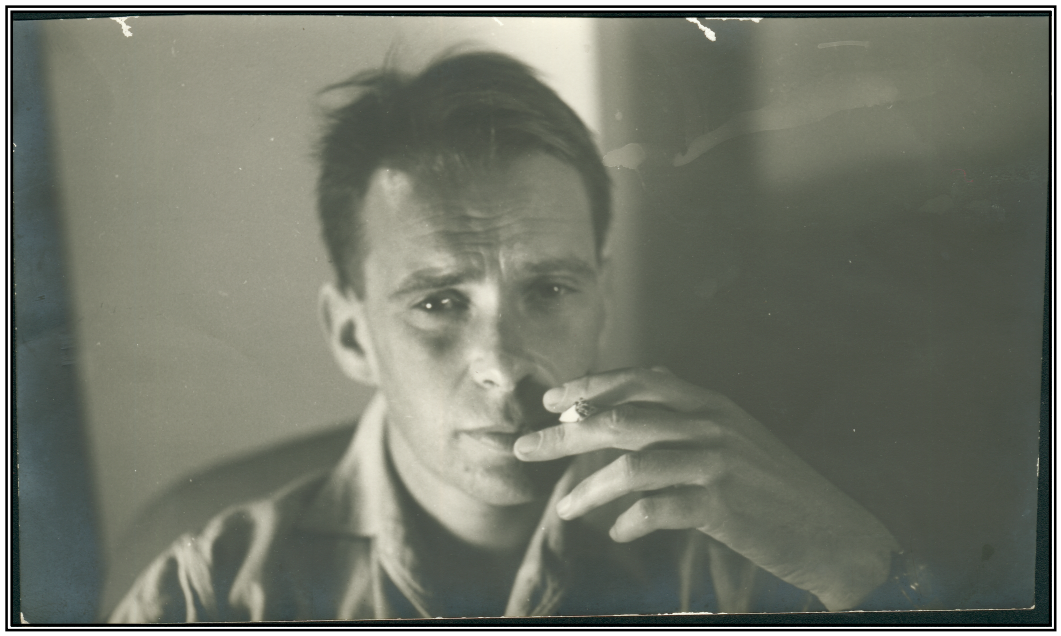
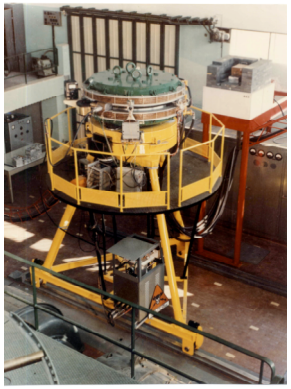
THE TRUE STORY OF TOUSCHEK'S BOND FACTOR : FROM BLOCH AND NORDSIECK TO REGGE POLES

G. Pancheri- INFN- Frascati - Euridice Network



About the title of this talk

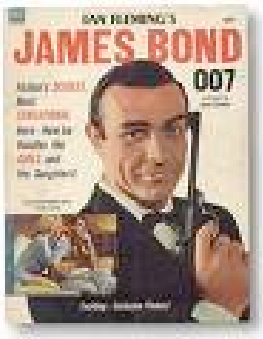
Recently a senior colleague, one of the original proposers of AdA, the first electron-positron collider,



asked me to write down the

True story of the Bond factor

WHAT IS THE BOND FACTOR?



And why was it called so or who called it like this?

From Ugo Amaldi's memories

In Autumn '77, Bruno was at CERN for a sabbatical leave and we had many more occasions to discuss physics…
He told me very explicitly in this conversation that he now believed that the future of accelerators would have been based on antiproton-proton and proton-proton collisions. He was worried not only about the radiation in electron rings, but also about the fact that the very high energy in a lepton dresses itself more and more. ..In the 1960's he had introduced what he called the Bond factor, 0.07, which is just the factor in front of the Weizäcker-Williams formula, when you take into account the energy of Adone. There is a log of energy divided by the mass of the electron and it happened to be 0.07 and he was calling it Bond factor, and he was saying "Of course, Bond factor increases with the logarithm of energy and so leptons get dressed very much in high energy"

THIS IS THE BOND FACTOR...

$$\beta = \frac{4\alpha}{\pi}\left(\log\frac{2E}{m_e} - \frac{1}{2}\right)$$

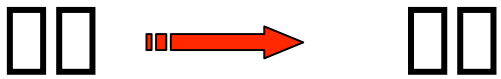
→ 0.07 at ADONE's energies

OUTLINE

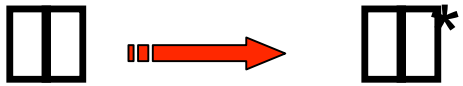
- Introduction of how we started
- The Bloch and Nordsieck theorem
- Schwinger's ansatz about exponentiation
- Touschek and Thirring covariant formalism
- Works in the 50' and early 60'
- Adone and the Bond factor: the radiative correction paper with Etim and Touschek
- Applying Radiative Corrections to the J/□ production
- Is the Bond factor a Regge pole?
- A 1971 poem just for closing the argument

HOW I CAME TO FRASCATI

- To be accepted as theoretical physics students I had to calculate the (LO) cross-section of the process



- In february 1966 I graduated with Benedetto De Tollis with a *tesi di laurea* on the process



The Box...

- Soon after, Paolo Di Vecchia and Giancarlo Rossi, who were already in Frascati (together with Mario Greco), told me that Touschek was building a theoretical group and I was accepted to join in

Radiative Corrections (1966)

•The work on radiative corrections is an example of what Bruno Touschek called "**earning our bread and butter**".

•According to his philosophy, to earn this bread and butter we had to take care of the "administration of the Radiative Corrections".

• His main message at the time was that straightforward perturbation theory does not lend itself easily to dealing with the flood of soft photons which emerge from a high energy collision between charged particles.

ABOUT RADIATIVE CORRECTIONS

Touschek liked to say that

the picture of an experimenter as of one counting soft photons is not entirely realistic,

since he does not see single photons but rather an

imbalance of energy and momentum between the incident and emergent particles.

On the other hand existing perturbation theory works in a representation in which the number of photons is diagonal and the emission of any additional photons requires a further step in the perturbation procedure

THE BLOCH AND NORDSIECK THEOREM

- The infrared divergence problem had been there since early 30’
- Bloch and Nordsieck in 1937 observed that
  - The probability of a transition accompanied by a finite number of light quanta is zero
  - The total transition probability however is finite
- hence only the emission of an infinite number of photons is finite

SCHWINGER'S ANSATZ ABOUT EXPONENTIATION

- Schwinger in 1949, using newly developed techniques of QED, included both virtual quanta and real emission and obtained a fractional decrease in the differential cross-section

$$\delta \sim 2\alpha/\pi \, (\log E/\Delta E - 1) \, (\log E/m + \ldots$$

- Schwinger never talks of "single" photons, but only of "inelastic events in which only a small fraction of the original energy is radiated"

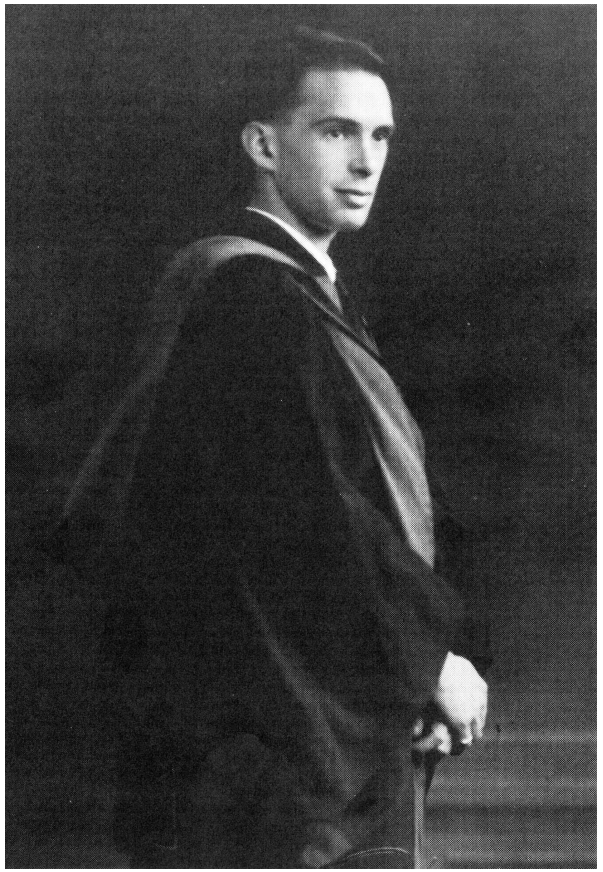
- He notices that the correction δ diverges logarithmically as $\Delta E \to 0$ and proposes the solution

$$1-\delta \; \delta > e^{-\delta}$$

- "The further terms in the series represent the effect of higher order terms, however for practical purposes the such a refinement is unnecessary"

TOUSCHEK'S INTEREST IN THE B-N PROBLEM

- In 1947, after obtaining his diploma from Gottingen, Bruno Touschek went to Glashow where with a fellowship and started being interested in the construction of the 350 MeV synchrotron under the direction of P.I. Dee
- He was awarded his PhD in 1947 , his internal rapporteur was J.Gunn and the external one Rudolph Peierls
- In 1950 Walter Thirring came to Glasgow as a Nuffield fellow and they worked on the covariant formulation of the Bloch-Nordsieck method in electrodynamics with external currents



1949

TOUSCHEK AND THIRRING COVARIANT FORMALISM

"Though the results obtained here are not new… the importance of the BN problem as the only problem in the theory of fields which admits an accurate solution seems to justify a general reformulation of the procedure"

W.Thirring and B. Touschek, Phil. Mag. 1951

$$j_\mu(k) = e\left(\frac{p_\mu}{(pk)} - \frac{p'_\mu}{(p'k)}\right)$$

$$\bar{n} = \frac{e^2}{(2\pi)^3}\int_\Delta dk\delta(k^2 - \mu_)^2\left[\frac{(p\epsilon)}{(pk)} - \frac{(p'\epsilon)}{(p'k)}\right]^2$$

Average number
Of emitted photons

WORKS IN THE 50' AND EARLY 60'

During these years cancelation to all orders and exponentiation were demonstrated by various authors

Jauch and Rohlich

Erikson

Lomon

Yennie Frautschi and Suura

….

Practical calculations however focused on first order corrections

ADONE AND THE BOND FACTOR: THE RADIATIVE CORRECTION PAPER WITH ETIM AND TOUSCHEK

- During the construction of ADONE, starting from 1964 Touschek became concerned about exploiting to the best the experimental results to be obtained at the new high energy machine
- He was thus very concerned about the best way to deal with the radiative corrections

KESSLER?

A story told by Ugo Amaldi about that time:

“Once, in 1964, I had gone to talk with Touschek on some details of te radiative corrections calculations I had been doing. Touschek asked me which method I was using. When I said I was following Paul Kessler’s work and asked Bruno “Do you know the Kessler method?”, Touschek immediately replied

“I only know the Kessler’s sisters”

HOW WE STARTED

- We were a rather unlikely trio when in may 1966 we started the radiative correction paper to Adone electron-positron experiments :
  - Bruno Touschek, the proposer of AdA, Austrian by birth, European to the core
  - Etim G. Etim, a Nigerian student, doing his ***tesi di laurea*** with Touschek,
  - And G.P. one of some 10 **young women physicists** just graduated from University of Rome

1987 Touschek's Memorial Lectures:
Etim G. Etim (left) with Mrs. Touschek and Francis Touschek

E. ETIM, *et al.*
11 Ottobre 1967
Il Nuovo Cimento
Serie X, Vol. 51 B, pag. 276-302

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)

Summary. – The infra-red corrections to be applied to the results expected from an electron positron colliding beam experiment are determined with the help of the Bloch-Nordsieck theorem. Experiments are characterized by a resolution function $\varrho(k)$ of a four-dimensional time-like energy-momentum vector, which represents the probability that a four-momentum loss k escapes detection. The results are applicable to a class of experiments in which the statistical error is matched to the error of the energy-momentum resolution. Various approximations which allow a rapid and accurate estimate of radiative corrections are discussed.

1. – Introduction.

Any search for a possible breakdown of quantum electrodynamics leads inevitably to the necessity of applying important radiative corrections to the measured results. This is due to the fact that renormalization theory makes the form of electrodynamics at low momentum (and energy) transfers a matter of definition, so that any discrepancy with the existing theory has to be searched for by either studying processes in which the transferred momentum is very large or by making high-precision measurements on processes with a moderately high momentum transfer. In either case radiative corrections are important: in the first because high-energy charged particles are created and destroyed—a process which leads to large currents and therefore to the liberation of a considerable portion of the energy in the form of relatively soft electromagnetic radiation—in the second case because the high precision of the experiment requires for its interpretation a high precision in the determination of any correction.

6608

PROBABILITY OF A 4-MOMENTUM LOSS

$$d^4P(K) = \sum_{n_k} \Pi_k P(\{n_k, \bar{n}_k\}) \delta^4(K - \sum_k k n_k) d^4K$$

$$d^4P(K) = \frac{d^4K}{(2\pi)^4} \int d^4x \; exp[-h(x) + iK \cdot x]$$

with

$$h(x) = \int d^3n_k (1 - exp[-ik \cdot x])$$

AN ELEGANT FORMULATION

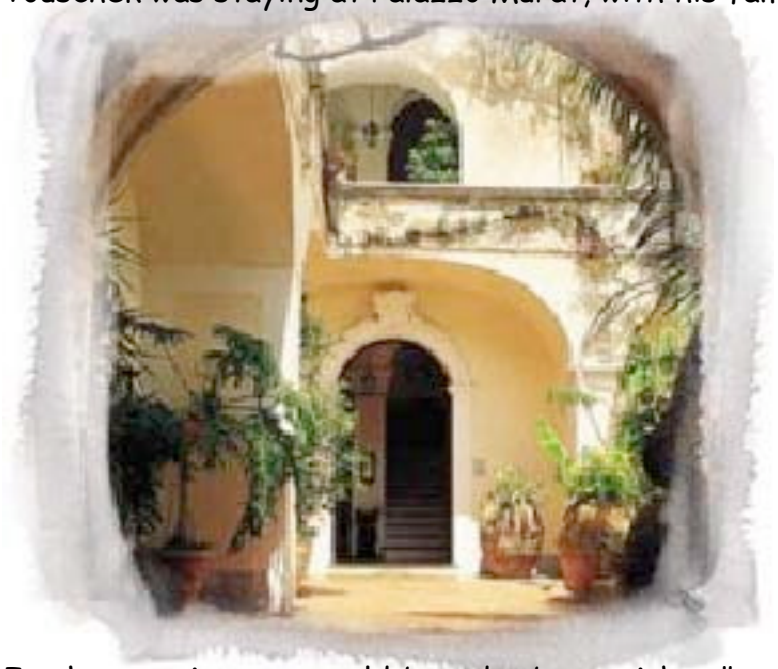
$$dP(\omega) = N\beta \frac{d\omega}{\omega} \left(\frac{\omega}{E}\right)^{\beta}$$

In the exponentiated form for the energy loss, the Bond factor is now an invariant function of the Mandelstam variables

THE HOLIDAY TO POSITANO: : SEPTEMBER 1966

On August 19 of 1966, Touschek, Etim and myself, we had just finished the Radiative Correction paper and Touschek suggested that the whole group join him in early September in Positano, where he was going to stay for a month with his family. We all went driving down, in Paolo Di Vecchia's "cinquecento" .

Touschek was staying at Palazzo Murat, with his family.



In the morning, we would board a boat with a "marinaio" who took us to isolated coves, not otherwise reachable. We carried sandwiches and swam all day with Touschek and his family until the "marinaio" would come and take us back to the village in the evening. We would have dinner in some relatively simple place, where Touschek had made friends with proprietors and customers alike. I do not recollect, myself, the content of our conversations in Positano, just the obvious pleasure of living that came from Bruno and his desire to share it with us. We stayed only a few days but those few days have left us with one of Bruno's most serene and happy images.

FURTHER WORK BY THE FRASCATI GROUP

- Application to resonant processes (G.P. 1969)
- Coherent state formulation by Greco and Rossi (1967)
- Application to J/ production
- Radiative Corrections to Z0 production
- ….. And then soft gluon resummation…

With M. Greco
And Y. N. Srivastava

IS THE BOND FACTOR A REGGE POLE?

In 1971 I found that by identifying the di-triple Regge limit with soft photon exponentiated emission in a charged particle reactions, one could obtain the identity

$$\square_{\square}(t)=1-\square(t)/4$$

where $\square(t)$ is again the (now relativistically invariant expression for) the old Bond factor and I called this phenomenon the reggeization of the photon in QED [Phys.Lett. 1971]

And now, let me conclude,
With
a Poem I wrote in
1971

I live in the complex J-plane.
Again and again,
I feel that my role,
of being a pole,
is rather a strain.
I'd like to be exotic
and slightly neurotic
and may be pathetic
but hidden
forbidden
and mostly, if I may,
to be off the way
and never to meet
the physical sheet.