

# 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 Gaillard - 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

**BNL 90/50/10 Celebration  
Program Committee**

Derek Lowenstein, *Chair*

Peter Bond, *BNL*

Helen Caines, *Yale*

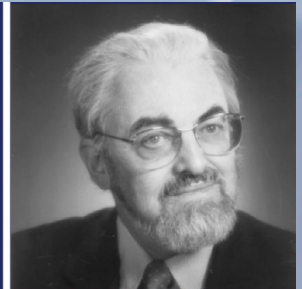
Satoshi Ozaki, *BNL*

Nicholas Samios, *BNL*

Julius Spiro, *BNL*

Steve Vigdor, *BNL*

**90**  
**Courant**  
(Birthday)



**50**  
**AGS**  
(Operations)



**10**  
**RHIC**  
(Operations)



# 90/50/10 Celebration

**June 10-11, 2010**

Berkner Hall

Brookhaven National Laboratory

Thursday, June 10, 2010

1:00 p.m. **Welcome**  
*Sam Aronson, BNL*

**Nicholas Samios, Session Chair**

1:10 p.m. **Ronnie Rau, BNL**  
“AGS History”

1:35 p.m. **Samuel C.C. Ting, MIT**  
“Precision Experiments on the Ground and in Space – The “J” Experiment at BNL and the AMS Experiment on the Space Station”

2:00 p.m. **James Cronin, University of Chicago**  
“Reminiscences of a Post Doc”

2:30 p.m. **Douglas Bryman, TRIUMF**  
“Seeking New Physics with Rare Kaon Decays”

3:00 p.m. **Break**

**Peter Bond, Session Chair**

3:25 p.m. **Konstantin Goulianos, Rockefeller University**  
“Two Neutrino Experiment”

3:55 p.m. **Paul Langacker, Institute for Advanced Study**  
“Frontiers in Neutrino Physics”

4:25 p.m. **David Kaplan, University of Washington**  
“Frontiers in Nuclear Theory”

5:00 p.m. **Sally Dawson, BNL**  
“Frontiers in Particle Physics”

5:35 p.m. **Ernest Courant, BNL**  
“Reminiscences”

5:55 p.m. **Mark Barton, BNL**  
“Reminiscences of Ernest Courant, and the Start up of the AGS and RHIC”

6:15 p.m. **Wine & Cheese Reception, Building 400 Lobby**

Friday, June 11, 2010

**Satoshi Ozaki, Session Chair**

9:00 a.m. **Nicholas Samios, BNL**  
“The Road to RHIC”

9:25 a.m. **Tom Ludlam, BNL**  
“How the RHIC Experiments Came to Be”

9:45 a.m. **Tom Hemmick, SBU**  
“Sailing the Perfect Liquid: Highlights and Discoveries of the Four RHIC Experiments”

10:15 a.m. **Break**

10:45 a.m. **Raju Venugopalan, BNL**  
“Lessons in Extreme Quantum Chromo Dynamics from RHIC”

11:20 a.m. **Frithjof Karsch, BNL**  
“30 Years of QCD Thermodynamics on the Lattice”

11:45 a.m. **Jamie Nagle, University of Colorado at Boulder**  
“The Science of RHIC II: Today and Tomorrow”

12:15 p.m. **Program Break**

**Derek Lowenstein, Session Chair**

2:00 p.m. **Robert Jaffe, MIT**  
“The Long Search for the Spin of the Proton”

2:35 p.m. **Gerry Bunce, BNL**  
“SPIN”

3:10 p.m. **Thomas Roser, BNL**  
“The Future of RHIC”

3:45 p.m. **Elke Aschenauer, BNL**  
“The Structure of Matter, What the Electron Ion Collider Will Teach Us”

4:20 p.m. **Steve Vigdor, BNL**  
“BNL NP/HEP Plan”

5:00 p.m. **Adjourn**

# The 2ν's – a personal account

1958 - 60 @ Columbia: graduate courses

➤ **some fellow students:**

Nari Mistry - the other neutrino

Mike Tannenbaum ( $\mu p \rightarrow \mu p$ ), David Bartlett ( $\mu \rightarrow e \gamma / \mu \rightarrow e \nu \bar{\nu} < 10^{-8}$ )

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  $\nu_{\mu} + A \rightarrow \mu + W(\rightarrow \mu + \nu_{\mu}) + A'$

➔ found evidence for neutral currents but quoted an upper limit.

❑ 1976: neutrino-proton elastic scattering: Phys.Rev.Lett.37:186-189,1976



# 2 $\nu$ -PAPERS

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

G. Danby, J.-M. Gaillard, K. Goulios, L. M. Lederman, N. Mistry, M. Schwartz,<sup>†</sup> and J. Steinberger<sup>†</sup>

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,<sup>†</sup> K. Goulios, L. M. Lederman, T. D. Lee,<sup>‡</sup> N. Mistry, M. Schwartz,<sup>‡</sup> and J. Steinberger<sup>‡</sup>

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. Goulios,<sup>†</sup> E. Hyman, L. Lederman, W. Lee, N. Mistry,<sup>‡</sup> J. Rettberg, M. Schwartz, and J. Sunderland

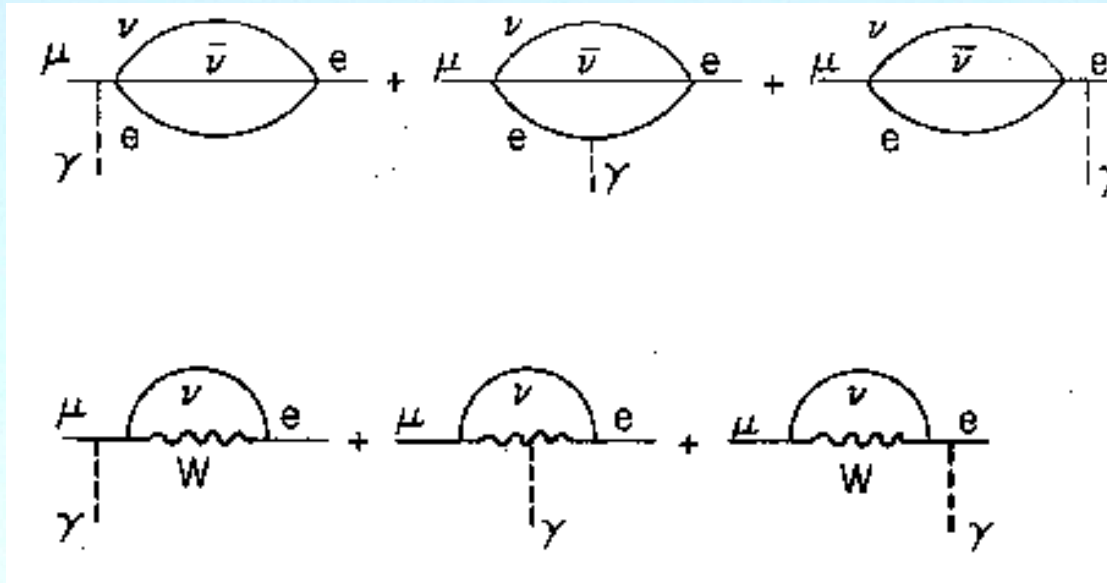
Columbia University, New York, New York, and Brookhaven National Laboratory, Upton, New York

and

G. Danby

Brookhaven National Laboratory, Upton, New York  
(Received 24 May 1965)

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



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

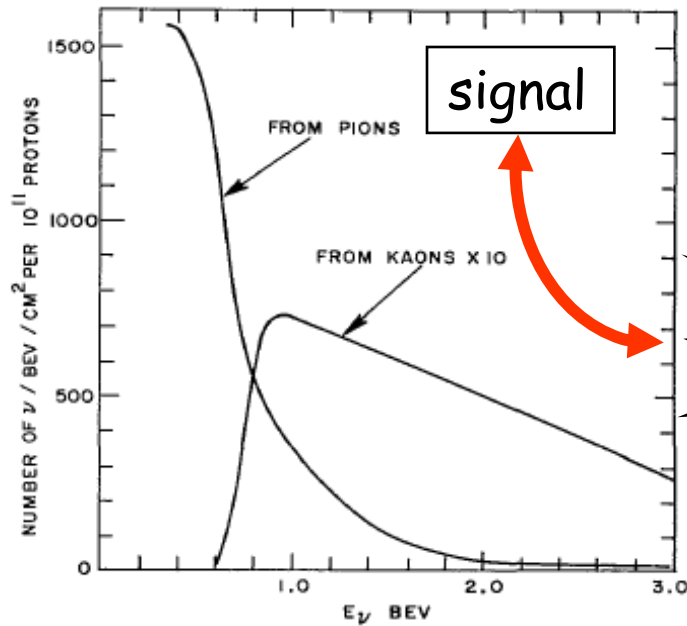
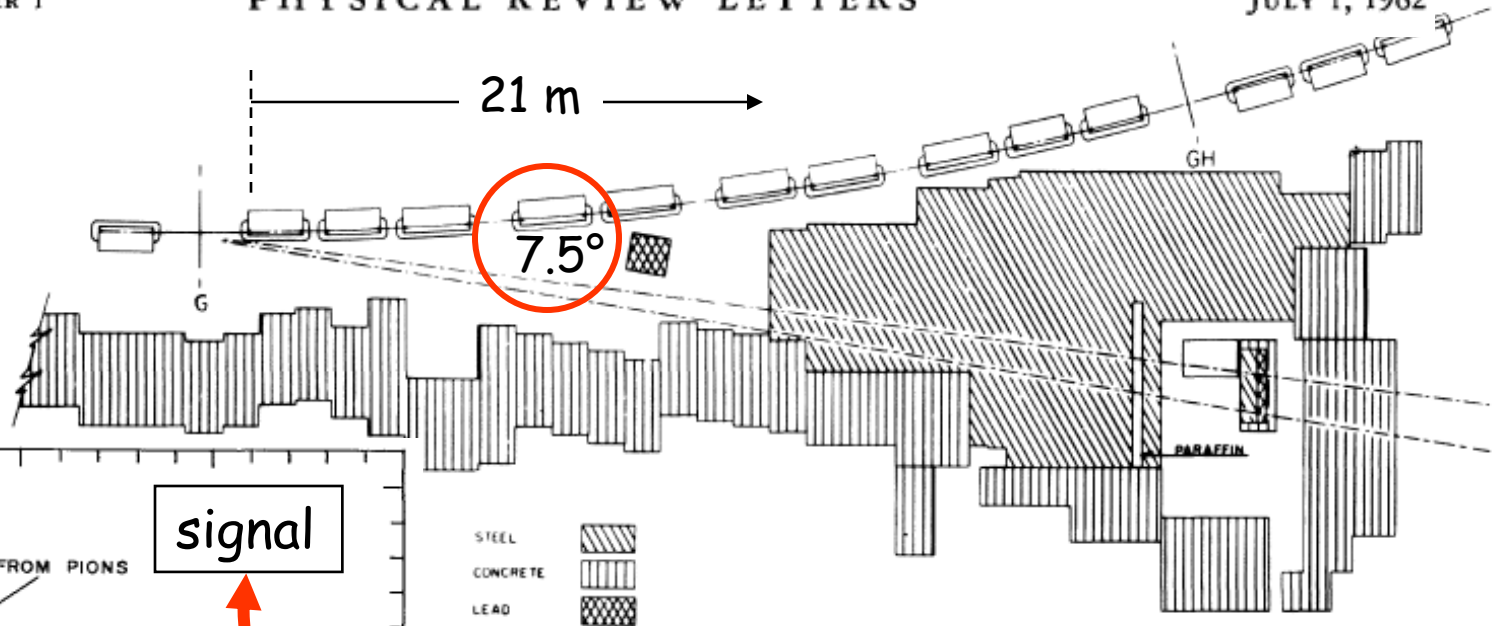
KONSTANTIN GOULIANOS

# Experimental set-up

VOLUME 9, NUMBER 1

PHYSICAL REVIEW LETTERS

JULY 1, 1962



BACKGROUND

15 - BeV  
shielding!!!

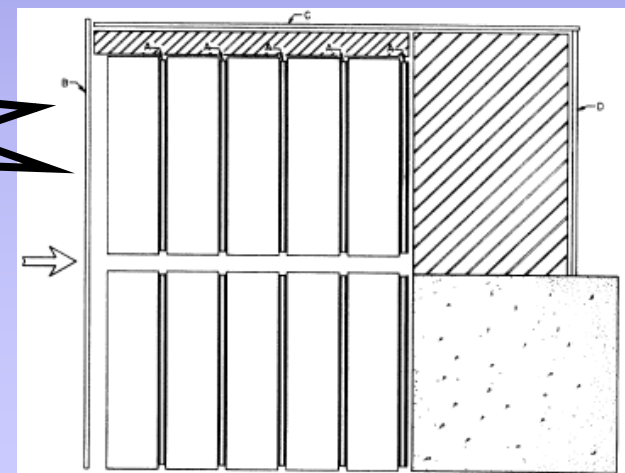
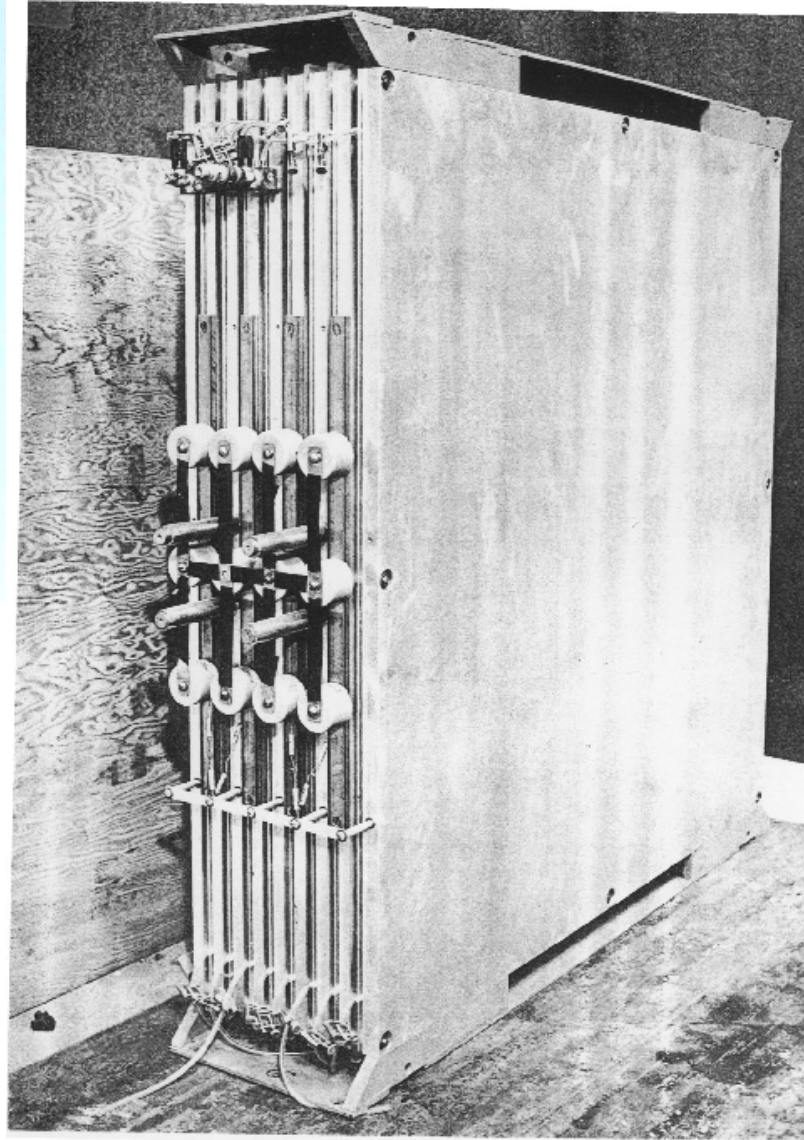


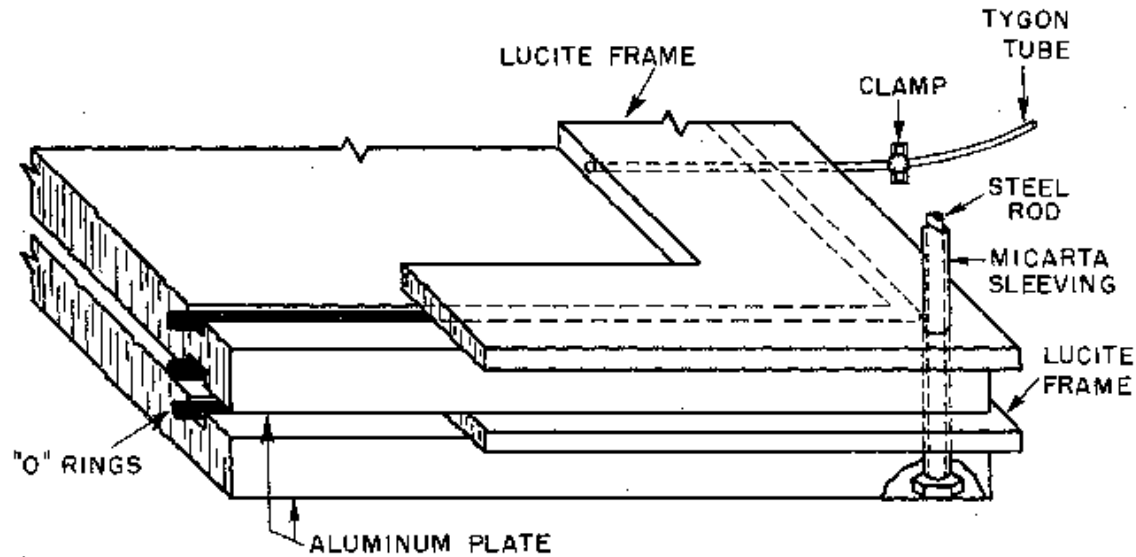
FIG. 2. Energy spectrum of neutrinos expected in the arrangement of Fig. 1 for 15-BeV protons on Be.

# SPARK CHAMBER – at Smithsonian?

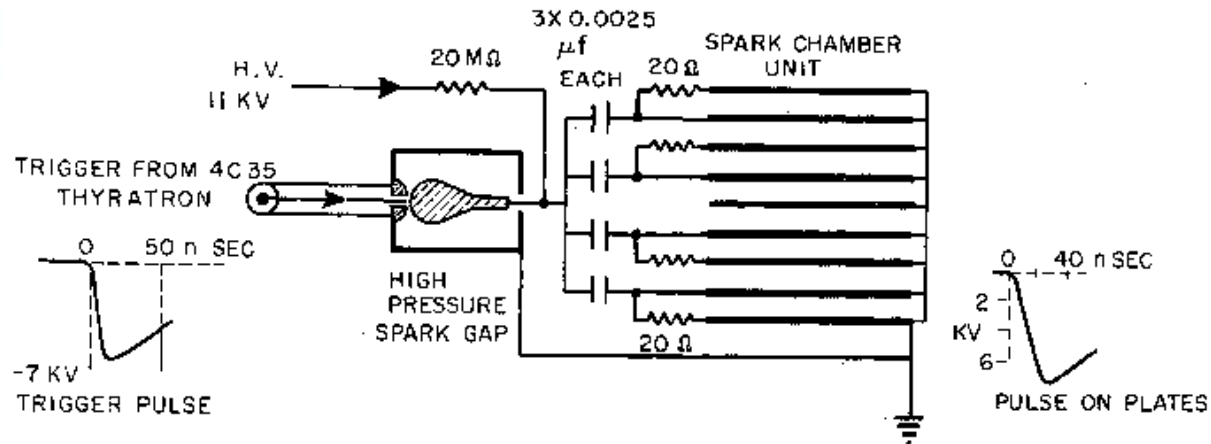




# CHAMBER CONSTRUCTION AND TRIGGERING

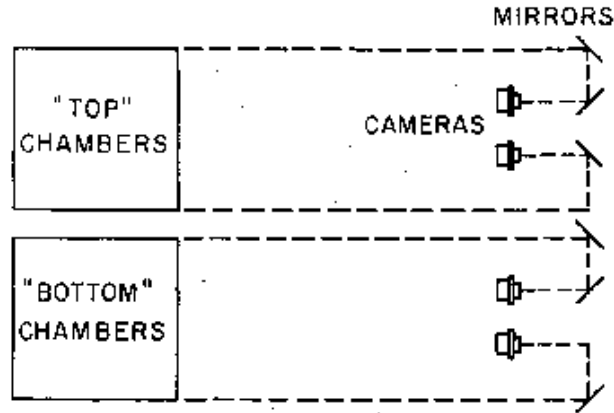


## SPARK GAP



# OPTICS

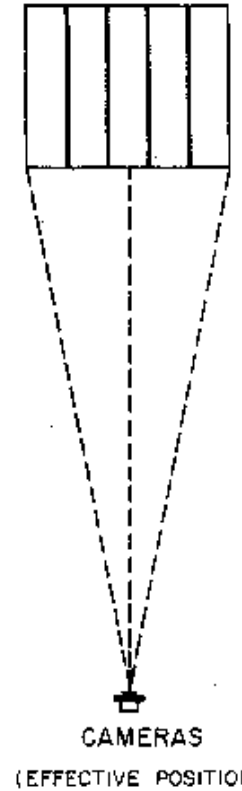
VERTICAL  
PROJECTION



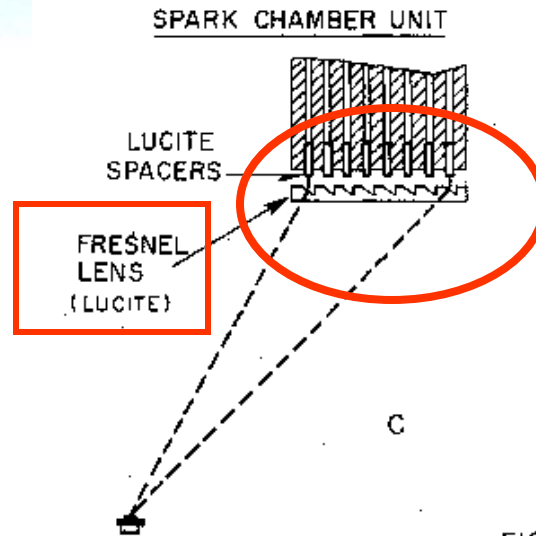
A

HORIZONTAL  
PROJECTION

SPARK CHAMBERS



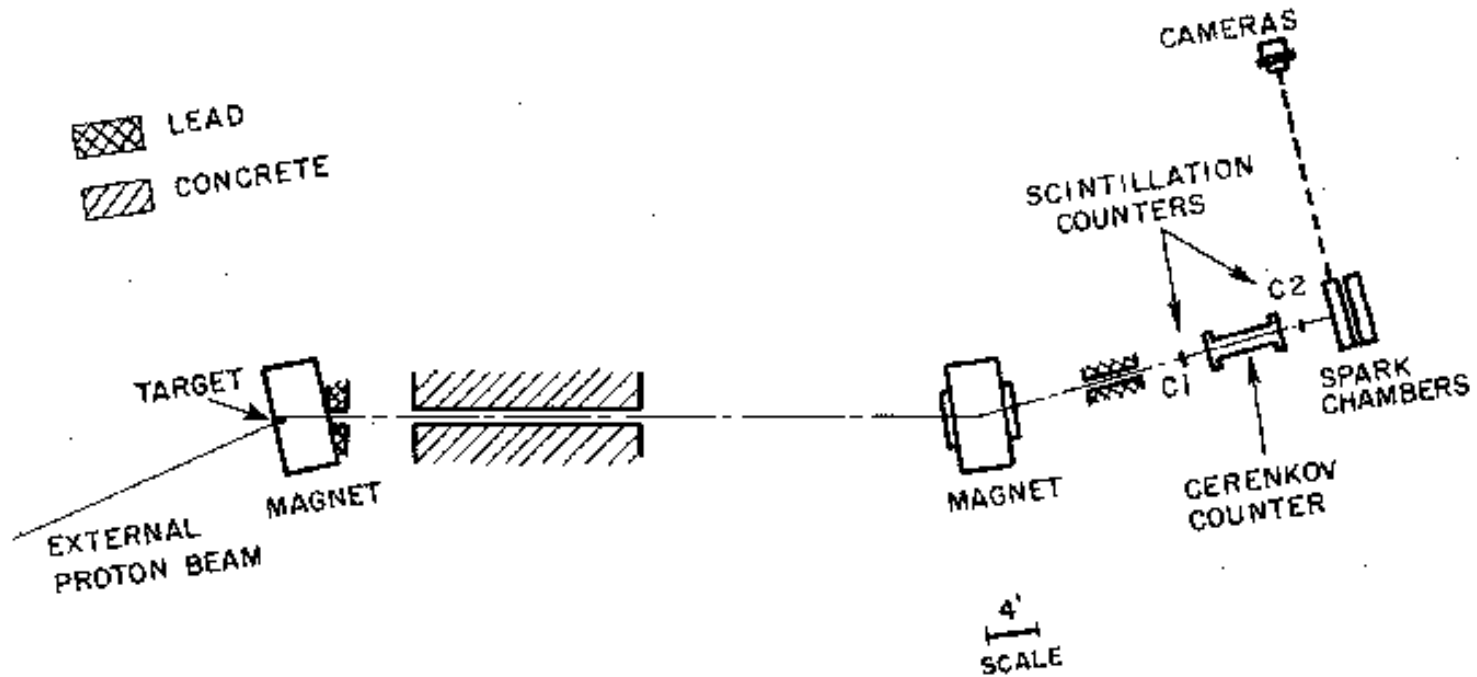
B



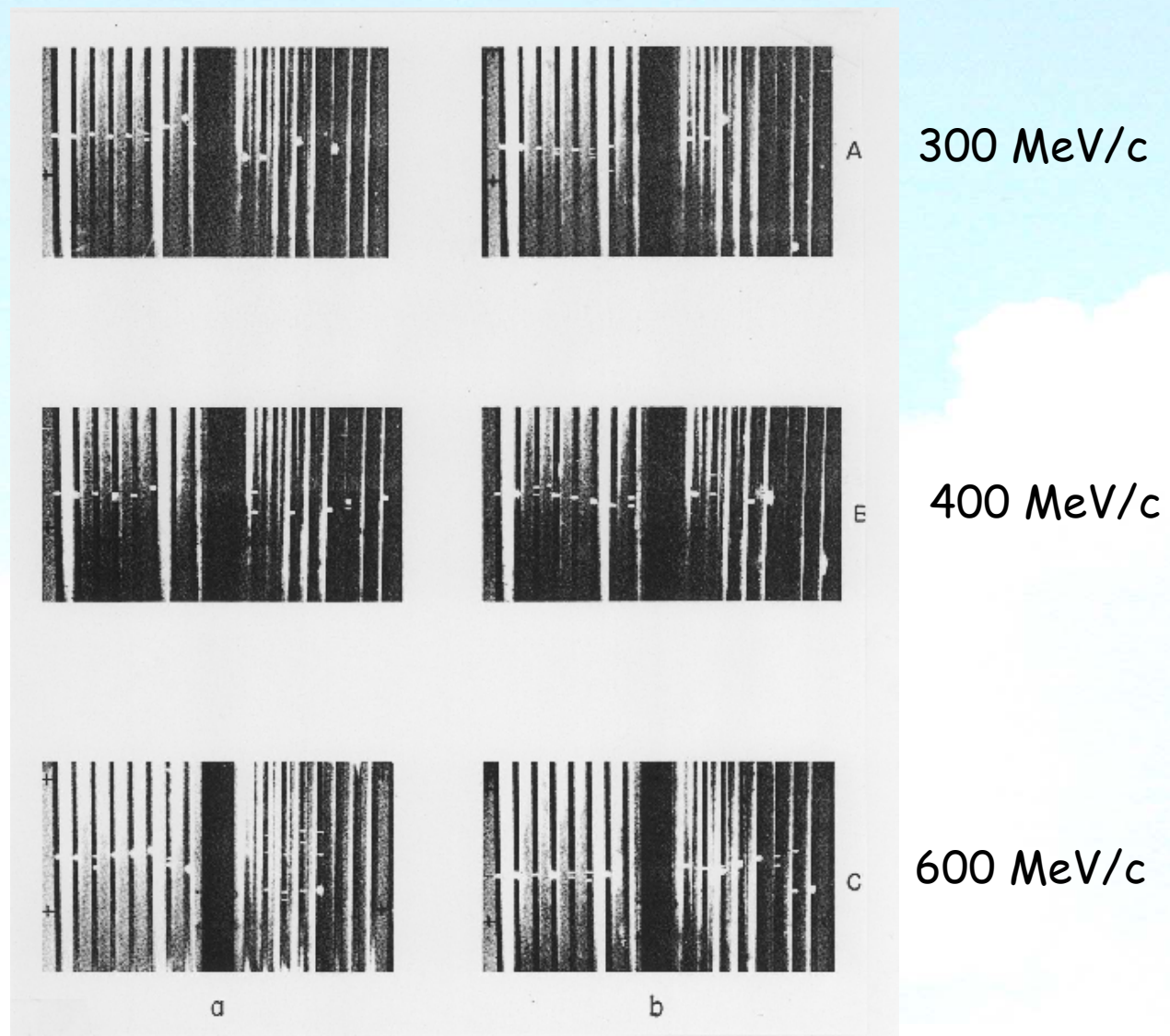
C

FIG. 17

# e-CALIBRATION AT THE COSMOTRON

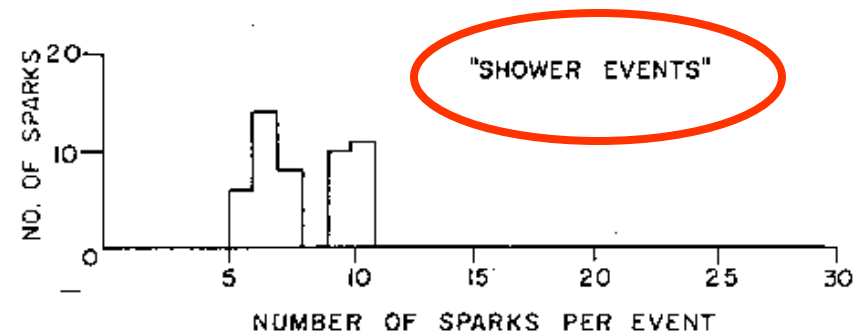
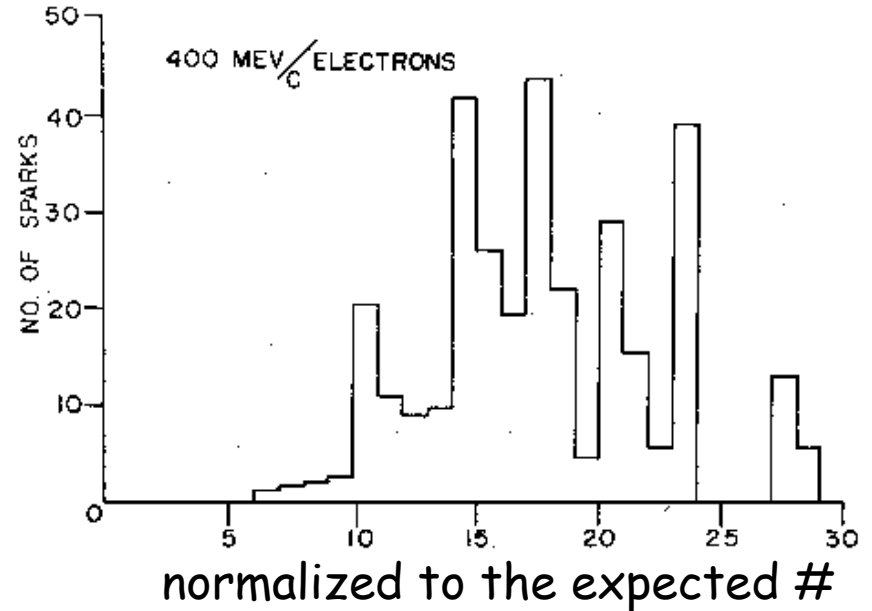
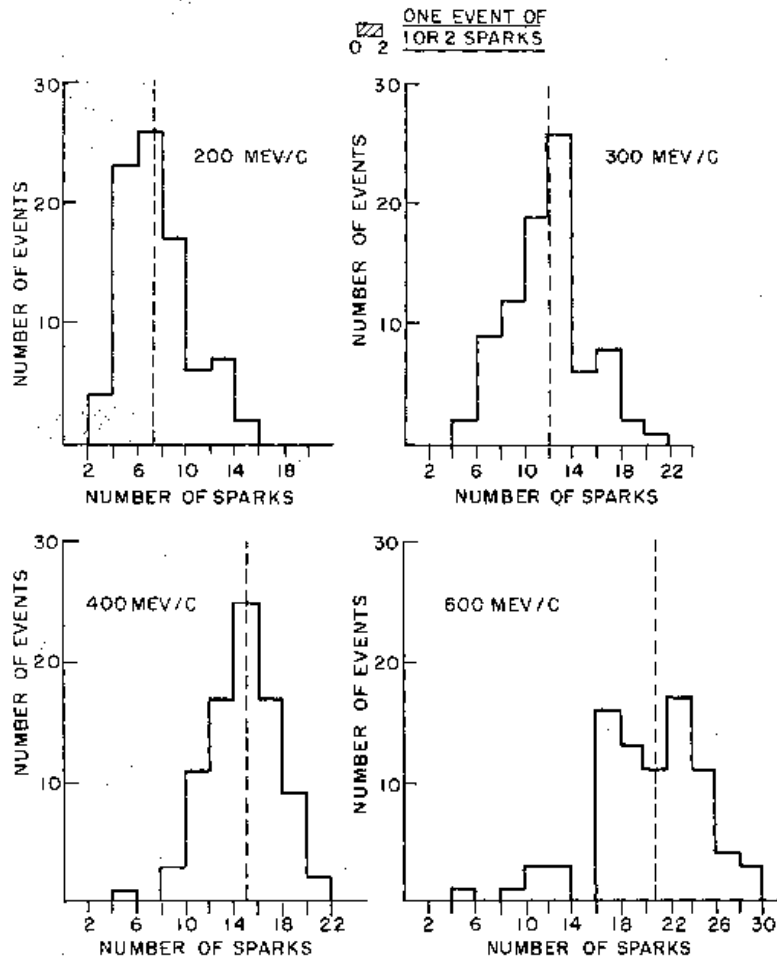


# e - SHOWERS FROM COSMOTRON TEST

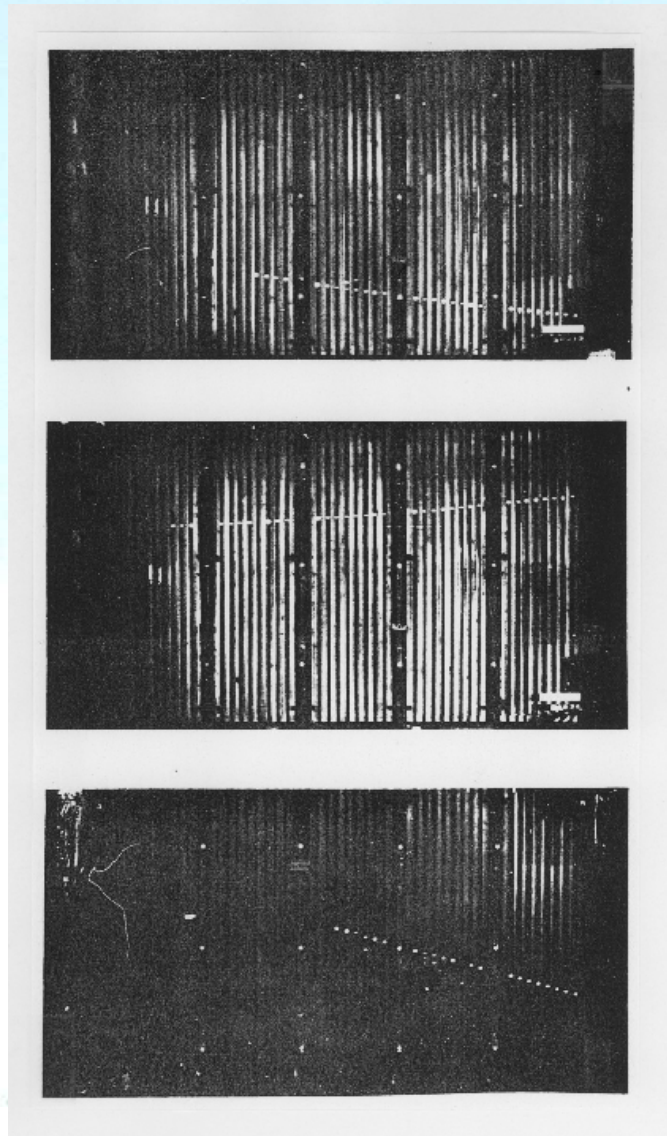




# e - CALIBRATION: NO. OF SPARKS



# SINGLE MUON EVENTS

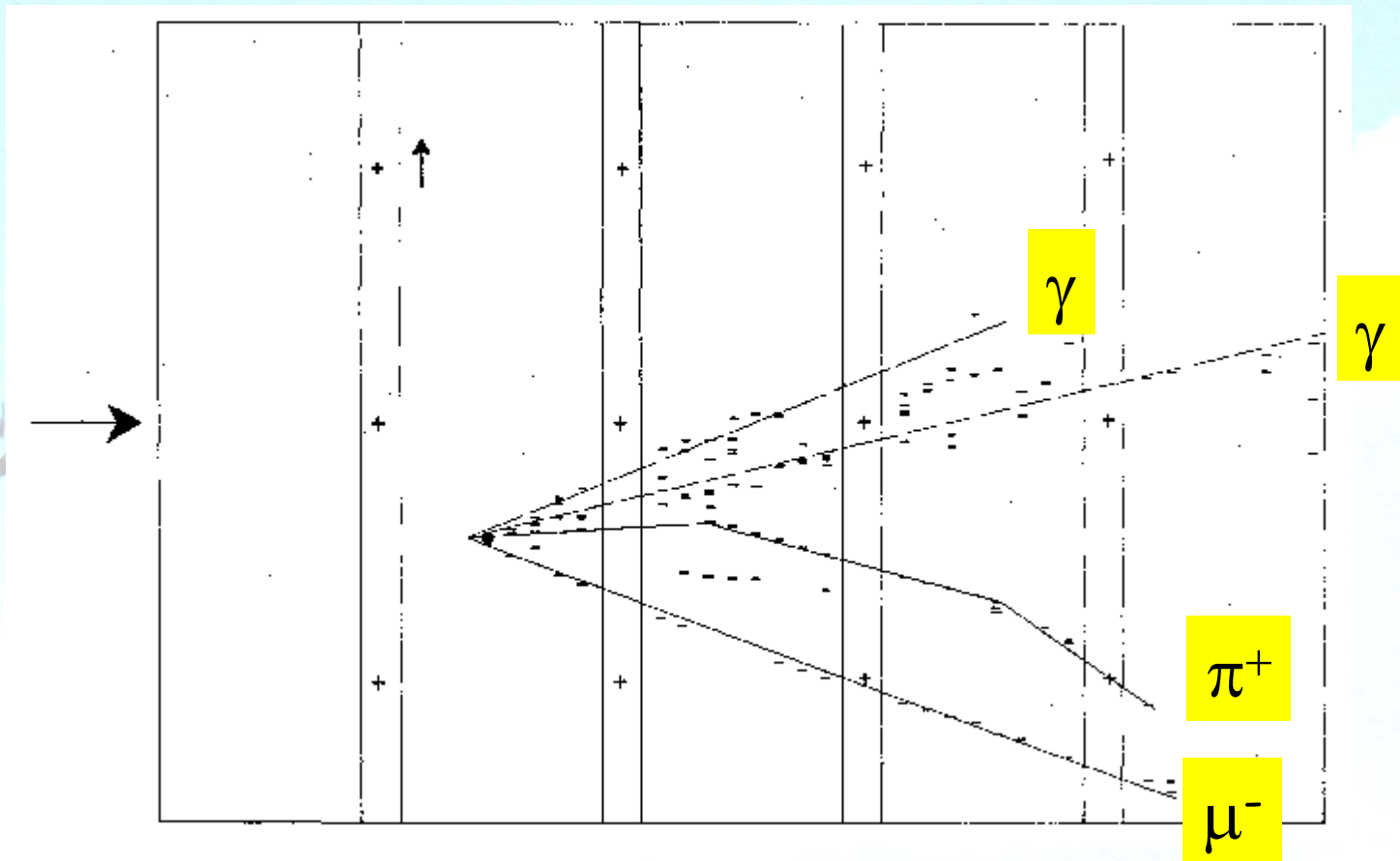


# A "VERTEX" EVENT: $E_{\text{total}}=2 \text{ BeV}$

$$\nu + p \rightarrow p + \mu^- + W^+$$

$$W^+ \rightarrow \pi^+ + \pi^0$$

$$\pi^0 \rightarrow \gamma + \gamma (?)$$



# TABLE OF OBSERVED EVENTS

## Classification of "Events"

### Single Tracks

$p_{\mu} < 300 \text{ MeV}/c^a$	49
$p_{\mu} > 300$	34
$> 400$	19
$> 500$	8
$> 600$	3
$> 700$	2
Total "single Muon Events"	34

### Vertex Events

Visible Energy Released $< 1 \text{ BeV}$	15
Visible Energy Released $> 1 \text{ BeV}$	<u>7</u>
Total vertex events	22

### "Shower" Events

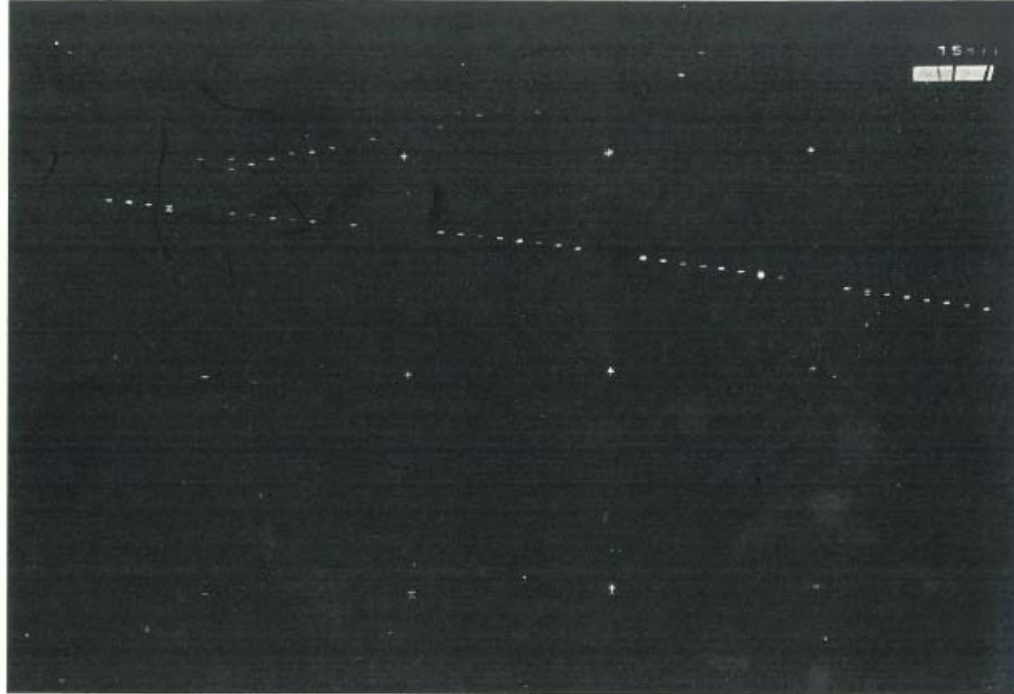
Energy of "electron" $\approx 200 \pm 100 \text{ MeV}$	3
220	1
240	1
280	<u>1</u>
Total "shower events" <sup>b</sup>	6

<sup>a</sup> These are not included in the "event" count.

<sup>b</sup> The two shower events which are so located that their potential energy release in the chamber corresponds to muons of less than  $300 \text{ MeV}/c$  are not included here.



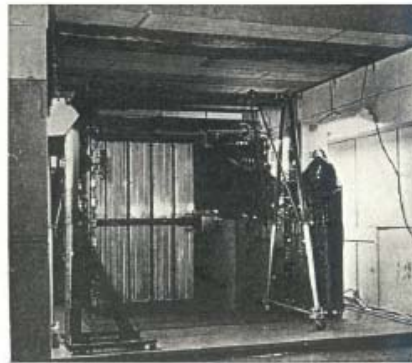
# The first event



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 Lanby  
 Jean-Marie Guillard  
 Dino Giulianes  
 Warner Hayes  
 Leon Lederman  
 Sari 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 book-keeping 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-





## «Η επιστημονική έρευνα στη φύση των Ελλήνων»

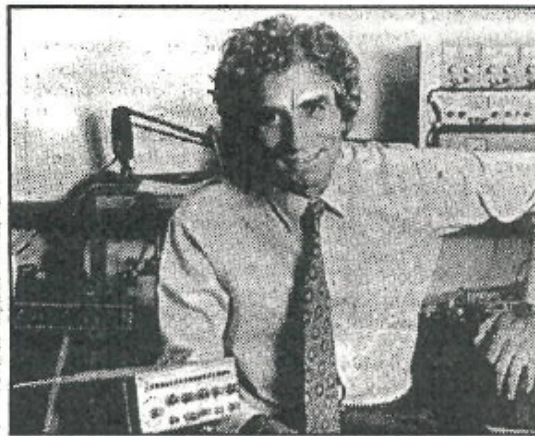
**Υποστηρίζει, σε αποκλειστική συνέντευξή του στην Πρωινή, ο συνεργάτης των Φετινών Νομπελιστών Φυσικής, κ. Κωνσταντίνος Γουλιανός**

**Νέα Υόρκη.**- «Το σπουδαιότερο πείραμα εις την ιστορία των Φυσικών Επιστημών, συμπληρώνεται εντός των προσεχών εβδομάδων. Πόρισμα 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 κοσμολογικό πείραμα, θα καθορίσει την δομή της

«Τρεις 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. Λέντμαν, διευθυντής του Εθνικού Εργαστηρίου Επιταχυντήρων Φέρμι στο Σικάγο, ο Δρ. Σονάρτς, διευθυντής της εταιρίας Ντίτζιτας Πάθγουις στην Καλιφόρνια και ο Δρ. Σταϊνπεργκερ, ερευνητής στο Ευρωπαϊκό Κέντρο Πυρηνικής Ερεύνης της Γενεύης.

Ο Δρ. Κωνσταντίνος Γουλιανός, είναι ιδιαίτερα ευτυχομένος για την τιμή αυτή. Παρ' όλο που τόσους



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 Έλληνα, του κ. Χριστόφιδου, ενός μηχανικού ανελκυστήρων», είπε ο Δρ. Γουλιανός.

Το πείραμα διήρκεσε 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 πραγματο-

του και ασχολήθηκε με πειράματα αντιτροφής 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 «κουόρτς», 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 Έλληνες 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 Έλληνες Φυσικοί, παρ' όλο που η χρηματοδότηση στην Ελλάδα είναι σχετικά μικρή. «Υπάρχει μεγάλο ενδιαφέρον στην Ελλάδα για τις φυσικές

**Του ΤΑΚΗ ΚΑΡΠΟΥΤΖΟΓΛΟΥ**

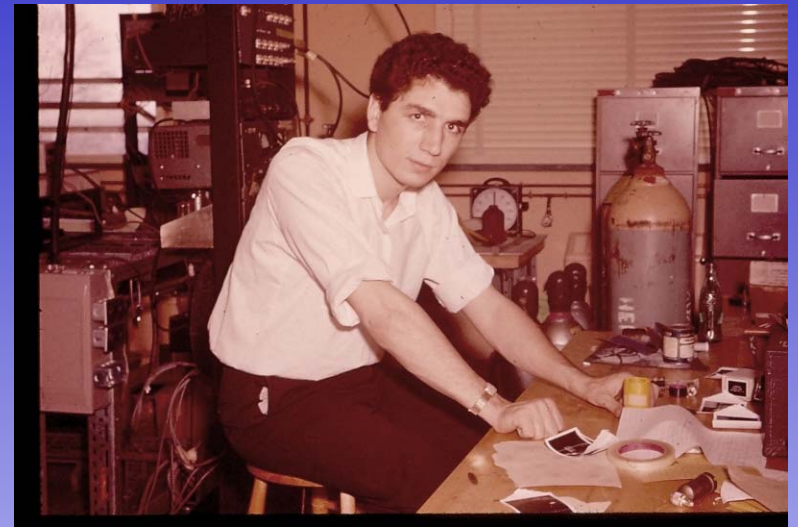
όλης—έρευνα δια το μυστηριώδες «νιουτρίνο»—Μετέχουν και Έλληνες επιστήμονες».

Λίγους μήνες μετά, την Κυριακή 1η Ιουλίου του 1962,

# 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



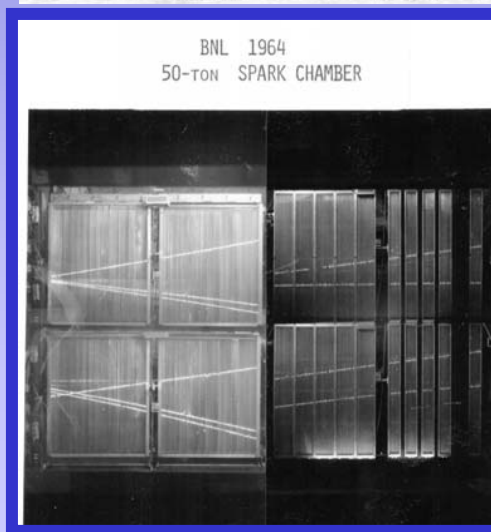
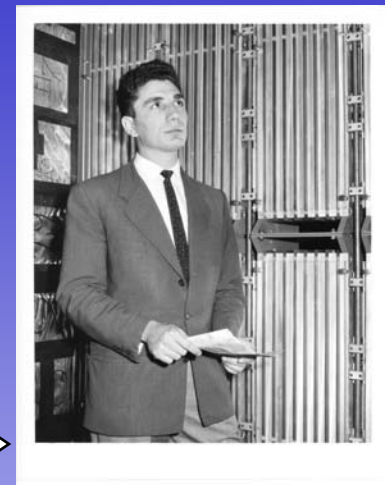
installing counters  
- Mel, Dino and 1/3 of (?)



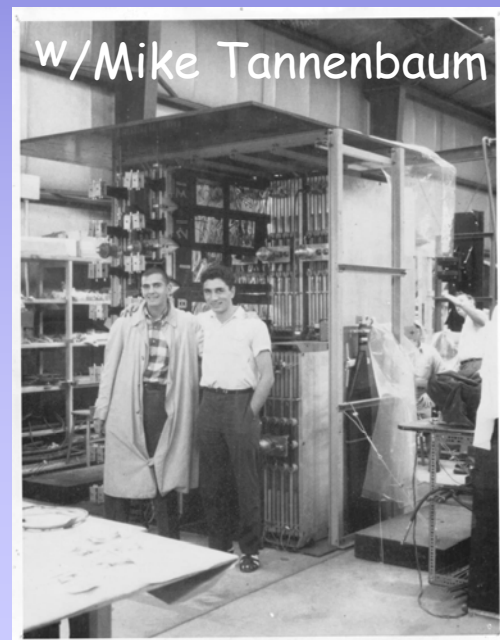
working



posing



TWO NEUTRINO EXPERIMENT



K. GOULIANOS

# 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. Goulios,† E. Hyman, L. Lederman, W. Lee, N. Mistry,‡  
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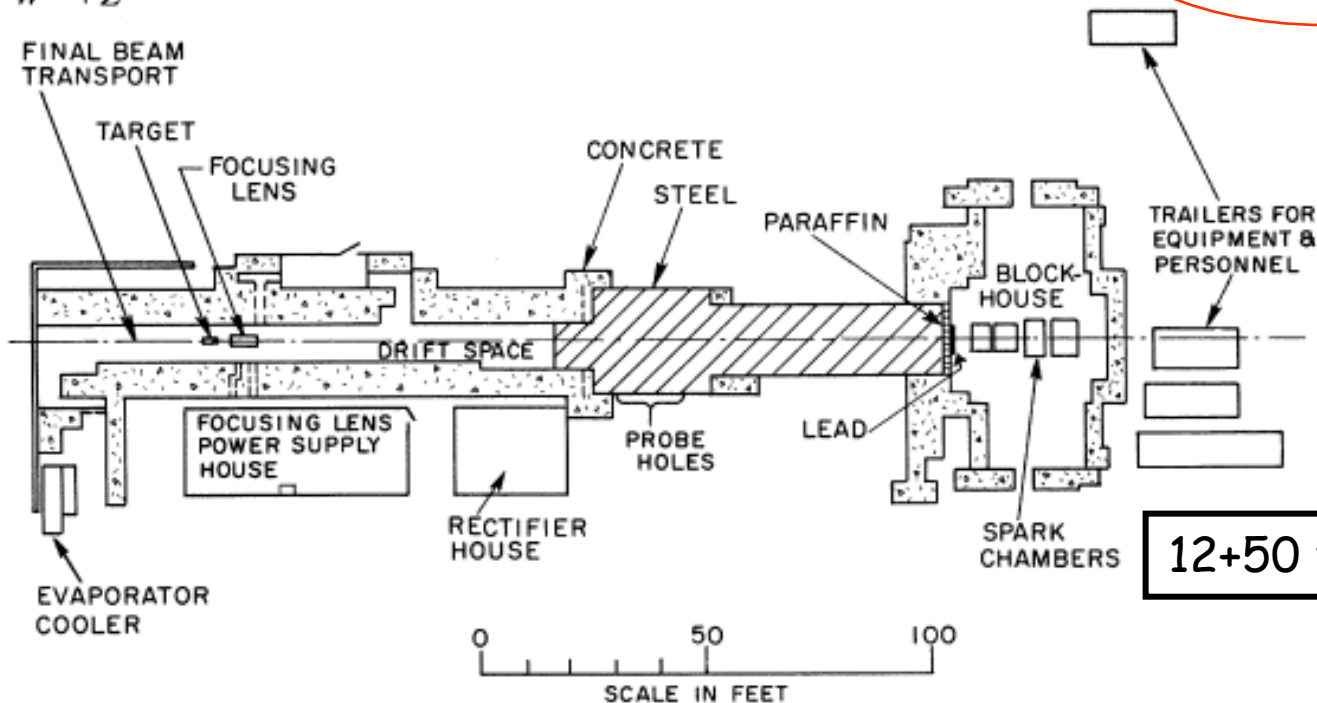
$$\nu_{\mu} + Z \rightarrow \mu^{-} + W^{+} + Z'$$

$$W \rightarrow e + \nu$$

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

set limit on  $m_W$

$$m_W > 2m_p$$



# In Stockholm in 1988





# From Gary and Jack

BNL-52214

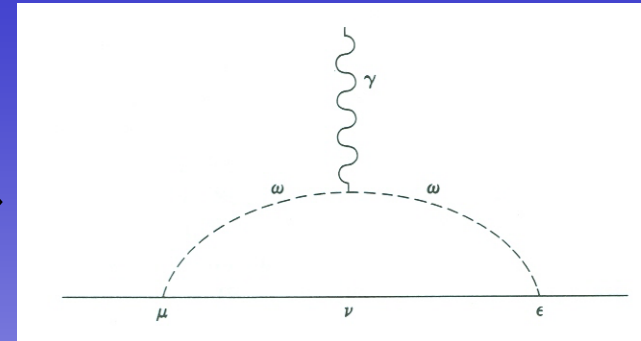
This Was  
The Particle Physics  
That Was:  
The Year's From  
P and C Violation  
to CP Violation

*Best wishes,  
Gary*

**A LECTURE  
GIVEN IN CELEBRATION  
OF THE 1988 NOBEL PRIZE  
IN PHYSICS**

**GERALD FEINBERG  
COLUMBIA UNIVERSITY**

**Brookhaven National Laboratory  
February 17, 1989**



28-12-88

Dear Dino,

*Many thanks  
for your kind congratulations  
on the occasion of my  
nomination to the Nobel Prize,  
and  
Best wishes for the New Year*

*Jack*  
Jack Steinberger

*Thank you for getting  
me all that money!*

# 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

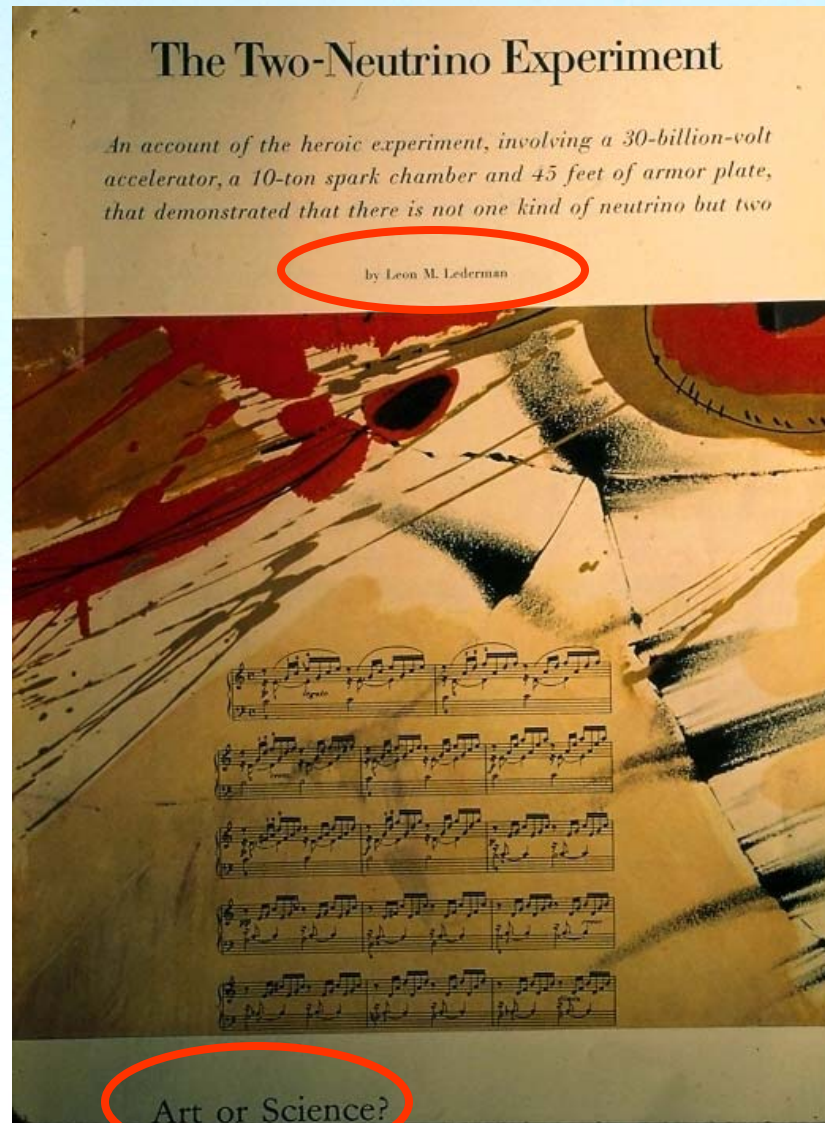
**Gordon, Jean-Marc, Nari  
Mel\*, Jack\*, Leon\*  
and The Peon**

**SLIDE 1: Art or Science?**

**SLIDE 2: The King and I.**

**SLIDE 3: Leon and the Peon.**

# SLIDE 1: Art or Science?

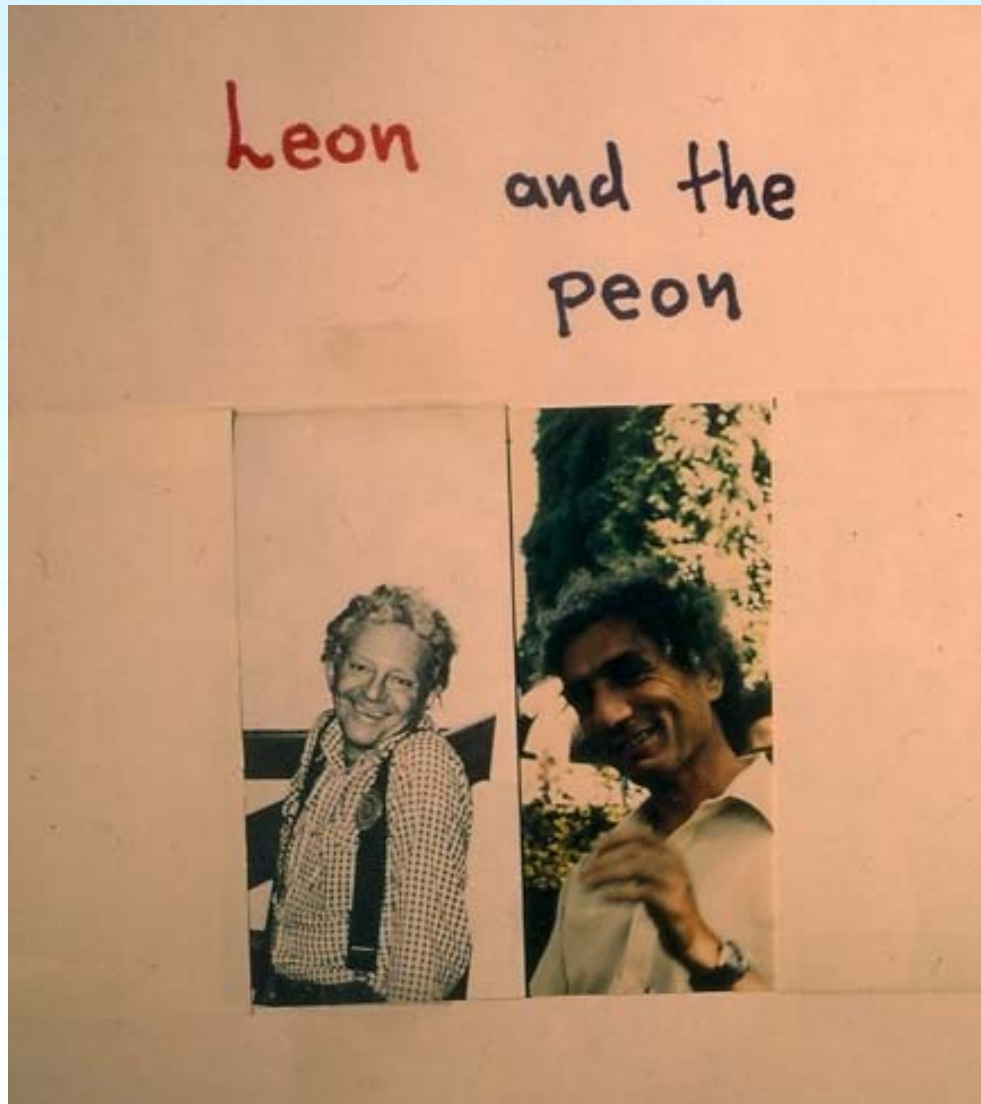


# SLIDE 2: The King and I.





# 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.



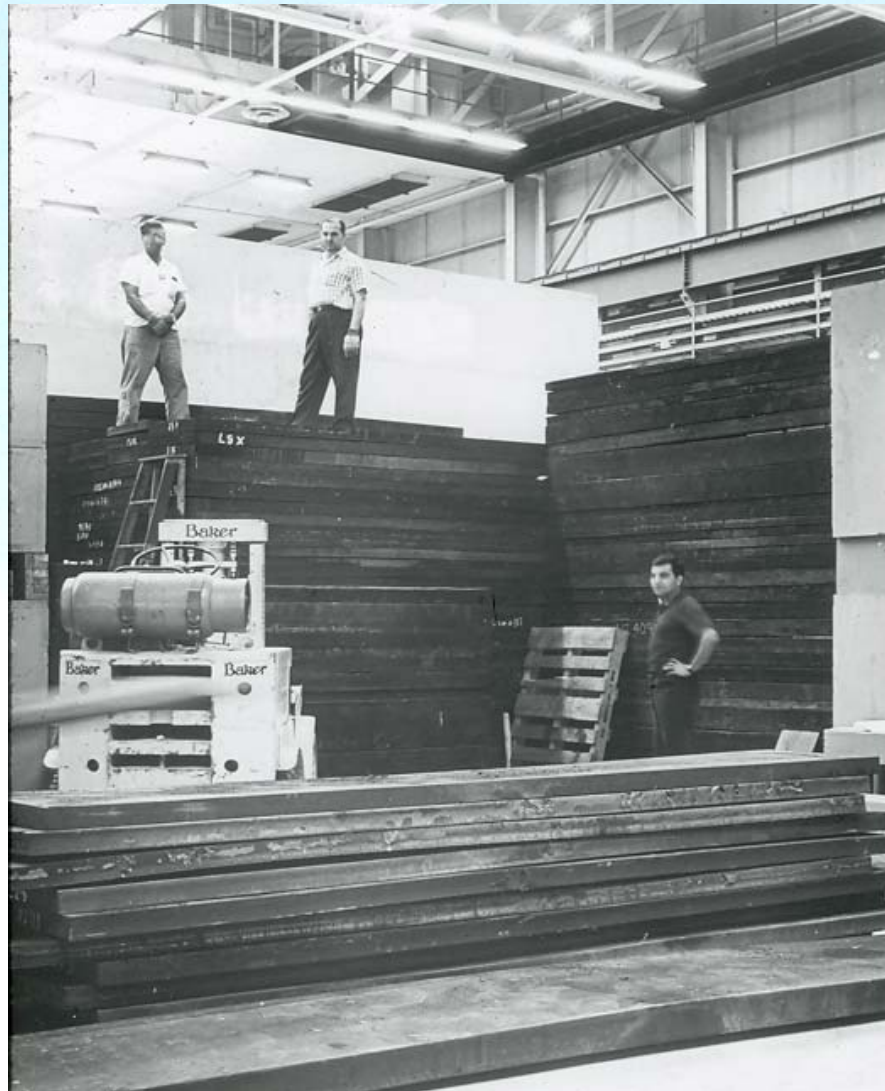


# VERSE 2b

**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.**

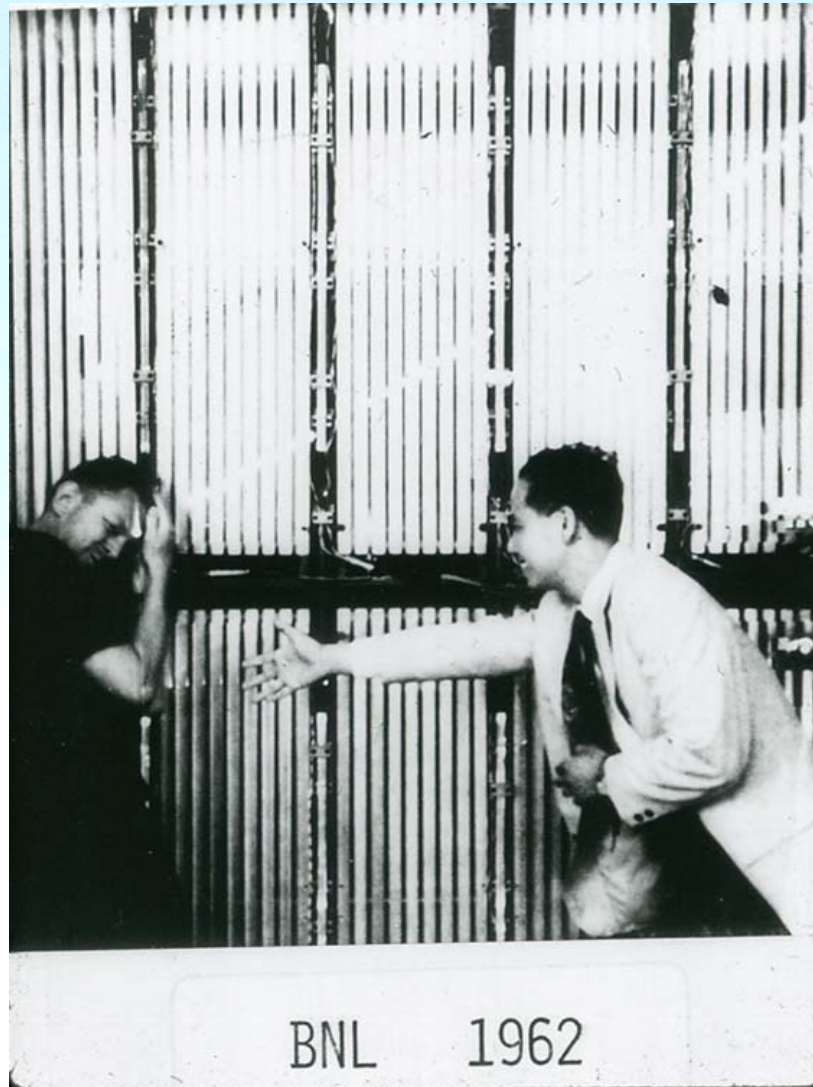
**.....!!!!!!!**

**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!**

IN  
STOCKHOLM!



# 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...

What Nari would have said, if he were  
here today:

at the Nevis reunion

You may think that  
working with Jack, Leon and Mel  
was like living in Hell;  
working with Mel, Jack and Leon  
made you feel like a Peon;  
with Leon, Mel and Jack  
you could never hit the sac;  
Well, the truth is:  
working with Jack, Leon and Mel  
was really swell !!!

# 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!