

search & discovery

Element 112 evidence starts a rush on proton beam stops

Suppose you bombard a tungsten target with very high-energy protons. Sometimes a tungsten nucleus might receive enough energy to climb the Coulomb barrier in a second tungsten nucleus and produce some superheavy nucleus. That was the hypothesis of Annon Marinov (on leave from Hebrew University at the Rutherford High Energy Laboratory) and his collaborators, C. J. Batty and A. I. Kilvington (Rutherford), G. W. A. Newton and V. J. Robinson (University of Manchester) and J. D. Hemingway (Universities Research Reactor, Risley, Lancashire), who examined two tungsten beam stops from the CERN proton synchrotron. After studying their alpha-decay properties and also observing spontaneous fission, they concluded that they may have observed production of element 112 by secondary reactions in tungsten targets irradiated by 24-GeV protons (*Nature* 229, 464, 1971).

Despite general skepticism about the conclusiveness of the evidence, many experimenters have rushed to obtain their own beam stops or to try other methods of studying such secondary reactions, in which the recoiling heavy nucleus produces the reaction. It is possible that a whole new field of nuclear chemistry will open up, using high-energy proton beams.

Marinov and his collaborators argue that either elastic scattering of protons or inelastic reactions such as (p, n), (p, p'), (p, d), (p, α) could produce recoil nuclei with energies sufficient to exceed the Coulomb barrier of about 1.0 GeV between two tungsten nuclei. This would lead to production of heavier nuclei, which either fission asymmetrically or otherwise lose mass to end as element 112.

The experimenters used two cylindrical tungsten beam stops, each 120 grams/cm². Assuming that the cross section for producing a high-momentum transfer reaction is 10⁻³⁰ cm², and you have 10¹⁸ protons hitting the tungsten, you could expect about 10¹² heavy particles with enough energy to mount the Coulomb barrier. Then assuming a cross section of 10⁻²⁹ cm² for the induced fission reaction, and noting that the 10¹² heavy particles will be strongly ionizing and thus have a very short

range, you could expect to produce about 1000 superheavy nuclei.

One beam stop had been exposed for about a year and was three or four months old when the experimenters obtained it. A second beam stop had been exposed for about four months,

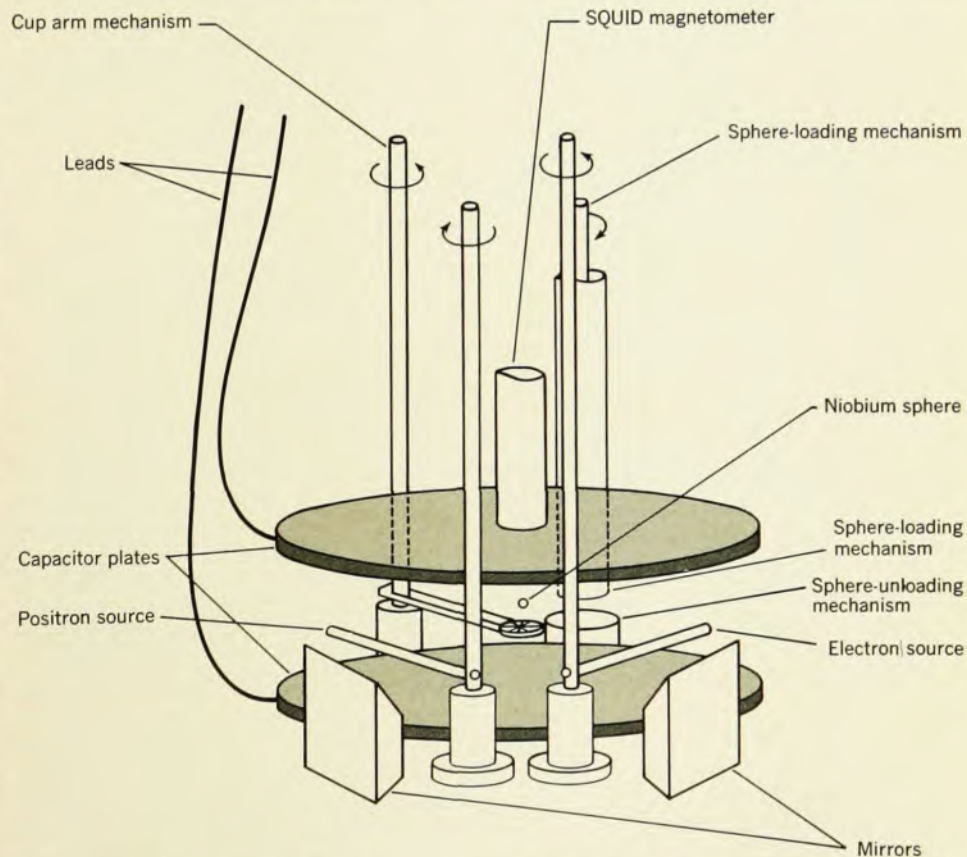
and the experimenters started chemical separation of it a few days later. They chemically separated the target and looked for eka-mercury, which would presumably be element 112. They are now looking at some of the other possibilities
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Quark search gets help from Millikan

Every once in a while in discussions about quarks, you hear the old story that Millikan occasionally saw fractional charges while doing his oil-drop experiment. Now William Fairbank and Arthur Hebard at Stanford University are repeating the experiment, replacing the oil drop with a superconducting niobium ball. They hope to

improve the chance of finding a fractional charge because the probability of finding such a charge is proportional to the mass of the sphere. Their sphere has a mass of 7×10^{-5} grams, in contrast to a typical Millikan oil drop of 3×10^{-11} grams.

Fairbank and Hebard reported at the Kyoto low-temperature conference that



Quark apparatus. Niobium sphere is supported in a vacuum against gravity on a magnetic field produced by two superconducting coils (not shown). Loading and unloading mechanisms plus cup arm mechanism allow charge measurements to be done with nine spheres without warming apparatus. Square-wave voltage is applied via leads with a period equal to that of ball's natural period.

they had observed a non-zero residual charge of approximately $-1/3$ on the first sphere they studied. They cautioned however that this result might be due to spurious charge forces. Since then they have repeated the measurements at several different positions and are now working with other spheres.

The experimenters float the 1/4-mm-diameter ball in a magnetic field at liquid-helium temperature, placing it between two horizontal capacitor plates separated by 6 mm. The ball oscillates in the magnetic field with a 1.5-sec period. There are several reasons for using low temperature: The magnetic field produced by a superconducting magnet gives very stable, drift-free suspension. The low temperature enables the experimenters to use a very sensitive detection scheme—a "SQUID" magnetometer placed above the plates, which observes motion of the ball. Because a resonance technique is used, it is desirable to have very low friction in the ball's suspension, a situation that is more easily attained at low temperatures.

Without applying a voltage to the plates they give the ball a series of small kicks with a little magnetic coil, building it up to a certain amplitude and then watching it decay. Knowing the loss factor Q , they then apply a constant-amplitude square-wave voltage to the plates at exactly the same frequency as the ball's resonant frequency. Such a driven oscillator will reach a maximum amplitude that is proportional to the product of the electric field E and the charge q on the ball.

When the ball is first introduced between the plates it is highly charged. A radioactive source of positrons or electrons is then introduced so that the ball is eventually neutralized close to zero. Individual measurements of the total charge on the ball range from $-4e$ to $+4e$. As the measurement proceeds the charge may change, giving a spurious value. To avoid that, they calculate what the charge is in the first half of the decay, the last half, and the middle. If the points disagree by a certain value, the point is discarded. For a given measurement they end up with about 40 charge points, which are distributed in integers that represent the separation of electronic charge with a certain amount of error. If the ball has a $1/3$ charge the integral charges will be asymmetric around zero. Fairbank and Hebard are able to calibrate the apparatus and use the known value of e to check this integral spacing.

The number of charges on the ball is always modulo one; so you can't tell the difference between $-1/3$ and $+2/3$. Provided there are sufficient quarks present, you would expect to see $-1/3$, $+1/3$ and zero with equal probability. An apparent $1/3$ residual charge does not necessarily imply the reality of

quarks because there might exist spurious charge forces that are caused by the apparatus.

These forces might arise, for example, if the induced electric dipole moment on the sphere, which is proportional to E , interacts with a fixed field gradient (caused, for example, by a surface dipole layer on the capacitor plates) to give a force linear in the electric field and hence indistinguishable from the charge force qE .

Fairbank and Hebard have checked that these spurious-charge effects are small by measuring the ball in six different positions over an eight-month period. They are now working with a second ball and hope to have some definitive answers soon.

Why would you expect to see quarks on the niobium ball at all? Fairbank and Hebard assume that the quarks are present from the fireball that marked the beginning of time, or that cosmic rays have been hitting the earth with enough energy to create free quarks that will combine with matter to form long-lived fractionally charged bits of matter.

Three other groups have used the Millikan oil-drop idea to look for quarks: G. Morpurgo and G. Gallinaro of the University of Genoa floated graphite particles in a magnetic field. R. W. Stover, T. I. Moran and J. W. Trischka of Syracuse University and Vladimir Braginski of Moscow State University used iron spheres. These experiments were done at room temperature and none of them reported the observations of quarks. —GBL

Element 112

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bilities: eka-platinum (110), eka-gold (111), eka-thallium (113) and eka-lead (114).

Examining the alpha-particle spectrum from the mercury fraction of each target, Marinov and his colleagues found a peak at 6.73 MeV that did not decay over a 24-day interval, and they believe that the peak is not due to any known decay of mercury, even from an isomeric state.

The evidence is more convincing for spontaneous-fission events, the experimenters believe. Using polycarbonate films to detect the fission products, they found about 93 fission fragments in the mercury fraction from the second target over a 37-day interval (and no fission fragments from the first target). To make a crude estimate of the lifetime of element 112, the experimenters assume a maximum of a million atoms of the isotope were formed in the target. The rate of decay would then imply an upper limit to the half life of about 500 years. They feel the spontaneous fission is unlikely to be caused by con-



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tamination from actinides or from fission from some new isomeric state of mercury.

What objections have been raised to the experiment? Many theorists argue that you couldn't possibly expect cross sections as large as 10^{-29} or 10^{-30} cm² for the proton to hand over a large fraction of its momentum and energy to the tungsten as a whole—unless there are some entirely new processes going on, as for example a variant of the Mössbauer effect. An equally far-out idea suggested by Peter Fowler (University of Bristol) involves effective rocket propulsion of the initial tungsten nucleus as a result of fragment boil-off from the hot spot created by proton impact. And over the years why wouldn't people have seen in emulsions the recoil of something like tungsten following high-energy interaction with a proton?

Others are saying that the alpha-particle evidence is weak, that you can account for the 6.73-MeV alphas from contaminants. And the fission fragments should have been found in both targets, they say.

If the British group has not seen element 112, what has it found? One possibility, suggested by Allan Bromley (Yale), is that they are seeing a very high-spin isomer of mercury, analogous to the intershell combination levels in atomic physics. Or they could be seeing an isomer of one of the contaminants, such as one of the actinide elements.

Another possibility is that when the proton hits the tungsten nucleus, spallation occurs, and one of the spallation

products mounts the Coulomb barrier of the second tungsten nucleus, making something in the actinide region, for example. Or a uranium contaminant in the beam stop could react with a spallation product, leading to a spontaneously fissioning species.

What next? Just about every available beam stop used at a high-energy accelerator has been spoken for. Brookhaven AGS targets, for example, have been sent to Oak Ridge, Argonne and Rutherford High-Energy Lab so that they can be searched for evidence of superheavies. In addition a group at Argonne is processing a uranium target from the ZGS for superheavies.

Marinov and his collaborators are doing a new experiment, using a thin source and sandwiching it between two surface-barrier detectors. They will try to measure the energy distribution of the fission fragments.

At Brookhaven several checks on the British work are in progress. In the chemistry department a group of investigators has put tungsten, uranium and gold targets into the AGS beam. They follow the target with a Mylar absorber and a fused-silica track detector and look for the cross section for production of very energetic, heavy fragments. Another experiment uses a thin target, followed by a stack of thin aluminum catcher foils, which are then processed chemically to look for very energetic spallation products. In a third experiment a uranium or lead target is irradiated and one uses track detectors to look for fission tracks from delayed fission. In the physics department a group is checking to see if the British group actually found a long-lived fissioning isomer of mercury. They bombarded a sample of normal hafnium with O^{16} or O^{18} ions and tungsten with C^{12} ions from the new tandem Van de Graaff. Solid-state detectors and plastic particle detectors are being used in a search for alpha emitters and fission events.

At Oak Ridge, Raymond Stoughton and his collaborators are using an AGS tungsten beam stop to look for neutrons being emitted. Because their background is very low, if the target contains element 112 they should be able to determine the number of neutrons emitted per fission by using a neutron multiplicity counter and looking for coincidences. The number is expected to be high (say 8 to 11 neutrons per fission), because element 112 is expected to be comparatively neutron rich.

At Argonne Paul Fields is using an AGS target to look for alpha particles and fissions from the actinide elements, as well as high- Z elements.

A CERN-Orsay collaboration involving René Bernas is trying to separate eka-lead and eka-mercury from a uranium target, rather than a tungsten

target. Because of their skepticism regarding the mechanism invoked by Marinov, the group is following the suggestion by A. M. Poskanzer, Gilbert Butler and Earl Hyde (Berkeley) that high-energy neutron-rich fragments can by secondary reactions on uranium

produce superheavies.

The experiments mentioned are only a few of the many now under way to check the validity of the British experiment. Although many doubts have been raised about the conclusions, many hopes have been raised, too. —GBL

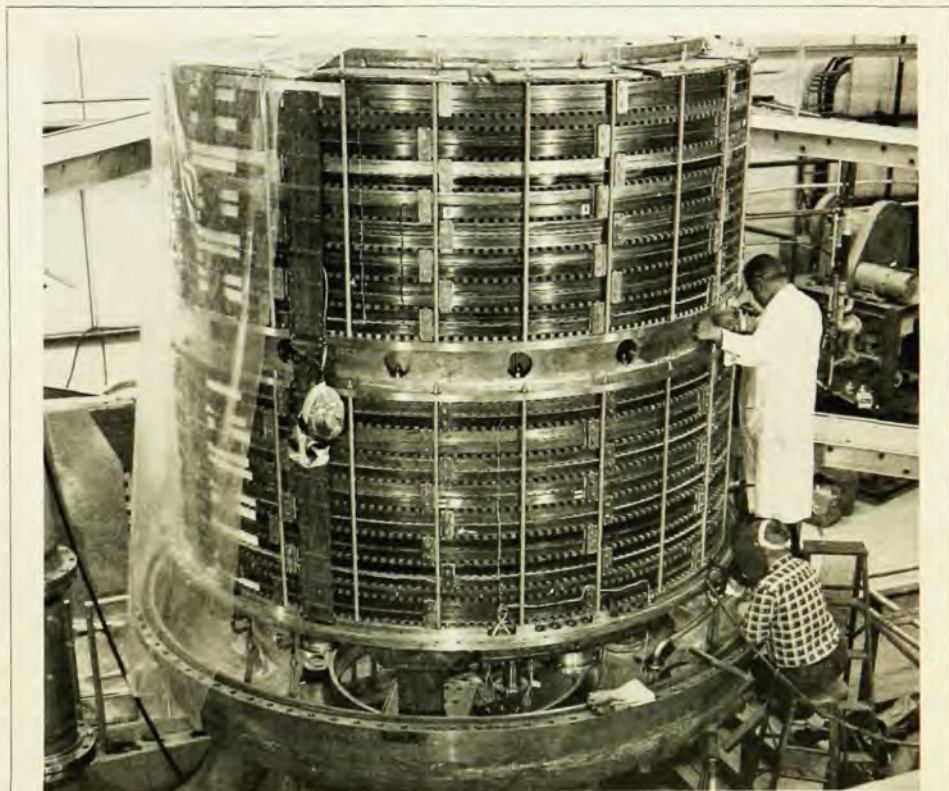
1000 GeV with superconducting magnets at Batavia?

With a modest extension the Batavia accelerator may be able to produce 1000-GeV protons, double the expected 500-GeV maximum, according to National Accelerator Laboratory director Robert R. Wilson. On 9 March Wilson told the Joint Congressional Committee on Atomic Energy how a relatively inexpensive device (\$10-20 million) consisting of small-bore superconducting magnets could act as an "energy doubler" that would pay for itself within the first few years of operation.

NAL construction has consistently been ahead of schedule and below estimated costs (see *physics today*, June 1970, page 29). The accelerator was originally designed to start operation with 200-GeV beams and have the capa-

bility of producing 500-GeV beams at some later date. It turned out, however, to have the capability for 500-GeV beams right from the start, and at a cost lower than that estimated for 200 GeV.

The energy-doubler concept would place very small-bore (3-cm) superconducting magnets just above the magnets in the one-and-a-quarter-mile diameter main ring, and would have the same configuration as the main-ring magnets—for example, focusing magnet above focusing magnet. After protons are accelerated in the main ring, they are transferred to the superconducting ring, whose magnetic field is maintained at the main-ring value. Then the field in the supercon-



SUPERCONDUCTING MAGNET for Brookhaven 7-foot bubble chamber. The 8-foot diameter, 8-foot high magnet, the largest and highest field air-core superconducting magnet ever built, has lived up to its designers' expectations; it achieved an operating field of 28.2 kG in a trial run. Other large bubble-chamber magnets have either iron cores (such as at the 12-foot Argonne bubble chamber) or water-cooled copper coils. The bubble chamber will be used to detect neutrino events produced in beams from the 33-GeV Alternating Gradient Synchrotron (AGS). Experiments are expected to begin in summer 1972 when modifications of the bubble chamber and construction of a new experimental area at the Brookhaven laboratories have been completed.