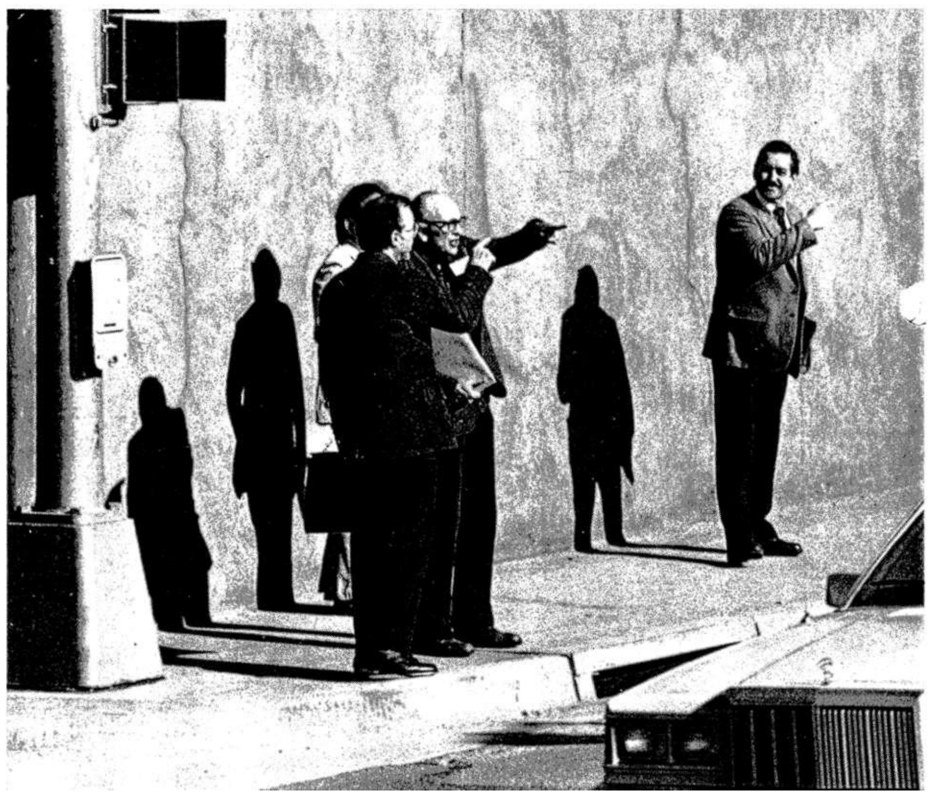
Santa Fe Accelerator Conference

A group of participants from the Accelerator Conference, visiting downtown Santa Fe, have different ideas as to the best direction to take for the future.



The 10th USA National Particle Accelerator Conference was hosted this year by the Los Alamos National Laboratory in Santa Fe from 21-23 March. It was a resounding success in emphasizing the ferment of activity in the accelerator field. About 900 people registered and about 500 papers were presented in invited and contributed talks and poster sessions. About a third of the papers and attendees were from outside the USA.

The opening session emphasized some of the newsworthy current events, ranging over Giorgio Brianti's and Rich Orr's coverage of the present status of the CERN proton-antiproton complex and the Fermilab Energy Saver, the applications of accelerators in magnetic fusion by N. Rostoker, and the experience with new heavy ion accelerators now coming on-line at GANIL (see April and May issues) and other institutes as covered by Pierre Lapostolle.

One of the eagerly attended talks was a report on China's accelerator projects by Xie Jialin. The Beijing electron-positron collider will provide an entry into charmed meson and heavy-lepton physics, a source of synchrotron radiation, and a fixed-target capability for nuclear physics. A cascade cyclotron at Lanzhou will support heavy-ion research and the Hefei Synchrotron Radiation Facility will enable China to begin work in the very wide range of research which synchrotron light makes accessible. These projects are in the planning, engineering, or prototype stage.

High energy machines were covered in talks on the Fermilab antiproton source, the Stanford linear collider, LEP at CERN, Tristan in Japan, the Berkeley Bevalac, a review of kaon factory plans, and the Brookhaven CBA. In low and intermediate energy accelerator centres, the successful initial operation of the first superconducting cyclotron, at Michigan, was reported. Two other superconducting machines — linear accelerators operated as boosters for tandems — were also reported operating, with up to 3 MeV per m accelerating field and 20 MeV output energy. Great interest was generated by the discussion of the first work on the Indiana electron cooling ring.

Technology developments

The development of the advanced technologies for accelerators was detailed in several sessions. Optimism was expressed on the role that superconducting magnets and r.f. cavities could play in the next generation of accelerators since recent experience has been good. The optimism is based, not on the appearance of some fantastic new material, but rather on the excellent prospects for continued development of the materials already at hand. It was stated that we now have the tools and understanding to increase the critic' current density at 10 T by improve^ ments in the purity and microstructure of the materials and developments in manufacturing and fabrication processes. For r.f. cavities, field gradients of 2 to 3 MV per m have been demonstrated, and the prospect for doubling these figures seems good. Superconductivity promises 10 T dipoles and around 5 MV per m accelerating gradients in the near future.

Fourteen years after the invention of the 'spatially uniform strong focusing' principle in the USSR, many Laboratories are developing radio-frequency quadrupole (RFQ) accelerating structures. Horst Klein, from Frankfurt, gave an up-to-date review of activities at some fifteen Laboratories, listing twenty RFQs, eight of which have now accelerated beam.

Cocktail time: (left to right) John Lavs/son, Giorgio Brianti, Phil Morton and Bob Jameson (Conference Chairman).

while the remaining twelve are near completion. These should provide a i^/ealth of information on the practicality of this exciting new accelerating structure. Y. Hirao from Tokyo discussed their 132 cell RFQ Linac 'LITL'. It has successfully accelerated ions from hydrogen to lithium, operating at 100 MHz. A proton current of 70 jiA has been measured with a transmission of 95% and the beam parameters agree satisfactorily with the computer simulations.

Beam physics

In beam dynamics, it was clear that computer simulation has reached a new level of sophistication. Elaborate programs, some running for hours on the latest high speed computers, have been written to study the long-standing problem of the stability of high current (amp to mega-amp) beams under the influence of self fields. Results are in reasonable agreement with measurements wherever available.

New levels of maturity were seen in the understanding of stochastic cooling especially of bunched proton and antiproton beams and of depolarization processes in stored polarized electron and positron beams. The former investigation indicates the possibility of cooling bunched beams and prescribes better optimized designs of cooling systems; the latter suggests methods of preserving polarization in high energy colliders such as PEP, PETRA, and LEP.

Topics pertinent to the many modern facilities requiring high currents fell into three main categories: instabilities in multi-kiloampere, high current electron accelerators; emittance growth and current limits of intense heavy ion beams in long transport lines; high order r.f. modes limiting performance of electron storage rings.

Q and transverse impedance measurements of accelerating modules for the multi-kiloampere Advanced Test Accelerator (ATA) were reported, with the implications for beam break-up instability. A companion paper discussed two methods — one measured, one proposed — of reducing beam oscillations by special Landau damping cells. Other methods were proposed to handle intense electron beams, including recirculation through induction cavities or betatrons with or without a toroidal field. Standing wave r.f. linacs with very high gradients may also be useful at very high currents.

The generation of intense, low emittance beams is crucial for driving inertial fusion with heavy ions. Several groups reported early phases of experiments to check emittance behaviour under space-charge conditions in electrostatic quadrupole (Berkeley, Brookhaven), magnetic quadrupole (Darmstadt) and solenoidal (Maryland-Rutherford) transport channels.

High order r.f. modes coupling to transverse beam motion constrain single bunch currents and bunch lengths in electron storage rings; wake field effects also limit ring performance. Three CERN papers discussed the design implications for bunch energy spread and bunch length in LEP. Comparison with PETRA performance provides a benchmark for optimizing the LEP design. An experimental study of single bunch instabilities in PETRA suggested several means of raising threshold currents. New computer codes have been written at DESY to study cylindrically symmetric cavity modes and wake fields including components up to the octupole.

The Chinese outlined a method of using Hertz potentials to solve for azimuthally periodic modes of axisymmetric r.f. cavities. The finite element approach has been extended to three dimensions, but we are still waiting for a versatile 3D code to handle a useful number of modes.

Special topics

All major US proposals for a medium-energy c.w. electron machine were aired in a special session where there was also a progress report, by H. Herminghaus, on the commissioning, in less than two months, of the second stage of the MAMI project at Mainz. In March, this stage delivered 15jiA at 178 MeV. A beam monitoring device, based on observing synchrotron light, gives precision information on the beam during each of the 58 turns. This will provide useful data on the performance of a microtron in the intermediate energy range.

Charlie Baltay giving one of the concluding talks about future particle physics facilities in the USA. His talk was based mainly on the American Physical Society Aspen meeting reported in the October issue last year.

Ion sources, electrostatic accelerators, and polarized beams received their share of attention. C. K. Sinclair of SLAC summarized polarized electron sources. The highest intensity type uses photoemission from GaAs with circularly polarized (up to 50%) photons of more than 1.4 eV. Intensity is up to 100 A peak and 0.1 A average.

Y. Jorgen of Louvain reported the performance of a superconducting ECR (electron cyclotron resonance) high charge state heavy ion source running reliably on the Louvain cyclotron. This is the latest and highest performance version of the ECR source: currents are 10 ejiA of the most abundant charge states of oxygen, neon, argon and krypton.

Antiproton production at Fermilab and CERN was described in several talks and posters. Intense-beam targeting, previously the province of the meson factories, must be dealt with. In similar vein was a well illustrated talk by M. Wilson of Los Alamos on state-of-the-art devices and techniques to install and service components in the high radiation environments of today's powerful accelerators.

Control systems

Instrumentation and control reports ranged from the awesome multi-accelerator control system at DESY (a real tour de force) to esoteric descriptions of software modeling and snoop Fastbus diagnostic modules. Surprisingly, most of the papers dealt with non-commercially-available hardware, though the CERN LEP and the Los Alamos PSR control systems were exceptions. Even in the custom hardware, however, heavy emphasis is placed on standard bus structures (Multibus is one of the clear favourites) and distributed intelligence. The latter emphasis results from the growing sophistication of inexpensive microprocessors, and the recognition that control system costs are increasingly dominated by software. Distributed intelligence is being exploited primarily to simplify the software and a prime example of this trend is the control system for the heavy ion medical accelerator at Berkeley.

An overview of the Fastbus system for data acquisition and control was given in a lively talk by Lou Costrell. This development is a major interlaboratory effort to cope with the vast amount of data generated in high energy accelerators and detectors.

Several novel devices to measure beam profiles were presented and attracted a great deal of interest. Devices from Los Alamos include a compact unit which is inserted in low energy beams, to provide rapid measurement of phase space density in one transverse dimension, and an ingenious and versatile system which digitizes multiple images of a beam from beam-emitted light and does phase space reconstruction. A mechanically simple, pneumatically-driven wirescanner developed at the National Bureau of Standards measures two-dimensional beam density profiles at a rate of up to ten per second. These devices all use microprocessors.

Permanent magnets

J. LeDuff and Y. Petroff presented a review of permanent magnet technology which is developing very rapidly. It is already possible to use it for electron storage rings for microlithography and the free electron laser. The machine energies would be in the several hundred MeV range. Klaus Halbach and Bob Gluckstern presented papers on permanent multipole magnets with variable strength. Halbach described an arrangement of both steel and permanent magnet material that results in n variable strength multipole unL_ Gluckstern described an arrangement of quadrupoles where the effective strength of the combinations could be varied by rotation of the individual quadrupole units. Both schemes look promising for practical applications.

Applications

It is a particular feature of the USA Accelerator Conference that a lot of attention is given to the practical applications of accelerator technology. J. Duggan spoke on applications of accelerators in greater and greater numbers to the solution of immediate problems, especially in medicine and industry. There are today more than 3000 accelerators in use in the USA for medical purposes

At the Conference banquet: (left to right) Gunther Plass, Bob Jameson and his wife, and foreground, Caltech astronomer Roger Blandford, banquet speaker on the subject of 'Cosmic accelerators'.

alone. They produce isotopes for a wide variety of radiopharmaceuticals ipnd they are used in diagnosis and Rherapy; they are a dramatic example of the transfer of science and technology to vital human needs.

It is now possible to consider seriously the application of heavy ion accelerators as driver candidates for power generators by inertial confinement fusion. However, many critical and difficult technological questions remain to be answered before economic feasibility can be evaluated. An alternate approach, presented by Al Maschke, would use low energy heavy ions, with velocities of about 75 cm per s to implode a sphere of deuterium-tritium gas. The drive energy required is 2.5 kJ per jig, and the driver mass is then about ten times greater than that of the fuel being imploded.

A new session on Radiation Sources was included for the first time at this Conference, since these applications have recently gone through a major expansion in the area of synchrotron radiation and the development of other novel radiation sources. The major emphasis was on special radiation sources, such as the free electron laser, FEL (driven either in the single pass mode or by an electron storage ring), undulators and wigglers in an electron storage ring and Compton backscattered laser radiation. Impressive laser amplification results for a single pass FEL were presented by C. Brau of Los Alamos, clearly indicating the benefit of using the tapered wiggler approach. Radiation enhancement by as much as 3 % was observed, which holds great promise for early results in the oscillator mode; the modifications for this are now being carried out.

A highlight was the presentation by S. Krinsky of the National Synchrotron Light Source, NSLS, at Brookhaven, during which he systematically derived the optimization criteria for undulators and wigglers in an electron ring and enumerated the limiting factors on source brightness due to diffraction limit, non-zero beam emittance magnitude and finite length of the special radiation undulator or wiggler source. These arguments will certainly play a role in the evolution of synchrotron radiation rings such as the Advanced Light Source (ALS) project, a 1.3 GeV, low emittance, synchrotron radiation source, described by R. Shah from Berkeley, and other rings being studied in the USA and Western Europe.

The scope of present electron storage ring synchrotron radiation sources is being broadened by the possibility of gamma radiation generation by Compton backscattering. A. Sandorfi spoke of a very high flux (over 10^7 per s) of polarized gammas up to 300 MeV in energy, which will be produced by colliding 3 eV laser photons with the 2.5 GeV electrons of the NSLS. This approach has been funded for construction and will extend the scientific disciplines at the NSLS to include low energy nuclear physics.

Techniques for the future

There was lively interest in new accelerator techniques, including collective accelerators such as recirculating linacs. Two such accelerators that control the potential well at the front of an intense relativistic electron beam were discussed — the ionization front accelerator (IFA) and the helix controlled accelerator. A second generation IFA was reported nearing completion at Sandia; it is designed to produce controlled accelerating fields of 100 MV per m over 1 m. Experiments at Maryland were reported for a helix structure and for ions collectively accelerated from laser-produced plasmas; ion energies up to several MeV per nucleon are routinely achieved. New collective accelerator ideas include use of a space charge wave instability in a dielectric guide and a travelling magnetic wave on a toroidal electron cloud.

Laser accelerator schemes, and particle simulations of them, attracted discussion. Some of these schemes employ lasers to produce a beatwave in a plasma at the electron plasma frequency. A very large electric field results over a very small region. It is speculated that very high electron energies (about 1 TeV) might be produced, but very high laser intensities are needed and the number of accelerated particles would be small. No experiments were reported for these concepts.

Several novel ideas were presented that deal with more conventional technologies. A racetrack induction accelerator was proposed with stellerator windings on the curved section to provide beam stability. A beam extracted from an induction accelerator was focused with a series of foils. And a transverse focusing field accelerator was proposed that produces a ribbon-shaped beam that is focused and accelerated between pairs of curved plates with alternating curvatures. An interesting design for a high-current induction accelerator with nine parallel beam channels (Hermes III) was presented.

The closing session offered three talks by renowned experts on areas of special interest. Eric Vogt from TRIUMF reviewed electron and heavy-ion machines for nuclear research. He denoted these approaches as conservative and speculative, respectively, and both have strong adherents. Charlie Baltay of Columbia gave a vigorous report on the Aspen reaction on future high energy facilities in the USA — what technology will be sufficiently powerful to go beyond the Tevatron, LEP, etc? What Laboratory will be big enough to hold the Desertron — the accelerator which will step into, or across, the 'desert' just over the present energy horizon? Finally, Pief Panofsky reminded us that it is difficult to see too far ahead. The utility of a new machine can be different fron our expectations, and plans may therefore need to change. He encouraged the planners: although the cost scaling rules for increasing energy look ominous. Laboratories have reduced unit cost per MeV to the point where total costs are not dominated by the accelerator alone. With development of the necessary talents for these great facilities, we always seem able to make the next step.

(We are grateful to Bob Jameson and 01 in van Dyck for organizing coverage of this Conference and providing the information for this article.)

Theoretical science and the future of large scale computing

Kenneth G. Wilson

There are extraordinary changes taking place in the business community, driven by the twin pressures of Japan and the computer. The change is not always recognized in the academic community or in government, which evolve much more slowly.

The timescale for research and development is shrinking fast. The old picture of research and development can be illustrated by the laser, discovered more than twenty years ago. Now there is going to be a revolution in communications based on lasers and optical fibres. In that twenty-year period, the laser has gone from being a scientific curiosity to the subject of a standard industrial R and D operation. But especially in the computing business, one no longer has twenty years to do R and D. One has maybe three or five years. A product lasts for three to five years, and then it's back to the drawing board. This pressure means that the style of R and D which tinkers with a well-defined object does not work any more. It also requires greater scientific understanding, to enable moving into new areas faster.

In the traditional industrial approach everything inside the industry is secret. Progress is now towards a situation where to gain industrial advantage companies have to learn early on about new developments