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PROPOSAL FOR A MUON EXPERIMENT IN GARGAMELLE

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ABSTRACT

It is proposed to expose Gargamelle to a muon beam of momentum between 10 and 15 GeV/$_c$, defined within a few percent, and to take 500.000 pictures in order to study some aspects of quantum electrodynamics and the hadronic vertex of the inelastic lepton-nucleon interaction.

INTRODUCTION

The study of the lepton-hadron electomagnetic interaction has become of increasing importance as higher energies and momentum transfer become available with suitable experimental apparatuses.
The experimental results together with the theoretical predictions and interpretations are now of great interest and further and more detailed information is needed.
On the other hand the muon-electron exchange symmetry is one of the most striking properties among the elementary particles since the leptons appear to have no other interaction except the electromagnetic and weak interactions.
The experiment we propose is an investigation of the μ - e symmetry and of some aspects of the inelastic lepton-hadron interactions. To this purpose we plan to study high energy μ interactions in Gargamelle, because the large bubble chamber gives a unique possibility to analyse completely the final state products in all the details and the μ leptons at high energy are better fit for bubble chamber study.

2) PROPOSED EXPERIMENT

We propose to take 500.000 pictures in Gargamelle filled with propane. The μ momentum should be defined to a few percent somewhere in between 10 and 15 GeV/$_c$, the beam intensity should be about 150 μ's per photo, the pion contamination less than 10^{-7}. Details of the beam are given in Section 4.
The physical problems involved are essentially of two kinds, namely the e - μ exchange symmetry and the structure of the nucleon.
For what concerns the first problem the events we will study are of the type: a scattered μ and an associated γ or electron. These events give information on

i) μ^* production, assumed to go mainly via the process

$$\mu + Z \to \mu^* + Z$$
$$\mu^* \to \mu + \gamma$$

ii) Bremsstrahlung

$$\mu + Z \to \mu + Z + \gamma$$

iii) Muon electron scattering (Bhabha scattering)

$$\mu + e^- \to \mu + e^-$$

On these processes the experimental knowledge is very poor: 729 Bremsstrahlung events (1), ∿ 120 events for μ - e scattering (2).
Finally one can get information on a possible interaction between electron and muon

$$\mu^+ + e^- \to \mu^- + e^+$$

based on a multiplicative lepton quantum number conservation. Also for this process the experimental limit is quite far from the expected value (4).

As far as the nucleon structure is concerned we propose to study the μ-nucleon inelastic interactions. These processes are nowadays of great importance, and a lot of experimental and theoretical work is devoted to them.

The experiments performed with the electronic technique look only at the incoming and outgoing states.

In the experiment we propose it is possible to study the final hadronic state in all details. This will strongly contribute to the understanding of both the features of the interaction at the hadronic vertex and the nucleon structure.

The problems involved are:

i) Nucleonic and mesonic resonances production to be compared with photo and electron-production, measurement of the axial vector nucleon form factor (5), etc.

ii) Features of deep inelastic scattering, in connection with with theoretical models (6).

iii) Strange particles production.

The processes under iii) provide the lacking knowledge on simultaneous conservation of strangeness and lepton quantum numbers.

The number of events we calculate for each channel are

1) One μ^* events corresponds to a cross section of $\sim 3.10^{-34} cm^2$
2) Bremsstrahlung events with $E\gamma > 1$ GeV and observable γ ~ 3000
3) $\mu + e^- \rightarrow \mu + e^-$ (Bhabha scattering) $\sim 1.5\ 10^{+6}$ events with $E_e > 0.5$ GeV
4) One event $\mu^+ + e^- \rightarrow \mu^- + e^+$ corresponds to a $\sigma \simeq 3.10^{-34} cm^2$
5) Number of inelastic events ~ 30.000 (7), most of which will be in the N^* resonance. Pionic and higher nucleonic resonances will be also available in large numbers.
6) Stange particles ~ 3000 (7).

3) EXPERIMENTAL DETAILS

Recent very interesting (8) experiments show the success of the electronic techniques and of nuclear emulsions (7) in the study of μ inelastic scattering. However a large bubble chamber filled with a relatively light liquid like propane has the great advantage that the final states can be studied in detail with good energy and momentum resolution, thus providing information on the products in the final state, which seems now to be one of the points of great interest, both for a deeper knowledge of the μ - e exchange symmetry and of the nucleon structure.
It is obviously too early to know exactly the precision with wich momenta can be measured in Gargamelle. However it should be emphasized that nearly all of the information on the four-momentum transfer from the μ will come directly from measurements of the final products and not only from measurements

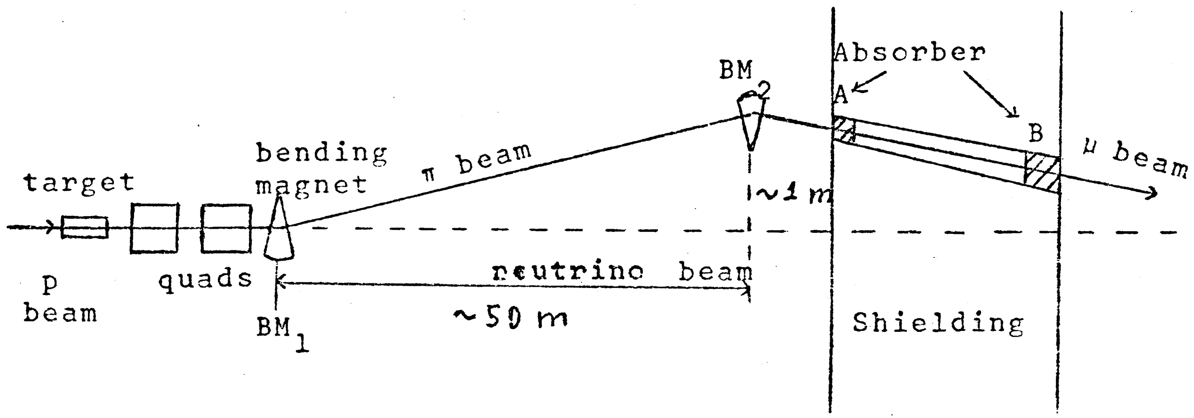
of the μ tracks. In propane one should be able to measure the energy of the final state products with an error not much larger than about 50 MeV. The size of the chamber is sufficiently large to make the average detection efficiency of π° mesons very high.

The efficiency of separation of hydrogen events from carbon events depends very much on the number and nature of the outcoming particles. For example, in those cases where the final state involves only charged particles, the sample of hydrogen events should contain a contamination of only about 10-15% of carbon events. (For π° events the contamination may be higher depending upon the measurability of γ rays).

We think that at last the first part of the exposure should be taken with eight photographic cameras, in order to explore the feasibility of using only some views.

SKETCH OF μ BEAM FOR GARGAMELLE

Only a brief descrip- ·;n will be given here of a μ beam which would be suitable for use with Gargamelle.
Because the cross-section for μ interactions is lower than that for π meson by roughly a factor of 10^{-4}, the contamination in the μ beam should at least be less than about 10^{-7}.
The only practical way to achieve this low level of contamination of pions is to use a thick absorber which absorbs all the strongly interacting components in the beam.
A sketch of the beam is shown below.



All deflections are in the vertical plane.

Fig. 1

The first bending magnet BM_1 deflects the pion beam so that about 20 GeV/c pions are focussed in BM_2. The aperture of BM_2 acts as a momentum slit for pions, but not for the muons produced by decaying pions while travelling from BM_1 to BM_2. The field in BM_2 is such that μ's of a nominal momentum of about 15 GeV/c will go down the taperable hole in the main neutrino shielding. This adjustable hole acts as a momentum slit for the muons from BM_2.

The purpose of the first absorber (A) is to prevent pions from entering the channel and decaying there into muons with wide momentum spread. The absorber (A) need be only of 2-3 geometrical m.f.p. in length.

The absorber (B) at the end of the channel can be an integral part of the normal neutrino shielding (perhaps 8-10 mfp). The μ's that come out of the end of the shielding will have a vertical width of about 18 cm, but due to the multiple scattering, the beam will fan out and have a vertical width of about 50 cm in the middle of the chamber.

It can be easily shown that the number of pions in equilibrium with the muons that come out of the back of the shielding is such that they would produce about the same number of interactions in a short length of material as the muons. However, these pions are all of low energy and will be swept out of the beam by the field of Gargamelle, and therefore are of little consequence.
If necessary a further BM could be put just before the chamber to serve the same purpose.

FACILITIES FOR FILM ANALYSIS.

The following scanning and measuring facilities will be available in 1971 for performing the experiment

2 Projectors with measuring devices in Padova

2 Projectors, one for scanning and one for measuring on line in Wisconsin.

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