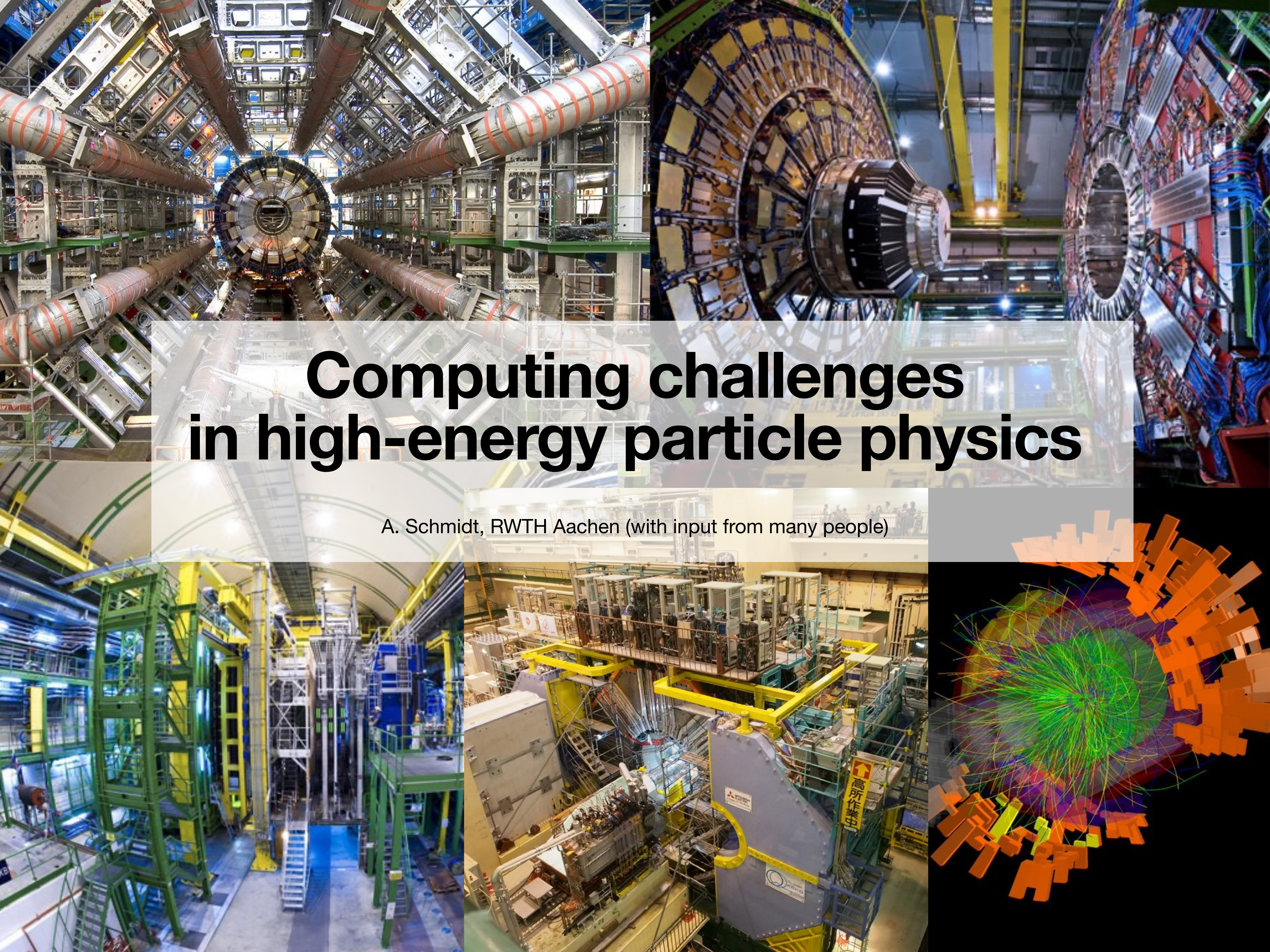


Computing challenges in high-energy particle physics

A. Schmidt, RWTH Aachen (with input from many people)

physics with large particle accelerators

- computing challenges in particle physics mainly driven by the experiments at the Large Hadron Collider (LHC at CERN) and Belle II at SuperKEKB (Japan)
  - large number of other experiments profit from these developments

- fundamental research of the structure of matter (e.g. discovery of the Higgs Boson)

- LHC operating since 2009
- SuperKEKB since 2018

- world wide LHC computing grid is processing data

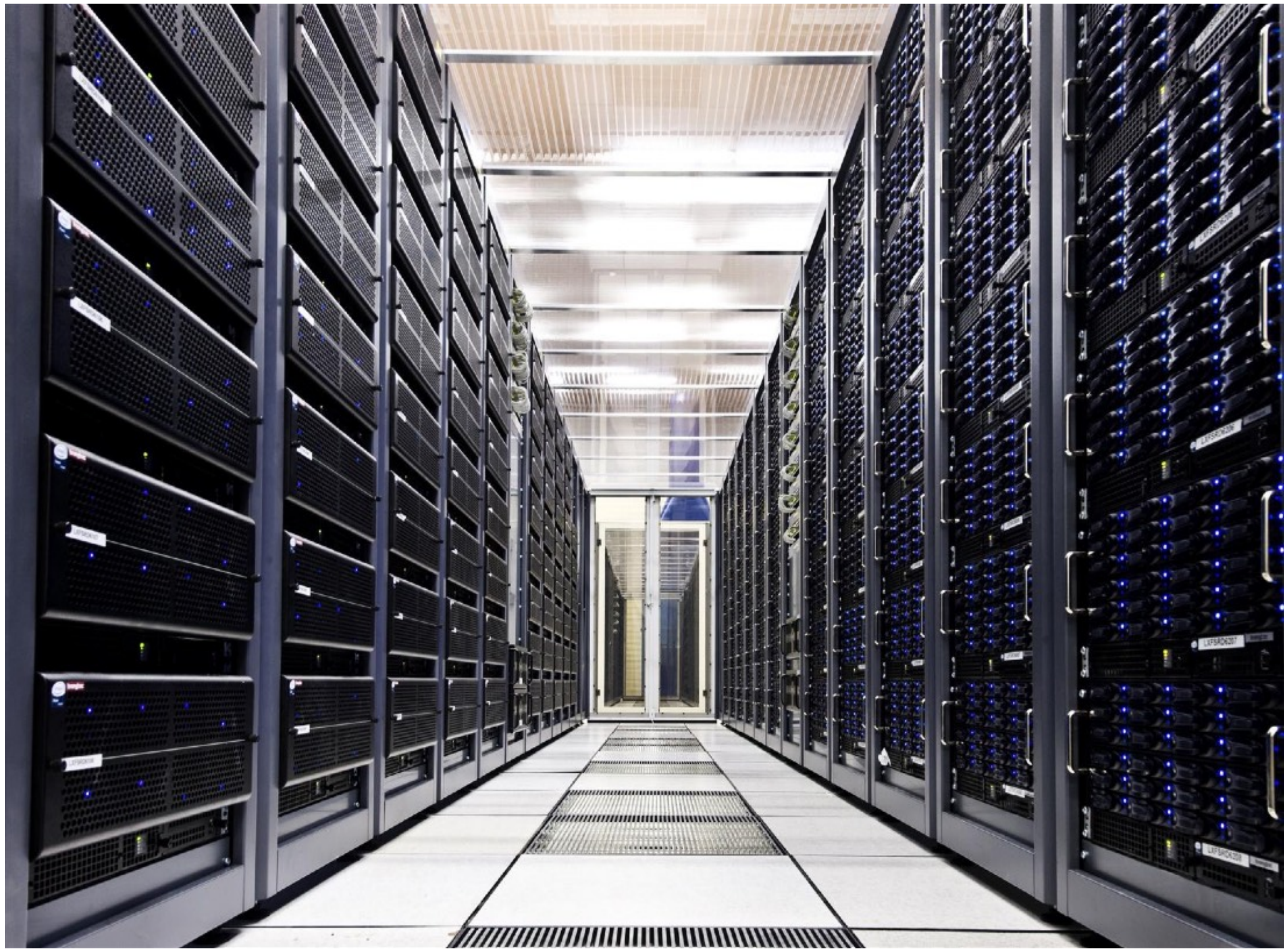
WLCG
Worldwide LHC Computing Grid

- it connects 170 computing centers in 40 countries

- 1 million computing cores
- 1000 Petabytes data

LHC

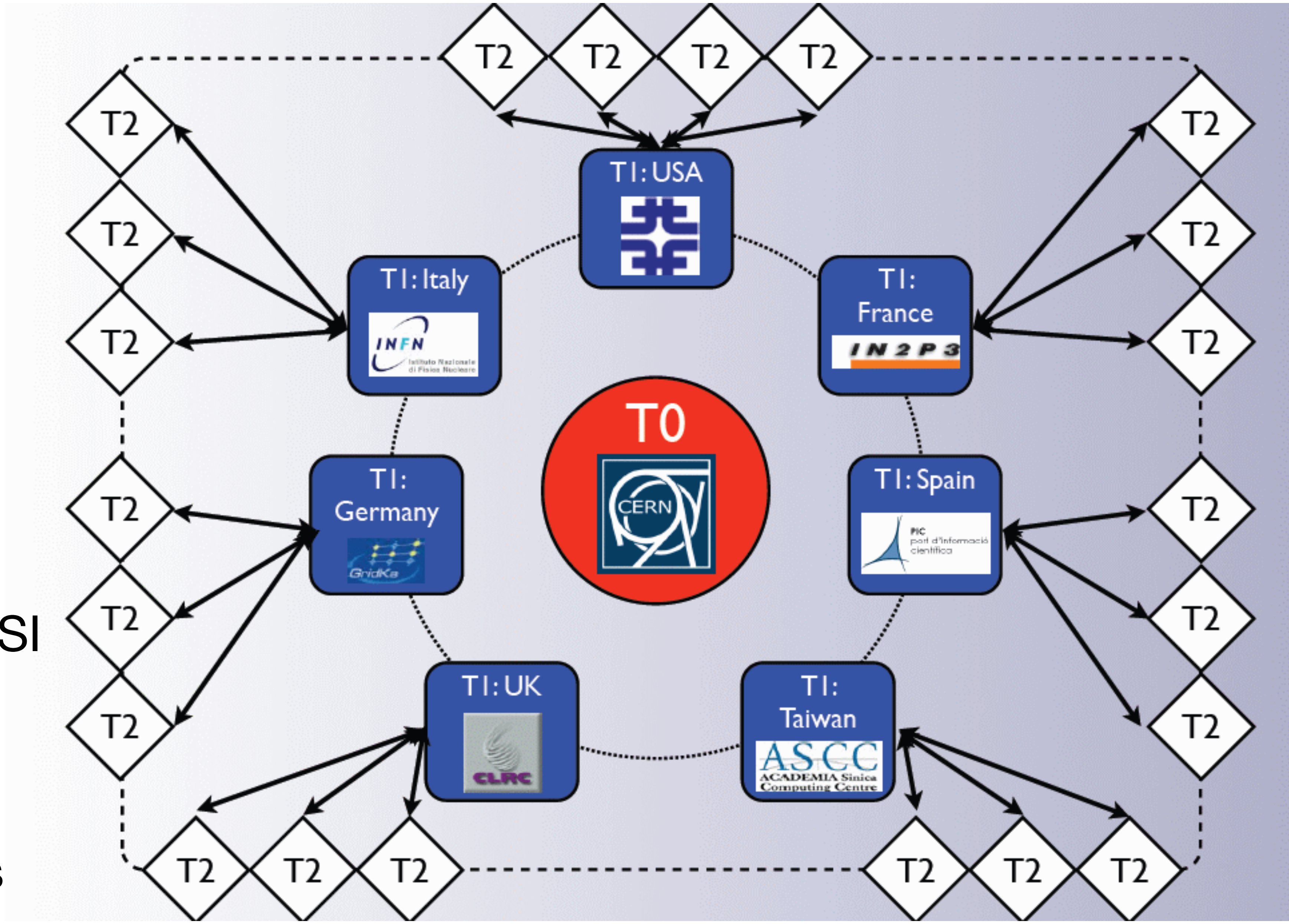
- with a proton-proton collision rate of 40 MHz, the initial theoretical data stream of ~1 Petabyte/s (non zero suppressed) is not to handle (actual numbers are strongly experiment dependent)
- same amount of simulated data needed



- real-time trigger systems (FPGAs) reduce the rate by five orders of magnitudes
- detector technologies are constantly improved and upgraded →increasing amount of data
- more data means better physics potential
- an excellent computing model and infrastructure is the prerequisite for excellent research in this area
- Belle II aims at collecting 50 times more data than the predecessor Belle

Tiered LHC computing infrastructure model

- german Tier-1 at Helmholtz-center GridKa

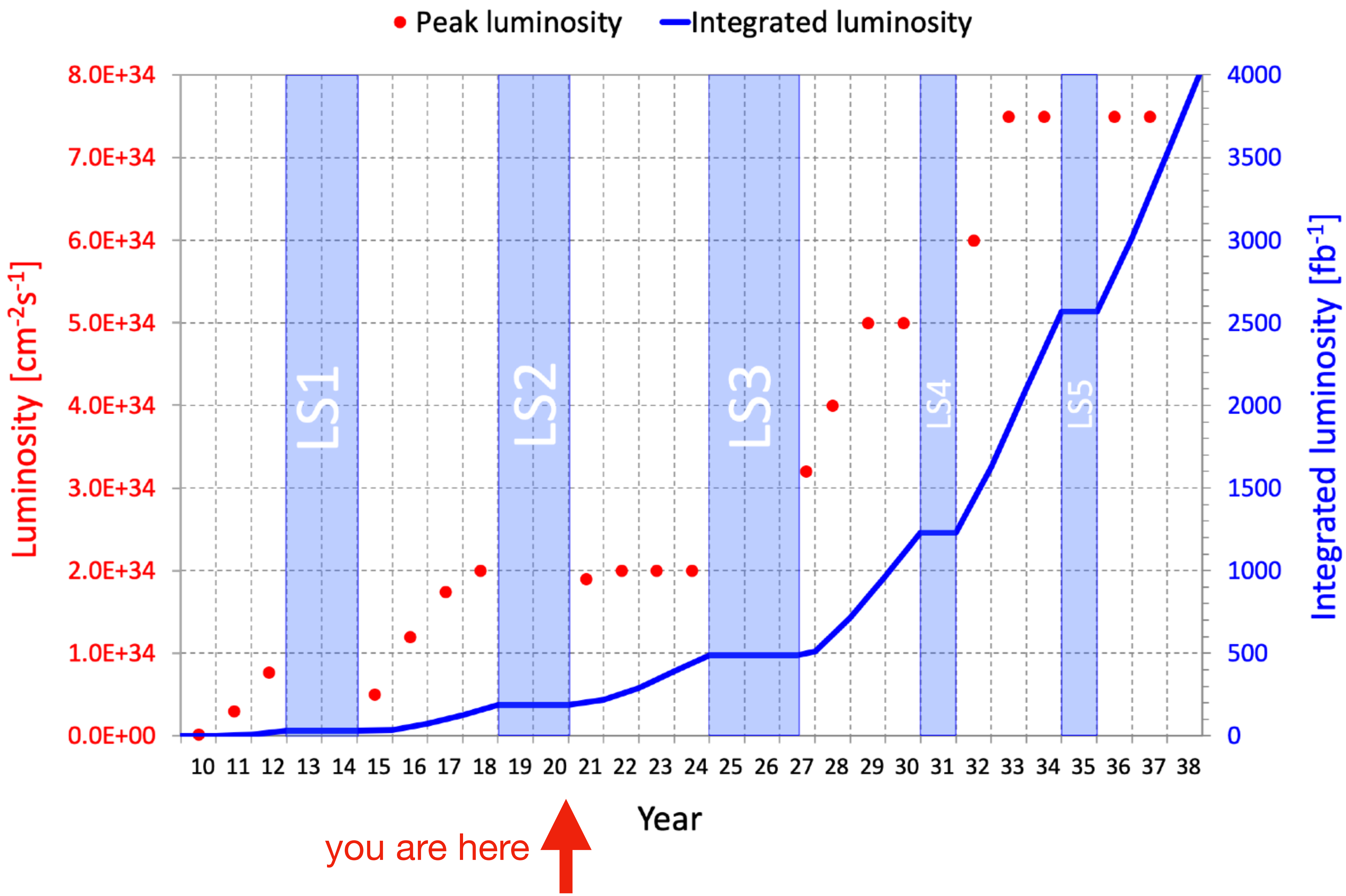


- Tier-2 predominantly located at universities, also DESY, GSI

- close collaboration between universities and large centers

- financial structure (BMBF, Helmholtz) needs to be consolidated in view of the future challenges

the High-Luminosity LHC (HL-LHC)

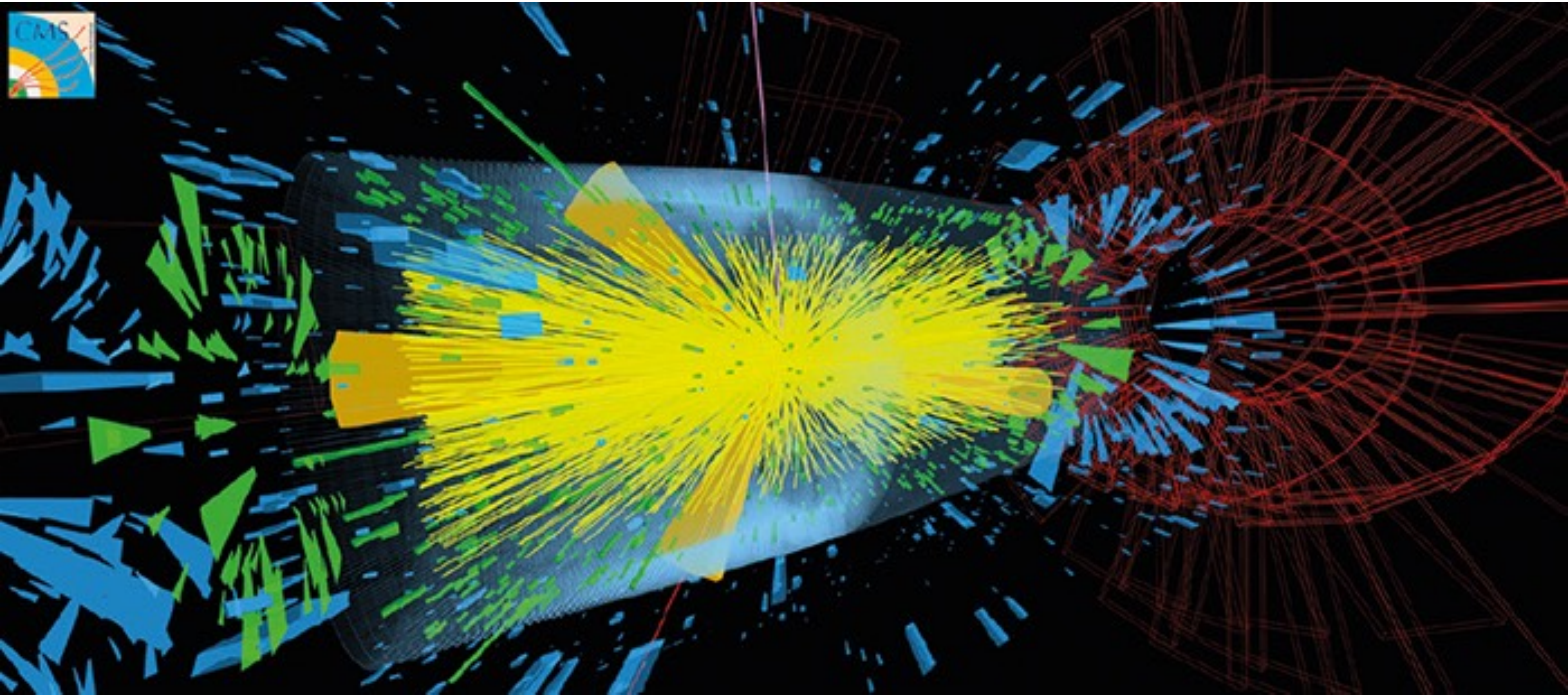


"integrated luminosity" corresponds to the "amount of data to process"

- the largest fraction of LHC data is still to come
- the main computing challenges are still ahead of us

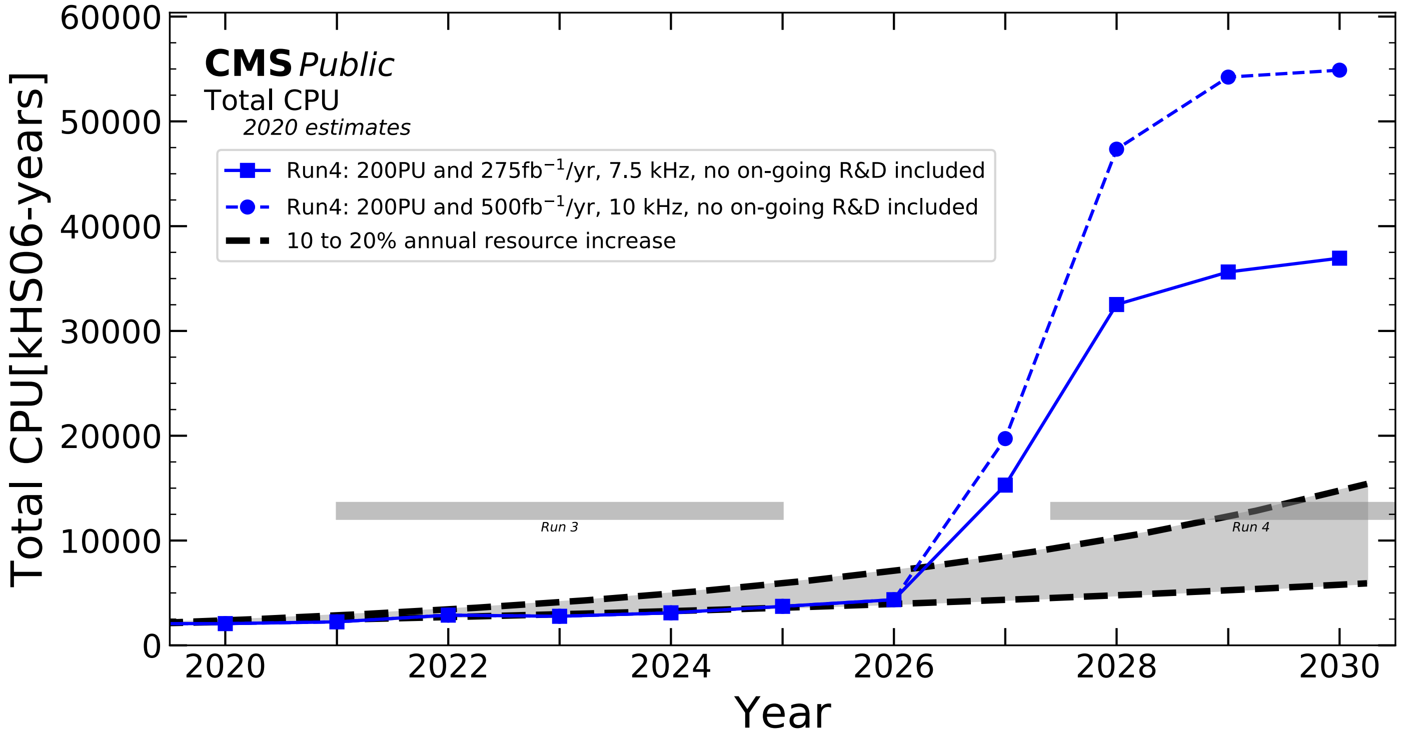
the High-Luminosity LHC (HL-LHC)

- not only more data, but also more complex events
- 200 simultaneous proton-proton collisions
- higher occupancy and combinatorial ambiguity

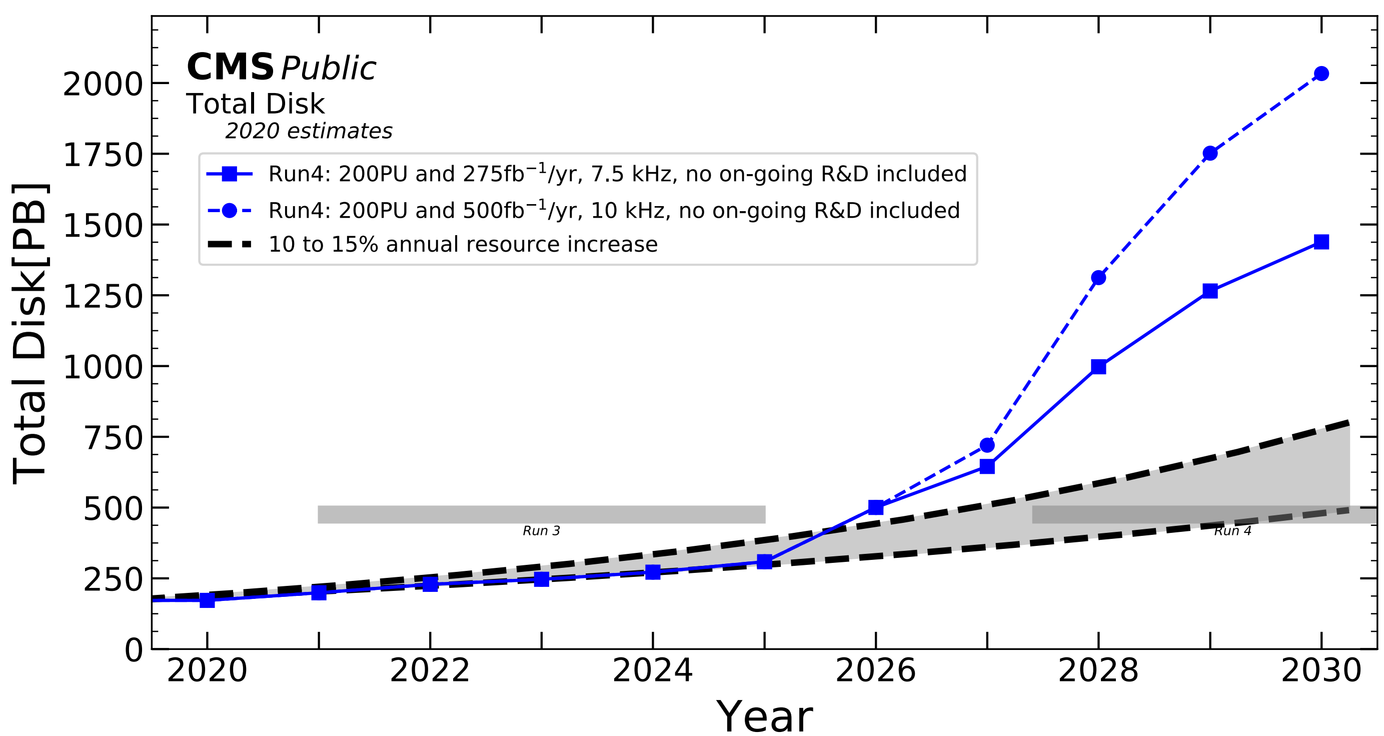


projections into the future

CPU



disk

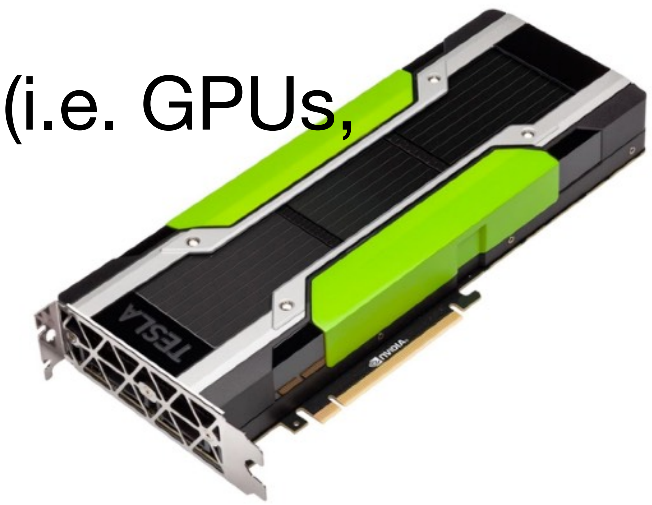


- estimated computing resource requirements for the CMS experiment at the HL-LHC for different running scenarios (blue)
- compared to the projected increase of computing resources, assuming 10%-20% annual increase with constant investment (dashed lines, grey band)
- large discrepancy between required and available resources to be mitigated
- similar situation for the ATLAS, ALICE and LHCb experiments

emerging solutions to the challenge

software, algorithms, analysis methods:

- optimised algorithms for experiment software (parallelisation, vectorisation) and simulation/theory
- adaptation to heterogeneous computing architectures (i.e. GPUs, FPGAs)



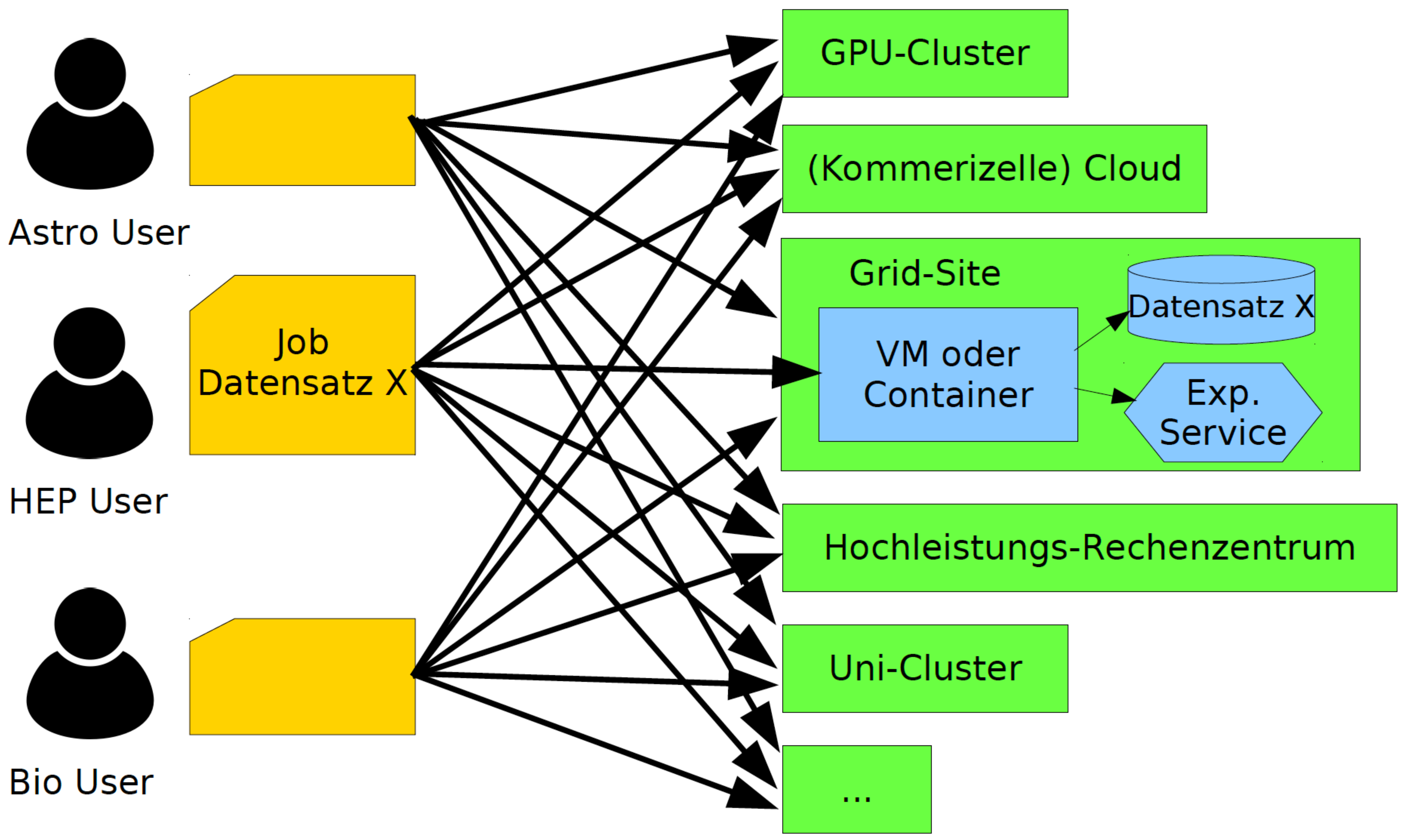
- machine learning

- future: quantum computing (?)

computing infrastructures:

- use of heterogeneous/opportunistic computing resources
- facilitated through abstraction layers
- data storage at big computing facilities (data lakes)

vision of a science cloud



ErUM Data Pilotmaßnahme

- IDT-UM project initiated in 2017, runs until mid 2021
- first steps towards a cross-community effort to develop and test solutions
- details in talks by T. Kuhr and G. Kasiecka

ErUM-Data IDT

Innovative Digitale Technologien für die Erforschung von Universum und Materie

Gemeinsamer Antrag von Gruppen aus den Bereichen Elementarteilchenphysik, Hadronen- und Kernphysik und Astroteilchenphysik

- Rheinisch-Westfälische Technische Hochschule Aachen, Prof. Dr. Martin Erdmann
- Rheinische Friedrich-Wilhelms-Universität Bonn, PD Dr. Philip Bechtle
- Friedrich-Alexander-Universität Erlangen-Nürnberg, Prof. Dr. Gisela Anton
- Goethe Universität Frankfurt am Main, Prof. Dr. Volker Lindenstruth
- Albert-Ludwigs-Universität Freiburg, Prof. Dr. Markus Schumacher
- Georg-August-Universität Göttingen, Prof. Dr. Arnulf Quadt
- Universität Hamburg, Jun.-Prof. Dr. Gregor Kasieczka
- Karlsruher Institut für Technologie, Prof. Dr. Günter Quast
- Johannes Gutenberg-Universität Mainz, Prof. Dr. Volker Büscher
- Ludwig-Maximilians-Universität München, Prof. Dr. Thomas Kuhr
- Bergische Universität Wuppertal, Prof. Dr. Christian Zeitnitz

Assoziierte Partner sind

- CERN, Dr. Markus Elsing
- DESY, Dr. Volker Gülzow
- GridKa, Dr. Andreas Heiss
- GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Dr. Kilian Schwarz
- Forschungszentrum Jülich, Dr. Elisabetta Prencipe
- Westfälische Wilhelms-Universität Münster, PD Dr. Christian Klein-Bösing

next step

- FIDIUM proposal submitted Nov 2020 to ErUM-Pro
- focuses on the heterogeneous computing infrastructures aspect (“federated infrastructures”)
- continuity needed, to avoid expensive interruptions of ongoing developments
- new proposal also planned for big data analytics (see G. Kasieczka’s talk)

Föderierte Digitale Infrastrukturen für die Erforschung von Universum und Materie (FIDIUM)

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[1] Sprecher des Verbundes
[2] Stellvertretender Sprecher des Verbundes

FIDIUM context, goals

- overcome the resource gap for particle physics computing
- exploit synergies with other communities (at FAIR and new large scale projects in astroparticle physics)
- continuity with the “Pilotmaßnahme ErUM-Data”
- community over-arching developments, solutions, applications
- embedded in international context

methods, technology

- optimal utilisation and load on heterogeneous ressources (universities, HPC centers, commercial services)
- deployment of complete “infrastructures as a service” (IaaS)
- deployment für HL-LHC foreseen starting in 2024/2025, developments are needed NOW

topics and working areas in FIDIUM

Themenbereich I

"Entwicklung von Werkzeugen zur Einbindung heterogener Ressourcen"

Arbeitspakete:

1. Erschließung und effiziente Einbindung von opportunistischen Ressourcen
    - Weiterentwicklung und Anpassung von COBalD/TARDIS
    - Entwicklung dynamischer Steuerungen des Job-Schedulings (Berücksichtigung von Datenlokalität, I/O-Raten)
    - "Compute Site in a Box"
2. Accounting und Controlling von heterogenen Ressourcen
    - Tools zum Aaccounting
    - Überwachung der Nutzungseffizienz

Themenbereich II

"Data-Lakes, Distributed Data, Caching"

Arbeitspakete:

1. Aufbau eines Echtzeit Data-Lake - Monitoring-Systems
    - Erfassung der Auslastung von Komponenten
    - Analyse von Zugriffsmustern
2. Technologien für Data-Lake - Caching
    - Entwicklung der Technologien und Konsolidierungsarbeiten
    - Einsatz paralleler ad-hoc Filesysteme
3. Technologien für Data-Lake - Daten- und Workflow - Management
    - Replikations und Platzierungsmechanismen
4. Data-Lake - Prototypen, Technologien für QoS und effiziente Anbindung
    - Aufbau von Data-Lake Prototypen
    - Quality of Service

Themenbereich III

"Anpassung, Test und Optimierung auf Produktions- und Analyse-Umgebungen"

Arbeitspakete:

1. Integration, Tests, Optimierung und Deployment der entwickelten Dienste
    - Zusammenführung der Komponenten
    - Funktionale Tests
    - Feedback an Entwickler
    - Integration in Produktionsumgebung
2. Spezifische Anpassung der Dienste an komplexe Workflows und Nutzung spezieller Technologien für die Analyse wissenschaftlicher Daten
    - Optimierung für spezielle Workflows, GPU Nutzung, Parallelisierung
3. Support
    - Einrichtung eines standortübergreifenden Support Teams

conclusions, comments

- particle physics has been dealing with large scale computing and data analysis for many years, but huge challenges ahead
- emerging ideas, solutions and projects exist
  - these are first steps
  - the final solution is far away and needs a huge cross community effort
- financial structure for computing resources needs to be consolidated in the coming years
- educational aspect is highly relevant, students and postdocs in the field are sought-after by large businesses
- Workshop on Computing Strategy in the HL-LHC Era, May 2020
  - https://indico.physik.uni-muenchen.de/event/33/
- Abschlussdokument:
  - https://indico.physik.uni-muenchen.de/event/33/attachments/142/242/Abschlussdokument.pdf

KET “Computing and Software panel” represents interests of the community backup

the High-Luminosity LHC (HL-LHC)