



# *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**

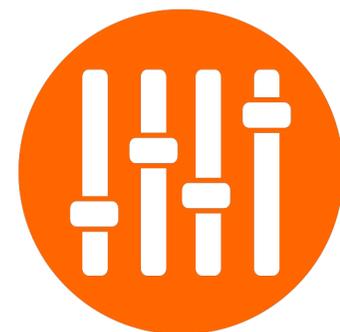
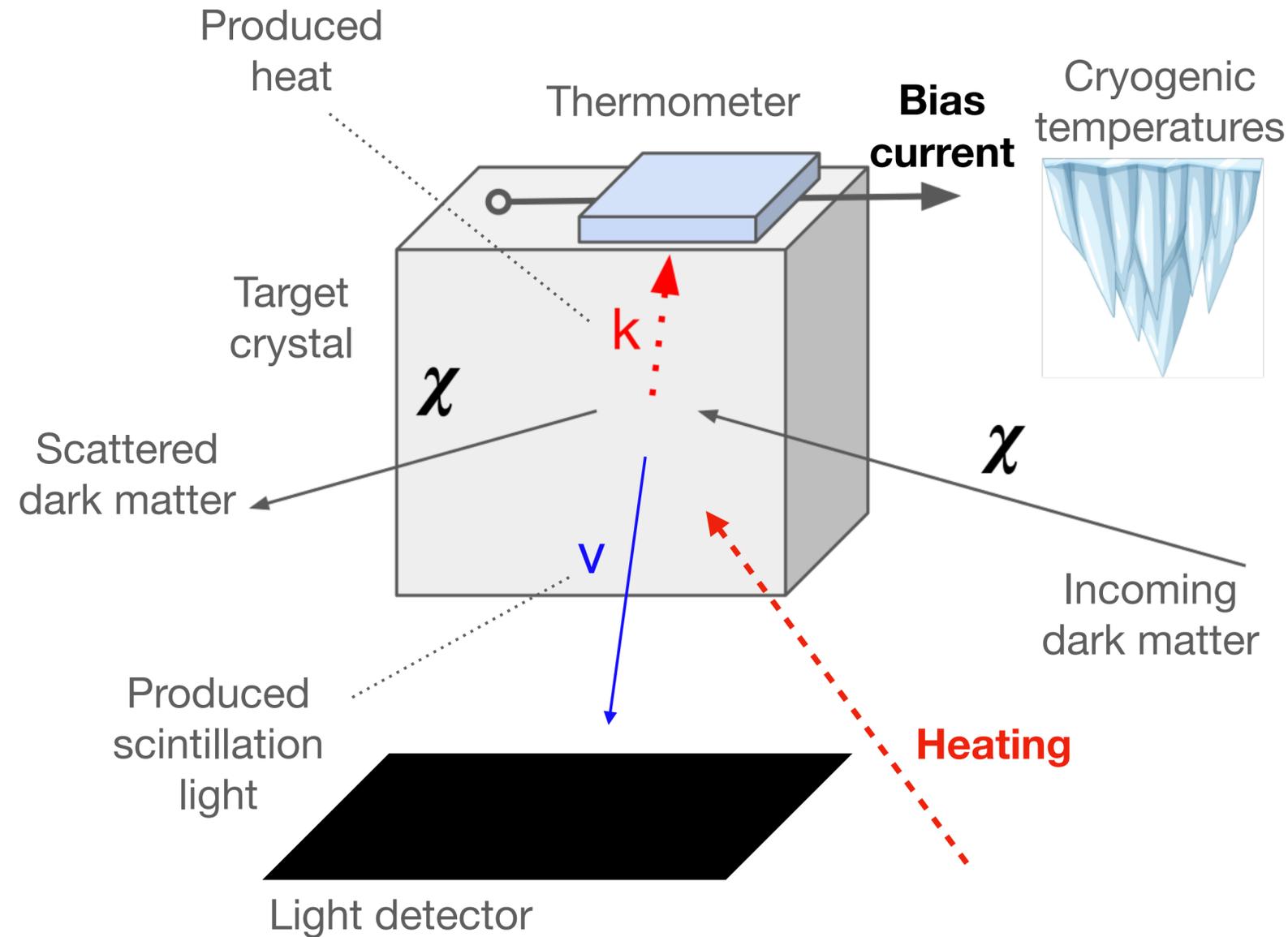
Institute of High Energy Physics of the  
Austrian Academy of  
31 October 2022





# A dark matter detector and how to use it

- Monocrystalline target coupled to superconducting thermometer.
- Cooled to millikelvin temperatures.
- Dark matter recoil produces measurable **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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Randy can't  
do that ....

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Not even with  
help of his friends.

# Many dark matter detectors and how to use them

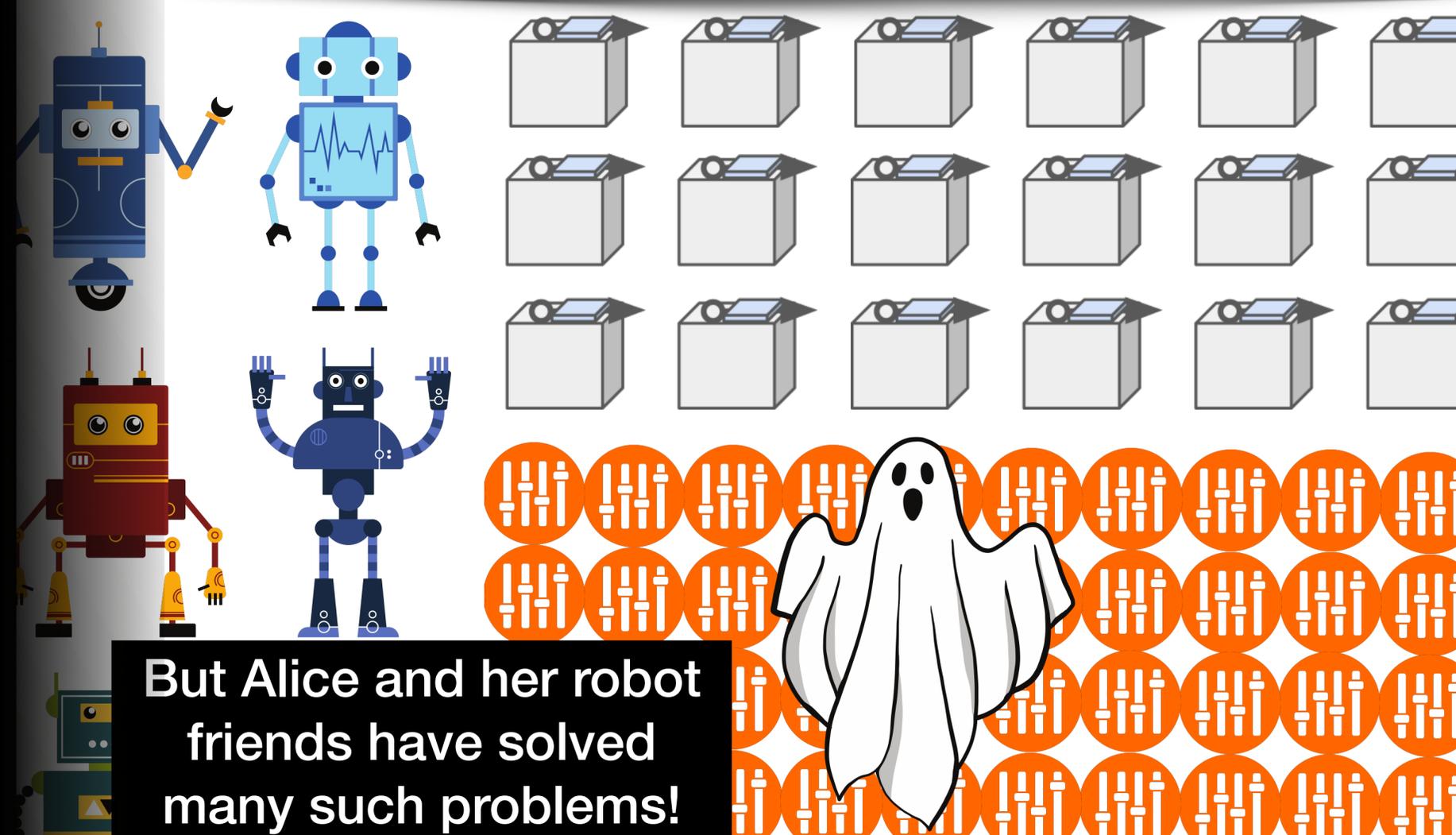
- We can optimise the detectors instead with **machine learning**.
- Currently **prototyping** is ongoing, good results in simulation.
- Later this year: first runs on **live experiment**.
- *Talk at ACAT Workshop '22: "Control of cryogenic dark matter detectors through deep reinforcement learning" (F.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

Published: 27 January 2016  
**Mastering the game of Go with deep neural networks and tree search**

David Silver, Julian Schrittwieser, Dominik Grewe, Koray Kavukcuoglu, Tuomas Silvermann, George Siu, Daniel Suck, Ian Dunning, Joel Schaefer, John Berwick, Simon Duane, David Grewe, Nils Hees, Marcin Moravcsik, Duane Schaefer, and Demis Hassabis  
Article | [Open Access](#) | [Published: 16 February 2022](#)

**Magnetic control of tokamak plasmas through deep reinforcement learning**

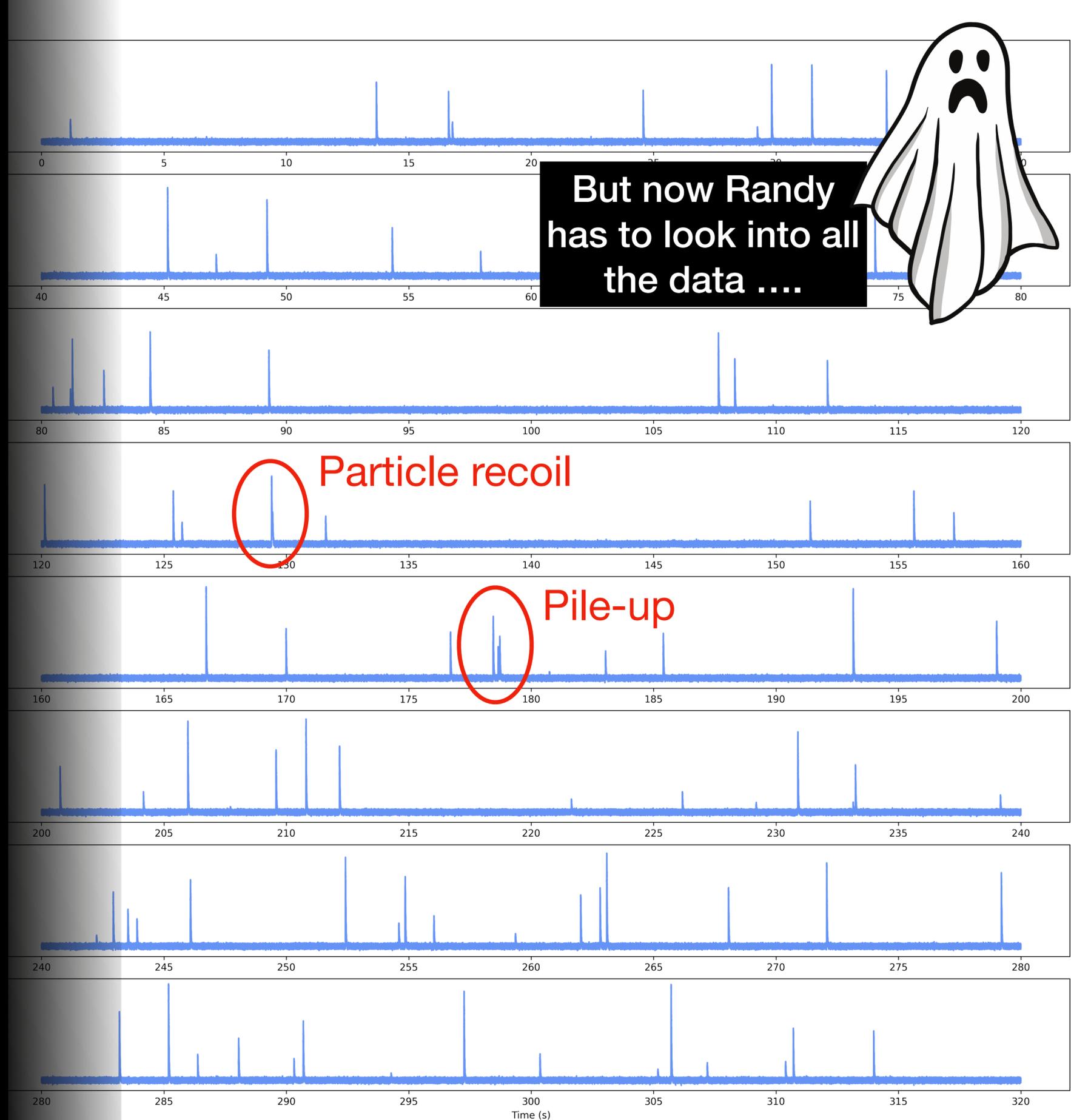
Jonas Degrave, Federico Ferrero, Carpanese, Timo Ewalds, R. Fritz, Cristian Galperti, Andre Jean-Marc Moret, Sel... Martin Riedmiller  
Sample-efficient reinforcement learning for CERN accelerator control  
Verena Kain, Simon Hirlander, Brennan Goddard, Francesco Maria Velotti, Giovanni Zevi Della Porta, 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. Schuppach, Kiyomi Seiya, Nhan Tran, Malachi Schram, Javier M. Duarte, Yunzhi Huang and Rachael Keller  
*Nature* **602**, 414–419  
153k Accesses | 45  
Phys. Rev. Accel. Beams **24**, 104601 – Published 18 October 2021



But Alice and her robot friends have solved many such problems!

# Many dark matter detectors and how to analyse them

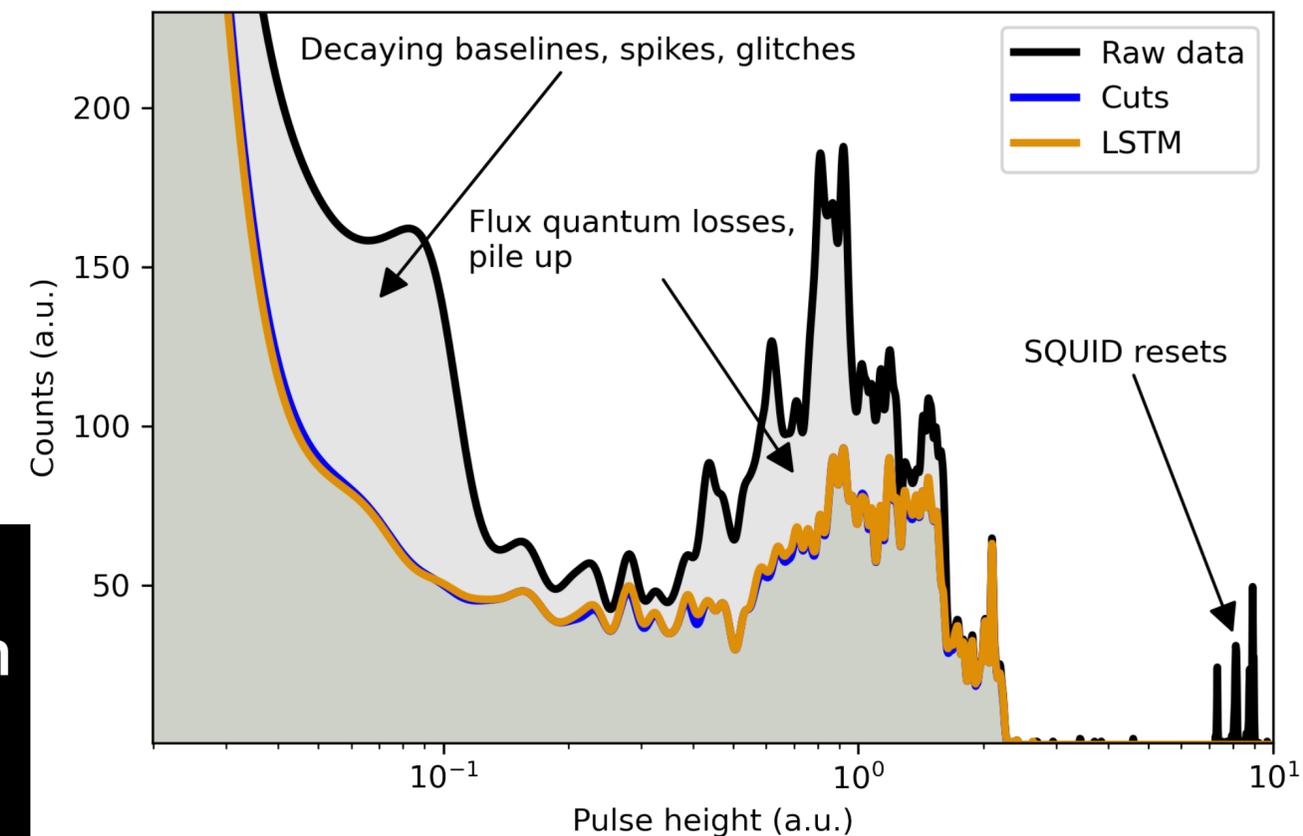
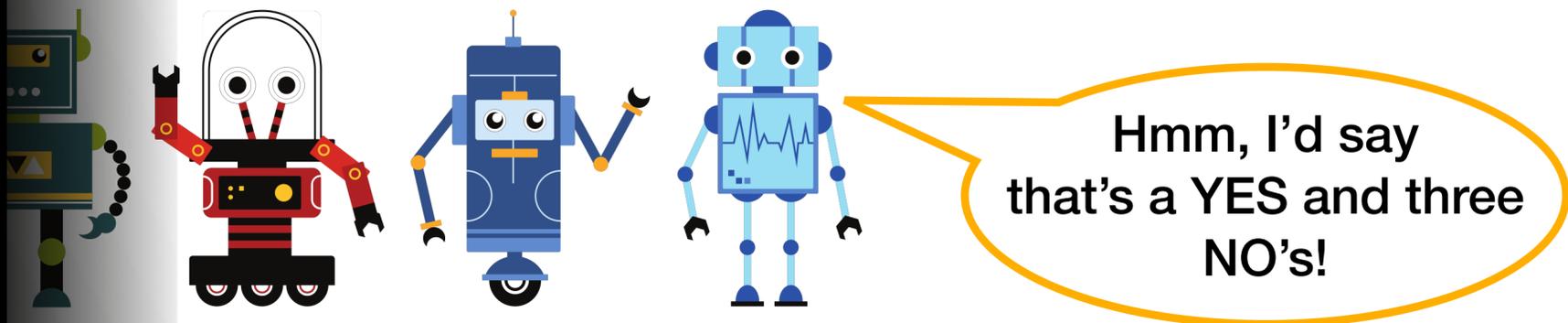
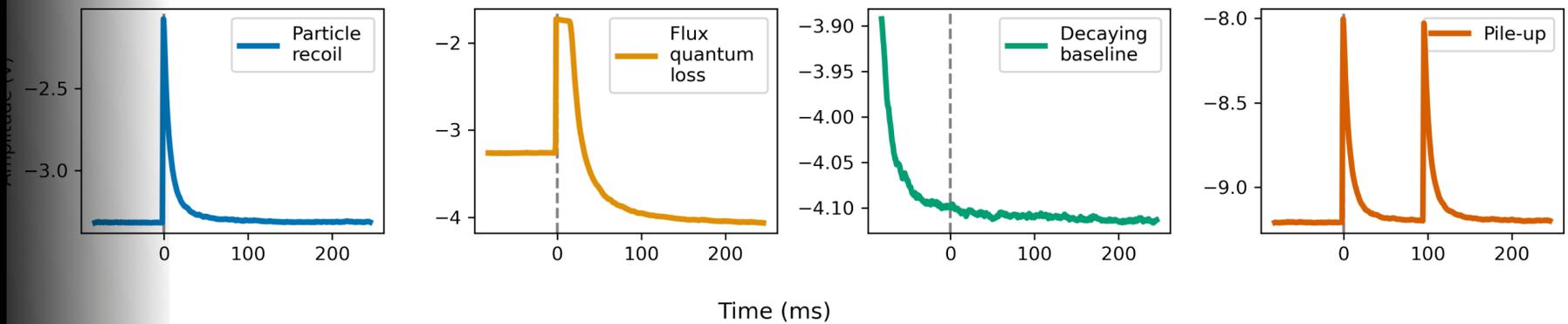
- We need to analyse the data and count the number of potential dark matter and background events.
- Harmful backgrounds are **astroparticles and radioactivity**, but also **artefacts** of the measurement setup.
- Data cleaning needs to be **automated** for analysis of future large-scale experiments.



# 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!



**H A L L O W E E N**

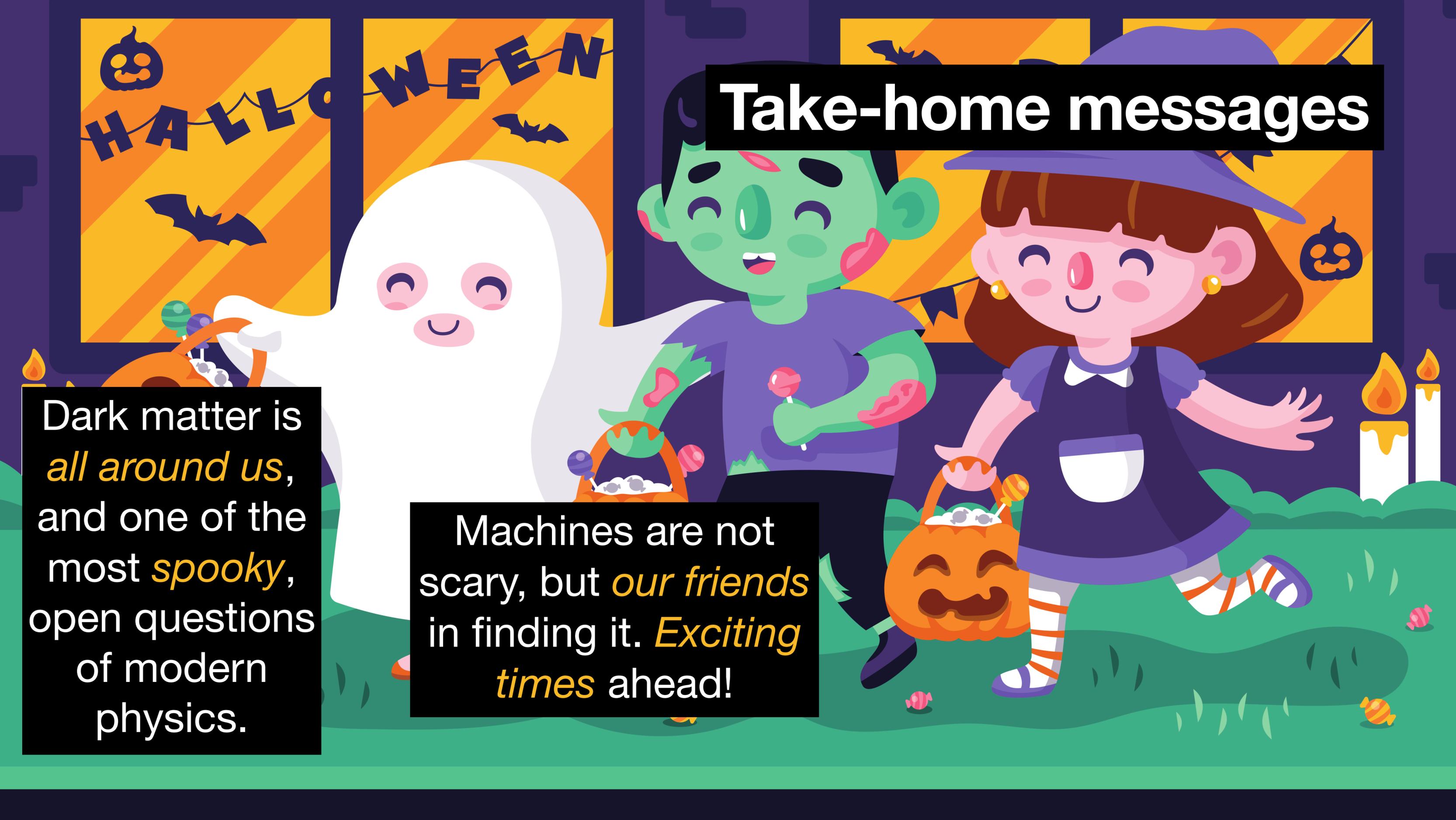
**Take-home messages**



# Take-home messages

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





# 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 white ghost with a friendly expression holds a basket of candy. To its right, a green alien with large eyes and a purple shirt holds a basket of candy. Further right, a young girl dressed as a witch in a purple dress and hat holds a basket of candy. The background features orange and yellow diagonal stripes, a 'HALLOWEEN' banner, pumpkins, and bats. In the foreground, there are lit candles and scattered candy on a green lawn.

# 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!*