

Summary, next workshop, and goodbye

GraphNeT Workshop / 4 May 2023

Andreas Søgaard

Niels Bohr Institute, University of Copenhagen



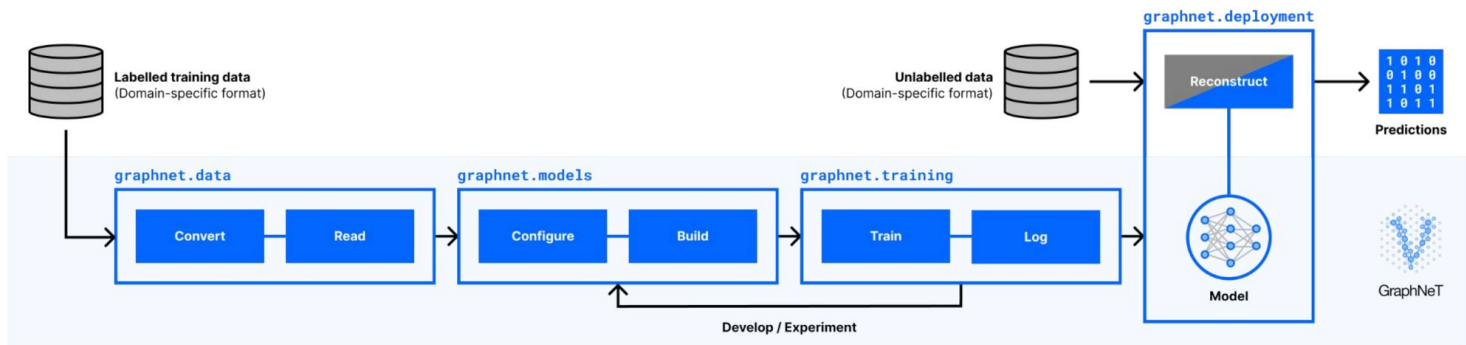
Danish
Data Science
Academy



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 890778.

Trying to make GNNs (more) easily available to physicists

Factoring out ML from physics



Learning meaningful representations on graphs

UNIVERSITY OF COPENHAGEN

Meaningful interpolation in latent space

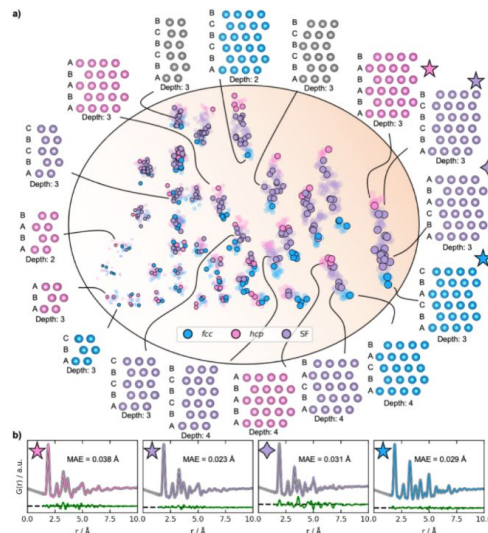


Fig. 6 | Latent space and reconstructions of stacking faulted nanoparticles. a) The latent space and reconstructed structures shown with their stacking sequence. The structures are shown in two dimensions, and

Anker .. Selvan et al. 2023, DeepStruc



Global reach, winning with transformers and ensembles

Stats

- 6,460 registrations
- 901 participants from 74 countries (!)
- 812 teams
- 11,206 submissions
- 220 Jupyter notebooks (<https://www.kaggle.com/competitions/icecube-neutrinos-in-deep-ice/code>)
- 194 Discussion threads (<https://www.kaggle.com/competitions/icecube-neutrinos-in-deep-ice/discussion>)

Philipp Eller (TUM)

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Top 3 Solutions

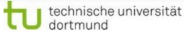
- All sub-degree Track resolution!!
- All use transformer architecture (attention models)
- 1 & 2 use vMF loss, 3 uses also a cross-entropy classifier, and 1 a modification
- A lot of ensembling going on
- **1st Place uses GraphNeT!!!**
- More technical details in write-ups:
→ <https://www.kaggle.com/competitions/icecube-neutrinos-in-deep-ice/leaderboard>




The collage includes a snippet of the Kaggle leaderboard showing the top 5 teams and their scores. It also features a detailed technical diagram of a neural network architecture, likely the GraphNeT mentioned in the text, and two histograms showing the distribution of scores for different categories.

Philipp Eller (TUM)

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Encoding domain knowledges in NNs



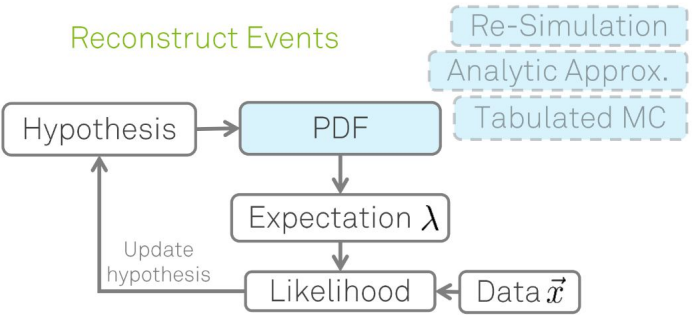
SFB 876 Providing information by Resource-Constrained Data Analysis

DFG Deutsche Forschungsgemeinschaft

Federal Ministry of Education and Research

Combining Deep Learning and Maximum-Likelihood Estimation

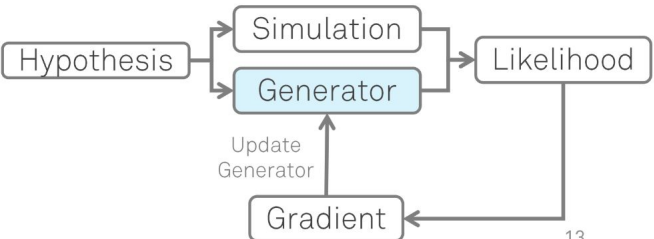
Reconstruct Events

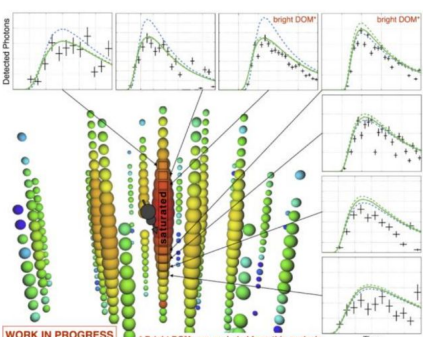


Replace PDF with a NN (“Generator”):

- Fast approximation of MC simulation
- Domain knowledge & symmetries can be easily incorporated into NN due to “forward” direction
- Exact detector geometry can be used
- Use in reverse mode for reconstruction
 - ➔ Fully differentiable: Gradient based minimizer

Train Generator via MC simulation





Detected Photons

Time

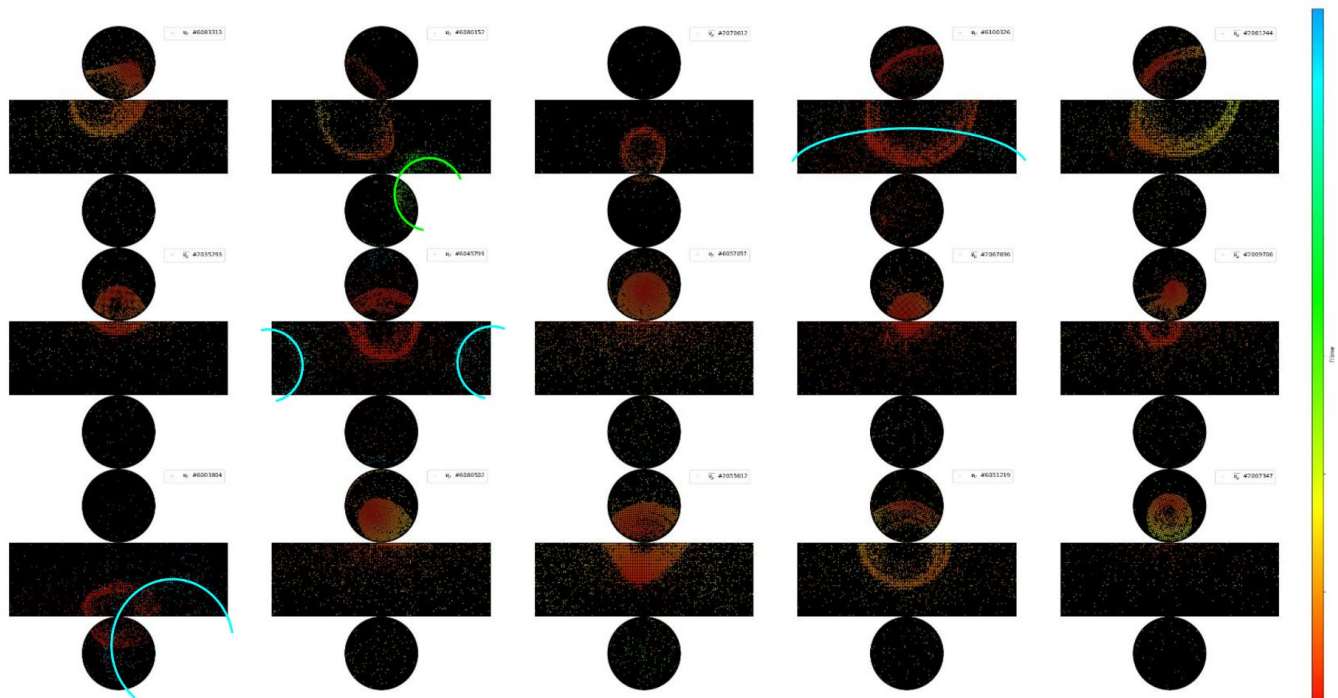
WORK IN PROGRESS

Bright DOMs are excluded from this analysis

Credit: HESE team

Using GraphNeT outside “NeT”

Event for which GraphNeT performs significantly better than fiTQun



Posters!

Ludwig

tu technische universität dortmund

Ideas to measure the prompt component of the atmospheric muon flux

Jean-Marco Alamérisse, Ludwig Neefen and Pascal Guéhen
3rd Workshop on Graph Neural Networks for Neutrino Telescope Event Reconstruction (GraphNet 1)

Introduction
The prompt component of the atmospheric muon flux is a key signature of dark matter annihilation. It is expected to be the most significant component of the muon flux at high energies. However, it is difficult to measure due to the large background of cosmic-ray muons. This poster presents ideas to measure the prompt component of the muon flux using a combination of machine learning and traditional techniques.

Methodology
The proposed method consists of two main steps: 1) Event selection: Events are selected based on their energy and direction. 2) Event classification: A neural network is trained to distinguish between prompt muons and cosmic-ray muons. The network takes as input the energy and direction of the muon and outputs a probability of being a prompt muon.

Results
The results show that the proposed method is able to identify prompt muons with a high efficiency and low background. The energy spectrum of the prompt muons is shown to be consistent with the expected dark matter annihilation signal.

Conclusion
The proposed method provides a promising way to measure the prompt component of the atmospheric muon flux. It is expected to be a key signature of dark matter annihilation.

References
[1] J. M. Alamérisse, L. Neefen, and P. Guéhen, "Ideas to measure the prompt component of the atmospheric muon flux," 3rd Workshop on Graph Neural Networks for Neutrino Telescope Event Reconstruction (GraphNet 1), 2023.

Pascal

tu technische universität dortmund

Muon Detection Simulation Using PROPOSAL

Pascal Guéhen
Workshop on Graph Neural Networks for Neutrino Telescope Event Reconstruction (GraphNet 1)

Introduction
The PROPOSAL (PROmpt muon OBServation) code is a Monte Carlo simulation of the muon flux. It is used to generate realistic muon event samples for neutrino telescope simulations. This poster describes the implementation of the PROPOSAL code and its application to neutrino telescope event reconstruction.

Methodology
The PROPOSAL code is implemented using the ROOT framework. It uses a combination of analytical models and Monte Carlo simulations to generate muon events. The code is designed to be flexible and easy to use.

Results
The results show that the PROPOSAL code is able to generate realistic muon event samples. The energy spectrum and direction distribution of the muons are shown to be consistent with the expected atmospheric muon flux.

Conclusion
The PROPOSAL code provides a powerful tool for generating realistic muon event samples. It is expected to be a key component of neutrino telescope event reconstruction.

References
[1] P. Guéhen, "Muon Detection Simulation Using PROPOSAL," 3rd Workshop on Graph Neural Networks for Neutrino Telescope Event Reconstruction (GraphNet 1), 2023.

Karljin

Detection and reconstruction of GeV neutrinos with IceCube

Karlijn Kruiswijk, Paulijn Kruiswijk (Dutchman) on behalf of the IceCube Collaboration

ICCCUBE fms UCLouvain

GeV neutrino Detection in IceCube
IceCube is a cubic kilometer neutrino observatory. It is designed to detect high-energy neutrinos. This poster describes the detection and reconstruction of GeV neutrinos using IceCube. The detection is based on the observation of muons produced by neutrino interactions in the detector.

Methodology
The detection of GeV neutrinos is based on the observation of muons. The muons are reconstructed using a combination of particle identification and kinematic fitting. The energy and direction of the neutrino are then estimated.

Results
The results show that GeV neutrinos can be detected and reconstructed with high efficiency. The energy spectrum and direction distribution of the neutrinos are shown to be consistent with the expected flux.

Conclusion
IceCube is a powerful tool for detecting and reconstructing GeV neutrinos. It is expected to provide valuable insights into the high-energy neutrino flux.

References
[1] K. Kruiswijk, P. Kruiswijk, "Detection and reconstruction of GeV neutrinos with IceCube," 3rd Workshop on Graph Neural Networks for Neutrino Telescope Event Reconstruction (GraphNet 1), 2023.

Juan

Improving the direction and energy estimation of low-energy events in ANTARES with ML

Guillaume Mendez, Yigimengmeng Lopez, Salvo Ardiz & Miguel Azeite on behalf of the ANTARES collaboration, Université Polytechnique de Valence

ANTARES in a nutshell
ANTARES is a neutrino telescope located in the Mediterranean Sea. It is designed to detect high-energy neutrinos. This poster describes the use of machine learning to improve the direction and energy estimation of low-energy events in ANTARES.

Methodology
The proposed method uses a neural network to estimate the direction and energy of low-energy events. The network takes as input the data from the detector and outputs the estimated direction and energy.

Results
The results show that the proposed method improves the direction and energy estimation of low-energy events. The energy spectrum and direction distribution of the events are shown to be consistent with the expected flux.

Conclusion
The proposed method provides a promising way to improve the direction and energy estimation of low-energy events in ANTARES. It is expected to be a key component of neutrino telescope event reconstruction.

References
[1] G. Mendez, Y. Lopez, S. Ardiz, and M. Azeite, "Improving the direction and energy estimation of low-energy events in ANTARES with ML," 3rd Workshop on Graph Neural Networks for Neutrino Telescope Event Reconstruction (GraphNet 1), 2023.

Jonathan

A GCN to search for solar-flare neutrinos with KM3NeT

Neutrino Production
Solar flares are high-energy emissions that occur in the sun. They produce neutrinos that can be detected by neutrino telescopes. This poster describes the use of a graph convolutional network (GCN) to search for solar-flare neutrinos in the KM3NeT detector.

Detection
The GCN is trained to identify solar-flare neutrinos in the KM3NeT data. It takes as input the data from the detector and outputs a probability of being a solar-flare neutrino.

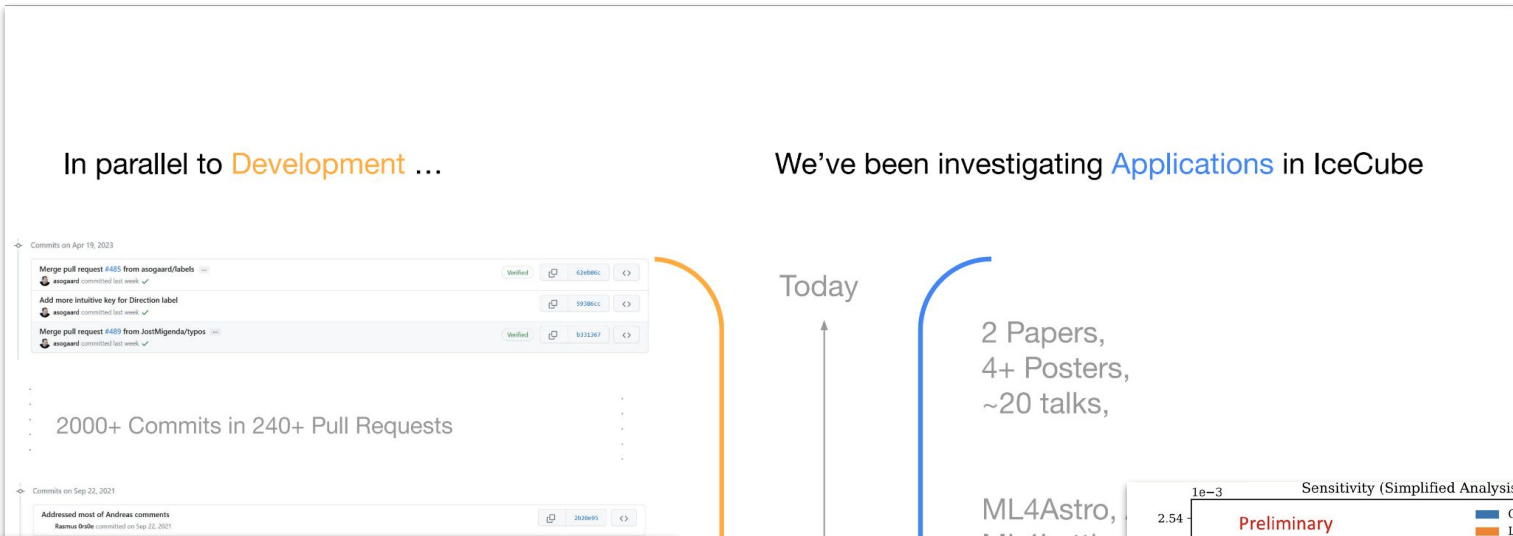
Results
The results show that the GCN is able to identify solar-flare neutrinos with high efficiency. The energy spectrum and direction distribution of the neutrinos are shown to be consistent with the expected flux.

Conclusion
The GCN provides a powerful tool for searching for solar-flare neutrinos in the KM3NeT detector. It is expected to be a key component of neutrino telescope event reconstruction.

References
[1] J. Kruiswijk, "A GCN to search for solar-flare neutrinos with KM3NeT," 3rd Workshop on Graph Neural Networks for Neutrino Telescope Event Reconstruction (GraphNet 1), 2023.

Using one framework to solve several physics problems

In parallel to **Development** ...



2000+ Commits in 240+ Pull Requests

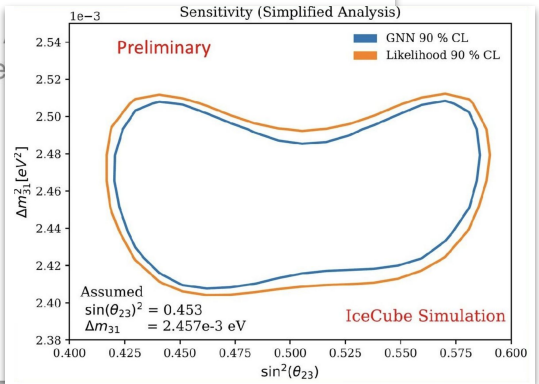
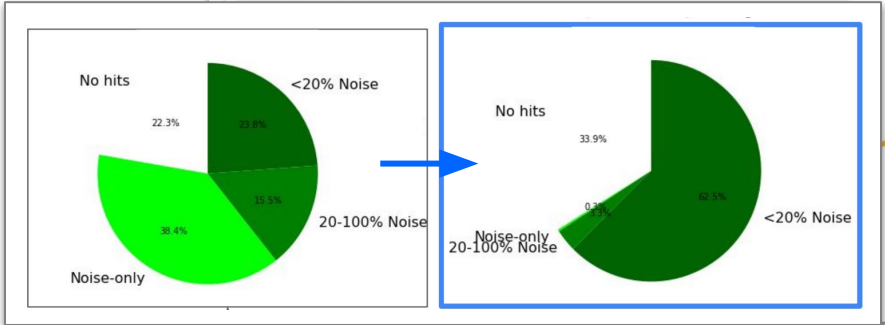
We've been investigating **Applications** in IceCube

Today


2 Papers,
4+ Posters,
~20 talks,

ML4Astro,
ML4Lattice

First Commit



Accelerating GNNs, and their use, with every release



Accelerating PyTorch Geometric

Current Stack:





```
graph TD; PT1[PyTorch] --> TS[torch-scatter]; PT1 --> TSP[torch-sparse]; TS --> PyG1[PyG]; TSP --> PyG1;
```

Accelerated Stack:

```
graph TD; PT2[PyTorch] --> PyG2[PyG]; PyG2 --> PyG3[PyG];
```

pyg-lib: A unified GNN engine for optimized low-level graph routines

[/pyg-team/pyg-lib](https://github.com/pyg-team/pyg-lib)

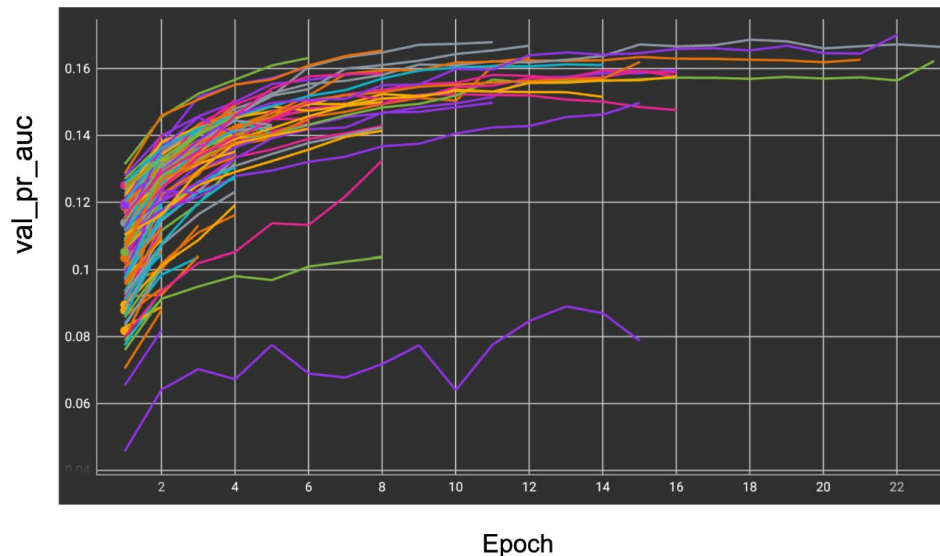
- ✓ Joint effort of  Kumo,  NVIDIA,  Intel &  PyTorch
- ✓ Accelerating graph sampling routines
- ✓ Accelerating heterogeneous GNNs
- ✓ Accelerating sparse aggregations
- ✓ Speed-ups with *no* line of code change

Optimising GNN hyperparameters with/-out automation

Second AHPO

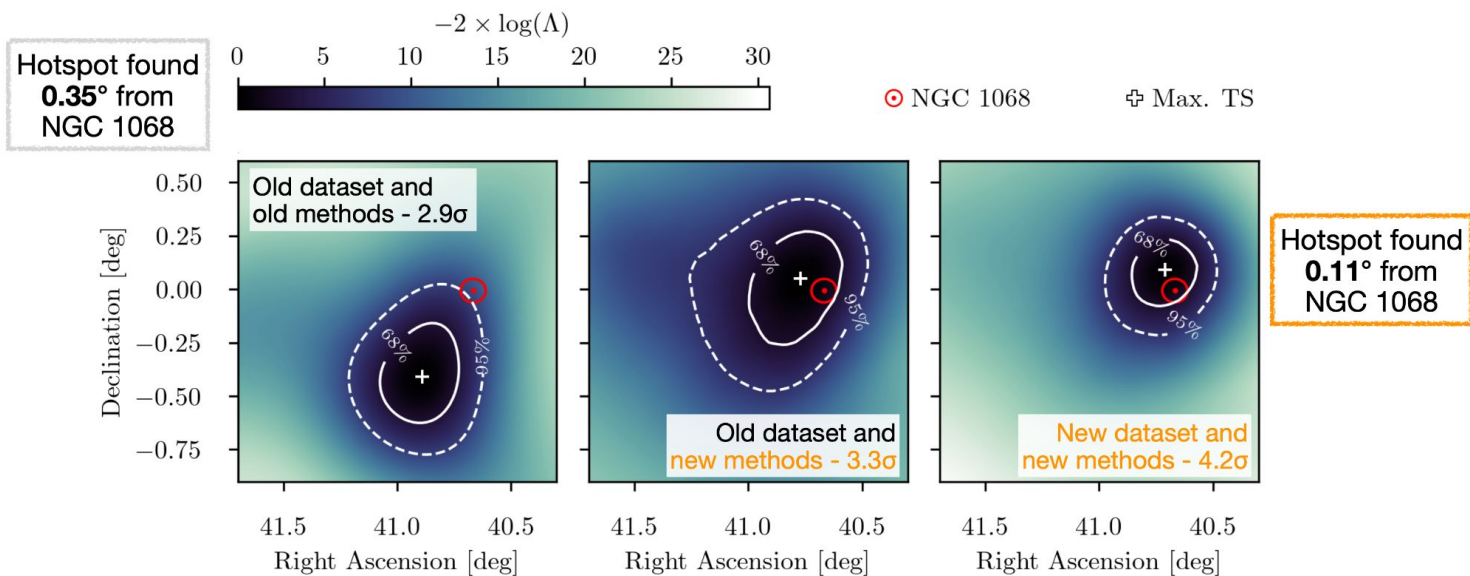


- Second AHPO is currently running
- Results look much more promising
- Analysis of the relevance of different hyperparameters is in preparation
- In total, I got granted 50k GPU hours from the NHR@FAU in Erlangen
- About 1/3 of that is used so far



Aiming for discoveries using better reconstruction

Evolution of the brightest neutrino spot



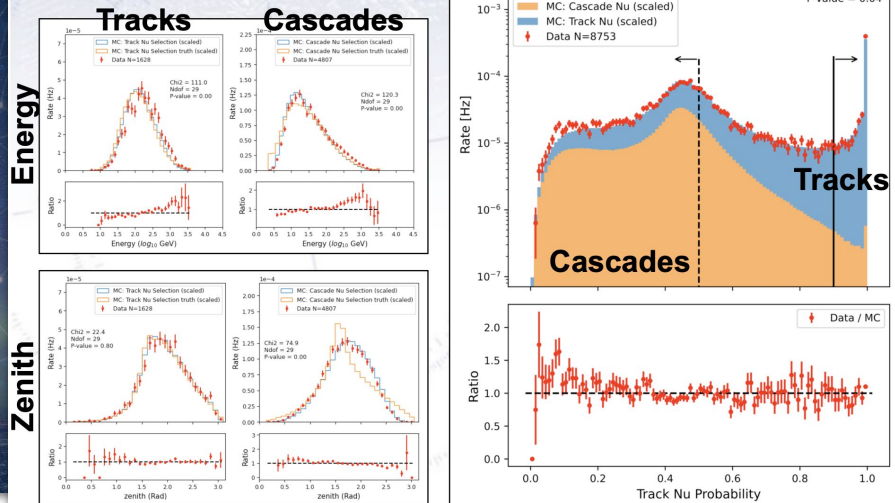
Pondering the myriad more ways to use GNNs for physics

OVERVIEW

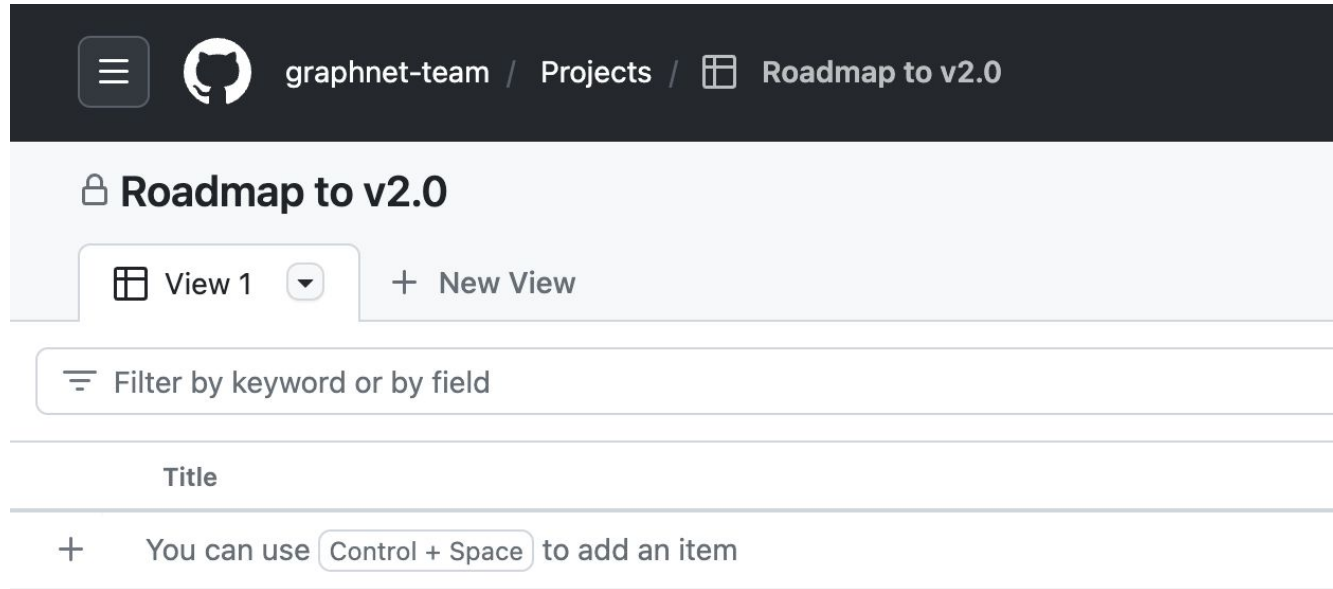
- Tasks using Monte Carlo only
- Large scale neutrino selection in data
- An AtmosphericEvent tagger (trained in data?)
- Real-time analysis/alerts
- Algorithm development
- Explaining / visualising GNN output
- Thoughts on where to begin

Low Energy Selection/Reco status

Things generally look "good" ... :-)



What's next?



The screenshot shows a dark header bar with a hamburger menu icon, the GitHub logo, and the breadcrumb path "graphnet-team / Projects / Roadmap to v2.0". Below the header, the title "Roadmap to v2.0" is displayed with a lock icon. A view selector shows "View 1" with a dropdown arrow and a "+ New View" button. A search bar contains the text "Filter by keyword or by field". A table header with the title "Title" is visible. The first row of the table contains a "+" icon and the text "You can use Control + Space to add an item", where "Control + Space" is enclosed in a rounded rectangular box.

Where to go from here

- [Feedback form](#), please complete by **Friday 12 May**.
- Stay in touch through the [GraphNeT Slack group](#).
- Weekly GraphNeT developer meetings on Zoom (Tuesdays, alternating weekly between 9:00 or 15:00 CEST) — announced in the Slack group.
- If you want a **certificate of attendance**, please let me know.

Those who have a bit of time before leaving: [Hammeren natural area and trail](#) (1 hr 20 mins)

Strandpromenaden

~STRANDHOTELLET





See you at the next GraphNeT workshop!

Tentatively autumn 2023 in Munich