Some personal memories of the PS and LEP.

Creation of the PS.

The "strong-focusing" or "alternate gradient" synchrotron was invented by Courant, Livingston and Snyder (3 outstanding physicists) in 1963. Christophilos had invented it some months before, but never published this.

At the time, CERN had the fortune to have an outstanding accelerator team, including John Adams, Marvin Hine, and Simon Vander Meer. The PS was a great achievement.

(**Not** to remember, in 1960, one of the first PS experiments: my own attempts, together with Roberto Salmeron, to see neutrino events in the Ramm 1m diameter bubble chamber. We didn't see any.)

where $N_{E''}$ is now a counting rate per constant energy (or range) difference.

One can also calculate the total number of electrons of energy E' which escape as a check of the above result. If this is again done for a volume with a square centimeter base at the surface, the total number of electrons of energy E' which escape from a volume element $d\tau$ at x is

$$\int_0^{2\pi}\int_0^{\cos^{-1}x/R'} \frac{N_{R'}}{4\pi}\sin\phi d\phi d\theta dx = \frac{N_{R'}}{2}\left[1-\frac{x}{R'}\right]dx.$$

Integration over x from 0 to R' gives $N_{R'}/4R'$.

If we integrate $N_{E''}$ over R'' from 0 to R' we get

$$\int_0^{R'} \frac{N_{R'}}{4}dR'' = \frac{N_{R'}}{4}R',$$

as we should, since the total count due to degraded pulses should equal the total number of electrons escaping.

The above result states that electrons of energy E' which escape from the crystal are degraded with equal probability into all energies below E', since the above results are independent of E' or E''. The fraction of electrons of energy E' which escape from the crystal is equal to $\frac{1}{4}$ the fraction of the volume of the crystal which lies in a surface layer of depth R'. These two facts can be used in a graphical method to correct distorted beta-spectra for the effect due to the escape of electrons.

A similar analysis can be made for the escape of photons from a crystal, substituting an exponential absorption for the range. The solution in this case involves the Γ-function, which is somewhat awkward, but one can consult tables of this function to obtain numerical answers.

APPENDIX II

Outline of the Calculation of the Transition Energy in K Orbital Electron Capture from a Knowledge of the Branching Ratio[15]

Marshak's lifetime formulas for first-forbidden β-decay and orbital electron capture are, respectively,

$$\frac{1}{\tau_T}=\frac{1}{\tau_0}\frac{|M|^2}{[1.3]^2}R^2B_1(z,W_0)$$

and

$$\frac{1}{\tau_c}=\frac{1}{\tau_0}\frac{|M|^2}{|1.3|^2}R^2B_c'(z,W_0),$$

where τ_0 is a decay constant, R is the nuclear radius, M is a nuclear matrix element, and the B's are quantities which depend on the order of the transition, on the nuclear charge, and on the energy difference between the parent and product nuclei.

Dividing one equation by the other one gets

$$\frac{\tau_c}{\tau_T}=\frac{B_1(z,W_0)}{B_c^{(1)}(z,W_0)}=\frac{\%\,\beta\text{ emission}}{\%\,K\text{ capture}}.$$

Except for a numerical factor, B_1 is the same function as Davidson's[7] f_1 (in the low Z limit) and can be calculated with the help of Feenberg and Trigg's[14] curves of f_1.

$B_c^{(1)}$ is given by Marshak, and for K orbital electron capture alone it has the form

$$B_c^{(1)}=\tfrac{1}{2}\pi(W_0+W_K)^4 n_K g_K^2,$$

where n_K is the number of electrons in the K shell and g_K is the "large" radial Dirac wave function, for which an expression is given by Marshak. Using these relationships one can solve for W_0.

[15] This method for calculating the transition energies was very kindly shown to us by M. Fuchs of this laboratory.

Also: N. Christophilos, 1950, unpublished.

PHYSICAL REVIEW VOLUME 88, NUMBER 5 DECEMBER 1, 1952

The Strong-Focusing Synchroton—A New High Energy Accelerator*

ERNEST D. COURANT, M. STANLEY LIVINGSTON,† AND HARTLAND S. SNYDER
Brookhaven National Laboratory, Upton, New York

(Received August 21, 1952)

Strong focusing forces result from the alternation of large positive and negative n-values in successive sectors of the magnetic guide field in a synchrotron. This sequence of alternately converging and diverging magnetic lenses of equal strength is itself converging, and leads to significant reductions in oscillation amplitude, both for radial and axial displacements. The mechanism of phase-stable synchronous acceleration still applies, with a large reduction in the amplitude of the associated radial synchronous oscillations. To illustrate, a design is proposed for a 30-Bev proton accelerator with an orbit radius of 300 ft, and with a small magnet having an aperture of 1×2 inches. Tolerances on nearly all design parameters are less critical than for the equivalent uniform-n machine. A generalization of this focusing principle leads to small, efficient focusing magnets for ion and electron beams. Relations for the focal length of a double-focusing magnet are presented, from which the design parameters for such linear systems can be determined.

BETATRON OSCILLATIONS

RESTORING forces due to radially-decreasing magnetic fields lead to stable "betatron" and "synchrotron" oscillations in synchrotrons. The amplitudes of these oscillations are due to deviations from the equilibrium orbit caused by angular and energy spread of the injected beam, scattering by the residual gas, magnetic inhomogeneities, and frequency errors. The

* Work done under the auspices of the AEC.

stability condition: $0<n<1$, where $n=-(r/B)(dB/dr)$. The frequencies of vertical and radial oscillations are given in terms of the frequency of revolution f_0 by:

$$f_z=n^{\frac{1}{2}}f_0;\quad f_r=(1-n)^{\frac{1}{2}}f_0. \tag{1}$$

The corresponding amplitudes are inversely proportional to these oscillation frequencies, for a given angular deviation. Therefore, the aperture required to accommodate either mode can only be reduced at the expense of the other mode, and the minimum aperture for both occurs with $n=0.5$.

The focusing forces can be greatly strengthened by letting n vary in azimuth. Suppose the circular orbit to consist of N sectors of equal length with n_1 and n_2 in alternate sectors. The equations of vertical and radial oscillations are then

$$d^2z/d\theta^2+n_1z=0;\quad d^2r/d\theta^2+(1-n_1)r=0;$$
(odd sectors). (2a)

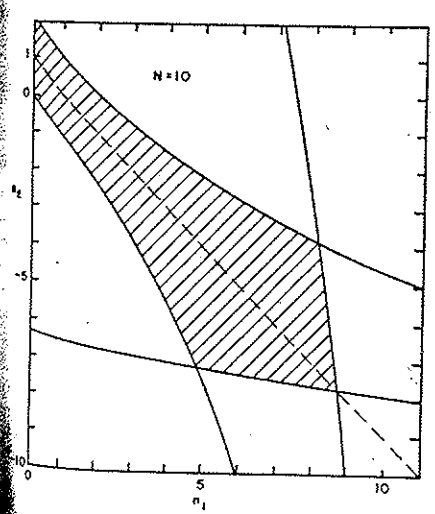
$$d^2z/d\theta^2+n_2z=0;\quad d^2r/d\theta^2+(1-n_2)r=0;$$
(even sectors). (2b)

Solutions can be obtained by the use of recursion formulas, and are of the form

$$Z_\kappa=Ae^{i2\pi\mu_z\kappa}\quad\text{and}\quad R_\kappa=Be^{i2\pi\mu_r\kappa}, \tag{3}$$

where the coefficient μ_z is given by

$$\cos2\pi\mu_z=\cos\frac{2\pi n_1^{\frac{1}{2}}}{N}\cos\frac{2\pi n_2^{\frac{1}{2}}}{N}-\frac{n_1+n_2}{2(n_1n_2)^{\frac{1}{2}}}\sin\frac{2\pi n_1^{\frac{1}{2}}}{N}\sin\frac{2\pi n_2^{\frac{1}{2}}}{N}. \tag{4}$$



1. Region of stability for both radial and vertical oscillations for $N=10$ sectors with n values alternating between n_1

W. Kerst and R. Serber, Phys. Rev. 60, 53 (1941).

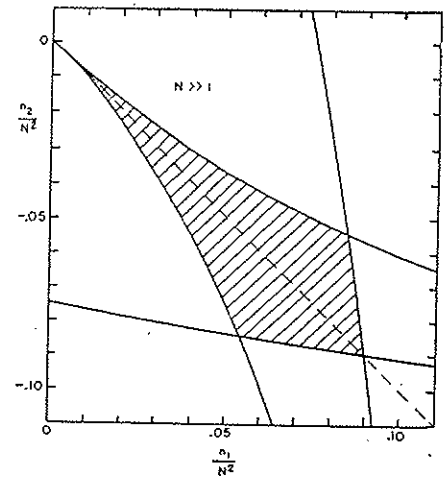


FIG. 2. Region of stability for radial and vertical oscillations for a large number of sectors N, in terms of the parameters n_1/N^2 and n_2/N^2.

The coefficient μ_r is given by the same expression, with n_1 and n_2 replaced by $(1-n_1)$ and $(1-n_2)$, respectively. If the motion is to be stable for both radial and vertical oscillations, the limits are established by the conditions

$$-1<\cos2\pi\mu_z<1,\quad -1<\cos2\pi\mu_r<1. \tag{5}$$

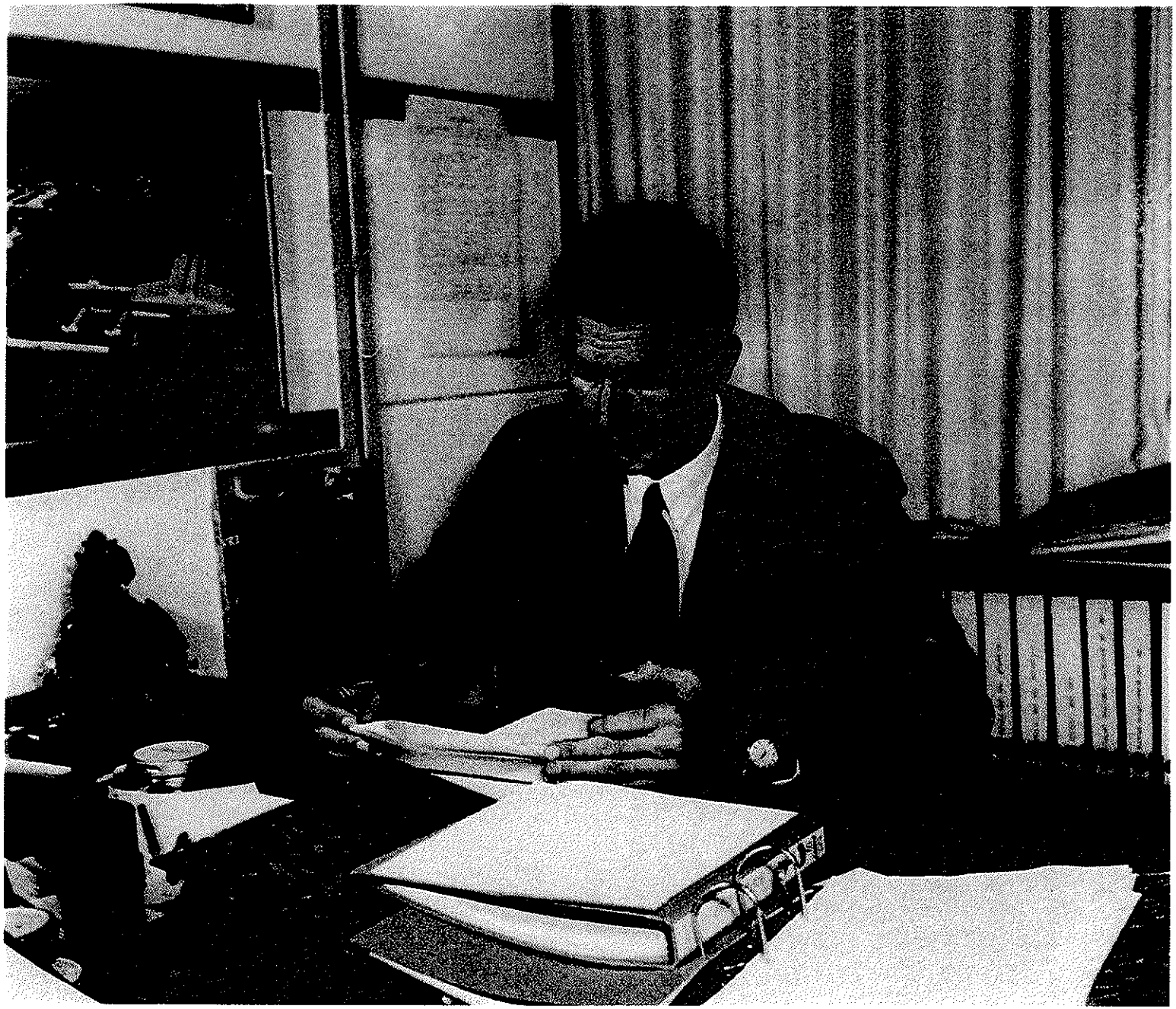
These limits have been plotted in Fig. 1 for the specific value $N=10$, and the region of stability is indicated. It is observed that the region of stability is widest for $n_2\simeq-n_1$. Figure 2 shows the stable region for very large N, and the coordinates are given in terms of n_1/N^2 and n_2/N^2. The range of stable values of n is widest when N is large and when $n_2=-n_1$, and the center of the region of stability ($\cos2\pi\mu=0$) occurs for

$$|n|=N^2/16. \tag{6}$$

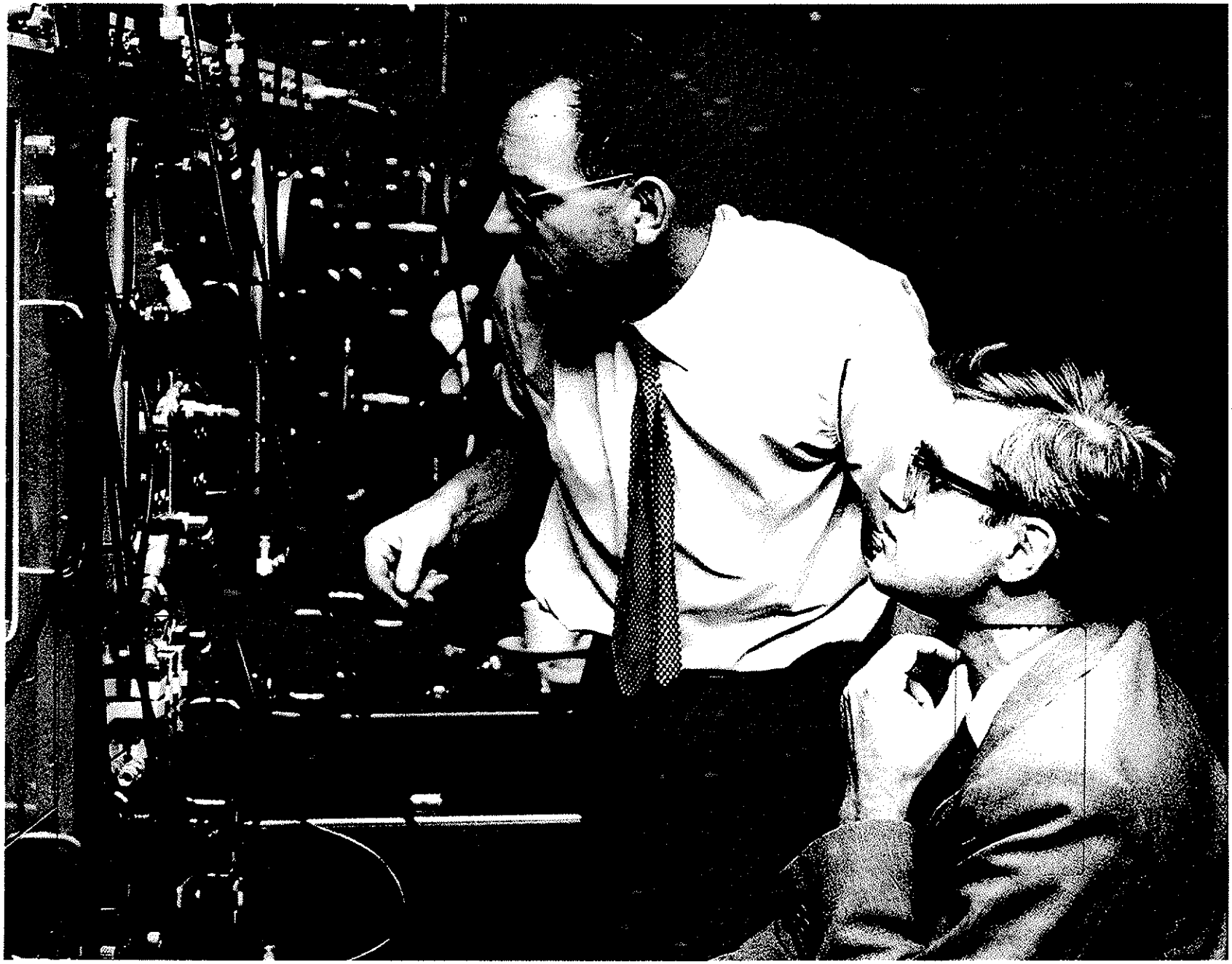
The effective frequency of the "betatron" oscillations is given by:

$$f_z=f_r=(\mu N/2)f_0\quad\text{(for large }N\text{)}, \tag{7}$$

which can be compared with the frequencies given in Eq. (1) for constant n. Therefore, the amplitudes of oscillation and the aperture requirements can be made much smaller by the use of a large number of sectors N and correspondingly large positive and negative values of n in successive sectors. As a numerical example, consider a synchrotron of 240 alternating sectors, with $n_1=3600$ and $n_2=-3600$. The radial aperture requirement is about 1/24 that for the corresponding synchrotron with a constant n of 0.6, and 1/20 for the vertical aperture. Ion trajectories are not sinusoidal as in the standard synchrotron, but are composed of sections of alternately harmonic and hyperbolic functions. Figure 3 is a schematic illustration of two typical oscillating orbits computed for the case discussed in the



John Adams



Mervyn Hine

Kjell Johnson

Simon
Van der Meer

K_S –K_L interference.

After CP violation was discovered in 1964, by Christenson, Cronin, Fitch and Turley, I had the idea that one way to learn more about CP violation was by studying the interference of K_S and K_L in the π^+ - π^- decay. End of '64 I came to CERN on sabbatical, for half a year, to do this. It turned out to be a longer job, and so I stayed an extra year.

K_S AND K_L INTERFERENCE IN THE $\pi^+\pi^-$ DECAY MODE, CP INVARIANCE AND THE K_S-K_L MASS DIFFERENCE

C. ALFF-STEINBERGER, W. HEUER *, K. KLEINKNECHT **, C. RUBBIA, A. SCRIBANO ***
J. STEINBERGER †, M. J. TANNENBAUM †† and K. TITTEL *
CERN, Geneva

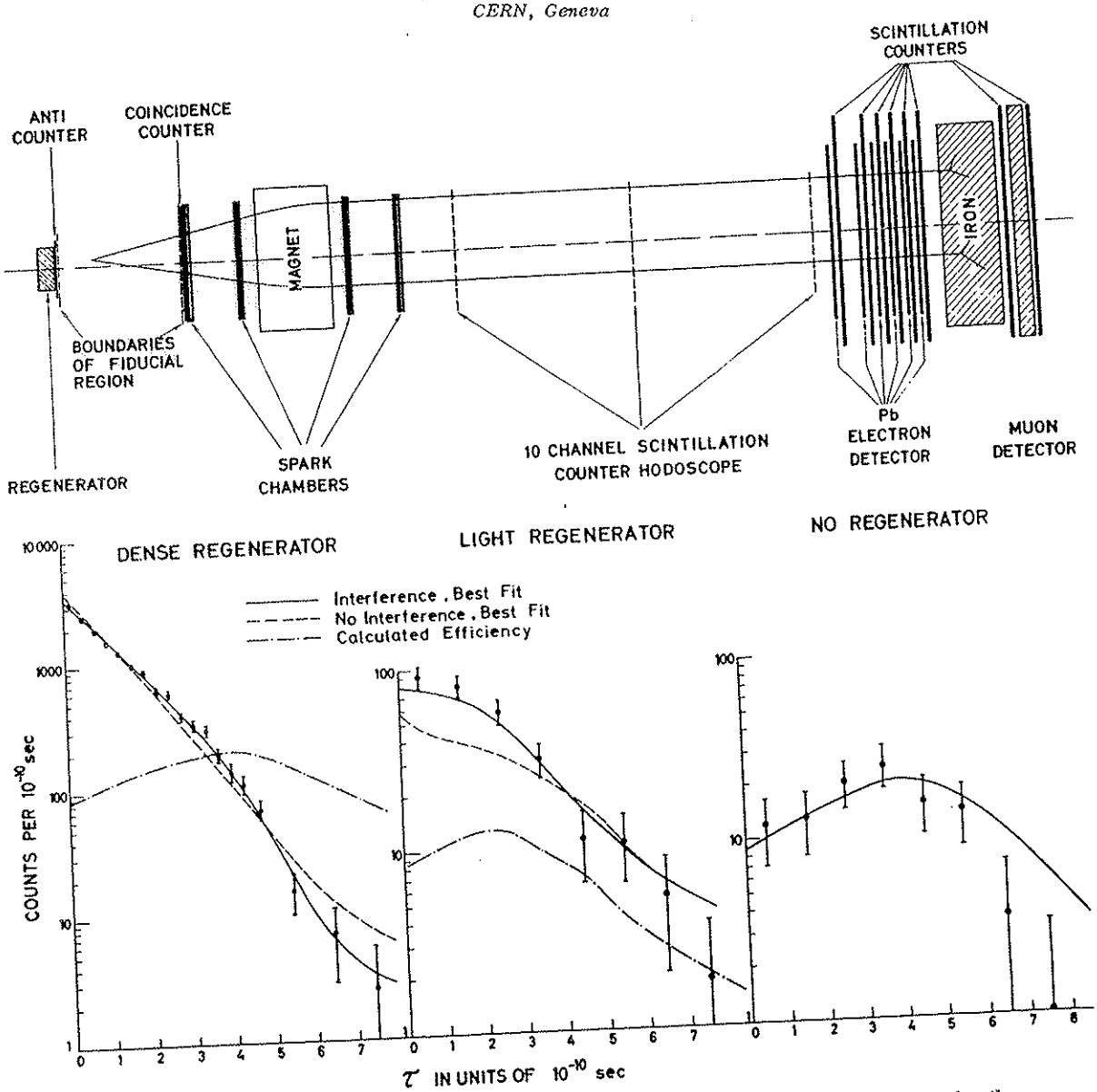


Fig. 3. Observed $K \to \pi^+\pi^-$ decay rate as a function of proper time. The best fit solutions for the cases of interference and no interference are shown, as well as the calculated efficiencies.

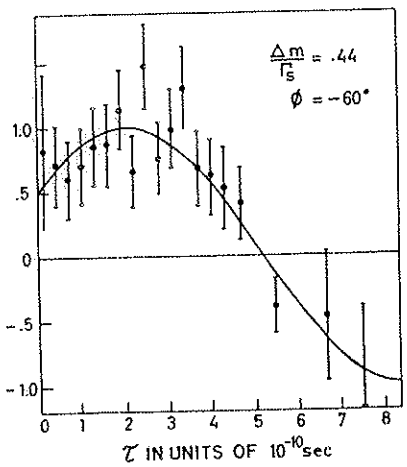


Fig. 4. Experimental data treated in such a way (see text) as to isolate the interference term $\cos(\varphi + \Delta m\tau)$.

Results:
K_S-K_L interference in $\pi^\pm\bar{\pi}^-$ decay demonstrated

$\phi_{\eta_{+-}} - \phi_{reg} = 72° \pm 14°$

$\frac{\Delta m}{\Gamma_S} = .44 \pm .06$

TIME-DEPENDENT INTERFERENCE EFFECTS IN TWO-PION DECAYS OF NEUTRAL KAONS

M. BOTT-BODENHAUSEN, X. DE BOUARD, D. G. CASSEL *, D. DEKKERS, R. FELST, R. MERMOD **, I. SAVIN ***, P. SCHARFF, M. VIVARGENT, T. R. WILLITTS and K. WINTER
CERN, Geneva

Received 28 December 1965

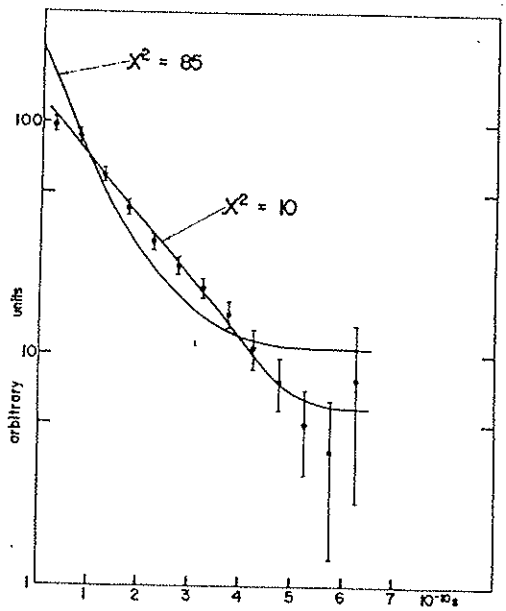


Fig. 3a. Time distribution of 2π decays observed behind a 4 cm carbon regenerator. The curve with $\chi^2 = 85$ represents the best fit assuming no interference, the curve with $\chi^2 = 10$ is the best fit assuming interference.

Result demonstrates $K_S - K_L$ interference in $\pi^+\pi^-$ decay.

$\phi_{\eta+-} - \phi_{reg} = -71^{+21}_{-25}{}^{\circ}$

Gargamelle, neutral currents, quarks.

In 1973 the weak neutral current was discovered at the PS, using the Gargamelle bubble chamber. This discovery established the E-W unified gauge theory, an enormous event in the history of particle physics.
In 1974 the Gargamelle team, comparing deep inelastic neutrino scattering with SLAC results of electron scattering, gave the first clear evidence for the charges and therefore the quark nature of the "partons".

1970–'72 Development of "renormalizable", consistent, gauge theory which:

- unifies electromagnetic and weak interactions
- predicts "neutral current" weak interactions
- predicts heavy vector particles W^+, W^-, Z^0

1973 CERN Gargamelle B.C.

P. Musset and J.P. Vialle, Neutrino physics with Gargamelle

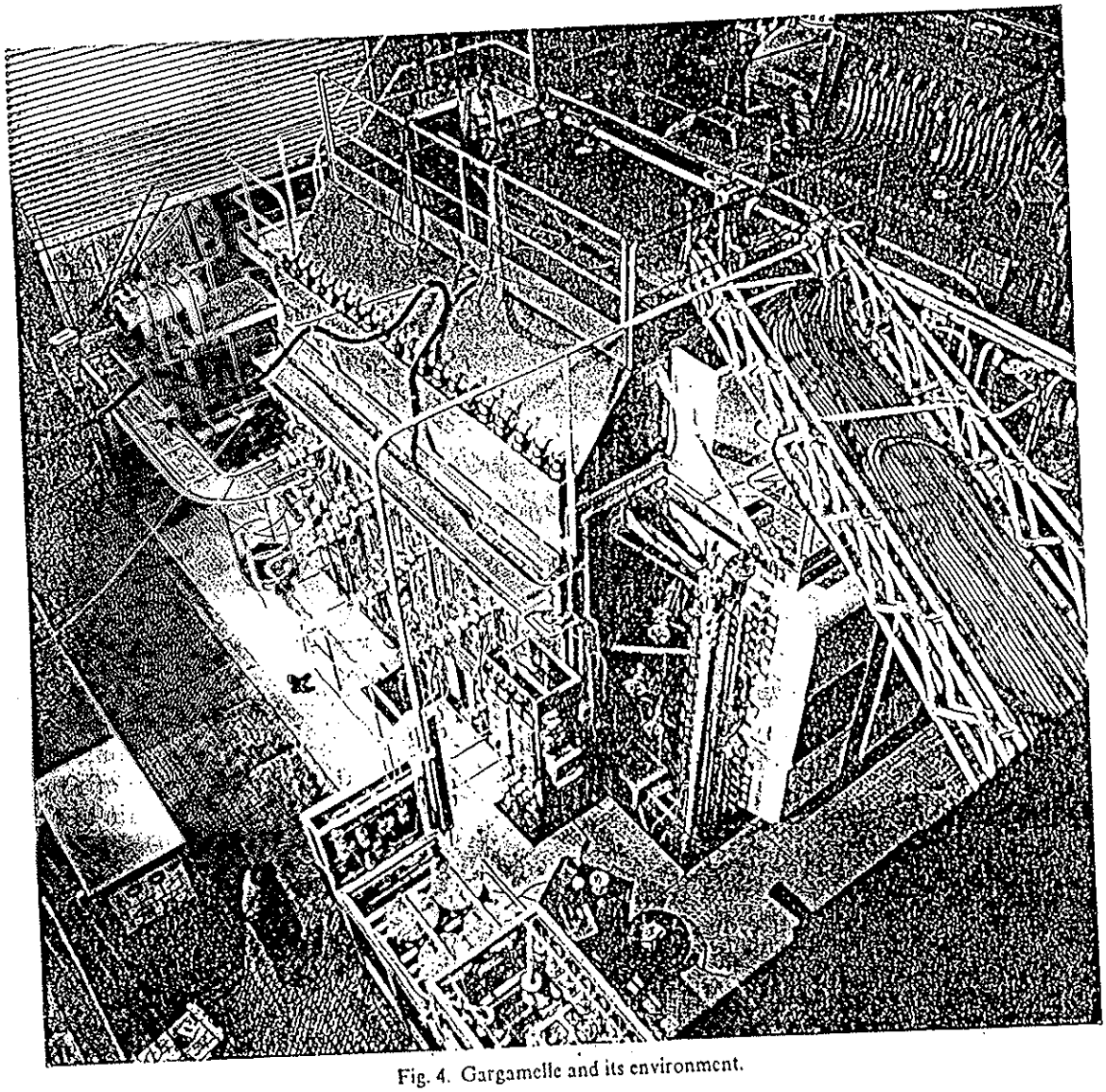
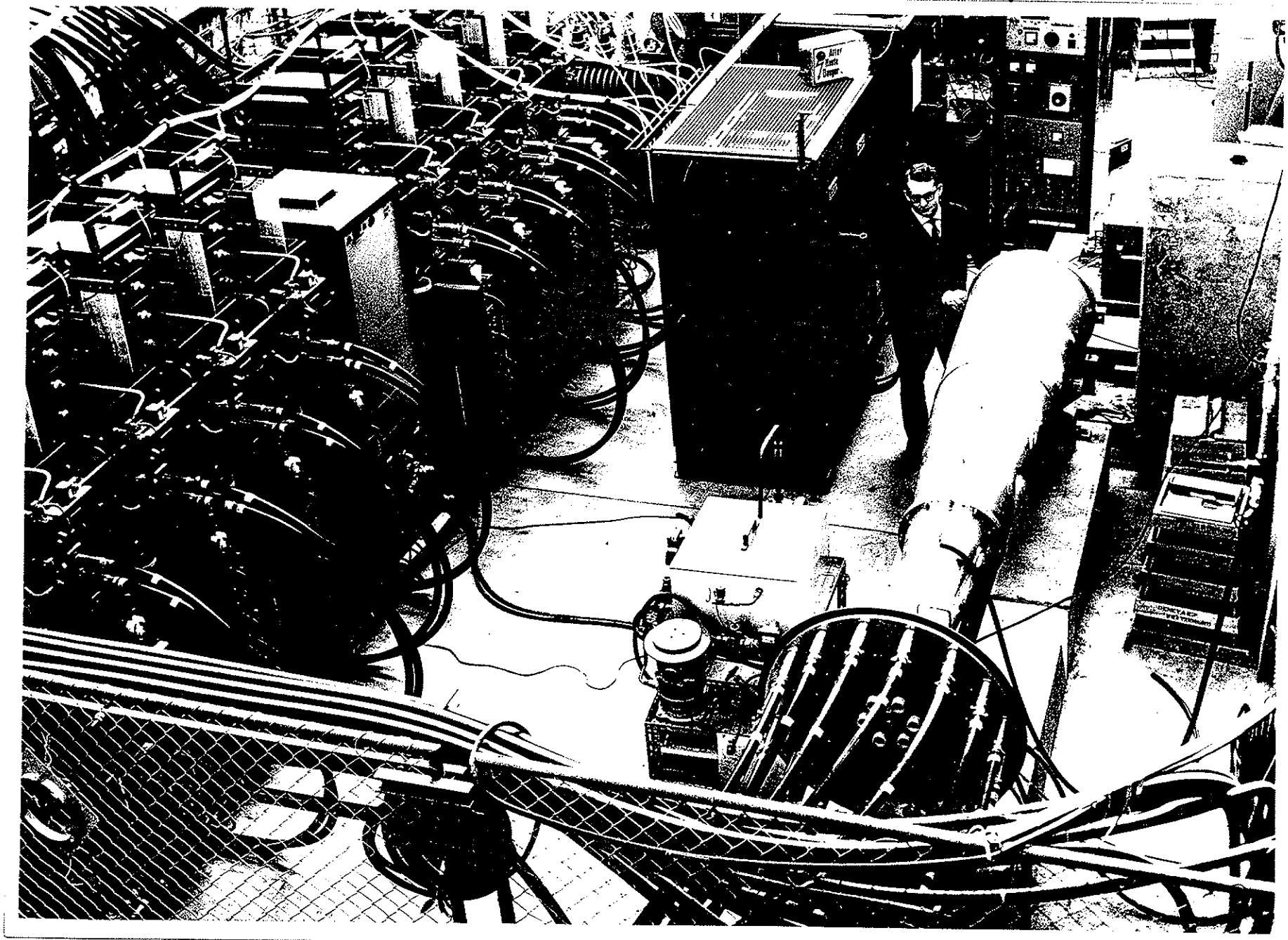


Fig. 4. Gargamelle and its environment.

Discovery of weak neutral current.
Establishes Electro-weak theory.

Van der Meer Horn for neutrino beam.



OBSERVATION OF NEUTRINO-LIKE INTERACTIONS WITHOUT MUON OR ELECTRON IN THE GARGAMELLE NEUTRINO EXPERIMENT

F.J. HASERT, S. KABE, W. KRENZ, J. Von KROGH, D. LANSKE, J. MORFIN, K. SCHULTZE and H. WEERTS
III. Physikalisches Institut der Technischen Hochschule, Aachen, Germany

G.H. BERTRAND-COREMANS, J. SACTON, W. Van DONINCK and P. VILAIN*[1]
Interuniversity Institute for High Energies, U.L.B., V.U.B. Brussels, Belgium

U. CAMERINI*[2], D.C. CUNDY, R. BALDI, I. DANILCHENKO*[3], W.F. FRY*[2], D. HAIDT, S. NATALI*[4], P. MUSSET, B. OSCULATI, R. PALMER*[4], J.B.M. PATTISON, D.H. PERKINS*[6], A. PULLIA, A. ROUSSET, W. VENUS*[7] and H. WACHSMUTH
CERN, Geneva, Switzerland

V. BRISSON, B. DEGRANGE, M. HAGUENAUER, L. KLUBERG, U. NGUYEN-KHAC and P. PETIAU
Laboratoire de Physique Nucléaire des Hautes Energies, Ecole Polytechnique, Paris, France

E. BELOTTI, S. BONETTI, D. CAVALLI, C. CONTA*[8], E. FIORINI and M. ROLLIER
Istituto di Fisica dell'Università, Milano and I.N.F.N. Milano, Italy

B. AUBERT, D. BLUM, L.M. CHOUNET, P. HEUSSE, A. LAGARRIGUE, A.M. LUTZ, A. ORKIN-LECOURTOIS and J.P. VIALLE
Laboratoire de l'Accélérateur Linéaire, Orsay, France

F.W. BULLOCK, M.J. ESTEN, T.W. JONES, J. McKENZIE, A.G. MICHETTE*[9], G. MYATT* and W.G. SCOTT*[6,9]
University College, London, England

Received 25 July 1973

Events induced by neutral particles and producing hadrons, but no muon or electron, have been observed in the CERN neutrino experiment. These events behave as expected if they arise from neutral current induced processes. The rates relative to the corresponding charged current processes are evaluated.

We have searched for the neutral current (NC) and charged current (CC) reactions:

$$\text{NC } \nu_\mu/\bar{\nu}_\mu + \text{N} \to \nu_\mu/\bar{\nu}_\mu + \text{hadrons}, \quad (1)$$

$$\text{CC } \nu_\mu/\bar{\nu}_\mu + \text{N} \to \mu^-/\mu^+ + \text{hadrons} \quad (2)$$

which are distinguished respectively by the absence of any possible muon, or the presence of one, and only one, possible muon. A small contamination of $\nu_e/\bar{\nu}_e$ exists in the $\nu_\mu/\bar{\nu}_\mu$ beams giving some CC events which are easily recognised by the e^-/e^+ signature. The analysis is based on 83 000 ν pictures and 207 000 $\bar{\nu}$ pictures taken at CERN in the Gargamelle bubble chamber filled with freon of density 1.5×10^3 kg/m^3 [1]. The dimensions of this chamber are such that most

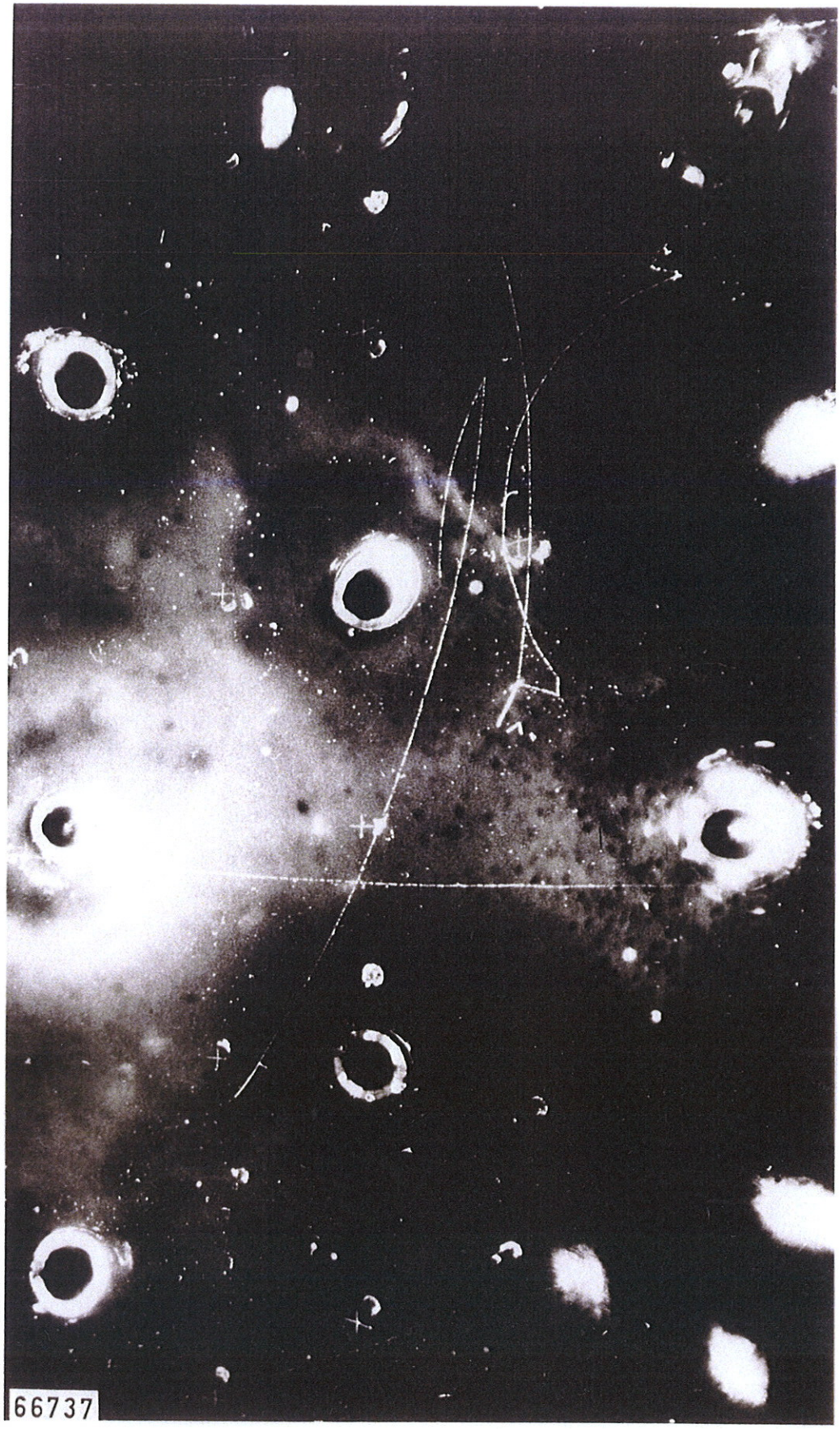
*[1] Chercheur agréé de L'Institut Interuniversitaire des Sciences Nucléaires, Belgique.
*[2] Also at Physics Department, University of Wisconsin
*[3] Now at Serpukhov.
*[4] Now at University of Bari.
*[5] Now at Brookhaven National Laboratory.
*[6] Also at University of Oxford.
*[7] Now at Rutherford High Energy Laboratory.
*[8] On leave of absence from University and INFN-Pavia.
*[9] Supported by Science Research Council grant.

[1] A more detailed account of the analysis of this experiment appears in a paper to be submitted to Nuclear Physics.

$\nu + p \rightarrow K^+ + \Lambda^0 + \nu$ (? ?)

K scatters twice, then stops and decays

Λ^0 decays, $\Lambda^0 \rightarrow p + \pi^-$



Gargamelle event without muon.

Event distributions in Gargamelle along chamber (beam) axis, showing nonhadronic origin.

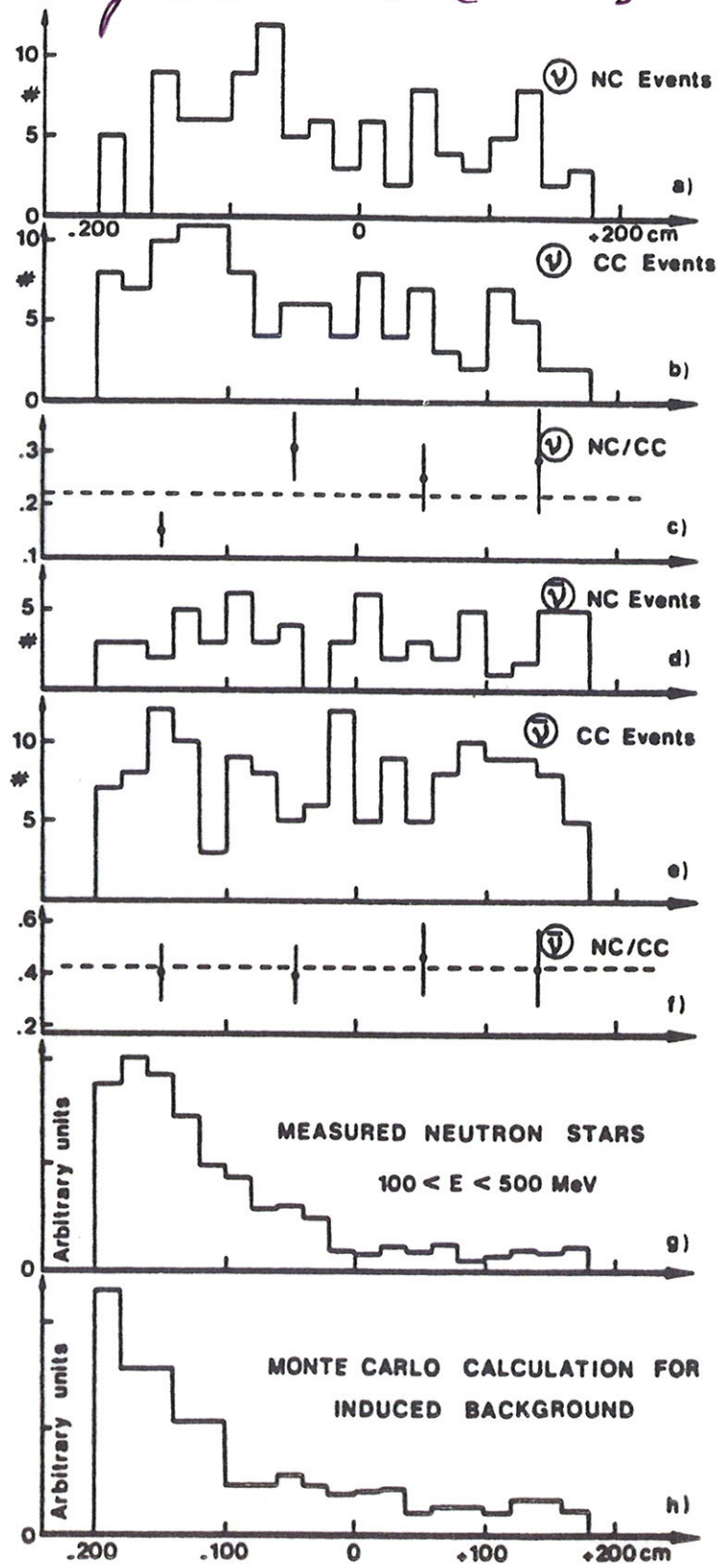
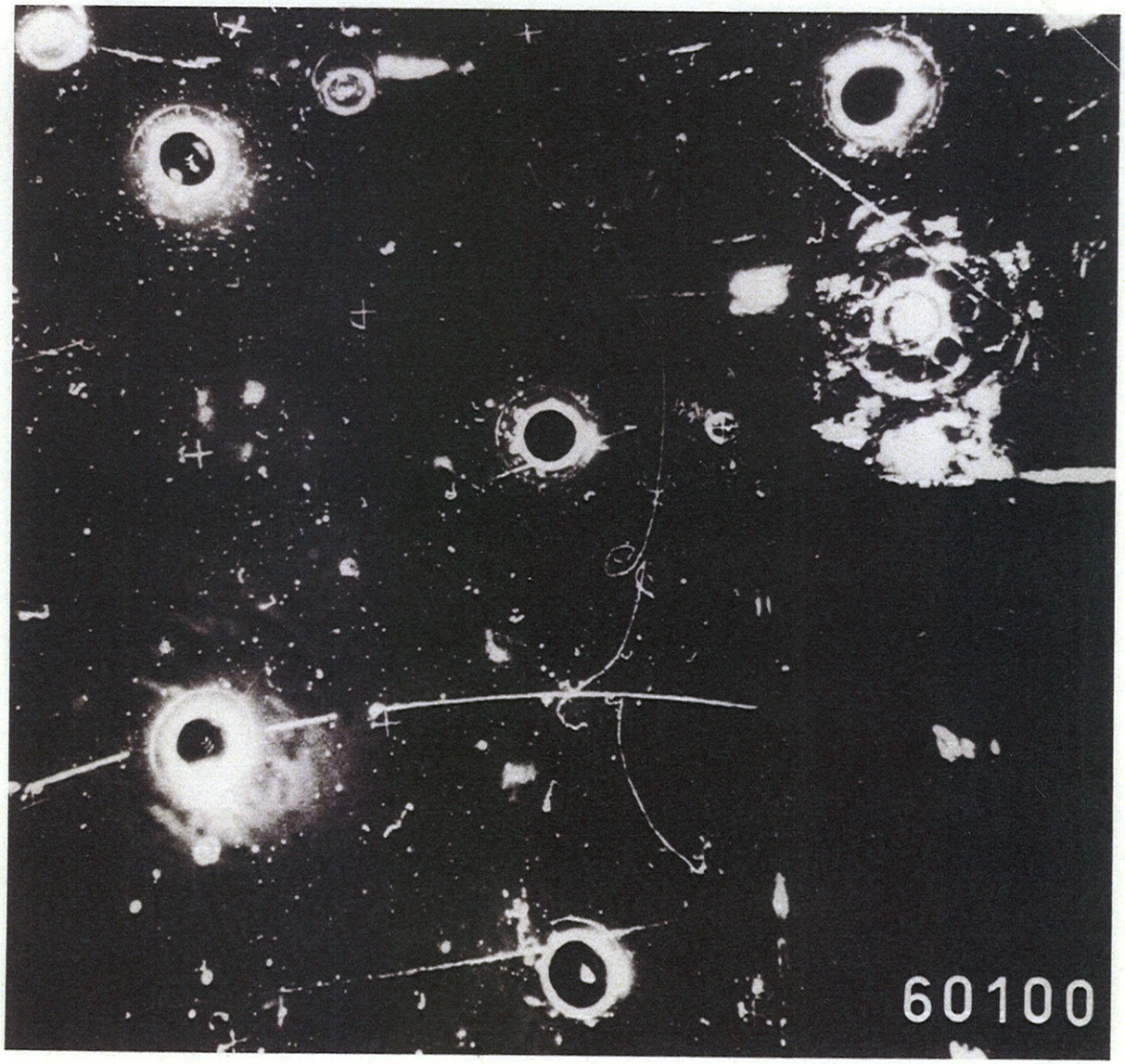


Fig. 35 Distribution of muonless events in Gargamelle along the beam direction. (Ref. 37.)

Leptonic neutral currents

$\bar{\nu} + e^- \rightarrow \bar{\nu} + e^-$

$\downarrow \nu_\mu$



EXPERIMENTAL STUDY OF STRUCTURE FUNCTIONS AND SUM RULES IN CHARGE-CHANGING INTERACTIONS OF NEUTRINOS AND ANTINEUTRINOS ON NUCLEONS

Gargamelle Neutrino Collaboration

H. DEDEN, F.J. HASERT, W. KRENZ, J. VON KROGH, D. LANSKE, J. MORFIN, K. SCHULTZE and H. WEERTS
III. Physikalisches Institut der Technischen Hochschule, Aachen, Germany

G.H. BERTRAND-COREMANS, J. SACTON, W. VAN DONINCK and P. VILAIN *
Interuniversity Institute for High Energies, U.L.B., V.U.B., Brussels, Belgium

D.C. CUNDY, D. HAIDT, M. JAFFRE, S. NATALI **, J.B.M. PATTISON, D.H. PERKINS ***, A. ROUSSET, W. VENUS + and H. WACHSMUTH
CERN, Geneva, Switzerland

V. BRISSON, D. DEGRANGE, M. HAGUENAUER, L. KLUBERG, U. NGUYEN-KHAC and P. PETIAU
Laboratoire de Physique Nucléaire des Hautes Energies, Ecole Polytechnique, Paris, France

E. BELLOTTI, S. BONETTI, D. CAVALLI, C. CONTA ++, E. FIORINI, C. FRANZINETTI +++, A. PULLIA and M. ROLLIER
Istituto di Fisica dell'Universita, Milano and I.N.F.N. Milano, Italy

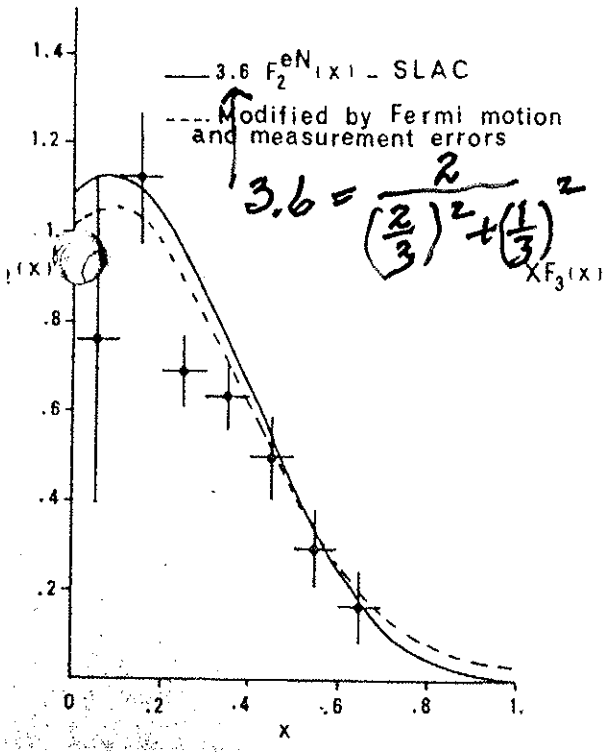
B. AUBERT, L.M. CHOUNET, J. GANDSMAN, P. HEUSSE, L. JAUNEAU, C. LONGUEMARE, A.M. LUTZ, C. PASCAUD and J.P. VIALLE
Laboratoire de l'Accélérateur Linéaire, Orsay, France

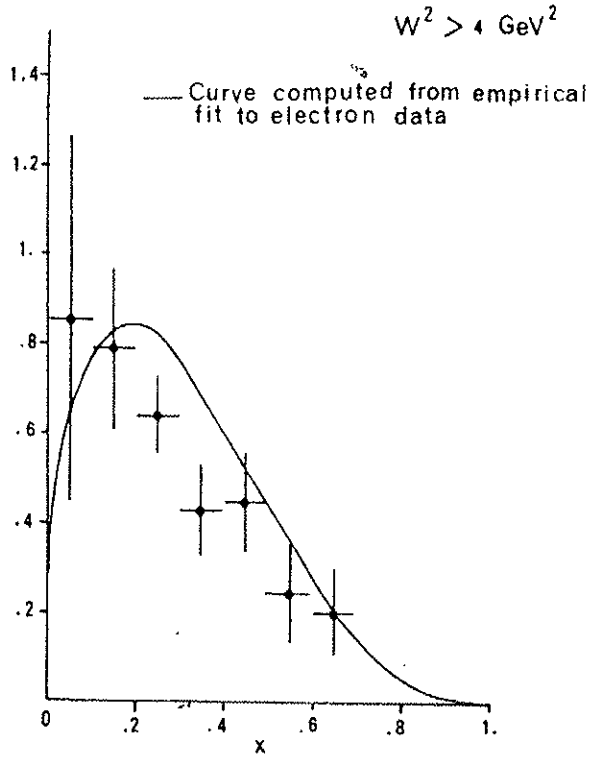
W. BULLOCK, M.J. ESTEN, T.W. JONES, J. McKENZIE, A.G. MICHETTE x, G. MYATT *** and W.G. SCOTT ***x
University College, London, England

Comparison of ν and SLAC e structure functions confirms quark model

Received 30 August 1974

STRUCTURE FUNCTIONS FOR EVENTS IN THE SCALING REGION $q^2 > 1$ GeV^2, $W^2 > 4$ GeV^2





Multiwire proportional (Charpak) chambers.

1968 Charpak invents the MWP chamber.

1969 A group of us decide to try to use this technology to achieve more precise measurements of CP violation parameters. The design of large, experimentally useful MWP chambers turned out to be a substantial challenge. Successful design was achieved in 1970, permitting very much improved understanding of CP violation in K decay.

NUCLEAR INSTRUMENTS AND METHODS 62 (1968) 262–268; © NORTH-HOLLAND PUBLISHING CO.

THE USE OF MULTIWIRE PROPORTIONAL COUNTERS TO SELECT AND LOCALIZE CHARGED PARTICLES

G. CHARPAK, R. BOUCLIER, T. BRESSANI, J. FAVIER and Č. ZUPANČIČ

CERN, Geneva, Switzerland

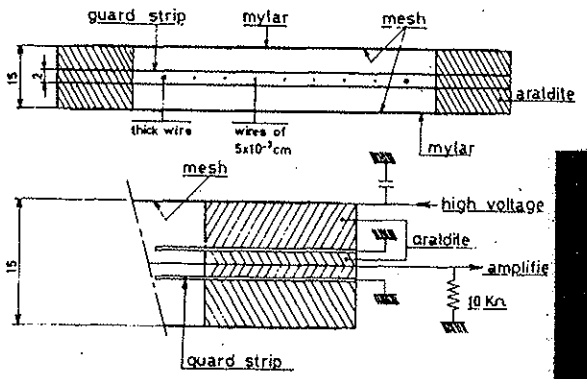


Fig. 1. Some details of the construction of the multiw chambers.
A copper shield protects the wires at their output from t chamber and contains the solid state amplifiers.

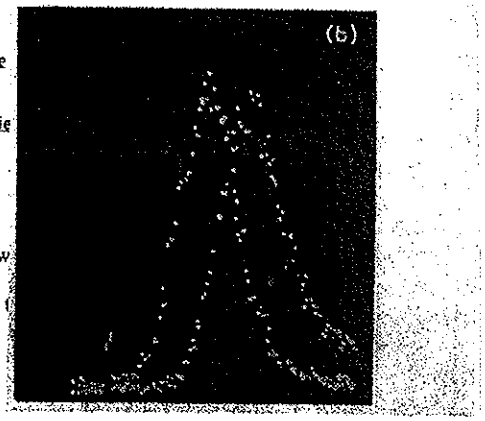


Fig. 10. Delay in the pulse as a function of the distance wire-particle.

NUCLEAR INSTRUMENTS AND METHODS 91 (1971) 221–230; © NORTH-HOLLAND PUBLISHING CO.

CERN
SERVICE D'INFORMATION SCIENTIFIQUE

CONSTRUCTION AND PERFORMANCE OF LARGE MULTIWIRE PROPORTIONAL CHAMBERS

P. SCHILLY, P. STEFFEN, J. STEINBERGER, T. TRIPPE, F. VANNUCCI and H. WAHL

CERN, Geneva, Switzerland

K. KLEINKNECHT and V. LÜTH

Institut für Hochenergiephysik der Universität Heidelberg, Heidelberg, Germany

Received 21 September 1970

Volume 48B, number 5 PHYSICS LETTERS 4 March 1974

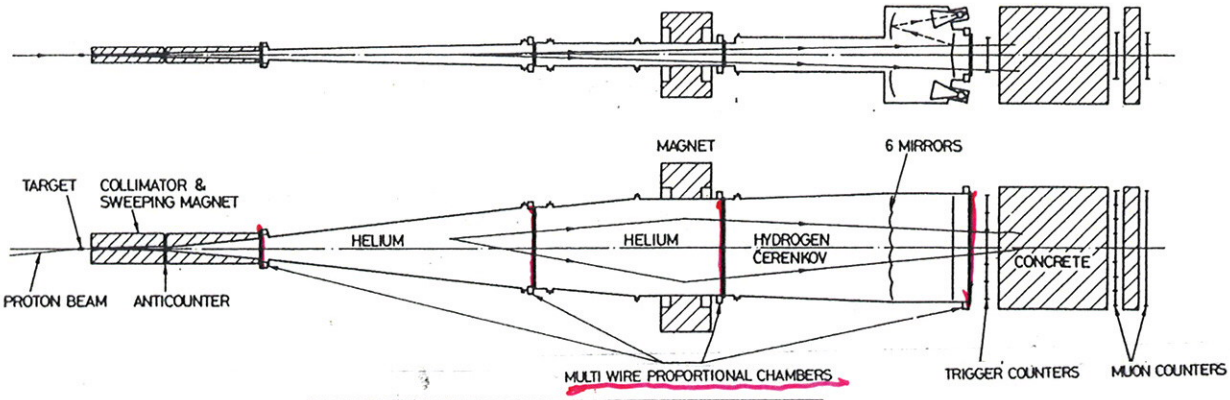
First use of MWP chambers.

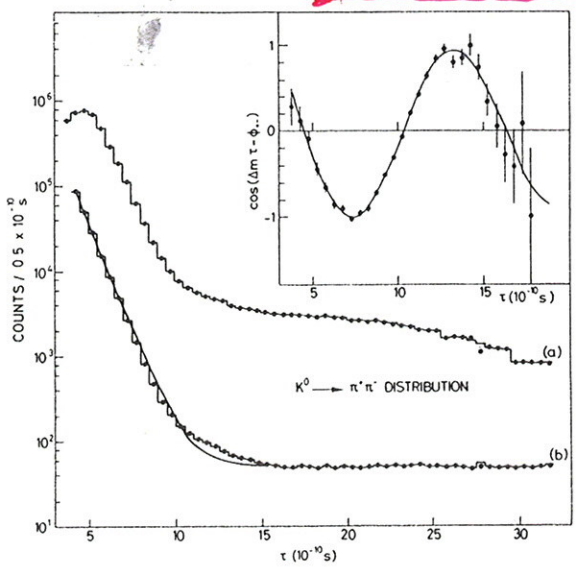
A NEW DETERMINATION OF THE $K^0 \to \pi^+\pi^-$ DECAY PARAMETERS

C. GEWENIGER*[1], S. GJESDAL*[2], G. PRESSER*[1], P. STEFFEN,
J. STEINBERGER, F. VANNUCCI*[3] and H. WAHL,
CERN, Geneva, Switzerland

F. EISELE*[1], H. FILTHUTH, K. KLEINKNECHT*[1], V. LÜTH and G. ZECH*[4]
Institut für Hochenergiephysik, Heidelberg, Germany

Received 4 February 1974





Results: $|\eta_{+-}| = (2.30 \pm .035) * 10^{-3}$

$\phi_{+-} = (49.4 \pm 1.0)^\circ + \left(\frac{\Delta m}{.540 * 10^{10}\ \text{sec}^{-1}} - 1\right) * 305^\circ$

$\left[\eta_{+-} = \frac{\langle \pi^+\pi^- | T | K_L \rangle}{\langle \pi^+\pi^- | T | K_S \rangle} = |\eta_{+-}| e^{i\phi_{+-}} = \epsilon + \epsilon' \right]$

$[\Delta m = m_L - m_S]$

Volume 48B, number 5 PHYSICS LETTERS 4 March 1974

MEASUREMENT OF THE CHARGE ASYMMETRY IN THE DECAYS $K_L^0 \to \pi^\pm e^\mp \nu$ AND $K_L^0 \to \pi^\pm \mu^\mp \nu$

C. GEWENIGER*[1], S. GJESDAL*[2], T. KAMAE*[3], G. PRESSER*[1], P. STEFFEN, J. STEINBERGER, F. VANNUCCI*[4] and H. WAHL
CERN, Geneva, Switzerland

F. EISELE*[1], H. FILTHUTH, K. KLEINKNECHT*[1], V. LÜTH and G. ZECH*[5]
Institut für Hochenergiephysik, Universität Heidelberg, Germany

Results: $\delta_L = \frac{N_+ - N_-}{N_+ + N_-} = 2 R_e \epsilon \; ; \; (\eta_{+-} = \epsilon + \epsilon')$

$\delta_{L,e} = (3.41 \pm .18) * 10^{-3}$

$\delta_{L,\mu} = (3.13 \pm .29) * 10^{-3}$

$R_e \epsilon = (1.67 \pm .08) * 10^{-3}$

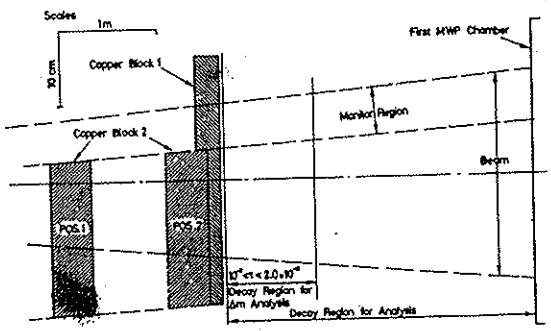
Volume 52B, number 1 PHYSICS LETTERS 16 September 1974

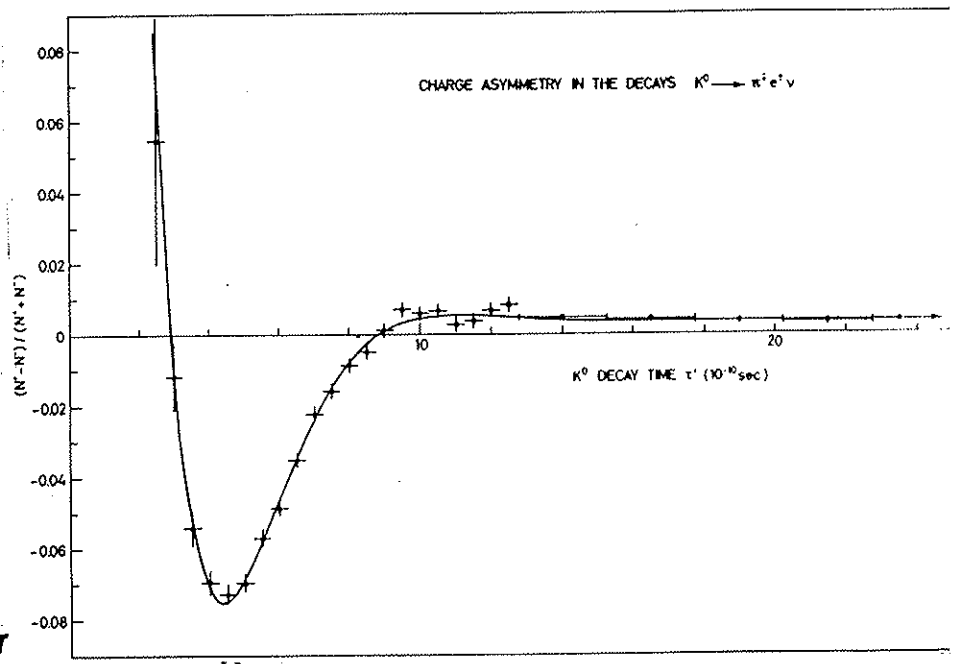
MEASUREMENT OF THE KAON MASS DIFFERENCE $m_L - m_S$ BY THE TWO REGENERATOR METHOD

C. GEWENIGER[1], S. GJESDAL[2], G. PRESSER[1], P. STEFFEN, J. STEINBERGER, F. VANNUCCI[3] and H. WAHL
CERN, Geneva, Switzerland

F. EISELE[1], V. LÜTH[4] and G. ZECH
Institut für Hochenergiephysik, Heidelberg, Germany

K. KLEINKNECHT
Universität Dortmund, Dortmund, Germany





Result: $\Delta m = (.533 \pm .004) * 10^{10}$ sec

$\Downarrow$

$\phi_{+-} = (45.9 \pm 1.6)^\circ$

(in agreement with prediction for $\epsilon' \ll \epsilon$, $\phi_{+-} = \phi_\epsilon = \arctan \frac{2\Delta m}{\Gamma_S - \Gamma_L} = (43.7 \pm .15)^\circ$

Example of other measurements with same detector: 1st measurement of Λ – nucleus crossection.

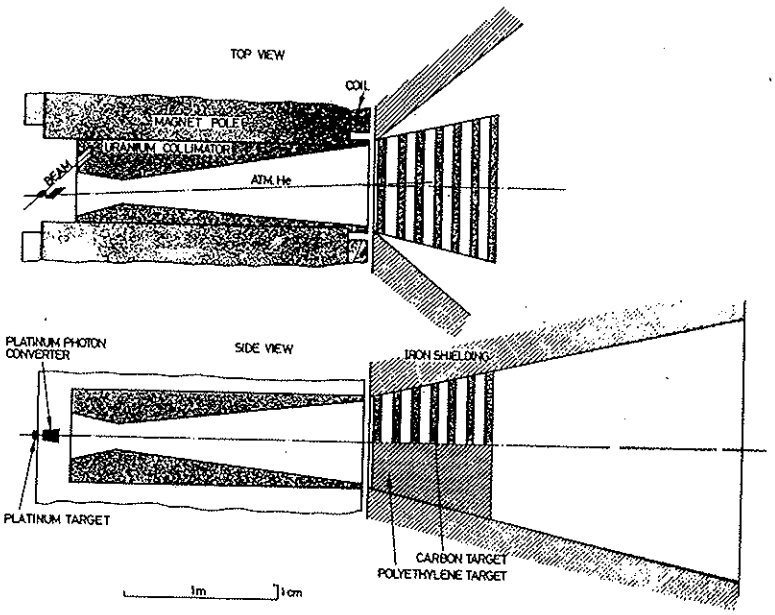
Volume 40B, number 1 PHYSICS LETTERS 12 June 1972

A MEASUREMENT OF THE TOTAL CROSS-SECTIONS FOR Λ HYPERON INTERACTIONS ON PROTONS AND NEUTRONS IN THE MOMENTUM RANGE FROM 6 GeV/c TO 21 GeV/c

S. GJESDAL, G. PRESSER, P. STEFFEN, J. STEINBERGER
F. VANNUCCI* and H. WAHL
CERN, Geneva, Switzerland

and

K. KLEINKNECHT, V. LÜTH and G. ZECH
Institut für Hochenergiephysik der Universität Heidelberg, Heidelberg, Germany



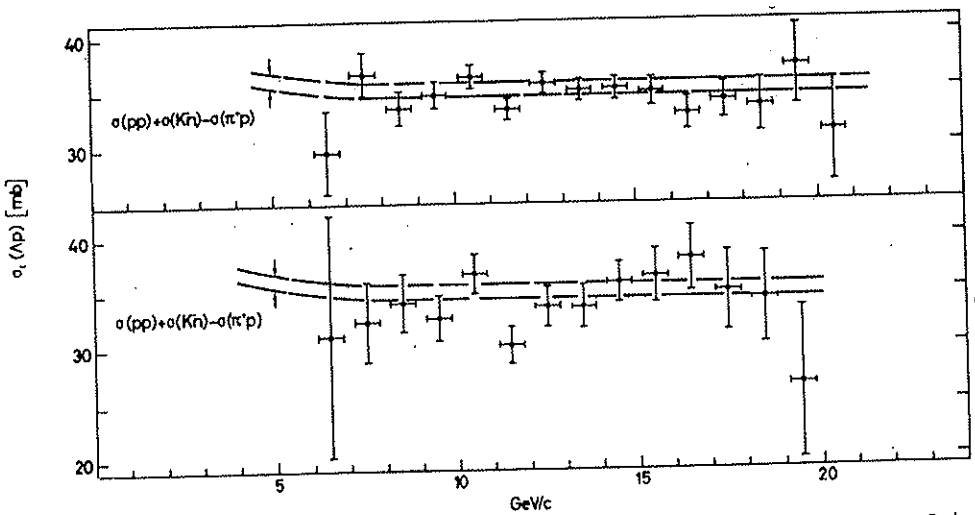


Fig. 3. (a) and (b) The measured total cross-sections σ(Λp) and σ(Λn) as a function of momentum. Only statistical errors are shown. The prediction from quark-model additivity sum rules is indicated by the broekn lines. The range between the lines covers the uncertainty of the data used in evaluating the sum.

Results in interval (6 – 21) GeV/c
σ(Λp) = 34.6 ± .4 mb
σ(Λn) = 34.0 ± .8 mb

Conclusion: the PS permitted good progress in particle physics.

LEP, the "ultimate" e^+ - e^- storage ring collider.

To my knowledge, first suggestion for the "ultimate e+ - e- collider came from Burt Richter, in the 70's.

N. B.: As best I know, Tini Veltman was responsible for the suggestion, in the late 70's, and which was accepted, that the tunnel should be constructed so as to permit a future p – p collider, now the LHC.

The beginning of the ALEPH collaboration was summer of '80. Maybe a dozen of us, including some members of the CDHS neutrino experiment, Jaques Lefrancois, and Rene Turley. We agreed that we would like to focus on a special purpose detector, but soon agreed that we could not think of an interesting "special purpose", and so focused on a general purpose detector.

My own first concept, given the expected isotropy of the Z decay, was not brilliant: a spherical magnet. This was not adopted.

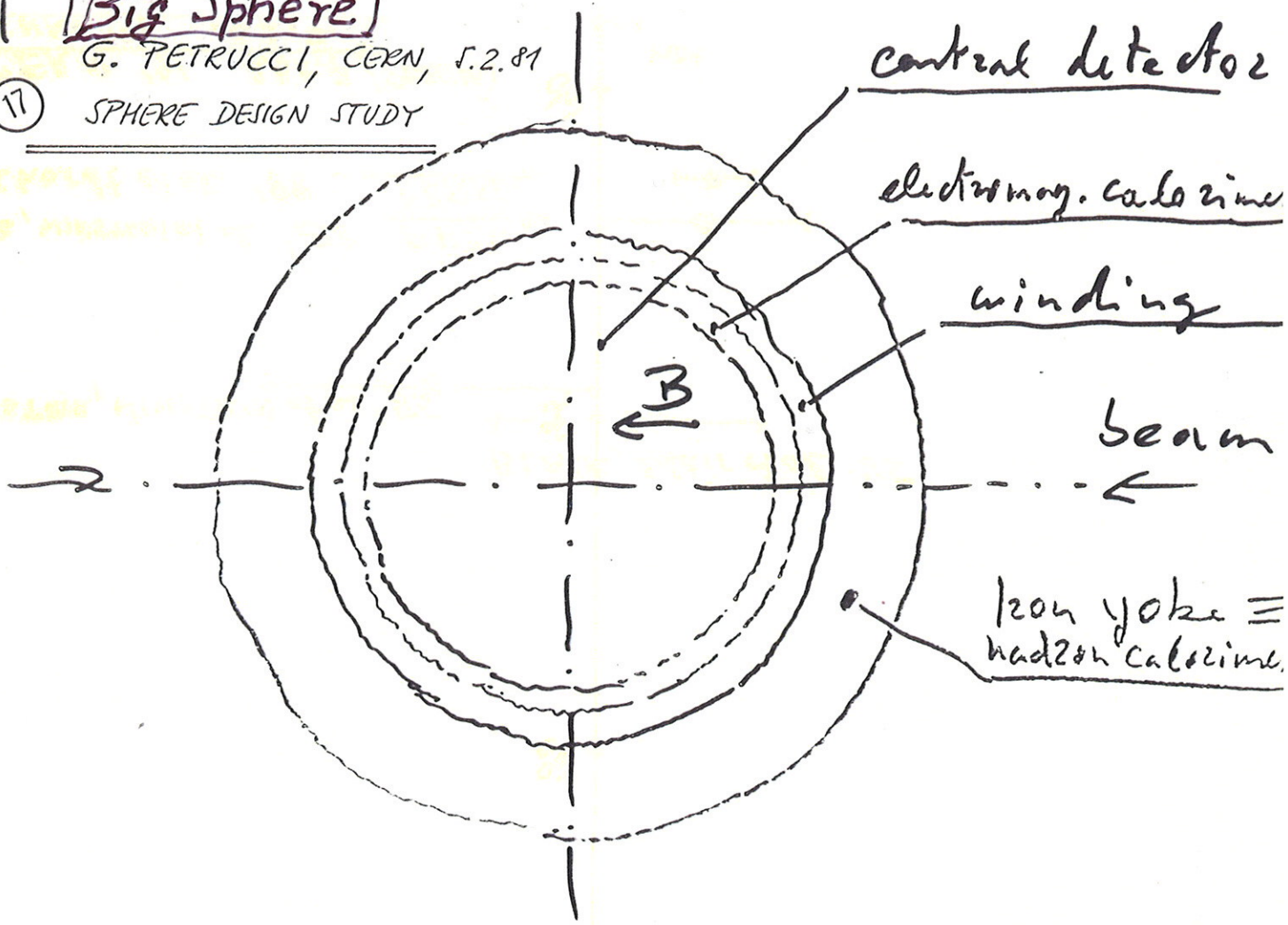
The most important insight, in my opinion, the one which dominated the ALEPH design, came from Jaques Lefrancois: the electro-magnetic calorimeter should focus on angular, rather than energy, resolution.

ALEPH construction: we were managed beautifully by the Technical Coordinator, Pierre Lazeyras.

Big Sphere

G. PETRUCCI, CERN, 5.2.81

(17) SPHERE DESIGN STUDY

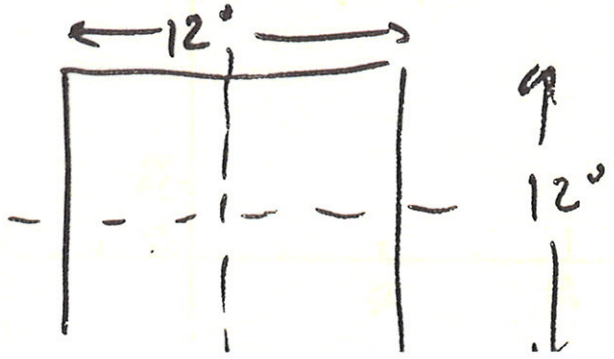


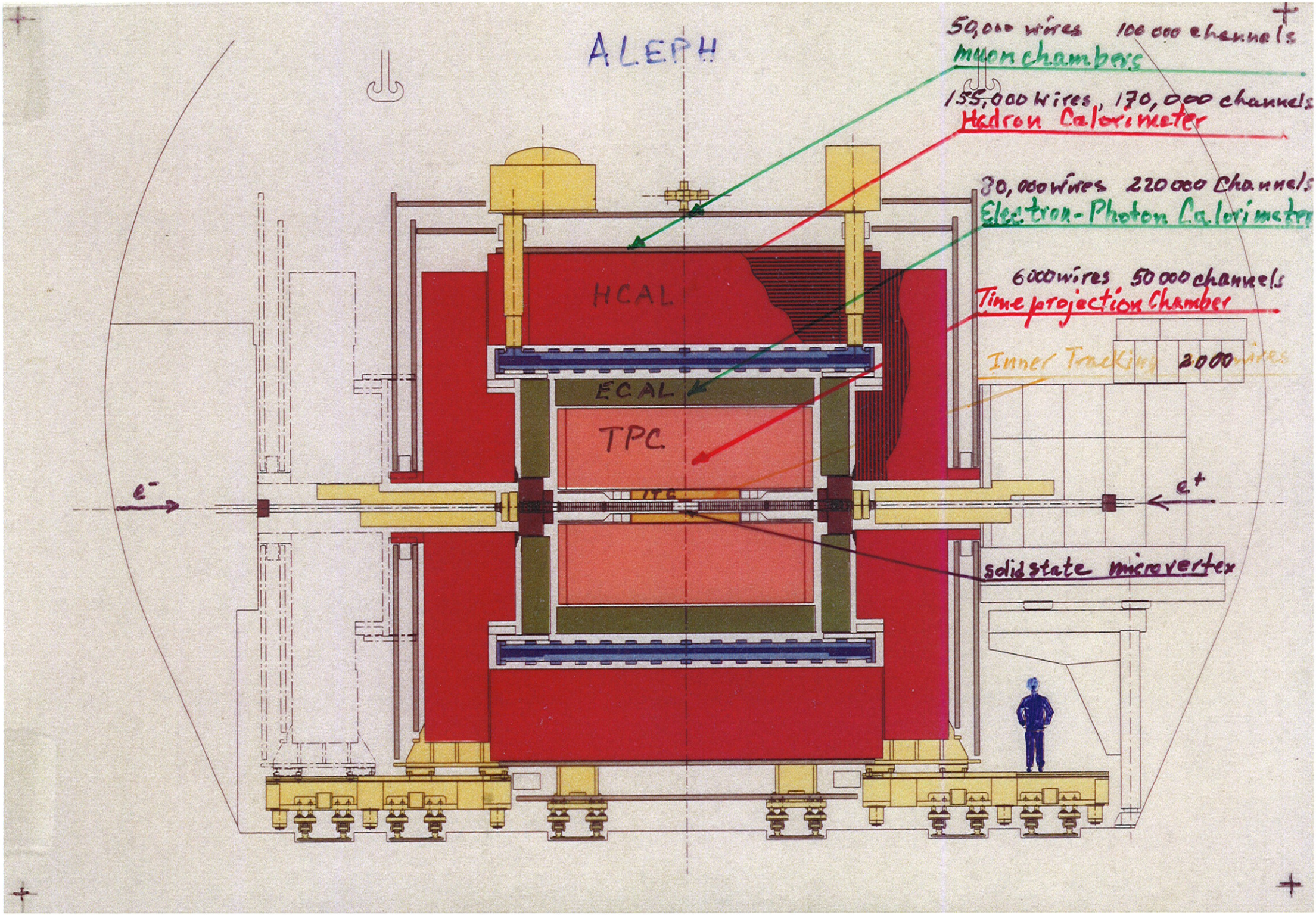
Subdivision in ~ equal elements (modules)
(~ equal solid angles from int. point)

Winding calorimetrized

Supermodules ~ 12° × 12°

split in 4 × 6° × 6°




ALEPH
50,000 wires 100 000 channels
muon chambers
155,000 wires, 170,000 channels
Hadron Calorimeter
30,000 wires 220 000 channels
Electron-Photon Calorimeter
6000 wires 50 000 channels
Time projection Chamber
Inner Tracking 2000 wires
solid state microvertex
HCAL
ECAL
TPC
ITC
e⁻
e⁺

LETTER OF INTENT

TO STUDY e^+e^- ANNIHILATION PHENOMENA AT LEP

Bari-CERN-Demokritos Athens-Dortmund-Ecole Polytechnique Palaiseau-
Edinburgh-Glasgow-Heidelberg-Lancaster-MPI München-Orsay-Pisa-Rutherford
Saclay-Sheffield-Torino-Trieste-Westfield College London-Wisconsin Collaboration

Geneva, 25 January 1982

Günther Wolff stimulated this study of the functioning of TPC's

ALEPH-LEP-Note: 77
June 10, 1982

F. RAGUSA
L. ROLANDI

$\vec{E}x\vec{B}$ EFFECT IN ALEPH TPC

The aim of this report is to study the $\vec{E}x\vec{B}$ effect measured in the TRIUMF TPC and make some quantitive estimates for the worsening of the $R\phi$ resolution of our TPC because of this effect.

SOME DATA ON TRIUMF TPC

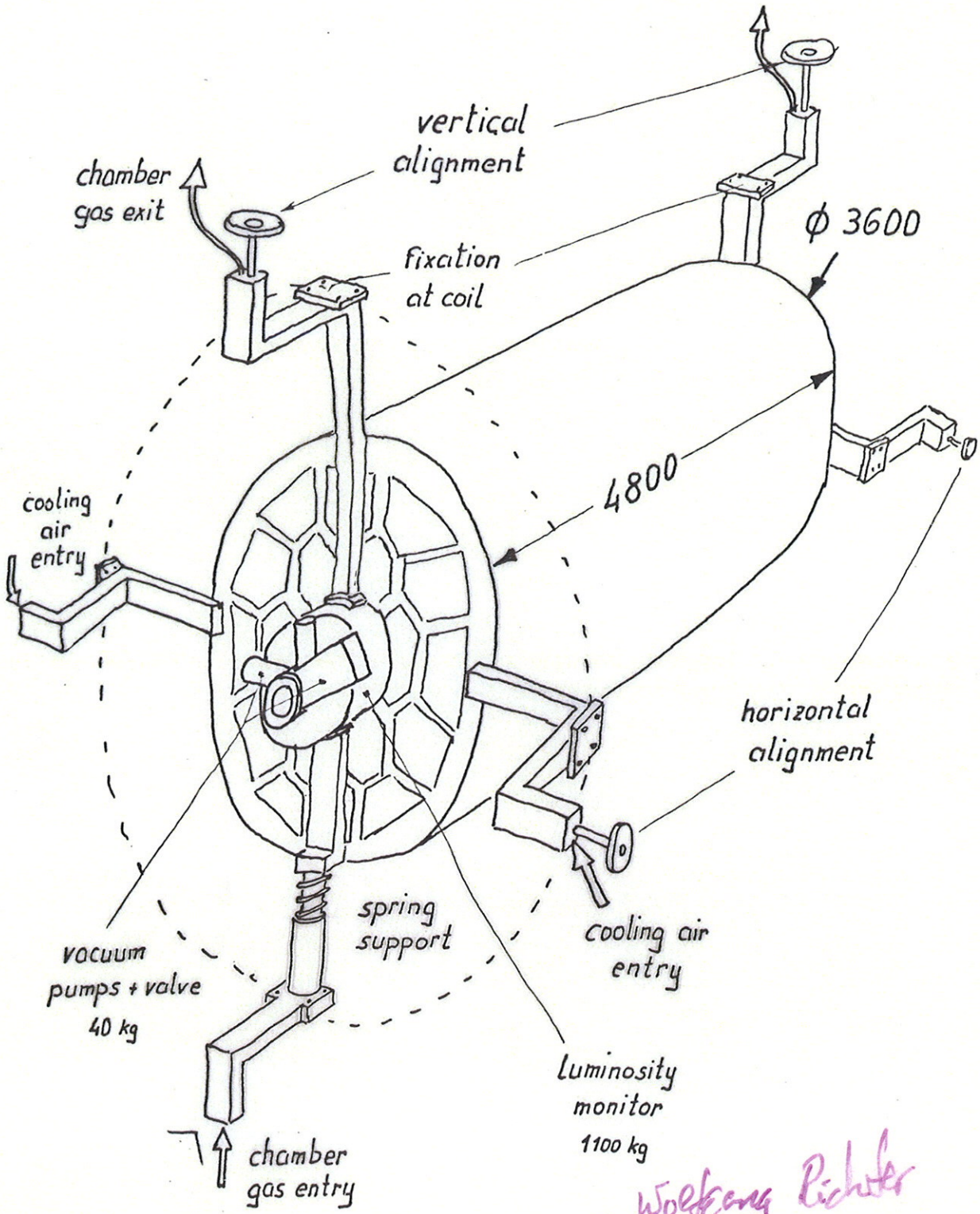
Effective dimension of the cell 6 mm
Gas 80% A + 20% CH_4
$\vec{E}x\vec{B}$ angle, at B = 8.5 Kg, $\psi = 32°$ (tg 32° = 0.624)
Resolution for 0° track .450 mm
Resolution for 32° track .180 mm
Resolution $\vec{E}x\vec{B}$ at 0° = $\sqrt{\sigma^2(0°)-\sigma^2(32°)}$ = .412 mm
the shape of the cell is shown in Fig. 2.
From Sauli report [1] at 80% A + 20 CH_4 we have
Primary ionization N_0 = 2.67 pair/mm
Total " N_{Tot} = 8.58 pair/mm

1. DRIFT OF ELECTRONS IN $\vec{E}$ AND $\vec{B}$ FIELDS

The familiar expression for the drift velocity of electrons in gas

$$\vec{v}_d = \frac{e\tau}{m}\vec{E} = \mu\vec{E}$$

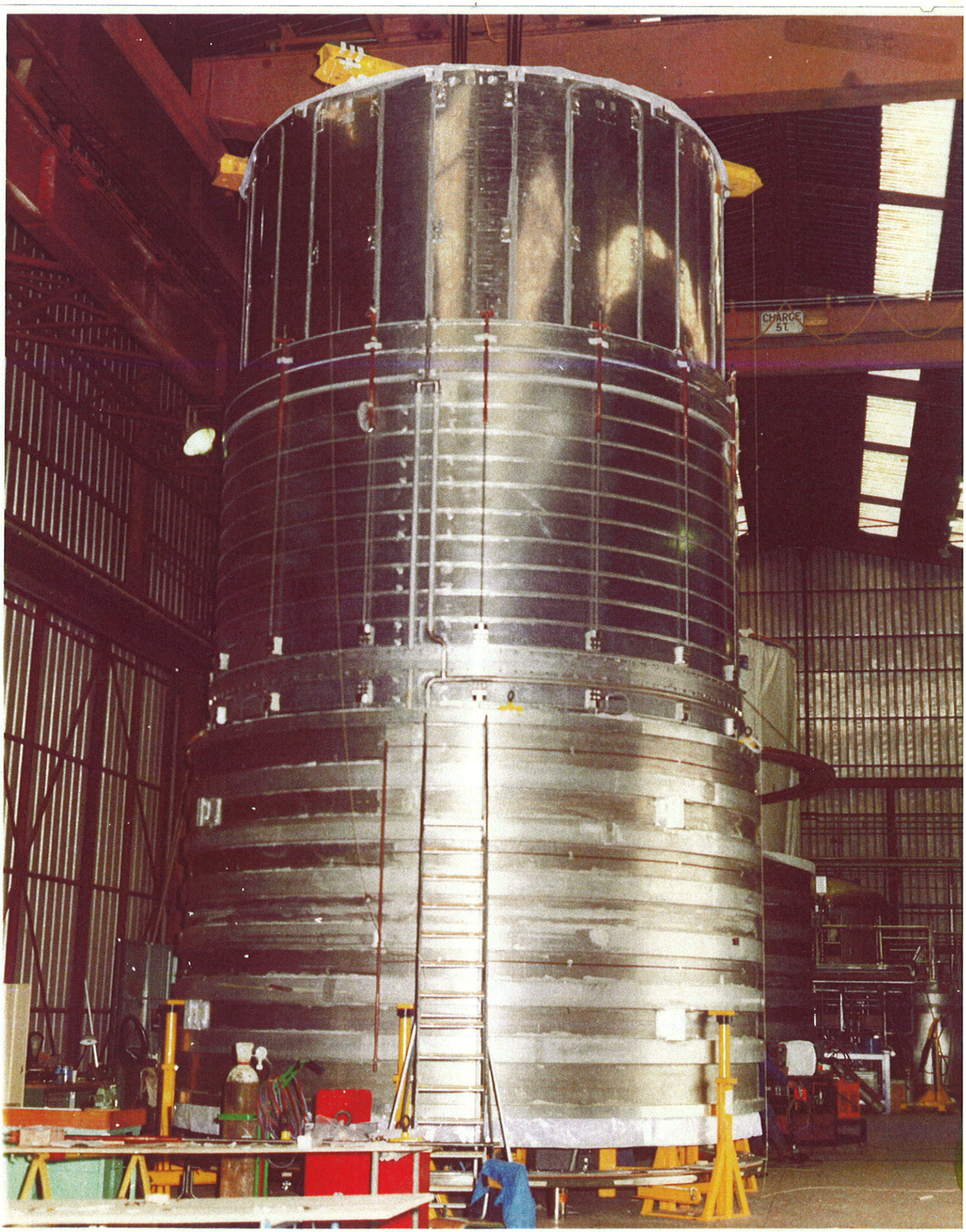
(with τ = mean time between two successive interaction with the gas molecule) is modified in presence of a magnetic field [2]

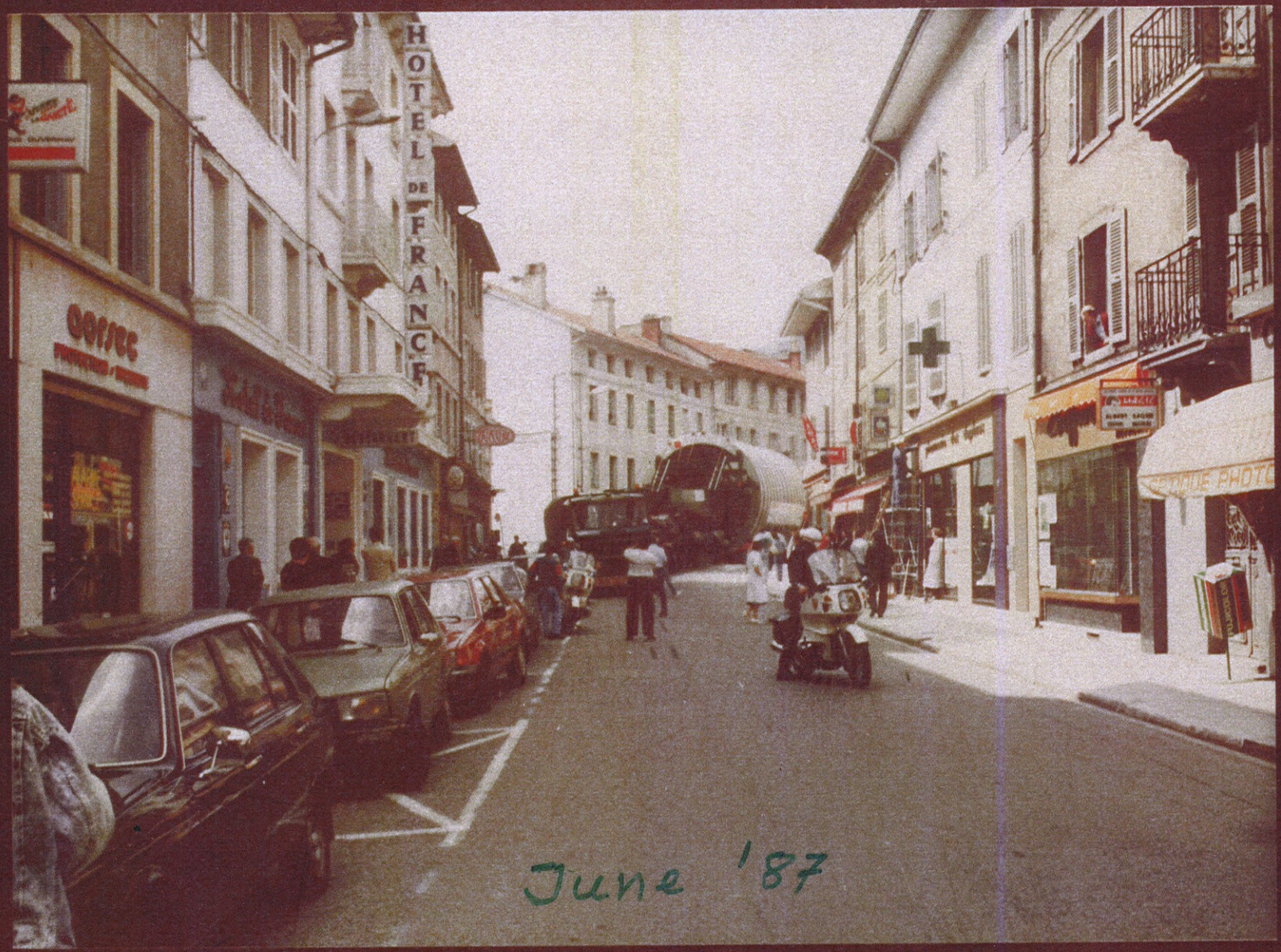


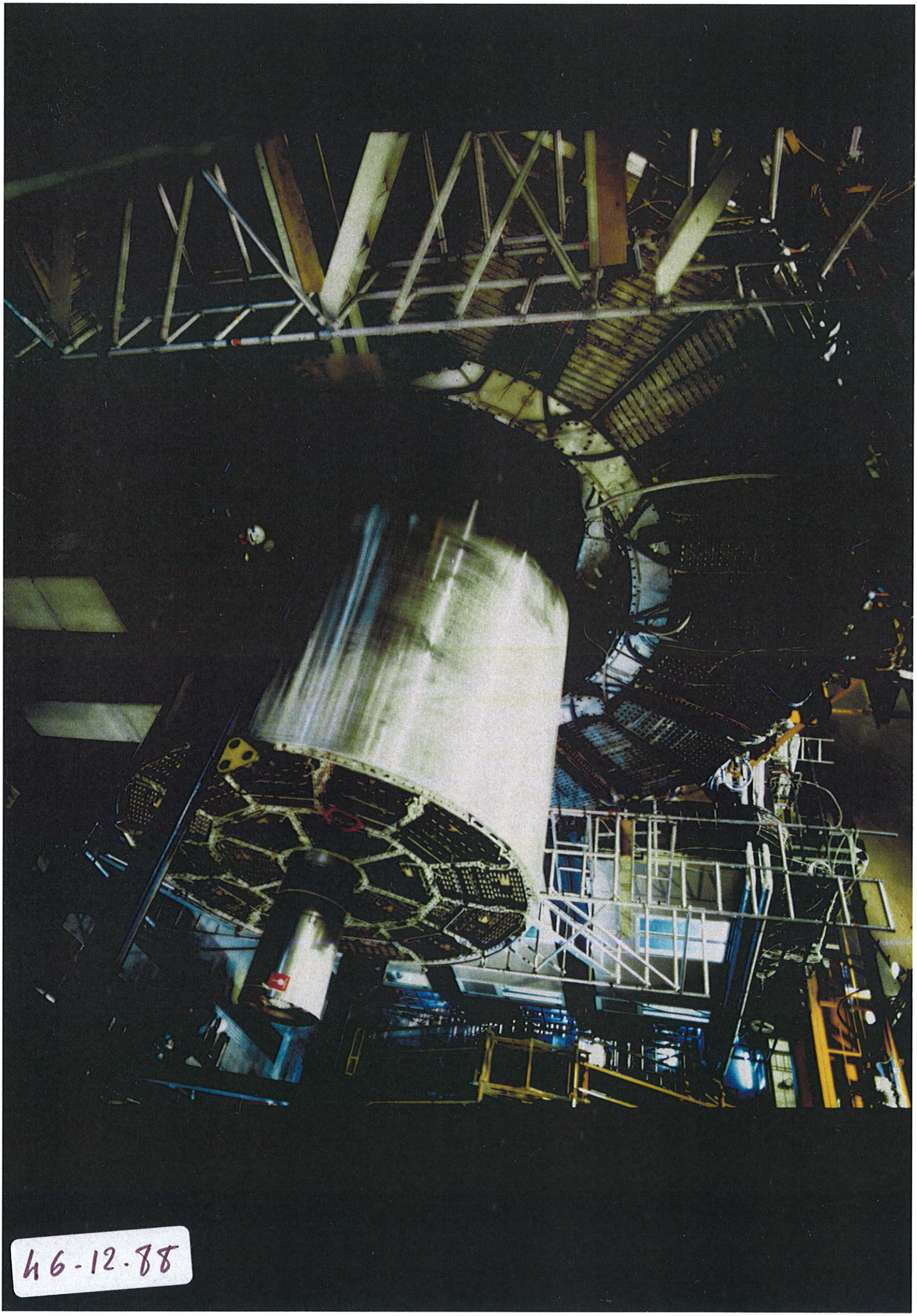
Wolfgang Richter

ALEPH TPC Support

Stirlin
Munich
CERN

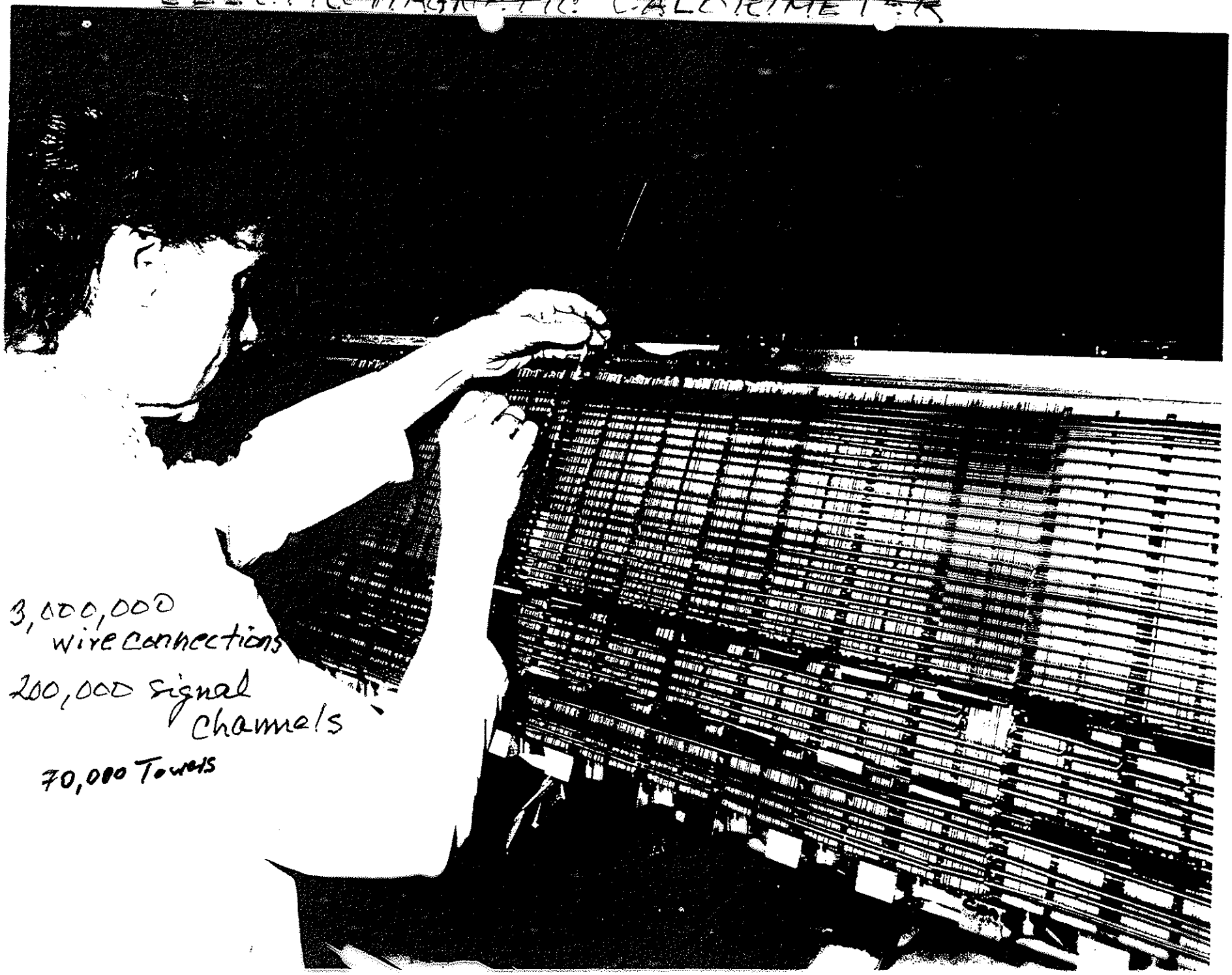

CHARGE
5t


HOTEL DE FRANCE
June '87



46-12-88

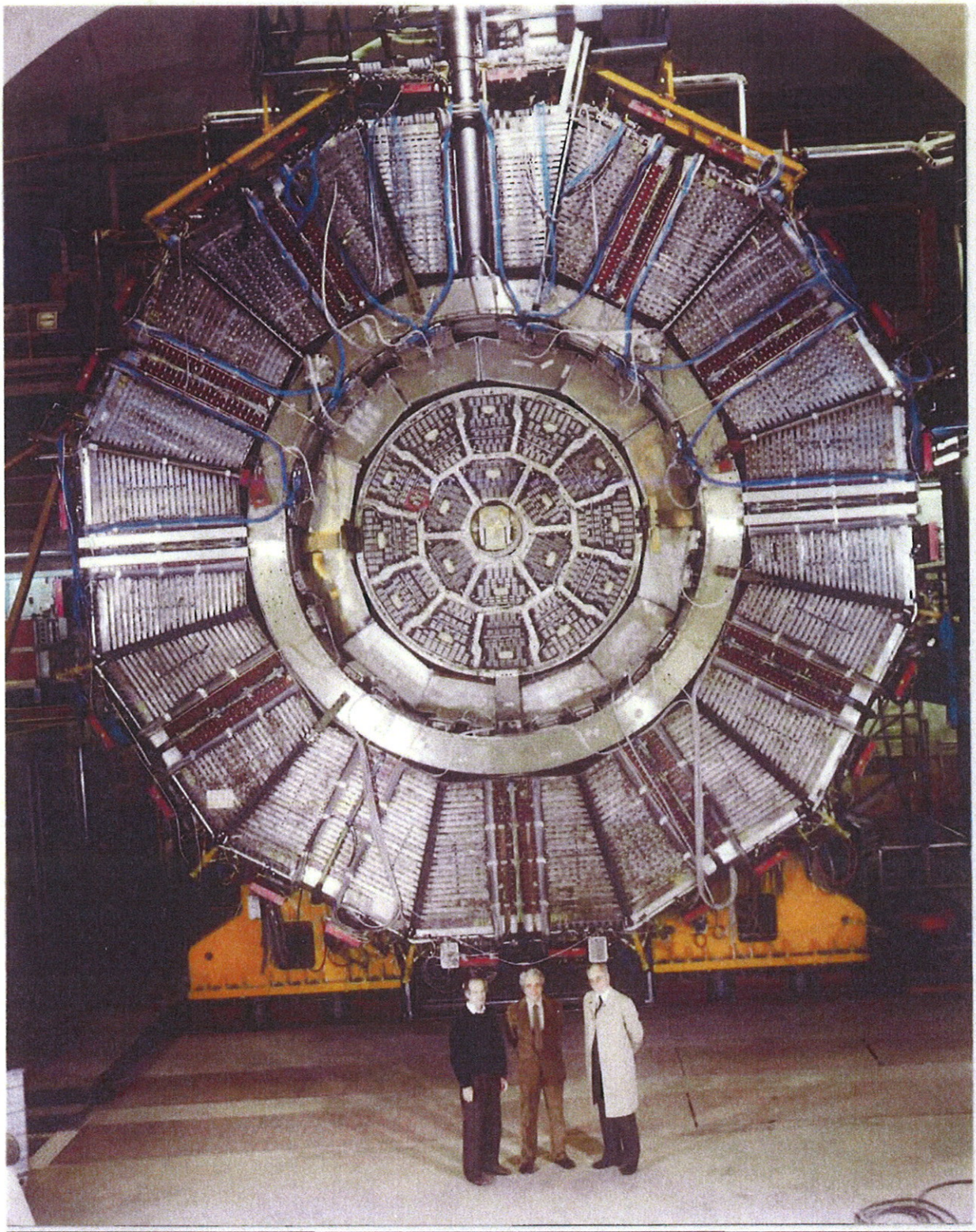
ELECTROMAGNETIC CALORIMETER



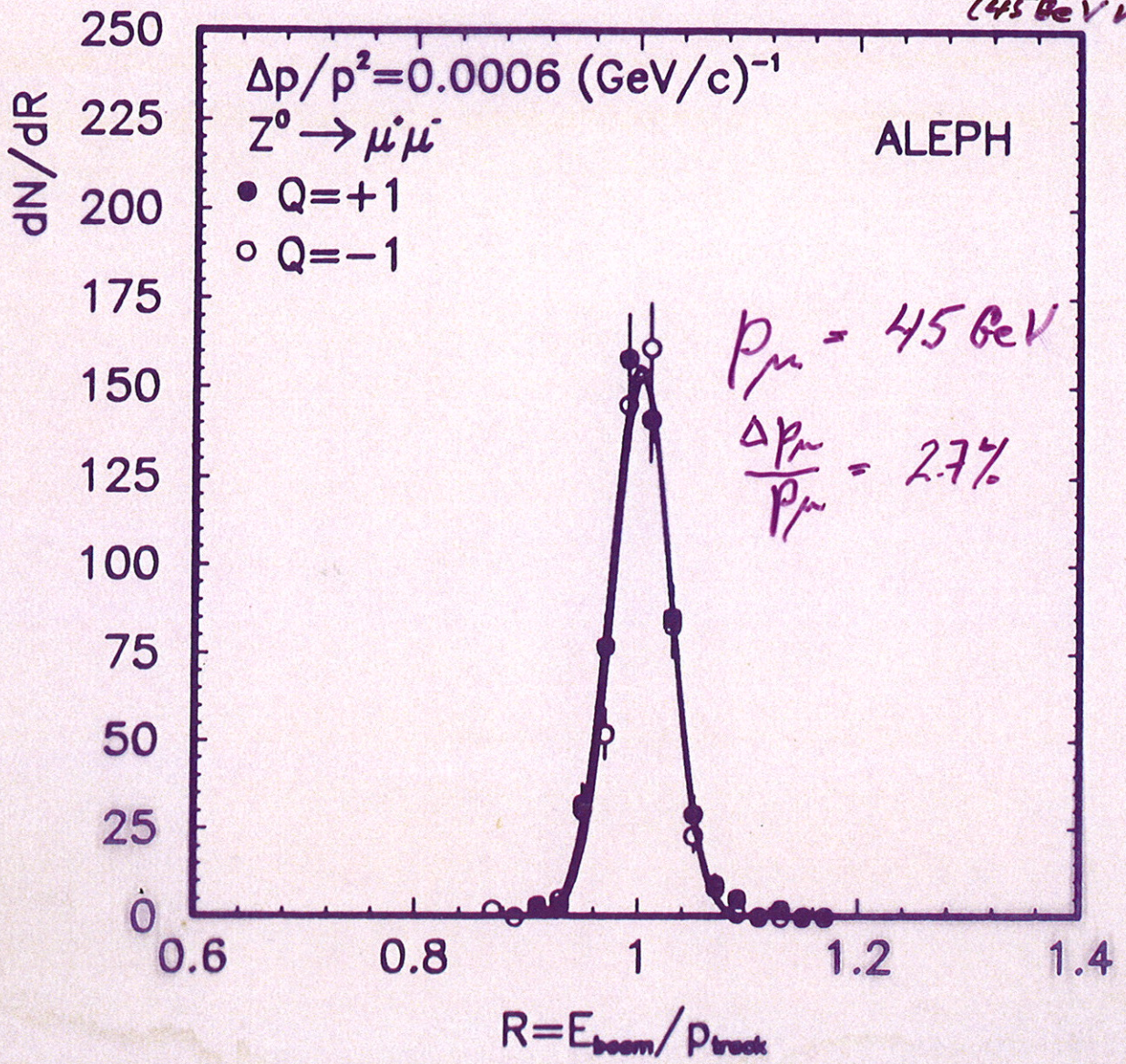
3,000,000 wire connections

200,000 signal channels

70,000 Towers



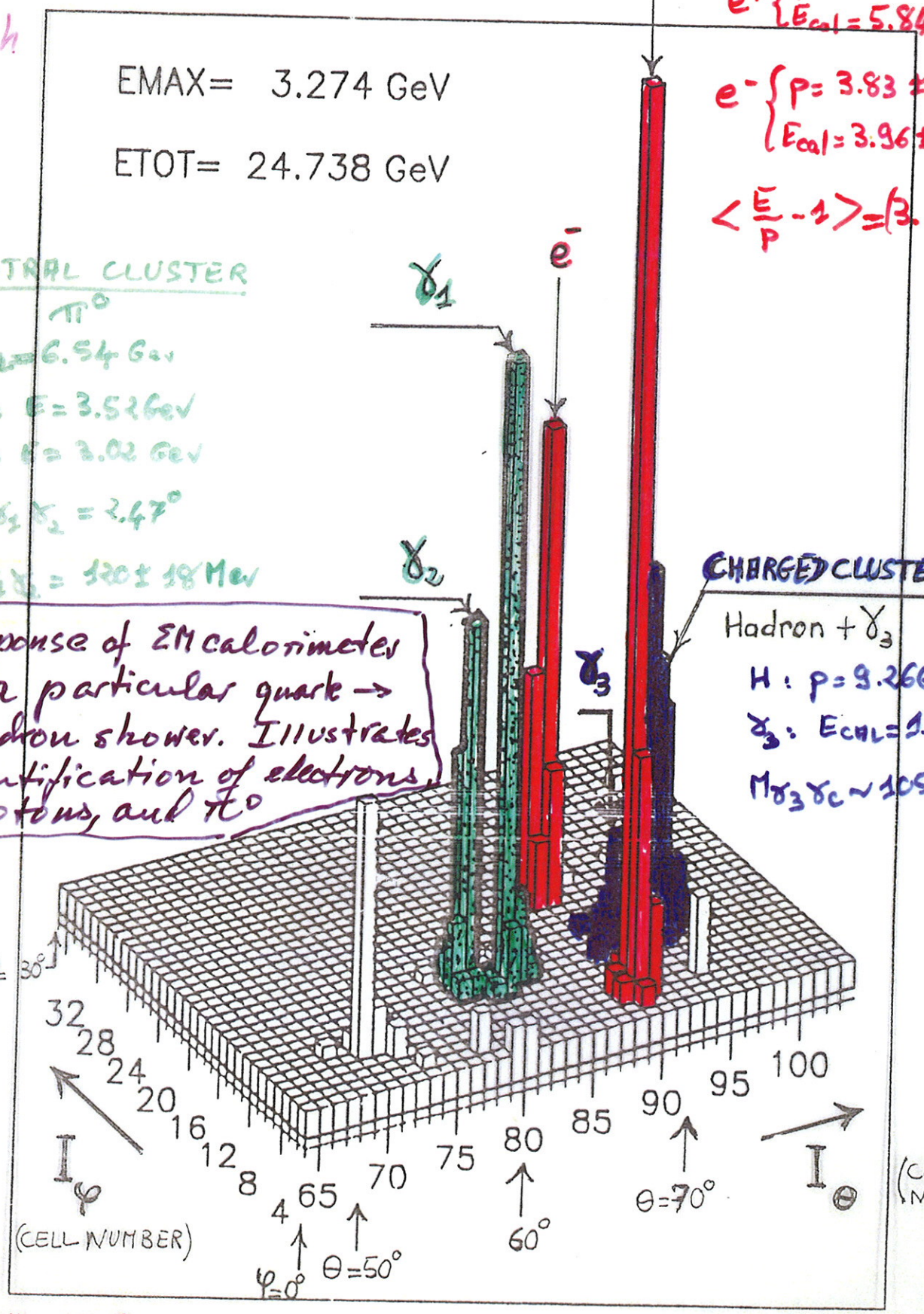
Momentum resolution of combined tracking system for highest momentum particles (45 GeV muons)



LEGO PLOT : Run 2516 , Event 146

(1/3 of a Barrel module)

Aleph



CONVERTED γ_c

$E = 3.56$ GeV

$e^+ \begin{cases} p = 5.73 \pm 0.10 \\ E_{cal} = 5.84 \pm 0.44 \text{ GeV} \end{cases}$

$e^- \begin{cases} p = 3.83 \pm 0.03 \\ E_{cal} = 3.96 \pm 0.36 \text{ GeV} \end{cases}$

$\left\langle \frac{E}{p} - 1 \right\rangle = (3. \pm 6)\%$

NEUTRAL CLUSTER

π^0

$E_{cal} = 6.54$ GeV

γ_1: $E = 3.52$ GeV

γ_2: $E = 3.02$ GeV

$\theta_{\gamma_1\gamma_2} = 2.47°$

$M_{\gamma_1\gamma_2} = 120 \pm 18$ MeV

$M_{\gamma_3\gamma_c} \sim 105$ TO 135 MeV

H : $p = 9.26$ GeV

γ_3: $E_{CHL} = 1.5$ TO 2 GeV

Response of EM calorimeter to a particular quark → hadron shower. Illustrates identification of electrons, photons, and π^0

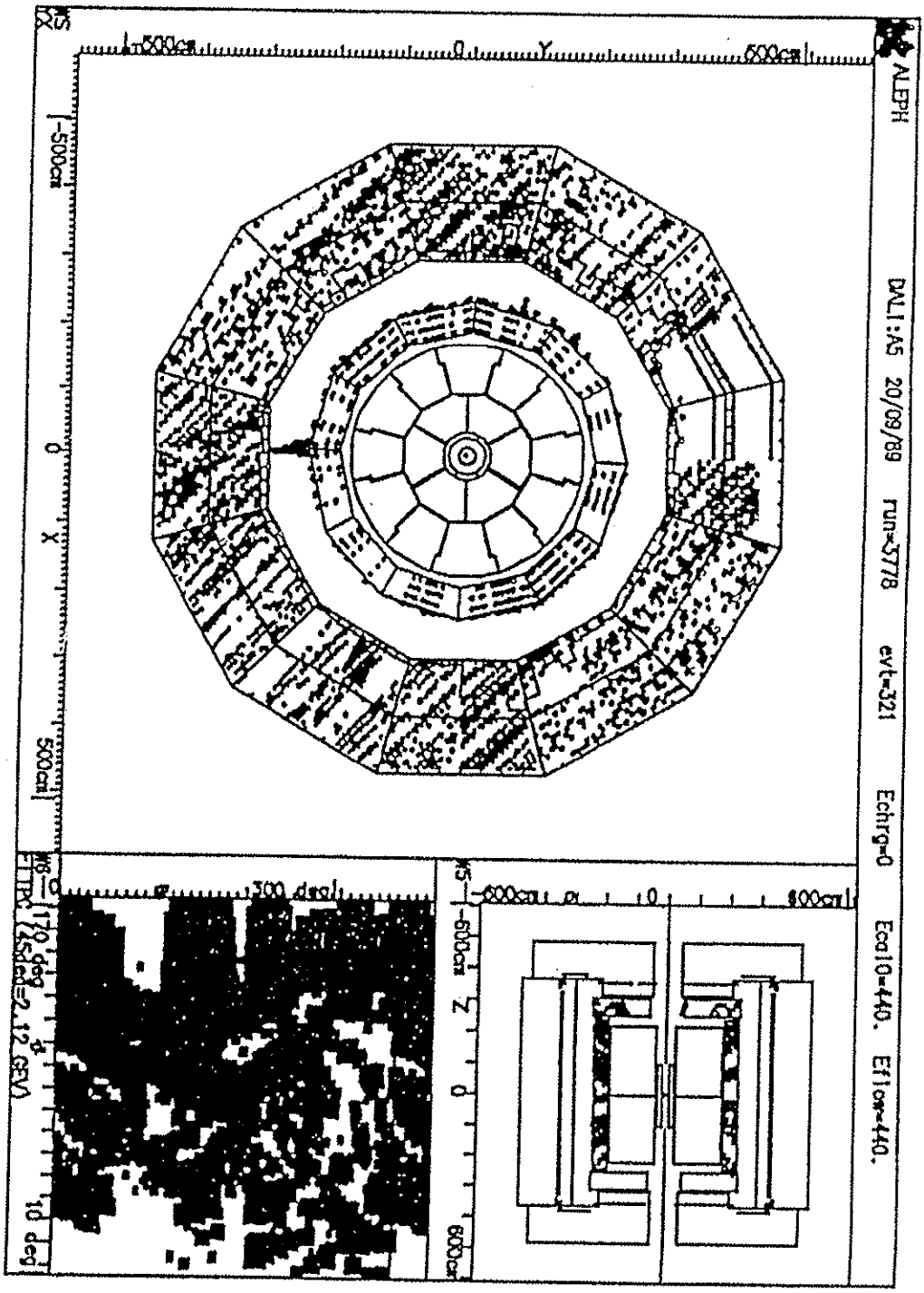
1 cell = 0.94°

ECAL TOWER ENERGY DEPOSITION IN MODULE 01 EVENT 00002516 / 00000146

BUON GIORNO!!

Cosmic ray event

Energy of cosmic ray ~ 10^7 GeV?



A cosmic ray shower of parallel muons in ALEPH.

Courtesy Monica Pepe Altarelli

160