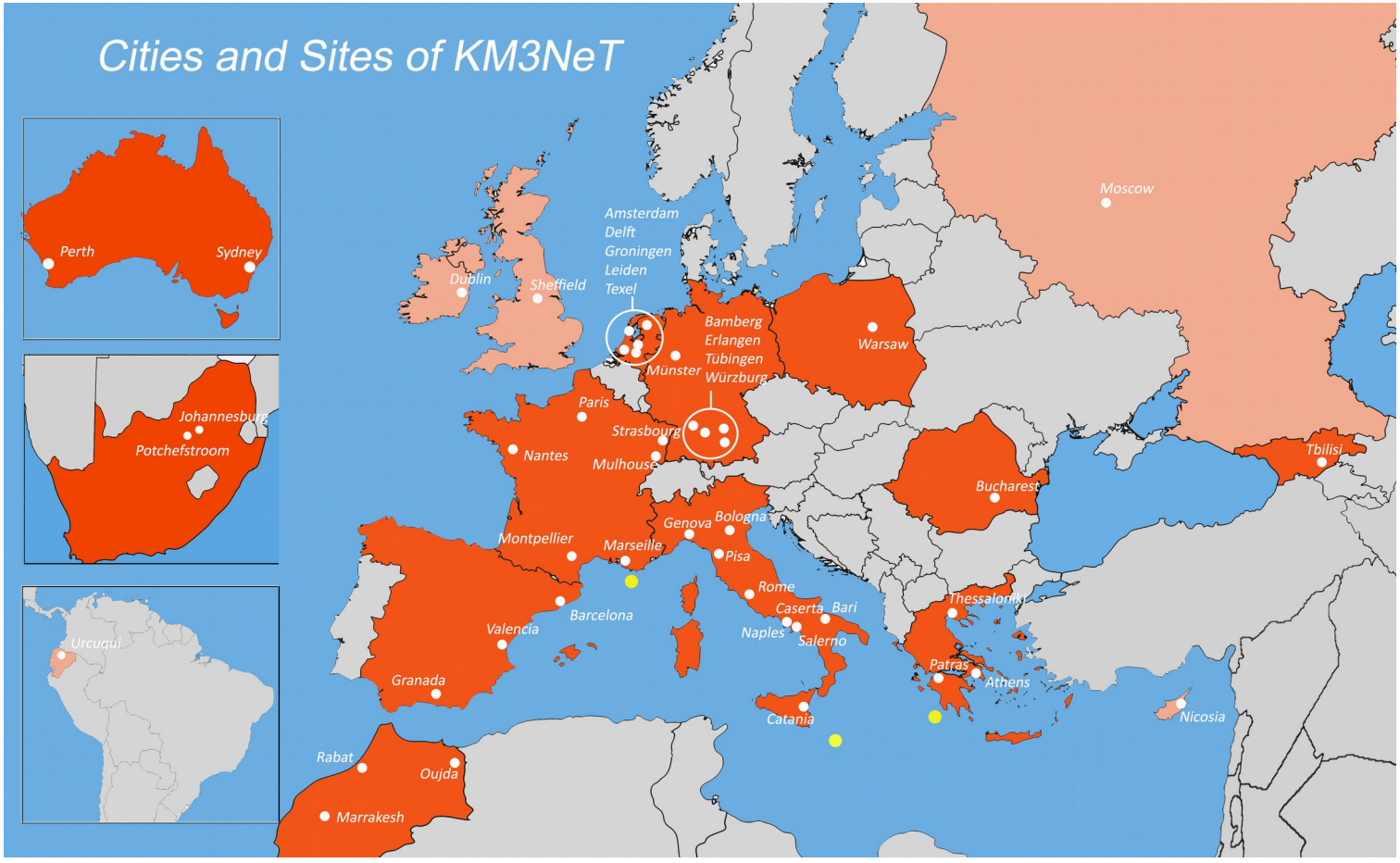
Machine learning in the experiments ANTARES/KM3Ne, NEXT and PETALO

J.D. ZORNOZA, M.KEKIC (IFIC-UV-CSIC), J.RENNER (IGFAE)

ANTARES/KM3NeT

- 55 institutes and groups
- 46 cities
- 17 countries
- 4 continents
- 250 researchers/ engineers



NEXT experiment

USA

UNIVERSITY OF TEXAS ARLINGTON

Argonne NATIONAL LABORATORY

HARVARD

Fermilab

IOWA STATE UNIVERSITY

Pacific Northwest NATIONAL LABORATORY

Spain

DIPC

IFIC INSTITUT DE FÍSICA CORPUSCULAR

Universitat de Girona

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

Universidad de Zaragoza

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

U C

universidade de aveiro

Ben Gurion University of the Negev

UAN UNIVERSIDAD ANTONIO NARIÑO

NEXT experiment

petalo

Spinoff of NEXT based in DIPC - DONOSTIA INTERNATIONAL PHYSICS CENTER

NEUTRINO?

Neutrinos are elementary particles:
- Weakly interacting
- Neutral
- Almost massless

quarks

u up	c charm	t top	γ photon
d down	s strange	b bottom	g gluon
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z Z boson
e electron	μ muon	τ tau	W W boson

leptones

force carriers

- great tool for **astronomy** (they can reach us from very far and/dense sources in the Universe) 🙂
- hard to detect 😕 ➡ need large detectors!

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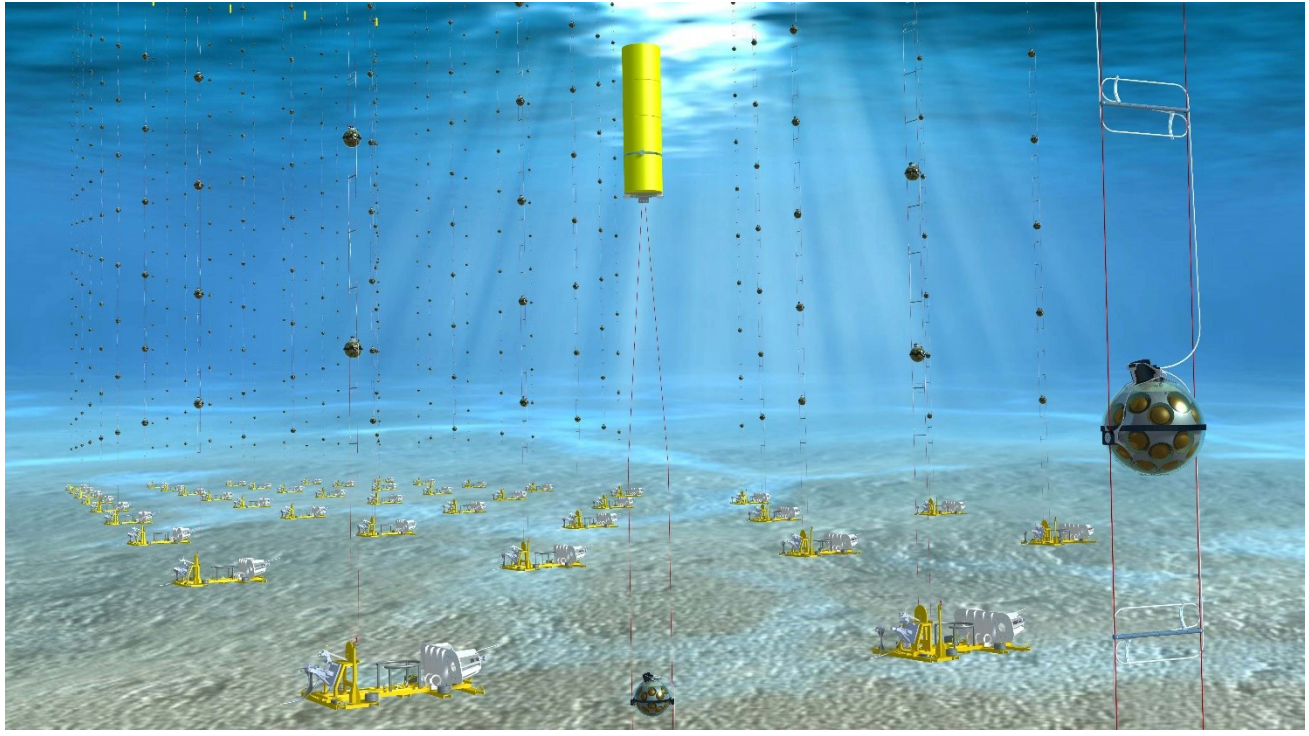

NEUTRINO TELESCOPE

ANTARES, in the Mediterranean Sea, is a small first “prototype”. **KM3NeT** will have the right size (1 km^3). (There is also IceCube in the South Pole.)

🤔

neutrino = antineutrino?

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- Weakly interacting
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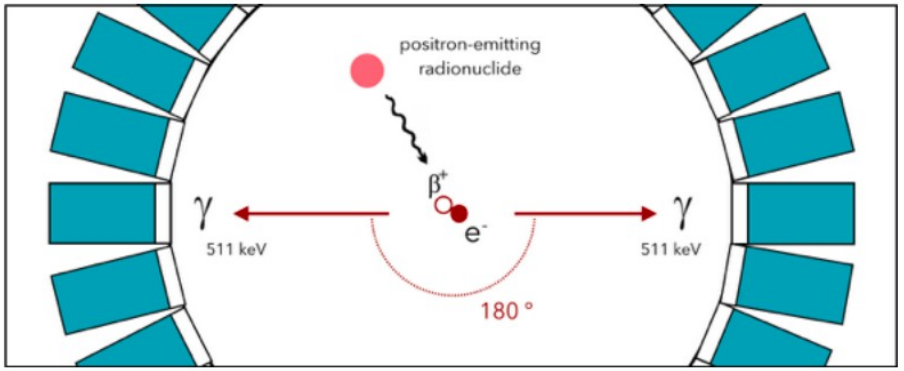
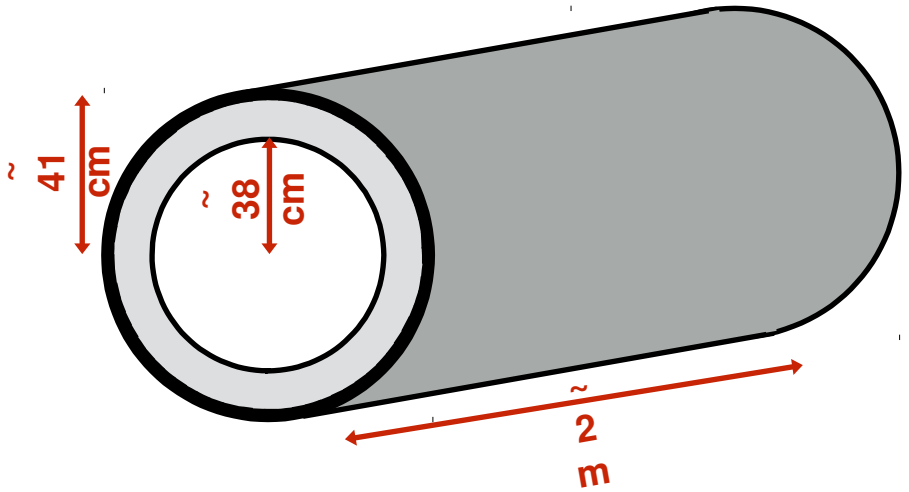
Search for neutrinoless double beta decay in ^{136}Xe

- Next-WHITE (NEW) **5** kg-scale demonstrator at the Canfranc Underground Laboratory (LSC)
- To be commissioned in 2020: **100** kg Xe
- Planned : **1 tonne** of Xe

next

Using similar detector technology with liquid Xe – **PET imager**



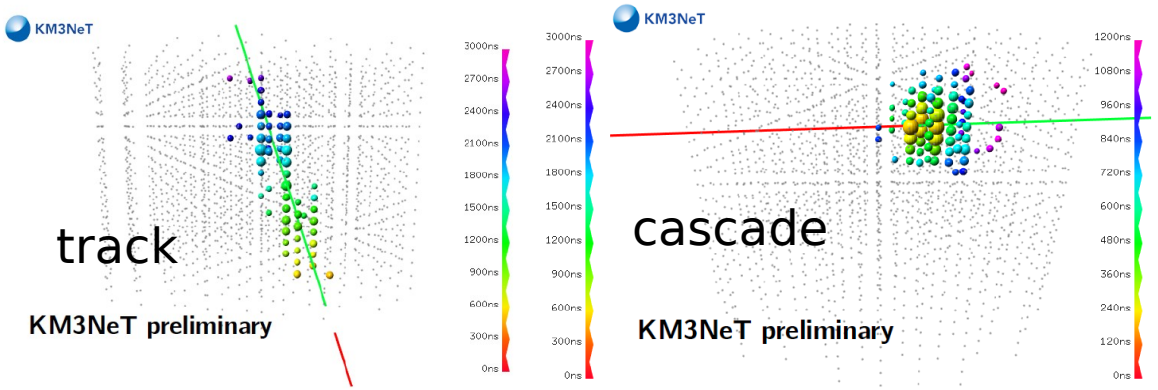


Increase precision and reduce exposure using liquid Xe instead of crystals

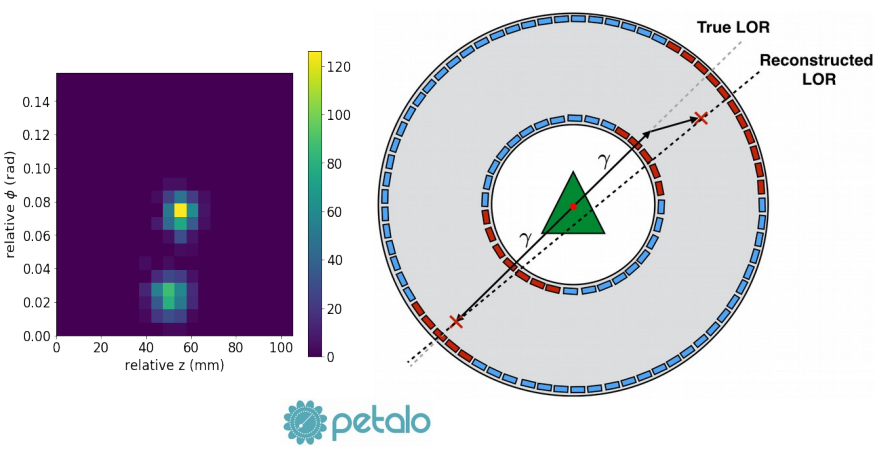
Awarded with 1.5 million of euros by **European Research Council (ERC)**

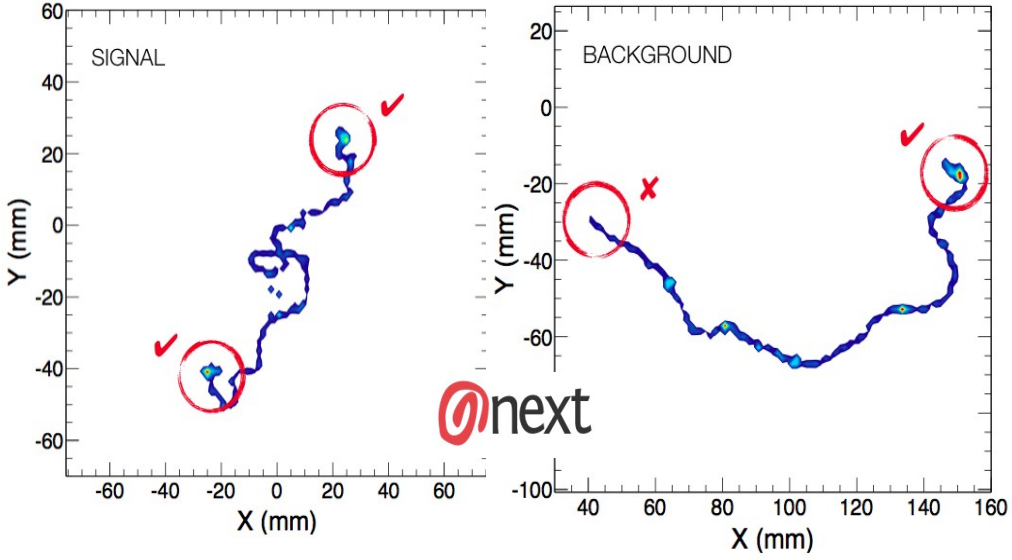
petalo

Why deep learning?



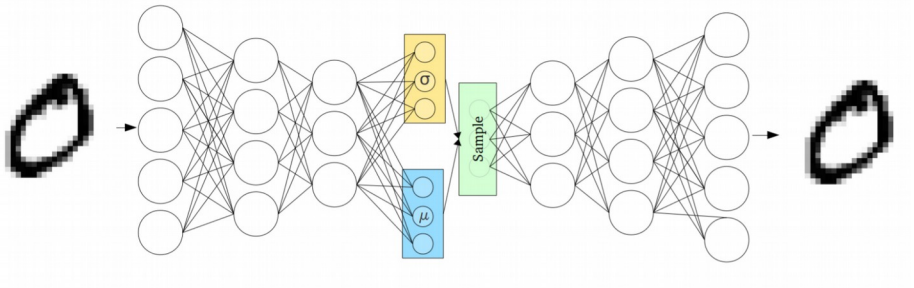
Standard in hep experiments:
Event classification





Ongoing research

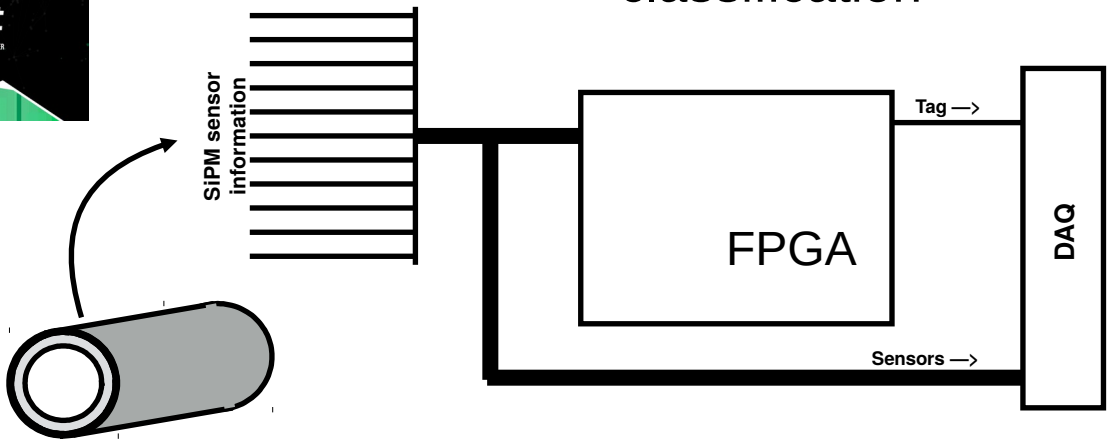
- GAN : MONTECARLO GENERATION
- neutrino energy estimation
- neutrino direction estimation ...



Explainability: Image segmentation instead of classification

- Optimize training: Switch to sparsenet; multi GPU, running on Summit @ Oak Ridge

- PET events could be tagged and potentially discarded *on-the-fly*



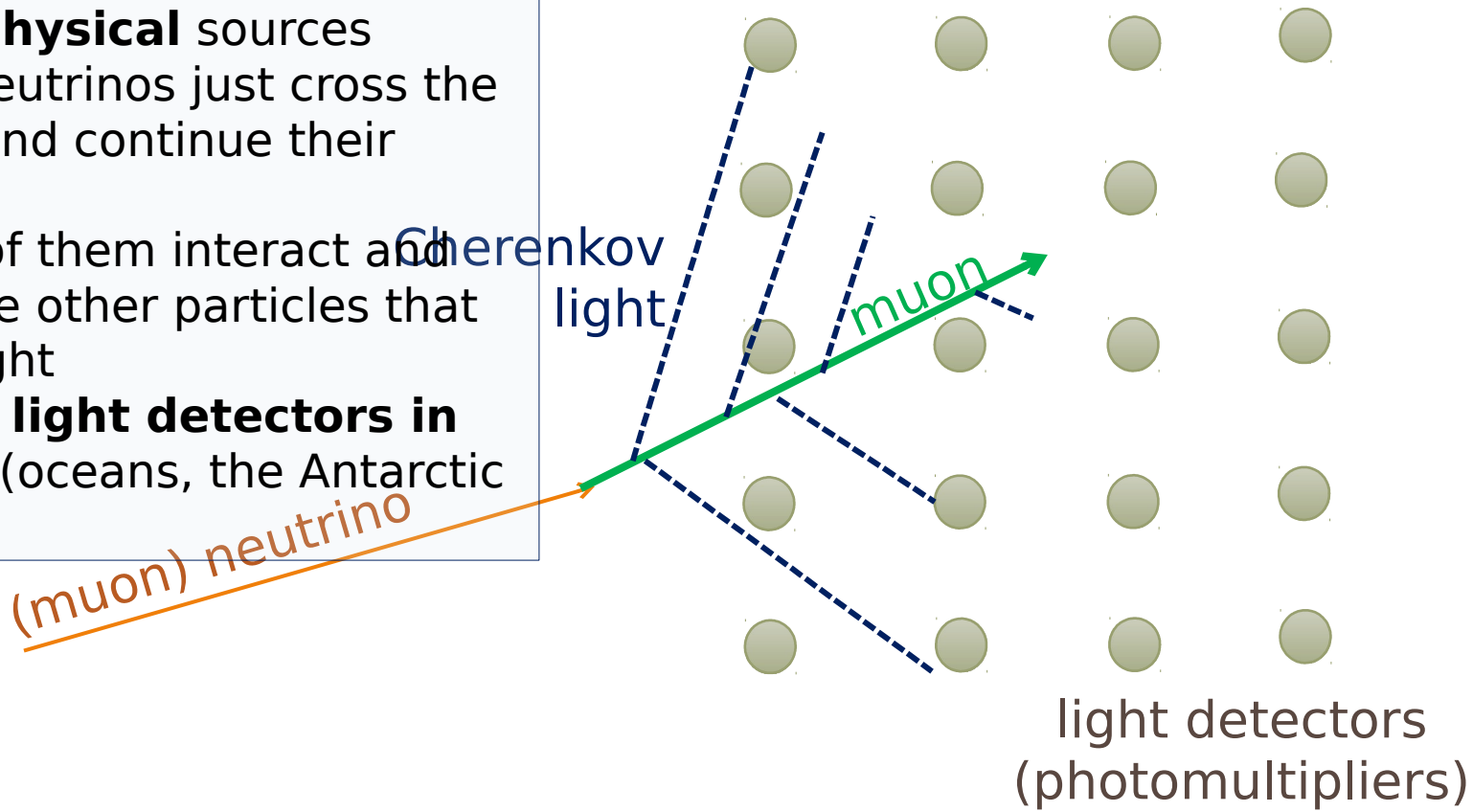
Publications:

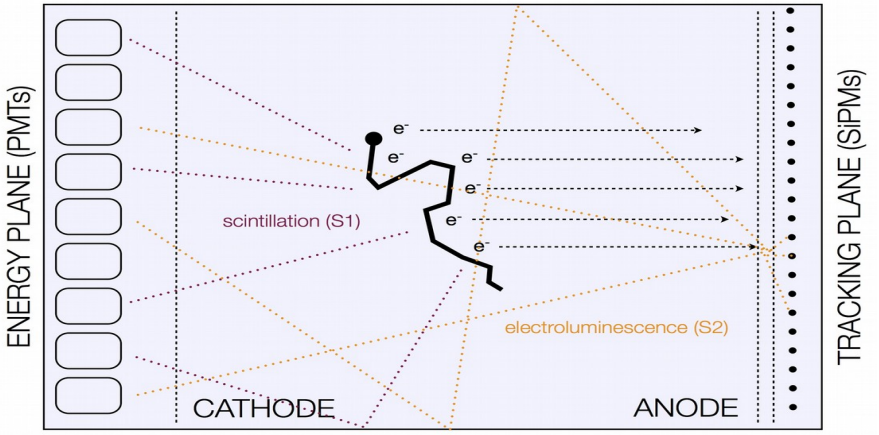
- A. Albert et al., (ANTARES Collaboration), First all-flavor neutrino pointlike source search with the ANTARES neutrino telescope” , Phys. Rev. D 96, 082001 (2017)
- Albert et al. (ANTARES Collaboration), The Search for Neutrinos from TXS 0506+056 with the ANTARES Telescope, A. , ApJL 863, L30 (2018)
- Machine learning for KM3NeT/ORCA, S. Hallmann et al, PoS(ICRC2019)904
- Machine learning in KM3NeT, C. D. Sio, EPJ Web Conf. 207 (2019) 05004
- Event Generation and Statistical Sampling for Physics with Deep Generative Models and a Density Information Buffer, S. Otten et al., arXiv:1901.00875
- M. Kekic, for the NEXT Collaboration. Event identification in the NEXT experiment using CNNs. Reconstruction and Machine Learning in Neutrino Experiments workshop, DESY, Hamburg (talk given by M. Kekic on September 17, 2019).
- J. Renner, for the NEXT Collaboration. Characterization of the NEXT-White Detector with Calibration Data. Neutrinos 2018 (poster presentation by J. Renner on June 4, 2018).
- J. Renner, A. Farbin, J. Muñoz Vidal, J.M. Benlloch-Rodríguez, A. Botas, P. Ferrario, J.J. Gómez-Cadenas et al. (NEXT Collaboration). Background rejection in NEXT using deep neural networks. JINST 12, T01004 (2017). [arXiv:1609.06202]

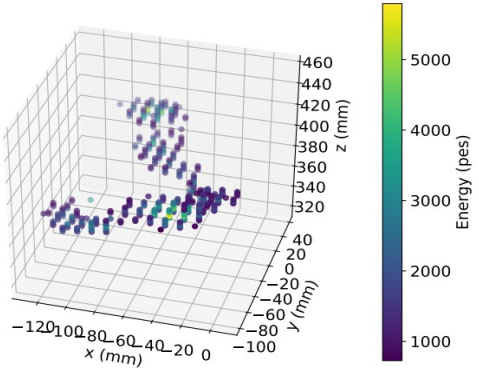
THANKS!

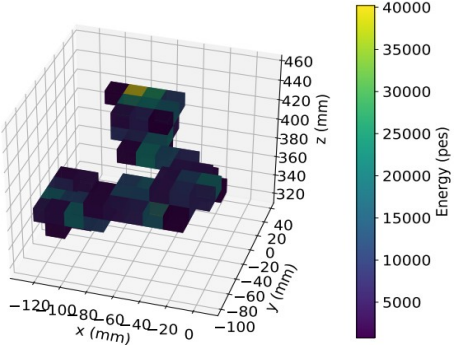
BACKUP

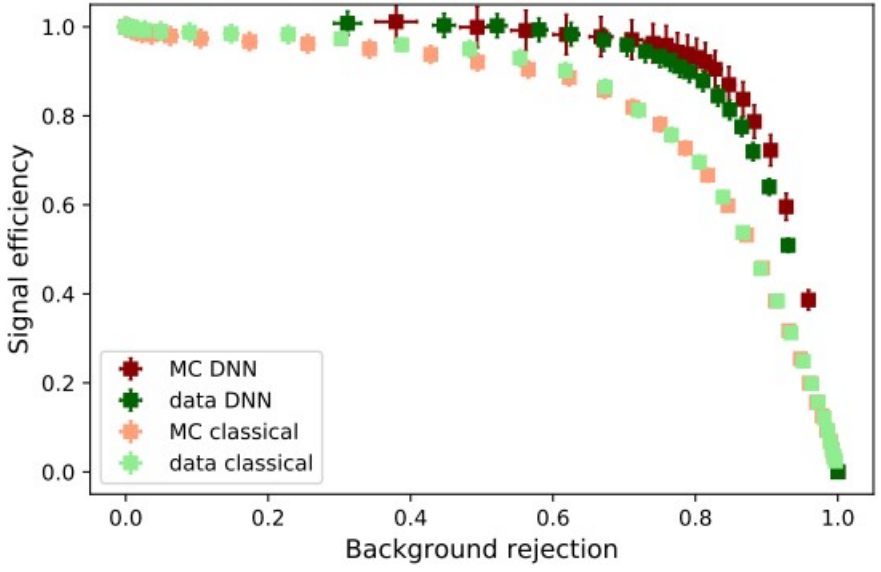
- Neutrinos are expected to be produced in many **astrophysical** sources
- Most neutrinos just cross the Earth and continue their travel
- A few of them interact and produce other particles that emit light
- We put **light detectors in water** (oceans, the Antarctic ice…)











arXiv:1905.13141 (2019)

- Predict error in z with a fully-connected net and cut on predicted error (< 12 mm, for example)