laborators are continuing to collect data with their present apparatus and are building a special 10-atmosphere chamber to look for particles with charge 1/3 *e*. — GBL

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K-Mesic Atoms Indicate A Nuclear Neutron Skin

A thin skin of neutrons apparently surrounds the nucleus, according to measurements with K-mesic atoms by Clyde E. Wiegand of Lawrence Radiation Laboratory, Berkeley (*Phys. Rev. Lett.* **25**, 1235, 1969). Such atoms offer a new tool for determining the extent of the nuclear wave function.

For many years theorists had suggested that the nuclear surface might be covered with neutrons. But conventional electron-scattering measurements, such as those done by Robert Hofstadter and his collaborators at Stanford, only measure the nuclear charge distribution. By analyzing analog states one can learn if the mean-square-density radius is different for neutrons and protons. There is some evidence for a larger neutron radius, but the conclusions remain controversial.

At much greater distances density falls off exponentially. Because the proton sees a Coulomb barrier, its wave function falls off much more rapidly than that of the neutron. So one would expect to find a larger neutron radius.

Using the external proton beam to make kaons at the 6-GeV Bevatron, Wiegand bombarded a variety of targets to make K-mesic atoms. Because the kaon is about 1000 times as massive as an electron, it forms a hydrogenlike atom in which the orbits are about 1000 times smaller than the ordinary electron shells.

Wiegand observed x-ray emission as the kaon dropped toward the nucleus. The highest-energy x ray observed tells how close the kaon got to the nuclear surface before it was absorbed by the nucleons there. Wiegand made 24 kinds of K-mesic atoms with atomic numbers ranging from $Z = 3$ to 92. Mesic atoms have previously been made using pions and muons, both lighter than kaons.

Wiegand says that his measurements on 24 elements show that the neutrons are distributed in a low-density tail and that the parameters of the tail are relatively insensitive to how you distribute the matter in the center.

Wiegand also observed x rays suggesting the formation of Σ^- hyperonic atoms. With high-Z atoms, he hopes to see a fine structure due to the magnetic moment of Σ^-. With more intense kaon beams and larger germanium detectors of improved resolution, he may be able to measure the Σ^- magnetic moment. (Only two hyperon magnetic moments are known.)

Serpukhov Data Suggest Asymptopia May Be Further Away Than Ever

With 70 GeV available at the Soviet Serpukhov accelerator, a new look into the asymptotic region is possible, and some observers are surprised at the glimpses reported at the Lund International Conference on Elementary Particles in July. Preliminary results suggest that the π^-–p and K^-–p total cross sections may be flattening out as energy increases; many theorists had predicted that these cross sections would go down as energies increased.

In another Serpukhov experiment the p–p differential elastic-scattering cross section shows shrinking of the forward diffraction peak as energy is increasing; this shrinking confirms an earlier trend.

New results from the Serpukhov quark search were reported by L. G. Landsberg's group. They find that if the quark has a mass less than 6 GeV, an average upper limit for the production cross section is 3×10^{-38} cm^2. (The actual cross section varies as a function of energy.)

The total cross-section curves are expected to agree with the Pomeranchuk theorem, originally proposed by Isaak Ya. Pomeranchuk in 1956. The theorem, which follows from the dispersion relations, predicts that in the high-energy limit the cross section for a particle hitting a given target will be equal to that for an antiparticle hitting the same target. For example, in the asymptotic limit, the π^-–p cross section should be the same at the π^+–p cross section.

The Serpukhov experiments, done by a collaboration between CERN and the Serpukhov Institute for High-Energy Physics (IHEP),[1] measured K^-–p, π^-–p and $\bar{p}$–p total cross sections in the range 20–65 GeV/*c*. The antiproton–proton cross sections appear to be falling off and approaching an extrapolated flat proton–proton total cross section.

The somewhat unexpected results are those for pions and kaons: Between 30 and 65 GeV/*c* the experimenters believe the pion cross section has become energy independent within the estimated 0.20 millibarn accuracy; the average value is about 24.4 millibarns. The kaon cross sections also show very little energy dependence over the region investigated; they average about 20.8 millibarns, but the estimated errors are larger.

Extrapolations from higher-accuracy lower-energy data obtained by S. J. Lindenbaum and his collaborators[2] predicted a declining π^-–p cross section, the curve tending towards the π^+–p curve. Regge-pole analyses, such as those made by Vernon Barger and his collaborators,[3] had also led to predictions of a declining π^-–p cross section.

If interpretation of the data is correct, one can explain the flatness of the π^- and K^- curves in several ways: Asymptopia is very far away and the particle and antiparticle cross-section curves are approaching each other very slowly as $1/\log E$ (where E is bombarding energy), for example; the π^+ and K^+ curves could start increasing, because the Pomeranchuk theorem says they must approach the π^- and K^- asymptotes, respectively; or the Pomeranchuk theorem is wrong.

Now information on π^+–p and K^+–p total cross sections in the new range is eagerly awaited.

The proton-proton differential elastic-scattering cross section was measured from 12 to 70 GeV at angles from 1 to 5 milliradians by a Dubna–IHEP collaboration.[4] In the early 1960's Regge-pole advocates predicted that the forward peak in the elastic differential cross section would shrink for both protons and pions. The prediction was verified for p–p scattering in the energy range below 30 GeV, but violated for π–p scattering, thus temporarily damping enthusiasm for Regge poles.

The Serpukhov data show that in the new energy region the rather broad p–p diffraction peak continues to shrink somewhat. Extrapolations from lower energy $\bar{p}$–p elastic differential cross sections show a narrow peak, which is expanding. Because the Pomeranchuk theorem predicts that both peaks will tend toward the same

width, the new data confirm theoretical expectations. —GBL

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PPA Proposes Heavy-Ion Improvement Program to AEC

Modifications to the Princeton-Pennsylvania Accelerator will give nuclear structure a unique new tool. Monochromatic proton beams, intense primary beams of 2.4-GeV deuterons and 4.8-GeV alpha particles are all expected by late this year. PPA has submitted to AEC a four-phase proposal to add a high-energy, heavy-ion capability.

In the initial improvement program the key modification is an all-solid-state power supply that will produce a 50-millisec flat top, constant to 0.01% at a pulse rate of 10 per second. With the new power supply, the 3-GeV proton beam is expected to be monochromatic within about ±300 keV or better. An external proton beam of about 4×10^{11} protons/sec is already available. The deuteron intensity is expected to be about the same as the proton intensity; because the alphas are more difficult to make, their intensity is expected to be between 0.1 and 0.5 as much.

Development work is expected to produce, by 1970–71, modest beams of relatively heavy ions with 10–100 MeV/nucleon, according to Milton G. White, PPA director.

The present PPA injector is 3 MeV. A 75-MeV high-current booster injector synchrotron is being designed. It would yield 20–30 times more proton current and would allow injection of polarized protons (which are not available with other high-energy accelerators because they automatically depolarize their protons). The same injector synchrotron could also be adapted to produce intense beams of very heavy ions with energies up to 1.2 GeV/nucleon (up to nickel) and 0.8 GeV/nucleon for uranium.

In the four-phase program, Phase 1 (costing $500 000) provides a ceramic vacuum chamber capable of reaching the 3×10^{-9} torr required for acceleration of the heaviest ions, such as xenon (though light ions could be accelerated at 10^{-7} torr). Xe^{8+} could be accelerated to 28 MeV/nucleon with a current of 5×10^{10} particles/sec, White estimates.

Phase 2 adds a small booster synchrotron and a Cockcroft–Walton accelerator ($2.25 million), thus permitting much wider choice of ion sources, higher heavy-ion currents and a proton current of 2×10^{13}/sec.

Phase 3 ($800 000) adds equipment to permit full stripping of the heaviest ions and subsequent acceleration to 800–1200 MeV/nucleon.

Phase 4 adds a second 4-MV injector, a polarized-proton ion source and a heavy-ion development program.

Experiments. Just before the Brookhaven Cosmotron was shut down at the end of 1967, Harry Palevsky and his collaborators (PHYSICS TODAY, October 1967, page 75) ran a series of experiments with 1-GeV protons that probed the distribution of matter in light nuclei. Energy resolution was about 3 MeV, and the beam retained a long-term stability of about 1.5 MeV.

PPA will be able to do similar studies but at a much faster rate; although the Cosmotron had ten times the intensity, it only pulsed once every 2 sec. (PPA pulses 10 times per second.) White explained that PPA experiments can look for deuterons or alphas inside the nucleus. With the small wavelengths associated with 3-GeV particles, one can probe fine details. Because so few nuclear-structure studies have been done in the 1–3 GeV range, White feels that interesting results are bound to show up.

Palevsky plans to do alpha–alpha reactions at PPA. Because the isospin and spin are both zero, one can see whether or not the constituent parts of the alpha particles behave independently.

With polarized protons, White noted, one could look at any spin-dependent process. Using the deuteron beam, they could make a highly collimated 1.4-GeV neutron beam; by polarizing the deuterons, a polarized neutron beam could be produced.

Besides the sharp increase in nuclear studies, PPA expects a steady increase in its current heavy backlog of elementary-particles experiments. At present, 14 experiments are on the experimental floor and taking data more or less simultaneously. (The average number of users taking data simultaneously is about 4.5.)

Program is Proposed for Outer-Planet Trips in 70's

A "grand tour" of several of the outer planets, possible in the late 1970's because of their unusual relative positions, has been recommended by a committee of the National Academy of Sciences. In a report called *The Outer Solar System: A Program for Exploration,* the group, headed by James A. Van Allen and Gordon J. F. MacDonald, notes that a similar juxtaposition will not recur for 200 years and that taking advantage of it would substantially reduce the time and money spent in exploring the outer solar system. A series of specific missions would start with a trip to Jupiter in 1974.

Prime objective of outer solar-system studies include experiments to:

- investigate the appearance, size, mass, magnetic properties and dynamics of the outer planets and their major satellites
- characterize the planetary atmospheres (chemical and isotopic composition, existence of biologically significant substances and conditions, description of their motions and temperature-density-composition structure)
- study in detail the external magnetic field and respective particle population of each planet
- study the solar wind (properties at great distances from the sun, mode of interaction with the planets, outer boundary of its flow)
- determine the composition, energy spectra and cosmic-ray fluxes in interstellar space.

IN BRIEF

Explorer 41, the seventh in the International Monitoring Platform series, was launched on 21 June. The satellite carries 12 experiments to study solar plasma, magnetic fields and cosmic rays. □