ATLAS and CMS: The Current Physics Landscape at the LHC



Lake Louise Winter Institute January 19, 2018

Sarah Demers, Yale University On behalf of ATLAS and CMS



Outline

• LHC, ATLAS, and CMS Performance

- how much data and under what conditions

• The Searches

- fueled by a jump in energy and luminosity

• The Measurements

precision measurements, and measurements as searches

• The Higgs

- improved sensitivities and new channels

The LHC delivered 50 fb⁻¹ to ATLAS and CMS in 2017

LHC Performance 2017



2017 was a Banner Year



CMS and ATLAS recorded a high fraction of the delivered data

CMS Integrated Luminosity, pp, 2017, $\sqrt{s} =$ 13 TeV



Much of the data we record passes our strict requirements for physics analysis



Experimental conditions are quite challenging, as we are operating above our design luminosity

CMS Peak Luminosity Per Day, pp

Data included from 2010-03-30 11:22 to 2017-11-10 14:09 UTC



This translates into events with many (~60 in 2018) overlapping simultaneous interactions in our detectors



From 2556 bunches to 1920 (8b4e structure)

This translates into events with many (~60 in 2018) overlapping simultaneous interactions in our detectors



From 2556 bunches to 1920 (8b4e structure)

Our Detectors and DAQ

- Radiation hard precision tracking using silicon near the beampipe
- High granularity calorimeters
- Muon chambers surrounding interaction region





Many techniques have been developed to maintain performance in the face of high pile-up

Some of our best techniques use tracking information, where the extent of the interaction region enables separating vertices. We do not have access to tracking information at our first level trigger. Isolation requirements can become inefficient in high-pileup environments

Physics Organization

ATLAS

B Physics and Light States Standard Model Top Higgs Supersymmetry Exotics Heavy Ions

CMS

Forward Physics B Physics and Quarkonia Standard Model Physics Top Physics Higgs Physics Supersymmetry Exotica Beyond 2 Generations Heavy-Ion Physics

There are hundreds of exciting analyses I could discuss. I have chosen highlights that give you a sense of our current capabilities. There are many talks this week that will go into greater detail.

ATLAS Public Results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic

CMS Public Results:

https://cms-results.web.cern.ch/cms-results/public-results/publications/

Analyzers have been busy...



an interactive plot from CMS:

http://cms-results.web.cern.ch/cms-results/public-results/publications-vs-time/

What's New?



It's instructive to take a look at the most recently published papers coming out of the LHC... There are exciting searches with new data and some beautiful measurements from Vs = 7 and Vs = 8 TeV!

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	Searches	$\begin{array}{l} \tilde{q}\tilde{q}, \tilde{q} \rightarrow \tilde{q} \tilde{k}_{1}^{0} \\ \tilde{q}\tilde{q}, \tilde{q} \rightarrow \tilde{q} \tilde{k}_{1}^{0} (\text{compressed}) \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q} \tilde{k}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q} \tilde{k}_{1}^{0} \rightarrow qq W^{\pm} \tilde{k}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q} (\ell \tilde{k}_{1}^{0}) \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q} (\ell \tilde{k}_{1}^{0}) \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q} (\ell \tilde{k}_{1}^{0}) \end{array}$	0 mono-jet 0 <i>ee, μμ</i> 3 <i>e</i> , μ	2-6 jets 1-3 jets 2-6 jets 2-6 jets 2 jets 4 jets	Yes Yes Yes Yes -	36.1 36.1 36.1 36.1 14.7 36.1	 φ φ	710 GeV	1.57 TeV 2.02 TeV 2.01 TeV 1.7 TeV 1.87 TeV	$m(\tilde{k}_{1}^{2}) < 200 \text{ GeV}, m(1^{st} \text{ gen.} \tilde{q}) = m(2^{nd} \text{ gen.} \tilde{q})$ $m(\tilde{q}) - m(\tilde{k}_{1}^{2}) < 5 \text{ GeV}$ $m(\tilde{k}_{1}^{2}) < 200 \text{ GeV}, m(\tilde{k}^{st}) = 0.5(m(\tilde{k}_{1}^{2}) + m(\tilde{g}))$ $m(\tilde{k}_{1}^{2}) < 200 \text{ GeV}, m(\tilde{k}^{st}) = 0.5(m(\tilde{k}_{1}^{2}) + m(\tilde{g}))$ $m(\tilde{k}_{1}^{2}) = 0 \text{ GeV}$	1712.02332 1711.03301 1712.02332 1712.02332 1611.05791 1706.03731
	Inclusive	388, g→qqWZt ^Q GMSB (č NLSP) GGM (bino NLSP) GGM (higgsino-bino NLSP) Gravitino LSP	0 1-2 τ + 0-1 ℓ 2 γ γ 0	7-11 jets 0-2 jets 2 jets mono-jet	Yes Yes Yes Yes Yes	36.1 3.2 36.1 36.1 20.3	\tilde{s} \tilde{s} \tilde{s} $F^{1/2}$ scale	865 GeV	1.8 TeV 2.0 TeV 2.15 Te ^v 2.05 TeV	$\begin{split} & m(\tilde{\mathbb{F}}_1^0) < 400 \ \text{GeV} \\ & cr(NLSP) < 0.1 \ \text{mm} \\ & m(\tilde{\mathbb{F}}_1^0) = 1700 \ \text{GeV}, \ cr((NLSP) < 0.1 \ \text{mm}, \ \mu > 0 \\ & m(\tilde{G}) > 1.8 \times 10^{-4} \ \text{eV}, \ m(\tilde{g}) = m(\tilde{g}) = 1.5 \ \text{TeV} \end{split}$	1708.02794 1607.05879 ATLAS-CONF-2017-080 ATLAS-CONF-2017-080 1502.01518
Strong production	rrks 3 rd gen. Vion 7 med.	$ \begin{array}{l} \tilde{g}\tilde{g},\tilde{g}\rightarrow b\tilde{b}\tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g},\tilde{g}\rightarrow t\tilde{k}_{1}^{0} \end{array} \\ \\ \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 t\tilde{\chi}_{1}^{\pm} \end{array} $	0 0-1 e,μ 0 2 e,μ (SS)	3 b 3 b 2 b 1 b	Yes Yes Yes Yes	36.1 36.1 36.1 36.1	ξ ξ δ ₁ δ ₁	950 GeV 275-700 GeV	1.92 TeV 1.97 TeV	$\begin{split} & m(\tilde{k}_1^0)\!<\!600~GeV \\ & m(\tilde{k}_1^0)\!<\!200~GeV \\ & m(\tilde{k}_1^0)\!<\!420~GeV \\ & m(\tilde{k}_1^0)\!<\!420~GeV \\ & m(\tilde{k}_1^0)\!<\!200~GeV, m(\tilde{k}_1^0)\!=m(\tilde{k}_1^0)\!+\!100~GeV \end{split}$	1711.01901 1711.01901 1708.09266 1706.03731
Naturalness and stops	3rd gen. squa direct product	$ \begin{split} \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} \to b\tilde{k}_{1}^{T} \\ \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} \to b\tilde{k}_{1}^{T} \text{ or } t\tilde{k}_{1}^{0} \\ \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} \to c\tilde{k}_{1}^{0} \\ \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} \to c\tilde{k}_{1}^{0} \\ \tilde{t}_{2}\tilde{t}_{2}, \tilde{t}_{2} \to \tilde{t}_{1} + Z \\ \tilde{t}_{2}\tilde{t}_{2}, \tilde{t}_{2} \to \tilde{t}_{1} + h \end{split} $	$0-2 \ e, \mu$ $0-2 \ e, \mu$ (C) $2 \ e, \mu$ (Z) $3 \ e, \mu$ (Z) $1-2 \ e, \mu$	1-2 b 0-2 jets/1-2 mono-jet 1 b 1 b 4 b	Yes 4. b Yes 21 Yes Yes Yes Yes Yes	.7/13.3 0.3/36.1 36.1 20.3 36.1 36.1	Î1 117-170 GeV Î1 90-198 GeV Î1 90-430 GeV Î1 90-430 GeV Î2 150 Î2 150	200-720 GeV 0.195-1.0 TeV -600 GeV 290-790 GeV 320-880 GeV		$\begin{split} m(\tilde{c}_{1}^{2}) &= 2m(\tilde{c}_{1}^{2}), \ m(\tilde{c}_{1}^{2}) = 55 \text{GeV} \\ m(\tilde{c}_{1}^{2}) &= 1 \text{GeV} \\ m(\tilde{c}_{1}) &= 1 \text{GeV} \\ m(\tilde{c}_{1}^{2}) &= 5 \text{GeV} \\ m(\tilde{c}_{1}^{2}) &= 5 \text{GeV} \\ m(\tilde{c}_{1}^{2}) &= 0 \text{GeV} \\ m(\tilde{c}_{1}^{2}) &= 0 \text{GeV} \end{split}$	1209.2102, ATLAS-CONF-2016-077 1506.08616, 1709.04183, 1711.11520 1711.03301 1403.5522 1706.03986 1706.03986
Electroweak production	EW direct	$ \begin{split} \tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell \tilde{x}_{1}^{0} \\ \tilde{\lambda}_{1}^{+}\tilde{\lambda}_{1}^{-}, \tilde{\lambda}_{1}^{+} \rightarrow \tilde{\ell}\nu(\ell \tilde{\nu}) \\ \tilde{\lambda}_{1}^{+}\tilde{\lambda}_{1}^{-}, \tilde{\lambda}_{2}^{+} \rightarrow \tilde{\ell}\nu(\tau \tilde{\nu}), \tilde{\lambda}_{2}^{0} \rightarrow \tilde{\tau}\tau(\nu \tilde{\nu}) \\ \tilde{\lambda}_{1}^{+}\tilde{\lambda}_{2}^{0} \rightarrow \tilde{\ell}_{\nu}\nu \tilde{\ell}_{\nu}(\ell \tilde{\nu}) \\ \tilde{\lambda}_{1}^{+}\tilde{\lambda}_{2}^{0} \rightarrow W \tilde{\lambda}_{1}^{0} (2\tilde{\nu}) \\ \tilde{\lambda}_{1}^{+}\tilde{\lambda}_{2}^{0} \rightarrow W \tilde{\lambda}_{1}^{0} \tilde{\lambda}_{1}^{0} \\ \tilde{\lambda}_{1}^{+}\tilde{\lambda}_{2}^{0} \rightarrow W \tilde{\lambda}_{1}^{0} \tilde{\lambda}_{1}^{0} \end{pmatrix} $	2 e, μ 2 e, μ 2 τ 3 e, μ 2-3 e, μ e, μ, γ	0 0 - 0-2 jets 0-2 h	Yes Yes Yes Yes Yes	36.1 36.1 36.1 36.1 36.1 20.3	₹ 90-500 \vec{x}_1^a \vec{x}_1^a \vec{x}_1^a \vec{x}_1^a, \vec{x}_2^a \vec{x}_1^a, \vec{x}_2^a \vec{x}_1^a, \vec{x}_2^a \vec{x}_1^a, \vec{x}_2^a 270 GeV	GeV 750 GeV 760 GeV 1.13 Te 580 GeV	≥V m(\tilde{k}_1^+)=r	$\begin{split} m(\tilde{\xi}_{1}^{0}) &= 0 \\ m(\tilde{\xi}_{1}^{0}) &= 0, \ m(\tilde{\xi}, \tilde{v}) &= 0.5(m(\tilde{K}_{1}^{+}) + m(\tilde{K}_{1}^{0})) \\ m(\tilde{K}_{1}^{0}) &= 0, \ m(\tilde{\tau}, \tilde{v}) &= 0.5(m(\tilde{K}_{1}^{+}) + m(\tilde{K}_{1}^{0})) \\ m(\tilde{K}_{2}^{0}) &= m(\tilde{\xi}, \tilde{v}) &= 0.5(m(\tilde{K}_{1}^{+}) + m(\tilde{K}_{1}^{0})) \\ m(\tilde{K}_{1}^{0}) &= m(\tilde{K}_{2}^{0}) &= 0.5(m(\tilde{K}_{1}^{+}) + m(\tilde{K}_{2}^{0})) \\ m(\tilde{K}_{1}^{0}) &= m(\tilde{K}_{2}^{0}) &= 0.5(m(\tilde{K}_{1}^{-}) + m(\tilde{K}_{2}^{0})) \\ m(\tilde{K}_{1}^{0}) &= m(\tilde{K}_{2}^{0}) &= 0.5(m(\tilde{K}_{1}^{-}) + m(\tilde{K}_{2}^{0})) \\ m(\tilde{K}_{1}^{0}) &= 0.5(m(\tilde{K}_{1}^{0}) &= 0.5(m(\tilde{K}_{1}^{0}) &= 0.5(m(\tilde{K}$	ATLAS-CONF-2017-039 ATLAS-CONF-2017-039 1708.07875 ATLAS-CONF-2017-039 ATLAS-CONF-2017-039 1501.07110
Relax assumptions		$\tilde{\chi}_{2}^{0}\tilde{\chi}_{3}^{0}, \tilde{\chi}_{2,3}^{0} \rightarrow \tilde{\ell}_{R}\ell$ GGM (wino NLSP) weak prod., $\tilde{\chi}_{1}^{0} \rightarrow \gamma \ell$ GGM (bino NLSP) weak prod., $\tilde{\chi}_{1}^{0} \rightarrow \gamma \ell$	4 e,μ Ğ 1 e,μ + γ Ğ 2 γ	0	Yes Yes Yes	20.3 20.3 36.1	x10-2 210 GOV X23 W 115-370 GeV W 115-370 GeV W	635 GeV 1.06 TeV	m($\tilde{\chi}_{2}^{0}$)=r	$n(\tilde{\chi}_{2}^{0}), m(\tilde{\chi}_{1}^{0})=0, m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_{2}^{0})+m(\tilde{\chi}_{1}^{0}))$ $c\tau<1 mm$ $c\tau<1 mm$	1405.5086 1507.05493 ATLAS-CONF-2017-080
(R parity violating)	Long-lived particles	$ \begin{array}{l} Direct \ \hat{k}_1^2 \ \hat{k}_1^- \ prod., \ long-lived \ \hat{k}_1^-\\ Direct \ \hat{k}_1^2 \ \hat{k}_1^- \ prod., \ long-lived \ \hat{k}_1^-\\ Stable, \ stoped \ \hat{k} \ R-hadron\\ Stable, \ stoped \ \hat{k} \ R-hadron\\ Metastable \ \hat{k} \ R-hadron\\ Metastable \ \hat{k} \ R-hadron\\ Metastable \ \hat{k} \ R-hadron\\ Stable, \ stoped \ \hat{k} \ R-hadron\\ GMSB, \ \hat{k}_1^0 \rightarrow \mathcal{G}, \ long-lived \ \hat{k}_1^0 \\ GMSB, \ \hat{k}_1^0 \rightarrow \mathcal{G}, \ long-lived \ \hat{k}_1^0 \\ R-hadron\\ R-hadron \ R-hadron\\ R-hadron \ R-hadron\\ \mathsf$	Disapp. trk dE/dx trk 0 trk dE/dx trk displ. vtx $1-2 \mu$ 2γ displ. $ee/e\mu/\mu$	1 jet - 1-5 jets - - - - - - -	Yes Yes - Yes - Yes - Yes	36.1 18.4 27.9 3.2 3.2 32.8 19.1 20.3 20.3	X [±] 460 Ge X [±] 495 l R 2 R 2 R 2 R 2 R 3 R 53 X ⁰ 440 Gev	V GeV 850 GeV 17 GeV 7 6 1.0 TeV	1.58 TeV 1.57 TeV 2.37	$\begin{split} m(\vec{\xi}^{2}_{1}) & m(\vec{\xi}^{2}_{1}) & -160 \; \text{MeV}, \tau(\vec{\xi}^{2}_{1}) & = 0.2 \; \text{ns} \\ m(\vec{\xi}^{2}_{1}) & m(\vec{\xi}^{2}_{1}) & -160 \; \text{MeV}, \tau(\vec{\xi}^{2}_{1}) & -15 \; \text{ns} \\ m(\vec{\xi}^{2}_{1}) & = 100 \; \text{GeV}, \text{ 10-10 \; ns} \\ m(\vec{\xi}^{2}_{1}) & = 100 \; \text{GeV} \; 10 \; \text{ctan} \\ m(\vec{\xi}^{2}_{1}) & = 100 \; \text{GeV} \\ 10 \; \text{ctan} & \tau(\vec{\xi}^{2}_{1}) \; \text{ctan}, m(\vec{\xi}^{2}_{1}) & = 100 \; \text{GeV} \\ 10 \; \text{ctan} & \tau(\vec{\xi}^{2}_{1}) \; \text{ctan}, \text{sp} \; \text{SPS8 model} \\ 1 \; -\tau(\vec{\xi}^{2}_{1}) \; \text{ctan} \; \text{mn}, m(\vec{\xi}_{1}) = 10 \; \text{JeV} \end{split}$	1712.02118 1506.05332 1310.6584 1606.05129 1604.04520 1710.04901 1411.6795 1409.5542 1504.05162
	RPV	$ \begin{array}{l} LFV pp \rightarrow \tilde{v}_r + X_r \tilde{v}_r \rightarrow e \mu/er/\mu\tau \\ Bilmont RPV CMSSM \\ \tilde{K}_r^{-1} \tilde{K}_r^{-1} \rightarrow \tilde{K}_r^{-1} \tilde{K}_r^{-1} \sim e r v_r \\ \tilde{K}_r^{-1} \tilde{K}_r^{-1} \rightarrow \tilde{K}_r^{-1} \tilde{K}_r^{-1} \rightarrow e q q \\ \tilde{K}_R^{-1} - \tilde{K}_r^{-1} \tilde{K}_r^{-1} \rightarrow q q \\ \tilde{K}_R^{-1} - \tilde{K}_r^{-1} \tilde{K}_r^{-1} \rightarrow q q \\ \tilde{K}_R^{-1} \tilde{K}_r^{-1} \tilde{K}_r^{-1} \rightarrow b s \\ \tilde{I}_r \tilde{I}_r, \tilde{I}_r \rightarrow b \\ \tilde{I}_r \tilde{I}_r \tilde{I}_r = \tilde{I}_r \delta s \\ \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \delta s \\ \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \delta s \\ \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \delta s \\ \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \tilde{I}_r \delta s \\ \tilde{I}_r \tilde{I}$	$e\mu, e\tau, \mu\tau$ $2 e, \mu$ (SS) $4 e, \mu$ $3 e, \mu + \tau$ $0 4-1 e, \mu 8$ $1 e, \mu 8$ 0 $2 e, \mu$		- Yes Yes Yes ets - b - b - - y -	3.2 20.3 13.3 20.3 36.1 36.1 36.1 36.7 36.1 20.3	k, ₹, ≵ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ ₹, ↑ 100-470 Gr ₹, ↑ 2	V 1.14 Tr V 480-610 GeV 0.4 GeV	1.9 TeV 1.45 TeV eV 1.875 TeV 2.1 TeV 1.65 TeV -1.45 TeV	$\begin{split} \lambda_{11}' = 0.11, \lambda_{122}(1_{31})_{233} = 0.07 \\ m(k) = m(k), e_{14,0} < 1 \text{ mm} \\ m(k)') = 0.006, \lambda_{12,0} < 0(k = 1, 2) \\ m(k^2) = 0.22 \text{ mm}(k^2), \lambda_{13,3} < 0 \\ m(k^2) = 1.102, \lambda_{13,2} < 0 \\ m(k^2) = 1.102, \lambda_{13,2} = 0 \\ m(k) = 1.102, \lambda_{13,2} = 0 \\ \text{BR}(k_1 = k_1 k_1 > 20\%) \\ m(k^2) = 0.006 \text{ mm} \end{split}$	1607.08079 1404.2000 ATLAS-CONF-2016-075 1405.5086 SUSY-2016-22 1704.08493 1704.08493 1710.07171 1710.05544 1501.0125
	*Only phe sim	scalar charm, $c \rightarrow c x_1$ a selection of the available mass nomena is shown. Many of the lin lified models, c.f. refs. for the as	s limits on r mits are bas sumptions	≥ c new state sed on made.	is or	20.3	0 ⁻¹	1		Mass scale [TeV]	101.0122

Mass limit

ATLAS SUSY Searches* - 95% CL Lower Limits December 2017

 e, μ, τ, γ Jets $E_{\rm T}^{\rm miss} \int \mathcal{L} dt [{\rm fb}^{-1}]$

Model

ATLAS Preliminary

Reference

 $\sqrt{s} = 7.8 \text{ TeV}$ $\sqrt{s} = 13 \text{ TeV}$

√s = 7. 8. 13 Te'

SUPERSYMMETRY RESULTS

ATLAS Supersymmetry Results:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

CMS Supersymmetry Results:

https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS/index.html

High transverse momentum Higgs bosons + missing transverse energy



https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-17-006/index.html

High transverse momentum Higgs bosons + missing transverse energy



https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-17-006/index.html

Top squark pair production with one lepton, jets and missing transverse energy



Feb 19, 2018

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2016-16/

Top squark pair production with one lepton, jets and missing transverse energy



Top squark pair production with one lepton, jets and missing transverse energy



Feb 19, 2018

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2016-16/

squark and gluino search with jets and missing transverse energy and no leptons



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2016-07/

squark and gluino search with jets and missing transverse energy and no leptons



Feb 19, 2018

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2016-07/

Electroweak production w/ compressed mass spectra

Two lepton final state Feynman diagrams for electroweakino and slepton pair production



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2016-25/ 23

Combination Exclusion Limits (two lepton and disappearing track analyses)

December 2017



EW production of charginos and neutralinos at √s = 13 TeV



https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-17-004/index.html

EW production of charginos and neutralinos at Vs = 13 TeV



https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-17-004/index.html

Search for R-parity violating SUSY with one lepton, bjets and high sum of large radius jet masses



https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS-16-040/index.html



EXOTICS RESULTS

ATLAS Exotics Results:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

CMS Exotics Results:

https://cms-results.web.cern.ch/cms-results/public-results/publications/EXO/index.html

Feb 19, 2018

high mass resonances decaying to $\tau\nu$



Feb 19, 2018

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2017-06/

high mass resonances decaying to $\tau\nu$



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2017-06/

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heavy neutral lepton search with at least three leptons



https://cms-results.web.cern.ch/cms-results/public-results/publications/EXO-17-012/index.html

heavy neutral lepton search with at least three charged leptons

Upper limits are set on the mixing parameters $|V_{eN}|^2$ and $|V_{\mu N}|^2$ This are the first direct limits at high mass (m_N > 500 GeV) and the first LHC probes at very low mass (m_N < 40 GeV)



^{Feb 19, 2018} https://cms-results.web.cern.ch/cms-results/public-results/publications/EXO-17-012/index.html

Many other searches are on-going... Long-lived particles are a particularly interesting category disappearing or displaced kinked tracks multitrack vertices non-pointing (converted) photons displaced leptons, emerging jets lepton-jets, or lepton pairs

trackless, low-EMF jets

multitrack vertices in the muon spectrometer

quasi-stable charged particles

<u>https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults</u>: Long lived massive particle <u>https://cms-results.web.cern.ch/cms-results/public-results/publications/EXO/LLP.html</u>

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Heavy Ions: Light-by-Light Scattering

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Maxwell's equations, relying on superposition, do not allow light-by-light scattering, which is purely a quantum mechanical effect



Feb 19, 2018 https://www.nature.com/nphys/journal/v13/n9/fig_tab/nphys4208_F3.html
With time to analyze comes great power, and with great power comes great responsibility. Every measurement is a search.



STANDARD MODEL RESULTS

ATLAS SM Results:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults

CMS SM Results:

https://cms-results.web.cern.ch/cms-results/public-results/publications/SMP/index.html

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Observation of same-sign WW



^{Seb 19, 2018} https://cms-results.web.cern.ch/cms-results/public-results/publications/SMP-17-004/index.html

Observation of same-sign WW

Limits can be placed on the H^{±±} allowed cross section, here for VBF production



³⁹ https://cms-results.web.cern.ch/cms-results/public-results/publications/SMP-17-004/index.html

Vector Boson Scattering



First LHC results for electroweak production of two Z bosons plus jets.

Most stringent limits on the T0, T1, T2, T8, and T9 anomalous quartic gauge couplings to date.

Feb 19, 2018

Phys. Lett. B 774 (2017) 682

W Boson Mass Measurement, Vs = 7 TeV

Measurements done using both transverse momentum and transverse mass distributions, for W⁺ and W⁻ in bins of eta.



Eur. Phys. J. C 78 (2018) 110

W Boson Mass Measurement



Understanding jet substructure

Jet "soft drop" mass, a jet substructure technique being used in analyses



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2017-04/

Understanding jet substructure

Jet "soft drop" mass, a jet substructure technique being used in analyses



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2017-04/

So massive, so promising, so well-behaved...



There are many new cross section results out

There are new properties measurements (mass)

There are searches for new physics using top

TOP PHYSICS RESULTS

ATLAS Top Results:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

CMS SM Results:

https://cms-results.web.cern.ch/cms-results/public-results/publications/TOP/index.html

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First ttbar cross section at $\sqrt{s} = 5.02$ TeV



https://cms-results.web.cern.ch/cms-results/public-results/publications/TOP-16-023/index.html

First ttbar cross section at $\sqrt{s} = 5.02$ TeV



https://cms-results.web.cern.ch/cms-results/public-results/publications/TOP-16-023/index.html

tZ cross section at $\sqrt{s} = 13$ TeV



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/TOPQ-2016-14/

Search for four t SM production



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¹⁸ https://cms-results.web.cern.ch/cms-results/public-results/publications/TOP-17-009/index.html

ATLAS and CMS Combination: Inclusive and Differential Charge Asymmetry



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/TOPQ-2016-16/

ATLAS and CMS Combination: Inclusive and Differential Charge Asymmetry



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/TOPQ-2016-16/ 51

Decay Width at Vs = 8 TeV using template fit with kinematic variables



 $\Gamma_t = 1.76 \pm 0.33(\text{stat.})^{+0.79}_{-0.68}(\text{syst.})\text{GeV}$

The result is consistent with the SM theory prediction of 1.322 GeV Feb 19, 2018 <u>https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/TOPQ-2017-02/</u> 52



B PHYSICS RESULTS

ATLAS b Physics Results:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BPhysPublicResults

CMS b Physics Results:

https://cms-results.web.cern.ch/cms-results/public-results/publications/BPH/index.html

Feb 19, 2018

Search for X(5568) $B_S^{0}\pi^{\pm}$

An unexpected observation from D0 of a narrow resonance, named X(5568), prompted a search at LHCb that returned a null result. This CMS measurement has limits a factor of two more stringent.



Upper limits on relative production rates of X(5568) and B_s⁰ states:

https://cms-results.web.cern.ch/cms-results/public-results/publications/BPH-16-002/index.html



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/BPHY-2017-02/

Measurements of Quarkonia Production



Measurements of Quarkonia Production



https://cms-results.web.cern.ch/cms-results/public-results/publications/BPH-15-005/index.html

Quarkonia production in pp, p+pb

differential cross sections in pp



No significant modification of the J/ψ production

 $\Upsilon(1S)$ production is found to be suppressed at low transverse momentum in p+Pb collisions relative to pp

Feb 19, 2018

^{*} <u>https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HION-2014-05/</u>

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Angular analysis of B_d^{0} ->K* $\mu^+\mu^-$ at $\sqrt{s} = 8$ TeV at ATLAS



Measurements are sensitive to heavy new particles contributing to FCNC decay amplitudes.

Results are compatible with theoretical predictions

BLACK: signal RED: background BLUE: total



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2017-023/

Angular analysis of B_d^{0} ->K* $\mu^+\mu^-$ at $\sqrt{s} = 8$ TeV at CMS



https://cms-results.web.cern.ch/cms-results/public-results/publications/BPH-15-008/index.html

Outline

- LHC, ATLAS, and CMS Performance - how much data and under what conditions
- The Searches
 - fueled by a jump in energy and luminosity
- The Measurements
 - precision measurements, and measurements as searches
- The Higgs

- improved sensitivities and new channels



We have a long road ahead of us still ...

HIGGS RESULTS

ATLAS Higgs Results:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults

CMS Higgs Results:

https://cms-results.web.cern.ch/cms-results/public-results/publications/HIG/index.html

Feb 19, 2018

The Higgs boson is looking SM-like



Run 2 Program: Increase precision, finding missing production and decay modes, and model independent measurements to characterize deviations from SM



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2016-21/

H->ZZ->IIII : Constraints on anomalous couplings



 $V = H + \theta_1$ $V = H + \theta_1$ V = 0 V = 0 V = 0



gluon-gluon fusion 5 decay angles two invariant masses

vector boson fusion
5 decay angles
two invariant masses
decay of V to 4l not shown

associated production (VH)

5 decay angles two invariant masses decay of V to 4l not shown

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When combined with lower COM energy measurements, 5.9σ

https://cms-results.web.cern.ch/cms-results/public-results/publications/HIG-16-043/index.html

Higgs decays to b quarks at CMS



Higgs decays to b quarks at ATLAS



Feb 19, 2018 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2016-29/

Search for Higgs decays to charm quarks



Feb 19, 2018

ttH at CMS

using H->WW, H->ZZ and H-> $\tau\tau$





Output of classifiers for the 2 lepton, same-sign channels

significance of 3.3 σ



71 http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/HIG-17-004/index.html



significance of 4.2 σ

Feb 19, 2018

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2017-02/2
Conclusions

- A diverse and aggressive program is moving ahead with full steam at the LHC.
- We continue to push forward with searches as our datasets grow, while simultaneously developing new techniques and making precision measurements.
- With orders of magnitude more data on our horizon, the best is yet to come.
- Thanks for your attention!