

Software upgrade for HL-LHC

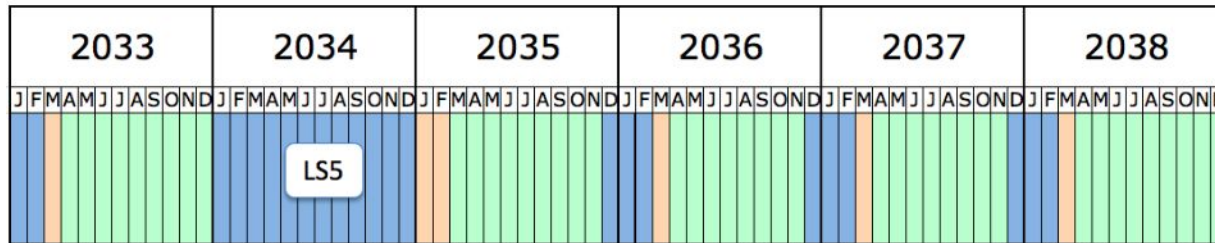
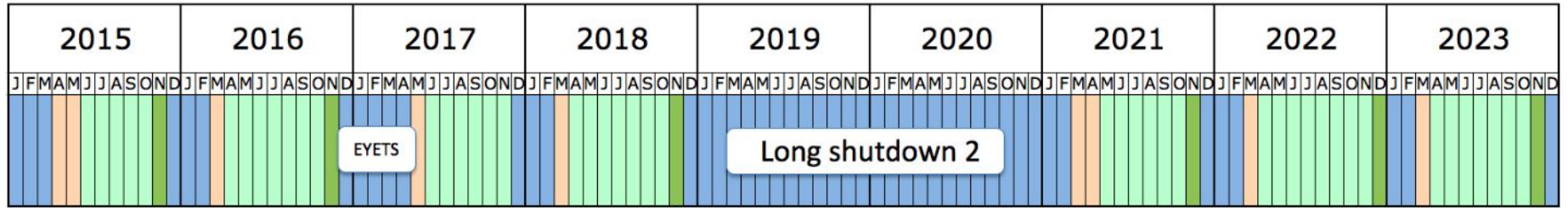
Preparation for an EU bid

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Tommaso Boccali (INFN Pisa, CMS)

22 Nov 2018

HL-LHC parameters. Big step up in Luminosity

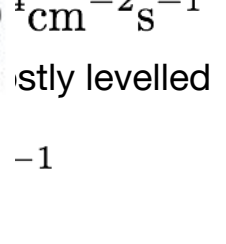
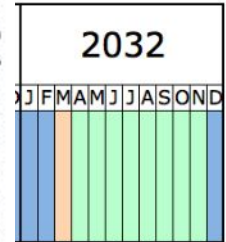
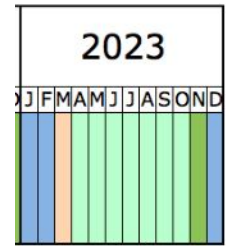
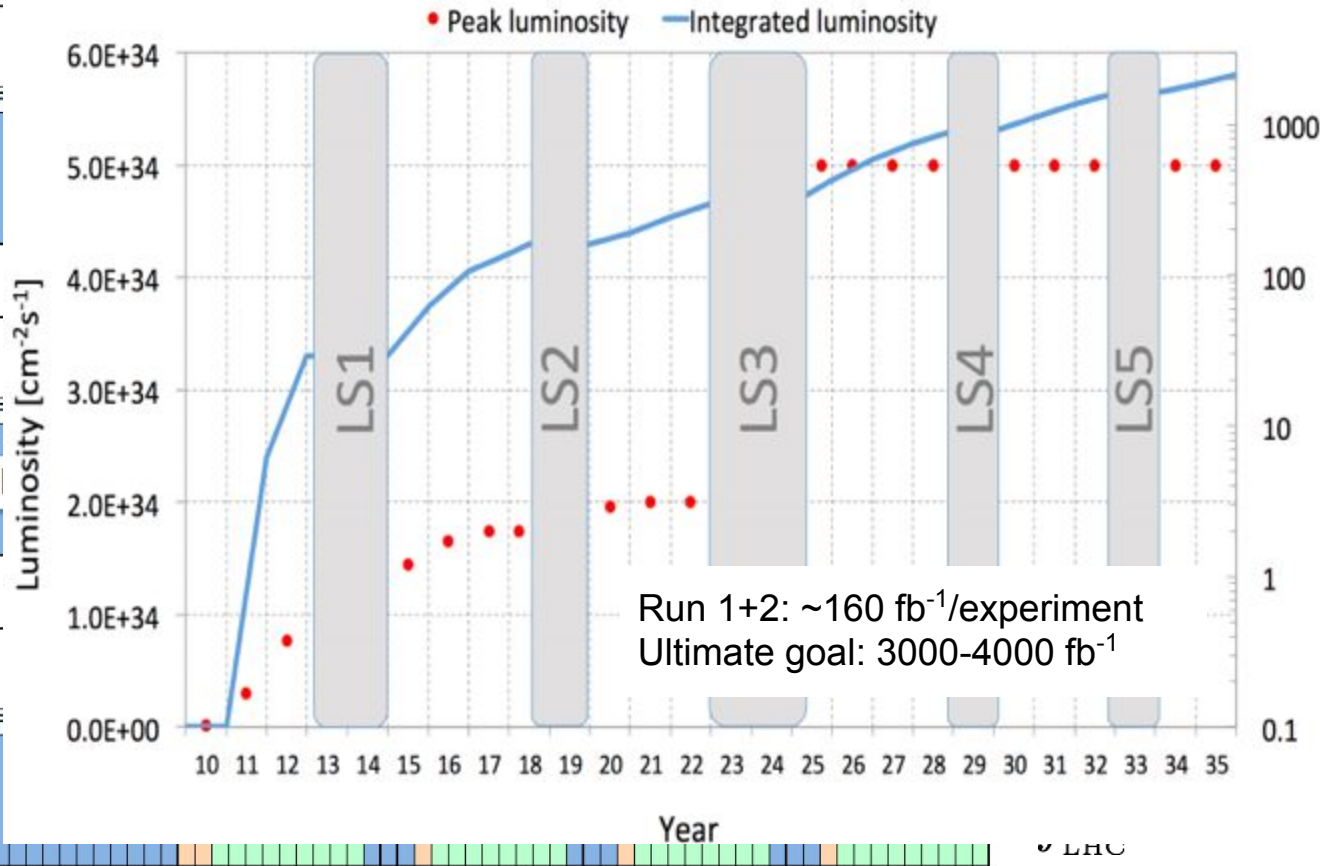
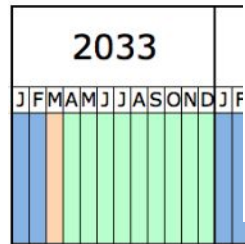
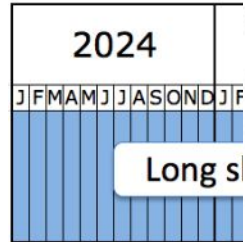
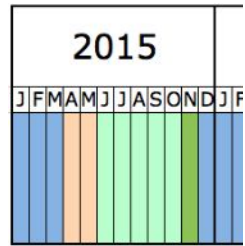


$$\mathcal{L} = 5\text{--}7.5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$$

$$\mu = 140\text{--}200 \text{ Mostly levelled}$$

$$\int_{\text{LHC}} \mathcal{L} = 3000 \text{ fb}^{-1}$$

HL-LHC parameters. We are just at the beginning...

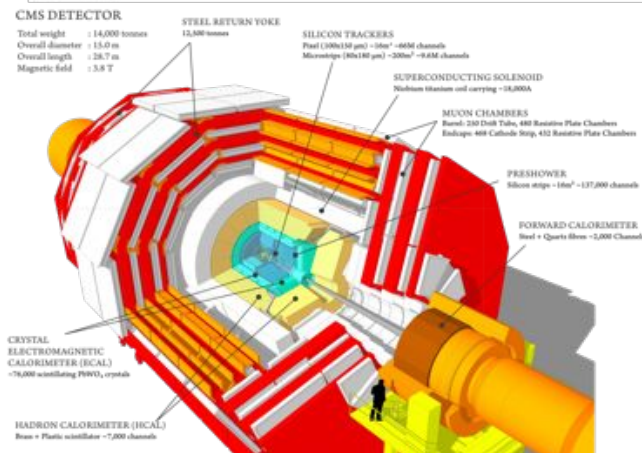
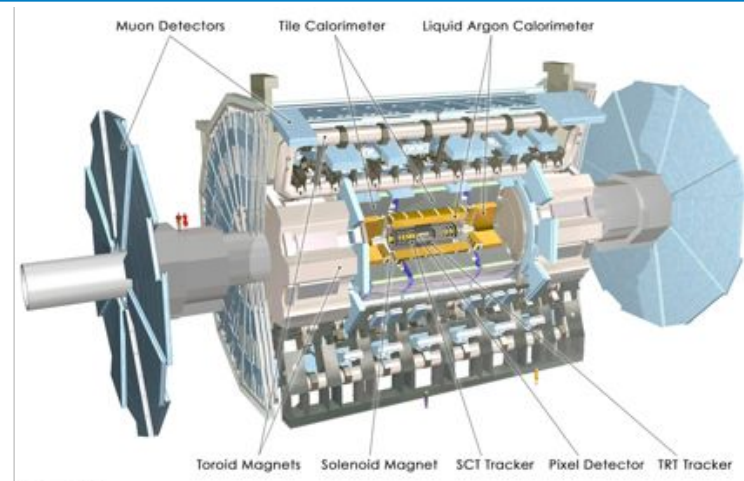


Integrated luminosity [fb^{-1}]

$1 \text{ cm}^{-2} \text{ s}^{-1}$
 stly levelled
 -1

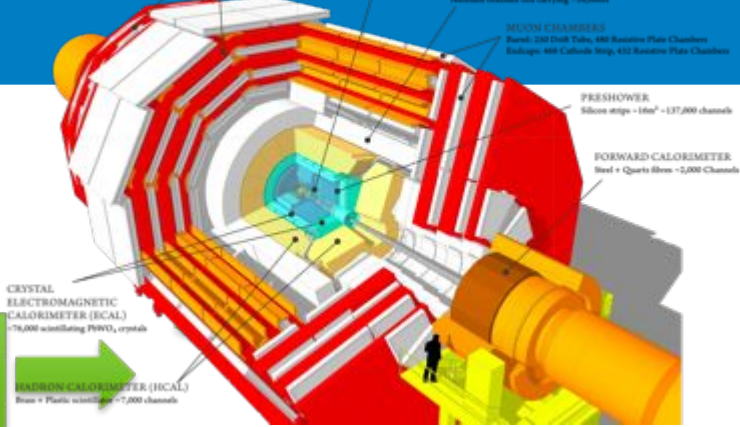
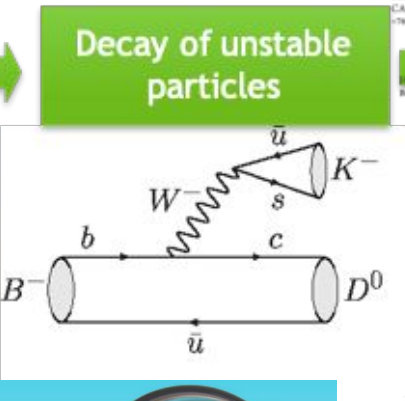
ATLAS and CMS

- Two general purpose detectors at the LHC
 - Largely different design choices
 - Comparable Physics performance
 - Charged particle reconstruction leads to tracking systems with 10-100M channels
 - Calorimeters for electrons/photons and jets
 - Large muon spectrometers defining the final detector envelopes
 - Trigger rates 1-2 kHz
- Towards HL-LHC
 - Major detector upgrade (~250 MCHF/detector) (even more readout channels)
 - Increase in event complexity (average number of collisions $\langle\mu\rangle$ 35 \rightarrow 200)
 - Upgrade in trigger system. Rate up to 10kHz
- **More data, bigger and more complex events**



Real data processing

Reality



Detector electronics

Trigger (selection)

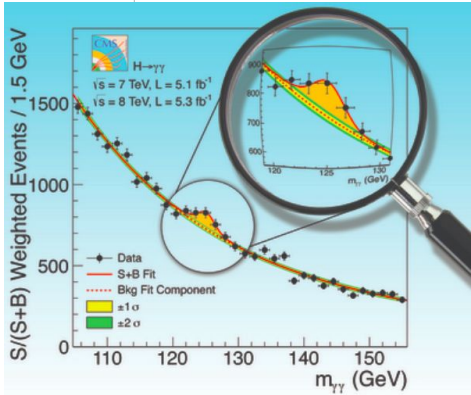
Reconstruction

Analysis

SW online

SW

SW



Simulation -- All Software!

Theoretical model

Simulation of decays of unstable particles

Simulation of interactions particle-detector



$$L_{QCD} = \sum_f \bar{\psi}_f (i\gamma_\nu D^\nu - m_f) \psi_f - \frac{1}{2} Tr [\bar{G}_\nu G^\nu]$$

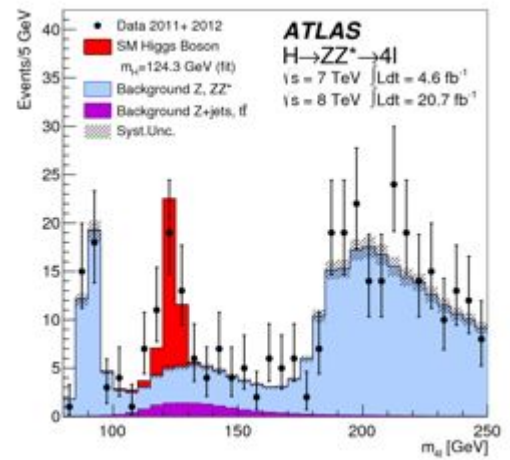


Simulation of detector electronics

Trigger Simulation

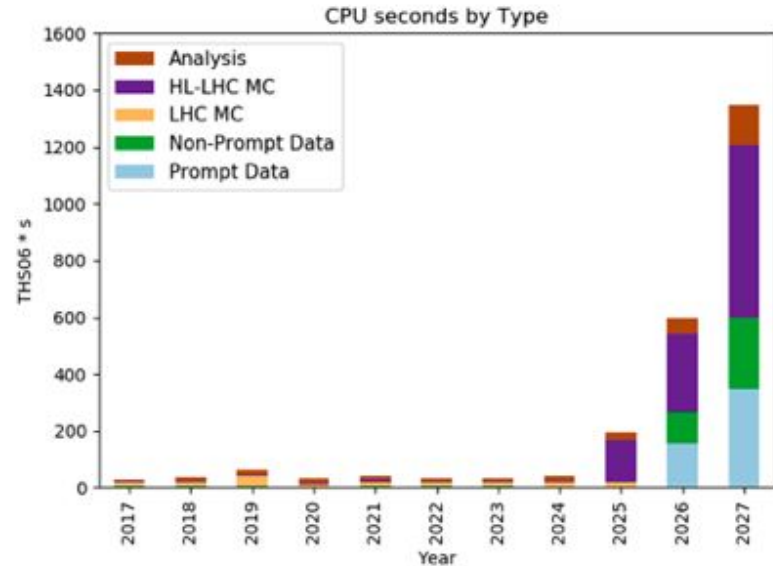
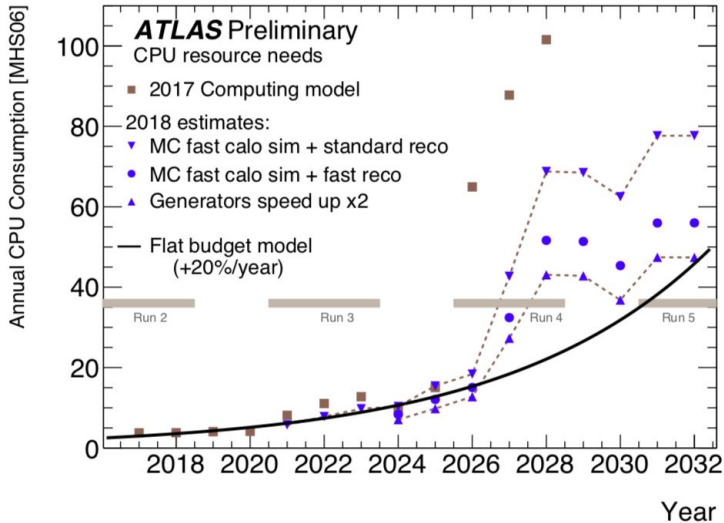
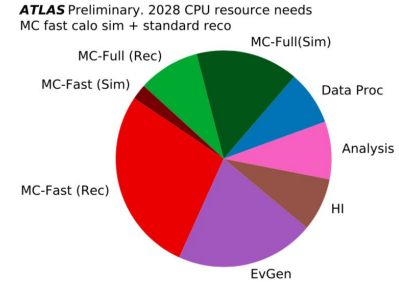
Reconstruction

Analysis



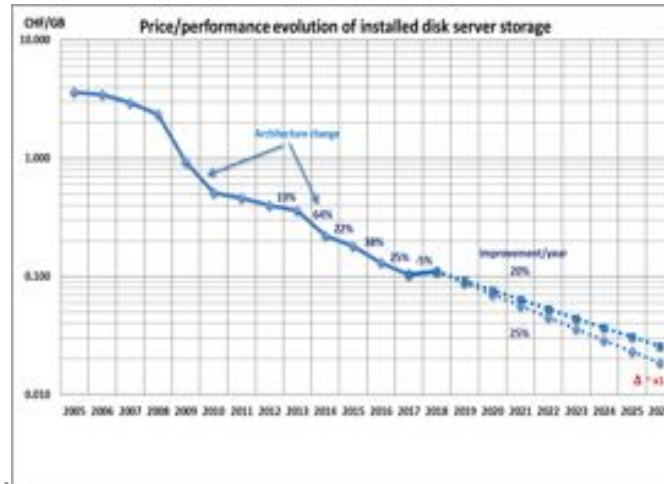
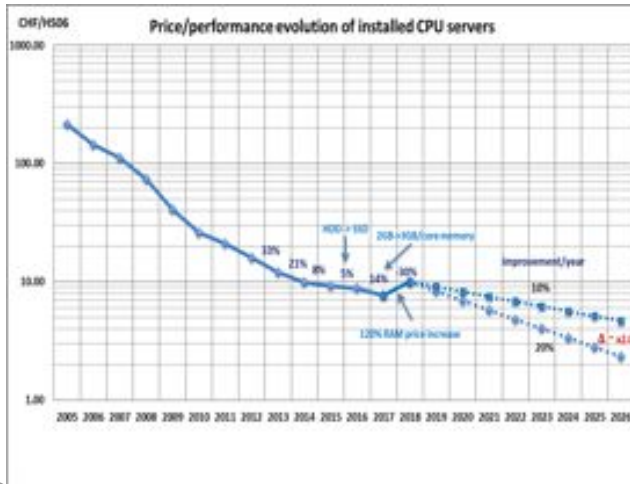
Latest resource estimates for ATLAS and CMS

- CPU estimates ~ 3-5 above “flat budget”
 - Some of it recoverable with loss of fidelity
 - Dominated by MC simulation
- Disk estimates also ~3-5x above flat budget
 - ~3EB/experiment
- Tape estimates: ~10 EB/experiment
- Change analysis model? Less MC? **Impact on Physics??**



Flat budget?

- Technology evolution will help up to a certain extent
 - Can not predict the future
 - General trends of CHF/HS06 and CHF/GB compatible with Moore law @ +15-20%/y
 - Future of tape (or other cold storage) technology?



(B. Panzer, CERN)

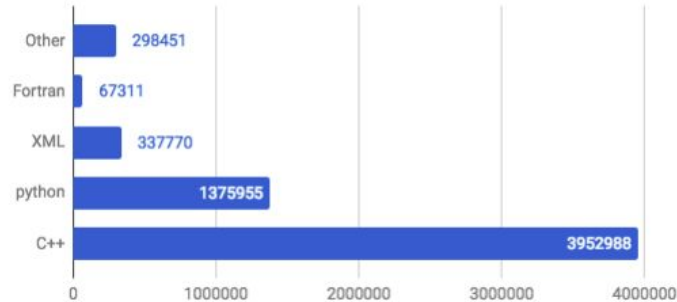
Computing hardware trends and LHC Software

ATLAS Software evolution:

Athena → AthenaMP → AthenaMT → ???

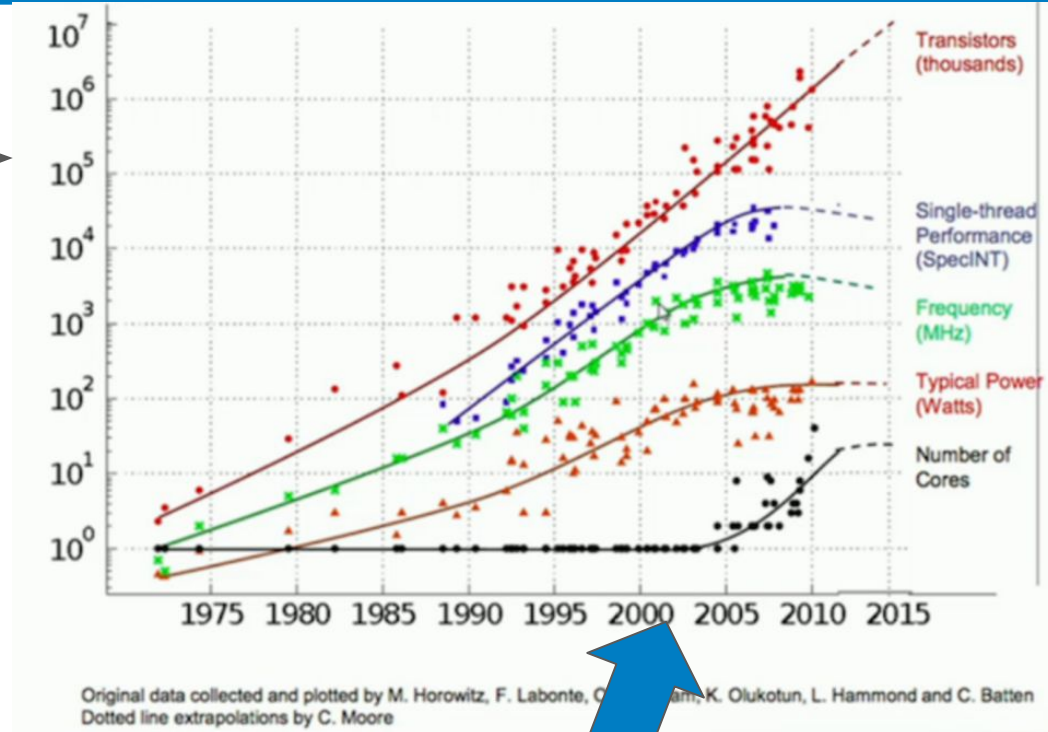
Run 1 Run 2 Run 3 Run 4
2010 2015 2020 2025
(Driven by LHC running periods)

ATLAS Software. Number of lines of code



R&D directed towards HL-LHC:

- Accelerators (GPUs) appearing as a major component of new machines (riding the hardware trend)
- Heterogeneous computing
- Finer granularity workflows



Initial SW development

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

HEP Software Foundation¹

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 sheer 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.



- Community white paper available on [arXiv](#)
- Summary on the [CERN Courier](#)
- 13 topical sections, 70 pages, 300 authors from 120 institutes
 - Separate in-depth papers on each topic
- 1 section on training and careers
- Workshop last April, next one in March 19

What can we do?

- Community effort to upgrade the LHC (and HEP) software
 - Complexity has increased over the years
 - Software projects are now larger than many subsystems (in terms of personpower)
 - Software is mission critical for the experiments
 - Initiative started from ATLAS and CMS computing coordination. We want to be inclusive with LHC experiments and beyond
- Large push in the US for and from the HSF process
 - Large grant awarded by NSF. 25M\$ over 5 years → IRIS-HEP
- We need to get organised in Europe
 - Some initiatives at the country level
 - From WLCG Management board minutes: <<stimulate more investment from the European Commission in the area of software, which presently is largely missing from its program of work>>
 - ITN bid as an initial step towards raising awareness in Europe. And of course work with our American colleagues
- Training the next generation
 - ITN-ETN bid also a community building exercise
 - Emphasis on training, to benefit the whole community
- Thanks to Borut for organising and coordinating this!