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C. Bernardini : VECTOR BOSON HUNTING WITH ADONE. -

(Nota interna: n. 299)

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1. - The one photon annihilation channel of $e^+ e^-$ reactions offers an unique possibility of producing single neutral non-strange vector bosons having charge conjugation number C = -1, parity P = -1(1). Furthermore, in a storage ring, where the center of mass and laboratory systems coincide, those mesons (v^o) can be produced at rest. Single production at rest allows some unusual semplicity in the kinematics of the decay products even in the case of 3 or more body decays. This fact must be contrasted with the conventional methods used to search for v^o's (e. g. antiproton annihilation in bubble chamber) where the difficulty at classifying invariant masses increases with the mass itself because of the high multiplicity of the decay products, the presence of neutrals, the presence of uncorrelated particles and so on.

Let us consider the two relevant facts of the single v^o production in $e^+ e^-$ annihilation:

a) it is very likely that there are two charged particles in the final state of a v^o decay;

b) it is very likely that the cross section for $e^+ + e^- \rightarrow v^o$ is strongly peaked around the v^o mass. The word strongly must be mitigated by some limit on the detectable mass width of the v^o's (both in the too large and too narrow width limits).

A ring like Adone should allow energy definition of the primary beams generally better than one MeV, possibly down to the hundred KeV range in some cases(2). This means that the counting rates for annihilation into any kind of events with at least 2 charged particles in the final state should look very similar to the total cross section without any substantial flattening due to instrumental resolution down to 1 MeV energy bits. An illustrative example is given in fig. 1 where this cross section is shown including only the well known v^o's (ρ^o, ω^o, ϕ^o). Peaks are reproduced according to Gatto[3]; the high energy tail is qualitative and roughly reproduces the E^{-2} behaviour of non resonant light particles production in the Born approximation without form factors; the contribution from $e^+ + e^- \rightarrow e^+ + e^-$ is of course very sensitive to the lower cutoff in the accepted angle. Small arrows on the energy axis in fig. 1 show the relevant thresholds.

2. - The problem is now: how to produce quickly a mass spectrum like the one shown in fig. 1? It is certainly not possible to spend a life carefully looking at each 1 MeV step from say 0.7 BeV to 3.0 BeV (in the case of Adone); something interesting could even be just in the last few scanned Mev's!

We propose here to detect coincidences of charged particles of any kind while the energy of the primaries is continuously varied on a wide range. For instance, it seems possible to modulate sinusoidally the energy in Adone from 350 to 1500 MeV with a 1 minute period[4].

Once a peak appears (even with a scanty statistical significance) in the multichannel representation of the counting rate versus energy, a larger time can be dedicated to that energy window and the peak can be conveniently enhanced over the backgroud.

Let us call ΔE the amplitude of the energy modulation; 2Γ a peak width (total). The duty cycle for detection of such a peak is roughly $2\Gamma / \Delta E$. Since Γ is in any case limited by the energy spread of the primaries we can tentatively put $\Gamma \gtrsim 1$ MeV so that the duty-cycle is $\gtrsim 2 \times 10^{-3}$ for a 1000 MeV amplitude of the energy modulation.

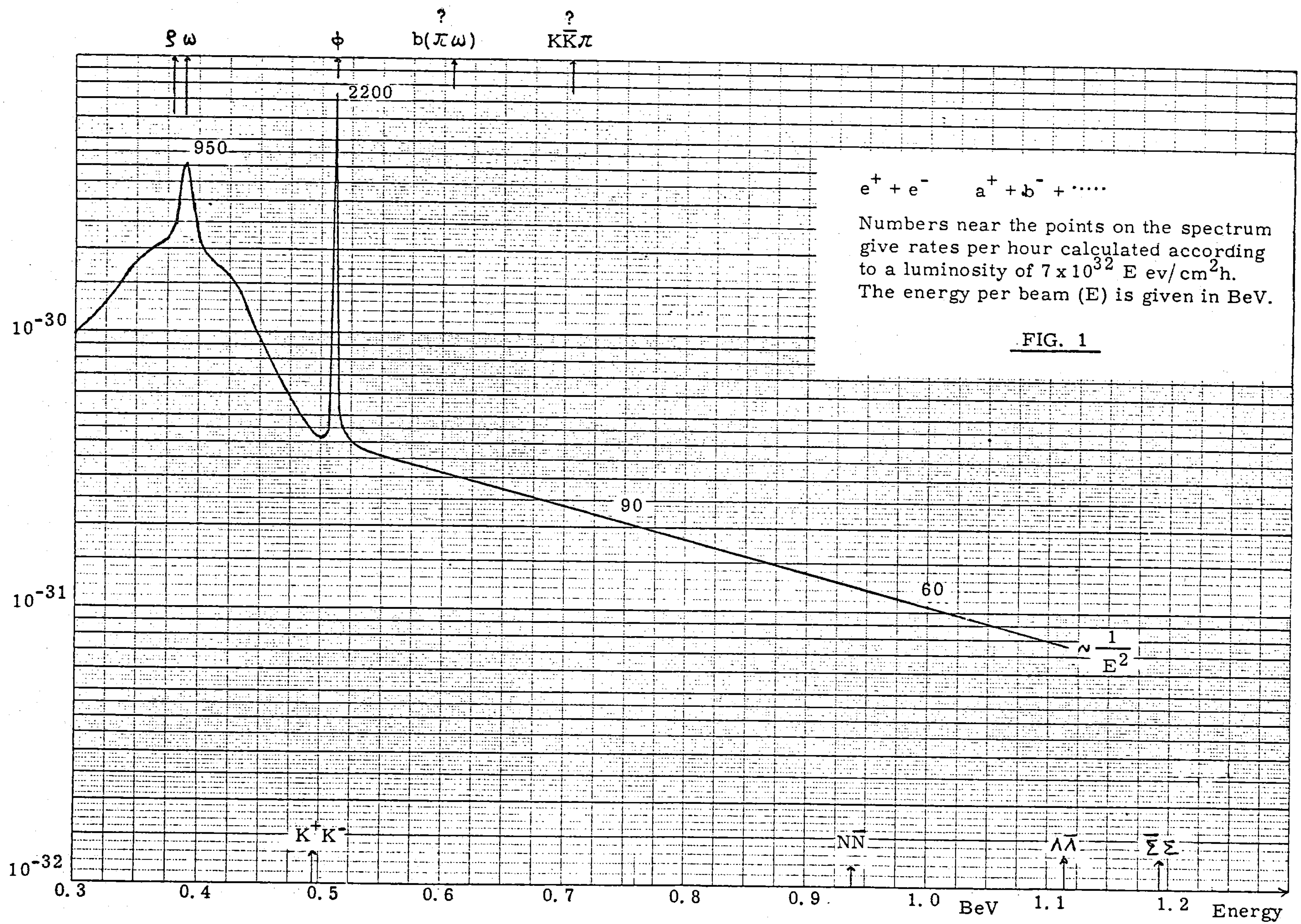
Background rates in Adone are expected to be in the 100 events/ /hour range (corresponding to a cross section of 10^{-31} cm^2 and a luminosity of 10^{33} cm^{-2} h^{-1}) so that after a 100 hrs run one should have collected about 10 background events per MeV. This means that a v^o with a 10^{-31} cm^2 peak cross section and a resonably narrow width should be located on the energy axis, after a 100 hours run, with a statistical significance not worse than that of many "evidences" in the current literature.

But consider then:

a) that every v^o in the sweeped energy range will be detected in the same run,

b) that the statistical significance can be readly improved by looking for a longer time at the "suspected" energy point.

a) and b) are the virtues of the method.



$e^+ + e^- \quad a^+ + b^- + \cdots$

Numbers near the points on the spectrum give rates per hour calculated according to a luminosity of 7×10^{32} E ev/cm^{2}h. The energy per beam (E) is given in BeV.

FIG. 1

It must be mentioned that the duty cycle is not uniform when the energy modulation is sinusoidal; this trouble is not relevant and will not be discussed here. May be there is some trick to get a better energy modulation waveform but we did not try to invent any till now.

3. - The detection apparatus could be extremely simple, like the one shown in fig. 2. In a cross sectional view the doughnut is shown with a dot in the center to indicate the $e^+ e^-$ crossing point; 1, 2, 3, 4 are scintillation counters; an anticoincidence roof to reduce cosmic ray rates is not shown.

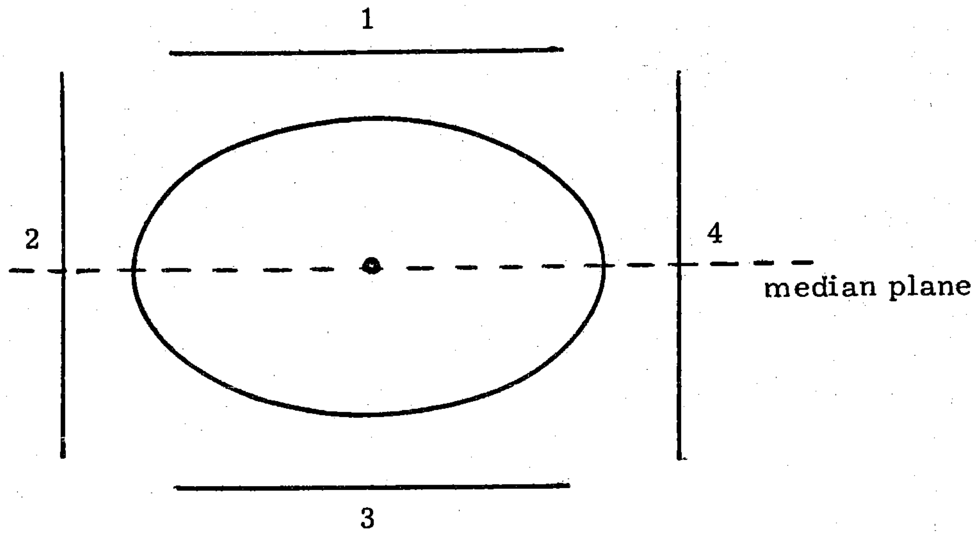


FIG. 2

Coincidences like 1 + 3, 2 + 4 will be called "two-particle events"; 1 + 2, 2 + 3, 3 + 4, 4 + 1 will be called "more than two-particle events". This means that a v^o decaying into 2 charged particles will trigger only 1 + 3, 2 + 4; a v^o decaying into at least 3 charged particles can trigger every combination.

A coincidence with the beam-beam crossing time is essential to reduce the unwanted background; a master pulse can be easily obtained by the synchrotron light or some pick up signal. We hope that true coincidence background due to particle losses on the walls can be reasonably contained: this is a hard matter to speculate on now and it might be that counters 2 and 4 (on the median plane in fig. 2) give troubles. A better disposition leaving some volume around the median plane of the ring out of the detectors is easily imagined (fig. 3).

The geometrical efficiency for two colinear particle detection, assuming a point crossing region, can easily be 50% for a $\sin^2 \theta$ distribution (when the efficiency is high an isotropic distribution gives nearly the same figure). This can be achieved, for instance, by using 30x30 cm^2 plastic scintillators in a square arrangement. The efficiency for "more than two-particle events" is a little bit more difficult to evaluate: remember that the three particle decays[5] are usually represented in terms of the angular distribution of the normal to the production plane and the angle, in this plane, between the momenta of two of the particles. Nevertheless in the three particle case the efficiency can be roughly estimated to be still such good as 50% or better.

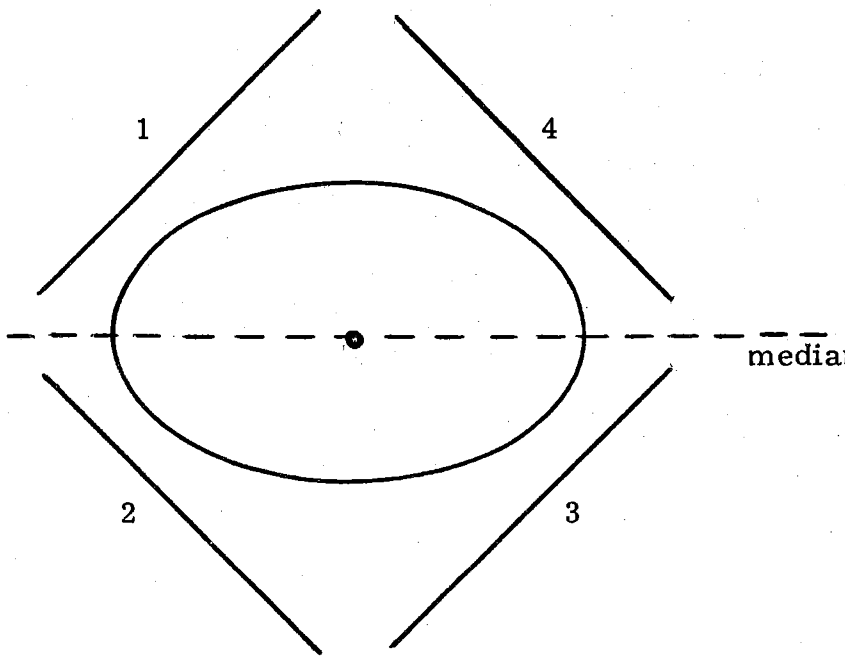


FIG. 3

4. - In conclusion, we want to say that the proposed method looks promisingly fast to scan the production of v^{o}'s in a wide mass range (0.7 to 3 BeV in Adone). There could be none; or the peak cross section could be so much less than 10^{-31} cm^2 and the width so much larger than some 10 MeV that this method to search for v^{o}'s will prove vane. We just mention that the b ($\pi\omega$) and a possible $K\bar{K}\pi$ bound state are well in the Adone energy range[6] but it is not clear whether they could be detected in this kind of hunting or not.

In any case, the method is easy and cheap and this encourages to try.