Simplified Models at the LHC

October 7, 2010

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Princeton Center for Theoretical Science

An update on the outcomes of the SLAC Topologies '10 Workshop
Organizers: Rouven Essig, ML, Philip Schuster, Tim Tait, Natalia Toro, Jay Wacker

Timeline

Characterization of New Physics at the LHC

Joint ATLAS/CMS/LPCC workshop in June @ CERN

http://indico.cern.ch/conferenceDisplay.py?confId=94910

Outcome:
Invitation to theorists for suggestions on how to include more theoretical possibilities in the planning of LHC searches

Workshop on Topologies for Early LHC Searches

Sept 24-26 @ SLAC

lhcnewphysics.org

Characterization of New Physics at the LHC-II

Nov 5-6 @ CERN

http://indico.cern.ch/conferenceDisplay.py?confId=107769

SLAC Topologies ’10

Organizers: Rouven Essig, ML, Philip Schuster, Tim Tait, Natalia Toro, Jay Wacker

An opportunity for the theory community to propose a set of “good” models to guide the search and characterization of new physics at the LHC

Over 100 participants, international presence

Leptons

S. Chang
W. Cho
J. Evans
E. Izaguirre
J. Kaplan
M. Lisanti
M. Luty
M. Nojiri
T. Okui
M. Park
M. Perelstein
J. Ruderman
V. Sanz
P. Schuster
D. Shih
S. Su
T. Tait
B. Thomas
S. Thomas
N. Toro
J. Wacker
F. Yu

Hadrons

D. Alves
J. Gainer
M. Gomez
E. Izaguirre
C. Kilic
M. Nojiri
D. Krohn
M. Schwartz
J. Shelton
M. Spannowsky
M.Strassler
J. Wacker

Resonances

Y. Bai
H. Cheng
J. Evans
A. Freitas
T. Han
J. Hewett
T. Liu
V. Rentala
S. Su
T. Tait

Photons

P. Fox
R. Kitano
T. Okui
D. Shih
T. Roy
J. Ruderman
S. Thomas

Exotics

S. Chang
M. Baumgart
R. Essig
J. Hubisz
D. Krohn
P. Meade
D. Morrissey
M. Papucci
D. Phalen
J. Shao
T. Volansky
I. Yavin
K. Zurek

Heavy Flavor

M. Buckley
R.S. Chivukula
L. Fitzpatrick
R. Francescini
P. Fox
J. Kaplan
P. Ko
E. Kuflik
R. Lu
S. Mrenna
M. Peskin
K. Rehermann
M. Schmaltz
M. Schwartz
E. Simmons
C. Spethmann
M. Strassler
T. Tait
N. Toro
W. Waltenberger

The LHC Era

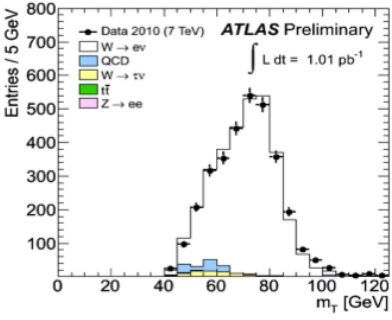
Several pb^{-1} have been recorded to date

100's of tops

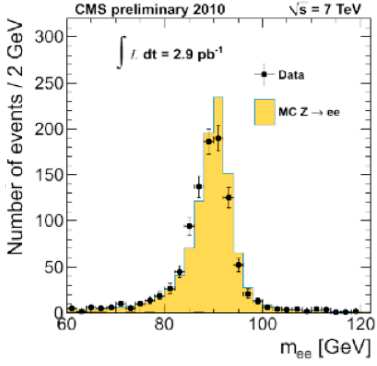
1000's of Z's

10000's of W's

W Boson



Z Boson



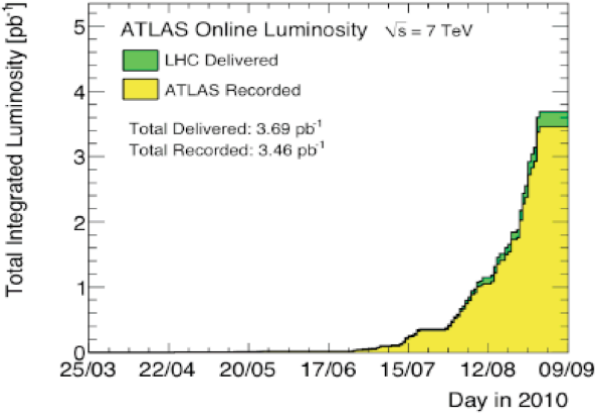
Andy Haas, ATLAS
Frank Würthwein, CMS

The LHC Era

The LHC is already probing new territory

30 pb^{-1} projected by the end of this year

1 fb^{-1} projected for next year



Andy Haas, ATLAS
Wolfgang Waltenberger, CMS

The LHC Era

Critical period for evaluating planned searches and analyses

Develop effective strategies for presenting data in the most useful manner

Don’t want to miss new physics just because we didn’t look

The LHC Era

"What do we want for Christmas?"

-- W. Waltenberger, CMS

Important questions for which theory input is needed now:

What are the critical searches for 20-50 pb^{-1}?

Are there signatures that would be missed by standard triggers?

ex: many low p_T jets

What signatures with non-standard features should be considered?

ex: displaced vertices, same-sign dilepton, taus, no-MET

Paul deJong, ATLAS
Wolfgang Waltenberger, CMS

Outline

Introduction to Simplified Models

Outcomes of Topologies ’10

The Next Step: An Online Reference

Designing Searches

The main ingredients for a new physics search:

1. Design event selection
2. Do the measurement
   a. Estimate background yields
   b. Measured yield of signal candidates

Can be done fairly model-independently

Strive to cover as many corners of SM phase space

3. Determine selection efficiency
4. Calculate cross section

Difficult to do model-independently, which then affects step 4

Model-Independent Searches

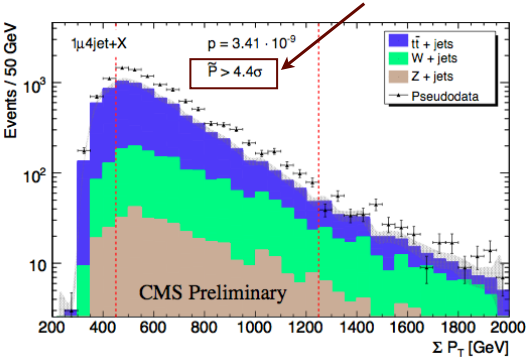
Scan data for systematic deviations from Monte Carlo

ex: MUSiC (EXO-08-005)

selection cuts are not optimized

300-400 classes of events considered

excess due to incorrect characterization in jet energy scale uncertainty



PRO:
very broad coverage to
many types of models

CON:
difficult to claim discovery
(detector effect?)

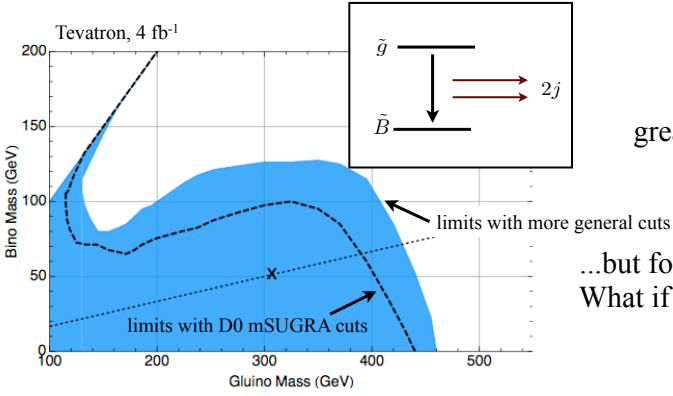
Targeted Searches

Optimize cuts for a particular model

ex: mSUGRA

only five parameters to set MSSM spectrum

often used as benchmark for searches



PRO:
great coverage...

CON:
...but for only one model.
What if that's not reality?

Alwall, ML, Le, Wacker, 0803.0019.

Exhaustiveness vs. Practicality

Exhaustive scans of parameter space useful to show what we are missing

Myeonghun Park:

- all SUSY mass parameters taken as free at weak scale
- lots of leptons!

	$n_v = 0$		$n_v = 1$		$n_v = 2$	
n_ℓ	$n_j = 1$	$n_j = 2$	$n_j = 1$	$n_j = 2$	$n_j = 1$	$n_j = 2$
0	79296	26880	12768	3360	1344	672
1	30240	10080	1824	480	192	96
2	19770	6030	1500	180	0	0
3	4656	1296	312	72	6	6
4	1656	396	66	6	0	0

Konar et al., 1008.2483

Jamie Gainer:

- 19 parameter pMSSM
- detector-stable charginos and models with compressed spectra tend to be missed

Number of analyses	Flat, 1 fb^{-1}	Flat, 10 fb^{-1}	Log, 1 fb^{-1}	Log, 10 fb^{-1}
0	0.56754	0.36796	31.823	27.024
1	1.3458	0.98841	6.2704	6.5374
2	3.396	2.5141	8.9525	10.072
3	13.175	10.635	11.816	11.098
4	22.014	18.455	16.491	16.344
5	9.5512	10.3	5.6905	6.6135
6	15.227	16.929	6.0529	7.1456
7	20.081	17.697	6.7416	6.1954
8	7.6394	11.75	3.0083	4.371
9	3.9205	6.3569	1.5223	2.6226
10	2.0825	2.7943	1.0511	1.1783
11	1.0013	1.2116	0.57992	0.79818

Conley et al., 1009.2539

Exhaustiveness vs. Practicality

Too many possibilities to search through or use every possible BSM reaction or model

Collapse options with common signatures into representative cases

* theory input needed *

Sufficiently striking signatures (e.g., many leptons) do not require dedicated models - inclusive searches are good enough

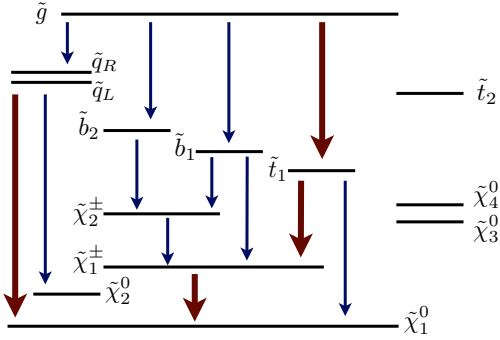
* theory input needed *

A Compromise

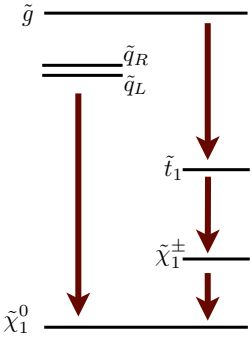
Simplified Models are an intermediate step between a complete theory and experimental signature

Removes complications of model details and allows one to focus on kinematics when designing cuts

Complete Spectrum



Simplified Model



Outline

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Outcomes of Topologies ’10

The Next Step: An Online Reference

Topologies ’10

Four important results from the working groups:

(1)
More complete parameterization of signature space

(2)
Models with the same signature, but different kinematics

(3)
New models or interesting new signatures

(4)
Simplified models that evade standard triggers

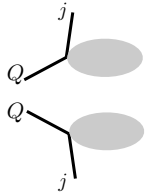
1. Parameterizing Signature Space

Can we write down a simplified model to cover lepton searches with and without MET?

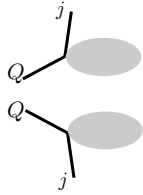
Symmetry arguments help to classify categories of events

Dark Matter
(R-parity, KK-parity, T-parity)

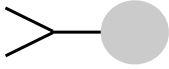
No Dark Matter



pair production



pair production

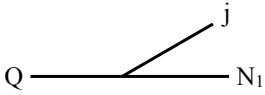


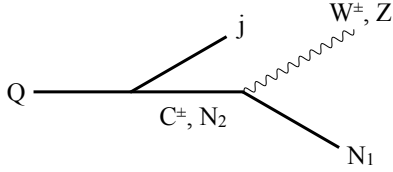
resonance

1. Parameterizing Signature Space

Dark Matter Models

	Q	N_1	N_2	$C^{\pm}$
susy	$\tilde{q}$	$\tilde{\chi}_1^0$	$\tilde{\chi}_2^0$	$\tilde{\chi}_1^{\pm}$
RS/UED	$U_{\rm kk}$	$Z_{\rm kk}^1$	$Z_{\rm kk}^2$	$W_{\rm kk}^{\pm}$



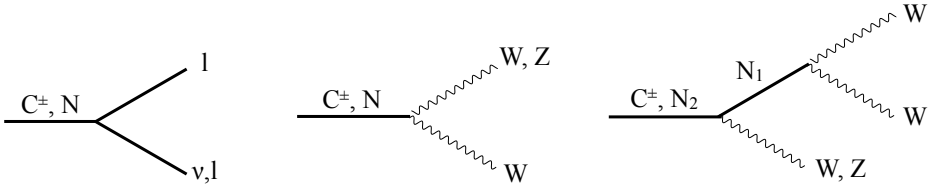


Pair-production gives 0-4 lepton signatures w/MET

1. Parameterizing Signature Space

No Dark Matter

	Q	N_1	N_2	$C^{\pm}$
susy	$\tilde{q}$	$\tilde{\chi}_1^0$	$\tilde{\chi}_2^0$	$\tilde{\chi}_1^{\pm}$
RS/UED	$U_{\rm kk}$	$Z_{\rm kk}^1$	$Z_{\rm kk}^2$	$W_{\rm kk}^{\pm}$



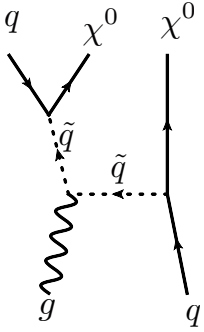
Resonance production gives 1-4 leptons, including 2SSL

no MET

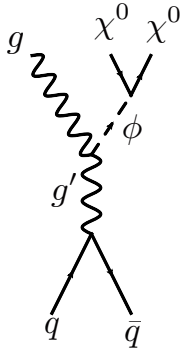
2. Same Signature, Different Kinematics

Four unique models that each give 1j+MET

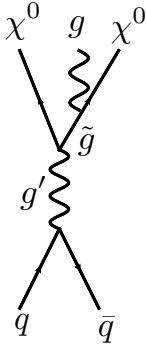
Squark-Neutralino Associated Production



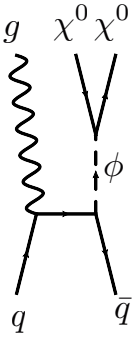
Composite gluon decay to DM



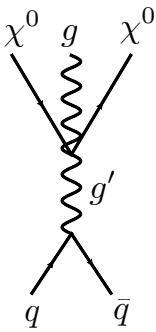
2-body coloron decay



ISR Production



3-body coloron decay

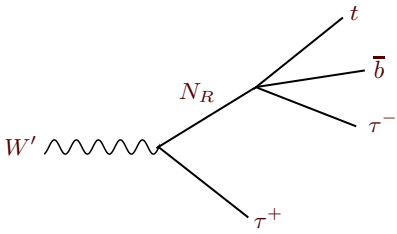


Different models result in different kinematics

3. New Signatures

Resonance Working Group

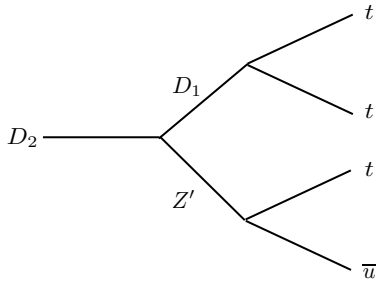
$$pp \to \tau\overline{\tau}t\overline{b}$$



Ex: Left-Right Models

Lepton Working Group

$$pp \to \overline{u}ttt$$



Ex: Diquarks

3SSL!

4. Evading Triggers

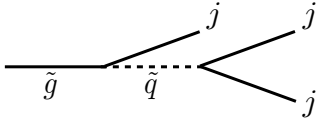
Experiments are in the process of defining triggers for next spring

Bandwidth already saturated;
need to make smart choices about what data to keep

Simplified models that evade standard triggers are useful examples

R-parity violating gluinos

simplified model with many low p_T jets



$$m_{\tilde{g}} \gtrsim 50 \text{ GeV}$$

Kaplan & Schwartz, 0804.2477

$\Rightarrow$ up to 6 jets, each with $p_T \sim 15$ GeV

Outline

Introduction to Simplified Models

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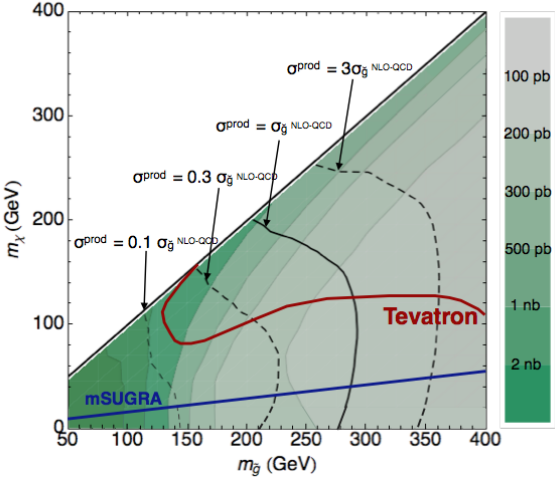
The Next Step: An Online Reference

Write-Ups

Each working group is responsible for writing a brief report for every simplified model

The reports will provide

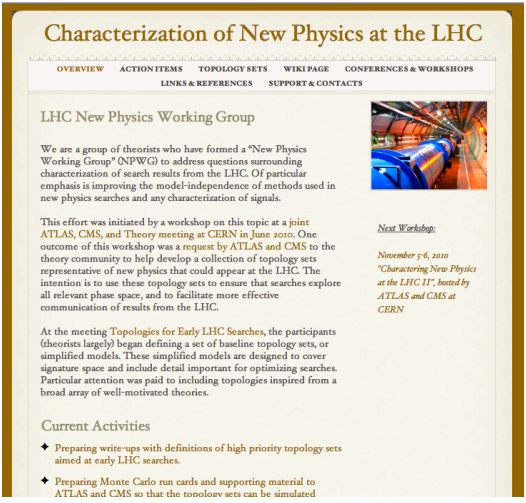
- background for each model
- relevant variables/plots
- existing limits
- possible reach of searches



Alves, Izaguirre, & Wacker, 1008.0407.

Web Resource

www.lhcnewphysics.org



Characterization of New Physics at the LHC

OVERVIEW ACTION ITEMS TOPOLOGY SETS WIKI PAGE CONFERENCES & WORKSHOPS LINKS & REFERENCES SUPPORT & CONTACTS

LHC New Physics Working Group

We are a group of theorists who have formed a "New Physics Working Group" (NPWG) to address questions surrounding characterization of search results from the LHC. Of particular emphasis is improving the model-independence of methods used in new physics searches and any characterization of signals.

This effort was initiated by a workshop on this topic at a joint ATLAS, CMS, and Theory meeting at CERN in June 2010. One outcome of this workshop was a request by ATLAS and CMS to the theory community to help develop a collection of topology sets representative of new physics that could appear at the LHC. The intention is to use these topology sets to ensure that searches explore all relevant phase space, and to facilitate more effective communication of results from the LHC.

At the meeting Topologies for Early LHC Searches, the participants (theorists largely) began defining a set of baseline topology sets, or simplified models. These simplified models are designed to cover signature space and include detail important for optimizing searches. Particular attention was paid to including topologies inspired from a broad array of well-motivated theories.

Next Workshop:

November 5-6, 2010 "Characterizing New Physics at the LHC II", hosted by ATLAS and CMS at CERN

Current Activities

- Preparing write-ups with definitions of high priority topology sets aimed at early LHC searches.
- Preparing Monte Carlo run cards and supporting material to ATLAS and CMS so that the topology sets can be simulated

Simplified model descriptions currently being uploaded to temporary wiki

More permanent website being developed that will include

refereed documents

signature↔model search capability

Christmas Wish List

Topologies ’10 has resulted in a compilation of simplified models that

- span wide regions of kinematic parameter space
- are critical for searches at 20-50 pb^{-1}
- sometimes have non-standard signatures
- sometimes require non-standard triggers