TWO NEUTRINO EXPERIMENT

Konstantin Goulianos

The Rockefeller University

A lecture dedicated to:
Mel Schwartz, - my mentor and thesis advisor
Leon Lederman and Jack Steinberger - my co-mentors and co-advisors
Nari Mistry – my twin neutrino
Jean-Marc Gailliard – visitor from Orsay
Gordon Danby, BNL
Warner Hayes, our technician at large
COLUMBIA AND BNL

BNL 90/50/10 CELEBRATION

BROOKHAVEN NATIONAL LABORATORY

JUNE 12, 2010

The 2ν's – a personal account

1958 – 60 @ Columbia: graduate courses

- some fellow students:
  - Nari Mistry – the other neutrino
  - Mike Tannenbaum ($\mu p \to \mu p$), David Bartlett ($\mu \to e\,\gamma / \mu \to e\,\nu\,\bar{\nu} < 10^{-8}$)
  - Richard Friedberg
  - Norman Christ
- some professors:
  - Lee, Rabi, Towns, Kush, Lederman, Schwartz, Steinberger, Feinberg

- 1960 – 61 @ Nevis: spark chamber R&D
  - (then) future Nobel recipients: Rainwater, Rubbia, Ting
  - Charlie Baltay, John Peoples, Lee Pondrom, Uriel Nauenberg, …+…
- 1961 @ BNL: assemble and test 10-ton spark chamber detector
- 1962 @ BNL: 2ν run (a six-month-long shift!)
- 1963: write thesis ➔ PhD
- 1964: follow-up neutrino experiment with a 50-ton spark chamber
  - ➔ search for W in di-muon production $\nu_\mu + A \to \mu + W(\to \mu + \nu_\mu) + A'$
  - ➔ found evidence for neutral currents but quoted an upper limit.
- 1976: neutrino-proton elastic scattering: **hys.Rev.Lett.37:186-189,1976**

2ν-PAPERS

OBSERVATION OF HIGH-ENERGY NEUTRINO REACTIONS AND THE EXISTENCE OF TWO KINDS OF NEUTRINOS*

G. Danby, J-M. Gaillard, K. Goulianos, L. M. Lederman, N. Mistry, M. Schwartz,† and J. Steinberger†

Columbia University, New York, New York and Brookhaven National Laboratory, Upton, New York

(Received June 15, 1962)

REMARKS CONCERNING THE RECENT HIGH-ENERGY NEUTRINO EXPERIMENT*

G. Danby, J.-M. Gaillard,† K. Goulianos, L. M. Lederman, T. D. Lee,‡ N. Mistry, M. Schwartz,‡ and J. Steinberger‡

Columbia University, New York, New York and Brookhaven National Laboratory, Upton, New York

(Received 4 February 1963)

SEARCH FOR INTERMEDIATE BOSONS IN HIGH-ENERGY NEUTRINO INTERACTIONS*

R. Burns, K. Goulianos,† E. Hyman, L. Lederman, W. Lee, N. Mistry,‡ J. Rettberg, M. Schwartz, and J. Sunderland

Columbia University, New York, New York, and Brookhaven National Laboratory, Upton, New York

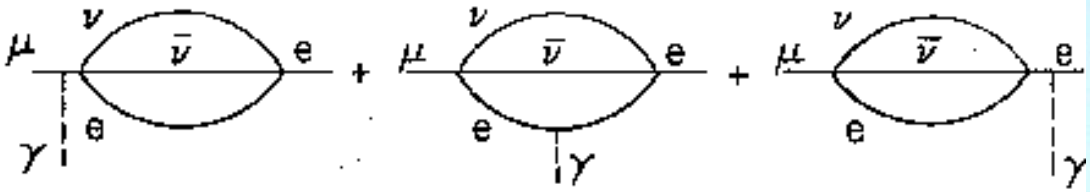
and

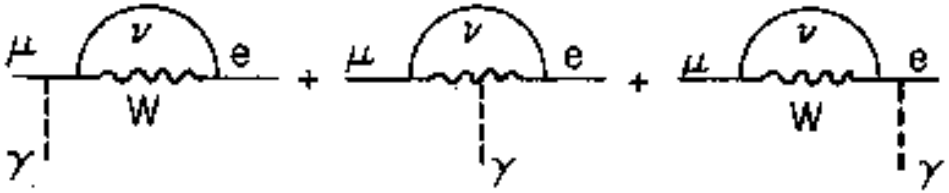
G. Danby

Brookhaven National Laboratory, Upton, New York

(Received 24 May 1965)

$\mu \nrightarrow e\,\gamma \rightarrow \nu_\mu \neq \nu_e$





R - 364
CU - 219
Nevis - 113

Nevis Laboratories
Columbia University
Physics Department
Irvington- on-Hudson
New York

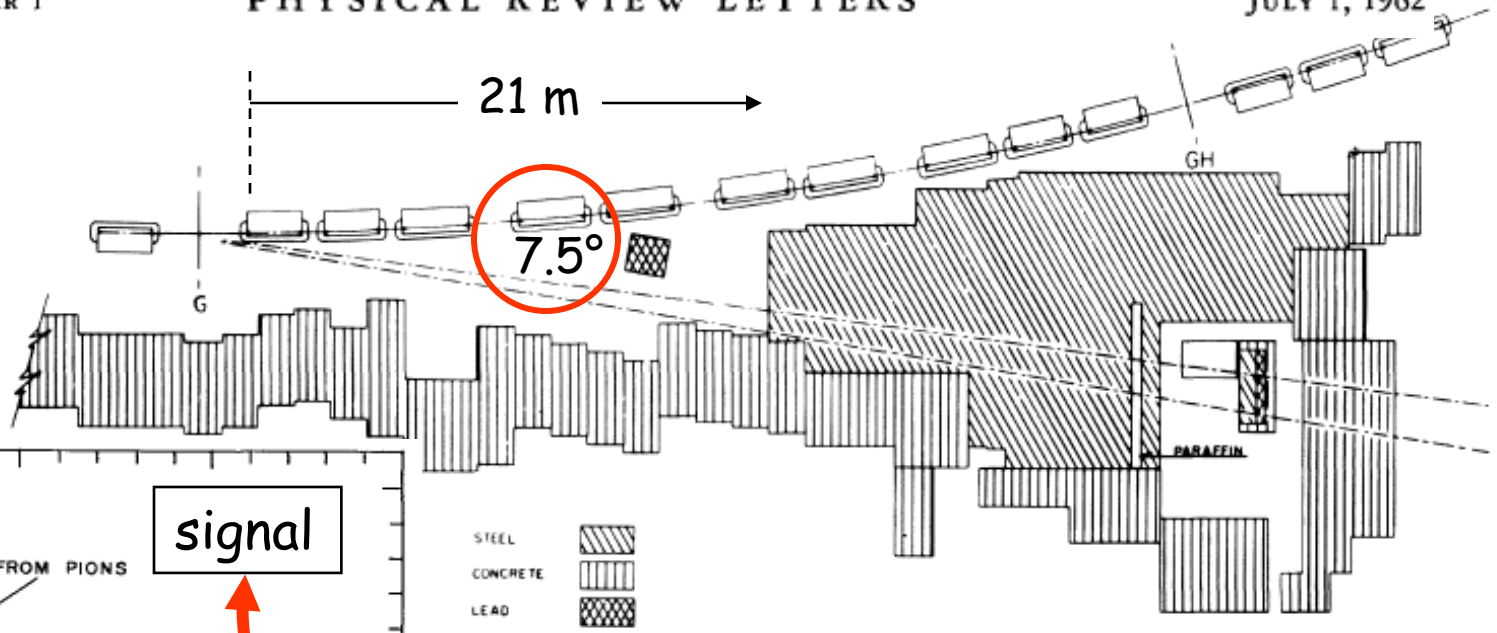
June 1963

Experimental Proof of the Existence of Two Neutrinos

KONSTANTIN GOULIANOS

Experimental set-up

VOLUME 9, NUMBER 1 PHYSICAL REVIEW LETTERS JULY 1, 1962



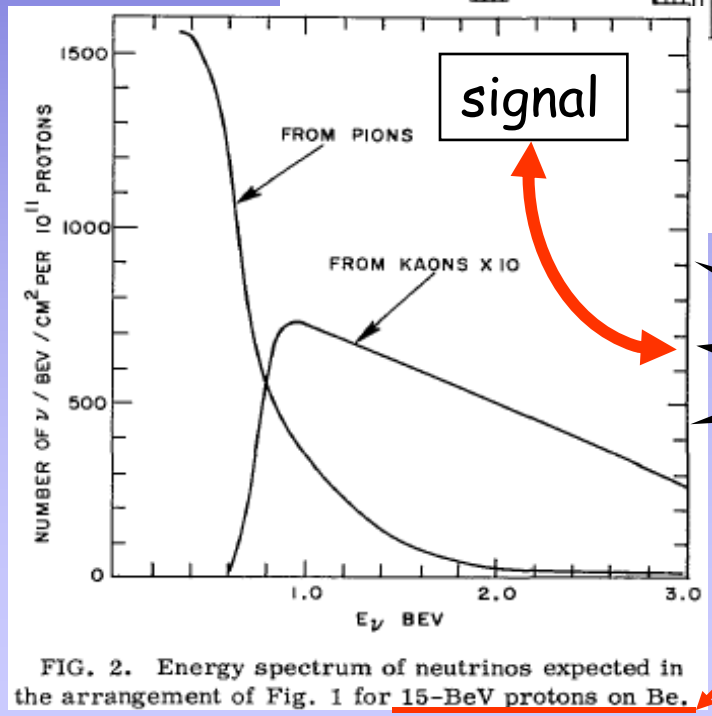
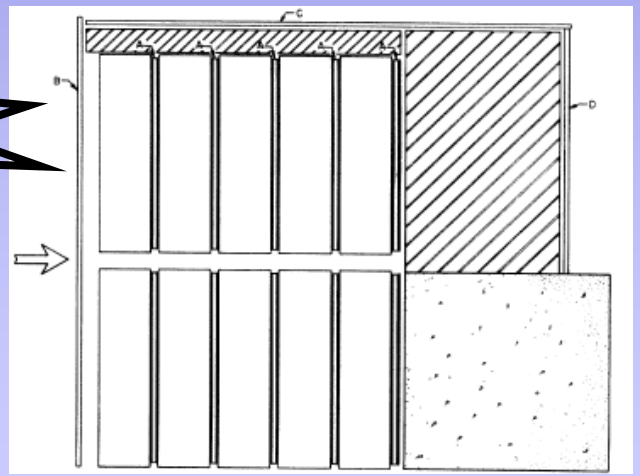


FIG. 2. Energy spectrum of neutrinos expected in the arrangement of Fig. 1 for 15-BeV protons on Be.

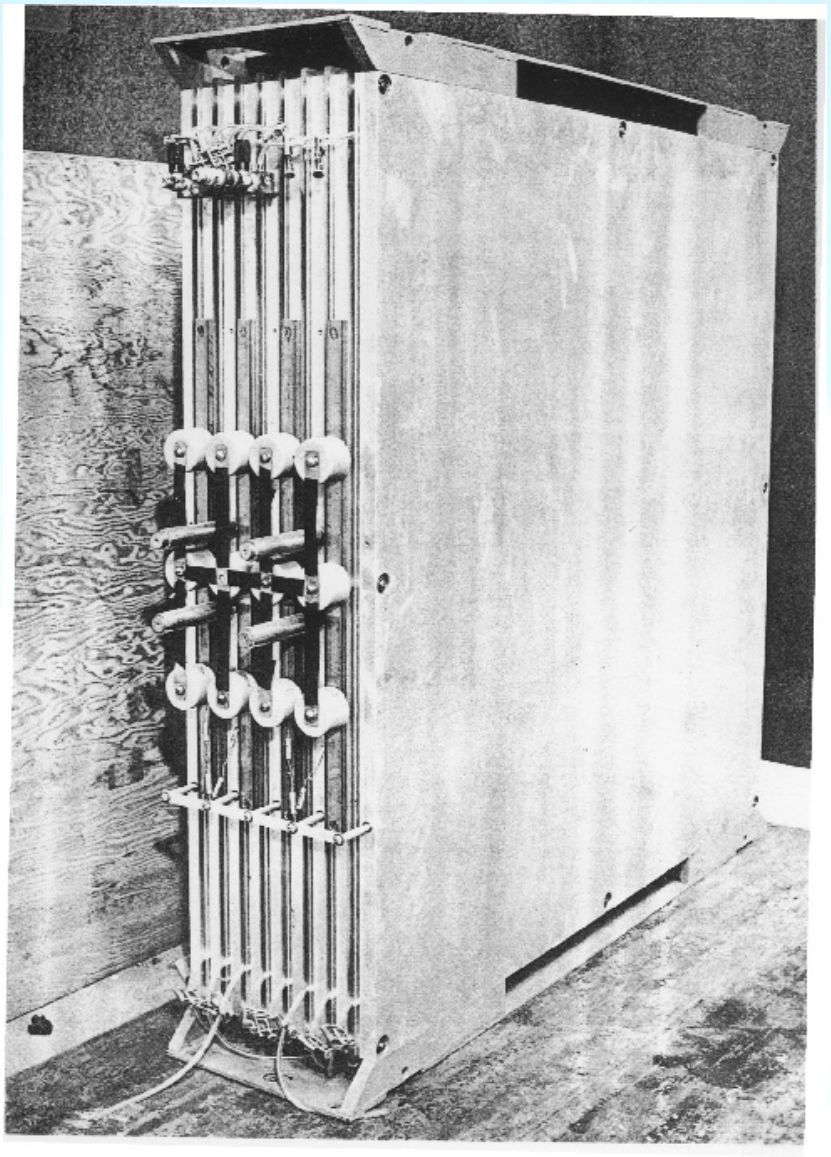
BACKGROUND

15 – BeV

shielding!!!

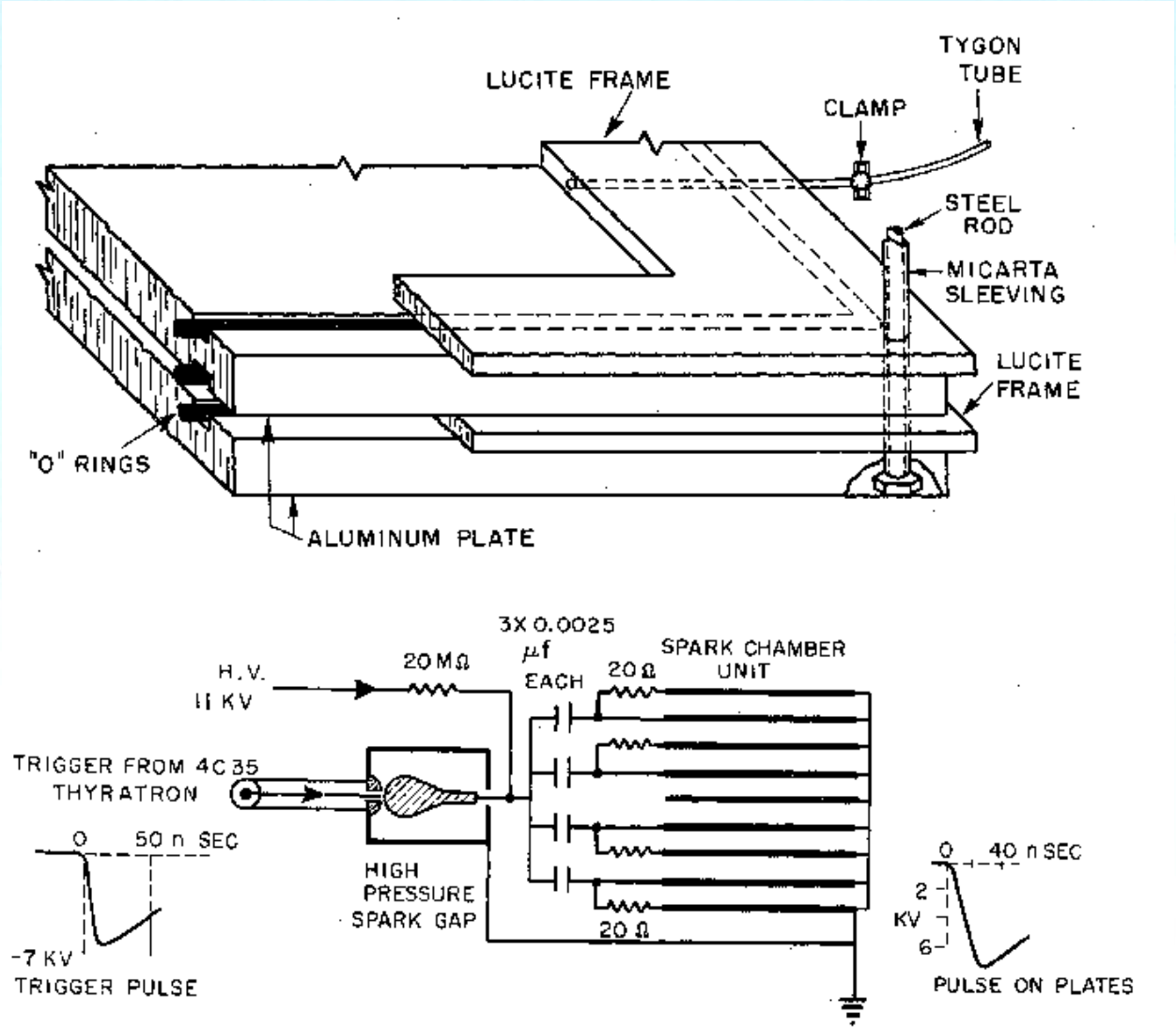


SPARK CHAMBER – at Smithsonian?



CHAMBER CONSTRUCTION AND TRIGGERING

SPARK GAP



OPTICS

VERTICAL PROJECTION

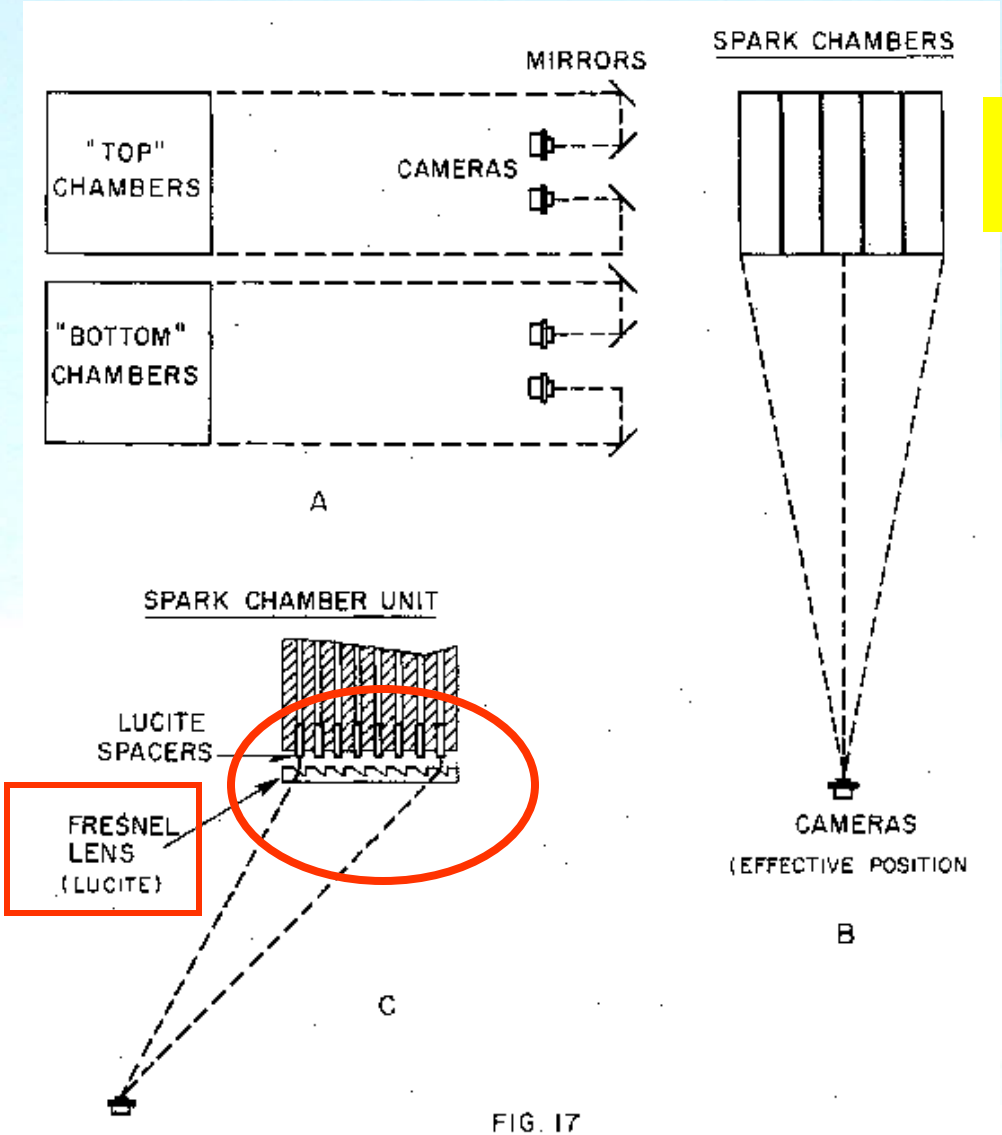
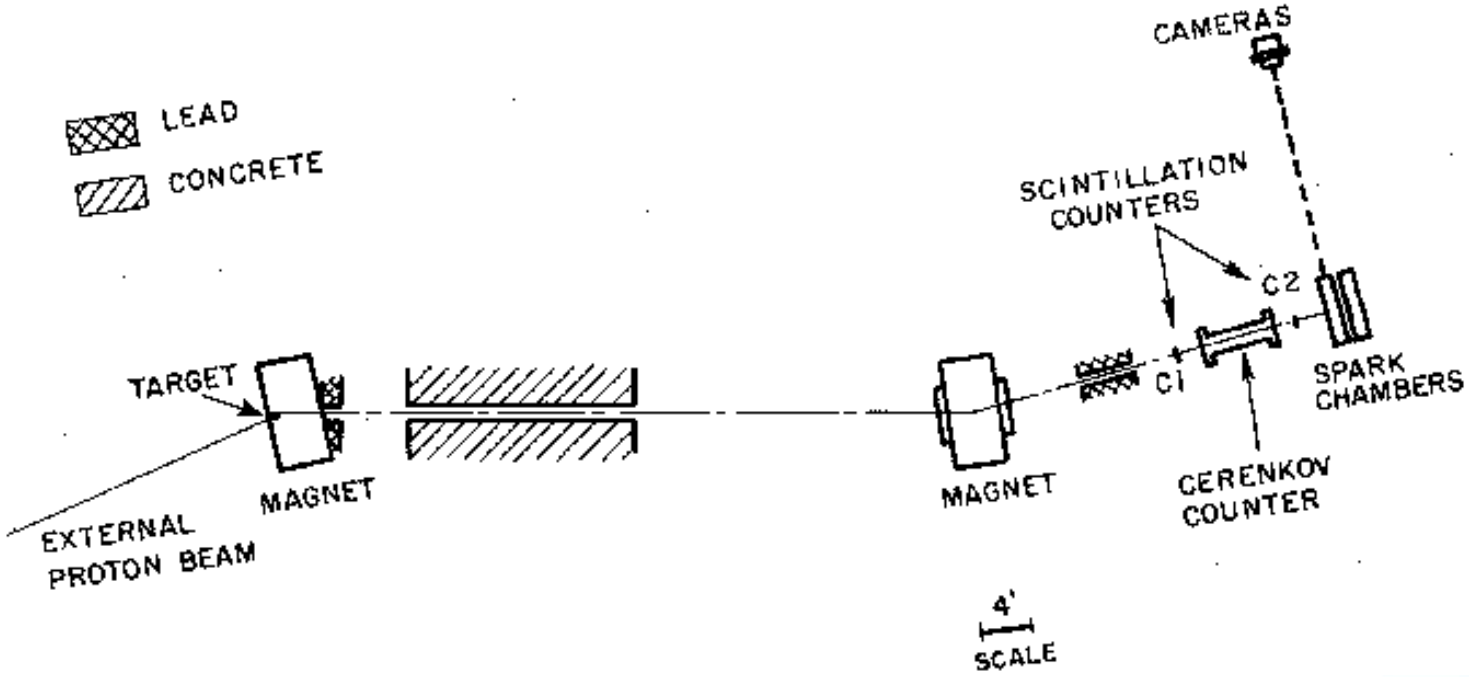


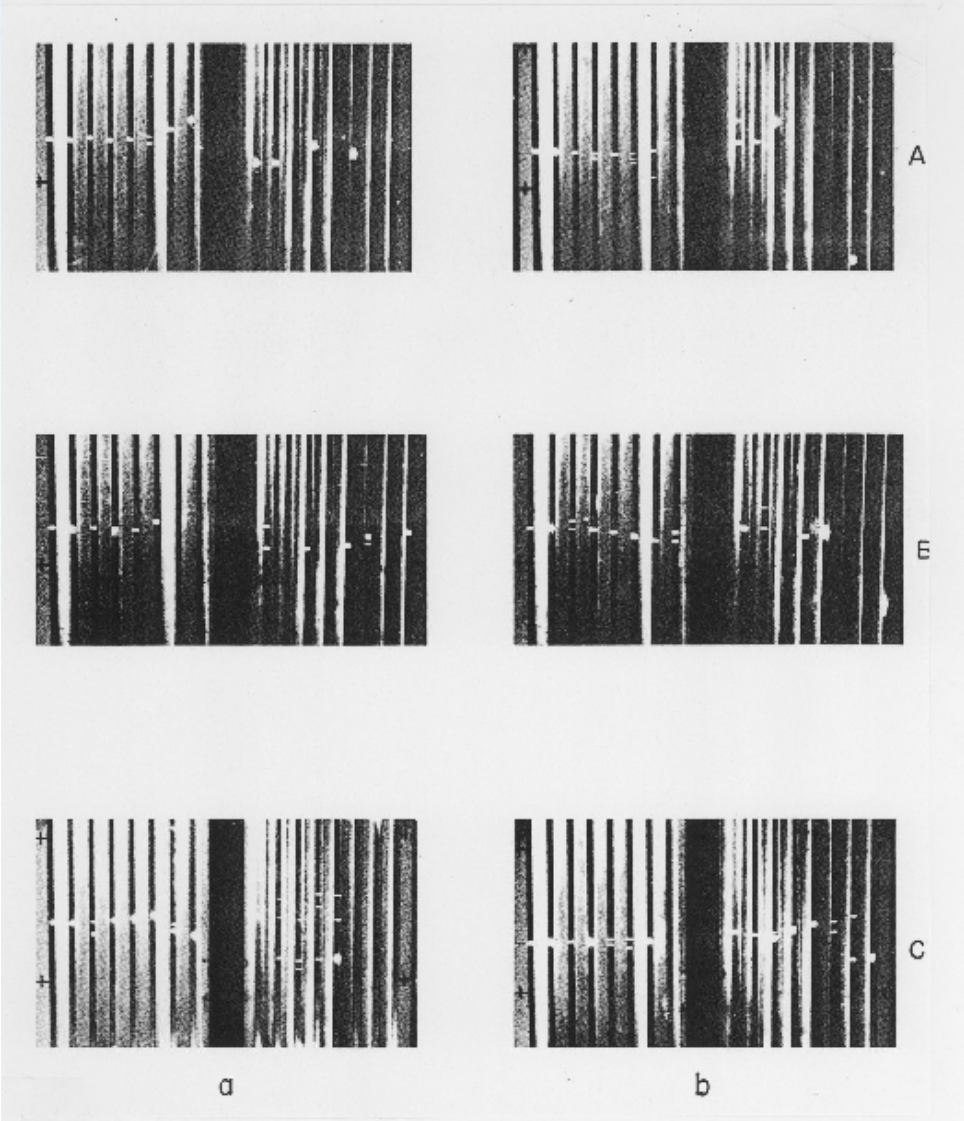
FIG. 17

HORIZONTAL PROJECTION

e-CALIBRATION AT THE COSMOTRON



e - SHOWERS FROM COSMOTRON TEST

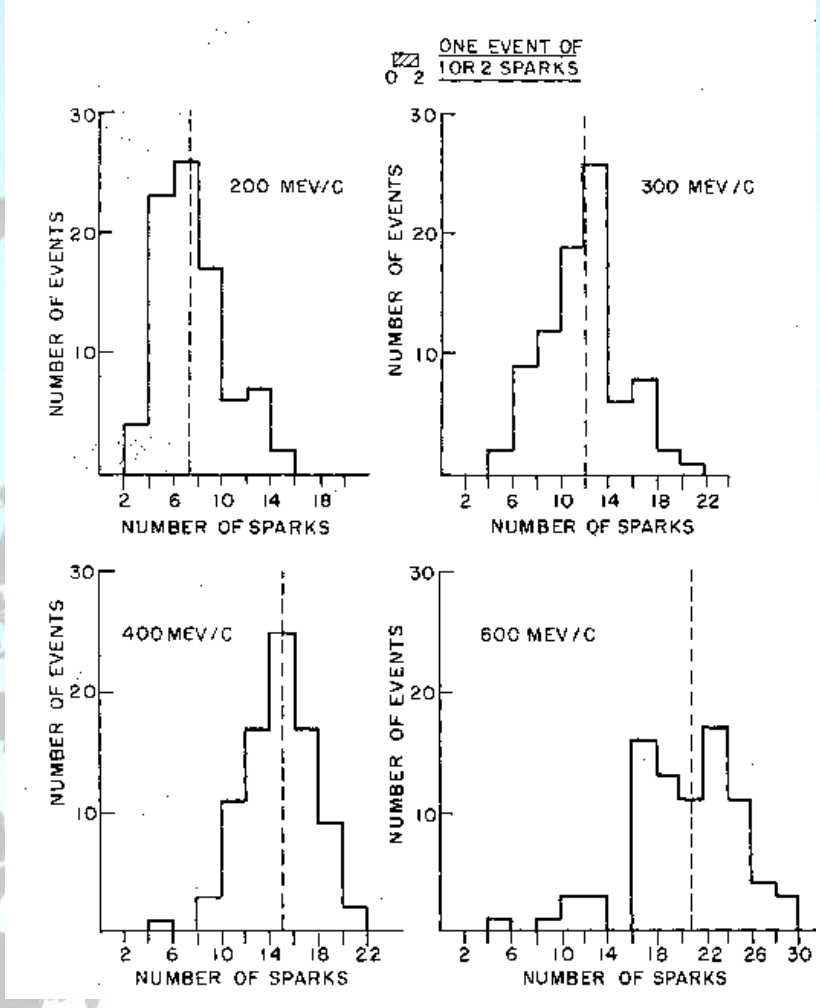


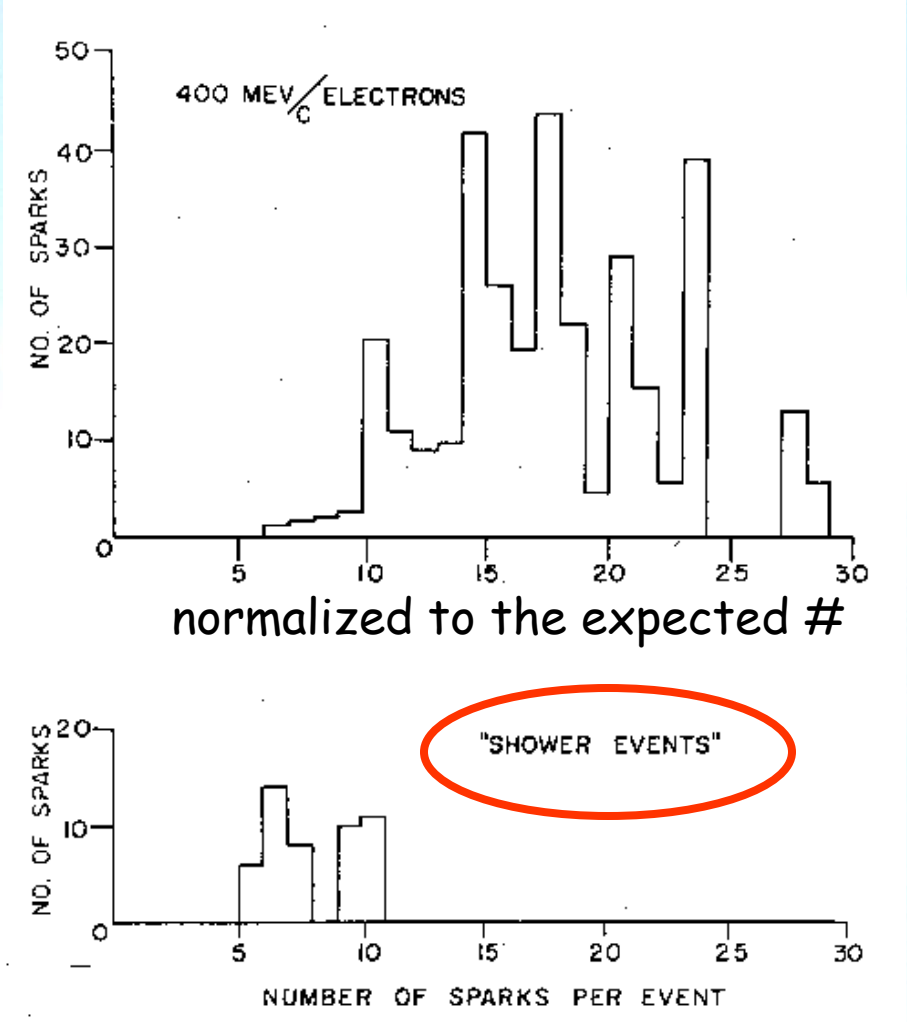
300 MeV/c

400 MeV/c

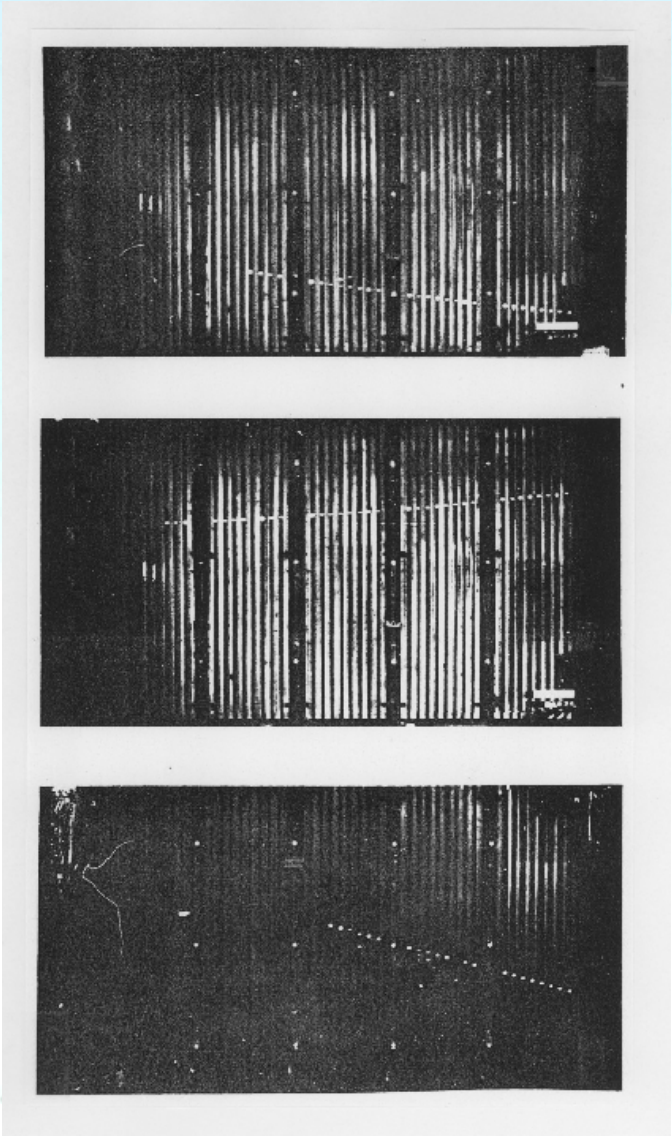
600 MeV/c

e - CALIBRATION: NO. OF SPARKS





SINGLE MUON EVENTS



A "VERTEX" EVENT: E_{total}=2 BeV

$\nu + p \rightarrow p + \mu^- + W^+$ $\quad W^+ \rightarrow \pi^+ + \pi^o$ $\quad \pi^o \rightarrow \gamma + \gamma$ (?)

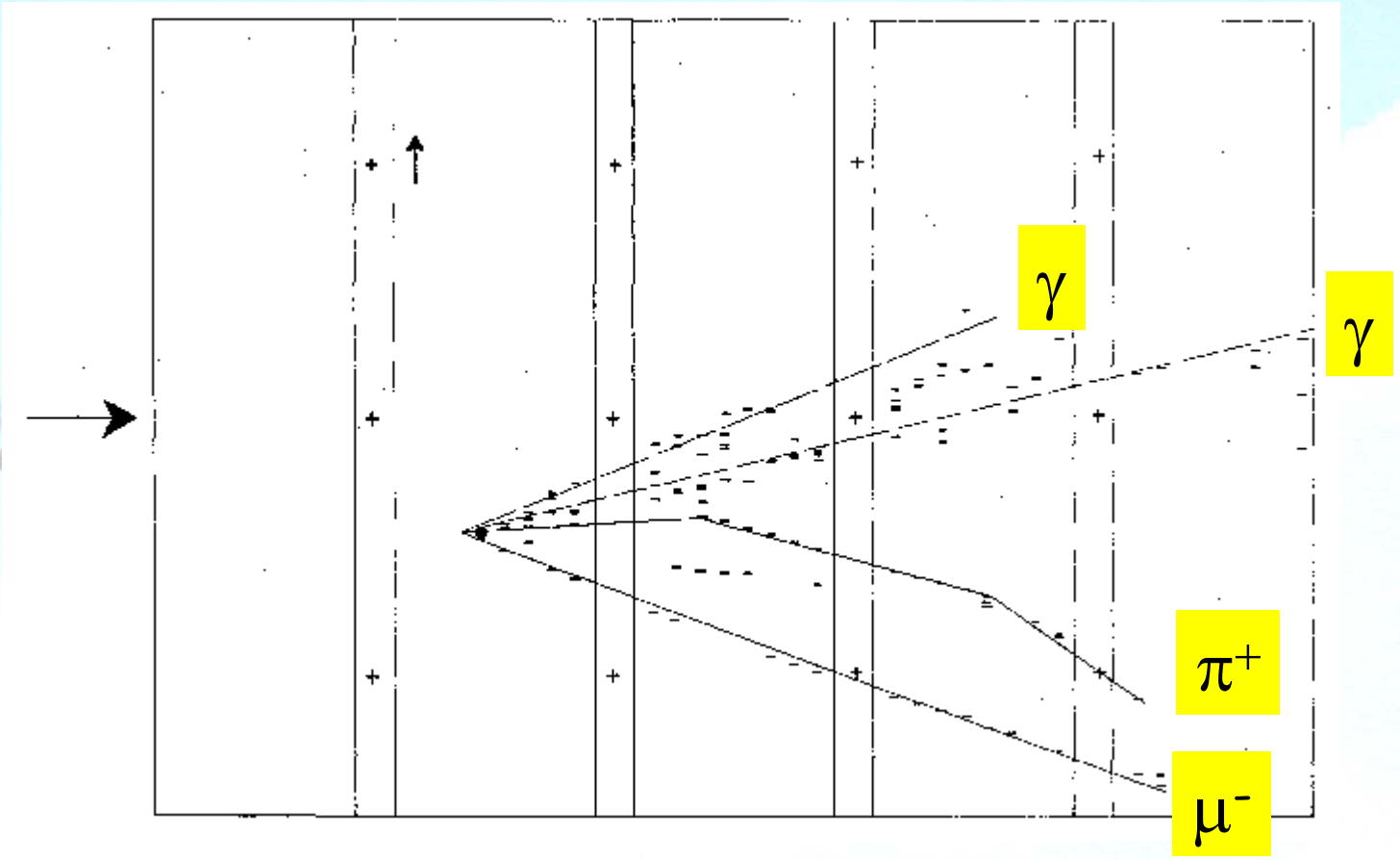


TABLE OF OBSERVED EVENTS

Classification of "Events"

Single Tracks

p_μ < 300 MeV/c[a]	49
p_μ > 300	34
> 400	19
> 500	8
> 600	3
> 700	2
Total "single Muon Events"	34

Vertex Events

Visible Energy Released < 1 BeV	15
Visible Energy Released > 1 BeV	7
Total vertex events	22

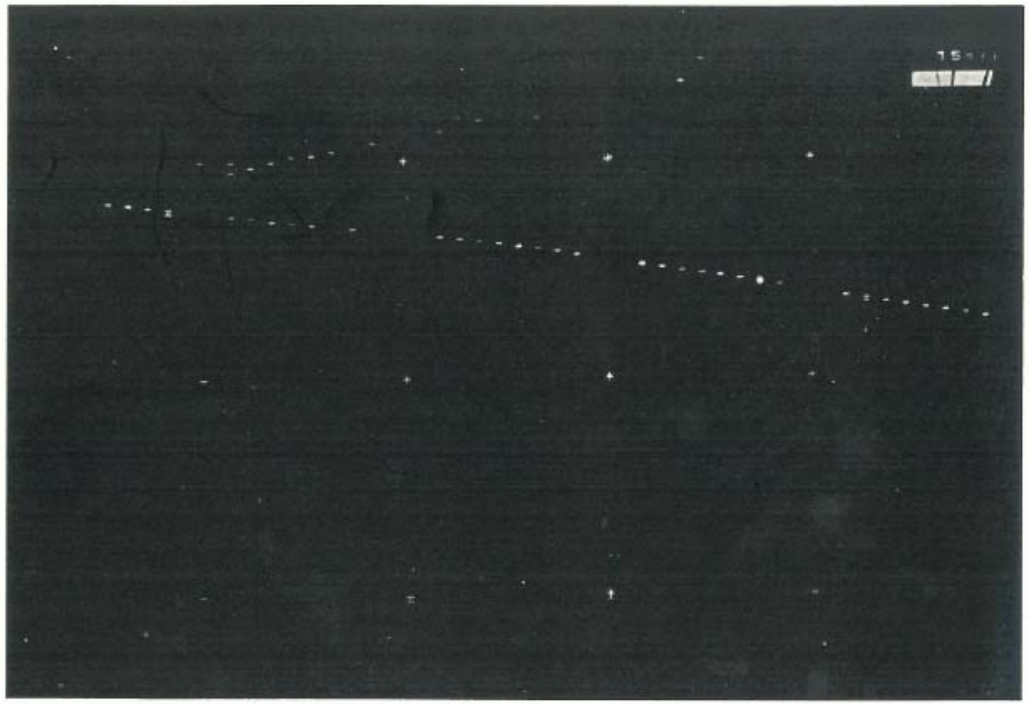
"Shower" Events

Energy of "electron" =	200 ± 100 MeV	3
	220	1
	240	1
	280	1
Total "shower events"[b]		6

[a] These are not included in the "event" count.

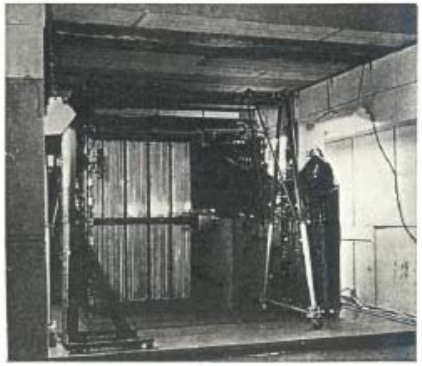
[b] The two shower events which are so located that their potential energy release in the chamber corresponds to muons of less than 300 MeV/c are not included here.

The first event



Neutrino Event

Columbia (Nevis)



BNL

In Token of Our Appreciation for Your Contribution to the Neutrino Run September 1961- June 1962.

"The Neutrino Group"

Gordon Danby
Jean-Marc Gaillard
Dino Goulianos
Warner Hayes
Leon Lederman
Nari Mistry
Mel Schwartz
Jack Steinberger

Mel & Gina Lollobrigida

Now La Lolla strikes her pose as a mock rock

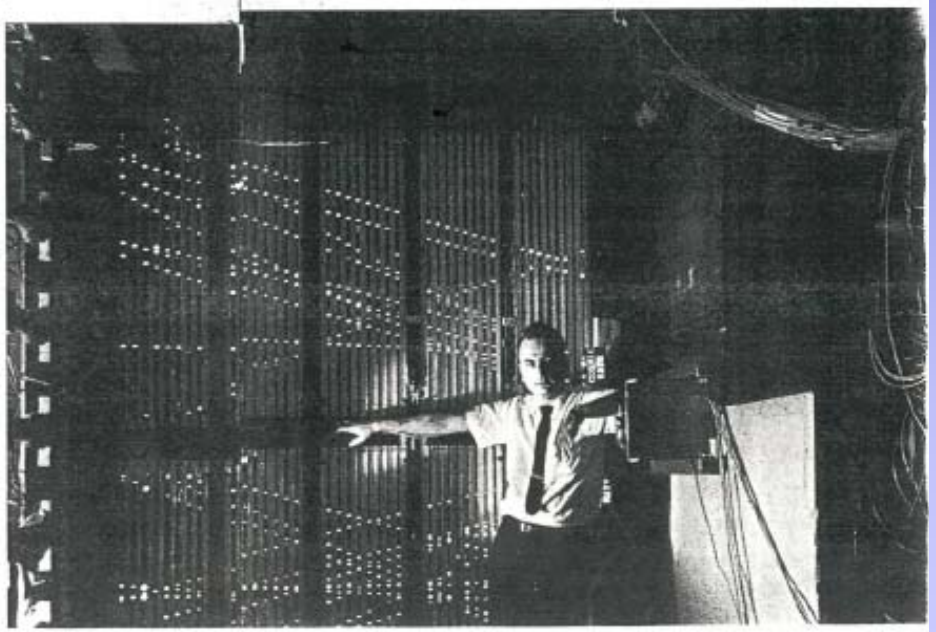
Pauline, sister of Napoleon, was both impulsive and generous, dispensing her favors to a scandalously long series of men, two of them actually her own husbands. In her prime Pauline was sculptured (*left*) by the Italian Antonio Canova in 1811. In the movie version of her life, *Imperial Venus*, Canova is first unmoved by the beauty of Pauline, played by Gina Lollobrigida. To inspire him she generously removes first one thing, then another, until finally (*below*) her kindness enables him to produce—so the script says—his masterpiece in marble.

Sparks to prove a way-out neutrino really exists

amos physicists, in 1956, proved that the neutrino really existed and was not a mere bookkeeping trick to make the equations balance.

Recently physicists have begun

atomic-age hardware that made the discovery possible. It is a 10-ton "spark chamber" at Brookhaven National Laboratory. The streams of fireworks in this time-



- but in the Greek Press…

ΟΜΟΓΕΝΕΙΑ

12 «ΠΡΩΙΝΗ» – Τρίτη 1 Νοεμβρίου, 1983

«Η επιστημονική έρευνα στη φύση των Ελλήνων»

Υποστηρίζει, σε αποκλειστική συνέντευξή του στην Πρωινή, ο συνεργάτης των φετινών Νομπελιστών Φυσικής, κ. Κωνσταντίνος Γουλιανός

Νέα Υόρκη.- «Το σπουδαιότερο πείραμα εις την ιστορία των Φυσικών Επιστημών, συμπληρώνεται εντός των προσεχών εβδομάδων. Παρίσματα μεγάλης σημασίας, θα προκύψουν δια την Επιστήμη», έγραφε τον Απρίλιο του '62, στην εφημερίδα «Ελευθερία», ο ανταποκριτής από την Νέα Υόρκη, κ. Σπ. Γρανίτσας, σε άρθρο με τίτλο «Ένα κοσμοϊστορικό πείραμα, θα καθορίσει την δομή της

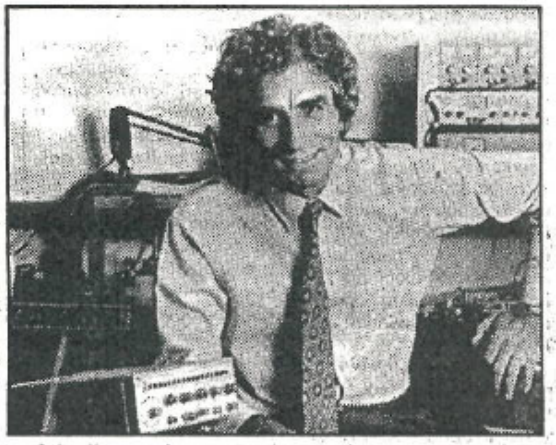
Του ΤΑΚΗ ΚΑΡΠΟΥΤΖΟΓΛΟΥ

ύλης—έρευνα δια το μυστηριώδες «νιουτρίνο»—Μετέχουν και Ελληνες επιστήμονες».

Λίγους μήνες μετά, την Κυριακή 1η Ιουλίου του 1962, «Τρείς Αμερικανοί Φυσικοί, κερδίζουν το βραβείο Νόμπελ για σημαντικό πείραμα—Το πείραμα τους οδήγησε στην δημιουργία της θεμελιώδους θεωρίας της σύγχρονης Φυσικής».

Το φετινό βραβείο Νόμπελ, των 390.000 δολ. θα μοιραστούν ο Δρ. Λέντερμαν, διευθυντής του Εθνικού Εργαστηρίου Επιταχυντήρων Φέρμι στο Σικάγο, ο Δρ. Σονάρτς, διευθυντής της εταιρίας Ντίτζιτας Πάθγουεϊς στην Καλιφόρνια και ο Δρ. Σταϊνμπεργκερ, ερευνητής στο Ευρωπαϊκό Κέντρο Πυρηνικής Ερεύνης της Γενεύης.

Ο Δρ. Κωνσταντίνος Γουλιανός, είναι ιδιαίτερα ευτυχισμένος για την τιμή αυτή. Παρ' όλο που τό όνομά



Ο Δρ. Κωνσταντίνος Γουλιανός σε πρόσφατη φωτογραφία του.

Στο πείραμα για τη διερεύνησή του, οι επιστήμονες δημιούργησαν για πρώτη φορά, εργαστηριακά το σωματίδιο αυτό, χάρη σε ένα επιταχυντή στο εργαστήριο του Μπρουκχέβεν. «Ο επιταχυντής αυτός, οφείλεται επίσης, σε ανακάλυψη κάποιου Ελληνα, του κ. Χριστόφιλου, ενός μηχανικού ανελκυστήρων», είπε ο Δρ. Γουλιανός.

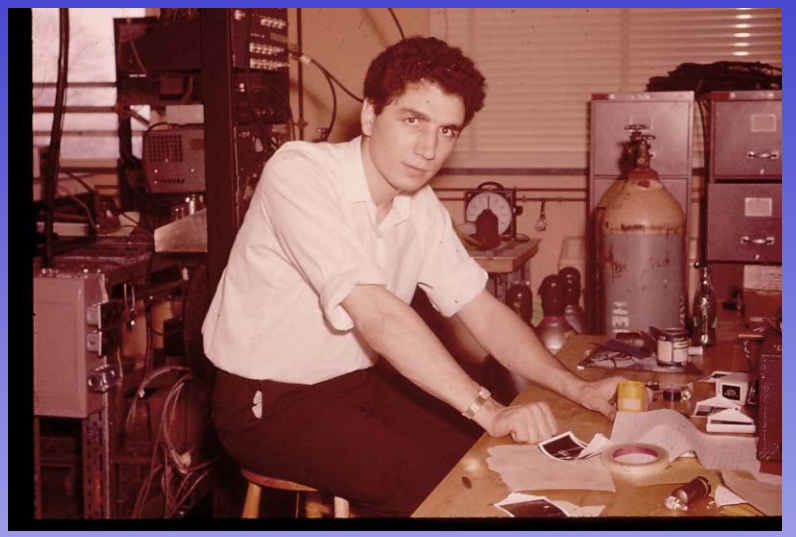
Το πείραμα διήρκησε συνολικά δύο χρόνια. «Μας πήρε ένα χρόνο μέχρι να φτιάξουμε την συσκευή για το πείραμα», είπε ο Δρ. Γουλιανός, που θυμάται με νοσταλγία το ενδιαφέρον και τον ενθουσιασμό των συνεργατών του ενώ πραγματοποιούσε [illegible] ασχολήθηκε με πειράματα αντιστροφής του χρόνου.

Στο Πανεπιστήμιο Ροκφέλερ, διδάσκει από το 1971. Αυτή την εποχή, παράλληλα με την θέση του στο Πανεπιστήμιο αυτό, συμμετέχει και στο πείραμα που διεξάγεται στο εργαστήριο Φέρμι του Σικάγο. «Στόχος του πειράματος είναι να ανακαλυφθεί ένα από τα «κουάρτζ», τα βασικά και στοιχειώδη σωματίδια. Στο πείραμα αυτό, συμμετέχουν περισσότεροι από 17 επιστήμονες από τις ΗΠΑ, την Ευρώπη και την Ιαπωνία. Είναι το μεγαλύτερο πείραμα που διεξάγεται αυτή την στιγμή σε ολόκληρο τον κόσμο», είπε ο Δρ. Γουλιανός, που πιστεύει επίσης ότι όταν ολοκληρωθεί το πείραμα αυτό, οι ΗΠΑ θα επανακτήσουν την ηγετική τους θέση στην επιστημονική έρευνα.

Δύο ακόμη Ελληνες έχουν συμμετάσχει σε πειράματα Φυσικής που βραβεύτηκαν με το Νόμπελ, λέει ο Δρ Γουλιανός: Ο Δρ. Τομ Υψηλάντης και ο Δρ. Τζου Ηλιόπουλος. Τονίζει το γεγονός ότι υπάρχουν πάρα πολύ καλοί θεωρητικοί Ελληνες Φυσικοί, παρ' όλο που η χρηματοδότηση στην Ελλάδα είναι σχετικά μικρή. «Υπάρχει μεγάλο ενδιαφέρον στην Ελλάδα για τις Επιστή-

At Nevis in 1960 - 61

wrapping counters
- all 130 of them!!!



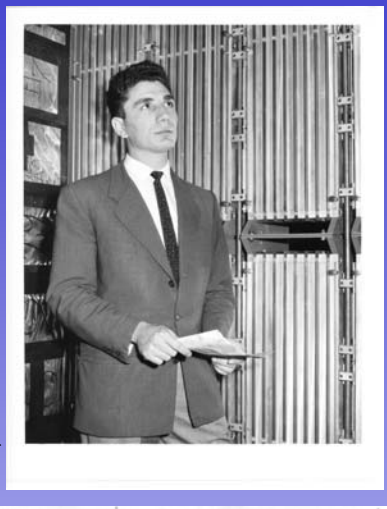
at my workbench
that doubled as a desk

-those were the days…

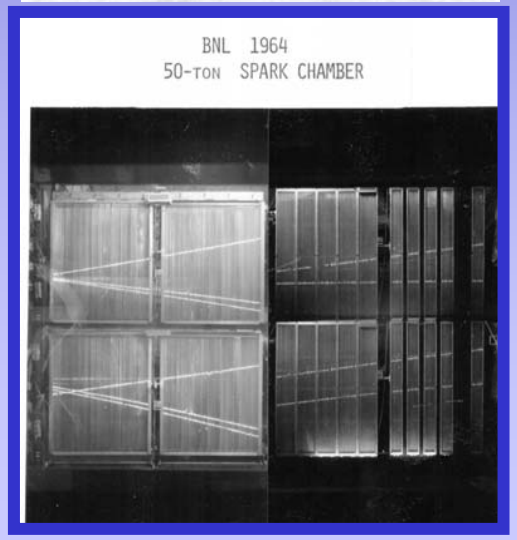
At BNL in 1961- 62 → 64

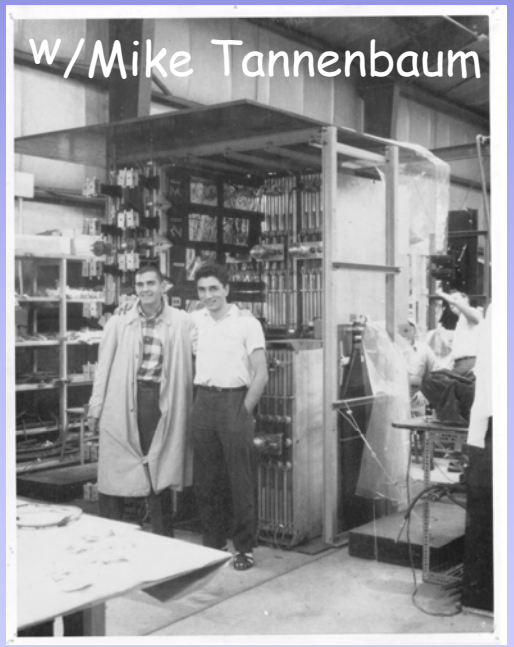
installing counters
- Mel, Dino and 1/3 of (?)

working



posing





SEARCH FOR THE W-BOSON

VOLUME 15, NUMBER 1 PHYSICAL REVIEW LETTERS 5 JULY 1965

SEARCH FOR INTERMEDIATE BOSONS IN HIGH-ENERGY NEUTRINO INTERACTIONS*

R. Burns, K. Goulianos,† E. Hyman, L. Lederman, W. Lee, N. Mistry,‡
J. Rettberg, M. Schwartz, and J. Sunderland

Columbia University, New York, New York, and Brookhaven National Laboratory, Upton, New York

and

G. Danby

Brookhaven National Laboratory, Upton, New York

(Received 24 May 1965)

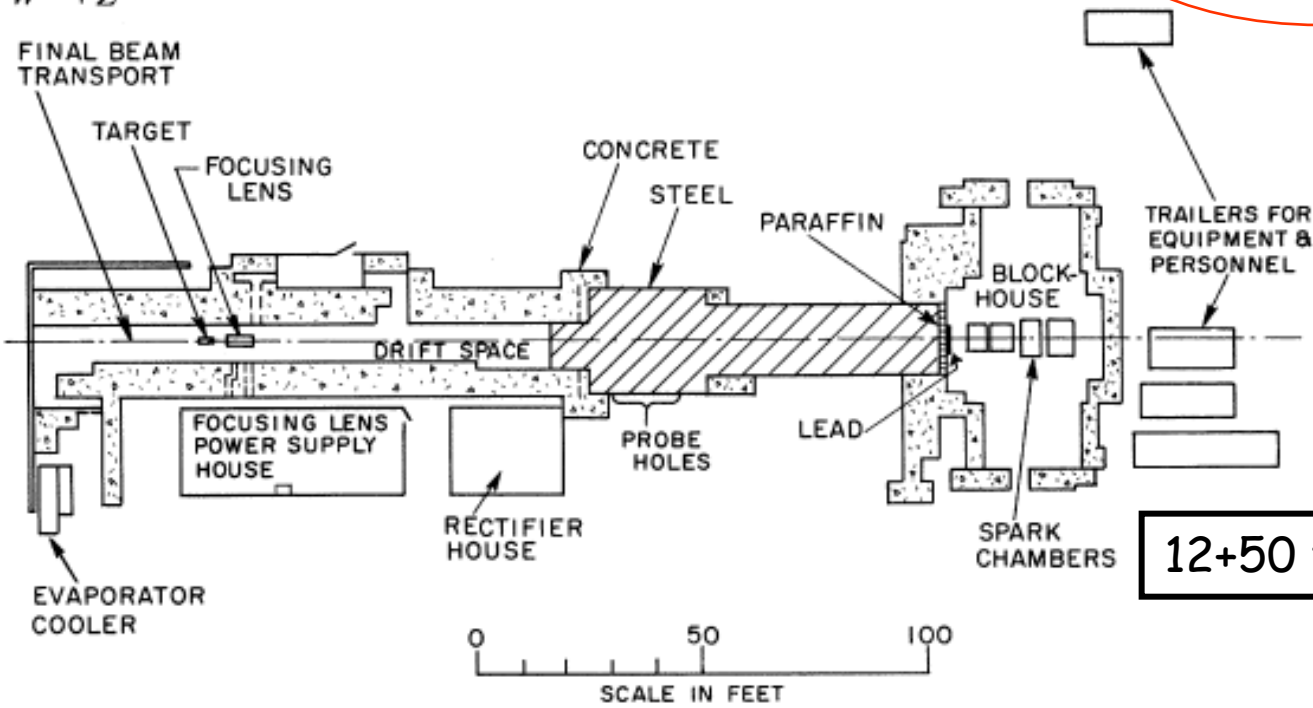
$$\nu_\mu + Z \rightarrow \mu^- + W^+ + Z'$$

$$W \rightarrow e + \nu$$

$$\bar{\nu} + Z \rightarrow \mu^+ + W^- + Z'$$

set limit on m_W

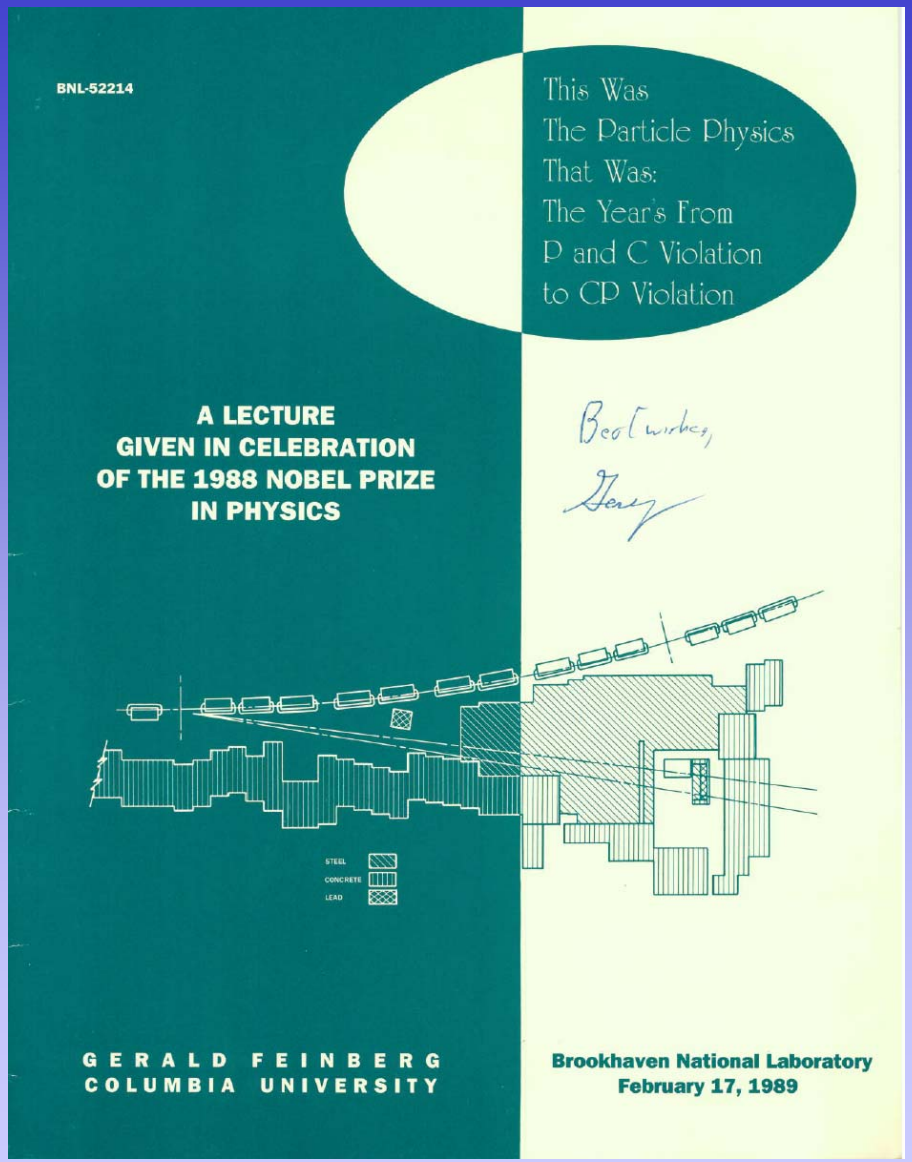
$$m_W > 2m_p$$

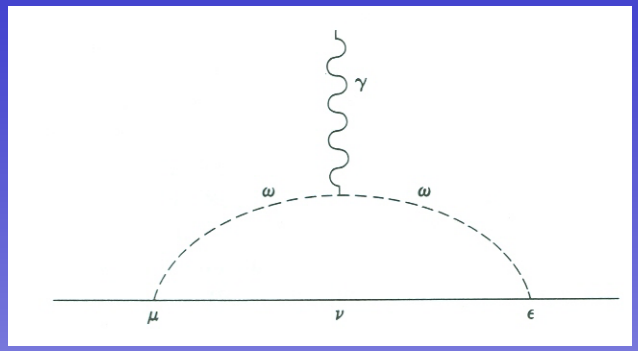


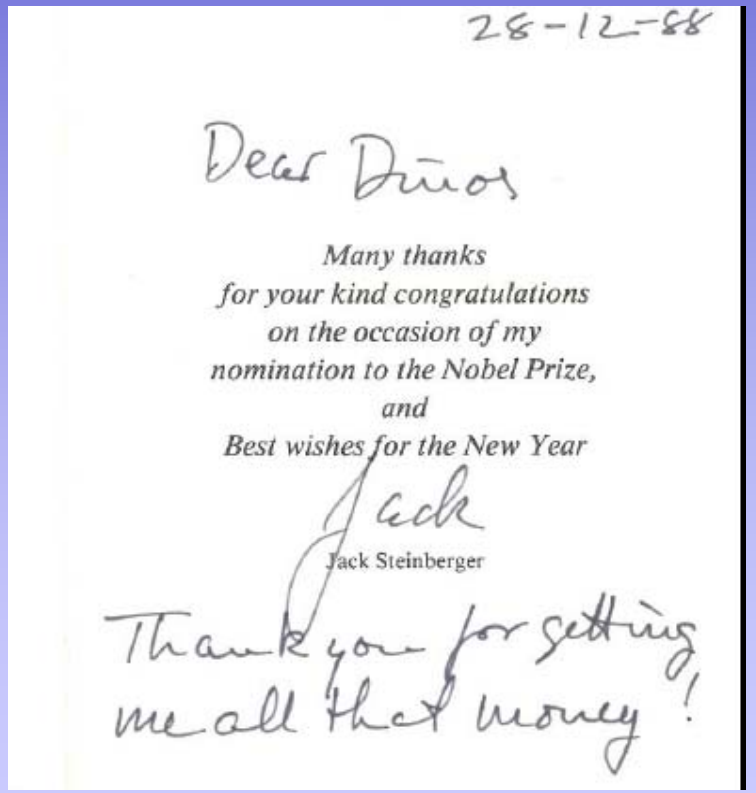
12+50 tons

In Stockholm in 1988

From Gary and Jack







NEVIS REUNION 18 FEB 1989

NEVIS REUNION

Feb. 18, 1989

10:30	Meet in Test Area Welcome & Introduction by Wonyong Lee
10:40-12:00	Talk by Mel Schwartz and Remarks by Leon Lederman and Jack Steinberger, the 1988 Nobel Laureates.
12:00- 2:00	LUNCH at Mansion House for Two-Neutrino Group and Guests LUNCH in Library for the Nevis Staff
2:00- 2:30	Talk by Dino Goulianos, student on the Two-Neutrino Experiment, with comments by Gordon Danby and Jean-Mark Gaillard.
2:00- 2:40	Film to be shown by Dave Hitlin.
2:40- 4:00	Reminiscences of Nevis in the 50's, 60's, 70's, etc. : David Berley, Warren Goodell, David Bartlett, and Charlie Baltay.
4:00	Concluding remarks by Allan Sachs.

THE NAMING OF THE MUON-NEUTRINO

FROM MY TALK AT THE NEVIS REUNION ON 18 FEB 1989

WHAT IS IN A NAME?

The Naming of
The Second Neutrino

Discovery story in Pictures

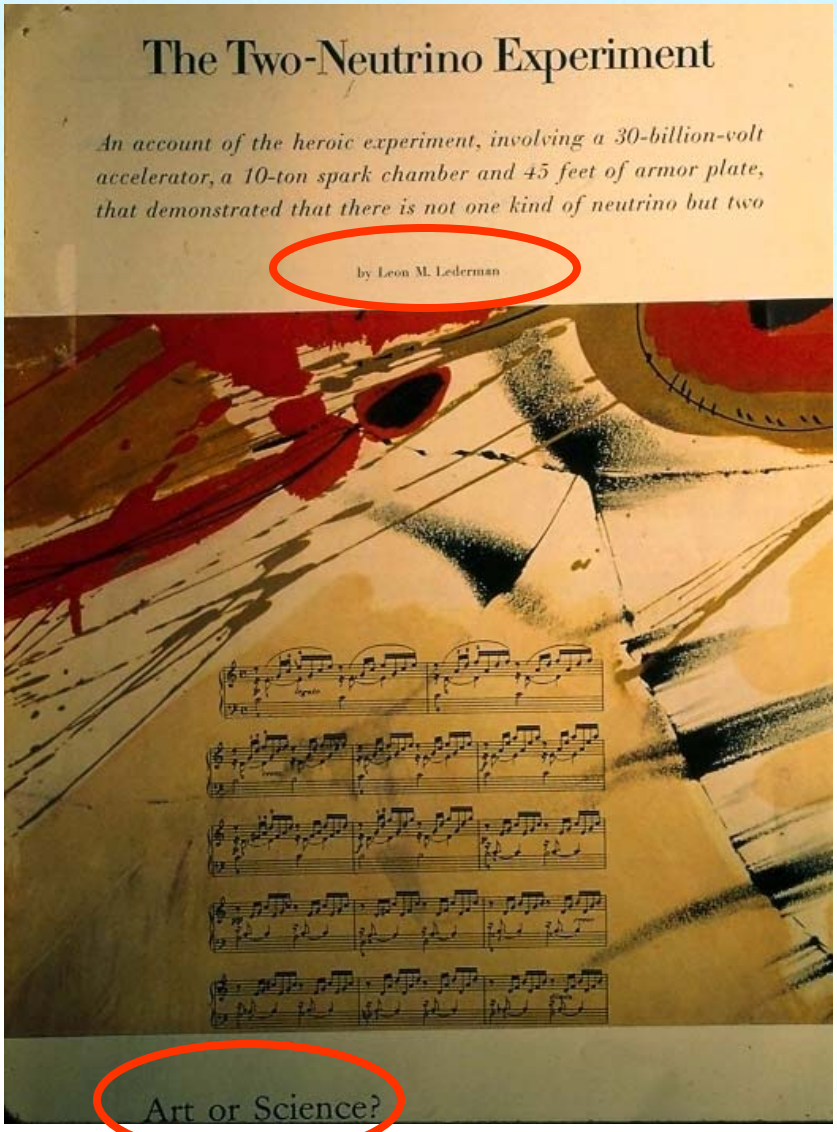
Gordon, Jean-Marc, Nari
Mel*, Jack*, Leon*
and The Peon

SLIDE 1: Art or Science?

SLIDE 2: The King and I.

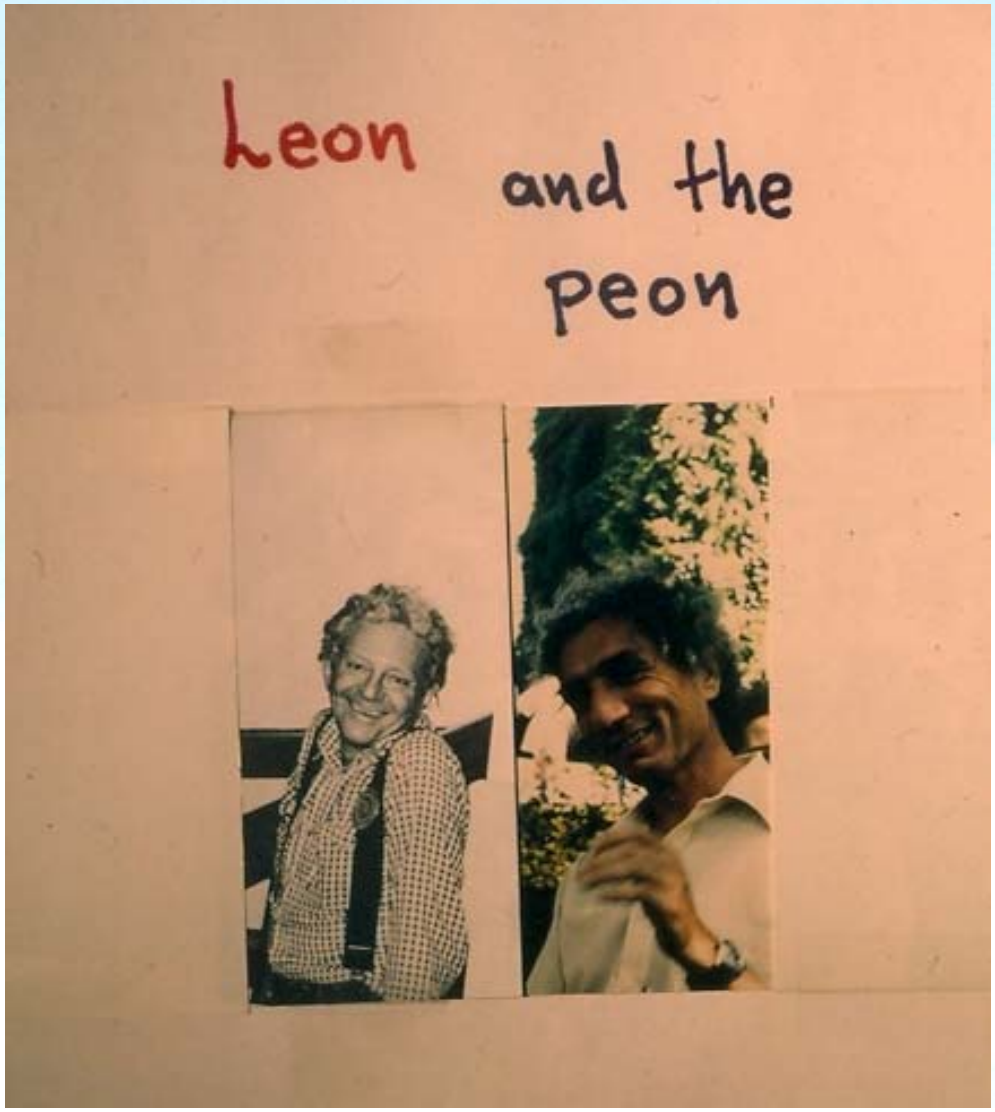
SLIDE 3: Leon and the Peon.

SLIDE 1: Art or Science?



SLIDE 2: The King and I.

SLIDE 3: Leon and the Peon.



VERSE 1

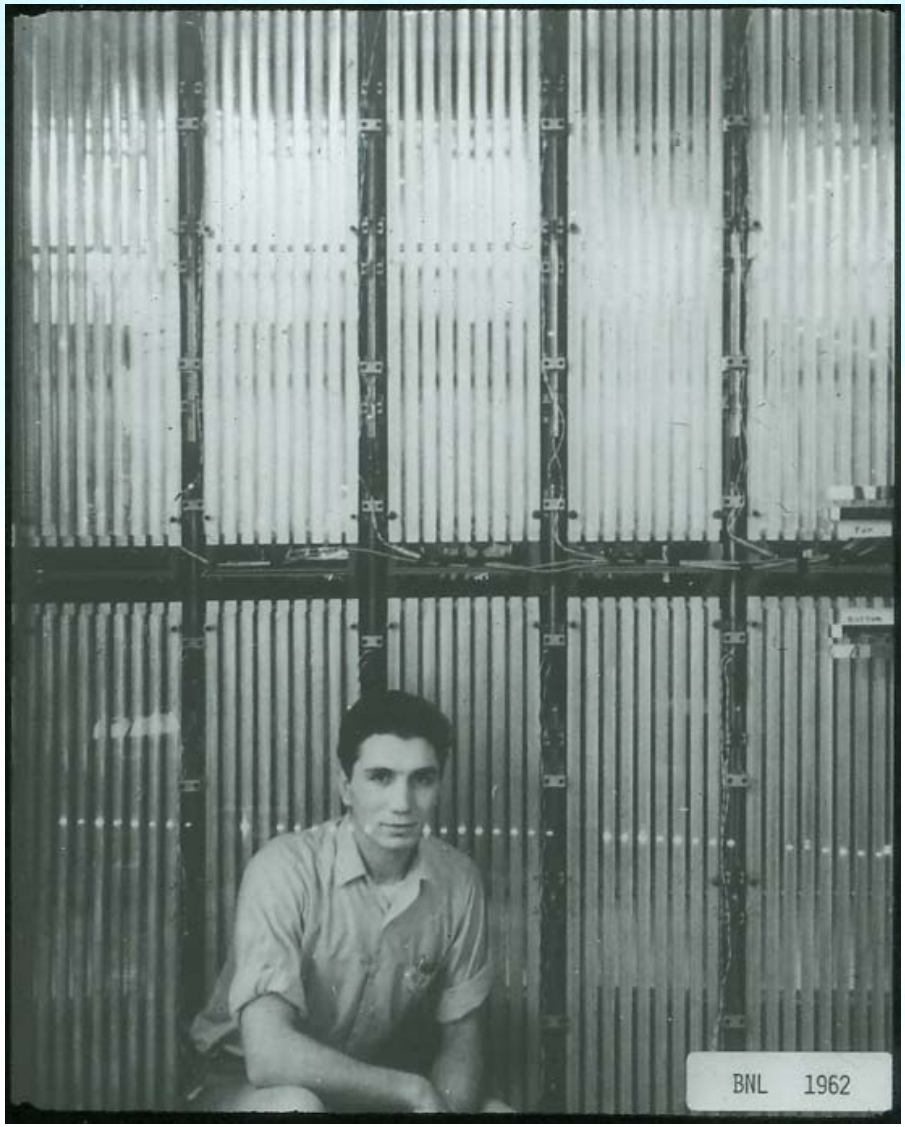
Once upon a time
in the distant past
Mel told me
that neutrinos are fast.

"To be my student - he said -
remember Dino:
you must be really good
to catch a fast neutrino"

"Oh! Let me be your student
- I said -
don't leave me in grief
I promise, I'll catch the
first neutrino
with my bare teeth!"

SL.4: Dino catching a neutrino

SL.4: Dino catching a neutrino



VERSE 2a

In our first encounter
Jack taught me
how to hug a counter.

SL. 5: Dino hugging a counter.

SL. 5: Dino hugging a counter.

VERSE 2b

Out in the field
Nari learned (and taught!)
how to stack the shield

SL.6: Nari stacking shield

SL.6: Nari stacking shield

VERSE 3a

We drove the spark chambers
to their final destination...

SL.7: Chamber transportation
Mel's car
Leon's car
Jack's car

Nari, Jean-Marc, Gordon
& Dino
o n f o o t !

SL.7: Chamber transportation

Mel's car
Leon's car
Jack's car

Nari, Jean-Marc, Gordon & Dino
on foot!

VERSE 3b

..and after the first
neutrino event
we posed in celebration!

SL.8: The neutrino group(1962)

SL.8: The neutrino group(1962)

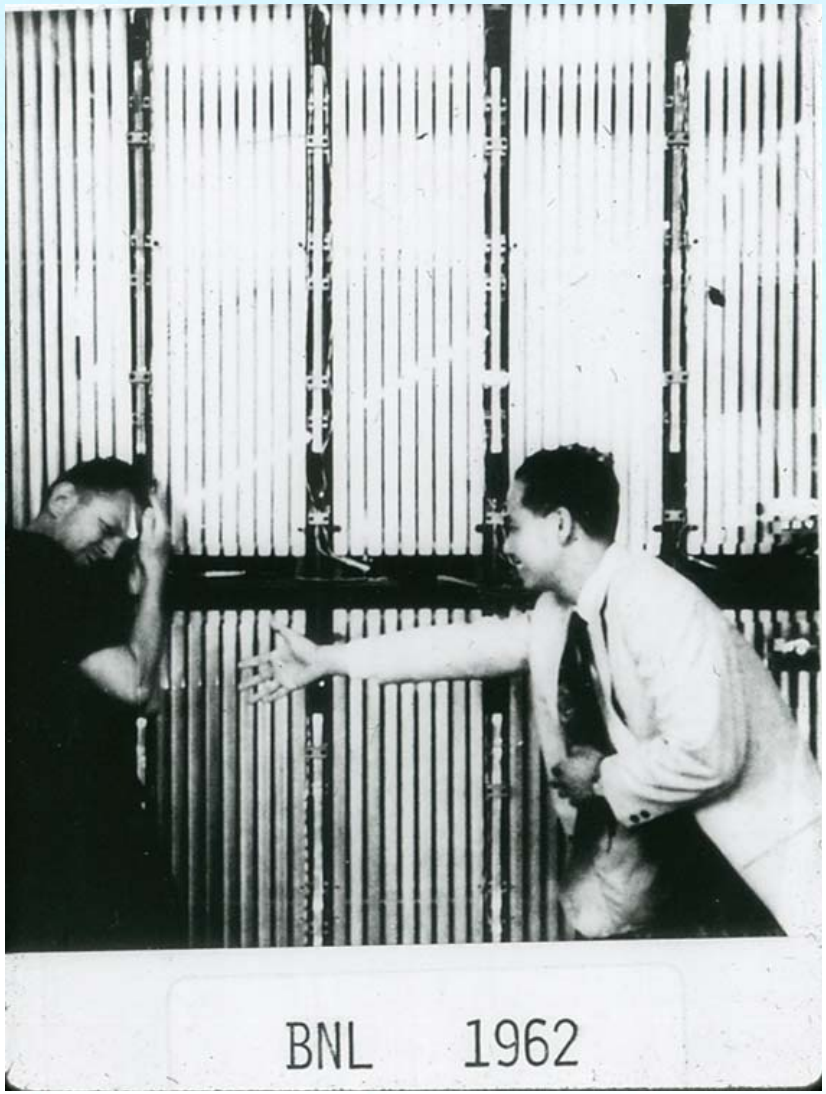
COLUMBIA (NEVIS)

VERSE 4

But despite what people claim
physics at that time
was not without pain.
.....!!!!!!!!!
Early one day
Leon was hit by a cosmic ray.
But as you can see
he was rescued by
Professor (T.D.) Lee!

SL.9: Leon rescued by Lee.

SL.9: Leon rescued by Lee.



VERSE 5a

Immediately he turned to me
and said:
In honor of T. D. Lee
who saved my life
remember PEON:
If we find a new particle
we'll have to call it LEE-ON!

VERSE 5b

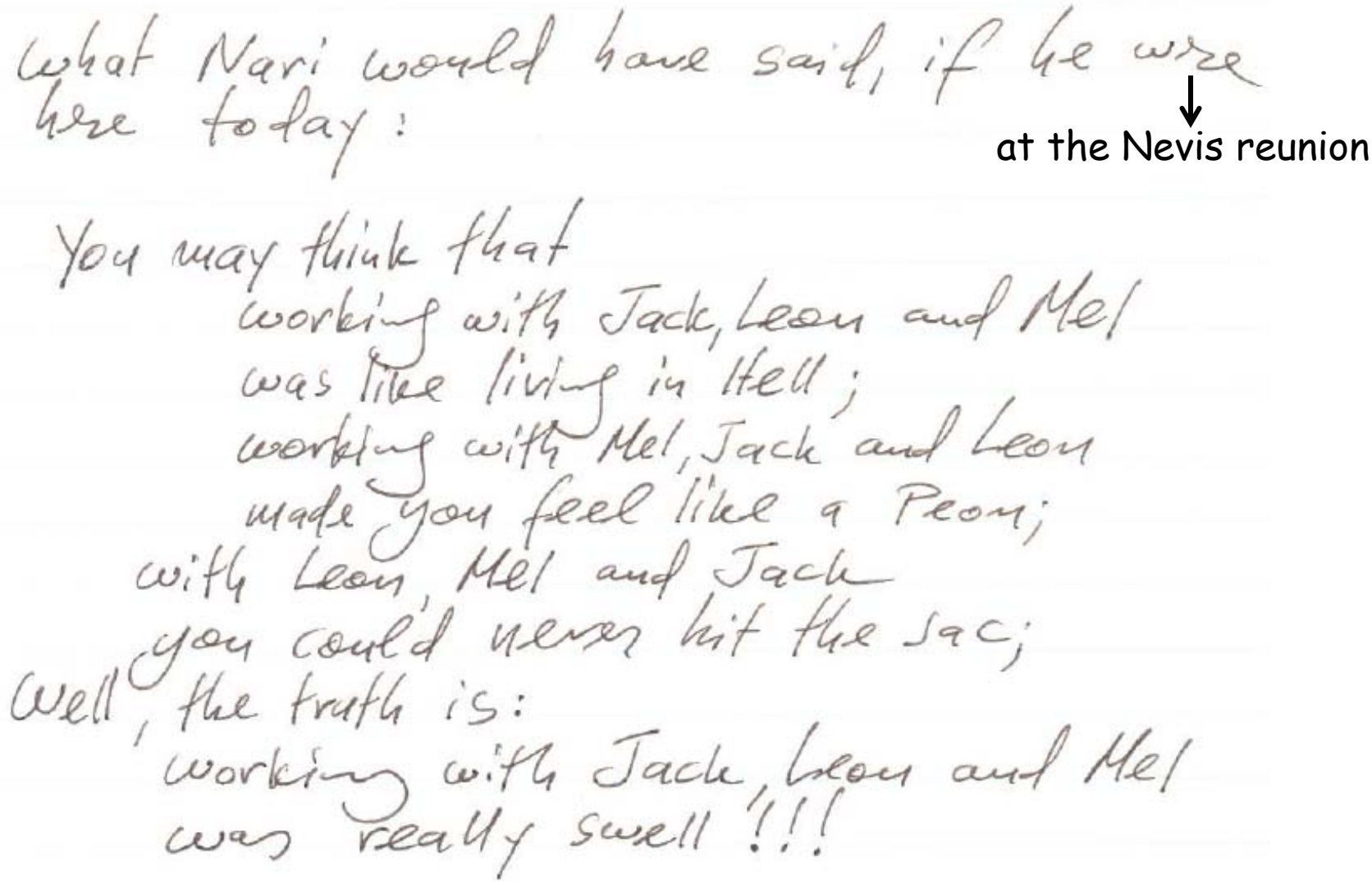
But the rest of us
wisely thought
that T.D. did not need more
fame
and "unanimously"decided
to leave the name
THE SAME!

SL.10: In Stockholm (1988)

SL.10: In Stockholm (1988)

MORE ?

What Nari would have said…



Ask me about it…

1-The summit at Nevis in 1960
2-Finding a mentor – Jack, Leon or Mel?
3-Harnessing the background
4-The first event - Helmut and the postcard
5-The "Melon"
6-The "crappers" that were neutral currents

…and more!