

— • INTW2026 • —

4th International Workshop on Nuclear Theory

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*Nuclei and Hypernuclei in
Relativistic Ion Collisions*



27 September – 3 October 2026



Antalya, Türkiye



PROGRAMME & ABSTRACTS

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TABLE OF CONTENTS

	Page
EDITORIAL PAGE	II
COMMITTEES	III
INVITED SPEAKERS	IV
CONFERENCE VENUE	V
SCIENTIFIC PROGRAMME	1
CONTENTS – ABSTRACTS	6
ABSTRACTS	9
LIST of PARTICIPANTS	55

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Iurii KARPENKO	Victor RIABOV
Jameel Un-NABI	Wolfgang TRAUTMANN
Jan STEINHEIMER	Xian-Rong ZHOU
Joerg AICHELIN	

Conference Venue

The conference is organised at the [Norm Oriental Hotel](#) in Kemer region, Antalya, Türkiye.

Address of the hotel: The Norm Oriental Hotel, Çamyuva Mah. Turizm Blv. No:19 Kemer / Antalya.

Excursion Venue



Phaselis (Ancient Greek: Φασηλίς) or **Faselis** (Turkish: *Faselis*) was a Greek and Roman city on the coast of ancient Lycia. Its ruins are located north of the modern town Tekirova in the Kemer district of Antalya Province in Türkiye. It lies between the Bey Mountains and the forests of Olympus National Park, 16 kilometres (9.9 mi) south of the tourist town of Kemer and on the 57th kilometre of the Antalya–Kumluca highway. Phaselis and other ancient towns around the shore can also be accessed from the sea by daily yacht tours. (<https://en.wikipedia.org/wiki/Phaselis>)



Phaselis, situated on a small peninsula extending into the Mediterranean Sea, was founded as a port city in the 7th century BC. The city has three ports: the North Harbor, the Central Harbor (also known as War Harbor), and the South Harbor. For a long time, Phaselis was the busiest port city in the eastern part of Lycia, and its main source of income was sea trade. The city's coins featured ship images to emphasize the importance of sea trade. However, the city's strategic importance was the main reason for its capture. Phaselis was ruled by the Persians before opening its doors to Alexander the Great, who stayed for a month. Later, it fell under pirate sovereignty for a period. During the Byzantine period, Phaselis became a bishopric center, but it eventually lost its significance and was abandoned in the early 13th century, like many other cities in the region. The History Hidden in Natural Beauty Phaselis is not only rich in history but also boasts magnificent natural beauty and a beautiful beach. Visitors can explore the ruins without being disturbed by the Mediterranean sun, thanks to the pine trees that surround and extend into the ancient city. The city walls, built along the seashore to protect the city from pirate attacks, are the first remarkable ruins near the harbours. Another important feature is the magnificent aqueducts built to bring water from Tahtalı Mountain. During the early periods, the water needs of the city were met by wells and cisterns. However, in the Roman period, arches were built to bring water from long distances and distribute it to all parts of the city through canals. The main port, located in the southern part of the city, is connected to the city center by a 25-meter-wide street paved with smooth stones. This street forms the main axis of the city and is flanked by Roman and Byzantine ruins on both sides. There are two baths, one large and one small. The smaller bath features details that shed light on how the baths were heated during the Roman period. The entrance to the South Harbor, built in honor of the Roman Emperor Hadrian's visit to the city, is still visible. Each building, including the monumental fountain and theater, is beautiful and takes visitors on a journey through history. Even the current ruins attest to Phaselis's ancient glory. However, it is believed that the city was much larger in the past. (<https://muze.gov.tr/muze-detay?SectionId=PHS01&DistId=PHS>)

SCIENTIFIC PROGRAMME

September 27, 2026, Sunday – Arrivals

September 28, 2026, Monday

Registration 8:30-9:20

Morning session 9:20 – 12:40 (Time Zone Istanbul GM+3)

Chair: Marcus BLEICHER

09:20- 09:30 *OPENING CEREMONY*

09:30-10:00 **Wolfgang TRAUTMANN**

ASY-EOS II and the nuclear equation of state

10:00-10:30 **Marcus BLEICHER**

Charmed nuclei and exotic charmed meson production at CBM@FAIR and ALICE@LHC

10:30 – 11:00 *COFFEE BREAK*

11:00-11:30 **Alexander BOTVINA**

Many-body nucleosynthesis in nucleus-nucleus collisions at intermediate and high energies

11:30-12:00 **Ryoko KINO**

Precision measurement of the hypertriton lambda-binding energy via decay-pion spectroscopy at MAMI

12:00-12:20 **Tom REICHERT**

Multi-fluid hydrodynamics with continuous decoupling

12:20-12:40 **Carl ROSENKVIST**

Strong color fields as a source of non-equilibrium strangeness enhancement in heavy-ion collisions

12:40 -16:00 *LUNCH BREAK*

Afternoon session 16:00 -18:40

Chair: Rıza OGUL

16:00-16:30 *COFFEE BREAK*

16:30-17:00 **Bao-An LI**

Trace anomaly of dense matter from heavy-ion reactions and neutron stars

17:00-17:30 **Pasi HUOVINEN**

The multi-fluid model MUFFIN: A status report

17:30-18:00 **Kai-Jia SUN**
Femtoscscopy reveals how light nuclei are formed at LHC

18:00-18:20 **Ismail BOZTOSUN**
Turkish accelerator and radiation laboratory

18:20- 18:40 **Necla CAKMAK**
Beta-decay properties of Rb-92 and Cs-142 within the pn-QRPA

September 29, 2026, Tuesday

Morning session 9:00 - 12:40 Time Zone Istanbul (GM+3)

Chair: Ismail BOZTOSUN

09:00- 09:30 **Takehiko SAITO**
Hunting for hypernuclei with heavy-ion beams and machine learning

09:30-10:00 **Iurii KARPENKO**
Construction and benchmarks of dynamic fluidisation model for FAIR energies

10:00-10:30 **Christoph BLUME**
Energy dependence of stopping and particle production

10:30 – 11:00 COFFEE BREAK

11:00-11:30 **Alberto CAMAIANI**
Deepening the latest INDRA FAZIA results at sub-saturation densities

11:30-12:00 **Shun FURUSAWA**
Nuclei, multi-neutron systems, and hypernuclei in hot and dense stellar environments

12:00-12:20 **Jan STEINHEIMER-FROSCHAUER**
The isospin-dependent CMF-EoS in UrQMD

12:20-12:40 **Nihal BUYUKCIZMECI**
Transport model simulations for normal and strange nuclei in heavy ion collisions

12:40 -16:00 LUNCH BREAK

Afternoon session 16:00 -18:40

Chair: Necla CAKMAK

16:00-16:30 COFFEE BREAK

16:30-17:00 **Riza OGUL**
Implications of the yield ratios in central heavy-ion collisions at 270 MeV/nucleon beam energy

17:00-17:30 **Joerg AICHELIN**

Subthreshold particle production - a very promising research field

17:30-18:00 **Elena BRATKOVSKAYA**

Probing the nuclear equation of state with clusters and hypernuclei

18:00-18:20 **Tianhao SHAO**

Measurement of Λ binding energies of light hypernuclei in Au+Au collisions at 3 GeV at RHIC

18:20- 18:40 **Ali Ihsan KILIC**

From condensed-matter electron screening to lattice-structured active shielding: Low-energy d+d fusion as a design pathway for compact space propulsion

September 30, 2026, Wednesday

Morning session 9:30 - 12:00 Time Zone Istanbul (GM+3)

Chair: Nihal BUYUKCIZMECI

9:30- 11:00 Discussion session

12:00-18:00 Excursion

October 1, 2026, Thursday

Morning session 9:00 - 12:40 Time Zone Istanbul (GM+3)

Chair: Serkan AKKOYUN

9:00- 09:30 **Victor RIABOV**

Status and preparation for the first physics with the MPD experiment at NICA

9:30- 10:00 **Arkadiy TARANENKO**

Anisotropic collective flow at high baryon density

10:00-10:30 **Jameel UN-NABI**

Enhanced heating rates for superburst ignition

10:30 – 11:00 COFFEE BREAK

11:00-11:30 **Josef POCHODZALLA**

The quest for light systems with extreme neutron content

11:30-12:00 **Christoph HEROLD**

Chronology of dilepton emission in baryon-rich QCD matter as a probe of the QCD phase structure

12:00-12:20 **Emrah TIRAS**

Investigating neutron interactions and capture with complementary detector technologies

12:20-12:40 **Lina JERITSLEV**
Dilepton production in the UrQMD transport approach at SIS energies

12:40 -16:00 LUNCH BREAK

Afternoon session 16:00 -18:40

Chair: Mahmut BOYUKATA

16:00-16:30 COFFEE BREAK

16:30-17:00 **Boris TOMASIK**
Elliptic flow of deuterons in ultrarelativistic heavy-ion collisions

17:00-17:30 **Vadim KOLESNIKOV**
The BM@N experiment at NICA: status of the detector and progress in data analysis

17:30-18:00 **Simone MANTI**
High-precision spectroscopy of kaonic atoms at SIDDHARTA-2: probing fundamental interactions

18:00-18:20 **Deineng LIU**
Hadron polarization and equation of state at FAIR/RHIC-BES energies

18:20- 18:40 **Ismail Hakki SARPUN**
Microscopic folding analysis of neutron elastic scattering on ^{90}Zr

19:00- 22:00 CONFERENCE DINNER

October 2, 2026, Friday

Morning session 9:00 - 12:40 Time Zone Istanbul (GM+3)

Chair: Emrah TIRAS

9:00- 09:30 **Emiko HIYAMA**
Structure of light $S=-2$ hypernuclei

9:30- 10:00 **Sandro BARLINI**
The INDRA+FAZIA experimental setup: recent developments and scientific opportunities at Fermi energies

10:00-10:30 **Frank NERLING**
Search for the $Y(2175)$ in the photoproduction cross section measurement of $\gamma p \rightarrow \phi \pi^+ \pi^- p$ at GlueX

10:30 – 11:00 COFFEE BREAK

11:00-11:20 **Serkan AKKOYUN**
Comparison of classical and quantum circuit-based machine learning approaches supported by feature engineering in nuclear radius prediction

11:20-11:40

Mahmut BOYUKATA

Genetic algorithm optimization of IBM-1 parameters for the study of some nuclear structure properties

11:40-12:10

Behruz KARDAN

Flow phenomena at high nuclear densities with HADES

12:10-12:40

Xian-Rong ZHOU

Effects of Λ hyperon on nuclear structure

12:40-13:10

Evgeny KOLOMEITSEV

Nuclear symmetry energy from neutron stars and heavy-ion collisions

13:10-13:20

CLOSING REMARKS

CONTENTS – ABSTRACTS

SPEAKER	TITLE	PAGE
Wolfgang Trautmann	ASY-EOS II and the nuclear equation of state	10
Marcus Bleicher	Charmed nuclei and exotic charmed meson production at CBM@FAIR and ALICE@LHC	11
Alexander Botvina	Many-body nucleosynthesis in nucleus-nucleus collisions at intermediate and high energies	12
Ryoko Kino	Precision measurement of the hypertriton lambda-binding energy via decay-pion spectroscopy at MAMI	13
Tom Reichert	Multi-fluid hydrodynamics with continuous decoupling	14
Carl Rosenkvist	Strong color fields as a source of non-equilibrium strangeness enhancement in heavy-ion collisions	15
Bao-An Li	Trace anomaly of dense matter from heavy-ion reactions and neutron stars	16
Pasi Huovinen	The multi-fluid model MUFFIN: A status report	17
Kai-Jia Sun	Femtoscopia reveals how light nuclei are formed at LHC	18
Ismail Boztosun	Turkish accelerator and radiation laboratory	19
Necla Cakmak	Beta-decay properties of Rb-92 and Cs-142 within the pn-QRPA	20
Takehiko Saito	Hunting for hypernuclei with heavy-ion beams and machine learning	21
Iurii Karpenko	Construction and benchmarks of dynamic fluidisation model for FAIR energies	22
Christoph Blume	Energy dependence of stopping and particle production	23
Alberto Camaiani	Deepening the latest INDRA FAZIA results at sub-saturation densities	24
Shun Furusawa	Nuclei, multi-neutron systems, and hypernuclei in hot and dense stellar environments	25
Jan Steinheimer-Froschauer	The isospin-dependent CMF-EoS in UrQMD	26
Nihal Buyukcizmeci	Transport model simulations for normal and strange nuclei in heavy ion collisions	27
Riza Ogul	Implications of the yield ratios in central heavy-ion collisions at 270 MeV/nucleon beam energy	28
Joerg Aichelin	Subthreshold particle production - a very promising research field	29
Elena Bratkovskaya	Probing the nuclear equation of state with clusters and hypernuclei	30

SPEAKER	TITLE	PAGE
Tianhao Shao	Measurement of Λ binding energies of light hypernuclei in Au+Au collisions at 3 GeV at RHIC	31
Ali Ihsan Kilic	From condensed-matter electron screening to lattice-structured active shielding: Low-energy d+d fusion as a design pathway for compact space propulsion	32
Victor Riabov	Status and preparation for the first physics with the MPD experiment at NICA	33
Arkadiy Taranenko	Anisotropic collective flow at high baryon density	34
Jameel Un-Nabi	Enhanced heating rates for superburst ignition	35
Josef Pochodzalla	The quest for light systems with extreme neutron content	36
Christoph Herold	Chronology of dilepton emission in baryon-rich QCD matter as a probe of the QCD phase structure	37
Emrah Tiras	Investigating neutron interactions and capture with complementary detector technologies	38
Lina Jeritslev	Dilepton production in the UrQMD transport approach at SIS energies	39
Boris Tomasik	Elliptic flow of deuterons in ultrarelativistic heavy-ion collisions	40
Vadim Kolesnikov	The BM@N experiment at NICA: status of the detector and progress in data analysis	41
Simone Manti	High-precision spectroscopy of kaonic atoms at SIDDHARTA-2: probing fundamental interactions	42
Deineng Liu	Hadron polarization and equation of state at FAIR/RHIC-BES energies	43
Ismail Hakki Sarpun	Microscopic folding analysis of neutron elastic scattering on ^{90}Zr	44
Emiko Hiyama	Structure of light $S=-2$ hypernuclei	45
Sandro Barlini	The INDRA+FAZIA experimental setup: recent developments and scientific opportunities at Fermi energies	46
Frank Nerling	Search for the $\Upsilon(2175)$ in the photoproduction cross section measurement of $\gamma p \rightarrow \phi \pi^+ \pi^- p$ at GlueX	47
Serkan Akkoyun	Comparison of classical and quantum circuit-based machine learning approaches supported by feature engineering in nuclear radius prediction	48
Mahmut Boyukata	Genetic algorithm optimization of IBM-1 parameters for the study of some nuclear structure properties	49
Behruz Kardan	Flow phenomena at high nuclear densities with HADES	50
Xian-Rong Zhou	Effects of Λ hyperon on nuclear structure	51

SPEAKER	TITLE	PAGE
Evgeny Kolomeitsev	Nuclear symmetry energy from neutron stars and heavy-ion collisions	52

ABSTRACTS

ASY-EOS II and the nuclear equation of state

Wolfgang Trautmann

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Abstract

The Experiment S122 of the ASY-EOS Collaboration was successfully conducted at the GSI Laboratory in March 2025. Beams of ^{197}Au nuclei with incident energies 280, 400, 600, and 1000 MeV/nucleon were directed onto ^{197}Au targets mounted within the newly built scintillation-fiber barrel KRAB (KRAkóW Barrel). The neutron detector NeuLAND (Boretzky et al., Nuclear Inst. and Methods A 1014 (2021) 165701) with its present depth of 130 cm was placed at a lateral angle and used to measure the azimuthal angular distributions of neutrons and isotopically resolved light charged particles with respect to the reaction plane whose orientation was reconstructed from the particle distributions recorded with KRAB and with 4 double rings of the CHIMERA multi-detector placed at forward angles (Pagano et al., Nucl. Phys. A 734, (2004) 504). Elliptic flow ratios deduced from this information are known to be sensitive to the nuclear equation of state at supra-saturation densities. The analysis of the collected data sets is still proceeding. Preliminary tests performed for 400 MeV/nucleon indicate that the results obtained from the earlier FOPI-LAND (Russotto et al., Phys. Lett. B 697 (2011) 471) and ASY-EOS I (Russotto et al., Phys. Rev. C 94 (2016) 034608) experiments are supported. Final results are expected to exhibit higher statistical accuracy than achieved previously and a sensitivity covering a broader interval of densities, the latter being related to the isotopic resolution of charged particles and to the broad range of incident energies covered in the ASY-EOS II experiment. The importance of contributions coming from laboratory experiments for determining the equation of state of neutron-rich matter was highlighted in recent papers (Huth et al., Nature 606 (2022) 276; Sorensen et al., Prog. Part. Nucl. Phys. 134 (2024) 104080). New and more precise information is, in particular, needed for the interval of densities between once and twice the saturation value as outlined in the recent review (Cozma and Trautmann, Int. J. Mod. Phys. E 34 (2025) 2530001). Constraints provided by astrophysical observations mainly apply to the density region above these values. In the talk, the present situation will be discussed in connection with new contributions from nuclear experiment and theory and from astrophysics.

Keywords: Nuclear equation of state; symmetry energy; heavy-ion collisions

Charmed nuclei and exotic charmed meson production at CBM@FAIR and ALICE@LHC

Marcus Bleicher^a, Thanaporn Chimruang^{b,e}, Christoph Herold^b, Ayut Limphirat^b, Yupeng Yan^b, Jan Steinheimer^e, Benjamin Dönigus^a, Tom Reichert^c, Volodymyr Vovchenko^d

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Abstract

We make predictions for the expected multiplicities of exotic charmed hadrons and charmed nuclei in Au+Au collisions at SIS100 and LHC beam energies, using input on light hadron and charm production from the UrQMD transport model, and applying the Thermal-FIST model. We demonstrate that the CBM experiment has the capability to explore these states with production rates of one per 3 seconds for $\chi_{c0}(1P)$ and $\chi_{c1}(1P)$, and one every 3 minutes for $X(3872)$ at the expected data taking rates. Due to the higher baryon density at CBM compared to the LHC, charmed nuclei, if they exist, will be equally abundant at CBM as at the LHC, even though the total charm production at CBM is much lower.

Keywords

Heavy ion collision, charm, clusters, FAIR, CBM

Many-body nucleosynthesis in nucleus-nucleus collisions at intermediate and high energies

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Abstract

In comparison with the standard nucleosynthesis in the Universe, we expect special mechanisms of the formation of nuclei in intermediate-and high-energy nucleus-nucleus collisions. In these reactions, the excited nuclear matter (including hyper-matter) can be produced. The fragment formation can take place during the rapid expansion and de-excitation of such matter. These processes give a chance to obtain novel nuclei, which are not possible to synthesise in the standard way at low densities and energies.

The talk provides a short description of the relevant reaction mechanisms and requirements for corresponding experiments.

Precision measurement of the hypertriton lambda-binding energy via decay-pion spectroscopy at MAMI

Ryoko Kino

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Abstract

The hypertriton ($^3_\Lambda\text{H}$) is the lightest Lambda-hypernucleus, consisting of one proton, one neutron, and one Lambda. Its Lambda-binding energy (B_Λ) is one of the most fundamental observables in strangeness nuclear physics, serving as a critical benchmark for ΛN interaction models and few-body calculations. The extremely shallow binding — approximately 130 ± 50 keV from the emulsion data of Jurič *et al.* — makes the hypertriton highly sensitive to the details of the ΛN interaction, and its precise mass directly constrains few-body calculations based on hyperon–nucleon potentials. A precise determination of B_Λ is therefore indispensable for constraining hyperon–nucleon interaction potentials and for understanding hypernuclear structure from first principles.

In October 2022, we conducted decay-pion spectroscopy of electro-produced s-shell hypernuclei at MAMI, exploiting the high momentum resolution of the spectrometer system. To maximize hypertriton yield and suppress background, we employed a long Lithium target ($2,403 \text{ mg/cm}^2$) at 90 degrees and introduced a novel beam energy measurement technique that reduces the systematic uncertainty on the hypernuclear mass to the 10–20 keV level.

We report the world's most precise measurement of the hypertriton B_Λ via momentum spectroscopy of the π^- from the two-body decay $^3_\Lambda\text{H} \rightarrow ^3\text{He} + \pi^-$. This result provides the most stringent experimental constraint to date on the ΛN interaction in the $A = 3$ system, and its implications for hyperon–nucleon interaction models and the broader landscape of hypernuclear physics will be discussed.

Keywords: Hypernuclei, hypertriton, decay-pion spectroscopy

Multi-fluid hydrodynamics with continuous decoupling

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Abstract

We present a novel three-fluid hydrodynamic model with continuous decoupling of hadrons from the hydrodynamic phase to the free streaming regime. The evolution of the system is consistently described by (ideal) relativistic hydrodynamic equations, explicitly propagating all conserved quantities, i.e. four-momentum as well as baryon number, strangeness and isospin. The equations-of-motion are closed with an equation-of-state of an ideal hadron resonance gas with excluded volume. A friction term acting on the projectile and target fluid generates the fireball fluid continuously. The decoupling of hadrons from the fluid is determined by the local momentum differential emissivity and the survival probability of the respective hadron. The model is suitable for heavy-ion collisions from \$1-200A\$ GeV kinetic beam energy.

Keywords: Heavy-ion collisions, three-fluid hydrodynamics, continuous decoupling

Strong color fields as a source of non-equilibrium strangeness enhancement in heavy-ion collisions

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Abstract

Strangeness enhancement has long been considered a key signature of quark–gluon plasma (QGP) formation in heavy-ion collisions. However, measurements by the ALICE experiment have revealed enhanced strange-particle production even in small collision systems, suggesting that non-equilibrium mechanisms may contribute to observables traditionally associated with QGP formation.

One such mechanism is color-rope formation, in which overlapping color fields combine into higher SU(3) color multiplets with an increased effective string tension. These stronger color fields enhance strange-quark production, while their fluctuations can generate thermal-like particle spectra without requiring local thermal equilibrium.

To investigate their role in heavy-ion collisions, we compare rope formation implemented in the transport model SMASH with the recently developed dynamical fluidization approach, which describes the Transition from transport dynamics to hydrodynamics.

We find that, at lower collision energies, collective color-field dynamics can account for a substantial fraction of the observed strangeness production without invoking rapid thermalization. The thermal-like particle spectra generated by rope formation further suggest that such dynamics may contribute to the onset of thermalization and precede the formation of a fully thermalized medium.

Keywords: Strangeness enhancement, color ropes, deconfinement transition, heavy-ion collisions, non-equilibrium dynamics

Trace anomaly of dense matter from heavy-ion reactions and neutron stars

Bao-An Li

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Abstract

The equation of state (EOS) of neutron-rich matter governs the properties of neutron stars and their mergers, yet remains uncertain, particularly regarding the density dependence of the nuclear symmetry energy. Terrestrial heavy-ion collisions provide complementary means to probe such matter under controlled laboratory conditions.

In this talk, I will first review recent progress in constraining the EOS using both neutron star observations and heavy-ion reaction data. I will then introduce the trace anomaly of dense matter, $\Delta \equiv 1/3 - P/\epsilon$, defined through the ratio $w \equiv P/\epsilon$ of pressure P to energy density ϵ , a dimensionless quantity that characterizes the stiffness of the EOS and enables direct comparison between astrophysical and laboratory systems. I will present the first Bayesian extraction of the trace anomaly from collective flow observables in intermediate-energy heavy-ion collisions. Remarkably, the results agree quantitatively with independent constraints from neutron stars. This agreement demonstrates that these vastly different systems probe the same coarse-grained macroscopic properties of cold dense matter, establishing the trace anomaly as a unifying bridge observable.

The multi-fluid model MUFFIN: A status report

Jussi Auvinen ^a, Pasi Huovinen ^{a,b}, Iurii Karpenko ^c, Clemens Werthmann ^d

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^c*Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Czech Republic*

^d*Department of Physics and Astronomy, Ghent University, Ghent, Belgium*

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Abstract

We have been developing a three-fluid model MUFFIN (MULTi Fluid simulation for Fast IoN collisions) for describing heavy-ion collisions at RHIC Beam Energy Scan (BES) and FAIR energies. We describe the new, improved friction terms implemented in the model, and our first attempts at a Bayesian analysis of the collisions at RHIC BES energies to constrain the parameters of the model.

Femtoscopia reveals how light nuclei are formed at LHC

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Abstract

Recent ALICE measurements show that there is a prominent Delta peak in the correlation function of pion-deuteron pairs. The measurement provides the first compelling evidence that most (anti-)deuterons originate from resonance decays followed by pion-catalyzed fusion rather than direct emission. In this talk, I will review recent progress on femtoscopic correlations from experimental and theoretical sides.

Keywords: Light nuclei, femtoscopy

Turkish accelerator and radiation laboratory

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Abstract

The Turkish Accelerator and Radiation Laboratory (TARLA) is a user facility based on a superconducting linear accelerator designed to reach 40 MeV and 1.6 mA. TARLA will be equipped with two beamlines: one for bremsstrahlung, and the other for a free-electron laser. Currently, the first accelerating section, providing 20 MeV acceleration, is completed, while the second, for 40 MeV, is under construction. At present, the utilization of the operational 20 MeV section for activation and other radiation physics experiments during a pause in the 40 MeV section's construction has begun. By activating samples and using the fast sample transfer system, measurements of bremsstrahlung and decay properties of nuclei can be made. These measurements aim at measurements of half-lives of a few short-lived nuclei as demonstrator of the accelerator and sample transfer system capabilities. The aim of this research was to measure the energy transitions and half-lives of these isotopes as a test of the detector and transfer system capabilities. Following transfer, the irradiated samples will be counted using two pairs of CLOVER and single-crystal HPGe detectors with BGO active Compton suppression. Both the use of CLOVER detectors and well as active Compton suppression with BGO are a first for Türkiye, and mastering the know-how for its utilization is needed. The first part of this presentation will be devoted to the presentation of the first set of results aiming to characterise and testing capabilities of all TARLA components from the accelerator to the detectors. As the next step, the construction of two beamlines is planned. Out of these two bremsstrahlung beamline is expected to be available first and start to serve Nuclear resonance fluorescence experiments as soon as available. Complementing the standard high-flux bremsstrahlung option, we plan to develop and implement a polarized bremsstrahlung capability at TARLA. Such capability would expand our experimental potential. The conceptual design and technical considerations for generating and controlling photon polarization within the existing beamline infrastructure will be outlined. The current status of the accelerator, project plans and beam application schedule will also be presented. This presentation will detail TARLA's future plans.

Keywords: Superconducting linac, bremsstrahlung, activation, gamma-ray spectroscopy

Beta-decay properties of Rb-92 and Cs-142 within the pn-QRPA

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Abstract

The beta (β) decays of Rb-92 and Cs-142 are among the most influential contributors to the reactor antineutrino spectrum due to their high fission yields, short half-lives, and large decay Q-values, which enhance the high-energy portion of the emitted spectra. The allowed and first-forbidden beta-decay properties of Rb-92 and Cs-142 isotopes were presented in the schematic model (SM) approach within the framework of the proton-neutron-Quasi Random Phase Approximation (pn-QRPA). The Woods-Saxon (WS) potential was employed as a mean-field basis in this study. A spherical shape is assigned to each nucleus throughout all simulations. The theoretical results were compared with the corresponding experimental data and other calculation results.

Keywords: Allowed and first-forbidden transitions, schematic model, pn-QRPA, Woods-Saxon potential.

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Hunting for hypernuclei with heavy-ion beams and machine learning

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Abstract

Studies of hypernuclei have contributed significantly to our understanding of fundamental baryonic interactions as well as the properties of dense nuclear matter. In recent years, experimental hypernuclear physics has entered a new era. Hypernuclei can be investigated using energetic heavy-ion beams, and several experiments have reported unexpected results for the lightest hypernucleus, the hypertriton, including indications of a shorter lifetime and a larger binding energy than previously anticipated. One experiment has also reported evidence for a possible bound state of a Lambda hyperon with two neutrons. We investigate light hypernuclear states using approaches that differ from those of other experiments. At GSI in Germany, we employ heavy-ion beams on fixed nuclear targets using the WASA detector in combination with the Fragment Separator FRS (the WASA–FRS project) to measure hypernuclear lifetimes with high precision. The experiment was performed in 2022, and the data analysis using machine learning techniques on the hypertriton lifetime has been completed with the best accuracy. In parallel, we analyze nuclear emulsion data from the J-PARC E07 experiment, in which emulsions were irradiated with kaon beams. Using machine learning methods, we have uniquely identified events corresponding to the production and decay of the hypertriton and $^4_\Lambda\text{H}$, and have determined the binding energy of the hypertriton. We are also searching for other single-strangeness and double-strangeness hypernuclei in the E07 emulsion data to probe Lambda–nucleon, Lambda–Lambda, and Xi–nucleon interactions. In this effort, we have uniquely identified the double-Lambda hypernucleus $^{13}_{\Lambda\Lambda}\text{B}$. In addition, we are preparing a new experiment at the KLF facility at Jefferson Lab to study double-strangeness hypernuclei. In this presentation, we will discuss these projects and their current status.

Keywords: Single-Lambda and double-Lambda hypernuclei, Heavy-ion beams, Image analyses, Machine learning

Construction and benchmarks of dynamic fluidisation model for FAIR energies

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Abstract

While hybrid approaches of relativistic hydrodynamics+transport have been well established for the dynamical description of heavy-ion collisions at high beam energies, moving to lower beam energies is challenging. In this talk, I outline the construction of dynamical switching between the string/hadronic transport (SMASH) and fluid-dynamic description (vHLLE code) at low to intermediate beam energies. They are comprised of core hadrons based on the local energy density during the pre-equilibrium hadronic evolution. The so-constructed SMASH-vHLLE hybrid approach is then applied to lower beam energies, achieving good agreement with measured bulk observables between $\sqrt{s_{NN}} = 3$ and 9.1 GeV, thus providing guidance for measurements in STAR-BES and CBM at FAIR.

Energy dependence of stopping and particle production

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Abstract

Today's accelerator facilities used for studies of relativistic heavy-ion collisions cover an energy range over three orders of magnitude, from a few GeV up to a few TeV in center-of-mass energy per nucleon pair. We present a systematic overview of hadron emission in heavy-ion collisions across this entire energy range. The presented energy excitation functions of the approximated baryon and meson yields at mid-rapidity reflect the interplay between baryon stopping and particle production, both of which evolve continuously with energy. At low energies (e.g., SIS18, AGS), strong nuclear stopping leads to high net-baryon densities at mid-rapidity and to the abundant formation of nuclear clusters. With increasing collision energy, the relative baryon stopping power decreases, and meson production becomes dominant. We discuss the evolution of the inelasticity and its relation to particle production and reaction dynamics. An outlook on the physics opportunities at the FAIR facility will be given.

Deepening the latest INDRA FAZIA results at sub-saturation densities

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Abstract

We present an overview of the main scientific results carried out by the INDRA–FAZIA collaboration at GANIL, with particular emphasis on exclusive data analyses that fully exploit the unique capabilities of the experimental apparatus. Indeed, heavy-ion collisions at Fermi energies provide an ideal laboratory for investigating the interplay between mean-field dynamics and nucleon–nucleon collisions, enabling the exploration of nuclear matter under a broad range of densities, from sub-saturation values up to approximately $0.2\rho_0$ and $1.2\rho_0$.

Within this framework, isospin transport phenomena, namely isospin diffusion and isospin migration, constitute sensitive probes of the nuclear equation of state. Their study offers direct access to the density dependence of the symmetry energy, one of the least constrained components of the equation of state, and to its associated parameters.

We will discuss the methodologies developed in the most recent analyses, highlighting the observables employed to disentangle the different isospin transport mechanisms and the strategies adopted for comparison with theoretical calculations.

Keywords: Nuclear equation of state, isospin dynamics, clusters, heavy-ion collisions

Nuclei in core-collapse supernovae

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Abstract

Core-collapse supernovae (CCSNe) are one of the most fascinating phenomena in astrophysics, but the explosion mechanism is not clearly understood yet because of their intricacies. Various nuclei such as deuterons, iron, and extremely neutron-rich nuclei compose the central engines of CCSNe. The center of a collapsing core is dominated by neutron-rich heavy nuclei prior to the occurrence of core bounce. Their weak interactions significantly affect the neutrino emission and the size of the produced proto-neutron star. After a core bounce, heavy nuclei are dissolved into protons, neutrons, and light nuclei between the expanding shock wave and the newly formed neutron star. Some of the key components in determining the shock-wave dynamics and supernova explosion of outer envelopes are neutrino interactions of nucleons and light nuclei such as deuterons. I will give an overview of the role of nuclear equation-of-state in supernovae and key nuclei.

Keywords: Nuclear matter, supernova, equation of state, nuclei, deuteron, exotic nuclei

The isospin-dependent CMF-EoS in UrQMD

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Abstract

The production of light (hyper-)nuclei in AuAu collisions at the LHC allows us to study several interesting aspects. In this talk, I will discuss how the system size dependence of light nuclei production can be used to constrain the annihilation and regeneration of baryons in the hadronic phase of heavy ion collisions. In addition, I will discuss how the coalescence size of hypernuclei has a significant impact on the system size dependence of their yield. To do so, I will present recent results with the UrQMD-hybrid model and a coalescence algorithm.

Keywords: Light and hypernuclei at the LHC, baryon annihilation and system size dependence

Transport model simulations for normal and strange nuclei in heavy ion collisions

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Abstract

In this talk, we introduce recent analyses to construct nuclei and hypernuclei from heavy-ion reactions. Hybrid transport model calculations are realized by using different model parameters, and the universality of results is discussed by comparing existing experimental data. We imply that internal excitation energies of hot nuclei play a key role in constructing final nuclei for reliable model predictions. This advantage serves as a new window to extend further steps for digging into the mysteries of the exotic and strange nuclei world.

Implications of the yield ratios in central heavy-ion collisions at 270 MeV/nucleon beam energy

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Abstract

The yield ratios of light nuclei p, d, t, ^3He and ^4He produced in central collisions of $^{132}\text{Sn}+^{124}\text{Sn}$ and $^{108}\text{Sn}+^{112}\text{Sn}$ at 270 MeV/nucleon have been calculated in the framework of the statistical model with the hypothesis of local equilibrium. In this model, one may consider that the nuclei are formed at a subnuclear density from the dynamically produced baryons, which can be subdivided into the local highly excited clusters. The nucleation takes place inside these clusters in rapidly expanding nuclear matter, when the clusters enter the phase coexistence region of the nuclear liquid-gas phase transition. We compare our scaling properties of the yield ratios of particles from two systems with experimental data measured in S π RIT experiment at the Radioactive Isotope Beam Factory (RIBF)-RIKEN. Spectral ratios of isotope yields of H and He isotopes from two systems show that the isoscaling phenomenon breaks down for the cluster particles at higher transverse momenta with $p_T/A > 280$ MeV/c.

Keywords: Central collisions, local equilibrium, yield ratio, isoscaling, transverse momentum

Subthreshold particle production - a very promising research field

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Abstract

One of the primary objectives of the Beam Energy Scan (BES) program at RHIC and the future heavy-ion experiments at FAIR is to determine the nuclear equation of state (EoS) at high baryon density and temperature. Achieving this goal requires a quantitative comparison of experimental data with microscopic transport approaches in which the EoS can be varied systematically. The nuclear EoS is characterized by the energy per nucleon as a function of the baryon density, i.e. the time-like component of the baryon current in the local rest frame of the interacting matter. Existing QMD-type transport approaches have important limitations in this respect. They are either non-relativistic, include only scalar mean-field interactions (such as RQMD and UrQMD), or treat vector mean fields only approximately (such as JAM). In this work, we present a fully Lorentz-invariant formulation of the dynamics of an N -nucleon system based on covariant equations of motion. We demonstrate how this theoretical framework provides a consistent implementation of relativistic scalar and vector mean fields and can be employed to determine the nuclear equation of state over a wide range of densities and temperatures.

Keywords: Cluster production, equation-of-state

Probing the nuclear equation of state with clusters and hypernuclei

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Abstract

The study of the nuclear equation-of-state (EoS) is one of the primary goals of experimental and theoretical heavy-ion physics. The comparison of recent high-statistics data from the STAR Collaboration with transport models provides a unique possibility to address this topic in a yet unexplored energy domain. Employing the microscopic N-body Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) transport approach, which allows for describing the propagation and interactions of hadronic and partonic degrees of freedom, including cluster and hyper-nucleus formation and dynamics, we investigate the influence of different EoS on bulk observables, the multiplicity, p_T and rapidity distributions of protons, ~~as well as clusters~~ ^{and clusters} on the collective flow. We explore three different EoS: two static EoS, dubbed 'soft' and 'hard', which differ in the compressibility modulus, as well as a soft momentum-dependent EoS. We find that a soft momentum-dependent EoS reproduces most baryon and cluster observables, including the flow observables, quantitatively; however, hard EOS show a similar trend.

Keywords: Cluster production, hypernuclei, equation-of-state

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Measurement of Λ binding energies of light hypernuclei in Au+Au collisions at 3 GeV at RHIC

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Abstract

Hypernuclei, which are special nuclei formed by nucleon cores and hyperons, are ideal platforms to study the hyperon-nucleon interactions. The Λ binding energies (B_Λ) of hypernuclei are direct observables encoding the ΛN and ΛNN interactions, which shed light on solving the “hyperon puzzle” of the neutron stars. However, the measurements on the B_Λ of light hypernuclei are still controversial. Recently, the B_Λ of $^3_\Lambda\text{H}$ was measured to be 523 keV by the A1 Collaboration, which is much larger than the world average value at about 120 keV and raises a new puzzle on $^3_\Lambda\text{H}$. For the mirror hypernuclei pair with $A = 4$, $^4_\Lambda\text{H}$ and $^4_\Lambda\text{He}$, there is Charge Symmetry Breaking (CSB) between them. The difference of their B_Λ in ground state was found to be much larger than that in their excited state, revealing special features of the ΛN interaction. Independent measurements on these light hypernuclei are desired to solve these puzzles.

As a part of the STAR fixed target program, the STAR detector collected data in Au+Au collisions at 3 GeV. The high production yield of light hypernuclei provides an opportunity to measure their B_Λ . In this talk, we will present the measurement of the B_Λ of $^3_\Lambda\text{H}$, $^4_\Lambda\text{H}$, and $^4_\Lambda\text{He}$ with about 2 billion Au+Au collision events at 3 GeV collected in 2021 to address the puzzles on $^3_\Lambda\text{H}$ and the CSB on $A = 4$ mirror hypernuclei. The preliminary results will be presented together with the methods, calibrations, and systematic uncertainties of the measurements.

Keywords: Hypernuclei, Λ binding energy, heavy-ion collisions

From condensed-matter electron screening to lattice-structured active shielding: low-energy d+d fusion as a design pathway for compact space propulsion

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Abstract

Low-energy deuterium–deuterium fusion in condensed matter provides a sensitive nuclear probe of how electronic, lattice, and geometric degrees of freedom modify sub-Coulomb reaction probabilities. In this contribution, we combine an analytic finite-length metallic-wire-mesh screening framework with a system-level application concept based on lattice-structured active shielding (LSAS) for compact fusion-driven space propulsion. The central idea is not to treat electronic screening as an uncontrolled correction to a bare nuclear cross section, but to formulate it as a measurable response function of material choice, deuterium loading, wire radius, mesh spacing, and finite conductor length. The first part of the talk summarizes a static and quasi-static description of screening in deuterated metallic meshes. Four complementary closures are considered: classical Thomas–Fermi screening, a fast D-ion response limit, a momentum-integrated Thomas–Fermi form, and a Lindhard response supplemented by a constant local-field factor. These closures are combined with bound-electron permittivity, image-charge, and cohesive lattice corrections while explicitly separating static screening from dynamic dielectric response. Within fabrication-realistic parameter windows for Cu, Ag, Au, and Pd, the framework predicts screening energies in the 1–2.5 keV range as testable upper bounds, with geometry providing the dominant leverage and Pd remaining attractive because of its deuterium uptake and thermal stability. The second part connects this condensed-matter nuclear response to LSAS. In this application layer, enhanced D+D reactivity is coupled to a porous, lithium-enriched lattice architecture intended to moderate and capture a fraction of neutron energy while preserving charged-product impulse where possible. The resulting architecture should be understood as an impulse-availability and mass-reallocation strategy, not as a thrust amplifier. It therefore provides a conservative bridge between low-energy nuclear-reaction measurements and spacecraft-level performance metrics such as shielding mass, propellant allocation, thermal management, and achievable ΔV . The combined framework offers a compact route from nuclear microphysics to engineering observables: material-dependent screening modifies the entrance-channel tunneling probability; mesh geometry controls the effective electronic response; and LSAS converts part of the reaction-product energy budget into a mission-level design variable. The predictions remain analytic and intentionally bounded, but they define clear experimental tests using deuterated mesh targets, controlled beam energies below a few tens of keV, simultaneous charged-particle and neutron diagnostics, and post-irradiation material characterization. The broader aim is to establish whether electronic screening in structured condensed matter can be treated as an engineerable, reproducible, and experimentally falsifiable parameter for compact fusion studies and future micropropulsion concepts.

Keywords: D+D fusion; electron screening; metallic meshes; Thomas–Fermi response; lattice-structured active shielding; space propulsion.

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Status and preparation for the first physics with the MPD experiment at NICA

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Abstract

The Multi-Purpose Detector (MPD) is the flagship heavy-ion experiment at the NICA facility, currently under construction at JINR. Operating at center-of-mass energies of $\sqrt{s_{NN}} = 4\text{-}11$ GeV in the collider mode and $\sqrt{s_{NN}} = 2.4\text{-}3.5$ GeV in the fixed-target mode, MPD is designed to explore the high net-baryon density region of the QCD phase diagram, search for the critical end point, and investigate the predicted first-order phase transition. The experiment is moving forward, aiming for commissioning and initial data taking with Xe beams in the end of 2026. The comprehensive MPD physics program encompasses hadron spectroscopy, hypernuclei production, collective flow, fluctuations, hyperon global polarization, and electromagnetic probes. This presentation provides an up-to-date status report on the project, highlights its global competitiveness, and evaluates the feasibility of key physics measurements using the first available beams.

Anisotropic collective flow at high baryon density

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Abstract

The anisotropic collective flow is one of the important observables sensitive to the equation of state (EoS) and transport properties of the strongly interacting matter created in relativistic heavy-ion collisions. In this work, we discuss the recent flow measurements from the Beam Energy Scan programs at SIS, RHIC and the anticipated performance of the BM@N and MPD experiments at NICA.

Enhanced heating rates for superburst ignition

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Abstract

The simulation of superbursts remains challenging when Cooper pair neutrino emission in neutron star crusts is taken into account. Additional heat sources are required to sustain the thermal conditions necessary for ignition of superbursts. The γ -emissions following electron captures to excited nuclear states constitutes an important heating mechanism that can partially compensate for energy losses carried away by weak-interaction neutrinos. The results indicate that γ -emission can significantly contribute to the thermal evolution of massive stars during late stages as well as the crustal heating of accreting neutron stars [1,2]. In this work, we investigate γ -heating rates associated with the top 100 electron-capturing and positron-decaying nuclei recently identified as key contributors to changes in the electron fraction of stellar matter [3]. Calculations were performed within a microscopic framework using three sets of nuclear deformation and four pairing gap prescriptions to investigate the sensitivity of γ -heating rates to nuclear structure inputs. Our results demonstrate an impactful dependence of γ -heating rates on both nuclear deformation and pairing correlations. Variations in deformation parameters led to enhancement in heating rates up to a factor of 26, while optimizing pairing gaps enhanced the heating mechanism up to a factor of 16. The enhanced γ -heating obtained from excited-state contributions suggests a possible solution for reducing superburst ignition depths and decreasing their recurrence times [4].

Keywords: Gamma heating rates, superbursts

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The quest for light systems with extreme neutron content

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Abstract

The properties of neutral systems or systems with extreme neutron-to-proton ratios provide important constraints on the multi-neutron interaction. Despite several promising experimental results in recent years, the question of whether bound or resonant light neutral nuclei exist is not yet answered beyond doubt. Furthermore, the existence of neutral nuclei which contain one or more hyperons hyperon remain questionable. Another fundamental issue in nuclear physics is how many neutrons can be bound in an atomic nucleus with a given (small) number of protons. In this talk I will review recent experimental results on these truly exotic systems. Finally, I will discuss future perspectives in this field.

Chronology of dilepton emission in baryon-rich qcd matter as a probe of the QCD phase structure

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Abstract

Dileptons probe the full space–time evolution of baryon-rich QCD matter at FAIR energies. We disentangle equation-of-state (EoS)–driven dynamics from microscopic hadronic rescattering in low-mass dilepton production using nonequilibrium chiral fluid dynamics. Two scenarios—a first-order phase transition and a smooth crossover—are implemented along trajectories at center-of-mass energies from 2.2 to 6.2 GeV, while resonance-driven in-medium ρ and ω self-energies are employed in both cases. The time-resolved emission shows a clear chronology signal: while the pole-mass window responds early to the high-density stage, the low-mass continuum accumulates enhanced late-time emission in the phase transition scenario due to its prolonged evolution. At the lowest energies, the pole-region yields differ by up to one order of magnitude between the two scenarios. The excitation function and invariant-mass spectra retain this spectral sensitivity, demonstrating that dileptons preserve differential time-ordering information of the underlying EoS dynamics in baryon-rich matter.

Keywords: Heavy-ion collisions, phase transition, dileptons

Investigating neutron interactions and capture with complementary detector technologies

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Abstract

Neutron interactions and neutron capture processes play a central role in a wide range of applications, including neutrino physics, nuclear science, radiation detection, and particle detector development. The Erciyes Neutrino Research Group (ENRG) at Erciyes University is developing complementary detector technologies to investigate neutron interactions and capture signatures across different detection platforms. In this work, we present two ongoing experimental activities focused on neutron detection and capture. The first is a 1-ton Gadolinium-doped Water Cherenkov Detector developed at Erciyes University. The detector is being prepared for neutron-capture studies using an Am-Be neutron source. The high neutron-capture cross section of Gadolinium enables investigation of neutron-capture signatures and the associated secondary gamma-ray emission, providing an opportunity to characterize neutron-detection performance in a large-scale water-based detector. The experimental program includes studies of detector response, neutron-capture signatures, and the potential application of these techniques to future neutrino and rare-event experiments. The second project focuses on the development and characterization of Radiation-sensing Field-Effect Transistor (RadFET) detectors for radiation monitoring and neutron-related applications. The response of RadFET-based systems to gamma radiation and neutron-induced signals is being investigated, with particular emphasis on radiation sensitivity and neutron capture processes. Together, these projects demonstrate ENRG's efforts to develop novel and complementary detector technologies for neutron detection and capture studies, with potential applications in neutrino physics, nuclear technologies, radiation monitoring, and advanced particle detection.

Keywords: Neutron interactions; Neutron capture; Gadolinium-doped Water Cherenkov detector; AmBe neutron source; RadFET; Gamma radiation; Neutron detection; Radiation detection; Neutrino physics; Detector development

Acknowledgement: E. Tiras gratefully acknowledges the financial support provided by Erciyes University Scientific Research Projects Coordination Unit (BAP) under Grant No. FYG-2024-13115 and the Turkish Academy of Sciences (TÜBA) for supporting his participation in this scientific meeting.

Dilepton production in the UrQMD transport approach at SIS energies

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Abstract

Dileptons, i.e. e^+e^- and $\mu^+\mu^-$ pairs, are a unique probe of the hot and dense matter created in relativistic heavy-ion collisions. Since leptons are not affected by the strong force, they escape the reaction zone almost undisturbed. Therefore, they carry direct information from the entire space-time evolution of the system, from the first hadron-hadron collisions to the final freeze-out. In this talk, we present recent work on the description of dilepton production within the UrQMD transport approach for proton-proton and nucleus-nucleus collisions at SIS energies.

Earlier UrQMD calculations for elementary and nucleus-nucleus reactions are reproduced and extended, including $pp@1.25\text{GeV}$, $pp@2.2\text{GeV}$, $pp@3.5\text{GeV}$ and $\text{ArKCl}@1.76\text{AGeV}$. The "shining" method, in which dileptons are emitted continuously during the full propagation time of each source, is compared to a simplified approach that uses only the vacuum decay width of each resonance.

We further investigate the role of baryonic N^* resonances in the dilepton spectrum. Our calculations are confronted with HADES pion-beam data for $\pi^- + p$ reactions at a pion laboratory momentum of 685 MeV/c, which provides a clean elementary baseline for disentangling the contributions of resonant and non-resonant baryonic dilepton sources.

Keywords: Dileptons, UrQMD, SIS energies, shining method, N^* resonances, HADES

Elliptic flow of deuterons in ultrarelativistic heavy-ion collisions

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Abstract

We propose that the two mechanisms of deuteron production—coalescence and statistical production—could be distinguished by their predictions for the elliptic flow. We test this hypothesis on simulations for the production at the LHC. While in a simplified approach where hadrons are produced from an enhanced blast-wave model we observe higher elliptic flow from coalescence than statistical production, in a dynamical simulation with the help of vHLL fluid-dynamical model with SMASH afterburner we obtain higher elliptic flow from statistical production. In both cases, coalescence is compatible with experimental data while the statistical production is not.

Keywords: Deuterons, elliptic flow, coalescence

The BM@N experiment at NICA: status of the detector and progress in data analysis

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Abstract

The main goal of the NICA physics program is to study the QCD phase diagram in the poorly explored region of high net baryon density. The BM@N experiment at NICA is well suited to measuring a variety of hadron species in high-multiplicity nucleus-nucleus collisions. In order to fill the gap between measurements at low energies at SIS-18 and higher energies at AGS, the BM@N took data with Ar and Xe projectiles at beam kinetic energies of 3-4 GeV per nucleon. The study of hadron and light nuclei production in intermediate-mass systems plays a crucial role in revealing the reaction dynamics and the nuclear matter Equation of State (EoS) at densities 2–4 times higher than normal nuclear density.

This report first provides an overview of the recent upgrade in the BM@N setup. The main part discusses recent results on charged pion, kaon, proton and light nuclei production in centrality-selected Ar+A ($A=C, Al, Cu, Sc, Pb$) and Xe+CsI collisions. Particle spectra, yields, and ratios are presented and compared to transport model predictions with different EoS implementations.

High-precision spectroscopy of kaonic atoms at SIDDHARTA-2: probing fundamental interactions

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Abstract

Kaonic atoms, in which a negatively charged kaon replaces an orbital electron, provide a unique laboratory for investigating the interplay between electromagnetic and strong interactions at low energies, while also offering sensitivity to possible signatures of physics Beyond the Standard Model (BSM). This presentation will report recent high-precision spectroscopic results from the SIDDHARTA-2 experiment at the DAΦNE collider of INFN-LNF. Particular emphasis will be placed on the first measurement of kaonic deuterium, a major experimental milestone that provides essential information on the low-energy antikaon-nucleon interaction and on non-perturbative quantum chromodynamics. The high-precision spectroscopy of kaonic neon will also be discussed as a probe of bound-state quantum electrodynamics in exotic atoms. Future measurements of kaonic fluorine are especially promising, since the electromagnetic field experienced by the kaon can exceed the Schwinger critical field, opening access to bound-state QED in a largely unexplored strong-field regime. Recent theoretical studies have further demonstrated that kaonic atoms can serve as sensitive probes of BSM physics. New feebly interacting particles could produce measurable shifts in atomic transition energies or modify the dynamics of the atomic cascade. Finally, the prospects of the EXKALIBUR project will be presented. By enabling systematic spectroscopic studies of kaonic atoms across a broad range of atomic numbers, EXKALIBUR aims to establish these systems as precision tools for hadron physics, strong-field QED, charged-kaon mass measurements, and searches for new physics.

Keywords: Kaonic Atoms, QCD, QED

Hadron polarization and equation of state at FAIR/RHIC-BES energies

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Abstract

The Λ global polarization indicates that hot and dense matter created in non-central heavy-ion collisions carries large orbital angular momentum. However, the relation between hadronic polarization and the medium's collective rotation remains to be validated. Using the UrQMD transport model, we calculate the thermal vorticity-induced polarization of Λ s in Ag+Ag and Au+Au collisions from $\sqrt{s_{NN}} = 2.24\text{--}7.7$ GeV and a range of centralities. Two different equations of state used in the UrQMD simulation are compared: one resembles a hadron resonance gas, while the other is based on the chiral mean field (CMF) model, providing a more realistic description of dense nuclear matter including a chiral transition that is consistent with lattice QCD expectations. The polarization is sensitive to the equation of state and a softer EoS leads to smaller values. In addition, we show that the Λ polarization in the experimental acceptance and centrality selection does not decrease for even lower beam energies. Our results indicate that the process leading to the large vorticity is a result of the large shear in the baryon current created by its stopping.

Keywords: Heavy-ion collisions, Λ polarization, equation of state, thermal vorticity, UrQMD transport model

Microscopic folding analysis of neutron elastic scattering on ^{90}Zr

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Abstract

In this study, neutron elastic scattering on the ^{90}Zr nucleus is investigated within a microscopic folding potential framework. Ground-state nucleon density distributions are obtained using the Hartree–Fock and Hartree–Fock–Bogoliubov approximations with Skyrme and Gogny forces. These density distributions are employed to construct the real part of the neutron–nucleus optical potential through the single-folding model.

In addition, the radius (r_v) and diffuseness (a) parameters are extracted directly from the nucleon densities, while the imaginary part of the potential (W) is determined in a consistent manner. The resulting parameters V , r_v , a , and W are then implemented in the TALYS nuclear reaction code to calculate elastic scattering angular distributions.

The calculated results are compared with available experimental data in the EXFOR nuclear data library. The present analysis demonstrates that neutron elastic scattering observables on ^{90}Zr are strongly sensitive to the underlying nuclear density distributions and to the choice of effective interaction within the adopted approximations.

Keywords: Optic model, elastic scattering, Talys, angular differential cross section

Structure of light $S=-2$ hypernuclei

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Abstract

One of the important goals in hypernuclear physics is to understand hyperon-hyperon interactions. However, due to no YY scattering experimental data, it is essential to study hypernuclear structure. Especially, for the study of ΞN interaction, it is important to study the level structure of Ξ hypernuclei. For this purpose, so far I have utilised ΞN interaction with basis of the first principle calculation such as HAL QCD. In this conference, I report the level structure of light Ξ hypernuclei and how we extract information on ΞN interaction.

The INDRA+FAZIA experimental setup: recent developments and scientific opportunities at Fermi energies

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Abstract

The INDRA+FAZIA setup represents the state of the art for charged-particle detection in Europe. The INDRA detector provides a large angular acceptance, enabling a comprehensive characterization of reaction events, while FAZIA, covering the forward angular region, allows the isotopic identification of quasi-projectile (QP) fragments up to atomic numbers of about $Z = 25$.

Recently, the INDRA apparatus underwent a major electronics upgrade, which significantly extended its isotopic identification capabilities up to $Z = 10$ and substantially reduced the overall dead time of the combined INDRA+FAZIA setup.

In this contribution, the main features of the INDRA+FAZIA apparatus will be presented, together with an overview of its recent upgrades and experimental capabilities. Particular emphasis will be placed on the opportunities offered by this unique detection system for the study of heavy-ion reactions and isospin-dependent phenomena at Fermi energies.

Search for the $Y(2175)$ in the photoproduction cross section measurement of $\gamma p \rightarrow \phi \pi^+ \pi^- p$ at GlueX

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Abstract

Based on 334 pb⁻¹ of photoproduction data collected with the GlueX detector at Jefferson Lab, we have measured for the first time the cross section of the exclusive reaction $\gamma + p \rightarrow \phi(1020) \pi^+ \pi^- p$ by reconstructing the final state $K^+ K^- \pi^+ \pi^- p$ produced with a photon beam of energies between 8.0 and 11.6 GeV. Based on the measured differential cross section, we have performed a search for the strangeonium-like exotic candidate $Y(2175)$, recently renamed to $\phi(2170)$. This state has been reported by different e⁺e⁻-annihilation experiments and it is addressed here for the first time in a photoproduction experiment.

We do not find evidence for this state when using the resonance parameters quoted by the Particle Data Group and provide upper limits on the photoproduction cross section. Instead, we find a structure at a mass of $m(\phi \pi^+ \pi^-) = 2.24$ GeV/c² with a statistical significance of about 5 σ . The parameters of this structure differ from those quoted by the Particle Data Group for the $\phi(2170)$ and are consistent with a previous observation in e⁺e⁻-annihilation. In addition, there is evidence for a second structure at 1.82 GeV/c².

Comparison of classical and quantum circuit-based machine learning approaches supported by feature engineering in nuclear radius prediction

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Abstract

The nuclear charge radius, one of the fundamental physical parameters of the atomic nucleus, is a critical indicator for testing the validity of nuclear structure theories and understanding the nature of fundamental interactions. Information on the radius, a reflection of the proton and neutron distributions in the nucleus, is vital not only for nuclear physics but also for modelling astrophysical processes and precise shifts in atomic energy levels. Predicting nuclear radii with high accuracy, especially in exotic nuclei far from the line of stability where experimental data is limited, remains one of the most challenging problems in modern nuclear physics.

To go beyond traditional models in solving this problem, this study applies classical and quantum machine learning methodologies enriched with advanced feature engineering techniques. The learning performance of the models is optimized by integrating physical attributes into the dataset. In addition to classical regression algorithms, parametric quantum circuits (Variational Quantum Circuits) that encode the data into quantum states are designed and tested on nuclear data. The analyses revealed that quantum-based models exhibited competitive prediction accuracy compared to classical methods and offered strong potential for capturing complex nuclear correlations.

To ensure accessibility and ease of use of the developed models by the nuclear physics community, a user-friendly graphical interface (GUI) covering the entire process has been designed. This interface allows users to select feature engineering parameters without dealing with complex code structures, switch between classical and quantum models, and obtain real-time radius predictions for target isotopes.

Keywords: Nuclear charge radius, feature engineering, quantum Circuits (VQC), machine learning, comparative analysis

Acknowledgement: I gratefully acknowledge the financial support provided by TÜBİTAK-BİDEB through the 2224-B Grant Program for Participation in Scientific Meetings within the Country for my participation in this scientific meeting.

Genetic algorithm optimization of IBM-1 parameters for the study of some nuclear structure properties

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Abstract

In this study, some nuclear structure properties of even-even isotopes in the Si-Mg region were investigated within the interacting boson model-1 (IBM-1). The first model Hamiltonian is constructed for the given isotopes. This study aims to determine the parameters of IBM-1 model by employing the genetic algorithm (GA) optimization method. This GA method, based on artificial intelligent (AI), was implemented in python 3 on colab. For this process, the experimental data of the investigated isotopes were loaded to AI platform where compiling the ibar code of IBM-1 model. Later, the energy levels and B(E2) values of the given isotopes were calculated and compared with corresponding experimental data. Moreover, the energy ratios of the ground-state bands of the even-even Si and Mg nuclei were analyzed to see their dynamical symmetrical characteristics along each isotopic chain. This developed AI-based optimization framework is planned to be extended to neighboring isotopes across the broader Si–Mg region, including even-even Ne, Si, S, Ar isotopes.

Keywords: Genetic algorithm, artificial intelligent, IBM-1 model, energy levels, B(E2) values, Si-Mg isotopes

Acknowledgement: M. Boyukata gratefully acknowledges the financial support provided by TÜBİTAK-BİDEB through the 2224-B Grant Program for Participation in Scientific Meetings within the Country.

Flow phenomena at high nuclear densities with HADES

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Abstract

Heavy-ion collisions in the few-GeV energy range allow the creation of strongly interacting matter under extreme net-baryon densities, conditions which are comparable to the ones in neutron star mergers. The precise investigation of the Equation-of-State (EoS) of this kind of matter is therefore of high relevance for the understanding of neutron stars.

In this contribution, we present new measurements by HADES, the *High-Acceptance Dielectron Spectrometer* located at the SIS18 at GSI in Darmstadt, which is currently the only experimental setup with the unique ability to measure rare and penetrating probes at the high- μ_B frontier of the QCD phase diagram.

We discuss recent high-statistics results on collective flow phenomena in Au+Au and Ag+Ag collisions. Moreover, flow coefficients v_n up to the 6th order are investigated for the first time in this energy regime. Their combined information allows to construct for the first time a full 3D picture of the angular particle emission in momentum space. The multi-differential analysis in different centrality classes over a large region of phase space will be shown, and various scaling properties will be discussed. Furthermore, the event-by-event flow fluctuations and the correlations between the different flow coefficients can be exploited for this purpose and will also be presented.

The data provide essential constraints for theoretical transport models utilised in the determination of the properties of dense baryonic matter, such as its *viscosity* and *equation-of-state* (EOS).

Keywords: Collective flow phenomena, flow coefficients, flow fluctuations, dense baryonic matter, viscosity, equation-of-state

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Effects of Λ hyperon on nuclear structure

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Abstract

As a strange baryon free from Pauli exclusion coupling with ordinary nucleons, the Λ hyperon serves as a unique impurity to modify the intrinsic structure and bulk properties of finite nuclear systems. Based on Skyrme Hartree-Fock (SHF) theory and the density-dependent ΛN effective interaction, we systematically investigate the structural responses of hypernuclear cores induced by embedded a Λ hyperon. The deeply bound 1s-state Λ produces central attractive polarization, triggering obvious nuclear core contraction, reducing nuclear charge radius and weakening the quadrupole deformation of prolate/oblate deformed core nuclei. The p-orbital Λ bidirectionally modulates nuclear deformation, with the increase or decrease in deformation depending on whether the anisotropic distribution of the Λp orbital matches the shape of the core nucleus. Moreover, the Λ impurity stabilizes neutron/proton drip-line exotic nuclear structures via extra strange binding. This talk focuses on the structural evolution of induced Λ hyperon with SHF method, and provides structural observables to constrain updated ΛN interaction models and hypernuclear structure theories.

Keywords: Λ Hypernuclei, Skyrme Hartree-Fock theory, ΛN interaction, Λ impurity effect

Nuclear symmetry energy from neutron stars and heavy-ion collisions

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Abstract

Density dependence of the nuclear symmetry energy has been at the center of theoretical and experimental studies for a long time. Properties of nuclear matter at densities well above the saturation can be probed in two ways: through observations of neutron star properties, e.g., mass and radius, which constrain the matter at the beta-equilibrium, and in heavy-ion collisions probing the equation of state of almost symmetric nuclear matter. We show that by combining the two sources of information, we can infer the symmetry energy as a function of baryon number density in a model-independent way. We consider the realistic npem composition of the neutron star core that extends the previous analysis in [1]. Using heavy-ion collision data [2] and state-of-the-art astrophysical observations [3], we reconstruct the symmetry energy—baryon density relation with good accuracy. Using our results, we discuss whether the symmetry density may turn out to be negative and if the direct Urca reactions may occur in neutron stars.

Keywords: Nuclear equation of state, symmetry energy, neutron stars, heavy-ion collisions

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