The Pulse

For the Personnel of the Laboratory for Nuclear Science

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STS-91

"Instead of being at the focus of the Universe, we sit on a fragile perch, looking up towards a large scale structure of galaxies, clusters and superclusters, measured in terms of many powers of ten, even when expressed in light-years, and downward towards a deep interior of atoms, nuclei, particles and quarks, measured in terms of just as many inverse powers of ten. With this new humility, mankind makes use of the limited means at our disposal, extended as best we can by our own ingenuity, to investigate this grand picture."

--Gordon Fraser

The Status

The Space Shuttle Discovery made a graceful landing on Friday, June 12 after 10 days in space. The Alpha Magnetic Spectrometer was flown on Discovery for checkout and initial data prior to a 3-year mission on the International Space Station. Although the main data-transmission channel on the Shuttle did fail, so all the data from AMS could not be transmitted to earth during the flight, the data were stored on disk and are now available for analysis by the AMS group. About 15 percent of the data was transmitted to earth during the mission and the detector was determined to be working well. The partial transmission was accomplished by activating a normally unused channel. The activation of this channel was accomplished by the astronauts on board.

The Collaboration

The AMS project is led by Prof. Samuel C.C. Ting and his MIT colleagues Ulrich Becker and Peter Fisher. The collaboration includes 38 research institutions in (with lead collaborators): China (H.S. Chen), Finland (J. Torsti), France (J.P. Vialle), Germany (K. Luebelsmeyer), Italy (R. Battiston), Portugal (G. Barreira), Romania (A. Mihul), Russia (Y. Galaktionov), Spain (C. Mana), Switzerland (M. Bourquin, H. Hofer), Taiwan (S.C. Lee), and the United Kingdom (R. Marshall).

The Background

In 1995 Prof. Ting's research proposal for the AMS space experiment was formally peer reviewed by DOE. The panel included Robert K. Adair, Yale; Barry C. Barish, Caltech; Stephen L. Olsen, Hawaii; Malvin A. Ruderman, Columbia; David N. Schramm, Chicago; George F. Smoot, Berkeley; and Paul J. Steinhardt, Pennsylvania. The distinguished panel strongly endorsed the project. Ting, together with many of his collaborators from L3, began constructing the 3 1/2 ton detector. Prof. Ting has received many awards and honors for his research, including the Nobel Prize in Physics in 1976 for the discovery of the "J" particle. The AMS experiment is the first of a new generation of space-based experiments which use particles instead of light to study the Universe.

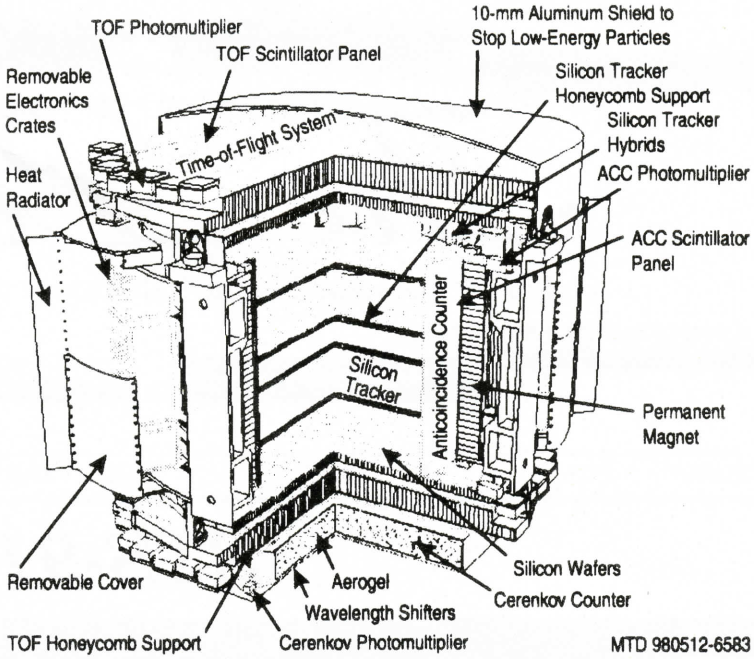
The Design

The Alpha Magnetic Spectrometer was the first large magnetic spectrometer ever placed in Earth's orbit. The scientific goal is to increase our understanding of the composition and origin of the universe. AMS is designed to search for and measure charged particles, including antimatter, outside the Earth's atmosphere. The charge of such particles can be identified only by their trajectories in a magnetic field.

AMS and How it Works

The Alpha Magnetic Spectrometer is a particle detector that consists of five major elements: a permanent magnet, time-of-flight scintillators, a silicon microstrip tracker, anticoincidence counters and an aerogel threshold Cerenkov counter. The AMS also has electronics, a support structure and interfaces to computers on the Space Shuttle and at Johnson Space Center.

The permanent magnet is a cylindrical shell made of blocks of magnetic material called neodymium-ferrous-boron. The blocks are arranged around the cylinder to create a magnetic field confined inside the magnet. The trajectory that a particle takes when it enters the magnetic field allows researchers to determine its charge.



Alpha Magnetic Spectrometer

The time-of-flight counters provide the primary trigger when a charged particle or anti-particle passes through the detector. This starts the read-out of the tracker and helps measure the particle's velocity.

The silicon microstrip tracker has 1,921 silicon sensors in six layered horizontal planes. The tracker measures the particles' trajectories.

The veto counters flag the entry of any secondary particles into the detector so the signals of these background particles can be rejected. The counters are arrayed in a cylindrical shell between the inner skin of the magnet and the tracker.

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The aerogel threshold Cerenkov counter at the bottom of the AMS enhances the detector's capability to identify particles. One hundred sixty-eight phototubes view the 10 cm thick layer of aerogel to measure its index of refraction as particles pass through. This ensures identification of anti-protons and also help distinguish positrons (anti-electrons) from other particles such as protons, pions and muons.

The electronics recognize that a particle of interest to scientists has passed through the detector, digitize the detector signals, collect the signals from the particle's passage into an "event," and transmit the event data to Earth. The electronics relay commands from Earth to the detector. They also monitor and control the detector.

The detector rests in a support structure of vertical aluminum I-beams. The entire payload weighs 9200 pounds and is mounted in the rear of the Space Shuttle payload bay.

NASA will fly AMS twice. During the STS-91 mission, AMS had 100 hours of dedicated system check-out and data gathering. During the Space Station mission, AMS will be an externally attached payload and gather data for three years. Commands will be issued and then data collected on the ground in real time. The high inclination and altitude of the Space Shuttle and Space Station missions are vital for the experiment because they provide data collection time near the geomagnetic poles where the influence of the Earth's magnetic field on inbound particles is minimized.

Additional information on the AMS, including photos and graphics, is available on the World Wide Web at: www-lns.mit.edu.

From My Desk

Five Minutes and Counting

On June 2, I watched the Discovery launch at Cape Canaveral, Florida. The shuttle was launched three miles from the press site, and the view was spectacular. Three seconds, two, one -- with a launch window of only 5 - 10 minutes, it was right on time. The STS-91 pulled away from the launch pad and then like a pause in a symphony, as the shuttle left the pad, the earth began to rumble and shake as the sound of the blast roared towards us. Up it flew, fuel crackling, red, yellow, white, like lightning and then smoke clouds across the early evening sky, six crew members on board with the Alpha Magnetic Spectrometer as a payload, the Discovery was on its way.

My first thought as it zoomed into the sky was actually about my father and how in the early 50's he would sit us before our Motorola TV and have us watch nuclear bomb tests. "This is history," he'd say. The explosion reminded me of those tests and the awesome majesty. And I also thought about my dear friend who died the morning of June 2nd after fighting cancer for 15 of her 51 years of life. She too was making her way towards the heavens. Scientific advances had not saved her life, but certainly had carried her far enough so that she could see her children grow to an age where they could be on their own. I thought about Sam Ting and how he must have been feeling as he watched an idea become reality and actually see the Discovery disappear before his eyes as it made its way to Mir and he would soon be on his way to Houston. I watched the Discovery as the fuel tanks dropped into the Atlantic Ocean. We sat quietly until the next booster rocket pushed them even further into space, until they were a speck and then we cheered. But we stayed there watching the sky for what seemed like a long time. I have watched many space launches on TV, but being there was a breathtaking experience. It increased my respect for our country and the space program. When I entered the NASA site the morning of the flight, the first building I saw on the flat land was a magnificent structure where the shuttles are built. A huge American flag is painted on the building and it reminded me of all the major advances that have been made in science and technology and I was very proud to be an American.

The AMS Collaboration has worked for three years and on a very tight schedule. The scientists and engineers from 37 different institutions world-wide have contributed their time, effort and expertise. At one of the press conferences, Russian General Yuri Glazkov, Deputy Director, Gagarin Cosmonaut Training Center said, "The people are the most critical aspect of our efforts in space."

Many staff and faculty members at LNS can take great pride in their role in the success of AMS. Maybe you helped push an invoice through, or made travel arrangements, helped with visas, ordered a special kind of equipment or tool, answered questions, worked on the budget, web page, or brochure. It is a triumph for the AMS Collaboration, and also for LNS and for the many contributions that were made by the Central Facilities staff.

-- Jean Flanagan

Send US A Postcard

We would like to know what retired folks from LNS are doing. Drop us a line, and let us know.

Reprinted from ***Tri-Town Transcript***

April 16, 1998

Three-way race for two library trustee seats

Audrey B. Iaorocci has served as Topsfield library trustee since in October 1997, appointed by the Board of Selectmen to fill a vacancy.

She is a founding member of both the Friends of the Topsfield Library (1969) and the Topsfield Council on Aging (1973). She serves as president of the Friends of the Topsfield council on Aging and was a founding member of that group in 1992. Iaorocci cited her record of community service and desire to remain on the board as reasons for running for library trustee. A Topsfield resident for 35 years, she holds a B.S. in journalism from Marquette University. She has five children and nine grandchildren.

Reprinted from the MIT Tech Talk May 6, 1998

Roman Jackiw Has been Elected for Membership in the National Academy of Sciences

Professor Jackiw has been recognized for imaginative use of quantum field theory to throw light on physical problems, including his work on topological solatons, field theory at high temperatures, the existence of anomalies and the role of these anomalies in particle physics. He seeks to uncover unexpected, subtle effects that may apply to particle, condensed matter and gravitational physics. Born in Poland, he received a bachelor's degree (1961) from Swarthmore College in Pennsylvania and a PhD (1966) from Cornell university. Professor Jackiw joined MIT as an assistant professor in 1969. He won the Dannie Heineman Prize for Mathematical Physics from the American Physical Society in 1995.

Peter T. Demos Awards

The Board of Directors of the Bates Linear Accelerator Users Group has awarded the 1996 and 1997 Peter T. Demos Awards. This is an annual graduate student achievement award in honor of Professor Peter T. Demos in recognition of his many contributions in developing and directing the Bates laboratory.

The selection is based on overall quality of the Ph. D. thesis, contributions to the Bates Center, and general performance in the field and contributions to younger students. Dr. David Barkhuff and Dr. Bryon Mueller are the winners of the 1996 and 1997 awards, respectively.

David Barkhuff's Citation: "For his essential contributions to the construction, commissioning and execution of the first Focal Plane Polarimeter project in the field of electron scattering, and for his mentoring role in training other students that worked on the project."

Bryon Mueller's Citation: "For his significant efforts in bringing the electron scattering parity-violating experiment SAMPLE to its very successful state, and for his impressive insight and personal initiative that led to major advances in the development of this ambitious experiment."

David Barkhuff (barkhuff@bates.mit.edu) is currently a postdoctoral fellow at MIT. He is a former UVa graduate student. His advisor was Prof. Robert W. Lourie.

Bryon Mueller (mueller@aspen.phy.anl.gov) is currently a postdoctoral fellow at Argonne National Laboratory. He is a former Caltech graduate student. His advisor was Prof. Robert D. McKeown.

Ask a Physicist

What is a Goldstone Boson?

You won't find them listed in the particle data tables, yet books on quantum field theory have long sections about them. A Goldstone boson (short for Nambu- Goldstone boson) is a particle with zero mass and zero spin which is predicted to exist in any theory which says the vacuum is a state of spontaneously broken symmetry (explained below). The only zero mass particles are the photon which has spin 1 and the neutrino with spin 1/2 so that rules out all such theories. End of story? Not quite. There are two ways to evade this result, both of which are important in the real world of particle physics described by the standard model. The three pions would be Goldstone bosons if the up and down quarks were massless. Since in fact these quarks are very light on the scale of the strong interactions the pions can be usefully described and their properties calculated as if they were Goldstone bosons. The W and Z are massive spin 1 particles. But a W or Z polarized along its direction of motion (a massless spin 1 particle like the photon can only be polarized at right angles to its direction of motion) is a Goldstone boson in disguise. This "Higgs phenomenon" is what makes the W and Z massive and the weak interactions weak.

Nambu and I were both trying to understand and use in particle physics the ideas of the recently (in 1960) discovered BCS theory of superconductivity. This describes the superconducting state as a condensed state of pairs of electrons, somewhat like the Bose-Einstein condensed state of helium atoms which explains superfluidity. A mysterious aspect was that the number of electrons fluctuated, even though standard quantum mechanics seemed to say this could not happen. But there is another quantity, a phase angle, which has an uncertainty relation with the electron number like the Heisenberg relation of position and momentum. The physics of the system does not change if this angle is changed. This should mean that in the lowest energy state the angle is spread over all possible values and the electron number is definite. But in a large system the symmetry under rotation of the phase angle can be spontaneously broken so that instead the angle is definite (which particular definite value does not matter, because of the symmetry) and instead the number fluctuates. This is analogous to other spontaneously broken symmetries which are common in condensed matter systems and much easier to visualize. For example in a ferromagnet all the atomic magnets line up pointing in the same direction. To predict from theory that this happens is usually difficult, but once you know it does there is a very simple consequence. You let the direction of the magnets vary slightly over a distance long compared to the distance between atoms. This must cost very little energy, which means the ferromagnet can carry long waves of low frequency. When this idea is applied to the vacuum the consequences are simpler still. Because of the principle of relativity the long, low frequency waves have to travel at the speed of light, and by the rules of quantum field theory have to correspond to massless, spinless particles, Goldstone bosons.

This idea works in the strongly interacting vacuum of quantum chromodynamics in almost exactly the way it works in superconductors. The vacuum is a condensed state of quark anti- quark pairs . In each pair the quark and the antiquark are spinning the same way about their directions of motion. What fluctuates is the number of left hand screw quarks and antiquarks minus the number of right hand screws. There is a complementary angle which takes some definite value. The long wavelength excitations are three massless pions (you find three pions when this is done with two flavors of quark). This would only work exactly with massless quarks, otherwise the screw sense of a quark changes as it travels and the picture breaks down, but it does give a good approximate picture of real pions, which are much lighter than other strongly interacting particles.

The standard theory of the electromagnetic and weak interactions has symmetries which if not spontaneously broken in the vacuum would make the weak interactions too strong and give the photon weak partners. This time, however, if the symmetries were not broken there would already be massless particles, the photon and its partners. When the symmetry is broken, as Higgs saw, all except the photon acquire an extra state of polarization and become the massive W and Z particles. Because of the underlying symmetry, many experimental results can be fit with only a small number of parameters.

There may be more to come. Supersymmetry may be the next theory to be experimentally verified. It is certainly a broken symmetry. And though no one has struck the e from my name to make goldstons, I may yet see a goldstino in the data book.

--Jeffrey Goldstone

Students from MIT Physics 8.02 class with David Barkhuff at Bates