AMERICAN PHYSICAL SOCIETY TOPICAL GROUP ON HADRON PHYSICS

http://www.aps.org/units/ghp/

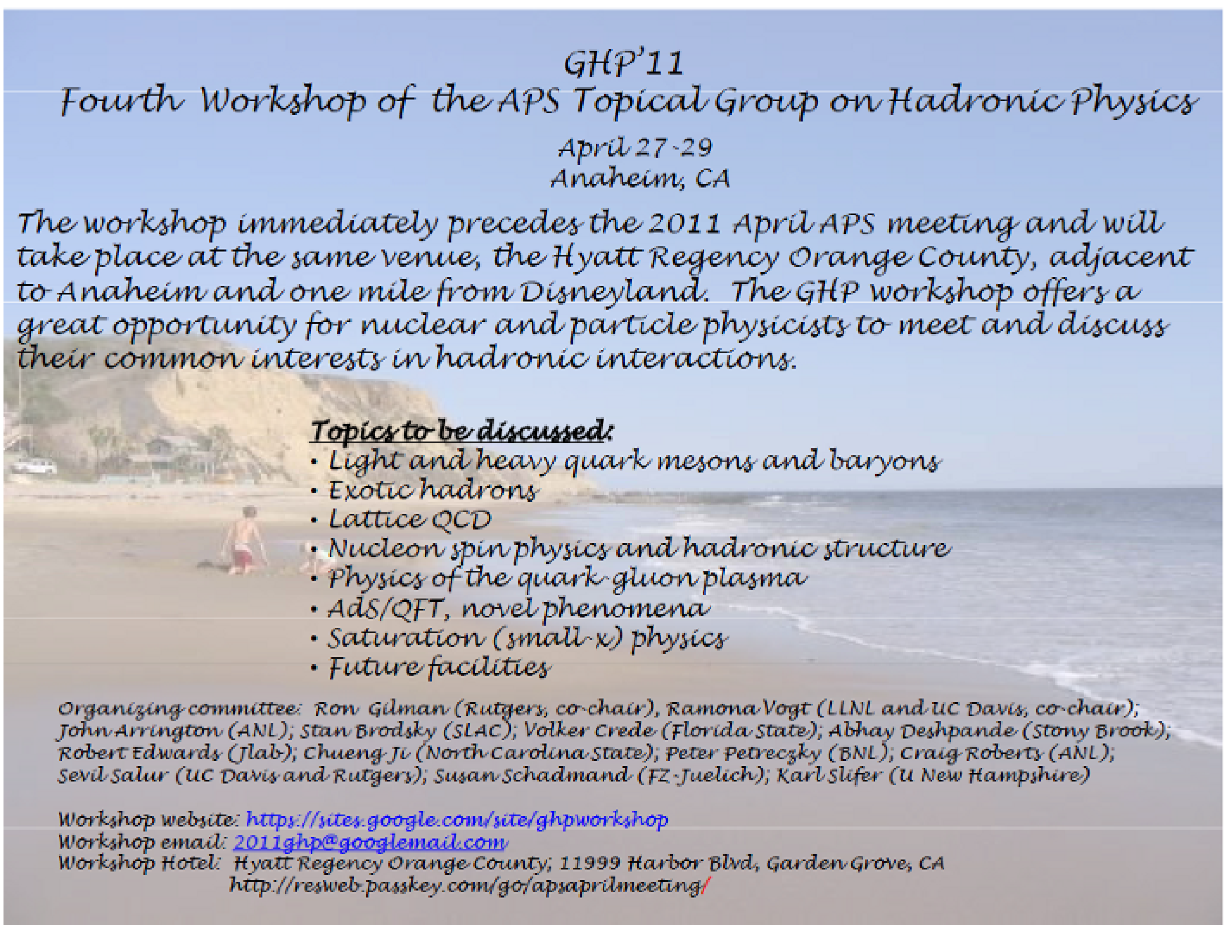
Executive Officers

Chair	*Chair-Elect*	*Vice-Chair*
Ron Gilman	Ramona Vogt	John Arrington
rgilman@physics.rutgers.edu	rlvogt@lbl.gov	johna@anl.gov

Past-Chair	*Secretary/Treasurer*	*Members at Large*	
Stanley Brodsky	Craig Roberts	Robert Edwards	Volker Crede
sjbth@slac.stanford.edu	cdroberts@anl.gov	edwards@jlab.org	crede@fsu.edu

NB. EMail addressed to ghpexec@anl.gov will reach all members of the Executive.

Join GHP by following a link on the lower-right of our web page; namely, from: http://www.aps.org/units/ghp/.



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1 From the President's Chair

The following link will take you to the "End of Year Message" from APS President Curtis Callan: http://www.aps.org/about/governance/letters/endyear2010.cfm, a large part of which is reproduced here.

"In the waning days of the 111th Congress, the Senate unexpectedly took up the reauthorization of the America COMPETES Act, which had been languishing for many months. After readjusting the authorization levels downward for the agencies covered DOE, NIST and NSF to accommodate Republican objections, the Senate passed the bill by unanimous consent. The House quickly approved the Senate version by a vote of 228 to 130.

Without the advocacy efforts of APS members, [and other scientists, mathematicians & engineers throughout the USA], the [Act would never have passed] into law. On behalf of the APS leadership, I want to thank the thousands of you who signed letters, contacted your [Congresspeople . . .], or visited their offices. [Members] played a crucial role in this success.

The COMPETES Act reaffirms the nations commitment to policies that will sustain American leadership in scientific research and strengthen American programs in science and math education. The language of the bill is an important reaffirmation of the central role of science in 21st century America, but it is only an authorization measure. It does NOT provide the actual funding for science. That task falls to the appropriations committees that will begin their work anew in the 112th Congress.

With the United States debt reaching unsustainable levels, the climate in 2011 for all civilian discretionary spending will be very grim. Although virtually all economists, liberal and conservative alike, agree that economic growth is largely driven by advances in science and technology, it will be very difficult to convince lawmakers that science should receive special treatment in the impending budget cuts. It will require extraordinary efforts on the part of the entire S&T community to deliver the message that large reductions in federal support for science would have a devastating impact on the innovation enterprise of this nation and greatly diminish its ability to create the jobs and new technologies on which our future prosperity depends.

Although we will not know in any detail what the President and Congress will propose for science funding until February at the earliest, preliminary signs are not encouraging. Projected cuts range from a minimum of 5 to a maximum of 30 percent. I need not tell you how destructive the latter would be. The APS Washington Office will be monitoring the situation closely and will be implementing strategies to ensure that members of Congress, particularly the newly elected members, are aware of the importance of a vibrant American S&T enterprise and the need for strong federal support. However, your help throughout the coming months will be essential for keeping our nation on track as a leader in science and innovation. Your involvement will also be essential in averting a crisis in federal support for research and education.

It has been an honor to serve the members of the APS as their president during the past year. In what will almost certainly be my last official communication in that role, I ask for your strong commitment to work with the APS leadership and the Washington Office to help sustain robust federal funding for science research and education in the coming year. Incoming APS president Barry Barish will have numerous occasions to ask for your help, and I urge you to be unusually responsive to his requests: the issues at stake are of more than usual gravity."

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2 Elections

Elections for two posts in the GHP Executive closed on 21st November 2010. The new Executive Committee is listed at the top of this newsletter.

On behalf of GHP, the Executive thanks the people who entered their names on the ballots.

In addition, we thank Winston Roberts and Sebastian Kuhn.

Elections will open again this year in October. We will fill two positions on GHP's Executive Committee:

- Vice-Chair (Ramona Vogt will become Chair and John Arrington will become Chair-Elect, leaving the position of Vice-Chair vacant. Naturally, Ron Gilman will become Past-Chair and Stan Brodsky will disappear … but only from the header of these pages.)

- and one Member-at-Large (Robert Edwards will by then have completed his stint.)

It is planned that in September, 2011, the Nominating Committee will solicit input from the GHP membership. The nomination of candidates will likely close on Fri. 30 September and an electronic ballot will subsequently be held over a four week period: 21 October – 18 November.

Our rules state that: *the Committee shall nominate at least two candidates for the office of Vice-Chair and for the open position of Member-at-Large; the slate of candidates will be balanced as much as possible to ensure wide representation amongst the various fields of physics included in the GHP's membership; the Nominating Committee shall be chaired by the immediate past Chair*, who is

Stan Brodsky (sjbth@slac.stanford.edu)

this year; *and shall include three members in addition to its Chair, one of whom shall be appointed by the APS.*

We urge GHP members now to begin considering whom they would like to see filling the two open positions in 2010 and encourage members with ideas to contact the *Chair of the Nominating Committee* and pass on their suggestions. There is strength in diversity and so the Executive would like to see nominations from across the entire spectrum of GHP's membership.

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3 Membership

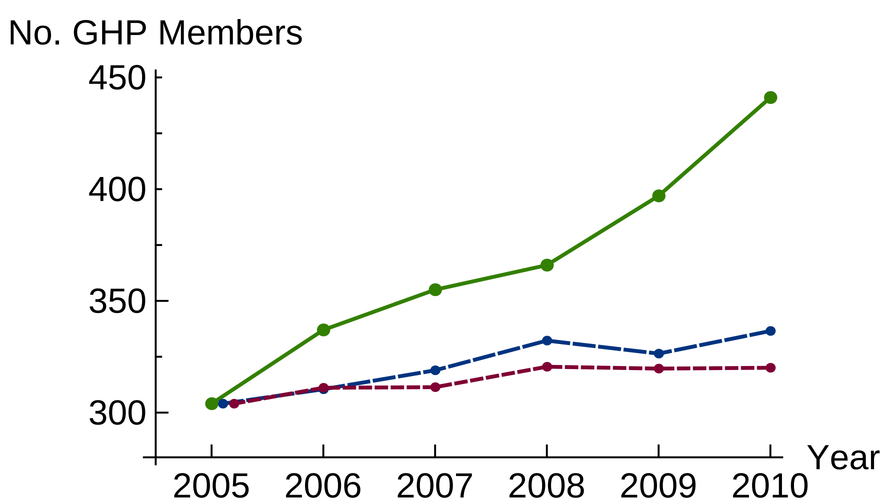

Figure 1: *Solid line* – GHP membership, true value, with "2010" representing the current APS Official Count; *long-dashed* – DNP membership normalized to GHP's value in 2005 (2401 → 304); and *short-dashed* – DPF membership normalized to GHP's value in 2005 (3291 → 304).

As of January, 2011, the GHP had 441 members, which represents 0.91% of APS membership. Of these people, 259 are also in DNP (Division of Nuclear Physics) and 238 are in DPF (Division of Particles and Fields). However, DNP has a total of 2658 members and DPF has 3465. Hence, it is certain that there are many Hadron Physics researchers who are not involved with GHP.

Importantly, if we can raise our membership to 500, then we will be able to make two regular-fellowship nominations each year. That would be an excellent boost for Hadron Physics. (At present we are only allowed one such nomination, although we were successful with two nominations in 2010 – see below.)

There are now eleven Topical Groups, of which the GHP is the 6th largest. Comparing 2009 membership with that in 2010, in relative terms, the GHP grew 11%. Neglecting the newest Group, *Energy Research and Applications*, GHP is the third most rapidly growing, behind *Quantum Information*, with 1084 members, which grew 17% and *Magnetism*, with 940 members, which grew 13%.

Membership in a strong GHP brings many benefits. A vital GHP

- establishes and raises the profile of Hadron Physics in the broader physics community, e.g., by nominating members
  - to APS governance committees,
  - to APS prize and award selection committees,
  - for election to Fellowship in the APS
- has a greater role in planning the program for major APS meetings;
- and provides a vehicle for community action on topics that affect the way research is conducted and funded.

Whether one considers the APS alone, or takes a broader perspective, the impact GHP can have is primarily determined by the number of members. (It is also influenced by the energy of the Executive, which exhibits quantum fluctuations.) The Executive urges existing members to encourage their colleagues to join us. We know there are absent-minded people who have overlooked the opportunity to join GHP but many will react positively to a little gentle prodding.

Membership is only $8. Of this, GHP receives $5 from the APS. (The remainder stays with the APS and covers the many services they provide.) With this support we can be an active force for Hadron Physics. The money can be used, for example, to assist with: the organization of meetings; the preparation of publications that support and promote the GHP's activities; and participation in those fora that affect and decide the direction of basic research.

Hence, if you are reading this newsletter but are not a member of GHP, please join. On the other hand, if you're already a member, please circulate this newsletter to your colleagues and encourage them to join.

Current APS members can add units online through the APS secure server by following a link on the lower-right of our web page; namely, http://www.aps.org/units/ghp/index.cfm.

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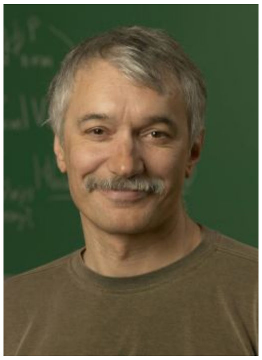
4 Fellowship

We take this opportunity to congratulate Ian Balitsky (JLab) and Eric Swanson (Pitt), both of whom in 2010 were elected to Fellowship in the APS under the auspices of the GHP:

Ian "For pioneering applications of quantum chromodynamics (QCD) to hadron physics, in particular, for development of light-cone QCD sum rules and contributions resulting in Balitsky-Fadin-Kuraev-Lipatov (BFKL) and Balitsky-Kovchegov (BK) equations;"

Ian Balitsky and Eric Swanson, GHP's 2010 Fellows.

and Eric "For contributions to the theory of hadron spectroscopy, especially in the areas of charm-quark mesons, gluonic excitations, and mesonic molecules."

This is a good time to remind the GHP that each year the APS allocates a number of Fellowship Nominations to a Topical Group. That number is based primarily on membership. A strong GHP can nominate more of our members for Fellowship. In 2011 we are allocated ONE Regular nomination and ONE Alternate, for a total of TWO nominations. However, as we have now seen, two extremely strong candidates will both reach the top!

The Executive urges members of GHP to be prepared in 2011 to nominate colleagues who have made advances in knowledge through original research and publication or made significant and innovative contributions in the application of physics to science and technology. They may also have made significant contributions to the teaching of physics or service and participation in the activities of the Society.

The instructions for nomination may be found at
http://www.aps.org/programs/honors/fellowships/nominations.cfm
The entire process is now performed on-line.

A few things to know before proceeding, however. One must

- Ensure the nominee is a member of the Society in good standing. The on-line site will do this for you but it's best to check beforehand, to save yourself time or get your nominee to join APS and/or GHP.
- A nomination requires a sponsor and a co-sponsor. During the on-line nomination process, you will be required to provide details for a co-sponsor. After you complete a nomination, the co-sponsor will be notified by EMail. It would be best to coordinate with the co-sponsor beforehand.
- You will require supporting letters, that will need to be up-loaded to the APS web site. Two letters of support are sufficient. Individuals providing letters of support do not have to be members of the APS, however, in practice it is preferable that sponsors be APS Fellows.
- The nomination process should be complete prior to GHP's deadline:
  Friday 1st April 2011

The APS will subsequently forward the Nominations to the GHP Fellowship Committee, which this year is

2011 GHP Fellowship Committee

John Arrington	Volker Crede	James Vary
johna@anl.gov	crede@fsu.edu	jvary@iastate.edu

John Arrington is Chair. Do not hesitate to contact John or his colleagues on the committee if you have questions.

The Executive urges members of GHP to react quickly to this call for nominations.

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5 GHP 2011: 4$^{\text{th}}$ Workshop of the GHP

Planning is fully underway for the Fourth Workshop of the APS Topical Group on Hadron Physics. It will take place over 2.5 days:

27-29 April 2011

https://sites.google.com/site/ghpworkshop

i.e., just before the 2011 APS April Meeting, and at the same venue:

Hyatt Regency, Orange County
11999 Harbor Blvd
Garden Grove, CA

immediately adjacent to Anaheim and one mile from Disneyland. Discounted room-rates are available until Thursday 31 March.
https://resweb.passkey.com/Resweb.do?mode=welcome_gi_new&groupID=2767030

The GHP workshop offers a very good opportunity for nuclear and particle physicists to meet and discuss their common interests in hadronic interactions. So please mark these dates and the location in your calendar and plan on attending.

Topics to be discussed include:

- Light and heavy quark mesons and baryons
- Exotic hadrons
- Nucleon spin physics and hadronic structure
- AdS/QFT, novel phenomena
- Future facilities
- Lattice QCD
- Physics of the quark gluon plasma
- Physics of gluon saturation

There will be six three-lecture Plenary Sessions. Four-six blocks of parallel sessions are also being organized. A reception will be held at 5pm on Thursday 28$^{\text{th}}$ April.

The development of the plenary program is advanced, but we welcome your suggestions for invited talks.

Workshop Email: 2011ghp@googlemail.com

We also have some travel funds that we intend to use to support the travel of junior scientists. The abstract submission deadline is March 1, 2011. To contact us on any of these matters, please use the workshop email.

Ron Gilman and Ramona Vogt are co-chairing the Organizing Committee, which is constituted from the entire Executive and selected members of GHP:
Organizing committee:

- John Arrington (Argonne),
- Stan Brodsky (Stanford),
- Volker Crede (Florida State),
- Abhay Deshpande (Stony Brook)
- Robert Edwards (Jefferson Lab),
- Ronald Gilman (Rutgers, co-chair),
- Chueng-Ryong Ji (NC State)
- Peter Petreczky (Brookhaven)
- Craig Roberts (Argonne),
- Sevil Salur (UC Davis)
- Susan Schadmand (FZ Jülich),
- Karl Slifer (U. New Hampshire)
- Ramona Vogt (Livermore and UC Davis, co-chair)

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6 APS April Meeting, 2011

A topical group is invited to participate in planning the program of major APS meetings. In 2010, for the 2nd year running, GHP was successful with the nomination of a ***Plenary Presentation*** approved by the Program Committee for the 2011 April Meeting, to be held in Anaheim, California

30 April – 3 May, 2011

http://www.aps.org/meetings/meeting.cfm?name=APR11

Namely, **W. J. Marciano** on the *Status of the Proton Charge Radius.* (In 2010, **N. Makins** spoke on the *Nucleon Spin Puzzle.*)

In addition, ***two*** sessions of Invited Talks are being sponsored by the GHP at the April meeting, one session arranged jointly with the DNP.

Session 1 – “Advances in the Strong Interaction”
Sunday, 1 May 2011, 10:45-12:33.

- Dmitry Kharzeev (BNL) – *Strong-parity violation at RHIC*
- Wit Busza (MIT) – *Initial results from the LHC*
- Arafat Mokhtar (SLAC) – *Charmonium*

Session 2 – "QCD in Nuclear Physics" (Joint with DNP)
Tuesday, 3 May 2011, 13:30-15:18.

- Seamus Riordan (U. Virginia) – *Nucleon form factors*
- Craig Roberts (ANL) – *Neutral-pion transition form factor: the BaBar anomaly*
- Kieran Boyle (BNL) – *Nucleon spin structure*

The speakers and schedule were developed by the 2010 GHP Program Committee: Abhay Deshpandhe (Stony Brook), Matthew Shepherd (Indiana) and Ron Gilman (Rutgers). Ron Gilman was Chair.

Another invited session features GHP's Past-Chair; namely,

Session – "Much Ado About Nothing: The Quantum Vacuum" (sponsored by DPF and DAP)
Tuesday, 3 May 2011, 13:30-15:18.

- Stanley J. Brodsky (SLAC) – *New Perspectives on Condensates in Quantum Chromodynamics and the Cosmological Constant*
- David Shih (Rutgers U.) – *The Particle Vacuum*
- Rachel Bean (Cornell U.) – *Vacuum Energy and Cosmology*

Moving on to next year, **Ramona Vogt** will serve as Chair of the GHP's 2012 Program Committee:

GHP Program Committee, preparing for April 2012

Spencer Klein (LBNL) srklein@lbl.gov	Peter Petreczky (BNL) petreczk@quark.phy.bnl.gov	Ramona Vogt (LLNL) rlvogt@lbl.gov

The 2012 April Meeting is scheduled for
April 28-May 1, 2012 – Atlanta, GA.
http://www.aps.org/meetings/meeting.cfm?name=APR12

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7 Unit Convocation

The Convocation is the gathering of unit officers. It provides for their familiarization with the ways of the APS, and is also an excellent opportunity for unit officers learn from each other.

In the past this meeting was held in the middle of February, but in a follow-up survey after the 2010 Convocation, the majority of participants indicated they favored an April Convocation date. As a result, the 2011 APS Unit Convocation is now scheduled to be held at the American Center for Physics (APS Headquarters) in College Park, Maryland on

Friday 15th April.

The Convocation will be large this year because an invitation is again being extended to all the APS Committee Chairs. There are 21 standing committees of the APS and often these committees operate quite independently from one another. The APS Executive Board feels it is important for APS Committees to develop a sense of the larger APS picture.

This year three members of the GHP's Executive are volunteering their time and will take part: John Arrington, Volker Crede and Ramona Vogt.

An important adjunct to the Unit Convocation is the participants' pre-convocation visits to Capitol Hill in order to meet their Congressional representatives and discuss the contributions that physics and physical science make to the nation. The APS Public Affairs office does a terrific job coordinating this, including providing briefing material, helping to set up appointments and initiating those first time participants.

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8 State of the Laboratories

8.1 Brookhaven Lab's Top Scientific Discoveries of 2010

(Communicated by Ramona Vogt – vogt@lbl.gov.)

Out of more than 800 peer-reviewed papers published in 2010, BNL's top picks are summarized below:

Physicists created a primordial state of matter known as quark-gluon plasma (QGP) at 4 trillion degrees Celsius - 250,000 times hotter than the center of the Sun. Within this hot quark soup, physicists found "bubbles" that seem to disobey so-called mirror symmetry, or parity. The observation that this symmetry appears to be broken in the QGP suggests that scientists may now have a way to test some crucial features of other symmetry-altering bubbles speculated to have played a role in establishing a preference for matter over antimatter in our world.

RHIC collisions have also created the most massive antinucleus to date. The exotic matter, known as an antihypertriton, contains an antiproton, an antineutron, and an anti-Lambda particle - and it's the first antinucleus found to contain a strange antiquark. The discovery may help elucidate models of neutron stars and opens up another way to explore fundamental asymmetries in the early universe.

"This experimental discovery may have unprecedented consequences for our view of the world," commented theoretical physicist Horst Stoecker, Vice President of the Helmholtz Association of German National Laboratories. "This antimatter pushes open the door to new dimensions in the nuclear chart – an idea that just a few years ago, would have been viewed as impossible."

Further details are available at
http://www.bnl.gov/bnlweb/pubaf/pr/PR_display.asp?prID=1221

8.2 Highlights from HERMES

(Communicated by Harold Jackson – hal@anl.gov. More information on the HERMES program and recent developments are available at the HERMES web site – http://www-hermes.desy.de.)

HERMES is an international collaboration, which has been studying the spin structure of the nucleon at HERA using internal polarized gas targets in the stored 27.6 GeV electron/positron beam of the HERA accelerator. Although data acquisition in the HERMES experiment ended in 2007 with the shutdown of the HERA accelerator, HERMES lives on. An active program of data analysis is envisaged to continue at least through 2012. A broad program of physics topics in semi-inclusive deep-inelastic scattering (SIDIS) continues to be studied. Some of the recent results are highlighted in the following paragraphs.

HERMES has extracted the gluon polarization in the proton from inclusive charged hadron asymmetries measured as a function of the transverse momentum of the hadron p_T using polarized proton and deuteron targets. Processes involving gluons have been enhanced relative to others by selecting hadrons with p_T above 1 GeV. These high p_T hadrons probe the gluon polarizations through their sensitivity to the photon-gluon process. The HERMES results (A. Airapetian *et al.*, JHEP **08** (2010) 130) demonstrate what has been long suggested by the observed absence of significant polarization of the sea quarks in the proton and less strongly from scaling violations observed in inclusive DIS. Namely, the gluons make only a small contribution to the spin of the proton. The gluon polarization obtained from single inclusive hadrons in the range $1\,\mathrm{GeV} < p_T < 2.5\,\mathrm{GeV}$ using a deuterium target is $\Delta g/g = 0.049 \pm 0.034 \pm 0.126$ at an average value of $\langle x \rangle = 0.22$, where x is the familiar Bjorken scaling variable. The precision of the HERMES result is the best available from leptoproduction experiments.

A large portion of the program is focused on the features of scattering cross sections which probe transversity and tranverse momentum dependent parton distributions. In 2002 a transversely polarized proton target was installed in the HERMES spectrometer, enabling for the first time the distinct separate measurement of the Sivers and Collins effects in single spin asymmetries (SSAs) as measured in SIDIS by transversely polarized protons. Azimuthal SSAs of leptoproduced pions and charged kaons were measured. The dependence of the cross section on the azimuthal angles of the target polarization, ϕ_s, and the hadron produced, ϕ, has distinct $\sin(\phi_s + \phi)$ and $\sin(\phi_s - \phi)$ modulations for the Collins and Sivers effects respectively. These modulations were measured for the production of $\pi^{\pm}$, π^0, $K^{\pm}$. The substantial $\sin(\phi_s + \phi)$ term in the SSAs observed (A. Airapetian *et al.*, Phys. Lett. B**693** (2010) 11) for $\pi^{\pm}$ and K^+ can be interpreted in terms of non-zero transversity distribution functions and non-zero favored and disfavored Collins fragmentation functions of opposite sign. For π^0 and K^- production this term is consistent with zero. Observation of sizable $\sin(\phi_s - \phi)$ modulations (A. Airapetian *et al.*, Phys. Rev. Lett. **103** (2009) 152002) in the SSAs for π^+, π^0, $K^{\pm}$ indicate a contribution from the naïve-T-odd, transverse-momentum-dependent Sivers parton distribution function.

The Sivers effect was postulated many decades ago to explain inclusive pion SSAs observed in nucleon-nucleon collisions, but experiments did not provide a means of distinguishing its contribution to the SSAs from those of the competing Collins effect. At HERMES, SSAs are under investigation for inclusive electroproduction of charged pions and kaons from a transversely polarized proton target. In the kinematic range $0.08 < p_T < 2.2\,\mathrm{GeV}$ and $0.0 < x_F < 0.55$ positive SSAs were measured for positive hadrons, while for negative hadrons the SSAs were found to be of smaller magnitude. While the results bear some similarity to results observed in SIDIS on polarized protons for the Sivers effect, the current state of the theoretical framework precludes a detailed interpretation of the HERMES results.

Azimuthal ($\cos\phi$ and $\cos 2\phi$) modulations are expected even in the case of unpolarized SIDIS. An example is the Cahn effect known in DIS for many years. At HERMES a kinematically four-dimensional extraction of these modulations has been made using unpolarized proton and deuteron targets for negatively and positively charged pions and kaons. These modulations can be viewed as being generated by a combination of Cahn, Boer-Mulders and Collins effects. The amplitudes extracted from proton and deuteron targets are found to be similar, suggesting Boer-Mulders distribution functions with the same sign and similar magnitudes for up and down quarks.

Owing to the analyzing power of its parity-violating weak decay, $\Lambda \to p\pi$, the Λ-hyperon is a uniquely useful tool for spin physics. Results at HERMES for the longitudinal spin transfer from the lepton beam to the hyperon and anti-hyperon, D_{LL}^{Λ}, as well as for the spin transfer in quasi-real photoproduction from longitudinally polarized proton and deuteron targets, K_{LL}^{Λ}, have been published. Most recently, spontaneous transverse Λ ($\bar{\Lambda}$) polarization (not related to beam or target polarization) has also been studied on a wide range of nuclear targets. This polarization is observed to be positive for light nuclei and to decrease with increasing atomic number A of the target, and to be compatible with zero for Kr and Xe. These results are in strong contrast to those observed for this quantity in hadron-hadron collisions, where no significant mass dependence is observed.

Spin density matrix elements (SDMEs), which are observables describing how the spin components of a virtual photon are transferred to a vector meson, have been extracted by HERMES in the exclusive production of ρ_0 and ϕ mesons in exclusive electroproduction $eN \to e\rho_0(\phi)N$. Both proton and deuteron targets have been studied and measurements spanned the kinematic region $1.0\,\mathrm{GeV}^2 < Q^2 < 7.0\,\mathrm{GeV}^2$, $3.0\,\mathrm{GeV} < W < 6.3\,\mathrm{GeV}$ and $-t' < 0.4\,\mathrm{GeV}^2$. Both unpolarized and polarized SDMEs were extracted. For ρ_0 meson production a small but statistically significant deviation from the hypothesis of s-channel helicity conservation was observed, and an indication of a contribution from unnatural-parity-exchange amplitudes is seen. For ϕ meson production, the data are consistent with s-channel helicity conservation, and no statistically significant evidence for the contribution of unnatural-parity exchange is observed.

Lepton beam-helicity asymmetries and lepton charge asymmetries as a function of azimuthal angle in hard electroproduction of real photons (DVCS) have been extensively studied by HERMES collaborators. Results are now available for proton and deuteron targets. Recently, charge-difference and charge averaged beam-helicity asymmetries in exclusive DVCS from a proton target have been exploited to separate the interference term from the squared DVCS term in the exclusive cross section. Such charge-decomposed beam helicity asymmetries have the potential to constrain generalized parton distributions (GPDs) when used in future GPD models or as input to global fits. A search for a mass dependence of beam-helicity SSAs in DVCS for targets ranging from hydrogen to xenon has yielded no measurable result.

During the last years of operation HERMES acquired data with a recoil detector designed to improve the exclusivity of DVCS measurements by detecting directly the recoiling proton. The detector consists of a central silicon strip detector of very large angular acceptance enclosed in a scintillating fiber tracker, and an outer calorimeter. Recent results obtained by imposing strong constraints on the coplanarity and other kinematic features of potential DVCS events, indicate that purely exclusive DVCS events can be separated from associated DVCS events in which the recoiling proton is left in an excited state with $\approx 99\%$ purity. Analyses in progress are focused on the study of angular distributions for photons of both purely exclusive and associated DVCS.

8.3 Highlights from JLab

(Communicated by R. D. McKeown – bmck@jlab.org.)

Thomas Jefferson National Accelerator Facility (JLab) is maintaining an active physics program at 6 GeV while construction has continued on its 12 GeV upgrade. The 6 GeV program, originally begun in 1995 at 4 GeV, will continue through May 2012, followed by a year-long shutdown to upgrade the CEBAF accelerator and the start of commissioning the upgraded facility in 2013. The ongoing physics program is very broad, and a few examples will be given below, followed by a description of some future plans.

Form Factors:
One focus of the JLab hadron physics program has been nucleon form factors: the form factors describe the charge and magnetization distributions within the hadron. The ratio of proton electric to proton magnetic form factors was determined up to 8.5 GeV^2, using a new recoil proton polarimeter in the Hall C HMS spectrometer, and published in Physical Review Letters. The new data for this ratio match the earlier measurements up to 5.7 GeV^2 and show a continued decrease towards zero. Future measurements planned for the 12 GeV program will extend the range of Q^2 to 12 GeV^2.

The neutron electric form factor was determined up to 3.4 GeV^2, using polarized electrons scattering from a polarized ^{3}He target in Hall A, and published in Physical Review Letters. The new results tend to agree better with modern VMD fits and Dyson-Schwinger equation predictions, rather than constituent quark models. It remains an issue that we do not have a good description of all four nucleon form factors from a single theoretical approach over the entire accessible momentum domain. Future measurements of G_E^n are planned for the 12 GeV program up to $Q^2 = 10\,\mathrm{GeV}^2$.

There is renewed interest in the proton form factors at very low Q^2 as a result of the report of a measurement at PSI of the Lamb shift in muonic Hydrogen. The muonic Lamb shift measurement indicates that the proton charge radius is $r_p = 0.84184(67)$ fm, which differs by 5.0 standard deviations from the CODATA value (fit to atomic hydrogen data) of 0.8768(69) fm. Jefferson Lab results reported in 2007, along with more recent data, have been analyzed to provide better constraints on the ratio G_E^p/G_M^p and yield an improved value of r_p from electron scattering data. These results are being prepared for publication. In addition, a new high-precision measurement of G_E^p/G_M^p at $Q^2 < 0.4\,\mathrm{GeV}^2$ is planned for running in Hall A in FY12.

Two-photon exchange:
Over the last few years, data from Jefferson Lab have established that the values of G_E^p extracted from recoil polarization measurements disagree with those extracted from traditional Rosenbluth separation. The resolution to this conundrum is thought to involve the contributions of two-photon exchange amplitudes. An experiment to address this issue by precise comparison of electron and positron scattering is currently in progress in Hall B. It is expected that the results will provide a definitive test of the contribution of two-photon exchange and its implications for the form factor measurements.

Parity violation:
The contribution of strange quarks to the electromagnetic form factors of the nucleon has been

investigated through parity-violating (PV) elastic electron scattering from protons and deuterons, at Bates, Mainz, and Jefferson Labs. The latest results from the G0 backward-angle measurements were published in 2010. Analysis of an even higher-precision measurement from fall 2009 of the forward-angle PV asymmetry, HAPPEX-III, is in progress and the result is expected to be reported in early 2011.

The PREX experiment ran in Hall A in 2010, studying parity violation in elastic scattering of electrons on ^{208}Pb. The neutral weak charge of the proton is suppressed by the factor $1 - 4\sin^2\theta_W$, so the PV asymmetry on such a heavy nucleus is dominated by the neutron. Thus such a measurement can be used to extract the neutron radius of ^{208}Pb. The experiment ran with very high luminosity, which became a challenge for the experimental hardware in Hall A, and as a result only a partial dataset was acquired. Nevertheless, the results are still expected to provide useful information on the neutron radius.

At even lower Q^2, where the strange quarks are expected to play a negligible role, PV can be used to measure the weak charge of the proton. As the standard model value is known, this can alternately be viewed as a measurement of the running of the weak mixing angle with momentum transfer, or as a search for physics beyond the standard model. The experiment, *Qweak*, is the largest experiment at JLab to date and was successfully installed and commissioned in Hall C during the fall of 2010. During this period the experiment received a record 170 μA of polarized beam from the accelerator facility and the liquid hydrogen target has been demonstrated to perform well, without significant boiling effects, at a record value of 2.2 kW of beam power deposition. This is a major technical advance in the subject of parity-violating electron scattering. The *Qweak* experiment is planned to acquire the full data set during the running period in 2011-12 before the 12 month shutdown beginning in May 2012.

Baryon Resonances:
A major experimental program is in progress in Hall B to, for the first time, uniquely determine (overdetermine in the case of Λ-production) the reaction amplitudes in meson-baryon photoproduction from the proton and neutron. In 2010 data on single, double, and triple polarization observables were successfully acquired, employing the polarized proton target FROST in combination with polarized photon beams and the measurement of recoil polarization in hyperon decays. The HDICE target is currently being constructed which will enable comparable data on polarized neutrons, utilizing polarized deuterium. The HDICE experiment is scheduled to begin in late spring of 2011 and continue after the 6 month shutdown during the period Nov. 2011 to May 2012.

LQCD:
General purpose GPU (graphics processing units) enhanced clusters are now even more cost effective than standard clusters for certain numerically intensive calculations in lattice-QCD . They have particularly nimble role in the "measurement" phase, where the gauge configurations generated on leadership-class and large-scale clusters are analysed to yield the physics results that can confront experiment. This performance boost requires significant investments in software porting and optimization, and USQCD collaborators at Boston University, Harvard and Jefferson Lab have produced, and put into production, quality matrix inversion routines that are parallelised across several GPUs. These accelerated kernels lower the cost of a significant portion of the work flow by a factor of ten. This is enabling the ARRA-funded GPU cluster at Jlab to tackle key theoretical calculations needed to capitalize on the 6 GeV and anticipated 12 GeV Jefferson Lab experimental program.

As an example of the new calculations facilitated by GPUs, researchers in the Jefferson Lab

Theory Center, with colleagues at Trinity College Dublin, have exploited their computational power, allied with novel theoretical methods, to demonstrate that an energy-dependent phase shift can be mapped out using lattice QCD methods. The techniques developed will soon be applied to hadron-scattering channels with resonant behavior to study excited-hadron decays of the type that will be measured in GlueX and in CLAS12. Furthermore, GPUs are efficient at performing the computations required for partial wave analyses, in which experimental data are separated into components with definite angular momentum; both GlueX in Hall D and CLAS12 in Hall B have a program with the 12 GeV upgrade to identify the light "exotics" theory is predicting.

Imaging the proton:
During 2010 an experiment was run in Hall A to study DVCS contributions on the proton and neutron at leading- and higher-twist. The generalized parton distributions (GPDs) extracted from such measurements can be used to get the first glimpse of a transverse spatial image of the nucleon's light-front quark- and spin-distributions. More detailed imaging will be possible with the 12 GeV upgrade.

Neutral Pion Decay:
The PRIMEX experiment in Hall B was run during 2010 with the goal of providing a precise measurement of the decay width of the π^0 using the Primakoff effect. This result will enable an important test of chiral perturbation theory at next to leading order.

EMC effect and Short-range correlations:
Jefferson Lab data relevant to the EMC effect (nuclear modification of parton structure) have been used in recent studies to shed new light on the origin of this long-standing issue in nuclear physics. The EMC ratios (nucleus/deuterium) for F_2 on light nuclei ($A \leq 12$) were analyzed in the region $.35 < x < 0.7$ to yield a best fit slope with respect to x. The slopes do not correlate well with the average nuclear density, especially for ^{9}Be which is well described as 2 α particles and a neutron. However, the slopes are well correlated with the average two-body density which takes into account the 2-nucleon short-range correlations. More recently the EMC slopes for a wider range of nuclei (up to $A = 56$) have been shown to have a linear correlation with the EMC ratios at $x > 1.5$, where it has been demonstrated that the two-nucleon short range correlations are responsible for the enhanced ratio values. Thus the evidence that the EMC effect in the region $0.35 < x < 0.7$ is related to short-range correlation effects in nuclei (as opposed to an effect owing to the nuclear mean field) is becoming stronger.

APEX: A new neutral weak vector boson, now referred to as A', with mass in the 10-1000 MeV range has been proposed to address issues related to dark matter in the universe. The APEX experiment has been proposed to search for such a particle in Hall A. The A' is produced via a bremsstrahlung process on at Tungsten ribbon target and detected through the decay into e^+-e^- pairs. The APEX experiment conducted a very successful test run in 2010, and expects to report new limits on the existence of the A' based on data obtained in the test run.

12 GeV Upgrade:
The 12 GeV upgrade project made excellent progress during 2010. The goal of this project is to double the beam energy to 12 GeV, implement enhanced experimental hardware in the existing experimental halls, and construct a new Hall D to include the GlueX experiment. The construction activities are visible across the JLab site for both the 12 GeV project and also for the new Technology and Engineering Development Facility, a modernization and enlargement of the existing Test Lab building. Major procurements are well underway, various detectors are being built by university groups, and the civil construction well advanced. In general the project remains on schedule and budget, and the civil construction achieved a major milestone

in Dec. 2010 with Hall D being granted "Ready for Equipment" status.

The 12 GeV physics program continues to develop. The August 2010 Program Advisory Committee (PAC36) meeting continued to assign beam time and rate scientific priorities in several categories: "The hadron spectra as probes of QCD," "The longitudinal structure of hadrons," and "Hadrons and cold nuclear matter." The report is available online at http://www.jlab.org/exp_prog/PACpage/PAC36/PAC36_report.pdf. In January 2011, PAC37 assigned beam time and rated scientific priorities to another category: "Low-energy tests of the Standard Model and Fundamental Symmetries." In addition, nine new proposals and four letters of intent were received and considered at PAC37. PAC38 is scheduled for August 2011, and the final category; namely, "The 3D structure of the hadrons," will be rated at that meeting.

Electron-Ion Collider:
During the spring of 2010, the JLab Users Group organized, in coordination with the Laboratory, a series of workshops to study the physics of a future electron-ion collider:

- Partonic Transverse Momentum in Hadrons: Quark Spin-Orbit Correlations and Quark-Gluon Interactions, Duke University, March 12-13, 2010, http://michael.tunl.duke.edu/workshop/index.php
- 3D mapping of the glue and sea quarks in the nucleon, Rutgers University, March 14-15, 2010, http://www.physics.rutgers.edu/np/2010rueic-home.html
- 3D tomography of nuclei, quark/gluon propagation and the gluon/sea quark EMC effect, April 7-9, 2010, ANL, http://www.phy.anl.gov/mep/EIC-NUC2010/
- Electroweak structure of the nucleon and tests of the Standard Model, May 17-18, 2010, College of William and Mary, https://eic.jlab.org/wiki/index.php/Electroweak_Working_Group
- EIC Detectors/Instrumentation, Jefferson Lab, June 4-5, 2010, http://conferences.jlab.org/eic2010/

These were very successful, well-attended workshops and most will publish summaries. In addition, a 10 week program at the INT was held in Sept.-Nov. 2010 on "Gluons and the quark sea at high energies: distributions, polarization, tomography." Proceedings of this program are also planned for publication. So the level of activity devoted to continued development of the physics case for an EIC has been quite remarkable during the last year, and we seem to be on a good path to be ready for consideration of such a project at the next NSAC Long Range Plan.

8.4 QCD at the Tevatron

(Communicated by Simona Rolli – rolli@fnal.gov.)

At the Fermilab Tevatron, the CDF and D0 experiments have performed many analyses of data collected at $\sqrt(s) = 1.96$ TeV in $p\bar{p}$ collisions. The general approach has been to test QCD theory, search for new physics phenomena, and enable electroweak and exotic measurements by informing Monte Carlo (MC) background models, while laying the groundwork for the LHC era of pp collisions.

The precise measurement of the **inclusive jet and dijet production cross-section** [1, 2, 3, 4] shows a remarkable agreement with the theoretical predictions over several order of magnitude. Comparisons of the measured cross section with pQCD predictions provide constraints on the parton distribution function (PDF) of the (anti)proton, in particular at high momentum fraction x ($x > 0.3$) where the gluon distribution is poorly constrained [5]. Further constraints on the gluon distribution at high-x will contribute to reduced uncertainties on theoretical predictions of many interesting physics processes both for experiments at the Tevatron and for future measurements at the Large Hadron Collider (LHC). The experimental precision achieved now at the Tevatron exceeds that of the PDF uncertainty, so that such measurements can be used, for the first time, to inform the PDF global fits. The inclusive jet cross section measurement has been used by the D0 collaboration to determine α_s and its dependence on the transferred momentum. The result is $\alpha_s(M_Z) = 0.1161 + 0.0041 - 0.0048$ and the $\alpha_s(p_T)$ results support the energy dependence predicted by the renormalization group equation. This is the most precise α_s result obtained at a hadron collider.

Within the standard model (SM), **two-jet (dijet) events** are produced in proton-antiproton collisions predominantly from hard QCD interactions of two partons. The **dijet mass spectrum** predicted by QCD falls smoothly and steeply with increasing dijet mass, while **dijet angular distribution** with respect to the hadron beam direction is directly sensitive to the dynamics of the underlying reaction. Many extensions of the SM predict the existence of new massive particles that decay into two energetic partons (quarks or gluons), which can potentially be observed as a narrow resonance in the dijet mass spectrum. In the dijet angular distribution, an excess at large angles from the beam axis would be a sign of new physics processes not included in the SM, such as substructure of quarks, or the existence of additional compactified spatial dimensions. CDF [10] and D0 [11] are both measuring the dijet mass distribution and angular distribution[13]) but do not find any significant deviation from QCD predictions, leading to exclusion limits on the existence of new exotic particles.

Photons originating in the hard interaction between two partons are typically produced in hadron collisions via quark-gluon Compton scattering or quarkanti-quark annihilation. Studies of these direct photons with large transverse momenta, p_T, provide precision tests of perturbative QCD (pQCD) as well as information on the distribution of partons within protons, particularly the gluon. These data were used in global fits of parton distribution functions (PDFs), and complement analyses of deep inelastic scattering, Drell-Yan pair production and jet production. Both CDF [14] and D0 [15] have measured the cross-section for **inclusive production of isolated photons**. Results from NLO pQCD calculations agree with the measurement within uncertainties. The ratio between data and pQCD prediction is in good agreement at high p_T but shows an enhancement at low p_T where the effects of theory resummation and background fragmentation is higher.

The **production of a photon with associated jets** in the final state is a powerful probe of the dynamics of hard QCD interactions. Different angular configurations between the photon and the jets can be used to extend inclusive photon production measurements and simultaneously test the underlying dynamics of QCD hard-scattering subprocesses in different regions of parton momentum fraction x and large hard-scattering scales Q^2. D0 [16] measures the differential cross section $d^3\sigma/dp_T^\gamma dy_\gamma dy_{jet}$ as a function of p_T^γ in four regions, differing by the relative orientations of the photon and the jet in rapidity. Different parametrizations of the NLO QCD predictions as well as theoretical scale variations do not simultaneously describe the measured normalization and p_T^γ dependence of the cross section in the measured regions. Thus, the data show a need for an improved and consistent theoretical description of the $\gamma+$jet production process.

Photons (γ) produced in association with heavy quarks Q (c or b) provide valuable information about the parton distributions of the initial state hadrons. The heavy quark and gluon content is an important aspect of QCD dynamics and of the fundamental structure of the proton. In particular, many searches for new physics, e.g. for certain Higgs boson production modes, will benefit from a more precise knowledge of the heavy quark and gluon content of the proton. D0 [17] has presented the first measurements of the differential cross sections $d^3\sigma/(dp_T^\gamma dy_\gamma dy_{jet})$ for the inclusive production of a photon in association with a heavy quark (b, c). The results are compared with next-to-leading order pQCD predictions. The pQCD prediction agrees with the measured cross sections for $\gamma + b + X$ production over the entire p_T^γ range, and with $\gamma + c + X$ production for $p_T^\gamma < 70$ GeV. For $p_T^\gamma > 70$ GeV the measured $\gamma + c + X$ cross section is higher than the prediction by about 1.6 to 2.2 standard deviations (including only the experimental uncertainties) with the difference increasing with growing p_T^γ.

Finally, collider signatures containing **bosons and jets** are particularly interesting. Recent theoretical effort has been devoted to predictions of $W^\pm/Z$ + multiple parton production; the high statistics sample of $W^\pm/Z+$jets events collected at the Tevatron is a valuable test-bed for probing the validity of these calculations. The final state containing a Z or W boson and one or more b-jets is a promising Higgs search channel at the Tevatron and could be a window to new physics at the LHC. These searches benefit from a deep understanding of the production of $W^\pm/Z+$ heavy-flavor jets which constitutes a significant background to the more exotic sources of these signatures. The CDF experiment has studied the production of jets in events with $W^\pm/Z$-bosons [18, 19]. The data were compared to some available theory predictions. The NLO prediction from MCFM accurately reproduces the jet E_T spectrum in $W^\pm+$ 1 or 2 jets. For higher multiplicity events, only LO calculations are available. The current preferred method for generating such events at LO relies on generating multiple samples using a matrix element calculation at fixed orders in α_s and then employing a parton shower program to include additional soft, colinear jets. Matching algorithms have been designed to identify events that could be double-counted in this recipe.

A recent measurement by D0 of the inclusive cross-section for $Z/\gamma^*(\rightarrow e^+e^-) +$ **jets** [20] tests NLO pQCD and provides an important control on background to new physics. Events are binned in the p_T of the Nth jet, for $N = 1, 2, 3$. Data agree well with NLO-MCFM but diverge increasingly from predictions by PYTHIA and HERWIG as jet p_T and N_{jet} grow. PYTHIA with p_T ordering is found to describe the leading jet well. SHERPA and ALPGEN are seen to improve upon the particle-shower-based generators. Some discrepancies persist nonetheless between data and predictions of production rates and jet p_T spectra.

$W+$**single**$-c$ production is an important process at the Tevatron. $W + single - c$ events are produced via gluon–s-quark scattering, and hence this process offers information on the strangeness content of the proton. The process also allows an opportunity to measure $|V_{cs}|$ in a Q^2 regime not yet probed. Also, $W + c$ contributes to the background to top production and prominent Higgs search channels at the Tevatron. CDF [21] and D0 [22] have measured the $W + c$ process in Run II using a similar strategies. The results are in agreement within the experimental uncertainty with the theoretical predictions.

Finally $W^\pm/Z + b$ **jet** signatures are important backgrounds to top and Higgs channels at the Tevatron. Separate analyses were undertaken to measure the b-jet cross section in $W^\pm$ and Z events with increased precision in the hope of improving the understanding of these final states. The b-jet cross section in $W^\pm$ events in 1.9fb^{-1} of CDF Run II data was measured to be $\sigma(W + b + jets) \times BR(W \rightarrow l\nu)$ =2.74±0.27(stat)±0.42(syst)pb, where the systematic error is dominated by the uncertainty in the vertex mass shape one assumes for b-jets. This jet cross section result can be compared to the prediction from ALPGEN of 0.78pb, a factor of 3-4 lower than what is observed in the data. Work is continuing to understand the difference. The $Z + b$-jet analysis used a similar technique to extract the b content of its tagged jet sample. This analysis has succeeded in examining differential cross sections for the b-jets in Z events. A differential analysis shows that Pythia appears to do a reasonable job in modeling low jet-p_T but less so as the jet-p_T increases. The ALPGEN and MCFM predictions are consistent with each other but not with the data, except for a few bins. It remains to be understood why the predictions are so different.

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8.5 QCD at the LHC

(Communicated by Wei Li – davidlw@MIT.EDU.)

Quantum Chromodynamics (QCD) has the peculiar properties of confinement and asymptotic freedom; that quarks and gluons interact strongly when they are far apart but appear to be almost free when approaching each other. Over the past decades, QCD has been tested in numerous experiments with great precision. The advent of the Large Hadron Collider (LHC) brings QCD to a new testing ground, accessing energy scales beyond TeV level, probing proton structure down to extremely small x ($\lesssim 10^{-7}$) and at extreme particle density. The study of QCD at the LHC will not only consolidate our understanding of the nature of strong force but also play a vital role in the search for new physics beyond the standard model.

With a center-of-mass energy of 7 TeV reached in proton-proton collisions during 2010, the LHC is a factory for energetic QCD jets. Both ATLAS and CMS collaborations, two general purpose detectors at LHC, reported measurements of inclusive jet, dijet and multijet production up to record-breaking momentum scales. These measurements provided important benchmarks for precision test of the standard model, including perturbative QCD calculations (NLO, NNLO), QCD factorization theorems and constraining parton distribution functions. Furthermore, with 45 pb^{-1} of data collected, LHC entered the era of searching for new physics. The observed dijet invariant mass spectra falls off smoothly by six orders of magnitude, reaching up to 2 TeV beyond the collision energy at the Tevatron. No new resonance bump has yet been found but we confirmed that the high transverse momentum process is behaving as expected at the LHC. A number of ongoing searches for exotic physics all involve a precise understanding of the high transverse-momentum QCD background.

Another important aspect of QCD lies in the non-perturbative region of soft processes, which poses a real challenge to theory. Important issues, like how hadrons are produced, how does hadronization occur, the unique principle of confinement, still remain unanswered. Recent experimental breakthroughs in soft QCD physics were made at the Relativistic Heavy Ion Collider (RHIC), where a deconfined state of QCD matter is believed to exist at a sufficiently high temperature in high energy nucleus-nucleus collisions, the so-called "Quark-Gluon Plasma" (QGP). The QGP at RHIC appears to behave like a perfect liquid with near-zero viscosity. At LHC, lead-lead collisions with energy 14-times that available at RHIC not only re-discovered the "perfect fluid" but also provided new probes, such as high energy jets, photons, Z-bosons etc., which will enable exploration of the properties of dense matter in more quantitative detail.

The LHC has even seen its first unexpected phenomena in proton-proton collisions, reported by the CMS collaboration during a special seminar at CERN and a paper entitled "Observation of Long-Range Near-Side Angular Correlations in Proton-Proton Collisions." The new finding describes a novel correlation: particles emerging from the collision are aligned in their azimuthal angle over a large pseudorapidity region, a "ridge"-like structure, which is absent in minimum bias events but emerges as particle multiplicity reaches very high values. This phenomenon has not previously been observed in proton-proton collisions but resembles a similar effect (e.g., hydrodynamic flow) following collisions of nuclei such as copper and gold at (RHIC). Although it is still too early to make any definitive claim about the physical origin of this effect, it certainly opens up a promising new direction for exploring high density QCD physics in a small volume and has built a connection between two very different colliding systems.

QCD at the LHC had an amazing year in 2010 and we expect more surprises soon.

This GHP Newsletter was edited by Craig Roberts for the Executive Committee.