实验粒子物理计算研讨会（2024）

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Pao Yue-Kong Library

Book of Abstracts

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Dark SHINE Simulation software framework

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This talk introduces the Dark SHINE Simulation software. Dark SHINE is a fixed-target dark photon search experiment based at Shanghai SHINE facility. The Dark SHINE Simulation software integrates generator, simulation, digitization, reconstruction, and analysis chain. There are three main parts, DSimu, DAna, and DDis. DSimu is a simulation software based on Geant4 and ROOT, characterized by Dark SHINE detector. DAna is a software framework for the analysis and reconstruction tools. DDis is the event display tool for Dark SHINE project specifically.

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HERD Global Track Reconstruction

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The High Energy cosmic-Radiation Detection (HERD) facility is scheduled to operate on Chinese Space Station (CSS) since 2027 for about 10 years. With the high accuracy silicon charge detector (SCD) and silicon tungsten detector (STK) forming a compact 5 side sensitive detection, HERD is capable to provide trajectory measurement of cosmic-rays. A cellular based track reconstruction algorithm is developed and validated on HERD MC simulation data. The efficiency of this algorithm reaches 96% from 50 GeV to 1 TeV for proton events while keeping low fake rate.

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Graph Neural Networks for High Energy Physics

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Machine learning has revolutionized the analysis of large-scale data samples in high energy physics (HEP) and greatly increased the discovery potential for new fundamental laws of nature. Specifically, graph neural networks (GNNs), thanks to their high flexibility and expressiveness, have demonstrated superior performance over classical deep learning approaches in tackling data analysis challenges in HEP. In this talk, I will go through the fundamentals of GNNs, the design of physics-driven GNN architectures, and their applications in solving data analysis challenges in ongoing and planned HEP experiments. Prospects and possible future directions will also be discussed.

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Jet Classify with More Interaction Particle Transformer

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We propose a new jet tagging method based on Transformer architecture called More Interaction Particle Transformer (miParT). This method improves upon the ParT algorithm by modifying the attention mechanism and increasing the embedding dimension of the pairwise particle interaction input, all while reducing the total number of parameters and computational complexity. We tested miParT on two ubiquitous jet tagging benchmarks and found that it achieved significant improvements over existing methods.

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GNN based tracking reconstruction in the Muon g-2 Experiment

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In the Muon g-2 experiment, the tracking reconstruction is a key component of the data reconstruction and analysis, it provides essential beam dynamics parameters and muon weighting parameters and determines the precision of muon EDM measurements. This presentation introduces the GNN-based tracking reconstruction method. Leveraging message-passing mechanisms and the Louvain algorithm, the GNN method efficiently identifies tracks. The GNN-based vertex fitting also shows promising results.

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Towards Graph Transformers at Scale

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Graphs are a popular mathematical abstraction for systems of relations and interactions that can be applied in various domains such as physics, biology, social sciences, etc. Towards unleashing the power of machine learning models for graphs, one fundamental challenge is how to obtain high-quality representations for graph-structured data with diverse scales and properties. We will talk about recent advances in building scalable Transformers as general-purpose encoders for graphs, including NodeFormer, SGFormer and DIFFormer. The first part will introduce NodeFormer which can flexibly model all-pair interactions within linear complexity. The second part will present SGFormer that further simplifies the model and scales to billion-sized graphs. The third part will introduce DIFFormer, a Transformer derived from principled diffusion process, and the latter lends us an interpretable way to understand the mechanism of scalable Transformers.

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Classifying cosmic-ray components for LHAASO-KM2A with ParticleNet

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The classification of cosmic-ray components in ground-based air shower experiments such as LHAASO is a challenging task. ParticleNet is a DGCNN-based model designed for particle physics applications. In this presentation, we use ParticleNet to identify the proton and light components from background cosmic-ray events in the simulation data of LHAASO-KM2A. The results show enhanced classification performance compared to the baseline method, demonstrating the promise of advanced deep learning techniques in cosmic-ray data analysis.

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GNN Tracking at the DarkSHINE Experiment Searching for Dark Photons in the Visible Decay Channel

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DarkSHINE is an electron-on-target experiment proposed to search for light dark matter. In this talk, we present the application of Graph Neural Networks (GNN) for the tracking and vertex reconstruction in the proposed DarkSHINE experiment with full simulation samples. Compared to the traditional Kalman Filter method, GNN method doubles the signal efficiency while significantly reducing the computation time. Signal sensitivities have been studied based on the GNN Tracking performance.

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The Geant4-based simulation program for the PandaX experiments

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PandaX is an experiment that aims to search for dark matter, neutrinoless double beta decay, and other rare processes using a liquid xenon time projection chamber. A good understanding of the energy deposition processes in the detector holds great importance to the experiment. To address this, BambooMC, a Geant4-based Monte Carlo simulation program, has been developed. In this presentation, the design and functionalities of BambooMC will be introduced, along with an innovative simulation acceleration scheme where a biasing technique is employed. The sensitive region of the detector is simulated in a layered fashion, with an amplified number of events in each layer. With this technique, the simulation speed is enhanced by approximately three orders of magnitude.

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Real Time Analysis Trigger of the LHCb Experiment

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The current Upgrade I data-taking of the LHCb experiment uses a fully software trigger to perform a real-time analysis of LHCb detector data at an input rate of 5TB/s which corresponds to an event rate of 30MHz. This trigger is implemented in two stages. The High Level Trigger 1 (HLT1) performs a partial but high throughput reconstruction on GPUs to inclusively select events. The HLT2 then performs a full offline quality reconstruction on CPUs and exclusively select events via a few thousand different triggers. The high quality reconstruction in both stages is possible thanks to the offline quality detector alignment and calibration of the LHCb experiment that is performed in real-time.

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The particle identification study based on neural networks for CEPC AHCAL prototype test beam data

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Particle Identification (PID) plays a central role in associating the energy depositions in calorimeter cells with the type of primary particle in a particle flow oriented detector system. In this talk, we hope to demonstrate novel PID methods based on the Residual Network (ResNet) architecture to classify experiment data collected at CERN in 2022 and 2023 for the CEPC AHCAL prototype Beam Test. Based on the Geant4 simulation samples with energy ranging from 5 GeV to 120 GeV, the performance of our model is compared with Boosted Decision Trees (BDT) and other pioneering machine learning approaches. In the end, the preliminary application results of our machine learning approach with the CEPC AHCAL Test Beam data will be presented.

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Neutral Hadron Reconstruction at BESIII: new developments and challenges

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The reconstruction of neutral hadrons, particularly (anti-)neutrons, presents a significant challenge in high-energy physics experiments, notably at BESIII, which lacks a dedicated hadronic calorimeter. This talk will cover the innovative techniques applied in the identification of neutrons, in the first observation of the $\Lambda_c^+ \to ne^+\nu$ process. Furthermore, it will discuss the ongoing exploration of (anti-)neutrons position and energy reconstruction, highlighting the latest advancements.

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Accelerating resonance search at the LHC via signature-oriented pre-training

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The search for heavy resonances beyond the Standard Model (BSM) is a key objective at the LHC. While the recent use of advanced deep neural networks for boosted-jet tagging significantly enhances the sensitivity of dedicated searches, it is limited to specific final states, leaving vast potential BSM phase space underexplored. In this talk, we introduce a novel experimental method, Signature-Oriented Pre-training for Heavy-resonance ObservatioN (Sophon), which leverages deep learning to cover an extensive number of boosted final states. Pre-trained on the comprehensive JetClass-II dataset, the Sophon model learns intricate jet signatures, ensuring the optimal constructions of various jet tagging discriminates and enabling high-performance transfer learning capabilities. We show that the method can not only push widespread model-specific searches to their sensitivity frontier, but also greatly improve model-agnostic approaches, accelerating LHC resonance searches in a broad sense.
This talk is based on arXiv:2405.12972.

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Fast Simulation and Evaluation of Pandax-II Data using GANs

Author: Jianqin XuN[one]

Generative Adversarial Networks (GANs), as a powerful framework in deep learning, have been widely applied in various fields. This study aims to develop a rapid data generator by training GAN networks on the data collected from the Pandax-II Run11 AmBe experiment. The data generated by the GAN network not only preserves the individual physical characteristics but also maintains the correlations between different physical quantities. During the network training process, we determine the optimal model through threshold searching and quantify the uncertainty in the training process to demonstrate that the generated data effectively represents the original dataset

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Machine learning applications in JUNO

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The Jiangmen Underground Neutrino Observatory (JUNO) is a next-generation neutrino experiment currently under construction in southern China. It is designed with a 20 kton liquid scintillator detector and 78% photomultiplier tube (PMT) coverage. The primary physics goal of JUNO is to determine the neutrino mass ordering and measure oscillation parameters with unprecedented precision. JUNO’s large mass and high PMT coverage provide a perfect scenario for the application of various machine learning techniques. In this talk, I present an overview of the recent progress of machine learning studies in JUNO, including waveform-level and event-level reconstruction, background rejection, and signal classification. Preliminary results with Monte Carlo simulations are presented, showing great potential in enhancing the detector’s performance as well as expanding JUNO’s physics capabilities beyond the traditional scope of large liquid scintillator detectors.

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鲲鹏处理器在科学计算领域的探索与实践

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本报告基于上海交大校级超算平台的实践经验，介绍国产鲲鹏超算平台的部署、优化、应用案例，展示鲲鹏生态在复杂计算任务中的卓越表现，以及 2024 年与华为成立鲲鹏□腾科教创新卓越中心后，致力于人才培养与生态推广的愿景。

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Detector Design and Fast Simulation Tool (DDFS)

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A Python-based software tool is developed for the performance evaluation of cylindrical tracking system. Incorporating fast simulation techniques, the tool facilitates the assessment of spatial resolution and the effects of multiple scattering, offering both analytical calculations and Kalman filter reconstruction. Additionally, a user-friendly graphical user interface (GUI) has been provided to enhance accessibility for a wide range of users. The software is installable via the Python Package Index (Pip) and supports further customization to meet specific user needs.

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Dr.Sai: An AI Agent for Physical Analysis of BESIII Experiment

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The BESIII experiment has collected the world’s largest sample of charm hadron data, yielding a wealth of physical results. Large AI models, with their comprehensive data and god’s-eye view, have the potential to significantly enhance the efficiency of human scientific discovery. The Computing Center and Experimental Physics Center at IHEP have collaborated to develop Dr. Sai, an AI agent for physical analysis. Dr. Sai aims to highly automate tasks such as literature review, code writing, case generation, case analysis, result interpretation, and paper writing, thereby freeing scientists from routine work with lower innovation requirements and promoting a shift in the research paradigm towards an intelligent model. This report will discuss the latest progress of Dr. Sai, including its

overall design, domain-customized HEP · Xiwu LLM, its perception layer, execution layer, memory layer, multi-agent collaborative system, and UI interface.

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Jet Origin ID and Its Impact on Higgs factory and High Energy frontier

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To enhance the scientific discovery power of high-energy collider experiments, we propose and realize the concept of jet-origin identification that categorizes jets into five quark species (b; c; s; u; d), five corresponding antiquarks, and the gluon.
Using state-of-the-art algorithms and simulated $\nu\bar{\nu}H$, $H \longrightarrow jj$
events at 240 GeV center-of-mass energy at the electron-positron Higgs factory, the jet-origin identification simultaneously reaches jet flavor tagging efficiencies ranging from 67% to 92% for bottom, charm, and
strange quarks and jet charge flip rates of 7%–24% for all quark species.
We apply the jet-origin identification to Higgs rare and exotic decay measurements at the nominal luminosity of the Circular Electron Positron Collider and conclude that the upper limits on the branching ratios of $H \longrightarrow s\bar{s}; u\bar{u}; d\bar{d}$ and $H \longrightarrow sb; db; uc; ds$ can be determined to 2 × 10−4 to 1 × 10−3 at 95% confidence level.
The derived upper
limit for $H \longrightarrow s\bar{s}$ decay is approximately 3 times the prediction of the standard model.
We also discuss its impact on other physics measurements at High energy frontier.

大数据采集与存储 / 21

The HEP Computing Platform at IHEP

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The HEP computing platform at IHEP is designed to support data processing for the HEP experiments in which IHEP is involved. The platform operates large-scale HTC and HPC clusters, along with WLCG grid sites, providing petabyte-level storage. Studies on optimizing job scheduling and enhancing I/O performance aim to improve resource utilization. Operational maintenance is managed through rigorous protocols and automated systems, ensuring stability and security. Additionally, the platform supports new IT technologies, such as AI and quantum computing.

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散裂中子源中子谱仪数据获取的进展与未来的发展

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介绍散裂中子源的数据获取特点和需求，其虽然在数据量上没有高能物理实验的海量规模，但各种先进的实验方法要求数据获取与控制提供双向链路和实时性等重要支持特性，数据获取也因而在这些特性方向上有了独特的发展。结合 CSNS 上的谱仪数据获取发展状况，报告进而介绍目前中子谱仪的基于数据流平台的数据获取框架及关键技术，进一步探讨未来中子谱仪的数据获取如何利用人工智能和大数据的优势，实现更加高效智能的数据处理。

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AI for complex physical simulation and inverse design

In science and engineering, fundamental problems include the forward problem of simulating the evolution of complex physical systems, and the inverse design/inverse problem of optimizing/inferring the system's high-dimensional parameters. Traditional numerical simulation and optimization methods often require extensive computation due to complex physical dynamics. In this talk, I will introduce our method for addressing these challenges with graph neural networks (GNN) and generative models. For accelerating simulation, I introduce a GNN-based architecture that can perform large-scale fluid simulation with more than 10 million nodes, and another method that can simultaneously optimize computation by adding/removing nodes while predicting the system evolution. For inverse design, I introduce the CinDM method based on diffusion generative models. CinDM combines simulation and inverse design/problem into a single task, and learns the joint probability distribution (represented as energy function) of state trajectory and system parameters. In inference, by composing the learned energy function, it can generalize to simulation and inverse tasks more complex than in training. We demonstrate CinDM ’ s capability in 1D PDE and 2D airfoil design tasks.

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Machine Learning in LHC Physics

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Machine learning (ML) has become a transformative tool in high energy physics. In this talk, I will demonstrate how high energy physics problems can be reframed as ML tasks, and highlight the application of ML techniques to enhance particle reconstruction and identification, particularly at the Large Hadron Collider (LHC). Additionally, I will discuss unsupervised ML methods for calorimeter shower simulations and anomaly detection, aimed at uncovering potential signals of new physics. This overview will provide insights into the current state and future directions of ML in advancing particle physics research.