Computing and Data Management – KET perspective –

- Overview

- Data management in HEP

- Opendata & FAIR

- ErUM-Data

Overview

- HEP computing clearly dominated by LHC collaborations, though of course substantial other activities

  - ongoing experiments (Belle II, ..)

  - plans for future colliders (FCCee, ILC/CLIC, …) w/ Key4hep-Ecosystem

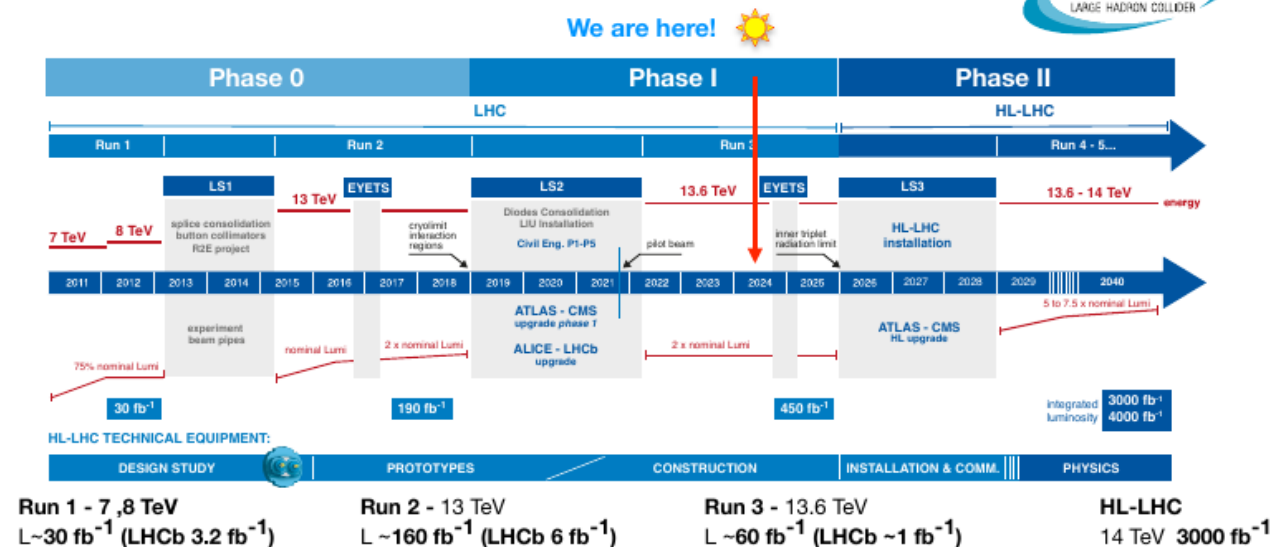 - many legacy experiments (Tevatron, Hera, LEP, …)

  - … and theory groups.

- LHC

  - Planned until 2041 – just half-way today

  - 85% of data yet to come...

Operations in 3 phases
- **15 years** of operations (since 2009): Phase 0 and Phase I
- **15 years** of future High Luminosity operations: Phase II

We are here!

Run 1 - 7 ,8 TeV
L ~30 fb⁻¹ (LHCb 3.2 fb⁻¹)

Run 2 - 13 TeV
L ~160 fb⁻¹ (LHCb 6 fb⁻¹)

Run 3 - 13.6 TeV
L ~60 fb⁻¹ (LHCb ~1 fb⁻¹)

HL-LHC
14 TeV 3000 fb⁻¹
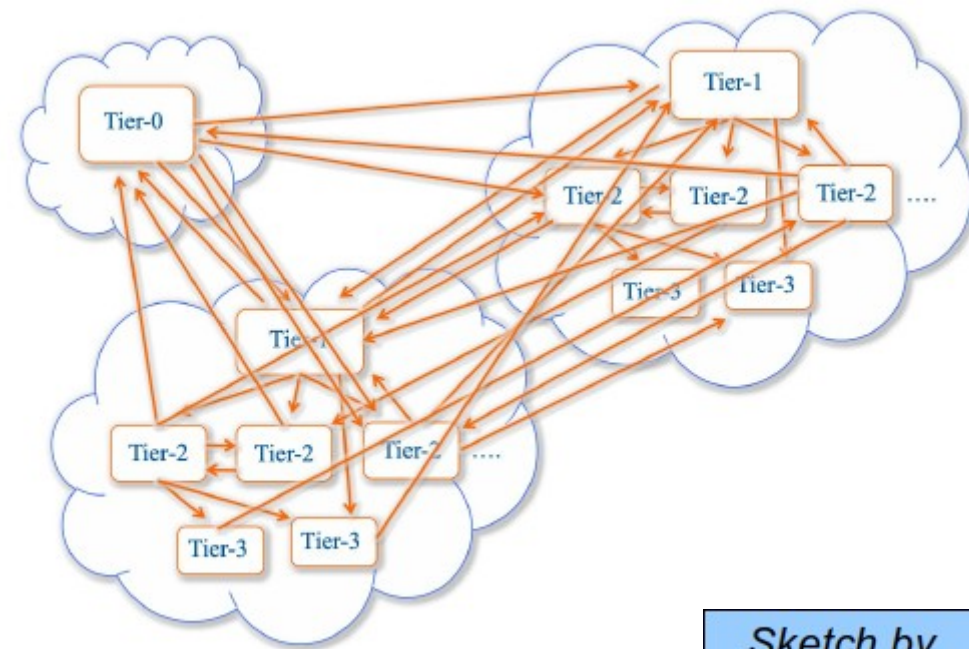
LHC computing evolution

- Started with rather strict and hierarchical distributed structure (Tier-0/1/2, Monarc model)

- Strict reqts on setup, services, Grid middleware, OS environment, ...

Sketch by D. South

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  - Better networks

  - Containers, cvmfs
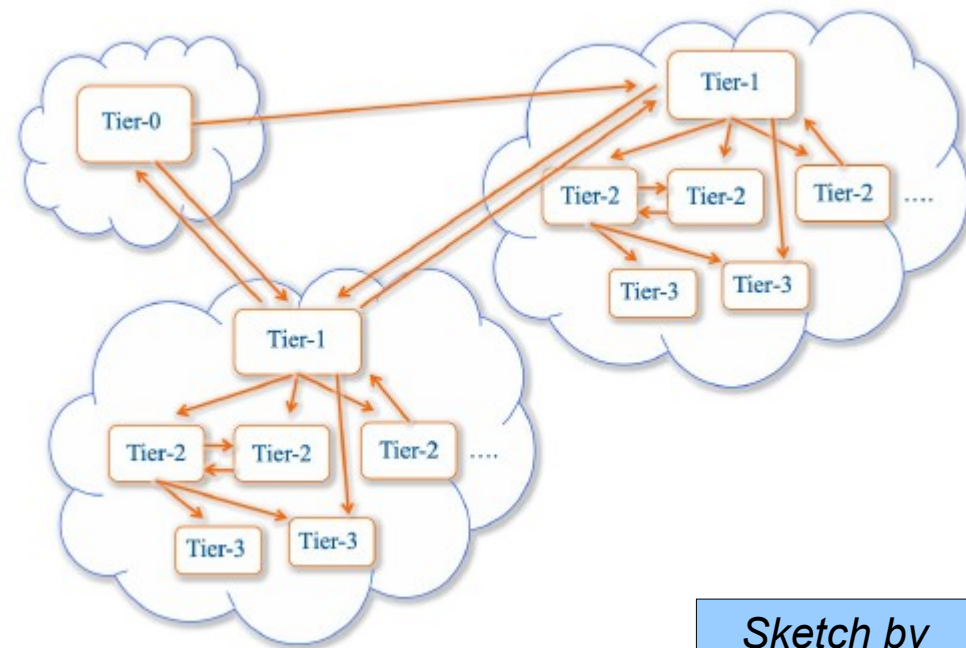
  - Opportunistic resources

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- Today rather mixed setup using also

  - HPCs (NHR, EuroHPC, …)

  - Cache-only sites

 - Clouds, Boinc, ...

Sketch by D. South
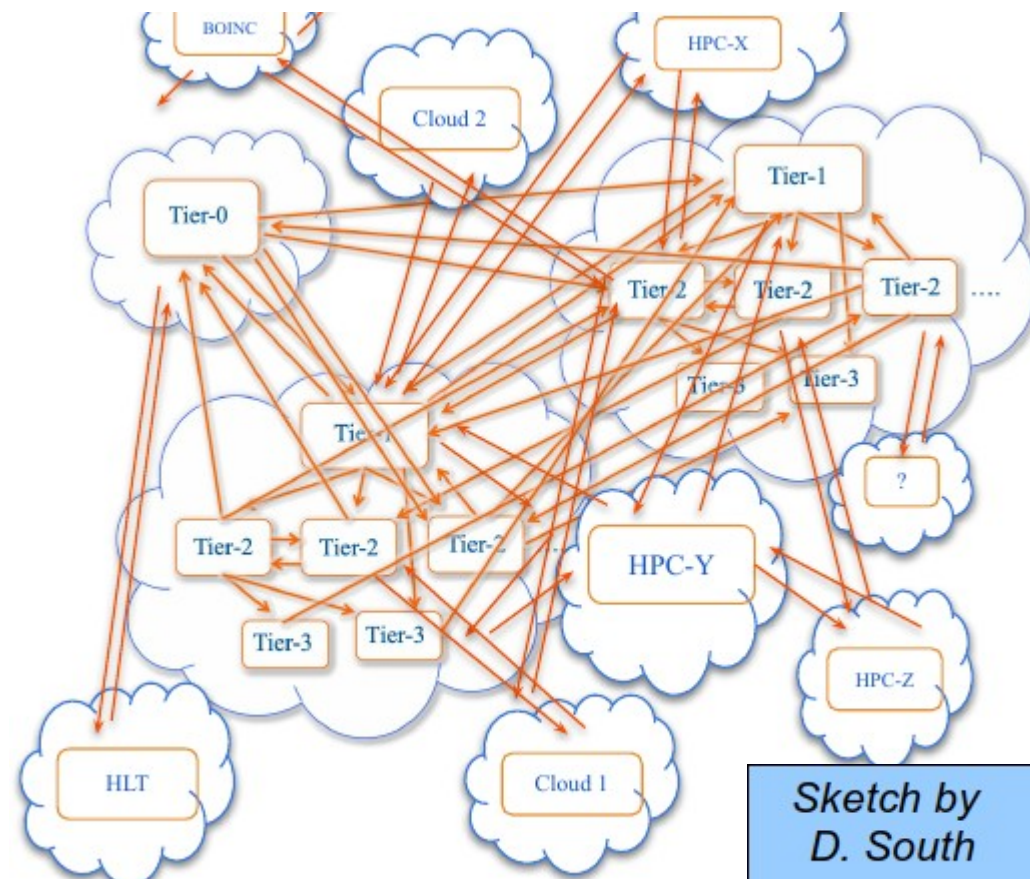
Ongoing Transition to NHR/HGF for DE LHC Computing (ATLAS+CMS)

- Tier-2s at universities (AC, FR, Goe, M, Wup) will be (largely) phased out

  - around 30% of DE ATLAS&CMS computing capacity

- Use CPU resources at NHR centres to replace Uni-T2 CPUs

  - Currently NHR sites: Horeka/KIT, Emmy/Goe, Claix/AC

    - all co-located at universities with active T1/2 site and HEP group

- Storage to be concentrated at large HGF data centers (GridKa@KIT and Desy-HH)

- transition phase from 2025 to ~2030

- Migration on track but many challenges to get all required services setup and fully operational

  - specific setup/restrictions at each site
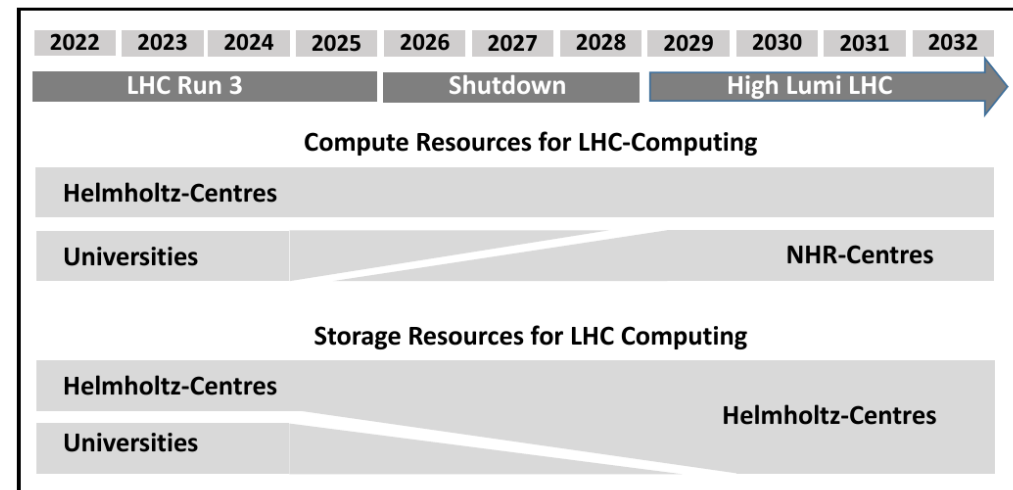
Data Management in HEP – RUCIO

- Rucio evolved into 'de-facto' HEP standard for DDM

- Used by ATLAS, CMS, Belle II

  - and many more groups from other communities

- Supports many protocols

  - webdav, xrootd, S3, gridftp, …

- And storage technologies

  - dCache, CTA, EOS, Xroot, …

- Evolution from community-specific protocols and formats (SRM, gridftp, dcap, root) to common standards (webdav/http, S3, hd5, parquet, ...)
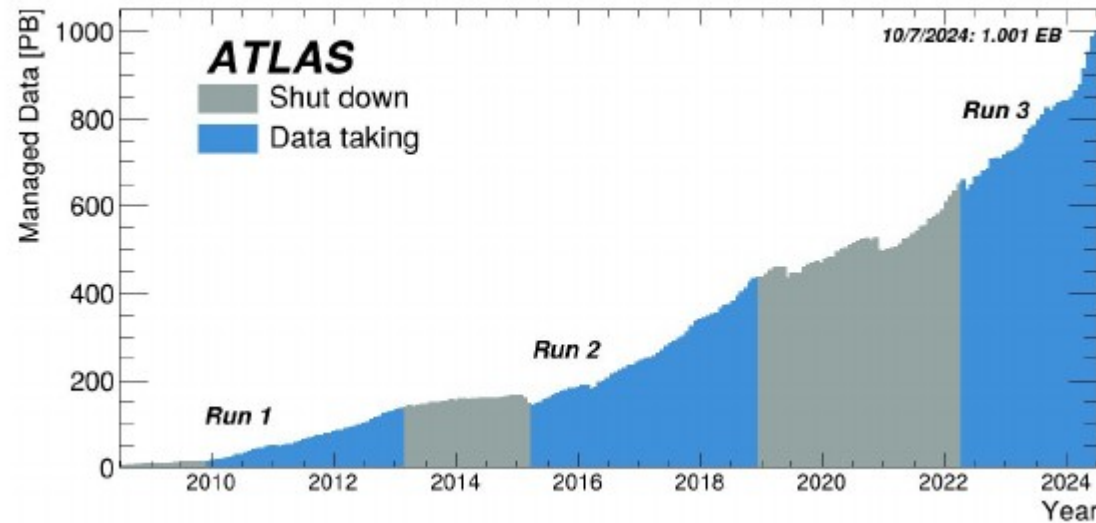
DDM challenge HL-LHC

- Massive increase of data-rate for HL-LHC poses substantial challenge

- Many ongoing efforts to reduce data-volume & event-size, adapt analysis model, etc.

- **'data-carousel'** is interesting approach to have larger share of data on tape

  - Factor 5-10 cheaper wrt size and power consumption

  - But random access of O(1 GB) files on O(20 TB) tape kills tape service

  - '**Smart writing** and **smart reading**' absolutely critical

  - Requires integrated&optimized **Tape+DDM+WFMS** systems
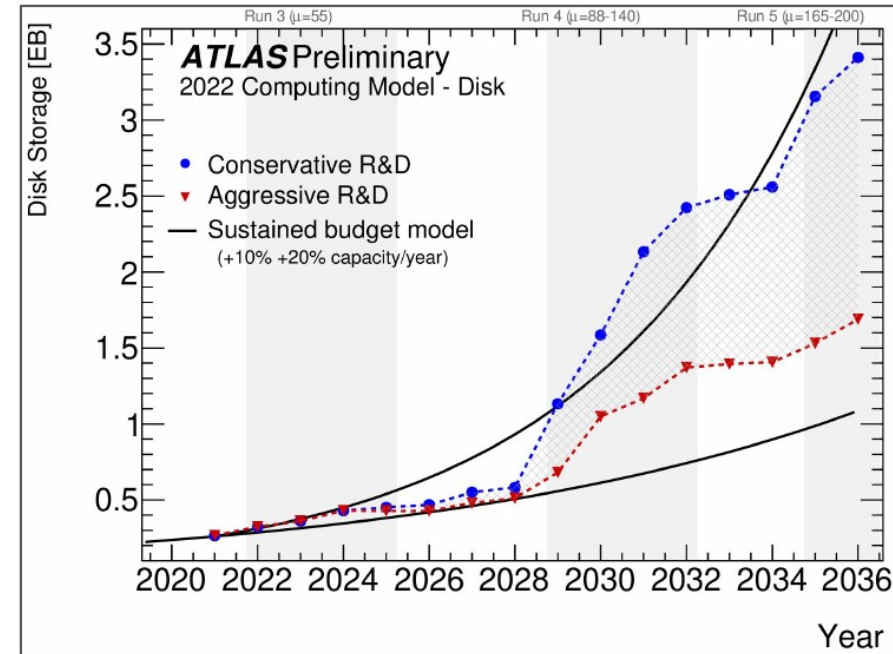
Sketch by X. Zhao

HEP Open Data

- Excellent talk by J. Boyd on Cern Open Data in PunchLunch last Thursday

- Strong connection between Open Data and Data Preservation

  - **DPHEP** Collaboration – HEP wide initiative founded in 2008

  - **FAIR** principles equally important for preservation and open access

- DPHEP defines four levels, adopted by CERN OpenData policy

  1) Scientific publications and associated additional data
     Regularly done since many years (HepData, Rivet, ...)

  2) Data for education and outreach
     Many data samples and tutorials available (CERN Open Data, Masterclasses, ...)

  3) Reconstruction level data useful for further event-level analysis
     Delicate part ...

  4) RAW data – *not considered feasible / useful for usage outside of collaboration*
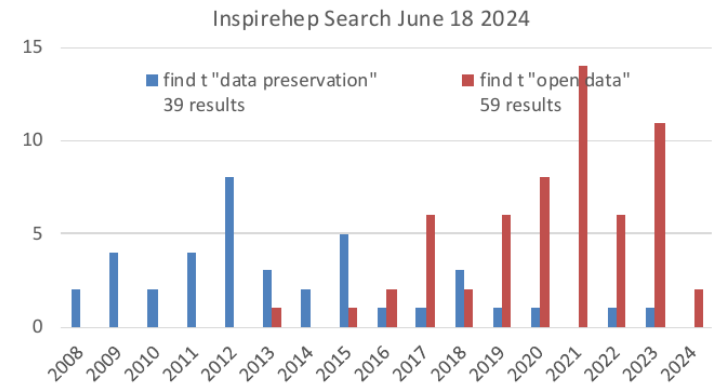
Level 3 data

- Reconstruction level data – in principle sufficient for large fraction of analyses

- Concerns about ownership, resources, effort, ...

- Basic agreement among 4 the LHC collaborations:

	ALICE	ATLAS	CMS	LHCb
Fraction of data released in: **5 yrs** (6 yrs for CMS)	10%	25% (but limiting to <20% of the total data at that time)	50% (but limiting to <20% of the total data at that time)	50%
Fraction of data released in: **10 yrs**	50%	50% (but limiting to <20% of the total data at that time)	100% (but limiting to <20% of the total data at that time)	100%
End-of-Collaboration	100%	100%	100%	100%

HEP Open Data and FAIR?

- ~ok for LHC experiments

  - Agreed on common policy

  - Resources provided by collaborations and CERN

- Smaller ongoing experiments – Belle II, small LHC & non-LHC expts, …

  - Discussions in progress – hope LHC open data policy sets example

- Huge legacy of previous experiments
  Petra, LEP, SLC, Hera, Tevatron, …

  - Strong incentive to preserve data for further analysis

    – Several examples of re-use

  - Practical status rather mixed

    – Expertise about to disappear in many cases (LEP, Hera, ...)

- Big issues are resources and funding

2023: Experiments Data Preservation Status

Laboratory/ Collider	Experiment	Data taking period	Preservation Level	Data Volume	Present status	Coll
DESY/PETRA	JADE	1979–1986	4	1 TB	Analysis running on preserved data; migrated from DESY to MPP	4
CERN/LEP	ALEPH,DELPHI,OPAL L3	1989-2000	4 3/4	0.5 PB	Analysis running on preserved data	3/4
DESY/HERA	H1, ZEUS	1992 – 2007	4 3/4	0.5 PB 0.2 PB	Analysis running on preserved data	3
SLAC/PEP II	BABAR	1999–2008	4	2 PB	Analysis running on preserved data; migrated from home lab to different centers	4
KEK/KEKB	Belle I	1999-2010	4	4 PB	Analysis running on preserved data; Compatible with Belle II computing	2
FNAL/TeVatron	DØ CDF	1983–2011	4 4	8.5 PB 9 PB	Archived on tapes	4
BNL/RHIC	PHENIX	2000–2016	3	25 PB	Analysis running on preserved data	3
FNAL/ν-beam	Minerva	2010–2019	3	10 TB	Analysis running	2
IHEP/BEPCII	BESIII	2009–2030	4	6 PB	Collecting and analyzing data	1
CERN/LHC	ALICE,ATLAS, CMS, LHCb	2010-2040	3 or 4	O(1EB)	Collecting and analyzing data	1

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DPHEP@CHEP24

HEP and ErUM-Data

- **FIDIUM** project (2021-2025) within ErUM-Data important to develop, test and deploy critical tools&services for HEP computing

  - COBalD/TARDIS, Auditor, XCache, analysis technologies, ...

  - Not just for opportunistic resources but crucial for NHR/HPC integration

  - Also PUNCH services (Compute4punch, …) building on these

- Next round of ErUM-Data call – proposals in preparation (deadline Jan 15, 2025)

  - Federated Infrastructures of particular relevance – building on FIDIUM
    Planned projects with DE HEP involvement:

    - Sustainable Federated Compute Infrastructures

    - Distributed Storage

    - Analysis Facilities

  - Software & Algorithms – also strong HEP interest

  - Research Data Management – ??

Summary

- Clear evolution & trend towards common standards, services & infrastructures

  - open data policies, FAIR RDM

  - NHR sites, EuroHPC

  - Community overarching projects
    - in DE: PUNCH4NFDI, Erum-Data, DIG-UM
    - and EU: JENA, Spectrum

  - Many synergies and mutual benefit

  - Combined impact of communities potentially important to achieve common standards for shared infrastructures – NHR, EuroHPC

- Large scope to further optimize use of Open Data at levels 1 & 3

  - combine data from different communities

  - support & incentive for small/legacy experiments

  - projects such as PUNCH4NFDI crucial for further progress