

# Computing and Software

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Bundesministerium  
für Forschung, Technologie  
und Raumfahrt

22.11.2025



# Our Input to ESPPU

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

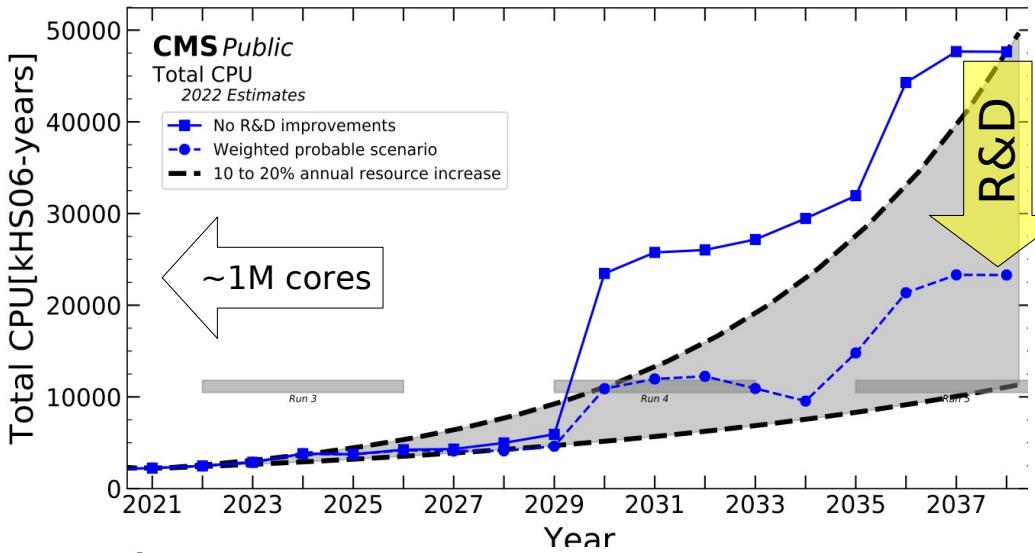
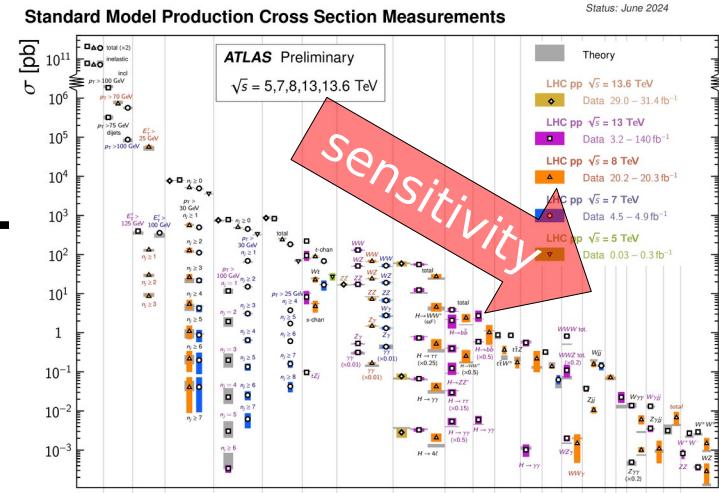
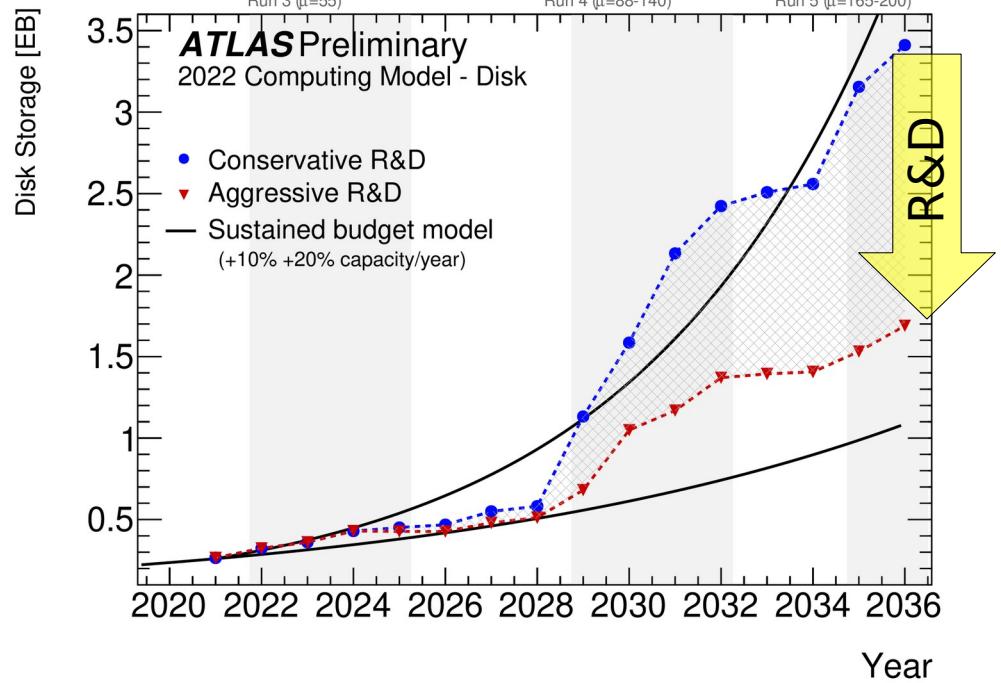
March 17, 2025

### 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.

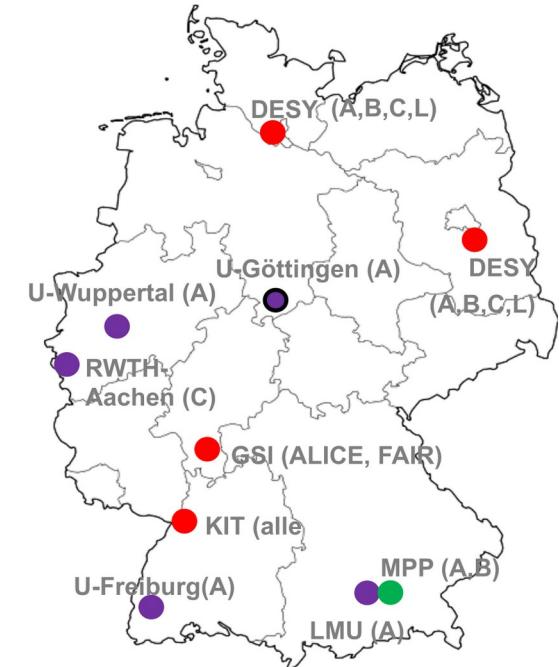
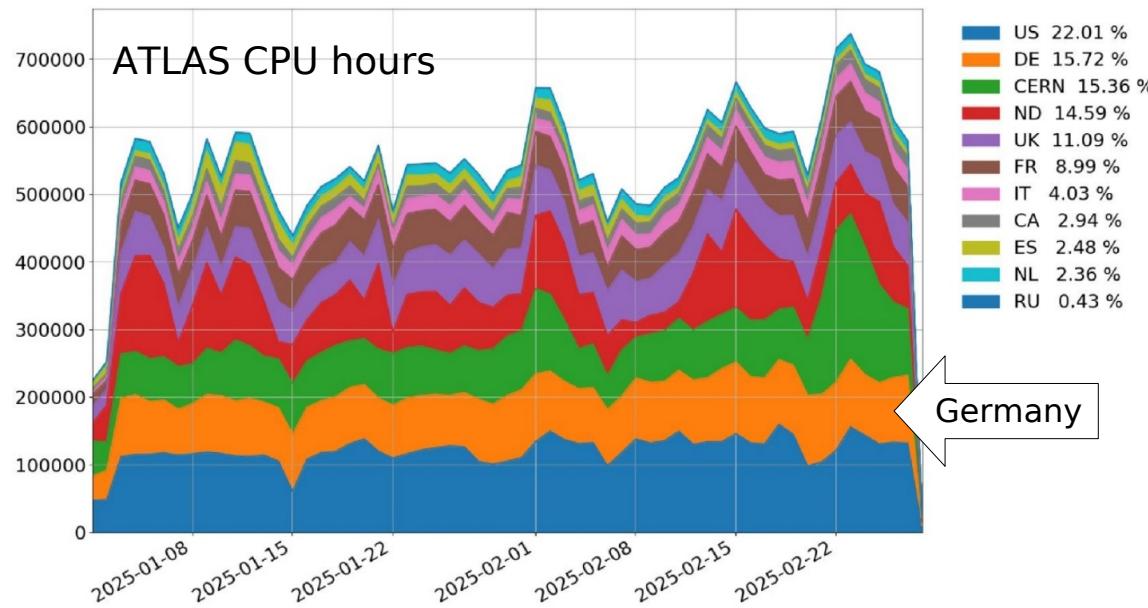
# Role of Computing & Software



- 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

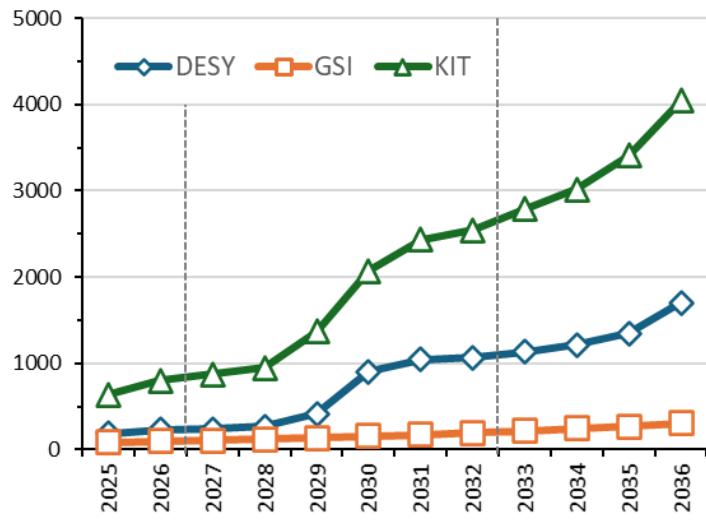


A=ATLAS B=BELLE C=CMS L=LHCb

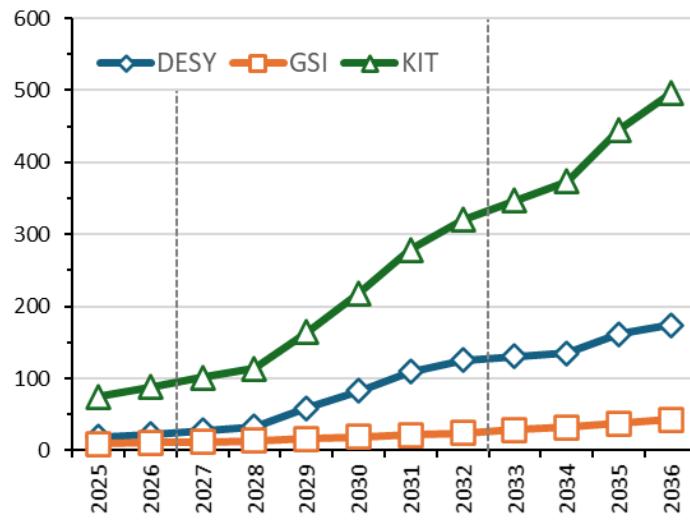
# Helmholtz Centers

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CPU [kHS23]



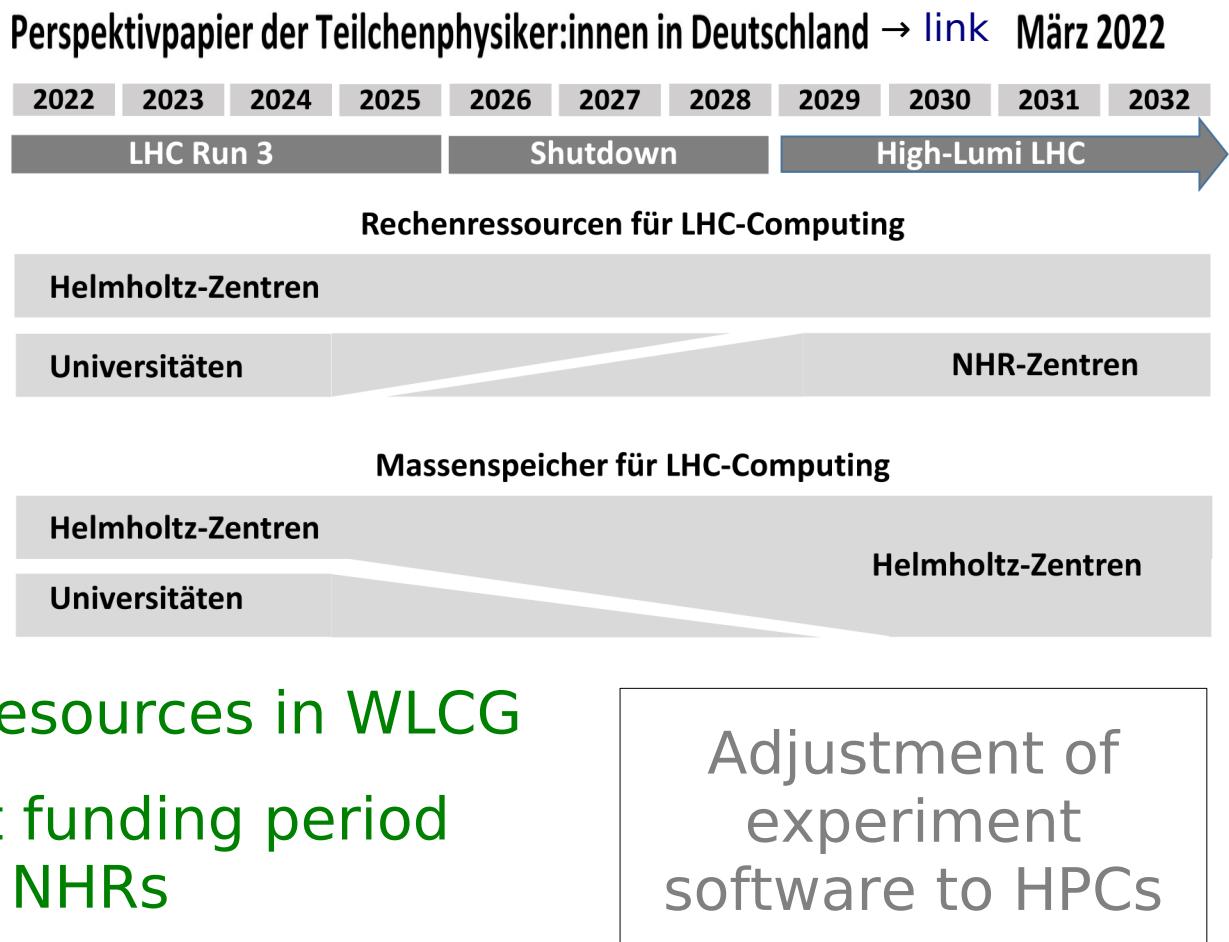
Disk [PB]



- Proposal “TIER-Upgrade – Upgrade of the Grid Computing Centers for the HL-LHC” for Helmholtz FIS Roadmap submitted by KIT, DESY, and GSI in July
- 33M€ for 2027-2032
- ➔ Success of proposal of utmost importance

# 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

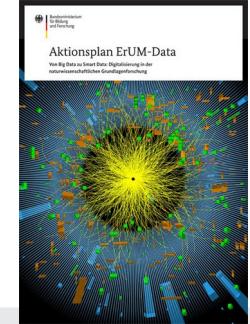


# Funding Source

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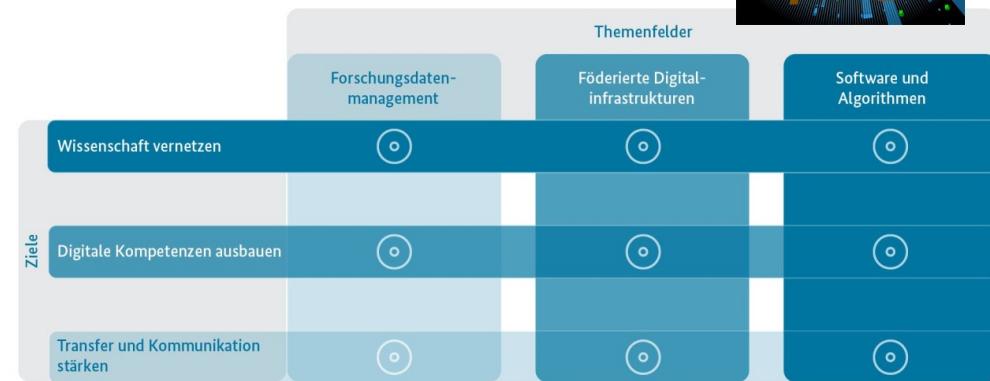
## ErUM-Pro

- 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 (to my knowledge)

### Software and Algorithms:

- AA Learning (AA, BN): Adversariales Lernen als neues Werkzeug in der Grundlagenphysik und darüber hinaus
- BRAID (KIT): Domänenübergreifende Vernetzung: KI-basierte, detektorunabh. Rekonstruktions-Frameworks für unregelmäßige hochdim. Daten
- DEEP (BN, KIT, FR): Steigerung der Dateneffizienz in eingebetteten Prozessoren durch künstliche Intelligenz
- ErUM-IFT-2 (AA): Informationsfeldtheorie für Experimente an Großforschungsanlagen
- PEARLS (FR): Präzision in energiebewusster KI-Forschung für CO2-arme Lösungen
- SciFM (AA, TUM): Grundlagenmodelle in Astrophysik und Teilchenphysik

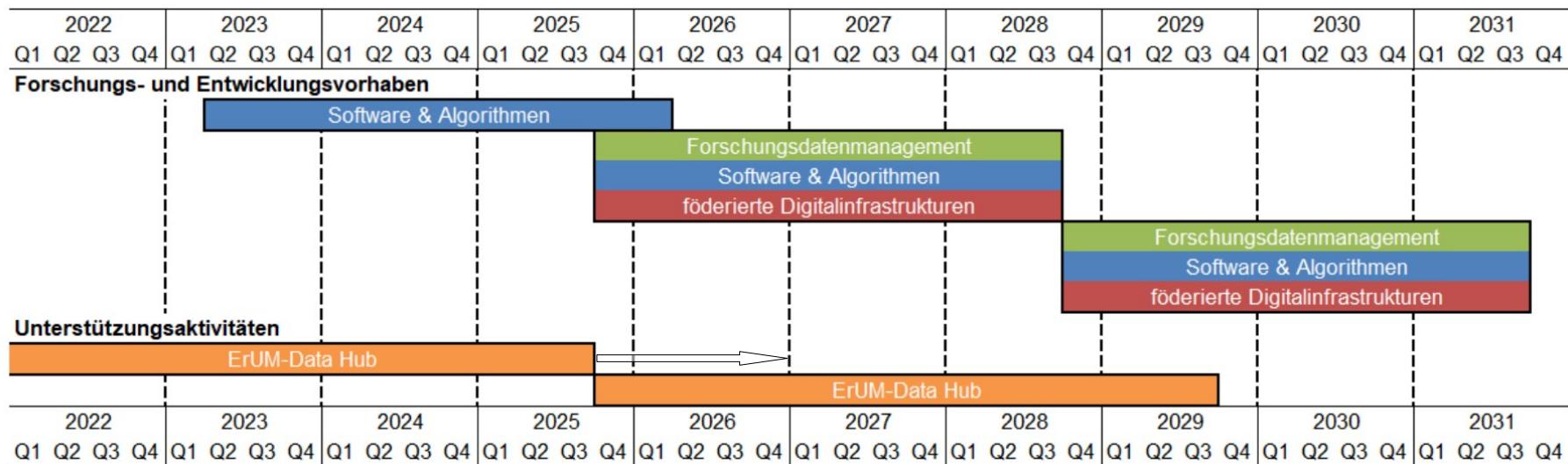
### Research Data Management:

- DEMOS (BO, LMU, MPP, TUM): Demokratisierung von Modellen: Plattform für den Austausch von Forschungsmodellen

### Federated Infrastructures:

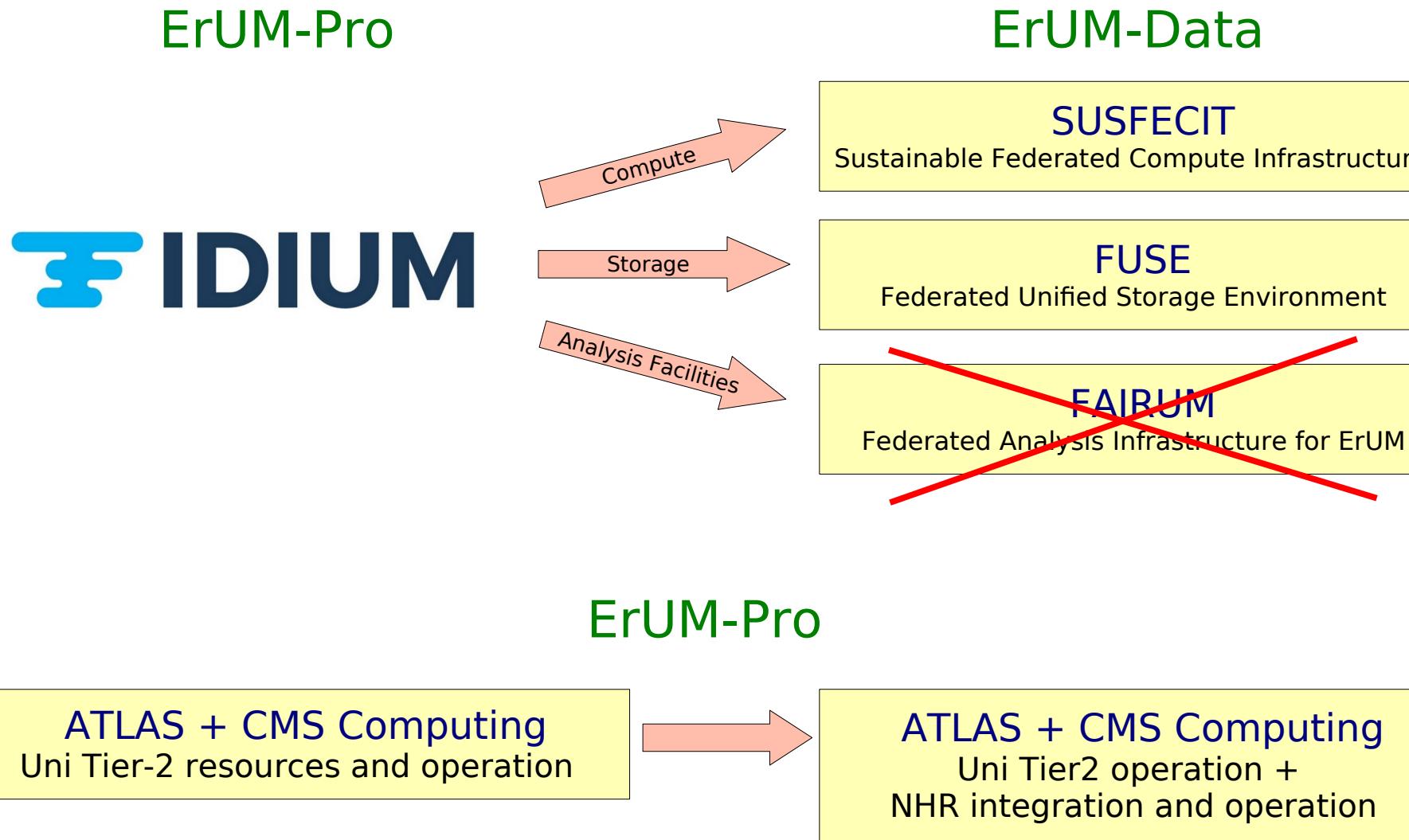
- FUSE (AA, DESY, GÖ, LMU, WU): Federated Unified Storage Environment
- SUSFECIT (BN, DESY, GÖ, FR, KIT): Nachhaltige Föderierte Computing-Infrastrukturen

Experiment specific needs not explicitly addressed



# Federated Infrastructure Projects

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# Analysis Facilities

- 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**  
(software stack, hardware, user support)

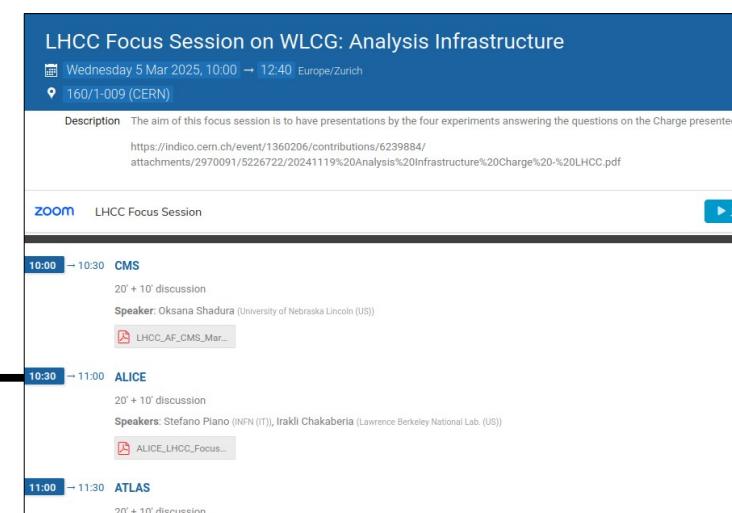
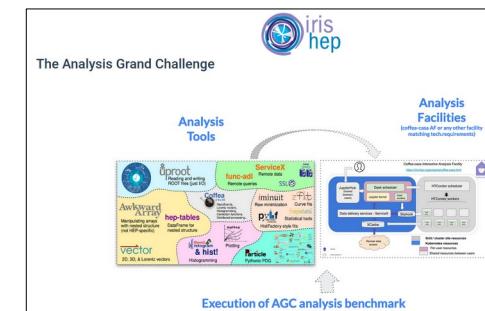
## Physics Briefing Book

### 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

## Analysis Facilities White Paper

C. Alpignani<sup>a</sup>, D. Cangatoglu<sup>a</sup>, A. Fer<sup>a</sup>, B. Heimann<sup>a</sup>, N. Sklenir<sup>a,b</sup>,  
K. S. Hwang<sup>a</sup>, M. Alay<sup>a</sup>, D. Benjamin<sup>a</sup>, B. Boehm<sup>a</sup>, L. Bryant<sup>a</sup>, J. Cataneo<sup>a</sup>, M. D'Alfonso<sup>a</sup>, A. Delgado Perez<sup>a</sup>, C. Doglioni<sup>a</sup>, C. Drabek<sup>a</sup>, P. Elmer<sup>a</sup>, J. Eschle<sup>a</sup>, M. Feikert<sup>a</sup>, J. Fries<sup>a</sup>,  
A. Gauthier<sup>a</sup>, V. Gavrilov<sup>a</sup>, M. Giffels<sup>a</sup>, J. Goedert<sup>a</sup>, E. Granatstein<sup>a</sup>, L. Grav<sup>a</sup>, B. Hegner<sup>a</sup>,  
A. Heij<sup>a</sup>, J. Hernández<sup>a</sup>, B. Helman<sup>a</sup>, B. Hwang<sup>a</sup>, B. K. Jashi<sup>a</sup>, D. Kostomarov<sup>a</sup>, E. Koulistis<sup>a</sup>,  
L. Krebs<sup>a</sup>, J. Kromymond<sup>a</sup>, T. Kuhn<sup>a</sup>, E. Latorre<sup>a</sup>, C. Lang<sup>a</sup>, D. Langlet<sup>a</sup>, J. Lange<sup>a</sup>, P. Louzi<sup>a</sup>,  
T. Linden<sup>a</sup>, V. Martini<sup>a</sup>, Ontescu<sup>a</sup>, S. Mekhora<sup>a</sup>, J. F. Molina<sup>a</sup>, M. Neubauer<sup>a</sup>, A. Novak<sup>a</sup>,  
I. Ouchchy<sup>a</sup>, F. Ould Serafy<sup>a</sup>, A. R. Barry<sup>a</sup>, K. Rehbein<sup>a</sup>, L. Brouca<sup>a</sup>, Yasuoka<sup>a</sup>, S. Rinaggio<sup>a</sup>,

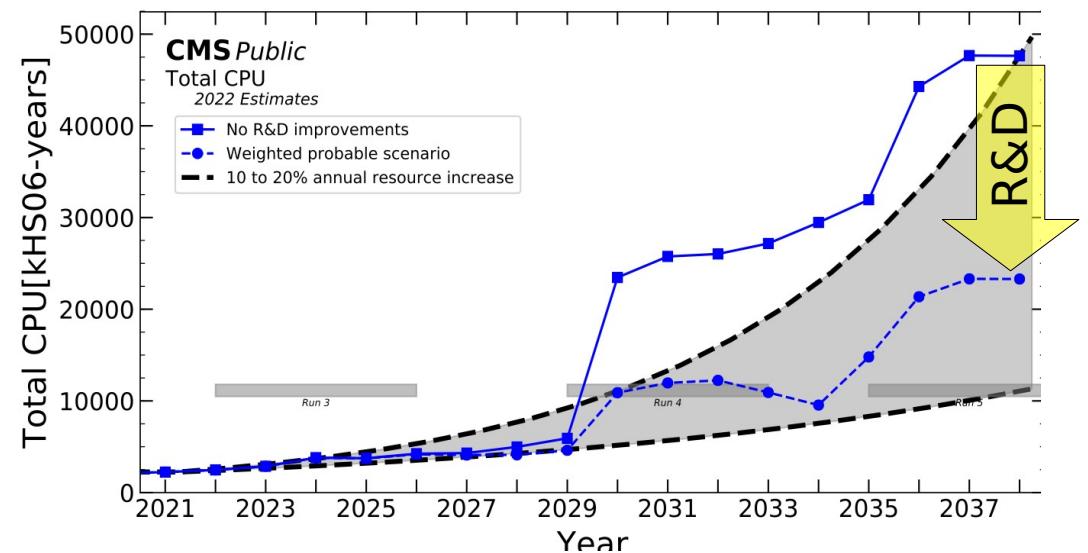


# High Impact Software Projects

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from the German community:

- Fast simulations developed in ErUM-Data project KISS
  - ML Integration and sampling for Sherpa und MadGraph (MadNIS)
  - GPU generator for Sherpa (Pepper) and MadGraph (CUDACPP)
  - Fast calorimeter simulations
  - ...
- Key4hep
- dCache
- COBaID/TARDIS
- AUDITOR
- ...



# 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

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- 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 (incl. NHRs) → ATLAS + CMS Computing Verbund (no hardware invest any more, some more personnel for NHR scaling)
  - ◆ Analysis facilities software R&D  
→ follow up on analysis technology developments in FIDICUM
  - ◆ 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

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