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Book of Abstracts

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IceCube: Neutrinos and Multimessenger Astronomy

Author: Markus Ahlers[1]

[1] *NBI*

The field of high-energy neutrino astronomy is undergoing a rapid evolution. After the discovery of a diffuse flux of astrophysical TeV-PeV neutrinos in 2013, the IceCube observatory has recently found first compelling evidence for neutrino emission from blazars. In this brief review, I will summarize the status of these neutrino observations and highlight the strong role of multi-messenger astronomy for their interpretation.

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The EXP pair-potential system

Author: Andreas Kvist Bacher[1]

Co-authors: Jeppe C Dyre [1]; Thomas Schrøder [1]; Ulf R Pedersen [1]

[1] *Glas & Time, Roskilde University*

It was recently shown that the exponentially repulsive EXP pair potential defines a system of particles in terms of which simple liquids'quasiuniversality may be explained[a,b]. The quasiuniversality was illustrated by showing that the structure of the Lennard-Jones system at four state points is well approximated by those of EXP pair-potential systems with the same reduced diffusion constant[c].

The fluid phase of the EXP pair potential system was studied in two companion papers[c,d]. The study revealed the existence of two regions in the fluid: A gas phase and a liquid phase which are distinguished pragmatically by the absence or presence of a minimum in the radial distribution function above its first maximum. The existence of isomorphs has been found in both the dilute gas phase, and in the condensed liquid. The simplicity of the gas phase allows for predictions of the virial potential-energy Pearson correlation coefficient R and the density-scaling exponent in the dilute limit.
In the latest work[e] also the crystal phase has been studied and both a bcc phase and a fcc phase has been found.

a: Bacher, A. K., Schrøder, T. B. & Dyre, J. C. Explaining why simple liquids are quasi-universal. Nat. Comm. 5, 5424 (2014)
b: Dyre, J. C. Topological review: Simple liquids'quasiuniversality and the hard-sphere paradigm. J. Phys. Condens. Matter 28, 323001 (2016)
c: Bacher, A. K., Schrøder, T. B. & Dyre, J. C. The EXP pair-potential system. I. Fluid phase isotherms, isochores, and quasiuniversality. J. Chem. Phys. 149, 114501 (2018)
d: Bacher, A. K., Schrøder, T. B. & Dyre, J. C. The EXP pair-potential system. II. Fluid phase isomorphs. J. Chem. Phys. 149, 114502 (2018)
e: Pedesen, U. R., Bacher, A. K., Schrøder, T. B. & Dyre, J. C. The EXP pair-potential system. III. Thermodynamic phase diagram. J. Chem. Phys. 150, 174501 (2019)

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Simulating time-resolved X-ray experimental observables from ensembles of dynamically evolving molecular structures following photo-excitation

Authors: Hansen Bianca[1]; Nielsen Kristian[1]

Co-authors: Haldrup Kristoffer [1]; Nielsen Martin Meedom [1]; Andreasen Jens Wenzel [1]

[1] *Technical University of Denmark*

The combination of the two monomers benzothiadiazole (BT) and thiophene (T), acting as a light-absorbing unit, is an interesting research area of polymer photovoltaics. Understanding the unit BT-1T could potentially reveal a fundamental insight in the ultrafast dynamics during a photoinduced process. By combining quantum mechanical and molecular dynamics (MD) computer simulations we can facilitate this insight of how the molecular structure theoretically evolves following an excitation of the electronic system. MD is primarily used for the investigation of the excited-state solvation structure of BT-1T through classical MD simulations in terms of the solvent-solvent and solute-solvent radial distribution functions (RDFs).

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Spherical harmonics expansion: excellent tool for analysis of anisotropic small-angle scattering data

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Co-authors: Jacob Kirkensgaard [2]; Kell Mortensen [3]; Kristoffer Almdal [4]; Ole Hassager [5]; Qian Huang [5]

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[4] *Technical University of Denmark, Department of Micro- and Nanotechnology*

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With small-angle scattering, we may study the structure of (soft) matter, e.g. polymer melts, on length scales of ~1-100 nm. If there is alignment in the system on these length scales, the small-angle scattering pattern will be anisotropic.

The anisotropy of the scattering patterns can be quantified by expansion in spherical harmonics which separates contributions based on their symmetries.

We demonstrate the power of the spherical harmonics expansion framework [1], by analyzing small-angle neutron scattering data for the relaxation of a polymer melt following fast uniaxial extension, previously published in [2]. We see that the chains initially retract which was proposed in 1978 [3] and has been debated since [1, 4-7].

References

[1] Z. Wang et al, Phys Rev X 7, 031003 (2017)
[2] J.J.K. Kirkensgaard et al, Phys. Rev. E 94, 020502(R) (2016)
[3] Doi and Edwards, J. Chem. Soc., Faraday Trans. 2, 74, 1802-1817 (1978)
[4] Boue et al, Journal de Physique, 43, 137-148 (1982)
[5] Mortensen et al, MRS Proceedings, 79, 259 (1986)
[6] Blanchard et al, Phys. Rev. Lett., 95, 166001 (2005)
[7] Hsu and Kremer, Phys. Rev. Lett., 121, 167801 (2018)

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A Search for Neutrino Sources in the Local Anisotropic Universe with IceCube

Author: Étienne Bourbeau[None]

The distribution of galaxies within the local universe (LU) is characterized by discernable anisotropic features. Observatories searching for the production sites of astrophysical neutrinos can take advantage of these features to establish potential directional correlations between a neutrino dataset and overdensities in the galaxy distribution in the sky. We present the results of a correlation search between a seven-year time-integrated neutrino dataset from the IceCube Neutrino Observatory and the 2MASS Redshift Survey (2MRS) Catalog. The analysis looks for low-luminosity sources within the LU, which would produce neutrino multiplets in the IceCube dataset that directionally correlate with the galaxy distribution. No significant correlations were observed. Constraints are placed on the density of standard candle sources of neutrinos at low luminosities.

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Entanglement in quantum thermal machines

Author: Jonatan Bohr Brask[1]

[1] *DTU Physics*

Entanglement is a key resource for quantum information processing, and generating and maintaining entanglement is therefore a central challenge in quantum information science.

Entangled states are fragile and generally degrade under unavoidable interactions of a system with its environment. Surprisingly, it has nevertheless been realised that dissipation may in some cases aid the generation and stabilisation of entanglement. In particular, heat gradients can induce entanglement in a steady state out of thermal equilibrium.

I will describe small quantum thermal machines capable of generating many interesting entangled states, both bipartite and multipartite, which would be useful for quantum information processing tasks such as teleportation, quantum cryptography, sensing, and ultimately quantum computing.

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Hadron scattering amplitudes from high-performance computing

Author: John Bulava[1]

[1] *CP3-Origins, University of Southern Denmark*

The strong nuclear force is the residual interaction between hadrons, which are bound states of quarks and gluons. These fundamental particles interact via Quantum Chromodynamics (QCD), a strongly-coupled non-abelian gauge theory, which must be simulated on a discrete space-time lattice using high-performance computing resources. Such simulations are necessarily performed in 'imaginary' time, so that Monte Carlo importance sampling may be applied. While certain properties like energies and matrix elements are independent of the time signature, determining real-time scattering amplitudes from imaginary-time simulations is a challenge. Nonetheless, I will discuss recent results and future prospects for hadron scattering amplitudes from lattice QCD simulations.

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LIFE Mobile laboratory

Author: Bjarke Takashi Røjle Christensen[1]

Co-author: Henrik Busch [1]

[1] *LIFE / Novo Nordisk Foundation*

The vision of LIFE (acronym of Learning, Inspiration, Fascination & Engagement) is to create a world class learning laboratory and contribute decisively to enhancing scientific learning and education in the Danish society. Specifically, modern physical sciences cover a variety of topics, such as Atomic, molecular, and optical (AMO) physics and solid state physics, highly relevant for the science curriculum in the Danish primary schools and high schools. However, teaching exercises within these topics places high requirements on the experimental facilities and the science teachers.

Currently, some schools do not have dedicated science laboratories. Furthermore, Danish primary schools have science classes covered with certified teachers in the range of only 68% and up to 95%. This teacher coverage varies for different scientific subjects, stages of education and geographical location.

Here, we present LIFE's two approaches to meet the requirements for supporting these varying needs for laboratory facilities and certified teachers.

First, we present the experimental facilities at LIFE visitor center in Lyngby. Visiting students and teachers will be able to perform experimental work, free of charge, in the laboratories of the visitor center. The specialized laboratories for AMO physics and for nano- and solid state physics will be presented in details.

The second approach is the development of flexible mobile laboratories with trained scientific staffs. However, a stand-alone visit of a mobile laboratory has a significant risk of becoming an isolated learning experience with no connection to the curriculum and with limited impact. Here, we present LIFE's mobile laboratories integrated in 4-6 weeks courses (learning packages) developed by LIFE in order to address this risk. The plan for LIFE's mobile laboratories and learning packages is to give teachers and students the possibility to study new ideas and acquire skills through inquiry-based teaching activities in their own school and on the mobile laboratory. This is done with a strongly student- and skill-oriented educational approach based on real-life technological and scientific cases. All this is done in collaboration with innovative Danish tech-companies and key actors in scientific education. The first LIFE mobile laboratory will be ready for test in Summer 2019. The activities of LIFE are expected to expand to: 30-40 learning packages, a digital universe, a nature and science visitor center and 10 mobile laboratories. The ambition is to physically reach 17% of all Danish students nationwide by 2023.

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ATLAS Detector Upgrade for High Luminosity - Danish Contribution

Authors: Mogens Dam[1]; Stefania Xella[2]; Craig Wiglesworth[1]; Alessandra Camplani[3]; Jan Oechsle[4]; Flavia Diaz[None]

[1] *Niels Bohr Institute*

[2] *hep*

[3] *Niels Bohr Institute, University of Copenhagen*

[4] *NBI*

The LHC will undergo a luminosity upgrade by nearly a factor ten during the 2024-2016 shutdown. For this, the ATLAS detector will undergo substantial upgrades. Most important is the replacement of the complete inner tracker for a new silicon based system. The Niels Bohr Institute contributes to this in three areas: a) In a consortium between NBI and the universities in Lund, Oslo, and Uppsala, we construct and test about 650 (~6 m^2 out of a total of 165 m^2) of silicon senor modules; b) In collaboration with DESY, Hamburg we develop and construct the so-called End-of-Substructure module which is responsible for all communication between the silicon sensor modules and the outside world. Specifically NBI is responsible for the power delivery based on local DC-to-DC conversion; c) For

an improved real-time event selection, a Hardware-based Track Trigger (HTT) is being developed. This is based on high-performance Field Programmable Gate Arrays (FPGAs). The talk will describe these contributions and their current status.

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Simulated Dynamics and Clustering of Colloidal Magnetic Nanoparticles

Authors: Frederik Durhuus[1]; Lau Wandall[1]; Mathias Boisen[1]

Co-authors: Cathrine Frandsen [1]; Marco Beleggia [1]

[1] *Technical University of Denmark*

A promising bottom-up method for fabricating novel devices and structures is by magnetically guided self-assembly. To this end, precise models of magnetic particle interaction, in particular dipole-induced clustering and the properties of the aggregate structures, are necessary. We present a model of magnetic nanoparticle (MNP) interactions, implemented with a molecular dynamics algorithm, which simulates the time evolution and aggregation of colloidally suspended MNPs. Through small scale simulations, visualised with 3D animations, we give an overview of the mechanisms by which different cluster types form. We recognise three distinct clustering regimes : dissociated, linear and clustered. Based on large scale simulations, we link the appearance of these regimes to the radii of the MNPs magnetic layer and surfactant layer.

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Reform of laboratory teaching at the department of physics and astronomy, Aarhus University

Author: Hans Otto Uldall Fynbo [1]

[1] *Department of physics and Astronomy, Aarhus*

I will report on a reform of the laboratory teaching at the department of physics and astronomy, Aarhus University. Instead of having the lab teaching be an integrated part of courses on mechanics, electrodynamics, and modern physics, we have now separated all lab teaching from theoretical courses and created a programme of three experimental phuysics courses with separate learning objectives focussed on laboratory work. I will explain the ideas behind the reform, its implementation with special focus on the final course on the programme, and experiences from the first two years of following the new programme.

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Searching for the Known Unknowns: Lightening up the Dusty Universe

Author: Christa Gall[1]

[1] *Dark Cosmology Centre*

I will talk about how to use astrophysical transients to address fundamental questions about the Universe we live in. Astrophysical transients, such as massive stars exploding as supernovae, are

the spotlights of the Universe, which is filled with small solid particles, 'cosmic dust', of unknown origin. Some question which shall be addressed are: Are supernovae the long sought production factories of large cosmic dust grains? Are all types of supernovae equally productive? The discovery space opened up by new transient surveys will also enable us to find and elucidate the nature of rare and yet unknown transients and their role in the dusty universe.

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The newest results on antihydrogen from the ALPHA collaboration

Author: Peter Granum[1]

[1] *Aarhus University*

Current standard model physics require atoms and antiatoms to have the same energy spectra, but it was only in 2012 that the ALPHA collaboration as the first managed to test this prediction, by measuring a transition in trapped antihydrogen. ALPHA has made great progress since then and published measurements of several line shapes. The challenge with antimatter is of course that it is extremely difficult to handle. The ALPHA collaboration has recently made a breakthrough on a new technique for working with antihydrogen as well as improved on the existing ones. This all brings us closer to our goal of achieving hydrogen like precision for antihydrogen. The newest results on antihydrogen spectroscopy and news on the work in progress of studying the gravitational effect on antimatter will be presented in this talk.

3

Rydberg quantum optics in ultracold atomic gases

Authors: Stuti Gugnani[1]; Philipp Lunt[1]; Aksel Neilsen[1]; Nina Stiesdal[1]; Hannes Busche[1]; Mohammad Noaman[1]; Sebastian Hofferberth[1]

[1] *SDU*

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons. In our group, we explore this novel approach to realizing effective photon-photon interaction in multiple experiment setups and following two complementary approaches employing Rydberg polaritons and superatoms.

We here present our recent work on a single Rydberg superatom, an optical medium smaller than a single Rydberg blockade volume, strongly coupled to a few-photon probe field. Due to the strong coupling and the large number of atoms in the blockade volume we achieve coherent interaction even if the probe contains only few photons. With the superatom we can study the dynamics of a single two level system strongly coupled to a quantized propagating light field in free space, enabling for example the investigation of intrinsic three photon correlations mediated by a single quantum emitter. We also discuss our experimental progress towards the formation of multiple superatoms coupled to a single probe-mode.

Further we discuss our development of a new experiment designed to study the interactions between a large number of Rydberg polaritons simultaneously propagating through a medium with extremely high atomic density. Our new setup employs for the first time ultracold Ytterbium, an alkaline-earth-like element, for Rydberg quantum optics experiments. We discuss details of our experimental implementation and report on the progress towards observation of few-photon nonlinearities in Yb.

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Direct reconstruction of neutrinos in IceCube

Author: Thomas Halberg[None]

The upcoming Upgrade for the IceCube neutrino observatory will in 2022-23 deploy seven new strings featuring multi-PMT optical modules and new calibration devices, enhancing the sensitivity to O(1-100) GeV neutrinos used in atmospheric neutrino oscillation measurements. Precision reconstruction of neutrino energy and direction is essential to maximising the sensitivity of these oscillation analyses. Here a likelihood-based reconstruction algorithm where each hypothesis is generated by optimised simulations running on GPUs is presented. This method can achieve greater accuracy than existing algorithms as well as mitigating technical challenges applying previous methods to the new detector hardware.

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High-energy Neutrinos from Off-axis Emission of GRBs

Author: Lea Halser[1]

Co-author: Markus Ahlers [2]

[1] *Niels Bohr Institute*

[2] *NBI*

Gamma-ray bursts (GRBs) are transient sources at cosmological distances which for a short period of seconds can outshine all visible gamma-ray sources in the Universe. The primary origin of GRBs are cataclysmic events like the core collapse of massive stars or mergers of neutron stars. The latter have recently been observed by coincident emission in gravitational waves and photons, establishing GRBs as multi-messenger sources. Neutrinos from such events are predicted to be produced in beamed outflow jets but have not been observed yet. We present model predictions of neutrino emission from internal GRB parameters and the relative orientation of the jet axis to the observer. These predictions are used by the IceCube experiments to probe neutrino emission in coincidence with high-energy gamma-ray emission and gravitational waves.

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Measurements of the unbound 10Li with (d,p)

Authors: Jesper Halkjær Jensen[1]; Karsten Riisager[1]

[1] *Aarhus University*

The region of neutron-rich light nuclei has seen a great rise in attention over the last few decades. 11Li is a famous example of a so-called "nuclear halo", where loosely bound neutrons extends to large distances. However, to understand and aid the theoretical description we require better experimental information on both 11Li itself, but also 10Li and 9Li.
I will present our current understanding as measured by (d,p). In particular I will report on results from a campaign of (d,p) reactions using 9Li that has been carried out at ISOLDE, CERN. The newly upgrade called HIE-ISOLDE has made it possible to reach a beam energy of 8 MeV/A, giving us a large range of different beam energies in which we can compare our theoretical models for both the structure and the reaction models. I will report from experiments carried out at 2.32, 2.65, 6.7 and 8 MeV/A, and compare them to (d,p) experiments carried out at other facilities, to establish a consistent theoretical description of 10Li.

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A small drop of Quark-Gluon-Plasma

Author: Frederik Kehn[None]

A prominent method to study the initial state properties of quark-gluon-plasma (QGP) are by anisotropic flow due to the collectivity of the system. The measurements of flow by the cumulant method in small collision system may provide more knowledge to the multiplicity dependence of c2{4} and possibly the creation of the smallest drop of QGP. By comparing experimental data from ATLAS and simulated data(without flow phenomena) of proton-proton collisions at 13 TeV it is evident that there are observed collectivity of unknown origin in the experimental data from ATLAS. If this collectivity should be due to the presence of QGP cannot be drawn from this reaserch alone.

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Isomorph invariance of hydrodynamics in Lennard-Jones system

Author: Solvej Knudsen[1]

[1] *Glass & Time, Roskilde University*

For a few years it has been know, that for liquids which exhibits a strong correlation between the potential energy and the virial in some subsets of their phase diagram (called R-simple liquids), contains isomorph lines, along which properties such as structure are invariant. In this work, the hydrodynamics near the hydrodynamic limit is explored for a simple Lennard-Jones system. In particular the isomorph invariance of the hydrodynamic properties are investigated.

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Detailed look at the stellar surface using SONG

Author: Heidi Korhonen[1]

Co-authors: Frank Grundahl [2]; Mads Fredslund Andersen [2]; Victoria Antoci [2]; SONG Team

[1] *DARK, Niels Bohr Institute, University of Copenhagen*

[2] *Stellar Astrophysics Centre, Aarhus University*

The existence of cool starspots on sun-like stars has been known for more than five decades based on photometric observations. The development of observing and analysis techniques that has occurred during the past three decades has also enabled us to map in detail the starspot configurations on other stars than the Sun. Here, we will present detailed stellar surface maps of the cool giant star sigma Geminorum. The maps have been obtained from high resolution spectra obtained by the Danish-led Hertzsprung SONG telescope at the Teide Observatory on Tenerife, Spain. The data covers seven consecutive rotations and can be used for analysing in detail the starspot configurations and their evolution during this time.

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Atmospheric pressure plasmas for surface processing

Author: Yukihiro Kusano[1]

[1] *DTU Wind Energy*

A plasma is useful for industrial and material processing due to high treatment effects and environmental compatibility. Surface modification for adhesion improvement is among the most promising applications for plasmas. Practically it is realized by introducing electrical energy to a gas to generate a plasma as a reactive gas, in which a material surface is exposed. During plasma
surface treatment, addition of polar functional groups, roughening, and removal of weak domains can take place simultaneously. All of them are important to improve adhesion by better interaction with adhesives or uncured polymers in composite manufacturing. For many practical applications, atmospheric pressure plasma processing is more preferable than low pressure plasmas, as it can avoid to use expensive vacuum systems.
Here, newly developed atmospheric pressure plasmas for surface processing are presented; a gliding arc and ultrasound enhanced plasma processing. The gliding arc is characterized by stable extension of the discharge into air up to several centimeters operated by a high frequency alternating current (AC). In the optimized conditions, highly oxidative radicals are efficiently produced and used for surface processing. In addition, the discharge may not necessarily extinguish at every half period, but can survive over a plurality of AC periods, suppressing unwanted energy consumption for discharge ignition. Ultrasound enhanced plasma processing demonstrated enhanced treatment effects, arc suppression, and improved treatment-uniformity, compared to plasma processing without ultrasonic irradiation.

4

Modelling the production of terrestrial gamma-ray flashes in different cloud electric fields in conjunction with ASIM measurements

Authors: Christoph Köhn[1]; Olivier Chanrion[1]; Matthias Heumesser[1]; Krystallia Dimitriadou[1]; Torsten Neubert[1]

[1] *DTU Space, Technical University of Denmark*

Terrestrial gamma-ray flashes (TGFs), the only known natural events on Earth with energies of several tens of MeV, are produced by energetic electrons accelerated in thunderclouds in the vicinity of conducting lightning channels. But what is the real production mechanism of energetic electron and photon beams?
Launched on April, 2nd, 2018, the Atmosphere-Space Interactions Monitor (ASIM) is a collaborative project amongst the Technical University of Denmark (DTU), the European Space Agency (ESA) and various international partners. One of its main scientific goals is to study the signatures of TGFs and their connection to the parenting lightning stroke.
Recent ASIM measurements indicate that the production of energetic electrons and TGFs occur immediately prior to intracloud lightning breakdown. Inspired by this finding, we model the acceleration of electrons and the subsequent production of energetic photons in the electric field of two lightning flashes of opposite polarity and of lightning channels moving into charged cloud regions. Applying a particle Monte Carlo code, we initiate an electron current of approx. 1–2 kA from the negative channel tip and explore the process at different cloud altitudes. The code traces electrons and photons from sub-eV to tens of MeV and takes into account the self-consistent electric field resulting from ionization and charge separation of electrons and ions. We present the temporal evolution of the
electron and photon densities, energies and spectra. Finally, we relate our results to consolidated ASIM measurements and discuss the relation between measurements and simulations.

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The impact of different plasma technologies on the coating properties

Author: Nielsen Lars Pleth[1]

[1] *Tribology Center, Danish Technological Institute*

Developing new coatings and bringing them out of the R&D phase into actual applications is not an easy task. The presentation illustrates how we have developed new coatings based on reactive sputtering processes utilizing different plasma techniques, HiPIMS, pulsed DC and DC magnetron sputtering. The HiPIMS platform was used to develop a very hard TiB2 coating characterized by a low residual stress level. Pulsed DC magnetron sputtering was used to deposit a stable 50 µm thick amorphous Al2O3 coating for CERN's next generation superconducting magnets. Finally, DC magnetron sputtering was used to deposit different types of low friction carbon-based coatings tailored for different applications, such as a low-friction coating for dental application and a Si-containing a-C:H:Si coating with increased hardness and improved temperature stability as compared to a-C:H.

The developed coatings were characterized by SEM, nanoindentation, RBS, XPS, EDS, GDOES, XRD, etc. The presentation will provide examples of model tests including different types of wear tests as e.g. pin-on-disk, reciprocal sliding tests, scratch testing as well as more application-oriented tests that might be more useful when bringing new coatings into industrial applications.

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Engaging Students in Authentic Scientific Practices in Physics Lab Courses

Author: Heather Lewandowski[1]

[1] *University of Colorado*

Physics is an empirical science. Therefore, learning physics must include learning how to design and conduct experiments, analyze and interpret data, and revise models and apparatus. Physics lab courses at the introductory and upper-division levels are one of only a few opportunities for students to engage in these authentic physics practices. For many students, instructional labs are the only opportunity. However, these courses do not always have the students reach the desired learning goals. Our work looks to improve lab experiences by improving students'competency with modeling of physical and measurement systems, troubleshooting skills, documentation practices, and views of the nature of experimental physics.

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computer simulation of single parameter aging

Author: Saeed Mehri[1]

[1] *PhD Student Roskilde University*

In experimental studies of aging, the temperature T is externally controlled and identified as the phonon "bath"temperature measured on a thermometer. Aging is a non-linear phenomenon. Thus the response of the system to a small perturbation is not linear and it depends on both sign and magnitude of input. For instance, consider small up temperature and down temperature jump to the same temperature (symmetry up and down jump). The two responses will not be mirror symmetric, the down jump will appear quite flat and reaching equilibrium much faster than the up jump. The up jump –while slower in the beginning –will show steeper approach to equilibrium. This is so called fictive temperature effect, an effect which comes from the fact that the relaxation rate is structure dependent and itself evolve with time. Our main purpose of this

study is to investigate the controlling parameter behind this effect in simulation as previously confirmed in experiments.
The TN-formalism interprets aging in terms of a material time, ξ. The material time maybe thought of as a time measured on a clock with a clock rate that changes as the system ages. The material time define from the clock rate γ(t) by dξ=γ(t)dt. Suppose a single parameter that controls both clock rate and measured quantity. The physical nature of this single parameter is irrelevant. If single parameter aging obeyed, it is possible to predict one jump from the relaxation function of another jump. Single parameter aging tests were derived by Hecksher et al.2015 for jumps that ending same temperature. Lisa et al.2018 tested single parameter aging either for ending to same temperature or to different temperature. Our main purpose is to study validity of single parameter aging theory by computer simulation.

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Exploring the Climate of Exoplanets

Author: Joao Mendonca[1]

[1] *Technical University of Denmark*

In the last two decades, the astrophysical community discovered a multitude of planets orbiting other stars. The variety of planetary environments that these exoplanets may harbour is still unknown. Most importantly it propels the fundamental scientific and philosophical quest of searching for the first detection of life beyond our own planet. As more observational data become available, models of exoplanetary atmospheres are essential, at a first level to interpret the data and more importantly to reproduce and explain the physical and chemical processes that generate the climate of planets.

In this presentation, I will summarize the main new advances in the characterization of exoplanet atmospheres and describe the new state-of-the-art 3D atmospheric model I have developed from scratch called THOR. Our new model can explore the large diversity of planets to understand how their climates are generated and maintained. THOR has been used to interpret observations of hot Jupiter planets from the Spitzer and Hubble Space Telescope space missions. I will present the comparison between the predictions from our 3D simulations and observations, and discuss what we discovered on the thermal structure, distribution of clouds and chemistry of hot Jupiter atmospheres.

I will also discuss how we are testing an advanced version of THOR to study planet's habitability and search for life in exoplanets.

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VME Readout at and Below the Conversion Time Limit

Author: Michael Munch[1]

[1] *Aarhus University*

The front-end signal processing for small and medium scale experiments mostly rely on off the shelf modular electronics, which is often housed in VME crates. In addition to the constraints imposed by hardware, the achievable acquisition rates of such modules depend heavily on the readout software. In this talk, I will introduce an asynchronous readout scheme that significantly improves the livetime of an otherwise synchronous triggered VME-based data acquisition system.

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Electro-optomechanical nanomembrane arrays

Author: Sepideh Naserbakht[1]

Co-authors: Andreas Naesby ; Aurelien Dantan [2]

[1] *PhD student*

[2] *Associate professor*

Nano electro-optomechanical (NEMO) systems consisting in high-quality mechanical resonators interacting with electrical and optical fields are widely used in sensing and photonics applications. We investigate such a NEMO formed by a pair of suspended, ultrathin silicon nitride membranes. By piezoelectrically controlling the membranes' tensile stress we demonstrate tuning of their vibrational mode spectrum, strong intermode electromechanical coupling as well as enhancement of their nonlinear response.

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Quasiparticles in Topological Quantum Systems

Author: Anne Nielsen[None]

We are used to that particles can be divided into two types, namely bosons and fermions. Nevertheless, it turns out that if one puts many bosons or many fermions together, it is possible, under certain conditions, to form quasiparticles that are neither fermions, nor bosons, but anyons. Anyons have strange properties. They can, e.g., have a charge that is only a fraction of the elementary charge, and if one exchanges two anyons, the wavefunction of the system changes either by a phase factor or is transformed into a different state. Surprisingly, the change is robust against local noise. Anyons have been created in the fractional quantum Hall effect in solid state systems, but realizing them in ultracold atoms in optical lattices would give new tools to study them in detail. We therefore discuss possibilities for constructing families of fractional quantum Hall models in lattices with and without anyons, and we compute the size, shape, charge and exchange properties of the anyons.

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The role of energetic ions in fusion plasmas

Author: Stefan Kragh Nielsen[1]

[1] *DTU Physics*

This contribution will give an overview of sources of energetic ions in fusion plasmas and discuss their dynamics. Specifically, we will discuss the importance of fusion born alpha particles and their role in making fusion energy a sustainable energy source for the future.

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Evaluation of the power fall-off length in ST40 from turbulence simulations

Authors: Jeppe Olsen[1]; Anders Nielsen[2]; Jens Juul Rasmussen[2]; Daniel Iglesias[3]; Christos Stavrou[4]; Steven McNamara[4]; Volker Naulin[2]

[1] *DTU, Tokamak Energy Ltd*

[2] *DTU*

[3] *Tokamak Energy Ltd.*

[4] *Tokamak Energy Ltd*

The realisation of magnetically confined fusion power plants offers a safe, clean and inexhaustible source of energy. So far the most promising device for realising such a power plant is the so-called tokamak, a doughnut shaped torus consisting of high field magnets to encase the fusion plasma. Conventional tokamaks, such as JET in the UK, have a large column in the centre of the doughnut shape, where a large solenoid is placed. This solenoid is used for start-up of the plasma discharge and for inducing a current in the plasma to generate helical field lines, generating a stable plasma configuration. Spherical tokamaks (ST) greatly reduce the size of this central column by stripping the inboard poloidal field coils and the ohmic heating solenoid and increase the minor radius of the tokamak to create a more apple-like shape.
ST have several advantages over conventional tokamaks, including lower magnetic field requirements to achieve fusion conditions, improved plasma stability and the possibility for smaller devices for net fusion gain, which lower the costs of manufacturing[1]. However, these ST have historically been limited by the lack of space in the central column for magnetic field coils and their shielding, limiting the magnitude of corresponding magnetic field strength and thus the possibility for high fusion power gains. Recent developments in the manufacturing process of high temperature superconductors (HTS) have allowed compact high field magnets to be produced for use in devices on the scale of medium sized tokamaks, which allows for ST with fusion conditions.
Before a fusion reactor sending energy into the grid can be realised, there are a several challenges that need to be addressed. Since ST have a high power density, the corresponding heat load along the magnetic field lines towards the so-called divertor plates will be high. This parallel transport is concentrated along a narrow channel, the width of which is known as the scrape-off layer (SOL) power fall-off length, denoted λ_q [2]. In order to estimate the heat load that arrives at the divertor plates it is crucial to know λ_q. In this contribution we investigate how this width scales with a variety of different plasma parameters using the numerical plasma model, HESEL[3, 4, 5], for scenarios relevant to ST40, a novel high field spherical tokamak, located at Tokamak Energy Ltd. in the United Kingdom.

References

[1] Gryaznevich M et. al. Phys. Rev. Lett. 1998;80(18):3972.
[2] Eich T et. al. Nucl. Fusion. 2009;53(9):093031.
[3] Madsen J et. al. Phys. Plasmas. 2016;23(3):032306.
[4] Nielsen A et. al. Plasma Phys. Contr. Fusion. 2017;59:025012
[5] Olsen J et. al. Plasma Phys. Contr. Fusion. 2018;60:085018

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Multi-species Model for study of Ion Plasma Filaments

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Co-authors: Jens Rasmussen [1]; Volker Naulin [1]; Matthias Wiesenberger [1]

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In future fusion devices, such as the international tokamak ITER, the main fuel will be comprised of a mix of deuterium and
tritium to achieve self sustained fusion reactions for energy production. Additionally, in such a plasma Helium and
radiating impurities are often main components which should be considered as they can cool the plasma. In order to

further the understanding of the effect the plasma mix has on plasma turbulence and transport it is necessary to be able to model the individual species separately.
We present results on the use of a multi-species model for simulating the influence of isotopes on plasma transport and turbulence in the edge of closed magnetic field lines and scrape off layer with open magnetic field lines. The model is an extension of a previously developed single ion species model [1].

We examine the influence on multiple species with different mass and charge on the propagation of seeded density perturbations, known as blobs, as a first application of the enhanced code.
Simulations of seeded blobs show that ions with different isotope mixes can be sufficiently well described by using an effective mass or charge for ions when the ratio of densities is uniformly distributed.
In general the use of a multi ion species model presents a much more versatile tools as it can describe systems that are ill suited for effective mass and charge studies such as non-uniform density ratios.

References
[1] Madsen, J. et al, Physics of Plasmas 23, 032306 (2016)

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Predicting the Effects of Broadband Radiofrequency Radiation on Radical Pairs in Biological Systems

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Is wireless charging of our electronic devices dangerous to our cells? Large tech companies are currently developing medium and long range radiofrequency radiation (RF) wireless charging devices, making it relevant to understand potential effects on humans. Recent experiments have reported an effect of weak radiofrequency magnetic fields in the MHz-range on the concentrations of reactive oxygen species (ROS) in living cells.

Including broadband radiofrequency (BBRF) radiation in calculations is non-trivial, as methods need to account for both the oscillating nature of the fields as well as the broad spectrum of frequencies present (ie., broadband radiation). Performing calculations numerically requires discretizing the fields, both with respect to time, space, and frequency band. The computational efforts can, however, be focused on radical pairs present in biological systems, as these are the ones that respond most strongly to weak external magnetic fields. I will give a brief introduction into the challenges of resolving these obstacles, as well as our current strategy for including BBRF radiation in computational model systems.

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Solar cells of CZTS (CuZnSnS) and the first working tandem cell based on a monolithic CZTS-silicon dual-junction cell.

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The semiconducting material CZTS is considered as a promising absorber for a thin-film solar cell. In contrast to the other existing, commercially available thin-film cells of CdTe and (GICS) CuInGaSe. CZTS consists exclusively of non-toxic, environmentally available and inexpensive elements. All thin-film cells have an absorbing layer of a thickness of about 1 µm, while silicon absorbers usually are more than 150 µm thick, since the light absorption in silicon is an indirect transition, while it is a direct transition for all thin-film absorbers. One additional advantage is that cells of CZTS can be constructed with the well-known architecture from CIGS cells. The efficiency (solar energy input/ electric output) of the CZTS cells has advanced by 0.5 % per year and has recently reached 11 %.
The silicon cells and the commercial thin-film cells have reached a price level, where solar energy is competitive to other types of sustainable energy. The well-known silicon cells are the dominant cells on the world market and can only be improved marginally, since the efficiency is already close to the theoretical limit.
However, a straight –forward improvement is to place a CZTS absorber on top of a standard silicon, bottom cell. With a band gap of 1.50 eV CZTS is more efficiently absorbing visible light than silicon (with a band gap of 1.1 eV). The difficulties are two-fold - the silicon surface is not a perfect substrate for CZTS growth, and copper diffusion from the top-layer of CZTS is detrimental for the bottom silicon cell. We have overcome the difficulties by depositing an extremely thin barrier layer of TiN with atomic layer deposition (ALD) between the silicon surface and the CZTS layer. With this procedure the first monolithic CZTS-Si tandem cell has been produced.

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Predicting Scaling Properties From Individual Configuration

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The dynamics and structural properties of several classes of highly viscous liquids are invariant during changing state points. These liquid classes, called Roskilde simple liquids, experience scaled invariant curves in their thermodynamics phase diagram, which are known as the isomorphs. The hidden scale invariant curves only appear at specified state points. Prior to that, exponent of the regression slope of potential and virial phase diagram was used to estimate these points. The scaled exponent method cannot be extended for the wide range of density and it is not efficient in terms of time and energy. We, therefore, presented scaled invariant dynamical methods, such as force and torque, to predict isomorphic state points. The asymmetric and symmetric dumbbell models with constraint and harmonic spring bonds were considered to test the new methods. Although each approach indicated different results in various models, predicted points revealed the proper isomorphs. In contrast, isomorphs are not supposed to be seen in harmonic spring bonded models. Evaluating the liquids system with harmonic spring bonds indicated the kind of isomorph-like behaviours through the scaling, which are called pseudomorphs. Generating pseudisoomorphs state points requires complex arithmetic methods, but it can provide appropriate temperatures, in which the pseudoisomorphs demonstrated. Overall, the new dynamical methods provided appropriate precise state points in both constraint and spring bonds models.

2

Free-space QED with Rydberg superatoms

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Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level

of individual photons. This approach forms the basis of a growing Rydberg quantum optics toolbox, which already contains photonic logic building-blocks such as single-photon sources, switches, transistors, and photonic two-qubit gates.

For an optical medium smaller than a single Rydberg blockade volume, a large number of individual atoms behave as a single Rydberg "superatom" which can be efficiently coupled to few-photon probe pulses. The strongly enhanced collective coupling and the highly directed collective emission of this system realizes an analogue to waveguide-QED systems, which enables the study of coherent emitter-photon interaction in free-space [1]. In this talk, we present our recent investigation of intrinsic three-photon correlations mediated by a single superatom [2]. We also present our steps towards the formation of multiple superatoms coupled to a single probe-mode to realize a cascaded system of quantum emitters.

[1] A. Paris-Mandoki, C. Braun, J. Kumlin, C. Tresp, I. Mirgorodskiy, F. Christaller, H. P. Büchler, and S. Hofferberth, Phys. Rev. X 7, 41010 (2017)

[2] N. Stiesdal, J. Kumlin, K. Kleinbeck, P. Lunt, C. Braun, A. Paris-Mandoki, C. Tresp, H. P. Büchler, and S. Hofferberth, Phys. Rev. Lett. 121, 103601 (2018)

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Systematic Uncertainties from the Atmospheric Neutrino Flux in IceCube

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English:
Leading measurements of neutrino oscillations using the IceCube detector at the South Pole rely on atmospheric neutrinos as the signal flux. Presently, signal simulation is done using Monte Carlo techniques. In the future the inclusive neutrino flux can be found with analytical solutions of the cascade equation, giving a much more physical and flexible treatment of the flux. The dominant sources of uncertainty on the atmospheric neutrino flux stems from cosmic ray spectra and hadronic interactions. I am presenting work on controlling these sources of uncertainty, with the objective of limiting the overall systematic uncertainty in the recent tau neutrino appearance analysis.

Norwegian:
Når IceCube-detektoren på Sydpolen måler effekten av nøtrino-oscillasjoner, bruker de en signalfluks fra nøytrinoer produsert i atmosfæren. I dag simuleres denne fluksen med Monte Carlo-teknikker, men i framtida kan fluksen av nøytrinoer fra atmosfæren beregnes med kaskade-ligningen. Dermed blir estimeringen av signalet mer fleksibelt, fordi man innenfor eksperimentet kan bytte ut modeller for atmosfæren, interaksjoner mellom hadroner eller kosmisk stråling. Usikkerheten i fluksberegningene kommer hovedsakelig fra usikkerheter knyttet til spektrumet av kosmisk stråling og i interaksjoner mellom hadroner. Jeg vil presentere hvordan jeg har forsøkt å kontrollere disse usikkerhetene. Målsetningen for arbeidet er å minske den systematiske usikkerheten i IceCubes analyse av "tau neutrino apperance".

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Probing environmentally-induced neutrino decoherence with IceCube

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The mismatch between neutrino mass and flavor states, combined with the mass difference between these states, produces the interference phenomena known as neutrino oscillation. However, any coupling between the neutrino and the environment in which it propagates degrades the coherence between neutrinos, resulting in the damping of neutrino oscillations probability over distance. Such an environment is predicted by quantum gravity models, meaning that precision measurements of neutrino oscillations as a function of distance provide one of the only known experimental methods to probe this Planck-scale physics.

The IceCube detector at the South Pole measures atmospheric neutrinos that have traversed a range of distances, up to 12,742 km for neutrinos crossing the Earth's diameter, making it sensitive to decoherence effects. This talk will present a phenomenological model of neutrino environmental decoherence using the formalism of open quantum systems, alongside an analysis searching for this signal using 3 years of IceCube data.

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Nuclear Fusion and microwave heating

Author: Andrea Tancetti[1]

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Abstract

Energy is the white gold of our era; it is precious and essential for a broad range of basic activities like cooking, heating, communications, food production, and transports. A sustainable energy source, i.e. at the same time reliable, clean, safe, and affordable, would then be the ideal solution to meet the needs of the global population in harmony with a farsighted preservation of the environment. Such optimal solution is already known and under development worldwide even though many technical and theoretical challenges still lay along the way toward its commercial exploitation: it is the nuclear fusion reaction. The main approach to fusion reactors is Magnetic Confinement Fusion (MCF); it envisages the confinement of a hot plasma using magnetic fields in two kinds of toroidal devices, Tokamaks and Stellarators, which mainly differ for the techniques employed to produce the confining field. Given their simplest, axial-symmetric geometry, the fusion community has so far mainly focused on Tokamaks, paving the way to the International Thermonuclear Experimental Reactor (ITER), currently under construction in Southern France, aiming at demonstrating the feasibility of a fusion power plant.
In both designs, the so-called ECRH is a fundamental system to provide the necessary heating to warm the plasma up to hundreds of millions of degrees Kelvin; it exploits the resonant absorption of microwaves from electrons in cyclotron motion along the magnetic field lines at the plasma centre. Injected microwaves can, nonetheless, be scattered at the plasma edge and decay in a wide zoology of daughter waves, of no interest for plasma heating and potentially dangerous for diagnostic systems; such process is known as Parametric Decay Instability (PDI). The survey of the drivers and of the properties of PDI can therefore provide a deeper insight in the physics of plasma/wave interaction, and reduce the power loss in fusion experiments due to scattered radiation.

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Neutron Stars and Black Holes: Mergers and More Magic

Author: Thomas Tauris[1]

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The recently detected gravitational wave signals of the merger events of pairs of black holes and neutron stars have revolutionized astrophysics by revealing new sources of fundamental importance for exploring the Universe. In this talk, I will demonstrate the exotic nature and awesome physical processes related to these binary compact objects. I will show examples of our recent theoretical work

on predicting their merger rates in the local Universe, as well as their masses and spins. Finally, I will report on future avenues in this field of research –all with some tricks and a personal touch.

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Probing the universe's primordial soup at the LHC

Author: You Zhou[1]

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The primary goal of the ultra-relativistic heavy-ion collision program at the Large Hadron Collider (LHC) is to study the properties of the Quark-Gluon Plasma (QGP), a novel state of strongly interacting matter which exists in the early universe. Anisotropic flow, which quantifies the anisotropy of the momentum distribution of final state particles, is sensitive to the initial conditions and the transport properties of the created QGP. The successful description of the measured anisotropic flow coefficients by hydrodynamic calculations suggests that the created medium behaves as a nearly perfect fluid.

In this talk, I will give an experimental overview of flow measurements in large (Lead-Lead, Xeon-Xeon) and small (Proton-Lead, Proton-Proton) collisions. I will try to address, based on the companions of flow measurements and theoretical calculations, what is the properties of the QGP and the possible smallest scale of the QGP.