Physics monitor

Report of a little bang

These days major physics conferences do not often bring something new and unexpected, a potential breakthrough. To many participants, the 1996 Quark Matter Conference held in Heidelberg from 20-23 May appeared as one of these exciting occasions, providing what could turn out to be the first glimpse of the ultimate aim of their research: a laboratory little bang producing the long-awaited quark-gluon plasma - the state of matter which briefly existed in the aftermath of the Big Bang before nuclei 'froze' out..

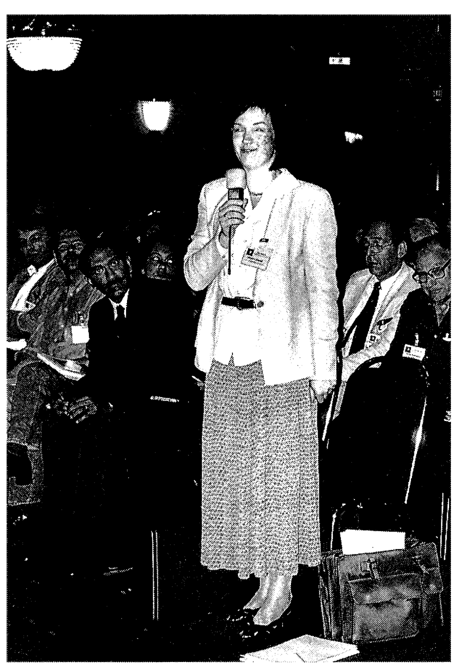
The meeting was the 12th in the series of International Conferences on Ultra-Relativistic Nucleus-Nucleus Collisions; it was organized by H. J. Specht and brought a record 550 physicists to Heidelberg. In over fifty presentations, they heard the first comprehensive overview of results from truly heavy ion collisions, using the 160 GeV/nucleon lead beam from CERN's SPS and the 12 GeV/ nucleon gold beam from Brookhaven's Alternating Gradient Synchrotron (AGS).

Previous studies of light projectiles on heavy targets had shown a number of effects indicating possible collective behaviour; but collisions of two large, heavy nuclei provide the best chance to produce strongly interacting matter in the laboratory.

Do the new data now confirm the production of such matter? The simplest way to answer this question is to consider the emerging system as a mini-universe and test whether at the end of its strong interaction era, when it breaks up into non-interacting hadrons, the relative abundances of the different species are determined by temperature and baryon density, similar to the abundances of the light elements in our universe.

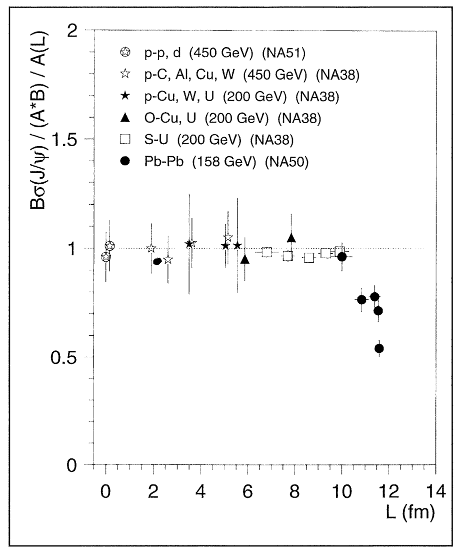
The present hadrosynthesis status was summarized by Johanna Stachel. In the past year, detailed studies of silicon-gold data from Brookhaven experiments E866 and E877 have shown that the most abundant particle species are indeed in accord with those expected to be emitted from such equilibrium. A first look at data from Brookhaven gold-gold collisions also seems supportive, although both for these and for corresponding lead-lead data at higher energies from CERN, further results are needed before the production of equilibrium matter at freeze-out can be fully established.

If high energy heavy ion collisions produce systems which are ultimately equilibrium hadronic matter, one can begin to explore the unknown earlier stages of higher temperatures and densities - with the ultimate aim of reaching the plasma of deconfined quarks and gluons predicted by quantum chromodynamics - the field theory of quarks and gluons.



Johanna Stachel - hadrosynthesis

The first glimpse of quark-gluon plasma formation? J/ psi production in different collisions, normalized to pre-resonance absorption A(L) in normal nuclear matter, as reported at the 1996 Quark Matter Conference held in Heidelberg from 20-23 May, showing the strongly reduced J/ psi production in lead-lead collisions now observed by the NA50 collaboration at CERN . The path length L through such matter also provides a measure of the average energy density achieved in the collision.



Below the critical boundary separating the confined and the deconfined state of matter, in a dense hadronic medium, the properties of hadrons may change, and an observation of such changes would provide important evidence for earlier states of higher density, as emphasized in a survey by W. Weise. The deconfinement transition should be associated by a drop of the effective quark mass from its constituent quark value to its nearly vanishing observed value, and this may well induce hadron mass changes.

Both the now completed HELIOS 3 experiment and the CERES collaboration had first reported an excess of dilepton production below the rho peak, observed in sulphur-gold collisions. All attempts to explain this low mass dilepton enhancement in terms of interactions between hadrons of the usual vacuum properties have so far failed; only an

Axel Drees - low mass lepton pairs.

in-medium change of the rho-meson mass is able to reproduce the effect, as noted at Quark Matter '95 by C. M. Ko and B. Friman.

The first and still preliminary lead data from CERES, presented by T. Ullrich, were therefore eagerly awaited. They again show a pronounced low mass dilepton enhancement; further analysis and increased statistics are needed to establish its strength and impact parameter dependence, as underlined in the summary of A. Drees.

The striking result presented at the meeting was the strongly reduced J/ psi production in lead-lead collisions, observed by the NA50 collaboration at CERN, reported in Heidelberg by M. Gonin.

Suppression of J/ psi production in nuclear collisions was predicted ten years ago as a signal of deconfinement. A considerably reduced J/ psi production was observed shortly afterwards in oxygen-uranium and sulphur-uranium collisions, but a similar reduction occurs as well in proton-nucleus interactions, suggesting a common origin in normal confined matter.

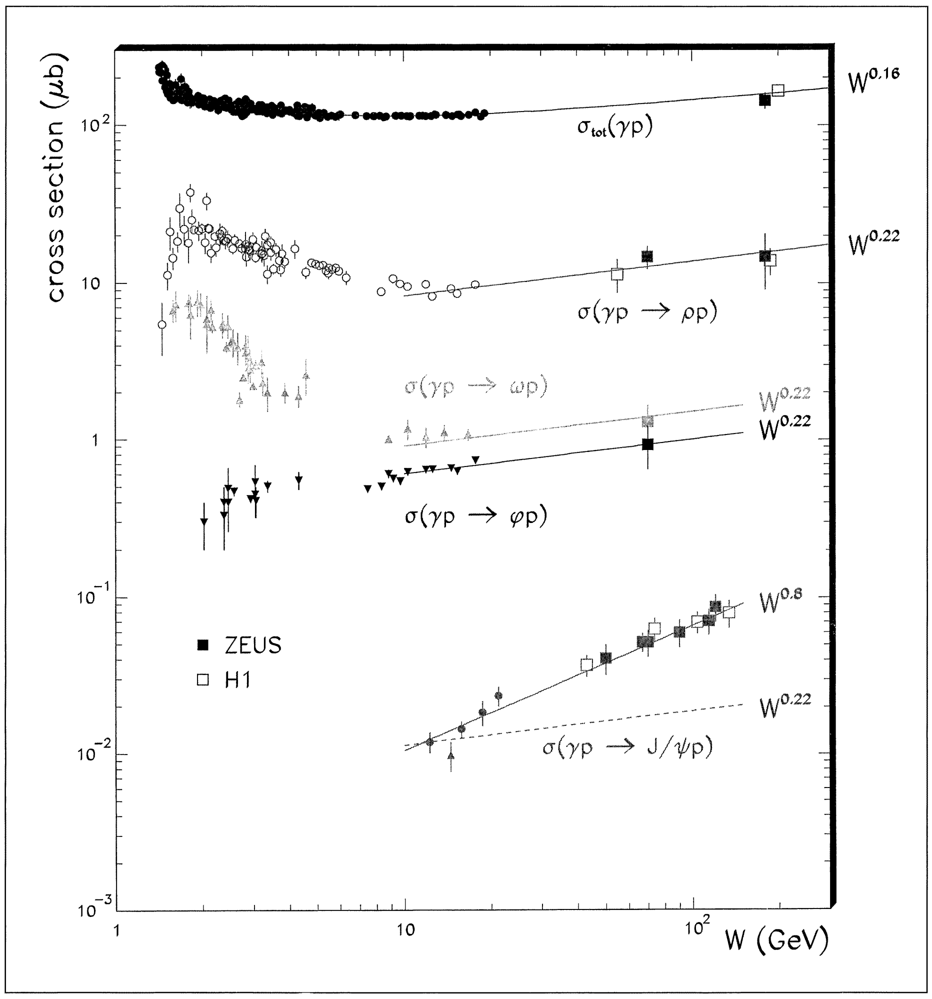
Today one can in fact understand all J/ psi suppression in different proton-nucleus interactions and up to the most central sulphur-uranium collisions as due to the absorption of pre-resonance charmonium in normal nuclear matter, as shown by C. Lourenco in a systematic study of NA38/NA51 data from CERN and E772 data from Fermilab. Such pre-resonance charmonium fits well into the theory of quarkonium production by hadronic collisions, summarized by E. Braaten.

One had therefore expected a corresponding suppression also in lead-lead collisions. However the production rates observed late last year by the NA50 collaboration instead show a factor two stronger reduction, and this anomalous J/ psi suppression moreover sets in quite abruptly just slightly above central sulphur-uranium or the most peripheral lead-lead collisions.

QCD calculations presented by D. Kharzeev show that J/ psi dissociation by collision with hadrons is essentially excluded at present momenta. Taken together with the sudden appearance of the anomalous suppression, this therefore suggests the onset of some kind of at least local deconfinement. In a short contribution, J.-P. Blaizot noted that the anomalous suppression can be understood if all J/ psis produced in the hot central part of the lead-lead interaction just melt. His question therefore summarized what many participants were wondering: is this the first glimpse of quark-gluon plasma formation?

As pointed out by Kharzeev and by Lourenco, it is very reassuring that the two points crucial for a definite conclusion - the sudden onset of the

Helmut Satz of Bielefeld (right), eager to see NA50 experiment spokesman Louis Kluberg's new results on J/psi suppression in lead-lead collisions from the at CERN's SPS before the recent Quark Matter conference at Heidelberg. A meeting at Bielefeld just before the Quark Matter conference marked Satz' 60th birthday. In 1982, Bielefeld was the scene of the first meeting on triggering for heavy ion collisions at the SPS.



Photoproduction over a wide energy range as seen at the HERA electron-proton collider at DESY, Hamburg. It shows the collision energy (W) behaviour of total photoproduction together with that of the diffractively produced vector mesons. For the light vector mesons the energy behaviour follows the gentle energy dependence expected by a soft Pomeron exchange process, while with the heavier J/psi, there is a transition to a hard process with a sharp energy increase.

suppression and the transparency of confined matter to J/ psis, can both be tested experimentally: the former by precision studies of more peripheral lead-lead collisions, the latter by an "inverse kinematics" experiment with a lead beam incident on a hydrogen or deuterium target.

The next steps in the search for the quark-gluon plasma thus appear to be quite well-defined. The production rates of the different hadron species and corresponding correlation studies will provide the information needed about the collective properties of the medium at freeze-out. Further studies of the low mass dilepton enhancement will determine to what extent the properties of hadrons are changed in a dense, strongly interacting medium. And precision measurements of quarkonium suppression will provide the necessary tool to probe colour deconfinement. Depending on the answers to these questions, Heidelberg 1996 could be remembered as the first report of a little bang.

From Helmut Satz

HERA's hard diffractive scattering

The unique research at the HERA electron-proton collider at the DESY Laboratory, Hamburg, was highlighted at the conference on "Hard Diffractive Processes" held in Eilat, Israel, from 18-23 February, and the second such conference in Israel to be devoted to HERA physics, the previous meeting in February 1994 having been devoted to "Deep Inelastic Scattering and Related Subjects". Of the 81 physicists from 13 countries, the largest delegation was from Germany and numbered 17 participants.

The unexpected observation of 'rapidity gaps' in deep inelastic electron-proton interactions by the ZEUS collaboration in 1993 (September 1993, page 6), in which the proton emerges almost unscathed and the secondary reaction products pile up on the electron, rather than the proton, side had rekindled an interest in the long neglected subject of diffractive scattering, and for good reasons.

Quantum Chromodynamics (QCD) has long since been established as the field theory of quarks and gluons and forms part of the 'Standard Model', on the same footing as the unified theory of electroweak interactions.

The underlying QCD symmetry is that of 'colour', the equivalent of the electric charge in electromagnetic interactions. The constituents of hadronic matter are coloured quarks and the carriers of strong interactions are gluons. What makes QCD different from the electromagnetic interactions is that the gluons also carry colour. A direct consequence is 'asymptotic freedom' - the interaction between two coloured objects decreases the shorter the distance between them, while it becomes stronger the further they are apart. This makes it possible to predict the properties of strong interactions in the perturbative QCD regime.

The pointlike structure of hadrons in terms of quarks and gluons finds a natural explanation in QCD, and is described by 'structure functions' - the density distribution of quarks inside the hadron.

On the other end of the scale, confinement of colour is believed to be responsible for the fact that the only observable strong interacting particles are colourless. The validity