Extra Dimensions Black Holes Dark Matter



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Wither New Physics?

- Standard Model takes a victory lap in 2012.
 - BEH Boson shows up where predicted by EWK asymmetries, top quark mass.
- But new physics?

New physics may well be hiding in some yet-to-be studied signatures.



New ways to think about new physics needed

Large Extra Dimensions



Large Extra Dimensions

- Arkani-Hamed, Dimipolous, Dvali (1998): SM confined to 4-D space-time, gravity free to propagate to 4+ N_{ed} dimensions
 - Solves problem of gravity being weak
 - Solves hierarchy problem
- One manifestation: Infinite tower of Kaluza-Klein towers.
 - Leading order controlled by single parameter: $\Lambda_{\rm T}$
 - Giudice, Rattazzi, Wells (GRW) convention

Large Extra Dimension in Dileptons

- LED shows up in the dilepton mass spectrum.
 Search similar to that for Zprimes.
- CMS searches in dimuon and dielectron.
 - Muons, pt > 45 GeV
 - Electrons, ET > 35 GeV
- Drell-Yan generated with POWHEG+PYTHIA.
- Zgamma*, tt, Z→ditau, ZZ etc. estimated from e-mu data.

Large Extra Dimensions (Dileptons)



Large Extra Dimensions (Dileptons)



CMS-EXO-12-027

Extra Dimension in Leptons



CMS-EXO-12-027, 031

Combined limits in Han, Lykken, Zhang (HLZ) convention.

Limits in the 3-4 TeV range even for high Ned.

M _s (ADD) at LO	Lumi.	δ=3	δ=3	δ=6	δ=6	Λ _T (GRW)
95% CL limits	[fb ⁻¹]	Exp.	Obs.	Exp.	Obs.	[TeV]
CMS dimuon	20.6	4.34	4.33	3.07	3.06	3.64
CMS dielectron	19.6	4.62	4.64	3.27	3.28	3.90
Combined:	20.6+19.6	4.76	4.77	3.37	3.37	4.01

Large Extra Dimensions (Monojet)

- Production of gravitons enhanced by extra phasespace available to in the ED.
 - Once produced, gravitons escape to ED → MET signatures.
- Monojets in detector:
 - Leading Jet > 110 GeV, $|\eta|$ <2.4
 - Allow 2nd jet (not back-to-back), $\Delta \phi$ < 2.5
 - No isolated leptons
 - Measure Z $\rightarrow \mu\mu$ + jets, predict Z $\rightarrow \nu\nu$ + jets

Large Extra Dimensons (monojet)

CMS-EXO-12-048



Good agreement with background expectations

Large Extra Dimension (monojet)

CMS-EXO-12-048



Monojet Candidate Event



Monojets as Dark Matter Signature

- We know Dark Matter exists
- WIMP miracle:
 - TeV scale DM particle with weak coupling produced at just the right density.
 - LHC can produce DM.
 - Search with ISR jet/photon



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Dark Matter with monojets



Dark Matter with monojets



Other invisibles with monojets (unparticles)



Black Holes

"END OF THE WORLD" LHC LAWSUIT TOSSED OUT Andy Chalk | 31 August 2010 12:31 pm

A lawsuit against the Large Hadron Collider has been dismissed because, according to the judge, it won't be the Americans' fault if the French and the Swiss suck the world into a black hole.

Black Holes

- Microscopic black holes
- If created would decay to multiple objects.
 - Jets, leptons, photons...
- Look at $S_T (p_T \text{ sum of } objects \text{ with } p_T > 50 \text{ GeV})$
- Extrapolate from low object multiplicity.



Microscopic Black Holes

CMS-EXO-12-009



ST for Control regions, N=2,3

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Microscopic Black Holes

CMS-EXO-12-009



ST for object multiplicity of 6,7,8 or more.

Black Holes

Black Holes

CMS-EXO-12-009

Model dependent limits on BH production

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ST vs Object Multiplicity

CMS-EXO-12-009

Limits on excess ST (ie new physics) for various object multiplicities.

Jet Extinction

CMS-EXO-12-051

 If black holes (or generally, some non-linear quantum gravity phenomenon) exists, it may not decay to isolated energy "objects".

- We may not even trigger on such events

- However, once the threshold is crossed, SM processes are highly suppressed.
 - Including jet production
 - arXiv:1207.3525 [hep-ph] (Kilic, Thomas)
 - Look for extinction of inclusive jet production.
 - Why inclusive jets? Because it's the biggest xscn there is.
 - Use jets with $p_{\rm T}$ > 592 and $|\eta|$ <1.5

Jet Extinction

Jet Extinction

Analysis driven by PDF and Jet scale systematics

Summary

- New physics will need to be rooted out.
 It does not appear to be "easy" at 8 TeV.
- New models of physics are needed!
 - Have presented a few, many analyses still going
 - Shown very good understanding of MET/ jet spectra, leptons, etc.
- Collaboration between theorists and experimentalists very important
 - Especially now. 2015 is just around the corner.