The use of new methods for processing data of a physical experiment. Application of machine learning methods on the NICA complex.

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Mendeleev hall, St. Petersburg, Nevsky 1

Book of Abstracts

Семинар "Использование новых методов обработки данных физического эксперимента. Применение методов машинного обучения на комплексе NICA"

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Сборник тезисов

This is the first seminar[1] for specialists, graduate students and students of leading Russian institutes who are interested in applying new methods for obtaining, processing and processing data from mega-class physical experiments. Modern physical experiments, especially in fundamental research at large facilities, provide an increasing amount of data and require more computer power to process the results. Therefore, more and more often new methods of working with data, including those based on machine learning methods, are being used to work on modern experiments.
The seminar is aimed at discussing new methods of processing data from a modern physical experiment, identifying the main problems that need to be solved and developing a further strategy. The experience of various groups in the implementation of MMO and AI methods at different stages of processing experimental data, as well as monitoring the parameters of detectors and the accelerator complex during data collection will be considered. All this can be used in the work on the program of studying the properties of dense baryonic matter in nuclear collisions at the new accelerator complex NICA (Nuclotron based Ion Collider fAcility) at JINR, Dubna).
The main topics of the workshop include
1) New methods of data collection of physical experiment, including the use of new methods of fast on-line trigger
2) Machine learning methods for the analysis of experimental data on the NICA complex
3) Experience in using AI in preparation for data analysis
4) Experience in the use of distributed computing and grid technologies in the analysis of experimental data of the LHC experiments and prospects for the NICA project
5) Processing the detector response and particle tracking using machine learning methods

Это первый семинар[1] для специалистов, аспирантов и студентов ведущих российских институтов, заинтересованных в применении новых методов получения, процессинга и обработки данных физических экспериментов класса МЕГА. Современные физические эксперименты, в особенности по фундаментальным исследованиям на больших установках, предоставляют все возрастающий объем данных и требуют все возрастающих компьютерных мощностей для обработки результатов. Поэтому, все чаще для работы на современных экспериментах начинают использоваться новые методы работы с данными, в том числе на основе методов машинного обучения.
Семинар направлен на обсуждение новых методов обработки данных современного физического эксперимента, выявление основных проблем, требующих решения и выработку дальнейшей стратегии. Будет рассмотрен опыт различных групп по внедрению методов ММО и ИИ на разных этапах обработки экспериментальных данных, а также мониторинга параметров детекторов и ускорительного комплекса во время набора данных. Все это может быть использовано в работе по программе исследований свойств плотной барионной материи в стокновениях ядер на новом ускорительном комплексе NICA (Nuclotron based Ion Collider fAcility) в ОИЯИ г.Дубна)
Основные вопросы семинара включают в себя:
1) Новые методы набора данных физического эксперимента, в том числе использование новых методик быстрого он-лайн триггера
2) Методы машинного обучения для анализа данных экспериментов на комплексе NICA
3) Опыт использования ИИ в подготовке к анализу данных
4) Опыт использования распределенных и грид технологий в анализе данных экспериментов Большого адронного коллайдера и перспективы для проекта NICA
5) Обработка отклика детекторов и построение треков частиц в детекторах с использованием методов машинного обучения

[1] `https://events.spbu.ru/events/new-methods`, `https://indico.cern.ch/event/1306558`

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Generative models for particle physics: hype, profits, and pitfalls.

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Generative ML models are widely used in the modern world to solve different practical problems. This approach is a very promising solution for various problems in experimental particle and nuclear physics. However, specific requirements of using such models for obtaining quantitative scientific results put restrictions on direct using industrial generative models out of the box.

This presentation will list main use cases of using generative models for experimental particle physics, discuss possible issues and specific requirements to such models, and demonstrate practical approaches to resolve those issues.

Использование методов машинного обучения для поиска оптимальных конфигураций детектирующих систем

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В настоящее время одним из актуальных направлений применения машинного обучения в физике высоких энергий являются задачи поиска оптимальных конфигураций детектирующих систем. Целью подобной оптимизации является нахождение баланса между способностью всех детекторов бесконфликтно выполнять поставленные задачи и стоимостью постройки, или модернизации установки.
В данной работе рассказывается о подходах к комплексной оптимизации с применение методов машинного обучения детекторных систем в сложных экспериментах на примере оптимизации мюонной защиты эксперимента SHiP. Основными факторами успеха оптимизации являются корректный выбор целевой функции, метода оптимизации и способа быстрой оценки конфигураций.
В докладе будут обсуждены проблемы выбора целевой функции, учет ее ограничений с точки зрения эксперимента. Представлены различные подходы к глобальной оптимизации, приемы ускорения расчетной компоненты задачи.

Способы обработки нерегулярностей в симуляционных данных на коллайдерных экспериментах

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Компьютерные модели детекторов на коллайдерных экспериментах могут иметь различную степень детальности: начиная от упрощенных Toy-моделей, отражающих основные характеристики физических процессов детектирования и исследуемых физических явлений, заканчивая детальным моделированием, включающего инженерные ограничения и alignment детектора. Последние модели удобны для получения симуляционных данных, имитирующих реальные данные в эксперименте. В докладе обсуждаются способы построения унифицированной системы реконструкции событий, позволяющей работать с компьютерными моделями различной степени детализации. Обсуждается пример реализации подобной системы реконструкции для модернизации электромагнитного калориметра LHCb.

Методы обработки данных в экспериментах физики высоких энергий. История, проблемы и перспективы

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ML Modelling of QGP

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The processes of collisions of relativistic nuclei are quite complex and include several stages. The main iportant one is the so-called thermal expansion of the medium, during which the matter is in the stage of local thermodynamic equilibrium. The behavior of such a medium is described by the equations of relativistic hydrodynamics. Due to the fact that the initial configurations of colliding nuclei are unique for each collision, this process must be described event by event, which requires significant computational resources.

In this work, for the approximate solution of the equations of relativistic hydrodynamics, the ML-approach based on convolutional neural networks is used. The set of Pb-Pb collisions at LHC energy generated within the VISH2+1 package was used as input data. Other types of nuclei were also used for validation at different energies. Several machine learning schemes have been developed, most of which have shown high efficiency to reconstruct the full space-time evolution of the medium up to the moment of the freezeout. The applicability of the approaches was validated on synthetic data. The azimuthal flows were calculated and copared with the results of the full modelling.

Using the experience of administering the Russian segment of ALICE WLCG to develop NICA data processing system

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Centrality estimation in nucleus-nucleus collisions by machine learning algorithms

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Estimation of centrality is crucial in any analysis sensitive to initial stages of nucleus-nucleus collisions. In heavy ion collisions experiments typically one can use forward detectors to measure energy of nucleon spectators as a proxy for centrality estimator. Precision of this determination in limited by the detector resolution and losses of particles on a way from an interaction point to the detector.

In this contribution we present results of application of machine learning algorithms for centrality determination in Ar+Sc collisions at SPS collision energies based on EPOS model. For this goal realistic simulations of the response of the Projectile Spectator Detector (forward hadronic calorimeter) of the NA61/SHINE experiment was used. Modular structure of detector in transverse plane allows us to use energy depositions in different modules as features for the symbolic regression, decision trees and the convolutional neural network.

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Gradient Boosted Decision Tree for Particle Identification in the MPD

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What Machine Learning Can Do for a Focusing Aerogel Detectors

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Reliable particle identification is a crucial component of modern physics experiments. The use of a Focusing multilayer Aerogel Ring Imaging CHerenkov detector FARICH is under intensive discussion for the SPD detector at NICA. The detector may use both seedless real-time signal finder to produce fast trigger and mitigate noise background, and seeded off-line reconstruction mode for precise identification.

In this presentation we demonstrate our approach to filtering signal hits in the FARICH detector. The approach is inspired by object detection techniques for computer vision. Several ML based approaches to the FARICH reconstruction problem in different settings are also discussed.

Triplet Siamese Network for Event Unraveling in the SPD Experiment

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The very high data acquisition rate as 20 GB/sec data flow resulting from a 3 MHz collision frequency is planned in the future SPD NICA experiment. It implies that tracks of several events will be overlapped and recorded in a single time-slice. Thus, after the step of recognizing all tracks in a time-slice, it is necessary to group the recognized tracks by events to determine their vertices. In this paper, a deep Siamese neural network with triplet loss function is proposed for this purpose. We present preliminary results of evaluation of the efficiency and speed metrics of the neural network after training on a dataset of simulated SPD data.

Fast simulation for forward hadronic calorimeters

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Forward hadronic calorimetes are used in HI experiments to determine centrality and reaction plane. To understand the response and calculate systematic uncertanties a large amount of simulated data has to be produced. However a GEANT4 simulation of hadronic calorimeters may take as much time as of the whole detector if the calorimeter was hitted by a large fraction of nucleon spectators due to origination of many hadronic showers.
I would like to present the solution which was developed for the NA61/SHINE*experiment at SPS CERN. It is a stand alone application based of fitted single nucleon responses, which allows practically instantaneous generation of a calorimeter responce even for Pb+Pb collisions.*SHINE is a fixed target experiment at SPS CERN. It has a hadronic calorimeter (PSD) which also plays a role of a beam dump. This detector has a very similar structure as the MPD's FHCal.

This work was supported by St. Petersburg State University project ID: 94031112

Neural Generative Modeling of the Time Projection Chamber responses at the MPD detector

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The accurate modeling of detector responses in high energy physics experiments is crucial for obtaining reliable physical results.However, nowadays, with the increasing luminosity of modern particle accelerators, the modelling requirements are growing faster than the available computational resources. Therefore, faster methods for modeling of detectors needs to be developed.
In this presentation, we discuss generative-adversarial neural networks in context of modelling the response of the Time Projection Chamber (TPC) for the Multi-Purpose Detector (MPD) at the NICA accelerator complex. We emphasize typical problems on this way and possible approaches of resolving them.

Operation of the ALICE Hyperloop analysis train system

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Hyperloop is a new analysis train system, developed and introduced for the data analysis in the ALICE experiment in the conditions of LHC Run 3. It has started a regular operation in early 2022, being available 24/7. Hyperloop, as a successor of the LEGO train system, used for analysis of Run 1 and Run 2 data, provides efficient management of the analysis process and economical usage of the Grid resources with a convenient web-based user interface. It utilizes all the modern features of new O2 Analysis Framework developed for the Run 3 data.

The analysis is based on the WLCG infrastructure and AliEn framework. The train consists of several wagons. Each wagon corresponds to a configurable workflow that can exchange the data between them. There are two types of wagons: service wagons made by experts providing additional information, such as advanced tracking or centrality, and user wagons for user analysis. The Hyperloop web application allows for automatized wagon test with estimation of the needed resources of CPU and memory, and, in most cases, the train submission is also done automatically. Hyperloop offers several tools for bookkeeping and preservation, including automatized changelogs for datasets, runlists and wagons, as well as comparison tools for wagons and trains.

In this talk, the user and operation experience of the Hyperloop system will be discussed, focusing on the most useful and innovative features. An overview of the current status of the analysis in Run 3 will also be presented.

The work is supported by Saint Petersburg State University, project ID: 94031112.

Application of neural networks in rapid estimation of the impact parameter of high-energy collisions from data obtained from microchannel plates detector.

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In this work, we present the results of series of computational experiments studying the neural network approach to event-by-event estimation of the impact parameter in heavy ion collisions. The configurations of detectors on microchannel plates, were simulated as a source of collision data for the computational algorithm. Originally, such detector systems were proposed in [1]. Computational experiments were carried out on the data of ^{197}Au+^{197}Au collisions generated by QGSM and EPOS models at energies $\sqrt{s_{NN}} = 11$ GeV and $\sqrt{s_{NN}} = 11.5$ GeV.

In the scope of this work, we present the advantages of the neural network approach in evaluation of the impact parameter. Moreover, we show that the developed algorithm is capable to provide sufficiently good and fast results on a single event, and that in our exercises the algorithm was able to successfully identify more than 90% of events with an impact parameter less than 5 fm or even 1 fm, and can be valuable as the fast trigger. In addition we will discuss the encountered problems, such as the variations in data obtained from different theoretical models, and further directions and prospects for research.

This work was supported by St. Petersburg State University project ID: 94031112

[1] A. A. Baldin, G. A. Feofilov, P. Har'yuzov, F.F.Valiev, Fast beam–beam collisions monitor for experiments at NICA, NIMA, 958, 162154, 2019, Reported at the VCI2019, DOI:10.1016/j.nima.2019.04.10

Neutron reconstruction in the highly granular time-of-flight neutron detector at the BM@N experiment.

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The compact highly granular time-of-flight neutron detector (HGN) is designed for the fixed target BM@N experiment at the NICA facility. This detector is aimed to measure anisotropy of azimuthal neutron flows, that are sensitive to the equation of state for dense nuclear matter. Neutrons are produced in nucleus-nucleus collisions with energies up to several GeV. The main reconstruction challenge is to deal with high background rates, that are expected in the detector acceptance. In this contribution we propose two machine learning models for neutron reconstruction: based on boosted decision tree (BDT) and graph neural network (GNN). Strong and weak points of BDT and GNN approaches will be discussed. Reconstruction performance of both models is evaluated on simulations in the full BM@N detector environment.

Рефрижератор растворения - криогенная платформа для охлаждения компонентов квантового компьютера до сверхнизких температур (<50мК).

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Квантовые технологии - одно из наиболее бурно развивающихся современных направлений науки и техники. Теоретически показано, что квантовые компьютеры позволяют достигать существенного преимущества над обычными компьютерами в ряде задач и алгоритмов: машинное обучение, молекулярное моделирование, криптография и т.д. Однако, практическая реализация квантового компьютера связана с решением множества сложных проблем. Одной из них является декогеренция. Квантовое состояние очень хрупкая система, кубиты в запутанном состоянии крайне нестабильны, любое внешнее воздействие может разрушить эту связь. Изменение температуры на мельчайшую долю градуса, давление, пролетевший рядом случайный фотон — все это дестабилизирует систему. Для решения этой проблемы создают рефрижераторы растворения ^{3}He в ^{4}He - низкотемпературные криогенные платформы, в которых поддерживается температура менее 50мК, с максимальной изоляцией внутренней камеры с процессором от всех (возможных) воздействий внешней среды. В связи с введением санкций прекращены поставки подобных устройств в Россию. В секторе низких температур лаборатории ядерных проблем объединенного института ядерных исследований (СНТ ЛЯП ОИЯИ) был создан один из самых первых в мире рефрижераторов растворения и с тех пор накоплен большой опыт в создании подобных устройств. В докладе приводится описание создаваемых в СНТ ЛЯП ОИЯИ рефрижераторов растворения, их основные характеристики и возможность модернизации под конкретные физические задачи.