# Cześć from Warszawa:

## my latest news + report from 0νββ AI Summer School and Neutrino ´26

**Miroslav Macko**

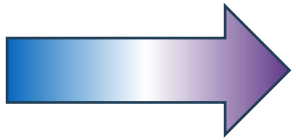
*Astrocent, Polish Academy of Sciences*

ASTROCENT

# My news since my last collaboration meeting

- **Thank you CTU and cześć Astrocent!**

INSTITUTE OF EXPERIMENTAL AND APPLIED PHYSICS CTU IN PRAGUE



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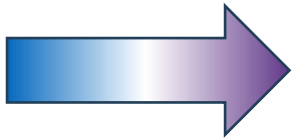

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**Astrocent**

- **Agenda (source: [https://astrocent.edu.pl/](https://astrocent.edu.pl/)):**
  - **a new institute** dedicated to **neutrinos, dark matter and gravitational waves**.

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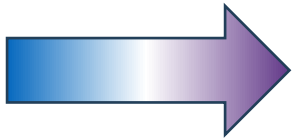

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  - within the Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences
  - a completely **new autonomous centre of excellence**.

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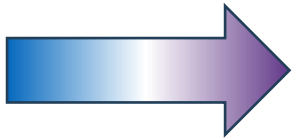

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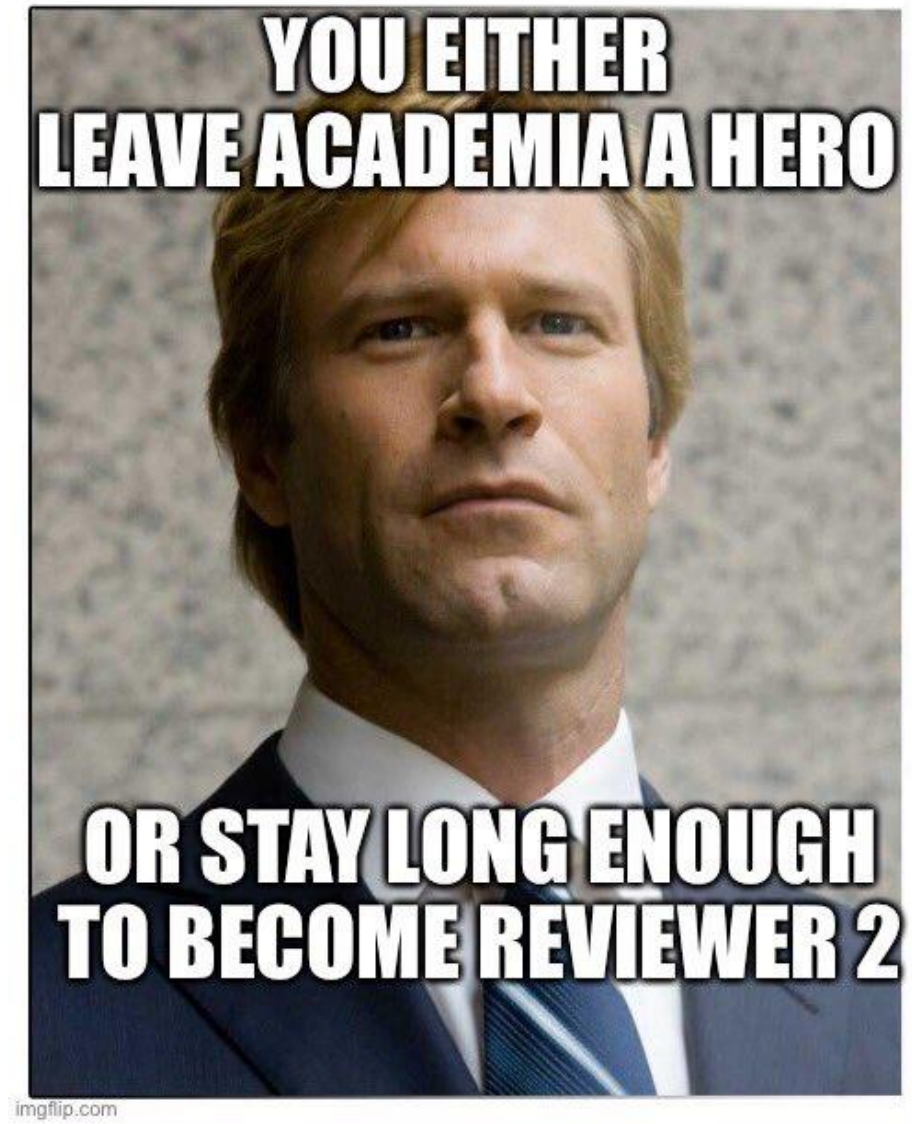
  - a completely **new autonomous centre of excellence**.
- **Since March 2026:**
  - **new institute within Polish Academy of Sciences**
  - founded by the Horizon Europe, IRAP grant and the Ministry of Science and Higher Education of Poland
  - **€30 million over 6 years** to provide a stable base to expand human and research infrastructure capacity, partnerships, and training.

**The veterans of the SuperNEMO:**



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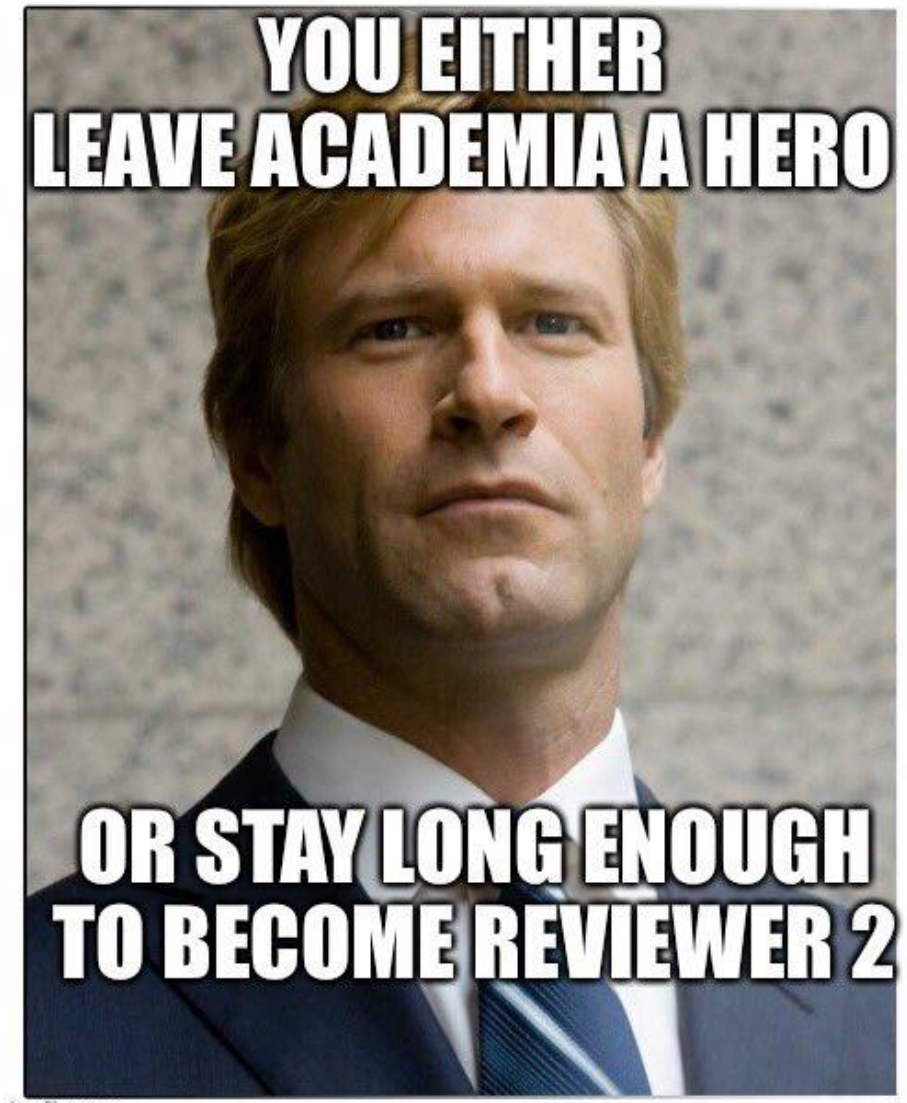

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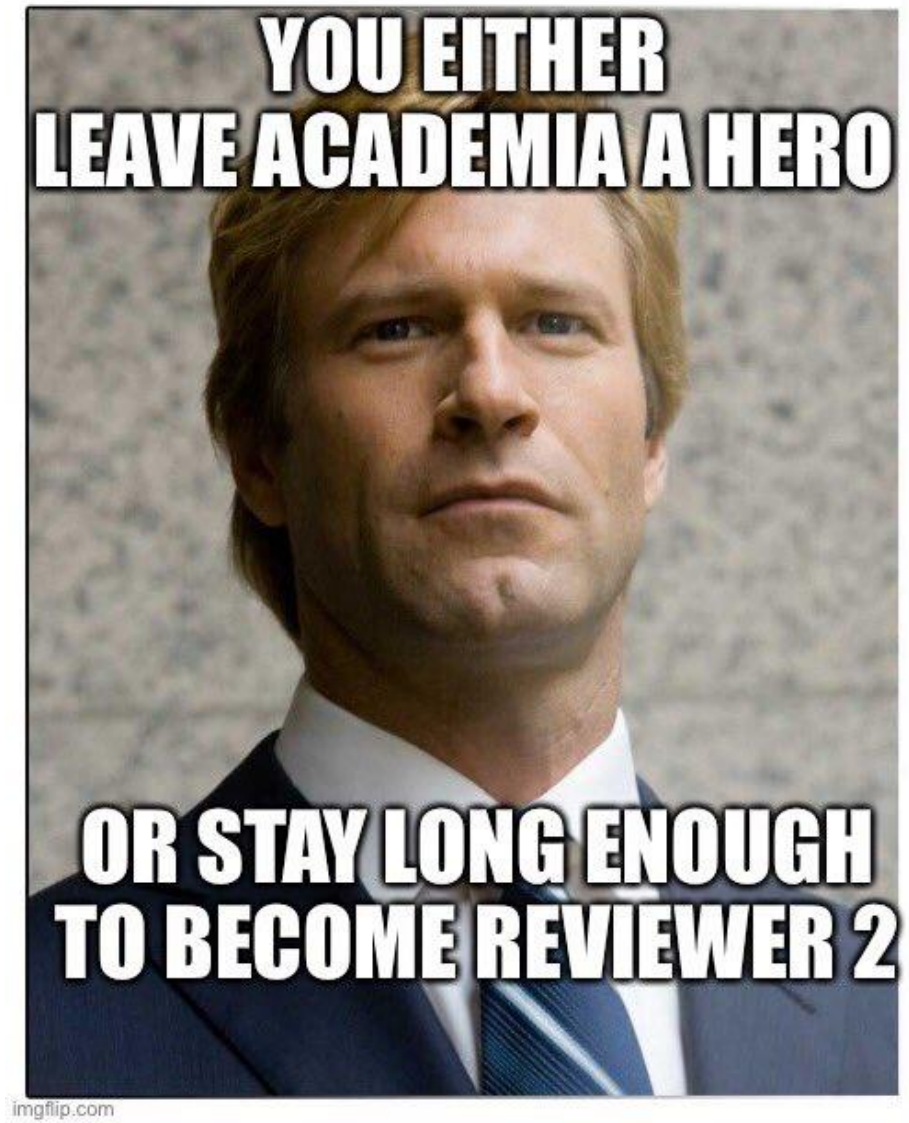

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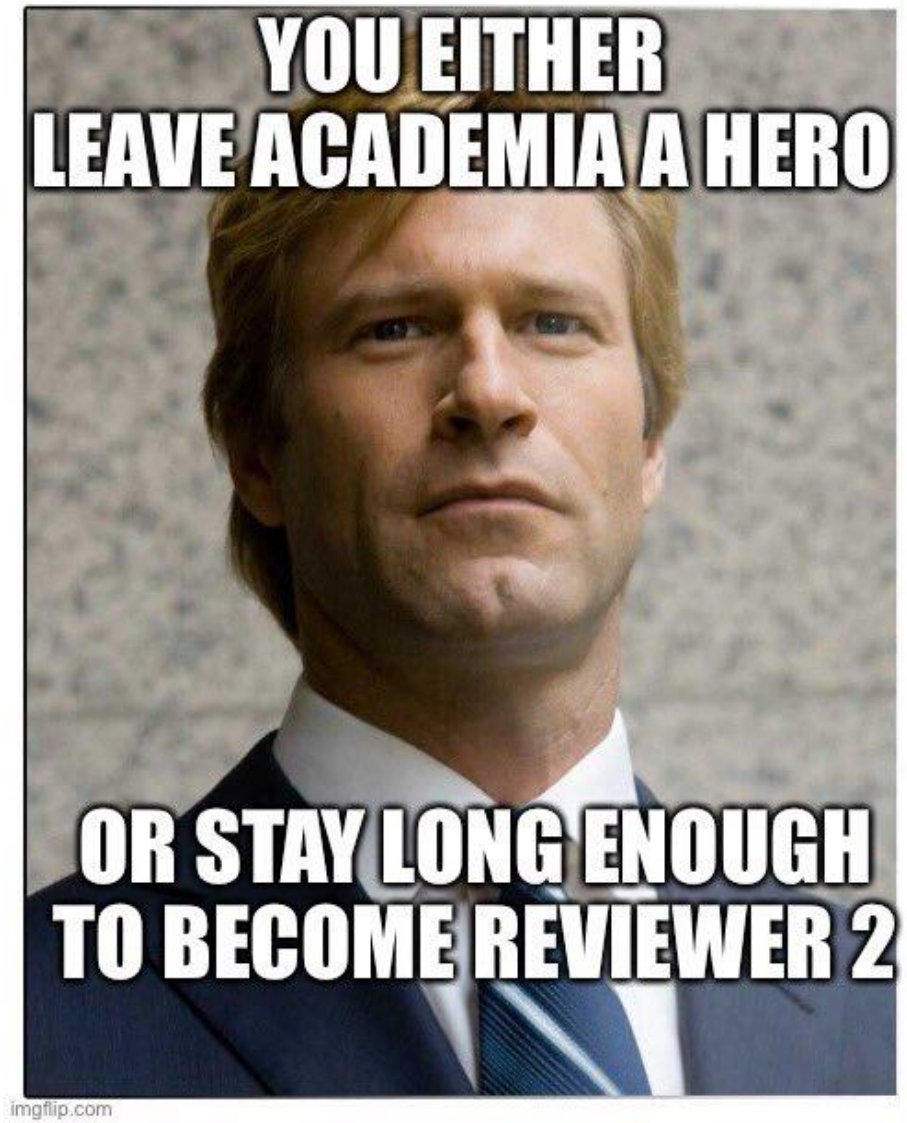

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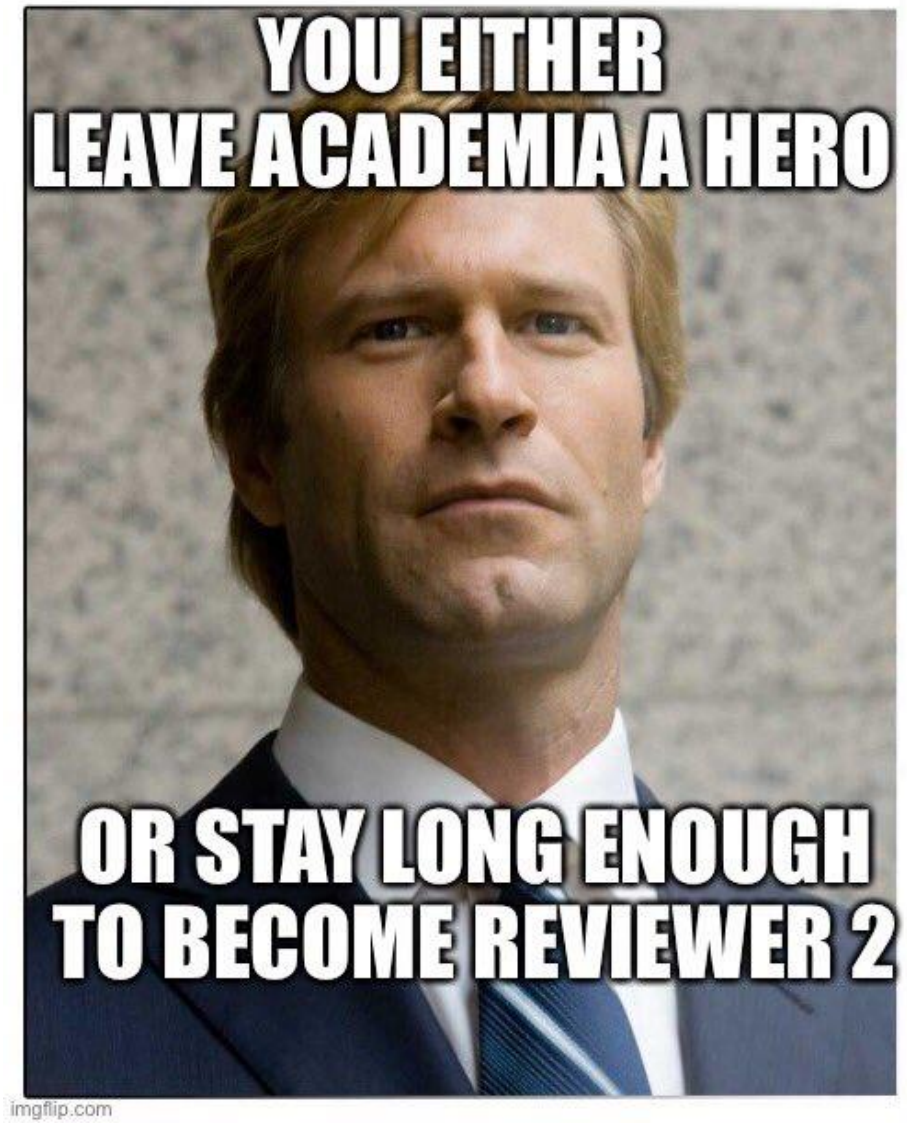

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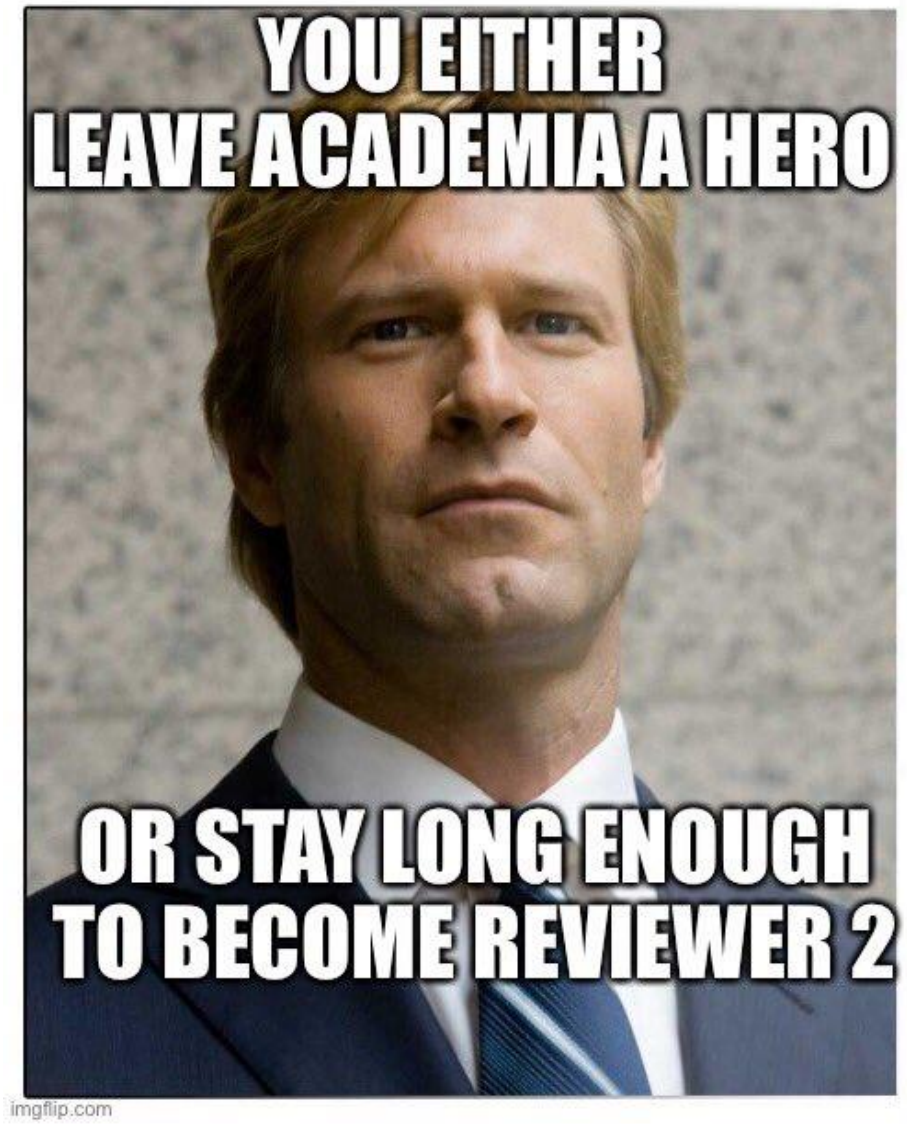
**Thanks for all the hard work! :)**

**I suggest everyone to profit from presence of Tomáš and Maroš as much as possible – this might be their last collaboration meeting!**



**Youth team:**


Neil Renic
@NC_Renic
“I’m not a regular lecturer; I’m a cool lecturer,” you tell yourself, as you reference another tv show cancelled before your students were born.
2:43 PM · 2023-04-24 · 121K Views

## Youth team:

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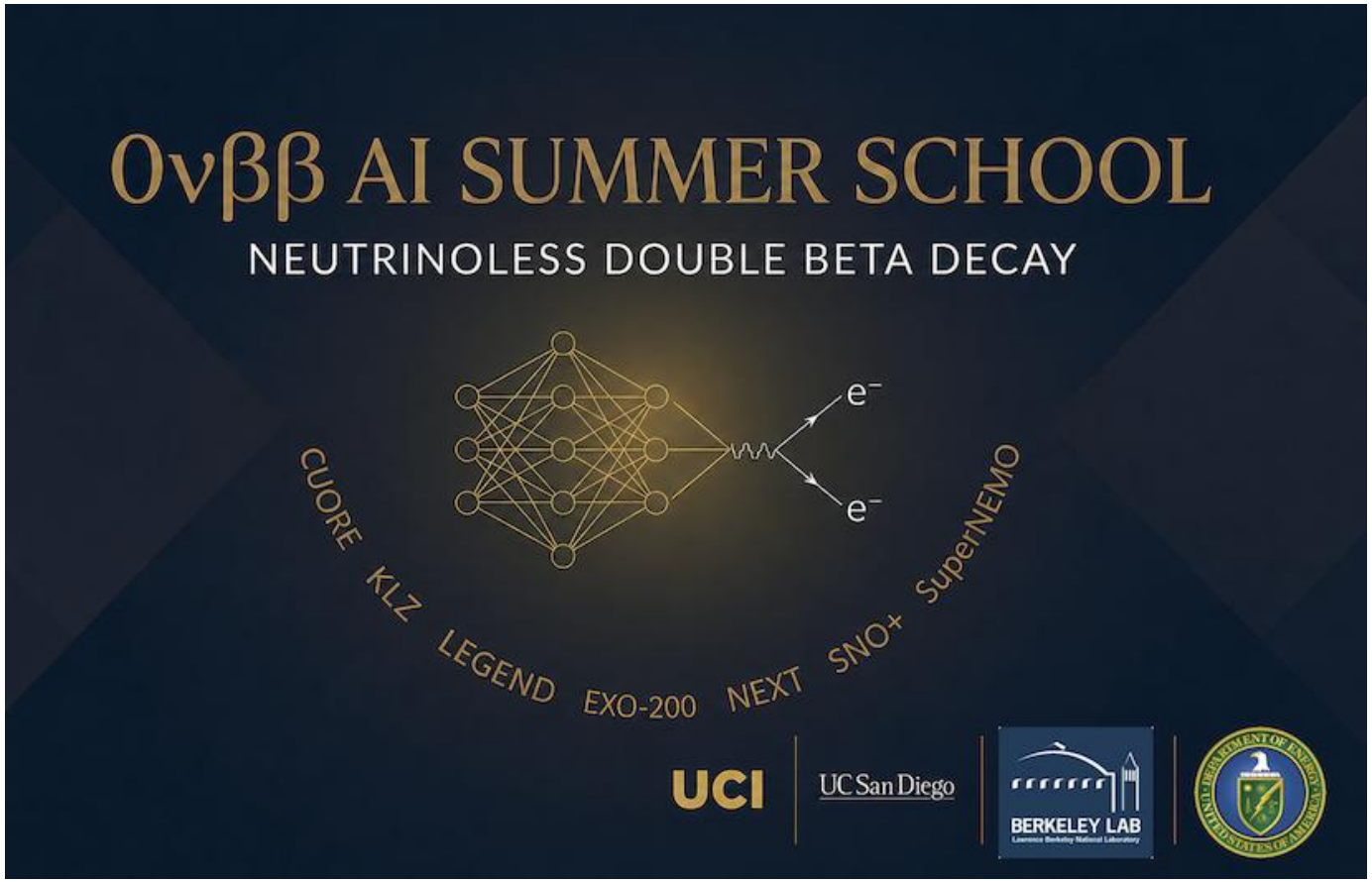
- **Oleksandra Halatova** (T. Shevchenko Univ. in Kyiv):
  - starts internship in July 2026.
  - internship will lead to bachelor thesis.
  - will perform optimization of Cimrman -  TBD with Tomáš.

# 0νββ AI Summer School

**I helped to organize AI / NN training school**

- I produced official SuperNEMO data release
- I participated in the workshop learning the basics of NN training, LLM, AI chatbots and vibecoding.



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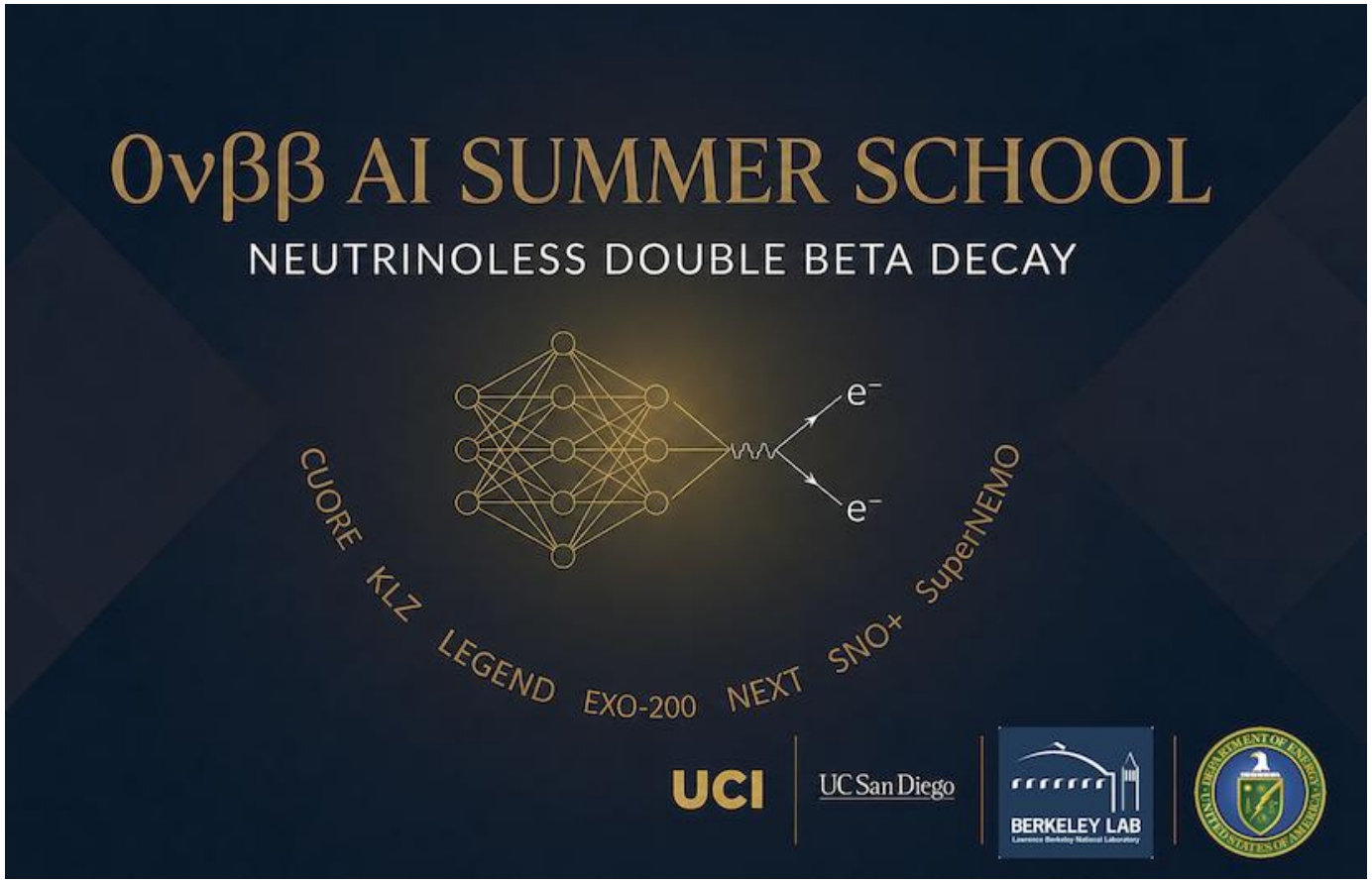
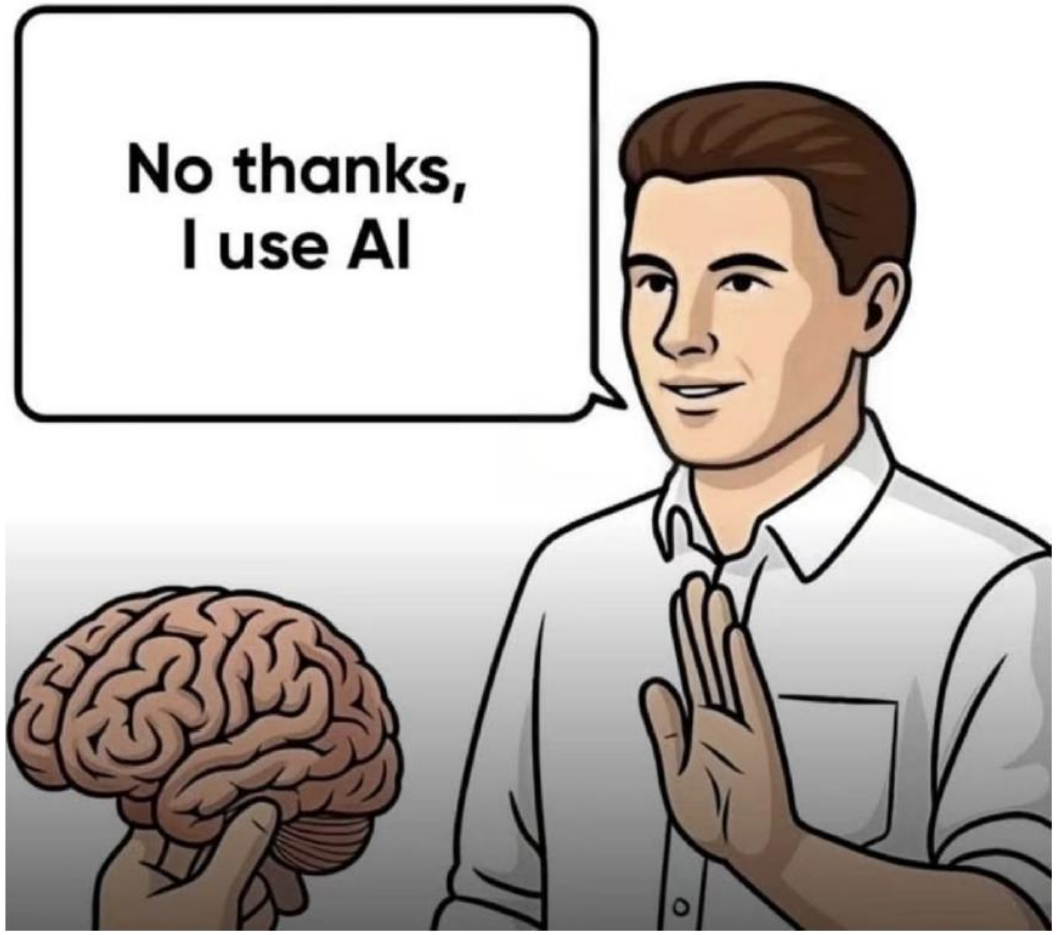
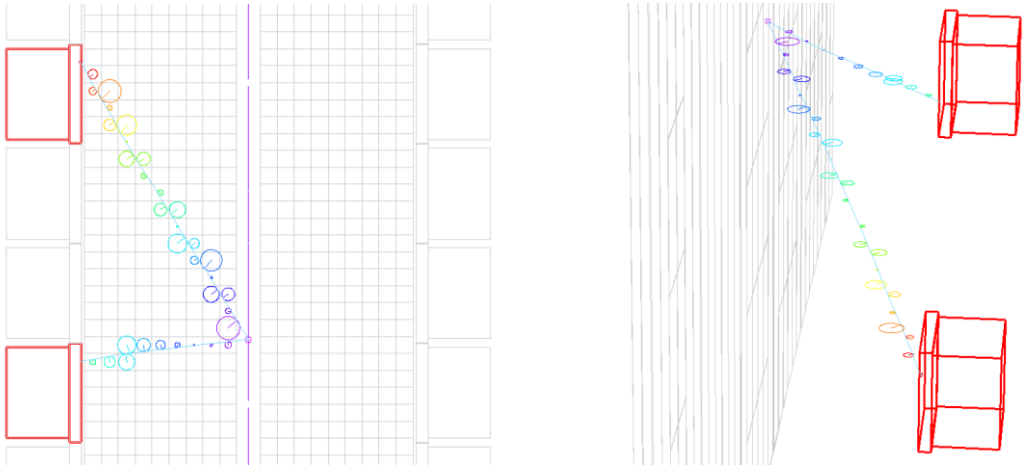
- I produced official SuperNEMO data release
- I participated in the workshop learning the basics of NN training, LLM, AI chatbots and vibecoding
- I managed **to design and to train my first NNs using only vibecoding**!





| ev_no | E1 | E2 | tX | tY | tZ | tR | dY | dZ | theta | phiS | phiR | label |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 951.75 | 1707.25 | 53.0 | 308.0 | 1025.75 | 14.691 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 53.0 | 352.0 | 977.5 | 10.381 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 97.0 | 352.0 | 1007.25 | 7.799 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 97.0 | 396.0 | 895.875 | 14.119 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 141.0 | 396.0 | 978.625 | 3.277 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 185.0 | 440.0 | 815.0 | 4.004 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 229.0 | 484.0 | 756.625 | 6.862 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 273.0 | 484.0 | 745.75 | 15.137 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
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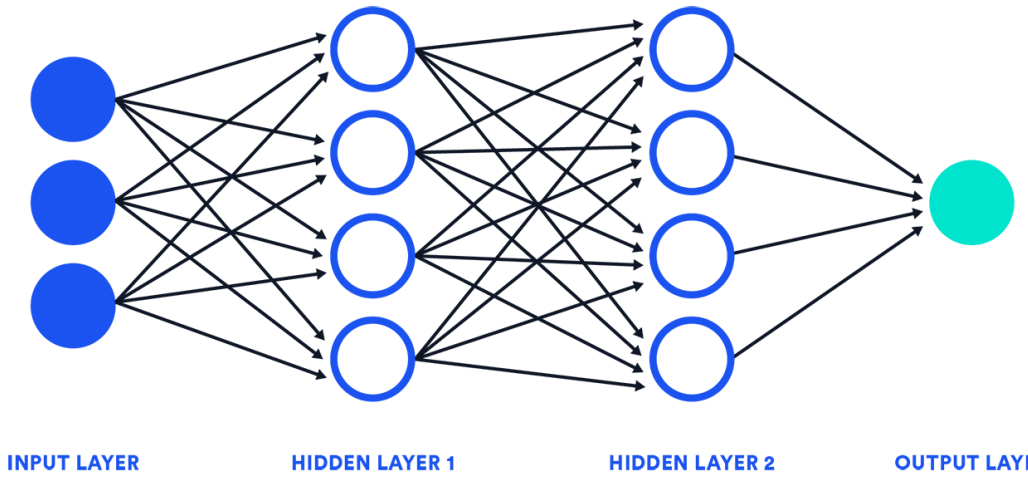
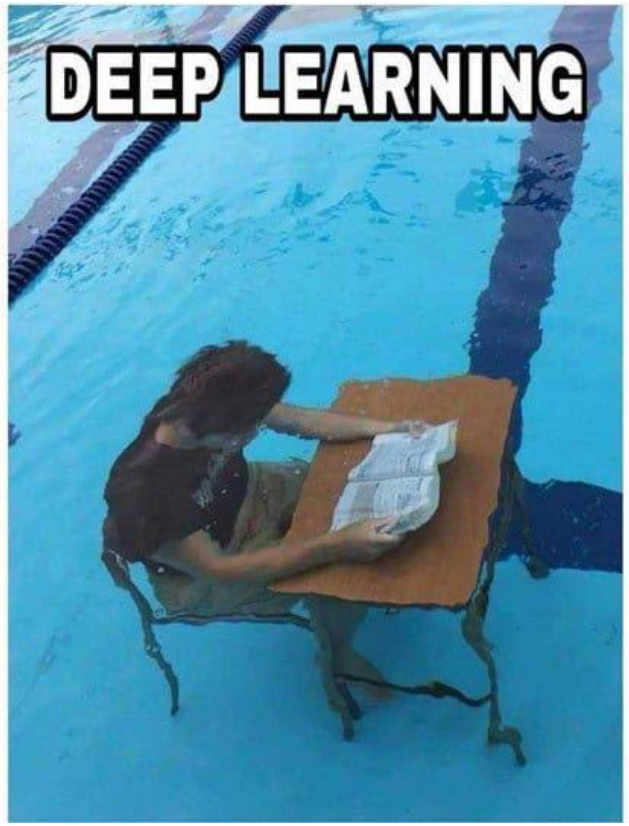
| 0 | 951.75 | 1707.25 | 317.0 | 528.0 | 646.125 | 2.977 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 361.0 | 528.0 | 603.125 | 15.117 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 361.0 | 572.0 | 868.125 | 6.196 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 405.0 | 572.0 | 548.25 | 5.644 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 405.0 | 616.0 | 848.5 | 1.925 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 361.0 | 616.0 | 426.25 | 13.752 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 317.0 | 660.0 | 390.813 | 3.722 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 273.0 | 660.0 | 372.563 | 15.924 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 229.0 | 704.0 | 342.438 | 6.534 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 185.0 | 704.0 | 335.938 | 17.207 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 185.0 | 748.0 | 323.5 | 15.988 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 141.0 | 748.0 | 310.938 | 10.984 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 97.0 | 792.0 | 285.813 | 7.329 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 53.0 | 792.0 | 268.688 | 11.584 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| 0 | 951.75 | 1707.25 | 317.0 | 572.0 | 905.5 | 21.145 | -577.75 | 809.125 | 31.594 | 50.734 | 91.391 | 0nubb |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

**`ev_no`**: event number
**`E1, E2`**: individual electron energies in *keV*
**`tX, tY`**: x- and y-position of the tracker hit center in *mm*
**`tZ`**: z-position of the tracker hit center in *mm*
**`tR`**: horizontal distance in mm of the closest flyby of the electron to the anode
**`dY, dZ`**: separation of foil trajectory projection points (TPPs) in *mm*
**`theta`**: simulated 3D decay angle in *degrees*
**`phiS`**: simulated 3D foil escape angle in *degrees*
**`phiR`**: 3D reconstructed angle in *degrees*
**`label`**: type of the decay: 0nubb, 2nubb, Bi214or Tl208, *string* type

The datasets and more info can be found at:
https://zenodo.org/records/20698789

# I trained two neural networks:



# I trained two neural networks:

- **NN1**: using **2 features**: E1, E2

**NN1:**
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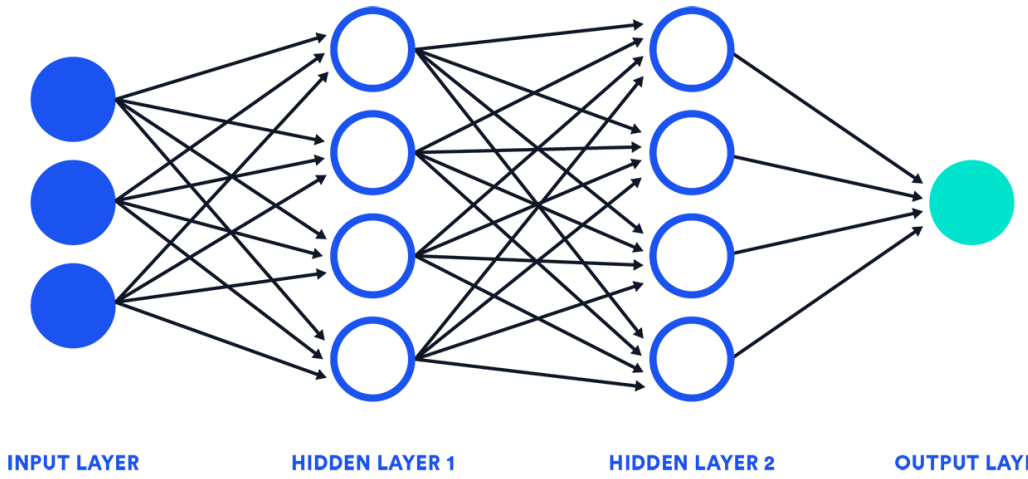


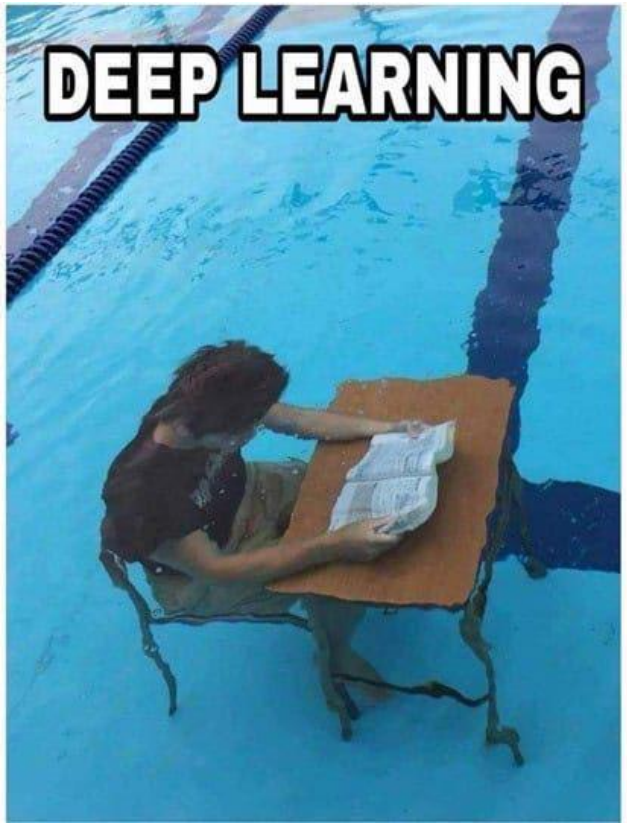

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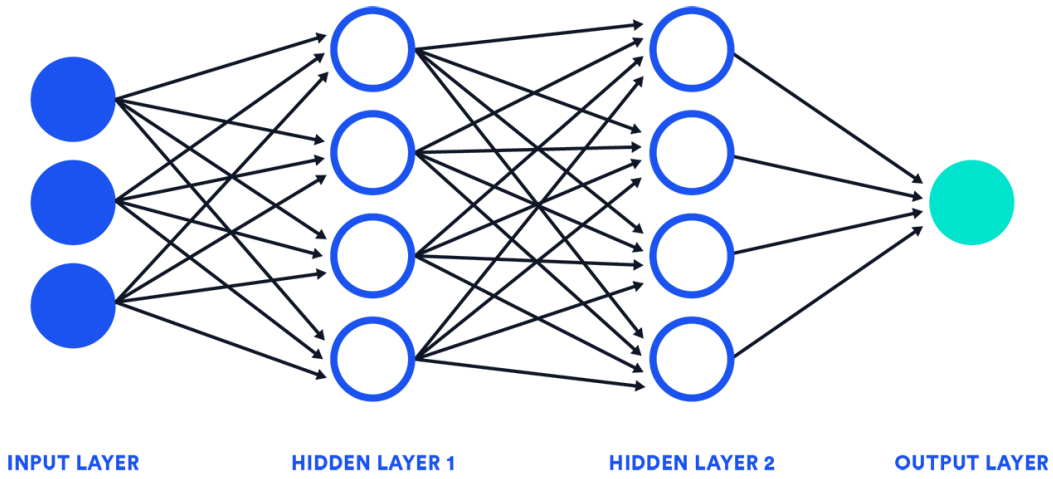


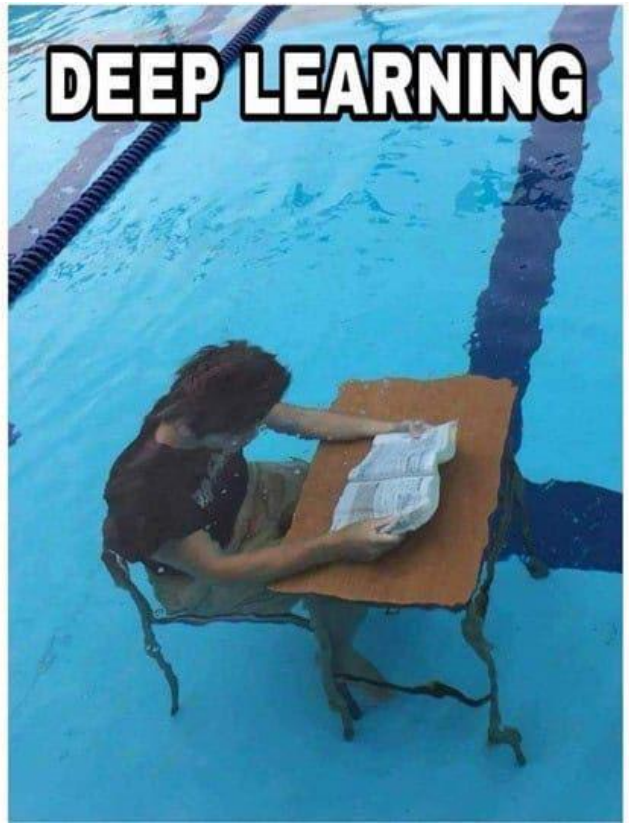

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- **NN1**: using **2 features**: E1, E2
- **NN2**: using **5 features**: E1, E2, dY, dZ, phiR
- Both networks were trained on simulation data from 0νββ (signal) and 0νββ (background)

**NN1:**
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**NN2:**
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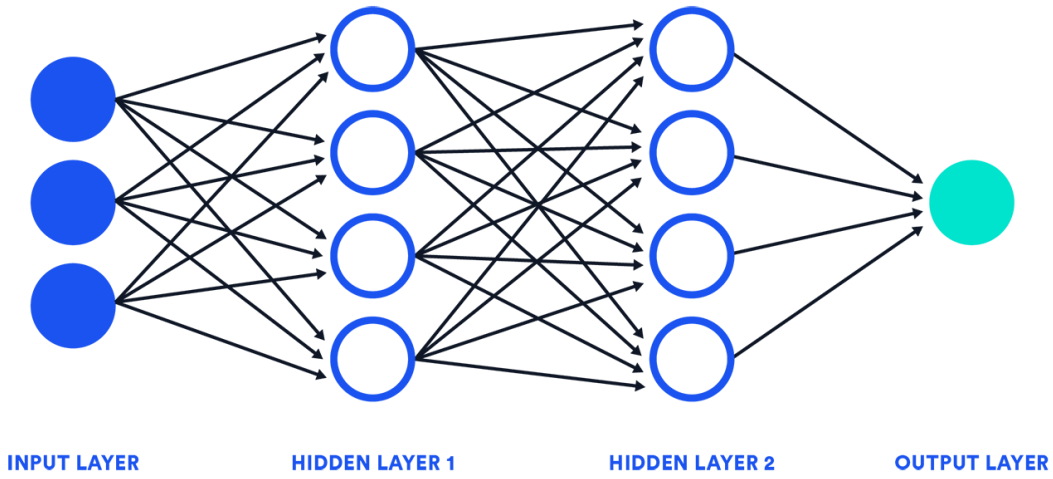


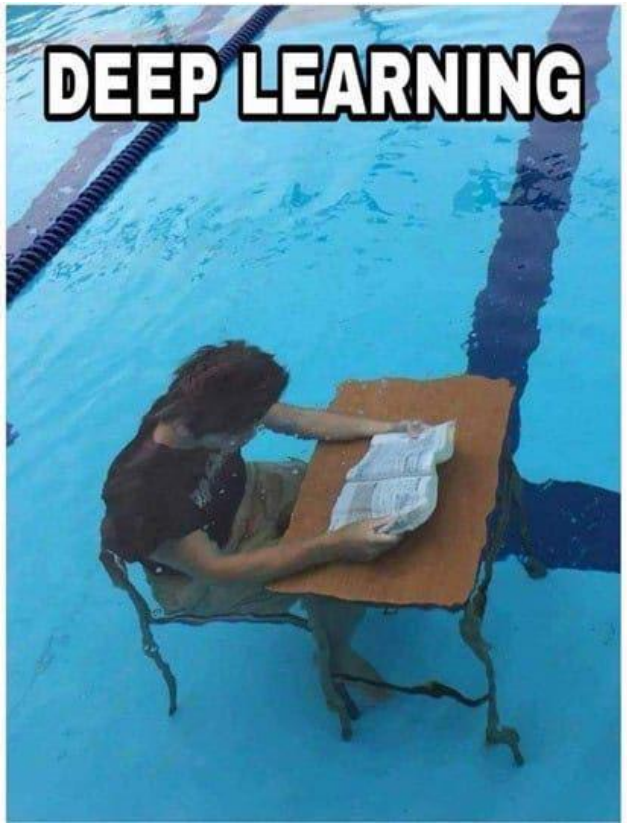

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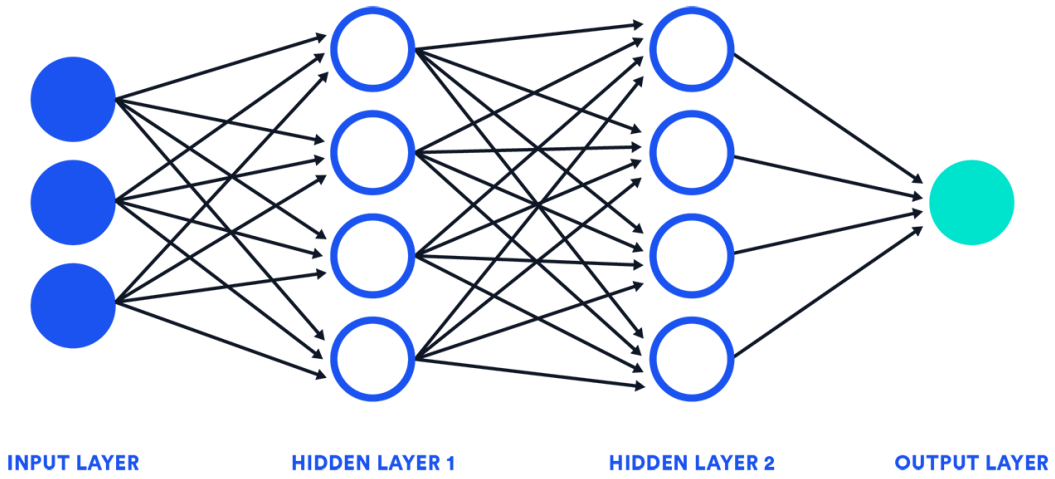
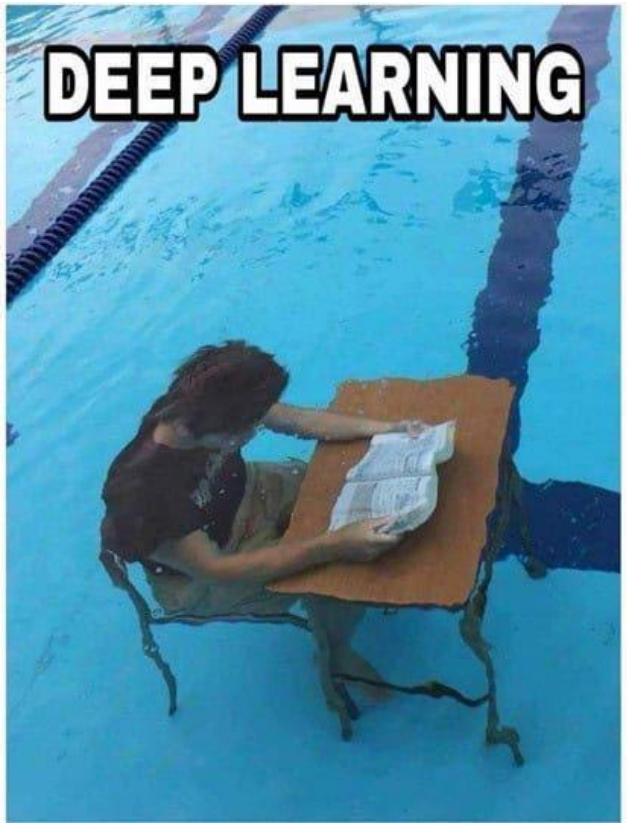



**Label 0νββ or 2νββ**



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- I did not write a single line, everything was vibecoded!

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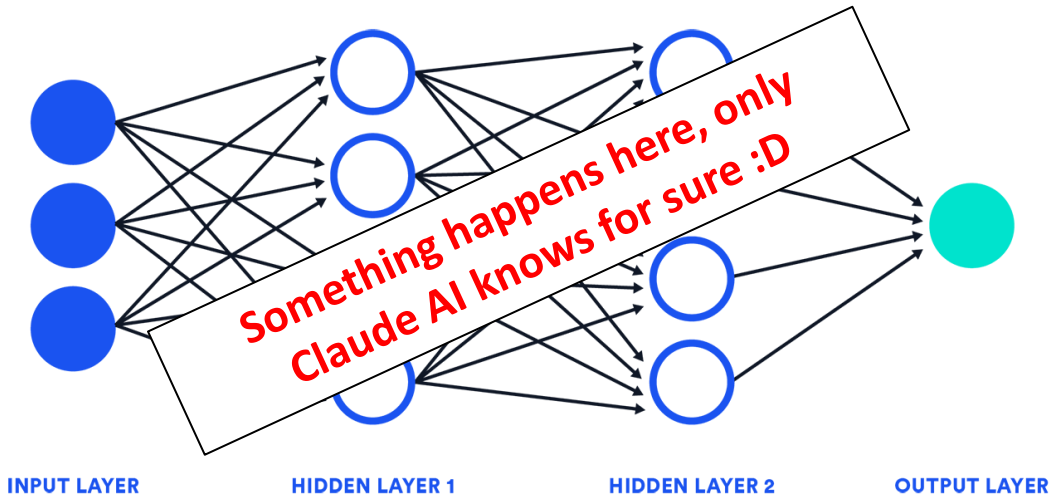


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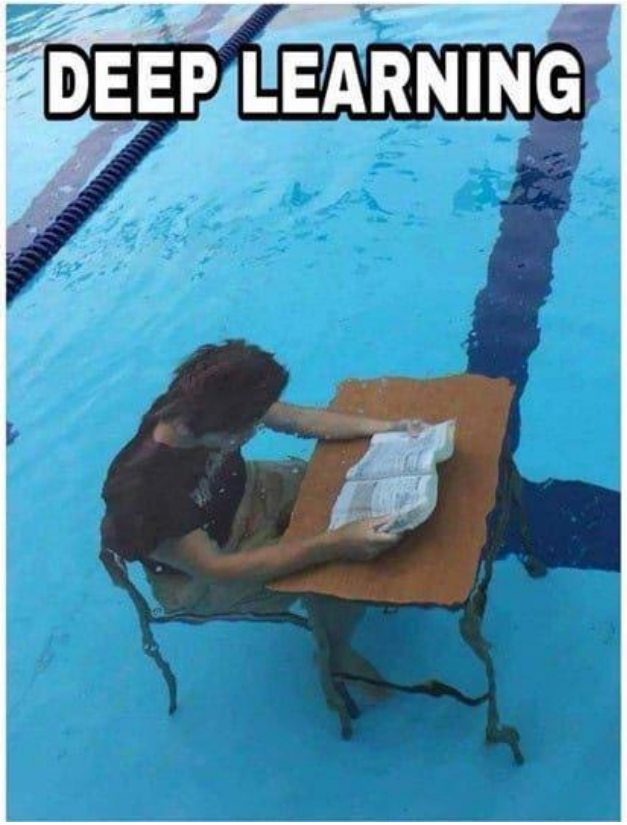
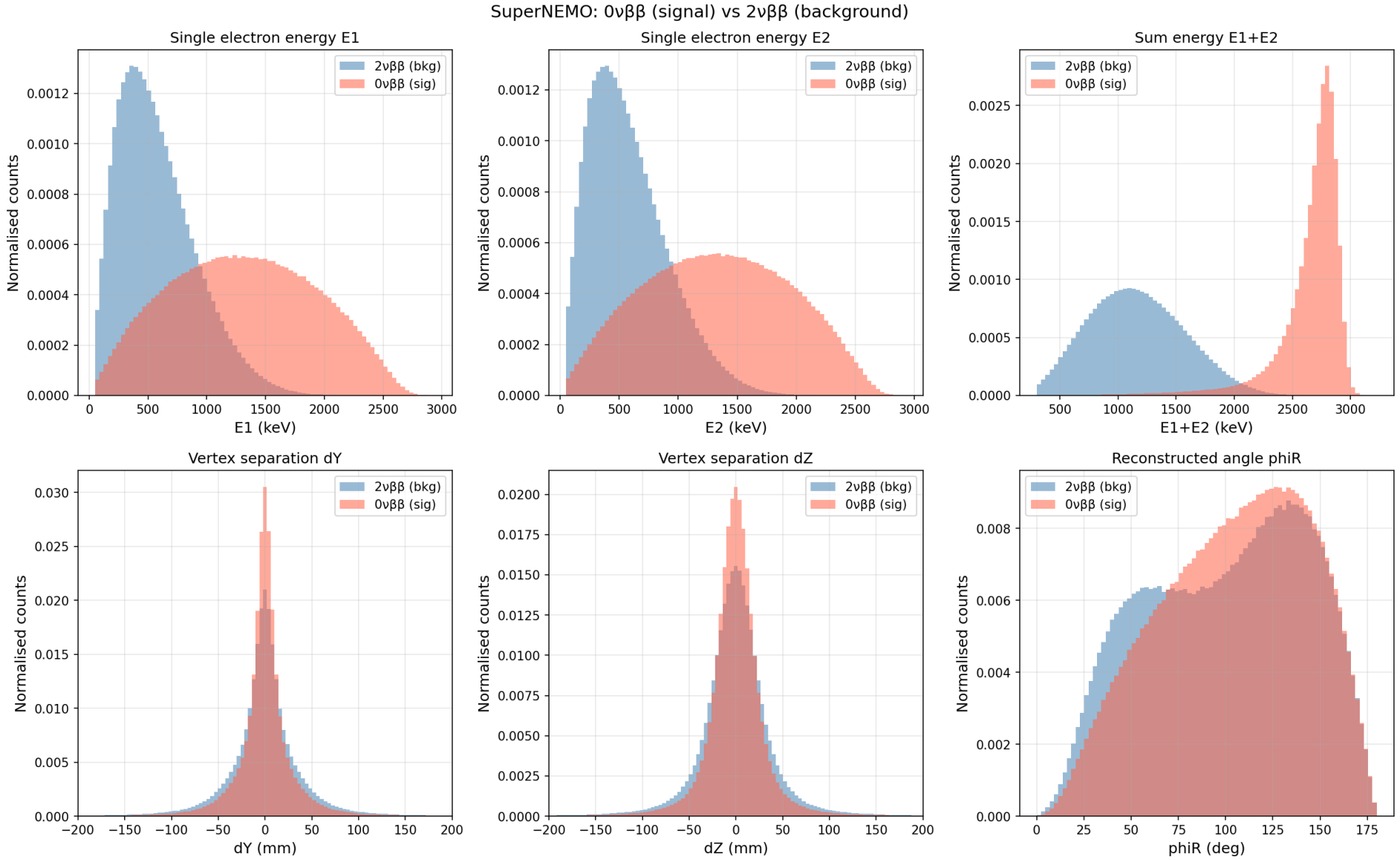
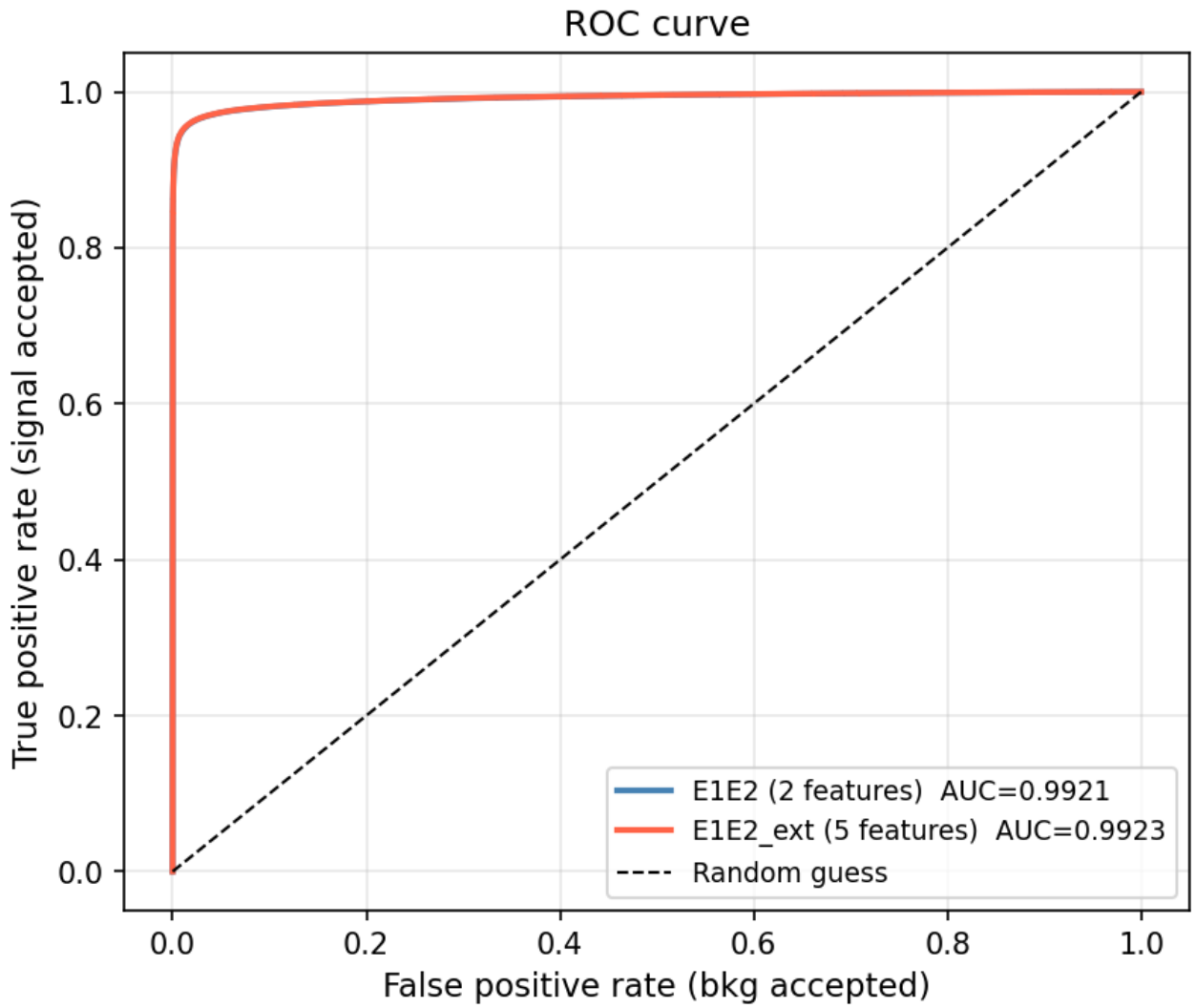


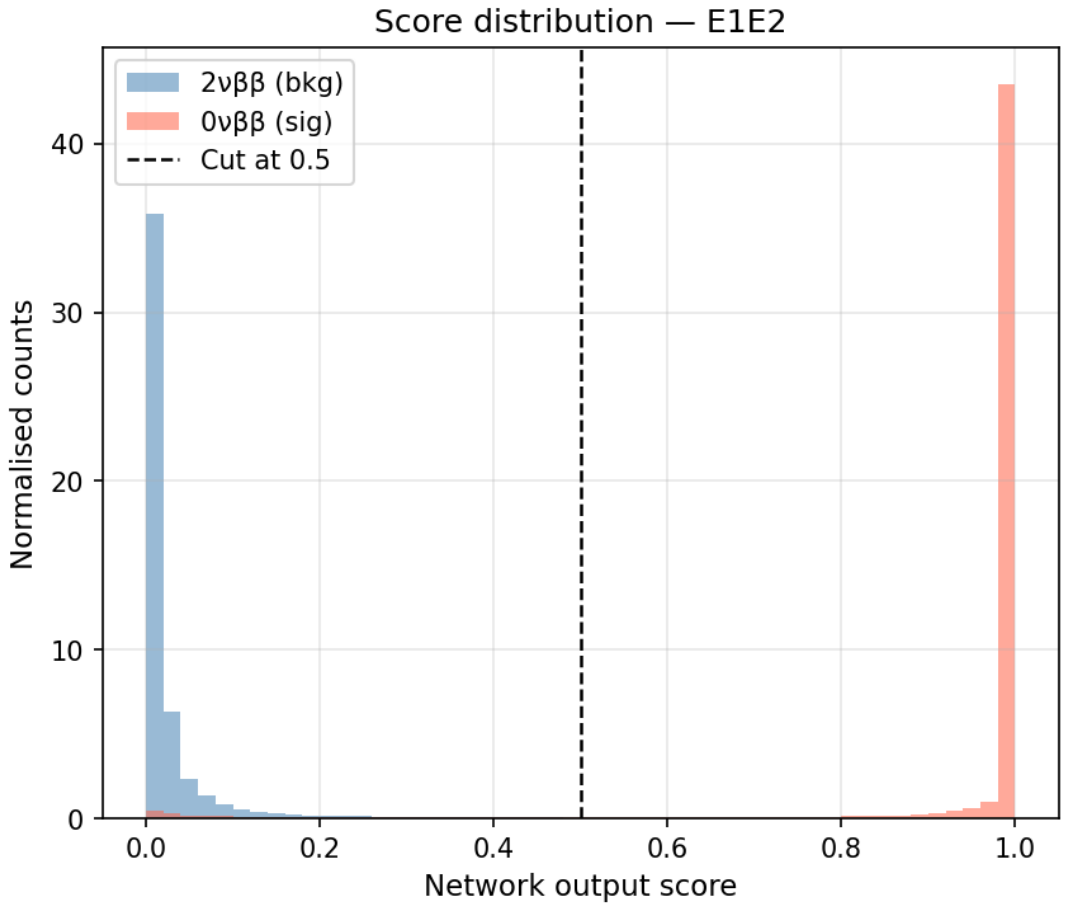
# Distribution of input features

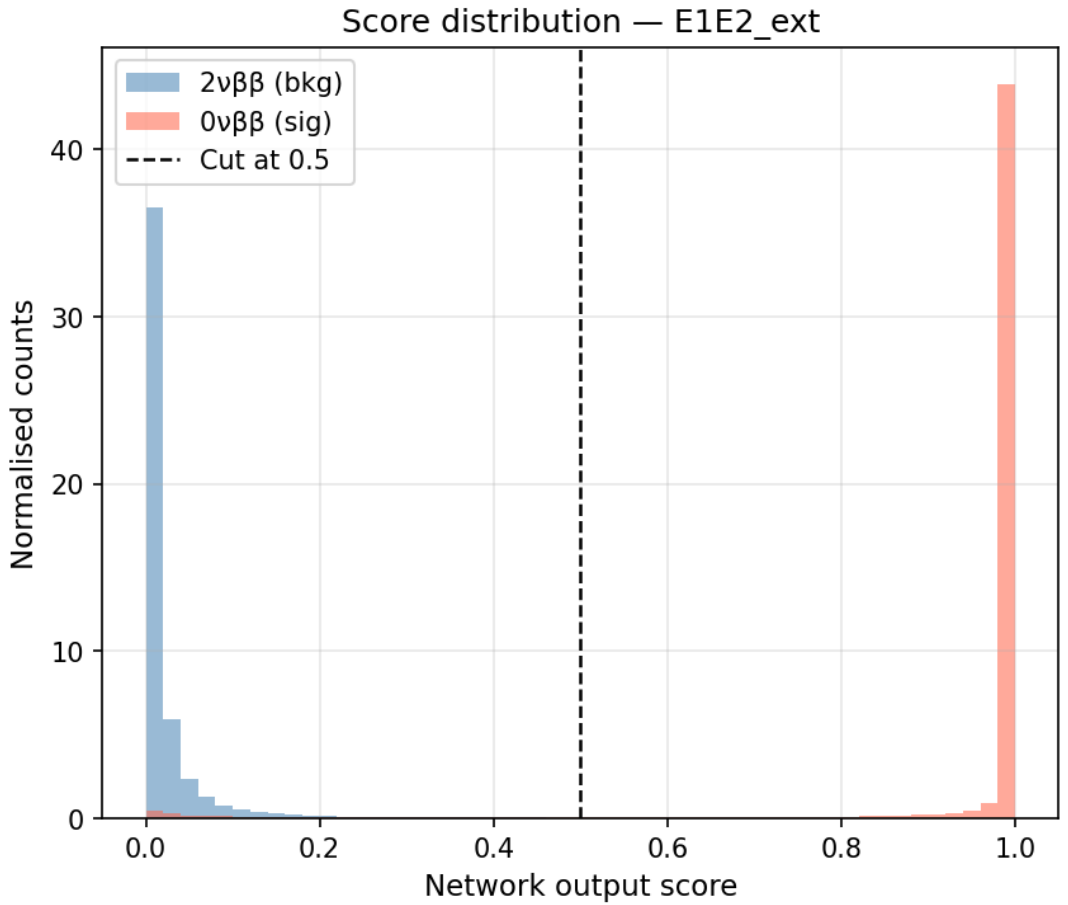


**ROC curve** gives us an information how powerful the NN for classification is: it is a relationship between the **true positive** and **false positive** classification.



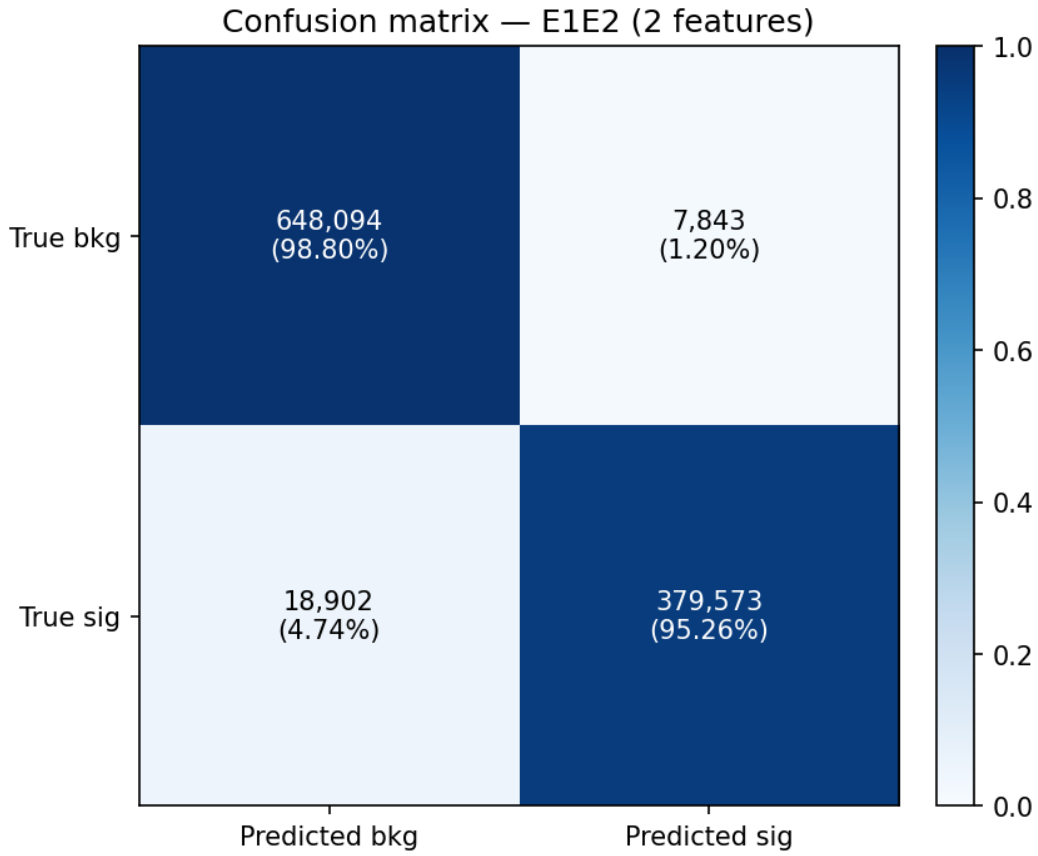
# Validation: Score distribution

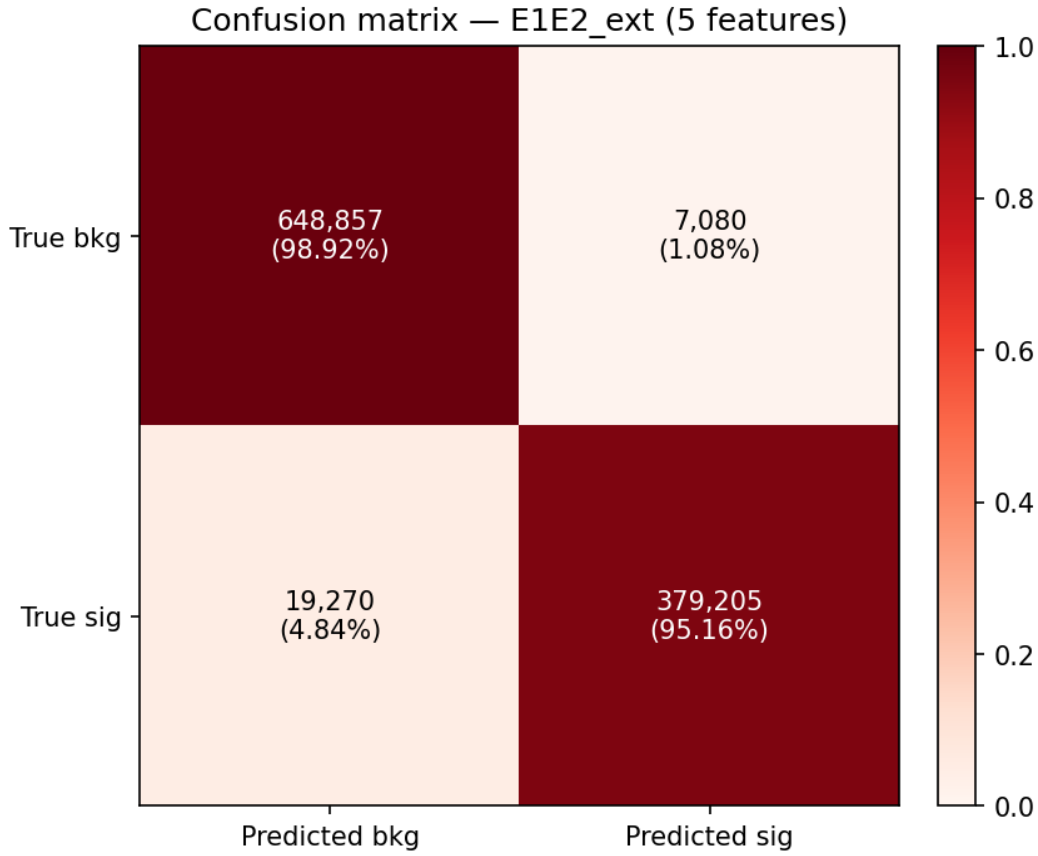


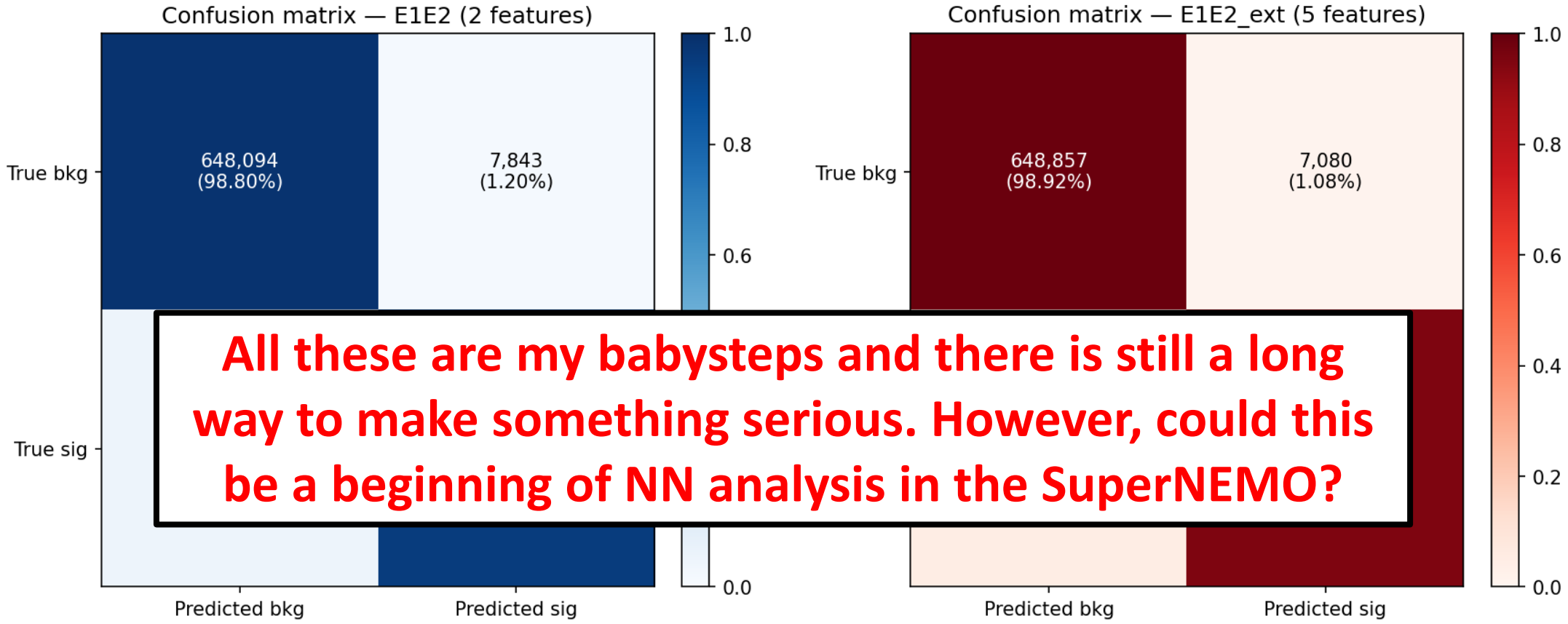

- NN outputs one number - score. These plots show the **histograms of the score** for all the events used for validation.
- **Left** plot shows **2-feature** NN, **right** plot shows **5-feature** NN

# Validation: Confusion matrix




- Confusion matrices are **relationship between true/false positive/negative** – like the testing in COVID times.
- **Left** plot shows **2-feature** NN, **right** plot shows **5-feature** NN




**All these are my babysteps and there is still a long way to make something serious. However, could this be a beginning of NN analysis in the SuperNEMO?**

- Confusion matrices are **relationship between true/false positive/negative** – like the testing in COVID times.
- **Left** plot shows **2-feature** NN, **right** plot shows **5-feature** NN


neutrino 2026


- Neutrino ´26 took place at the University of California, Irvine last week to celebrate 70 years since the neutrino was discovered!
- I presented a poster representing the SuperNEMO Demonstrator at Neutrino ´26

# 0νββ AI Summer School Report & Award

**Purpose:** AI are coming, we need to educate AI workforces for 0νββ community in the era of AI

**Key Highlights:**

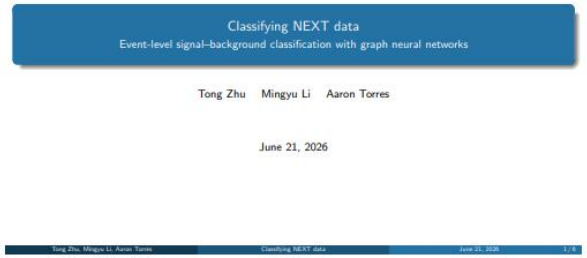
- AI-Ready Datasets: **CUORE**, **EXO-200**, **Majorana Demonstrator**, NEXT, Project-8, SuperNEMO
- Vibe Coding: using **Large Language Model** to quickly learn, build, and benchmark different AI modes

**Vibe Coding Competition Award:**

Tong Zhu (UC Berkeley)

Mingyu Li (MIT)

Aaron Torres (Virginia Tech)



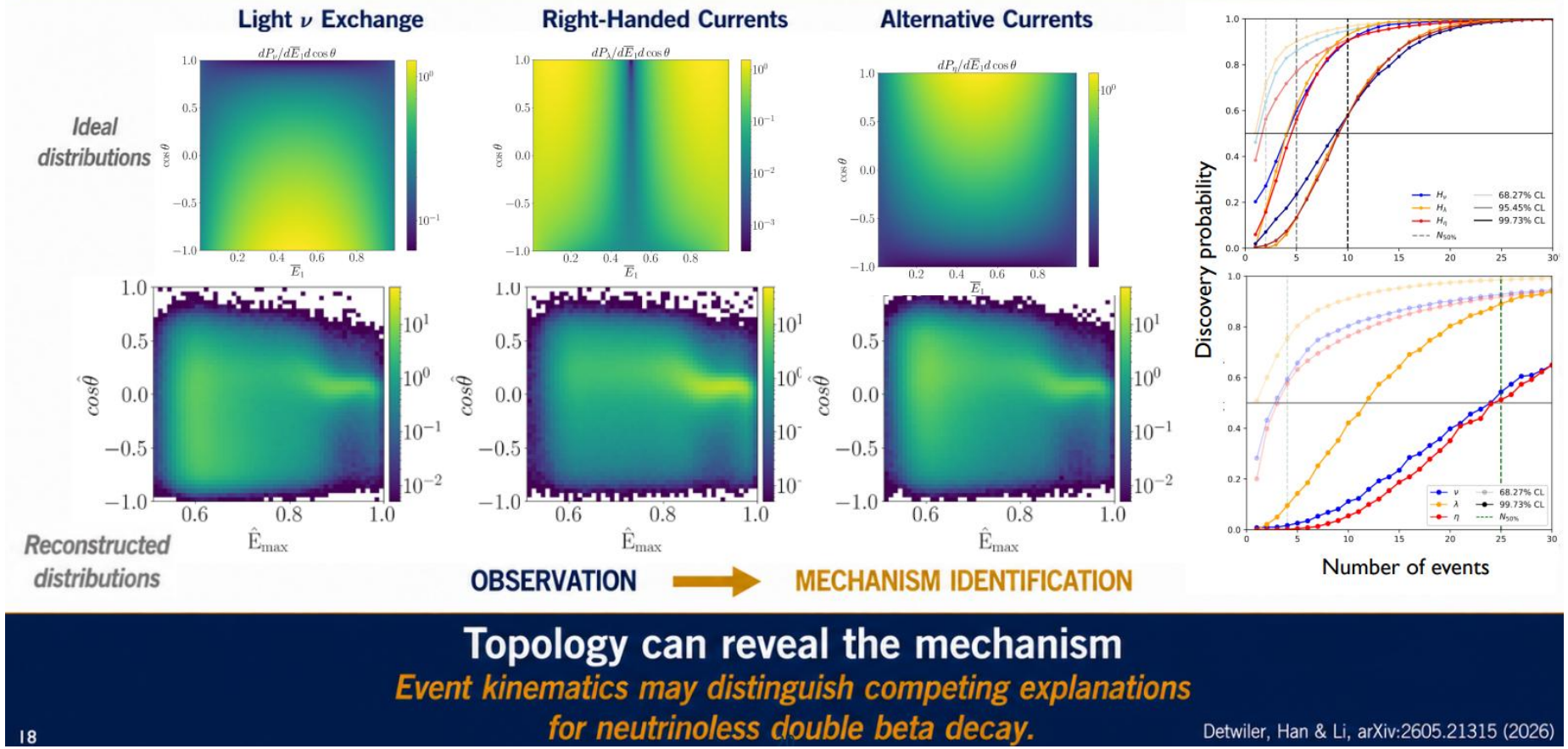

All datasets, course materials, and lecture records are available to everyone at course website:

http://0vbb-ai.physics.ucsd.edu

During the plenary sessions the SuperNEMO was mentioned in the context of 0νββ AI Summer School along with the large projects!

# Beyond Discovery

*Can discovery become diagnosis?*




**Topology can reveal the mechanism**

*Event kinematics may distinguish competing explanations for neutrinoless double beta decay.*

Detwiler, Han & Li, arXiv:2605.21315 (2026)

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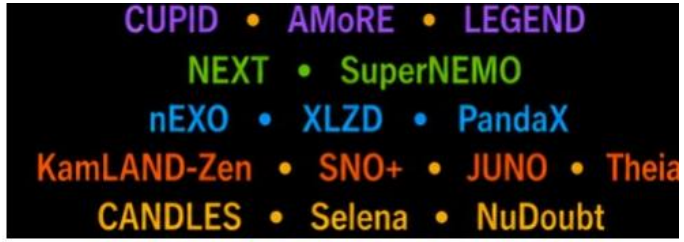
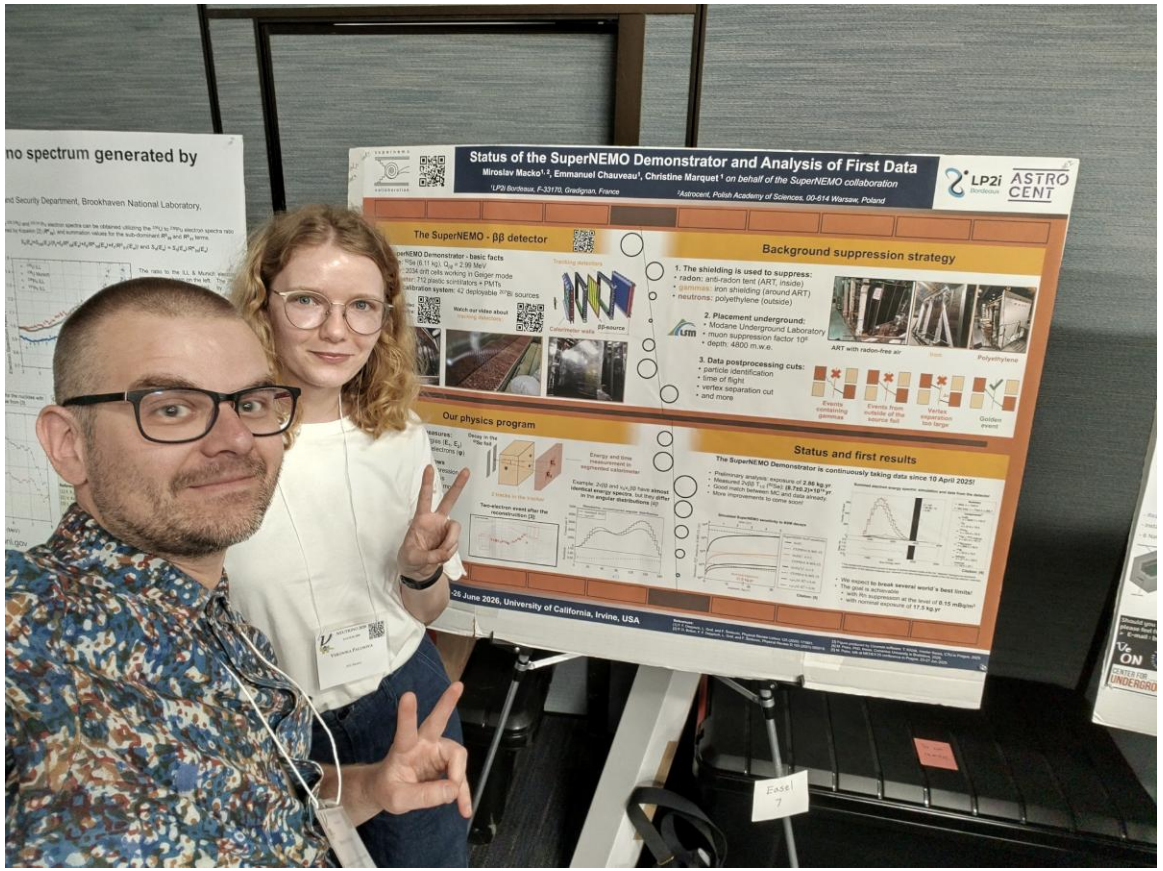
During the talk of Gabriel Orebi Gann the need for reconstruction of topology was underlined!

# 0νββ

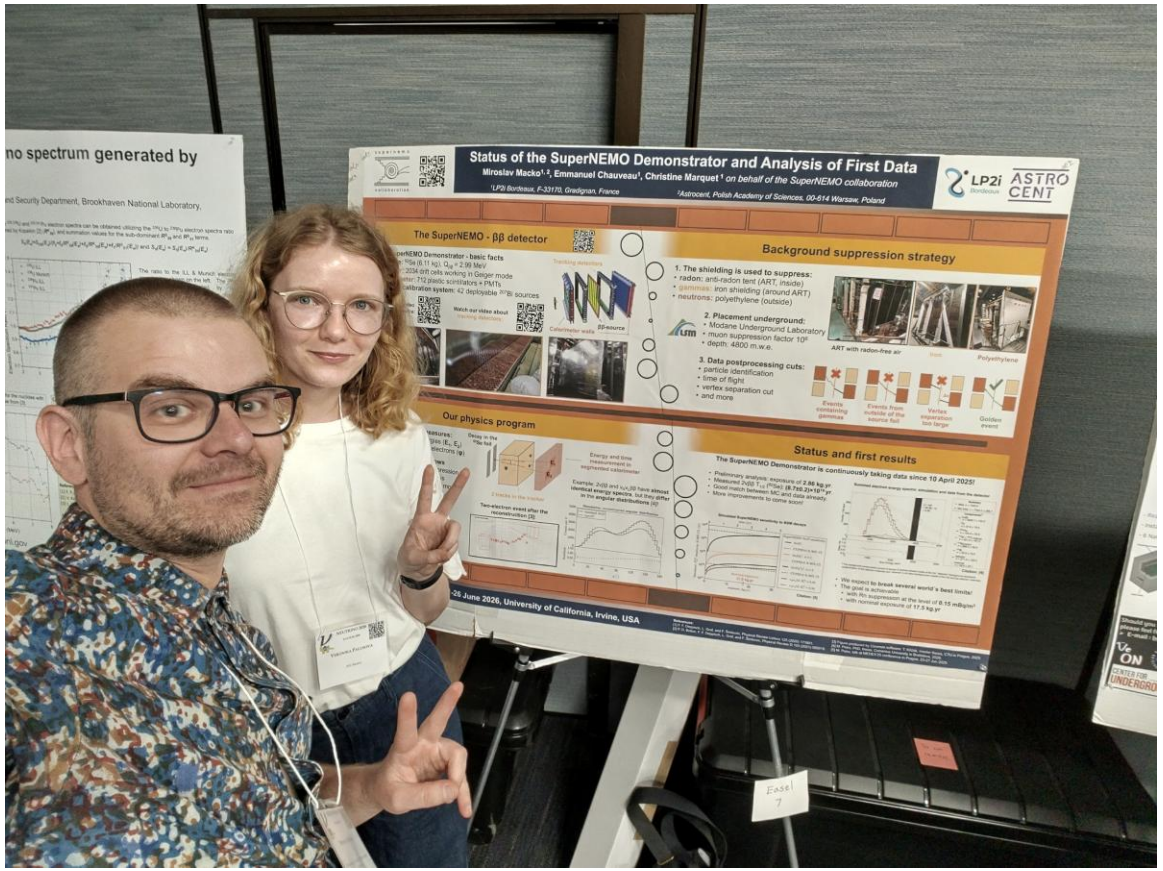



- See G. Orebi Gann's great summary!
- My less well informed take: the field has spent a significant time developing detectors and methods, carrying out long term tests at intermediate scales, and is on the cusp of scaling
- An equally impressive campaign still in progress (J. Engel) to calculate ββ nuclear matrix elements for the nuclei of interest
- Many short term targets/landmarks to look forward to:
  - 2025-: SuperNEMO taking data
  - 2026: CUORE completed 10 year campaign
  - 2027: SNO+ $^{130}$Te loading
  - 2028: KamLAND2-Zen DAQ start
  - 2028: Panda-20T physics data
  - 2028: LEGEND-200 3x current exposure

Callum Wilkinson placed the SuperNEMO data taking ot the list of highlights to look forward to in the summarizing plenary talk at the end!




- Neutrino was a place of **meeting of old friends** from the SuperNEMO and the Comenius University in Bratislava!
- **Thanks to Christine to make this possible!**

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**Thank you for your attention!**