2012 Workshop
Exploring QCD frontiers: from RHIC and LHC to EIC
Stellenbosch, South Africa

January 30 to February 3, 2012
STIAS Conference Center

Topics Include:
saturation and its measurement; parton densities, nuclear spin and angular momentum, and generalized and transverse parton distribution functions; constraints on initial energy-density formation and connecting initial conditions to hydrodynamics in heavy ion collisions

http://www.phy.uct.ac.za/conf/cpteic

Local Organizers:
J. Cleymans
A. Hamilton
W.A. Horowitz (chair)
A. Peshier
Z. Vilakazi
H. Weigert (co-chair)
General information

Organizational setup
The workshop program is laid out to provide both full length talks and discussion time.
The social program consists of an opening reception on Monday evening, an excursion Wednesday afternoon and a conference dinner on Thursday evening.

Map

Shuttle Services
- Centurion Tours (Recommended for transport from the Cape Town International Airport to Stellenbosch and back.) Contact Nisreen Bulbulia: nisreen@centuriontours.co.za; Cell: +27 (0)71 602 1916; Tel: +27 (0)86 111 5388; Fax: +27 (0)21 934 8282.
- Bettina Shuttle (Recommended for transport within Stellenbosch and its surrounds.) Contact Bettina or Steve at: info@bettinashuttle.co.za; Cell: +27 (0)82 076 2958; Tel: +27 (0)21 887 0702; Fax: +27 (0)86 691 5883. Note that the workshop will cover the round trip cost of your shuttle transportation from the airport to Stellenbosch; simply inform the shuttle company that you are involved in the workshop and to invoice UCT. We suggest reserving a place on a shuttle for transport to and from Stellenbosch before you arrive in Cape Town.

Restaurants
A huge thanks to Rene for compiling this list of restaurants. Note that we will have the workshop dinner at Lanzerac.

Upscale Restaurants
- Volkskombuis (021-887-2121)
- Lanzerac (021-887-1132)
- Umami (021-887-5204)

Nice Restaurants
- The Big Easy (021-887-3462)
- Bistro and Tappas at Asara (021-888-8060)
- Bukhara (021-882-9133)
- Cape Town Fish Market (021-883-9216)
- JC le Roux (021-865-8200): a great venue for a breakfast or for a sparkling wine tasting
- Tokara Delicatessen (021-808-5950)
- Tokara Restaurant (021-885-2550)
- Wijnhuis Restaurant and Wine shop (021-887-5844)
- Moyo Restaurant (021-809-1133): in Spier and will require transport
- Terroir (021-880-0717)

**More Relaxed Restaurants**

- Asta la pasta (021-887-7300)
- Gino’s (021-887-9786)
- Col’Cacchio Pizzeria (021-886-7088)
Detailed schedule of talks

Monday

- 08:10-90:00 Deshpande “Science and Prospects of the Electron Ion Collider in the US”
  I will present science case, and the status and prospects of realizing the Electron Ion Collider in the US.
- 09:00-09:50 Gelis “Towards thermalization in heavy ion collisions”
  In this talk, I will present some recent ideas and progress on the problem of thermalization of the dense matter produced in heavy ion collisions.
- 09:50-10:40 Rummukainen “Plasma instabilities and thermalization”
  TBD
- 14:30-15:20 Schnell “Highlights from HERMES”
  HERMES has taken a wealth of deep-inelastic scattering data using the 27.6 GeV polarized lepton beam at HERA and various pure gas targets, both unpolarized and polarized, which opened the door to several unique results. Among them are the first evidences for the naive-T-odd Sivers and Collins effects and also the recent first measurement of beam-helicity asymmetries in exclusive lepton production of real photons using recoil-proton detection. An overview of HERMES results will be given with emphasis to the exploration of the three-dimensional structure of the nucleon.
- 15:50-17:30 Lappi “Multi-gluon correlations in the Color Glass Condensate”
  We discuss recent work on computing the energy dependence of higher point Wilson line correlators from the JIMWLK renormalization group equation. These correlators are relevant for computing multiparticle correlations in high energy collisions. We find that while the large-Nc approximation used so far in the phenomenological literature is not very accurate. On the other hand a Gaussian finite-Nc approximation is a surprisingly good approximation of the result from the full JIMWLK equation.
- 16:40-17:30 Chirilli “High energy QCD factorization: from DIS to inclusive Hadron Production in pA collision”
  I will present the NLO photon impact factor for DIS at high energy in momentum space. This result is obtained using the operator product expansion applied to two electromagnetic vector currents. Then I will discuss the One-loop Factorization for Inclusive Hadron Production in pA Collisions in the Saturation Formalism. The collinear divergences associated with the incoming parton distribution of the nucleon, the outgoing fragmentation function of the final state hadron and the rapidity divergence with small-x dipole gluon distribution of the nucleus are factorized into the splittings of the associated parton distribution and fragmentation functions and the energy evolution of the dipole gluon distribution function.

Tuesday

- 08:10-90:00 Lamont “e+A physics with an electron collider at RHIC”
  It is believed that the dense matter created in A+A collisions at RHIC and LHC evolves from an initial state involving the collision of soft gluon fields of each nucleus rapidly producing a thermalized state. The behavior of these fields at the relevant regimes of A+A collisions at RHIC or LHC are only vaguely known. Deep Inelastic Scattering on nuclear targets (e+A) can access these gluon fields with well controlled kinematics. The absence of final state interactions and the obscuring of the initial conditions that occurs in the explosive evolution that follows the A+A collisions makes e+A the ideal tool to study the nature of the initial state. In this talk I will review the capabilities and aspirations of the physics obtainable with e+A collisions at a future eRHIC collider.
09:00-09:50 Giataganas “Observables in Strongly Coupled Anisotropic Plasma in AdS/CFT”
We present some ways to introduce consistently spatial anisotropy in AdS/CFT. Then we show some recent results for gravity dual anisotropic plasmas. The jet quenching, the drag force, the quark-antiquark potential and other observables are calculated using a spatial anisotropic gauge/gravity duality. We comment on these results and also compare them with their corresponding weakly coupled plasma observables.

09:50-10:40 Cleymans “The Thermal Model at the LHC”
An overview is presented of recent results with identified particles at the Large Hadron Collider with special attention to the question of chemical equilibrium. Possible deviations from the standard statistical distributions are investigated by considering in detail results obtained using the Tsallis distribution. Some very high quality fits have been made by the ALICE and CMS collaborations using a Tsallis inspired distribution. A critical discussion of these and alternatives are presented.

14:30-15:20 Buthelezi “ALICE Physics Capabilities Overview”
The ALICE experiment is one of the 4 major experiments at the CERN LHC and has been taking data since year 2009. ALICE is a general purpose heavy-ion detector, with the main physics goal to investigate the formation of a de-confined Quark-Gluon Plasma in high-energy heavy-ion collisions. Heavy quarks are regarded as sensitive probes for the study of the properties of this high-density state of QCD matter. ALICE has measured heavy-flavour production in pp and Pb-Pb collisions at central and forward rapidity using different decays final states. In this presentation we will give a summary of the first ALICE results on heavy-flavour production. Furthermore, we will give a detailed outline of a new study: the measurement of W⁺a bosons via the single muon decay in the forward rapidity range in ALICE, opened up by large statistics obtained from the 2011 data. The objective of the study, amongst other reasons, is to investigate the use of W⁺a as a reference for observing QGP induced effects on QCD probes.

15:50-17:30 Heinz “Initial shape and final flow fluctuations in event-by-event hydrodynamics for RHIC and LHC”
Viscous hydrodynamics with and without a hadronic afterburner is used to describe anisotropic collective flow in relativistic heavy-ion collisions with fluctuating initial conditions. Event-by-event hydrodynamical evolution of individual bumpy initial profiles is compared to a single-shot approach where the initial profiles are averaged first before being evolved hydrodynamically. A simultaneous analysis of elliptic and triangular flow data is shown to remove the most important initial state ambiguities and constrain both the distribution of initial fireball deformations and the specific shear viscosity of the quark-gluon plasma. The presently most precise extraction of the QGP shear viscosity from RHIC and LHC data is presented.

16:40-17:30 Muronga “Third order relativistic dissipative fluid dynamics”
In this presentation I will discuss Causal Relativistic Fluid Dynamics beyond second order approach. I will also discuss the properties of the thermodynamic coefficients appearing in the theory.

Wednesday

08:10-09:00 Biro “Mimicking thermal sources by Unruh radiation”
We demonstrate that by semiclassical calculation of the photon field of an accelerating charge a thermal scale can be generated which is proportional to the acceleration. The $p_T$ distribution features a slope $\pi$ times the Unruh temperature, while the rapidity distribution is flat for an infinite time integration, like in Bjorken hydrodynamics, and Landau-like for short acceleration times.

09:00-09:50 Jakovac “Nonlocal Effective Theories”
We usually think about interacting matter that it consists of weakly interacting quasiparticles. The description of the thermodynamics or the nonequilibrium, transport properties of the plasma
is based on this picture. However, there are situations where this simple picture fails. Examples are QCD near the critical temperature which is probably a liquid; or the description of the hadronic transport where besides the (broad) resonances there is a non-particle like continuum. If it is possible at all to give a perturbative representation of these situations, the basic degrees of freedom must be non-particle like excitations. This talk aims to present a consistent method, how these non-particle like excitations can be described by a Lagrangian, what are the degrees of freedom, how thermodynamics and transport coefficients should be calculated from this model.

- **10:10-10:35 Paradza** “Flux corrected transport applied to hydrodynamics”
  We apply the flux corrected transport technique to study the dynamical evolution of energy density distributions.

  The hadron resonance gas model and its extension to include the Hagedorn spectrum is discussed. The Hagedorn temperature, $T_H$, is determined from the number of hadronic resonances including all mesons and baryons. This leads to the result $T_H = (174 \pm 11)$ MeV consistent with the critical and the chemical freeze-out temperatures at zero chemical potential. We apply this result to calculate the speed of sound and other thermodynamic quantities in the resonance hadron gas model for a wide range of baryon chemical potentials using the chemical freeze-out curve. We compare some of our results to those obtained previously papers.

- **11:00-11:50 Gotsman** “A Model for Soft Interactions motivated by AdS/CFT and QCD”
  We construct a model based on two conjectures: (i) the results of the Ads/CDF correspondence for $N = 4$ SYM, and (ii) the requirement of matching with high energy QCD. In keeping with these postulates, we assume that the soft Pomeron intercept is relatively large, and the slope of the Pomeron trajectory is equal to zero. We derive analytical formulae that sum both the enhanced and semi-enhanced diagrams for elastic and diffractive amplitudes. Parameters of the model are obtained by fitting to experimental data, up to and including LHC energies, and we predict cross sections at all energies accessible at the LHC and beyond. Predictions of the model are in agreement with measured values obtained by CMS, ATLAS and ALICE. We compare our results with experimental data and competing models.

---

**Thursday**

- **08:10-90:00 Radescu** “PDFs from HERA to LHC and possible impact of LHeC”
  Knowledge of the parton distribution functions (PDFs) of the proton comes mainly from deep-inelastic lepton scattering experiments covering a broad range of $Q^2$, the negative four-momentum transfer squared, and of Bjorken $x$. Neutral (NC) and charged (CC) current measurements at HERA, the world’s first ep collider which collected data for 15 years up until summer of 2007, give access to the sea quark and the up and down valence quark densities. The gluon density is determined at lower $x$ from the structure function $F_2$ scaling violation. It has been cross checked using recent H1 and ZEUS measurements of the structure function $F_L$. The lepton-nucleon scattering data from HERA can be complemented by the measurements at $pp$ and $p\bar{p}$ experiments which measure Drell-Yan and jet production. Such measurements provide extra information on the $\bar{d}/\bar{u}$ and the gluon density at high $x$. The impact of possible new generation electron-proton collider LHeC has been investigated as well.

- **09:00-09:50 Diehl** “Imaging partons with exclusive scattering processes” The spatial distribution of partons in the proton or a nucleus can be probed in suitable exclusive scattering processes. I review the theoretical foundation and the physics interest of this idea, and I report on recent performance estimates for parton imaging in the proton.

- **09:50-10:40 Horowitz** “Exclusive Vector Meson Production in Nucleons vs. Nuclei”
  We compare exclusive vector meson production (EVMP) predictions for an electron-ion collider when the gluon distribution in nuclei is evolved in $Q^2$ versus $x$. We find that unitarization of the DGLAP dipole exchange significantly alters the shape of the differential cross section and show
explicitly the nontrivial difference in small-\(x\) predictions when the dipole is assumed to interact coherently versus incoherently with the nucleons in the nuclei.

- **14:30-15:20 Toll** “A new Monte Carlo event generator for diffraction in eA”
  I will present the now finished new Monte Carlo event generator for exclusive and diffractive vector mesons and DVCS for electron-ion collisions. As such, it is the first of its kind.

- **15:50-17:30 Burkardt** “Transverse (Spin) Structure of Hadrons”
  Jefferson Lab in Newport News, VA is currently undergoing a $350 million upgrade to 12 GeV. One of the main science motivations that drives this upgrade is the measurement of ‘Generalized Parton Distributions (GPDs)’, which will allow for the first time to engage in nuclear tomography to uncover the true three-dimensional structure of the nucleon. Likewise, one of the two science motivations for a proposed electron-ion collider is ‘precision imaging of the sea-quarks and gluons to determine the spin, flavor and spatial structure of the nucleon’. In the near term, determination of GPDs is also one of the main goals of the COMPASS II program. I will explain how these experiments can access the spatial nucleon structure and how that relates to other observables, such as quark orbital angular momentum, the nucleon anomalous magnetic moment, and transverse single-spin asymmetries.

- **16:40-17:30 Prokudin** “Studies of three dimensional partonic structure at an EIC”
  I will discuss how three dimensional partonic structure will be studied at an EIC. In particular I will concentrate on studies of Transverse Momentum Dependent distributions.

### Friday

- **08:10-90:00 Litvinenko** “High-Energy High-Luminosity Electron-Ion Collider eRHIC”
  I will present the design of a future high-energy high-luminosity electron-hadron collider at RHIC called eRHIC. The plan is adding 30 GeV energy recovery linacs to accelerate and to collide polarized and unpolarized electrons with hadrons in RHIC. The center-of-mass energy of eRHIC will range from 30 to 200 GeV. The luminosity exceeding 1034 cm-2s-1 can be achieved in eRHIC using the low-beta interaction region which a 10 mrad crab crossing. A natural staging scenario of step-by-step increases of the electron beam energy by building-up of eRHIC’s SRF linacs. I discuss the progress of eRHIC design, cost estimate and R&D projects ranging from the polarized electron source to the coherent electron cooling.

- **09:00-09:50 Venugopalan** “Building bridges with ridges”
  We discuss the physics underlying a ridge like structure seen in high multiplicity collisions and discuss its implications for our understanding of the high energy structure of the proton and for heavy ion collisions.

- **09:50-10:40 Kovner** “Angular Correlations in Gluon Emission: are Pomeron loops responsible?”
  I discuss a simple mechanism for angular correlations between emitted gluons at high energy. The correlations are of the same type to those observed as the Ridge in p-p collisions by the CMS experiment at LHC. I argue that such correlations exist in QCD in the leading order in \(1/N_c\), but that to properly account for them one needs to include effects of Pomeron loops.

- **14:30-15:20 Weigert** “The Color Glass Condensate: QCD at modern collider facilities”
  Nonlinear effects become more and more important in our understanding of QCD as experimental efforts progress to higher energies and/or large nuclear targets. I will present an infrared safe, nonlinear renormalization group approach, justified for central collisions at small Bjorken \(x\) (large energies) and large nuclei. The emergence of a new density driven scale leads to a self-consistent treatment with consequences that apply to a wide variety of experiments such as ep, eA and AA collisions as performed or planned at HERA, EIC, RHIC and LHC. HERA total cross sections and diffractive data are confronted with pseudo scaling solution from JIMWLK evolution in the Gaussian truncation.

- **15:50-17:30 Iancu** “JIMWLK evolution in the Gaussian approximation”
  We show that the Balitsky-JIMWLK equations describing the high-energy evolution of the n-point functions of the Wilson lines admit a controlled mean field approximation of the Gaussian
type, for any value of the number of colors $N_c$. This approximation is strictly correct in the weak scattering regime at relatively large transverse momenta, where it reproduces the BFKL dynamics, and in the strong scattering regime deeply at saturation, where it properly describes the evolution of the scattering amplitudes towards the respective black disk limits. The approximation scheme is fully specified by giving the 2-point function (the S-matrix for a color dipole), which can be related to the solution to the Balitsky-Kovchegov equation, including at finite $N_c$. Any higher n-point function with $n \geq 4$ can be computed in terms of the dipole S-matrix by solving a closed system of evolution equations (a simplified version of the respective Balitsky-JIMWLK equations) which are local in the transverse coordinates.

16:40-17:30 **Beuf** “NLO dipole factorization for DIS structure functions at low x.”

I will present the NLO generalization of the dipole factorization formula for the DIS structure functions $F_2$ and $F_L$, with the appropriate NLO impact factors. That result will allow precise predictions for $F_2$ and $F_L$ at low $x$ at the EIC, both including or excluding gluon saturation effects. That result also gives some insight into the exact kinematics of parton cascades in mixed space.