PHOTOPRODUCTION OF 2 π^0 AND ω MESONS AT GRAAL

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GENERAL PROCEDURE

1- Two sets of data corresponding to 2 periods of measurement:

- January 2000: UV lines $\rightarrow$ E_γ= 700-1500 MeV
- October 2000: green line $\rightarrow$ E_γ= 650-1100 MeV

2- Analysis of several channels with the 2 sets and as far as possible with the same programs:

- to check the quality and the consistency of the 2 sets
- to validate our programs of simulation and analysis by comparing our results with previous known ones.
- to extract with the same conditions the channels under study

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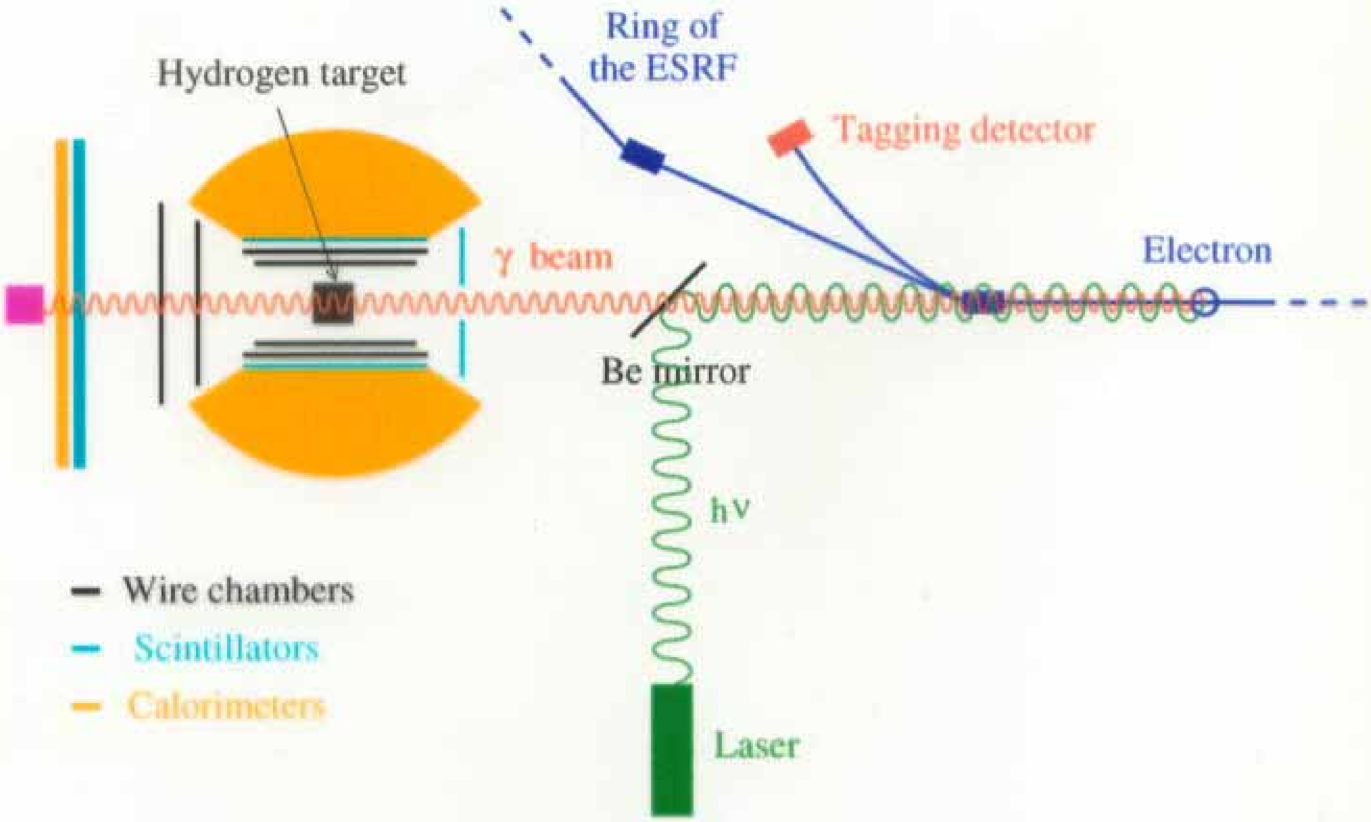
Setup of GRAAL



CENTRAL ASSEMBLY: $25 \leq \theta \leq 155$
- **BGO ball as calorimeter: θ and ϕ and E_γ**
- **barrel of scintillators: t and ΔE**
- **two cylindrical wire chambers.**

FORWARD ASSEMBLY: $1 \leq \theta \leq 25$
- **shower wall: (n and γ) and tof of n**
- **double wall of scintillators: θ and ϕ and tof**
- **two planar wire chambers**

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PHOTOPRODUCTION OF 2 π^0

1) Configurations of the events:

- The proton in forward wall or in the BGO ball
- 4 γ in the BGO or 3 γ in the BGO and 1 γ in the shower wall

2) Identification of the events:

- 4 conservation laws to deduce the energies of the proton and 1 γ when in the shower wall and to filter the events.
- control of the time and the ΔE of the proton by the scintillator walls or the barrel
- control of the contamination by γ p $\rightarrow$ p $\eta \rightarrow \pi^0\pi^0\pi^0$

3) Two parametrisations:

- grouping the proton and 1 π^0: γp $\rightarrow$ (pπ^0) π^0
- grouping the 2π^0: γp $\rightarrow$ p ($\pi^0\pi^0$)

4) efficiency:

- variables: E_γ, $\theta(\pi^0\pi^0)$, P($\pi^0\pi^0$)
- event generators: γp $\rightarrow \Delta^+\pi^0$,$\gamma$p $\rightarrow$ p π^0 π^0

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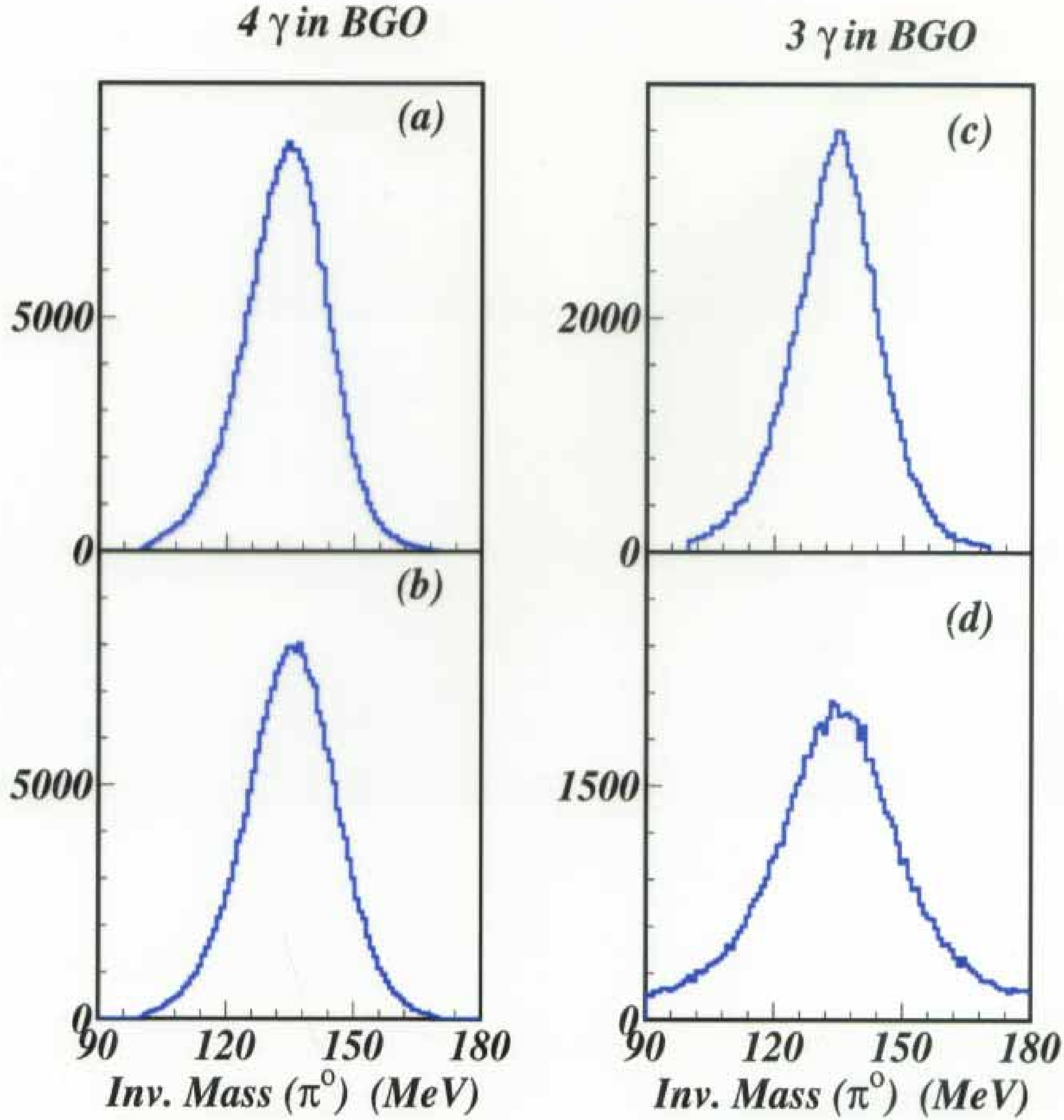
$$\gamma\ \mathbf{p} \rightarrow \mathbf{p}\ \pi^0\ \pi^0$$

(Reconstruction of Inv. Mass of π^0 from 2γ)



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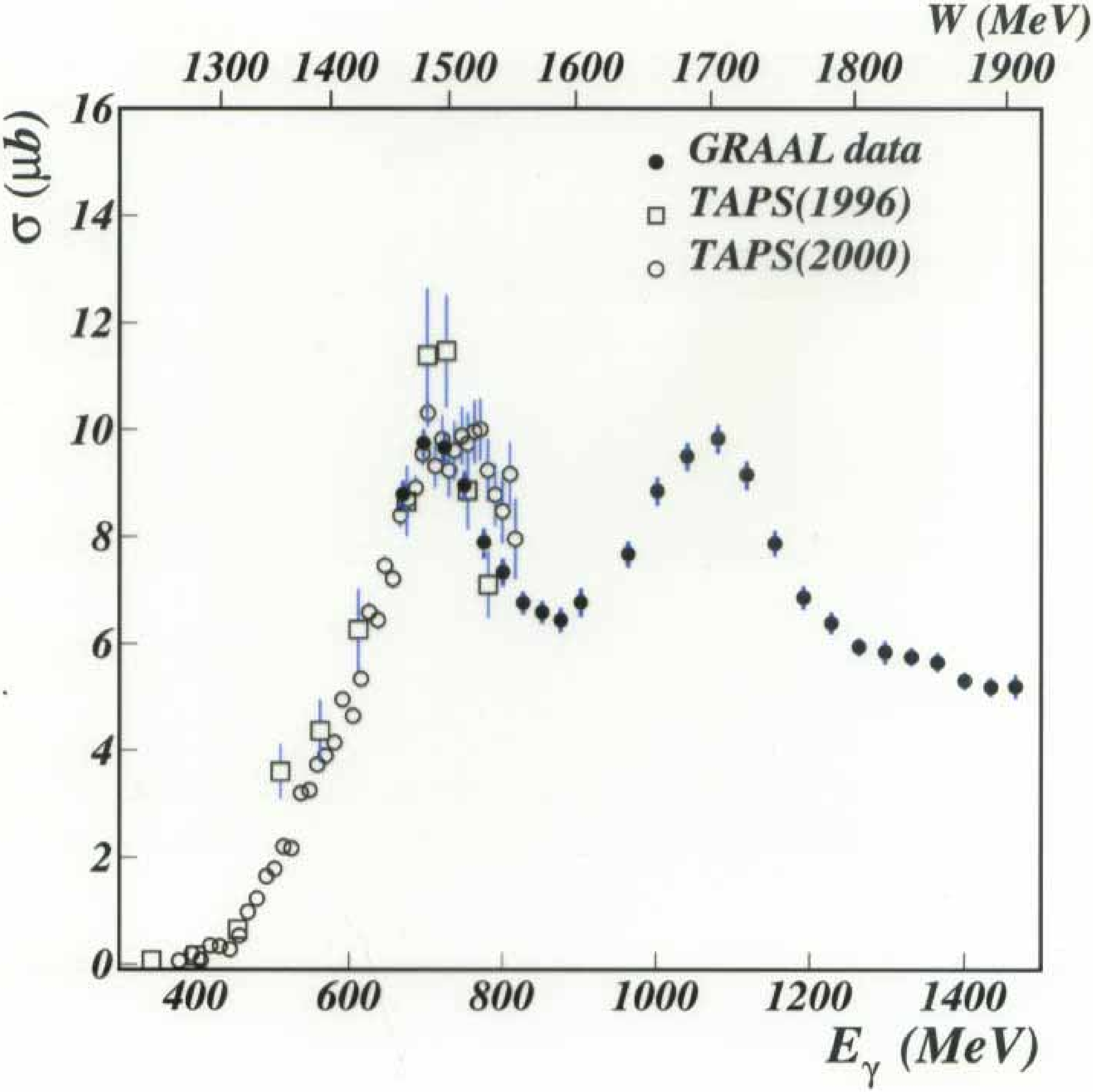
γp → pπ°π°



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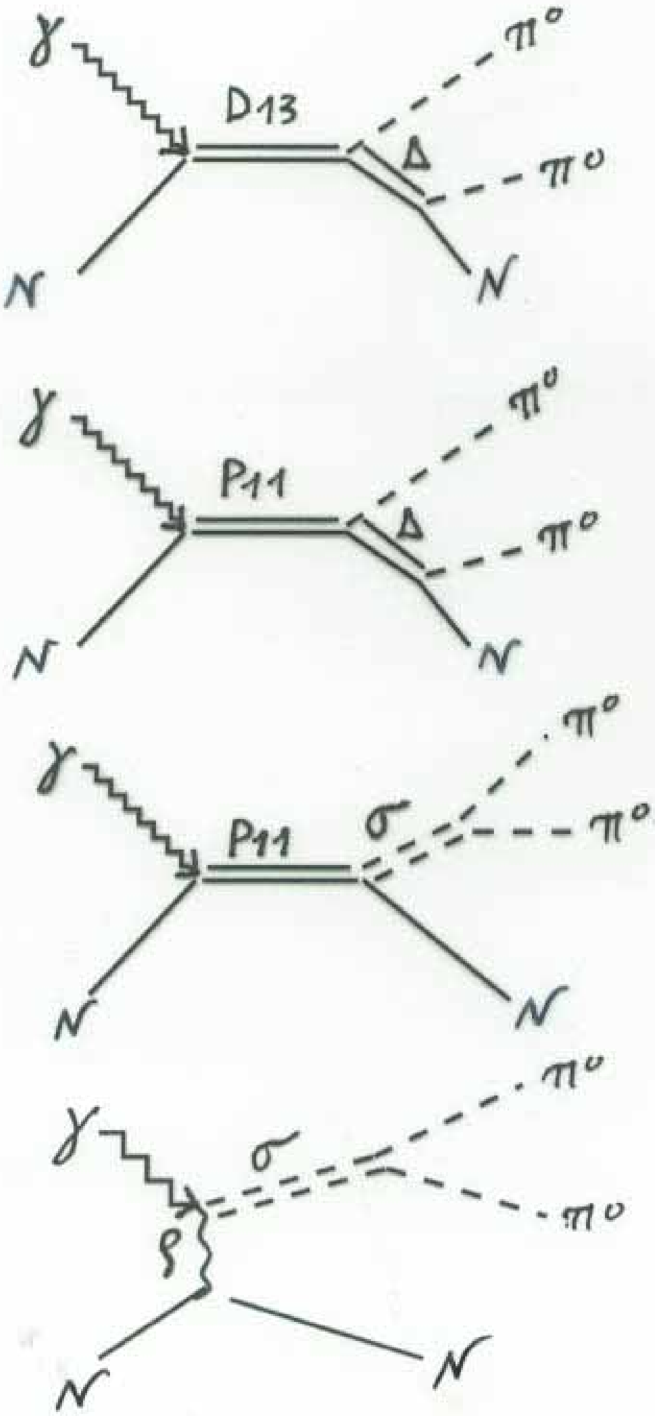
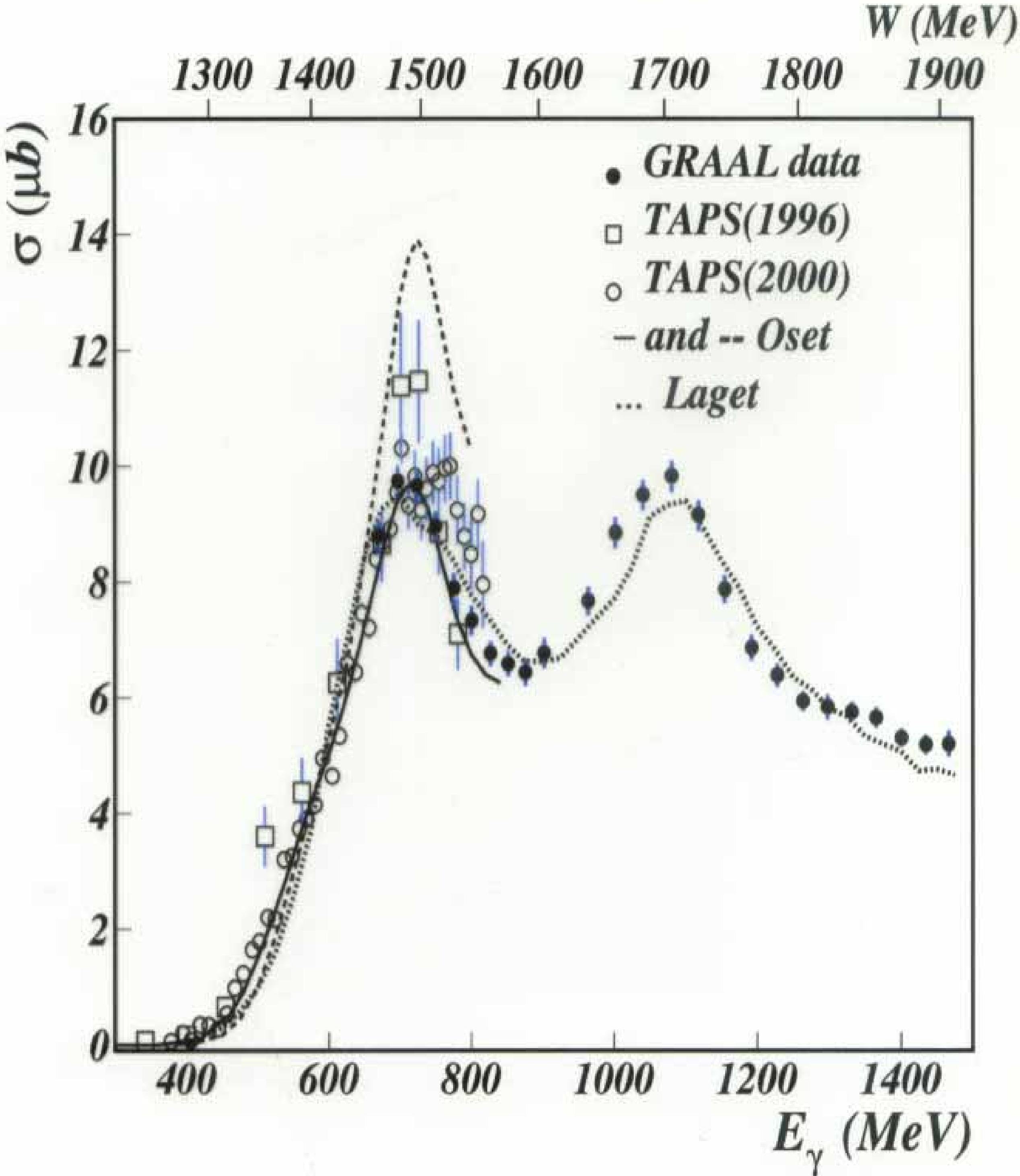
Diagrams in Laget Model



D13 (1520)
D13 (1710)

P11 (1440)
P11 (1710)

Total cross section of γ p $\rightarrow$ p π^0 π^0



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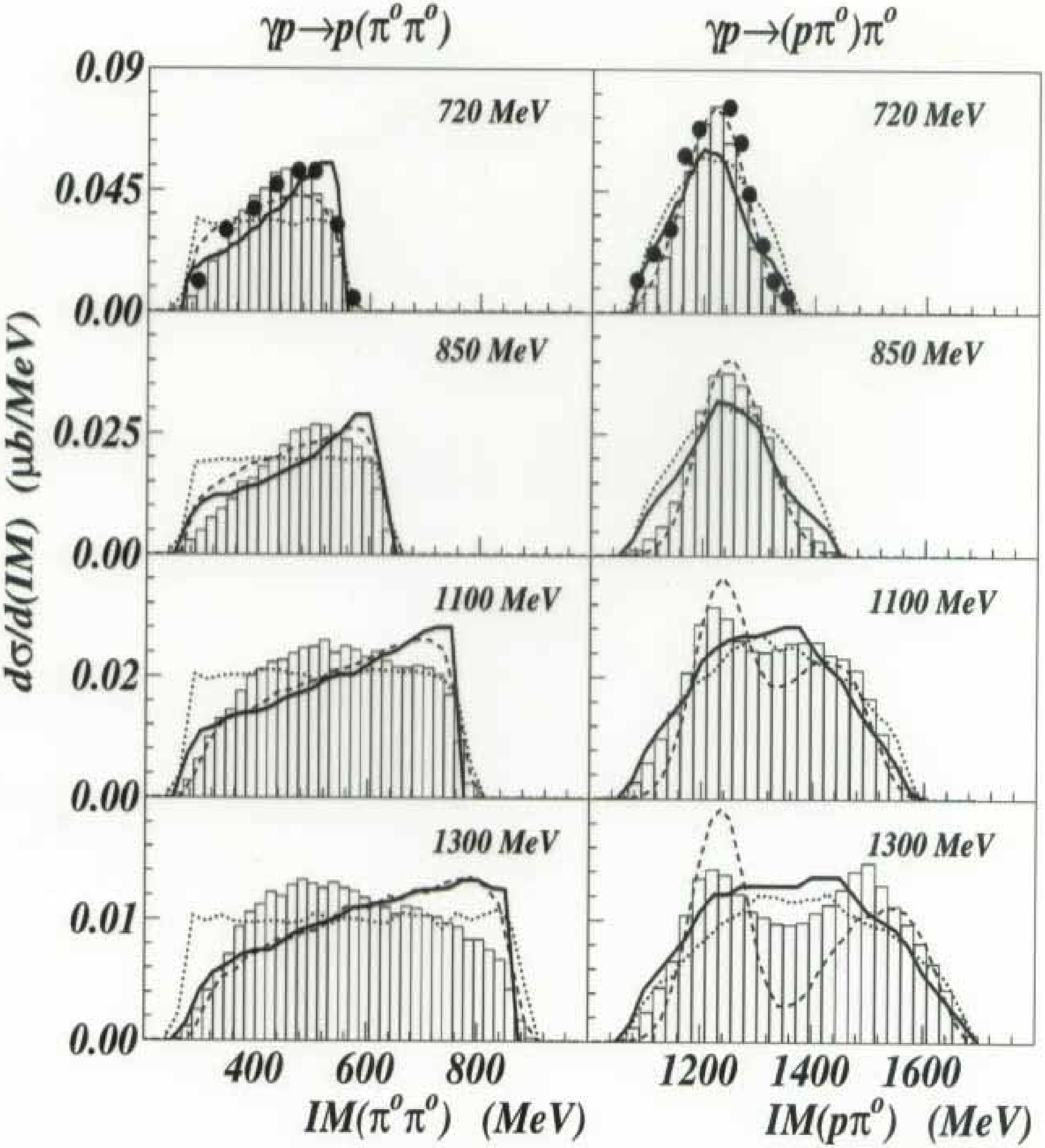
Differential cross sections of $\gamma\ p \rightarrow p\ \pi^0\ \pi^0$

Histograms: GRAAL data **Dots at 720 MeV: from TAPS**
Continuous line: Laget model
Dashed line: phase space calculation for $\gamma p \rightarrow (p\pi^0)\pi^0$
Dotted line: phase space calculation for $\gamma p \rightarrow p\pi^0\pi^0$



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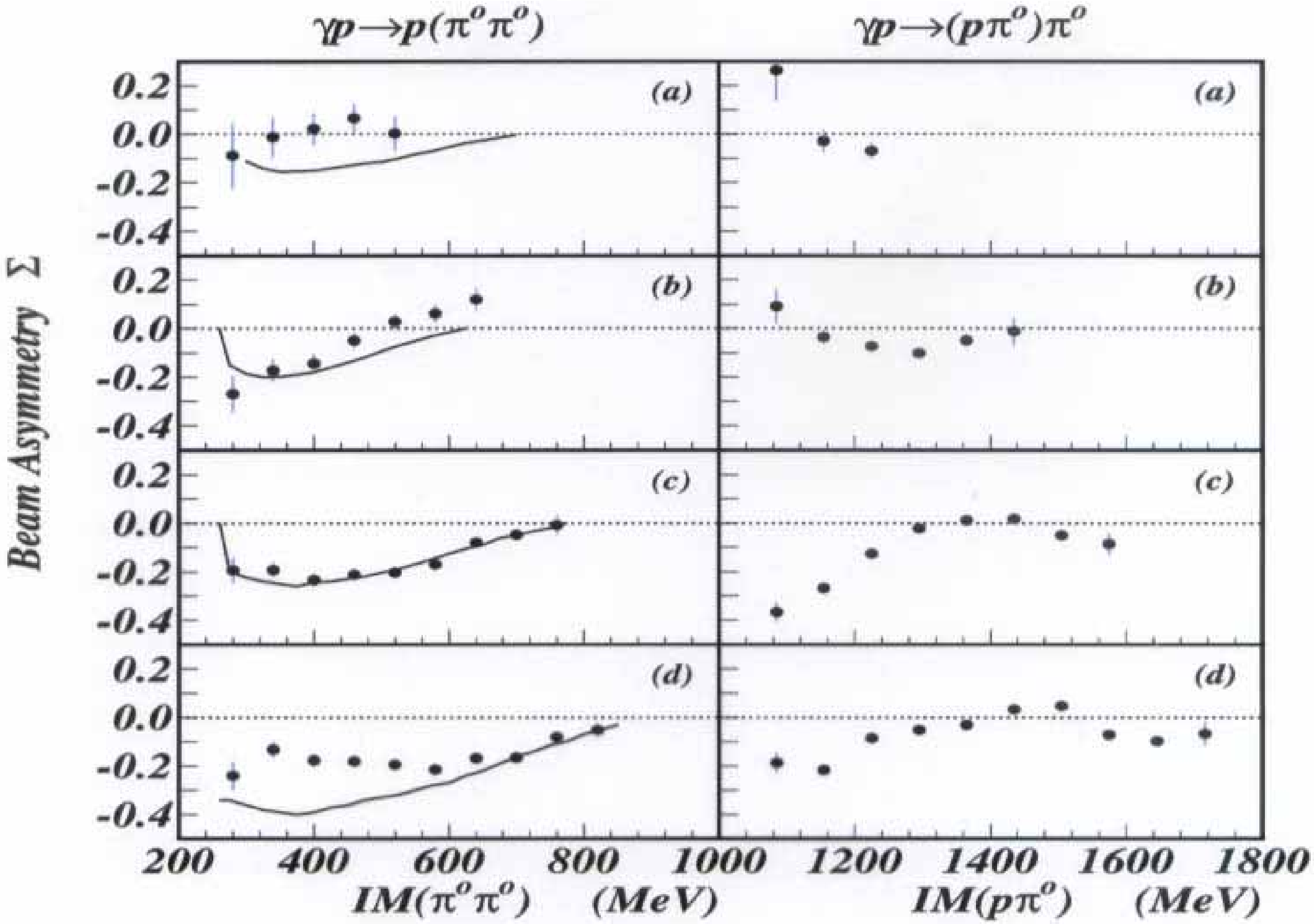
Beam asymmetry Σ of γ p $\rightarrow$ p π^0 π^0

(Comparison with Laget model)

(a) E_γ= 650-780 MeV
(b) E_γ= 780-970 MeV
(c) E_γ= 970-1200 MeV
(d) E_γ= 1200-1450 MeV



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PHOTOPRODUCTION OF ω MESONS

$$\gamma\, p \rightarrow p\, \omega$$
$$\omega \rightarrow \pi^+\pi^-\pi^0 \qquad (88.8\%)$$
$$\omega \rightarrow \pi^0\gamma \qquad (8.5\%)$$

CHARACTERISTICS

- Mass: 782 ± 8 MeV
- Threshold in photoproduction: 1100 MeV
- Isospin=0 → excitation of I=1/2 resonances
- Spin=1 → polarization, measurable with the angular distribution of its decay products.

DOUBLE POLARIZATION: beam-recoil

Formalism for γ p → p ω when $\omega \rightarrow \pi^+\pi^-\pi^0$
by K. Schilling et al. NP B15(1970)397, B18(1970)332
for a linear polarization of the photon beam

$$W(\cos\theta,\phi,\Phi) = W^0(\cos\theta,\phi)$$
$$- P_\gamma.\cos(2\Phi).W^1(\cos\theta,\phi) - P_\gamma.\sin(2\Phi).W^2(\cos\theta,\phi)$$

* θ and ϕ are the angles of the unit vector of the normal to the decay plane in the rest frame of ω.

* Φ is the azimuthal angle between the production plane of ω and the polarization P_γ of the beam.

* W^0, W^1 and W^2 depend on 9 spin-density matrix elements ρ^α_{ij}

BEAM ASYMMETRY Σ: integration on θ and ϕ

$$W(\Phi)= K(1+P_\gamma\, \underbrace{\frac{2\rho^1_{11}+\rho^1_{00}}{2\rho^0_{11}+\rho^0_{00}}}_{\Sigma}.\ \cos(2\Phi))$$

Q.Zhao, NP,A675 (2000)217

PHOTOPRODUCTION OF ω MESONS AT GRAAL

$$\gamma\, p \rightarrow p\, \omega$$
$$\omega \rightarrow \pi^+\pi^-\pi^0 \qquad (88.8\%)$$
$$\omega \rightarrow \pi^0\gamma \qquad (8.5\%)$$

1) Advantages of the charged mode ($\omega \rightarrow \pi^+\pi^-\pi^0$):

- Higher branching ratio (measured at SAPHIR and TJLAB)
- Formalism of Double Polarization written by Schilling
- At GRAAL: larger covering of the phase space and better control of the background.

2) Analysis

a) Charged:
- π^0 reconstructed in the central calorimeter
- θ and ϕ angles of p, π^+ and π^- measured
- conservation laws $\rightarrow$ magnitudes of p_1, p_2 and p_3
- identification of the p and charged pions.
- the background comes from $\gamma p \rightarrow p\pi^+\pi^-\pi^0$

b) Neutral:
- π^0 and γ measured in the central calorimeter
- the proton in the central or forward parts.
- The background comes from $\gamma p \rightarrow p\pi^0\pi^0$

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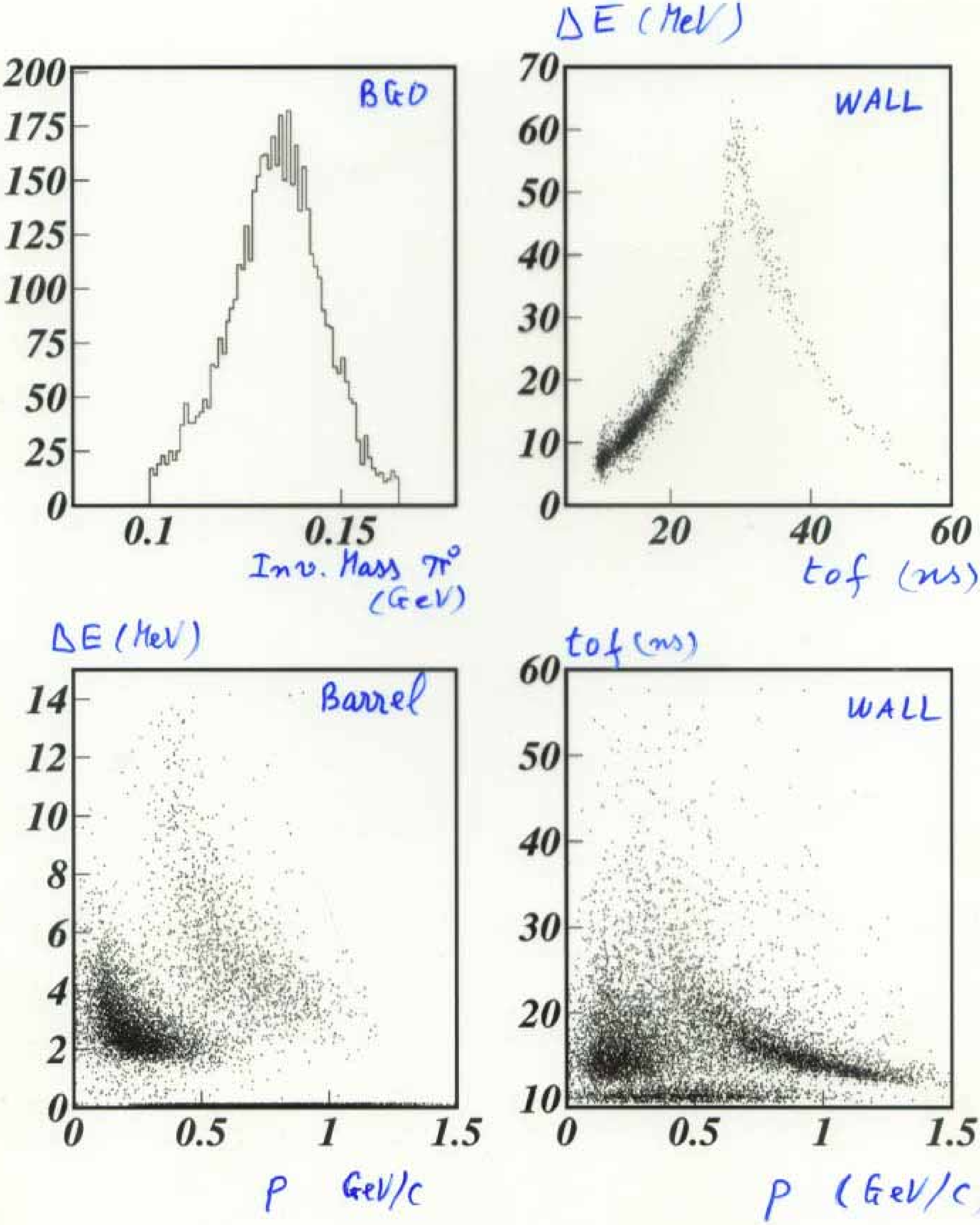
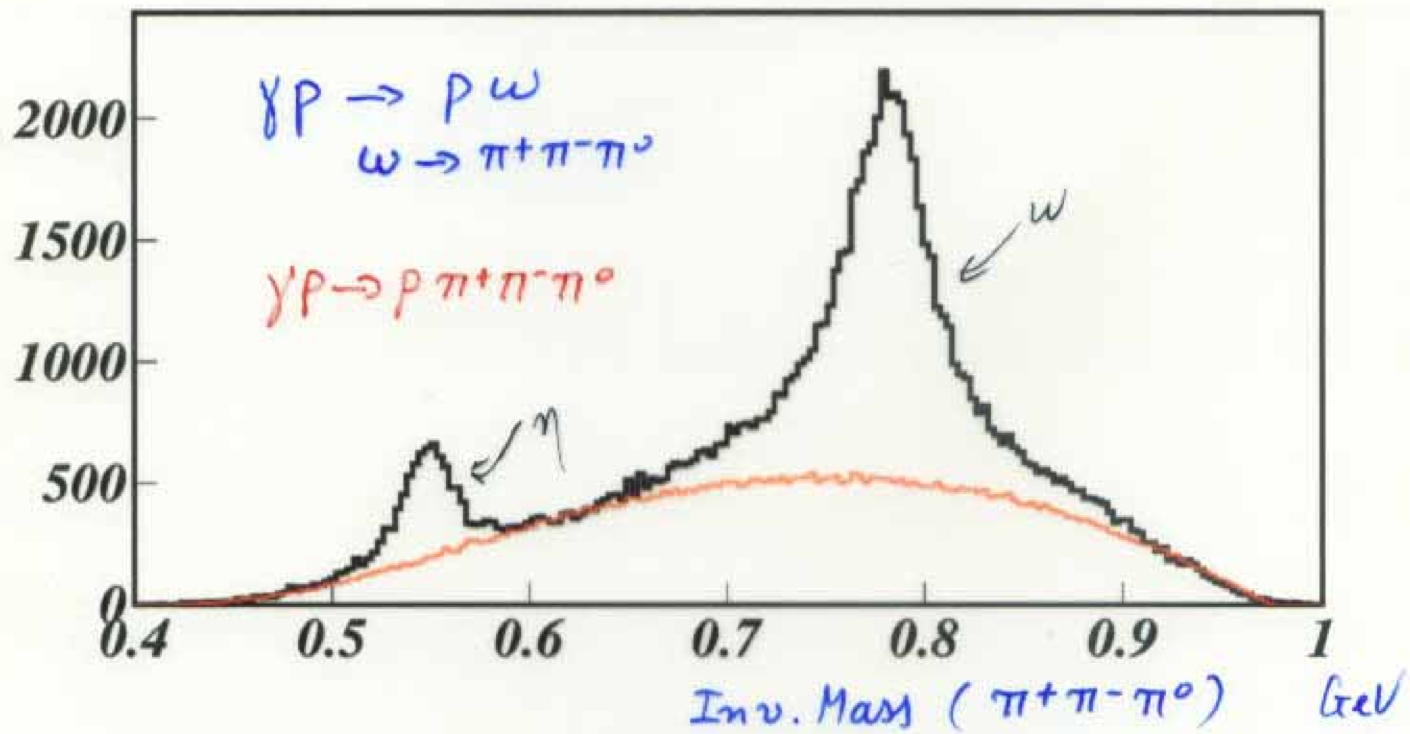
$\gamma p \rightarrow p \omega \quad \omega \rightarrow \pi^+ \pi^- \pi^0$

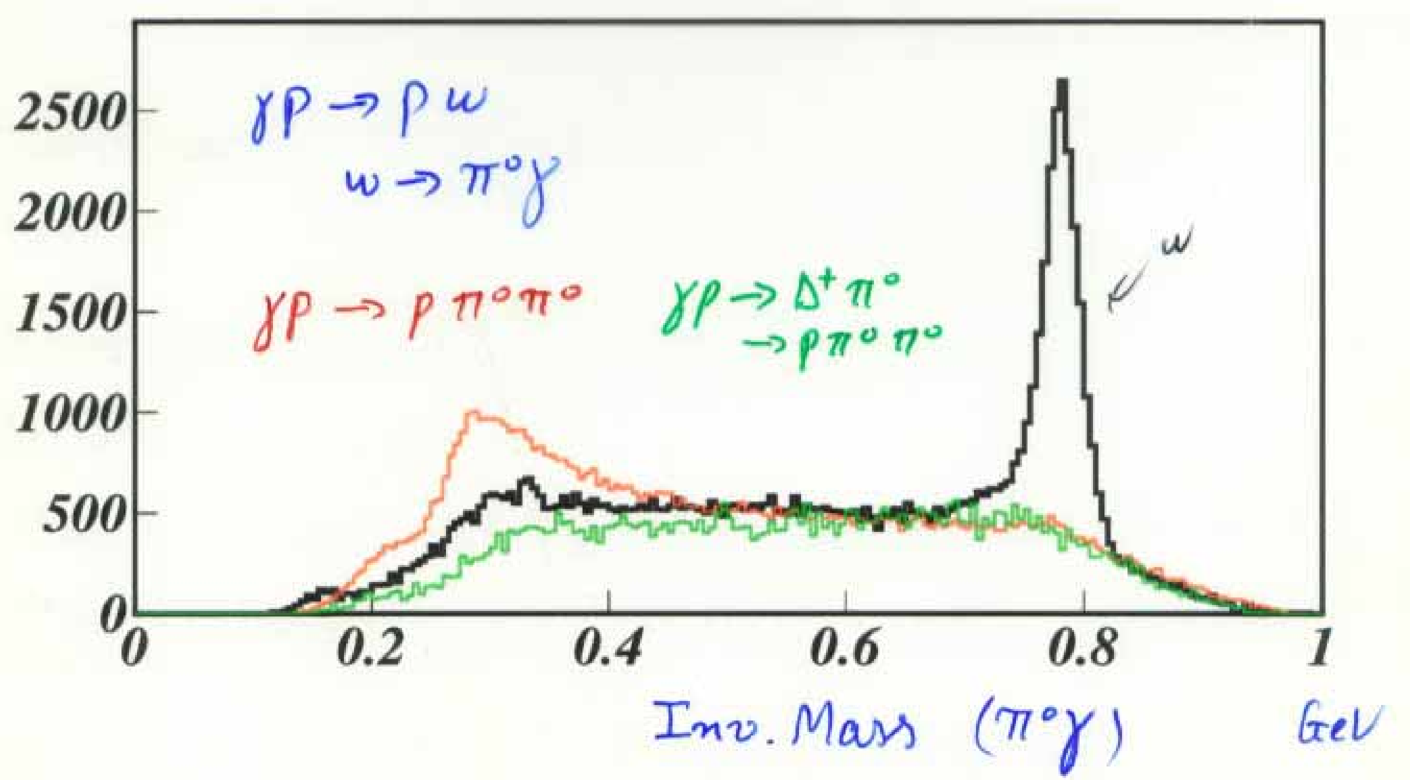
Identification Spectra



Invariant Mass Spectra

- in black : experimental data
- in colour : background simulated





Spectral Decomposition

$$\gamma p \rightarrow p\omega$$
$$\omega \rightarrow \pi^+\pi^-\pi^0$$

1) Decomposition of the Invariant Mass Spectra of $\pi^+\pi^-\pi^0$

(a)- Simulation of $\gamma p \rightarrow p\omega \rightarrow p\pi^+\pi^-\pi^0$
(b)- Simulation of $\gamma p \rightarrow p\pi^+\pi^-\pi^0$ **4-body process**
(c)- fit of the experimental spectrum with (a) + (b)

$\rightarrow$ **the fraction of** $\gamma p \rightarrow p\omega$ **events in the exp. spec.**

2) Decomposition after binning

i) differential cross section dσ**/dt**

11 bins in E_γ **and 30 bins in** $t = -(K_\gamma - K_\omega)^2$
$\rightarrow$ **330 spectra to be decomposed**

ii) beam asymmetry Σ

4 bins in E_γ**, 7 bins in** $\theta_{CM}(\omega)$ **and 12 bins in** $\phi(\omega)$
$\rightarrow$ **336 spectra**

3) Efficiency correction

The fraction of $\gamma p \rightarrow p\omega$ **events extracted from each spectrum is then corrected from efficiency before use.**

Quark Model Approach of Q. Zhao
γ p $\rightarrow$ p ω

NUCLEON RESONANCES:

- Nucleon: 3 constituent quarks and SU(6)$\otimes$O(3) symmetry.

- Resonances associated to excited states of this model

- Resonances used:
S11(1535), D13(1520), P13(1720), F15(1680), P11(1440), P11(1710), P13(1900), F15(2000)

REACTION MECHANISM:

- s- and u- channels: contribution of the resonances
Effective Lagrangien for quark-meson interaction.

$$L_{eff} = -\overline{\psi}\gamma_\mu p^\mu \psi + \overline{\psi}\gamma_\mu e_q A^\mu \psi + \overline{\psi}(a\gamma_\mu + \frac{ib\sigma_{\mu\nu}q^\nu}{2m_q})\Phi^\mu_m \psi$$

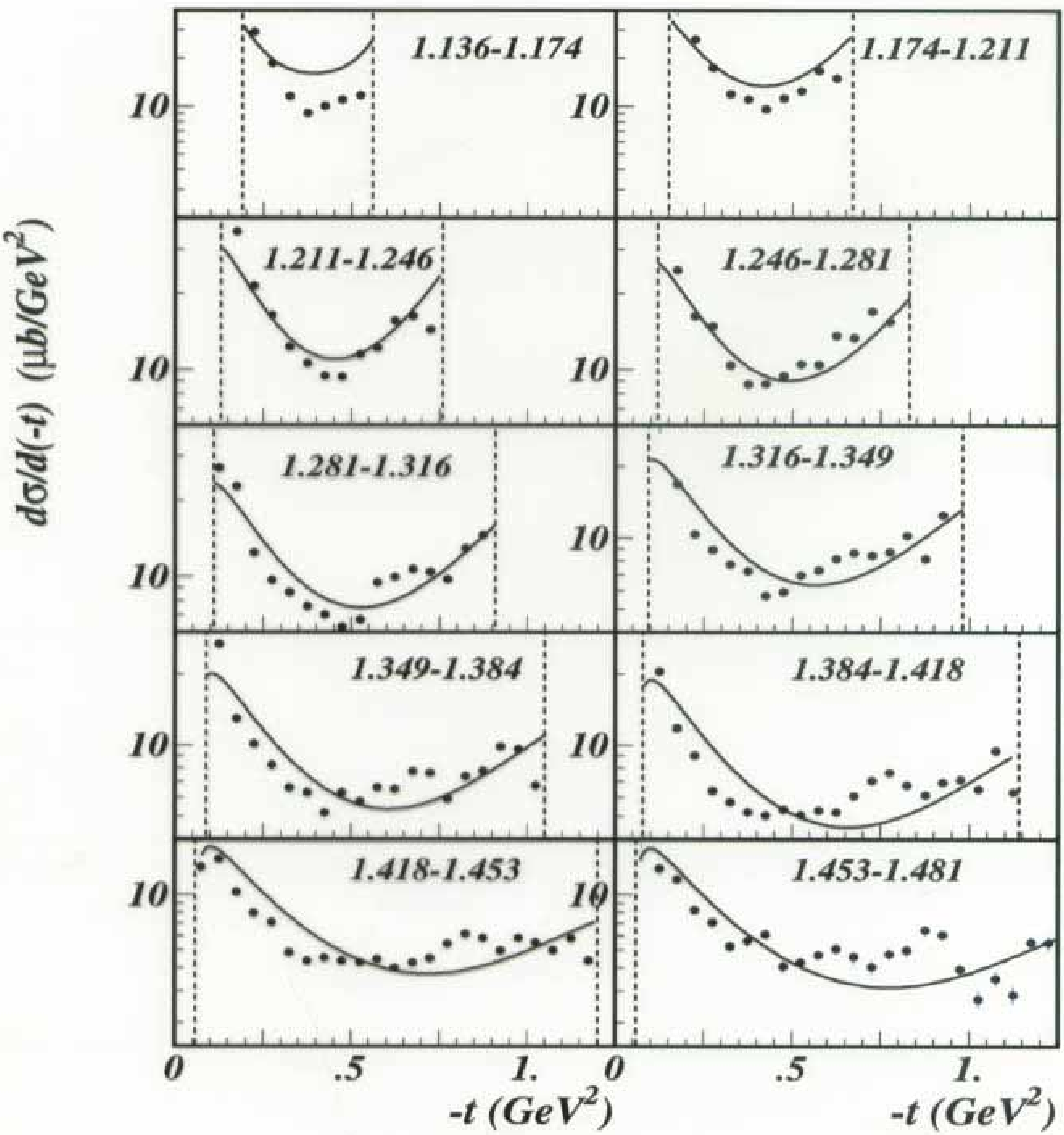
a=4, b=0.

- t- channel: diffractive phenomenon
Pomeron exchange, exchange of natural parity: β_0= 0.00127
π^0 exchange, exchange of non natural parity: α_π= 270 MeV

Q. Zhao et al. P.R.C 58 (1998)2393
Q. Zhao Nucl. Phys. A675 (2000) 217

Differential cross sections of $\gamma\ p \rightarrow p\ \omega$

$(\omega \rightarrow p\ \pi^+\ \pi^-\ \pi^0)$



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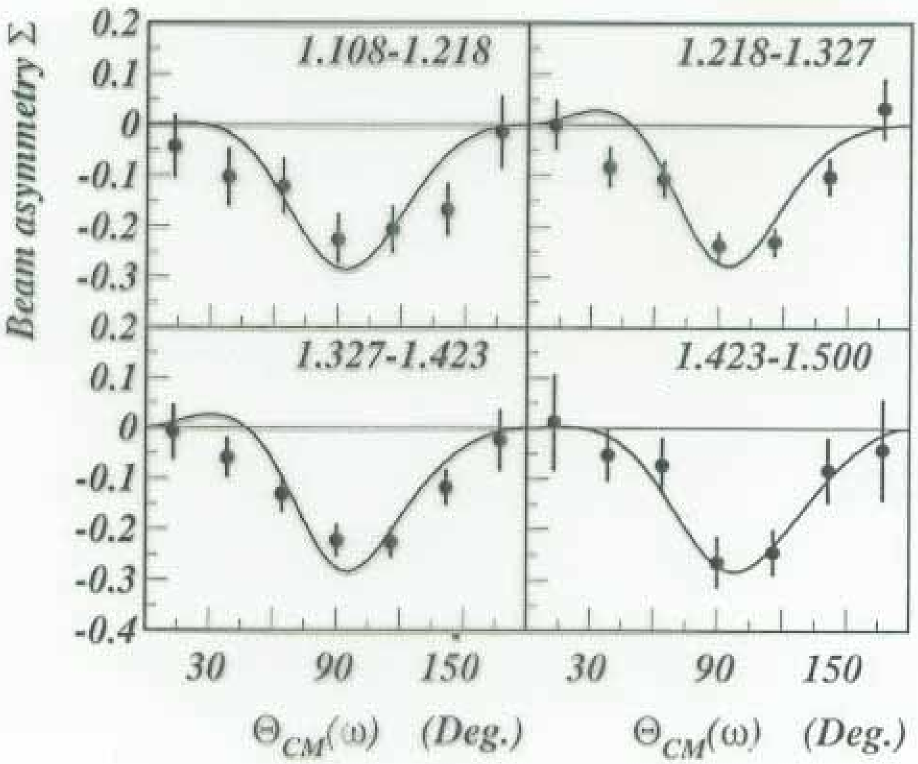
γp → pω



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Summary

We analysed the $2\pi^0$ and ω photoproducion channels in GRAAL data.

- The $2\pi^0$ channel shows an inportant excitation of resonances located at 1700 MeV
- The ω channel shows:
  - a significant contribution from the resonances.
  - the model of Zhao infers the excitation of P13(1900) and F15(2000).

Checks of analysis:

- $\gamma p \to p\pi^0\pi^0$ by $\gamma p \to p\eta$ $(\eta \to \gamma\gamma)$.
- $\gamma p \to p\omega$ $(\omega \to \pi^+\pi^-\pi^0)$ by $\gamma p \to p\pi^+\pi^-$ and $\gamma p \to p\eta$ $(\eta \to \pi^+\pi^-\pi^0)$

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