



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))

Nahuel Ferreiro Iachellini

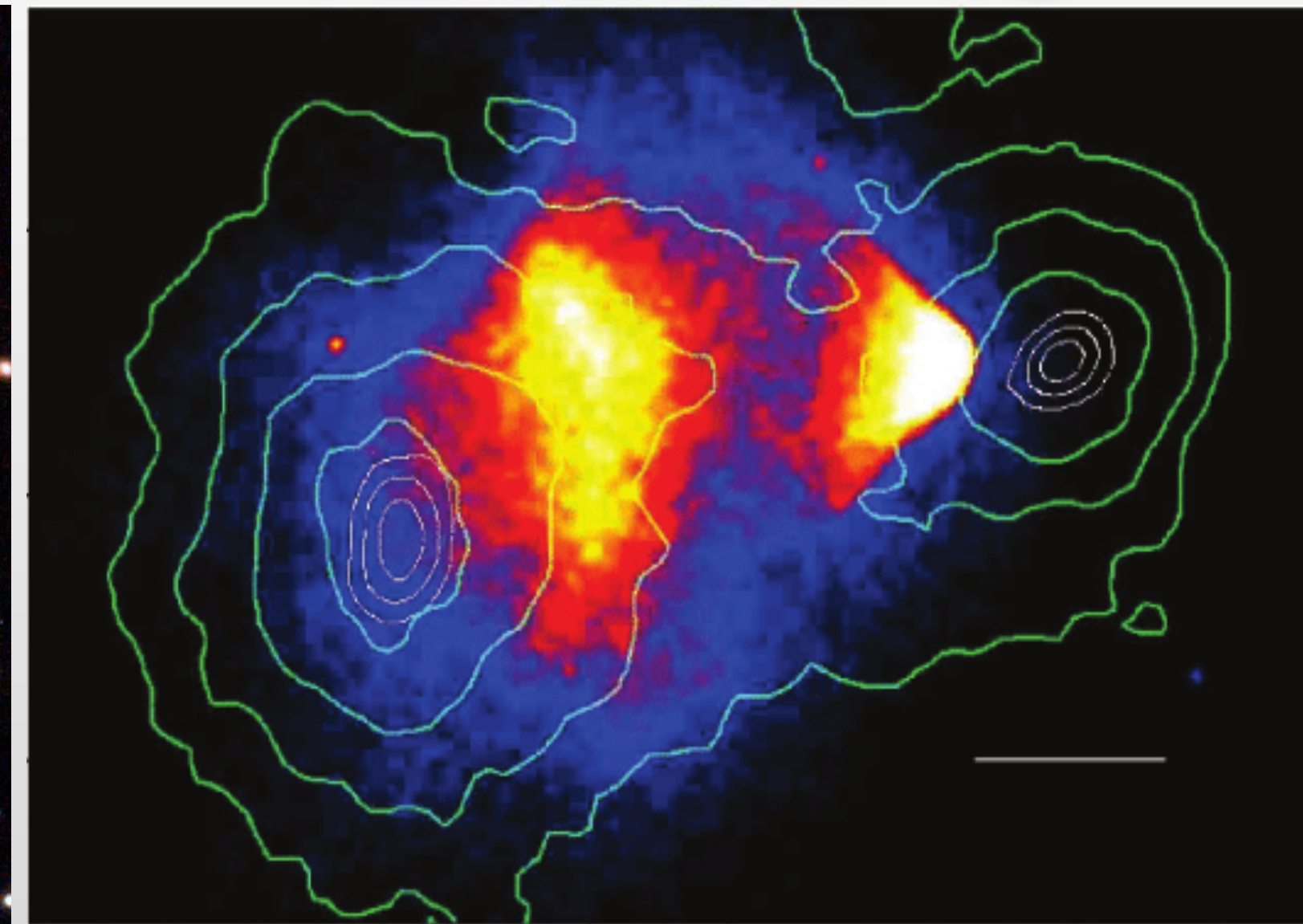
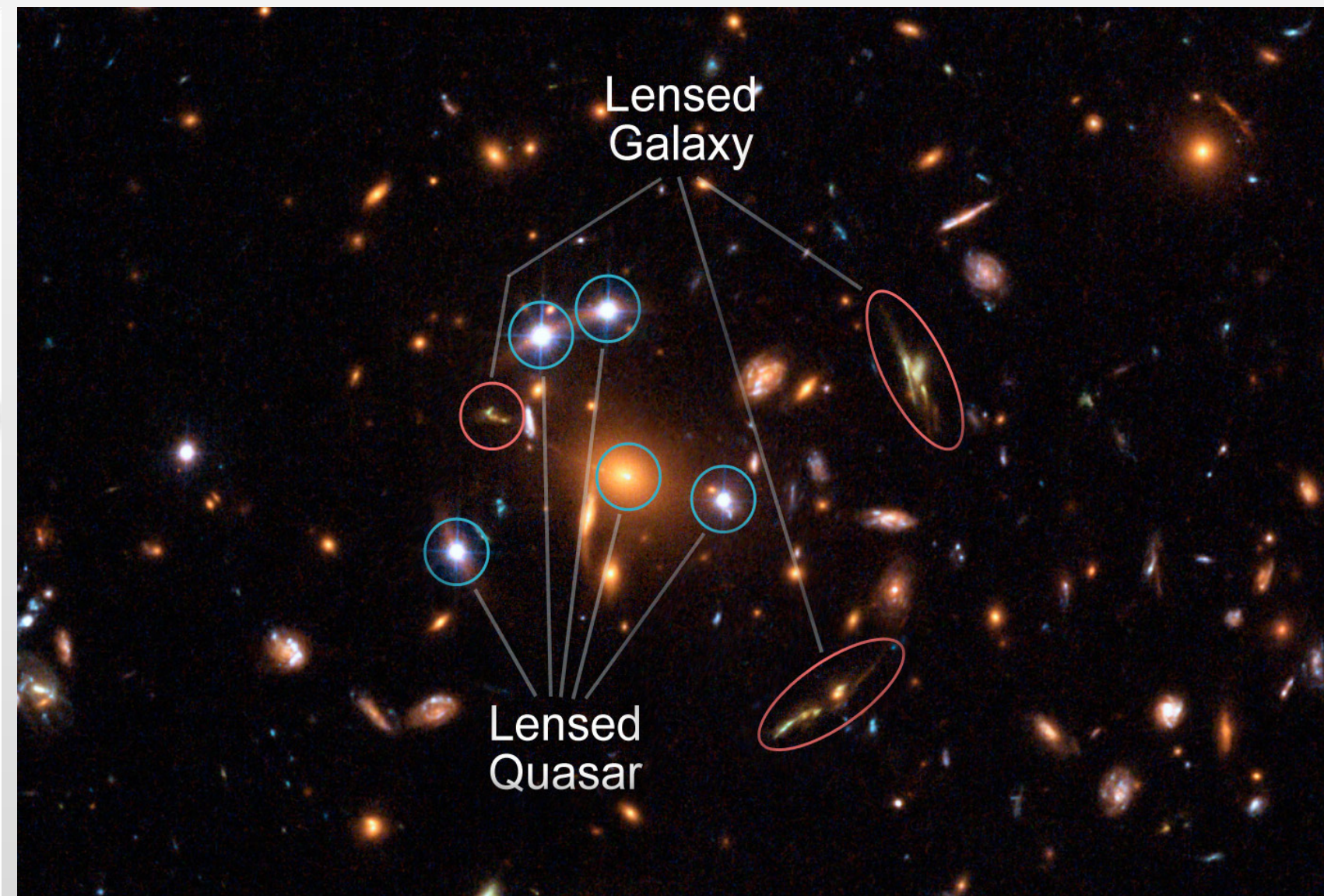
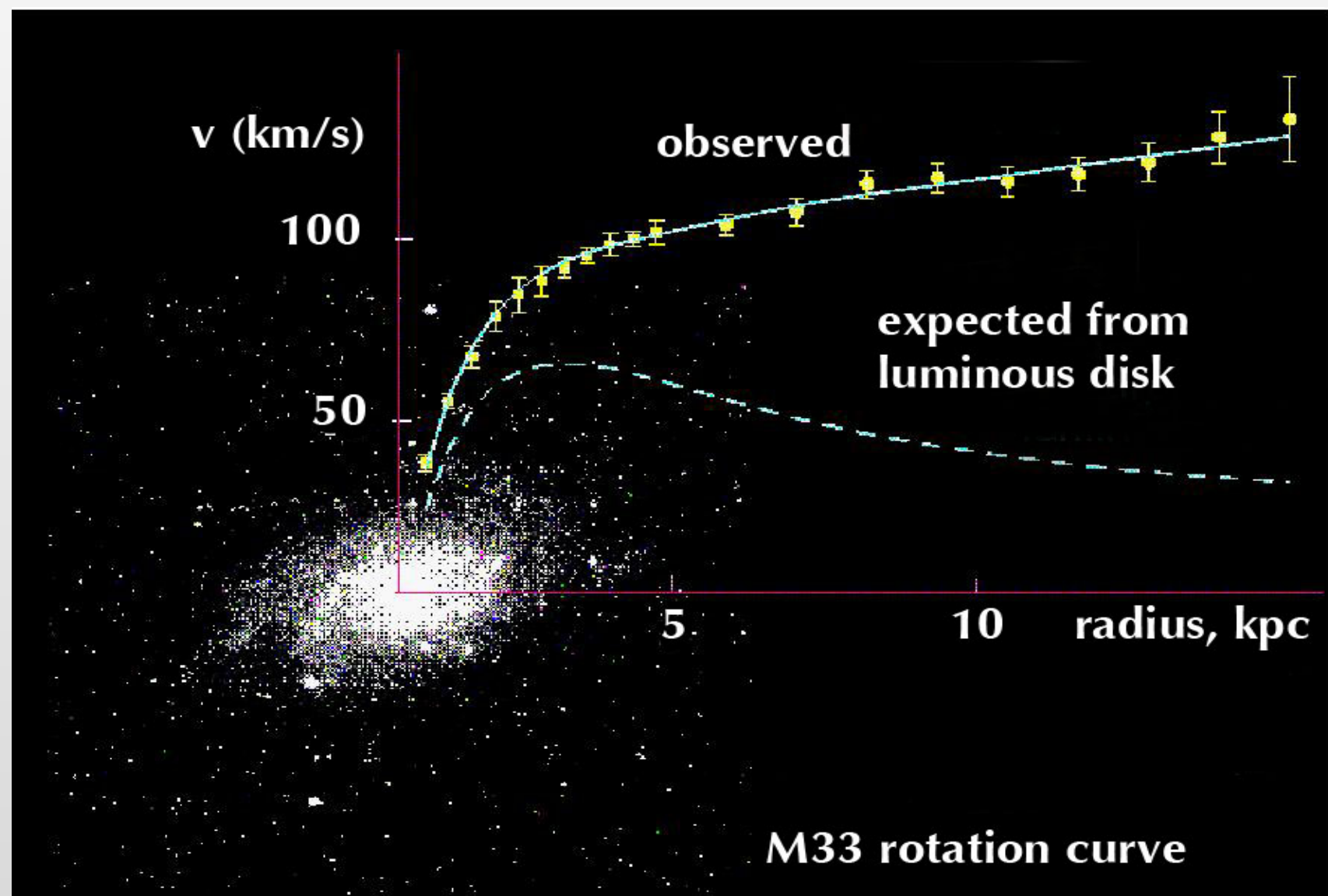
([ferreiro@mpp.mpg.de](mailto:ferreiro@mpp.mpg.de))

SUSY 2022, Ioannina





# All Roads Lead to...Dark Matter!



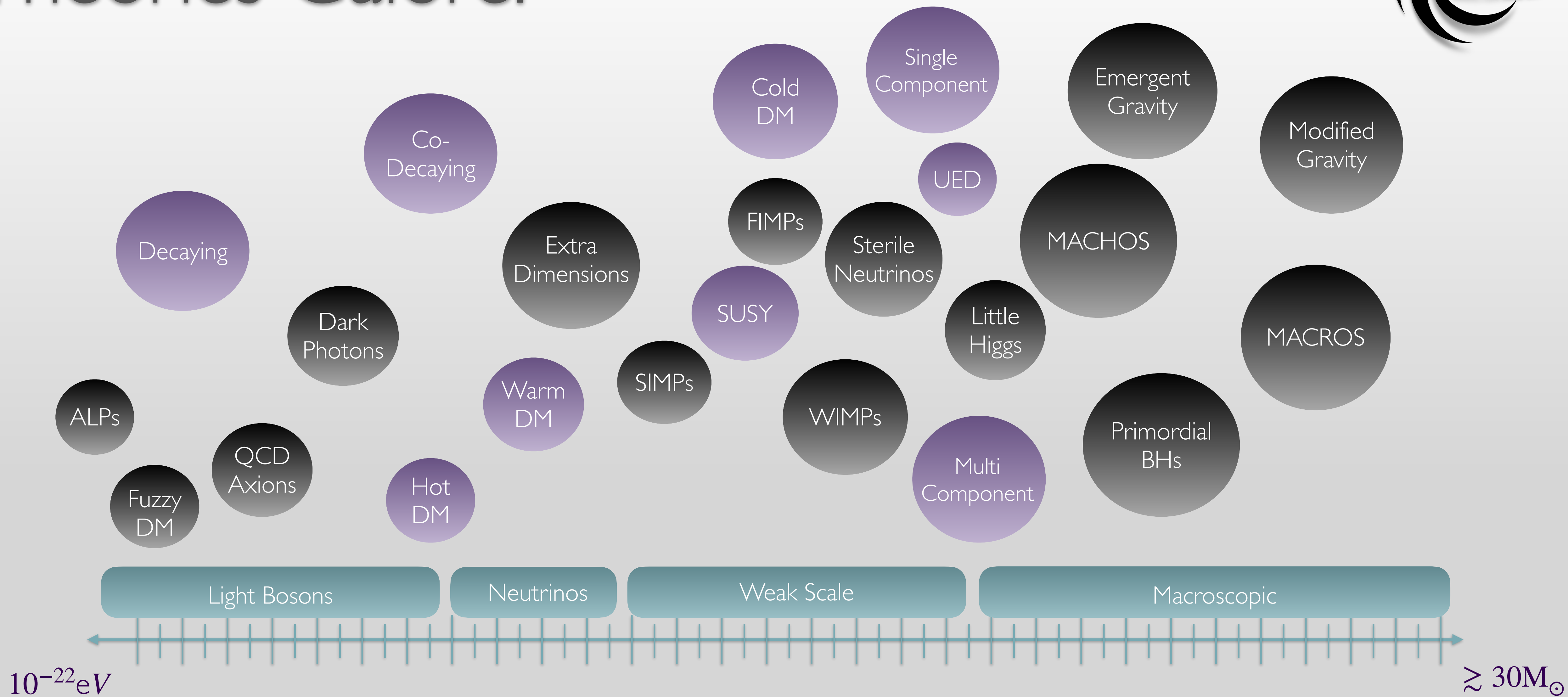
- ✓ Galactic Rotation Curves of spiral galaxies
- ✓ Velocity Distribution in elliptical galaxies and globular clusters
- ✓ Mass estimation in galaxy clusters. Dark Matter : Visible Matter = 5:1

✓ Gravitational Lensing

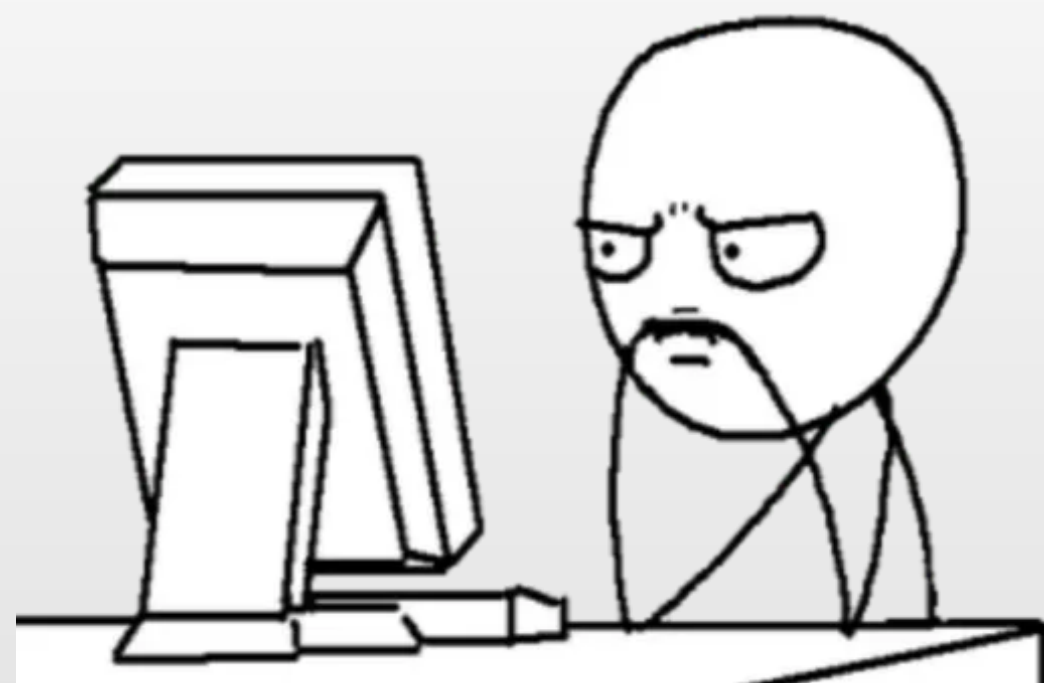
- ✓ CMB anisotropy acoustic peaks : COBE (1992), BOOMERang (2000), WMAP (2012), PLANCK (2015)
- ✓ Structure Formation



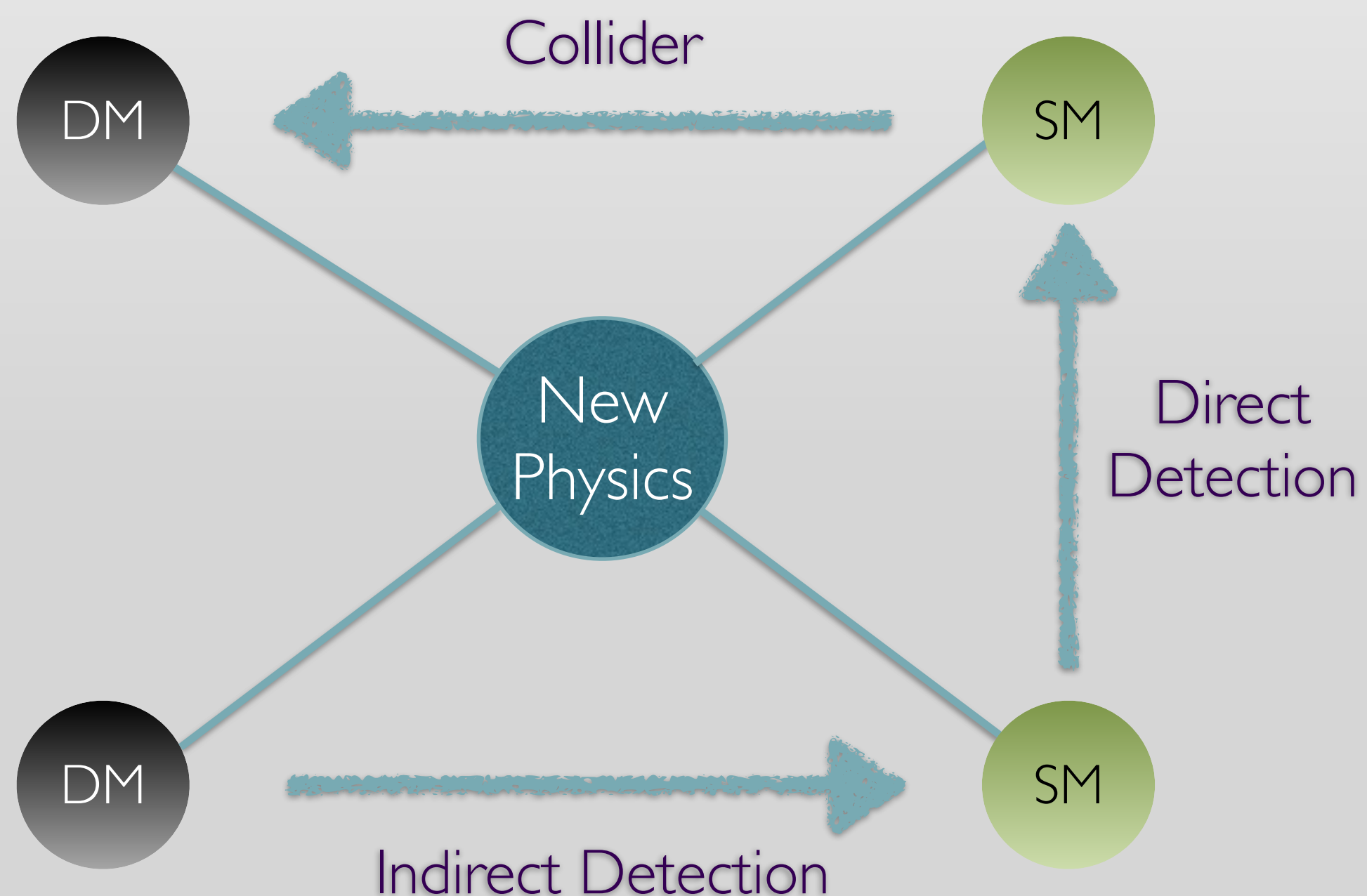
# Theories Galore!



# Threading a Needle in the Dark...

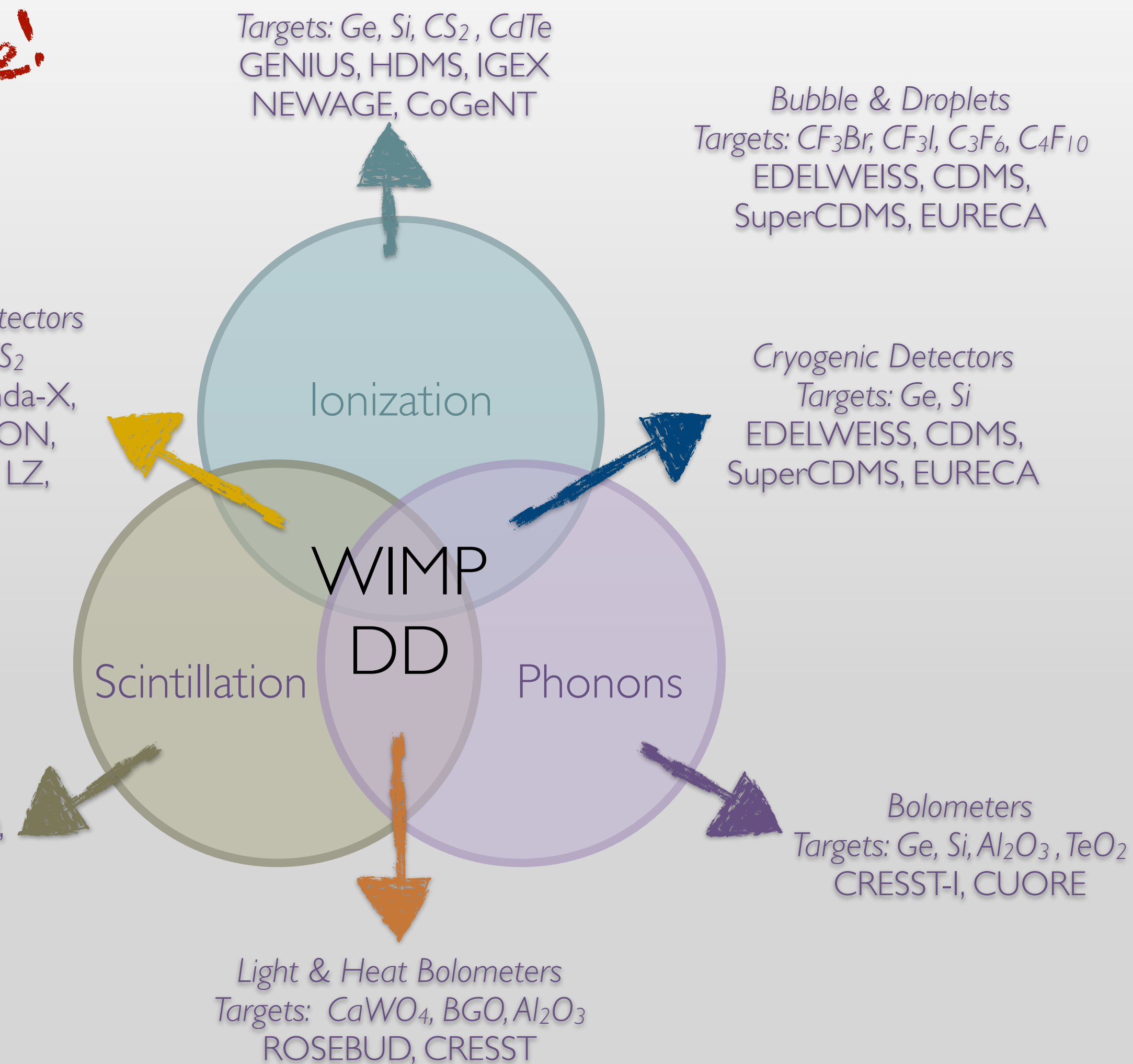


*already a maze!*



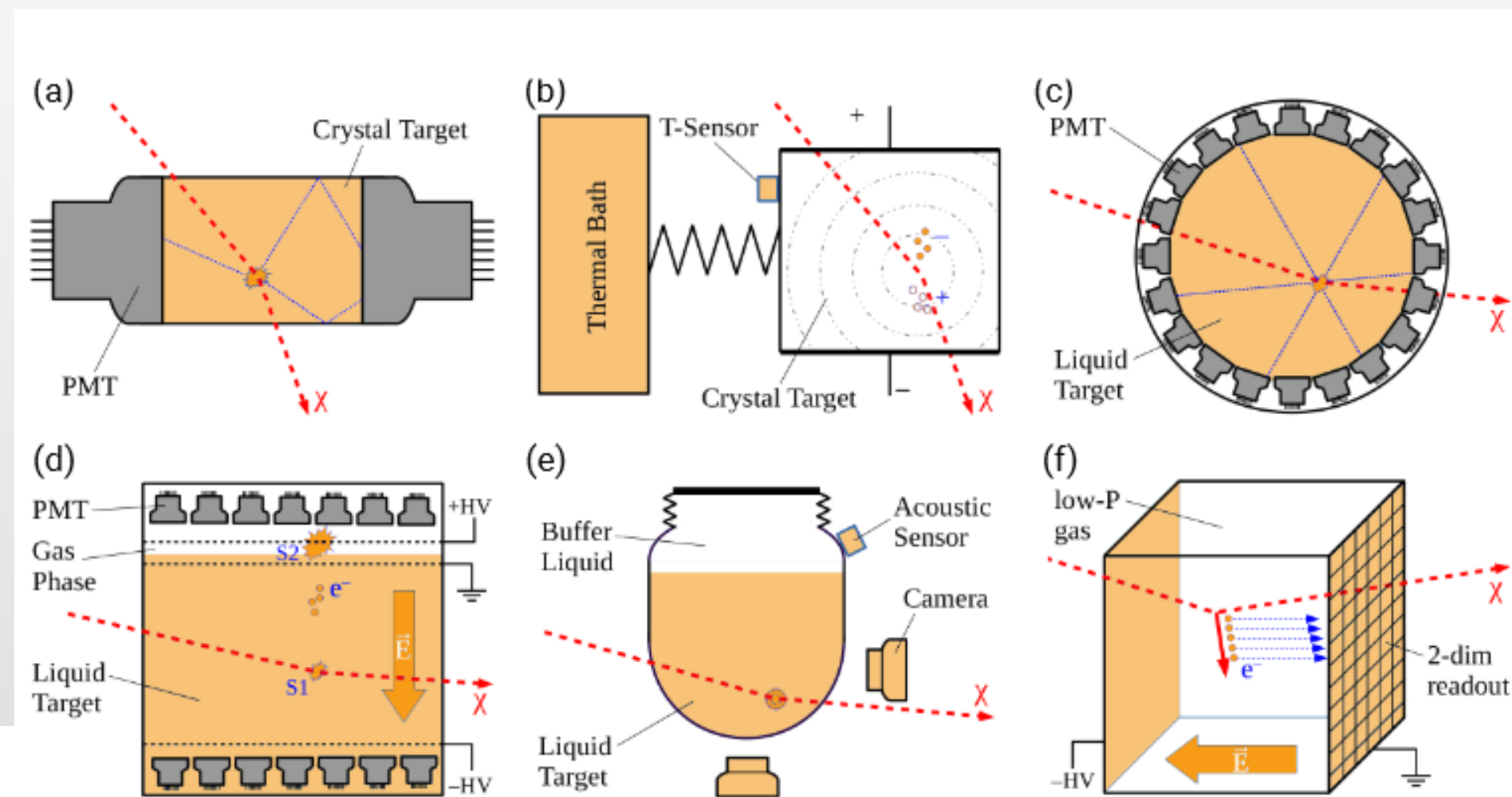
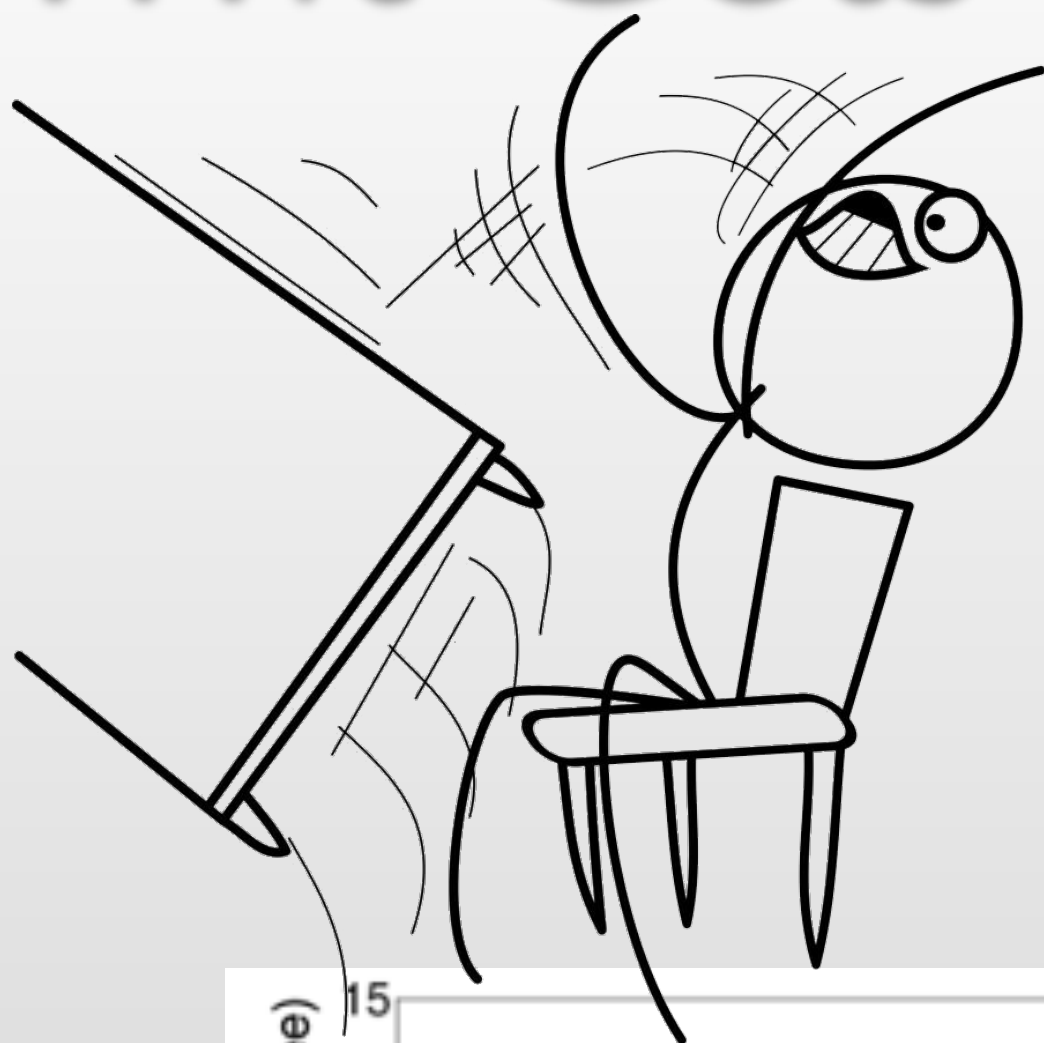
Light & Ionization Detectors  
Targets: Xe, Ar, CS<sub>2</sub>  
WARP, ZEPLIN, Panda-X,  
LUX, DRIFT, XENON,  
DarkSide, ARDM, LZ,  
Darwin

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

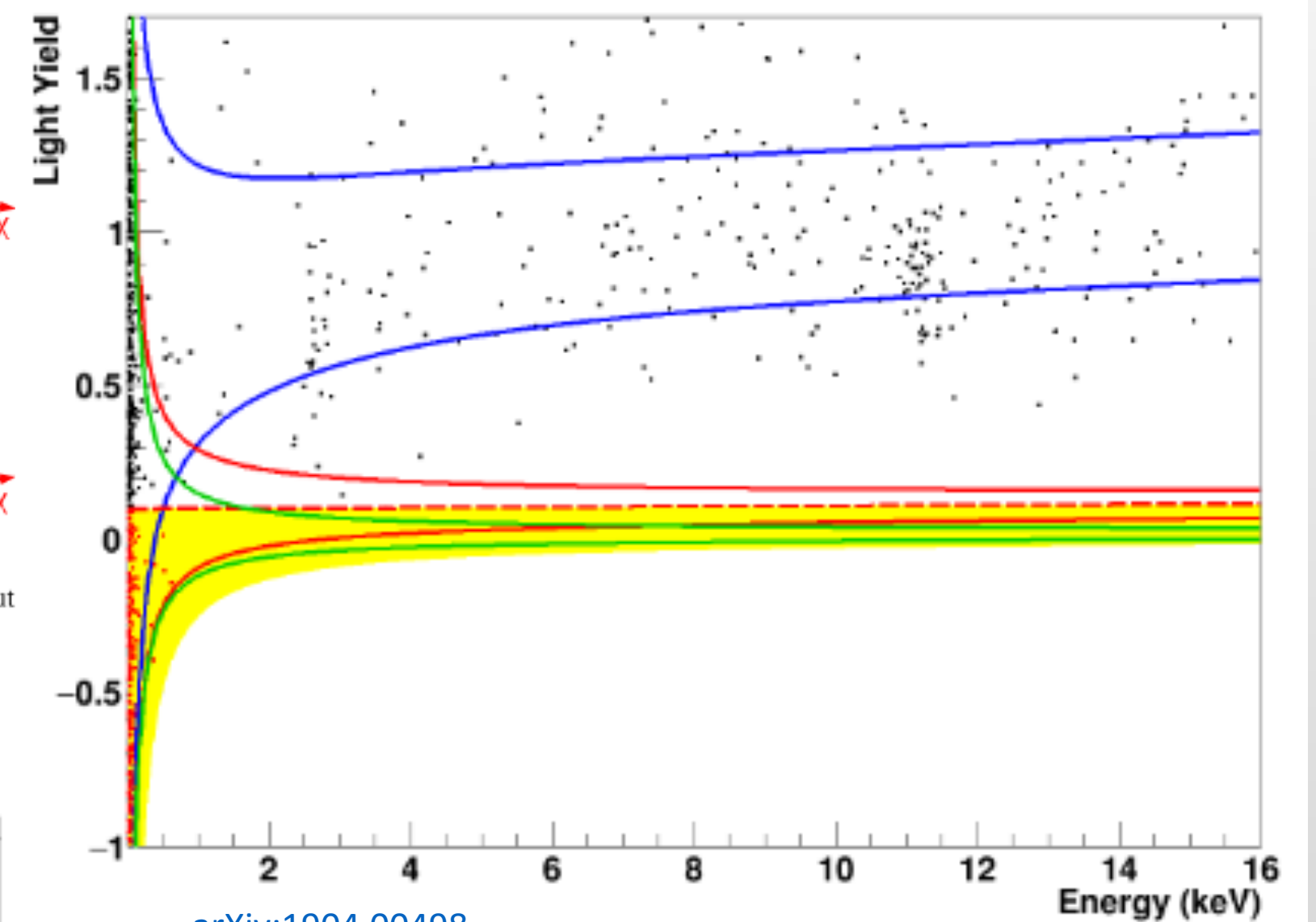
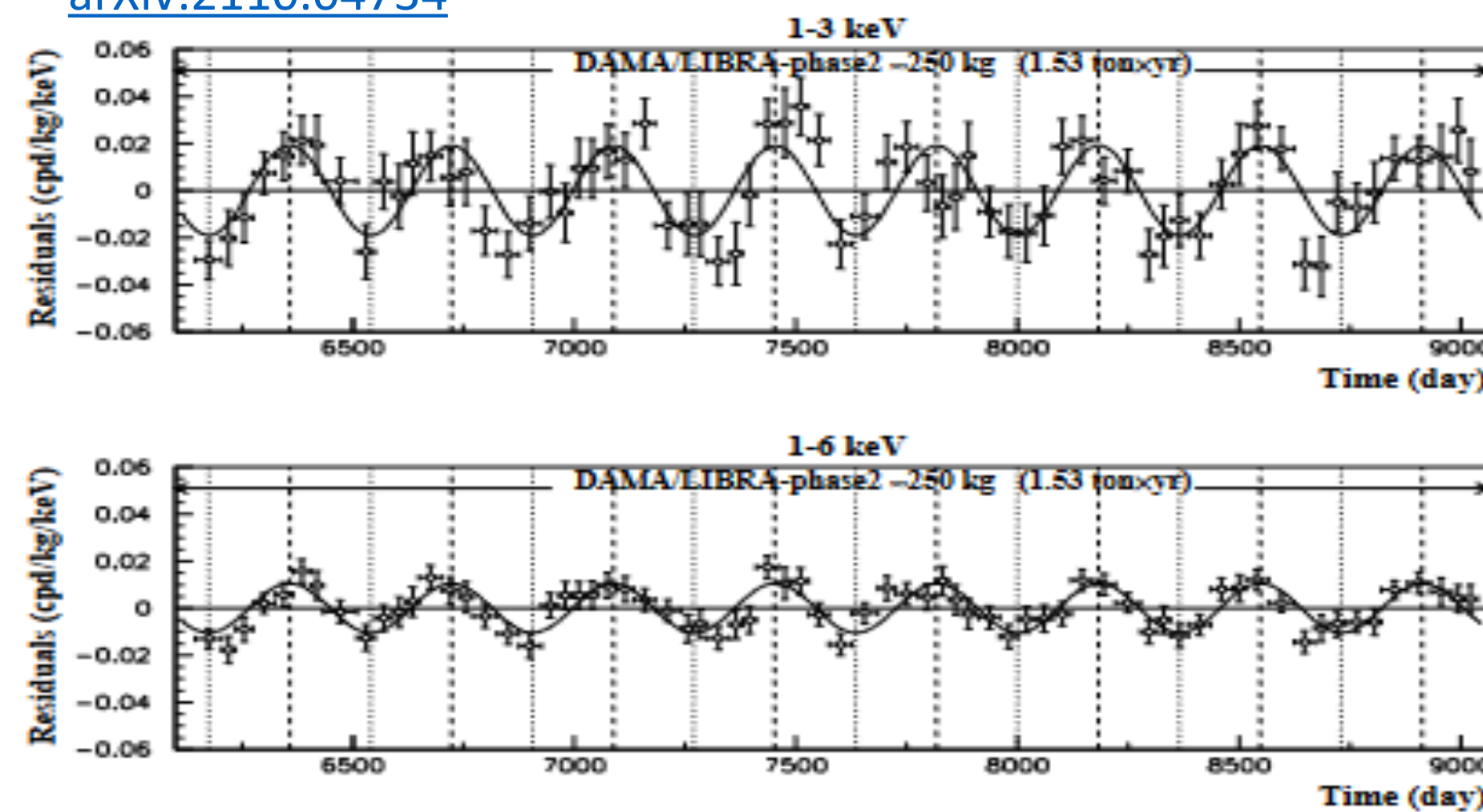




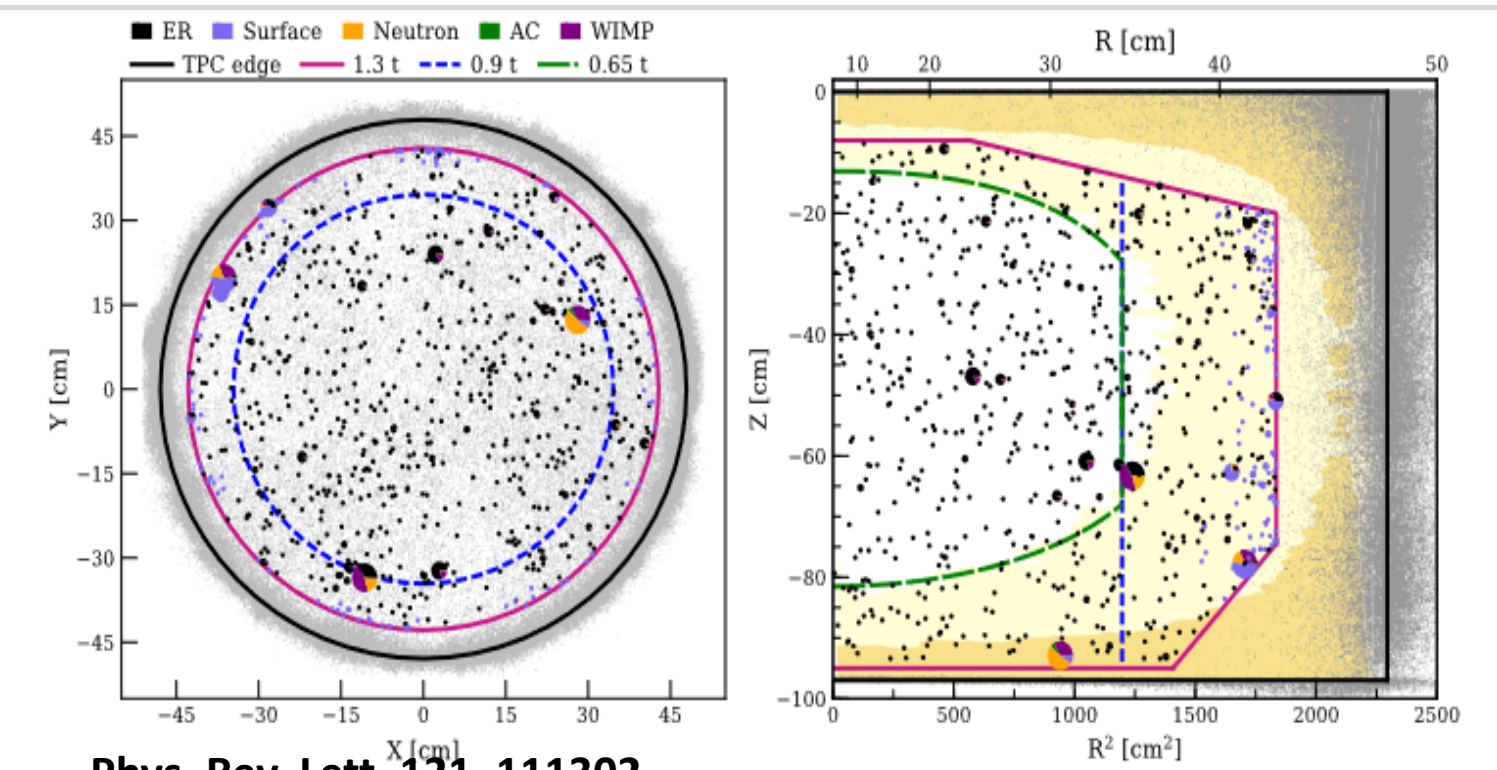
# ...It Gets Better!



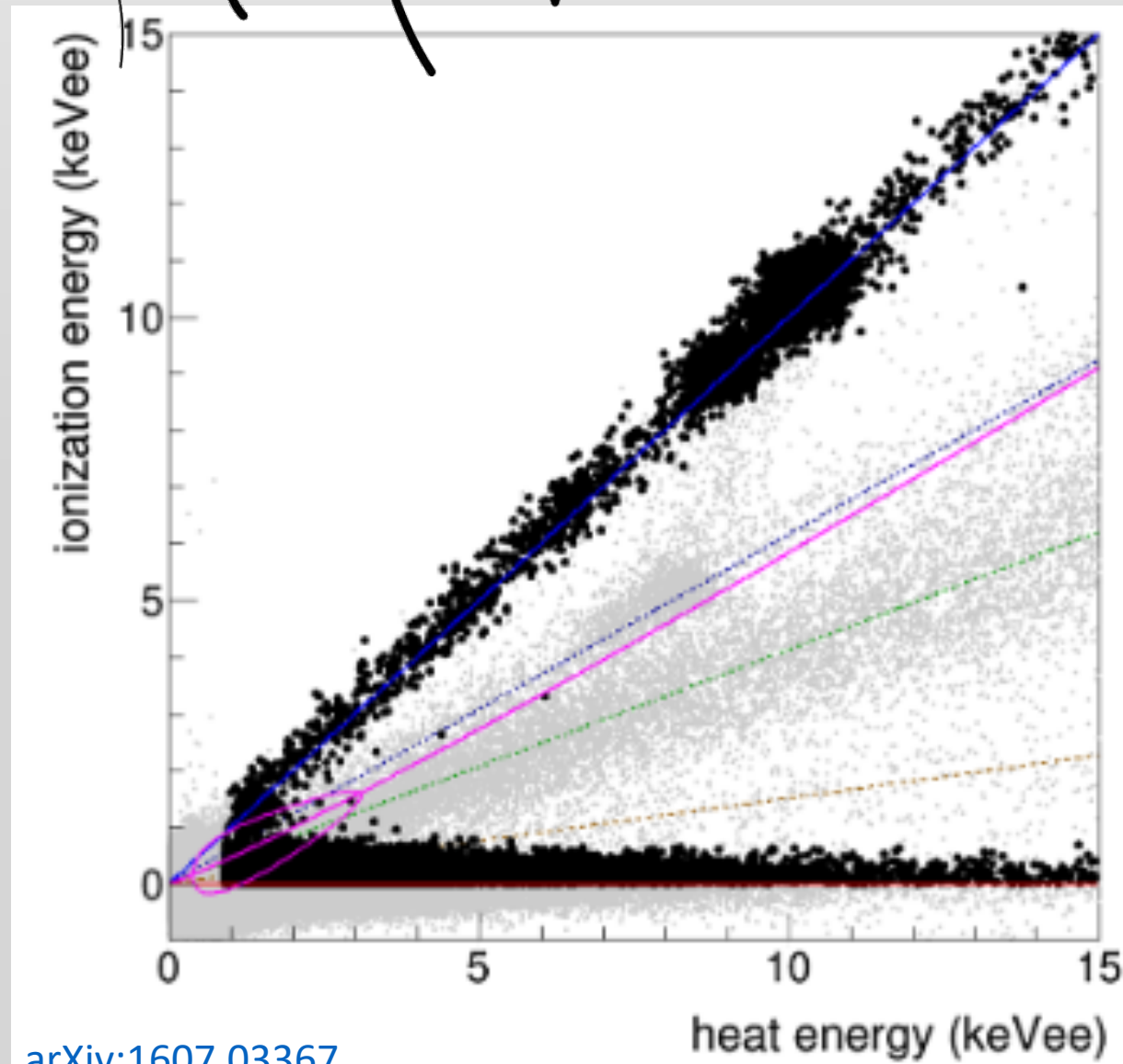
[arXiv:2110.04734](https://arxiv.org/abs/2110.04734)



[arXiv:1904.00498](https://arxiv.org/abs/1904.00498)



Phys. Rev. Lett. 121, 111302



[arXiv:1607.03367](https://arxiv.org/abs/1607.03367)



# The Dark Matter Data Center



Open Data!  
Open Science!

Efficiency  
of Research

Reliability  
of Results

Resilience  
to societal  
challenges

ORIGINS  
Excellence Cluster

ForschungAktuellesORIGINS für alleInfrastrukturÜber 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.

Overview

- Explore Data
- Publish Data
- Publish Code

Team

CN-3 / ODSL / P-S / RU-A / RU-B




Heerak Banerjee (TUM)

Postdoc and ODSL Fellow

@ heerak.banerjee(at)tum.de

Details

CN-1 / CN-3 / CN-7 / ODSL / P-S / RU-A / RU-B / RU-D



Dr. Mahuel Ferreiro Iachellini (MPP)

Postdoc and ODSL Fellow

@ ferreiro(at)mpp.mpg.de

Details

Available Datasets

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

- CRESST
- XENON

Available software

Submit data or software

Dark Matter Data Center | Heerak Banerjee | Technische Universität München

SUSY 2022 | 27th June 2022 | 6



# The Team



**Heerak Banerjee**

*Phenomenologist with experience in  
astroparticle searches and data analysis*

**Nahuel Ferreiro Iachellini**

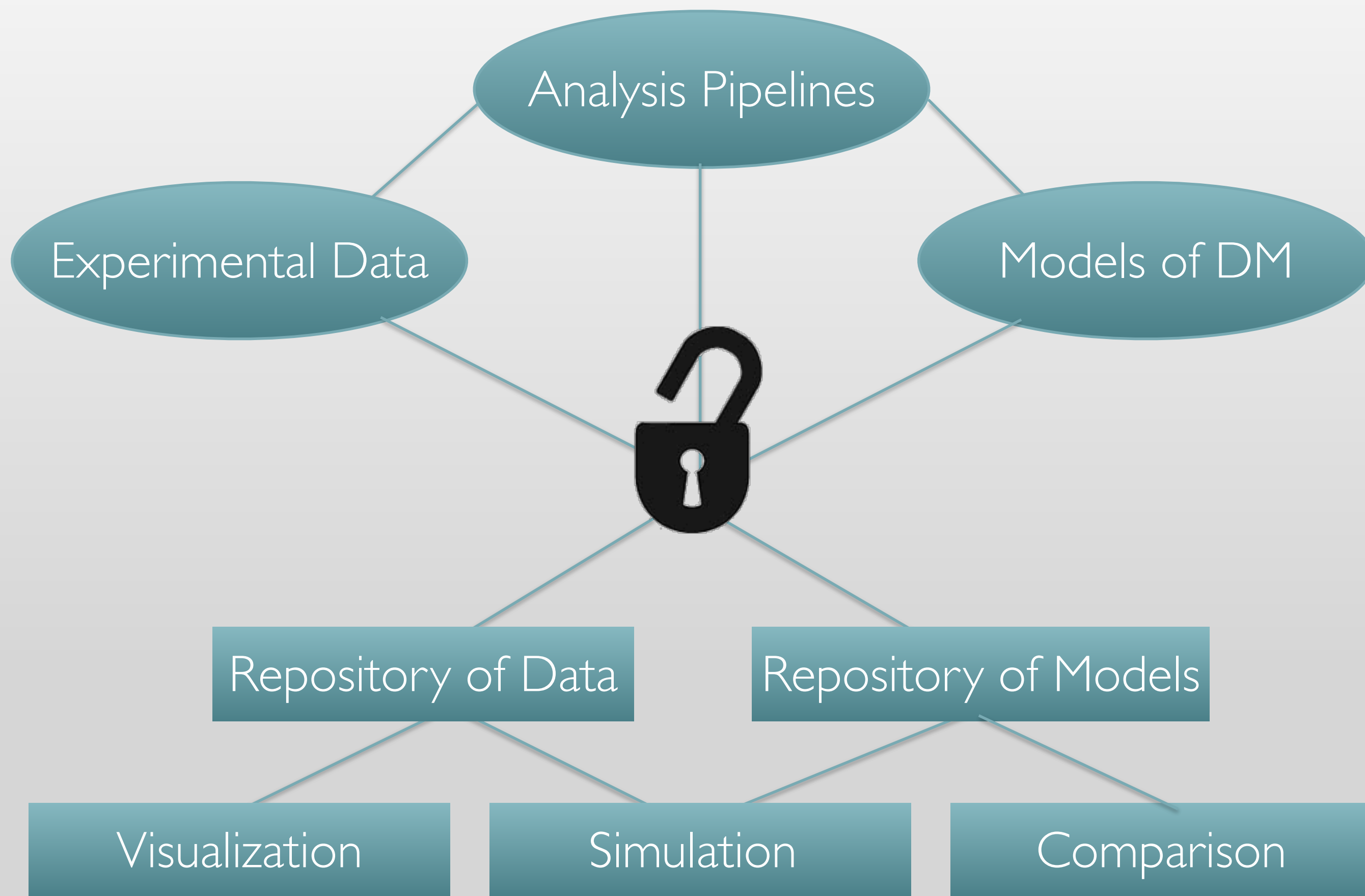
*Experimentalist with background in  
direct searches with cryogenic detectors*



The Max Planck Computation and Data Facility provides us with the necessary computational power. The public data is stored on the MPCDF servers to be fetched from our website on the ORIGINS domain. The Binders and the online services run on MPCDF servers as well.



# The Dark Matter Data Center



**ORIGINS**  
Excellence Cluster

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[Details](#)

CN-1 / CN-3 / CN-7 / ODSL / P-S / RU-A / RU-B / RU-D

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Postdoc and ODSL Fellow  
[@ ferreiro\(at\)mpp.mpg.de](mailto:ferreiro(at)mpp.mpg.de)  
[Details](#)

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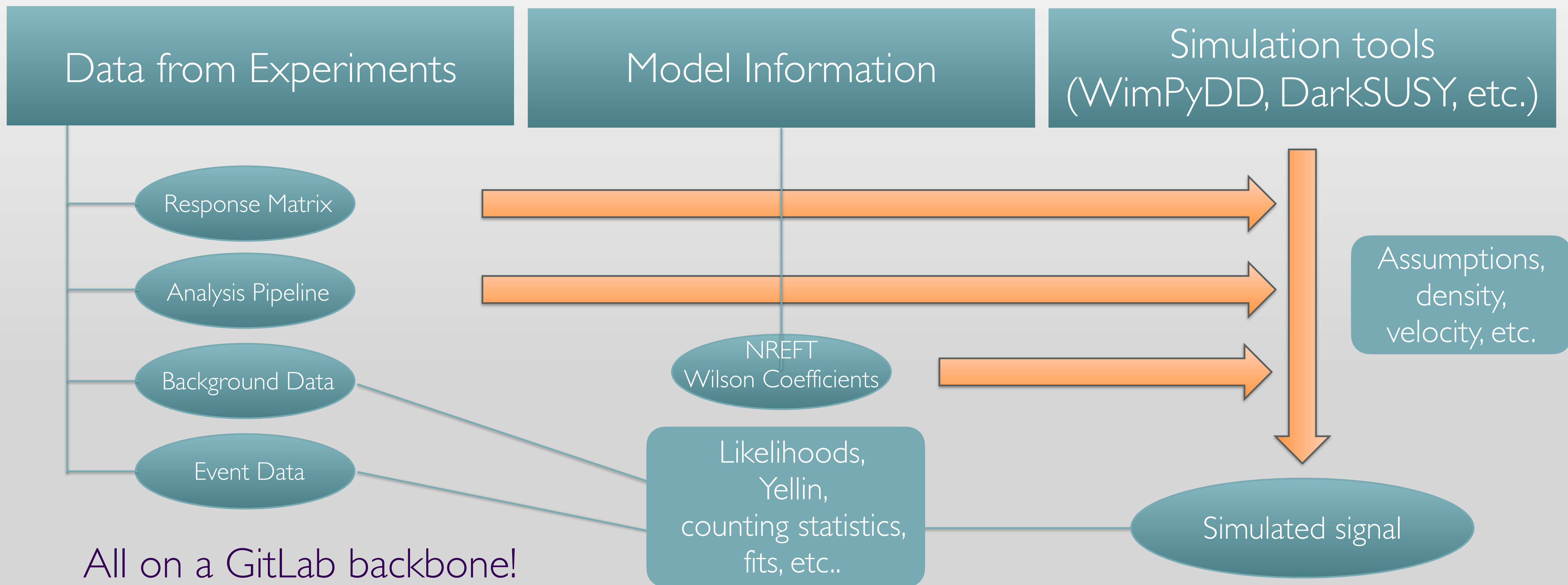
- CRESST
- XENON

Available software

[Submit data or software](#)



# A Little More Detail





# For Example

## Data from Experiments

Response Matrix

Analysis Pipeline

Background Data

Event Data

- Documented
- Easily findable (Metadata)
- Directly citable (Publication & DOI)
- Usage Instructions (Also in form of JuPyTer notebooks)

### XENON1T S2-Only Data Release

Detector Module	XENON1T
Material	Liquid Xenon
Technology	Dual-phase time projection chamber
Fiducial mass	2 tonne
Total exposure	356770 Kg days
Threshold	0.7 keV for NR, 0.186 keV for ER
Acceptance region	150-3000 Photoelectrons
Citeable sources	<a href="#">Phys. Rev. Lett. <b>123</b>, 251801</a>
Data and Description	<a href="https://github.com/XENON1T/s2only_data_release">https://github.com/XENON1T/s2only_data_release</a>

An example analysis for using this data release to constrain a model of Dark Matter has been provided by the Collaboration in the form of a JuPyTer Notebook.

Click here to launch a binder for a JuPyTer session with the notebook pre-loaded: [launch](#) [binder](#)

Resource	description
<a href="#">DetA AR</a>	Recoil energies in the acceptance region
<a href="#">C3P1_DetA_cuteff</a>	Cut efficiency
<a href="#">C3P1_DetA_eff_AR_Ca</a>	Fraction of events from the Ca recoil band in the ROI
<a href="#">C3P1_DetA_eff_AR_O</a>	Fraction of events from the O recoil band in the ROI
<a href="#">C3P1_DetA_eff_AR_W</a>	Fraction of events from the W recoil band in the ROI
<a href="#">C3P1_DetA_full</a>	Energies of events surviving da selection
<a href="#">C3P1_DetA_DataRelease_SD</a>	Spin dependent limit
<a href="#">C3P1_DetA_DataRelease_SI</a>	Spin independent limit



# For Example

## Data from Experiments

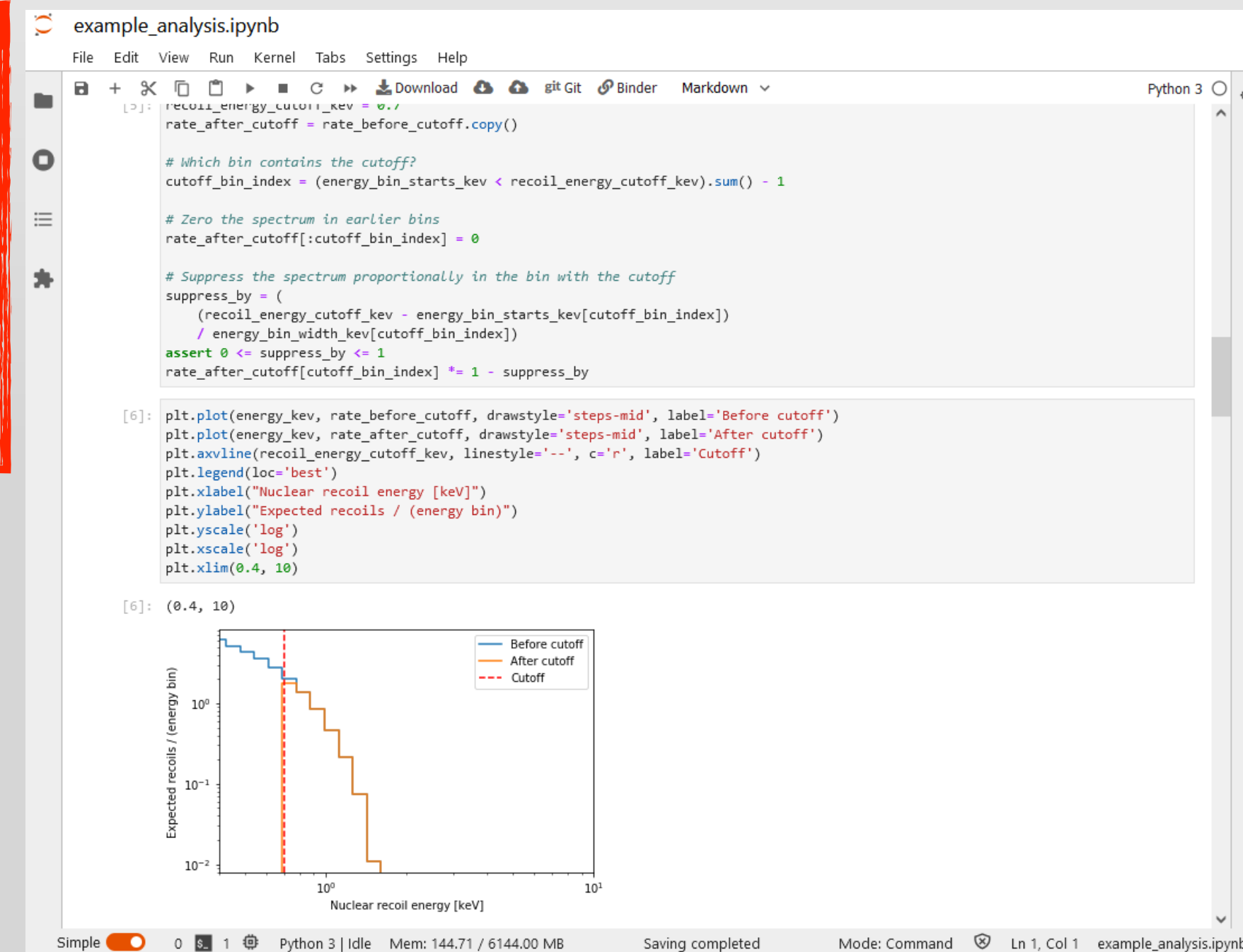
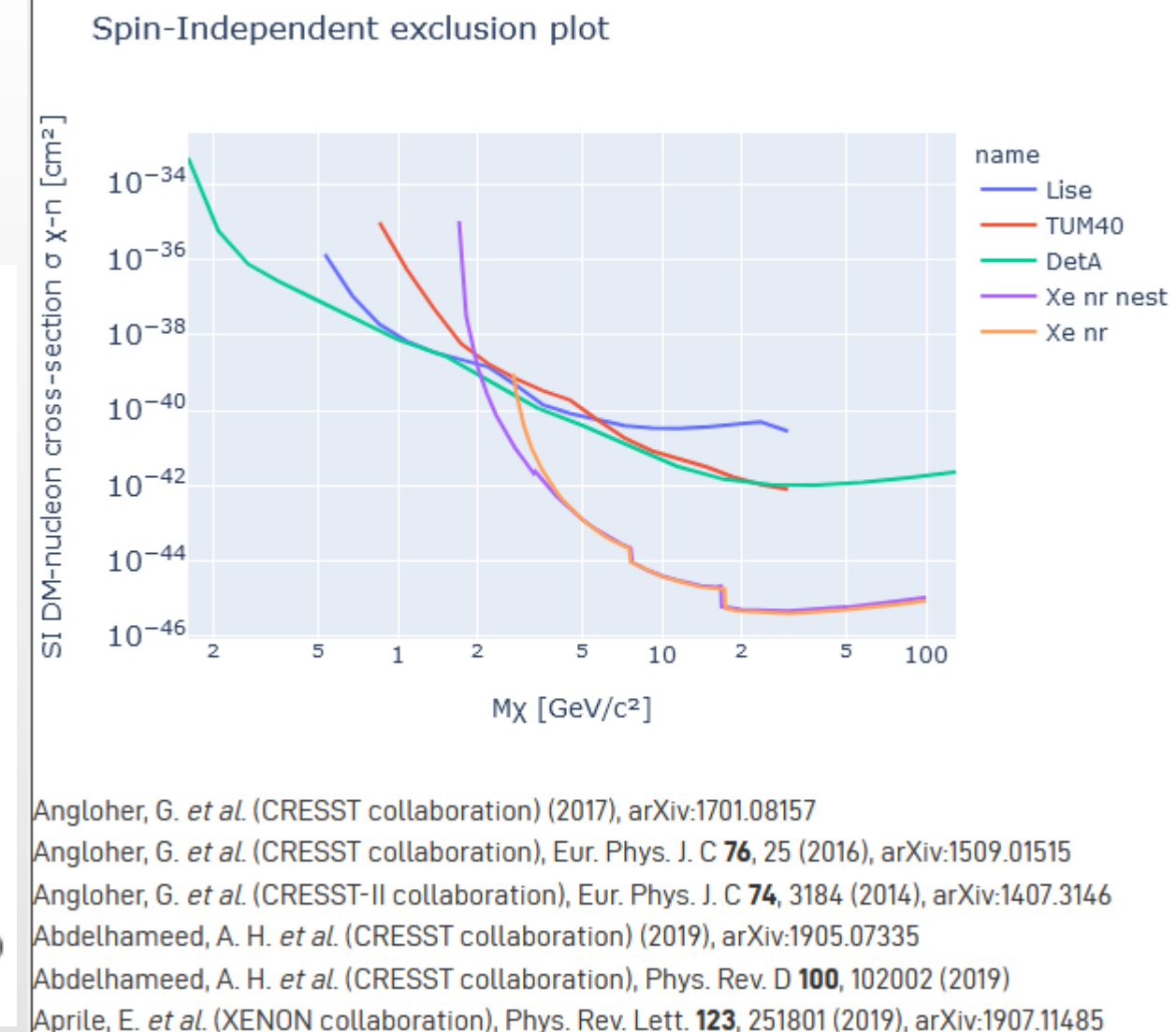
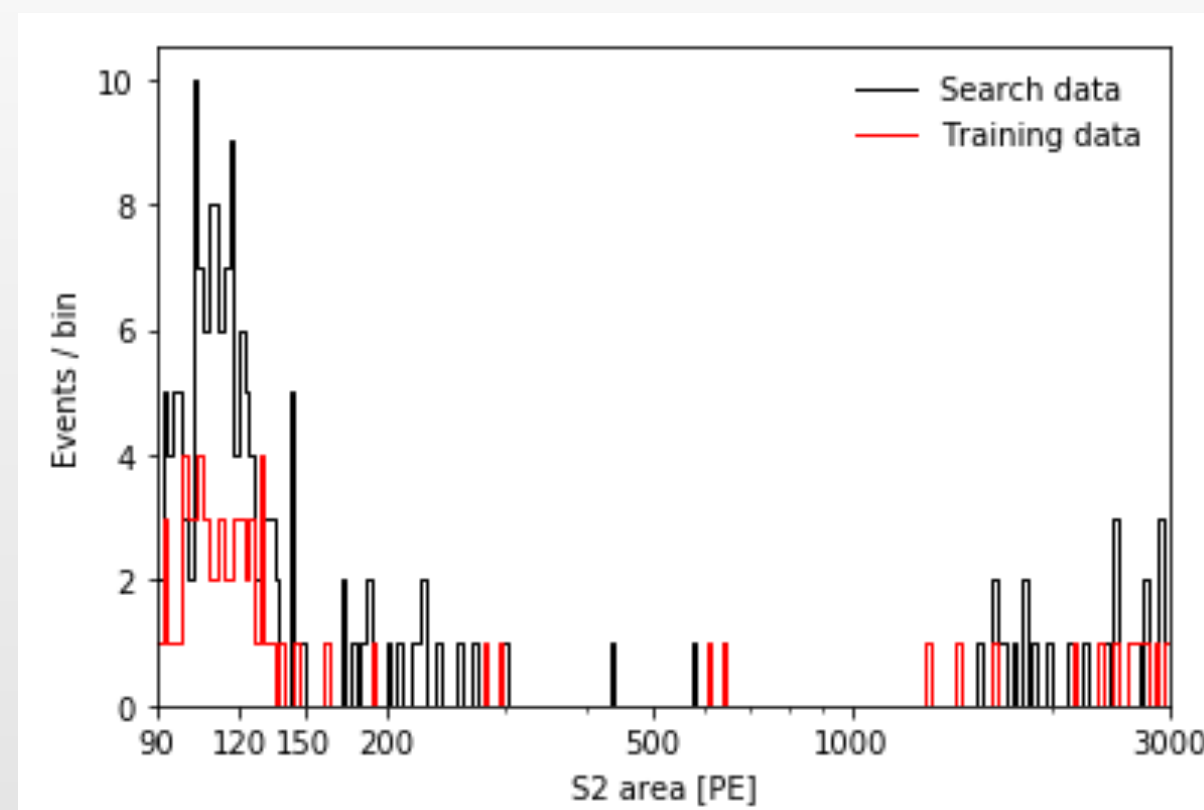
Response Matrix

Analysis Pipeline

Background Data

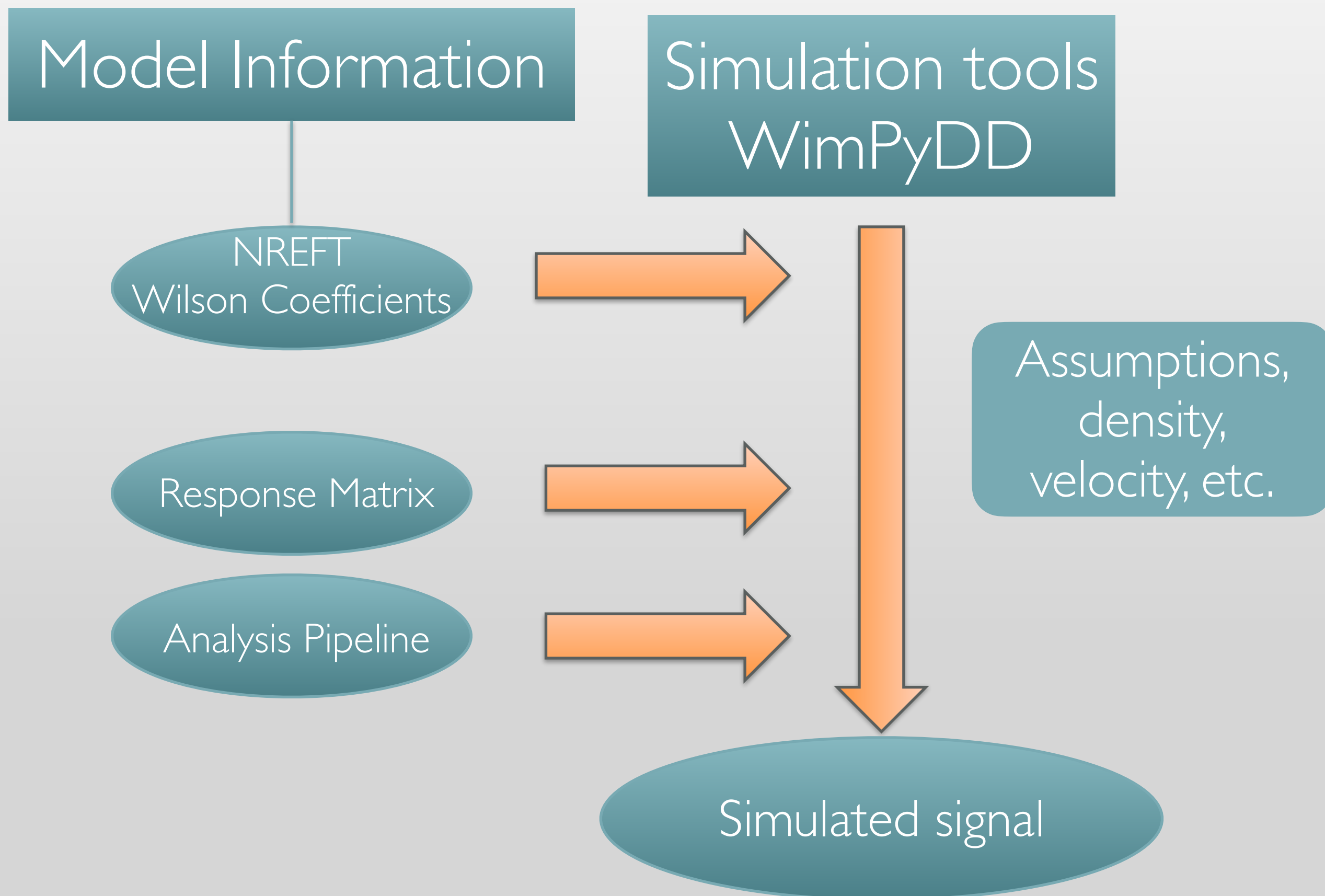
Event Data

- Easy Visualization  
(Recoil energies, time series, limits, etc.)
- Interactivity





# For Example



Usage through user-friendly web-GUI

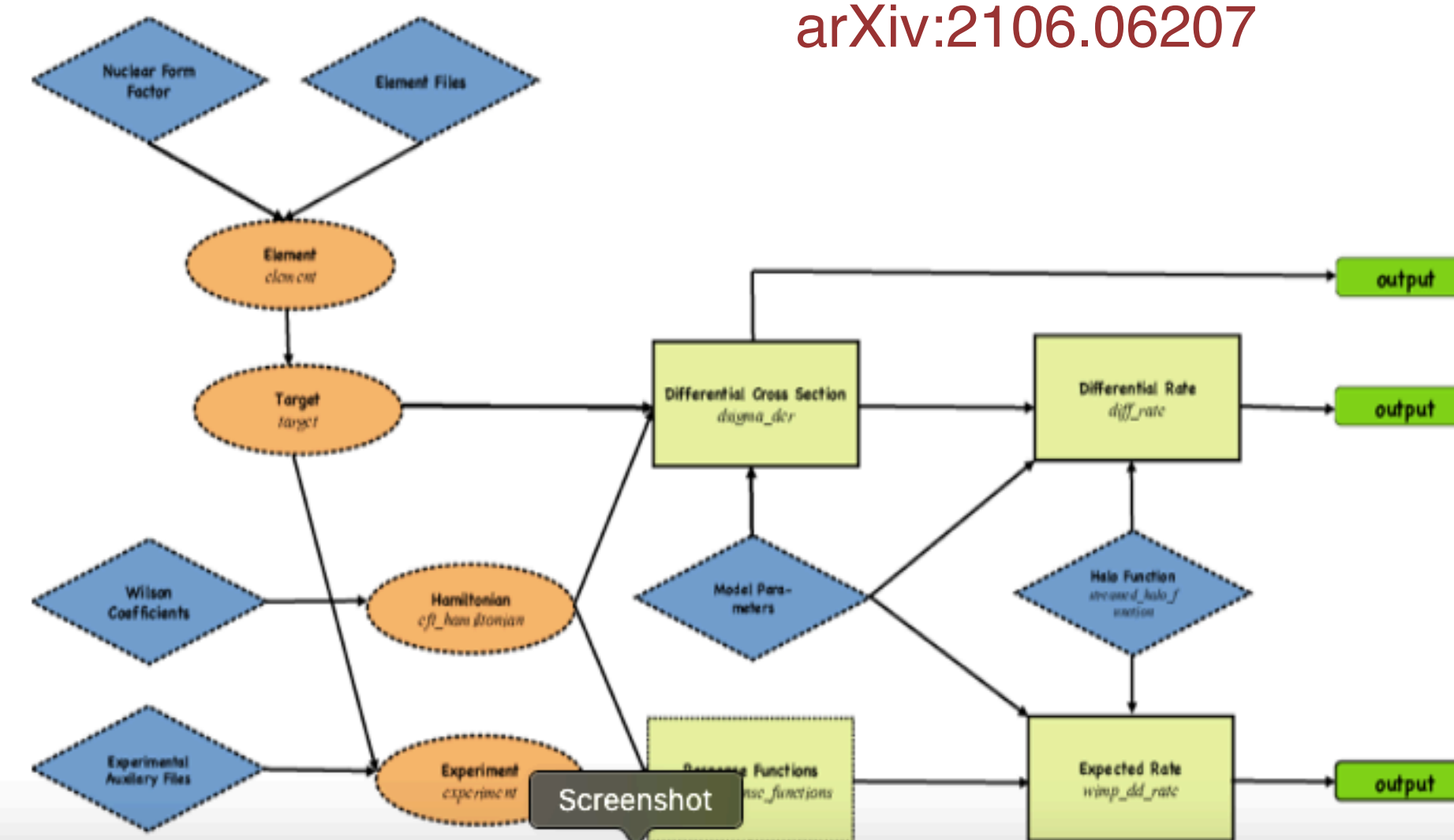


## WimPyDD

WimPyDD is a object-oriented and customizable Python code that calculates accurate predictions for the expected rates in WIMP direct-detection experiments within the framework of Galilean-invariant non-relativistic effective theory. WimPyDD handles different scenarios including **inelastic scattering**, **WIMP of arbitrary spin** and a **generic velocity distribution** of WIMP in the Galactic halo.

WimPyDD is written by **Stefano Scopel, Gaurav Tomar, Sunghyun Kang, and Injun Jeong**.

arXiv:2106.06207





# From the Collaborations

## Event Data

- Post efficiency and selection cuts.
- Preferably full data and not just published ROI
- Photoelectrons, heat, timestamp, positions, etc. as available.

## Background Info

- Numerical background data and/or background models.
- Preferably for each component

## Detector Response

- Efficiencies, thresholds, cuts, quenching factor, conversions from recoil energy to detector parameters, etc.
- In essence, information required to generate simulated signal at an experiment from predicted cross section.

## Analysis Pipeline

- Analysis used by the collaboration to generate published exclusions using published data.
- As publishable software, in the form of Binders, JuPyTer Notebooks, etc.



# From Theorists/Phenomenologists

## Simulation Tools

- New tools for simulating predicted signal at experiments.
- Publishable as downloadable package. DOI assignment.
- Run online as an integrated tool or on a Binder.

## Physics Model Info

- Pertinent interaction vertices as NREFT coefficients, limits on their strengths, dependencies.
- Background model(s) used (if new ones used).

## Implementation

- Experiments used, method used for comparison, tool used for simulation.
- Packaged to be run online on a Binder.
- Connected to published work. Please provide sources of citeable data/software.

## Analysis Pipeline

- Packaged tool using all of above describing workflow for publication.
  - Primary tool for reproducibility of publication.
  - To run as a Binder online.
- We provide support in preparation!



# 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



# In Brevity



- Establish a repository for the technical aspects behind publications
- Ease and maximize the utilization of published data
- Build a comprehensive catalog of data and models in the field of DM

THANK YOU!

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

Please contact us at [heerak.banerjee@tum.de](mailto:heerak.banerjee@tum.de), [banerjee@mpp.mpg.de](mailto:banerjee@mpp.mpg.de), [ferreiro@mpp.mpg.de](mailto:ferreiro@mpp.mpg.de)  
if you would like to submit data/model or need support for your project!