New Correlations or New Signatures?

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LHC New Physics Forum

preamble

- I am not sure what the convenors wanted…
- As an experimenter, I will not try to talk about the theory.
- So I interpret the phrase

New Correlations or New Signatures

with the mind of an experimenter.

- I hope this will not be too pedestrian!

Anticipating Discovery: Approaches from Theorists

There is a very wide range of approaches –
all of them worthwhile, none of them complete.

I will try to outline them, as I see them, followed by approaches from experimenters.

Approaches from Theorists, con't.

Very Specific Signatures

A theoretical solution to some outstanding problem leads to a prediction for a specific signature for the LHC (or Tevatron, ILC, etc.)

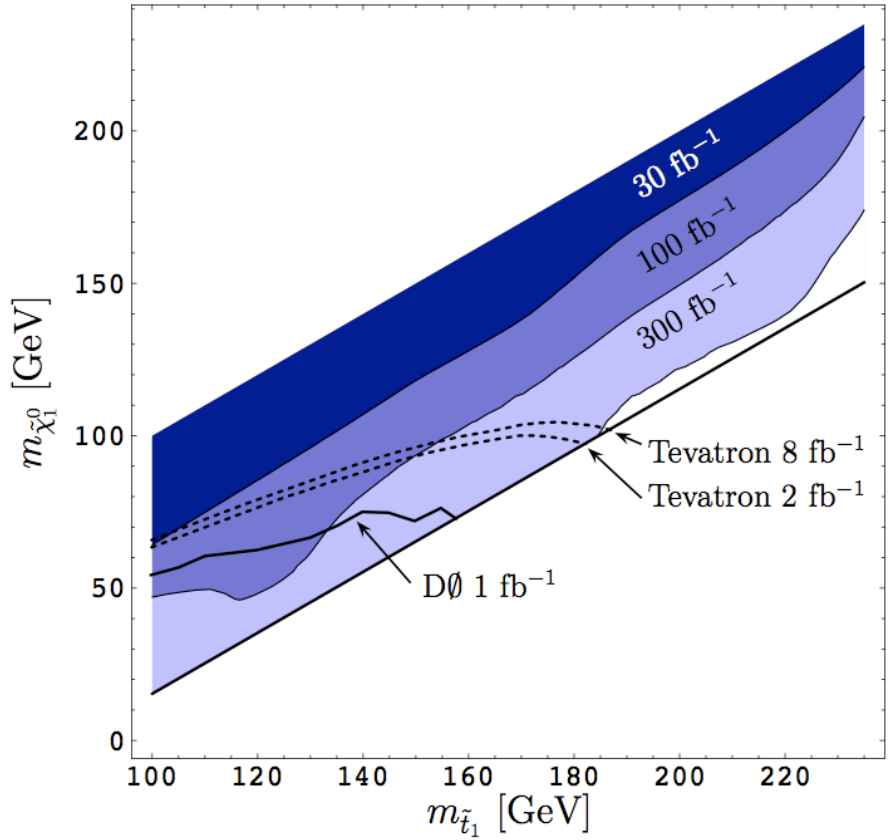
A. Freitas

example: *light stops* predicted in theories of electroweak baryogenesis

Such cases can be confirmed or confounded, in principle.

LHC is useful for testing the specific idea, but little is learned in a broader sense.

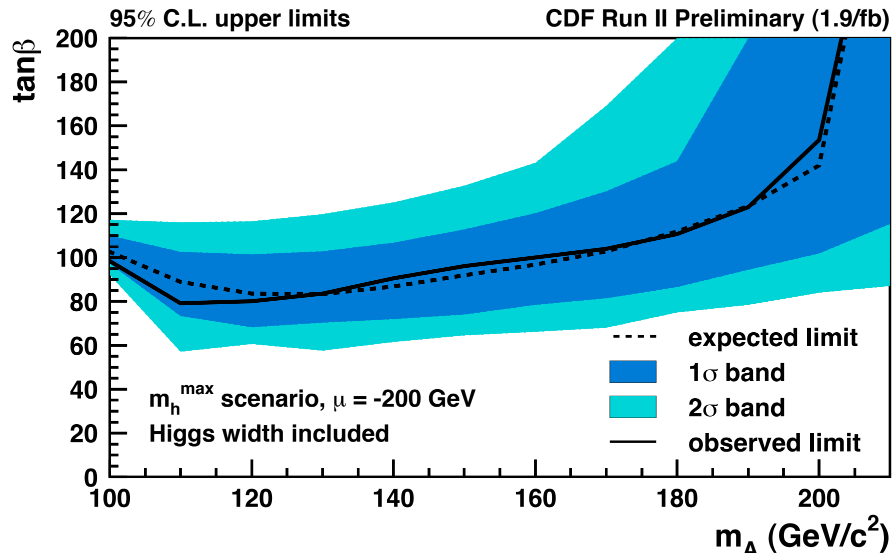
Is it correct? - a bit of a long shot.



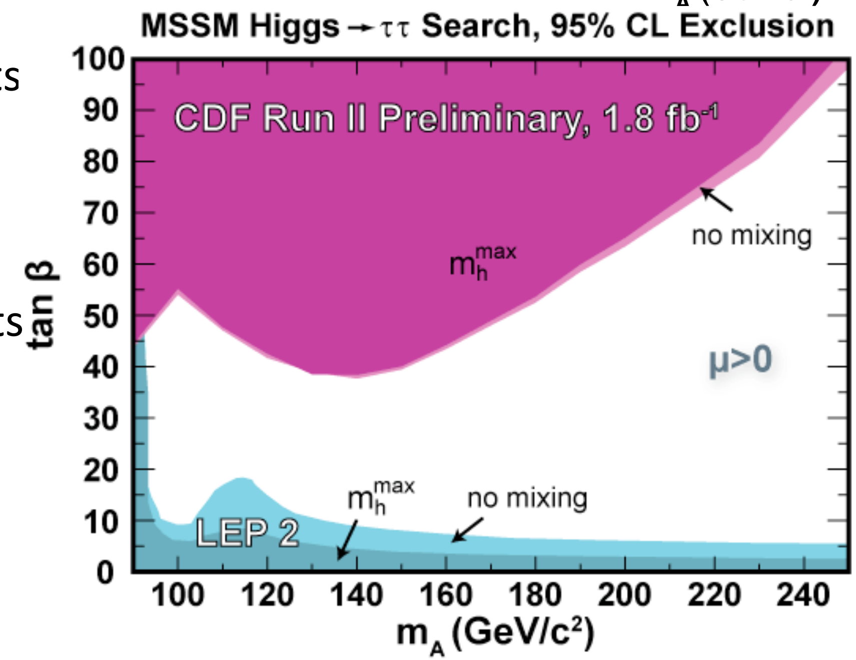
Approaches from Theorists, con't.

General Sectors

example: two Higgs doublet model, as in the (N)MSSM



This gives a set of related, interlocking signatures for discoveries and measurements



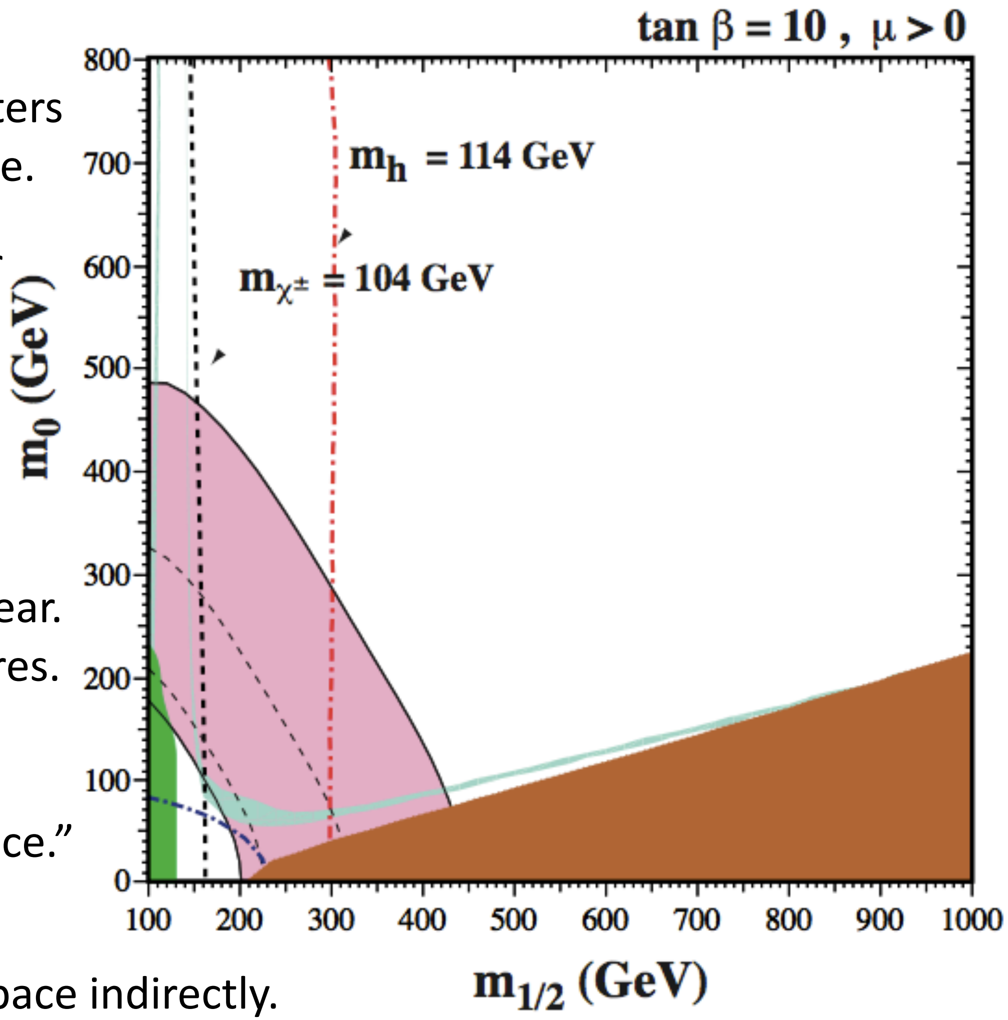
A series of observations and measurements could confirm and ultimately constrain the parameters related to this sector.

Likely true if theorists are on the right track.

Approaches from Theorists, con't.

Restricted Models

J. Ellis et al.



Arbitrarily reduce the freedom of parameters of a model so as to make it more predictive.

Also, potentially, constraint the parameter space using precision measurements, etc.

examples: CMSSM, UED, littlest Higgs

General outlines of the phenomena are clear. Sometimes striking, characteristic signatures.

Difficult to rule out.
Different models overlap in "signature space."

May be possible to constrain parameter space indirectly.

Approaches from Theorists, con't.

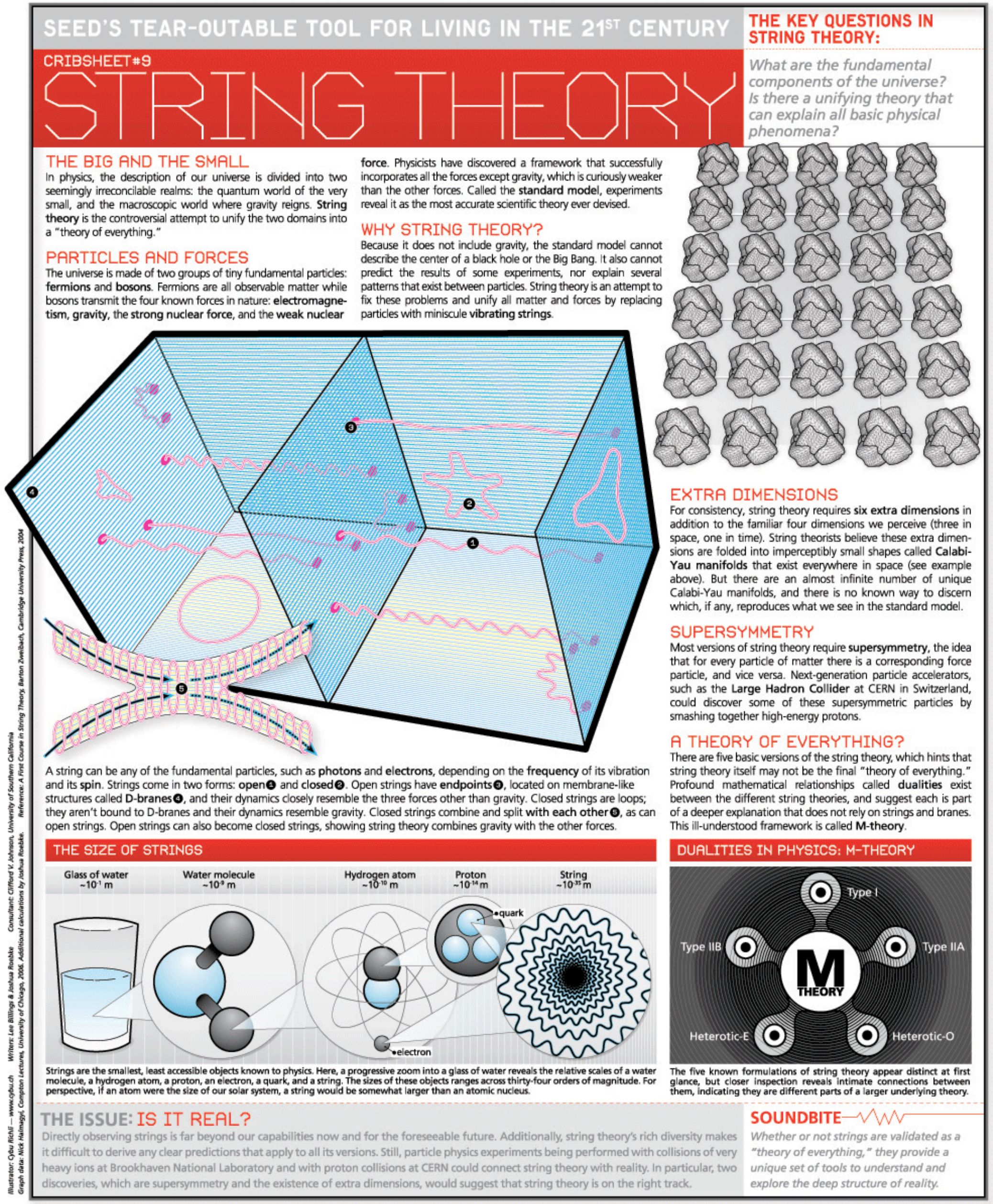
Unrestricted Models or Classes of Models

examples: SUSY, Extra Dimensions, String Theory, Hidden Sectors, …

These are too broad for general characterizations.

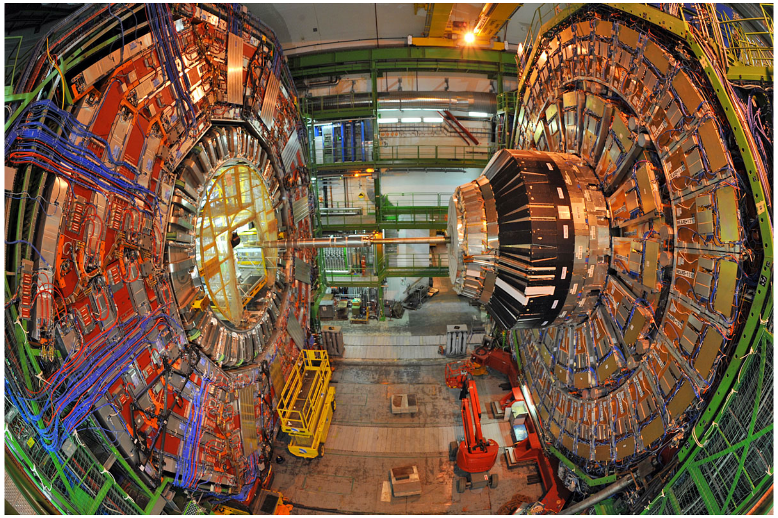
Can't be ruled out or falsified – almost by construction.

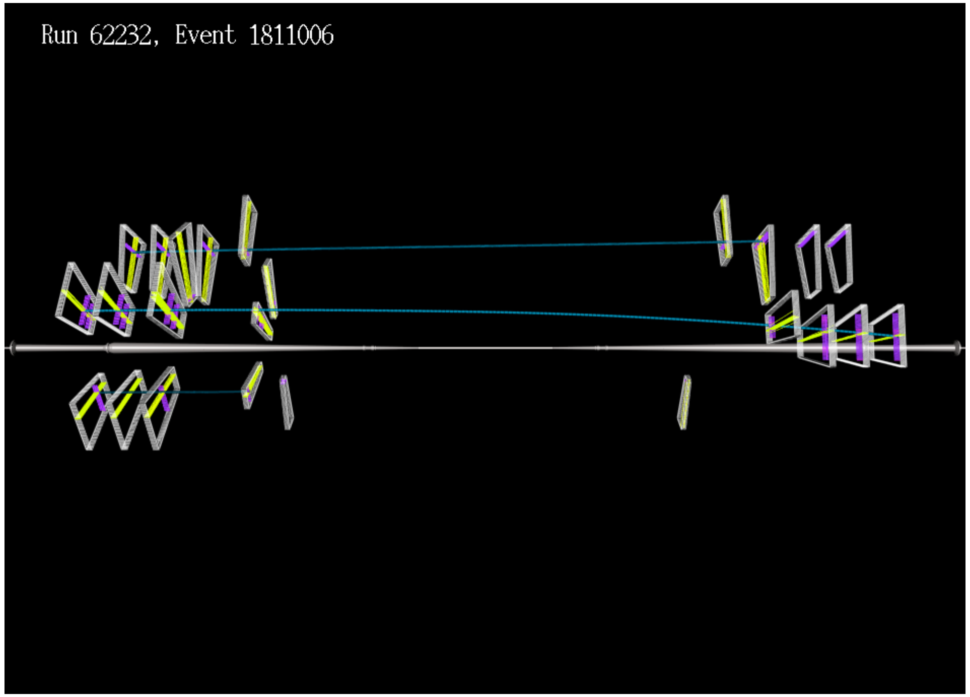
Fairly like to contain some truth about Nature, somewhere?



Anticipating Discovery: Approaches from Experimenters

Generally the experimenters have been busy building CMS and ATLAS (as well as analyzing data from the Tevatron).





That said, I perceive two distinct competing approaches…

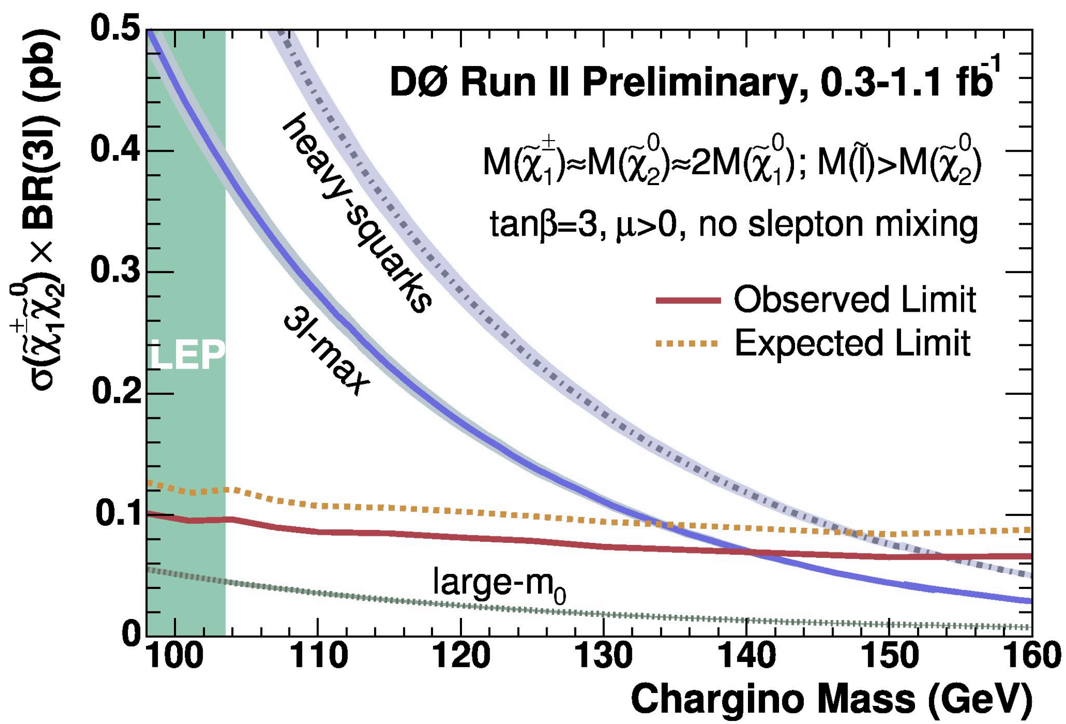
Model-specific Searches (or Model-inspired Searches)

Attack specific models / scenarios proposed by theorists.

Very much a theory-driven enterprise.

Might be useful for constraining the given theoretical framework.

Hit or miss?



Signature-based Searches

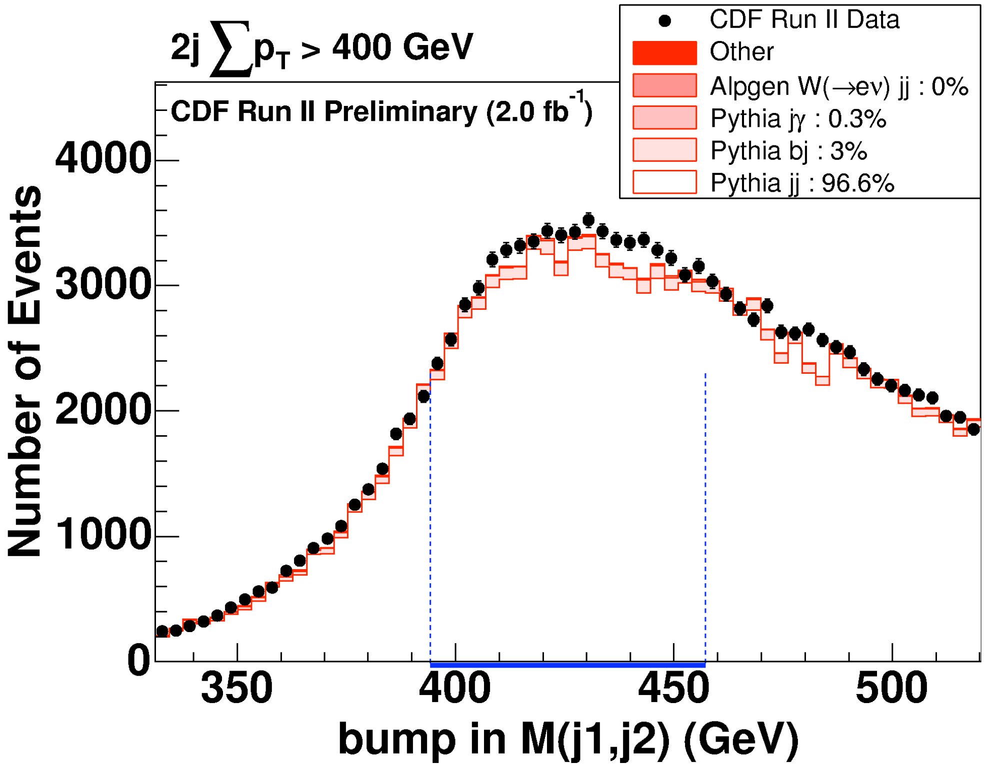
Rebel against theoretical guidance.

"Follow the data."

Will tend to be limited to what appears in SM event samples.

Unlikely to uncover very small or very peculiar signals.

One might end up staring at problems of systematics which have no bearing on new physics.

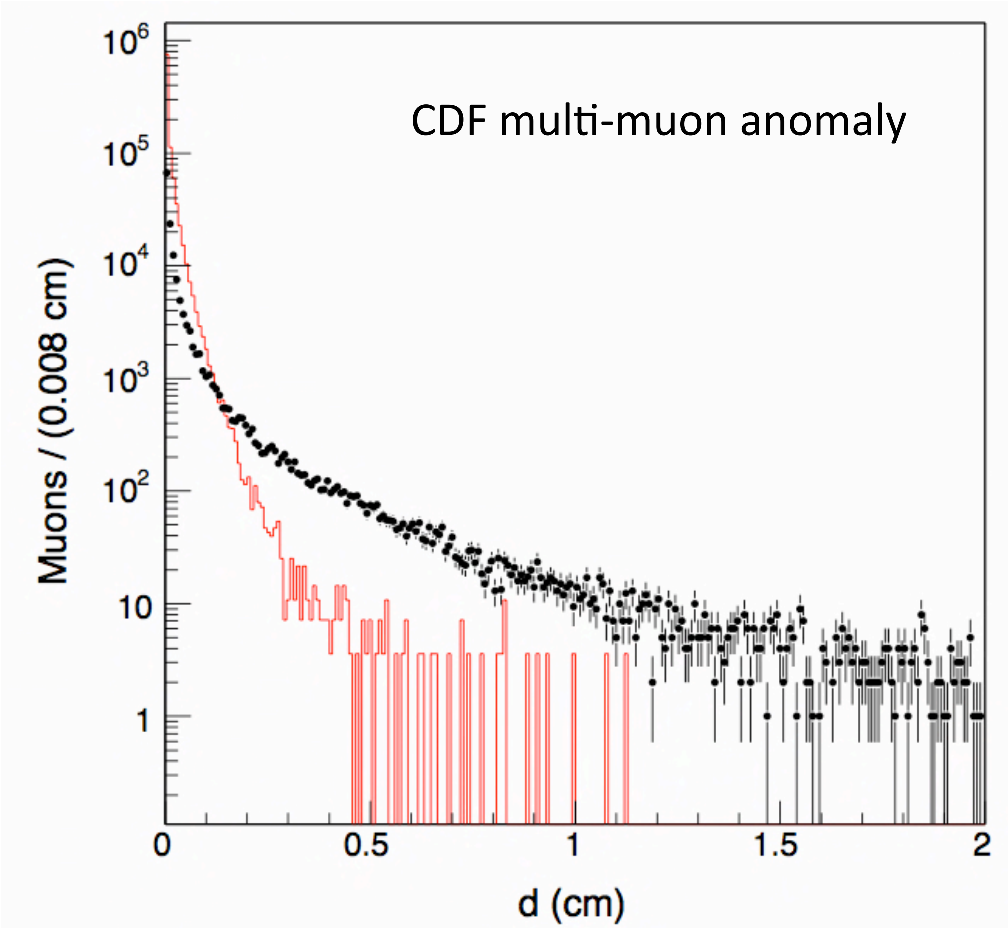


Experiment vs. Theory

Nearly everyone would like to see experimental data defy theoretical prejudice.

"Nature is too grand for us to figure out without data from experiments."

But sometimes experiments are wrong – and violate known laws of physics.



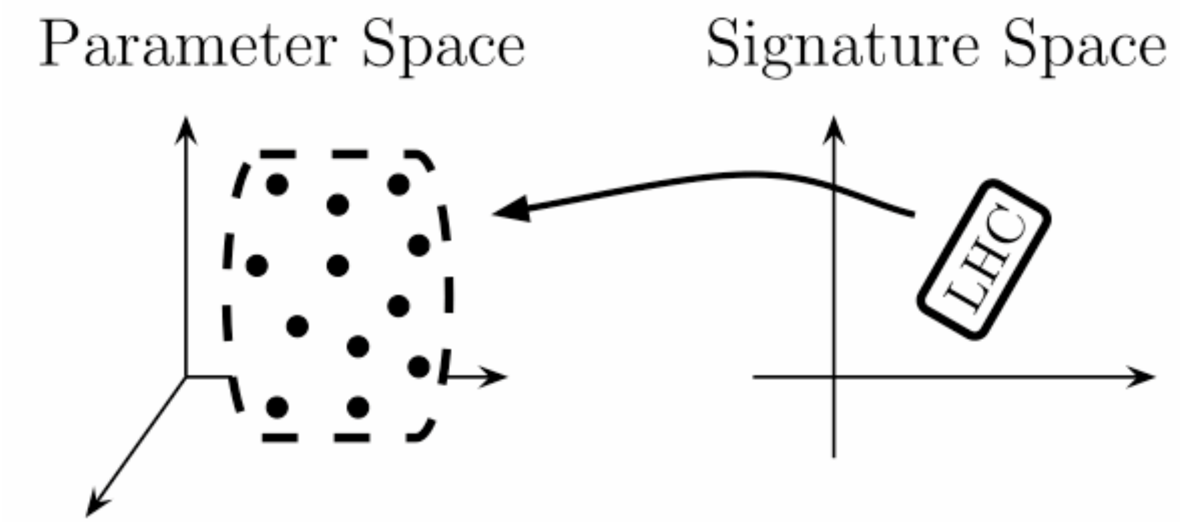
To what extent will theory help us to separate "good" results from "bad" ?

<u>Theory:</u> you can't live with it, and you can't live without it…

Hybrid Approaches (The Middle Way)

The Inverse Problem

Try to map experimental observations onto unconstrained classes of models.



Arkani-Hamed et al.

Hybrid Approaches, con't.

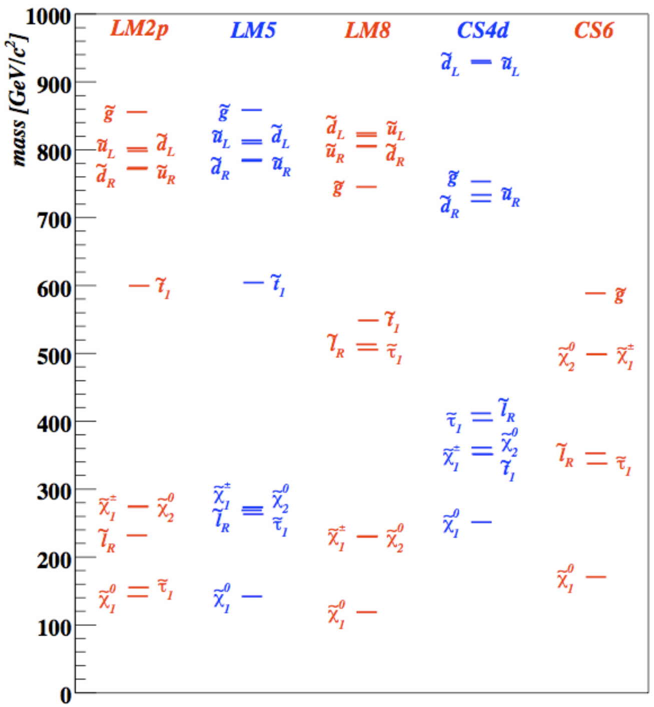
- assume generic low-energy minimal SUSY
- a set of observations and measurements map onto a set of distinct "islands" in parameter space
    - these islands correspond to qualitatively different models
        - this is the real point, after all…
- there are a finite, manageable number of degeneracies (10 – 100)
    - these would present a challenge, but not a hopeless one
- degeneracies have clear-cut relationships:
    - "flippers" – model A and model B have interchanges some particles
    - "slides" – model A and model B have same mass differences
    - "squeezers" – model A and model B have some particles very close together in mass
- this toy analysis is based on simple kinematic quantities – effective and invariant mass
    - curious quantile method
    - quasi-statistical measures to distinguish different signatures and different models
- authors suggest new additional variables could make a difference
    - leptons important since they relate to the electroweak gaugino sector
- outside info may ultimately prove crucial to remove degeneracies
    - EDMs, (g-2)mu, flavor physics precision measurements

This analysis was extended by Hewett et al. to show that an ILC at 1 TeV would resolve many but not necessarily all of these degeneracies.

Hybrid Approaches, con't.

Lykken, Spiropulu & others

Twenty Questions



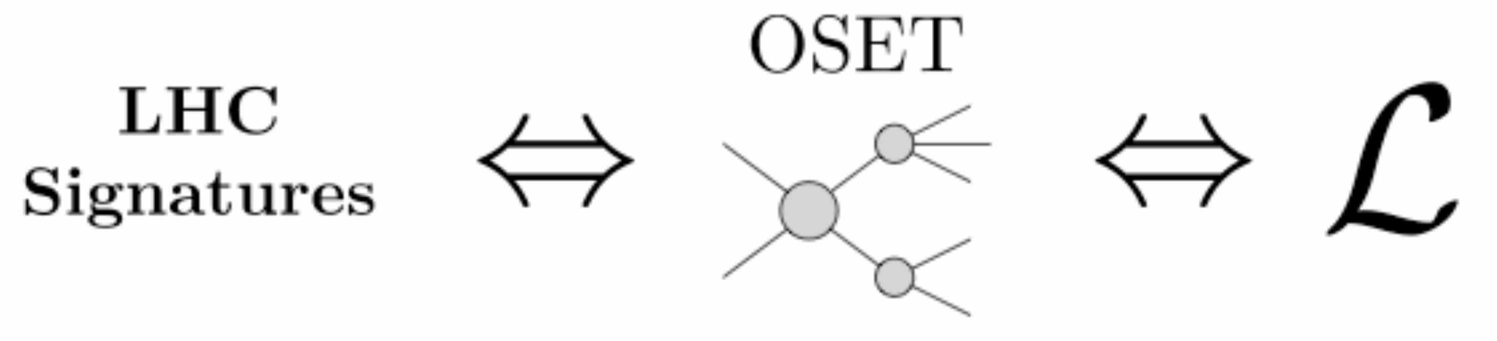
- carefully craft a set of observables
    - event counts from four trigger paths
    - ratios of yields (N jets, n muons)
    - very coarse-grained kinematic distributions
    - event "topology" variables
    - poor (wo)man's tau and b-tagging
- user them to make (sort of) binary decisions
    - consistent with model class A or model class B?
- study assumes an excess in early data an examines the "DM case" only
- pick out a number of candidate theories and make pair-wise comparisons
    - meant to represent potentially difficult cases ("look-alikes")
    - choice is intelligent and insightful rather than exhaustive
    - look for one quantity which is highly discriminating for any given pair
- conclusion is that a small amounts of data are sufficient to resolve most look-alikes
- more extensive investigations in the offing

Hybrid Approaches, con't.

Empirical Lagrangian Methods

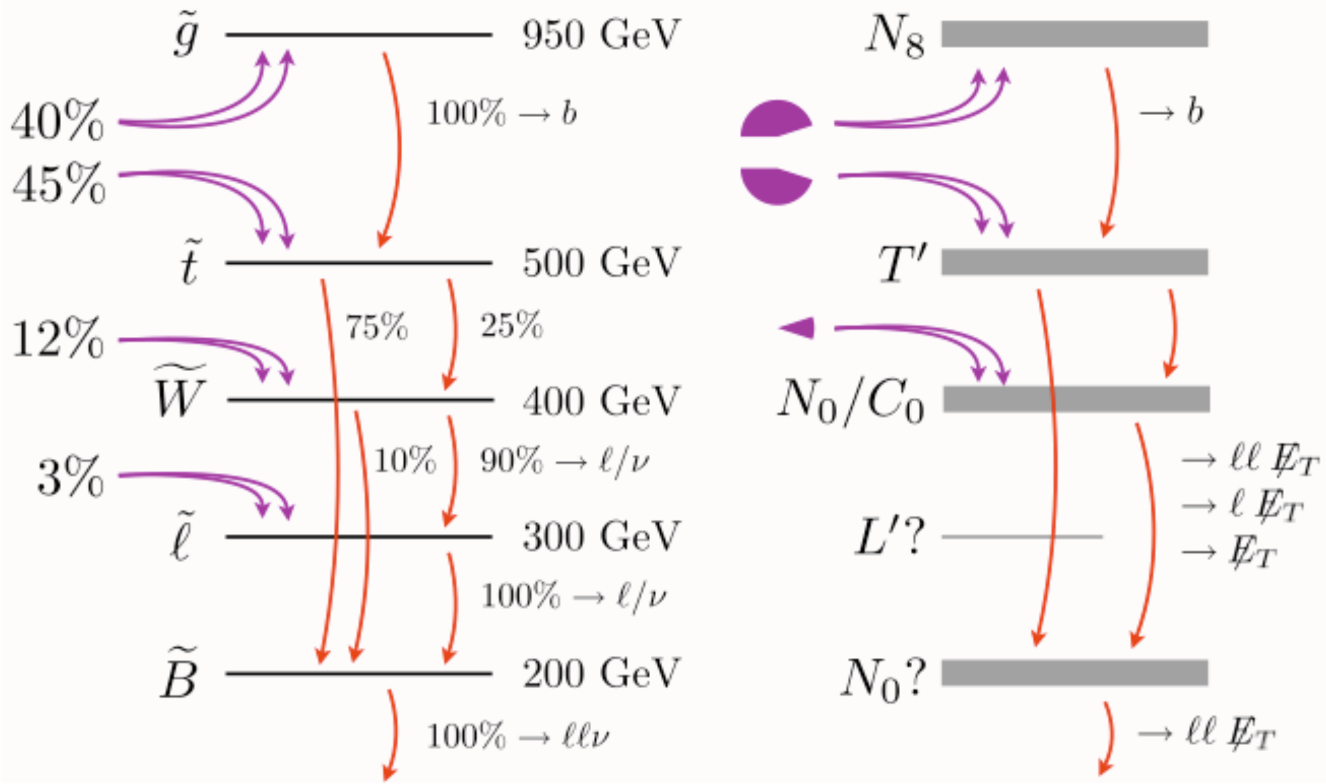
MARMOSET
Arkani-Hamed, Mrenna, others

on-shell effective theory



- imprudent to try to construct the full Lagrangian in the absence of sufficient information
- LHC observations amount to production mechanisms and decays
  - effective Lagrangian methods with free parameters can describe these well
  - fit the parameters to describe the data
  - correlations among processes are taken into account
  - no "extra" mathematical structure to obscure the process
  - analogous to, for example, the Michel parameters in muon decay
- note wedded to any specific model or phenomenology
- afterward, check whether model X is consistent with the fitted parameters

Hybrid Approaches, con't.



- given examples demonstrate impressive success (see above)
- additional independent observables will help
- not an automatic process – requires human thought and guidance
- of course!

Hybrid Approaches
(The Middle Way)

- These happy friendships between the theory and experimental community bode well for the success of the LHC program.

- one good point: these latest methods are more data-driven, and the studies are limited but still good “dress rehearsals” for what we will have to do when the data arrive.

- one weak point: in essence, they are still driven by known classes of models
  (is anything else even possible?)
  - one assumes ultimate consistency with at last <u>some</u> model.

a parting comment / question

What happens if multiple "signatures" appear?

e.g., Jets+MET <u>and</u> a Z' ?

e.g., gravitons <u>and</u> a metastable stau ?

e.g., 4^{th} generation b' <u>and</u> photons + met ?

Do we question the signals, simple extend the theories, oder ?