

8 TeV Non-Resonant Dilepton Search at ATLAS

18.02.15

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Theoretical Motivation

Contact Interactions (CI)

CI encompasses a range of new physics, we are looking at quark-lepton compositeness.

Broad excess deviation from SM¹ invariant mass spectrum, parameterised by the compositeness binding energy scale, Λ .

$$\sigma_{\text{tot}} = \sigma_{\text{DY}} - \eta_{ij} \frac{F_{\text{I}}}{\Lambda^2} + \frac{F_{\text{C}}}{\Lambda^4}$$

3 chiral structures are investigated ($\eta_{\text{LL}}, \eta_{\text{LR}}, \eta_{\text{RR}}$).

Constructive and destructive interference effects between CI and SM are investigated.

Large Extra Dimensions (LED)

To solve the hierarchy problem;

$$M_{\text{Pl}} \sim 10^{16} \text{ TeV} \gg M_{\text{EW}} \sim \text{TeV},$$

ADD² postulated n additional LED.

Gravitons propagate in these LEDs and are observable as a KK³ tower of mass states.

Mass splitting $\sim 1/R$ (observable broad excess from SM invariant mass spectrum)

$$\sigma_{\text{tot}} = \sigma_{\text{DY}} + \mathcal{F} \frac{F_{\text{int}}}{M_{\text{S}}^4} + \mathcal{F}^2 \frac{F_{\text{G}}}{M_{\text{S}}^8}$$

Search parameter M_{S} is related to fundamental Planck scale M_{D} ($\sim M_{\text{EW}}$).

\mathcal{F} is a chosen formalism – 3 are investigated.

Analysis

Searching for non resonant signatures in the dilepton (electron & muon) channel

Event Selection

- Search is conducted in the dielectron and dimuon channels.
- Select two highest p_T , well isolated leptons, with opposite sign charges.

Background Estimation

- Dominant and irreducible Drell-Yan (DY) modeled with Monte Carlo (MC).
- Irreducible Photon-Induced and reducible Top and Diboson processes estimated with MC.
- Multi-jet and W +jets contribution estimated using a data-driven method.

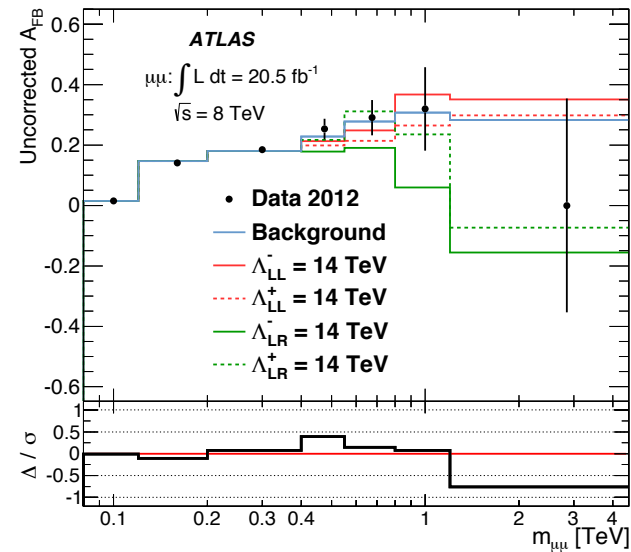
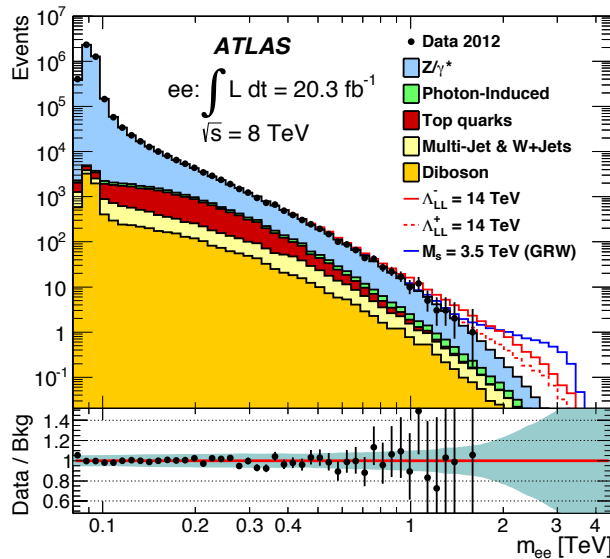
Search Strategy

CI - 6 mass bins – split into forward & backward events depending on decay angle.

LED - single high mass bin, chosen to produce the strongest expected limit.

Results

- Dilepton invariant mass is used as the discriminating variable in both non-resonant searches.



- Lepton decay angle also has high discriminating power from DY events for some CI models.

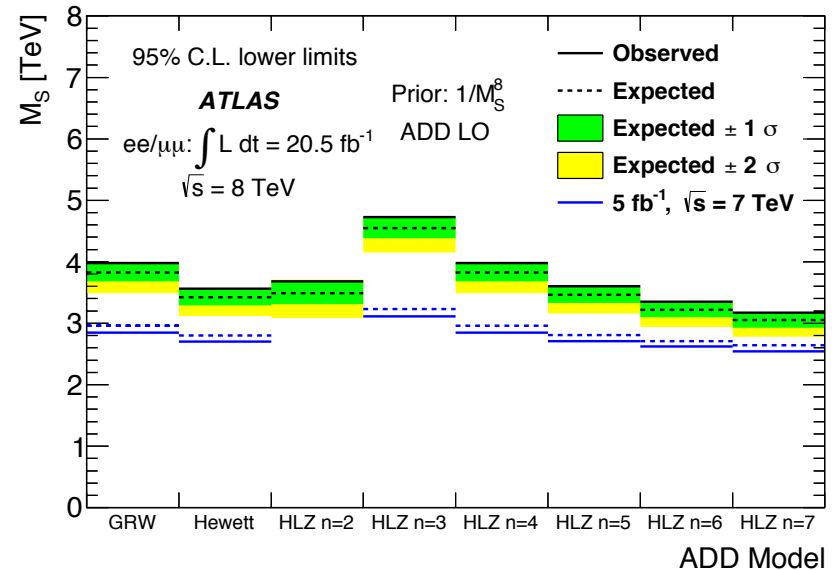
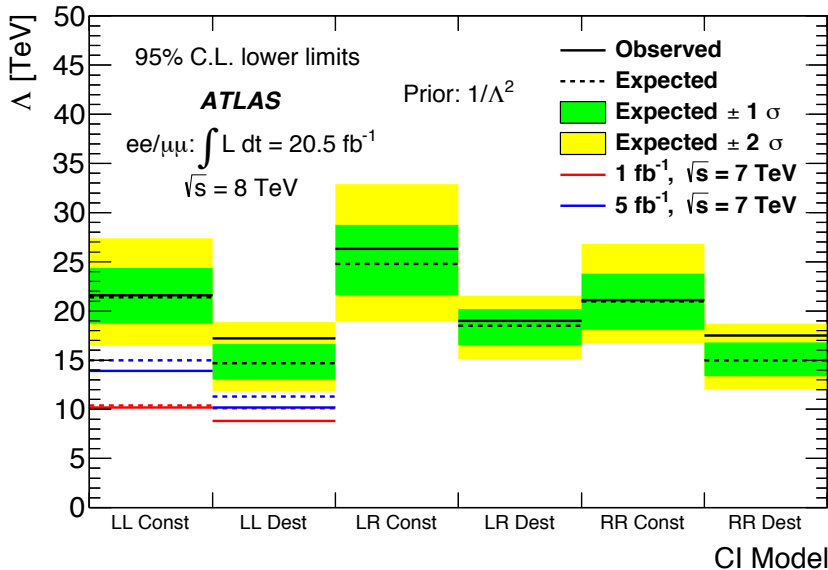
Good agreement is observed between the data and the SM in both the dilepton mass and A_{FB} distributions.

Statistical Interpretation


A Bayesian approach was used to quantify any excess.

Prior probabilities flat in $1/\Lambda^2$ or $1/\Lambda^4$ for CI and $1/M_S^4$ or $1/M_S^8$ for LED – motivated by cross-sections.

No significant deviation is observed and lower limits on Λ & M_S are calculated at 95% credibility level.



Please see me at my poster for more details and questions!



LLWI15 Poster Session – Lake Louise, 18th February 2015

8 TeV Non-Resonant Dilepton Search at ATLAS

Introduction

- Search for non-resonant new phenomena in **dilepton** and **dimuon** final states originating from **contact interactions** or **large extra dimensions** [1].
- Invariant mass spectrum is used as a discriminating variable alongside dilepton decay angle.
- A Bayesian approach is used to set lower limits on the new physics parameters of interest at the 95% credibility level.

Contact Interactions (CI)

Could be a manifestation of:

- quark-lepton compositeness
- new interaction with a massive mediator.

Described by four-fermion CI Lagrangian [2]:

$$\mathcal{L} = \frac{1}{\Lambda^2} [(\bar{q}_i \gamma_\mu q_j)(\bar{l}_k \gamma^\mu l_l) + \text{h.c.} + (\bar{q}_i \gamma_\mu q_j)(\bar{l}_k \gamma^\mu \gamma_5 l_l) + \text{h.c.} + (\bar{q}_i \gamma_\mu \gamma_5 q_j)(\bar{l}_k \gamma^\mu l_l) + \text{h.c.} + (\bar{q}_i \gamma_\mu \gamma_5 q_j)(\bar{l}_k \gamma^\mu \gamma_5 l_l) + \text{h.c.}]$$

with contact interaction scale Λ , chiral structure η_i where sign of η_i dictates if interference is constructive or destructive.

CI cross-section: $\sigma_{\text{int}} = \sigma_{\text{DY}} - \eta_i \frac{F_i}{\Lambda^2} + \frac{F_C}{\Lambda^4}$

with Drell-Yan component, interference (F_i) and pure CI (F_C) terms.

Large Extra Dimensions

To solve the hierarchy between the electroweak and Planck scales, ADD [3] postulated n additional spatial dimensions of size R .

“Fundamental” Planck scale M_5 can be modified from M_n through:

$$M_{\text{Pl}}^2 \sim M_n^{2+2n} R^{2n}$$

ADD cross-section:

$$\sigma_{\text{int}} = \sigma_{\text{DY}} + \mathcal{F} \frac{F_{\text{int}}}{M_n^2} + \mathcal{F}' \frac{F_C}{M_n^2}$$

with Drell-Yan component, interference (F_{int}) and pure graviton (F_C) terms. \mathcal{F} corresponds to a chosen formalism GRW, Hewett or HLZ [4, 5, 6].

Backgrounds

- Drell-Yan
- Top
- Multi-jet & W+Jets*
- Di-Boson
- Photon-induced processes

*Simulated using Monte-Carlo and reconstructed using Geant4

*estimated by data-driven method (negligible in dimuon channel).

Event Selection

Dilepton

$|\eta| < 2.47$ (excluding 1.37 – 1.52)
 $p_T > 40$ (30) GeV

Dimuon

$|\eta| < 2.5$
 $p_T > 25$ GeV
 $|z_d| < 1$ mm
 $|z_l| < 0.2$ mm

highest lepton p_T pair with opposite signs & invariant mass > 80 GeV.

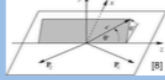
Cos θ^*

Angular distribution can increase search sensitivity in some CI modes.

The dilepton decay angle, θ^* , is defined in the Collins-Soper frame [7]:

- angle between the outgoing lepton and the incoming quark direction in the dilepton rest frame

Initial quark direction is chosen to be the dilepton boost direction.



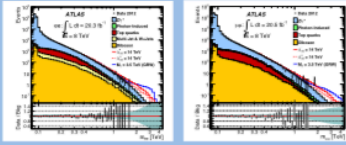
Search Strategy

Invariant Mass

Contact Interactions - 6 invariant mass bins:
 400-550, 550-800, 800-1200, 1200-1800, 1800-3000 and 3000-4500 GeV.

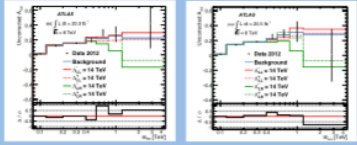
Large Extra Dimensions

- Single invariant mass bin; 1900-4500 GeV.



Dilepton Decay Angle

An asymmetry (A_{FB}) is measured in each CI mass bin by counting the number of $\text{Cos}\theta^*$ events in the forward (>0) and backward (<0) regions.

$$A_{\text{FB}} = \frac{N_F - N_B}{N_F + N_B}$$


Systematics

Mass-dependent systematic uncertainties affect the shape of the discriminating variables.

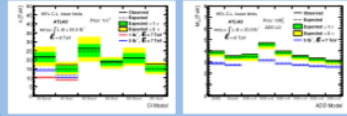
Source	Dilepton		Dimuon	
	Signal	Background	Signal	Background
ATLAS	1.4%	0.4%	1.4%	0.4%
PDF Uncertainties	4.1%	10.0%	3.9%	10.4%
EW Corrections	0.4%	1.0%	0.4%	1.0%
Di-Boson	0.4%	1.0%	0.4%	1.0%
EW Corrections	0.4%	1.0%	0.4%	1.0%
Photon-induced	0.4%	1.0%	0.4%	1.0%
EW Corrections	0.4%	1.0%	0.4%	1.0%
Multi-Jet & W+Jets	0.4%	1.0%	0.4%	1.0%
Di-Boson	0.4%	1.0%	0.4%	1.0%
EW Corrections	0.4%	1.0%	0.4%	1.0%
Charge Misidentification	1.2%	0.4%	1.2%	0.4%
All Systematics	4.4%	14.0%	4.1%	14.0%
Total	4.5%	14.4%	4.2%	14.7%

Results

Most significant deviation from the expected background:

- CI search: μ ; p-value of 8% (η_{11} , destructive interference and $1/\Lambda^2$ prior).
- ADD search: μ ; p-value of 24% (GRW formalism and $1/M_n^4$ prior).

Bayesian limits are set using the product of Poisson probabilities for each mass-cos θ^* bin.



References

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