



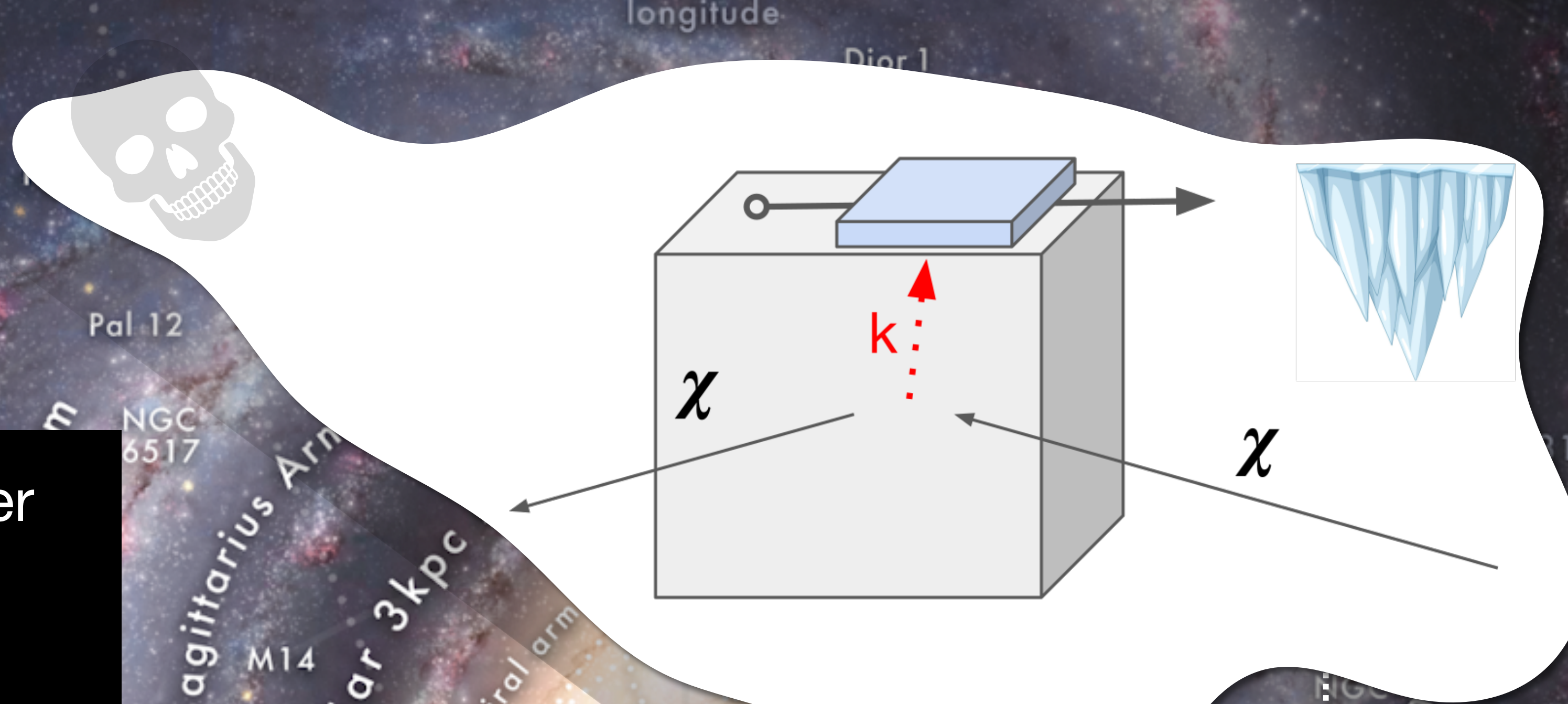
Spooky dark matter and how to find it with *scary* machines

A Dark Matter Day - Halloween cross over,
and it's also about Machine Learning.

Felix Wagner

Institute of High Energy Physics of the
Austrian Academy of
31 October 2022

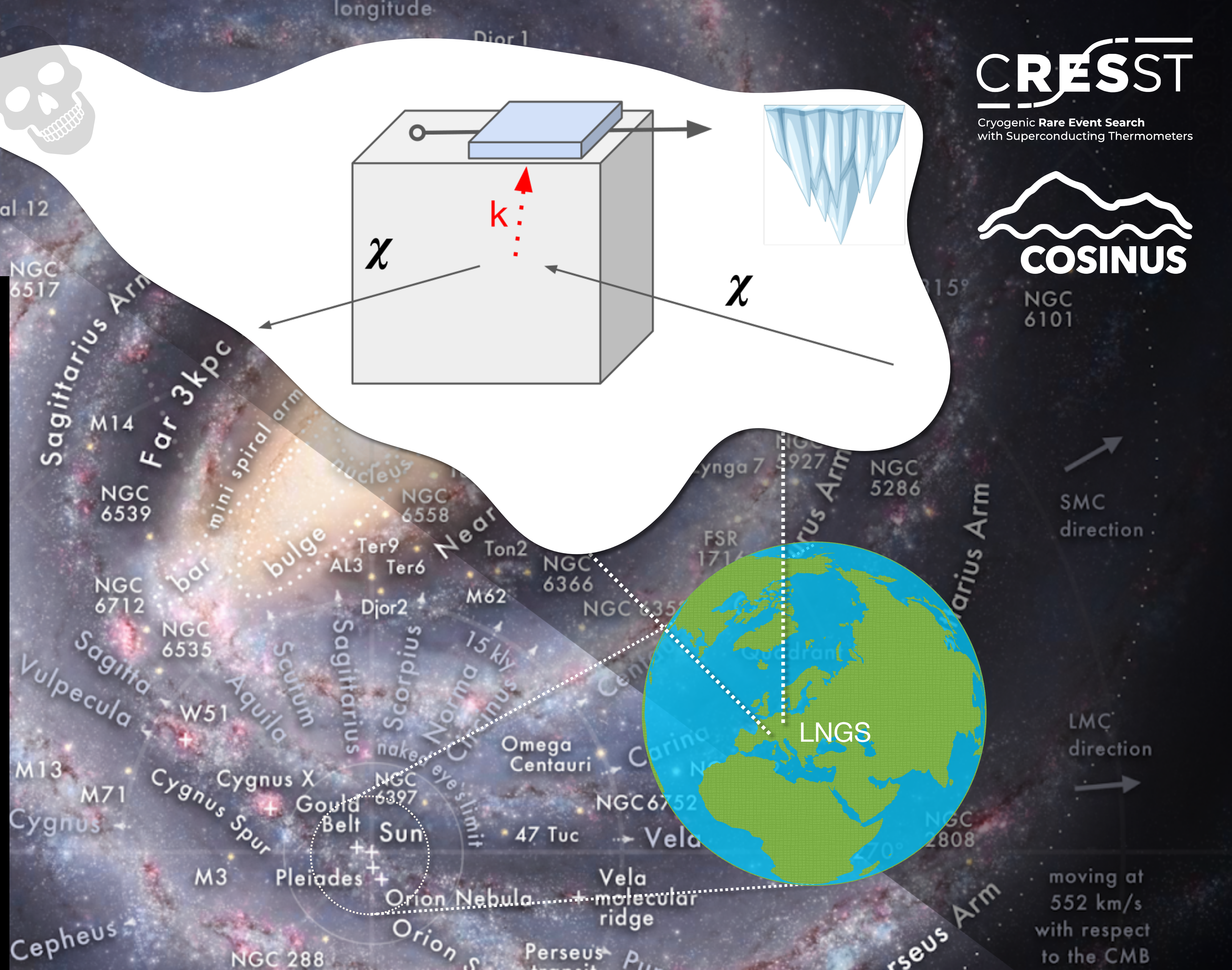




Earth is inside a
**galactic dark matter
halo.**

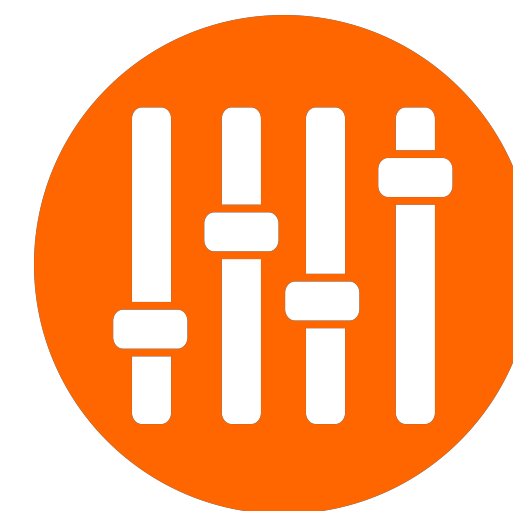
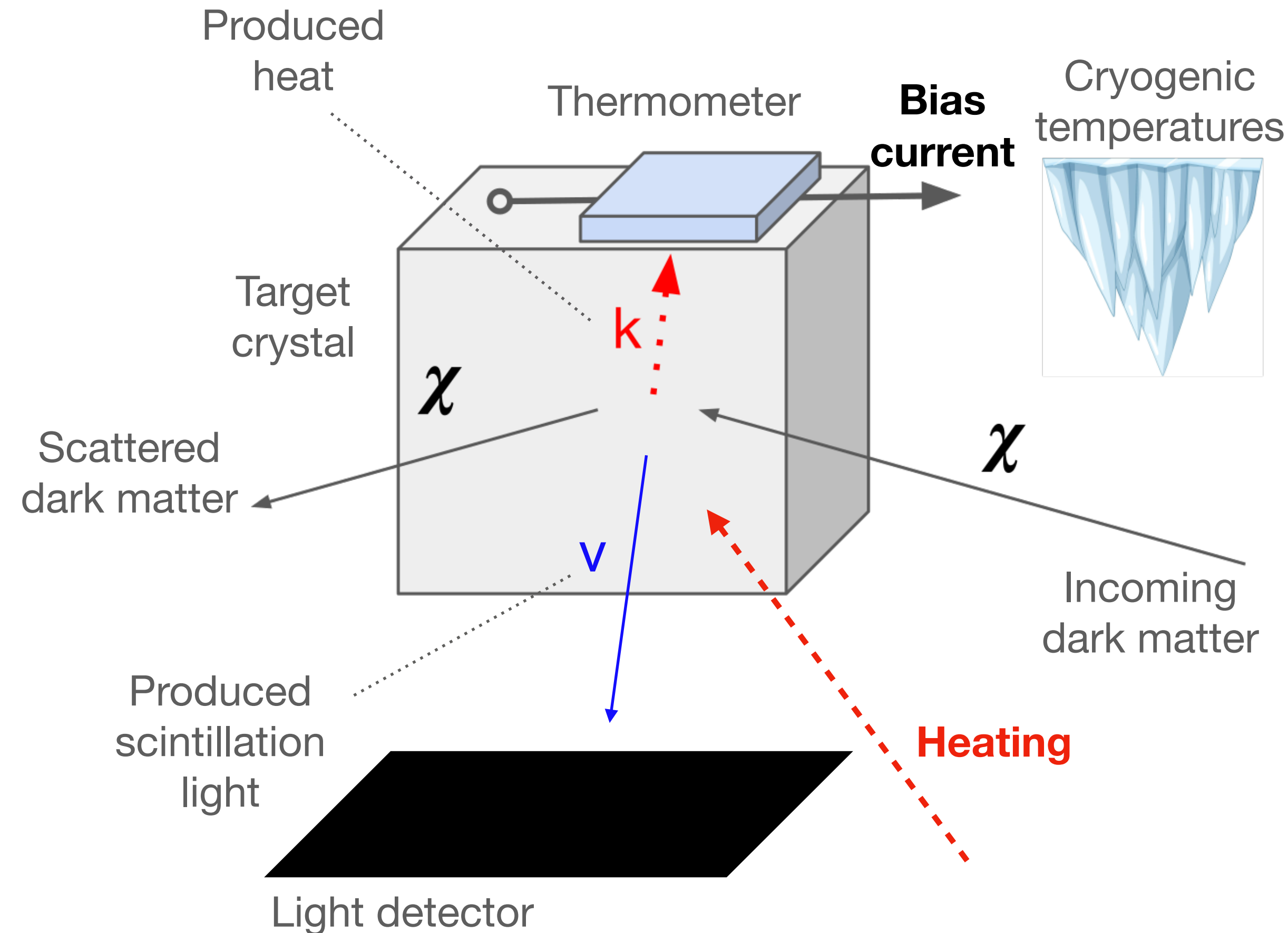
We expect that dark matter particles are **all around us**: $\sim 1/\text{cm}^3$.

Their recoils are
 extremely weak, we
 need a **super-sensitive
 detector** to see them.



A dark matter detector and how to use it

- Monocrystalline target coupled to superconducting thermometer.
- Cooled to millikelvin temperatures.
- Dark matter recoil produces measureable **heat** and **scintillation light**.
- Operation requires careful optimisation of constant **heating** and **bias current**.
- Optimisation is **time consuming** and requires **manual interventions**.



2 x 2 control parameters



“Randy”, our poltergeist, can optimise the detector in a few hours!

Many dark matter detectors ~~and how to use them~~

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In future experiments,
the operation of
hundreds of detectors is
planned.



Randy can't
do that

Many dark matter detectors ~~and how to use them~~

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the operation of
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planned.



Not even with
help of his friends.

Many dark matter detectors and how to use them

- We can optimise the detectors instead with **machine learning**.
- Currently **prototyping** is ongoing, good results in simulation.
- Later this year: first runs on **live experiment**.
- *Talk at ACAT Workshop '22: "Control of cryogenic dark matter detectors through deep reinforcement learning" (F. Wagner).*

Published: 27 January 2016

Mastering the game of Go with deep neural networks and tree search

David Silver

Article | [Open Access](#) | [Published: 16 February 2022](#)

Julian Schrittwieser

Dominik Schreier

Koray Kavukcuoglu

Nature 550

427k Accesses

Magnetic control of tokamak plasmas through deep reinforcement learning

Jonas Degraeve, Federico Fassi

Carpanese, Timo Ewalds, R

Fritz, Cristian Galperti, And

Jean-Marc Moret, Sel

... Martin Riedmiller

Nature 602, 414–419

153k Accesses | 45

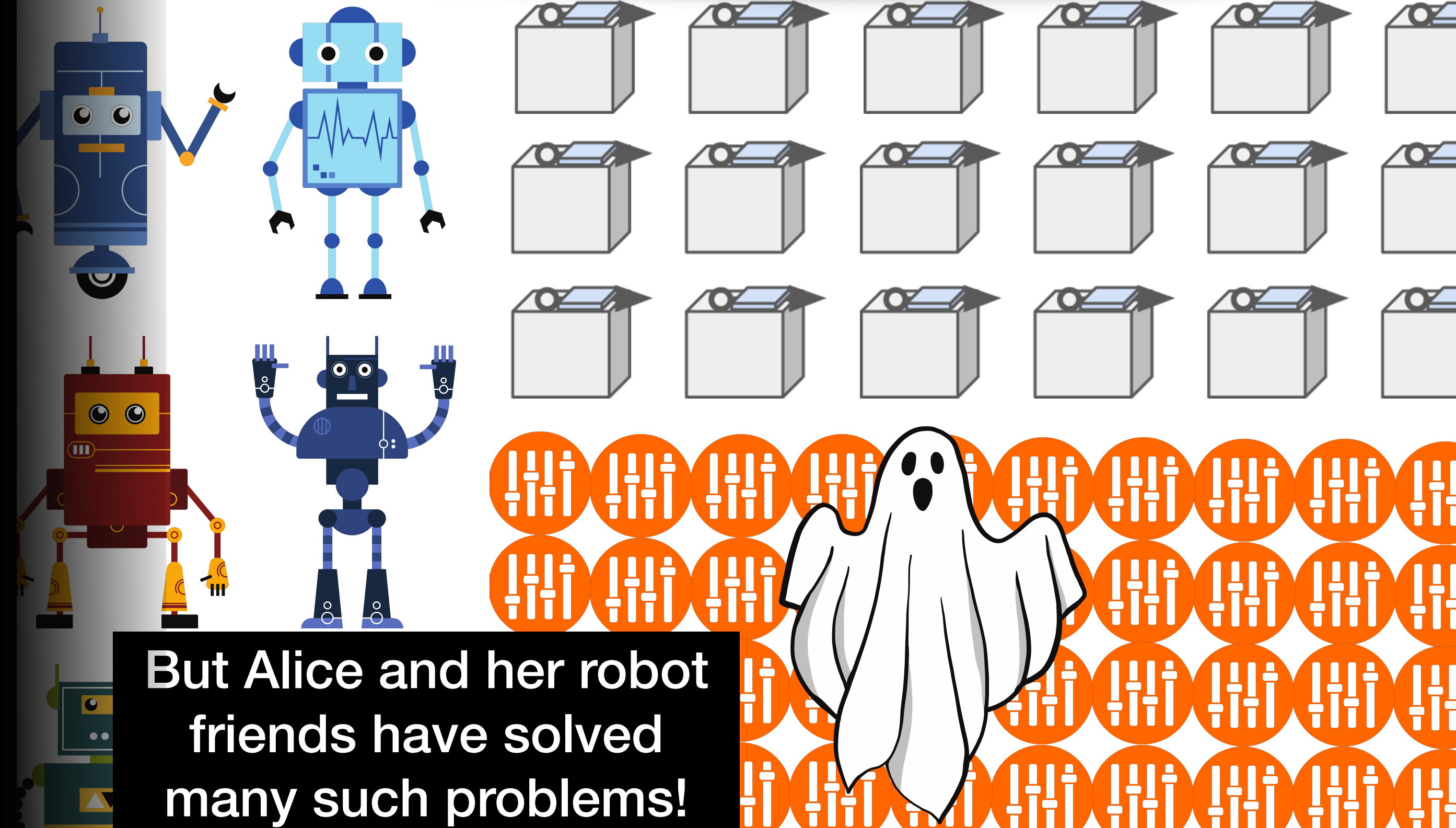
Sample-efficient reinforcement learning for CERN accelerator control

Verena Kain, Simon Hirlander, Brennan Goddard, Francesco Maria Velotti, Giovanni Zevi Della Porta, Niky

Real-time artificial intelligence for accelerator control: A study at the Fermilab Booster

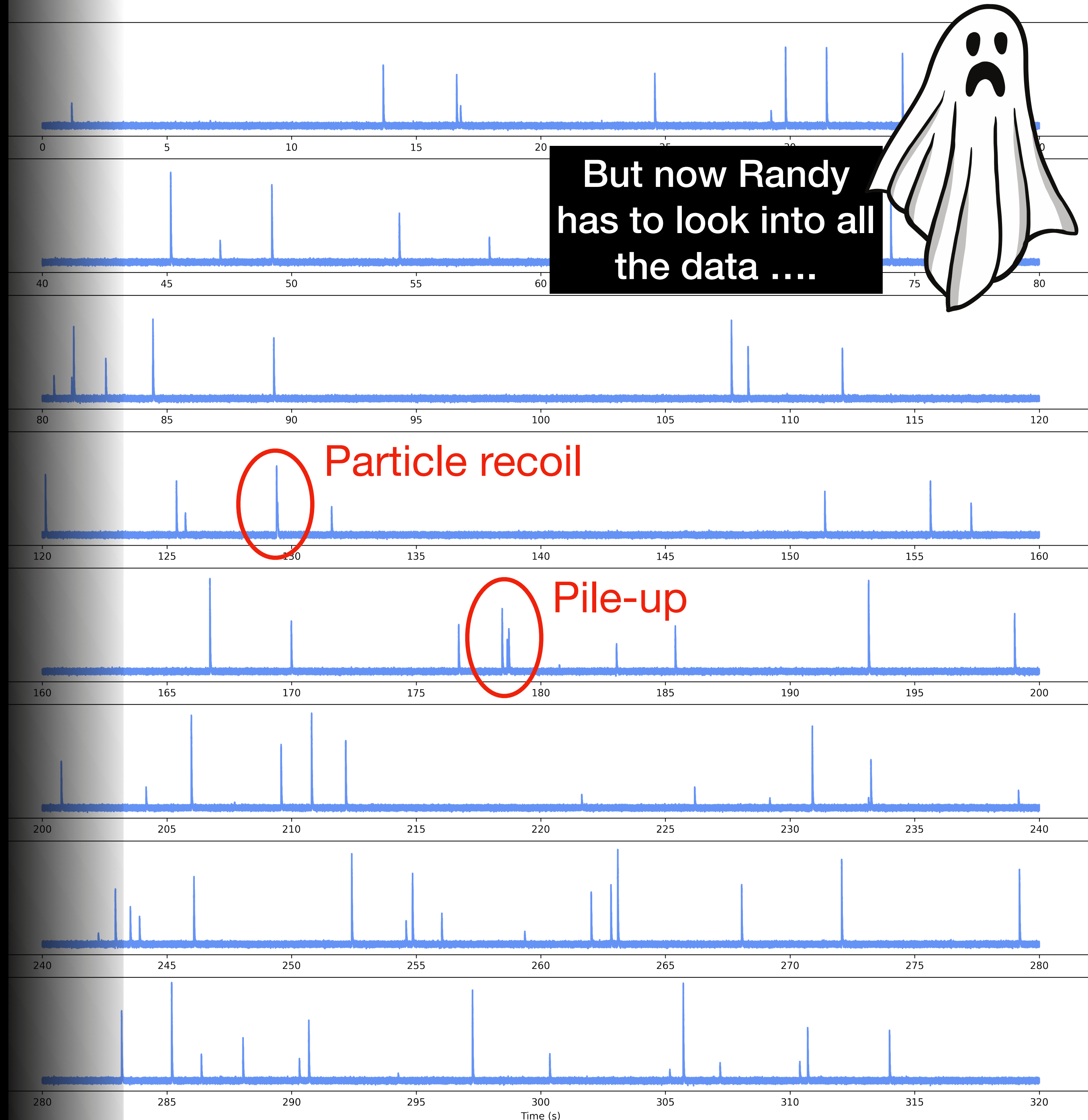
Jason St. John, Christian Herwig, Diana Kafkes, Jovan Mitrevski, William A. Pellico, Gabriel N. Perdue, Andres Quintero-Parra, Brian A. Schupbach, Kiyomi Seiya, Nhan Tran, Malachi Schram, Javier M. Duarte, Yunzhi Huang and Rachael Keller

Phys. Rev. Accel. Beams **24**, 104601 – Published 18 October 2021



Many dark matter detectors and how to analyse them

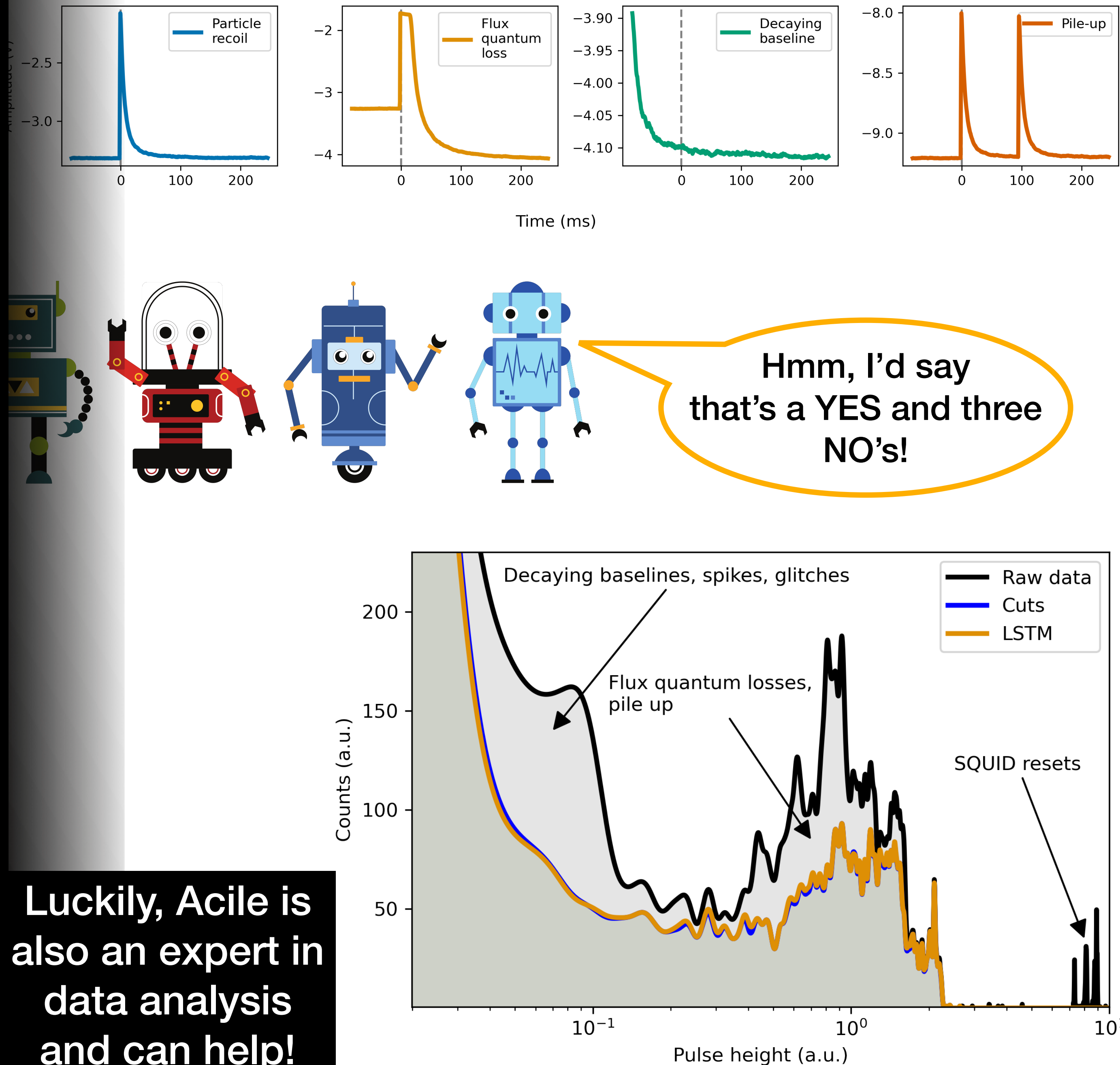
- We need to analyse the data and count the number of potential **dark matter** and **background events**.
- Harmful backgrounds are **astroparticles and radioactivity**, but also **artefacts** of the measurement setup.
- Data cleaning needs to be **automated** for analysis of future large-scale experiments.



Many dark matter detectors and how to analyse them

- We trained a **neural network classifier** for the data cleaning task.
- The neural network discriminates on an event-by-event basis **particle recoils** from **artefacts**.
- **Fully automated and universally applicable**: no additional information about the individual detector required!
- *Preprint on ArXiv: "Towards an automated data cleaning with deep learning in CRESST" (CRESST Collaboration).*

Luckily, Acile is also an expert in data analysis and can help!



HALLLOWEEN

Take-home messages



Take-home messages

Dark matter is
all around us,
and one of the
most *spooky*,
open questions
of modern
physics.



A vibrant Halloween-themed illustration. In the background, a banner reads "HALLOWEEN" with a jack-o'-lantern and bats. A white ghost with a friendly face is on the left. In the center, a boy with green skin and a purple shirt holds a basket of candy. On the right, a girl in a purple witch costume and hat holds a pumpkin-shaped basket. The scene is set at night with lit candles and scattered candy on the grass.

Take-home messages

Dark matter is *all around us*, and one of the most *spooky*, open questions of modern physics.

Machines are not scary, but *our friends* in finding it. *Exciting times* ahead!

A vibrant Halloween-themed illustration. In the center, a friendly-looking ghost with a white sheet and pink eyes stands next to a green-skinned boy with a purple shirt and a girl in a purple witch costume. They are all holding baskets of candy. The background features orange and yellow diagonal stripes, a 'HALLOWEEN' banner, pumpkins, and bats. Three lit candles are on the right. Three black text boxes are overlaid on the image.

Take-home messages

Dark matter is *all around us*, and one of the most *spooky*, open questions of modern physics.

Machines are not scary, but *our friends* in finding it. *Exciting times* ahead!

Happy *Dark Matter Day*!
Happy *Halloween*!