Computing and Software

G. Duckeck, F. Gäde, L. Heinrich, M. Klute,
T. Kuhr, M. Schumacher, K. Schwarz,
T. Stockmanns, ...

Bundesministerium
für Forschung, Technologie
und Raumfahrt

22.11.2025

LMU LUDWIG-
MAXIMILIANS-
UNIVERSITÄT
MÜNCHEN

Our Input to ESPPU

Statement by the German Particle Physics Community as Input to the Update of the European Strategy for Particle Physics

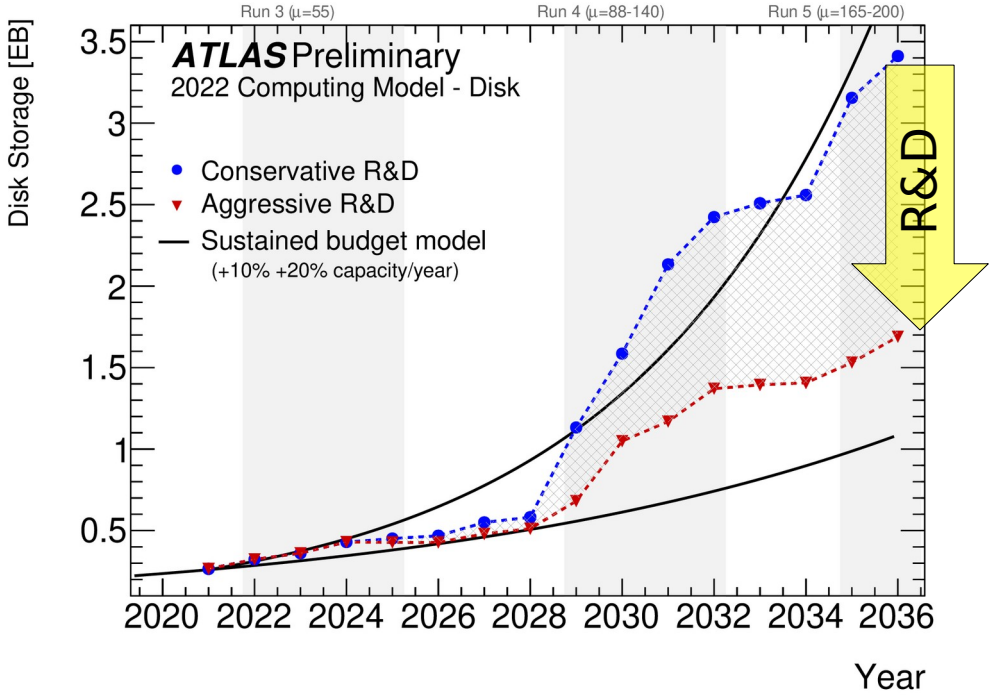
March 17, 2025

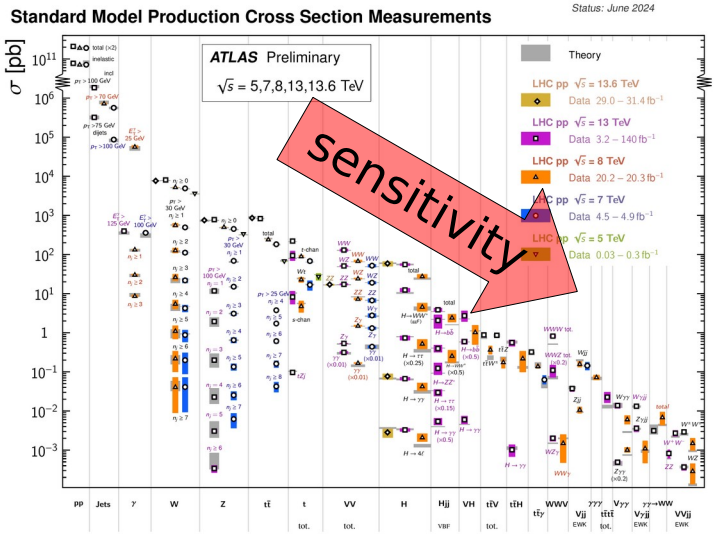
5.5 Computing, software, algorithms, and data science

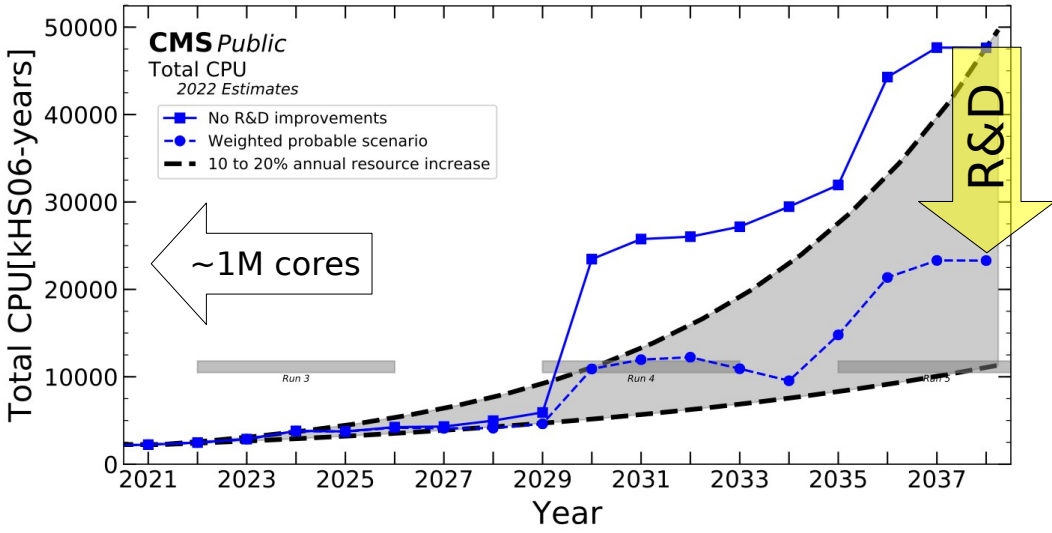
The full exploitation of the unique physics potential of the European particle physics programme requires the development and application of state-of-the-art software and machine learning methods and the provision of extended computing and storage resources beyond the increase provided by technological evolution.

Meeting the computing needs of major future projects in an environmentally sustainable way requires embracing of new technologies and enhanced interdisciplinary use of IT infrastructures and cooperation. The implementation of FAIR principles, the retention of expertise, and the recognition of work are priorities.

Role of Computing & Software





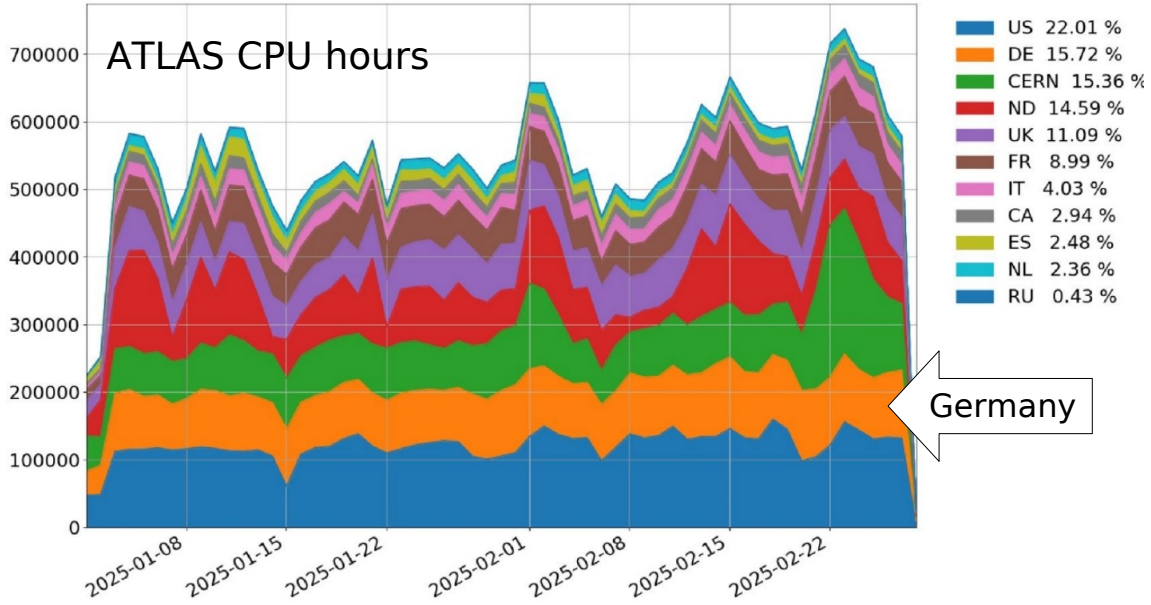


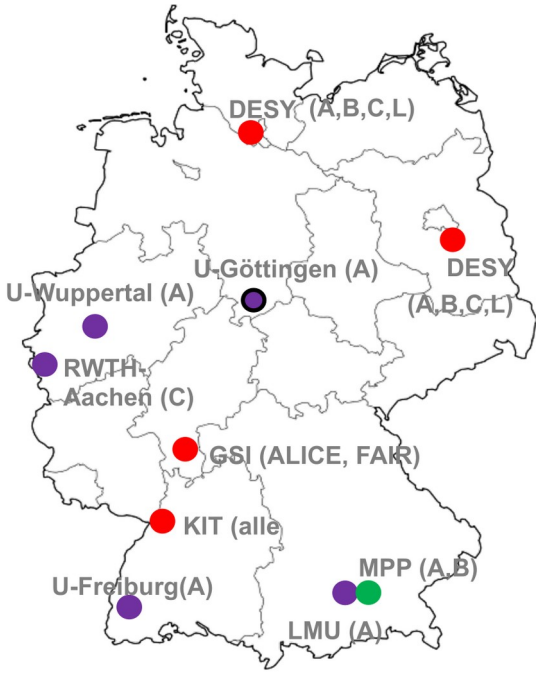
- Huge and rising computing demands
- ➔ Requires increasing computing resources, a reliable infrastructure, and efficient software

Computing Resources

- Established procedures for deciding and approving (by funding agencies) the pledged computing resources for ATLAS, CMS, LHCb, and Belle II

➔ German share of resources and infrastructure provided by GridKa, DESY, MPP + University Tier2 / NHR for ATLAS/CMS

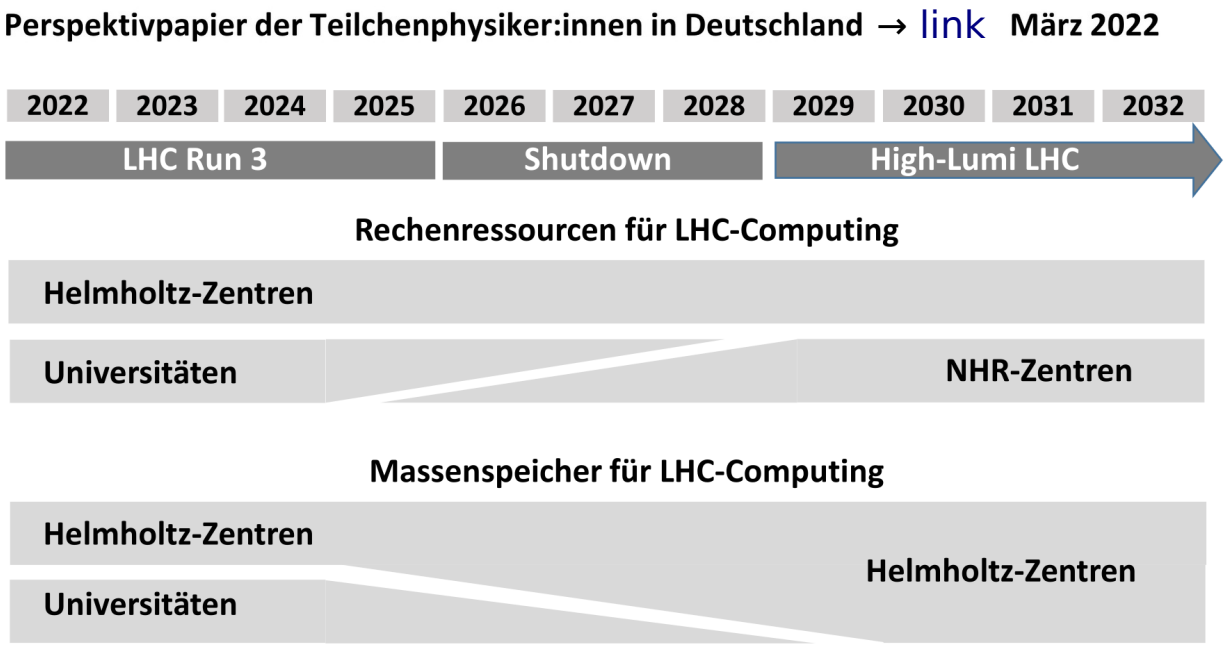




A=ATLAS B=BELLE C=CMS L=LHCb

Uni Tier2 → NHR

- NHR: Alliance of National High Performance Computing Centers
- Technologies for transition prepared in FIDIUM project
- Migration on track, 20% of resources provided by NHRs in GÖ, KA, AA
- Maintenance and operation of services for integration of NHR resources in WLCG
- Scaling to 100% in next funding period → integration of further NHRs

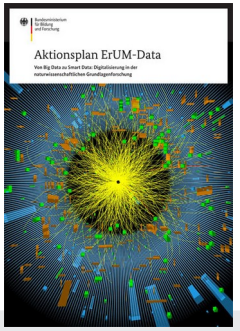


Adjustment of experiment software to NHRs

Funding Source

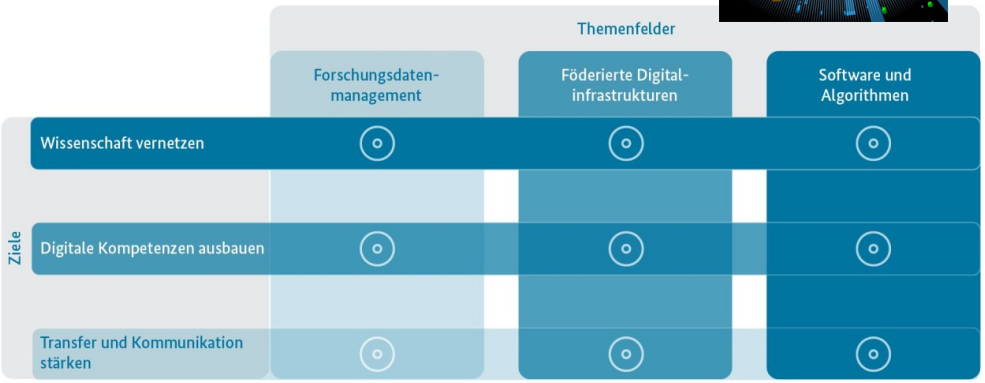
ErUM-Pro

- Longer term funding for experiment specific works



ErUM-Data

- Action plan for 10 years
- 3-year experiment/community overarching projects



NFDI

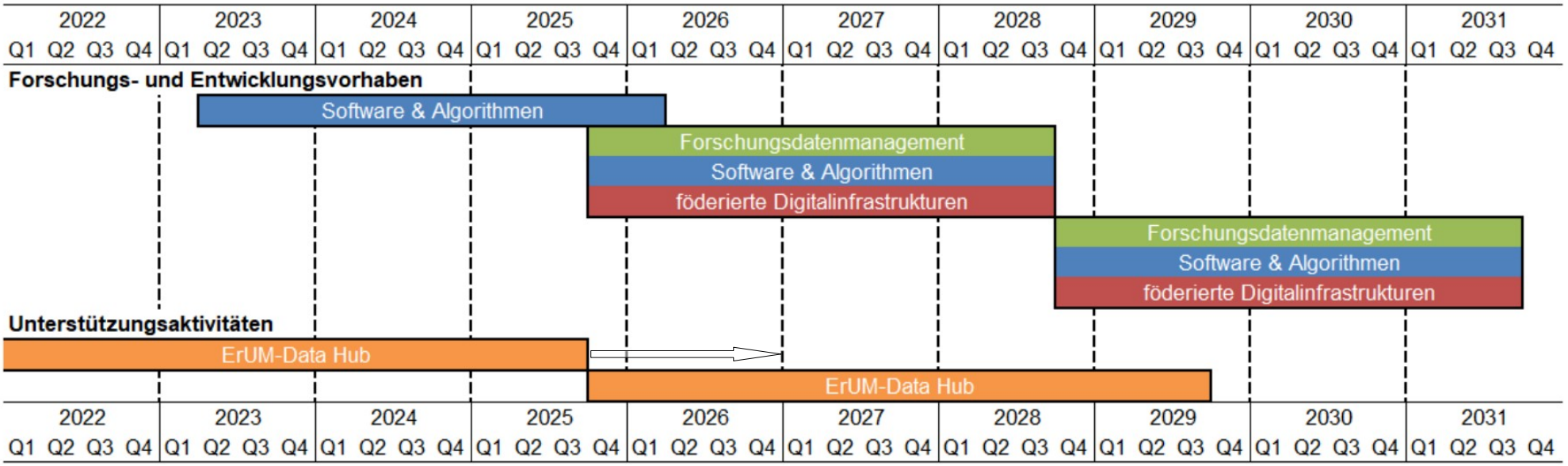
- Services for a national research data infrastructure
- Structure evolving from bottom-up to top-down
- PUNCH4NFDI consortium → Proposal for second phase submitted

New ErUM-Data Projects

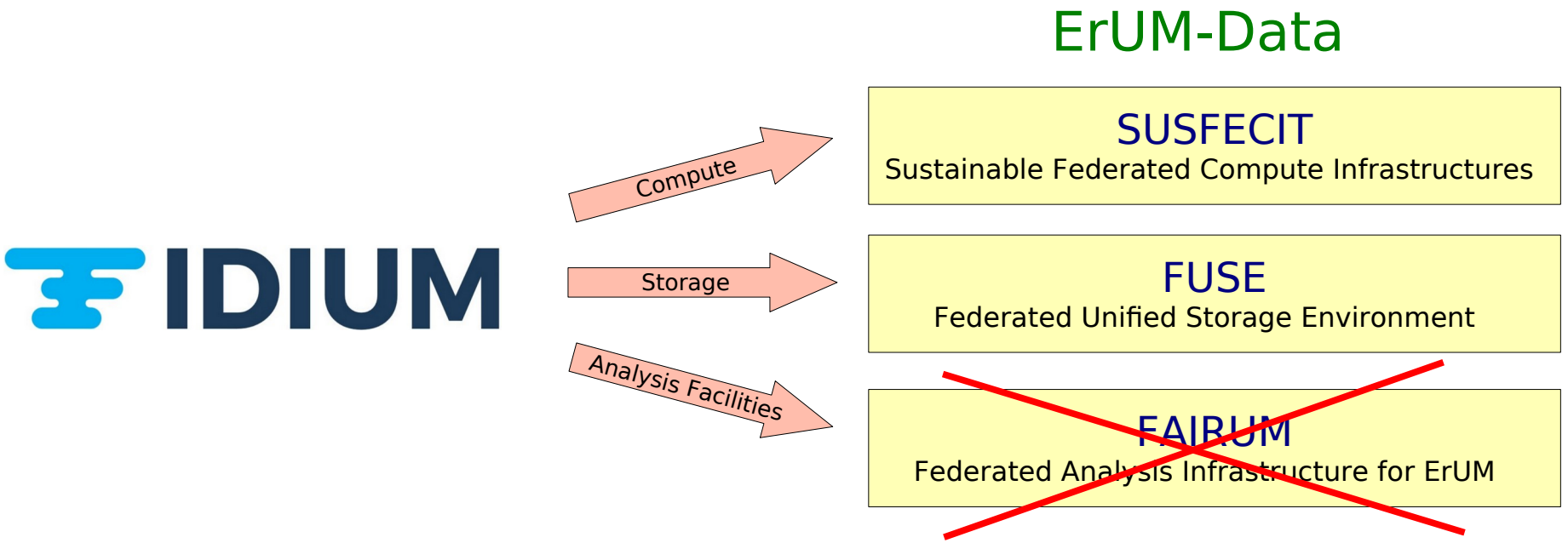
With particle physics participation

- AALearning (AA, BN): Adversariales Lernen als neues Werkzeug in der Grundlagenphysik und darüber hinaus
- BRAID (KA): Domänenübergreifende Vernetzung: KI-basierte, detektorunabhängige Rekonstruktions-Frameworks für unregelmäßige hochdimensionale Daten
- DEEP (KA, FR, BN): Steigerung der Dateneffizienz in eingebetteten Prozessoren durch künstliche Intelligenz
- DEMOS (BO, LMU, TUM, MPP): Demokratisierung von Modellen: Plattform für den Austausch von Forschungsmodellen
- ErUM-IFT-2 (AA): Informationsfeldtheorie für Experimente an Großforschungsanlagen
- PEARLS (FR): Präzision in energiebewusster KI-Forschung für CO2-arme Lösungen
- SciFM (TUM, AA): Grundlagenmodelle in Astrophysik und Teilchenphysik
- FUSE (GÖ, AA, WU, LMU, DESY): Federated Unified Storage Environment
- SUSFECIT (GÖ, AA, BN, FR, KIT, DESY): Nachhaltige Föderierte Computing-Infrastrukturen

Experiment specific needs not explicitly addressed



Federated Infrastructure Projects



Analysis Facilities


THE HEP SOFTWARE FOUNDATION (HSF)

HSF-TN-2024-01
April 2024

Analysis Facilities White Paper

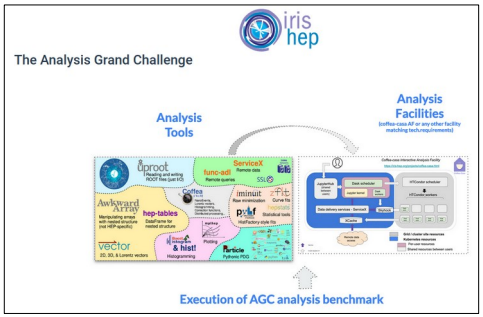
- Required resource will be rising not only for computing managed centrally by experiments, but also for analyses, including needs for GPUs

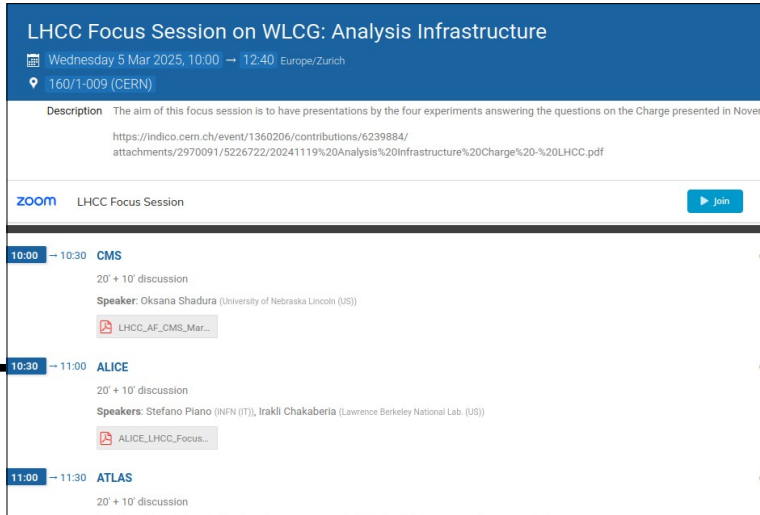
➔ Solution for scaling of analyses needed in Germany if we want to keep playing a leading role in physics analyses

➔ Concepts of successful scaling in grid computing:

  - Worldwide, interoperable infrastructure
  - Shared resources → more efficient use

➔ **Analysis Facilities**




LHCC Focus Session on WLCG: Analysis Infrastructure

Wednesday 5 Mar 2025, 10:00 → 12:40 Europe/Zurich

160/1-009 (CERN)

Description The aim of this focus session is to have presentations by the four experiments answering the questions on the Charge presented in Nove

https://indico.cern.ch/event/1360206/contributions/6239884/attachments/2970091/5226722/20241119%20Analysis%20Infrastructure%20Charge%20-%20LHCC.pdf

zoom LHCC Focus Session Join

10:00 → 10:30 CMS
20' + 10' discussion
Speaker: Oksana Shadura (University of Nebraska Lincoln (US))
LHCC_AF_CMS_Mar...

10:30 → 11:00 ALICE
20' + 10' discussion
Speakers: Stefano Piano (INFN (IT)), Irakli Chakaberia (Lawrence Berkeley National Lab. (US))
ALICE_LHCC_Focus...

11:00 → 11:30 ATLAS
20' + 10' discussion

Physics Briefing Book

12.1.5 Specialized Analysis Infrastructure

As the volume and the complexity of data from HEP experiments increase, the analysis phase of the scientific workflow becomes more demanding and more specialized. Traditional batch computing models are ill-suited to the needs of modern analysts, who require fast, interactive access to large datasets and scalable processing environments. This shift has spurred the development of specialized analysis facilities that blend interactivity with elasticity. Elastic Analysis Facilities (see [ID237] for example) offer on-demand compute capacity tailored for user-driven workflows. These platforms are being designed with a strong emphasis on usability, featuring seamless access to data, low-latency storage, and intuitive interfaces that reduce the technical overhead for users. The goal is to create environments that support both novice and expert users, enhance scientific productivity, and enable efficient sharing of infrastructure across ex-

Sustainability and Transfer

- Both topics addressed by hightech computing and software developments in ErUM (e.g. AI),
  including in particular education in cutting-edge technologies
- Strongly supported by ErUM-Data Hub

Conclusions

- Further developments in computing and software are essential to reach our physics goals!
- ErUM-Data helps to address some, but certainly not all computing and software needs of the community

➔ ErUM-Pro funding required for:

- WLCG operation (at NHRs) → ATLAS + CMS Computing Verbund
  (no hardware invest any more, some more personnel for NHR scaling)
- Analysis facilities R&D
  → follow up on analysis technology developments in FIDIUM
- Experiment specific computing operation (e.g. GridKa contact)
  → experiment Verbünde
- Experiment specific software developments
  → experiment Verbünde
- Experiment overarching (but community specific) software developments (e.g. Key4HEP, ACTS) → see Jan's talk

➔ High potential for impact on sustainability and technology transfer