Photon beam asymmetry Σ for η, η', and ω photoproduction from the proton

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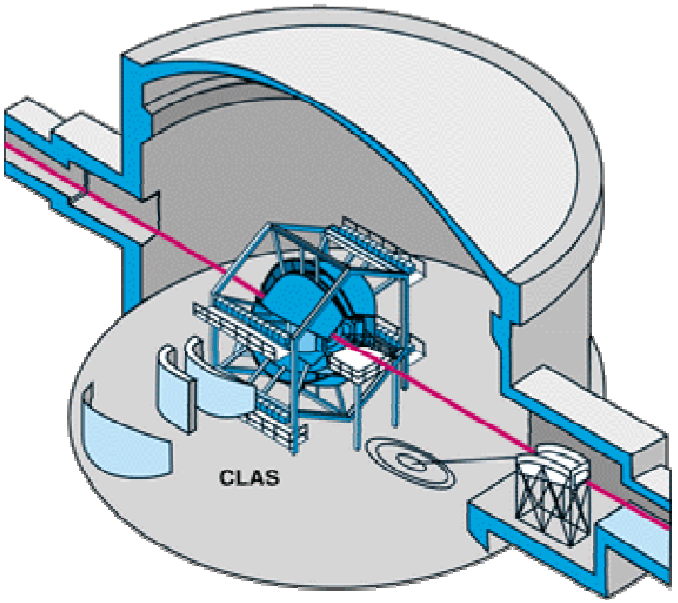

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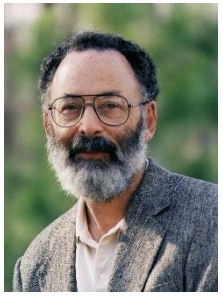
a longstanding mystery…

VOLUME 44, NUMBER 13 PHYSICAL REVIEW LETTERS 31 MARCH 1980

Where Have All the Resonances Gone? An Analysis of Baryon Couplings in a Quark Model with Chromodynamics

Roman Koniuk and Nathan Isgur
Department of Physics, University of Toronto, Toronto, Ontario M5S 1A7, Canada
(Received 26 November 1979)



- one of the principle motivations for "old" CLAS
- the nucleon represents a key testbed
- "*still crazy after all these years*" (~4 decades)
  - only 11 of 27 hinted *N* states have reached "****" status
  - only 7 of 22 hinted Δ states have reached "****" status

Meson photoproduction with polarized photons

- Photoproduction of mesons from nucleons with polarized photons provides **a powerful and precise tool** for picking apart the nucleon resonance spectrum.
- At ASU, we've focused on **non-strange** mesons.
- Photoproduction of η, η', and ω mesons is particularly interesting since:
  - these mesons provides an "isospin filter" for the nucleon resonance spectrum, isolating contributions from I=½ excitations.
  - different $s\bar{s}$ components in their quark compositions may lead to stringent tests of quark-based models of their production.

Photon beam asymmetry Σ

- A relatively simple observable using an unpolarized target and linearly-polarized photons:

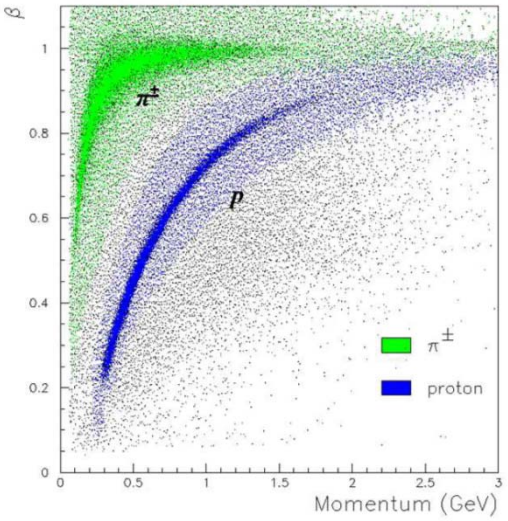
$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega}\left[1 - P_\gamma \Sigma \cos\{2\,(\varphi - \alpha)\}\right]$$

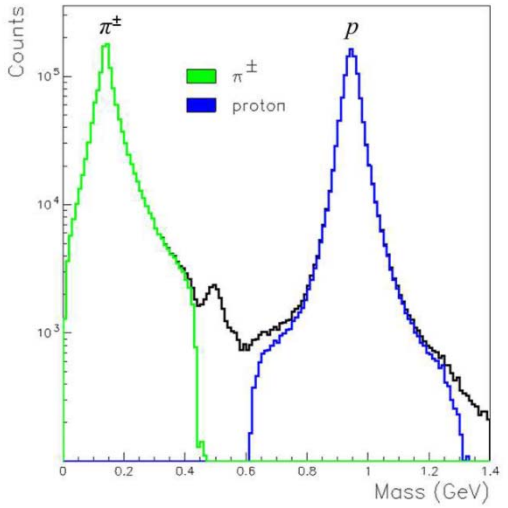
$$\Sigma = \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel}$$

- For pseudoscalar mesons, the photon beam asymmetry Σ is given by 2 $Re(S_1^* S_2 - ND)$

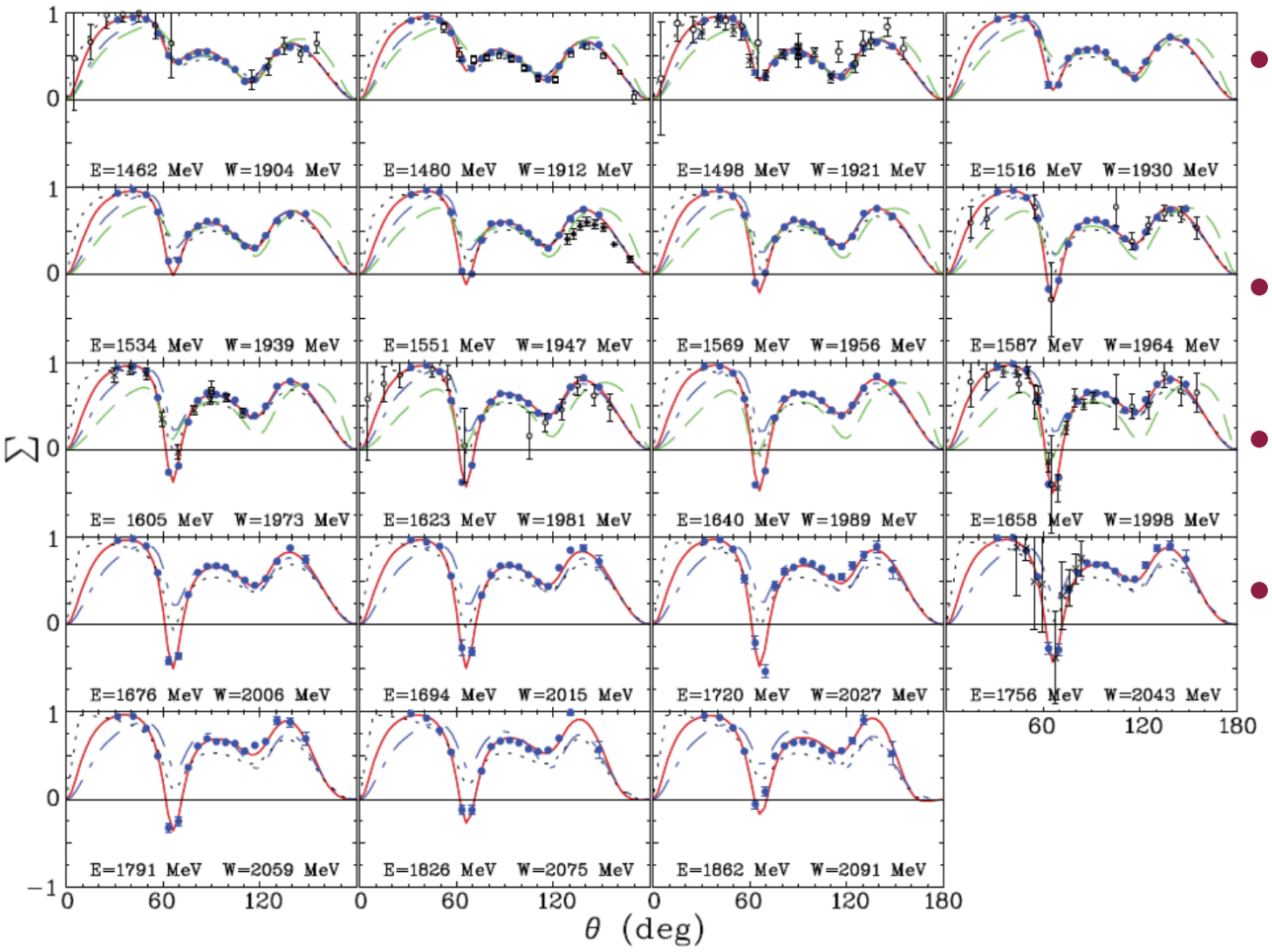
g8b: June 28-September 1, 2005

- Longitudinally-polarized photons
  - coherent bremsstrahlung (50 μm diamond)
  - coherent edge at E_γ= 1.3, 1.5, 1.7, 1.9 GeV
- 40-cm liquid hydrogen target
- CLAS: nominal photon running configuration
  - 50% maximum **B** field, positive out-bending
  - time-of-flight info from 24-element Start Counter array + CLAS TOF system



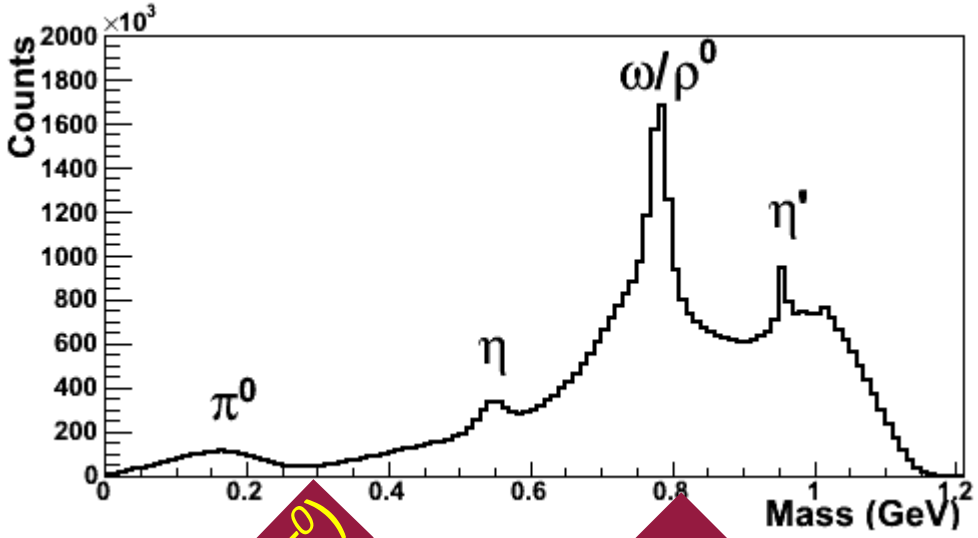


g8b: previously-published Σ data for π^+ and π^0 on proton



- CLAS: M. Dugger *et al.*, Phys Rev C **88**, 065203 (2013).
- Introduced Fourier-moment method
- 700 π^0 and 386 π^+ data points
- Significant changes in SAID analysis at higher *W*

η, η', and ω photoproduction



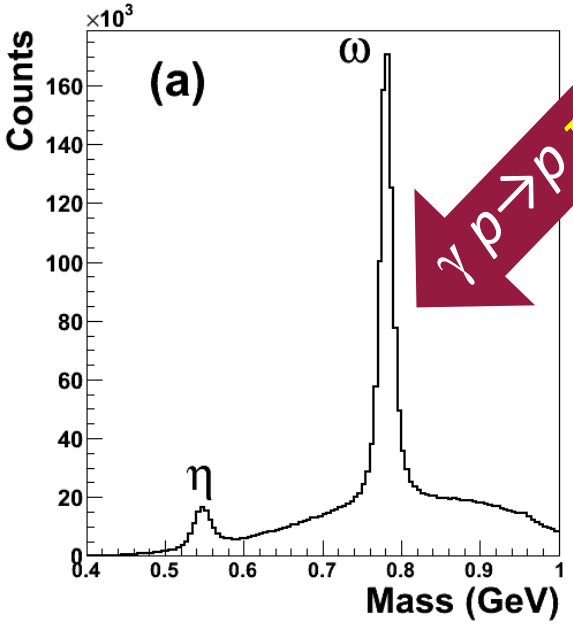
$\gamma p \rightarrow p \pi^+ \pi^- (\pi^0)$

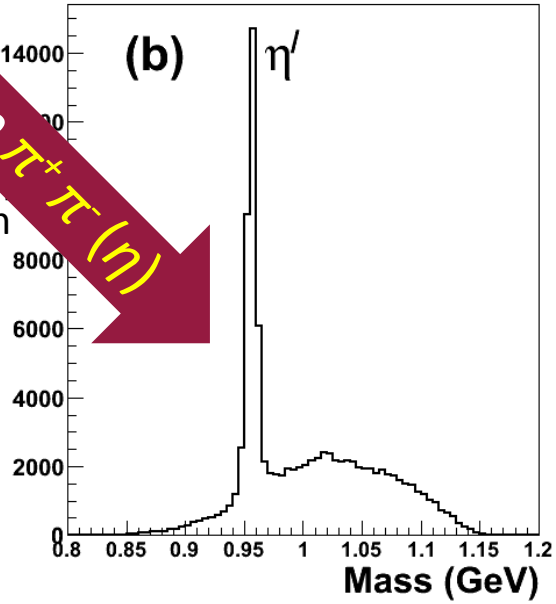
η: 22.9% branch

ω: 89.2% branch

$\gamma p \rightarrow p \pi^+ \pi^- (\eta)$

η': 42.9% branch

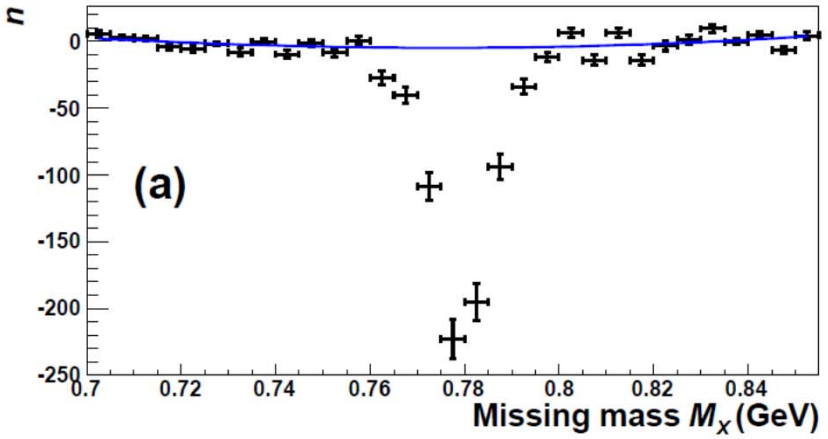


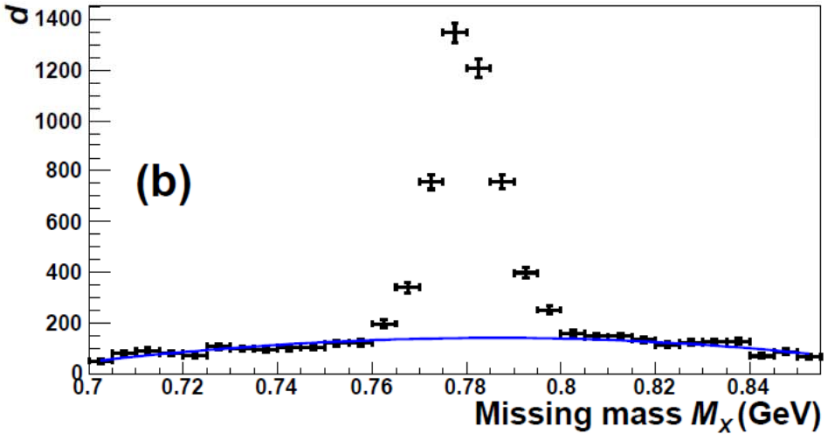


Σ using Fourier-moment method

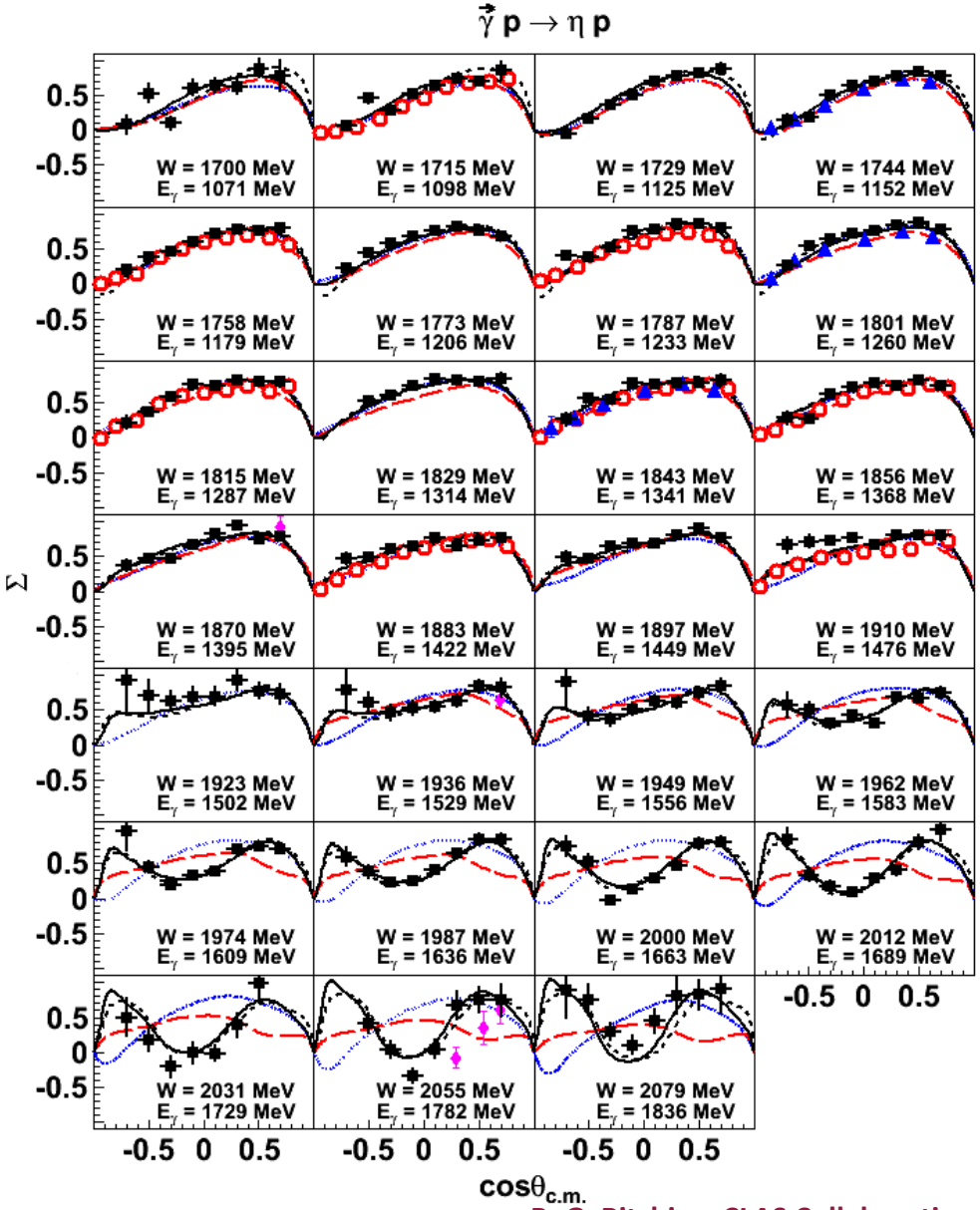
$$\Sigma = \frac{\tilde{Y}_{\perp 2} - \tilde{Y}_{\parallel 2}}{\frac{P_\parallel}{2}(\tilde{Y}_{\perp 0} + \tilde{Y}_{\perp 4}) + \frac{P_\perp}{2}(\tilde{Y}_{\parallel 0} + \tilde{Y}_{\parallel 4})}$$

- Each $Y_{\perp m}$ is the
  - photon-normalized yield for ⊥ polarization
  - weighted by cos $m\varphi$
  - where $P_\perp$ is degree of linear polarization for the ⊥ orientation
- Similar expressions for $Y_{\parallel m}$





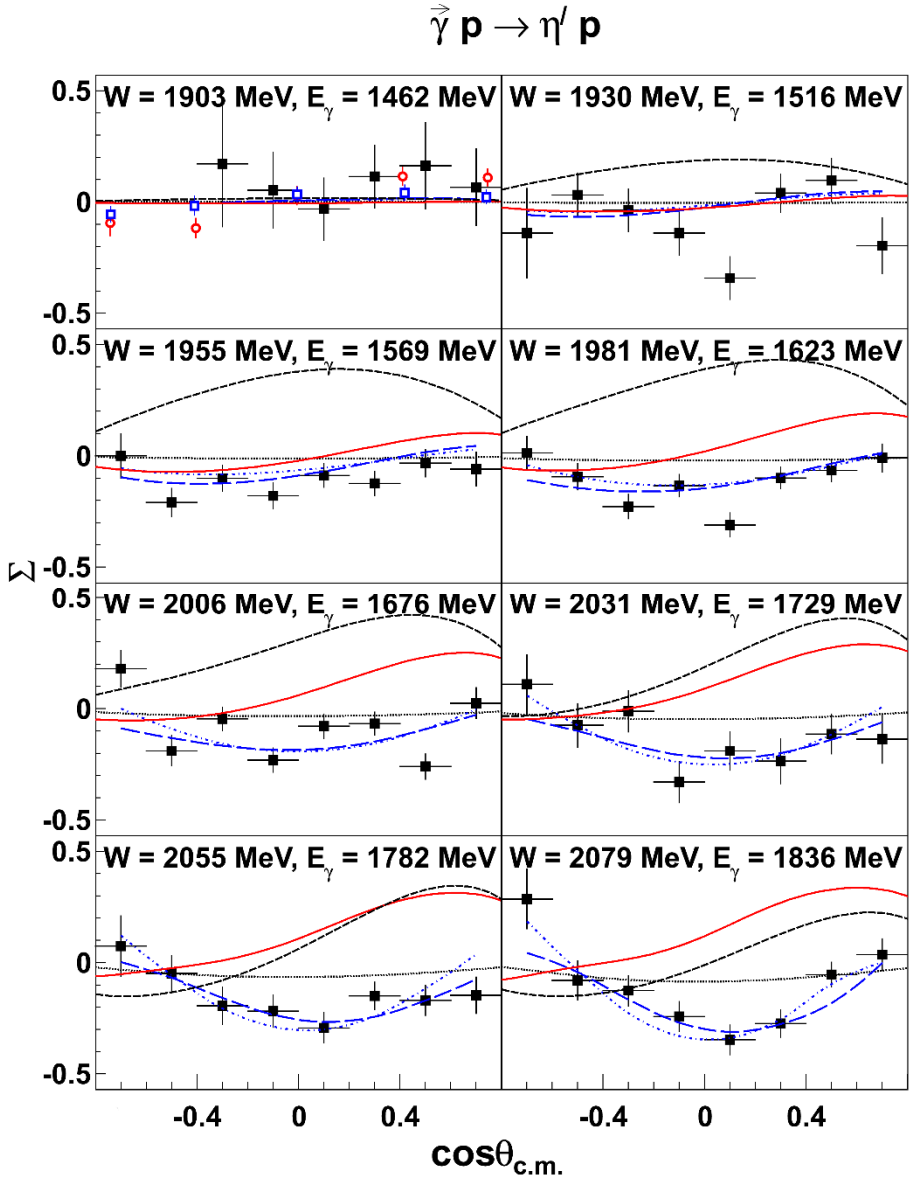
η photoproduction results



- CLAS: P. Collins *et al.*, Phys Lett B **771**, 213 (2017) - 266 points distributed over 27 *W* bins
- ▲ CB-ELSA/TAPS (2007)
- ○ GRAAL (2015)
- ◆ Vartapetian, Piliposian (1980)

will come back to the curves in a moment…

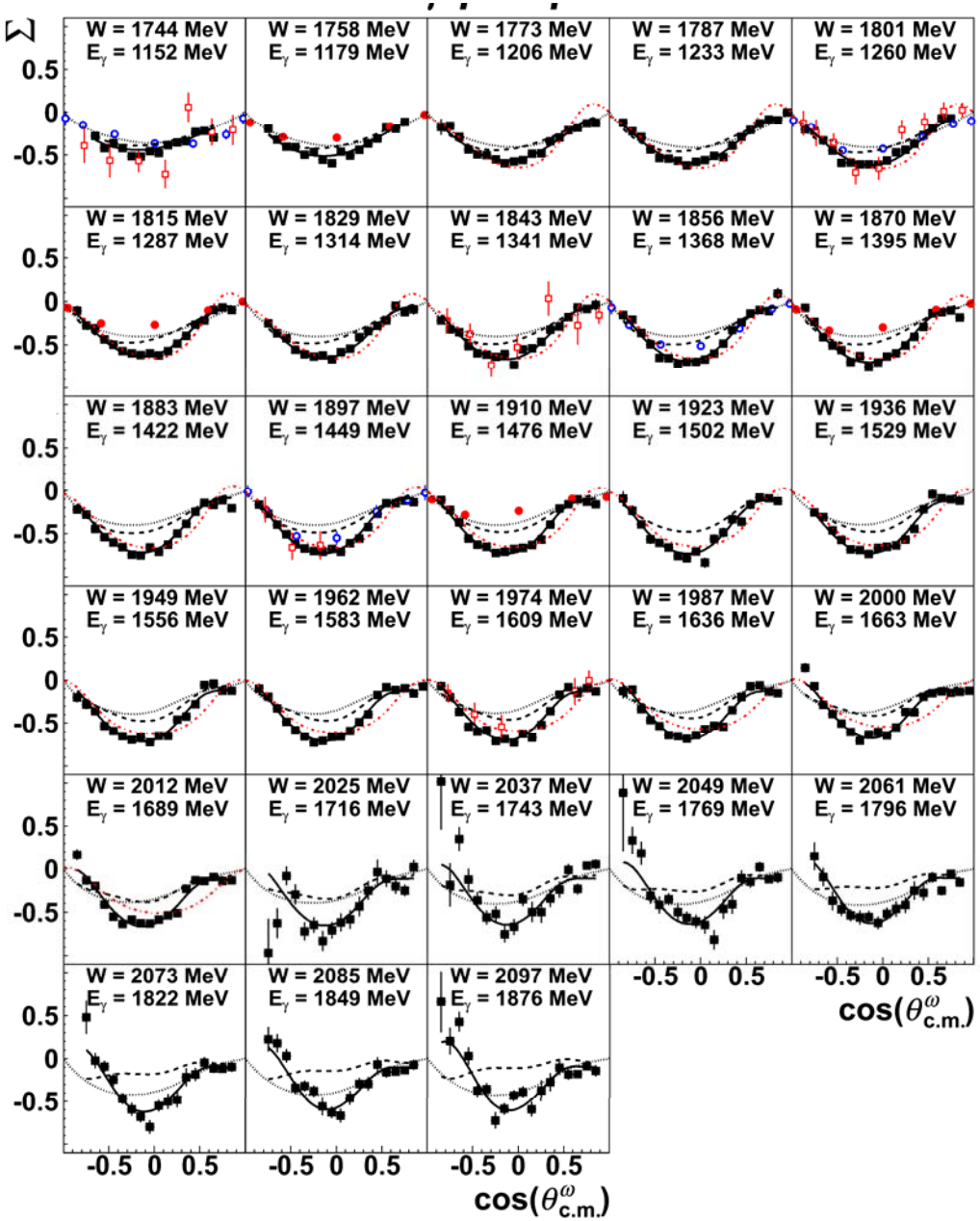
η' photoproduction results



- CLAS P. Collins *et al.*, Phys Lett B **771**, 213 (2017) - 62 points distributed over 8 *W* bins
- GRAAL, 1.461 GeV
- GRAAL, 1.480 GeV

will come back to the curves in a moment…

ω photoproduction results

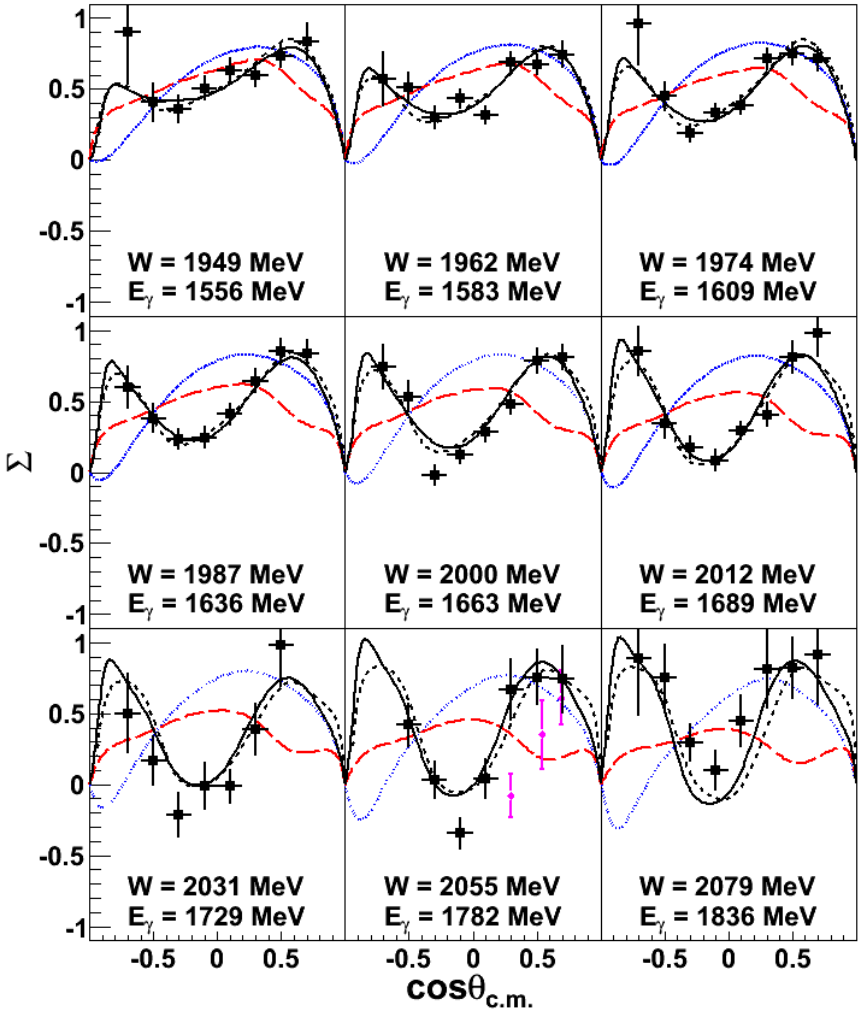


- CLAS P. Collins *et al.*, submitted to Phys Lett B - 547 data points distributed over 28 *W* bins
- GRAAL (2006)
- GRAAL (2015)
- CB-ELSA/TAPS (2015)

will come back to the curves in a moment…

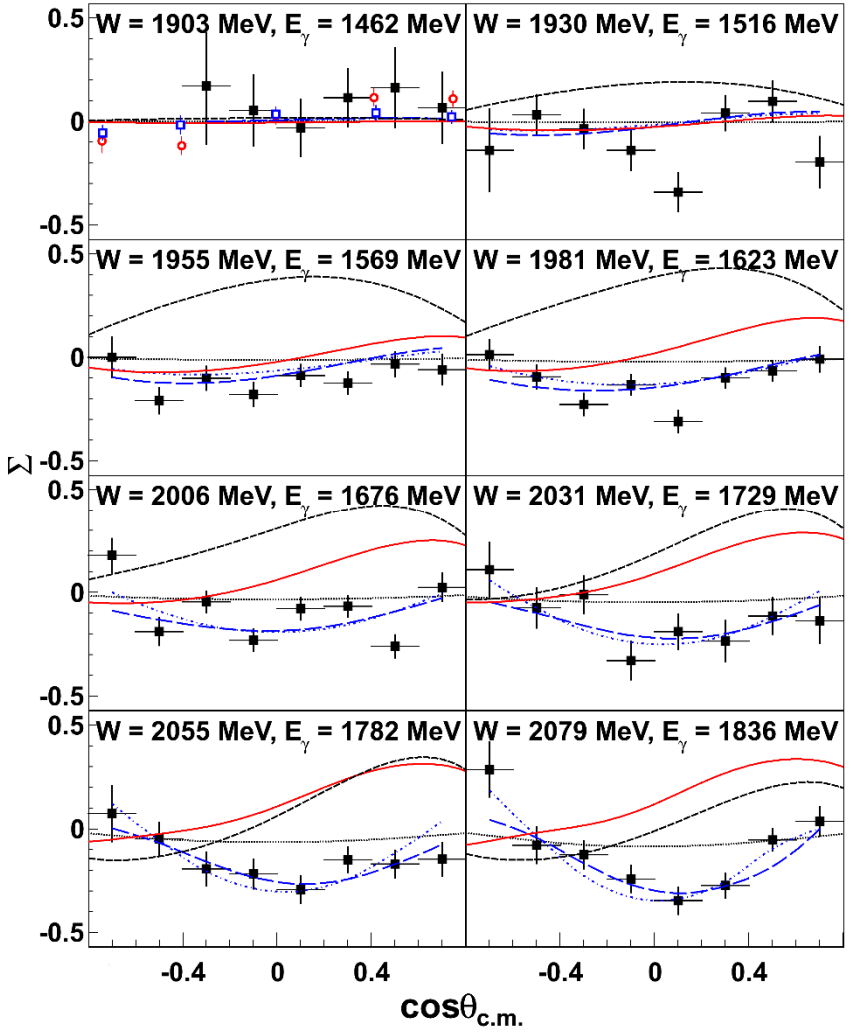
η photoproduction study with Jülich-Bonn model

- SAID (blue dotted line) and ETA-MAID (red dashed line) do not predict the structure in Σ above W=1.96 GeV.
- One question: How important is the N(1900)3/2$^+$ state in η photoproduction?
- Fits to these new data gave sizeable changes in the contributions from N(1720)3/2$^+$ and N(1900)3/2$^+$.
- Are those changes significant for Σ?
  - No. Compare black dashed and black solid lines.
  - So may not a good channel to test how important the N(1900)3/2$^+$ is.
- Stay tuned: More work is in progress.

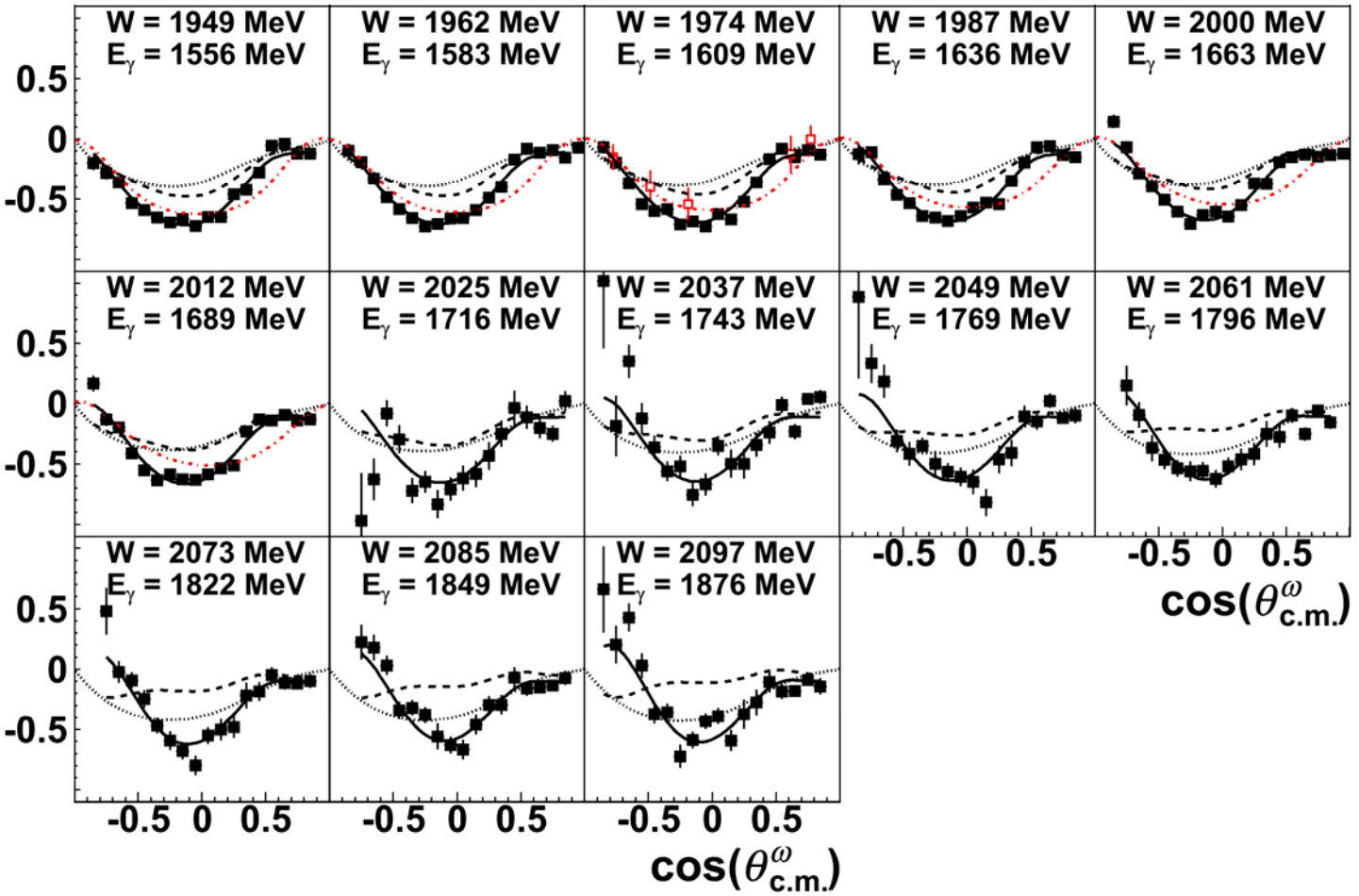


η' photoproduction study with Bonn-Gatchina model

- SAID (black dotted line), ETA-MAID (red solid line), and NH (black dashed line) don't work so well.
- New fits with BG model work well
  - Two solutions give comparable fits
  - *N*(1900)3/2+ is important! May push this state to "****"
  - Statistically significant η' branches for *N*(1895)1/2$^-$, *N*(1900)3/2$^+$, *N*(2100)1/2$^+$, and *N*(2120)3/2$^-$
- Stay tuned: More work in progress (Anisovich *et al.*, submitted to PLB).



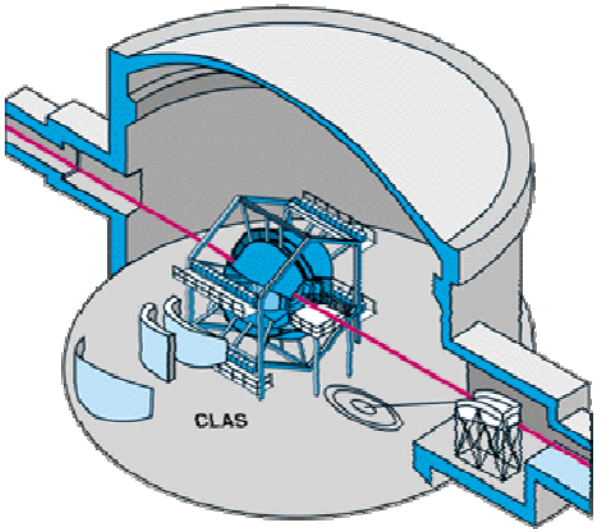
ω photoproduction study with Bonn-Gatchina model



- BG fit with (black solid line) and without (black dashed line) incorporating these new data
- Refinement of leading amplitude (Pomeron and $3/2^+$ partial waves) inter-ferences

Conclusions

- Lots of new Σ data on multiple channels.
- Strengthened cases for the $N(1895)1/2^-$, $N(1900)3/2^+$, $N(2100)1/2^+$, and $N(2120)3/2^-$ states
- Very fruitful collaborations working closely with JB and BG theory groups
- Polarization observables are great tools
- New/more FROST data will be particularly helpful in gaining further progress
- *"Still crazy after all these years…"*



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