Physics Comment

A Southern African Physics Magazine

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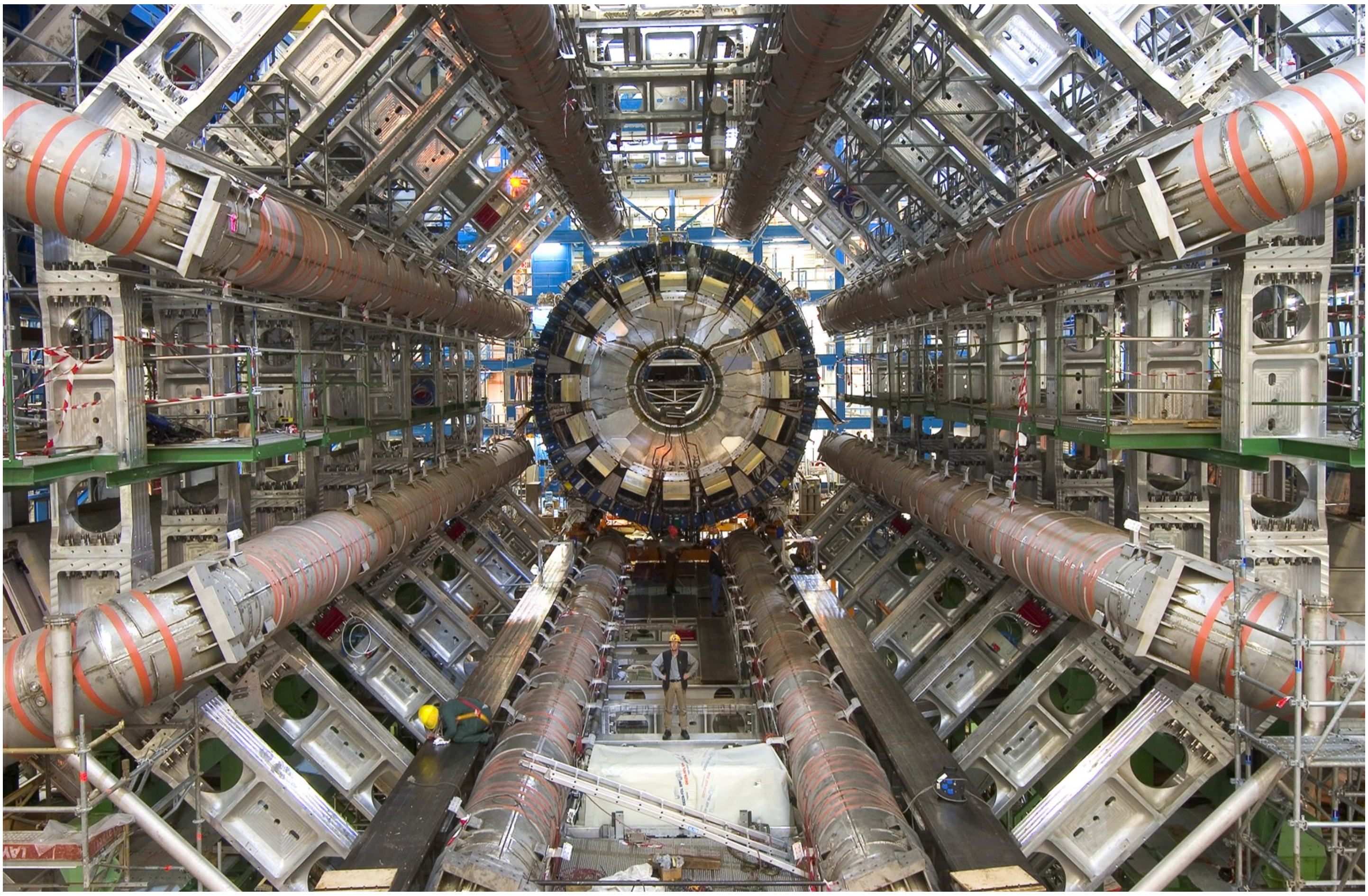
The Search for the Higgs Particle



Editor: Prof. Thomas Konrad

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Editor's Note

The year is nearly over and we had exciting news – especially concerning Physics in South Africa. In this issue we are not going to report about the SKA or the SAIP as a professional body but instead as promised on the discovery of the particle which could be the Higgs Boson. Prof Herbert Weigel from Stellenbosch University writes on the role of the elusive particle in elementary particle physics including the Higgs mechanism that generates according to the Standard Model the mass of elementary particles (pp.10). In addition, Dr Sahal Yacoob from UKZN raises the question whether the events observed in July this year at the European Centre for Nuclear Research (CERN) in Geneva, Switzerland, indicate the discovery of the famous Higgs boson. The answer is: maybe. Details can be found on pages 15 and 16. One conclusion is in my opinion inevitable from the outset, the quest for the secrets of elementary matter and forces will continue.

News & reports, as well as opportunities and conference announcements can be found as usual in this end-of-the-year issue of Physics Comment.

With my best wishes for a healthy, successful and exciting new year 2013!

Prof Thomas Konrad

Caption of photo on the title page: Photo from the installation of the ATLAS calorimeter. The eight torodial magnets can be seen on the huge ATLAS detector with the calorimeter in the centre before it was moved into the middle of the detector. **ATLAS Experiment © 2012 CERN**

Physics Comment is a journal published by the South African Institute of Physics (SAIP) and appears quaterly . The vision of the SAIP is to be the voice of Physics in South Africa.

News from South Africa

Review of Undergraduate Physics Teaching and Learning

By Dr Sam Ramaila – Chairperson: Council Education Committee (SAIP)

In terms of the key dynamics underpinning the Review of Undergraduate Physics Teaching and Learning Project, Physics departments at South African universities (traditional universities and universities of technology) have submitted the online self-evaluation reports within the stipulated deadline. The self-evaluation reports will serve to provide and develop an orientation towards the successful generation of the national report. The reports will be analyzed and evaluated by a group of experts. Given the need to reflect the profile of universities in South Africa, the Group of Experts was consolidated as follows:

Prof Craig Comrie	University of Cape Town (Retired) [Convenor]
Dr Lutz Ackermann	University of Limpopo (Retired)
Dr Mmantsae Diale	University of Pretoria
Prof Harm Moraal	North West University
Prof Ramon Lopez	University of Texas at Arlington
Prof David Wolfe	University of New Mexico (Emeritus)
Prof Makaiko Chithambo	Rhodes University
Prof Carl Wieman	University of British Columbia
Dr Joseph Asante	Tshwane University of Technology

The Group of Experts is expected to meet at the end of January 2013 to reflect on the modalities of the provisional report which will subsequently lead to the final report to be made available during March 2013. Consistent with the imperative for the provision of an analytical and critical self-appraisal of undergraduate physics teaching and learning, regional discussions were held in a bid to provide additional meaningful platforms to engage with the self-evaluation reports and to foster progressive intellectual discourse. These discussions were held as part of regional meetings hosted by University of Stellenbosch, University of KwaZulu-Natal, Nelson Mandela Metropolitan University and University of the Witwatersrand. Information elicited from these discussions will provide further valuable insights into the nature of undergraduate physics teaching and learning at South African Universities. It is envisaged that the final national report should provide contextually appropriate recommendations whose implementation would require meticulous monitoring as well as evaluation.

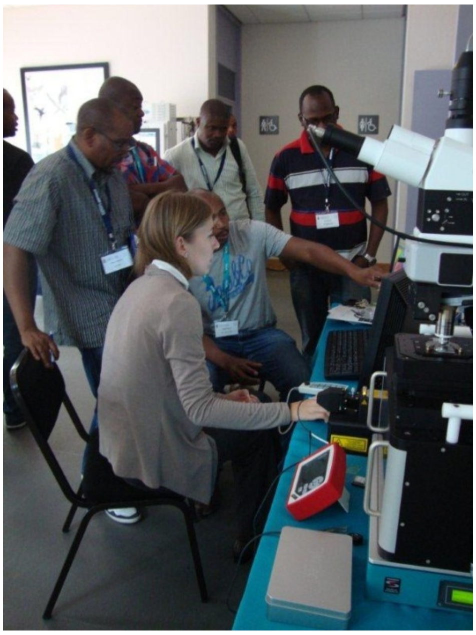
The South African Raman Workshop 2012

By Dr Werner Barnard (SASS)

The very first South African Raman Workshop was held at the University of Pretoria on the 27th and 28th of November 2012 under the auspices of the South African Spectroscopic Society (SASS) and the Physics Department of the University of Pretoria. The two-day programme was packed with lectures regarding the fundamental theory of Raman spectroscopy, the instrumental components of the Raman spectrometer and many industrial and academic research applications. The topics ranged from lasers, their safety and the application of Raman spectroscopy to the analysis of biological, geological, catalytic, material science research and online gas analysis. Four international speakers representing the various sponsors gave the workshop an international flair. These speakers, Drs Jan Toporski and Elena Bailo (WITec), Dr Tim Batten (Renishaw) and Mr Jeremy Brites (Horiba JobinYvon) gave the audience new insight into cutting edge technologies such as 3D Raman, AFM Raman and more. Professor Casper Schutte provided a fitting end to the two-day workshop with a thought provoking talk on what it means to be a spectroscopist.

It became clear from this initial workshop that two days may not be enough to cover all the needs and burning questions users in the Raman community have, as evidenced by the 170 delegates from disciplines across the scientific spectrum that attended the workshop. The buzz was palpable as many delegates (some for the first time) saw what modern Raman spectroscopy can potentially contribute to the research topics. The interaction and feedback from the workshop will contribute significantly to the way forward for the next event! We once again thank our six sponsors (WITec, Renishaw, Optograf Kaiser Analytics, Bruker Optics, Horiba Jobin Yvon and Thermo Fisher Scientific) that have made this exciting event possible through their generous sponsorships.

Sponsors of The South African Raman Workshop 2012



Dr Elena Bailo (WITec) showing delegates the mapping capabilities on their system

Delegates during a tea break at the Raman Workshop

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TUT Introduces Diploma in Industrial Physics

By Dr Joseph Asante (Tshwane University of Technology)

The Department of Physics at Tshwane University of Technology will offer a new programme, **Diploma in Industrial Physics,** as from January 2013. There are two electives under the diploma that students will be required to choose from. These are Photonics (Laser Technology) and Nuclear Technology (Radiation Protection Officer).

WHAT IS INDUSTRIAL PHYSICS?

Industrial Physics is a term used to describe physics-related work in industry. There is a global demand for skilled people within the field of Industrial Physics. Photonics and Nuclear Technology are the physics-related disciplines that the diploma seeks to equip students, along with the necessary practical skills.

Photonics

Photonics is listed as a scarce skill according to the *National Master Scarce Skills List for South Africa* published *by* the Ministry of Labour (2007). There is a need for qualified and skilled people in the Photonics and related fields. The field of Photonics is a fast growing industry in need of trained technicians. TUT Department of Physics is the only [department at a] University in South Africa that is offering this diploma programme to train photonics technicians to meet this high demand.

Nuclear Technology and Radiation Protection Officer

There is a growing demand for qualified, skilled and competent nuclear technicians in the Mining Industries, ESKOM, TELKOM, the Department of Health, NECSA and others. The technicians in the nuclear and related fields like Radiation Protection have become very scarce. Whether in producing electricity or radioactive isotopes and sources, and its applications, the nuclear industry is mindful of the environment and its protection. The qualified and skilled Nuclear Technician is required in the production, application and monitoring of all aspects and processes in the nuclear production and monitoring fields.

WHAT IS THE PURPOSE OF THIS COURSE?

The Diploma in Industrial Physics seeks to produce competent and skilled physics-related-work technicians for industry, and more so, for the photonics and nuclear industries.

The course structure of the Diploma in Industrial Physics qualification has been developed to produce students with the necessary competencies in Vacuum Technology, Non-destructive Testing, Industrial Ventilation, Metrology as well as in *either* Photonics *or* in Nuclear Technology fields.

The means of creating the physics-related-work technician will be classroom theory offering and hands on experimental practical as well as industry exposure.

Further articulation to post graduate degrees in Photonics or Nuclear Technology is also possible, after attaining the diploma.

WHAT ARE THE BENEFITS FROM THIS COURSE?

- The course will equip the student with good theoretical, scientific and practical skills and techniques needed to work in industry.
- One will obtain a qualification that is benchmarked against international standards.
- Good chances of getting work related to your qualification.
- Employment positions are:
    - Optical instrument technicians;
    - Lens coating technicians;
    - Laser application technicians;
    - Vacuum technicians and non destructive testing technicians;
    - General nuclear technician;
    - Radiation protection technicians;
    - Waste management technicians;
    - Radiation risk technicians; and
    - Radioactive contamination risk technicians.
- On successful completion of this course, Diploma in Industrial Physics, it will give the individual access to:

- various other study opportunities, e.g., Advanced Diploma, Post Graduate Diploma, masters and doctorate degrees in Photonics and Nuclear Technology;
- promotional positions in industry; and
- national or international research qualifications and bursaries.

WHY IS THIS COURSE SO UNIQUE?

- The Diploma in Industrial Physics as a study programme is offered only at TUT and no other university in the country.
- It is a study programme that has been developed from inputs from the Department of Science and Technology (DST), Photonics Initiative of South Africa (PISA), NLC-CSIR, DPSS-CSIR, Goldfields Mining, ESKOM, NECSA, Carl Zeiss, Department of Health and other industries.
- Industries have agreed to assist in the work integrated learning component of the programme.
- Well-equipped laboratories are available for practical experiments.
- Competent and experienced lecturers are involved in the delivery of the learning content.

WHAT ARE THE ADMISSION REQUIREMENTS?

A minimum total admission point score (APS) of 21 is needed for admission. A National Senior Certificate or an equivalent qualification with an achievement level of at least 4 for English (home language or first additional language), Mathematics and Physical Sciences, will be required. However, candidates with a total admission point score of 24 and more will be considered for admission. Candidates with a score of 21 to 23 will be invited to write and academic proficiency test. The APS will contribute 80% to the final admission score and the academic proficiency test, 20%.

Minimum duration: 3 years

Admission intake: only in January.

Presentation: Full time

More information:

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Join Saip Membership

By Brian Masara (SAIP office, Pretoria)

Physics is a basic science that is a basis for all science and technology disciplines. This results in physics graduates working in every sector imaginable. Therefore SAIP caters for a wide range of industries and economic sectors.

SAIP membership includes any physicists who graduated with at least physics related degree working in either; industry, commerce, government, academia, research, theoretical physics, experimental physics, and uses physics skills and thought processes in their job/career.

Why Professional Membership is Important

Academic qualifications are only the beginning of a career in physics and its applications. The need for continuing professional development is widely recognised to be the mechanism by which professionals maintain their knowledge after the formal education process has been completed. By becoming a member of a professional society one demonstrates their commitment to maintaining competence in their field through continuing your professional development from activities such as conferences, schools and workshops and abiding by an acceptable code of conduct. Membership of a professional society is an important addition to a physicist's personal credentials for example when competing for a job membership of professional society will distinguish one from other applicants with similar qualifications but no professional affiliation.

What Members say about SAIP membership

	**Dr Igle Gledhill -** It's useful to have a professional home that is not an employer or an alma mater. I came back from four years in the USA and switched fields at the same time. Funnily enough, SAIP is home – the banquet is a hoot, the conferences keep me up to date, the Institute is serious about science in South Africa and gets things done, and my colleagues keep me on my toes.
	**Dr Daniel Moeketsi -** SAIP provide a platform to showcase physics research progress and direction in the country and expose students to many career opportunities both in public and private sector. I encourage postgraduate students to subscribe for SAIP membership and actively participate in the organisation's annual activities.

Membership Benefits:

1. **Stay informed -** News flashes and alerts are sent directly to your email. Physics Comment, which appears quarterly, will keep you briefed on physics news, government policy and jobs in industry and academia.

2. **Specialist Groups and Networking -** Through the various activities of SAIP, networks have been established with the African and International Physics communities, to benefit all our members. You'll make important new contacts and forge lifelong professional relationships by getting involved in a specialist group.

3. **Save Money -** You'll receive discounted rates for SIAP conferences, and have the benefit of paying affiliate membership fees for IOP membership.

4. **Employment opportunity information -** Job advertisements will be displayed on our new website and mailed to members from time to time.

5. **Access to current information on sources of funding grants and scholarships** - Exclusive service provided to our members via a direct email system.

6. **Scientific meetings** - The annual conferences and workshops provide learning opportunities for different specialisation areas and varying degrees of experience.

7. **Especially for the global physics community -** You'll have the opportunity to partake in events organised by the SAIP for the Physics community in South Africa as well as Africa: developmental workshops, schools and conferences.

8. **Additional resources -** Your membership privileges also include information and guidance when applying for and acquiring visas to study, participate in scientific meeting and research

opportunities in South Africa and abroad. There is also an exclusive member-only area on our website.

9. **Career guidance and resources**- Career assistance is provided to all members to find their career path in industry or academia.
10. **Opportunities to win awards for excellence** - SAIP recognises contributions to physics in SA by awarding two different medals and various student prizes at the annual conference.
11. **Teaching and Learning Resources for schools** - As part of our growing outreach programme we provide teachers and learners with the tools and opportunities to allow and motivate more learners to follow careers with physics as a background.

JOIN SAIP TODAY CLICK THE LINK BELOW FOR MORE INFORMATION ON HOW TO APPLY

http://www.saip.org.za/index.php/members/membership-info

SA Physics Graduates Database

By Brian Masara (SAIP office, Pretoria)

If you have a degree in physics and you are currently working, studying or unemployed and resident in South Africa, or have studied physics in South Africa we kindly request you to sign up and give us your personal statistics. We need you! The statistics we collect, with your help, will be used to influence legislation, decision-making and all matters related to physics funding required for training more physicists.

Read more details on confidentiality and great benefits of signing up and updating your details

http://graduates.saip.org.za/background.php

To register click here http://graduates.saip.org.za/register.php?action=new

For enquiries contact SAIP Office at info@saip.org.za

Articles

The Higgs Boson in the Standard Model

By Herbert Weigel (Stellenbosch University)

Abstract

Without going into the theory details we describe the role of the Higgs boson in our current understanding of elementary particle physics.

Introduction

Elementary particle physics is described by relativistic quantum field theories. Fields are functions that depend on both position and time. A relativistic field theory is formulated to be consistent with Einstein's theory of special relativity and the quantum excitations of such fields represent elementary particles. The specific form of a field theory describes the particular interaction between the particles. This concept has proven most successful in the framework of quantum electro-dynamics (QED), the theory for the electro-magnetic interactions of charged particles such as the electron and its anti-particle, the positron. Most prominently this theory predicts the (anomalous) magnetic moment of the electron with a precision of one part in a billion. The Higgs boson is an essential ingredient to formulate a consistent quantum field theory for short range interactions [1].

Electro-Dynamics as a Quantum Field Theory

Charged particles exert the Coulomb force onto each other. In the field theory formulation this corresponds to the exchange of a photon, the quantum excitation of the electro-magnetic field. At this point Feynman diagrams (an elegant feature of quantum field theories that picture calculations for transition amplitudes and provide an intuitive description of particular processes) prove to be highly beneficial. Figure 1 contains examples for electron-positron scattering. The process in the left panel describes the emission of a photon (wiggly line) by an electron (straight line) and the subsequent absorption of the photon by the positron. The right panel represents electron-positron annihilation into a photon which then disintegrates into a new electron-positron pair.

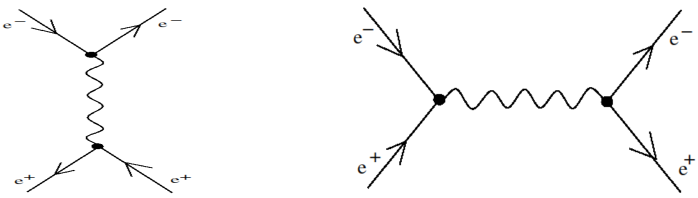

Fig. 1: Feynman diagrams for electron positron scattering with photon exchange.

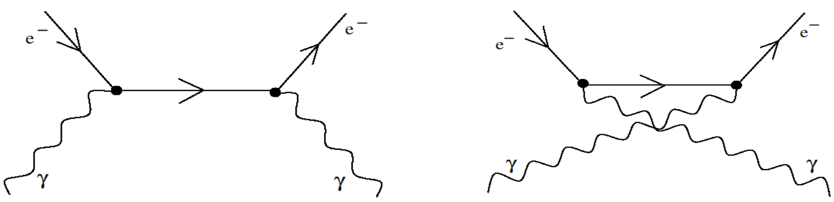

Fig. 2: Feynman diagrams for Compton scattering with electron exchange.

Feynman diagrams that represent Compton scattering are shown in figure 2. In that process an electron is exchanged. The diagrams consist of vertices, external lines that are attached to a single vertex and internal lines that connect two vertices. Vertices represent the interaction, external lines refer to particles in the initial or final states and internal lines denote exchanged particles. Energies, momenta and charges are conserved at each vertex. The most important rule for drawing diagrams in QED is that each interaction vertex has two electron/positron lines but only one photon line. Transition amplitudes are maximal when the total energy matches the mass of the exchanged particle as in resonance scattering. Quantum field theories are typically treated in perturbation theory with the order counted by the number of interaction vertices.

The photon has two degrees of freedom that measure the allowed helicities. Consistency with special relativity requires to formulate the theory in terms of the electro-magnetic potentials whose derivatives are the electric and magnetic field strengths. There are four (one scalar and three vector) potentials leaving two field components redundant. On the theory side this is reflected by the invariance of the dynamics under particular transformations among the potentials. In certain circumstances some may even be completely eliminated. This invariance is the *gauge principle* and the field containing the potentials is called the *gauge field*. To maintain this invariance gauge field interactions must render a linear relation between the energy and the momentum for the particles associated with the gauge fields. Hence these particles are massless and the celebrated mc^2 contribution to the energy is dispensed. For its force mediating role the zero mass of the photon is reflected by the long range property of the Coulomb force.

The gauge principle is generalized to other interactions (we will discuss the weak nuclear force later) by postulating that the exchange of quantum excitations of gauge fields (relatives of the photon) are the cause for the forces between matter fields (relatives of the electron).

Higher order diagrams, like the one in figure 3 that is relevant for Compton scattering, are typically singular: The momenta of the internal particles cannot be fully determined from those of the external particles (which are fixed) by momentum conservation at the vertices. This requires to integrate over all possible momenta but these integrals diverge in the ultra-violet.

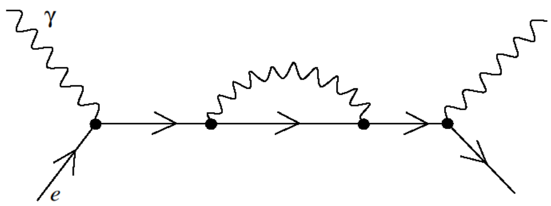

Fig. 3: Electron self-energy contribution to Compton scattering

This poses a severe problem as it would turn (at least perturbative) quantum field theory calculations meaningless. This is not the case, fortunately. The divergences can be quantified by elegant mathematical techniques and subsequently eliminated by proper redefinition of the theory parameters. Though this seems obscure, it is completely consistent. After all, the measured electron mass, charge, etc. contain all self-interactions. Yet this approach to eliminate the divergences is not possible for all quantum field theories. Those that allow this procedure are called renormalizable. Gauge theories are renormalizable [1]. This is a major reason why gauge theories are the building block for modelling elementary particle physics.

Weak Nuclear Force as a Gauge Theory

In view of the success of the gauge principle for the electro-magnetic interactions it is natural to adopt it as a prescription to model for the weak nuclear interaction. This force manifests itself most prominently in neutron β-decay: $n \rightarrow p + e^{-} + \bar{\nu}_e$, the decay products being a proton, an electron and the associated (anti)neutrino. Neutrons and protons are not elementary particles, rather they are composites characterized by their valence quark content in terms of up and down quarks: $p \sim (uud)$ and $n \sim (udd)$. On that level the β-decay is the transformation of a down quark into an up quark with the emission of an electron-(anti)neutrino pair.

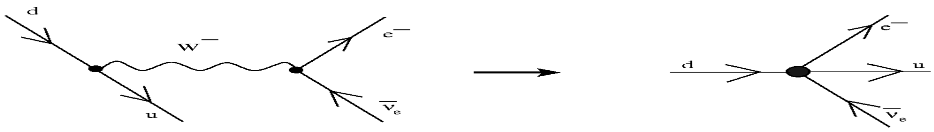

Fig. 4: Neutron β-decay on the level of elementary particles.

Since the electric charges of proton and neutron differ by one unit of elementary charge, the exchanged boson must be negatively charged. It is called the W^- boson. Its oppositely charged counterpart, the W^+ boson occurs in the inverse β-decay as*, e.g.* observed in the nuclear process of a sodium isotope: $^{22}Na \rightarrow ^{22}Ne + e^+ + \nu_e$ into neon. Both, the $W^{\pm}$, should be represented by gauge fields.

There is a major obstacle in expressing the weak nuclear interaction as a gauge theory: this force is short range and therefore cannot be described by the exchange of a massless particle. On the contrary, in the low energy regime, the weak nuclear interaction can adequately be described by a contact interaction, the Fermi-model, as suggested in the right panel of figure 4. However, this model is not renormalizable so it fails for larger energies and thus cannot be considered fundamental.

At this point the Higgs field comes in handy and resolves the dilemma: it allows to formulate a gauge invariant (and thus renormalizable) theory in which massive gauge fields are generated from self-interactions of the Higgs field without destroying renormalizability that is required for consistency of any fundamental theory.

Spontaneous Symmetry Breaking

Consider a field with two components ϕ_1 and ϕ_2 with possible self-interactions potentials as displayed in figure 5.

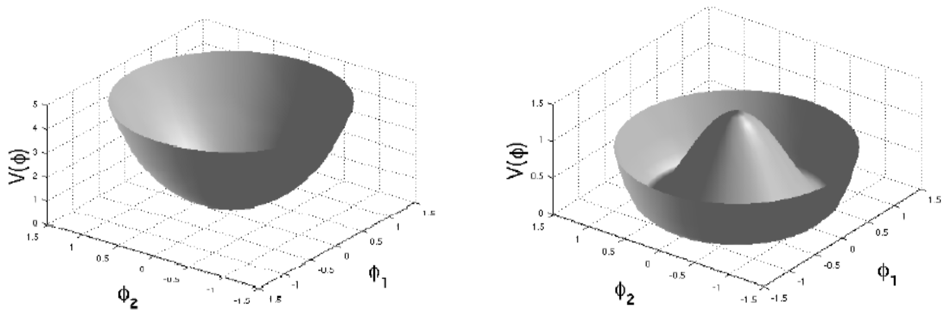

Fig. 5: Rotationally invariant potentials for the Higgs self-interaction (arbitrary units)

Gauge invariance is manifest for both examples as the potential only depends on the *length* $\phi = \sqrt{\phi_1^2 + \phi_2^2}$. However, there is a fundamental difference between the two examples of figure 5: At the center $\phi = 0$ the left one has a minimum while the right one has a (local) maximum. The quantum fluctuations are constructed about the (classical) ground state, called *vacuum*. Hence for the potential on the right, the vacuum can be any point in the circular valley of minimal potential. The radius $v \neq 0$ of this valley is the vacuum expectation value (vev) of the Higgs field. Any point on this circle qualifies for a possible vacuum configuration. A gauge transformation, here represented by rotations in the ϕ_1-ϕ_2 plane, changes the chosen vacuum state into a different but equivalent one that also minimizes the potential. This feature is known as *spontaneous symmetry breaking*. The symmetry of the interaction is not destroyed, but the vacuum state changes under the corresponding transformation. In a particular case it may actually be very difficult to deduce the symmetry. Just imagine living in a ferro-magnet where all the spins are aligned in a certain direction and try to discover that the underlying interactions do not favor a particular direction. When spontaneous symmetry breaking occurs, the quantum field formulation for the Higgs field ϕ introduces small fluctuations h about the chosen vev, and identifies the quantum excitations of h as the Higgs particle. The components ϕ_1 and ϕ_2 dwell in an internal vector-space (called weak iso-spin). They cannot be space/time components because a particular choice along the valley would then single out a particular space/time direction and thus violate the symmetry of special relativity. Hence the Higgs particle must be a boson with zero spin.

Gauge invariance then requires particular combinations of various interaction terms between the Higgs and the $W^{\pm}$. They generate Feynman diagrams in which two $W^{\pm}$ lines are connected to a single Higgs line and one in which two Higgs lines are involved. The latter is displayed on the left hand side of figure 6. The right hand side pictures the expansion $\phi \sim v + h$.

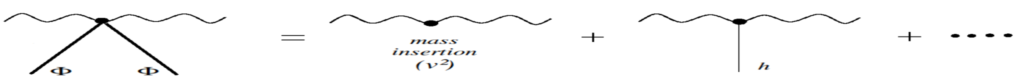

Fig. 6: Mass insertion for gauge field

The leading order, in which the dynamic Higgs field is merely replaced by its vacuum expectation value, generates the desired mass for the gauge field. The next term (linear coupling of the Higgs to the gauge field) is then a prediction of the theory. This diagram contributes to the partial decay width of the Higgs into two gauge bosons. Squaring that diagram then describes the Higgs exchange in $W^{\pm}$ scattering. That is, the corresponding cross section should be enhanced if the energy of the initial $W^{\pm}$ system approaches the Higgs boson mass.

A similar scenario holds for the (fermionic) matter fields. The expansion about the Higgs vacuum expectation value generates the fermion masses in leading order and subsequently a Feynman diagram in which the Higgs fluctuation is connected to two fermion lines. Hence the cross sections with final state fermions should also be enhanced around the Higgs mass. When combining the results from CERN searches in available channels, an enhancement at about 126GeV/c^2 was observed [2,3]. Yet this is not a complete existence proof of the Higgs boson, as the quantum numbers of the resonance have not been fully established so far.

Higgs Mechanism

In a field theory approach the mass of the quantum excitation is the curvature of the self-interaction potential at the equilibrium position. There is a remarkable feature once spontaneous symmetry breaking occurs. As seen from the right panel of figure 5, the potential does not change for fluctuations that keep the Higgs field at fixed distance from the center of the potential. Hence there is no curvature and thus the mass of these fluctuations should vanish. (This is consistent with the above statement that all points on such a circle qualify for a vacuum configuration.) This constitutes the Goldstone theorem stating that spontaneous breaking of a continuous symmetry creates massless bosons. However, for gauge symmetries this is not the end of the story. Fully identifying the particle content of the theory shows that these massless modes mix with longitudinal modes of gauge bosons that acquire a mass through the expansion pictured in figure 6. They now have three degrees of freedom, in contrast to the massless photon which only has two degrees of freedom. The Goldstone bosons are *eaten up* by the gauge fields and they do not emerge as dynamical objects. The only relevant Higgs fluctuation with particle interpretation is that orthogonal to the equi-potential circle of the self-interaction potential. So it must be massive.

Finally the particular point on the minimizing circle about which the Higgs field fluctuates must be identified. This attempts at unifying the electro-magnetic and the weak nuclear interactions to the electro weak theory that builds the *standard model*. Apart from the exchange of charged weak bosons $W^{\pm}$ the existence of a neutral weak boson Z has been empirically established, however, its coupling to the fermions differs somewhat. The unified theory starts with four gauge bosons $W^{\pm}$, W^{0} (superscripts indicate electrical charges) and B, all couple to the Higgs field and could thus acquire mass. The W's build a triplet that couples with a unique strength to the Higgs while that of the singlet B may be different. Since this singlet is electrically neutral, nothing prevents it from mixing with W^{0}. Apart from coupling constants and the value of v, the matrix that characterizes the interaction between W^{0} and B, involves the dyadic product of the vector that characterizes the direction of symmetry breaking in the ϕ_1-ϕ_2 plane. Since such a matrix can only span a subspace, it must have a zero eigenvalue. That is, a particular combination of W^{0} and B remains massless despite its coupling to a field that undergoes spontaneous symmetry breaking. This massless combination is the celebrated photon. The orthogonal combination, Z, acquires a mass which, however, is different from the $W^{\pm}$ mass. This nicely explains why the neutral and charged weak interactions differ. When constructing the standard model, the reverse path is taken. The direction of symmetry breaking is chosen such that a gauge boson with photon quantum numbers stays massless. In turn this enforces the physical component of the Higgs field (which is not eaten up by the massive gauge fields) to be electrically neutral.

Concluding Remarks

A straightforward generalization of the successful gauge principle from electro-dynamics to the weak nuclear interaction requires to postulate the Higgs boson to account for the empirically established short range of this interaction. Furthermore the introduction of this particle elegantly paves the way to unify the electro-magnetic and weak nuclear interactions into the standard model which also incorporates the strong nuclear interaction on the level of the constituents of protons and neutrons. This model has extensively been tested over the past decades with no serious failure. Yet the existence of the Higgs boson as a physical particle and in particular the determination of its mass has so far been outstanding.

All the above discussion considered the (potential) Higgs particle as an external line or as having a direct connection to an external line in Feynman diagrams. In analogy to the internal photon line of figure 3, the Higgs boson also appears as internal particle of Feynman diagrams for various processes. As a result the calculations predict a (mild, logarithmic) dependence of observables on the Higgs boson mass that effect processes other than Higgs resonance scattering. By comparing these prediction to experimental data upper limits on the Higgs mass of about 143(149)GeV/c^2 at the 95(99)% confidence level have been deducted [4]. This is consistent with recent results from CERN [2,3].

If the recent CERN findings indeed materialize as the Higgs boson they would nicely confirm the standard model. On the other hand it would be equally exciting if they did not. The latter case would signal new physics or even demand a scenario for mass generation different from the Higgs mechanism combined with spontaneous symmetry breaking.

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2. G. Aad *et al.* [ATLAS Collaboration], Phys. Lett.. B**716** (2012) 1.
3. S. Chatrchyan *et al*. [CMS Collaboration], Phys. Lett.. B**716** (2012) 30.
4. Results of precision measurements are summarized by M. Baak *et a*l., Eur. Phys. J., C**72** (2012) 2003.

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Prof Weigel has authored or co-authored two books and more than 140 articles on subjects from elementary particle physics and quantum field theory. He worked at the Universities of Tübingen and Siegen in Germany as well as at the Massachusetts Institute of Technology in the US before he joined Stellenbosch University in South Africa.

Still Searching For the Higgs Boson - how and why the new particle discovered at the LHC may not be the missing piece in the standard model puzzle

By Dr Sahal Yacoob (School of Chemistry and Physics at UKZN, Durban)

'The Higgs mechanism is responsible for electroweak symmetry breaking'. The origin of this statement lies in the unification of forces which were previously thought to be separate forces. The first time 2 different forces were 'unified' was the realisation that the descriptions of the electric and magnetic forces were linked at a fundamental level, eventually leading to the well-known Maxwell equations. The unification was the statement that these forces were linked at a fundamental level, and had a common source.

The weak nuclear force and the electromagnetic force could also be unified into a common description of the electroweak force, but for one caveat, the range of the forces concerned. Electromagnetic forces extend to infinity, while the weak force is short range (around 10^{-16} m). In a quantum field theory description this amounts to the statement that the force-carrying bosons of the electromagnetic part of the force are massless, but that the corresponding bosons responsible for the weak interaction are massive. The presence of masses for the weak force carriers is the broken symmetry that is mentioned in the opening sentence. The symmetries of the standard model require all bosons in the Lagrangian to be massless. Almost. The model requires that the Lagrangian has no *explicit* mass terms. Mass terms may be introduced dynamically via coupling to a complex valued scalar field. This is, in a nutshell, the Higgs Mechanism (described in the previous article, pp. 9). It is the simplest way to introduce a mass term dynamically while respecting the symmetries of the standard model Lagrangian. A consequence of the additional field is that there must exist a new boson with spin 0 and positive parity. Fields with a more complicated structure may be introduced to the model and have the same effect, and can be constructed to have many other observable effects while providing the mechanism for mass generation. There are many models which exist with more complicated structure than the standard model and these models may be accompanied by the prediction, or requirement that there be more than one additional fundamental particle added to those which we commonly accept to have been observed. The standard model of particle physics includes the Higgs mechanism with exactly one spin 0 positive parity boson in addition to the already discovered fundamental particles.

The standard model of particle physics which has the very annoying property of withstanding experimental scrutiny for the better part of 50 years is unfortunately incomplete (even if we have found THE Higgs boson). There are too many questions that it does not answer, for example this model of fundamental particles and their interactions does not provide a dark matter candidate, nor do we have an explanation for the chiral nature of the weak interaction. Further examples may include more fundamental questions like why we have 4 spatial dimensions, or 3 generations / families of matter. Glaringly, it fails to describe gravity. Being in the position of having a model which stands up to experimental scrutiny in all tests that one can conceive yet fails to satisfy as a true full description of all fundamental interactions is frustrating to say the least. The requirement from the standard model that the Higgs Boson must exist, and the experimental lack of observation has long been the most promising avenue to search for a hint as to what may be the true theory behind the standard model. Precision measurements of massive particles provide constraints on the allowed mass of the Higgs boson, and direct experimental searches determine whether or not a particle which has the properties of the Higgs boson exists in the allowed mass space. Without the Higgs boson the standard model is not able to accommodate the observed massive bosons of the weak force, even more alarmingly without either the Higgs boson (or a similar new particle from a more involved model) certain probabilities will have values greater than unity at high momentum transferred.

Within this context we can say right now that a new particle has been discovered jointly by the ATLAS and CMS collaborations at the Large Hadron Collider in Geneva, Switzerland. The background-only hypothesis (i.e. that there is no new particle) is disfavoured by 5.9 standard deviations by the ATLAS collaboration and 6.8 standard deviations by the CMS collaboration (for comparison 6 (7) standard deviations amounts to a 1 in 1013594692 (781364430890) chance that we are observing a fluctuation of the background and not a new particle). One now has to characterise this new particle. Is it the Higgs boson of the standard model? If not – is it well described by any of the plethora of other models that have been proposed? Does it give us a clue to the underlying theory?

The process of determining whether or not the new particle is the standard model Higgs boson is relatively straight forward. The standard model Higgs boson properties are fixed (once its mass is known). The high resolution decay channels (where the Higgs decays into either two photons or two Z bosons which decay further to either electron or muon pairs) in which the new particle was seen can be used to determine its mass. The CMS collaboration measures this to be 125.8 ± 0.4 (stat.) ± 0.4 (syst.) in agreement with indirect constraints from the standard model. The information about the production rates and branching fractions is presented in terms of the dimensionless parameter μ which is defined such that a value of 1 means that the values agree with the standard model expectations. Information about the spin and parity is best determined from the angular distribution of the previously mentioned high resolution decay channels.

There are 4 production modes for the standard model Higgs boson and 5 significant decay modes (in the mass range of the newly discovered particle) which are probed at the LHC. In order to characterise the new particle the following measurements are ongoing:

- The uncertainty on the mass of the new particle is constantly being reduced
  - This comes from the Higgs → γγ and Higgs → ZZ decay channels.
- The expected number of events in each decay channel is updated with new data and compared with the expectation from the standard model.
  - Additionally the breakdown from each decay channel can sometimes be separated by production mode to add further comparison points to the standard model predictions – a significant deviation in any single one of these could be the breakthrough that we seek.
- The Spin and Parity measurements are being updated with more data.

The slightly disappointing news at this point is that the new particle looks very much like the standard model Higgs boson. The mass is in the range 122.5 to 127 GeV allowed by indirect constraints of the standard model. The number of detected events is consistent with the expectation from the standard model in each channel and when broken down by production mechanism. There are channels which deviate from the expected μ value of 1, but agree within uncertainties. The combined value of μ over all measurements is 1.3 ± 0.3 (ATLAS) and 0.88 ± 0.21 (CMS). The angular distribution of decay products is consistent with that of a spin-0 particle, and measurements sensitive to the parity are consistent with that of a positive parity particle. The ATLAS collaboration claims that the compatibility of their measured value of μ with the standard model is 23 %.

The uncertainties on most of these measurements is still much larger than the systematic limits, and are expected to be reduced drastically with increased data providing stronger constraints on the compatibility of the new particle with expectations. At the same time the LHC experiments will continue to search directly for other signs of deviation from the standard model by tightening the constraints on measurements of the previously known particles at a new energy of 14 TeV when the collider resumes running in 2014 (it will shut down in early 2013), as well as searches for other new particles. One can see that the new particle discovered in July has properties consistent with the expectations for a standard model Higgs boson, but also that many of these properties are not yet known accurately enough to make a definitive statement. Both experiments have further data at 8 TeV to analyse and updates will continue at a furious pace.

Dr Sahal Yacoob is involved with the experiments at the European Centre for Nuclear Research (CERN) in Geneva, Switzerland, which lead to the discovery of the Higgs-like particle. He joined the School of Chemistry and Physics at the University of KwaZulu-Natal in Durban in 2012. Dr Sahal Yacoob is part of the Atlas collaboration at CERN and currently sets up a virtual laboratory link for school lerners to witness the experiments at CERN in real time.

South Africa hosts International Workshop on DISCOVERY PHYSICS AT THE LHC - KRUGER 2012

By Prof Jean Cleymans

High Energy Physics is in a discovery phase. In July this year, CERN released news of the discovery of the Higgs-like Boson. It is therefore very appropriate that South African high energy physicists organised and hosted the international conference on ``*Discovery Physics at the LHC : Kruger 2012''.*

This event is now the second of this newly established bi-annual series, and it was held at the Protea Krugergate Hotel from Monday December 3 until Friday December 7 2012. The conference has now become a calendar event for the High Energy Physics community. It is conveniently placed in the year to allow the release of new results which are available between the main summer and winter High Energy Physics events. In fact, Kruger-2012 saw the release of several new results from the major High Energy Physics collaborations. It is also an opportunity to review the status of the field. Kruger-2012 soon attracted its full current capacity of 110 participants coming from Germany, Russia, France, Switzerland, Italy, Poland, Armenia, USA, Canada, Slovakia, United Kingdom, Brazil, Switzerland, Belgium, Sweden, Spain, Israel, Czech republic, Norway and South Africa. A total of 87 talks were presented of which 27 were plenary talks.

Kruger2012 Group Photo

The latest results from the ALICE, ATLAS, CMS and LHCb experiments at the Large Hadron Collider at CERN in Geneva, Switzerland, were presented as well as results from the STAR collaboration at the Brookhaven National Laboratory in Long Island, New York and from BABAR at the Stanford Linear Accelerator Center in California. Results obtained at the ISOLDE detector were also presented. This programme of talks reflects another unique feature of this conference - it unites particle physics, high energy nuclear physics and theory. All the participants were impressed by the high level of the talks at the conference and by the beautiful environment provided by the Kruger National Park. Although Kruger-2012 is a fully fledged international conference as a regular calendar event, it still has a strong focus on developing the careers of students. Kruger-2012 was therefore preceded by the International Workshop on Hot and Dense Nuclear and Astrophysical Matter, which is aimed at students in this research area and where some of the KRUGER-2012 invited delegates also lectured. Kruger-2012 also had several features planned to highlight student work and to develop the research networks of the students.

Further information may be found at http://www.kruger2012.tlabs.ac.za/.

Opportunities

WiPiSA Call for Demonstration/Experimental Equipment Competitions

WiPiSA would like to invite interested individuals to enter a competition to design low cost fascinating physics experiment gifts/kits that can be given as Physics Gifts to pupils during physics outreach events.

Click here for more details

Opportunities for post-graduate studies at Wits University

Postgraduate studentships in Theoretical High Energy Physics at Wits are available. Research areas include non-perturbative methods in quantum field theories, strings, AdS-CFT and gravitation.

For further details please contact Prof. JAP Rodrigues (rodfam@mweb.co.za until the end of 2012, Joao.Rodrigues@wits.ac.za afterwards).

Upcoming Conferences & Schools

6th International Conference On The Frontiers Of Plasma Physics And Technology

4-8 March 2013, Gaborone, Botswana

ABSTRACT SUBMISSION & REGISTRATION STILL OPEN PLEASE EMAIL jainpk@mopipi.ub.bw

We are pleased to organize the "6th International Conference on the Frontiers of Plasma Physics and Technology" in Gaborone, Botswana during 4-8 March 2013. This is the sixth conference in the series and the earlier conferences were held in India (Bangalore-2002 and Goa-2005), Thailand (Bangkok-2007), Nepal (Kathmandu-2009) and Singapore (2011). Success of the preceding conferences has given us a deeper satisfaction and encouraged us to move beyond the borders of Asia and establish an alliance with African countries.

Emphasis of the conference will be on all the frontiertopics of plasma physics and technologies, and classified in the following three categories but not limited to.

1. Fundamental plasmas: Advances in plasma sources, plasma diagnostics, astrophysical, cosmic and space plasmas, condensed and extreme state matter, high energy density matter, laboratory astrophysical, planetary, supernova, turbulent plasmas, etc.

2. Innovative trends in Applications and Technologies: Advances in particle /photon acceleration, Lasers, Nanotechnologies, Novel radiation sources and applications in Biology, Chemistry, Environment, Health, Industries, Safety, etc.

3. Advances in Nuclear Energy: Development of ultra-laser pulses, Laser-plasma interaction, Magnetically confined plasmas, Inertial fusion plasmas, Nuclear physics under transient state, Recent progress in Fusion studies, Target and reactor physics, Unconventional energy sources, Z pinch, Hybrid (fission plus fusion) reactors etc.

For scientific information please contact Tara Desai on: fppt@fppt-series.com or P.K.Jain jainpk@mopipi.ub.bw

Please download additional information here

International Conference on Optics and Lasers Applications ICOLA2013

Optics and laser technology is a fast growing technology, which has wide range of applications in all the branches of science and engineering. Optics and laser applications are used in medicine, agriculture, energy and mines, defense, computers, industries, and entertainments. Recently the University of Namibia started the Faculty of Engineering and Information Technology at the northern campus in Ongwediva with the blessings of the Government of Namibia. The faculty is equipped with latest available equipment and technology in the world. The faculty has several departments and all the departments have highly specialized experts hired from all over the world. We wish to share the excellent existing facilities and expertise of UNAM with rest of the world to further advance the knowledge in the relevant fields of lasers. Therefore, we will organize an international conference on optics and laser applications (ICOLA2013) in 2013 from July 9 to 12, 2013, during the best climatic conditions of Namibia in Windhoek.

For more information and how to register click here http://www.unam.na/icola2012/index.html

SAIP 2013 Annual Conference

The South African Institute of Physics Annual Conference for 2013 (SAIP 2013) will be held at the University of Zululand in Rirchads Bay from 8 to 12 July 2013.

Please diarise these dates for information to follow.

9th International Workshop on Adaptive Optics for Industry and Medicine 2 – 6 Sept 2013

ABSTRACT SUBMISSION & REGISTRATION NOW OPEN

To register or submit an abstract visit www.saip.org.za/aoim2013/

The aim of the workshop is to discuss the use of novel adaptive optical elements, concepts and systems as they apply to high power lasers, medical devices, imaging, industrial lasers and microscopy. The International Workshop on Adaptive Optics for Industry and Medicine (AOIM) provides scientists and engineers from both industry and academia with opportunities to explore recent developments, current practices and future trends in adaptive optics and related fields. A key feature of this single-session meeting is the relaxed atmosphere with all participants encouraged to present and discuss their work either as a talk or a poster.

Topics will include:

- Adaptive optical (AO) devices,
- Wavefront sensing and measurement,
- Aberration correction,
- AO in imaging systems,
- Digital holograpy in AOs,
- Spatial light modulators,
- Applications of AOs.

South Africa

AOIM 2013

9th International Workshop on Adaptive Optics for Industry and Medicine

2 – 6 September 2013
Stellenbosch, South Africa

One day Spring School: 2nd September 2013

9th International Workshop on Adaptive Optics for Industry and Medicine

2 – 6 September 2013

STIAS Conference Centre
Stellenbosch
South Africa

www.saip.org.za/aoim2013

Enquiries: aoim2013@saip.org.za

Programme Chair
Andrew Forbes (South Africa)

International Organising Committee
Alexis Kudryashov (Russia)
Pablo Artal (Spain)
Sergio Restaino (USA)
John Gonglewski (UK)
Jean Claude Kieffer (Canada)
Ulrich Wittrock (Germany)

Important Dates
1 Oct 2012: 1st call
30 Jan 2013: Abstracts due
30 April 2013: Registration for authors
30 June 2013: Payment of registration fees

Topics include all aspects of wavefront control and measurement, adaptive optics and spatial light modulators, with emphasis on applications, and a **Spring School** on related topics.

Training on Science Utilisation and Science Communication

The Centre for Research on Evaluation, Science and Technology (CREST) at Stellenbosch University, will over the next five years offer a number of short courses on Research Uptake and Utilisation. The first two short courses offered are:

SCIENCE UTILISATION AND IMPACT

Scientific utilisation is part of the broader notion of knowledge utilisation. In this short course the focus is on how to successfully plan for and facilitate knowledge utilisation in order to impact upon the lives and activities of a project's intended beneficiaries. Participants will be introduced to knowledge utilisation in its various disciplinary forms as well as to current models and approaches to knowledge utilisation. After completion of the short course participants will have a good overview of the field of knowledge utilisation and will be in a position to guide knowledge utilisation activities at their own institution.

SCIENCE COMMUNICATION

The purpose of this short course is to empower researchers to translate their science for lay-audiences. Science communication involves a variety of approaches of which publications remain central (e.g. brochures, reports, web content, newspaper clippings) together with more "entertaining" approaches such as exhibitions, public demonstrations, science theatre and television documentaries.

The short courses run over four days, two days per short course, and will be presented in Stellenbosch from 25 to 28 September 2012. The courses cost USD 350 for both (4 days) or USD 200 for one (2 days). For more information and online registration, please visit: www.sun.ac.za/CREST/DRUSSA

6th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions (Hard Probes 2013)

By W A Horowitz and Heribert Weigert for the LOC

It is with great pleasure that we announce that the "6th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions (Hard Probes 2013)" will take place from Nov 4 to Nov 8, 2013 at the Stellenbosch Institute for Advanced Studies in Stellenbosch, South Africa, a delightful 30 minute drive into the wine country surrounding Cape Town.

We anticipate topics for the conference will include Jet quenching and observables; High transverse momentum light and heavy flavor hadrons; Initial state and proton-nucleus collision phenomena; Heavy flavor production and quarkonia; and Hard and thermal electroweak probes. A student summer school will be held prior to the conference.

We plan to construct a website, set registration dates, etc. soon. In the meantime, please mark your calendars, forward this notice to any potentially interested parties, and if you have any questions feel free to send them to this address, hp2013@tlabs.ac.za

Deadline for submissions for the March 2013 issue of Physics Comment is 28 February 2013

Physics Comment Editorial Policy

Physics Comment is an electronic magazine for the Physics community of South Africa, providing objective coverage of the activities of people and associations active in the physics arena. It also covers physics-related ideas, issues, developments and controversies, serving as a forum for discussion. It is not a peer review journal.

Physics Comment publishes innovative reports, features, news, reviews, and other material, which explore and promote the many facets of physics. Physics Comment endeavours to:

- support and inform the physics community
- promote membership of the South African Institute of Physics
- promote the understanding of physics to interested parties and the general public
- represent the readers' point of view
- focus on issues and topics of importance and of interest to the physics community

We accept submissions on any physics-related subject, which endeavours to inform readers and to encourage writers in their own researches. We aim to be politically, socially and geographically inclusive in the articles, which we commission and receive. Therefore we shall not discriminate according to political or religious views. Physics Comment does not support or endorse any individual politician or political party. However, contributions, which are being published, may contain personal opinions of the authors.

It is our desire to present unfettered the opinions and research of our readers and contributors. All articles submitted for publication are subject to editorial revision. Such revisions, if necessary, will be made in cooperation with the author.

The views expressed in published articles are those of the authors and are not attributed to the Editorial

The Editor will make the final determination of the suitability of the articles for publication.

Declaration by Author

When an author submits material for publication, this means:

1. The author(s) assures the material is original, his/her own work and is not under any legal restriction for publication online (e.g., previous copyright ownership).
2. The author allows PC to edit the work for clarity, presentation, including making appropriate hypermedia links within the work.
3. The author gives PC permission to publish the work and make it accessible in the Magazine's archives indefinitely after publication. The author may retain all other rights by requesting a copyright statement be placed on the work.

Authors should respect intellectual integrity by accrediting the author of any published work, which is being quoted.

Publication Deadlines

Physics Comment is published four times a year.

Issue	Closing Date	Publication Date
Issue 1	28 February	15 March
Issue 2	31 May	15 June
Issue 3	31 August	15 September
Issue 4	30 November	15 December

Specification and Submission of Content

Editorial Tone. As the voice of the physics community, the magazine will create a provocative, stimulating, and thoughtful dialogue with the readers; and provide a variety of perspectives that reflects the dynamism of the physics community.

Article types. The magazine is devoted to articles, reports, interesting facts, announcements and recent developments in several areas related to physics:

Manuscripts. Solicited manuscripts will be judged first for reader interest, accuracy and writing quality. The editor reserves the right to request rewrite, reject, and/or edit for length, organization, sense, grammar, and punctuation.

Re-use. The publisher reserves the right to reuse the printed piece in full or in part in other publications.

Submission and Format. Manuscripts must be submitted to the editor on or before the designated due date Manuscripts must be submitted electronically, on the prescribed Microsoft Word template available for download from http://www.saip.org.za/PhysicsComment/. Manuscripts are to be submitted directly to the editor: PhysicsComment@saip.org.za.

Style. AP style is followed for punctuation, capitalization, italics and quotations.

Photography and Illustration. All solicited photography and illustration should be part of an article and will be judged first for technical quality and editorial appropriateness. The editor and art director reserve the right to request revision or reject any material that does not meet their criteria. The publisher reserves full rights to all solicited photography and illustration, including the right to reprint or reuse graphic material in other publications.

Categories of Content Contributions

Technical articles and reports: These are generic articles of about 1 500 words plus diagrams and pictures. A technical article covers a relevant feature topic. Articles are authored by the writer and publishing a 40-word resume of the author could enhance its credibility. By submitting an article that has been previously published the author confirms that he/she has the right to do so, and that all the necessary permissions have been received. Acknowledgement must be made within the article.

News: These are short editorial items usually not more than 250 words. Full colour pictures must be clearly referenced on the editorial submission and on the picture or picture file.

Advertorials: Advertorials could be published when supplied by the client. We recommend a maximum of 500 words plus one or two pictures for maximum impact. A PDF file of the laid out advertorial should be emailed by the client along with an MS Word file of the text and separate image files of the pictures. It is the client's responsibility to ensure that the advertorial is correct as it is in fact a paid for advert page.

Letters to the Editor: Letters to the Editor are encouraged. The Editor reserves the right to edit for length and format. The Editor will not change the political position of the initial letter. Physics Comment does not publish anonymous letters.

Advertising Policy: The Editorial Board will determine advertising prices for Physics Comment, subject to approval by SAIP Council. The objective will be to obtain revenue to maintain and develop the magazine. Physics Comment offers classified advertising to subscribers of the magazine for free. The advertisements must be a maximum of 60 words including the telephone number, and there is a limit of three free classifieds per subscriber, per issue. Advertisements may include a photo, which may be reduced in size or resolution by the editor to optimize loading time. All items or opportunities, which are being advertised for free, should be physics-related. The Editor reserves the right to refuse any advertising, which does not conform to the objectives of the magazine.

Submission of Articles

All articles must be submitted on the prescribed template available for download from http://www.saip.org.za/PhysicsComment/