CSCS
Centro Svizzero di Calcolo Scientifico
Swiss National Supercomputing Centre

ETHzürich

Commissioning CERN Tier-0 reconstruction workloads on Piz Daint at CSCS

HEPiX Autumn/Fall 2018 – Barcelona

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Motivation

- **CSCS HPC resources are integrated with WLCG as part of the CSCS-LCG2 site**

- **CERN and CSCS have planned R&D projects for a deeper integration of the CSCS Computing resources with the LHC computing environment**
  (*in view of the challenges posed by the foreseen scale of the HL-LCH computing needs*)
- **"*Development and testing of an infrastructure for accessing compute and storage resources in an HPC Centre*"**

- **First use case proposed by ATLAS and CMS to CSCS:**
  - ***Implementation of an environment supporting Tier-0 spill-over to Piz Daint***
    - **Goals**
      - Elastic provisioning of Tier-0 prompt reconstruction of the experiment RAW data
      - Support steady and on-demand spill-over / support computational peaks
      - Evaluate solutions and interaction in preparation for Run 3 (in 2021+)

Background

- **The Swiss HEP computing community and CSCS have started working on the HPC integration with the LHC experiment Tier-2 facilities in 2014**

  - **ATLAS Geant4 simulation**
    – Ran in production for 6 months on a Cray XK7
    – Integrated by means of a modified ARC CE, submitting remotely from Bern to CSCS

  - **LHConCray project (ATLAS, CMS, LHCb)**
    – Ran for about 2 years in 2016-17
    – Aimed at integrating Piz Daint with the LHC experiment frameworks
    – Targeted all experiment workflows (including user analysis)
    – Went in production with 1.6k cores in 2017

  - **WLCG Tier-2 facilities migrated to Piz Daint**
    – Decision taken at the end of 2017
    – >4k cores by April 2018,>10k by April 2019

Challenges

- **HPC is awesome**
  - Powerful machines featuring top of the range technologies
  - Piz Daint at CSCS: https://www.cscs.ch/computers/piz-daint/ (see M. Passerini talk)
  - Benefits from economy of scales both in procurement and operational costs

Challenges

- **HPC is awesome**
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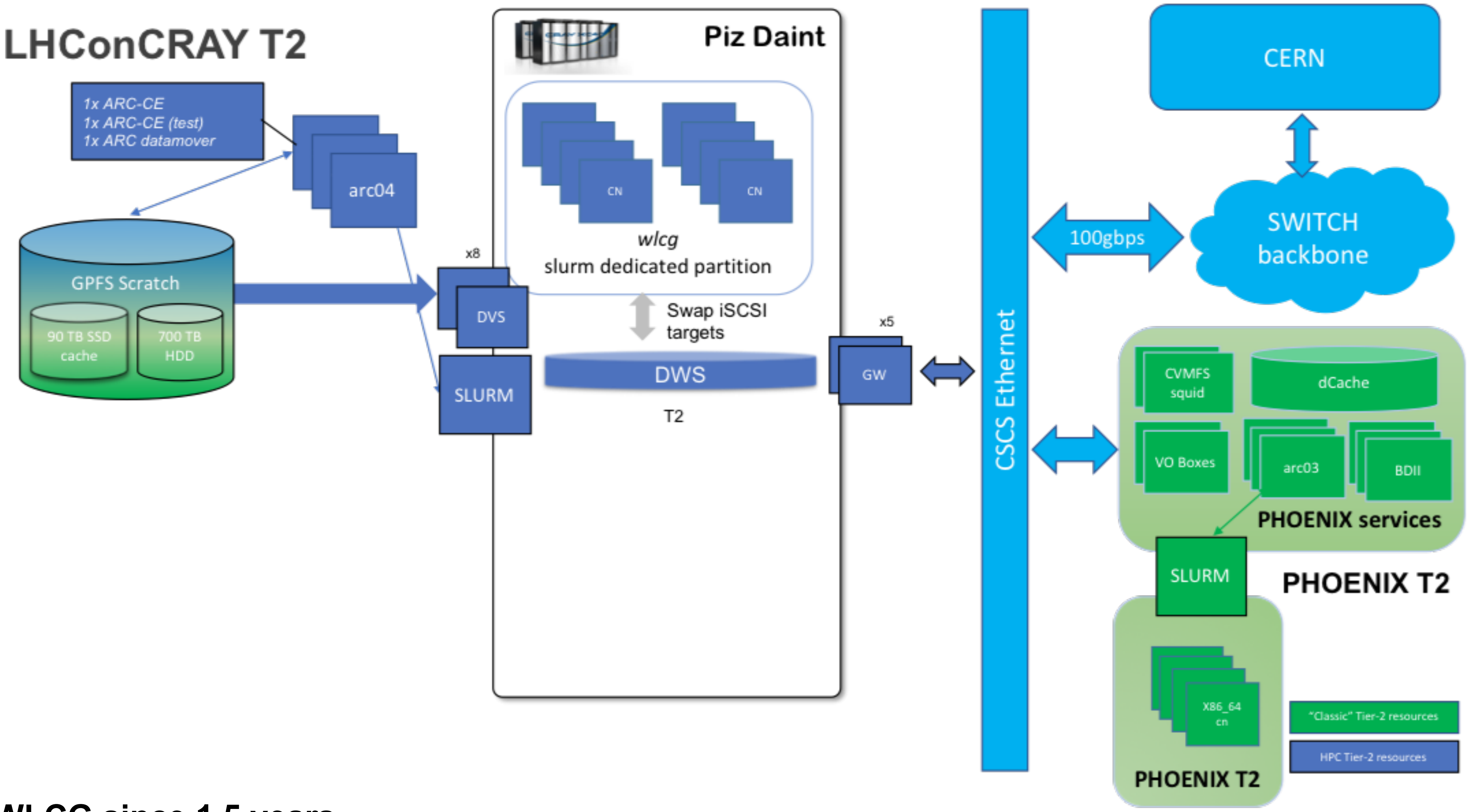
- **HPC is awkward** => *for HEP*
  - Technologies and OS are optimized to accelerate parallel software
  - Many expected linux tools missing
  - Diskless nodes with 1 GB/core, some with 2 GB/core, no swap
  - Network usage and I/O patterns not typical compared to standard HPC workflows

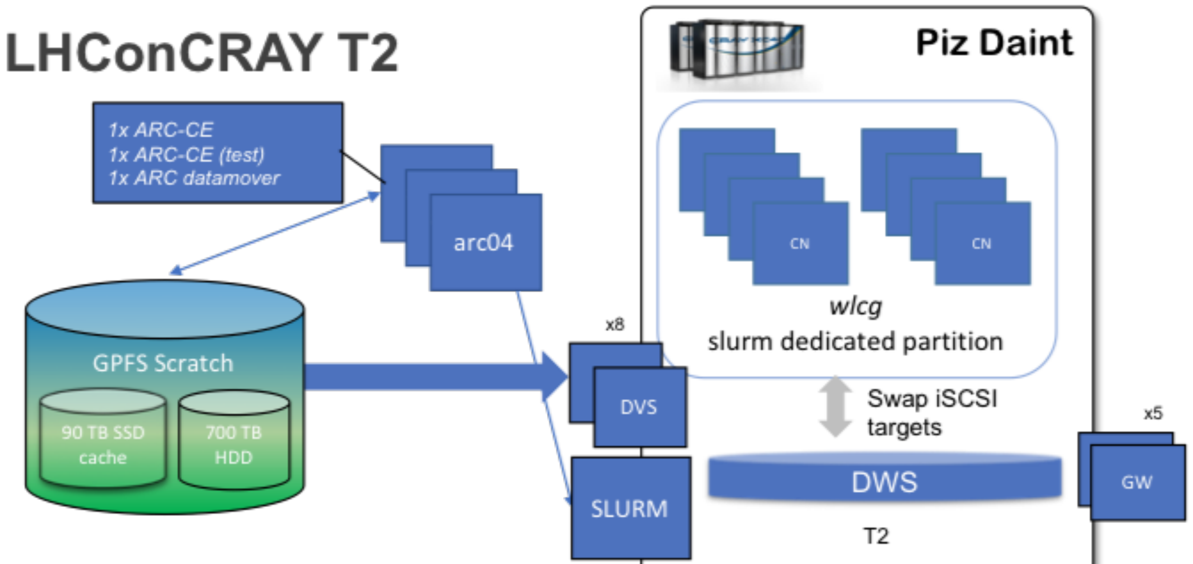
- **Container technology has gone a long way to make them look more like traditional linux systems**
  - But could not solve all challenges related to the integration with the complex LHC experiment frameworks

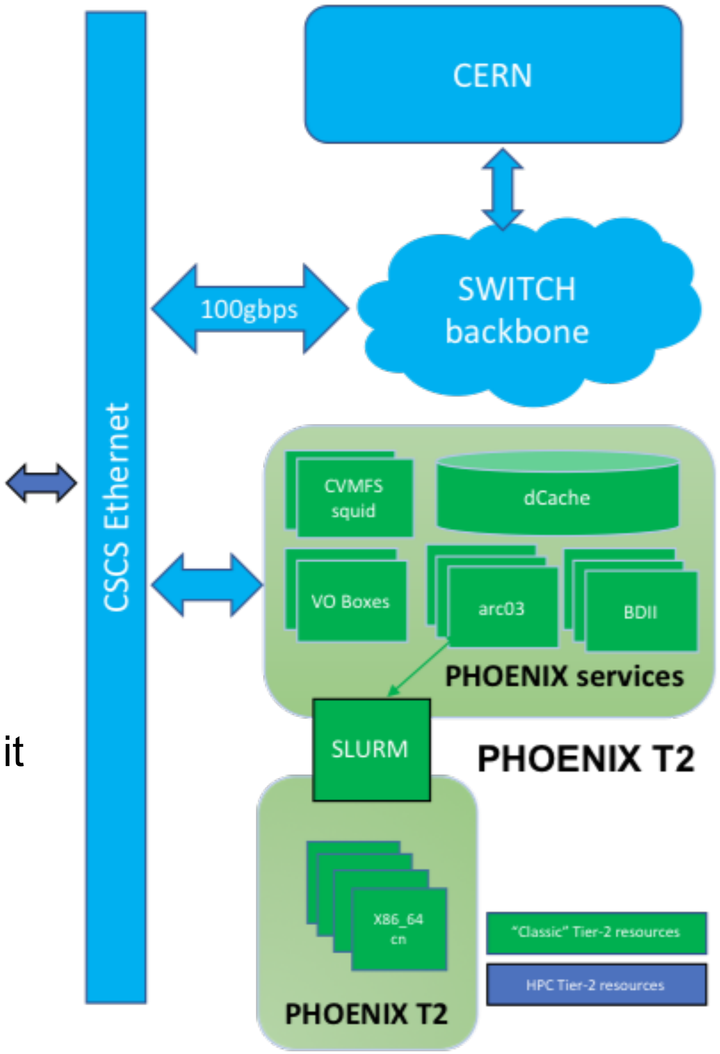
Tier-2 facility integration



- **In production in WLCG since 1.5 years**

Tier-2 facility integration





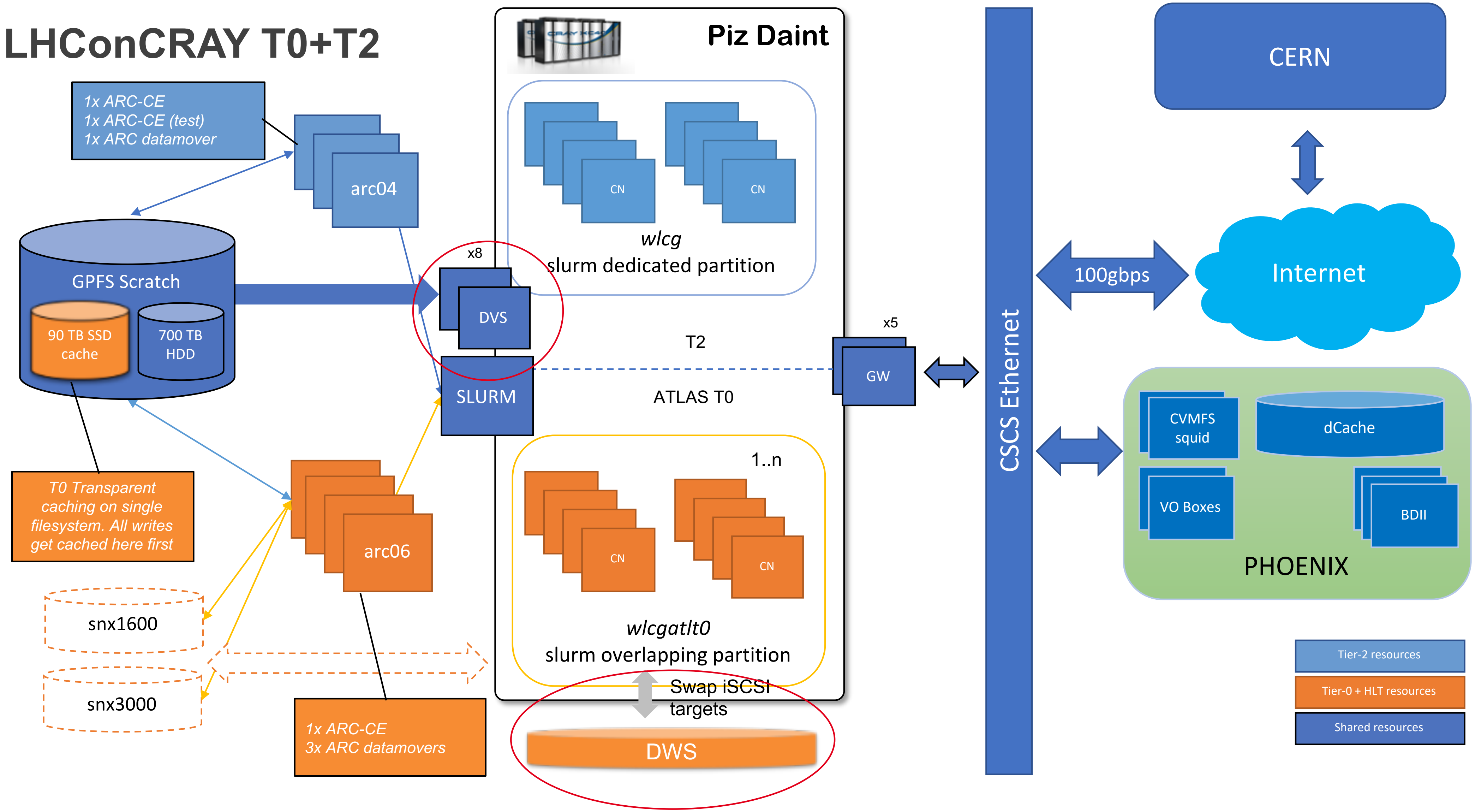
- Jobs run in Docker containers using Shifter, or singularity (CMS)
- Images (full WNs) on the Cray Sonexion 1600/3000 Lustre FS
- 68 cores, 2GB/core, memory is not consumable in SLURM. Enforce 6GB/core limit
- CVMFS tiered cache (6GB in RAM, pre-loaded on GPFS)
- DVS (Cray Data Virtualisation Service) exposing a dedicated GPFS via 40GbE links
- DWS for swap and /tmp (WiP)
- **In production in WLCG since 1.5 years**

From Tier-2 to Tier-0 integration

Tier-0 spillover integration

- **Extension of proven production Tier-2 design**
  - Dedicated ARC servers and data-stagers
  - GPFS as shared file system and ARC cache, with a dedicated SSD cache layer in front of it
- **No reserved resources, no node draining**
  - ARC submits to a dedicated SLURM partition with up to 150 nodes (~10k cores) that overlaps with standard HPC jobs
  - Jobs from ARC get higher priority, taking over nodes as they become free (no idle resources)
  - Nodes re-configured on the fly, CVMFS mounted on demand, when needed
  - Can run multi-core or single-core jobs (up to 128GB RAM/64 cores per node).*Swap available*.
  - Allows for both Tier-0 *burst* and *steady* spillover to be processed without operational differences (*in principle*)
- **WLCG environment isolation**
  - Tier-2 jobs continue running (*on dedicated nodes*) along Tier-0 jobs
- **Excellent connectivity**
  - 4x40gbps between Daint and dCache, 100 gbps link to Internet/CERN border

Tier-0 spillover integration



Results

ATLAS workloads validation

- Dedicated PanDA queue, dedicated storage token on dCache
- Input RAW data copied asynchronously to the CSCS dCache, staged in via ARC
- Basics validation with HammerCloud tests (lightweight MC simulation jobs)

- **RAW data reconstruction on *physics_BphysLS stream*** O(10%) of *physics_Main*
  - Run continuously on O(20) nodes (~1300 cores) - 0.7 TB input (710k events)
  - ***Considerable tuning needed***: OOM (solved by adding swap), job corecount, cgroups and slurm config, CVMFS in-RAM, I/O (doubled the nr of DVS nodes), nr. of input events per job, PanDA brokerage, etc.

	Turnaround time	CPU/WC efficiency	CPU time/event	Wall time/event
Piz Daint	13h	32% (32-core)	20.8	78.4
Grid	18h (90%), 46h (100%)	53% (various)	13.6	33.5

ATLAS workloads validation

- **RAW data reconstruction on *physics_Main*** (input 35 TB, 32M events)
  - On demand runs on O(150) nodes (~10000 cores)
  - Memory needs slightly higher, swap needed, but failed to instantiate (Cray DWS bug)
  - Tried tuning corecount, could not pack the nodes
  - 3x16-core jobs performed better, but too many job transient files => DVS could not cope (another Cray bug)
  - Settled on 2x16-core jobs per node, run steadily, but <u>large waste of resources</u>

	Jobs per node	CPU/WC efficiency	Turnaround time	CPU time/event	Wall time/event
Piz Daint	2x32 core	27%			
Piz Daint	1x56 core	23% (effective 11%)			
Piz Daint	3x16 core	42% (effective 32%)			
Piz Daint	2x16 core	62% (effective 31%)	7d 7h	22.4	55.0
Grid	various	62%	5d 9h	18.2	31.6

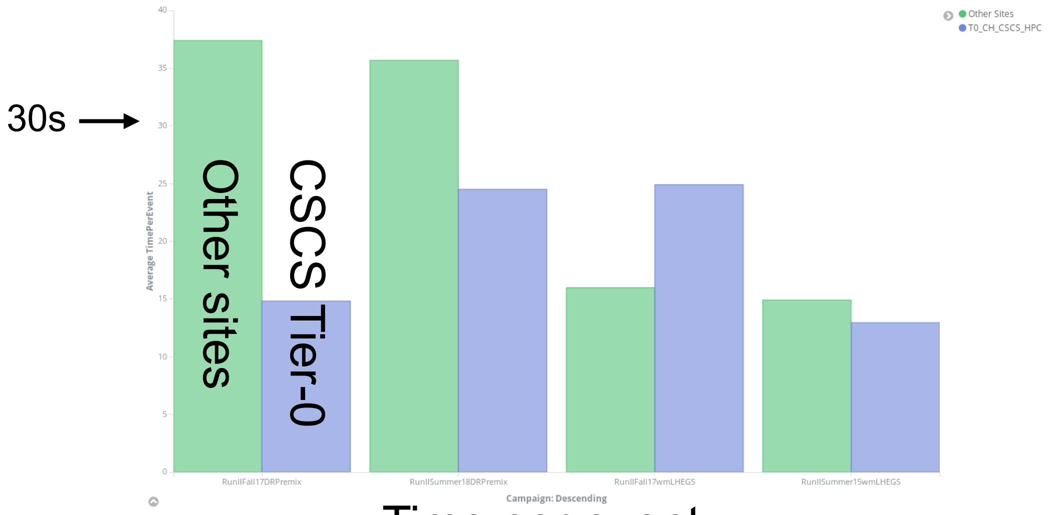
ATLAS conclusions

- **We have (~)succeeded in validating Piz Daint for ATLAS Tier-0 spill-over**
  - Validated for *Physics_BphysLS* stream
    - Higher WC/event due to high corecount used (serial portions of the workload)
  - Understood the current limitation for *Physics_Main* (Cray bugs)
    - Still not too far from the target
  - This has been a *very* laborious exercise that has involved several experts on both sides
  - Not surprisingly: we aimed at fitting a workload to a system that *does not entirely fulfil the hardware requirements*, so a lot of tuning needed be put in place
- **We consider validating Piz Daint for Tier-0 workloads an outstanding achievement**

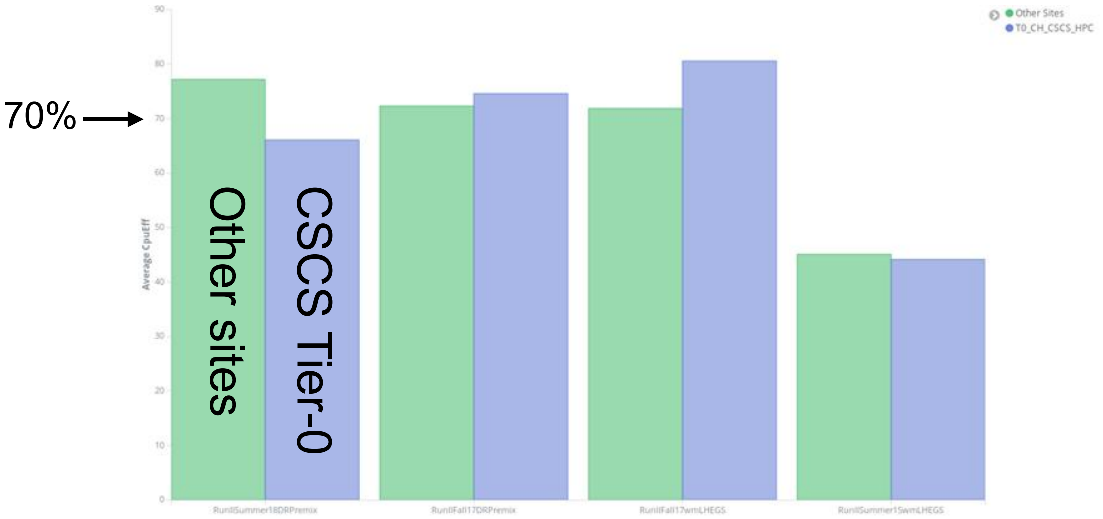
CMS health check

- Hammercloud commissioning – first check things are right
  - Initial issues with CVMFS stability and low efficiency, solved with cgroups configuration

- Production workflows – check the “site” can do regular Tier-2 prod
  - Few hundred cores, very low error rates, good time/event, good efficiency



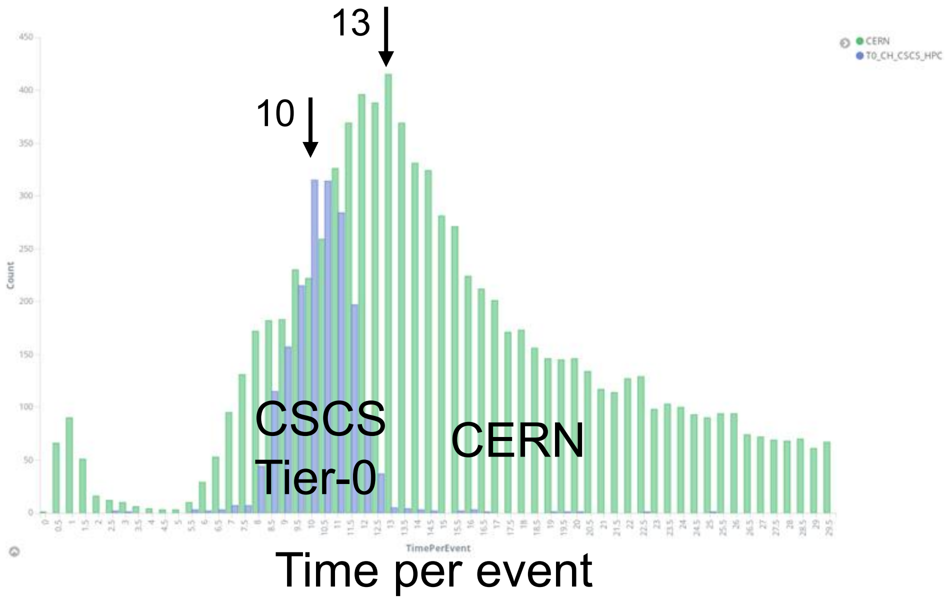
Time per event

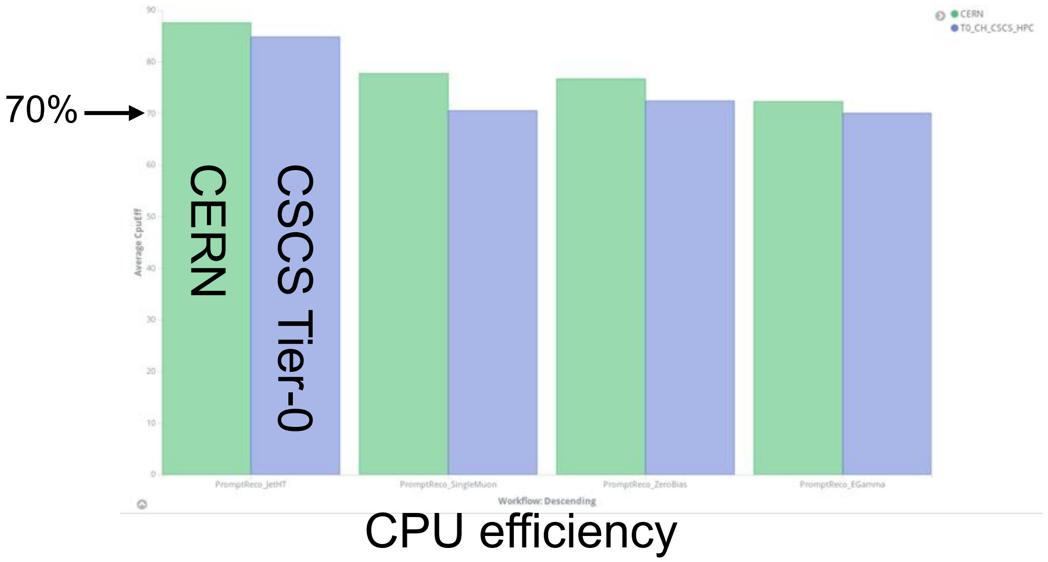


CPU efficiency

CMS Tier-0 replay test

- ~2000 cores allocated at CSCS
  - Reconstruction jobs: processing 20% of a typical run with 8-thread jobs
- All data hosted at EOS @ CERN (local CSCS grid SE not used)
  - 13 TB input data read, 17 TB output data produced
  - Input read directly from CERN through the network
  - Output written to local scratch, then shipped to EOS at the end of the job





CMS conclusions

- Data to be taken with care, since the jobs running on both sites were not the same (still Tier-0 Reco)
- CPU efficiency is very much comparable for both sites
  - Slightly lower for CSCS, which can be explained by remote data read/write
- Time per event is difficult to compare
  - Still no evidence of significant performance difference
- We are probably ready to go into production.
  - We would need a longer sustained test, but we have no real evidence of huge problems

Lessons Learned

- We have shown that LHC experiments can use a general purpose HPC system transparently for all their workflows
  - Integration efforts were costly, first time Tier-0 workloads go to a HPC system
  - Plenty of complexities, but no major technical showstopper
- This required the centre to relax some policies
  - But nothing major against design decisions or PRACE level policies
- We hope some HEP requirements will drive the design of the next generation machine(s)

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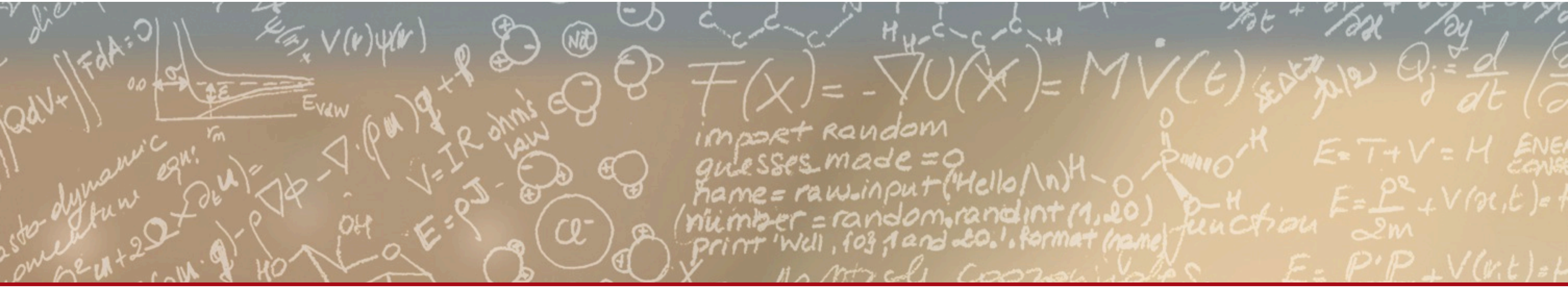

Thank you for your attention.