DM ML

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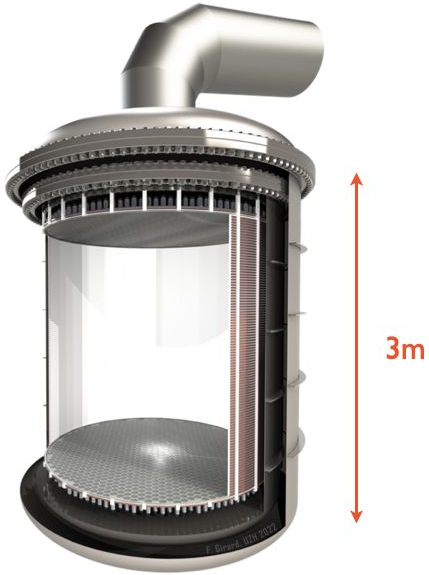
Liquid Xenon based Rare Event Experiments

Main activity: 1. Search for Galactic Dark Matter, e.g. WIMP, axion, ALPs
2. Neutrinoless double beta decay

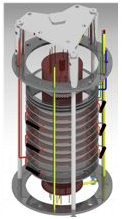
XENONnT

DARWIN / XLZD

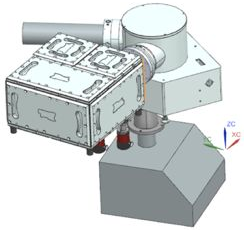


Our Lab

XAMS R&D

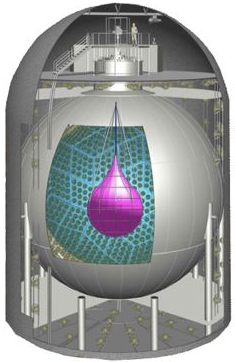


VULCAN R&D

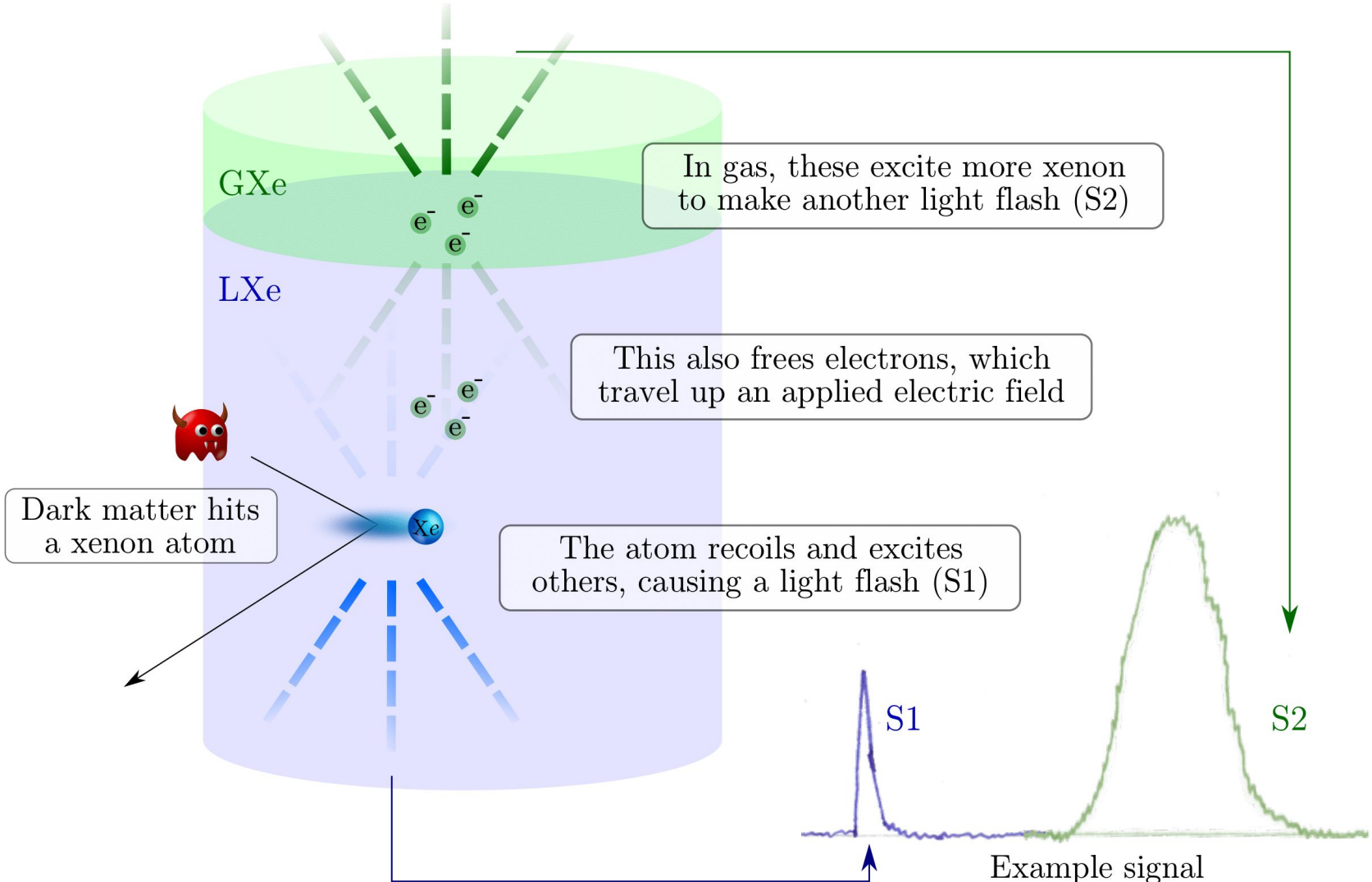


Small Contributions

KamLAND-Zen



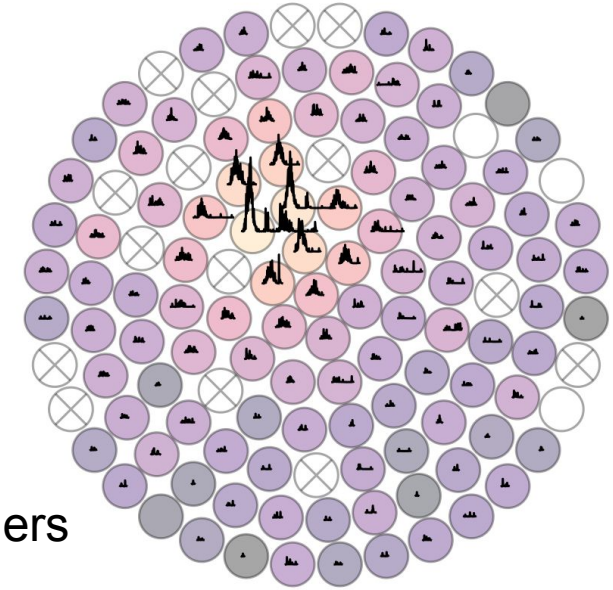
PTOLEMY R&D


GXe
LXe
e-
e-
e-
e-
e-
e-
In gas, these excite more xenon to make another light flash (S2)
This also frees electrons, which travel up an applied electric field
Dark matter hits a xenon atom
Xe
The atom recoils and excites others, causing a light flash (S1)
S1
S2
Example signal

How we use Machine Learning

1) Efficient heuristic
2) Modelling unknowns

S2 Position reconstruction



S2 hitpattern -> (x, y), maybe uncertainty?

If optical response known, likelihood wins, but

- ML is faster
- Response not perfectly known, likelihood hates outliers

Different neural nets (simple, convolutional, graph)

Finding the optical response from data, unsupervised:

- From nothing: autoencoders
- Refining the model: sequential fit, …?

Noisy autoencoder for position reconstruction

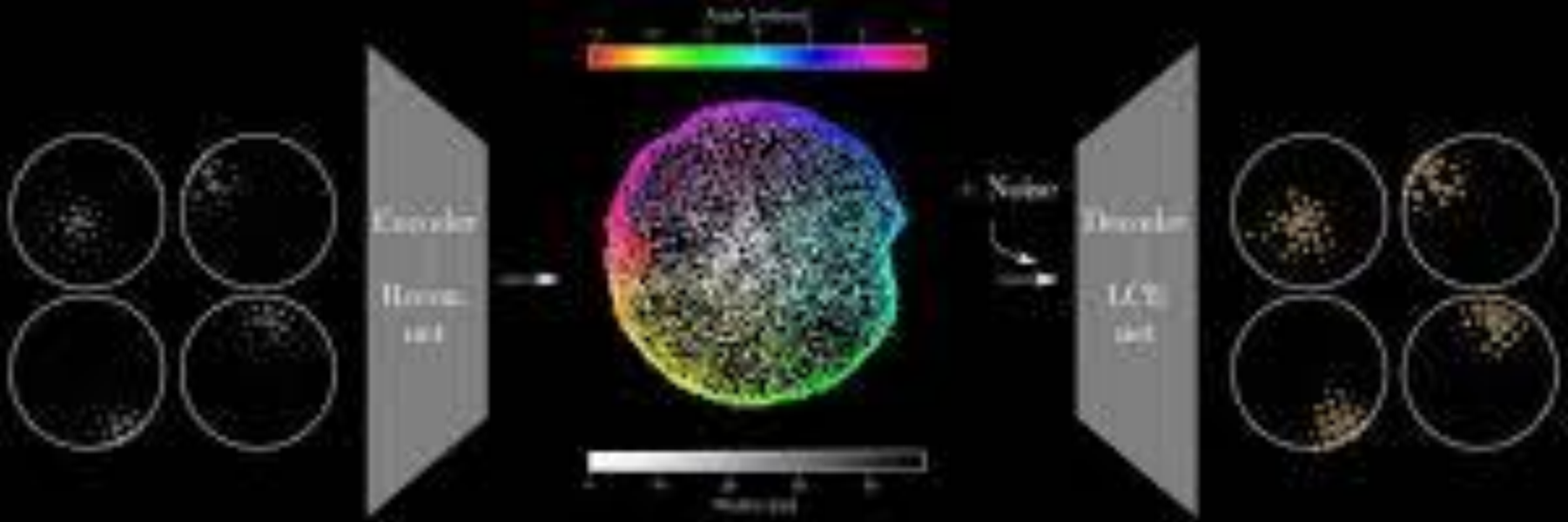
in LXe TPCs

Erik Althaus and Hans Peissner
Stockholm University

2D latent space
Network does NOT know
true positions, PMT locations, gains, ...

Input:
Real ^{83m}Kr
S2 top PMT hitpatterns

Output:
Predicted hitpatterns

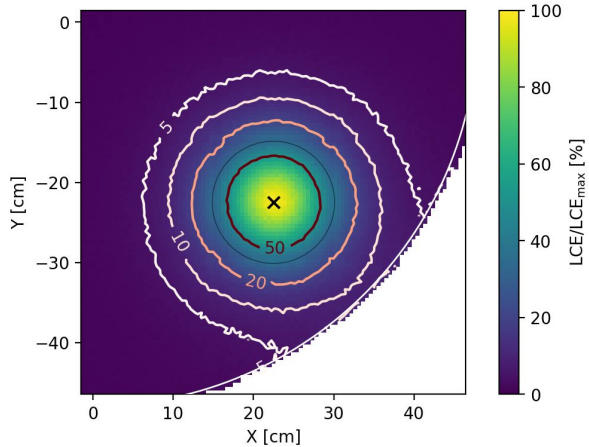


Colors are positions from regular, optical MC based reconstruction.

ML for modelling PMT detection eff

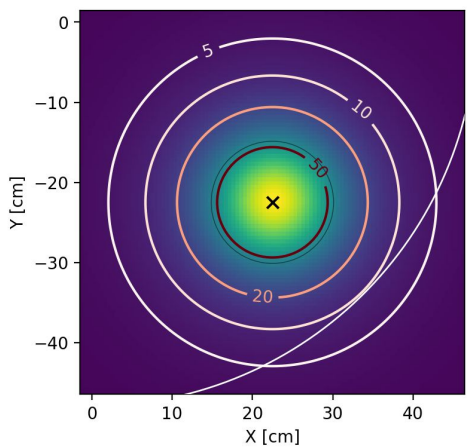
(Old study from me on XENON1T data)

Reconstruct positions → Fit optical response



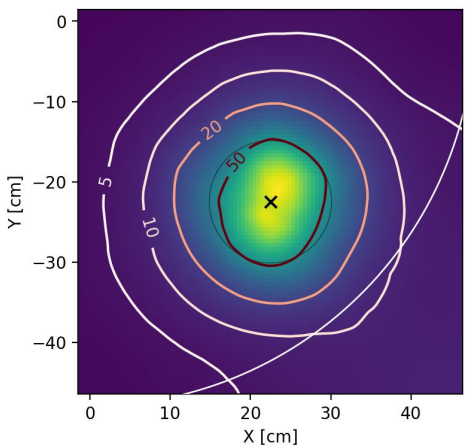
Optical simulation

$\chi^2/n = 10$



Symmetric model

$\chi^2/n = 2.5$



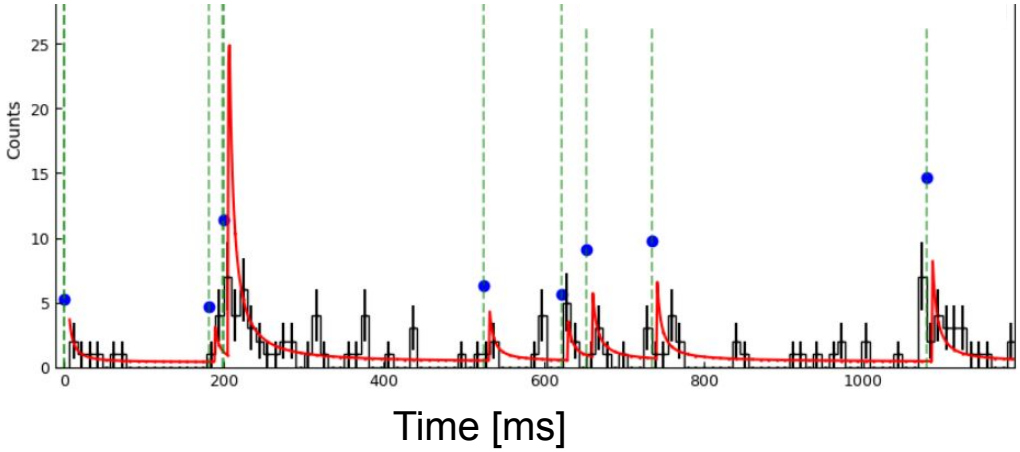
Neural net model

$\chi^2/n = 2.0$

Mean discrepancy between observed hitpatterns and those expected at reconstructed positions (83mKr calibration events)

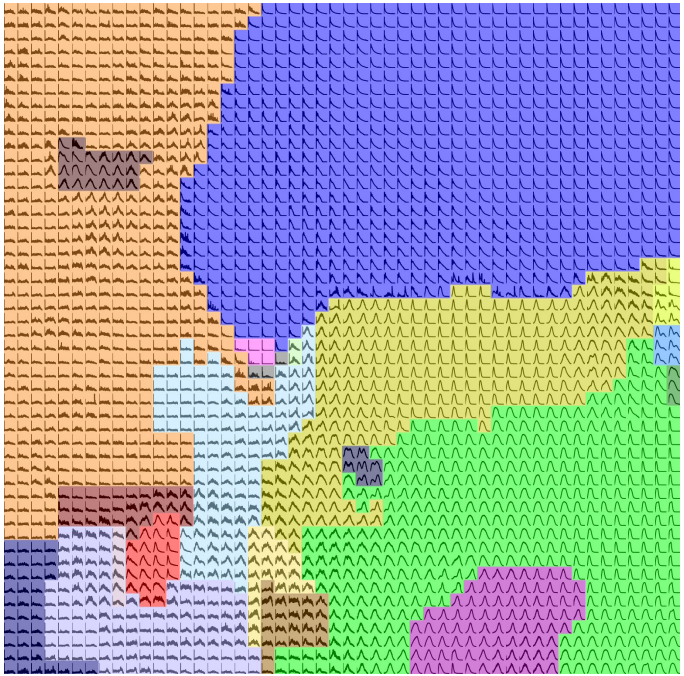
More ML for modelling

Delayed electron signals



(Red is a simple analytical model, ML should do better)

From: Umesh 2024 (BSc thesis)



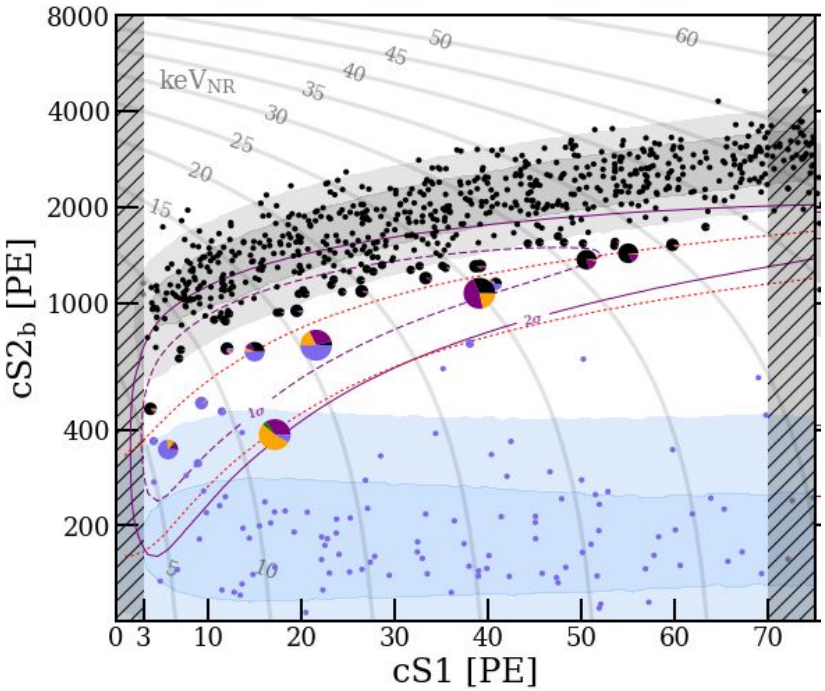
Clustering to assist classification of XAMS waveforms by shape; collaboration with Rice U. (Sanchez et al., in prep)

Other developments / opportunities

WIMP analysis likelihood:

- Flamedisx: using tensorflow for large rate computations (not ML)
- …or, use ML to approximate the 6D likelihood?

Decision trees for cuts against accidental coincidences / combinatorical bg.



XENON1T 2018, [1805.12562]