Success of the International Collaboration

James Stone

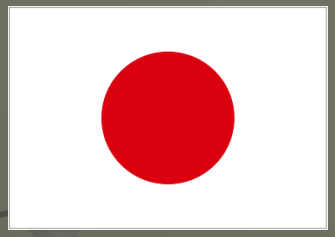
Boston University

10th Anniversary of Super-Kamiokande

May 14, 2006 Toyama

Super-Kamiokande Collaboration

Initially (1992): Japan, USA



Now Includes: Korea, China, Poland

~ 140 Scientists

~ 35 Institutions

Still Together After 14 Years …

Completion of Super-K I 1996

Completion of Super-K II 2002

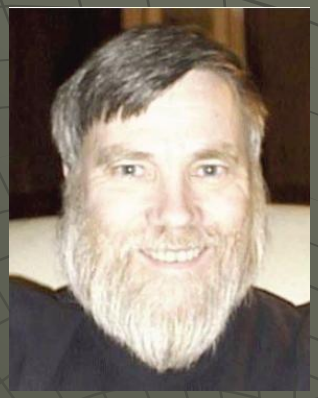
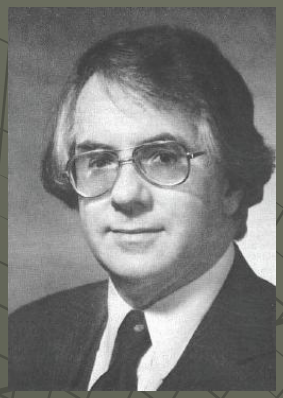
Waiting for the last train at the Mozumi entrance …

Super-K III 2006

Still Smiling …

Avalanche at the Atotsu Entrance

How it all began …

A group of theorists H. Georgi, S. Glashow, J. Pati, A. Salam and Others …

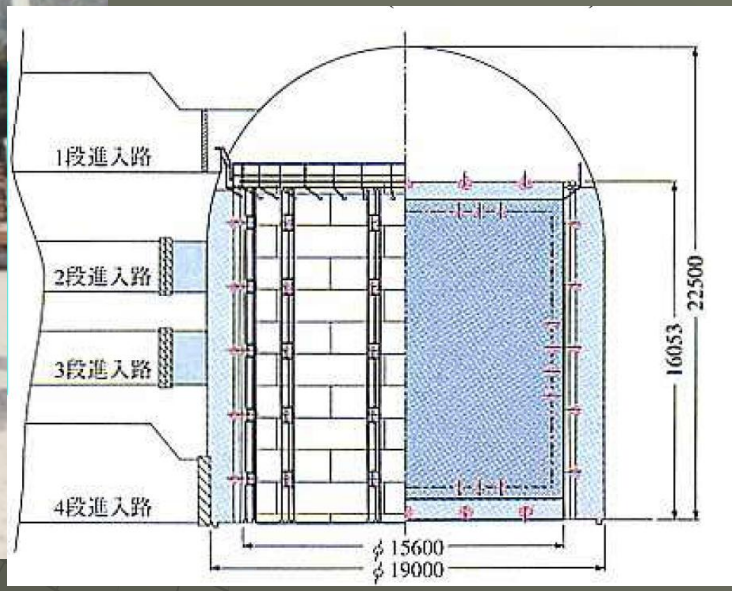
Grand Unification Theory called SU(5)

Proton Lifetime predicted to be ~$10^{29 \pm 1.7}$ years

Kamioka Nucleon Decay Experiment = Kamiokande

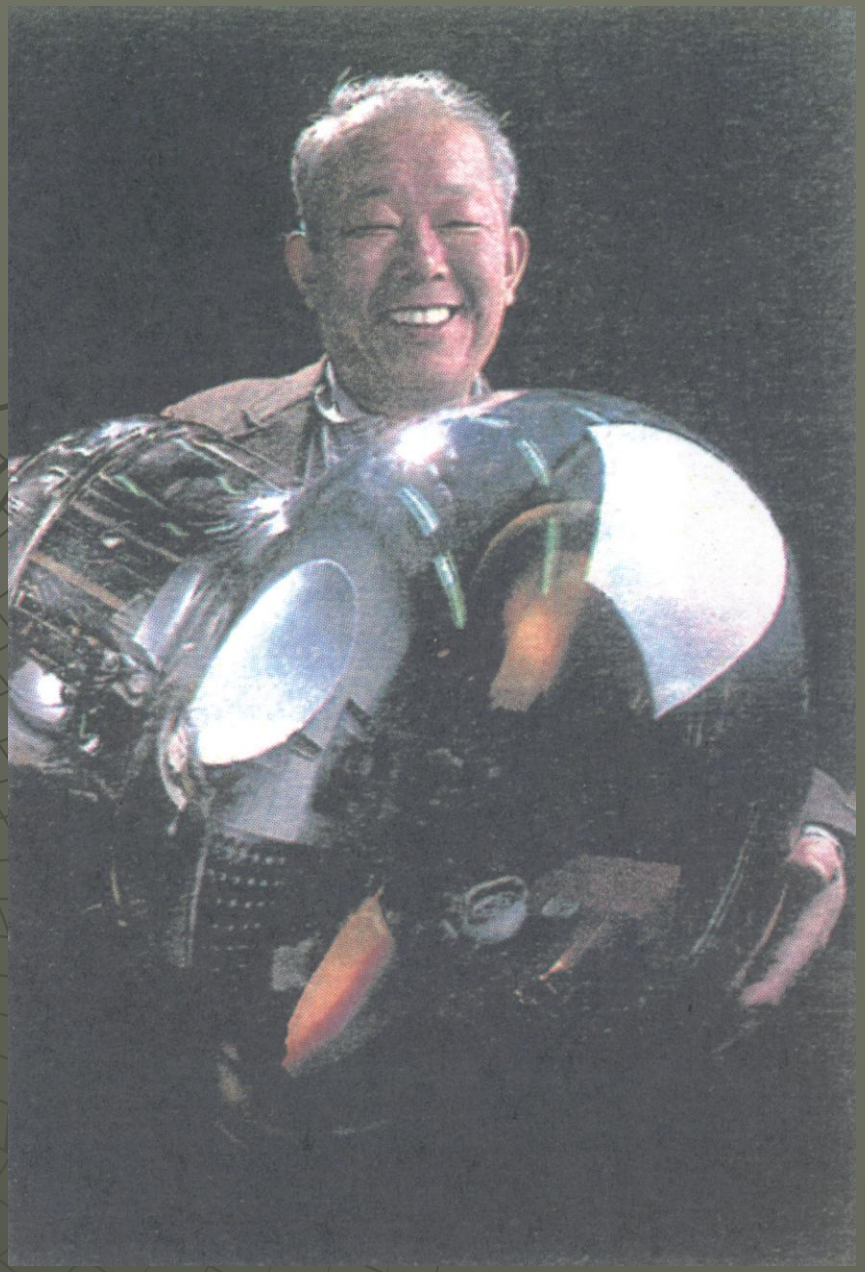
Irvine, Michigan, Brookhaven = IMB

Kamiokande Detector circa 1980 built by ICRR University of Tokyo



Masatoshi Koshiba

The initial hemispherical PMT, 50 cm diameter, was developed by ICRR, University of Tokyo and Hamamatsu Corporation.



Work at bottom of detector.

Kamiokande

Wire mesh shielded Earth's magnetic field and held PMTs in place.

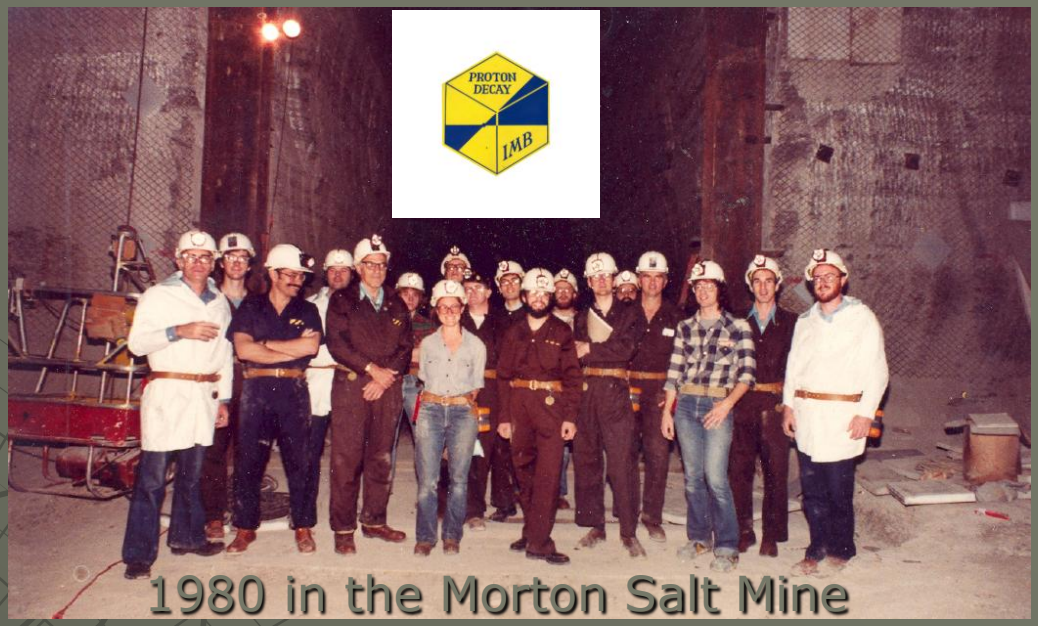
IMB Collaboration

Current members of the Irvine-Michigan-Brookhaven group are:

C. Bratton	Cleveland State U.
M. Goldhaber	Brookhaven
T.W. Jones	U. Michigan/U. College (London)
W. Kropp	U.C. Irvine
J. Learned	U.C. Irvine/U. Hawaii
J. LoSecco	U. Michigan
F. Reines	U.C. Irvine (Co-spokesman)
J. Schultz	U.C. Irvine
D. Sinclair	U. Michigan
D. Smith	U.C. Irvine
H. Sobel	U.C. Irvine
J. Stone	U. Michigan
L. Sulak	U. Michigan
J. Vander Velde	U. Michigan (Co-spokesman)

Graduate Students:

B. Cortez	Harvard/Michigan
W. Foster	Harvard/Michigan
E. Shumard	Michigan
C. Wuest	Irvine

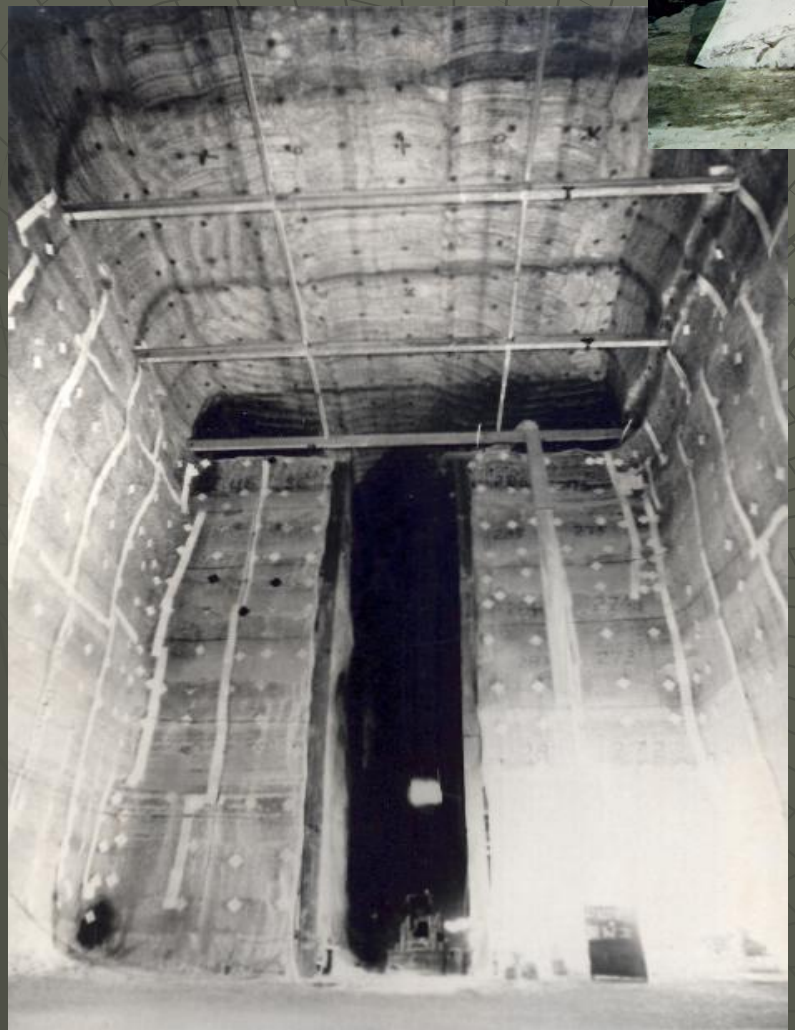


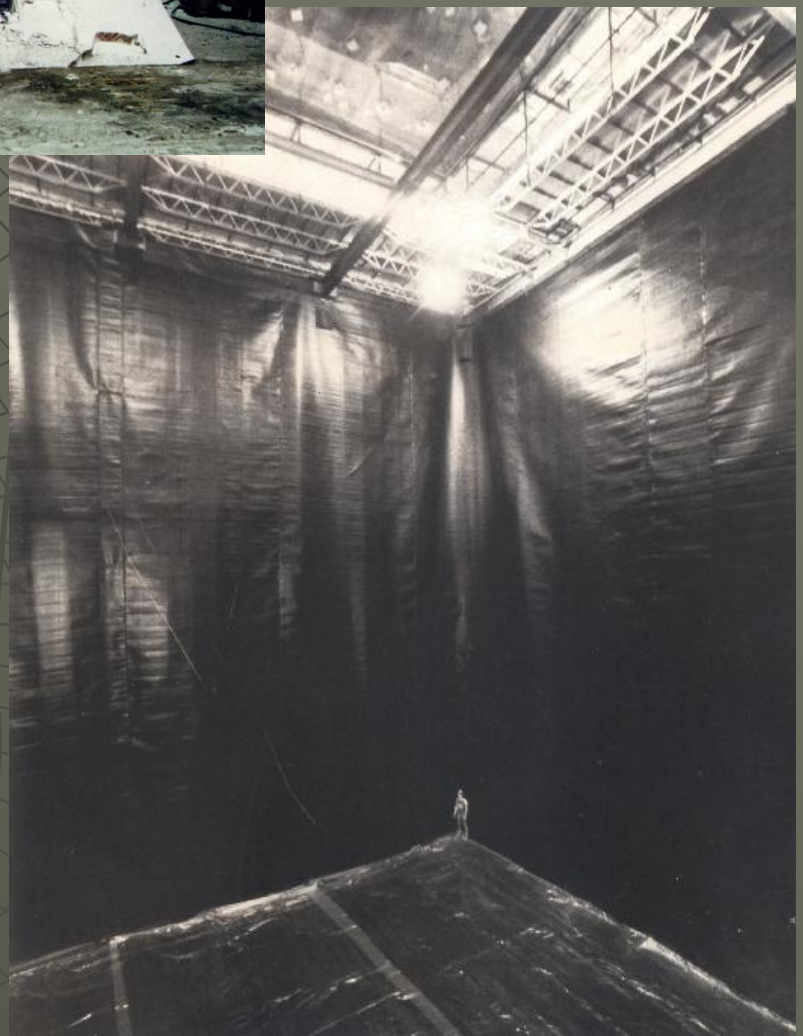
1980 in the Morton Salt Mine


1985 at UC Irvine

DOSCO Machine excavated the cavity: ~20 m x 40 m x 25 m

Two HDPE Plastic Liners form the Water Tank





Diver in IMB-III Tank

8 Inch PMTs + Waveshifter Plates

616 of these PMTs are still in Super-Kamiokande III Detector

The 1980's …

- Both IMB and Kamiokande Collaborations published many papers on the same topics.
- A friendly scientific competition spanned a decade.
- Independent scientific results made a strong impact on the physics community.

VOLUME 51, NUMBER 1 PHYSICAL REVIEW LETTERS 4 JULY 1983

Search for Proton Decay into $e^+\pi^0$

R. M. Bionta, G. Blewitt, C. B. Bratton, B. G. Cortez,[a] S. Errede, G. W. Forster,[a] W. Gajewski, M. Goldhaber, J. Greenberg, T. J. Haines, T. W. Jones, D. Kielczewska,[b] W. R. Kropp, J. G. Learned, E. Lehmann, J. M. LoSecco, P. V. Ramana Murthy,[c] H. S. Park, F. Reines, J. Schultz, E. Shumard, D. Sinclair, D. W. Smith,[d] H. W. Sobel, J. L. Stone, L. R. Sulak, R. Svoboda, J. C. van der Velde, and C. Wuest

The University of California at Irvine, Irvine, California 92717, and The University of Michigan, Ann Arbor, Michigan 48109, and Brookhaven National Laboratory, Upton, New York 11973, and California Institute of Technology, Pasadena, California 91125, and Cleveland State University, Cleveland, Ohio 44115, and The University of Hawaii, Honolulu, Hawaii 96822, and University College, London WC1E 6BT, United Kingdom

(Received 13 April 1983)

Observations were made 1570 meters of water equivalent underground with an 8000-metric-ton water Cherenkov detector. During a live time of 80 d no events consistent with the decay $p \to e^+\pi^0$ were found in
that the limit on the lifetime for bou
ratio is $\tau/B > 6.5 \times 10^{31}$ yr; for free
dence). Observed cosmic-ray muon

PACS numbers: 13.30.Eg, 11.30.Ly

IMB

Proton Decay

Kamiokande

~~SU(5)~~

Journal of the Physical Society of Japan
Vol. 54, No. 9, September, 1985, pp. 3213–3216

Search for Nucleon Decay into Charged Lepton+Mesons

Katsushi ARISAKA, Takaaki KAJITA, Masatoshi KOSHIBA, Masayuki NAKAHATA, Yuichi OYAMA, Atsuto SUZUKI, Masato TAKITA, Yoji TOTSUKA, Tadashi KIFUNE,† Teruhiro SUDA,† Kasuke TAKAHASHI†† and Kazumasa MIYANO†††

Department of Physics and ICEPP, University of Tokyo, Tokyo 113
†Institute for Cosmic Ray Research, University of Tokyo, Tokyo 188
††KEK, National Laboratory for High Energy Physics, Ibaraki 305
†††Department of Physics, University of Niigata, Niigata 950–21

(Received July 19, 1985)

With a 3000 ton water Cerenkov detector operated 2700 m.w.e. underground, 103 fully contained events were observed during a live time of 343 days. Most of the events are well interpreted as due to ν interactions. Four multi-ring events survive after applying criteria for nucleon decay. The lower limits on τ/B obtained from these data exceed 10^{31} yr (90% C.L.) for most of the possible decay modes.

VOLUME 56, NUMBER 9 PHYSICAL REVIEW LETTERS 3 MARCH 1986

Search for High-Energy Muons from Cygnus X-3

Y. Oyama, K. Arisaka,[a] T. Kajita, M. Koshiba, M. Nakahata, A. Suzuki, M. Takita, and Y. Totsuka
Department of Physics, and International Center for Elementary Particle Physics, University of Tokyo, Tokyo 113, Japan

T. Kifune and T. Suda
Institute for Cosmic Ray Research, University of Tokyo, Tokyo 188, Japan

N. Sato
Department of Astronomy, University of Tokyo, Tokyo 113, Japan

K. Takahashi
National Laboratory for High Energy Physics (KEK), Ibaraki 305, Japan

and

K. Miyano
Department of Physics, University of Niigata, Niigata 950-21, Japan
(Received 15 October 1985)

A total of 1.9×10^{6} good-quality high-energy muon events were analyzed from the data of the underground Kamioka nucleon-decay experiment. No definite sign of excess flux was observed in the direction of Cygnus X-3 and in its phase interval of 0.7 to 0.8. The 90%-C.L. (confidence level) upper limit for the excess flux is 2.2×10^{-12} cm^{-2} sec^{-1} for rock overburden greater than 2400 m of water equivalent.

Kamiokande

Cygnus X-3

IMB

PHYSICAL REVIEW D VOLUME 36, NUMBER 1 1 JULY 1987

Underground search for muons correlated with Cygnus X-3

R. M. Bionta,[l] G. Blewitt,[d] C. B. Bratton,[e] D. Casper,[b,n] A. Ciocio,[n] R. Claus,[n] M. Crouch,[i] S. T. Dye,[f] S. Errede,[j] G. W. Foster,[o] W. Gajewski,[a] K. S. Ganezer,[a] M. Goldhaber,[c] T. J. Haines,[a] T. W. Jones,[g] D. Kielczewska,[h] W. R. Kropp,[a] J. G. Learned,[f] J. M. LoSecco,[m] J. Matthews,[b] H. S. Park,[k] L. R. Price,[a] F. Reines,[a] J. Schulz,[a] S. Seidel,[b,n] E. Shumard,[p] D. Sinclair,[b] H. W. Sobel,[a] J. L. Stone,[n] L. Sulak,[n] R. Svoboda,[a] G. Thornton,[b] J. C. van der Velde,[b] and C. Wuest[l]
[a]*The University of California, Irvine, California 92717*
[b]*The University of Michigan, Ann Arbor, Michigan 48109*
[c]*Brookhaven National Laboratory, Upton, New York 11973*
[d]*California Institute of Technology, Pasadena, California 91125*
[e]*Cleveland State University, Cleveland, Ohio 44115*
[f]*The University of Hawaii, Honolulu, Hawaii 96822*
[g]*University College, London WC1E 8BT, United Kingdom*
[h]*Warsaw University, Warsaw PL-00-681, Poland*
[i]*Case Western Reserve, Cleveland Ohio 44106*
[j]*The University of Illinois, Urbana, Illinois 61801*
[k]*University of California, Berkeley, California 94720*
[l]*Lawrence Livermore National Laboratory, Livermore, California 94550*
[m]*Notre Dame University, Notre Dame, Indiana 46556*
[n]*Boston University, Boston, Massachusetts 02215*

VOLUME 58, NUMBER 14 PHYSICAL REVIEW LETTERS 6 APRIL 1987

Observation of a Neutrino Burst from the Supernova SN1987A

K. Hirata,[a] T. Kajita,[a] M. Koshiba,[a,b] M. Nakahata,[b] Y. Oyama,[b]
N. Sato,[c] A. Suzuki,[b] M. Takita,[b] and Y. Totsuka[a,c]
University of Tokyo, Tokyo 113, Japan

T. Kifune and T. Suda
Institute for Cosmic Ray Research, University of Tokyo, Tokyo 118, Japan

K. Takahashi and T. Tanimori
National Laboratory for High Energy Physics (KEK), Ibaraki 305, Japan

K. Miyano and M. Yamada
Department of Physics, University of Niigata, Niigata 950-21, Japan

E. W. Beier, L. R. Feldscher, S. B. Kim, A. K. Mann, F. M. Newcomer, R. Van Berg, and W. Zhang
Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104

and

B. G. Cortez[d]
California Institute of Technology, Pasadena, California 91125
(Received 10 March 1987)

A neutrino burst was observed in the Kamiokande II detector on 23 February 1987, 7:35:35 UT (±1 min) during a time interval of 13 sec. The signal consisted of eleven electron events of energy 7.5 to 36 MeV, of which the first two point back to the Large Magellanic Cloud with angles 18° ± 18° and 15° ± 27°.

Kamiokande

Supernova 1987A

IMB

VOLUME 58, NUMBER 14 PHYSICAL REVIEW LETTERS 6 APRIL 1987

Observation of a Neutrino Burst in Coincidence with Supernova 1987A in the Large Magellanic Cloud

R. M. Bionta,[12] G. Blewitt,[4] C. B. Bratton,[5] D. Casper,[2,14] A. Ciocio,[14] R. Claus,[14] B. Cortez,[16]
M. Crouch,[9] S. T. Dye,[6] S. Errede,[10] G. W. Foster,[15] W. Gajewski,[1] K. S. Ganezer,[1]
M. Goldhaber,[3] T. J. Haines,[1] T. W. Jones,[7] D. Kielczewska,[1,8] W. R. Kropp,[1] J. G. Learned,[6]
J. M. LoSecco,[13] J. Matthews,[2] R. Miller,[1] M. S. Mudan,[7] H. S. Park,[11] L. R. Price,[1]
F. Reines,[1] J. Schultz,[1] S. Seidel,[2,14] E. Shumard,[16] D. Sinclair,[2] H. W. Sobel,[1] J. L. Stone,[14]
L. R. Sulak,[14] R. Svoboda,[1] G. Thornton,[2] J. C. van der Velde,[2] and C. Wuest[12]
[1]*The University of California, Irvine, Irvine, California 92717*
[2]*The University of Michigan, Ann Arbor, Michigan 48109*
[3]*Brookhaven National Laboratory, Upton, New York 11973*
[4]*California Institute of Technology, Jet Propulsion Laboratory, Pasadena, California 91109*
[5]*Cleveland State University, Cleveland, Ohio 44115*
[6]*The University of Hawaii, Honolulu, Hawaii 96822*
[7]*University College, London WC1E6BT, United Kingdom*
[8]*Warsaw University, Warsaw, Poland*
[9]*Case Western Reserve University, Cleveland, Ohio 44106*
[10]*The University of Illinois, Urbana, Illinois 61801*
[11]*The University of California, Berkeley, California 94720*
[12]*Lawrence Livermore National Laboratory, Livermore, California 94550*
[13]*The University of Notre Dame, Notre Dame, Indiana 46556*
[14]*Boston University, Boston, Massachusetts 02215*
[15]*Fermi National Accelerator Laboratory, Batavia, Illinois 60510*
[16]*AT&T Bell Laboratories, Summit, New Jersey 07910*
(Received 13 March 1987)

A burst of eight neutrino events preceding the optical detection of the supernova in the Large Magellanic Cloud has been observed in a large underground water Cherenkov detector. The events span an interval of 6 s and have visible energies in the range 20–40 MeV.

The Early 1990's …

- Low energy threshold becomes important for supernovae neutrinos and solar neutrinos.
- IMB's small PMTs not competitive for this physics.
- Easter weekend, 1991, IMB tank developed a leak that caused much damage to the detector. IMB Finished.

INSTITUTE FOR COSMIC RAY RESEARCH

ICRR

UNIVERSITY OF TOKYO

Now funded!

ICRR-Report-227-90-20

SUPER-KAMIOKANDE

Y. Totsuka

(Dec. 1990)

Invited talk presented at the International Symposium on Underground Physics Experiments, at Science Council of Japan, April, 1990

3-2-1 Midori-cho Tanashi, Tokyo 188 Japan

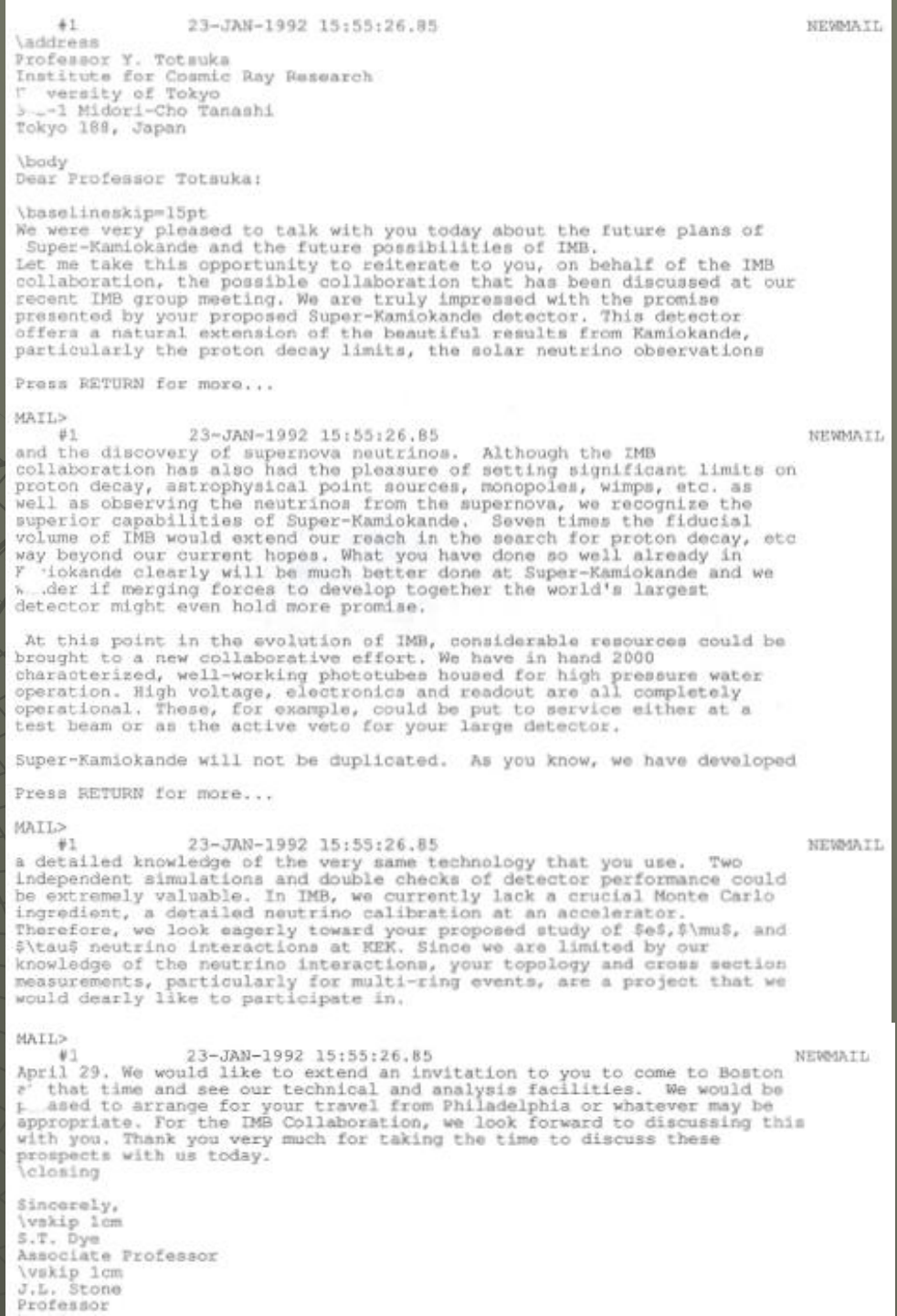
Telephone (0424)-61-4131, Telefax (0424)-68-1438

First Contact

Email sent to Professor Totsuka on January 23, 1992 follows a conference phone call the previous night.

IMB proposed:

- Merge forces on Super-Kamiokande
- Use IMB PMTs to build anti-detector (outer)
- Independent simulations
- Work on KEK beam test
- Visit Japan
- Totsuka to visit Boston



#1 23-JAN-1992 15:55:26.85 NEWMAIL

\address
Professor Y. Totsuka
Institute for Cosmic Ray Research
[illegible] versity of Tokyo
[illegible]-1 Midori-Cho Tanashi
Tokyo 188, Japan

\body
Dear Professor Totsuka:

\baselineskip=15pt
We were very pleased to talk with you today about the future plans of Super-Kamiokande and the future possibilities of IMB. Let me take this opportunity to reiterate to you, on behalf of the IMB collaboration, the possible collaboration that has been discussed at our recent IMB group meeting. We are truly impressed with the promise presented by your proposed Super-Kamiokande detector. This detector offers a natural extension of the beautiful results from Kamiokande, particularly the proton decay limits, the solar neutrino observations

Press RETURN for more...

MAIL>
#1 23-JAN-1992 15:55:26.85 NEWMAIL

and the discovery of supernova neutrinos. Although the IMB collaboration has also had the pleasure of setting significant limits on proton decay, astrophysical point sources, monopoles, wimps, etc. as well as observing the neutrinos from the supernova, we recognize the superior capabilities of Super-Kamiokande. Seven times the fiducial volume of IMB would extend our reach in the search for proton decay, etc way beyond our current hopes. What you have done so well already in [illegible]iokande clearly will be much better done at Super-Kamiokande and we [illegible]der if merging forces to develop together the world's largest detector might even hold more promise.

At this point in the evolution of IMB, considerable resources could be brought to a new collaborative effort. We have in hand 2000 characterized, well-working phototubes housed for high pressure water operation. High voltage, electronics and readout are all completely operational. These, for example, could be put to service either at a test beam or as the active veto for your large detector.

Super-Kamiokande will not be duplicated. As you know, we have developed

Press RETURN for more...

MAIL>
#1 23-JAN-1992 15:55:26.85 NEWMAIL

a detailed knowledge of the very same technology that you use. Two independent simulations and double checks of detector performance could be extremely valuable. In IMB, we currently lack a crucial Monte Carlo ingredient, a detailed neutrino calibration at an accelerator. Therefore, we look eagerly toward your proposed study of e,μ, and τ neutrino interactions at KEK. Since we are limited by our knowledge of the neutrino interactions, your topology and cross section measurements, particularly for multi-ring events, are a project that we would dearly like to participate in.

MAIL>
#1 23-JAN-1992 15:55:26.85 NEWMAIL

April 29. We would like to extend an invitation to you to come to Boston [illegible] that time and see our technical and analysis facilities. We would be [illegible]ased to arrange for your travel from Philadelphia or whatever may be appropriate. For the IMB Collaboration, we look forward to discussing this with you. Thank you very much for taking the time to discuss these prospects with us today.
\closing

Sincerely,
\vskip 1cm
S.T. Dye
Associate Professor
\vskip 1cm
J.L. Stone
Professor

Response from Professor Totsuka

Excerpted from letter dated: 2/17/92

The summary of our discussions are;

(1) We are in general quite positive to organize an international collaboration for the Super-Kamiokande experiment, especially to collaborate with the IMB group, which we greatly respect for their excellent achievements on proton decay and neutrino physics.

(2) Obviously the collaborating people must agree on the importance of the physics goals, and the design of the Super-Kamiokande detector.

(3) It is indeed a very good idea to have the anti-counters from the beginning by help of the foreign participation. In this respect we welcome your proposal of bringing the IMB inventories to Kamioka.

(4) Of course there are many technical details that have to be worked out. Therefore, we welcome some of you from Boston and Irvine to come to the ICRR, Tokyo and to see the Kamioka facility. We like to discuss the matters that were already addressed in your conversation with Yoichiro Suzuki.

(5) Also we would like to discuss with you on the initial beam-test experiment (with e and μ beams) scheduled in 1993 (construction in 1992).

(6) Sometime later when we are agreeable on the technical points, we would like to discuss the issues related to

(i) a possible contract between your institute(s) and ours,

(ii) a structure of the collaboration, such as the role of the collaboration meeting, etc.

Sincerely yours

Yoji Totsuka

The First Celebration …

At ICRR Tanashi Campus in spring of 1992, our agreement to work together on Super-Kamiokande and to prepare a formal collaboration document is celebrated.

Collaboration Agreement Signed October 18, 1992 in Takayama

SuperKamiokande Collaboration
Agreement Between the Collaborating Groups

Purpose

The purpose of this document is to define the terms and conditions under which the collaborating groups (at present Japanese and American) agree to work together in building and operating a 50,000 ton water Cherenkov detector at the Kamioka mine. The experiment shall be known as SuperKamiokande. The goals of the experiment include a search for nucleon decay, atmospheric neutrino studies, solar neutrinos, and studies of/searches for other astrophysical and particle physics phenomena. It is agreed that all collaborating groups are free to participate in all aspects of the experiment.

History

The SuperKamiokande (SK) project was initially considered and later materialized in a detailed form by M. Koshiba and his collaborators in 1984. After many years of intense effort, the full project was funded by the Japanese Ministry of Education, Science, and Culture in 1991. The final design and production of various detector parts started the same year.

In February 1992, some members of the IMB Collaboration called the SK Spokesman (Y. Totsuka) and expressed an interest in joining the SK Collaboration.

Several meetings and discussions have followed the initial February 1992 contact by the IMB group. This agreement is the result of our efforts to merge the two largest water Chrenkov groups in the world for the purpose of building and operating SuperKamiokande.

Organization of the Collaboration

The SK Collaboration has 4 levels of organization:

1) Spokesman (Yoji Totsuka)
2) Executive Committee (Initially, Y. Totsuka, K. Nakamura, A. Suzuki, H. Sobel, and J. Stone)
3) Collaboration Council (Defined below)
4) Collaboration Meeting (All Collaborators)

Signatures

Yoji Totsuka — 10/18/92 — Date
Institute for Cosmic Ray Research - University of Tokyo
Spokesman for the SuperKamiokande Collaboration

Atsuto Suzuki — 10/18/92 — Date
KEK

Kenzo Nakamura — 18 — Date
Institute of Cosmic Ray Research
University of Tokyo

Members of the Executive Committee

Henry Sobel — 10/18/92 — Date
University of California - Irvine

James Stone — 18 Oct 92 — Date
Boston University

Members of the Executive Committee

Masatoshi Koshiba — Oct. 18, 92 — Date
Tokai University

John Learned — 18 — Date
University of Hawaii

Teruhiro Suda — Oct 20, '92 — Date
Kobe University

Todd Haines — 20 Oct 92 — Date
University of Maryland

Kazumasa Miyano — 10/18/92 — Date
Niigata University

Robert Svoboda — 19 Oct 92 — Date
Louisiana State University

Yorikiyo Nagashima — 10/18/92 — Date
Osaka University

Clyde B. Bratton — 20 Nov — Date
Cleveland State University

The first project performed together as a Collaboration was the KEK Beam Test

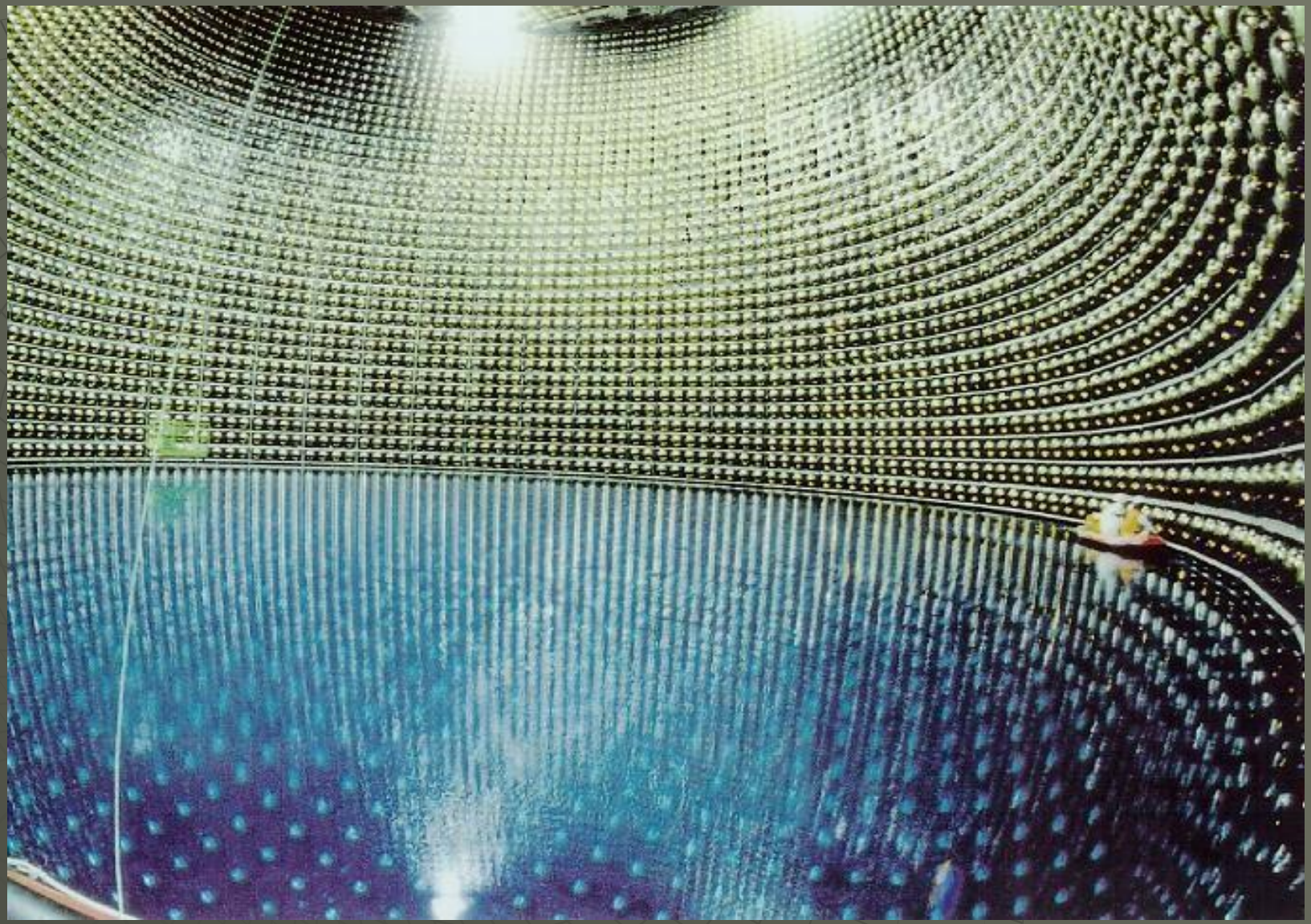
ca. 1993 - 95

This test served as a detailed calibration of the 50 cm diameter PMTs used in Kamiokande and 8 inch PMTs used in the IMB Experiments.

Construction and Work in the SuperK Tank …

Dates from ca.
1994 - 95

Outer Space – Inner Space



Measures of success for a Collaboration can be many things:

VOLUME 81, NUMBER 8 PHYSICAL REVIEW LETTERS 24 AUGUST 1998

Evidence for Oscillation of Atmospheric Neutrinos

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(Super-Kamiokande Collaboration)

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We present an analysis of atmospheric neutrino data from a 33.0 kton yr (535-day) exposure of the Super-Kamiokande detector. The data exhibit a zenith angle dependent deficit of muon neutrinos which is inconsistent with expectations based on calculations of the atmospheric neutrino flux. Experimental biases and uncertainties in the prediction of neutrino fluxes and cross sections are unable to explain our observation. The data are consistent, however, with two-flavor $\nu_\mu \leftrightarrow \nu_\tau$ oscillations with $\sin^2 2\theta > 0.82$ and $5 \times 10^{-4} < \Delta m^2 < 6 \times 10^{-3}$ eV^2 at 90% confidence level. [S0031-9007(98)06975-0]

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