The University Of Sheffield.

ATLAS EXPERIMENT

# Software and Computing Needs for ATLAS

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On behalf of the ATLAS Collaboration

# Context

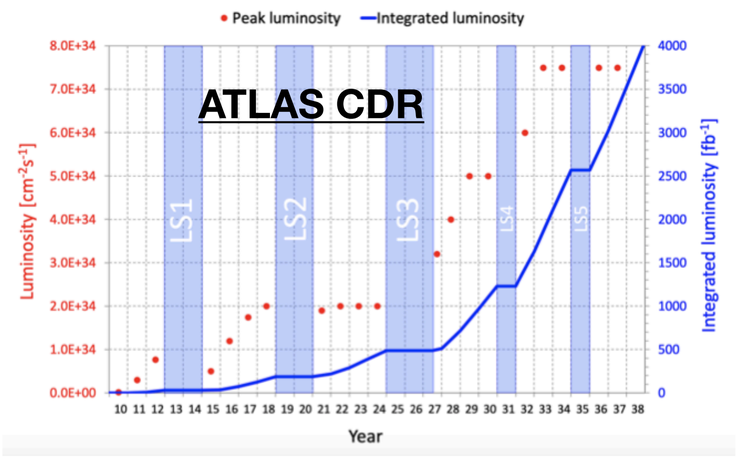
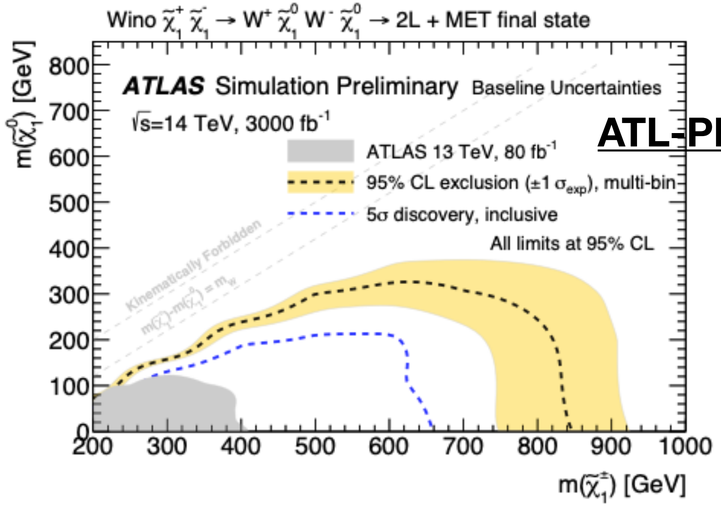



Figure 4: Schedule and luminosity forecast for the LHC.

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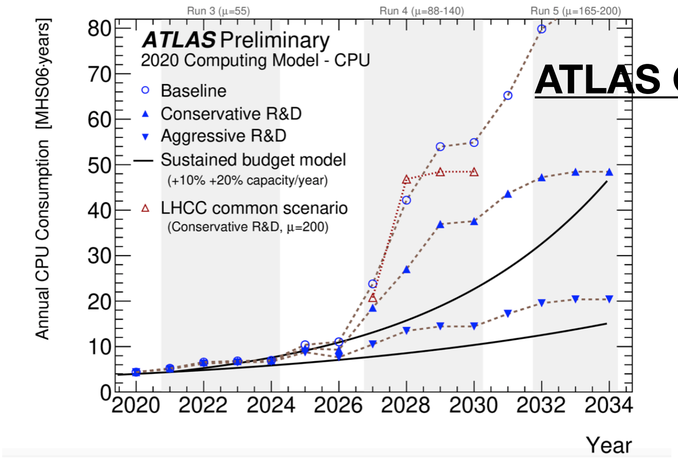
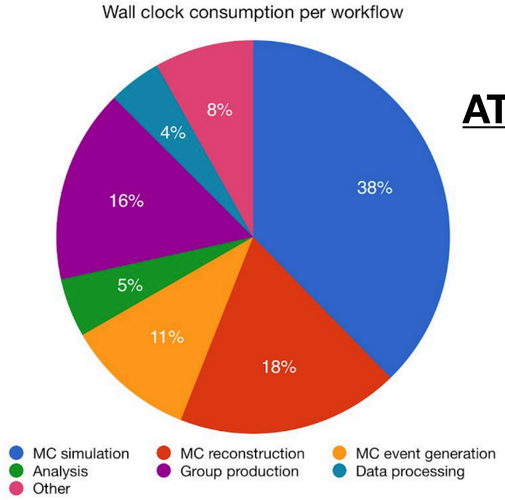
- ATLAS has collected only a small fraction of its total luminosity so far (left)
  - Increased statistics will allow further reach for Beyond Standard Model (BSM) searches and increased precision for SM measurements.
  - For example with Run 2 data ATLAS saw evidence of 4-top production and measured the cross-section with a precision of ~29% - full LHC dataset reduces this to 11%.
  - Another example, shown on the right, illustrates the potential to discover production of charginos and neutrinos at masses well beyond the current exclusion limit with Run 2 data.
- Davide Costanzo has written a short draft document for PPTAP on this topic, available here, which expands on the highlights shown in these slides.

# Software and Computing Challenges



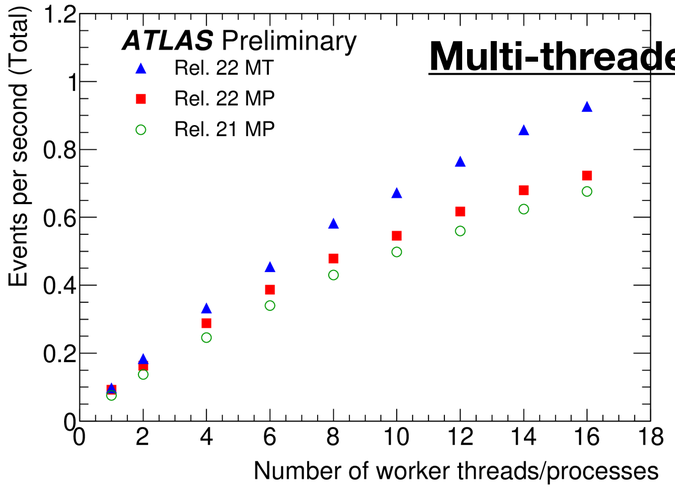

**ATLAS CDR**



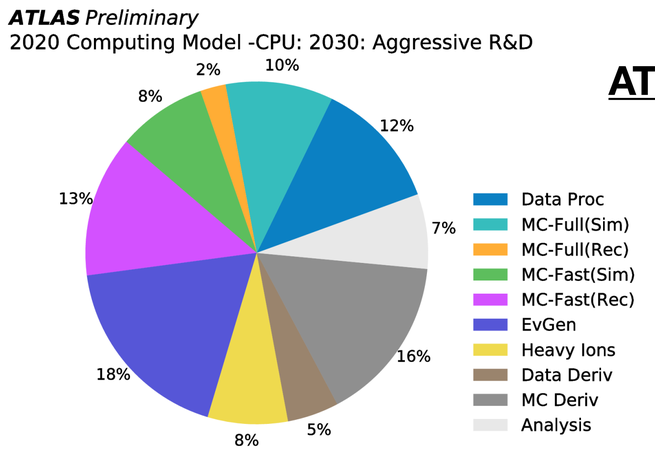

**ATLAS CDR**

- HL-LHC will deliver up to 200 events per bunch crossing - Run 3 at roughly a quarter of that.
  - Each “event” therefore more complex due to many additional particles from the extra pileup and rate of events 10 times higher than at present.
  - Can see how resource usage scales by year in different scenarios (left) - similar plots for disk and tape storage are also public (see backup slides).
- Integrated luminosity collected so far is a small fraction of the total (right).
  - Eventually far more MC needed to match this - more MC reconstruction and more storage.
- Major challenges are thus more events (in both data and Monte Carlo), which are more complex than at present, to process and store.

# Addressing those challenges




**Multi-threaded Reconstruction in ATLAS**




**ATLAS CDR**

- Strategies to improve performance:
  - For Run 3 ATLAS has migrated offline and online software to multi-threaded paradigm allowing better usage of existing resources.
  - Further optimise CPU algorithms (already saw gains for Run 3 from this approach for offline reconstruction and it is believed more can be gained from this approach for the offline reconstruction).
  - Machine learning already used quite a lot, additional R&D ongoing for Run 4 already. Often motivated by improving reconstruction performance for data analysis, but does it also eventually bring resource usage gains?
  - Further convergence of online and offline software communities, using the same algorithms with different run time configurations, helps to work more efficiently. Also possibilities to share hardware between online and offline.
  - GPU, FPGA, other technologies instead of or in addition to CPU - active research programs in ATLAS towards Run 4 already underway. Longer term more disruptive technologies such as quantum computing may come into play.
  - More compact Run 4 Analysis Object Data (AOD) file prototypes will be provided in Run 3 for testing purposes, alongside Run 3 AOD. Alongside decrease in storage footprint, will need to take advantage in growth of storage - all need to play our part to help where possible here.

# Current strengths in UK ATLAS

- ATLAS-UK has large expertise in software and computing and has provided, and does provide currently, coordinators in a number of areas discussed in this slide.
    - We provide significant contribution to the construction of the ITK detector and the development of the trigger system - natural to expect we also contribute to software developments required from that, as well as downstream client software making best use of the output.
- Trigger
    - Provide overall coordinator of trigger software and also provide a large community contributing to the development and maintenance of trigger software.
- Offline Reconstruction:
    - We provide current co-convenor of this area and also provide many contributions to this software (some of which is shared with the trigger software).
- Simulation:
    - We provide current co-convenor of this area and also provide many contributions to this software
- Testing:
    - Have had numerous validation convenors over the past years - crucial for ensuring performance of our software is as expected via both testing of physics output and technical software performance. Also have provided, and currently still do so, contributions to the testing itself.
- A number of ATLAS-UK members have also contributed to ECHEP/SwiftHEP/Excalibur work in the last couple of years in different areas, which will potentially feedback into future technology choices that ATLAS makes in addition to helping the wider community survey potential technology choices.

# Conclusions

- Further details in D. Costanzo's draft (to be finalised in next few weeks) PPTAP document, as well as in the ATLAS 2020 Computing Design Report (CDR).

- Needs of ATLAS will become more complex with HL-LHC - more complex events combined with higher data taking rates and larger MC samples required.

- In addition to some increase in resources in the context from a flat inflation protected budget we need to:

    - Make usage of additional technologies that are currently available (GPU, FPGA etc). Requires increased investment in skilled Research Software Engineers (RSE) as well as additional training of current ATLAS UK members.

    - Lead research into potentially disruptive new technologies that will come on stream in the future (e.g. quantum computing).

    - To achieve this collaboration between UK universities needs to be maintained via initiatives such as GridPP and SWIFT-HEP.