

# Hardware & Design Optimization

## Organization of Activities

EuCAIFCon24, Amsterdam, The Netherlands

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If you are reading this as a web page: have fun! If you are reading this as a PDF:  
please visit

[https://www.hep.uniovi.es/vischia/persistent/2024-04-30\\_OrganizationOfExperimentDesignActivitiesAtEuCAIFCon24\\_vischia.html](https://www.hep.uniovi.es/vischia/persistent/2024-04-30_OrganizationOfExperimentDesignActivitiesAtEuCAIFCon24_vischia.html)

to get the version with working animations

# Good (?): AI is aware of us

The screenshot shows a chat interface from the University of Hamburg. On the left is a sidebar with navigation options: 'Modell' (with 'GPT 3.5 Turbo' and 'GPT 4 Turbo' buttons), 'Konversation', 'Virtuelles Büro', 'Team', 'Lernraum', 'Wiss. Arbeiten', 'Organisation', and 'Kreativität'. The main chat area shows a user prompt: 'Please list the top 9 topics for a talk on experimental particle physics and AI'. The AI response, starting with 'Certainly!', lists nine topics. The fourth topic, 'AI in Detector Design and Optimization', is circled in red. The user's prompt and the fourth topic are also circled in red.

**U+H** Universität Hamburg  
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Modell ⓘ  
GPT 3.5 Turbo GPT 4 Turbo

Konversation ⓘ  
Chat

Virtuelles Büro ⓘ  
Team

Lernraum ⓘ  
<> Wiss. Arbeiten  
Organisation  
Kreativität

Ich Please list the top 9 topics for a talk on experimental particle physics and AI

KI Certainly! Combining experimental particle physics with artificial intelligence (AI) can be quite fascinating. Here are nine compelling topics that can be discussed or presented in a talk:

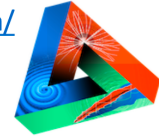
1. AI-driven Data Analysis: Discuss how AI and machine learning algorithms are used to process and analyze the massive amounts of data generated in particle physics experiments like those conducted at the Large Hadron Collider (LHC).
2. Pattern Recognition and Event Selection: Explore how neural networks and deep learning techniques help in identifying interesting events from background noise, such as distinguishing particle collision events from ordinary interactions.
3. Simulation and Modeling: Discuss the of AI in creating accurate simulations of particle interactions and detector responses, which are crucial for designing experiments and interpreting data.
4. AI in Detector Design and Optimization: Present the ways AI helps in optimizing the design and functionality of particle detectors to improve efficiency, resolution, and cost-effectiveness.
5. Real-time Data Processing: Explain how AI algorithms are employed for real-time data processing in particle physics experiments, allowing for instant data analysis and quick decision-making during live experiments.

# Good (!) JENA also aware

- Collaborate with the other Eols (e.g. Eol 3: MODE)

## JENA Eol

<http://nupecc.org/jenaa/>



### Expression of Interests (Eol)

1. Dark Matter - iDMEu (<https://indico.cern.ch/event/869195/overview>)
2. Gravitational Waves for fundamental physics (<https://agenda.infn.it/event/22947/overview>)
3. Machine-Learning Optimized Design of Experiments - MODE (<https://mode-collaboration.github.io>)
4. Nuclear Physics at the LHC (<https://indico.ph.tum.de/event/4492/>)
5. EDM - Search of Charged-Particle Electric Dipole Moments (<https://indico.ph.tum.de/event/4482/>)
6. Synergies of EIC with LHC - EIC; kick-off happened in June 2022 (<https://indico.ph.tum.de/event/7004/>)
7. EuCAIF (2023): Machine learning as analysis tool (<https://indico.nikhef.nl/event/4875/>)

- **Contact persons from ENA communities**
- **Request for presentations at JENASymposium 2025**
- **Discussions on status, plans, requests regularly with ENA chairs**
- **currently all are validated as community overarching networks and supported by JENA**

# Hardware and Design

- Offline design
  - Speed not the main concern
  - Large memory footprint
  - Large energy footprint
- Online control
  - Need fast systems (FPGA, ASIC, Neuromorphic systems)
  - Often simplified algorithms



# Possible working groups:

## Applications...

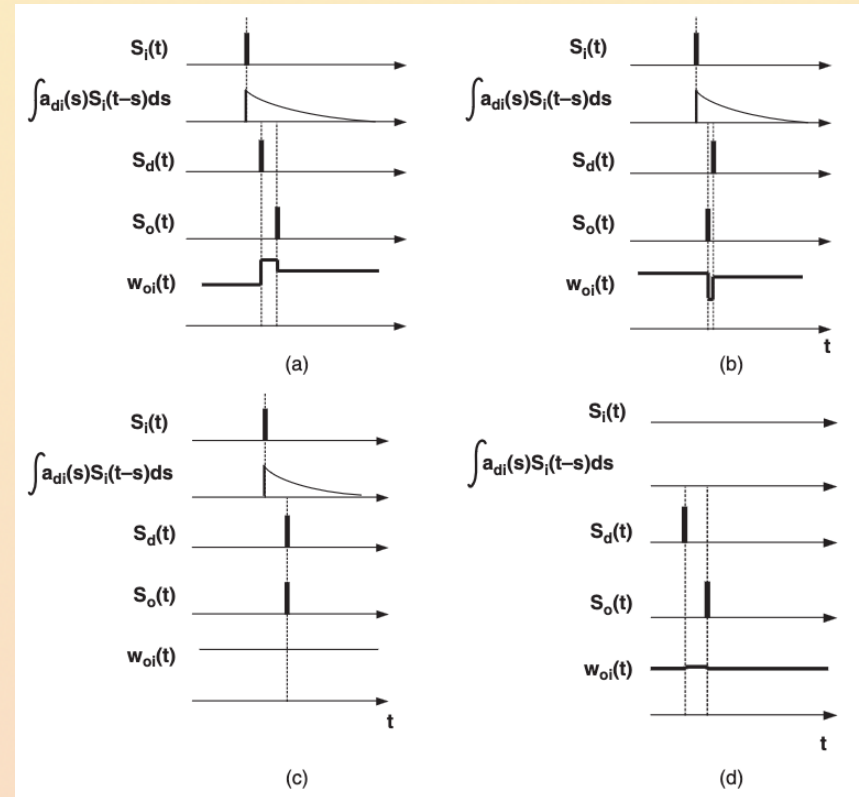


- Granular calorimeters optimization
- Neutrino telescopes geometry optimization
- Muon tomography
- Spiking networks and neuromorphic computing
  - Calorimetry
  - Neutrino radio telescopes
- Online control for accelerators

# Possible working groups:

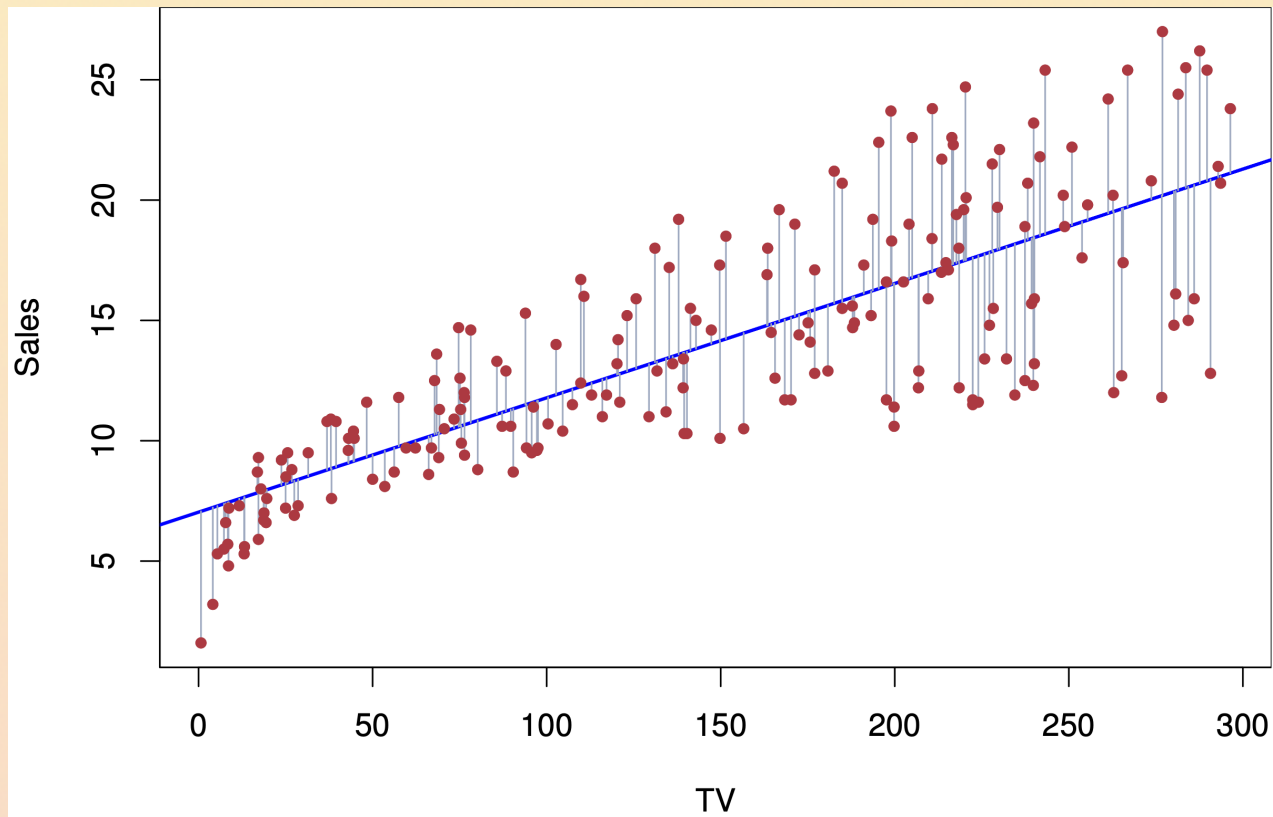
## ...and techniques

- Modelling and Surrogates
- (Non)differentiability
  - Quantum machine learning for intrinsic differentiability
- Learning strategies
  - Both classical GD in perceptron-based NNs, and spiking network training strategies
  - Reinforcement learning
- Hardware support (e.g. FPGA, neuromorphic)
  - Acceleration strategies
  - Memory footprint



# Physics is (not) everything

- Crucial to include or keep in the loop interested mathematicians, statisticians, and computer scientists
  - e.g., MODE has several members from these communities





# Goals

- Short term
  - Demonstrators in simple cases
  - Prototypes for large-scale optimization
  - Focus on providing open source software
- Medium/Long term
  - Assist all the major (and not major) projects for next generation instruments (accelerator and astro/cosmo)
  - Cohalesce a community with all the relevant know-how (not only physicists)
- Policy discussions
  - e.g. Release software under licenses prohibiting military applications

# Possible deliverables and activities

- A brief report to be inserted in a broader EuCAIF white paper or programme?
- Periodic progress reports at yearly EuCAIFCon?
  - In MODE we are releasing periodic progress updates
- Periodic online workshops on advancements in Design Optimisation
  - See e.g. the yearly MODE workshop!

## Progress in End-to-End Optimization of Detectors for Fundamental Physics with Differentiable Programming

Max Aehle<sup>1,2</sup>, Lorenzo Arsini<sup>3,4</sup>, R. Belén Barreiro<sup>5</sup>, Anastasios Belias<sup>6</sup>, Florian Bury<sup>7</sup>,  
Susana Cebrian<sup>8</sup>, Alexander Demin<sup>9</sup>, Jennet Dickinson<sup>10</sup>, Julien Donini<sup>1,11,12</sup>,  
Tommaso Dorigo<sup>\*1,12,13</sup>, Michele Doro<sup>13</sup>, Nicolas R. Gauger<sup>1,2</sup>, Andrea Giammanco<sup>†1,14</sup>,  
Lindsey Gray<sup>10</sup>, Borja S. González<sup>15,16</sup>, Verena Kain<sup>17</sup>, Jan Kieseler<sup>1,18</sup>, Lisa Kusch<sup>1,2</sup>,  
Marcus Liwicki<sup>19</sup>, Gernot Maier<sup>20</sup>, Federico Nardi<sup>1,11,21</sup>, Fedor Ratnikov<sup>1,9</sup>,  
Ryan Roussel<sup>22</sup>, Roberto Ruiz de Austri<sup>23</sup>, Fredrik Sandin<sup>19</sup>, Michael Schenk<sup>17</sup>,  
Bruno Scarpa<sup>21</sup>, Pedro Silva<sup>17</sup>, Giles C. Strong<sup>1,13</sup>, and Pietro Vischia<sup>‡1,24</sup>

# Strategy and impact

- Define strategic directions
- Impact on the broader landscape
  - Inform ethical considerations in policy for the AI-assisted design of complex system



# How to push this further?



# To discuss further.. come to Valencia!

- Series of yearly workshops by the MODE Collaboration
  - Louvain-la-Neuve 2021, Kolybari 2022, Princeton 2023
- **Valencia (Spain), 23-25 September 2024**
  - Register (and submit your abstract!) at <https://indico.cern.ch/event/1380163/>

