This report covers the period
1 April 2015 to 31 March 2016

Some of the results presented in this report are in part preliminary and should not be quoted without the approval of the authors

Editors: Zinhle Buthelezi
Jean Cleymans
Vincent Spannenberg

Front cover:
Pictures taken during the event of the 12th International Masterclass for ALICE measurement held at iThemba LABS.
Picture taken during the event of the 11th International Masterclass for ATLAS measurement at UCT, courtesy of A Hamilton (UCT).
SA members at the EMS experimental station on the GPS beam line in the ISOLDE Hall, together with other members of the EMS collaboration. Photo courtesy of K Bharuth-Ram (UKZ, SA-ISOLDE team).

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University of Cape Town

ATLAS
Dr Andrew Hamilton since 1 January 2015
University of Cape Town

ISOLDE
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University of Kwazulu Natal

THEORY
Prof Steven Karataglidis
University of Johannesburg
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1 Foreword

The national SA-CERN programme gives South Africa access to the largest open research facility in the world, CERN, located in Geneva, Switzerland, a central facility for physics research, serving about 7000 scientists, representing 500 institutions and over 90 nationalities. CERN remains at the forefront of developments in nuclear, particle and computational physics. All of the BRICS countries (Brazil, Russia, India, China and South Africa) are actively engaged in research at CERN with India poised to join as an Associate Member in 2016.

Discussions remain ongoing to enhance the collaboration between SA-CERN and SA-JINR.

The LHC is now collecting data at twice the previous beam energy and expectations for new discoveries are very high. An unexpected excess of pairs of photons, together carrying around 750 giga-electron volts (GeV) of energy, have been observed in proton-proton collisions. This could be a sign of a new unexpected fundamental particle decaying into two photons. If so, the particle would be about four times more massive than the next heaviest particle discovered so far, the top quark, and six times more massive than the Higgs boson. A breakthrough in the elucidation of dark matter is also keenly being anticipated.

Some of the highlights in the year 2015-2016 for the national SA-CERN programme are: Professor Bruce Mellado from the Wits School of Physics has recently announced (February 2016) that the electronics boards of the ATLAS Tile Calorimeter Super Readout Driver (now referred to as PPr) manufactured by TraX have recently passed X-ray quality control and are now ready for mounting. The Physics Department of the University of Cape Town has made available a post-doctoral position to strengthen the SA-CERN efforts. The Department of Physics and Electronics of Rhodes University, Grahamstown, is now part of the ALICE, together with University of Cape Town (UCT), iThemba LABS and the University of Witwatersrand (WITS). Two new academic staff members have accepted positions at the WITS where they will work within the ATLAS collaboration.

After several years of discussions the South Africa – ISOLDE Collaboration MoU was finally signed during the past year, on 21 August 2015 in South Africa and on 11 September at CERN. The signing of the MoU with the ISOLDE collaboration brings with it many benefits. The South Africa group involved in experiments with the Emission Mössbauer Collaboration at ISOLDE have been allocated beam time for measurements in May - June 2016. Prof. Nico Orce has been able to join a major nuclear physics experiment with an international multi-institutional collaboration which has also been allocated beam time in May 2016. The two projects for which Prof. Nico Orce (University of the Western Cape) and Dr Mathis Wiedeking (iThemba LABS) are the respective spokespersons will mostly likely be allocated beam time in the second half of 2016.

A major outcome of the formalisation of our interaction with ISOLDE/CERN is the leap in the number of South African participants in experiments utilising radioactive ion beams at the ISOLDE facility at CERN, from five (2 senior scientists and 3 research students) in 2014 to 18 (9 scientists and 9 research students).

Results obtained during previous years are still being analysed and bring new knowledge to light about processes in heavy ion collisions, new information about the Higgs boson and limits on physics beyond the standard model.

The national SA-CERN programme continues to have a major impact on the development of physics in South Africa. It strengthens the South African physics community and makes research at the highest level accessible to local scientists. Public interest in results from the Large Hadron Collider remains high as witnessed by numerous newspaper and magazine articles and continued interest from radio and TV shows.

Prof Jean Cleymans
2 Governance and Structures

In terms of the Memorandum of Agreements dated October 2010 and July 2013, the South African-CERN (SA-CERN) programme, under the auspices of the National Research Foundation and the Department of Science Technology (DST), are managed by iThemba Laboratory for Accelerator Based Sciences under the direction of the SA-CERN Governing Body.

The SA-CERN Governing Body is constituted of representatives from the various active projects at CERN including a Theory group. The members of the Governing Body include:

Programme Board Members

Dr Kobus Lawrie – iThemba LABS – Host Institution and Responsible NRF Executive

Prof Jean Cleymans – Chairperson

Prof Krish Bharuth-Ram – SA-ISOLDE and UKZN representative

Dr Thomas Dietel – SA-ALICE and UCT representative

Dr Andrew Hamilton – SA-ATLAS and UCT representative since 1 January 2015

Prof Steven Karataglidis – SA-THEORY and UJ representative

Mr V Spannenberg – Head of Finance and Business

Dr Siegfried Förtsch – Scientific and Secretarial Services until 31 December 2015

Dr Zinhle Buthelezi - Scientific and Secretarial Services from 1 January 2016

The Governing Body meets quarterly to discuss performance, budgets, strategic plans and any new items that require deliberation. The Governing Body meetings are followed by open meetings which are attended by all principal investigators and progress on scientific projects are discussed.

The Governing Body is supported by project committees that meet regularly and all discussions at meetings are recorded. Monthly financial reports are generated and circulated to all members of the Governing Body. Quarterly reports are prepared by the Scientific Secretary with inputs from all project representatives and a consolidated report, signed by the Chairperson, is sent to the NRF and the DST. Quarterly reports include both Performance and Financial information.

In 2010 the Governing Body approved a Governance Document together with financial and operational policies that directs daily operations. These policies are in line with the policies of the NRF and to the Public Finance Management Act, Act 1, 1999 as amended by Act 29, 1999 and the National Treasury Regulations of 2005.
3 Programmes

3.1 ALICE

3.1.1 SA Team members:

**Principal Scientists**: Tom Dietel (UCT), Jean Cleymans (UCT), Zinhle Buthelezi (iThemba LABS), (iThemba LABS), GF Steyn (iThemba LABS), Dino Giovannoni (Rhodes), Anthony Sullivan (Rhodes), Siegfried Förtsch (iThemba LABS), Zeblon Vilakazi (WITS)

On 10 November 2015 GF Steyn resigned from SA-ALICE to concentrate on his research at iThemba LABS

**Highlights**: On 26 June 2015, Rhodes University from South Africa became an associate member of the ALICE Collaboration. Lecturers from Rhodes University, Messrs. Dino Giovannoni and Anthony Sullivan, together with SA-ALICE Team Leader, Dr T Dietel (UCT), visited CERN to officialise the collaboration. As shown below this was reported on the ALICE Newsletter published in July 2015, see link http://alicematters.web.cern.ch/?q=content/node/861

S V Förtsch is currently serving as ALICE Run Coordinator at CERN since 1 January 2016. He will serve his term until 31 December 2016. His appointment was reported on the ALICE newsletter published in February 2016, see link http://alicematters.web.cern.ch/?q=content/node/909 for details.

Post-doctoral fellows:

1. Francesco Bossú (iThemba LABS): On 31 July 2015 a 3-year long post-doctoral fellowship contract for Dr F Bossú came to an end.

2. Massimiliano Marchisone (WITS, iThemba LABS): Dr M Marchisone commenced his post-doctoral position on 1 July 2015. It is a joint position between (WITS and iThemba LABS) He is based at iThemba LABS.

Postgraduate Students:

MSc:

Completed:
1. Ms Sibaliso Mhlanga has been approved for M.Sc. graduation in June 2016 at UCT. Topic: “Study of single muon production as a function of multiplicity in pp collisions at 8 TeV with ALICE at LHC energies”

Registered:
2. Ms Nomvelo Dindikazi, MSc, registered at the University of Zululand. Topic: “Study of single muon as a function of charged-particle multiplicity at LHC energy”. 
3. Mr S Murray registered at the University of Cape Town. Topic: “The Trigger Optimization of the HLT on ALICE”.


5. Mr. A Whitehead, PhD, registered at the University of Cape Town. Topic: “Direct Photon Measurement”.

3.1.2 Summary of Research Activities

Physics activities:

*Status update on W studies:*

Studies of $W^\pm$ bosons in proton-proton (pp) at centre-of-mass energies of 7 and 8 TeV using the new Muon Tracker Resolution task and latest alignment files are ongoing. The purpose of the analysis is to full-proof the analysis methods and to compare our results with those published by the LHCb experiment [1] at CERN and with theoretical calculations. The study is done in collaboration with the team at Subatech (Nantes, France) and Wuhan (China). Regular updates are presented at the PAG-HFM meetings at CERN via teleconferencing facility.

A combined paper on W and Z boson production in proton-lead (p-Pb) collisions at 5.02 TeV has been approved by the ALICE Physics Board. At the moment, both Physics Analysis Groups are making sure that the uncertainties associated with the results, e.g. transverse momentum ($p_T$) differential yields normalized to the number of binary collisions (Figure 1) and cross sections (Figure 2), converge. Currently, we are re-checking the systematic uncertainties on the yield per binary collisions for the p-Pb / Pb-p collisions at 5.02 TeV results. In addition, Mr Senosi is re-weighting the full-production of new alignment files, provided by the Subatech Group, with different PDFs and the systematics on the input parton distribution functions (PDFs). In parallel, he is working on p-p data, mainly producing the W yield, cross sections and charge asymmetry, integrating over the $p_T$ region between 10 - 80 GeV/c and 15 - 80 GeV/c for comparison purposes with CMS and LHCb results.

An analysis note titled ”Production of muons from W boson decays at forward rapidity in p-Pb collisions at 5.02 TeV can be found in https://aliceinfo.cern.ch/Notes/node/237. The note is currently under review by the Physics Working Group - Heavy Flavour. A separate note for the ”Production of muons from W boson decays at forward rapidity in pp collisions at $\sqrt{s} = 8$ TeV” is being updated and is available in https://aliceinfo.cern.ch/Notes/node/406.

A common paper on W and Z boson production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV is under review by the ALICE Internal Review Committee. Comments on the third draft have been received.

People involved: KJ Senosi (UCT / iThemba LABS) and Z Buthelezi (iThemba LABS), F Bossù (LPN Orsay, France), D Stocco (Subatech, France), J Zhu and S Li (CCNU, China).
**Figure 1:** Cross-sections of W-boson production at forward ($2.03 < y_{\text{cms}}^{\mu} < 3.53$) and backward ($-4.46 < y_{\text{cms}}^{\mu} < -2.96$) rapidity in p-Pb at $\sqrt{s_{NN}} = 5.02$ TeV compared with theoretical predictions with pQCD NLO, (a) without nPDF (CT10) \[2\] and with nPDF (CT10+EPS09) \[3\].

**Figure 2:** Yields of muons from W-boson decays normalized to $<N_{\text{col}}>$ in different event activity classes. The event activity is estimated with three multiplicity estimators: V0A, CL1, ZNA. The rapidity of the reconstructed muon is $2.03 < y_{\text{cms}}^{\mu} < 3.53$ (forward) and $-4.46 < y_{\text{cms}}^{\mu} < -2.96$ (backward).

**References:**

Status of the analysis of single muons vs charged particle multiplicity in pp at 8 TeV in the forward rapidity

The analysis of proton-proton data at 8 TeV at forward rapidity of ALICE is progressing reasonably well. We are studying the correlation of the yield of single muons from heavy flavour decays with respect to the charged particle multiplicity. So far we have extracted the yield of high-$p_T$ single muons (integrated in the range $6 < p_T < 20$ GeV/c) per equal multiplicity bins and have corrected the results for detector acceptance and efficiency. Now, we are working towards obtaining the signal: number of muons from heavy flavour decays. Extra selection criteria on the vertex information have been implemented in order to improve the "goodness" of the vertex information, which in turn, will improve the measurement of charged particle multiplicity. The analysis forms part of the MSc projects of Ms S Mhlanga and Ms N Dindikazi. Ms N Dindikazi and S Mhlanga are analysing results obtained when using the MAXIMUM value for the number of tracklets vs vertex position (tracklet profile) to correct for the Silicon Pixel Detector (SPD) efficiency, which is necessary for the extraction of charged-particle multiplicity. Ms Dindikazi is analysing TZERO (T0) triggered data sample while Ms Mhlanga is analysing VZERO (V0) triggered data sample. While, Dr Marchisone is looking into both V0 and T0 triggered data, mainly the results obtained when using the MINIMUM value for the number of tracklets vs vertex position. In all analyses the active modules of the SPD detector during data taking were taken into account run-by-run, which is necessary in order to precisely extract the number of tracklets per given vertex position. Currently, we are looking at pile-up studies as well as Monte Carlo simulations for background subtraction. Results from these analyses are regularly presented at weekly meetings of the Physics Analysis Group - Heavy Flavour Muons (PAG-HFM). A status report was also given by M Marchisone at the meeting of the Physics Working Group – Heavy Flavour (PWG-HF) on 10 November 2015 (https://indico.cern.ch/event/459667/)

People involved: S Mhlanga (UCT / iThemba LABS), N Dindikazi (UZULU / iThemba LABS), M Marchisone (WITS / iThemba LABS) and Z Buthelezi (iThemba LABS)

Performance of the muon trigger during Run 2

In parallel, Dr Marchisone is monitoring since the beginning of the LHC-Run2 (March 2015) the following variables of the MTR: efficiency, cluster size, (dark) current, (dark) rate, total charge and charge per hit. It is done to continuously check the performance of the MTR and to give feedback to the people at CERN.

The same observables are being studied in particular for one RPC equipped with a prototype of a new FEE (FEERIC) which is meant to replace the present one (ADULT) in view of the LHC-Run3. This work represents the last step in the validation of the FEE which was started more than one year ago. Figure 3 shows results from HV and threshold scans with early pp collisions at 13 TeV.

People involved: M Marchisone (iThemba LABS/Wits), M Gagliardi (Turin, Italy) and P Dupieux (Clermont Ferrand, France)
Figure 3: RPC MT22_inside_3 equipped with new FEE (FEERIC) vs HV. Three values of thresholds have been used for the scan. Left: efficiency dependence - bending and non-bending planes are shown separately. On the right: Cluster size. Cluster size refers to strips of 2 cm.

Measurement of Photon Production

The measurement of direct photons from heavy ion collision is considered the most direct determination of the temperature of the Quark-Gluon Plasma that is created in these collisions. We are currently preparing the measurement of direct photons using the lead-lead collisions that are currently being recorded at CERN. In preparation of this measurement, we have measured neutral pions and eta mesons in proton-proton collisions at $\sqrt{s} = 13$ TeV. The decay of these mesons into two photons is the dominant background, which needs to be under very good control to extract a direct photon signal. We are now moving to the measurement of these mesons in Pb-Pb collisions, which will lead directly to a high-statistics measurement of direct photon production in the highest energy heavy-ion collisions recorded so far.

A Whitehead visited our collaborators in Germany and at CERN to work with them on the finalization of the pion and eta measurement in proton collisions, and to start the analysis of the newly collected lead data.

People involved: A Whitehead, T Dietel (both UCT), A Marin (GSI Darmstadt, Germany), M Danisch (U Heidelberg, Germany), Friederike Bock (UC Berkeley, USA)

Development of the Common Readout Unit for the TRD

D Giovannoni and A Sullivan from the Department of Physics and Electronics at Rhodes University in Grahamstown joined the ALICE Collaboration as associate members in July 2015, with the goal to develop high-throughput electronics for the upgrade of the ALICE Detector in 2018/19. They submitted a proposal to Rhodes University for an Electronics Research Laboratory (ERL) and are currently seeking funding. The ERL will lead the development of the TRD-specific firmware components for the Common Readout Unit, which will form an essential part of the ALICE upgrade in
2018/19. The Common Readout Unit itself is an FPGA-based PCIe board that receives the raw data from the detectors and forwards them to the Front-Level Processors of the Online-Offline, or O², computing farm. We will design and develop the TRD-specific firmware components for the CRU and install at CERN. A Sullivan has started to familiarize himself with the current readout electronics of the TRD and to draft a specification document for this project.

3.1.3 Training

1. After attending post-graduate classes at the University of Cape Town, Ms N Dindikazi engaged in the analysis of data collected in 2012 by ALICE in proton-proton collisions at 8 TeV as part of her MSc project which she presented at the University of Zululand on 20 May 2015.

2. Mr Pennefather (M.Sc. student, Rhodes University) visited CERN and met with Stefan Kirsch (U Heidelberg) to learn about the Global Tracking Unit (GTU) of the Transition Radiation Detector. Information has been passed on to A Sullivan from the visit.

3. Mr Whitehead’s PhD Service task is on HLT TRD components.


5. Ms N Dindikazi is busy writing up her MSc thesis. The aim is to submit before end of June 2016.

6. Ms S Mhlanga submitted her MSc thesis on 2 November 2015. Reports from examiners were received on 27 Jan 2016. She was subsequently approved for graduate in June 2016 by the Dean of Science at the University of Cape Town.

3.1.4 Research Outputs

Publications:

1. Centrality dependence of the nuclear modification factor of charged pions, kaons and protons in Pb-Pb collisions at √sNN = 2.76 TeV, Physics Review C 93 (2016) 034913

2. Transverse momentum dependence of D-meson in Pb-Pb collisions at √sNN = 2.76 TeV, ALICE collaboration, JHEP 03 (2016) 081.


9. Forward-backward multiplicity correlations in pp collisions at $\sqrt{s} = 0.9$, 2.76 and 7 TeV, ALICE collaboration, JHEP 05 (2015) 097.


19. Precision measurement of the mass difference between light nuclei and anti-nuclei, ALICE collaboration, Nature Physics (August 2015).


29. Two-pion femtoscopy in p-Pb collisions at $\sqrt{s_{NN}}$=5.02TeV, ALICE collaboration, Phys. Rev. C 91, (2015), 034906

30. Inclusive photon production at forward rapidities in proton–proton collisions at $\sqrt{s} = 0.9$, 2.76 and 7 TeV, ALICE collaboration, Eur. Phys. J. C (2015) 75-146


32. Forward-backward multiplicity correlations in pp collisions at $\sqrt{s} = 0.9$, 2.76 and 7 TeV, ALICE collaboration, JHEP 05 (2015) 097


34. Rapidity and transverse-momentum dependence of the inclusive $J/\Psi$ nuclear modification factor in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, ALICE collaboration, JHEP 06 (2015) 055

35. Inclusive, prompt and non-prompt $J/\psi$ production at mid-rapidity in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, ALICE collaboration, JHEP 06 (2015) 055


Annual Report contribution:
1. F Bossù¹, Z Buthelezi¹, N Dindikazi¹,², S Förgsch¹, S Li³,⁶, J Martin-Blanco⁴, S Mhlanga¹,⁵, J Senosi¹,⁵, D Stocco¹, J Zhu³,⁶, iThemba LABS Annual Report 2014 - 2015, Scientific contribution: Update on the analysis of proton-proton and proton-lead data collected with ALICE at LHC energies.

ALICE Paper reviews:
1. Z Buthelezi is serving on the Internal Review Committee (IRC) to review the paper "Measurement of electrons from beauty-hadron decays in p-Pb and Pb-Pb collisions at the LHC”
2. S. V Förgsch is serving on the Internal Review Committee (IRC) to review the paper “Study of the high muon multiplicity cosmic events with ALICE at LHC”.
3. The team participated in the review of papers titled:
• “Event activity dependence of the inclusive \(\Psi(2S)\) production in p-Pb collisions at \(\sqrt{s_{NN}} = 5.02\) TeV”.
• Team participated in the review of paper titled “Direct Photon Production in Pb-Pb collisions at \(\sqrt{s_{NN}} = 2.76\) TeV
• Elliptic Flow of Muons from Heavy-flavour Decays at forward rapidity in Pb--Pb collisions at \(\sqrt{s_{NN}} = 2.76\) TeV

Manuscript Reviews:

1. In May 2015 – 31 March 2016 SA-ALICE participated in 3 ALICE Institute Reviews of the following papers:
   • Elliptic Flow of Muons from Heavy-flavour Decays at forward rapidity in Pb-Pb collisions at \(\sqrt{s_{NN}} = 2.76\) TeV.
   • Direct Photon Production in Pb-Pb Collisions at \(\sqrt{s_{NN}} = 2.76\) TeV
   • Event activity dependence of the inclusive \(\Psi(2S)\) production in p-Pb collisions at \(\sqrt{s_{NN}} = 5.02\) TeV.

2. The following were reviews for the South African Institute of Physics:
   • Z Buthelezi reviewed 4 manuscripts on ATLAS topics for SAIP 2015.
   • M Marchisone reviewed 1 manuscript on ATLAS topic for SAIP 2015.
   • S V Förtsch reviewed 3 manuscripts on ATLAS topics for SAIP 2015.

Conference Proceedings:


3.1.5 Visits to CERN

1. M Marchisone visited CERN on 29 February – 7 April 2016. He has performed central DCS and Shift Leader shifts for ALICE in preparation of his Run Manager period.

2. KJ Senosi visited CERN on 29 February – 4 March 2016 to participate in the LHCC Student Poster session and to take training on ALICE Detector Control Systems (DCS).

3. T Dietel visited CERN on 25 - 29 January 2016 to participate in the ALICE Mini week.

4. A Whitehead visited CERN from 24 October to 19 December 2015 to discuss his physics analysis with collaborators.

5. T Dietel visited CERN on 14 -18 December 2015 to participate at the ALICE week.

6. M Marchisone, Z Buthelezi and S V Förtsch visited CERN in November - December 2015. They performed 24 Shift Leader shifts during the Pb-Pb campaign at centre-of-mass energy of 5.02 TeV. M Marchisone also served as on-call expert for the Muon Trigger system.

7. S Pennefather visited CERN from 9 to 14 November 2015 to learn about the Global Tracking Unit (GTU) of the Transition Radiation Detector.


9. S Förtsch visited CERN from 1 September to 2 October 2015. During his visit he performed Shift Leader shifts and started the processes to learn about his tasks and duties concerning the ALICE Run Coordination.

10. Z Buthelezi is visiting CERN from 10 August to 7 October 2015. She performed Shift Leader central shifts in preparation for her Period Run Coordination term, which commenced on 1 September and lasted until 4 October 2016.

11. N Dindikazi visited CERN from 21 September to 7 October 2015 to learn about the ALICE detector.

12. J Cleymans visited CERN on 1 - 6 August 2015. During his visit he held discussions with Dr. Roberto Preghenella, chair of the Physics Working Group - Light Flavour about aspects of the results obtained by ALICE.

13. F Bossù visited CERN from 1 January to 30 June 2015. During this period he served as System Run Coordinator for the MUON Spectrometer.


15. S Mhlanga visited CERN from 29 May – 13 June 2015. She was trained for on-call shifts for the ALICE Muon Tracking Chambers.


17. F Bossù served as System Run Coordinator for the ALICE Muon Spectrometer from January to June 2015

3.1.6 Conference / Workshop Attendance and Presentations

1. Mr Senosi presented the latest results obtained from the W study in p-Pb collisions at 5.02 TeV at the LHCC student poster sessions held at CERN on 2 March 2016.

2. M Marchisone attended the XIII workshop on Resistive Plate Chambers and Related Detectors (RPC2016) held on 22 - 26 Feb 2016 at Ghent University (Belgium). His presentation was titled "Performance of a resistive-plate chamber equipped with a new prototype of amplified front-end electronics". http://rpc2016.ugent.be/.
3. T Dietel organised a workshop on the upgrade of the ALICE Transition Radiation Detector, held from 25 - 27 January 2016 at CERN. The purpose of the workshop was to review the current status of the TRD software and to assess the necessary work to prepare the TRD for data taking at a Pb-Pb interaction rate of 50 kHz, as it is foreseen from LHC Run-3 onwards. The workshop brought together about 20 experts on the TRD and on online and offline data processing in ALICE.

4. J Cleymans, T Dietel and Z Buthelezi are serving on the Local Organising Committee for the International Workshop on Discovery Physics at the LHC (Kruger2016) to be held on 5 - 9 December 2016 at Protea Hotel, Kruger Gate.

5. The following talks were presented at the High Energy Particle Physics Workshop 2016 (HEPPW2016) on 9 February 2016 held at iThemba LABS:
   - Quarkonia and open heavy-flavour production at forward rapidity with ALICE by M Marchisone.
   - Measurement of open heavy-flavour production as a function of charged particle multiplicity with ALICE by S Mhlanga.
   - Vector-boson production in p-Pb collisions with ALICE at the LHC by KJ Senosi.

6. M Marchisone gave a seminar at the School of Physics at WITS. The title was Quarkonia and open heavy-flavour production at forward rapidity with ALICE.

7. Ms S Mhlanga and N Dindikazi attended the annual SAIP conference held in Port Elizabeth on from June 28 to July 3, 2015. Ms Mhlanga gave an oral presentation titled "Measurement of single muon vs charged particle multiplicity in proton-proton collisions at LHC - an outlook study" and Ms Dindikazi presented a Poster, titled "Single muon pT distributions from heavy quark decay in pp collisions at 7 TeV with ALICE".

8. F Bossù, T Dietel, J Cleymans and ZZ Vilakazi attended the Strangeness in Quark Matter conference (SQM 2015) held in Dubna (Russia) on 6 - 11 July 2015. F Bossù presented a talk on "Heavy flavour and W boson production measurements via leptonic decay channels with ALICE at the LHC". J Cleymans was a member of the International Advisory Committee. On Saturday July 11 2015 he gave a concluding talk titled "Overview of the Theory Talks at SQM2015."

9. KJ Senosi attended the 2nd Conference on Heavy Ion Collisions in the LHC era and beyond held at Quy Nhon, Vietnam on 26 - 31 July 2015. He gave a talk on "Measurements of W boson production in p-Pb collisions at the LHC with ALICE".

10. J Cleymans, Mr KJ Senosi and A Whitehead attend the ALICE week at GSI in Darmstadt (Germany) on 22 – 26 June 2015. J Cleymans was the Chairman of the plenary session on 23 June, 2015 at 14h25 - 17h00.

11. Z Buthelezi attended the XXIII International Workshop on Deep-Inelastic Scattering and related subjects (DIS2015) held in Dallas, (USA) on 27 April to 1 May 2015. The title of her presentation was "Production of W bosons in p-Pb collisions measured with ALICE at the LHC".

12. Z Buthelezi, S Mhlanga, F Bossù and S Förtsch attended the Muon Workshop held at Chia in Cagliari (Italy) from 25 to 29 May. The following contributions were made at this workshop:
   - On 25 May F Bossù reported on the status of the Muon Trigger detector.
   - On 26 May F Bossù reported on the performance and general status of the Muon Tracking Chambers.
   - On 27 May S Förtsch and F Bossù attended the Muon Institutional Board meeting.
On 28 May JK Senosi presented a talk on W-boson production in pp collisions. On 28 May S Mhlanga and Z Buthelezi presented a talk on heavy-flavour decay muons vs multiplicity in pp collisions.

### 3.1.7 Stakeholder / collaborator engagement

**Key roles played by members:**

1. M Marchisone served as Run Manager for the ALICE Run Coordination for period 22 March - 5 April 2015. He is profiled on the ALICE newsletter published on 31 July 2016 [here](http://alicematters.web.cern.ch/?q=content/node/926).

2. T Dietel is TRD Offline Coordinator since 1 January 2016.

3. From 1 January 2016 Z Buthelezi took over from SV Förtsch the roles of Scientific Secretary for the SA-CERN programme and Deputy Team Leader of SA-ALICE. She is also a member of the MUON Institutional Board (MUON-IB).

4. M Marchisone is Convener of the Physics Analysis Group – Heavy Flavour Muons (PAG-HFM) from 1 January 2016.

5. M Marchisone is deputy System Run Coordinator of the Muon Trigger from 1 November 2015.

6. In July 2015 S Förtsch was elected for the role of ALICE RUN Coordinator for period 1 January – 31 December 2016.
**Other activities:**

1. T Dietel visited Rhodes University in Grahamstown from 30 November to 2 December 2015 to interact with collaborators, Messrs. Dino Giovannoni and Anthony Sullivan, both lectures with the Department of Physics and Electronics.

2. In July 2015 J Cleymans presented a talk at the Egyptian Centre for Theoretical Physics of the Modern University of Technology and Information in Cairo, (Egypt).

3. KJ Senosi met with potential collaborators Prof. S Masciocchi and Dr R Averbeck at GSI (Darmstadt, Germany) during the ALICE week in June 2015 to discuss a potential common project: study of W boson via the semi-electronic channel.

4. On 6 May 2015 F Bossù coordinated the participation of the Muon spectrometer in test measurements at first proton-proton collisions with "quiet beams" at √s = 900 GeV as part of the start-up of the LHC and in preparation of Run 2.

5. On 21 May 2015 Z Buthelezi performed shift leader duties during the first proton-proton collisions at √s =13 TeV, the highest energy ever delivered by an accelerator. See: [http://home.web.cern.ch/about/updates/2015/05/first-images-collisions-13-tev](http://home.web.cern.ch/about/updates/2015/05/first-images-collisions-13-tev)

6. On 24 February 2015 S Förtsch took over from J Cleymans as member of the Institutional Board (muons).

### 3.1.8 Outreach

1. On 3 March 2016 Z Vilakazi interacted with 15 B.Sc. Honours students in Physics at the University of Witwatersrand. He presented a talk titled “ALICE: It’s hot!” which was intended to highlight activities and available projects within SA-ALICE.

2. On 14 July 2015, Z Buthelezi interacted with 1st Year B.Sc. students from the University of Cape Town, under the auspices of "Dating a Scientist" organized by the CIT group of iThemba LABS.

3. On 23 April 2015 KJ Senosi and Z Buthelezi participated in the ALICE video conference with about 20 German middle school children. The event was organized by our German collaborator, Dr R Averbeck (GSI, Darmstadt).

4. **The 12th International Particle Physics Masterclasses 2016**

   International Masterclasses in particle physics give secondary school students the opportunity to discover the world of quarks and leptons for themselves, by performing measurements on real data from CERN, to meet active particle physics researchers, and to link up with like-minded students from other countries. Each year about 10 000 high school students in 37 countries, including South Africa, come to one of about 160 nearby universities or research centres for one day to attend these International Master classes. Lectures given by active scientists provide insight in topics and methods of basic research at the fundamental level of matter and forces, enabling the students to analyse real data from particle physics experiments by themselves. At the end of each day, similar to international research collaboration, the participants join in a video conference for discussion and combination of their results.

   International Masterclasses are led by Technical University Dresden and QuarkNet, in close cooperation with the International Particle Physics Outreach Group (IPPOG). IPPOG is an independent group of outreach representatives from countries involved in the research at leading research laboratories worldwide. QuarkNet is a United States teacher professional development program supported by the National Science Foundation and the U.S. Department of Energy. Since 2013 the outreach programs of both iThemba LABS and UCT are also involved in this program.
On 18 March 2016 iThemba LABS hosted the 12th International Masterclass event. Forty five learners from different schools around the City of Cape Town participated in this event. The event was organized by Dr Z Buthelezi (Department of Nuclear physics, iThemba LABS) who was assisted by postgraduate students: Ms. Nomvelo Dindikazi (MSc, UZULU) and Messrs. KJ Senosi (3rd year PhD, UCT) and A Whitehead (2nd year PhD, UCT) working on ALICE related topics. The organization was done in collaboration with the CIT outreach team of iThemba LABS. The program was opened by the deputy director, Dr Rudzani Nemutudi (iThemba LABS). It included introductory lectures on the fundamentals of particle physics, particle accelerators and detectors, with an emphasis on the ALICE detector. The lectures were given by Dr Tom Dietel (UCT) while the practical (hands-on) session, i.e. the measurement: “Looking for strange particles in ALICE”, was led by Mr Senosi, with the help of facilitators Mr Andile Whitehead, Ms Nomvelo Dindikazi as well as Drs Zinhle Buthelezi and Tom Dietel.

Participants at 12th International ALICE Masterclass held at iThemba LABS on 18 March 2016

Participating countries in the “Looking for strange particles in ALICE” video-conference session
3.2 ATLAS

3.2.1 SA Team Members:

**Academic Staff**
Ashfaq Ahmad (Wits), Simon Connell (UJ), Andrew Hamilton (UCT), Deepak Kar (Wits), Bruce Mellado (Wits), Xifeng Ruan (Wits), Elias Sideras Haddad (Wits), Sahal Yacoob (UKZN/UCT)

**Scientific and Technical Staff**
Ballestrero, Sergio (UJ) Padavatan, Jonathan (Wits)
Govender, Vincent (Wits) Peters, Gerrard (Wits)
Lee, Christopher (UJ/UCT) Sandrock, Charles (Wits)
Govender, Nicolin (UJ)

**Post-Docs**
Ruan, Xifeng (Wits) Kureba, Oscar (Wits)
Meehan, Samuel (UCT) Castaneda, Elizabeth (UJ)
Mthokozisi Masuku (Wits) Lee, Claire (UCT)
March-Ruiz, Luis (Wits)

**Students (MSc and PhD)**
Carlson, Warren (Wits) Reed, Robert (Wits)
Dingane Hlaluku (Wits) Sacks, Marc (Wits)
Hartmann, Roman (Wits) Sekonya, Kamela (Wits)
Jivan, Harshna (Wits) Chuene Mosomane (Wits)
Liao, Shell-may (Wits) Skhathisomusa Mthembu (Wits)
Mcconnell, Luke (UCT) Spoor, Matthew (Wits)
Mwowa, Chilufya (UCT) Thusini, Xoli (UCT)
Ntsoele, Phineas (UJ) Tomiwa, Kehinde Gbenga (Wits)
O’Connel, Sheena (Wits) Tshidiso Molupe (Wits)
Ohene-Kwofie, Daniel (Wits) Unwochola, Doomnull (UJ)
Pelwan, Chad Dean (Wits) Von Buddenbrock, Stefan (Wits)
Radovanovic, Lidija (UCT)

**Post-Graduate Student Completions and Graduations**
1. Lee, Claire (UJ, PhD completed)
2. Smith, Josh (UCT, MSc graduated)
3. Hamity, Guillermo, (Wits, MSc graduated)
4. Schenck, Ferdinand (UCT, MSc graduated)
5. Cox, Mitch (Wits, MSc completed)
6. Sinclair, Peter (UKZN, MSc completed)
7. Singh, Shuvay (UKZN, MSc completed)
### 3.2.2 Highlights of Scientific Contributions

**Potential New Bosons around 270 GeV and 750 GeV**

Physics today is at a crossroads similar to the times of Einstein and the fathers of Quantum Mechanics. It is now clear that the physics understanding of the Universe is ostensibly incomplete. The discovery of the Higgs boson at the Large Hadron Collider (LHC) in 2012, which was awarded the Nobel Prize in physics in 2013, has opened the way to even more groundbreaking discoveries: the observation of new bosons that are linked to forces and particles unknown before. The data reported by experiments at the LHC show strong hints of the existence of new bosons.

The experiments at the Large Hadron Collider (LHC) display a number of hints in their data that are indicative of the existence of new bosons. One of these bosons, the Madala Boson was hypothesized by the High Energy Physics (HEP) group of the University of the Witwatersrand. The discovery of new bosons would be a revolution in physics and would have implications reaching further than the discovery of the Higgs boson in 2012. These new bosons could explain the origin of unknown mass in the Universe and unveil new forces in nature.

The significance of the discovery of new bosons goes beyond that of the Higgs boson. The Higgs boson was needed to complete the Standard Model of Particle Physics. However, this boson did not signify the discovery of a new force or family of particles. The discovery of new bosons would be evidence for forces and particles formerly unknown. Therefore, and without a reasonable doubt, the discovery of new bosons would be worth a Nobel Prize in Physics.

The plot below on the left gives the evidence for the Madala boson with a mass around 270 GeV. This plot is the result of a phenomenological study performed by the HEP group at Wits. If confirmed with new data, this prediction would lead to a ground-breaking discovery, a South Africa-led discovery.

The plot below on the right is the evidence for a boson around 750 GeV recently reported by the ATLAS experiment. The SA-ATLAS group has contributed directly to the results reported by the ATLAS collaboration.

Most of the members of the SA-ATLAS group are students, which are predominantly South African. High Energy physics is a field that combines the knowledge of theory and experimental techniques in conjunction with analytics, Big Data and leadership skills. Upon finishing their degrees our students are able to find outstanding jobs either in the field, other fields of research or in industry.
New data is expected to stream in by the end of April 2016 till October 2016. The amount of data to be delivered is sufficient to declare the discoveries discussed above. In order for SA-CERN students to remain at the forefront of the data analysis it is imperative that the researchers spend sufficient time at CERN. This is necessary in order to effectively participate in decision making and be properly acknowledged as leaders in the discoveries.

**Exclusive di-lepton Interactions**

The measurement of the exclusive $\gamma\gamma \rightarrow \ell^+\ell^- (\ell=e,\mu)$ cross-section in proton-proton collisions at a centre-of-mass energy of 7 TeV by the ATLAS experiment at the LHC, based on an integrated luminosity of 4.6 fb$^{-1}$ was completed with the participation of the SA-ATLAS group. For the electron or muon pairs satisfying exclusive selection criteria, a fit to the dilepton acoplanarity distribution is used to extract the fiducial cross-sections. The cross-section in the electron channel is determined to be $\sigma(\text{excl.}$ $\gamma\gamma \rightarrow e^+e^-)$ = 0.428±0.035(stat.)±0.018(syst.) pb for a phase-space region with invariant mass of the electron pairs greater than 24 GeV, in which both electrons have transverse momentum $p_T>12$ GeV and pseudorapidity $|\eta|<2.4$. For muon pairs with invariant mass greater than 20 GeV, muon transverse momentum $p_T>10$ GeV and pseudorapidity $|\eta|<2.4$, the cross-section is determined to be $\sigma(\text{excl.}$ $\gamma\gamma \rightarrow \mu^+\mu^-)$ = 0.628±0.032(stat.)±0.021(syst.) pb. When proton absorptive effects due to the finite size of the proton are taken into account in the theory calculation, the measured cross-sections are found to be consistent with the theory prediction.

The plot on the left gives the primary signal extraction parameter, acoplanarity, showing the exclusive di-muon spectrum above the dissociative and inclusive backgrounds. The plot on the right shows the comparison of the ATLAS measurement to a previous CMS measurement, demonstrating the increased precision of the ATLAS result.

![Plot](image)

**3.2.3 Research Outputs**

*Full list of ATLAS Papers for FY2015/16:*

1. Search for new phenomena with photon+jet events in proton-proton collisions at $\sqrt{s}=13$ TeV with the ATLAS detector
   
   JHEP 1603 (2016) 041

2. Measurement of the charge asymmetry in highly boosted top-quark pair production in $\sqrt{s} = 8$ TeV pp collision data collected by the ATLAS experiment
   

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1 The current schedule of the LHC can be found at [https://espace.cern.ch/be-dep/BEDepartmentalDocuments/BE/LHC_Schedule_2016.pdf](https://espace.cern.ch/be-dep/BEDepartmentalDocuments/BE/LHC_Schedule_2016.pdf)
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<td>Search for strong gravity in multijet final states produced in pp collisions at √s = 13 TeV using the ATLAS detector at the LHC</td>
<td>JHEP 1603 (2016) 026</td>
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<td>8</td>
<td>Evidence for single top-quark production in the s-channel in proton-proton collisions at √s=8 TeV with the ATLAS detector using the Matrix Element Method</td>
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<td>11</td>
<td>Measurement of the correlations between the polar angles of leptons from top quark decays in the helicity basis at √s=7 TeV using the ATLAS detector</td>
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<td>Measurement of the differential cross-section of highly boosted top quarks as a function of their transverse momentum in √s = 8 TeV proton-proton collisions using the ATLAS detector</td>
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<td>Search for magnetic monopoles and stable particles with high electric charges in 8 TeV pp collisions with the ATLAS detector</td>
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<td>Search for a high-mass Higgs boson decaying to a $W$ boson pair in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector</td>
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Searches for Higgs boson pair production in the $hh \to bb\tau\tau$, $\gamma\gamma WW$, $\gamma\gamma bb$, $bbbb$ channels with the ATLAS detector

Search for pair production of a new heavy quark that decays into a $W$ boson and a light quark in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

Constraints on new phenomena via Higgs boson couplings and invisible decays with the ATLAS detector

Summary of the ATLAS experiments sensitivity to supersymmetry after LHC Run 1 interpreted in the phenomenological MSSM

Search for lepton-flavour-violating $H \to \mu\tau$ decays of the Higgs boson with the ATLAS detector

Measurement of transverse energy-energy correlations in multi-jet events in pp collisions at $\sqrt{s}=7$ TeV using the ATLAS detector and determination of the strong coupling constant $\alpha_s m_Z$

Determination of the ratio of $b$-quark fragmentation fractions $f_s/f_d$ in pp collisions at $\sqrt{s}=7$ TeV with the ATLAS detector

Measurement of the branching ratio $\Gamma(\Lambda_b^0 \to \psi(2S)\Lambda^0) / \Gamma(\Lambda_b^0 \to J/\psi \Lambda^0)$ with the ATLAS detector

$Z$ boson production in $p+Pb$ collisions at $\sqrt{s_{NN}}=5.02$ TeV measured with the ATLAS detector

Search for photonic signatures of gauge-mediated supersymmetry in 8TeV pp collisions with the ATLAS detector

Summary of the searches for squarks and gluinos using $\sqrt{s}=8$ TeV pp collisions with the ATLAS experiment at the LHC

Determination of the top-quark pole mass using $tt\bar{t} + 1$-jet events collected with the ATLAS experiment in 7 TeV pp collisions

ATLAS Run 1 searches for direct pair production of third-generation squarks at the Large Hadron Collider

Measurement of the production of neighbouring jets in lead-lead collisions at $\sqrt{s_{NN}} = 2.76$TeV with the ATLAS detector
Measurement of exclusive $\gamma\gamma \rightarrow HH$ production in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector


Study of $(W/Z)H$ production and Higgs boson couplings using $H \rightarrow WW'$ decays with the ATLAS detector

JHEP 1508 (2015) 137

Search for heavy Majorana neutrinos with the ATLAS detector in pp collisions at $\sqrt{s}=8$ TeV

JHEP 1507 (2015) 162

Search for the associated production of the Higgs boson with a top quark pair in multilepton final states with the ATLAS detector


Measurement of colour flow with the jet pull angle in $t \bar{t}$ events using the ATLAS detector at $\sqrt{s}=8$TeV


Study of the spin and parity of the Higgs boson in diboson decays with the ATLAS detector


Modelling $Z \rightarrow \tau\tau$ processes in ATLAS with $\tau$-embedded $Z \rightarrow \mu\mu$ data

JINST 10 (2015) no.09, P09018

Modelling $Z \rightarrow \tau\tau$ processes in ATLAS with $\tau$-embedded $Z \rightarrow \mu\mu$ data

JINST 10 (2015) no.09, P09018

Search for metastable heavy charged particles with large ionisation energy loss in pp collisions at $\sqrt{s} = 8$ TeV using the ATLAS experiment


Measurements of the top quark branching ratios into channels with leptons and quarks with the ATLAS detector


Search for type-III Seesaw heavy leptons in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS Detector


Search for heavy lepton resonances decaying to a $Z$ boson and a lepton in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

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67 Search for new light gauge bosons in Higgs boson decays to four-lepton final states in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector at the LHC

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68 A search for $t\bar{t}$ resonances using lepton-plus-jets events in proton-proton collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

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69 Search for production of vector-like quark pairs and of four top quarks in the lepton-plus-jets final state in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

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70 Search for Higgs bosons decaying to $\mu^+\mu^-\tau^+\tau^-$ in the $\mu\mu\tau\tau$ final state in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment


71 Search for high-mass diphoton resonances in pp collisions at $\sqrt{s}=8$TeV with the ATLAS detector


72 Measurements of the Total and Differential Higgs Boson Production Cross Sections Combining the H and HZZ*4 Decay Channels at $\sqrt{s}=8$TeV with the ATLAS Detector


73 Search for massive, long-lived particles using multitrack displaced vertices or displaced lepton pairs in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector


74 Analysis of events with b-jets and a pair of leptons of the same charge in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

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75 Search for invisible decays of the Higgs boson produced in association with a hadronically decaying vector boson in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector


76 Measurement of charged-particle spectra in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS detector at the LHC

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77 Measurement of the top pair production cross section in 8TeV proton-proton collisions using kinematic information in the lepton+jets final state with ATLA

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78 Search for heavy long-lived multi-charged particles in pp collisions at $\sqrt{s}=8$ TeV using the ATLAS detector


79 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


80 Measurement of the correlation between flow harmonics of different order in lead-lead collisions at $\sqrt{s_{NN}}=2.76$ TeV with the ATLAS detector


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100 Evidence of W Production in pp Collisions at $s=8$TeV and Limits on Anomalous Quartic Gauge Couplings with the ATLAS Detector

101 Constraints on the off-shell Higgs boson signal strength in the high-mass ZZ and WW final states with the ATLAS detector

102 Two-particle Bose Einstein correlations in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV measured with the ATLAS detector

103 A search for high-mass resonances decaying to $\tau^{+}\tau^{-}$ in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

104 Differential top-antitop cross-section measurements as a function of observables constructed from final-state particles using pp collisions at $\sqrt{s}=7$ TeV in the ATLAS detector

105 Search for massive supersymmetric particles decaying to many jets using the ATLAS detector in pp collisions at $\sqrt{s} = 8$ TeV

106 Search for a CP-odd Higgs boson decaying to $Zh$ in pp collisions at $\sqrt{s} = 8$TeV with the ATLAS detector

107 Search for new phenomena in final states with an energetic jet and large missing transverse momentum in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

108 Search for new phenomena in final states with an energetic jet and large missing transverse momentum in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

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110 Search for new phenomena in final states with an energetic jet and large missing transverse momentum in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

111 Observation of top-quark pair production in association with a photon and measurement of the $t\bar{t}b\bar{b}$ production cross section in pp collisions at $\sqrt{s}=7$ TeV using the ATLAS detector

112 Measurement of the charge asymmetry in dileptonic decays of top quark pairs in pp collisions at $\sqrt{s}=7$ TeV using the ATLAS detector

113 Search for direct pair production of a chargino and a neutralino decaying to the 125GeV Higgs boson in $\sqrt{s} = 8$ TeV pp collisions with the ATLAS detector

114 Evidence for the Higgs-boson Yukawa coupling to tau leptons with the ATLAS detector
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<td>Search for squarks and gluinos in events with isolated leptons, jets and missing transverse momentum at $\sqrt{s}=8$ TeV with the ATLAS detector</td>
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<td>117</td>
<td>Search for Higgs and Z Boson Decays to J/ and (nS) with the ATLAS Detector</td>
<td>Phys.Rev.Lett. 114 (2015) no.12, 121801</td>
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<td>Search for Scalar Charm Quark Pair Production in pp Collisions at $\sqrt{s}=8$ TeV with the ATLAS Detector</td>
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<td>Search for charged Higgs bosons decaying via $H\pm \rightarrow \tau^\pm \nu$ in fully hadronic final states using pp collision data at $\sqrt{s} = 8$ TeV with the ATLAS detector</td>
<td>JHEP 1503 (2015) 088</td>
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<td>Centrality and rapidity dependence of inclusive jet production in $\sqrt{s_{NN}} = 5.02$ TeV proton-lead collisions with the ATLAS detector</td>
<td>Phys.Lett. B748 (2015) 392-413</td>
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<td>Observation and measurement of Higgs boson decays to WW$^*$ with the ATLAS detector</td>
<td>Phys.Rev. D92 (2015) no.1, 012006</td>
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<td>Measurement of the transverse polarization of $\Lambda$ and $\bar{\Lambda}$ hyperons produced in proton-proton collisions at $\sqrt{s}=7$ TeV using the ATLAS detector</td>
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<td>129</td>
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<td>Phys.Rev.Lett. 114 (2015) no.7, 072302</td>
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131 Search for new phenomena in events with a photon and missing transverse momentum in pp collisions at \( \sqrt{s}=8 \) TeV with the ATLAS detector

132 Search for new phenomena in events with a photon and missing transverse momentum in pp collisions at \( \sqrt{s}=8 \) TeV with the ATLAS detector

133 Search for new phenomena in events with a photon and missing transverse momentum in pp collisions at \( \sqrt{s}=8 \) TeV with the ATLAS detector

134 Search for new phenomena in events with a photon and missing transverse momentum in pp collisions at \( \sqrt{s}=8 \) TeV with the ATLAS detector

135 Measurement of the inclusive jet cross-section in proton-proton collisions at \( \sqrt{s}=7 \) TeV using 4.5 fb\(^{-1}\) of data with the ATLAS detector

136 Measurement of the inclusive jet cross-section in proton-proton collisions at \( \sqrt{s}=7 \) TeV using 4.5 fb\(^{-1}\) of data with the ATLAS detector

137 Measurement of the inclusive jet cross-section in proton-proton collisions at \( \sqrt{s}=7 \) TeV using 4.5 fb\(^{-1}\) of data with the ATLAS detector

138 Measurement of the inclusive jet cross-section in proton-proton collisions at \( \sqrt{s}=7 \) TeV using 4.5 fb\(^{-1}\) of data with the ATLAS detector

139 Measurement of the WW+WZ cross section and limits on anomalous triple gauge couplings using final states with one lepton, missing transverse momentum, and two jets with the ATLAS detector at \( \sqrt{s} = 7 \) TeV

140 Search for invisible particles produced in association with single-top-quarks in proton-proton collisions at \( \sqrt{s} = 8 \) TeV with the ATLAS detector

141 Search for the \( X_b \) and other hidden-beauty states in the \( \pi^+\pi^- \gamma(1S) \) channel at ATLAS

142 Search for dark matter in events with heavy quarks and missing transverse momentum in pp collisions with the ATLAS detector

143 Search for \( W' \rightarrow t\bar{b} \) in the lepton plus jets final state in proton-proton collisions at a centre-of-mass energy of \( \sqrt{s} = 8 \) TeV with the ATLAS detector

144 Search for s-channel single top-quark production in proton-proton collisions at \( \sqrt{s}=8\)TeV with the ATLAS detector

145 Measurements of the W production cross sections in association with jets with the ATLAS detector

146 Search for resonant diboson production in the \( llqq \) final state in pp collisions at \( \sqrt{s} = 8 \) TeV with the ATLAS detector
147 Search for the $bb\bar{b}$ decay of the Standard Model Higgs boson in associated $(W/Z)H$ production with the ATLAS detector

148 Search for $H \rightarrow \gamma \gamma$ produced in association with top quarks and constraints on the Yukawa coupling between the top quark and the Higgs boson using data taken at 7 TeV and 8 TeV with the ATLAS detector

149 Measurement of the top-quark mass in the fully hadronic decay channel from ATLAS data at $\sqrt{s}=7$ TeV

150 Measurements of Higgs boson production and couplings in the four-lepton channel in pp collisions at center-of-mass energies of 7 and 8 TeV with the ATLAS detector

151 Measurement of the production and lepton charge asymmetry of $W$ bosons in Pb+Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV with the ATLAS detector

152 Performance of the ATLAS muon trigger in pp collisions at $\sqrt{s}=8$ TeV

153 Search for $W'\rightarrow tb \rightarrow \gamma \gamma \bar{b}b$ decays in pp collisions at $\sqrt{s} =8$TeV with the ATLAS detector

154 Search for new phenomena in the dijet mass distribution using p-p collision data at $\sqrt{s}=8$ TeV with the ATLAS detector

155 Measurement of the $t\bar{t}$bar production cross-section as a function of jet multiplicity and jet transverse momentum in 7 TeV proton-proton collisions with the ATLAS detector

156 Simultaneous measurements of the $t\bar{t}$bar, $W^+W^-$, and $Z\gamma^* \rightarrow \tau\tau$ production cross-sections in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

157 Search For Higgs Boson Pair Production in the $\gamma \gamma$ $bb\bar{b}$ Final State using pp Collision Data at $\sqrt{s}=8$ TeV from the ATLAS Detector

158 Jet energy measurement and its systematic uncertainty in proton-proton collisions at $\sqrt{s}=7$ TeV with the ATLAS detector

159 Measurements of $W\gamma$ and $Z\gamma$ production in pp collisions at $\sqrt{s}=7$TeV with the ATLAS detector at the LHC

160 Measurements of $W\gamma$ and $Z\gamma$ production in pp collisions at $\sqrt{s} = 7$TeV with the ATLAS detector at the LHC

Other Publications (Members of SA-ATLAS author these publications, but they do not carry the full ATLAS Collaboration author list)


Papers submitted to the ArXiv:
2. B. Mellado et. al. "The compatibility of LHC Run 1 data with a heavy scalar of mass around 270 GeV" arXiv:1506.00612, Submitted to PLB

3.2.4 Conference, Workshops and Seminars

The High Energy Particle Physics Workshop 2016

The second edition of the High Energy Particle Physics Workshop took place at iThemba LABS – North, February 8th-10th. The workshop was chaired by Prof. Alan Cornell and Prof. Bruce Mellado and it was supported by the National Institute for Theoretical Physics. The workshop comes at a time when the experiments at the Large Hadron Collider may be seeing hints of new discoveries. If confirmed with new data, we would be facing a revolution in Particle Physics and our understanding of the Universe. This workshop bears witness to the direct involvement of South African students and physicists in these exciting searches.

The workshop was opened by the Wits DVC research, Prof. Zeblon Vilakazi, Prof. Azwinndini Muronga, President of the SAIP, Prof. Jean Cleymans, Chair of the SA-CERN consortium, and the Head of the School of Physics, Prof. Joao Rodrigues. Following the opening we will have lectures on Quantum Field Theory by Dr. Will Horowitz, on data analysis by Dr. Deepak Kar and statistics by Prof. Eilam Gross. Prof. Eilam Gross was a convenor of the Higgs group of the ATLAS experiment when the Higgs boson was discovered in 2012.

The goal of this workshop is to give an opportunity to students and young researchers to give presentations and to write proceedings. The topics to be covered will be high-energy theory and phenomenology (heavy ions, pp, ep, ee collisions), ATLAS physics and ALICE physics and instrumentation. Given the format, all students had the chance to present to their peers and senior physicists.

The number of students attending the workshop has increased to the point that this year we could not have a workshop dinner due to lack of funds - a good problem to have. It was also noted that the quality of the abstracts and presentations also has improved significantly. Particularly noteworthy is the integration of the SA-ALICE and SA-ATLAS students in the data analysis chain of the experiments. With this, South African students are becoming competitive in the context of an international collaboration, providing research outputs as a whole that are becoming world-class.

Below are pictures of Prof. Vilakazi during the opening, addressing the audience. In the audience was Sarah Wild, a multi-award winning science journalist who writes for the Mail and Guardian. After the opening ceremony experiment and theory leaning students split into two groups. Theoretically leaning students moved to the board room to listen to Dr. Horowitz’s lectures on Quantum Field Theory (QFT), pictured on the right. The experiment leaning students stayed in the conference room to listen to Dr. Kar’s tutorial on data analysis and Monte Carlo techniques. These techniques are essential for experimentalists to deal with large amounts of data, data analytics, data mining, etc. and their connection with fundamental physics. After the lunch break the experiment leaning students and some of the theory leaning students attended Prof. Gross’ lectures on statistics. Statistics is used to dig out interesting signals from background and it is essential to declare discoveries.
SAIP Conference, 29 June - 5 July 2015, Port Elizabeth, South Africa

Below are the SA-ATLAS contributions to SAIP2015

1. Shell-May Liao, “Radiation hardness tests on different plastic scintillator grades for the upgrade of the Tile Calorimeter of the ATLAS detector”
2. Shell-May Liao, “Search for the Higgs boson in the di-photon decay in association with intermediate missing energy with the ATLAS detector”
3. Chad Pelwan, “A study of radiation damage in plastic scintillators using magnetic resonance techniques for the upgrade of the ATLAS detector”
4. Marc Sacks, “GPU-based Computation of Energy and Time for the Upgrade of the Tile Calorimeter of the ATLAS Detector”
5. Guillermo Nicolas Hamity, “Search for a Neutral MSSM Higgs bosons in the tau-tau final state in early Run II collision data at ATLAS”
6. Harshna Jivan, “Comparative study of proton induced radiation damage in plastic scintillators for the Tile Calorimeter of ATLAS”
   - Matthew Spoor, “Developing the high data-throughput ADC daughter board of the PROMETEO test-bench for the upgrade of the ATLAS Tile Calorimeter”
   - Sheena Leigh O’Connell, “Viability of map-reduce algorithms for the measurement of Higgs boson properties with the ATLAS detector at the LHC”
   - Mitchell Cox, “Online energy reconstruction on ARM for the ATLAS TileCal sROD co-processing unit”
   - Robert Graham Reed, “A di-Higgs Search in the γγbb Decay Channel Using the ATLAS Detector”
   - Robert Graham Reed, “An Integration Framework Tool for ATCAs in the ATLAS Detector Control System”
   - Stefan Erich Von Buddenbrock, “Dark matter production in association with Higgs bosons through heavy scalar resonance at the LHC”
   - Daniel Ohene-Kwofie, “Efficient processing of physics quantities for the Processing Unit for the upgrade of the Tile Calorimeter of ATLAS”
   - Chamunorwa Oscar Kureba, “A Portable ReadOut ModulE for Tilecal ElectrOnics (PROMETEO) test-bench for the certification of the Tile Calorimeter of the ATLAS detector”
   - Bruce Mellado Garcia, “Status of the measurements of Higgs boson properties with the ATLAS detector”
   - Bruce Mellado Garcia, “Probing new physics in the Higgs sector with effective field theories at the Large Hadron Collider”
   - Deepak Kar, “Jet substructure: a discovery tool at the LHC”
Other Conferences, Workshops, and Schools Attended

1. S. Yacoob attended Frontier Detectors for Frontier Physics, the 13th Pisa meeting, May 2015
3. B. Mellado “Anomalies in the Higgs boson data at the LHC and the potential for a new scalar with a mass around 300 GeV”, HEP seminar, University of the Witwatersrand, May 26th 2015.
4. Xoli Thusini, Luke Mcconnell; attended CERN Summer Student program, Geneva
5. Xoli Thusini, Luke Mcconnell, Ferdinand Schenk; attended CERN Computing School, Greece
6. Deepak Kar: Boost 2015 Workshop, Chicago
7. Bruce Mellado Co-convener of Higgs boson session LHCP 2015, St. Petersburg, Russia, August 30th-September 5th 2015.
14. NECSA-Wits workshop on Radiation, Material Sciences and High Energy Physics: This workshop was intended for NECSA R&D and research activities at the University of Witwatersrand to find synergies. The areas of covered were Radiation, including education, Material Sciences and instrumentation in High Energy Physics. Overview of activities:
   a. MPRI & HEP Speakers:Prof. Elias Sideras-Haddad, Prof. Bruce Mellado
   b. Upgrade of the readout electronics of the Tile Calorimeter of the ATLAS detector Speaker:Matthew Spoor
   c. The ATCA system for advanced electronics Speaker: Robert Graham Reed
   d. Radiation damage of plastic scintillators for the Tile Calorimeter of the ATLAS detector Speaker:Harshna Jivan
15. Sahal Yacoob; Siyavula Physics Teachers Conference at National Science Week
18. Deepak Kar, MPI@LHC at ICTP. Trieste (fully funded by ICTP)
19. Deepak Kar, MB&UE WG Meeting (19th Nov) CERN
20. Stefan von Buddenbrock, seminar at Wits: Evidence for a new scalar boson with a mass of 275 GeV with the LHC data
21. Deepak Kar, seminar at iThemba Lab, Cape Town: First results from ATLAS Run 2
26. Bruce Mellado gave seminar “The compatibility of the LHC data with a scalar with a mass around 270 GeV and its possible connection with the X(750) excess”, JINR, Dubna, Russia, January 25th 2016.
27. Bruce Mellado gave seminar “The compatibility of the LHC data with a scalar with a mass around 270 GeV and its possible connection with the X(750) excess”, Moscow State University, Moscow, Russia, January 26th 2016.
30. Deepak Kar attended ATLAS Standard Model Workshop at Madrid from March 29th – April 1st, c-o-convened the soft-QCD session, and gave an overview talk.
31. Deepak Kar gave a seminar “Showering at the LHC” at JINR, Dubna, Russia on 23rd March, 2016.
32. Deepak Kar gave a seminar “Soft-QCD results from ATLAS” at JGU, Mainz, Germany on 29th February.
33. Deepak Kar gave a seminar “First Run 2 results from ATLAS” at IISER, Pune, India on 14th December, 2015.

### 3.2.5 Positions of Leadership within ATLAS

1. Deepak Kar is the convenor of the soft-QCD subgroup of Standard Model group
2. Xifeng Ruan is the analysis contact for intermediate Higgs+MET paper
3. Xifeng Ruan and Deepak Kar MC coordinators of the HSG1
4. Bruce Mellado ATLAS convenor of the LHC Higgs XS WG1.
5. Robert Reed, convenor of ATCA group
6. Bruce Mellado is the Deputy Chairman of iThemba LABS-Gauteng Users Committee
7. Bruce Mellado co-convenor of Beyond the Standard model session of ICHEP 2016, 3rd to the 10th of August 2016 Chicago
8. Simon Connell is in the ATLAS Collaboration Board Chair Advisory Group
9. Sahal Yacoob Group Space Manager for South Africa
10. Sahal Yacoob Muon IB representative
11. Sahal Yacoob Inner Detector IB representative
12. Sahal Yacoob International Particle Physics Outreach Group representative
13. Bruce Mellado TileCal IB representative

### 3.2.6 Maintenance, Operations, and Upgrade Contributions

The ATLAS detector is complex system requiring significant effort to maintain and operate. In addition to operating the current detector, effort must be invested in the design and construction of the ATLAS upgrades expected for 2019 and 2023. The members of the ATLAS Collaboration take responsibility for both the maintenance and operation of the detector as well as the design and construction of the upgrades. This section documents the contributions made by SA-ATLAS in these areas.

**Tile Calorimeter**

The ATLAS Tile Calorimeter PreProcessor board, successfully manufactured by Trax, is the most complex electronics board ever produced in South Africa. The SA-ATLAS group has designed and built, in collaboration with the European Organization for Nuclear Research (CERN), part of the next generation hardware for the ATLAS detector electronics. The Tile Calorimeter (TileCal) of the ATLAS detector at CERN is the central hadronic calorimeter, used to measure the energy and direction of
hadrons, jets and tau leptons. The energy of the detected particles is sampled by plastic scintillators and signals are collected from the photomultipliers (PMTs) and processed by the read-out electronics.

The High Luminosity LHC (HL-LHC) has led to a mandatory complete re-design of the read-out electronics in the TileCal. The re-design aims at replacing the majority of the on- and off-detector electronics so that all calorimeter signals are digitized and sent to the off-detector electronics in the counting room.

The Figure below shows a schematic of the new electronics architecture. Here, Wits has contributed by, among other things, designing and manufacturing a prototype of the new back-end architecture, formerly known as the super ReadOut Driver (sROD) and now termed the Tile PreProcessor (TilePPPr).

In March 2016, Dr Oscar Kureba (Postdoctoral Research Fellow) and Dr Deepak Kar (Lecturer) travelled to the CSIR International Convention Centre in Pretoria to witness the momentous occasion of the unveiling of Trax Interconnect Company’s new capabilities. The enhancement of the capabilities of the company have been a direct result of their involvement in manufacturing the Printed Circuit Boards (PCBs) for the new TilePPPr. The event was attended by a huge number of technology enthusiasts, hoping to learn from the experiences of Trax Interconnect as the company boosted their production capabilities. In the company’s presentation, the TilePPPr was announced as the most complicated electronics board ever produced, not only by Trax Interconnect but in South Africa as a whole. The packed audience was taken through the company’s long journey from their ability to only produce up to a maximum of 8-layer PCBs to the new 16-layer capability, thanks to the design of the TilePPPr. The Department of Science and Technology (DST) funded part of the upgrade of Trax Interconnect’s PCB manufacturing equipment. The company has since increased it’s employee numbers and is actively involved in skills development and transfer in the South African electronics manufacturing industry. Below are a couple of pictures taken during the event: (left) Oscar showing off either side of one of the functional TilePPPr PCB units (right) a high-resolution microscope scanning the various tracks in 1 of 16 layers of the TilePPPr PCB.
New Small Wheel

The Large Hadron Collider (LHC) was recently upgraded to operate at its design energy of 14TeV after the first long shutdown (LS1) between 2013 and 2015. Currently, it is in Run II of its operation and is operating at a nominal luminosity of $10^{34}$ cm$^{-2}$s$^{-1}$. However, in 2018, the LHC is expected to undergo another shutdown (LS2) in order to be upgraded to its design luminosity of $2 \times 10^{34}$ cm$^{-2}$s$^{-1}$ for Run III. Such a high luminosity is anticipated to affect, among other things, the tracking and triggering of muons in the muon spectrometer due to large cavern background. To address this problem, the ATLAS collaboration has proposed to replace the muon spectrometer’s small wheels with a set of precision tracking and trigger detectors capable of handling high rates - the New Small Wheels (NSW). The NSW design is proposed to have two types of detector technologies: Small Strip Thin Gap Chambers (sTGCs) for triggering and Micromegas (MM) for precision tracking. The performance of this detector technology at these high rates is currently being studied in simulations. The SA-ATLAS group is contributing to a study to check how well the digitization software depicts the geometry of the NSW MM detector planes and testing the radiation hardness of the Zebra connector components.

Track Based Missing ET Estimation

The reconstruction of the missing transverse momentum ($E_{T\text{miss}}$) in the ATLAS detector is accomplished with various reconstruction and calibration algorithms, exploiting both calorimeter energy deposits and tracks reconstructed by the ATLAS inner detector. The effects arising from additional proton-proton interactions superimposed on the hard scattering processes become critical as the LHC moves to a higher pile-up environment for Run 2. The SA-ATLAS group has made significant contributions to the development of the track-based technique.

Trigger and Data Acquisition

The ATLAS Trigger and Data Acquisition (TDAQ) system is responsible for the online processing of live data, streaming from the ATLAS experiment at the Large Hadron Collider (LHC) at CERN. The online farm is composed of ~3000 servers, processing the data readout from ~100 million detector channels through multiple trigger levels. During the two years of the first Long Shutdown (LS1) there has been a tremendous amount of work done by the ATLAS TDAQ System Administrators, implementing numerous new software applications, upgrading the OS and the hardware, changing some design philosophies and exploiting the High Level Trigger farm with different purposes. During the data taking only critical security updates are applied and broken hardware is replaced to ensure a stable operational environment. In FY15/16 the SA-ATLAS group has participated in: upgrading the main ATLAS Operation web servers and services to SLC6, upgrading the TDAQ operations web servers to SLC6, migrated all infrastructure servers from CERN’s CVI Microsoft system to the new OpenStack virtualised services, upgraded monitoring servers from ICINGA 1 to ICINGA 2, fully integrated ICINGA 2 with our Configuration Database to allow automatic inclusion and monitoring, implemented automatic SMS notification for Sub-Detector groups in development, assisted Sub-Detectors in the upgrading of all SBC’s in Point 1 to the new VPE24. The SA-ATLAS group looks forward to continuing the ATLAS TDAQ activities in the next years of ATLAS data taking.

3.2.7 Outreach and Public Awareness

The outreach and human capacity development activities of the SA-ATLAS for this fiscal year include organization of and participation in summer schools, international master-classes, public lectures, and school visits. The highlights are summarized here.

IPPOG International Masterclass on Particle Physics

Hosted at UCT on 1 April 2015, the master-class gives approximately 25-30 high school learners the opportunity to discover the world of quarks and leptons for themselves, by performing measurements on real data from CERN, to meet active particle physics researchers, and to link up with like-minded
In the morning, the students are introduced to particle physics, experiments and detectors in lectures given by active particle physics researchers. After having lunch with lecturers and tutors, they will work on their own with data from the LHC collider at CERN. Afterwards they join a video conference where they will discuss and compare their results with students from other countries and with the moderators at CERN. More information can be found at www.physicmasterclasses.org

**CERN Beamline Competition**

The CERN Beamline Competition (http://beamline-for-schools.web.cern.ch/) invites groups of high school students to propose experiments to be run in the CERN beam lines. The winning group gets a trip to CERN where they actually carry out their experiment in the CERN beamline. S. Connell mentored the winning application with St. John’s and Barnato Park High schools. The South African high school students went to CERN for several weeks to conduct their experiment in one of CERNs beam lines. S. Yacoob acted as a judge for the competition.

**Invited Public Lectures and Press**

The following media organizations covered SA-ATLAS contributions to ATLAS results:
http://www.rdm.co.za/technology/2015/12/17/wits-scientists-may-have-discovered-new-particle
http://www.news24.com/Green/News/cern-boffins-may-have-found-another-new-particle-20151217
http://www.timeslive.co.za/sundaytimes/stnews/international/2015/12/17/New-particle-a-thrill-for-Wits-scientists
http://thegremlin.co.za/international-news/wordpress/2015/12/18/cern-boffins-may-have-found-another-new-particle/
http://wirelessgoodness.com/2015/12/18/cerns-large-hadron-collider-might-have-discovered-a-new38855/
http://sokolako.com/africa-cern-boffins-may-have-found-another-new-particle/
http://wwnradio.com/2015/12/18/this-new-particle-has-physicists-very-excited-if-its-real.html
http://www.riversstatenews.com/africa-cern-boffins-may-have-found-another-new-particle/
http://bonhamjournal.com/2015/12/18/wits-scientists-may-have-discovered-new-particle.html
http://financialcv.com/2015/12/wits-scientists-may-have-discovered-new-particle/
http://canonplace.com/2015/12/physicists-find-tantalising-hints-of-a-mysterious-new/
http://steellerslounge.com/2015/12/physicists-find-tantalising-hints-of-a-mysterious-new/84510/
http://www.ofm.co.za/article/national/176228/cern-boffins-may-have-found-another-new-particle
Public Lectures
3.3 ISOLDE

3.3.1 SA Team members:

Research Scientists and Students:

Scientist:

ISOLDE-Emission Mössbauer Collaboration:

Prof. Krish Bharuth-Ram (KBR), (UKZN and Durban University of Technology),
Assoc. Prof. Deena Naidoo ((DN) (Wits),
Dr Hilary Masenda (HM) (Wits)

HIE-ISOLDE:

Dr Mathis Wiedeking, iThemba LABS,
Prof Nico Orce and Prof S. Triambak (UWC)

Post-doctoral Fellows:

Dr S. N. T. M. Sithole (US and iThemba LABS)
Dr Kumar Raju (UWC)

Students:

PhD:

M Ncube (MN) (WITS),
N. Erasmus (UWC),
N.A. Khumalo (UWC),
V. Masondo (DUT)

MSc:

V Adoons (VA) (UKZN)
C. Mehl (UWC)
3.3.2 Research

The ISOLDE-Emission Mössbauer Spectroscopy (EMS) Collaboration had three experiments that were active during the year, namely,

**IS501**: Emission Mössbauer spectroscopy of advanced materials for opto- and nano- electronics.

**IS576**: Magnetic and structural properties of manganese doped (AlGa)N studied with Emission Mössbauer spectroscopy.

**IS578**: Atomic scale properties of magnetic Mn-based alloys probed by Emission Mössbauer spectroscopy.

KBR, DN, HM and MN participated in the $^{57}$Mn and $^{119}$In beam times for these experiments which were allocated in May-June 2015. Upgrades to the eMS implantation chamber, multi-target mounting systems, sample heating and temperature control systems and a sample holder for rapid quenching measurements at liquid N2 temperatures were undertaken at iThemba LABS. The upgraded systems were utilised at ISOLDE in the May-June 2015 beam time, and proved to be most effective, in particular in yielding good new data on the defect quenching studies on Mn/Fe implanted Si.

The inserts below show the SA members at the EMS experimental station on the GPS beam line in the ISOLDE Hall, together with other members of the EMS collaboration.

Count-rates of 8000/second on average were achieved during the $^{119}$Sn-eMS measurements, a factor of approx. 16 times higher than in previous beam times. This was largely due to the upgrades of the implantation chamber undertaken at iThemba LABS and the implementation of the new laser ionization system now in use in the ISOLDE facility. In the $^{57}$Fe-eMS measurements, however, the count rate (2000/s) was a factor of 4 to 5 lower than during the last beam-time, a problem that was eventually traced to mis-alignment of the lasers. Longer data collection times were consequently required in order to obtain data with acceptable statistics.

In general, our measurements on rapid quenching of implantation induced defects in Si (part of MN's PhD project) and measurements at low and high temperatures, as well as external magnetic field and angle dependent measurements on a suite of materials that included oxides, nitrides, Heusler alloys and topological insulators such as BiSe and BiTe, proved quite successful. Visual inspection of the data highlighted some interesting spectral features. Data are currently being analysed by research students at various international centres.

Research student M Ncube has now collected sufficient data for his PhD thesis, the finalisation of which is dependent on his completion of the data analysis and interpretation.

KBR also participated in Emission Channeling (EC) measurements on diamond and 3c-SiC single crystal samples implanted with radioactive transition metal and rare earth ions, in his long standing collaboration (since 1993) with the ISOLDE EC group now led by Dr Uli Wahl (ITN- Lisbon). Because
of the lack of good SA students, research students from Lisbon have been brought into some of the experiments and are currently busy with data analysis.

**Infrastructural Developments**

Focus on research infrastructure development at home institutions continued during the past year, with $^{57}$Co sources purchased for Mössbauer Spectroscopy facilities at the University of the Witwatersrand (Wits) and iThemba LABS. In addition, a new MS system is being set up at DUT. MSc and PhD students at the home institutions have been brought into projects which complement the studies undertaken at ISOLDE and which also prepare students for the beam times on projects at ISOLDE/CERN.

The focus of the conversion electron Mössbauer Spectroscopy (CEMS) measurements at Wits was on suites of milled powders and sintered samples important for technological applications. The CEMS studies are being complemented with detailed sample characterisation utilising a range of techniques such as X-ray diffraction, Optical Microscopy, Scanning Electron Microscopy, Energy Dispersive Spectroscopy and density, hardness, magnetic saturation and coercivity measurements.

The DUT and UKZN focus is on the formation and shaping of nanoclusters in ion implanted metal oxides and multiferroics, which began in 2013 within a DFG-NRF funded bi-lateral research collaboration. To this end, a swift heavy ion (SHI) irradiation facility has been developed at iThemba LABS, utilizing 15 – 32 MeV $^{86}$Kr$^{13+}$ ions from the injector cyclotron. Studies on the shape dependence of Ag nanoclusters (NCs) in LiNbO$_3$ on irradiation angle were undertaken at iThemba LABS. These studies formed part of the PhD thesis of student Steffen Wolf, University of Jean, Germany, who graduated with his PhD degree in March 2015. The first publication resulting from the use of the iThemba SHI facility appeared in print during the year. Over the past two years, CEMS and magnetization measurements were also completed on multiferroics LiNbO$_3$ and SrTiO$_3$ implanted with $^{57}$Fe and SHI irradiated with $^{86}$Kr ions. These measurements form part of the PhD project of student Vusi Masondo.

**Nuclear Physics at the HIE ISOLDE facility**

Two South Africa led experiments have been approved for beam time by the INTC committee at ISOLDE, namely, i) Shape Conundrum in $^{70}$Se (Spokesperson: Prof J N Orce (UWC), and ii) Statistical properties of warm nuclei: "Investigating the low-energy enhancement in the gamma strength function of neutron-rich nuclei (Co-spokesperson: Dr Mathis Wiedeking (iThemba LABS).

In preparation for beam time in 2016 for his experiment, Prof Orce attended the MINIBALL Workshop on 1 December and the ISOLDE Users Workshop on 2-4 December 2015. At the latter he gave a talk on nuclear polarization effects in Coulomb Excitation studies, entitled *Nuclear polarizability: the sleeping beauty of nuclear physics.*

Prof Orce again this year organised the “Tastes of Nuclear Physics” Workshop at UWC, 4-6 November 2015. A notable participant at the Workshop was Professor Maria Garcia Borge, Physics Leader of the ISOLDE Collaboration and ISOLDE spokesperson on the CERN Council. Prof Borge also participated in the iThemba LABS RIB Demonstrator Project Workshop held on 3 November and made a presentation in *Beta decay studies of light nuclei.*

The SA-ISOLDE collaboration supported the visit of Professor Borge to the University of Western Cape and iThemba LABS. This was the first time that UWC received a senior scientist from CERN as participant in its Tastes of Nuclear Physics workshop series, which celebrated its 5th anniversary last November. UWC has been very successful in attracting internationally-recognized scientists to the ‘Tastes’ workshop, which hence provides a forum to improve the skills of potential research students in advanced mathematics, nuclear physics and astrophysics, builds their self-confidence and encourages them to proceed to higher degree (e.g. PhD) studies. In 2015 the ‘Tastes’ workshop attracted a record 80 attendees, mainly black South African postgraduate students from institutions throughout the country.
In preparation for their CERN experiments, Profs Orce and Smarajit and Dr Wiedeking continued in 2015-16 with experiments both at iThemba LABS and international research institutes. This is reflected in their publications which are included below.

### 3.3.3 Conference, Workshops and Meetings

1. KBR attended the International Conference on Magnetism held in Barcelona, Spain, 05-10 July 2015, where he presented a paper on the *Instability Ferromagnetic Nanoclusters in Fe implanted SiO$_2$*.

2. Several members of the ISOLDE Mössbauer collaboration attended the International Conference on Applications of the Mössbauer Effect, ICAME 2015, which was hosted by the DESY laboratory at the University of Hamburg, September 13 -18, 2015. Papers presented at ICAME included:
   - H. Masenda: *Emission Mössbauer Spectroscopy study of fluence dependence of paramagnetic relaxation in Mn/Fe implanted ZnO.*
   - K Bharuth-Ram: *Emission Mössbauer spectroscopy: A sensitive probe of ion irradiation effects in ZnO.*
   - K. Bharuth-Ram: *CEMS study of Fe implanted AlN.*

3. KBR, HM and MN attended the Workshop on Emission Mössbauer Spectroscopy (WEMS) and Research Review Meeting at the Johan Kepler University, Linz, Austria, 4 - 6 March 2015. Our participation included:
   - KBR chaired the opening session.
   - M. Ncube presented data analysis on the defect quenching experiments on Si, carried out during our beam time in September 2014, as well as an overview on outstanding issues in Mn/Fe implanted Si and the way forward on future eMS measurements on Si.
   - KBR presented results of eMS measurements on ZnO pre-implanted with Ar and C, undertaken during beam times in 2011 and 2014.
   - HM gave a comprehensive presentation on the analysis and results obtained on eMS measurements in AlGaN(:Mn), also based on 2014 ISOLDE/CERN experiments.
   - KBR led the discussions on the authorship in papers resulting from work undertaken by the collaboration.

4. Two meetings of the SA-eMS group were held during the year, at CERN, on 28 May 2015 and at King Shaka International Airport, Durban, on 29 August 2015, to review progress of postgraduate students and to discuss ISOLDE membership and current projects, status of Publications and Conference presentations.

5. DN attended the Annual Conference of the South African Institute Physics (SAIP), jointly hosted by the Nelson Mandela Metropolitan University and Rhodes University, 29 June-02 July 2015, where he interacted with SA-CERN members and students.

6. DN was elected as a new member of the SAIP council, and given responsibility for Conference Management and Physics Education initiatives for the period 2015-2018.
7. DN and HM attended a WITS-NECSA Workshop held at Pelindaba on 10-11 September. DN gave a presentation on the “Applications of the Mössbauer Effect at WITS and ISOLDE”.

8. HM participated in the ISOLDE Workshop at CERN, 02-04 December 2015. He presented a poster entitled: “Emission Mössbauer study of $^{57}$Fe in InN following $^{57}$Mn$^+$ implantation”.

9. KBR represented South Africa at the ISOLDE Collaboration Committee meeting at CERN on 9 November 2015.

10. Dr Mathis Wiedeking attended the HIE-ISOLDE Experiments meeting at CERN on 1 February 2016, where beam time planning for his experiments was discussed.

11. A SA-ISOLDE group meeting was held on 06 February 2016 at iThemba LABS, Cape Town, where (i) KBR provided a report back on the SA-CERN meeting held on 29 January 2016, updates on the SA-ISOLDE MoU and report on upgrades on HIE-ISOLDE and eMS facilities at CERN.

12. In addition, as per directions from the SA-CERN Committee, the election of head/Coordinator of the SA-ISOLDE group was conducted. KBR was the only nomination and was duly elected as coordinator of the SA-ISOLDE Group for the next three year period, 01 April 2016 – 31 March 2018.

### 3.3.4 Training and Human Capacity Development

1. MN’s appointment as an Assistant Lecturer at the University of Zululand (UniZul) ended in December 2015. He has now taken up a new appointment with a Patents Company in Pretoria – this has resulted in the slow progress on the analysis of eMS and Emission Channeling data on Mn/Fe implanted n- and p-type Si.

2. VA’s appointment at UniZul also came to an end during the year. He is currently completing his data analysis and the writing up of his MSc dissertation.

3. HM completed his short-term (01 November 2015–31 January 2016) postdoc at the Katholieke Universiteit (KU) Leuven, Belgium, where he conducted research within the group led by Professor Lino Pereira. His work focussed on assisting in setting up a low temperature (4.2 K) CEMS system mainly to investigate nanoparticles embedded in multiferroics (Fe implanted SrTiO$_3$) and as well as on research on topological insulators (SnTe and Sn$_x$Ge$_{1-x}$Te films). He was also introduced to several techniques such as Rutherford backscattering/channeling (RBS/C), Magnetization measurements using a Superconducting Quantum Interference Device (SQUID) and thin film growth using Molecular Beam Epitaxy (MBE).

4. Vusumuzi Masondo has registered for the PhD degree at the Durban University of Technology. He will join the Mössbauer Collaboration at ISOLDE for part of his project and will participate in forthcoming experiments in 2016.

5. A major outcome of the formalisation of our interaction with ISOLDE/CERN is the leap in the number of South African participants in experiments utilising radioactive ion beams at the ISOLDE facility at CERN, from five (2 senior scientists and 3 research students) in 2014 to 18 (9 scientists and 9 research students).
3.3.5 Research Outputs


- PS Conf. Proc. 6, 020004 (2015) [6 pages]
- Proc. Conference on Advances in Radioactive Isotope Science (ARIS2014)


### 3.3.6 Outreach

1. DN presented a talk on research programmes and career opportunities to ~300 Physics I major students, which was also attended by representatives of the NSTF, NRF, CSIR and the Moipone Academy.

2. DN gave a specialist lecture in September 2015 to the WITS PHYSICS III Major students focusing on “Mössbauer Spectroscopy at WITS and ISOLDE”.

3. HM presented a talk on “Lattice sites, charge states and spin–lattice relaxation of Fe ions in $^{57}$Mn$^+$ implanted III-Nitrides” at IKS, KU, Leuven on 17 December 2015 in the institute’s seminar series given by visiting scientists.

4. DN presented introductory talks on research programs at ISOLDE/CERN to: (a) “Women in Physics – undergraduate and postgraduate students” during the month of August 2015. (b) ~100 Grade 10 and 11 learners in January 2016, at the University of the Witwatersrand.

5. NO organised the Tastes in Nuclear Physics Workshop at UWC, November 3-6, 2015, which attracted more than 80 postgraduate students, mainly black South Africans.
3.4 THEORY

3.4.1 SA Team members:

Principal Scientists:

Prof Steven Karataglidis (UJ), Head of SA-CERN/Theory
Prof Jean Cleymans (UCT), Head of SA-CERN
Prof Heribert Weigert (UCT)
Prof Andre Peshier (UCT)
Prof Alan Cornell (Wits/)
Prof Azwinndini Muronga (UJ)
Dr W A Horowitz (UCT)

Postdoctoral Fellows:

Dr Razieh Morad (UCT)
Dr G Kemp (UJ)
Dr T Bhattacharyya (UCT)

Students (registered with home institutions):

PhD:

D. Unchuwola (UJ)
I. Kolbe (UCT)
B. Meiring (UCT)
W. Carlson (Wits)
M. Khojali (Wits)

MSc:

G. Harmsen (Wits)
S. von Buddenbrock (Wits)
X. Ngcobo (Wits)
C. Mosomane (Wits)
G. Jackson (UCT)
B. Viljoen (UCT)
H. Mohamed (UCT)
B. Harrison (UCT)
H. Elboghady (AIMS/UCT)
3.4.2 Research

This has been a productive year for the Theory Section of SA-CERN. There were more visits to CERN, as a result of the agreement reached between SA-CERN/Theory and CERN/Theory. This has allowed for more collaboration between SA-CERN/Theory and CERN/Theory and has allowed students to see CERN first-hand and have contact with both local theorists and experimenters alike.

Alan Cornell was co-chair for the High Energy Particle Physics workshop at iThemba LABS (Gauteng), and will be co-editor of the Proceedings.

Also, with Dino Giovannoni joining the group, as a joint member with SA-CERN/ALICE, Rhodes University has returned to the membership of SA-CERN. (It should be remembered that SA-CERN/Theory began as the Theory group from Rhodes University originally.)

Highlights:

**The Prof Steven Karataglidis**

The research has continued into the Multi-Channel Algebraic Scattering (MCAS) Theory, a collaboration which includes the University of Melbourne, Australia; the University of Manitoba, Canada; the INFN, Italy; and Curtin University, Australia. While development in the shell model aspects of the theory continues, we have branched into application to nuclear astrophysics, looking at the structures of mass-22 and mass-23 nuclei, as relevant to the reactions that lead beyond the CNO cycle. Also, we have looked more closely to issues of energy levels of mirror nuclei, which are important when developing the potentials for use in MCAS.

A more recent development within MCAS has been to modify the Green’s functions that enter the integrals from which the $T$ matrices are calculated, in order to include details of the widths of target states that are involved in the coupled-channel formalism. This is of particular interest in cases where the target nuclei, such as halo nuclei, have states that are unbound but which otherwise contribute to the scattering. One example is alpha scattering from $^{6}$He, for which the excited states are unbound.

A new collaboration is with the SCRIT group of RIKEN and Tohoku University in Japan. That experiment will be the first to measure the elastic electron scattering form factors of exotic nuclei, from which information of the proton densities of such systems will be directly obtained. We will be calculating the form factors for isotopes of Sn and Xe in the first instance, using the shell and Skyrme models. Preliminary calculations indicate that the variations in the Sn isotopes will be small, suggesting that the increase in neutron number will have little effect. This is consistent with the results of predictions made for light exotic nuclei (isotopes of He and Li) published in 2007.

Finally, work has begun in applying the analytic density functional theory to finite nuclei. The first example will be to investigate the density and energy functional for $^{6}$Li, which may be treated as a two-body system outside of an alpha core.

**Prof Jean Cleymans**

The problem of chemical freeze-out in heavy ion collisions, at all energies, from 1 GeV to those available at the Large Hadron Collider, has been investigated. This has relied on the development of the mathematics and thermodynamics of the Tsallis distribution and its use to fit transverse momentum distributions up to 200 GeV. The distribution uses only one new parameter while standard models for the transverse momentum distributions use hundreds of parameters via the parton distribution functions. These come in several flavours and have to be tuned each time new data become available. The use of the Tsallis distribution thus represents a major development in the description of chemical freeze-out.
Prof Andre Peshier

Prof Peshier’s group works on topics related to the physics of the quark-gluon plasma, as explored by the heavy-ion program at CERN. The spectrum of research interest includes thermodynamic equilibrium properties of the strongly coupled many-body quantum system, transport phenomena related to the fast equilibration of the plasma in heavy-ion collisions as well as electromagnetic probes, whose thorough understanding is essential to link theoretical concepts to experimental results.

As part of outreach, we have the Project Hi-π-4-mans, where we built a “supercomputer” with raspberry-pi boards to introduce undergrad students hands-on to both parallel computing technology as well as physics concepts relevant for CERN physics. Below are the pictures of the “supercomputer” as well as Prof A Peshier with his UCT team involved in the building of the computer. Picture credits go Michael Hammond / UCT.

With Greg Jackson (MSc student) we have calculated in an improved scheme the shear viscosity of the quark-gluon plasma, which is a key observable in the apparent fast equilibration observed in heavy-ion collisions. With Brandon Viljoen (MSc) we develop a novel code for non-ideal relativistic hydrodynamics; Brandon submitted his thesis in February 2016. With Husam Mohamed (MSc) we work on finite size effects in lattice QCD calculations. With Brent Harrison (MSc) we explore the isotropization of the quark-gluon plasma in heavy-ion collisions. With Hager Elboghady (MSc, AIMS) we investigate medium modifications of QCD cross sections. With Dino Giovanni (PhD student and meanwhile lecturer at Rhodes University) we study the possibility of a Bose-Einstein condensate forming in heavy-ion collisions.

Prof Alan Cornell

We have conducted studies into a proposed high-energy circular hadron-electron collider, which would provide sufficient energy in a clean environment to probe di-Higgs production. With such a machine, we showed that the azimuthal angle correlation between the missing transverse energy and the forward jet is a very good probe for the non-standard hhh and hhWW couplings.

Further, excesses in ATLAS and CMS data have been studied, where those have been interpreted as being due to the existence of another, heavier, scalar particle, and a possible CP-odd scalar particle at an even higher energy. Using a minimalistic model, we predicted the kinematics of these final states and compare the prediction against the data directly. A statistical combination of those results shows that a best-fit point is found for these particles.

We are also developing a gauge-Higgs unification model in extra dimensions, in the collaboration with the University of Lyons, France. We study the problem at the one-loop level with the hopes of generating a large running of parameters like the Weinberg angle. That such a large running has not been observed before has been a problem for many extra-dimensional models in the past.
Finally, we have been working on the description of spin-3/2 particles in curved spacetime. Among the phenomenological implications of this study would be the inclusion of gravitinos in collider black hole simulators (the only piece of information missing for upgrading such simulators to include supersymmetry).

**Dr Will Horowitz**

*With R. Morad:*

We have considered the case of light quark jet energy loss in AdS/CFT and our studies have shown that the energy loss depends sensitively on the initial conditions of the string. Currently there is no known way to constrain the multiply infinite dimensional space of string initial conditions. The ideal way to compute get observables in AdS/CFT may be to calculate the energy-momentum tensor associated with falling string on the dual field theory and then “run” a jet finding algorithm on the result. One can solve Einstein’s equations for the perturbation in the 5d geometry due to the presence of the string and, according to the bulk to boundary map, interpret the near-boundary behaviour of the metric perturbation as that in the SYM energy-momentum tensor by the presence of the jet.

*With A. Rasoanaivo:*

We have derived the soft-collinear factor for the stimulated emission of gluons for the zero momentum transfer “colour flip case” for the fully symmetric emission for any number of bremsstrahlung gluons. We are working on its generalisation for different symmetries, fully antisymmetric as well as mixed symmetry.

*With B. Meiring:*

We have been finalising some details on a few of the results towards publication of a few papers. Particularly, we are attempting to include radiative effects into the spacetime description of jets, and numerically simulate the evolution of such structures in time. Consistent with our previous work, we have shown how analytic expressions for the conditional expectation value for the momentum of hard partons can be related to the differential cross section. The (expected) result further encourages confidence in the formalism developed for Mr Meiring’s thesis.

*With I. Kolbe:*

We have been completing two papers for submission, one of which has been submitted to Physics Letter B, for which we are now addressing referees’ comments. Also, we have been investigating small system size corrections to the Debye mass in a thermal plasma.

*With A. Ibrahim and G. Kemp:*

The computation into the next-to-leading order corrections to QCD Rutherford scattering processes continue. We have derived a finite expression for the total and differential cross sections for the s-channel $e^+e^-\rightarrow q\bar{q}$ process using dimensional regularisation and MS-bar renormalisation. We have also made progress on the t-channel process, and understand the necessary steps to compute an infrared finite t-channel cross sections. That involves working on surmounting the integrations for the soft and hard collinear bremsstrahlung processes necessary to cancel the infrared divergences from the vertex correction.

*With R. Moerman:*

The calculation of the full virtuality and all-time calculation of a light quark thermalizing in a strongly-coupled quark-gluon plasma has been completed. We are extending the the result for early and late times to quantify the ballistic and diffuse regimes of propagation.
With D. Adamiak:

We have finished the calculation of the cross section for pA collisions and compare those with pp-collisions (cross sections, parton contributions, and spectral indices). We are working on energy-loss calculations in small system sizes.

With R. Hambrock:

We have investigated azimuthal and momentum correlations of bb-bar pairs in a strongly-coupled plasma. By comparing those with weak-coupling based computations, we found that the azimuthal correlations are not of particular utility in distinguishing between strong and weak-coupling energy-loss mechanisms in a quark-gluon plasma. However, the momentum correlations of pairs in the domain of 1 – 10 GeV diverge by approximately one order of magnitude at leading order production and thus likely constitute a potential experimental observable. We are also looking at next-to-leading order production as well.

3.4.3 Visits

1. Prof Karataglidis visited several universities in Brazil, Chile, and Mexico as part of a university delegation to foster collaboration. While in Chile, he gave a seminar on scattering theory and the structures of exotic nuclei at the University of Chile, Santiago. He also visited Italy in June, and presented a talk on MCAS and the isotopes of oxygen at the 14th International Conference on Nuclear Reaction Mechanisms in Varenna, and also spent time at CERN as part of the trip, where he also gave a seminar at ISOLDE. In November, he visited Japan, where he gave a talk at the High-resolution Spectroscopy and Tensor interactions Workshop in Osaka, and gave two seminars: at RIKEN and also at Tohoku University, on the matter densities of exotic nuclei.

2. Prof Cornell visited CERN in April, while Dr Horowitz visited the ECT* in Trento, Italy, and Dr Morad visited the Institute for Research in Fundamental Science (IPM) in Tehran, Iran.

3. Dr Horowitz took his students on an extended visit to CERN, a trip which also included attending the 7th International Conference on Hard and Electromagnetic probes (Hard Probes)
State University, and Duke University), giving talks. In July, he attended the 15th International Conference in Strangeness in Quark Matter (SQM2015) in Dubna, Russia, and attended the Round Table discussion on NICA, held at the JINR, at which Profs Cleymans, Muronga, and Peshier were also present.

4. In September/October, Dr Horowitz attended the conference, Looking Beyond $10^{10}$ Mini-bangs, CGCs, Perfect Fluids, and Jet Tomo/Holography, in Wuhan China. He then attended the Quark Matter 2015, held in Kobe, Japan. His students (Rasoanaivo, Meiring, and Kolbe) and postdoc (Morad), also attended the Quark Matter meeting, as well as another visit to CERN. Mr Meiring also visited Tohoku University for a research visit.

5. Prof Peshier and Mr Jackson also both attended the conference Strangeness in Quark Matter, SQM 2015, in Dubna, Russia, where they both gave presentations.

![The Intersection of Experiment with Theory: Dr. W A Horowitz visiting the CMS detector at LHC.](image)

### 3.4.4 Awards

1. Prof Muronga became President of the South African Institute of Physics in July 2015.

2. Prof Cornell was awarded a B3 Rating by the NRF.

3. Ms Isobel Kolbe was awarded an MSc with distinction.

4. Mr Ben Meiring was awarded an MSc with distinction.

### 3.4.5 Research Outputs

**Prof Steven Karataglidis:**


**Prof Jean Cleymans:**


**Prof Alan Cornell:**


**Dr Will Horowitz:**


### 3.4.6 Proceedings / Conferences

**Prof Steven Karataglidis:**

1. Prof Karataglidis was co-editor of the Proceedings of the 59th National Conference of the South African Institute of Physics, 2014, published in March 2015.


**Prof Jean Cleymans:**

6. Jean Cleymans was Editor of the proceedings for *Kruger 2014, 3rd International Workshop on Discovery Physics at the LHC*, which has been published by the Institute of Physics Publishing, Bristol, UK, in the Journal of Physics: Conference Series, volume 263. He was also a roundtable organiser of the Physics of NICA, held at the JINR, July 2015, and was a member of the International Advisory Committee of the International Conference on Strangeness in Quark Matter, SQM2015, July 2015


**Prof Andre Peshier**


**Prof Alan Cornell**


**Prof Azwinndini Muronga**


**Dr Will Horowitz**


### 3.4.7 Seminars

**Prof Steven Karataglidis**

S. Karataglidis, *Mapping the densities of exotic nuclei*, seminar presented at RIKEN, Japan, at the Research Centre for Electron Photon Science at Tohoku University, Sendai, Japan, and at iThemba LABS (Cape).

**Prof Jean Cleymans**

J. Cleymans, *An introduction to the Thermal Model*, Talk given at the Egyptian Centre for Theoretical Physics of the Modern University of Technology and Information, Cairo, Egypt, August 12, 2015.

### 3.4.8 Outreach

**Prof Alan Cornell**
1. After being co-chair for the High Energy Particle Physics workshop in iThemba - North (February 2015), I was involved with the publishing of the proceedings, acting as editor along with Prof. Bruce Mellado (J. Phys.: Conf. Ser. 645). I also presented an introduction to the Standard Model lecture at the African Institute for Mathematical Sciences in October.

**Prof Azwinndini Muronga**
2. SAIP Membership Drive in Limpopo. 3 schools and two universities visited. 3000 learners and 300 university students reached.

**Dr Will Horowitz**
3. Dr Horowitz delivered lectures on the Introduction to Quantum Field Theory at the High Energy Particle Physics Workshop, 2016, at iThemba LABS (Gauteng). He is a member of the Electron Ion Collider User Group Institutional Board representative for UCT, and was a convenor and chaired a session at the EIC User Group Meeting, 2016, at the University of California Berkeley, January 2016.
3.5 Grid Computing - CHPC

The period started with attempts being made to run jobs at a far higher rate than it would appear our network could handle. We then proceeded to run at a fairly stable rate of 700 concurrent jobs before again attempting in October 2015 to increase the rate. This attempt was also doomed due to bandwidth.

![Running Jobs](image)

**Overview of running jobs in the period Period January 2016 to March 2016 at the CHPC**

We ran with an average of 638 concurrent jobs for the year. On 24 March 2016 CHPC successfully completed 76k ALICE jobs with an average over the time period of 538 concurrent running jobs, and complete a total of 475k jobs for ALICE successful over the year.

![Done jobs in ZA_CHPC](image)
ALICE is now consistently running at 1000 concurrent jobs, and stable as of 15 March 2016. In addition, ALICE is now also successfully passing all its SAMS tests, for WLCG accounting purposes as a TIER 2.

ATLAS processing started on 24 March 2016 with a series of pilot jobs and then promptly stopped pending a scheduled down time at INFN Tier1, due to that being designated, temporarily, the storage site.

On 1 March 2016 CHPC appointed a dedicated staff member, Mr Sean Murray. Hopefully, things will start to run more consistently.

Bandwidth however remains an issue causing a disproportionately large number of failed jobs due to timeouts on data retrieval and ttl limits being exceeded for jobs on ALICE. There is a real possibility of getting more bandwidth in the coming financial year on the WACS cable via DST, and finally fully harnessing the full quota of 2400 cores for both ALICE and ATLAS.
## Key Performance Indicators

<table>
<thead>
<tr>
<th>SA-CERN Key Performance Indicators</th>
<th>Financial Years</th>
<th>2014/15</th>
<th>2015/16</th>
<th>Comments on Y/Y Variances</th>
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<tbody>
<tr>
<td><strong>Research Outputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of peer review articles</td>
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<td>143</td>
<td>218</td>
<td>Articles submitted in 2014-2015 published in 2015-2016. Long shutdown yet continued to contribute leading to an increase in publications and conferences</td>
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<td>Number of Research Reports</td>
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<tr>
<td>Number of Full Length Conference proceedings</td>
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<td>60</td>
<td>Higher focus on conferences attributed to Long shutdown</td>
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<td><strong>Human Capacity Development</strong></td>
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<tr>
<td>Number of students supervised- Doctoral</td>
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<td>11</td>
<td>20</td>
<td>Theory realised growth and Isolde participation by UWC and Research Staff at iThemba LABS, naturally students</td>
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<tr>
<td>Number of students supervised- Masters</td>
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<td>34</td>
<td>58</td>
<td>Theory realised growth and Isolde participation by UWC and Research Staff at iThemba LABS, naturally students</td>
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<tr>
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<td>Progress over the entire programme</td>
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<td>Number of students completed - graduated- Masters</td>
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<td>14</td>
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<td>Proportion of investment in HCD</td>
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<td>34%</td>
<td>39.6%</td>
<td>Increase to in local investments and Upgrade contributions at CERN</td>
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<td><strong>Visits to CERN</strong></td>
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<td>Number of Visits - Students</td>
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<td>22</td>
<td>Due to a larger student pool</td>
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<td>Number of Visits - Researchers</td>
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<td><strong>Investment in Infrastructure</strong></td>
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<tr>
<td>Proportion of Investment in infrastructure</td>
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<td>39.6%</td>
<td>Increase to in local investments and Upgrade contributions at CERN</td>
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<td><strong>Science Advancement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of learners reached</td>
<td></td>
<td>12670</td>
<td>10955</td>
<td>The lower number largely supported by the higher focus on teachers in this years</td>
</tr>
<tr>
<td>Number of teachers reached</td>
<td></td>
<td>1072</td>
<td>1315</td>
<td>Higher achievement naturally supports the lower number of learners reached</td>
</tr>
<tr>
<td>Number of Public talks</td>
<td></td>
<td>38</td>
<td>14</td>
<td>Supported by the higher number of teachers reached</td>
</tr>
</tbody>
</table>
NOTES:

Though the SA-CERN programme are reporting commendable results compared to the previous year on both Budget spending trends and Key Performance Indicators, the budget was severely impacted by the weaker South African Rand in 2014 and 2015. The original budget, compiled in 2012, used an exchange rate of R9 / 1CHF. The average exchange rate over the past year exceeded R13 / 1CHF representing approximately 40% erosion of the budgets and planned targets/outputs. The negative impact of the ZAR and the impact on the funding were reported the Department of Science and Technology, quarterly.

Total YTD income R12, 7M include current year funds R9M and R3, 6M prior year carry forward funds. Running expenses R10M include R8,8M actual expenses and R1,2 M firm pre-payments or expense commitments. Running expenses comprise Subsistence and Travel costs R5M for research visits to CERN and R3M membership fees paid to CERN. The capital expense R1,8 M is for infrastructure investment for upgrades at local institution and upgrade contributions at CERN. The reported unspent funds have already been committed in April 2016. More than 95% of the budget was spent by 31 March 2016.

Finally, the SA-CERN next three year funding cycle proposal was submitted to the DST. The proposal makes provision for an increase in budget, taking into account the negative impact of the weaker ZAR when compared to the Swiss Franc as well as the positive growth within the collaboration.

The financials presented are final pre audited figures and will be presented during May 2016.

### SA-CERN YEAR TO DATE INCOME AND EXPENSES 31 March 2016

<table>
<thead>
<tr>
<th>LINE ITEMS</th>
<th>Actual - March 2014/15</th>
<th>Actual March 2015/16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income R'000's</td>
<td>9 010</td>
<td>9 550</td>
</tr>
<tr>
<td>DST Grant</td>
<td>9 010</td>
<td>9 550</td>
</tr>
<tr>
<td>DST Once-off funding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carry Forward funds from prior year</td>
<td>3 612</td>
<td>3 079</td>
</tr>
<tr>
<td><strong>Total Income</strong></td>
<td><strong>10 451</strong></td>
<td><strong>12 629</strong></td>
</tr>
<tr>
<td>Expenditure R'000's</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CERN Visits R'000's</td>
<td>4 562</td>
<td>5 842</td>
</tr>
<tr>
<td>Student Scholarships -</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Meetings -</td>
<td>425</td>
<td>232</td>
</tr>
<tr>
<td>Post-Doc</td>
<td>153</td>
<td>-</td>
</tr>
<tr>
<td>CERN Visitors in RSA -</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CERN Annual/Joining Fees R'000's</td>
<td>2 348</td>
<td>2 866</td>
</tr>
<tr>
<td>National Workshop and Seminars -</td>
<td>321</td>
<td>337</td>
</tr>
<tr>
<td>Programme Manager</td>
<td>101</td>
<td>108</td>
</tr>
<tr>
<td>Computing and equipment R'000's</td>
<td>1 002</td>
<td>1 884</td>
</tr>
<tr>
<td>Administration costs</td>
<td>631</td>
<td>669</td>
</tr>
<tr>
<td>Commitments R'000's</td>
<td>1 993</td>
<td>61</td>
</tr>
<tr>
<td><strong>Total Expenses</strong></td>
<td><strong>11 536</strong></td>
<td><strong>11 999</strong></td>
</tr>
<tr>
<td>Remaining Funds R'000's</td>
<td>1 086</td>
<td>630</td>
</tr>
</tbody>
</table>
### List of acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALICE</td>
<td>A Large Ion Collider Experiment</td>
</tr>
<tr>
<td>ATLAS</td>
<td>A Toroidal LHC Apparatus</td>
</tr>
<tr>
<td>CERN</td>
<td>Centre Européen pour la Recherche Nucléaire</td>
</tr>
<tr>
<td>DST</td>
<td>Department of Science &amp; Technology</td>
</tr>
<tr>
<td>GeV</td>
<td>Giga electron volt</td>
</tr>
<tr>
<td>ISOLDE</td>
<td>Isotope On-Line Detector</td>
</tr>
<tr>
<td>JINR</td>
<td>Joint Institute for Nuclear Research</td>
</tr>
<tr>
<td>LHC</td>
<td>Large Hadron Collider</td>
</tr>
<tr>
<td>MTEF</td>
<td>Medium Term Expenditure Framework</td>
</tr>
<tr>
<td>MoU</td>
<td>Memorandum of Understanding</td>
</tr>
<tr>
<td>M.Sc</td>
<td>Master of Science / <em>Magister Scientiae</em></td>
</tr>
<tr>
<td>Ph.D</td>
<td>Doctor of Philosophy / <em>Philosophiae Doctor</em></td>
</tr>
<tr>
<td>UCT</td>
<td>University of Cape Town</td>
</tr>
<tr>
<td>UJ</td>
<td>University of Johannesburg</td>
</tr>
<tr>
<td>SCT</td>
<td>Semi-Conductor Tracker</td>
</tr>
<tr>
<td>TeV</td>
<td>Tera electron volt</td>
</tr>
<tr>
<td>TDAQ</td>
<td>Trigger Data Acquisition</td>
</tr>
<tr>
<td>UKZN</td>
<td>University of Kwazulu-Natal</td>
</tr>
<tr>
<td>WITS</td>
<td>University of the Witwatersrand</td>
</tr>
<tr>
<td>UWC</td>
<td>University of the Western Cape</td>
</tr>
</tbody>
</table>