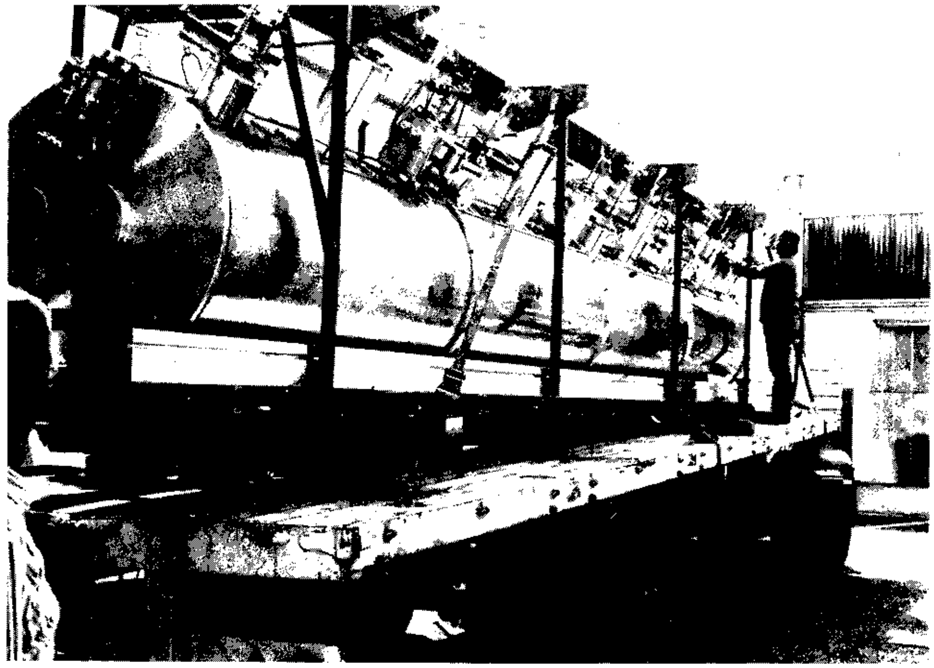
cause the overlap of the nucleus with extra-orbital electrons is small, the spin exchange time is slow, of the order of a few hours. Once the alkali vapour is removed, the inert helium can retain its nuclear polarization for 100 hours.

Helium nuclear spin is so isolated from all perturbations except magnetic that the gas can be compressed above 1 bar in a mechanical pump while retaining most of its polarization, as shown by a group at Mainz.

With spin exchange and helium, a Princeton-Syracuse team at LAMPF has manufactured highly-polarized muonic atoms. In the process of capture, a negative muon will eject both electrons from a helium atom. Polarization transfer to the muonic atom from a nearby polarized alkali electron occurs by spin exchange through the magnetic moments or by capture of the electron by the helium ion. With adequate density of optically-pumped polarized rubidium, the muonic atom polarizing time is less than the 2 microsecond muon lifetime and high polarizations are achieved. Results in the last few months show muonic atom polarizations more than ten times that resulting from retention of polarization in the muon beam, opening the door to new spin-sensitive experiments in the fundamental interactions.

From Olin van Dyck



One of the superconducting cavities arriving at CERN's LEP electron-positron collider, where it will help push collision energies towards 200 GeV.

WORKSHOPS
Radiofrequency superconductivity

In the continual push towards higher energy particle beams, superconducting radiofrequency techniques now play a vital role, highlighted in the fifth workshop on r.f. superconductivity, held at DESY from 19 - 24 August 1991.

Since the previous workshop at KEK, Japan, in 1989, there has been increased operational experience of superconducting electron and heavy ion accelerators. At KEK a total of 32 superconducting cavities are now routinely operated in the TRISTAN electron-positron collider.

At CERN three modules with four superconducting cavities each (two of solid niobium and one of niobium-sputtered copper cavities) have been installed in the LEP electron-positron collider as the first step towards higher energy running. In addition two more niobium-copper cavities are routinely operated in the SPS synchrotron. At DESY twelve four-cell cavities have been installed in the HERA electron ring.

In the domain of electron accelerators for nuclear physics, the first recirculating beam has been achieved at the Darmstadt S-DALINAC (May 1991, page 10), and an electron energy of 103 MeV attained. At the CEBAF machine under construction at Newport News, Virginia, the 45 MeV injection energy has been reached in cryomodules with eight superconducting cavities (September 1991, page 28), and the production of a total of 360 cavities at industry is steadily advancing. At Saclay in France the MACSE test facility with 5 superconducting cavities at 1.5 GHz has been started.

Higher acceleration fields are vital for new projects, and a large coordinated effort is going on, particularly at Cornell, Saclay and Wuppertal. Field emission of electrons by surface defects is the most limiting factor. New and refined diagnostics like field emission microscopes have been developed and it is hoped that this will lead to a better understanding of the defects causing field limitations.

It has been shown that small surface areas can withstand electric surface r.f fields up to 140 MV/m (corresponding to accelerating fields of some 70 MV/m). For large accelerating cavities (low frequency or multicell) these values are considerably reduced by surface defects which still escape control.

Nevertheless continuous accelerating fields of 25 MV/m have been repeatedly reached in single-cell cavities at 1.5 and 3 GHz, while multicell cavities in this frequency range have attained 15-20 MV/m.

At present the highest fields are achieved by high temperature annealing under ultrahigh vacuum at 1500 C. It is hoped that this treatment, combined with the use of very pure niobium, can push field limits even higher.

Recent promising results at Cornell used pulsed high power processing at many 100 kW, a method already used extensively at the kW level. Rinsing with clean dust-free water at high pressure has been applied successfully at CERN.

The sputtered niobium on copper cavities pioneered at CERN for 350 MHz are now applied elsewhere at higher frequency and to more complex structures (at INFN Legnaro).

The natural extension of this method to reactive sputtering for superconductivity at higher temperatures is being pursued in a number of laboratories. The increased use of high purity niobium for better thermal stabilization of defects has sometimes unexpectedly degraded cavity resonance. In a remarkable common effort, this has been traced to hydrogen introduced into the niobium by chemical treatments. Remedies like annealing at 700 C have been developed.

One review talk was devoted to high temperature superconductivity and its r.f. properties. Although a large number of sophisticated production processes are now at hand, performance is severely limited by high defect density. Small-scale applications for passive microwave devices are already under development at Wuppertal.

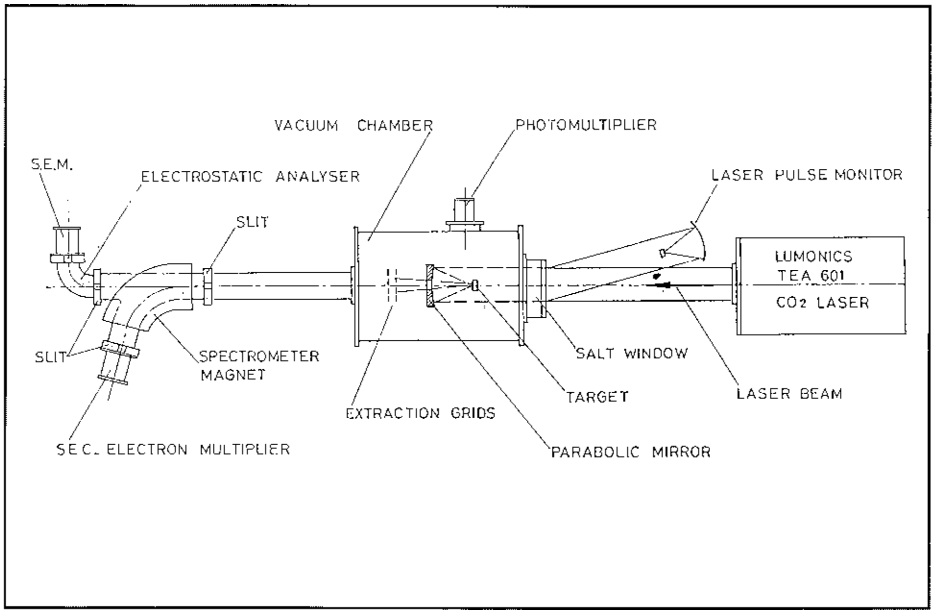
Superconducting cavities are now considered for new applications such as particle factories and linear colliders. For the former, new geometries have been designed, combining low impedances with extremely strong damping of higher order modes against multibunch instabilities (Cornell).

The biggest challenge is in the field of linear colliders, and a special series of talks concentrated on the TeV Energy Superconducting Linear Accelerator (TESLA) idea, with the two last days of the Workshop devoted to a TESLA collider in the 500 GeV range.

The basic advantage of superconducting cavities is the very efficient storage of r.f. energy, so a low frequency (around 1 GHz) and a rather long pulse (1 ms) can be used. The former gives a large aperture (low wakes, long bunches, low alignment tolerances, ...) while the latter allows multibunch operation (with long bunch separation, modest peak power, r.f. feedback, ...). Niobium cavities at 1.3 GHz with an accelerating field up to 25 MV/m are anticipated.

In a final talk Maury Tigner from Cornell underlined the considerable progress achieved since 1960. Superconductivity is at the heart of new and fascinating challenges in modern accelerators and hopefully the remarkable progress so far will continue.

The Workshop was attended by 150 participants from 35 institutions and from industry, and was splendidly organized by local chairman D. Proch and his team.



At CERN, recent work using this 50J carbon dioxide laser setup has given lead ions up to charge 28.

Ion sources

Against a background of increasing use of radiofrequency- or microwave-driven ion source plasmas, the recent International Conference on Ion Sources - ICIS 92, held at the GSI Darmstadt Laboratory, included some interesting new developments.

I.A. Bykovsky and V.N. Nevolin from Moscow surveyed 20 years of work on laser-induced ion source plasmas, including commercially available machines built in the Ukraine for ion beam analysis with 100 nanometre resolution, or for ion implantation for surface modification.

Ray Sherwood of CERN showed recent results using a 50 J carbon dioxide laser, giving lead ions up to charge 28. A collaboration with ITEP Moscow has also investigated five-microsecond pulses and a repetition rate of 1 Hz, well suited for synchrotron injection.

A good source of metallic ions is the MEVVA - Metal Vapour Vacuum Arc - technique. These sources are usually pulsed, but now there are results with DC operation with ion currents up to 1A (I. Brown, Berkeley). For metallic ion production, negative ion sources also show remarkable results, with 10 mA DC or more than 100 mA pulsed (Y. Mori, KEK Japan). .

Special applications like microprobes for ion beam analysis or for direct writing or etching of micromechanics or microelectronics are the domain of liquid metal sources (R. Muehle, Jena). For ion etching, broad low energy ion beams are used (H.C. Scheer, Berlin). Large area intense ion beams of some 10 keV are needed for ion beam assisted deposition techniques (W. Ensinger, Heidelberg).

C. Jaquot of the French Cadarache centre reported on the joint European programme for neutral beam injection into Tokamaks. Large cusp ion sources generate 4 A of negative deuterium ions which will be accelerated to 1.2 MV.

Ion beams are also used as thrusters in satellites and space probes. Although producing low thrust, they can be maintained from solar panels for a very long period and are well suited for long-term stabilization (H.W. Loeb, Giessen).

On-line mass separators need efficient ion sources. Besides classical discharge and microwave (electron cyclotron resonance - ECR) sources, surface ionization is also effective, while laser ion sources provide a fresh approach.

ECR sources are widely used to generate high currents of multiple charged ions. By injecting electrons or by coating the source chamber, high charge yields can be improved. Special source optimization to an afterglow mode of 100 microamps of lead 28+ during a 0.4 ms pulse and at a repetition rate of 1-4 Hz have been detected (P. Sortais, GANIL, France).

Even higher charge states with moderate intensities can be produced in electron beam ion sources (EBIS) and are mainly used for atomic physics experiments.

In an electron beam ion trap (EBIT), extremely high charges (thallium 80+ and uranium 70+) have been created, stored and used for spectroscopy (D. Schneider, Livermore). Until now such highly charged ions could only be generated by stripping high energy beams of heavy ions.

The next meeting in the series - ICIS 93 - will be held end-August 1993 in Beijing. Contact Zhao Weijian, Institute of Heavy Ion Physics, Beijing University, Beijing 100871, China, fax +86-1-2564095.

*From **B.** Wolf*

Theory flexes its muscles

With the Standard Model of interactions between the fundamental quark and lepton constituents of matter so

A highlight of the 1991 DESY Theory Workshop was the interest in possible baryon and lepton number violation at high temperatures. Among the speakers looking at the implications were V. Rubakov (right) and L McLerran.

successful at describing laboratory experiments, theorists have looked at the possibility of new phenomena occurring under extreme conditions - high temperatures, high densities or high energies.

Thus the 1991 event of the annual DESY Theory Workshop looked at 'The Standard Model at High Temperature and Density'. Three main topics were covered - baryon and lepton number violation at high temperatures and energies; high temperature transitions between ordinary hadronic matter and the quark-gluon plasma; and cosmological and astrophysical implications.

The mathematical structure of the Standard Model allows for baryon (B) and lepton (L) numbers - the numbers of strongly and weakly interacting particles respectively - to be not strictly conserved. However under usual conditions the effects are tiny, and can only happen via highly damped quantum tunneling. For example, the deuteron is in principle unstable, decaying into an antinucleon and three antileptons. Its lifetime, however, is of the order of 10^{200} years!

At the Workshop, V. Rubakov (INR Moscow) reviewed (B+L) violation at high temperatures. At temperatures of order 10 TeV and above (B+L) violation is no longer a quantum effect. Quantitative studies and real-time computer simulations support this expectation.

M. Shaposhnikov (INR Moscow and CERN) reported on the cosmological implications of unsuppressed high-temperature (B+L) violation. The explanation of matter/antimatter asymmetry in the Big Bang model of the Universe is a challenge for theoretical physicists. However the weak interactions in the hot plasma of the early Universe fulfilled all necessary conditions for such an asymmetry - B is violated strongly at high temperatures; weak interactions violate charge and charge/space reflection (CP) parity; and there are large effects in the electroweak phase transition between the high-temperature phase of massless particles, and the low-temperature phase, where the W and Z particles become heavy.

As a result, the matter asymmetry of the Universe may originate from the electroweak phase transition at temperatures around 100 GeV, without resorting to 'Grand Unified Theories' incorporating strong interactions as well, and needing energies of 10^{16} GeV.

Electroweak generation of matter asymmetry requires a relative light Higgs boson, preliminary estimates giving an upper limit of 64 GeV in the minimal Standard Model. No stringent bounds come from extended versions of the Standard Model with multiple Higgs particles.

While electroweak (B+L) violation comes into its own at very high temperatures, it is not yet clear whether it would show up in high energy collisions above 10 TeV. L. McLerran (Minneapolis) thought that while at first sight it might look difficult to provide the conditions for (B+L) violation in high energy scattering, the heavily damped tunneling factor may go away.

A. Ringwald (CERN) looked at ways of estimating effects at energies around 10 TeV. Extrapolating existing calculations shows that the exponential suppression of (B+L) violation disappears at collision energies around 30 TeV, so that these processes might be seen at future supercolliders.

G. 't Hooft (Utrecht), the 'father' of low-energy electroweak (B+L) violation, concluded the first day by presenting an alternative method for investigating high energy (B+L) violation and looking at the implications.

The workshop also looked at quark systems at high temperature - the thermodynamics of hot and dense strongly interacting matter. The theoretical basis is provided by quark field theory of a lattice, explored by computer simulation.

F. Karsch (Juelich) reviewed these studies, which concentrate on the predicted deconfinement of quarks in dense matter and on the properties of the resulting new state of matter, the quark-gluon plasma. The deconfinement temperature is found to depend on the number of quark 'flavours', and the best present estimate for the 'physical' case of two light quark species lies around 150 MeV.

This means quark deconfinement sets in when matter reaches twice the density of a single nucleon. The transition itself has been the centre of much attention; three light quark species behave one way (first order transition), two such species another (continuous changeover). Which of these two alternatives is correct in the real world of two light and one heavy (strange) quark appears to require more extensive studies on still larger lattices.

An experimental test of quark thermodynamics is the ultimate aim of high energy heavy ion collision studies. Experiments were started at CERN and Brookhaven just five years ago, and have so far used only rather light ions (silicon-28 and sulphur-32). J. Schukraft (CERN) summarized the present experimental situation, concentrating on the overall conditions reached so far, on evidence for thermalization, and on possible probes of the early phase of the produced matter.

READER SERVICE FORM

CERN COURIER

JANUARY/FEBRUARY 1992

Please send information on items circled:

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
40	42	43	44	45	46						

Please send to:

Nina Ruderman, **CERN COURIER**
P.O. Box 786, Cooper Station
New York, NY 10276, USA

Name__________ Title__________

Employer__________ Dept.__________

Address__________

City__________ State__________ Zip__________

Telephone ( ) __________ Country__________

At the DESY Theory Workshop, R. Barbieri of Pisa provided a theory overview of solar neutrinos, neutrino masses and neutrino mixing.

The achieved energy densities are indeed sufficient for deconfinement. There are clear nuclear effects which point to an onset of thermalization and indicate the formation of very dense initial systems.

The third day of the workshop was given over to astroparticle physics. I. Appenzeller (Heidelberg) reviewed the current status of structure in the Universe. The known mass in the Universe forms a sponge-like structure with 'walls' of galaxies, clusters and superclusters, and intervening Voids'. Structure is observed to at least sizes of 300 Mparsecs (galaxies are in the 0.01 to 0.3 Mpc range while clusters go from about 1 to 20). Beyond 500 - 1000 Mpc the mass distribution appears to be more smooth.

M. Turner (Fermilab) discussed the formation of structure in the Universe. This is in a certain sense an initial data problem: given the matter content and the initial density fluctuations at the epoch when the Universe becomes matter-dominated, one may evolve the system and determine the typical final structures produced by gravitational growth of fluctuations. There is no 'Standard Model' of structure formation, only different scenarios corresponding to different choices of matter content and density fluctuations. The limits on irregularities in the microwave background put stringent limits on the initial fluctuations. The matter content is not so well determined, apart from the fact that the baryonic matter content is constrained from primordial nucleosynthesis.

Turner discussed some recent observations which suggest a considerable amount of non-baryonic dark matter. He presented in detail one possible scenario for structure formation, with most of the Universe consisting of so-called cold dark matter (for example light neutrinos, axions, neutralinos) and where the initial fluctuations are scale-invariant. The result is that galaxies form first and the larger structures later (even now).

The experimental status of solar neutrinos, neutrino masses and mixing was reviewed by M. Spiro (Saclay). Direct mass measurements of the three known species of neutrinos yielded so far only upper bounds, 9.5 electronvolts for the electron neutrino, 170 keV for the muon neutrino, and 35 MeV for the tau neutrino. Other bounds come from double beta decay limits (December 1991, page 16). If neutrinos are massive, they can mix, giving neutrino oscillations. So far there is no evidence. Evidence for a 17 keV neutrino (April 1991, page 9) is still controversial.

The new solar neutrino experiments SAGE and GALLEX may help resolve the solar neutrino problem - the conflict between the flux of solar neutrinos predicted by calculations and the observed levels - as they can see neutrinos from the dominant proton-proton fusion reaction. Initial data is appearing, but Spiro urged physicists to 'wait and see'.

In the closing talk, John Ellis (CERN) summarized our understanding of phase transitions in the early Universe. In ttie quark-hadron transition quark confinement made its first appearance, the quarks combining to form strongly interacting elementary particles. Although lattice studies have given semi-quantitative results for this transition for very low baryon density, there remains a need for corresponding studies of baryon-rich systems, such as possible quark stars.

In the electroweak phase transition, the W and Z bosons acquired mass, unlike the photon. This transition is sensitive to the as yet unknown masses of the Higgs boson and the top quark, and could lead to bounds on these masses. In addition, this transition could be responsible for matter dominance in our present Universe.

Beyond both these transitions lies the question of the fate of the Standard Model at temperatures higher than the Planck mass (10^{19} GeV). Ellis concluded with a 'triple symbiosis' of theory, with model and lattice calculations; experiment, with heavy ion studies as well as particle searches; and cosmology, with neutron stars, element abundances and the baryon asymmetry of our Universe.

From H. Satz and A. Ringwald