finds that his model fits the data better than physically more realistic models. The systematic data on superheavy elements measured at GSI over the past five years were very useful in fine tuning Smolańczuk's model. His model reproduces within a factor of two the cross sections for a number of nuclei synthesized at GSI. Theorists are already working to try to understand the success of this simple model and how the more sophisticated approaches might be modified.

Serendipitous timing

Smolańczuk's predictions stood in stark contrast to the prevailing expectations. Why, then, did the Berkeley experimenters bother to test them? Such tests had not been in their plans six months earlier; rather, they had been gearing up to confirm the report of element 114. While they made the necessary preparations, however, beam time was available on the 88-Inch Cyclotron. They used the time to look for element 118. Ninov, Gregorich, and their colleagues were as amazed as everyone else when three candidates were seen in two runs.

For the experiment, the Berkeley experimenters struck a ^{208}Pb target with ^{86}Kr ions accelerated to an energy of 459 MeV. These ions were the heaviest projectiles they had ever used. They looked for reactions in which the compound nucleus emitted a single nucleon and subsequently decayed by a chain of alpha decays. They found three chains of six alpha decays; in each chain, the decays all occurred within a small region on the detector, as one would expect for a chain of descendants from the same parent nucleus. If the researchers are correct in their identification of the residual nucleus as ^{293}118, the other isotopes in the chain are ^{289}116, ^{285}114, ^{281}112, ^{277}110, ^{273}108, and ^{269}106. None of these isotopes has been produced before. More experiments will be needed to confirm these results.

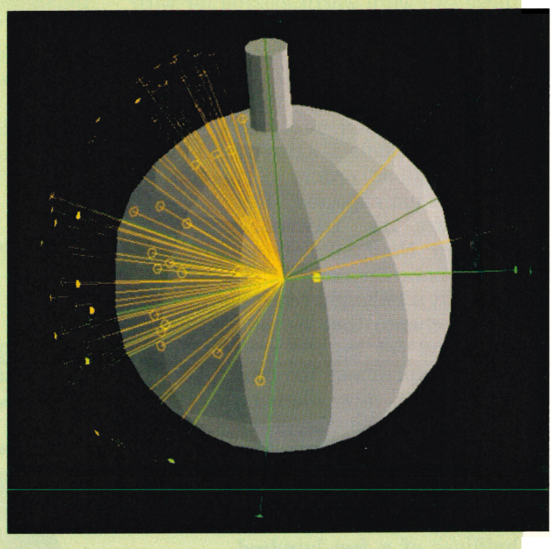
The experiment marked the debut of Berkeley's new gas-filled isotope separator, built to give the lab higher efficiency and greater background suppression for superheavy element production (see the figure on page 17). The researchers were looking for reactions in which the compound nucleus, formed by colliding ^{86}Kr ions with the ^{208}Pb target, decayed by emitting a single neutron. Such residual ions recoiled into the separator, where charge-changing collisions with the gas molecules brought them to an average charge state. Strong bending magnets separated out any beam ions or transfer reaction products (blue path). The residual nuclei of interest (red path) passed through a parallel plate avalanche counter and became embedded in an ion-implanted silicon detector. Correlations between the PPAC and the detector helped distinguish two types of events: those associated with an atom flying through the separator and those resulting from the decay of atoms already embedded in the detector.

Ninov, who spent 11 years at GSI before going to Berkeley, told us that the Berkeley group got tremendous support from his former GSI colleagues, who couldn't undertake their

First Events Seen at Sudbury Neutrino Observatory

Fifteen years after it was initially proposed, the Sudbury Neutrino Observatory (SNO) has begun collecting data on solar and atmospheric neutrinos. Built by a collaboration of scientists from Canada, the US, and the UK, SNO is the second of a new generation of powerful neutrino detectors (see PHYSICS TODAY, July 1996, page 30 and December 1997, page 56). It consists of an acrylic container holding 1000 metric tons of heavy water, surrounded by an array of about 9600 photomultiplier tubes (PMTs) in ordinary water and buried 2 km underground in a nickel mine near Sudbury, Ontario.

Reconstructed here is one probable solar neutrino event recorded at SNO. Seventy-five PMTs (yellow hexagons) detected the Čerenkov radiation emitted by an electron that was produced when a neutrino collided with the heavy water (gray sphere). The yellow lines show the inferred photon paths from the calculated location of the neutrino strike to the PMTs.



Two different reactions between neutrinos and the deuterons in the heavy water give SNO its unique ability to measure both the flux of electron neutrinos from the Sun and the total flux of all solar neutrinos, including muon and tau neutrinos. An electron neutrino striking a deuteron can produce an electron through $d + \nu_e \rightarrow p + p + e$. Any of the three flavors of neutrinos can break apart the deuteron: $d + \nu \rightarrow p + n + \nu$. (In contrast, the Super Kamiokande neutrino detector in Japan uses light water; its single observable reaction—elastic scattering of neutrinos off electrons—is sensitive primarily to electron neutrinos but cannot distinguish between neutrino flavors. Super Kamiokande has recently begun detecting neutrinos produced by the KEK proton accelerator—see page 9 of this issue.)

"By comparing the measurements of the two reactions," explains SNO director Art McDonald of Queen's University at Kingston, "we can know whether all of the solar neutrinos striking the detector are electron neutrinos or whether some of them have changed to another flavor." Because only electron neutrinos are produced in the Sun, such information is key for solving the "solar neutrino problem," the name given to the observation by earlier neutrino detectors of a solar neutrino flux that was much less than expected.

Muon and tau neutrinos can also be produced in the atmosphere by cosmic rays. Such atmospheric neutrinos will have much larger energy, however, and will be readily distinguishable from solar neutrinos at SNO. In addition, the event rate for atmospheric neutrinos should be significantly smaller—only a few hundred per year, compared to between 10 and 20 solar neutrino events per day above SNO's threshold of about 5 MeV.

To prevent distortion of the spectra recorded from neutrino events, keeping the detector free of radioactive contamination was a major focus throughout construction. "The radioactive background is where we hoped to have it at this stage," McDonald told us. Natural decay and the continuous purification of the water are expected to reduce the background even further.

In future experiments, SNO will employ two additional detection mechanisms—an array of detectors filled with ^{3}He and placed inside the heavy water, and magnesium chloride salt dissolved in the water—for better sensitivity to the neutrons produced in the deuteron dissociation reaction. RICHARD FITZGERALD