ATLAS TDAQ system: How to pick potentially interesting events out of $4 \cdot 10^7$ proton-proton collisions per second?

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LHC in numbers

- 27 km long circular accelerator at CERN
- Accelerates protons to 99.9999991% of speed of light and collides them after
- Protons travel in bunches containing $\mathcal{O}\left(10^{11}\right)$ protons on average
- Bunches are crossing each other $4 \cdot 10^7$ times per second
- $60 - 70$ collisions per bunch crossing on average
- Protons collide in dedicated points where large experiments (detectors) are located

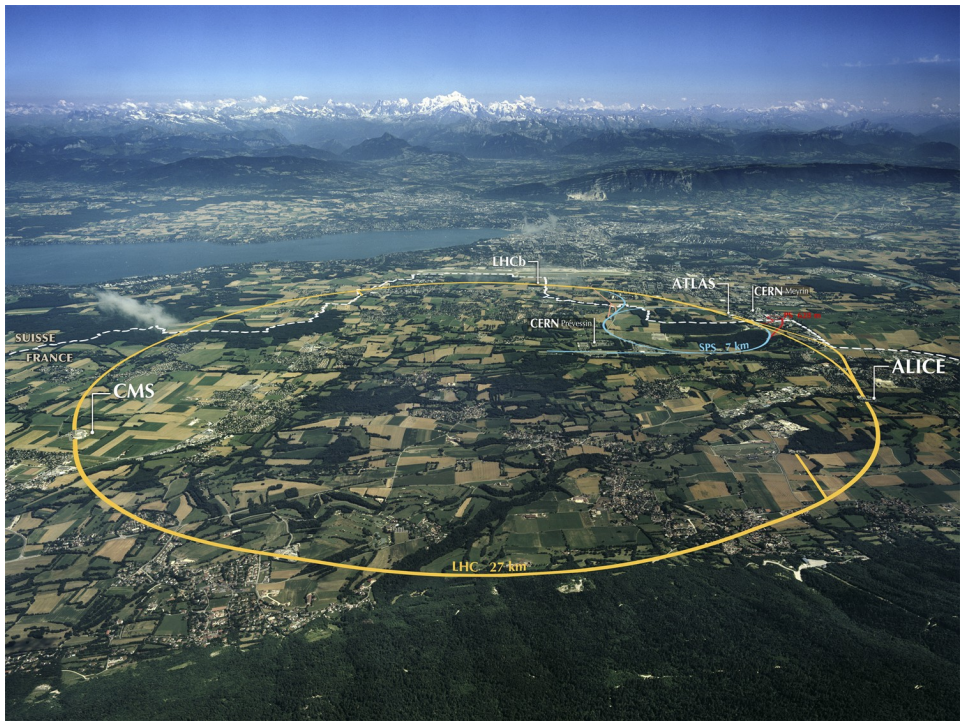

Figure: Location of LHC. Illustration taken from [1].

Experiment ATLAS

- A huge particle detector
  - one of the two largest experiments at the LHC
  - weights as much as the Eiffel tower
  - designed to cover the widest possible range of physics at the LHC
  - Higgs boson was discovered here
- ATLAS measures positions of particles in time, particle momenta and their energies $\Longrightarrow$ this allows reconstruct what is happening in p-p collisions

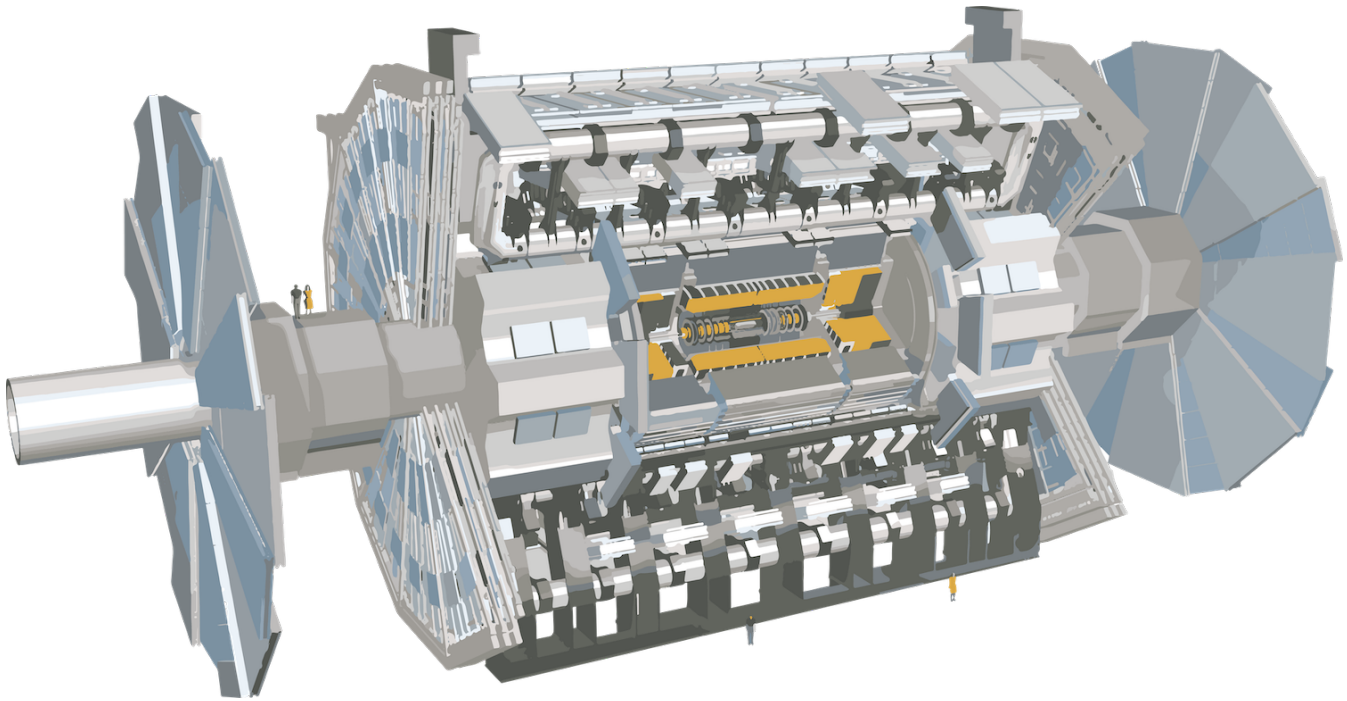

Figure: Model of the ATLAS experiment. Illustration taken from [2].

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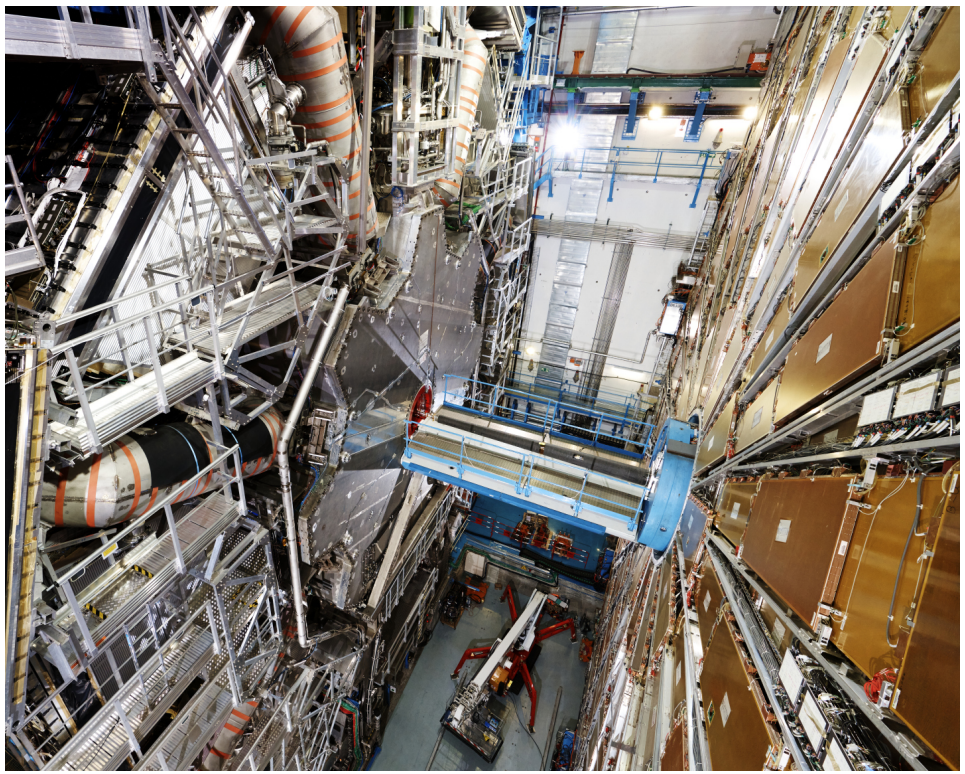

Figure: Photo of a part of ATLAS detector. Photo taken from [3].

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$$4 \cdot 10^7 \, \frac{\text{events}}{\text{s}} \times 2 \, \frac{\text{MB}}{\text{event}} \sim 80 \, \frac{\text{TB}}{\text{s}}$$

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$$4 \cdot 10^7 \, \frac{\text{events}}{\text{s}} \times 2 \, \frac{\text{MB}}{\text{event}} \times 86400 \, \frac{\text{s}}{\text{day}} \sim 6.9 \, \frac{\text{EB}}{\text{day}}$$

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Impossible to store and process $\Longrightarrow$

trigger system

What is TDAQ and why we need it?

- TDAQ = **T**rigger and **D**ata **Ac**Q**uisition** System
- ATLAS has two levels of trigger

- Level 1 trigger
  - hardware level
  - information from the Calorimeter and Muon Trigger System
  - the fastest decisions are made within 2.5 μs (by 2030: 10 μs)
- High Level Trigger
  - CPU farm (possibly accelerated by FPGAs by 2030)
  - trigger decision made within 0.5 s on average (by 2030: 0.5 – 1 s)

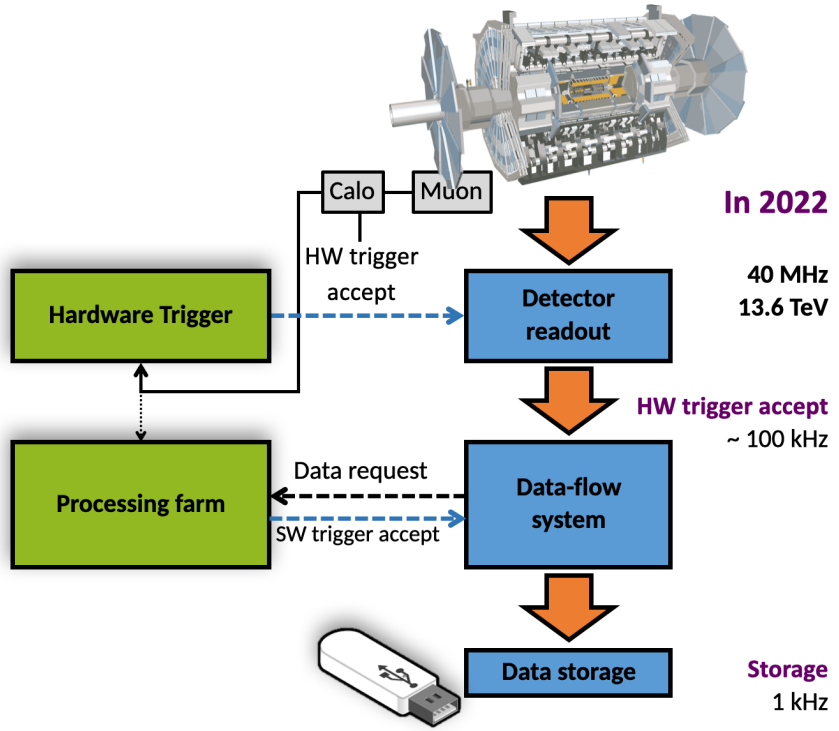

Figure: Schema of ATLAS TDAQ system. Illustration adapted from lectures [4].

ATLAS jet trigger

- One of trigger subsystems
- Selects events containing high transverse momentum hadronic jets
- Requires optimal jet energy resolution to reject overwhelming background while retaining good efficiency for interesting jets

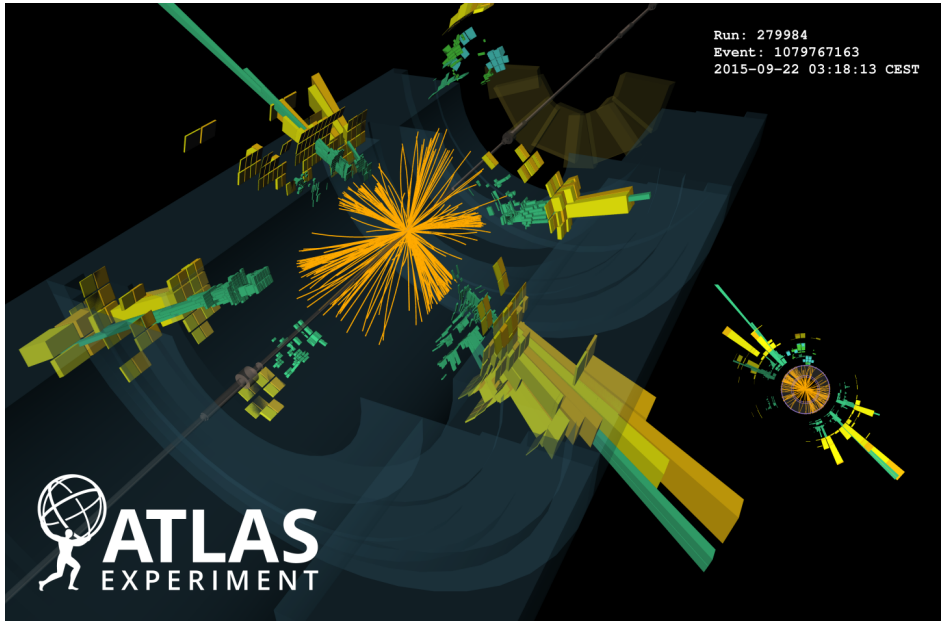

Figure: Jets inside ATLAS detector. Illustration taken from [5].

What is a jet?

- Narrow cone of particles produced in interaction of quarks and gluons during proton-proton collisions

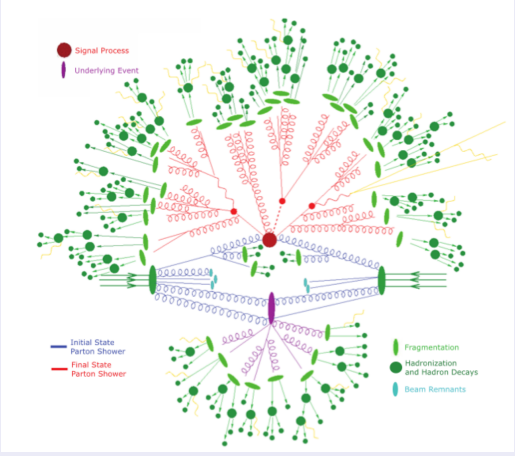

Figure: Diagram depicting concept of jet. Illustration adapted from lectures [4].

Outlook

What is all this useful for?

- Understanding the basic building blocks of the Universe
- We want to study events which are often very rare $\Longrightarrow$ we need good statistics

Message to take away

- Experiments at the LHC can produce huge amount of data
- TDAQ system filters the data in real time and reads them out
- Jet trigger selects potentially interesting events with jets
  - events with jets are extremely interesting both for understanding the standard model of particle physics and for our searches for new physics

Thank you for your attention.