Expression of Interest
for a synergic research plan of potential interest of the JENA group

Project title:

European Coalition for AI in Fundamental physics (EuCAIF)

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1. Introduction

The field of fundamental physics, which here encompasses nuclear, astroparticle, and particle physics, is driven by profound objectives and faces significant challenges. Goals include the study of matter, particles and forces, unraveling the nature of dark matter and dark energy, and exploring the structure of our universe. Managing the continuously expanding volumes and quality of data, detecting exceptionally rare yet significant signals, and confronting complex astrophysical and cosmological models with data present considerable obstacles that must be overcome in this endeavor.

The role of Artificial Intelligence (AI) and Machine Learning (ML) in fundamental physics research is expanding at an unprecedented rate. These powerful techniques have demonstrated their ability to tackle large multi-dimensional scientific datasets and models and to unlock new insights. AI/ML accelerates scientific exploration and enables discoveries unfeasible with more traditional means[1]. However, despite the immense potential of AI and ML, European researchers in fundamental physics do not yet have a platform where they can coordinate joined efforts, collaborate and learn from each other.

In response to this pressing and timely need, we propose to establish a new European initiative on "ML and AI in Fundamental Physics." This initiative will strengthen research efforts across Europe by bringing together AI/ML experts in particle physics, astroparticle physics, nuclear physics, and gravitational wave research with computational experts and AI/ML researchers. By establishing a collaborative and strategic network, this initiative will set up a stage for interdisciplinary collaboration, knowledge exchange, and resource sharing, thereby empowering researchers to tackle complex scientific challenges more effectively. Through conferences, thematic workshops, training programs, joint funding opportunities, networking activities among physicists and AI/ML experts, and common activities with similar initiatives, we will create a vibrant ecosystem that attracts, retains, and promotes top talent in Europe. Moreover, the initiative aligns with Europe's broader vision of becoming a global leader in AI/ML research.

We think that the JENA community provides the right structure for our initiative, which is supported by particle and nuclear physicists, gravitational wave experts and astroparticle

[1] see e.g. Machine Learning in High Energy Physics Community White Paper, https://arxiv.org/pdf/1807.02876.pdf and A Living Review of Machine Learning for Particle Physics, https://arxiv.org/abs/2102.02770, also Machine Learning in Nuclear Physics, https://arxiv.org/abs/2112.02309, and Enhancing Gravitational-Wave Science with Machine Learning https://arxiv.org/abs/2005.03745

physicists, but open to other areas of fundamental physics. Together, we can build a robust, interconnected, and forward-thinking research environment that accelerates scientific discovery and fosters innovation.

2. Background

2.1 Evolution of AI and ML in Physics Research

Over the past decade, the fields of AI and ML have witnessed remarkable advancements that have significantly impacted various scientific disciplines, including physics. AI and ML techniques have emerged as powerful tools for analyzing complex, high-dimensional datasets, enabling researchers to extract valuable insights and make predictions with unprecedented accuracy.

2.2 Importance of AI and ML in Fundamental Physics

In the realm of fundamental physics the importance of AI and ML cannot be overstated. These fields involve large-scale experiments, sophisticated detectors, and ever-increasing volumes of data. Traditional analysis methods are often time-consuming, resource-intensive, and may not fully capture the complexities (and physical mechanisms, relations, assumptions or inductive biases) present in the data. AI and ML techniques have shown great potential in several key areas of fundamental physics research. In (accelerator-driven) particle and nuclear physics, for example, ML algorithms have been successfully used for particle identification, classification and calibration, online (trigger-level) and offline data selection, improving simulations via generative models, optimizing particle identification, track reconstruction, anomaly detection, improving signal-background discrimination in the search for new physical phenomena, and for the determination of the structure of the proton. In astroparticle physics, ML methods provide essential improvements e.g. in the identification of cosmic ray particles, in the analysis of astrophysical images, in the accurate reconstruction of neutrinos, in background reduction in dark matter search experiments, in the reconstruction of gravitational wave signals and of gamma-ray data, and in the analysis of data from large-scale cosmological surveys. The research questions within the nuclear physics community are driven by providing deeper insights in strongly (non-perturbative) interacting matter at various length and energy scales. The usage of ML and AI techniques give promising perspectives to reveal the appropriate degrees of freedom in these complex many-body systems. Furthermore, ML is increasingly playing a pivotal role in the design, optimization, and control of scientific instruments and particle accelerators, driving advancements in their performance and efficiency. To cope with scalability and financial constraints, the application of ML algorithms and AI will likely become a necessity to operate and process data for the next generation accelerator-driven facilities (f.e. EIC, FAIR, FCC) and their scientific instruments. In particular in the emerging field of gravitational wave physics, ML techniques will play a crucial role in detecting, disentangling and characterizing gravitational wave signals from astrophysical sources, with the upcoming advanced detectors. What is more, large language models and other general AI systems are likely to find their way into fundamental physics research by providing rapid access to physics knowledge, efficient code generation, and possibly being used as research assistants.
In addition, it is important to consider ethical considerations and challenges such as privacy and bias when integrating large-scale language models and other general AI systems into fundamental physics research. Careful evaluation and mitigation of any ethical implications

of their potential role as research assistants should be considered. This initiative can play an important role in this upcoming discussion.
Fundamental Physics has a long history of dealing with large complex datasets, and uncovering fundamental phenomenons with inference backed by a critical assessment of possible biases. Recent Machine Learning breakthroughs in Fundamental Physics are all the more important in that they often improve over already sophisticated baselines. Hence, these developments are also relevant in other scientific domains, where the data deluge is more recent.

2.3 Current Challenges and Fragmentation in European Research

AI and ML offer immense potential for advancing fundamental physics research. However, the current landscape in Europe could benefit significantly from an initiative that increases the area of interaction between various research groups, and that acts as a catalyst for coordinated European and international efforts. At present, the progress in AI/ML in fundamental physics is based on the work of individual research groups and institutions. As a consequence, efforts are often fragmented, leading to duplication, limited collaboration, and suboptimal resource utilization. This fragmentation hinders Europe's ability to effectively harness the transformative power of AI/ML to advance knowledge in fundamental physics. Furthermore, the rapidly evolving nature of AI/ML requires a continuous exchange of expertise, techniques, and best practices. By establishing a European initiative, we can create a platform that fosters collaboration, facilitates knowledge sharing, and encourages the development of standardized approaches and benchmarking, thereby addressing these challenges and positioning Europe at the forefront of AI/ML in fundamental physics research.

2.4 Global Landscape and the Need for European Leadership

On the global stage, several countries and regions have recognized the significance of AI and ML in scientific research and have already made substantial investments in related initiatives. Notably, efforts such as the United States' National Artificial Intelligence Research Institutes and China's Artificial Intelligence in Science Programs have contributed to propelling these countries to the forefront of AI research.
In order to maintain Europe's competitiveness and leadership in scientific research, it is essential to establish a coordinated and comprehensive European initiative. In the subsequent chapters, we will outline the objectives, key features, and implementation plan for the proposed European Initiative on Machine Learning and AI in Fundamental Physics.

3. Objectives and Key Focus Areas

The European Initiative for Machine Learning and AI in Fundamental Physics aims to foster collaboration, integrate AI/ML into data infrastructure, propose algorithm development, data challenges and benchmarking, encourage the use of questioning and dialogue-based teaching methods in education and training, and provide infrastructure and resources in the future. These key focus areas will be essential in structuring and advancing research efforts in particle physics, astroparticle physics, nuclear physics, and gravitational wave research in Europe. By addressing these areas, the initiative will foster scientific progress, encourage interdisciplinary collaboration, and empower researchers with the tools and knowledge necessary for transformative discoveries.

3.1 Promote Cross-disciplinary Collaboration

To foster collaboration and knowledge exchange, the initiative will establish platforms, such as dedicated workshops, symposia, and conferences, that bring together researchers and institutions involved in particle physics, astroparticle physics, nuclear physics, and gravitational wave research across Europe. These platforms will provide opportunities for researchers to share their expertise, discuss challenges, and collaborate on projects of mutual interest. Fostering collaboration and sharing best practices and expertise with industry partners and other AI-in-science initiatives is also paramount. Examples include uncertainty assessment, explainability, and responsible integration of AI.

Moreover, the initiative will actively encourage collaboration between the fundamental physics community and prominent AI/ML organizations such as ELLIS (European Laboratory for Learning and Intelligent Systems) and CLAIRE (Confederation of Laboratories for AI Research in Europe), fostering cross-disciplinary partnerships and accelerating the application of AI/ML techniques in physics research.

3.2 Promote the integration of AI/ML into Data & Computing Infrastructure for Current and Upcoming Experiments

Recognizing the importance of data-driven discoveries, the initiative will actively promote the integration of ML and AI techniques into the data infrastructure of current and upcoming experiments in particle physics, astroparticle physics, nuclear physics, and gravitational wave research. It is important to provide feedback to the computational infrastructure needed for ML and AI, e.g., in the form of heterogeneous systems, hardware accelerators (FPGAs, GPUs, etc.), and (upcoming) neuromorphic computing. This integration will enable efficient analysis, processing, and interpretation of large-scale datasets generated also by future experiments such as the Electron-Ion Collider, the Future Circular Collider (FCC), Cherenkov Telescope Array (CTA), the next generation for neutrino telescope (KM3NeT), Einstein Telescope (ET), Facility for Antiproton and Ion Research (FAIR), and others.

3.3 Promote the development of Novel Algorithms for Physics

The initiative will foster the development of innovative machine learning algorithms tailored to address challenges specific to particle physics, astroparticle physics, nuclear physics, and gravitational wave research. These algorithms will explore the interplay between physics, simulations, and machine learning to address the challenges of high-dimensional models and data, real-time trigger-level inference, fast surrogate models, anomaly detection, experiment design, explainable AI, the reconstruction of particle trajectories, physics-informed machine learning, accurate uncertainty estimation, and other critical areas. Important aspects for these developments are also the reusability/maintenance of software, the re-interpretability of the physical results, the maintainability of the AI/ML pipelines and the sustainability and (energy) efficiency of the algorithms.

By encouraging the development of novel algorithms, the initiative will facilitate breakthroughs in data analytics, enable efficient data-driven decision making, improve the interpretability of algorithms, and promote cutting-edge research at the interface of AI and fundamental physics.

3.4 Promote and validate Benchmarks, Open Data and (upcoming) scientific AI systems like question answering machines

Enhancing the capabilities of researchers to analyze vast (open) datasets and interpret complex phenomena, the initiative will support the adoption of advanced ML and AI methodologies in fundamental physics research. This includes developing frameworks for (open) experimental data preservation and analysis, benchmarking the performance of ML algorithms for physics-related tasks, and exploring the potential of ML/AI techniques in general AI question answering machines with a focus on fundamental physics understanding and reasoning.

3.5 Training and Education and Outreach

To ensure the continued development of expertise in the interdisciplinary field of ML/AI in fundamental physics, the initiative will establish and promote comprehensive training programs and educational initiatives. These programs will provide researchers, students, and professionals with the necessary skills and knowledge to effectively apply ML and AI techniques in their research. Additionally, we will promote graduate and doctoral programs that provide opportunities for AI and data science students to engage in ML/AI projects within the realm of fundamental physics. Through summer schools, workshops, and online courses, the initiative will foster a new generation of researchers equipped with the expertise to tackle complex challenges at the intersection of ML/AI and fundamental physics.[2] The initiative will also promote and establish outreach activities for schools and the general public to advance the understanding of fundamental physics and its intersection with ML and AI.

3.6 Infrastructure and Resources

Recognizing the importance of robust computational resources and state-of-the-art infrastructure, the initiative will facilitate access to such resources for researchers working on ML and AI in fundamental physics. This includes high-performance computing clusters, data repositories, and specialized computational hardware for ML/AI applications. By helping researchers find and apply for the necessary infrastructure, the initiative will empower them to conduct cutting-edge research, develop innovative algorithms, and leverage large-scale datasets efficiently.

In the following chapters, we will outline the implementation plan for each focus area, detailing the specific initiatives, collaborations, and actions required to achieve the objectives of the European Initiative on Machine Learning and AI in Fundamental Physics. By addressing these key areas, we will establish a thriving ecosystem that fosters collaboration, accelerates scientific discovery, and positions Europe at the forefront of ML and AI research in fundamental physics.

4. Concrete Activities

The European Coalition for AI in Fundamental physics (EuCAIF) will carry out a range of concrete activities to foster collaboration, promote research projects, facilitate training programs, organize conferences and workshops, and establish networking and exchange

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[2] Recent examples for ongoing efforts is the annually planned “Simulation-based inference with Swyft” workshop (https://indico.nikhef.nl/event/4025/), the Como ML school https://aiep.lakecomoschool.org/ and the MITP ML for theory school https://indico.mitp.uni-mainz.de/event/332/timetable/#20230703

opportunities. These activities will drive innovation, knowledge exchange, and the application of ML and AI techniques in fundamental physics research.

4.1 Workshops and Conferences

To foster collaboration, share research findings, and explore emerging trends in the application of ML and AI in fundamental physics, the initiative will organize regular workshops and conferences. One of the key events will be the "*Yearly/Bi-yearly European EuCAIF Conference on Machine Learning and AI in Fundamental Physics*". This conference will serve as a flagship event for the initiative and will bring together researchers, experts, and stakeholders from across Europe. The first conference is planned to take place in May 2024 in Amsterdam, serving as a kick-off meeting for the initiative. It will provide a platform for presenting cutting-edge research, discussing challenges, and fostering collaborations among participants.

4.2 Initiate new Research Projects

In the future this initiative could be tasked to actively encourage interdisciplinary research projects that promote collaborations between experts from particle physics, nuclear physics, astroparticle physics, and gravitational wave research, with a specific focus on AI applications. The initiative could also help transfer existing projects to another field (e.g., HEP -> astroparticle physics). These research projects will facilitate the exploration of new methodologies, the development of innovative algorithms, and the integration of ML/AI techniques into fundamental physics experiments.

4.3 Data Challenges and Benchmarks

To drive innovation and benchmark the performance of ML/AI algorithms in fundamental physics, the initiative will promote the organization of data challenges. These challenges will present specific problems or datasets for researchers to tackle using ML/AI techniques. By relying on standardized frameworks and evaluating the performance of different approaches, the data challenges will stimulate advances in algorithm development and encourage researchers to push the boundaries of ML/AI in fundamental physics research.

4.4 Training Programs and Outreach activities

Recognizing the importance of education, the initiative will encourage and support the development of comprehensive training programs, summer schools, and online resources to provide researchers and students with the necessary skills and knowledge. In addition, the initiative will promote outreach activities to secondary schools and the general public.
The initiatives will provide researchers and students with the necessary knowledge and expertise to effectively utilize ML and AI techniques in fundamental physics research. By empowering researchers with the necessary skills, the initiative will enhance the utilization of ML and AI in fundamental physics and foster a community of ML/AI practitioners in the field.

4.5 Networking and Exchange

To facilitate networking, collaboration, and the exchange of ideas and expertise, the initiative will establish a network and encourage participants to prepare applications for exchange program funding. These programs will enable researchers and institutions to connect, share knowledge, and promote cross-pollination of ideas. The initiative will facilitate collaboration through matchmaking activities, research visits, and joint projects. These initiatives will create a vibrant community of researchers working on ML and AI in fundamental physics.

4.6 Webpage and Online Presence

To provide a central hub for the initiative's activities, resources, and updates, a dedicated webpage will be developed. The webpage, such as www.eucaif.org, will serve as a platform to structure and showcase the initiative's activities, provide access to relevant resources, and facilitate communication among researchers and stakeholders. It will feature information about upcoming events, research projects, training programs, data challenges, and provide a repository for shared knowledge and best practices.

5. Coordinating and Setting Up the Initiative

Coordinating and setting up the European Coalition for AI in Fundamental physics (EuCAIF) requires a strategic and collaborative approach. This chapter outlines the key steps involved in establishing and coordinating the initiative, ensuring its success in fostering collaboration, driving research advancements, and positioning Europe at the forefront of ML and AI in fundamental physics research.

5.1 Establishing Initiative Organizers and Management Board

The first critical step in establishing our initiative is to create a dedicated structure that ensures representation from multiple disciplines. Our goal is to create a diverse roster of Initiative Organizers and a Management Board composed of experts in particle physics, astroparticle physics, gravitational wave research, ML/AI, and relevant stakeholders. This committee will provide guidance, expertise, and strategic direction to the initiative through regular meetings. In our effort to be inclusive and to continuously improve, we recognize that the current list of Initiative Organizers may not reflect the diversity and representation we desire. We are open to adding more people and strive to expand our network.
The Initiative Organizers, which will be responsible for overseeing the implementation of the initiative, will be composed of individuals who bring diverse expertise and effective leadership. The initial list of Initiative Organizers consists of the following individuals (in alphabetical order), and we will continually reach out to individuals to update and improve representation.

- Helena Albers - Nuclear Physics

  Expertise in experimental nuclear physics, detector development and data acquisition, AI methods applied to low-energy physics

- Lucio Anderlini - Experimental Particle Physics
  Expertise in Machine Learning for ML-based detector simulation and coordinator of the Italian initiative ML_INFN

- Anastasios Belias - Experimental physics, currently at FAIR, experience in KM3NeT, FNAL, CERN; AI/ML-driven hardware developments for detectors and beams.

- Stefano Carrazza - Theoretical Particle Physics, expertise in AI applications to QCD, Monte Carlo simulations and quantum computing.

- Sascha Caron - Particle Physics

  Expertise in particle physics experiments (member ATLAS), data analysis, experise in ML/AI applications in high-energy physics and astroparticle physics

- Elena Cuoco - Gravitational Wave Research

  Expertise in gravitational wave physics, signal analysis, and the integration of ML/AI techniques in gravitational wave experiments.

- Tommaso Dorigo - Optimization in fundamental physics

  Leadership of MODE collaboration (https://mode-collaboration.github.io), exploring end-to-end optimization of experiment design; experimental particle physics

- Martin Erdmann, ML in experimental high-energy & astroparticle physics and education (textbook). German initiative: spokesperson community organization DIG-UM, project leader ErUM-Data-Hub

- Thomas Eberl - Experimental particle and astroparticle physics
  Expertise in ML and DL for event classification and regression in neutrino telescopes.

- Stefano Forte - Theoretical Particle Physics

  Expertise in ML applications to QCD modeling, specifically for precision and uncertainty-aware techniques

- Tobias Golling - Experimental Particle Physics

  Automating and accelerating scientific discovery with predictive, generative and anomaly detection models

- Stephen Green - Gravitational Waves
  Expertise in gravitational-wave parameter estimation using neural simulation-based inference.

- Will Handley - Bayesian inference & machine learning in cosmology, particle physics & beyond
  Expertise in developing Bayesian numerical algorithms and applying to a range of data intensive science problems.

- Ik Siong Heng - Gravitational Wave Research

  Expertise in gravitational wave data analysis and the application of ML for gravitational wave detection and astrophysics, knowledge exchange with industry

- Andreas Ipp - Theoretical Particle Physics
  Simulations of earliest stages of heavy ion collision, theoretical description of quark gluon plasma physics and observables, study of lattice gauge equivariant neural networks.

- Gregor Kasieczka - Machine learning in particle physics

  Experimental particle physics, application and development of ML/AI for fundamental physics

- Verena Kain - Accelerator physics and data science
  ML-based optimal control and optimisation applied to particle accelerators, data-driven modeling of complex processes; Leading the AI/ML task force of the CERN accelerator sector and the data science team for beam operation; member of the international organizing committee of the workshop series on Machine Learning Applications for Particle Accelerators.

- Johan Messchendorp - Nuclear Physics

  Expertise in the field of nuclear- and hadron physics, data processing, high-level physics analysis, and coordinating the design of the computing infrastructure at the Facility for Antiproton and Ion Research (FAIR), Germany.

- Daniel Nieto – Experimental astroparticle physics
  Expertise in gamma-ray telescopes, development of ML tools for the analysis of data from imaging atmospheric Cherenkov telescopes.

- Lorenzo Moneta - Experimental Particle Physics
  IML coordinator and expertise in software development for statistical analysis and machine learning for particle physics.

- Adrian Oeftiger - Accelerator Physics

  Expertise in accelerator physics for GSI/FAIR and CERN synchrotrons and experiments on collective effects; experience in machine learning applications to computational beam dynamics and digital twin generation.

- Julian Garcia Pardinas - Experimental Particle Physics

  CERN IML coordinator, expertise in the application and development of ML/AI for the reconstruction of collision events, data analysis in LHCb

- Hiranya V. Peiris – Astroparticle physics

- Annalisa Pillepich - Astronomy

Computational cosmology and galaxy formation; development and analysis of large cosmological galaxy simulations; large-scale structure of the Universe, nature of dark matter and dark energy; machine learning applications to astronomy and cosmological-parameter inference.

- Maurizio Pierini - Machine Learning applications for particle physics Expertise in design and deployment of machine learning applications to data analysis, simulation, anomaly detection and real-time fast processing

- Tilman Plehn - Theoretical Particle Physics

  Expertise in theoretical physics for the LHC, application of ML/AI to LHC analysis and simulation, development of uncertainty-aware precision networks.

- David Rousseau IJCLab-Orsay- Organisation of Machine-Learning competitions and open datasets. Generator models for detector simulation, advanced tracking algorithms, systematics-aware training.

- Roberto Ruiz de Austri - Theoretical Particle and Astroparticle Physics

  Expertise in physics beyond the standard model and astroparticle physics, including the application of AI/ML techniques to the discovery of new physical phenomena and statistical inference.

- Veronica Sanz - Theoretical Physics and Knowledge Transfer through AI

  Expertise in theoretical particle physics and connection from Particle Physics to other areas (Ecology, Seismicity, Space Weather…) through data science techniques.

- Steven Schramm - Experimental Particle Physics and Gravitational Wave Research

  Former CERN IML coordinator/founder, currently primarily involved in ML for hadronic physics, with a growing involvement in ML for gravitational wave data processing

- Steffen Schumann - Theoretical Particle Physics

  Expertise in ML assisted Monte Carlo simulations for collider experiments, co-chair of the MCnet collaboration for the development of particle physics event generators

- Nicola Serra - Experimental Particle Physicist

  Currently applying Machine Learning (ML) methodologies to projects in LHCb, SHiP, SND@LHC, and CTA. My work involves using ML to better understand and mitigate systematic uncertainties, enhancing simulation accuracy, and optimizing detector performance. The goal is to exploit the potential of ML in improving the reliability and efficiency of experimental setups in particle physics.

- Roberto Trotta - Astrostatistics

- Sofia Vallecorsa - Experimental Particle Physics
  Expertise in AI and Machine Learning and Quantum Machine Learning in CERN IT.

- Pietro Vischia - Optimization problems in fundamental physics, Constrained optimization of complex systems, applications to Particle Physics detectors and accelerators and industry apparata, experimental particle physics (Higgs and Top physics in CMS), CERN IML coordinator, MODE Collaboration steering board member and deputy

- Benjamin Wandelt - Cosmological physics, computation, statistics, and machine learning
- Christoph Weniger - Theoretical astroparticle physics and machine learning
  Expertise in astroparticle physics and cosmology, development of AI/ML techniques for the analysis of complex astrophysical data.

- Gabrijela Zaharijas - Astroparticle physics/gamma ray astrophysics
  Gamma ray astrophysics, including dark matter searches and development of ML algorithms for discovery and classification of point-like and diffuse sources.

This committee brings together experts from diverse backgrounds, ensuring comprehensive coverage of particle physics, astroparticle physics, nuclear physics, gravitational wave research, AI/ML, and representatives from related initiatives. With their collective expertise and leadership, the committee will guide the initiative, drive collaboration, and oversee the successful implementation of the European Initiative on Machine Learning and AI in Fundamental Physics.

5.2 Securing Funding

A comprehensive funding strategy should be developed, identifying potential funding sources such as European research funding programs, governmental grants, private foundations, and industry collaborations. The steering committee, with the support of dedicated staff or consultants, will play a vital role in seeking and securing funding opportunities to sustain the initiative's activities and operations. Developing strategies to facilitate resource sharing is essential for ensuring the success and impact of a European initiative focused on machine learning.

5.3 Engaging Stakeholders

Engaging key stakeholders is critical to the success and impact of the initiative. Outreach efforts should target research institutions (ECFA, APPEC, NUPECC, CERN etc.), universities, national laboratories (e.g. DESY, NIKHEF, INFN, FAIR, …) , ML/AI organizations (ELLIS, CLAIRE, IAIFI, …), and European scientific bodies. It is important to communicate the vision, objectives, and benefits of the initiative, emphasizing the value of collaboration and the significance of ML/AI in fundamental physics research.
Stakeholders also include researchers and scientists (called participants hereafter), i.e., experts and professionals in the fields of particle physics, nuclear physics, astroparticle

physics, and gravitational wave research who actively use AI and ML techniques in their work.

5.4 Fostering Collaboration among the participants

Active collaboration is a fundamental aspect of the initiative. One of our main tasks is the organization of AI in physics conferences and workshops in Europe and networking events to bring together researchers, students, industry experts, and ML/AI practitioners. These platforms will facilitate knowledge exchange, the sharing of best practices, and interdisciplinary collaboration. Establish online platforms (webpage), online forums , and dedicated communication channels (email list, social media accounts) to foster continuous engagement and collaboration among participants.

5.5 Developing a Roadmap

Developing a comprehensive roadmap is essential for effective planning and implementation of the initiative. The roadmap should outline the timeline, milestones, and key activities, providing a clear path for the initiative's progression. It should align with the defined objectives and focus areas, allowing for regular review and adjustment as necessary (a “living roadmap”).

5.6 Establishing Partnerships

Establishing partnerships is crucial for the success of the initiative. Collaborating with ML/AI organizations, research institutions, and industry stakeholders will enhance its impact and reach. Key partnership activities include:

1. Collaborating with ML/AI Organizations:
    - We will engage with organizations such as ELLIS and CLAIRE to leverage their expertise and networks in ML/AI, foster collaborations on joint projects, shared funding opportunities, and knowledge exchange.
    - We will closely engage with the Inter-experimental Machine Learning (IML) Working Group. IML provides a forum for the ML community at the LHC. The goal is to bring together scientists from the LHC experiments, collaborate with data science, promote common solutions between experiments, and provide training and benchmarks. Each LHC experiment is represented by an IML coordinator. We have common goals and this initiative would like to support IML in its plan to further create connections and opportunities.
    - We will collaborate with other AI-in-Science initiatives, e.g., in the areas of materials design, molecular dynamics, etc., to promote cross-fertilization.
2. Partnering with Research Institutions and Initiatives:
    - We will establish partnerships with prominent research institutions and universities across Europe.
    - CERN can play an important role in this initiative. By leveraging its expertise, resources, collaborations, and influence, CERN can contribute significantly to the success and impact of the European AI initiative in fundamental physics, facilitating the development and deployment of centralized software needed by the AI physics community. CERN can also serve as a hub for the community and as a liaison to industrial partners, both to import knowledge and outreach developments carried out by this consortium.

- We will establish partnership with data infrastructures (e.g. virtual research environment) for Open Science (ESCAPE) used for ML (e.g. zenodo, gitlab).
- Through the participation of the founder and chair of the MODE collaboration (a consortium of physicists and computer scientists from 24 research institutes) we will synergize efforts in AI use for big fundamental physics challenges in future experiment design.
- We will seek partnership with the HEP Software Foundation, DIG-UM and ErUM-Data-Hub ErUM-Data-Hub, for facilitating software and data sharing and distribution.

3. Industry Collaborations:
    - We plan to forge collaborations with technology companies and startups, explore ML/AI applications in industry-relevant areas and facilitate technology transfer. We strive to promote best practices in our field, focusing on areas that may not receive as much attention in private research. For instance, emphasizing detailed results validation and uncertainties estimation can enhance AI interpretability, while prioritizing FAIR models for knowledge sharing ensures transparency and accessibility within our community.
4. International Collaborations:
    - We will see opportunities for collaborations with research organizations beyond Europe. We aim to establish partnerships with global institutions and participate in collaborative projects.
    - We aim to have strong links to ML institutes and activities outside Europe, e.g. the NSF AI Institute for Artificial Intelligence and Fundamental Interactions (IAIFI), the Institute for Research and Innovation in Software for High Energy Physics (IRIS-HEP), the Flatiron Institute, etc
    - We also want to create opportunities for monitoring, information sharing, and collaboration with the Snowmass process in the United States to enable a fruitful exchange of ideas in the field of AI/ML.
    - We have also contacted various individuals to serve as scientific advisors for our initiative, also beyond physics.

By actively pursuing these partnerships, the initiative will benefit from collective expertise, resources, and networks. These collaborations will accelerate ML and AI advancements in fundamental physics and strengthen Europe's global leadership in the field.

6. Summary

The initiative will engage in various activities to foster collaboration, promote research projects, facilitate training programs, organize conferences and workshops, and establish networking and exchange opportunities. These activities aim to drive innovation, knowledge exchange, and the application of ML and AI techniques in fundamental physics research (currently HEP/GW/Astroparticle/NuclearPhysics). The initiative will organize regular workshops and conferences, including the "Yearly/Bi-yearly European Conference on Machine Learning and AI in Fundamental Physics," to encourage collaboration, share research findings, and explore emerging trends. The first conference is scheduled for May 2024 in Amsterdam, serving as a kick-off meeting. To promote interdisciplinary collaboration, the initiative will support research projects that bring together experts from particle physics, astroparticle physics, nuclear physics and gravitational wave research, with a specific focus on ML and AI applications. It will tap funding opportunities and foster cross-disciplinary partnerships. Along with other initiatives, data challenges will be proposed to drive innovation and evaluate the performance of ML and AI algorithms in fundamental physics. These challenges will provide researchers with specific problems or data sets to address to drive algorithm development. Training programs, summer schools, and online resources are encouraged and developed to educate researchers and students on the use of ML and AI techniques in basic physics research. These initiatives will empower individuals with necessary skills and knowledge.

Networking and exchange programs will facilitate collaboration and the exchange of ideas and expertise among researchers and institutions. Matchmaking activities, research visits, and joint projects will foster a vibrant community and promote cross-pollination of ideas.

A dedicated webpage, such as www.eucaif.org, will be developed to serve as a central hub for the initiative's activities, resources, and communication.

Through these activities, the European Initiative on Machine Learning and AI in Fundamental Physics aims to foster collaboration, drive research advancements, provide training opportunities, facilitate knowledge exchange, and establish a strong and vibrant community at the forefront of ML and AI in fundamental physics research. Finally, we are aware that this initiative is a challenging project and we greatly appreciate the help of JENAS.