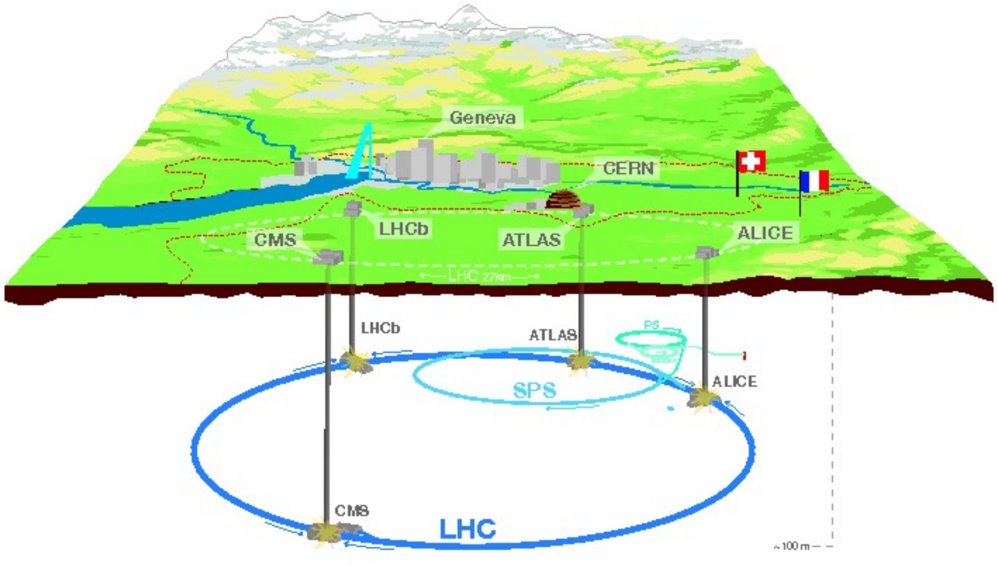
LHCb Software and Computing

Stefan Roiser

CEPC Workshop, Beijing

14 November 2018

CERN and the LHC Accelerator Complex



The Large Hadron Collider:

- 27 km tunnel originally built and used for LEP experiments 1989 – 2000
- For LHC used for proton – proton collisions
- 4 main experiments: CMS ALICE, ATLAS and LHCb

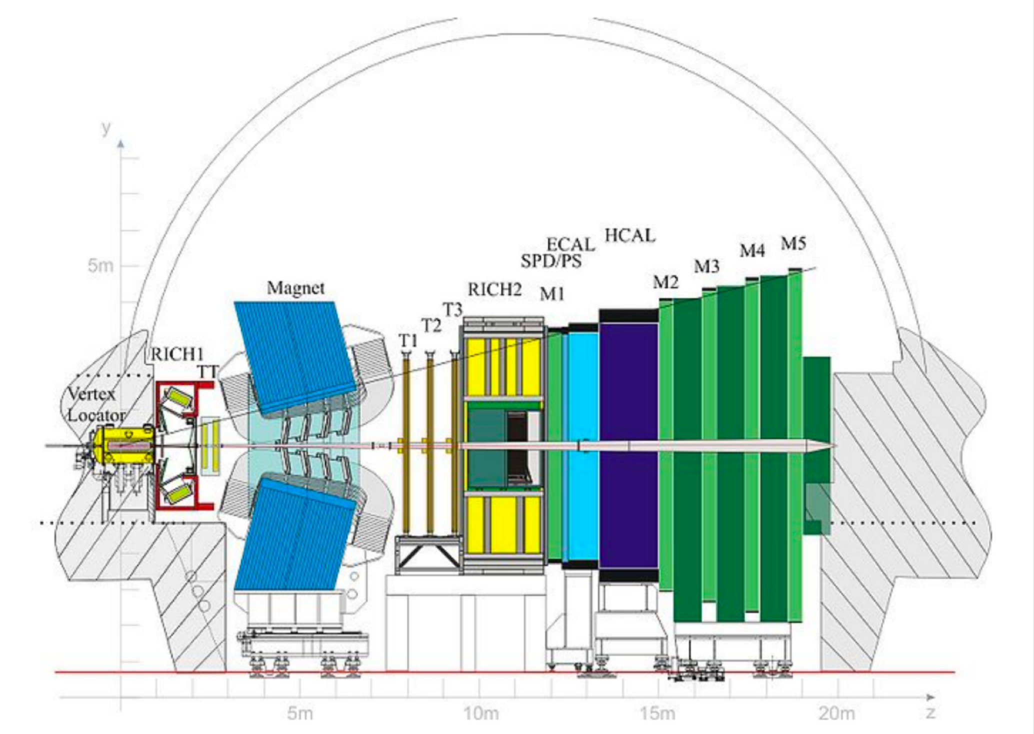
LHC Operation and Shutdown Years:

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	…	203x
Run 1				Shutdown 1		Run 2				Shutdown 2		Run 3			Shutdown 3			Run 4				

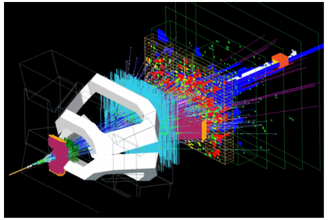
The LHCb Experiment

Collaboration of 1250 members from 79 institutes

Run 1: ~ 3 fb^{-1} of pp collisions
Run 2: ~ 6 fb^{-1} of pp collisions
Run 3: plan for ~ 10 fb^{-1} of pp collisions per year



Run 2 Data Processing Model



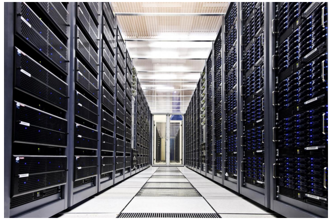
LHC bunch crossing

40 MHz

L0 hardware Trigger

L0 Hardware Trigger

1 MHz



High Level Trigger (HLT)
+ partially full event reconstruction

700 MB/s

"Online"

"Offline"

Reconstruction

Generate physics objects

100 %

Stripping

Slimming, streaming and selecting of events

60 %

Full Stream

100 %

Fully reconstructed physics objects out of HLT

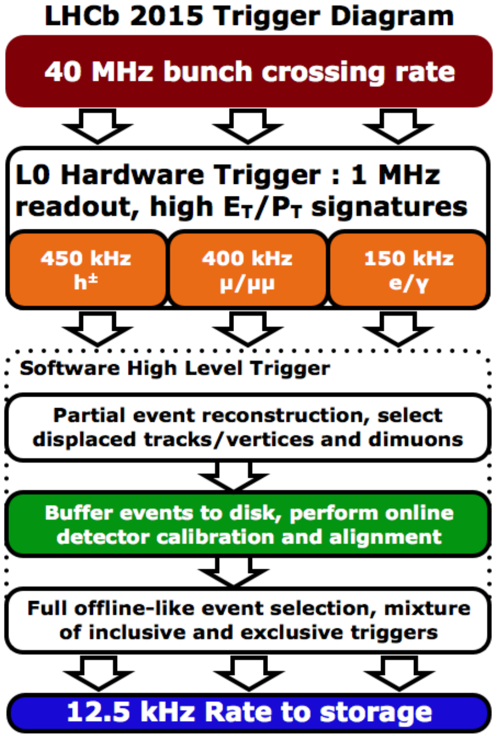
Turbo Stream

Physicist start selecting and analyzing the data

Online kHz: event rate
Offline %: data retention

Real Time Calibration & Turbo Stream

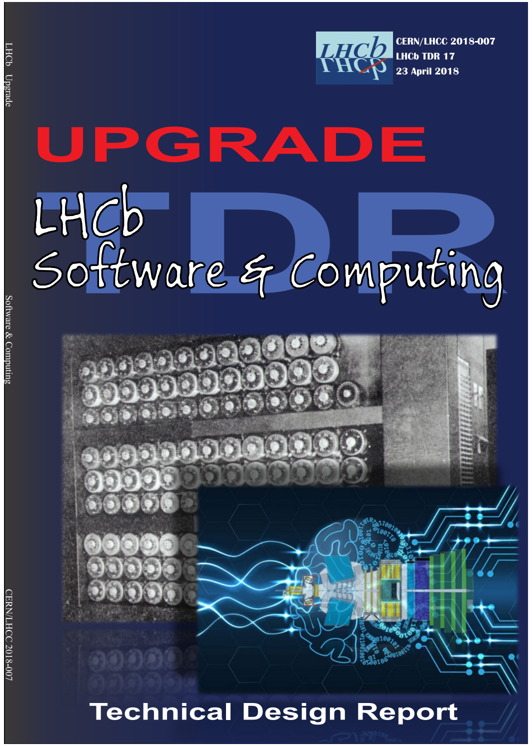
- Introduced during Run 2
- Split HLT into two stages
  - HLT 1 runs synchronous to collisions
  - Data buffering for final detector calibration and alignment
    - No re-reconstruction of data offline needed
  - HLT 2 runs asynchronous with buffered data
- Part of data (Turbo) fully reconstructed in HLT
  - Export physics objects ready for analysis
  - RAW data is discarded after HLT processing



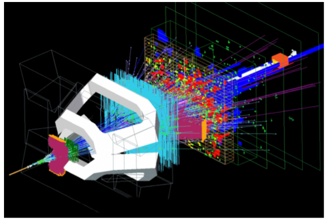
Upgrading the Data Processing for LHC Run 3

- Remove L0 hardware trigger → improved selection via software trigger
- LHC beam luminosity increases by factor 5 to $2*10^{33}\ cm^{-2}s^{-1}$
- Full reconstruction of events during HLT processing

- HLT software needs to cope with 40 MHz event input rate
- Bandwidth out of pit and offline storage needs increase because of better signal selection and luminosity increase
- Offline CPU needs for monte carlo simulation increase
  - Simulation scales with the recorded luminosity

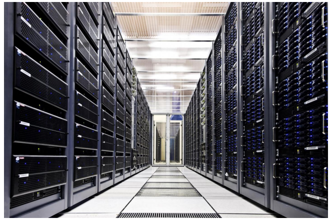


Run 3 Data Processing Model



LHC bunch crossing

40 MHz



High Level Trigger (HLT)
+ full event reconstruction

"Online"

"Offline"

Physicist start selecting and analyzing the data

Full Stream

80 %

Stripping

Slimming, streaming and selecting of events

Turbo Stream

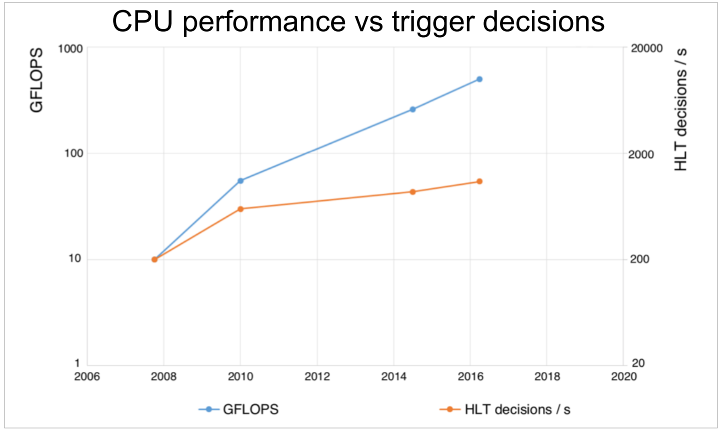
100 %

Fully reconstructed physics objects out of HLT

Online kHz: event rate
Offline %: data retention

Software Development for the Run 3 Upgrade

- Gaudi framework software development started 17 years ago
  - Developed in C++ together with ATLAS collaboration
  - Now move to multi-threaded task-parallel execution
  - Invest into vectorization of algorithms
- Major improvements in memory consumption and throughput
  - More work needed towards Run 3

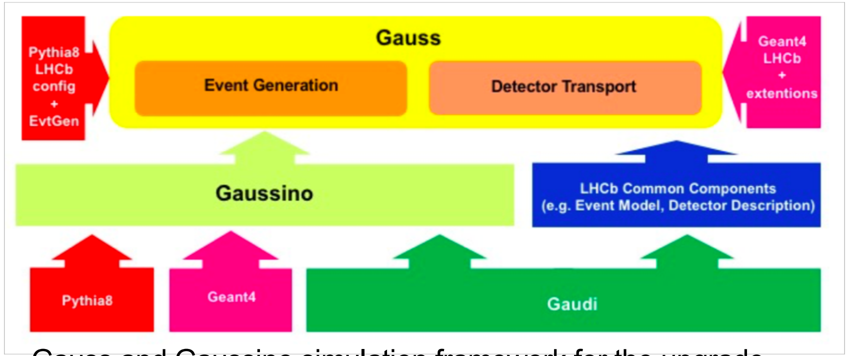


RICH ray tracing improvements via vectorization

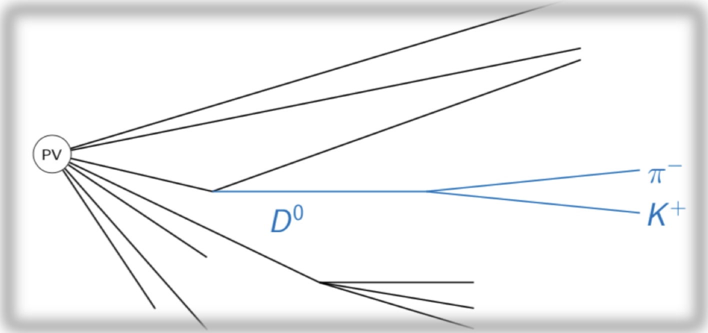
		SSE4		AVX2	
		time (s)	Speedup	time (s)	Speedup
double	scalar	233.462		228.752	
double	vectorized	122.259	1.90	58.243	3.93
float	scalar	214.451		209.756	
float	vectorized	55.707	3.85	26.539	7.90

Monte Carlo Simulation

- Simulation based on same software Gaudi core framework
  - Re-engineering for multi-threaded execution needed
  - Now split into experiment agnostic (Gaussino) and specific (Gauss) part
    - Development of experiment agnostic part is shared with FCC
- Investing into fast and parametric simulation techniques
  - Re-decay, inject signal multiple times
  - Possibility to switch off subdetectors
  - Calorimeter shower libraries
  - Full parametrization via Delphes



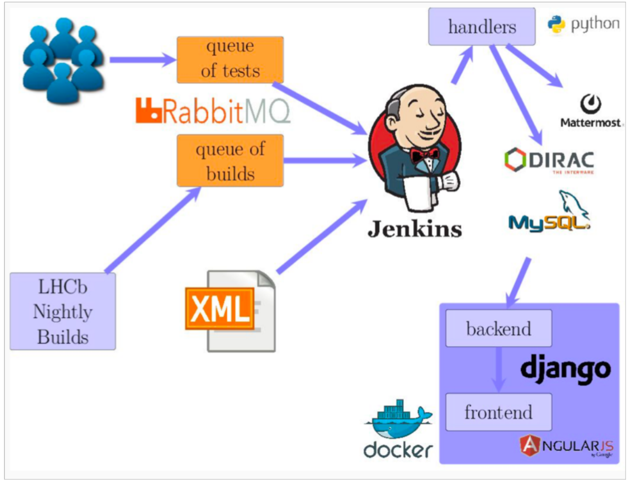
Gauss and Gaussino simulation framework for the upgrade

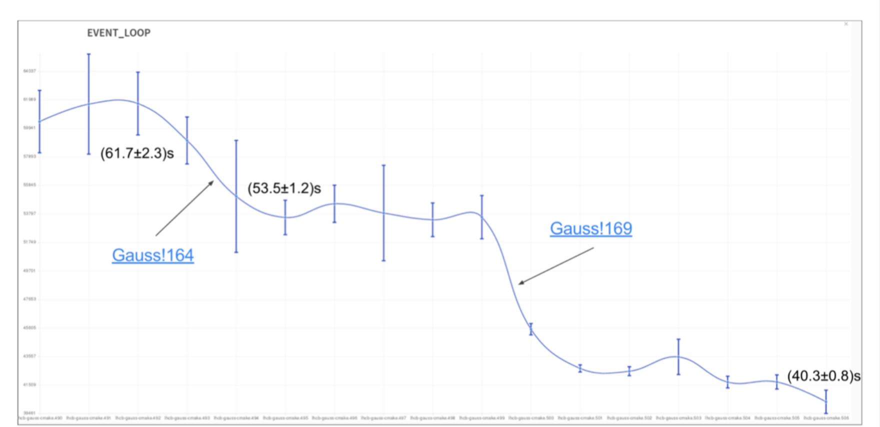


ReDecay, inject signal information multiple times

Testing, Performance Checking and Release Build

- Software compiled and tested in various configurations every 24 hours
  - Testing functionality of the software
  - Checking performance evolution
  - Build and deploy releases
- Helps to easily test new configurations, latest compiler versions, etc.
- Used for trigger, data processing and simulation software packages
- Infrastructure based on standard industry available packages

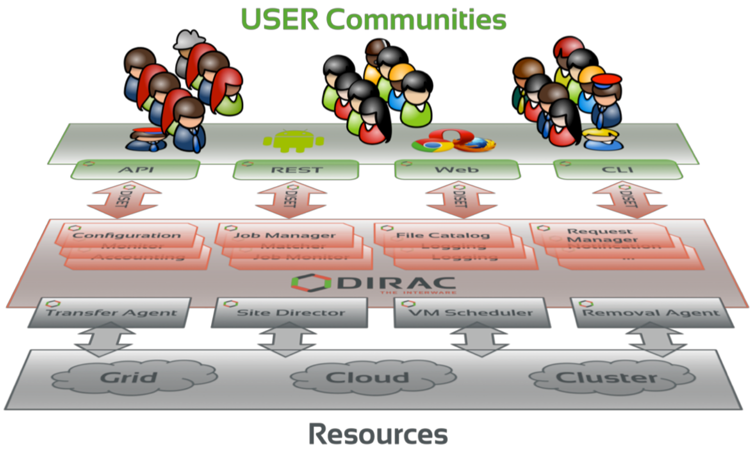




Performance evolution of simulation framework

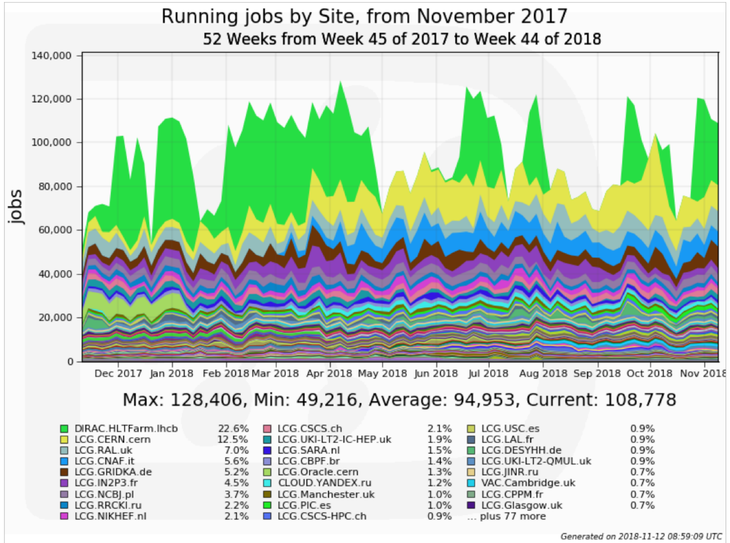
Distributed Computing – Interface

- DIRAC project provides an interface to grid resources
  - Governed by consortium of 7 partners CNRS (France), CERN (Switzerland), Barcelona (Spain), KEK (Japan), IHEP (China), PNNL (USA), Montpellier (France)
- LHCb uses DIRAC for all workload and data management operations
- Evolution of the framework needed in Run 3 to cope with increased load



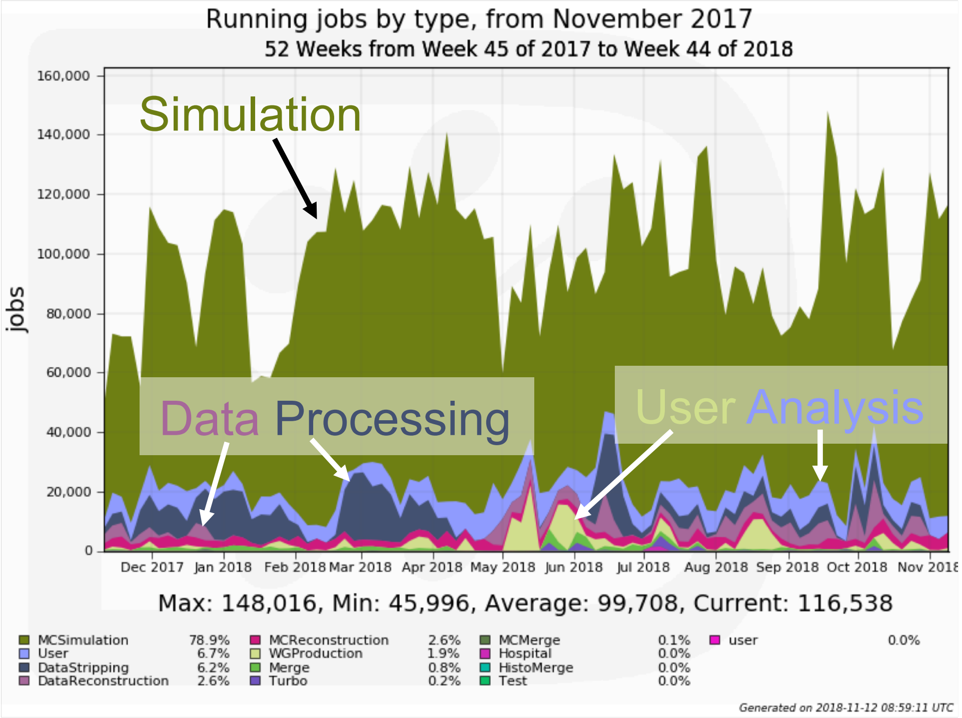
Distributed Computing – Resources

- Offline computing work executed on O(100) compute sites
  - Used for data processing, simulation and user analysis
- Resources provided via
  - Worldwide LHC Computing Grid
  - Unpledged resources (e.g. HPCs)
  - Experiment HLT farm when otherwise idle
- Peak usage at ~120k parallel jobs



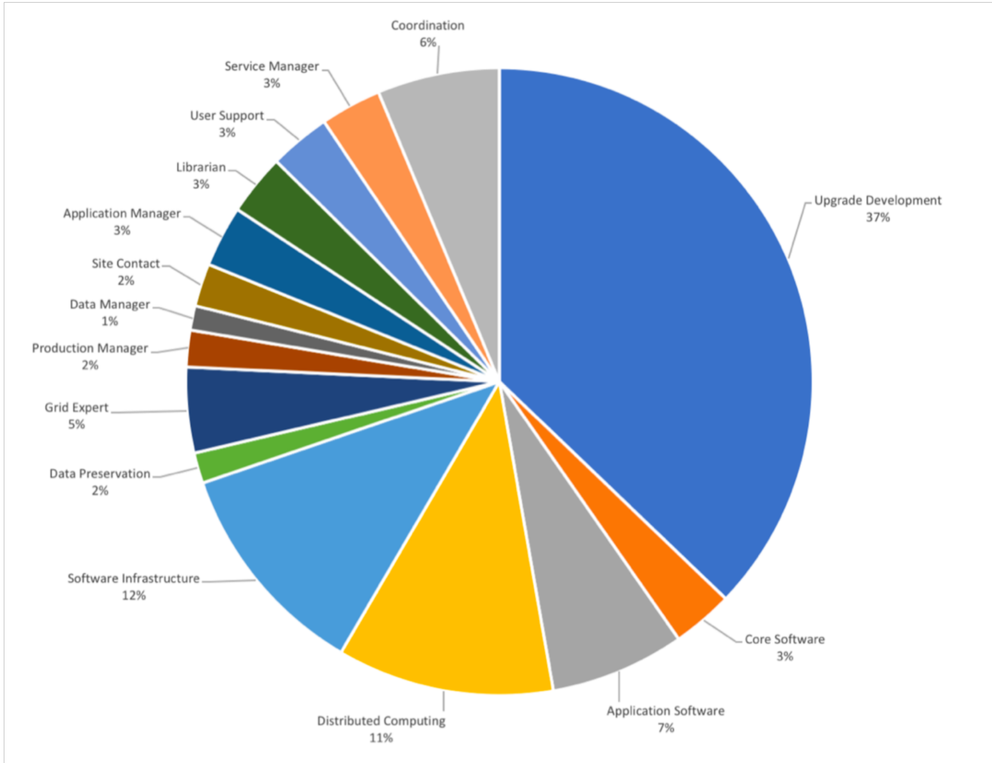
Work Spent on Distributed Computing Resources

- ~ 80 % of resources used for Monte Carlo simulation
- Data processing ~ 10 %
  - Expected to decrease during Run 3 b/c of reconstruction in the trigger
- User analysis ~ 10 %
  - Individual analysis jobs + centralized working group productions



Computing Project Person Power

- Computing project effort:
  - 31 FTEs from 35 institutes
  - ~ 1/3 of person power currently involved in upgrade work



HEP Software Foundation

- "Community White Paper" with focus on R&D in HEP during the coming years
  - Paper covers 14 areas of HEP software and computing
- Followup in HSF in 3 working groups
  - Groups are currently being setup on: Trigger & Reconstruction, Simulation, User Analysis
  - Aim to look for synergies and common R&D activities in the various areas
  - In addition to already existing working groups: PyHEP, Packaging, Training, Frameworks, …

arXiv:1712.06982v4 [physics.comp-ph] 8 Jul 2018

HSF-CWP-2017-01
December 15, 2017

A Roadmap for HEP Software and Computing R&D for the 2020s

HEP Software Foundation[1]

Abstract: Particle physics has an ambitious and broad experimental programme for the coming decades. This programme requires large investments in detector hardware, either to build new facilities and experiments, or to upgrade existing ones. Similarly, it requires commensurate investment in the R&D of software to acquire, manage, process, and analyse the shear amounts of data to be recorded. In planning for the HL-LHC in particular, it is critical that all of the collaborating stakeholders agree on the software goals and priorities, and that the efforts complement each other. In this spirit, this white paper describes the R&D activities required to prepare for this software upgrade.

[1] Authors are listed at the end of this report.

Summary

- Major software engineering effort for the upgrade towards LHC Run 3
  - Modernizing software framework which started development 17 years ago
  - Investing into faster simulation techniques to cope with offline CPU needs
- Use of industry provided standard tools whenever possible
- Collaboration for the software development efforts shared in many areas with other experiments
  - Core framework, simulation, distributed computing