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Objectifs

The targets of the project are

1. Within collaboration between LAL and LPT-Orsay work on calculations related to heavy quarks. Such calculations include that of the strong coupling constant and decay of the B-mesons, which are essential in the search of the New Physics with LHC data.
2. Within collaboration between LAL, LPT, CEA, Inria work on the project dedicated to development of a Domain Specific Language which would allow easy and efficient pathway from high-level symbolic description of Quantum Chromodynamics action to the executable parallel code.
3. Within LAL, lead a project on creation of a unique FPGA based fiber optical network interface, which would allow creating of a toroid interconnect within future R&D supercomputing project

Results

1. $B \rightarrow D^*$ +leptons : The Cabibbo-Kobayashi-Maskawa mechanism of mixing among quark flavours is in the Standard Model the dominant source of CP violation observed in Nature. Unitarity of the CKM matrix translates in a "unitarity triangle" which is the main focus of the studies. The analytical expression of the strongly constraining εK parameter on its apex involves the fourth power of the CKM matrix element Vcb, which is at the moment the largest uncertainty. Hence reducing the error on Vcb below the up to date value of 4% is crucial; the favored experimental process is the semi-leptonic decay $B \rightarrow D^*$ +leptons. We tried to estimate the associated form factors by analyzing the statistical ensembles provided by the ETM Collaboration and using a very promising approach to smoothly extrapolate to the b quark mass results obtained from lighter quarks. It is at present the most promising attempt in the world. Reduction of the error on Vcb also requires the understanding of other semileptonic decay channels, as $B \rightarrow D^{**}$ +leptons for which theoretical and experimental status are still puzzling. On this phenomenologically relevant question, our group has done a worldwide pioneering work.

We computed the decays B→D∗0 and B→D∗2 with finite masses for the b and c quarks. For a start we analyze the spectral properties of both the B meson as a function of its momentum and of the D∗0 and D∗2 at rest. We compute the theoretical formulae leading to the decay amplitudes from the three-point and two-point correlators. We then compute the amplitudes at zero recoil of B→D∗0 which turn out not to be vanishing contrary to what happens in the heavy quark limit. This opens a possibility to get a better agreement with experiment, although our extrapolation to the continuum and the physical B mass has more than 100% uncertainty. The B→D∗2 vanishes at zero recoil and we show a statistically significant signal which is in a range between 1 to 10 times the heavy quark limit prediction. The improvement of these preliminary results will come mainly from adding smaller lattice spacing to our sample.

2. Second part of my activity is related to the development of a new domain-specific language, QIRAL, for the automatic code generation of OpenMP codes for Lattice QCD simulations. QIRAL language offers to physicists the possibility to implement iterative methods and preconditioners, literally ``from the book'' using LaTeX, or design new ones, and test them on large parallel shared memory machines or on accelerators such as the Xeon Phi. The language enables the composition of preconditioners and iterative methods, and the compiler checks automatically the validity of application for each method. This makes possible a more systematic exploration of the algorithmic space as it removes from the physicists the burden of long and stressful validations of their new code since it will be automatically generated, then safer, and the time-to-market for a viable product will be much shorter. The QIRAL compiler generates OpenMP parallel code using BLAS or specialized versions of BLAS functions. Further hand-tuning is possible on the code generated by QIRAL, and we have shown that the performance on various multi-core architectures and on Xeon Phi accelerator it compares or outperforms the performance of a hand-tuned Lattice QCD application, tmLQCD. Among the perspectives of this work, the automatic generation of a communication code for multi-node computation would enable to run Lattice QCD simulations on a larger scale. Besides, the fine tuning of the library functions used by QIRAL on different architectures, in particular their SIMDization, could be improved.
3. Project NEPAL was conceived by Gilbert Grosdidier and me to address the issue of the discrepancy between connectivity of the parallel nodes (usually infiniband fat tree) and the simulated model (close-coupled interactions). Project received support from the Scientific Counsel of the laboratory and two engineers were dedicated to design the hardware. Financial means for chips and electronic parts, which are bleeding edge in FPGA and fiber optics, was provided by the laboratory. The design and implementation are complete.

Publications

1. arXiv:1401.2039

Automated Code Generation for Lattice Quantum Chromodynamics and beyond

Denis Barthou, Olivier Brand-Foissac, Romain Dolbeau, Gilbert Grosdidier, Christina Eisenbeis, Michael Kruse, Olivier Pene, Konstantin Petrov, Claude Tadonki

Subjects: High Energy Physics - Lattice (hep-lat); Distributed, Parallel, and Cluster Computing (cs.DC); Programming Languages (cs.PL)

2. arXiv:1312.2914

Semileptonic $B \to D^{**}$ decays in Lattice QCD : a feasibility study and first results

M. Atoui, B. Blossier, V. Morénas, O. Pène, K. Petrov

Comments: 28 pages with 20 figures

Subjects: High Energy Physics - Lattice (hep-lat); High Energy Physics - Phenomenology (hep-ph)

3. arXiv:1312.1514

A novel method for the physical scale setting on the lattice and its application to N_f=4 simulations

B. Blossier, Ph. Boucaud, M. Brinet, F. De Soto, V. Morènas, O. Pène, K. Petrov, J. Rodríguez-Quintero

Comments: 5 pages, 2 tables

Subjects: High Energy Physics - Lattice (hep-lat)

4. arXiv:1310.4087

Three-gluon running coupling from lattice QCD at $N_f=2+1+1$: a consistency check of the OPE approach

Ph. Boucaud, M. Brinet, F. De Soto, V. Morenas, O. Pène, K. Petrov, J. Rodríguez-Quintero

Comments: Revised version (8 pages, 5 figures)

Subjects: High Energy Physics - Phenomenology (hep-ph)

5. arXiv:1310.3763

High statistics determination of the strong coupling constant in Taylor scheme and its OPE Wilson coefficient from lattice QCD with a dynamical charm

B. Blossier, Ph. Boucaud, M. Brinet, F. De Soto, V. Morenas, O. Pène, K. Petrov, J. Rodríguez-Quintero

Comments: 15 pages, 7 figs

Journal-ref: Phys. Rev. D 89, 014507 (2014)

Subjects: High Energy Physics - Phenomenology (hep-ph); High Energy Physics - Lattice (hep-lat)

6. arXiv:1304.3296

Testing OPE for ghosts, gluons and $α_s$

Benoit Blossier, Philippe Boucaud, Mariane Brinet, vincent Morenas, Olivier Pene, Konstantin Petrov, Jose Rodriguez-Quinteiro, Feliciano de Soto

Comments: arXiv admin note: substantial text overlap with arXiv:1301.7593

Journal-ref: PoS(Confinement X)043, 2013

Subjects: High Energy Physics - Lattice (hep-lat)

7. arXiv:1301.7593

Testing the OPE Wilson coefficient for A^2 from lattice QCD with a dynamical charm

B. Blossier, Ph. Boucaud, M. Brinet, F. De Soto, V. Morenas, O. Pène, K. Petrov, J. Rodríguez-Quintero

Comments: 12 pages, 11 figures, 3 tables

Journal-ref: Phys. Rev. D 87(2013) 074033

Subjects: High Energy Physics - Phenomenology (hep-ph)

Relevance within P2IO

To our opinion, all three parts of the project are well placed within larger framework of physics of two infinities.

Purely physics part of the project is an attempt to do a bleeding edge calculation, with a hope that it might give us indications of the influence of the Physics Beyond Standard Model onto experiments performed at LHC-B etc. To my knowledge, the work is not being continued.

Hardware development, outside of possible valorization, could pave the way to French analogue of BlueGene/Q, a supercomputer most suitable for massively parallel jobs. This would allow for efficient simulations for many systems, from proton to helium nuclei. There is nobody in LAL who would be able to continue this development beyond basic network interface.

Automated code generation turned out to be a success surpassing our expectations. While we were aiming to achieve moderate performance, we managed to beat the hand-tuned code. Our model provides maintainable source code (2 pages of symbolic notation) and could have been the new way of doing computational particle physics, enhancing use of existing computer resources and streamlining development. To my knowledge, there is nobody left at the laboratory to provide support for the target community, and the tool is being re-structured for problems outside physics.

Conclusion

While I had significant support of people in my collaboration, for which I am extremely thankful, CNRS repeatedly refused to hire me (4 attempts), and, in fact, did not hire anybody in the area of Computational Particle Physics since many years. Therefore, I was forced to make a decision to leave physics.