Displaced Decays & Hidden Showers

Constraining Uncolored Naturalness with Hidden Glueballs

HXSWG Exotic Higgs Decay Meeting
Fermilab

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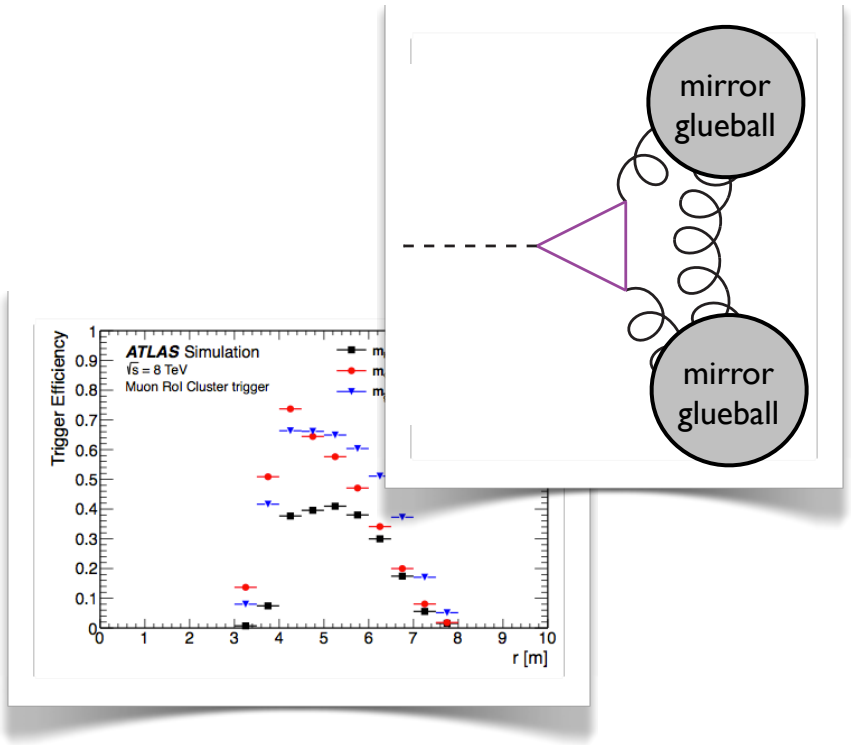
David Curtin
University of Maryland

based on
DC, Verhaaren [in preparation]



LHC reach for uncolored Naturalness

Can classify solutions to Hierarchy problem by physical properties of the top partner. Glueballs *can* be present in Twin-Higgs-type theories...

1501.05310 Craig, Katz, Strassler, Sundrum

... but are *required** to be there for Folded-SUSY-type theories.

⇛ **Spectacular exotic Higgs decays h→glueballs→SM**

DC, Verhaaren [in preparation]

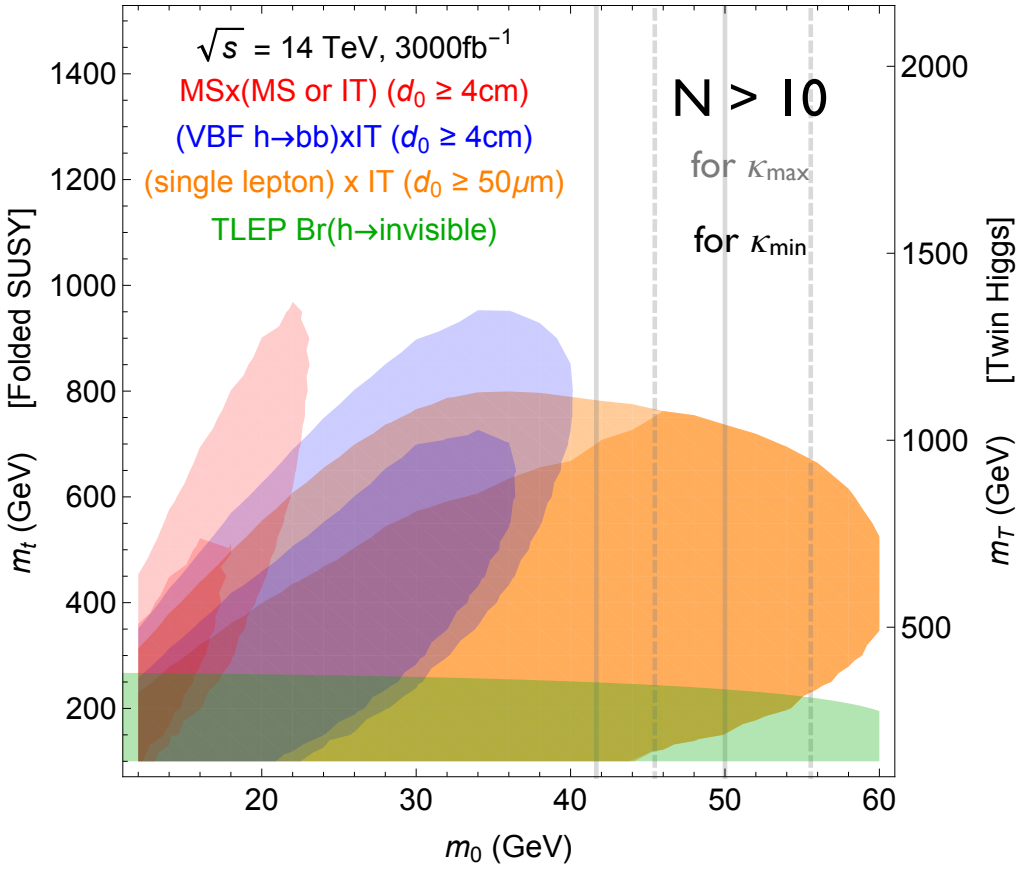
If glueballs are present, masses of 10-60 GeV preferred by RG.

With Hidden Glueballs

	scalar	*fermion*
colored	SUSY	CH/RS
EW	Folded SUSY	Quirky Little Higgs
singlet	?	Twin Higgs

up to ~ TeV reach at HL-LHC!

Glueballs are *Smoking Gun* of Folded SUSY!

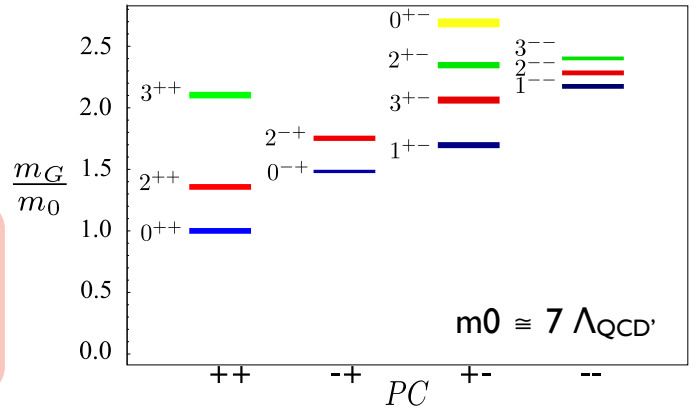


Hidden sector hadronization

To estimate discovery reach for h → glueballs:

1. Assume h always decays to TWO glueballs.
   This is Pessimistic!
2. Define parameter

$$\kappa = \frac{\mathrm{Br}(h \to 0^{++}0^{++})}{\mathrm{Br}(h \to g_B g_B)\sqrt{1 - \frac{4m_0^2}{m_h^2}}}$$



Naively, expect κ to lie somewhere between

κ_{max} = 1 and κ_{min} = Br of phase space factors (democratic decay)

But could in principle have additional ≲10x enhancement or suppressions from NP effects (h-$0^{++(n)}$ mixing) for certain m_0.

→ Obtain signal estimates for range of κ, say $\kappa = \kappa_{min}$ and $\kappa = \kappa_{max}$.

→ Can interpret each search as a κ-exclusion in the (m_0-M) parameter space.

With some reasonable assumptions on κ this becomes an actual exclusion on the parameter space.

This simple approach works for glueballs (few states, large lifetime differences). Would need something different for `hadronic' hidden valleys, but maybe observables more robust (higher multiplicity, fewer lifetime differences?).

How to estimate LHC sensitivity

Displaced Vertices (DV) are a pain. How to model simply?

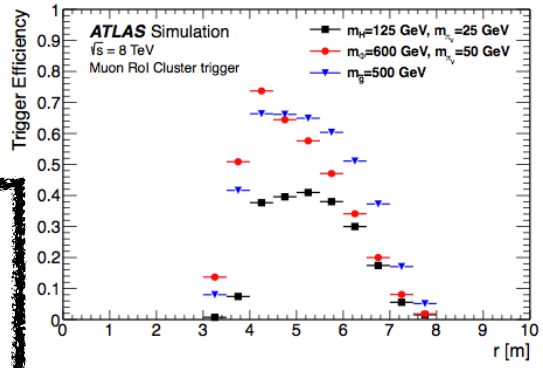
Compute number of *detected* h → 0^{++} 0^{++} → 4b (displaced) decays:

Signal Cross Section: SM higgs production, exotic decay branching ratios

Kinematics: MG + Pythia, simulate p p → h → s s → 4b

Non-DV Detector: PGS or Delphes is fine for standard trigger efficiencies.

DV: ATLAS efficiency curves for equivalent hidden valley model, convolve with decay probability event-by-event for given life-time.

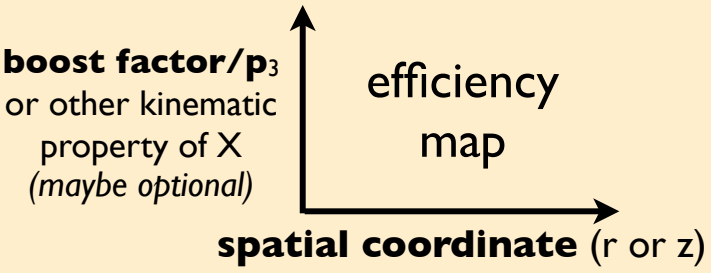


That was easy! To facilitate future DV studies, need 'standard b-tag curves' for displaced decays!

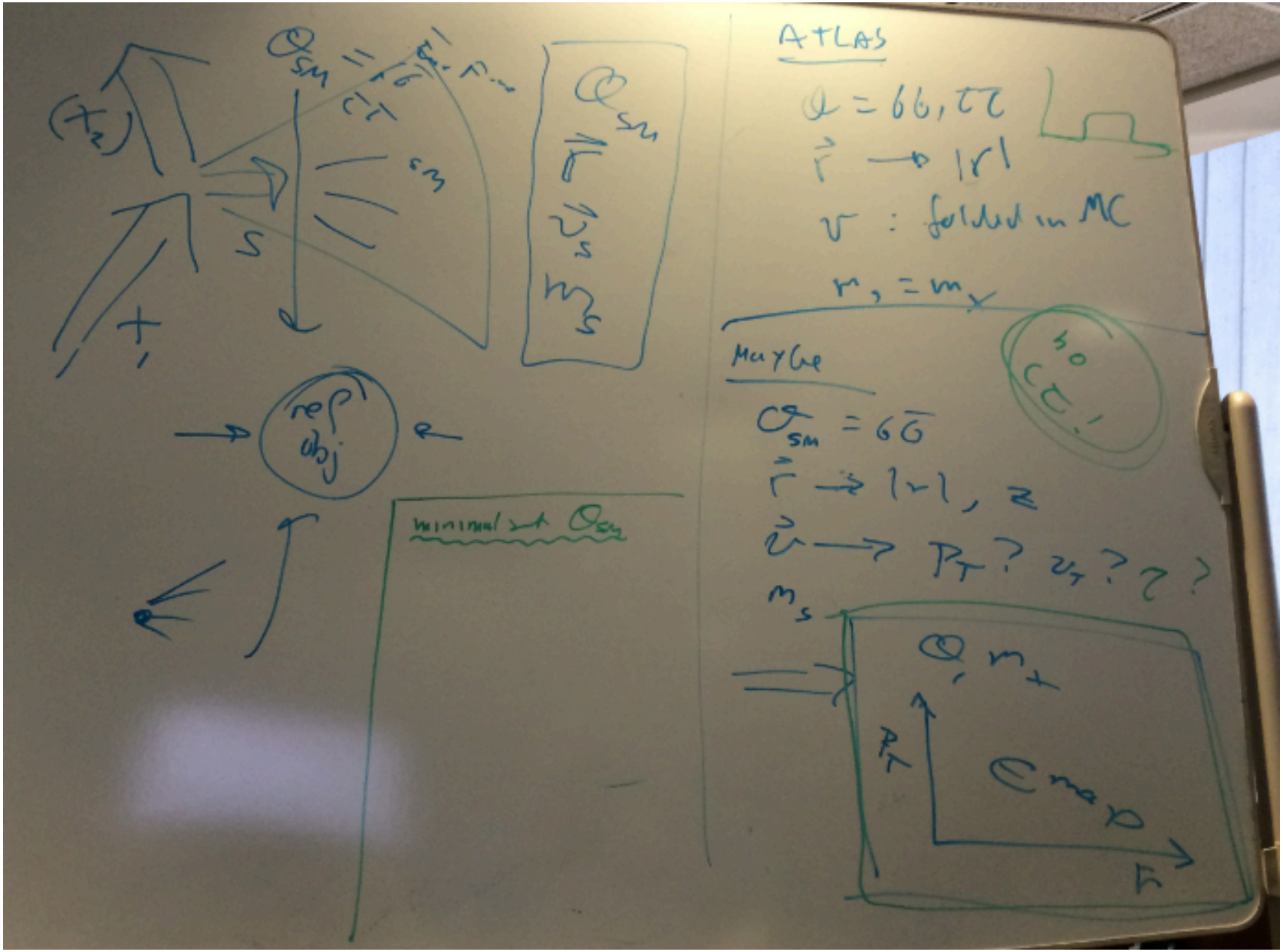
Suggested Parameterization: [ALREADY IN DISCUSSION :)]

For starters, assume DV are `factorizable' from rest of event (no 'fireworks').

Then, for a **given** parton-level decay **X→{y}** and mass **m_X**.



This would increase # of DV theory studies by order-of-magnitude :).


ATLAS
MuyGe

Discussion

Experimentally, two regimes for hidden valley/shower type models: (yes?)

1) isolated DVs.

→ definition of 'standard objects' facilitate searches. eff maps for th studies.

2) many DVs. "Fireworks" or "Emerging Jet" regime see e.g. 1502.05409 Schwaller, Stolarski, Weiler

→ individual DV's difficult, but could use 'easier' 'collective' observables?

some overlap between (1) and (2). (2) is MORE conspicuous. (?)

What variables/searches catch (2)?

do these two limits cover everything?

Hidden sector uncertainties: THEORIST'S JOB

?? DISCUSS ??

→ parameterize uncertainties honestly & exhaustively

(1) for small # DV, can probably use nuisance parameters for mult/hadron chem

these uncertainties should not greatly affect search design (?)

(2) for large # DV,

→ benchmark hidden showers have to span range of 'unknown' params

make sure exp analyses don't overtrain on unphysical properties

Does this cover what we need for DISCOVERY?

Separate issue: DIAGNOSIS!

what properties of discovered events should exps report to allow th's to disentangle hidden sector?