling.
- Many proposed solutions haven't been confirmed by LHC searches
 - We haven't seen top partners, Higgs compositeness, etc.
- Neutral Naturalness framework [3] is interesting possibility
 - Naturalness = no fine-tuning of Higgs mass
 - Neutral = top partner is QCD color neutral (can still have other color)



Loop Corrections: [3] Batell, *et al.* arXiv:[2203.05531v1](https://arxiv.org/abs/2203.05531v1)
[4] Burdman, *et al.* arXiv:[1411.3310v2](https://arxiv.org/abs/1411.3310v2)

Neutral Naturalness

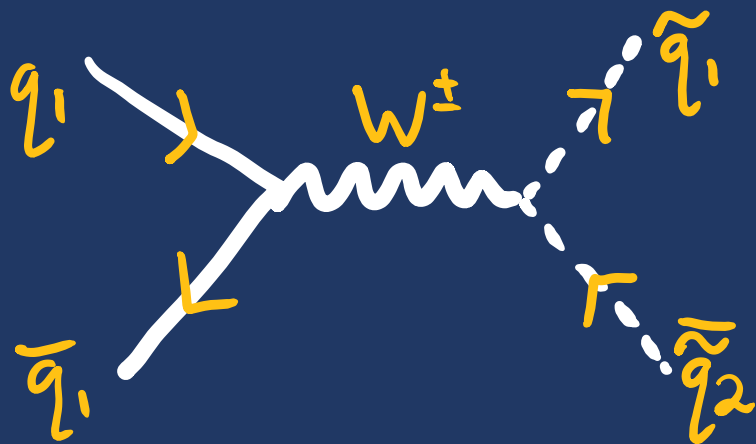
- Z_2 symmetry relating $SU(3)$ to hidden $SU(3)$
- Consider quirks charged under hidden $SU(3)$ group.
 - Higher masses (if EW charged)
 - Confinement scale a few GeV
- Some interesting models predict these kinds of quirks
 - **Folded SUSY** [5], Quirky Little Higgs, etc.

[5] Burdman, *et al.* arXiv:[0609152v2](https://arxiv.org/abs/0609152v2)

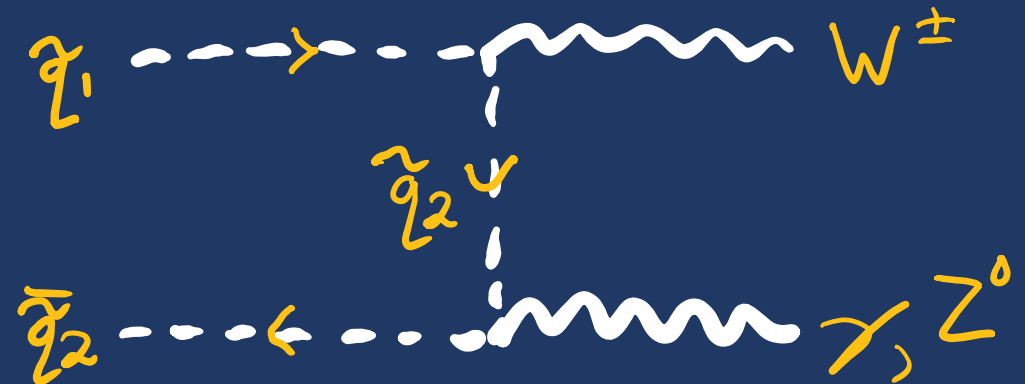
Folded SUSY Charged Squirkonium

- Charged squirk production through W
 - Highest sensitivity of signals in FSUSY squirks.
 - Decays into $W\gamma$ or WZ
 - The invariant mass of the $W\gamma$ signal = mass of the bound state

Production:

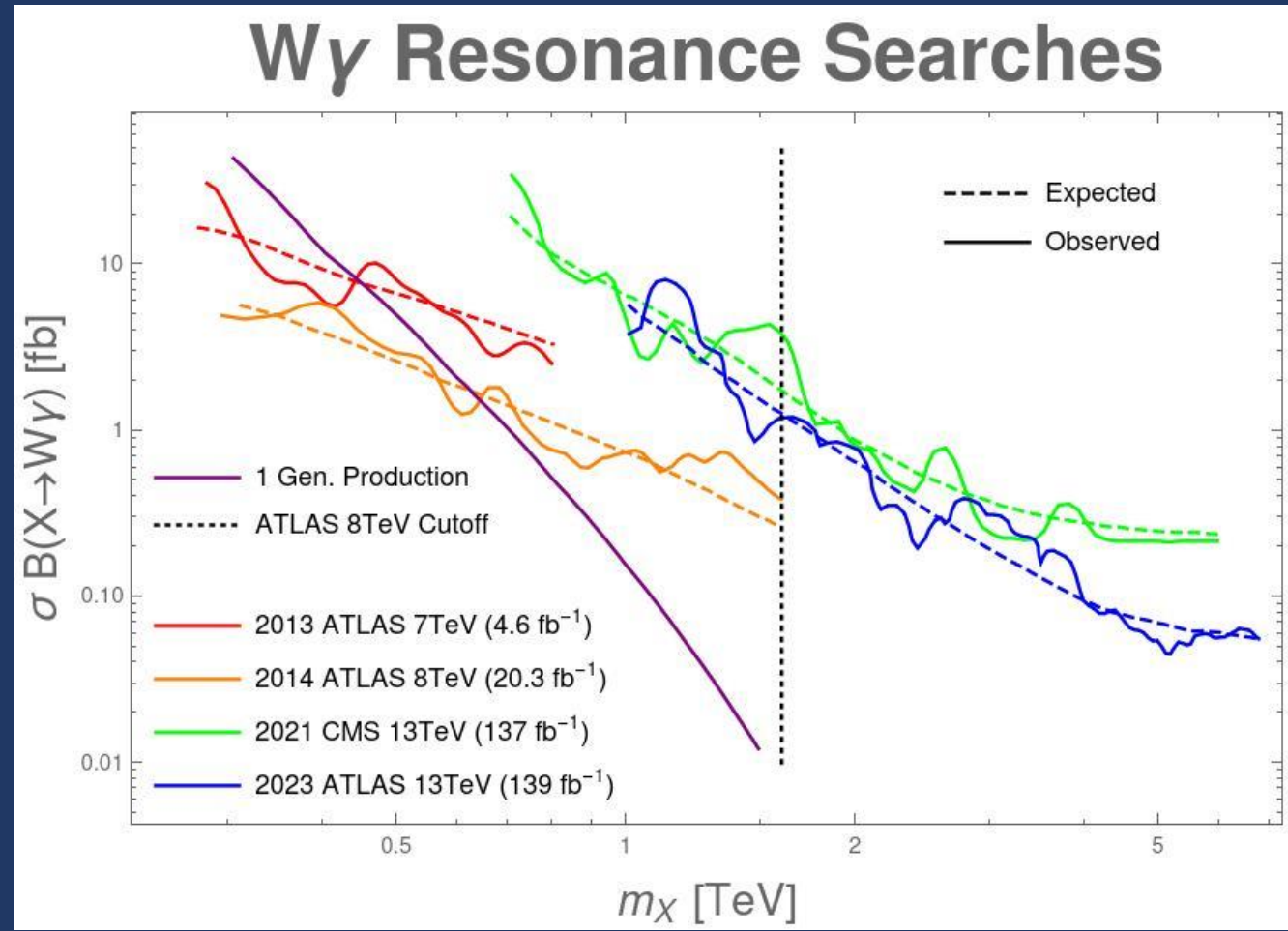


Decay:



LHC $W\gamma$ Resonance Searches

- 8 TeV has placed the most stringent bounds on searches
 - $m_q \lesssim 320$ GeV (be more specific)
 - More beyond the cutoff?
- Can we correlate signals to improve searches?



Production Line: [4] Burdman, *et al.* arXiv:[1411.3310v2](https://arxiv.org/abs/1411.3310v2)

- Could be new EW states at $m_q \lesssim 320$ GeV waiting to be discovered.
 - Prioritizing searches could help us find them
- Future work
 - Fully characterizing these FSUSY signals.
 - Characterize more general NN motivated quirk signals.
 - Neutral squirkonium & fermionic quirkonium decay signals
 - Displaced decays through hidden glueballs.
 - New python tool for GlueShower tool [7]

Thank you

[6] Curtin, *et al.* arXiv:[2202.12899](https://arxiv.org/abs/2202.12899)