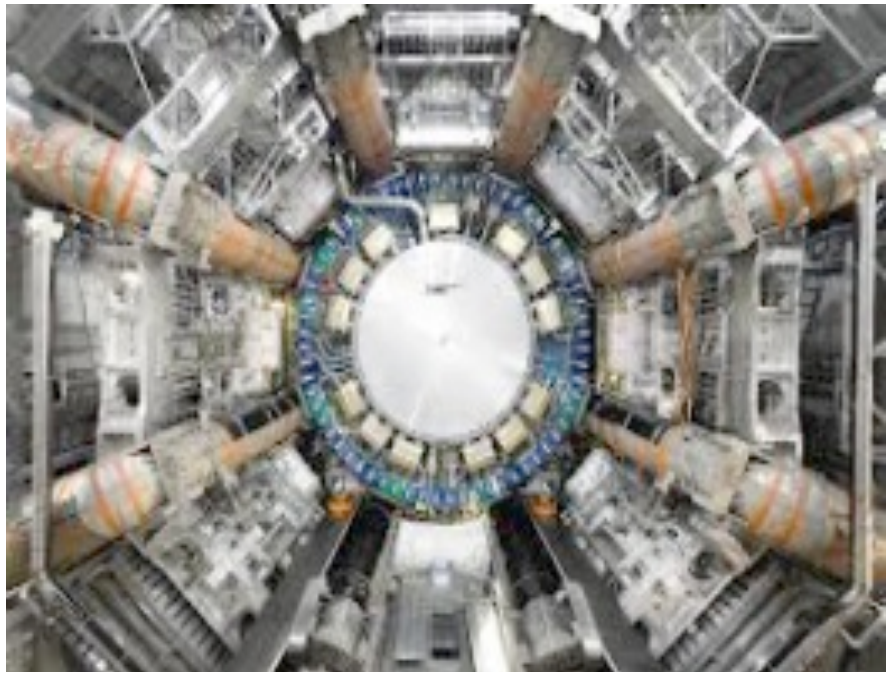
Origins of the SA-CERN PROGRAMME



Zeblon Z. Vilakazi
(University of the Witwatersrand)

Layout of the presentation

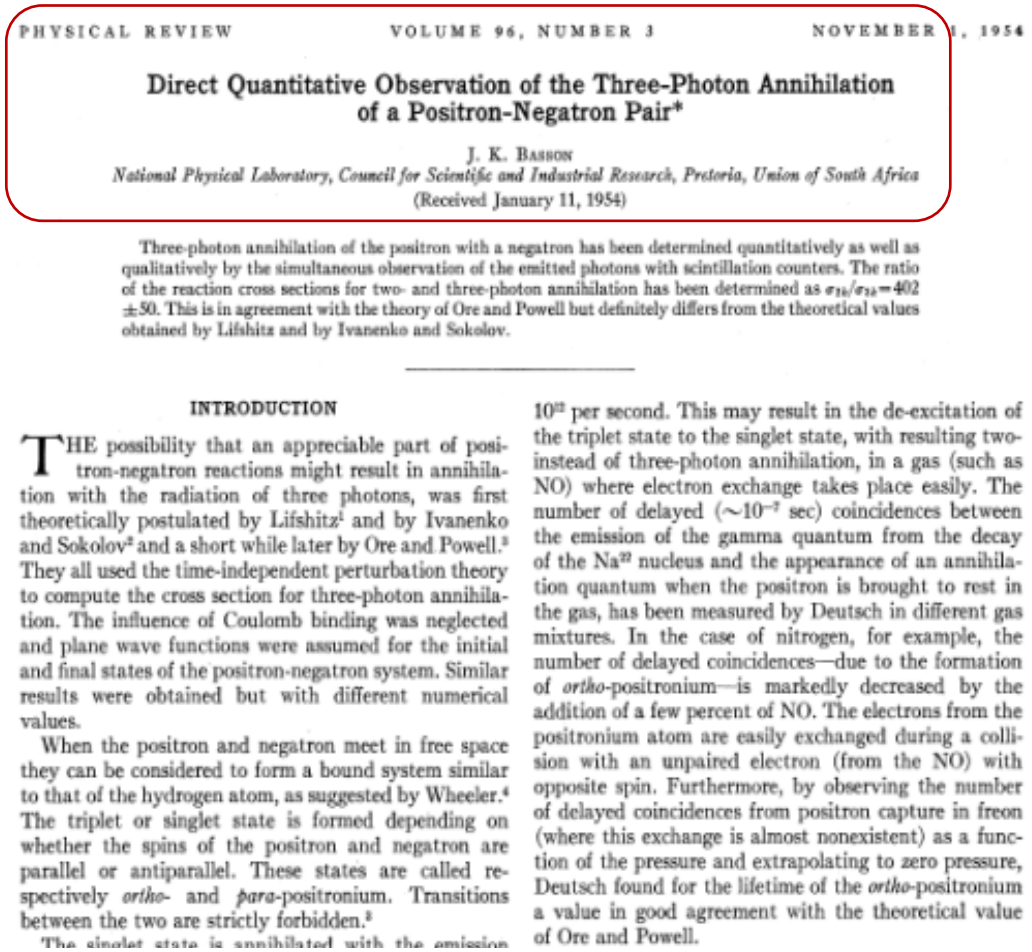
- Early origins of SA HEP activity
- How did SA-CERN start?
- What has been achieved?

Context and South Africa's history of HEP

Some prominent physicists/cosmologists who were educated in RSA

- Stanley Mandelstam (Dirac medal); B. Sc. Hons (Witwatersrand)
- Jonathan Dorfan [ex SLAC director]; B. Sc. (Cape Town)
- Werner Israel [Cosmologist]; B. Sc (Cape Town)
- Saul Teuklosky [Dirac Medal] B. Sc Hons (Witwatersrand)
- Peter Sarnack (Maths Wolf Prize); B. Sc. Hons (Witwatersrand)
- George Ellis (FRS) – still at UCT

All the above – barring Ellis – were based abroad.



PHYSICAL REVIEW VOLUME 96, NUMBER 3 NOVEMBER 1, 1954

Direct Quantitative Observation of the Three-Photon Annihilation of a Positron-Negatron Pair*

J. K. Bassom
National Physical Laboratory, Council for Scientific and Industrial Research, Pretoria, Union of South Africa

(Received January 11, 1954)

Three-photon annihilation of the positron with a negatron has been determined quantitatively as well as qualitatively by the simultaneous observation of the emitted photons with scintillation counters. The ratio of the reaction cross sections for two- and three-photon annihilation has been determined as $\sigma_{2\gamma}/\sigma_{3\gamma}=402 \pm 50$. This is in agreement with the theory of Ore and Powell but definitely differs from the theoretical values obtained by Lifshitz and by Ivanenko and Sokolov.

INTRODUCTION

THE possibility that an appreciable part of positron-negatron reactions might result in annihilation with the radiation of three photons, was first theoretically postulated by Lifshitz[1] and by Ivanenko and Sokolov[2] and a short while later by Ore and Powell.[3] They all used the time-independent perturbation theory to compute the cross section for three-photon annihilation. The influence of Coulomb binding was neglected and plane wave functions were assumed for the initial and final states of the positron-negatron system. Similar results were obtained but with different numerical values.

When the positron and negatron meet in free space they can be considered to form a bound system similar to that of the hydrogen atom, as suggested by Wheeler.[4] The triplet or singlet state is formed depending on whether the spins of the positron and negatron are parallel or antiparallel. These states are called respectively *ortho-* and *para*-positronium. Transitions between the two are strictly forbidden.[5]

The singlet state is annihilated with the emission 10^{10} per second. This may result in the de-excitation of the triplet state to the singlet state, with resulting two- instead of three-photon annihilation, in a gas (such as NO) where electron exchange takes place easily. The number of delayed ($\sim 10^{-7}$ sec) coincidences between the emission of the gamma quantum from the decay of the Na^{22} nucleus and the appearance of an annihilation quantum when the positron is brought to rest in the gas, has been measured by Deutsch in different gas mixtures. In the case of nitrogen, for example, the number of delayed coincidences—due to the formation of *ortho*-positronium—is markedly decreased by the addition of a few percent of NO. The electrons from the positronium atom are easily exchanged during a collision with an unpaired electron (from the NO) with opposite spin. Furthermore, by observing the number of delayed coincidences from positron capture in freon (where this exchange is almost nonexistent) as a function of the pressure and extrapolating to zero pressure, Deutsch found for the lifetime of the *ortho*-positronium a value in good agreement with the theoretical value of Ore and Powell.

H SA

EVIDENCE FOR HIGH-ENERGY COSMIC-RAY NEUTRINO INTERACTIONS*

F. Reines, M. F. Crouch, T. L. Jenkins, W. R. Kropp, H. S. Gurr, and G. R. Smith

Case Institute of Technology, Cleveland, Ohio

and

J. P. F. Sellschop and B. Meyer

University of the Witwatersrand, Johannesburg, Republic of South Africa

(Received 26 July 1965)

are favored over the 3π and $\eta+2\pi$ modes, although it probably is still insufficient to account for the vast differences in decay rates between these two types of processes without introducing symmetry-breaking effects. The $\rho+2\pi$ and $\omega+2\pi$ modes are found to be comparable. For a detailed list of branching ratios, see reference 2.

[7]H. Harari, H. J. Lipkin, and S. Meshkov, Phys.

other way with equal amounts. Therefore, the statistical average of the $\rho+3\pi$ processes should not be greatly perturbed.

[9]See reference 1 for a summary of the experimental data.

[10]R. Armenteros et al., Phys. Letters 17, 170 (1465); N. Barash et. al., "Antiproton Annihilation in Hydrogen at Rest I, Reaction $\bar{p}+p \to K+\bar{K}+\pi$" (to be published).

EVIDENCE FOR HIGH-ENERGY COSMIC-RAY NEUTRINO INTERACTIONS*

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The flux of high-energy neutrinos from the decay of K, π, and μ mesons produced in the earth's atmosphere by the interaction of primary cosmic rays has been calculated by many authors.[1] In addition, there has been some conjecture[1] as to the much rarer primary flux of high-energy neutrinos originating outside the earth's atmosphere. We present here evidence[2] for the interactions of "natural" high-energy neutrinos obtained with a large area liquid scintillation detector (110 m^2) located at a depth of 3200 m (8800 meters of water equivalent, average $Z^2/A \simeq 5.0$) in a South African gold mine.

The essential idea of the present experiment[3] is to detect the energetic muons produced in neutrino interactions in a mass of rock by means of a large area detector array imbedded in it. Backgrounds are reduced by the large overburden and by utilizing the fact that the angular distribution of the residual muons from the earth's atmosphere is strongly peaked in the vertical direction at this depth. The angular distribution of the muons produced by neutrino interactions should show a slight peaking in the horizontal direction.[4]

The detector array, shown schematically in Fig. 1, consists of two parallel vertical walls made up of 36 detector elements. The array is grouped into 6 "bays" of 6 elements each. Each detector element, Fig. 2, is a rectangular box of Lucite of wall area 3.07 m^2 containing 380 liters of a mineral-oil based liquid scintillator,[4] and is viewed at each end by two 5-in. photomultiplier tubes. The array constitutes a hodoscope which gives a rough measurement of the zenith angle of a charged particle passing through it. In addition, the event is located along the detector axis by the ratio of the photomultiplier responses at the two ends. The sum of the responses then pro-

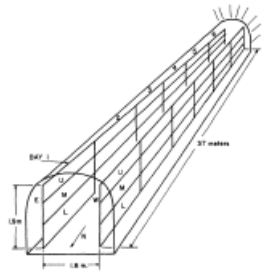
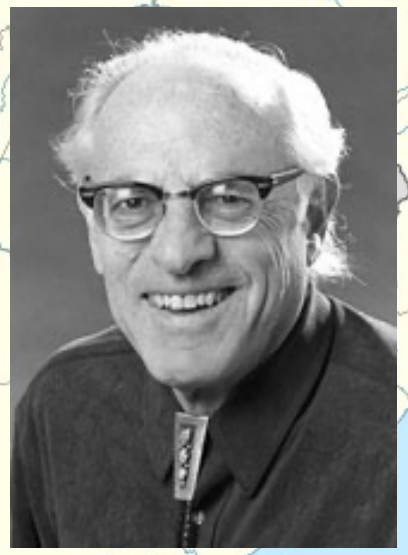
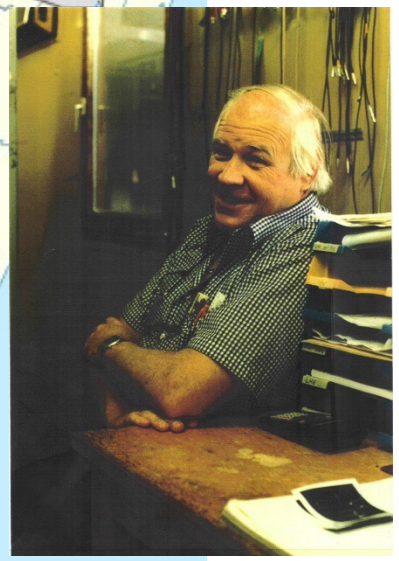


FIG. 1. Schematic of detector array.



Frederick Reines



Friedel Shellschop

Phys Rev Lett, 15, 429 (1965)

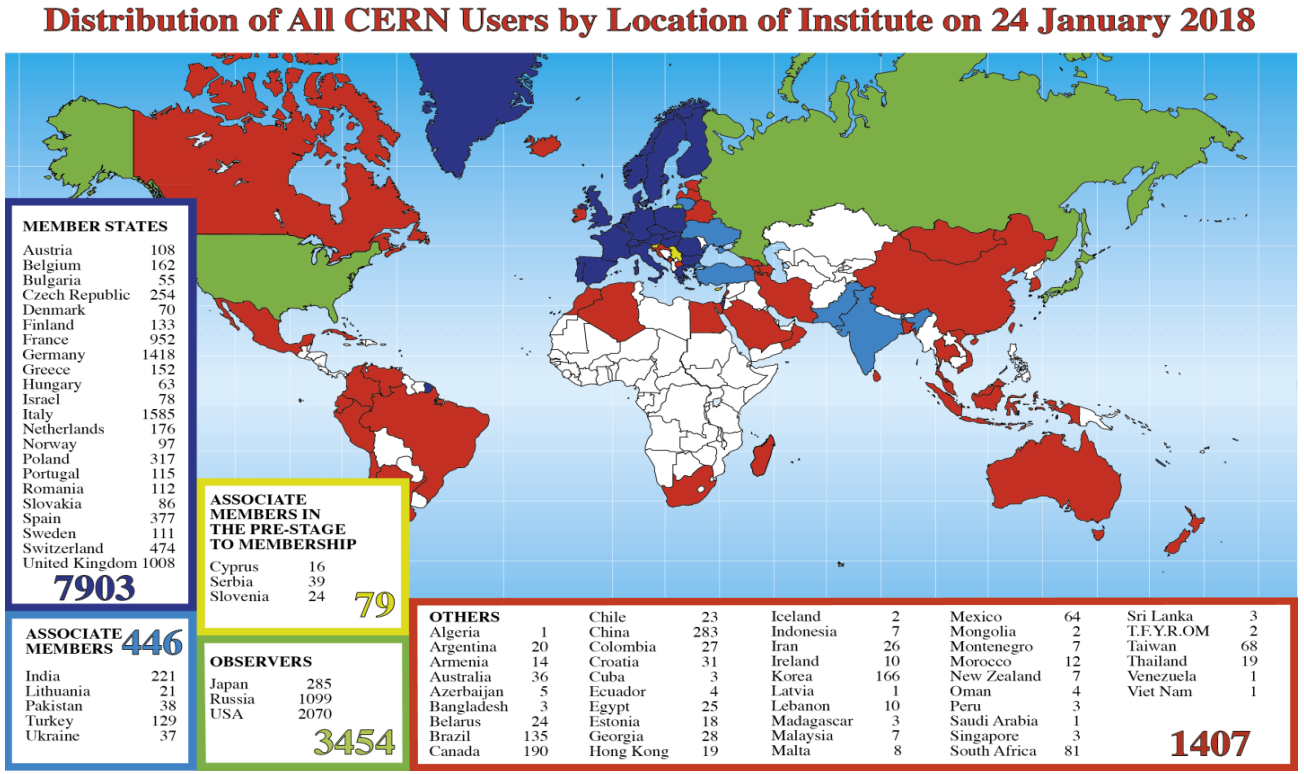
Current issues and the African context

About 0.5% of CERN users are African Nationals

Low participation of African scholars in major research labs around the world. Some examples:

- CERN users
- Users of LHC experiments

Not limited to CERN. Broader issue



Opportunity: African Youth Bulge and fast growing economies (albeit from low-base) like Asian economies of past decades.

Personal Journey

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

- 1994 —1997 : Ph. D.; CERN- NA43 experiment (Wits/Aarhus)
- 1998 —1999:Post-Doc;CERN- NA59 experiment [M. Velasco (Northwestern)]
- 1999 — 2006 : Faculty at University of Cape Town -> SA-ALICE : initiated HEP
- 2007 —2013 : Director: iThemba LABS —> **SA-CERN programme**
- Deputy V-C Research: university of the Witwatersrand (2014 –) [ALICE + ATLAS]

SA OFFICIALS AT CERN

1992: Signing of first Co-operation Agreement by FRD (NRF) President R Arndt and CERN DG C Rubbia.

2005: Visit by Minister of Science of Technology Mr Mangena

2011: Visit by Minister of Science of Technology Mrs N Pandor

Background: History from UCT-ALICE to UCT-CERN

- UCT joins ALICE (November 2001)
- UCT-CERN Research Centre (August 2003)
- SA-CERN (15 December 2008)
  - ALICE: UCT and iThemba LABS
- MoU – Muons & Grid Computing (21 March 2011)
- Wits joins ALICE (March 2014)
- CHPC signs MoU: computing for ALICE&ATLAS (April 2015)
- SA-ALICE joins LS-2 Upgrade (March 2018)

City boffins join Alice for a Big Bang

The University of Cape Town is among key sites in a world computer linkup on the Net that aims to recreate the beginning of the universe. Education Reporter **Jeanne van der Merwe** reports

SCIENCE

A GIANT project, involving UCT and spearheaded by the world's largest nuclear physics research centre, seeks to recreate the first few microseconds after the Big Bang and create pre-atomic "particle soup".

It will take about a thousand scientists from 28 countries, representing 78 institutes, several years to complete the experiment, led by the European Organisation for Nuclear Research (Cern) near Geneva, Switzerland.

The team of eight University of Cape Town physicists, led by world-class A-rated nuclear physicist Professor Jean Cleymans, is the only representative of Africa and the Southern Hemisphere to take part in the project.

And the Cape Town scientists will also be helping create the next generation of the World Wide Web.

Dubbed Alice (short for "A Large Ion Collider Experiment"), the experiment seeks to recreate a kind of the "particle soup" that existed for a few fractions of a second after the Big Bang (the moment the universe started) while it was still too hot for atoms to be formed.

The experiments themselves will be done at Cern, but in order to analyse the mass of data generated when millions upon millions of atoms collide, they need thousands of scientists and enormous computer capacity.

Cleymans, one of the world's leading thinkers in the field of nuclear physics, explained: "With this experiment we are trying to get as close as we can to the Big Bang. We can never get to the Big Bang itself, because that only happened once and can never happen again.

"But if we collide different ions together at high enough speed, we might make them "melt" into one, making the different atom nuclei indistinguishable and recreate that condition of quark gluon plasma ("particle soup") that probably existed a microsecond or so after the Big Bang, long before atoms started defining themselves in electrons, protons and neutrons."

In the experiments, scientists will use a Cern accelerator 28km in circumference to collide lead ions (lead atoms with an electric charge) at a fraction slower than light speed.

To ascertain whether they succeeded in making the quark gluon plasma, they have to track the paths of millions upon millions of subatomic particles generated by the atoms' collisions in the accelerator. This is why they need a completely new kind of computer "grid" with enough collective brainpower to receive and process all information.

This revolutionary "data grid" is similar to the World Wide Web, but it can run programmes collectively instead of merely exchanging data files as the current Web does.

The project will cost more than R650 million, funded mostly by western European countries, with substantial contributions from Japan, the United States and India.

Team member Zebion Vilakazi, a UCT lecturer who has done post-doctoral studies at Cern, said Cleymans's expertise on nuclear physics was one of the main reasons why the university had been asked to join the programme.

"Jean Cleymans has been actively involved in this field for more than 20 years and he is regarded as one of the leading authorities in the world."

The UCT team's job within the experiment is to design a way of selecting the data most relevant to the experiment.

"The experiment simply creates too much data, and there are certain events within the experiment that are more important than others. We are finding a way of streamlining the information and selecting only the most useful events. For that we need a computer programme that can make thousands of decisions a second. This is crucial for the success of the project, because if you lose one track of an important ion, you could lose a valuable part of the experiment, and finding it again would be like finding a needle in a haystack."

Cleymans said it was a seminal moment for South African science to collaborate in such a comprehensive programme.

"In the past we have not been able to participate in this kind of project, particularly due to sanctions and the political situation. It also doesn't happen often that such a large number of researchers from one department takes part in a programme – currently we have about a third of the physics department's staff working on this, and we would like to get more students on board."

He said the fact this was the biggest and most expensive physics experiment currently in the world could lead to pitfalls.

"With so many researchers on one project, sociology does come into play. There are a lot of big egos involved, and the whole enterprise has to be co-ordinated very well."

Cleymans said a data grid in Cape Town would enable scientists to investigate how well the computer system worked over a long distance.

UCT joined the Alice collaboration last November, and Cleymans estimated that the group would be ready for computer tests by September.

The Department of Arts, Culture, Science and Technology has approved a R300 000 donation for the project, and UCT's research committee has approved funding for 20 computers to be used in the International data grid.

Pinball wizards: UCT physics professor Jean Cleymans and colleague Zebion Vilakazi with an electronic image of atomic particles while they are colliding in an accelerator.

UNRAVELLING THE MYSTERIES OF THE ORIGIN OF THE UNIVERSE

Scientists believe that there was a Big Bang from which everything in the universe emerged. Fifteen billion years later, the universe is so huge that it would take light millions of years to cross

To understand the first moments of the Universe's life, the European Organisation for Nuclear Research (CERN) are using particle accelerators to smash ions into each other. The purpose is find and study matter called Quark Gluon Plasma (QGP)

SECTION OF A PARTICLE ACCELERATOR

These machines are housed in a massive complex of circular underground tunnels, the largest being 27km round. Accelerators use powerful electric fields to push energy into into a beam of particles which go round and round collecting more energy with each lap

Inside the CERN accelerator lead ions will be smashed into each other head-on

The energy at that moment will be high enough to make J/ψ (pronounced J-psi) particles whose fate will depend on what happens next

The protons and neutrons in the lead ions will split up, forming a dense soup of particles

As the QGP cools down, ordinary matter condenses out, like water condensing from steam. By measuring how many J/ψ's, how many particles containing strange quarks and how many electron pairs emerge from the collision, researchers will be able to tell whether a QGP formed, and learn about how it evolved

GLOSSARY OF TERMS

Protons: positively charged sub-atomic particles forming the nucleus of an atom

Neutrons: sub-atomic particles making up the nucleus of an atom along with protons

Electrons: sub-atomic particles circling the nucleus of an atom

Ions: atoms with some electrons missing

Quarks: "sub-sub-atomic" particles that form protons and neutrons

Gluons: the "sub-sub-atomic" particles that keep quarks together

Quark gluon plasma: a "soup" of quarks and gluons that is created when ions are compressed so tightly that their cores start overlapping

SOURCE: CERN PROF JEAN CLEYMANS, UCT GRAPHIC: MALCOLM BURCH, ROB CRETCHLEY

Explosion of data set t revolutionise the Wel

RECREATING the "soup" of sub-atomic particles that existed in the few microseconds after the Big Bang may be of no consequence at all to ordinary people.

But the computer system that will be used in the experiment could revolutionise the World Wide Web.

The International Alice collaboration, an experiment involving a thousand scientists all over the world and spearheaded by the European Organisation for Nuclear Research (Cern) near Geneva in Switzerland, is the second undertaking of its kind in history.

The first one in 1979 sought to find out why positive-charged protons and neutrons stick together in the nucleus of the atom instead of shooting apart like similar poles of two magnets.

In that experiment, led by 1984 Nobel physics laureate Carlo Rubbia, scientists developed a system of interlinked computers able to exchange data files – the start of the World Wide Web, which changed the world forever.

In the Alice collaboration, Cern and its participating institutes will form a "data grid" of thousands of inter-linked computers working in concert all over the world – but instead of merely exchanging data files like the Web, the data grid will be capable of running programmes simultaneously.

The system will consist of several tiers of computers linked in parallel to create enormous data processing capacity.

UCT physicist Zebion Vilakazi explained the need for such powerful computers.

"The experiments in the accelerators generate 40 000 individual tracks (of the movements of individual sub-atomic particles as they collide with one another in the accelerator) per second. To store a day's worth of data, you'd need 50 000 CDs. That is simply too much to work with. We must create a computing system that will be able to make millions of decisions a minute about which tracks to keep and which to discard, and to store them."

The data of the experiment, which takes place in a giant accelerator, will be fanned out from Cern's computer "farm" ("Tier Zero") to several "Tier One" centres, of which UCT is one. These centres, all equipped with "farms" of parallel-linked computers, will analyse data or send it through to other linked computers.

UCT physics professor Jean Cleymans explains

THE INTERNATIONAL ALICE COLLABORATION

The Alice (A Large Collider Experiment) collaboration uses a data grid of thousands of inter-linked computers working in concert all over the world

37 people from 11 institutes involved

Already in production

THE CAPE ARGUS (1ST MAY 2002)

Participation of SA in ALICE

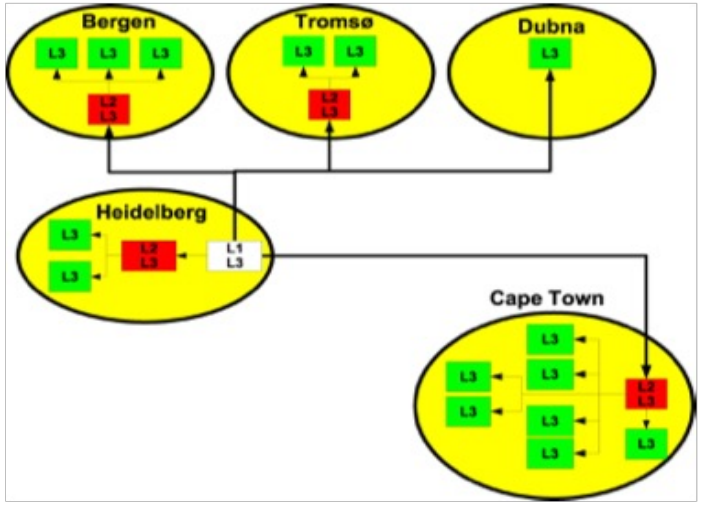
Dimuon Arm: algorithms for online High Level Trigger (dHLT, commissioned in 2008)

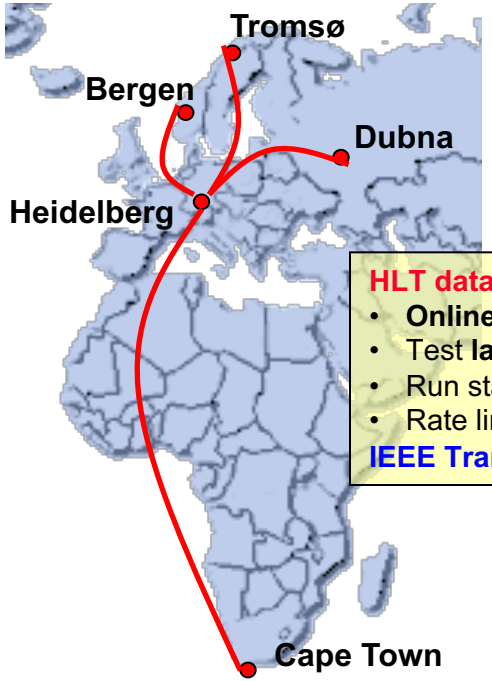
- Real-time processing of heavy-ion collisions:
  - online event selection
  - compression
- calibration and quality monitoring

- 25 GB/s, up to 1000 ev/s
- Extreme computing, networking and process control demands in 2008

Grid Computing: Computing Cluster integrated into ALICE GRID

Physics: Dimuon studies (acceptance, efficiency); W production in pp; ..





HLT data challenge: Nov. 2004
- **Online test** on 'Grid' !
- Test **latency tolerance**
- Run stable for > 15 hours
- Rate limited by bandwidth

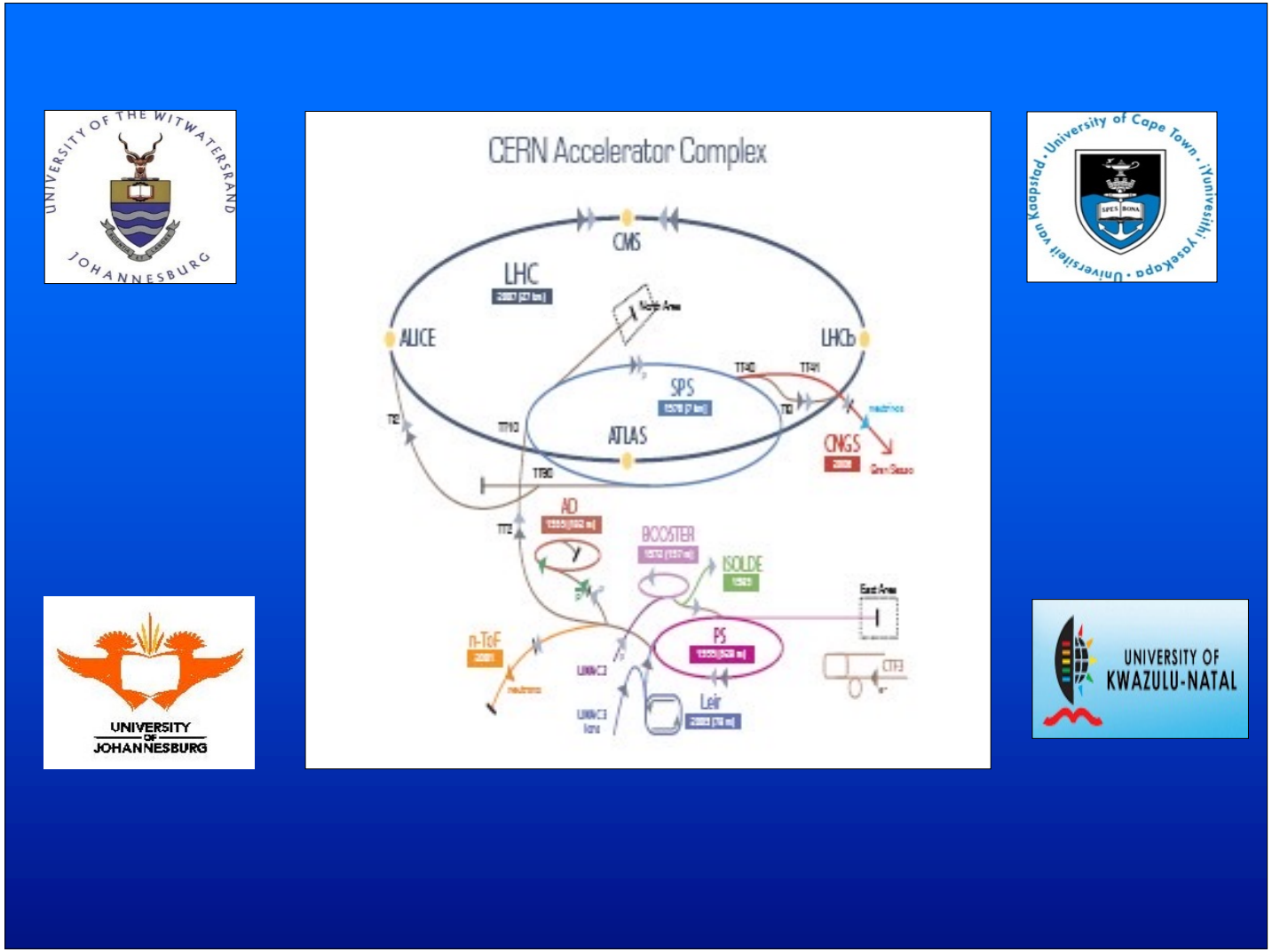
IEEE Trans.Nucl.Sci.55:703,2008.

The SA-CERN Programme

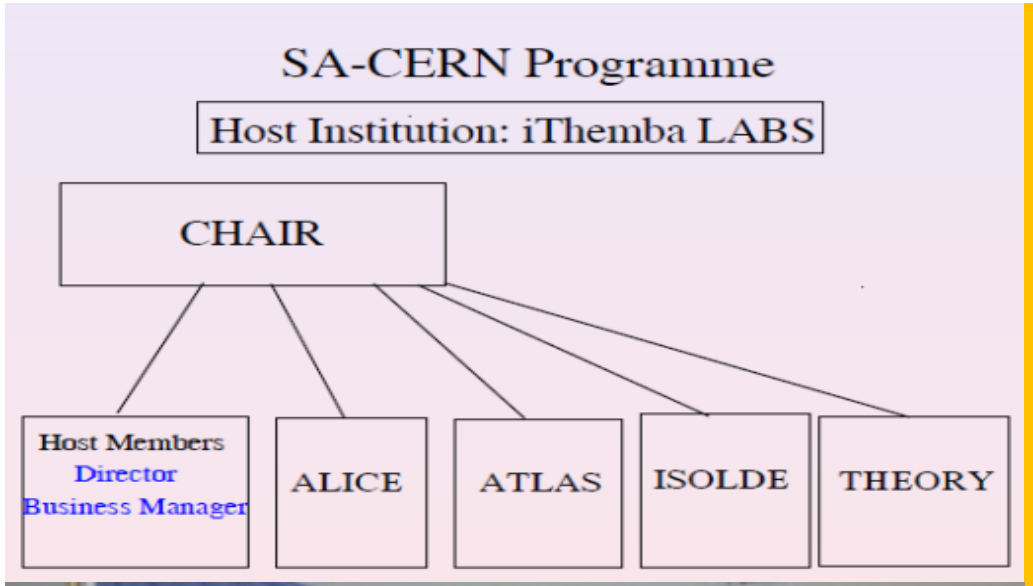
1. **Started as a consortium of researchers who had long standing research program with CERN**

2. **Modelled along the Australian, Indian and Brazilian programs.**
   - **Allows for central point of coordination and resource allocation.**

3. **Agreement was that iThemba LABS would act as a neutral institutional hosts for the SA-CERN program:**



Has been recognised by the ministry as an exemplar for other multi-lateral collaborations: SA-JINR



Host of the National SA-CERN Programme: iThemba LABS

National coordinators are elected.

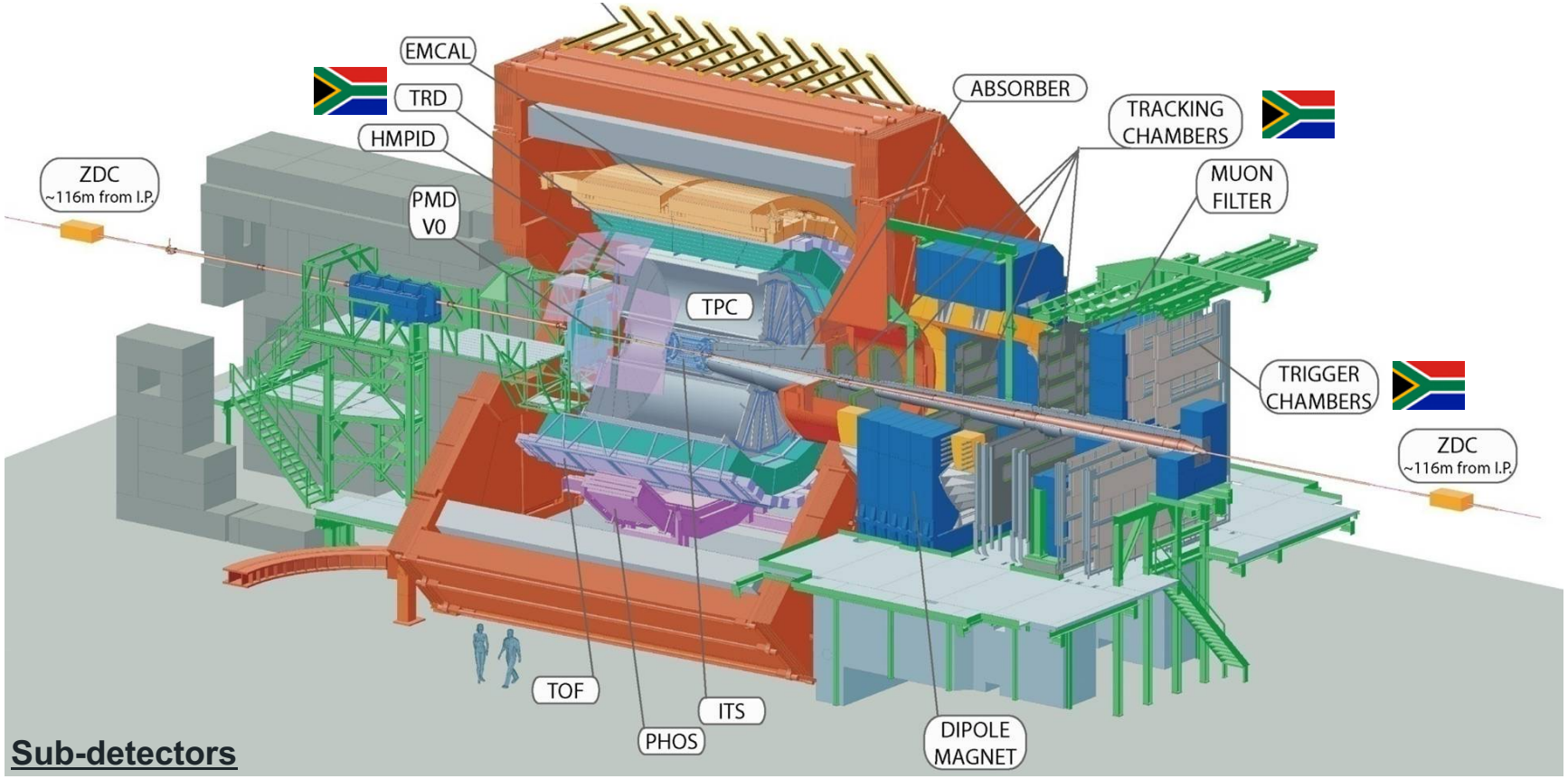
Chairman is elected by the national coordinators.

Launch of the SA-CERN consortium December 2008.

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SOUTH AFRICA IN ALICE
MAINTENANCE AND OPERATIONS

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG



Sub-detectors

Muons Tracking and Trigger

High Level Trigger (HLT)

→ Design and Commissioning of dimuon spectrometer HLT (dHLT)

W-Z Boson — Standard Model Test

- **pp:** PDFs at large Q2
- **p-Pb:** Cold Nuclear Matter (CNM) effects, nuclear PDFs
- **Pb-Pb:** binary collision/N_{coll} scaling of hard processes

JHEP

PUBLISHED FOR SISSA BY SPRINGER

RECEIVED: November 11, 2016
ACCEPTED: February 4, 2017
PUBLISHED: February 15, 2017

W and Z boson production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

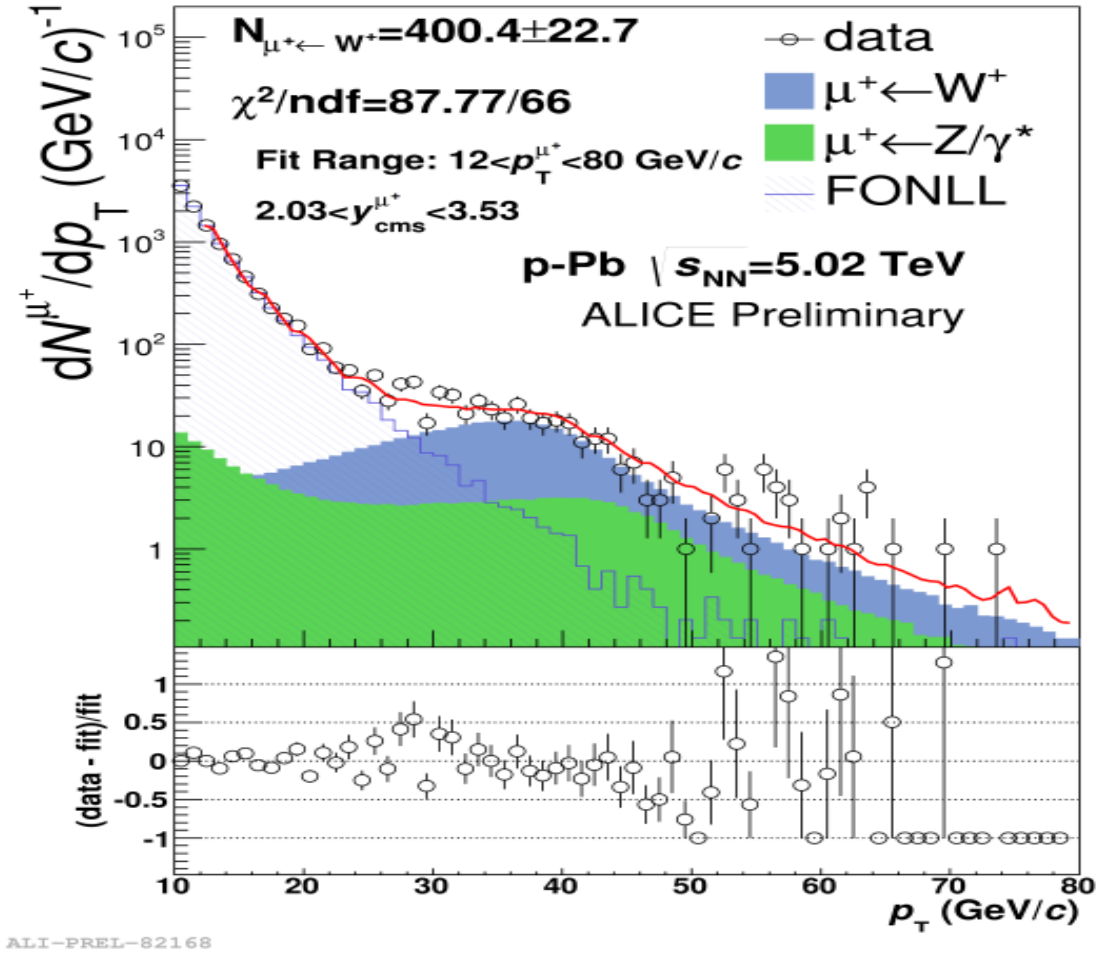
ALICE

The ALICE collaboration

E-mail: ALICE-publications@cern.ch

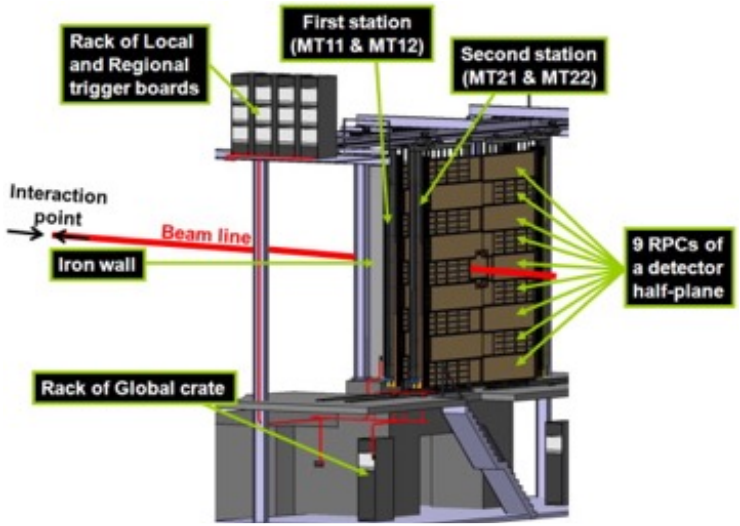
ABSTRACT: The W and Z boson production was measured via the muonic decay channel in proton-lead collisions at $\sqrt{s_{NN}} = 5.02$ TeV at the Large Hadron Collider with the ALICE detector. The measurement covers backward ($-4.46 < y_{cms} < -2.96$) and forward ($2.03 < y_{cms} < 3.53$) rapidity regions, corresponding to Pb-going and p-going directions, respectively. The Z-boson production cross section, with dimuon invariant mass of $60 < m_{\mu\mu} < 120\,\mathrm{GeV}/c^2$ and muon transverse momentum (p_T^{μ}) larger than 20 GeV/c is

JHEP02(2017)077



Work done in collaboration with Subatech (France) and Wuhan (China)

Muon Tracking Detector



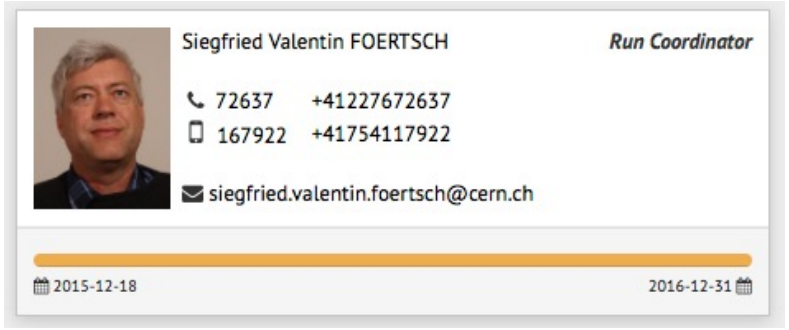
Detector Maintenance during LS-1

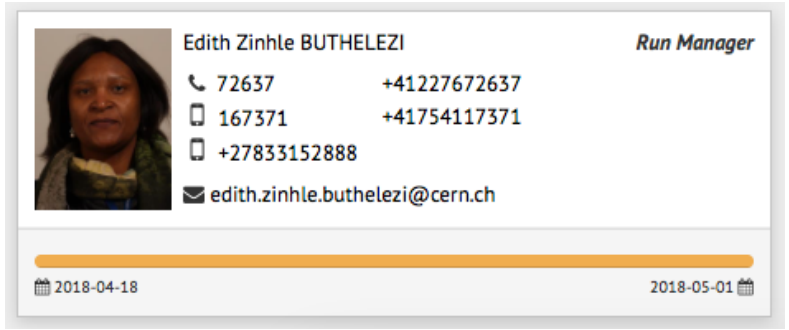
Testbeam for LS-2 Upgrade

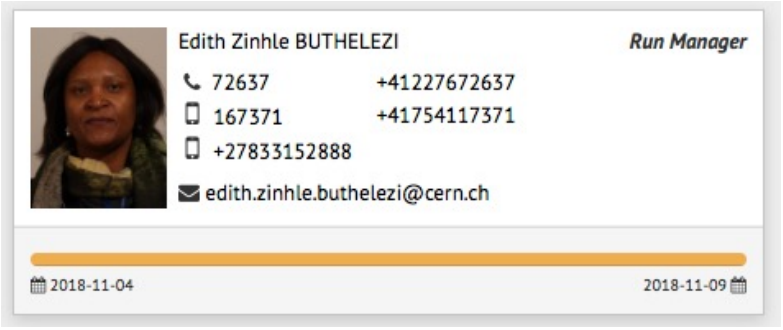
F Bossu, S Arkar, D Azmi, J Senosi, R Kuriakose, S Mhlanga, C Monteverdi, S Delsanto, D Steyn, Z Buthelezi, S Förtsch

Run Coordination

- Siegfried Förtsch
  - Run Coordinator 2016
- Zinhle Buthelezi
  - Run Manager
  - April 2018: start of data taking
  - November 2018: start of Pb-Pb run

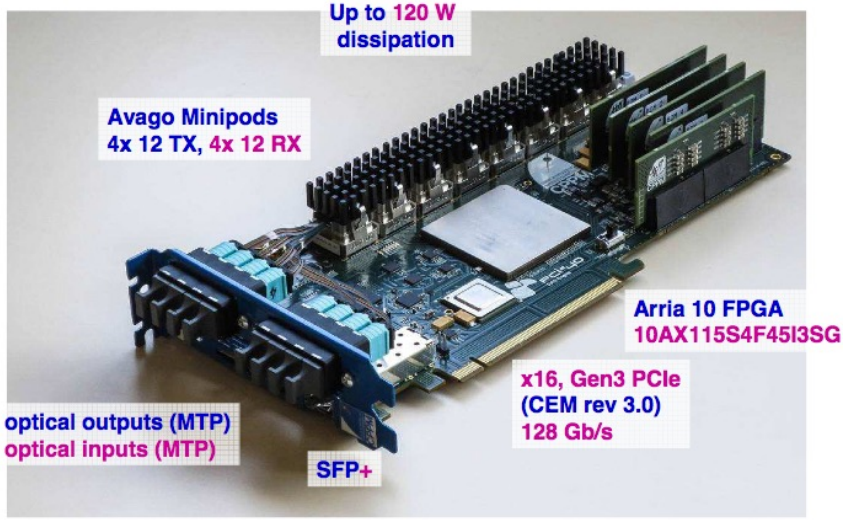






Muon Arm Upgrade

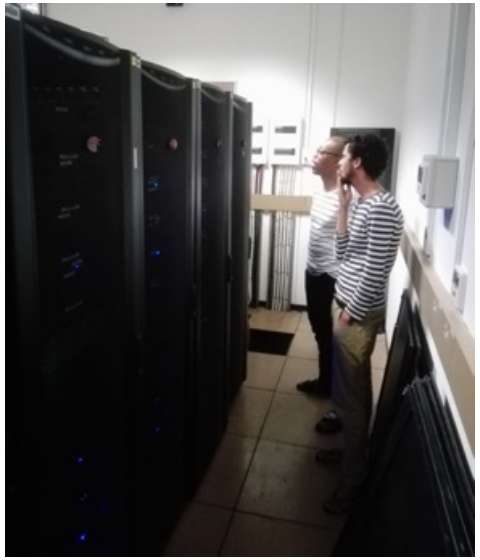
- Muon Identifier: Common Readout Unit On-The-Fly Data Conditioning @ 51.2Gb/s

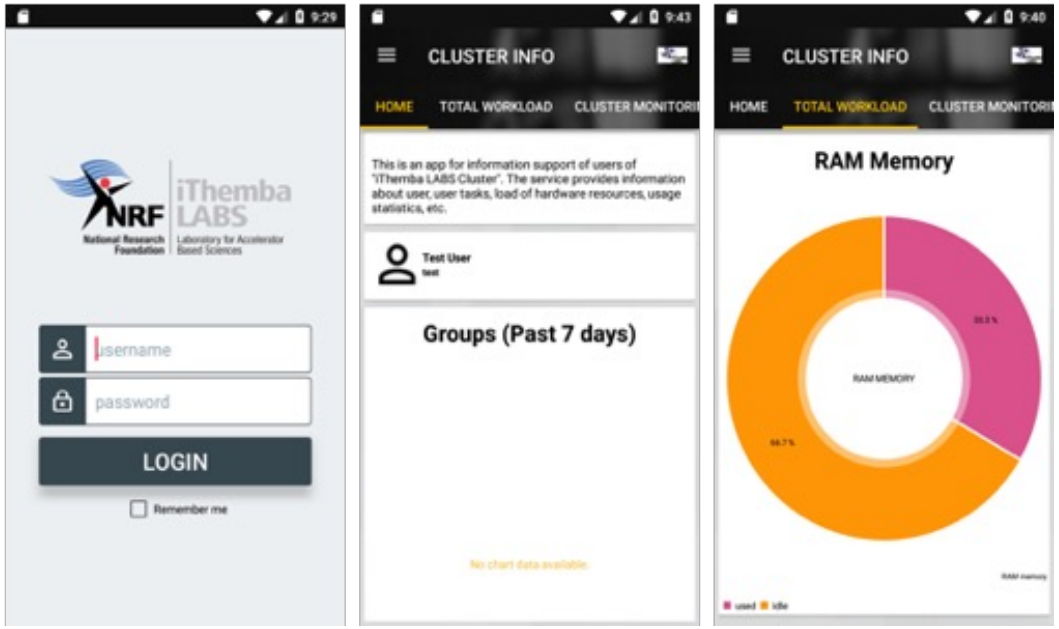


- Muon Tracking: Low-Voltage System

Tier-3 Cluster at iThemba LABS

- 264 CPUs / 528 GB RAM / 32 TB HDD
- used by ALICE + other iThemba groups
- re-using donated Run-1 HLT
- Android monitoring app





THE ALICE GRID IN SOUTH AFRICA

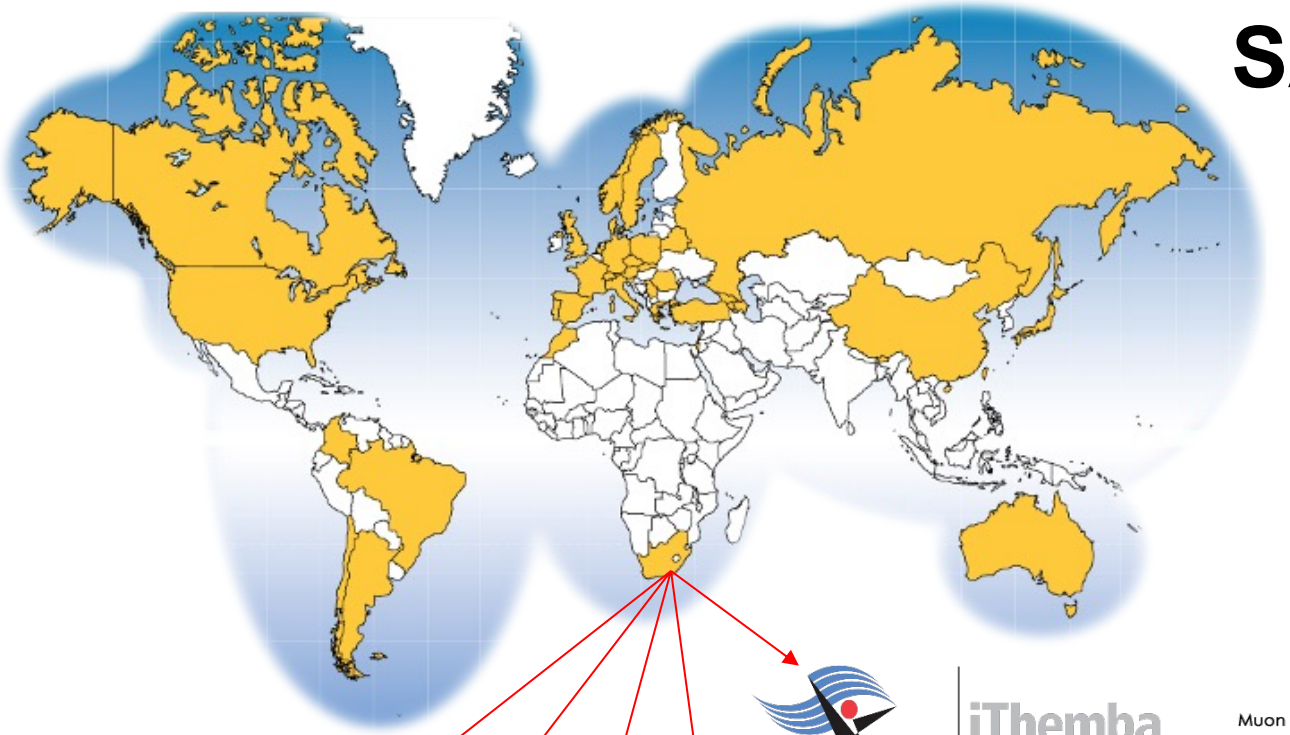
ALICE grid requires sustained and reliable bandwidth to sites.

Despite lack, SA Tier2 was processing MC data 2004-2009 with contributed resources.

ALICE monitoring system has been used to “map” the effect of SANReN:

- National network performs very well,
- International bandwidth no longer limiting factor.

SA@ATLAS



NRF National Research Foundation | iThemba LABS Laboratory for Accelerator Based Sciences

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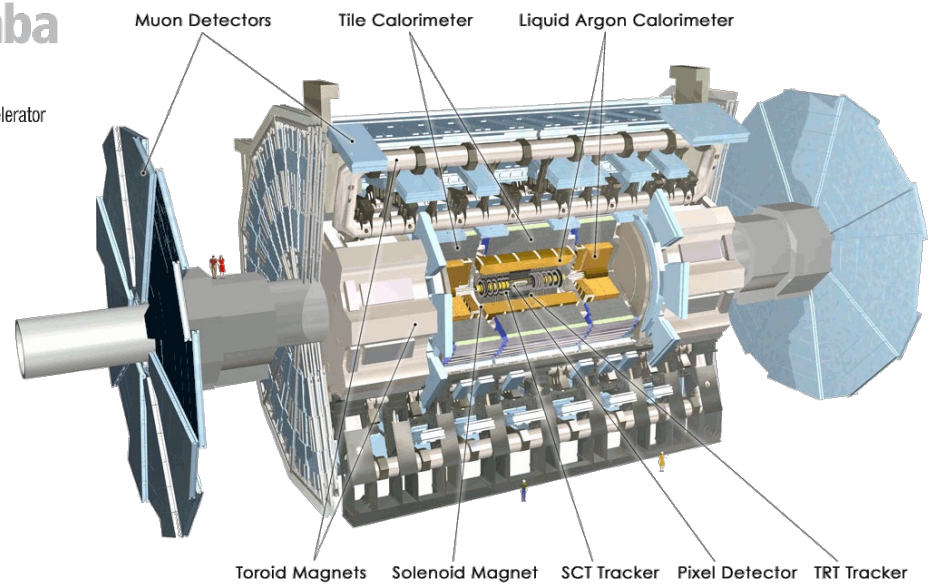

ATLAS (as of a few years ago…)

- Principal Scientists *:
  - Simon Connell (UJ),
  - **Bruce Mellado** (Wits), Deepak Kar (Wits), Xifeng Ruan (Wits),
  - Elias Sideras-Haddas (Wits), Sahal Yacoob (UCT)
- Post-doctoral fellows:
  - Debarati Roy (Wits), Yesenia Hernandez (Wits), Loan Truong (UJ),
  - Robert Reed (Wits)
- Students: 26 MSc and PhD Students

*** List not exhaustive**

ISOLDE

Principal Scientists:

- **Krish Bharuth-Ram** (KwaZulu-Natal and Durban U. of Technology)
- Hillary Masenda & Deena Naidoo (Witwatersrand),
- Nico Orce & S. Trambak (Western Cape)
- Mathis Wiedeking (iThemba LABS), Christine Steenkamp (Stellenbosch)

- Post-doctoral fellows:
  - S. Sithole (Stellenbosch and iThemba LABS) Kumar Raju (Western Cape)

- Students: 13 MSc and PhD students

UNIVERSITY OF KWAZULU-NATAL

Outreach

International masterclass April 2014

- **“Looking for Strange Particles in ALICE”**
  - Organized by SA-ALICE and iThemba LABS
  - 24 students from 6 schools
  - International video discussion with Cairo, Geneva &Warsaw

2015: CERN Beamline for Schools Competition

St. John’s College and Barnato Park High School team

Simon H. Connell (University of Johannesburg)

Conferences in South Africa

June 2004	ALICE Dimuon Workshop
September 2004	Strange Quark Matter
December 2008	Inauguration of SA-CERN
December 2010	First Kruger Workshop
2012	ALICE Dimuon Workshop
December 2012	Kruger Workshop
November 2013	Hard Probes
December 2014	Kruger Workshop
January 2015	Chris Engelbrecht Summer School
December 2016	Kruger Workshop
December 2018	Kruger Workshop
April 2019	ALICE Muon Week

THE BIENNIAL AFRICAN SCHOOL OF FUNDAMENTAL PHYSICS AND APPLICATIONS (ASP)

- **International Organizing Committee (IOC)**
  - The IOC is the main organizer of the school
  - The IOC Members:
    - B. Acharya (ICTP & King's College London)
    - K. A. Assamagan (BNL)
    - A. Dabrowski (CERN)
    - C. Darve (ESS)
    - J. Ellis (CERN & King's College London)
    - S. Muanza (CNRS-IN2P3)
    - R. Voss (CERN)
- **Local Organizing Committee (LOC)**
  - Local committee in the host country
- **International Advisory Committee (IAC)**
  - Advises on various aspects of the organization including fund raising

http://www.africanschoolofphysics.org/

WITS

Thank YOU

South Africa and CERN
for making this possible.

UCT

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