

Exotic searches with ATLAS

Results and Perspectives in Particle Physics La Thuile - 01-07 March 2015



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on behalf of the ATLAS Collaboration



Andrea Coccaro 6 March, 2015

Exotics land



Exotics compass

dijet resonances, dijet angular, photon+jets, multi-(b)-jets dilepton, diphoton, multi-photon resonant and non-resonant searches searches 626.924 diboson resonances, SS and multi-lepton searches mono-X searches long-lived particles, exotics tracking, lepton-jets, tt and tb resonances, VLQ unconventional signatures searches Ebackground picture by H. Murayama]

Outline

- 1. Mono-jet search
- 2. High-mass resonance to photon pairs*
 - 3. High-mass resonance to tau pairs*
 - 4. Charged lepton search
 - 5. Same-sign lepton search
 - 6. VLQ search in Wt+X*
 - 7. Multi-charge particle search*
 - 8. Displaced jets*
 - 9. Displaced lepton-jets

DISCLAIMER

Impossible to cover the whole spectrum of searches. Had to make choices, focus on fresh results.

* Searches presented at this conference for the first time!

All ATLAS exotics results can be accessed at ExoticsPublicResults.

Mono-X searches for dark matter (and not only!)

- DM itself invisible to detector
 - need something to tag (and trigger) on
 - MET-based searches
- Assumptions:
 - interaction mediated by a new particle too heavy to be produced directly
 - EFT approach



contact interaction described with EFT approach







Mono-jet search [arXiv:1502.01518]

- ▶ at least one jet with $E_T > 120$ GeV and no leptons
- nine signal regions with increasing MET requirements up to 700 GeV
- SUSY and invisible Higgs interpretations included



Extensive search program conducted by ATLAS. The Higgs is also entering in the game.



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High-mass resonance to τ pairs [arXiv:1502.07177]

Heavy Z' search

- both leptonic and hadronic τ decays considered
- ▶ background for the hadronic channel estimated from simulated $Z/\gamma^* \rightarrow \tau \tau$ and validated with data using decays to electrons and muons
- background at low mass dominated by QCD multi-jet





High-mass resonance to photon pairs [publication coming!]

Looking for high-mass state decaying to photons

- clean experimental signature with excellent mass resolution
- irreducible background from prompt di-photon production and photon misidentification
- looking for excited gravitons assuming different couplings with the SM



Search with charged leptons [arXiv:1411.2921]

General search

- at least three charged leptons
- at least two electrons or muons
- interpretation for excited leptons and pair-production of doubly charged Higgs bosons (with a focus on LFV)
- H_T for opposite-sign, same-flavor leptons in events with at least three leptons





p_T distribution for hadronic tau candidates



Search with same-sign leptons [arXiv:1412.0237]

Generic search

- isolated lepton pairs with the same electric charge
- invariant mass distributions inspected
- charge misidentification probability in electrons is studied in data with Z decays
- charge misidentification in muons is found negligible
- constraints on doubly charged Higgs bosons





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VLQ search in Wt+X [publication coming!]

Searching for pair production of heavy vector-like down-time quarks (*B* quarks)

- events with one lepton, MET and jets are considered
- tagging of b-jets and W/Z hadronic decays
- ▶ signal region defined as at least 6 jets, at least 1 *b*-jet, at least one hadronic W/Z and $H_T > 500$ GeV





Extensive search program conducted by ATLAS. More signatures being planned for Run-II.



Multi-charge particle search [publication coming!]

Looking for anomalously high ionisation loss consistent with stable massive particles

- single muon and MET triggers
- ionisation estimators defined using pixel dE/dx, TRT dE/dx, MDT dE/dx and fraction of high threshold TRT hits
- charges from 2e to 6e
- DY production mode







Displaced jets [PLB 743 (2015) 15-34]

Unique analysis, signature never explored before

- signature-driven trigger
 [JINST 8 (2013) P07015]
- two object strategy looking for displaced hadronic jets (unbalanced energy deposit in the calorimeters)
- background dominated by QCD jets and estimated with a data-driven technique



trigger efficiency vs decay position



exclusion limit as a function of the lifetime



Displaced lepton-jets [JHEP 11 (2014) 088]



Analysis optimized for looking into displaced lepton-jets in a model-independent way

- QCD multi-jet background calculated with ABCD method
- cosmics background estimated analysis the empty bunches
- benchmarks targeting dark photon production through exotic Higgs decay



Vector portal model interpretation [JHEP 11 (2014) 088]



 $U_d(1)$ gauge invariance resulting in a kinetic mixing between the SM hypercharge and the dark photon

- the strength of the interaction by the ε parameter
- production of prompt/displaced collimated/nearly-collimated leptons



Hadron-collider experiment entering into the mass vs ϵ plot of the vector-portal interpretation.

Previously unexplored region is now constrained by ATLAS.

Impressive Run-I legacy results - and more to come in the coming weeks/months! Energy increase in Run-II is a tremendously exciting opportunity for finding new physics and it's just around the corner!

ATLAS Exotics Searches* - 95% CL Exclusion Status: ICHEP 2014							ATLAS Preliminary	
	Model	ί.γ	Jets	Emiss	∫£ dt[ft	1] Mass limit	j=	Reference
Exta dimensions	$\begin{array}{l} \text{ADD } G_{\text{DAC}} + g/q \\ \text{ADD } \text{cms-second} \ell \left(\ell \\ \text{ADD } \text{OB}^{(k)} - \ell_q \\ \text{ADD } \text{OB}^{(k)} + \ell_q \\ \text{ADD } \text{OB}^{(k)} \text{Max} \\ \text{ADD } \text{Max} \\ \text{Max} \\ \text{ADD } \text{Max} \\ \text{Max} \\ \text{Max} \\ \text{ADD } \text{Max} \\ \text{ADD } \text{Max} \\ \text{ADD } \text{Max} \\ \text{Max} \\ \text{ADD } \text{Max} \\ \text{Max} \\ \text{Max} \\ \text{ADD } \text{Max} \\ \text{Max} \\ \text{ADD } \text{Max} \\ \text{Max} \\ \text{ADD } \text{Max} \\ $	$\begin{array}{c} -\\ 2e,\mu\\ 1e,\mu\\ -\\ 2\mu (83)\\ \geq 1e,\mu\\ 2e,\mu\\ 2e,\mu\\ 2e,\mu\\ -\\ 1e,\mu\\ 2e,\mu\\ 2e,\mu\\ -\\ 1e,\mu\\ 2e,\mu\\ 2y\\ \end{array}$	1-2 j - 1 j 2 j - 2 j/1 J 4 b ≥ 1 b,≥ 1 J -	Yes - - - Yes - 2) Yes - Yes	4.7 20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.3	No. 4.2 Yet No. 5.2 Yet	$\begin{array}{l} a=2\\ a=38.2\\ a=6\\ a=6\\ b=15 \ {\rm Me}, {\rm model} \ {\rm BH}\\ a=6, {\rm Me}_{\rm c}=15 \ {\rm W}, {\rm model} \ {\rm BH}\\ a=6, {\rm Me}_{\rm c}=15 \ {\rm W}, {\rm model} \ {\rm BH}\\ 1/{\rm De}_{\rm c}=10\\ 4/{\rm De}_{\rm c}=10\\ {\rm He}_{\rm c}=0.00\\ $	1210.4491 ATLAS-CONF-2014-030 1311.2006 b be submitted to PRD 1203.4075 1405.4254 1405.4123 1203.2800 ATLAS-CONF-2014-039 ATLAS-CONF-2014-039 ATLAS-CONF-2014-039 ATLAS-CONF-2014-035 21203.2535 ATLAS-CONF-2012-022
a Gauge bosons	$\begin{array}{l} \text{SSM } Z' \rightarrow \ell\ell \\ \text{SSM } Z' \rightarrow \tau\tau \\ \text{SSM } W' \rightarrow tr \\ \text{EGM } W' \rightarrow WZ \rightarrow \ell\tau\ell\ell' \\ \text{EGM } W' \rightarrow WZ \rightarrow qq\ell\ell \\ \text{LRSM } W'_R \rightarrow tb \\ \text{LRSM } W'_R \rightarrow tb \\ \hline \end{array}$	2 e, µ 2 τ 1 e, µ 2 e, µ 1 e, µ 0 e, µ	2j/1J 2b,0-1j 21b,1J 2j	- Yins Yins - Yins -	20.3 19.5 20.3 20.3 14.3 20.3 14.3 20.3 4.8	Zessi 2.2010 Yessi 1.2000 Witsen 3.2010 A 7.611	80() q = +1	1405.4123 ATLAS-CONF-2013-086 ATLAS-CONF-2014-017 1405.4455 ATLAS-CONF-2014-029 ATLAS-CONF-2013-020 to be submitted to EPJC 1210.1718
0	Cl autt	2 e,μ 2 e,μ(SS		j Yks	20.3 14.3	A 3.3 TeV	21.5 TeV 4 = -1 C = 1	ATLAS-CONF-2012-051
N	EFT D5 operator (Dirac) EFT D9 operator (Dirac)	0 e, μ 0 e, μ	1-2 j 1 J, ≤ 1 j	Yes Yes	10.5 20.3	M, 731 GeV M, 2.4 TeV	at 90% CL for $m(\chi) < 80~{\rm GeV}$ at 90% CL for $m(\chi) < 100~{\rm GeV}$	ATLAS-CONF-2012-147 1209.4017
50	Scalar LQ 1 st gen Scalar LQ 2 nd gen Scalar LQ 3 nd gen	2 e 2 μ 1 e, μ, 1 s	≥2j ≥2j r 1b,1j	-	1.0 1.0 4.7	LO mass 680 GeV LO mass 685 GeV LO mass 534 GeV	$\beta = 1$ $\beta = 1$ $\beta = 1$	1112.4828 1203.3172 1303.0526
Heavy quarks	$ \begin{array}{l} \text{Wector-like quark $TT \rightarrow Ht + X$} \\ \text{Wector-like quark $TT \rightarrow Wb + X$} \\ \text{Wector-like quark $TT \rightarrow Zt + X$} \\ \text{Wector-like quark $BB \rightarrow Zb + X$} \\ \text{Wector-like quark $BB \rightarrow Wt + X$} \end{array} $	1 e, μ 1 e, μ 2/≥3 e, μ 2/≥3 e, μ 2 e, μ (SS	$\geq 2 \text{ b}, \geq 4$ $\geq 1 \text{ b}, \geq 3$ $\geq 2l \geq 1 \text{ b}$ $\geq 2l \geq 1 \text{ b}$ $\geq 2l \geq 1 \text{ b}$ $\geq 2l \geq 1 \text{ b}$	j Yes J Yes – J Yes	14.3 14.3 20.3 20.3 14.3	T maa 720 GeV T maa 670 GeV T maa 775 GeV B maa 775 GeV B maa 775 GeV	T in (T.B) doublet isospin singlet T in (T.B) doublet B in (T.B) doublet B in (T.B) doublet	ATLAS-CONF-2013-018 ATLAS-CONF-2013-080 ATLAS-CONF-2014-035 ATLAS-CONF-2014-035 ATLAS-CONF-2014-035 ATLAS-CONF-2012-051
Excited	Excited quark $q^* \rightarrow q\gamma$ Excited quark $q^* \rightarrow qg$ Excited quark $b^* \rightarrow Wt$ Excited lepton $\ell^* \rightarrow \ell\gamma$	1 γ - 1 or 2 e, μ 2 e, μ, 1 γ	1 j 2 j 1 b, 2 j or 1 r –	- J Yes -	20.3 20.3 4.7 13.0	q° mass 3.5 TeV q° mass 4.09 TeV Å [°] mass 870 GeV f° mass 22 TeV	only u^* and d^* , $A = m(q^*)$ only u^* and d^* , $A = m(q^*)$ liet-handed coupling A = 2.2 TeV	1309.3230 to be submitted to PRD 1301.1583 1308.1364
Other	LSTC $a_T \to W\gamma$ LRSM Majotina v Type III Sessaw Higgs triplet $H^{**} \to \ell\ell$ Multi-charged particles Magnetic monopoles	1 e,μ, 1 γ 2 e,μ 2 e,μ 2 e,μ (SS -	- 2 j 	Yes 	20.3 2.1 5.8 4.7 4.4 2.0 8 TeV	Sec GaV Sec GaV V ² max SS GaV V ² max 245 GaV V ² max 440 GaV	$\label{eq:main_state} \begin{split} &m(Ws) = 2 \ \mbox{TeV}, \mbox{no mixing} \\ V_1 = 0 \ \mbox{SSS}, V_2 = $	to be submitted to PLB 1203.5420 ATLAS-CONF-2013-013 1201.5070 1201.5070 1207.6411

*Only a selection of the available mass limits on new states or phenomena is shown.

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