η′N 束縛状態の
(間接的) 探索計画

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possible existence of η'N bound state

attractive interaction

between $\bar{K}$ and nucleon (nucleus)

(large) mass reduction of η' in nucleus

NJL, linear-σ, QMC

CBELSA/TAPS

η'N bound state?

Λ(1405)

small η'N scattering length

Re $a_{\eta'N}$ = 0±0.43 fm

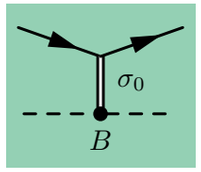
Im $a_{\eta'N}$ = $0.37^{+0.40}_{-0.16}$ fm

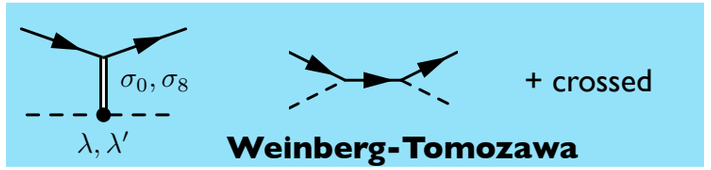
Czerwiński et al., PRL 113, 062004 (2014)

η'-N interaction

Sakai, DJ, PRC88 (13) 064906; in preparation

η'-nucleon interaction in LσM





B term : anomaly effect

cancel each other at chiral limit thanks to ChS

interaction strength (symmetric limit)

$V_{\eta' N} = 6B \cdot \frac{g/\sqrt{3}}{-m_{\sigma_0}^2} \simeq$ -0.053 [MeV^-1]

cf. - 0.086 MeV^{-1} WT term of K^{bar}N (I=0)

→ 10-15 MeV binding of K^{bar}N

two-body bound state

~ 6 MeV calculated in the same way as Λ(1405) of K^{bar}N bound state

coupled channel effect (η'N, ηN)

BE = 12 - 3i [MeV] scattering length = -1.9 + 0.2i [fm]

the details numbers are sensitive to the parameters of symmetry breaking

D. Jido 21 EXA2014

Thursday, 18 September 14

D. Jido, EXA2014

$\bar{K}$N scattering length,

repulsive shift of K^-p 1s atomic state

（直接的）探索実験 (1)

Introduction ~ $\eta'N$ bound state

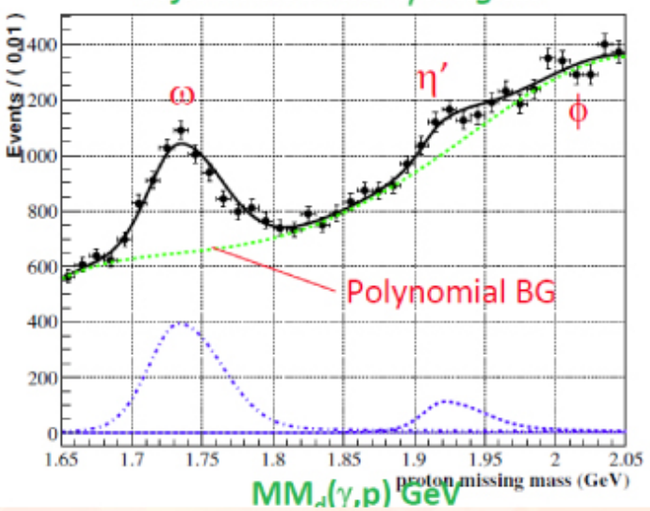
search for $\eta'n$ bound state … N. Muramatsu (LEPS collaboration)

Fitting test using the LD_2 1/10 sample

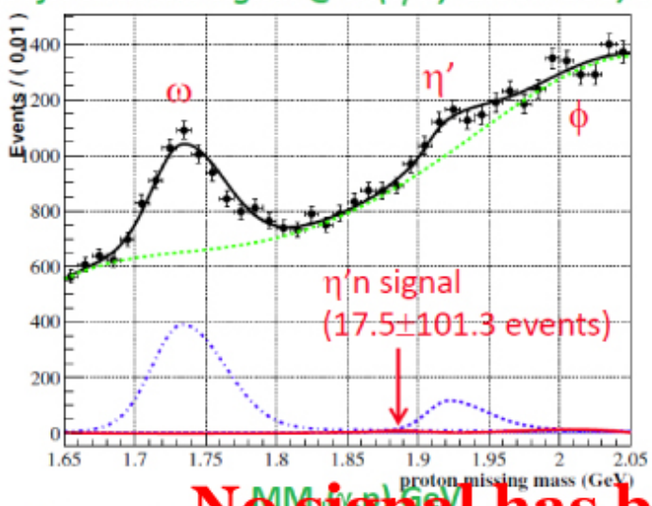
After applying E_γ>2.1 GeV & θ_p^{lab}<5 ° to the 1/10 sample of 200-2007 LD_2 data, unbinned fits were performed with the 2 assumptions without & with a signal process.

- **Quasi-free η', ω, & φ photoproduction**: Template shapes were fixed by MC simulation. Only scale factors were made free.
- **Non-resonant BG (multi-πs)** : 4th order Chebychev polynomial function
- **η'n bound state signal** : **Gaussian with σ=16.1 MeV** (mass resolution from MC sim.)

A fit without the η'n signal



A fit with the signal @ M(η'n)=1.887 GeV/c²



No signal has been observed

N. Muramatsu (T. Ishikawa),
Status and Prospects of the BGO calorimeter experiments at SPring-8/LEPS2, 04 November 2014

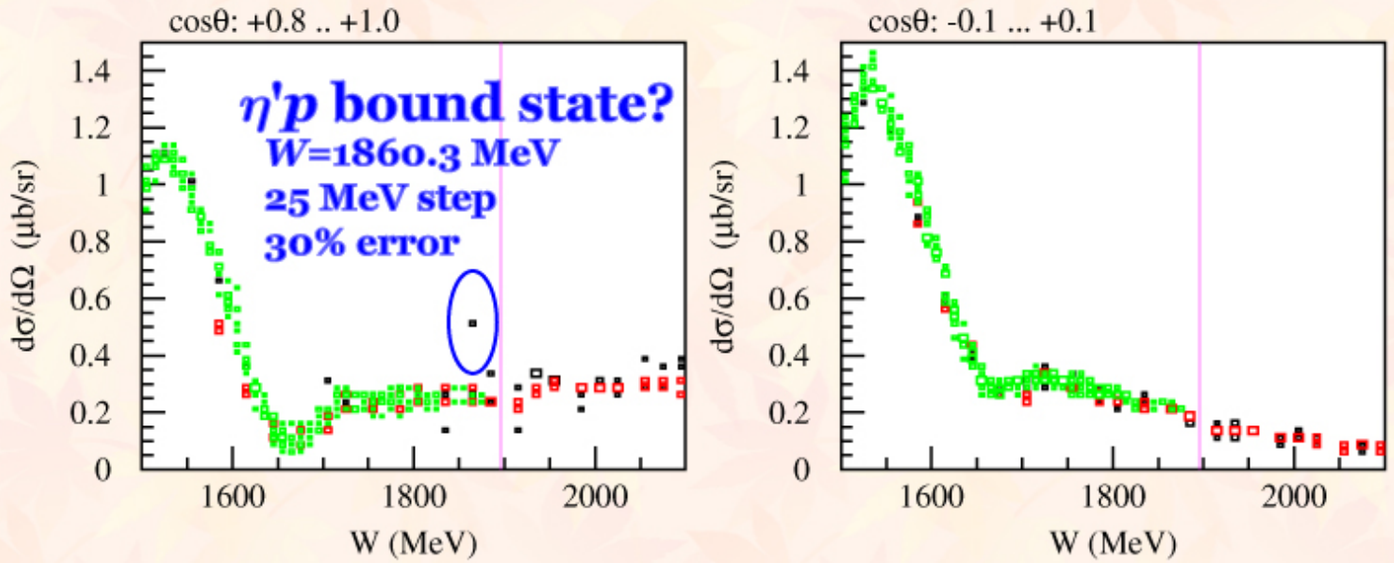
ELPH workshop C009, progress of the hadron interaction study by photoproduction

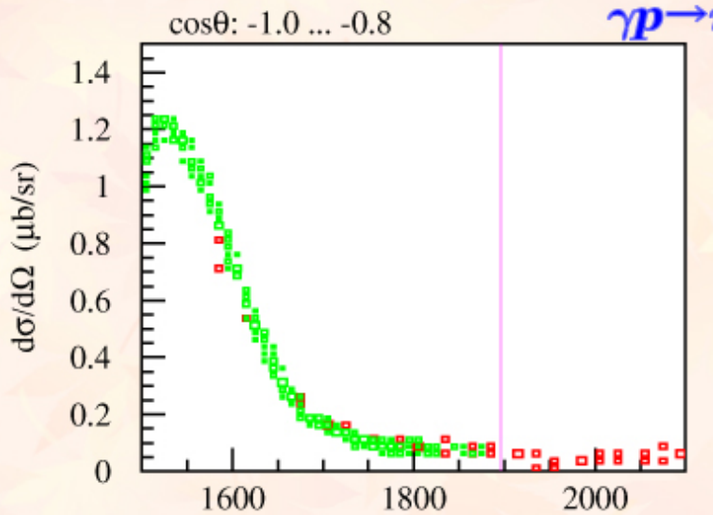
T. Ishikawa, ELPH C009 workshop (2014)

（直接的）探索実験 (2)

Introduction ~ $\eta' N$ bound state

search for $\eta' p$ bound state via the $\eta' p \to \eta p$ conversion





$\gamma p \to \eta p$ database for the Bonn-Gatchina PWA

O. Bartholomy et al., Eur.Phys.J. A33, 133 (2007) [CB-ELSA]
V. Crede et al., Phys.Rev. C80, 055202 (2009) [GRAAL]
E.F. McNicoll et al., Phys.Rev. C82, 035208 (2010)[MAMI-C]

High statistics and precise data are desired for $\gamma p \to \eta p$ cross sections.

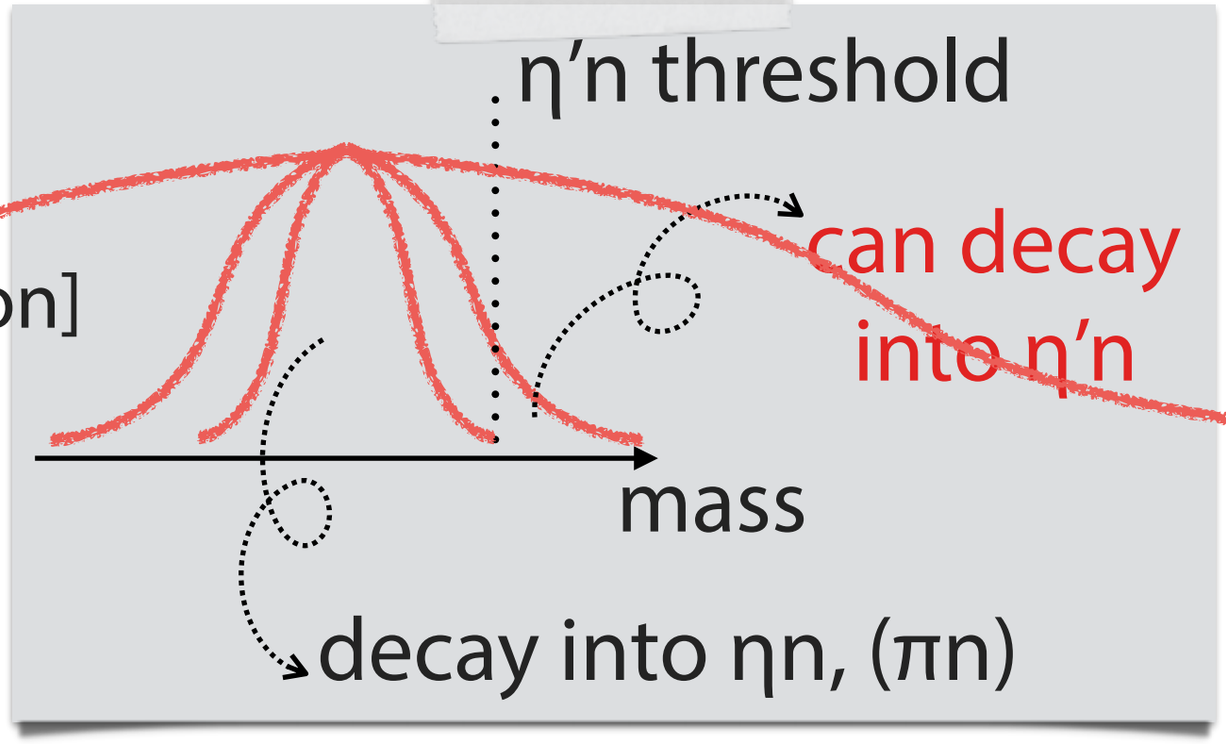
N. Muramatsu (T. Ishikawa),
Status and Prospects of the BGO calorimeter experiments at SPring-8/LEPS2, 04 November 2014

ELPH workshop C009, progress of the hadron interaction study by photoproduction

T. Ishikawa, ELPH C009 workshop (2014)

η'N 束縛状態の探索実験

- direct search [bound region]
  - $\gamma+d \rightarrow (\eta' n)+p$ or $\pi^+ + d \rightarrow (\eta' p)+p$ (cf. $K^- + d \rightarrow \Lambda(1405)+n$)
  - $\gamma+p \rightarrow \eta+p$ or $\pi^- + p \rightarrow \eta+n$
- indirect search [unbound region]
  - $\pi^- + p \rightarrow \eta' + n$
    - signature of η'n bound state just above η'n threshold?
    - (merit) no background *(as far as N* dominance model is valid)*
    - (demerit) only sensitive in case of small B.E. ~ Γ

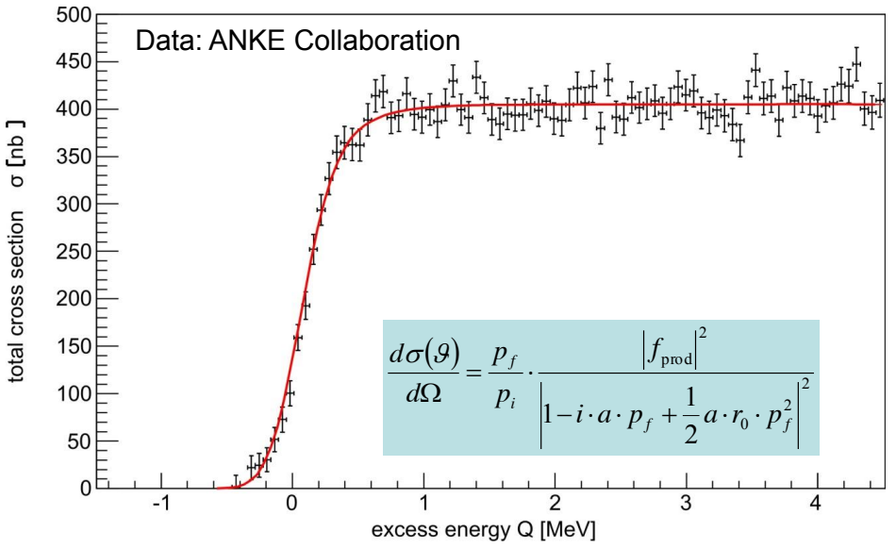


cf. η-^{3}He system

Westfälische Wilhelms-Universität Münster

The Reaction d+p → ^{3}He+η

Fit to data very close to threshold: Only s-wa

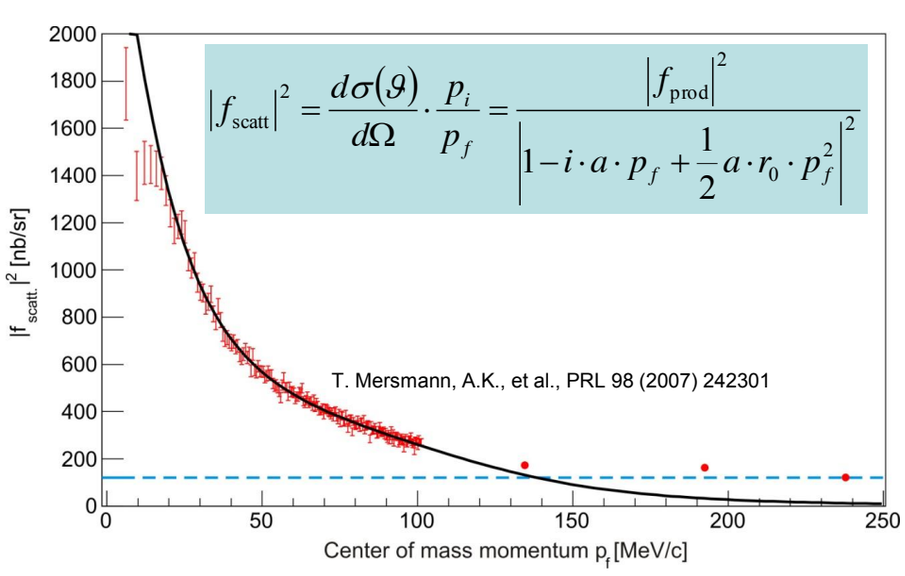


Fit
- C le
- C ra
- Fi w ac

Westfälische Wilhelms-Universität Münster

The d+p → ^{3}He+η Scattering Amplitude

Extracted scattering amplitude (Q > 0 MeV)



- Scattering amplitude decreases rapidly with increasing final state momentum p_f
- Scattering amplitude almost constant at high energies

→ strong FSI in η^{3}He system

A. Khoukaz et al., HIN2013

previous measurement (in 1970s, at RAL)

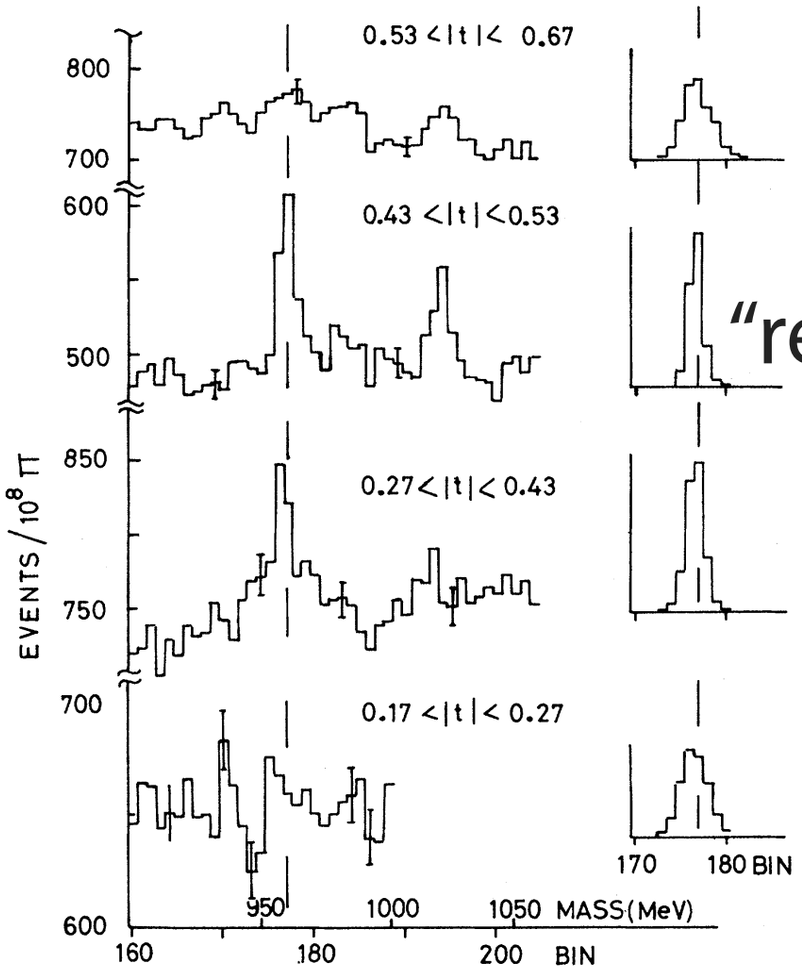


FIG. 15. Mass spectra between about 900 and 1060 MeV for several intervals of t. No decay selection has been used. Note the expanded scales. The X^0 and ϕ both show clearly near threshold. On the right are the X^0 signals predicted for a pure S-wave cross section normalized to the value close to threshold ($t = -0.45$). It appears that $d\sigma/dt$ falls for t both greater and less than this value. There is also some indication of a drop in the background levels near bin 185.

D. Binnie et al., PRD 8, 2789 (1973)

"reanalysis"

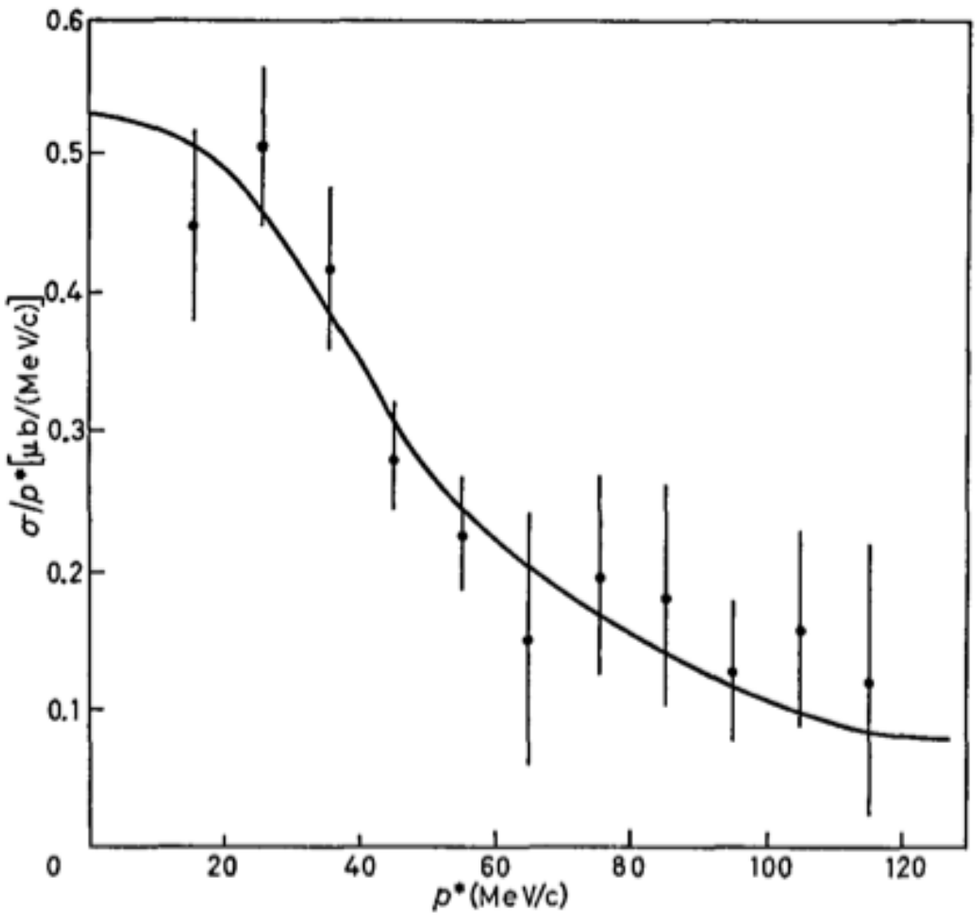


Fig. 5. – $E_0 = 1889.3$ MeV, $\Gamma_{el} = 1.36^{+5.8}_{-0.7}$ MeV, $\Gamma_0 = 1.2^{+9.2}_{-0.9}$ MeV, $J = \frac{1}{2}$, $\gamma = 0.015$.

P. G. Moyssides et al., Nuovo Cimento 75, 163(1983)

"an alternative explanation … could lie in a rapid modulation of the cross section by an s-channel effect such as a narrow N*."

previous measurement (in 1970s, at RAL)

注: X^0はη'のこと。

$$\sigma_{X^0 n} = \frac{2}{3} \frac{\pi \lambda^2 (J + \frac{1}{2}) \Gamma_{el} \Gamma_{X^0 n}}{(E - E_0)^2 + \frac{1}{4}(\Gamma_{el} + \Gamma_{X^0 n} + \Gamma_0)^2}$$

$\Gamma_{X^0 n}$ = width for decay into $X^0 n$, (=γp*)

Γ_{el} = width of $X^0 n$ resonance of rest mass E_0,

Γ_0 = partial width to all other channels,

E = total c.m.s. energy,

J = angular momentum of $\mathcal{N}^*$.

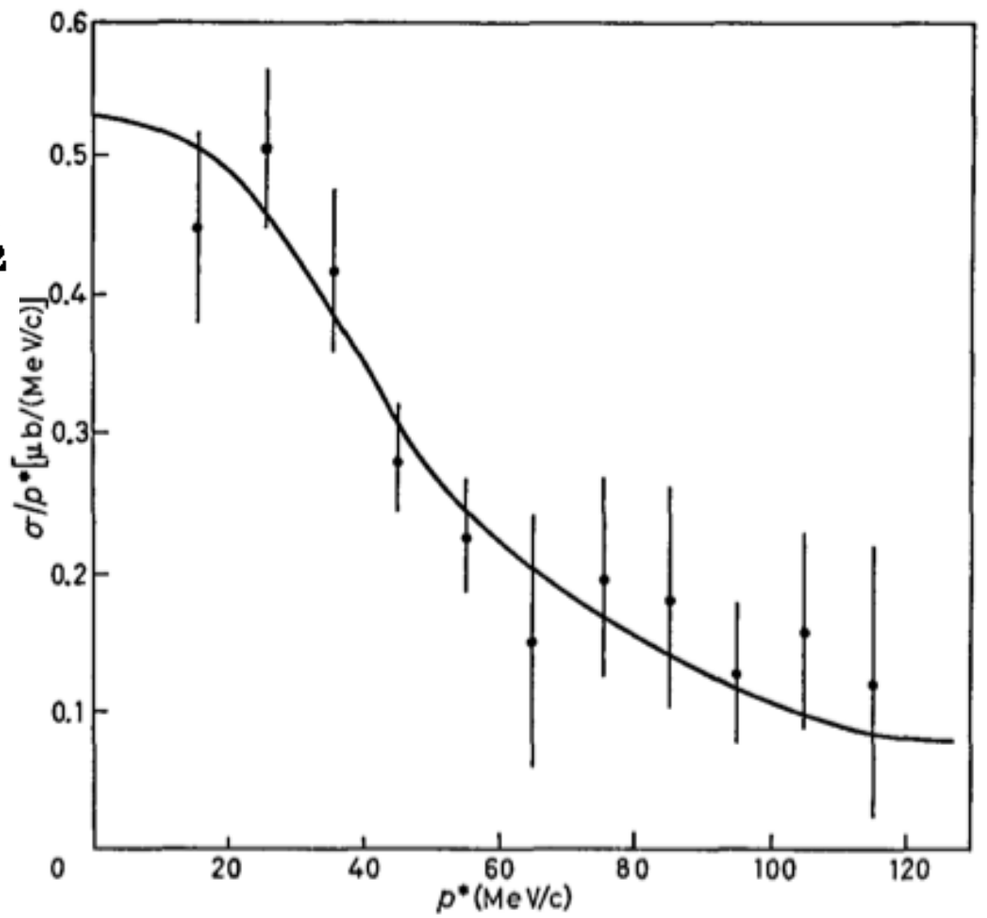


Fig. 5. – $E_0 = 1889.3$ MeV, $\Gamma_{el} = 1.36^{+5.8}_{-0.7}$ MeV, $\Gamma_0 = 1.2^{+9.2}_{-0.9}$ MeV, $J = \frac{1}{2}$, $\gamma = 0.015$.

P. G. Moyssides et al., Nuovo Cimento 75, 163(1983)

binding energy ~8MeV
total width ~3MeV

relatively large B.R. into πN?

photoproduction cross section close to threshold

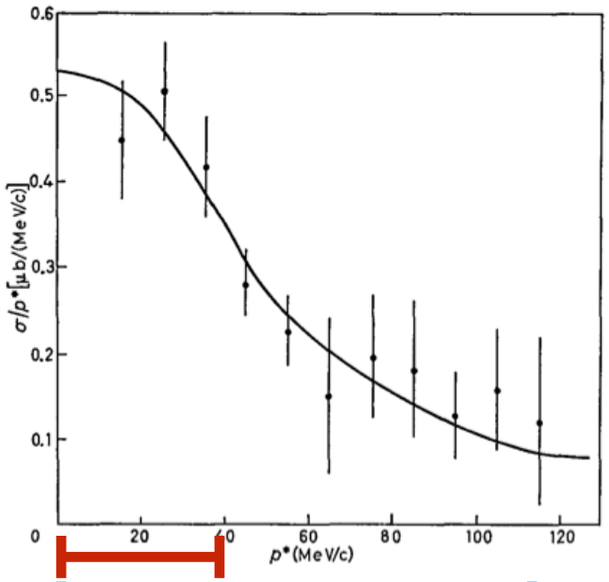
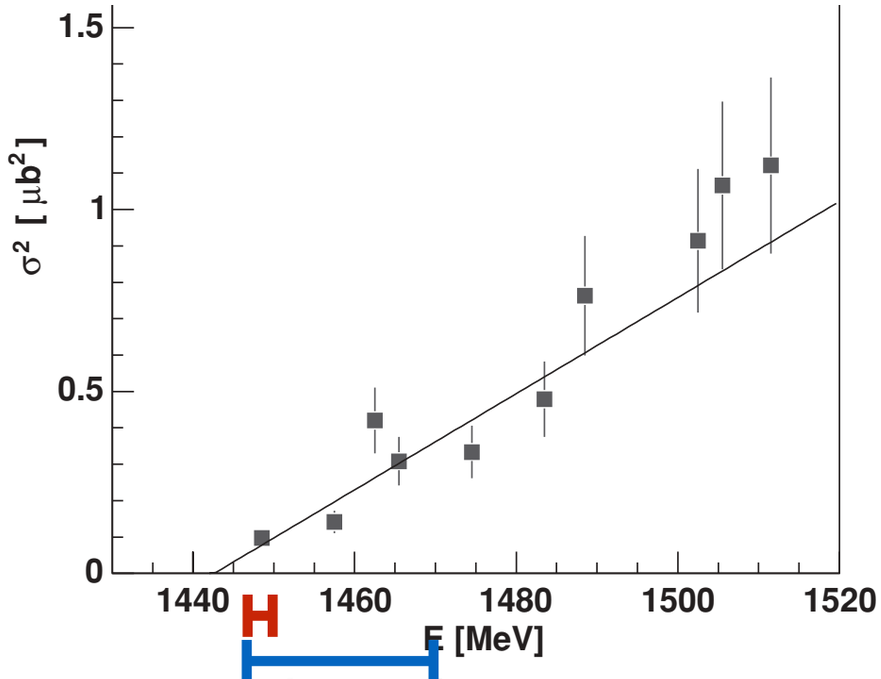


Fig. 5. – $E_0 = 188$ [illegible], $J = \frac{1}{2}$, $\gamma = 0.015$.

p_π=1432.1 1435.6 (MeV/c)



V. Crede et al., PRC 80, 055202 (2009)

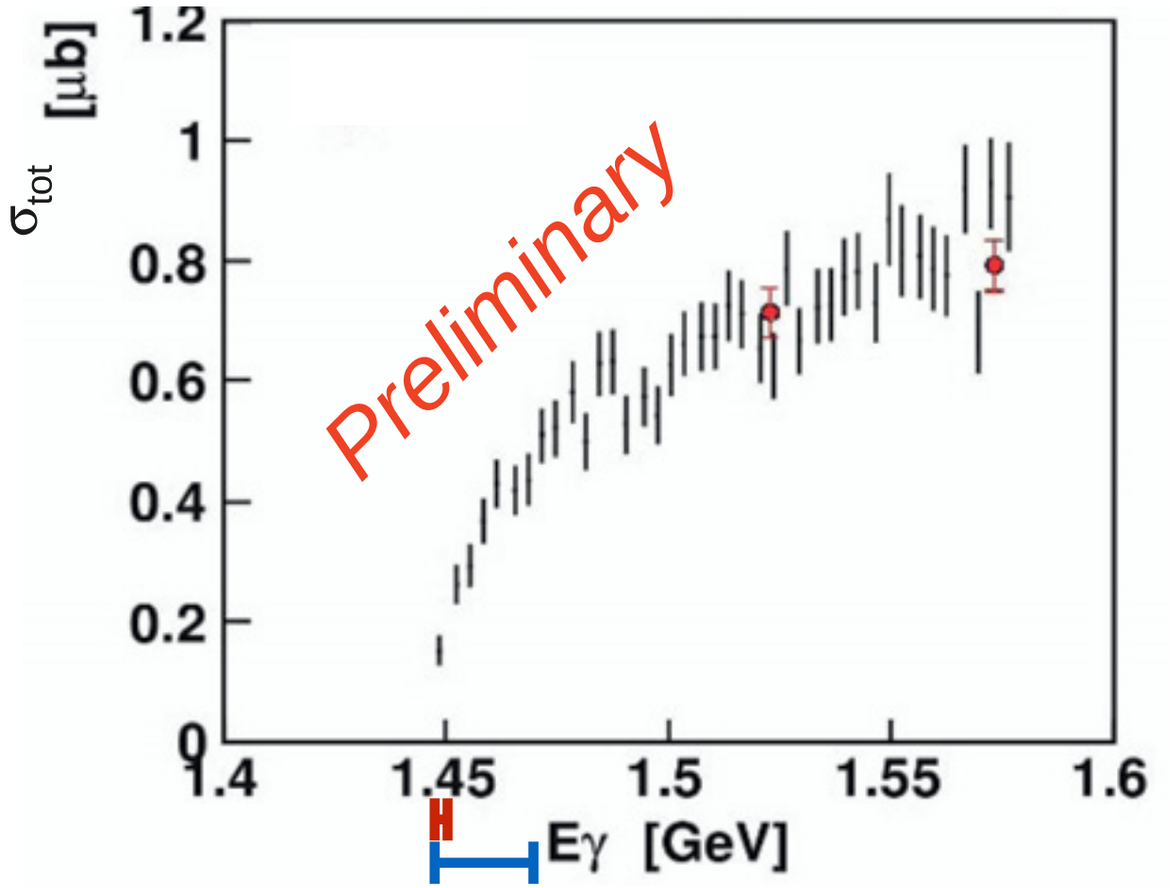


Figure 4. Preliminary total cross section for $\gamma p \rightarrow \eta' p$ from the Crystal Ball/TAPS experiment at MAMI-C (black error bars). Uncertainties are of statistical nature only. These data are compared to CBELSA/TAPS results [25]

M. Unverzagt for the A2 collaboration,
EPJ Web of Conferences 72, 00024 (2014)

possible experiment at J-PARC

$\pi^- p \rightarrow \eta' n$ *detected by forward neutron counter*

$\eta' \rightarrow \pi^+\pi^-\eta$ *B.R.=43%*

$\eta \rightarrow \pi^+\pi^-\pi^0$ *detected by "HypTPC"* *B.R.=23%*

@ J-PARC K1.8 (existing beamline)

feasibility study in progress

K. Hosomi, presentation at NSTAR2015

J-PARC E45

Studies of Baryon resonances in (π,2π) reaction for

- Deeper understanding of non-pertabative QCD
- Preceise measurements of baryon resonance properties
  - Many resonance have not been established experimentally
  - πN→ππN: "Critical missing piece" for the N* spectroscopy
  - New πN→ππN data will provide
    1.significant modifications to the current N* mass
    2.discovery of new N* states.
- Search for new type baryon states
  - e.g. hybrid baryons (qqqg)

NSTAR2015 3

E45 HypTPC Spectrometer

Measure (π,2π) in large acceptance TPC in dipole magnetic field

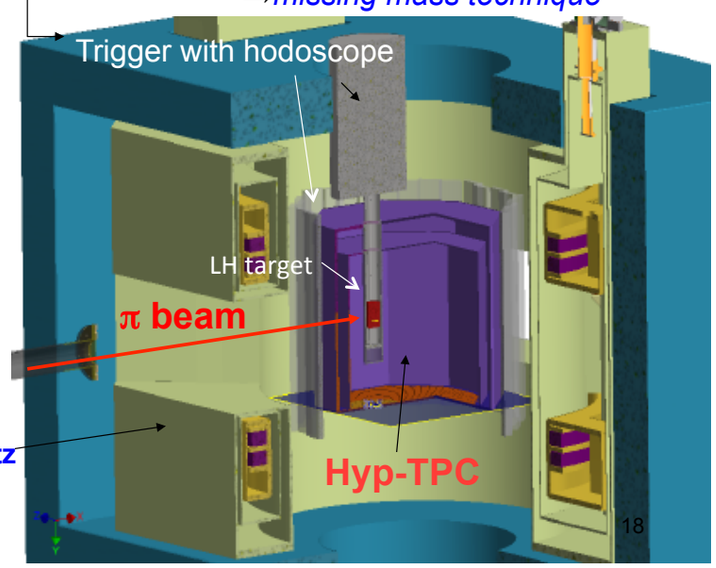
$\pi^- p \rightarrow \pi^+\pi^- n$, $\pi^0\pi^- p$
$\pi^+ p \rightarrow \pi^0\pi^+ p$, $\pi^+\pi^+ n$

2 charged particles + 1 neutral particle
→missing mass technique

$\pi N \rightarrow KY$ *(2-body reaction)*
$\pi^- p \rightarrow K^0 \Lambda$,
$\pi^+ p \rightarrow K^+ \Sigma^+$ *(I=3/2, Δ*)*

π^{+-} beam on liquid-H target
(p= 0.73 – 2.0 GeV/c
W=1.5-2.15 GeV)

LH target: Φ5cm



Superconducting Helmholtz Dipole magnet (1.5 T)

18

まとめ

- $\eta'N$ 束縛状態の存在が理論的に予想されている
- $\pi^- p \to \eta' n$ 反応の断面積が閾値の直上で急激に立ち上がり、phase space の大きさに比例しない
  - $\eta'N$ 束縛状態が閾値付近に存在すれば、この振る舞いを説明できるかもしれない
- J-PARC で HypTPC+中性子検出器 を用いた精密な断面積測定の実験を計画中