Photoproduction of $\gamma\,\mathrm{p} \rightarrow \mathrm{p}\,\pi^0\,\eta$ and $\gamma\,\mathrm{p} \rightarrow \mathrm{p}\,\eta\,\eta$ at ELSA in Bonn

NStar 2002

Pittsburgh, USA

Volker Credé

- Introduction
- The excitation spectrum of Δ resonances
- The Crystal Barrel Experiment at ELSA in Bonn
  - Experimental setup
  - Measurement and study of $\gamma\,\mathrm{p} \rightarrow \mathrm{p}\,\pi^0\,\eta$
  - Acceptance corrections and measurement of $\gamma\,\mathrm{p} \rightarrow \mathrm{p}\,\pi^0$
- The CB-TAPS configuration and first results
- Summary and outlook

Helmholtz–Institut für Strahlen– und Kernphysik,
Universität Bonn, D–53115 Bonn

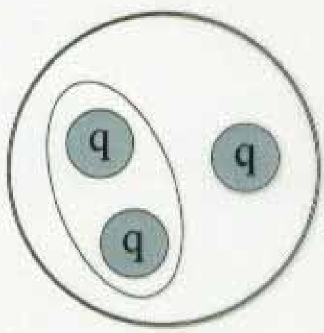
General Physical Motivation

⇒ Search for missing resonances

Quark Model: more baryons predicted than observed

Possible solutions:

a) Baryons have a quark-diquark structure:



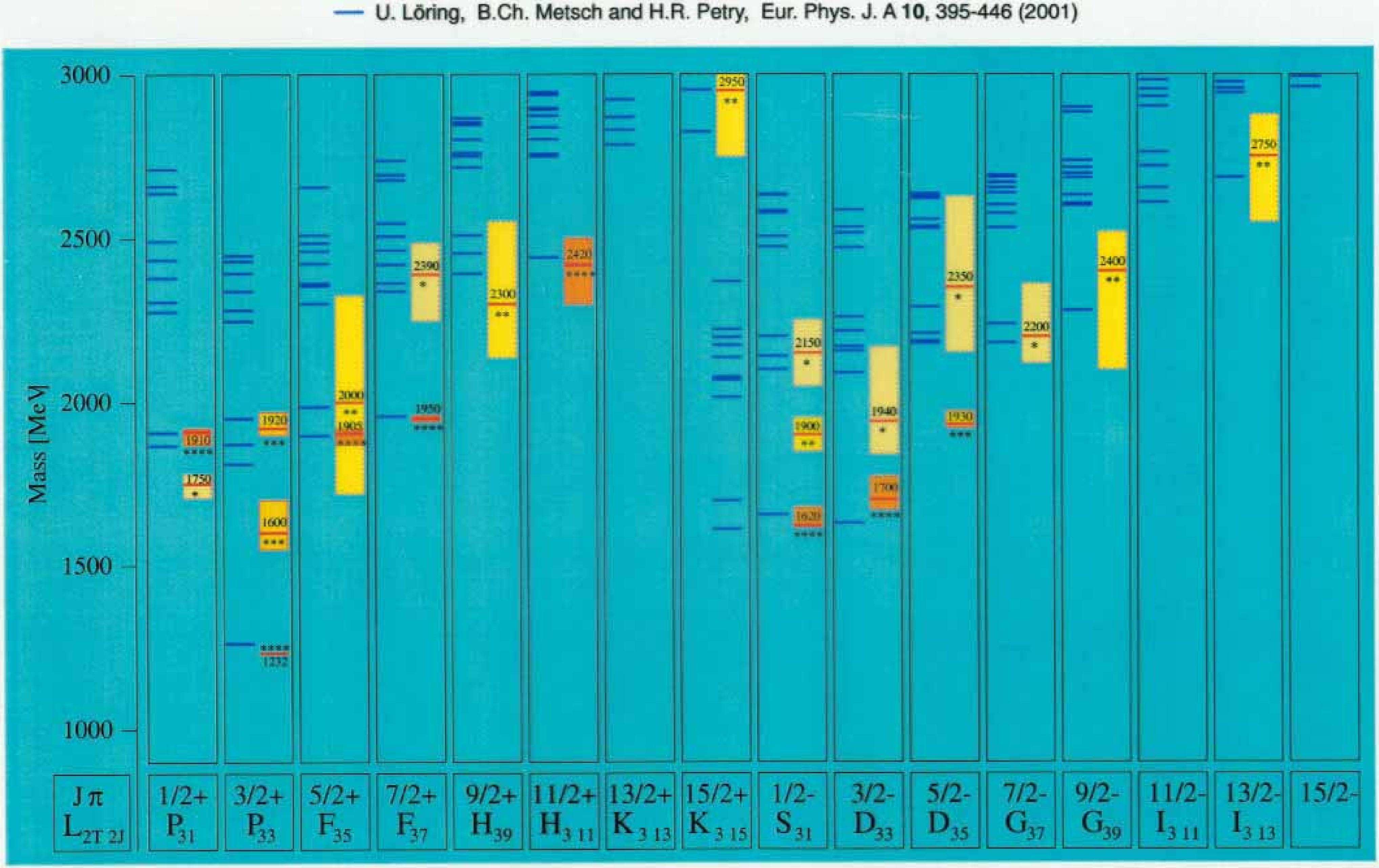
one of the internal degrees of freedom is frozen

b) They have not been observed up to now

Nearly all existing data result from πN-scattering experiments

⇒ If the missing resonances do not couple to Nπ, they would not have been discovered!!
(supported by theory)

Δ-resonances



K_α line of nucleon: N(1535)S_{11} or N(1650)S_{11} ?

Negative parity baryons and η decays:

$s = \frac{3}{2}$	N(1650)S_{11}	N(1700)D_{13}	N(1675)D_{15}
$s = \frac{1}{2}$	N(1535)S_{11}	N(1520)D_{13}	

$\hookrightarrow$ Nη $\hookrightarrow$ $\pi^0\pi^0$p ($\pi^0\pi^-$n)

$s = \frac{3}{2}$	Λ(1800)S_{01}	Λ(????)D_{03}	Λ(1830)D_{05}
$s = \frac{1}{2}$	Λ(1670)S_{01}	Λ(1690)D_{03}	

$\hookrightarrow$ $\Lambda\eta$ $\hookrightarrow$ $\pi^0\pi^0\Lambda$

$s = \frac{3}{2}$	Σ(1750)S_{01}	Σ(????)D_{03}	Σ(1775)D_{05}
$s = \frac{1}{2}$	Σ(1620)S_{01}	Σ(1670)D_{03}	

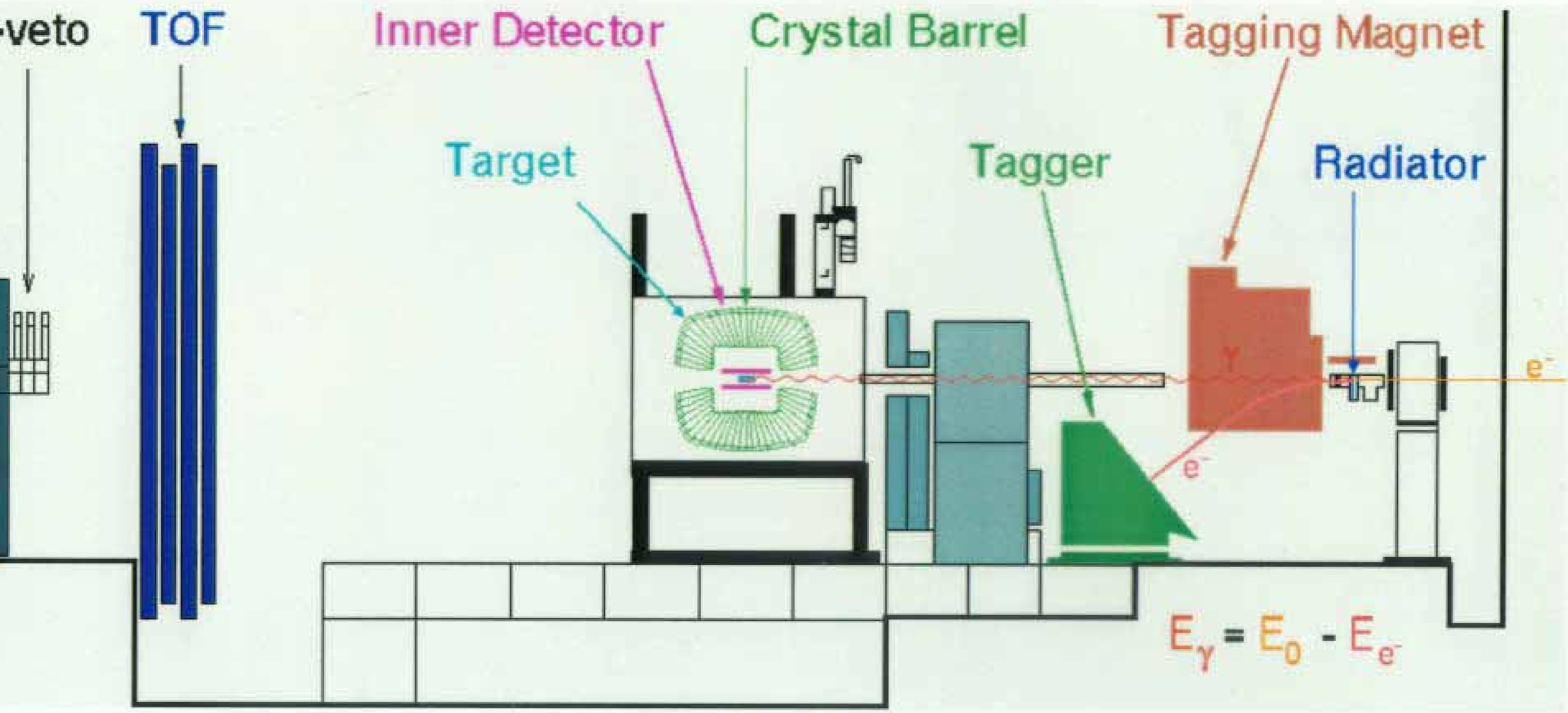
$\hookrightarrow$ $\Sigma\eta$ $\hookrightarrow$ $\pi^0\pi^0\Sigma^0$

- Octets Λ^* and Σ^* upgrades of N^* by 150 MeV
  $\Rightarrow$ Baryons favor $SU(3)_{flavor}$
- Spin flip required from states with $s = \frac{3}{2}$
  $\Rightarrow$ decay suppressed

$s = \frac{3}{2}$	Δ(1900)S_{31}	Δ(1940)D_{33}	Δ(1930)D_{35}
$s = \frac{1}{2}$	Δ(1620)S_{31}	Δ(1700)D_{33}	

$\hookrightarrow$ $\Delta\eta$? $\hookrightarrow$ $\pi^0\pi^0\Delta$?

The Crystal Barrel experiment at the electron accelerator ELSA



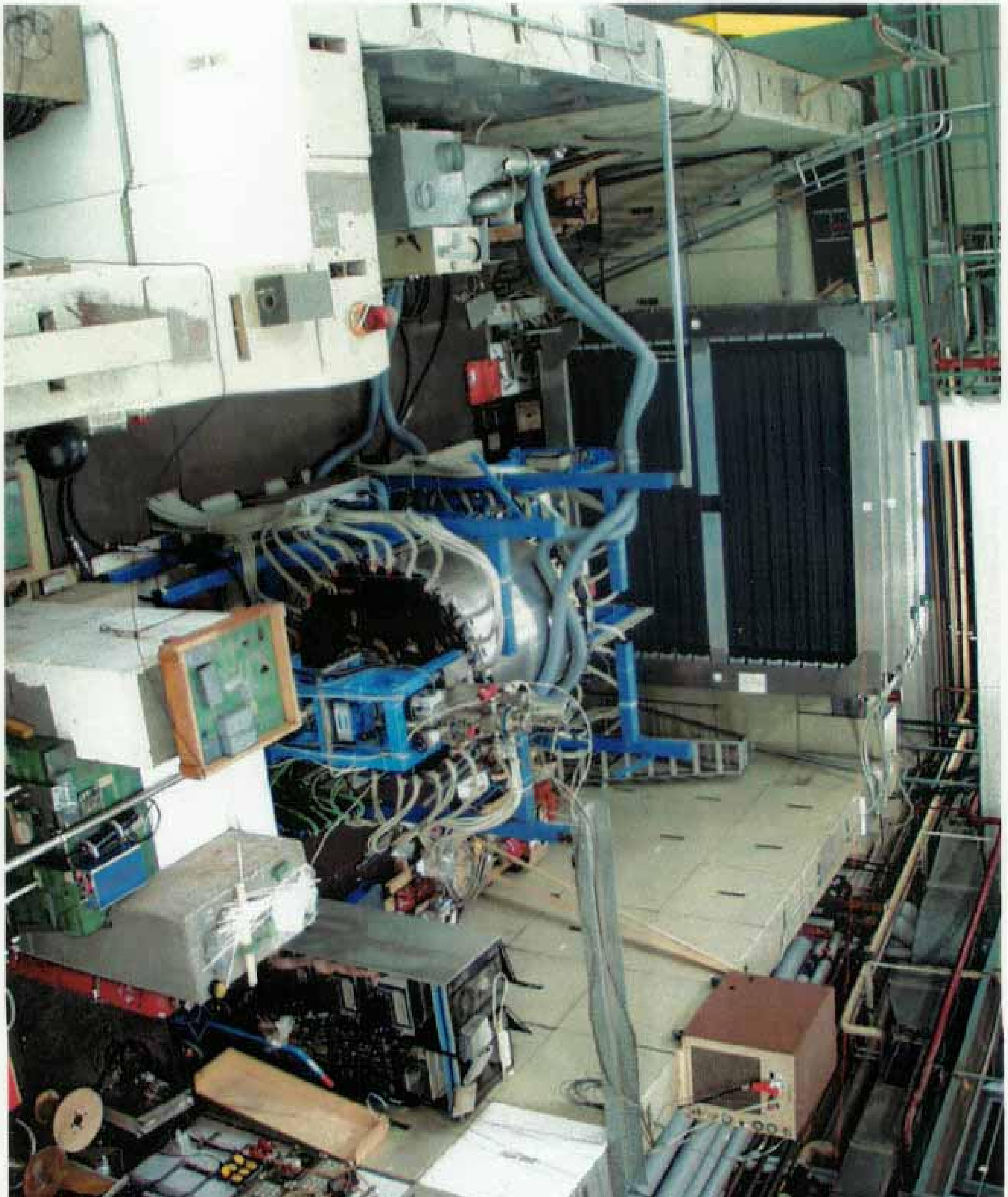
LH_2 target

Crystal Barrel
1380 CsI crystals
98% 4π coverage

Photon tagging system:
$0.31\,E_0 < E_\gamma < 0.94\,E_0$
total flux: $2\;10^6$/s

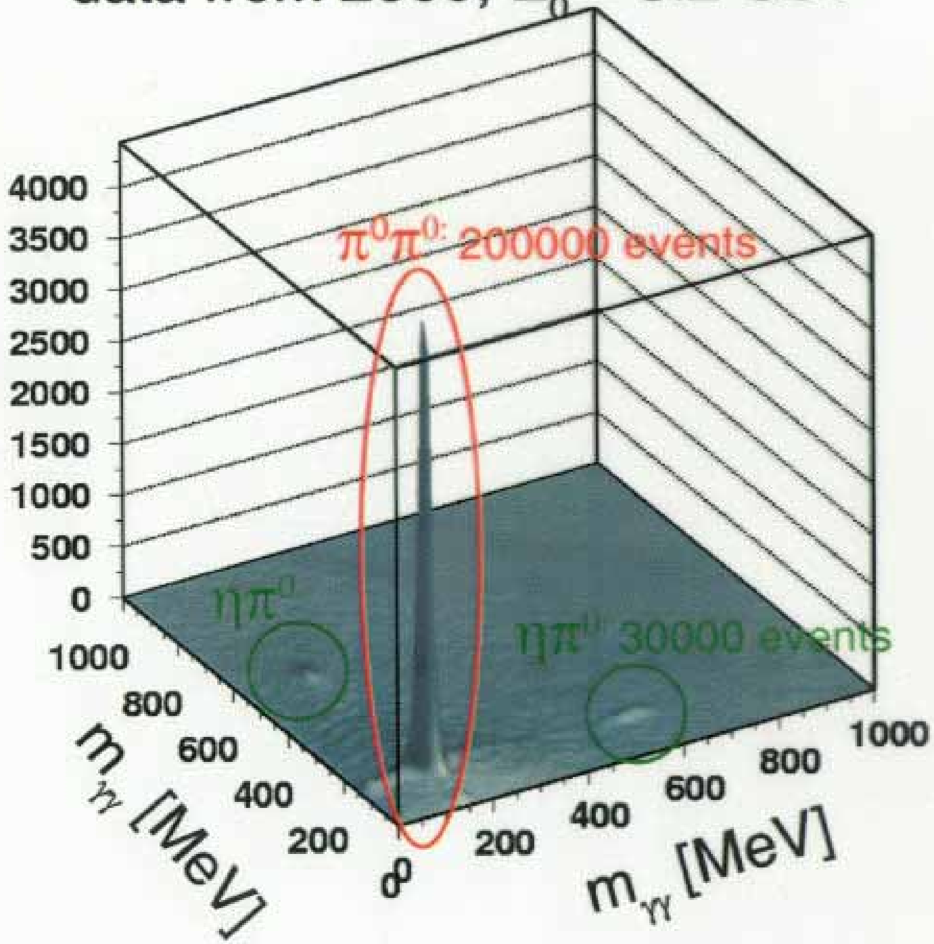
electron beam
from ELSA
$E_0 \leq 3.2$ GeV

The Crystal Barrel Experiment

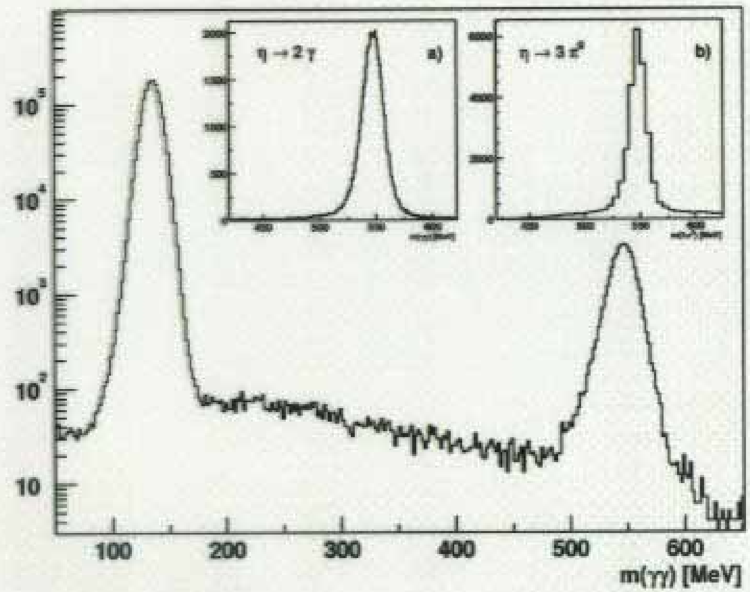


CB detects multiphoton final states

data from 2000, E_0 = 3.2 GeV



Energy resolution



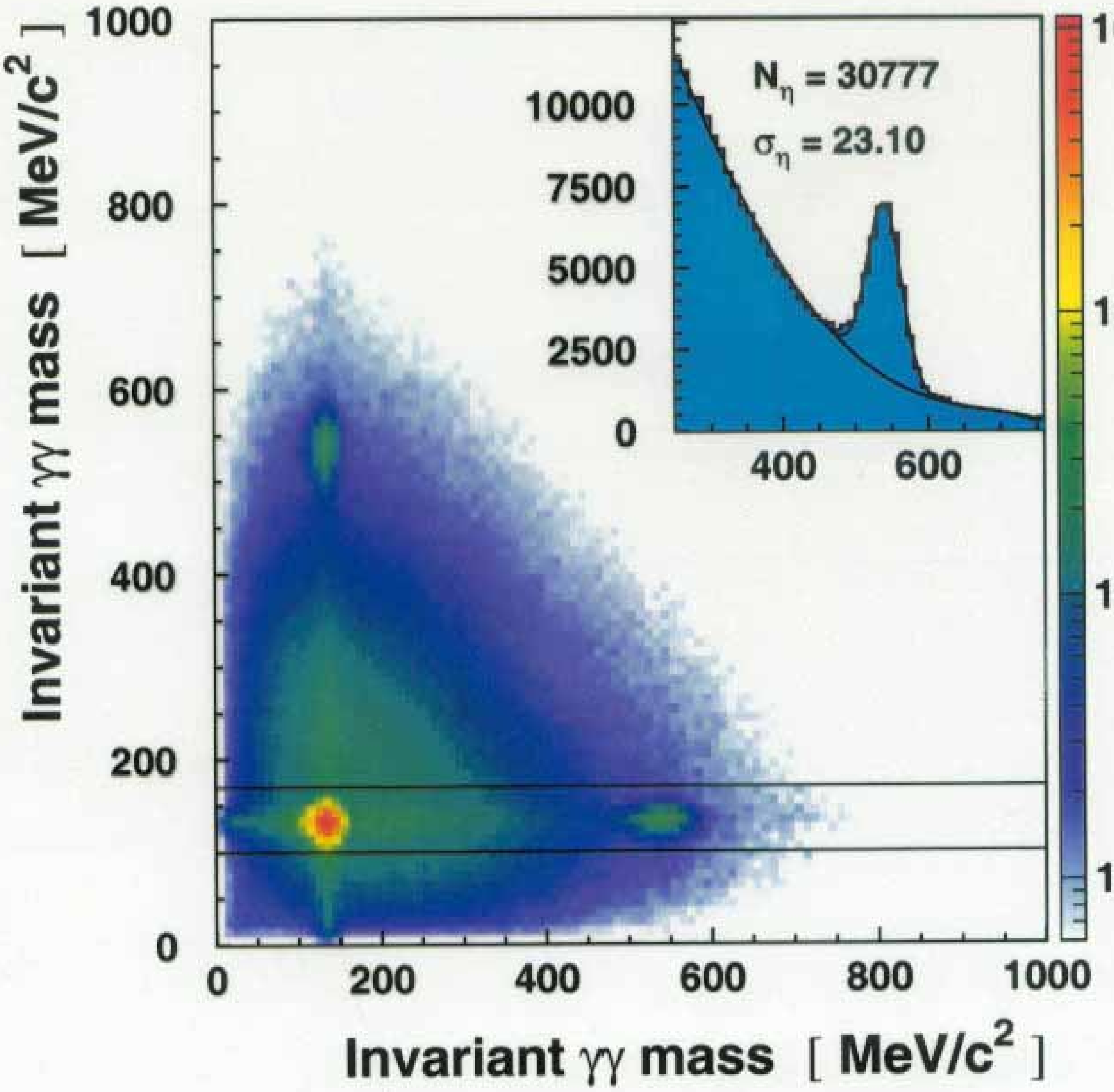
$\sigma(\pi^0) = 8.5$ MeV $\quad$ $\sigma(\eta) = 12$ MeV

η also reconstructed from 6 γ ($\eta \to \pi^0\pi^0\pi^0$)

$\gamma\,\mathbf{p} \;\rightarrow\; \mathbf{p}\,\pi^0\,\eta$

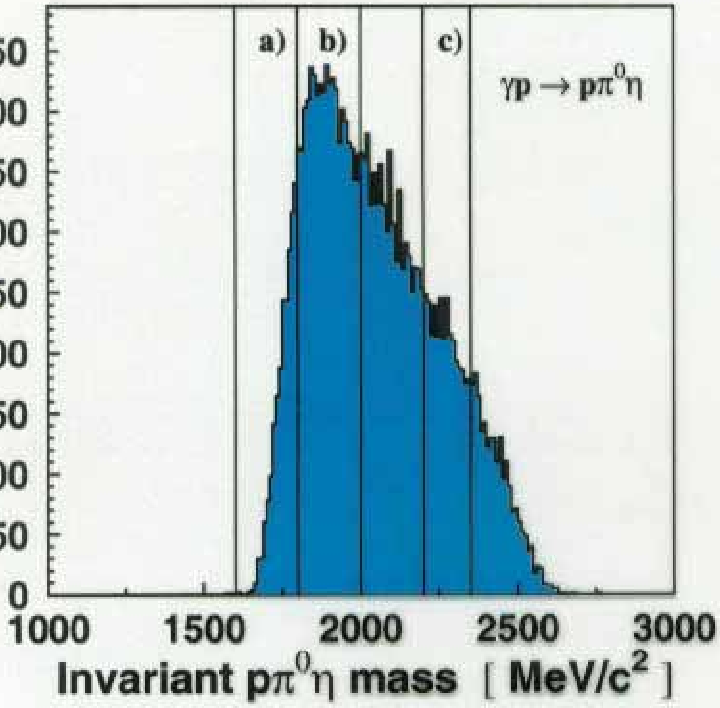
Data comprises full statistics of 3.2 GeV data:

- $\approx$ 200 000 events of $\gamma\,p \;\rightarrow\; p\,\pi^0\,\pi^0$
- $\approx$ 50 000 events of $\gamma\,p \;\rightarrow\; p\,\pi^0\,\eta$

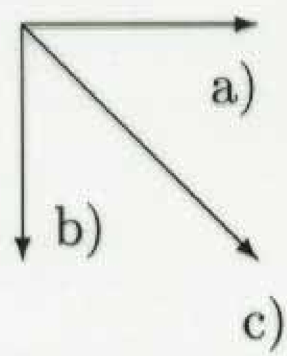


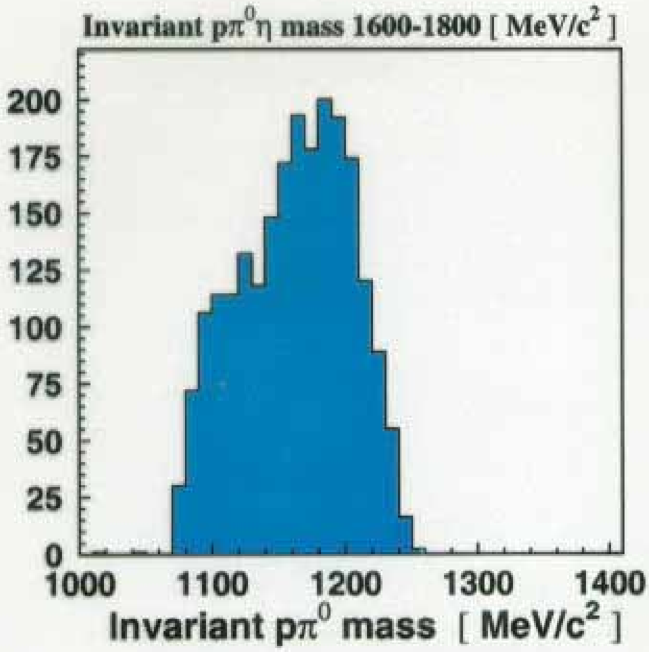
Clear evidence for $\gamma\,p \;\rightarrow\; p\,\pi^0\,\eta$

$\gamma\,\mathbf{p} \;\rightarrow\; \mathbf{p}\,\pi^0\,\eta$



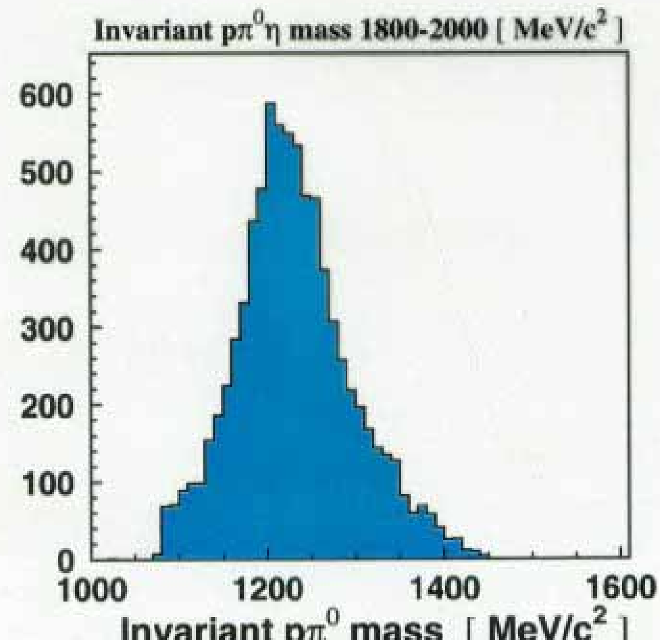
Very preliminary results!!

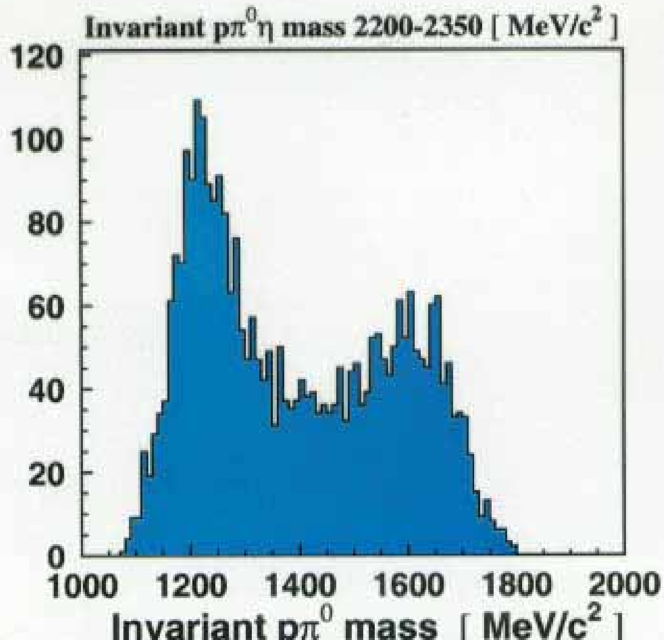




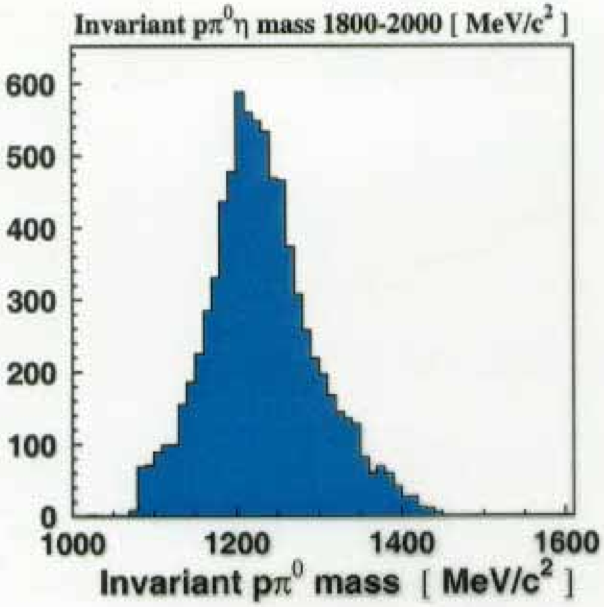
Indications for

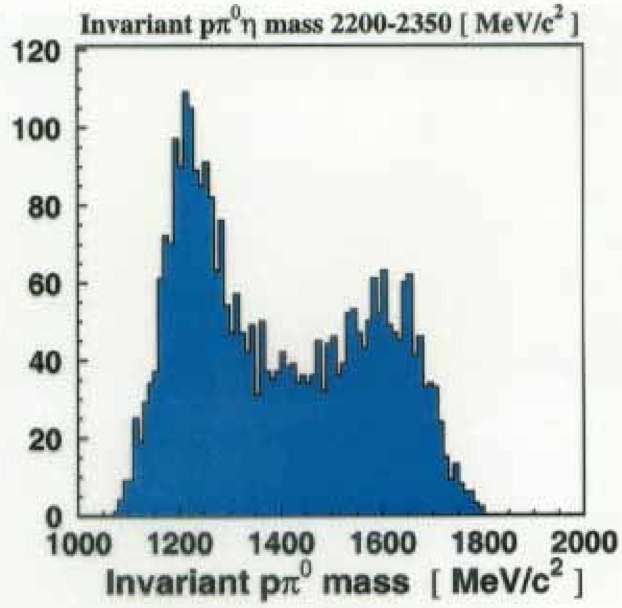
$\Delta(1940)D_{33} \rightarrow \Delta\eta$?





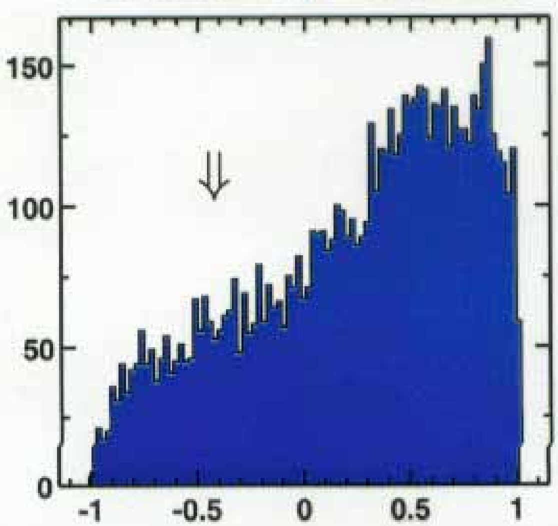
Identification of higly-excited states





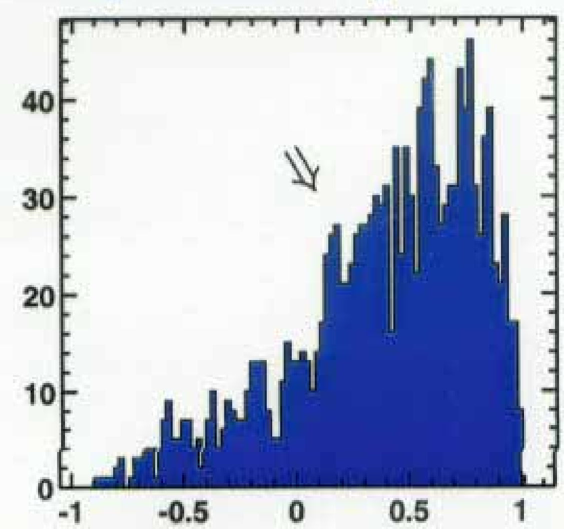
⇓ Cut on the $\Delta(1232)$ ⇓

resonance production



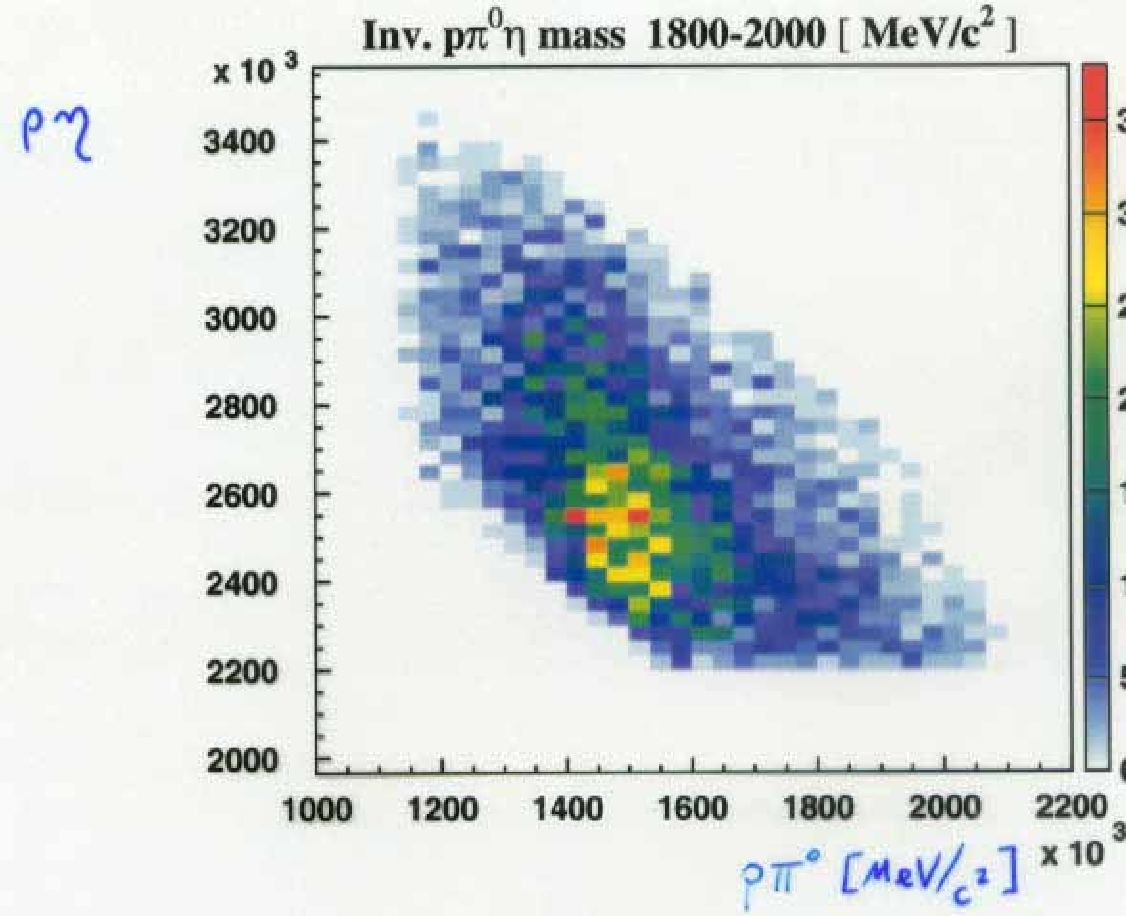
$\cos(\theta)_{\rm CMS}$ of η

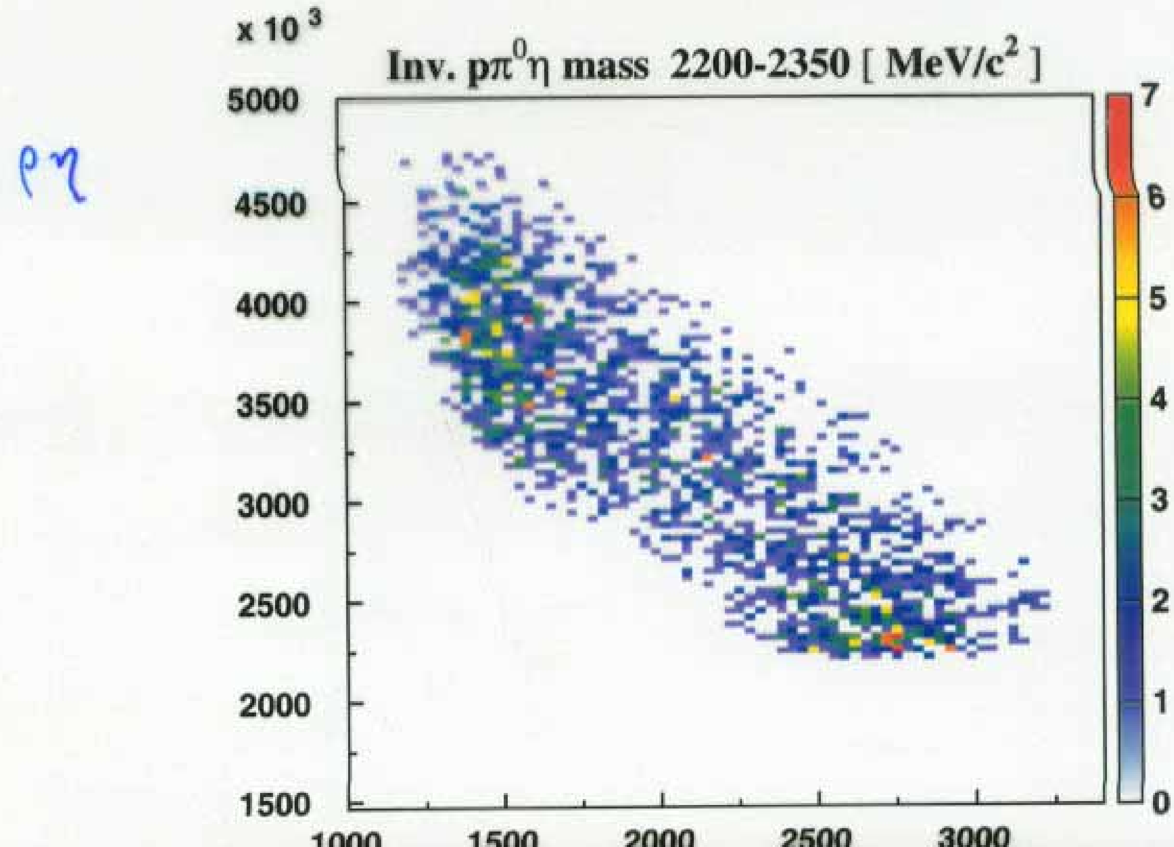
mainly diffractive production



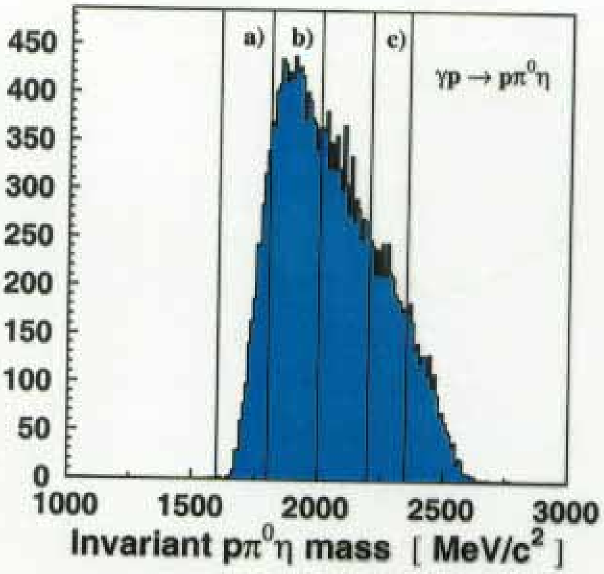
$\cos(\theta)_{\rm CMS}$ of η

$\gamma\,\mathbf{p} \;\rightarrow\; \mathbf{p}\,\pi^0\,\eta$





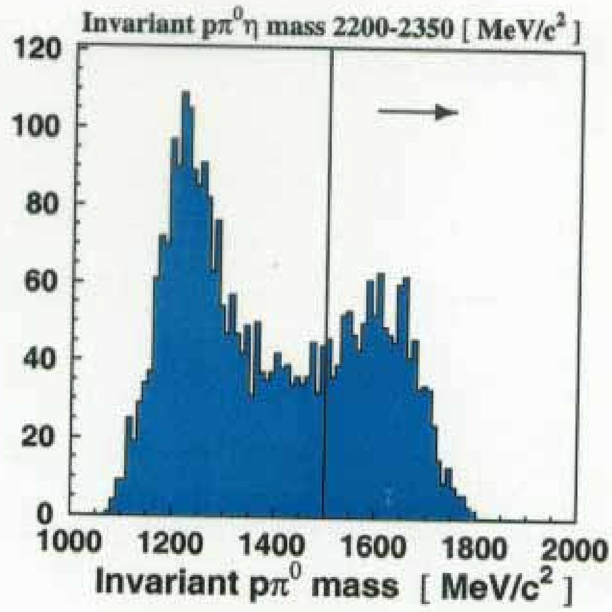
Identification of higly-excited states

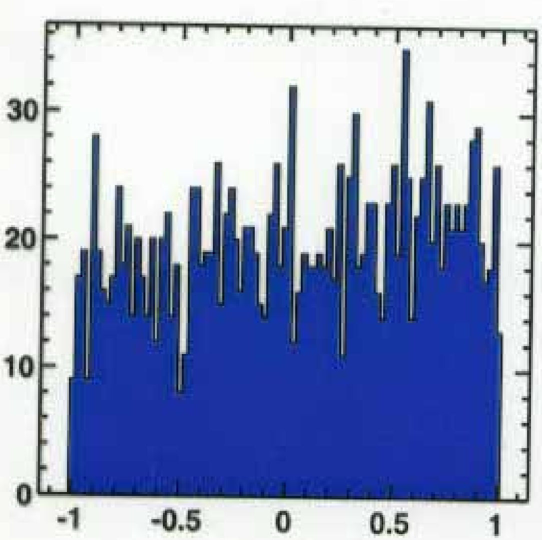


$p\pi^0$ invariant mass of (c)

Cut on structure

$> 1500\ \mathrm{MeV}/c^2$





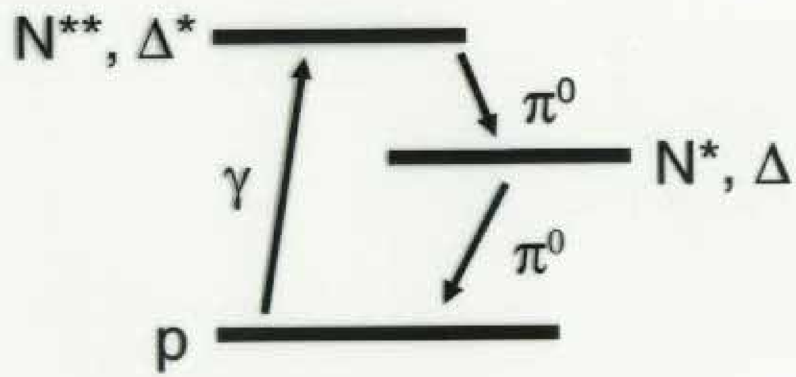
$\cos(\theta)_{\mathrm{CMS}}$ of η

resonance production

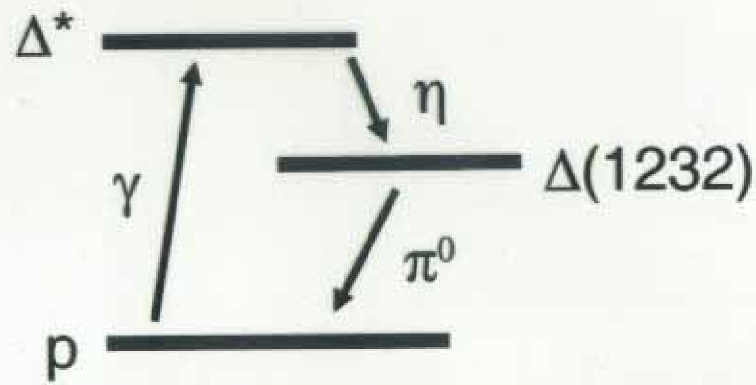
Multiphoton final states

Advantages: suppress non–resonant production
look for subsequent decays

$\gamma p \rightarrow p \pi^0 \pi^0$



$\gamma p \rightarrow p \pi^0 \eta$



Emission of isoscalar η and cut on $\Delta(1232)$: $\Rightarrow 1^{st}$ resonances Δ^* only

Effective chiral restoration of highly-excited baryons I

QCD: approximate $SU(2)_L \times SU(2)_R$ symmetry

$\Downarrow$

spontaneously broken

parity doublets of highly-excited baryons

$\Downarrow$

restoration of chiral symmetry in the limit of large excitation energies

(L.Ya. Glozman, Phys. Lett. **B475** (2000) 329)

(i) $(\frac{1}{2},0) \oplus (0,\frac{1}{2}) \rightarrow$ parity doublets for N spectrum

(ii) $(\frac{3}{2},0) \oplus (0,\frac{3}{2}) \rightarrow$ parity doublets for Δ spectrum

(iii) $(\frac{1}{2},1) \oplus (1,\frac{1}{2})$
$\rightarrow$ one parity doublet in N spectrum and one in Δ spectrum of same spin that are degenerate in mass

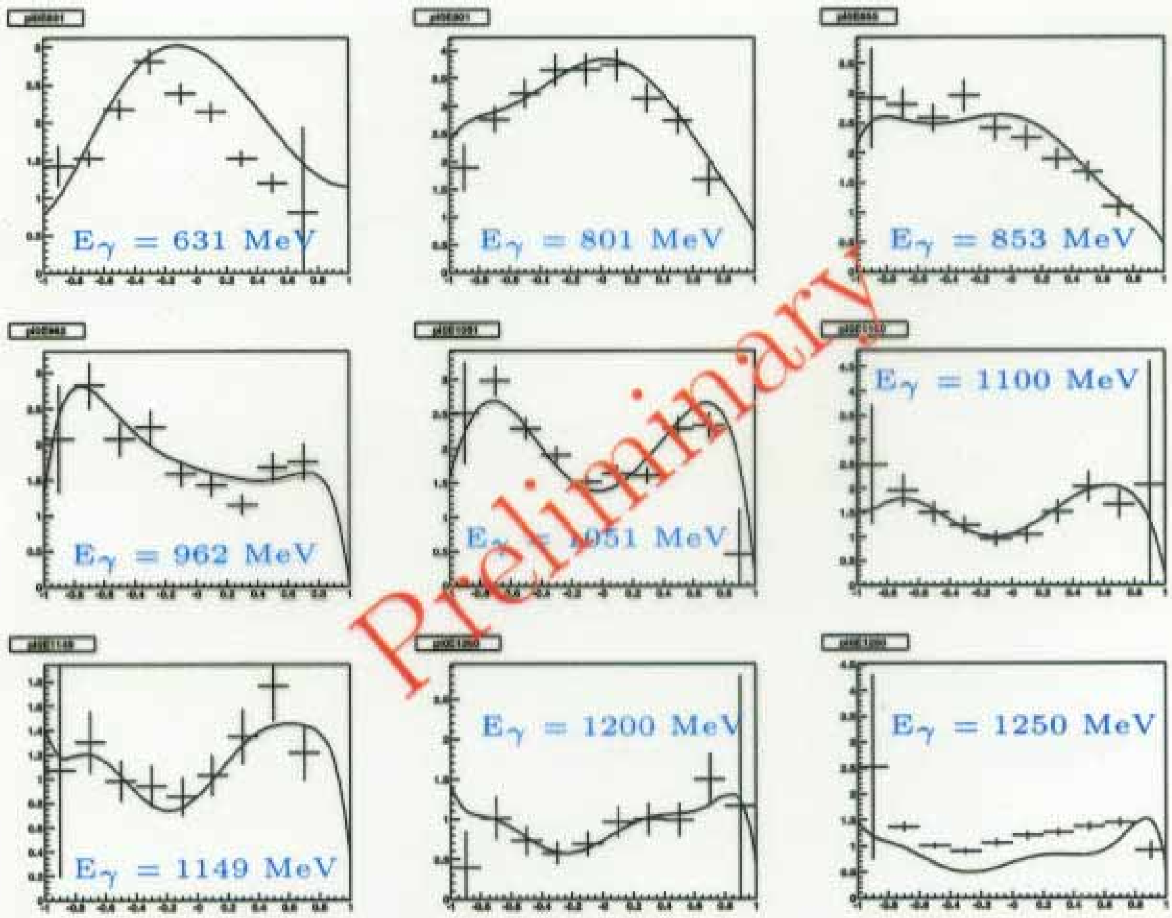
$\Rightarrow$ spectroscopic data for nonstrange baryons in the ≈ 2 GeV range is consistent with all possibilities

$\Rightarrow$ However: approximate degeneracy of parity doublets in N and Δ spectrum support (iii)

$J = \frac{1}{2}$	$N_{\frac{1}{2}+}(2100)(*)$	$N_{\frac{1}{2}-}(2090)(*)$
	$\Delta_{\frac{1}{2}+}(1910)$	$\Delta_{\frac{1}{2}-}(1900)$
$J = \frac{3}{2}$	$N_{\frac{3}{2}+}(1900)$	$N_{\frac{3}{2}-}(2080)$
	$\Delta_{\frac{3}{2}+}(1920)$	$\Delta_{\frac{3}{2}-}(1940)(*)$
$J = \frac{5}{2}$	$N_{\frac{5}{2}+}(2000)$	$N_{\frac{5}{2}-}(2200)$
	$\Delta_{\frac{5}{2}+}(1905)$	$\Delta_{\frac{5}{2}-}(1930)$
$J = \frac{7}{2}$	$N_{\frac{7}{2}+}(1990)$	$N_{\frac{7}{2}-}(2190)$
	$\Delta_{\frac{7}{2}+}(1950)$	$\Delta_{\frac{7}{2}-}(2200)(*)$
$J = \frac{9}{2}$	$N_{\frac{9}{2}+}(2220)$	$N_{\frac{9}{2}-}(2250)$
	$\Delta_{\frac{9}{2}+}(2300)$	$\Delta_{\frac{9}{2}-}(2400)$
$J = \frac{11}{2}$	?	$N_{\frac{11}{2}-}(2600)$
	$\Delta_{\frac{11}{2}+}(2420)$	?
$J = \frac{13}{2}$	$N_{\frac{13}{2}+}(2700)$	?
	?	$\Delta_{\frac{13}{2}-}(2750)$
$J = \frac{15}{2}$	?	?
	$\Delta_{\frac{15}{2}+}(2950)$	?

Acceptance studies

$$\gamma\, p \;\rightarrow\; p\, \pi^0$$



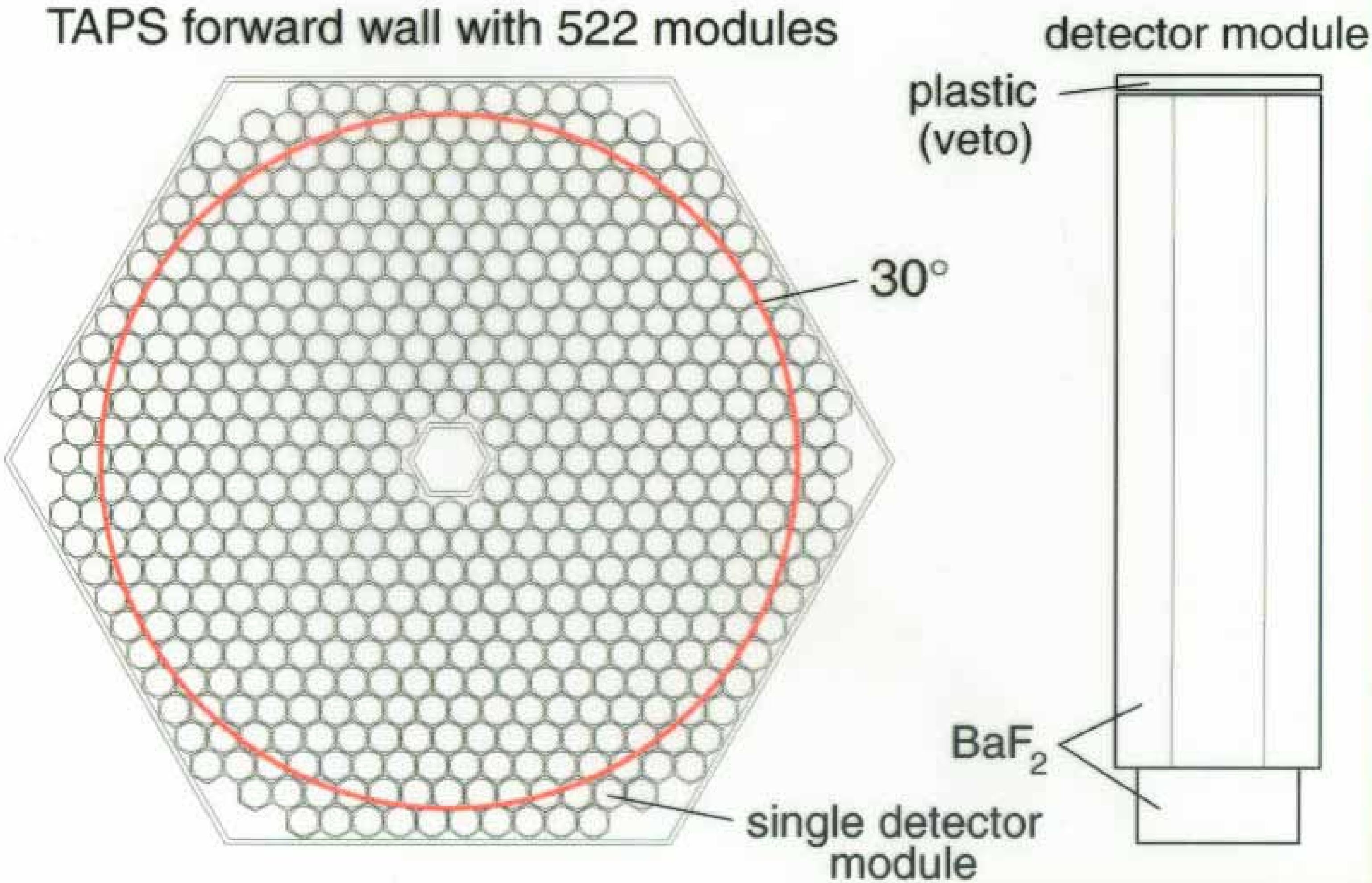
black line: SAID predictions

- Distributions normalised to SAID
- Angular distributions from CB-ELSA in the energy range E_γ = 800 - 1200 MeV are well reproduced by the SAID predictions

⇒ Differential cross sections in preparation

The Crystal Barrel and TAPS

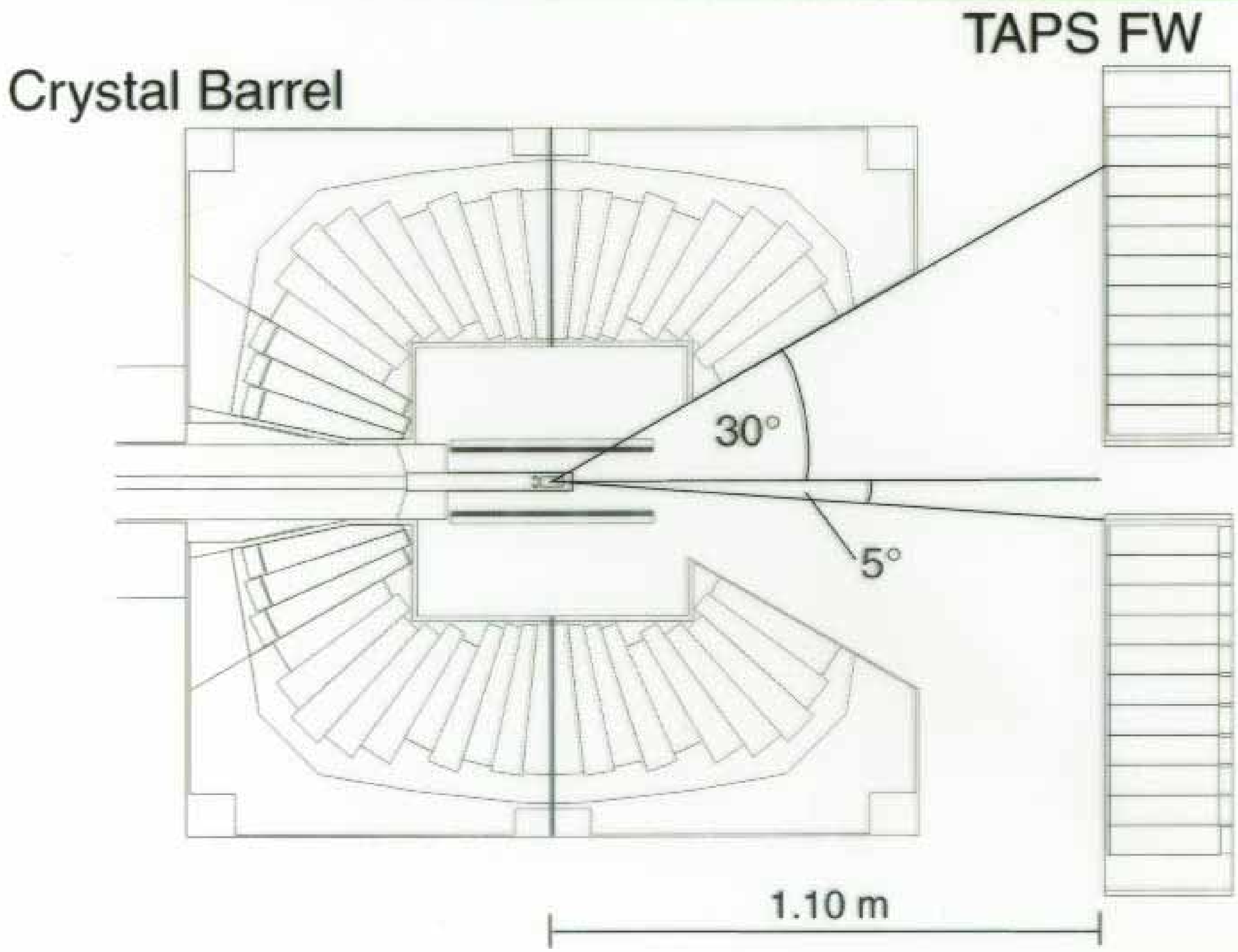
CB ELSA Collaboration



TAPS

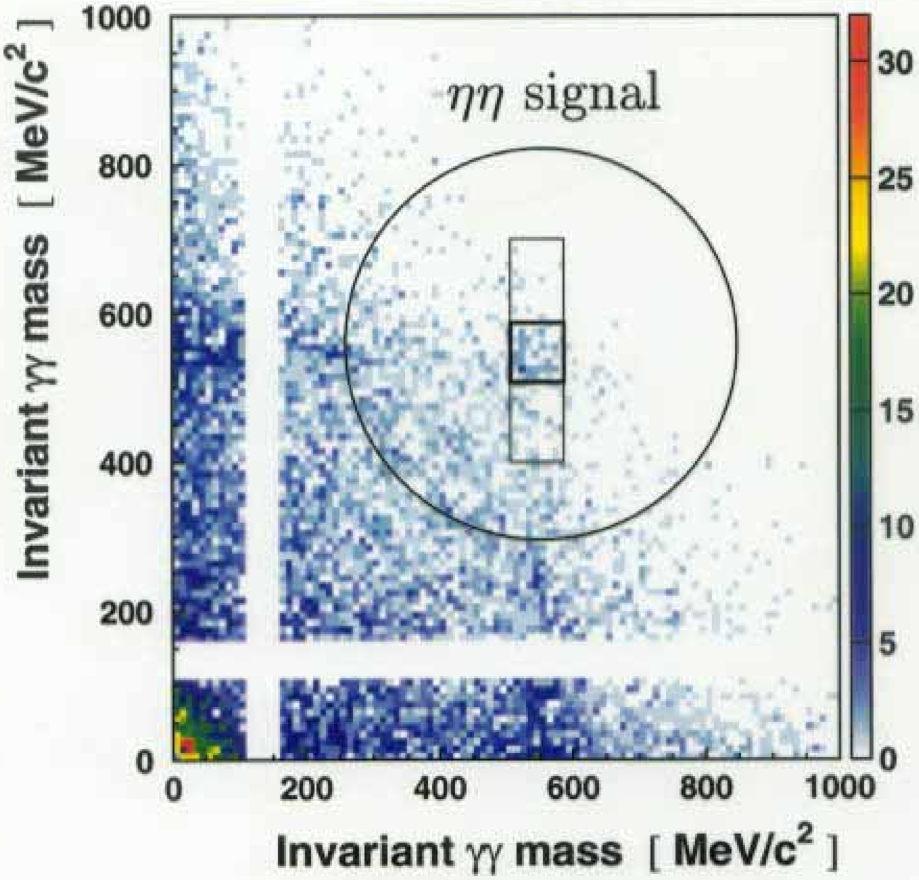
The Crystal Barrel and TAPS

CB ELSA Collaboration

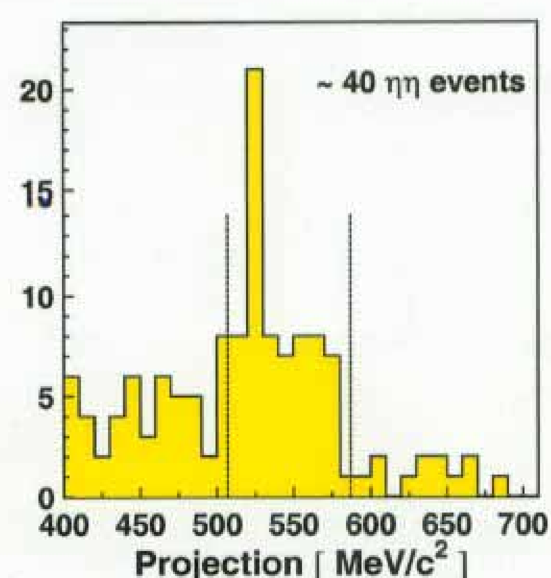


TAPS

$\gamma p \rightarrow p \eta \eta$



10 days of beam time ⇘



From September 2002

- higher beam intensity
- faster DAQ

$\Rightarrow$ 8× faster data rate

Summary and outlook

Good quality of data in various channels.

$\Downarrow$

Nucleon-resonance structures already visible

Missing resonances?

Hints for resonance production of $\Delta(1900)$

Further investigation of nucleon excitation spectrum!

- Improvement of reconstruction
- Determination of cross sections
  - $\gamma p \rightarrow p\pi^0$ and $\gamma p \rightarrow p\eta$
  - $\gamma p \rightarrow p\pi^0\pi^0$ and $\gamma p \rightarrow p\pi^0\eta$
- Partial wave analyses (PWA)