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EXPERIMENTAL PROPOSAL

TO STUDY LEPTONIC DECAY OF VECTOR MESONS

1. Personnel: The physicists involved will be exactly the same as those of the pair production experiment.
2. Experimental setup: Will be exactly the same as that of the pair production experiment.
3. Energy and beam intensity needed: 6.2 Bev and 3-5 ma (as high as possible).
4. The physics of leptonic decays of vector mesons:

a. Comparison of the branching ratio of $\rho \to \mu^+\mu^-$ and $\rho \to e^+e^-$ gives us a clear cut (and the only) test of μ, e universality in the time-like region without using colliding beams. Test of μ, e universality (i.e. the difference of form factors between muons and electrons) in the space-like region can be achieved by comparing μ-p with e-p elastic scattering. However, in the time-like region, with the presently available A. G..S. intensities, it is not possible to compare the ratio of $\bar{p}p \to \mu^+\mu^-$ with $\bar{p}p \to e^+e^-$. Therefore, comparing $\rho \to \mu^+\mu^-$ with $\rho \to e^+e^-$ is the only way to test μ, e universality in the time-like region.

b. Precision konwledge of $\omega \to e^+e^-$ and $\varphi \to e^+e^-$ gives us some information about the (ω, φ) mixing angle - an important quantity in the understanding of strong interaction symmetries (SU_3 , ...). (Appendix I). The detection of $\omega, \varphi \to e^+e^-$ can be easily achieved with our hodoscopes, as the width of the ω, φ is $\lesssim$ 10 MeV and our hodoscope has a mass resolution of 15 MeV. Therefore, all the $\omega, \varphi \to e^+e^-$ events will fall into one mass bin whereas the $\rho \to e^+e^-$ events will have a broad mass spectrum since the width of the ρ is $\sim$ 150 MeV.

We plan to use a small 30 cm H_2 target for the ω, φ experiment, since there the Bethe-Heitler cross section will be small and the production cross section of ω, φ on hydrogen is known, and therefore for this part of the experiment no differential Cerenkov counter is needed.

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c. Precision knowledge of leptonic decay of vector mesons is essential to the understanding of elastic proton form factors.

5. Experimental results and activity

In the field of leptonic decays of vector mesons, the $\rho \rightarrow u^+u^-$ branching ratio has been measured to be 0.33×10^{-4}. There is no significant information on $\rho \rightarrow e^+e^-$ and $\omega,\phi \rightarrow e^+e^-$. We quote the following for the sake of completeness:

Summary of experimental results on leptonic decays of vector mesons:

1.) Rho Ref. 1

$$\frac{\rho \rightarrow e^+ + e^-}{\rho \rightarrow \pi^+ + \pi^-} = 5.{}^{+6.}_{-3.} \times 10^{-5}$$

[Assuming ω-ϕ mixing angle = 38°

Ref. 2

$$\frac{\rho \rightarrow \mu^+ + \mu^-}{\rho \rightarrow \pi^+ + \pi^-} = 3.3{}^{+1.6}_{-.7} \times 10^{-5}$$

2.) Omega Ref. 1

$$\frac{\omega \rightarrow e^+ + e^-}{\omega \rightarrow \pi^+\pi^-\pi^0} = 10.{}^{+12}_{-8} \times 10^{-5}$$

[mixing angle = 38

Ref. 3

$$\frac{\omega \rightarrow e^+ + e^-}{\omega \rightarrow \pi^+\pi^-\pi^0} = R, \quad R > 5 \times 10^{-5}, \quad < 6 \times 10^{-4}$$

95 % confide level

3 events

3.) PHI Ref. 1

$$\sigma_\phi \times \left[\frac{\phi \rightarrow e^+ + e^-}{\phi \rightarrow all}\right] = (2.9 \pm 1.5) \times 10^{-4} \text{ mbarns}$$

All the experiments done so far and all the experiments planned on $V \rightarrow e^+e^-$ are greatly handicapped by the low intensities available.

For u-pair experiments it is very hard to clear the μ from the incoming Pi-beam; thus one always faces a difficult background problem.

In the coming six month's time three groups are going to do the $\rho \rightarrow u^+u^-$, e^+e^- and hope to do the ω,ϕ as well. They are a C.I.T. group at UCRL, Zichichi at CERN and Hayms at CERN. This demonstrates the importance and the interest of the physics involved. But in no way does it imply that a better experiment could be done there than here. On the other hand, as the attached preliminary data show, with our rejection of pions of 10^{12}, with all our system working and free of background, with all programs functioning and with our experience in handling this particular experiment it would be a very simple and very clean task for us to finish this experiment in the earliest possible time.

Estimated Counting Rates and Required Machine Time:

For a 30 Cm H_2 target, the expected counting rates are:
(Using σ_ρ = 16 ub., σ_ω = 3 ub., σ_φ = 0.4 μb [4] and an incident intensity of 3×10^{10} eq. quanta/sec.)

$\rho \rightarrow e^+e^-$		2 / shift
$\omega \rightarrow e^+e^-$		0.35 / shift
$\varphi \rightarrow e^+e^-$		0.5 / shift

The counting rates from Bethe-Heitler pair production in the mass range accepted are:

ρ mass	0.015 / shift
ω mass	0.015 / shift
φ mass	0.007 / shift

For a 2.5 Gm/cm^2 Carbon target, we expect the following counting rates (assuming an $A^{1.6}$. dependence only)

$\rho \rightarrow e^+e^-$	10 / shift
$\omega \rightarrow e^+e^-$	1.75 / shift
$\varphi \rightarrow e^+e^-$	2.5 / shift

with a Bethe-Heitler rate of

ρ mass	0.5 / shift
ω mass	0.5 / shift
φ mass	0.2 / shift

Of course the Bethe-Heitler events are spread out over the 200 MeV mass range of the spectrometer.

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In a 4-shift run at the end of the last running period we obtained 82 events in the region of the ρ mass (the Bethe-Heitler contribution should be 50 events). From this information one can guess the branching ratio to be 5×10^{-5}. (This is a very crude estimate and is not intended to be quoted.)

To get a 10% measurement of the $\frac{\rho \rightarrow e^+e^-}{\rho \rightarrow \pi^+\pi^-}$ branching ratio, this group proposes to use a 2.5 gm/cm^2 carbon target for a period of 30 parasite shifts, at an energy > 5 BeV and an intensity > 1 ma.

For the ω, ϕ experiment we ask 30 shifts of prime time at 6.2 GeV/c and maximum intensity. Ideally one would like at least 10-15 events each of $\overset{\omega}{\phi} \longrightarrow e^+e^-$, which would be accumulated in 30 shifts on the basis of the above estimated counting rates.

Because of the scanty knowledge of the branching ratios and production cross sections however, the estimates cannot be trusted to better than a factor 2. Thus it is possible we may need to request more machine time at the end of the above 30 shifts to complete the program.

Time schedule: We would like to start immediately after the shut down, finish the run as soon as possible and make the space available to other experiments. Delaying the starting time of this experiment can only cause malfunctioning and drifting of the fast electronics in the system which has taken us 10 shifts to align.

APPENDIX I

Theoretical predictions for leptonic decay rates

The following relationship, between the partial widths for the leptonic decays at ρ, ω, ϕ is predicted by SU_3 (assuming that the ω, ϕ mixing angle is $\sim \sin^{-1} \frac{1}{\sqrt{3}}$.) [5,6]:

$$\frac{\Gamma_{\rho \to e^+ e^-}}{M_\rho} = \frac{9\, \Gamma_{\omega \to e^+ e^-}}{M_\omega} = \frac{9\, \Gamma_{\phi \to e^+ e^-}}{2\, M_\phi}$$

Using the physical masses and widths, the branching ratios are then given by:

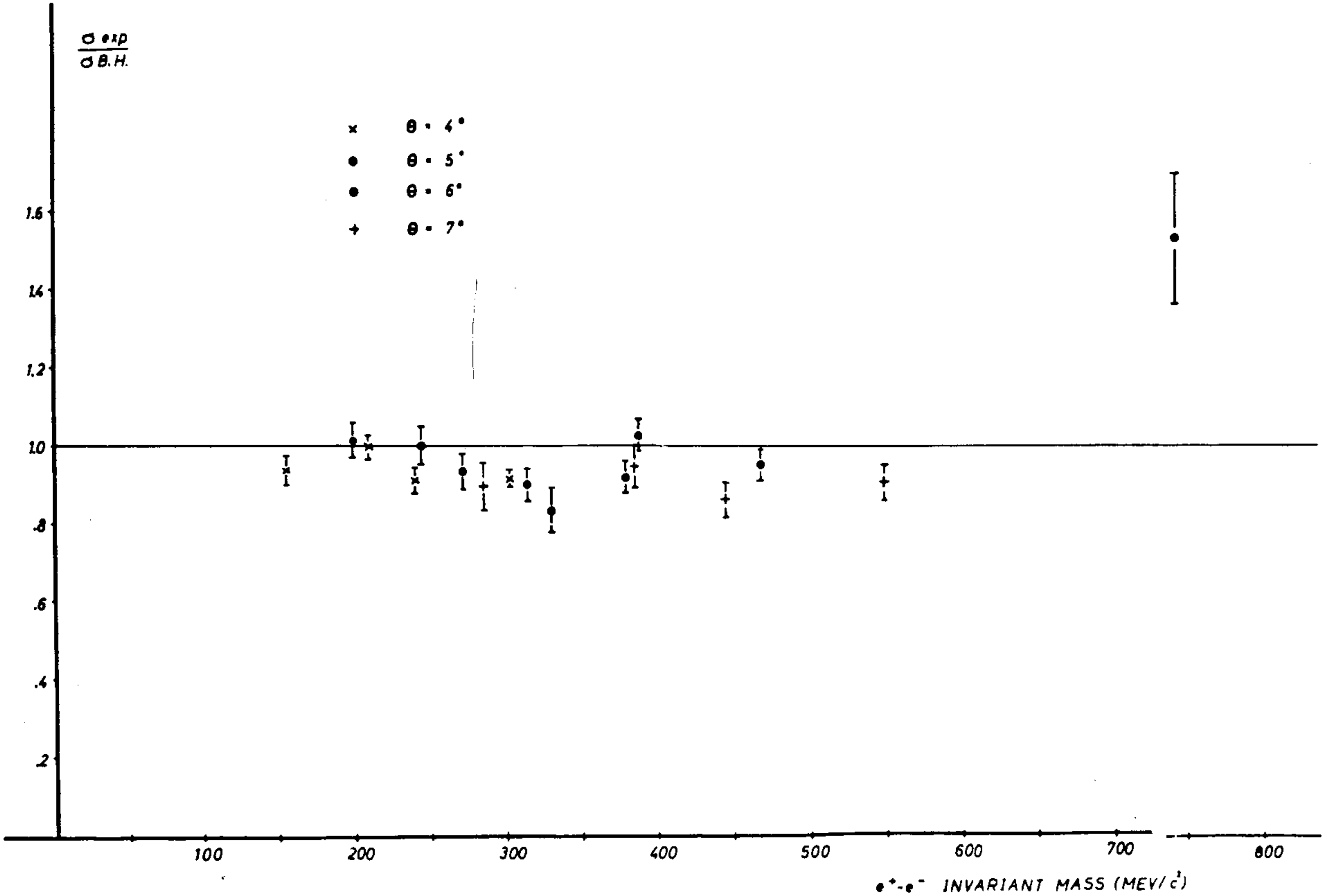
$$\frac{R_{\rho \to e^+ e^-}}{\dfrac{R_{\omega \to e^+ e^-}}{R_{\phi \to e^+ e^-}}} = \frac{1.}{\dfrac{0.93}{10.}}$$

Further, if the ρ-γ coupling constant is obtained from the width $\Gamma\ (\rho \to \pi\pi)$ (assuming SU_3)[7], the absolute branching ratios are:

$$R_\rho \to e^+ e^- = 6.5 \cancel{\times 10}^{-5}$$

$$R_\omega \to e^+ e^- = 6. \times 10^{-5}$$

$$R_\phi \to e^+ e^- = 6.5 \times 10^{-4}$$


σ exp / σ B.H.
θ = 4°
θ = 5°
θ = 6°
θ = 7°
1.6
1.4
1.2
1.0
.8
.6
.4
.2
100
200
300
400
500
600
700
800
e⁺-e⁻ INVARIANT MASS (MEV/c²)