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NEW BEGINNINGS

The past year has been a year full of new beginnings pointing out the directions for the future work at the Discovery Center. The contours of these beginnings were already presented at the Discovery Center retreat in Elsinore in May 2015 and became more and more clear as the year passed.

Starting at the largest of scales, the scale of the Universe, I mentioned last year that the Planck team was able to dismantle a claim from the BICEP2 experiment of having seen primordial gravity waves. This was done by demonstrating that the signal could be explained by microwave emissions from interstellar dust. However, the search for signatures of gravity waves remains a holy grail for observational cosmology. So in 2015, newly appointed professor Pavel Naselsky from the Discovery Center joined a new project called DeepSpace at the Summit site at the middle of the Greenland inland ice. This project will exactly
address the foreground dust emissions and provide a solid basis for future searches for gravity waves. It is mainly financed by American NSF, but has now, thanks to the Villum Foundation and the Discovery Center, also a very important Danish contribution.

This was also the first year of the 5-year extension of the Discovery Center and thus the year where the IceCube activities at the South Pole were formally included in the activities of the center. The Discovery IceCube team is now consolidated with two PhD students and one Master student under assistant professor Jason Koskinen’s leadership. We were extremely proud to host the IceCube collaboration meeting in October 2015, with 250 people assembled in the Lundbeck Auditorium for a full week. The future activities will be influenced by a Villum Foundation grant to Jason Koskinen for a project to fully use the IceCube capabilities to constrain the conservation of probability in neutrino oscillations, the possible violation of which clearly would require “new physics”.

The theoretical activities were in 2015 more strongly focused on possible “new physics”, jargon for deviations from the Standard Model. Assistant professor Michael Trott, also supported by the Villum Foundation, has laid out a clear program for probing tensions in the data with respect to the Standard Model in a way that is model-independent, but still will point out the directions of future research in the case where a signal beyond the explanation power of the Standard Model is found.

At the end of 2015, the new associate professor, Oleg Rychayskiy, joined the NBI permanent staff in order to perpetuate the unique collaboration between theory and experiment at the Discovery Center. He is in particular pursuing the possible existence of a right-handed neutrino as a Dark Matter candidate and has even found a hint in the sky, a weak two-sigma signal, of a 7 keV mass Dark Matter particle decay into two X-rays. It will be enormously exciting to see if this signal is upheld in future satellite observations. He is also pushing the proposed SHIP experiment at CERN and was in 2015 joined by associate professor Stefania Xella of the Discovery Center contributing a concrete instrumental part of the proposed experiment in collaboration with Stockholm and Uppsala.

The “new beginning” with the highest worldwide attention was without doubt the start-up of LHC with 13 TeV proton-proton collision energy. Commissioning of the collisions started in May and had first to fight “Unidentified Flying Objects” and “Unidentified Lying Objects” shaken loose from the inner walls of the vacuum beam pipes by the new monster energy beams. The ATLAS detector was now upgraded with a new inner Silicon Pixel Layer and with a better very
forward ALFA detector with contributions from Discovery. The ALICE detector was upgraded with better particle identification capabilities. In September, the hunt for new physics started in earnest with a new tiny 25 ns spacing between each bunch-crossing. At the end of the year we could present many amazing results at 13 GeV.

Among those, there was one that stood out as an object of intense worldwide interest, namely a “bump” in the two-photon mass spectrum at about 750 GeV. Hundreds of theory papers from all over the world have ticked in with each their explanation of such a signal. We at Discovery have been busy checking everything and calculating the significance of the signal. The overall result is 3 sigma, maybe only 2. This is something that could happen by chance in one in a hundred times. By the time of the summer conferences 2016, we will know for sure whether it was indeed a statistical fluctuation or really is “new physics”.

During the last month of the year, LHC produced 208Pb + 208Pb collisions at a collision energy in the nucleon-nucleon center of mass of 5 TeV. For the most central collisions the total kinetic energy of the colliding heavy nuclei is then about 1000 TeV, the highest energy collision ever made by mankind. The first results obtained already after a few days of running and published at record speed show that the total number of charged particles produced in a single central Pb+Pb collision reaches 24000 particles, indicating that we have reached energy densities in excess of 20GeV fm-3! Two other fast track papers were completed by members of the Discovery team showing that collectivity persists and that the viscosity increases at these extreme energy densities. So stay tuned to the “Discovery channel” and read more details in the following.

January 2016

Peter Hansen

Director of the Discovery Center
NEWS FROM THE ATLAS GROUP

In June 2015, the Run II period for the Large Hadron Collider (LHC) commenced.

The ATLAS experiment has been upgraded to match the challenge of higher energy and higher rate of proton-proton collisions for 2015, and Discovery team members have contributed significantly to this upgrade.

The LHC Run II opens up the possibility for studying more rare phenomena and discovering new physics that was inaccessible in the previous run period (2010-2013). Discovery members have in 2015 focused on several research projects, which will make possible the investigation of very interesting particle physics phenomena not yet addressed. In addition, the Discovery team has also contributed to establishing the spin and parity nature of the new particle that was observed in Run I, as well as its decay into fermions.

The mass of the top quark is a fundamental parameter of the Standard Model. It is the largest scale of the model and it has the strongest interaction with the Higgs field and therefore a large effect on the yet unknown behavior of the Higgs sector. As a quark, it is neither possible nor meaningful to isolate a top quark in order to measure its mass without large, and poorly defined, theoretical corrections. A new method has been proposed by Discovery members in ATLAS that attempts to mitigate these problems by inferring the mass from quantities that only depend on the charged leptonic decay products of top quarks. This is a new approach, and it will during Run II surely provide an interesting new estimate of the mass of the heaviest of the quarks and further insights into the electroweak symmetry breaking mechanism.

The existence of a new particle has been established during Run I of the LHC. Discovery team members have helped establish its nature and determine whether it is the Standard Model Higgs boson being observed or an altogether different particle. In particular, Discovery members have proposed a new method to determine the spin of the new particle, using its decay to a pair of Z bosons, and have played a fundamental role in the statistical determination of the spin of this new particle.
The latest results state that the new particle is a state of spin 0 and parity CP=+1 at a high confidence level, consistent with the interpretation that it is the Higgs boson predicted by the Standard Model. Results can be seen in the figures below and in references [5,6].

Multi-variate techniques developed by Discovery ATLAS members can determine the nature of the newly discovered particle and discriminate spin 0 and CP=+1 from other possibilities.
This method allows for a significant enhancement in both the size and shape of the boson mass peak, together with an improved separation of the background distribution, as demonstrated in the data analysis of Run I [2,3], thereby paving the way for an increased new physics reach for Run II. This is very important, in order to assess with better tools the significance of the slight excess in diboson hadronic final states hinted by Run I data. See the figures below and reference [4].

A multi-variate technique exploiting the novel wavelet analysis method (left) developed by Discovery members, will help better discriminate signal from new heavy resonances decaying into quarks (right) and improve the sensitivity of the ATLAS experiment to new physics [1,4].


EARLY NEWS FROM RUN II AND RECENT THEORY DEVELOPMENTS

This year the Large Hadron Collider experiment at the European Center for Nuclear Physics (CERN) restarted at 13 TeV. In its initial run, it recorded a new high energy data set that has lead to analyses using 3.2 fb-1 (for the ATLAS experiment) and 2.6 fb-1 (for the CMS experiment) of data. These initial analyses have recently been reported in a special meeting at CERN on 15 December. The results of the initial data analysis indicated that the Standard Model of particle physics is, on the whole, doing quite well in describing the reported data even at this new collision energy.

Tantalizingly, there is some small evidence of an excess of measured events, in a diphoton search in both the ATLAS and CMS experiments at around 750 GeV. It deserves to be emphasized that this excess is small, and can simply be a fluctuation in the data. However, theoretical theorists are paid to be excited about such excesses, even if they are not statistically significant, and are doing their job admirably.

An enormous amount of data was recorded and reported for 13 TeV in the initial high energy run, and much more data will come in a flood in 2016. Although the current sensitivity of the data set to the SM Higgs particle is still, on the whole, poorer than the data reported at lower energies, the new operating environment of the machine offers access to many signals of more massive particles that were out of reach of the initial run, and will offer further insight into the diphoton excess.

The figure below shows the diphoton excess as reported by ATLAS.

There are great hopes for new physics scenarios at high mass scales in the context of an overall picture of LHC data, well described by the Standard Model at lower mass scales, proximate in mass to the W and
Z bosons, and even the Higgs boson. In such a situation, the approach of an Effective Field Theory (EFT) generalization of the Standard Model is extremely well motivated to develop. This effort is undergoing an intense development at the Discovery Center.

In the last year, the EFT phenomenology group has been fortunate to advance two very strong results that will have a broad impact on the use of the data set in the near future. In the context of a consistent effective field theory extension of the Standard Model, Christine Hartmann reported the full calculation of the decay of the SM Higgs boson in the context of this effective field theory to one loop order. This is a world leading calculation in this area, and has set the standard for one loop improvements of this theoretical formalism, that is simply required as the data set on the Higgs like bosons properties become more precise in the future data set. Christine went on to receive her PhD in late November of 2015 after reporting this result. In another important development, PhD student Laure Berthier reported the most comprehensive global fit to the known (pre-LHC) particle physics data, in the context of this effective field theory generalization. If the tentative hints for new physics hold up and become more statistically significant in the near future, then consistency checks against the well measured global data set in the EFT context will be required to narrow in on the most likely scenario to explain new phenomena.

In this context, these steady theory developments, combined with the tantalizing hints of a diphoton excess at larger mass scales guarantee an exciting year of LHC physics and results from the phenomenology group at the Discovery center.

This figure shows the consistency of the diphoton excess with SM Higgs data in minimal scalar models. The curves are values of a mixing parameter with the SM Higgs given as {0.1, 0.05, 0.02, 0.01} coming in from the outermost curve. The results are overlaid on the 68% and 95% CL curves from the Run I Atlas-CMS Higgs combination, fitting only to \( h \rightarrow gg, h \rightarrow \gamma \gamma \). From 1512.06799 Berthier, Cline, Shepherd, Trott.
Q-CUTS AND THE THEORY FRONTIER
The theory and phenomenology group at the Discovery Center has in 2015 continued its central international role as an important node for theoretical research in scattering amplitudes and in general particle physics phenomenology with a focus on especially effective field theory extensions of the Standard Model. This year, the group grew by three new members as David McGady and Changyong Liu were hired in postdoc positions and William Shepherd was employed as new Assistant Professor.

In formal theory, this year was marked in particular by a number of remarkable strides. Firstly, in a collaboration between the Discovery Center members Assoc. Prof. N. Emil J. Bjerrum-Bohr, Prof. Poul Henrik Damgaard, Ass. Prof. Jacob Bourjaily and MSc student Christian Baadsgaard Jepsen it was shown that
the scattering equations, recently discovered in gauge theories, can be solved using special integration rules.

Next, the same integration rules were promoted from tree level to loop level rules by the same authors in collaboration with visiting professor and Discovery Center associate Bo Feng from China. In collaboration with another Discovery Center member, Ass. Prof. Simon Caron-Huot, it was finally shown that the special linear structure of the scattering equations in fact suggests the existence of a tantalizing new concept in the amplitude field: the Q-cut. It will be exciting to investigate further in 2016 the application of the discovery of the Q-cut in particle physics computations.

2015 was also the year that NBIA and Discovery Center Assistant Professor Guido Festuccia was granted a prestigious Starting Grant from the European Research Council. Guido’s research aims at shedding light on the dynamics of strongly coupled quantum systems. These are ubiquitous in Nature: they are, for instance, central to many phenomena in condensed matter (e.g. non-Fermi liquids) and underpin also some of our understanding of nuclear forces.

In 2015, Jacob Bourjaily continued his work on providing further progress in understanding the Grassmannian formalism for amplitudes together with Prof. Nima Arkani-Hamed from the Institute for Advanced Study in Princeton. Prof. Nima Arkani-Hamed visited the Discovery Center in the fall of 2015 and gave a colloquium on a solution to the naturalness problem of the Standard Model and a specialized seminar on the recent progress in understanding the concept of the Amplituhedron, an amplitude concept of which he is the pioneer.

Discovery member Emil Bjerrum-Bohr, Prof. Barry Holstein, Ludovic Planté, Prof. John Donoghue and Prof. Pierre Vanhove also researched how to use gravity as an effective field theory, a systematic low-ener-
gy expansion of the otherwise unknown underlying quantum field theory of gravity. Its approach to computations of quantum gravity effects provides a simple path forward for quantum computations in gravity and sets a standard for how to investigate quantum effects in gravitational contexts.

In August, the group organized for the third time the workshop Current Themes in High-energy Physics and Cosmology addressing the current and future themes in theoretical particle physics and cosmology. The meeting in 2015 was well attended and featured again this year a number of top international speakers. The meeting in 2015 had a stronger focus on cosmology and many interesting and stimulating discussions took place in the informal atmosphere of the meeting.
NEWS FROM THE ALICE GROUP
The year 2015 has been an eventful one for the study of superdense strongly-interacting systems and of the Quark Gluon Plasma.

In the summer, the Large Hadron Collider resumed its physics program with p+p collisions at the unprecedented center of mass energy of 13TeV. The ALICE detector and the Danish built FMD detector were ready for the first data taking. Substantial effort has gone into improving the entire data collection and detector control system to cope with increased beam energies and intensities and ensuring a high data collection efficiency.

In late September the major conference in the field, QuarkMatter2015, took place in Kobe, Japan. The Discovery ALICE team was strongly represented with...
two talks and three posters, addressing diverse topics such as multiplicity distributions and search for Color Glass Condensate effects, study of collective effects in the Quark Gluon Plasma, full systematics of charged particle production for LHC-Run1, long range correlations in the QGP, and electrons from semi-leptonic decays of D and B mesons in Uranium collisions at RHIC.

The discussions at the meeting underscored one of the central current questions in relativistic collisions and QGP studies. What observables are unambiguous indicators of QGP formation and collectivity and to what extent is the QGP formed also in smaller collision systems such as p+p and p+Pb? The question becomes increasingly relevant as collision energies increase and very high particle production is achieved even in elementary p+p collisions.

Finally, the big highlight was the start of 208Pb + 208Pb collisions on November 25 at a collision energy in the nucleon-nucleon center of mass of 5 TeV. For the most central collisions (full overlap of the collision partners) the total kinetic energy of the colliding heavy nuclei is about 1000 TeV. So, for the first time, man-made collisions reach the petaelectronvolt (PeV) regime. We estimate that about 60% of this energy can be used to produce new particles.

This figure below shows one of the first collisions between two heavy ions (of lead) at the record-breaking energy 5.02 TeV recorded with the ALICE detector on November 25, 2015. The total energy in the collision reaches, for the first time, 1 PeV = 1000 TeV. The energy density now surpasses 20 GeV fm-3, i.e., more than 40 times the energy density of the proton.

Indeed, the first results obtained only after a few days of running and published at record speed show that the number of charged particles produced at midrapidity is dN/deta = 1943 and the total number of charged particles produced in a single central Pb+Pb collision reaches 24000 particles. A truly gigantic number that, by including the contribution from unobserved neutral particles (1/3 of the total), suggests that we have reached energy densities in excess of 20 GeV fm-3!

Similarly, another fast track paper showed that collectivity in the extremely dense strongly interacting fireball persists and that its viscosity increases with energy.

The Discovery team was at the very lead of these first publications from LHC-run 2 with team members being responsible for the analysis and paper writing of these 3 seminal papers whose results will be textbook examples for years to come.
NEWS FROM THE ICECUBE GROUP
The IceCube Neutrino Observatory is the world’s largest neutrino detector, embedded down to 2.5 km in the South Pole ice. Encompassing a total of one cubic kilometer of instrumented ice, it is the largest and most sensitive telescope for high energy neutrinos originating from violent astrophysical sources. The Discovery IceCube group focuses on using the low-energy sub array, DeepCore, to study fundamental particle physics such as neutrino oscillations and the nature of dark matter. In order to account for unexpected properties of the detector at these energies, researchers at the Discovery Center were integral in modeling, fitting, and releasing new calibrations of the glass fluorescence occurring in the detector. In addition, work is ongoing to accurately model the individual efficiencies of electronic components in the ice of Antarctica for the first time.

Photograph of the participants of the IceCube Collaboration meeting. In front, Discovery member Jason Koskinen with Discovery associate Subir Sarkar.
Students at the Discovery Center have also spent the year investigating the properties of dark matter in the galaxy. Using a previously published analysis as a template, Morten Medici has shown a significant increase in sensitivity using more accurate reconstructions and more inclusive sampling criteria. With the coming of the new year, the Discovery Center will continue to be one of the leading groups in the probing of galactic dark matter through neutrinos.

Fundamental neutrino physics is also under investigation at the Discovery Center, where Michael Larson has been studying the elusive tau neutrino events at the lowest energies of IceCube. For the first time, these events are being used to characterize and constrain the properties of neutrino oscillations. Michael is also participating in complementary analyses using the muon neutrino to measure neutrino oscillations as well as matter effects. The work done at Discovery will be instrumental in these investigations.

The Discovery Center is also invested in the proposed extension to DeepCore, the Precision Ice Cube Next Generation Upgrade (PINGU). The denser infill of the central part of the detector will lower the energy threshold even further, in order to enable crucial studies, such as determining the neutrino mass hierarchy and searches for tau neutrino appearance. Eva Hansen has developed a data filtering algorithm, allowing a direct estimate of PINGU’s ability to reject background events from atmospheric muons. This program is essential for calculating the sensitivity of the detector to all analyses, which will be decisive for the assurance of the PINGU construction.

The neutrino physics, IceCube and Antarctica combination is also great for physics outreach. The 2015 IceCube MasterClass invited high school students from all over Denmark to join a day focused on IceCube and astro-particle physics. They all expressed an honest interest and admiration for the project after the event. At the Culture Night event, IceCube group members were engaged in outreach throughout the evening, where the posters and presentations of IceCube sparked the interest of visitors, both young and old alike.
ICECUBE FALL COLLABORATION MEETING 2015

The Discovery Center hosted the IceCube Fall Collaboration Meeting with discussions on data analysis, detector operations and future extensions, which took place in October 2015 in the Lundbeck Auditorium. Discovery member Jason Koskinen and Discovery associate Subir Sarkar were chairmen of the meeting. Three talks were open to the public with one given by Discovery associate Subir Sarkar who, with his collaborators, has computed the flux of neutrinos that come from the decay of charmed mesons that are produced in the collisions between cosmic rays and the atmosphere. This neutrino flux is expected to dominate at high energies and is important to quantify in order that the cosmic origin of neutrinos can be safely established. This component of the neutrino flux has not been detected yet but the calculations suggest an imminent detection.
MEASURING B-MODE POLARIZATION FROM GREENLAND

In February 2015, Discovery member Pavel Naselsky and Discovery associate Subir Sarkar hosted a workshop that discussed the details of a future experiment on Greenland that measures the polarization of the microwave background radiation.

The dirty but most necessary aspects of the analysis of the microwave background radiation that deals with foregrounds were an important topic. Foregrounds are astrophysical sources of microwave radiation that must be subtracted from the full microwave signal before a cosmological analysis can be made. If this is
not done properly, the inferred cosmology is likely to be completely wrong. Foregrounds, which are astrophysical in origin, can therefore mimic cosmological signals. The contamination of the cosmic microwave background radiation was discussed at this workshop. New possible foreground sources of polarized radiation, such as magnetized grains and spinning dust, were also discussed. Since the intensity and emission of microwave radiation from foregrounds is not the same in all directions and for all frequencies, frequency bands and directions to probe are important considerations of such an experiment.

Later same year, the proposed experiment received financial support by the Villum Foundation. The telescope named DeepSpace will be placed on Summit Camp, which is located in the middle of Greenland.
NEWS FROM THE PLANCK TEAM
About 50 years ago, Arno Penzias and Robert Wilson, while working on the installment of a high precision microwave antenna, noticed a faint and isotropic noise-like signal—indelible and impossible to explain by known sources. With help of Robert Dicke, it was soon concluded that this “noise” in fact was of cosmological origin, namely the Cosmic Microwave Background (CMB)—a key piece of evidence for the Hot Big Bang theory. Since it decoupled from baryonic matter in the early Universe almost 14 billion years ago, this radiation has been propagating in space. Later surveys were able to measure this background more carefully from within our atmosphere as well as from space, revealing a pattern of hotter and colder areas which directly portray the fluctuations in the density of the matter the light escaped so long ago. The detailed statistical investigation of this pattern (in intensity and polarization) can therefore help probe cosmological theories at a very distant point in the past. So far this resulted in the establishment and subsequent confirmation of the so called CDM model—the (now) Standard Model of Cosmology. As some cosmological questions still remain unanswered it is of course of interest to search for possible deviations from this model, so called anomalies.

The statistical investigation of the CMB have been of major interest to our group over the last years. The involvement in the ESA mission “Planck”—the so far most precise measurement of the CMB—has brought a variety of tasks with it, including amongst others the study of systematics, anomalies, consistency with other data sets and especially foregrounds. The term “foreground” includes every non-cosmological signal which disturbs our view on the pure CMB. Our understanding of foregrounds unfortunately seems insufficient to remove these signals completely from the total signal.

Especially the recent discovery of a large galactic structure on CMB maps, namely the Galactic Radio Loop I, raises the question if there may be possible variations on known foreground components which escape current foreground removal techniques.

Large-scale correlations of the galactic radio loops with the CMB suggest the maps are contaminated.
The DeepSpace telescope which will be deployed to Greenland is light enough to be carried by two physicists.
It appears that the anomalies we notice on large scales in CMB maps resulting from these foregrounds removal procedures, may arise due to residual foreground signal. In order to be able to remove foregrounds successfully, a deeper understanding of them is essential. In contrast to the analysis of their spectral behavior, so far not much research was devoted to the statistical specification of foregrounds. In collaboration with staff from the NBIA we attempt to develop methods to do so, firstly increasing our knowledge on the more standard foregrounds, to later on perhaps draw conclusions on possible non-standard components.

Attacking the problem of foregrounds by statistical as well as physical means, we strive towards a truly clean CMB—then opening the doors to even deeper quests, like the detection of primordial gravitational waves, a general prediction of cosmological inflation. In an early phase of rapid expansion, gravitational waves are expected to be produced and stretched to cover large scales, distorting the polarization properties of the CMB in a very specific way. Measuring the CMB polarization fluctuations requires even more rigor than temperature measurements. This extremely high precision will only be achieved if we are in equally good control of the foregrounds.

Most recently, in collaboration with the University of California, Santa Barbara, a new CMB experiment is being built in Greenland and should provide the first data already in 2017. This brings our group even closer to a small scale CMB experiment, which will increase our knowledge on the CMB as well as on astrophysical matter.
DEFENDED PHD AND MSC THERSES IN 2015

PhD
Laura Jenniches:
Understanding Theoretical Uncertainties in Perturbative QCD Computations

Mads Søgaard:
Scattering Amplitudes via Algebraic Geometry Methods

Valentina Zaccolo:
Charged-Particle Multiplicity Distributions over Wide Pseudorapidity Range in Proton-Proton and Proton-Lead Collisions with ALICE

Ask Emil Løvschall-Jensen:
Search for new physics in multilepton final-states using multivariate techniques

Almut Pingel:
Tau lepton identification and studies of associated Higgs boson production with the ATLAS detector

Anne Mette Frejse:
Large Scale Anomalies of the Cosmic Microwave Background with Planck

Christine Hartmann:
A Quest for New Physics - Loop Calculation of the Higgs Decay to Two Photons in the Standard Model Effective Field Theory
MSc

Andreas Søgaard:
Boosted Bosons and Wavelets

Gorm Galster:
ATLAS Trigger: Preparations for Run II

Jeppe Trøst Nielsen:
Supernovae as Cosmological Probes

Kristoffer Levin Hansen:
Search for new physics in diphoton production with the
ATLAS detector at the LHC

Christopher Robert Jacobsen:
Automated matrix-element re-weighting in effective
field theories

Christian Brønnum-Hansen:
Event-by-event discrimination using the Matrix Element Method at Next-to-Leading Order

Anders Hammer Holm:
Starting Run 2 at the LHC – Statistical approaches
to electron identification and detector alignment in
ATLAS

Christian Baadsgaard Jepsen:
Amplitudes from string theory and the CHY formalism
SEMINARS, WORKSHOPS AND COURSES

Nordic Winter School on Cosmology and Particle Physics, 2-7 January

Measuring B-mode Polarization from Greenland, 2-4 February

Current Themes in High Energy Physics and Cosmology, 17-21 August

IceCube Collaboration Meeting, 11-16 October

Several seminars and symposia have also been arranged, see: http://discoverycenter.nbi.ku.dk/calendar/2015/prev_events2015/

DISCOVERY CENTER FINANCING

The Discovery budget for 2015 from the Danish National Research Foundation is DKK 6,797,825 (including overhead).

This amount was also in 2015 supplemented by a large number of other grants and by contributions from the University of Copenhagen. In the figure below, overhead is not included.
DISCOVERY CENTER PEOPLE

Scientific staff
Alberto Guffanti
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Ante Bilandzic
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Harald Ita, University of Freiburg  
Ian Hincliffe, Lawrence Berkeley Lab.  
Igor Novikov, Moscow University  
James Nagle, Univ. of Colorado, Boulder  
Jürgen Schukraft, CERN  
Katri Huito, University of Rome  
Leif Lönnblad, Lund University  
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Maxim Perelstein, Cornell University  
Oleg Verkhodanov, SAO, Russia  
Peter Coles, University of Sussex  
Peter Skands, Monash University, Australia  
Pierre Vanhove, IHES & Saclay  
Raju Venugopalan, Brookhaven  
Richard Ball, University of Edinburgh  
Rutt Britto, Saclay  
Slava Mukhanov, Ludwig-Maximillian University  
Stefano Forte, University of Milano  
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Urs Wiedemann, CERN  
Valery Rubakov, Brookhaven  
Zvi Bern, UCLA

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Philip Mertsch, Stanford University, USA
Kimmo Kainulainen, Jyväskyla University, FI
Roya Mohayae, University of Paris, FR
L. Planté, IHES, FR
DISCOVERY PUBLICATIONS 2015


[2] Measurement of the top pair production cross section in 8 TeV proton-proton collisions using kinematic information in the lepton+jets final state with ATLAS.

[3] Search for long-lived, weakly interacting particles that decay to displaced hadronic jets in proton-proton collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector.


[5] Search for low-scale gravity signatures in multi-jet final states with the ATLAS detector at $\sqrt{s} = 8$ TeV.

[6] Search for a new resonance decaying to a W or Z boson and a Higgs boson in the $\ell\ell/\ell\nu/\nu\nu+bb\bar{b}$ final states with the ATLAS Detector.


[8] Measurement of the top quark mass in the $tt\rightarrow$ lepton+jets and $tt\rightarrow$ dilepton channels using $\sqrt{s}$ =7 TeV ATLAS data.

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