Foreword

During the week of 13–17 June, over 230 physicists gathered in the Künstlerhaus, in the heart of Munich, to attend the biennial international hadron physics conference.

Hadron2011, the 14th International Conference on Hadron Spectroscopy, was the latest in a long series that started 1985 in Maryland. Originally conceived as a conference on light-meson spectroscopy it now covers all aspects of hadron physics, though spectroscopy and hadron production are still the topics that characterize the meeting. As many as 37 plenary talks, 128 presentations in parallel sessions and 37 posters offered ample possibilities to find out about the latest developments and results, from hypernuclear physics to meson and quarkonium spectroscopy, from nucleon structure and meson-baryon interaction to heavy-ion physics.

The topics included were

- Spectroscopy of light- and heavy-quark mesons
- Baryons
- Quarkonia
- Glueballs, hybrids, and multiquarks
- Phenomenological models
- Effective field theories
- QCD on the lattice
- Hadron structure
- Hadrons in matter
- Heavy-ion collisions
- Future facilities

The conference began by looking at issues related to light mesons, with a summary of recent theoretical progress and experimental tests in chiral dynamics and low-energy scattering phenomena. There are new results on light-meson spectroscopy from the BESIII experiment in Beijing and COMPASS at CERN. While COMPASS impressively confirms previous findings on the $\pi_1(1600)$, an exotic meson seen in high-energy diffraction, new structures have been observed in radiative J/ψ decays pointing towards new and narrow meson states between 1.8 and 2.5 GeV/c^2, the details and nature of which have still to be unraveled.

Even after many years of precision experiments, the size of the proton is still a hot topic. New findings in laser spectroscopy of muonic hydrogen, which give a proton radius more than 6σ smaller than previously determined, have opened the hunt for new explanations, although theory cannot offer effects large enough to solve the puzzle.

Research in nucleon structure has for many years shifted to spin degrees of freedom. After precision measurements on the helicity contribution of quarks in polarized nucleons, COMPASS has also set new limits on spin effects resulting from polarized gluons. These

findings are confirmed by spin experiments at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven. With this, the focus now turns towards transverse-spin degrees of freedom (transversity). Non-collinear treatment of partons inside the nucleon offers a large number of new observables, which can link to quark angular momenta. Both COMPASS and RHIC have new physics programs on transverse polarization effects; measurements of Drell-Yan processes using polarized targets are also on the way. Hopes are high that the unexpected single spin asymmetries that have been observed in pion production at RHIC may finally be understood.

On the low-Q^2 side, big efforts at various laboratories, such as Bonn, Mainz, Jefferson Lab etc., are offering real- or virtual-photon beams. These allow a coherent set of (double-)polarized scattering and production experiments, also with many-body final states. Using the complete set of polarized measurements, the puzzle of baryon resonances, their identification and quantum numbers seems now to be in reach via new and sophisticated partial-wave analyses.

Quarkonium spectroscopy and the hunt for further quarkonium-like states that seem not to fit the $q\bar{q}$ picture of the meson have been and still are highlights in hadron physics. Precision experiments finally allowed the BELLE and BaBar experiments at KEK and SLAC, respectively, to observe missing quarkonium states such as $h_b(1S)$, $h_b(2S)$ as well as η_c and $\eta_c(2S)$. More precise determination of masses and widths as well as unexpected decay patterns were revealed also by BESIII, which has observed about 10^9 J/ψ decays. The puzzle of the mass and width of the $D(D_s)$ meson states seems to be solved with their spin assignments being resolved. The conference also heard of the remarkable progress in achieving a comprehensive and unified theory description of quarkonium properties at zero and finite temperature in an effective field theory framework.

The biggest current puzzle in hadron physics concerns the large number of exotic quarkonium-like states with narrow widths and high excitation energies as compared to the open-flavor meson channel. New work was reported on the $X(3872)$ and other, partly new states. Theoretical investigations offer a rich choice of possibilities. The $X(3872)$ has a good chance of just being the radial excitation of the χ_c state, but there is also a beautiful effective field theory description in the molecular interpretation case. However, further stunning observations were reported from the beauty sector. Two charged quarkonium-like states found by BELLE lie close in mass to the open b-threshold and have been dubbed Z_b in analogy to the charm sector.

Lattice calculations have shown huge progress with new algorithms allowing the extraction of excited baryon and meson state energies. A report from the Flavianet Lattice Averaging Group presented lattice results for kaon and pion physics with the aim of making them easily accessible to the community. There are also new calculations of hadron structure, the baryon and meson form-factors and the $g-2$ factor.

First and impressive results were reported from all of the LHC experiments. In particular, CMS and LHCb, offering the best mass resolutions, have confirmed the potential of hadron

machines in this field. In addition to the usual quarkonium states, exotic states have also been observed and the elusive B_c mesons have already been seen. At this stage, the focus on the production cross-section of heavy quarkonia, which can now be understood at LHC energies, assuming color octet contributions and next-to-leading order (NLO) processes to be relevant. The descriptions follow data up to transverse momenta as high as 20 GeV/c. The largest uncertainties come from unknown polarization effects that influence acceptance calculations. On the theoretical side, huge progress has been achieved with the full NLO calculation of the J/ψ cross section in non-relativistic QCD (NRQCD) and a combined global data analysis of all existing experiments that hints at the universality of the long-distance NRQCD matrix elements.

Hadron machines are unique in the production of b-baryons and Fermilab's Tevatron has so far been leading this field. The CDF collaboration reported on recent progress with the observation of excited Σ_b states and a radially excited Λ_c. CDF and DØ also presented new precision measurements of mass and width of other charmed baryons.

A thermal medium, of the type generated in heavy-ion collisions at the LHC, can modify hadron properties, especially in the case of heavy quarks and quarkonia. The theory of such modifications was reviewed and first results of lead-lead collisions at the LHC presented. Results from ATLAS and CMS show the striking effects of jet-quenching and also the melting of the excited Y states as compared to the ground-state partner. At lower energies, mass shifts and absorption cross-sections of vector mesons have been studied in the medium. Mass shifts — a long-standing issue, where many predictions have stimulated experimental efforts — have not been observed but small effects have been reported by the HADES experiment at GSI, Darmstadt, on the width of mesons in nuclei.

Recent and impressive progress in light-meson and quarkonium spectroscopy is in good part a result of recent high-luminosity experiments, which offer 10-100 times the statistical sample of their predecessors. Heavy-meson physics, for long the domain of lepton colliders, is now seeing LHC experiments starting to compete in an impressive way and using their low-luminosity data from 2010 to catch up with the Tevatron experiments. An interesting future lies ahead with even further increases in luminosity and precision being offered by future experiments such as BELLE II, the SuperB facility and the PANDA experiment at the Facility for Antiproton and Ion Research (FAIR).

Two impressive summary talks concluded the conference. Stefano Bianco of Frascati/INFN reviewed the experimental situation, a challenging task in view of the large number of new results presented. On the theoretical side, Chris Quigg of Fermilab gave a very inspiring outlook on hadron physics. He recognized the enormous diversity and reach of experimental programs, which offer insights from unexpected quarters, while remarkable progress has been achieved in theory with the emergence of lattice QCD. However, many puzzles remain, leaving ample opportunities with much work to do, as there are still "simple" questions that the field cannot answer.

Participants enjoyed the coffee breaks in the sun-covered courtyard of the Künstlerhaus, a

building erected for artists to meet and enjoy social events more than 100 years ago. Long and intense discussions also offered vital scientific exchange around the poster session, making this event a pleasant ending to the day. Long hours of sitting were compensated on Wednesday afternoon by a bicycle tour through the old town of Munich and the English garden with refreshing drinks in the beer garden. Last but not least, the conference enjoyed a guest talk on neutrino physics by Thierry Lasserre of Saclay, who discussed the mass determination from flavor oscillation and reported fresh results from T2K on hints of $\nu_\mu \to \nu_e$ oscillation.

In order to promote young scientists an international jury was set up to select the best young-scientist talks from both, experimental and theoretical physics. The prizes were awarded to **Sebastian Neubert** (TU-München) for his overview talk on "Light-Meson Spectroscopy" and **Andreas Jüttner** (CERN) for his "Review on Recent Results of the FLAG Working Group". The very lively poster session also was acknowledged with two similar prizes for the best posters presented by **Jenifer Nebrada** (Univ. Computense Madrid): "Quark mass dependence of meson-meson resonances and phase shifts within standard and unitarized ChPT" and **Michael Kunkel** (Old Dominion University): "Dalitz Decay of Pseudoscalar Mesons from Photoproduction on Hydrogen Target with CLAS". We thank the selection committees for their thorough work.

For all the speakers and their contributions see the conference web site: www.hadron2011.de

Thanks

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For the organizers (TU-München)

Stephan Paul
Nora Brambilla
Boris Grube

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A history of hadron conferences. From right: A. Zaytsev (Protvino 2001), S.-U. Chung (Brookhaven 1999), A. Reis (Rio de Janeiro 2005), S. Bianco (Frascati 2007), S. Paul (Munich 2011) and P. Eugenio (Tallahasse 2009).

Harry Lipkin, left, of the Weizmann Institute, who turned 90 on 16 June, receives a birthday gift from hadron2011.

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