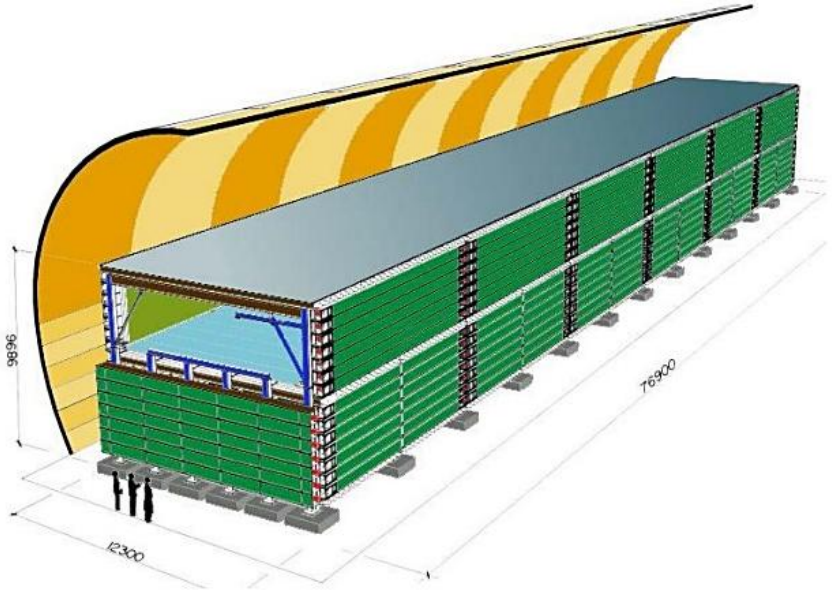
Back to the Pre-MACRO days: Theory and Experiment

MACRO Reunion, L'Aquila and Gran Sasso, June 27, 2025, Steve Ahlen

Kajita's colorized sketch of MACRO from Nobel Lecture



LNGS showing high road to L'Aquila

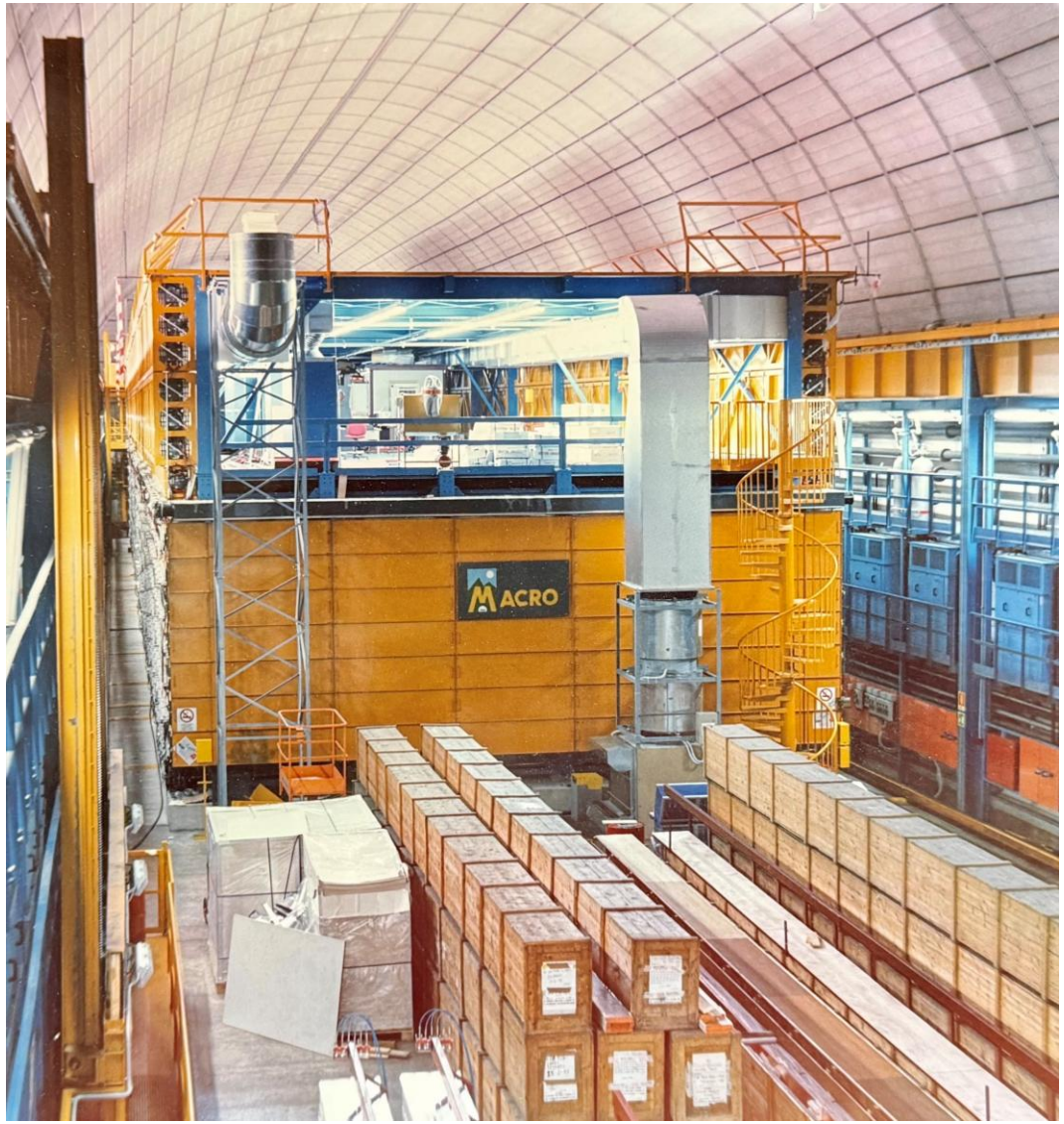


Photo of MACRO from Jim Stone

Key Monopole Theory Developments Before MACRO

- **1931**: **P. Dirac**, quantization of charge.
- **1951**: **J. Schwinger**, pair production in strong fields.*
- **1969**: **J. Schwinger**, dyons, and a magnetic model of matter.
- **1974**: **H. Georgi and S.L. Glashow**, SU(5) GUT.
- **1974**: **G. ‘t Hooft and A.M. Polyakov**, GUT monopoles.
- **1979**: **J. Preskill**, the monopole problem.
- **1981**: **A. Guth**, Inflation.

***Non-perturbative cross section calculation enables lower limit on monopole mass. Sensitivity of about 2.5 TeV at FCC-hh (100 TeV collision energy, 2070-2095), possibly in the range of electroweak monopoles. Mass limit M > 80-120 GeV has been set with ATLAS at the LHC in 2025.**

Lecture Notes 9

THE MAGNETIC MONOPOLE PROBLEM

Physics 8.286: The Early Universe
Prof. Alan Guth

November 29, 2018

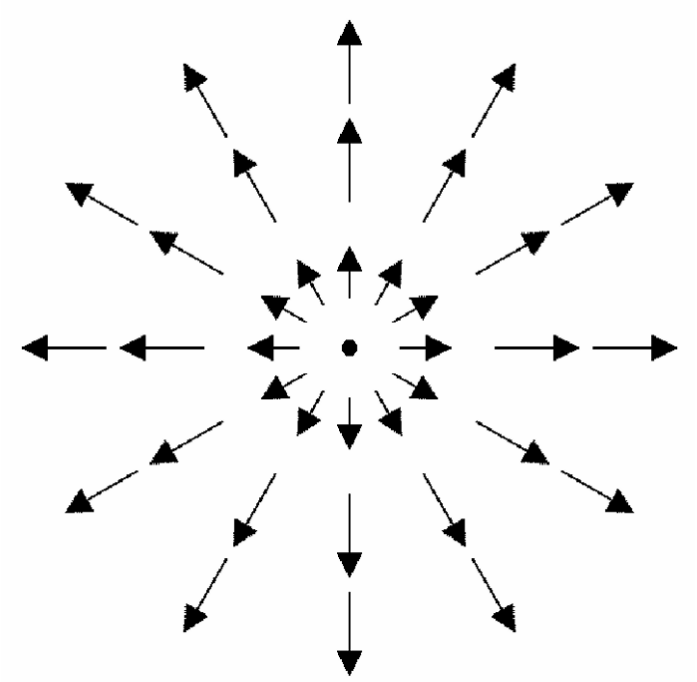


Figure 9.4: Graphical represention of the three-component Higgs field in the vicinity of a magnetic monopole.

Ann. Rev. Nucl. Part. Sci. 1984. 34 : 461–530

MAGNETIC MONOPOLES[1]

John Preskill[2]

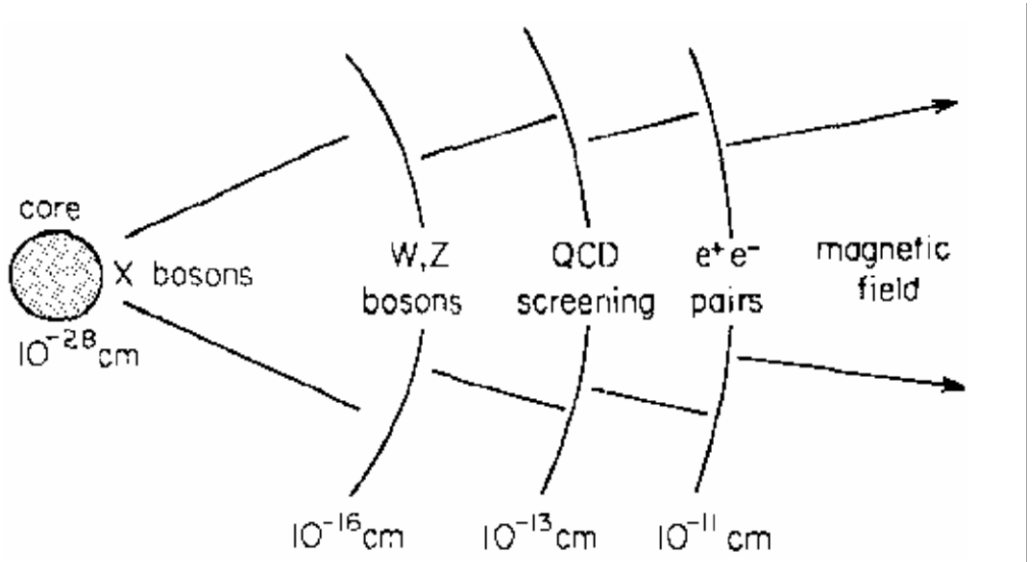


Figure 1 Structure of a grand unified monopole.

inside its core is a region in which the scalar field respects symmetries different from those respected by the vacuum state. This scalar field configuration is energetically unfavorable, so the core cannot expand. But the magnetostatic energy of the core prevents it from shrinking. So the core is stable.

Could monopoles be cosmologically coupled and drive the exponential expansion of the Universe?

Physics Letters B

Volume 327, Issues 3–4, 19 May 1994, Pages 208-213

Monopoles as big as a universe

Andrei Linde

Abstract

We show that, contrary to the standard belief, primordial monopoles expand exponentially during inflation in the new inflationary universe scenario. Moreover, inflation of monopoles continues without end even when inflation ends in the surrounding space. Therefore primordial monopoles (as well as other topological defects produced during inflation) can serve as seeds for the process of eternal self-reproduction of inflationary universe.

My Introduction to Magnetic Monopoles, Berkeley, 1975

Price, Shirk, Osborne and Pinsky saw an extremely unusual event in a balloon-borne detector using Lexan and G-5 nuclear emulsion designed to measure Pt/Pb and actinide cosmic ray abundances. They announced the discovery of a magnetic monopole in 1975.

THREE PROBLEMS: enormous cosmic ray background, no Pb or U calibration beams, we did not know how to calculate dE/dx then.

VOLUME 35, NUMBER 8 PHYSICAL REVIEW LETTERS 25 AUGUST 1975

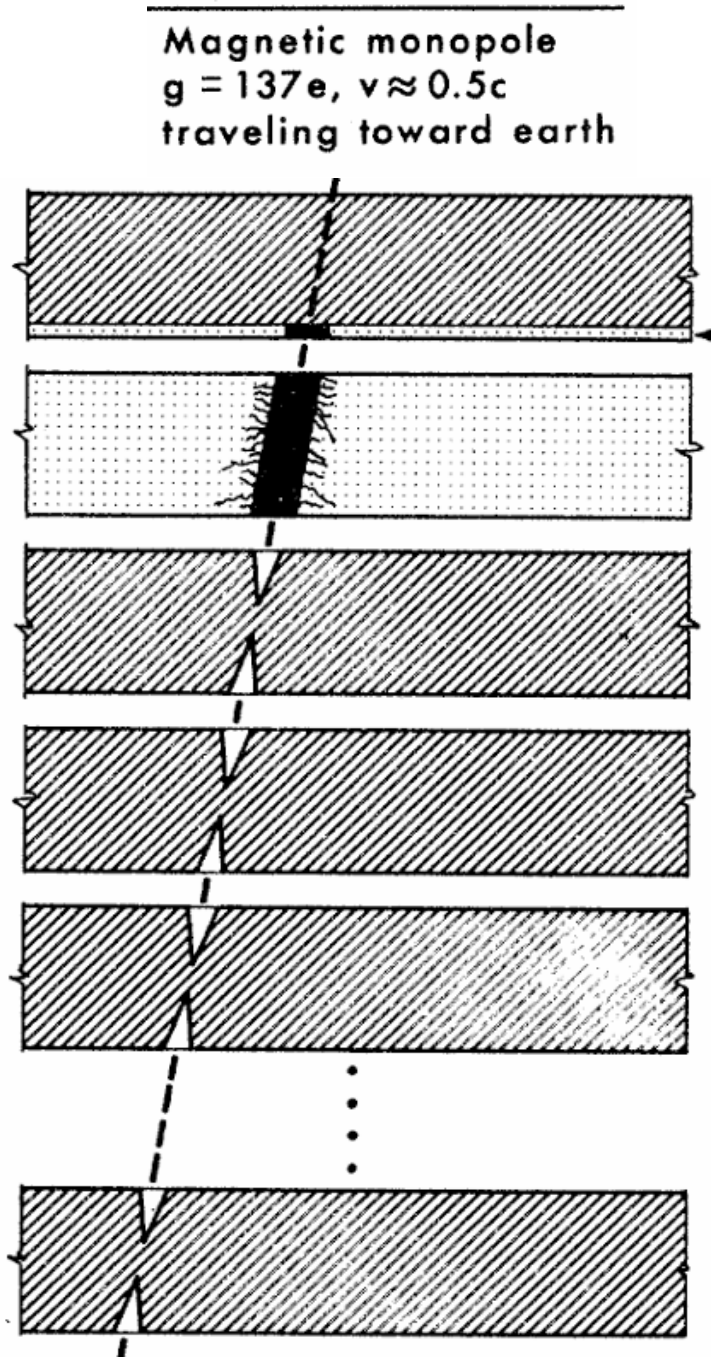
Evidence for Detection of a Moving Magnetic Monopole

P. B. Price* and E. K. Shirk*
Physics Department, University of California, Berkeley, California 94720

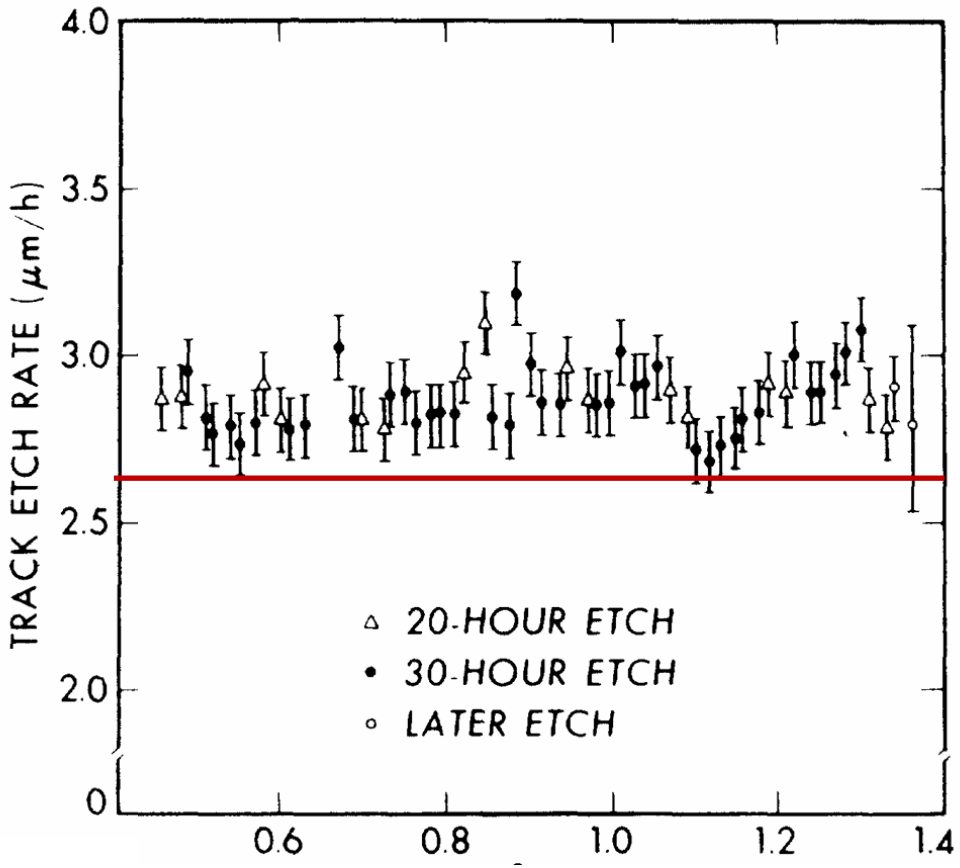
and

W. Z. Osborne† and L. S. Pinsky‡
Physics Department, University of Houston, Houston, Texas 77004
(Received 4 August 1975)

Emulsion track diameter = 100 μm



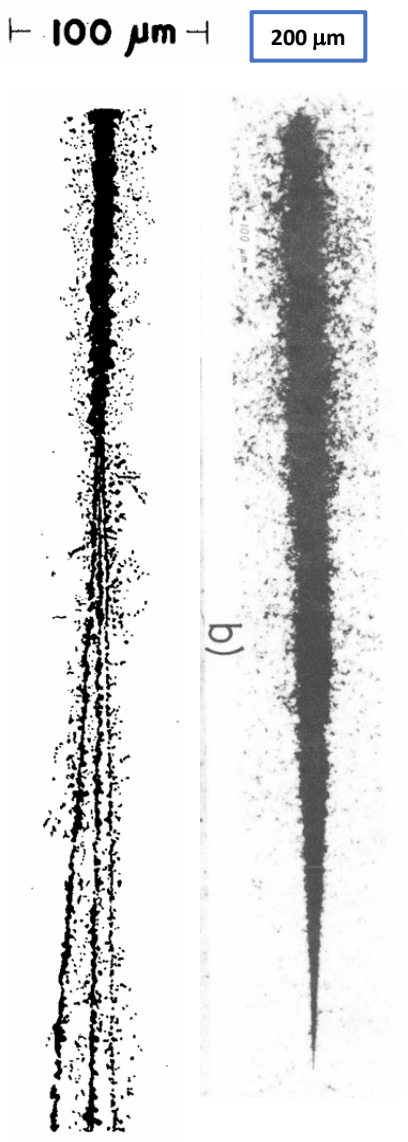
The "monopole" track-etch data. Electric charge, mass, speed, and sign of charge can be estimated by inspection of these data. Note the two electron capture and loss events.



Using restricted energy loss model, and calibrating with stopping iron gives:
Electric charge = +90e
v_{in} = 0.890c
v_{out} = 0.879c (thorium-232)
for "monopole" event.

Price et al., Phys. Rev. D ***18****, 1382 (1978).*

Uranium tracks from Heckman et al. from the first Bevalac uranium beams in 1982.



v = 0.86c 0.51c > v > 0

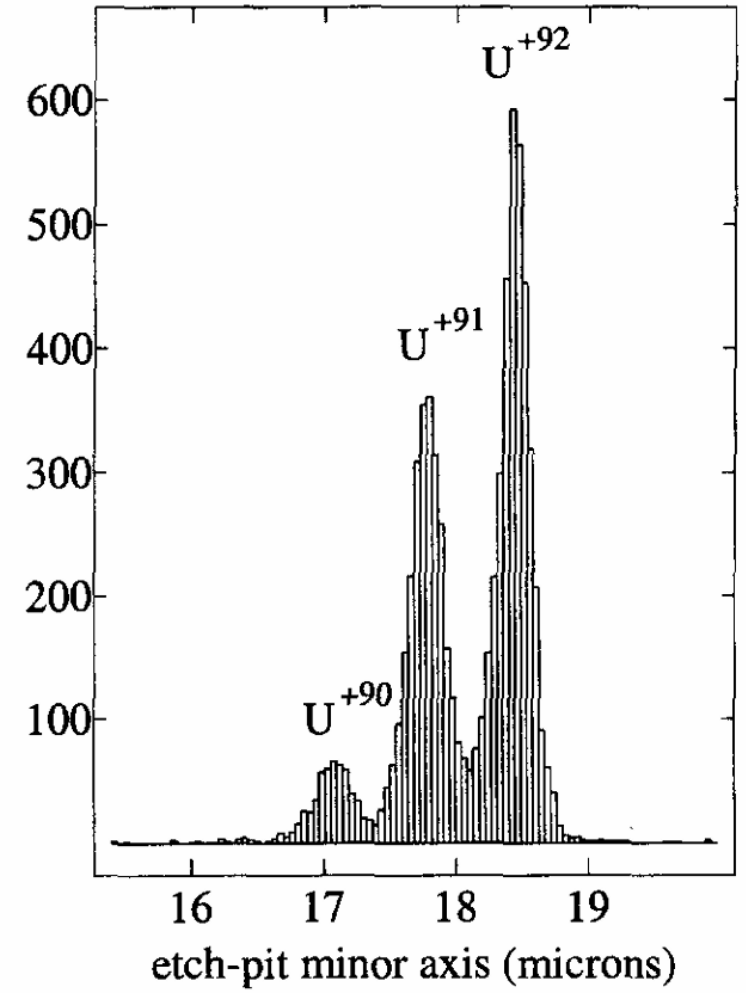


Fig. 3. Histogram of etch-pit semi-minor axes in an etched BP-1 detector exposed to 1 GeV/amu U.

Andrew J. Westphal[1], Benjamin A. Weaver[1], and Gregory Tarlé[2]

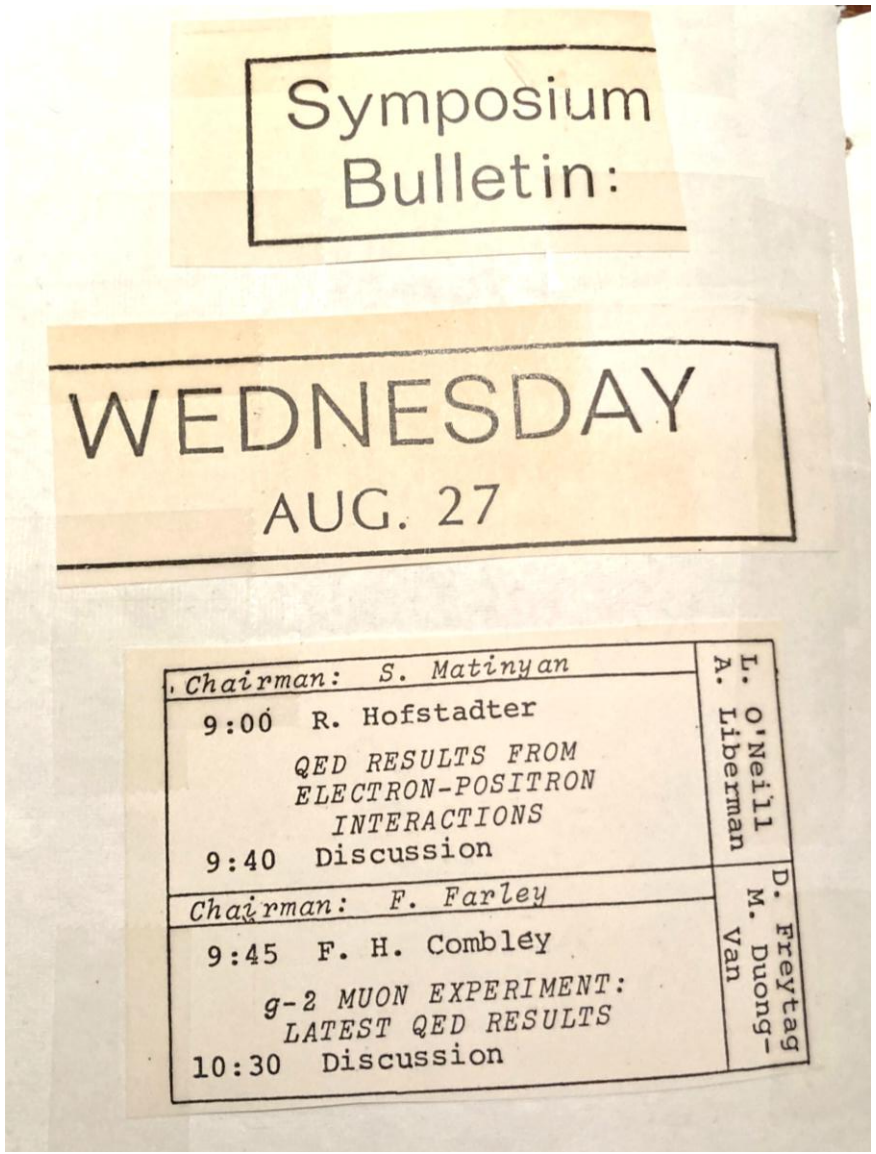
Adv. Space Res. Vol. 27, No. 4, pp. 797–802, 2001

Invited talk presented at the Stanford International Conference on Leptons and Photons, Stanford, CA, August 27, 1975

ANALYSIS OF A REPORTED MAGNETIC MONOPOLE

Luis W. Alvarez

September 16, 1975



Symposium Bulletin:

WEDNESDAY
AUG. 27

Chairman: S. Matinyan — L. O'Neill, A. Liberman

9:00 R. Hofstadter
QED RESULTS FROM ELECTRON-POSITRON INTERACTIONS
9:40 Discussion

Chairman: F. Farley — D. Freytag, M. Duong-Van

9:45 F. H. Combley
g-2 MUON EXPERIMENT: LATEST QED RESULTS
10:30 Discussion

10:35-10:55 Coffee

Chairman: A. Sessler — J. Liu, W. Johnson

10:55 L. Di Lella
LARGE TRANSVERSE MOMENTUM PROCESSES IN HADRON COLLISIONS
11:40 Discussion

Chairman: W.K.H. Panofsky

11:50 L. Alvarez
COMMENTS ON COSMIC-RAY MONOPOLE EVENT
12:05 S. Ahlen
CALCULATION OF MONOPOLE ENERGY LOSS IN LEXAN
12:15 Discussion

12:30-2:00 Lunch

Chairman: S. Drell — M. Weinstein

2:00 R. Dashen
THEORIES OF QUARK CONFINEMENT
2:45 Discussion

Chairman: C. N. Yang — R. Giles, D. Fryberger

3:00 J. Bjorken
SYMPOSIUM SUMMARY AND PROGNOSIS
4:00 Discussion

(4:30 End of Symposium)

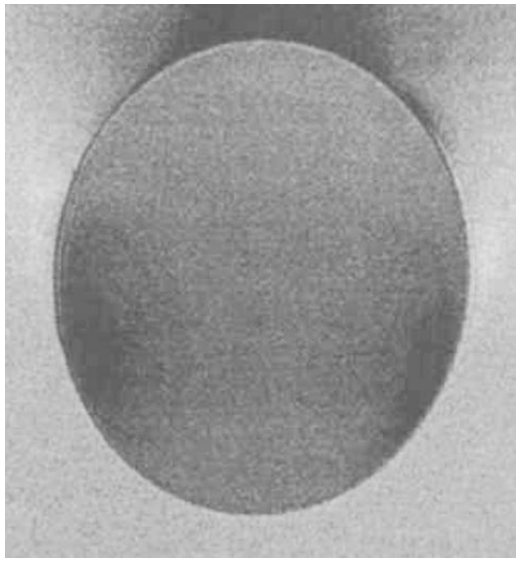
Luis Alvarez did not trust the emulsion data. Peter Fowler, the world-expert on emulsion tracks (and grandson of Rutherford), claimed that determining the velocity from the track width is not valid for v > 0.45c. Alvarez proposed that the monopole was a heavy nucleus that underwent several charge changing nuclear interactions.

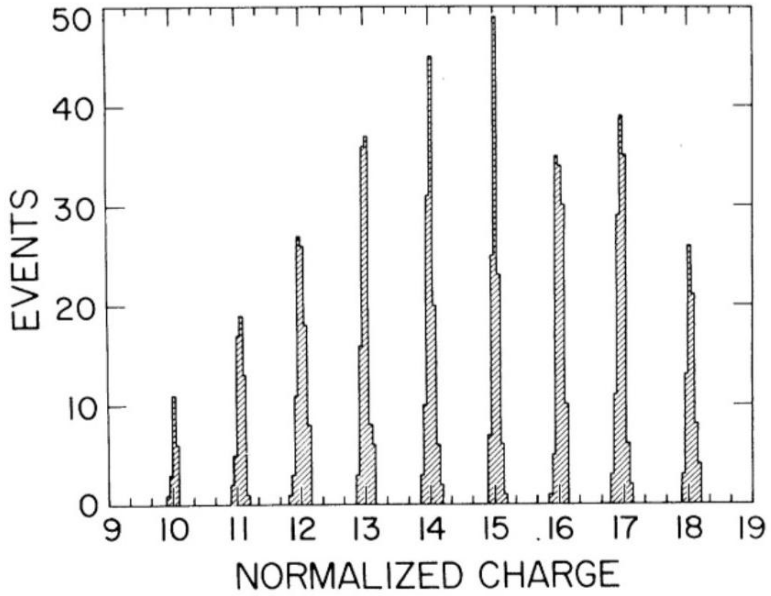
There are many stories from those days, involving: Stephen Hawking, Kip Thorne, Barbara Walters, The US Secretary of Transportation, Emilio Segre, Ed McMillan, Jacques Vallee…

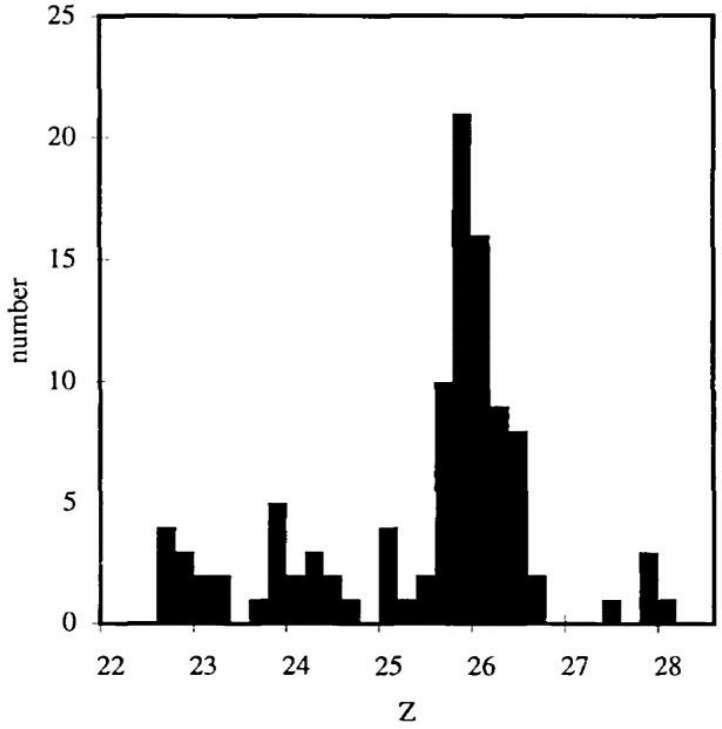
After monopole event the Price Group developed improved detectors, used relativistic nuclei calibrations as beams became available (up to U), and did calculations of dE/dx for electric and magnetic particles. Brian Cartwright, Ed Shirk, and Buford Price discovered CR-39 track detector in 1978.

Both CR-39 and Lexan were used in MACRO.

CR-39 resolution from fractional charge search with heavy ion fragments at Bevalac.







CR-39 resolution from 1980 balloon flight.

Another event in 1982, this one possibly being a GUT monopole

First Results from a Superconductive Detector for Moving Magnetic Monopoles

Blas Cabrera

Phys. Rev. Lett. **48**, 1378 – **Published 17 May, 1982**

Abstract

A velocity- and mass-independent search for moving magnetic monopoles is being performed by continuously monitoring the current in a 20-cm^2-area superconducting loop. A single candidate event, consistent with one Dirac unit of magnetic charge, has been detected during five runs totaling 151 days. These data set an upper limit of $6.1\times10^{-10}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}\ \mathrm{sr}^{-1}$ for magnetically charged particles moving through the earth's surface.

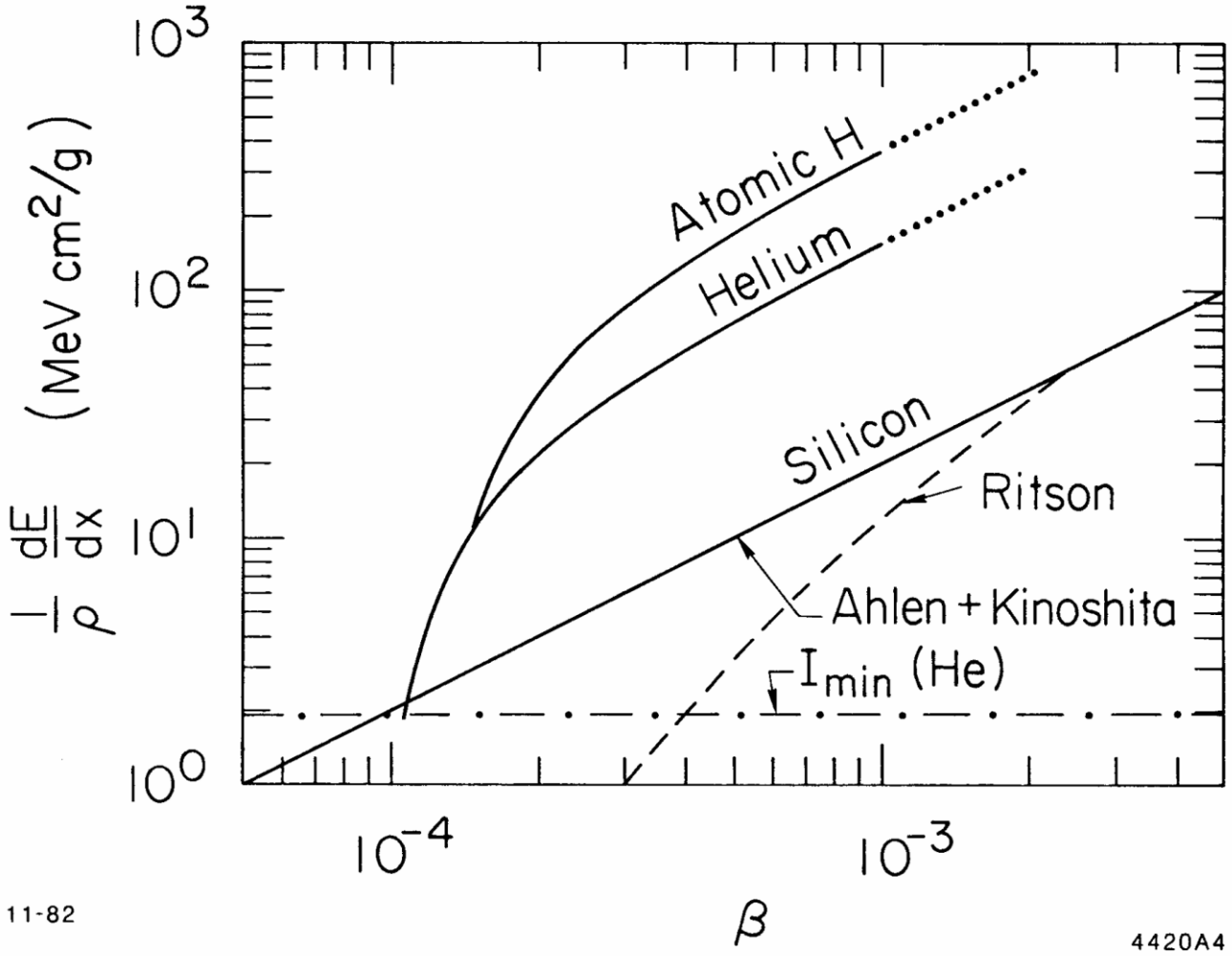
How to check Cabrera? It was known that GUT monopoles would be moving slowly (v/c ≈ 0.001). At the time, many physicists thought that such particles would be unable to excite and ionize atoms. This led to a calculation by Kay Kinoshita and me. *Phys. Rev.* D 26, 2347 (1982).

Sid Drell and colleagues showed that helium could be excited by slow monopoles by level crossing a year later. This could be exploited by the Penning effect.

Helium + n-pentane was used in the streamer tubes for this purpose in MACRO.

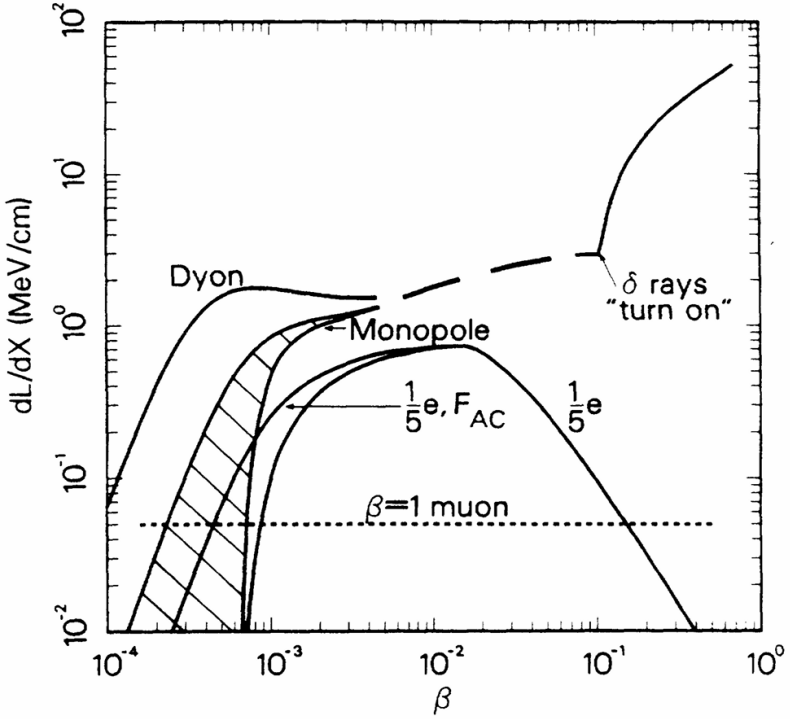
SLAC-PUB-3012
November 1982
T/E

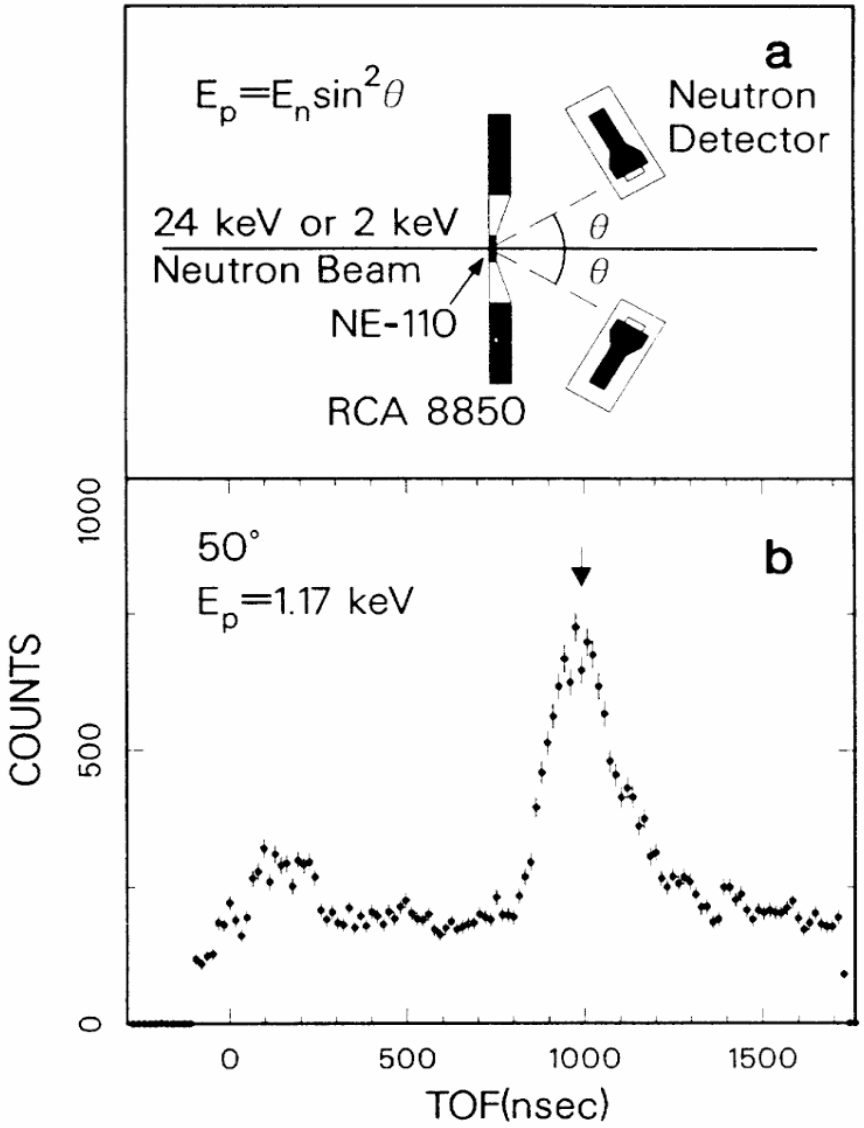
S.D. Drell, N.M. Kroll, M.T. Mueller, S.J. Parke, and M.A. Ruderman.



What about MACRO scintillators? Scintillation from neutron induced hydrogen recoils was measured by Ficenec et al., *Phys. Rev. D* 36, 311 (1987).

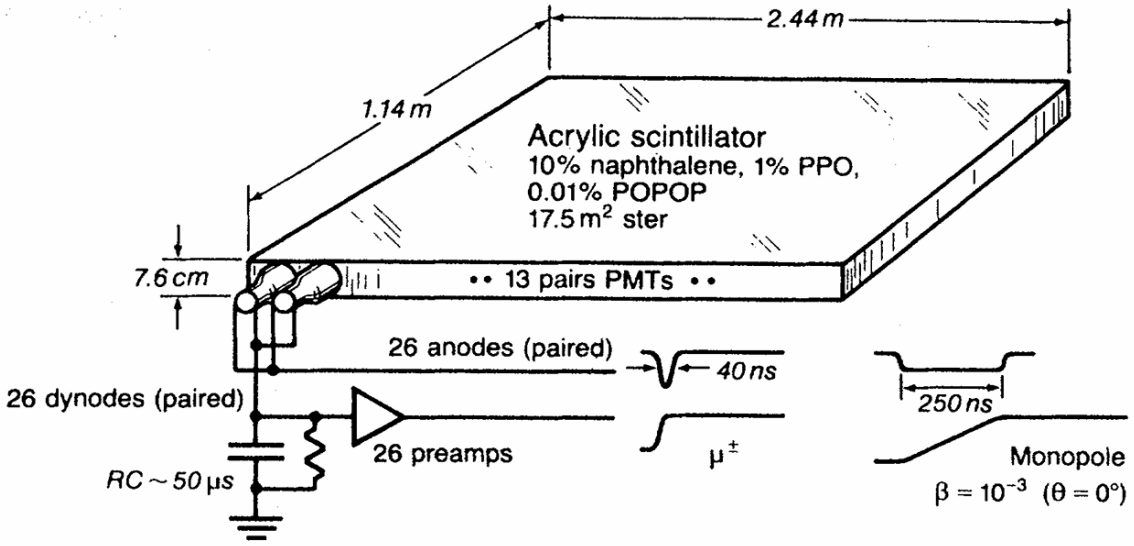
We almost did not get the funding (a very modest amount for a very simple experiment) for this. Bob Adair thought we were too young and inexperienced to do such an experiment due to all the neutron background at the BNL High Flux Beam Reactor.





Lots of small experiments started looking for GUT monopoles.* We were advised to get together and form a single group to do a large monopole and neutrino experiment. Barry took the lead in organizing the Americans and talking to the Italians, and MACRO was born.

***For example see Tarle, Ahlen, Liss, Phys. Rev. Lett. 50, 90 (1984).**



CALIFORNIA INSTITUTE OF TECHNOLOGY

CHARLES C. LAURITSEN LABORATORY OF HIGH ENERGY PHYSICS
PASADENA, CALIFORNIA 91125

Prof. Steven P. Ahlen
Department of Physics
Indiana University
Bloomington, IN 47405

January 5, 1984

Dear Steven:

As You know, I share your interest in monopole detection and am particularly keen on developing a realistic plan for a very large scale detector (eg. approaching $10^4\ m^2$). It seems to me that such a project is only realistic if a strong collaboration is formed around a coherent well-conceived proposal. Much hard work needs to be done before we will really know how to build such a detector. Some of the information will certainly come from the present generation of detectors, and other questions, directly concerned with optimization for the large scale detector, need to be addressed separately. I believe it would be useful, at this point, to form an informal working group pointed toward such a major facility. Anyway, I solicit your interest. Please call me (213-356-6684) or write me at Caltech. If there is sufficient interest, I propose we start holding meetings soon.

In the meanwhile, I have been in communication (see attached) with the French-Italian group who are forming a proposal for Gran Sasso. I hope to attend their next collaboration meeting and then I will be able to inform you in detail of their plans and any possibilities of collaboration.

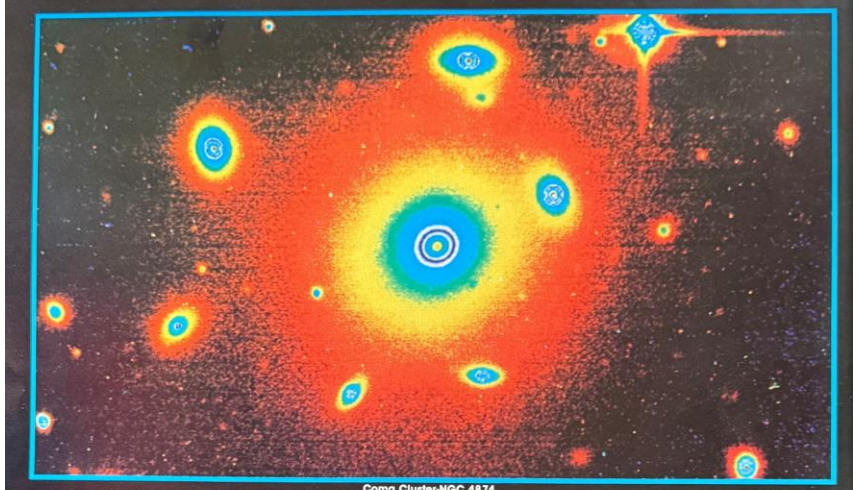
I hope to hear from you soon and hopefully, we can join together on this challenging project.

Sincerely,

Barry Barish

Barry Barish
Professor of Physics

MONOPOLE 83



Coma Cluster-NGC 4874

October 6-9, 1983 The University of Michigan
Ann Arbor, Michigan

Purpose

The subject of this conference is superheavy magnetic monopoles in the context of grand unified theories and astrophysics including the early and present universe. The status of monopole search experiments will be reported and monopole detection techniques will be reviewed.

General Information

Attendance at the conference is open; however, since space is limited early registration is strongly encouraged. All participants (excluding graduate students) will be charged a registration fee, which will include the banquet and the conference proceedings.

For further information, contact the conference secretary: Ms. Alice Carroll, Department of Physics, University of Michigan, Ann Arbor, Michigan, 48109 USA. Telephone: (313) 763-2151. TELEX 810 2236056

Advisory Committee

J. Stone (Chairman)	Michigan
R. Carrigan, Jr.	FNAL
J. Ellis	SLAC/CERN
G. Giacomelli	Bologna, Italy
A. Goldhaber	SUNY
D. Ritson	SLAC
F. Wilczek	ITP, Santa Barbara

Sponsors

U.S. Department of Energy
National Science Foundation
NATO

PROPOSAL

for

A LARGE AREA DETECTOR DEDICATED TO
MONOPOLE SEARCH, ASTROPHYSICS, AND COSMIC RAY PHYSICS

at the

GRAN SASSO LABORATORY

Bari-Bologna-Caltech-CERN-Drexel

Frascati-Indiana-Michigan-Pisa

Roma-Texas A&M-Torino-Virginia Tech

Collaboration

NOVEMBER 1984

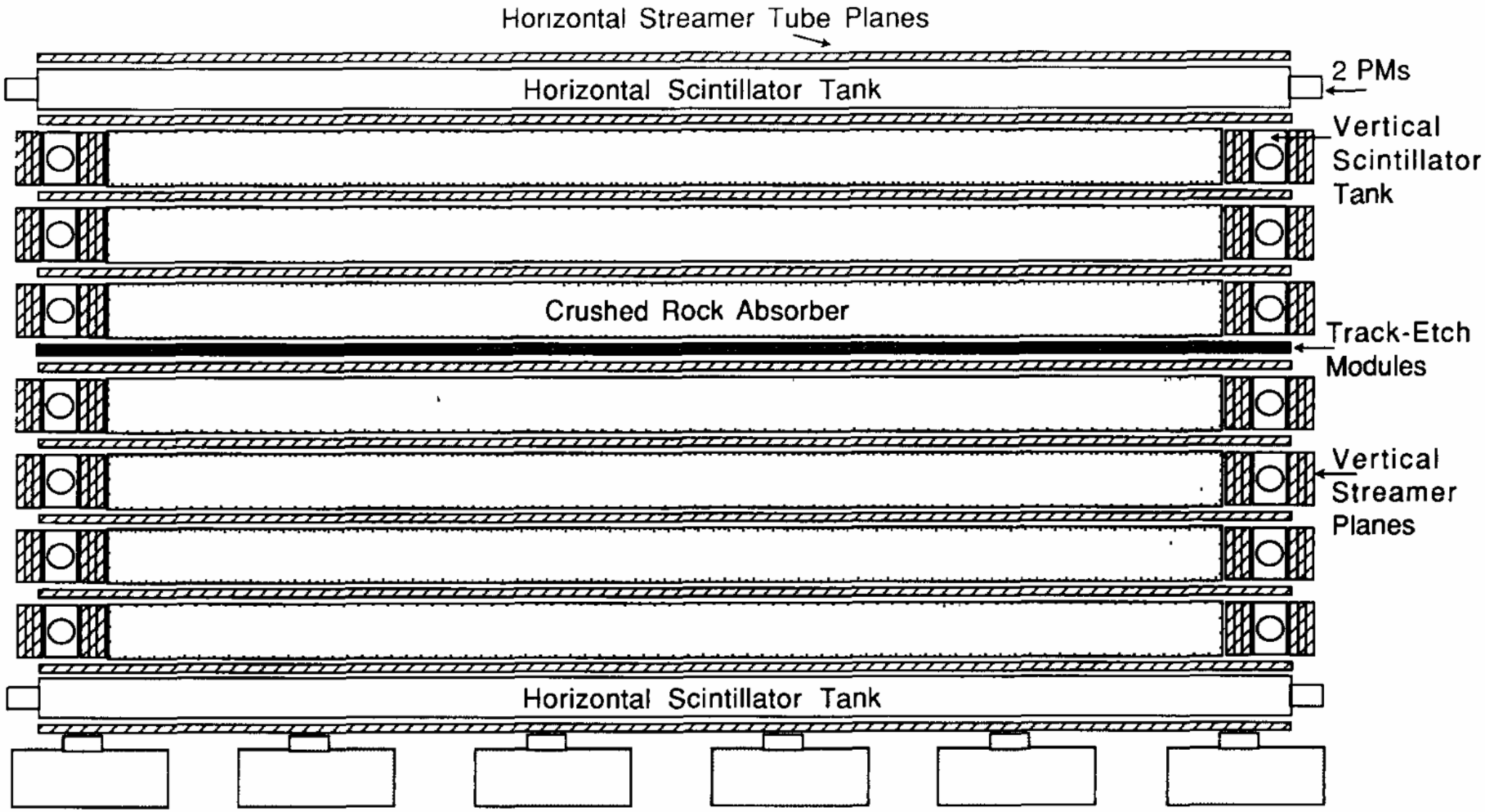
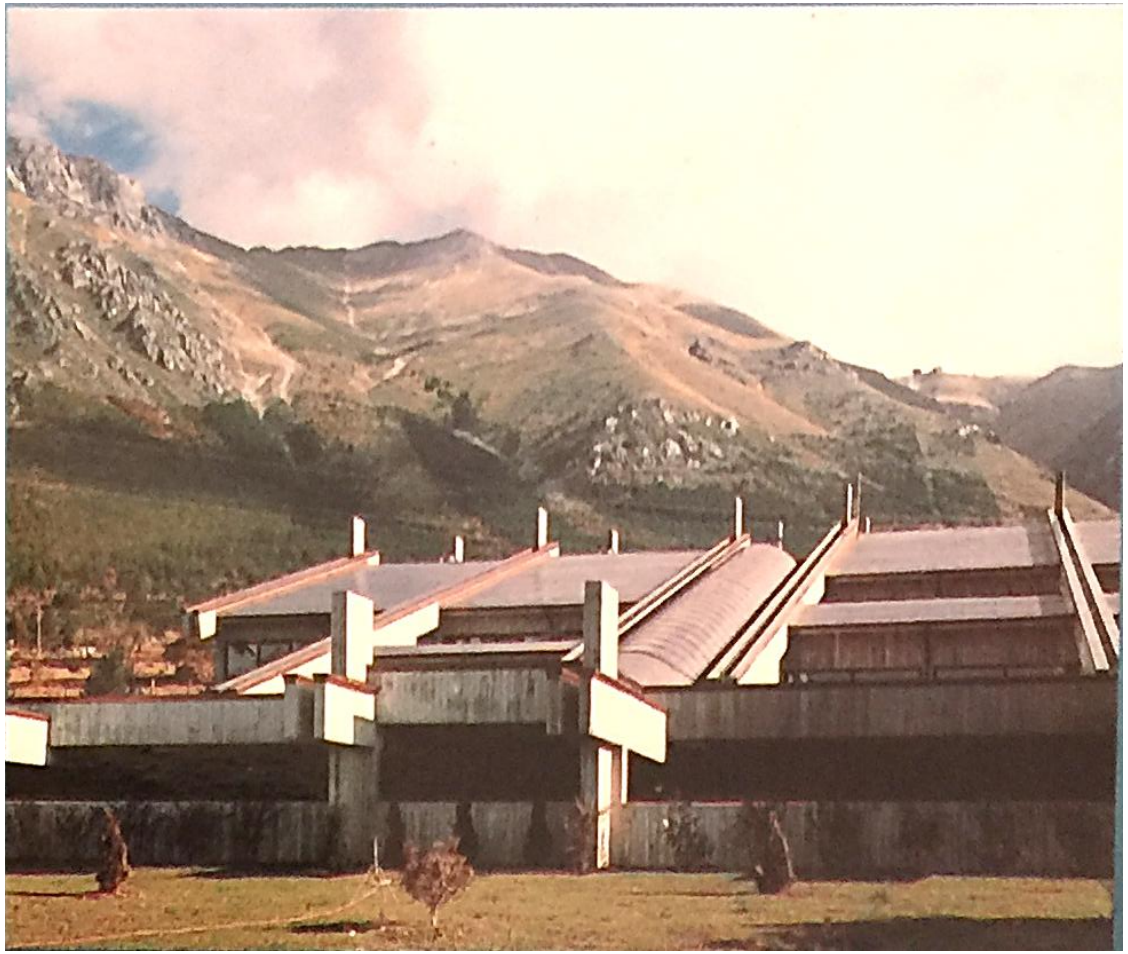


Fig. 2. Cross-sectional end view (not to scale) of the lower part of a MACRO supermodule

Hall B 1985

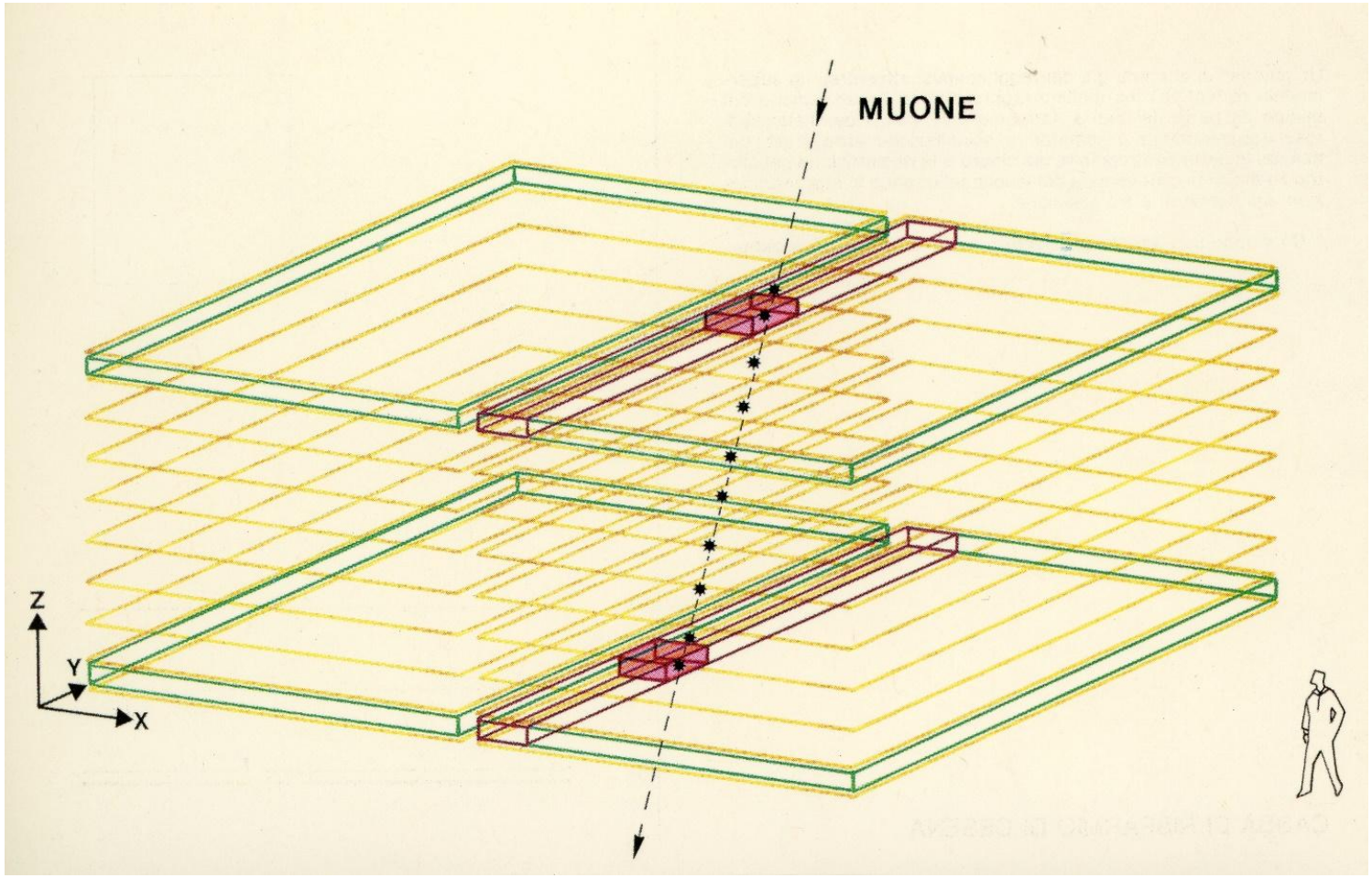
I moved to Italy in summer 1988

I LABORATORI NAZIONALI DEL GRAN SASSO

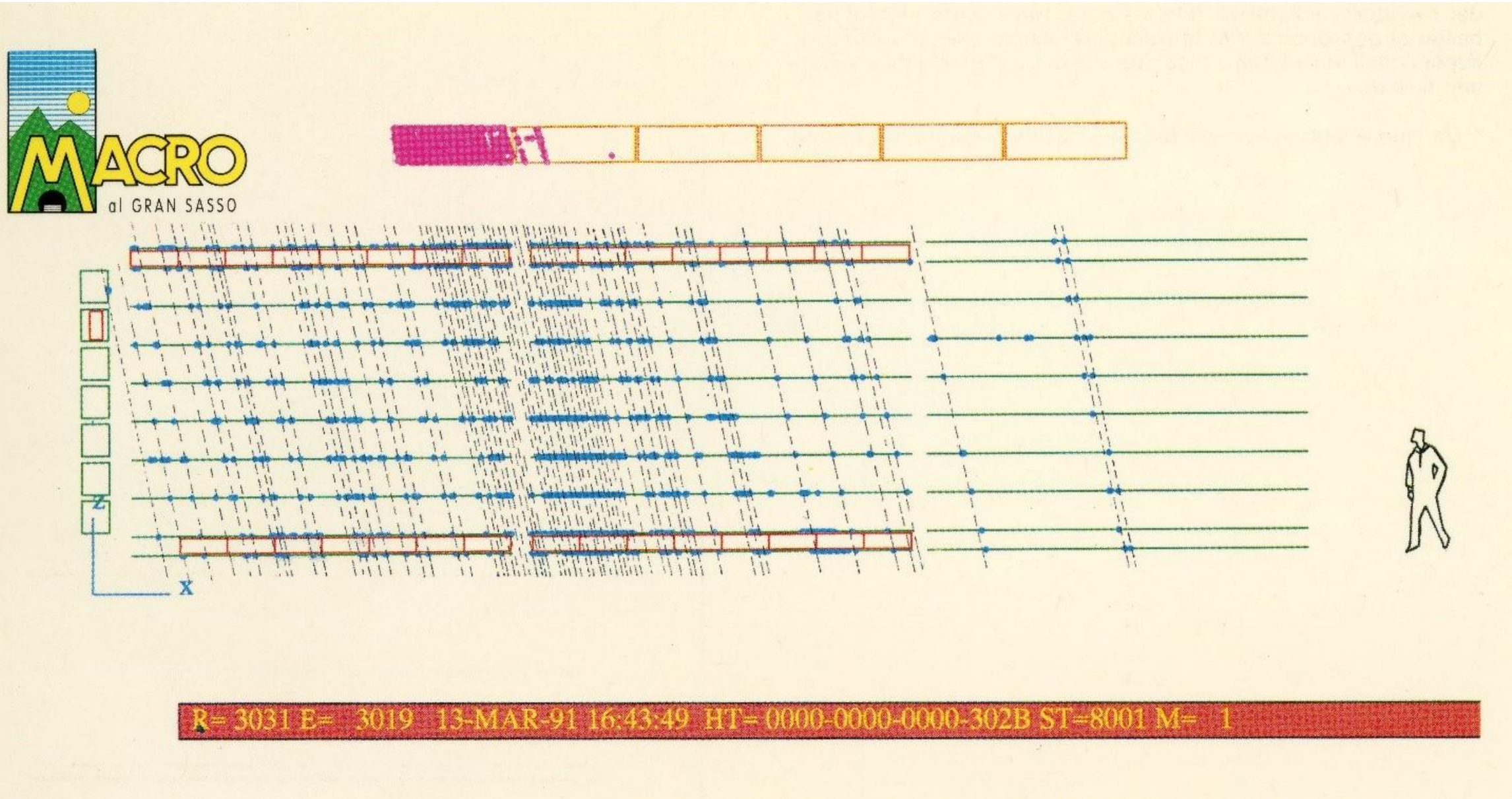


Hall B 1988

The first supermodule. Its construction was finished and data taking began in February, 1989



I am most familiar with the scintillator and electronics work in Italy before February 1989, which was carried out by many people, including to the best of my recollection (and not limited to) Barry Barish, Chuck Bower, Stephane Coutu, Ed Diehl, Dave Ficenec, Phil Green, Alec Habib, Doug Heine, Dick Heinz, Ed Kearns, Spencer Klein, Dave Kouba, Chuck Lane, Larry (technician from Caltech), Dan Levin, Gary Liu, Mike Longo, Alex Marin, Doug Michael, Stu Mufson, Jim Musser, Scott Nutter, Charlie Peck, John Petrakis, Jan Reynoldson, Jim Stone, Larry Sulak, Greg Tarle, Bill and Susan Thompson, Bob Webb, and Bill Worstell. Please forgive me if I have mistakenly left you off the list.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X
R= 3031 E= 3019 13-MAR-91 16:43:49 HT= 0000-0000-0000-302B ST=8001 M= 1