

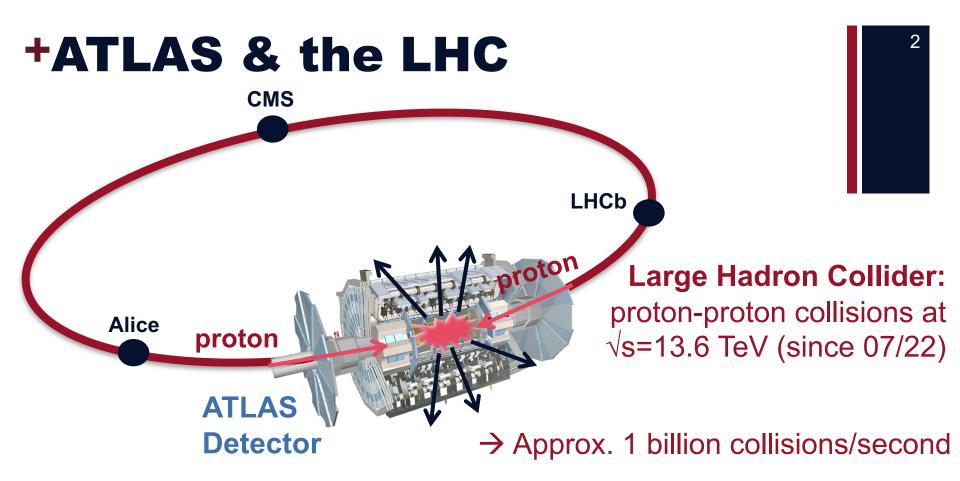
ATLAS Experiment: Physics Analysis, Operations and Maintenance

Elisabeth Schopf on behalf of the ATLAS UK community

PPAP Community Meeting, Manchester 2022







ATLAS: multi-purpose experiment recording collisions since 2010

On average 1000 collisions/second saved for physics analysis → Increasingly large data sets: transition to precision measurements and searches for ultra-rare processes

+ ATLAS & LHC Roadmap

■ Data set of Run-2 available for analysis (13 TeV, 140 fb⁻¹)

 \rightarrow Many results published (1000 papers by the ATLAS collaboration in 06/21!) and more analyses ongoing

Run-3 data taking started in 07/22 after intense preparations and upgrades (13.6 TeV, projected ~250 fb⁻¹)

10 fb⁻¹ already recorded



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ATLAS UK Community

14 universities + RAL

~400 active ATLAS members

~160 students

Activities: Physics research, data reconstruction, computing, experiment operation & maintenance, detector upgrade

Elisabeth Schopf, PPAP Community

UNIVERSITY OF BIRMINGHAM



OYA

21.09.2022





Lancaster University



UNIVERSITY OF SUSSEX

UNIVERSITY OF LIVERPOOL

THE UNIVERSITY of EDINBURGH



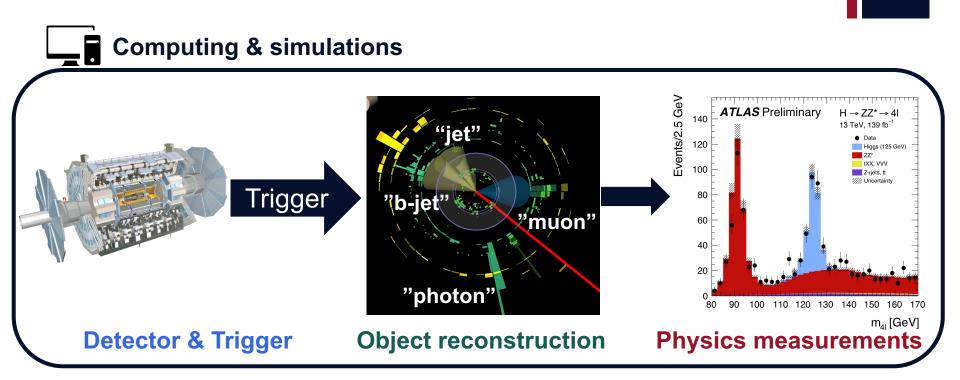






University of Glasgow

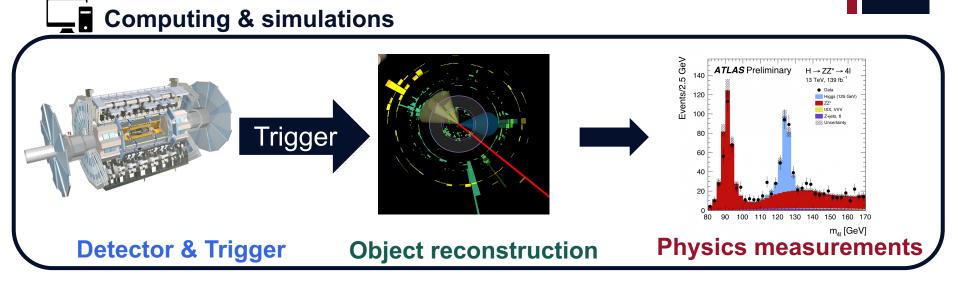
+ ATLAS UK Activities



Strong and continued involvement and leadership from the UK ATLAS community across key areas of experiment operation and physics measurements

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+ ATLAS UK Activities



- Semiconductor tracker (SCT) and trigger (L1Calo, HLT) operation, maintenance and upgrade
- Object reconstruction (tracking, muons, jets, b-jet and tau ID)
- Measurements (Standard Model incl. Higgs boson, searches for new physics)
- + providing **computing** resources and (improved) **simulated data**

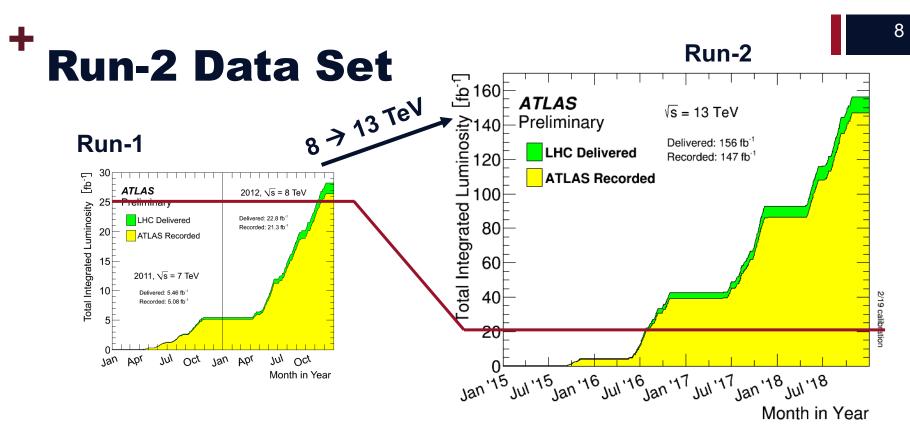
Run-2 Physics Highlights

Immense amount of results, including key milestones and first observations, with **major UK involvement and leadership** (sub-group convenerships, analysis coordination)

Areas span:

- Higgs boson, W, Z, top and B-hadron measurements, incl. precision measurements and searches for rare processes

- Searches for new particles, extended Higgs sector, invisible particles, Supersymmetry (SUSY)



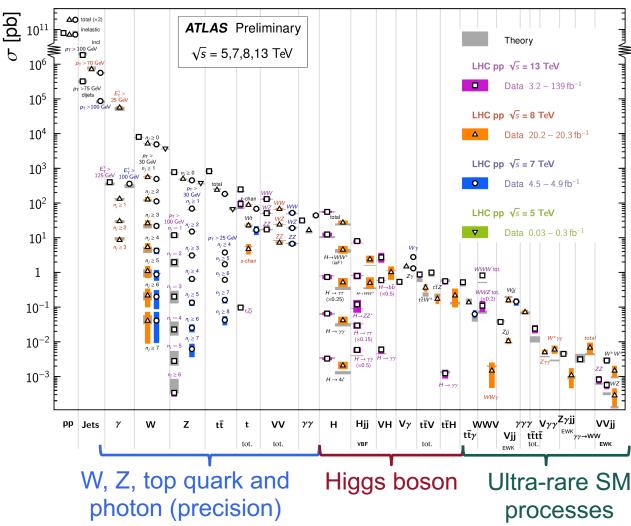
Run-2: massively successful and resulted in immense data set

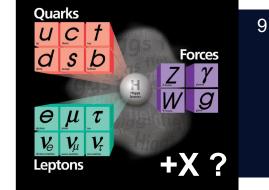
Thanks to dedicated LHC and experiment operations teams

W bosons	~26 billion
Z bosons	~8 billion
Top quarks	~275 million
Higgs bosons	~8 million
Higgs bosons Higgs pairs	~8 million ~4000

+ Run-2 Physics

Standard Model Production Cross Section Measurements





ATL-PHYS-PUB-2022-009

Status: February 2022

Run-2: many first observations (e.g. $H \rightarrow bb, \gamma\gamma \rightarrow WW$) and unprecedented precision

→ Most extensive knowledge about SM

More data will allow to unravel fundamental processes in more detail and probe extreme phase space regions where new physics might be hidden

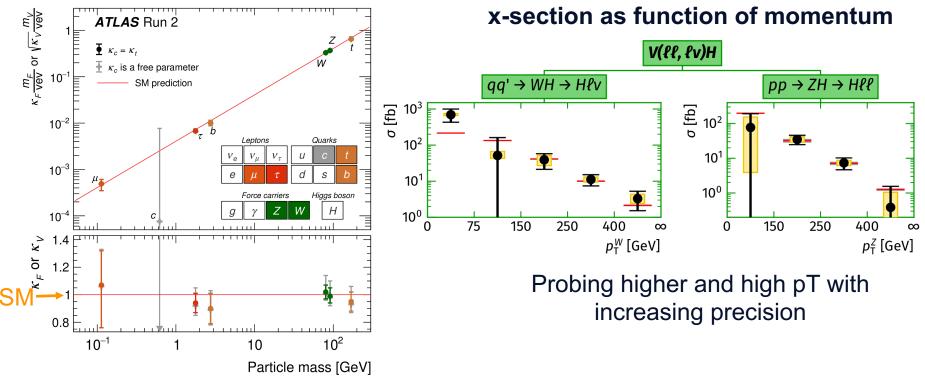
Nature 607, 52-59 (2022)



The Higgs Boson

Combining all measurements → most comprehensive map of Higgs boson interactions All major production modes – ggF, VBF, WH, ZH, ttH – observed!

Coupling strength to SM particles

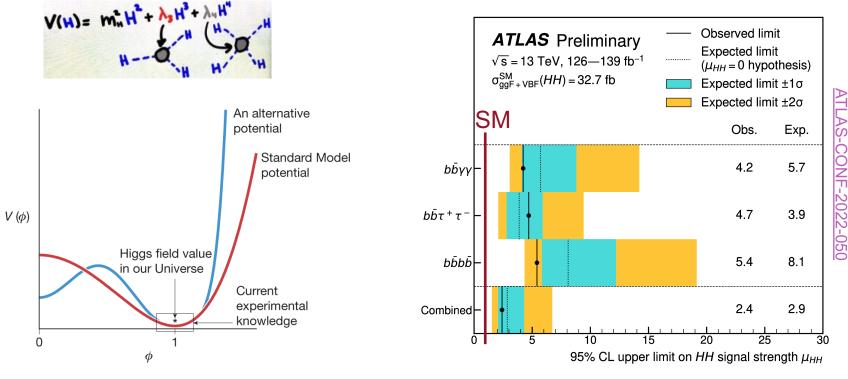


plot thickens: Higgs boson connected to mass generation of all (?) SM particles

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+ What about two Higgs Bosons?

Higgs boson self-interaction connected to shape of Higgs field potential \rightarrow Insights into electro-weak symmetry breaking during universe's early stages and long-term stability

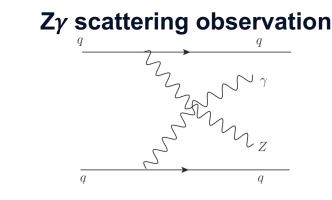


x-section*branching ratio < 2.4*SM expectation → reaching SM sensitivity (& beating earlier projections)!

Elisabeth Schopf, PPAP Community Meeting

+ W, Z and Top Quark Precision Measurements

- Ultra-rare (never observed before) SM processes are especially susceptible to new physics
- Their measurement further probes validity of SM
 - Electro-weak processes, e.g. vector-boson scattering, also connected to electro-weak symmetry breaking

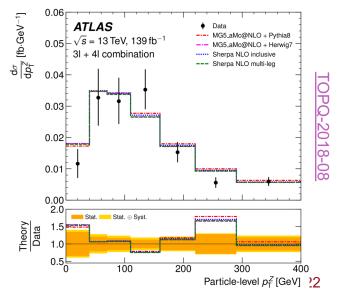


 $\sigma_{EW} = 4.49 \pm 0.40 \text{ (stat.)} \pm 0.42 \text{ (syst.) fb}$

\rightarrow (so far) everything in agreement with SM

ATLAS-CONF-2021-038

ttZ x-section measurement



+ Search for New Physics

Many searches for e.g. light/heavy new bosons (\rightarrow extended Higgs sector), supersymmetry including lightest SUSY particle (\rightarrow dark matter, ...), exotic signatures (\rightarrow axions, majorana neutrinos, ...)

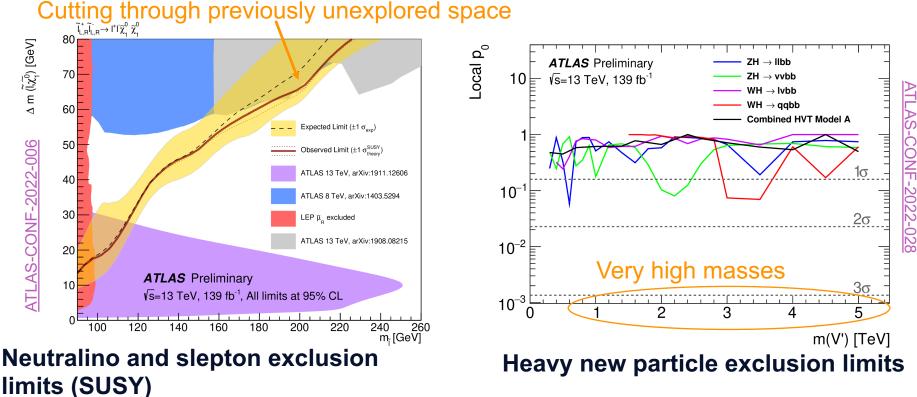
SUSY ATL-PHYS-PUB-2022-013 Long-lived particles ATL-PHYS-PUB-2022-034 ATLAS Preliminary ATLAS SUSY Searches* - 95% CL Lower Limits ATLAS Long-lived Particle Searches* - 95% CL Exclusion ATLAS Preliminary $\sqrt{s} = 13 \text{ TeV}$ Model Signature L dt [fb] Mass limit Reference $\int \mathcal{L} dt = (32.8 - 139) \text{ fb}^{-1}$ $\sqrt{s} = 13 \text{ TeV}$ $\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_{1}^{0}$ 0 e, µ nono-iet 2-6 jets 1-3 jets E_T^{miss} E_T^{miss} 139 139 1.85 m(\tilde{t}_{1}^{0})<400 Ge/ m(\tilde{t}_{1})=5 Ge/ 2010.14293 Model Signature (L dt [fb⁻¹] Lifetime limit Reference RPV $\tilde{t} \rightarrow \mu q$ $\tilde{g}\tilde{g}, \tilde{g} \rightarrow g\tilde{g}\tilde{\chi}_{1}^{0}$ 0 e.u 2-6 jets E_{π}^{miss} 139 2.3 $m(\tilde{t}_{1}^{0})=0 \text{ Ge}^{0}$ $m(\tilde{t}_{1}^{0})=1000 \text{ Ge}^{0}$ 2010.14293 2010.14293 136 0.002-6.0 m(T)= 1.4 TeV 2002 1105 1.15-1.95 $\tilde{x}\tilde{x}, \tilde{x} \rightarrow a\tilde{a}W\tilde{X}$ 2.2 m($\hat{\ell}_1^0$)<600 Ge 2101.01629 $RPV \tilde{\chi}_1^0 \rightarrow e$ 32.8 ⁰ lifetim 0.003-1.0 m $m(\tilde{q}) = 1.6 \text{ TeV}, m(\tilde{\chi}_1^0) = 1.3 \text{ TeV}$ 1907.10037 E_T^{miss} E_T^{miss} $\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(\ell \ell)\tilde{\chi}$ $\tilde{g}\tilde{g}, \tilde{g} \rightarrow qqWZ\tilde{\chi}$ 2 jets 139 2.2 m(k1)<700 Ge CERN-EP-2022-014 $GGM \tilde{r}_{1}^{0} \rightarrow Z\tilde{G}$ 32.9 ⁰ lifetim $m(\tilde{g}) = 1.1 \text{ TeV}, m(\tilde{\chi}_1^0) =$ 1808.0305 0 e,μ SS e,μ 7-11 jets 6 jets 139 139 1.97 m(\tilde{t}_{1}^{0}) <600 Ge/ m(\tilde{t}_{1}^{0})=200 Ge/ 2008.06032 1909.08457 1.15 GMSE 139) lifetime 0.24-2.4 п $m(\tilde{\chi}_{1}^{0}, \tilde{G}) = 60, 20 \text{ GeV}, \mathcal{B}_{H} = 29$ ERN-EP-2022-05 $\tilde{v}\tilde{v}, \tilde{v} \rightarrow t \tilde{t} \tilde{\chi}_1^0$ E_T^{miss} 0-1 e.μ SS e.μ 3 b 6 jets 79.8 139 2.25 m($\hat{\ell}_1^0$)<200 Ge' m($\hat{\varrho}$)-m($\hat{\ell}_1^0$)=300 Ge' ATLAS-CONF-2018-041 1909.08457 6-750 mm $GMSB \tilde{l} \rightarrow l\tilde{G}$ 139 lifetime $m(\tilde{\ell}) = 600 \text{ GeV}$ 2011.07812 δıδı 0 e.µ 26 1.255 $m(\tilde{\ell}_1^0) < 400 \text{ Ge}'$ $0 \text{ GeV} < \Delta m(\tilde{b}_1, \tilde{\chi}_1^0) < 20 \text{ Ge}'$ 2101.12527 2101.12527 lifetime GMSB $\tilde{\tau} \rightarrow \tau \tilde{G}$ 139 9-270 mm m(7)= 200 GeV 2011.07812 $\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_2^0 \rightarrow b h \tilde{\chi}_1^0$ 0.23-1.35 30 GeV, m(\hat{t}_1^0)=100 Ge =130 GeV, m(\hat{t}_1^0)=0 Ge 1908.03122 * lifetime 0 e,μ 2 τ 6 b 2 b 139 139 AMSB $pp \rightarrow \tilde{\chi}_{1}^{\pm} \tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{\pm} \tilde{\chi}_{1}^{-}$ disappearing track 136 0.06-3.06 $m(\tilde{\chi}_{1}^{+}) = 650 \text{ GeV}$ 2201.02472 0.13-0.85 $\begin{array}{l} \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 {\rightarrow} t \tilde{t}_1^0 \\ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 {\rightarrow} W b \tilde{t}_1^0 \\ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 {\rightarrow} \tilde{\tau}_1 b v, \tilde{\tau}_1 {\rightarrow} \tau \tilde{G} \end{array}$ E_T^{miso} E_T^{miso} E_T^{miso} E_T^{miso} E_T^{miso} E_T^{miso} * lifetim 0.3-30.0 m 0-1 e.u ≥ 1 iet 139 1.25 $m(\hat{k}_{1}^{0})=1$ GeV 2004.14060.2012.0379 AMSB $pp \rightarrow \tilde{\chi}_{1}^{+} \tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{+} \tilde{\chi}_{1}^{-}$ large pixel dE/dx 130 n(\$2) = 600 GeV 2205 06013 3 jets/1 b 2 jets/1 b 1 e,μ 1-2 τ 139 139 m(t⁰)=500 Ge m(t)=800 Ge 2012.03799 Stealth SUS 2 MS vertices 36.1 0.1-519 m 1811.07370 2108.07665 5 lifetime $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow c \tilde{\chi}_1^0 / \tilde{c} \tilde{c}, \tilde{c} \rightarrow c \tilde{\chi}_1^0$ 2 c mono-iet 36.1 139 0.85 m(\tilde{t}_1^0)=0 Ge' m(\tilde{t}_1,\tilde{c})-m(\tilde{t}_1^0)=5 Ge' 1805.01649 2102.10874 Solit SUSY large pixel dE/dx 139 i lifetime > 0.45 m 2205.06013 1-2 e, µ 1-4 b E_T^{miss} E_T^{miss} 139 2006.05880 $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow t \tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow Z/h \tilde{\chi}_1^0$ $\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$ 0.067-1.18 m(x2)=500 Ge/ $m(\bar{x}) = 1.8 \text{ TeV}, m(\bar{x}_1^0) = 100 \text{ Ge}$ Solit SUSY displaced vtx + E^m 32.8 1710.04901 3 e, µ 1.b 139 0.86 $n(\tilde{t}_1^0)=360 \text{ GeV}, m(\tilde{t}_1)-m(\tilde{t}_1^0)=40 \text{ Ge}$ 2006.05880 Solit SUSY 0/2 = 6 jets $\pm F^{mi}$ 0.0-2.1 m $m(\bar{g}) = 1.8 \text{ TeV}, m(\bar{\chi}_1^0) = 100 \text{ Ge}$ 36.1 LAS-CONF-2018- $\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0$ via W2 Multiple *l*/jet 2106.01676, 2108.075 139 139 m(\hat{k}_{1}^{0})=0, wino-l m(\hat{k}_{1}^{0})=5 GeV, wino-l > 1 iet 0.20 2 MS vertices 139 0.31-72.4 m 2203.0058 $H \rightarrow s s$ m(s)= 35 GeV $\tilde{X}_{1}^{\pm}\tilde{X}_{1}^{\mp}$ via WW 2 e.u $\begin{array}{c} E_T^{\rm miss}\\ E_T^{\rm miss}\\ E_T^{\rm miss}\\ E_T^{\rm miss}\\ E_T^{\rm miss}\\ E_T^{\rm miss}\\ E_T^{\rm miss}\end{array}$ 139 0.42 $m(\tilde{k}_{1}^{0})=0$ wing-bi 1908.08215 lifetime $\tilde{\chi}_{1}^{\pm} \tilde{\chi}_{2}^{0}$ via Wh $\tilde{\chi}_{1}^{\pm} \tilde{\chi}_{1}^{\mp}$ via $\tilde{\ell}_{L}/\tilde{\nu}$ Multiple {/jets (x⁰)=70 GeV, wino-b 10894,2108.0 $H \rightarrow ss$ 2 low-EMF trackless jets lifetime 139 0.19-6.94 n m(s)= 35 GeV 2203.01009 139 $2e,\mu$ $n(\hat{\ell},\hat{r})=0.5(m(\hat{x}_{1}^{+})+m(\hat{x}_{1}^{0}))$ 1908.08215 2τ 2e,μ ee,μμ 139 0.16-0.3 0.12-0.39 1911.06660 m(t): VH with $H \rightarrow \infty$ 139 lifetime m(s) = 35 GeV2107.06092 liplip. l→R 0 jets ≥ 1 jet 139 139 $m(\tilde{\ell}_{1}^{0})=$ $n(\tilde{\ell})-m(\tilde{\ell}_{1}^{0})=10 \text{ Ge}^{2}$ 1908.08215 0.256 $FRVZ H \rightarrow 2\gamma_d + \lambda$ 2 u-jets 139 ra lifetin $m(\gamma_d) = 400 \text{ MeV}$ 2206.12181 ŘŘ Ř.→6/2Č 0 e,µ 4 e,µ 0 e,u $\geq 3 b$ 0 jets $\geq 2 \text{ large jets}$ E_T^{miss} E_T^{miss} 0 13-0 23 0 29-0 88 $BR(\tilde{t}_{\parallel}^{0} \rightarrow h\tilde{G})=$ $BR(\tilde{t}_{\parallel}^{1} \rightarrow Z\tilde{G})=$ $BR(\tilde{t}_{\parallel}^{1} \rightarrow Z\tilde{G})=$ 36.1 139 139 1806.04030 0.55 2103.11684 2108.07586 FRVZ $H \rightarrow 4\gamma_d + \lambda$ 2 u-jets 139 va lifetime $m(\gamma_d) = 400 \text{ MeV}$ 2206.12181 0.45-0.93 $H \rightarrow Z_A Z_A$ displaced dimuon 32.9 Z₄ lifetime 0.009-24.0 m $m(Z_d) = 40 \text{ GeV}$ 1808.0305 Direct $\tilde{\chi}_{1}^{+}\tilde{\chi}_{1}^{-}$ prod., long-lived $\tilde{\lambda}$ 0.66 Pure Win Pure higgsin 2201.02472 2201.02472 0.21 $H \rightarrow 77$ 2 e. u. + low-EME trackless iet 36 1 Z Jifetime 0.21.5.2 m $m(Z_i) = 10 \text{ GeV}$ 1811 02542 E_T^{miss} E_T^{miss} E_T^{miss} E_T^{miss} Stable # B-hadro pixel dE/do 139 2.05 CERN-EP-2022-02 Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_{1}^{0}$ $\tilde{\ell}\tilde{\ell}, \tilde{\ell} \rightarrow \ell \tilde{G}$ nivel dE/dr 139 139 CEDN ED 2022 02 [r(ā) =10 ne] $m(\tilde{\ell}_{1}^{0})=100 \text{ Ge}$ 1902.0309 Displ. lep $\tau(\tilde{\ell}) = 0.1 \text{ m}$ $\tau(\tilde{\ell}) = 0.1 \text{ m}$ $\tau(\tilde{\ell}) = 10 \text{ m}$ 2011.07812 2011.07812 CERN-EP-2022-029 ₽(600 GeV) 1902.0309 ss jets, MS vtx 36.1 lifetime Emiss pixel dE/dx 139 0.06-52.4 1902.0309 less jets, MS vtx 36.1 lifetime $\times \mathcal{B} = 1 \text{ pb. } m(s) = 150$ $\begin{array}{c} \tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\mp} / \tilde{\chi}_1^0 , \tilde{\chi}_1^{\pm} \rightarrow Z \ell \rightarrow \ell \ell \ell \\ \tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\mp} / \tilde{\chi}_2^0 \rightarrow W W / Z \ell \ell \ell \ell \nu \nu \\ \tilde{g} \tilde{g} , \tilde{g} \rightarrow q q \tilde{\chi}_1^0 , \tilde{\chi}_1^0 \rightarrow q q q \\ \tilde{tt} , \tilde{t} \rightarrow t \tilde{\chi}_{1_1}^0 \tilde{\chi}_{1_2}^0 \rightarrow t b s \end{array}$ Pure Win 2011.10543 4 e.µ 0 jets E_{τ}^{mis} 139 1.55 2103.11684 m(2)=200 Ge $W \rightarrow N\ell N \rightarrow \ell \ell \lambda$ displaced vtx (uu.ue, ee) + u 139 0 74-42 mm m(N)- 6 GeV Direc 2204 11088 36.1 36.1 Large X' ($\hat{\chi}_1^0$)=200 GeV, bino-lik ATLAS-CONF-2018-00 $W \rightarrow N\ell N \rightarrow \ell \ell \lambda$ displaced vtx (µµ,µe, ee) + µ 139 1.33 mm m(N)= 6 GeV, Majorana 2204.11988 $\overline{r} \rightarrow b\overline{r}^{\pm} \overline{r}^{\pm} \rightarrow b\overline{r}$ m(22)=500 Ge 2010.01015 2 jets + 2 / 36.7 1710.07171 $W \rightarrow N\ell N \rightarrow \ell\ell_{2}$ displaced vtx (uu.ue. ee) + e 139 m(N) = 6 GeV. Dirac 2204 11988 2 e,μ 1 μ 2 b DV 36.1 136 0.4-1.45 1710.05544 2003.11956 $W \rightarrow N\ell, N \rightarrow \ell\ell\gamma$ N lifetim m(N)= 6 GeV. Maic 2204 1198 $\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}/\tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{0} \rightarrow tbs, \tilde{\chi}_{1}^{+} \rightarrow bb;$ $1.2 e, \mu$ ≥6 jet: 120 0.2-0.32 Pure higgsi 2106.09609 ¹⁰⁰ cτ [m] 0.001 0.01 0.1 10 - 13 Te 10-Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on Mass scale [TeV] 100 *Only a selection of the available lifetime limits is shown. 0.001 0.01 0.1 1 10 plified models, c.f. refs. for the assumption τ [ns]

Large range of signatures covered spanning large mass ranges and lifetimes

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+ Searches for New Particles

Combining many Run-2 measurements to reach improved sensitivity esp. at ultra-high masses and unexplored phase spaces



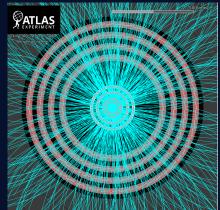
Systematically mapping out new phase spaces → (so far) no sign of new physics

ATLAS Experiment Operations and Maintenance

In the following focussed on the systems with major UK involvement

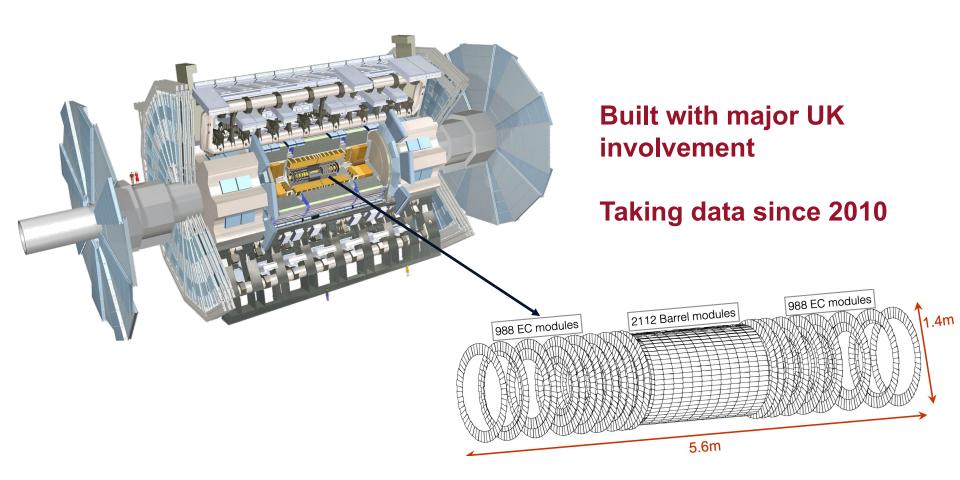
Major to-do items transitioning from Run-2 to Run-3:

- maintaining aging systems
- handling ultra high and dense data rates due to large amount of parasitic collisions (pile-up)
- upgrade and fine tune where possible



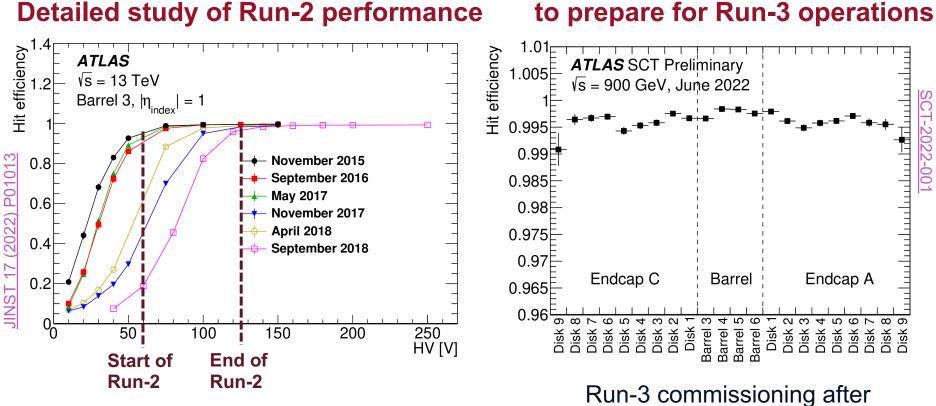
+ Semiconductor Tracker (SCT)

Detector providing tracking information one of the systems closest to the interaction point (immense radiation doses)



+ SCT: from Run-2 to Run-3

Detector providing tracking information one of the systems closest to the interaction point (immense radiation doses)



 \rightarrow High voltage needs to be adjusted

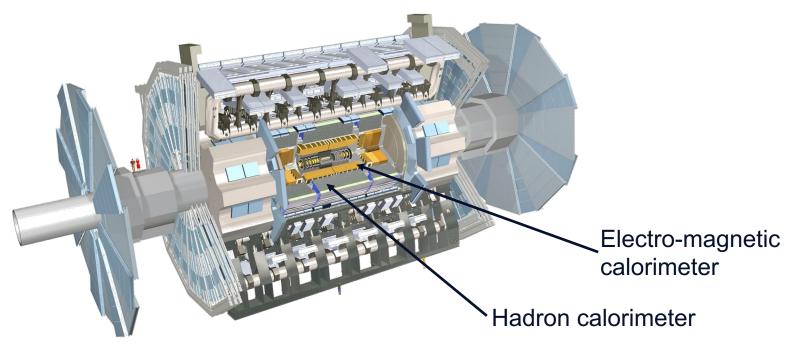
Run-3 commissioning after tweaking operational settings

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+ L1Calo Trigger

Hardware trigger delivering decisions with rate of 40,000,000/second keeping 100,000 events/second

■ Combines information about dense activity in the calorimeters (→jets, electrons, hadronically decaying tauleptons) or imbalance of activity (→ missing energy)

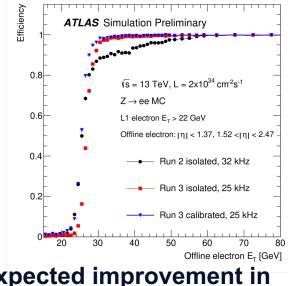


+ L1Calo Trigger Upgrade

Currently being upgraded (for usage during Run-3) with UK institutes dominating leadership -> improvements in electron and tau trigger + better performance vs. pile-up

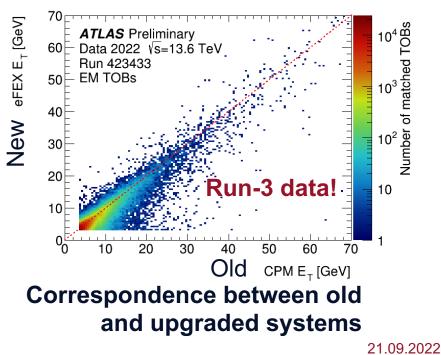
Status:

- Installation and integration into ATLAS completed (as of last week!)
- Next year: finalise operation/monitoring software and fine-tuning



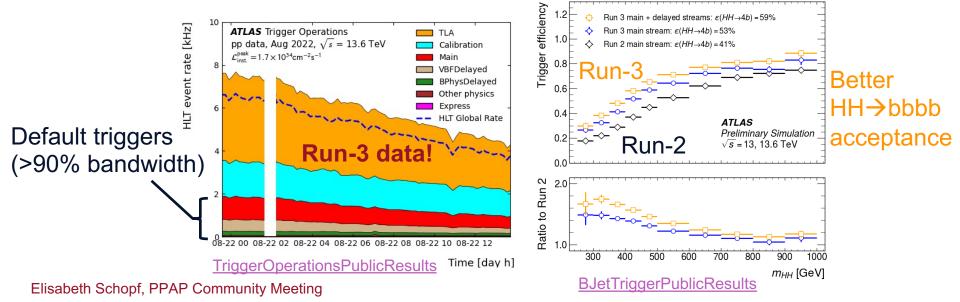
Expected improvement in electron trigger performance

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+ High-Level Trigger

- Software based trigger receiving ~100,000 events/second to reduce to ~1000 events/second kept for physics
- Software optimisation and upgraded computing facilities towards Run-3 → more frequent and more complex operations (e.g. track reconstruction) possible
- → Expanded and improved triggering for Run-3! (dedicated long-lived particles trigger, b-jets, ...`



Run-3 Outlook

Elisabeth Schopf, PPAP

Community Meeting

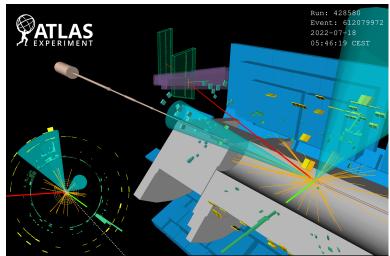
22

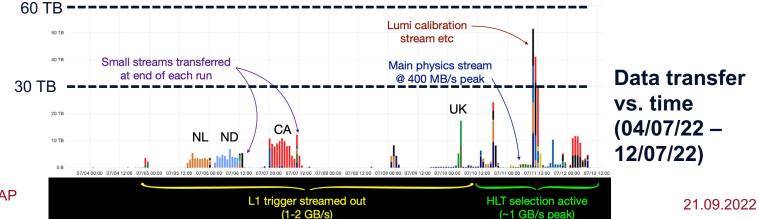
ATLAS Run-3 data taking at collision energy of 13.6 TeV officially started on 05/07/22

ATLAS Control Room: first 13.6 TeV collision

+ First Collisions





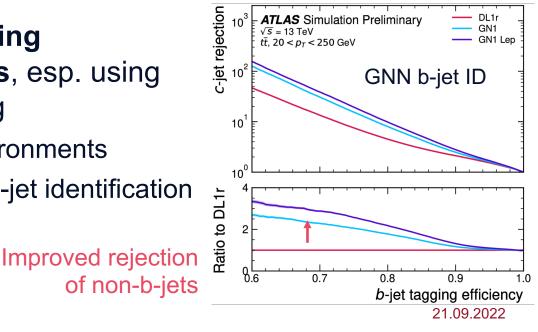


Transfer Volume

Early Run-3 top quark pair (17/07/22)

+ Run-3: New Opportunities

- Larger dataset expected and increased x-sections due to higher collision energy (HH +11%, Z' with 6 TeV mass +70%)
- Upgraded & new detector systems, e.g. "New Small Wheel" for improved muon trigger and muon reconstruction in forward region
- Improved triggers and new trigger signatures for increased acceptance of SM and new beyond SM signatures
 ATL-PHYS-PUB-2
- Continued work on improving reconstruction algorithms, esp. using advanced machine learning
 - Tracking in ultra-dense environments
 - Graph neural networks for b-jet identification



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- Run-2 was a hugely successful data taking period with many major physics milestones reached
- Run-3 data taking is ongoing, which will collect at least ~2 times the data of Run-2
- Upgrading ATLAS experiment's systems (where possible) and improving data collection/reconstruction continues
- Many exciting physics results still awaiting as we enter high-precision era!

Large involvement from UK community in key areas and leadership: continues to be integral part of the collaboration

Backup





L1Calo Phase-1: UK major tasks

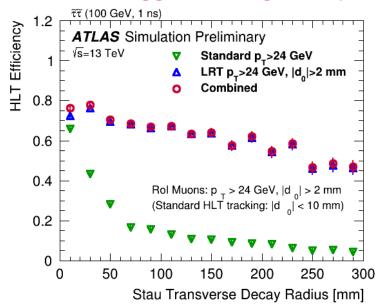


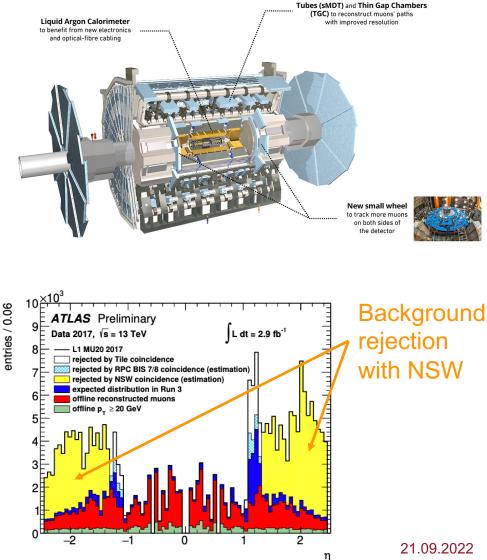
- <u>eFEX</u> module
 - Main processor for identifying electron/tau objects
 - Firmware well established and fairly stable
 - Long history of module production problems, but now installed
- ROD sub-module
 - Readout for <u>eFEX</u> and <u>iFEX</u> modules
 - Used for some time in Point-1, 100 kHz readout established
- Online and offline software
 - Used to configure and validate hardware
 - Reaching maturity for UK modules
 - Will require more features for full operational monitoring
- Commissioning, Run Coordination and Management
 - UK has significant CERN presence and responsibility in all areas
 - Also supported remotely and regular visits from UK experts

- Last year
 - Installation
 - Low-level debugging (mapping, link stability)
 - Integration with ATLAS (LArg and TDAQ)
- Next year
 - Establish stable operation
 - Calibrate and fine-tune triggers
 - Expect to switch on new triggers in 2023
 - Finish production of <u>eFEX</u> spares

+ Run-3 Opportunities – additional material

Dedicated trigger for long-lived particles





+ Simulation

- Simulated data used to be able to develop analysis strategies before full data is available and perform "blind analysis" to avoid bias
 - Several hundred billions of events produced
- Full chain of theoretical description of a given process, detector response, object reconstruction has to be simulated
- Strong UK involvement in improving description of simulation (compared to data) and making simulation of detector/reconstruction response faster
- \rightarrow Better MC and more efficient MC production for Run-3

+ Computing

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 UK pledges large storage and computing resources (between 10-15% share in CPU resources; several tens of PB storage in form of tape and disk)

As data sets increases more work put in efficient (lowering time and CPU costs) towards Run-3

