



Max-Planck-Institut für Physik  
(Werner-Heisenberg-Institut)



# DARK MATTER DATA CENTER

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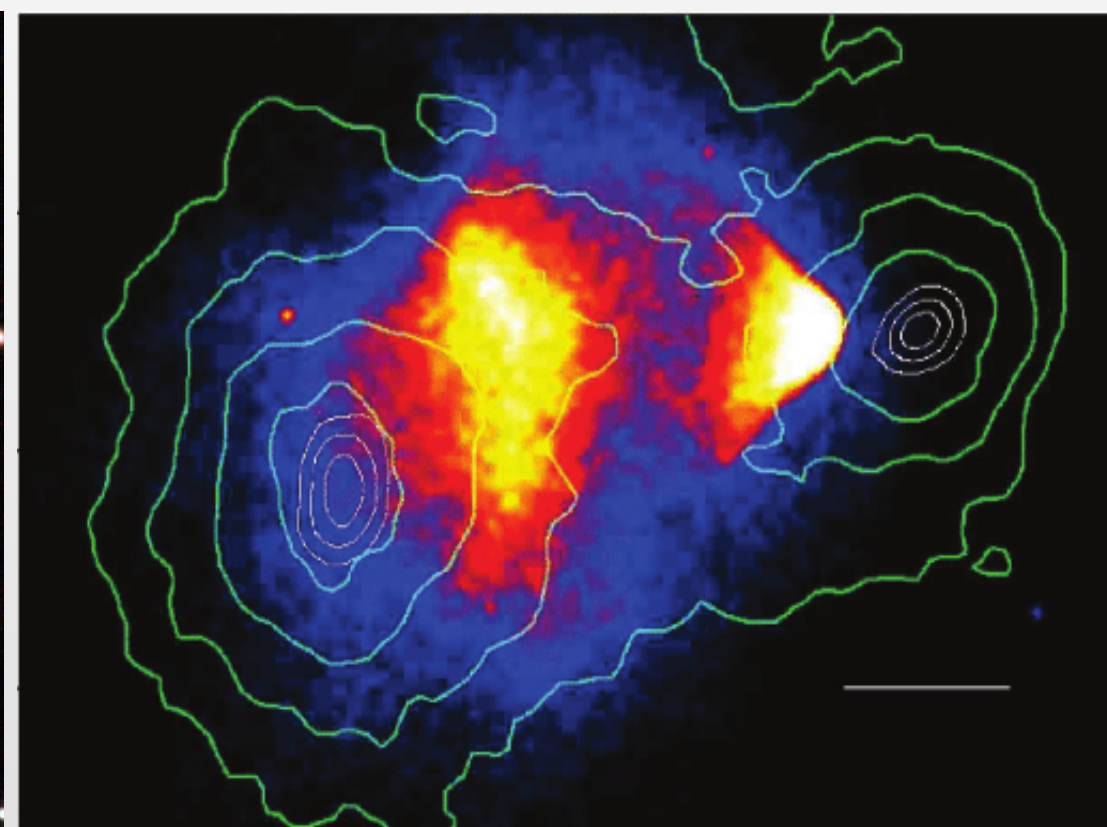
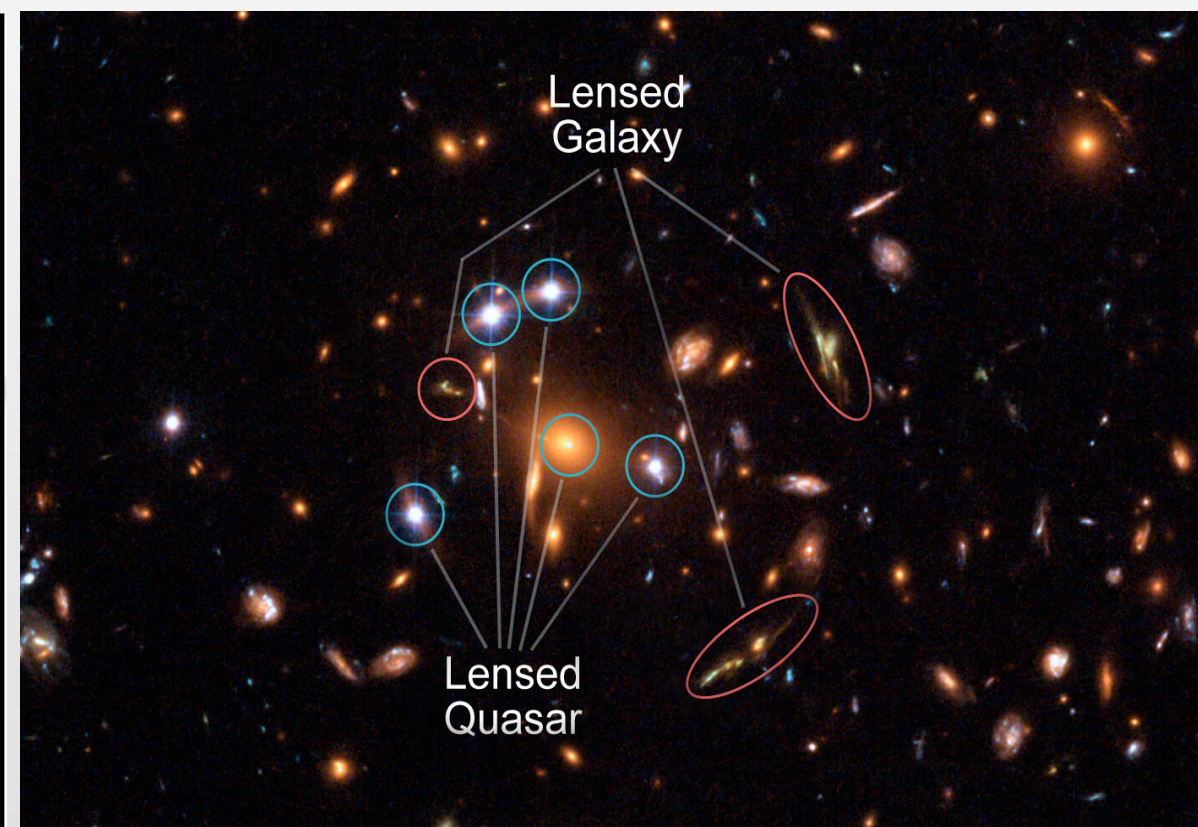
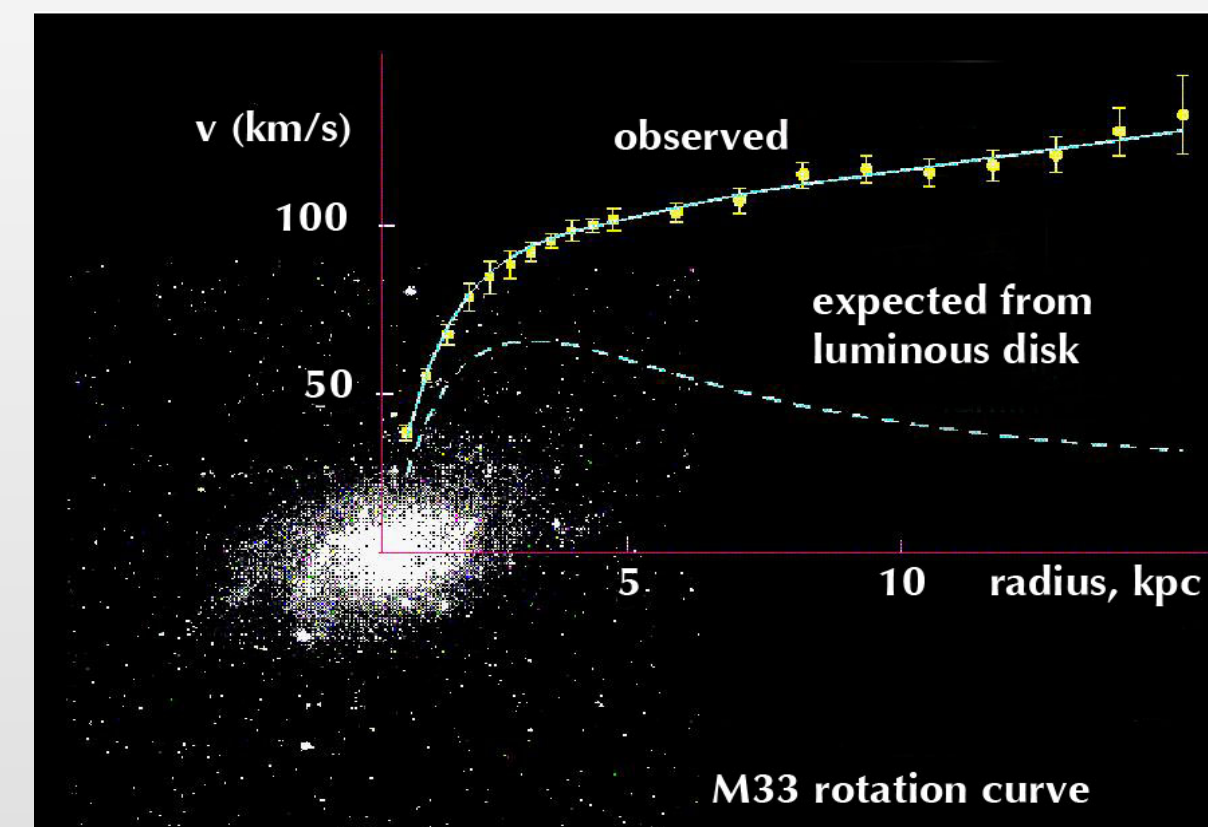
Heerak Banerjee

[heerak.banerjee@tum.de](mailto:heerak.banerjee@tum.de)

TAUP 2023 - Vienna



# Threading a Needle in the Dark...



## Proliferation of DM searches:

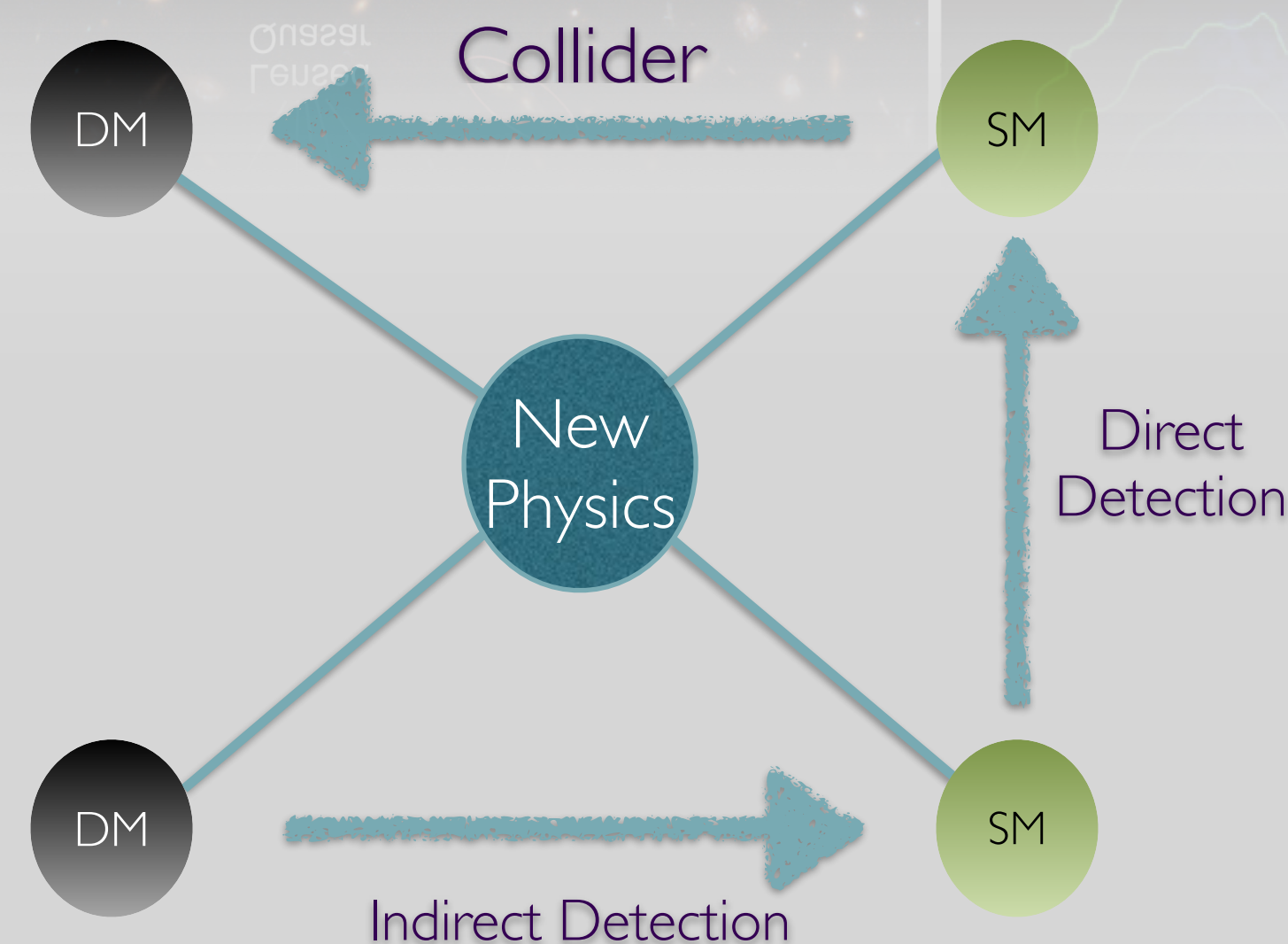
Increasing complexity of analyses  
Increasing necessity of public data policy

## Proliferation of DM Theories:

ALPs to MACROs via Axions, WIMPs, FIMPs & SIMPs

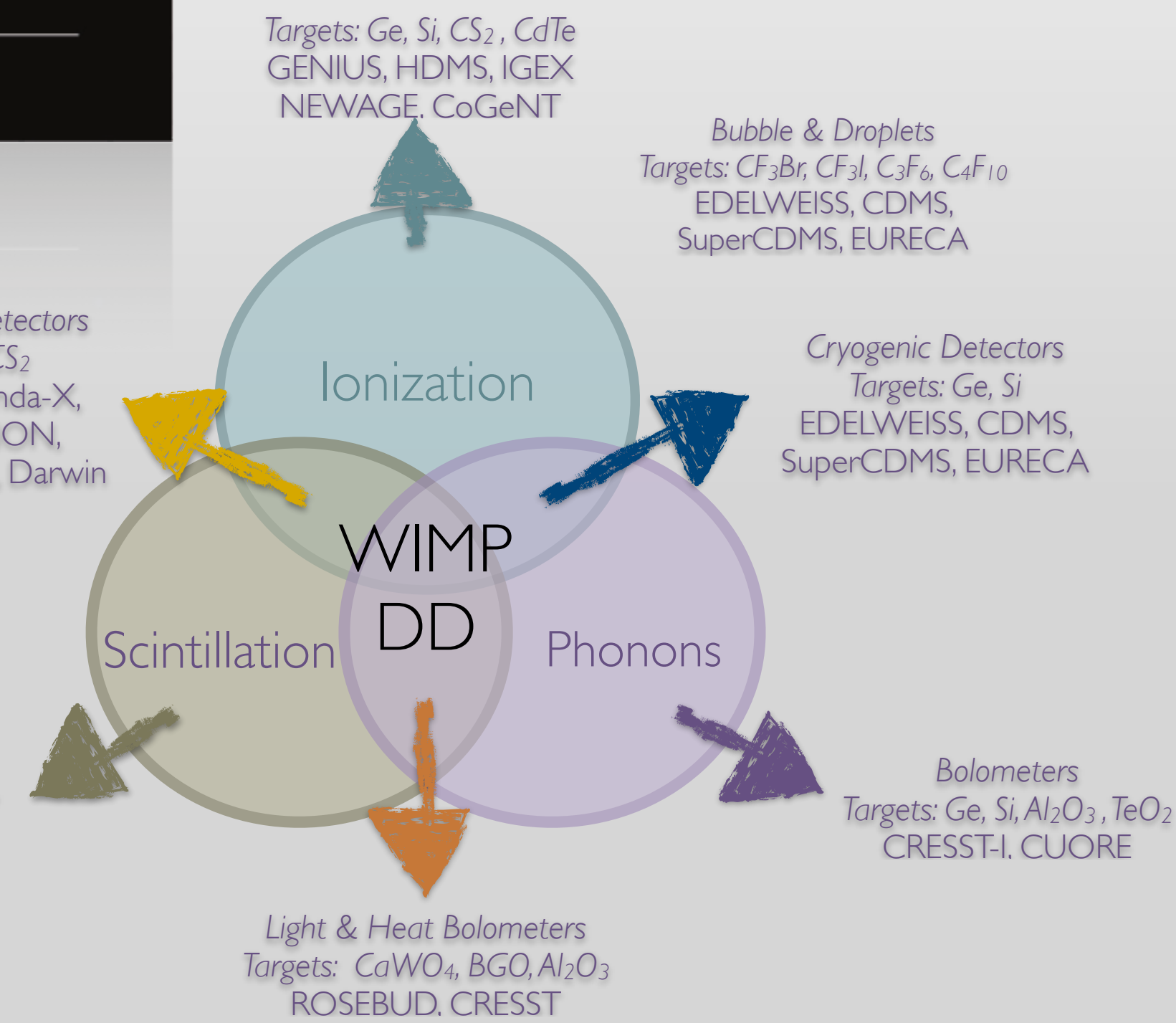
100s of paradigms: Ultra Light Bosons, light Fermions, Weak Scale Fermions and Bosons, Macroscopic objects, Modified Gravity.

$$10^{-22} \text{eV} \longrightarrow \gtrsim 30 M_{\odot}$$

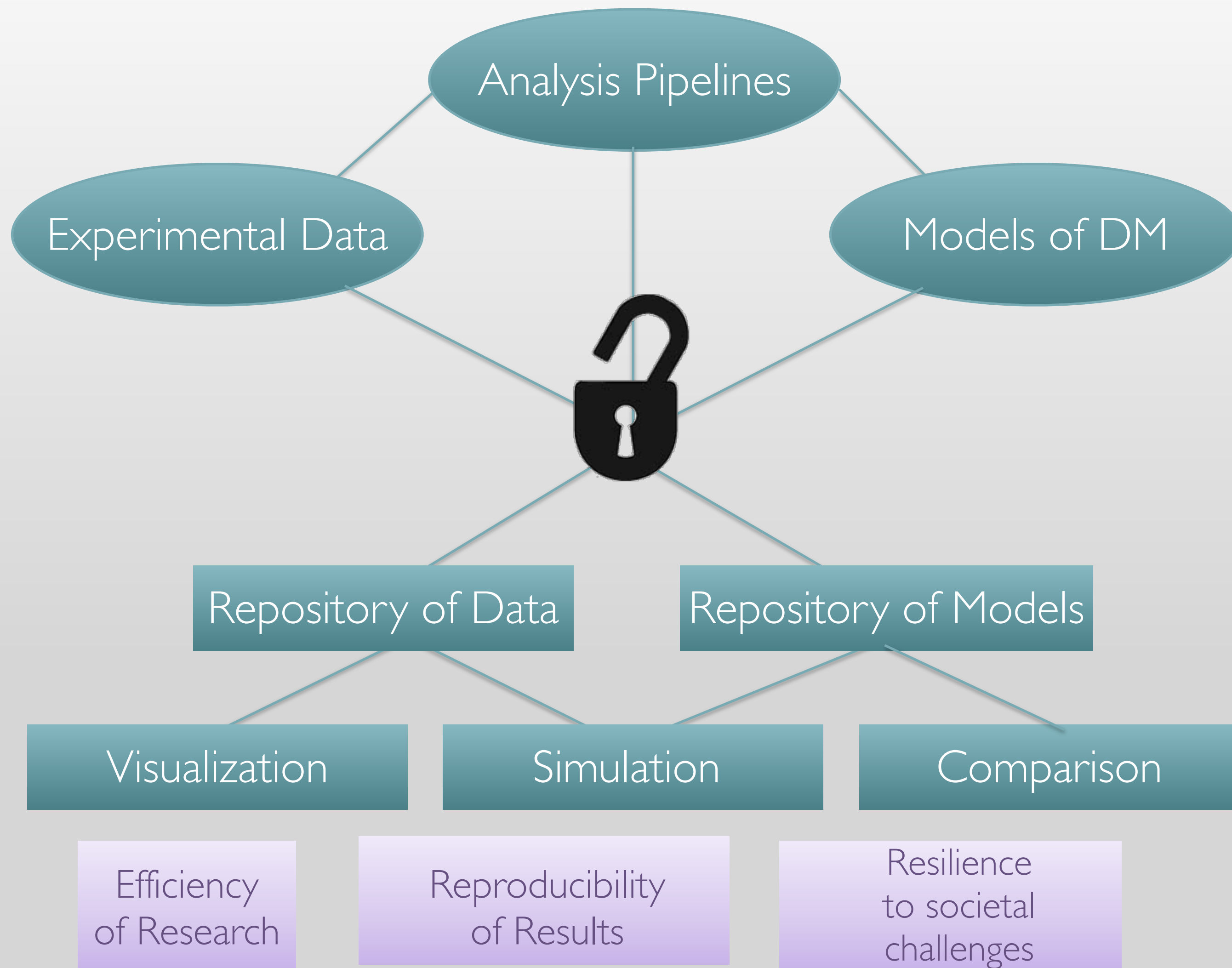


Light & Ionization Detectors  
Targets: Xe, Ar,  $\text{CS}_2$   
WARP, ZEPLIN, Panda-X,  
LUX, DRIFT, XENON,  
DarkSide, ARDM, LZ, Darwin

Targets: NaI, Xe, Ar  
ZEPLIN-I, KIMS, NAIAD,  
DAMA/LIBRA, ANAIS,  
DEAP, XMASS, CLEAN



# The Dark Matter Data Center



**ORIGINS**  
Excellence Cluster

[Forschung](#) [Aktuelles](#) [ORIGINS für alle](#) [Infrastruktur](#) [Über uns](#)

THE DARK MATTER DATA CENTER (INTEGRATED INTO ODSL)

Fostering Data and Information Sharing for The Dark Matter Community

### Open Data, Open Science!

Open science has become a pillar in the research world and it's fuelling exchange of knowledge, data and ideas. The extraordinary impact of open science accelerates scientific research and the creation of new knowledge. We believe that open data is deeply rooted in the scope and spirit of fundamental research and we support this culture, offering a place where data from experiments and phenomenology can meet.

### Dark Matter

Dark matter searches are an extraordinary endeavor of the human kind to shed light on one of the biggest mysteries of the cosmos and the physics that governs it. The understanding of the composition of our Universe expands through a variety of experimental approaches and a rich zoo of models and ideas. The discovery of dark matter and the investigation of its nature must follow complementary paths, for no single evidence would uniquely identify the nature of dark matter making up our Universe.

### Bringing Experiments and Theories Together

With the ORIGINS Dark Matter Data Center we want to fully leverage the potential of open science to bring together observations from different experiments, the implications of different models and all the associated software. At the DMDC we aim at increasing accessibility to scientific process and knowledge, open data and open source software: key ingredients for the nourishing of open science (From "Open Data to Open Science" Earth and Space Science [doi:10.1029/2020EA001562](https://doi.org/10.1029/2020EA001562)), by offering a repository for experimental data, models and code. The Dark Matter Data Center supports data comparison, combination and interpretation using clear and reproducible methodologies, easing the usability of this data, enabling one to make the most out of it. Our sights are set on sharing knowledge in all its relevant forms: data, methodologies and software with the ultimate goal of offering a consistent and unified view of the field in all its facets.

**Heerak Banerjee (TUM)**  
Postdoc and ODSL Fellow  
[@ heerak.banerjee\(at\)tum.de](mailto:heerak.banerjee@tum.de)

[Details](#)

### Available Datasets

Click on a Collaboration to view the datasets it has made available

- CRESST
- XENON
- ANAIS

### Available software

#### Submit data or software

#### Simulate

Simulate event rates for listed experiments with your model (Coming Soon!)

# Present Status

## Data from Experiments

Response Matrix

Analysis Pipeline

Background Data

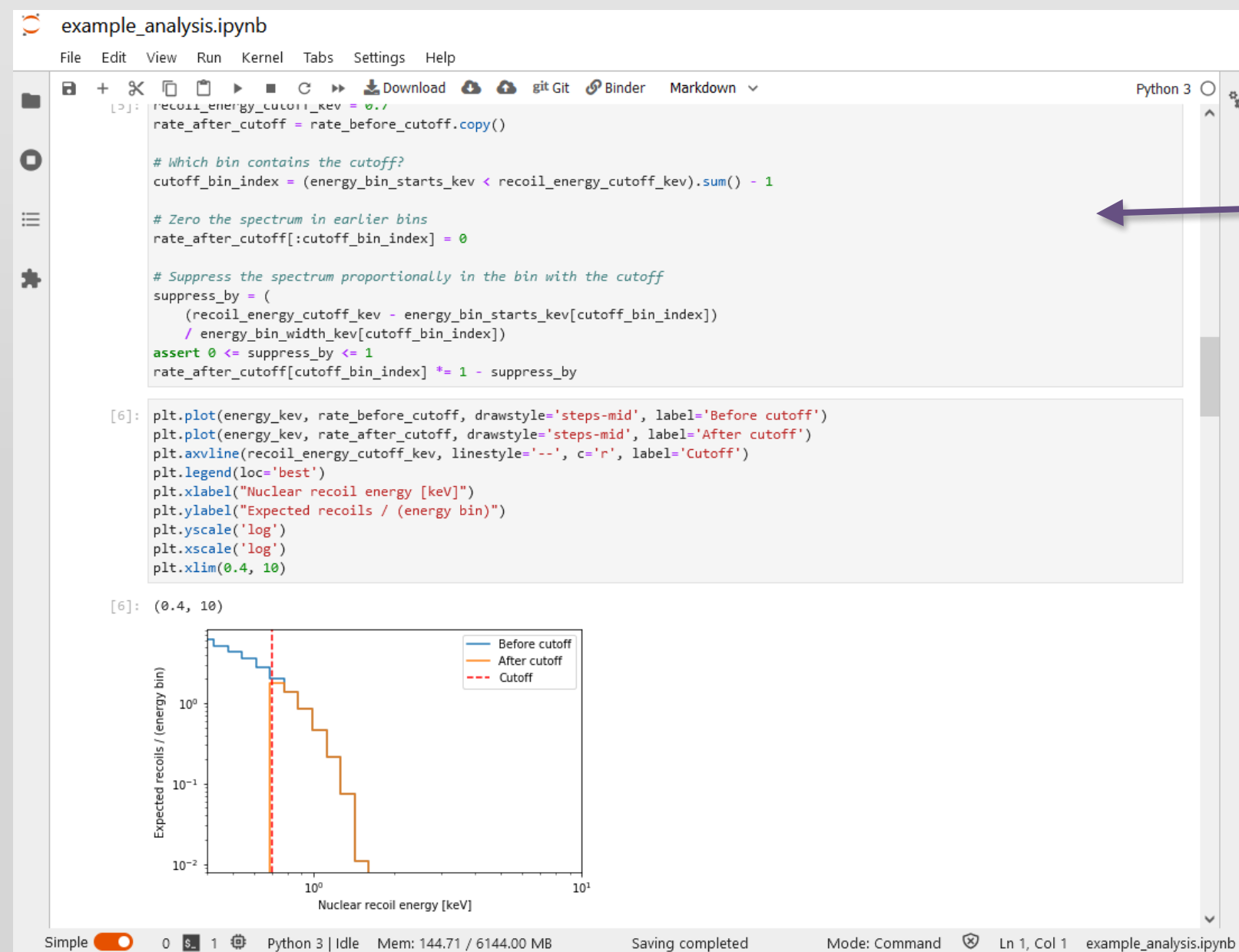
Event Data

**ANAIS**  
**CRESST**  
**COSINE**  
**XENON**  
**SuperCDMS**

### Front-end:

<https://www.origins-cluster.de/odsl/dark-matter-data-center>

- Documented
- Easily findable (Metadata)
- Directly citable (Publication & DOI)
- DOI Assignment through MPDL
- Data usage instructions (Also in form of JuPyTer notebooks)



### ANAIS-112 Three Year

Detector Module	ANAIS-112
Material	NaI(Tl)
Technology	3 × 3 Array of NaI(Tl) scintillating crystals D0-D8 using two Photo Multiplier Tubes (PMTs) each to detect scintillation light signal.
Fiducial Mass	12.5 Kg each. Total 112.5 Kg
Total Live Time	1013.83 days **Sec III of PhysRevD.103.102005 misquotes this as 1018.6 days. The last bin, bin 111, live time: 4.74 days, was not considered for the analysis in this publication.)
Threshold	1 keV (Electron equivalent energy. All energies are in keVee, aliased by keV)
Acceptance Region	1-6 keV and 2-6 keV
Average Resolution	$\sigma = (-0.008 \pm 0.001) + (0.378 \pm 0.002) \times \sqrt{E(\text{keV})}$

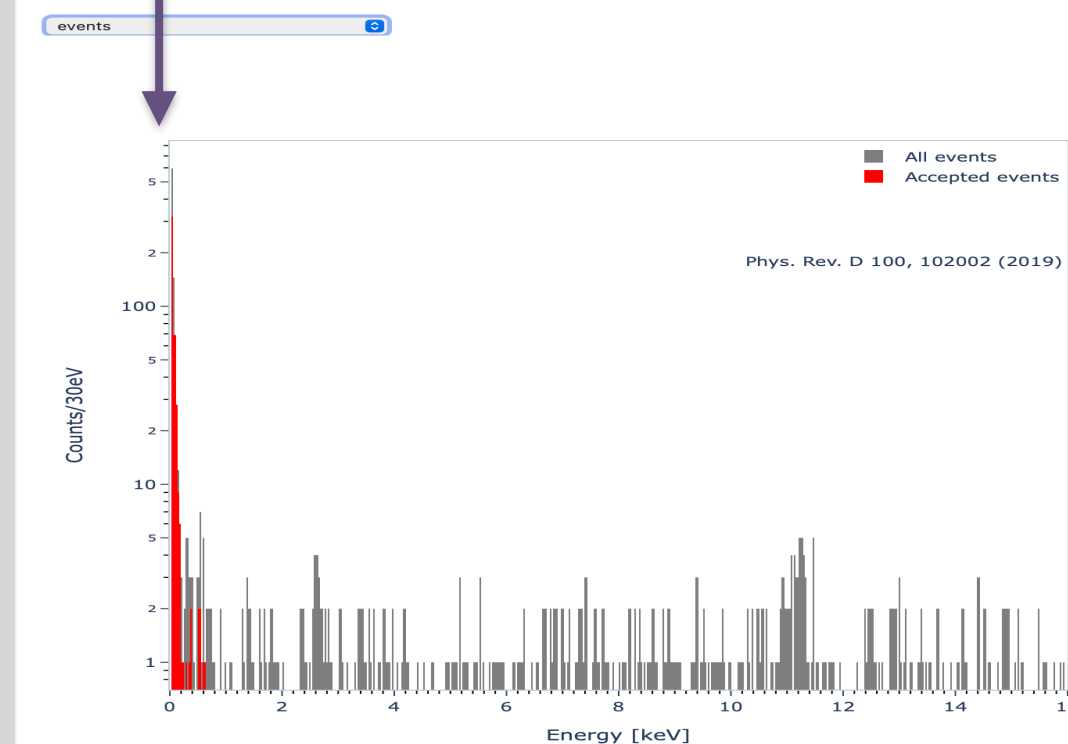
ANAIS provides a JuPyter Notebook with examples of how to plot the data in these datasets and to run the RooFit macro for fitting the data.  
Launch a Binder session with the notebook preloaded: [launch](#) [binder](#)

Download full repository as tar.gz: [GitLab](#)

If you use this dataset, please cite:  
[PhysRevD.103.102005](#)  
[arXiv:2103.01175 \[astro-ph.IM\]](#)

Resources Visualize

### CRESST-II Detector A Visualization



### Anais112 Available Resources

Resource	Description
Event Data	Experimental event data in counts/kg/day (corrected by efficiency and live time) in 10 days bins. One CSV file for each detector D0-D8 for [1-6]keV energy region and another for [2-6]keV energy region. Format: bin_center(days) , events(counts/kg/d) , error(counts/kg/d)
Simulated Background	MC simulated background in counts/kg/day for every detector D[0-8] in energy regions [1-6]keV and [2-6]keV in 15 days bins. Format: bin_center(days) , events(counts/kg/d).
Efficiency	Efficiency vs energy for every detector(0-9) from 1-6 keV. Format: bin_center(keV) , efficiency , error.
Live Time	Live time in days for every 10-days bin
Chi2 Minimization (RooFit)	Fitting Root macro (RooFit). ROOT Version 6.19/02 Perform the chi2 minimization according to PHYS. REV. D 103, 102005 (2021) equations (2) and (6). output: figures (13) and (14) Usage: a112modFit(int enel, bool useMC=1, bool phaseFree=0) Input parameters:  <b>enel: initial energy. Possible values:</b> 1 -> fit [1-6] keV (figure 13) 2 -> fit [2-6] keV (figure 14)  <b>useMC: background model</b> 1 (default) -> use MC background model (equation 6) 0 -> use single exponential approximation for background (this result is not included in PRD103,102005(2021) )  <b>phaseFree: fix/free phase parameter</b> 0 (default) -> phase fixed to 2nd June 1 -> perform a phase free analysis**  **** be aware that in this case the fit is biased , see details in PHYS. REV. D 103, 102005 (2021) output: simple version of figure (17)

- Visualize resources online
- Explore workflows online (Binders)
- Vetted code snippets as starting points

# Present Status

## Data from Experiments

Response Matrix

Analysis Pipeline

Background Data

Event Data

## Homepage Visualization:

- Ready reckoner of current exclusions on homepage
- Interactive visualization: Toggle visibility by clicking on legend items, download exclusion dataset on double-click
- Constantly updated and maintained

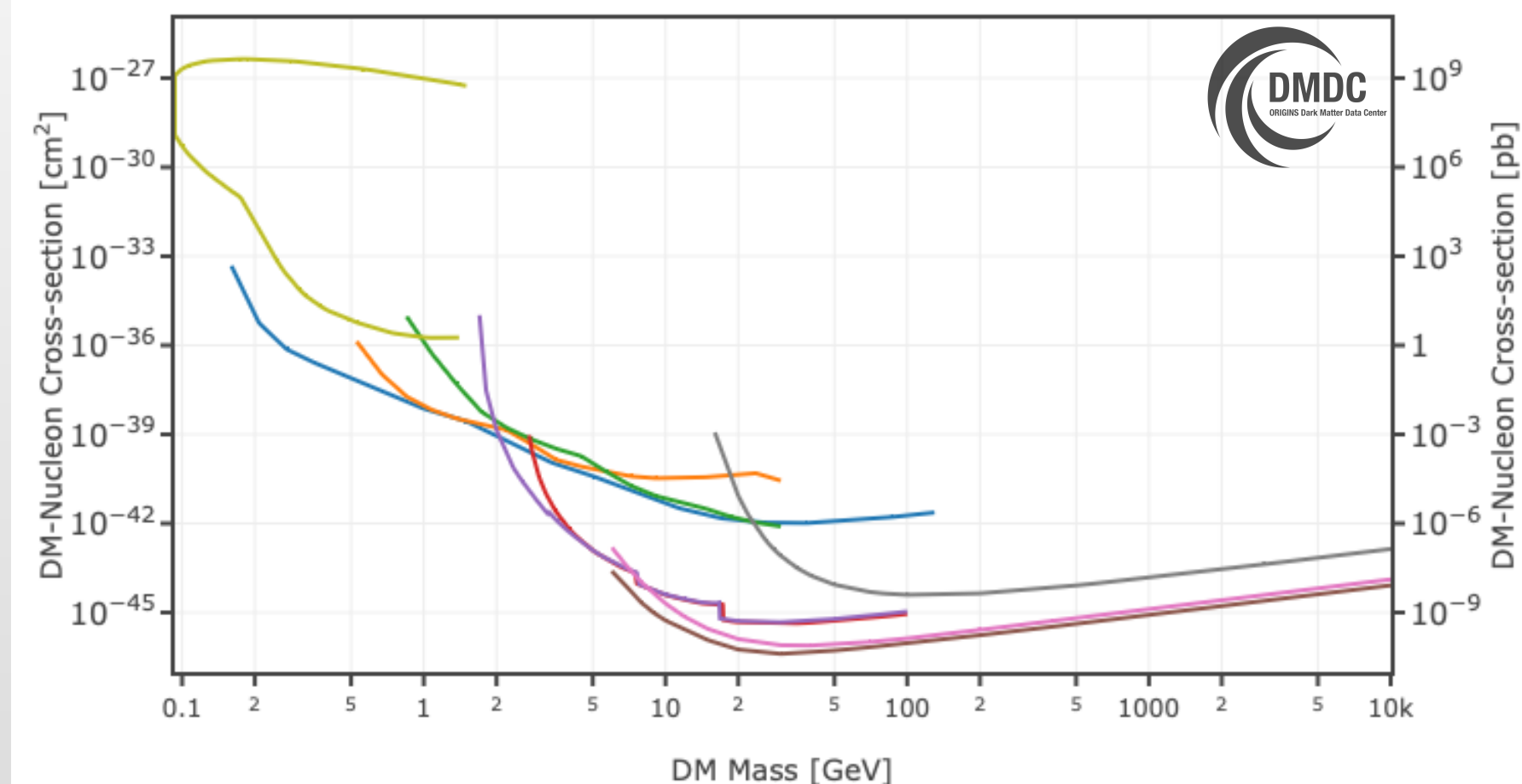
**ANAIS**

**CRESST**

**COSINE**

**XENON**

**SuperCDMS**



Double-click legend items to download the exclusion data (Remember the citations)!

### Spin-Independent

— CRESST-III Det A  
[Phys. Rev. D. 100, 102002 (2019)]  
— CRESST-II LISE  
[Eur. Phys. J. C 76, 25 (2016)]  
— CRESST-II TUM-40  
[Eur. Phys. J. C 74, 3184 (2014)]  
— XENON1T S2-Only  
[Phys. Rev. Lett. 123, 25181 (2019)]  
— XENON1T S2-Only NEST v2.0.1  
[Phys. Rev. Lett. 123, 25181 (2019)]  
— XENON1T (2018)  
[Phys. Rev. Lett. 121, 111302 (2018)]  
— XENON1T (2017)  
[Phys. Rev. Lett. 119, 181301 (2017)]  
— DEAP-3600 (2019)  
[Phys. Rev. D 100, 022004 (2019)]  
— SNOLAB-CPD (2020)  
[Phys. Rev. Lett. 127, 061801 (2021)]

### Spin-Dependent (Neutrons only)

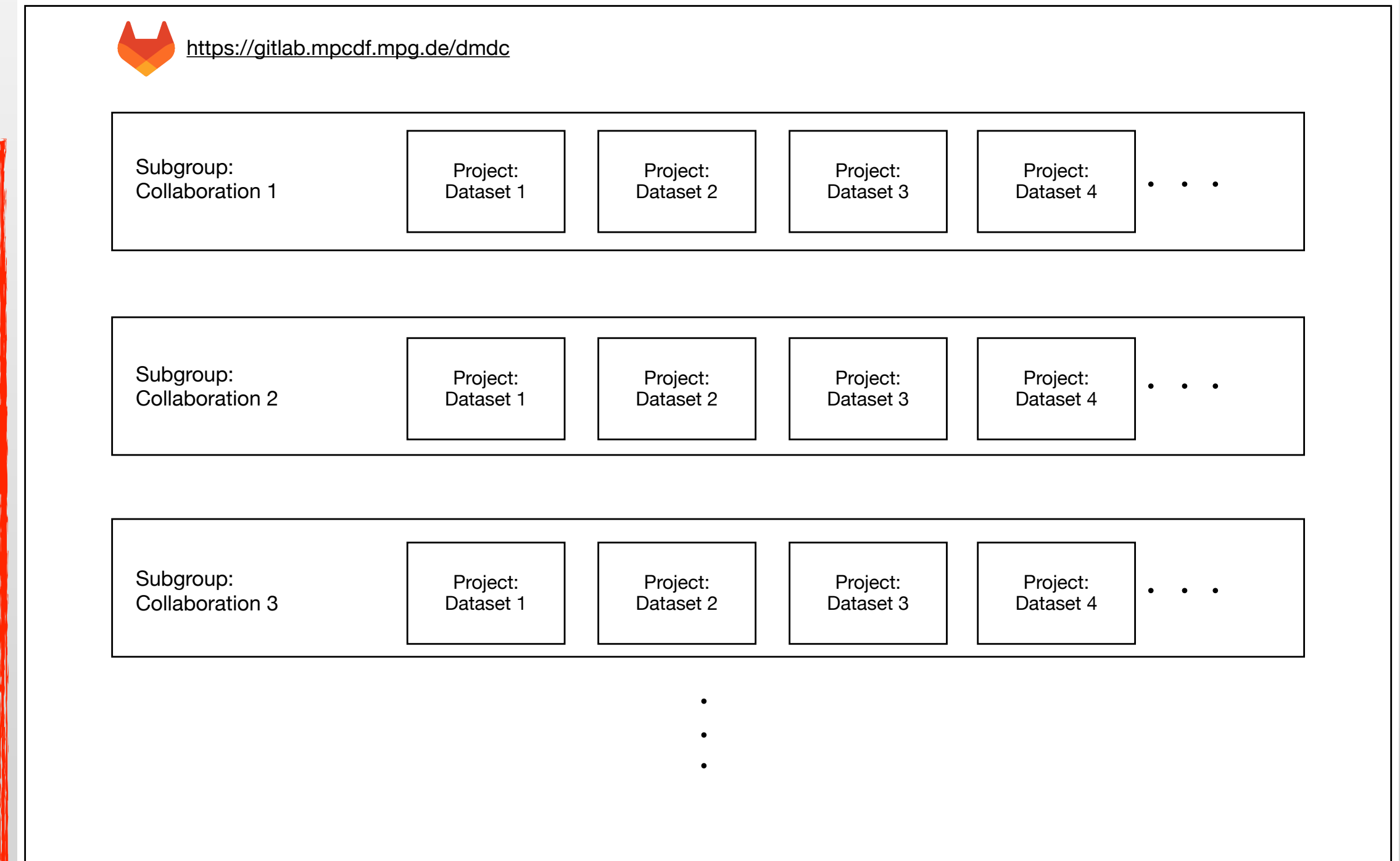
— CRESST-III Det A  
[arXiv:1905.07335 [astro-ph.CO]]  
— XENON1T S2-Only  
[Phys. Rev. Lett. 123, 25181 (2019)]  
— XENON1T S2-Only NEST v2.0.1  
[Phys. Rev. Lett. 123, 25181 (2019)]

# Present Status

## Data from Experiments

### Back-end:

- Familiar GitLab backbone for datasets.
- Each Collaboration has a self-maintained subgroup (up to two maintainers per Collaboration).
- Information on front-end controlled completely from Project metadata updated on GitLab.
- Dataset visualizations controlled through GitLab via GitLab Pages.



**AN AIS**

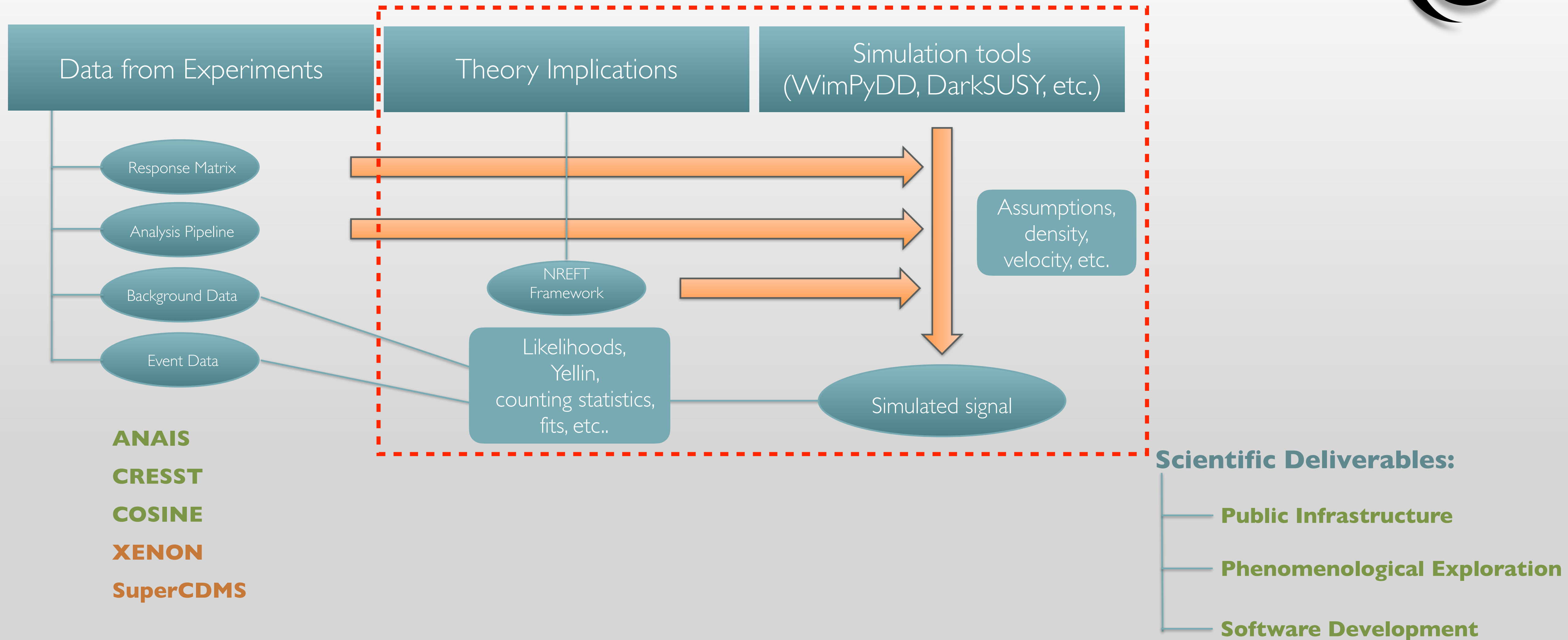
**CRESST**

**COSINE**

**XENON**

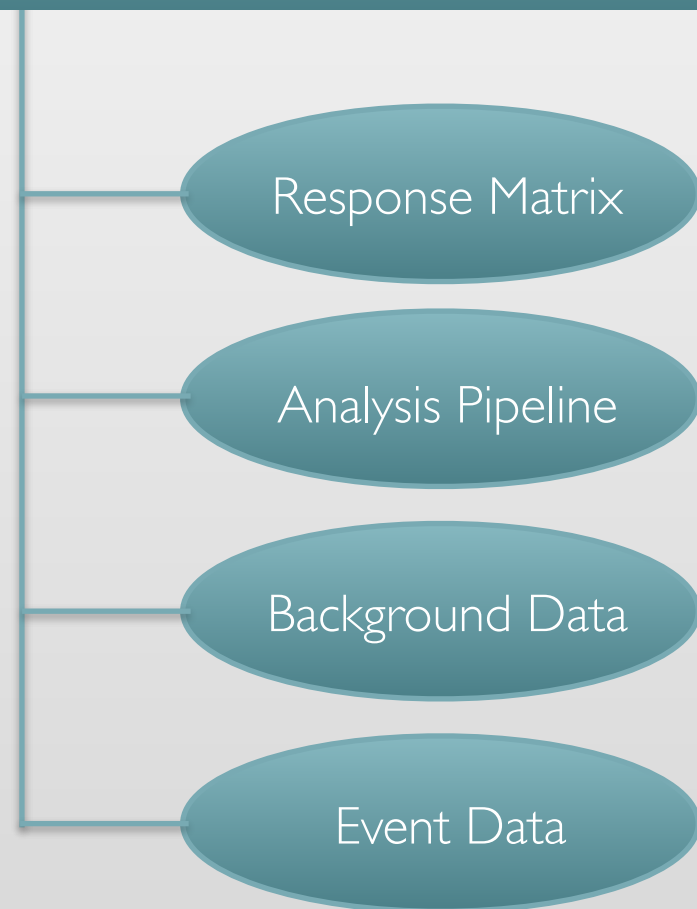
**SuperCDMS**

# Future Plans



# Future Plans

## Data from Experiments



**ANAIS**

**CRESST**

**COSINE**

**XENON**

**SuperCDMS**

## Public Infrastructure

- Global limits on EFT (beside the standard xsec limits) parameters + maintaining it.
- Expand current database. Reach out to more collaborations.
- Expand to Indirect and Collider Searches.
- Tag & query based search. Better automation. General feature improvements.

## Scientific Deliverables:

**Public Infrastructure**

**Phenomenological Exploration**

**Software Development**

# Future Plans

## Data from Experiments



**AN AIS**

**CRESST**

**COSINE**

**XENON**

**SuperCDMS**

## Phenomenological Exploration

- Obtaining Global limits and making them public. Fully Open-source.
- Focus on Collective analysis from Theoretical as well as Experimental points of view.
- Target:
  - ✓ Enhance global sensitivity to a possible signal.
  - ✓ Global analyses of anomalies.
  - ✓ Reinterpretation in terms of models of physics and statistical methods.
  - ✓ Going the public likelihood way.

## Scientific Deliverables:

- **Public Infrastructure**
- **Phenomenological Exploration**
- **Software Development**

# Future Plans

## Data from Experiments



**ANAIS**

**CRESST**

**COSINE**

**XENON**

**SuperCDMS**

## Software Development

- Current project on a simulation tool for Direct Searches
- Project on a reinterpretation and analysis tool.
- All to be offered as downloadable packages and for (limited) online usage.

## Scientific Deliverables:

**Public Infrastructure**

**Phenomenological Exploration**

**Software Development**

# Intersection between experimentalists and theorists in the DM community



For the Collaborations	For Phenomenologists
Data preservation (DOI assignment if needed, non-exclusivity). Workflow preservation.	Instructions and examples of data analyses
Full long-term reproducibility of published results	Virtual machines and computing power
Easy usage (Binders and friendly web-GUI)	Online visualization
Facilitate proper and maximum utilization of data by the community	Persistence, usability and citability of new models