Proceedings of the Big data analysis tasks on the supercomputer GOVORUN Workshop (SCG2020)
Dubna, Russia, September 16, 2020

SOFTWARE DEVELOPMENT AND COMPUTING FOR THE MPD EXPERIMENT

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Programs development and computing for the offline analysis of Multi Purposes Detector (MPD) experiment at NICA collider are considered. Detailed detectors simulation of the MPD and event generation with Monte Carlo methods are very important in the experimental analysis for the determination of the detector acceptance and resolution, and to distinguish background event with known processes from new physics. Support of the interactive graphical presentation of simulated and experimental data at all levels, from the event display are shown also.

Keywords: computing for HEP, NICA, MPD, Monte-Carlo data generation, data analysis

1. Introduction

Recently a few experiments for heavy-ion physics are being prepared to work at the NICA collider, which will come into operation soon. Three detectors MPD, BM@N and SPD with many complex components will be used in these experiments, which are performed by large international collaborations with a few hundreds of physicists. The lifetime of the experiments will be more than tens years, as usual. With typical event rates of a few KHz and size of each event about hundreds of KB, the raw data will be of the order of 10 PB per year. So the software and computing systems for experiments at NICA collider need to cover a broad range of activities including the design, evaluation, construction, and calibration of the detector before the experiment start and then, the storage, access, reconstruction, analysis of data with the support of a distributed computing infrastructure for physicists engaged in these tasks during experiment runs.

2. Detectors simulation

The main objectives of the HEP experiment computing frameworks are the simulation of the primary interactions with the realistic detector response and the reconstruction and analysis of the data coming from simulated and real interactions. For NICA experiments the frameworks inherited from the FAIRRoot framework [1] are used.

The frameworks for each experiment of the NICA project: MPD, BM@N and SPD, named as MPDRoot, BMNRoot and SPDRoot correspondingly. They differ only with description of different sets of detectors. These frameworks have the same structure and use the same external programs included in the FAIRsoft package. FAIRsoft package includes external packages for the software development like BOOST, GSL, GEANT4 (3), Millepede and ZeroMQ. All of these packages are free, available under the LGPL license and works at different flavors of Linux operational systems.

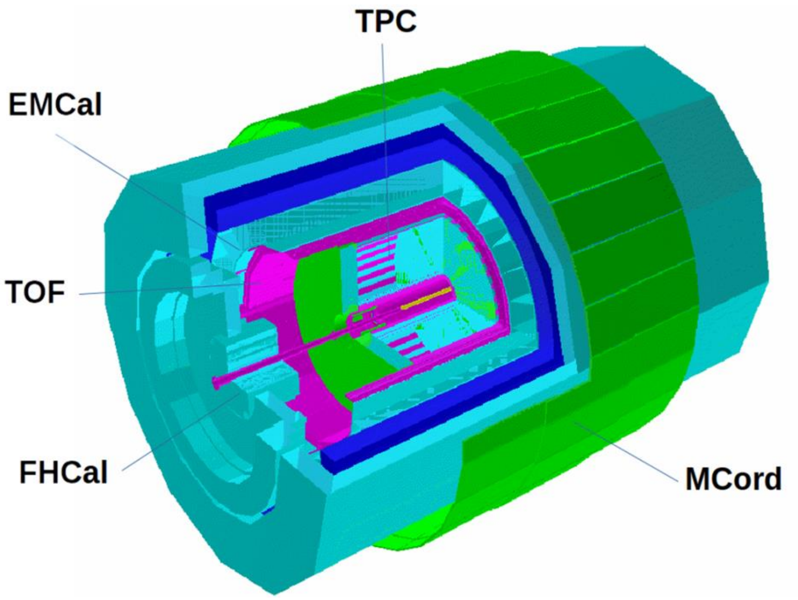

Fig.1. MPD 1-st stage setup

For the experiment MPD it was developed the framework MpdRoot [2]. The detectors in which the response of the detector should simulated are:

- Time projection chamber (TPC),
- Time of Flight (TOF),
- ElectroMagnetic Calorimeter (EMCal),
- Forward Hadronic Calorimeter (FHCal).

The geometry for these detectors are used for the optimization of the detector design and for the development of reconstruction algorithms.

Table 1. Detectors for the 1-st stage of experiment MPD

detector	geometry	responce
TPC	v.9	pads
TOF	v.8.2	strips
FHCal	v.1(7 sect.)	towers
ECal	v.3	towers
FFD	v.6	scint.
MCORD	v.3	scint.

The above listed MPD detectors have a complicated geometry. For the geometry description of whole detectors of MPD experiment the GEANT4 package [3] was used. This package allows one to make a simulation of the geometry and response on particle interactions in each detector. The geometry simulation of the detectors for the 1-st stage of the MPD experiment is shown on the Fig. 1. Also, the table I presents geometry version and response elements of listed detectors. For more detailed simulation of the the TPC other package, Garfield [4] was used for proper consideration the physics processes in it. A detailed check of detector simulation should be performed by measurements in a test run.

3. Monte-Carlo event generation

Monte Carlo generators, used for simulation of nuclei-nucleus collisions at NICA energies for MPD experiment are listed in table II. The simple generators were used for the developments of the reconstruction programs and for the simulation of detector responses but few of them can be also used for the investigation the feasibility of some physics signatures.

Table 2. Monte-Carlo event generators used for MPD physics simulations in Mock Data Challenges

Generator	PWG	coll.	$\sqrt{s}$	# of events (10^6)	reco
UrQMD [5]	PWG4	AuAu	11	15	+
		BiBi	9	10	+
		BiBi	9.46	10	+
	PWG2	AuAu	11	10	+
	PWG3	AuAu	7.7	10	+
		BiBi	9	10	+
			7.7	10	+
SMASH [6]	PWG1	AuAu	4/7/9/11	20/20/20/20	-
		ArAr	4/7/9/11	20/20/20/20	-
		XeXe	4/7/9/11	20/20/20/20	-
		CC	4/7/9/11	20/20/20/20	-
		pp	4/7/9/11	50/50/50/50	-
PHQMD [7]	PWG2	BiBi	8.8	15	+

4. Data analysis software

During the experimental runs there is a lot of information, which must be stored for the further experimental data analysis. Currently databases for generated MC events (MCDB) Fig.2 and Detector Construction Database (DCDB) under development for MPD experiment but many others must be elaborated in the nearest future:

- Experiment Control System (ECS) DB
- Data Acquisition (DAQ) DB
- Trigger DB
- Detector Control System (DCS) DBs
- High-Level Trigger (HLT) DB
- NICA collider DB

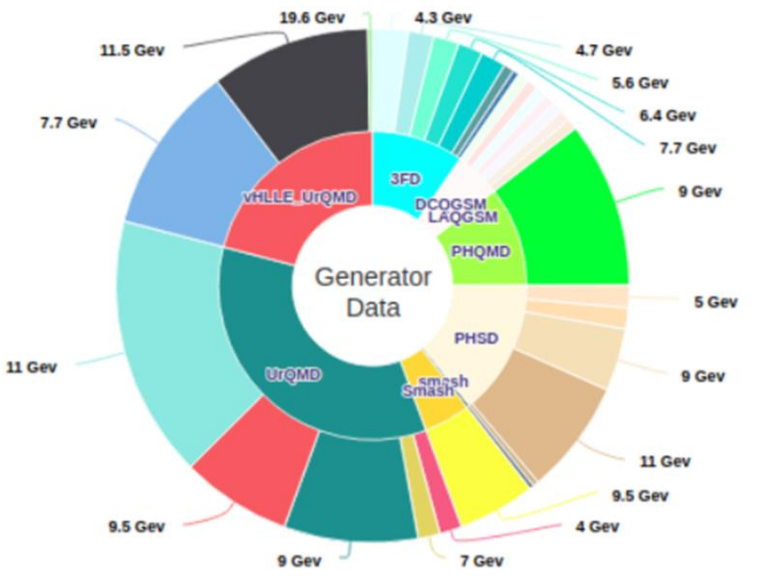

Fig.2. MPD MC events DB

To work with these relative data for the NICA experiments it plans to use the open source relational database PostgreSQL.

Event display programs are the useful tools in high energy physics experiments. Usually event display programs are solid, stand-alone programs, special for each experiment; there may be even two or more specialized event display programs in a single big experiment. For the MPD the new interactive 3D Web event display was developed with very detailed simulation of detector geometry and responses. On the Fig. 3 shown the sensitive volume of TPC with MC points, hits and reconstructed tracks. Also projections of the hits on endcap pad planes are visible.

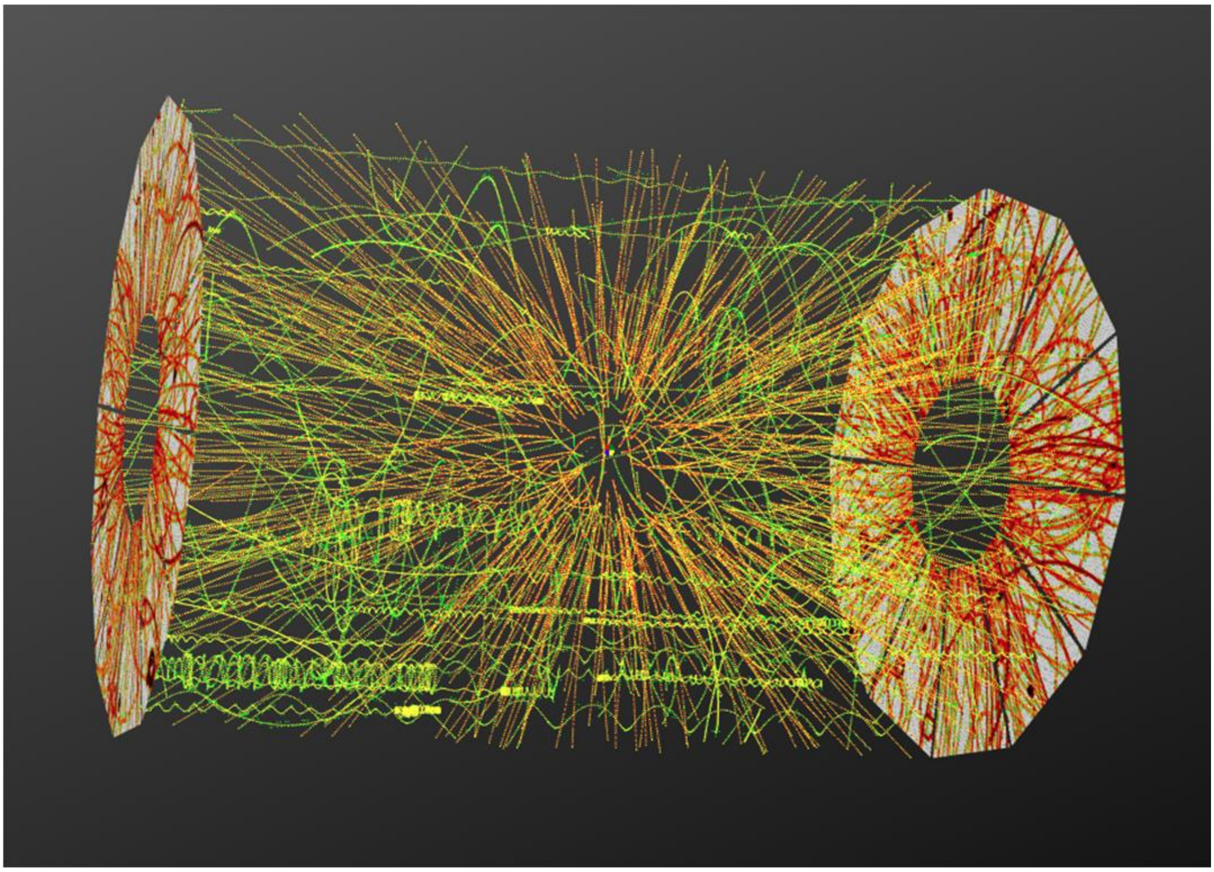

Fig.3. Interactive Web event display for MPD TPC

The storage, networking and processing power needed to analyse data of NICA experiments is well in excess of LHEP and LIT computer facilities and exceed any reasonably projected capabilities of JINRs computing systems in the future.

Fig.4. NICA LHEP PC-Farm

Fig.5. Supercomputer “Govorun” in LIT

The MPD computing model [8] is therefore must be highly distributed, with a primary computing centers at JINR LHEP (Fig. 4) and LIT (Fig. 5) laboratories being supplemented by computing centers at other collaboration laboratories and universities worldwide. For NICA experiments computing grid technologies should be used to facilitate the exploitation of these distributed centers. Close collaboration is maintained with running NICA experiments to learn from their experience and adopt and extend appropriate computing technologies they have developed.

This year (2020), Mock Data Challenges (MDC) generation of tens of millions events for different MC generators with or without reconstruction had been performed in order to check the feasibility of software algorithms and computing resources to obtain physics results from MPD in acceptable time. To involve all computer resources of JINR and Mexica university the interware "DIRAC" (Distributed Infrastructure with Remote Agent Control) [9] were used. The results for MDC are shown in the table 2.

5. Conclusion

The offline data processing of MPD experiment at NICA collider are presented. Frame-work for simulation MPD experiment and general data analysis for simulated and experimental events is available now. Many other important task also are solved for MPD experiment: TPC alignment algorithm, Web interactive event displays for other MPD detectors, calibration task for MPD TPC and others.

Acknowledgement

The authors are grateful to the members of Laboratory of Information Technologies for help in the MPD software development and for implementation of "DIRAC" interware in the JINR computing resources. The authors would like to thank Dr. Kuzmin V.A. for help in developing some algorithms.

This work was supported by grant of Russian Foundation for Basic Research № 18-02-40102.

References

[1] FaiRoot framework, available at https://fairroot.gsi.de/

[2] MpdRoot framework, available at https://mpdroot.jinr.ru

[3] Allison, J et al. Recent developments in Geant4 // NIM A vol. 835 p. 186

[4] Veenhof, Rob available at http://gar eldpp.web.cern.ch/gar eldpp

[5] Bleicher, M., et al., Relativistic Hadron-Hadron Collisions in the Ultra-Relativistic Quantum Molecular Dynamics Model, J. Phys. G vol. 25, 1999, p. 1859

[6] Weil, J., et al., Particle production and equilibrium properties within a new hadron transport approach for heavy-ion collisions Phys. Rev. C vol. 94 2016 p. 054905

[7] Bratkovskaya, E., et al. Parton Hadron Quantum Molecular Dynamics (PHQMD) { a Novel Microscopic N-Body Transport Approach for Heavy-Ion Dynamics and Hypernuclei Production, arXiv:1911.11892 2019

[8] Network and computing infrastructure for the NICA complex at JINR TDR (2017) available at http://mpdroot.jinr.ru/doc/mpd-tdr/

[9] DIRAC available at http://diracgrid.org/