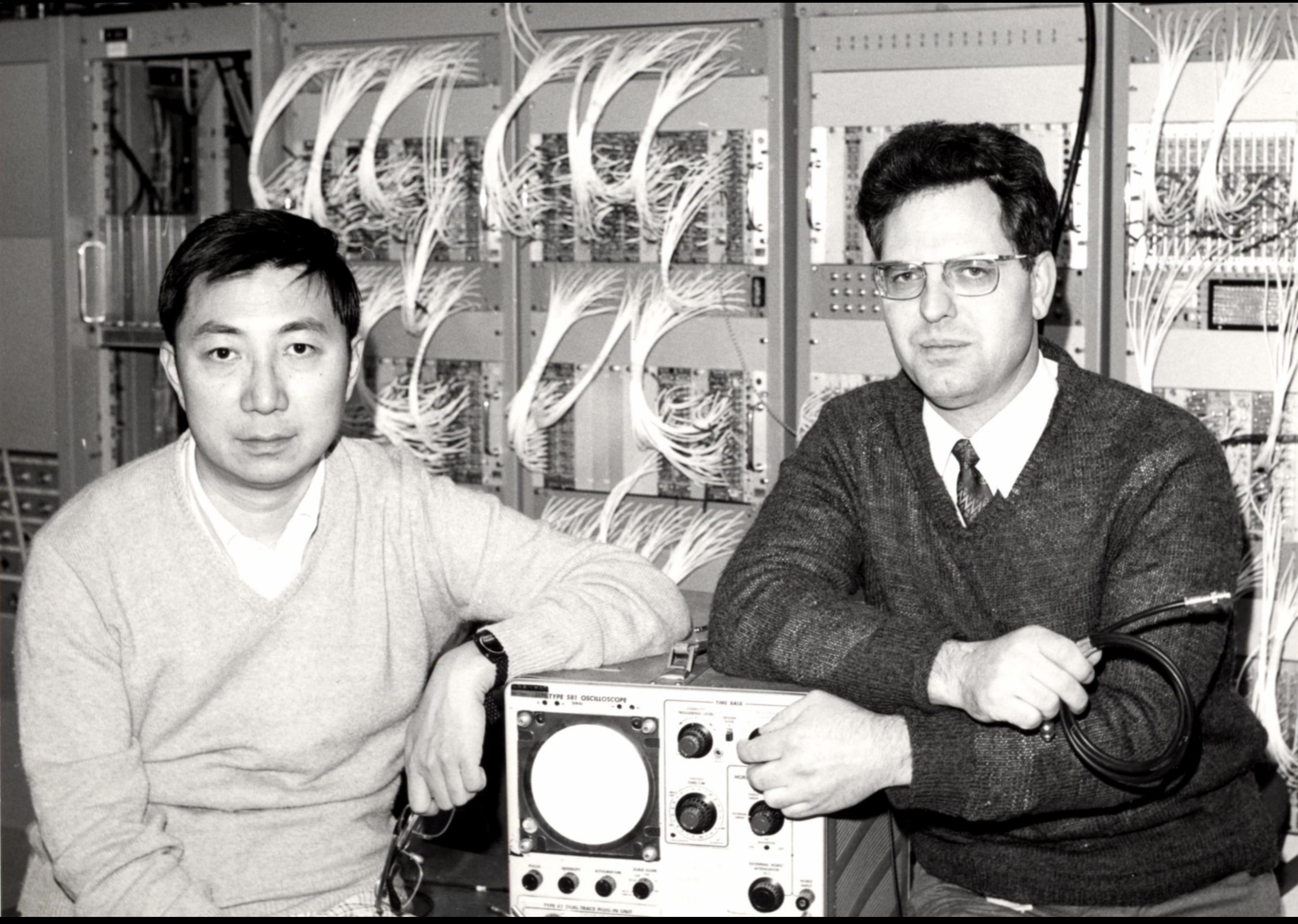
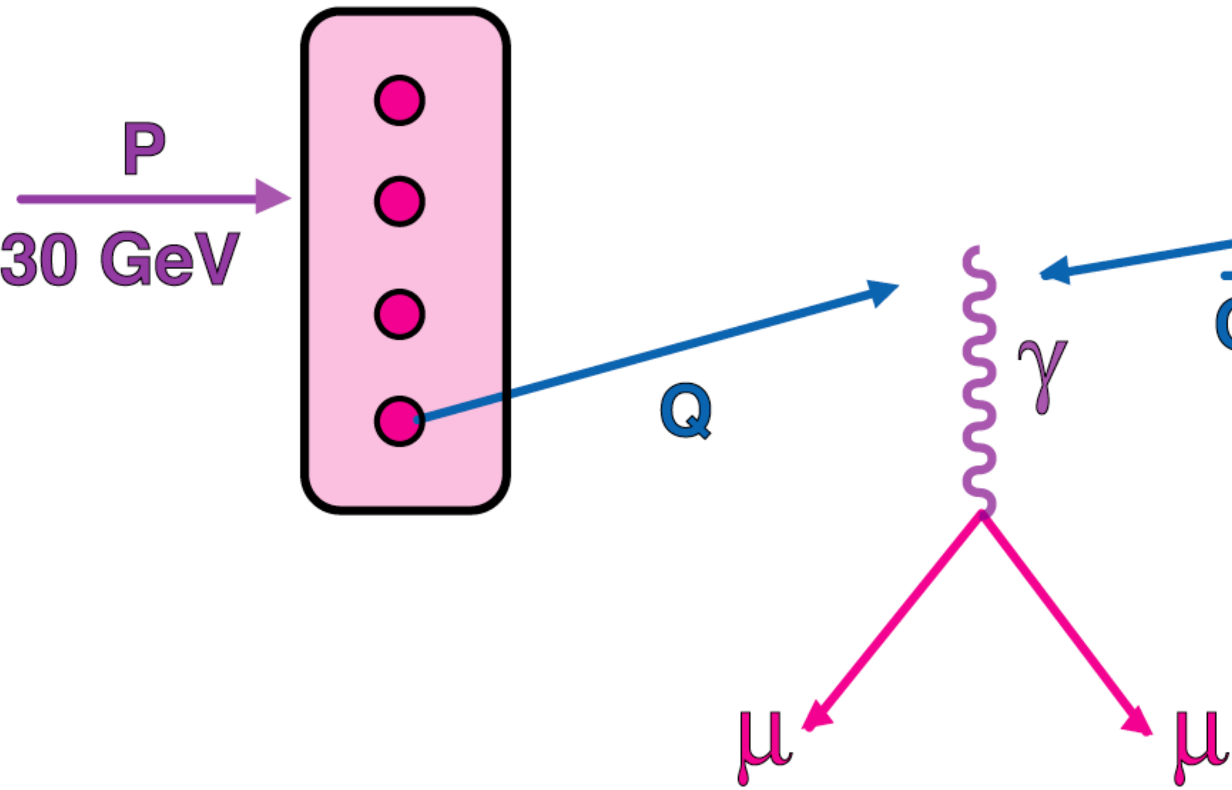

TYPE 581 OSCILLOSCOPE
TIME BASE
TYPE 82 DUAL-TRACE PLUG-IN UNIT

December 10, 1976 at Nobel Prize Ceremony. Ulrich and Gerda Becker together with Herman Feshbach.

1976

1980, Third Experiment with Ulrich Becker

CERN - I.S.R.

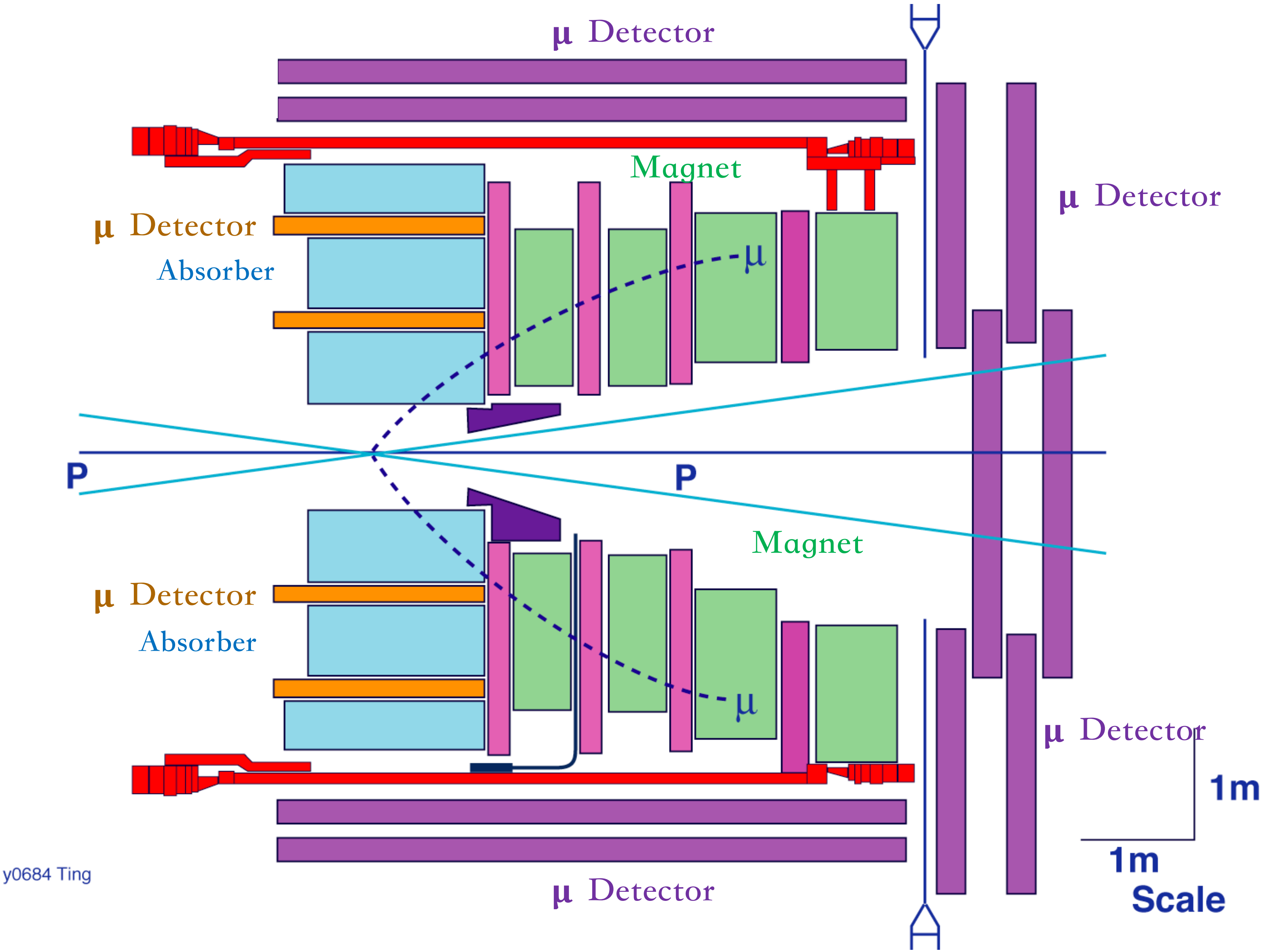


$$\tau = \frac{m^2}{s} \quad x = \frac{p_{11}}{p}$$

First check of scaling in PP interaction in the time-like region

97139/lb

P.R.L. vol. 45, 863, 1980


μ Detector
Magnet
μ Detector
μ Detector
Absorber
μ
P
P
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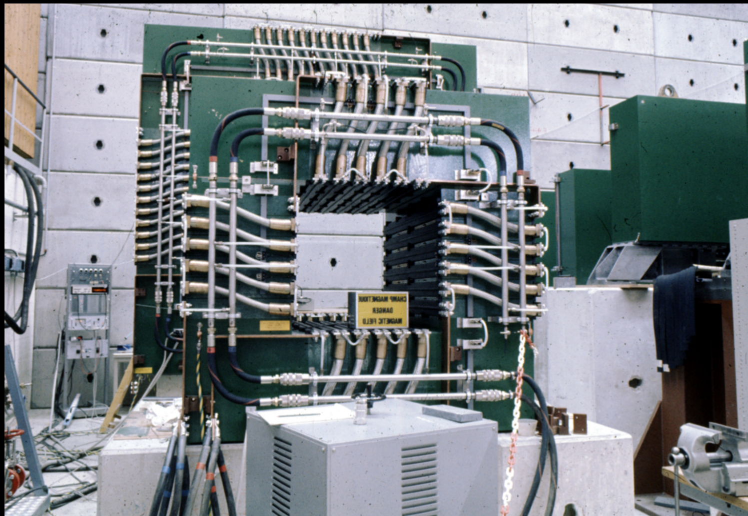
μ
μ Detector
1m
1m
Scale
y0684 Ting
μ Detector

Magnet System



1974-1980 at ISR CERN

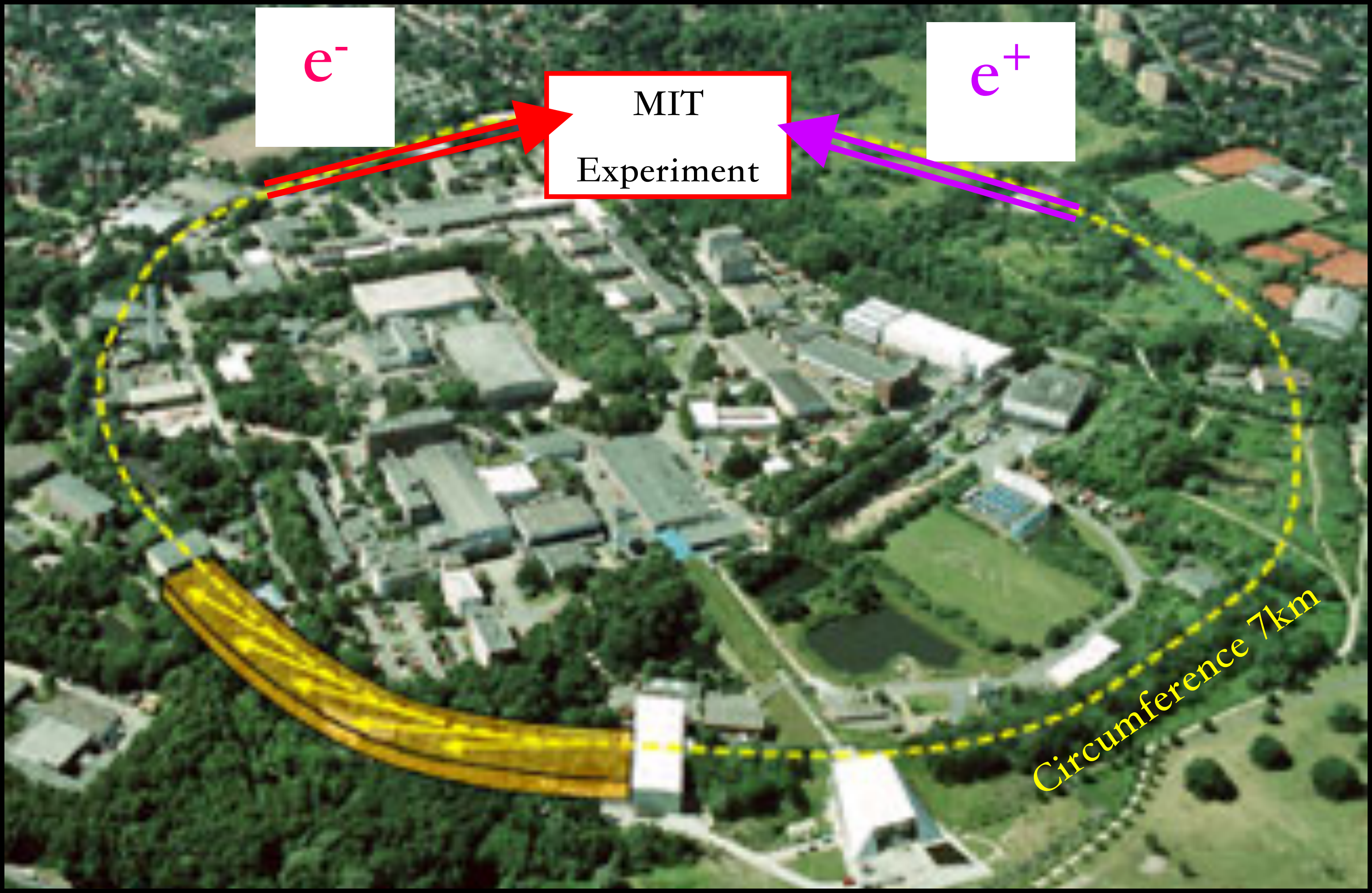
Young collaborators

R. Battiston	Professor University of Perugia - AMS-02 Tracker
J. G. Branson	Professor University of California
J. Burger	Senior Physicist MIT - AMS-02 Thermal and TRD
F. Cervelli	Professor University of Pisa - AMS-02 ECAL
T. Lagerlund	M.D., Professor, Mayo Clinic, Rochester, MN
H. Newman	Professor , CALTECH
J. Paradiso	Professor, MIT
T. Sanford	Senior Scientist, Sandia National Laboratory
P. Spillantini	Professor University of Florence
S. Sugimoto	Professor University of Kyoto
W. Toki	Professor University of Colorado
F. Vannucci	Professor University of Paris V

1977, Fourth Experiment with Ulrich Becker

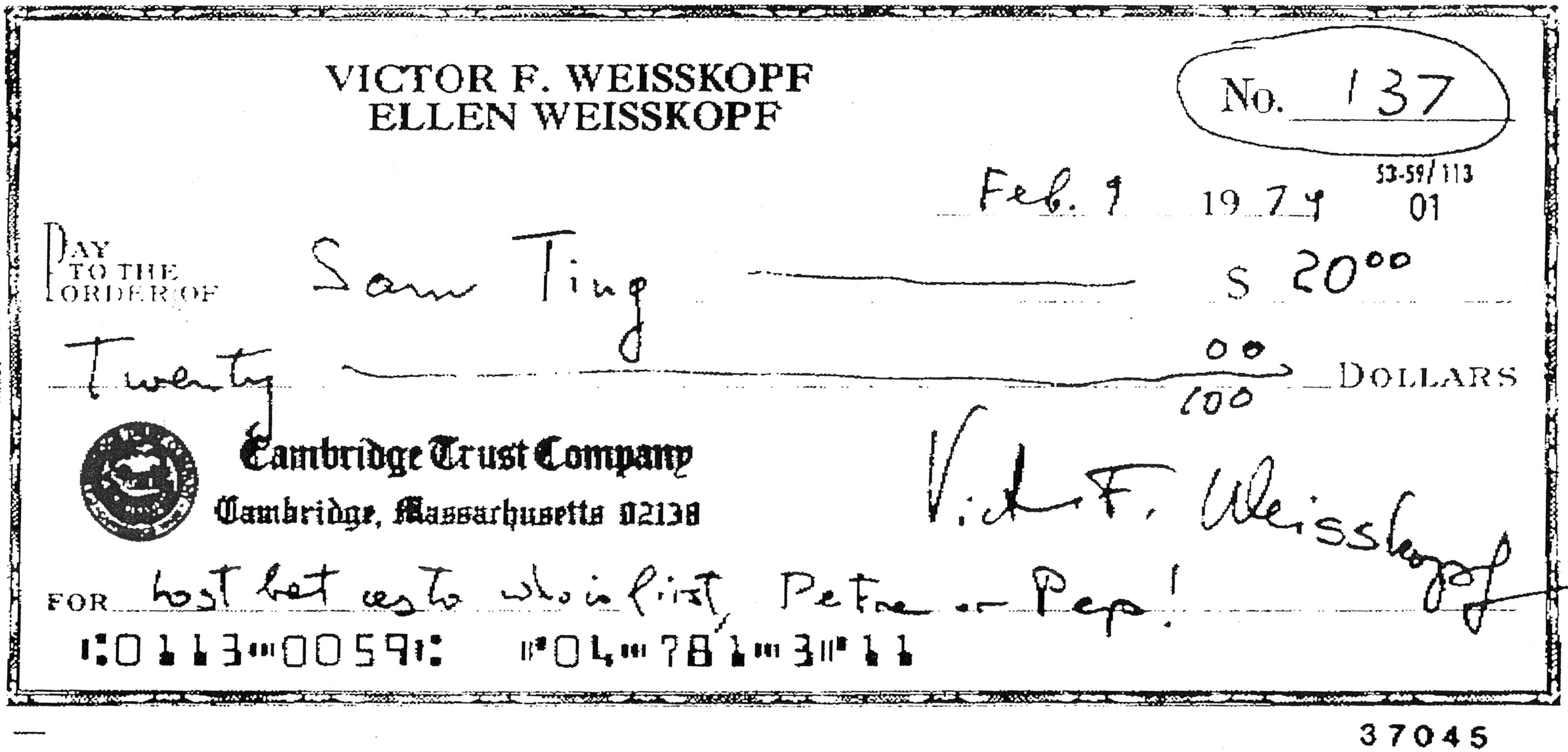
PETRA in Germany

Discovery of Gluons



A partial list of Ph.D. Students: Bolek Wyslouch, Jean-Pierre Revol, Mike Capell, Yuan-Hann Chang, Bob Clare, Marion White, Bing Zhou

PETRA or PEP



VICTOR F. WEISSKOPF
ELLEN WEISSKOPF

No. 137

53-59/113
01

Feb. 9 1979

PAY TO THE ORDER OF Sam Ting $ 20.00

Twenty 00/100 DOLLARS

Cambridge Trust Company
Cambridge, Massachusetts 02138

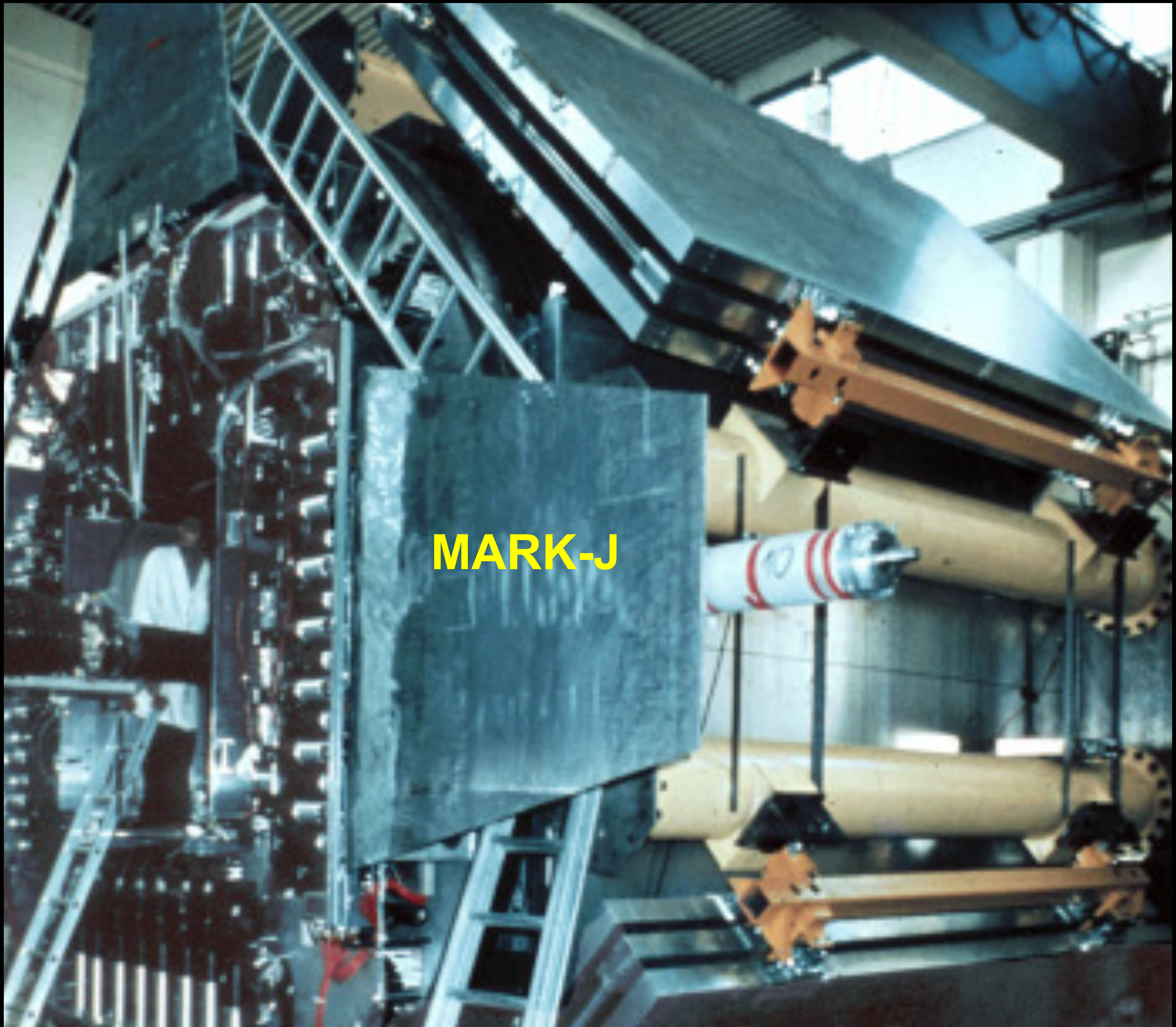
Victor F. Weisskopf

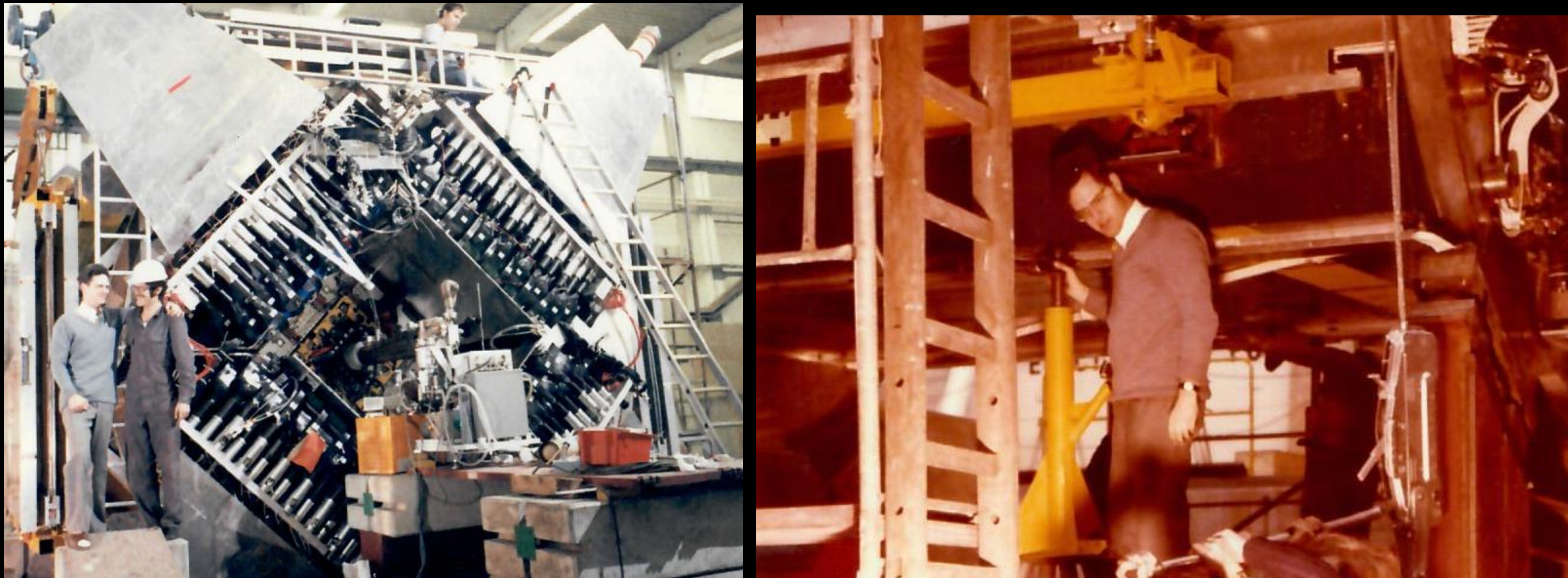
FOR Lost bet as to who is first, Petra or Pep!

⑆0113⑉0059⑆ ⑈04⑉781⑉3⑈11

37045

PETRA 30 GeV Collider in Germany





Assembly of MARK-J at PETRA

Construction of the Drift Tubes, Building 44

Nuclear Instruments and Methods 180 (1981) 61–63

The drift tubes for Mark-J were developed and led by Ulrich Becker

DRIFT-TUBE ARRAYS FOR HIGH SPATIAL RESOLUTION

U. BECKER
CERN, Geneva, Switzerland, and MIT, Cambridge, MA, U.S.A.

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MIT, Cambridge, MA, U.S.A.

Received 18 September 1980

An array of 32 thin-walled drift tubes was traversed by a 20 GeV proton beam and the resulting track reconstructed. The spatial resolution was measured as a function of the number of individual coordinates recorded. The frequency of δ-rays and the criteria for the rejection of non-statistically distributed coordinates were studied. A value of $\sigma = (156 \pm 5)\ \mu m/\sqrt{N}$ was obtained using N drift tubes, while the accuracy of an individual tube was found to be $\sigma_{tube} \simeq 135\ \mu m$.

1. Introduction

Charged-particle detectors for future storage-ring experiments [1] will require high spatial resolution [2] and compact design, combined with maximum operating reliability under high rate conditions. Thin-walled drift tubes meet the above requirements.

The arrays consisted of 32 drift tubes of 1 cm diameter with 0.25 mm aluminium walls. They had a length of 30 cm and a tungsten wire of 40 μm in their centre. They were tested with 20 GeV protons at the CERN PS, with different gas mixtures and at beam rates up to 600 counts/s · cm. A spatial resolution of $\sigma_{tube} \lesssim 135\ \mu m$ has been achieved. Combining several tubes results in a substantial improvement in resolution. Measurements incompatible with probability criteria demanding a straight track are rejected and therefore most of the δ-rays are eliminated.

These tubes are operating at present with excellent reliability under severe synchrotron radiation background at MARK J at PETRA [3].

2. Set-up and results

The beam b_{16} of the CERN PS was used for the studies. Fig. 1 shows the test set-up. Protons of 20 GeV energy traverse an array of 32 drift tubes in a 2 mm wide beam, defined by the two counters trig 2 • trig 3. Trig 1 is used for suppression of accidentals. The drift-tube array can be displaced perpendicular to the beam and sense-wire direction with an accuracy of 0.01 mm. The signal from the positive sense wire (typically at +2.20 kV) is shaped in a preamplifier and recorded in a LeCroy 2228 8-channel time-to-digital converter (TDC) with a resolution of

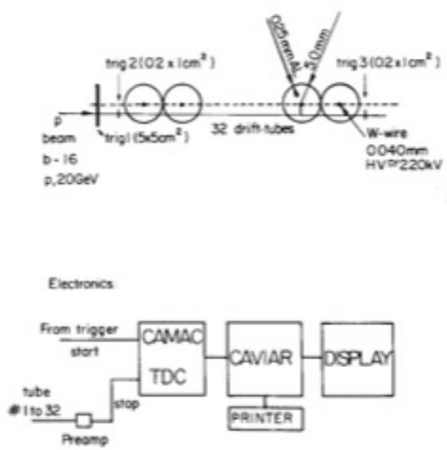
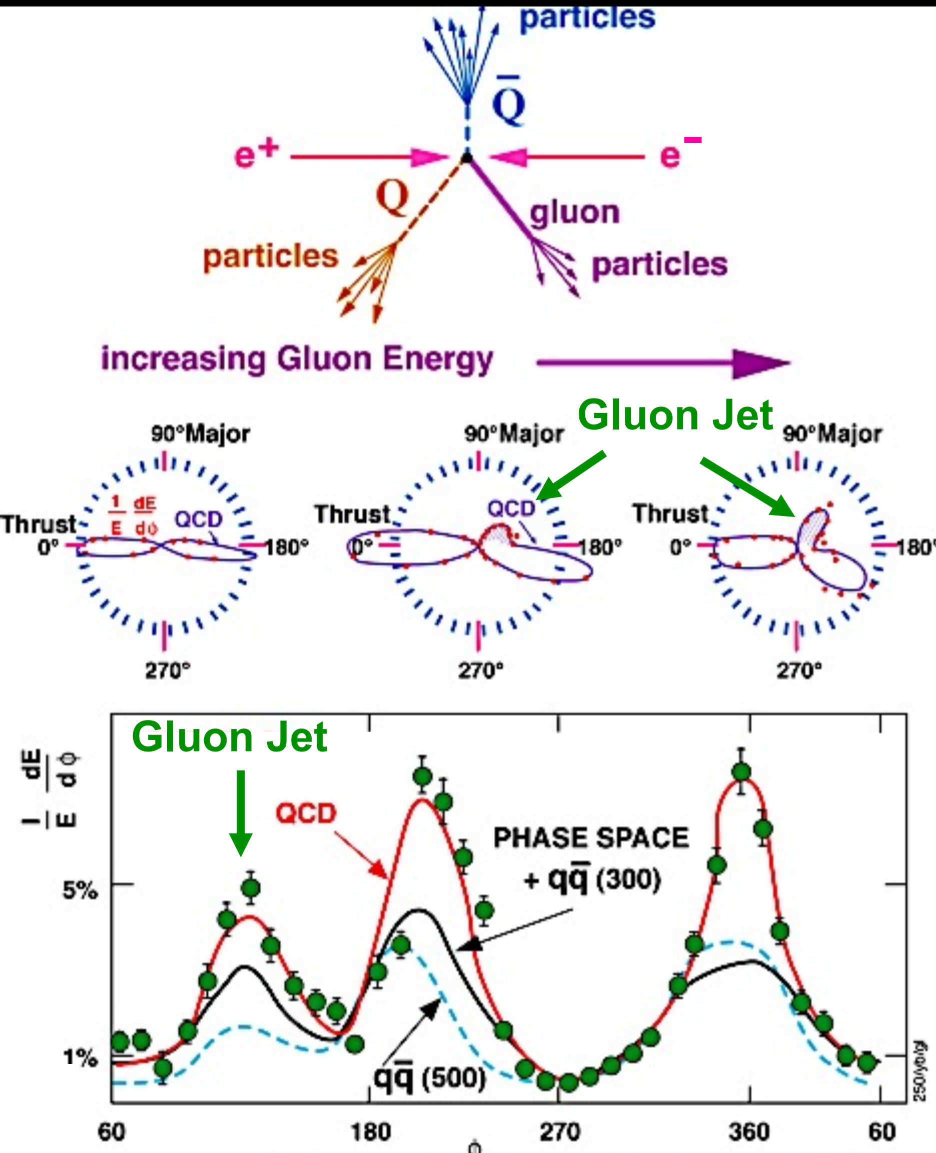


Fig. 1. Experimental set-up.

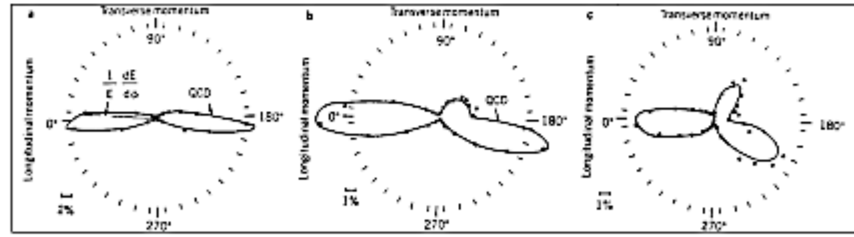
Discovery of Gluons at PETRA Germany

Physics Today, February 1980 (p.17)



search & discovery

Evidence from PETRA adds support for QCD and gluons



Jets of hadrons produced in electron-positron collisions at PETRA. Each event has been rotated into a frame where both the longitudinal momentum and transverse momentum are maximized. Figures a, b and c are samples where the events become increasingly oblate. The distance from the center of the circle $(1/E)dE/d\phi$ is a measure of the energy of the particles. In a the two large lobes are jets from decays of quark-antiquark pairs. The gluons have too little energy to create an additional jet. In b the third small lobe is mostly due to the jet from the decays of a low-energy gluon. In c the gluon has enough energy to create a distinct jet of its own (in the 90–180° region). (From reference 2.)

Over the past several years a theory of the strong interactions known as quantum chromodynamics has been developing. This theory assumes the existence of fractionally charged quarks of spin ½ and that the force between the quarks is carried by a gluon, a massless spin-1 quantum. Like the quark, it is widely believed that the gluon is not directly observable.

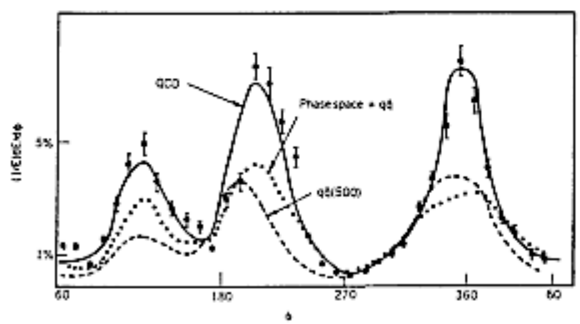
Now experiments at PETRA, the new electron-positron storage ring at DESY in Hamburg, Germany, which started operating last year with roughly 15 GeV in each beam, are showing evidence for the existence of gluons and are in agreement with the general picture of quantum chromodynamics. Very recent analyses of the PETRA data have determined a value of the strong-interaction coupling constant, α_s, which is consistent with earlier measurements involving the inelastic scattering of either neutrinos or muons on protons.

The experiments are being done by four groups at DESY—Jade, Mark J, Pluto and Tasso. Preliminary results were reported last summer and more recently at The American Physical Society meeting in Chicago in January.

At present we have evidence for five kinds of quark—up, down, strange, charmed, bottom—and the strong expectation of a sixth—top. Quantum chromodynamics requires that each kind of quark have a quantum number called color, which comes in three varieties. The three quark colors transform as a functional triplet of the group SU(3). To make this SU(3) symmetry a local gauge symmetry, one introduces eight vector gauge fields—colored gluons. Because the gluons carry color, they interact with each other and thereby lead to a decrease of the coupling as the energy is increased (asymptotic freedom).

Most of the evidence in favor of quantum chromodynamics preceded the theory. For example, the rate of a neutral pion decay into two photons was evidence that up and down quarks must come in three colors. In electron-positron interactions, the ratio of hadron production to lepton production could be explained by having colored quarks. Until QCD, no one could find a quantum field theory that could explain all the experimental results.

At about the same time as QCD was being developed, experiments on deep



Unfolded energy flow diagram based on figure c, compared with QCD, quark-antiquark production (with average transverse momentum 500 MeV/c) and a model mixing $q\bar{q}$ and phase space.

There are many sources of three jets events. By measuring many three jets events, we discovered that their distribution only agrees with QCD predictions.

DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 79/79
December 1979

NEW RESULTS IN e^+e^- ANNIHILATION FROM PETRA

by

H. Schopper

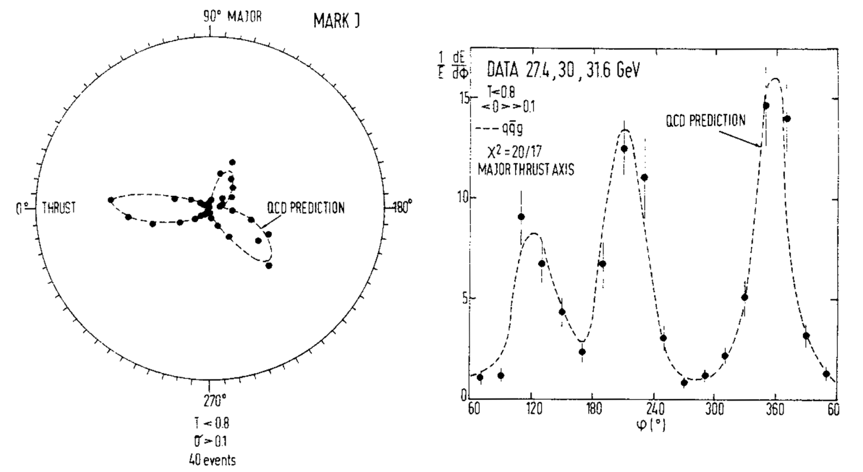


Fig. 23: a) Energy distribution in the event plane. The energy value is proportional to the radial distances. The dashed line is prediction of the $q\bar{q}g$ model.
b) Energy flow in the event plane as function of the polar angle φ.
(MARK J data)

MARK J has provided[21)] the first statistically relevant observation of the 3-jet pattern.

NOTKESTRASSE 85 · 2 HAMBURG 52

Celebration of Gluon Discovery at DESY and MIT

After the Cultural Revolution, in August 1977, Chinese scientists suggested sending 10 scientists each year to collaborate with our group. Since then, many Chinese scientists joined our group and have made major contributions recognized worldwide.

Trip to China to select students, November 1978

Reception with Minister of Science Fang Yi