EMMI RRTF - TOP3 short summary

Vitaly Shklyar

TOP3 short summary

In-medium physics

- heavy ion physics: in-medium physics, vector mesons (dilepton spectra)
- consistent treatment of ρ, N*, Δ^* is important: $\Gamma_{\Delta\to\pi N} \neq$ const
- model uncertanties (N* couplings, $\Gamma_{N^*\to\rho N} =?$)

Baryon spectroscopy

- reaction theory: understand elementary reactions in terms of meson and baryon degrees of freedom
- baryon spectroscopy: properties of baryon resonances
- bridge between LQCD, DSE, Quark model and experiment

Main questions

- Properties and decay strength of N^* and Δ^*:
- $N^*, \Delta^* \to \rho N$,
- $N^*, \Delta^* \to \Delta(1232)\pi$,
- $N^* \to \omega N$

Resonance → Nρ Branching Ratios

	GiBUU12	UrQMD09	KSU12	KSU92	BnGa12	CLAS12	PDG12	
$N(1520)3/2^-$	21	15	20.9(7)	21(4)	10(3)	12.7(4.3)	20(5)	D13
$N(1720)3/2^+$	87	73	1.4(5)	87(5)	10(13)	47.5(21.5)	77.5(7.5)	P13
$\Delta(1620)1/2^-$	29	5	26(2)	25(6)	12(9)	37(12)	16(9)	S31
$\Delta(1905)5/2^+$	87	80	<6	86(3)	42(8)		>60	F35

Partial courtesy of Piotr Salabura, Sept 2013

CLAS12: V. Mokeev *et al*, Phys Rev C **86**, 035203 (2012); V. Mokeev, PC
BnGa12: A.V, Anisovich *et al*, Eur Phys J A **48**, 15 (2012)
GiBUU12: J. Weil *et al*, Eur Phys J A **48**, 111 (2012); J. Weil, PC
KSU92: D.M. Manley and E.M. Saleski, Phys Rev D **45**, 055203 (1992)
KSU12: M. Shrestha and D.M. Manley, Phys Rev D **86**, 055203 (2012)
PDG12: J. Beringer *et al* [RPP] Phys Rev D **86**, 010001 (2012)
UrQMD09: K. Schmidt *et al*, Phys Rev C **79**, 4002 (2009)

Why $\pi N \to 2\pi N$ is important?

Pion-induced reactions:

$\pi^+ p \to \pi^0\pi^+ p$, $\pi^+ p \to \pi^+\pi^+ n$
$\pi^- p \to \pi^+\pi^- n$, $\pi^- p \to \pi^+\pi^- n$
$\pi^- p \to \pi^0\pi^0 n$ (...1.5 GeV Crytal Ball)

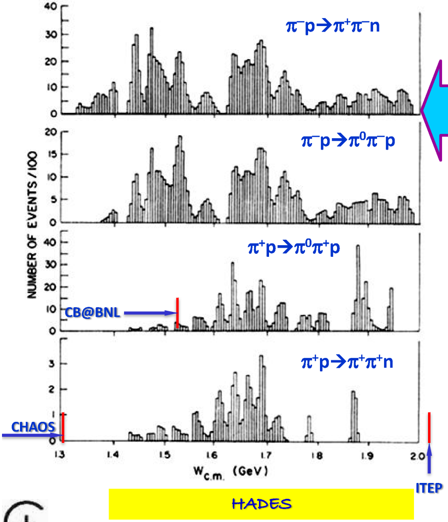
- Isospin decomposition : 4 independent isospin amplitudes (in isobar approximation)
- optical theorem $ImT^{JP}_{\pi N\to\pi N} = \frac{k^2}{4\pi}(\sigma^{JP}_{\pi N\to\pi N} + \sigma^{JP}_{\pi N\to 2\pi N} + \ldots)$

Photon-induced reactions:

$\gamma p \to \pi^+\pi^- n$, $\gamma p \to \pi^0\pi^- p$,
$\gamma p \to \pi^0\pi^0 p$

- No isospin decomposition is possible (separation between $I = \frac{1}{2}$ and $\frac{3}{2}$ states is more difficult)
- difficulties with the gauge invariance
- need input from hadronic reactions

Previous $\pi N \rightarrow \pi\pi N$ Measurements

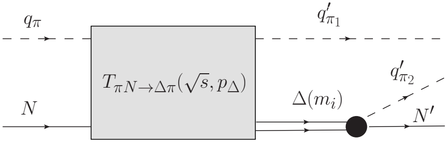


- **241,214** **Bubble Chamber** events for **$\pi N \rightarrow \pi\pi N$** have been analyzed in **Isobar-model PWA** at W = **1320** to **1930** MeV.
  [D.M. Manley, **R. Arndt**, Y. Goradia, V. Teplitz, Phys Rev D **30**, 904 (1984)]

- Recent **post-Bubble Chamber** measurements:
  - **349,611** events for **$\pi^- p \rightarrow \pi^0\pi^0 n$** from **CB@BNL** at W = **1213** to **1527** MeV. [S. Prakhov *et al* Phys Rev C **69**, 045202 (2004)]
  - **20,000** events for **$\pi^{+-} p \rightarrow \pi^{+-}\pi^{-+} n$** from TRIUMF **CHAOS@TRIUMF** at W = **1257** to **1302** MeV. [M. Kermani *et al* PRC **58**, 3431 (98)]
  - **40,000** events for **$\pi^- \vec{p} \rightarrow \pi^-\pi^+ n$** from **ITEP** at W = **2060** MeV. [I. Alekseev *et al* Phys At Nucl **61**, 174 (1998)]

Manley, Arndt, Goradia, Teplitz PRD**30**,(1984) 904.

- isobar appoximation $\pi N \to 2\pi N$ via σN, ρN, $\pi\Delta \to 2\pi$



$$T^{J\,P}_{\pi N \to 2\pi N} = T^{J\,P}_{\pi N \to \Delta\pi}(\sqrt{s})\, S_\Delta(p_\Delta, m_\Delta)\, \Gamma_{\Delta\pi N}(q'_{\pi_2}, N')$$

- no three-body unitarity
- no dependence on isobar mass (momentum)
- poor database based on 240000 events from old bubble-chamber experiments W = 1.2...2 GeV: $\approx$ 9000 events per energy/angular (θ, ϕ) bin for
  $\pi^- p \to \pi^+\pi^- n$, $\pi^- p \to \pi^0\pi^- p$,
  $\pi^+ p \to \pi^0\pi^+ p$, $\pi^+ p \to \pi^+\pi^+ n$
  $\approx$ 2000...3000 events per energy bin for each reaction
  $\theta = 0...\pi$ and $\phi = 0...2\pi$

π-p → Nπ π statistics for energy scan

p=0.7 - 2 GeV/c W=1.48 - 2.15 GeV
Energy scan in steps of 25 MeV (26 points)
80 evts/bin (8000 bins cos(θππ), Mπ+N , Mπ-N)

	π-p→ pπ-π0	**π-p→ nπ+π-**
Time for 26 points in W	21 shifts (~ 7 days)	

In total
~ 21 106 π+π-(114 000 existing)
~ 15 106 π0π- (72 000 existing)

Other interesting and accessible channels

- ✓ ϕn and other strange channels (Laura)
- ✓ multiparticle production

e.g. Δ0η→pπ-η (missing resonances study)

- ✓ and with an EMC: π0 π0 n, ηn, ωn, …

What HADES can do

ρN dynamics: N(1520)$\frac{3}{2}^-$, N(1720)$\frac{3}{2}^+$, D(1620)$\frac{1}{2}^-$, D(1905)$\frac{5}{2}^+$

- $\pi^- p \to \pi^+\pi^- n$
- $\pi^- p \to \pi^+\pi^0 p$
- $\pi^- p \to \pi^-\eta p$

direct access to time-like E.M. formfactors

- $\pi^- p \to e^+ e^- n$

PDG: indications for new N^* states from $\gamma p \to K^+\Lambda$

- $\pi^- p \to K^0\Lambda^0$: great impact on hadron spectroscopy

ωN-meson in-medium properties

Building block: ωN scattering amplitude

ωN scattering length

- $\bar{a} = -0.026 + i0.28$ fm, Giessen (coupled-channel) NPA780 187
- $\bar{a} = -0.44 + i0.20$ fm, Lutz, et al(coupled-channel, low partial waves) NPA706:431
- $\bar{a} = +1.60 + i0.30$ fm, Kling, Weise (single channel) NPA630:299

Common feature of above analysis:

- constrained by the $\pi N \to \omega N$ experimental data
- agrees on the value of the imaginary part of the scattering lengths

low density theorem: $i0.28$ corresponds to ≈ 60 MeV broading

but too small to explain the strong absorption of ω in medium

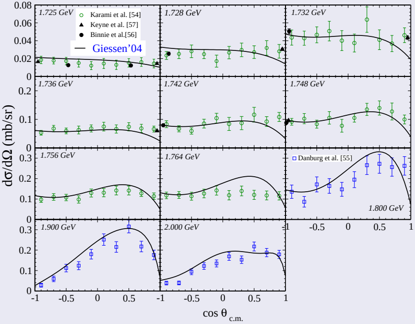
- theory: take in-medium corrections into account
- experiment: is everything clear with old $\pi N \to \omega N$ data?

Giessen model. Results for the $(\pi,\gamma)N \to \omega N$ reactions

ωN: coupled channel analysis Shklyar et al PRC 71:055206:

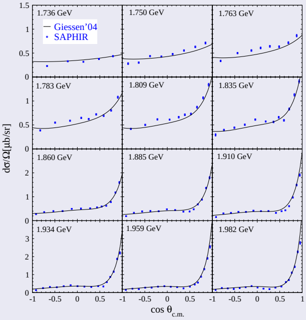
Aim: extract resonance coupling to ωN

$\pi N \to \omega N$



few measurements, low statistic

$\gamma N \to \omega N$

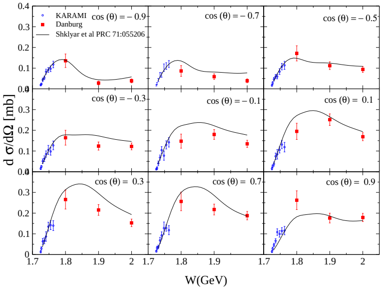


strong t-channel pion exchange screens other reaction mechanisms

$\pi N \to \omega N$ database

- W=1.72 to 1.76 GeV: H. Karami, et al NPB154 503 (1979) : 80 datapoints threshold region
- W=1.8 to 2.1 GeV: J.S. Danburg, PR2, 2564(1970) from $\pi^+ D \to \pi^+ \pi^- \pi^0 p(p)$: 41 datapoints Fermi-motion, final state interaction!

Shklyar et al,
PRC 71:055206,2005

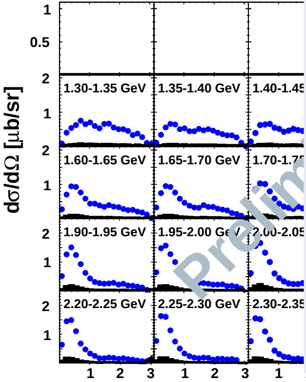


Difficulties:

- ωN has three helicities: need ω-polarization measurements
- Karami data - close to threshold
- region 1.76...2.0 GeV is almost empty - standard PWA not possible
- no polarization measurements
- Problem: N^* extraction ...

$\gamma p \to p\omega$

My own research → to be p



θc.m.[rad]

BnGa Analysis

- Pomeron exchange is large overall.
- At threshold, $\frac{3}{2}^-$ wave is equivalent to Pomeron exchange.
- $\frac{3}{2}^+$ and $\frac{5}{2}^-$ waves are significant.

Earlier Analyses
Threshold Contributions

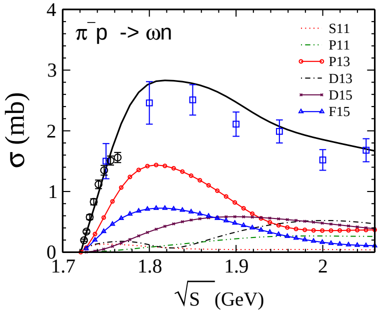
V. Shklyar *et al.*,Phys. Rev. C **71** (2005) 055206.
$N(1675)\frac{5}{2}^-$, $N(1680)\frac{5}{2}^+$

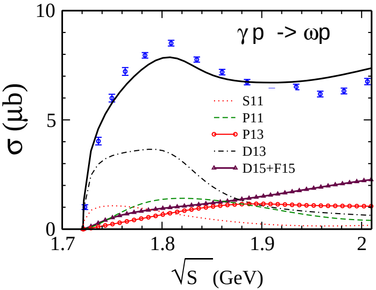
M. Williams *et al.* Phys. Rev. C **80** (2009) 065209.
$N(1700)\frac{3}{2}^-$, $N(1685)\frac{5}{2}^+$

Labeled with incoming photon energy.

Giessen model. Results for $(\pi, \gamma)N \to \omega N$

Giessen model, Shklyar et al, PRC 71:055206,2005





- P_{13}: interference between resonance and background
- strong $N^*(\frac{5}{2})$ coupling to ωN
- D_{13} shows minor influence

- strong Born and π^0-exchange contributions
- D_{13} is due to π^0-exchange

$\Longrightarrow$ hard to see any resonance contribution !

Summary of $(\pi/\gamma)N \to \omega N$ reactions

- $\gamma p \to \omega p$: strong t-channel background $\to$ other reaction mechanisms are shadowed: hard to see any resonance contributions
- $\pi N \to \omega N$: almost NO data in the region region 1.76...2.0 GeV - standard PWA not possible
- contributions from many groups: Lutz, Wolf, Friman, Titov, Sibirtsev, Zhao, Shklyar, Mosel, Penner - no general conclusion on N^* contributions

NEED $\pi^- p \to \omega p$ measurements in order to

- get information on N^* couplings to ωN - fill white pages in PDG
- construct microscopical model of ω-dynamics in nuclear medium; explain large collisional broading