B.T. and Physics at Frascati at the time of AdA and Adone

Mario Greco
Univ. and INFN - Roma Tre

LNF - December 3, 2021

January 1965 → I joined the Adone Team

- AdA had successfully completed its cycle at Orsay.
  C. Bernardini, G. Corazza, G. Giugno, J. Haissinski and P. Marin, "Measurements of the rate of interaction between stored electrons and positrons", Nuovo Cimento, 34(6), 1473 (Dec.1964).

- Adone was in great turmoil. General feeling of sharing a new adventure.
  F. Amman et al., "Adone - The Frascati 1.5 GeV Electron Positron Storage Ring", 5th Int. Conf. on High Energy Accelerators (HEACC '65, Frascati).

--→ C. Pellegrini asked me to face the calculation of double bremsstrahlung, as a monitor of luminosity, not an easy task. (Bayer and Galitsky, Bander differ by a factor of 2).

B.T. was collaborating with C. Pellegrini and E. Ferlenghi on beam instabilities.

First meeting with B. Touschek.

B.T. had proposed to P. Di Vecchia the study the soft photon limit.

Starting of a long collaboration and friendship.

LNF - Theory Group: (G. De Franceschi, M.G., E. Etim, G. Pancheri, P. Di Vecchia, G. Rossi, F. Drago, P. Di Stefano)

- B.T.'s main problem: evaluate radiative corrections for Adone exp.s (new e+e- coll.)
  P. Di Vecchia → $e^+ e^-$ + 2 soft photons
  E. Etim → Proposal for the administration of rad. corrections
  G. Rossi → Application of the Bloch-Nordsieck theorem to rad. corrections in Adone exps.

- Two different approaches were used:

  i) Statistical one using Bloch-Nordsieck theor.
  E. Etim. G. Pancheri and B. Touschek , Nuovo Cimento B51 (1967)

  ii) Field theory: define a finite S-Matrix using realistic definition of initial and final states. Introduction of Coherent States in QED.
  M.Greco and G. Rossi, Nuovo Cimento 50A (1967)

(β -> Bond Factor)

$$d\sigma = \frac{1}{\gamma^\beta} \frac{1}{\Gamma(1+\beta)} \left(\frac{\Delta\omega}{E}\right)^\beta d\sigma_E$$

$$\beta_i = \frac{4\alpha}{\pi}\left[\log\frac{W}{m_i} - \frac{1}{2}\right],$$

- Coherent States in QED played a major role in the description of radiative effects in J/Ψ and Z production (see later)

- Extension of Coherent States in QCD.

  M.G, F. Palumbo, G. Pancheri and Y. Srivastava, Phys. Letts. 77B (1978)

  M. Ciafaloni, S. Catani, …

→ Many important QCD results, as Exponentiation, Resummation formulae, K- Factors, P_t-distributions in DY pairs, W/Z, H production, have their roots in B. T. ideas on exponentiation and resummations in QED.

G. Curci, and M.G.; G. Parisi; G. Curci, M.G. and Y. Srivastava;

G.Pancheri and Y. Srivastava; G. Parisi and R. Petronzio;

G. Altarelli, K. Ellis, M.G. and G. Martinelli; …

This is also a Bruno Touschek's legacy!

Violation of QED ?

- Apparent viol. of QED in wide-angle e-e+ pairs prod. (E ≈ 1-6 GeV): R.B. Blumenthal et al. (Harvard), Phys.Rev.Lett. 14, 660 (1965) and Phys.Rev. 144, 1199 (1966).

VOLUME 14, NUMBER 16 PHYSICAL REVIEW LETTERS 19 APRIL 1965

DEVIATION FROM SIMPLE QUANTUM ELECTRODYNAMICS*†

R. B. Blumenthal, D. C. Ehn, W. L. Faissler, P. M. Joseph,
L. J. Lanzerotti, F. M. Pipkin, and D. G. Stairs‡

Harvard University, Cambridge, Massachusetts
(Received 23 February 1965)

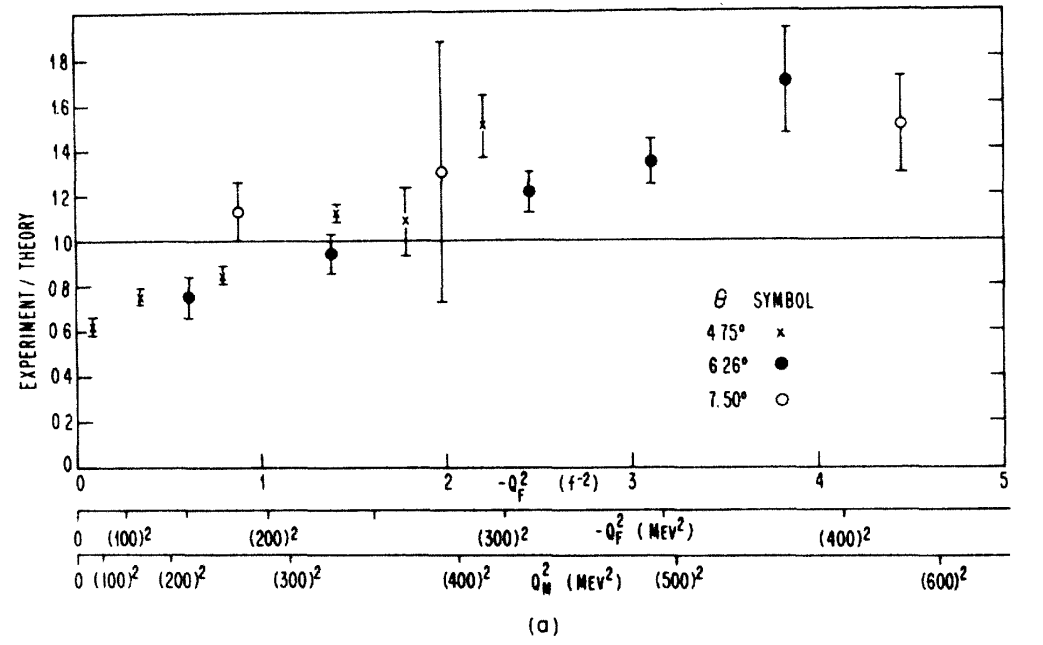
PHYSICAL REVIEW VOLUME 144, NUMBER 4 29 APRIL 1966

Wide-Angle Electron-Pair Production*†

R. B. Blumenthal, D. C. Ehn, W. L. Faissler, P. M. Joseph, L. J. Lanzerotti,‡
F. M. Pipkin, and D. G. Stairs§
Harvard University, Cambridge, Massachusetts
(Received 6 October 1965; revised manuscript received 19 January 1966)

An experiment testing quantum electrodynamics at high energies and small distances is described. The photoproduction from carbon of electron-positron pairs was measured at laboratory angles of 4.60°, 6.23°, and 7.46°. Symmetrical electron-positron pairs in the energy range from 1 to 5 BeV were detected with a magnet-counter system which consisted of two mirror-image arms. Extensive internal checks of the apparatus were made and the results were reproducible. The theoretical values for the electron-pair yield were calculated by integrating the differential pair-production cross section over the acceptance of the apparatus using a Monte Carlo technique. The ratio R = (experimental yield)/(theoretical yield) was not 1.0. R was approximately given by

$$R=0.62\{(1.00\pm0.05)+k^2/(4.31\pm0.17)^2\},$$



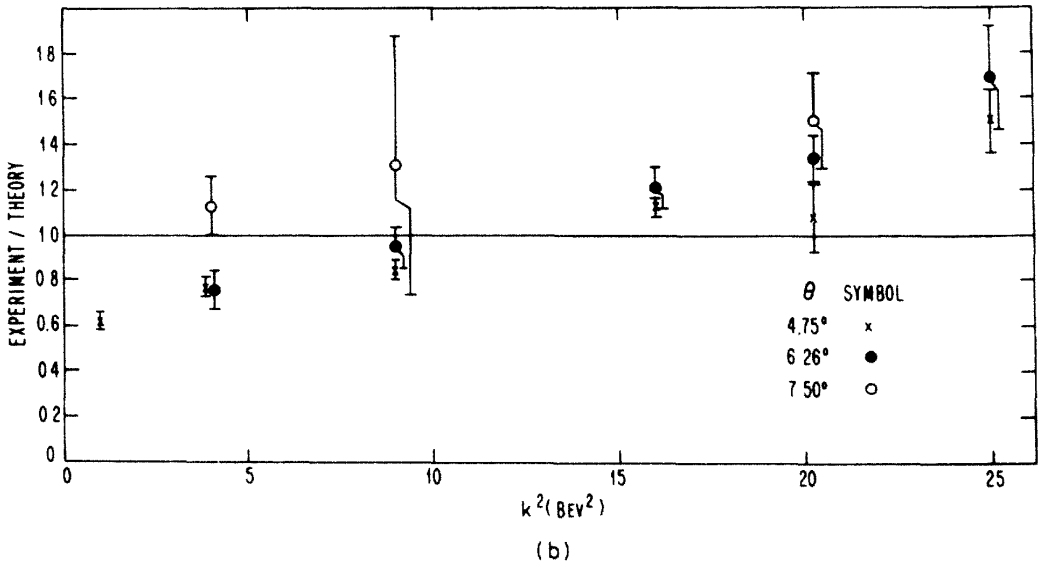


FIG. 2. This figure summarizes the ratio, R, of the experimental yields to the calculated yields. (a) R as

- At Frascati C. Bernardini starts an experiment of Wide-Angle-Bremsstrahlung (WAB). (More exps. in USA)
- B. Touschek suggests a simple model of modifying QED with vertices

  eeγ + eeγγ (N. Kroll -> ee-nγ) and studying constraints from other exps.

APPENDIX B

Unpublished work by M. Greco and B. Touschek, 1966

On the extension of minimal coupling in QED
(M. Greco and B. Touschek)

Recently Pipkin, et al. have observed an anomaly in the production of electron positron pairs by γ rays, which could be interpreted as indicating a possible breakdown of quantum electrodynamics.

This theory is based on the following axioms:

1) - relativistic invariance
2) - the correspondence principle
3) - Gauge invariance
4) - Locality
5) - Minimality

It is difficult to picture a theory, which could do without the first four of these axioms: a violation of (1) or (4) leaves us without the mathematical tools necessary to construct a theory, whereas (2) and (3) are needed to define electrodynamics and to distinguish it from other theories.

The most expendable of the axioms seems to be the last- it is not based on any single experimental fact, nor is there any motive to retain it apart from the convenience of not having to review the theory of renormalization.

→ New experiments confirm the validity of QED.

LNF-68/42

Nota Interna: n° 409
8 Luglio 1968

C. Bernardini: HIGH ENERGY EXPERIMENTS ON QED. -
(Two Lectures at Boulder, Colo.)

I - Many physicists would bet in favour of predictions of QED in it's

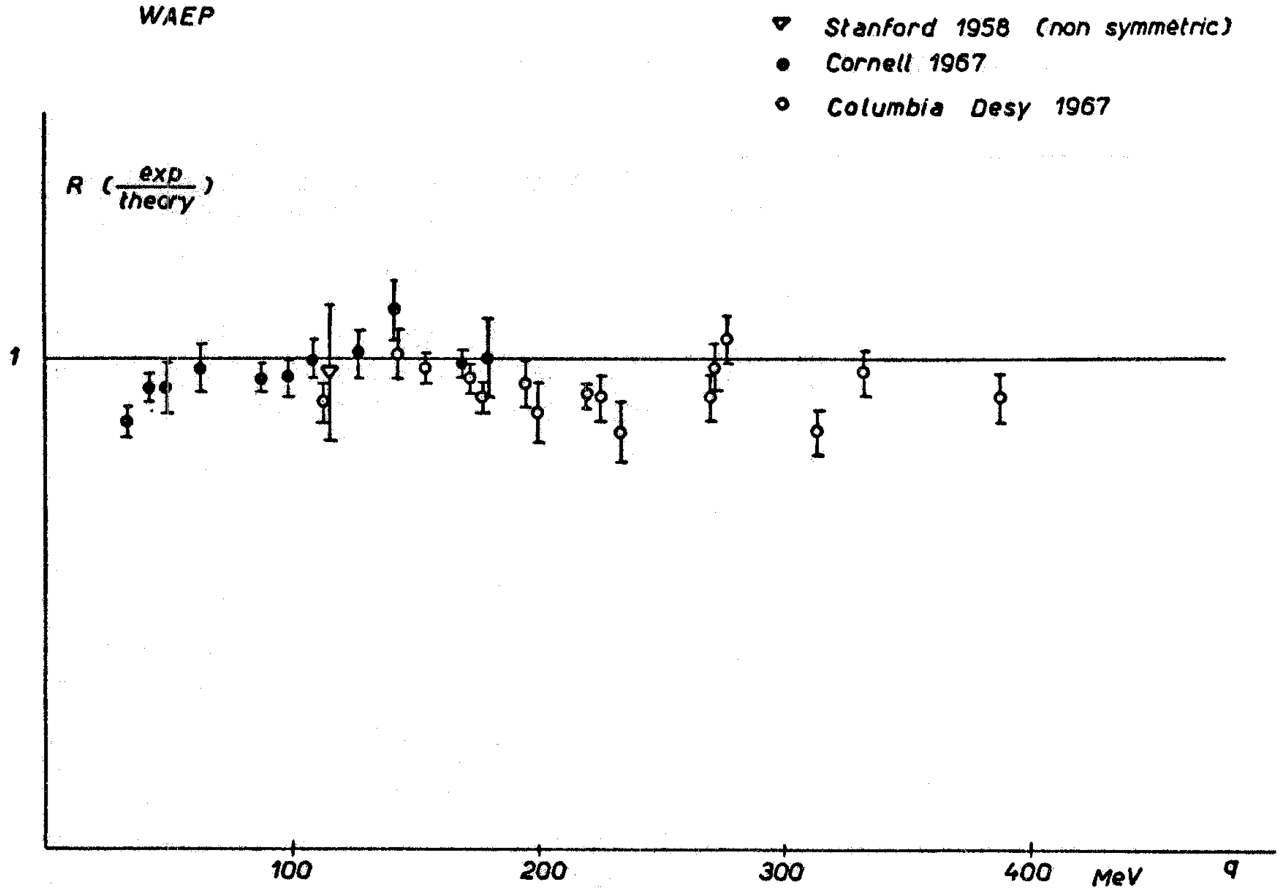

WAEP
Stanford 1958 (non symmetric)
Cornell 1967
Columbia Desy 1967
R (exp / theory)
1
100
200
300
400
MeV
q

FIG. 12

(20) - WAEP: B. Richter, Phys. Rev. Letters 1, 114 (1958); R. B. Blumenthal, D. C. Ehn, W. L. Faissler, P. M. Joseph, L. J. Lanzerotti, F. M. Pipkin, D. G. Stairs, Phys. Rev. 144, 1199 (1966); E. Eislander, J. Feigenbaum, N. Mistry, P. Mostek, D. Rust, A. Silverman, C. Sinclair, R. Talman, Phys. Rev. Letters 18, 425 (1967); J. G. Asbury, W. K. Bertram, U. Becker, P. Joos, M. Rohde, A. J. S. Smith, S. Friedlander, C. L. Jordan, S. C. C. Ting, Phys. Rev. 161, 1344 (1967).

Model-independent WAB experiments have been undertaken in some laboratories. The only one to my knowledge presently completed[28] has provided an absolute measurement of the WAB cross section at space-like momenta of ~300 MeV and time-like momenta of up to 100 MeV (compare Fig. 6) using a proton target and detecting the three outgoing particles

(28) - Frascati-Napoli-Roma group at Frascati, 1968, to be published.

Adone: th. framework and expectations

i) e.m. properties of hadrons mediated by vector mesons ρ, ω and ϕ (VMD): J.J. Sakurai

ii) T.D.Lee, N. Kroll and B. Zumino tried to give a field th approach to VMD

$$\sigma(s) \approx [1/s]^2$$

iii) DIS at Slac and scaling, Feynman parton model, Drell-Yan for pair. prod.

$$\left.\frac{\sigma_{e^+e^-\to hadr}}{\sigma_{e^+e^-\to\mu^+\mu^-}}\right|_{q^2\to\infty} = \frac{1}{4}\sum_{i=spin0} Q_i^2 + \sum_{i=spin\,1/2} Q_i^2$$

N.Cabibbo, G.Parisi and M.Testa, Lett. N. Cimento **4**, 35 (1970)

iv) Departures from VMD observed in radiative decays of mesons and possible existence of new vector mesons (as sugg. by Veneziano model) A.Bramon, and M. G. , Lett. N. Cimento 152, 739 (1971)

Adone: experiments

- Bosone (C. Bernardini et al.) --> MEA

- $\gamma\,\gamma$ (G. Salvini et al.)

- $\mu\,\pi$ (M. Conversi et al.)

- Bologna - Cern - Frascati (A. Zichichi et al.)

- B–Bbar (Frascati, Napoli, Pisa)

--->> (i) High multi-hadronic production ($\sigma \approx 2\,\sigma(\mu\mu)$)

(ii) Evidence for $\rho\,'$ (1.6 GeV) --> 4 π^{+-}

A.Bramon, and M. G.,
Lett. N. Cimento **3**. 693 (1972)

e+ e- Physics at ADONE

C. Bernardini and L. Paoluzi 1974. 17 pp.

Conference: C74-01-28, p.3-19 Proceedings

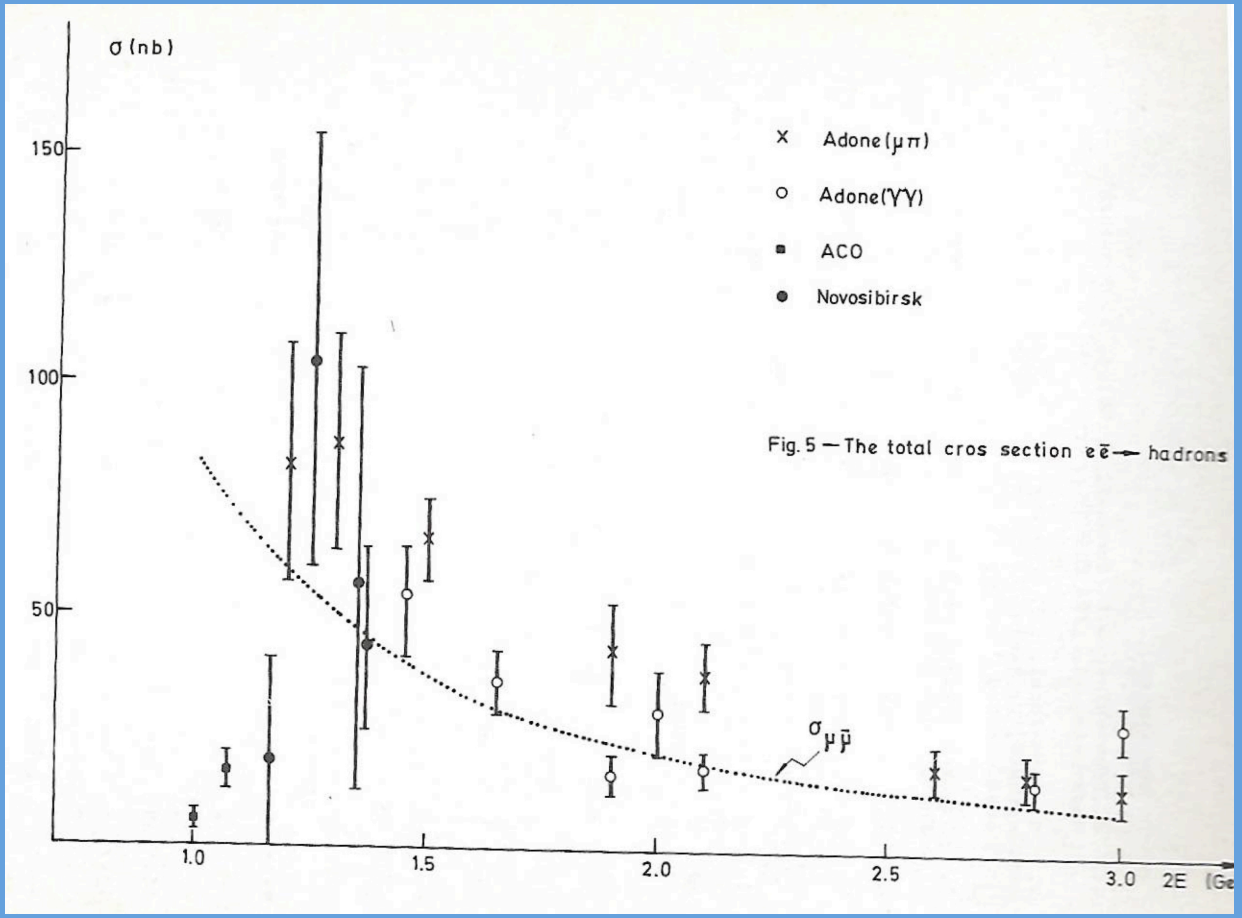
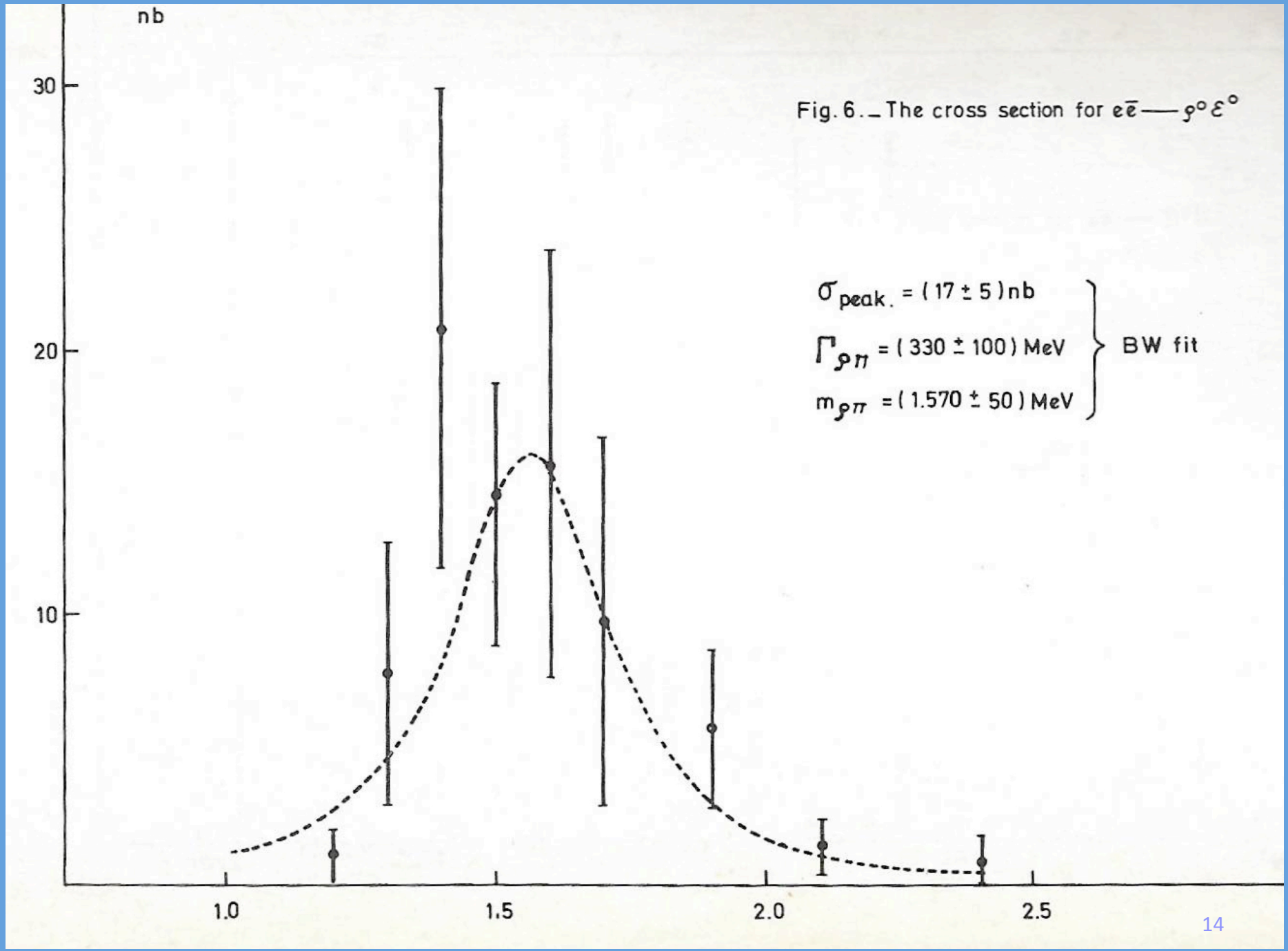


Fig. 5 — The total cros section $e\bar{e} \rightarrow$ hadrons


nb
30
20
10
1.0
1.5
2.0
2.5
Fig. 6. – The cross section for $e\bar{e} \to \rho^0 \varepsilon^0$
$\sigma_{peak.} = (17 \pm 5)$ nb
$\Gamma_{\rho\pi} = (330 \pm 100)$ MeV
$m_{\rho\pi} = (1.570 \pm 50)$ MeV
BW fit

Duality in e^+e^- annihilation

i) Adone results + scaling + Veneziano's duality ideas led us to propose a scheme where the asymptotic scaling is reached through the low energy resonances (∞) mediating the asymptotic behavior. → R is also related to low energy reson. couplings.

A. Bramon, E.Etim and M.G., Phys . Letters B41 (1972) 609.

J.J. Sakurai, Phys. Letters B46 (1973) 207;

J.S. Bell and R. Bertlmann, Z. Phys.C4 (1980)11 and Nucl. Phys.B177(1981)218.

ii) e^+e^- duality sum rules from canonical trace anomaly of energy-moment. tensor

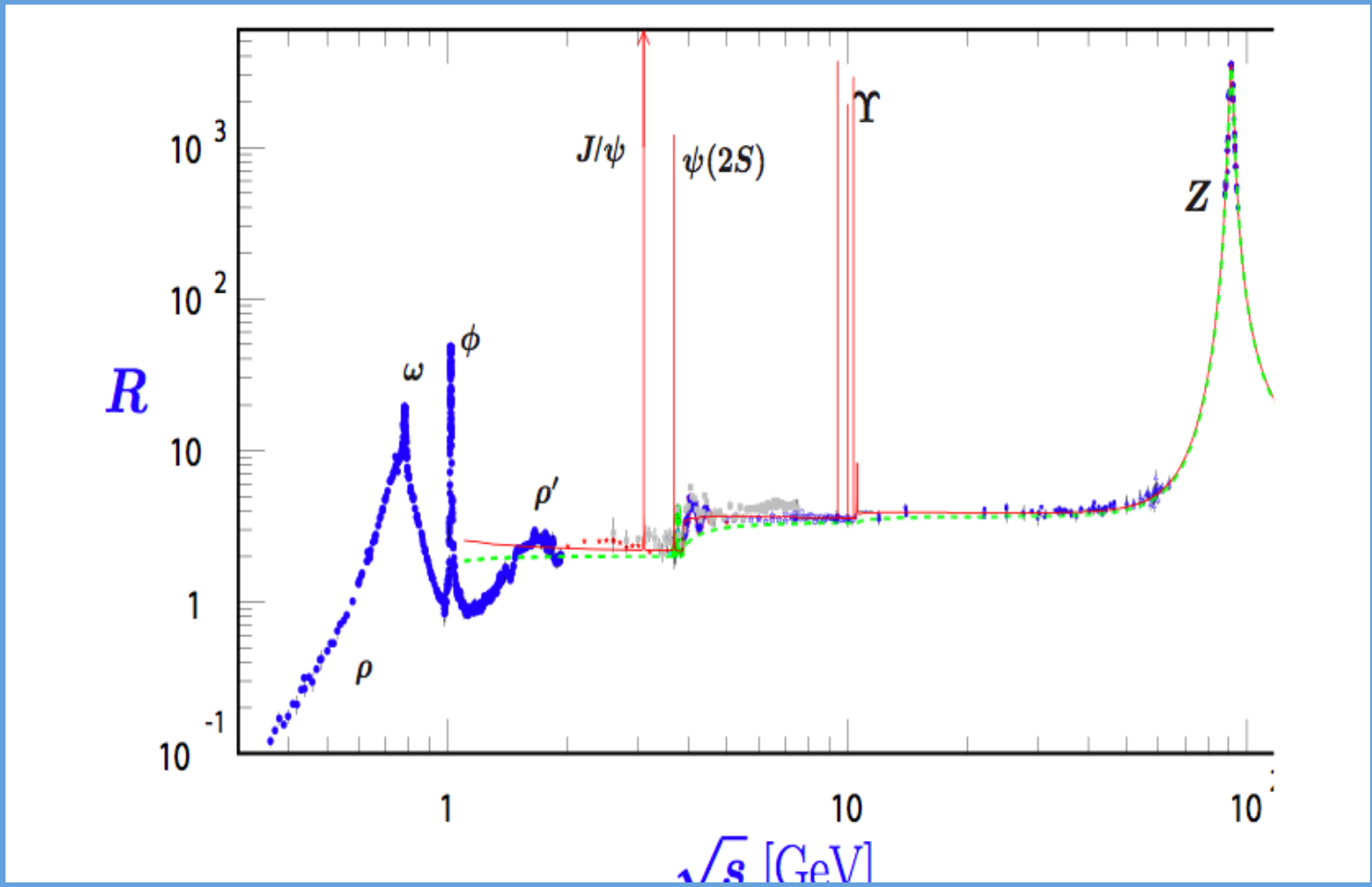
E.Etim and M.G., Lett. N.Cimento 12 (1975)91 (earlier of the russian sum rules)

$$\int_{s_0}^{\bar{s}} ds \left(Im\Pi(s) - \frac{\alpha R}{3} \right) = 0,$$

where

$$Im\Pi(s) = \frac{s}{4\pi\alpha}\sigma_{\mathrm{had}}(s)$$

QCD was not there yet!


R
10 3
10 2
10
1
10 -1
1
10
10
J/ψ
ψ(2S)
ϒ
Z
ω
ϕ
ρ′
ρ
√s [GeV]

November revolution - J/ψ : exps. vs. th.

- J. J. Aubert et al., Phys. Rev. Lett. 33, 1404 (1974).
- J. E. Augustin et al., Phys. Rev. Lett. 33, 1406 (1974).
- C. Bacci et al., Phys. Rev. Lett. 33, 1408 (1974).

Preliminary Result of Frascati (ADONE) on the Nature of a New 3.1-GeV Particle Produced in e+ e- Annihilation.

- C. Bacci, R.Balbini Celio, M. Berna-Rodini, G. Caton, R. del Fabbro, M. Grilli, E. Iarocci, M. Locci, C. Mencuccini, G.P. Murtas, G. Penso, G.S. Spinetti, M. Spano, B. Stella, V. Valente, B. Bartoli, D. Bisello, B. Esposito, F. Felicetti, P. Monacelli, M. Nigro, L. Paolufi, I. Peruzzi, G.Piano Mortemi, M. Piccolo, F. Ronga, F. Sebastiani, L. Trasatti, F. Vanoli, G. Barbarino, G. Barbiellini, C. Bemporad, R. Biancastelli, F. Cevenini, M. Celvetti, F. Costantini, P. Lariccia, P. Parascandalo, E. Sassi, Cherrill M. Spencer, L. Tortora, U. Troya, S. Vitale.

Are the New Particles Baryon-Antibaryon Nuclei?

Alfred S. Goldhaber and Maurice Goldhaber

Interpretation of a Narrow Resonance in e+ e- Annihilation

Julian Schwinger

Possible Explanation of the New Resonance in e+ e- Annihilation

S. Borchardt, V. S. Mathur, and S. Okubo

Model with Three Charmed Quarks **R. Michael Barnett**

Heavy Quarks and e+ e- Annihilation **Thomas Appelquist and H. David Politzer**

Is Bound Charm Found? **A. De Rújula and S. L. Glashow**

Possible Interactions of the J Particle

H. T. Nieh, Tai Tsun Wu, and Chen Ning Yang

Is the 3104-MeV Vector Meson the psi - Charm or the W0?
G. Altarelli, N. Cabibbo, R. Petronzio, L. Maiani, G. Parisi

Charm, EVDM and Narrow Resonances in e^+e Annihilation
C. A. Dominguez and M. Greco

Fig. 15. Immediate interpretations of the J/ψ, with their titles. PRL is Phys. Rev. Lett. **4**, Jan. 6th, 1975. The last two papers[88,89] are in Lett. Nuovo Cim.

Samuel Ting at BTML 2013

Radiative corrections for J/ψ, Z, H line-shapes

i) Crucial role for precision physics played by the th ideas of early times
(Exponentiation, Coherent States, …)

J/ψ: M.G. , G. Pancheri and Y. Srivastava, Phys. Letts. and Nucl. Phys. (1975).

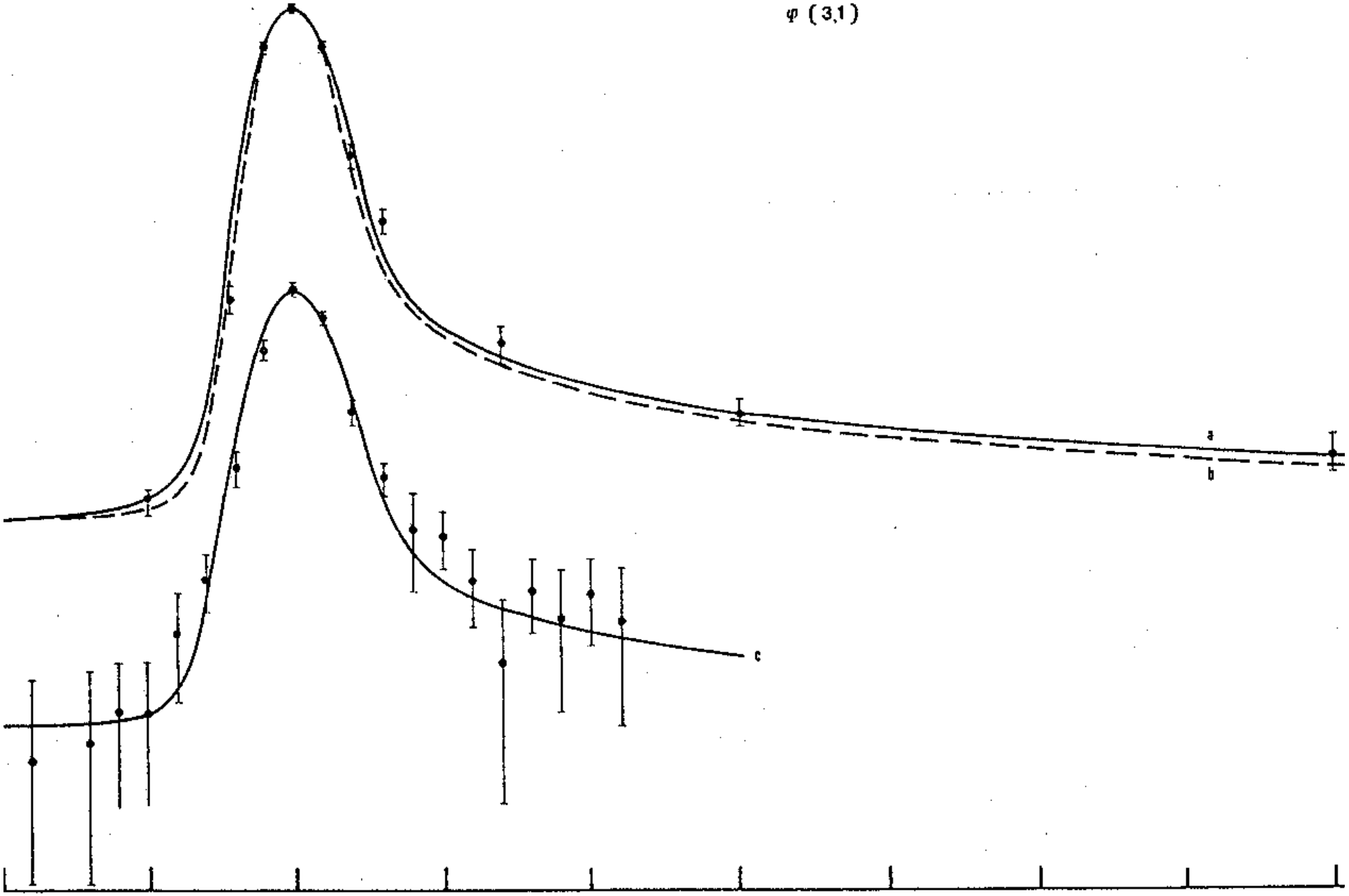
Comment by B.T.

Correction factor $\propto (\Gamma/M)^{(4\alpha/\pi)\log(2E/m)}$

ii) SLAC data had been analyzed with wrong rad. corrs. formulae for >10 years.
Change in 1988 in Particle Data Group properties of charmed particles.

iii) First study of rad. corrs. for the Z line-shape (LEP/SLC).
M.G. , G. Pancheri and Y. Srivastava, Nucl. Phys. (1979)

iv) H line-shape in a muon collider Higgs factory.
M.G., T. Han and Z. Liu, Phys. Letts. B763 (2016)
Strong constraints on the beam energy spread.



Data from SPEAR and ADONE

Radiative corrections for J/ψ, Z, H line-shapes

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Bruno Touschek's legacy

- AdA/Adone → LEP/LHC → Future L/H Colliders.

- Seminal ideas in theor. physics, from QED to many problems in the Standard Model, in the era of colliders.

BTML: Bruno Touschek Memorial Lectures

BTML 1987

BTML 1987