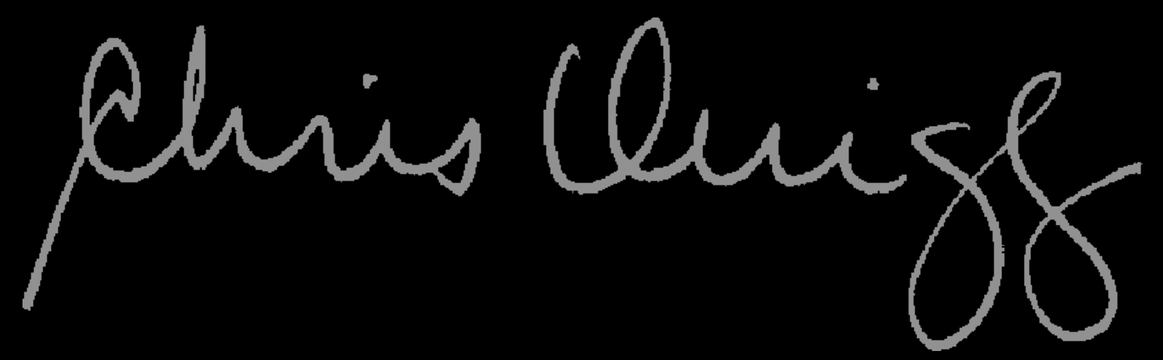
FERMILAB-SLIDES-18-036-T

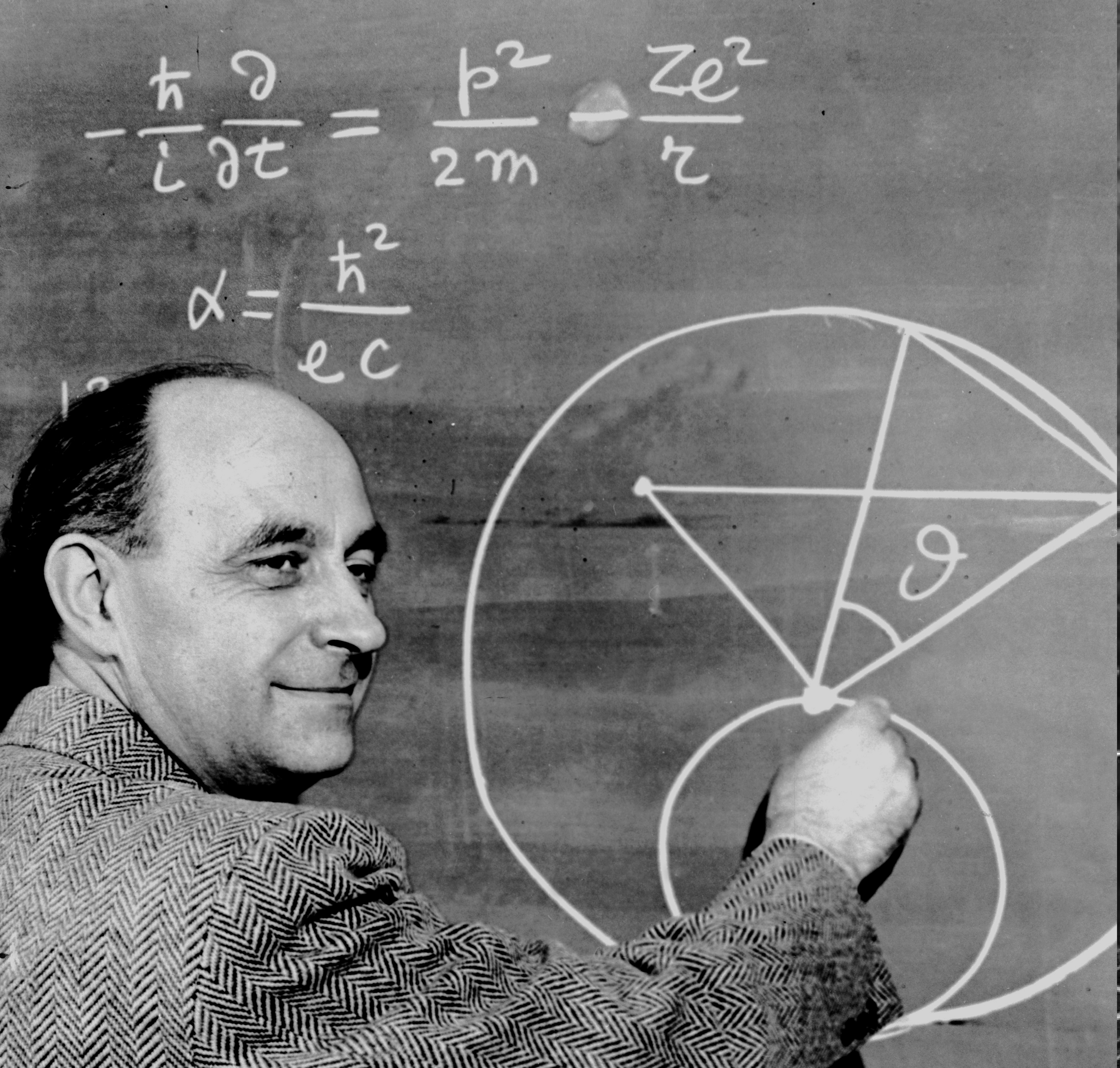
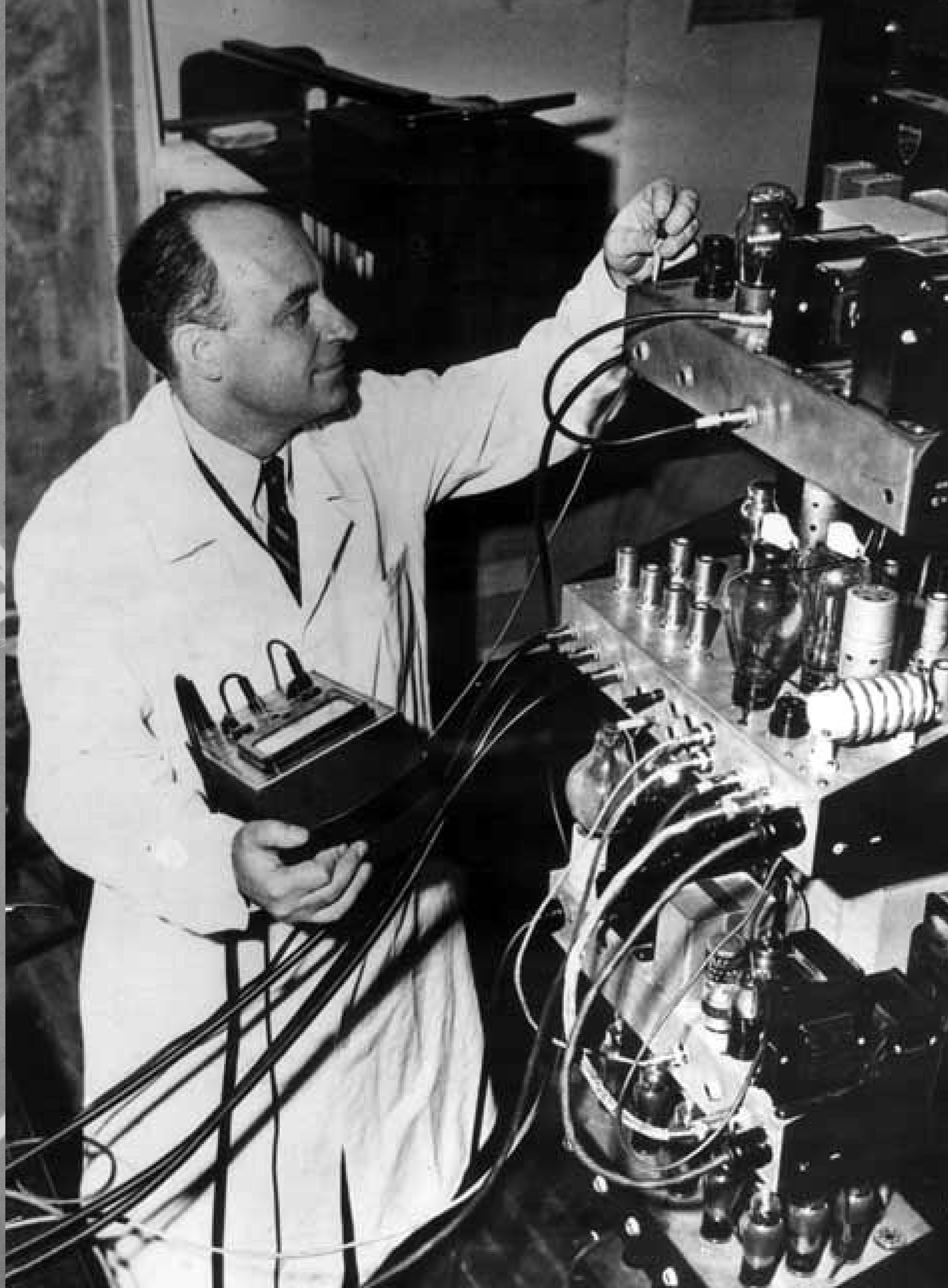
Fermilab’s Greatest Hits:

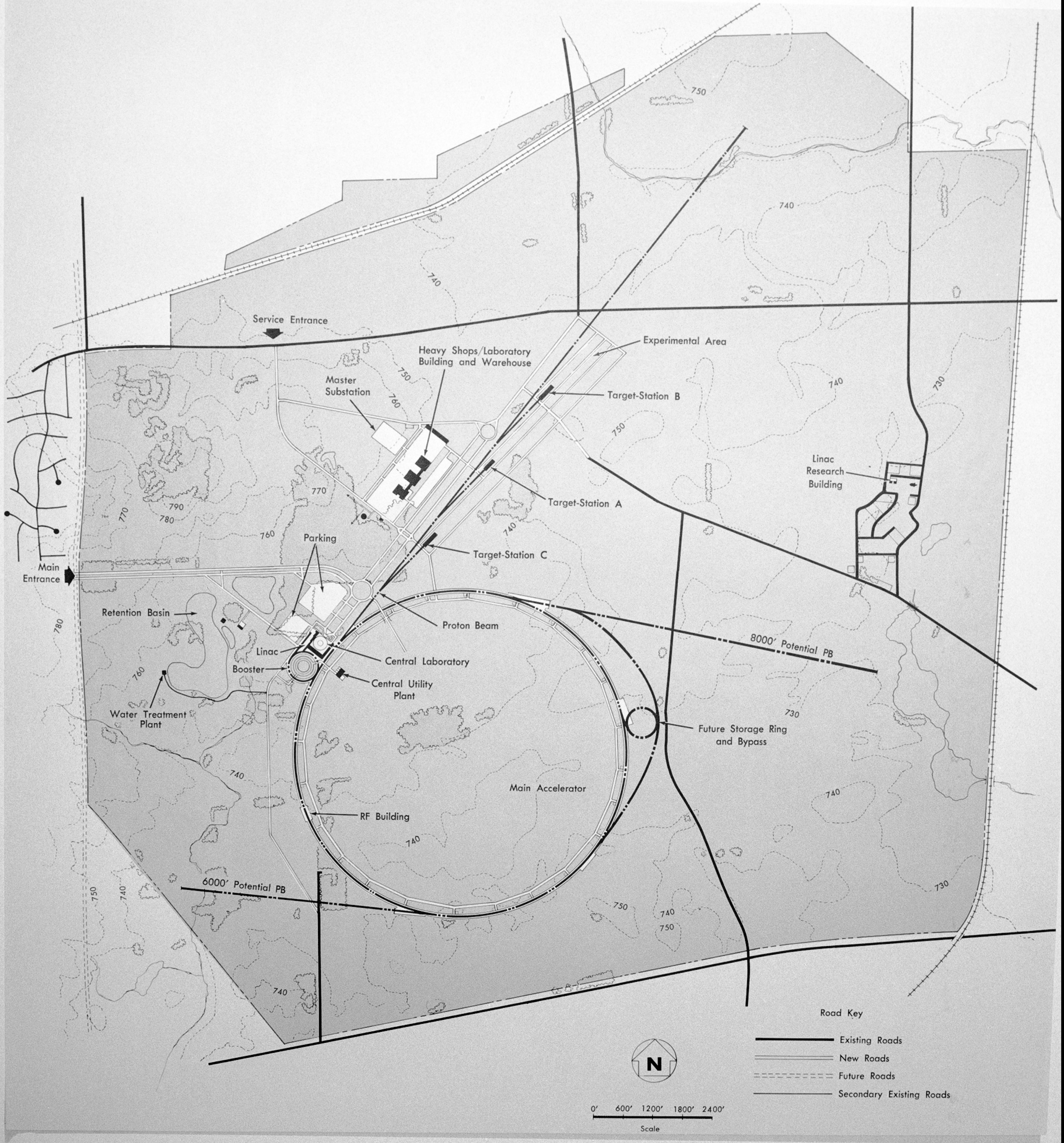
Highlights from the First Fifty Years



This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

doi: 10.5281/zenodo.1137821


$-\frac{\hbar}{i}\frac{\partial}{\partial t} = \frac{p^2}{2m} - \frac{Ze^2}{r}$
$\alpha = \frac{\hbar^2}{ec}$
ϑ



Service Entrance
Heavy Shops/Laboratory Building and Warehouse
Experimental Area
Master Substation
Target-Station B
Target-Station A
Target-Station C
Linac Research Building
Parking
Main Entrance
Retention Basin
Proton Beam
8000′ Potential PB
Linac
Central Laboratory
Booster
Central Utility Plant
Water Treatment Plant
Future Storage Ring and Bypass
Main Accelerator
RF Building
6000′ Potential PB
750
740
730
760
770
780
790
Road Key
Existing Roads
New Roads
Future Roads
Secondary Existing Roads
N
0′ 600′ 1200′ 1800′ 2400′
Scale

POLICY STATEMENT ON HUMAN RIGHTS

The following Policy Statement on Human Rights was issued March 15, 1968, by Robert Rathbun Wilson, director, National Accelerator Laboratory, and Edwin L. Goldwasser, deputy director:

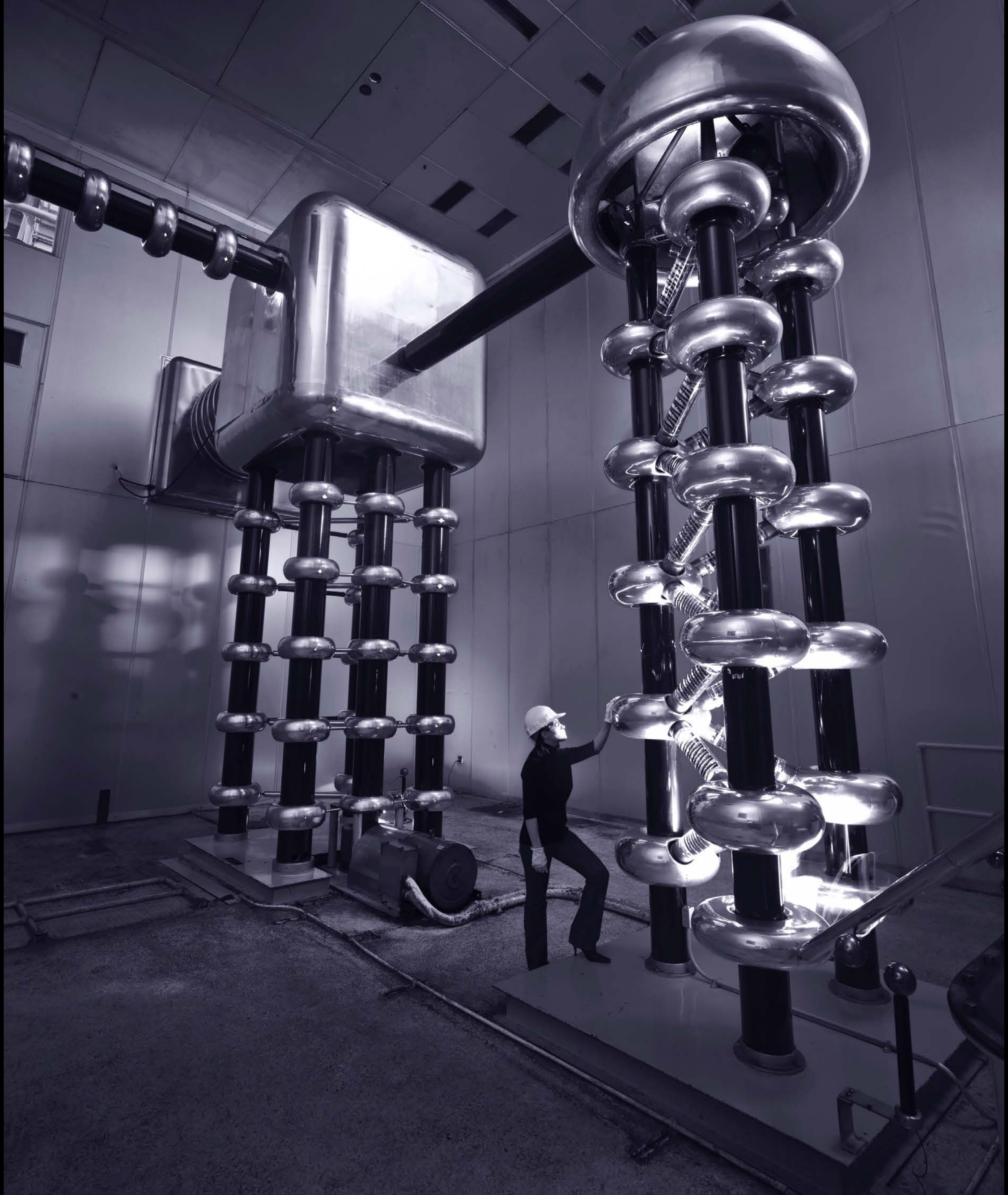
It will be the policy of the National Accelerator Laboratory to seek the achievement of its scientific goals within a framework of equal employment opportunity and of a deep dedication to the fundamental tenets of human rights and dignity.

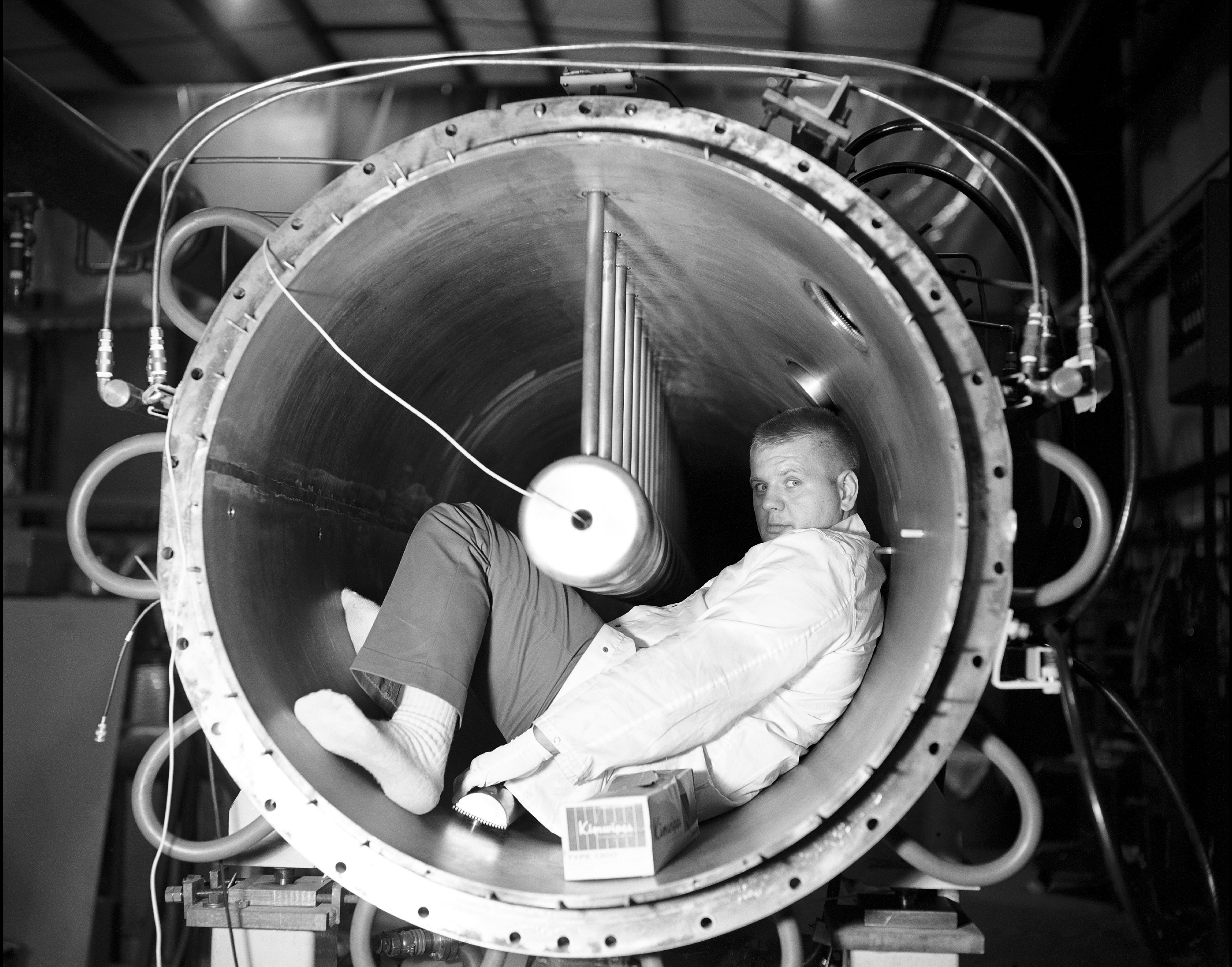
We have seen the creation of NAL near Chicago in a year of social tension and urban unrest, and we have observed the destiny of our Laboratory to be linked to the long history of neglect of the problems of minority groups. We intend that the formation of the Laboratory shall be a positive force in the progress toward open housing in the vicinity of the Laboratory site. We intend that it shall also make a real contribution toward providing employment opportunities for minority groups. For this, the principle of equal opportunity is not enough. Special opportunity must be provided to the educationally deprived if they are to be able to exploit their inherent potential to contribute to, and to benefit from, the development of our Laboratory. This is a matter of personal conviction as well as of practical necessity. We expect to create conditions for special opportunity by adopting aggressive employment practices and by instituting special educational and apprentice training programs.

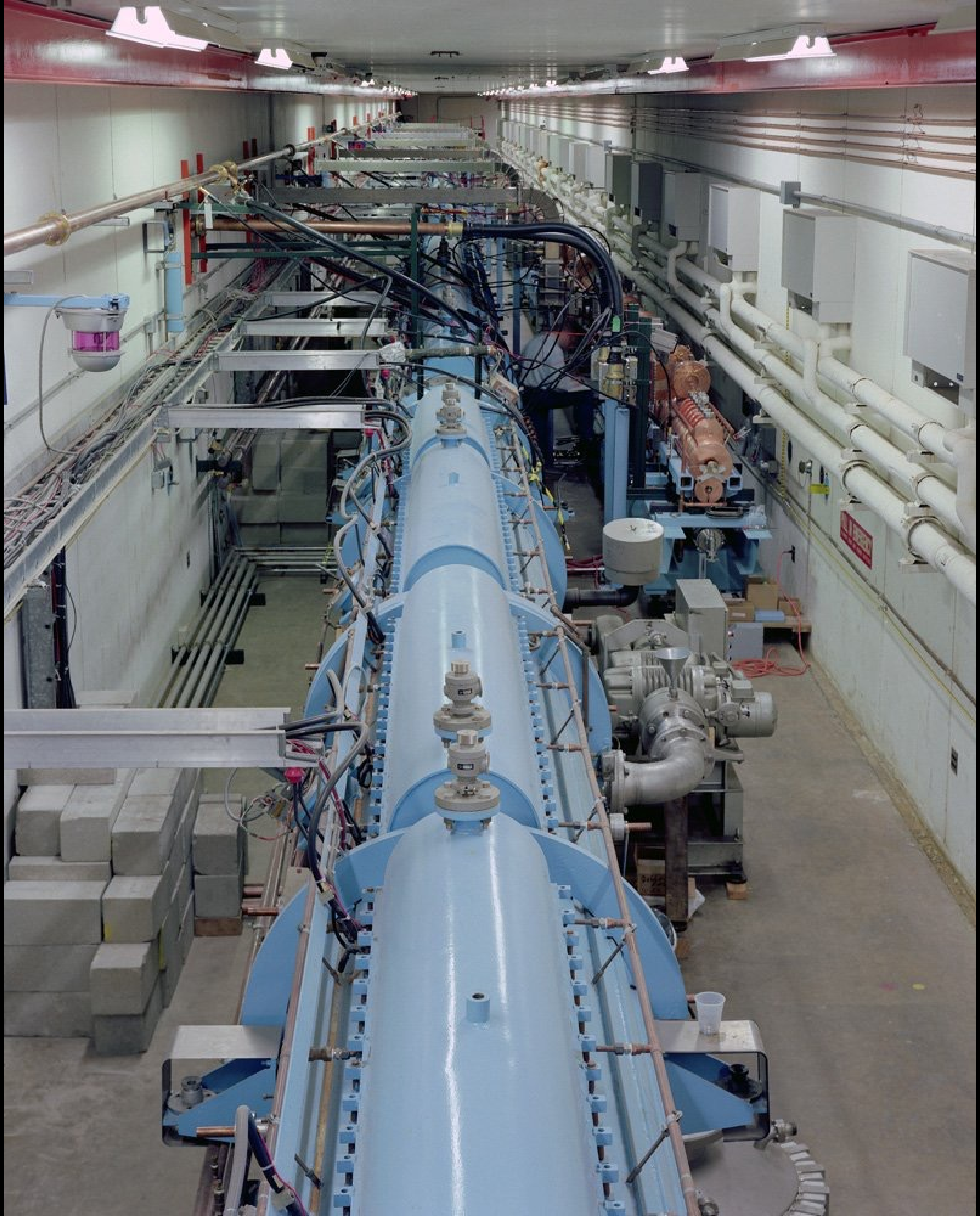
Prejudice has no place in the pursuit of knowledge. Perhaps this is why most scientists are sensitive to discrimination in any form. The National Accelerator Laboratory is in a position to attract to its program some of the greatest physicists, not only of this country but of other nations as well. Thus the Laboratory will be, in a very real sense, one of the windows through which the United States will be viewed by the rest of the world. Foreign visitors, laymen as well as scientists, will come to the Laboratory for short periods of time to observe, and for extended periods to participate in our work. These men will come from varied backgrounds with a variety of beliefs. It is essential that the Laboratory provide an environment in which both its staff and its visitors can live and work with pride and dignity.

In any conflict between technical expediency and human rights, we shall stand firmly on the side of human rights. This stand is taken because of, rather than in spite of, a dedication to science. However, such a conflict should never arise. Our support of the rights of members of minority groups in our Laboratory and in its environs is inextricably intertwined with our goal of creating a new center of technical and scientific excellence. The latter cannot be achieved unless we are successful in the former.


EXIT
OPEN
DELTA
DELTA




Kimwipes



The Village Crier

national accelerator laboratory

Operated by Universities Research Association Inc.
Under Contract with the United States Atomic Energy Commission

Vol. 4 No. 8 February 24, 1972

....Broad smiles at NAL on February 11, 1972....(L to R) R. R. Wilson, D. Sutter, E. L. Goldwasser, T. Collins, S. Mori, E. Hubbard, and E. Malamud....

....Reason for the smiles.... 100 BeV on that date....

A DAY TO REMEMBER!!

There were indications in the NAL Main Control Room all day on Friday, February 11th, that it was going to be a good day. The elusive proton beam was more responsive than usual to the control system and to the crew working hard to train the beam into going to higher and higher energies around the four-mile NAL race track.

The entire Accelerator Section, under the guidance of Robert R. Wilson and Donald E. Young, had been marshalled all week -- all month, in fact, having attained 20 BeV on January 22nd and 53 BeV on February 4th. The experience and know-how they had gained in the past weeks spurred on their efforts to reach for further acceleration.

Ernest Malamud, Ryuji Yamada and Frank Nezrick led the day shift on Friday, the 11th. Transition energy (17 BeV) was achieved in the morning; tuning continued throughout the day, adjusting to get all of the component systems to function at the same time. Operations went very well during the day; some of the day shift people stayed on into the evening shift, hoping to see success before they left.

At 7:30 p.m. the evening crew, led by Shigeki Mori, Tom Collins, Dave Sutter and Chuck Schmidt, once again attained beam at transition energy, but for some time they could not get the energy to increase. Activity moved back and forth between the Main Control Room and the men on duty six blocks away in the Radio Frequency Building, Jim Griffin, Ray Stiening, K. C. Cahill, Ed Higgins and J. Hoelscher. The two groups continued adjusting and watching for results on the oscilloscope screens. At 9 p.m., after Jim Griffin made a simple adjustment of the B dot knob, the energy of the beam began to climb upward. Each additional pulse of the machine brought cheers from the Main Control Room on the inter-com to the R. F. building. In a very short time,

(Continued on Page 2)

.....Gift from Dubna..
Photo by Tony Frelo, N

....(L to R) J. Griffin, K. C. Cahill, R. Stiening, E. Higgins in R.F. Building....

....(L to R) D. Sutter, F. Nezrick, D. Jovanovic, in the Main Control Room....

the beam touched 100 BeV.

A telephone call brought the Laboratory Director, Robert R. Wilson, to the Main Control Room. He was carrying a bottle of vodka, inscribed in handwriting on the label: "For Bob Wilson and colleagues when energy is greater than 76 BeV...A. A. Kuznetsov, Dubna." Wilson led a group to the R. F. Building, the scene of the breakthrough, where he shared the beverage and the undisguised joy of the occasion.

Tension gone, replaced by the inspiring realization that enormous efforts of countless persons and groups had begun to bear fruit, the crews shortly resumed their duties and the machine continued its magnificent performance throughout the night.

Experiment Number 36 personnel were called about 10 p.m., for they had been scheduled to test equipment installed in the Main Ring beam pipe beneath Service Building C-0 as soon as 100 BeV beam was achieved. Now, they had their chance to observe an accelerated beam react in their experimental apparatus, at 4 a.m. on February 12th.

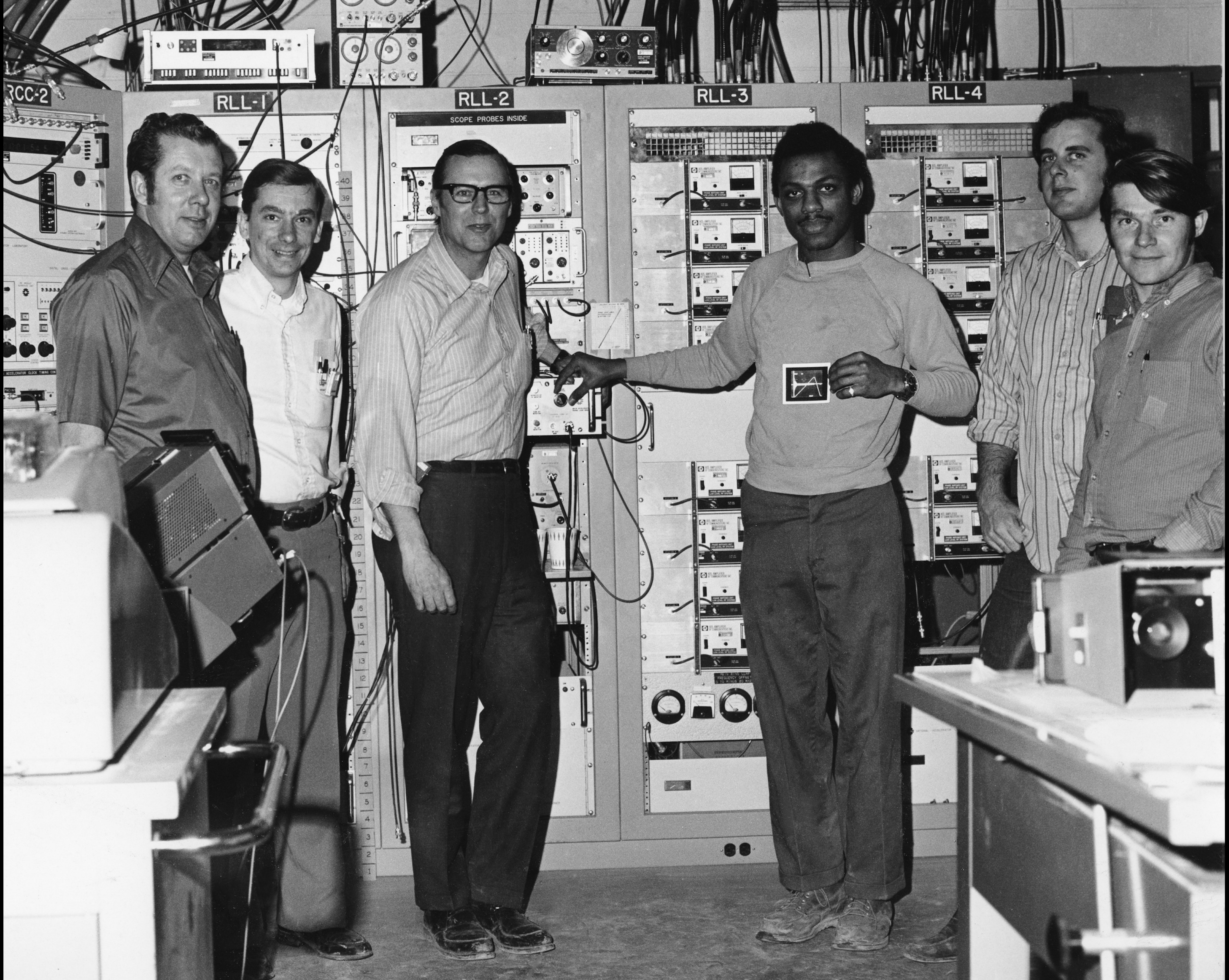
Later, a shut-down was called for, to start unsplitting power supplies. By Monday morning, as word of the achievement spread like wildfire through the Laboratory, plans were already being posted for preparations that will lead to design energy (200 BeV) soon. The Accelerator Section obviously will be anxious to try for this new thrill, having so thoroughly enjoyed the last one!!

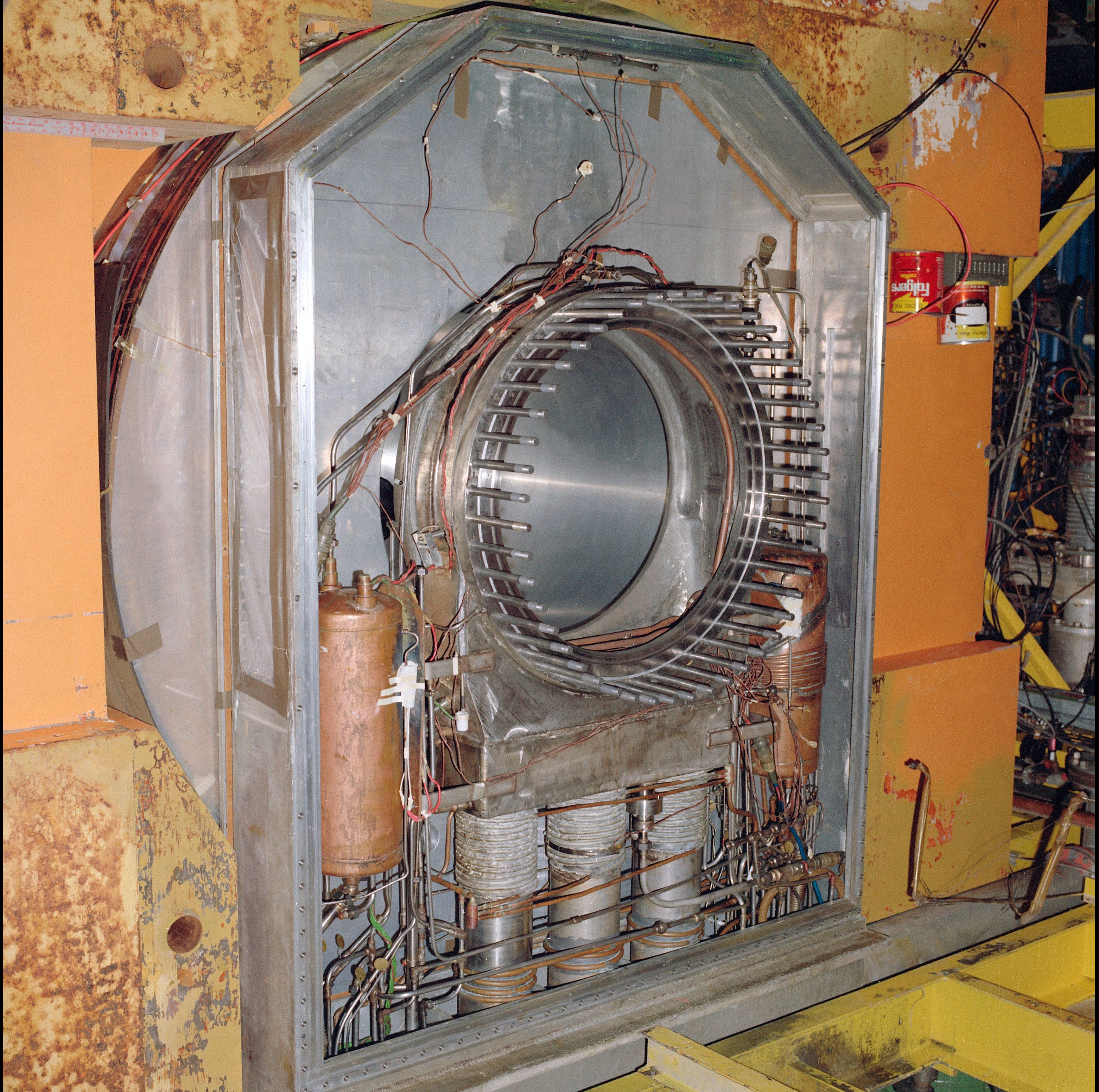
(Except as noted, all photographs in this article were taken by Ryuji Yamada, NAL.)

....(L to R) R. Flora, R. Cassel, H. Edwards at the console in the Main Control Room....

....T. Collins (L), Shigeki Mori shortly after reaching 100 BeV....


EXPT. 36
ROCKEFELLER
DUBNA
ROCHESTER
NAL
35
D


RCC-2
RLL-1
RLL-2
SCOPE PROBES INSIDE
RLL-3
RLL-4


Folgers

First experimental publication

Charged-Particle Multiplicity Distribution from 200-GeV *pp* Interactions*

G. Charlton, Y. Cho, M. Derrick, R. Engelmann, T. Fields, L. Hyman, K. Jaeger, U. Mehtani, B. Musgrave, Y. Oren,† D. Rhines, P. Schreiner, and H. Yuta
Argonne National Laboratory, Argonne, Illinois 60439

and

L. Voyvodic, R. Walker, and J. Whitmore
National Accelerator Laboratory, Batavia, Illinois 60510

and

H. B. Crawley
Iowa State University, Ames, Iowa 50010

and

Z. Ming Ma
Michigan State University, East Lansing, Michigan 48823

and

R. G. Glasser‡
University of Maryland, College Park, Maryland 20742
(Received 21 July 1972)

From 2728 events of 205-GeV *pp* interactions found in 15 000 pictures taken with the 30-in. hydrogen bubble chamber at the National Accelerator Laboratory, a total cross section of 39.5 ± 1.1 mb was measured. The mean charged-particle multiplicity for inelastic *pp* collisions was measured to be 7.65 ± 0.17. The prong distribution from 2 to 22 prongs is broader than a Poisson distribution and has a width parameter $f_2^- = \langle n_-(n_- - 1)\rangle - \langle n_-\rangle^2 = 0.95 \pm 0.21$.

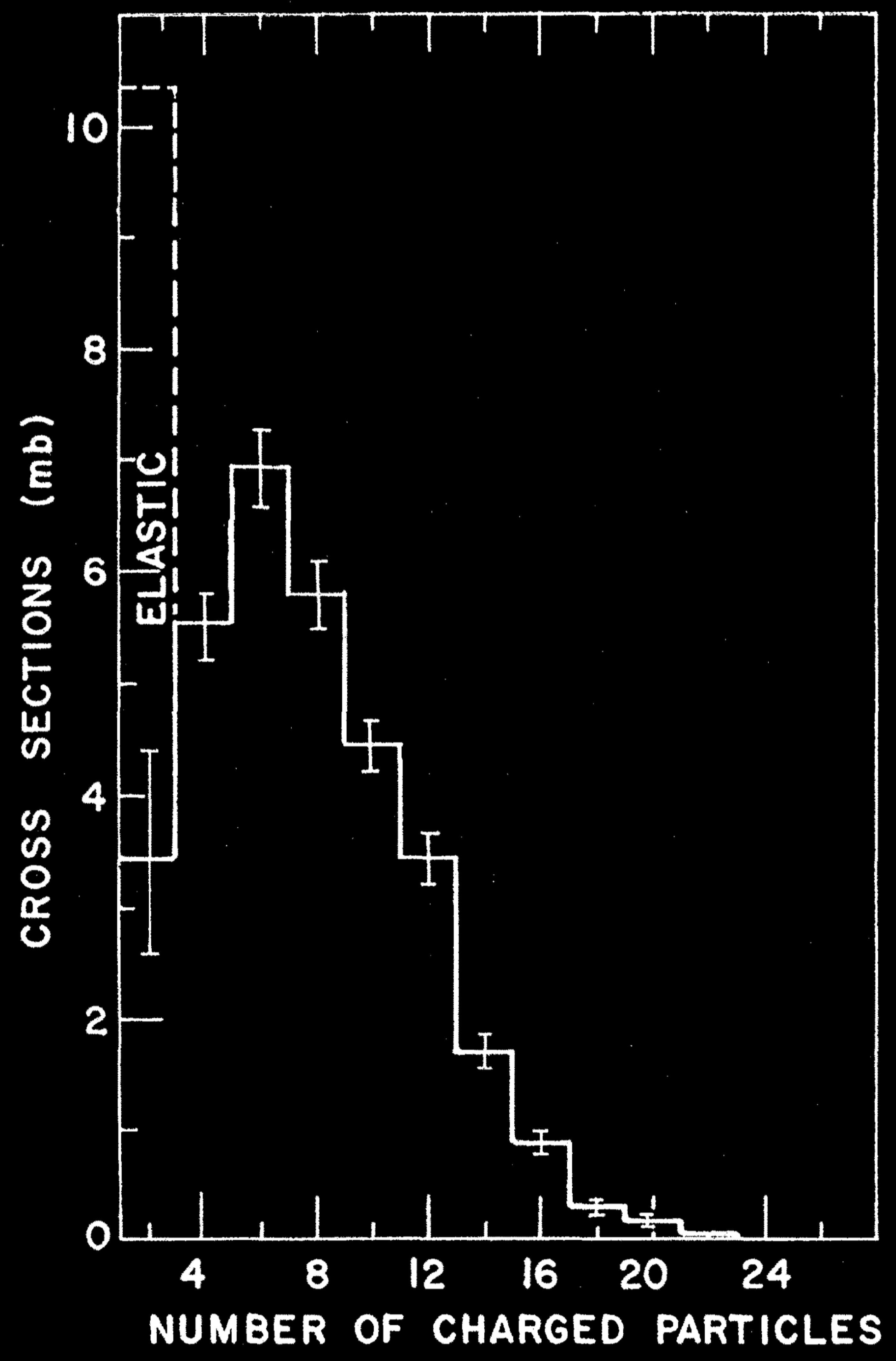
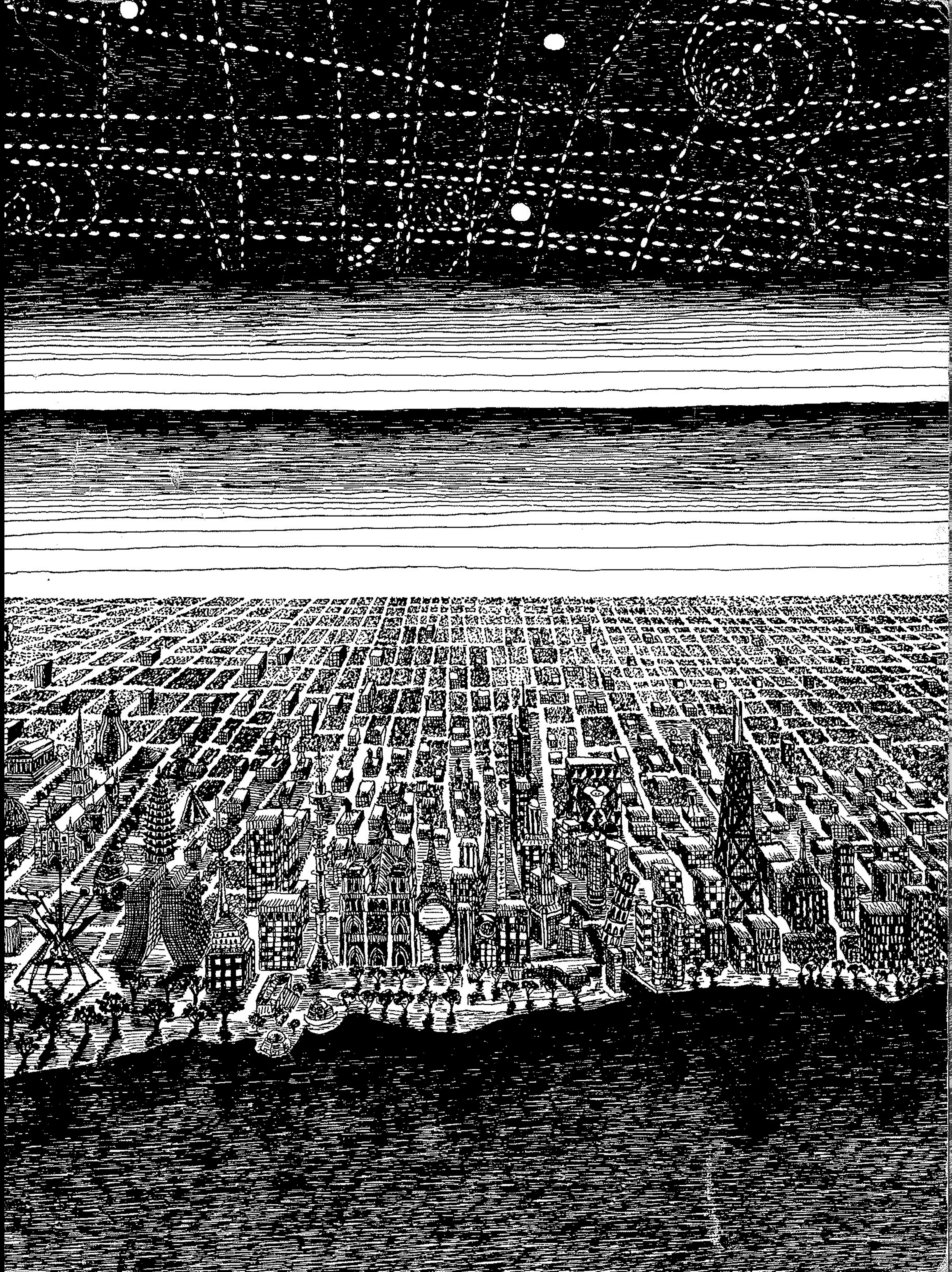
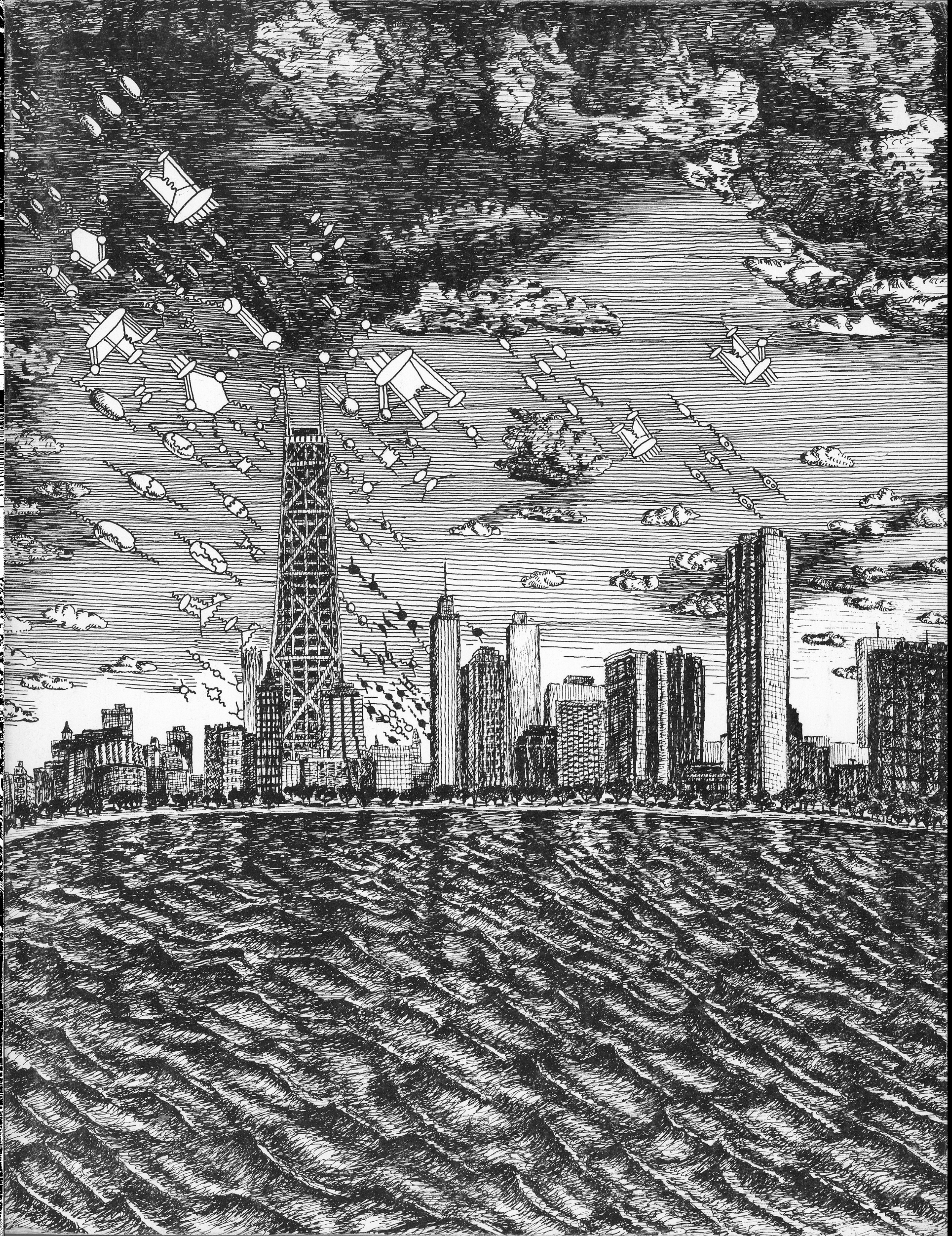
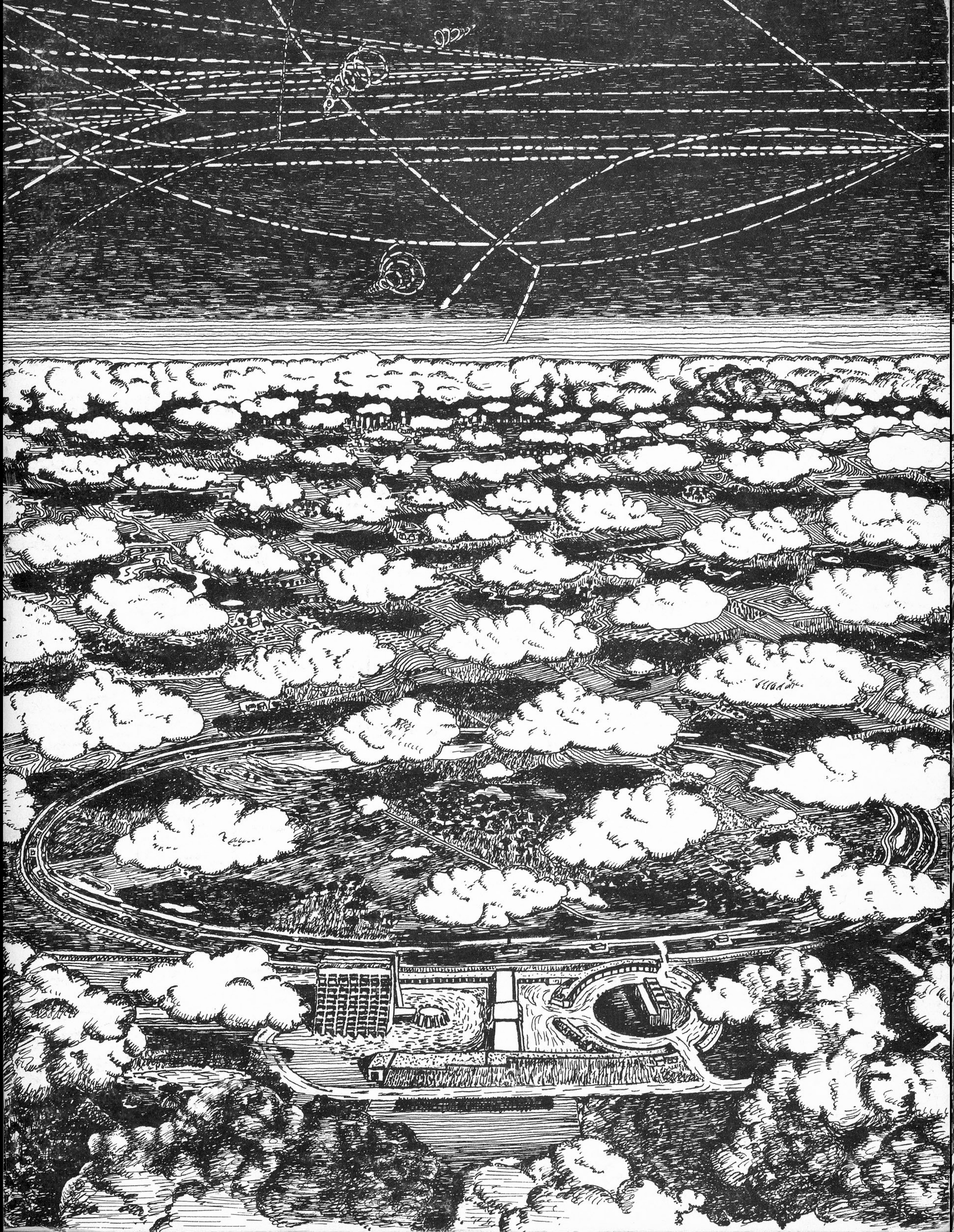


FIG. 1. Partial cross sections for events with 2 through 22 prongs. The dashed histogram shows the contribution of elastic scattering to the two-prong events.

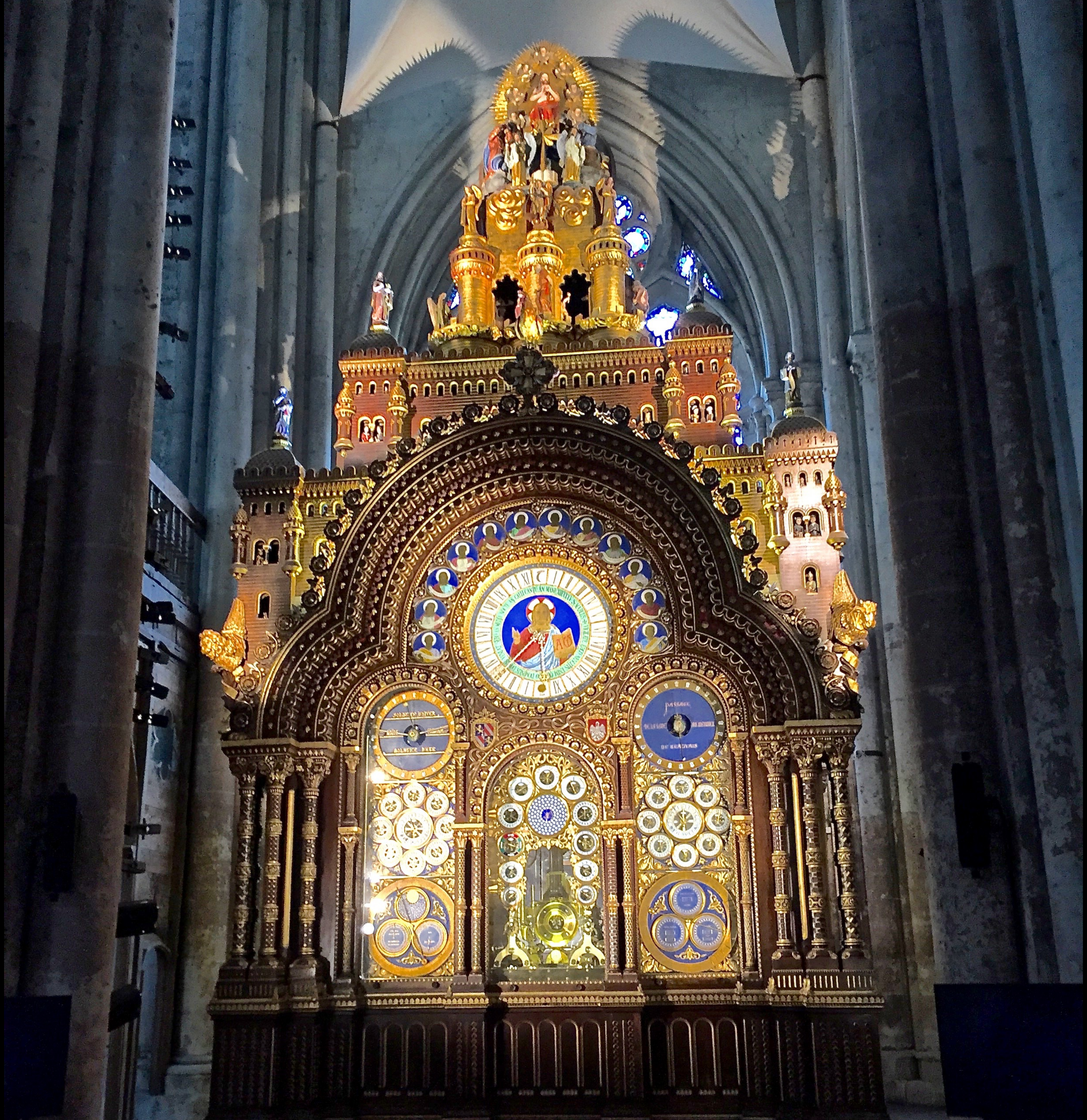







Publications from Fermilab Experiments
1970 Summer Study
The Energy Doubler
Fermilab Industrial Affiliates Roundtable on
The Science-Technology Spiral
and the Pace of Progress
Future Directions in Particle and Nuclear Physics at Multi-GeV Hadron Beam Facilities
December 2-3, 1994
Fermilab Industrial Affiliates Roundtable on
Fermilab III, the Great Computer Debate and Technology for the Nineties
Fermilab
May 31 and June 1, 1990
1969 Summer Study
Volume 1
Tiger Teams at Fermilab
FERMILAB
1982
FERMILAB
FERMILAB
1991
FERMILAB 1987
FERMILAB 1981





Edward Tufte sculpture

NAL PROPOSAL # 288

Scientific Spokesman:

L. M. Lederman
Physics Department
Columbia University
New York, New York 10027

FTS/Off-net: 212 - 460-0100
280-1754

A Study of Di-Lepton Production in Proton Collisions at NAL

J. A. Appel, M. H. Bourquin, D. C. Hom, L. M. Lederman, J. P. Repellin, H. D. Snyder, J. K. Yoh (Columbia University); B. C. Brown, P. Limon, T. Yamanouchi (NAL).

(Formerly #70 Phase III)

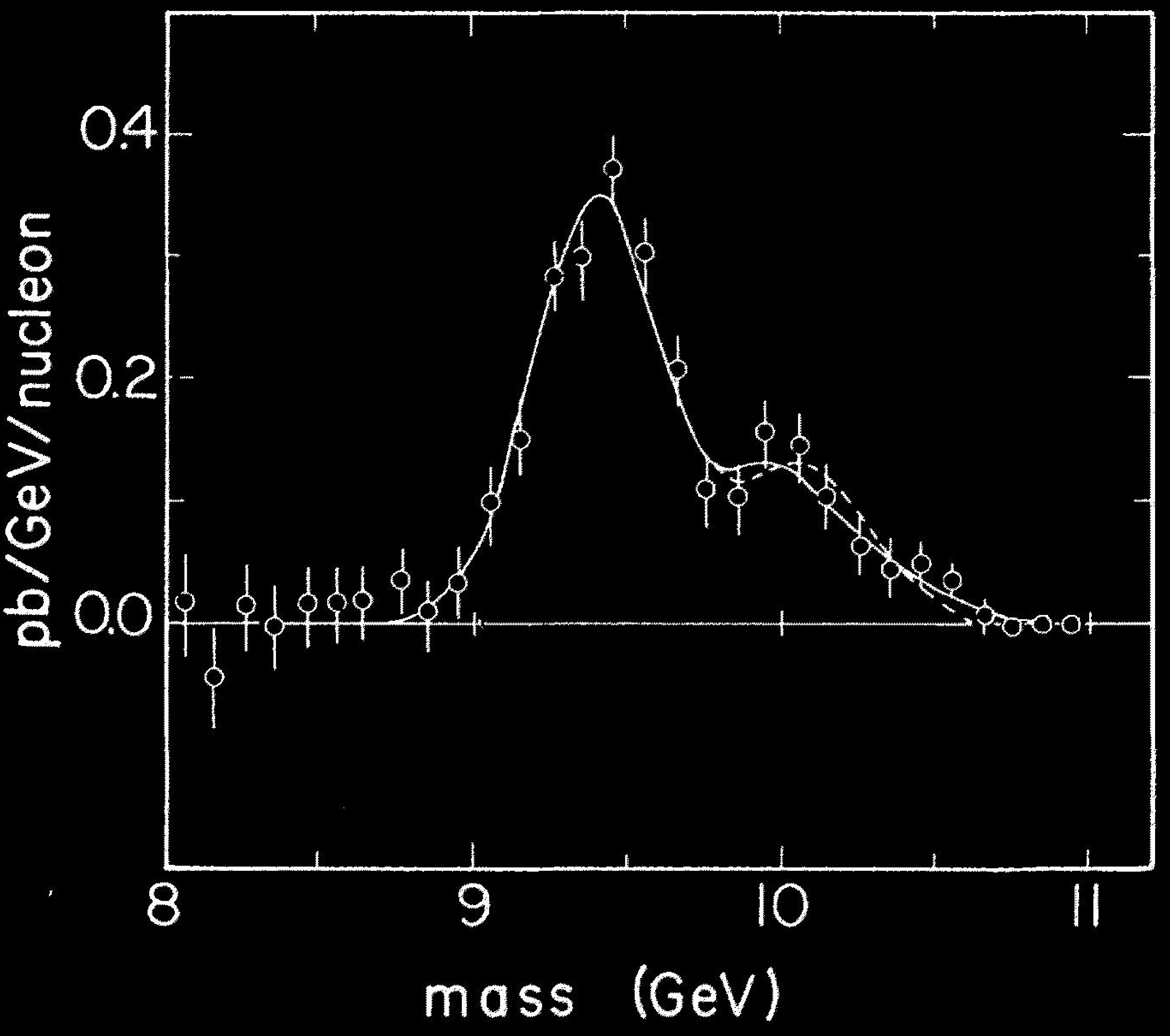
February 1974

AHR5581

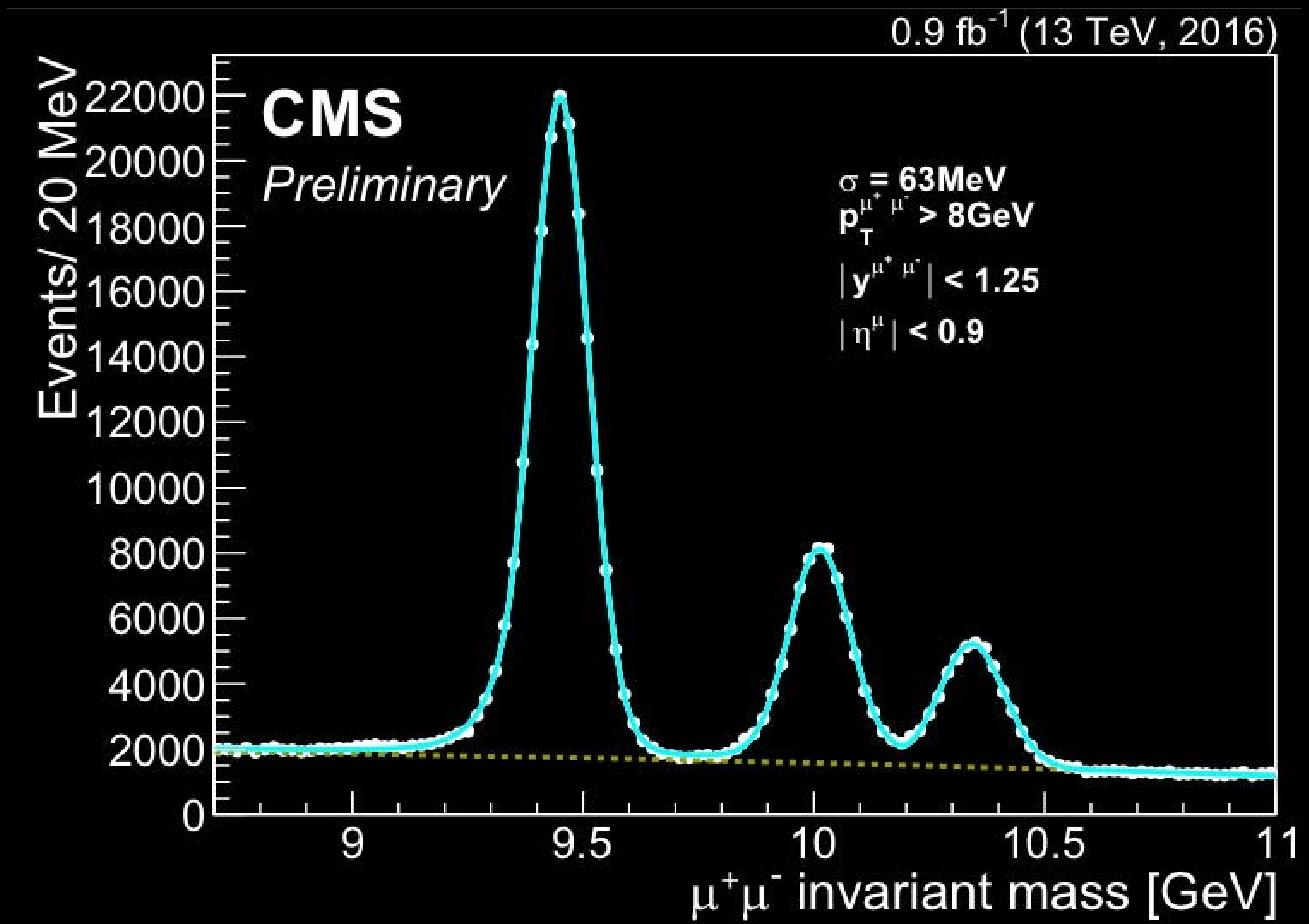
A Study of Di-Lepton Production in Proton Collisions at NAL

1. Observe and measure the spectrum of virtual photons emitted in p-nucleon collisions via the mass distribution of e^+e^- pairs: $p + p \rightarrow e^+ e^- +$ anything. (1)
   Study characteristics, e.g. parity violation, $p_\perp$ behavior.
2. Search for structures in the above spectrum, publish these and become famous, e.g. W°, B°.
3. Qualitatively study the mass spectrum of hadron pairs ($\pi\pi$, πp, etc). This is an interesting background for (1). It uses a crude hadron calorimeter, also required for hadron rejection in (1).
4. Check μe universality by looking, in the same arrangement but with the addition of a pion filter, at $\mu^+\mu^-$ pairs.
5. Extend the Experiment #70 study of single leptons in the double arm arrangement, i.e. $W^\pm$ etc. Publish these and become famous.
6. Look at $\pi^\circ\pi^\circ$ pairs by double conversion of $\pi^\circ - \gamma$'s in thin aluminum radiators. This data comes free since one adds 0.1 radiation length to enable an extrapolation to zero target thickness in (1).

Discovery



Calibration




Energy


Fermilab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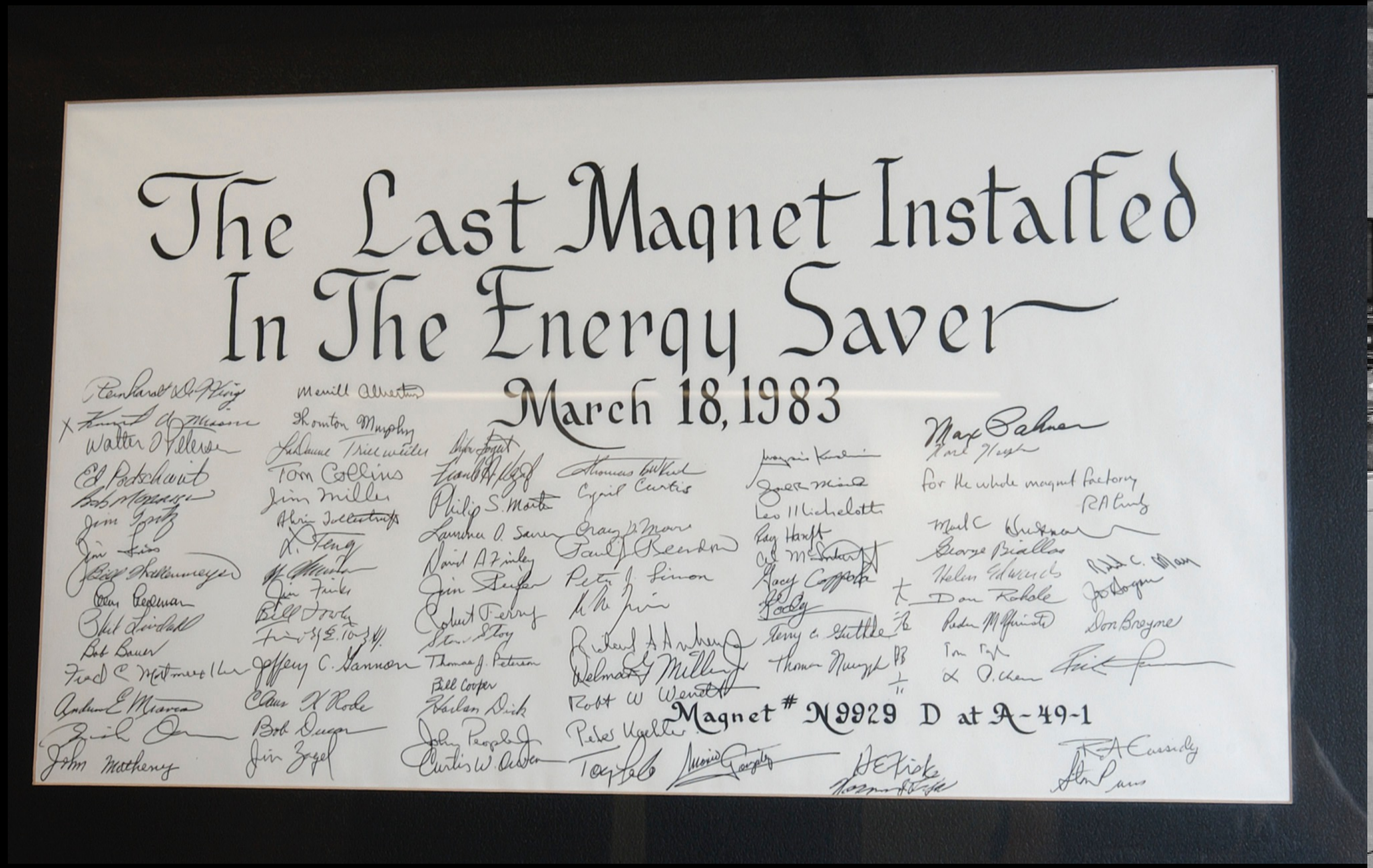
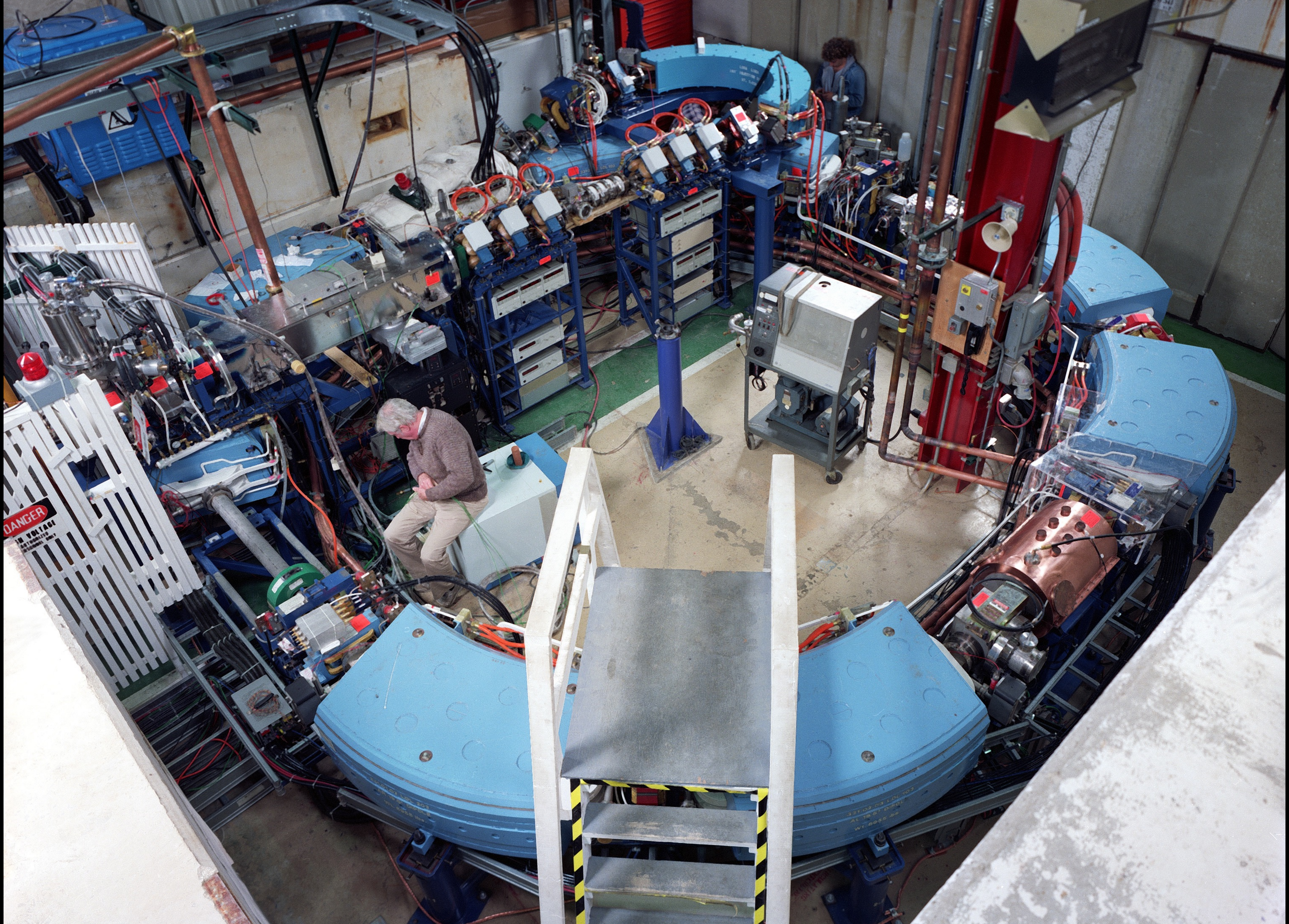
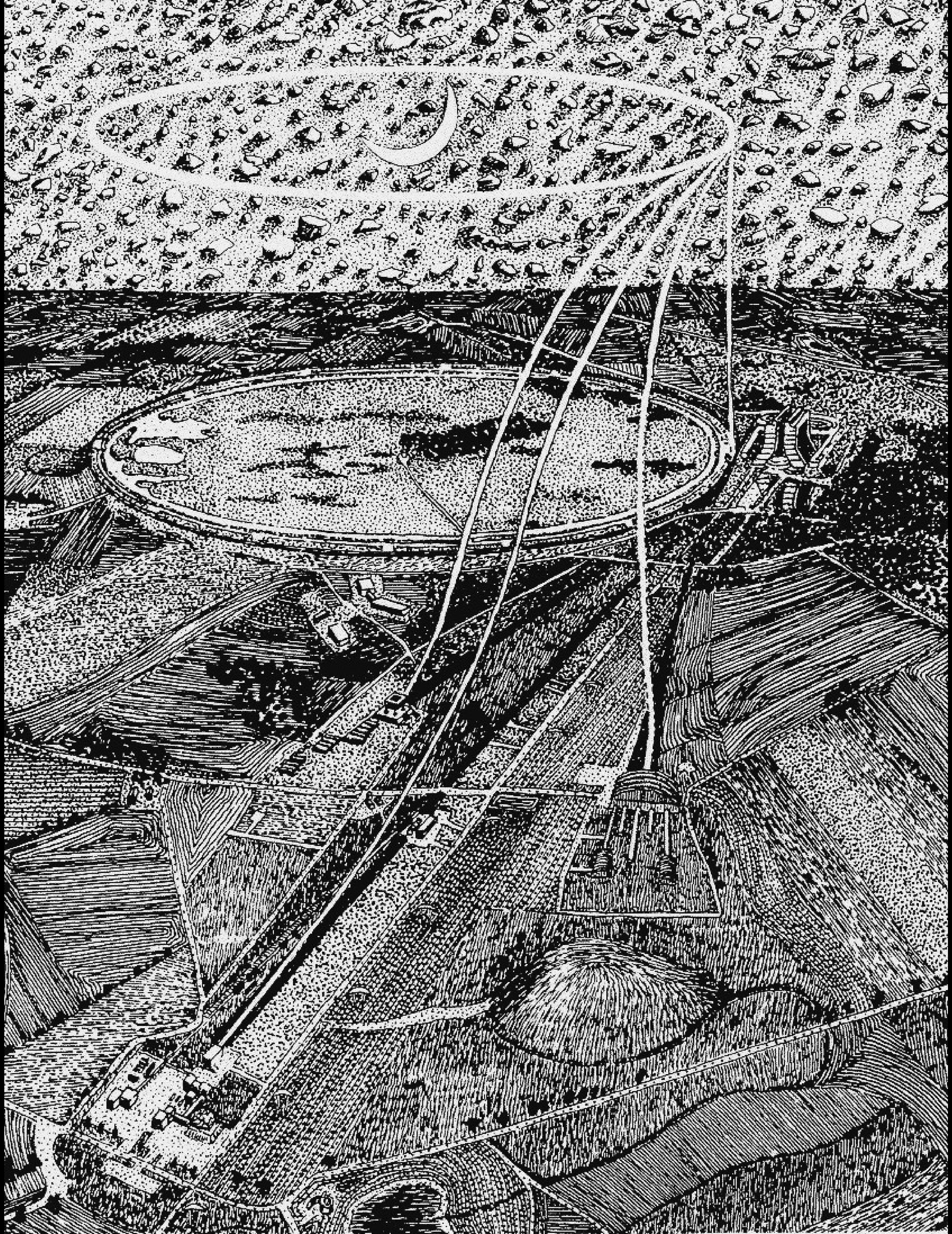
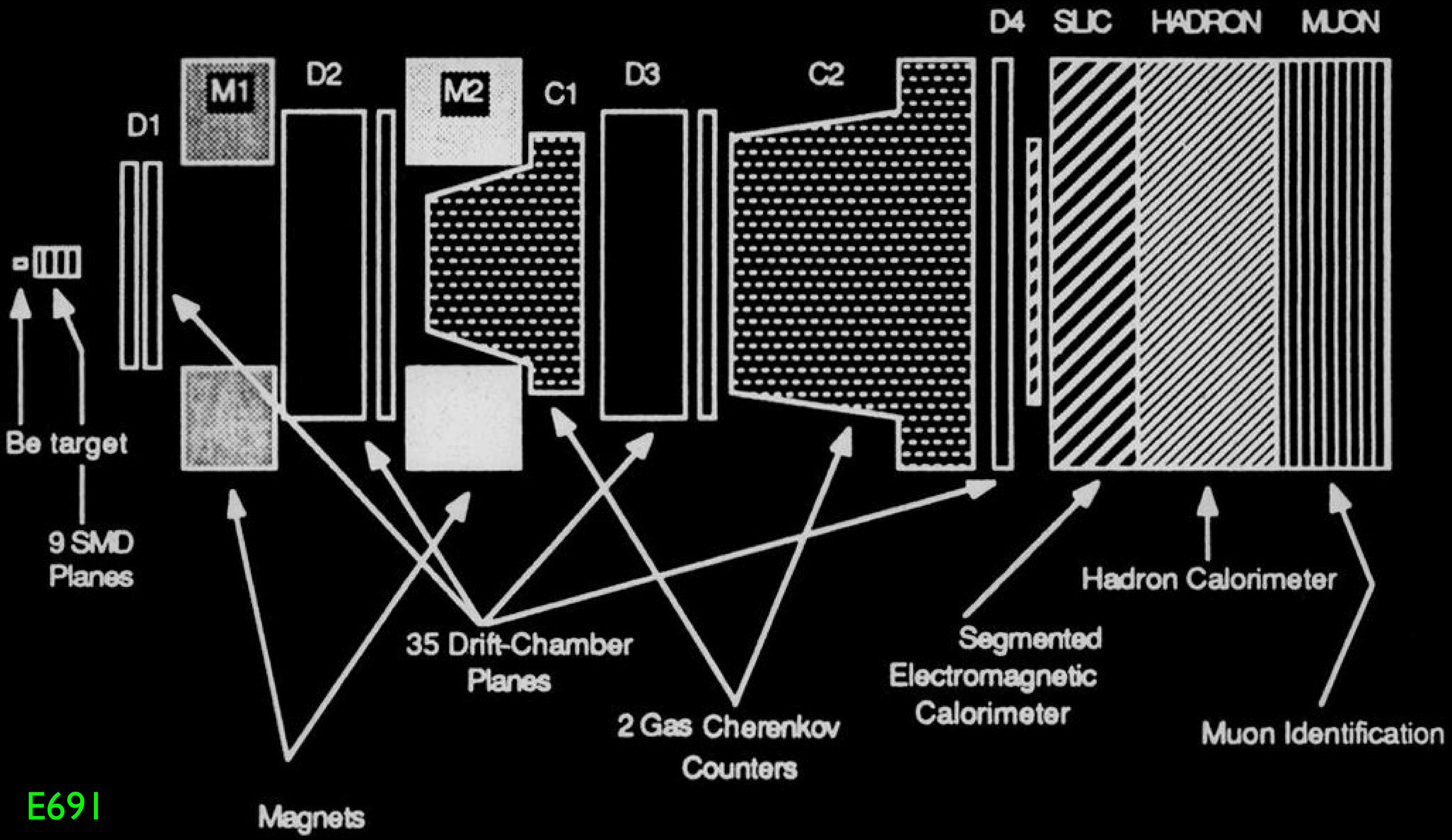
DIPOLE
QUADRUPOLE


The Last Magnet Installed
In The Energy Saver
March 18, 1983
Magnet # N9929 D at A-49-1

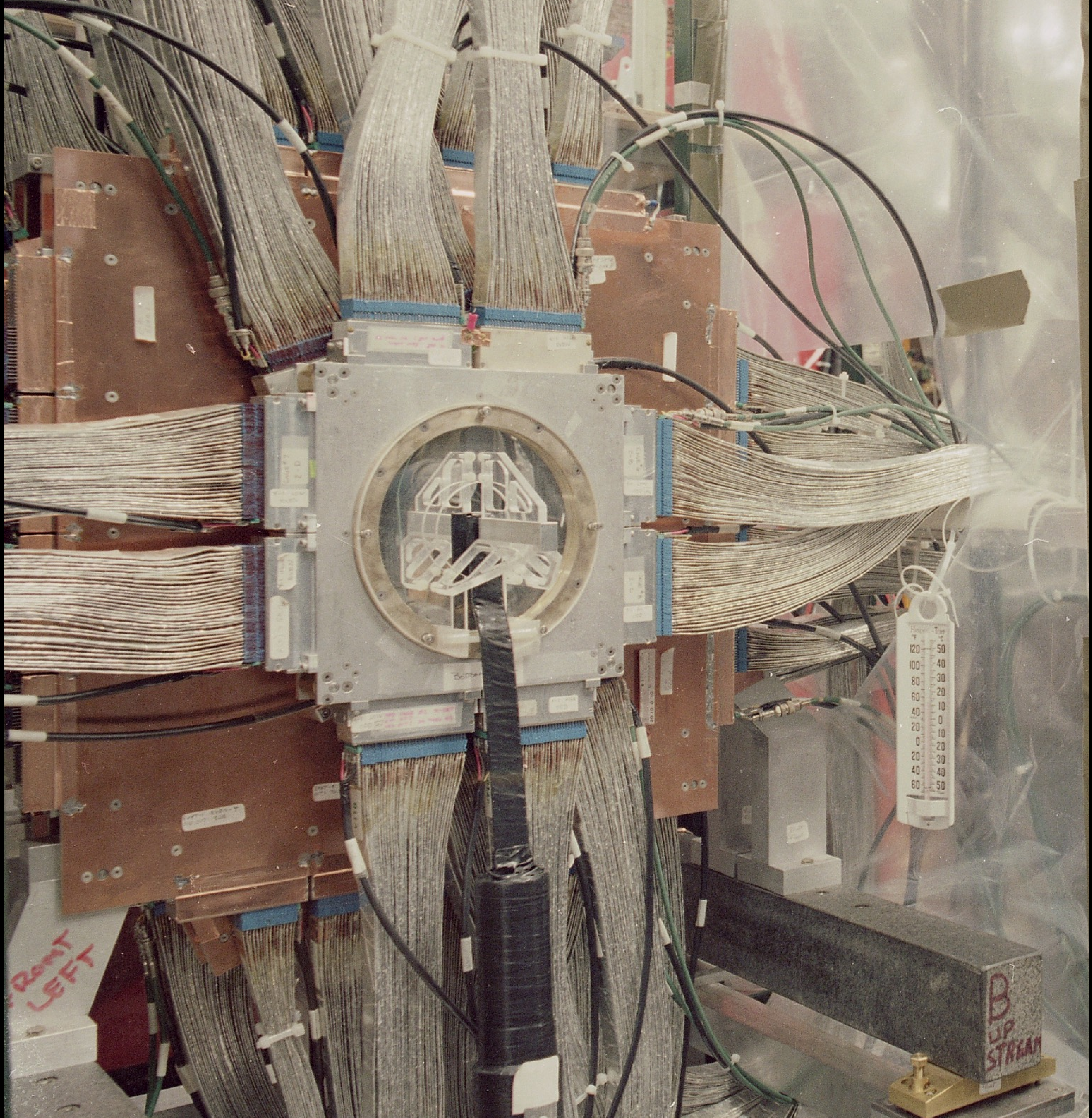

SiliconGraphics


DANGER



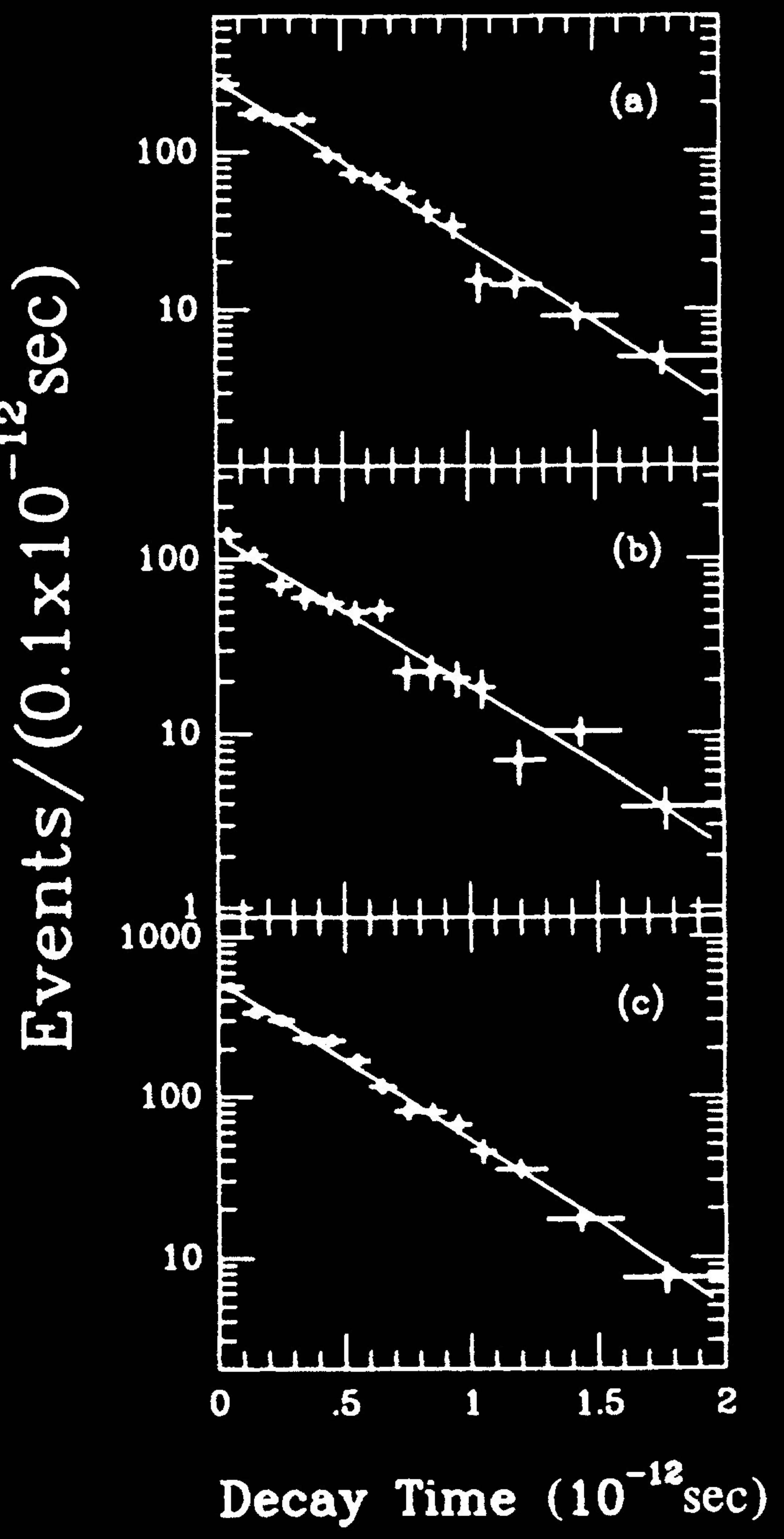

D4
SLIC
HADRON
MUON
M1
D2
M2
C1
D3
C2
D1
Be target
9 SMD
Planes
35 Drift-Chamber
Planes
Magnets
2 Gas Cherenkov
Counters
Segmented
Electromagnetic
Calorimeter
Hadron Calorimeter
Muon Identification

E691


LEFT
B
UP
STREAM

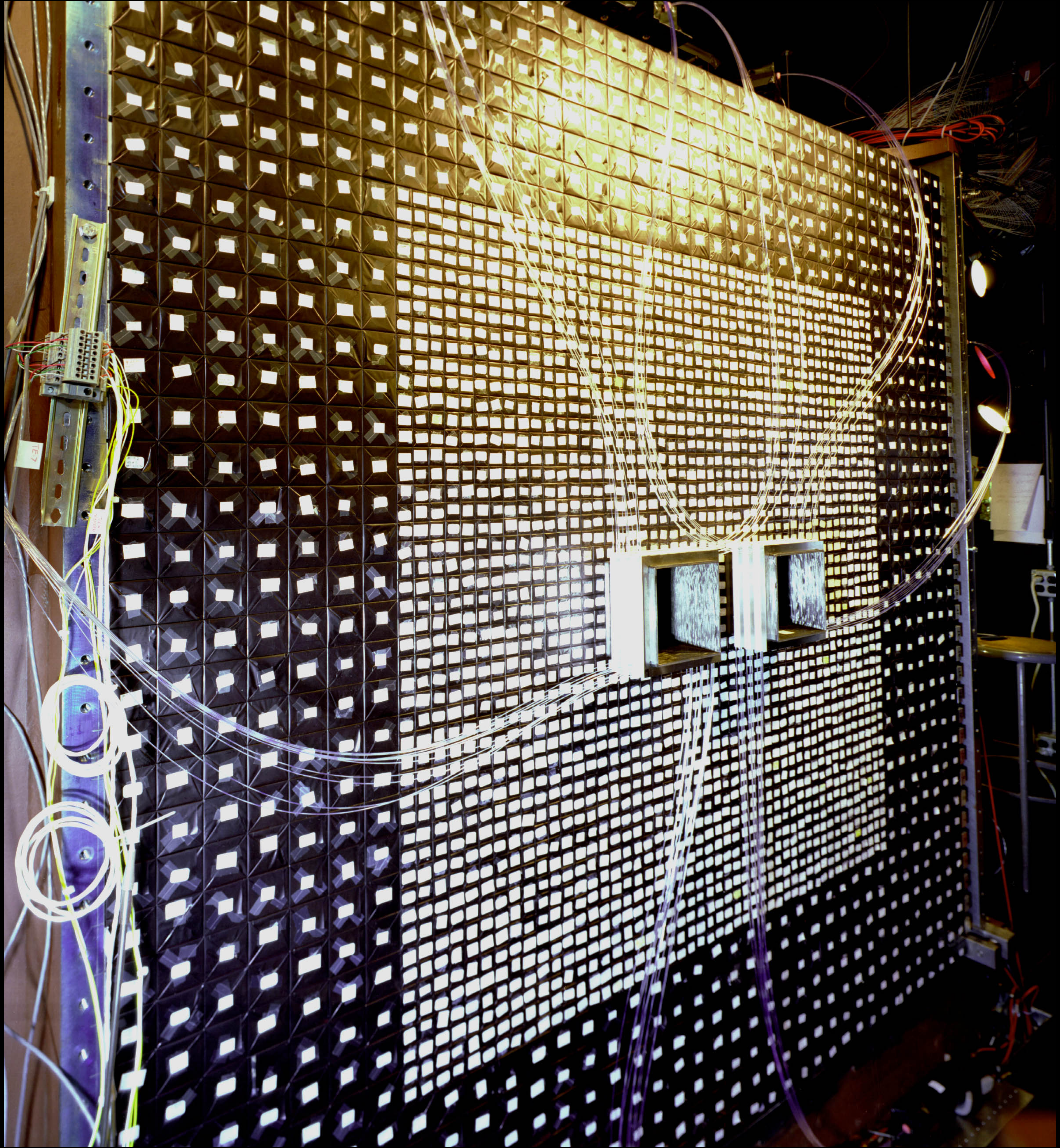

dec magtape
decassette
decpack
decpack
digital pdp11


CONTROL DATA
CONTROL DATA
CONTROL DATA

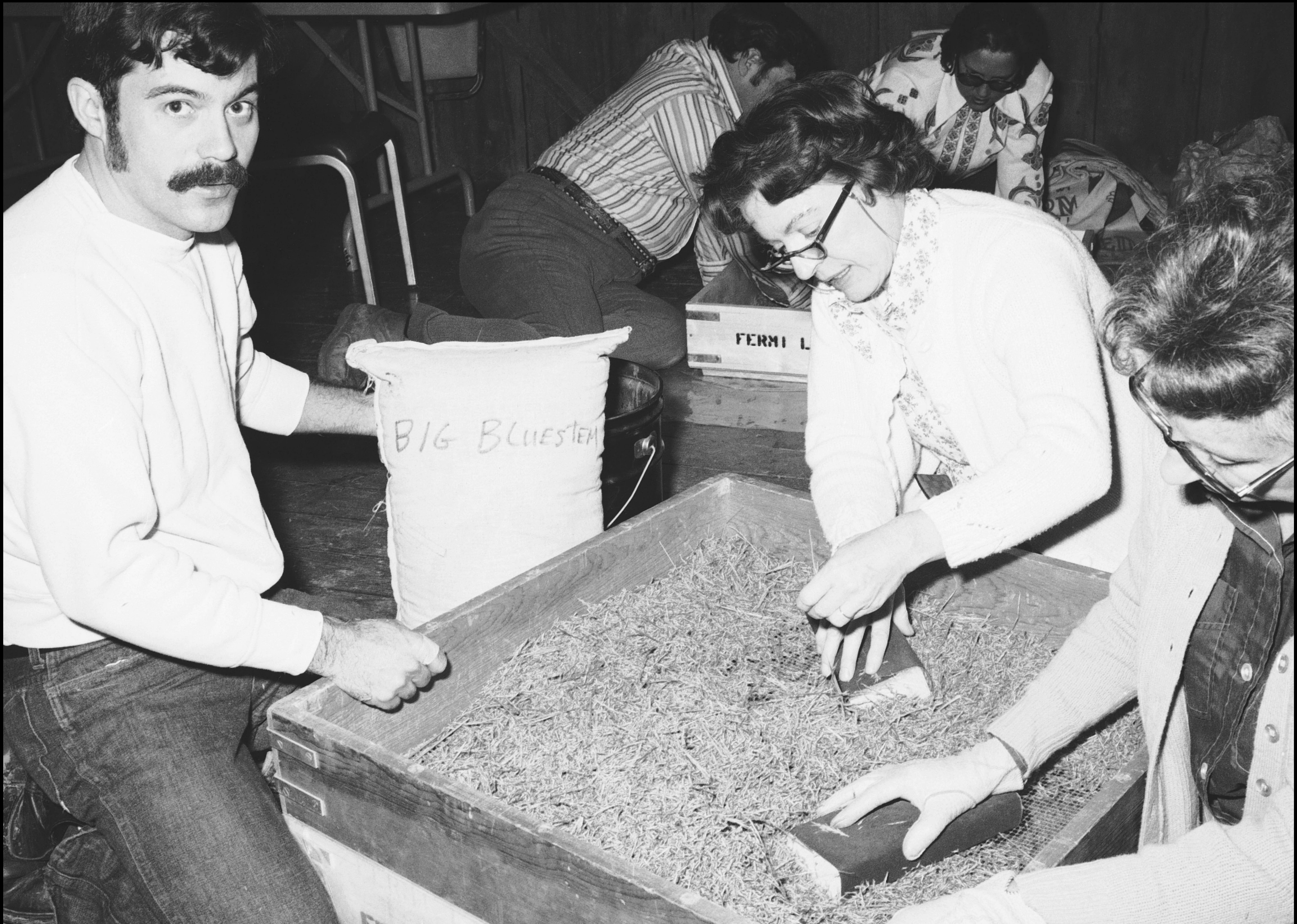


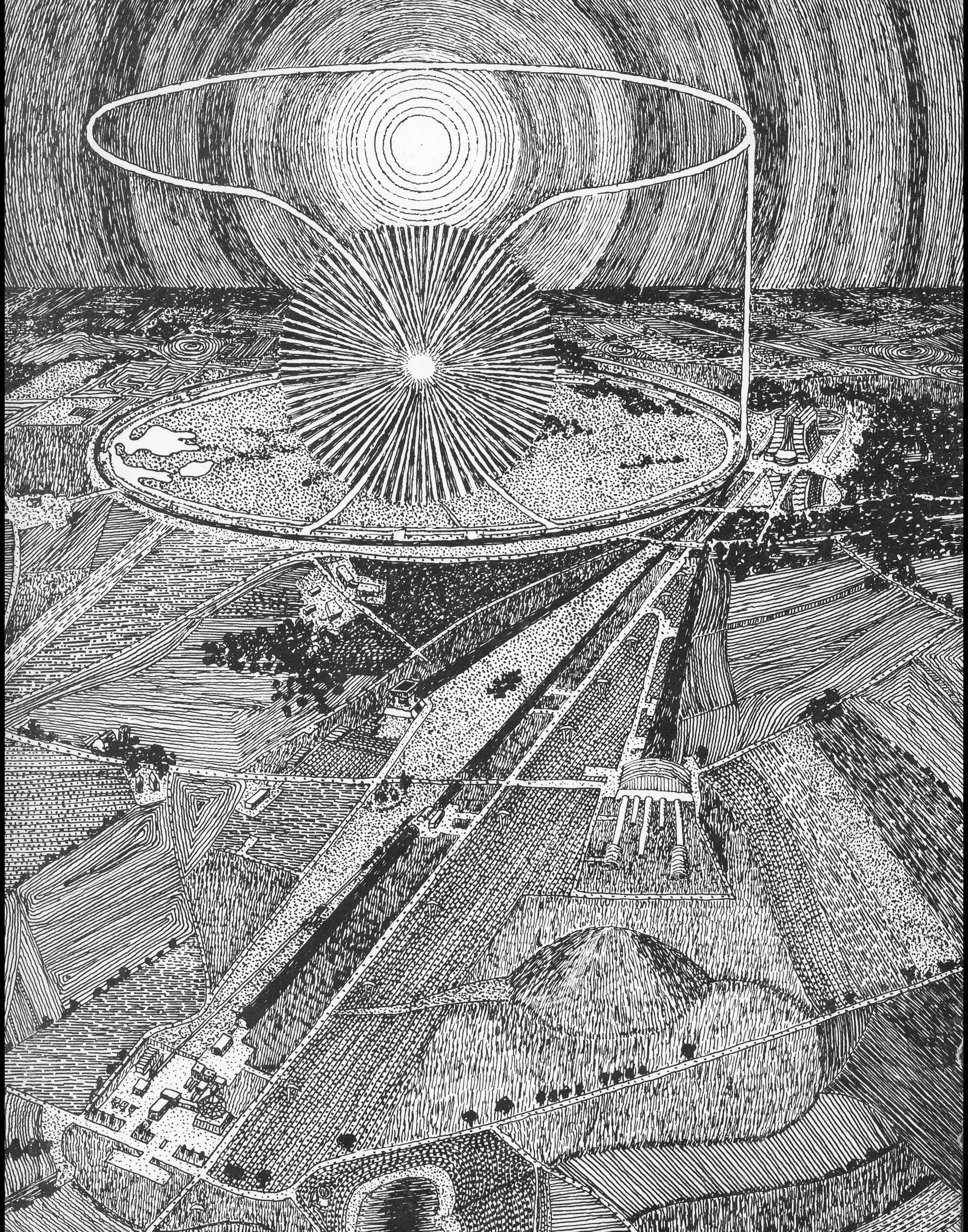
D^0 meson lifetime
~0.4 picoseconds
(4200 events)


A
B
C
D

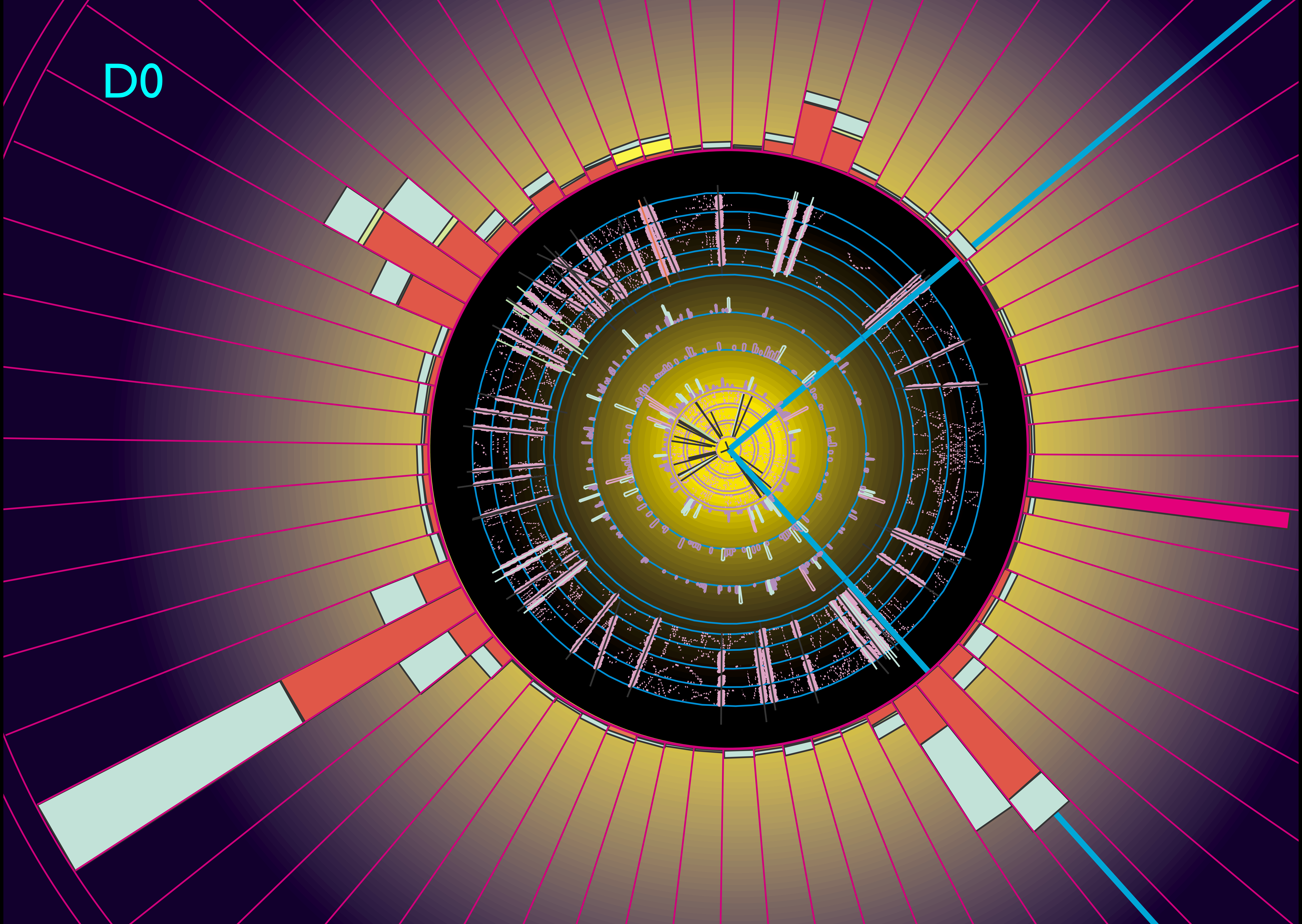


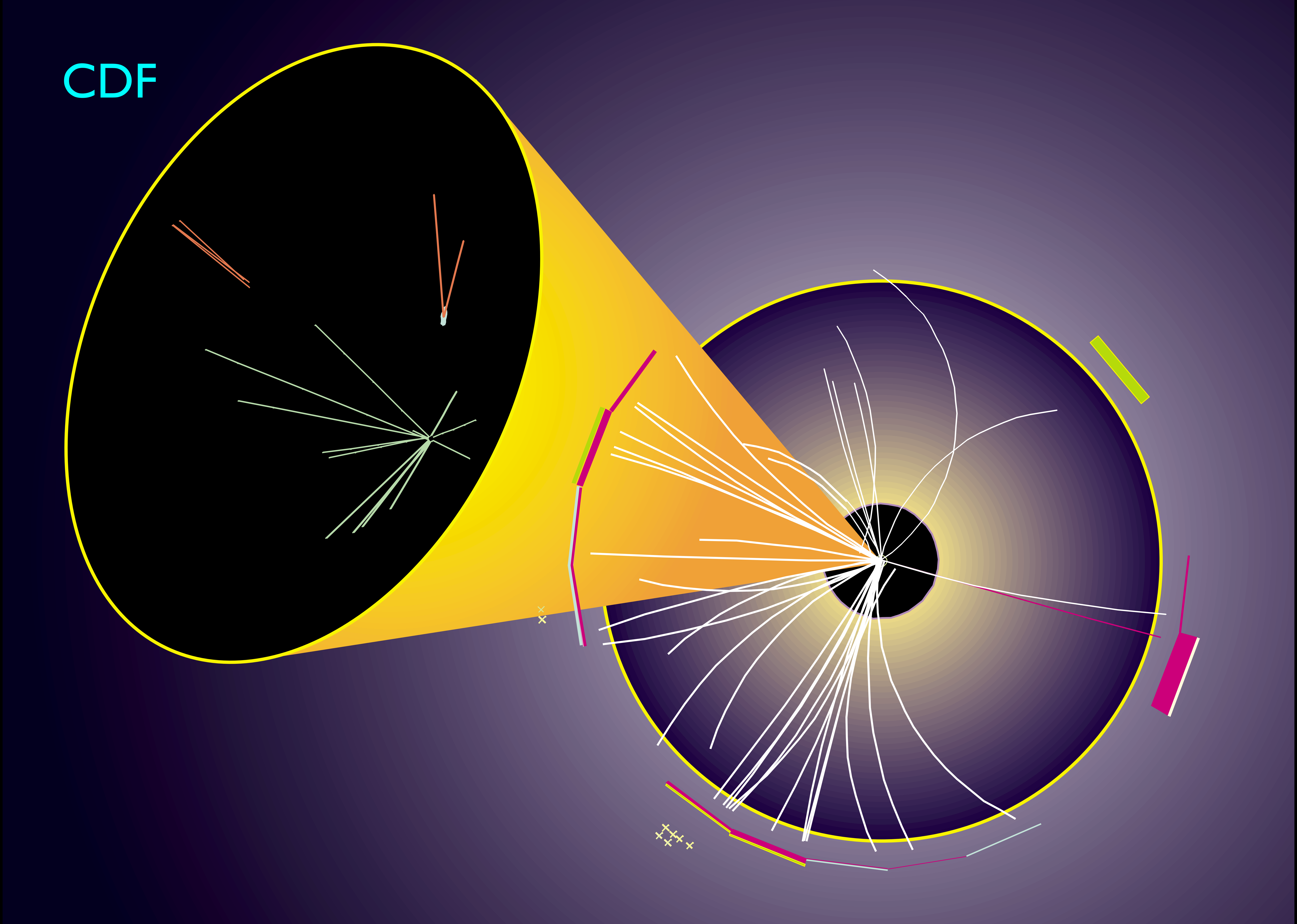
KTeV


BIG BLUESTEM
FERMI L


FERMILAB

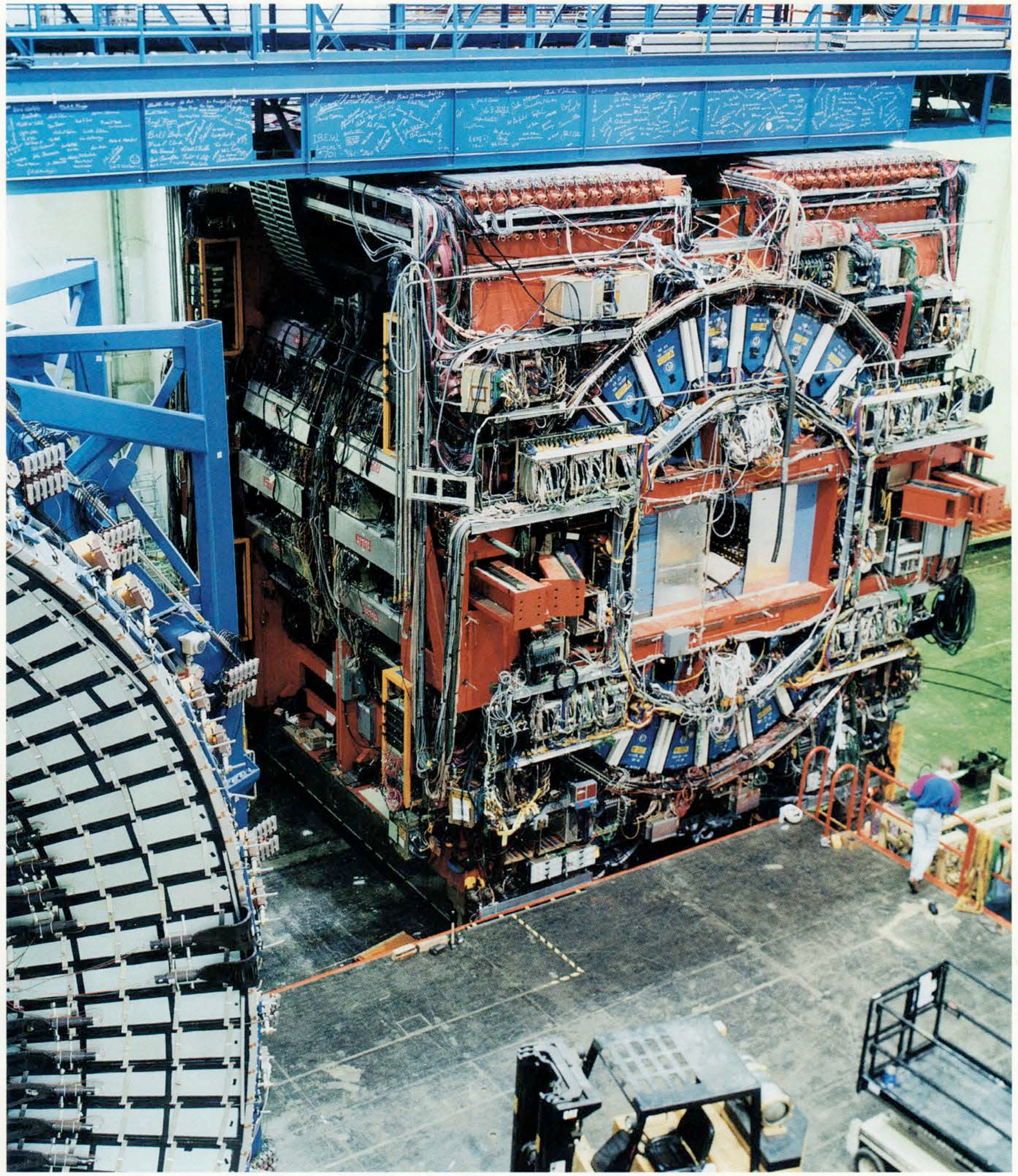

D0


CDF

'94十大最佳科技成果
3. El último ladrillo
Jetzt gibt es das "Top-Quark" offiziell
Researchers announce 'top quark' discovery
Joining its tiny cousins — up, down, strange, charm and bottom — the top quark is coaxed into being with lots of energy and money.
日米伊中心に450人参加
Laatste ontbrekende topquark lijkt ontdekt
Cultura e Spettacoli
CORRIERE DELLA SERA
Dove vai, cacciatore di quark?
Batavia is center of universe
Alles Quark, oder was?
I predatori del quark perduto
For physicists, last piece of a puzzle
Nation
Publikaties met meer dan 100 auteurs komen steeds vaker voor
RICERCA ITALIANA
EPPUR SI MUOVE
Truth by Consensus
Deciding which scientific findings to trust is an imprecise process that goes on in the lab as well as in court.
Tajemniczy szósty kwark
AUJOURD'HUI
Quand les particules livreront leur dernier secret
'94十大最佳科技成果
The Quark Is a Porker
Physicists Weigh In
LA STAMPA
tuttoscienze
Kwark T – najdziwniejszy z osobliwej rodziny
LES BRICOLAGES DE LA VIE
Ora la fisica è al Top
Fine del viaggio al centro della materia
Topquark-jagers eindigen ex aequo
一九九四年世界十大科技进展
国籍を超えて「究極」探索

PHYSICS TODAY

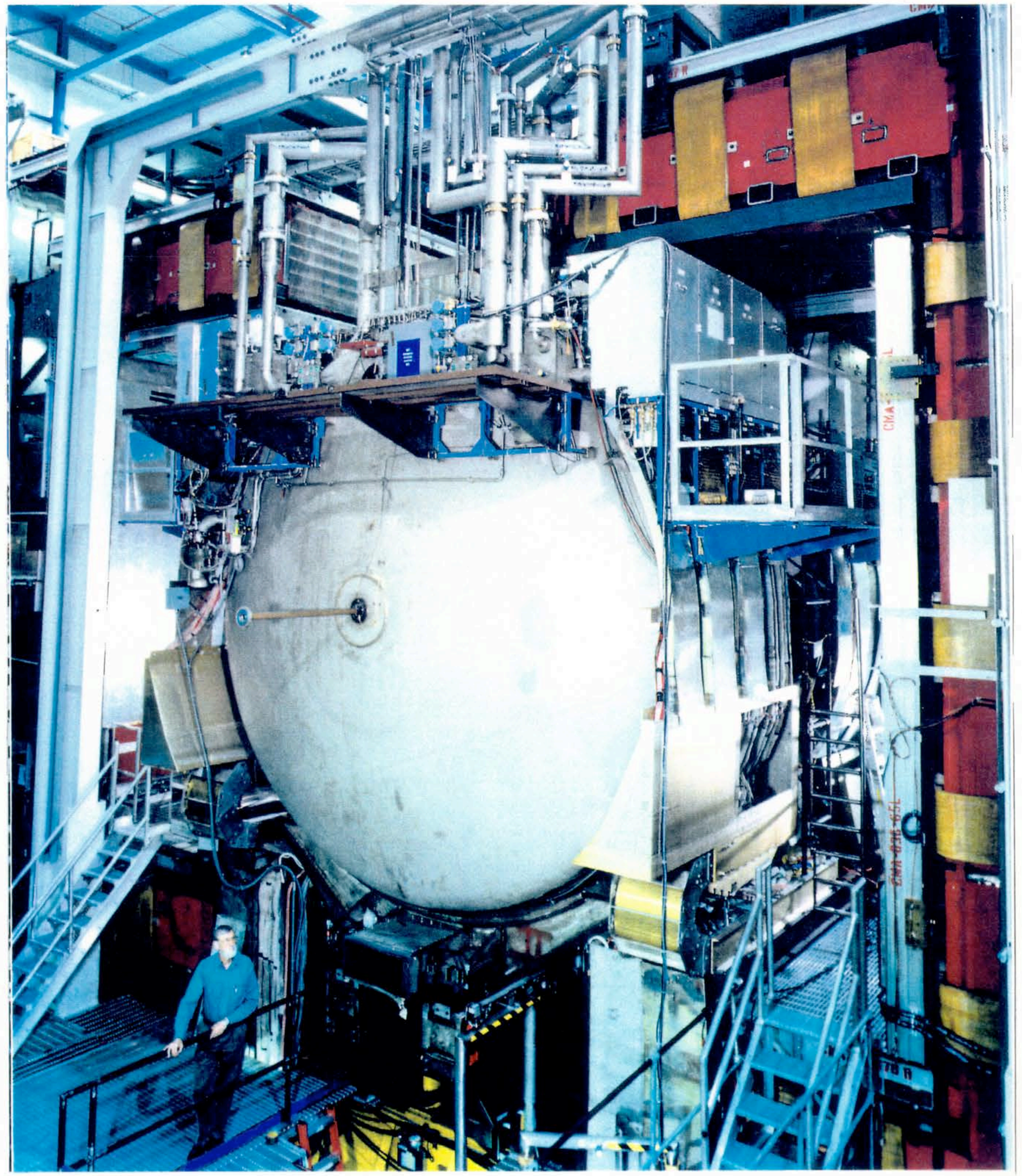
MAY 1997



THE REMARKABLE TOP QUARK

PHYSICS TODAY

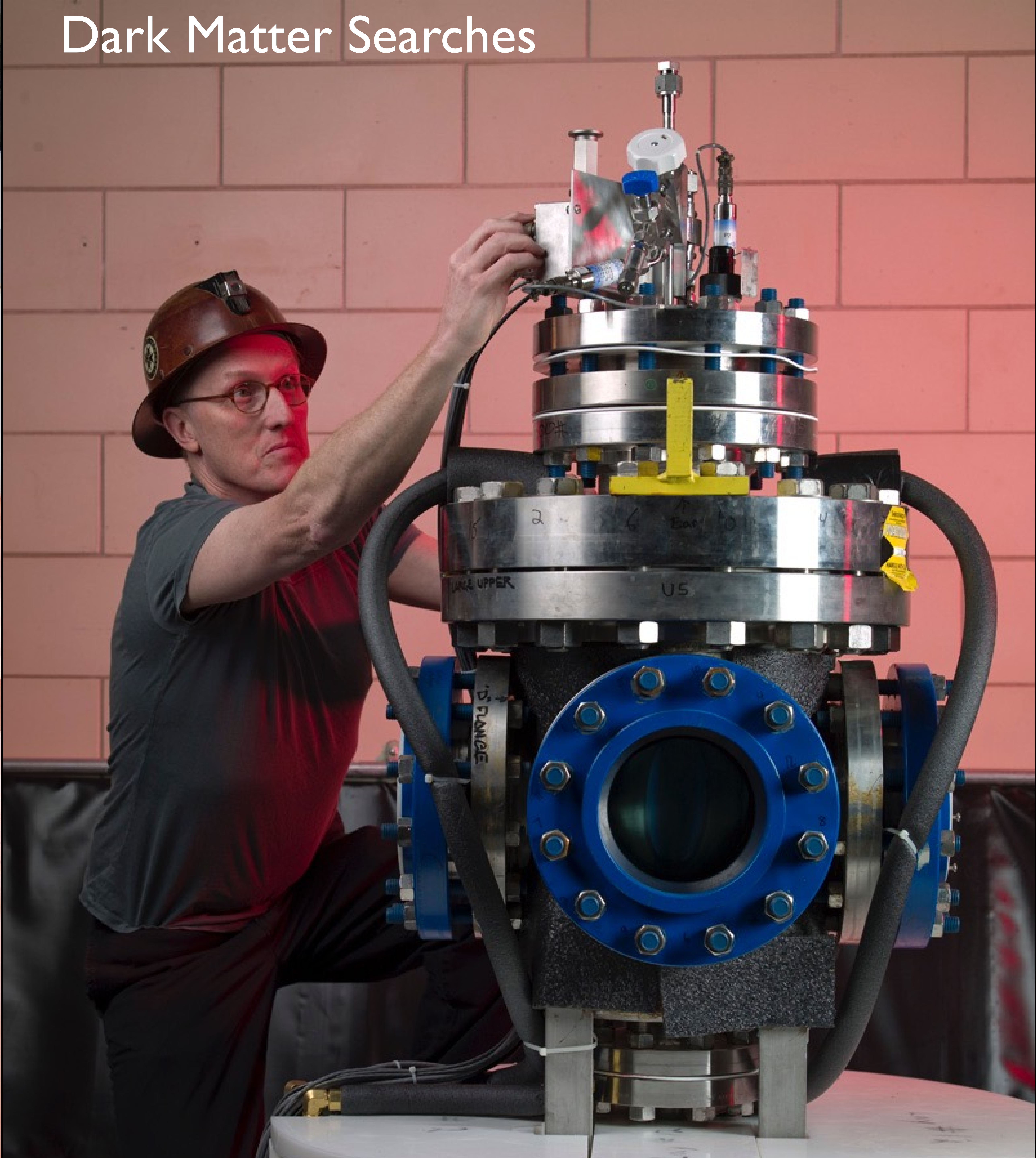
MAY 1997



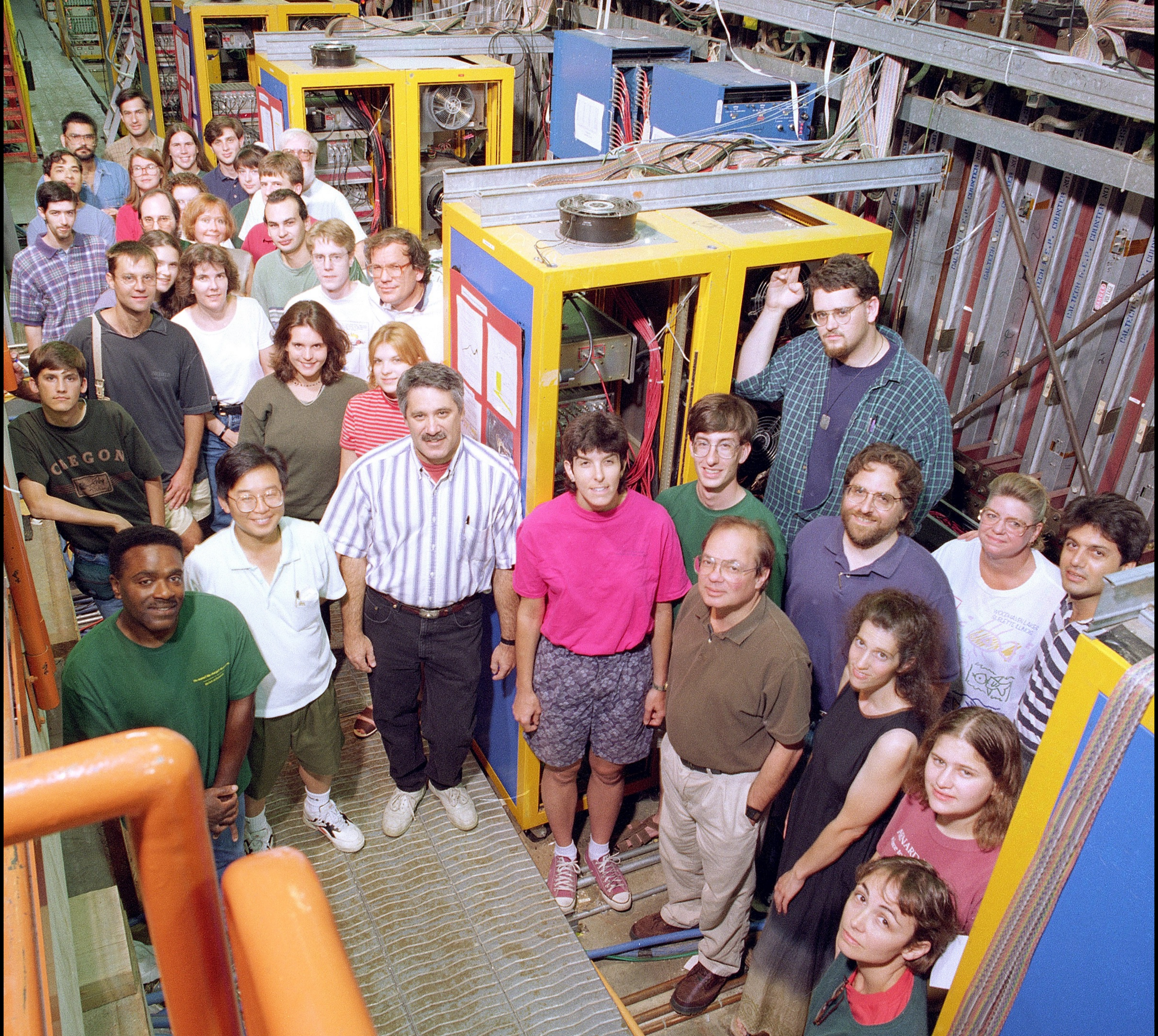
THE REMARKABLE TOP QUARK


LOYAL TO NONE
BRINGING THE HEAT!
Hello!

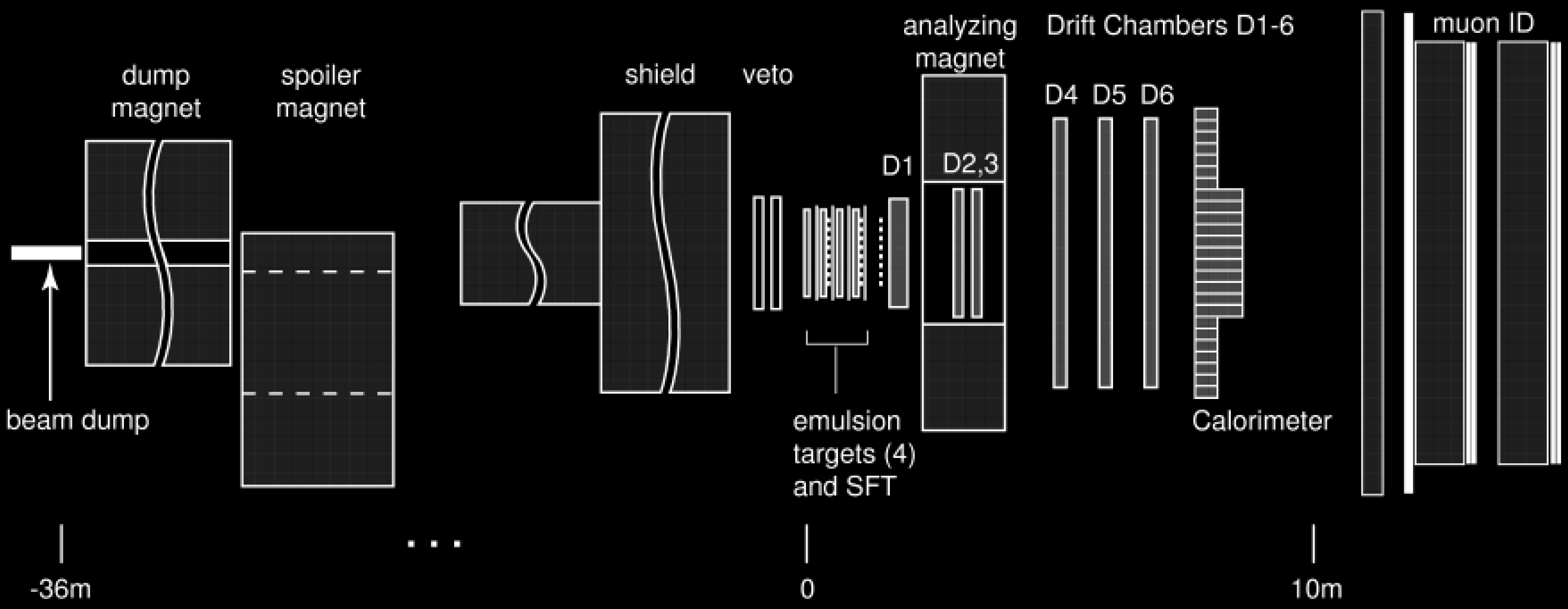
Dark Matter Searches

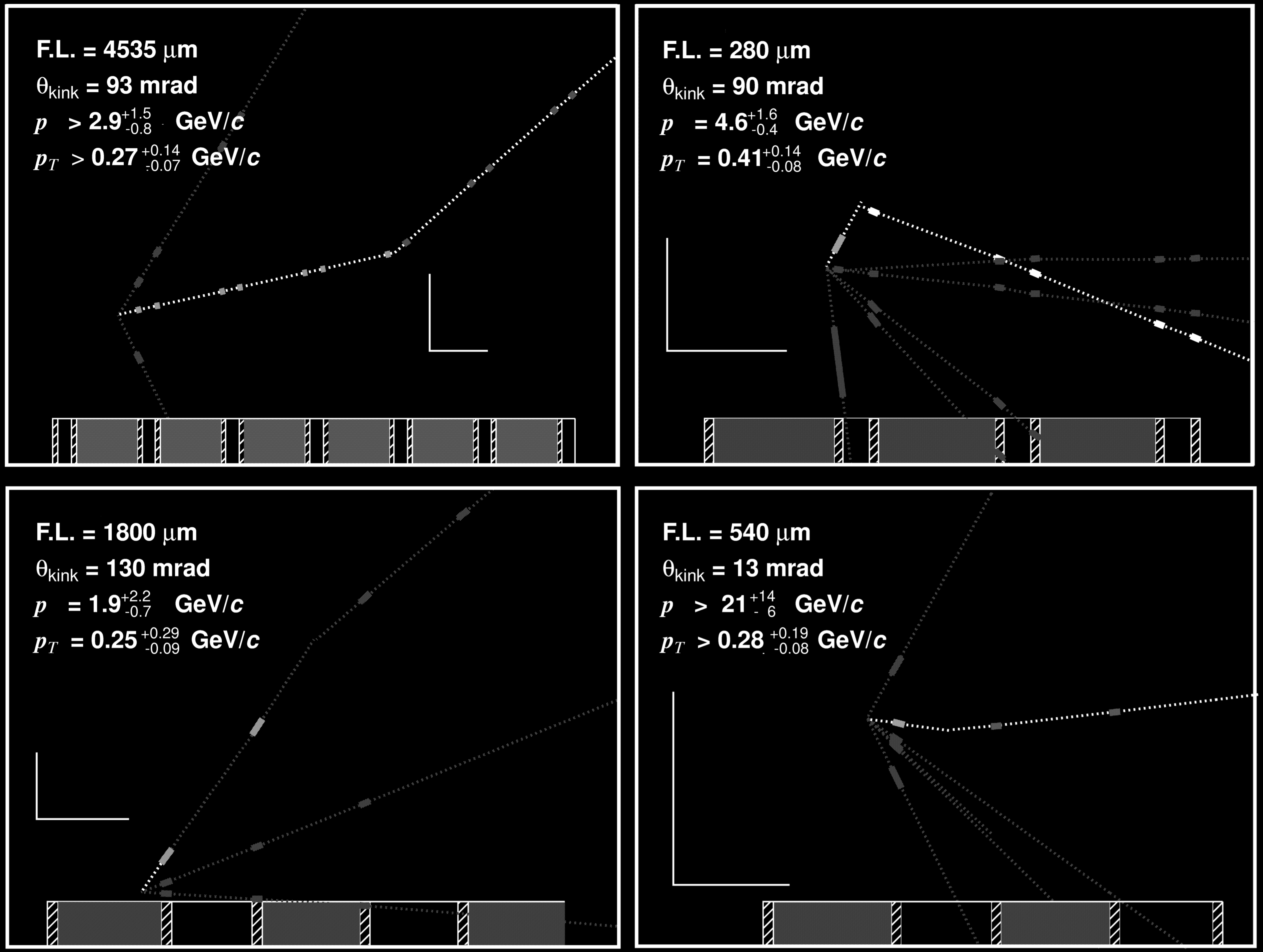


Neutrinos

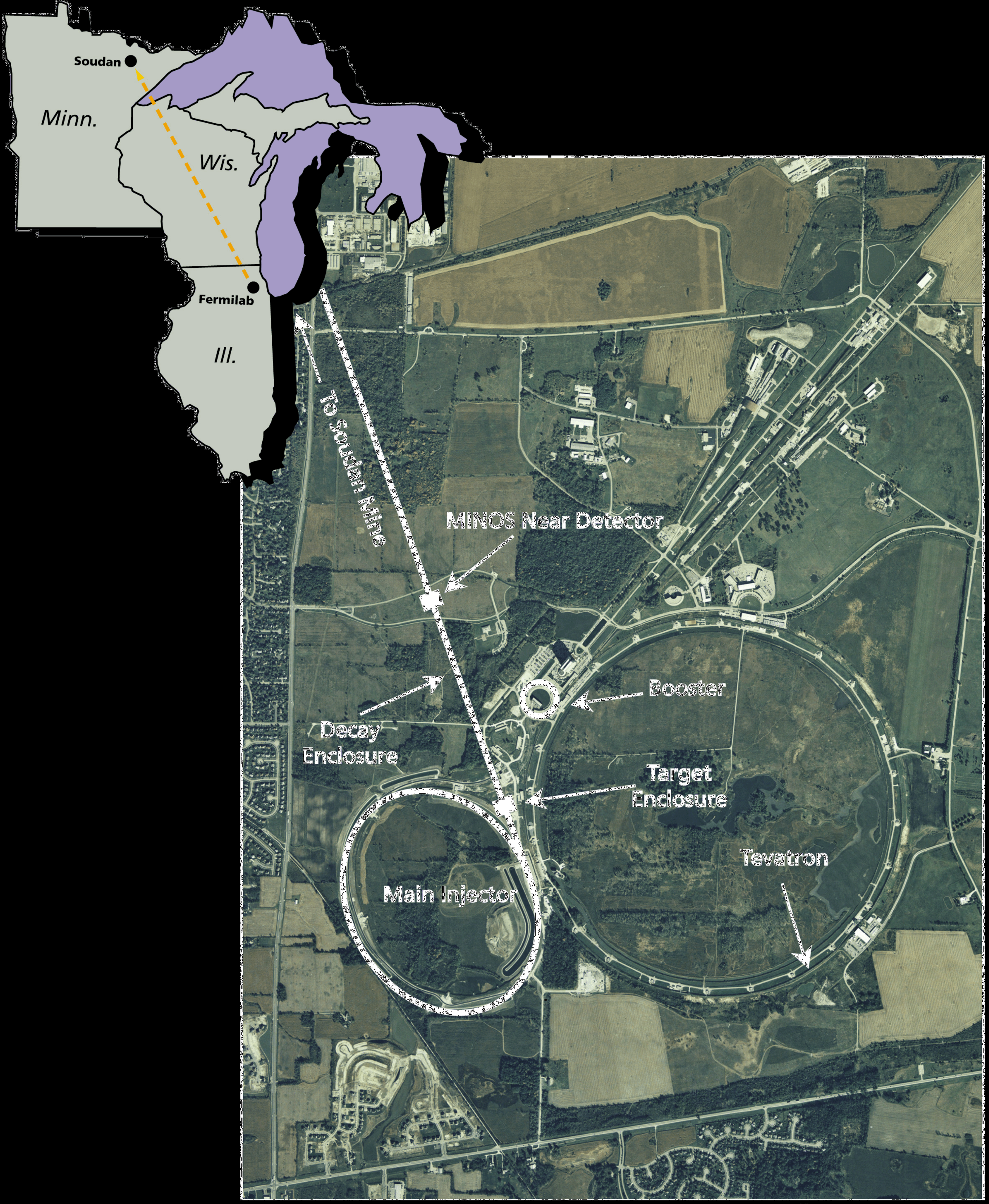


Direct Observation of the tau neutrino




F.L. = 4535 μm
θ_{kink} = 93 mrad
$p > 2.9^{+1.5}_{-0.8}$ GeV/c
$p_T > 0.27^{+0.14}_{-0.07}$ GeV/c
F.L. = 280 μm
θ_{kink} = 90 mrad
$p = 4.6^{+1.6}_{-0.4}$ GeV/c
$p_T = 0.41^{+0.14}_{-0.08}$ GeV/c
F.L. = 1800 μm
θ_{kink} = 130 mrad
$p = 1.9^{+2.2}_{-0.7}$ GeV/c
$p_T = 0.25^{+0.29}_{-0.09}$ GeV/c
F.L. = 540 μm
θ_{kink} = 13 mrad
$p > 21^{+14}_{-6}$ GeV/c
$p_T > 0.28^{+0.19}_{-0.08}$ GeV/c


EXIT


Soudan
Minn.
Wis.
Fermilab
Ill.
To Soudan Mine
MINOS Near Detector
Booster
Decay Enclosure
Target Enclosure
Tevatron
Main Injector


485

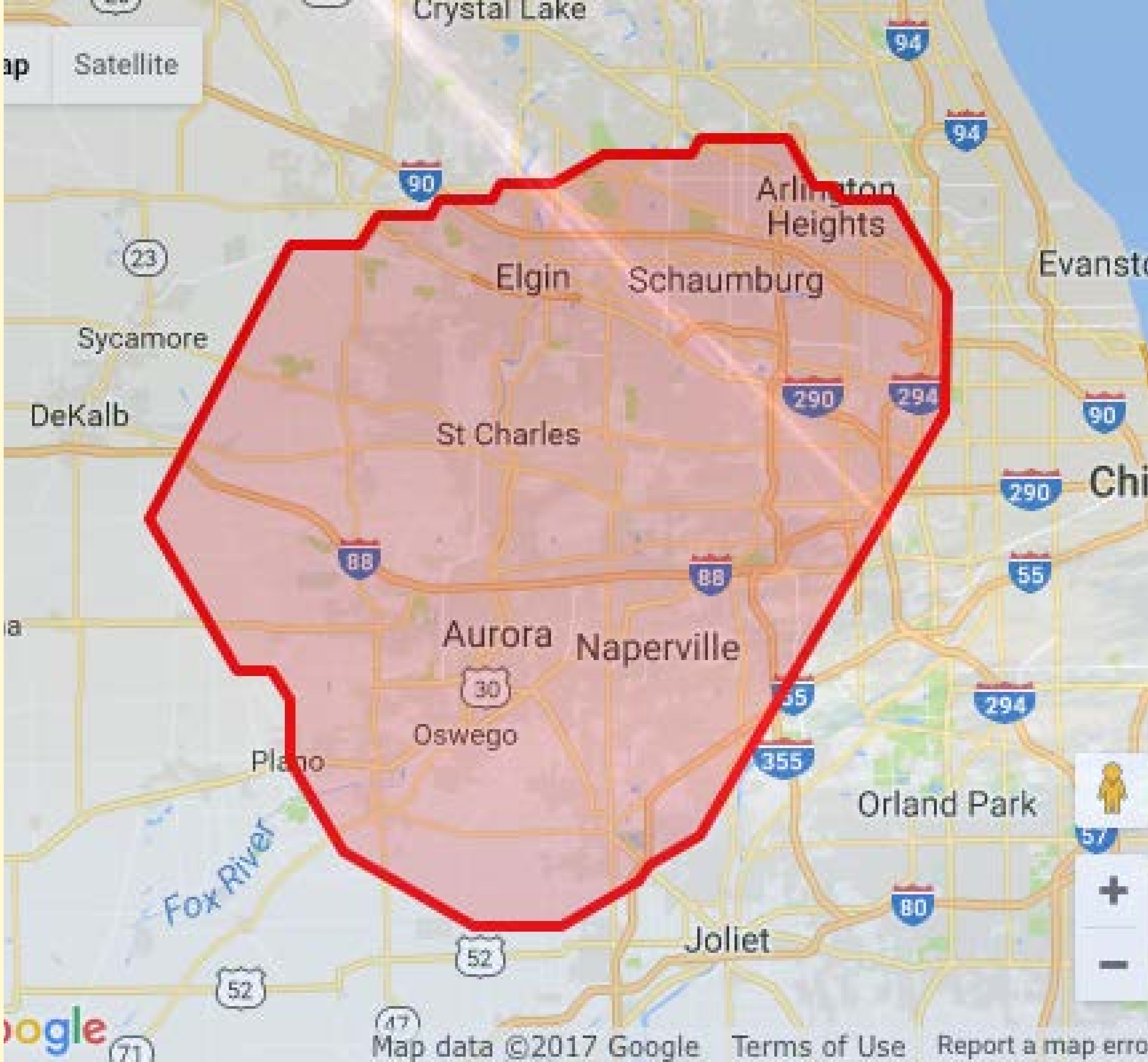
WHAT ARE COSMIC RAYS?

Revised and Enlarged American Edition

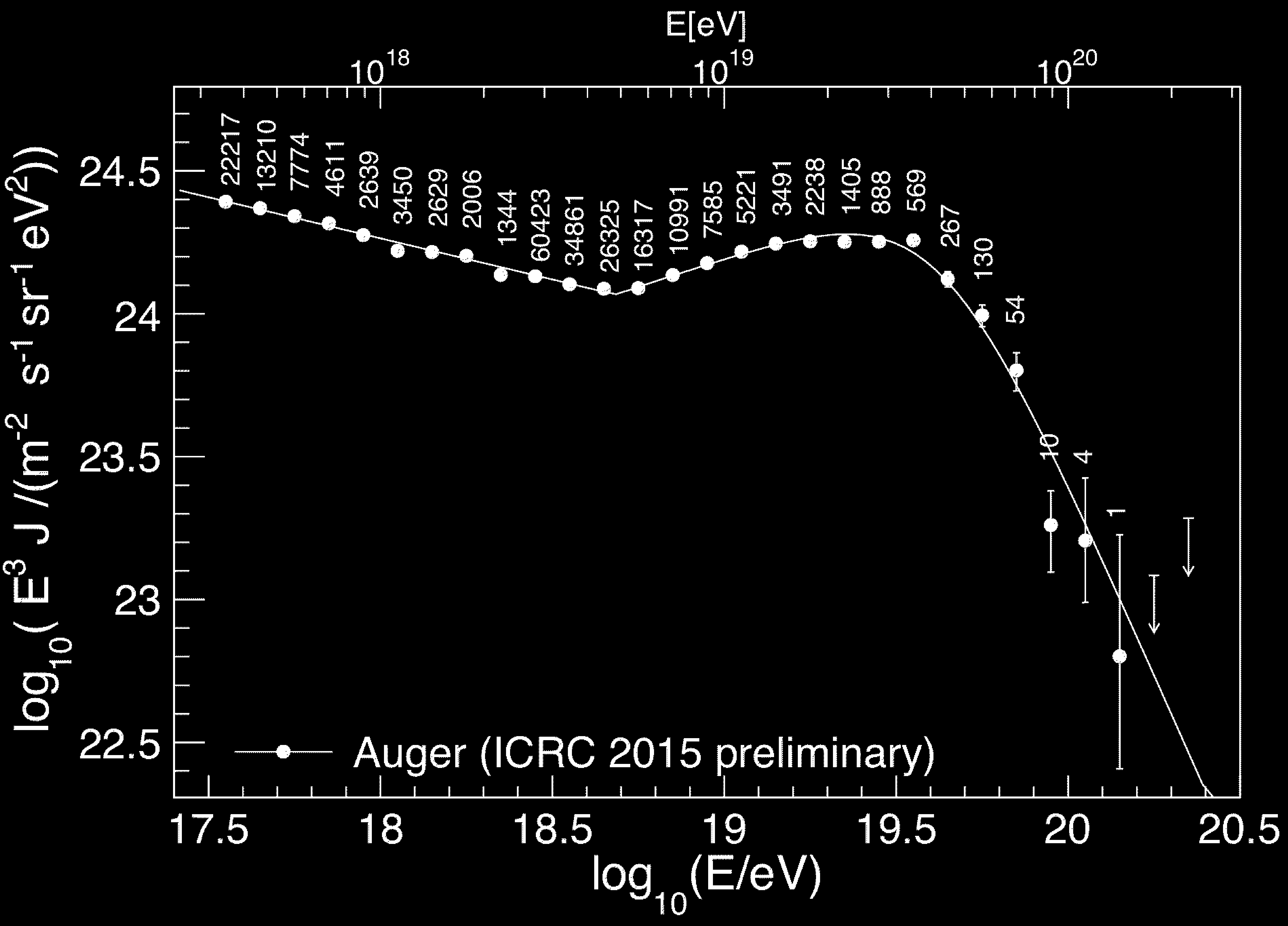
BY PIERRE AUGER

TRANSLATED FROM THE FRENCH
by
MAURICE M. SHAPIRO

UNIVERSITY OF CHICAGO PRESS · CHICAGO

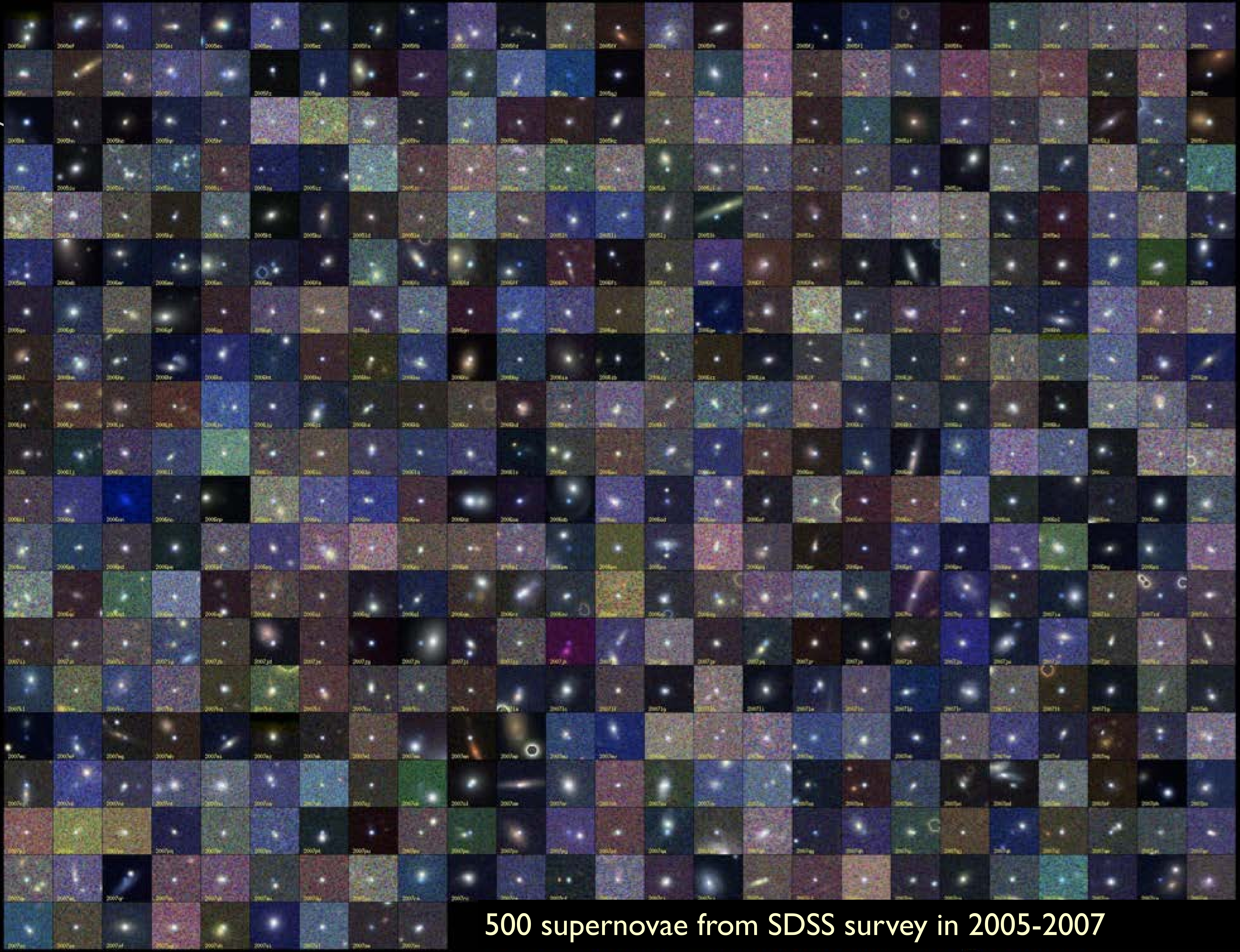



Malargüe



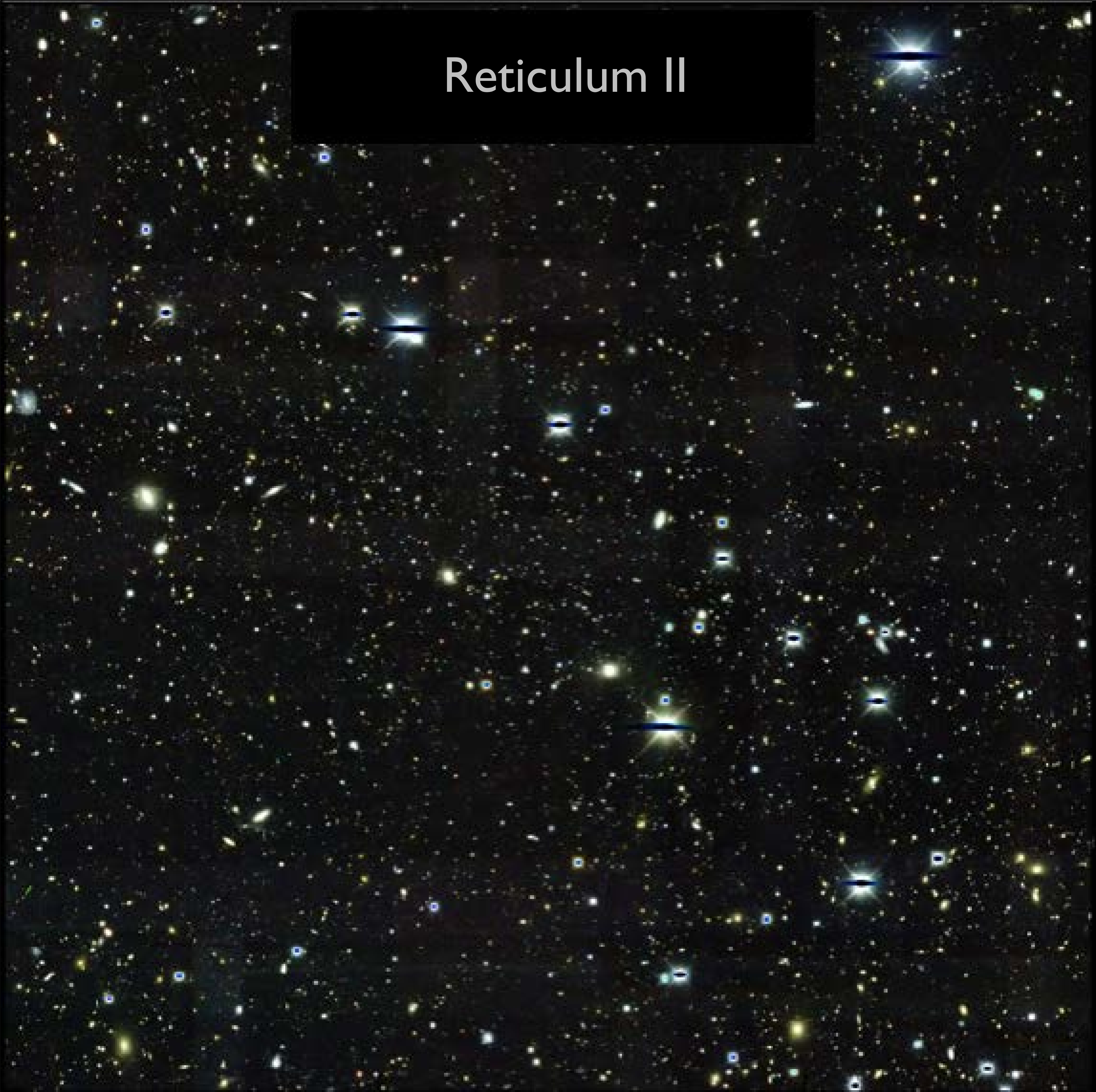
E[eV]
10^{18}
10^{19}
10^{20}
$\log_{10}(E^3 J/(m^{-2}\ s^{-1}\ sr^{-1}\ eV^2))$
24.5
24
23.5
23
22.5
17.5
18
18.5
19
19.5
20
20.5
$\log_{10}(E/eV)$
22217
13210
7774
4611
2639
3450
2629
2006
1344
60423
34861
26325
16317
10991
7585
5221
3491
2238
1405
888
569
267
130
54
10
4
1
Auger (ICRC 2015 preliminary)

B. Dilday



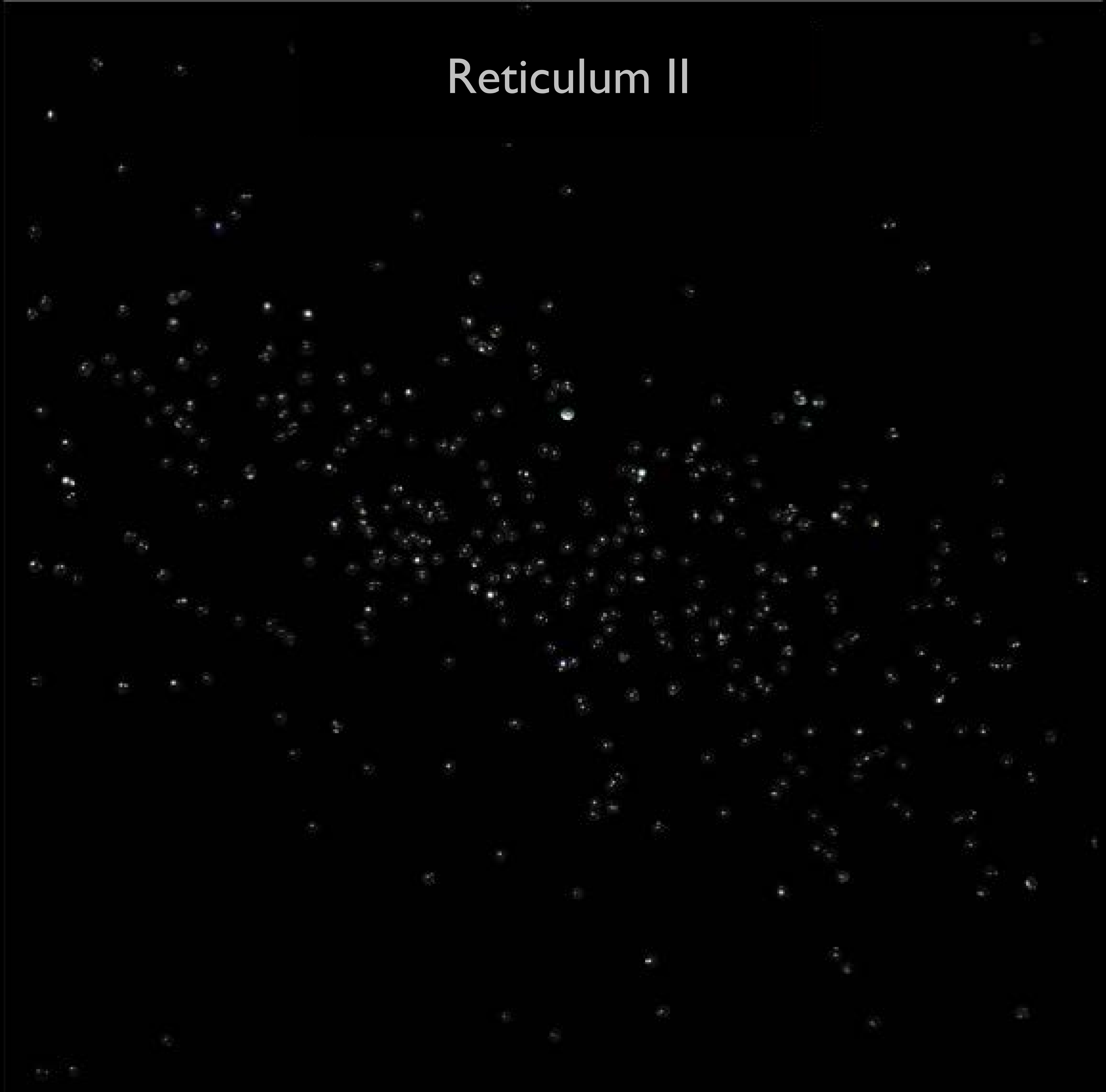
500 supernovae from SDSS survey in 2005-2007

Reticulum II



Dark Energy Survey

Reticulum II

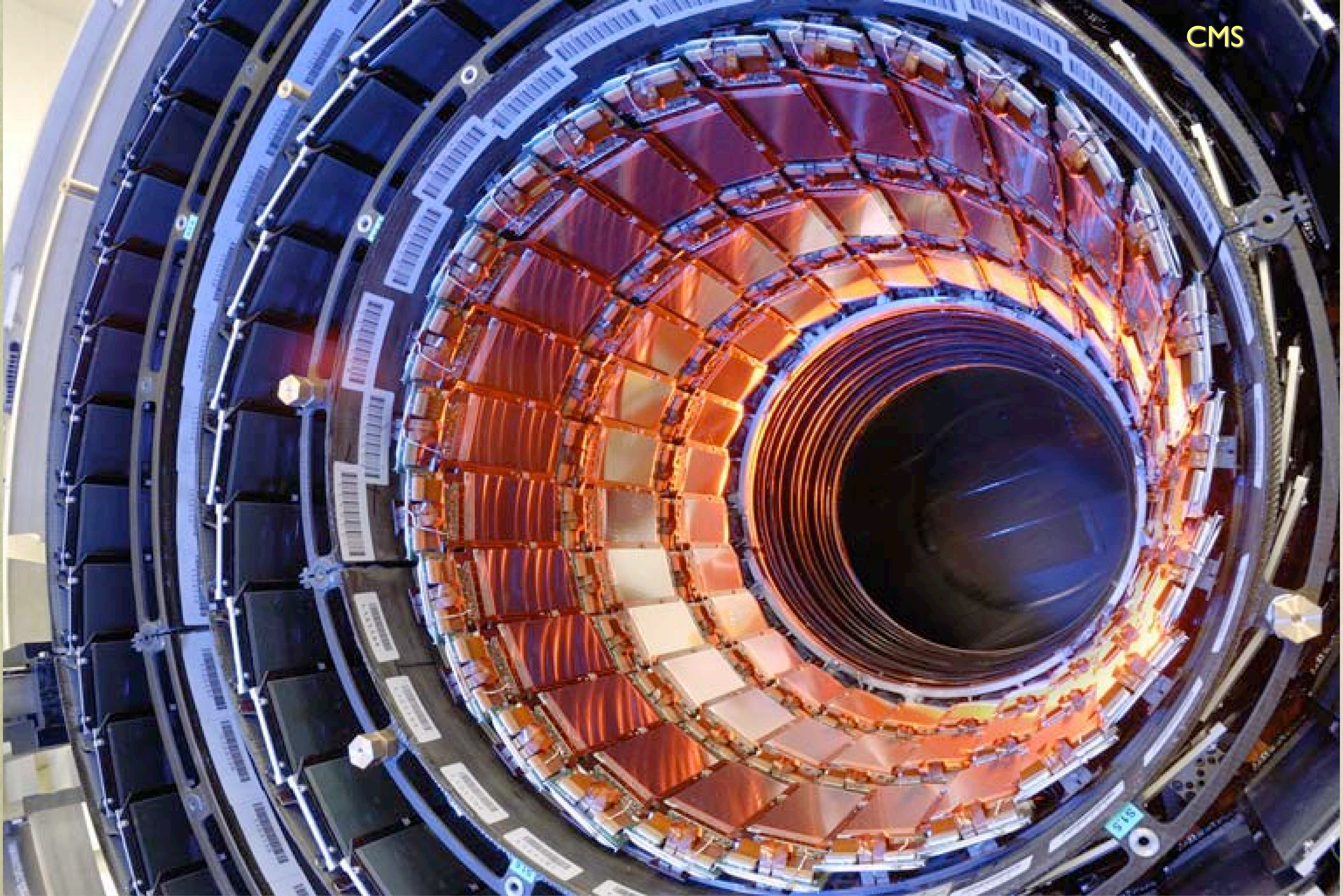


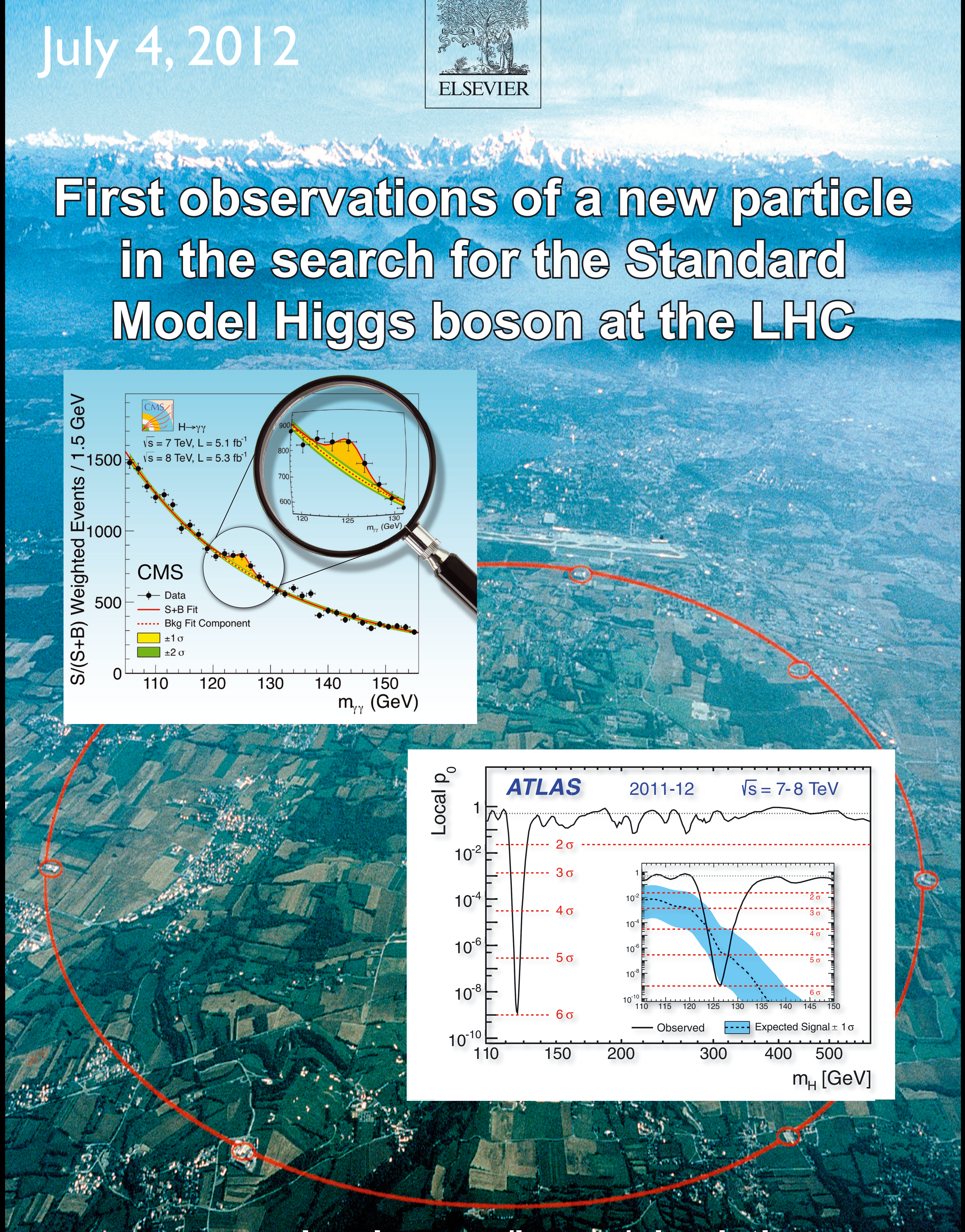
Dark Energy Survey

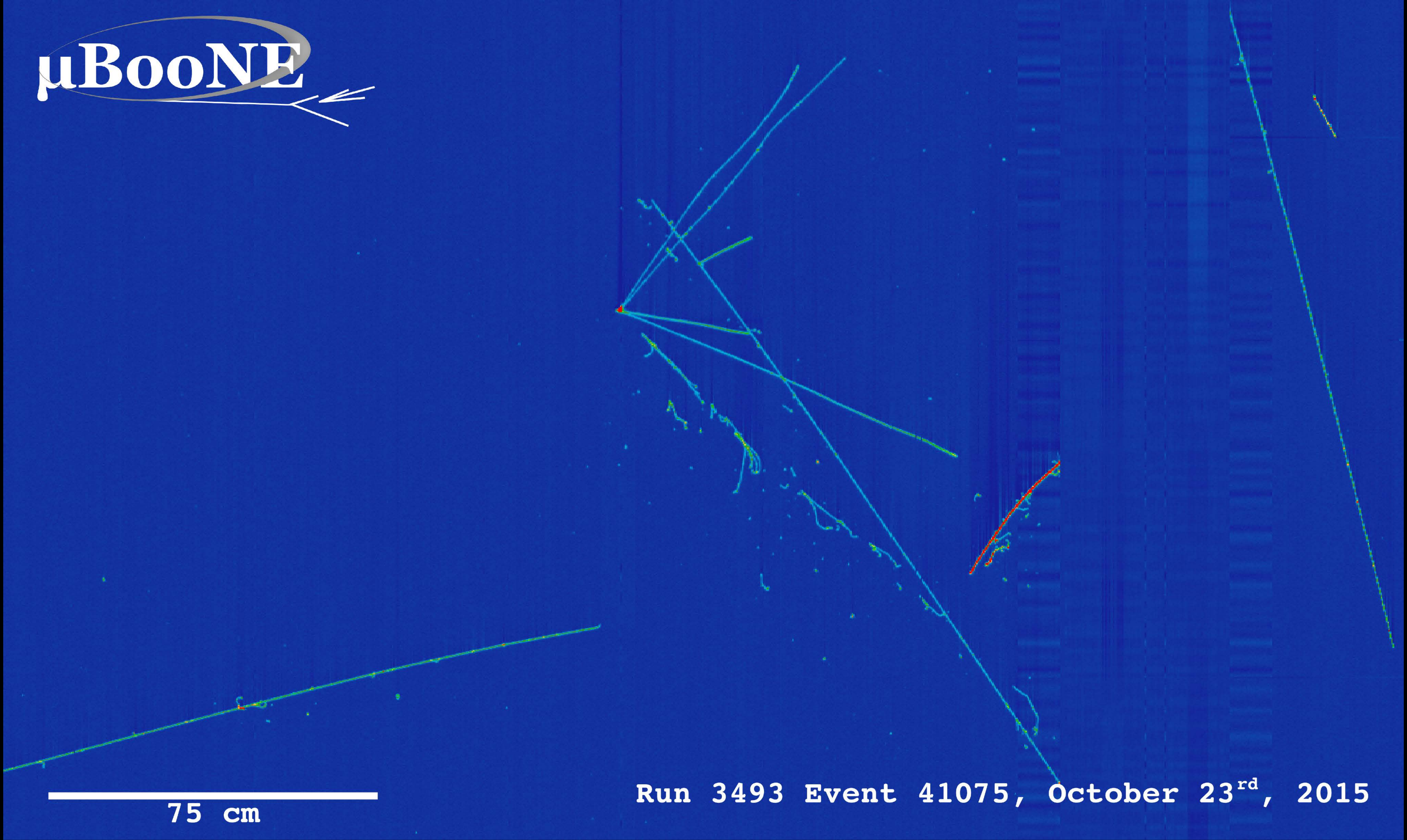

fermilab
MAGNET TEST FACILITY


STUDIOS
12
CIRCLE OF
SAFETY


CMS


CMS


July 4, 2012
ELSEVIER
First observations of a new particle in the search for the Standard Model Higgs boson at the LHC
CMS
$H\to\gamma\gamma$
$\sqrt{s}$ = 7 TeV, L = 5.1 fb^{-1}
$\sqrt{s}$ = 8 TeV, L = 5.3 fb^{-1}
S/(S+B) Weighted Events / 1.5 GeV
Data
S+B Fit
Bkg Fit Component
±1 σ
±2 σ
$m_{\gamma\gamma}$ (GeV)
ATLAS
2011-12
$\sqrt{s}$ = 7-8 TeV
Local p_0
2 σ
3 σ
4 σ
5 σ
6 σ
Observed
Expected Signal ± 1 σ
m_H [GeV]


μBooNE
75 cm
Run 3493 Event 41075, October 23rd, 2015

EXIT

DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

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Sergei Nagaitsev, Tom Nash, Heath O'Connell, John Peoples,
Liz Quigg, Kurt Riesselmann, Adam Schwartz, Karen Seifrid
Jim Shultz, Alvin Tollestrup, Edward Tufte, John Voirin, …