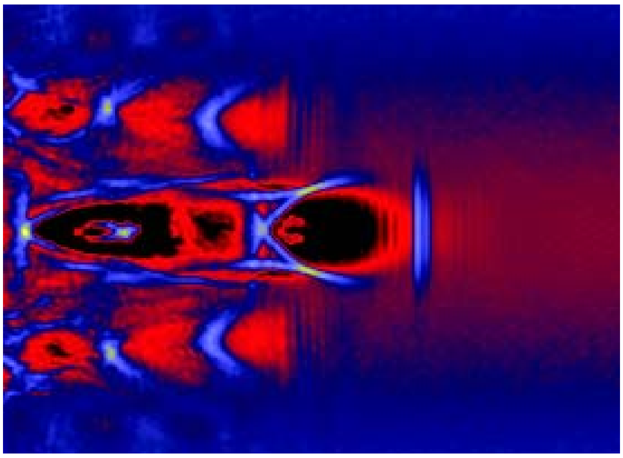


Simulation (of laser wakefield acceleration guided by plasma channel) by Cameron Geddes using the VORPAL code, with the Visualization Group at Lawrence Berkeley National Laboratory. (Courtesy Lawrence Berkeley National Laboratory.)

taining around 0.3-0.5 nC of charge (Geddes *et al.* 2004). The normalized emittance was estimated to be of the order of 1-2 π mm-mrad (rms). Once again several factors seem to be involved in keeping the energy spread small, with the most important one being the control of the acceleration distance to match the dephasing distance, *i.e.* the distance where the electrons start to outrun the wave. Simulations of the process with the particle-in-cell code VORPAL indicate that the laser pulse first self-steepens while propagating in the plasma. As a result larger amplitude waves are excited as the laser pulse propagates deeper into the channel. When the wave amplitude reaches levels sufficient to trap background electrons and the acceleration process is extended to the dephasing distance, momentum bunching occurs and this results in a narrow energy spread for the beam. Combined with sufficient beam loading to suppress trapping in trailing accelerating buckets, this leads to the quality of the electron beams observed, with low divergence and energy spread.

These results represent a great achievement, but all three groups point to the need for further work, on efficiency and shot-to-shot stability for example. Also it is still far from clear as to how an accelerator based on this technique could be "staged" to reach the teravolt energies now generally required for research at the high-energy frontier. However, the results provide great hope for progress towards compact, high-brightness machines operating in the giga-electronvolt region. These would have many applications, for example in materials science, ultrafast chemistry and medicine.

Further Reading

C. G. R. Geddes *et al.*, 2004 Nature **431**, 538.
J. Faure *et al.*, 2004 Nature **431**, 541.
S. P. D. Mangles *et al.*, 2004 Nature **431**, 535.

HERA Gets Set to Demonstrate Its Full Potential[4]

When the electron-proton storage ring HERA at DESY began its summer shutdown in mid-August, it had broken several records. It had delivered a luminosity of $3.8 \times 10^{+31}$ cm^{-2}s^{-1}, exceeding its previous record of $2.0 \times 10^{+31}$ cm^{-2}s^{-1}, with an integrated luminosity of 87 pb^{-1}, which beat the previous record in 2000, and it had become the first storage ring to provide longitudinally polarized high-energy positrons in colliding-beam mode.

It has been a long and hard struggle to get HERA back into successful operation after a challenging upgrade in 2000 and 2001. Unexpectedly severe backgrounds prevented the collider experiments H1 and ZEUS from taking data when HERA restarted in 2001. The main causes were found to be the strong heating of the beam pipe due to the short positron bunches and the intense synchrotron radiation from the positrons close to the experiments. These resulted in a degradation of the vacuum, and the spray of particles from the interaction of the proton beam with the residual gas produced the unacceptable backgrounds.

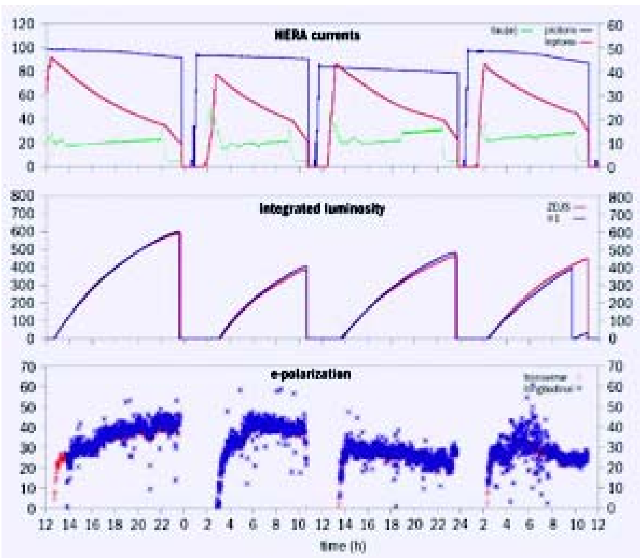
Close collaboration between the HERA machine crew and the experiments, aided by external and internal advisory committees, allowed one problem after the other to be identified, understood and solved. Major changes to the beam collimation system, the vacuum system and the detectors were required. Finally, early in 2004, the improvements were such that H1 and ZEUS were able to take data at the nominal HERA beam currents (100 mA of protons and 50 mA of positrons).

[4] *The permission for reprinting the present report, as published previously in CERN Courier, Vol. 44, No. 8, October 2004, was granted through DESY and CERN Courier.*

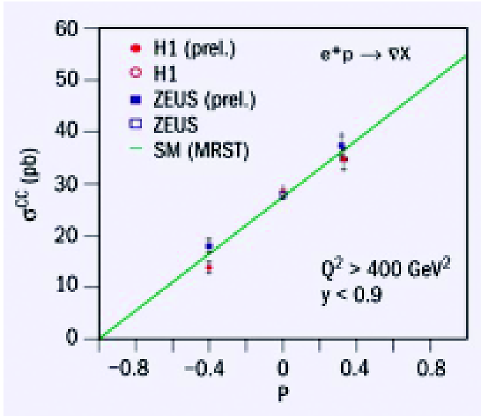
From then on, the HERA machine crew could concentrate on steadily increasing the HERA currents while the experimenters could focus on taking data efficiently. In parallel, the positron polarization was improved steadily and values in excess of 50% were reached. However, work still remains to be done to achieve high polarization reliably at high luminosities.

All three experiments at HERA—H1 and ZEUS as well as the HERMES experiment with a polarized gas target—have successfully taken data in 2004, with results already presented at ICHEP'04, the International Conference on High Energy Physics held in Beijing in August. Examples include the first, long-awaited measurement of the polarization dependence of the weak interaction cross-section by H1 and ZEUS, and the world's first determination of the structure of the proton by measuring the scattered positron and the hadronic final state using a target transversely polarized to the direction of the positron beam by the HERMES experiment. While the results are interesting, they demonstrate that about 10 times more data, taken with both electrons and positrons, are required to exploit the scientific potential of the upgraded HERA collider.

During the two months of the summer shutdown, the HERA crew has continued to improve the vacuum system, exchanged components that have caused inefficiencies in running and carried out the regular safety checks that are legally required. When HERA comes back into operation this month (October), the challenge will be to demonstrate that the machine and its experiments are also able to run and take data efficiently with electrons—as they have now proved they can do with positrons.



A display of the HERA machine cycle demonstrating good performance with, at top, the proton current (blue), the positron current (red) and the positron lifetime (green); at centre, the luminosity accumulated by the experiments H1 and ZEUS; and at bottom, the positron polarization as measured by the two HERA polarimeters.



The polarization dependence of the charged-current cross-section is visible in the measurement shown here, which was made possible by longitudinally polarized positron beams in HERA. The plot demonstrates parity violation in the weak interaction in lepton-proton collisions at the highest energies.