Run 2 is over!

Huge thanks to the LHC division for efficient and smooth operation

- 2018: ~ 70 /fb
- Run-2 integrated: ~ 160 /fb (goal: 120 /fb)
Run 2 is over!

Huge thanks to the LHC division for efficient and smooth operation

- 2018: ~ 70 /fb
- Run-2 integrated: ~ 160 /fb (goal: 120 /fb)

usable for physics: ~ 140 /fb

To come:

- Run 3: 2021—2023, 150 /fb at 14 TeV
- Run 4: 2027+, 3000 /fb at 14 TeV
Run 2: exquisite understanding

electron momentum scale & resolution; $p_T$(miss) resolution

tagging (boosted) hadronic W, top decays: moving to advanced techniques

limited by parton shower & hadronisation systematics
ATLAS physics programme

Standard Model measurements:
- electroweak measurements
- top quark physics
- flavour-changing neutral current processes

Searches for BSM physics:
- generic SUSY
- dark matter
- exotic signatures: long-lived heavy particles

Higgs boson physics:
- H(125) properties
- search for di-Higgs production

Heavy-ion physics

Over 800 publications submitted by ATLAS in total (~100 in 2018)
Full details at https://twiki.cern.ch/twiki/bin/view/AtlasPublic
Standard Model Production Cross Section Measurements

ATLAS Preliminary
Run 1,2 $\sqrt{s} = 7,8,13$ TeV

<table>
<thead>
<tr>
<th>LHC pp $\sqrt{s} = 7$ TeV</th>
<th>Data 4.5 – 4.9 fb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHC pp $\sqrt{s} = 8$ TeV</td>
<td>Data 20.2 – 20.3 fb$^{-1}$</td>
</tr>
<tr>
<td>LHC pp $\sqrt{s} = 13$ TeV</td>
<td>Data 3.2 – 79.8 fb$^{-1}$</td>
</tr>
</tbody>
</table>
Observation of EW WW, WZ production

Sensitive probes of triple gauge-boson couplings

- studied for leptonic W, Z decay modes

- WW: $W^+W^+ / W^-W^-$ only
Observation of EW WW, WZ production

Sensitive probes of triple gauge-boson couplings

- studied for leptonic W, Z decay modes

- WW: \( W^+W^+ / W^-W^- \) only

Signal significances:

- WZ: 5.6 \( \sigma \) observed (3.3 \( \sigma \) expected)

- same-sign WW: 6.9 \( \sigma \) observed (4.6 \( \sigma \) expected)
Measurement of $\sin^2(\theta_W)$

Of continued importance due to tension between LEP-era measurements

New measurement using 8 TeV data (2012)

- at LO and ignoring acceptance effects:
  \[
  \frac{d\sigma}{dy^{\ell\ell} \, dm^{\ell\ell} \, d\cos \theta} = \frac{3}{16\pi} \frac{d\sigma^{U+L}}{dy^{\ell\ell} \, dm^{\ell\ell}} \left( 1 + \cos^2 \theta + A_4 \cos \theta \right)
  \]

- good agreement overall between data & predictions (not using absolute rates)
  + cross-check with results obtained using unfolded differential $d\sigma$

full phase space: $A_{FB} = \frac{3}{8} A_4$
Measurement of $\sin^2(\theta_W)$

Of continued importance due to tension between LEP-era measurements

New measurement using 8 TeV data (2012)

- at LO and ignoring acceptance effects:

$$\frac{d\sigma}{dy^{\ell\ell} \, dm^{\ell\ell} \, d\cos \theta} = \frac{3}{16\pi} \frac{d\sigma^{U+L}}{dy^{\ell\ell} \, dm^{\ell\ell}} \left( 1 + \cos^2 \theta + A_4 \cos \theta \right)$$

- good agreement overall between data & predictions (not using absolute rates)
  + cross-check with results obtained using unfolded differential $d\sigma$

$\sin^2 \theta_{\text{eff}}^\ell = 0.23140 \\ \pm 0.00021 \text{ (stat.)} \\ \pm 0.00024 \text{ (PDFs)} \\ \pm 0.00016 \text{ (syst.)}$
Angular analysis of $B_d \to K^* \mu^+\mu^-$ decays

FCNC process, of great (renewed) interest following LHCb $3.4 \sigma$ tension with SM predictions

$$\frac{1}{d\Gamma/dq^2} \frac{d\Gamma}{d \cos \theta_L \ d \cos \theta_K \ d\phi \ dq^2} = \frac{9}{32\pi} \left( ... + \sqrt{F_L(1-F_L)} \ P_5' \sin 2\theta_K \sin \theta_L \cos \phi + ... \right)$$

fraction of longit. polarized $K^*$

1/7 Wilson coefficients

Measurement for $q^2 \equiv m_{\mu\mu}^2 < 6 \text{ GeV}^2$
(to avoid radiative $J/\psi$ tail) in 8 TeV data

- most discrepant result for $P_5'$ in 4 - 6 GeV$^2$ bin (2.7 $\sigma$), but not precise enough to make a firm statement
- measurement statistically limited
$B_{d,s} \rightarrow \mu^+\mu^-$

Rare FCNC decay sensitive to BSM loop contributions

Multivariate analysis (BDT) to suppress continuum bg, yields extracted from $m(\mu^+\mu^-)$ distributions in different BDT intervals

- same variables as in Run-1 analysis; BDT output not correlated with mass

![Dimuon invariant mass](image)
Rare FCNC decay sensitive to BSM loop contributions

Multivariate analysis (BDT) to suppress continuum bg, yields extracted from $m(\mu^+\mu^-)$ distributions in different BDT intervals

- same variables as in Run-1 analysis; BDT output not correlated with mass

- results (combined w/ Run 1):
  \[ B(B_s \rightarrow \mu^+\mu^-) = 2.8^{+0.8}_{-0.7} \cdot 10^{-9} \]
  \[ B(B_d \rightarrow \mu^+\mu^-) < 2.1 \cdot 10^{-10} \]

- SM: $3.65 \pm 0.23 \cdot 10^{-9}$, $1.06 \pm 0.09 \cdot 10^{-10}$
Spin correlations in tt decays

Top-quark spin transmitted to decay products, charged lepton is a sensitive probe also for spin correlations in dilepton tt events

- used earlier to search for stop pair production with $m(\tilde{t}) \approx m(t)$
- consider $\Delta\phi(e, \mu)$ in lab frame
- integrated & in bins of $m(tt)$

Find stronger spin correlations than predicted by SM (3.2 $\sigma$)

- possible hint for un-understood production (e.g. $\tilde{t}\tilde{t}^* \rightarrow t\chi^0\tilde{t}\chi^0$) or decay (e.g. $t \rightarrow H^+ b$) characteristics
Search for resonances decaying to $t\bar{t}$

Searched for in lepton+jets events

- high branching fraction, “tractable” kinematic constraints, exploit top tagging
- absence of a signal used to set limits on several benchmark signal models
- $Z'$ (top-colour-assisted technicolour & simplified DM models)
- RS $g_{KK}$, $G_{KK}$
Search for resonances decaying to tt

Searched for in lepton+jets events

- high branching fraction, “tractable” kinematic constraints, exploit top tagging
- absence of a signal used to set limits on several benchmark signal models
  - Z' (top-colour-assisted technicolour & simplified DM models)
  - RS g_{KK}, G_{KK}

ATLAS
\(\sqrt{s} = 13\text{ TeV}, 36.1\text{ fb}^{-1}\)

Expected 95% CL upper limit
Observed 95% CL upper limit

\(\sigma\) [pb] \(\times\) \(\sigma\)

<table>
<thead>
<tr>
<th>mediator mass [TeV]</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data / Pred.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Boosted (\mu) (cat. 3)</td>
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<tr>
<td>Post-Fit</td>
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<td></td>
</tr>
</tbody>
</table>

Mediator mass [TeV]

\(m_{\text{data}}\) [GeV]

Data / Pred.
# Searches for BSM physics

## ATLAS Exotics Searches - 95% CL Upper Exclusion Limits

**Status:** July 2018

\[ \mathcal{L} \ dt = (3.2 - 79.8) \text{ fb}^{-1} \]

\[ \sqrt{s} = 8, \ 13 \text{ TeV} \]

### Model
- **ADD G\(_{\chi\chi} \rightarrow g/q\)**: 0 e, µ → 1 - 4 j | Yes | 36.1 |
- **ADD non-resonant \(g\gamma\)**: 2 γ → 37.0 |
- **ADD BH high \(\sum p_T\)**: 1 e, µ ≥ 2 j | 3.2 |
- **ADD BH multifit**: 3.6 |
- **RS1 \(G_{\chi\chi} \rightarrow W/\gamma\)**: 2 γ → 36.7 |
- **Bulk RS \(G_{\chi\chi} \rightarrow WW/ZZ\)**: multi-channel | 36.1 |
- **Bulk RS \(G_{\chi\chi} \rightarrow t\bar{t}\)**: 1 e, µ ≥ 1 b, ≥ 1 j2j | 36.1 |
- **2UED / RPP**: 1 e, µ ≥ 2 b, ≥ 3 j | 36.1 |
- **SSM \(Z^\prime \rightarrow \ell\ell\)**: 2 e, µ → 36.1 |
- **SSM \(Z^\prime \rightarrow t\bar{t}\)**: 2 t → 36.1 |
- **Leptophobic \(Z^\prime \rightarrow bb\)**: 2 b → 36.1 |
- **SSM \(W^\prime \rightarrow lv\)**: 1 e, µ → 79.8 |
- **SSM \(W^\prime \rightarrow t\bar{t}\)**: 1 t → 36.1 |
- **HVT \(V^\prime \rightarrow WW\)**: model B 0 e, µ → 79.8 |
- **HVT \(V^\prime \rightarrow WH/2H** model B**: multi-channel | 36.1 |
- **LRSM \(W_{LQ} \rightarrow tb\)**: multi-channel | 36.1 |
- **Cl \(\ell\ell\)**: 2 e, µ → 36.1 |
- **Cl \(\ell\ell\)**: 2 e, µ → 36.1 |
- **DM**: 0 e, µ → 36.1 |
- **Scalar LO 1st gen**: 2 e, µ → 3.2 |
- **Scalar LO 2nd gen**: 2 e, µ → 3.2 |
- **Scalar LO 3rd gen**: 1 e, µ, ≥ 1 b, ≥ 3 j | 20.3 |
- **VLQ \(T_T \rightarrow H/ZZ/\gamma W_B + X\)**: multi-channel | 36.1 |
- **VLQ \(BB \rightarrow W/\gamma W_B + X\)**: multi-channel | 36.1 |
- **VLQ \(T_T \rightarrow T_L + b + T_L \rightarrow W + X\)**: 2i(S)/3 | 36.1 |
- **VLQ \(T_T \rightarrow b + X\)**: 1 e, µ ≥ 1 b, ≥ 1 j | 3.2 |
- **VLQ \(\tilde{Q} \rightarrow H_0 + X\)**: 0 e, µ, γ → 79.8 |
- **VLQ \(QQ \rightarrow W/W_B + X\)**: 1 e, µ → 20.3 |
- **Excited quark q → qg**: 2 j → 37.0 |
- **Excited quark q → qy**: 1 j → 36.7 |
- **Excited quark b → bg**: 1 b, 1 j → 36.1 |
- **Excited lepton \(\ell^*\)**: 3 e, µ, τ → 20.3 |
- **Type III Seesaw**: 2 e, µ → 79.8 |
- **LRSM Majorana**: 2 e, µ → 20.3 |
- **Higgs triplet \(H^\prime \rightarrow \ell\ell\)**: 2, 3 e, µ (SS) → 36.1 |
- **Higgs triplet \(H^\prime \rightarrow t\bar{t}\)**: 3 e, µ, τ → 20.3 |
- **Monopole (non-res prod)**: 1 e, µ, 1 b → 20.3 |
- **Multi-charged particles**: – → 20.3 |
- **Magnetic monopoles**: – → 7.0 |

### Extra dimensions

### Gauge bosons

### DM

### Scalar

### LQ

### Heavy quarks

### Excited fermions

### Other

\[ \sqrt{s} = 8 \text{ TeV} \]
\[ \sqrt{s} = 13 \text{ TeV} \]

- **\(m(W_{LQ}) = 2.4 \text{ TeV}, \) no mixing**
- **DY production**: 1710.09748
- **DY production**: 1411.2921
- **DY production**: 1411.2921
- **DY production**: 1506.06200

**Reference**

<table>
<thead>
<tr>
<th>Model</th>
<th>Jets</th>
<th>(E_{\text{miss}}^T)</th>
<th>Limit</th>
<th>( [\mathcal{L} \ dt] \text{ fb}^{-1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 e, µ → 1 - 4 j</td>
<td>Yes</td>
<td>36.1</td>
<td>7.7 TeV</td>
<td></td>
</tr>
<tr>
<td>0 e, µ → 1 - 4 j</td>
<td>Yes</td>
<td>36.1</td>
<td>8.6 TeV</td>
<td></td>
</tr>
<tr>
<td>1 e, µ → 2 j</td>
<td>37.0</td>
<td>8.9 TeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 e, µ ≥ 2 j</td>
<td>3.2</td>
<td>8.2 TeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 e, µ ≥ 2 j</td>
<td>3.6</td>
<td>9.55 TeV</td>
<td></td>
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<tr>
<td>2 γ</td>
<td>36.7</td>
<td>4.1 TeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 e, µ ≥ 2 b, ≥ 3 j</td>
<td>36.1</td>
<td>2.3 TeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 e, µ ≥ 1 b, ≥ 1 j2j</td>
<td>36.1</td>
<td>3.8 TeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 e, µ ≥ 2 b, ≥ 3 j</td>
<td>36.1</td>
<td>1.8 TeV</td>
<td></td>
<td></td>
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<tr>
<td>2 e, µ → 36.1</td>
<td>4.5 TeV</td>
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<tr>
<td>2 e, µ → 36.1</td>
<td>2.42 TeV</td>
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<tr>
<td>2 e, µ → 36.1</td>
<td>2.1 TeV</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2 e, µ → 36.1</td>
<td>2.1 TeV</td>
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<tr>
<td>1 e, µ → 79.8</td>
<td>5.8 TeV</td>
<td></td>
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<tr>
<td>1 e, µ → 36.1</td>
<td>3.7 TeV</td>
<td></td>
<td></td>
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<tr>
<td>1 t → 79.8</td>
<td>4.19 TeV</td>
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<tr>
<td>2 e, µ → 36.1</td>
<td>2.93 TeV</td>
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<tr>
<td>1 e, µ → 36.1</td>
<td>3.25 TeV</td>
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<tr>
<td>2 e, µ → 36.1</td>
<td>1.16 TeV</td>
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<tr>
<td>1 e, µ, ≥ 1 b, ≥ 3 j</td>
<td>20.3</td>
<td>480 GeV</td>
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<tr>
<td>2 e, µ, γ → 79.8</td>
<td>1.37 TeV</td>
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<tr>
<td>1 e, µ, γ → 79.8</td>
<td>1.34 TeV</td>
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<tr>
<td>1 e, µ, ≥ 1 b, ≥ 1 j</td>
<td>3.2</td>
<td>1.64 TeV</td>
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<tr>
<td>1 e, µ, ≥ 1 b, ≥ 1 j</td>
<td>3.2</td>
<td>1.44 TeV</td>
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<td>1 e, µ, ≥ 4 j</td>
<td>20.3</td>
<td>1.21 TeV</td>
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<td>2 e, µ, γ → 6.0 TeV</td>
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<tr>
<td>1 e, µ → 5.3 TeV</td>
<td></td>
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</tr>
<tr>
<td>1 e, µ → 2.6 TeV</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3 e, µ, τ → 20.3</td>
<td>1.6 TeV</td>
<td></td>
<td></td>
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<tr>
<td>1 e, µ, ≥ 2 j</td>
<td>79.8</td>
<td>560 GeV</td>
<td></td>
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<tr>
<td>2 e, µ → 20.3</td>
<td>2.0 TeV</td>
<td></td>
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<tr>
<td>2.3, 3 e, µ (SS) → 36.1</td>
<td>870 GeV</td>
<td></td>
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<tr>
<td>3 e, µ, τ → 20.3</td>
<td>460 GeV</td>
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</tr>
<tr>
<td>1 e, µ, 1 b → 20.3</td>
<td>1170 GeV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– → 20.3</td>
<td>765 GeV</td>
<td></td>
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</tr>
</tbody>
</table>

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

**Small-radius (large-radius) jets are denoted by the letter \(j\) (\(J\)).**

**Note:** The table above presents ATLAS Exotics Searches - 95% CL Upper Exclusion Limits as of January 2019. The results are based on data collected at the Large Hadron Collider (LHC) at the CERN laboratory. The searches aim to find evidence for new physics beyond the Standard Model (BSM). The table lists various models and processes, along with the number of events observed or expected, and upper limits on the mass of potential new particles. The limits are calculated at a confidence level of 95%, with the data taken at the LHC running at 13 TeV.
Both for strong ($\tilde{q}\tilde{q}, \tilde{g}\tilde{g}$) and EW ($\tilde{\chi}^{\pm}\tilde{\chi}^{0}$) production

- also using new reconstruction techniques (RJR)

also $W \rightarrow \ell\nu$
Searches for supersymmetry

Both for strong ($\tilde{q}\tilde{q}, \tilde{g}\tilde{g}$) and EW ($\tilde{\chi}^{\pm}\tilde{\chi}^0$) production

- also using new reconstruction techniques (RJR)

Significantly enlarged excluded region for strong production; excess in EW search in both 2$\ell$, 3$\ell$ regions (largest deviation: 3$\sigma$)

- compatible with compressed scenario ($m_{\tilde{\chi}^0_2, \tilde{\chi}^\pm_1} - m_{\tilde{\chi}^0_1} \approx 100$ GeV)

$\tilde{g}$ production, $B(\tilde{g} \to q\bar{q}\tilde{\chi}_1^0) = 100\%$, $m(_{\tilde{\chi}_1^0}) = (m(\tilde{g}) + m(\tilde{\chi}_1^0))/2$

$\tilde{q}$ production, $B(\tilde{q} \to q\bar{q}\tilde{\chi}_1^\pm) = 100\%$, $m(_{\tilde{\chi}_1^\pm}) = (m(\tilde{q}) + m(\tilde{\chi}_1^\pm))/2$

ATLAS
$\sqrt{s} = 13$ TeV, 36.1 fb$^{-1}$
0-leptons, 2-6 jets
MER or RJR (Best Expected)
All limits at 95% CL

Expected limit ($\pm 1$ $\sigma_{\text{exp}}$)
Observed limit ($\pm 1$ $\sigma_{\text{SUSY}}$)

2/3-lepton SRs
Statistical Combination
All limits at 95% CL

$\tilde{\chi}_1^\pm \to W(\to l\nu / q\bar{q})\tilde{\chi}_2^0$, $Z(\to ll)\tilde{\chi}_1^0$
Searches for heavy, long-lived particles

Arise in many BSM models (Hidden Valley, SUSY, ...); $c\tau$ poorly constrained

ATLAS searches for both heavy charged (through $dE/dx$) & neutral particles (decays in Muon System)
 Searches for Dark Matter

Mono-H(bb) (Z’+2HDM simplified model) as a test case for reconstruction improvements

- variable-radius jets (R ~ 30 GeV/p_{T}) to reconstruct high-p_{T} H \rightarrow bb as “pencil” jets inside large-R jet

\[ \text{Events / 20 GeV} \]

<table>
<thead>
<tr>
<th>Data</th>
<th>SM Vh</th>
<th>Diboson</th>
<th>h(t) + single top</th>
<th>Z+jets</th>
<th>W+jets</th>
<th>Background Uncertainty</th>
</tr>
</thead>
</table>

\[ \text{Pre-fit Background} \]

mono-H Z’-2HDM = 600 GeV
\[ \tan \beta = 1 , g_{Z} = 0.8 , m_{h} = 100 \text{ GeV} , m_{H} = m_{H^{\pm}} = 300 \text{ GeV} \]
Searches for Dark Matter

Mono-H(bb) (Z’+2HDM simplified model) as a test case for reconstruction improvements

- variable-radius jets (R ~ 30 GeV/p_T) to reconstruct high-p_T H → bb as “pencil” jets inside large-R jet

Combination of DM searches
Higgs boson physics

\[ \sigma(pp \rightarrow H + X) [pb] \]

- \( pp \rightarrow H \) (NNLO+NNLL QCD + NLO EW)
- \( pp \rightarrow qqH \) (NNLO QCD + NLO EW)
- \( pp \rightarrow WH \) (NNLO QCD + NLO EW)
- \( pp \rightarrow ZH \) (NNLO QCD + NLO EW)
- \( pp \rightarrow bbH \) (NNLO and NLO QCD)
- \( pp \rightarrow ttH \) (NLO QCD)

\[ M_H = 125 \text{ GeV} \]

MSTW2008

\( \sqrt{s} \) [TeV]
Observation of VH production, $H \rightarrow bb$

Aim: demonstrate $H \rightarrow bb$. Evidence already last year

Analysis with 80 /fb: 4.9 $\sigma$ signal (expected: 4.3 $\sigma$)

- leptonic W, Z decays

$Z \rightarrow bb$ peak as standard candle
Observation of VH production, $H \rightarrow bb$

Aim: demonstrate $H \rightarrow bb$. Evidence already last year

Analysis with 80 fb: $4.9 \sigma$ signal (expected: $4.3 \sigma$)

- leptonic $W, Z$ decays
- combination with other channels suffices to claim observation
  - $VH: H \rightarrow ZZ^* \rightarrow \ell^+ \ell^- \ell'^+ \ell'^-, H \rightarrow \gamma\gamma$
  - $H \rightarrow bb: ttH, VBF$

$H \rightarrow bb: 5.4 \sigma$ (expected: 5.5)  $VH: 5.3 \sigma$ (expected: 4.8)
Observation of $ttH$ production

Essential to obtain unambiguous information on $y_t$ information (no loop contributions)

- decay modes: $\gamma\gamma, ZZ^* \rightarrow 4l, bb, \text{multi-leptons (WW, } \tau\tau)$

![Graph showing data and background contributions](image)
Observation of $ttH$ production

Essential to obtain unambiguous information on $y_t$ information (no loop contributions)

- Decay modes: $\gamma\gamma, ZZ^* \rightarrow 4l, bb$
  - Multi-leptons ($WW, \tau\tau$)

Observed significances:
- $5.8 \sigma$ w/o (6.3 $\sigma$ w/) Run-1
- Expected: $4.9 \sigma / 5.1 \sigma$
BSM interpretations

Constraints both from H(125) measurements, searches for other Higgs bosons

- example: hMMSM

ATLAS Preliminary

hMSSM, 95% CL limits

- Observed
- Expected

m_A [GeV]
Di-Higgs production

An essential step towards probing the Higgs potential

- also (alternatively) probe heavy resonance ($\rightarrow HH$) production ($G_{KK}$, ..)
- highest sensitivity for at least one $H \rightarrow bb$ decay ($bb\gamma\gamma$, $bb\tau\tau$)

ATLAS

- Observed 95% CL limit
- Expected 95% CL limit

$\sigma(pp \rightarrow G_{kk} \rightarrow HH \rightarrow b\bar{b}b\bar{b})$ [fb]

$G_{kk} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$

$\sigma(G_{kk} \rightarrow HH \rightarrow b\bar{b}b\bar{b})$ [pb]

$G_{kk} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$

$G_{kk} \rightarrow HH \rightarrow bb\gamma\gamma$

$G_{kk} \rightarrow HH \rightarrow bb\tau\tau$

$G_{kk} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$

$G_{kk} \rightarrow HH \rightarrow bb\gamma\gamma$

$G_{kk} \rightarrow HH \rightarrow bb\tau\tau$

ATLAS

Resolved Signal Region, 2016

Data / Bkgd

$0.5 \quad 1 \quad 1.5$ 

$1 \quad 10 \quad 10^2 \quad 10^3 \quad 10^4 \quad 10^5 \quad 10^6 \quad 10^7$

$\text{Events / } 100 \text{ GeV}$

$\text{Data}$

$\text{Multijet}$

$\text{t\text{Hadronic t}}$

$\text{t\text{Semi-leptonic t}}$

$\text{Scalar (280 GeV)}$

$\text{SM HH} = 1)$

$\text{PlM}_{800 \text{ GeV}, k/KK G} = 2)$

$\text{PlM}_{1200 \text{ GeV}, k/KK G}$

ATLAS

Resolved Signal Region, 2016

$|\text{BDT score}|$

$0.2 \quad 0.4 \quad 0.6 \quad 0.8 \quad 1$

$\text{Events / Bin}$

$\text{Data}$

$\text{NR HH at exp limit}$

$\text{Top-quark fakes (Multi-jets)}$

$\text{had\tau \rightarrow jet}$

$\text{jet \rightarrow t\text{had\tau \rightarrow jet}}$

$\text{had\tau \rightarrow Z}$

$\text{Other}$

$\text{SM Higgs}$

$\text{Uncertainty}$

$\text{Pre-fit background}$

$\text{Stat+Syst Uncertainty}$

$\text{ATLAS}$

$|\text{BDT score}|$

$0.2 \quad 0.4 \quad 0.6 \quad 0.8 \quad 1$

$\text{Events / Bin}$

$\text{Data/Pred.}$

$0.5 \quad 1 \quad 1.5$ 

$1 \quad 10 \quad 10^2 \quad 10^3 \quad 10^4 \quad 10^5 \quad 10^6 \quad 10^7$

Resonance Mass [GeV]

$300 \quad 400 \quad 500 \quad 600 \quad 700 \quad 800 \quad 900 \quad 1000$

$\text{Observed 95% CL limit}$

$\text{Expected 95% CL limit}$

$\sigma_1 \pm \sigma_2 \pm$
Di-Higgs production

An essential step towards probing the Higgs potential
- also (alternatively) probe heavy resonance ($\rightarrow$HH) production ($G_{KK}$, ..)
- highest sensitivity for at least one $H \rightarrow bb$ decay ($bbbb$, $bb\gamma\gamma$, $bb\tau\tau$)

Combination of multiple channels starts to yield interesting results

$-5.0 < \kappa_\lambda \equiv \lambda_{HHH}/\lambda_{HHH, SM} < 12.1$
Many fresh results in both pp (and heavy ion!) collisions
• in this presentation could only cherry-pick from the highlights

Only a few results used even the 80 /fb 2015—2017 (pp) dataset
• next few years: expect many analyses to use the full Run-2 dataset..
• as well as the advances in understanding & reconstruction techniques
Heavy-flavour properties in Pb-Pb collisions

Recent results: $J/\psi$, $\mu$ from semimuonic b/c decays

ATLAS
Prompt $J/\psi$, $|y| < 2$


$\omega_2 = 20.6 \text{ GeV}$

no evidence for centrality dependence
Heavy-flavour properties in Pb-Pb collisions

Recent results: J/ψ, μ from semimuonic b/c decays

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Prompt J/ψ, |y| < 2


ωc = 20.6 GeV

no consistent model yet for description of both HF suppression & flow

no evidence for centrality dependence
Interference between $b\bar{t}W$, $t\bar{t}$ production

Important source of systematics for many analyses involving the $bWbW$ final state

- analysis in dilepton final states, using proxy for $m(bW)$
  
  
  
  $m_{bl}^{\text{minimax}} = \min\{ \max(m_{b_1,\ell_1}, m_{b_2,\ell_2}), \max(m_{b_1,\ell_2}, m_{b_2,\ell_1}) \}$

- only the full $bWbW$ prediction provides an adequate description of the high-mass tail
Angular analysis of $B_d \rightarrow K^* \mu^+\mu^-$ decays

FCNC process, of great (renewed) interest following LHCb 3.4 $\sigma$ tension with SM predictions

\[
\frac{1}{d\Gamma/dq^2 \ d \cos \theta_L \ d \cos \theta_K \ d\phi \ dq^2} = \frac{9}{32\pi} \left( \ldots + \sqrt{F_L(1-F_L)} \ P'_5 \ \sin 2\theta_K \ \sin \theta_L \ \cos \phi + \ldots \right)
\]

Measurement for $q^2 \equiv m_{\mu\mu}^2 < 6 \text{ GeV}^2$

(to avoid radiative $J/\psi$ tail) in 8 TeV data

- most discrepant result for $P_5'$ in 4 - 6 GeV$^2$ bin (2.7 $\sigma$), but not precise enough to make a firm statement

- measurement statistically limited