# Ninth Workshop on Non-Perturbative Quantum Chromodynamics
**June 4-8, 2007**
**l'Institut Astrophysique de Paris**

## Abstracts

**Arotisenet, Pierre:** "*Heavy Quarkonium Production in Hadron Collisions*"
In this talk, I will discuss heavy quarkonium production in the framework of Non-Relativistic Quantum ChromoDynamics. I will briefly describe the main features of this theory, highlighting both the successes and the current open questions in quarkonium production in collider experiments. I will next move on to an updated analysis of $J/psi$ production at Tevatron, considering the recently calculated NLO contributions to heavy quarkonium production via color singlet transitions. Finally I will comment on the implications of the current data on the non-perturbative dynamics in heavy quarkonium production.

**Balitsky, Ian:** "*Small-x Evolution of Color Dipoles in the Next-to-Leading Order*"
The small-$x$ deep inelastic scattering in the saturation region is governed by the non-linear evolution equation for Wilson-lines operators. In the leading logarithm approximation it is given by the BK equation for the evolution of color dipoles. I present the results of the next-to-leading order calculation and discuss the argument of the coupling constant in the BK equation.

**Bender, Carl:** "*Faster than Hermitian Quantum Mechanics*"
Given initial and final quantum states $|I>$ and $|F>$, there exist Hamiltonians $H$ under which evolves into $|F>$. The quantum brachistochrone problem is to find the Hamiltonian that achieves this transformation in the least time $\tau$, subject to the constraint that the difference between the largest and smallest eigenvalues of H is held fixed. For Hermitian Hamiltonians $\tau$ has a nonzero lower bound. However, for non-Hermitian PT-symmetric Hamiltonians satisfying the same energy constraint, $\tau$ can be made arbitrarily small. This does not violate the time-energy uncertainty principle because for such Hamiltonians the path from $|I>$ to $|F>$ can be made short. The mechanism is similar to that in general relativity in which the distance between two space-time points can be made small if they are connected by a wormhole. This result may have applications in quantum computing.

**Brandhuber, Andreas:** "*Refining MHV Diagrams*"
It has been known for some time that the standard MHV diagram formulation of perturbative Yang-Mills theory is incomplete, as it misses rational terms in one-loop scattering amplitudes of non-supersymmetric Yang-Mills. In this talk we review recent ideas that circumvent this limitation. In particular, we propose that certain Lorentz violating counterterms, when expressed in the field variables which give rise to standard MHV vertices, produce precisely these missing terms. These counterterms appear when Yang-Mills is treated with a regulator, introduced by Thorn and collaborators. As an illustration we show that a simple one-loop, two-point counterterm is the generating function for the infinite sequence of one-loop, all-plus helicity amplitudes in pure Yang-Mills, in complete agreement with known expressions.

**Brower, Richard:** "*AdS Graviton Exchange at High Energies*"

The high energy limit for scattering in the $AdS^5$ gravity dual of Yang Mills theory will be presented both in terms of the eikonal summation of Witten diagrams and 'tHooft's shock wave analysis. Comparisons with flat space gravity and the role of the transverse $AdS^3$ impact geometry will be explored.

**Cudell, Jean-Rene:** "*Does the Hard Pomeron Contibute to Soft Scattering?*"
I review the various clues that lead to the conclusion that a hard BFKL-like pomeron may be a significant actor even in soft and exclusive scattering. I show that such a possibility leads to an LHC total cross section as large as 150 mb. This may have strong implication on future forward experiments, such as TOTEM.

**de Forcrand, Philippe**: "*The Phase Diagram of QCD from Lattice Simulations*"
I review the successes and the failures of lattice QCD simulations in determining the phase diagram of QCD as a function of temperature and baryon density.

**D'Elia, Massimo:** "*Deconfinement in QCD at Finite Temperature and Density*"
We report on recent results about the confinining properties and the structure of the QCD phase diagram at finite temperature and density, as obtained from numerical lattice simulations.

**d'Enterria, David:** "*Small-x QCD: from HERA and RHIC to the LHC"*
I will summarize the current experimental and phenomenological status of gluon-saturation and non-linear QCD physics accessible at high-energy colliders. Existing data at RHIC (nucleus) and HERA (proton) and prospects at the CERN LHC (in collisions with both protons and nuclei) will be discussed.

**Di Giacomo, Adriano:** "*"Confinement and Dual Superconductivity of QCD vacuum*"
The status of dual superconductivity as a mechanism of color confinement in QCD is reviewed. New lattice results are presented , together with analytic developments which allow a better insight into the mechanism.

**Eden, Burkhard:** "*"Non-perturbative Anomalous Dimension for Twist Propagators in N=4 SYM*"
We analyze the all-loop Bethe ansatz for the sl(2) twist operator sector of the N=4 gauge theory in the limit of large spacetime spin at large but finite twist, and find a novel all-loop scaling function. We discuss possible phase factors for the S-matrix of the Bethe ansatz. One particularly natural dressing phase is non-perturbatively related to a recently conjectured crossing-symmetric phase factor for perturbative string theory on AdS(5)*S(5). Our proposal might therefore resolve the long-standing discrepancies between the gauge and string theory sides of the AdS/CFT duality.

**Ferreiro, Elena:** "*Multiplicities, Fixed $p_T$ Suppression, Elliptic Flow and $J/\psi$ Suppression at the LHC*"
Using a final state interaction model which describes the data on these four observables at RHIC energy, we make predictions at the much higher energy of the Large Hadron Collider (LHC). All the parameters in the model, such as the $p_T$-shift induced by the final state interaction and the cross-section of the latter are taken to be the same as at RHIC energy. The increase in the medium density between these two energies (by more than a factor 2) produces striking effects on these observables .such as an increase in the fixed pT suppression by more than an order of magnitude and an increase of the elliptic flow $v2$ by a factor close to 2 at low $p_T$ . The $J/\psi$ suppression is computed with a cross section $\sigma_{co} = 0.65$ (the same value used at SPS and RHIC energies) and $\sigma_{abs} = 0$ (ansatz consistent with the $d - Au$ data at RHIC when shadowing is taken into account). The $J/\psi$ suppression increases by a factor 5.

**Fried, Herb:** "*Analytic, Non-Perturbative, Almost-Exact QED: the 2-Point Functions*"
This work-in-progress presentation deals with a new approach to Analytic, Non-Perturbative, QED, as the first step en route to QCD. It makes use of a special gauge in which scaling properties (akin to those of Renormalization Group analyses) of relevant functional integrals can be applied to every n-point function; and these, coupled with a strict adherence to current conservation (or gauge invariance of) the physical result, provide a systematic procedure for obtaining almost exact, non-perturbative results.

**Giacomelli, Giorgio:** "Bose-Einstein Correlations in $e + e-$ Collisions at LEP"
Bose-Einstein correlations (BECs) in pairs of identical particles were experimentally studied in e+e- annihilations at 91.2 GeV at LEP. The first studies involved identical charged pions with the purpose of determining the emitting source size, assumed to be spherical, and the chaoticity parameter. Then the study was applied to charged kaons to determine if the source radius depends from the mass of the emitted particles. Subsequenty the dependence of the source radius R and of the chaoticity parameter from the event multiplicity was analized. The study of the correlations in neutral pions and neutral kaons extended these concepts to neutral particles. Then the shape of the source was analyzed in 3 dimensions and was found not to be spherically symmetric. The velocity of the source elements with respect to the overall center of mass system was studied in heavy ion collisions to find indications of the quark gluon plasma formation. In the present work we present the results of BECs studies (in e+e- collisions at 91.2 GeV) analyzed in intervals of the average pair transverse momentum and of the pair rapidity in order to study the correlations between the pion production points and their momenta ( position-momentum correlations).

**Gogokhia, Vakhtang:** "*The Mass Gap and Solution of the Gluon Confinement Problem in QCD*"
Since due to color confinement the gluon is not a physical state, we propose to realize a mass gap in QCD not imposing the transversality condition on the full gluon self-energy, while preserving the color guge invariance condition for the full gluon propagator. This allows one to establish the general structure of the full gluon propagator in the presence of a mass gap. The direct nonlinear iteration solution of the transcentential equation for the full effective charge is developed. It is explicitly shown that such a solution confines QCD. The exact and gauge-invariant criterion of gluon confinement is derived.

**Grandou, Thierry:** "*Twin Paradox and Causality"*
The striking ( and physically established) non-trivial differential aging phenomenon is presented as a necessary consequence of the sole principle of a causality attached to both the existence of a global time orientation of the spacetime manifold, and the existence of a finite velocity limit to energy/information transfers.

**Haegler, Philipp:** "*Hadron Structure from Generalized Parton Distributions in Full Lattice QCD*"
Generalized Parton Distributions (GPDs) play a central role in our understanding of the internal structure of hadrons in terms of quark and gluon degrees of freedom. They are directly related to e.g. the orbital angular momentum of quarks in the nucleon, probability densities of quarks in impact parameter space, and the transverse size of the nucleon. In this talk, we present and discuss recent results from full lattice QCD calculations on moments of GPDs and implications for our understanding of the quark substructure of hadrons.

**Hatta, Yoshitaka:** "*Recent Developments in Saturation Physics*"
I give an introductory review on saturation physics in QCD at high energy, with particular emphasis on evolution beyond the BK-JIMWLK equation. I also discuss the result for the saturation momentum at strong coupling, as obtained from the gauge/string duality.

**He, Yang-Hui:** "*Probing the Geometry of N=1 Vacua*"
We present a new and efficient method for explicitly computing the vacuum of N=1 gauge theories. We emphasize the importance of finding special geometric properties of these spaces in connecting phenomenology to guiding principles descending from high-energy physics. Focusing on the MSSM, we exemplify how our results can be used to rule out certain top-down constructions of electroweak physics.

**Heller, Michal:** "*Viscous Hydrodynamics Relaxation Time from AdS/CFT*"
Studying the dynamics of N=4 SYM energy-momentum tensor in boost-invariant setting is briefly reviewed using AdS/CFT correspondence. Calculation of relaxation time in second order viscous hydrodynamics is sketched, with result about 30 times shorter than weak coupling expectation. Regularity of geometry in string frame is shown to require nonvanishing dilaton leading to nonzero expectaction value of $tr(F2)$ behaving like $\tau^{(-10/3)}$.

**Hirn, Johannes:** "*Bottom-up Approach to Holographic QCD*"
I'll review various steps taken from the purely field-theory side to implement features of QCD into 5D models: chiral symmetry breaking, linear confinment, quark masses, condensates, running of the gauge coupling, four-quark effective operators.

**Iancu, Edmond:** "*The Hadron in Black and White*"
I discuss the physical picture of a high-energy hadron as emerging from the non-linear evolution equations in perturbative QCD. I emphasize the role of fluctuations leading to a granular structure with dense, 'black' spots, and dilute, 'white', regions. I comment on the possibility to describe this structure by a conformal effective theory similar to quantum gravity in two dimensions.

**Ilderton, Anton:** "*Gribov copies and confinement*"
I will present an elegant and explicit construction of a wide class of Gribov copies, both topologically trivial and non-trivial. Although they may be generated infinitesimally, the copies are manifestly non-perturbative. As a consequence it will be demonstrated that the existence of copies prevents the construction of physical coloured charges beyond perturbation theory.

**Jameson, Paul:** "*Collinear Divergences from Very Soft Gauge Bosons*"
The standard theoretical response to soft and collinear divergences is the Lee-Nauenberg theorem. A not widely recognised part of Lee and Nauenberg's work is that, in processes with initial and final state massless particles such as those which occur at the LHC, disconnected diagrams must be incorporated at the S-matrix level as they can contribute to the (connected) cross-section through interference effects. A new class of collinear divergences associated with particles which are both soft and collinear will be discussed within Coulomb scattering. We will see that these are not cancelled in the same way as soft divergences. Various responses to this are discussed.

**Khoze, Valeri:** "*Forward Proton Tagging at the LHC as a Tool to Study QCD and New Physics at the LHC*"
There has been increasing interest in the past years in the possibility of using dffractive processes as a search tool for new physics at the LHC. We discuss the theoretical motivations behind recent proposals to add forward proton tagging detectors to the LHC experiments.

We show that the so called central exclusive production processes may provide an exceptionally clean environment to search for, and identify the nature of, new particles at the LHC.

The main emphasis is on Higgs production,where the central system could consist of 2-b-quark jets or WW* ,and no other activity. Special attention is paid to the Higgs sector of the MSSM, where the CEP is found to have special advantages as compared to the traditional non-diffractive

strategies.

**Li, Shi-yuan:** "*Arranging Dirac Structures for Hadron-quark Vertices in Bethe-Salpter Framework Under Covariant Instantanious Ansatz*"
To study the hadronic interactions (or decays) in various energies at the quark (gluon) level and by QCD, it is crucial to set the hadron-quark vertex. This relates with the inner structure of hadron, which is the bound state of quarks (and/or gluons). This could be one of the the most difficult and old problems in QCD, especially considering its non-perturbative aspect. The framework of covariant instantanious ansatz provides a general way to construct the Bethe-Salpter wave function from the quark-hadron vertex, hence provides one way to relates the inner structure of hadron with the interaction process. We discuss in this framework how to arrange the Dirac structures of the vertex, so that one can set the most general platform for various models of hadron structure to be tested via the hadronic interaction/decay processes. Calculations employing the leading order Dirac structures for vector/p-scalar mesons is provided and discussed.

**Merino, Carlos**" "*Open Charm Production in pp and Heavy Ion Collisions in QCD*"
The RHIC data on charm production are compared to the $k_T$-factorization approach and both standard NLO QCD and FONLL predictions. The calculated results underestimate the STAR Collaboration data. The role of possible nuclear effects is discussed.

**Moffat, John:** "*Modified Gravity and Its Consequences for the Solar System, Astrophysics and Cosmology*"
A relativistic modified gravity (MOG) leads to a self-consistent, stablel gravity theory that can describe the solar system, galaxy and clusters of galaxies data and cosmology without dark matter. A review is given of fits to galaxy rotation curves, mass profiles of X-ray clussters and weak and sstrong lensing of galaxy clusters including the bullet cluser E10657-56. MOG can explain the CMB power spectrum and the observed acceleration of the expansion of the universe.

**Mueller, Berndt:** "Why is the Quark-Gluon Plasma a "perfect" Liquid?"
Experiments at the Relativistic Heavy Ion Collider (RHIC) have shown that the matter produced in nuclear collisions contains unconfined quarks and has a shear viscosity near the theoretical lower bound. In my talk I will discuss possible mechanisms for such a low viscosity and possible ways of probing whether the quark-gluon plasma formed at RHIC is a strongly coupled state.

**Munier, Stephane:** "*"From High-Energy QCD to Statistical Physics*"

**Nesterenko, Alexander V.** : "*Adler Function Within the Analytic Approach to QCD"*
New integral representations for the Adler function and the R-ratio of the electron-positron annihilation into hadrons are derived in the general framework of the analytic approach to QCD. These representations capture both the effects due to the interrelation between spacelike and timelike domains and the effects due to the nonvanishing mass of the lightest hadron state. The latter plays a crucial role in this analysis, forcing the Adler function to vanish in the infrared limit. Within the developed approach the Adler function is calculated by employing its perturbative approximation as the only additional input. The obtained result is found to be in reasonable agreement with the experimental prediction for the Adler function in the entire energy range.

**Orginos, Kostas:** "*Meson Scattering Lengths in Lattice QCD*
I present results from a calculation of pseudo scalar meson scattering lengths in lattice QCD. The computation is done in full QCD with 2+1 dynamical flavors on one lattice spacing and with pion masses as low as 300 MeV. Matching on to chiral perturbation theory allows as to compute the scattering lengths at the physical point with very high accuracy.

**Pancheri, Giulia:** "*"QCD Predictions for Total Cross-sections and the Froissart Bound*"
We give predictions for the total proton-proton cross-sections using an model in which the rise is driven by QCD mini-jets and te asymptotic softening is controlled by soft gluon emission. Connections with the limitations imposed by the Froissart bound are discussed.

**Payaud, Bernard:** *Experimental Studies of $K_{e4}$ and $K_{3\pi}$ Decays from the NA48/2 Experiment*"
The NA48/2 experiment at the CERN SPS has collected about $10^6$ $K_{e4}(K^{\pm} \to \pi^+\pi^- e^{\pm} V)$ decays in 2003 and 2004. The analysis of 680000 events from the 2003 subset has been used for a precise measurement of the $K_{e4}$ decay parameters. This includes the measurement of the phase shift $\delta_{\pi\pi}$ as a function of the $\pi\pi$ invariant mass which in turn gives access to the $\pi\pi$ scattering lengths $a_0^0$ and $a_0^2$. The measurement of $\delta_{\pi\pi}$ is model independent and can be confronted with predictions made in the framework of Chiral Perturbation Theory. The same experiment has also collected an unprecedented amount of $K^{\pm} \to \pi^0\pi^0\pi^{\pm}$ decays which is another precise tool for extracting $a_0^0$ and $a_0^2$ and for testing different theoretical models.

**Ryckbosch, Dirk:** "*Nucleon Spin Structure: recent results from HERMES*"
The origin of the nucleon spin is, after decades of experiments, still not completely understood. The contributions from the spin of the quarks, the orbital motion of the quarks and of the gluons are not all known with good precision. In fact, only on the first contribution is there any reasonably accurate information. In this talk the recent analyses and measurements that were performed by the HERMES experiment at the HERA accelerator, are presented and discussed. It has become clear that the question of the origin of the nucleon spin is only a part of the much broader study of the spin structure of the nucleon. Various other aspects have attracted great interest, such as the transverse spin structure. This provides independent information on the parton structure of the nucleon, on the same level as the number density and the helicity structure. The HERMES experiment has provided data that allow a first insight into this new aspect of the nucleon. Recent progress in the field is presented.

**Sanz, Veronica:** "*Holography and the LHC: non-QCD-like Technicolor Models*"
If electroweak symmetry is broken by strong interactions, those are non-QCD-like. That would seriously challenge the description of LHC phenomena. Using the gauge/string duality we explore non-QCD-like scenarios and their signatures at colliders.

**Sarcevic, Ina:** *Black Hole Production at the LHC*
We propose a novel way to detect black hole production at the LHC by measuring the charged hadron spectra in Pb+Pb collisions. We compute the charged hadron spectra from the decay of black hole and show that it dominates at transverse momenta $p_T$ $30 - 100$ GeV compared to usual QCD processes and black hole production. In models with several large extra dimensions and fundamental Planck scale of the order of 1 TeV, LHC is expected to be a black hole factory. We show that a measurement of the charged hadron spectra probes Planck scales up to 5 TeV for any number of extra dimensions. Black holes can also be created in $pp$ collisions at the LHC, but the rates in $Pb$+$Pb$ collisions are higher due to an enhancement given by the number of binary collisions. We discuss the interactions of the partons produced in the decay of the black hole with the quarks and gluons around it. The energy loss is expected to be small at high transverse momentum, but at $p_T$ below 10 GeV the effect in the QCD spectrum is significant. There is a possibility to have enhanced particle yield around $p_T \sim 10$ GeV/c, because the hadron spectra is much steeper than that of the QCD spectra and feedback from the emitted gluons could be non-negligible. If this is the case, the black hole signal could be detected in the lower $p_T$ region. We discuss the possible absorption of the particles surrounding the black hole which, in principle, would affect the decay

of the black hole.

**Scorzato, Luigi:** "*Title: "Results from $N_f = 2$ QCD with a Twisted Mass"*
I will present results from $N_f = 2$ QCD simulations with a twisted mass term. I will focus on the comparison with ChPT including finite size effects. I will also mention preliminary resluts about a mixed approach with twisted mass sea-quarks and overlap valence-quarks.

**Spradlin, Marcus:** "*Multiloop Gluon Amplitudes and AdS/CFT"*
A new method is introduced for extracting certain quantities out of multiloop gluon scattering amplitudes, which are otherwise notoriously difficult to compute. This tool is applied to calculate the four-loop cusp anomalous dimension in N=4 super Yang-Mills theory, a quantity of particular recent interest in AdS/CFT. Our new method allows for a significant improvement in precision and provides strong evidence in favor of a recent conjecture based on integrability.

**Tan, Chung-I:** "*AdS Pomeron Exchange at High Energies"*
The first strong coupling corrections to $AdS^5$ gravity leads to the strong BFKL Pomeron of Brower, Strassler, Polchinski and Tan. The high limit energy limit in the eikonal approximation and the saturation of the Friossart bound in confining duals will be presented. Comparison with the flat space string eikonal approximation of Amati,Ciafaloni and Veneziano will be made.

**Tannenbaum, Michael J.** : "*Hard-Scattering and QCD Fundamentals at RHIC*"
In 1998, at the 4th QCD workshop, Rolf Baier asked me whether jets could be measured in $Au+Au$ collisions because he had a prediction of a QCD medium-effect (energy loss via soft gluon radiation induced by multiple scattering) on color-charged partons traversing a hot-dense-medium composed of screened color-charges. I reviewed the possibilities in a talk explaining that there was a general consensus that for $Au + Au$ central collisions at $\sqrt{s_{NN}} = 200GeV$, leading particles are the only way to find jets, because in one unit of the nominal jet-finding cone, $\Delta r = \sqrt{(\Delta_\eta^2 + (\Delta\phi)^2}$, there is an estimated $\pi\Delta r^2 \times \frac{1}{2\pi}\frac{dE_T}{d\eta} \sim 375\,GeV$ of energy !(!) The good news was that hard-scattering in p-p collisions was originally observed by the method of leading particles and that these techniques could be used to study hard-scattering and jets in $Au + Au$ collisions. Notably, I described ?How everything you want to know about jets can be found using 2-particle correlations?. In fact, the predicted ?jet quenching? and other new phenomena were discovered by this method. However, this past year, I had to soften the statement to almost everything because we found by explicit calculation in PHENIX that the away-side two-particle correlation $P_{T_a}$ spectrum from a $a\pi^0$ trigger with $p_{T_t}$ is not sensitive to the fragmentation function?overturning a belief dating from the seminal paper of Feynman, Field and Fox in 1977. The shape of the $p_{T_a}$ spectrum depends only on the power $\eta$ of the parton invariant cross section so that NLO pQCD calculations of the two particle away-side correlations are, in fact, less sensitive to the shape of the fragmentation function than calculations of the inclusive $\pi^0$ cross section. On the positive side, we found that the opposite-side correlation function is sensitive to the ratio of the transverse momentum of the away-side jet ($\hat{p}_{T_a}$ to that of the trigger-side jet ($\hat{P}_{T_t}$ and thus provides a way to measure the relative energy loss of the two jets from a hard-scattering which escape from the medium in an $A + A$ collision.

**Thorn, Charles:** "*The $Q\bar{Q}$ Flux Tube on the Lightcone Worldsheet"*
Following a strategy proposed in 1999 by Rozowsky and me, I show how to decribe the sum of planar diagrams for the $Q\bar{Q}$ flux tube on the lightcone worldsheet. The key to a successful lightcone treatment is to localize the sources of the flux tube on two sparated 1-branes parallel to the $z \equiv (x^+ - x^-)/\sqrt{2}$ axis. Thus the sources, which we call branions, have a limited 1+1 dimensional dynamics. In this context, I discuss branion-branion scattering via planar diagrams

through one loop (i.e. we are studying the flux tube in the $N_c \to \infty$ limit).

**Vaman, Diana:** "*"Bubbling AdS Geometries"*
I will present the supergravity duals of certain BPS states in N=4 super Yang-Mills. More specifically these are the states which are s-waves and are charged under the R-symmetry group. Therefore in order to describe these duals, it is appropriate to begin with a sequence of breathing mode reductions of IIB supergravity: first on S3, then $S3 \times S1$, and finally on $S3 \times S1 \times CP1$. The complete supersymmetry analysis yields the 1/8, 1/4 and 1/2 BPS configurations, respectively. The 1/8 BPS geometries, which have an $S3$ isometry and are time-fibered over a six-dimensional base, are determined by solving a non-linear equation for the Kahler metric on the base. Similarly, the 1/4 BPS configurations have an $S3 \times S1$ isometry and a four-dimensional base, whose Kahler metric obeys another non-linear, Monge-Ampere type equation. Despite the non-linearity of the problem, it is possible to develop a universal bubbling AdS description of these geometries by focusing on the boundary conditions which ensure their regularity.

In the 1/8 BPS case, the $S3$cycle shrinks to zero size on a five-dimensional locus inside the six-dimensional base. Enforcing regularity of the full solution requires that the interior of a smooth, generally disconnected five-dimensional surface be removed from the base. The $AdS_5 \times S5$ ground state corresponds to excising the interior of an $S5$, while the 1/8 BPS excitations correspond to deformations (including topology change) of the $S5$ and/or the excision of additional droplets from the base. In the case of 1/4 BPS configurations, regularity conditions must be imposed on three-dimensional surfaces inside the four-dimensional base which separate the regions where the $S3$ shrinks to zero size from those where the $S1$ shrinks.

**Van Haarlem, Yves:** "*Nuclear $p_t$-Broadening at* HERMES
The HERMES experiment (at DESY-Hamburg) uses a 27.6 GeV $e^{\pm}$ beam on a "fixed" gaseous target. By studying semi-inclusive deep inelastic scattering on nuclear targets the space-time evolution of hadronization can be studied. This process is ideal because of the absence of initial state interactions and, in the HERMES kinematics, hadronization most likely takes place inside the nucleus. $p_t$-broadening is the difference between average transverse momentum of produced hadrons on a nuclear target and that of deuterium. This is sensitive to the time/length scale of hadronization. The first measurement of the $p_t$-broadening for different hadron types and versus several kinematic variables is presented.

**Veneziano, Gabriele:** "*Planar Equivalence: an update*"
I will present the present status of Orientifold Planar Equivalence from the points of view of i) its proof and ii) its consequences.

**Volovich, Anastasia:** "*Gluon Scattering Amplitudes and Twistor String Theory.*

*noindent I will review recent progress in calculation of gluon scattering amplitudes in QCD and N=4 Yang-Mills inspired by twistor string theory.*

**Wosiek, Jacek:** *"From Planar Quantum Mechanics to Planar Field Theory"*
*Restricting a Hilbert space to the fixed number of quanta, and removing subsequently the cutoff, allows to calculate qualitatively spectra of many quantum mechanical systems. The following models will be discussed: Supersymmetric Yang-Mills Quantum Mechanics with the $SU(2)$ gauge group; A nontrivial, exactly soluble, cousin of the space-reduced $SYM_2$ at infinite N - it's phase transition and equivalences to the Heisenberg chain and q-bosonic gas and; Some two-dimensional field theories in the planar limit.*

**Xie, Qu-bing:** *"Universality of Quark Combination Mechanism"*

*We have extended the quark combination model, which had been successfully applied to the high energy $e^+e^-$ and $pp/p\bar{p}$ collisions, to ultrarelativistic heavy-ion collisions and successfully described many features of multi-particle production at RHIC. Using a Gaussian-type rapidity distribution for constituent quarks as a result of Landau hydrodynamic evolution, we explain well the energy and centrality dependence of rapidity/ pseudorapidity distributions for charged particles at various collision energies $\sqrt{S_{NN}}$ = 200; 130; 62:4; 19:6 GeV in Au + Au collisions. We carry out a systematic study of the different contributions to the deviations of the elliptic flow from the quark number scaling at low $p_\tau$ in Au + Au collision.*