Candidate event for: \( pp \rightarrow tt \rightarrow \mu + 4 \text{ jets (2 b-jets)} \)

proton-proton collisions at
13 TeV centre-of-mass energy

Run: 266919
Event: 19982211
2015-06-04 00:21:24

First ATLAS Results from Run-2
Andreas Hoecker (CERN) on behalf of the ATLAS Collaboration
EPS-HEP 2015, 27 July 2015, Vienna, Austria
Harvest of results from Run-1 (447 papers to date) confirming predictive power of SM

→ Covered by plenary speakers: Maxime Gouzevitch, Nicholas Hadley, Pierre Savard, Alessandro Tricoli

Run-1 is not over yet: high-quality, extremely well understood data sample for precision measurements
We also did a vast amount of BSM searches — with no significant anomaly seen so far

Theory-agnostic, signature based searches, as well as highly targeted model-dependent ones

→ Covered by plenary speakers: Ivan Mikulec, Anna Syfryla

Not unexpectedly, a few of these searches ended up showing some anomaly, a legacy to check in Run-2
Long-Shutdown 1 — Preparing Run-2
The (Run-1) ATLAS Detector

- Muon chambers
- Toroid magnets
- Solenoid magnet
- Transition radiation tracker
- Semiconductor tracker
- Pixel detector
- LAr electromagnetic calorimeters
- LAr hadronic end-cap and forward calorimeters
- Tile calorimeters

Dimensions:
- 44m
- 25m
ATLAS went through important upgrades during LS1
In all areas: detector, online, offline, computing

**Infrastructure upgrades:** magnet & cryogenic systems, additional muon chamber shielding, new beam pipes

**Detector consolidation:** muon chamber completion \((1.0 < |\eta| < 1.3)\) & replacements, calorimeter electronics repairs, improved inner detector read-out capability to cope with 100 kHz L1 trigger rate, new pixel detector services and module repairs

**New topological L1 trigger and new central trigger processor, restructured high-level trigger**

**New Insertable B-layer:** fourth pixel layer at 3.3 cm from beam, consisting of planar & 3D (forward) silicon sensors, smaller pixels

**New software, new production system, new analysis model, …**
At $10^{34} \text{ cm}^{-2} \text{s}^{-1}$ @ 13 TeV

**pp** the LHC produces:

- $200 \text{ Hz } W \rightarrow l\nu$
- $19 \text{ Hz } Z \rightarrow ll$
- $8 \text{ Hz } \text{top pair}$
- $0.5 \text{ Hz } \text{Higgs}$
13 TeV data summaries

Luminosity

Measured with forward detectors, calibrated with “mini van-der-Meer” scan during low-µ run to 9% precision

Data quality

All good for physics: 93.3%

An additional set of data recorded in special conditions for detector calibration purposes is not included in physics analysis

ATLAS pp run: June-July 2015

<table>
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<th>Inner Tracker</th>
<th>Calorimeters</th>
<th>Muon Spectrometer</th>
<th>Magnets</th>
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<td>Pixel</td>
<td>SCT</td>
<td>TRT</td>
<td>LAr</td>
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<tr>
<td>97.3</td>
<td>99.6</td>
<td>100</td>
<td>98.4</td>
</tr>
</tbody>
</table>

All good for physics: 93.3%

Luminosity weighted relative detector uptime (in percent) and good quality data delivery during 2015 stable beams in pp collisions at $\sqrt{s} = 13$ TeV between 3 June and 16 July – corresponding to 91 pb$^{-1}$ of recorded data.
Soft physics with tracks at 13 TeV

One of the very first proton–proton collisions recorded by ATLAS in “quiet beam” conditions in May 2015
Inner tracking performance

**ATLAS tracking in Run-2 features the new IBL, reduced material within acceptance, and algorithmic improvements** (eg, huge speed-up, tracking in dense environment [ATL-PHYS-PUB-2015-006])

Sketch of ATLAS inner tracking detectors

Hit reconstruction in data and MC
Inner tracking performance with IBL

Detector alignment and material studies crucial for new detectors and services

Material studies

Based on:
- Hadronic interactions
- Photon conversions
- “SCT extension”

Material uncertainty dominates tracking systematics

“Radiography” pictures used to validate material description in simulation

Impact parameter resolution improvement from IBL

Measured improvement of impact parameter resolution with IBL depending on track $p_T$
Properties of inelastic pp collisions at 13 TeV

Key input to pileup and underlying event modelling, uses low-µ data

Measurement of primary charged particle production: $dN_{ch}/d\eta$, $d^2N_{ch}/d\eta dp_T$, $N_{ch}$, $<p_T>/N_{ch}$

Fiducial cuts: $p_T > 0.5$ GeV, $|\eta| < 2.5$, $N_{ch} \geq 1$

- Trigger events with as little “bias” as possible: $\geq 1$ hit in forward scintillators (MBTS, $2.07 < |\eta| < 3.86$)
- Measure trigger and vertexing efficiencies from data
- Measure and subtract secondary interactions and fake tracks
- Correct for tracking inefficiency
- Unfold measured spectra from detector effects

ATLAS Preliminary
$\sqrt{s} = 13$ TeV
$n_{sel}^{BL} \geq 1$, $p_T > 500$ MeV, $|\eta| < 2.5$

1 vertex required with $\geq 2$ tracks of $p_T > 100$ MeV
Properties of inelastic pp collisions at 13 TeV

Key input to pileup and underlying event modelling, uses low-μ data

Measurement of primary charged particle production: $dN_{\text{ch}}/d\eta$, $d^2N_{\text{ch}}/d\eta dp_T$, $N_{\text{ch}}$, $<p_T>/N_{\text{ch}}$

Fiducial cuts: $p_T > 0.5$ GeV, $|\eta| < 2.5$, $N_{\text{ch}} \geq 1$

- Trigger events with as little “bias” as possible
- Measure trigger and vertexing efficiencies from data
- Measure and subtract secondary interactions and fake tracks
- Correct for tracking inefficiency
- Unfold measured spectra from detector effects

Tracking efficiency dominant uncertainty:
1.1% central, 6.5% forward

Secondary after fit:
$2.6 \pm 0.6\%$ of tracks in SR

Secondaries after fit:
$2.6 \pm 0.6\%$ of tracks in SR

---

ATLAS Preliminary

$\sqrt{s} = 13$ TeV

Minimum Bias MC

Data

Primary

Secondary

ATLAS Simulation Preliminary

$\sqrt{s} = 13$ TeV

Minimum Bias MC

Data

Primary

Secondary

$\sqrt{s} = 13$ TeV

Minimum Bias MC

Data
Properties of inelastic pp collisions at 13 TeV
Key input to pileup and underlying event modelling, uses low-µ data

Difficult to provide one universal tune that describe MB and UE data equally well (→ next slides)

Overall, the EPOS and PYTHIA 8 tunes describe the data most accurately
EPOS best in $\eta$, $p_T$, and $<p_T>$, while PYTHIA 8 (A2 – ATLAS MB default) best in $N_{ch}$
Properties of inelastic pp collisions at 13 TeV

Key input to pileup and underlying event modelling, uses low-µ data

Average charged-particle multiplicity per unit of rapidity for $\eta = 0$ vs CM energy

For comparison, the strange baryon contribution is included at 13 TeV (1.5% correction factor)
Properties of inelastic pp coll. at 13 TeV

Key input to pileup and underlying event modelling, uses low-µ data

We also studied underlying event (UE) spectra to further validate the energy extrapolation of the MC modelling

Uncorrected detector level quantities

[ ATL-PHYS-PUB-2015-019 ]

→ Thorsten Kuhl
Long-range two-charged-particle angular correlations

In high-multiplicity pp collisions using low-µ data

Near-side ($\Delta \phi \sim 0$) “ridge” shape along $\Delta \eta$ seen in pp, pPb and PbPb collisions

Effect increases with particle multiplicity and moderate $p_T$

**CMS, pp at 7 TeV:**
$N_{ch} > 110$, $1.0 < p_T < 3.0$ GeV

**ATLAS, pPb at 5.02 TeV:**
$N_{ch} > 220$, $1.0 < p_T < 3.0$ GeV

**ATLAS, PbPb at 2.76 TeV:**
Centrality 0–5%

[ CMS, 1009.4122 ]

[ ATLAS, 1212.5198 ]

[ ATLAS, 1504.01289 ]

[ Enhancement found to be also present at $\Delta \phi \sim \pi$, when subtracting hard scattering contributions ]
Two-charged-particle angular correlations at 13 TeV
In high-multiplicity pp collisions using low-μ data

How does the pp ridge evolve with CM energy?

- Trigger on MBTS (97M events) & high charged multiplicity (9.5M)
- Exploit work on tracking corrections from minimum bias analysis
- Extract two-particle correlation function → $C(\Delta \eta, \Delta \phi) = \frac{S(\Delta \phi, \Delta \eta)}{B(\Delta \phi, \Delta \eta)}$
  (background from mixed events)

![Graphical representations showing correlation functions and efficiency](chart)

ATLAS Preliminary
$\sqrt{s} = 13$ TeV, $L_{int} = 14$ nb$^{-1}$
Data 2015

Integrate:
- $2 < |\Delta \eta| < 5$
- $0.5 < p_T^{a,b} < 5.0$ GeV
- $10 \leq N_{ch}^{rec} < 30$

ATLAS Preliminary
$\sqrt{s} = 13$ TeV, $L_{int} = 14$ nb$^{-1}$
Data 2015
- $10 \leq N_{ch}^{rec} < 30$
- $0.5 < p_T^{a,b} < 5.0$ GeV
- $2.0 < |\Delta \eta| < 5.0$

[ ATLAS-CONF-2015-027 ]
→ Miguel Arratia
Two-charged-particle angular correlations at 13 TeV
In high-multiplicity pp collisions using low-µ data

How does the pp ridge evolve with CM energy?

- Trigger on MBTS (97M events) & high charged multiplicity (9.5M)
- Exploit work on tracking corrections from minimum bias analysis
- Extract two-particle correlation function → \( C(\Delta \eta, \Delta \phi) = \frac{S(\Delta \phi, \Delta \eta)}{B(\Delta \phi, \Delta \eta)} \)
  (background from mixed events)

\[ \text{ATLAS Preliminary} \]

\( \sqrt{s} = 13 \text{ TeV}, L_{\text{int}} = 14 \text{ nb}^{-1} \)

Data 2015

Integrate:
\( 2 < |\Delta \eta| < 5 \)

\[ \text{ATLAS Preliminary} \]

\( \sqrt{s} = 13 \text{ TeV}, L_{\text{int}} = 14 \text{ nb}^{-1} \)

Data 2015

\( N_{\text{ch}}^{\text{rec}} \geq 120 \)

\( 0.5 < p_T^{a,b} < 5.0 \text{ GeV} \)

\( 2.0 < |\Delta \eta| < 5.0 \)
Two-charged-particle angular correlations at 13 TeV
In high-multiplicity pp collisions using low-µ data

How does the pp ridge evolve with CM energy ?

- Trigger on MBTS (97M events) & high charged multiplicity (9.5M)
- Exploit work on tracking corrections from minimum bias analysis
- Extract two-particle correlation function → \[ C(\Delta \eta, \Delta \phi) = \frac{S(\Delta \phi, \Delta \eta)}{B(\Delta \phi, \Delta \eta)} \]
  (background from mixed events)

Integrate:

2 < |\Delta \eta| < 5

0.5<p_T^{a,b}<5.0 \text{ GeV}

\[ N_{\text{ch}}^{\text{rec}} \geq 120 \]

\[ \sqrt{s} = 13 \text{ TeV}, L_{\text{int}} \approx 14 \text{ nb}^{-1} \]

Data 2015
Two-charged-particle angular correlations at 13 TeV
In high-multiplicity pp collisions using low-µ data

Integrated “ridge yield” versus charged multiplicity and $p_T$ range

\[ Y_{\text{int}} = \text{integral of } Y(\Delta \phi) - b_{\text{ZYAM}} \text{ between ridge minima in } \Delta \phi \text{ (} b_{\text{ZYAM}} \text{ is simple } Y \text{ offset correction at minima)} \]

Systematic effects dominated by tracking efficiency, ZYAM procedure, MC closure

→ Compatible yield at different CM energies

CMS uses $2 < |\Delta \eta| < 4.0$. The yields from 1210.5482 were multiplied by 3.6 in above plots (see ATLAS-CONF-2015-027)
Physics with photons and jets at 13 TeV

Now moving to higher luminosity and $p_T$
Photon production at 13 TeV
Test perturbative QCD in cleaner environment than jets

Measurement of isolated photon yield
Subtract mis-identification background from data

Photon production vs. $E_{T,\gamma}$ and $|\eta_{\gamma}|$ (detector level, MC normalised to data)

Systematics dominated by photon energy scale, resolution and efficiency

Systematic uncertainties dominated by: photon energy scale, photon ID, background subtraction

Good agreement of shape with SHERPA 2.1 (LO + ≤3 partons)
Jet production at 13 TeV
Early central-jet cross-section measurement at 13 TeV

Measurement performed within fiducial region $350 < p_T < 840$ GeV and $|y_{jet}| < 0.5$:

- Single jet trigger, fully efficient above 300 GeV jet $p_T$
- Reconstruct anti-$k_t R=0.4$ jets, calibrated using MC and Run-1 data, validated in Run-2 data
- Unfold to particle level
- Dominant systematic uncertainty: jet energy scale and resolution

Compare with NLO theory (incl. PS+UE corrections) of measured diff. cross sections vs. $p_T$
Physics with leptons at 13 TeV

One of the very first $J/\Psi \rightarrow \mu \mu$ candidates recorded by ATLAS in “quiet beam” conditions in May 2015.
J/Ψ production at 13 TeV

Good environment in early data with low trigger thresholds

J/Ψ are produced promptly and via weak decays of b-hadrons

Use the initial 6.4 pb⁻¹ data to measure non-prompt J/Ψ fraction via 2D fit to $m_{\mu\mu}$ and proper decay time distribution: $\tau = \frac{L_{xy}}{m_{J/\Psi}/p_{T,\mu\mu}}$

$J/Ψ \rightarrow \mu\mu$

$J/Ψ \rightarrow e^+e^-$

See also: ATLAS-CONF-2015-024
J/Ψ production at 13 TeV

Good environment in early data with low trigger thresholds

Selection:
\[ p_{T,\mu} > 4 \text{ GeV}, |\eta_\mu| < 2.3, p_{T,\mu\mu} > 8 \text{ GeV}, |y_{\mu\mu}| < 2, \]

70k candidates, fully data-driven analysis

Non-prompt J/Ψ fraction:
\[ f_{J/\psi}^{np} \equiv \frac{pp \rightarrow b + X \rightarrow J/\psi + X'}{pp \rightarrow \text{Inclusive} \rightarrow J/\psi + X'} \]

Depending on CM energy

Non-prompt contribution to total rate rises rise from approximately 25% at \( p_{T,\mu\mu} \) of 8 GeV to 65% at 40 GeV
W and Z boson production at 13 TeV

Displays of one $Z(\rightarrow \mu\mu) + \text{jets}$ candidate event
Z and W production at 13 TeV

Expect increase of cross section by factors of 1.7 and 1.6, respectively

Leptonic decays are important standard candles to verify and calibrate e/µ performance

Following plots are normalised to NNLO QCD and to luminosity. Observed Z and W yields agree with SM expectations within uncertainty. Error bands in plots do not include 9% luminosity uncertainty.
Z and W production at 13 TeV

Expect increase of cross section by factors of 1.7 and 1.6, respectively.

Leptonic decays are important standard candles to verify and calibrate e/µ performance.

Following plots are normalised to NNLO QCD and to luminosity. Observed Z and W yields agree with SM expectations within uncertainty. Error bands in plots do not include 9% luminosity uncertainty.

Large number of additional kinematic distributions in ATL-PHYS-PUB-2015-021
Z and W production at 13 TeV

Expect increase of cross section by factors of 1.7 and 1.6, respectively

We also looked into Z production in association with jets

Important channel for QCD studies and background to new physics searches.

Good description by SHERPA 2.1 generator (up to 2 partons at NLO, 4 partons at LO ME)

(note: detector level plots)
Display of $ZZ \rightarrow \mu^+\mu^- + e^+e^-$ candidate event ($m_{\mu\mu/ee} = 94/86$ GeV, $m_{\mu\mu ee} = 191$ GeV)
Display of $ZZ \rightarrow \mu^+\mu^- + e^+e^-$ candidate event ($m_{\mu\mu}/ee = 90/92$ GeV, $m_{\mu\mu ee} = 305$ GeV)
Display of $\mu^+\mu^-$ event with 881 GeV invariant mass
High-mass dilepton production

Insufficient luminosity yet to challenge Run-1 sensitivity to new physics

Drell-Yan production at high $q^2$

Dominant irreducible backgrounds taken from MC simulation, DY normalised to Z peak

$pp \rightarrow \mu\mu + X$

$pp \rightarrow e\mu + X$

[EXOT-2015-001, EXOT-2015-004]

→ Woiciech Fedorko
Top-quark production at 13 TeV

Display of $t\bar{t} \rightarrow e\mu + 2\ b$-jets candidate event

Run: 267638
Event: 193690558
2015-06-13 23:52:26 CEST
Top-antitop production at 13 TeV

Expect increase of 8 TeV cross section by a factor of 3.3

Cleanest channel: $t\bar{t} \rightarrow (e + \nu + b\text{-jet}) + (\mu + \nu + b\text{-jet}) = e\mu + 2 \text{ b-jets} + E_{T,\text{miss}}$

Select: OS electrons & muons with $p_T > 25 \text{ GeV}$, at least one b-tagged jet with $p_T > 25 \text{ GeV}$
(clean channel, no $E_{T,\text{miss}}$ requirement needed → reduce systematics)

Shape comparison only. MC normalised to data.
Top-antitop production at 13 TeV

Extraction of top-pair cross section

Apply robust data-driven method that provided most precise Run-1 measurements (7, 8 TeV)

Following relation allows to simultaneously determine $\sigma_{tt}$ and $\epsilon_b$ from data

$$
N_1 = L \cdot \sigma_{t\bar{t}} \cdot \epsilon_{e\mu} \cdot 2\epsilon_b \cdot \left(1 - C_b\epsilon_b\right) + N_1^{bkg}
$$

$$
N_2 = L \cdot \sigma_{t\bar{t}} \cdot \epsilon_{e\mu} \cdot C_b\epsilon_b^2 + N_2^{bkg}
$$

Where:

- $N_{1(2)}$ – number of selected events with 1(2) b-tags
- $N_{1(2)}^{bkg}$ – number of background events with 1(2) b-tags
- $L$ – luminosity of data sample
- $\epsilon_{e\mu}$ – $(t\bar{t} \rightarrow e\mu)$ selection eff & acc (~0.9%) incl. BR
- $\epsilon_b$ – probability to b-tag q from $t \rightarrow Wq$
- $C_b = \epsilon_{bb}/\epsilon_b$ is non-factorisation correction ($1.005 \pm 0.006$ from MC)

Observe: $N_1 = 319, N_2 = 167$

Expect: $N_1^{bkg} = 37.3 \pm 5.5, N_2^{bkg} = 8.5 \pm 3.5$, dominated by Wt (MC, approx. NNLO), then mis-id. e/µ (MC & data)
Top-antitop production at 13 TeV
Extraction of top-pair cross section

Solving the equation gives the following 13 TeV pp $\rightarrow$ tt + X cross section

$$\sigma_{tt} (13 \text{ TeV}) = 825 \pm 49 \text{ (stat)} \pm 60 \text{ (syst)} \pm 83 \text{ (lumi)} \text{ pb}$$

$$\sigma_{tt}[\text{SM}] (13 \text{ TeV}) = 832^{+40}_{-46} \text{ pb (at NNLO + NNLL accuracy, } m_t = 172.5 \text{ GeV, Top++ 2.0)}$$

Systematic uncertainty (7.3%) dominated by

- tt hadronisation (4.5%) $\rightarrow$ large Pythia8 / Herwig++ parton shower effect, to be further studied
- tt NLO modelling, ISR/FSR radiation & PDF (2.9%)
- Electron ID + isolation (4.2%)
- Muon ID + isolation (1.6%)
- Lepton mis-identification (1.3%)
- Lepton triggers (1.3%) $\rightarrow$ will improve with more data

Overall uncertainty dominated by luminosity (9%) $\rightarrow$ will improve with full van-der-Meer luminosity scan

We also measure: $\varepsilon_b = 0.527 \pm 0.026 \pm 0.006$, in good agreement with simulation: 0.543
Top-antitop production at 13 TeV
Extraction of top-pair cross section

Solving the equation gives the following 13 TeV $pp \rightarrow tt + X$ cross section

$$\sigma_{tt} (13 \text{ TeV}) = 825 \pm 49 \text{ (stat)} \pm 60 \text{ (syst)} \pm 83 \text{ (lumi)} \text{ pb}$$
Conclusions

Display of t-channel single-top candidate event: muon with $p_T$ of 30 GeV, central b-tagged jet of 50 GeV, forward jet 30 GeV, $E_{T,\text{miss}}$ of 40 GeV
The LHC is back again — great data for physics collected: thanks to the CERN accelerator teams for tireless efforts

ATLAS is fully engaged into analysis of 13 TeV data, only a fraction of work shown today

New detector systems, software & analysis model successfully integrated & commissioned

Remarkable understanding of new 13 TeV data after only a few weeks of running

Performed soft physics measurements including verification of “Ridge” at 13 TeV
Minimum bias and underlying event studies show good extrapolation from Run-1 tunes
Measurement of differential 13 TeV central jet cross section and photon studies
Early measurements of J/Ψ, W and Z production in agreement with expectations
Measurement of top-pair production cross section: heaviest particle known at highest collider energies ever reached — consistently predicted by the Standard Model

See next pages for a full list of ATLAS references to 13 TeV physics & performance analysis documents
List of 13 TeV ATLAS references for EPS-HEP 2015
PHYSICS OBJECT & TRIGGER PERFORMANCE

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<th>Electron and photon</th>
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<td>Vertexing Performance</td>
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<td>Inner detector Alignment</td>
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<td>MET performance for 13 TeV</td>
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<td>Uncertainty treatment</td>
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<th>Trigger</th>
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<tr>
<td>Early 13 TeV commissioning</td>
<td>The above link points to results from all trigger signatures</td>
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Use CDS to find ‘PUB’ and ‘CONF’ notes: https://cds.cern.ch

Performance plots (eg, IDTR-2015-007, that is not ‘CONF’ or ‘PUB’) can be directly accessed via the following bulk address: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS

For example, for ‘IDTR-2015-007’, the link is: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/IDTR-2015-007
List of 13 TeV ATLAS references for EPS-HEP 2015

**PHYSICS ANALYSIS**

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A few extra slides…
13 TeV / 8 TeV inclusive pp cross-section ratio

At $10^{34}$ cm$^{-2}$ s$^{-1}$ @ 13 TeV

- 200 Hz $W \rightarrow l\nu$
- 19 Hz $Z \rightarrow ll$
- 8 Hz top pair
- 0.5 Hz Higgs
### 13 TeV data taking history


#### April

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<th>Week</th>
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- **Start LHC commissioning with beam**

#### May

- **May 30**: Easter Monday

- **May 31**: ATLAS Online Luminosity: 13 TeV

- **June 1**: Total Integrated Luminosity: 13 pb⁻¹

- **June 8**: First 13 TeV stable-beam collisions, low and high pileup

- **June 8**: MD 2

- **June 15**: TS1

- **June 22**: Special physics run

- **June 29**: IONS

#### June

- **June 23**: Reconmissioning with beam

- **June 30**: Special physics run

#### July

- **July 14**: Machine checkout

- **July 21**: May 31 - Total Integrated Luminosity: 13 pb⁻¹

- **July 28**: First 13 TeV stable-beam collisions, low and high pileup

- **July 35**: Special physics run

#### August

- **August 1**: Machine checkout

- **August 8**: MD 1

- **August 15**: TS2

- **August 22**: Jeune G

- **August 29**: Intensity ramp-up with 50 ns beam

- **August 36**: Intensity ramp-up with 25 ns beam

#### September

- **September 6**: Easter Monday

- **September 13**: Total Integrated Luminosity: 13 pb⁻¹

- **September 20**: First 13 TeV stable-beam collisions, low and high pileup

- **September 27**: MD 2

- **September 34**: TS2

- **September 41**: Jeune G

- **September 48**: IONS

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- **We are here, ATLAS recorded 100 pb⁻¹ of 13 TeV pp data**

  - 83 pb⁻¹ for physics (5 pb⁻¹ muon alignment, rest DAQ/DQ ineff.)
The ATLAS data path in a nutshell

**Large Hadron Collider**

- 50 ns bunch distance
- $L_{\text{max}} \sim 1.7 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

**ATLAS Detector**

**Trigger & Online monitoring**

- L1 (HW, up to 100 kHz) + HLT (SW, 1 kHz)
- Low-threshold single lepton triggers, single MET and jet triggers, and low-threshold di-object & topological triggers

**Calibration & Reconstruction**

- 48h calibration & data quality processing, then prompt reconstruction of data in Tier-0

**Distributed computing**

- Production of standardised derived datasets for physics and performance analysis

**Analysis**

- Performance groups provide standard physics objects with calibrations and uncertainties, unified in analysis release
- Analysis groups build physics analyses upon this ground work

Also: MC production — 1.8 billion 13 TeV events
Diphoton production at 13 TeV

Irreducible background to Higgs, new physics sensitivity

Isolated diphoton yield

Raw diphoton $p_T$ spectrum (not background subtracted)

Diphoton mass, compared to SM prediction