Drell-Yan measurements at 13 TeV and 13.6 TeV using ATLAS

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Cherenkov counter (LUCID) measures luminosity

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Measurements anchored by van der Meer scans

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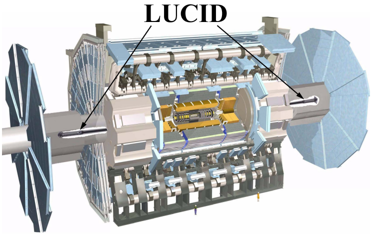
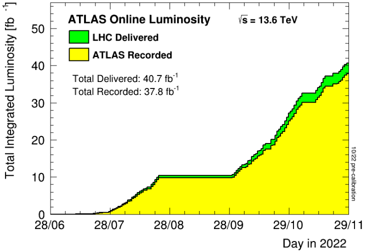
Best hadron collider luminosity measurement made at 13 TeV with uncertainty = 0.83% [1]

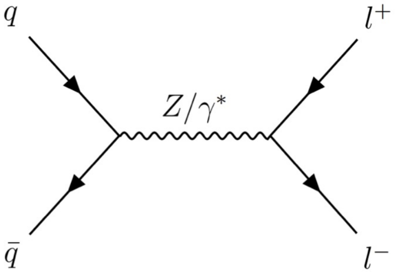
Counting Z bosons an independent check for data-taking at **13.6 TeV**





[1] ATLAS Collaboration, 'Luminosity determination in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector at the LHC', arXiv [hep-ex], 19-Dec-2022.

Z-counting basics



$$\mathcal{L} = \frac{N}{\sigma}$$

where $\ell = e$ or μ

Theoretical cross-section of process well known

Z-counting luminosity measured for $\Delta t \approx 60$s.

Methodology: Z-counting

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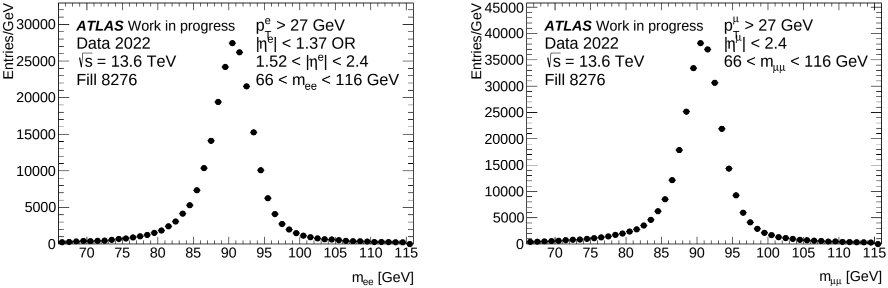
$$\mathcal{L}_{Z\to\ell^+\ell^-}(\Delta t) \propto N_{Z\to\ell^+\ell^-}(\Delta t)$$

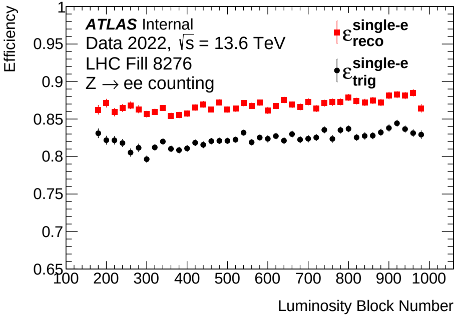


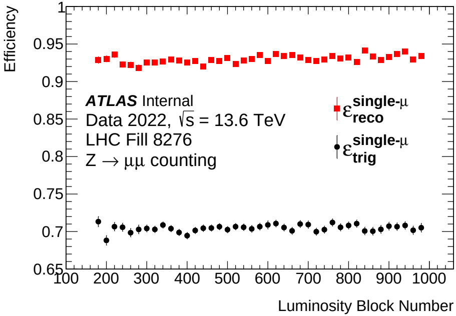
$$p_T^\ell > 27\text{ GeV},\ 66\text{ GeV} < m_{\ell\ell} < 116\text{ GeV}$$

Fill = Period of data taking ∼ 9 hours

$$\mathcal{L}_{Z\to\ell^+\ell^-}(\Delta t) \propto \frac{N_{Z\to\ell^+\ell^-}(\Delta t)}{\varepsilon^{T\&P}_{Z\to\ell^+\ell^-}(\Delta t)}$$

Efficiencies determined in situ



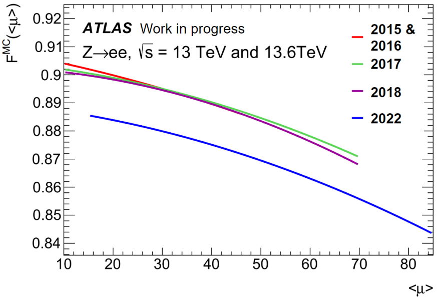


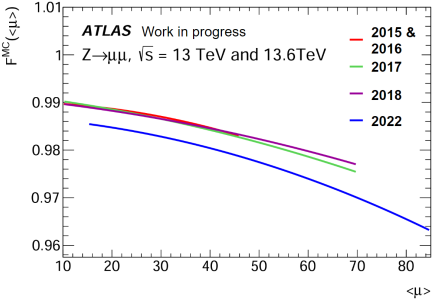
1 Luminosity Block $= \Delta t$

$$\varepsilon^{T\&P}_{Z\to\ell^+\ell^-} = \left(1-(1-\varepsilon_{trig,1\ell})^2\right)\times\varepsilon^2_{reco,1\ell}$$

Methodology: Monte-Carlo correction factor

$$\mathcal{L}_{Z\to\ell^+\ell^-}(\Delta t) \propto \frac{N_{Z\to\ell^+\ell^-}(\Delta t)}{\varepsilon^{T\&P}_{Z\to\ell^+\ell^-}(\Delta t)\cdot F^{MC}_{Z\to\ell^+\ell^-}(\langle\mu\rangle)}$$





$< \mu >$ = mean number of proton-proton collisions

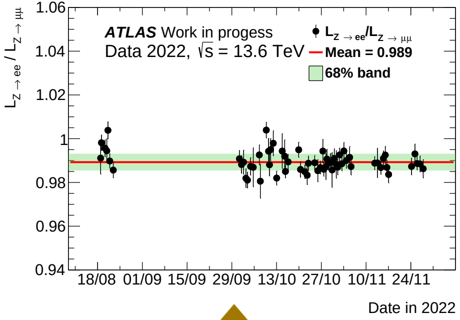
$$F^{MC}_{Z\to\ell^+\ell^-}(<\mu>) = \frac{N^{\text{reco, fiducial, MC}}_{Z\to\ell^+\ell^-}(<\mu>)}{N^{\text{truth, nocut, MC}}_{Z\to\ell^+\ell^-}(<\mu>)} \times \frac{1}{A^{MC}_{Z\to\ell^+\ell^-}\cdot\epsilon^{\text{T\&P, MC}}_{Z\to\ell^+\ell^-}}$$

Methodology: The full equation

$$\mathcal{L}_{Z\to\ell^+\ell^-}(\Delta t) = \frac{N_{Z\to\ell^+\ell^-}(\Delta t)\cdot(1-f_{bkg})}{\sigma_{theory}\times A^{MC}_{Z\to\ell^+\ell^-}\cdot\varepsilon^{T\&P}_{Z\to\ell^+\ell^-}(\Delta t)\cdot F^{MC}_{Z\to\ell^+\ell^-}(\langle\mu\rangle)\cdot t(\Delta t)}$$

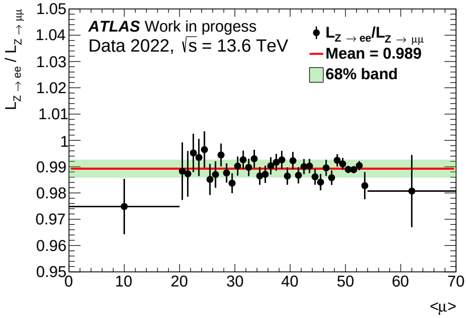
- $f_{bkg} = 0.65\%$ - from previous precision Z measurements.
- $\sigma_{theory} = 2067.5$ pb, $m_{\ell\ell} > 60$ GeV for 13.6 TeV.
  - FEWZ (CT18A PDF) @ NNLO QCD.
  - 5% higher than for 13 TeV.
- $A^{MC}_{Z\to\ell^+\ell^-}$: Geometric acceptance corrects to full phase space.
- $t(\Delta t)$: live-time (Δt minus detector's dead time).

Z decay channel comparison



Dependence on time

Dependence on mean number of proton-proton interactions



2022 data normalised time dependence

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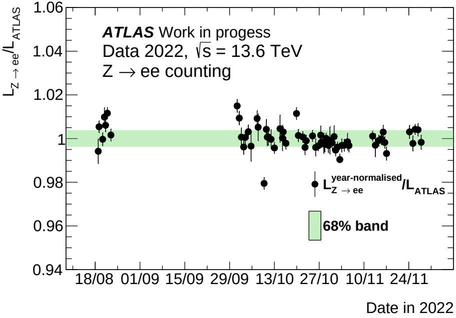
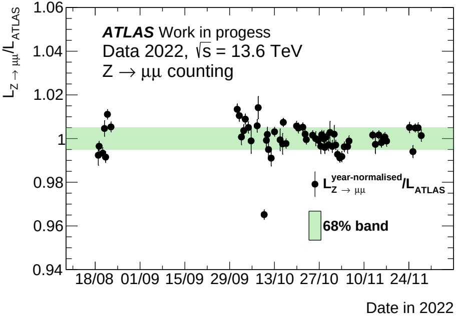
Normalised to the total luminosity measured by Cherenkov counter

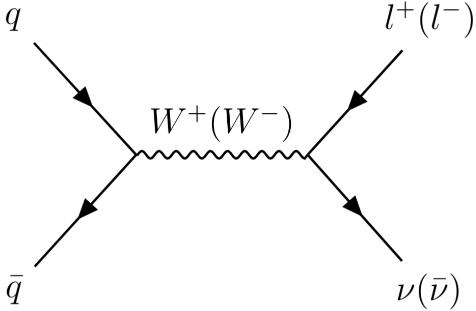




Monitors time dependence over the year per fill (∼9 hours)

- Spent the past year working in the offline luminosity group.
- Task to become ATLAS qualified author to update framework for new physics running from 2022 where Josh will take over for 2023.
- Huge effort updating to new version of analysis framework.
- Will form part of my thesis $\rightarrow$ Z-counting for new 13.6 TeV data.

- Focus on charged current Drell-Yan
- Search for W' carred out with data at 13 TeV (2015-2018) [2]
- No new resonances < 6 TeV $\rightarrow$ precision measurements



[2] The ATLAS Collaboration, 2019. Search for a heavy charged boson in events with a charged lepton and missing transverse momentum from *pp* collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. Physical Review D, 100(5).

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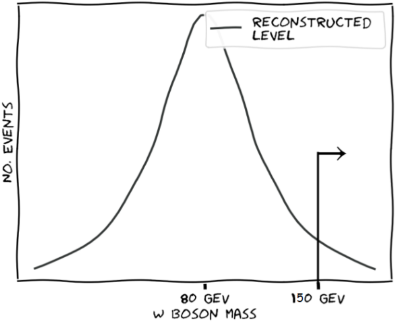
- 1D cross-section - as a function of m_T
- For e and μ channels - 4 measurements!
- "High mass" - $m_T > 150$ GeV
- Measurement previously made but NOT unfolded

$$m_T^W = \sqrt{2 p_T E_T^{\text{miss}} (1 - \cos \Delta\phi_{\ell,\nu})}$$



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The steps

Investigate data/MC for control regions

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Implement systematics and perform study

↓

Unfold cross-section

What does this mean?

For signal region as well as background rich control regions

Systematics dominate our measurement e.g. muon sagitta bias

Unfolding corrects for experimental uncertainties
Using Baysian iterative tool

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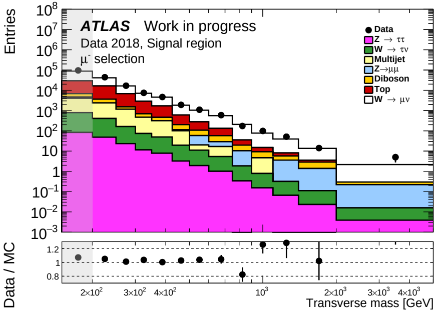
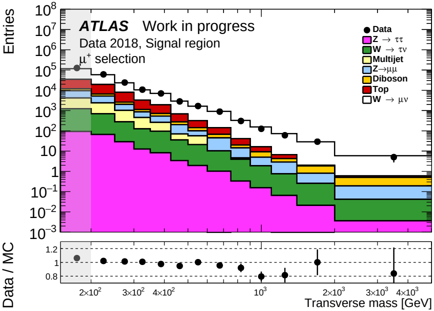
Measuring m_T range up to 5 TeV

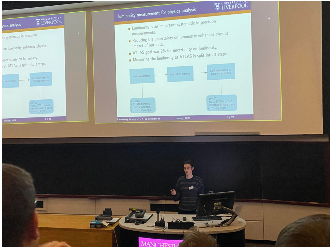




Shadow bin used to control migration from peak region

Summary

- Now qualified ATLAS author after updating Z-counting for 2022.
- Presentation on luminosity at ATLAS UK.
- Roughly 6000 Z bosons counted during this talk!
- Returned from LTA at CERN to resume analysis.
- Clear plan for remaining analysis within ATLAS subgroup.



Backup Slides

Definitions

- Luminosity Block: Unit of time for data taking ∼60s
- Fill: One complete fill of the LHC from which data taking lasts ∼9 hours
- Pseudorapidity: $\eta = -\ln(\tan(\theta/2))$
- Transverse mass: $m_T^W = \sqrt{2 p_T E_T^{\text{miss}} (1 - \cos \Delta\phi_{\ell,\nu})}$

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Reconstruction

T&P selectron: tight lepton used to tag event, probe lepton used to determine fail/pass criteria to measure reco efficiency.

$$\varepsilon^{1\ell}_{reco} = \frac{N^{OS}_{pass} - N^{bkg}_{pass}}{N^{OS}_{pass} + N^{OS}_{fail} - N^{bkg}_{total}}$$

Electron channel reco

Probe consists of ID track matched to EM calo cluster. Background obtained using template method.

Muon channel reco

Probe consists of ID track passing loose preselection. Background obtained applying same cuts to tag muon.

Trigger

N_1: events where exactly 1 lepton passes the trigger. N_2: events where both leptons pass the trigger. $\varepsilon^{1\ell}_{trig} = \frac{1}{\frac{N_1}{2N_2} + 1}$