Workshop Summary

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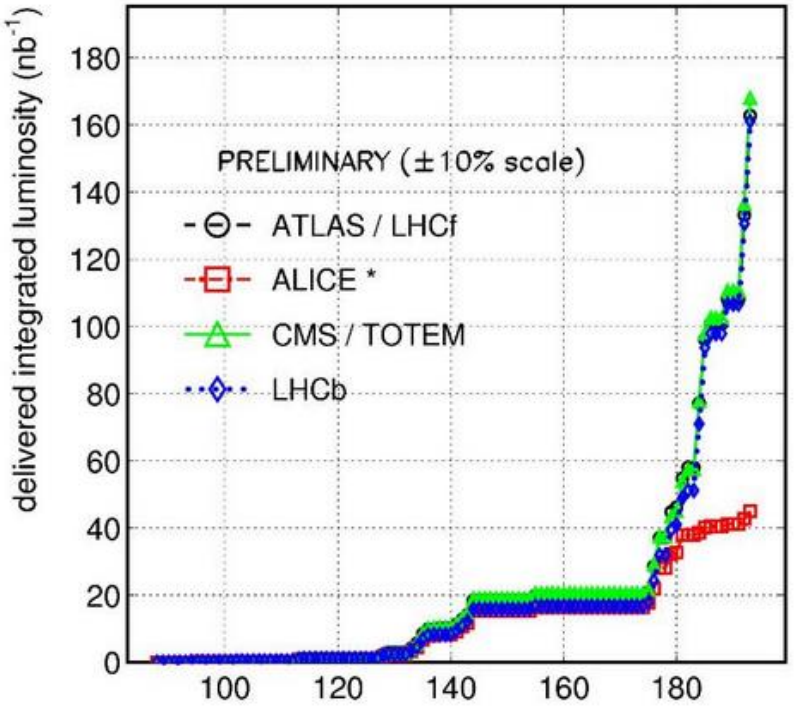
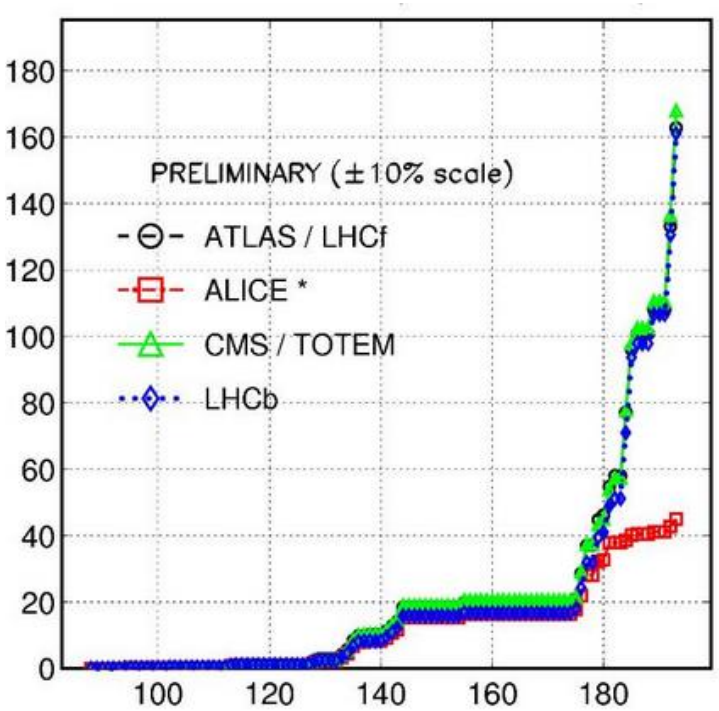


time

brainpower

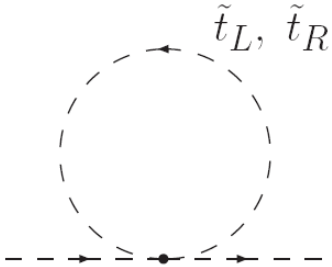


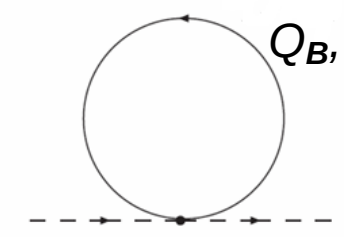
time

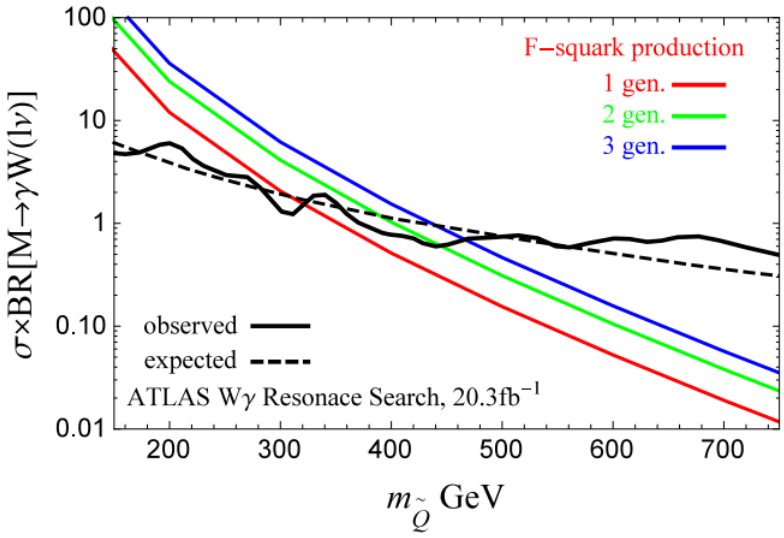
Overview Talks

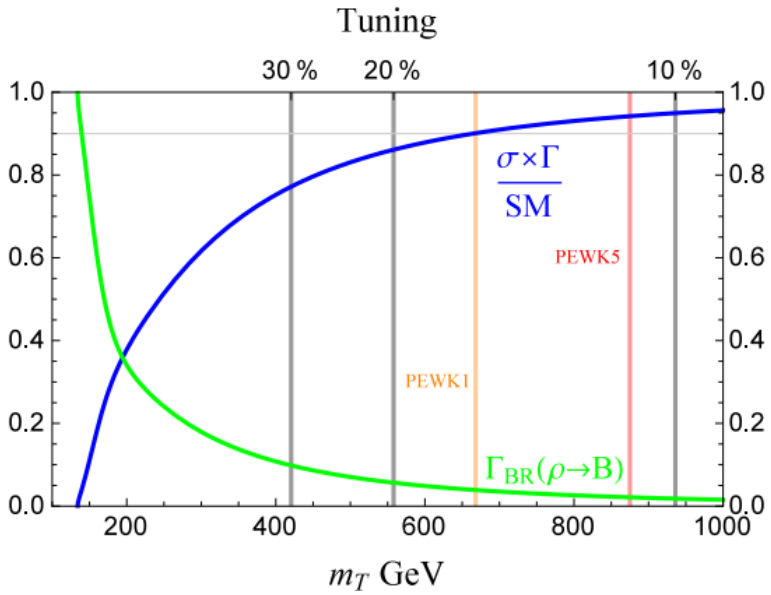
- **Burdman:** ***Folded Supersymmetry***
- **ZC:** ***Twin Higgs***

A discussion of the minimal modules and their current status.









- **Harnik:** **Cancelation in strongly coupled UV completions of minimal twin Higgs module is not guaranteed. Works in O(8), but not U(4).**

New Low Energy Modules

Katz: ***The fraternal twin Higgs***

- **Below 5 TeV, the only mirror states in low energy theory are those required by naturalness or consistency (anomaly cancellation).**
- **No light quarks, so lightest mirror hadrons can be glueballs.**
- **Exotic pheneomenology, such as displaced vertices.**

Torre: ***Exceptional twin Higgs***

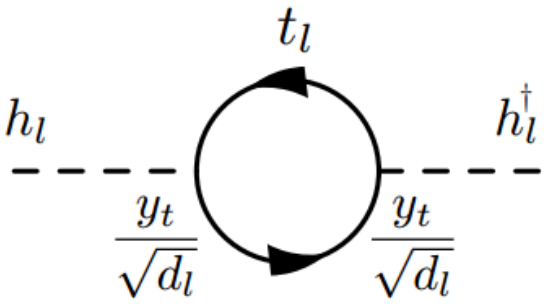
- **Based on $SO(7)/G_2$ coset. Low energy spectrum is fraternal.**
- **Twin partners carry electric charge!**

Batell: ***3 right-handed neutrinos as top partners***

- **Mirror color is not gauged.**
- **Neutrino Yukawa couplings can be large.**
- **Can be probed in tests of lepton universality & lepton flavor violation.**

Craig & Knapen: *Neutral Naturalness from Orbifolds*

- **Orbifolds are organizing principle for theories of neutral naturalness.**
- **Orbifolds can be used to find novel realizations of these theories.**
- **The number of top partners need not be 3 !**



$$\delta m_{h_l}^2 = -\frac{N_c d_l}{8\pi^2}\frac{y_t^2}{d_l}\Lambda^2$$
$$= -\frac{N_c}{8\pi^2} y_t^2 \Lambda^2$$

Pinner: *Less Folded Supersymmetry*

- **Can obtain EW symmetry breaking by not doing full twist.**
- **Not completely colorless.**
- **At present, not significantly constrained. Very mild tuning.**

UV Completions of the Twin Higgs

Howe: ***Supersymmetric UV Completion of the minimal module***

- **Improves fine-tuning relative to NMSSM. Maintains unification.**
- **The twin Higgs may be kinematically accessible. Di-Higgs resonance.**

Geller, Tesi & Wulzer: ***Composite twin Higgs***

- **Based on RS (Geller) and 4D constructions (Tesi, Wulzer)**
- **Composite top sector leads to a firm prediction of states with mixed SM and twin quantum numbers.**
- **Precision EW presents a more severe constraint than LHC.**
- **The mirror spectrum can be close to fraternal.**

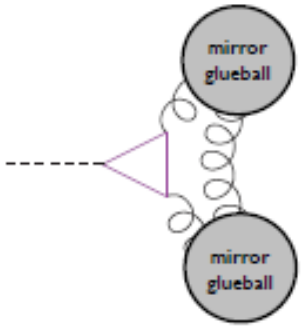
Phenomenology of Neutral Naturalness

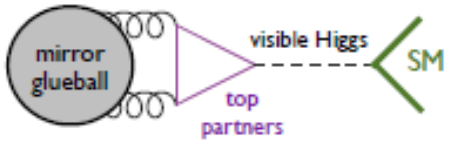
Farina: ***Precision Higgs studies***

- **Precision Higgs studies at future lepton colliders will powerfully constrain the existing models of neutral naturalness.**

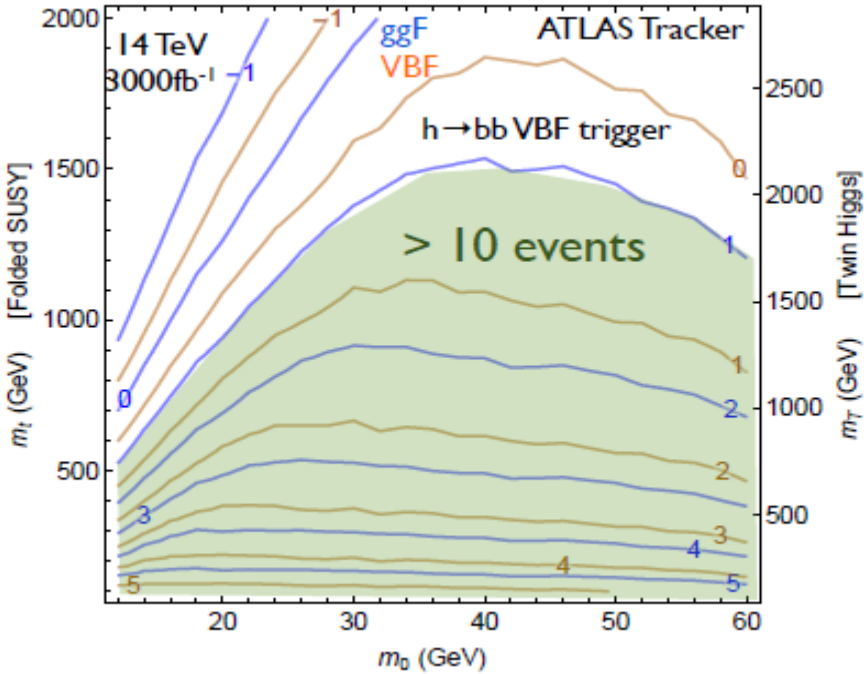
Curtin: ***Higgs Portal to Mirror Color***

- **In scenarios where mirror sector has no light quarks, Higgs decays to mirror glueballs are a powerful probe.**
- **The mirror glueballs typically decay with displaced vertices.**





0903.0883 Juknevich, Melnikov, Strassler
0911.5616 Juknevich
1501.05310 Craig, Katz, Strassler, Sundrum



Cosmology of Neutral Naturalness

Lee: ***SIMP Dark Matter & Neutral Naturalness***

- **Dark QCD in theories of neutral naturalness can accommodate SIMP dark matter.**

Farina: ***Dark Matter in Mirror Twin Higgs***

- **Mirror baryons can be asymmetric dark matter in mirror twin Higgs.**

March-Russell: ***Dark Matter in Mirror Twin Higgs***

- **Many possible DM candidates. Often multi-component.**
- **Natural asymmetric DM candidates are fraternal taus or bottoms.**

Schweiller: ***Gravitational Waves in Twin Higgs Scenario***

- **Twin QCD may have 1st order phase transition → gravitational waves.**

Competition to Neutral Naturalness

Csaki: ***Dynamical RPV***

- **Non-holomorphic RPV can sometimes dominate.**
- **Non-prompt RPV supersymmetry now tightly constrained.**

Hyung Do Kim: ***Higgs with Coleman- Weinberg potential***

- **Predicts deviations in Higgs trilinear coupling.**

March-Russell: ***Scherk-Schwarz supersymmetry breaking***

- **Additional source of supersymmetry breaking to cancel cosmological constant drives electroweak symmetry breaking.**
- **Low tuning.**

Is neutral naturalness the beautiful reason we haven't seen anything, or the last desperate hope of theorists?

Gian

My Perspective

The basic modules look fine, BUT . . . .

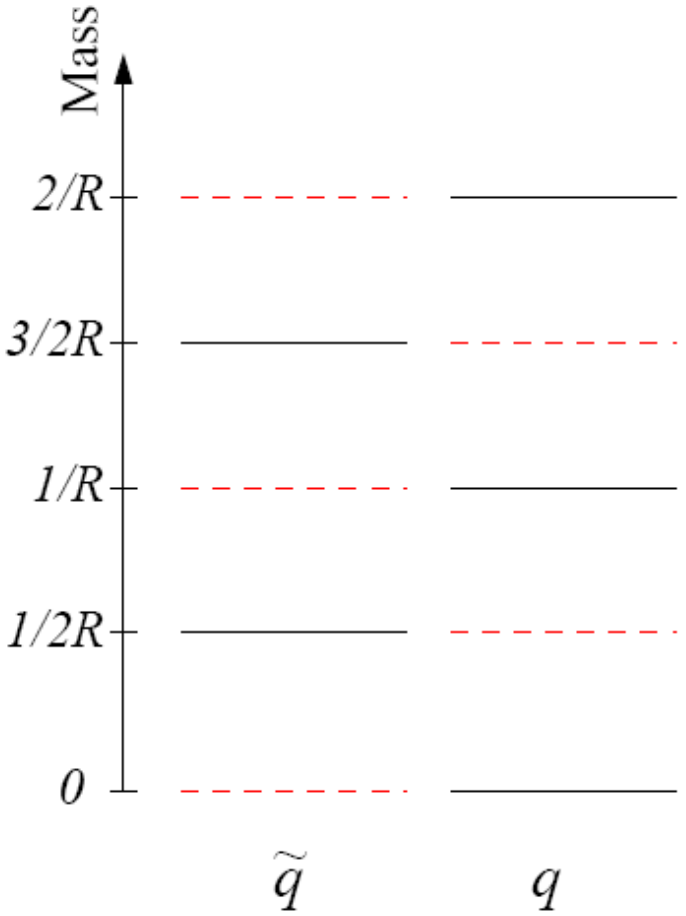
a UV completion is needed to be able to discuss in a comprehensive way issues like flavor, cosmology, and even naturalness.

We saw UV completions of the twin Higgs based on the supersymmetry and composite Higgs frameworks.

But no UV completions of folded supersymmetry.

Nevertheless, neutral naturalness has already motivated several interesting searches.

An obstacle to 4D UV completions of folded supersymmetry.



If discrete symmetry and supersymmetry are exact in the UV, then equal numbers of fermions in SM and F-sectors. Heavy fermions have vector-like masses. SM sector has odd number of fermions, unlike F-sector.

Thanks to the organizers for a wonderful workshop!