A Life of Two Halves

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$\nu_e \neq \nu_\mu$

BRUNO PONTECORVO

PISA 22·8·1913

DUBNA 24·9·1993

FISICO

HARWELL to DUBNA: 01 . 9.1950

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Experimenter and Theorist

A Life of Two Halves

$\nu_\mu \neq \nu_e$

BRUNO PONTECORVO

PISA 22.8.1913

DUBNA 24.9.1993

FISICO

HARWELL to DUBNA: 01 . 9.1950

Loved physics; Hated fascism

4 September 1979: The day I nearly met Bruno

Б. Понтекорво
Окунь 4/9-79.

Some Remarks on Slow Processes of Transformation of Elementary Particles

L. OKUN' AND B. PONTECORVO
Joint institute for Nuclear Research
(Submitted to JETP editor March 26, 1957)
J. Exptl. Theoret. Physics (U.S.S.R.) 32, 1587-1588
(June, 1957)

AS IS KNOWN, there are two types of slow processes:

(a) lepton:

$$n \to e + \bar{\nu} + p,\ \mu \to e + \nu + \bar{\nu},\ \mu + p \to n + \nu,\ \pi \to \mu + \nu,$$
$$K \to \mu + \nu,\ K \to \mu + \nu + \pi,\ K \to e + \nu + \pi,$$

(b) non-lepton:

$$K \to 2\pi,\ K \to 3\pi,\ \Lambda\,(\Sigma) \to N + \pi,\ \Xi \to \Lambda + \pi.$$

The constants of the interactions responsible for these processes in units of $\hbar = \mu = c = 1$ (where μ is the π-meson mass) are of the same order of magnitude as $G^2 = 10^{-14} - 10^{-12}$. This suggests that the same mechanism (for example, the universal Fermi interaction[1]) may lie at the basis of all* these processes. This idea is supported by the fact that

*Non-conservation of parity in the decay of hyperons, although it has not yet been proved experimentally, almost inescapably follows from the established parity non-conservation in the decay of K-mesons.

Pontecorvo:Ideas for experiments giving rise to Nobel prizes

Two types of neutrinos; accelerator expt to prove it

L.Lederman,J.Steinberger, M.Schwarz Nobel 1988

.

Inverse beta decay at reactors

F. Reines Nobel 1995

radiochemical methods for neutrino detection

Chlorine experiment , R. Davis Nobel 2002

Oscillations

Koshiba Nobel 2002

Pontecorvo:Ideas for experiments giving rise to Nobel prizes

Two types of neutrinos; accelerator expt to prove it

L.Lederman,J.Steinberger, M.Schwarz Nobel 1988

.

Not known in west
Couldn't do in ussr
did BP expect positive?

Inverse beta decay at reactors

F. Reines Nobel 1995

Reactors = antineutrinos
Chlorine fails
Forbidden access reactor in ussr

radiochemical methods for neutrino detection
Chlorine experiment , R. Davis Nobel 2002

Oscillations

Koshiba Nobel 2002

BP died 24.9.93
Otherwise would surely have shared Nobel 2002

Pontecorvo 1951-1953: Associated Production and Strangeness

Associated Production of strange Particles

A Pais

.

Concept of strangeness

Pais and Gell Mann

Pre Pais but classified

What did BP do?

radiochemical methods for neutrino detection

Chlorine experiment , R. Davis Nobel 2002

Oscillations

Koshiba Nobel 2002

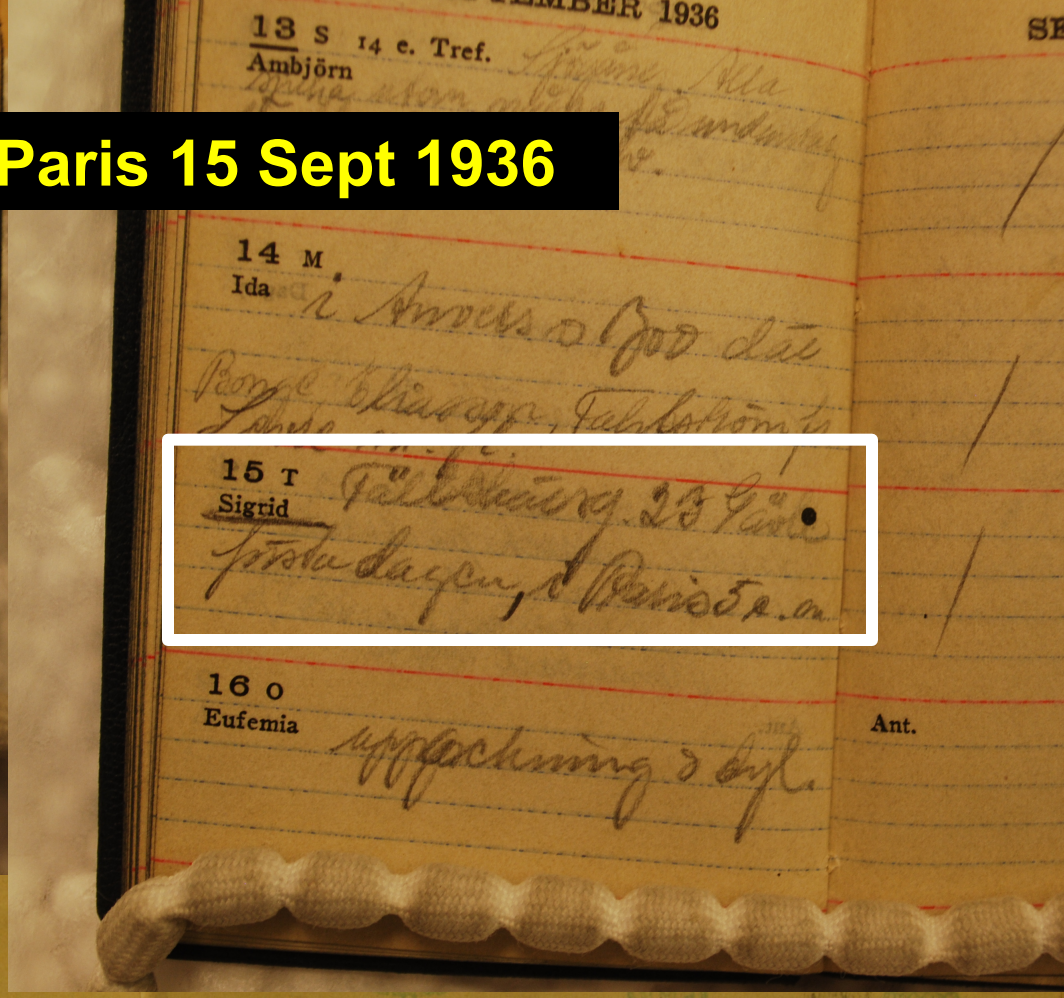
BP died 24.9.93

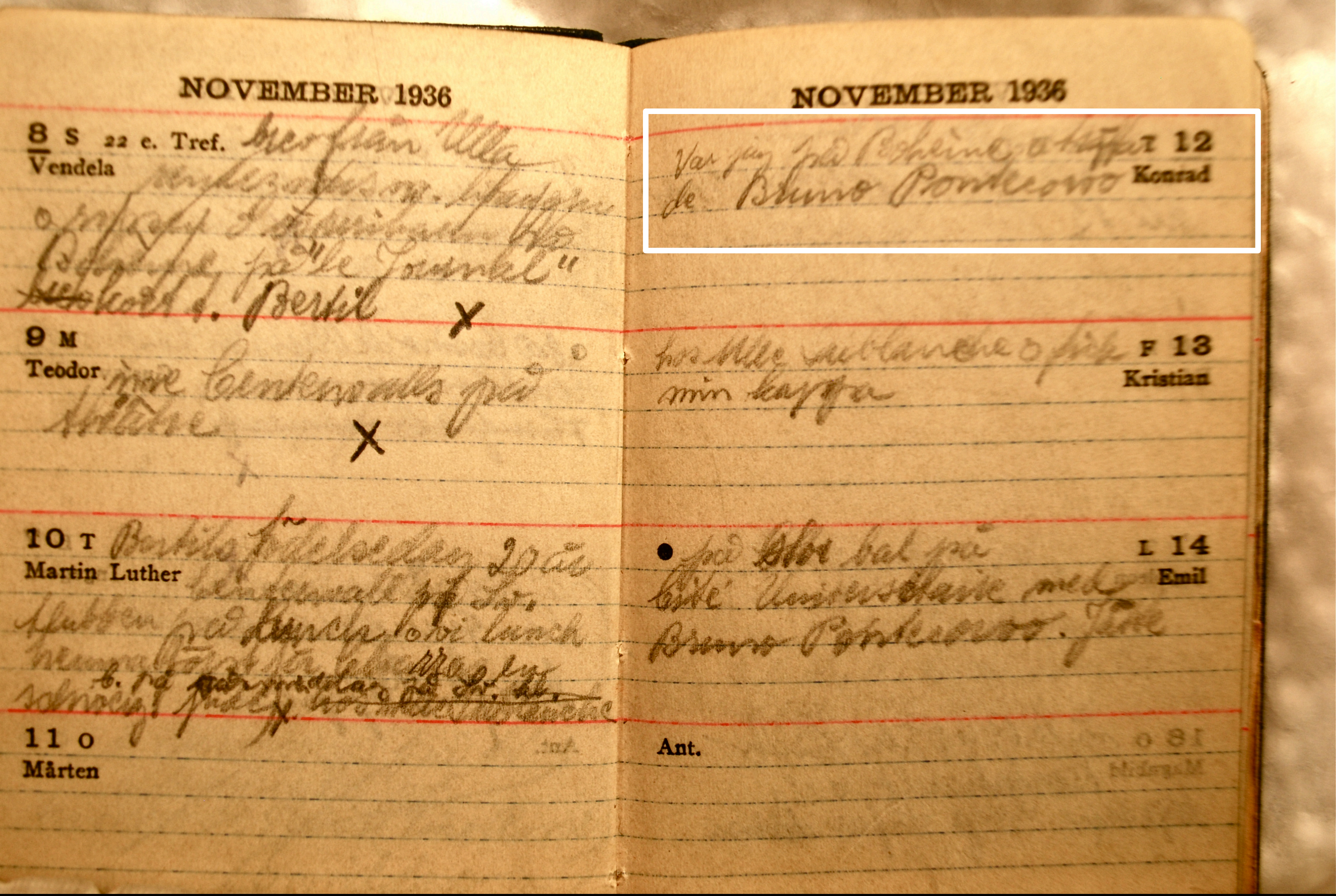
Otherwise would surely have shared Nobel 2002

Bruno Pontecorvo: Discovered in Archives

- First half life: Paris to Chalk River
- Solar Neutrinos 45 (!) and 46
- Harwell
- Second Half Life: Strange Particles 1951-3
-

Marianne arrives Paris 15 Sept 1936





NOVEMBER 1936

8 S 22 e. Tref.
Vendela

9 M
Teodor

10 T
Martin Luther

Bertils födelsedag

11 O
Mårten

NOVEMBER 1936

T 12
Konrad

Var jag på Bohème o kaffe
de Bruno Pontecorvo

F 13
Kristian

min kaffa

L 14
Emil

Bruno Pontecorvo.

Ant.

Marianne meets Bruno 12 Nov 1936

NOVEMBER 1936

T 12 Konrad

F 13 Kristian

L 14 Emil

Ant.

Ball at Cite Universitaire with Bruno Pontecorvo. Great

1938 Aug-Sept

Youth Hostels with Gil

+ Phys conference

Marianne+Gil in Sweden Sept38-August 39.
Bruno refused visit (June 39) by Swedes

ad.Kons.Paris N° 307/39.P.90.

FRÅGEFORMULÄR

att ifyllas av personer, som önska resa till Sverige.

Questionnaire	Fragebogen	Form
à remplir par les personnes qui désirent se rendre en Suède.	der von Personen, die nach Schweden zu reisen wünschen, auszufüllen ist.	to be filled in by persons, desirous of proceeding to Sweden.

Fråga: Question: Frage: Question:	*Svar: Réponse: Antwort: Answer:*
1. Fullständigt för och tillnamn? Nom et prénoms complets? Vollständiger Vor- und Zuname? Christian- and surname in full?	1. Bruno Pontecorvo
2. Yrke (titel)? Profession (Qualité)? Beruf (Titel)? Profession (title)?	2. Docteur en Physique
3. Födelsedatum? Jour et année de naissance? Geboren am? Date of birth?	3. 22 Août 1913
4. Födelseort? Lieu de naissance? Geburtsort? Place of birth?	4. Pisa (Italie)
5. Hemort? Lieu d'origine? Wohnort? Domicile?	5. 17 Place du Panthéon Hôtel des Grands Hommes Paris V
6. Nationalitet (om förändring av nationalitet ägt rum, skall detta angivas)? Nationalité (indiquer éventuellement tout changement de nationalité qui a pu avoir lieu)? Nationalität (hat eine Nationalitätsveränderung stattgefunden, soll diese angegeben werden)? Nationality (if nationality has been changed, this must be stated)?	6. Italienne.
7. Trosbekännelse? Confession? Konfession? Religion?	7. Sans religion. Un des parents est juif. La mère est catholique.
8. Vilken myndighet har utfärdat Edert pass, dess nummer och datum? Quelle autorité a délivré votre passeport; sous quel numéro et à quelle date? Welche Behörde hat Ihren Pass ausgestellt? Nummer … d your passport; number and …	8. Consulat d'Italie à Paris le 28 Fevrier 1939 Numero de Passeport: 673818
… xpire le … rt expires the	9. 4 Août 1939. Visa de retour en France de même validité. Carte d'identité française Avril 1940. Visa d'émigration U.S.A.
… i Sverige räcka? … vous séjourner en Suède? … n Schweden zu weilen? … to sojourn in Sweden?	10. 15 jours au maximum

Fråga: Question: Frage: Question:	*Svar: Réponse: Antwort: Answer:*
11. Vad är anledningen till resan? Quel est le but du voyage? Zweck der Reise nach Schweden? What is the object of your journey to Sweden?	11. Saluer des amis et en même temps visiter un Laboratoire de Physique à Stockholm
12. På vilka orter i Sverige ämnar Ni uppehålla Eder (vid resa genom Sverige uppgivas de gränsorter, som skola passeras)? A quels endroits en Suède comptez-vous vous arrêter (En traversant la Suède, indiquez les stations de frontière par lesquelles vous vous proposez de passer)? Angabe der Orte in Schweden, die besucht werden sollen (Bei Durchreise durch Schweden Angabe der Grenzstationen)? Where in Sweden do you intend to sojourn (if only travelling through Sweden, kindly state frontier stations of arrival and departure)?	12. A Stockholm et peut-être à Sandviken, où j'ai des amis; Station de frontière: probablement Gotenburg, mais ce n'est pas encore decidé.
13. Till vilka firmor eller personer i Sverige kan Ni referera? Quelles maisons ou quelles personnes pouvez-vous indiquer en Suède comme références? Welche Firmen oder Personen können Sie in Schweden als Referenzen angeben? To which firms and persons in Sweden can you refer?	13. Professor Siegbahn, Forskningsinstitutet för Fysik - Vetenskapsakademien Stockholm 50 Fröken Marianne Nordblom Sandviken
14. Har Ni tidigare haft affärsförbindelser i Sverige och i så fall under vilken tid? Avez-vous eu précédemment des relations d'affaires en Suède et dans ce cas à quelle époque? Haben Sie früher Geschäftsverbindungen in Schweden gehabt und wenn so, während welcher Zeit? Have you previously had any business connections in Sweden; if so, when?	14. J'ai été en Suède pour 15 jours, pour un voyage d'étude et Tourisme en Octobre 1938.
15. När anträdes resan? Quel est le jour du départ? Wann wird die Reise stattfinden? When do you intend to proceed to Sweden?	15. C'est probablement en Juin, mais le jour n'est pas encore été decidé.

den / le / den / day of 15 Mai 1939

Adress: Hôtel des Grands Hommes 17 Place du Panthéon

Egenhändig underskrift. Signature. Eigenhändige Unterschrift. Signature. Bruno Pontecorvo

UD. Skr. N:o Tgm. N:o

N:o .... Viserat för resa ....

till och ....

för vistelse i Sverige ....

från och med / 19 ....

till och med / 19 ....

Kungl. Svenska ....

.... den / 19

Avgift ....

(Fotografi)

Centraltr., Essette, Sthlm 37 744

Marianne returns France 7 Aug 39; visa until 2 Aug 40;

Wedding announcement for January 1940

HANS E GERDA NORDBLOM
ANNUNZIANO IL MATRIMONIO
DELLA LORO FIGLIA MARIANNE
COL SIGNOR

BRUNO PONTECORVO

MASSIMO PONTECORVO E MARIA
PONTECORVO MARONI ANNUNZIA-
NO IL MATRIMONIO DEL LORO
FIGLIO BRUNO CON LA SIGNORINA

MARIANNE NORDBLOM

(9)
10 GENNAIO 1940
PARIS
HOTEL DES GRANDS HOMMES
(PLACE DU PANTHÉON)

SANDVIKEN (SVEZIA)

PISA

RÉPUBLIQUE FRANÇAISE

SAUF-CONDUIT

valable pour un seul déplacement

10411

Aller et ~~retour~~ à Toulouse
(Biffer retour, s'il y a lieu.)

Nom et prénoms Pontecorvo née Nordblom

né le 5 juillet 1917 Hélène

à Sandviken

Nationalité Suédoise

Titulaire de la carte d'identité nº 0007 délivrée le CC 1569000

par le Préfet de Police

Le titulaire du présent titre est autorisé à se rendre à Toulouse

département Haute Garonne

But Nazi invasion

June 1940….

Sudden flight to USA via Toulouse Spain Portugal

17 Place du Panthéon

ns accompagnant le titulaire dans son déplacement

ut âgé de 21 mois

ré à PARIS, le 24 MAI 1940

Le Capitaine JOUFFRE, Commandant
la 1ère Section de Gendarmerie de PARIS

(Cachet.)

Sourcils :
Barbe :
Yeux :
Nez :
Menton :
Front :
Teint :
Signes particuliers :

PARIS, le 14 Juin 19 40

Le Capitaine JOUFFRE, Commandant
la 1ère Section de Gendarmerie de PARIS

GENDARMERIE NATIONALE
1re SECTION DE PARIS

Mod. 19. — Imp. Chaix (B) — 2481-39.

Marianne+Gil train to Toulouse

Bruno + Gillo… by bike On day of Nazi invasion !

1940-42: Oil prospecting in Oklahoma. **Neutron detector for minerals**

1942: Lack of radioactive sources; talks Fermi + Auger, Halban…

1943: Montreal..Chalk River. Anglo-Canadian
Heavy water Nuclear Reactor + Uranium prospecting

1945: Chalk River.
How to detect neutrino using cleaning fluid

BP: On a method for detecting neutrinos

Not the 1946 famous paper

This is the 1945 original

Classified secret until 1964 !!!

PD 141
Copy 5A

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Consists of 5 Page(s)
No. 5 of 15 Copies Series A.

Regraded by authority of the Declassification Office, A.E.R.E.
DATE AND SIGNATURE 6/3/64
UNCLASSIFIED

AUDITED 25 JAN 1963

ON A METHOD FOR DETECTING FREE NEUTRINOS

By

B. Pontecorvo

AUDITED
25 JAN 1962
S.R.O. HARWELL

AUDITED 18 OCT 1963

Issued May 21st, 1945.

AUDITED
10 FEB 1961
S.R.O. HARWELL

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adequate care is taken and necessary control experiments are performed.

Thanks are due to Dr. Pryce for very useful discussion and advice.

B. Pontecorvo.

There is no mention in the paper of solar neutrinos

BP thanks "Dr Pryce"

and adds a Note as postscript

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B. Pontecorvo.

Note: Dr. Pryce pointed out to the author that the flux of neutrinos from the sun is quite considerable. Actually, the flux of neutrinos received from the sun at the earth's surface may be estimated to be of the order of 10^{10} neutrinos/sec./cm.^{2}, providing Bethe's carbon cycle is assumed as the source of energy of the sun.

This value is too low for an experiment of the type suggested. If sources of neutrinos other than the sun should produce on the earth's surface a neutrino flux as high as 10^{16} neutrinos/sec./cm.^{2}, the neutrinos would induce a radioactivity very slight - but measurable by the chemical concentration method - in a number of substances.

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Chalk River: 1946- 48

Muon identified as heavy electron with flavour

Muon decays to three particles (indirect neutrino)…. J Steinberger

Universal weak interaction

Universal Weak Interaction.

Traditionally cited:
G Puppi Nuovo Cimento 5 587 1948
Tiomno J,Wheeler J.A Rev Mod Phys 21 144 , 1948
Lee T.D ,Rosenbluth M,Yang C.N. Phys Rev 75 905 1949

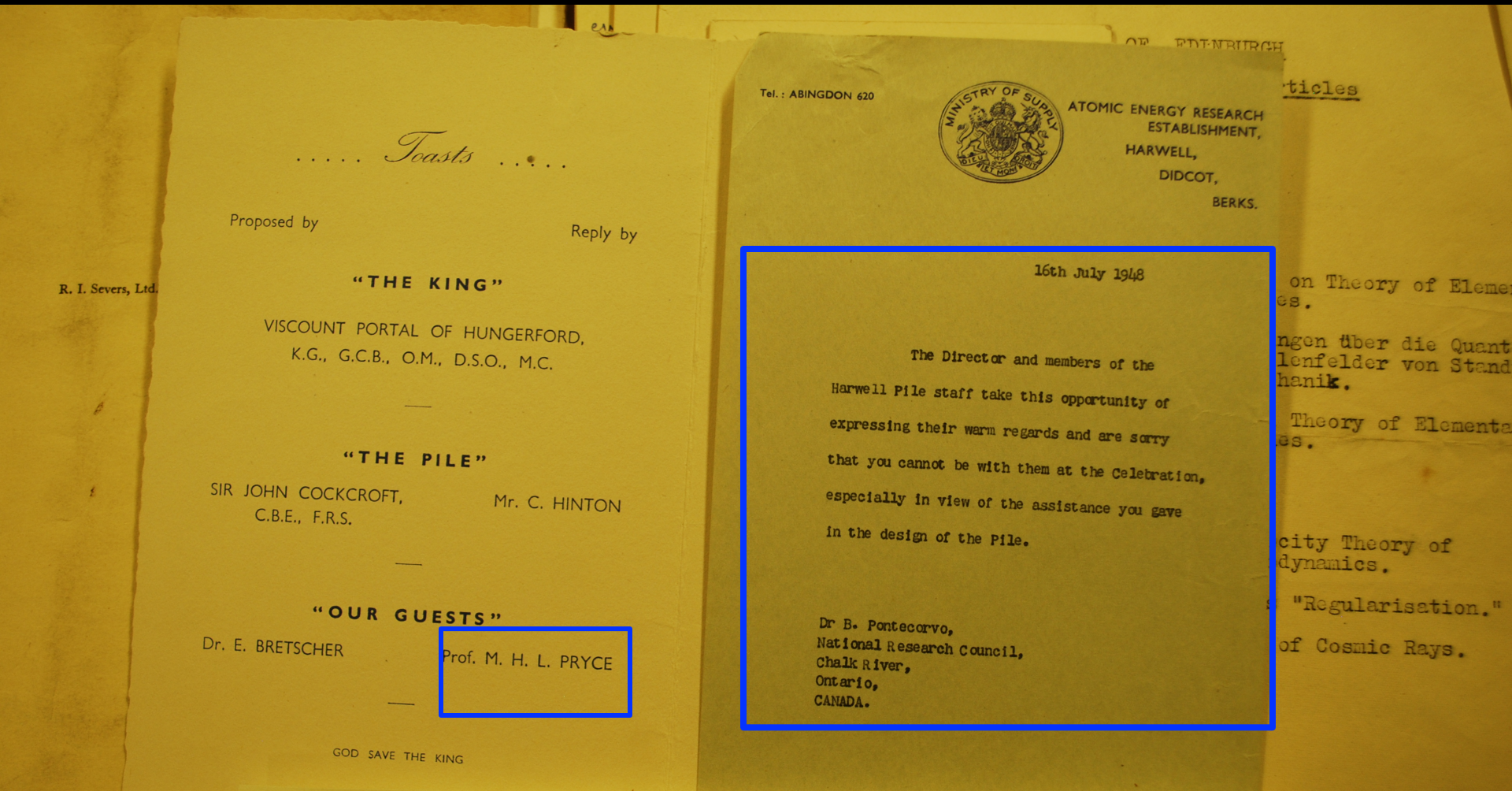
BP's first proposal of Universality not recognized.

See: J. Steinberger **.Personal debt to Bruno Pontecorvo**
Selected works of Bruno Pontecorvo pg 455

1946-48 Chalk River NRX design; consultant to Harwell

1949: moves to Harwell

Nuclear reactor design, beta decay and Cosmic Rays



. . . . . *Toasts* . . . . .

Proposed by — Reply by

"THE KING"

VISCOUNT PORTAL OF HUNGERFORD,
K.G., G.C.B., O.M., D.S.O., M.C.

—

"THE PILE"

SIR JOHN COCKCROFT, C.B.E., F.R.S. — Mr. C. HINTON

—

"OUR GUESTS"

Dr. E. BRETSCHER — Prof. M. H. L. PRYCE

—

GOD SAVE THE KING

R. I. Severs, Ltd.

Tel.: ABINGDON 620

MINISTRY OF SUPPLY

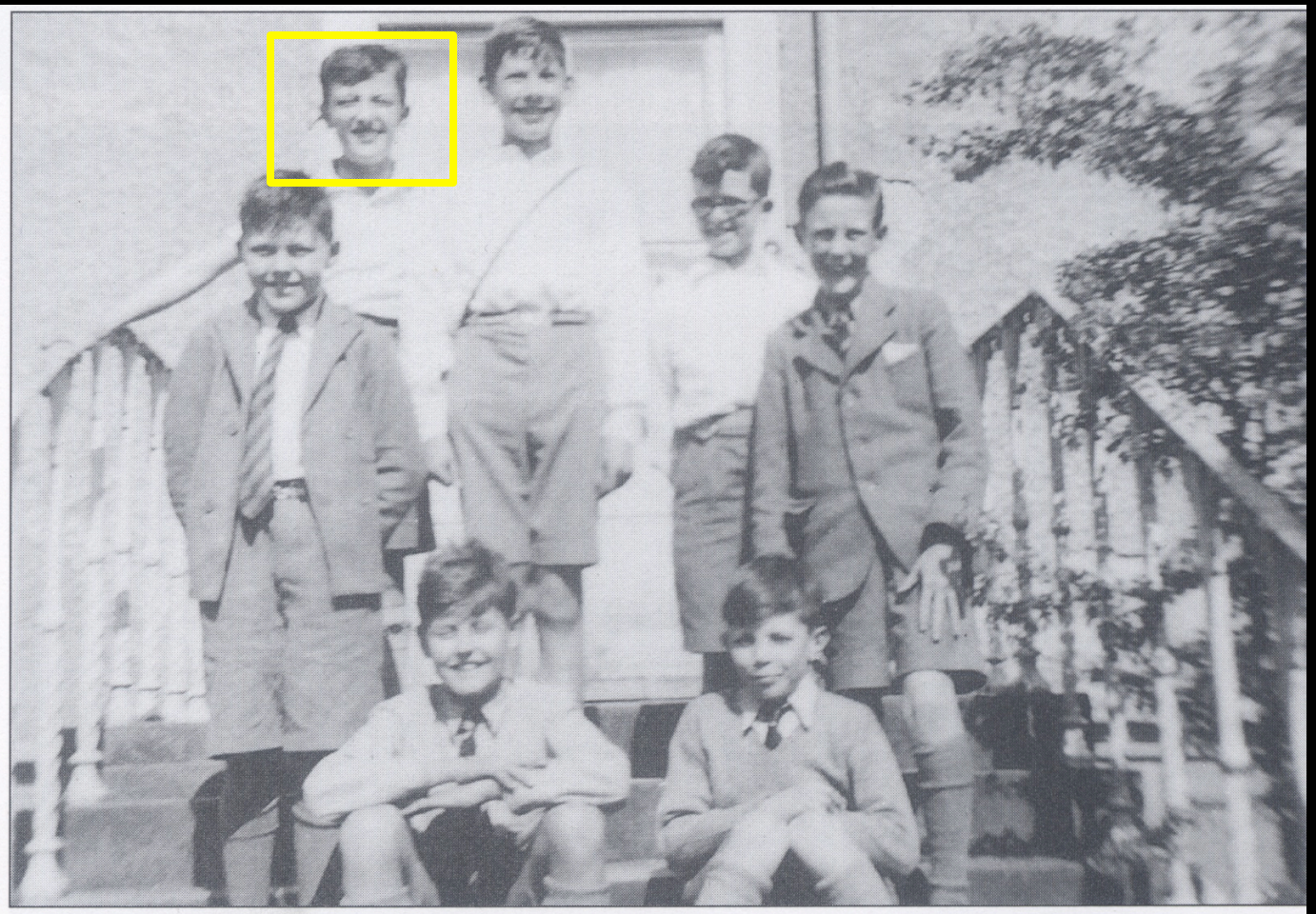
ATOMIC ENERGY RESEARCH ESTABLISHMENT,
HARWELL,
DIDCOT,
BERKS.

16th July 1948

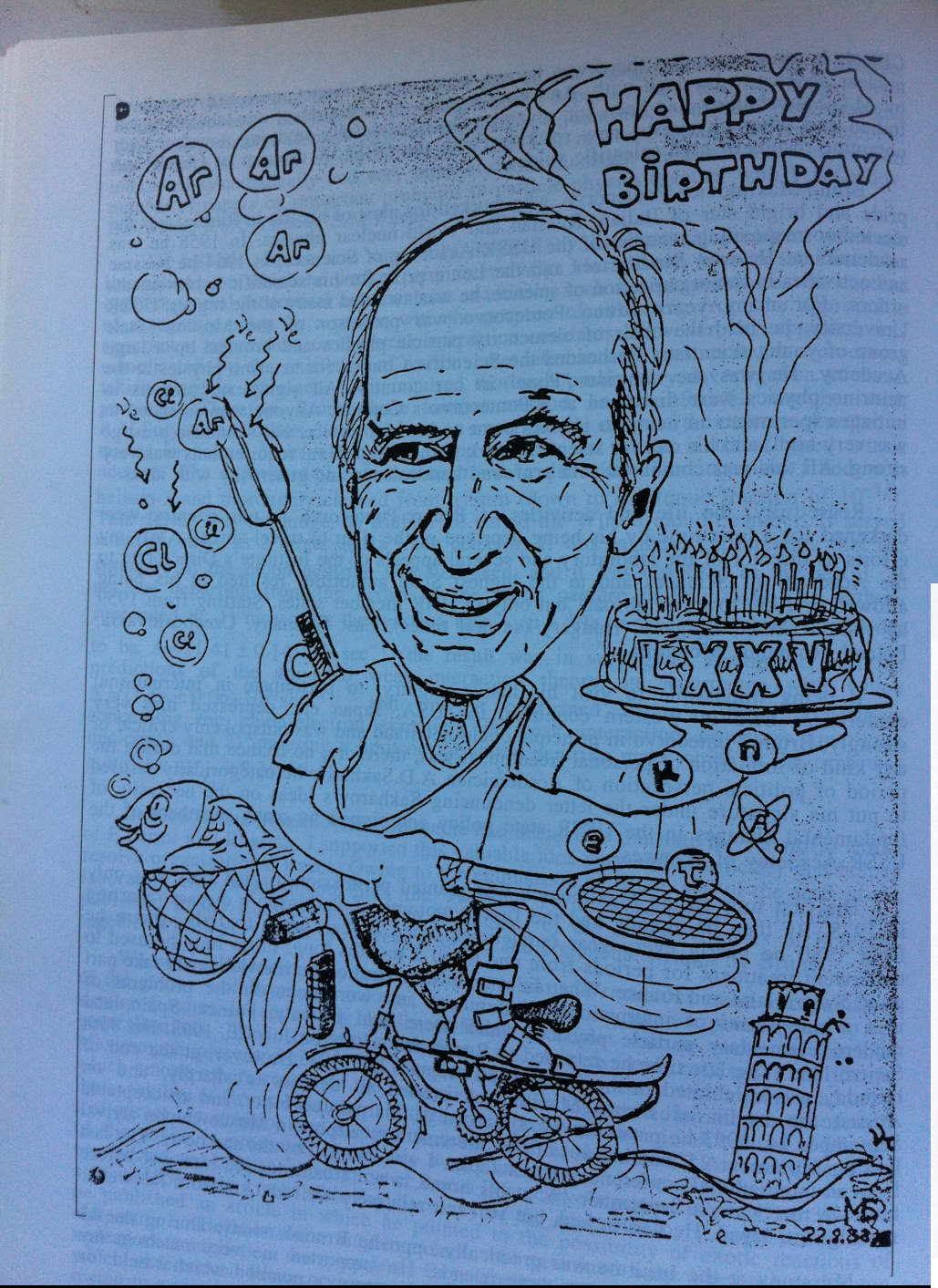
The Director and members of the Harwell Pile staff take this opportunity of expressing their warm regards and are sorry that you cannot be with them at the Celebration, especially in view of the assistance you gave in the design of the Pile.

Dr B. Pontecorvo,
National Research Council,
Chalk River,
Ontario,
CANADA.

Harwell/Abingdon 1949. Not Gil Pontecorvo



Fitzharris Manor, 1949. Seven eleven-year olds photographed on the steps of the house shortly before its demolition. Sitting, left to right: Tony Gardner, Brian Winkett. Standing Barry Gardner, Gil Pontecorvo, Nigel Hammond, Jonathan Fry, Brian Jenkins.



Tony Gardner

Fitzharris Manor, 1949. Seven eleven-year olds photographed on the steps of the house sh
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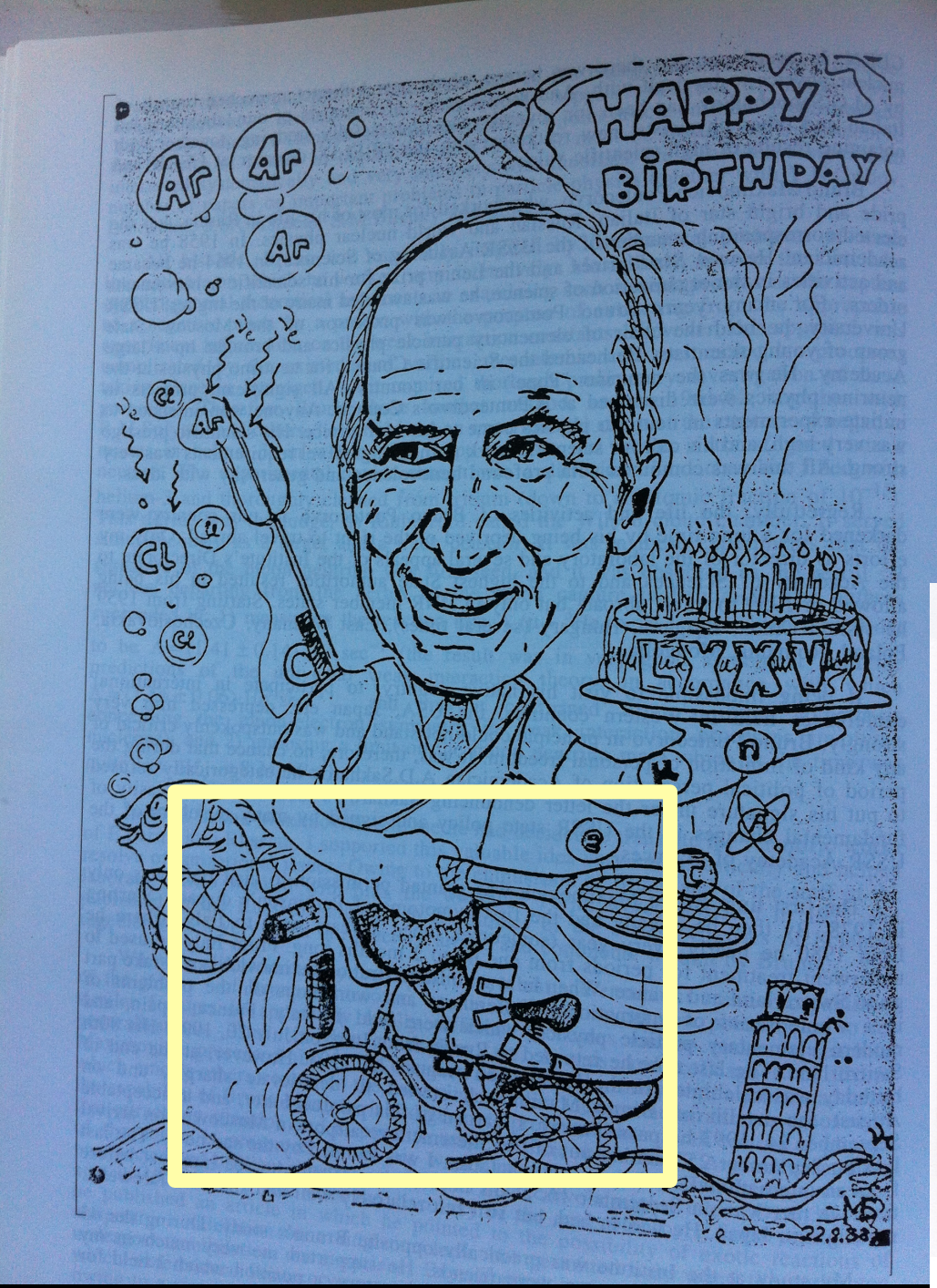
Gardner, Gil Pontecorvo, Nigel Hammond, Jonathan Fry, Brian Jenkins.



Tony Gardner 2013:

"I remember Bruno riding his bicycle up the street … backwards"

Fitzharris Manor, 1949. Seven eleven-year olds photographed on the steps of the house sh
before its demolition. Sitting, left to right: Tony Gardner, Brian Winkett. Standing
Gardner, Gil Pontecorvo, Nigel Hammond, Jonathan Fry, Brian Jenkins.

1950-55 Bruno Pontecorvo work classified (again!)

Discovery of Associated Production and Strangeness

IX. ОТЧЕТЫ О НАУЧНО-ИССЛЕДОВАТЕЛЬСКИХ РАБОТАХ

ЛАБОРАТОРИИ, ОПУБЛИКОВАННЫЕ В 1953 ГОДУ.

№ п/п	Наименование отчета	Авторы	Инв.	Примечание.
1	2	3	4	5
	II. ВЗАИМОДЕЙСТВИЕ МЕЗОНОВ С ЯДРАМИ.			
1.	Некоторые замечания феноменологического характера о процессах образования тяжелых мезонов и V-частиц.	Б.Понтекорво	850	

From Dubna Report 1953

1) Б.Понтекорво, Г.Селиванов, В.Жуков. Тезисы к докладу: "Образование π^0-мезонов n-n и p-p столкновениях".

2) Б.Понтекорво, Г.Селиванов. Отчет [redacted] АН С[redacted] 1952, инв 638, 684.

3) Сборник отчетов [redacted], 1952, инв 760, стр. 74-8[redacted] 81-85, 86-92, 273-280.

Тема 19: Исследование взаимодействия быстрых заряженных π-частиц с протонами и дейтронами с помощью сцинтилляционных счетчиков.

Руководитель: Понтекорво Б.М.

В 1953 году работа по этой теме развивалась по двум направлениям: 1) изучение условий вывода пучков мезонов различной энергии в "мезонную лабораторию"; 2) проектирование опытов и подготовка аппаратуры для измерения: а) полных сечений взаимодействия π-мезонов различных энергий с водородом и дейтерием; б) углового распределения π-мезонов, рассеянных на водороде с и без обмена заряда; в) сечения процесса $(\pi^-, 2\pi^0)$ на сложных ядрах.

Dubna Internal Report 1953….Translated by Gil Pontecorvo

2. О процессах образования тяжелых мезонов и V -частиц.

Исполнитель: Понтекорво Б.М.

Написан отчет[1], в котором излагаются некоторые замечания феноменологического характера о процессах образования тяжелых мезонов и V -частиц. Основные идеи этой работы обсуждались на семинаре в нашей лаборатории в 1951г. Хотя представленные рассмотрения имеют характер поисков, они могут помочь сформулировать рабочие гипотезы при интерпретации экспериментальных данных и при обсуждении возможности постановки экспериментов по образованию новых частиц.

Выводы работы следующие:

1) Тот факт, что в соударениях при высокой энергии с большой вероятностью образуются мезоны (мезоны класса τ), распадающиеся с продолжительным временем жизни на π -мезоны, указывает на то, что рождение этих мезонов не может происходить по схеме:

$(N) \rightarrow (N) + (\tau)$ ($N \equiv$ нуклон)

From Report prepared in 1953

.....

.....

2. On the production of heavy mesons and V-particles.

Executor: Pontecorvo B.M.

A report has been written [B. Pontecorvo, Report numb. ..., 1953], in which certain comments of phenomenological character concerning the production of heavy mesons and V-particles are presented. The main ideas of this work have been discussed at the seminar of our laboratory in 1951. Although the issues presented are of a search nature, they may help in formulating operative hypotheses for interpretation of experimental data and the discussion of future experiments relevant to the production of new particles.

The conclusions are the following:

1. The fact that high energy collisions with a high probability result in the production of mesons (mesons of the τ class), decaying with a long lifetime into π-mesons indicates that the production of such mesons cannot proceed according to the following scheme:

$(N) \rightarrow (N) + (\tau)$ ($N \equiv$ nucleon).

3) Предполагается, что мезоны класса τ и частицы класса V появляются вместе согласно схеме:

$$(N) \rightarrow (V) + (\tau) \qquad (1)$$

Таким образом одновременно решаются трудности, связанные с продолжительным временем жизни частиц класса V и мезонов класса τ. Кроме того, эта схема подразумевает сильное взаимодействие между нуклонами и V-частицами.

4) Если схема (1) верна, то следует ожидать, что в благоприятных условиях должны осуществляться квази-стабильные системы из нуклонов и V-частиц.

Некоторые экспериментальные указания о справедливости этих выводов появились в литературе[2].

3. The assumption is made that mesons of the τ class and particles of the V class appear together according to the scheme:

$$(N) \rightarrow (V) + (\tau) \qquad (1)$$

Thus, difficulties related to the long lifetime of particles of the V class and of mesons of the τ class are resolved simultaneously. Moreover, this scheme implies strong interaction between nucleons and V-particles.

4. If the scheme (1) holds true, then quasi-stable systems of nucleons and V-particles can be expected to be realized in favourable conditions.

3) Предполагается, что мезоны класса τ и частицы класса V появляются вместе согласно схеме:

$$(N) \rightarrow (V) + (\tau) \qquad (I)$$

Таким образом одновременно решаются трудности, связанные с продолжительным временем жизни частиц класса V и мезонов класса τ. Кроме того, эта схема подразумевает сильное взаимодействие между нуклонами и V-частицами.

4) Если схема (I) верна, то следует ожидать, что в благоприятных условиях должны осуществляться квази-стабильные системы из нуклонов и V-частиц.

Некоторые экспериментальные указания о справедливости этих выводов появились в литературе[2].

3. The assumption is made that mesons of the τ class and particles of the V class appear together according to the scheme:

Associated: Lambda + K

$$(N) \rightarrow (V) + (\tau) \qquad (1)$$

Thus, difficulties related to the long lifetime of particles of the V class and of mesons of the τ class are resolved simultaneously. Moreover, this scheme implies strong interaction between nucleons and V-particles.

4. If the scheme (1) holds true, then quasi-stable systems of nucleons and V-particles can be expected to be realized in favourable conditions.

Hypernuclei

Очевидно, что сечение реакции

$$N + N \rightarrow N + V$$

должно быть крайне малым при справедливости схемы (1).

Evidently, the cross section of reaction

$$N + N \rightarrow N + V$$

should be extremely small, if the scheme (1) is valid.

$$N + N \rightarrow V + V \qquad (3)$$

$$N + N \rightarrow V + V \qquad (3)$$

если мезон имеет массу только $550 m_e$[3]. Реакция (3), при справедливости наших предположений, должна происходить путем промежуточных виртуальных переходов, представляющих собою испускание первой V-частицы с мезоном класса τ, а затем поглощение этого мезона с испусканием второй V-частицы. Порог реакции (3) равен 770 Мэв (масса V^0-частицы предполагается равной

JETP, **21** (1951) 1062]. In the case of our assumptions being valid reaction (3) should proceed via intermediate virtual transitions representing emission of the first V-particle together with a meson of the τ class, then absorption of this meson involving emission of the second V-particle. The threshold of reaction (3) is 770 MeV

Очевидно, что сечение реакции

$$N + N \to N + V$$

должно быть крайне малым при справедливости схемы (1).

Evidently, the cross section of reaction

$$N + N \to N + V$$

should be extremely small, if the scheme (1) is valid.

Yes. Dubna confirms this

No. Strangeness is additive

$$N + N \to V + V \qquad (3)$$

если мезон имеет массу только $550 m_e$[3]. Реакция (3), при справедливости наших предположений, должна происходить путем промежуточных виртуальных переходов, представляющих собою испускание первой V-частицы с мезоном класса τ, а затем поглощение этого мезона с испусканием второй V-частицы. Порог реакции (3) равен 770 Мэв (масса V^0-частицы предполагается равной

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Oscillations + Neutrino Astrophysics…..
Modern legacy: Worth entire conference…….

Figure 3: Dubna 1988. Neutrino oscillations.

Pontecorvo: Cartoon from Bilenky “Mister Neutrino”

Pontecorvo:Ideas for experiments giving rise to Nobel prizes

Two types of neutrinos; accelerator expt to prove it

L.Lederman,J.Steinberger, M.Schwarz Nobel 1988

.

Not known in west
Couldn't do in ussr
did BP expect positive?

Inverse beta decay at reactors

F. Reines Nobel 1995

Reactors = antineutrinos
Chlorine fails
Forbidden access reactor in ussr

radiochemical methods for neutrino detection
Chlorine experiment , R. Davis Nobel 2002

Oscillations

Koshiba Nobel 2002

BP died 24.9.93
Otherwise would surely have shared Nobel 2002

Pontecorvo: What would have been different if he had stayed in Oxford?

Two types of neutrinos; accelerator expt to prove it

L.Lederman,J.Steinberger, M.Schwarz Nobel 1988

.

CERN (but would he have had the idea?)

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Harwell not intense enough (?)
And Cl to A don't work

Associated production and strange particles

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Associated production and strange particles

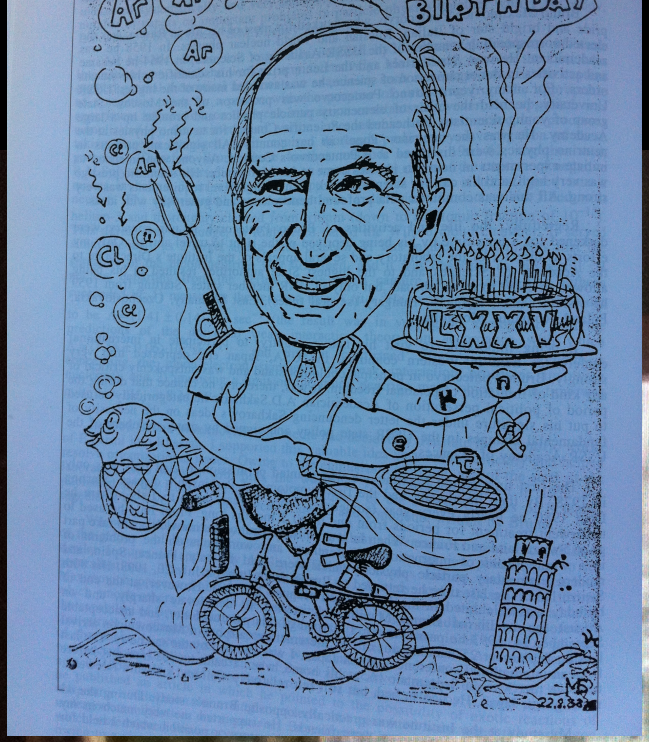
Parity violation
Dalitz and Theta-Tau puzzle
BP "Do an experiment"….?

Pontecorvo: What would have been different if he had stayed in Oxford?

“There is no subjunctive tense in history”

Gil Pontecorvo

…. in a multiverse somewhere…….



A Life of Two Halves

$\nu_\mu \neq \nu_e$

BRUNO PONTECORVO

PISA 22.8.1913

DUBNA 24.9.1993

FISICO

HARWELL to DUBNA: 01 . 9.1950

Experiment and theory

Loved physics; Hated fascism