Exotics Searches for New Physics with the ATLAS Detector

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19th Particles & Nuclei International Conference
24-29 July 2011

Outline

- The LHC has reached a new milestone with more than 1.3 fb^{-1} of deliver integrated luminosity
- As it is a “mission impossible” task to cover all the Exotics Searches in ATLAS in 15 min (**over 19 CONF Notes and 11 Papers**), I will give the headlines of the following analysis:
  - Monojet + missing E_t
  - Dijet final states
  - Dilepton final states
  - Lepton and missing E_t
  - Semileptonic $t\bar{t}$
  - Diphoton final states
- [ATLAS Exotics public results web page](#)

New results with $\sim 1 \text{ fb}^{-1}$

Large diversity of theoretical models (Extra-Dimensions, Sequential SM, Lepto-Quark, ...) giving alternative solutions to the hierarchy problem, weakness of gravity dark matter, grand unification, etc.

Monojet + missing Et

$p_t=602$ GeV; $\eta=-1$; $\phi=2.6$
Missing Et = 523 GeV

Monojet+MET final states

Physics Model:
Arkani-Hamed, Dimopoulos, Dvali
(ADD) Kaluza-Klein Graviton

Observable

- Large missing E_T
- High p_T jet

Event Selection

- High p_T jet and large MET
- No second jet above threshold
- No reconstructed lepton (e, μ)

Main background

- EW SM (Z/W +jets)

Monojet+MET final states

No evidence for new physics signal found
Observed (Expected) 95% C.L. Limits (2011 data)
ADD graviton $M_D > 3.16$ to 1.99 (2.98 to 1.92) TeV for $n=2$ to 6

Dijet final states

Very high energy jet event
 $m_{jj} = 4040 \text{ GeV}$
 $pt_{j1} = 1850 \text{ GeV}$
 $pt_{j2} = 1840 \text{ GeV}$
ATLAS-CONF-2011-081

Dijet final states: resonances

Physics Models:

Excited quarks q^*

Axigluons

Color-octet scalars

Observable

- Dijet invariant mass

Events Selection

- Two highest pt jets with $|\eta| < 2.5$ and $|\Delta\eta_{jj}| < 1.3$

Background

- SM QCD parametrization

$$f(x) = p_1(1-x)^{p_2} x^{p_3+p_4 \ln x}$$

Dijet final states: angular distribution

Physics Model:

Quark contact interactions

Randall-Meade QBH

χ : Centrality in cm frame

➤ Observable

➤ Dijets angular distribution

F_χ : Centrality ratio in cm frame

➤ Event Selection

- At least two jets with $pt_{j1} > 60$ GeV and $pt_{j2} > 30$ GeV

➤ Background

➤ SM QCD (NLO) prediction

Dijet final states: Limits

No evidence for new physics signal found

Observed (Expected) 95% C.L. Limits
(2011 data)

Excited quarks (q^*)	$M > 2.77$ (2.91) TeV
Axigluons	$M > 3.02$ (3.21) TeV
Color Octet Scalar	$M > 1.71$ (1.91) TeV

Observed (Expected) 95% C.L. Limits
(2010 data)

RMQ Black Hole ($n=6$)	$M > 3.67$ (3.64) TeV
Contact interaction	$\Lambda > 6.7$ (5.7) TeV

Dilepton final states

Dilepton final states

ATLAS-CONF-2011-083

New public results with 1/fb

Physics Models:

Z' (SSM, E6)

Randall-Sundrum Graviton

Contact interactions

➤ Observable

- Dilepton invariant mass

➤ Event Selection

- Select events with two leptons (same flavor, e or μ)

➤ Main background

- SM EW background ($Z/\gamma^* \rightarrow \ell\ell$)

Dilepton final states

ATLAS-CONF-2011-083

New public results with 1/fb

No evidence for new physics signal found

Observed (Expected) 95% C.L. Limits (2011 data)

E6 Z' bosons M in the range 1.50-1.64 (1.50-1.64) TeV

Z' SSM $M > 1.83$ (1.83) TeV

RS G , $k/M = 0.1$ $M > 1.63$ (1.61) TeV

RS G , $k/M = 0.01$ $M > 0.7$ (0.7) TeV

(2010 data) Contact interaction Dimuon $\Lambda > 4.9$ (5.1) TeV

Lepton+MET final states

YZ view

XY view

Run Number: 180149, Cells: Tiles, EMC
Event Number: 25360846
Date: 2011-04-22, 20:17:34 CET

Lepton+MET final states

Phys. Lett. B 701 (2011) 50
ATLAS-CONF-2011-082
New public results with 1/fb

Physics Models:

W' SSM

W^* Chiral boson

- Observable
  - Transverse mass
- Event Selection
  - Select events with just one high pt lepton (e, μ) and high MET
- Background
  - SM EW background (W)
  - QCD faking electron

Lepton+MET final states

Phys. Lett. B 701 (2011) 50
ATLAS-CONF-2011-082
New public results with 1/fb

No evidence for new physics signal found
Observed (Expected) 95% C.L. Limits
(2011 data)
W' SSM $M > 2.23$ (2.15) TeV
(2010 data)
W* (chiral boson) $M > 1.35$ (1.31) TeV

Semileptonic $t\bar{t}$ final states

$$m_{t\bar{t}} = 1602 \text{ GeV}$$

Semileptonic $t\bar{t}b\bar{a}$ final states

Search for $t\bar{t}b\bar{a}$ resonances:

Kaluza-Klein gluon
 Z' (TC2 leptophobic)

Observable

- Invariant mass of the jets, lepton and MET

Selection

- ≥ 4 jets
- ≥ 1 b-jet
- Just one lepton, $p_T > 20$ GeV
- Large MET

Background

- Main background SM $t\bar{t}b\bar{a}$

Semileptonic $t\bar{t}$ final states

No evidence for new physics signal found
 Observed (Expected) 95% C.L. Limits
 (2011 data)
 KK-gluon $M > 650$ (825) GeV
 No exclusion limits on Z' TC2 Leptophobic

Diphoton final states

ATLAS
EXPERIMENT

Run Number: 166786, Event Number: 77246540

Date: 2010-10-14 10:16:28 CEST

Diphoton final states

Physics Model:
Randall-Sundrum Graviton

- **Observable**
  - Diphoton invariant mass
- **Selection**
  - Two photons with $p_T > 25$ GeV
- **Background**
  - SM diphoton production
  - fake photons from QCD

Dimensionless RS coupling
 k/M_{Pl} (from 0.02 to 0.1)

Diphoton final states

No evidence for new physics signal found
Observed (Expected) 95% C.L. Limits (2010 data)
 $G \rightarrow \gamma\gamma$, $k/M=0.02$ $M>545$ (503) GeV
 $G \rightarrow \gamma\gamma$, $k/M=0.1$ $M>920$ (975) GeV

Summary

- Very good performance for the LHC in 2011.
- ATLAS data taking has been very efficient, recording up to 1.3 fb^{-1} .
- ATLAS Exotics searches for New Physics showed no significant excess beyond the Standard Model predictions
- Most of the observed limits are already beyond Tevatron results, and some of them are world best records

ATLAS Searches* - 95% CL Lower Limits (EPS-HEP 2011)

ATLAS
Preliminary

$$\int L dt = (0.031 - 1.21) \text{ fb}^{-1}$$

$$\sqrt{s} = 7 \text{ TeV}$$

Large ED (ADD) : monojet

$L=1.00 \text{ fb}^{-1}$ (2011) [ATLAS-CONF-2011-096] 3.2 TeV $M_D (\delta=2)$

UED : $\gamma\gamma + E_{T, \text{miss}}$

$L=36 \text{ pb}^{-1}$ (2010) [arXiv:1107.0561] 961 GeV Compact. scale 1/R

RS with $k/M_{\text{Pl}} = 0.1 : m_{\gamma\gamma}$

$L=36 \text{ pb}^{-1}$ (2010) [ATLAS-CONF-2011-044] 920 GeV Graviton mass

RS with $k/M_{\text{Pl}} = 0.1 : m_{e\bar{e}/\mu\bar{\mu}}$

$L=1.08-1.21 \text{ fb}^{-1}$ (2011) [preliminary] 1.63 TeV Graviton mass

RS with top couplings $g_L=1.0, g_R=4.0 : m_{tt}$

$L=200 \text{ pb}^{-1}$ (2011) [ATLAS-CONF-2011-087] 650 GeV KK gluon mass

Quantum black hole (QBH) : $m_{\text{dijet}}, F(\chi)$

$L=36 \text{ pb}^{-1}$ (2010) [arXiv:1103.3864] 3.67 TeV $M_D (\delta=6)$

QBH : High-mass $\sigma_{t+\bar{t}}$

$L=33 \text{ pb}^{-1}$ (2010) [ATLAS-CONF-2011-079] 2.35 TeV M_D

ADD BH ($M_{\text{th}}/M_D=3$) : multijet $\Sigma p_T, N_{\text{jets}}$

$L=35 \text{ pb}^{-1}$ (2010) [ATLAS-CONF-2011-068] 1.37 TeV $M_D (\delta=6)$

ADD BH ($M_{\text{th}}/M_D=3$) : SS dimuon $N_{\text{ch. part.}}$

$L=31 \text{ pb}^{-1}$ (2010) [ATLAS-CONF-2011-065] 1.20 TeV $M_D (\delta=6)$

qqqq contact interaction : $F_\chi(m_{\text{dijet}})$

$L=36 \text{ pb}^{-1}$ (2010) [arXiv:1103.3864 (Bayesian limit)] 6.7 TeV Λ

qq $\mu\mu$ contact interaction : $m_{\mu\mu}$

$L=42 \text{ pb}^{-1}$ (2010) [arXiv:1104.4398] 4.9 TeV Λ

SSM : $m_{e\bar{e}/\mu\bar{\mu}}$

$L=1.08-1.21 \text{ fb}^{-1}$ (2011) [preliminary] 1.83 TeV Z' mass

SSM : $m_{T, e/\mu}$

$L=1.04 \text{ fb}^{-1}$ (2011) [preliminary] 2.15 TeV W' mass

Scalar LQ pairs ($\beta=1$) : kin. vars. in $e\bar{e}jj, e\nu jj$

$L=35 \text{ pb}^{-1}$ (2010) [arXiv:1104.4481] 376 GeV 1st gen. LQ mass

Scalar LQ pairs ($\beta=1$) : kin. vars. in $\mu\bar{\mu}jj, \mu\nu jj$

$L=35 \text{ pb}^{-1}$ (2010) [arXiv:1104.4481] 422 GeV 2nd gen. LQ mass

4th family : coll. mass in $Q_4 \bar{Q}_4 \rightarrow WqWq$

$L=37 \text{ pb}^{-1}$ (2010) [ATLAS-CONF-2011-022] 270 GeV Q_4 mass

4th family : $d_4 \bar{d}_4 \rightarrow WtWt$ (SS dilepton)

$L=34 \text{ pb}^{-1}$ (2010) [preliminary] 290 GeV d_4 mass

Major. neutr. ($V_{4\text{-ferm.}}, \Lambda=1 \text{ TeV}$) : SS dilepton

$L=34 \text{ pb}^{-1}$ (2010) [preliminary] 460 GeV N mass

Excited quarks : m_{dijet}

$L=0.81 \text{ fb}^{-1}$ (2011) [ATLAS-CONF-2011-095] 2.77 TeV q^* mass

Axigluons : m_{dijet}

$L=0.81 \text{ fb}^{-1}$ (2011) [ATLAS-CONF-2011-095] 3.02 TeV Axigluon mass

Color octet scalar : m_{dijet}

$L=0.81 \text{ fb}^{-1}$ (2011) [ATLAS-CONF-2011-095] 1.71 TeV Scalar resonance mass

10^{-1}

1

10

Mass scale [TeV]

*Only a selection of the available results shown

Backup slides

A Toroidal LHC Apparatus

Inner Detector:

- $|\eta| < 2.5$
- $\sigma/pT \sim 3.8 \times 10^{-4} \text{ pT(GeV)} \oplus 0.015$
- Precise tracking and vertexing

Muon Spectrometer

- $|\eta| < 2.7$
- pT resolution $< 10\%$
- E_μ up to 1 TeV

Length: 46m
Diameter: 24m
Weight: 7000 tons

HAD calorimeter

- $|\eta| < 5$
- Central: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$
- Forward: $\sigma/E \sim 90\%/\sqrt{E} \oplus 0.07$

EM calorimeter:

- $|\eta| < 3.2$
- Resolution $\sigma/E \sim 10\%/\sqrt{E}$

LHC and ATLAS Operations

- Good performance in 2010
(45 pb⁻¹ recorded)
- Remarkable increase of LHC performance in 2011; 1.3 fb⁻¹ delivered up to now
- Good data taking efficiency in ATLAS
- New results with ~1fb⁻¹

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.8	100	89.0	92.4	94.2	99.7	99.8	99.7	99.8	99.7	99.3	99.0

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at $\sqrt{s}=7$ TeV between March 13th and June 29th (in %). The inefficiencies in the LAr calorimeter will partially be recovered in the future. The magnets were not operational for a 3-day period at the start of the data taking.

Diphoton with Large Missing Et

Physics Model:

GMSB with $\tilde{G}$ LSP ($\tilde{X}^0_1 \rightarrow \gamma \tilde{G}$)

UED ($\gamma^* \rightarrow \gamma + G$)

Observable

- Diphoton invariant mass

Event Selection

- Two photons, $E_T > 30(20)$ GeV
- missing $E_T > 125$ GeV

Background

- fake photons from QCD, γ +jet
- W+X and $t\bar{t}$ (electron and jet faking photons)

- **No candidate events survive the selection**

Diphoton plus large missing Et

UED: $N = 6$, $M_D = 5$ TeV, $\Delta R = 20$

GGM: bino-like neutralino, $\tan\beta = 2$, $c\tau_{\text{NLSP}} < 0.1 \text{ mm}$

No evidence for new physics signal found
Observed (Expected) 95% C.L. Limits (2010 data)
UED: $1/R > 961$ (961) GeV
GMSB gluino: $M > 560$ (560) GeV

Dijet+lepton+MET final states

Physics Models:
??

- Observable
  - Dijet invariant mass
- Event Selection
  - Two jets with one lepton (e, μ) and MET
- Main backgrounds
  - EW background (W+jets)
  - Diboson (WW, WZ)

Dijet+lepton+MET final states

No significant excess beyond the SM expectation is observed

Extra Spatial Dimensions

- Alternative to solve the hierarchy problem
- Extra spatial dimensions explain the apparent weakness of Gravity (relevant scale ~ 1 TeV)

ADD
Arkani-Hamed, Dimopoulos, Dvali,
Phys Lett B429 (98)
Many large compactified EDs
In which G can propagate

$$M_{pl}^2 \sim R^n M_{Pl(4+n)}^{(2+n)}$$

Effective $M_{pl} \sim 1\text{TeV} \rightarrow$ if compact space (R^n) is large

RS
Randall, Sundrum,
Phys Rev Lett 83 (99)
1 highly curved ED
Gravity localised in the ED

Planck   TeV brane

$$\Lambda_\pi = \bar{M}_{pl} e^{-kR_c \pi}$$

$$\Lambda_\pi \sim \text{TeV}$$

if warp factor $kR_c \sim 11-12$
 k/M_{pl} , k : curvature scale