Giordano Diambrini Palazzi's time at Cornell

Richard Talman
Laboratory of Elementary-Particle Physics, Cornell University
E-mail: `richard.talman@cornell.edu`

Abstract

Giordano Diambrini Palazzi spent one year, 1969, of his long and distinguished career at Cornell University's Laboratory of Nuclear Studies (LNS). During his visit Giordano contributed to the setting up of a polarized γ ray beam and, using that beam, participated in measurements of the polarization dependence of vector meson photoproduction. As well as describing these accomplishments, this report goes on to describe some subsequent developments that Giordano's visit helped to set in motion.

1 Introduction

Especially during the 1960's there was a kind of informal "sister institution" relationship between the Frascati and Cornell LNS laboratories. From the Cornell side this relationship was established by Bob Wilson. This made it natural for physicists to share visits between the two laboratories. It was probably Boyce McDaniel or Al Silverman who invited Giordano to join the group of Al Silverman, Nari Mistry and me, in order to collaborate on polarized photoproduction of vector mesons at the newly constructed 12 GeV Synchrotron Laboratory (later renamed as the Wilson Laboratory).

By 1969 rho meson photoproduction from various elements had been measured at Cornell by Mistry, Silverman, me, and others [1, 2]. Diambrini had brought with him the goniometer needed to produce polarized photons by bremsstrahlung scattering from the electron beam incident on an oriented diamond target. Giordano also supplied a recipe for analysing polarized data [3]. We provided the electron beam, a diamond from the posh Harry Winston jewelry store in New York City and the double-arm spectrometer needed for the measurements.

Soon we had measured the polarization dependence of ρ [4] photoproduction and found it to be maximal - the rho meson "remembers" the photon polarization and displays it by the plane defined by the two pions into which the ρ meson decays. Shortly later [5, 6] ϕ meson measurements were completed.

2 Polarized bremsstrahlung beam produced from diamond

Work of Giordano in the period before his time at Cornell is well known, especially at Frascati. GeV-scale photons are produced by bremsstrahlung from material targets. In 1956, Überall showed that, by using an appropriately-oriented single crystal as the target, the radiation could have quite high polarization, especially close to a "resonance edge" in the energy spectrum. By 1968, workers at Frascati, especially Diambrini, had demonstrated the feasibility of this method.

The definitive review article then (and perhaps still) was written by Giordano [7]. Most of the theoretical predictions had already been confirmed experimentally. Another possible mechanism for producing polarized photons had been predicted but not yet applied. Quoting from reference [7], "Finally we consider the works of Cabibbo, Da Prato, De Franceschi and Mosco concerning the production and analysis of linearly and circularly polarized high-energy γ rays by using very thick crystals. The conclusions of these authors have not been tested experimentally until now."

While at Cornell Diambrini called our attention to this work [8]. For the Cabibbo process the photon beam passes through a thick, properly-oriented single crystal. Photons polarized in one transverse plane are preferentially absorbed by pair production. As with visible light passing through a polaroid film, the surviving radiation is polarized.

Relying on differential absorption, there is an important trade-off between intensity and degree of polarization. This restricts the maximum practical polarization that can be obtained with the Cabibbo process. But its essential advantage is that the high energy end of the spectrum is polarized in this process. This is not true for the Überall process, in which the (polarized) photon peak occurs, typically, near the middle of the energy spectrum.

3 Polarization dependence of meson photoproduction

By 1970, Richter and Schwitters and others had measured polarization dependence of π^+ photoproduction using a beam polarized by the Überall process. Their method of measurement used a subtraction procedure relying on the edge in the diamond bremsstrahlung energy spectrum. Back then the data for this technique was referred to as an "excitation curve". Nowadays it would be referred to as an "inclusive" measurement. This technique was adequate for the early measurements, but one feature was found to be disadvantageous. The edge near which the high polarization exists lies well below the upper end point of the energy spectrum. Photons above the edge gave background counts that tended to swamp the foreground signal.

Later during 1970 I was on sabbatic leave in the group of Dave Ritson at SLAC. Bjorn Wiik, Dave Gustafson, and I realized that the photons polarized by the Cabibbo process would not be subject to the background encountered using the Überall process. For inclusive measurements like this, the low degree of polarization disadvantage is completely out-weighed by the advantage of being able to polarize the high energy end of the spectrum.

As mentioned earlier, the ρ-photoproduction cross section is highly sensitive to the transverse polarization of the incident photon beam, and the plane of polarization manifests itself by the plane defined by the two decay photons. Having earlier established these dependencies with measurements using the Überall process, we were in a position to use ρ-photoproduction as an analyser to measure the polarization of a Cabibbo polarized beam.

We submitted a proposal to use the Cornell rho photoproduction apparatus, mentioned earlier, as an analyzer to test the Cabibbo process and to measure the degree of polarization. McDaniel, the Cornell lab director, assigned us a few weeks of running time at the Cornell Synchrotron, some months into the future. Such proposals were far less formal in those days than they are today, but it was still a serious commitment. We intended to use a long single crystal of silicon which was one of the examples in the Cabibbo paper.

To our horror, with the help of code originally written for the Überall process by Roy Schwitters, and adapted to the Cabibbo process by Dave Gustafson in preparation for our test, we realized that the method was not going to work with silicon. The Debye temperature is too low. For that matter, the other material analysed by Cabibbo, namely copper, would also have been unsatisfactory. (Communication with Cabibbo at the time made it clear that their group had not attempted to identify the optimal target material for the polarization-by-absorption processes.)

There is nothing like the threat of hanging to concentrate a person's mind. After a few feverish days in the Stanford library I came to realize that carbon was the unique practical material for the Cabibbo process. All we needed was a foot-long diamond – obviously out of the question.

Then I thought of graphite and, to my amazement, found that carbon exists in crystalline graphite form. Nowadays this form is known as "graphene". Scarcely a week goes by without a seminar on its remarkable properties. At the time, based on its fabrication method, this form of carbon was referred to as "pyrolytic graphite".

A trip to meet Arthur Moore, of Union Carbide, in Cleveland, established that he had some graphene samples. They were shaped like inch-square countertop tiles. They were a few millimeters thick, which was conservatively thicker than our millimeter beam width. With care a dozen or so of these tiles could be (accurately) lined up to form the equivalent of a foot-long single crystal. Moore showed us how sub-micron thick layers of graphene could be cleaved (actually just peeled off) with extreme precision using Scotch tape.

I was surprised, just a few years ago, to read of this technique for working with graphene being an amazing new discovery - we had routinely used the technique more than thirty years earlier. We were also fully aware of the essential sheet-like crystalline structure of the pyrolytic graphite. It was obvious that monotonic layers were extraordinarily strong but that, like sheets of paper in a ream of printer paper, essentially uncoupled from layer to layer.

Mainly, though, we were aware of the singular appropriateness of graphite for coherent crystalline pair production. In this process it is critically important for the Bragg scattering condition to be met over substantial areas of each two dimensional crystalline layer. But the coherent enhancement depends only weakly on constructive interference between amplitudes from different layers. Expressed by mosaic spread, the "single crystals" were not of very high quality. But this degree of imperfection is not very important for the Cabibbo process.

Unfortunately the "single crystal" pyrolytic tiles were too expensive for us to purchase. Fortunately, through Moore, Union Carbide allowed us to borrow the material. With the crisis averted (and hardly anyone even aware it had ever occurred) we completed planning for the test of the Cabibbo process at Cornell using the rho meson process as a polarization analyzer.

The Cornell measurements [9] confirmed the (appropriately-refined) Cabibbo theory. Though the measurements were not very accurate, they were sufficiently promising to justify proceeding to the rest of the story.

4 Development of the graphene polarized beam

Everything up to this point could be called research. What followed next was development. At that time Bob Siemann, who had been a graduate student at Cornell, and later became a professor at Cornell, held a postdoctoral position in the Richter group at SLAC. He, along with Charles Sinclair, another ex-Cornellian, and several others set about developing a high-power, polarized beam at SLAC [10]. Even Union Carbide (whose support had been motivated by altruistic pure science) profited; they later sold the very crystals we had used to SLAC.

Development of the SLAC graphene absorption-polarized beam was a *tour de force* of experimental science. It will not be described here. The beam itself was much used at SLAC throughout the 1970's for polarized photoproduction experiments [11].

This ended what was surely one of the most important chapters in the long and illustrious career of Giordano Diambrini Palazzi.

References

[1] G. McClellan, N. Mistry, P. Mostek, H. Ogren, A. Osborne, A. Silverman, J. Swartz, R. Talman, and G. Diambrini-Palazzi, *Incoherent Photoproduction of ρ^0 Mesons From Complex Nuclei and Comparison with Vector Dominance Predictions*, Phys. Rev. Lett. **23**, 554 (1969).

[2] G. McClellan, N. Mistry, P. Mostek, H. Ogren, A. Osborne, A. Silverman, J. Swartz, R. Talman, and G. Diambrini-Palazzi, *Search for Mesons Suggested by the Veneziano Model*, Phys. Rev. Lett. **23**, 718 (1969).

[3] G. Diambrini, *Notes on Data Reduction for rho and ϕ meson Photoproduction by Coherent Bremsstrahlung*, CLNS-78, 1969.

[4] G. Diambrini-Palazzi, G. McClellan, N. Mistry, P. Mostek, H. Ogren, J. Swartz, and R. Talman, *Photoproduction of rho Mesons from Hydrogen and Carbon by Linearly Polarized Photons*, Phys. Rev. Lett. **25** , 478 (1970).

[5] G. McClellan, N. Mistry, P. Mostek, H. Ogren, A. Osborne, J. Swartz, R. Talman, and G. Diambrini-Palazzi, *Photoproduction of ϕ^0 Mesons from Hydrogen, Deuterium and Complex Nuclei*, Phys. Rev. Lett. **26**, 1593, (1971).

[6] G. McClellan, N. Mistry, B. Sandler, J. Swartz, R. Talman, P. Walstrom, and G. Diambrini-Palazzi, *Photoproduction of ϕ^0 Mesons from Hydrogen and Carbon by Linearly Polarized Photons*, Phys. Rev. Lett. **26**, 1597, (1971).

[7] G.Diambrini Palazzi, *High-Energy Bremsstrahlung in Thin Crystals*, Reviews of Modern Physics, **40**, 611 (1968).

[8] N. Cabibbo, G. Da Prato, G. De Franceschi, and U. Mosco, *New Method for Producing and Analyzing Linearly Polarized Gamma-Ray Beams*, Phys. Rev. Lett., **9**, 270 (1962).

[9] C. Berger, F. McClellan, N. Mistry, H. Ogren, B. Sandler, J. Swartz, P. Walstrom, R. Anderson, D. Gustavson, J. Johnson, I. Overman, R. Talman, B. Wiik, D. Worcester, and A. Moore, *Polarization of High-Energy Photons Using Highly Oriented Graphite*, Phys. Rev. Lett. **25**, 1366 (1970).

[10] R. Eisele, D. Sherden, R. Siemann, C. Sinclair, D. Quinn, J. Rutherford, and M. Shupe, *A Polarized Photon Beam Produced by Coherent Pair Production in Oriented Graphite*, Nuclear Instruments and Methods **113**, 489 (1973).

[11] D. Quinn, J. Rutherford, M. Shupe, D. Sherden, R. Siemann, and C. Sinclair, *Study of Charged-Pseudoscalar-Meson Photoproduction from Hydrogen and Deuterium with 16-GeV Linearly Polarized Photons*, Phys. Rev. **D20**, 1553 (1979). This is the last in a series of related papers.