

EXPLORING THE UNIVERSE FROM MICROSCOPIC TO MACROSCOPIC SCALES



# Research Data Management at the Institute for Nuclear Physics:

## The Example of the Research Cluster ELEMENTS

Johann Isaak

Technische Universität Darmstadt

### Spokespersons:

Prof. Dr. Luciano Rezzolla (GU Frankfurt)

Prof. Dr. Tetyana Galatyuk (TU Darmstadt, GSI)

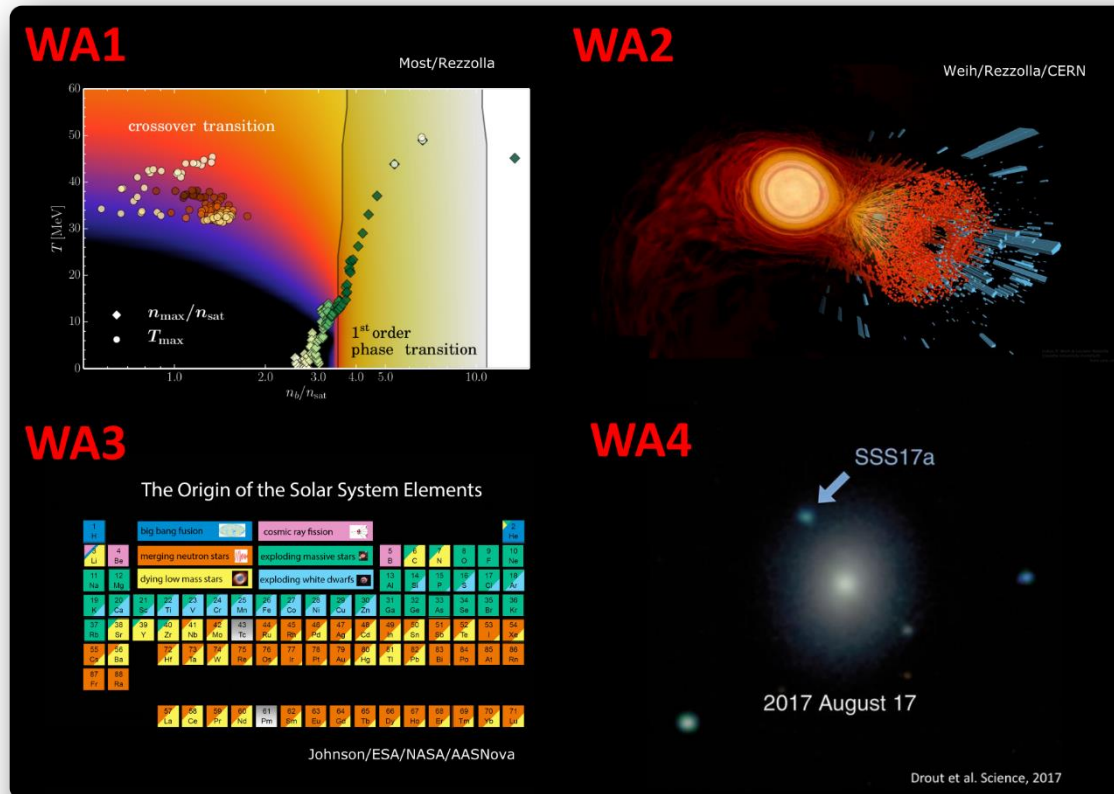
Prof. Dr. Dr. h.c. mult. Norbert Pietralla (TU Darmstadt)

# Research in ELEMENTS

... addresses the physics of gravity, hadrons, nuclei, and atoms with numerical simulations and accelerator-based experiments.



*From microscopic dynamics  
to the equation of state (EOS)  
of dense nuclear matter*



*From collisions of heavy ions  
to collisions of neutron stars*

*Nucleosynthesis of  
heavy elements*

*Electromagnetic signals  
from compact stars*

# Research in ELEMENTS



## Macrophysics:

- Neutron-star mergers and supernovae
- Lightcurves and nucleosynthesis

## Microphysics:

- Matter under extreme conditions
- Nuclear structure
- Nuclear and atomic reactions

## Infrastructure:

- Particle accelerators
- GSI/FAIR & S-DALINAC

GSI/FAIR



S-DALINAC/TU Darmstadt



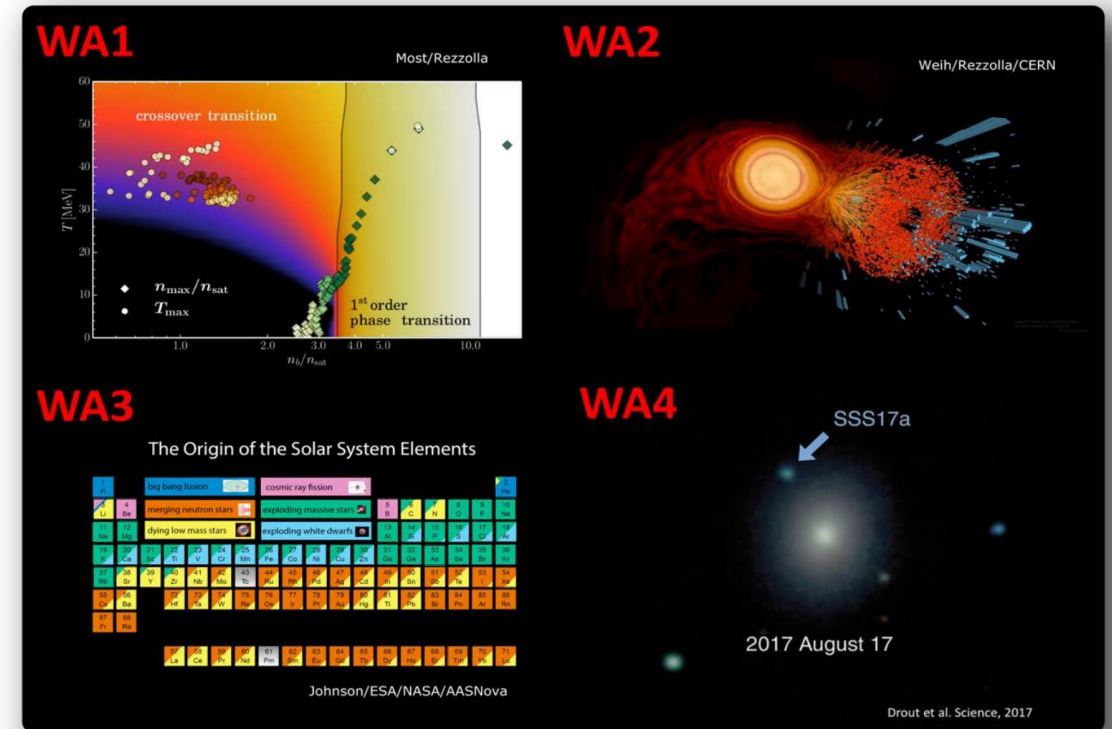


# Research data in ELEMENTS



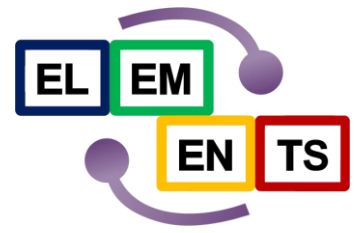
## Expected generated data very diverse

- measurement of raw data / signals (experiments with stable & unstable nuclei , astronomical observations, ...)
- calculation of observables with different theoretical approaches (chiral EFT, EDF, lattice QCD, ...)
- analysis software (Python, C++, ROOT, ...)
- visualization of data (nuclear spectra, EOS, ...)



**diverse projects with huge differences in data formats, processing, data sizes and storage requirements**

# Data management plan (DMP)



TUdmo

Feedback Language Login

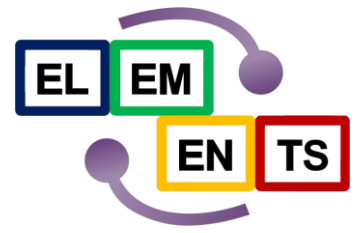
## TUdmo

- The tool to support the planning and implementation of research data management at TU Darmstadt.

<https://tudmo.ulb.tu-darmstadt.de/>

- systematically deal with your research data from the very beginning!
- important to make your data interpretable and reusable for later time; also for third parties
- similar platform: Goethe-RDMO (<https://rdmo.server.uni-frankfurt.de/>)

# Data management plan (DMP)



tudmo

Feedback Language+ Login

## TUdmo

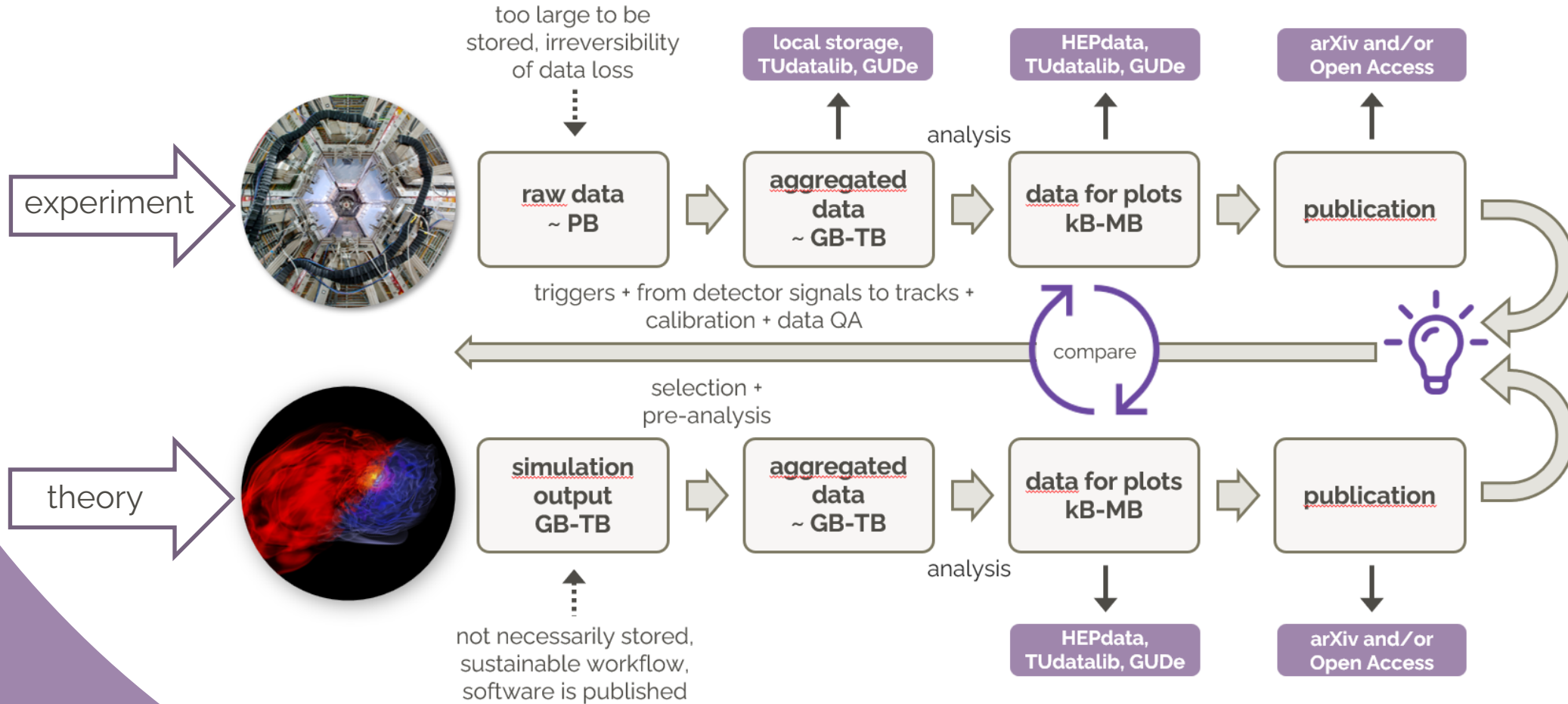
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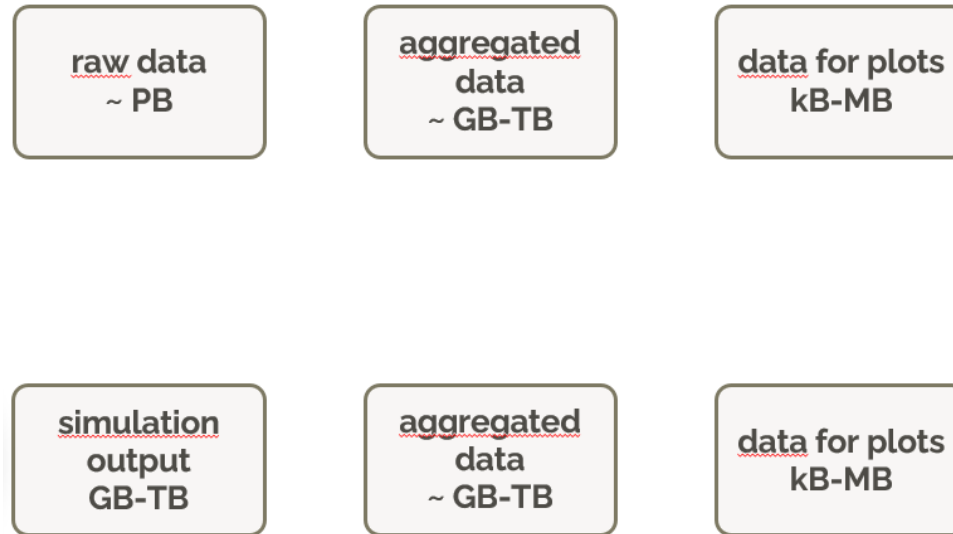
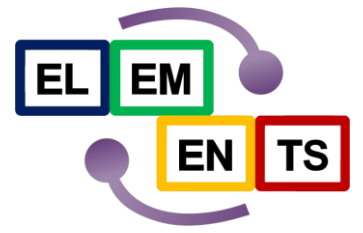
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- important to make your data interpretable and reusable for later time; also for third parties
- similar platform: Goethe-RDMO (<https://rdmo.server.uni-frankfurt.de/>)

- each project: collaboratively create and maintain a DMP in the beginning
- update DMP regularly (every six months)
- templates being continuously further developed towards our field-specific needs

# RDM workflow

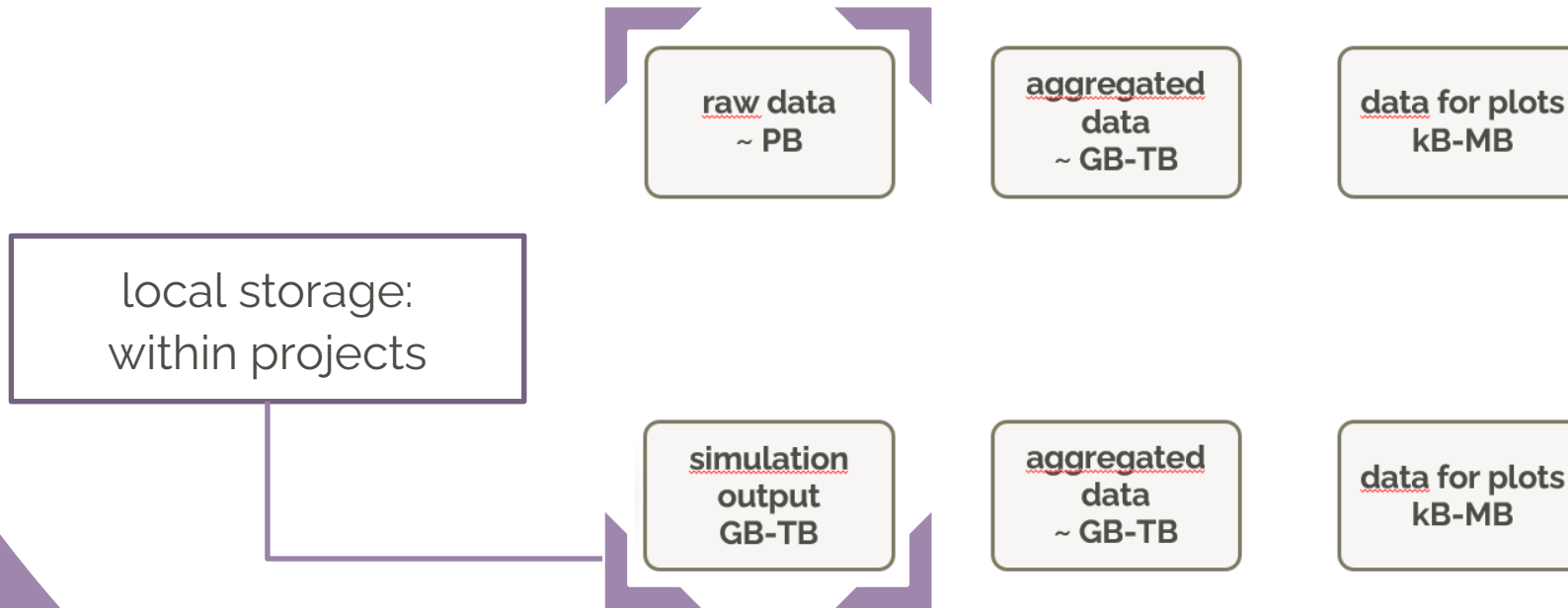


# Data classification: difference in scales of data sizes

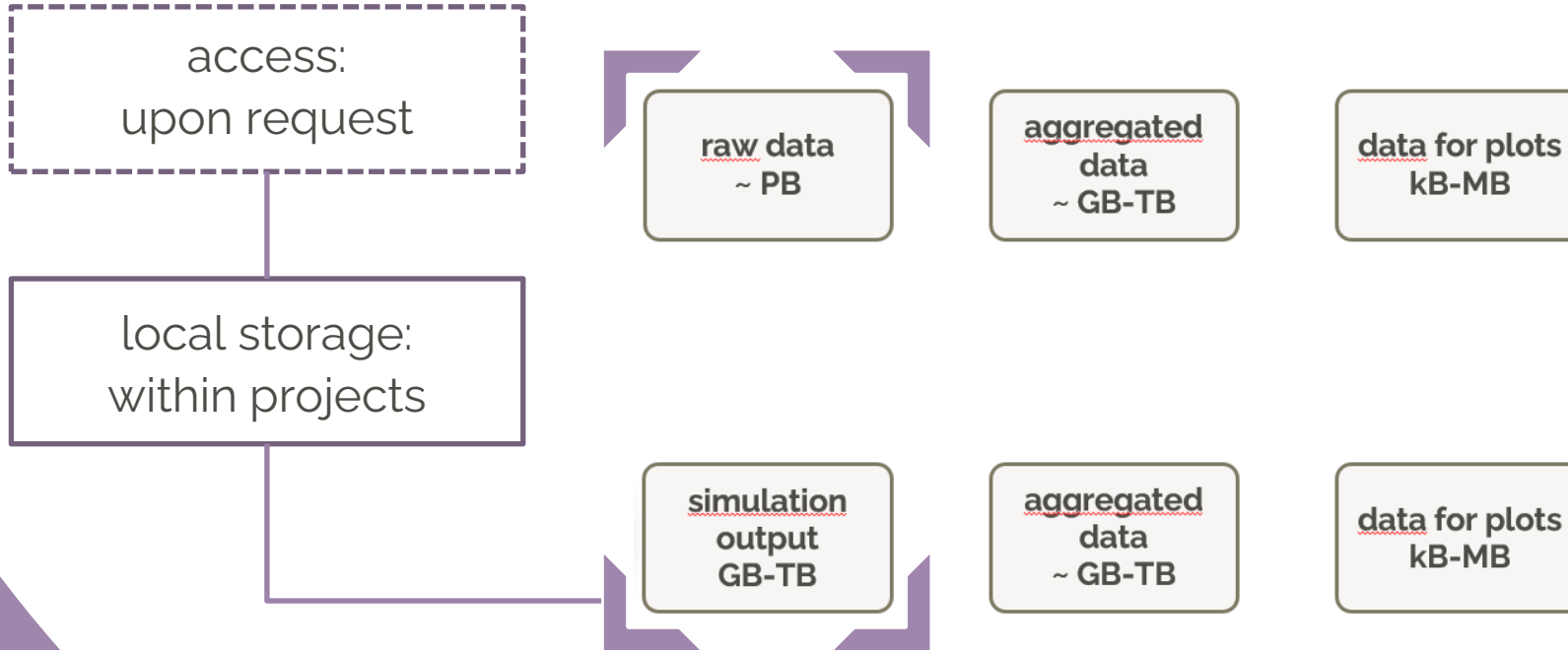




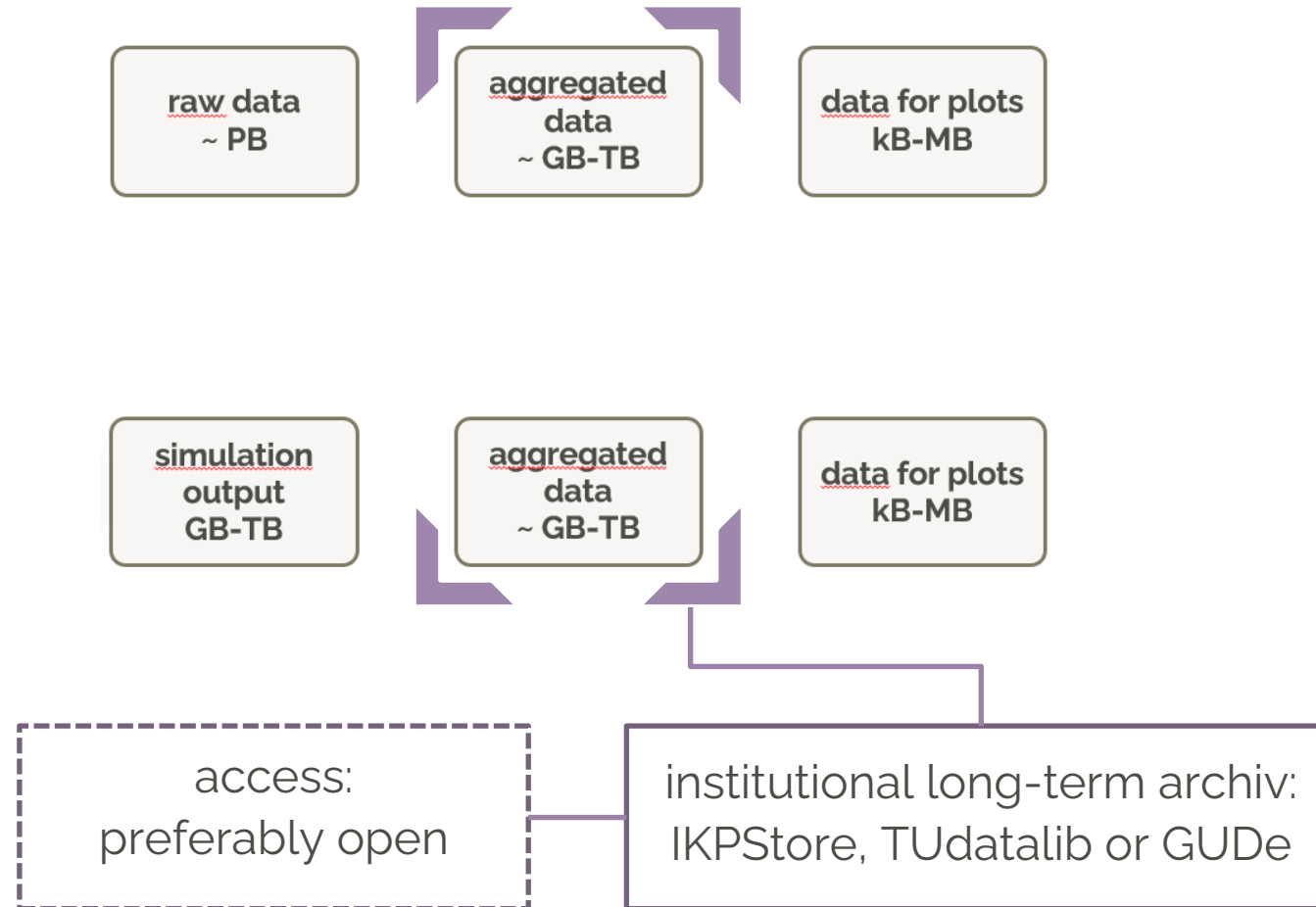
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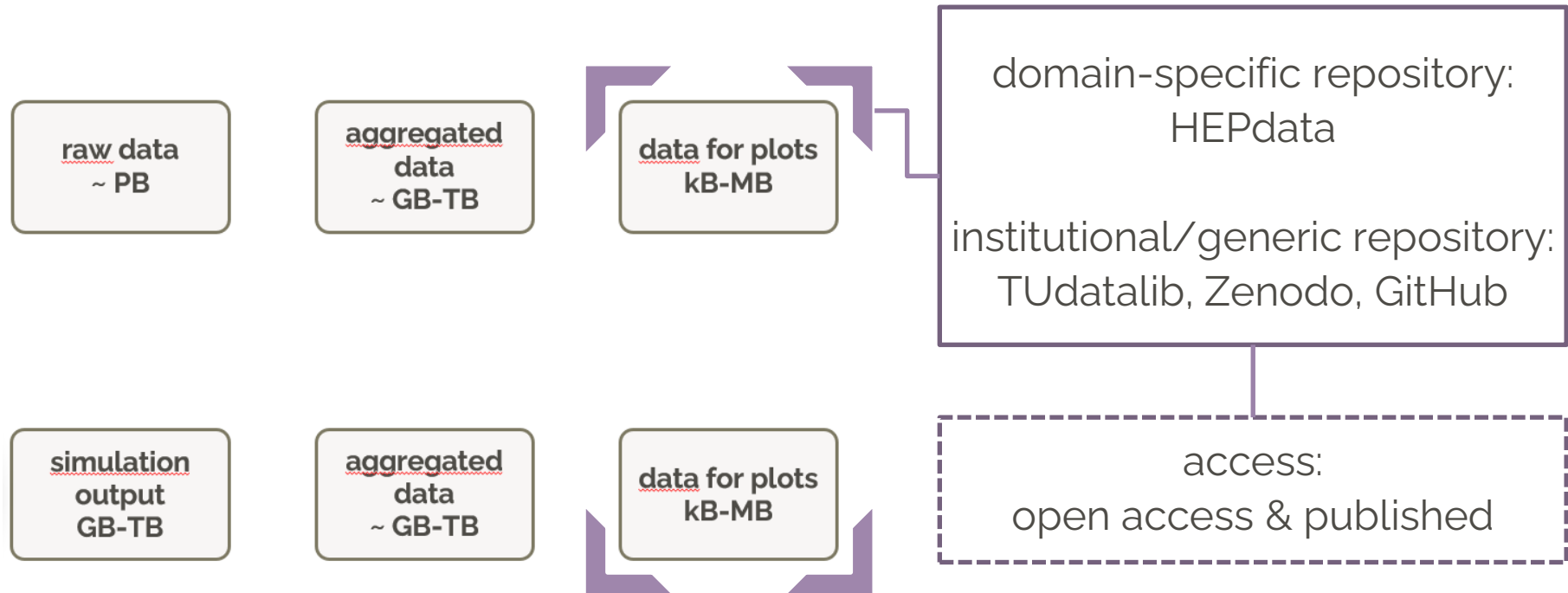
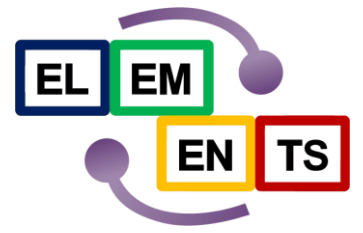
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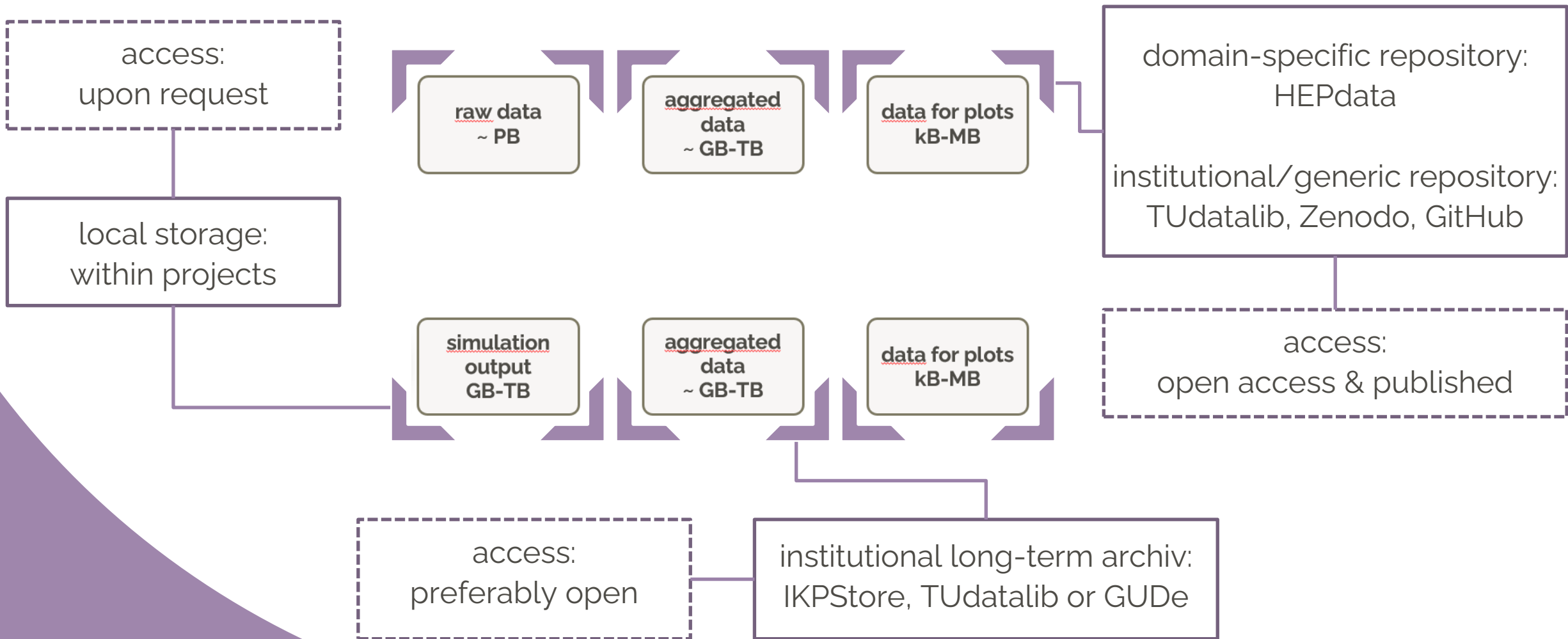


# Data classification: difference in scales of data sizes





# Data classification: difference in scales of data sizes



# Accompanying data publication



nature physics

Article

<https://doi.org/10.1038/s41567-022-01856-w>












## Realization of a multi-turn energy recovery accelerator

Received: 28 March 2022

Accepted: 26 October 2022

Published online: 26 January 2023

 Check for updates

Felix Schliessmann  , Michaela Arnold , Lars Juergensen ,  
Norbert Pietralla , Manuel Dutine , Marco Fischer , Ruben Grewe ,  
Manuel Steinhorst , Lennart Stobbe  & Simon Weih 

Conventional electron linear accelerators are essential research tools but limited in providing high beam currents. Energy recovery technology

# Accompanying data publication



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Article

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- datasets stored locally at IKP / accelerator group
- manuscript submitted
- in parallel: preparation of data publication on TUdatalib inkl. analysis code

A screenshot of the TUdatalib website showing a data set page for 'Data set for the Twofold Energy-Recovery Mode at S-DALINAC'. The page includes a search bar, navigation links, a list of files (data.zip, 287.2KB), and a description of the data set. The description states that the data set belongs to the twofold energy-recovery mode realized at the Darmstadt electron accelerator S-DALINAC in August 2021. It also lists the authors and provides a DOI link.

Search

Search TUdatalib  
 This Collection

BROWSE

- All of TUdatalib
- Communities
- Titles
- Authors
- Type
- By Submit Date
- Subjects
- DFG subject classifications
- This Collection

Count of file(s): 1  
data.zip (Data set) (287.2KB)

Date  
2022

Author  
Schliessmann, Felix   
Arnold, Michaela   
Juergensen, Lars   
Pietralla, Norbert   
Dutine, Manuel   
Fischer, Marco   
Grewe, Ruben Bernhard Frederic   
Steinhorst, Manuel   
Stobbe, Lennart   
Weih, Simon

Type  
Dataset

Data set for the Twofold Energy-Recovery Mode at S-DALINAC

No Thumbnail

Description  
This data set belongs to the twofold energy-recovery mode realized at the Darmstadt electron accelerator S-DALINAC in August 2021. It contains measurements for different acceleration modes at different beam currents. This data set can be used under the Creative Commons Attribution 4.0 International (CC BY 4.0) license.

Subject  
ERL,energy recovery,S-DALINAC,accelerator,LINAC

DFG subject classification  
309-01 Kern- und Elementarteilchenphysik, Quantenmechanik, Relativitätstheorie, Felder

URI  
<https://tudatalib.ulb-tu-darmstadt.de/handle/tudatalib/3594>  
<https://doi.org/10.48328/tudatalib-964>

Related Resources  
Is cited by: DOI:10.1038/s41567-022-01856-w  
Is cited by: DOI:10.1038/s41567-022-01933-0  
Is part of: <https://doi.org/10.48328/tudatalib-963>

Collections



# Accompanying data publication







nature physics

Article





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Published online

### Data availability

 Check for updates

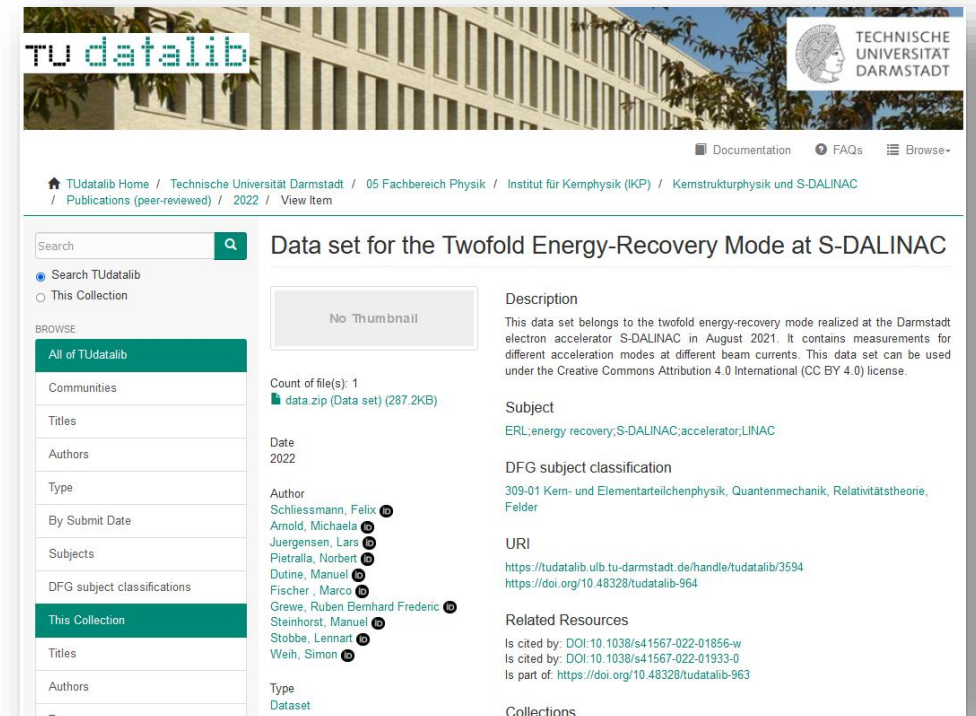
The experimental data presented in this manuscript are available from a TUDatalib repository<sup>43</sup>. [Source data](#) are provided with this paper.

### Code availability

The codes that support the findings of this study are available from a TUDatalib repository<sup>37</sup>.

published scientific article explicitly linked  
to data publication via DOI's

- datasets stored locally at IKP / accelerator group
- manuscript submitted
- in parallel: preparation of data publication on TUDatalib inkl. analysis code

The screenshot shows the TUDatalib website interface. At the top, there's a header with the TUDatalib logo and the Technische Universität Darmstadt logo. Below the header, there's a navigation bar with links for Documentation, FAQs, and Browse. The main content area displays a search bar and a list of search results. The selected result is "Data set for the Twofold Energy-Recovery Mode at S-DALINAC". The page shows the count of files (1), the file name (data.zip), and the date (2022). The author list includes Felix Schliessmann, Michaela Arnold, Lars Juergensen, Norbert Pietralla, Manuel Dutine, Marco Fischer, Ruben Grewe, Manuel Steinhorst, Lennart Stobbe, and Simon Weih. The description states that the data set belongs to the twofold energy-recovery mode realized at the Darmstadt electron accelerator S-DALINAC in August 2021. The subject is "ERL:energy recovery;S-DALINAC;accelerator;LINAC". The DFG subject classification is "309-01 Kern- und Elementarteilchenphysik, Quantenmechanik, Relativitätstheorie, Felder". The URI is "https://tudatalib.ulb-tu-darmstadt.de/handle/tudatalib/3594" and "https://doi.org/10.48328/tudatalib-964". The related resources section shows that the data set is cited by DOI:10.1038/s41567-022-01856-w and DOI:10.1038/s41567-022-01933-0, and is part of https://doi.org/10.48328/tudatalib-963.

# Peer-reviewed software publication



A flexible, multi-purpose, single-zone nuclear reaction network.

## Documentation [↗](#)

See [WinNet-documentation](#) for documentation and further information.

## Literature [↗](#)

arxiv [2305.07048](#) DOI [10.5281/zenodo.8220550](#)

Please read and cite [Reichert et al. 2023](#) when you use this reaction network in a publication. Furthermore give credit to the data that you are using (reaction rates, thermodynamic conditions, equation of state, etc.). For this you can be guided by the example cases that contain the relevant literature in the header of their parameter files in the [par/](#) folder. Additionally, the [Readme](#) in the [data/](#) folder contains relevant information about the references of input files. The origin of the thermodynamic trajectories is given in the list of examples when running `python makerun.py --example` or in the Readme of the data folders of the examples (e.g., [Readme](#)).

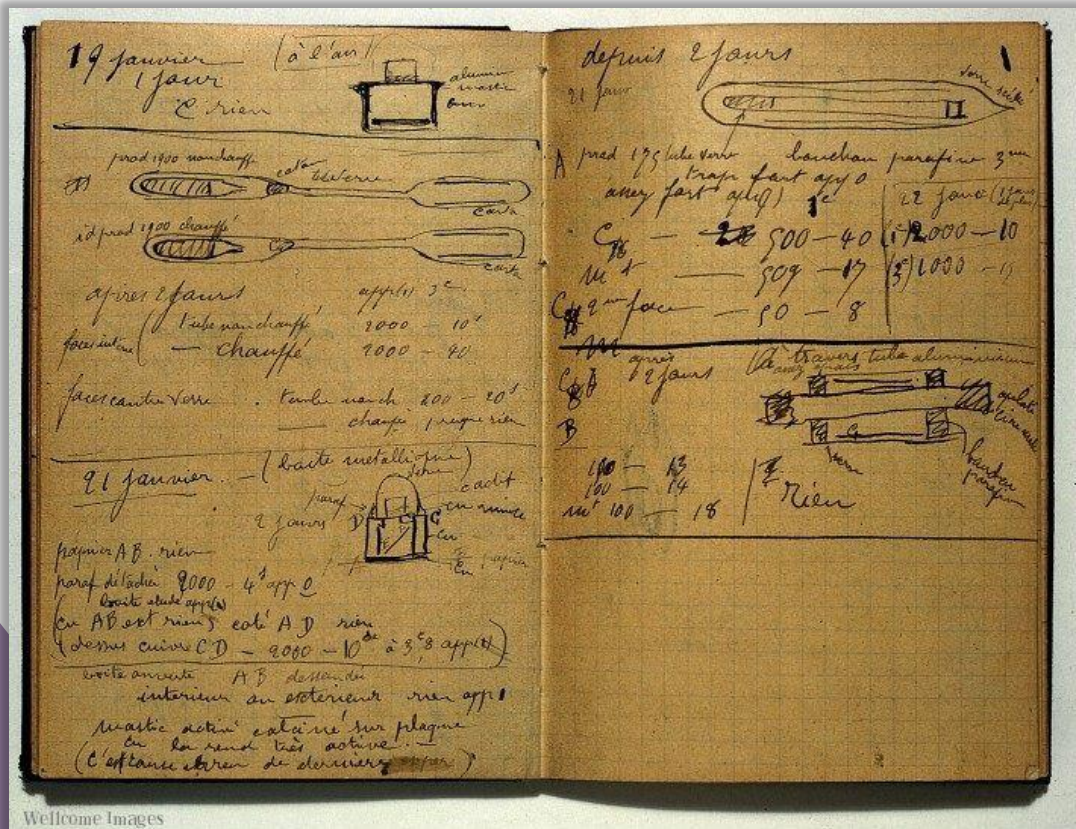
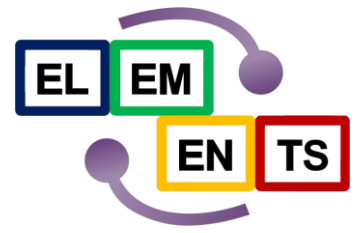
## License [↗](#)

WinNet is available as open source under the terms of the revised BSD 3-Clause License. See the LICENSE file for more details.

- code publicly available on GitHub
- peer-review of code in journal
- published via Zenodo with DOI

A screenshot of a Zenodo record page for the software package "nuc-astro/WinNet: v1.0.2". The page has a blue header with the Zenodo logo, a search bar, and links for "Communities" and "My dashboard". Below the header, it shows the publication date "Published August 17, 2023 | Version v1.0.2" and a "Software" tag with an "Open" button. The title "nuc-astro/WinNet: v1.0.2" is prominently displayed. Below the title, a list of authors is shown with their ORCID iD icons: Reichert, Moritz; Winteler, Christian; Korobkin, Oleg; Arcones, Almudena; Bliss, Julia; Eichler, Marius; Frischknecht, Urs; Fröhlich, Carla; Hirschi, Raphael; Jacobi, Maximilian; Kuske, Jan; Martínez-Pinedo, Gabriel; Martin, Dirk; Mocej, Darko; Rauscher, Thomas; Thielemann, Friedrich-Karl. A "Show affiliations" button is located to the right of the author list. Below the author list, it says "WinNet version of the accepted manuscript." Under the "Files" section, a file "nuc-astro/WinNet-v1.0.2.zip" is listed. Below this, a directory tree is shown: "nuc-astro-WinNet-6a321d6" containing a "github" directory, which in turn contains a "workflows" directory. Inside "workflows", three files are listed: "cleanup.yml" (867 Bytes), "doxygen.yml" (1.3 kB), and "run\_tests.yml" (5.2 kB).

# Documentation: from paper to digital logbooks

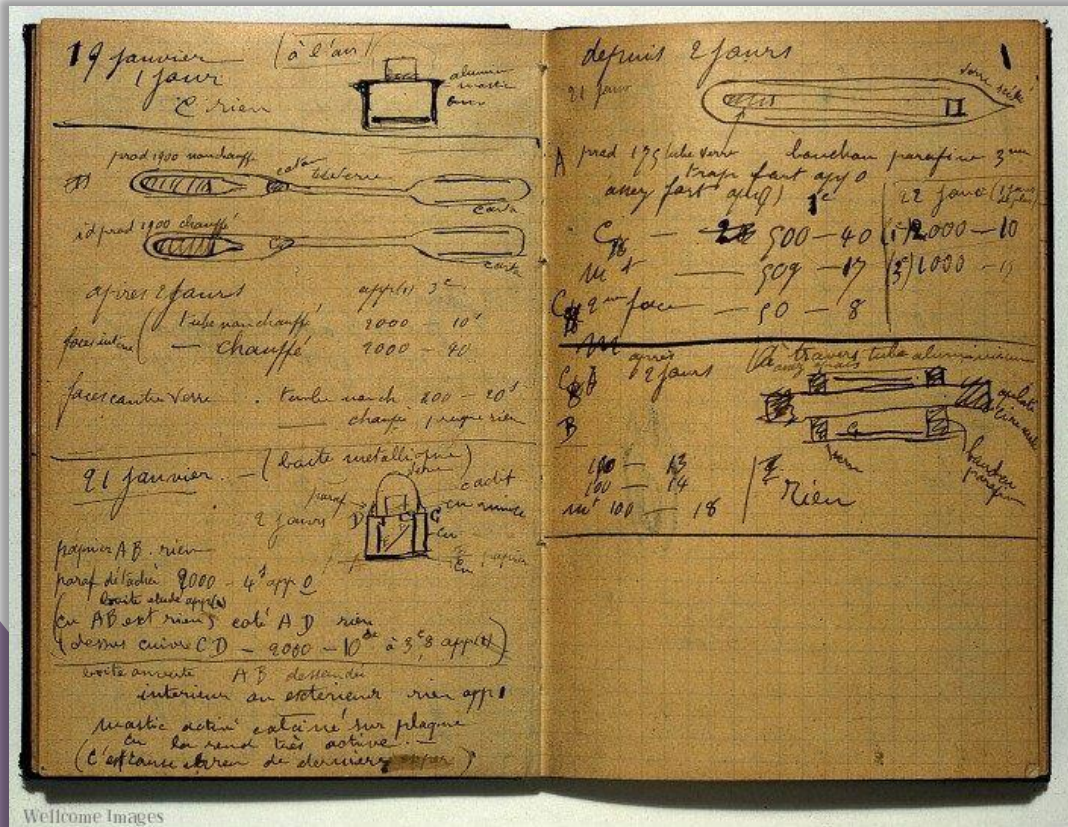


Marie Curie's experimental notebook

<https://twitter.com/wellcometrust/status/496323565239955456>



# Documentation: from paper to digital logbooks



Marie Curie's experimental notebook  
<https://twitter.com/wellcometrust/status/496323565239955456>

ELOG

All | HlyS | S-DALINAC | NRF | External Experiments | Demo | clovershare | gamma3 | gamma3 2015-2017 | gamma3 2012-2014

Clovershare @ HlyS, Page 1 of 103 Logg

[New](#) | [Find](#) | [Select](#) | [Import](#) | [Logout](#) | [Last day](#) | [Help](#)

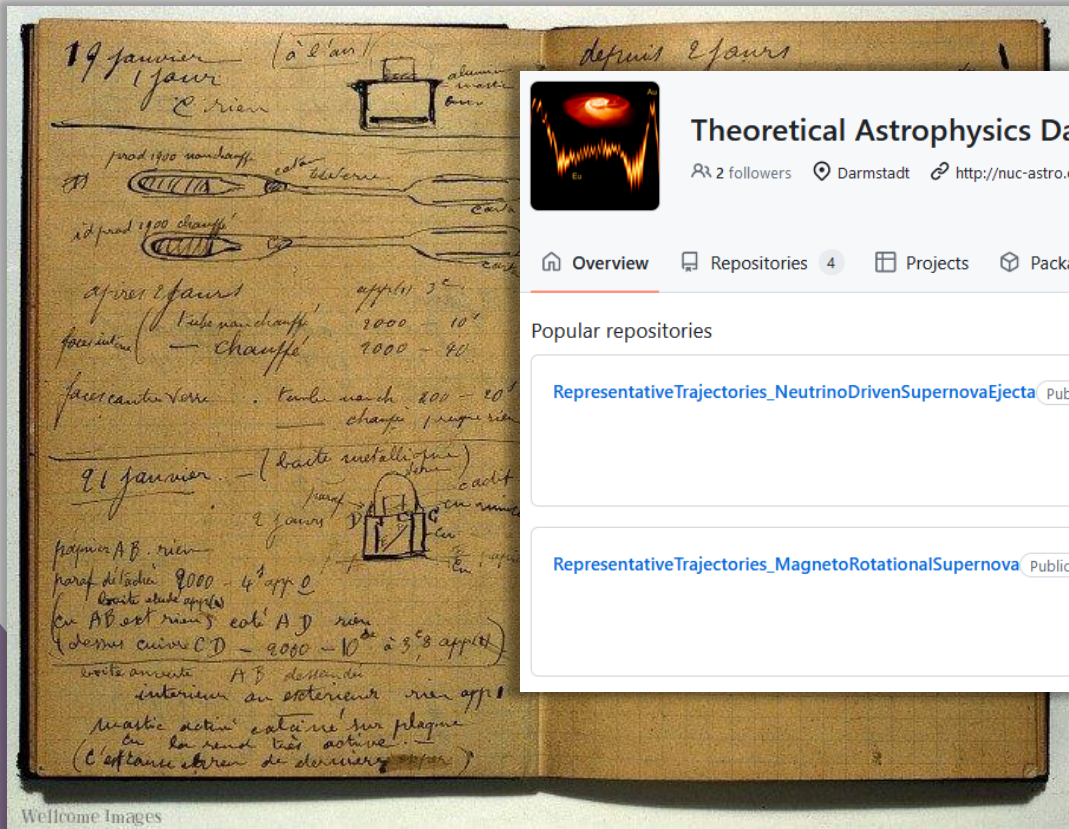
Full | Summary | Threaded
-- All entries --
-- Author --
-- Category --
-- Status --
-- Subject --

Goto page 1, 2, 3 ... 101, 102, 103 [Next](#)

ID	Date	Status	Author	Category	Run	Subject	Text
2070	Mon, 2022-04-25 19:15:47 CEST	Finished	Udo	Run Beam	220411_184018	Beam Energy Calibration @ 5.1 MeV (40 mA)	Start time: 2022-04-25 13:20:57 EDT Stop time: 2022-04-25 13:26:09 EDT
2069	Tue, 2022-04-19 13:33:20 CEST	Finished	Udo	Run Calib	220418_073241	Background	Start time: 2022-04-19 07:32:40 EDT Stop time: 2022-04-19 07:32:40 EDT Attachment 3: clover_array_5_annotated.pdf 1.930 MB Uploaded Tue, 2021-1
2068	Tue, 2022-04-19 00:02:53 CEST	Finished	Udo	Run Calib	220418_180125	Background	Start time: 2022-04-19 00:02:53 CEST Stop time: 2022-04-19 00:02:53 CEST
2067	Sat, 2022-04-16 00:19:57 CEST	Finished	Calvin, Udo	Run Beam	220415_181936	Flux Calibration @ 8.86 MeV (135 mA) 3x8.00 + 5.932"	Start time: 2022-04-16 00:19:57 CEST Stop time: 2022-04-16 00:19:57 CEST
2066	Sat, 2022-04-16 00:15:48 CEST	Finished	Calvin, Udo	Run Beam	220415_181517	Flux Calibration @ 8.86 MeV (135 mA) 2.45 + 3x8.00 + 5.932"	Start time: 2022-04-16 00:15:48 CEST Stop time: 2022-04-16 00:15:48 CEST
2065	Sat, 2022-04-16 00:12:10 CEST	Finished	Calvin, Udo	Run Beam	220415_181145	Flux Calibration @ 8.86 MeV (135 mA) 4.90 + 3x8.00 + 5.932"	Start time: 2022-04-16 00:12:10 CEST Stop time: 2022-04-16 00:12:10 CEST



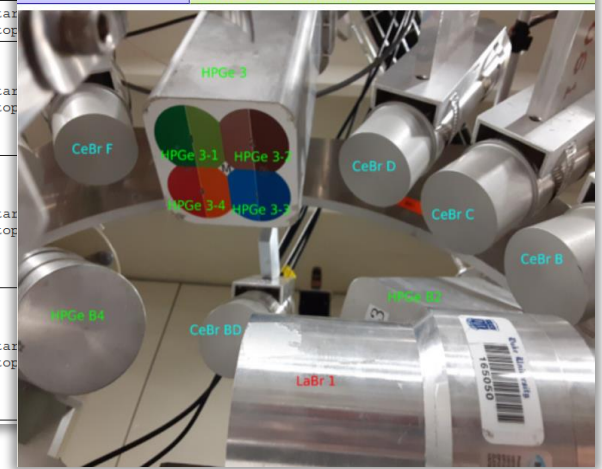
# Documentation: from paper to digital logbooks



Marie Curie's experimental notebook  
<https://twitter.com/wellcometrust/status/496323565239955456>

A composite image showing a digital logbook interface (ELOG) and a GitHub repository page. The ELOG interface includes a navigation bar with 'All', 'HlyS', 'S-DALINAC', 'NRF', 'External Experiments', and 'Demo'. Below it is a table with columns for 'Subject' and 'Text'. The GitHub page shows the profile for 'Theoretical Astrophysics Darmstadt' with several repositories listed, including 'RepresentativeTrajectories\_NeutrinoDrivenSupernovaEjecta', 'public\_data-RepresentativeTrajectories\_NuclearPhysicsUncertainties', and 'WinNet'.

Subject	Text
Beam Energy Calibration @ 5.1 MeV (40 mA)	Start time: 2022-04-25 13:20:57 EDT Stop time: 2022-04-25 13:26:09 EDT
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Flux Calibration @ 8.86 MeV (135 mA) 4.90 + 3x8.00 + 5.932"	Start Stop



# Training & education in RDM



- introductory to RDM policy & common RDM tools
- regular training to raise awareness for RDM
- recent event: ECR-Day on October 19, 2023

development of (compact) training material  
presentation / slides & hands-on exercises

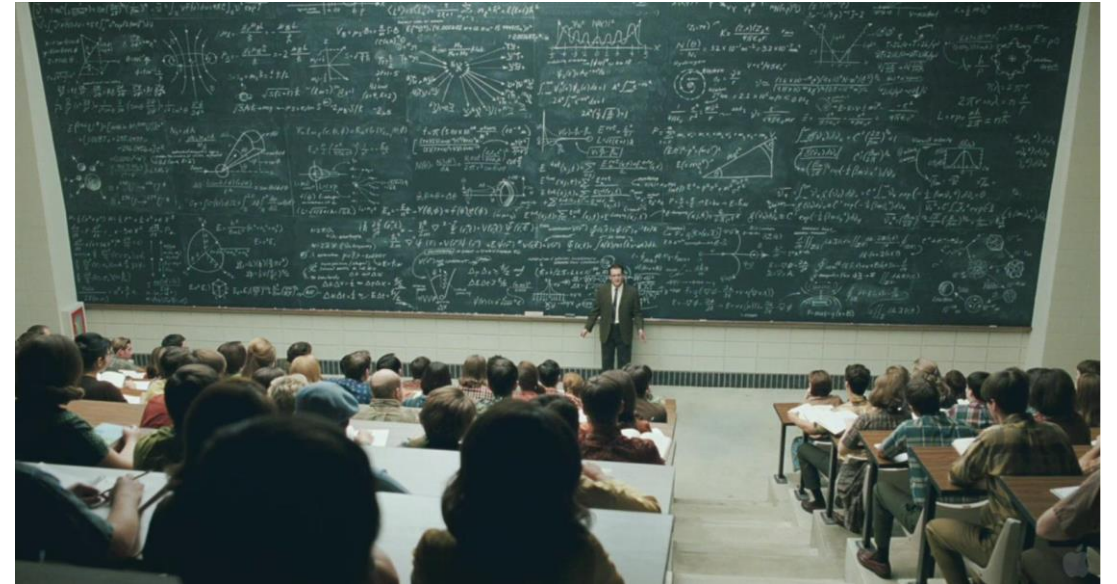
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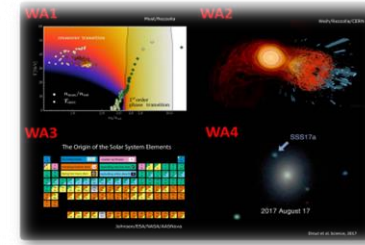
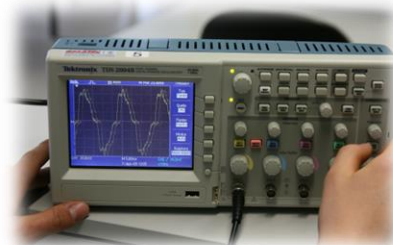
development of (compact) training material  
presentation / slides & hands-on exercises

- "good RDM from the very beginning..."
- train students in RDM at early stage of their studies
- implement RDM in the curriculum
- theoretical basics and practical application of methods and tools
- **make sustainable RDM common practice!**



Screenshot from a scene of "A serious man", 2009.

# Research-oriented teaching: advanced lab courses



**Setup**

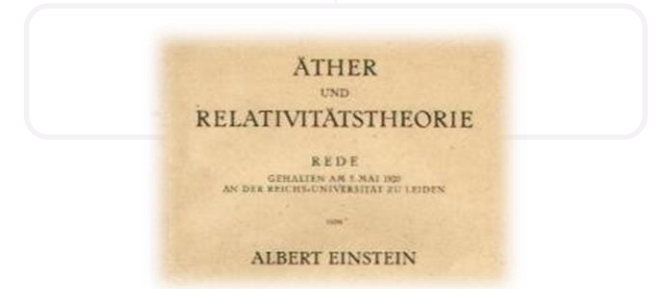
**Analysis**

**Report**

**Preparation**

**Measurement**

**Visualization**





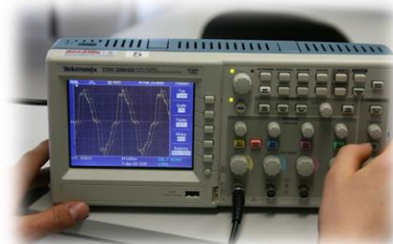
# Research-oriented teaching: advanced lab courses



TU dmo

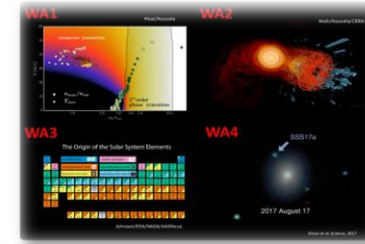


ELOG



python  
powered

TU datalib



GitLab

PlotID

Setup

Analysis

Report

Preparation

Measurement

Visualization



ELOG



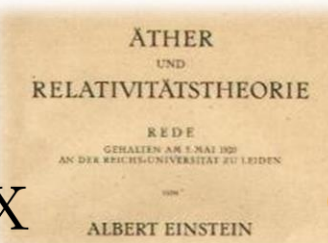
python  
powered

TU datalib

GitLab

L<sup>A</sup>T<sub>E</sub>X

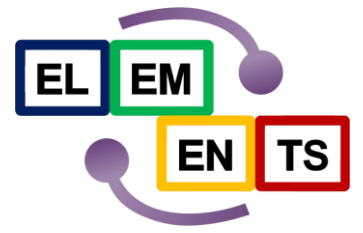
TU datalib



doi



# Networking with other RDM initiatives in progress



## National research data infrastructures (NFDI)

- DFG initiative to establish (inter)national coordinated access to valuable science and research data in a sustainable and qualitative manner



NFDI consortium of particle, astro-, astroparticle, hadron and nuclear physics

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## Helmholtz Metadata Collaboration (HMC)

- "From the Past To the Future: Legacy Data in Small and Medium-Scale PUNCH Experiments - a Blueprint for PUNCH and Other Disciplines"



Many activities on FAIR data taking in the future

## But what about already existing datasets?

- „FAIRification“ of datasets on IKPStore

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## Metadata for Nuclear Physics experiments in EURO-LABS partners

- Joined effort to define common metadata schema



Research communities of nuclear physics, accelerator and detector technologies for high energy physics

