2024

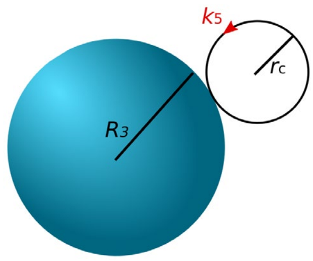
High-energy heavy-ion physics is connected to a large variety of physics disciplines. Researches probe fundamental concepts of classical and modern thermodynamics, hydrodynamics, and quantum theory. Therefore, they have several theoretical and practical topical research directions covering a wide spectrum, such as: thermodynamics, perturbative and non-perturbative QCD, high-energy nuclear effects, hadronization, hadron phenomenology, phenomenology of compact stars, and gravity/cosmology. These studies are strongly motivated by the needs of several recent and planned large-scale facilities, such as collaborations at the LHC (CERN, Switzerland) and RHIC (BNL, USA), and future experiments at Hi-Lumi LHC or FCC (CERN), and FAIR (GSI, Germany). They have continued these theoretical investigations in the direction of high-energy physics phenomenology connected to existing and future state-of-the-art detectors. Concerning international theoretical collaborations, they have established joint work with the Goethe Institute (Germany), University of Wroclaw, (Poland), LBNL (USA), CCNU, MAP (China), UNAM (Mexico), University of Madrid (Spain), IIT Indore ((india) and ERI (Japan). The most important published results are highlighted below.

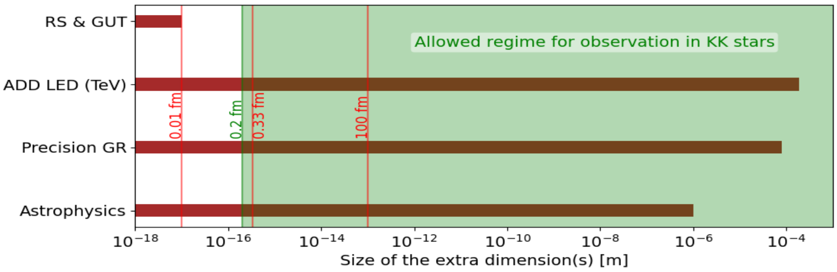
Investigating heavy-ion collisions — High-energy heavy-ion collisions are one of the best testbeds for the non-ideal, non-equilibrium, finite systems, these methods are especially successful in the theoretical description of small systems.

Together the Indian Institute of Technology (IIT) Indore they investigated the momentum asymuthal anisotropy parameter (v_2 – the second Fourier component), measured in non-central collisions of Oxigen nuclei at LHC energies. One of the important observables for studying QGP is the transverse collective flow. Their work was focused towards designing experimental techniques to measure the flow coefficients, mainly the second order flow coefficient known as the elliptic flow (v_2). Oxigen nuclei have double magic structure, which based on their Monte Carlo simulations, affect well the elliptic flow values in comparison to the standard Saxon-Woods distribution-based model. This work showed a promising effect, which can be measured in the LHC experiments.

In collaboration with the University of Berkeley (USA) and IoPP CCNU (Wuhan, China), they further developed the HIJING++ heavy-ion Monte Carlo Generator with G. Papp (ELTE)

Figure 1: Compact stars in Kaluza-Klein spacetime, and the estimates for the size of compactified extra dimension within this framework.





and X.N. Wang (IoPP CCNU, LBNL).

In a joint project between Wigner RCP and the ICN UNAM, they identified the limit between the soft and hard part of the hadron spectra.

Multi-wavelength astronomy and investigations of extreme matter in the Universe — Investigation of cold compact stars provides the opportunity to understand cold super-dense nuclear matter. These theoretical developments are strongly connected to recent measurements of compact stars by multi-wavelength observations and gravitational waves and the future Einstein Telescope, which are supported by a NRDIO ADVANCED theoretical project until 2027

They studied compact stars with extra spatial dimensions in the Kaluza-Klein model. They provided a simple equation of state for the extra dimensional space-time, which ensures the realistic description of maximal mass pulsars [1]. Further feature of the model, that they could provide ans estimate for the size of the extra compactified dimensions. They also investigated the same model for the case of multi-dimensions (Fig 1).

The effective field theory of the strong interaction — They studied the effect of isospin-symmetry breaking in the framework of the extended linear model in vacuum. In this model, several particles mix with each other at tree level, due to the three nonzero scalar condensates (nonstrange, strange, isospin). They resolved these mixings with the help of various field transformations. Finally, they computed all possible meson mixings and decay widths at tree level and perform a fit to Particle Data Group data. A very good fit is found if they exclude the (very small) decay. As further observation the violation of Dashen's theorem were investigated [3].

Education, PR and prizes. — They had 8 young PhD fellow associated with the research group. Senior colleagues are members of the ELTE, BME, PTE doctoral programmes. Győző Kovács and János Takátsy have defended their PhD theses at the ELTE Physics Doctoral School. Gábor Bíró had also received the Györgyi Géza Price of the Wigner RCP. Anna Horváth has passed the mid-time complex exam at the Eötvös University Physics Doctoral School.

Group members played key role in the following workshop, conference and seminar organizations: "WSCLAB GPU Day 2024" at the at Wigner RCP; "Zimányi Winter School 2024," Budapest, Hungary, "PP2024, – Particles and Plasmas 2023", Lectures on Modern Scientific Programming 2024, and the V4HEP events by a Visegrad Fund grant. Group members participated in PR activities at their alma mater and high-school invitations, indeed the 'Researcher's Night.

References (choose maximum 5 articles, each must begins with https://):

[1] A. Horváth, E. Forgács-Dajka, G.G. Barnaföldi: Application of Kaluza–Klein theory in modelling compact stars: exploring extra dimensions , *Monthly Notices of the Royal Astronomical Society*, 536, (2025) 816–826, https://doi.org/10.1093/mnras/stae2637

[2] P Kovács Gy Wolf N. Weickgenannt, D.H. Rischke Phenomenology of isospin-symmetry breaking with vector mesons, Phys. Rev. D **109**, 096007 **2024,** DOI: https://doi.org/10.1103/PhysRevD.109.096007