

High-Energy Physics Activities in South Africa

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University of the Witwatersrand, South Africa

Special Thanks to: J. Cleymans, S. Connell, and Z. Vilakazi

May 25, 2010

Symposium in High Energy Physics for the
Mediterranean and Africa, Paris, France



The Past...

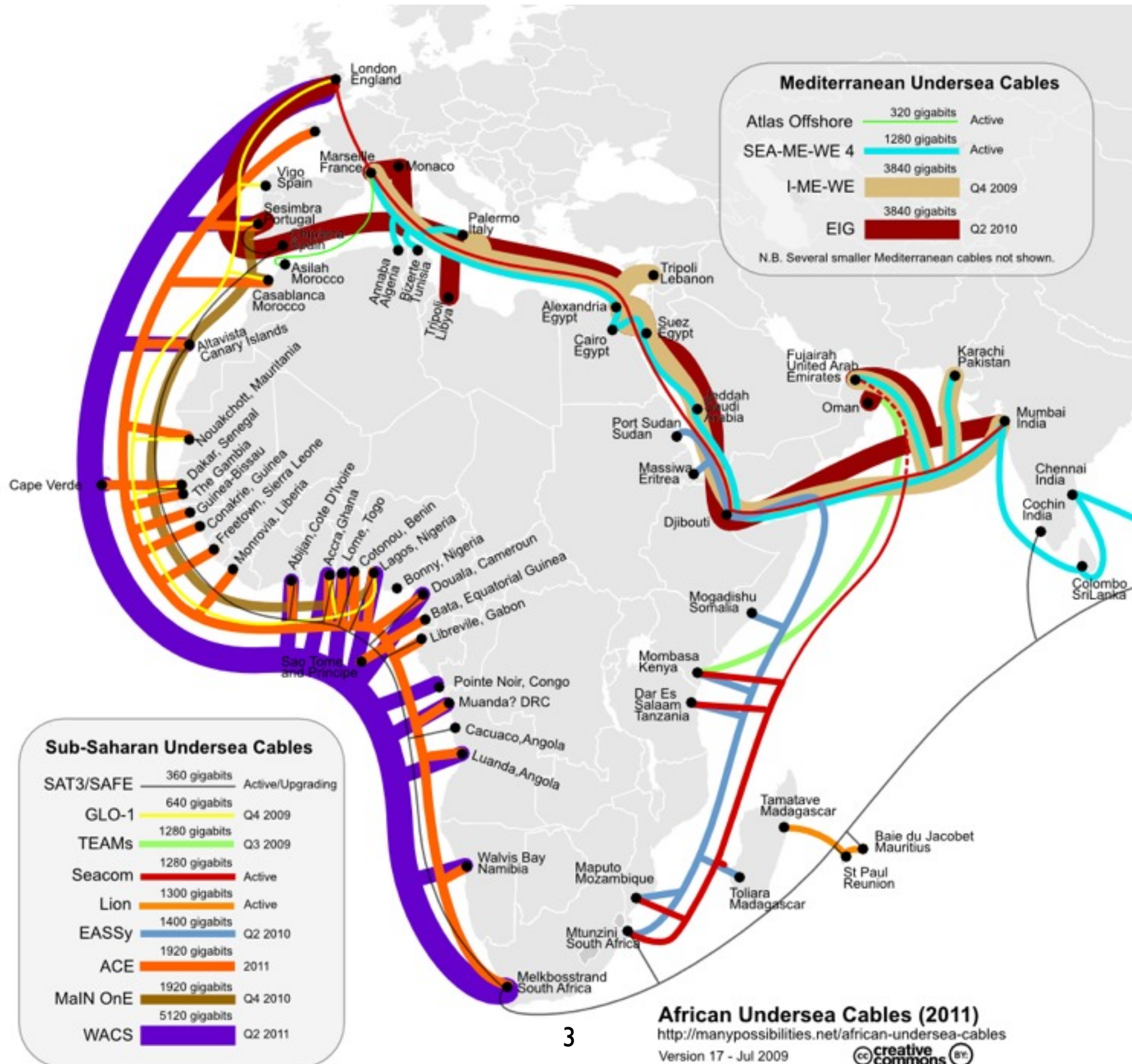
- **SA Graduates who have made a major impact in the subject**

- S. Mandelstam [BSc (Wits)]: Variables for calculating kinematics for particle interactions [IoP Dirac medal]
- J. Dorfan [BSc (UCT)]: Director of Stanford Linear Accelerator (SLAC) between 1999 - 2007
- S. Teuklosky [BSc (Wits)]: Mathematical / numerical calculations; cosmology
- Note: All of the above left the country to pursue their research careers in the USA or UK

- **Contributions by scientists working (or on work done) in SA**

- Lower limits on electron neutrino mass at ERPM: F. Reines (Nobel Prize 1995) & J.P.F. Sellschop (Wits)
- Highly cited “Strangeness enhancement...” paper: J. Rafelski (UCT) & Muller (more than 1000 citations)
- Development of a highly successful statistical model for the description of particle production in Heavy-Ion collisions: J. Cleymans (UCT)
- Highly regarded papers in String Theory: R. de Mello Koch & J. Rodrigues (Wits)
- South Africans have built one of the most respected cyclotrons in the world (iThemba LABS)

The Future...



South African involvement at CERN

- ISOLDE Collaboration
 - **K. Bharuth-Ram (UKZN)**
 - D. Naidoo (Wits) [PhD UKZN; 2007]
 - More than 50 publications
- ALICE Collaboration
 - **J. Cleymans (UCT), Z. Vilakazi (iTL), Z. Buthelezi (iTL) & S. Foertsch (iTL)**
 - B. Becker (MERAKA Inst.) [PhD UCT; 2007]
 - S. Mohlali (Univ. of Lesotho) [MSc UCT; 2009]
 - G. de Vaux [MSc UCT; 2009]
 - A. Szostak (postdoc in Italy) [PhD UCT; 2009]
 - A. Comrie [MSc UCT; 2010]
 - Numerous papers, book chapters and technical reports
- ATLAS Collaboration
 - **S. Connell (UJ) & T. Vickey (Wits)**
 - S. Yacoob (Wits postdoc) [PhD Northwestern; 2010]
 - A number of graduate students
 - On-track to be a full member of the collaboration



**Signing of first Co-operation agreement (1992):
R. Arndt (FRD president) & C. Rubbia (CERN-DG)**

South African involvement at CERN (con't)

- CERN NA-43

- **Collaboration with Aarhus, Wits (Sellschop, Connell), and Florence**
- 1992 - 1997
- Z.Vilakazi (iTL) [PhD Wits; 1998]

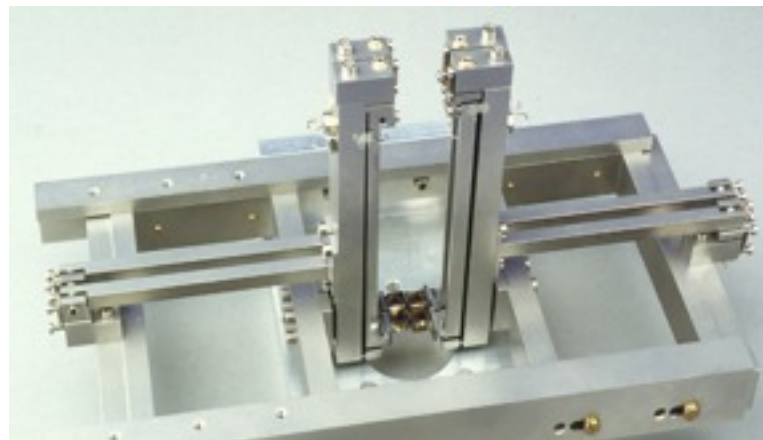
- CERN NA-59

- **Collaboration with Aarhus, Wits (Sellschop*, Connell), Florence, Northwestern, NIKHEF**
- 1998 - 2007
- R. Groess [MSc Wits; 2001]
- Z.Vilakazi (part of postdoc at CERN)

- CERN NA-63

- **Collaboration with Aarhus, UJ (Connell, Ballestrero), Florence, Northwestern, NIKHEF**
- 2008 - 2009
- Includes a FP7 application to develop Gamma Ray Lasers using diamond crystal undulators

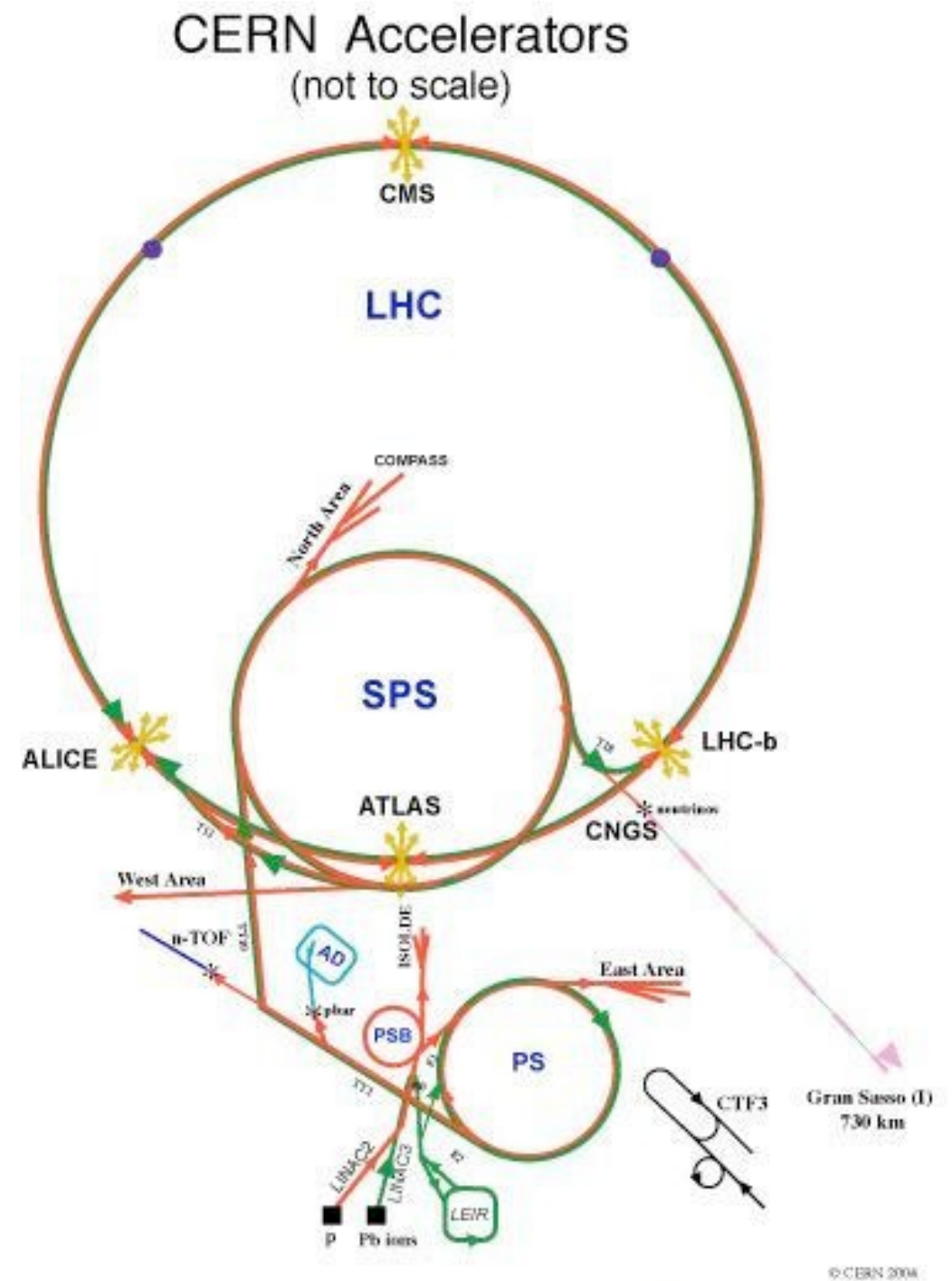
~25 papers



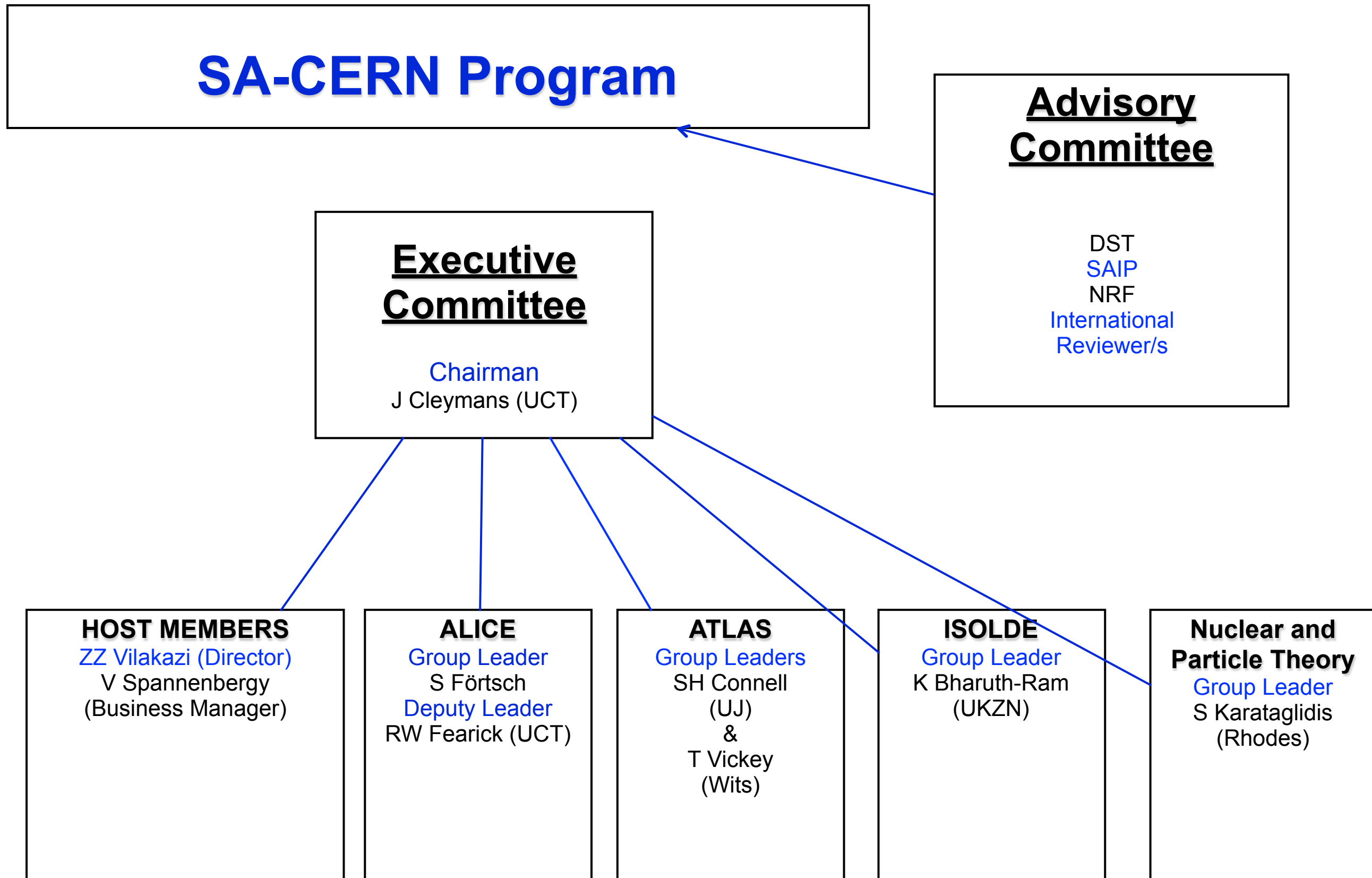
Diamond Radiator
CERN Press Office :
"photo of the month -00707"
in the CERN Courier

The SA-CERN Program

- Origins of SA-CERN
 - Started as a consortium of researchers who had a long-standing research program with CERN
 - Modeled along the Australian, Indian and Brazilian programs
 - Allows for a central point of coordination and resource allocation
- Agreement was that iThemba Labs would act as a neutral institutional host for the SA-CERN program



Governance Structure



Participants in the SA-CERN Program



Existing SA Activities at CERN

Program	Principal Investigators	Field
ALICE Experimental High Level Trigger for the Dimuon Spectrometer	Z.Z. Vilakazi (iThemba/UCT) R.W. Fearick (UCT) S. Förtsch (iThemba) Z. Buthelezi (iThemba) G. Steyn (iThemba) B. Becker (iThemba/CSIR))	Computing: simulation, analysis, data acquisition, algorithms.
ALICE Theory	J. Cleymans (UCT) , A.T. Muronga (UCT)	Hadron Physics, QGP Physics, Hydrodynamics, Thermal Modelling.
Nuclear and Particle Theory	S. Karataglidis (RU) J. Williams(RU)	Nuclear reaction theory, Nuclear Structure, Exotic nuclei, Nuclear astrophysics.
ISOLDE	K. Bharuth-Ram (UKZN) D. Naidoo (Wits)	Hyperfine interactions Mössbauer and channelling, solid state defects. Nuclear Physics
ATLAS	S .H. Connell (UJ) & T Vickey (wits)	Higgs, Exotic Physics.
SPS Projects	S.H. Connell (UJ)	QED with strong fields Bent Crystal beam extraction Crystal Undulator
GRID High Performance Computing	J. Cleymans (UCT) Z.Z. Vilakazi (iThemba) S.H. Connell (UJ) A.T. Muronga (UCT) B. Becker (iThemba/CSIR)	GRID applications Cluster computing

South African Advantages

Location	Local time	Time zone
Geneva (Switzerland)	Monday, 1 March 2010, 00:00:00	UTC+1 hour CET
Johannesburg (South Africa)	Monday, 1 March 2010, 01:00:00	UTC+2 hours
Corresponding UTC (GMT)	Sunday, 28 February 2010, 23:00:00	

Fall / Winter

Location	Local time	Time zone
Geneva (Switzerland)	Monday, 29 March 2010, 00:00:00	UTC+2 hours CEST
Johannesburg (South Africa)	Monday, 29 March 2010, 00:00:00	UTC+2 hours
Corresponding UTC (GMT)	Sunday, 28 March 2010, 22:00:00	

Spring / Summer

**EVO Server in
South Africa**



Paris ↔ Johannesburg
on the A-380

Leave at night,
arrive in the morning.
No jet-lag.

Participation of SA in ALICE

● Cape Town in ALICE: currently 6 senior staff + several students

⇒ **UCT** joined **2001**, became **UCT-CERN** research center in **2003**

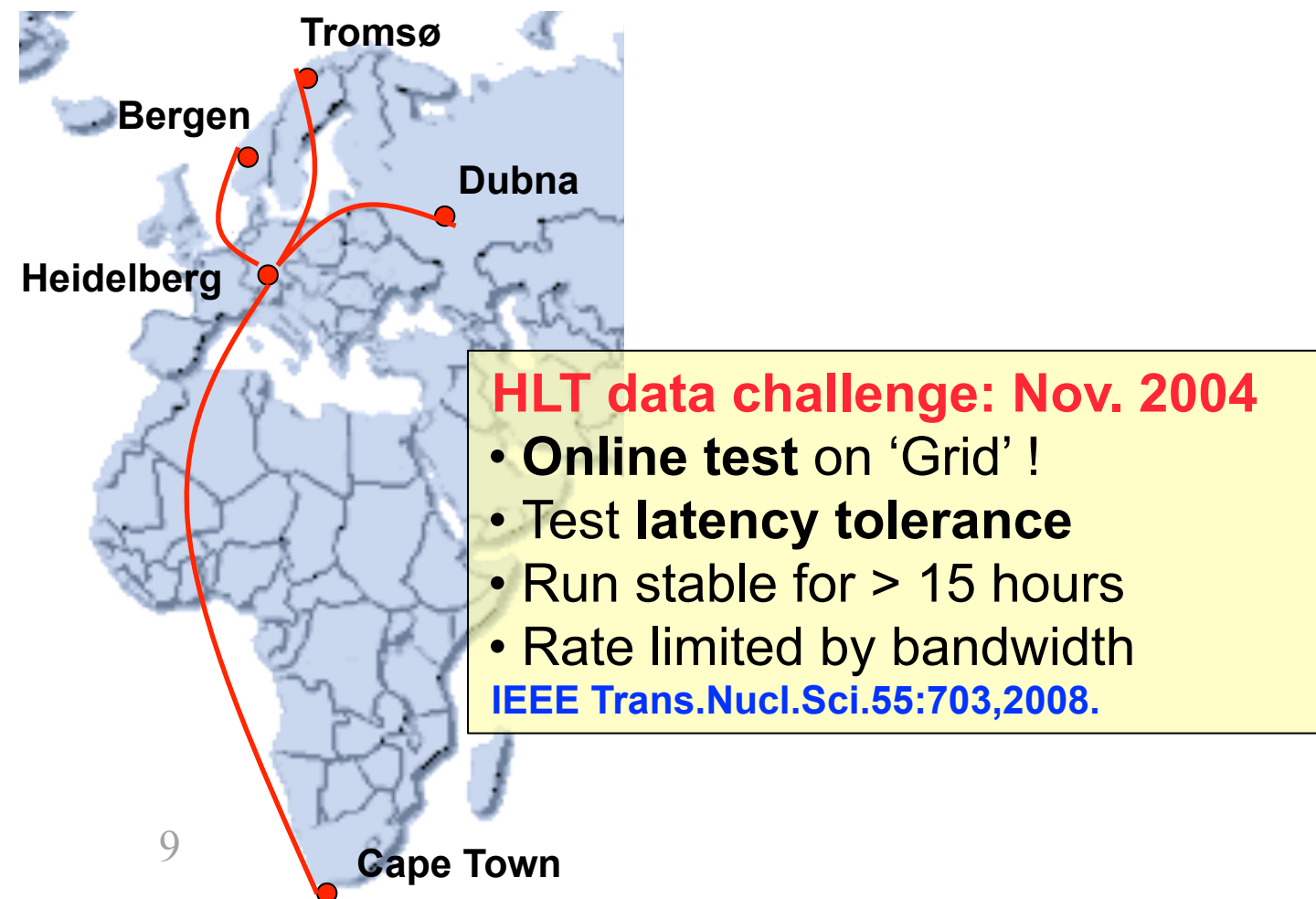
⇒ **iThemba Labs** joined in **2008**

● Projects

⇒ **Di-muon Arm**: algorithms for online High Level Trigger (dHLT, commissioned in 2008)

⇒ **Grid Computing**: Computing Cluster integrated into ALICE GRID

⇒ **Physics**: Di-muon studies (acceptance, efficiency); W production in pp; ..



Participation of SA in ATLAS

Status: July 2008

37 Countries

169 Institutions

2500 Scientific Authors total
(1800 with a PhD, for M&O share)

**SA formal Expression
of Interest to Join
submitted in Feb.
2010**

**Collaboration will
vote in early July
2010**



Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow,

UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow,

MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, UFRJ Rio de Janeiro, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

ATLAS at Univ. of Johannesburg



- **Staff**

2 Staff (Simon Connell, Sergio Ballestrero (CERN Associate), 3 students

- **Facilities**

Developed the UJ Research Cluster : 240 cores, 8.5 TB, developing Tier 3. Part of DOSAR.

- **Service Work**

The sub-group will also take on responsibilities for muon software maintenance and development.

- **Growth**

A search for the a UJ ATLAS postdoc is underway

Additional Staff – just hired a HEP Theorist and search is on for a new Chair

- **Outreach**

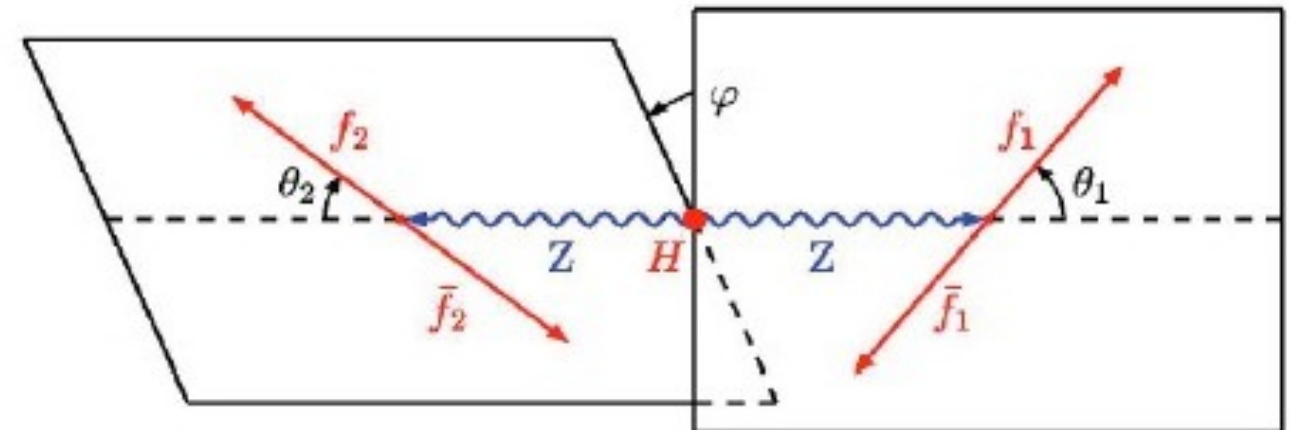
- HEP and Computing Training : OSG and ATLAS resources, gLite resources.
- Schools : **ASP 2010** <http://africanschoolofphysics.web.cern.ch/> in Stellenbosch August 2010
- Public : via HEP Masterclasses and SciBono Science Centre

3 Projects : K. Assamagan and S. Connell

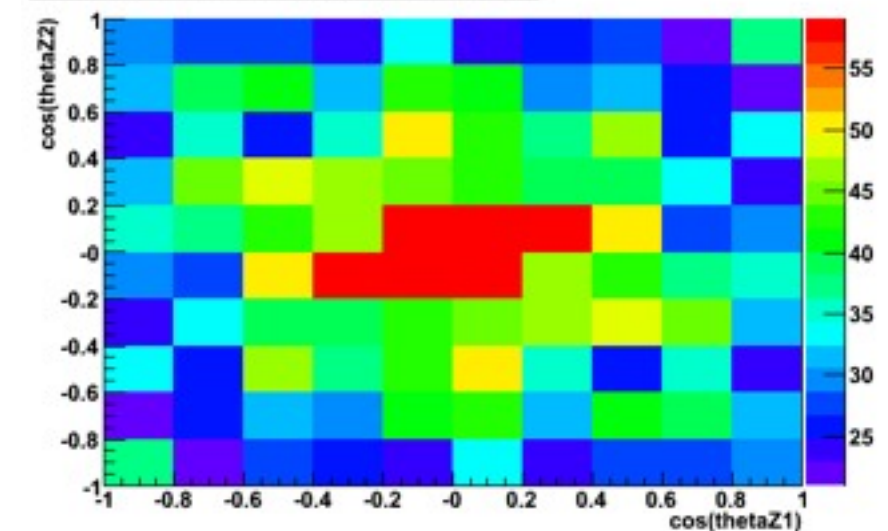
1. Search for the SM Higgs boson through its decay into a pair of new gauge bosons of very low mass, leading to four leptons (electrons or muons) in the detector; an evidence of new gauge bosons
(PhD - Claire Lee)
2. Measure the total width of the top-quark, at the level of 10% or less, this could be an evidence for new physics, for example the decay of the top-quark in charged Higgs will change the total width from its SM value. In general, the existence of Super Symmetry or charged Higgs could affect the total width of the top quark.
(PhD – Neil Koch)
3. Measure the single to di-lepton ratio in the top-quark/anti-top quark production at the LHC. Once radiative corrections are accounted for, this ratio is fixed in the SM. Any deviation from the SM expectation would constitute an evidence of new physics which could be either super-symmetry, exotic physics or the charged Higgs lighter than the top-quark.
(MSc – Phineas Ntsoele)

Hidden sector Higgs decays

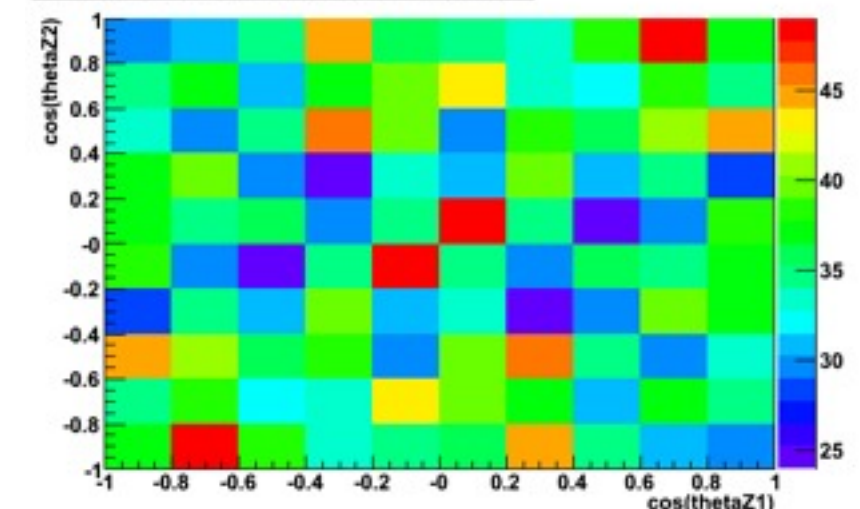
- Wells et al describe a model in which a hidden sector Higgs and Z' boson interact with the SM only through mixings with the SM Higgs and hypercharge gauge boson. (arXiv:0801.1243 & 0801.3456)
- This leads to the possible decay of the SM Higgs into two Z' bosons with a reasonable branching ratio (eg 50%).
- The Z' can have a very low mass, and thus must decay into SM fermions (leptons or light quarks) with a very narrow width.
- Our group is investigating this $H \rightarrow Z'Z' \rightarrow 4l$ channel in ATLAS.
- Search strategy: same as for $H \rightarrow ZZ \rightarrow 4l$ except for constraint on Z' mass
- The SM Higgs is CP even scalar (spin 0). Spin information in its decay products. The Z bosons from Higgs decay are polarized.
- Since we replace $H \rightarrow ee$ with $H \rightarrow Z'Z'$ we may get systematic effects from possibly neglecting spin correlations.
- In progress: comparing the angular distributions of leptons from $H \rightarrow ZZ \rightarrow 4l$ with $H \rightarrow Z'Z' \rightarrow 4l$, for 200 GeV Higgs and $M_{Z'}=M_Z$
- Using a variety of event generators
- If needed, we can reweight the events at the analysis level



Z1 vs Z2 decay angle $\cos(\theta)$ for $H \rightarrow ZZ$



Z1 vs Z2 decay angle $\cos(\theta)$ for $H \rightarrow Z'Z'$



ATLAS at Univ. of the Witwatersrand



- **Staff:** T.Vickey (Senior Lecturer), S.Yacoob (Postdoc)
- **Facilities:** Contributing to the Witwatersrand Research Cluster, as well as SA Tier 3 that was started by UJ
- **Service work:** Working on the SemiConductor Tracker (DAQ, Read-out Driver, DSP code, etc.); data-taking shifts for the SCT
- **Growth:** Interviews for another Senior Lecturer took place very recently; expect additional postdocs, graduate students, BSc (Hons) students
- **Outreach:** A member of the African School of Physics Local Organizing Committee

ATLAS at Univ. of the Witwatersrand



T. Vickey and S. Yacoob

- Tau performance / fake rate with data
- W to tau nu
- Z to tau tau
- Z' to tau tau search / limits
- Leptoquark search / limits
- MSSM neutral Higgs search / limits
- SM Higgs to tau tau search / limits

Today

$\sim 100 \text{ pb}^{-1}$

$\sim 200 \text{ pb}^{-1}$

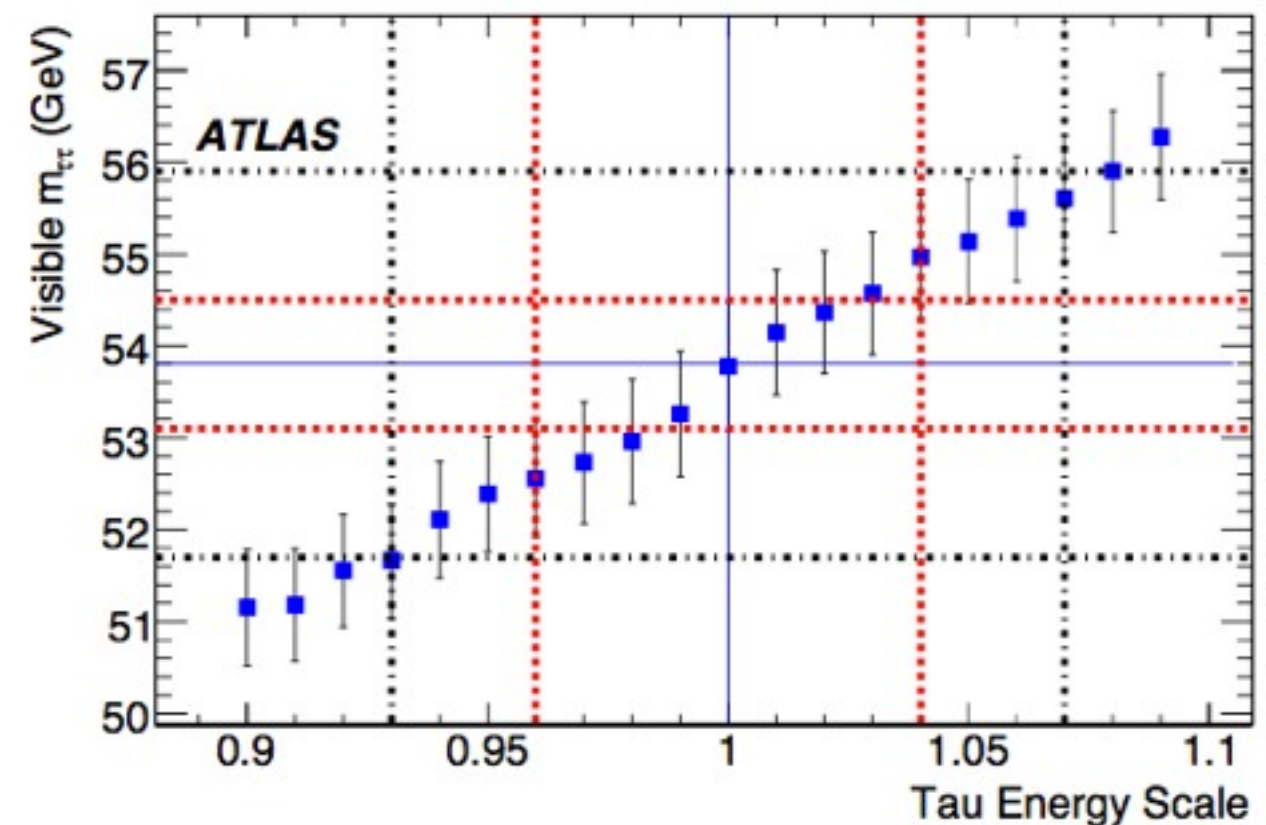
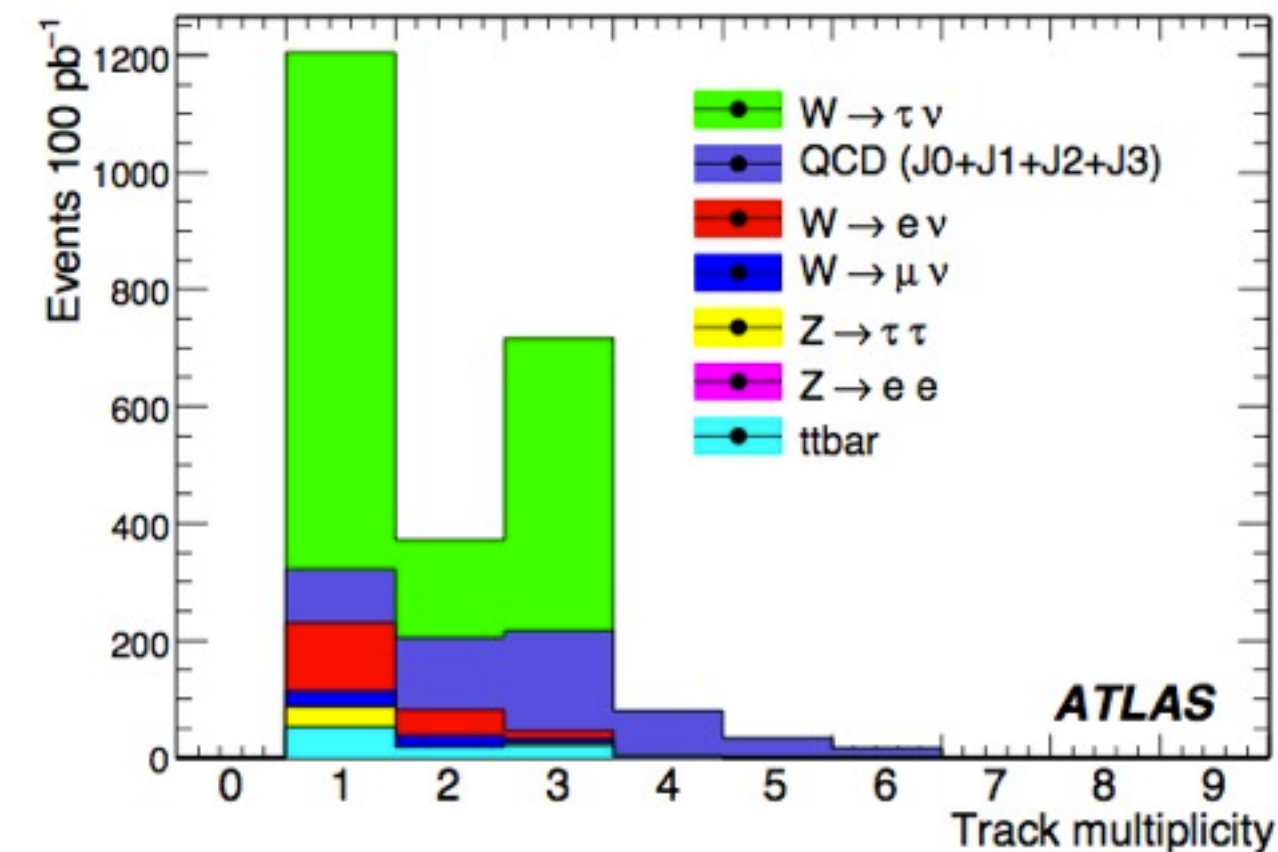
$\sim 10\text{s fb}^{-1}$



W to Tau Nu and Z to Tau Tau



- **W cross-section is 10x that for Z production**
 - The starting point for studying taus in ATLAS collision data
 - Studied extensively during the CSC era and more recently
 - Wits postdoc did a W to e nu thesis at D-Zero; a significant background to this channel
- **Z to tau tau**
 - The prospects for analysis are a bit more robust
 - Will allow us to determine the hadronic tau energy scale



ATLAS CSC Book

Z' to Tau Tau



Extra Dimensions? Grand Unification?

- Some models predict an extra gauge boson, referred to as the Z'

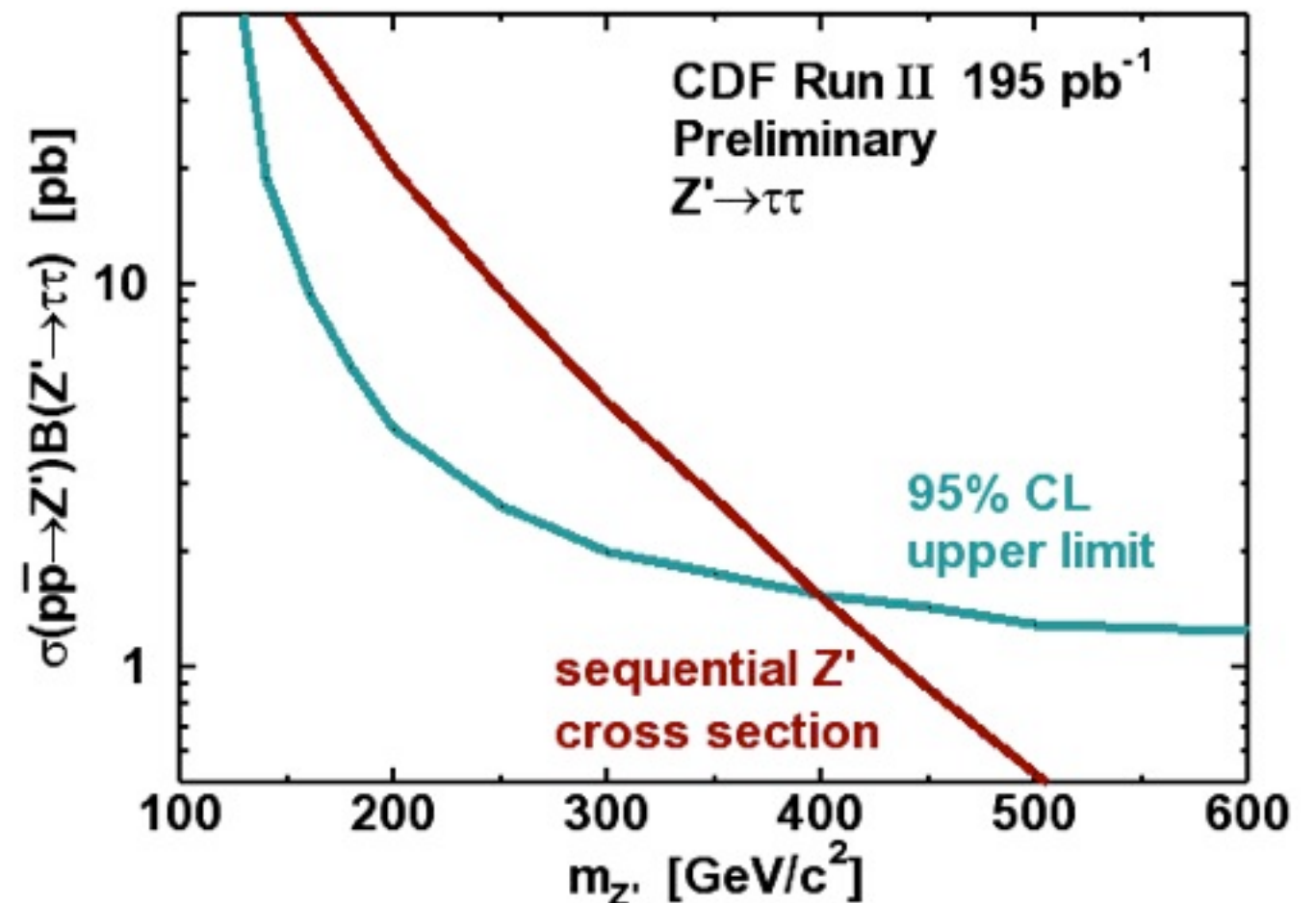
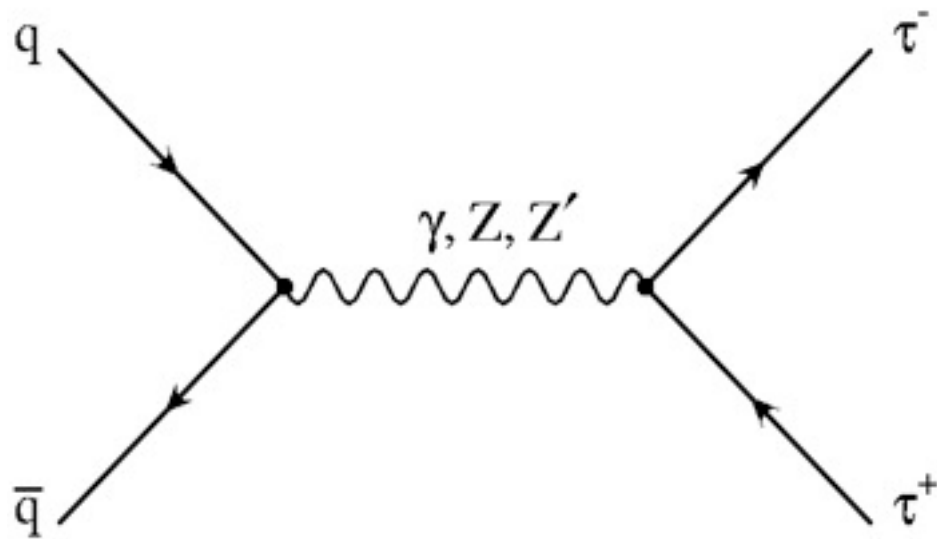
Would appear as a high mass resonance

- Z' could couple equally to all generations (inclusiveness)
- Or preferentially to the third (exclusiveness)

The current limit on Z' → tau tau searches comes from the Tevatron

- From CDF > ~400 GeV/c² @ 95% CL
- Reference: [D. Acosta et al., Phys. Rev. Lett. 94, 091803 \(2005\)](#)

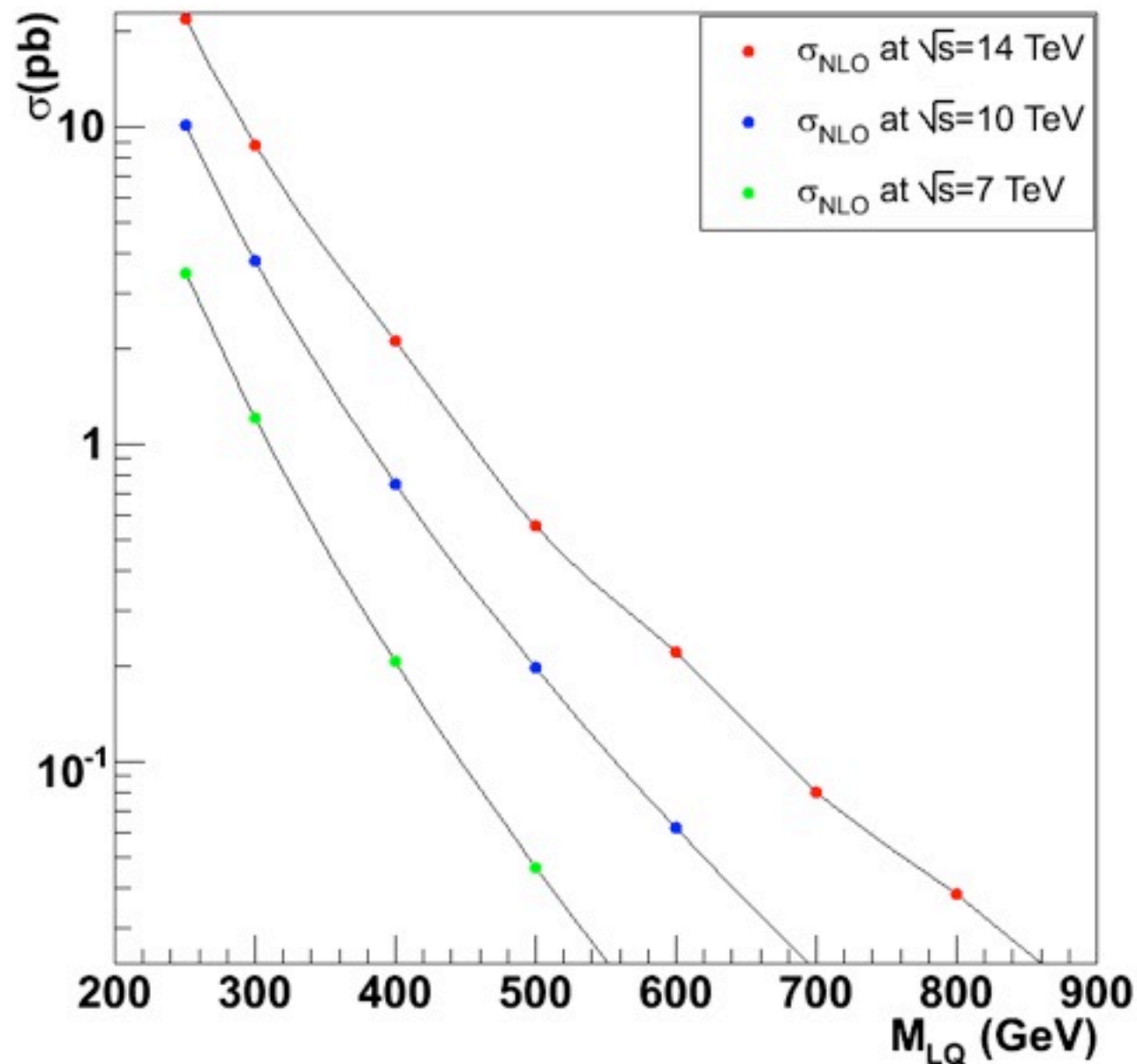
A massive graviton could be another source of di-tau resonances



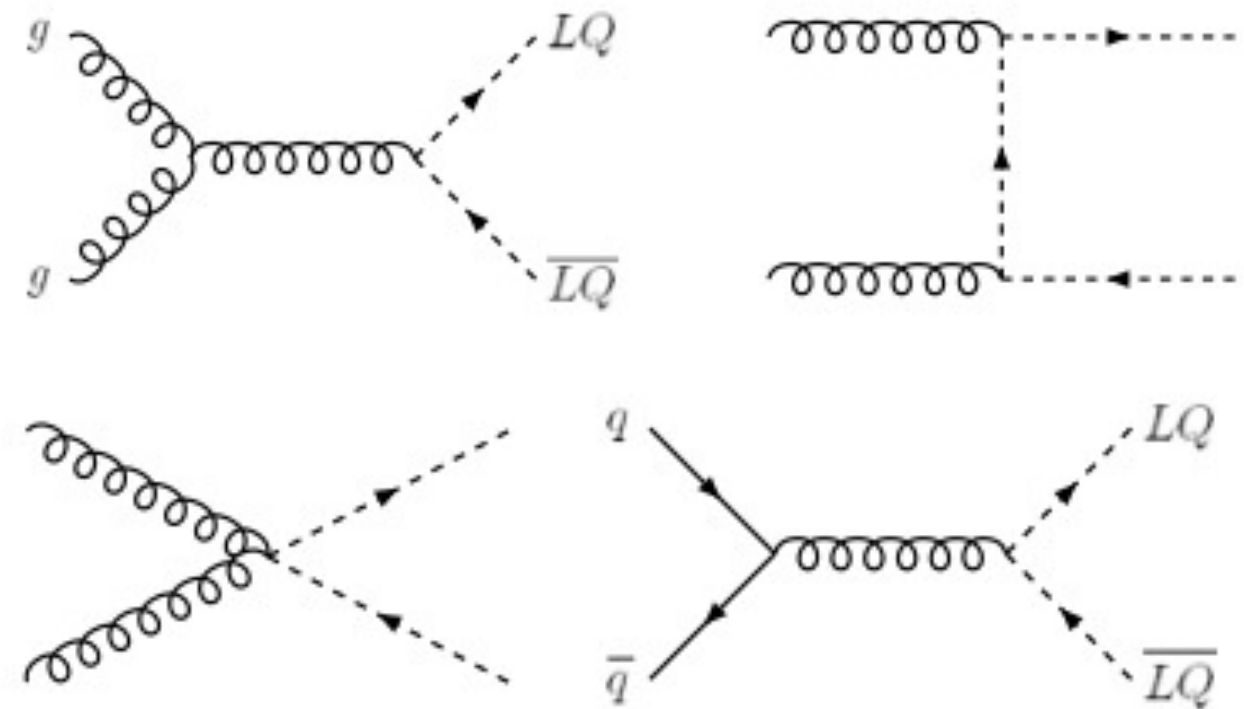
Leptoquark Searches



- Hypothetical bosons carrying both quark and lepton numbers (as well as fractional charge)
 - Predicted by many Beyond the Standard Model scenarios
 - In principle, could decay into any combination of quarks and leptons (but within one family at a time)



Plot: Oana Vickey-Boeriu



Has the potential
for becoming one of
the first published
limits from the LHC

SA-CERN: Raise the Bar

1.Capacity building

- Student calibre and throughput specifically treated further on
- HEP skills very productive (deep physics, deep maths, team-work, networking, computer skills, high tech)

2.Science Awareness

- Massive worldwide public interest generated around LHC
- SA Public in unprecedented science literacy and thirst for news

3.Outreach

4.Physics program

- Networks, collaborators, facilities, infrastructure accepted as world's best.
- Direct access to CERN Outreach Engine
- Teacher Programme
- Summer student programme
- High Energy Physics Master classes for local deployment

5.Student magnet

- Students are strongly attracted to HEP

6.Tech transfer

- GRID technology

SA-CERN: High-Level Capacity Building

1. Co-supervision

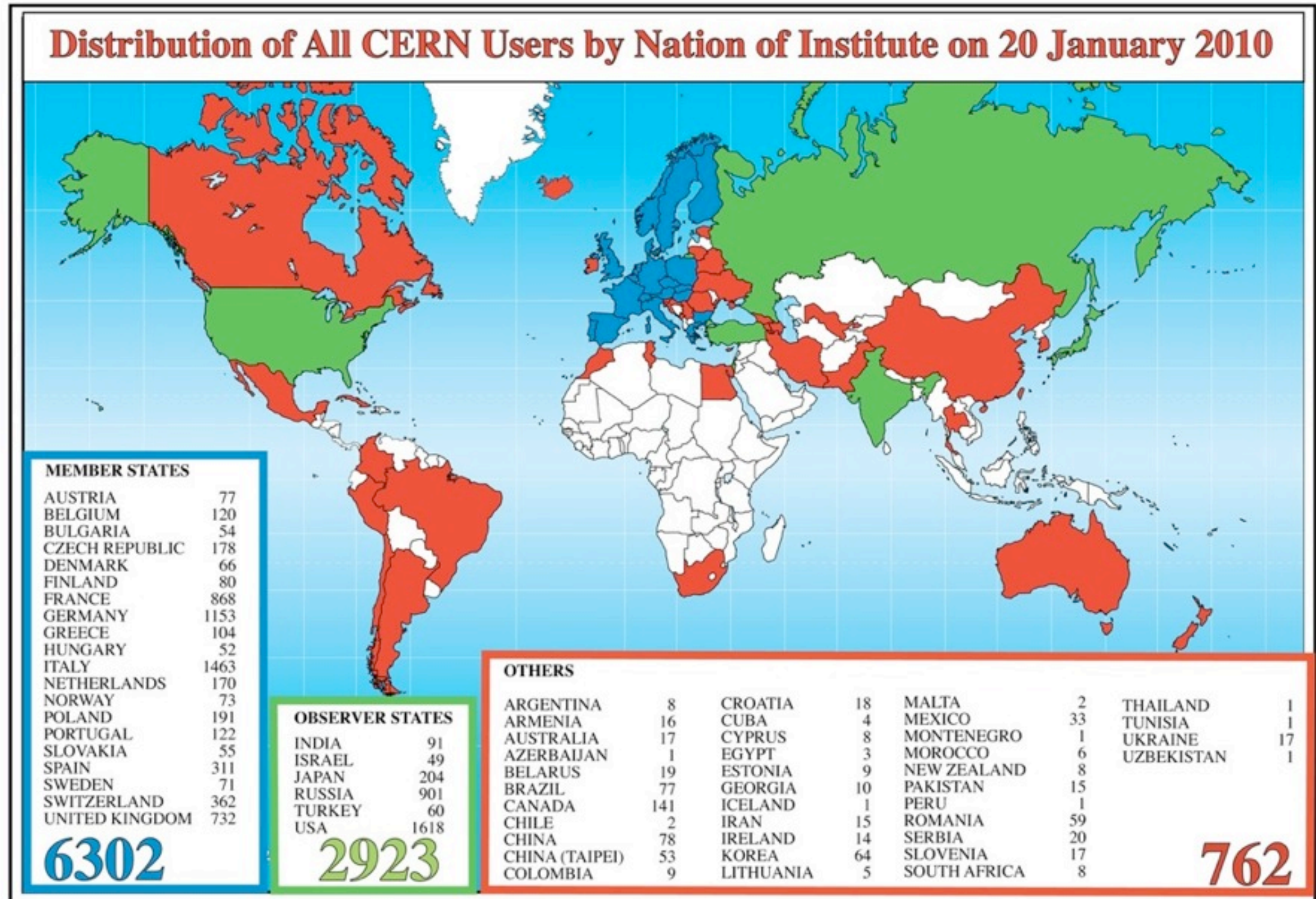
- The NRF has requested a 5-fold increase in post-graduate student throughput – need to involve calibre colleagues outside of SA with expertise and capacity
- CERN collaboration can allow us to meet the NRF targets.

2. Student support

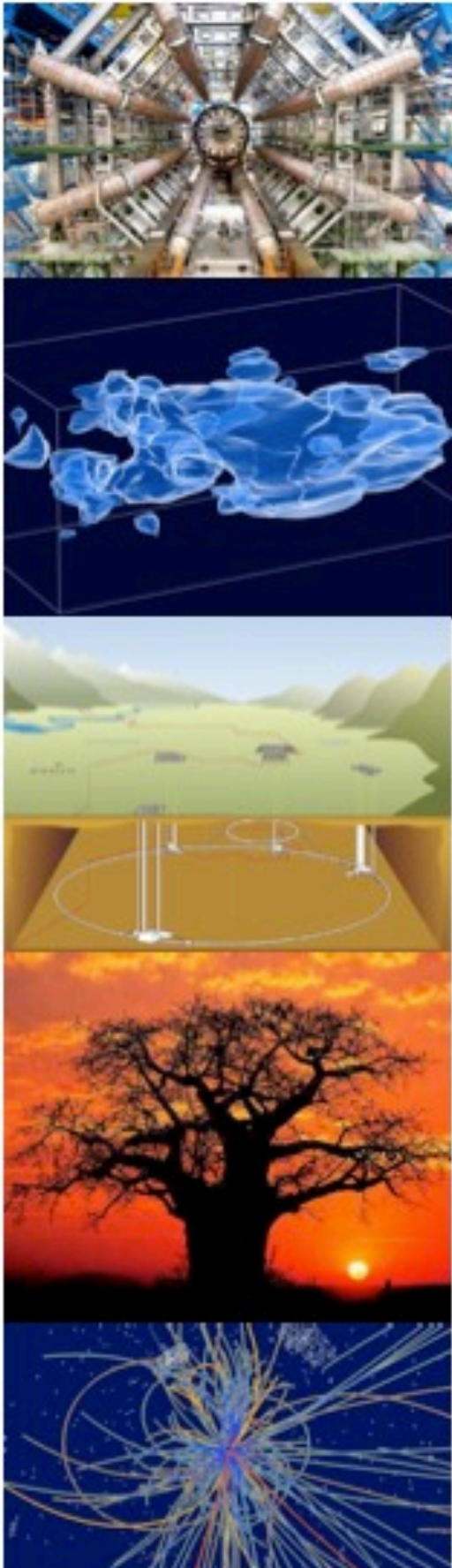
- Students are embedded in topical teams within a network of working groups
- Many senior scientists and PG student peers are active in a supportive role
- Regular revision of work, assessment of outputs, discussion and advice in well co-ordinated environment
- Strongly supportive and productive environment maintained in periods back at SA using web based collaborative tools.
- Synergy between SA and CERN supervisor
- Students subjected to global standards of competition and excellence.
- Student regularly presents work at working visits, in teleconferences, video conferences, Working Group meetings, Collaboration Meetings, Conferences.

3. Throughput: Many leaders in European Academe & High-tech industry have been trained at CERN.

SA could be a gateway to allow access to CERN



Kruger 2010: Workshop on LHC Physics



First Announcement

5 - 10 December 2010

**Kruger 2010: Workshop on
Discovery Physics at the LHC**

Venue: Protea Hotel Kruger Gate, Portia
Shabangu Rd, Skukuza, Kruger National Park,
Mpumalanga, South Africa

Topics:

To include Standard Model physics at hadron colliders as well as Higgs boson, SUSY and exotic particle searches. Discussions on the latest Monte Carlo tools, cross-section calculations for signal and background processes to higher orders, as well as strategies for new physics searches are expected. The status of the CERN Large Hadron Collider, along with first measurements from the LHC experiments, will also be presented.

Goals:

Six days of plenary talks and parallel sessions where some of the very latest experimental results from the LHC (ALICE, ATLAS, CMS and LHCb), as well as topical beyond the Standard Model theories, will be presented. The surroundings of one of the world's largest national parks, and the physics results presented during this workshop, will serve to inspire discussions between theorists and experimentalists on the latest LHC and Tevatron measurements as well as our expectations for the future.

Early Registration Deadline:

31 August 2010

Full travel and conference bursaries available for students (Honours level and above; see the website for details)

Workshop Organizer:

The South African Institute of Physics
Secretariat
Pretoria, SA

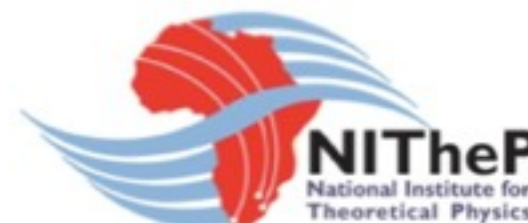
Tel: +27 (0) 12 843-6561

Fax: +27 (0) 86 648-8474

e-Mail: kruger2010@saip.org.za

website: <http://www.saip.org.za/events/kruger2010/>

- Invited Theory speakers include:
 - Nima Arkani-Hamed
 - Jean Cleymans
 - Aldo Deandrea
 - John Ellis
 - Tao Han
 - Sven Heinemeyer
 - Robert de Mello Koch



Conclusion

- South Africa has a long history of important contributions to the field
 - Can assist in ushering in other African countries / nationals
- SA-CERN Program
 - SA involvement in cutting edge science at CERN
 - ALICE and ATLAS programs are sure to revolutionize the field
 - Huge opportunities for capacity building, technology transfer, attracting students to physics, etc.
- There are a number of areas that I did not focus on (e.g, theory)
 - The high-energy physics university groups in South Africa are growing
- Mark your calendars!
 - Kruger 2010: Workshop on Discovery Physics at the CERN LHC December 5 - 10th; Kruger National Park, South Africa