The ATLAS data processing chain: from collisions to papers

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Based on slides purloined from:
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Karsten Köneke
Walter Lampl
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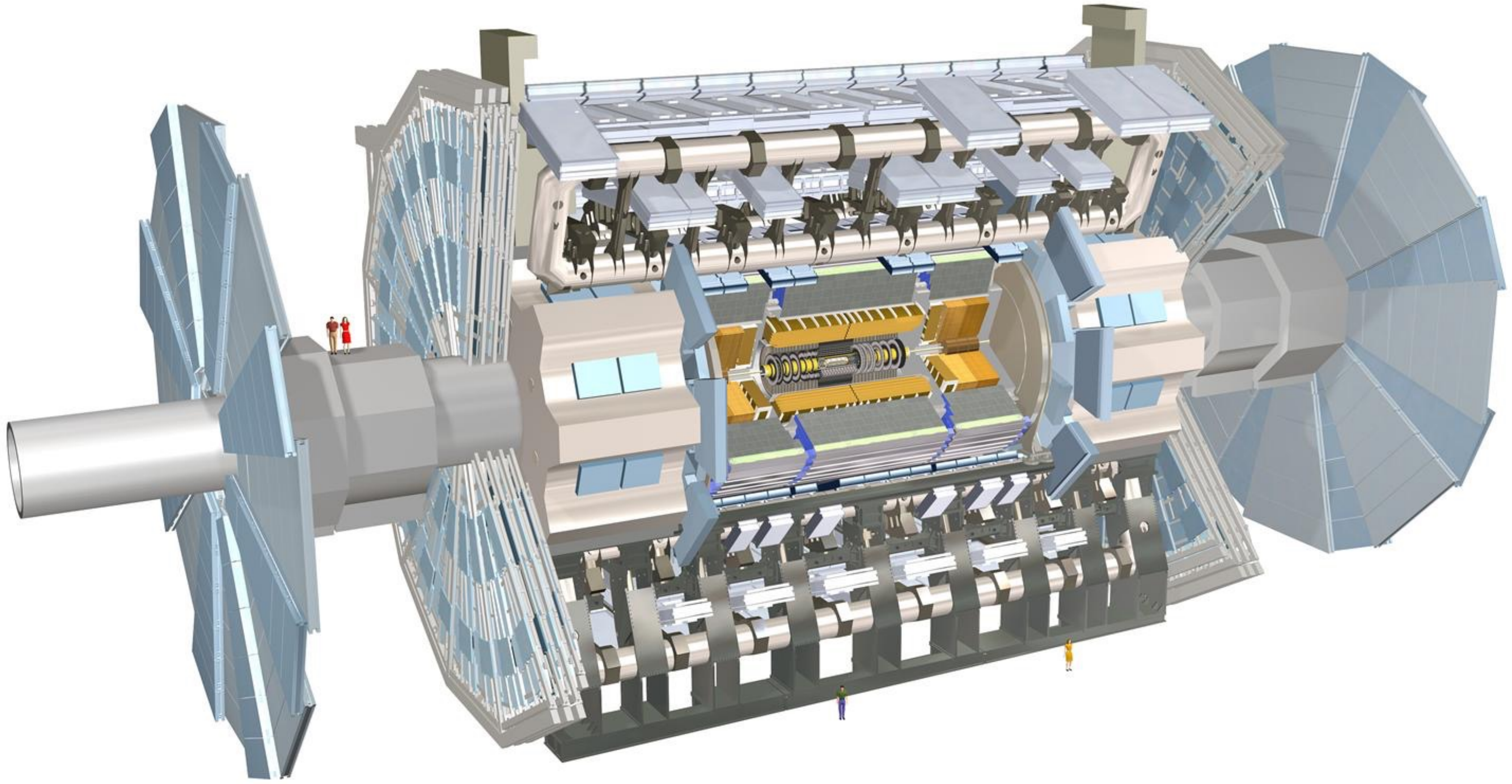
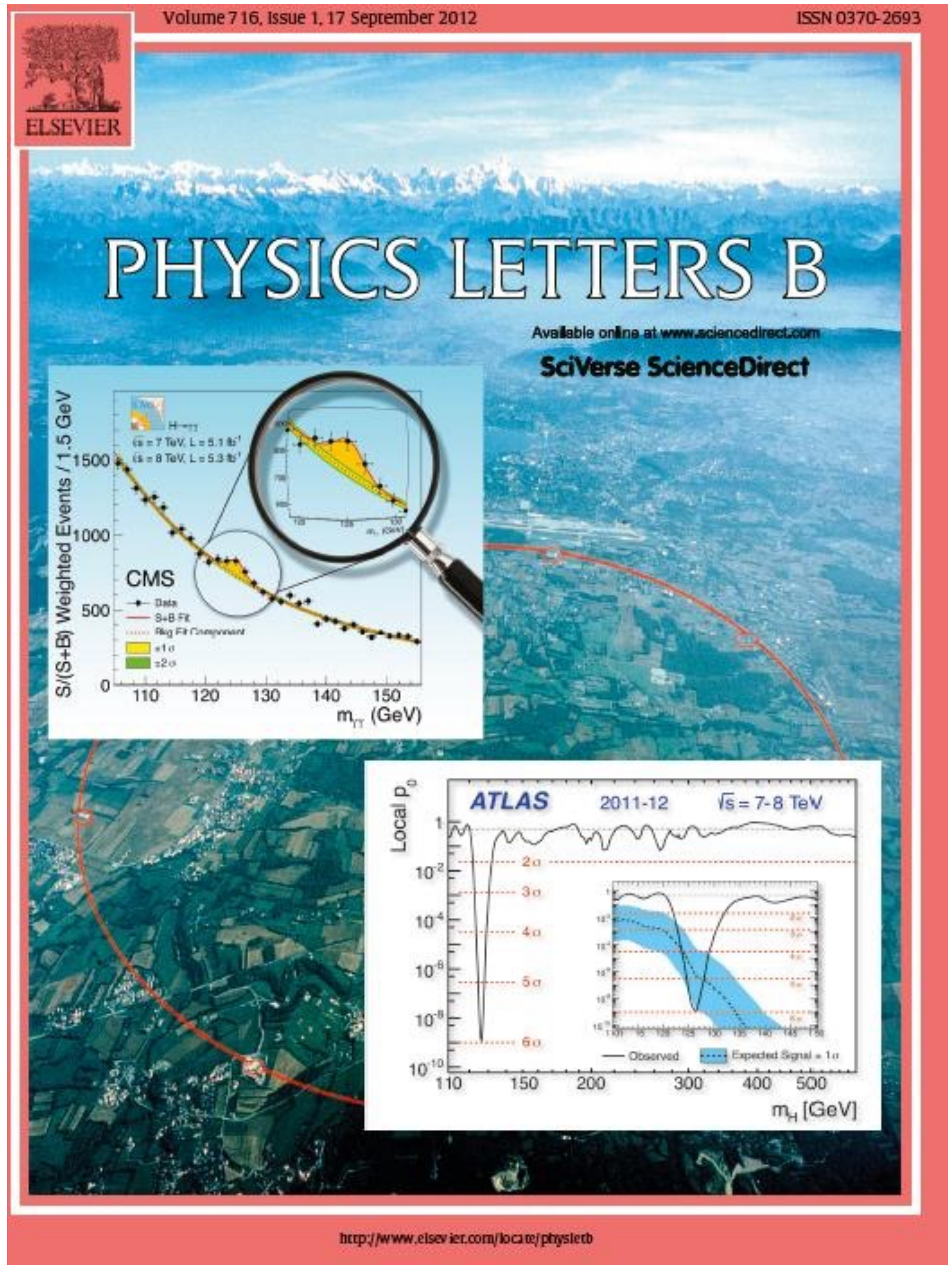
and others

How do we get from this….



to this…?




GENERATION
Monte Carlo
SIMULATION
Data
TRIGGER
DIGITIZATION
RECONSTRUCTION
RECONSTRUCTION
Online
Tier-0
Grid
Local
DERIVATION
DERIVATION
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ATLAS
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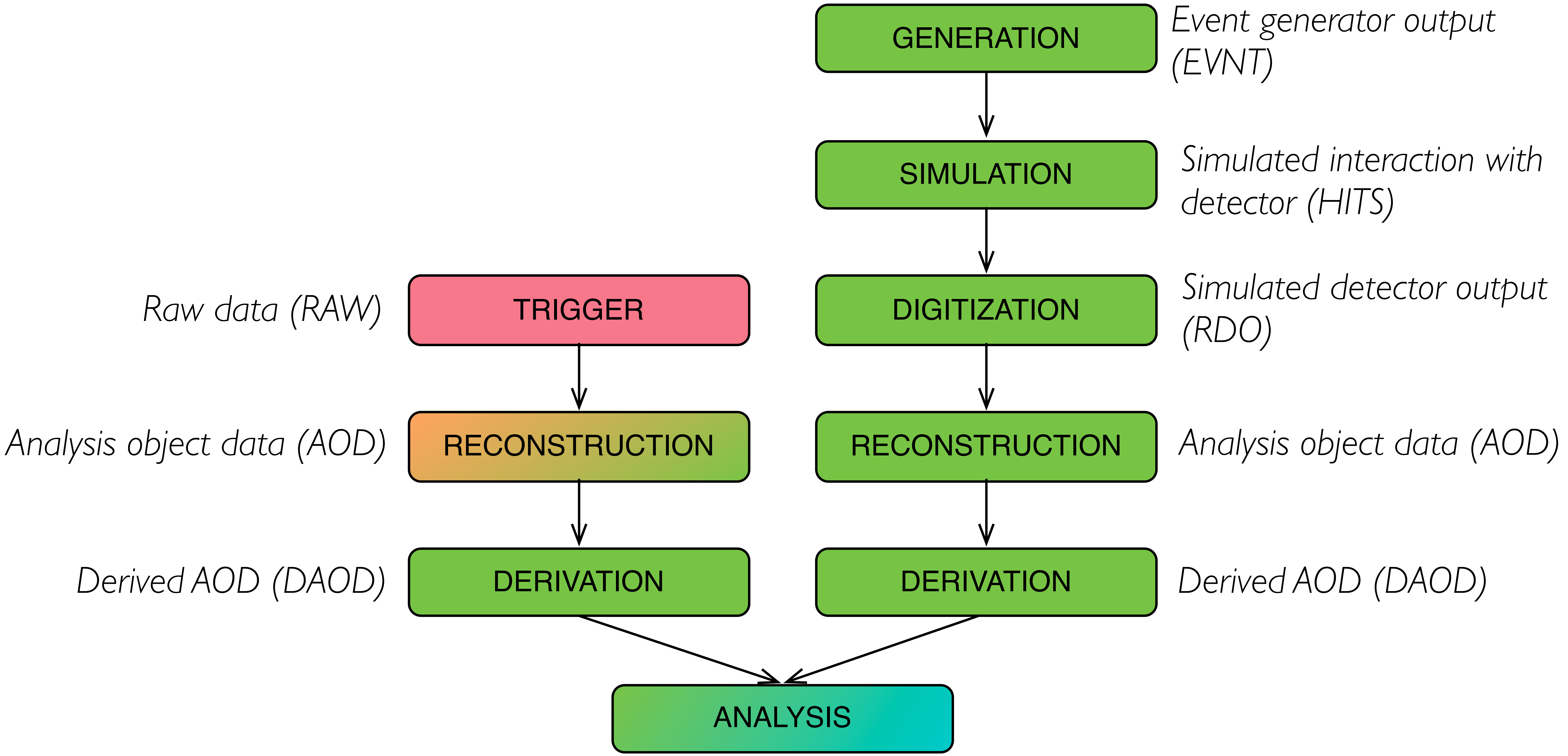
Contents

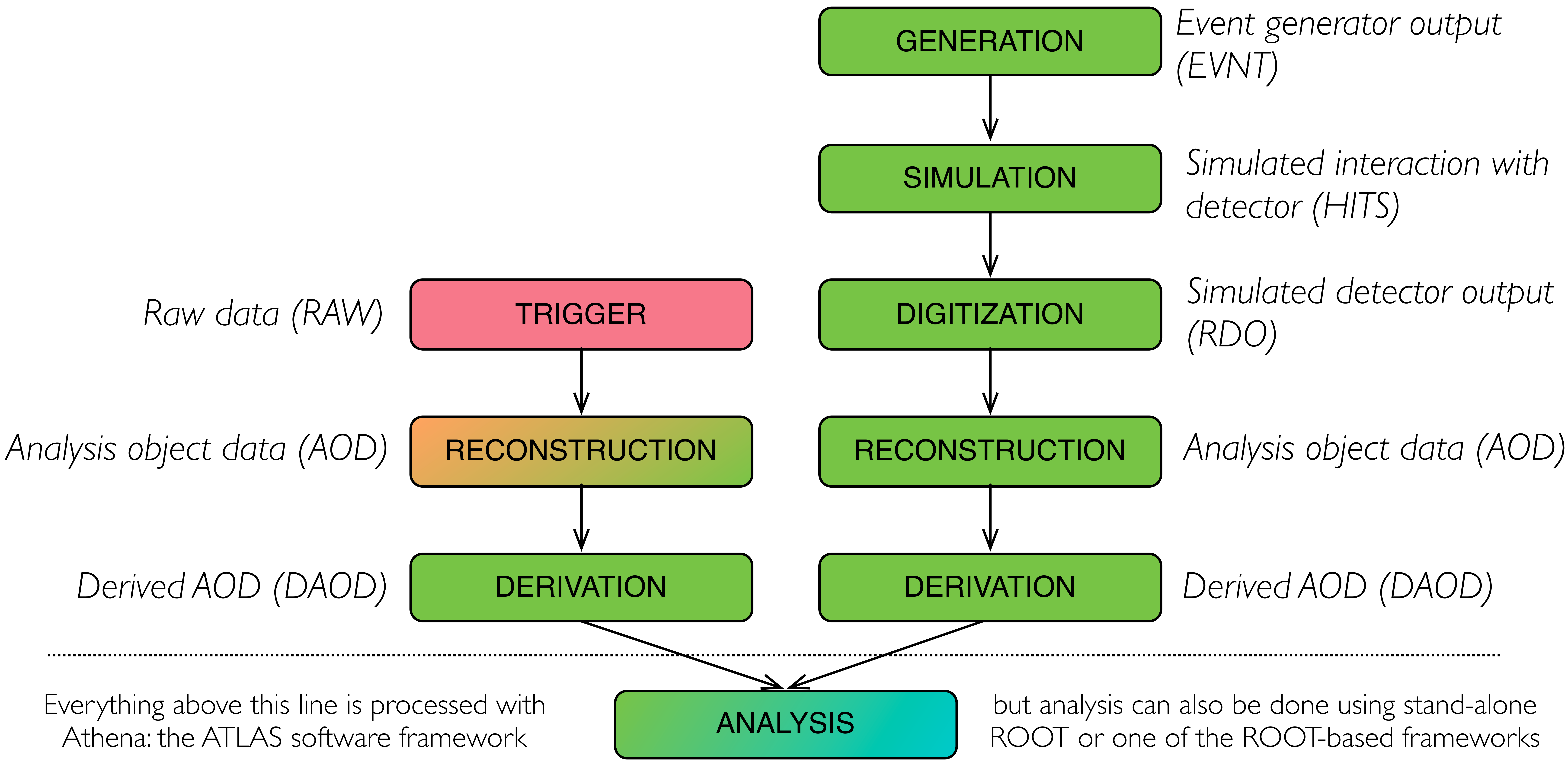
- Data formats in ATLAS
- Data preparation
- Simulation
- Computing: Grids, Clouds and HPCs

Later in the week:
- Derivations
- Analysis
- Using the Grid

Data formats in ATLAS

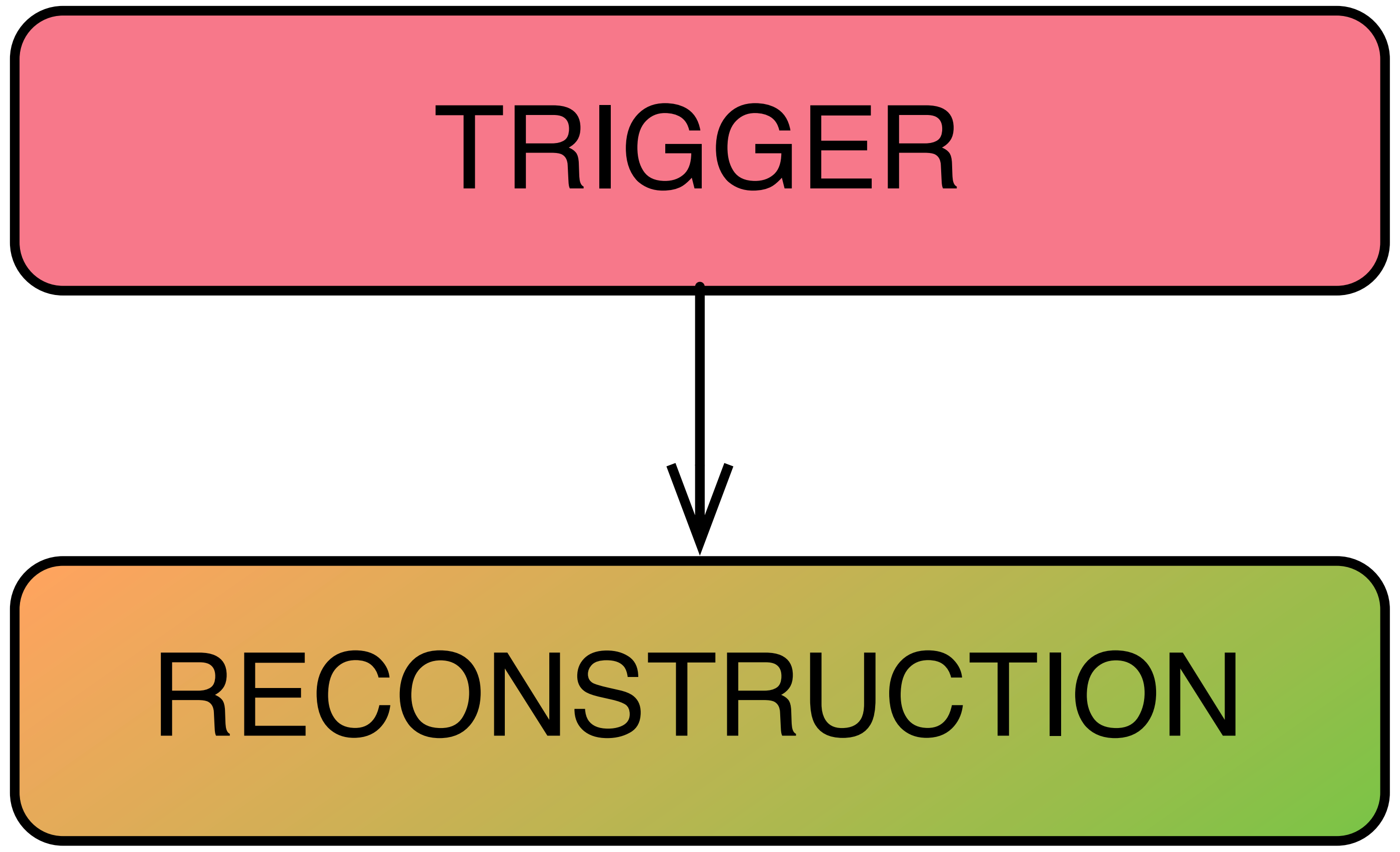


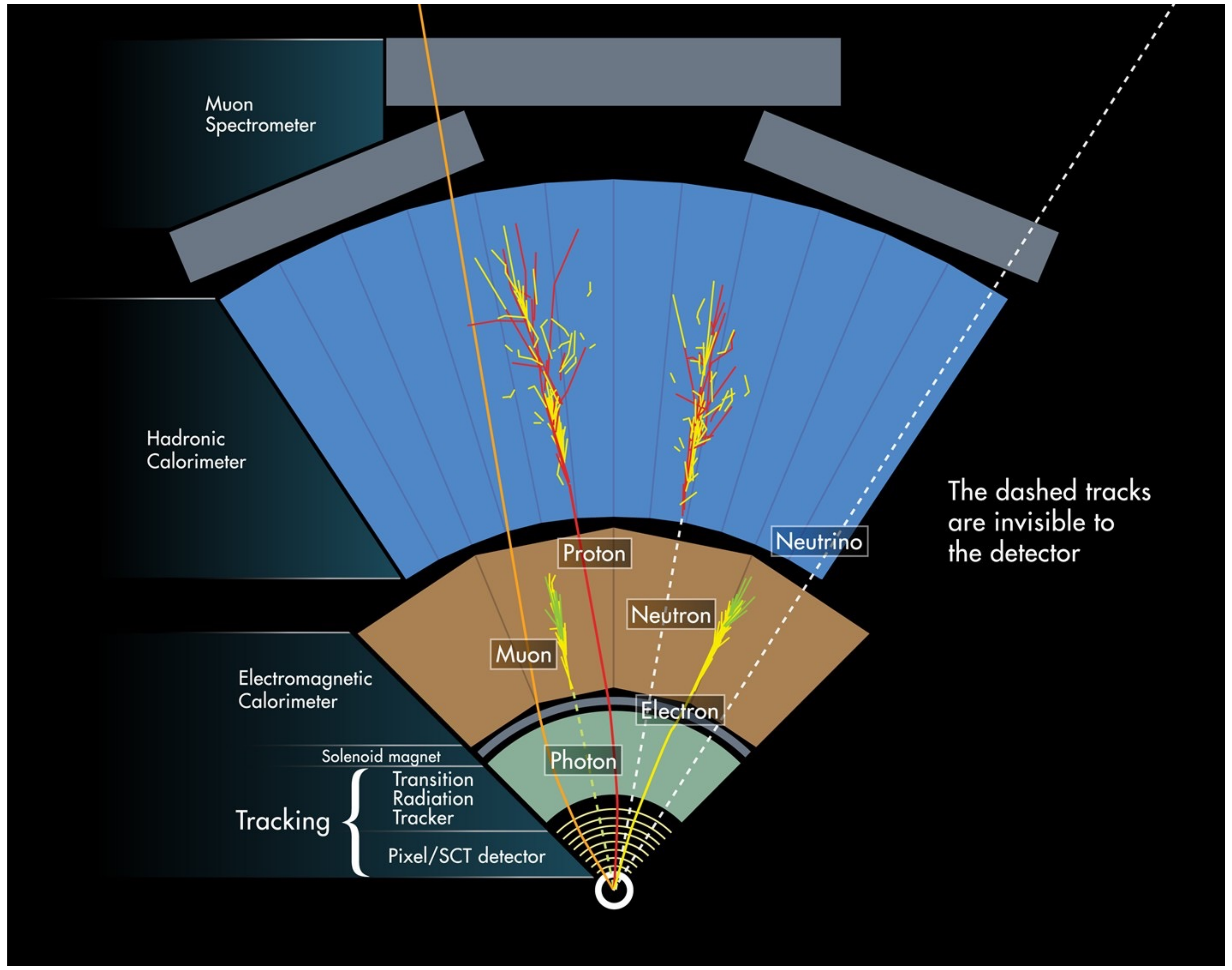
Data formats in ATLAS



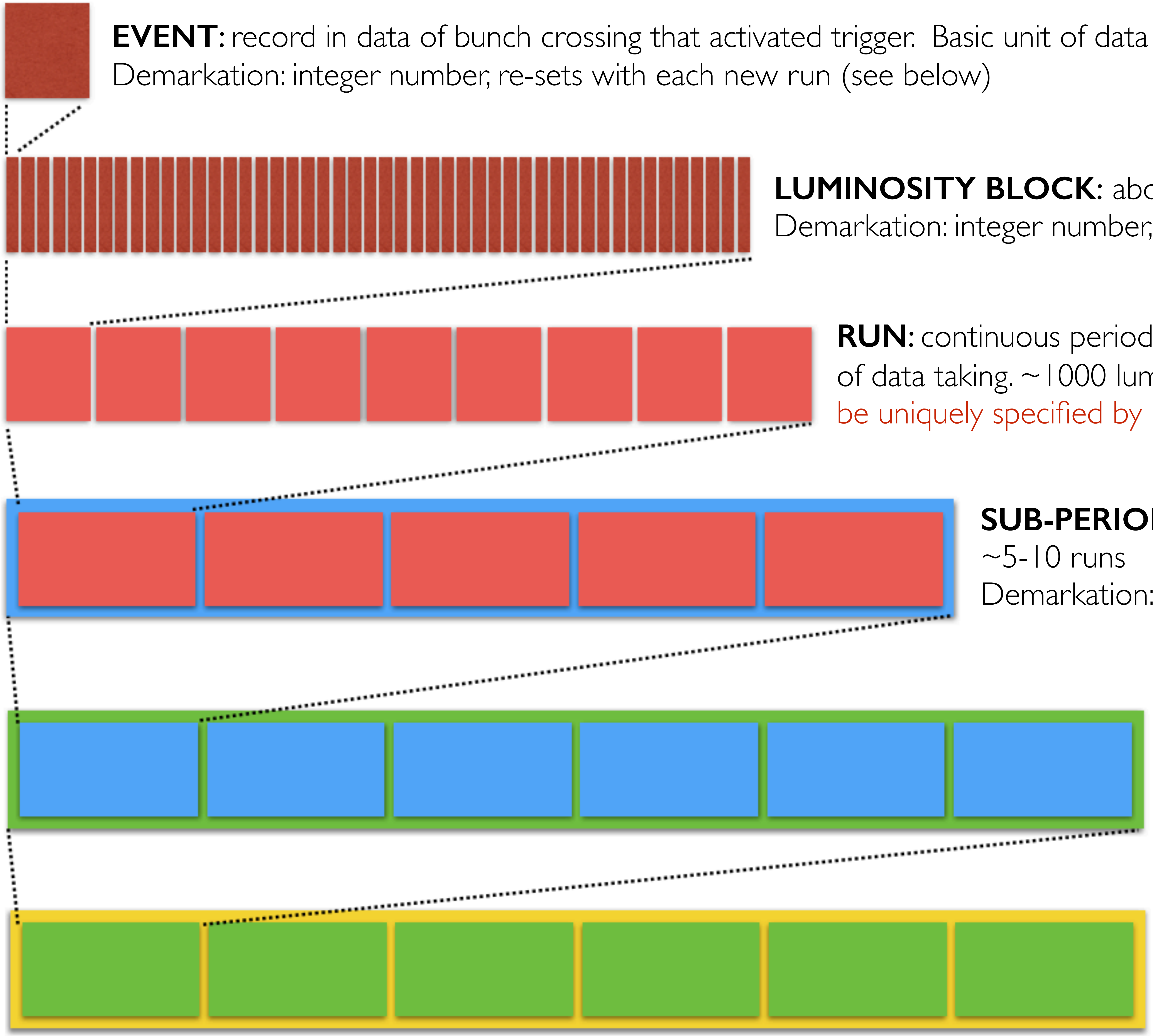
What is data preparation?

- Taking the raw data from the detector, calibrating it, turning this into analysis objects (electrons, muons, jets, ...), delivering this to you, the user
- Tracking when the detector is in a bad state and the recorded data shouldn't be used
- Determining how much data was recorded in the first place
- Managing the *prompt processing* and *reprocessing* workflows





How data is divided up in ATLAS



EVENT: record in data of bunch crossing that activated trigger. Basic unit of data taking. Defines a single cycle of Athena. Approximately 1K per second.
Demarkation: integer number, re-sets with each new run (see below)

LUMINOSITY BLOCK: about 1 minute of data taking. Unit of known luminosity. ~100K events
Demarkation: integer number, re-sets with each new run

RUN: continuous period of ATLAS data recording. Usually corresponds to a single LHC fill, e.g. hours of data taking. ~1000 luminosity blocks. Demarkation: integer number. Never resets → each event can be uniquely specified by its run and event number

SUB-PERIOD: group of runs taken with very similar conditions (e.g. trigger, LHC).
~5-10 runs
Demarkation: letter and number (e.g. E5)

PERIOD: group of sub-periods taken with similar conditions, or during some period (e.g. increments after technical stop). ~5-10 sub periods
Demarkation: letter (e.g. E); resets each year

LHC RUN: long period of data taking, between shutdowns. 2009-2012 was Run 1, we are now in Run II, and Run III will start in 2021.
Typically 20-30 periods per LHC run.

Good Runs Lists

- Remember those luminosity blocks? ~ 1 minute of data taking
  - Several hundred lumi blocks per run; one or several lumi blocks per file
  - Some lumi block ranges will have bad data quality and should not be used for analysis

- The data quality flags are set in the *data quality monitoring*
- They are encoded in a database and accessed in your analysis via a *Good Runs List* file
- Different versions of the data quality flags get a different name, e.g. DetStatus-v61

What a GRL looks like inside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…….
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</LumiRangeCollection>
```

GRLs and luminosity calculation

- The luminosity "seen" by your analysis depends on three things:
  - the luminosity blocks processed (from the GRL)
  - the trigger prescales applied
  - the level-1 trigger live-time (fraction of delivered luminosity that ATLAS recorded)
- To get the luminosity you pass the GRL to the lumi-calc tool and provide it with the trigger you used
- The tool will calculate the luminosity by adding up the lumi-blocks and applying the prescales to each
  - Uses both the trigger DB and the luminosity DB
- **Important**: if you use the number from this tool in your analysis, you MUST ensure that you processed ALL of your data!
  - You will find out how to do this later in the week…

GRLs and luminosity calculation

https://atlas-lumicalc.cern.ch

Recommendations

Data Sample	Recommended Luminosity Tag	Recommended Livefraction Trigger	Comments
data13_hip	OflLumi-HI-002	L1_LUCID_A_C	Preliminary vdM calibration
data13_2p76TeV	OflLumi-2p76TeV-002	L1_LUCID_A_C	Final 2.76 lumi
data12_8TeV	OflLumi-8TeV-003	L1_EM30	Preliminary 2012 vdM calibration
data11_7TeV	OflLumi-7TeV-004	L1_EM30	Final 2011 results (with beam-beam corrections)
data10_7TeV	OflLumi-7TeV-004	L1_MBTS_2	Final 2010 results (with beam-beam corrections)
data11_2p76	OflLumi-2p76TeV-002	L1_LUCID_A_C	Final 2.76 lumi
data10_hi	OflLumi-HI-000	L1_LUCID_A_C	Online estimate

Luminosity Calculator

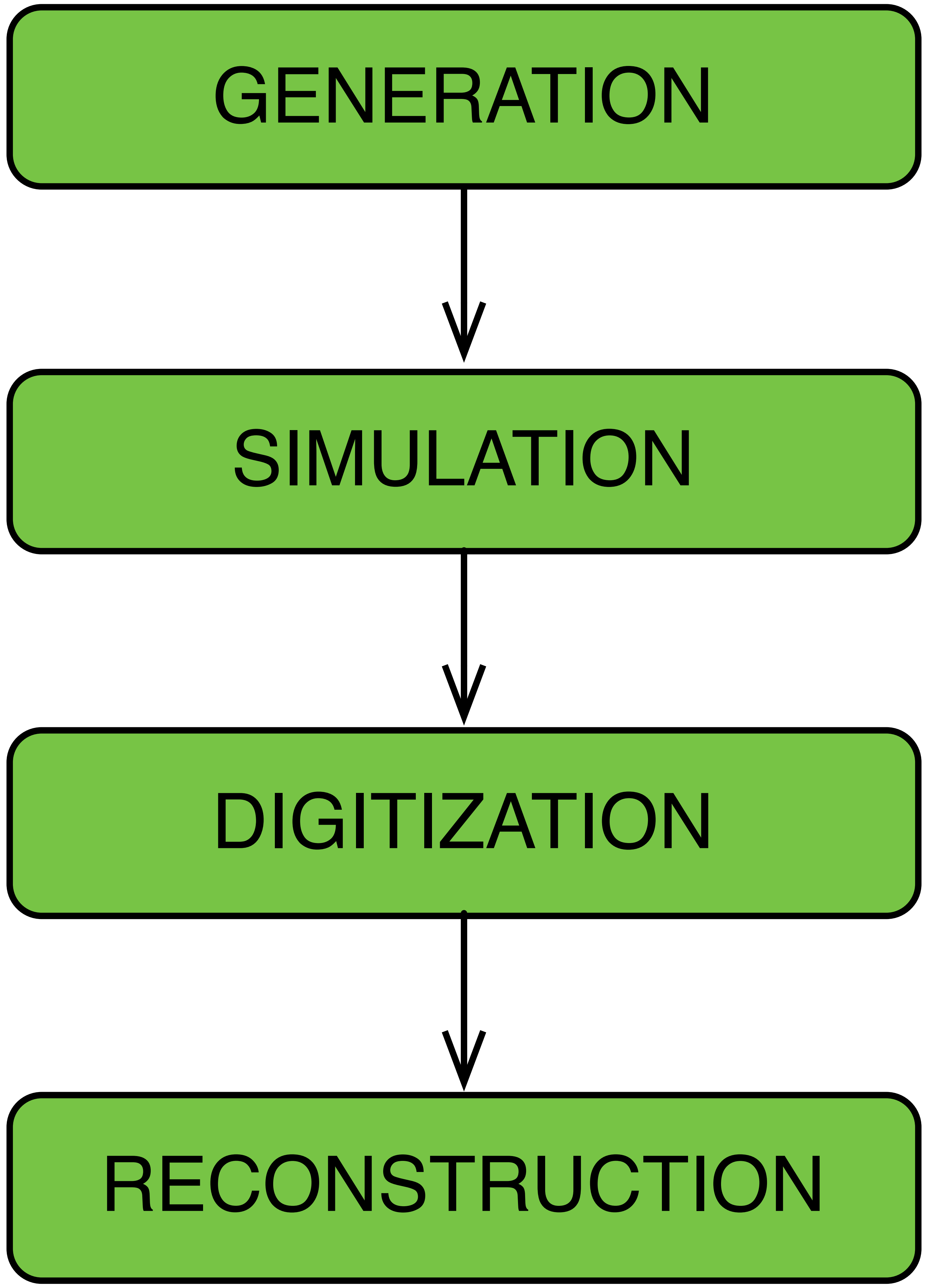
See below for a synopsis of these quantities.

GRL XML File:	Choose File no file selected	GRL XML file which defines the data sample of interest. See below for information how to specify a subset of a GRL.
Luminosity Tag:	OflLumi-8TeV-003 (preferred 2012)	Tag which defines the specific version of the luminosity measurement. Only use --online for diagnostic checks.
Live Fraction Trigger:	L1_EM30	This trigger is only used to compute the L1 live fraction. Any high rate L1 trigger can be used. Please see below for recommendations.
Physics Trigger:	None	This trigger is used to compute the prescale correction. It is possible to use a L1 trigger, but if that trigger is prescaled at the HLT, you will get the wrong result! Specify None to assume a prescale of 1 for all luminosity blocks.
LAr EventVeto Tag:	LARBadChannelsOflEventVeto-UPD4-04 (recommended)	Tag which defines the LAr Event Veto information. Must be used to assess LAr Event Veto inefficiency. Use None to turn this off. See below or here for details.
Other Options:	☐ Calculate BGRP7 luminosity (--lumichannel=17) ☐ Require online beamspot (--beamspot) ☐ Create output plots and ntuples (--plots) ☐ Verbose output (--verbose) Additional options	Add any additional options here. Use --help, or just click the Calculate Luminosity button below with no GRL specified, to find other possibilities.

Remember, this process can take considerable time (minutes) for large data samples. Pushing the button again will only make things worse. Please be patient!

Calculate Luminosity

Monte Carlo Production



Why do we need Monte Carlo

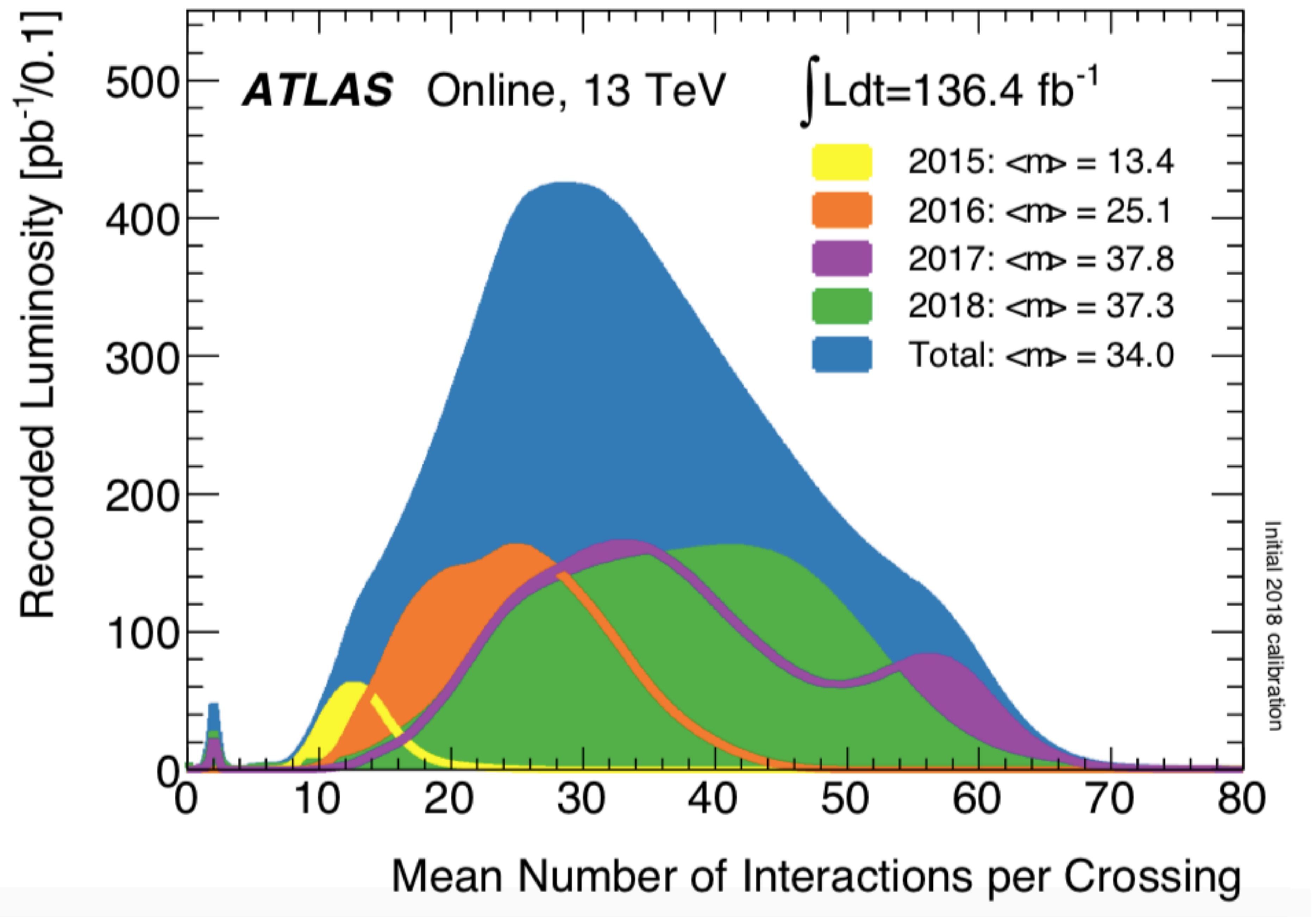
- Testing whether we understand the performance of the detector
- Calculating reconstruction efficiencies (usually for validating data-driven methods)
- Modelling the expected background under a process of interest
- Modelling the process of interest
- Training multivariate classifiers (neural networks, boosted decision trees etc)
- Setting systematic uncertainties
- etc etc etc

Monte Carlo production (i)

- All official Monte Carlo production is done on the Grid
  - Several-step process
  - Event generation: simulation of the interaction between the quarks and gluons in the colliding protons, the subsequent parton showering and hadronization and decays into stable particles
  - Detector simulation: calculation of how the particles from the generator interact with the detector material; how they shower into secondaries; how much energy they deposit in each sensitive element.
  - Digitisation: turning the simulated energy deposits into a detector response that "looks" like the raw data from the real detector
  - After this step, the process is the same as for real data
- The analysis data for MC and real data looks the same, except that in MC the original generated events (the "truth") are available as well as the reconstructed objects

Monte Carlo production (ii)

- Extra low momentum events must be injected into the chain to simulate the presence of multiple proton collisions ("pile-up") in a given LHC bunch crossing
- Complication: the average number of collisions per bunch crossing is a function of the LHC parameters, and we typically do not know these when we start the Monte Carlo production
- Monte Carlo events must be weighted in analysis to account for discrepancies between the real and simulated pile-up. This re-weighting is something you will learn to "love" during your ATLAS career
- Monte Carlo campaigns are targeted at matching a given period of data taking, usually a year, but sometimes more
- The campaigns are named like "MC15, MC16" - whilst this may look like a year, it doesn't match the year exactly, e.g. we currently use MC16 for all data since 2015
- Within a given campaign there may be sub-campaigns representing different time periods or guesses at the pile-up. Often these are discarded as our knowledge of the LHC conditions improves



mc16a	2015-2016 data, actual pile-up
mc16d	2017 data, actual pile-up
mc16e	2018 data, pile-up guess
mc16f	2018 data, actual pile-up (probably not needed)

Datasets

- Datasets are collections of files that were made in the same way, e.g. the same MC sample or run etc
- They are defined by and catalogued in the distributed data management system *Rucio* which is a major component of our computing system
- You will hear much more about Rucio and how to access the data later on in the tutorial
- Nomenclature:

DATA

Project	Run number	Stream	Step	Format	AMI tag
data18_13TeV	00349051	physics_Main	deriv	DAOD_EGAM1	f926_m1955_p3544

`data18_13TeV.00349051.physics_Main.deriv.DAOD_EGAM1.f926_m1955_p3544`

MONTE CARLO

Project	Dataset ID	Physics description	Step	Format	AMI tag
mc16_13TeV	364250	Sherpa_222_NNPDF30NNLO_llll	deriv	DAOD_EGAM1	e5894_s3126_r9364_p3526

`mc16_13TeV.364250.Sherpa_222_NNPDF30NNLO_llll.deriv.DAOD_EGAM1.e5894_s3126_r9364_p3526`

Dataset nomenclature

- Physics containers (data only)

Period / Format

`data18_13TeV.periodM.physics_Main.PhysCont.DAOD_EXOT0.grp18_v01_p3583`

Project / Stream / Compound tag

Physics container: collection of datasets defined after a period closes, either by data preparation (for AODs) or the physics group (for DAODs)

AMI tags

- There is too much metadata concerning the creation of the datasets to record in the dataset name
- Instead a code is used that can be entered into the ATLAS Metadata Interface (AMI) to get the full details
- You will hear much more about AMI later in the week
- The tags consist of strings of letters and numbers
- The letters indicate what production steps have been run to create the dataset

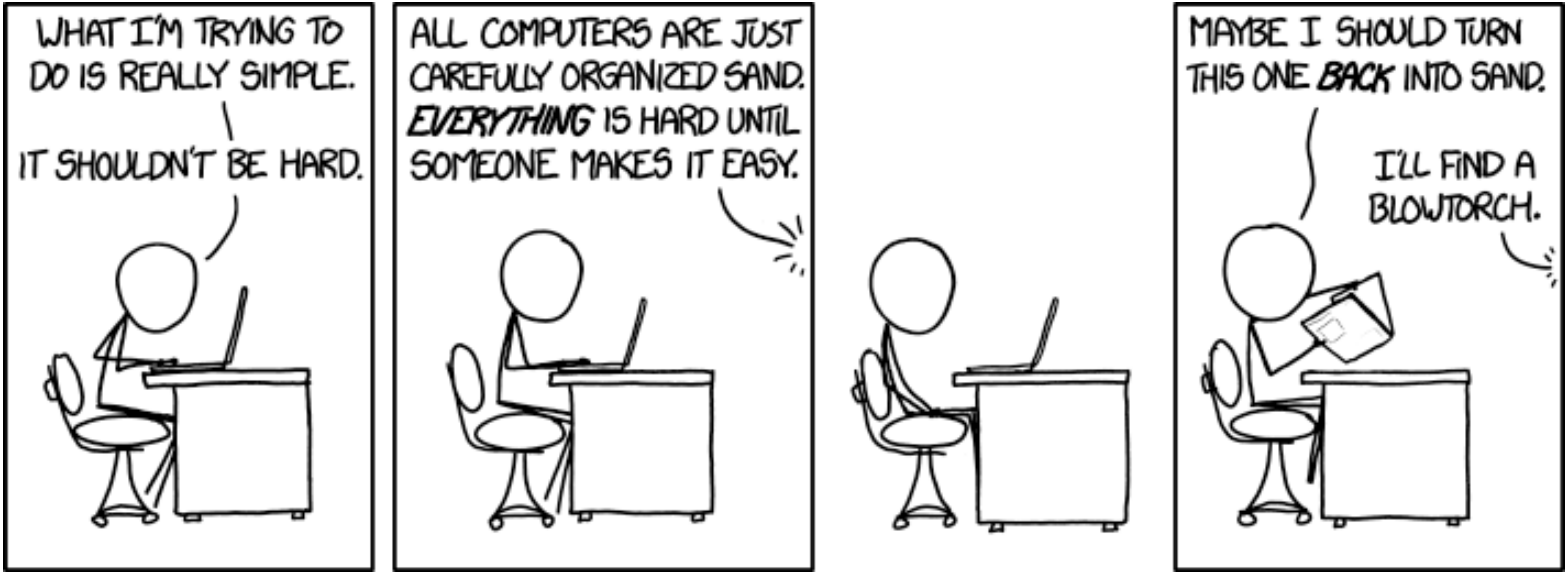
`e5894_s3126_r9364_p3526`

Letter	Step	Step name in dataset
`e`	Event generation	`evgen`
`s`	Full simulation	`simul`
`a`	Fast simulation	`simul`
`r`	Reconstruction on the grid	`recon`
`p`	DAOD production	`deriv`
`f`	Reconstruction at Tier-0	`recon`
`m`	Merging of AODs at Tier-0	`merge`

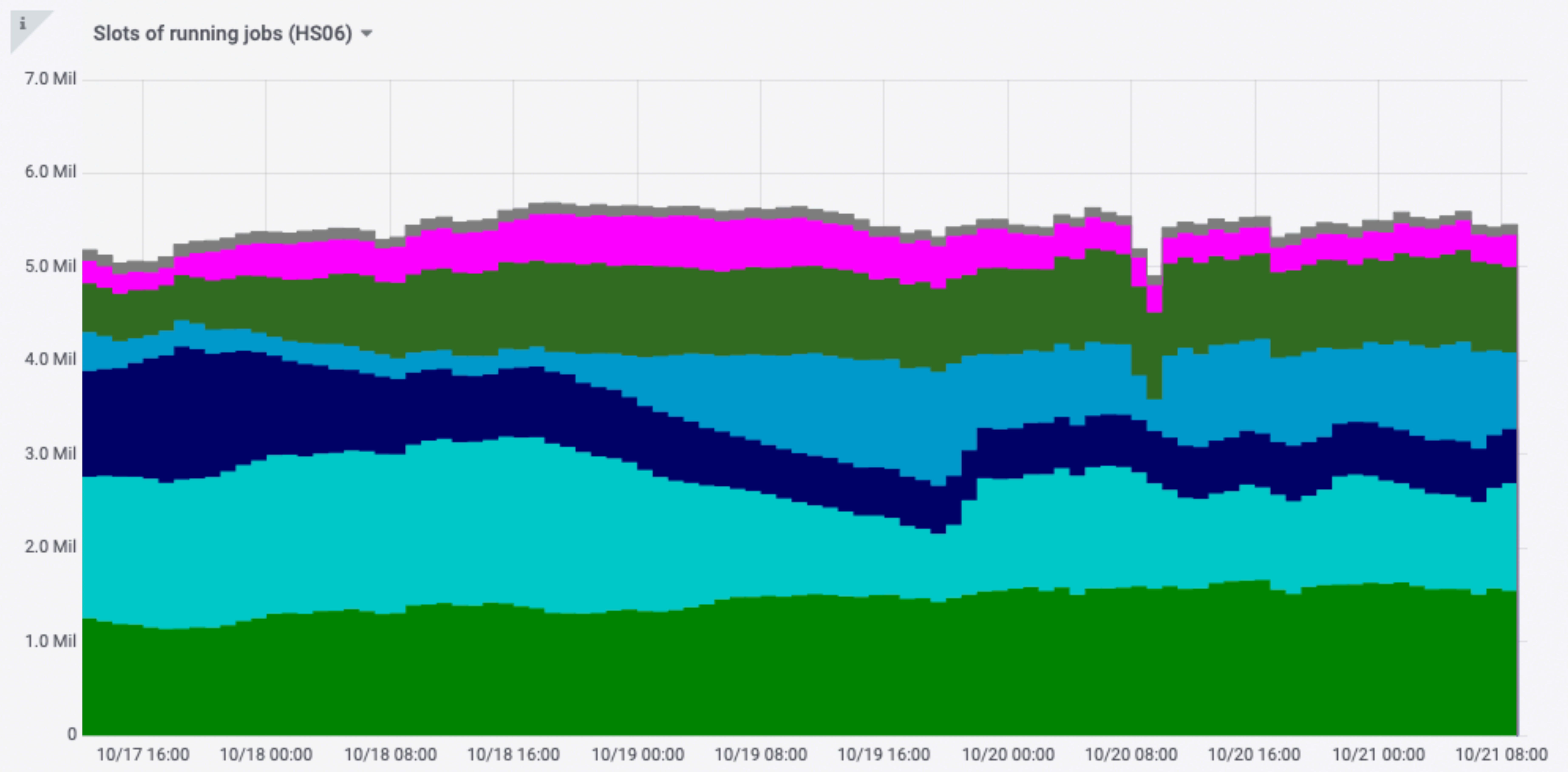
Metadata repositories

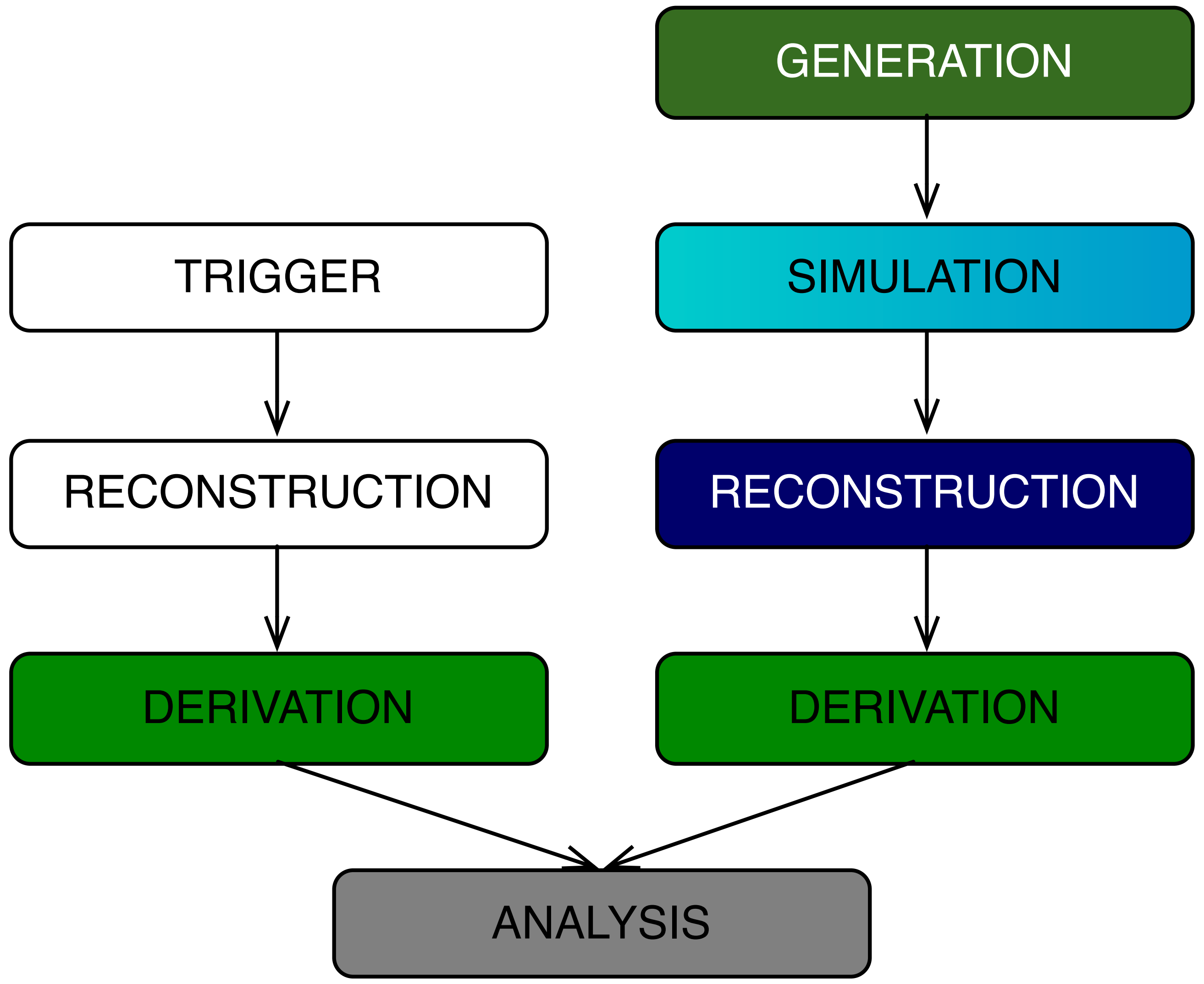
- ATLAS Metadata Interface (AMI):
  - extensive information on datasets (data and MC)
  - interpretation of the AMI tags
- COMA
  - detailed information on data, including luminosity, data periods, trigger configuration, data quality etc
- For quick information you can also use the Run Query Tool, although COMA is better for browsing (e.g. if you want to look at a lot of runs at once)
- You will see more these during the tutorial!

Computing and software

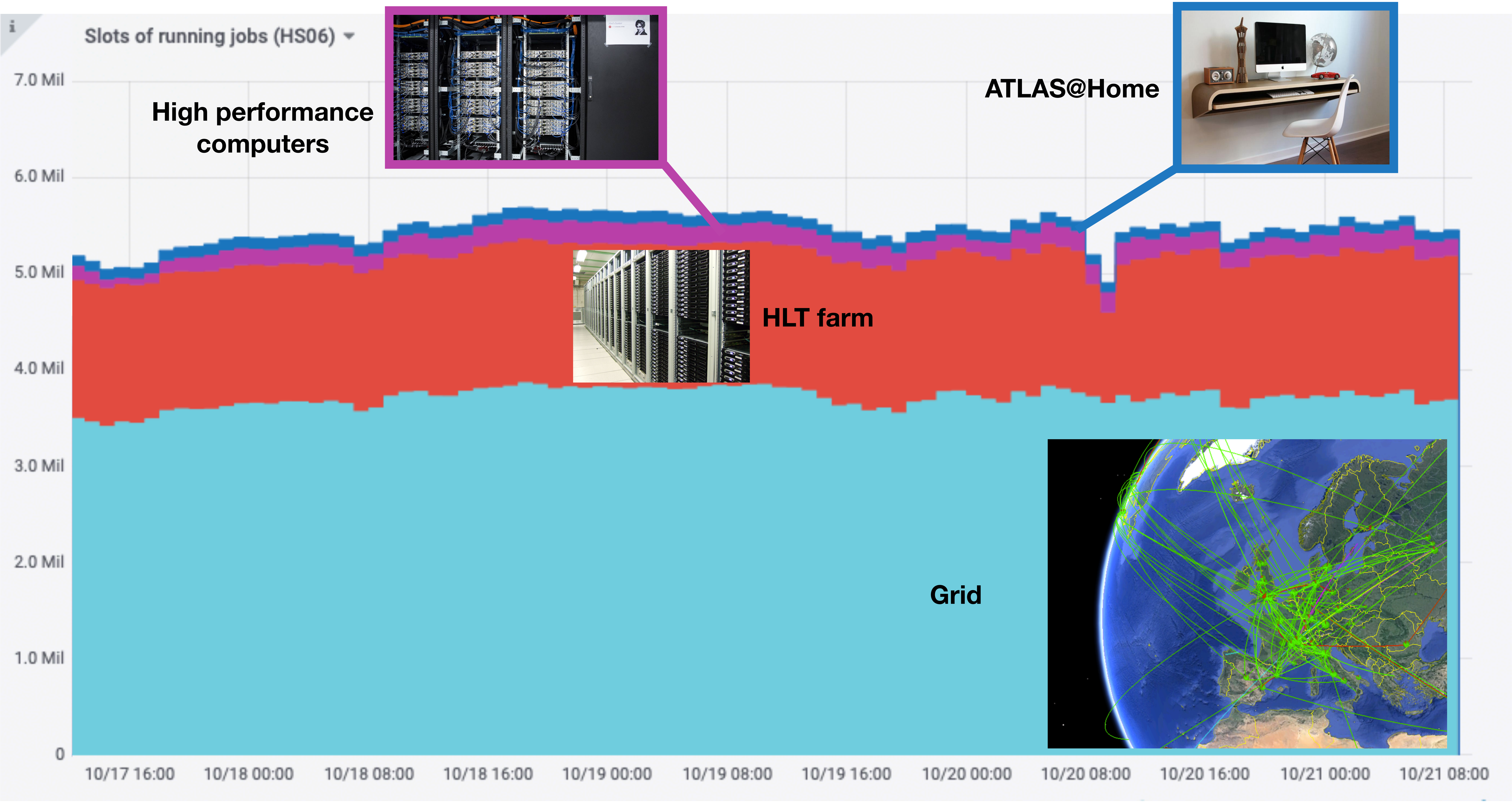


What are we running?

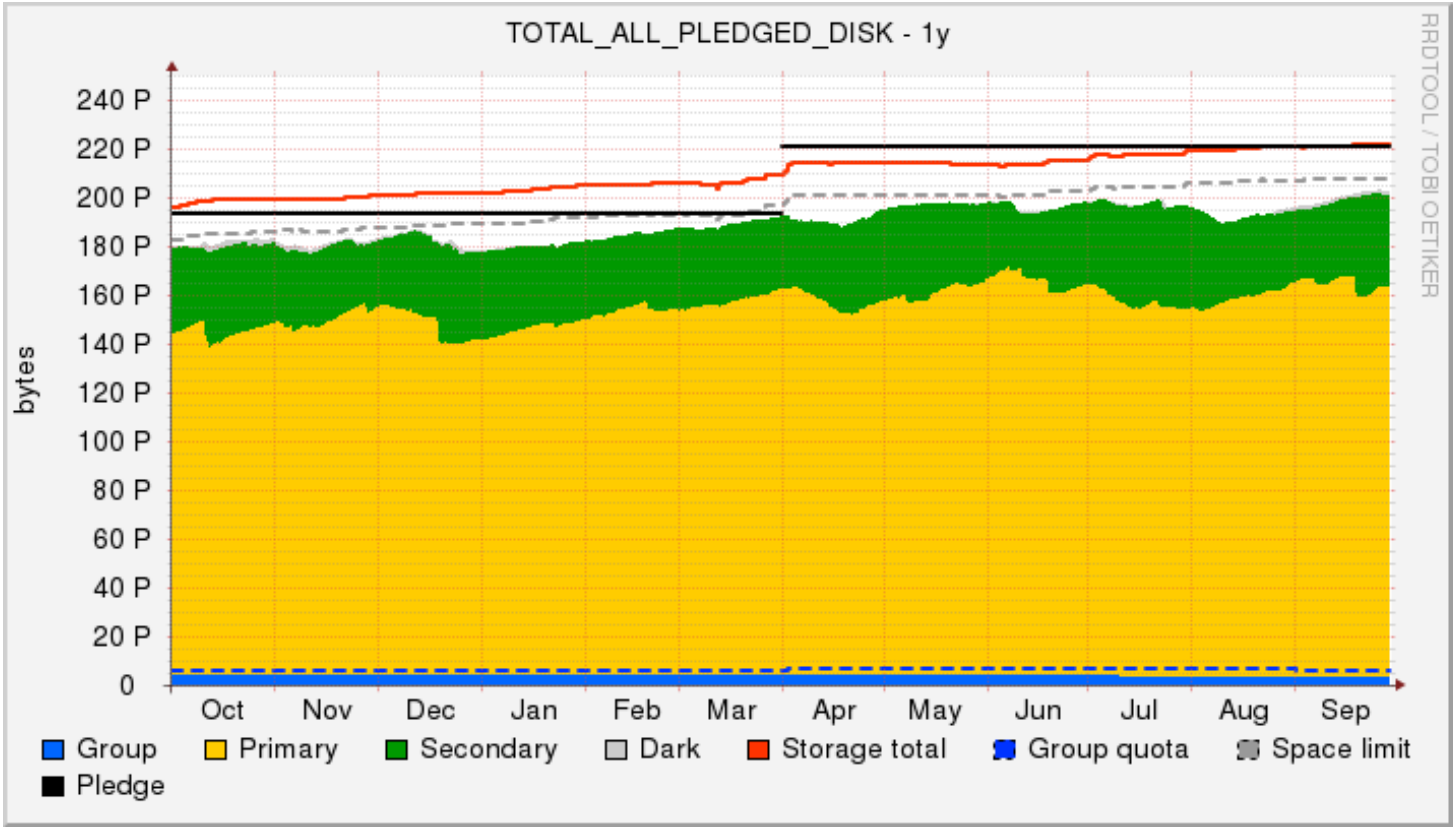




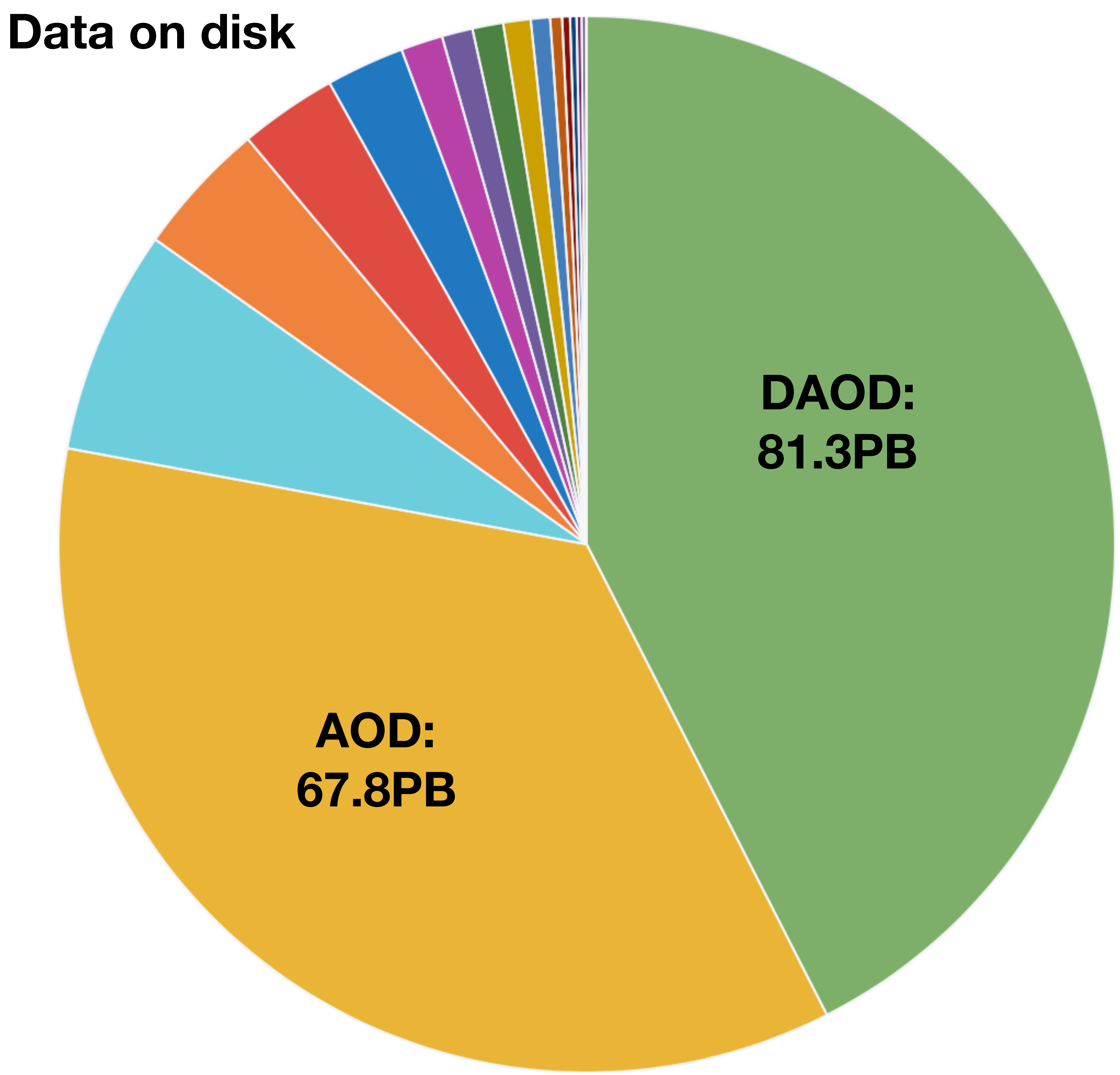
Where are we running it?

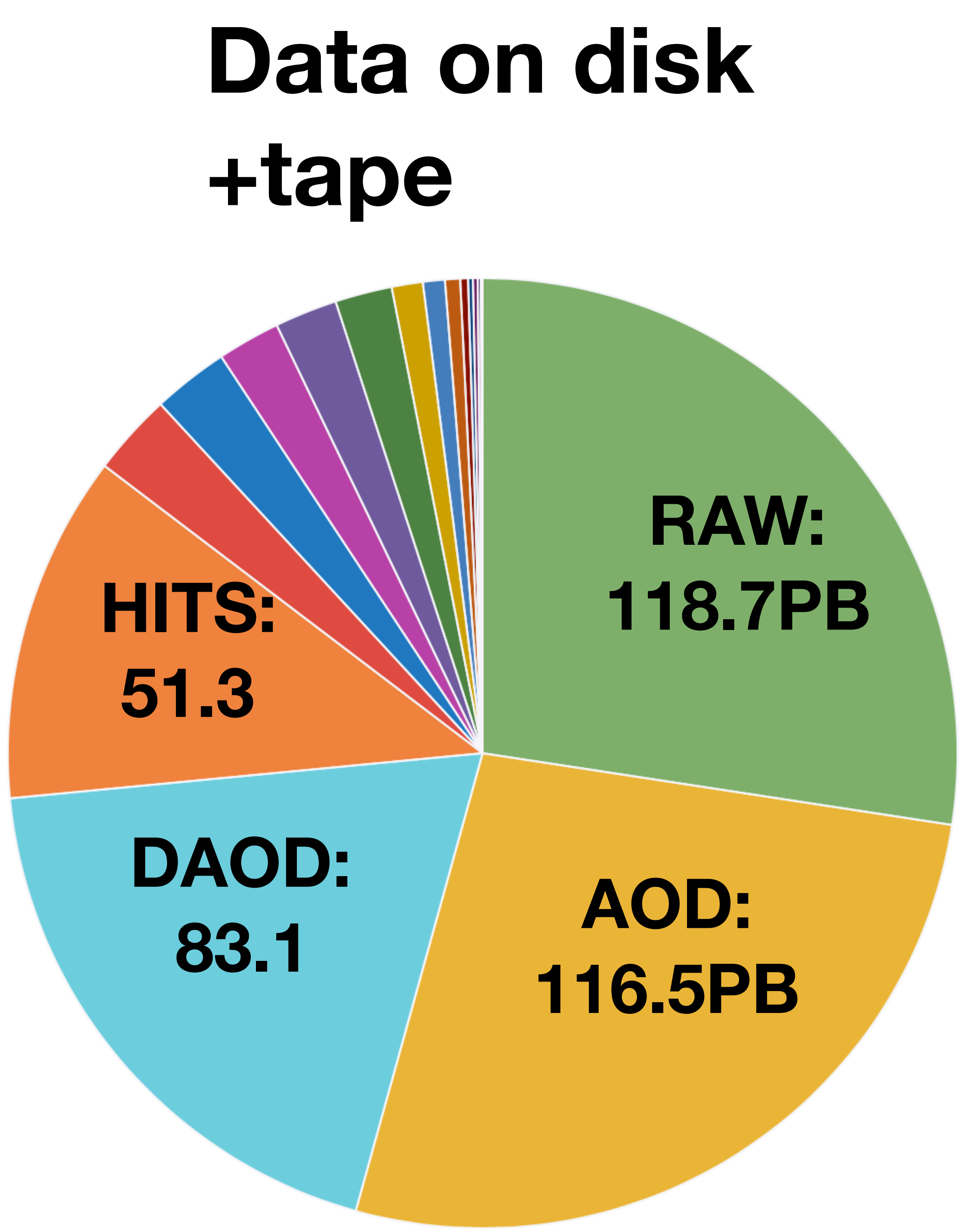


Our computing resources aren't infinite…



… and analysis takes up most of the space





Message: don't assume that computing resources are infinite. Keep disk space usage in mind when planning your work.

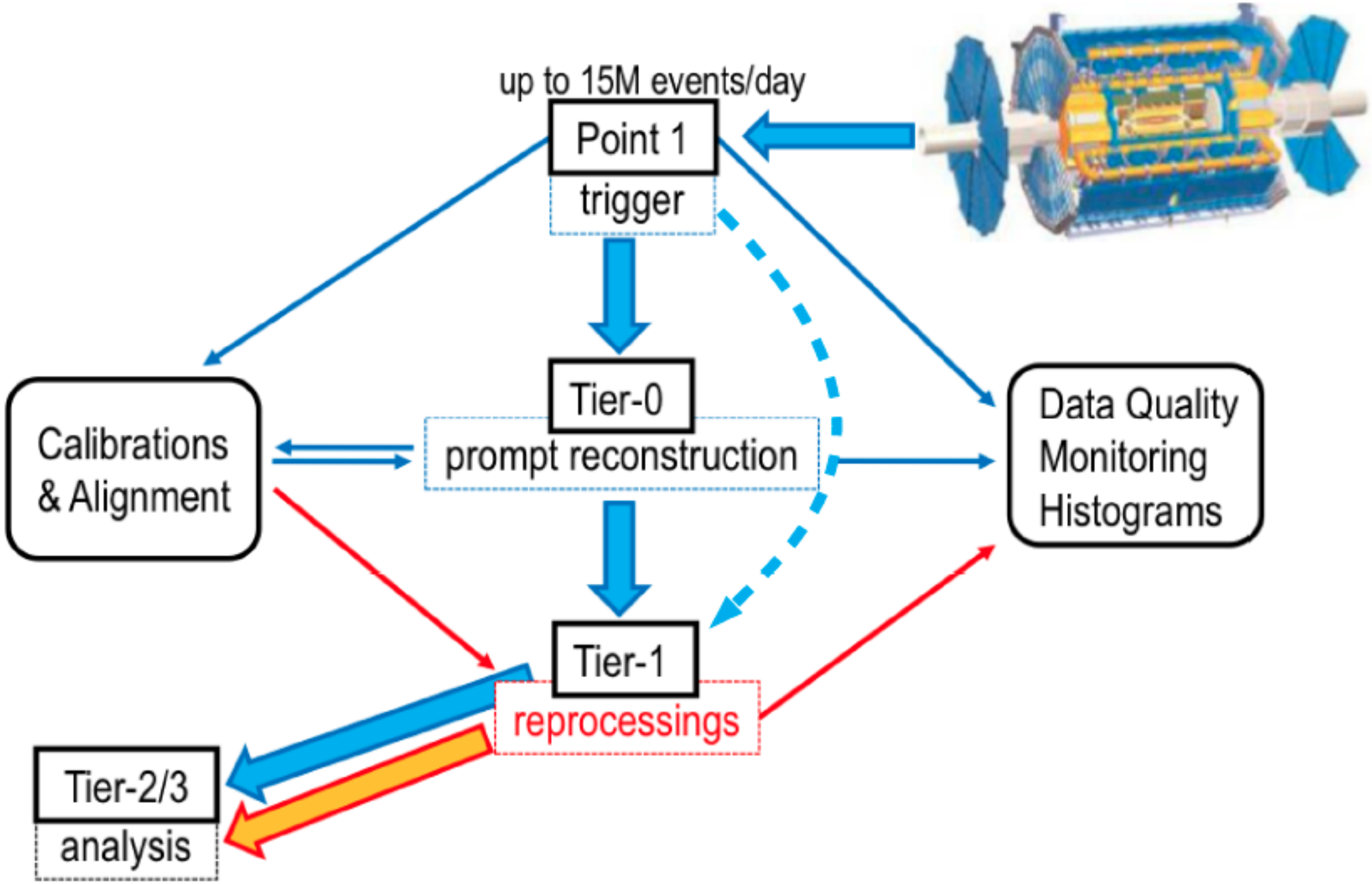
Computing is a shared resource.

Getting involved!

- Data Preparation & Computing have lots of things to do
  - luminosity measurement
  - data quality monitoring
  - multithreading upgrade to reconstruction software
  - optimization to handle high pileup
  - running ATLAS software on supercomputers and GPUs
  - improved fast simulation
    & so many others
- Involvement can range from taking shifts to a long-term commitment starting with a qualification task
- **See open tasks in Data Preparation, Computing**
- Much of our work is as intellectually stimulating as physics analysis
- Experience with large-scale dataset preparation and computing/software is clearly highly relevant in the wider employment market

Extra slides

What is Data Preparation?

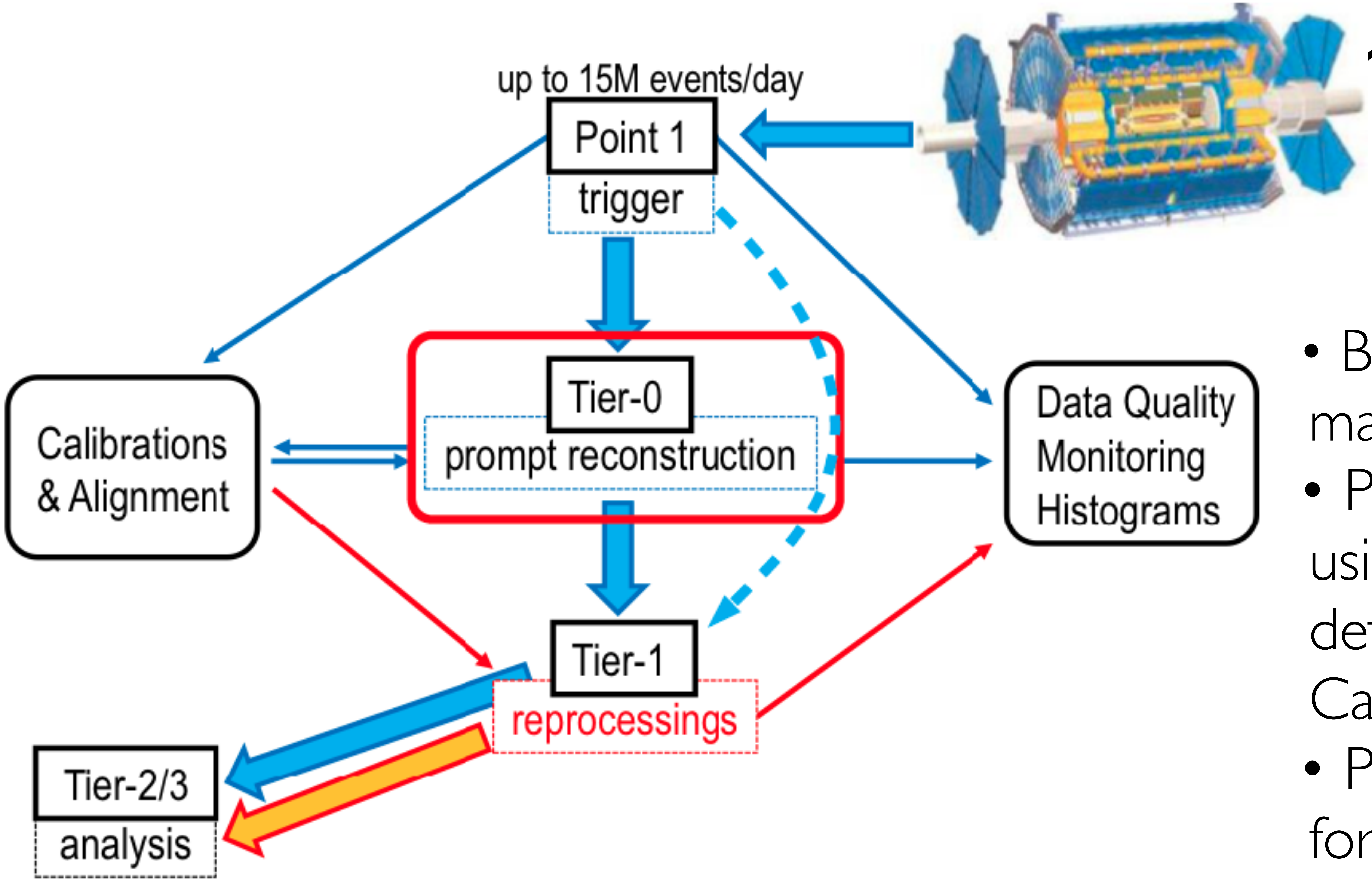


- Question - What is Data Preparation?
  - One answer - "everything" between the detector and your analysis !

Prompt calibration

- Some things are important to know for high quality reconstruction, but impossible to know without looking at data
  - where is the detector exactly? (alignment) where is the beam? (beamspot)
  - how noisy is the detector? how does it respond to particles? (calibration)
- This time-dependent info is generically called "conditions"; stored in a "conditions database"
  - if you hear people refer to "COOL", this is what they mean
- **Immediately as data are taken**: first pass reconstruction of express stream & needed streams for calibration.
  - derive alignment, beamspot, calorimeter noisy channel list, ... Databases updated with new alignment & calibrations.
- **48 hours after end of run**: launch processing of Main stream.
  - also rerun express to ensure calibrations did what they were supposed to!

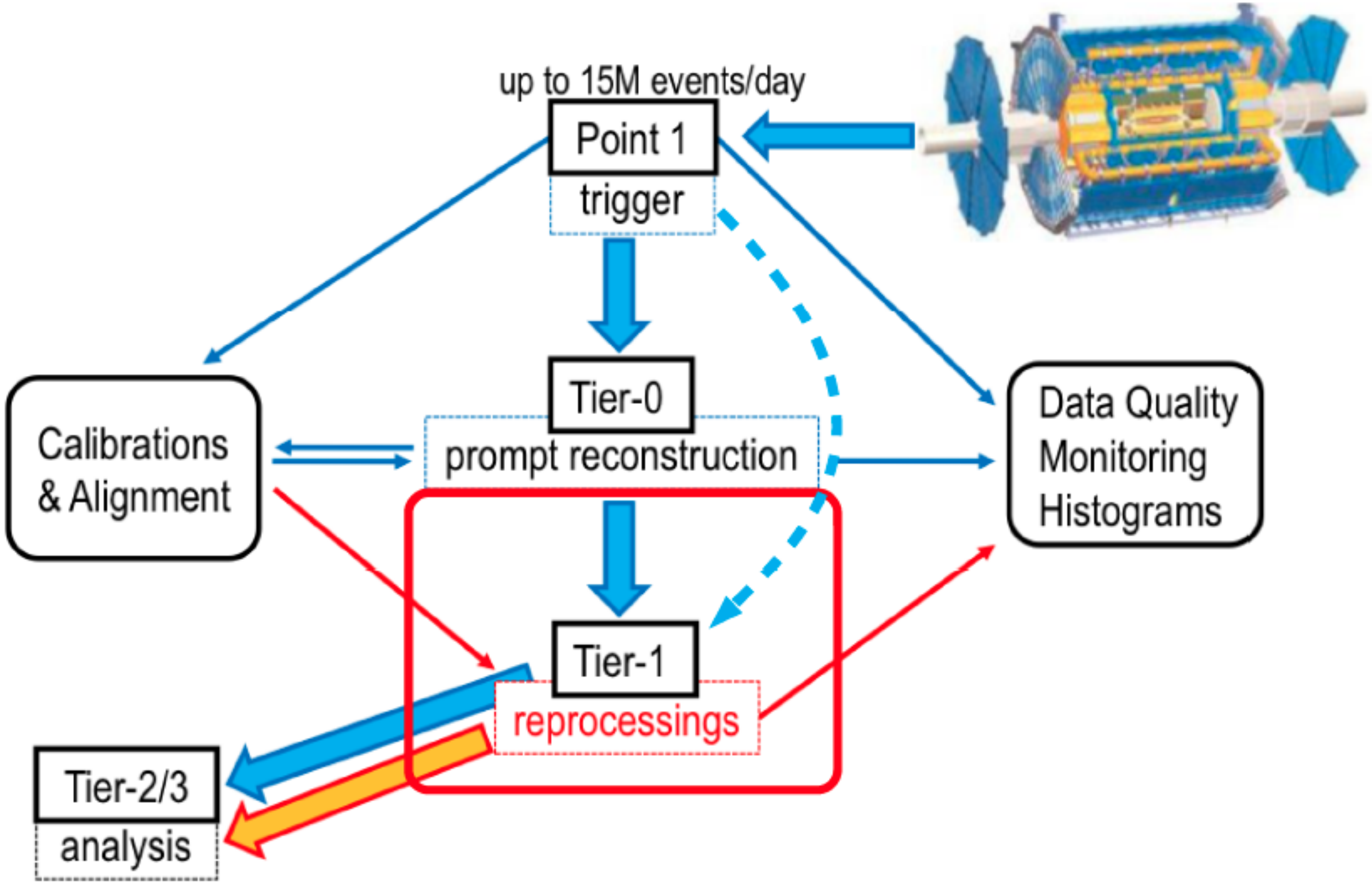
Bulk reconstruction



- Bulk reconstruction uses the majority of the Tier0 resources
- Processes the RAW data using updated calibrations determined in the Prompt Calibration
- Produces many outputs used for a variety of purposes, the most important being the AOD

Reprocessing

Reprocessing at Tier-1s



- Over time we improve our knowledge of the conditions
- We may make improvements to the reconstruction performance or find and fix bugs
- After a time, we reprocess the existing raw data with the improved software/ conditions
- This has to be done on the Grid since the Tier-0 will be busy with prompt data processing
- Once we start a reprocessing, we also switch the Tier-0 to the new software to ensure a consistent dataset

Lumi blocks and analysis

- When you do your analysis you need to filter out the bad lumi blocks
  - This is done by means of a *good runs list* (GRL)
  - XML file listing each run and the range of good lumi blocks in each: read in by the analysis code
  - GRLs are produced for each database tag
  - In principle there can be many types of GRL restricting the selection to (e.g.) muons or calorimetry, but in practice almost everyone uses the "All Good" lists
  - Location of GRLs: /afs/cern.ch/user/a/atlasdqm/grlgen/
  - GRL documentation: https://twiki.cern.ch/twiki/bin/view/AtlasProtected/GoodRunListsForAnalysisRun2

ATLAS Computing and Software

- Responsibilities
  - The core software of ATLAS; the Athena framework
  - Software that
    - Steers the event generation and simulation
    - Does the reconstruction and analysis
  - The computing resources on which the above is run, especially: distributed computing grid and associated software (distributed data management, job management layers, etc)
  - Databases
  - Infrastructure used to manage software and computing (code repositories, build systems, analytics etc)
  - Managing overall use of resources by ATLAS - disk, CPU, network, etc etc
- **More on all of this later in the week!**

ATLAS Computing and Software