

***A review of the exotic states:
Tetraneutron and $d^*(2380)$ dibaryon***

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- Introduction
- Reviews:
 - Tetraneutron
 - $d^*(2380)$ dibaryon
- Summary

1. Introduction

Two talks from the last Reimei workshop at Inha U.

- SIA's talk:

"Investigation of the trineutron in pionless EFT"

Trineutron is a part of Tetraneutron state.

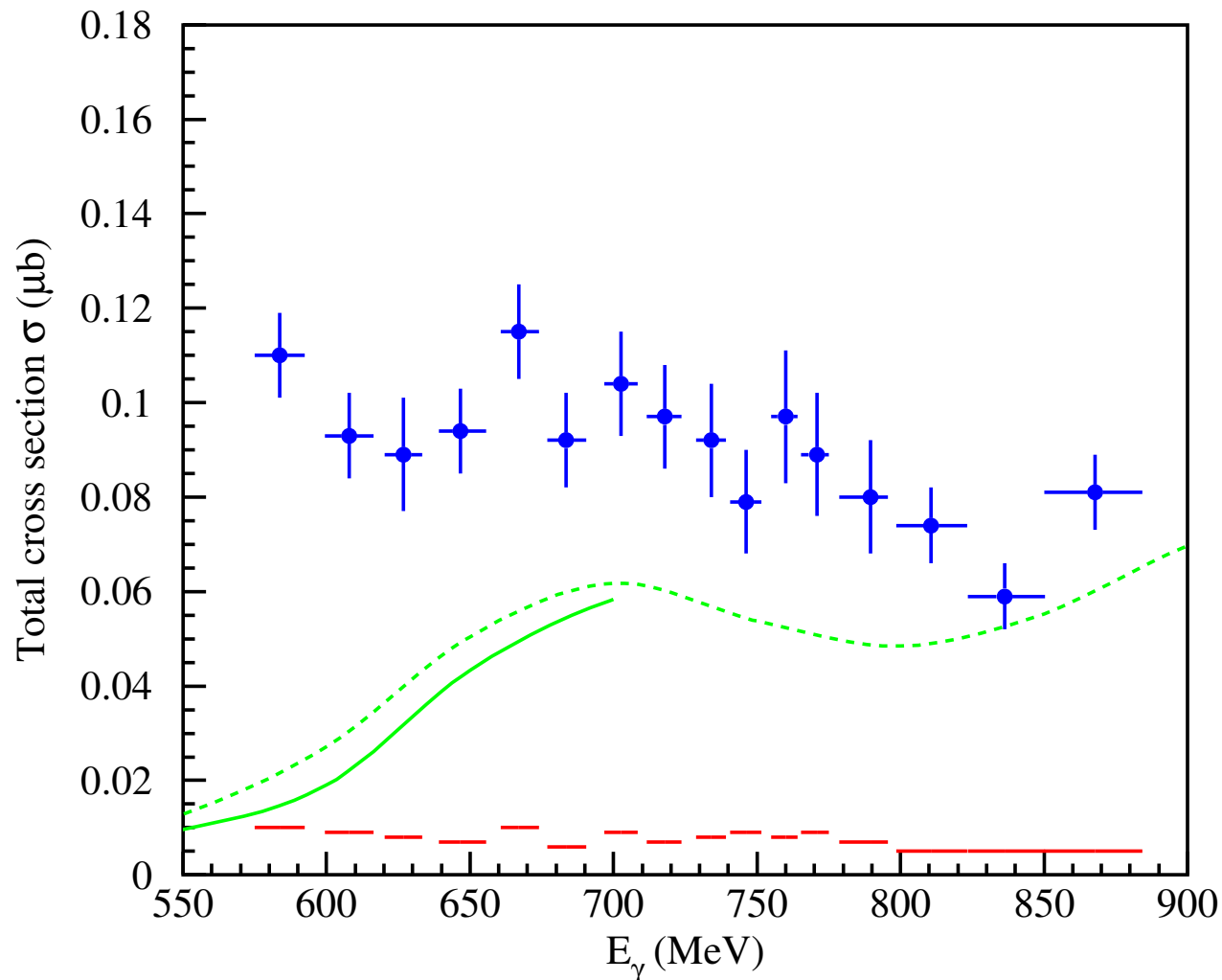
"A study of Tetraneutron in pionless EFT?"

- T. Ishikawa's talk:

"Study of baryon resonances and meson-nucleon interactions using photoproduction reactions at ELPH"

First half of his talk: an experimental study of the $d^*(2380)$ dibaryon in the $d\gamma \rightarrow d\pi^0\pi^0$ reaction at ELPH.

- Fig. 4 from arXiv:1610.05532v1



Egorov and Fix, NPA933,104(2015), Fix and Arenhovel, EPJA25,115(2005)

Tetraneutron (review)

- Recent RIKEN result suggested a formation of tetraneutron at $E = 0.83 \pm 0.65(stat) \pm 1.25(syst)$ MeV

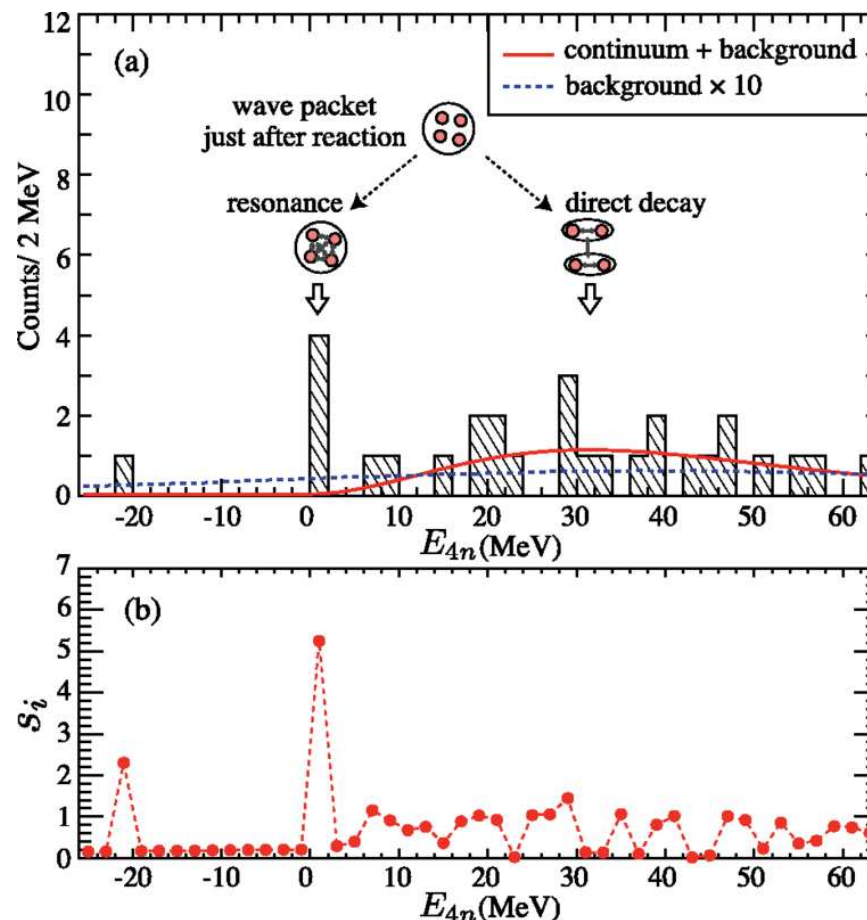


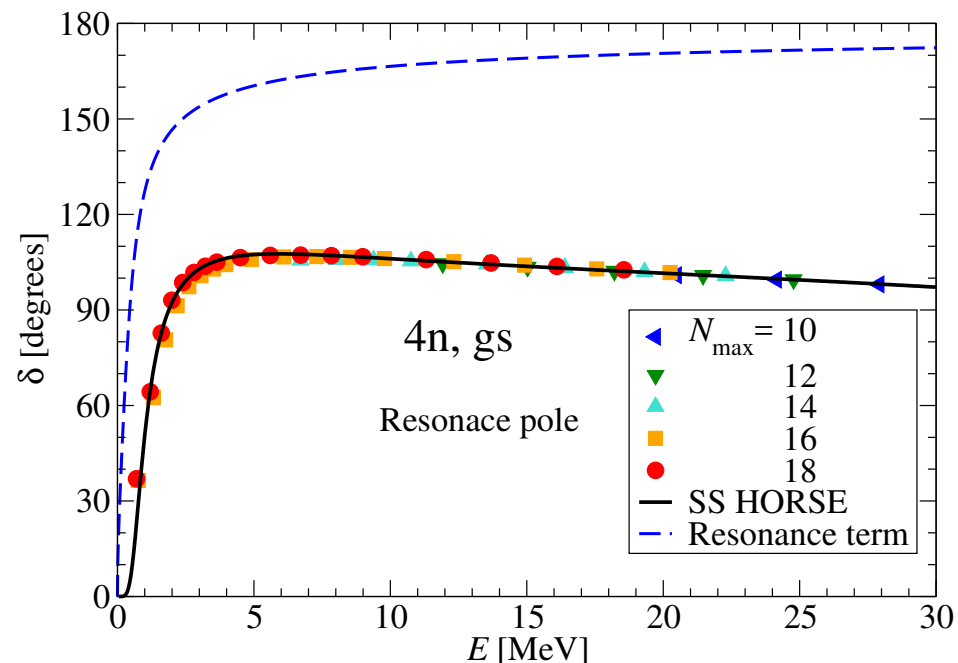
Fig. 3 from K. Kisamori et al., PRL116,052501(2016)

- Recent theoretical works reported difficulty of its formation.

See, e.g., Hiyama et al., PRC93,044004(2016)

- While a theory work (NCSM) predicted a resonance state, $E_r = 0.8$ MeV and $\Gamma = 1.4$ MeV

Fig.2 from Shirokov, Papadimitriou, Mazur, Roth, Vary, PRL117,182502(2016)



New experiments for the tetraneutron search

- S. Shimomura et al.,
"Tetra-neutron resonance produced by exothermic double charge exchange reaction," proposal for nuclear-physics experiments at the RI Beam Factory NP1512-SHARAQ10 (2015) at RIKEN.
- H. Fujioka et al.,
"Search for tetraneutron by pion double charge exchange reaction on ^4He ," letter of Intent at J-PARC.

Q: Can I do something for it in pionless EFT ?

$d^*(2380)$ ***dibaryon (review)***

- ABC (Abashian, Booth, Crowe) effect in the 1960s
"An unexpected enhancement at low energies in invariant $\pi\pi$ mass spectrum $M_{\pi\pi}$ "
- WASA at COSY experiments from 2009 to present
 $np \rightarrow d\pi^0\pi^0, d\pi^+\pi^-$
 $pp \rightarrow d\pi^+\pi^0$
 $np \rightarrow pp\pi^0\pi^-$
 $np \rightarrow np\pi^0\pi^0$
 $\vec{n}p \rightarrow np$
" $d^*(2380)$ dibaryon in $I(J^P) = 0(3^+)$ state"
- KEK exp. in 1979 [Ikeda et al. PRL42,1321(1979)]
 $d\gamma \rightarrow \vec{p}n$
"a dibaryon $I(J^P) = 0(3^+)$ or $0(1^+)$ at $\simeq 2360$ MeV"

- New exp. from ELPH at Tohoku experiment

$$d\gamma \rightarrow d\pi^0\pi^0$$

" $d^*(2380)$ dibaryon hardly seen in the reaction"

Q: "Is it worth studying the $d\gamma \rightarrow d\pi^0\pi^0$ reaction in theory ?"

- Recent review papers:

Bashkanov, Clement, Skorodko, EPJA51,87(2015),

Bashkanov, Clement, Watts, JPS Conf. Proc. 10 (2016) 021002,

Clement, arXiv:1610.05591v1.

- Review of the theory works for $d\gamma \rightarrow d\pi^0\pi^0$ process

Egorov and Fix, NPA933(2015)104,

Fix and Arenhovel, EPJA25(2005)115.

- Let us see Dr. Ishikawa's slides for a while...

The calculation for the $d\gamma \rightarrow d\pi^0\pi^0$ reaction:

- Impulse approximation
- One-body operator ($N\gamma \rightarrow N\pi\pi$) is calculated by including σ , ρ , $L_{2T2J}(M^*)$ resonances ($P_{33}(1232)$, $P_{11}(1440)$, $D_{12}(1520)$, $S_{11}(1532)$, $S_{31}(1620)$, $D_{15}(1675)$, $F_{15}(1680)$, $D_{33}(1700)$, $P_{13}(1720)$).
- Large suppression of the isosinglet channel is found.

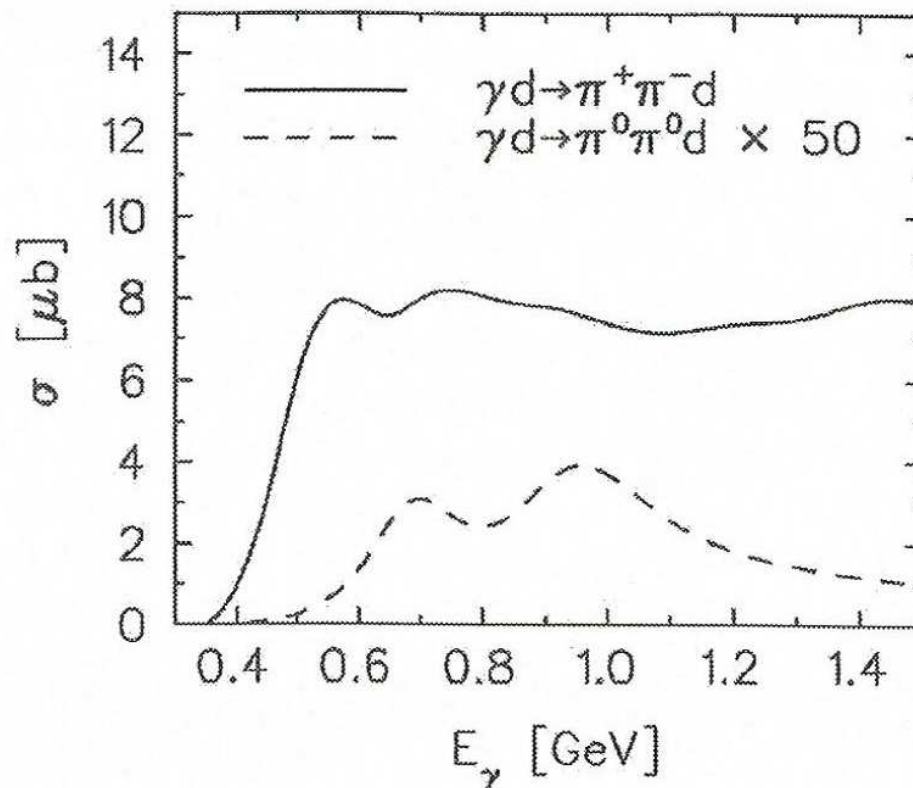


Fig. 12. Total cross sections for coherent double-pion photo-production on a deuteron. The solid and the dashed curves represent the $\pi^+\pi^-$ and $\pi^0\pi^0$ channels, respectively. The $\pi^0\pi^0$ cross section is multiplied by a factor 50.

Taken from the Fix and Arenhovel's paper.

- Tetraneutron in pionless EFT
- $d^*(2380)$ via the $d\gamma \rightarrow d\pi^0\pi^0$ reaction