ICFA Data lifecycle panel:

Recommendations for data preservation and open science in particle physics

HSF Seminar - April 29, 2026

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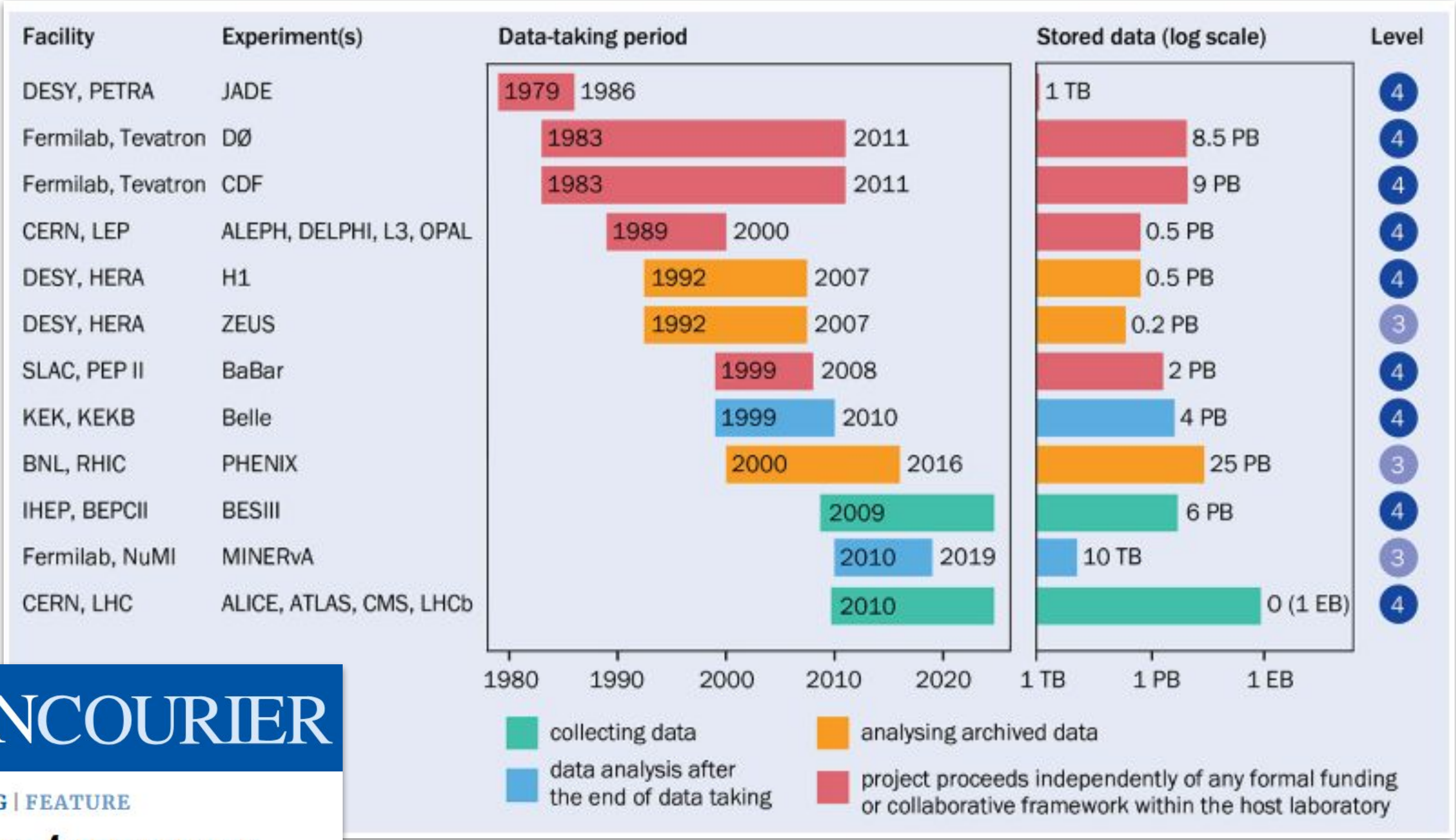
ICFA Data Lifecycle panel
Helsinki Institute of Physics - Finland

Great progress in data preservation

Continuing and renewed interest
Emerging tools
Scientific impact



CERNCOURIER

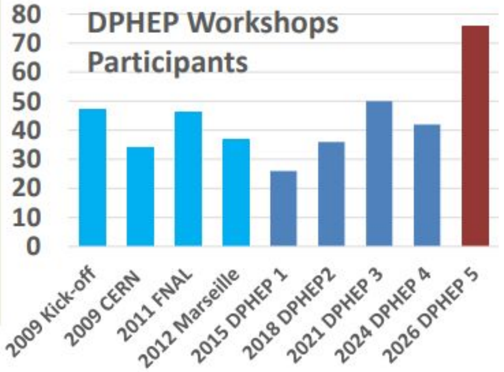
COMPUTING | FEATURE

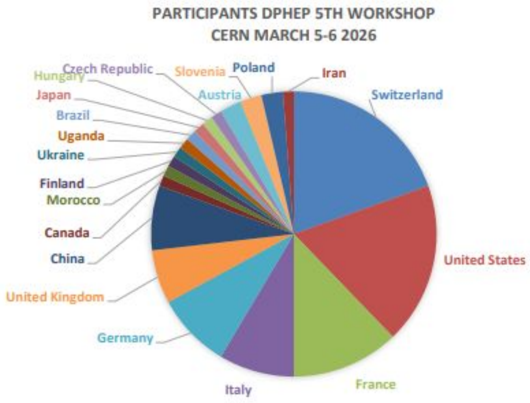
Hidden treasures

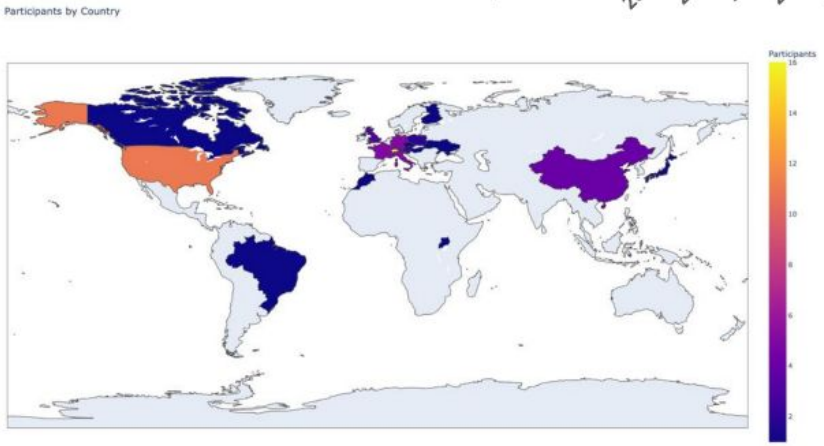
9 September 2025

5th DPHEP Workshop 2026

- High participation increasing interest
  - 76 registrants, 26 abstracts
- International coverage
- Representation of ”known” experiments and sites







Data preservation and open science?

What makes them happen?

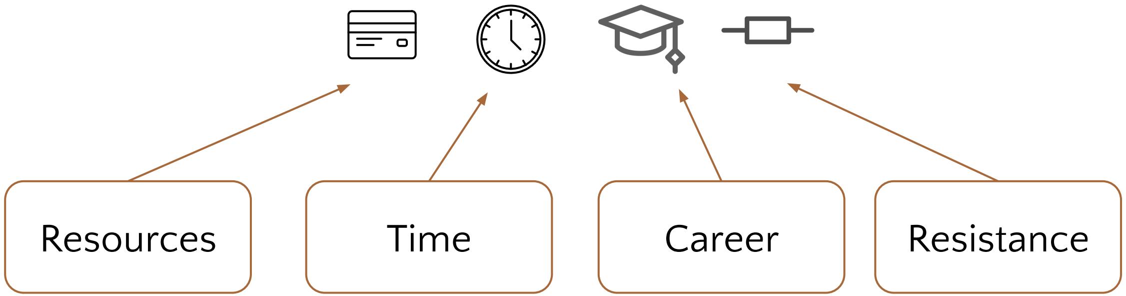
A structured approach or …

Magic?

Data preservation and open science:

…people with good will and necessary skills in positions in which they can do what they believe should be done despite of challenges!

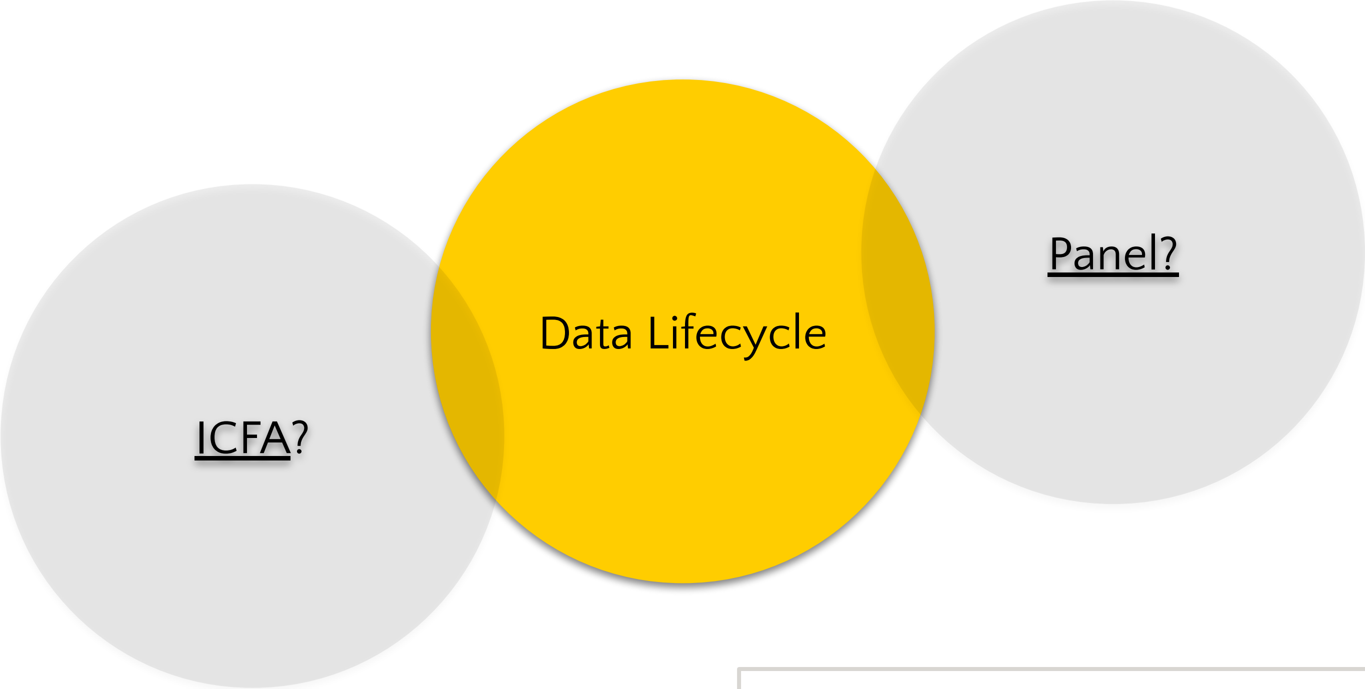
Challenges related to:



Part 1: Recommendations

Who are we?
How to spread the magic?
How to overcome the obstacles?
⇒ What are the best practices in HEP?

Who? Why?



ICFA: International Committee for Future Accelerators
ICFA Data Lifecycle panel: members, mission and mandate

What?

ICFA | Data Lifecycle? | Panel

ICFA Panel on the Data Lifecycle (Chair – Kati Lassila-Perini, Helsinki)

The mission of the panel is to enhance global coordination on all aspects of the data lifecycle including acquisition, processing, distribution, storage, access, analysis, simulation, preservation, management, software, workflows, computing and networking in particle physics, with a focus on open science and FAIR practices.

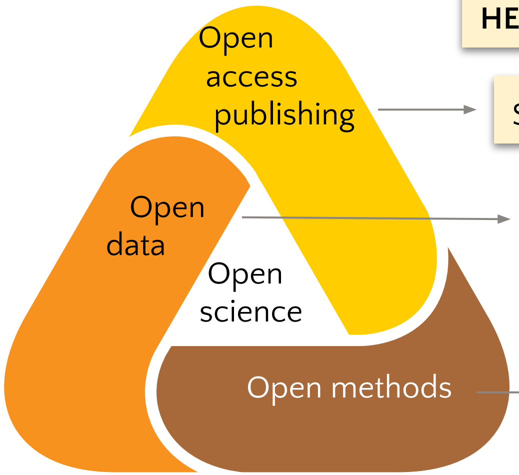
FAIR: Findable, Accessible, Interoperable, and Reusable digital assets (data, software, workflows, …)

In panel's mandate → [...] → formulate recommendations for Open Science

- Editorial group:
  - Panel + scientists and experts involved in the preservation of high-energy physics data.
  - Call for volunteers through
    - Data Preservation in High Energy Physics (DPHEP)
    - HEP Software Foundation (HSF) training
    - Open Science “service providers” in the community

The goal and the current situation in HEP

Key indicator of success: **long-term scientific usability of experimental data.**



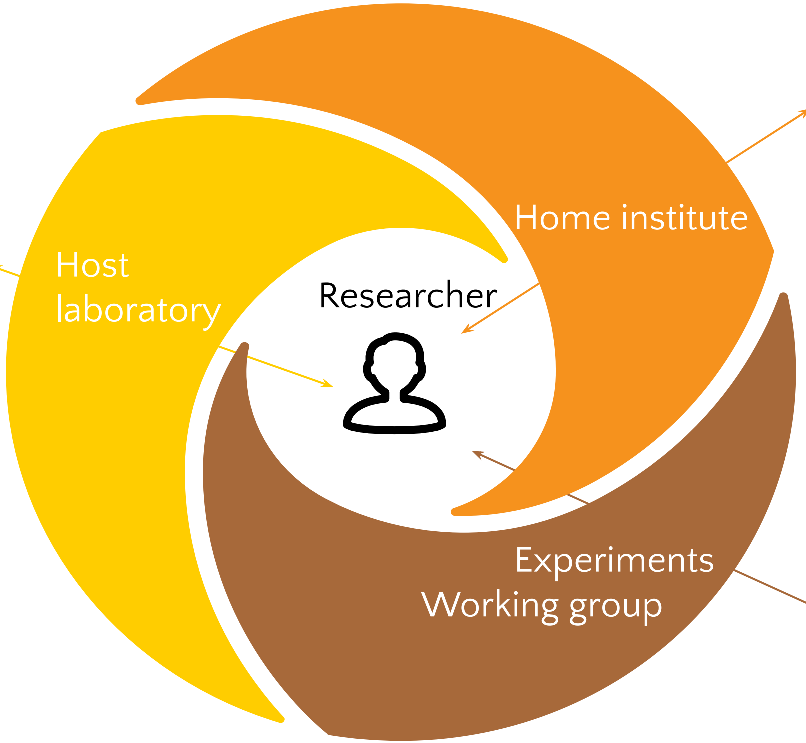
HEP community:

Strong standards.

Good progress.

Significant challenges in preserving analysis knowledge:
the workflows, software,
and contextual documentation.

Many stakeholders



Task definition, share of time on them
Resources (salary, travel, personal tools)
Education, training
Research/data management guidelines

Infrastructure
Resources
Open science guidelines

Responsibilities
Resources (computing, software)
Practices ("how do we work")
Policies

Design principles

Concrete

Use clear, practical language instead of high-level terms.

Specific

Keep specific to large (HEP) collaborations
Consider domain-specific tools and practices

Relevant

Indicate the audience, and use proper terminology for the reader.

Actionable

Outcome

High Energy Physics - Experiment

[Submitted on 26 Aug 2025]

Recommendations for Best Practices for Data Preservation and Open Science in HEP

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These recommendations are the result of reflections by scientists and experts who are, or have been, involved in the preservation of high-energy physics data. The work has been done under the umbrella of the Data Lifecycle panel of the International Committee of Future Accelerators (ICFA), drawing on the expertise of a wide range of stakeholders.
A key indicator of success in the data preservation efforts is the long-term usability of the data. Experience shows that achieving this requires providing a rich set of information in various forms, which can only be effectively collected and preserved during the period of active data use.
The recommendations are intended to be actionable by the indicated actors and specific to the particle physics domain. They cover a wide range of actions, many of which are interdependent. These dependencies are indicated within the recommendations and can be used as a road map to guide implementation efforts.
These recommendations are best accessed and viewed through the web application, see this https URL

Comments: These recommendations are best accessed and viewed through the web application, see this https URL Corresponding editor: Kati Lassila-Perini (contact via icfa-data-best-practices-contact at this http URL)
Subjects: **High Energy Physics - Experiment (hep-ex)**
Cite as: arXiv:2508.18892 **[hep-ex]**
(or arXiv:2508.18892v1 **[hep-ex]** for this version)
https://doi.org/10.48550/arXiv.2508.18892

Recommendations for best practices for data preservation and open science in HEP

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Filter by Actors

- [ ] host laboratory
- [ ] experiment management
- [ ] home institute
- [ ] WG leaders
- [ ] funding agency
- [ ] tool developers
- [ ] analysts
- [ ] data management
- [ ] open data group

Deselect all

Filter by Class

- [ ] Policy and management
- [ ] Infrastructure and services
- [ ] Software skills development
- [ ] Licenses, copyright and citations
- [ ] Community-wide software development
- [ ] Collaboration-specific software development
- [ ] Software and workflow management - analysis-specific SW
- [ ] Analysis preservation tools and practices
- [ ] Data management tools and practices
- [ ] Documentation and knowledge preservation
- [ ] Long-term sustainability
- [ ] Cost, funding and return of investment
- [ ] International collaboration

Deselect all

Show all descriptions Hide all descriptions

ID	Class	Recommendation	Actors	Depends on	Enables	Description
PM1	Policy and management	Develop a comprehensive archival policy that encompasses all relevant scientific research outputs generated through the organization's research activities, supported by clear governance frameworks and technical safeguards to ensure their long-term preservation.	host laboratory		PM13, PM9, PM3, PM17, PM16, PM14, PM19, DK4	Show description
PM2	Policy and management	If not directly governed by national open science policies, establish a comprehensive open science policy that commits the laboratory to making all relevant research outputs, including datasets, related software, and research findings, publicly accessible and freely available.	host laboratory		CF6, PM5, PM13, PM9, PM3, PM17, CF2, PM16, PM11, PM7, CF1	Show description

https://icfa-data-best-practices.app.cern.ch/
https://arxiv.org/abs/2508.18892
ICFA statement

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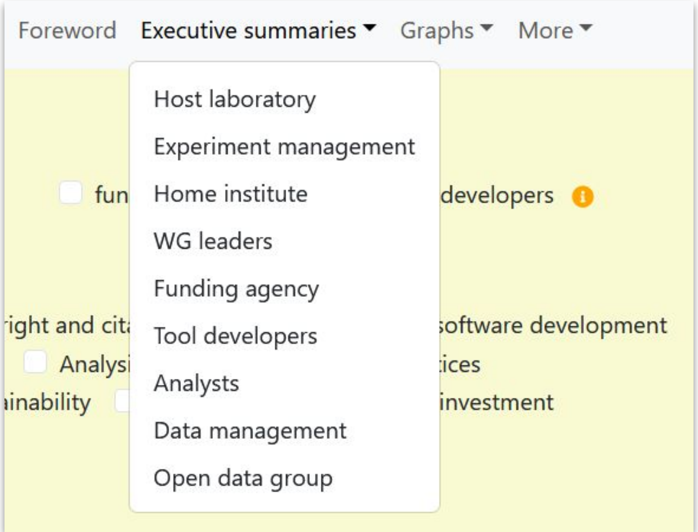
- [ ] International collaboration

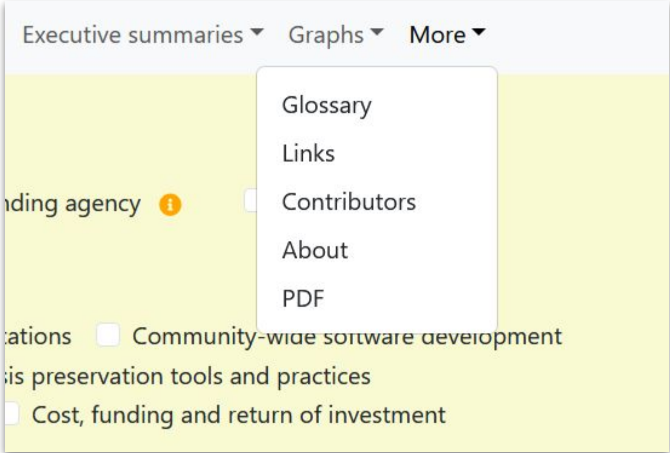
Deselect all

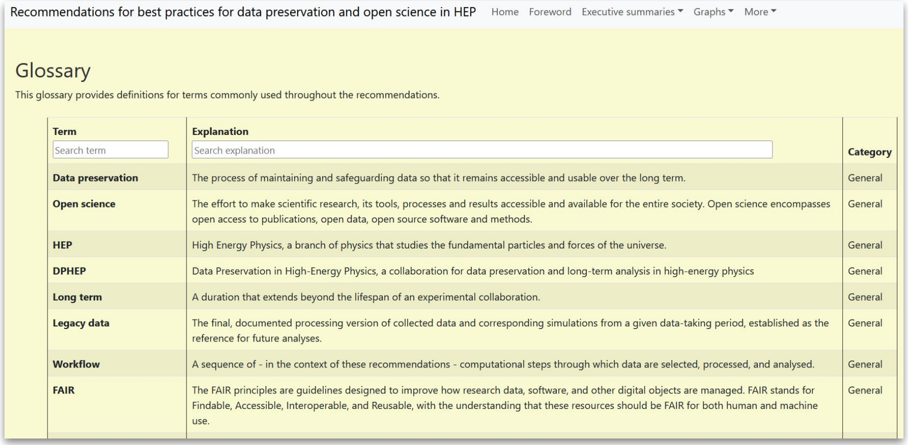
Show all descriptions Hide all descriptions

ID	Class	Recommendation	Actors	Depends on	Enables	Description
SW2	Software and workflow management - analysis-specific SW	From the early stages of an analysis, store your code in findable and accessible repositories within the version control infrastructure designated by the experiment.	analysts	SW1, IR1	SW11, SW9, SW8	Hide description
		Motivation Common analysis code repositories within an experiment make analysis code findable and accessible to all members of the experiment. This facilitates the use of common tools, sharing knowledge, and transparent analysis review.				
SW3	Software and workflow management - analysis-specific SW	Use code versioning tools (e.g. Git), and commit changes frequently to the common repository.	analysts	SK3, IR1	SW4, AP7, SW11	Hide description
		Motivation Code versioning ensures a clear history of changes, and enables easy rollback to previous versions. Frequent commits help catch issues early, make your progress visible, and reduce conflicts by integrating small, manageable updates regularly.				

For the best readability, select an actor role
Short recommendation, further description/motivation text available



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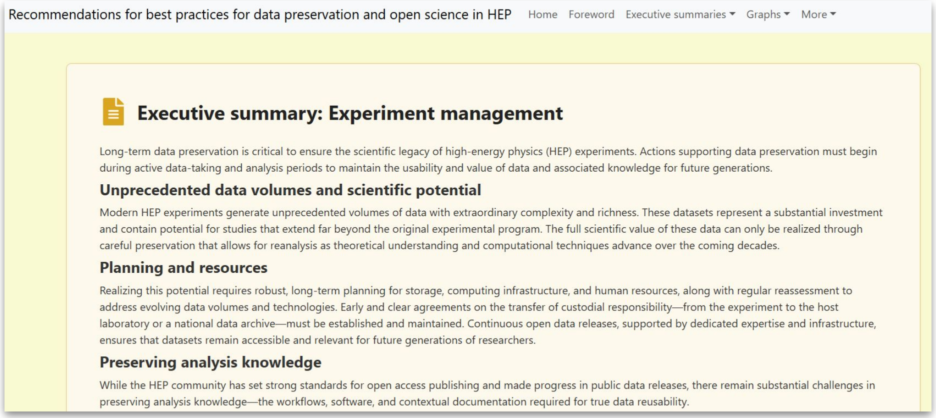
Glossary

This glossary provides definitions for terms commonly used throughout the recommendations.

Term	Explanation	Category
Search term	Search explanation	
Data preservation	The process of maintaining and safeguarding data so that it remains accessible and usable over the long term.	General
Open science	The effort to make scientific research, its tools, processes and results accessible and available for the entire society. Open science encompasses open access to publications, open data, open source software and methods.	General
HEP	High Energy Physics, a branch of physics that studies the fundamental particles and forces of the universe.	General
DPHEP	Data Preservation in High-Energy Physics, a collaboration for data preservation and long-term analysis in high-energy physics	General
Long term	A duration that extends beyond the lifespan of an experimental collaboration.	General
Legacy data	The final, documented processing version of collected data and corresponding simulations from a given data-taking period, established as the reference for future analyses.	General
Workflow	A sequence of - in the context of these recommendations - computational steps through which data are selected, processed, and analysed.	General
FAIR	The FAIR principles are guidelines designed to improve how research data, software, and other digital objects are managed. FAIR stands for Findable, Accessible, Interoperable, and Reusable, with the understanding that these resources should be FAIR for both human and machine use.	General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Executive summary: Experiment management

Long-term data preservation is critical to ensure the scientific legacy of high-energy physics (HEP) experiments. Actions supporting data preservation must begin during active data-taking and analysis periods to maintain the usability and value of data and associated knowledge for future generations.

Unprecedented data volumes and scientific potential

Modern HEP experiments generate unprecedented volumes of data with extraordinary complexity and richness. These datasets represent a substantial investment and contain potential for studies that extend far beyond the original experimental program. The full scientific value of these data can only be realized through careful preservation that allows for reanalysis as theoretical understanding and computational techniques advance over the coming decades.

Planning and resources

Realizing this potential requires robust, long-term planning for storage, computing infrastructure, and human resources, along with regular reassessment to address evolving data volumes and technologies. Early and clear agreements on the transfer of custodial responsibility—from the experiment to the host laboratory or a national data archive—must be established and maintained. Continuous open data releases, supported by dedicated expertise and infrastructure, ensures that datasets remain accessible and relevant for future generations of researchers.

Preserving analysis knowledge

While the HEP community has set strong standards for open access publishing and made progress in public data releases, there remain substantial challenges in preserving analysis knowledge—the workflows, software, and contextual documentation required for true data reusability.

Executive summaries for different actor groups
\+ Dependence graphs, glossary, links, contributor list, PDF note

Long-term preservation & scientific usability of experimental data.

Key takeaways:

Analysis software & workflow descriptions must be integral research outcomes.

Supplementary information & contextual knowledge for data understanding and (re)use must be preserved..

Software skills to follow these practices should be developed.

Policies & resources should support these practices.

Picked up for you…

- Some examples…

PM7 Policy and management **Actor:** experiment management

Agree on and approve a software management plan for data and simulation processing software, and for analysis and publication-related code, with the ultimate goal of making all research products—including analysis code—open, and establishing reusable workflows as the standard for all analyses.

Motivation

Establishing this goal recognizes that software is an essential component of research products, alongside data and results, and that science cannot be fully open without access to code. Making software openly available as a research product is an emerging practice, and these recommendations offer a roadmap of actions for achieving this.

Adopting the practice of making code accessible to others brings concrete benefits. In the short term, it streamlines analysis work by making code sharing and collaborative contributions easier within the analysis team. In the longer term, it ensures that the knowledge and technical implementation of the analysis remain accessible for future work within the collaboration. Sharing the code provides a precise and unambiguous description of the analysis procedure, and makes it reusable within the experiment for future analyses and collaborative efforts.

Descripti

The plan can be pa ... document, and should contain:

- What: Description of management, preservation, ...
- When: The schedule for software archiving and sharing.
- Where: Location where software will be shared and archived over the long-term.
- How: Enable reuse of software through assigning a DOI, license, contribution guidelines, etc.

Note: Not proposing changes to the data release model (i.e. data releases with an embargo period). This is about releasing code as unambiguous description of analysis methods.

Analysis software & workflow descriptions must be integral research outcomes.

Supplementary information & contextual knowledge
for data understanding and (re)use must be preserved..

CS3	Collaboration-specific software development	Ensure that the source code for all versions of the central data-taking, simulation, and reconstruction software of the experiment is preserved, accessible and operable.	experiment management, tool developers
CS4	Collaboration-specific software development	Ensure that all collaboration-specific software not included in central dataset processing —such as code for deriving physics object corrections —is preserved, accessible, and properly documented with respect to the use of its outputs.	experiment management, tool developers
CS5	Collaboration-specific software development	Provide comprehensive documentation that corresponds to all available source code releases.	experiment

Provide

Preserve

Recognise

Encourage

Require

Keep accessible

Documentation, documentation, documentation…

DK1	Documentation and knowledge preservation	Provide sufficient documentation in each software repository for other researchers to understand and use the code.	analysts
DK2	Documentation and knowledge preservation	Incorporate thorough documentation of work as a criterion in employee performance evaluations, with appropriate recognition or rewards.	experiment management, home institute
DK3	Documentation and knowledge preservation	Avoid using proprietary or closed-source formats for documentation, instructions, and tutorials.	analysts, experiment management, WG leaders
DK4	Documentation and knowledge preservation	Establish procedures to guarantee that documentation stays accessible throughout the experiment's lifecycle and can be openly shared when appropriate, with clear protocols for preservation and access management beyond the experiment's duration.	experiment management, host laboratory
DK5	Documentation and knowledge preservation	Establish guidelines for making public relevant sections of internal notes and documentation.	experiment management, WG leaders
DK6	Documentation and knowledge preservation	Encourage developers and maintainers of relevant software tool repositories to provide clear documentation on code design principles and contributing practices to facilitate easy and efficient onboarding of new team members.	WG leaders
DK7	Documentation and knowledge preservation	Accompany openly released data with example analysis workflows to increase their usability.	open data group
DK8	Documentation and knowledge preservation	Through application guidelines and funding decisions, ensure that funded projects contributing to the experiments or utilizing their data provide sufficient documentation of their research outputs to guarantee their reusability.	funding agency

PM15 | Policy and management | **Actor:** experiment management, host laboratory

Develop and approve a comprehensive metadata preservation plan that captures all collaboration information not covered by the data management (PM3), web presence (PM14), or software management (PM7) plans.

Description

These can be metadata related to specific analysis, such as lead editors or authors, code repositories, and internal documentation. They can include systems through which analysis-critical metadata are provided, e.g. configuration databases, cross-section or calibration data.

IR5 | Infrastructure and services | **Actor:** host laboratory

Work with experiments' management to identify long-term needs and provide suitable infrastructure for hosting conditions databases and essential related services that support future data reuse.

Motivation

Conditions databases store critical information such as calibrations, detector settings, and environmental parameters needed to accurately interpret preserved data. Maintaining fully operational systems over many years can be costly and challenging to sustain. By consulting with experiment teams to assess scientific needs, laboratories can prioritize maintaining essential components while gradually phasing out less critical services. This approach keeps preserved data usable for future research without overburdening infrastructure and staffing.

Supplementary information & contextual knowledge
for data understanding and (re)use must be preserved..

Software skills
to follow these practices should be developed.

ID	Class	Recommendation	Actors
SW1	Software and workflow management - analysis-specific SW	Mandate the use of findable and accessible version control infrastructure for analysis-specific software.	experiment management
SW2	Software and workflow management - analysis-specific SW	From the early stages of an analysis, store your code in findable and accessible repositories within the version control infrastructure designated by the experiment.	analysts
SW3	Software and workflow management - analysis-specific SW	Use code versioning tools (e.g. Git), and commit changes frequently to the common repository.	analysts
SW4	Software and workflow management - analysis-specific SW	Use, where available and appropriate, repository collaboration tools such as issue tracking and merge/pull requests, category tags, and milestones.	
SW5	Software and workflow management - analysis-specific SW	If contributions to an analysis code repository from other developers are welcomed, provide clear "how-to-contribute" instructions.	
SW6	Software and workflow management - analysis-specific SW	Avoid hardcoding input parameters that are likely to change within the lifecycle of your analysis or for similar analyses in the future; make the code configurable instead.	
SW7	Software and workflow management - analysis-specific SW	Structure the analysis code into repositories or subdirectories that correspond to different steps in the analysis workflow.	analysts
SW8	Software and workflow management - analysis-specific SW	Use well-defined environments, such as software containers or virtual environments, and make them explicit in the code repository.	analysts
SW9	Software and workflow management - analysis-specific SW	Implement meaningful automated tests at multiple levels to ensure code quality and facilitate reproducible analyses.	analysts, tool developers
SW10	Software and workflow management - analysis-specific SW	Implement and use well-defined software workflows, and provide detailed comments and/or dedicated documentation.	analysts
SW11	Software and workflow management - analysis-specific SW	Create checkpoints of analysis code repositories, for example through Git tags, to clearly correspond to the stages of the analysis.	WG leaders, analysts
SW12	Software and workflow management - analysis-specific SW	Prioritize contributions to established software infrastructure over the development of new tools in funding guidelines and evaluations.	funding agency

Software and workflow management skills - analysis-specific SW

AP1	Analysis preservation tools and practices	Provide tools and storage for internal analysis information, and enforce their use.	experiment management
AP2	Analysis preservation tools and practices	Encourage the adoption of best practices (SW2-11) starting from the early stages of an analysis.	experiment management, WG leaders
AP5	Analysis preservation tools and practices	Encourage the use of, and contributions to, common analysis tools.	experiment management, WG leaders
AP6	Analysis preservation tools and practices	Integrate automated analysis workflows into analysis software or common software tools, and encourage their implementation across working groups and experiments.	experiment management, WG leaders, tool developers, analysts
AP7	Analysis preservation tools and practices	Require that code in analysis code repositories be checkpointed using a version-control tag or archived to correspond to the publication.	experiment management, WG leaders
AP8	Analysis preservation tools and practices	Require that all code and configuration necessary to produce the final plots in an analysis be findable, available, and reusable as a condition for approval.	experiment management, WG leaders

Software skills
to follow these practices should be developed.

AP10	Analysis preservation tools and practices	Provide selected reusable analysis workflows that are compatible with the released or forthcoming open data.	experiment management, WG leaders, analysts
AP11	Analysis preservation tools and practices	Set a goal to establish reproducible analyses as a standard, and provide clear, actionable guidelines covering code, software environments, workflows, metadata, and documentation.	experiment management, WG leaders
AP13	Analysis preservation tools and practices	Provide analysis metadata and supplementary data products, such as corrections, in centrally managed, version-controlled locations so that they can be linked unambiguously to an analysis.	experiment management, WG leaders, analysts

“Provide”

“Encourage”

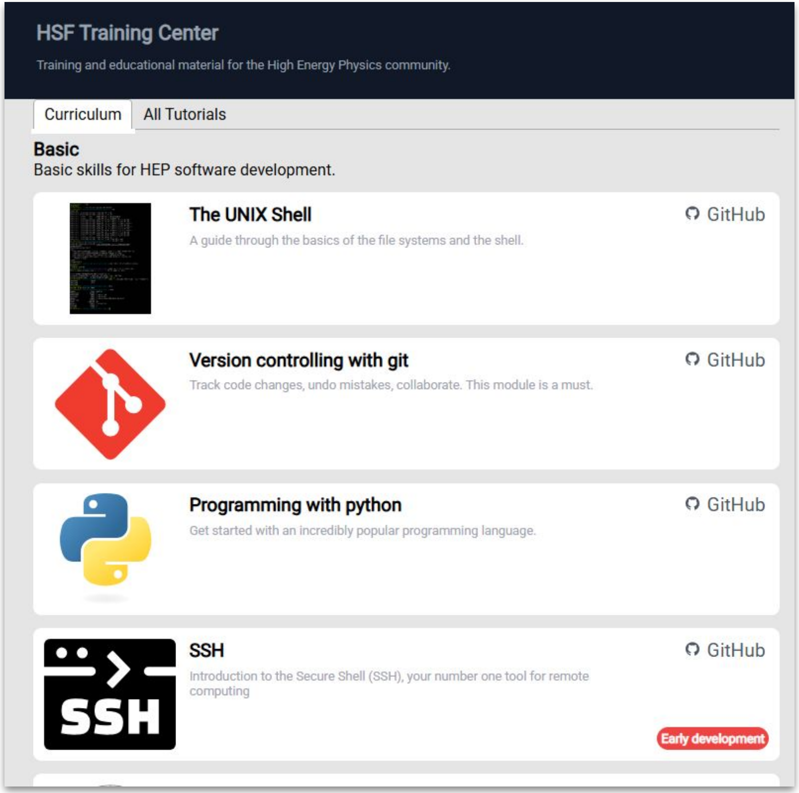
“Require"

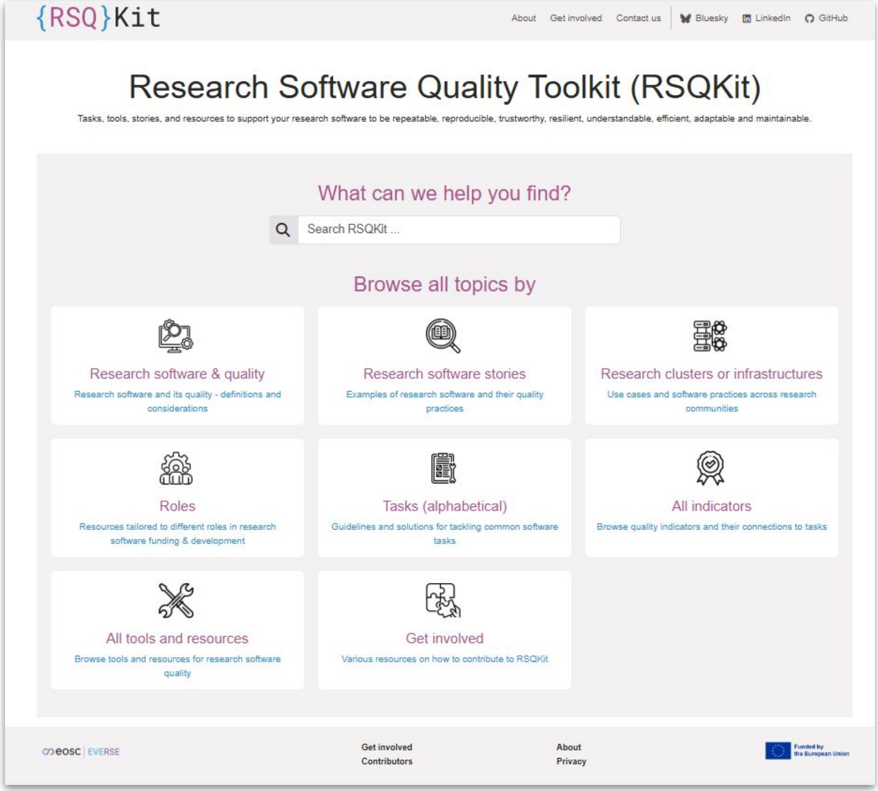
***Experiment management**: Analysis preservation tools and practices*

AP4	Analysis preservation tools and practices	Record and store analysis configuration information in human- and machine-readable form.	analysts
AP6	Analysis preservation tools and practices	Integrate automated analysis workflows into analysis software or common software tools, and encourage their implementation across working groups and experiments.	experiment management, WG leaders, tool developers, analysts
AP9	Analysis preservation tools and practices	Make the analysis code and configuration information needed for final plots and results findable, available, and reusable.	analysts
AP10	Analysis preservation tools and practices	Provide selected reusable analysis workflows that are compatible with the released or forthcoming open data.	experiment management, WG leaders, analysts
AP12	Analysis preservation tools and practices	Document or package the software environments used to produce the final analysis results.	analysts
AP13	Analysis preservation tools and practices	Provide analysis metadata and supplementary data products, such as corrections, in centrally managed, version-controlled locations so that they can be linked unambiguously to an analysis.	experiment management, WG leaders, analysts
AP14	Analysis preservation tools and practices	Publish analysis-specific code and workflow descriptions to archival repositories at the time of the paper publication. for DOI generation.	WG leaders, analysts

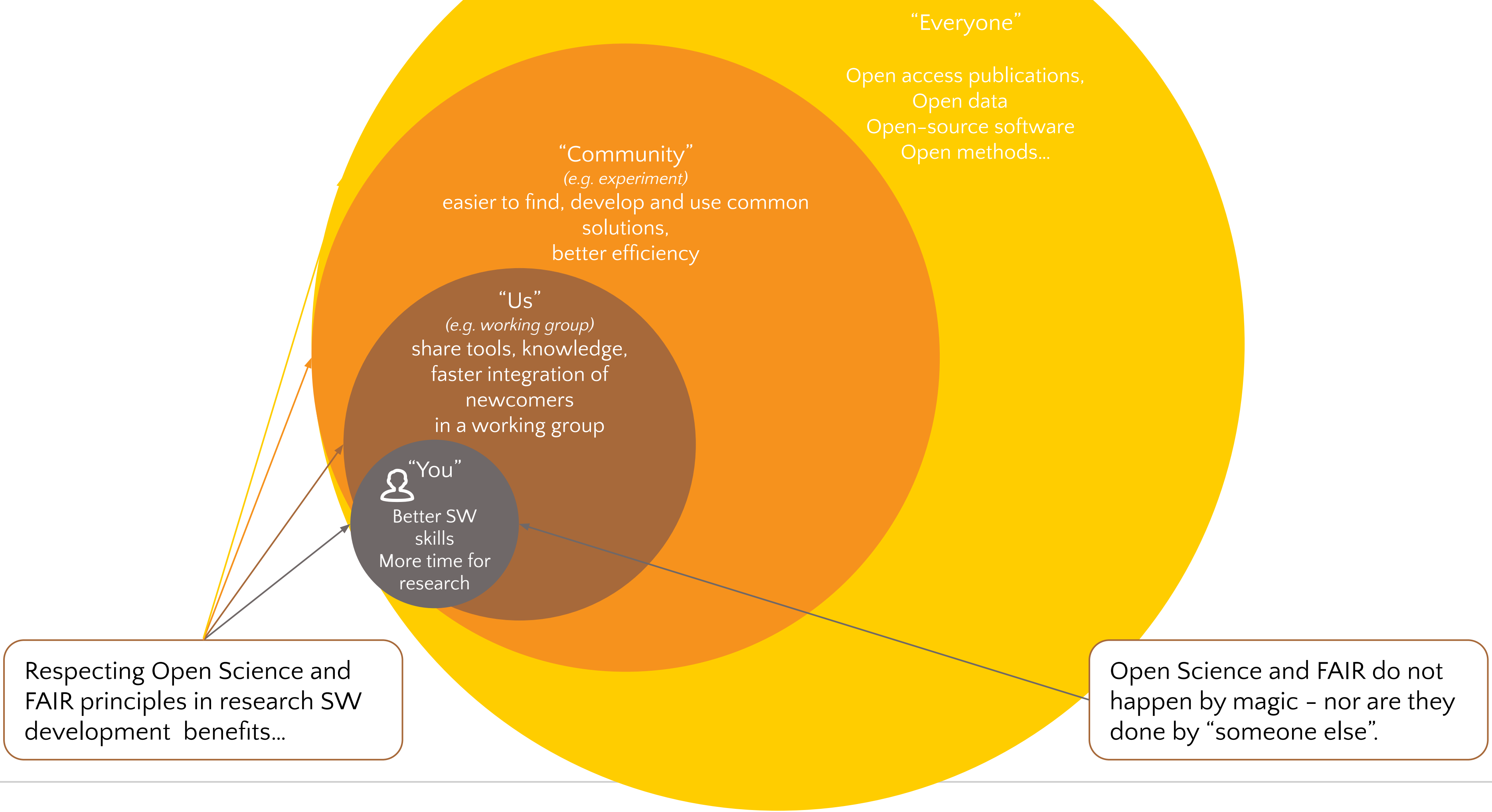
Software skills
to follow these practices should be developed.

Analysts: *Analysis preservation tools and practices*





Common points and a productive overlap with the HSF training initiative and EVERSE activities: see Caterina's slides



"Everyone"
Open access publications,
Open data
Open-source software
Open methods...
"Community"
(e.g. experiment)
easier to find, develop and use common solutions,
better efficiency
"Us"
(e.g. working group)
share tools, knowledge,
faster integration of newcomers
in a working group
"You"
Better SW skills
More time for research
Respecting Open Science and FAIR principles in research SW development benefits...
Open Science and FAIR do not happen by magic – nor are they done by "someone else".

Impact?

What's next?

Part 2: Assessment

Make recommendations known
Evaluate how different actors implement these recommendations
Report and share solutions

Next?

Discuss

Within the community and with neighbouring fields

Seminars, presentations

Assess

Start with the decision-level actor groups that make possible actions by others

- **Host laboratories**, **experiment managements**
- Funding agencies
  - with the help of national or regional committees or bodies that provide input to them.

Assessment design principles

Impact

Reach out through high-level management.
Request verifiable information (not just yes/no).

Good user experience

Well-defined options. Also “non applicable”
Allow intermediate save. Allow working in teams.

Reuse

Store responses to be compared to later.
Plan for regular assessment rounds.

Careful planning, proper tooling

Assessment - impact

- Increase awareness at the decision-making level
    - Reach out to high-level management
    - Experiments:
        - the assessment **team** (not a single person) should present the experiment management
- Report back
    - share solutions.

Assessment - verifiable information

Status options:	The assessment team should…
Applied	provide links to the relevant information (document/services/instructions)
Partially applied	provide links to the relevant information (document/services/instructions) indicate what is missing
Planned	indicate the timeline
Not yet considered	indicate reasons for not being yet considered. indicate the timeline to be considered.
Not applicable	indicate the reasons why

Links can be internal.

Invite some collaboration members to verify their findability, accessibility, and relevance.

They will report back to the assessment team who may update responses accordingly.

Use this information: **to build experiment-specific recommendation facets if desired**
to improve and update the recommendations if needed.

CS4	Partially applied Links to the relevant information (documents/ services/ instructions). You can use markdown. What is missing?	Collaboration-specific software development	Ensure that all collaboration-specific software not included in central dataset processing—such as code for deriving physics object corrections —is preserved, accessible, and properly documented with respect to the use of its outputs.	experiment management, tool developers			Show description
CS5	Partially applied Links to the relevant information (documents/ services/ instructions). You can use markdown. What is missing?	Collaboration-specific software development	Provide comprehensive documentation that corresponds to all available source code releases.	experiment management, tool developers			Show description
CS6	Planned -- Select timeline -- -- Select timeline -- Within 6 months Within 1 year Within 2 years Longer term	Collaboration-specific software development	Promote the use of documentation building tools and provide training on their use.	experiment management, tool developers	CS3		Show description
SW1		Software and workflow management - analysis-specific SW	Mandate the use of findable and accessible version control infrastructure for analysis-specific software.	experiment management	IR1	AP5, AP6, AP3, SW4, SW2	Show description

Assessment - outcome?

Assess

Raise awareness:
regular assessments rounds at ~2y intervals
sync with management changes
start with an introduction session
highlight benefits

Report

Share solutions:
focus on the overall picture
why certain actions not taken
identify common challenges
highlight successful actions
no emphasis on specific shortcomings

Impact

Monitor progress:
compare to previous rounds
encourage change
keep the impact positive

Summary:
From recommendations to action

- The recommendations:
  - **Concrete, Specific & Relevant:** actionable best-practice recommendations for data preservation and open science co-created by the HEP community.
  - Well aligned with and complementing the work done in **HSF** and **EVERSE** projects.
- The assessment process (starting soon):
  - **Raise awareness**: reach beyond the DPHEP community.
  - **Share solutions**: highlight good practices and working examples.
  - **Improve**: encourage actions to prevent future pain points.
  - **Measure impact**: repeat at regular intervals.

Outlook

Ultimately:
next-to-nextGen particle physicist in *2070*'s* preparing for *pp** datataking:

We had these awesome data from the old *LHC**, but nobody knows how to use them anymore….

These awesome data and knowledge from the old *LHC** were properly preserved, and are still usable!!!

LET US TAKE THE RIGHT SIDE OF HISTORY!

*: choose your input parameters

Thank you!

Questions?
Discussion?

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