

Raoul Gatto and Bruno Touschek's joint Legacy in the Rise of e^+e^- Physics

The Rise of Particle Physics

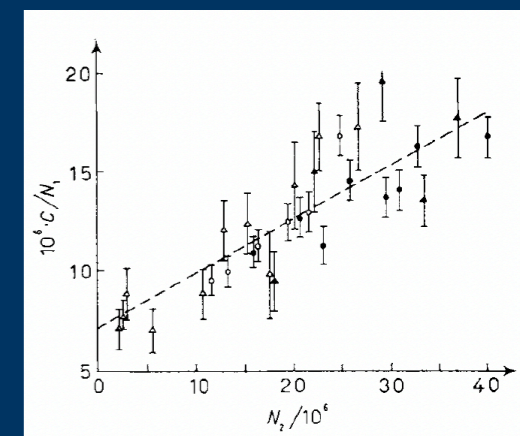
23-24 September, Physics Dept., Sapienza U Rome

Luisa Bonolis

Max Planck Institute for the History of Science, Berlin

In collaboration with
Franco Buccella and Giulia Pancheri

<https://arxiv.org/abs/2311.01293v2>



PHYSICAL REVIEW

VOLUME 124, NUMBER 5

DECEMBER 1, 1961

Electron-Positron Colliding Beam Experiments

N. CABIBBO AND R. GATTO

*Istituti di Fisica delle Università di Roma e di Cagliari, Italy and
Laboratori Nazionali di Frascati del C.N.E.N., Frascati, Roma, Italy*

(Received June 8, 1961)



Raul Gatto and Fermi's legacy through Ferretti



1948, 8th Solvay Conference on *Elementary Particles*
from left: F Bloch, B Ferretti, H Bhabha and W Pauli



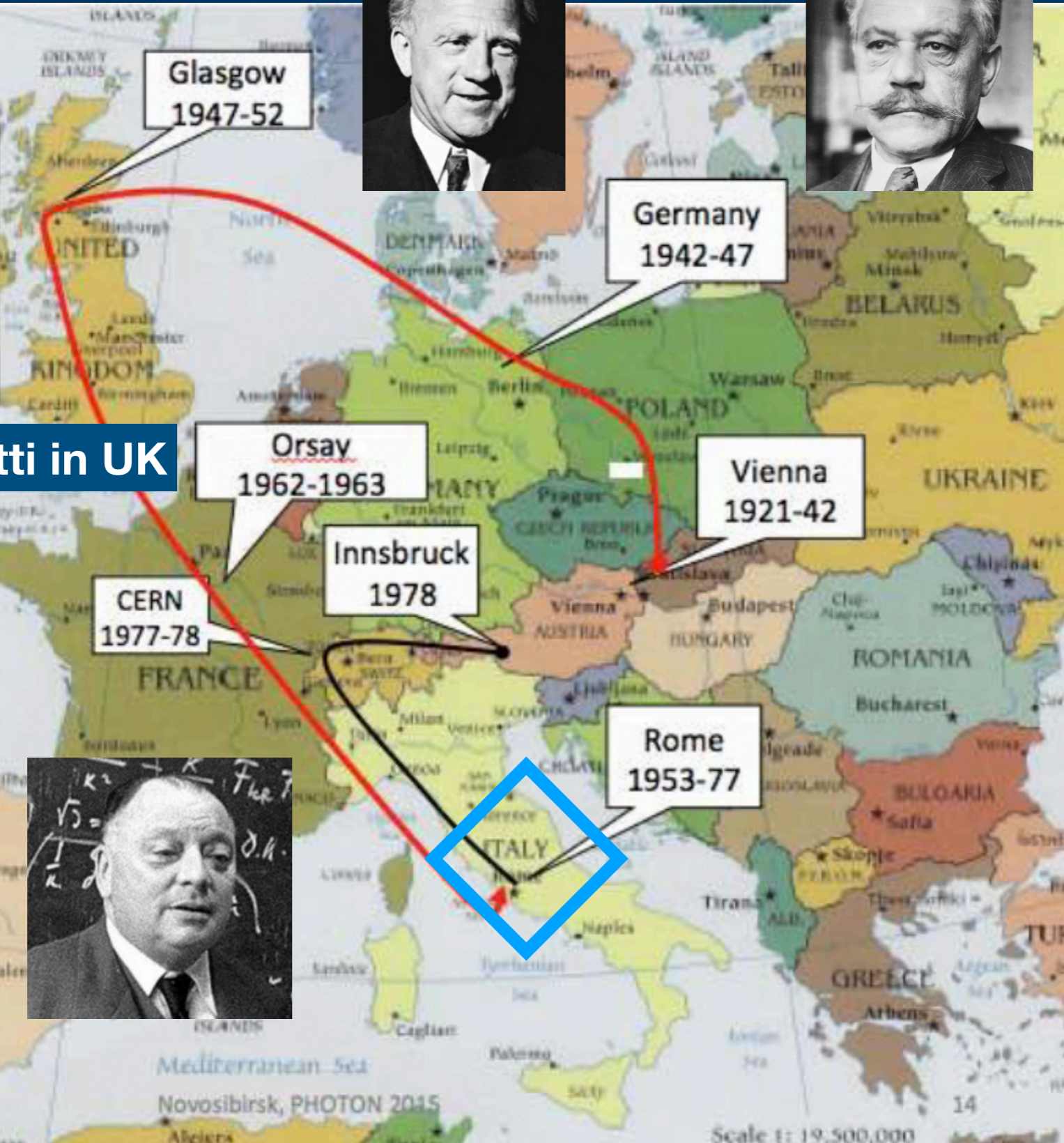
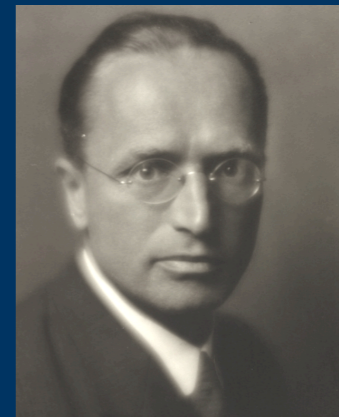
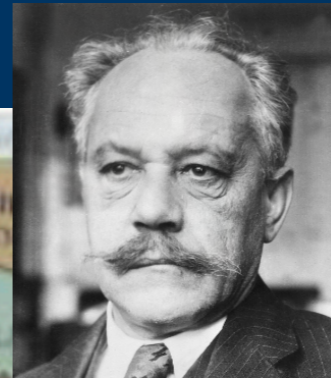
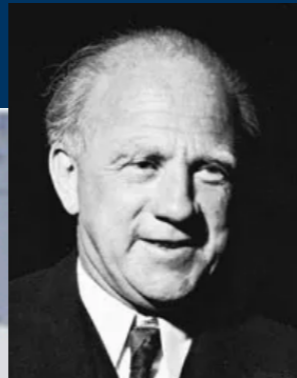
Marcello Conversi in 1941, soon after graduating with Ferretti. He then started with Oreste Piccioni (later joined by Pancini) experiments on the capture of the mesotron of CR in different materials



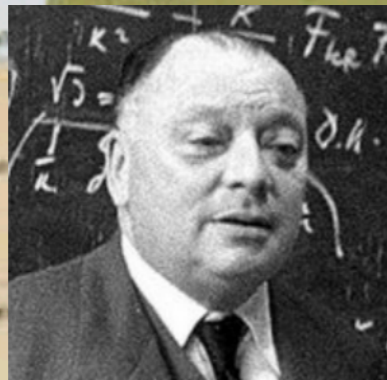
Raul Gatto

Dissertation on the nuclear shell model with
Ferretti and Conversi as supervisors

Touschek's life across Europe: 1942-1952



BT met Ferretti in UK



Influenced by Hans Thirring, Sommerfeld, Heisenberg, Born, Pauli...



BT with Amaldi soon after his arrival in Rome

B Touschek. 1954. **A speculation on the capture mechanism for K-mesons**

M Cini, G Morpurgo, B Touschek. 1954. **A non-perturbation treatment of scattering and the “Wentzel-example”**

R Gatto. 1953. **On the scattering of π -mesons by nuclei**

R Gatto. 1955. **Phenomenological study of the new particles. Λ -particles and Λ -nuclei**



1953: BT with Pauli at the Conference of the Italian Physical Society, Cagliari

I remember, I was 22, at a Conference in Cagliari. He [Touschek] was sitting at a café with Pauli, [...] He called me and wanted me to sit down with him and Pauli and participate in the discussion.



Gatto

G Morpurgo, B Touschek, L Radicati. 1954. **On time reversal**

G Morpurgo, B Touschek. 1955. **Remarks on time reversal**

G Morpurgo, B Touschek. 1955. **Space and time reflection of observable and non-observable quantities in field theory**

G Morpurgo, B Touschek. 1956. **Space and time reflection in quantum field theory**



Anti-nucleons were discussed during a session at the Rochester Conference in 1956. Touschek participated in the discussion.

The idea of parity nonconservation in weak processes was also discussed

IL NUOVO CIMENTO

VOL. III, N. 2

1° Febbraio 1956

About the Capture and Annihilation of Antiprotons.

R. GATTO

Istituto di Fisica dell'Università - Roma

Istituto Nazionale di Fisica Nucleare - Sezione di Roma

(ricevuto il 5 Gennaio 1956)

Summary. — The mechanism of annihilation of antiprotons is discussed. It is shown that large multiplicities for the number of pions emitted should be infrequent and some considerations are reported concerning the average number of neutral pions to be expected. It is suggested that a $K-\bar{K}$ pair could also be emitted. An event recently found and interpreted as due to the annihilation of an antiproton is discussed, and it is shown that, using Gell-Mann's model, arguments, can be given against its interpretation in terms of a new long-lived heavy boson.

1957: Gatto in Berkeley

R. Gatto. 1956. **About the possible annihilation mode of a nucleon-antinucleon system into a antiK-K pair**

R. Gatto. 1956. **Coherence effects in the Lee-Yang parity doublet theory of strange particles**

R. Gatto. 1957. **K^0 Decay Modes and the Question of Time Reversal of Weak Interactions**

R. Gatto. 1957. **The annihilation of a nucleon-antinucleon system into a K-antiK pair**

R. Gatto. 1957. **Test of Charge-Conjugation Invariance in Hyperon Decay**

R. Gatto. 1958. **Possible experiments on the behaviour of the weak hyperon decay interactions under P, C, and T**

R. Gatto & G Lüders. 1958. **Invariants in muon decay**



1957: BT with TD Lee and Pauli
Padova-Venezia Conference,
and his drawing of TD Lee

B. Touschek. 1957. **Parity conservation and the mass of the neutrino**

B. Touschek. 1957. **The mass of the neutrino and the non-conservation of parity**

L. Radicati, B. Touschek. 1957. **On the equivalence theorem for the massless neutrino**

M. Cini, B. Touschek. 1958. **The relativistic limit of the theory of spin $1/2$ particles**

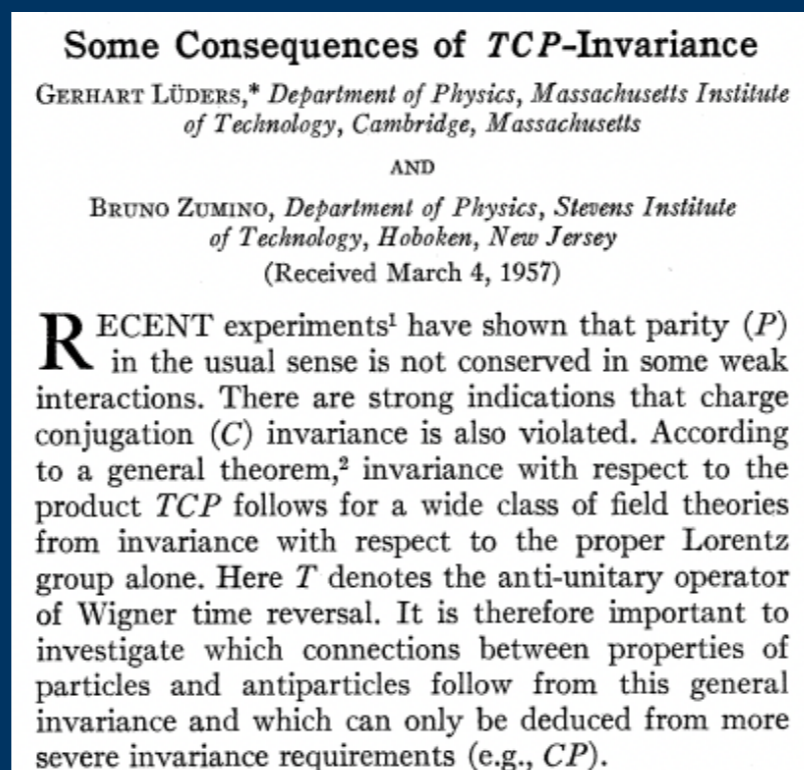
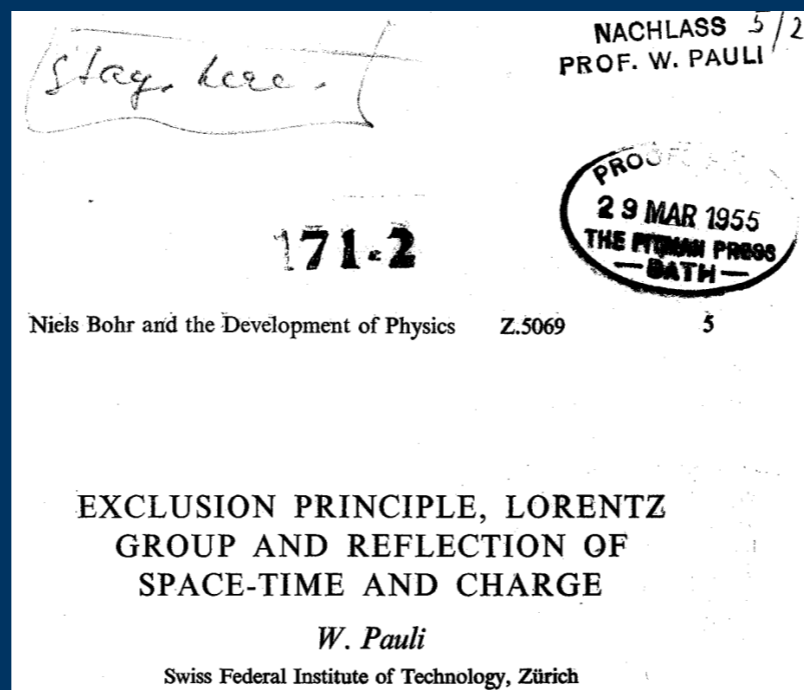
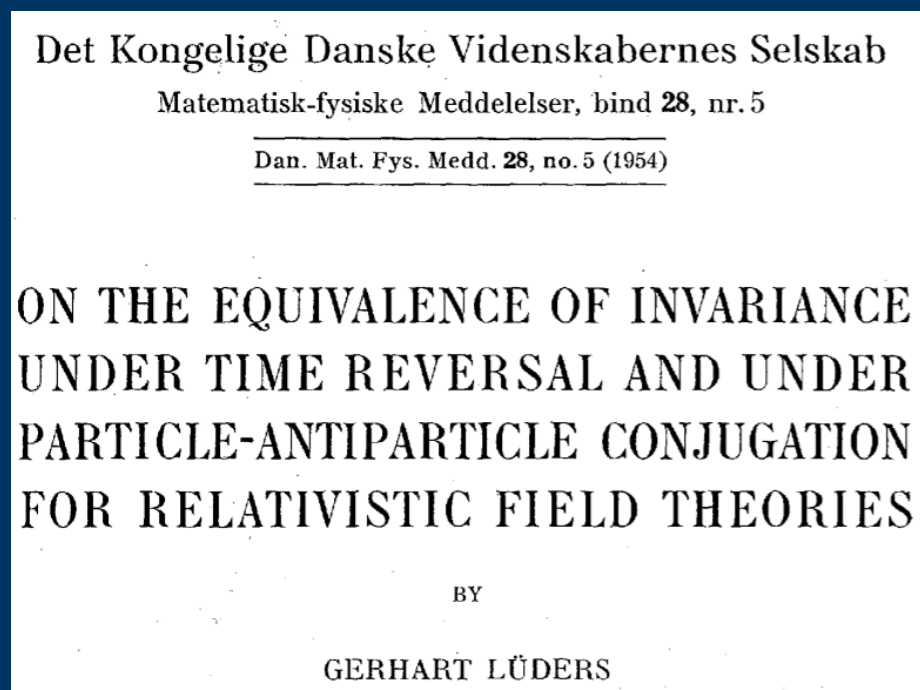
B. Touschek. 1958. **The symmetry properties of Fermi Dirac fields**

B. Touschek. 1959. **A note on the Pauli transformation**

W. Pauli and B. Touschek. 1959 **Report and comment on F. Gürsey's "Group Structure of Elementary Particles"**

Parity violation and the CPT Theorem

The roots of the CPT theorem, are related to the problem of identifying the correct formulation of time reversal in relativistic QFT (Blum et al. 2022)



Touschek to Pauli,
31 January 1957

Discussing Lee & Yang,
Salam works, neutrino,
K-decay etc.

Last words:

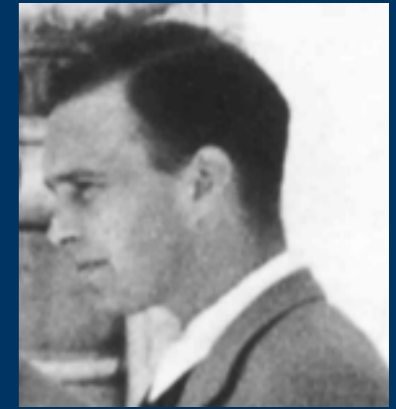
«I've been trying to figure out for about a week whether invariance under CP (and not under P) means that one can distinguish between particles and antiparticles...»

The CPT theorem, deeply connected to the physics of weak interactions, achieved a central significance after the experimental discovery of parity violation in 1957.

Toward e^+e^- collisions



Pief Panofsky presented the 2-mile linear accelerator and the US Princeton-Stanford e^-e^- project at ICHEP 1959, Kiev, in July and during a seminar in Frascati (and probably also in Rome) in October



Touschek



Gatto

Bruno kept insisting on CPT invariance, which would grant the same orbit for electrons and positrons inside the ring

It was after the seminar that Bruno Touschek came up with the remark that an e^+e^- machine could be realized in a single ring, 'because of the CTP theorem'



N.Cabibbo

Early works on e^+e^- collisions

VOLUME 4, NUMBER 6

PHYSICAL REVIEW LETTERS

MARCH 15, 1960

EFFECTS OF PION-PION INTERACTION IN ELECTROMAGNETIC PROCESSES

L. M. Brown*

Istituto di Fisica dell' Università, Roma, Italia

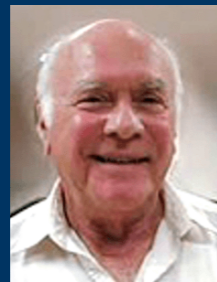
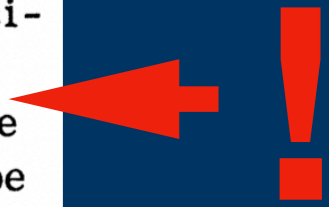
and

F. Calogero

Istituto di Fisica dell' Università, Roma, Italia,
and Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italia

(Received February 5, 1960)

However, while the positron-electron experiment appear to be the most promising for elucidating the pion form factor, electron-electron experiments will probably be done first and the above corrections for Møller scattering may be of interest. We are investigating other electro-



F Calogero and Laurie Brown

Supervisor: Bruno Touschek
Dissertation on weak interactions



Cabibbo and Gatto

VOLUME 4, NUMBER 6

PHYSICAL REVIEW LETTERS

MARCH 15, 1960

PION FORM FACTORS FROM POSSIBLE HIGH-ENERGY ELECTRON-POSITRON EXPERIMENTS

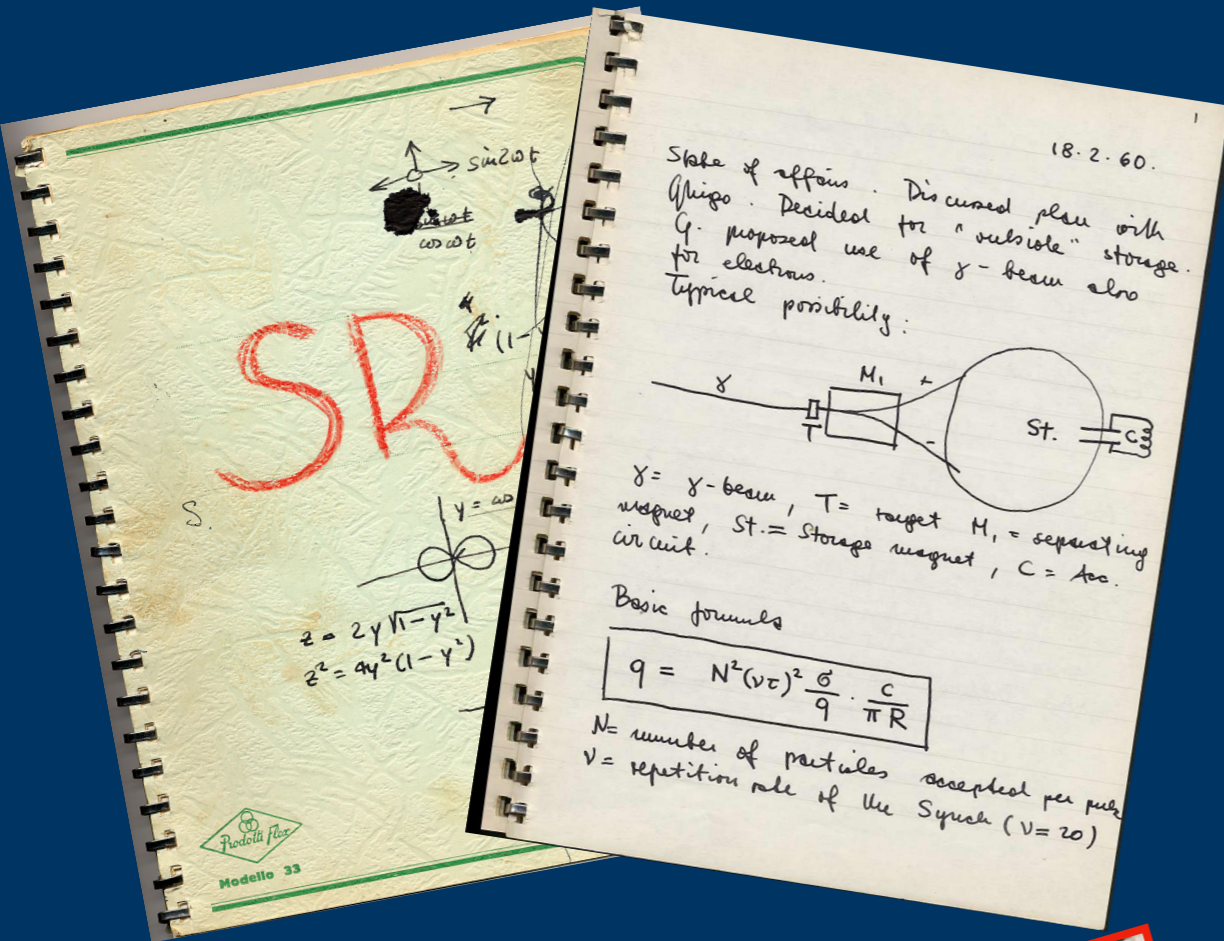
N. Cabibbo and R. Gatto

Istituti di Fisica delle Università di Roma e di Cagliari
e Scuola di Perfezionamento in Fisica Nucleare dell' Università di Roma, Roma, Italia

(Received February 17, 1960)

Title of dissertation: "*Pauli invariants in the decay of the mu meson*"

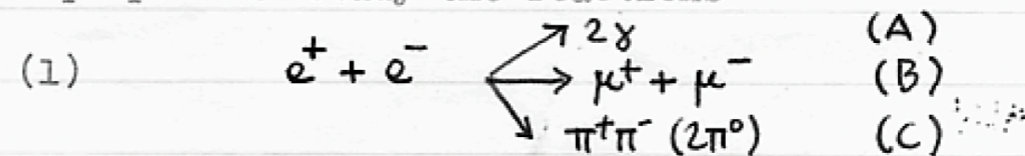
Touschek & Gatto From CPT to AdA



On The Storage Ring.

The following is a very sketchy proposal for the construction of a storage ring in Frascati. No literature has been consulted in its preparation, since this invariably slows down progress in the first stage, necessary though it may be in the consecutive stages of the development. I shall

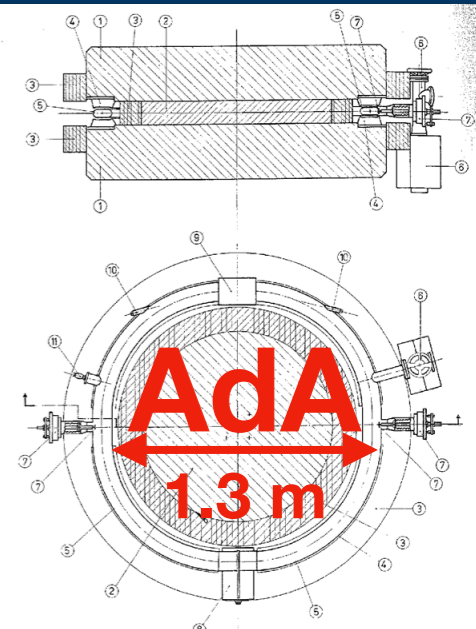
At this stage it appears necessary to define the project a little better: I prefer to think of it as an experiment rather than as a machine - a fact which may change considerably our attitude to the project. As I think I will be able to demonstrate the project is closer to an experiment than to a machine in two important respects: in cost and in the limited range of applicability of the ironware. Talking of it as an experiment I propose to study the reactions



Experiment proposed measure:
 $(e^+e^-) : (\mu^+\mu^-) : (\pi^+\pi^-)$
 Ask Gatto, what can be learned from this measurement!

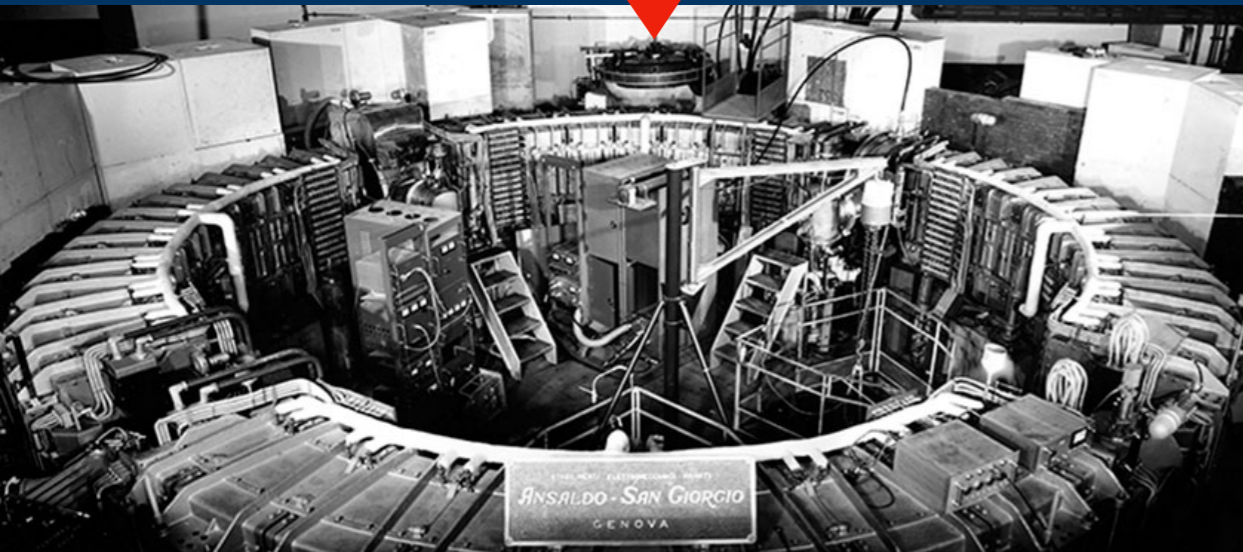
The Frascati Storage Ring.

Electrons and positrons of 250 MeV each are stored in a DC weak focussing magnet. The electrons and positrons circulate on the same orbit (this is guaranteed by the TCF theorem) meeting in the gap of the radio frequency and

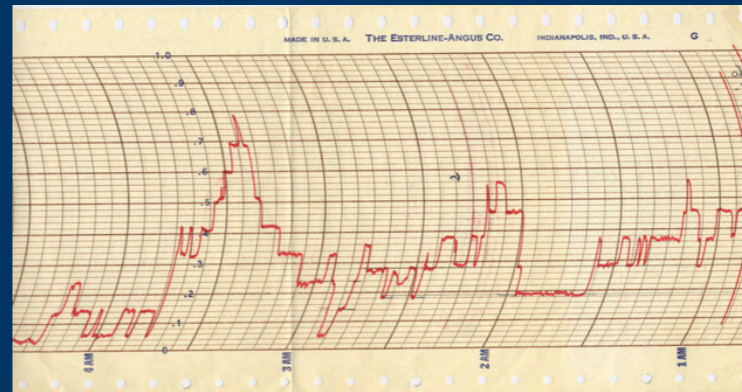


250 MeV beams

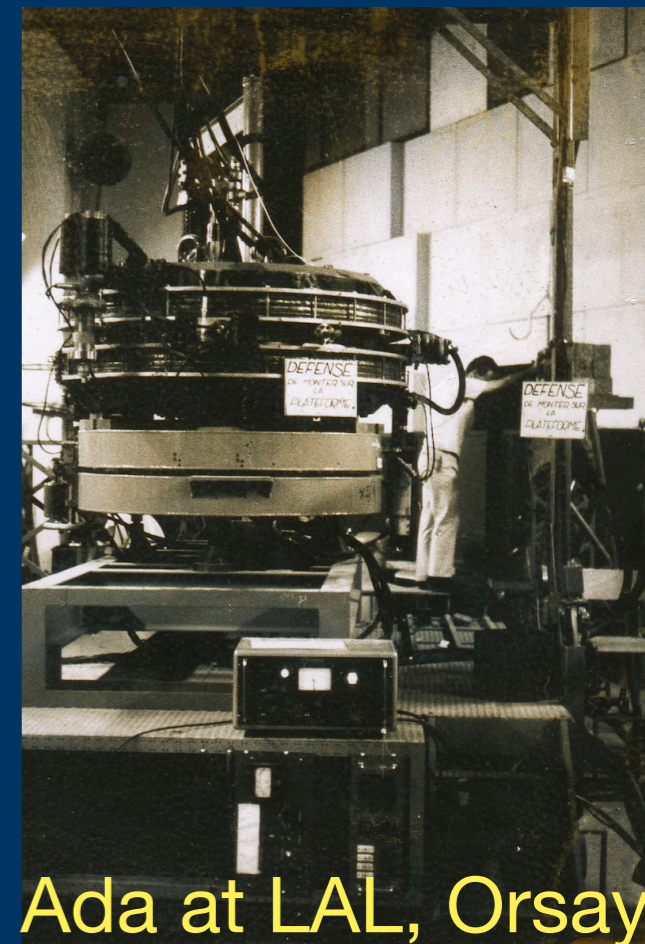
AdA in Frascati and Orsay: 1961-1964



AdA near the Electron Synchrotron



First electrons in AdA
February 1961



Ada at LAL, Orsay

Franco Buccella and Guido Altarelli



Dissertation under Gatto's supervision on the cross-section for "Single photon emission in high-energy e^+e^- collisions"

IL NUOVO CIMENTO Vol. XXXIV, N. 5 1° Dicembre 1964

Single Photon Emission in High-Energy e^+e^- Collisions.

G. ALTARELLI and F. BUCCELLA

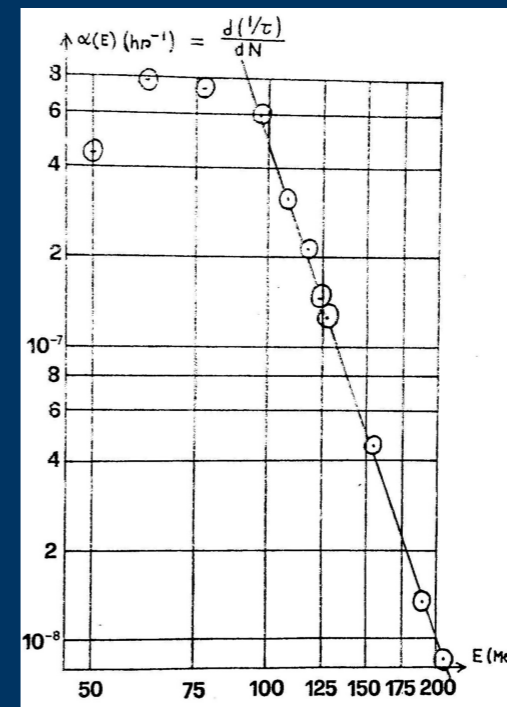
Istituto di Fisica Teorica dell'Università - Firenze

(ricevuto il 17 Giugno 1964)

Summary. — In this work we evaluate, for the process $e^+ + e^- \rightarrow e^+ + e^- + \gamma$, the angular distribution of the emitted photons, their energy spectrum, and the total cross-section for the emission of photons of energy $\geq \epsilon$ in the extreme relativistic limit.



$$e^+ + e^- \rightarrow e^+ + e^- + \gamma$$



Touschek effect

Measurements of the Rate of Interaction between Stored Electrons and Positrons (*).

C. BERNARDINI and G. F. CORAZZA
Laboratori Nazionali - Frascati

G. DI GIUGNO
Istituto di Fisica Superiore dell'Università - Napoli

J. HAISSINSKI and P. MARIN
Laboratoire de l'Accélérateur Linéaire - Orsay

R. QUERZOLI
*Istituto di Fisica Superiore dell'Università - Napoli
Laboratori Nazionali - Frascati*

B. TOUSCHEK
Istituto Nazionale di Fisica Nucleare - Sezione di Roma

(ricevuto il 16 Luglio 1964)

Formation of young theorists Gatto between Rome and Florence



The Galileo Galilei Institute for Theoretical Physics - Arcetri, Florence

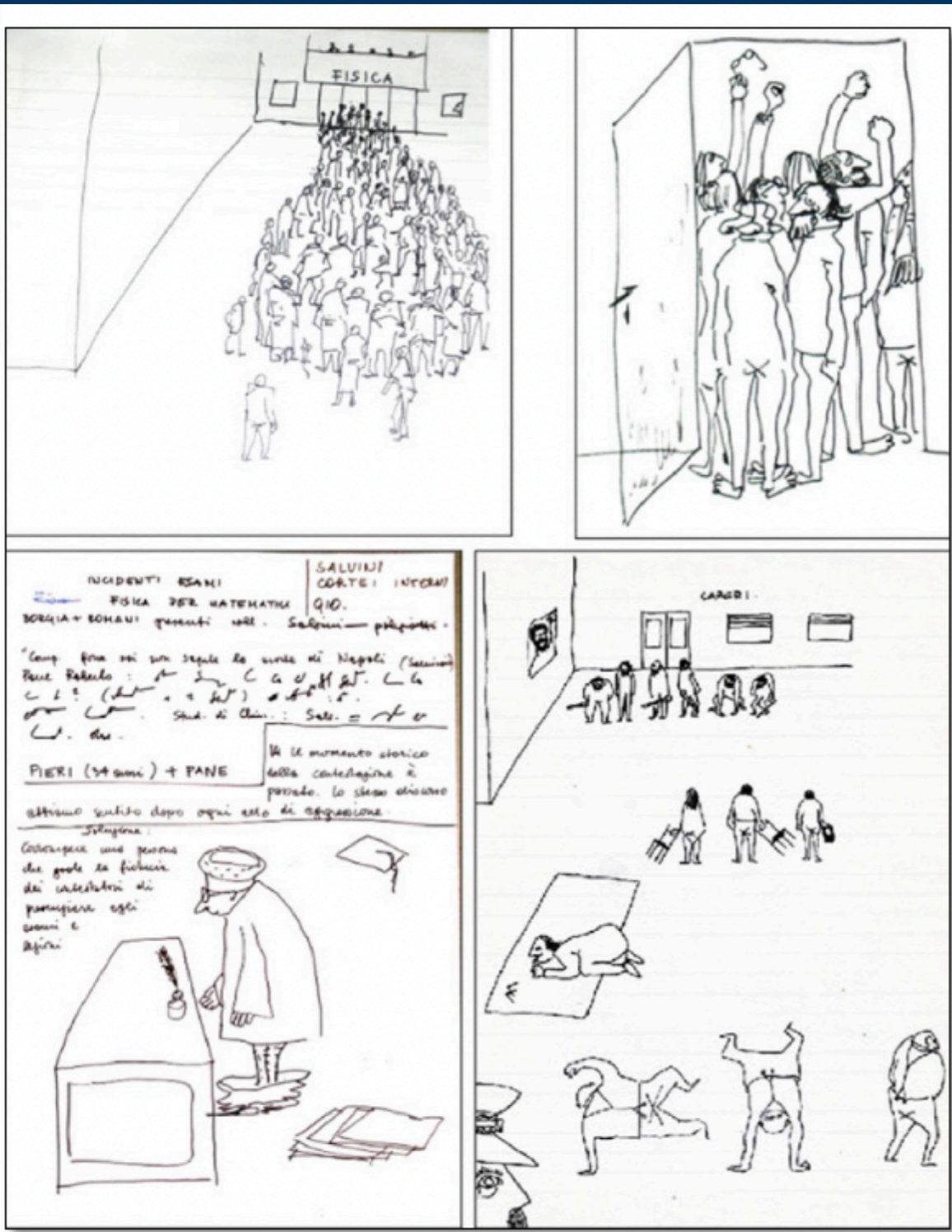


50 years of Theoretical Physics
A tribute to Raoul Gatto for his 80th birthday

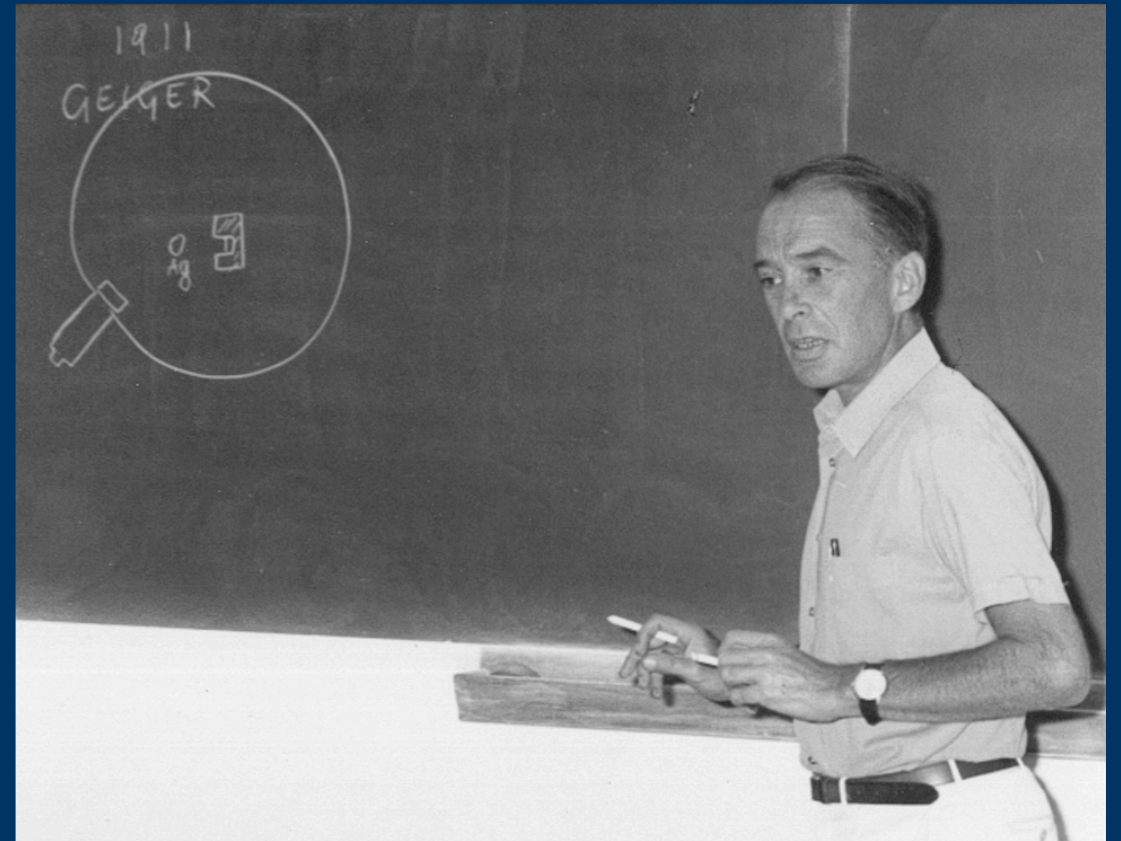


From left:
Luciano Maiani,
Giorgio Capon,
Giuliano Preparata

Formation of young theorists Touschek between Rome and Frascati



Touschek's drawings of 1968

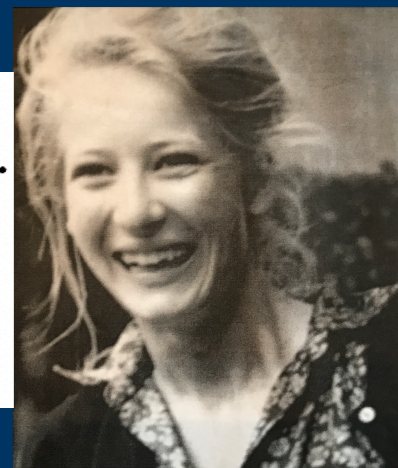


The enthusiasm of the new generation...

**The Infra-Red Radiative Corrections
for Colliding Beam (Electrons and Positrons) Experiments.**

E. ETIM, G. PANCHERI and B. TOUSCHEK
Laboratori Nazionali di Frascati del CNEN - Frascati

(ricevuto il 30 Gennaio 1967)



Giulia Pancheri

Beyond AdA: ADONE

A D O N E - a Draft Proposal for a
Colliding Beam Experiment.

B. Touschek,
Rome, 9. Nov. 60.

It is proposed to construct a synchrotron like machine capable of accelerating simultaneously electrons and positrons in identical orbits. The suggested maximum energy is 1.5 Gev for the electrons as well as the positrons. This energy allows one to produce pairs of all the so called 'elementary particles' so far known, with the exception of the neutrino, which only becomes accessible via a weak interaction channel.

It is assumed that experiments in which there are only two particles in the final state are most easy to interpret. There are 16 such reactions, namely:

(1) 2γ . This is the only reaction in which the ~~weak~~ intermediate state is 'quasi real' and in which therefore there should be no 'radiative corrections'. This reaction should serve as a 'monitor'. The cross-section is $2.6 \cdot 10^{-31} \text{ cm}^2$.

(2) e^+, e^- . This reaction will show strong angular variations and may require 'good geometry'. It would give information on the breakdown of electrodynamics at distances corresponding to about 1/3 the Comptonwavelength of the proton.

(3) μ^+, μ^- . Test of electrodynamics in 'bad geometry'. May also serve as an indication of the fundamental difference between electrons and muons.

(4) $\pi^+ \pi^-$ reveals the interaction between pions in odd parity states.

(5) $2\pi^0$: charge exchange interaction for pion-pion scattering.

(6) $K^+ K^-$: interaction of K-mesons in odd parity states.

(7) \bar{K}^0, K^0 : Charge exchange interaction between K-mesons.

(8) p, \bar{p} : interaction of proton and antiproton in even parity odd charge parity states.

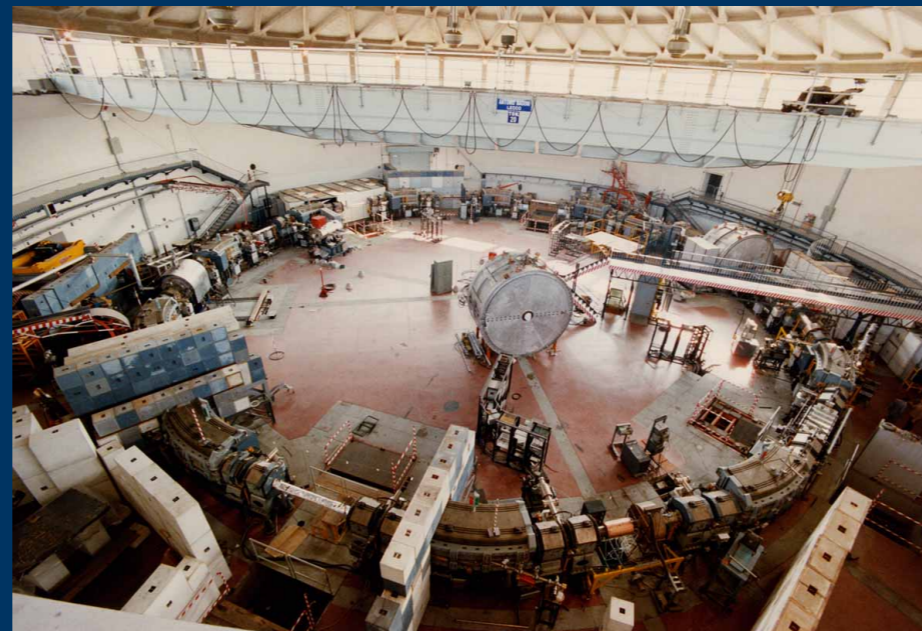
(9) n, \bar{n} : same as (8) but for the charge exchange reaction.

(10) through (15). Interactions simple or with charge exchange of hyperons.

Laboratori Nazionali di Frascati

Nota interna n° 68
27 Gennaio 1961

F. Amman, C. Bernardini, R. Gatto, G. Ghigo, B. Touschek:
ANELLO DI ACCUMULAZIONE PER ELETTRONI E POSITRONI (ADONE)



ADONE
3 GeV - 100 m

Cross section for e^+e^-
annihilation into hadrons as
measured at various colliders

LETTERE AL NUOVO CIMENTO VOL. IV, N. 1 4 Luglio 1970

Hadron Production in e^+e^- Collisions (*).

N. CABIBBO

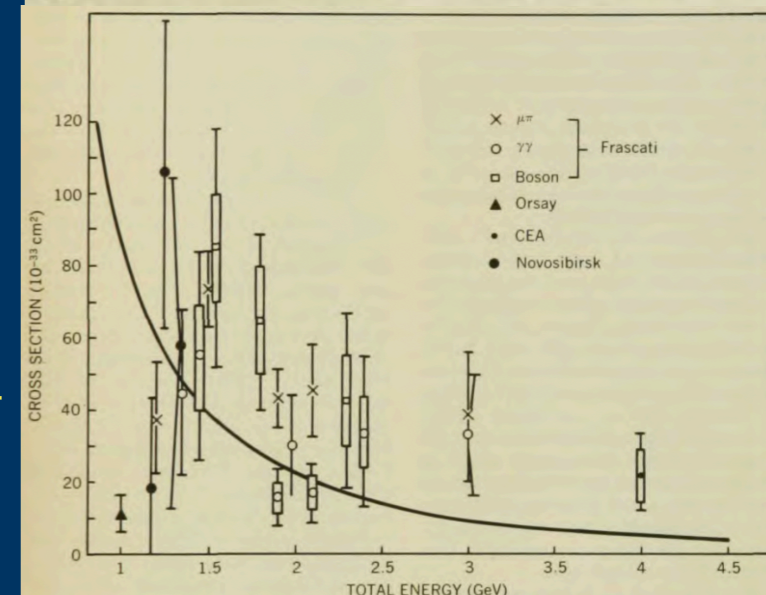
Istituto di Fisica dell'Università - Roma
Istituto Nazionale di Fisica Nucleare - Sezione di Roma

G. PARISI and M. TESTA
Istituto di Fisica dell'Università - Roma

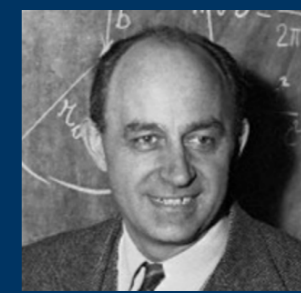
(ricevuto il 30 Maggio 1970)

PHYSICS TODAY / JANUARY 1973

Multihadron production
greater than expected



Continuity and Renewal



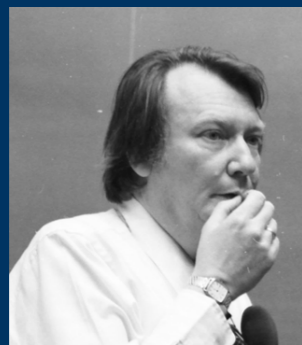
FERMI



WICK



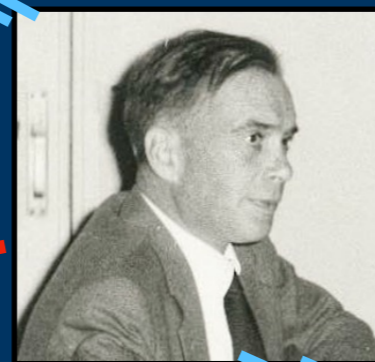
CONVERSI



RUBBIA



FERRETTI



TOUSCHEK



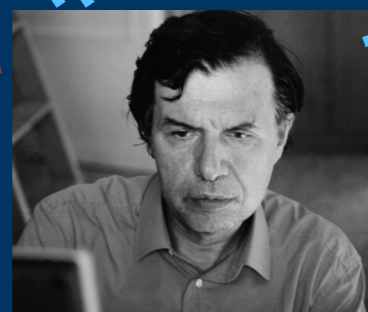
GATTO



CABIBBO



MAIANI



PARISI

Raoul Gatto was the heir of Fermi, who best transmitted his legacy to the next generation
Gabriele Veneziano

After working with Gatto on $SU(3)$, I had all the mathematics of group theory at hand that was needed...

Transition to a new era...

Gatto to Touschek

19 December 1972

Carissimo Bruno,

Personalmente, non dimentico di avere da te imparato, attraverso le tue lezioni e le tante discussioni, durante i primi anni della mia formazione, uno stile ed un gusto della professione che sempre mi sono stati di modello. Ti ho sempre considerato mio maestro, anche se, per pudore e per paura della retorica, non ti ho forse mai esternato, come avrei dovuto, questa mia infinita stima e gratitudine.

Raoul Gatto

Dearest Bruno,
[...] [...] Personally, I do not forget that I learned from you, through your lessons and the many discussions, during the first years of my training, a style and a taste for the profession that have always been a model for me. I have always considered you my master, even if, out of modesty and fear of rhetoric, I have perhaps never expressed to you, as I should have, this infinite esteem and gratitude of mine.