THE ρ RADIATIVE DECAY WIDTH: A MEASUREMENT AT 200 GeV

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Abstract

The ρ^- radiative decay width has been measured at CERN (experiment NA29), by studying the production of ρ^- via the Primakoff effect by 200 GeV/c incident π^- on Cu and Pb targets. We obtain $\Gamma(\rho^- \to \pi^- \gamma) = 81 \pm 4 \pm 4$ keV, a result in good agreement with the quark model.

Introduction

In the quark model, the meson radiative decays $V \to P + \gamma$ (such as $\rho^- \to \pi^- \gamma$) are considered a magnetic dipole transition, where one of the constituent quarks of the vector meson flips its spin, with a consequent emission of a photon.

These transitions rapresent a sensitive test of the quark model, since the predictions for $\Gamma(\rho^- \to \pi^- \gamma)$, presented in the literature, range from ~120 keV to ~57 keV[3-4], according to the various assumptions made in the theory.

A more model indipendent value is $\Gamma(\rho^- \to \pi^- \gamma)/\Gamma(\omega \to \pi\gamma) \simeq 1/9$, which would indicate a $\Gamma(\rho^- \to \pi^- \gamma) \simeq 92 \pm 7$ keV from the experimental value $\Gamma(\omega \to \pi\gamma) = 860 \pm 60$ keV.

Two different values of the $\Gamma(\rho^- \to \pi^- \gamma)$ were available: 35±10 keV at 22 GeV and 71±7 keV at 156-260 GeV; for the ρ^+ the only measurement gives 60±4 keV at 200 GeV. Given the large discrepancy between the existing measurements, it seemed important to attempt a clarification of the situation by a new, high statistics measurement of $\Gamma(\rho^- \to \pi^- \gamma)$.

Procedure

Since the branching ratio $B(\rho^- \to \pi^- \gamma)(\lesssim 10^{-3})$ is much smaller than the branching ratio $B(\rho^- \to \pi^- \pi^o)$ and the transition $\rho^- \to \pi^- \gamma$ would be overwhelmed by the $\rho^- \to \pi^- \pi^o$ background, we have measured $\Gamma(\rho^- \to \pi^- \gamma)$ using the inverse process

$$\pi^- \gamma \to \rho^- \to \pi^- \pi^o$$

where the Coulomb field of a heavy nucleus is employed as a source of gamma (Primakoff effect).

The cross section for Coulomb production is (using the usual notation):

$$\frac{d\sigma_c}{dt} = 24\pi\alpha Z^2 \cdot C_M \cdot \frac{t - t_{min}}{t^2} \cdot \Gamma(\rho^- \to \pi^- \gamma) \cdot |F_c(t)|^2 \qquad (1)$$

where $F_c(t)$ is the e.m. form factor and, for a broad resonance as the ρ

$$C_M = \frac{1}{\pi} \cdot \int dM^2 \, \frac{M^2}{(M^2 - m_\pi^2)^3} \cdot \frac{m_\rho^2 \cdot \Gamma(\rho \to \pi\pi)}{(M^2 - m_\rho^2)^2 + m_\rho^2 \cdot \Gamma^2(\rho \to all)} \qquad (2)$$

If this process were the only mechanism contributing to the ρ^- production, measuring the total production cross section would be sufficient to calculate the value of Γ; but the ρ meson could also be strongly produced, for example via ω or A_2 exchange, and the cross section for this process is

$$\frac{d\sigma_s}{dt} = A^2 \cdot C_s \cdot (t - t_{min}) \cdot |F_s(t)|^2 \qquad (3)$$

where $F_s(t)$ is the nuclear form factor and C_s is a normalization factor for strong production on a single nucleon.

Because of the interference between the two processes (Coulomb and strong), $\Gamma(\rho^- \to \pi^- \gamma)$ has been measured by fitting the differential cross section as a function of t:

$$\frac{d\sigma}{dt} = \left| \Gamma_\gamma^{1/2} \cdot f_c(t) + e^{i\phi} \cdot C_s \cdot f_s(t) \right|^2 \qquad (4)$$

where f_c (f_s) is the Coulomb (strong) production amplitude (see ref. 2 for details on the values assumed) and ϕ is the phase between the two amplitudes.

The $d\sigma/dt$ is calculated by normalizing the ρ^- yield to the $K^- \to \pi^- \pi^0$ decay from the K^- present in the beam: this procedure has the advantage that, because of the similar kinematics of the processes $\rho^- \to \pi^- \pi^0$ and $K^- \to \pi^- \pi^0$, any inefficiencies of the detectors and off-line programs, cancelled to the first order, are automatically taken into account.

We use the relation:

$$\frac{d\sigma}{dt} = C_{target} \cdot \frac{dN_\rho}{dt} \cdot \frac{1}{N_K} \cdot \frac{X_K}{X_\pi} \cdot \frac{D_K}{D_\pi} \cdot \frac{\varepsilon_K}{\varepsilon_\rho} \cdot T$$

where:

- $C_{target} = \frac{A}{\rho \cdot d \cdot N_{Av}}$, (d=1.mm and 2.5 mm for Pb target and Cu target respectively);
- dN_ρ and N_K are the number of produced ρ^- and K^-, respectively, decaying into the $\pi^- \pi^0$ channel;
- ε_ρ and ε_K are the efficiencies for ρ^- and K^- detection and reconstruction (including the subtraction of contributions from background channels);
- X_π and X_K are the fraction of π^- and K^- in the beam at the primary target.
- D_K is the probability that a beam K^- decays into $\pi^- \pi^0$ in the region chosen for the K decays and D_π is the probability that the incident π survives up to the target;
- T is a correction factor, which takes into account the different inefficiencies for the two processes and has been evaluated with special runs.

Experimental apparatus

To enhance the Coulomb ρ^- production versus the strong ρ^- production, one needs (see (1) and (3)):

- a high energy beam;
- a high Z target;
- a spectrometer with good acceptance for low t events, beam particle identification, photon energy measurements and charged particle momentum analysis.

A schematic view of the apparatus is presented in fig. 1. At 200 GeV/c and 10^6 ppb, the beam was composed by 95% π^- and 4.5% K^-. We used two different targets (Pb and Cu) of ≈ 0.18 radiation length.

Asking one charged particle (out of the beam) and at least one gamma in the spectrometer, we collected 2×10^5 events on Pb and 6×10^5 events on Cu.

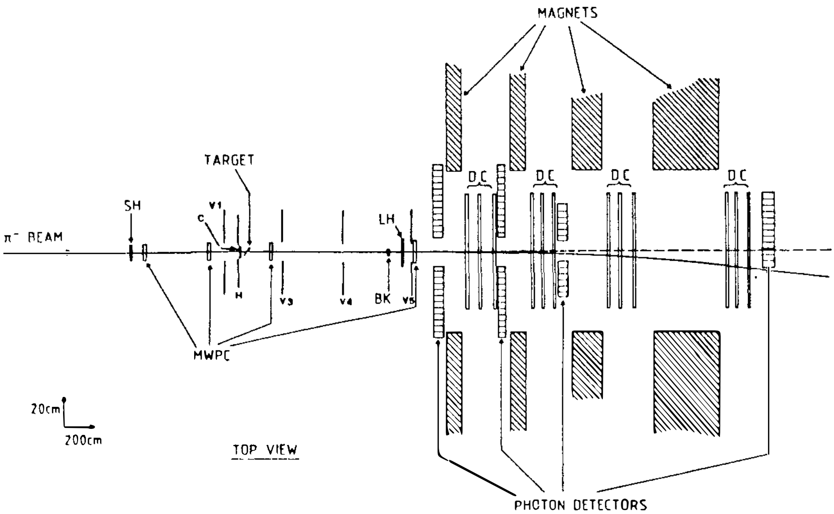


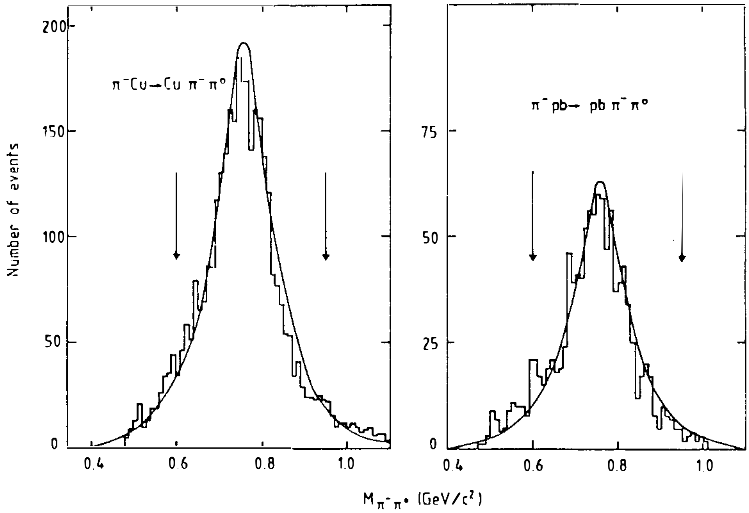
Fig. 1. Top view of the NA29 apparatus, showing the target, the beam and vertex chamber (MWPC), the veto scintillator counters (V's), the trigger counters and hodoscopes (SH, C, H, LH) and the drift chambers (DC) magnets and photon detectors of the FRAMM spectrometer.

Analysis.

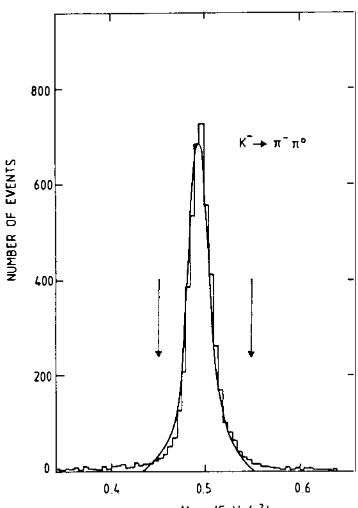
We applied the following cuts (in this order):

- a reconstructed vertex around the target for the ρ^- ($-20. < z_\rho < +10.$cm) and well outside the target for the K^- decay ($-130. < z_k < -50.$cm; $+20. < z_k < +100.$cm) (the target was at -10.cm);
- only one charged track in the spectrometer and two e.m. showers in the photon detectors;
- a reconstructed $\gamma\gamma$ invariant mass between 80 and 190 MeV/c^2;
- a convergent two constraint kinematics fit, with a fixed π^0 mass;
- a reconstructed total energy of the secondary particles ($E_{\pi^-} + E_{\pi^0}$) between 150 and 250 GeV.
- $t < 0.01$ $(\text{GeV/c})^2$.

The $\pi^-\pi^0$ mass distributions are presented in fig. 2a and fig. 2b for the events which satisfied all the above conditions (the lines are Monte Carlo predictions).



a)



b)

Fig. 2. $\pi^-\pi^o$ invariant mass distribution.
a) π^- interactions;
b) K^- decays.

To define the ρ^- and K^- events, cuts from 600 to 950 and from 450 to 550 MeV/c^2, respectively, were introduced in the $\pi^-\pi^o$ spectra.

The background subtractions are summarized in table I.

The final numbers are:

for the ρ^- production: 2935 events on Cu and 967 on Pb;

for the K^- decay: 4590 events on Cu and 1863 on Pb.

The efficiencies (the ε's and T in (5)), evaluated with the Monte Carlo, are ε_ρ=0.35 for Cu and =0.34 for Pb; ε_K=0.40; T=0.98.

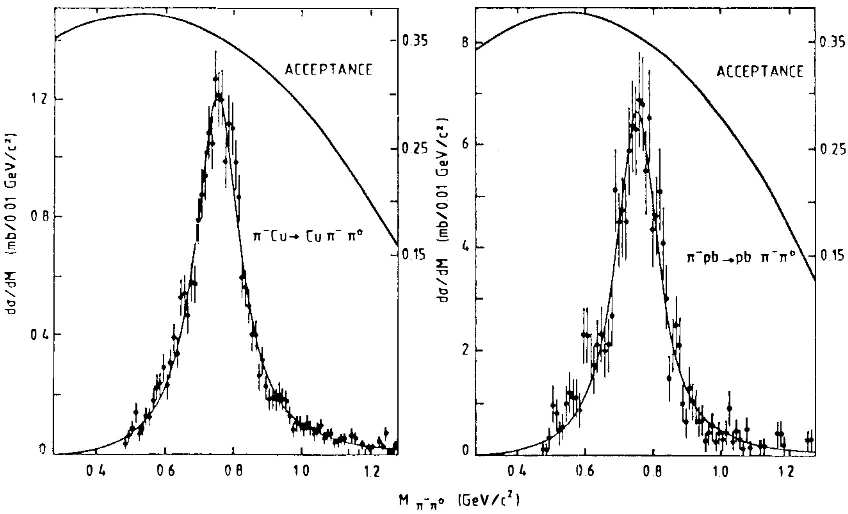


Fig. 3. $\pi^-\pi^0$ invariant mass distributions for the events selected by our analysis for the π^- interactions: the full line is the Breit-Wigner formula written for a broad resonance and fitted on the experimental distributions.

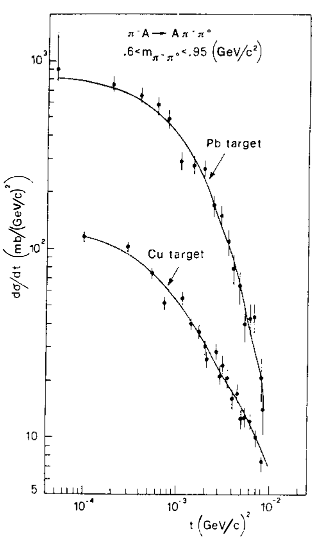


Fig. 4. Differential cross sections dσ/dt for the ρ^- production on Cu and Pb. The full line is the theoretical formula (4) with the resolution folded in, fitted on the experimental data.

Results

The distributions of the invariant mass for the selected events, corrected for geometrical acceptance, are shown in fig. 3; fitted by eqs. (1) and (2) and intergrated in t up to $0.01(GeV/c)^2$, for the ρ mass and width we obtained the values presented in table II.

The differential cross section for the ρ^- production on copper and lead is shown in fig. 4.

Fitting these data with eq. (4) (folding in the experimental t resolution), we obtained the results summarized in table III.

TABLE I

Background Subtractions

	$\pi^- Cu \to Cu \pi^- \pi^0$	$\pi^- Pb \to Pb \pi^- \pi^0$	K^-
empty target events	1.4 %	1.8 %	
$\pi^- \pi^0 \pi^0$ channel	3.8 %	1.3 %	
K → 3 bodies channels			0

TABLE II

Fit of the $\pi^- \pi^0$ invariant mass spectrum with eq. (1).

$\pi^- A \to A \pi^- \pi^0$	m_ρ (MeV/c^2)	$\Gamma(\rho \to all)$ (MeV/c^2)	χ^2/DF
A = Cu	767.±2.	155.±7.	24/20
A = Pb	761.±3.	154.±9.	43/33

TABLE III

Fit up to $t=0.01(GeV/c)^2$ of the t distribution with eq.(4)

The first error is the statistical one; the second error takes into account the uncertainties due to the corrections performed in the analysis.

$\pi^- A \to A \pi^- \pi^0$	Γ_γ keV	C_s mb/GeV^4	ϕ rad.	χ^2/DF	σ_c(mb) $t<.005(GeV/c)^2$	σ_s (mb) $t<.005(GeV/c)^2$
A=Cu	81.±5.±4.	2.7±.4±.4	4.9±.3±.2	32/21	.155±.01	.030±.004
A=Pb	82.±8.±9.	4.1±.9±1.4	4.8±.4±.5	25/26	1.16±.11	.17±.04
global	83.±4.±4.	2.9±.3±.4	4.8±.2±.2	62/47		

References

1) Clermont-Ferrand, Frascati, Milano, Pisa, Torino, Trieste and London Collaboration; for the author list see ref. 2;
2) L. Capraro et al., CERN-EP/87 - 37 (1987), to be published on Nuclear Physics B.
3) P.J. O'Donnel, Rev. Mod. Phys. 53 (1981) 698;
4) G. Morpurgo, talk presented at the Frontier of Physics, Bologna 1983, Genova preprint (1984).