ATLAS Highlights and Outlook

US LHC Users Association

Argonne National Laboratory November 13, 2014

Chip Brock, for the ATLAS Collaboration Michigan State University

24 October

Hello,

This is a talk for the U.S. LHC Users Organization at Argonne Lab scheduled for November 13.

https://indico.hep.anl.gov/indico/conferenceDisplay.py?confld=410

The assigned title is "ATLAS Highlights and Outlook" and I've chosen to interpret this as not just the most recent results, but as much as possible a look back at Run I as compared with what we might have expected. Also a quick run-through of preparations for Run 2 are included. I've not included heavy ion physics, pleading time, a lack of expertise, and an audience dominated by, if not exclusively, particle physicists.

What's shown is a <u>superset</u> of what I can possibly include in a half-hour, but because I've got 2 talks in a couple of weeks, I hoped to get approval sooner rather than later so I can tweak during the first week of November.

In some cases, I've just included plots I might show without yet adding commentary. In some cases, I've still got some clips and notes to myself. My understanding for this review is that appropriate attribution and most recent results are the basic concern.

Thanks, Chip Brock <u>brock@pa.msu.edu</u>



ATLAS @work efficient and productive

~90% usable data efficiency 2010: $\sqrt{s} = 7$ TeV, 0.05/fb 2011: $\sqrt{s} = 7$ TeV, 4.6/fb 2012: $\sqrt{s} = 8$ TeV, 20.3/fb

Run I results: a 2014 publication stream

350 publications, ~150 performance

5

~100 to come

600 CONF notes

660 conference talks





Snowmass Energy Frontier

Research Program:

1. Measure properties of the Higgs boson.

Including: mass, CP properties, and especially couplings

2. Measure properties of the: t, W, and Z

Because they talk "loudly" to the Higgs

3. Search for TeV-scale particles

A scale inspired by naturalness

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1'll add:

- 4. Wrestle the Standard Model to the ground.
- 5. Search for kinematical anomalies wrt SM (see #4)

Is excitement about Run 2...

lost in the huge Phase 1 preparation?

a rule of \mathscr{L} : a x10 increase in \mathscr{L} is like x2 in E_{cm}

and visa versa

Run 2 gives us:

Unprecedented precision

W 's, tops, Higgs!, flavor, inclusive σ 's,

Enormous discovery reach

surpass the 1 TeV SUSY scale, Z'/W', BSM Higgs

More parton luminosity



If we think "natural," then ~ TeV is interesting

+ Higher cross sections



Run 1 is essentially a wrap

Higgs Boson Physics Notable results

from Run 1 we anticipated:

Discovery, first looks

from Run 1 we achieved:

Discovery, the beginnings of a precision Higgs program:

mass, couplings, important final states, differential distributions

in Run 2, we expect:

Cross sections 13/14 TeV, ttH, high mass BSM searches, combination precision couplings, differential distributions

~x10 statistics



 $m_{\rm H}$ precisely = 125.36 ± 0.37 ± 0.18 GeV



Higgs width? smart ideas



ATLAS-CONF-2014-042

so far, 1 sd compatible

Higgs in slices differential distributions



the details corrected to the particle level



arXiv:1408.3226

Higgs couplings, 1 signal strengths, small, vibrant industry



least constrained, signal strength:

other fits with constraints

 $\mu_{VBF+VH} = \mu_{VBF} = \mu_{VH} \qquad \mu_{ggf+t\bar{t}H} = \mu_{ggf} = \mu_{t\bar{t}}$







Higgs couplings, 2 global fitting, big, growing industry



global fitting







higgs ww

higgs tau tau

VH bb

spin/CP gg, zz, ww,



Standard Model Physics Notable results



from Run 1 we anticipated:

"Rediscovery"...Precision total & inclusive cross sections, VV studies, differential cross sections. Did we expect MW?

from Run 1 we achieved:

Rediscovery, indeed.

in Run 2, we expect:

Rerediscovery...Precision couplings, differential distributions, much pileup study.

First MW?

Standard Model Paleontology



pick your favorite dinosaur



The basics Elastic and total pp cross section



ALFA

07

Q6

ALFA detectors at ±240m C-side A-side ALFA Q5 D2 Q3 Q1 Q1 Q3 D2 Q5 Beam 1 Q6 Beam 2 Q7 Q4 ATLAS Q2 D1 σ [mb] D1 Q2 Q4 140 ATLAS A7L1 B7L1 A7R1 TOTEM 120 Lower energy pp A1 A3 A5 Lower energy and cosmic ray pp Cosmic rays Arm 1 Arm 2 100 COMPETE RRpl2u IP ----- 13.1 - 1.88ln(s) + 1.42ln²(s) A6 A2 A4 80 237 m 237 m 241 m 60 o_{tot} 40 ATLAS 20 σ_{a} Λ 10² 10^{3} 10⁴ 10 TOTEM *s* [GeV]

arXiv:1408.5778

Result: $\sigma_{tot}(pp \to X) = 95.35 \pm 0.38$ (stat) ± 1.25 (exp) ± 0.37 (extr) mb and elastic slope $B = 19.73 \pm 0.14$ (stat) ± 0.26 (syst) GeV $^{-2}$



100

105

110

 $\sigma_{tot}(pp \rightarrow X)[mb]$

115

90

95



Sensitive test of NLO and pdf predictions





arXiv:1312.3524



QCD jet physics 3 jet cross sections





ATLAS-CONF-2014-045

jet gaps





arXiv:1407.5756

W+jets up to 8!



leptonic decay modes

differential in many quantities, e.g.



Electroweak physics multibosons

Standard Model processes

TCG for Z/γ - WW QGC for WWWW

Non-standard (anomalous) couplings

 Z/γ - Z/γ - Z/γ

Results on:

Wγ, Zγ ZZ W+W-

W±*Z*, fully leptonic and semileptonic

W+W-

continues to be interesting



ATLAS-CONF-2014-033



Z production

heavy flavor: W + c (arXiv:1402.6263) and $Z \rightarrow b\bar{b}$ (arXiv:1404.7042) underlying event ZpT

jet structure

boosted W/Zs

Multi-bosons

aQGCs electroweak Zjj production WWjj scattering



Top quark Physics Notable results



from Run 1 we anticipated:

precision cross sections, precision mass of 1-3.5 GeV, rediscovery of single top, single top W_t channel

from Run 1, we achieved:

precise cross sections, mass, distributions ttbar and single top

in Run 2, we expect:

20x statistics!

Top quark cross section

σ_t[pb]

win-win

Combined ATLAS+CMS

 $\sigma_{t\bar{t}} = 242.4 \pm 1.7 \pm 5.5 \pm 7.5 \pm 4.2 \,\mathrm{pb}$ (stat/syst/lumi/beam energy)

 $\sigma_{tar{t}}=241.4\pm1.4\pm5.7\pm6.2\,\mathrm{pb}~@m_t=172.5\,\mathrm{GeV}$ (stat/syst/lumi)



ATLAS-CONF-2014-054





Single top, Wt

win-win



September 2014

stat. uncertainty

total uncertainty

60

70

Top quark mass win-win-win

2008 estimates for 1/fb: ±1-3.5 GeV three channels

better than advertised

Single top

t channel template

top cross sections

all hadronic final states, tau final states, ttbar/Z/WW

differential distributions: parton level, boosted ttbar, associated production with jets and heavy flavor, W/Z, high pt boosted

single top

CP violation

top mass

pole mass from cross section tail, t -T mass difference

top properties

charge, W polarization, FCNC searches, charge asymmetry, t polarization

from Run 1 we anticipated:

supersymmetry discovery? no Higgs? Higgs? BSM Higgses (SP?), extension of Tevatron IVB' searches by x2 or more,

from Run 1 we achieved:

supersymmetry limits! one Higgs, BSM Higgs searches, IVB' searches

in Run 2, we expect:

supersymmetry discovery? BSM Higgs hints, additional IVB' searches

Supersymmetric Physics squarks and gluinos

DESPERATELY

Squark-gluino-neutralino model 2800 2600 2400 $m(\tilde{\chi}_{1}^{0})=0$ GeV Exp. limit (±1 σ_{exp} m(x̃⁰)=0 GeV Obs. limit (±1 o =395 GeV Exp. limit)=395 GeV Obs. limit $m(\chi)$ Squark 2200 $m(\tilde{\chi}_{1}^{U})$ =695 GeV Exp. limit m(x)=695 GeV Obs. limit 2000 7TeV (4.7fb⁻¹) m(χ̃⁰)=0 GeV Obs. 1800 1600 1400 **ATLAS** 1200 L dt = 20.3 fb⁻¹, √s=8 TeV 1000 0-lepton, 2-6jets 800 + 2200 800 1000 1200 1400 1600 1800 2000 2400 Gluino mass [GeV]

arXiv:1405.7875

stop stealthy stop?

$$M_{H}^{2} = M_{\text{tree}}^{2} + \left(\underbrace{\bigcup_{H}}_{H} \right) + \left(\underbrace{-H}_{H} \underbrace{\bigcup_{H}}_{t} \right) + \left(\underbrace{-H}_{H} \underbrace{\bigcup_{H}}_{H} \right) + \left(\underbrace{-H}_{H} \underbrace{-H}_{H} \underbrace{-H}_{H} \right) + \left(\underbrace{-H}_{H} \underbrace{-H}_{H} \underbrace{-H}_{H} \right) + \left(\underbrace{-H}_{H} \underbrace{-H}_$$

stop stealthy stop?

Run 2 cms Energy directly extends searches

ATL-PHYS-PUB-2012-001

Run 2 cms Energy directly extends searches

ATL-PHYS-PUB-2012-001

Z prime electrons and muons

a standard way to extend the SM

Phys. Rev. D 90, 052005 – Published 19 September 2014 G. Aad et al. (ATLAS Collaboration)

Wprime electrons and muons

a partner

arXiv:1407.7494v1

Exotics in a nutshell

a big nutshell

ATLAS Exotics Searches* - 95% CL Status: ICHEP 2014						Exclusion TeV scale $f(t) dt = (1.0 - 20.3) fb^{-1}$			4S Preliminary $\sqrt{s} = 7.8$ TeV	
	Model	<i>ℓ</i> ,γ	Jets	$\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}$	∫£ dt[ft	⁻¹]	Mass limit	J-		Reference
Extra dimancione	ADD $G_{KK} + g/q$ ADD non-resonant $\ell\ell$ ADD QBH $\rightarrow \ell q$ ADD QBH ADD QBH ADD BH high N_{trk} ADD BH high $\sum p_T$ RS1 $G_{KK} \rightarrow \ell\ell$ RS1 $G_{KK} \rightarrow \ell\ell$ RS1 $G_{KK} \rightarrow WW \rightarrow \ell\nu\ell\nu$ Bulk RS $G_{KK} \rightarrow ZZ \rightarrow \ell\ell qq$ Bulk RS $G_{KK} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$ Bulk RS $g_{KK} \rightarrow t\bar{t}$ S^1/Z_2 ED UED	$\begin{array}{c} - \\ 2e, \mu \\ 1 e, \mu \\ - \\ 2 \mu (SS) \\ \ge 1 e, \mu \\ 2 e, \mu \\ 2 e, \mu \\ 2 e, \mu \\ 2 e, \mu \\ - \\ 1 e, \mu \\ 2 e, \mu \\ 2 \gamma \end{array}$	1-2 j - 1 j 2 j - 2 j / 1 J 4 b ≥ 1 b, ≥ 1 J -	Yes Yes /2j Yes Yes	4.7 20.3 20.3 20.3 20.3 20.3 20.3 4.7 20.3 19.5 14.3 5.0 4.8	M_{D} M_{S} M_{th} M_{th} M_{th} M_{th} M_{th} $G_{KK} mass$ $G_{KK} mass$ $G_{KK} mass$ $G_{KK} mass$ $M_{KK} \approx R^{-1}$ Compact. scale R^{-1}	1.23 730 GeV 590-710 GeV	4.37 TeV 5.2 TeV 5.2 TeV 5.2 TeV 5.82 TeV 6.2 TeV 2.68 TeV V 2.0 TeV 4.71 TeV	n = 2 n = 3 HLZ n = 6 $n = 6, M_D = 1.5 \text{ TeV, non-rot BH}$ $n = 6, M_D = 1.5 \text{ TeV, non-rot BH}$ $k/\overline{M}_{Pl} = 0.1$ $k/\overline{M}_{Pl} = 0.1$ $k/\overline{M}_{Pl} = 1.0$ BR = 0.925	1210.4491 ATLAS-CONF-2014-030 1311.2006 to be submitted to PRD 1308.4075 1405.4254 1405.4123 1208.2880 ATLAS-CONF-2014-039 ATLAS-CONF-2014-005 ATLAS-CONF-2013-052 1209.2535 ATLAS-CONF-2012-072
CI Gaine hosons	$SSM Z' \to \ell\ell$ $SSM Z' \to \tau\tau$ $SSM W' \to \ell\nu$ $EGM W' \to WZ \to \ell\nu \ell'\ell'$ $EGM W' \to WZ \to qq\ell\ell$ $LRSM W'_R \to t\overline{b}$ $LRSM W'_R \to t\overline{b}$ $Cl qqqq$ $Cl qq\ell\ell$	2 e, µ 2 τ 1 e, μ 3 e, μ 2 e, μ 1 e, μ 0 e, μ	- 2 j / 1 J 2 b, 0-1 j ≥ 1 b, 1 J 2 j -	- Yes Yes - Yes J -	20.3 19.5 20.3 20.3 20.3 14.3 20.3 4.8 20.3	Z' mass Z' mass W' mass W' mass W' mass W' mass A A A		2.9 TeV 1.9 TeV 3.28 TeV 2 TeV 39 TeV 1.84 TeV 1.77 TeV 7.6 TeV	$\eta = +1$ 21.6 TeV $\eta_{LL} = -1$	1405.4123 ATLAS-CONF-2013-066 ATLAS-CONF-2014-017 1406.4456 ATLAS-CONF-2014-039 ATLAS-CONF-2013-050 to be submitted to EPJC 1210.1718 ATLAS-CONF-2014-030
WC	EFT D5 operator (Dirac) EFT D9 operator (Dirac)	2 e, μ (SS 0 e, μ 0 e, μ	5) ≥ 1 b, ≥ 1 1-2 j 1 J, ≤ 1 j	y Yes Yes Yes	14.3 10.5 20.3	л М. М.	731 GeV	3.3 TeV 2.4 TeV	C = 1 at 90% CL for $m(\chi) < 80$ GeV at 90% CL for $m(\chi) < 100$ GeV	ATLAS-CONF-2013-051 ATLAS-CONF-2012-147 1309.4017
0	Scalar LQ 1 st gen Scalar LQ 2 nd gen Scalar LQ 3 rd gen	2 e 2 μ 1 e, μ, 1 τ	≥ 2 j ≥ 2 j τ 1 b, 1 j	- - -	1.0 1.0 4.7	LQ mass LQ mass LQ mass	660 GeV 685 GeV 534 GeV		$\beta = 1$ $\beta = 1$ $\beta = 1$	1112.4828 1203.3172 1303.0526
Heavy	Vector-like quark $TT \rightarrow Ht + X$ Vector-like quark $TT \rightarrow Wb + X$ Vector-like quark $TT \rightarrow Zt + X$ Vector-like quark $BB \rightarrow Zb + X$ Vector-like quark $BB \rightarrow Wt + X$	1 <i>e</i> , μ 1 <i>e</i> , μ 2/≥3 <i>e</i> , μ 2/≥3 <i>e</i> , μ 2 <i>e</i> , μ (SS		j Yes j Yes – j Yes	14.3 14.3 20.3 20.3 14.3	T mass T mass T mass B mass B mass	790 GeV 670 GeV 735 GeV 755 GeV 720 GeV		T in (T,B) doublet isospin singlet T in (T,B) doublet B in (B,Y) doublet B in (T,B) doublet	ATLAS-CONF-2013-018 ATLAS-CONF-2013-060 ATLAS-CONF-2014-036 ATLAS-CONF-2014-036 ATLAS-CONF-2013-051
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	1j 2j µ1b,2jor1 y –	- - 1jYes -	20.3 20.3 4.7 13.0	q* mass q* mass b* mass /* mass	870 GeV	3.5 TeV 4.09 TeV 2.2 TeV	only u^* and d^* , $\Lambda = m(q^*)$ only u^* and d^* , $\Lambda = m(q^*)$ left-handed coupling $\Lambda = 2.2$ TeV	1309.3230 to be submitted to PRD 1301.1583 1308.1364
Other	LSTC $a_T \rightarrow W\gamma$ LRSM Majorana ν Type III Seesaw Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$ Multi-charged particles Magnetic monopoles	$1 e, \mu, 1 \gamma$ $2 e, \mu$ $2 e, \mu$ $2 e, \mu$ (SS - - - - - - - - - - - - -	y – 2j – 5) – – – –	Yes _ _ _ _ _	20.3 2.1 5.8 4.7 4.4 2.0 8 TeV	ar mass N ⁰ mass N [±] mass H ^{±±} mass multi-charged particle mass monopole mass 10 ⁻¹	960 GeV 409 GeV 490 GeV 862 GeV	5 TeV	$m(W_R) = 2 \text{ TeV, no mixing}$ $ V_e =0.055, V_{\mu} =0.063, V_{\tau} =0$ DY production, BR($H^{\pm\pm} \rightarrow \ell\ell$)=1 DY production, $ q = 4e$ DY production, $ g = 1g_D$	to be submitted to PLB 1203.5420 ATLAS-CONF-2013-019 1210.5070 1301.5272 1207.6411
1						10			Mass scale [TeV]	

SUSY in a nutshell

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

full data

 $\sqrt{s} = 8 \text{ TeV}$

partial data

 $\sqrt{s} = 8 \text{ TeV}$

full data

A Sta	TLAS SUSY Sea atus: ICHEP 2014	arches	s* - 9	5% (CL Lo	ower Limits	Iscale ATLA	AS Preliminary $\sqrt{s} = 7, 8$ TeV
	Model	e, μ, τ, γ	Jets	$E_{\mathrm{T}}^{\mathrm{miss}}$	$\int \mathcal{L} dt [\mathbf{fb}]$	⁻¹] Mass limit		Reference
Inclusive Searches	$ \begin{array}{l} MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ MSUGRA/CMSSM \\ \tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_1^0 \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q \tilde{q} \tilde{\chi}_1^0 \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q q \tilde{\chi}_1^{\pm} \rightarrow q q W^{\pm} \tilde{\chi}_1^0 \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q q (\ell \ell / \ell \nu / \nu \nu) \tilde{\chi}_1^0 \\ GMSB (\ell NLSP) \\ GMSB (\ell NLSP) \\ GGM (bino NLSP) \\ GGM (bino NLSP) \\ GGM (mino NLSP) \\ GGM (higgsino-bino NLSP) \\ GGM (higgsino NLSP) \\ GGM (higgsino NLSP) \\ GGM (higgsino NLSP) \\ GFavitino LSP \end{array} $	$\begin{matrix} 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 0 \\ 1 \ e, \mu \\ 2 \ e, \mu \\ 2 \ e, \mu \\ 1 - 2 \ \tau + 0 - 1 \ \ell \\ 2 \ \gamma \\ 1 \ e, \mu + \gamma \\ \gamma \\ 2 \ e, \mu \ (Z) \\ 0 \end{matrix}$	2-6 jets 3-6 jets 2-6 jets 2-6 jets 3-6 jets 0-3 jets 0-2 jets - 1 <i>b</i> 0-3 jets mono-jet	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 4.7 20.3 20.3 20.3 4.8 4.8 5.8 10.5	\tilde{q}, \tilde{g} \tilde{q} \tilde{g} 1.2 \tilde{g} 1.1 T \tilde{q} 850 GeV \tilde{g} 1.1 T \tilde{g} 900 GeV \tilde{g} 900 GeV \tilde{g} 690 GeV \tilde{g} 690 GeV \tilde{g} 690 GeV	$\begin{array}{c c} \textbf{1.7 TeV} & m(\tilde{q}) = m(\tilde{g}) \\ \textbf{eV} & any m(\tilde{q}) \\ & any m(\tilde{q}) \\ & m(\tilde{\chi}_1^0) = 0 \text{ GeV}, m(1^{st} \operatorname{gcn}, \tilde{q}) = m(2^{nd} \operatorname{gcn}, \tilde{q}) \\ \textbf{TeV} & m(\tilde{\chi}_1^0) = 0 \text{ GeV} \\ \textbf{sV} & m(\tilde{\chi}_1^0) = 0 \text{ GeV} \\ & m(\tilde{\chi}_1^0) = 0 \text{ GeV} \\ \textbf{feV} & tan\beta < 15 \\ \textbf{1.6 TeV} & tan\beta > 20 \\ \textbf{TeV} & m(\tilde{\chi}_1^0) > 50 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 50 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 20 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 20 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 20 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 50 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 20 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 200 \text{ GeV} \\ & m(\tilde{\chi}_1^0) > 10^{-4} \text{ eV} \end{array}$	1405.7875 ATLAS-CONF-2013-062 1308.1841 1405.7875 ATLAS-CONF-2013-062 ATLAS-CONF-2013-062 ATLAS-CONF-2013-089 1208.4688 1407.0603 ATLAS-CONF-2014-001 ATLAS-CONF-2012-144 1211.1167 ATLAS-CONF-2012-152 ATLAS-CONF-2012-147
3 rd gen. ẽ med.	$\begin{array}{l} \tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow t \tilde{\chi}_{1}^{0} \\ \tilde{g} \rightarrow b \tilde{\chi}_{1}^{+} \end{array}$	0 0-1 <i>e</i> , μ 0-1 <i>e</i> , μ	3 <i>b</i> 7-10 jets 3 <i>b</i> 3 <i>b</i>	Yes Yes Yes Yes	20.1 20.3 20.1 20.1	\$ 1.2 \$ 1.1 T \$ 1 \$ 1	$\begin{array}{lll} \textbf{TeV} & m(\tilde{k}_{1}^{0}){<}400 \mbox{ GeV} \\ & m(\tilde{k}_{1}^{0}){<}350 \mbox{ GeV} \\ \hline \textbf{TeV} & m(\tilde{k}_{1}^{0}){<}400 \mbox{ GeV} \\ \hline \textbf{TeV} & m(\tilde{k}_{1}^{0}){<}300 \mbox{ GeV} \end{array}$	1407.0600 1308.1841 1407.0600 1407.0600
3 rd gen. squarks direct production	$ \begin{split} \tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_1^0 \\ \tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_1^1 \\ \tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_1^1 \\ \tilde{r}_1 \tilde{r}_1 (\text{light}), \tilde{r}_1 \rightarrow b \tilde{\chi}_1^0 \\ \tilde{r}_1 \tilde{r}_1 (\text{light}), \tilde{r}_1 \rightarrow b \tilde{\chi}_1^0 \\ \tilde{r}_1 \tilde{r}_1 (\text{medium}), \tilde{r}_1 \rightarrow b \tilde{\chi}_1^1 \\ \tilde{r}_1 \tilde{r}_1 (\text{medium}), \tilde{r}_1 \rightarrow b \tilde{\chi}_1^1 \\ \tilde{r}_1 \tilde{r}_1 (\text{heavy}), \tilde{r}_1 \rightarrow t \tilde{\chi}_1^0 \\ \tilde{r}_1 \tilde{r}_1 (\text{heavy}), \tilde{r}_1 \rightarrow t \tilde{\chi}_1^0 \\ \tilde{r}_1 \tilde{r}_1 (\text{natural GMSB}) \\ \tilde{r}_2 \tilde{r}_2, \tilde{r}_2 \rightarrow \tilde{r}_1 + Z \end{split} $	$\begin{array}{c} 0\\ 2\ e,\mu\ ({\rm SS})\\ 1\text{-}2\ e,\mu\\ 2\ e,\mu\\ 2\ e,\mu\\ 0\\ 1\ e,\mu\\ 0\\ 0\\ 1\ e,\mu\ (Z)\\ 3\ e,\mu\ (Z) \end{array}$	2 b 0-3 b 1-2 b 0-2 jets 2 jets 2 b 1 b 2 b nono-jet/c-t 1 b 1 b	Yes Yes Yes Yes Yes Yes Yes ag Yes Yes Yes	20.1 20.3 4.7 20.3 20.3 20.1 20 20.1 20.3 20.3 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{split} & m(\tilde{k}_{1}^{0}){<}90~GeV \\ & m(\tilde{k}_{1}^{\pm}){=}2~m(\tilde{k}_{1}^{0}) \\ & m(\tilde{k}_{1}^{0}){=}55~GeV \\ & m(\tilde{k}_{1}^{0}){=}55~GeV \\ & m(\tilde{k}_{1}^{0}){=}1~GeV \\ & m(\tilde{k}_{1}^{0}){=}200~GeV, m(\tilde{k}_{1}^{\pm}){=}m(\tilde{k}_{1}^{0}){=}5~GeV \\ & m(\tilde{k}_{1}^{0}){=}0{~GeV} \\ & m(\tilde{k}_{1}^{0}){=}0~GeV \\ & m(\tilde{k}_{1}^{0}){=}150~GeV \\ & m(\tilde{k}_{1}^{0}){>}150~GeV \\ & m(\tilde{k}_{1}^{0}){>}150~GeV \\ & m(\tilde{k}_{1}^{0}){>}200~GeV \\ \end{split}$	1308.2631 1404.2500 1208.4305, 1209.2102 1403.4853 1403.4853 1308.2631 1407.0583 1406.1122 1407.0608 1403.5222 1403.5222
EW direct	$ \begin{array}{l} \tilde{\ell}_{\mathbf{LR}} \tilde{\ell}_{\mathbf{LR}}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_{1}^{0} \\ \tilde{\chi}_{1}^{\dagger} \tilde{\chi}_{1}, \tilde{\chi}_{1}^{\dagger} \rightarrow \tilde{\ell} \nu(\ell \tilde{\nu}) \\ \tilde{\chi}_{1}^{\dagger} \tilde{\chi}_{1}^{-}, \tilde{\chi}_{1}^{\dagger} \rightarrow \tilde{\tau} \nu(\tau \tilde{\nu}) \\ \tilde{\chi}_{1}^{\dagger} \tilde{\chi}_{2}^{0} \rightarrow \tilde{\ell}_{\mathbf{L}} \nu \tilde{\ell}_{\mathbf{L}} \ell(\tilde{\nu}\nu), \ell \tilde{\nu} \tilde{\ell}_{\mathbf{L}} \ell(\tilde{\nu}\nu) \\ \tilde{\chi}_{1}^{\dagger} \tilde{\chi}_{2}^{0} \rightarrow W \tilde{\chi}_{1}^{0} Z \tilde{\chi}_{1}^{0} \\ \tilde{\chi}_{2}^{\dagger} \tilde{\chi}_{2}^{0} \rightarrow W \tilde{\chi}_{1}^{0} h \tilde{\chi}_{1}^{0} \\ \tilde{\chi}_{2}^{\dagger} \tilde{\chi}_{3}, \tilde{\chi}_{2,3}^{0} \rightarrow \tilde{\ell}_{\mathbf{R}} \ell \end{array} $	$\begin{array}{c} 2 \ e, \mu \\ 2 \ e, \mu \\ 2 \ \tau \\ 3 \ e, \mu \\ 2 \text{-} 3 \ e, \mu \\ 1 \ e, \mu \\ 4 \ e, \mu \end{array}$	0 0 - 0 2 <i>b</i> 0	Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c} m(\tilde{\chi}_{1}^{0}){=}0 \; \text{GeV} \\ m(\tilde{\chi}_{1}^{0}){=}0 \; \text{GeV}, m(\tilde{\ell},\tilde{\nu}){=}0.5(m(\tilde{\chi}_{1}^{+}){+}m(\tilde{\chi}_{1}^{0})) \\ m(\tilde{\chi}_{1}^{0}){=}0 \; \text{GeV}, m(\tilde{\tau},\tilde{\nu}){=}0.5(m(\tilde{\chi}_{1}^{+}){+}m(\tilde{\chi}_{1}^{0})) \\ m(\tilde{\chi}_{1}^{+}){=}m(\tilde{\chi}_{2}^{0}), m(\tilde{\chi}_{1}^{0}){=}0, m(\tilde{\ell},\tilde{\nu}){=}0.5(m(\tilde{\chi}_{1}^{+}){+}m(\tilde{\chi}_{1}^{0})) \\ m(\tilde{\chi}_{1}^{+}){=}m(\tilde{\chi}_{2}^{0}), m(\tilde{\chi}_{1}^{0}){=}0, sleptons \; decoupled \\ m(\tilde{\chi}_{1}^{+}){=}m(\tilde{\chi}_{2}^{0}), m(\tilde{\chi}_{1}^{0}){=}0, sleptons \; decoupled \\ m(\tilde{\chi}_{2}^{0}){=}m(\tilde{\chi}_{3}^{0}), m(\tilde{\chi}_{1}^{0}){=}0, m(\tilde{\ell},\tilde{\nu}){=}0.5(m(\tilde{\chi}_{2}^{0}){+}m(\tilde{\chi}_{1}^{0})) \end{array}$	1403.5294 1403.5294 1407.0350 1402.7029 1403.5294, 1402.7029 ATLAS-CONF-2013-093 1405.5086
Long-lived particles	$\begin{array}{l} \text{Direct} \ \tilde{\chi}_{1}^{+} \widetilde{\chi}_{1}^{-} \ \text{prod., long-lived} \ \tilde{\chi}_{1}^{+} \\ \text{Stable, stopped } \tilde{g} \ \text{R-hadron} \\ \text{GMSB, stable } \tilde{\tau}, \ \tilde{\chi}_{1}^{0} \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, \\ \text{GMSB}, \ \tilde{\chi}_{1}^{0} \rightarrow \gamma \tilde{G}, \ \text{long-lived} \ \tilde{\chi}_{1}^{0} \\ \tilde{q} \tilde{q}, \ \tilde{\chi}_{1}^{0} \rightarrow q q \mu \ (\text{RPV}) \end{array}$	Disapp. trk 0 μ) 1-2 μ 2 γ 1 μ , displ. vb	1 jet 1-5 jets - - -	Yes Yes Yes	20.3 27.9 15.9 4.7 20.3	$egin{array}{cccc} \dot{x}_{1}^{+} & 270 \ { m GeV} & 832 \ { m GeV} & \dot{x}_{2}^{0} & 475 \ { m GeV} & \dot{x}_{1}^{0} & 230 \ { m GeV} & \dot{q} & 1.0 \ { m TeV} \end{array}$	$\begin{array}{l} m(\tilde{\chi}_1^z) \text{-}m(\tilde{\chi}_1^0) \!=\! 160 \; MeV, \; \tau(\tilde{\chi}_1^z) \!=\! 0.2 \; ns \\ m(\tilde{\chi}_1^0) \!=\! 100 \; GeV, \; 10 \; \mu s \!<\! \tau(\tilde{g}) \!<\! 1000 \; s \\ 10 \!<\! \! tan \! \beta \!<\! 50 \\ 0.4 \!<\! \tau(\tilde{\chi}_1^0) \!<\! 2 \; ns \\ 1.5 \!<\! c\tau \!<\! 156 \; mm, \; BR(\mu) \!=\! 1, \; m(\tilde{\chi}_1^0) \!=\! 108 \; GeV \end{array}$	ATLAS-CONF-2013-069 1310.6584 ATLAS-CONF-2013-058 1304.6310 ATLAS-CONF-2013-092
RPV	$ \begin{array}{l} LFV pp \rightarrow \tilde{\mathbf{v}}_{\tau} + X, \tilde{\mathbf{v}}_{\tau} \rightarrow e + \mu \\ LFV pp \rightarrow \tilde{\mathbf{v}}_{\tau} + X, \tilde{\mathbf{v}}_{\tau} \rightarrow e(\mu) + \tau \\ Bilinear \ RPV \ CMSSM \\ \tilde{\mathcal{X}}_{1}^{+} \tilde{\mathcal{X}}_{1}^{-}, \tilde{\mathcal{X}}_{1}^{+} \rightarrow W \tilde{\mathcal{X}}_{1}^{0}, \tilde{\mathcal{X}}_{1}^{0} \rightarrow ee\tilde{v}_{\mu}, e\mu \tilde{v}_{e} \\ \tilde{\mathcal{X}}_{1}^{+} \tilde{\mathcal{X}}_{1}^{-}, \tilde{\mathcal{X}}_{1}^{+} \rightarrow W \tilde{\mathcal{X}}_{1}^{0}, \tilde{\mathcal{X}}_{1}^{0} \rightarrow \tau \tau \tilde{v}_{e}, e\tau \tilde{v}_{\tau} \\ \tilde{\mathcal{S}} \rightarrow qqq \\ \tilde{\mathcal{S}} \rightarrow \tilde{i}_{1} t, \tilde{i}_{1} \rightarrow bs \end{array} $	$\begin{array}{c} 2 e, \mu \\ 1 e, \mu + \tau \\ 2 e, \mu (\text{SS}) \\ 4 e, \mu \\ 3 e, \mu + \tau \\ 0 \\ 2 e, \mu (\text{SS}) \end{array}$	- 	- Yes Yes Yes - Yes	4.6 4.6 20.3 20.3 20.3 20.3 20.3	$ \begin{array}{c} \bar{y}_{\tau} & & & \\ \bar{y}_{\tau} & & & 1.1 \text{ T} \\ \bar{q}, \bar{g} & & & 1 \\ \bar{x}_{1}^{\dagger} & & 750 \text{ GeV} \\ \bar{x}_{1}^{\dagger} & & 450 \text{ GeV} \\ \bar{g} & & & 916 \text{ GeV} \\ \bar{g} & & & 850 \text{ GeV} \\ \end{array} $	1.61 TeV $\lambda'_{311}=0.10, \lambda_{132}=0.05$ $\lambda'_{311}=0.10, \lambda_{1(2)33}=0.05$ 5 TeV $m(\tilde{q})=m(\tilde{g}), c\tau_{LSP} < 1 \text{ mm}$ $m(\tilde{\chi}_{1}^{0})>0.2 \times m(\tilde{\chi}_{1}^{+}), \lambda_{121} \neq 0$ $m(\tilde{\chi}_{1}^{0})>0.2 \times m(\tilde{\chi}_{1}^{+}), \lambda_{133} \neq 0$ BR(t)=BR(b)=BR(c)=0%	1212.1272 1212.1272 1404.2500 1405.5086 1405.5086 ATLAS-CONF-2013-091 1404.250
Other	Scalar gluon pair, sgluon $\rightarrow q\bar{q}$ Scalar gluon pair, sgluon $\rightarrow t\bar{t}$ WIMP interaction (D5, Dirac χ)	0 2 <i>e</i> , <i>µ</i> (SS) 0	4 jets 2 b mono-jet	- Yes Yes	4.6 14.3 10.5	sgluon 100-287 GeV sgluon 350-800 GeV M* scale 704 GeV	incl. limit from 1110.2693 $m(\chi){<}80~{\rm GeV}, limit~{\rm of}{<}687~{\rm GeV}~{\rm for}~{\rm D8}$	1210.4826 ATLAS-CONF-2013-051 ATLAS-CONF-2012-147

Mass scale [TeV]

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1 σ theoretical signal cross section uncertainty.

10⁻¹

spin correlations

Electroweak-ino production, many channels and assumptions

- GSMB models, delayed and non-pointing photons
- out of time events and disappearing tracks
- R-parity violating final states

Additional searches

W' searches to hadronic final states dijet, ZZ, ZW, W\gamma, Z\gamma resonances Vector like quarks Mono jets, tT, b, t LFV and long-lived neutral particles

Flavor Physics Notable results

from Run 1 we anticipated:

measure: $bb \rightarrow J/\psi$, $pp \rightarrow J/\psi$, and $B^+ \rightarrow J/\psi + K^+$ cross section ratios begin to contribute to world averages on B-hadron properties; start to set limits on rare decays

from Run 1 we achieved:

many production studies, χ , ψ studies, new physics searches, new b states

in Run 2, we expect:

increased statistics, improved performance/triggers, robust against \mathscr{L}

First excited B_c open beauty discovery

In conclusion, the distribution of the mass difference $Q = m(B_c^{\pm}\pi^{+}\pi^{-}) - m(B_c^{\pm}) - 2m(\pi^{\pm})$ for events with the B_c^{\pm} meson reconstructed in its decay to $J/\psi\pi^{\pm}$ has been investigated in pp collisions at the LHC using the ATLAS detector. The analysis is based on an integrated luminosity of 4.9 (19.2) fb⁻¹ of pp collisions at a center-of-mass energy of 7 (8) TeV. A new state is observed at $Q = 288.3 \pm 3.5 \pm 4.1$ MeV (calculated as the error weighted mean of the 7 TeV and 8 TeV mass values) corresponding to a mass of $6842 \pm 4 \pm 5$ MeV, where the first error is statistical and the second is systematic. The significance of the observation is 5.2 σ with the "look

Production and Decays, incl

 $\psi(2s)$ in many distributions, prompt and non-prompt W+ incl double parton scattering contribution χ_c production, prompt? $\Upsilon(1s,2s,3s)$ production open charm/beauty, in jets, inclusive

Spectroscopy, incl

 $\chi_b(3P)$ discovery, Λ_b mass, lifetime, PV in $\Lambda_b \rightarrow J/\psi \Lambda^0$, Rare Decays

Searches, incl

FCNC search for $B_{d/s} \rightarrow \mu^+ \mu^-$

Long Shutdown 1 Projects

Tracking system Insertable B Layer, aka IBL

5.1 to 3.3 cm to IP pixels reduced: 50 x 250 µm new sensors and readout chip

May 7:

Gains:

impact param light jet reject

redundancy

Status: live >99.9%

Tracking system many other projects, "Consolidation"

SCT readout enhanced

high pileup and trigger rate mandates enhanced readout 90 ->128 S links and compression

100 kHz @ **µ** = 87

TRT

enhanced readout, data compression, different gating

104 KHz with 2% occupancy

gas studies

Pixel brought to surface, reinstalled

B layer, 6.3% to 1.4%; Layer 2, 7% to 1.9%; 98% functional of 1744 new diamond/Si beam monitors installed

Calorimeter system

LAr and Tile

LAr

LV power supplies replaced by manufacturer readout tested to more than 100 kHz

Phase 1 "demonstrator" installed

Tile

Power supply replacements Min-bias trigger scintillators

Muon system staged from Run 1

New ROD for CSC system

limited ATLAS L1 trigger rate to 70 kHz...now 100 kHz

New EE endcap chambers

Repairs

Broken CSC chambers, repaired, reinstalled

RPC leak repairs

TGC chamber replacement requires detector to be closed

Trigger system considerable enhancements

E_{CM} from 8 to 13 TeV (x2.5) +

\mathscr{L}_{peak} 0.8 to 1.6 x 10³⁴/cm²/s

5x trigger rates from Run 1

Upgrades to:

L1 rate, 70 kHz - 100 kHz operation, factor 4/3 increase. **hardware**

HLT rate, 400 Hz - ~1 kHz operation, factor of ~2 increase **algorithms**

Trigger system hardware

New preprocessors (nMCM)

80 MHz digitization, lower noise

New merger modules (CMX)

x4 speed enhancement over CMM

L1 Topo processor

trigger on object relations at L1 e.g. $\Delta \phi(E^{miss}T, j)$

Commissioning underway in-situ

Commissioning multiple "Milestone weeks"

24/5! M's cosmic rays HLT & reco'd Tier 0

М3	M4	M5	M6	M7
May19- May 23	Jul 7- Jul 11	Sep 8- Sep 12	Oct 13- Oct 17	Nov 24- Dec 08
	X ¹ , X ²	Х ²		
	X1	X ²		
	Х	X ²		
	Х			
	Х			
	Х			
	Х ²	Х ³	X ⁴	
		X ²	X ²	
X1				
			X ²	
		Х		
			Х	
		Х		
	M3 May19- May 23 	M3 M4 May19- May 23 Jul 7- Jul 11 X1, X2 X1, X2 X1 X X X X <th< th=""><th>M3 M4 M5 May19: May23 Jul 7: Jul 11 Sep 8: Sep 12 X¹, X² X² X¹, X² X² X X² X X² X X² X X² X X <t< th=""><th>M3 M4 M5 M6 May19 Jul 7- Sep 8- Oct 13- X¹, X² X² I X¹, X² X² I X¹ X² I X¹ X² I X¹ X² I X¹ X² I X X² I X X² I X I I X I I X I I X I I X I I X I I X I I X I I X I I X X X³ X¹ I I X¹ I I</th></t<></th></th<>	M3 M4 M5 May19: May23 Jul 7: Jul 11 Sep 8: Sep 12 X ¹ , X ² X ² X ¹ , X ² X ² X X X X <t< th=""><th>M3 M4 M5 M6 May19 Jul 7- Sep 8- Oct 13- X¹, X² X² I X¹, X² X² I X¹ X² I X¹ X² I X¹ X² I X¹ X² I X X² I X X² I X I I X I I X I I X I I X I I X I I X I I X I I X I I X X X³ X¹ I I X¹ I I</th></t<>	M3 M4 M5 M6 May19 Jul 7- Sep 8- Oct 13- X ¹ , X ² X ² I X ¹ , X ² X ² I X ¹ X ² I X X ² I X X ² I X I I X I I X I I X I I X I I X I I X I I X I I X I I X X X ³ X ¹ I I X ¹ I I

Commissioning multiple "Milestone weeks"

24/5! M's cosmic rays HLT & reco'd Tier 0

	M3	M4	M5	M6	M7
	May19- May 23	Jul 7- Jul 11	Sep 8- Sep 12	Oct 13- Oct 17	Nov 24- Dec 08
ΡΙΧ		X ¹ , X ²	X ²		
IBL		X1	X ²		
SCT		Х	X ²		
TRT					
LAR	ЛТ				
TIL	AI				
MBTS	rea	adin	σOI	jt	
L1Calo			8	X	
	sin	ce "	'M5'	/	
CSC			X ²	X ²	
MDT					
RPC	X1				
TGC				X ²	
BCM					
ALFA			Х		
LUCID				Х	
Lumi			Х		

Computing & Software systems speed/efficiency and pileup

- Many algorithmic, mathematical, fitting changes
 - factor >3 gains
 - pileup robustness
- Completely redesigned analysis model
 - "xAOD" Athena reconstruction is ROOT-readable, tuning.
 - disk usage tight...working on xAOD sizes
 - memory usage gymnastics CP tools mostly migrated

conclusion

nothing yet