The Birth of the Nobel Prize in Japan
Hideki Yukawa and Osaka University

Yutaka Hosotani
Osaka University

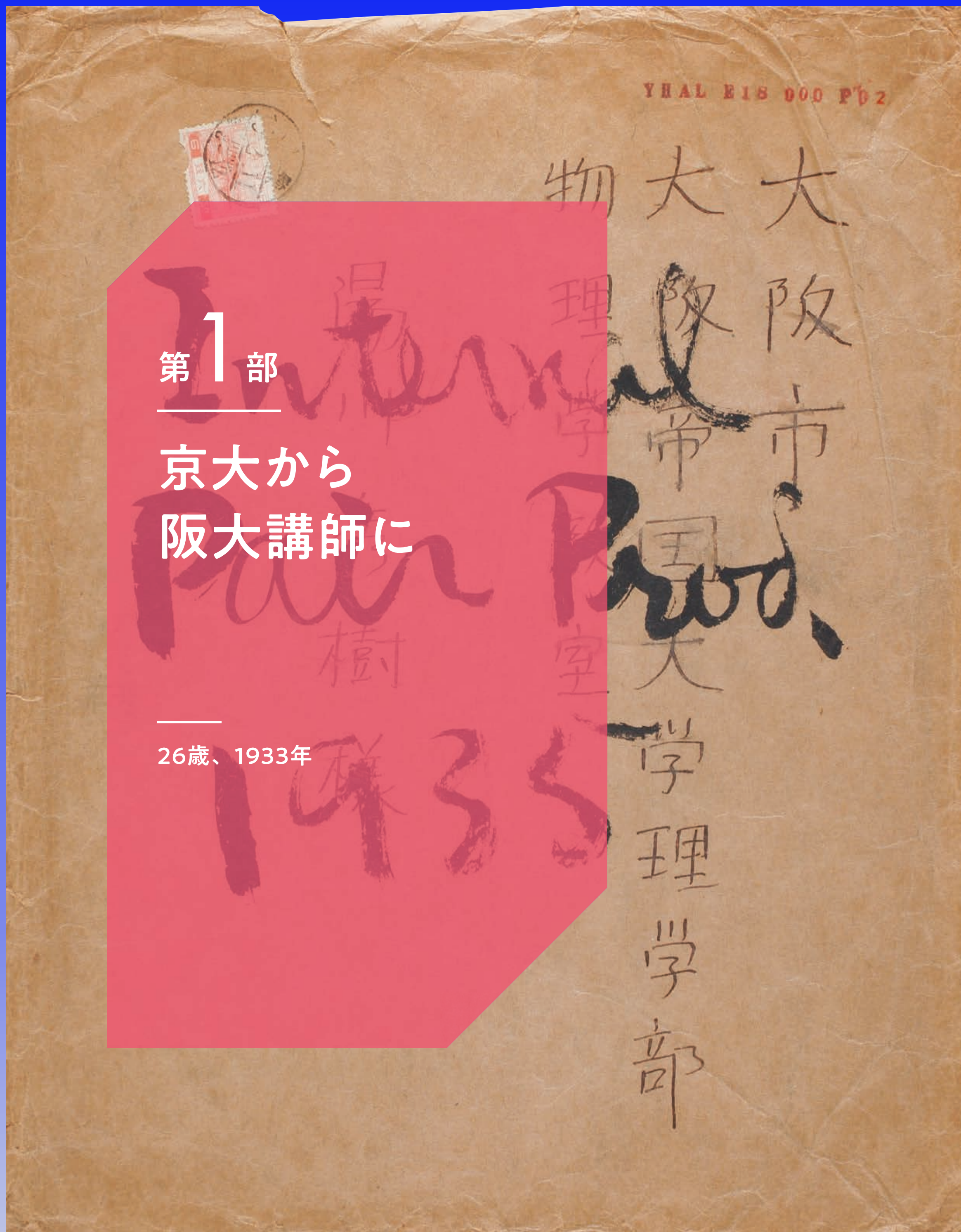
HPNP2021

Osaka University, 25 March 2021

Hideki Yukawa

1907.1.23		Born
1929.3	(age 22)	Graduated from Kyoto Imperial Unive
1932	(age 25)	Lecturer, Kyoto Imperial University
1933.5.13	(age 26)	Lecturer, Osaka Imperial University
1934.11	(age 27)	His first paper submitted (→ Nobel Prize)
1936.3.31	(age 29)	Associate Professor, Osaka Imperial University
1938.4.5	(age 31)	Ph.D., Osaka Imperial University
1939.5	(age 32)	Professor, Kyoto Imperial University
1949	(age 42)	Visiting Professor, Columbia University
1949.12	(age 42)	Nobel Prize
1981.9.8	(age 74)	Passed away

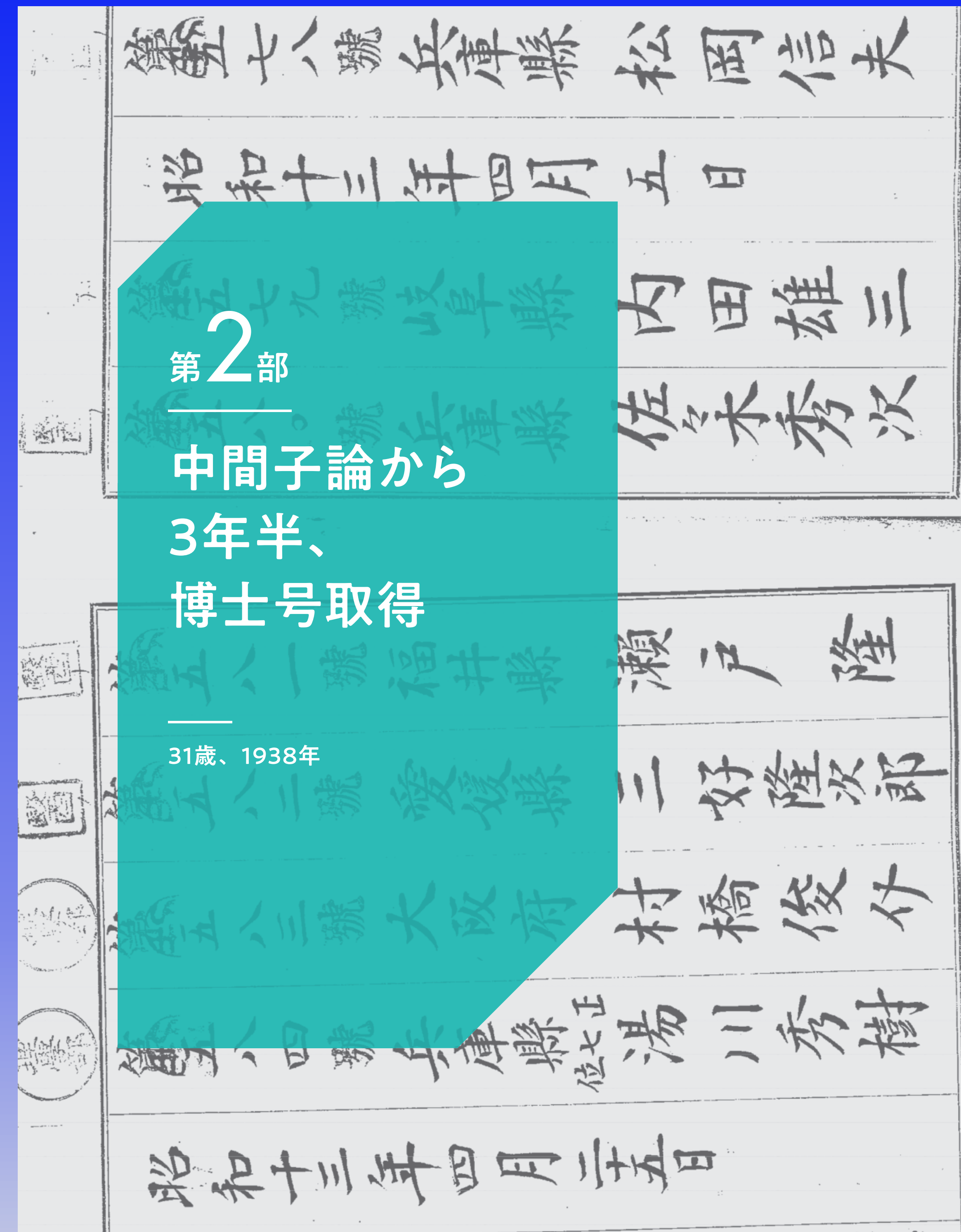
Physics OSAKA UNIVERSITY



第1部

京大から
阪大講師に

26歳、1933年



第2部

中間子論から
3年半、
博士号取得

31歳、1938年

Historical Documents

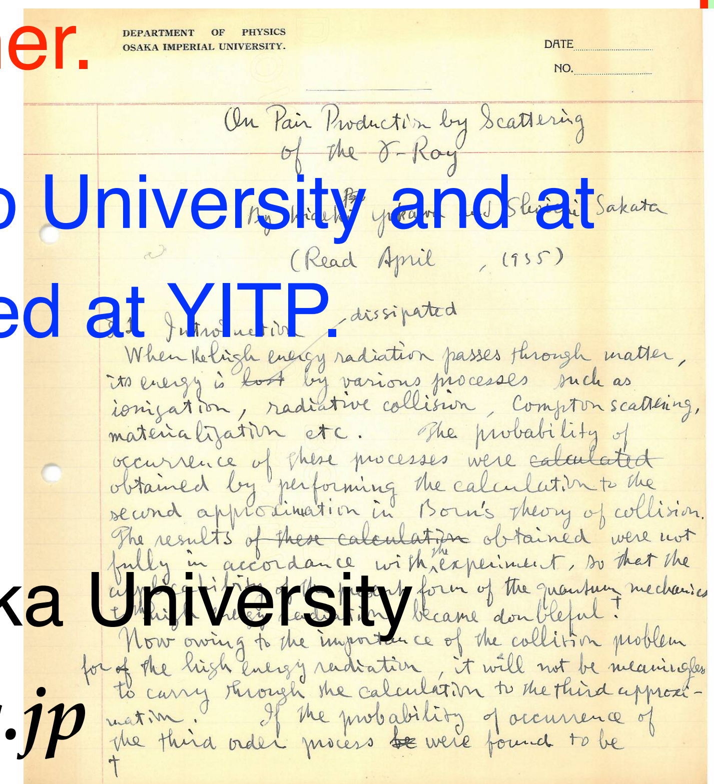
★ Yukawa kept all notes, paper drafts, lecture drafts, letters, …. in order, in a neat, original, artistic manner.

These documents were discovered at Kyoto University and at his house in the 80's and have been archived at YITP.

Documents in the Osaka Imperial Univ period:

See the homepage of Yukawa Memorial, Osaka University

https://www-yukawa.phys.sci.osaka-u.ac.jp



★ Yukawa's Doctor Thesis (Ph.D.) (1938)

application documents, judging process, report …

Preserved in a storage room, found in 2020.

— Osaka University Archives

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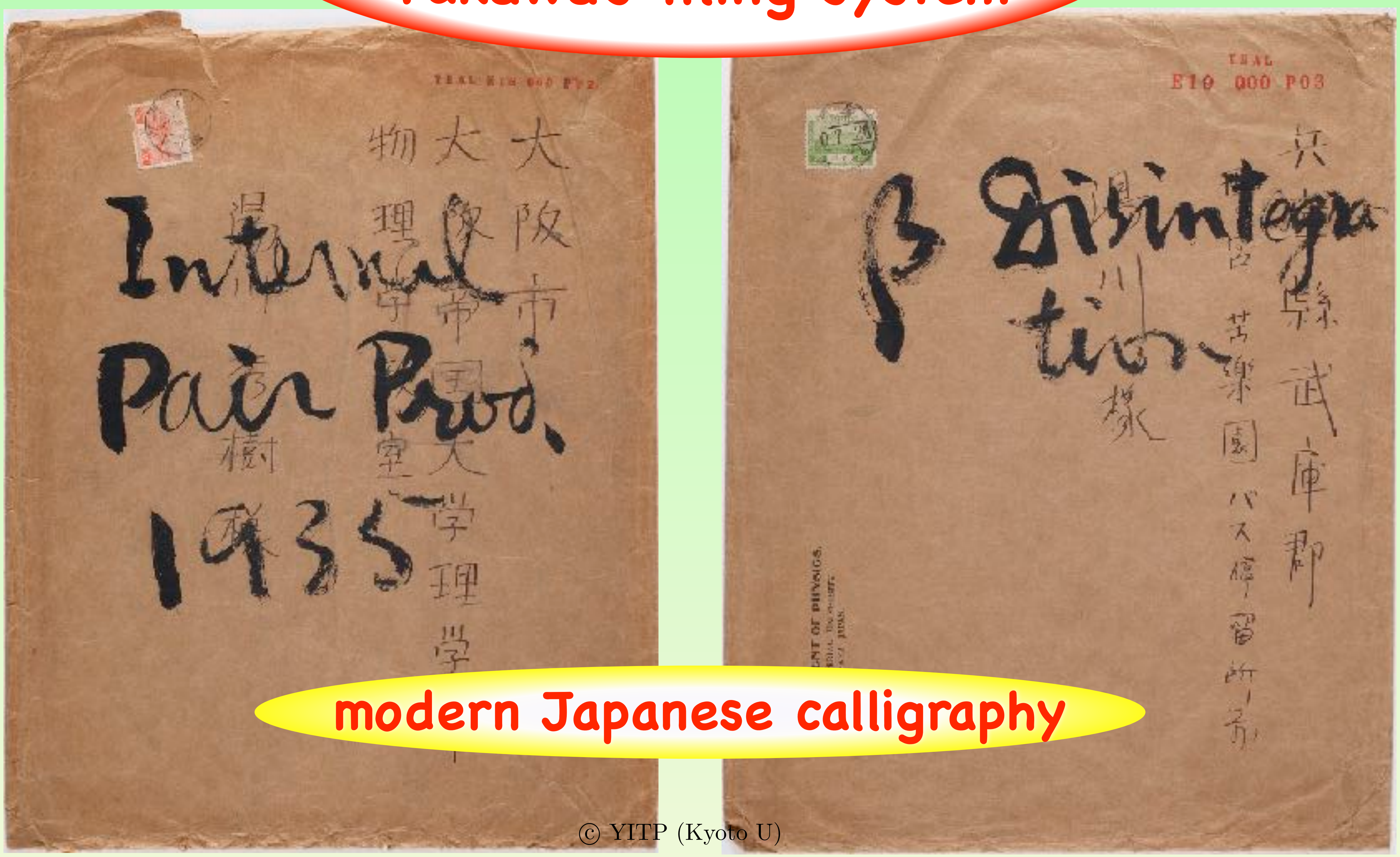
Aesthetics

Yukawa's filing system



modern Japanese calligraphy

Envelopes tell us about life in the 30's.

Physics
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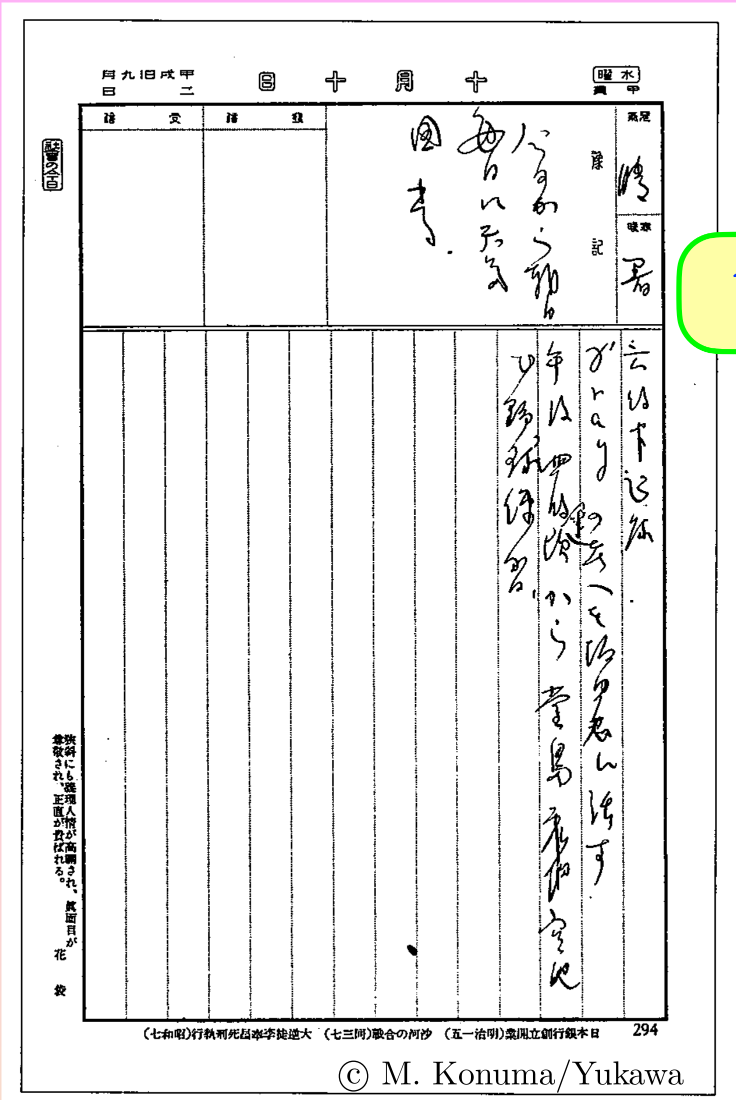
γ′ ray



© M. Konuma/Yukawa

Yukawa's diary

10 October 1934 Fair, Hot

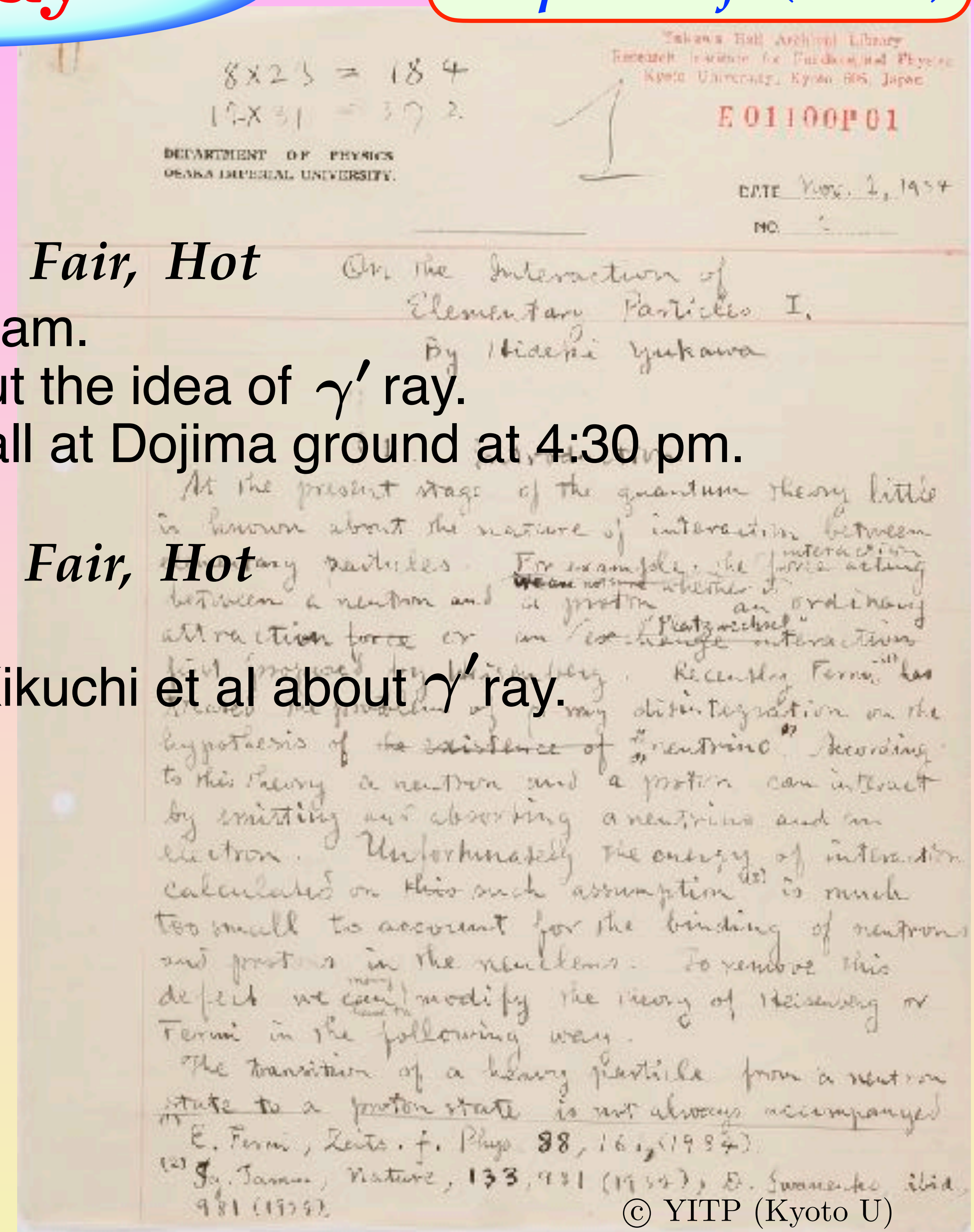
Woke up at 6:30 am.
Told Sakata about the idea of γ' ray.
Practiced baseball at Dojima ground at 4:30 pm.

11 October 1934 Fair, Hot

• • •

Discussed with Kikuchi et al about γ' ray.

Paper draft (Nov 1)



8×23 = 184
12×31 = 372

DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.

DATE Nov. 1, 1934
NO. 1

On the Interaction of Elementary Particles I.
By Hideki Yukawa

At the present stage of the quantum theory little is known about the nature of interaction between elementary particles. For example, the interaction force acting between a neutron and a proton ... an ordinary attraction force or an "exchange interaction" ("Platzwechsel") ... Recently Fermi[1] has treated the problem of β-ray disintegration on the hypothesis of "neutrino". According to this theory a neutron and a proton can interact by emitting and absorbing a neutrino and an electron. Unfortunately the energy of interaction calculated on such assumption[2] is much too small to account for the binding of neutrons and protons in the nucleus. To remove this defect we may modify the theory of Heisenberg or Fermi in the following way.

The transition of a heavy particle from a neutron state to a proton state is not always accompanied

(1) E. Fermi, Zeits. f. Phys. 88, 161, (1934)
(2) Ig. Tamm, Nature, 133, 981 (1934), D. Iwanenko, ibid. 981 (1934).

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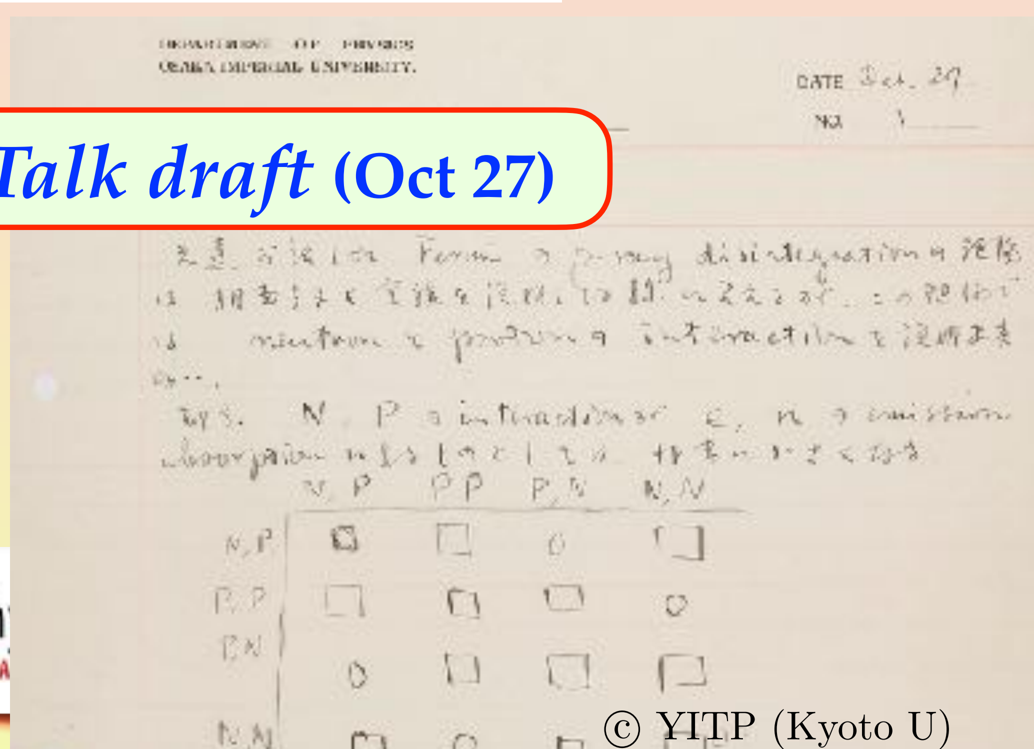
Talk draft (Oct 27)



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OSAKA IMPERIAL UNIVERSITY.

DATE Oct. 27
NO. 1

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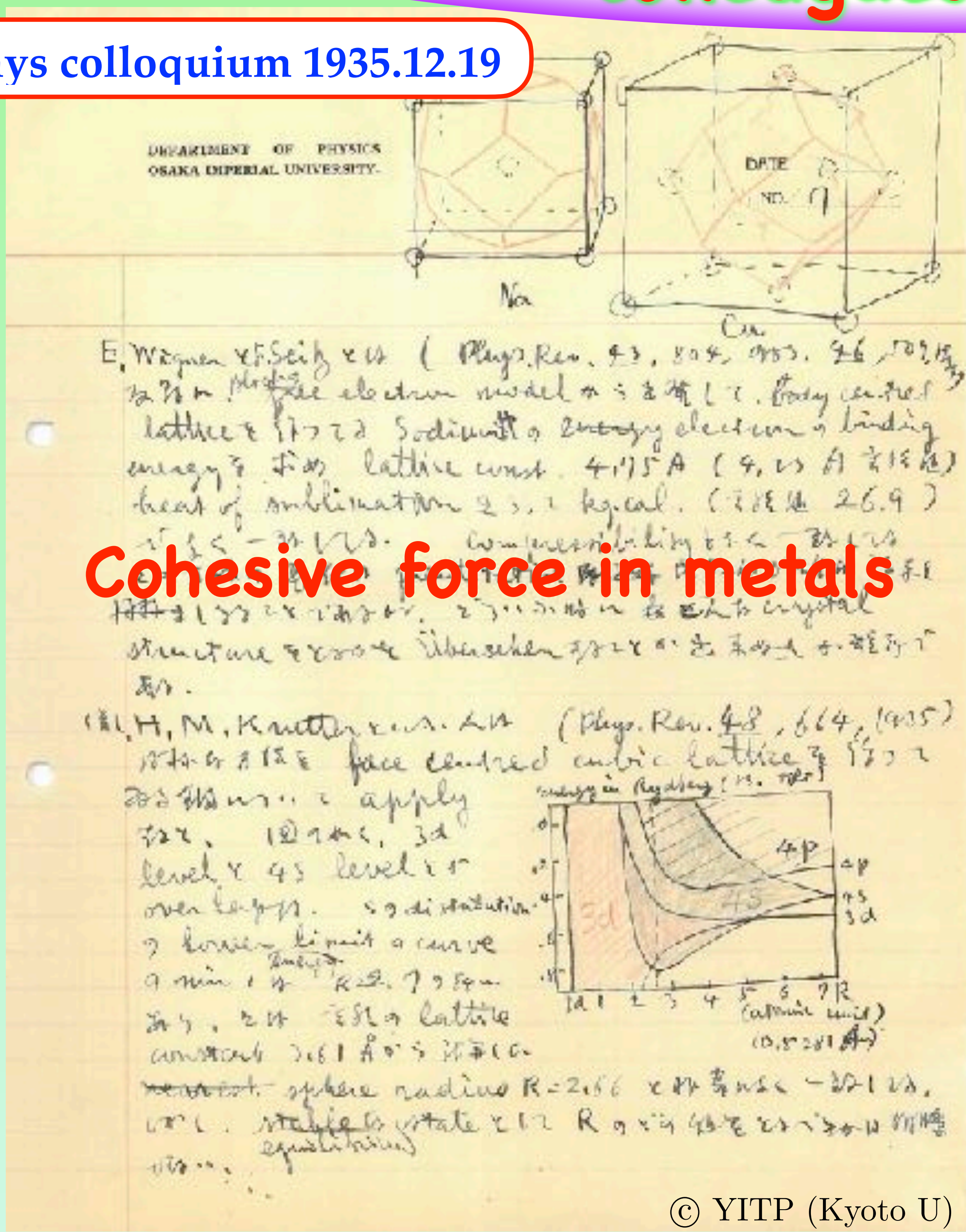
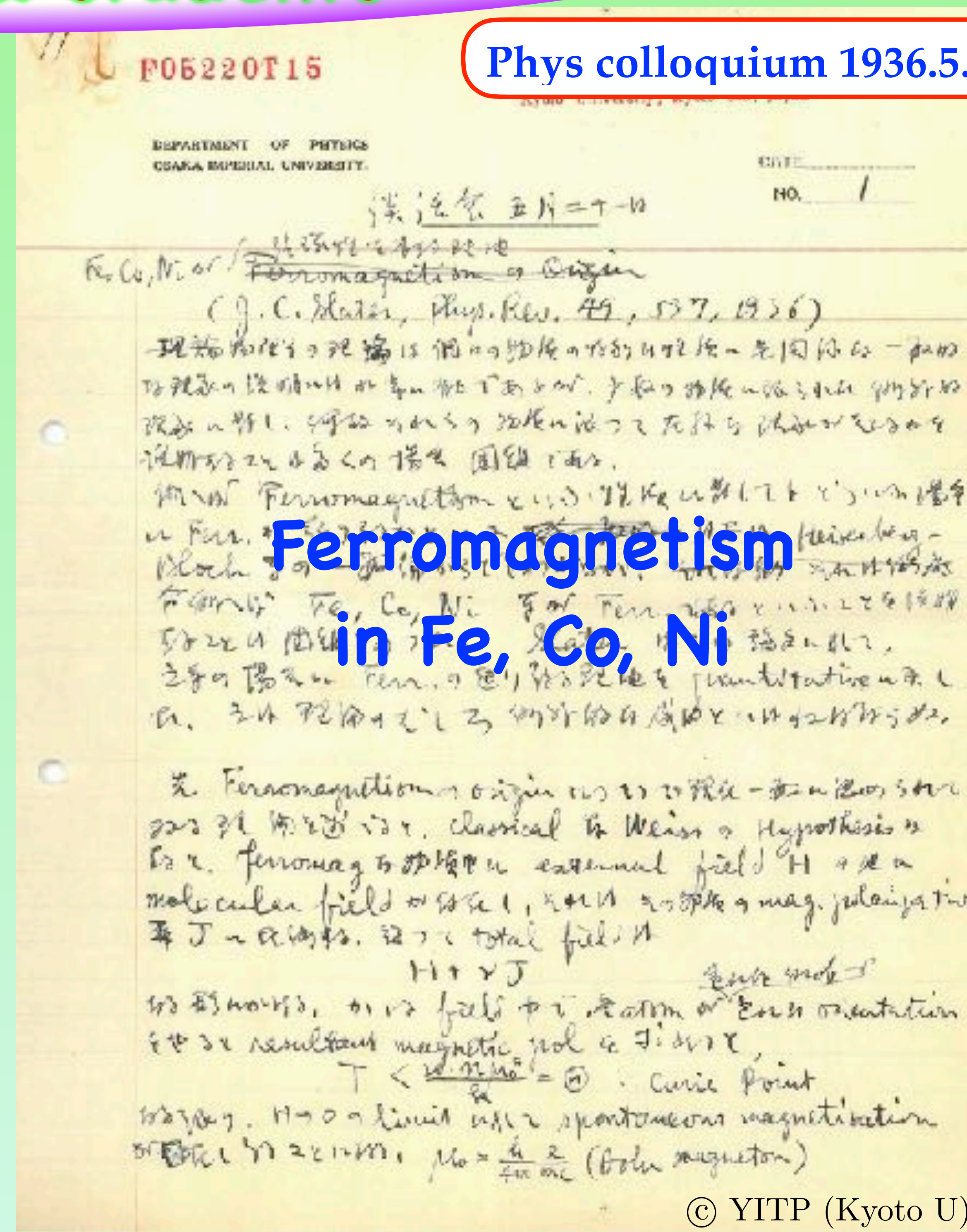
Explain to, educate, and stimulate colleagues & students

Phys colloquium 1935.12.19



Cohesive force in metals

Phys colloquium 1936.5.21



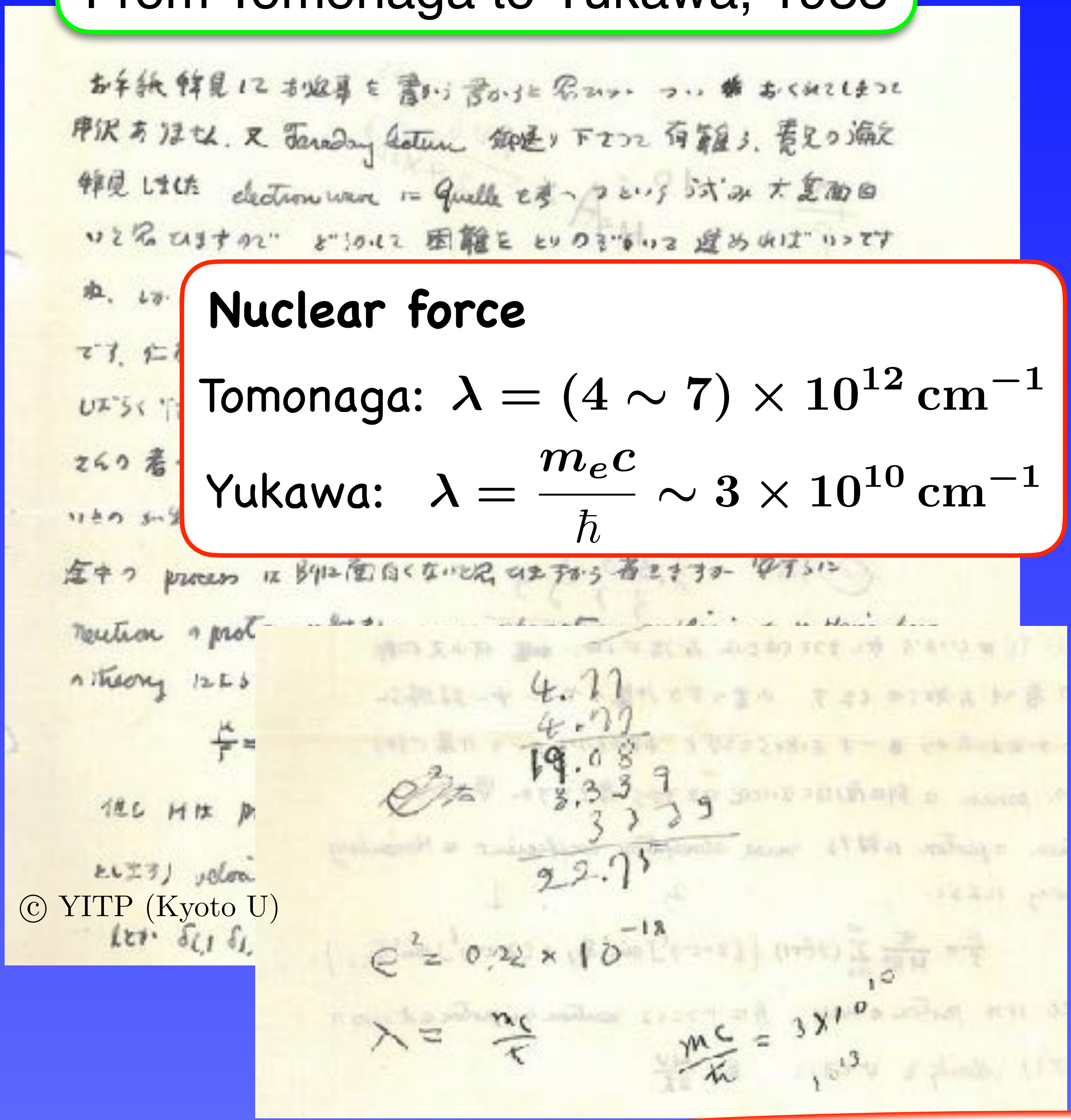
Ferromagnetism in Fe, Co, Ni

A sense of mission with courage and heart.

Physics OSAKA UNIVERSITY

The best friend/rival

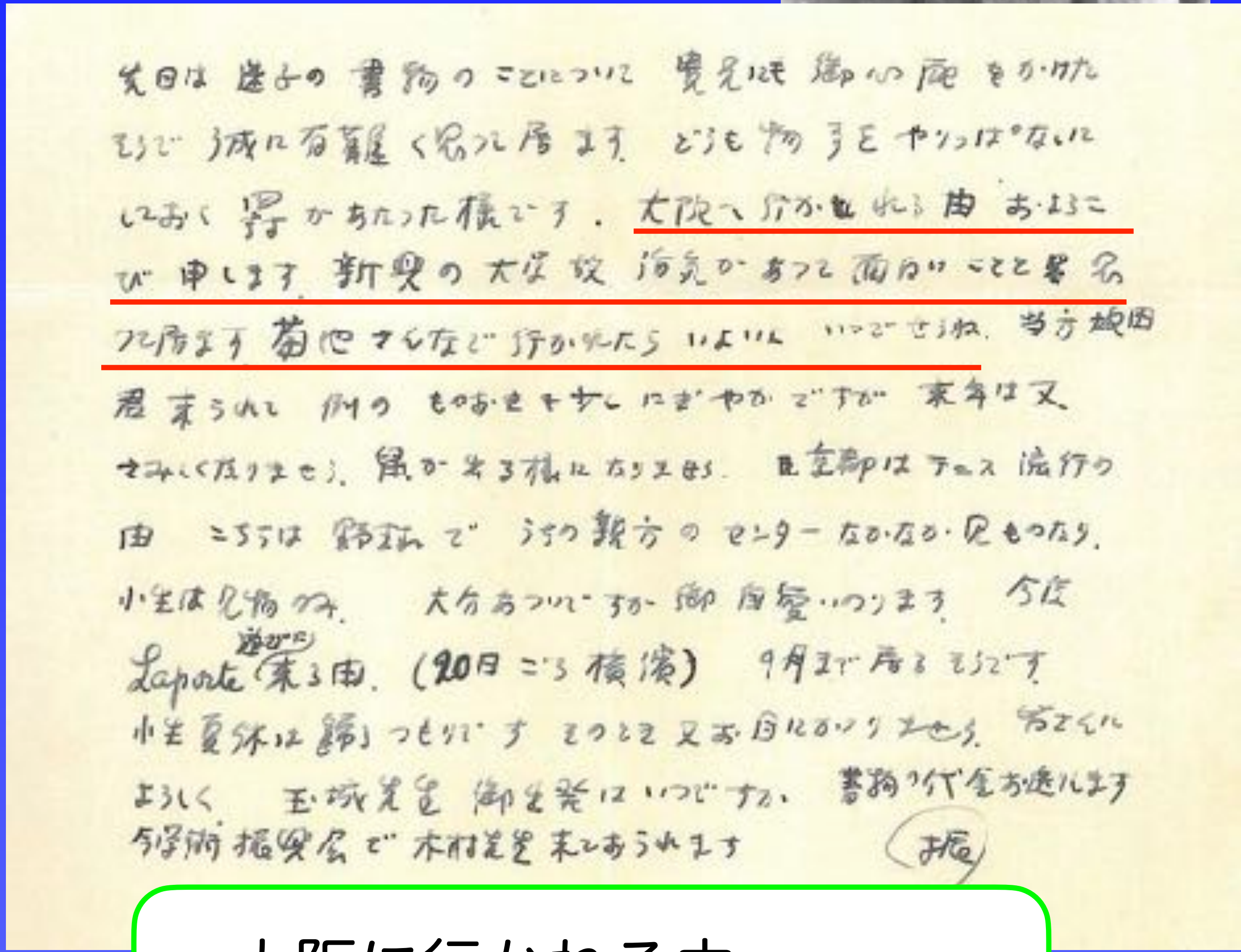
From Tomonaga to Yukawa, 1933



Nuclear force

Tomonaga: $\lambda = (4 \sim 7) \times 10^{12}\,\mathrm{cm}^{-1}$

Yukawa: $\lambda = \dfrac{m_e c}{\hbar} \sim 3 \times 10^{10}\,\mathrm{cm}^{-1}$



大阪に行かれる由・・・
・・・いよいよいいでせうね

RIKEN and Osaka : frontier centers in Japan

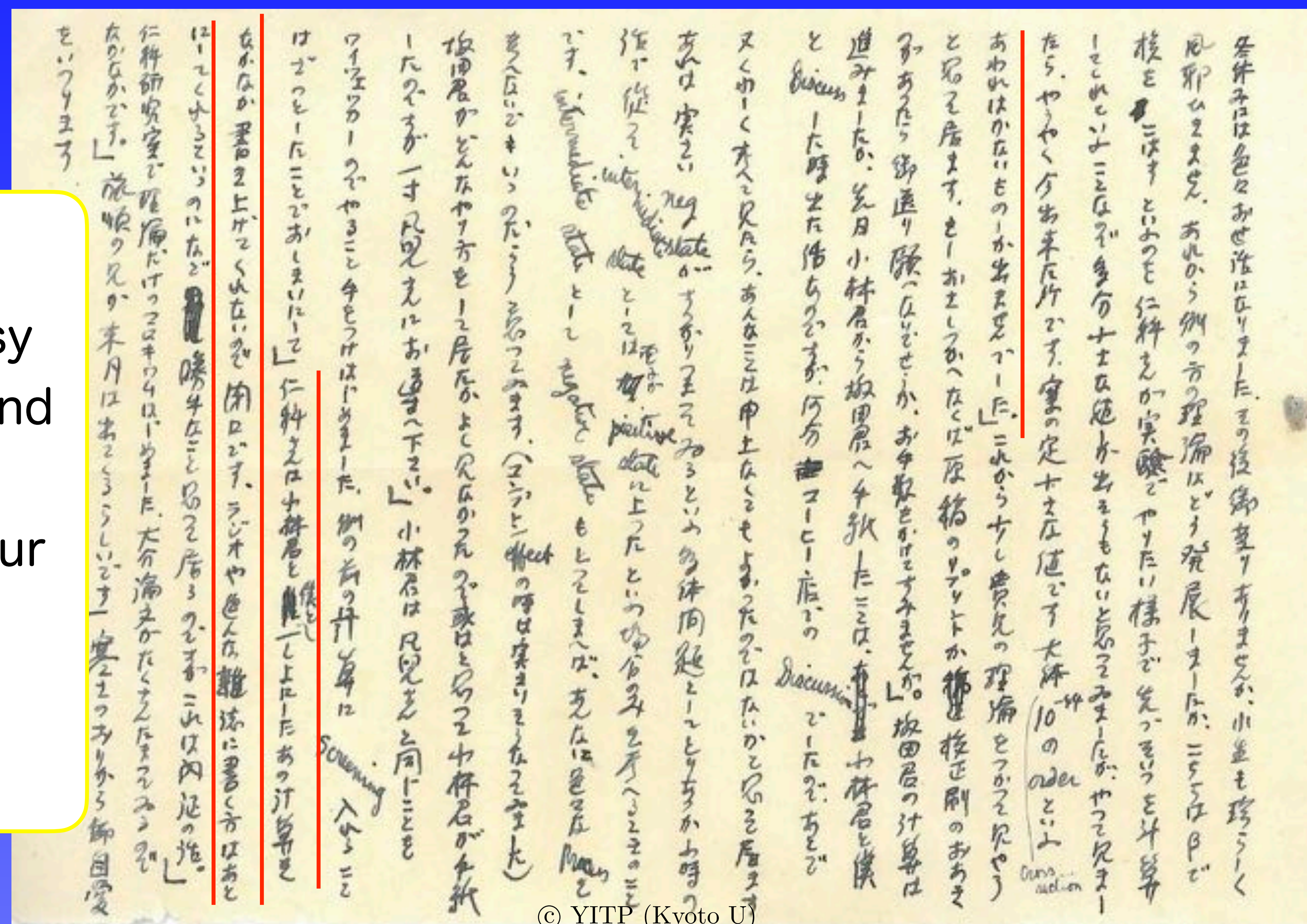
Physics
OSAKA UNIVERSITY

From Tomonaga to Yukawa, 1935.1.23

Nishina's exp. plan : smash a nucleus with electrons

-> Tomonaga's estimate:

Miserably small number !



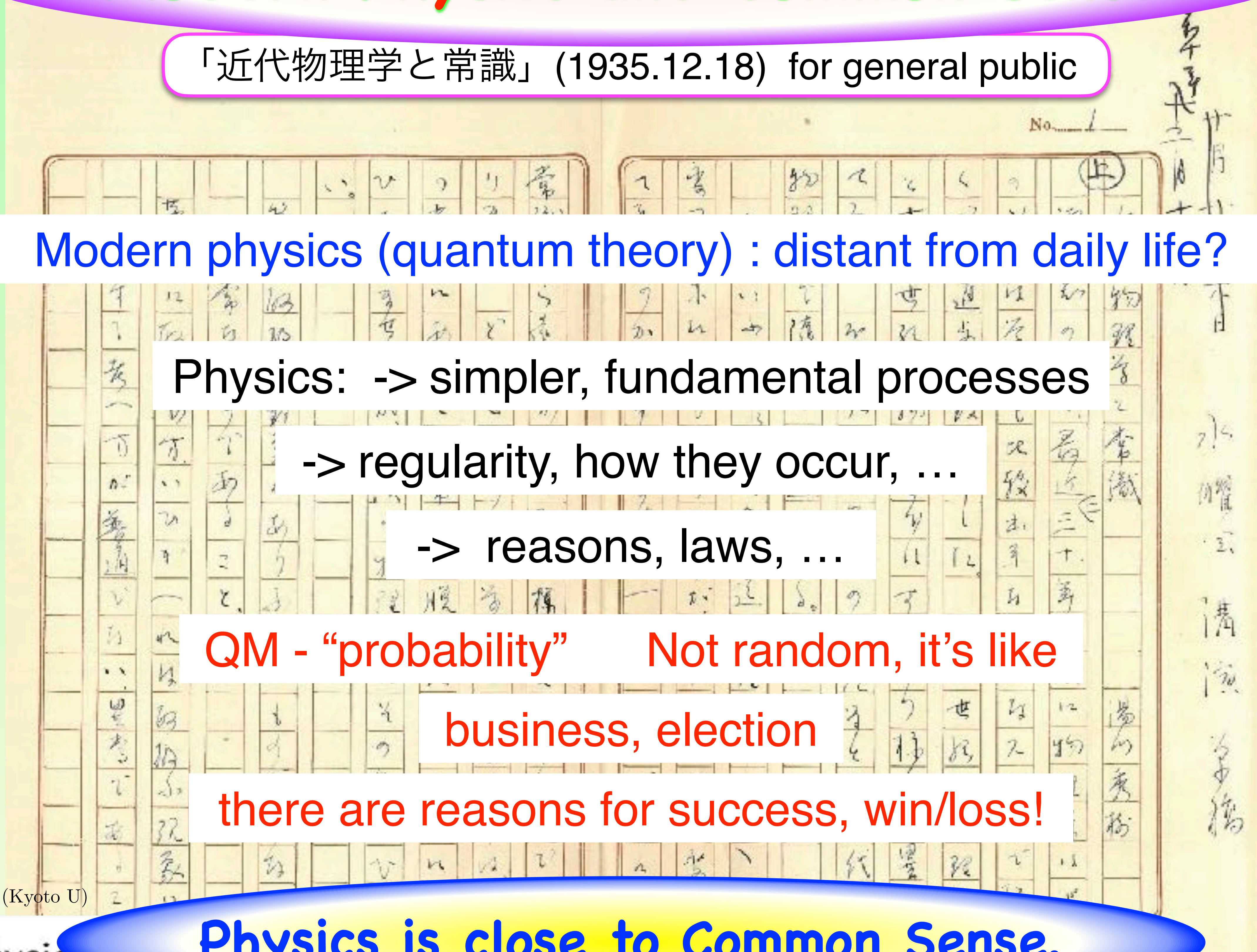
Tomonaga complains:

"Nishina-san is too busy with radio interviews and magazine articles.
Wish him to write up our paper quickly.
Please keep it secret."

これは内証の話

Modern Physics and Common Sense

「近代物理学と常識」(1935.12.18) for general public



Modern physics (quantum theory) : distant from daily life?

Physics: -> simpler, fundamental processes

-> regularity, how they occur, …

-> reasons, laws, …

QM - “probability”   Not random, it’s like

business, election

there are reasons for success, win/loss!

Physics is close to Common Sense.

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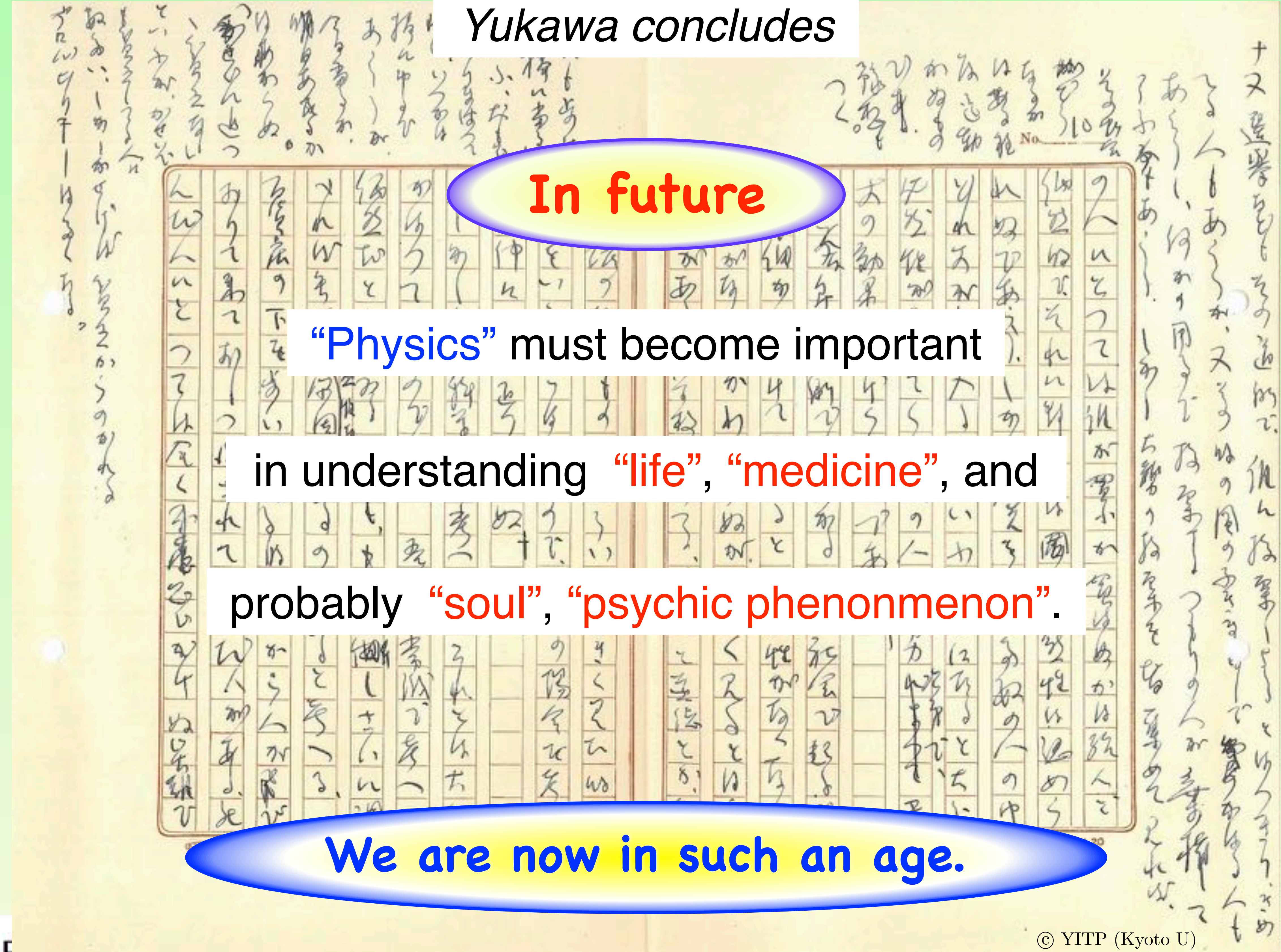
Yukawa concludes



In future

"Physics" must become important

in understanding "life", "medicine", and

probably "soul", "psychic phenonmenon".

We are now in such an age.

Ph.D. in 1938

1934.11

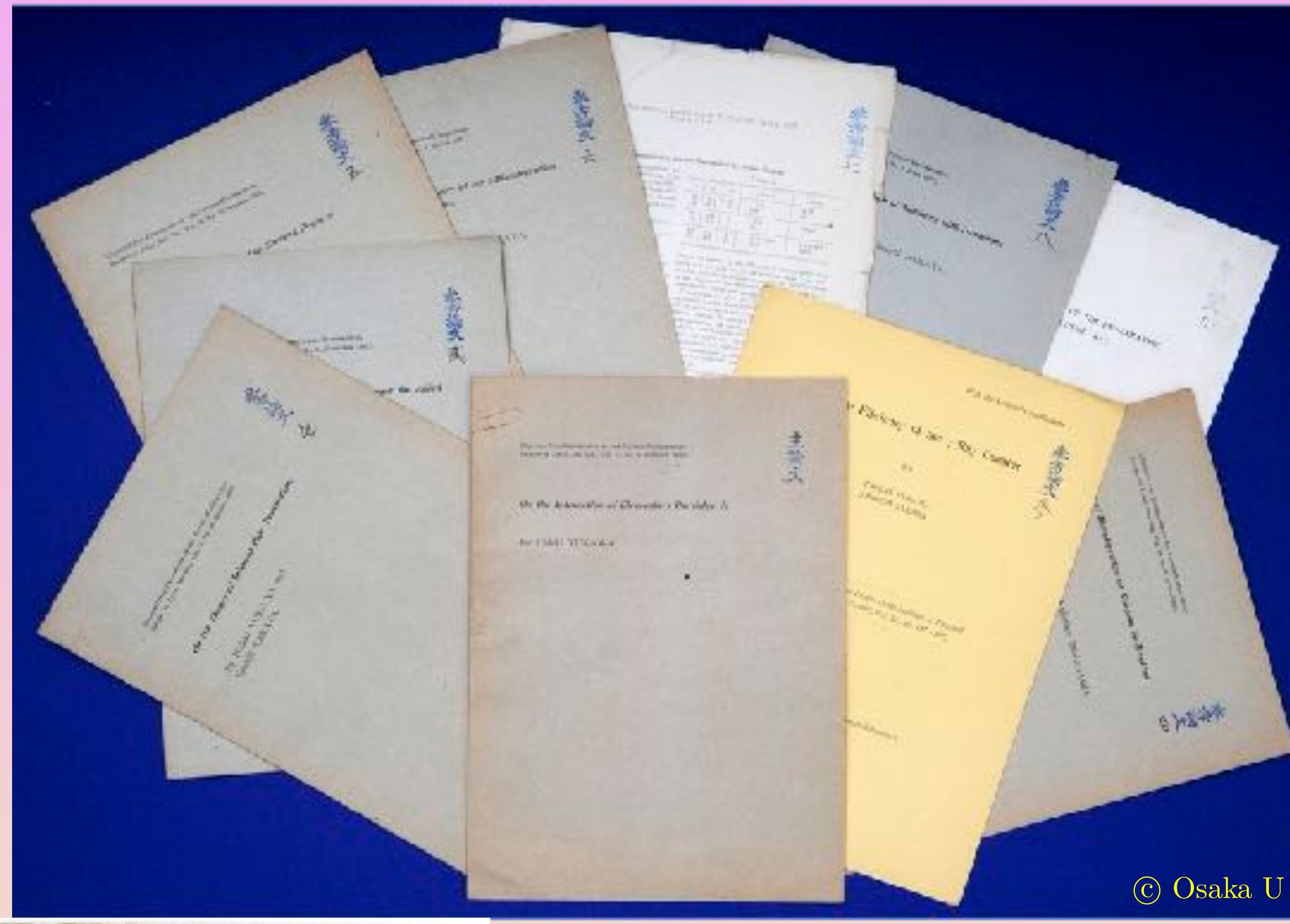
1st paper submitted

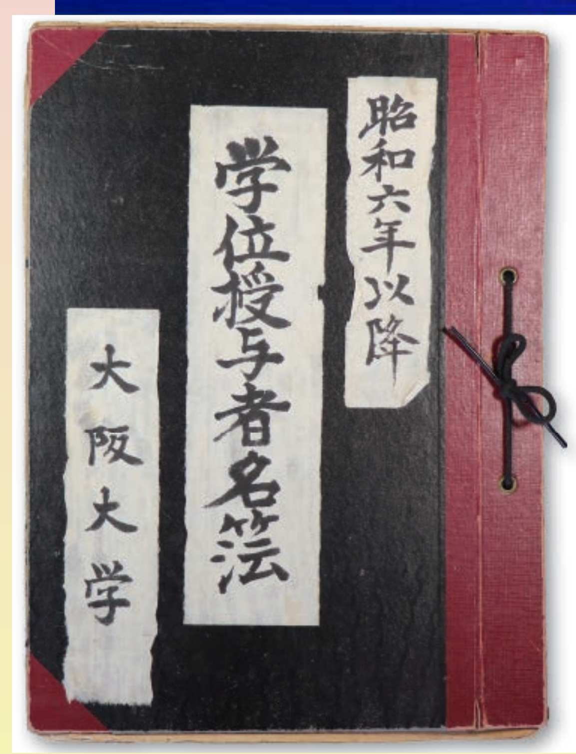
1937.11.15

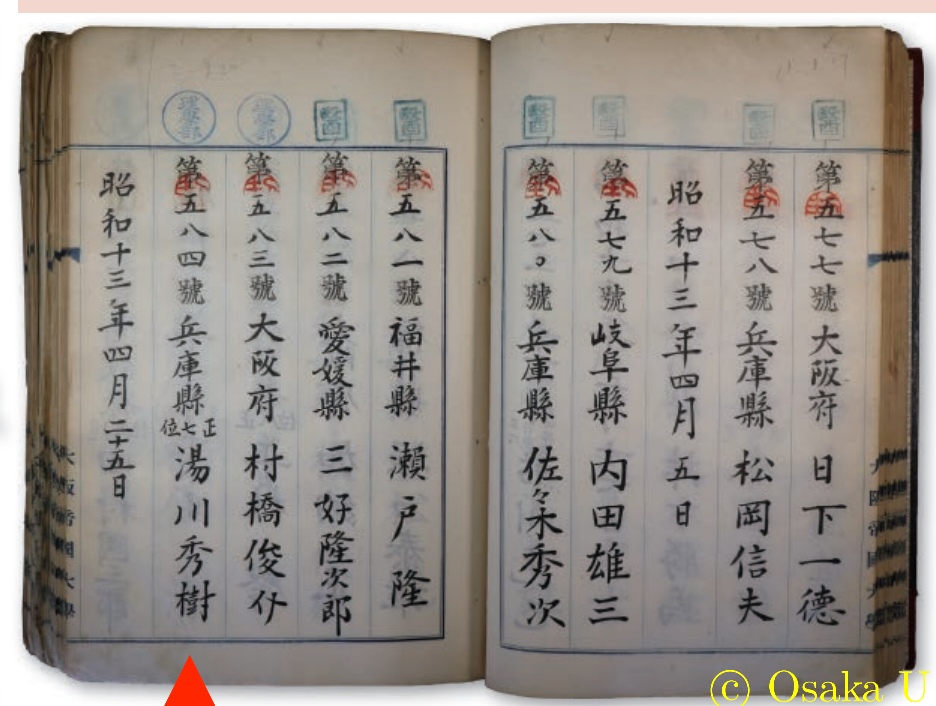
application for Ph.D.

1938.4.5

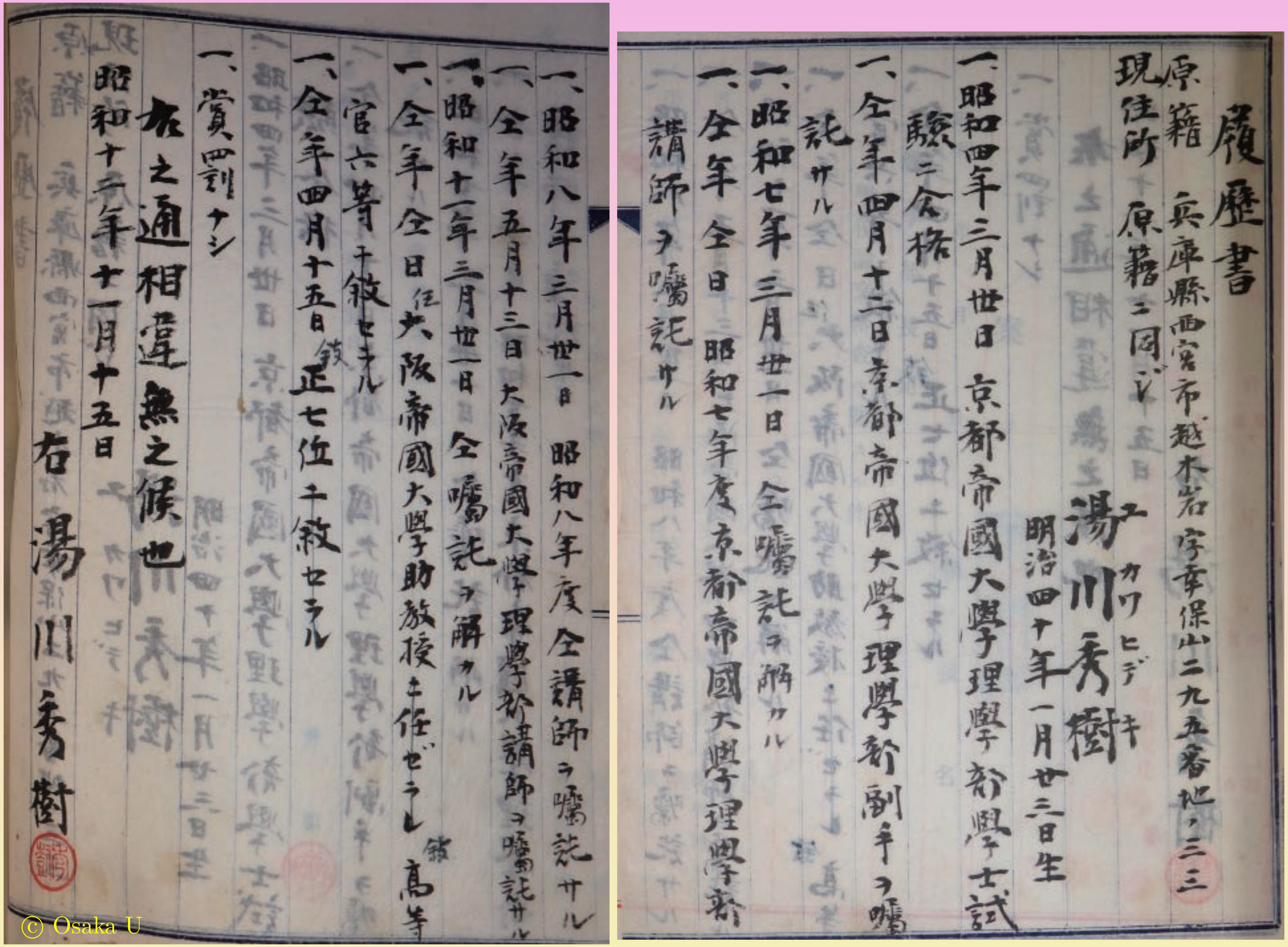
Ph.D. confered from Osaka Imperial Univ







Yukawa's curriculum vitae



履歴書

原籍　兵庫縣西宮市越木岩字幸保山二九五番地ノ三三

現住所　原籍ニ同ジ

湯川秀樹（ユカワヒデキ）

明治四十年一月廿三日生

一、昭和四年三月卅日　京都帝國大學理學部學士試驗ニ合格

一、仝年四月十二日　京都帝國大學理學部副手ヲ囑託サル

一、昭和七年三月卅一日　仝囑託ヲ解カル

一、仝年仝日　昭和七年度京都帝國大學理學部講師ヲ囑託サル

一、昭和八年三月卅一日　昭和八年度仝講師ヲ囑託サル

一、仝年五月十三日　大阪帝國大學理學部講師ヲ囑託サル

一、昭和十一年三月卅一日　仝囑託ヲ解カル

一、仝年仝日　大阪帝國大學助教授ニ任ゼラレ高等官六等ニ敍セラル

一、仝年四月十五日　正七位ニ敍セラル

一、賞罰ナシ

右之通相違無之候也

昭和十二年十一月十五日

右　湯川秀樹

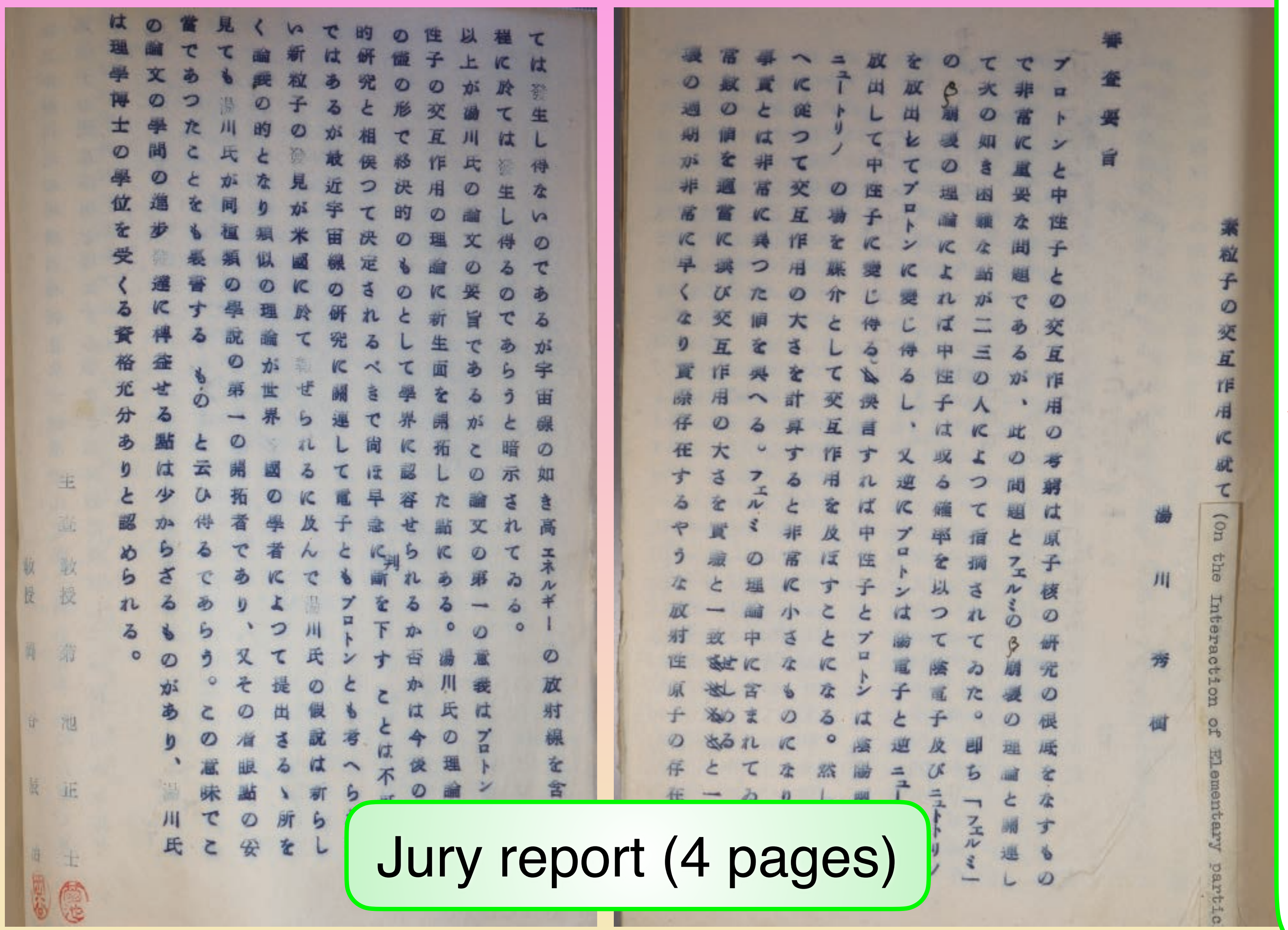
Judging of the Ph.D. thesis

Jury committee: 1937.11.15

Report submitted to Faculty meeting : 1938.2.17

U. President -> Minister of Education: 1938.2.25

Ph.D. conferred to Yukawa: 1938.4.5



Jury report (4 pages)

Principal juror: S. Kikuchi

*Nuclear force & beta decay
*Yukawa's proposal of
a new particle of $m \sim 200\, m_e$
*Can be produced in cosmic rays

*It is premature to make a judgment. Need to be confirmed by exp. or observation.

*C. Anderson/Neddermeyer's discovery (1937)

*Yukawa is qualified for a Ph.D.

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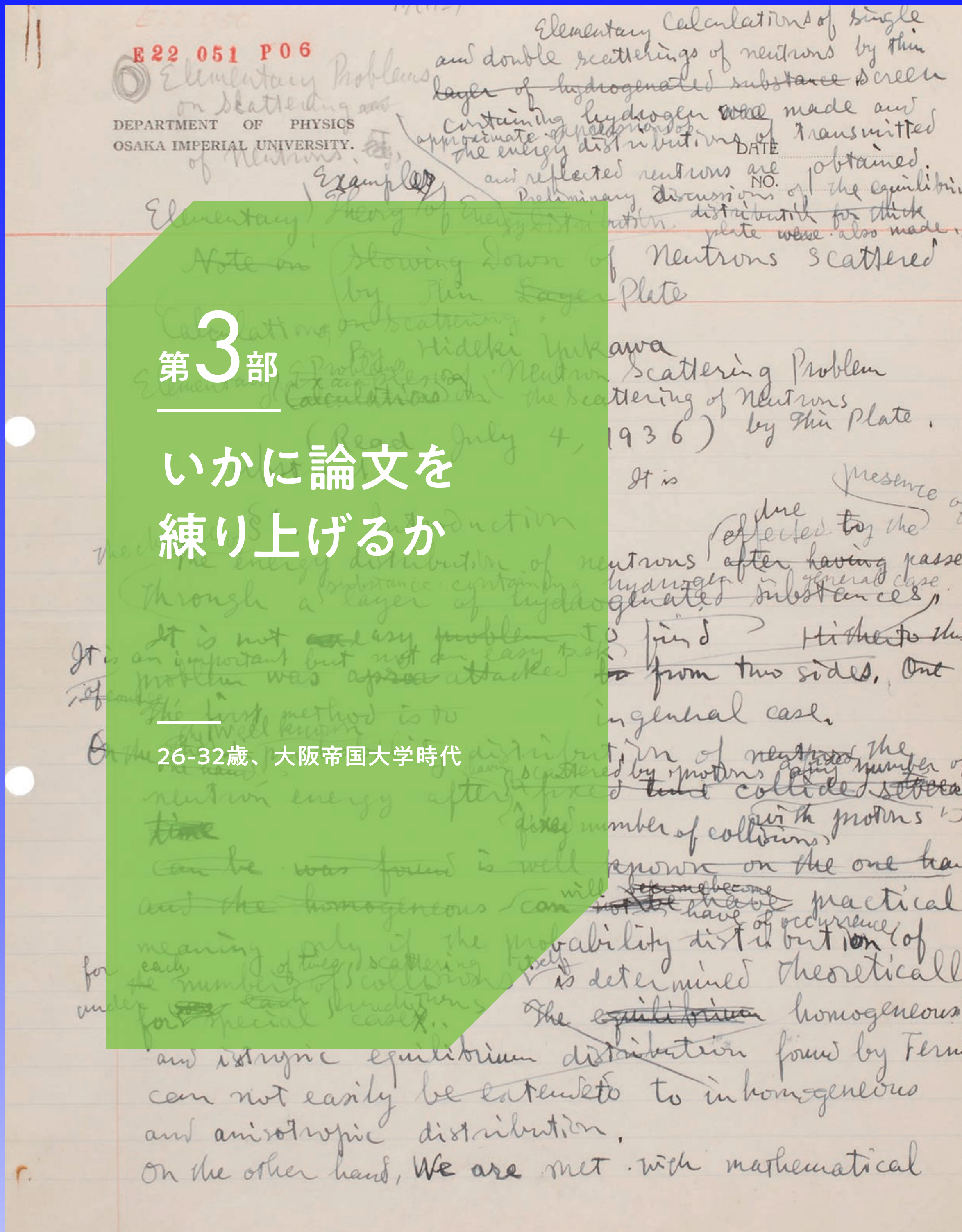
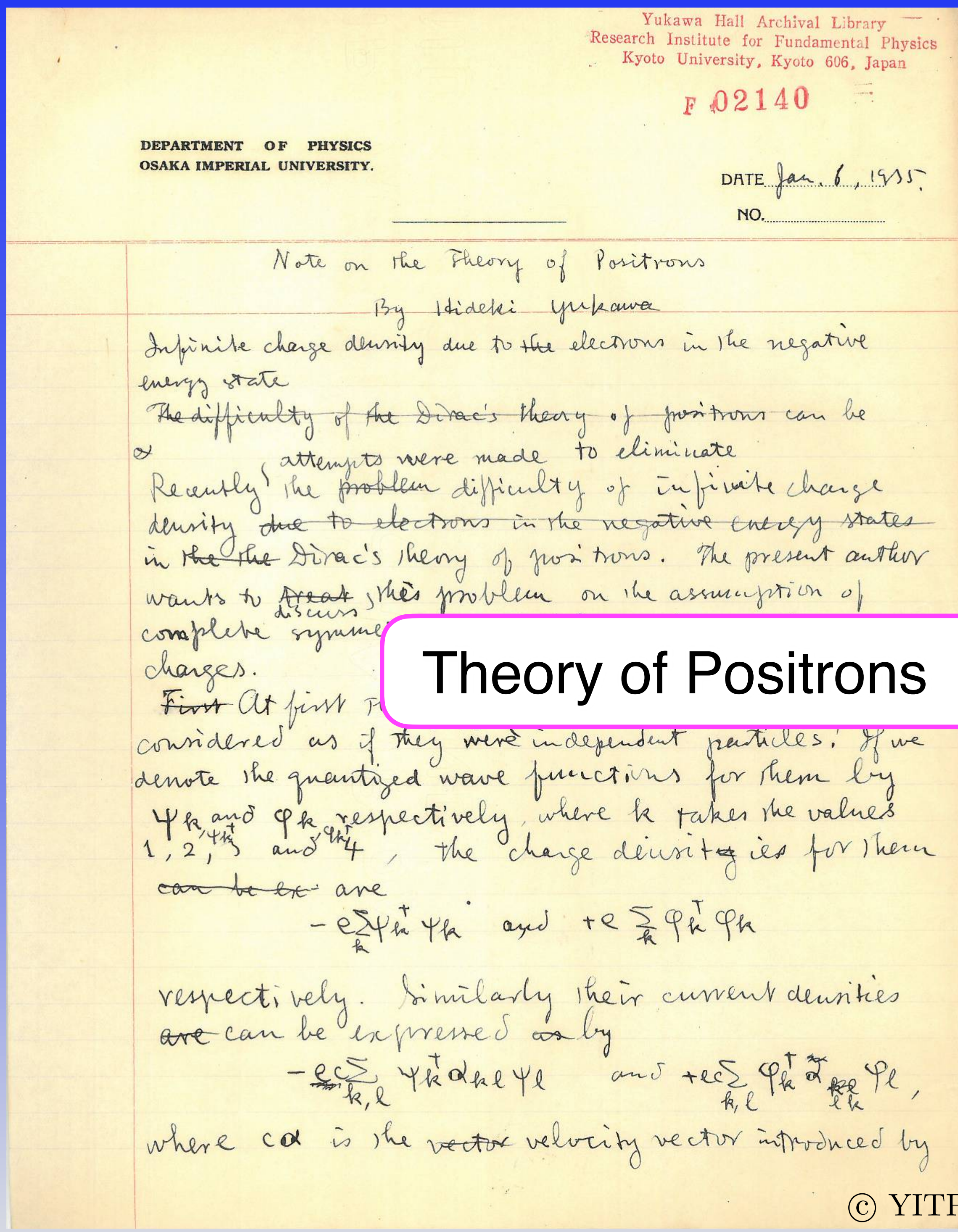

E22 051 P06
DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.
第3部
いかに論文を
練り上げるか
26-32歳、大阪帝国大学時代


第4部
日本の「博士」に
—ノーベル賞受賞
42歳、1949年

Notes, notes, notes



DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.

DATE Jan. 6, 1935.
NO.

Note on the Theory of Positrons

By Hideki Yukawa

Infinite charge density due to the electrons in the negative energy state

~~The difficulty of the Dirac's theory of positrons can be~~

Recently, attempts were made to eliminate the ~~problem~~ difficulty of infinite charge density ~~due to electrons in the negative energy states~~ in ~~the the~~ Dirac's theory of positrons. The present author wants to ~~treat~~ discuss this problem on the assumption of complete symme... charges.

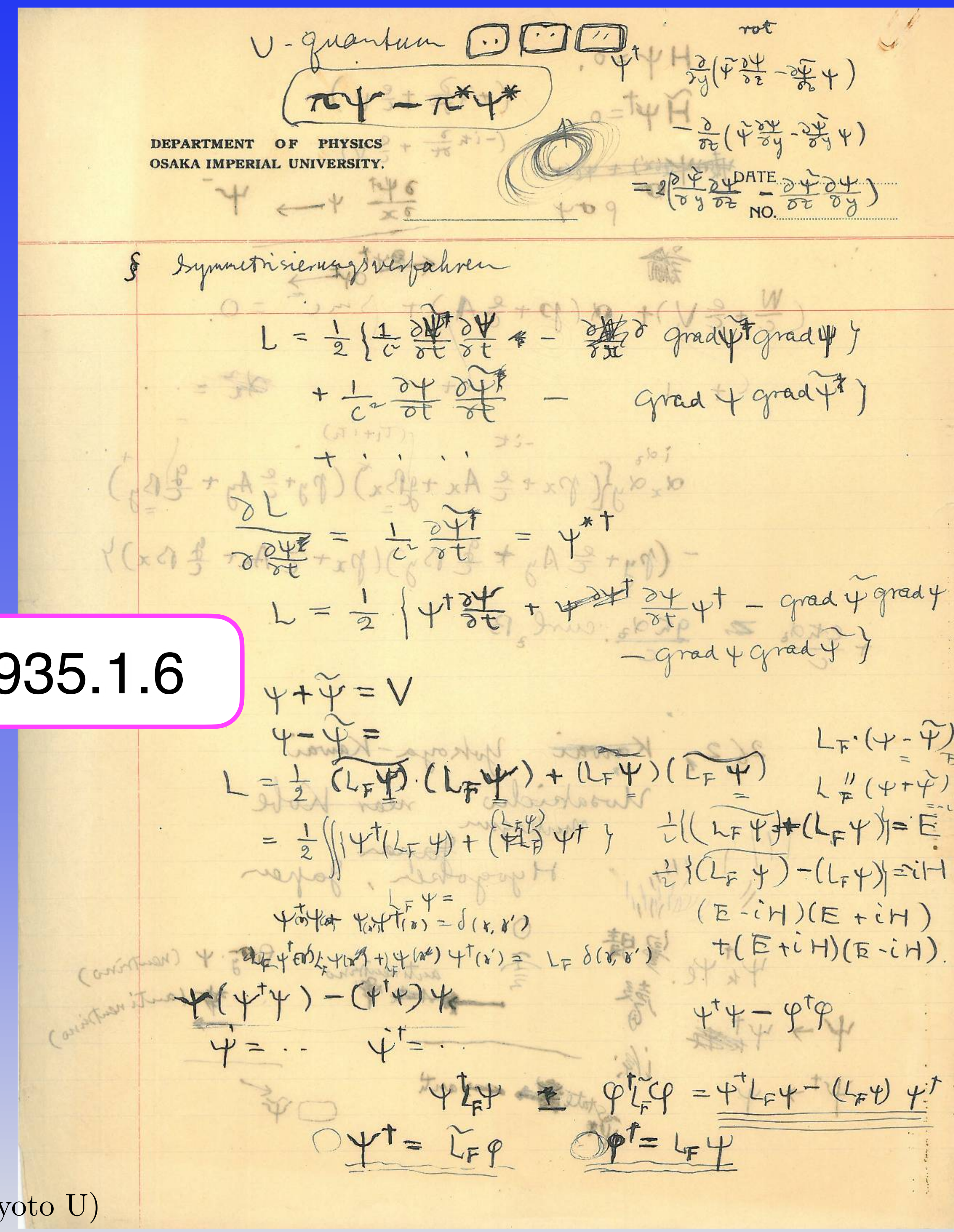
~~First~~ At first p... considered as if they were independent particles. If we denote the quantized wave functions for them by ψ_k and φ_k respectively, where k takes the values 1, 2, 3 and 4, the charge densities for them ~~can be ex~~ are

$$-e\sum_k \psi_k^\dagger \psi_k \quad \text{and} \quad +e\sum_k \varphi_k^\dagger \varphi_k$$

respectively. Similarly their current densities ~~are~~ can be expressed ~~as~~ by

$$-ec\sum_{k,l} \psi_k^\dagger \alpha_{kl} \psi_l \quad \text{and} \quad +ec\sum_{k,l} \varphi_k^\dagger \alpha_{lk} \varphi_l ,$$

where $c\alpha$ is the ~~vector~~ velocity vector introduced by



U-quantum

DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.

DATE
NO.

§ Symmetrisierungsverfahren

$\psi + \tilde\psi = V$

Theory of Positrons 1935.1.6

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Physics
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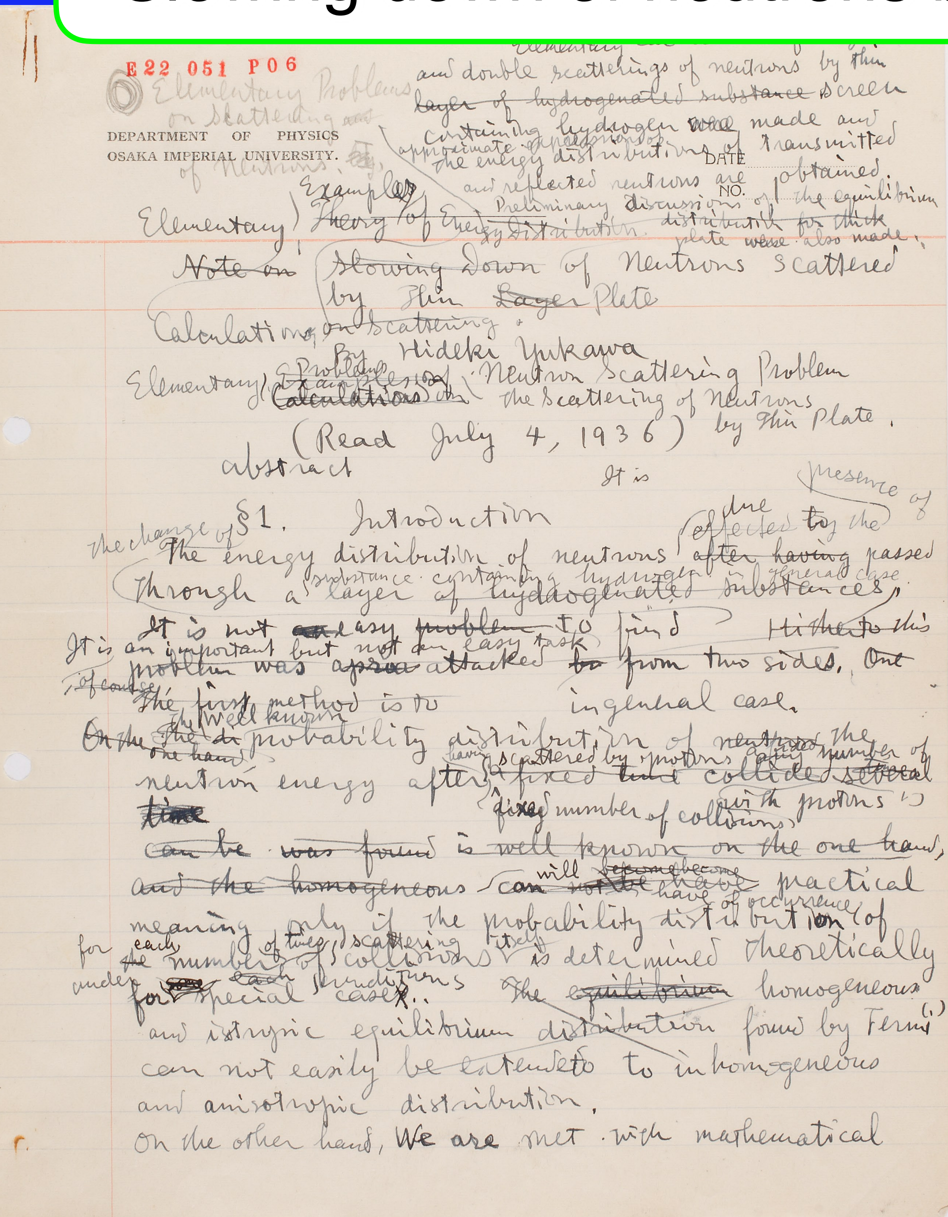
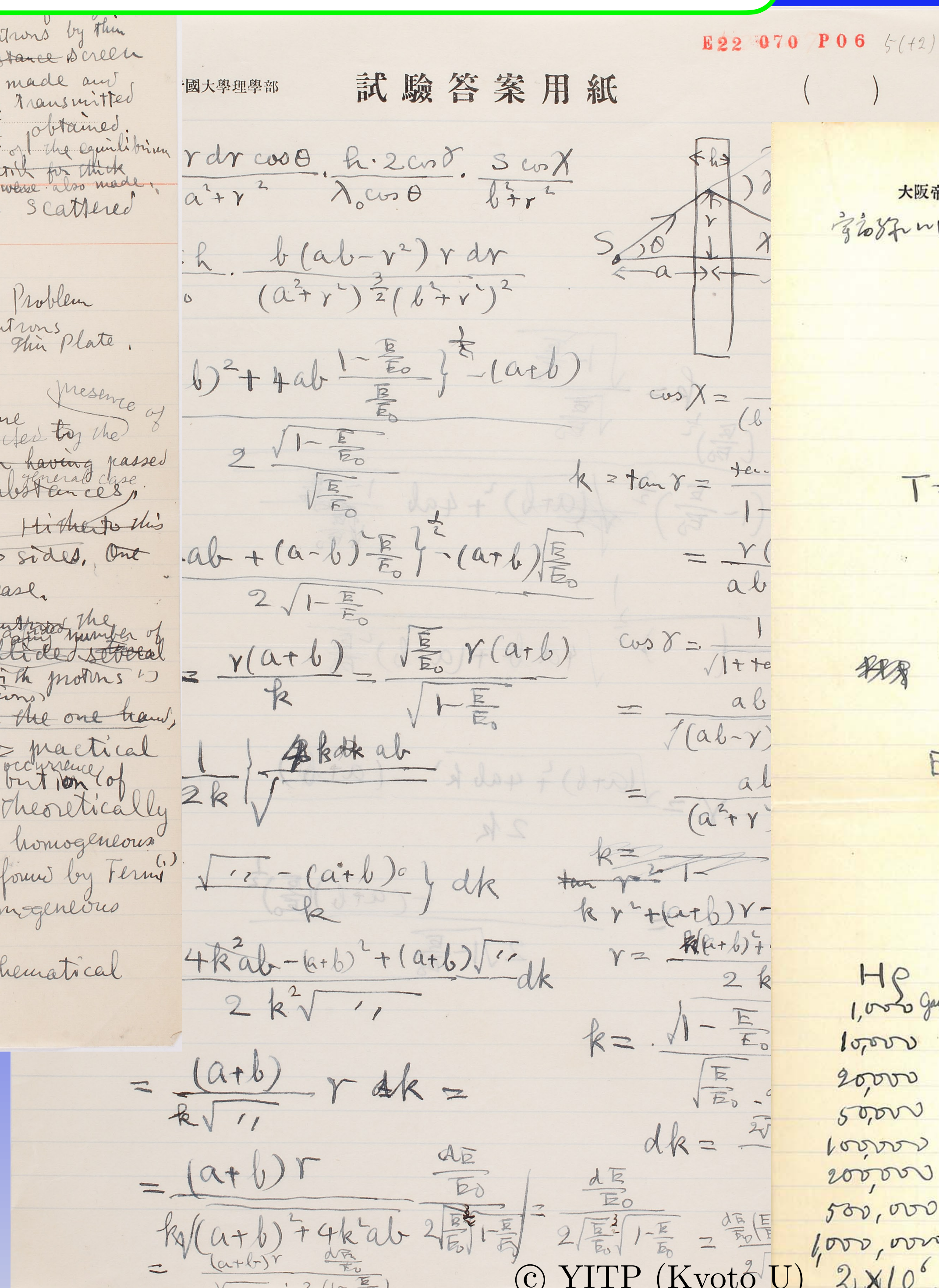
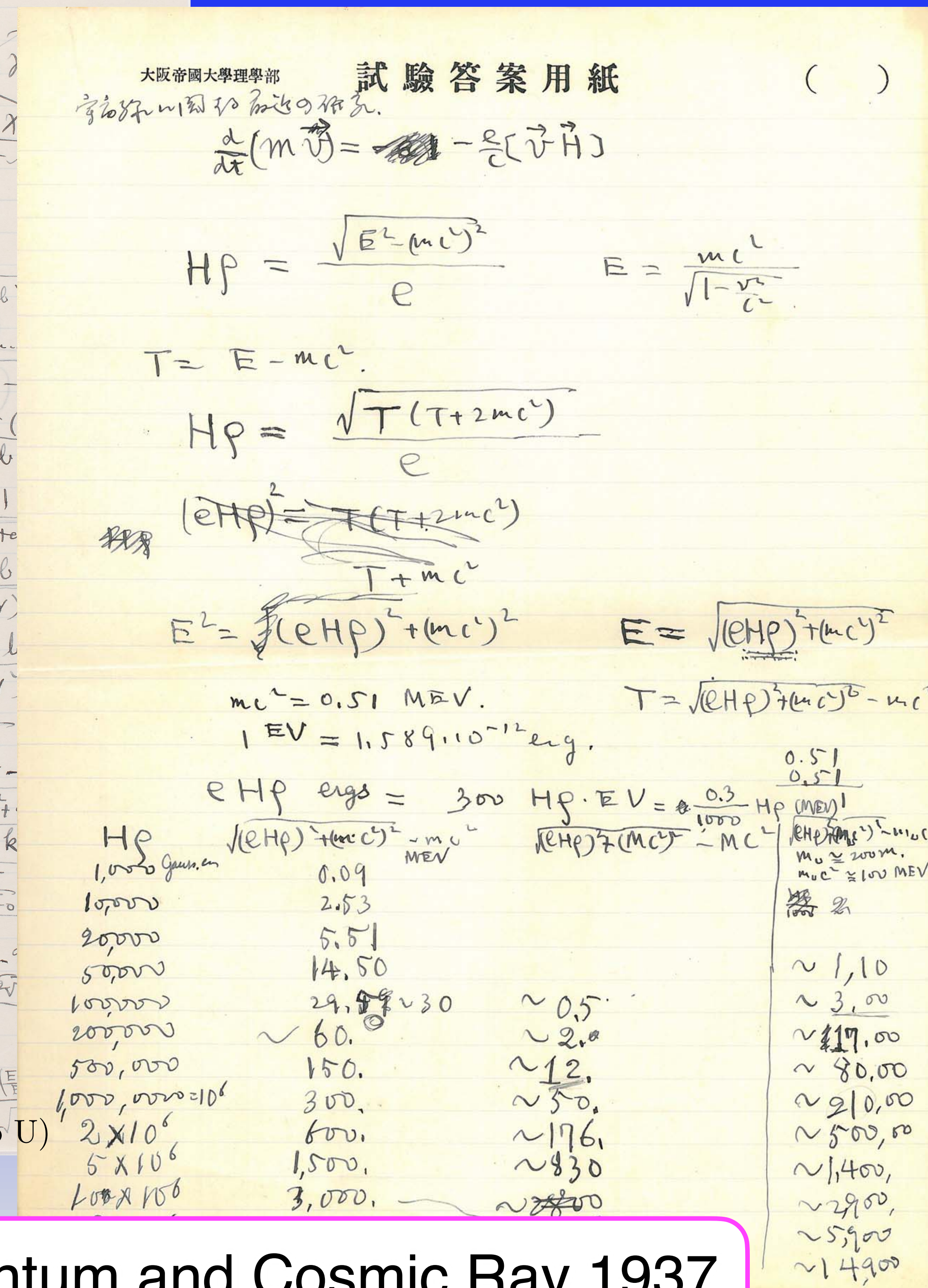
Slowing down of neutrons by thin plate 1936.7.4







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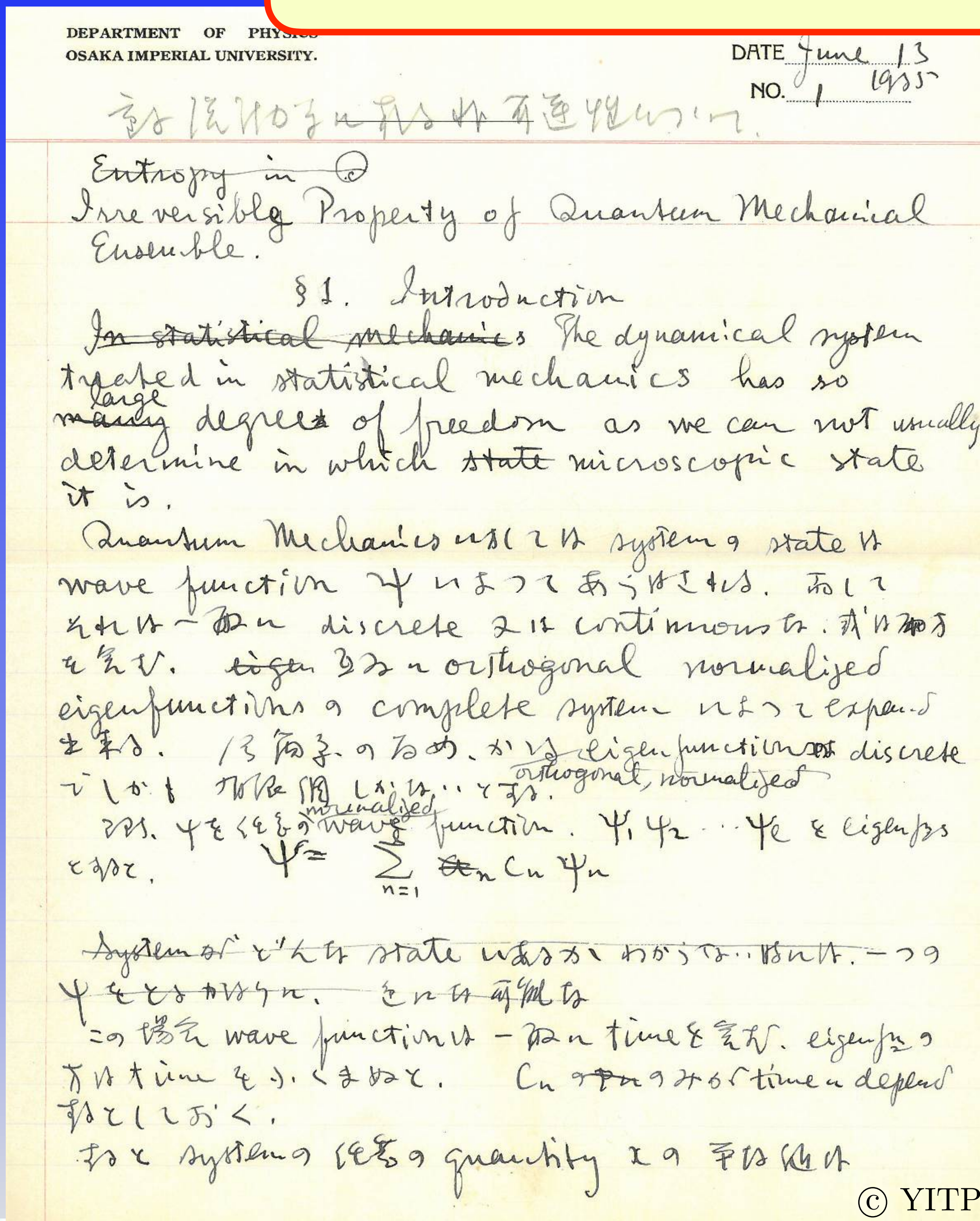
Heavy Quantum and Cosmic Ray 1937

Physics OSAKA UNIVERSITY

(~~Entropy in Q~~)

Irreversible Property of Quantum Mechanical Ensemble

1935.6.13



DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.

DATE June 13 1935
NO. 1

~~Entropy in Q~~
Irreversible Property of Quantum Mechanical Ensemble.

§1. Introduction

~~In statistical mechanics~~ The dynamical system treated in statistical mechanics has so ~~many~~ large degrees of freedom as we can not usually determine in which ~~state~~ microscopic state it is.

Quantum Mechanicsにおいては systemの stateは wave function ψによってあらはされる. 而してそれは一般に discrete 又は continuousな. 或は両方を含む. ~~eigen~~ 値を有する orthogonal normalized eigenfunctions の complete system によって expand 出来る. 以下簡単のため、かかる eigenfunctions は discrete でしかも有限個しかないとする. (orthogonal, normalized)

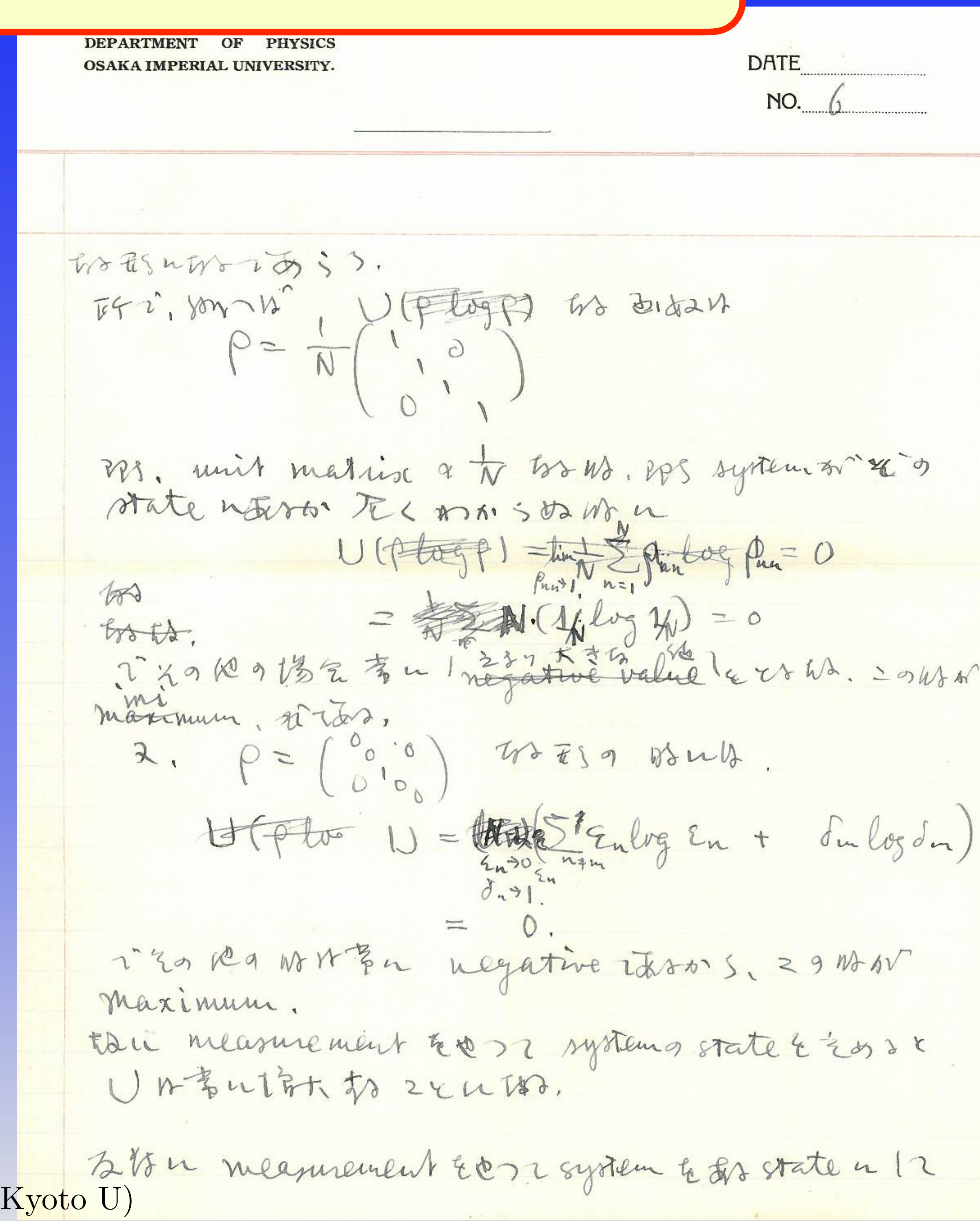
そこで、ψを任意の normalized wave function. $\psi_1, \psi_2 \cdots \psi_l$ を eigenfns とすると、

$$\Psi = \sum_{n=1}^{l} c_n \psi_n$$

~~Systemがどんな stateにあるかわからない時には、一つのψをとるかわりに、それは可能な~~

この場合 wave functionは一般に timeを含む. eigenfnの方は timeをふくまないで. c_n のみが time に depend するとしておく.

すると systemの任意の quantity X の平均値は



DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.

DATE
NO. 6

なる形になるであらう.

所で、例へば U(~~ρ log ρ~~) なる函数は

$$\rho = \frac{1}{N}\begin{pmatrix} 1 & & 0 \\ & 1 & \\ 0 & & 1 \end{pmatrix}$$

即ち、unit matrix の $\frac{1}{N}$ なる時、即ち systemが全くどの state にあるか全くわからぬ時に

$$U(\rho \log \rho) = \lim_{\rho_{nn}\to 1} \frac{1}{N}\sum_{n=1}^{N} \rho_{nn} \log \rho_{nn} = 0$$

$$= N\left(\frac{1}{N}\log \frac{1}{N}\right) = 0$$

で其の他の場合常に 1 より大きな値をとるから. この時が minimum である.

又、$\rho = \begin{pmatrix} 0 & & 0 \\ & 1 & \\ 0 & & 0 \end{pmatrix}$ なる形の時には

$$U = \lim_{\substack{\varepsilon_n \to 0 \\ \delta_m \to 1}} \left(\sum_{n \neq m}{}' \varepsilon_n \log \varepsilon_n + \delta_m \log \delta_m \right) = 0.$$

で其の他の時は常に negative であるから、この時が maximum.

故に measurement をやつて systemの state をきめると U は常に増大することになる.

反対に measurement をやつて system をある state にして

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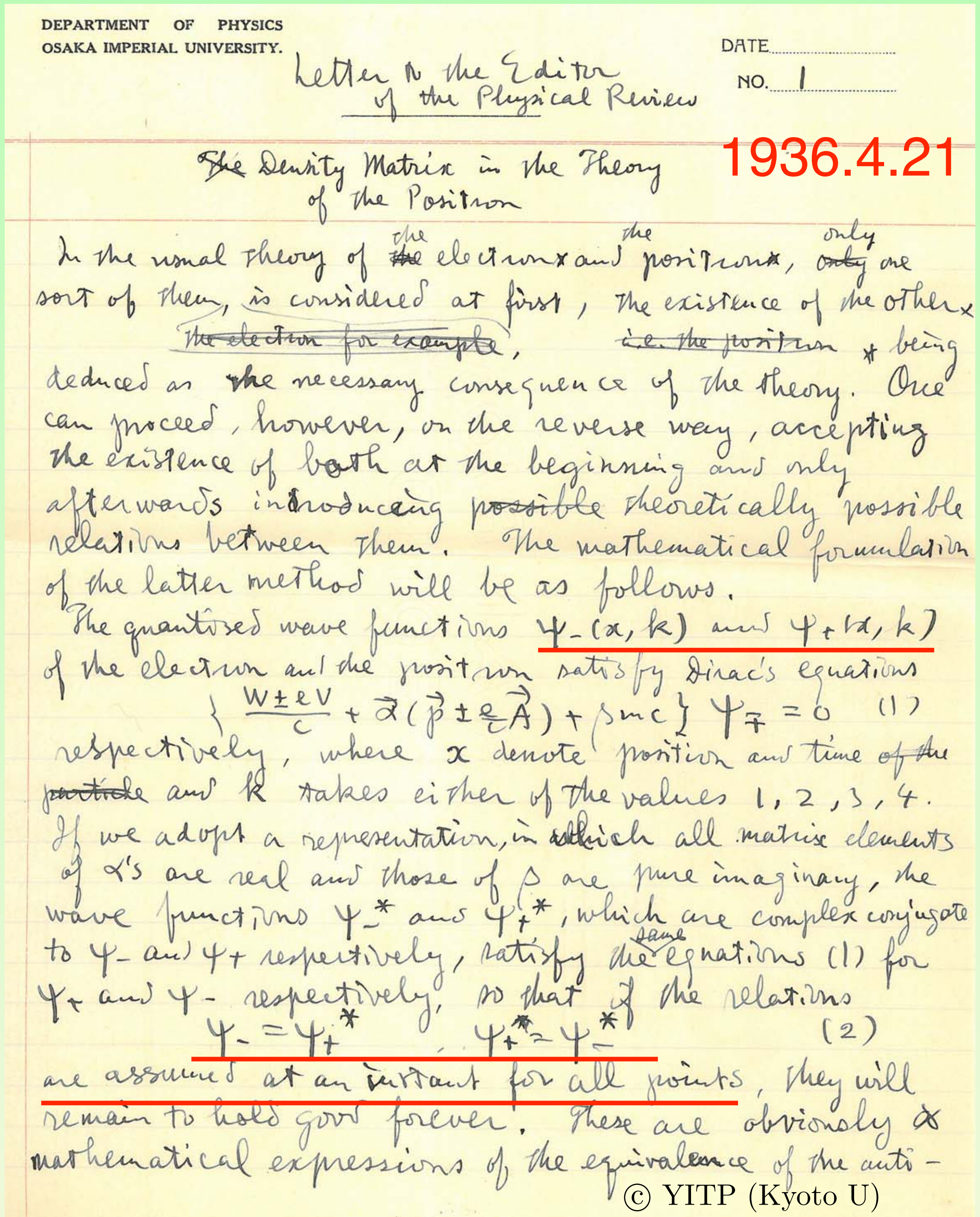
Dirac sea

Infinite negative charges filled in the vacuum ?



DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.

Letter to the Editor of the Physical Review

DATE

NO. 1

1936.4.21

The Density Matrix in the Theory of the Positron

In the usual theory of the electron and positron, only one sort of them, is considered at first, ~~the electron for example~~, ~~i.e. the positron~~ the existence of the other being deduced as the necessary consequence of the theory. One can proceed, however, on the reverse way, accepting the existence of both at the beginning and only afterwards introducing ~~possible~~ theoretically possible relations between them. The mathematical formulation of the latter method will be as follows.

The quantised wave functions $\psi_-(x,k)$ and $\psi_+(x,k)$ of the electron and the positron satisfy Dirac's equations

$$\left\{ \frac{W \pm eV}{c} + \vec{\alpha}\left(\vec{p} \pm \frac{e}{c}\vec{A}\right) + \beta mc \right\} \psi_{\mp} = 0 \quad (1)$$

respectively, where x denote position and time of the ~~particle~~ and k takes either of the values 1, 2, 3, 4.

If we adopt a representation, in which all matrix elements of α's are real and those of β are pure imaginary, the wave functions ψ_-^* and ψ_+^*, which are complex conjugate to ψ_- and ψ_+ respectively, satisfy the same equations (1) for ψ_+ and ψ_- respectively, so that if the relations

$$\psi_- = \psi_+^*, \quad \psi_+^* = \psi_-^* \quad (2)$$

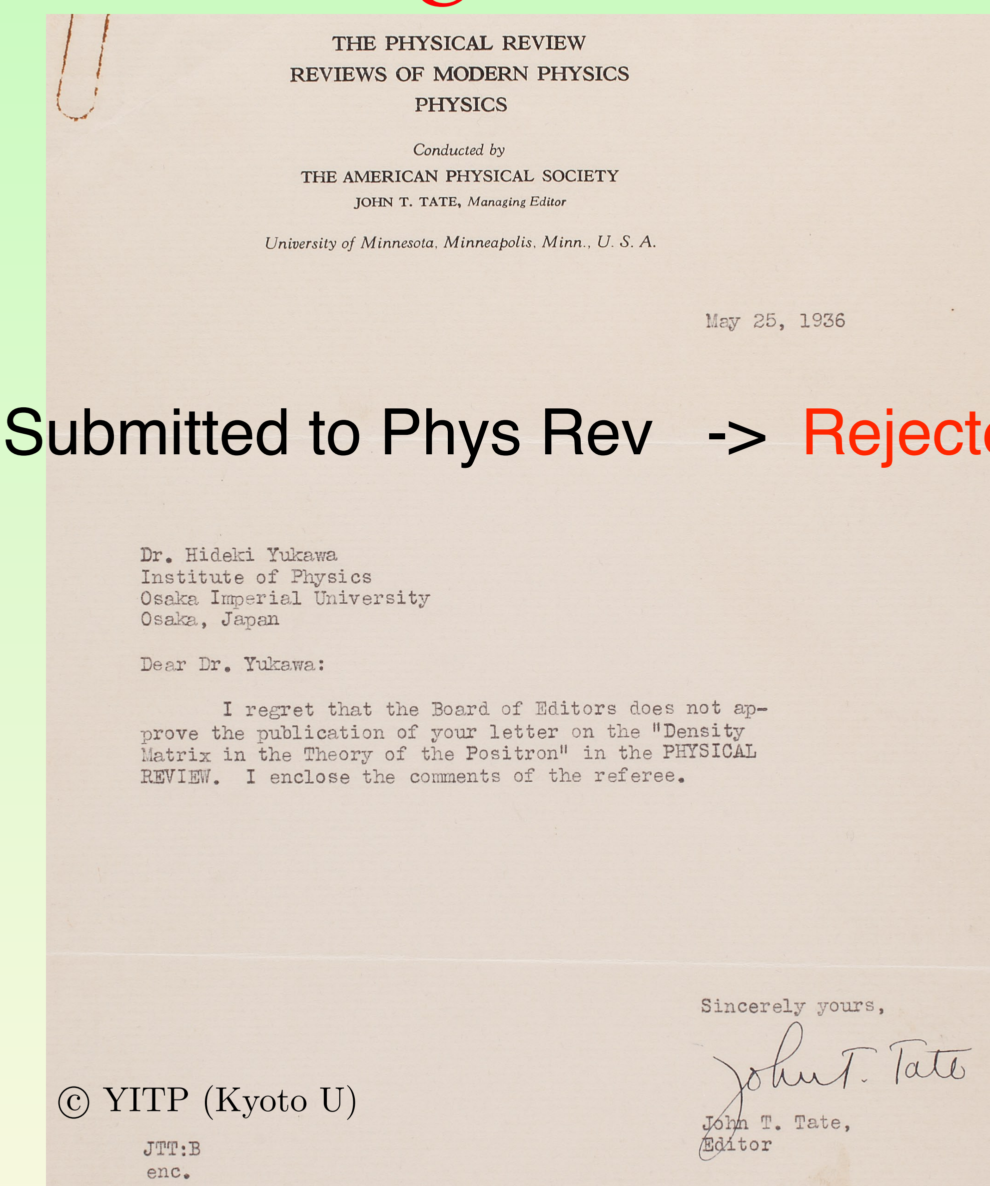
are assumed at an instant for all points, they will remain to hold good forever. These are obviously mathematical expressions of the equivalence of the anti-

Yukawa:

electron field $\psi_- \rightarrow e^-$ sea
positron field $\psi_+ \rightarrow e^+$ sea
} offset

Notion of charge conjugation : yet to be found

C



THE PHYSICAL REVIEW
REVIEWS OF MODERN PHYSICS
PHYSICS

Conducted by
THE AMERICAN PHYSICAL SOCIETY
JOHN T. TATE, Managing Editor

University of Minnesota, Minneapolis, Minn., U. S. A.

May 25, 1936

Dr. Hideki Yukawa
Institute of Physics
Osaka Imperial University
Osaka, Japan

Dear Dr. Yukawa:

I regret that the Board of Editors does not approve the publication of your letter on the "Density Matrix in the Theory of the Positron" in the PHYSICAL REVIEW. I enclose the comments of the referee.

Sincerely yours,

John T. Tate

John T. Tate,
Editor

JTT:B
enc.

Submitted to Phys Rev -> Rejected

Physics OSAKA UNIVERSITY

The new particle in cosmic ray

by Yukawa, Sakata, Taketani : submitted to Phys Rev (1937.10.22)

Rejected (1937.12.2)

U particles: nuclear force & cosmic ray

YHAL E16 011 U05

Letter to the Editor of the Physical Review.

On the Theory of the New Particle in Cosmic Ray.

As already suggested by several authors[1]
particle in cosmic ray, if confirmed, will be
theory which had been proposed by one of the
ly by Stueckelberg. Thus it will not be usele
account of further consequences of the theory
cosmic ray and nuclear phenomena.

The aim of the theory was to remove the
the so-called "β-hypothesis of the nuclear f
by introducing a new field, which was respons
exchange force between the neutron and the pr
β-disintegration. We could arrive at consis
the interaction of the new field with the hea
larger than that with the light particle. As
sible forms, the field was considered to be d
potentials U and $\tilde{U}$ conjugate complex to eac
wave equations

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \kappa^2\right) U = -4\pi g \tilde{\Psi} \ldots$$

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \kappa^2\right) \tilde{U} = -4\pi g \tilde{\Psi} \ldots$$

1) Oppenheimer and Serber, Phys. Rev. 51, 111
Phys.-Math. Soc. Japan 19, 712, 1937; Stu
41, 1937. It should be noticed that the c
and Serber is not well founded, since many
current theory do not appear in our theory
following paragraphs.
2) Yukawa, Proc. Phys.-Math. Soc. 17, 4 ... 19

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THE PHYSICAL REVIEW
REVIEWS OF MODERN PHYSICS

Conducted by

THE AMERICAN PHYSICAL SOCIETY
JOHN T. TATE, *Managing Editor*

University of Minnesota, Minneapolis, Minn., U. S. A.

December 2, 1937

Mr. Hideki Yukawa
Kurakuen, Nisinomiyasi
Hyogoken, Japan

Dear Mr. Yukawa:

The Letter to the Editor by yourself and associates ...
by an associate editor who reports as follows:

"The Letter suggests that the theory ...
to account for the facts of nuclear physics than it actually is. The
theory as presented gives 1) like-particle forces too small by a factor
of 10-20, 2) wrong spin-dependence, and 3) non-saturating like-particle
forces. It also gives no account of the anomalous ...
the proton and neutron. None of the suggested modifications are accept-
able in detail.

"A factor of 4π is omitted on page 2."

In view of these criticisms we thought it best to return the paper
... for ... consideration ...

Sincerely yours,

J. W. Buchta,
Assistant Editor

JWB:B
Enc.

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Referee (associate editor):

1) p-p, n-n int. too small
2) spin dependence in nuclear force
3) anomalous mag. moment of p, n

Yukawa et al:

1) neutral meson necessary
3) anomalous mag. moment of n : quantum effect $n \to p + U^- \to n$

Even in 1937 Yukawa's meson theory: not accepted by most physicists

Physics OSAKA UNIVERSITY

Meson theory in perspective

1939.4.3 Japan Phys-Math Soc Meeting in Kyoto
— special session on Mesotrons —

talk 30. Yukawa : summary & outlook
31. Nishina
32. Tamaki-Ozaki
33. Kobayashi-Okayama
34. Kobayashi-Okayama
35. Sakata-Tanigawa
36. Yukawa-Sakata
37. Yukawa : On the limits of field theories

(talks 33–36: Yukawa's group)

Starts in a pessimistic tone;

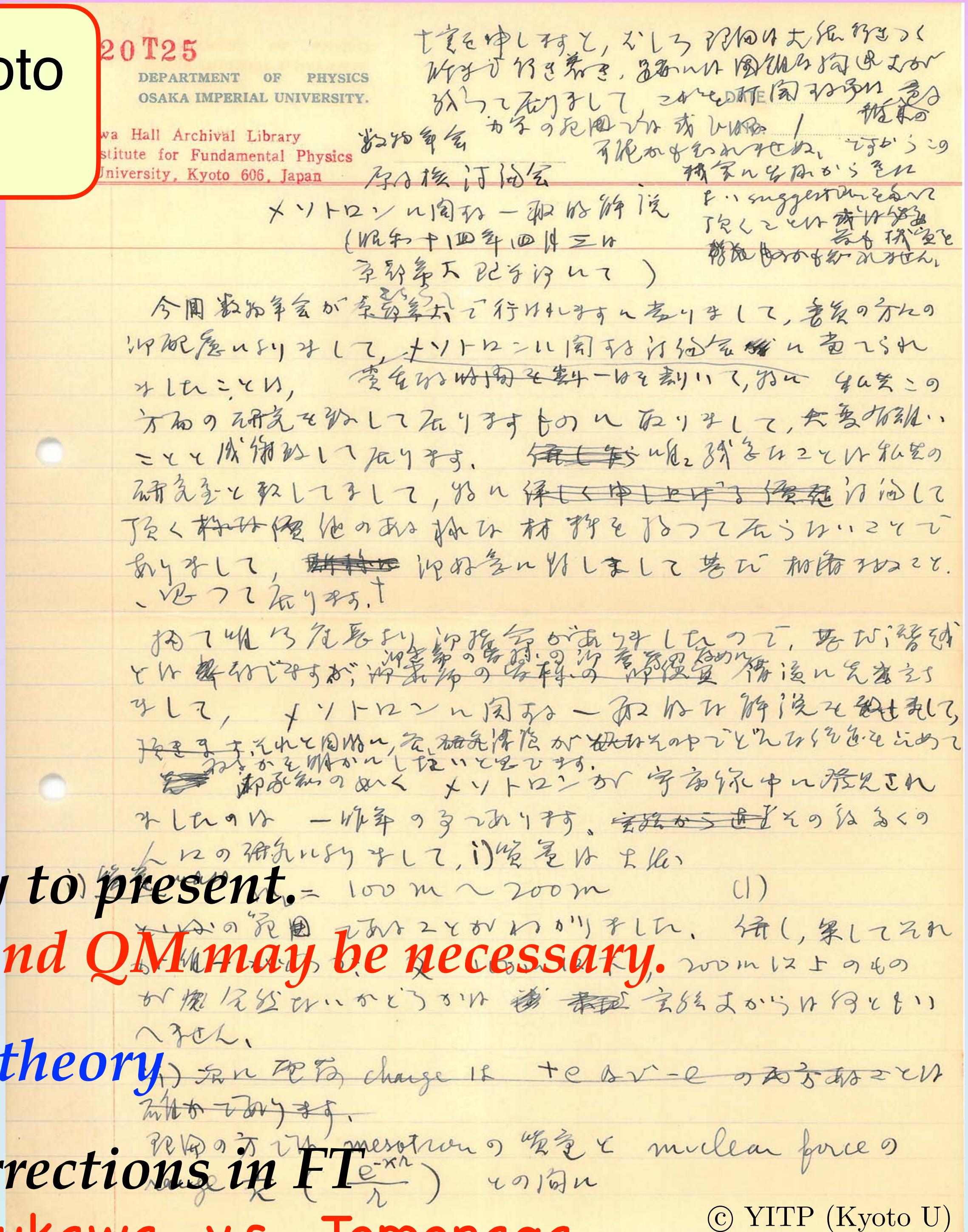
Our group does not have anything worthy to present.

Many difficult problems. Something beyond QM may be necessary.

Brilliant summary: the status of the meson theory

talk 37: *infinities in quantum corrections in FT*

Yukawa v.s. Tomonaga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メソトロンに関する一般的解説
(昭和十四年四月三日 京都帝大理学部にて)

Osaka Imperial University period

1933-1939 Age 26-32

Yukawa's endeavor in physics

He struggled and educated colleagues/strudents/public.

With passion and a sense of mission.

Vision for the future

Physics
OSAKA UNIVERSITY