Rare Decays of Vector Mesons

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Abstract

We consider rare decays of vector mesons: modes of interest and considerations when searching them out.

Among the photon's various guises are vector mesons. A high intensity beam of energetic photons, therefore, offers the opportunity to study vector mesons in some detail. Large numbers increase the likelihood of spotting suppressed, disallowed, or unexpected decay channels of these particles. In the past, such studies have led to the identification of Zweig suppression, of state mixing, and of constituent content. The availability of a high intensity photon flux at Thomas Jefferson National Accelerator may make the laboratory a fruitful place to undertake such investigations.

Interesting motivations for looking at such processes, aside from accounting for the full width of the parent mesons, include lepton universality (e.g., $\Gamma(\rho^0 \to \mu^+\mu^-) = \Gamma(\rho^0 \to e^+e^-) \times 0.99785$), symmetry violations (e.g., charge symmetry violation in $\omega \to \eta\pi^0$), and quark-gluon structure of daughter particles (e.g, s-quark content of the η' from $\phi \to \eta'\gamma$). The table below lists some modes, some notes regarding their interest, and their limits as given by the PDG[1] and Novosibirsk[2].

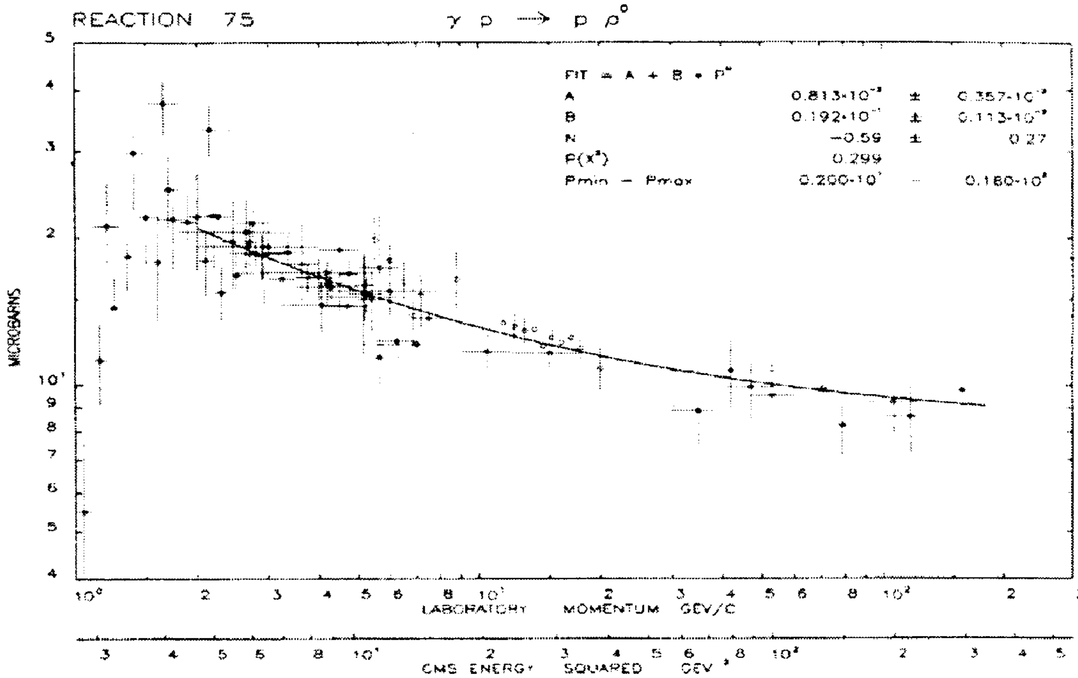
Naturally, searching for decays at a part in a million or more requires care with regard to backgrounds. A robust mechanism for doing so is to tag the parent, which can readily be done with $\phi(1020)$ diffractive production, but may be a little trickier with ω and ρ (in particular), due to the latter's width. The graphs below show cross-section measurements for exclusive production of these vector mesons. One notices the falloff as photon energy increases in the ω and ρ cross-sections. Unless the boost provides better detection opportunities, higher energy beams offer no advantage when culling these channels.

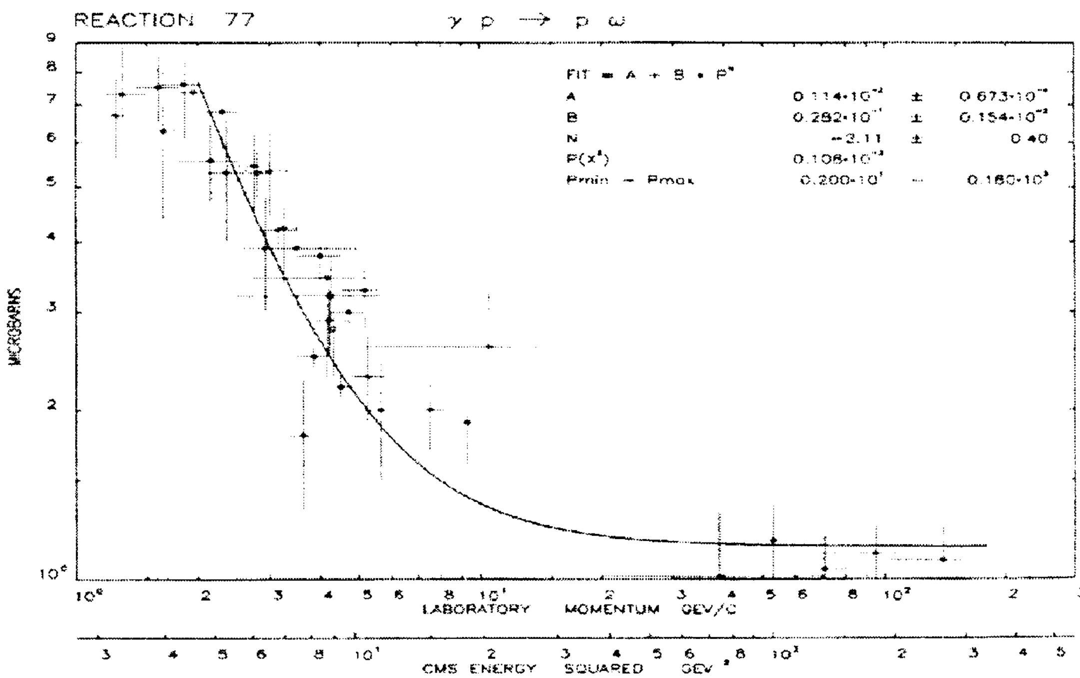
Another typical method for beating down backgrounds in sensitive searches is to design carefully the detector and trigger configurations so as to minimize the chances that backgrounds and feedthrough could appear in signal space. This may require cutting deeply into acceptance of the mode of interest as long as the suppression of backgrounds is adequate. This singular focus, and the sacrifices required, may conflict with the philosophy behind and motivation for a multipurpose detector with an open trigger. Faster electronics and increased cpu power may make such searches more viable with these kinds of detectors, but this surely comes only with extra consideration of the impact and additional cost.

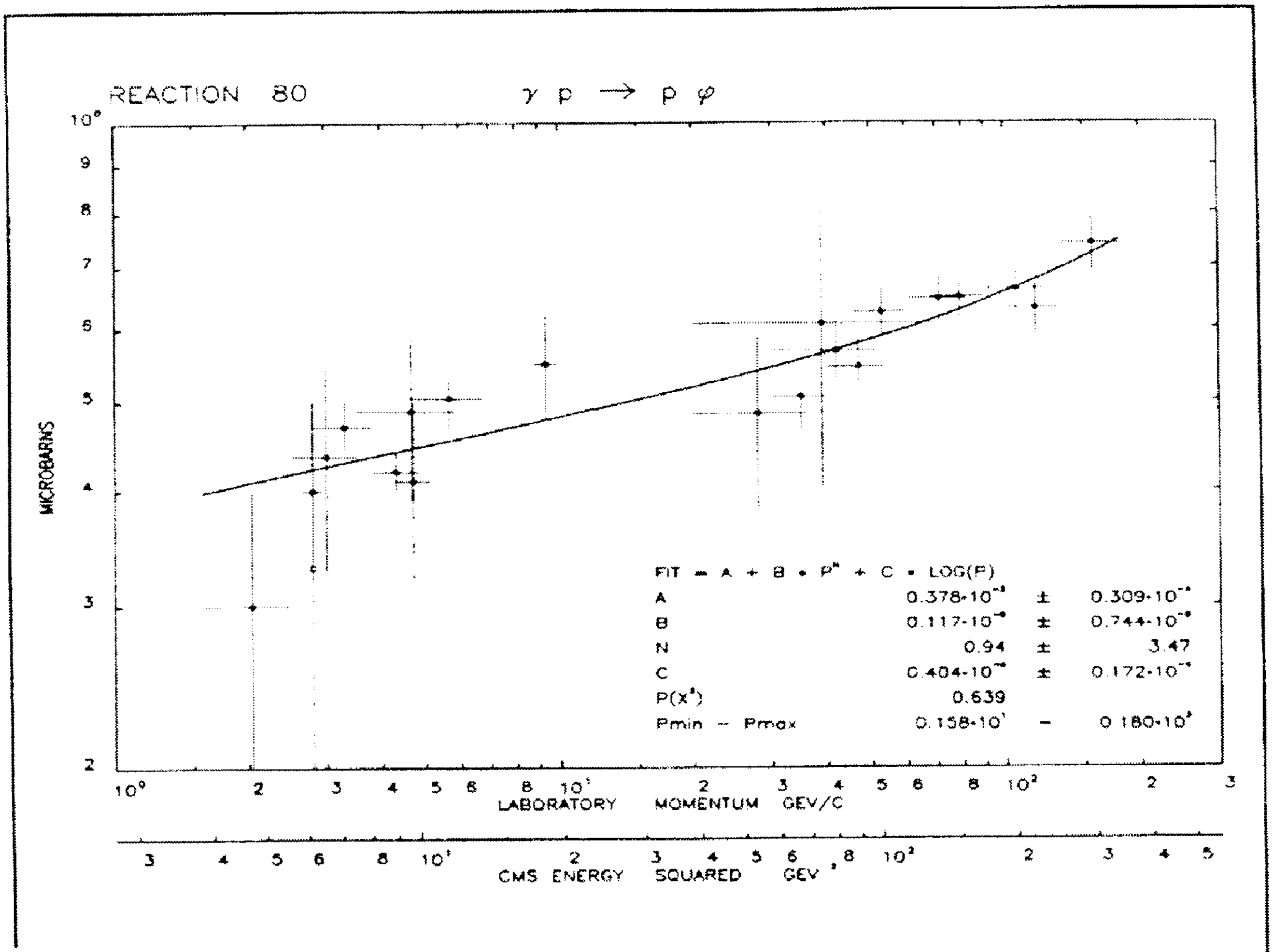
[1] "Review of Particle Properties, Part 1," Physical Review D, **54**:1 (1996).
[2] Achasov, *et al.*, hep-exp/9710017 v2, (Oct 1997)

Table 1: Selected Vector Meson Decay Modes

Mode	Notes	PDG	Novosibirsk
$\rho \to \mu^+\mu^-$	universality	$(4.60 \pm 0.28) \times 10^{-5}$	
$\rho \to e^+e^-$	universality	$(4.48 \pm 0.22) \times 10^{-5}$	
$\rho \to \pi^+\pi^-\pi^0$		$< 1.2 \times 10^{-4}$	
$\rho \to \pi^+\pi^-\pi^+\pi^-$		$< 2 \times 10^{-4}$	
$\rho \to \pi^+\pi^-\pi^0\pi^0$		$< 4 \times 10^{-5}$	
$\omega \to \pi^+\pi^-\pi^0\pi^0$		$< 2\%$	
$\omega \to \pi^+\pi^-\gamma$		$< 3.6 \times 10^{-3}$	
$\omega \to \pi^+\pi^-\pi^+\pi^-$		$< 1 \times 10^{-3}$	
$\omega \to \pi^0\pi^0\gamma$		$(7.2 \pm 2.5) \times 10^{-5}$	
$\omega \to \mu^+\mu^-$	universality	$< 1.8 \times 10^{-4}$	
$\omega \to 3\gamma$		$< 3.6 \times 10^{-3}$	
$\omega \to \eta\pi^0$	charge	$< 3.6 \times 10^{-3}$	
$\omega \to 3\pi^0$	charge	$< 3.6 \times 10^{-3}$	
$\phi \to \omega\gamma$		$< 5\%$	
$\phi \to \rho\gamma$		$< 2\%$	$< 3 \times 10^{-4}$ (CMD-2)
$\phi \to \pi^+\pi^-\gamma$		$< 7 \times 10^{-3}$	$< 1.5 \times 10^{-5}$ (CMD-2)
$\phi \to f_0(980)\gamma$	f_0 structure	–	$(4.7 \pm 1.0) \times 10^{-4}$ (SND)
$\phi \to \pi^0\pi^0\gamma$		$< 1 \times 10^{-3}$	$(1.1 \pm 0.2) \times 10^{-4}$ (CMD-2)
$\phi \to \pi^+\pi^-\pi^+\pi^-$		$< 8.7 \times 10^{-4}$	$< 3 \times 10^{-5}$ (CMD-2)
$\phi \to \eta'\gamma$	η' structure	4.1×10^{-4}	$< 1.7 \times 10^{-4}$ (SND)
$\phi \to \pi^0 e^+e^-$		$< 1.2 \times 10^{-4}$	$(1.1 \pm 0.8) \times 10^{-5}$ (CMD-2)
$\phi \to \pi^0\eta\gamma$		–	$(1.3 \pm 0.5) \times 10^{-4}$ (SND)
$\phi \to a_0\gamma$	a_0 structure	$< 5 \times 10^{-3}$	


REACTION 75
γ p → p ρ°
FIT = A + B · P^N
A 0.813·10 ± 0.357·10
B 0.192·10 ± 0.113·10
N −0.59 ± 0.27
P(X²) 0.299
Pmin − Pmax 0.200·10 − 0.180·10
MICROBARNS
LABORATORY MOMENTUM GEV/C
CMS ENERGY SQUARED GEV²


REACTION 77
γ p → p ω
FIT = A + B · P^N
A 0.114·10 ± 0.673·10
B 0.282·10 ± 0.154·10
N −2.11 ± 0.40
P(X²) 0.108·10
Pmin − Pmax 0.200·10 − 0.180·10
MICROBARNS
LABORATORY MOMENTUM GEV/C
CMS ENERGY SQUARED GEV²


REACTION 80
γ p → p φ
MICROBARNS
FIT = A + B * P^N + C * LOG(P)
A 0.378·10 ± 0.309·10
B 0.117·10 ± 0.744·10
N 0.94 ± 3.47
C 0.404·10 ± 0.172·10
P(X²) 0.639
Pmin – Pmax 0.158·10¹ – 0.180·10³
LABORATORY MOMENTUM GEV/C
CMS ENERGY SQUARED GEV²