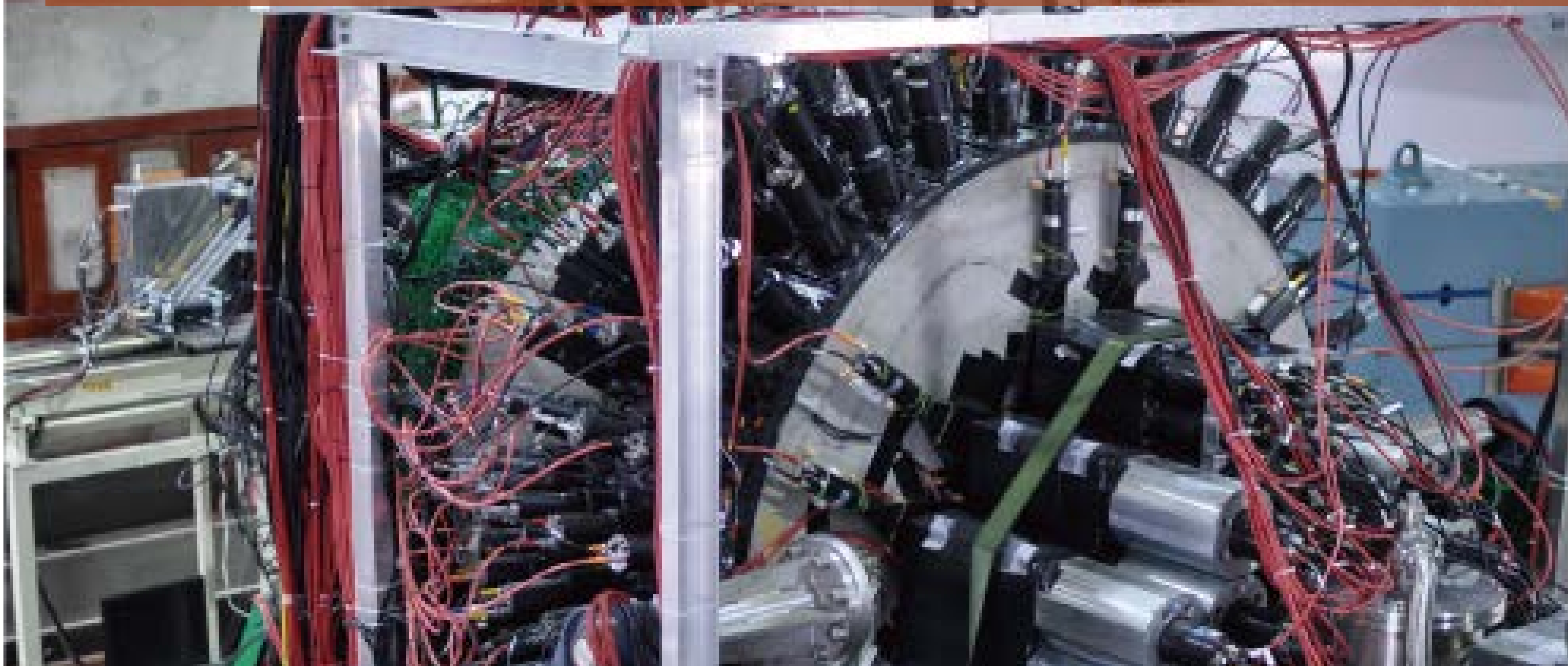
光子ビームを使ったηN散乱長の精密測定による核子共鳴$N(1535)S_{11}$の研究



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- 6th Symposium on Clustering as a window on the hierarchical structure of quantum systems, June 19, 2021

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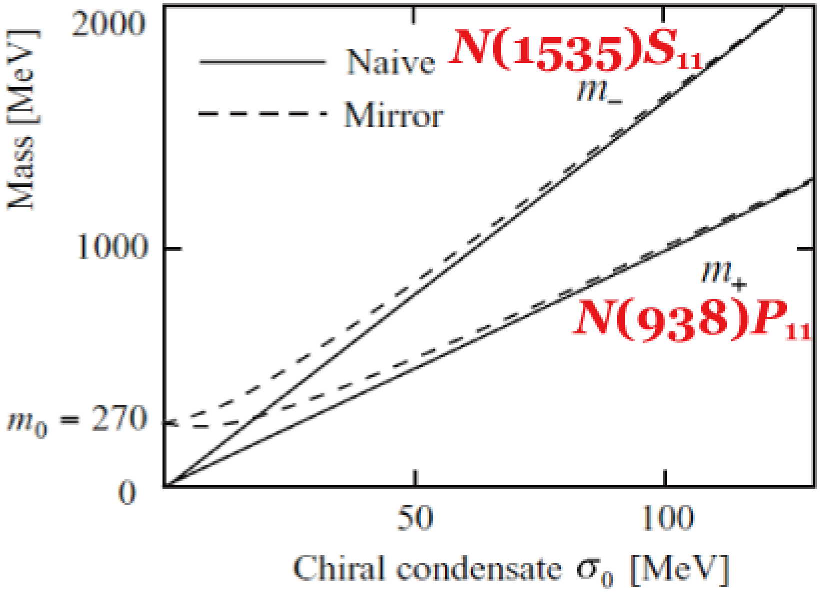
N(1535) with J^{π}=1/2^{-} **J^{π}=1/2^{+}**

chiral partner of the nucleon N(940) ?
N(940) and N(1535) degenerate at high density and/or high temperature



C. DeTar and T. Kunihiro, Phys. Rev. D 39, 2805 (1989);

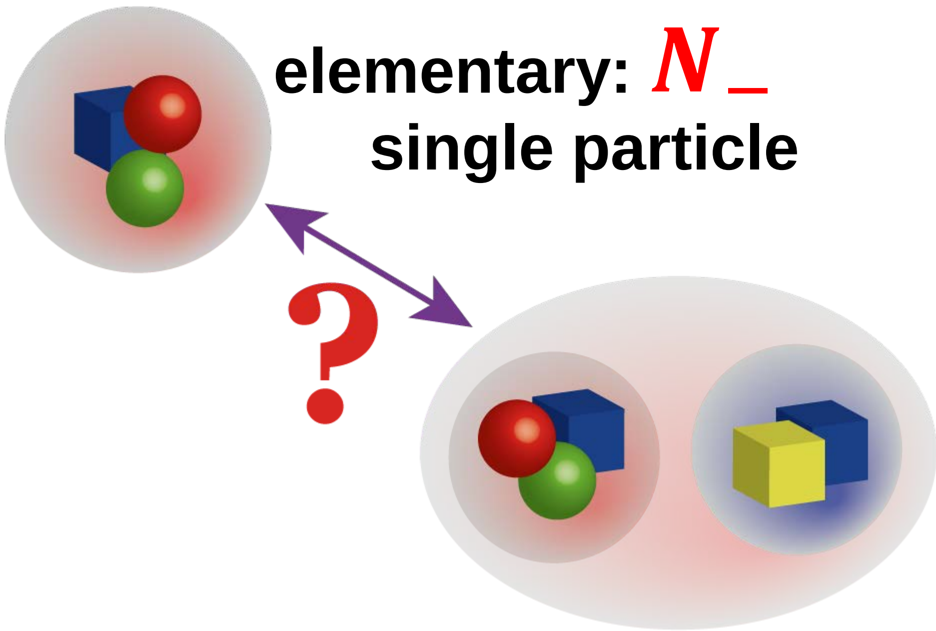
T. Hatsuda and M. Prakash, Phys. Lett. B 224, 11 (1989);

D. Jido, M. Oka, and A. Hosaka, Prog. Theor. Phys. 106, 873 (2001).

strongly couples to the eta meson (η) and nucleon (N) **I=0, J^{π}=0^{-}**

***N*(1535) with J^π=1/2$^-$**

chiral partner of the nucleon *N*(940) ?
***N*(940) and *N*(1535) degenerate at high density and/or high temperature**



strongly couples to the eta meson (η) and nucleon (N)

Introduction ~ $N(1535)S_{11}$

compositeness *X*:

overlap with the two-body scattering state

X* is directly given by the scattering length *a* and effective range *r

$$a = \frac{2X}{X+1}R, \quad r = \frac{X-1}{X}R, \quad R = \left(2\mu B\right)^{-1/2}$$

S. Weinberg, Phys. Rev. 137, B672 (1965).

***X* can be also used for the near threshold resonances**

T. Hyodo, Phys. Rev. Lett. 111, 132002 (2013).

compositeness for $N(1535)S_{11}$

$$X_{\eta N} = 0.04 + i0.37$$

T. Sekihara *et al.*, Phys. Rev. C 93, 035204 (2016).

Scattering length

low-energy scattering is characterized with the *S*-wave phase shift $\delta(p)$

$$p\cot\delta(p) = \frac{1}{a} + \frac{1}{2} r p^2 + O(p^4)$$

a **: scattering length**

r **: effective range**

positive (negative) a **provides attraction (repulsion)**

a **is negative if a bound state is available**

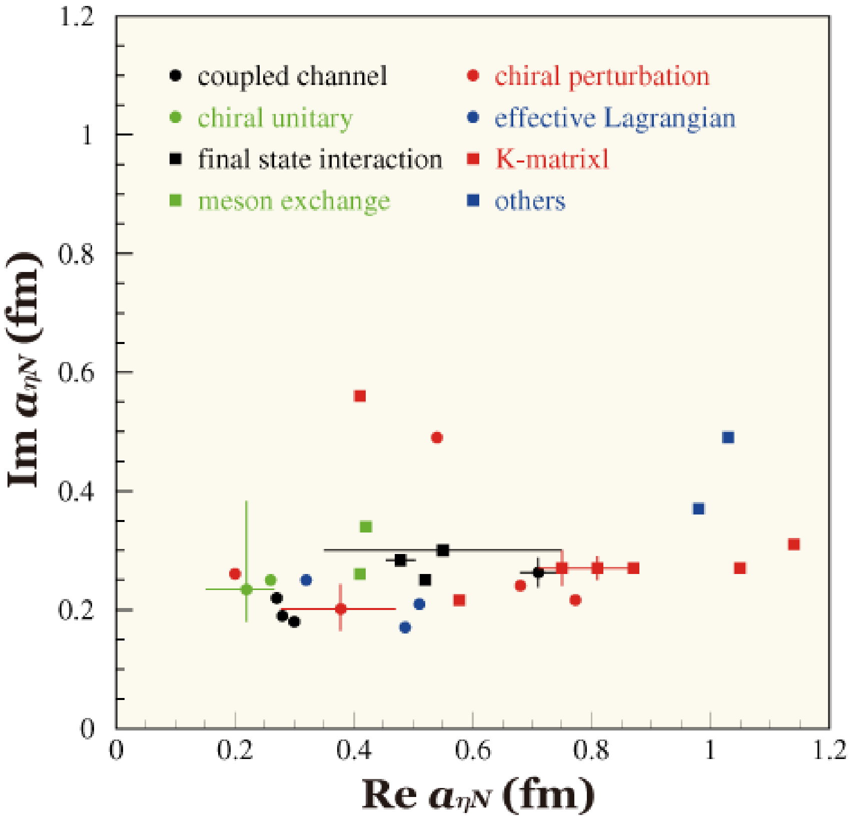
Scattering length

fundamental and important

difficult to determine the scattering length between neutral hadrons

eta-nucleon scattering from $\pi N \rightarrow \pi N, \pi N \rightarrow \eta N$, $\gamma N \rightarrow \pi N, \gamma N \rightarrow \eta N$

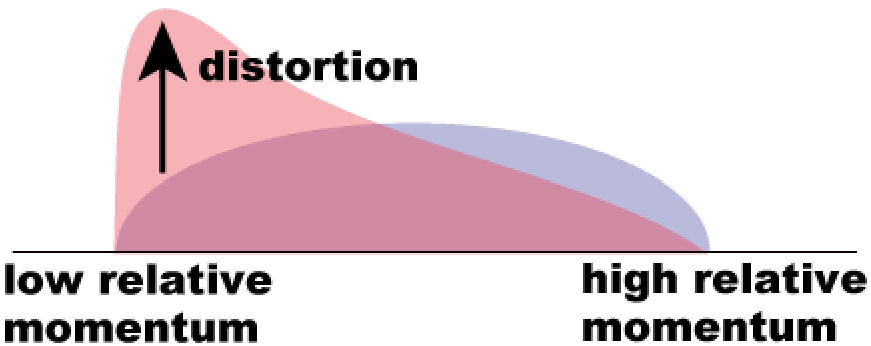
Im: ~ 0.25 fm
Re: widely distributed

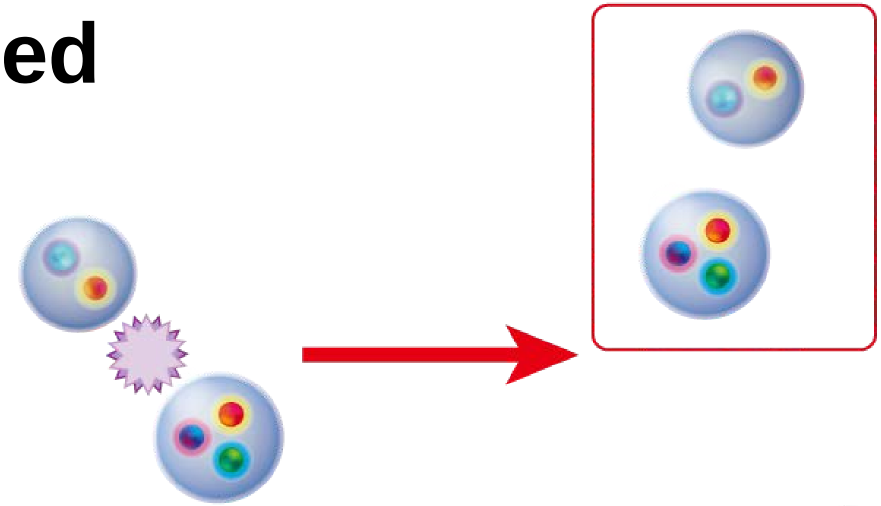


Q. Haider and L.C. Liu, J. Mod. Phys. E 24, 1530009 (2015).

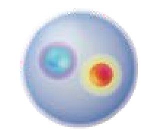
Final state interaction

- the final-state interaction (FSI) is often utilized when a direct scattering experiment is difficult to be realized





1) low relative momentum between the two hadrons of interest



2) small or well-known FSI effects for the others
3) well-known production mechanism effects

Scattering length from FSI

ωN scattering length from $\gamma p \to \omega p$

T. Ishikawa *et al.*, Phys. Rev. C 101, 052201 (R) (2020).

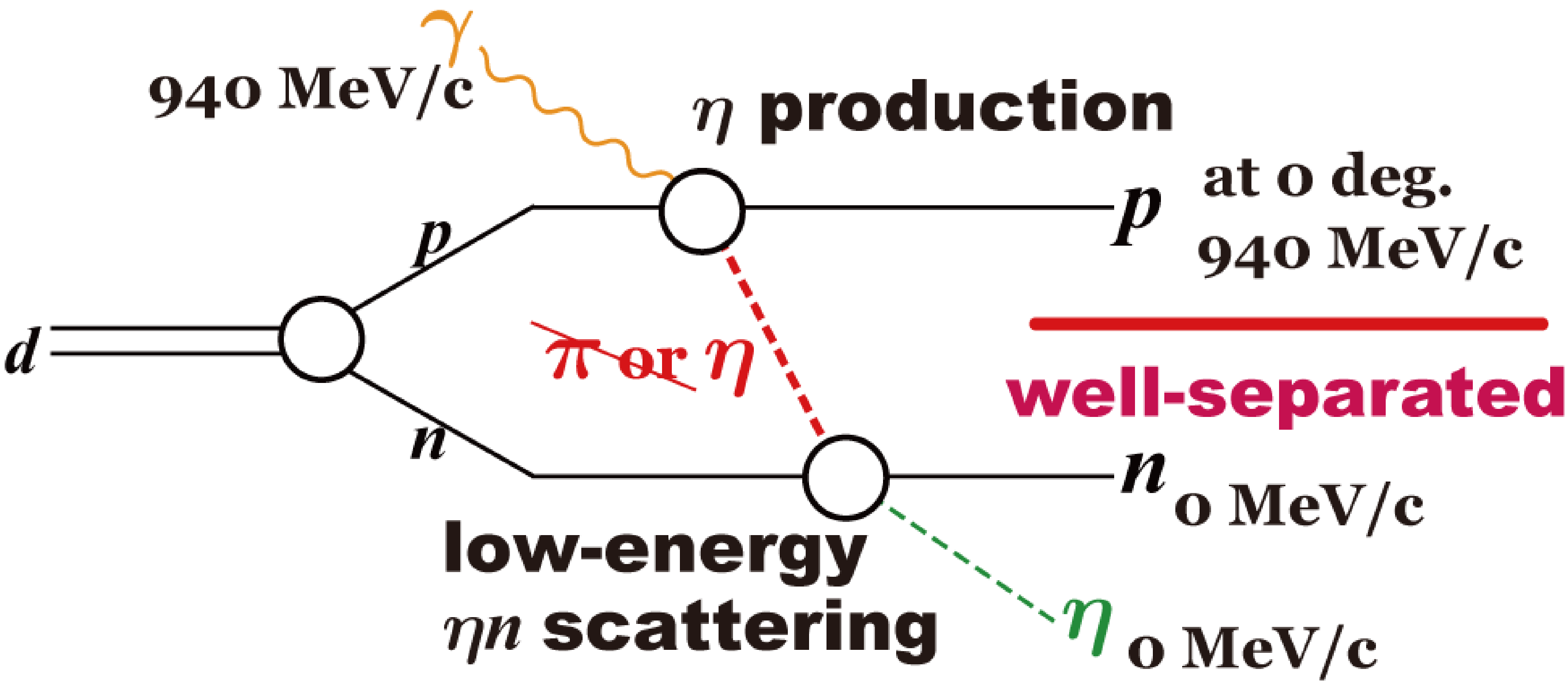
1) **relative momentum: low**
2) **FSI with another: no**
3) **production: small effects**

nn scattering length from $ed \to e'\pi^+ nn$ [planned]

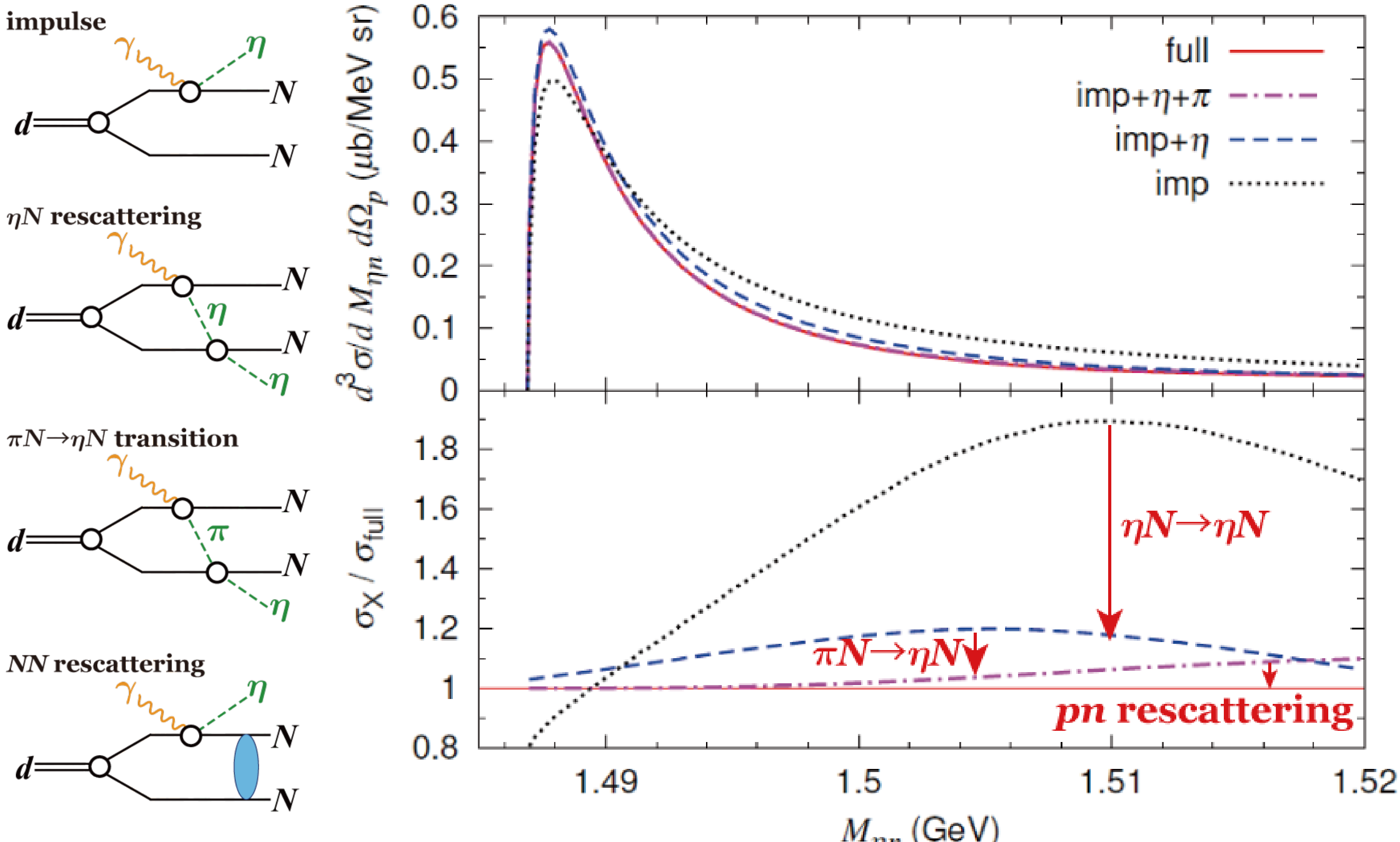
S.X. Nakamura, T. Ishikawa, T. Sato, arXiv:2003.02497 (2020).

1) **relative momentum: low**
2) **FSI with another: known & small**
3) **production: known & small effects**

proposed kinematics for $a_{\eta N}$ determination using $\gamma d \to \eta p n$



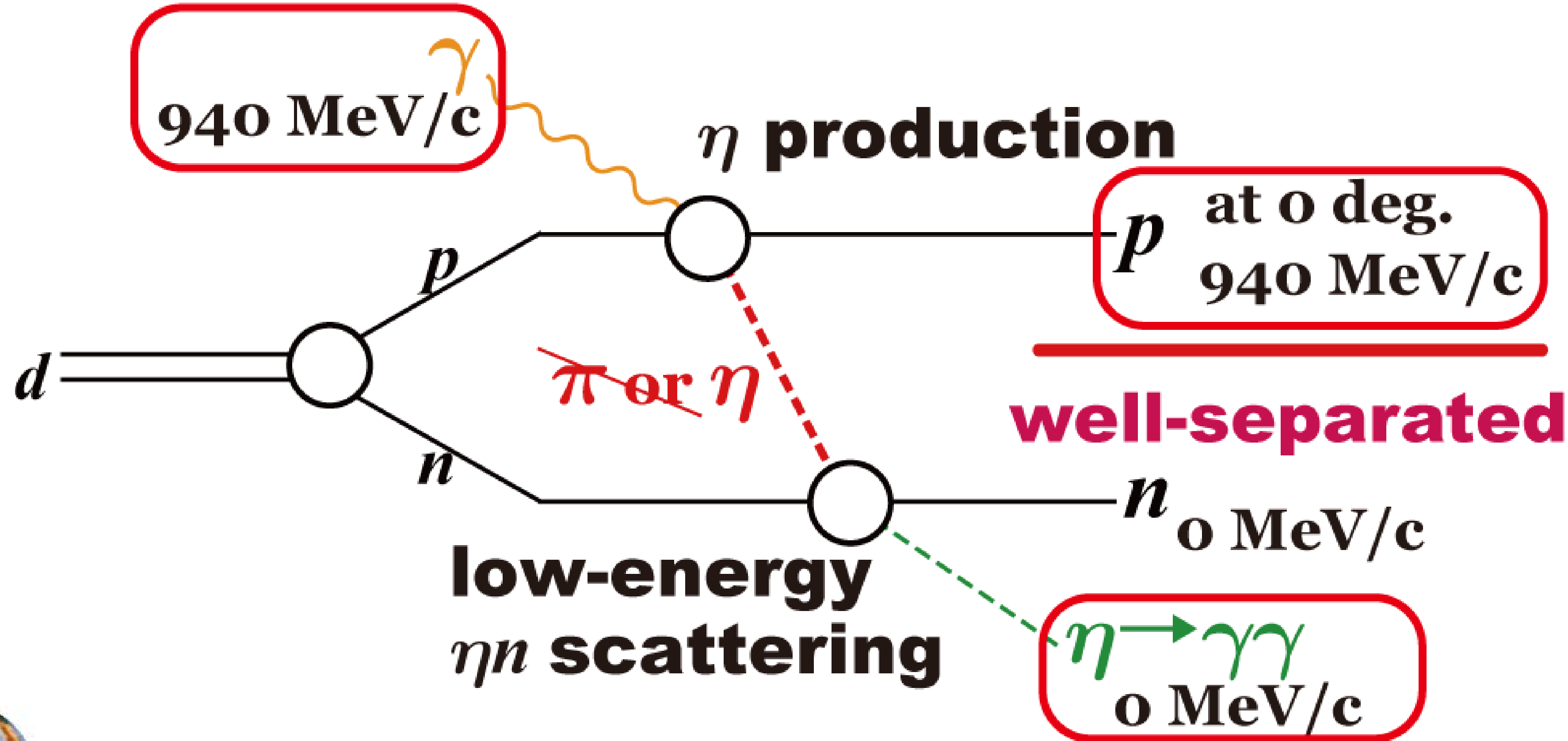
differential cross section for for $\gamma d \rightarrow \eta p n$ as a function of ηn invariant mass



S.X. Nakamura, H. Kamano, T. Ishikawa, Phys. Rev. C 96, 042201 (R) (2017).

Experiment

1) **energy-tagged photon beam**
2) **eta-meson identification (EM calorimeter)**
3) **forward proton detection (spectrometer)**



T. Ishikawa

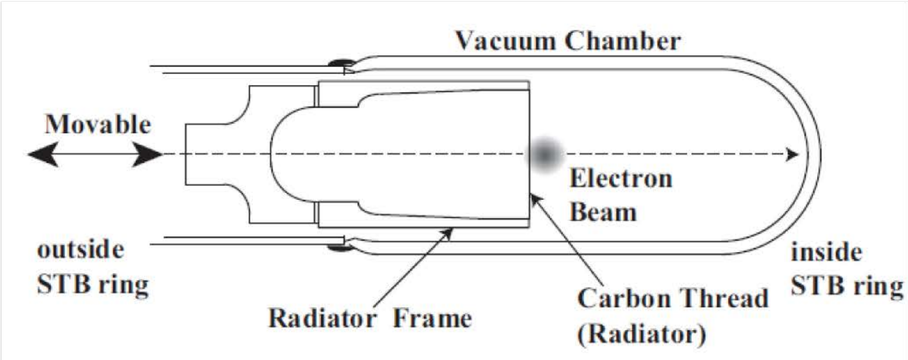
Experiment

1) energy-tagged photon beam

2) eta-meson identification (EM calorimeter)

3) forward proton detection (spectrometer)

1.3 GeV Booster STorage Ring



the energy of each produced photon:
determined by detecting the corresponding post-bremsstrahlung electron

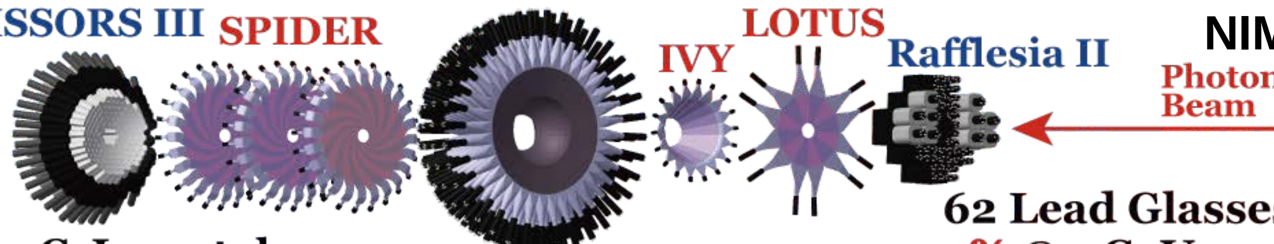
$$E_\gamma = 0.80 \sim 1.25\ \mathrm{GeV}$$

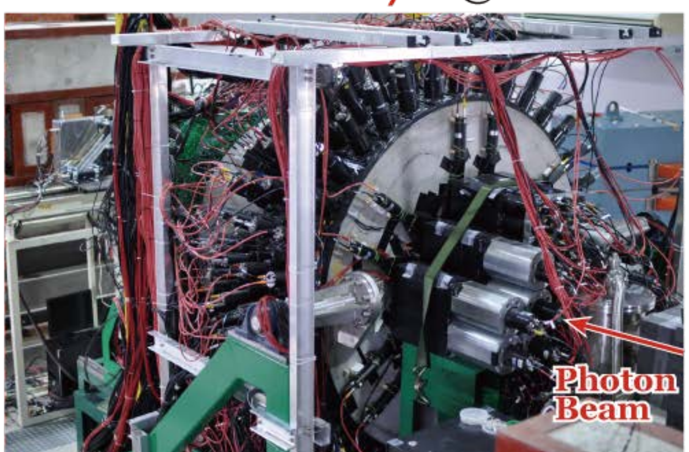
T. Ishikawa *et al.*, NIMA 622, 1 (2010); T. Ishikawa *et al.*, NIMA 811, 124 (2016); Y. Matsumura *et al.*, NIMA 902, 103 (2018); Y. Obara *et al.*, NIMA 922, 108 (2019).

Experiment

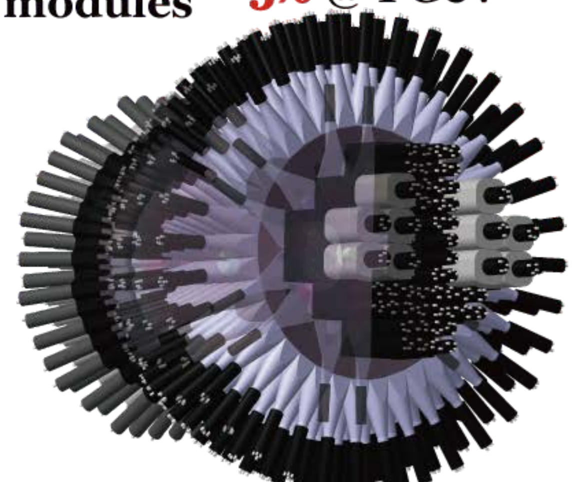
1) **energy-tagged photon beam**
2) **eta-meson identification (EM calorimeter)**
3) **forward proton detection (spectrometer)**

T. Ishikawa *et al.*, NIMA 832, 108 (2016).





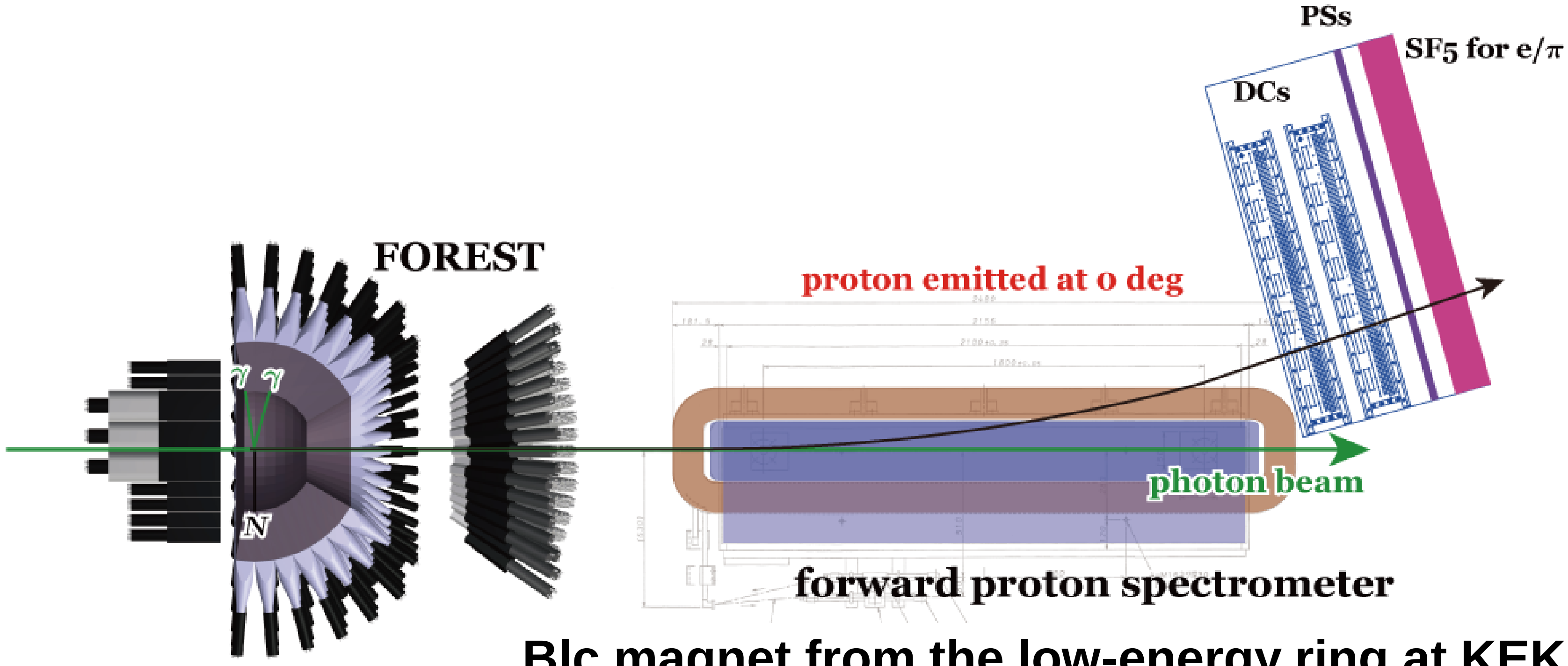
Target: 45 mm thick LH2 & LD2
T. Ishikawa



FOREST electro-magnetic calorimeter

Experiment

1) energy-tagged photon beam
2) eta-meson identification (EM calorimeter)
3) forward proton detection (spectrometer)



Blc magnet from the low-energy ring at KEK-B

Current status

data acquired

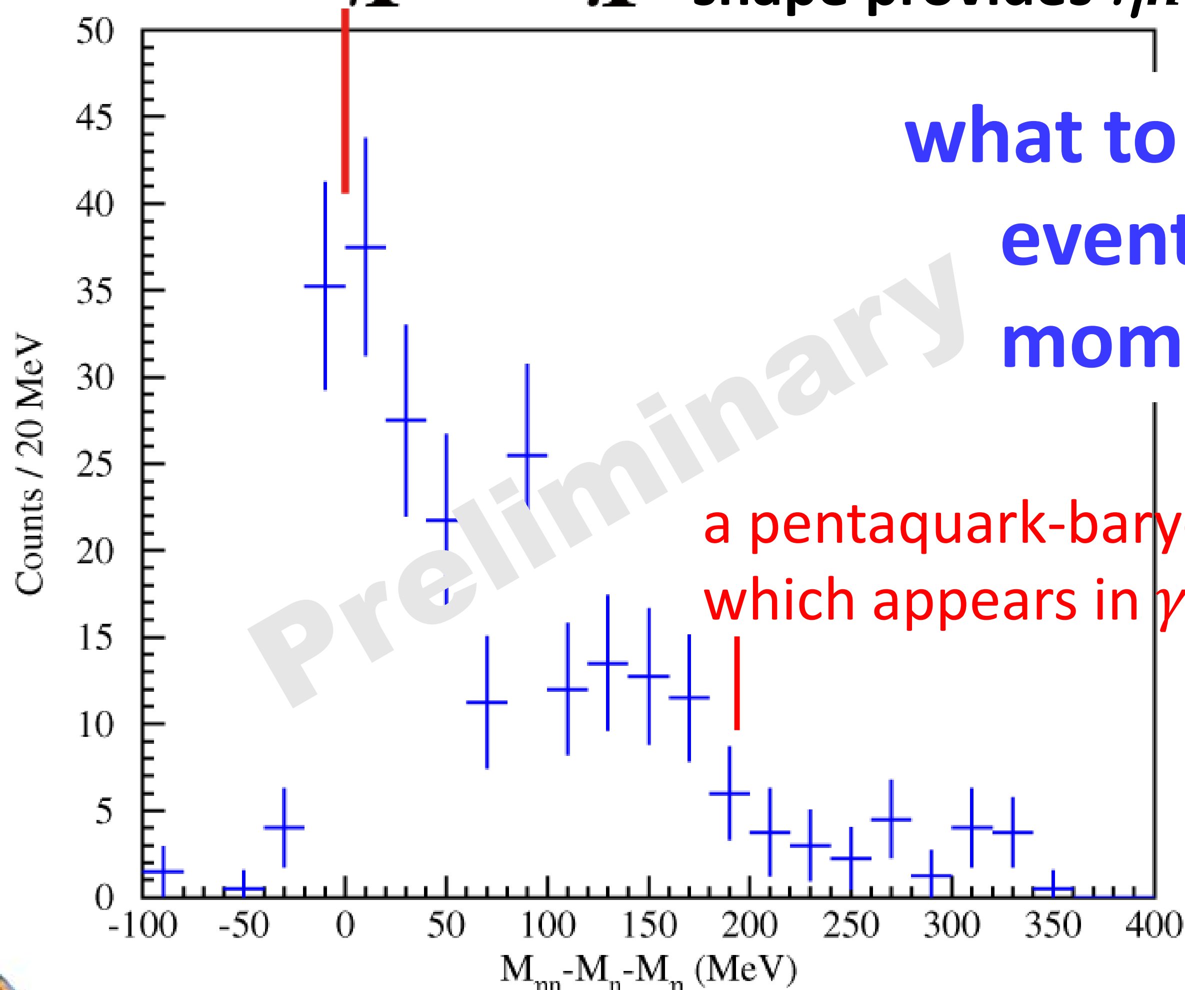
two particles in FOREST
in coincidence with photon-tagging signals

	hydrogen	deuterium	empty
2017.10.30~11.20	0.40 G	0.31 G	0.02 G
2017.11.23~11.30	0.20 G	—	0.05 G
2018.06.07~06.25	0.47 G	0.49 G	0.09 G
2018.10.12~11.04	0.75 G	0.88 G	0.07 G
2019.04.08~05.06	0.75 G	1.39 G	0.12 G
2020.04.09~05.21	0.99 G	2.72 G	0.13 G

current statistics: $\sim 2/3$ that of the original plan

ηn invariant mass distribution

$\gamma p' \to \eta p$ shape provides ηn rescattering



what to do:

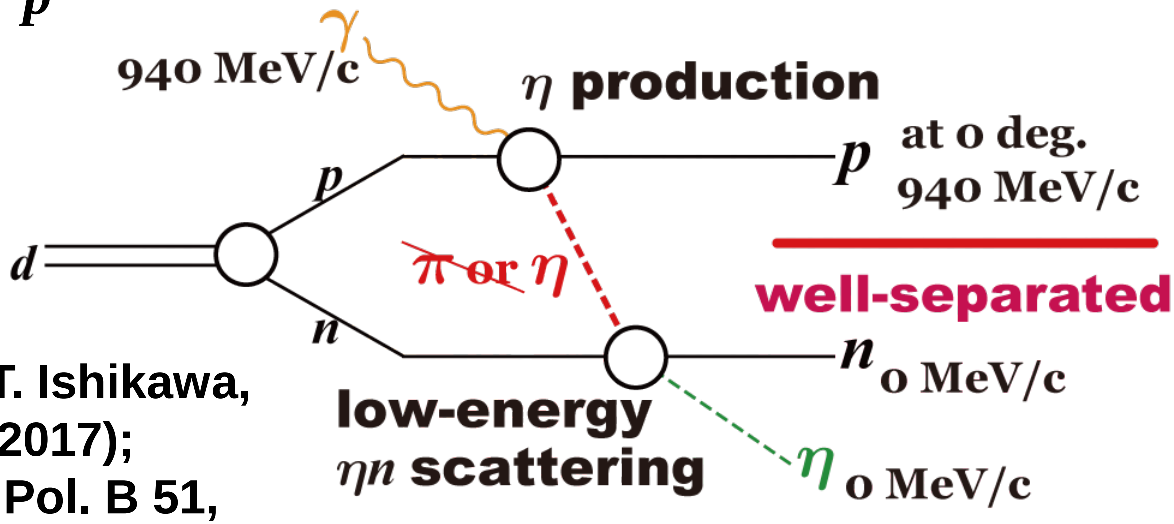
event selection

momentum analysis

a pentaquark-baryon candidate $N(1680)$, which appears in $\gamma n \to \eta n$ is not observed

differential cross section for $\gamma p \to \eta p n$ is measured to extract $a_{\eta N}$

E_γ=940 MeV and θ_p=0° is the ideal condition



S.X. Nakamura, H. Kamano, T. Ishikawa, Phys. Rev. C 96, 042201 (R) (2017);
T. Ishikawa *et al.*, Acta Phys. Pol. B 51, 27 (2020).

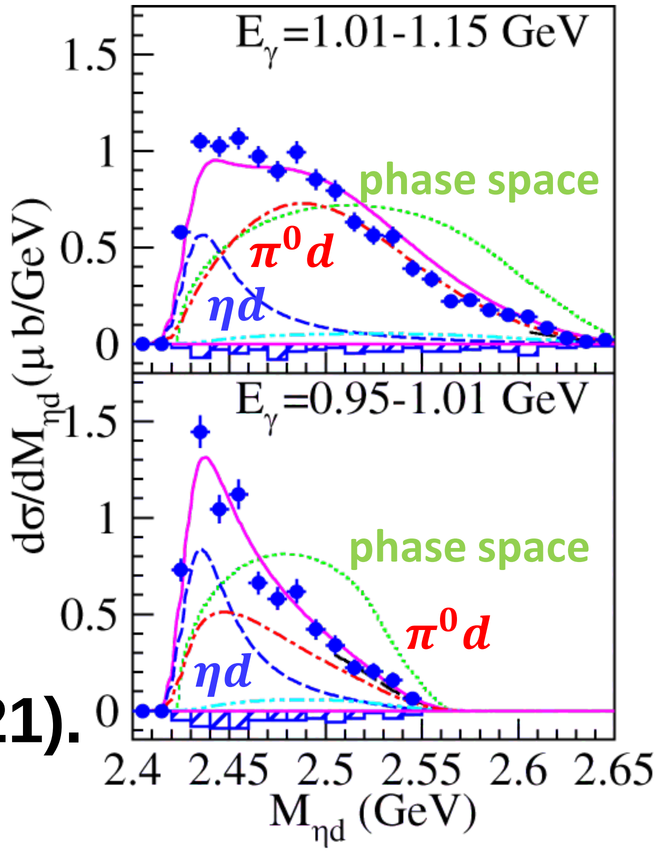
current statistics: ~2/3
analysis is on-going

Related topics

interaction between N and $N(1535)S_{11}$

ηd threshold structure in $\gamma d \to \pi^0 \eta d$

1) **1^- ηNN bound state coupling to πNN**
2) **strong ηd attraction**



T. Ishikawa et al., arXiv: 2105.10887 (2021).

Related topics

interaction between N and $N(1535)S_{11}$

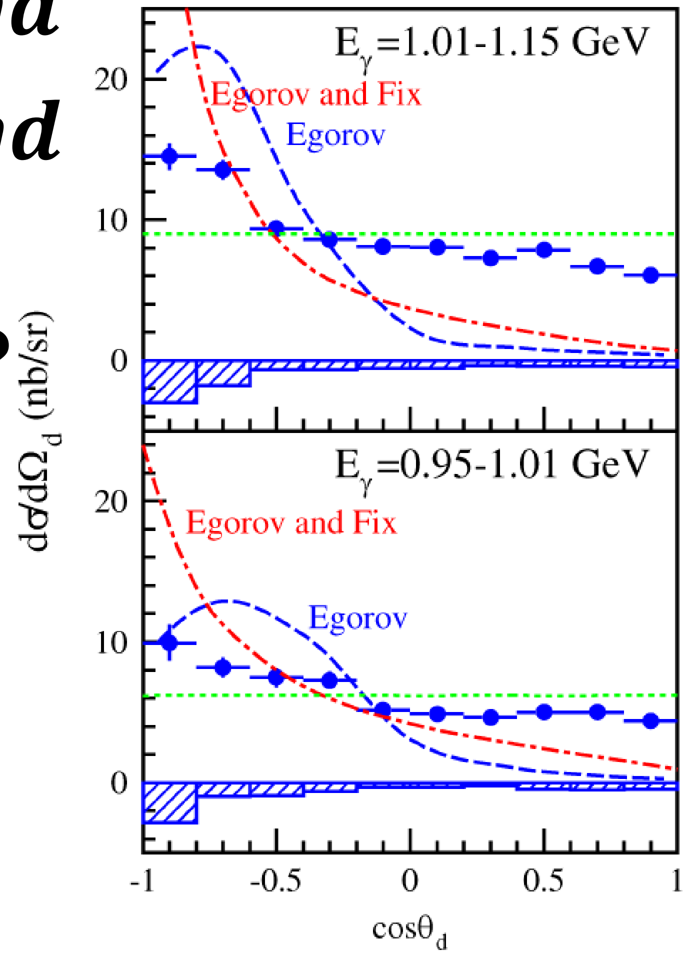
reaction mechanism of $\gamma d \to \pi^0 \eta d$

1) $\gamma d \to 0^- \to \pi^0[\eta d]_{1^-} \to \pi^0 \eta d$

2) $\gamma d \to 2^+ \to \eta[\pi^0 d]_{2^+} \to \pi^0 \eta d$

rather flat

appearance of NN^* dibaryon?



ηd scattering length, related to ηN scattering length

T. Ishikawa et al., in preparation.

FOREST/BLC collaboration

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