ADVANCING NEUTRINO INTERACTION RECONSTRUCTION: A DEEP LEARNING STRATEGY IN HIGHLY-SEGMENTED DENSE DETECTORS

Dr. Saúl Alonso-Monsalve

ETH Zürich

salonso@ethz.ch / saul.alonso.monsalve@cern.ch

ICHEP 2024| Prague

20 July 2024

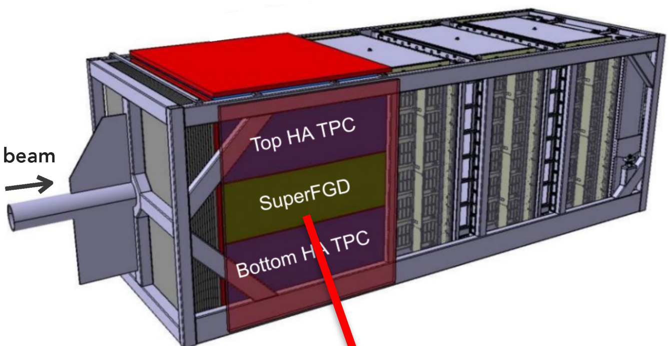
ML in neutrino oscillation experiments

- Neutrino Physics and Machine Learning Workshop (NPML 2024):
  - 25-28 June.
  - https://indico.phys.ethz.ch/e/npml2024.
  - Showed us ML models are mainly **trained on simulation**, eventually **tested on experimental data**.

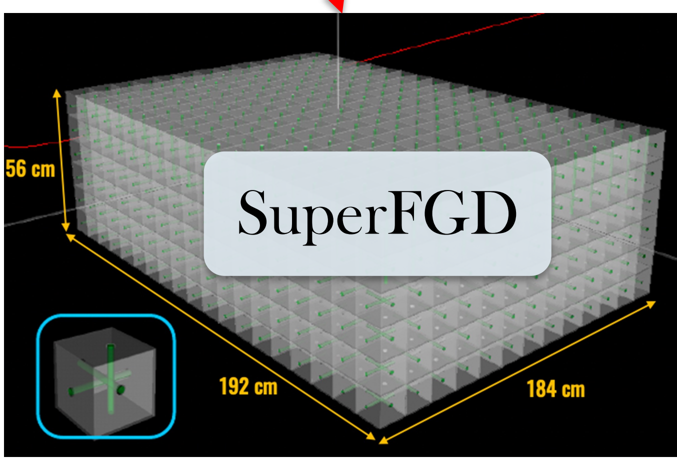
- Risk: neutrino generators (e.g., GENIE, NEUT) are great, but not perfect.
  - They rely on a variety of **theoretical models and assumptions** to simulate the complex interactions of neutrinos with matter (e.g. determining the final-state particles).
  - Other uncertainties can be fixed by tuning the simulation with calibration data.

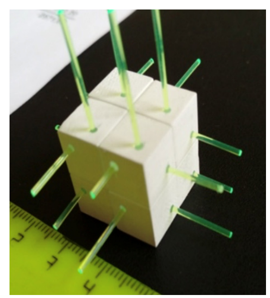
- Our **alternative**: train only on GEANT4 for **controlled single-particle simulations**.
  - PGUN or PBomb samples.
  - Provides **precise control over initial conditions**.
  - Facilitates **systematic study of detector response**.

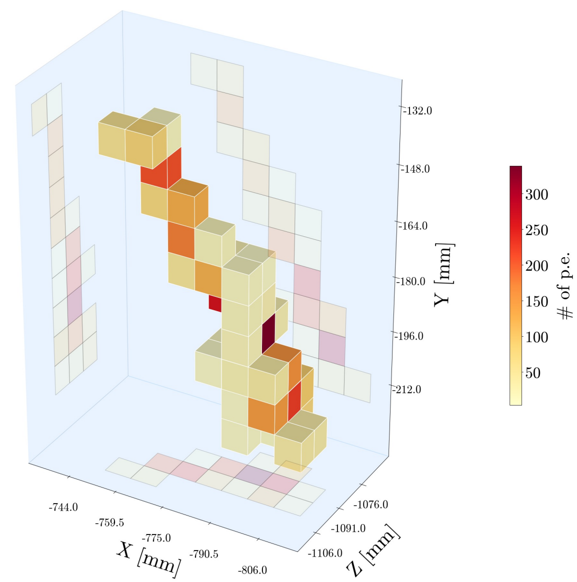
Inspiration: T2K's Near Detector (ND280)



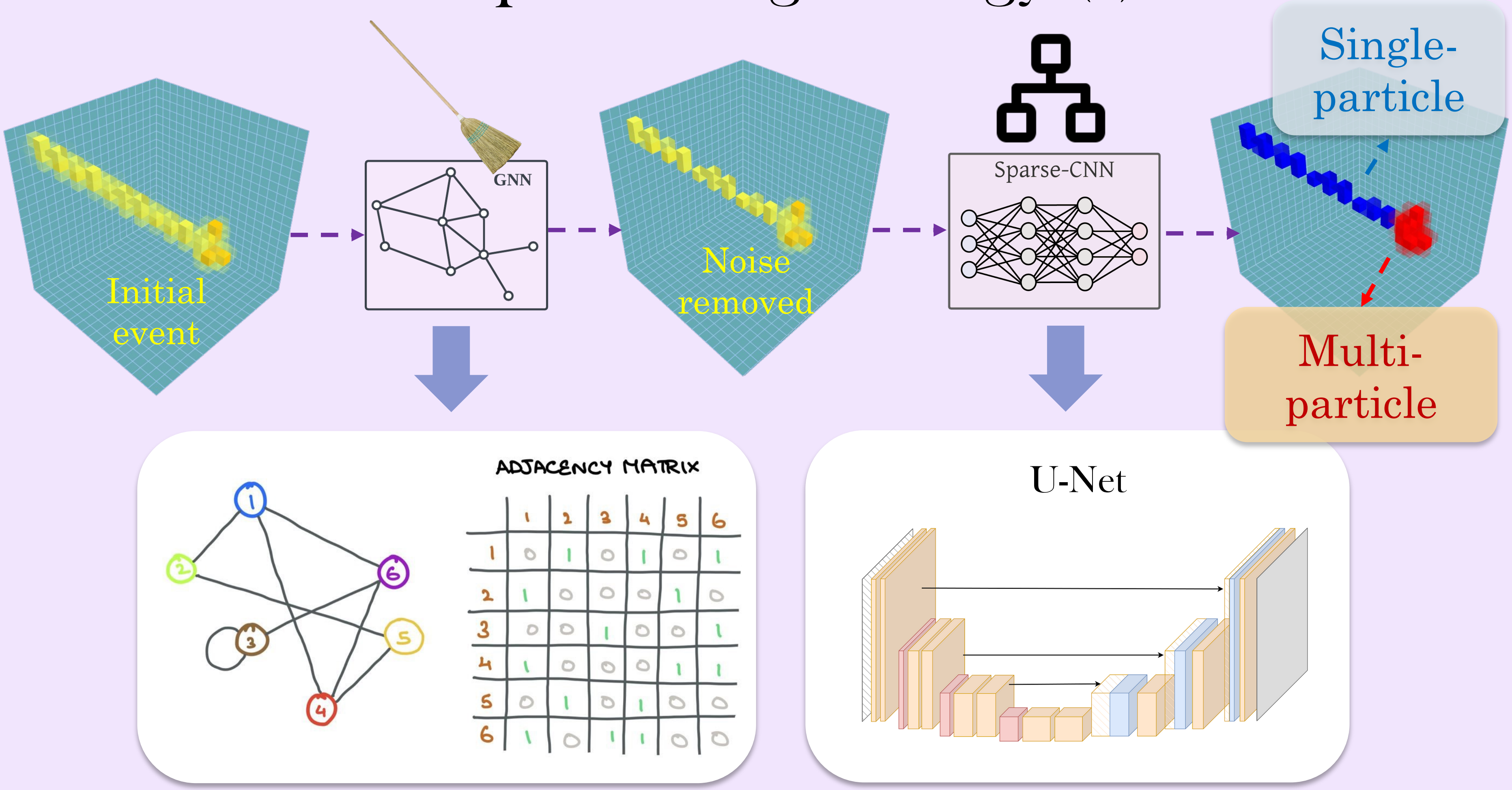
- The nearby detector **ND280** of the T2K (and HyperK) experiment **measures neutrino interactions before oscillations occur**.
- A key component is the **SuperFGD**, comprised of optically isolated plastic scintillator cubes measuring 1x1x1 cm^3 in size (see Thomas Kutter's talk on Thursday!).
- We developed our ML strategy with a simulated detector analogous to the SuperFGD.







Deep learning strategy (I)

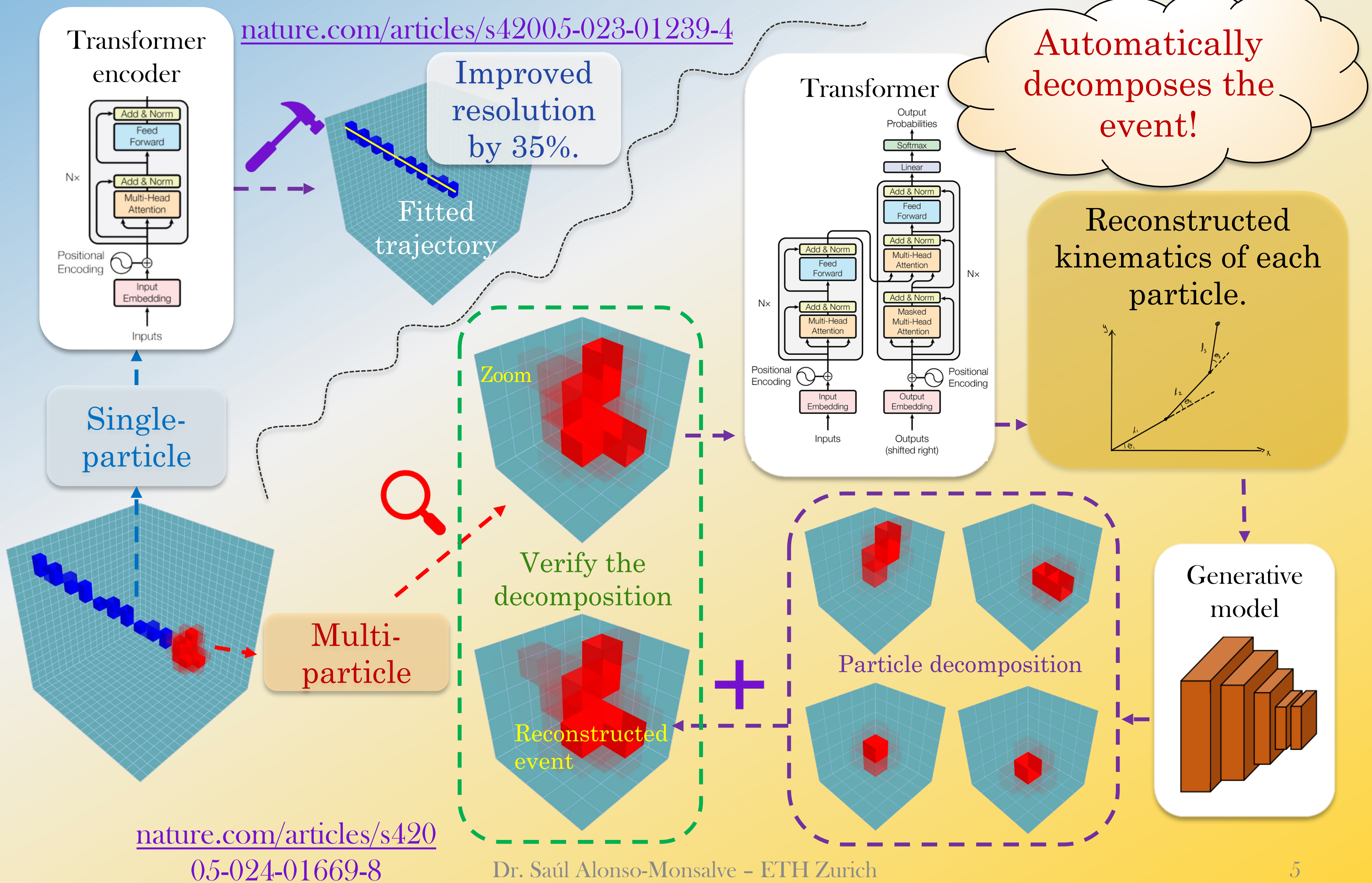


90% of the noise is eliminated without harming the signal.

~95% accuracy!

doi/10.1103/PhysRevD.103.032005

Deep learning strategy (II)



Summary

- **Deep learning strategy for the reconstruction in highly-segmented dense detectors, relying on single-particle simulation.**
  - Avoid biases due to **mismodellings of neutrino generators**.

- Several steps:
  - **Noise removal** (geometrical ambiguities, light leakage).
  - **Single/multi particle hit discrimination**.
  - **Trajectory track fitting**.
  - **Vertex activity fitting** (allows us to build a likelihood per event).

- Tested on different neutrino generators with **promising results**!

- Next steps include the full **validation of the different methods on experimental data**.

AI image generator (Bing)

- Prompt: "AI and High Energy Physics in Prague."

ADVANCING NEUTRINO INTERACTION RECONSTRUCTION: A DEEP LEARNING STRATEGY IN HIGHLY-SEGMENTED DENSE DETECTORS

Dr. Saúl Alonso-Monsalve

ETH Zürich

salonso@ethz.ch / saul.alonso.monsalve@cern.ch

ICHEP 2024| Prague

20 July 2024