César Lattes e as técnicas de produção e detecção de mésons:
a prática científica como objeto histórico

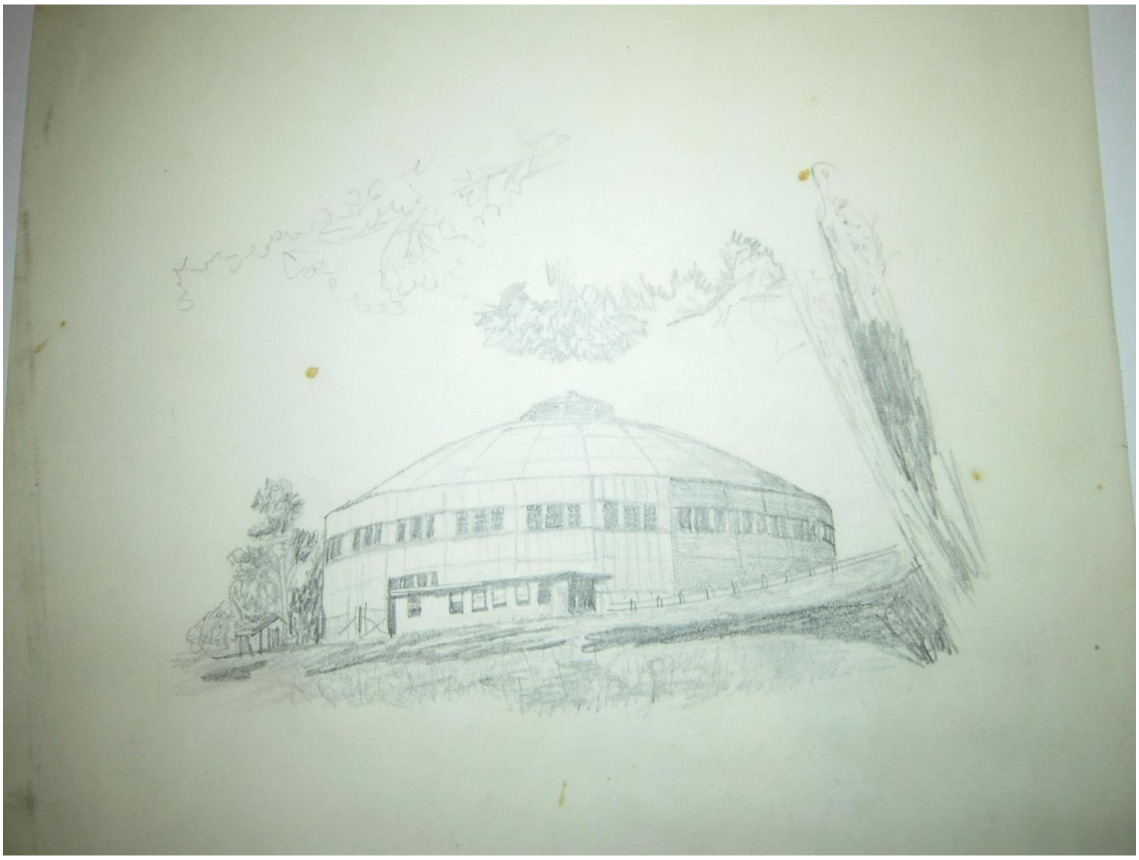
Documentos citados

em artigo publicado na Revista Brasileira de Ensino de Física - 2020

Heráclio Tavares, Ivã Gurgel e Antonio A. P. Videira

Documentos primários referenciados provenientes do Arquivo Central da Universidade de Campinas, SP, Brasil, do *National Archives and Records Administration*, San Bruno, CA, EUA, e da *Bancroft Library* da Universidade da Califórnia, Berkeley, CA, EUA

[13] E. Gardner, Lawrence Radiation Laboratory (Research and Development Records and Administrative Files of Eugene Gardner, National Archives and Records Administration, San Bruno), pasta 30, caixa 2.



[42] G. Wataghin e M.S. Santos para E. Lawrence (The Bancroft Library, University of California, Berkeley, 1945), correspondência, rolo 27, caixa 18, pasta 13.

DC

Chicago, Nov. 28, 1945.

Dear Prof. Lawrence

The University of S. Paulo (Brasil), to whish we belong, is planning now the construction of a Nuclear Physics Laboratory.

For that purpose, the Department of Physics was given about USA $ 1.000.000 by the Brasilian Government and USA$ 75.000 by the Rockefeller Foundation, which has given us several grants since 1940 for cosmic ray researches.

We are now in this country as guests of that foundation, and the principal purpose of our trip is to buy equipment, get some advice on how to plan our new laboratory and visit american universities.

We hope to buy a 100 MEV betatron (GE) and to build a 60" cyclotron.

Dr Warren Weaver and Prof. Rabi advised us to get in touch with you and Dr. G.T. Seaborg was so kind as to take this letter with him and talk with you about it.

We hope to be able to pay a short visit to Berkeley , sometime in January, and would very much like to know if we could get some advice from you. We understand there are several difficulties now and would like to know if a clearance is necessary in order to see the cyclotron, but even if that is not possible, we would be very glad to get your advice.

With many thanks,

Yours, sincerely

G. Wataghin

M.D. de Souza Santos

c/o Dr H.M. Miller Jr.
The Rockefeller Foundation
49W, 49 Street
New York 20

[45] E. Lawrence para G. Wataghin e M.S. Santos (The Bancroft Library, University of California, Berkeley, 1945), correspondência, rolo 27, caixa 18, pasta 13.

Visitors

December 4, 1945

Dr. G. Wataghin and
Dr. M. D. de Sousa Santos
c/o Dr. E. M. Miller, Jr.
The Rockefeller Foundation
49 W. 49th Street
New York 20, New York

Dear Drs. Wataghin and Sousa Santos:

We will be delighted to have you visit us here in January and will do everything we can to assist you in your plans for a cyclotron. There will be no difficulty about visiting the laboratory housing the 60" cyclotron and I think it is quite possible by that time we may be able to take you up on the hill and show you the 184" instrument which is now under construction.

There is quite a group of us here working on cyclotron developments, particularly on frequency modulation to overcome the difficulty of increase of mass with energy and it now appears that it will be possible to reach considerably higher energies than heretofore. I think very likely these new developments will be of considerable interest to you.

Looking forward to your visit,

Sincerely yours,

Ernest O. Lawrence

EOL:EI

[51] J.L. Lopes, em: César Lattes 70 anos: a nova física brasileira, editado por A. Marques (CBPF, Rio de Janeiro, 1994), p. 72-73.

Física Teórica e Física Superior na F.N.Fi. Eis a carta que me escreveu Latt naquele ano:

Bristol 7- Março-1946

Caro amigo Leite,

Estou trabalhando no H.H.Wills Physical Laboratory da Universidade de Bristol. Cheguei há poucos dias e comecei a trabalhar com o Prof. C.F. Powell sobre o método das chapas fotográficas aplicado à física nuclear. Vamos iniciar experiências sobre o scattering neutron-proton, em condições muito melhores do que as dos trabalhos anteriores.

Lí seu trabalho, publicado na Revista da Academia Brasileira, sobre o deuteron, e estou muito interessado no seu trabalho sobre o scattering . Um dos teóricos que aqui trabalham está estudando o mesmo assunto. mostrei-lhe o trabalho do deuteron e, em particular a nota final, sobre o outro trabalho a ser publicado, e ele me pediu para ver se consigo arranjá-lo o mais cedo possível. Poderá você enviá-lo por via aérea ?

Meus parabéns pelas suas atividades nos E.E.U.U.. Faço votos para que você continúe suas pesquisas aí no Rio, apesar da falta de ambiente

(você poderá criá-lo).

Logo que tenha resultados interessantes sobre o scattering, se for permitido, comunicar-lhe-ei. Os trabalhos anteriores não tinham evidência experimental suficiente.

Minhas recomendações ao pessoal da Faculdade e um abraço do amigo

Lattes

[51] J.L. Lopes, em: César Lattes 70 anos: a nova física brasileira, editado por A. Marques (CBPF, Rio de Janeiro, 1994), p. 73-78.

Bristol 21 de Abril de 1946
H.H. Wills Physics Lab.
Royalfort

Dr. José Leite Lopes
Fundação Getulio Vargas
Núcleo de Matemática
Praia de Botafogo 186
Rio de Janeiro-Brasil

Caro Leite:

Recebi somente ontem sua carta de 27/3/46. Muito obrigado pelas informações. Vejo, com prazer, que você trabalhou "no duro"em Princeton. Ainda não pude ler com o devido cuidado o apanhado geral do seu trabalho sobre o N-P scattering e forças nucleares mas vou fazê-lo logo que tenha oportunidade, pois estou muito interessado no problema.

As experiências de Champion e Powell, de fato, confirmaram os resultados de Amaldi & Cia., mas não apresentavam evidência experimental (estatística) suficiente. Essas experiências foram repetidas por Powell, Heitler e Occhialini e as medidas estão em andamento. O n^{o} de tracks medidos até o presente momento não é suficiente para tirar-se uma conclusão segura (cerca de 900 tracks) mas toda a evidência é a favor de scattering isotrópico no sistema baricêntrico, contrariamente aos resultados anteriores. Estas novas experiências foram feitas com neutrons de 9 e 13 MeV obtidos de reações D-n provocadas pelos Deuterons do ciclotron de Liverpool. Os novos resultados merecem mais confiança do que os anteriores pois a experiência foi feita com uma técnica melhor do que no caso anterior e estão sendo

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levadas em conta todas as correções necessárias em vista da geometria da experiência. Amaldi está informado do progresso das experiências feitas aqui e creio que o grupo de Roma vai repetir as experiências que você conhece (naturwiss.). Ferretti esteve aqui para discutir os resultados mas isso foi há alguns mêses, isto é, antes de termos a atual evidência. Havia um ponto fraco nos cálculos das experiências do grupo Amaldi mas Ferretti, que é o responsável por toda a "calculeira", após três dias de verificações febrís, chegou à conclusão de que os resultados não são alterados e que está tudo O.K. Como você vê, a situação está bastante confusa e meu conselho é que será melhor, para você, ignorar os resultados experimentais até mais completa evidência. Logo que haja mais certeza avisá-lo-ei.

Eu não estou trabalhando no N-P scattering, por enquanto, pois trata-se de experiências já iniciadas há muito tempo. Logo que o Ciclotron de Liverpool esteja em condições, iniciaremos (Powell, Heitter, Occhialini e eu) o estudo do scattering de neutrons de 17 MeV da reação B+D (de 5MeV do Ciclotron). Nessa experiência usaremos um novo tipo de placa que permite uma precisão muito melhor do que com as antigas. Vou mandar-lhe separata de um artigo que vai sair dentro de poucos dias no Journal of Sc. Instr., descrevendo as "virtudes"das mesmas e que, segundo posso garantir, vai eliminar o scepticism que ainda existe em alguns meios, sobre a aplicação das chapas fotográficas aos problemas da física nuclear.

Somente um físico daqui, Ramsey, está trabalhando na parte teórica do scattering N-P. Ele está usando a teoria de Møller-Rosenfeld. Parece-me, todavia, que ele é "rather obtuse".

Meu trabalho aqui está dividido em várias partes e tem sido, por enquanto, quase que puramente experimental. Em Bristol estou estudando e desenvolvendo a técnica da medida automática nas emulsões. Iniciei, também, uma experiência para a determinação da radioatividade do Samario; trata-se de uma terra rara que emite espontaneamente partículas alfa e, segundo uma fraca evidência experimental, protons. Com as placas que tenho à disposição o problema será resolvido facilmente. Em Cambridge estou estudando reações provocadas por deuterons de 1 MeV produzidos pelo gerador de alta tensão. No momento estou interessado em "targets" leves (D,Li,Be,B,F); vou procurar esclarecer alguns pontos obscuros relativos a essas reações, ao mesmo tempo, determinar a relação energy-range para partículas alpha, protons e deuterons nas placas que serão usadas no futuro (até pouco tempo atrás, as placas foram tratadas com desprezo pela maioria dos físicos nucleares - veja relatório de Smith - agora a situação está mudando e está se preparando uma verdadeira corrida) . Vou estudar também, desintegrações produzidas por neutron na própria placa, carregando a mesma com sais de D, Li, Be, etc. Essas experiências de Cambridge serão feitas por Cuer (um físico francês que aqui chegou pouco depois de mim, para aprender a técnica das chapas) e por mim.

Em Liverpool vou tomar parte nas experiências de scattering (N-P, P-P, D-P e scattering por gases). Essas experiências serão dirigidas pelo Powell e, provavelmente, contarão com a colaboração de Chadwick. Na parte teórica estou estudando a ação das partículas nucleares nas emulsões fotográficas. Esse estudo estou fazendo em colaboração com um físico do research lab da Kodak, que está aqui pesquisando sob a orientação do Prof. Mott. Trata-se de um jóvem de grande capacidade e tenho aprendido muito com ele. Estamos estudando, também, a possibilidade de fabricar placas sensíveis a eletrons. Se isto for conseguido, será um resultado muito útil para as pesquisas sobre raios beta. Caso haja essa possibilidade, é provável que faça um estágio na fábrica Kodak em Londres, pois estou em ótimas relações com o pessoal do research lab de lá.

Como você pode ver, trabalho não falta. Mal consigo dar conta do recado. As condições de trabalho aqui são ótimas. Estou aqui a convite da Universidade de Bristol (o Occhialini conseguiu isso), recebo um ordenado mensal e tenho ampla liberdade de trabalho e iniciativa. Posso trabalhar no que mais me interessa e ficar o tempo que quiser. É uma verdadeira "mamata".

Quanto à experiência que você sugere, relativa ao inelastic scattering N-P, seria muito interessante fazê-la mas, infelizmente, não temos meios. Os neutrons mais enérgicos de que dispomos são de 17 MeV. Creio que para essa energia a porcentagem de scattering inelástico será desprezível. Seria mesmo muito difícil detectar os 3% que você calculou pois teremos background de neutrons provenientes do tank do Ciclotron, que teem um espectro contínuo. Qualquer outra sugestão que você tenha a fazer será recebida com todo o interesse por nós.

Quanto ao artigo sobre o método das chapas fotográficas, já comecei a escrevê-lo. Falei com Powell e Occhialini e é provável que seja feito em colaboração por nós três. Ficará pronto em pouco tempo, pois temos todos os dados e fotografias. Pretendo (ou pretendemos) escrever uma coisa do tipo Rev. Modern Phys. e, se não houver nada em contrário será escrito em inglês, pois muita gente estará interessada no mesmo como fonte de dados e informações. A publicação ou não desse artigo depende ainda de circunstâncias especiais mas espero que tudo se resolva dentro desta semana. As "Summas" da fundação pedem sugestões à respeito de "improvements" eventuais que possam ser feitos nas mesmas. Sugiro, e será importante para o artigo das chapas fotográficas, que se procure melhorar a reprodução fotográfica (veja boletim da Biologia, artigo do Karen) . Seria interessante se as fotografias e fotomicrografias fossem reproduzidas em papel especial (como é feito em muitas revistas científicas). Isso é particularmente importante se queremos fazer propaganda da revista de maneira a poder publicar os artigos na mesma e ter certeza de que serão lidos no estrangeiro, pois, será necessário, pelo menos no início, contar com a colaboração e interesse de alguns cientistas estrangeiros e estes não estarão muito inclinados a publicar numa revista que não tenha boa reprodução fotográfica. Outra sugestão que tenho a fazer, e que com certeza deve ter ocorrido a vocês, é que, uma vez que a Summa da fundação é a única revista de física no Brasil, seja criada na mesma a seção de cartas ao Editor ou notas prévias, cuja utilidade é bem conhecida. Já falei com o Powell e Occhialini sobre o convite para colaboradores permanentes. Eles, assim como o abaixo assinado, sentem-se honrados, aceitam e agradecem. Vou convidar, também, Rosemblum (físico francês que trabalhou no espetro de estrutura fina das partículas alfa), e outros, quando aparecer a oportunidade. Saiba me dizer se a fundação concorda.

A separata do Dirac seguirá apenas a consiga. O Mário tem uma e eu emprestei (ou dei, não me lembro) a minha ao Freire. Vou, também, lhe enviar separatas dos trabalhos de Born e Peng. Quanto aos de Powell enviar-lhe-ei um microfilme, pois estão esgotadas. Livros bons são coisa rara aquí; imagine que não consigo encontrar o Dirac, Heitler, Gamov etc. A guerra aquí deixou uma miséria miseravel.

Soube com prazer que você está na Fundação. Pelo que tive oportunidade de observar o pessoal de lá está com uma ótima orientação e animados a fazer alguma coisa séria pela Ciência no Brazil. Queira transmitir minhas recomendações aos Drs. Assiz Ribeiro, Othon Leonardos, Manoel Ferreira e Charles Javes, assim como ao pessoal do núcleo de matemática.

Ficar-lhe-ia grato se você mandasse cópia da parte da carta em que dou informações sobre as experiências do scattering N-P ao Mario, pois sei que ele está interessado no problema e prometí escrever. Pergunte a ele quais são as separatas de que mais precisa, que procurarei manda-las. Vou escrever a ele por estes dias.

A impressão que tivemos, o Occhialini e eu, é de que voce vai aguentar firme no trabalho e não se deixará influenciar pelo "clima tropical". São esses, também, os votos que fazemos. De minha parte, espero poder colaborar quando voltar, ou mesmo aqui: às ordens.

Tive uma idéia. Talvez seja muita fantasia, mas, em todo caso, lá vai. O que pensa voce de escrevermos um livro em português sobre física atomica e nuclear; dois volumes, talvez. Não há nada sobre o assunto no Brazil e parece-me que seria interessante começar. Voce poderia se encarregar da parte mais teórica e eu da parte mais experimental. Não seria uma perda de tempo, pois, escrevendo, aprenderiamos muito e teriamos muitas sugestões para pesquizas eventuais. Que tal ? Aguardo sua resposta assim como sua opinião sobre as possibilidades praticas da ideia. Naturalmente será uma coisa difícil devido ao escasso número de leitores mas não devemos esquecer Fisica Nuclear é o assunto do dia. Inicialmente poderia se publicar sob forma de apostila.

Como vai o Tiomno em S. Paulo ? Ele vai pedir bolsa para este ano ? Caso ele esteja interessado em vir para a Inglaterra, e caso ele consiga uma bolsa, diga-lhe para me escrever, pois estou em condição de dar informações sobre os melhores lugares para trabalhar aqui. Existe em S. Paulo um rapaz que está cursando o 3º ano, Hugo Camerini. Trabalhou comigo durante o ano passado e é um rapaz de talento. Peço-lhe que o ajude caso o mesmo precise de orientação. Parece que o Mario vai aos E.U. e o laboratorio de São Paulo ficaria como você sabe.

Espero para breve a notícia fatal de seu casório. Não se esqueça de comunicar. Quanto à mim, você já deve saber das novidades...sentimentais. Provavelmente você já tinha previsto.

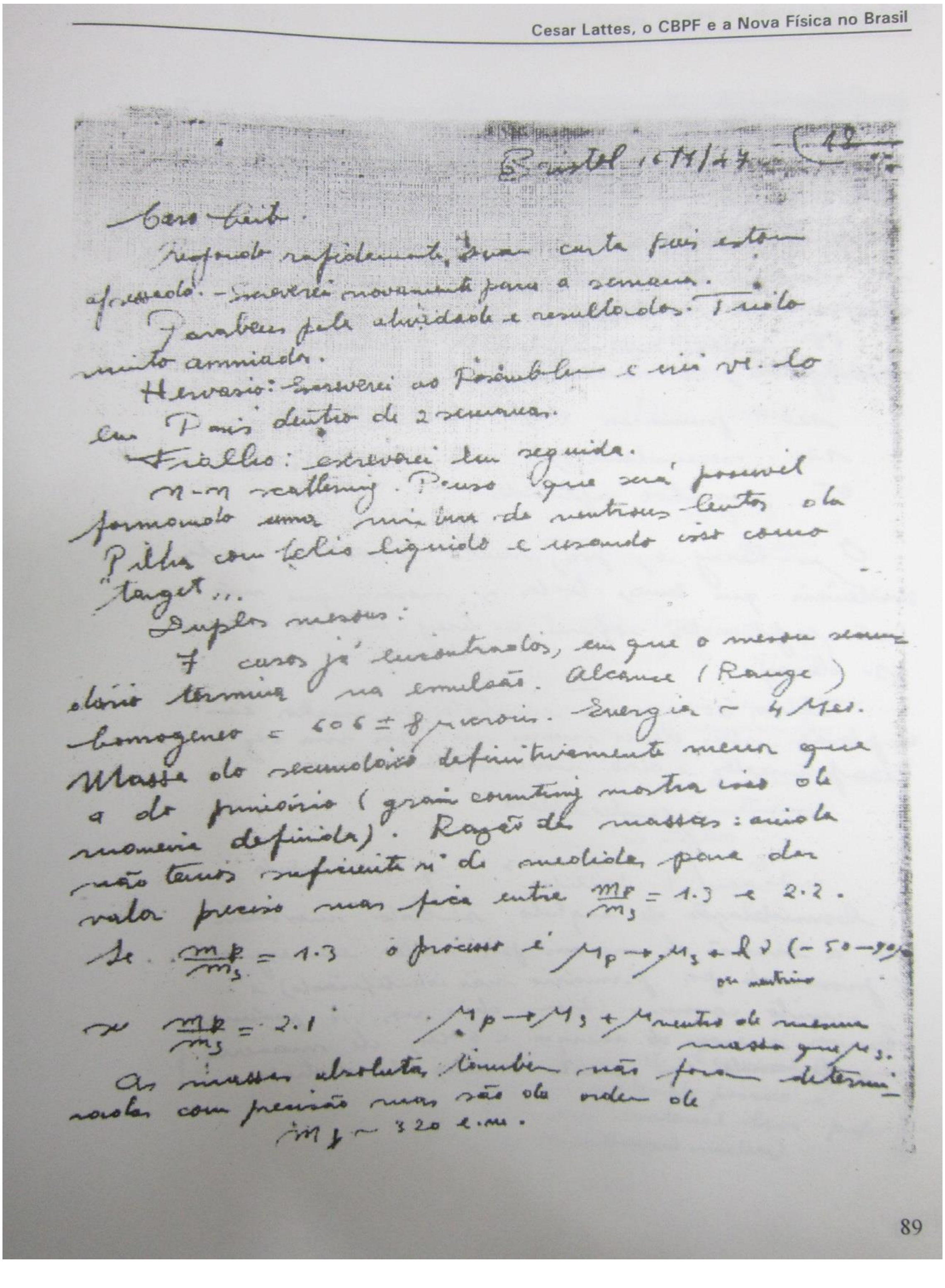
Bom. Por hoje é só.

Um abraço de seu amigo

Cesar Lattes

P.S. Para conseguir colaboração estrangeira é indispensável melhorar a reprodução fotográfica. A promessa de rápida publicação dos trabalhos deverá ser mantida rigorosamente.

[51] J.L. Lopes, em: César Lattes 70 anos: a nova física brasileira, editado por A. Marques (CBPF, Rio de Janeiro, 1994), p. 89-92.



Cesar Lattes, o CBPF e a Nova Física no Brasil

Bristol 16/4/47

Caro Leite.

Respondo rapidamente sua carta pois estou afobado. — Escreverei novamente para a semana.

Parabens pela atividade e resultados. Tudo muito animado.

Hervasio: Escreverei ao Rosenblum e irei vê-lo em Paris dentro de 2 semanas.

Fialho: escreverei em seguida.

n-n scattering. Penso que será possível formando uma mistura de neutrons lentos da Pilha com helio liquido e usando isso como "target"...

Duplos mesons:

7 casos já encontrados, em que o meson secundário termina na emulsão. Alcance (Range) homogeneo = 606 ± 8 microns. Energia ~ 4 Mev.

Massa do secundário definitivamente menor que a do primário (grain counting mostra isso de maneira definida). Razão de massas: ainda não temos suficiente nº de medidas para dar valor preciso mas fica entre $\frac{m_p}{m_s} = 1.3$ e 2.2.

Se $\frac{m_p}{m_s} = 1.3$ o processo é $\mu_p \to \mu_s + h\nu$ (~50–90%) ou neutrino

se $\frac{m_p}{m_s} = 2.1$ $\mu_p \to \mu_s + \mu_{neutro}$ de mesma massa que μ_s.

As massas absolutas também não foram determinadas com precisão mas são da ordem de $m_p \sim 320$ e.m.

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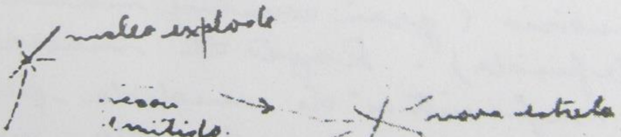
Em 400 mesons que terminam nas emulsões 7 teem secundário maior que 600μ (espessura da emulsão 50μ e 100μ). Considerações de angulo solido mostram que esses 7 correspondem na realidade a ≈120 duplos meson (com mesmo o processo de μ-decay).

85 mesons são capturados por nucleos e os desintegram, de maneira que dos 400μ temos

120 primarios (π) → π-meson
120 secundários (μ) } μ-meson
85 negativos capturados

O μ-decay é, pois, muito commum e, pela evidência que temos, todos os mesons que não são capturados sofrem μ-decay antes de darem β-decay.

Temos 10 mesons emitidos por nucleos em explosão, dois desses mesons são por sua vez capturados e dão nova estrela:



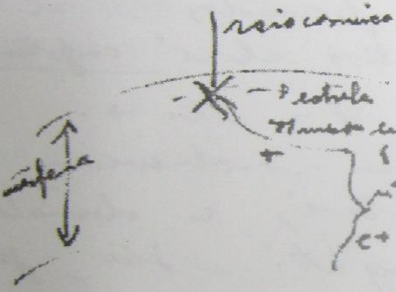
Considerações de angulo sólido mostram que a emissão de mesons por nucleos em explosão (provocada por primário não identificado) é muito commum. Além disso nós só podemos observar mesons de energia < 6 Mev, de maneira que, levando em conta o angulo solido e o espectro de energia (supondo-o, p. ex., conforme ....) — verifica-se que em 1ª aproximação, mesons são emitidos por nucleos, sempre que haja energia suficiente para isso.

Simples calculo mostra que os mesons que observamos terminar na placa são produzidos pelo material mesmo da placa. Não há lugar para mesons(π) provindo da atmosfera, o que indica que a vida é bem mais curta que 2×10^{-6} seg (10^4 cm).

X ———— X

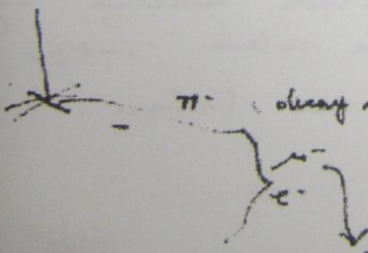
Nossa teoria por enquanto é a seguinte:

a) positivo π



(10^{-6} seg) constitue a componente dura dos raios cosmicos em baixa altitude. É o meson das exp. de Conversi et al e tem fraca interação com os nucleos

b) negativo π



este é o meson de Conversi, que quando para em material pesado é capturado e em material leve prefere decair (fraca interação nuclear)

(2)

c) negativo

• se o π meson para antes de desintegrar, ele é sempre capturado (forte interação)

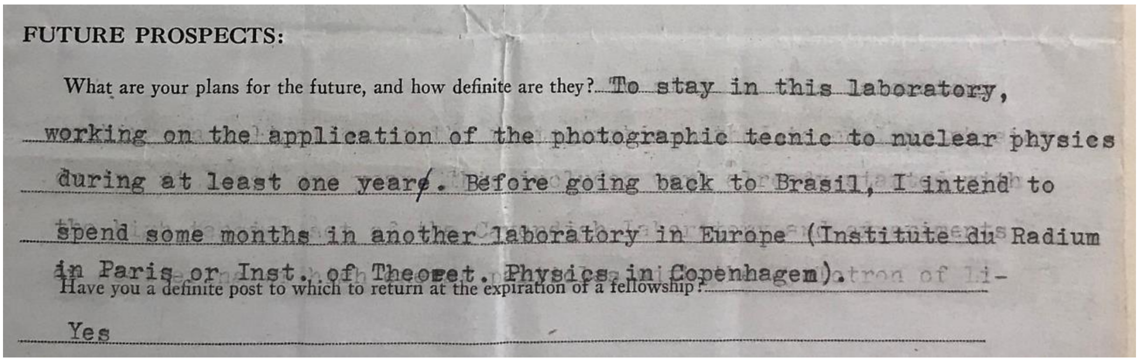
c) Explica porque nossos μ mesons não dão estrelas apesar de serem + e − (Conversi), enquanto que Conversi acha que π são capturados, se o material de stopping é pesado. De fato, os μ mesons que observamos são devidos a decay de π parados e se o π que para é negativo ele é capturado, de maneira que nossos μ são +. Por outro lado, Conversi observou μ de energia considerável, isto é, μ devidos a decay de $\pi^{+ \text{ ou } -}$ em flight. São, pois, + e −.

Duvido que o que escrevi acima seja compreensível, mas dará uma ideia. Logo mandarei cópia do trabalho à sair em Nature.

Escreva

Lattes

[64] Personal History and application for a fellowship (Rockefeller Archive Center, Sleepy Hollow, 1946), número localizador 244, caixa 81, pasta 1541.



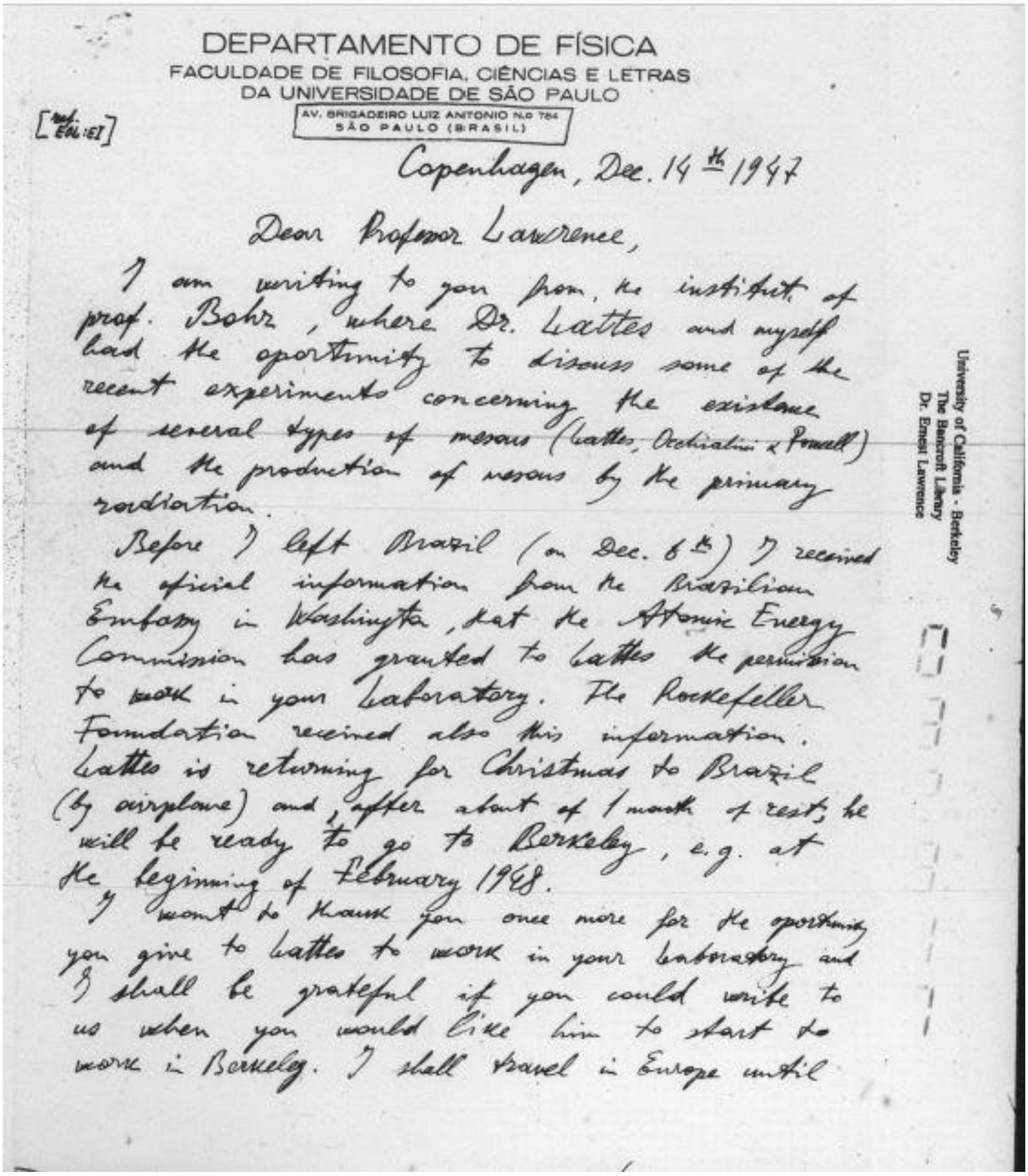
FUTURE PROSPECTS:

What are your plans for the future, and how definite are they? To stay in this laboratory, working on the application of the photographic tecnic to nuclear physics during at least one year. Before going back to Brasil, I intend to spend some months in another laboratory in Europe (Institute du Radium in Paris or Inst. of Theoret. Physics in Copenhagem).

Have you a definite post to which to return at the expiration of a fellowship?

Yes

[76] G. Wataghin para E. Lawrence (The Bancroft Library, University of California, Berkeley, 1947), correspondência, rolo 15, caixa 10, pasta 35.



DEPARTAMENTO DE FÍSICA
FACULDADE DE FILOSOFIA, CIÊNCIAS E LETRAS
DA UNIVERSIDADE DE SÃO PAULO
AV. BRIGADEIRO LUIZ ANTONIO N.o 784
SÃO PAULO (BRASIL)

Copenhagen, Dec. 14th 1947

Dear Professor Lawrence,

I am writing to you from the institute of prof. Bohr, where Dr. Lattes and myself had the oportunity to discuss some of the recent experiments concerning the existence of several types of mesons (Lattes, Occhialini & Powell) and the production of mesons by the primary radiation.

Before I left Brazil (on Dec. 6th) I received the oficial information from the Brazilian Embassy in Washington, that the Atomic Energy Commission has granted to Lattes the permission to work in your Laboratory. The Rockefeller Foundation received also this information. Lattes is returning for Christmas to Brazil (by airplane) and, after about of 1 month of rest, he will be ready to go to Berkeley, e.g. at the beginning of February 1948.

I want to thank you once more for the oportunity you give to Lattes to work in your laboratory and I shall be grateful if you could write to us when you would like him to start to work in Berkeley. I shall travel in Europe until

DEPARTAMENTO DE FÍSICA
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DA UNIVERSIDADE DE SÃO PAULO
AV. BRIGADEIRO LUIZ ANTONIO N.o 784
SÃO PAULO (BRASIL)

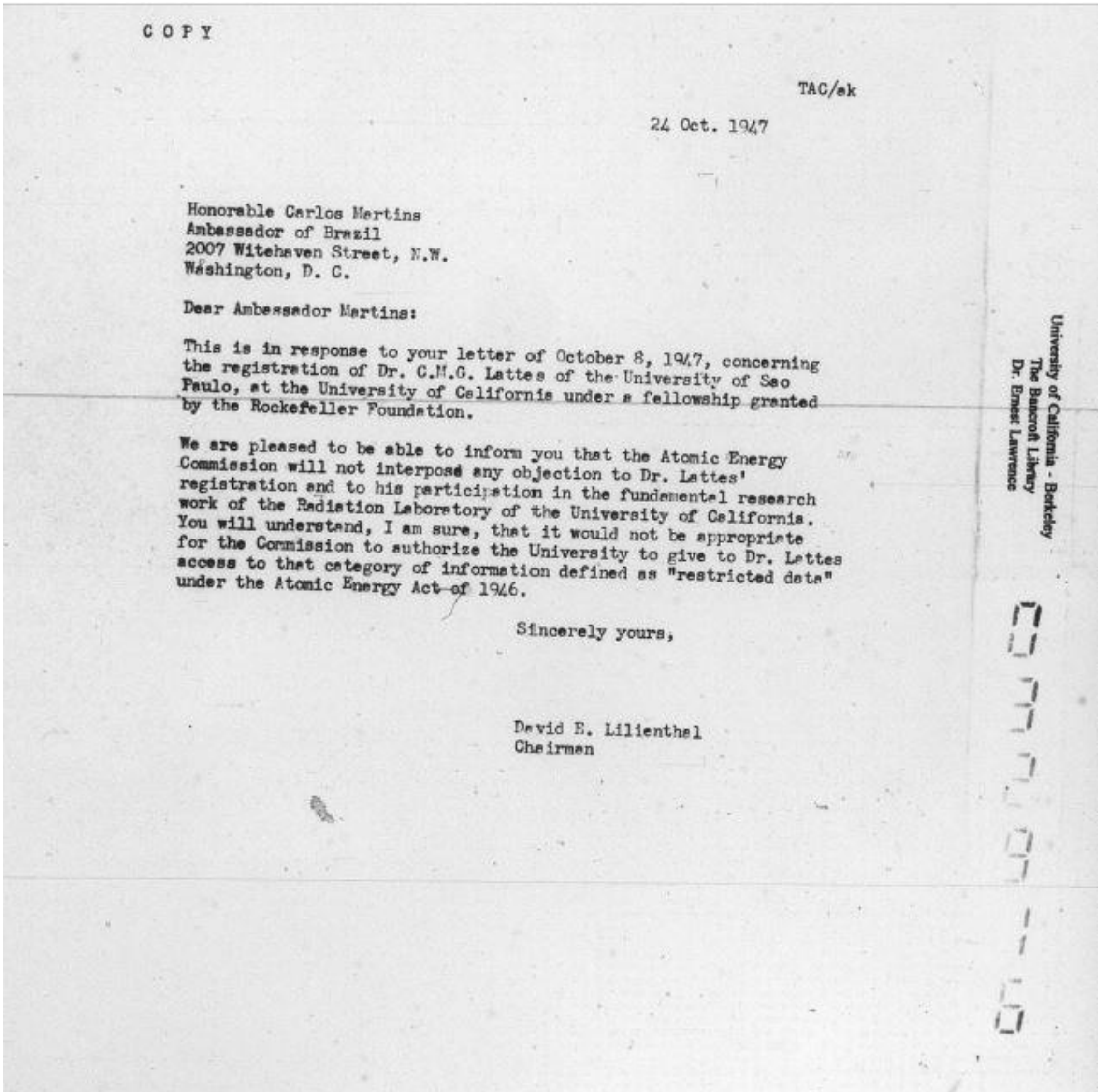
February 15th, so I take the liberty to ask if you could write directly to C. Lattes at the adress of our Department of physics in S. Paulo. I took already the necessary steps in order that the brasilian authorities (the Rector and the Dean of our Faculty) give to Lattes the permission to stay abroad for more one year as a fellow of the Rockefeller Foundation.

Lattes and myself are both really happy about the possibilities of work he will have in Berkeley, and we both are sending to you our best wishes for Merry Christmas and Happiest New Year.

Yours very cordially
Gleb Wataghin

Professor Ernest O. Lawrence
Radiation Laboratory
Berkeley 4, California.

[77] D. Lilienthal para C. Martins (The Bancroft Library, University of California, Berkeley, 1947), correspondência, rolo 15, caixa 10, pasta 35.



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TAC/ak

24 Oct. 1947

Honorable Carlos Martins
Ambassador of Brazil
2007 Witehaven Street, N.W.
Washington, D. C.

Dear Ambassador Martins:

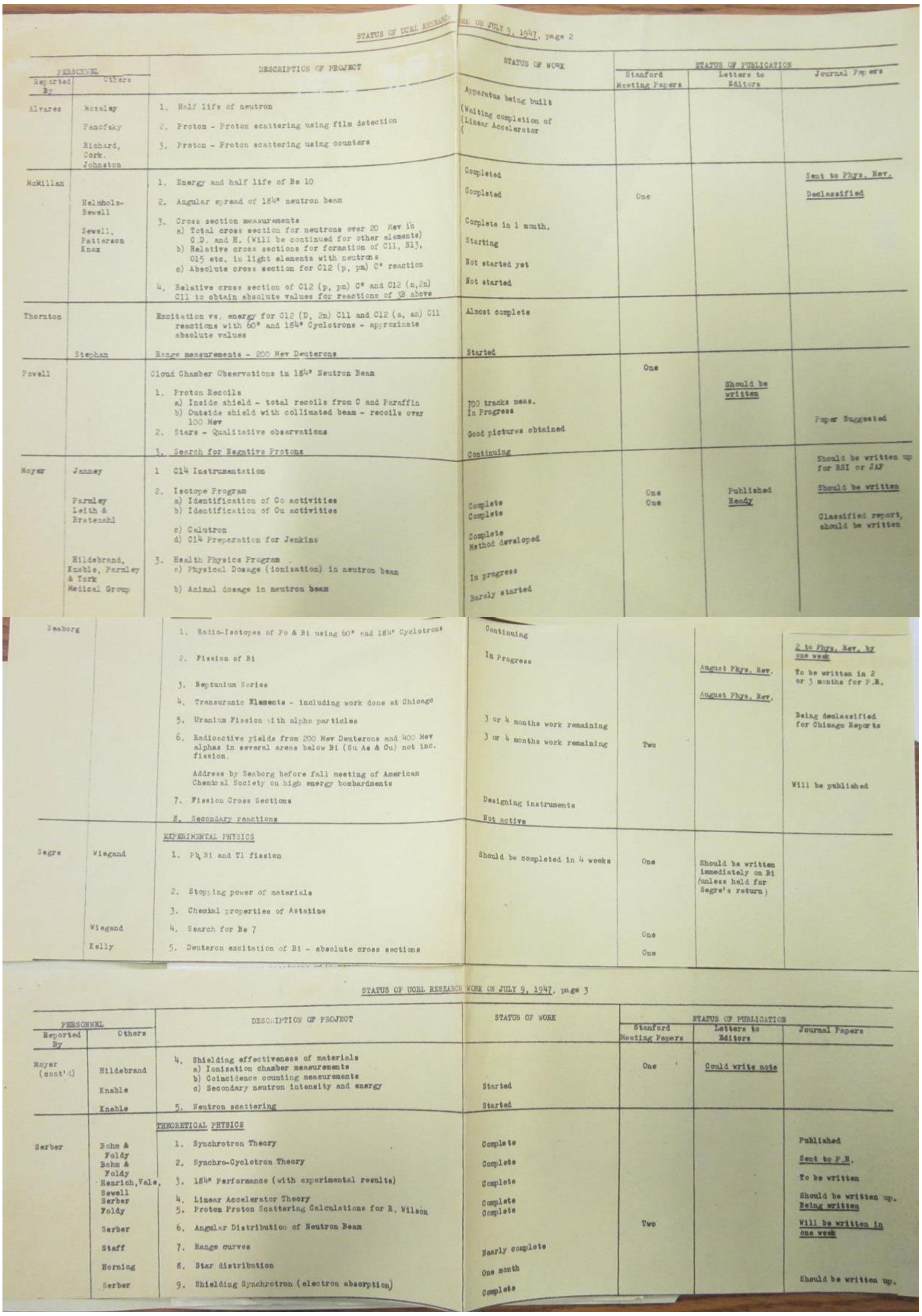
This is in response to your letter of October 8, 1947, concerning the registration of Dr. C.M.G. Lattes of the University of Sao Paulo, at the University of California under a fellowship granted by the Rockefeller Foundation.

We are pleased to be able to inform you that the Atomic Energy Commission will not interpose any objection to Dr. Lattes' registration and to his participation in the fundamental research work of the Radiation Laboratory of the University of California. You will understand, I am sure, that it would not be appropriate for the Commission to authorize the University to give to Dr. Lattes access to that category of information defined as "restricted data" under the Atomic Energy Act of 1946.

Sincerely yours,

David E. Lilienthal
Chairman

[78] *Status of the UCRL research work on July 09* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), caixa 1, pasta: 6 Photoemulsion method of meson detection.



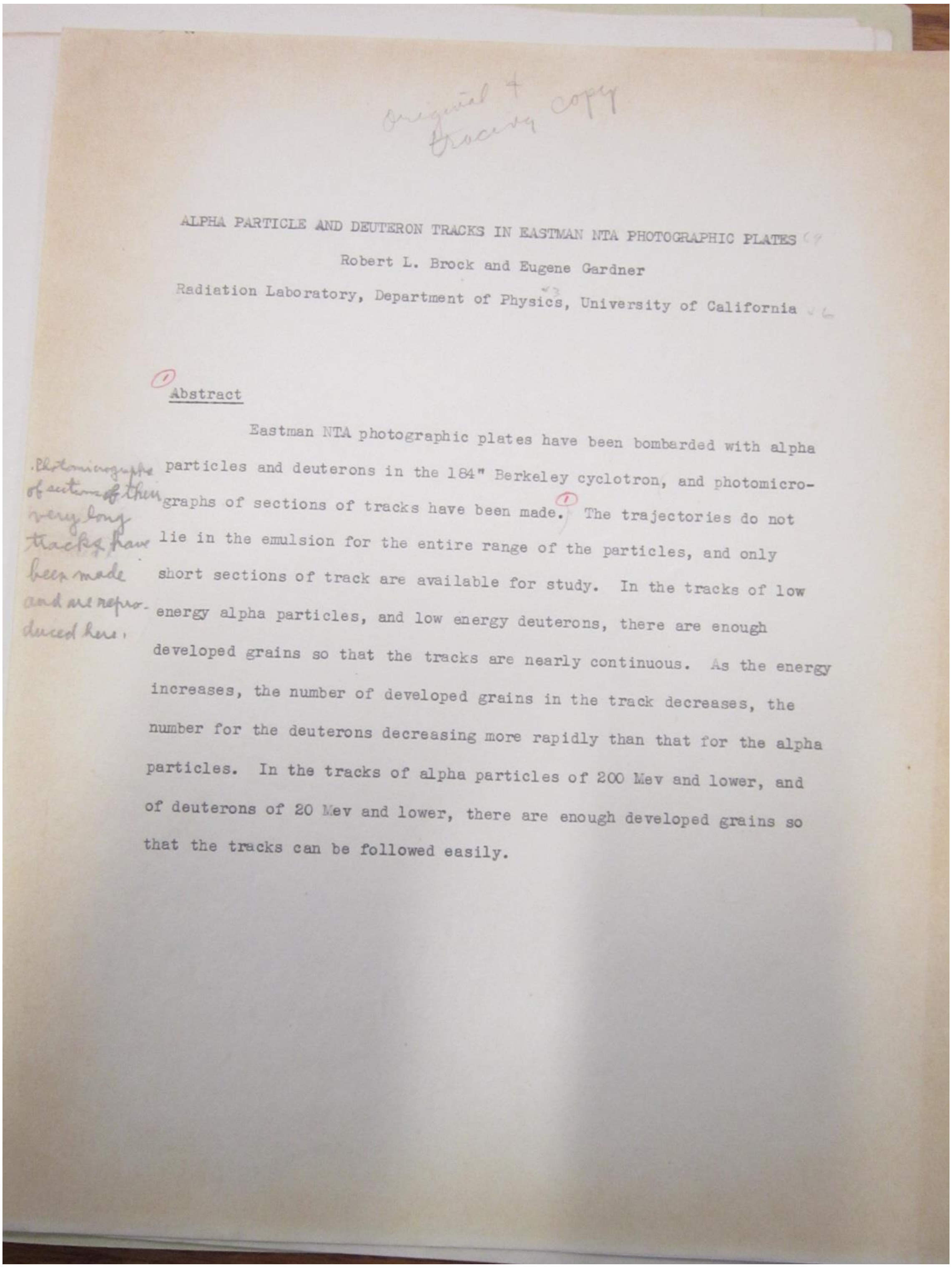
STATUS OF UCRL RESEARCH WORK ON JULY 9, 1947, page 2

PERSONNEL Reported By	Others	DESCRIPTION OF PROJECT	STATUS OF WORK	STATUS OF PUBLICATION Stanford Meeting Papers	Letters to Editors	Journal Papers
Alvarez	Moseley	1. Half life of neutron	Apparatus being built			
	Panofsky	2. Proton - Proton scattering using film detection	(Waiting completion of (Linear Accelerator			
	Richard, Cork, Johnston	3. Proton - Proton scattering using counters	(			
McMillan		1. Energy and half life of Be 10	Completed			Sent to Phys. Rev.
	Helmholz-Sewell	2. Angular spread of 184" neutron beam	Completed	One		Declassified
	Sewell, Patterson Knox	3. Cross section measurements a) Total cross section for neutrons over 20 Mev in C.D. and H. (Will be continued for other elements)	Complete in 1 month.			
		b) Relative cross sections for formation of C11, N13, O15 etc. in light elements with neutrons	Starting			
		c) Absolute cross section for C12 (p, pn) C* reaction	Not started yet			
		4. Relative cross section of C12 (p, pn) C* and C12 (n,2n) C11 to obtain absolute values for reactions of 3B above	Not started			
Thornton		Excitation vs. energy for C12 (D, 2n) C11 and C12 (a, an) C11 reactions with 60" and 184" Cyclotrons - approximate absolute values	Almost complete			
	Stephan	Range measurements - 200 Mev Deuterons	Started			
Powell		Cloud Chamber Observations in 184" Neutron Beam		One		
		1. Proton Recoils a) Inside shield - total recoils from C and Paraffin b) Outside shield with collimated beam - recoils over 100 Mev	700 tracks meas. In Progress		Should be written	
		2. Stars - Qualitative observations	Good pictures obtained			Paper Suggested
		3. Search for Negative Protons	Continuing			
Moyer	Janney	1 C14 Instrumentation				Should be written up for RSI or JAP
	Parmley Leith & Bratenahl	2. Isotope Program a) Identification of Co activities	Complete	One	Published	Should be written
		b) Identification of Cu activities	Complete	One	Ready	
		c) Calutron	Complete			Classified report, should be written
		d) C14 Preparation for Jenkins	Method developed			
	Hildebrand, Knable, Parmley & York Medical Group	3. Health Physics Program a) Physical Dosage (ionization) in neutron beam	In progress			
		b) Animal dosage in neutron beam	Barely started			
Seaborg		1. Radio-Isotopes of Po & Bi using 60" and 184" Cyclotrons	Continuing			2 to Phys. Rev. by one week
		2. Fission of Bi	In Progress		August Phys. Rev.	To be written in 2 or 3 months for P.R.
		3. Neptunium Series			August Phys. Rev.	
		4. Transuranic Elements - including work done at Chicago				Being declassified for Chicago Reports
		5. Uranium Fission with alpha particles	3 or 4 months work remaining			
		6. Radioactive yields from 200 Mev Deuterons and 400 Mev alphas in several areas below Bi (Su As & Cu) not inc. fission.	3 or 4 months work remaining	Two		
		Address by Seaborg before fall meeting of American Chemical Society on high energy bombardments				Will be published
		7. Fission Cross Sections	Designing instruments			
		8. Secondary reactions	Not active			
		EXPERIMENTAL PHYSICS				
Segre	Wiegand	1. Pb, Bi and Tl fission	Should be completed in 4 weeks	One	Should be written immediately on Bi (unless held for Segre's return)	
		2. Stopping power of materials				
		3. Chemical properties of Astatine				
	Wiegand	4. Search for Be 7		One		
	Kelly	5. Deuteron excitation of Bi - absolute cross sections		One		

STATUS OF UCRL RESEARCH WORK ON JULY 9, 1947, page 3

PERSONNEL Reported By	Others	DESCRIPTION OF PROJECT	STATUS OF WORK	STATUS OF PUBLICATION Stanford Meeting Papers	Letters to Editors	Journal Papers
Moyer (cont'd)	Hildebrand	4. Shielding effectiveness of materials a) Ionization chamber measurements b) Coincidence counting measurements		One	Could write note	
	Knable	c) Secondary neutron intensity and energy	Started			
	Knable	5. Neutron scattering	Started			
		THEORETICAL PHYSICS				
Serber	Bohm & Foldy	1. Synchrotron Theory	Complete			Published
	Bohm & Foldy	2. Synchro-Cyclotron Theory	Complete			Sent to P.R.
	Henrich, Vale, Sewell	3. 184" Performance (with experimental results)	Complete			To be written
	Serber	4. Linear Accelerator Theory	Complete			Should be written up.
	Foldy	5. Proton Proton Scattering Calculations for R. Wilson	Complete			Being written
	Serber	6. Angular Distribution of Neutron Beam		Two		Will be written in one week
	Staff	7. Range curves	Nearly complete			
	Horning	8. Star distribution	One month			
	Serber	9. Shielding Synchrotron (electron absorption)	Complete			Should be written up.

[79] *Alpha Particles and Deuterons Tracks in Eastman NTA Photographic Plates* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno), caixa 1, pasta: Typescripts of publications and correspondence Robert L. Brock.



ALPHA PARTICLE AND DEUTERON TRACKS IN EASTMAN NTA PHOTOGRAPHIC PLATES

Robert L. Brock and Eugene Gardner

Radiation Laboratory, Department of Physics, University of California

Abstract

Eastman NTA photographic plates have been bombarded with alpha particles and deuterons in the 184" Berkeley cyclotron, and photomicrographs of sections of tracks have been made. The trajectories do not lie in the emulsion for the entire range of the particles, and only short sections of track are available for study. In the tracks of low energy alpha particles, and low energy deuterons, there are enough developed grains so that the tracks are nearly continuous. As the energy increases, the number of developed grains in the track decreases, the number for the deuterons decreasing more rapidly than that for the alpha particles. In the tracks of alpha particles of 200 Mev and lower, and of deuterons of 20 Mev and lower, there are enough developed grains so that the tracks can be followed easily.

ALPHA PARTICLE AND DEUTERON TRACKS IN EASTMAN NTA PHOTOGRAPHIC PLATES

Robert L. Brock* and Eugene Gardner

Radiation Laboratory, Department of Physics, University of California

Photographic plates[1] have been bombarded with high energy alpha

(2) [1]For references to work on the use of photographic plates as charged particle detectors up to 1941, see review article by Maurice M. Shapiro, R.M.P. 13, 58 (1941). For references to more recent work, see C. F. Powell and G. P. S. Occhialini, Nuclear Physics in Photographs (Clarendon Press, Oxford, 1947). (2)

particles and deuterons in the 184" Berkeley cyclotron[2] for the purpose

[2]W. M. Brobeck, E. O. Lawrence, et al. Phys. Rev. 71, 449 (1947)

of studying stars in the emulsion produced by high energy particles. (3) 3, 4, 5 (3a) Although the primary objective of the program was the study of stars, the plates afforded an opportunity for observation of the alpha particle and deuteron tracks, and in this paper these tracks will be described in order to illustrate the applicability and to show the limitations of the photographic plate method of detecting high energy charged particles. (3a)

Description of results

(4) The plates are exposed in the cyclotron with the plane of the emulsion approximately tangent to the beam trajectories. When the developed plates are viewed under the microscope it is seen that some tracks enter from the edge of the emulsion, and some come in from the top or bottom. Most of the particles leave the emulsion before they stop, so that only sections of tracks are available. Although the sections of tracks can be followed through many fields of view under the microscope, the actual

Because the range is so much greater than the thickness ... in various parts of their range

start / start at and some start at the bottom showing that the particles have come in from the glass support.

*Now at the University of Washington, Seattle, Washington lengths are rather short, seldom over a few millimeters in length. If a section of track is close to the edge where the beam first strikes the emulsion, it is assumed that the energy of the particle causing the track is the same as the energy of the beam particles at that radius. By placing plates at various radii, it is possible to obtain bombardments by particles of any energy up to the maximum available from the cyclotron. This maximum energy is about 380 Mev for alpha particles and 190 Mev for deuterons.[3]

Table I shows the ranges for various energies of α rays and of deuterons (which may amount to as much as several mm of emulsion)

Table I

[3] Walter Stephan and R. L. Thornton, To be published

(4) It is possible to find tracks which stop in the emulsion, but when these tracks are followed in the direction of higher energy, it is found that most of them leave the emulsion within a millimeter or so of the low energy end. Sometimes the high energy ends of deuteron tracks are lost in the general background of developed grains before they leave the emulsion. A group of six alpha particle tracks and six deuteron tracks whose low energy ends lie in the emulsion are shown in Fig. 1. The tracks have been arranged so that their low energy ends are at the zero on the scale. Tracks of length greater than 0.8 mm are shown in two sections, both the tracks and the scale being broken at the 0.8 mm point. The plate from which these tracks were taken was exposed at a position in the cyclotron corresponding to 20 per cent of the full energy available. The particle trajectories did not, however, lie in the emulsion for their entire range, and the sections of tracks shown in Fig. 1 correspond to energies of the order of 60 Mev for the alpha particles and 20 Mev for the deuterons. Sections of some of the tracks shown in Fig. 1 are shown on a larger scale in Fig. 2. The sections shown in Fig. 2 are at a distance of about 0.4 mm from the low energy ends of the tracks.

Max energy

Grain densities. (5) The grain densities (i.e., number of grains per unit length) of the tracks shown in Fig. 1 have been plotted in Fig. 3. On the basis of studies of this kind, it is often possible to distinguish between the two types of tracks, since the points corresponding to the alpha particle tracks lie above those for the deuteron tracks. For long tracks which stop in the emulsion, it is easy to distinguish between alpha particle and deuteron tracks. If a track does not stop in the emulsion, however, one does not know where on the abscissa scale the grain density values are to be plotted, and it may not be possible to identify the track, particularly if only a small section of track is available. (6) In studies which involve tracks in random directions (e.g., studies of particles from stars in photographic emulsions) a large fraction of the sections of track observed may be too short to enable one to identify the particle causing the track. (6)

It might be expected that the grain density as shown in Fig. 3 would be proportional to the rate of energy loss of the particle causing the track, and this is probably true for portions of tracks where the grain density is ~~very~~ low. As the rate of energy loss becomes larger and larger, more and more grains in the path are rendered developable, but this cannot go on indefinitely because there are only a fixed number of grains along the path, and when all of these grains have been rendered developable, the grain density cannot increase any more no matter how large the rate of energy loss becomes. Thus, for portions of the track where the grains are close together, the grain density is not a good measure of the rate of energy loss.

Maximum energy recorded. (7)

In the low energy ends of both alpha particle and deuteron tracks there are enough developed grains so that the tracks are nearly continuous, as can be seen in Fig. 1. As the energy increases, the number of developed grains in the track decreases, as shown in Fig. 3. At very high energies, there are so few developed grains that the tracks become lost in the general background of developed grains. It is hard to give a definite value for the energy above which tracks cannot be followed, because grain density required for following a track depends to such a great extent on the background of developed grains. If a plate is given a heavy exposure (i.e., is exposed to a large number of high energy particles) there may be so many developed grains on the plate that no individual tracks can be seen. On the other hand, if the plate has been given a very light exposure, it may be possible to follow tracks which consist of a very few developed grains. We have, at times, seen tracks on plates exposed to alpha particles at the full energy of the cyclotron, but this is only possible when the exposure is extremely light. (7) For tracks of very small grain density, local fluctuations in the grain density become important, and the eye will catch those tracks which have a few more grains than the average, and miss those which have a few less. Thus it is often possible to see tracks when it is not possible to count them accurately. In the tracks of alpha particles of 200 Mev and lower, and of deuterons of 20 Mev and lower, the tracks are continuous enough so that they can be followed easily, and they can be counted without much danger of missing any. Sections of tracks found in a plate exposed to 200 Mev alpha particles are shown in Fig. 4. In this figure, several alpha particle tracks are seen in the same field of view.

(8) All of the tracks shown in Fig. 1 were taken from the same plate, and the tracks shown in Fig. 4 were taken from a plate of the same emulsion number (i.e., same manufacturer's batch). Although we have exposed several hundred Eastman NTA plates on the cyclotron, nearly all of them have been of this same emulsion number. We are informed by Eastman Kodak Company that for NTA plates, as well as for other photographic materials, it is recommended that experimenters using these plates for quantitative work calibrate each emulsion of different emulsion number that they use. (8)

, as regards stopping power & maximum energy recorded?

Ackn. Other types of plates. (9)

Ilford Nuclear Research plates[7] are being used in experiments on

[7] Powell, Occhialini, Livesey and Chilton, J. Sci. Instr. 23, 102 (1946)

the 184" cyclotron, and we have had opportunity to observe alpha particle and deuteron tracks in various types of these plates. In Ilford B.1 and C.2 plates we have been able to follow deuteron tracks at higher energies than in Eastman NTA plates, but not at energies approaching the maximum available from the cyclotron. The work with these plates, as well as the work with the Eastman NTA plates was done in the spring of 1947, and since that time new types of plates have been developed. The Ilford type B.2 has superseded type B.1, and the Eastman NTB plates have been added to the NTA plates. We have not had enough experience with these new types of plates to be able to comment on them at this time. However, the manufacturers are aware of the need for plates which will record high energy deuterons, and it is to be expected that more sensitive plates have been, or will be, developed. (10) These more sensitive plates will [probably] not be suitable for distinguishing between alpha particle and deuteron tracks, [from grain counts] because both low energy alpha particles and low energy deuterons will render developable practically all of the grains in the track. (10)

Proton tracks. (11)

No experimental data on proton tracks has been presented in this paper. It was easier to study alpha particles and deuterons, since the 184" cyclotron is arranged to accelerate these particles. Information obtained from the deuterons can be applied to proton tracks, since protons and deuterons of the same velocity produce very closely the same grain density.[8]

[8] T. R. Wilkins and H. J. St. Helens, Phys. Rev. 54, 783 (1938)

Still a comparison of the mean curvature of the tracks, which [is] greater for [the] deuteron, [m]ay allow the distinction to be made. See fig 1

-7-

Thus we would expect the tracks of 10 Mev protons to have about the same grain density as the tracks of 20 Mev deuterons.

Acknowledgements (12)

The authors wish to express their appreciation to Professor Ernest O. Lawrence for his continued interest in this problem. We are indebted to Professor R. L. Thornton for helpful discussions. We also wish to thank Mr. A. J. Oliver for photographic work, Mr. Duane Sewell and the cyclotron crew for bombarding the plates, and the Eastman Kodak Company for information regarding Eastman NTA plates.

This paper is based on work performed under contract W-7405-Eng-48, with the Atomic Energy Commission, in connection with the Radiation Laboratory, University of California, Berkeley, California.

(13) Fig. 1.- Alpha particle and deuteron tracks formed in Eastman NTA photographic plate. (3-mm apochromatic objective lens.) (13)

Fig. 2.- Enlarged sections of tracks shown in Fig. 1.

Fig. 3.- Grain densities of tracks shown in Fig. 1.

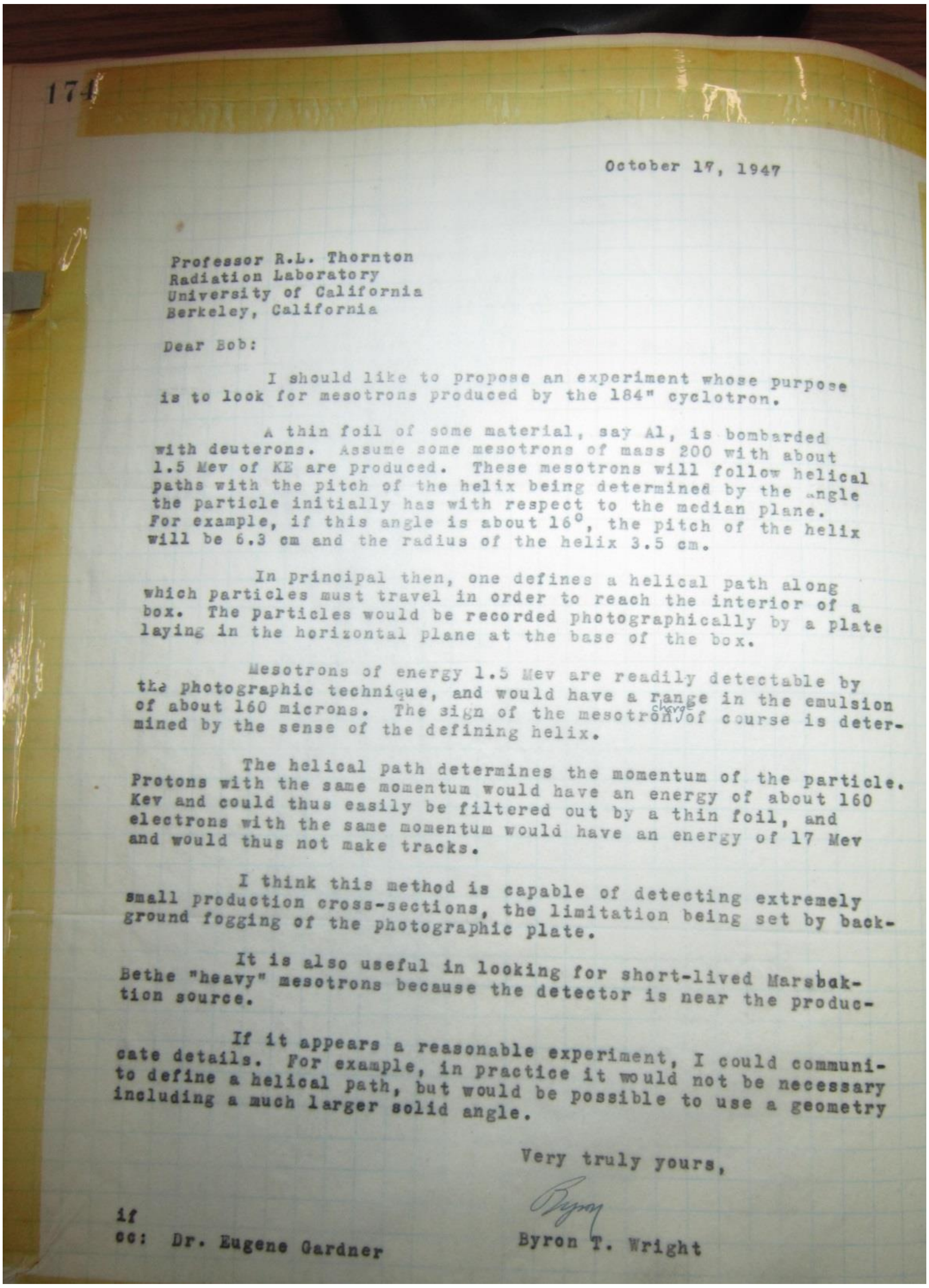
Fig. 4.- Sections of tracks taken from Eastman NTA plate exposed to 200 Mev alpha particles. (3 mm apochromatic objective lens.)

265   265   [illegible]

assembled from 250 prints from 250 negatives of photomicrographs. The grain density decreases from end (0.0 mm) to beginning. The grain densities are greater, and the tracks are more nearly straight for α rays.

Would the authors care to draw a representative curve through each series of points?

[80] B. Wright para R. Thornton (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), correspondência, caixa 5, livro 09, página174.



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October 17, 1947

Professor R.L. Thornton
Radiation Laboratory
University of California
Berkeley, California

Dear Bob:

I should like to propose an experiment whose purpose is to look for mesotrons produced by the 184" cyclotron.

A thin foil of some material, say Al, is bombarded with deuterons. Assume some mesotrons of mass 200 with about 1.5 Mev of KE are produced. These mesotrons will follow helical paths with the pitch of the helix being determined by the angle the particle initially has with respect to the median plane. For example, if this angle is about 16^{0}, the pitch of the helix will be 6.3 cm and the radius of the helix 3.5 cm.

In principal then, one defines a helical path along which particles must travel in order to reach the interior of a box. The particles would be recorded photographically by a plate laying in the horizontal plane at the base of the box.

Mesotrons of energy 1.5 Mev are readily detectable by the photographic technique, and would have a range in the emulsion of about 160 microns. The sign of the mesotron charge of course is determined by the sense of the defining helix.

The helical path determines the momentum of the particle. Protons with the same momentum would have an energy of about 160 Kev and could thus easily be filtered out by a thin foil, and electrons with the same momentum would have an energy of 17 Mev and would thus not make tracks.

I think this method is capable of detecting extremely small production cross-sections, the limitation being set by background fogging of the photographic plate.

It is also useful in looking for short-lived Marshak-Bethe "heavy" mesotrons because the detector is near the production source.

If it appears a reasonable experiment, I could communicate details. For example, in practice it would not be necessary to define a helical path, but would be possible to use a geometry including a much larger solid angle.

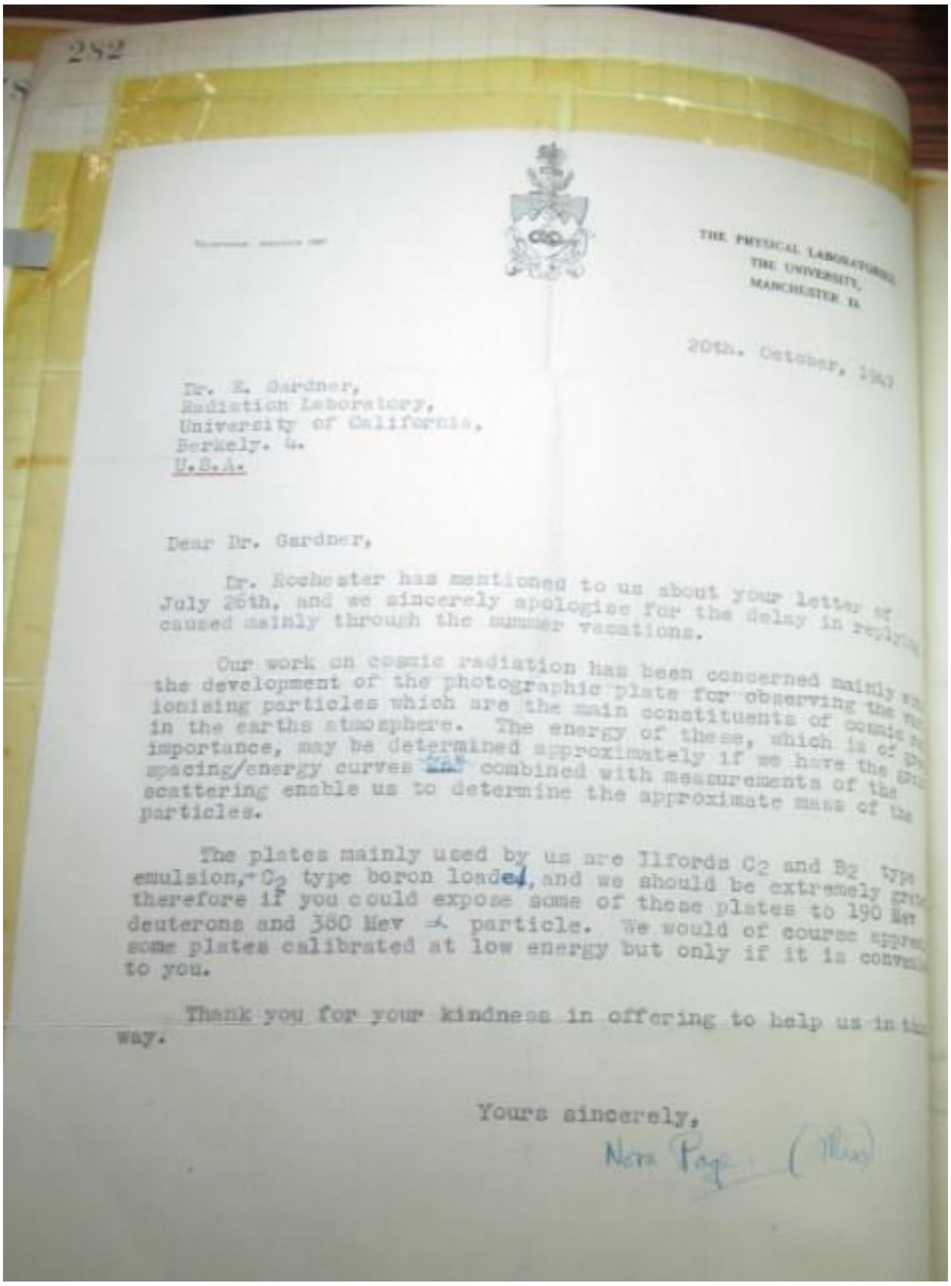
Very truly yours,

Byron

Byron T. Wright

lf
cc: Dr. Eugene Gardner

[81] N. Page para E. Gardner (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), correspondência, caixa 5, livro 09, página 282.



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THE PHYSICAL LABORATORIES,
THE UNIVERSITY,
MANCHESTER 13

20th. October, 1947

Dr. E. Gardner,
Radiation Laboratory,
University of California,
Berkely. 4.
U.S.A.

Dear Dr. Gardner,

Dr. Rochester has mentioned to us about your letter of July 26th, and we sincerely apologise for the delay in replying caused mainly through the summer vacations.

Our work on cosmic radiation has been concerned mainly with the development of the photographic plate for observing the [illegible] ionising particles which are the main constituents of cosmic [illegible] in the earths atmosphere. The energy of these, which is of [illegible] importance, may be determined approximately if we have the [illegible] spacing/energy curves [illegible] combined with measurements of the scattering enable us to determine the approximate mass of the particles.

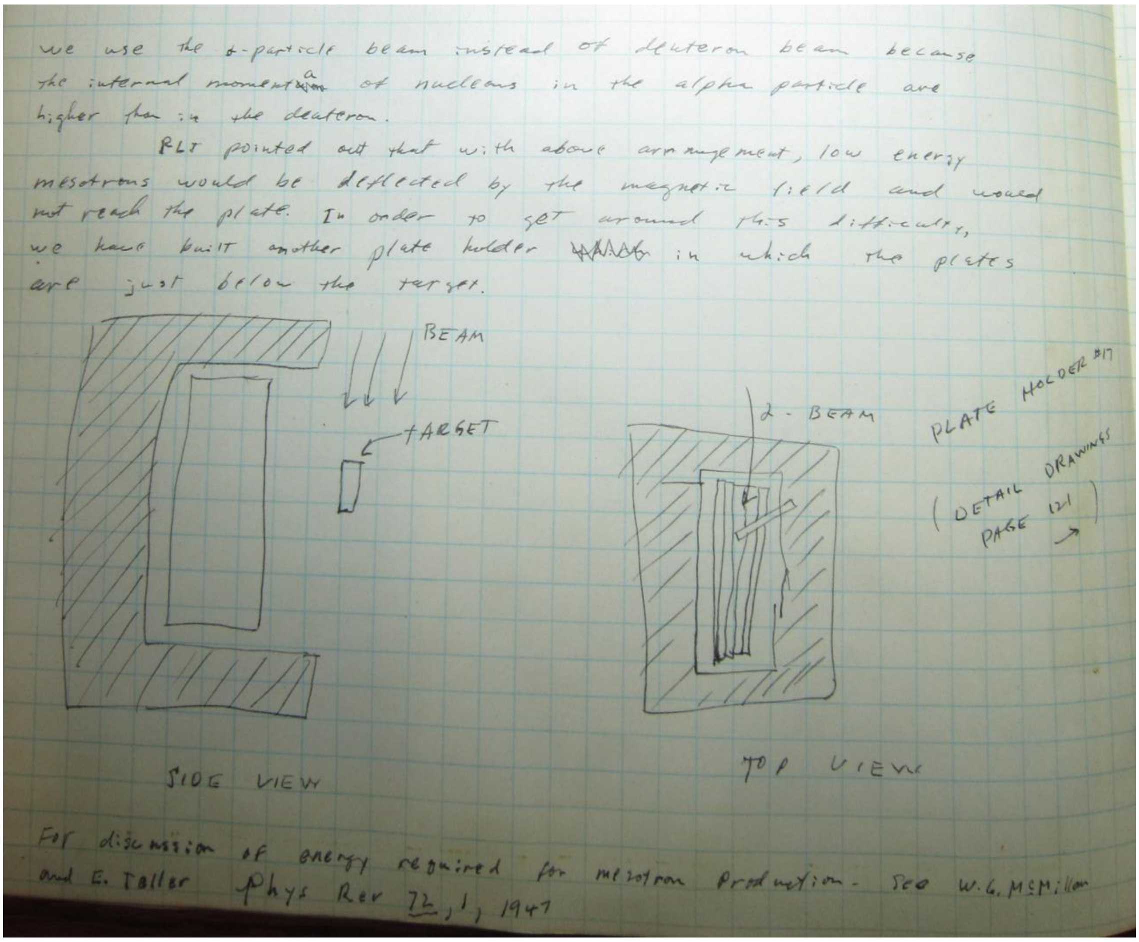
The plates mainly used by us are Ilfords C_2 and B_2 type emulsion, C_2 type boron loaded, and we should be extremely [illegible] therefore if you could expose some of these plates to 190 Mev deuterons and 380 Mev α particle. We would of course [illegible] some plates calibrated at low energy but only if it is [illegible] to you.

Thank you for your kindness in offering to help us in this way.

Yours sincerely,

Nora Page (Miss)

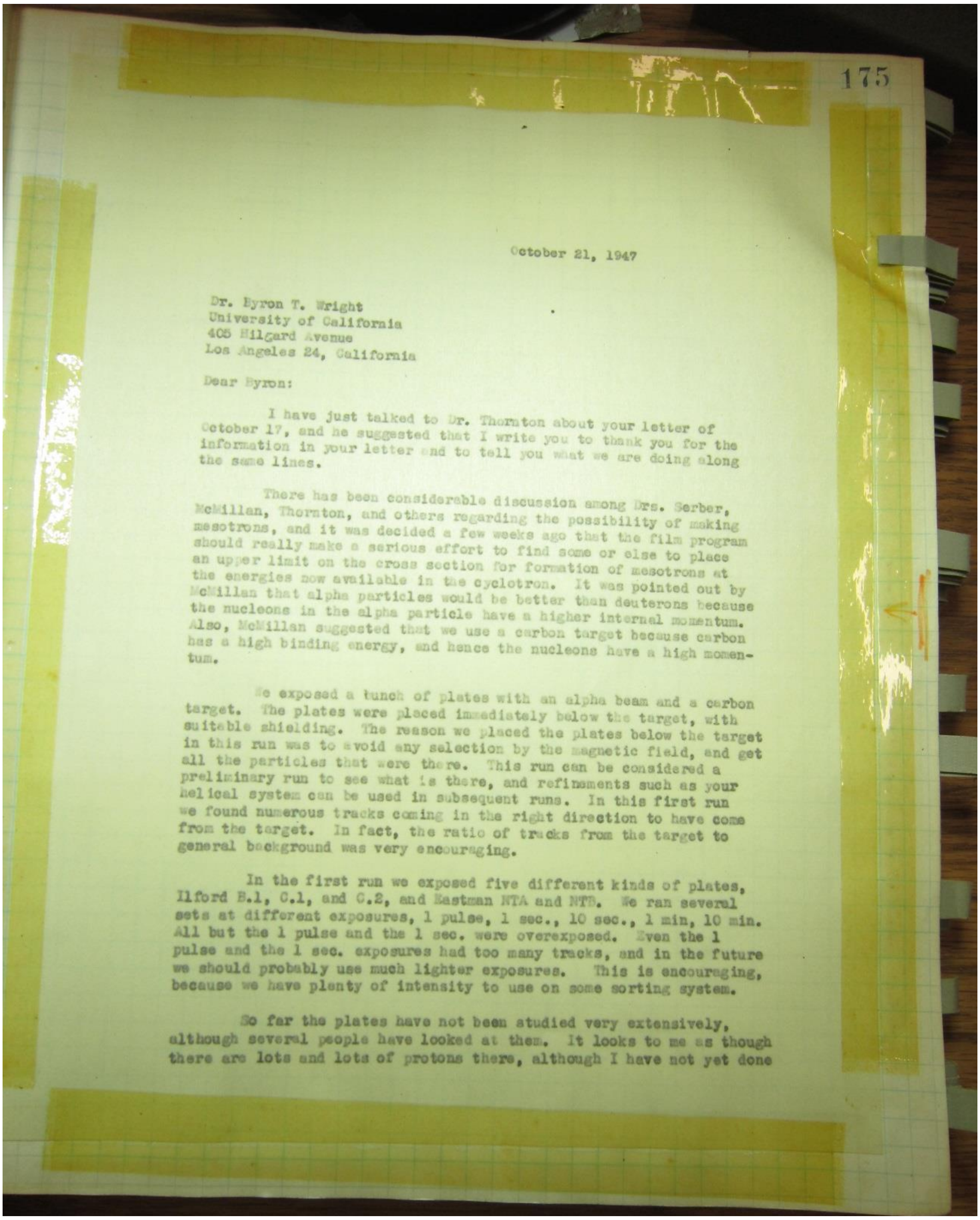
[82] *[Arranjo do aparato sugerido por E. McMillan, desenhado por E. Gardner, para tentar capturar mésons]* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), caixa 5, livro 9, página 120.


we use the α-particle beam instead of deuteron beam because the internal momenta of nucleons in the alpha particle are higher than in the deuteron.

RLT pointed out that with above arrangement, low energy mesotrons would be deflected by the magnetic field and would not reach the plate. In order to get around this difficulty, we have built another plate holder [illegible] in which the plates are just below the target.

For discussion of energy required for mesotron production - See W. G. McMillan and E. Teller Phys Rev 72, 1, 1947

[83] E. Gardner para B. Wright (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), correspondência, caixa 5, livro 09, página 175.



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October 21, 1947

Dr. Byron T. Wright
University of California
405 Hilgard Avenue
Los Angeles 24, California

Dear Byron:

I have just talked to Dr. Thornton about your letter of October 17, and he suggested that I write you to thank you for the information in your letter and to tell you what we are doing along the same lines.

There has been considerable discussion among Drs. Serber, McMillan, Thornton, and others regarding the possibility of making mesotrons, and it was decided a few weeks ago that the film program should really make a serious effort to find some or else to place an upper limit on the cross section for formation of mesotrons at the energies now available in the cyclotron. It was pointed out by McMillan that alpha particles would be better than deuterons because the nucleons in the alpha particle have a higher internal momentum. Also, McMillan suggested that we use a carbon target because carbon has a high binding energy, and hence the nucleons have a high momentum.

We exposed a bunch of plates with an alpha beam and a carbon target. The plates were placed immediately below the target, with suitable shielding. The reason we placed the plates below the target in this run was to avoid any selection by the magnetic field, and get all the particles that were there. This run can be considered a preliminary run to see what is there, and refinements such as your helical system can be used in subsequent runs. In this first run we found numerous tracks coming in the right direction to have come from the target. In fact, the ratio of tracks from the target to general background was very encouraging.

In the first run we exposed five different kinds of plates, Ilford B.1, C.1, and C.2, and Eastman NTA and NTB. We ran several sets at different exposures, 1 pulse, 1 sec., 10 sec., 1 min, 10 min. All but the 1 pulse and the 1 sec. were overexposed. Even the 1 pulse and the 1 sec. exposures had too many tracks, and in the future we should probably use much lighter exposures. This is encouraging, because we have plenty of intensity to use on some sorting system.

So far the plates have not been studied very extensively, although several people have looked at them. It looks to me as though there are lots and lots of protons there, although I have not yet done

Page Two
Dr. Byron T. Wright
Los Angeles, California

October 21, 1947

any grain count to tell for sure. The exposures on these plates are really too heavy to make them very good for study, and I think that we will run some more plates before doing any very serious looking.

Bob Thornton has worked out some of the details of helix trajectories in connection with proton-proton scattering. I think that they decided not to use them in proton-proton scattering, but his calculations might be a good start on calculation of some helix trajectories for mesotron study.

We have just sent a paper on grain density to the Review of Scientific Instruments for publication. I am sending you a copy for your files.

Very best regards to Reg and Ken, and to Lorna.

Yours truly,

EG:ck

Eugene Gardner

Enclosure

cc: R. L. Thornton
E. M. McMillan
R. Serber

[84] Film Program (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), caixa 5, livro 09, página 211.

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Film Program. October, 1947.

Recent theoretical work[1,2] indicates that there is a possibility of making mesotrons at the energies now available from the 184" cyclotron. The cross sections predicted, however, are so small (e.g., 10^{-30} cm^2) that the mesotrons might not have been observed even though they are being made. Some preliminary work is now being done on a program which is designed to detect the mesotrons or to set a definite upper limit on the cross section for production. In this program we plan to use photographic plates as detectors and to identify the mesotrons by the change in grain space of the tracks. From the cosmic ray photographs published by Powell and Occhialini[3], it seems clear that mesotrons can be identified by this technique.

We are looking first for negative mesotrons because these can be separated from protons and alpha particles by a magnetic field. The method used in a preliminary run was to place the photographic plates at a greater radius than the target, in such a position that particles from the target cannot reach the photographic plates unless they are bent by the magnetic field in the direction appropriate to a negative charge. Thus the protons and alpha particles from the target do not reach the plates. There are, however, numerous tracks on the plates caused by the neutron background.

In the first run, the plates were close to the target, in a position to receive low energy mesotrons. This position is convenient because all of the apparatus can be mounted on the probe. Also, it is in a region of fairly uniform magnetic field. A search for higher energy mesotrons will probably require more elaborate apparatus. No indication of mesotron production has so far been found.

[1] W. G. McMillan and E. Teller, Phys. Rev. 72, 1 (1947)

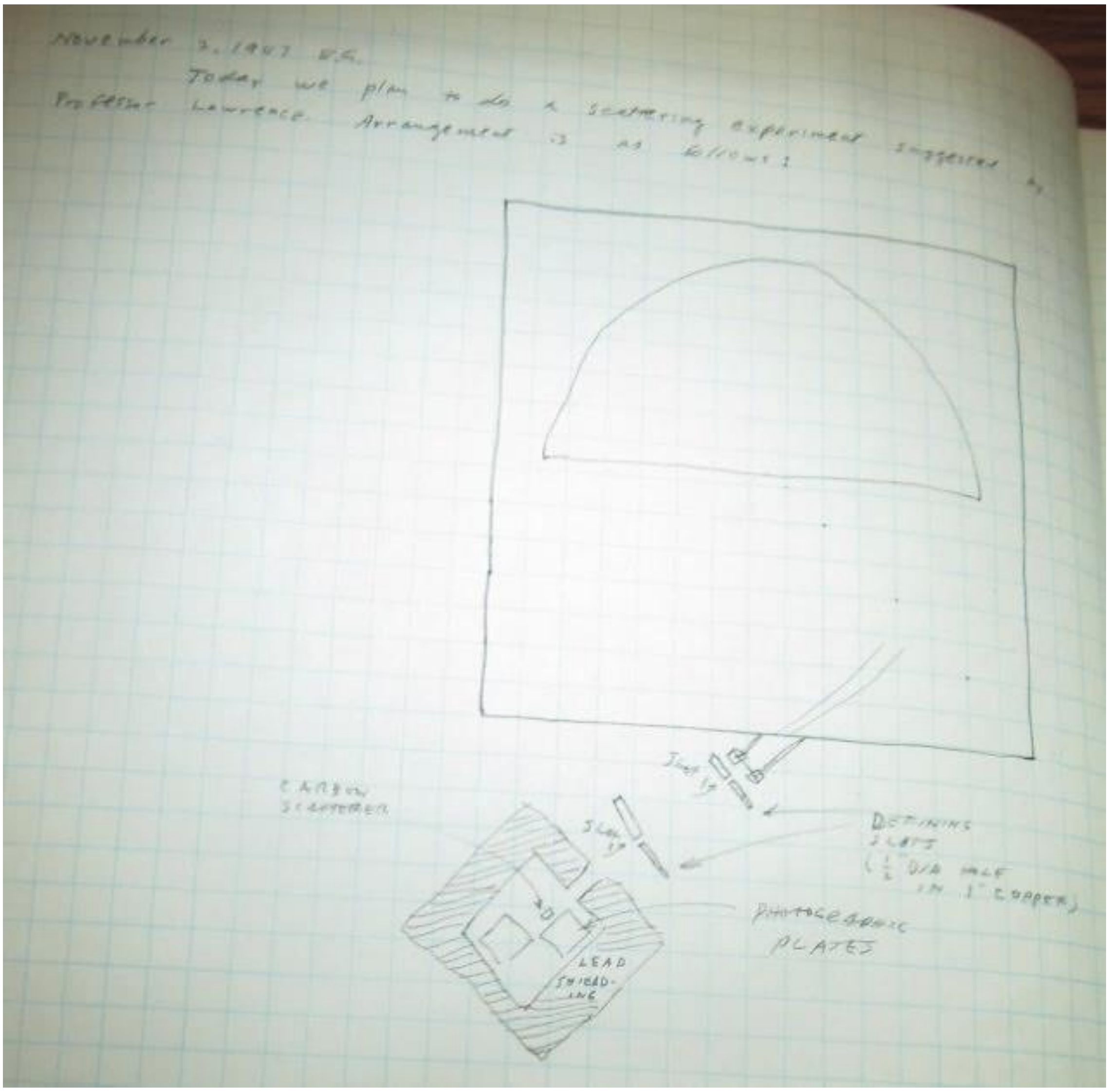
[2] W. Horning and M. Weinstein, Phys. Rev. 72, 251 (1947)

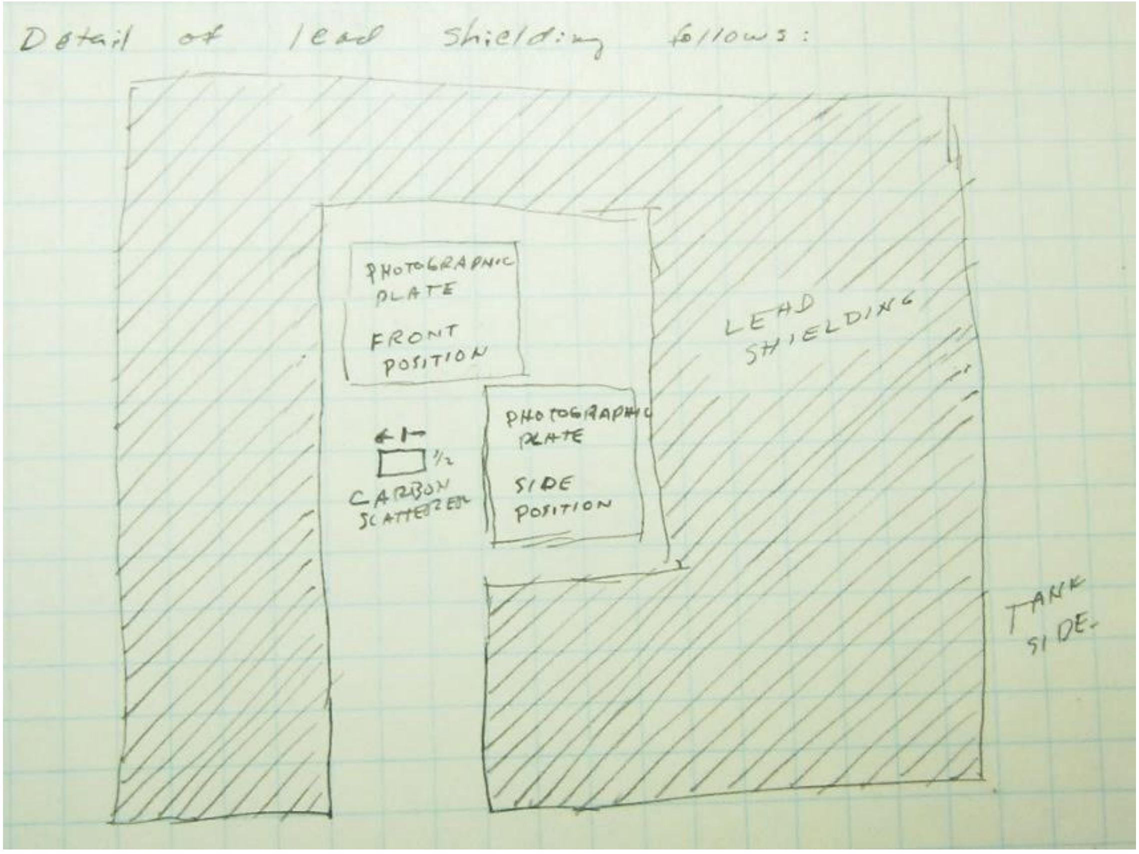
[3] C. F. Powell and G. P. S. Occhialini, Nuclear Physics in Photographs (Clarendon Press, Oxford, 1947)

10-30-47 EG

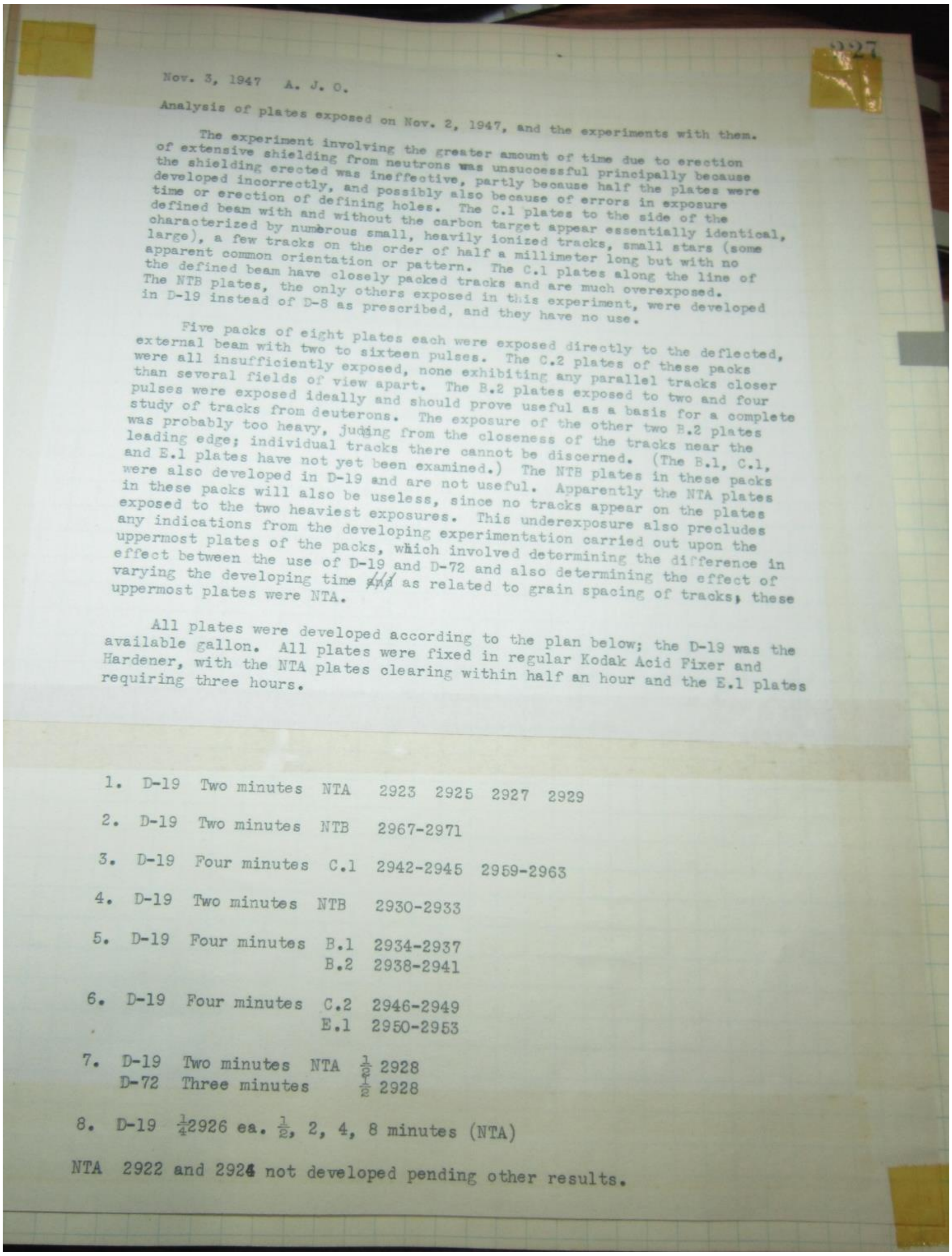
Distribution:
R. L. Thornton
R. Serber
Wilson Powell
Films Log

[85] *[Experimento sugerido por Ernest Lawrence]* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), caixa 5, livro 09, página 221.




Detail of lead shielding follows:
PHOTOGRAPHIC PLATE
FRONT POSITION
PHOTOGRAPHIC PLATE
SIDE POSITION
1/2
CARBON SCATTERER
LEAD SHIELDING
TANK SIDE

[86] *Analysis of plates exposed on Nov. 03, 1947, and the experiment with them* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), caixa 5, livro 09, página 227.



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Nov. 3, 1947 A. J. O.

Analysis of plates exposed on Nov. 2, 1947, and the experiments with them.

The experiment involving the greater amount of time due to erection
of extensive shielding from neutrons was unsuccessful principally because
the shielding erected was ineffective, partly because half the plates were
developed incorrectly, and possibly also because of errors in exposure
time or erection of defining holes. The C.1 plates to the side of the
defined beam with and without the carbon target appear essentially identical,
characterized by numerous small, heavily ionized tracks, small stars (some
large), a few tracks on the order of half a millimeter long but with no
apparent common orientation or pattern. The C.1 plates along the line of
the defined beam have closely packed tracks and are much overexposed.
The NTB plates, the only others exposed in this experiment, were developed
in D-19 instead of D-8 as prescribed, and they have no use.

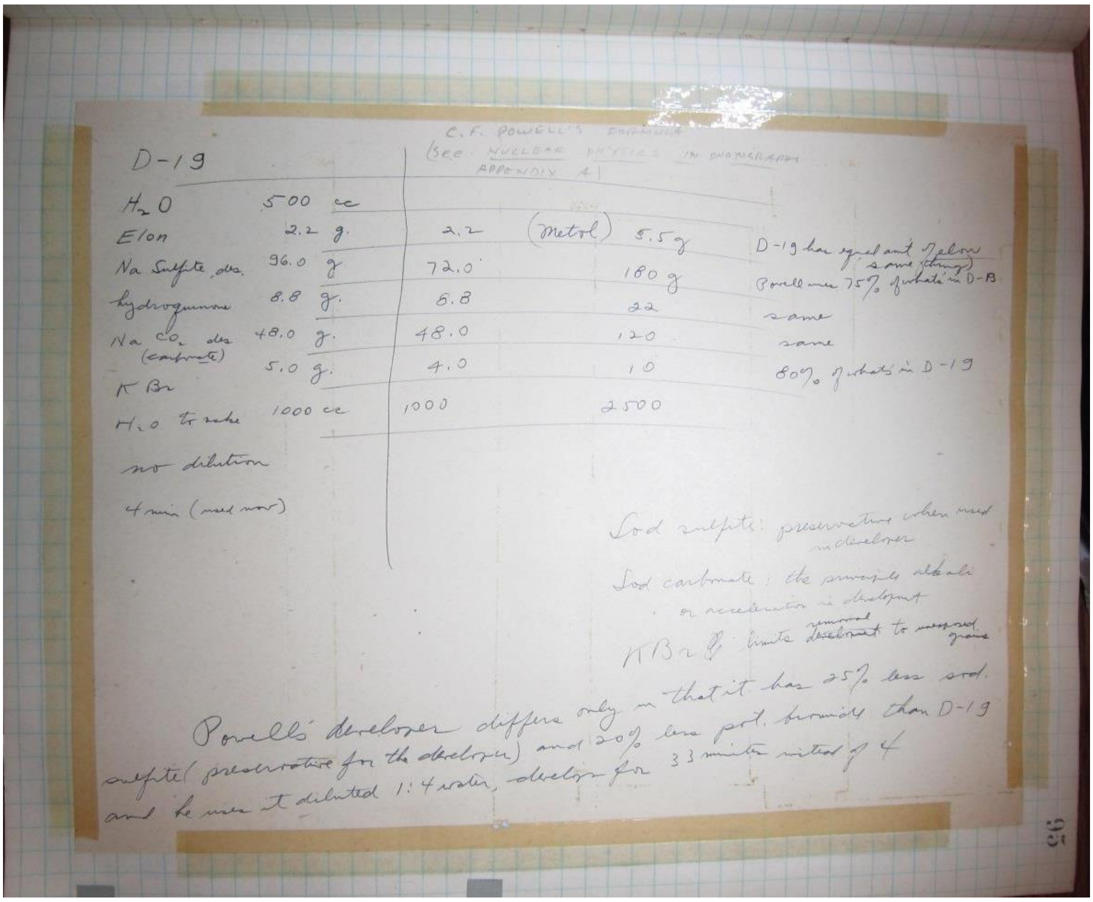
Five packs of eight plates each were exposed directly to the deflected,
external beam with two to sixteen pulses. The C.2 plates of these packs
were all insufficiently exposed, none exhibiting any parallel tracks closer
than several fields of view apart. The B.2 plates exposed to two and four
pulses were exposed ideally and should prove useful as a basis for a complete
study of tracks from deuterons. The exposure of the other two B.2 plates
was probably too heavy, judging from the closeness of the tracks near the
leading edge; individual tracks there cannot be discerned. (The B.1, C.1,
and E.1 plates have not yet been examined.) The NTB plates in these packs
were also developed in D-19 and are not useful. Apparently the NTA plates
in these packs will also be useless, since no tracks appear on the plates
exposed to the two heaviest exposures. This underexposure also precludes
any indications from the developing experimentation carried out upon the
uppermost plates of the packs, which involved determining the difference in
effect between the use of D-19 and D-72 and also determining the effect of
varying the developing time ~~and~~ as related to grain spacing of tracks; these
uppermost plates were NTA.

All plates were developed according to the plan below; the D-19 was the
available gallon. All plates were fixed in regular Kodak Acid Fixer and
Hardener, with the NTA plates clearing within half an hour and the E.1 plates
requiring three hours.

1. D-19 Two minutes NTA 2923 2925 2927 2929
2. D-19 Two minutes NTB 2967-2971
3. D-19 Four minutes C.1 2942-2945 2959-2963
4. D-19 Two minutes NTB 2930-2933
5. D-19 Four minutes B.1 2934-2937
   B.2 2938-2941
6. D-19 Four minutes C.2 2946-2949
   E.1 2950-2953
7. D-19 Two minutes NTA $\frac{1}{2}$ 2928
   D-72 Three minutes $\frac{1}{2}$ 2928
8. D-19 $\frac{1}{4}$2926 ea. $\frac{1}{2}$, 2, 4, 8 minutes (NTA)

NTA 2922 and 2924 not developed pending other results.

[87] *[Nota escrita à mão por Eugene Gardner sobre os procedimentos adotados por Cecil Powell para revelar emulsões fotográficas]* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), caixa 6, livro 10, página 95.



C. F. POWELL'S FORMULA
(SEE NUCLEAR PHYSICS IN PHOTOGRAPHY APPENDIX A)

D-19				
H_2O	500 cc			
Elon	2.2 g.	2.2	(metol) 5.5 g	D-19 has equal amt of elon (same thing)
Na Sulfite, des.	96.0 g	72.0	180 g	Powell uses 75% of what's in D-13
hydroquinone	8.8 g.	6.8	22	same
Na CO_2 des (carbonate)	48.0 g.	48.0	120	same
K Br	5.0 g.	4.0	10	80% of what's in D-19
H_2O to make	1000 cc	1000	2500	

no dilution

4 min (used now)

Sod sulfite: preservative when used in developer

Sod carbonate: the principle alkali or accelerator in development

KBr [illegible] limits removal to exposed grains

Powell's developer differs only in that it has 25% less sod. sulfite (preservative for the developer) and 20% less pot. bromide than D-19 and he uses it diluted 1:4 water, develop for 33 minutes instead of 4

[88] Film Program (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), caixa 6, livro 10, página 88.

Film Program. December, 1947

Search for Mesotrons

Work has continued on the search for mesotrons produced in the 184" cyclotron using photographic plates as detectors (see Progress Report, Film Program, October, 1947). The installation of the proton tube in the cyclotron makes available protons of energy considerably higher than the 95 Mev per nucleon previously available in the alpha particle beam. One experiment was done with a 1/16" carbon target placed in position to receive incident protons of energy 160 Mev. Photographic plates were placed at various radii on both sides of the target in order to record either positive or negative mesotrons over a considerable energy range. The plates show a rather high neutron background. The equipment for use in the proton tube is being redesigned in an effort to reduce the neutron background. No evidence of mesotron production has yet been found.

12-23-47 JWB

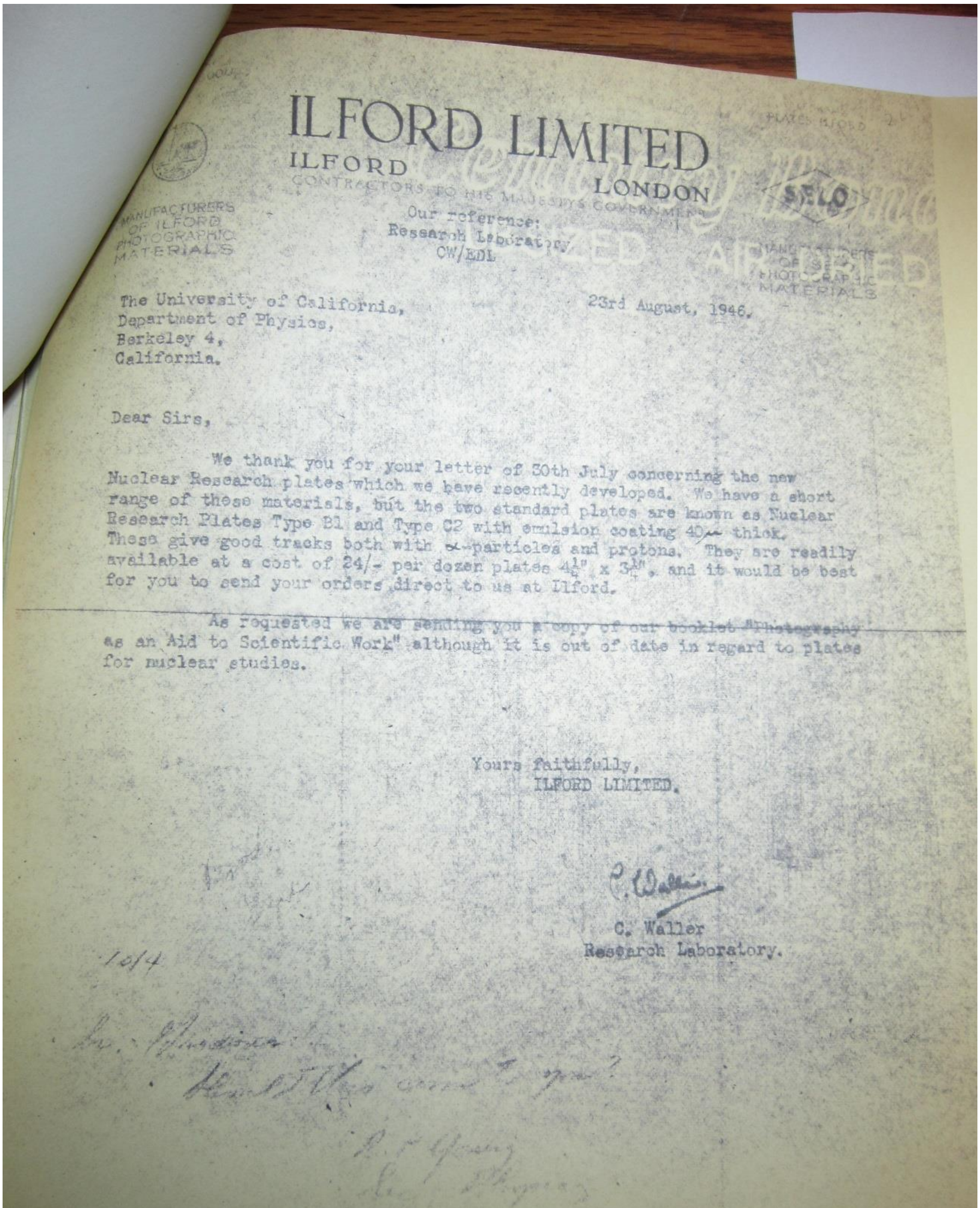
Scattering of Deuterons

Exploratory runs have continued in a study of the scattering of deuterons on lead and other materials. The first work was done with the circulating beam inside the tank, but more recent work with the deflected deuteron beam has been so much more promising that scattering in the circulating beam has been abandoned. The deflected deuteron beam has been brought out through the concrete shielding, so that the scattering experiment can now be done at a position where the neutron background is low. A scatterer is placed in the deuteron beam, and photographic plates are placed in positions to receive scattered particles in various directions. From the directions of the tracks observed on the plates, it is possible to tell which particles came from the vicinity of the scatterer. So far the experiments have been done in air, but we now plan to put the apparatus in a vacuum chamber.

12-31-47 EG

Distribution:
R. L. Thornton
R. Serber
Wilson Powell
Films Log

[89] C. Waller para Departamento de Física da Universidade de Berkeley (Research and Development Records and Administrative Files of Eugene Gardner, National Archives and Records Administration, San Bruno, 1946), correspondência, caixa 2, pasta 26.



ILFORD LIMITED
ILFORD LONDON
CONTRACTORS TO HIS MAJESTY'S GOVERNMENT
MANUFACTURERS OF ILFORD PHOTOGRAPHIC MATERIALS

Our reference:
Research Laboratory
CW/EDL

The University of California,
Department of Physics,
Berkeley 4,
California.

23rd August, 1946.

Dear Sirs,

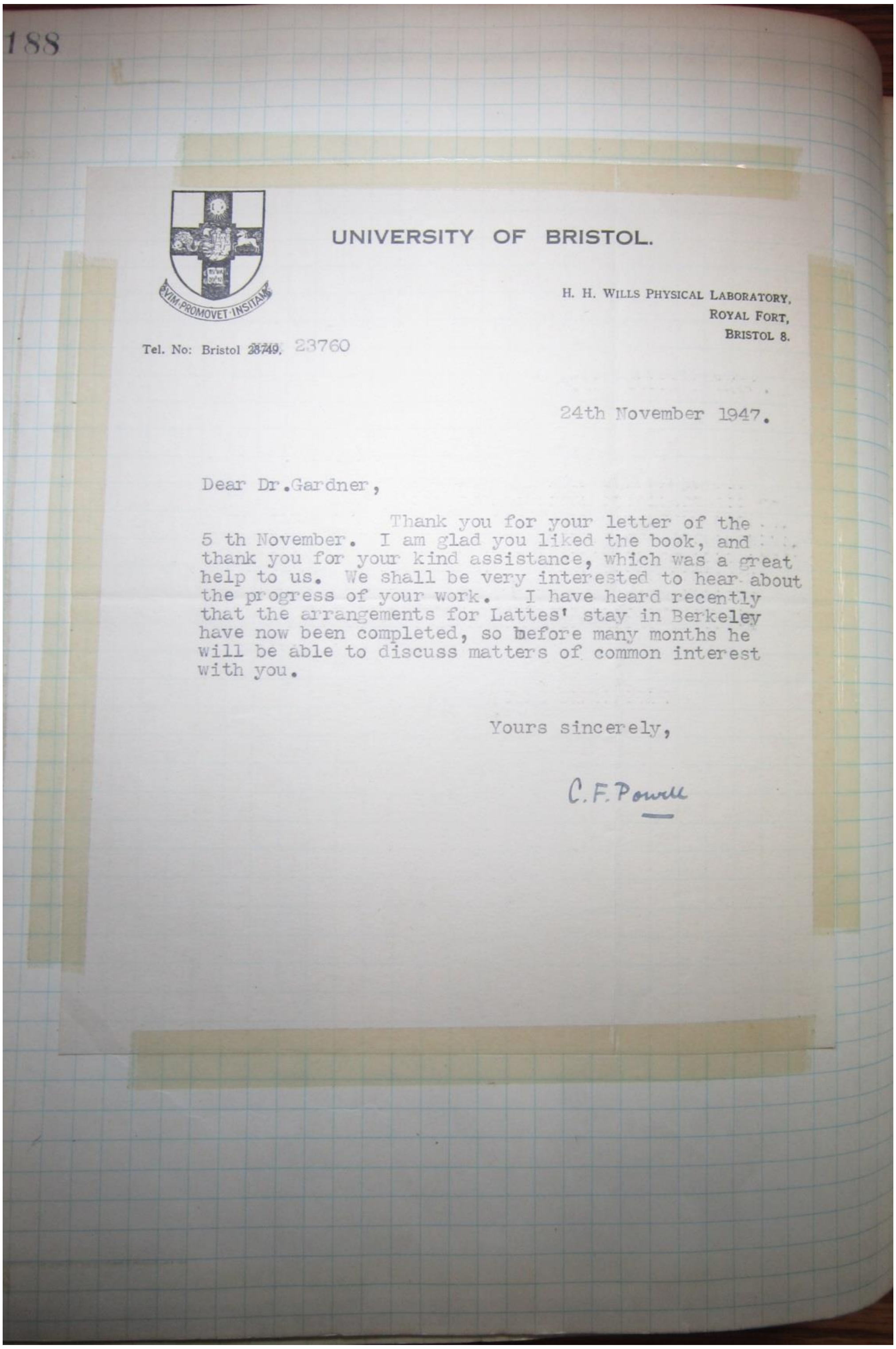
We thank you for your letter of 30th July concerning the new Nuclear Research plates which we have recently developed. We have a short range of these materials, but the two standard plates are known as Nuclear Research Plates Type B1 and Type C2 with emulsion coating 40μ thick. These give good tracks both with α-particles and protons. They are readily available at a cost of 24/- per dozen plates $4\frac{1}{4}$" x $3\frac{1}{4}$", and it would be best for you to send your orders direct to us at Ilford.

As requested we are sending you a copy of our booklet "Photography as an Aid to Scientific Work" although it is out of date in regard to plates for nuclear studies.

Yours faithfully,
ILFORD LIMITED.

C. Waller
Research Laboratory.

[90] C. Powell para E. Gardner (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), correspondência, caixa 6, livro 10, página 188.



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UNIVERSITY OF BRISTOL.

H. H. WILLS PHYSICAL LABORATORY,
ROYAL FORT,
BRISTOL 8.

Tel. No: Bristol 28749. 23760

24th November 1947.

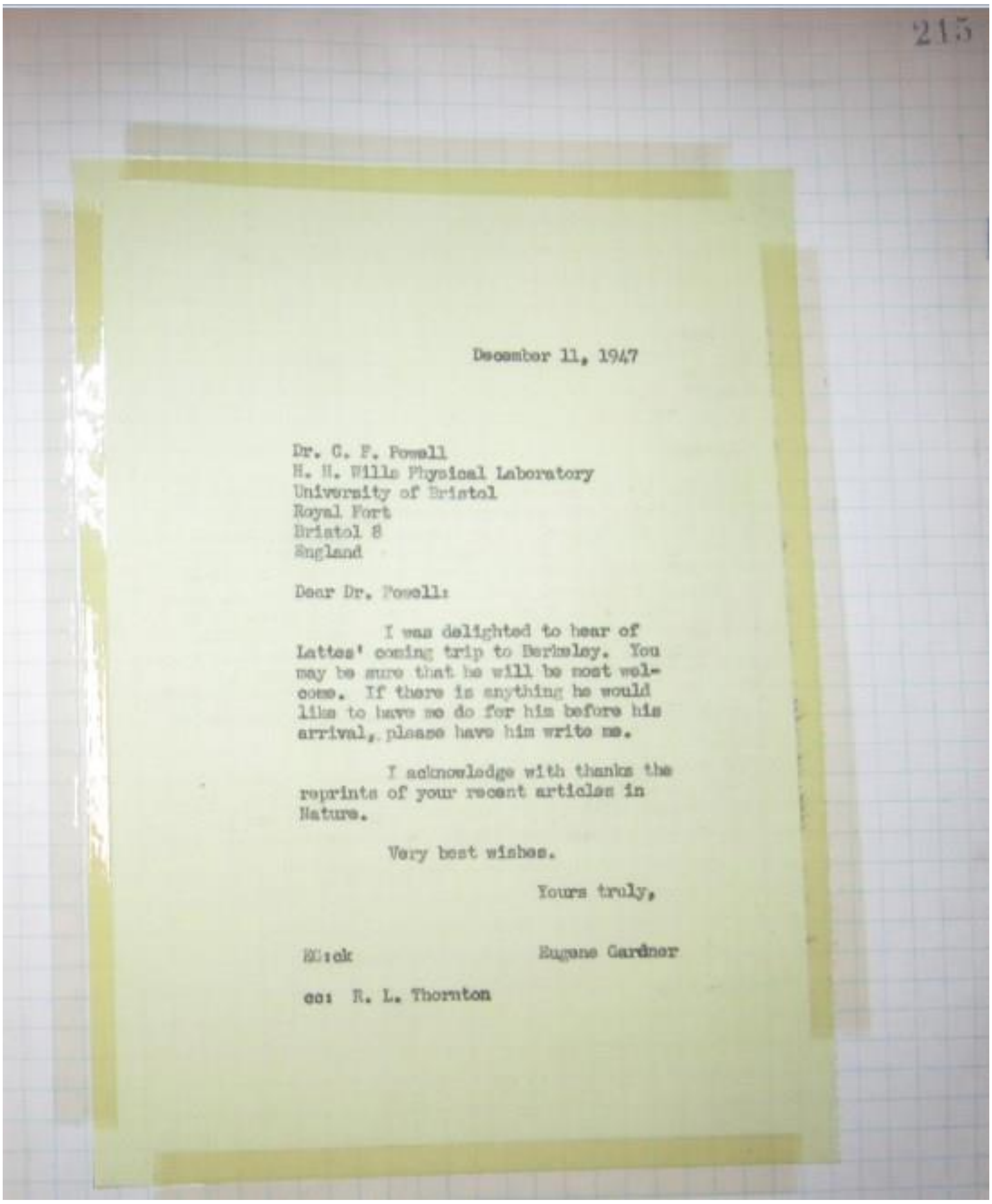
Dear Dr.Gardner,

Thank you for your letter of the 5 th November. I am glad you liked the book, and thank you for your kind assistance, which was a great help to us. We shall be very interested to hear about the progress of your work. I have heard recently that the arrangements for Lattes' stay in Berkeley have now been completed, so before many months he will be able to discuss matters of common interest with you.

Yours sincerely,

C.F. Powell

[91] E. Gardner para C. Powell (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1947), correspondência, caixa 6, livro 10, página 215.



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December 11, 1947

Dr. C. F. Powell
H. H. Wills Physical Laboratory
University of Bristol
Royal Fort
Bristol 8
England

Dear Dr. Powell:

I was delighted to hear of Lattes' coming trip to Berkeley. You may be sure that he will be most welcome. If there is anything he would like to have me do for him before his arrival, please have him write me.

I acknowledge with thanks the reprints of your recent articles in Nature.

Very best wishes.

Yours truly,

EG:ck

Eugene Gardner

cc: R. L. Thornton

[92] C. Lattes para E. Lawrence (The Bancroft Library, University of California, Berkeley, 1948), correspondência, rolo 15, caixa 10, pasta 35.

DEPARTAMENTO DE FÍSICA
FACULDADE DE FILOSOFIA, CIÊNCIAS E LETRAS
DA UNIVERSIDADE DE SÃO PAULO
AV. BRIGADEIRO LUIZ ANTONIO N.o 784
SÃO PAULO (BRASIL)

January, 2nd 1948

Dear Prof. Lawrence,

Prof. Gleb Wataghin has written to you some months ago inquiring whether it would be possible for me to spend 12 months working in Berkeley with a Rockefeller fellowship. Prof. Wataghin sent me a copy of your kind reply, and I want to thank you very much for the opportunity of working in your laboratory. As you probably know, I spent the last two years in Bristol, working in colaboration with Dr. Occhialini and Dr. Powell on the photographic tecnique. I would like to go on working with the same tecnique so that I welcome your suggestion of working in collaboration with Dr. Gardner in Berkeley.

I have seen Prof. Wataghin in Copenhagen where I have been recently, and he was just going to write to you about my comming to Berkeley. He has probably told you that the Atomic Energy Commission has granted permission for me to work in Berkeley so that all what is to be done now is to decide which would be the best time for me to come.

I am just back in Brazil and I will be free to come to the United States anytime after January the 31st. It would be most convenient for me to be there about the 2nd week of February. I am writing you, therefore, in order to know if it will be all right for me to come in that date.

I would also be very obliged if you or Dr. Gardner could inform me about the situation in Berkeley for getting rooms or a flat where to live. I have been informed that the situation is not very good in the States and I am rather concerned since I am planning to take my wife with me.

I will be staying in S.Paulo until the end of this month, so I would be obliged if you could send any reply to my home address:

Rua Itapolis, 880
S. Paulo

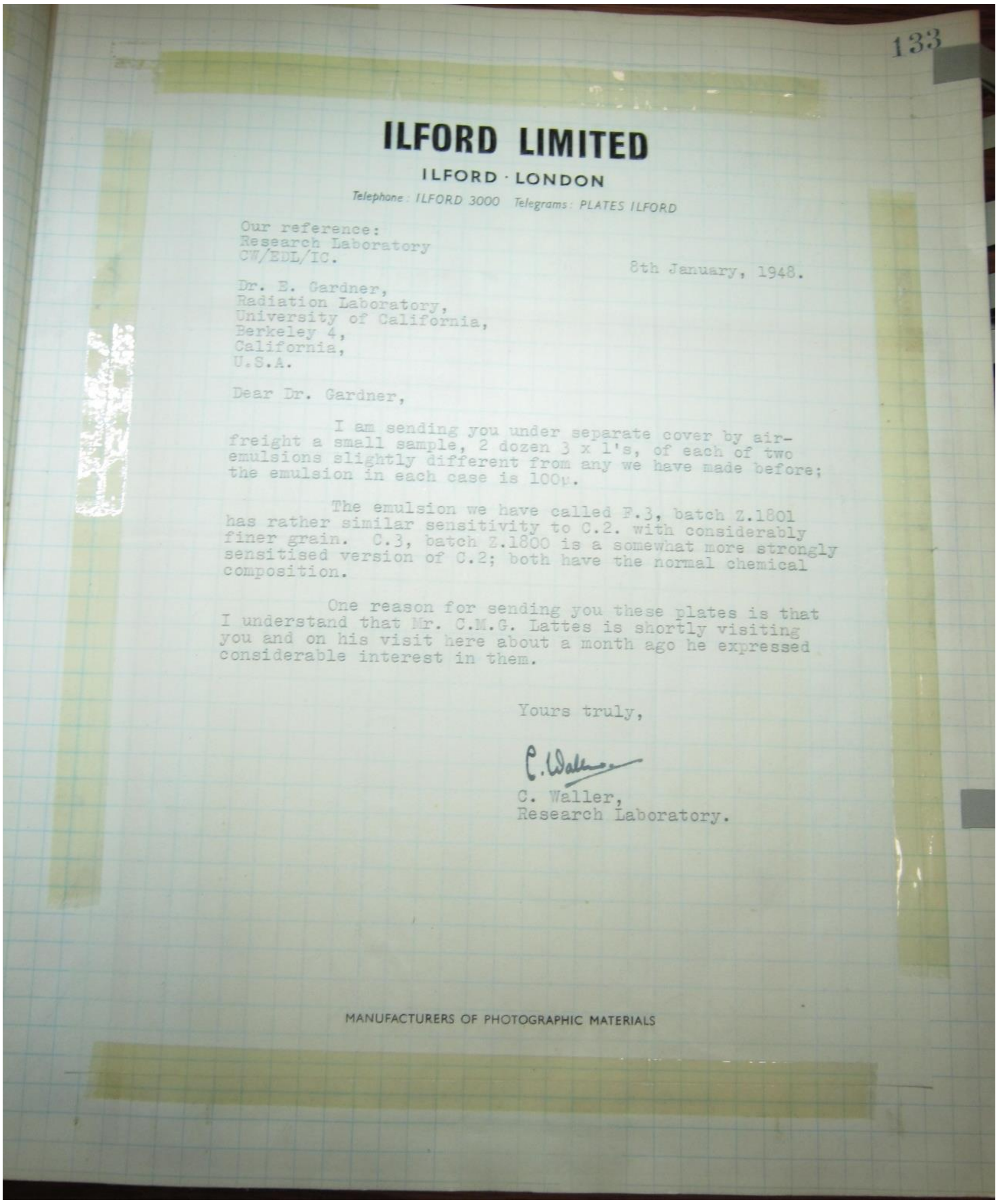
Thanking you very much for all

Sincerely yours

Cesare Lattes

Dr. Ernest O. Lawrence
Radiation Laboratory
Berkeley, 4 - California

[93] C. Waller para E. Gardner (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), correspondência, caixa 5, livro 09, página 133.



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Telephone: ILFORD 3000 Telegrams: PLATES ILFORD

Our reference:
Research Laboratory
CW/EDL/IC.

8th January, 1948.

Dr. E. Gardner,
Radiation Laboratory,
University of California,
Berkeley 4,
California,
U.S.A.

Dear Dr. Gardner,

I am sending you under separate cover by air-freight a small sample, 2 dozen 3 x 1's, of each of two emulsions slightly different from any we have made before; the emulsion in each case is 100μ.

The emulsion we have called F.3, batch Z.1801 has rather similar sensitivity to C.2. with considerably finer grain. C.3, batch Z.1800 is a somewhat more strongly sensitised version of C.2; both have the normal chemical composition.

One reason for sending you these plates is that I understand that Mr. C.M.G. Lattes is shortly visiting you and on his visit here about a month ago he expressed considerable interest in them.

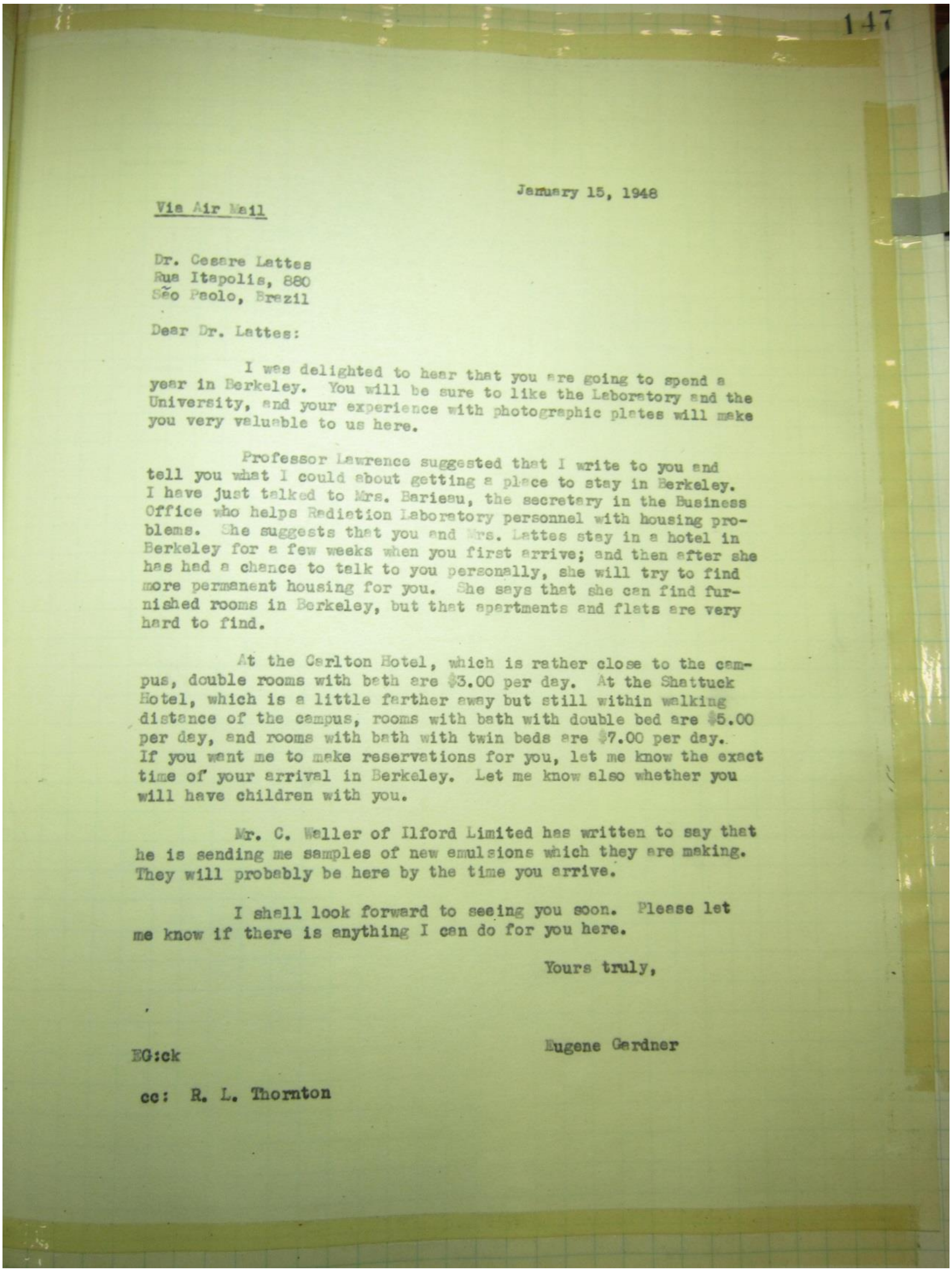
Yours truly,

C. Waller

C. Waller,
Research Laboratory.

MANUFACTURERS OF PHOTOGRAPHIC MATERIALS

[94] E. Gardner para C. Lattes (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), correspondência, caixa 5, livro 09, página 147.



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January 15, 1948

Via Air Mail

Dr. Cesare Lattes
Rua Itapolis, 880
São Paolo, Brazil

Dear Dr. Lattes:

I was delighted to hear that you are going to spend a year in Berkeley. You will be sure to like the Laboratory and the University, and your experience with photographic plates will make you very valuable to us here.

Professor Lawrence suggested that I write to you and tell you what I could about getting a place to stay in Berkeley. I have just talked to Mrs. Bariesu, the secretary in the Business Office who helps Radiation Laboratory personnel with housing problems. She suggests that you and Mrs. Lattes stay in a hotel in Berkeley for a few weeks when you first arrive; and then after she has had a chance to talk to you personally, she will try to find more permanent housing for you. She says that she can find furnished rooms in Berkeley, but that apartments and flats are very hard to find.

At the Carlton Hotel, which is rather close to the campus, double rooms with bath are $3.00 per day. At the Shattuck Hotel, which is a little farther away but still within walking distance of the campus, rooms with bath with double bed are $5.00 per day, and rooms with bath with twin beds are $7.00 per day. If you want me to make reservations for you, let me know the exact time of your arrival in Berkeley. Let me know also whether you will have children with you.

Mr. C. Waller of Ilford Limited has written to say that he is sending me samples of new emulsions which they are making. They will probably be here by the time you arrive.

I shall look forward to seeing you soon. Please let me know if there is anything I can do for you here.

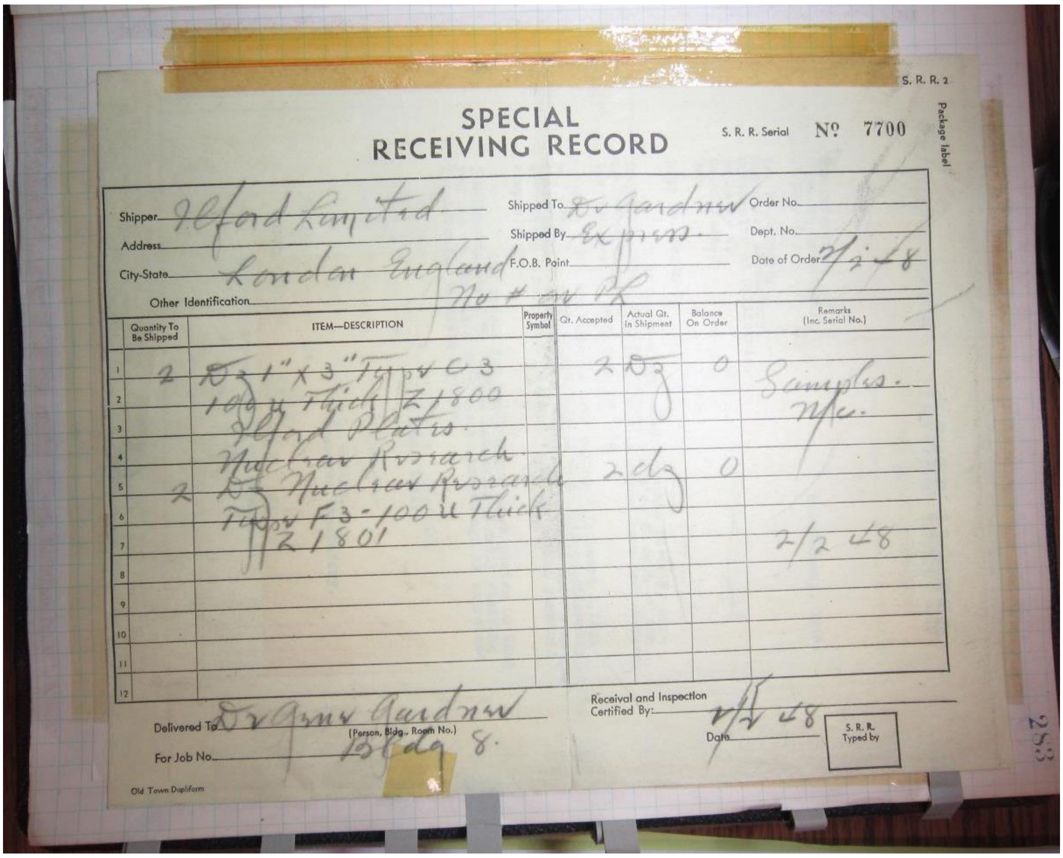
Yours truly,

Eugene Gardner

EG:ck

cc: R. L. Thornton

[95] *Special receiving record* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), caixa 5, livro 09, página 283.



S. R. R. 2

SPECIAL RECEIVING RECORD

S. R. R. Serial Nº 7700

Package label

Shipper Ilford Limited
Address
City-State London England
Other Identification No # on Pl

Shipped To Dr Gardner
Shipped By Express.
F.O.B. Point

Order No.
Dept. No.
Date of Order 2/2/48

	Quantity To Be Shipped	ITEM—DESCRIPTION	Property Symbol	Qt. Accepted	Actual Qt. in Shipment	Balance On Order	Remarks (Inc. Serial No.)
1	2	Dz 1"x3" Type C3		2 Dz		0	Samples.
2		100 u Thick Z1800					N/c.
3		Ilford Plates.					
4		Nuclear Research					
5	2	Dz Nuclear Research		2 dz		0	
6		Type F3-100 u Thick					
7		Z1801					2/2 48
8							
9							
10							
11							
12							

Delivered To Dr Gardner (Person, Bldg., Room No.) Bldg 8.
For Job No.

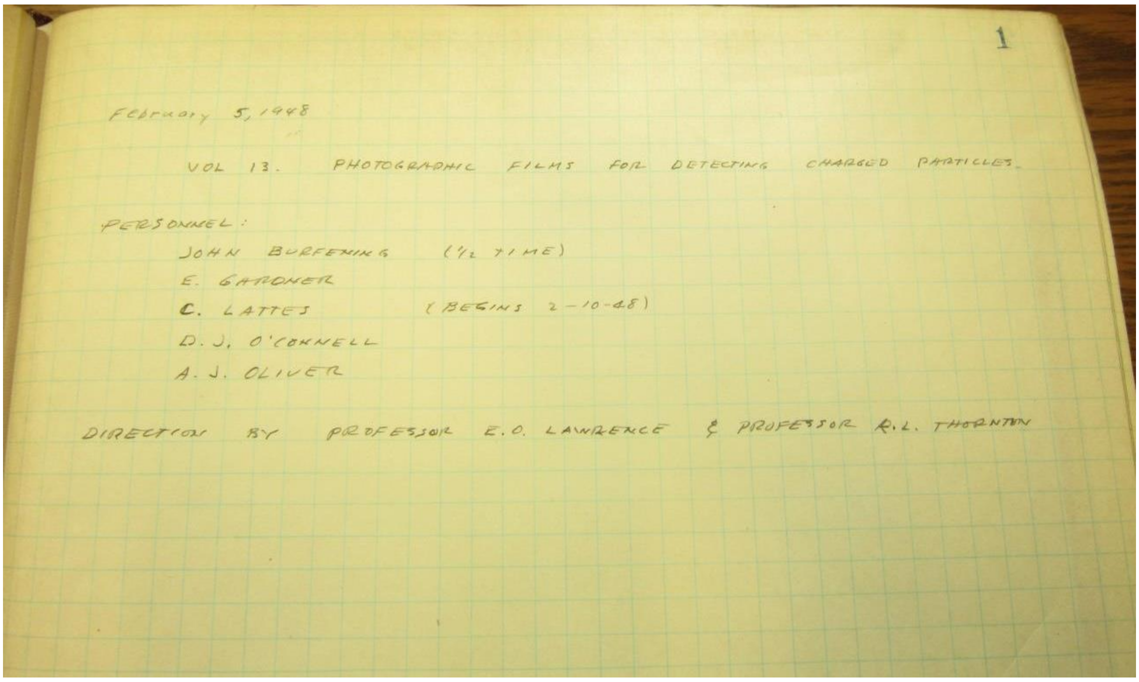
Receival and Inspection Certified By:
Date 2/2 48

S. R. R. Typed by

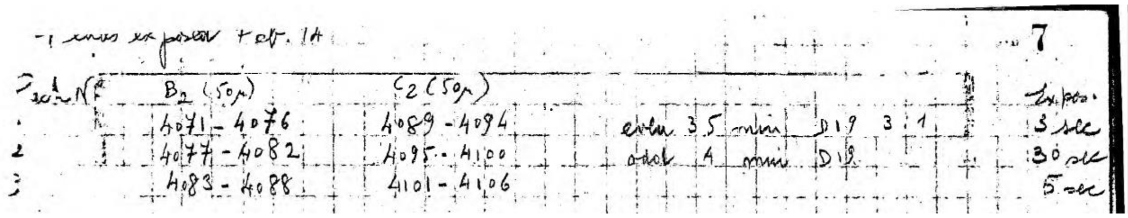
Old Town Dupliform

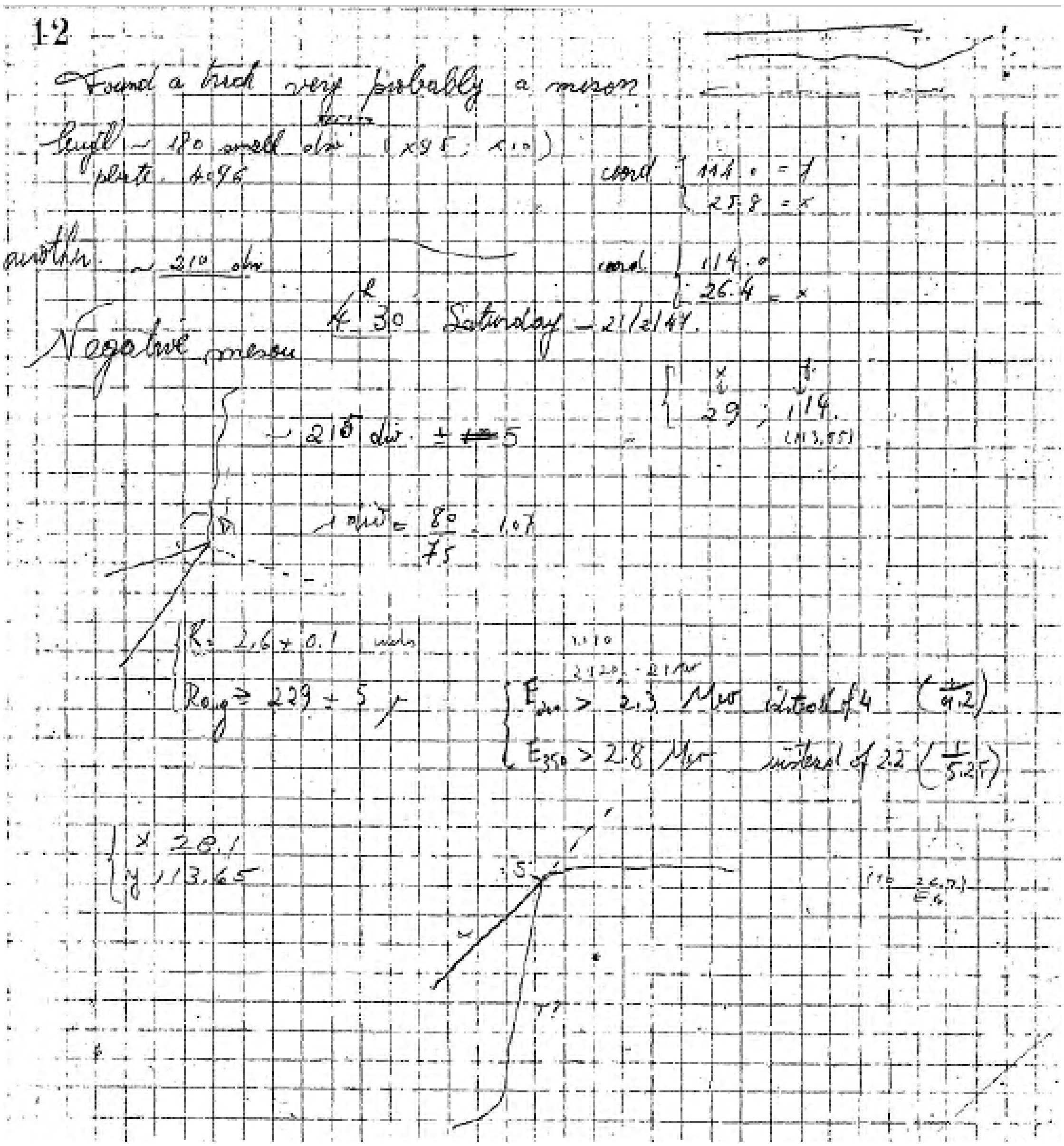
283

[96] *[Registro em 05 de fevereiro de 1948]* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), caixa 7, livro 13, página 1.



[97] *Caderno de Berkeley* (Arquivo Central do Sistema de Arquivos, Universidade Estadual de Campinas, Campinas), volume 15, pp. 07, 12, 13, 14.





4.5
113.5 { plate 4096.
could be proton (more probable.

30.7 meson coming from surface
stopping near the surface.

28.9
112.8 } meson very near the surface
goes out from surf.

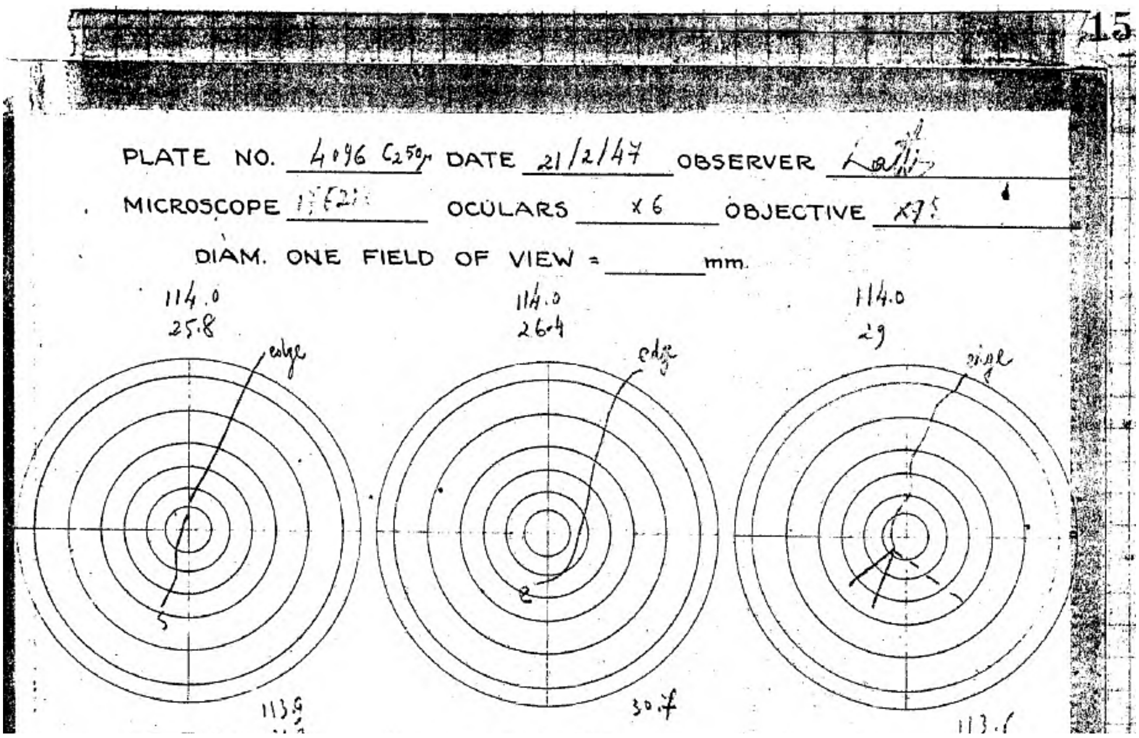
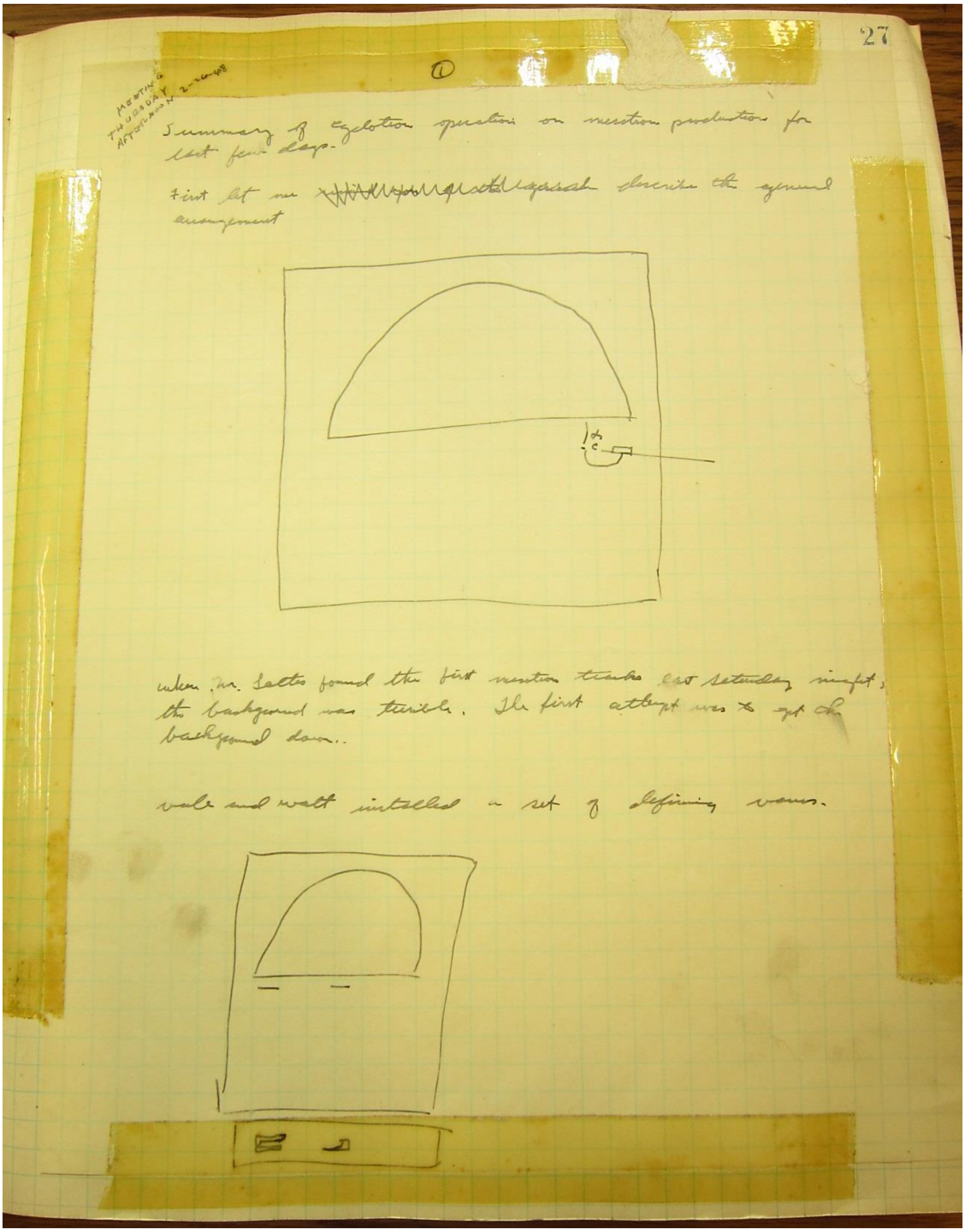

15

PLATE NO. 4096 C2 50μ DATE 21/2/47 OBSERVER Lattes
MICROSCOPE [illegible] OCULARS x6 OBJECTIVE x95
DIAM. ONE FIELD OF VIEW = ______ mm.

[98] *Meeting on Thursday* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), caixa 7, livro 13, página 27.



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①

MEETING THURSDAY AFTERNOON 2-26-48

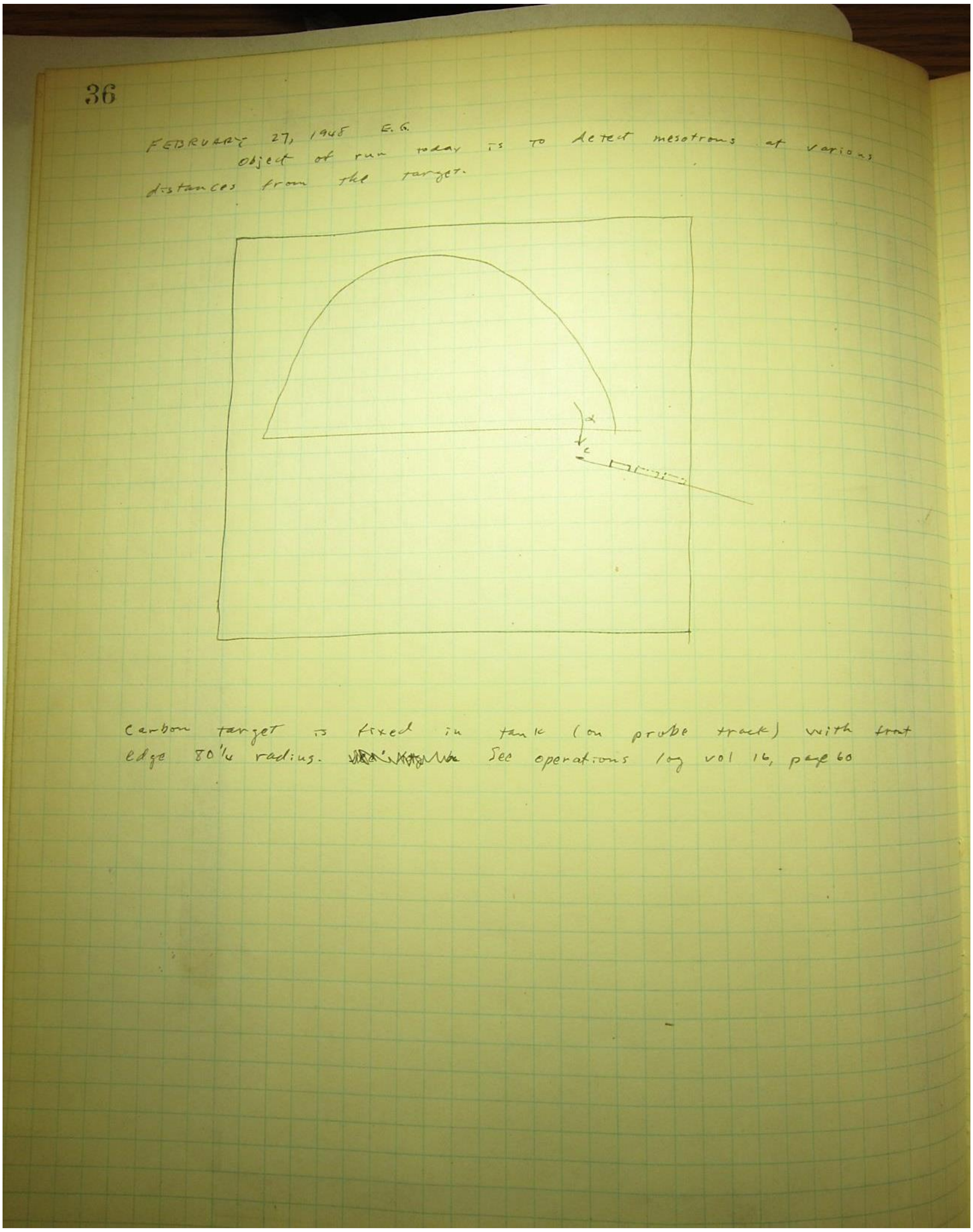
Summary of cyclotron operation on meson production for last few days.

First let me describe the general arrangement

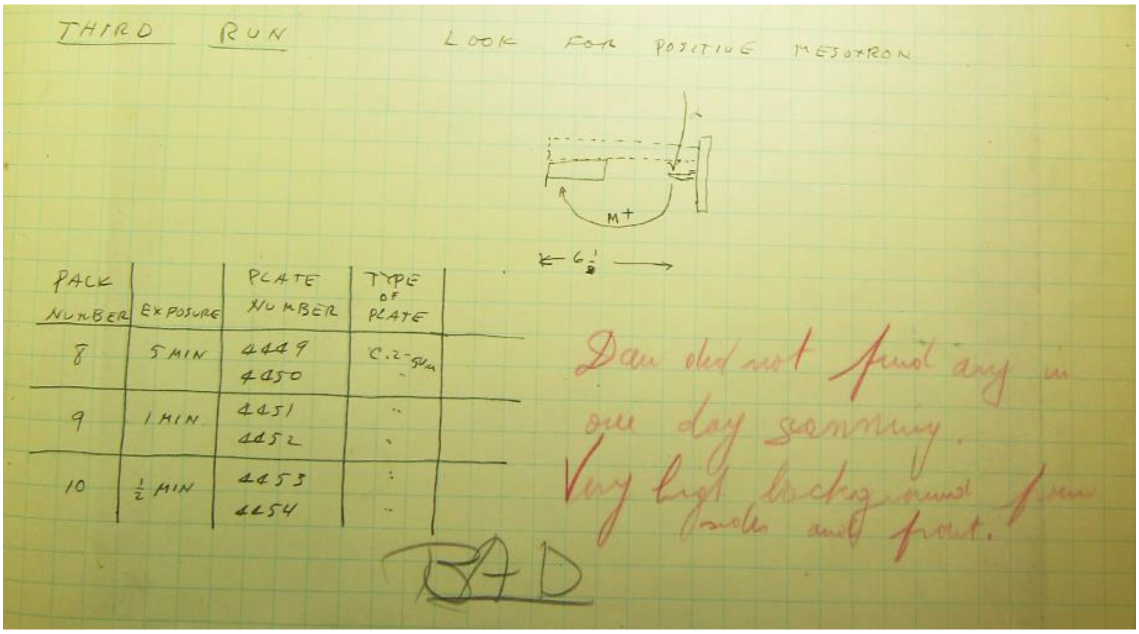
when Mr. Lattes found the first meson tracks last saturday night, the background was terrible. The first attempt was to get the background down..

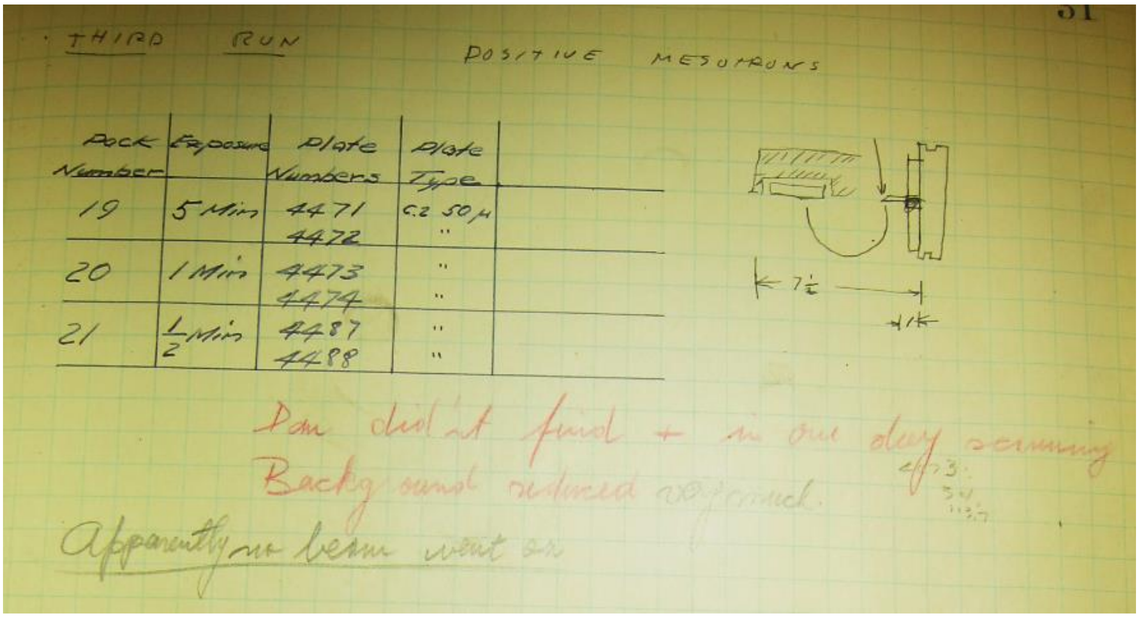
Dale and Walt installed a set of defining vanes.

[99] *[Desenho de arranjo com emulsões a várias distâncias do alvo]* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), caixa 7, livro 12, página 36.

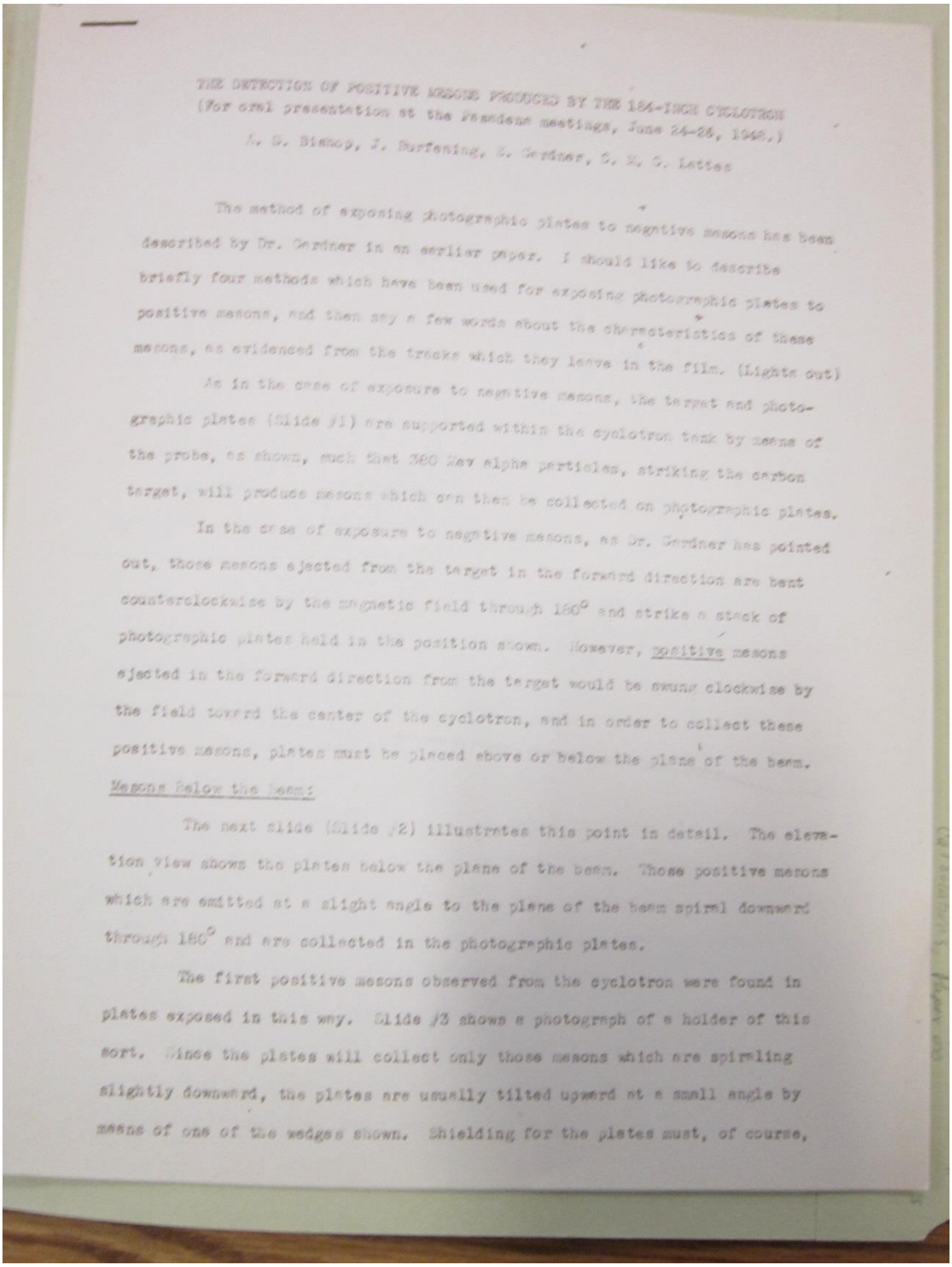


[102] *Buscas frustradas por mésons positivos* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno), caixa 7, livro 12, página 27 e 31.





[103] *The detection of positive mesons produced by the 184 cyclotron for oral presentation at the Pasadena meeting 24–28 June 1948* (Research and Development Records and Administrative Files of Eugene Gardner, National Archives and Records Administration, San Bruno, 1948), caixa 1, pasta 10.



THE DETECTION OF POSITIVE MESONS PRODUCED BY THE 184-INCH CYCLOTRON
(For oral presentation at the Pasadena meetings, June 24-28, 1948.)

A. S. Bishop, J. Burfening, E. Gardner, C. M. G. Lattes

The method of exposing photographic plates to negative mesons has been described by Dr. Gardner in an earlier paper. I should like to describe briefly four methods which have been used for exposing photographic plates to positive mesons, and then say a few words about the characteristics of these mesons, as evidenced from the tracks which they leave in the film. (Lights out)

As in the case of exposure to negative mesons, the target and photographic plates (Slide #1) are supported within the cyclotron tank by means of the probe, as shown, such that 380 Mev alpha particles, striking the carbon target, will produce mesons which can then be collected on photographic plates.

In the case of exposure to negative mesons, as Dr. Gardner has pointed out, those mesons ejected from the target in the forward direction are bent counterclockwise by the magnetic field through 180° and strike a stack of photographic plates held in the position shown. However, positive mesons ejected in the forward direction from the target would be swung clockwise by the field toward the center of the cyclotron, and in order to collect these positive mesons, plates must be placed above or below the plane of the beam.

Mesons Below the Beam:

The next slide (Slide #2) illustrates this point in detail. The elevation view shows the plates below the plane of the beam. Those positive mesons which are emitted at a slight angle to the plane of the beam spiral downward through 180° and are collected in the photographic plates.

The first positive mesons observed from the cyclotron were found in plates exposed in this way. Slide #3 shows a photograph of a holder of this sort. Since the plates will collect only those mesons which are spiraling slightly downward, the plates are usually tilted upward at a small angle by means of one of the wedges shown. Shielding for the plates must, of course, be provided on the side from which the beam comes, in order to prevent stray fast particles in the beam from striking the plates.

Exposure to positive mesons has never been as satisfactory as exposure to negative mesons. The reason for this fact is that alpha particles and protons from the target can travel exactly the same trajectories as that travelled by the mesons. In order to prevent fast charged particles from entering the plates and causing undue background, it has been found necessary to add the copper baffle (shown in the slide) over the entrance to the photographic plates. With this baffle in position, charged particles with a large radius of curvature, ie., low energy, can pass through the openings in the baffle. This means, of course, that low energy protons and alpha particles, as well as low energy mesons, can all enter the photographic plates. But of these particles only the mesons will penetrate appreciably into the emulsion, since the range of a meson is a number of times greater than an alpha particle or a proton with the same momentum. The alpha particles and protons which pass through this baffle are thus stopped in a few microns of emulsion while the mesons penetrate much deeper. To date the baffles have been only partially successful, however, in shutting out the high energy particles. Even with the baffles there are still so many background tracks that searching for mesons is difficult.

Mesons Ejected Backward:

Another type of holder for exposing plates to positive mesons, and that which has been most successful, is shown in Slide #4. It has been found experimentally that some mesons are emitted in the backward direction, i.e., opposite to that of the beam. Positive mesons emitted in this direction, however, can be collected very simply, in plates positioned as shown, merely by modifying the position of the heavy copper shielding to allow free passage of these mesons. Exposures made in this way allow the collection of both positive and negative mesons on the same plate; the positive mesons entering the back edge of the plate, the negative mesons entering the front edge.

270° Focusing (Slide #5)

A third, but less successful, method of exposure which has been used (and which I shall merely mention) is a variation of the method last shown. The mesons are bent through 270° and enter plates positioned as shown.

360° Focusing

The fourth method of exposure is that shown in the next slide (Slide #6). In general, each and every meson emitted from the target will follow a spiral path, due to the effect of the magnetic field, and will eventually return to a point directly above or directly below the target. Thus a small stack of photographic plates, positioned as shown, should collect the majority of mesons of both positive and negative charge, emitted over a wide range of energies and angles. Once again, to shield out the high energy alpha particles and protons, one copper shield is inserted between the target and the plates, and another in the usual position. Holders for exposing plates in this way have been built and used, but to date they have not given very satisfactory results.

Ratio of Positive to Negative Mesons

I should like to mention at this time one point of interest which is now being studied. It concerns the relative number of positive and negative mesons which are emitted from the target. To study this question plates have been exposed in a holder (Slide #7) which provides, as nearly as possible, the same geometry in the collection of positive and negative mesons. Positive mesons, spiraling in toward the center of the cyclotron, are collected in one set of plates, placed below the beam in the usual way; negative mesons, spiraling away from the cyclotron center, are collected in another set of plates which are also placed below the plane of the beam for purposes of symmetry. The wedges again are for the purpose of tilting the plates slightly upward. Here again it has been found desirable to place baffles over the entrance to the photographic plates -- on the left side in order to shut out the high energy protons and alpha particles; on the right side for purpose of symmetry in the geometry. Photographic plates have been exposed to mesons in this way and are now in the process of being examined.

Analysis of Tracks:

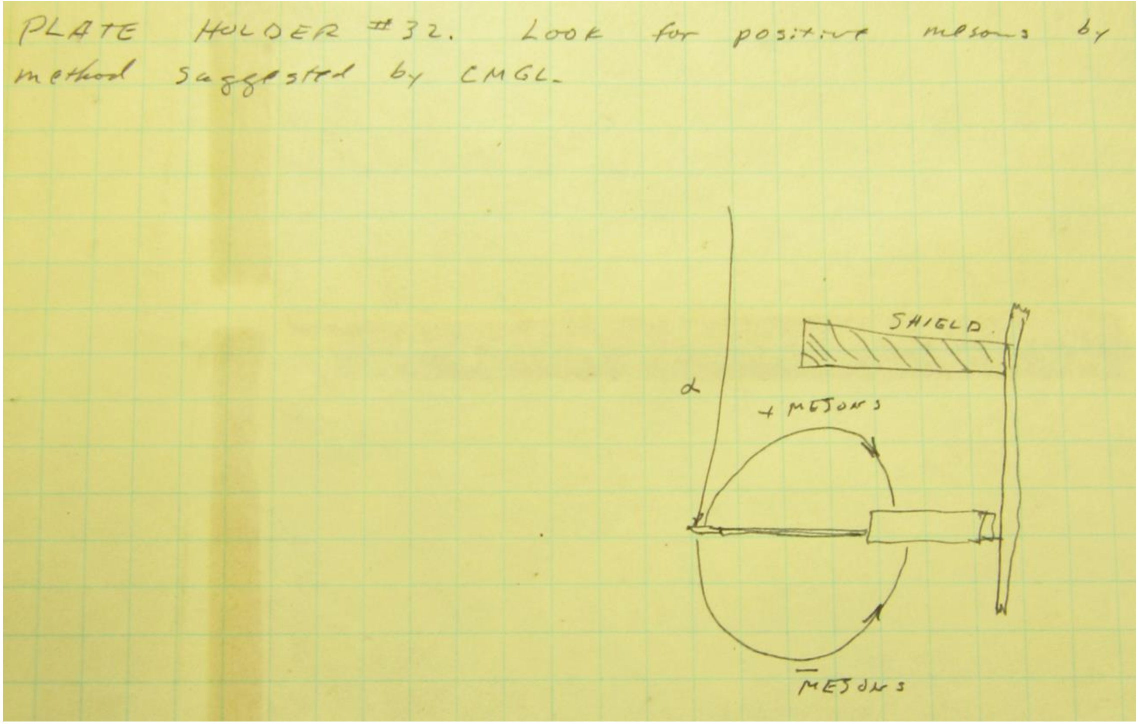
Study of the plates exposed in the four ways which have been described have yielded, to date, the tracks of several hundred positive heavy mesons. Because of their charge, heavy positive mesons do not enter nuclei and make stars, but instead decay, giving rise to light mesons.

The next slide (Slide #8) shows the track of one of the first heavy positive mesons found, using the holder first shown which positions the plates under the plane of the beam. The high background is evident, particularly at the edge of the plate. Here the heavy positive meson is seen to come to rest in the emulsion. Although the track of the light meson does not show very well on this slide, it may be seen in the original plate, going off to the right and eventually leaving the emulsion. In most of the events which have been found of a heavy positive meson coming to rest, tracks of these light secondary mesons have been observed, and it is believed that in actuality all heavy positive mesons decay into light mesons. These light mesons are not always seen, however, because of unfavorable angle of emission or because the background is too high.

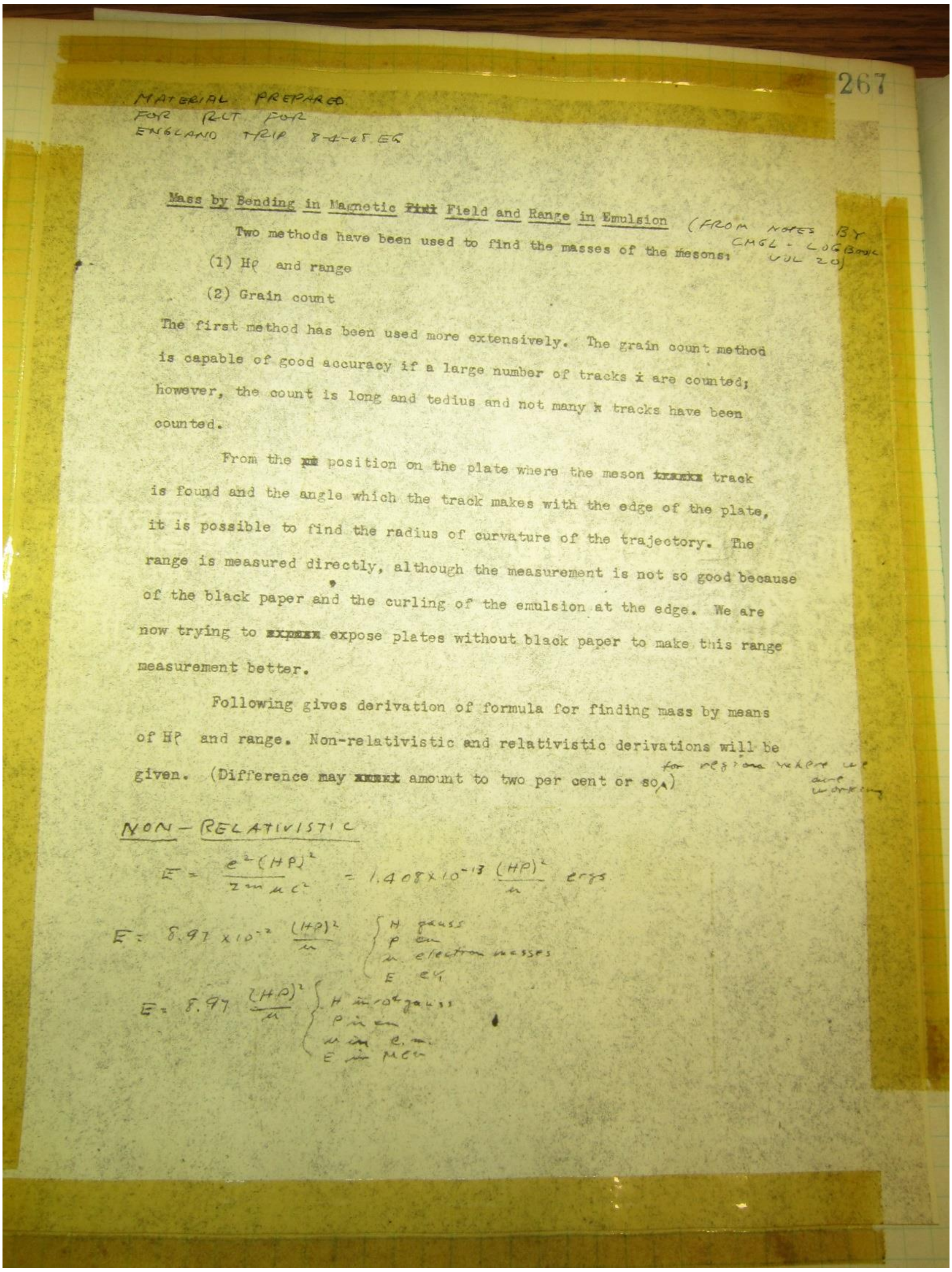
This meson was found in an Ilford C.2 film, 50 microns in thickness. Recently, photographic plates of 100 micron thickness have been used in order to increase the probability of finding events in which the track of the light meson remains in the emulsion throughout its entire range. Dr. Lattes and Dr. Barkas have recently succeeded in finding ten such cases, mostly in Eastman NTB plates, 100 microns thick.

The next slide shows a composite microphotograph of such an event (Slide #9). The primary meson is observed to come to rest in the upper left-hand corner, and to give rise to the secondary meson, which slows down and stops in the emulsion. No particle is observed to originate from the terminus of the light meson track. If the light meson itself decays with the emission of an electron, this electron would not be observed, due to the insensitivity of the emulsion to electrons of moderate energy. The ranges of the secondary mesons, in the ten cases which have been observed, are closely distributed about 600 microns. This range agrees very well with the observations of Lattes, Occialini, and Powell in England on the decay of positive mesons in cosmic rays. A range of 600 microns corresponds to an initial energy of 4 Mev for the light meson, which explains the lightness of the track in the region of the decay. An enlarged photograph (Slide #10) shows that the light meson really does originate at the terminus of the heavy meson track. No track has yet been observed of any particle going off in the opposite direction to that of the light meson. (Lights on)

[104] *Look for positive mesons suggested by CMGL* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), caixa 7, livro 12, página 154.



[105] *Mass by bending in magnetic field and range in Emulsion* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno), caixa 6, livro 11, página 267.



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MATERIAL PREPARED FOR RLT FOR ENGLAND TRIP 8-4-48 EG

Mass by Bending in Magnetic Field and Range in Emulsion (FROM NOTES BY CMGL - LOGBOOK VOL 20)

Two methods have been used to find the masses of the mesons:

(1) Hρ and range

(2) Grain count

The first method has been used more extensively. The grain count method is capable of good accuracy if a large number of tracks are counted; however, the count is long and tedius and not many tracks have been counted.

From the position on the plate where the meson track is found and the angle which the track makes with the edge of the plate, it is possible to find the radius of curvature of the trajectory. The range is measured directly, although the measurement is not so good because of the black paper and the curling of the emulsion at the edge. We are now trying to expose plates without black paper to make this range measurement better.

Following gives derivation of formula for finding mass by means of Hρ and range. Non-relativistic and relativistic derivations will be given. (Difference may amount to two per cent or so for regions where we are working)

NON-RELATIVISTIC

$$E = \frac{e^2 (H\rho)^2}{2 m \mu c^2} = 1.408 \times 10^{-13} \frac{(H\rho)^2}{m} \text{ ergs}$$

$$E = 8.97 \times 10^{-2} \frac{(H\rho)^2}{m} \quad \begin{cases} H & \text{gauss} \\ \rho & \text{cm} \\ m & \text{electron masses} \\ E & \text{eV} \end{cases}$$

$$E = 8.97 \frac{(H\rho)^2}{m} \quad \begin{cases} H & \text{in } 10^4 \text{ gauss} \\ \rho & \text{in cm} \\ m & \text{in e.m.} \\ E & \text{in MeV} \end{cases}$$

Mass by Bending in Magnetic Field and Range in Emulsion. Page 2

$$\bar{E} = 0.305\, M^{0.447} R^{0.553}$$ (SEE SECTION ON RANGE-ENERGY)

$$\begin{cases} E \text{ in MeV} \\ M \text{ proton masses} \\ R \text{ microns} \end{cases}$$

$$E = 1.06\, \mu^{0.447} R^{0.553} \times 10^{-2} \quad \begin{cases} e.m. \\ \mu \\ \text{MeV} \end{cases}$$

COMBINE WITH: (FROM PAGE 1)

$$E = 8.97 \frac{(H\rho)^2}{\mu}$$

$$\mu = (847.8)^{\frac{1}{1.447}} \frac{(H\rho)^{1.382}}{R^{0.382}}$$

$$\mu = 171 \frac{\rho^{1.382}}{R^{0.382}}$$

NON-RELATIVISTIC FORMULA FOR MASS OF MESONS IN TERMS OF RADIUS OF CURVATURE AND RANGE

RELATIVISTIC

$$p = \frac{e}{c} H\rho$$

$$\begin{cases} E_T = E_c + E_0 \\ E_T^2 = p^2c^2 + E_0^2 \end{cases} \qquad E_0 = mc^2$$

$$E_c^2 + 2E_0E_c + E_0^2 = p^2c^2$$

$$E_c^2 + 2mc^2E_c = (eH\rho)^2$$

$$\begin{cases} \dfrac{(eH\rho)^2}{2mc^2} = \dfrac{E_c^2}{2mc^2} + E_c \\ E_c = \alpha\, m^{1-n} R^n \end{cases}$$

$$m^{1-n} \alpha R^n = \frac{(eH\rho)^2 - E_c^2}{2mc^2}$$

$$m = \left\{ \frac{(eH\rho)^2 - E_c^2}{2\alpha c^2 R^n} \right\}^{\frac{1}{2-n}}$$

$$m = \left\{ \frac{e^2}{2\alpha c^2} \right\}^{0.691} (H)^{1.382} \frac{\left(\rho^2 - \frac{E^2}{(eH)^2}\right)^{0.691}}{R^{0.382}}$$

$$m = 171 \frac{(\rho^2 - 0.055 E^2)^{0.691}}{R^{0.382}}$$

$$m_r = m_c \left[1 - 3.8 \times 10^{-2} \left(\frac{E}{\rho}\right)^2 \right]$$

↑ (m_r) mass on relativistic calculation

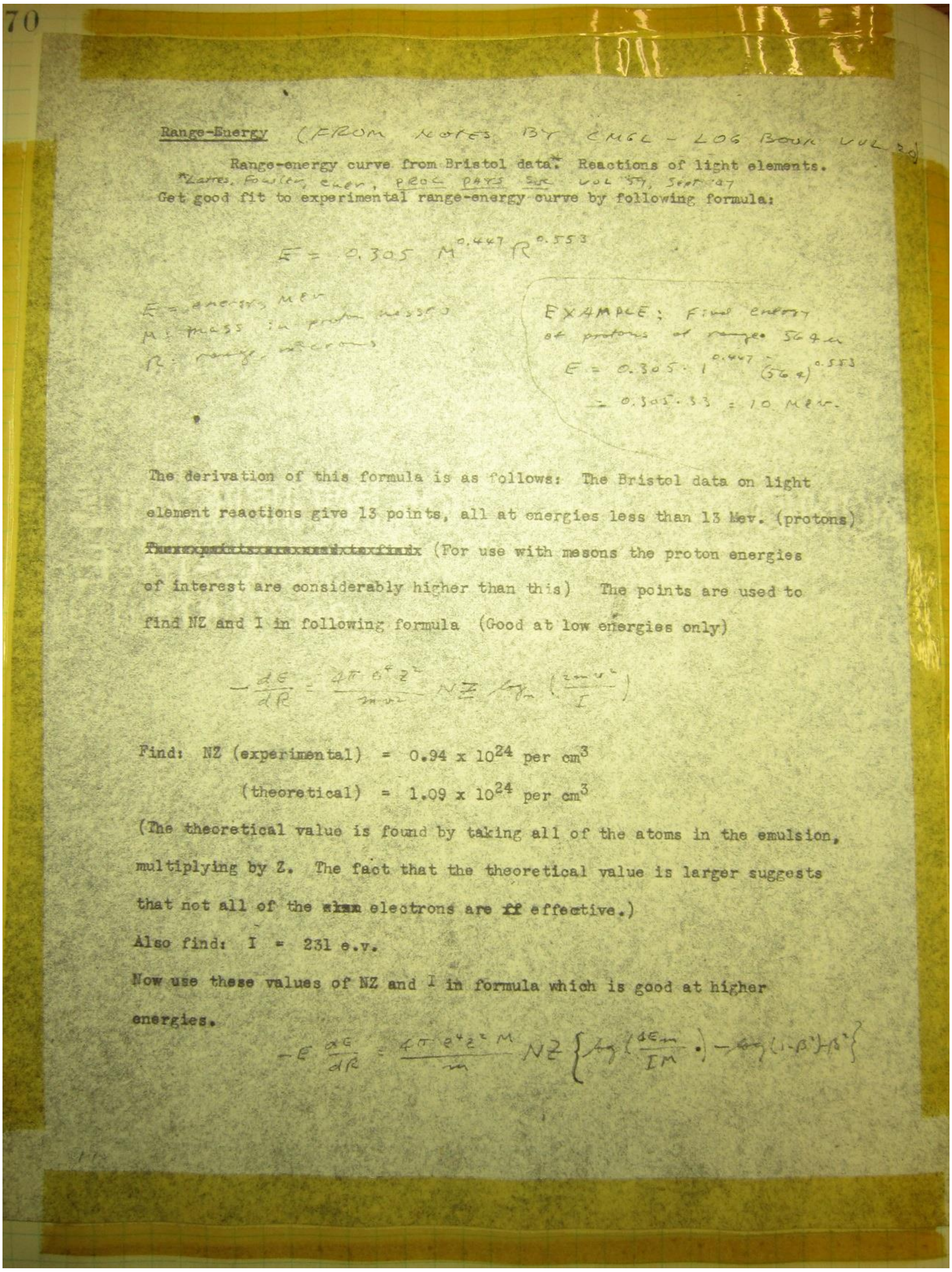
↑ (m_c) mass on non-relativistic calculation

↑ E in Mev, m in e.m., ρ in cm

RELATIVISTIC FORMULA FOR MASS OF MESONS IN TERMS OF RADIUS OF CURVATURE AND RANGE

— END —

[106] *Range energy* (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno), caixa 6, livro 11, página 270.



<u>Range-Energy</u> (FROM NOTES BY CMGL – LOG BOOK VOL 20)

Range-energy curve from Bristol data.* Reactions of light elements.

*Lattes, Fowler, Cuer, Proc Phys Soc vol 59, Sept '47

Get good fit to experimental range-energy curve by following formula:

$$E = 0.305\, M^{0.447} R^{0.553}$$

E = energy, Mev
M = mass in proton masses
R = range, microns

EXAMPLE: Find energy of protons of range 564 μ

$$E = 0.305 \cdot 1^{0.447} \cdot (564)^{0.553}$$

$$= 0.305 \cdot 33 = 10 \text{ Mev.}$$

The derivation of this formula is as follows: The Bristol data on light element reactions give 13 points, all at energies less than 13 Mev. (protons) ~~[illegible]~~ (For use with mesons the proton energies of interest are considerably higher than this) The points are used to find NZ and I in following formula (Good at low energies only)

$$-\frac{dE}{dR} = \frac{4\pi e^4 z^2}{m v^2} NZ \log_e \left(\frac{2mv^2}{I}\right)$$

Find: NZ (experimental) = 0.94×10^{24} per cm^3

(theoretical) = 1.09×10^{24} per cm^3

(The theoretical value is found by taking all of the atoms in the emulsion, multiplying by Z. The fact that the theoretical value is larger suggests that not all of the ~~shan~~ electrons are ~~ff~~ effective.)

Also find: I = 231 e.v.

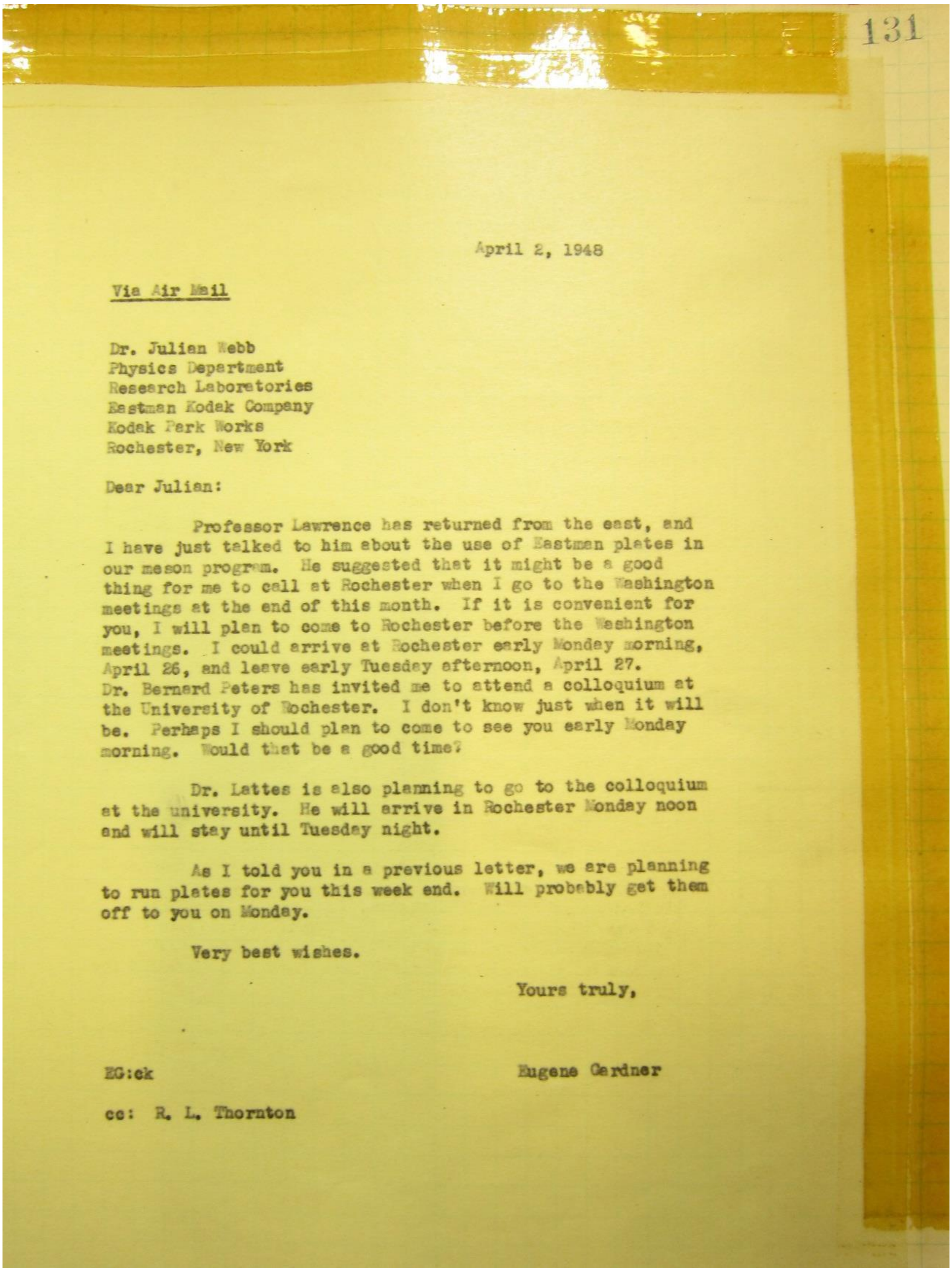
Now use these values of NZ and I in formula which is good at higher energies.

$$-\frac{dE}{dR} = \frac{4\pi e^4 z^2 M}{m} NZ \left\{ \log\left(\frac{4E\,m}{IM}\right) - \log(1-\beta^2) - \beta^2 \right\}$$

Solve for R by numerical integration. The result is a table of values for range as a function of energy. This table of values is now fitted by best equation for E as function of mass and range. ~~Rxxxltx~~ Result is equation top page 1. Equation is estimated to be correct to within ± 2 per cent. It is found to check the range energy curve within 0.4 per cent.

One point from the linear accelerator (32 Mev protons) was measured (gave 4.55 mm). ~~Fitx~~ Fits equation well within the 2 per cent estimated error of the equation.

[107] E. Gardner para J. Webb (Logbooks of Meson detection experiments by Gardner Research Group, National Archives and Records Administration, San Bruno, 1948), correspondência, caixa 7, livro 13, página 131.



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April 2, 1948

Via Air Mail

Dr. Julian Webb
Physics Department
Research Laboratories
Eastman Kodak Company
Kodak Park Works
Rochester, New York

Dear Julian:

Professor Lawrence has returned from the east, and I have just talked to him about the use of Eastman plates in our meson program. He suggested that it might be a good thing for me to call at Rochester when I go to the Washington meetings at the end of this month. If it is convenient for you, I will plan to come to Rochester before the Washington meetings. I could arrive at Rochester early Monday morning, April 26, and leave early Tuesday afternoon, April 27. Dr. Bernard Peters has invited me to attend a colloquium at the University of Rochester. I don't know just when it will be. Perhaps I should plan to come to see you early Monday morning. Would that be a good time?

Dr. Lattes is also planning to go to the colloquium at the university. He will arrive in Rochester Monday noon and will stay until Tuesday night.

As I told you in a previous letter, we are planning to run plates for you this week end. Will probably get them off to you on Monday.

Very best wishes.

Yours truly,

EG:ck

Eugene Gardner

cc: R. L. Thornton

[108] *Conference on nuclear particle plates* (The Bancroft Library, University of California, Berkeley, 1948), rolo 13, caixa 06, pasta 25.

CONFERENCE ON NUCLEAR PARTICLE PLATES

April 26, 1948

Present: Dr. Eugene Gardner, University of California; Mr. E. R. Davies of Kodak Limited; Dr. C. E. K. Mees, Dr. C. J. Staud, Dr. J. A. Leermakers, Dr. W. Vanselow, Dr. W. West, Dr. B. H. Carroll, Mr. W. F. Swann, and Dr. J. H. Webb of Eastman Kodak Company

Dr. Staud opened the meeting by asking Dr. Gardner to tell us a little about the recent experiments on the observation of laboratory produced mesons at the University of California.

Dr. Gardner made a few remarks about the experiments in which the mesons were observed and then discussed mainly the use of the photographic plates in their experiments. Dr. Gardner stated that the mesons had been observed using Ilford C2 plates and that these plates were exposed and processed under the direction of Dr. C. M. G. Lattes who was well versed in the most up-to-date techniques for handling the Ilford plates to get the most from them. Dr. Lattes recently returned from Bristol University where much work has been done on the observation of cosmic ray mesons. In Bristol, both heavy (313 Me) and light (200 Me) mesons were studied by means of the photographic plate, and Ilford plates had shown ample sensitivity to register considerable path lengths for these particles. Dr. Gardner pointed out that the development recommended by Dr. Lattes was considerably longer than the development that had previously been given Ilford plates by the University of California Laboratory and that this probably accounted for the fact that they had not observed mesons on the Ilford plates previous to Dr. Lattes' visit.

Dr. Gardner pointed out that Eastman plates had been used to look for mesons but without success and that they had attributed this failure to lack of sensitivity of the Eastman plates or to improper processing conditions. However, it was pointed out that the trials made with Eastman plates had not been extensive and furthermore that the plates that had been used were several months old and certainly not recent NTB plates that are known to be capable of registering mesons (3-5 Mev) and electron tracks (50 Kev). Dr. Gardner pointed out that it had been difficult to obtain Eastman plates without considerable delay and that it had been necessary for them to buy fairly large quantities and store them for future use.

Dr. Gardner was very emphatic in pointing out that their experience with the Eastman nuclear track plates had shown them to be variable in their response to high-speed particles. He said that some batches of the Eastman plates had been very insensitive. Dr. Gardner said he thought that the manufacturer of nuclear track plates should be very frank in telling scientists the true qualities of these plates and that if they are inconstant in their properties, the scientists should be told so. Dr. Gardner pointed out that scientists were prone to take a plate and use it assuming that it were absolutely constant in its properties. Therefore, he thought it was up to the manufacturer to point out to the scientist the variations to be expected so that he would not be misled and thereby publish incorrect conclusions. Everyone agreed with Dr. Gardner that frank information should be given on the plates.

Dr. Spence pointed out that the NTB plates had been somewhat variable in their properties. However, these plates have always been sold on an experimental basis and sold under the label of an experimental product. He said that the experimentation on these plates had been the cause of some changes in the plate, but generally speaking, the sensitivity had been on the upgrade all the way through.

Dr. Gardner pointed out that Eastman plates in some ways were superior to Ilford plates, e.g., in having lower background.

Dr. Gardner passed around pictures of meson tracks obtained on Ilford plates at the University of California, and Dr. Spence passed around pictures of meson tracks obtained on the latest NTB Eastman plates (exposed at California and processed here at Rochester). Dr. Spence also showed some electron tracks of about 20 grain lengths obtained on our recent NTB plates. Everyone showed great interest in the meson tracks obtained on the Ilford plates in California, and Dr. Gardner was pleased with the meson tracks of 400 µ length shown on the recent NTB emulsion.

Dr. Spence raised the question of devising good tests for our NTB plates. This test should be easy to perform, repeatable, and adequate for determining the limit of sensitivity for low ionizing particles. All of these criteria seem to be met by a test using electron tracks. Photoelectrons obtained by irradiation with known voltage x-rays can be used for exposing the plates. The length of electron tracks obtained as well as the density of grains in the tracks will serve as a testing procedure that can be carried out here. Mr. Davies suggested that a test might be devised whereby direct density measurements of the x-ray exposures can be used instead of looking at tracks. The exposure in the case of x-rays being mostly due to electrons, density measurements might be sufficient for measuring sensitivity. The general feeling was, however, that in addition to a density measurement, it would also be necessary to observe some tracks.

Considerable discussion was devoted to the subject of standardization of the NTB plate. At present this plate is sold as an experimental plate in various thicknesses and sizes. The consensus of opinion seemed to be that we should standardize this plate as a fixed commercial item.

Size	1" x 3"
Thickness	50 µ
Sensitivity	To show electron tracks to 50 KV.

Dr. Spence pointed out that 12 good batches of these plates had already been made and therefore we should have no trouble in reproducing them now. It was further agreed that we should sell these plates in any size up to 8" x 10" and in thicknesses up to 100 μ on special order. However, plates on special order would not be delivered as promptly as the standard plates. It was suggested by Mr. Swann that all of this information should be included in the pamphlet on these plates that is now being prepared.

The matter of quantity production of the NTB plates was discussed at some length. Dr. Gardner stated that the Radiation Laboratory of California could probably get along with 5000-1" x 3" plates per year. He pointed out that in the near future there would be a number of other accelerators coming into use over the country and that each one would probably use as many plates as the University of California. It appeared, after some discussion, that a good production figure to aim at would be 100,000-1" x 3"--50 μ thickness-- plates per year. It was further agreed that we should plan to build up a stock of these plates so that orders can be filled promptly.

Mr. Swann asked what the shelf life of the plates is. Dr. Spence stated that the plates would keep 6 months at 70°F. However, the plates should be refrigerated for better keeping, and it was suggested that we advise the users to keep the plates in deep-freeze units. This type storage would not only preserve the plates against fog but to some extent against fog from cosmic rays and Radioactive contaminants in the glass plates.

There was some discussion among the Kodak people concerning the facilities for manufacturing 100,000-1" x 3" plates per year. It was pointed out that if the spectroscopic plates are moved from Building 3, then there will be additional space available for the nuclear particle plate work. Dr. Staud said that possibly production could be increased by putting three shifts to work on the production of plates. Dr. Spence was asked to look into the possibilities for doing this.

Dr. Leermakers asked Dr. Gardner if he could tell us about the uniformity of Ilford plates in connection with their use on the Cyclotron.

Dr. Gardner said that they had recently received some bad batches of Ilford plates--bad fog without exposure and variations in sensitivity from batch to batch. Dr. Gardner was of the opinion that Ilford makes their emulsions in very large batches. Variations within a single emulsion batch are very small.

It was suggested that we make NTB emulsions in large batches by blending several small batches of emulsion to make one large batch.

Dr. Spence said that this procedure was being followed at present.

Dr. Gardner remarked that in addition to the regular production of standard plates, they would like special experimental products from time to time--he referred to the plates that Dr. E. O. Lawrence had requested earlier impregnated with various elements. Dr. Gardner said that at the present time, e.g., they wanted plates with heavy metals distributed in small discrete specks in the emulsion, e.g., gold, lead, etc., that would act as targets in the emulsion. Such small specks of metal hit by mesons would be the centers of stars and would enable the experimenter to see the type of star originating from particular types of atoms.

It was pointed out to Dr. Gardner by Dr. Mees that we can probably incorporate metal in an emulsion by first dispersing the metal in an oil emulsion and then putting this into the photographic emulsion. The oil acts as a protective agent around the metal. It was suggested that Dr. Carroll be consulted on this job.

Dr. Gardner said that we should talk directly to Dr. C. M. G. Lattes about this problem, since he was the one mainly interested and he is the one who will use the plates.

The question of development of our NTB plates was brought up for discussion by Dr. Leermakers.

Dr. Gardner said that they had missed observing mesons on the Ilford plates earlier by not using the recommended long-time development. He added that he did not know what would be the effect of prolonged development on Eastman NTB plates.

It was pointed out by Dr. Spence that the good meson tracks on Eastman NTB plates shown earlier at this meeting were obtained with 2'-development in D-8 developer. He added that 5'-development would show only very slight improvement.

Dr. Staud said that Dr. A. Newton would spend 2 weeks at the Research Laboratory (May 3-17) studying development condition of the nuclear track plates and that he would convey all information thus gained back to Berkeley.

Dr. Leermakers pointed out further that we are getting a woman scientist from the University of Wisconsin for the coming summer to study the processing conditions of plates. She will be working with Dr. W. Vanselow.

It was suggested by Dr. Mees that further work might profitably be done on the microscopy of images of tracks. In this connection, he referred to the work of Burch at Oxford who had recently published work on the reflecting microscope, and it was suggested that we look into this work.

Dr. Gardner remarked that the Eastman Laboratory had made some nice emulsions for him with varying AgBr content for the study of star formation. This work was carried out for the purpose of ascertaining what elements of the plate are mainly responsible for star formation. He expressed thanks to the Eastman Laboratory for preparing these plates.

Dr. Spence mentioned that different impregnating compounds can now be put in our plates including: Boron, Lithium, Beryllium, and Bismuth. Where we incorporate these elements in the emulsion, we specify the processing conditions. However, it was pointed out that when the customer does his own impregnating of plates, it should be up to the customer to determine his own processing condition.

Dr. Staud summed up the main points of the meeting as follows:

Production

1. We have so far made 12 good batches of the high sensitivity NTB plates that record good meson tracks and 20 grain electron tracks. We will go

ahead and try to standardize on this plate. We will build up a stock file of these plates with the idea of filling orders in future. We won't make any statement right now about delivery dates.

2. We shall aim to produce large quantities of this emulsion--10,000 dozen (1 x 3) per year.

3. We shall standardize on 1" x 3" plates, 50 μ thick.

4. We shall supply any size plates up to 8" x 10" and thickness up to 200 μ on special order. We shall state in our literature that these special plates will be slower in delivery.

Tests

1. We shall try to work out a standard electron track exposure for testing our plates. We shall look into the matter of the x-ray-density type test suggested by Mr. Davies to see if this is a good test. It appears that it might be, since most of the x-ray exposure is due to electrons.

2. We now have 50 dozen of the Harrow high sensitivity proton plates for distribution to scientists. These will be distributed 1 dozen to each customer free. At the same time, we shall send one dozen NTB plates and tell the customer to try both and let us know which he likes best. In this way, we shall get information on both the Harrow and Rochester plates for comparison.

Processing

1. Dr. Newton will spend two weeks in Rochester working on processing NTB plates, and he will take the results of this study back to Berkeley.

2. We are getting a woman scientist to work with Dr. Vanselow during the coming summer, and she will spend some time on development.

Observing Tracks

1. We shall look into the matter of the Burch reflecting microscope to see if this has any advantages for observing tracks.

Research Work

1. We shall do follow-up work on the variable AgBr content emulsions already sent to Dr. Gardner. Dr. Gardner is still working on the plates we sent him earlier.

2. We shall discuss with Lattes and do work on the problem of incorporating specks of heavy metals in the emulsion.

3. Dr. Spence will continue to experiment in an attempt to push sensitivity of the nuclear track plates up to the ultimate limit. We should like to send experimental plates to Dr. Gardner for tests--possibly meson and electron exposures. This must be worked out between Gardner, Spence, and Webb.

JHWebb:mem

J.H. Webb

[109] Cy para E. Lawrence (The Bancroft Library, University of California, Berkeley, 1948), correspondência, rolo 13, caixa 06, pasta 25.

EASTMAN KODAK COMPANY

ROCHESTER 4, N. Y.

May 24, 1948

Dr. E. O. Lawrence
Radiation Laboratory
University of California
Berkeley 4, California

Dear Ernest,

arrived 5-29-48

Mr. E. R. Davies, who is director of the Harrow Research Laboratory of Kodak Limited, has been in Rochester for some weeks and, before returning to England, is making a rather hurried trip to the west coast. He is expecting to arrive in Los Angeles this morning, May 24, and according to his present plan will reach San Francisco Saturday evening, May 29, and expects to leave Sunday evening, May 30. Mr. Davies would like very much to see your cyclotron, if arrangements could be made, and if it would be any more convenient for you, I think that he could cut his stay in Hollywood by one day and arrive in San Francisco on Friday evening, May 28.

I do not know whether the laboratory would be open, or whether there would be any regulations concerning the admission of aliens from a security standpoint. It occurred to me that if the admission aspect was clear, possibly Amos Newton might be able to show Mr. Davies about for an hour or two on the hill. I am sure that Mr. Davies would appreciate an opportunity to say hello to you during his brief stay in San Francisco, if this can be arranged conveniently.

We enjoyed having Amos Newton here, and appreciated the visit of Dr. Gardner and Dr. Lattes. They are both fine men, and I know you must feel fortunate to have them on your staff.

It appears to us that the NTB plates are now generally useful where they apparently had some shortcomings earlier, and we are planning to produce plates with a given formula rather than carry our experimentation into the cyclotrons. However, we hope and expect to be able to send experimental plates to Berkeley as part of our joint cooperative program. Dr. Lattes made some suggestions for types of plates to be used in specific problems in which he is interested, and those of us concerned here you may be sure will do our best to provide Dr. Lattes the best plates we can make for his investigational work.

Dr. E. O. Lawrence -2- May 24, 1948

We have issued a small mimeographed pamphlet to various users of nuclear track plates, which we hope will get our information into a concise form and make it generally available. I do not know whether Amos Newton took back a copy of it with him when he left, but I am attaching one to this letter.

We are still trying to get a lawn started at 260 Kilbourn Road but, at the present rate, the color of the yard is not changing rapidly from brown to green.

Both May and I recall with pleasure your last visit here, even though it called for dinner in 12.45 minutes. We are looking forward to your next visit, and hope that on one of these occasions we may be able to work out a better schedule than the early evening train which you take to Schenectady.

With best regards to Molly and yourself,

Sincerely yours,

Research Laboratories

CJStaud/LM