Lawrence Berkeley National Laboratory

Recent Work

Title

A CLOUD CHAMBER FOR THE STUDY OF PARTICLES OF LOW ENERGY

Permalink

<https://escholarship.org/uc/item/051817w3>

Authors

Merkle, T. C.

Need, J. L.

Publication Date

1952-11-06

UNCLASSIFIED

UCRL-1995

Unclassified-Instrumentation Distribution

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-eng-48

A CLOUD CHAMBER FOR THE STUDY OF PARTICLES OF LOW ENERGY

T. C. Merkle and J. L. Need

November 6, 1952

Berkeley, California

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

A CLOUD CHAMBER FOR THE STUDY OF PARTICLES OF LOW ENERGY

T. C. Merkle¹ and J. L. Need²

Radiation Laboratory, Department of Physics
University of California, Berkeley, California

November 6, 1952

ABSTRACT

A cloud chamber with a magnetic selection favoring low energy particles is discussed. Technical aspects of shielding, expansion, mechanism, sweeping field, and poisoning troubles are included. Discussion of the present mode of operation for a study of π^- capture in helium is given.

1. Physics Department, and Radiation Laboratory, University of California, Berkeley, California
2. Radiation Laboratory, University of California, Berkeley, California

A CLOUD CHAMBER FOR THE STUDY OF PARTICLES OF LOW ENERGY

T. C. Merkle and J. L. Need

Radiation Laboratory, Department of Physics,
University of California, Berkeley, California

November 6, 1952

In many problems of nuclear physics it would be convenient to study processes which occur as an ionizing particle is brought to rest in a gas. Such a requirement suggests that a cloud chamber would be the natural instrument to select. However, unless very high pressures may be employed, the probability of stopping a particle in a cloud chamber of reasonable proportions is quite small. A cloud chamber built into a magnetic selection device has been developed and is currently being used in a study of the capture of π^- mesons at rest by helium nuclei. An assembly drawing of the cloud chamber portion of the apparatus is shown in Fig. 1.

The important dimensions of this chamber are: height 19 inches, diameter 18 inches, glass cylinder diameter 16 inches, height of cylinder six inches, depth of illuminated region three inches, copper base thickness two and 3/4 inches, neutron and scattered particle shield thickness five inches.

In this apparatus, the particles to be studied are produced in a target located in the base block of the cloud chamber. This target may be easily changed or removed during operation. Since the entire apparatus is located in a magnetic field produced by a pair of Helmholtz coils, some of the particles produced (in the present case mesons) will follow helical paths from the target into the illuminated region of the chamber. By suitable adjustment of the magnitude of the magnetic field and the channel angle in relation to the stopping power of the chamber gas, some of these particles will come to rest in the illuminated region. Particles which are too energetic will pass out through the chamber walls below the illuminated region and thus will not create visible background, while particles of too low an energy will fail to advance into the illuminated region, with the same result. For π^- mesons stopping in helium of about 1-1/3 atmo-

spheres pressure, a field of about 7,000 gauss is a good value.

In order to increase further the probability of capture we have, following a suggestion made by Prof. Wilson M. Powell, distorted the field due to the Helmholtz coils by decreasing the ampere turns in the rear coil to one-half that of the front. This distortion results in a field which increases from the target to the illuminated region by about fifteen percent. Such an increasing field causes the spiral trajectory to rise upward into the illuminated region of the chamber, and then to sink again as the particle comes to rest. Thus the time spent by a particle in the illuminated region is increased, and a longer trajectory is available for measurement. Since a meson loses energy rather rapidly near the end of its range, the trajectories are, when seen in projection, spirals rather than circles. Thus mesons which stop in the chamber usually come to rest approximately half way between the center and the chamber wall. Fig. 2 shows a negative π meson and a positive μ meson stopping in the gas.

When the 340 Mev protons from the 184-inch cyclotron strike the target, a large number of ionizing particles are emitted. These ionizing particles may be scattered protons, high energy mesons, and star fragments. All of these particles are stopped by the lower half of the proton and meson shield shown in the drawing. Protons scattered by the air in the path of the main beam within the chamber diameter are effectively stopped by the copper base of the chamber. However, neutrons are also made in the target in considerable quantity. These neutrons diffuse through the copper shield and, when the chamber is full of helium, produce a large number of low energy recoil helium nuclei in the illuminated region. These recoil alpha particles were observed to be principally of a few Mev energy. For this reason the upper half of the neutron shield was installed, and it produced a sufficient attenuation of these neutrons. It seems likely that protons scattered through small angles by the target impinge upon the copper base and create a large number of nuclear gamma rays. These gamma rays convert in the copper and the electrons and positrons so produced spiral upward, with small radius, around the magnetic flux lines and enter the chamber. This background is fortunately not excessive.

These shielding requirements make it impossible to construct the cloud chamber along conventional lines. Thus the usual expansion mechanisms have been replaced by a transparent lucite piston sealed to the main body of the chamber by a 1/32 inch thick rubber sleeve as shown in Fig. 1. The back of the chamber is now the top, and is made of a slab of lucite. Thus the camera views the chamber through the expansion mechanism from the top. Air pressure between the piston and the lucite plate is maintained by a commercial pressure regulator so that the expansion ratio is pressure controlled rather than volume controlled. Of course, in the compressed position the plane of the piston is not necessarily parallel to the front lucite. In the original design, three long rods were let into the chamber through Wilson seals in the base. These rods could be adjusted so that in the compressed position the piston was lightly pushed against the ends of the rods. In this way the initial position of the piston could be set parallel with the final position. However, for the rather low expansion rates (90 milli-sec.) which are satisfactory for the present experiments, the rods have not been found necessary. Since the air used to compress the chamber is supplied by the usual building compressors, a glass wool filter has been placed in the air line. With this arrangement no objectionable deposits were formed on either the front glass or transparent piston during several days of continuous operation. Expansion is accomplished through two one inch diameter rubber hoses about four feet in length, which lead from the front of the chamber to an expansion valve. This valve is released by a magnetic device located outside the stray field of the coils.

One of the major problems encountered in operating the cloud-chamber in the presence of relatively large amounts of ionizing radiation was the provision of a suitable clearing field. To obtain rapid removal of excess ions before expansion, rather large sweeping potentials are used. (400 to 700 volts across a six inch gap). These potentials, particularly in a water vapor chamber, can and do cause conduction along damp glass and rubber surfaces. Under some conditions these conduction currents appear to be associated with a heavy condensation background in the chamber. In this particular chamber, the positive

side of the clearing field is provided by a brass ring at the top of the glass cylinder, and to break conduction paths lucite spacer rings, somewhat smaller in inner diameter than the brass ring, were installed on each side of the clearing field ring. With such an arrangement considerable track "bleeding" was encountered. This bleeding appeared to be due to static charge accumulation on the glass cylinder, and could be greatly reduced by mounting a grounded guard ring at the top of the glass cylinder.

Water vapor was used as the condensable gas in order to keep nuclei other than helium at a minimum. For a chamber of this size operated on its side, it was found necessary to install pads around the inside of the glass cylinder below the level of the light beam so that by capillary action a large surface to return water vapor to the upper region of the chamber was available. With such pads on the sides and bottom of the chamber it is possible to expand the chamber once every two minutes in the presence of large ion background and still maintain reasonable condensation conditions over the entire chamber volume. With shorter cycle times the water vapor is gradually removed from the upper part of the chamber so that track condensation becomes uncertain.

When this chamber was being placed in operation for the first time, a very stubborn form of poisoning was encountered. Since this particular difficulty was finally found to have a definite set of symptoms it may be worthy of mention here. The symptoms were:

1. A heavy background beginning at the negative ion limit, becoming a complete fine fog at the positive ion limit.
2. This fog may be removed by slow expansions or by fast expansions below the negative ion limit.
3. Electron tracks made by a gamma ray source may not, and usually are not, visible at any expansion ratio.
4. This background of fog shows very little response to clearing fields as high as five kilo-volts across a six inch gap. Striations are visible in the background at potentials of the order of a few hundred volts.
5. If the chamber is operated in total darkness, near the negative ion limit, and a tungsten filament viewing light turned on briefly

after the fast expansion, fair performance with low background may be obtained. Water cells and thick sheets of glass placed in the path of the viewing light have no effect on this photo-sensitivity. The effect does not seem to be a photo effect on any of the surfaces of the chamber since it frequently appears to be strongest in the path of the light beam. Further, the same chamber, with the same conditions on the same day did not show this phenomena when filled with oxygen. Moreover, changing polarity of the clearing field had no effect. The photo effect was noticed to increase roughly with increasing duration of the viewing light. In addition it was observed to be considerably larger on several occasions when the viewing light was on for a short time during a slow expansion.

6. In this particular case the phenomena is presumed to have been associated with the helium used since nitrogen, oxygen, argon, and air did not show these effects in the chamber under the same conditions. This helium was of the best commercially available (oil free) grade, and several different bottles showed the same phenomena, though many bottles used since have not.

7. Filtering the helium through liquid air traps filled with activated charcoal produced no effect. Passing the helium over hot copper oxide had no effect. Washing by passage through a water bubbling tower had no effect.

8. When the helium was filtered by passage through four sintered glass filters in series (finest grade) which had distilled water standing over the filters it gave very good results up to the positive ion limit.

Filtering through several layers of a special aerosol filter paper developed during the war for gas masks also seems to be effective.

While no final conclusions may be drawn until further "bad" bottles become available for experiment, the evidence on hand seems to indicate that the helium contained a fine aerosol as a contaminant. Aerosols of small particle size (of the order of three microns) are not readily removed by charcoal or liquid air filters, nor are they usually shown in a mass-spectrographic analysis. Further, quantities of the order of a few parts per million by weight can produce to an enormous number of condensation centers when the individual particle size is small. It is

not impossible that such particles could be photo sensitive in the visible portion of the spectrum so that large ions are created in considerable quantity in the gas by the action of visible light. These would not be removed by a large clearing field. Perhaps, indeed, a cloud chamber might be an exceedingly sensitive device for the study of photo-chemical processes occurring in aerosols.

Under normal cosmic ray background it is possible to operate this cloud chamber many hours without slow expansions. However, when used with the proton beam, good operation required two slow expansions per cycle

The advantages of this type of cloud chamber arrangement may be summarized as follows:

1. Relatively large solid angle for the observation of particles.
(About one steradian in this particular case.)
2. Strong selection favoring the observation of particles of low energy.
3. Production of the particles within the magnetic field so that large fields may be used, thus increasing the precision of magnetic rigidity measurements.
4. Complete symmetry for positive and negative particles produced at one time.
5. Production target close to viewing region so that particles of small lifetime may be observed.
6. Sufficient freedom from background so that particles resulting from a small production cross section may be observed in the presence of other radiation.

In conclusion we wish to express our indebtedness to Professor W. M. Powell for his constant and enthusiastic interest in this work. This development was in part supported by the Atomic Energy Commission.

Figure Captions

- Fig. 1 Plan view of the cloud chamber apparatus. Diameter is 18 inches. The height is about 19 inches.
- Fig. 2 Unretouched photograph showing two mesons which stop in the cloud chamber. The upper spiral is a μ^+ meson. The lower spiral is a π^- meson which is captured.
- Fig. 3 Photograph of the cloud chamber without coils and expansion valve.

Fig. 1

ZN-480

Fig. 2

Fig. 3