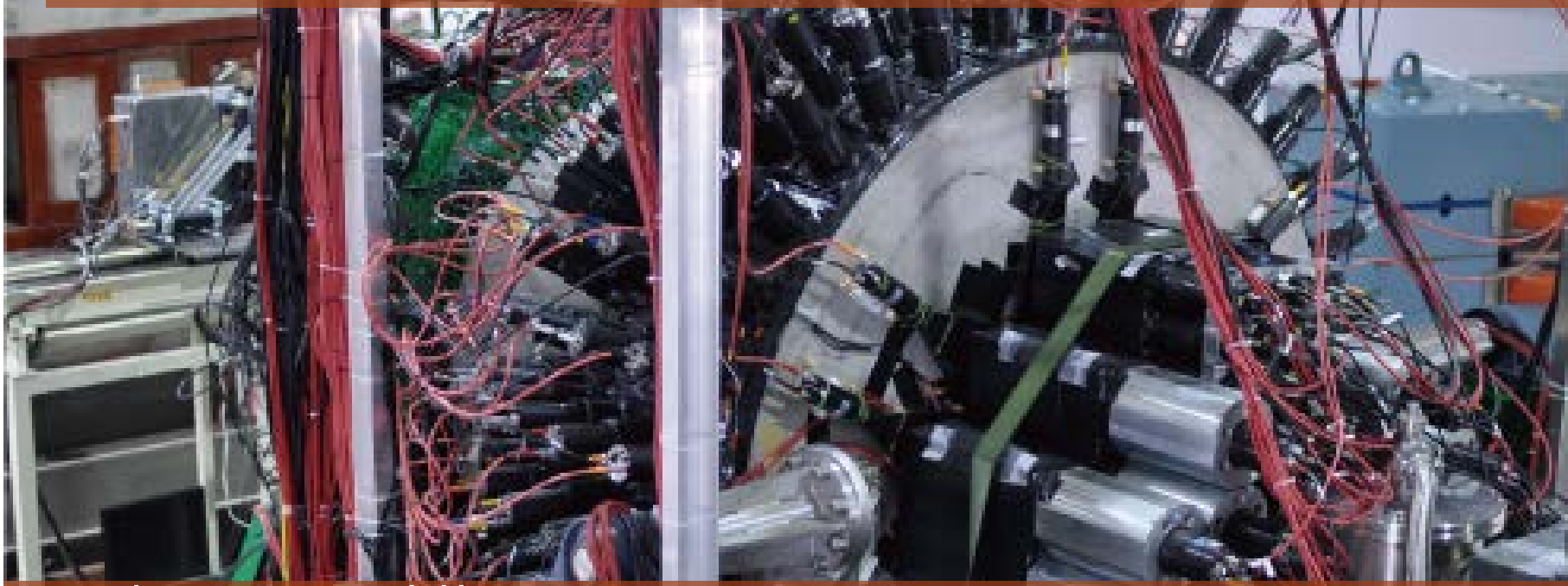
Determination of eta-nucleon scattering length from eta photoproduction on the deuteron



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- 3rd Symposium on Clustering as a window on the hierarchical structure of quantum systems, May 18, 2020

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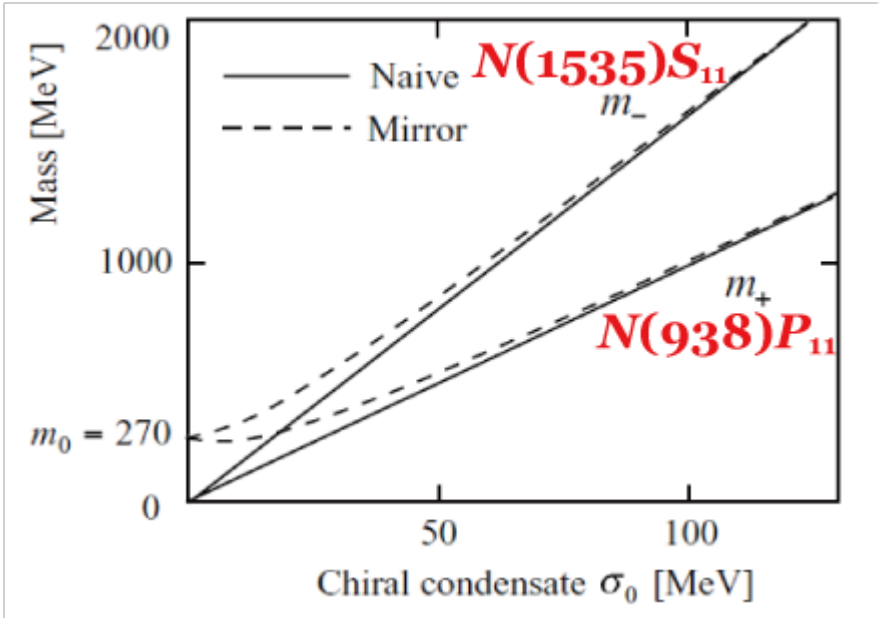
$N(1535)$ with $J^{\pi}=1/2^{-}$

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)

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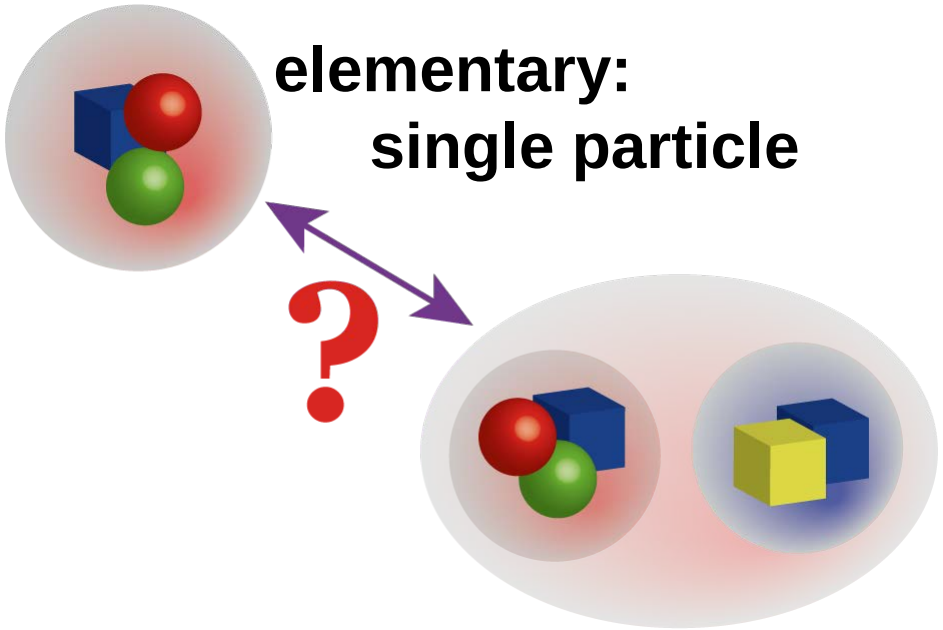


strongly couples to the eta meson (η)
and nucleon (N)

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 $\delta(p)$

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

a : scattering length

r : effective range

positive (negative) a provides attraction (repulsion)

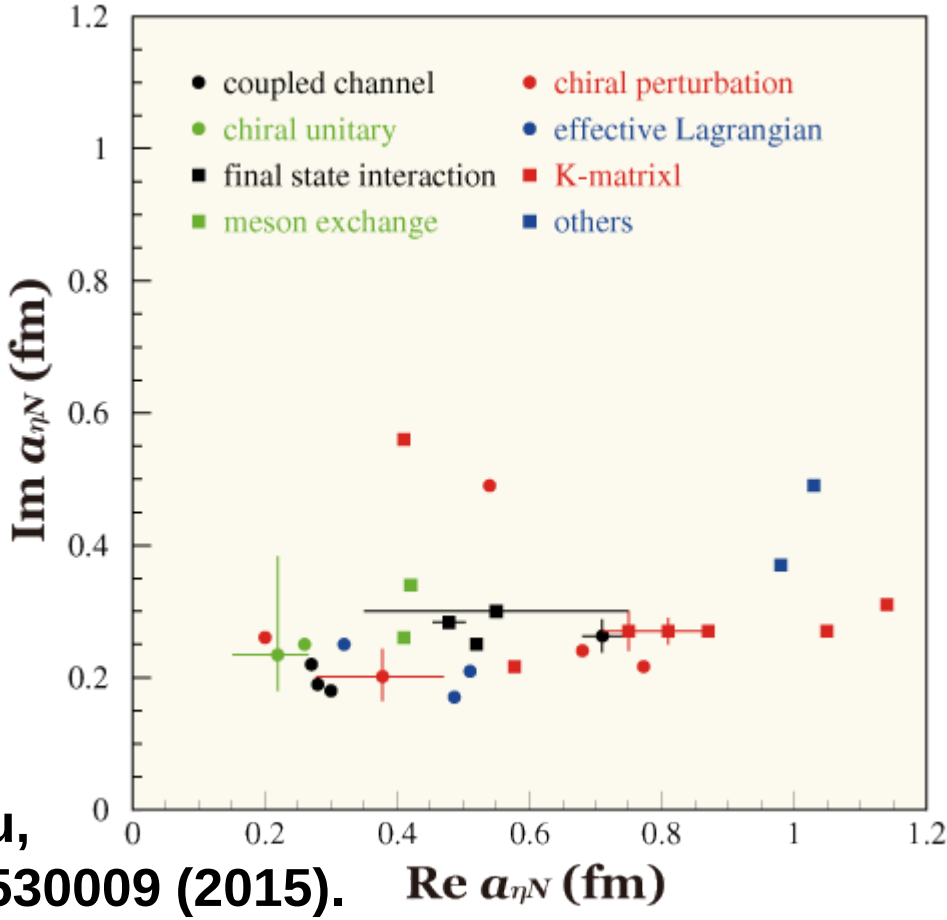
a is negative if a bound state is available

scattering length

fundamental and important

difficult to determine the scattering length between neutral hadrons

eta-nucleon scattering
Im: ~ 0.25 fm
Re: scattered



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

scattering length

final-state interaction (FSI) is utilized
1) relative momentum: low
2) FSI with another: known or small effects
3) production: known or small effects

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

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

1) low; 2) no; 3) small effects

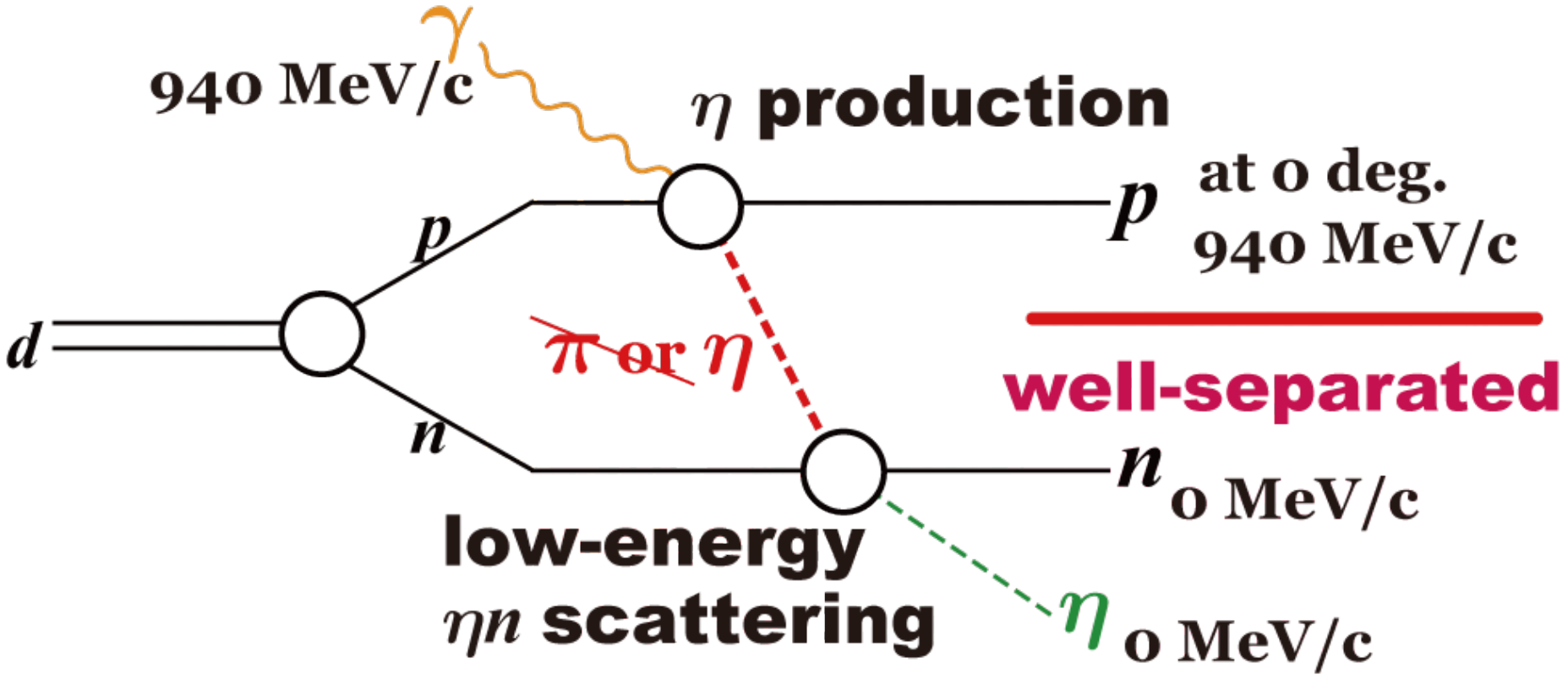
nn scattering length from $\gamma^* d \to \pi^+ nn$

S.X. Nakamura, T. Ishikawa, T. Sato, arXiv:2003.02497.

1) low; 2) known & small effects; 3) known & small effects

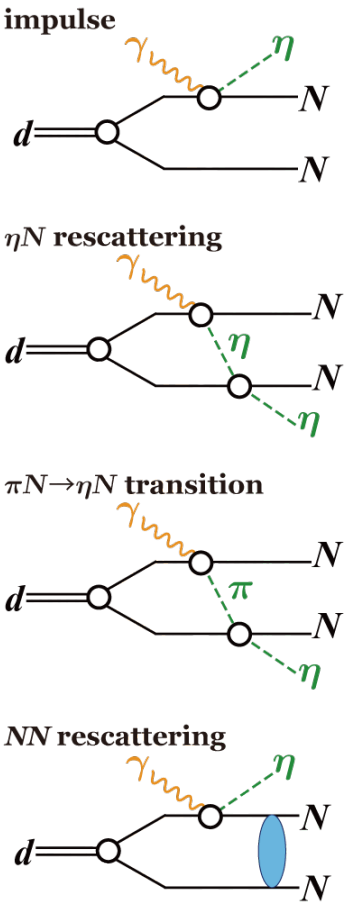
ηN scattering length

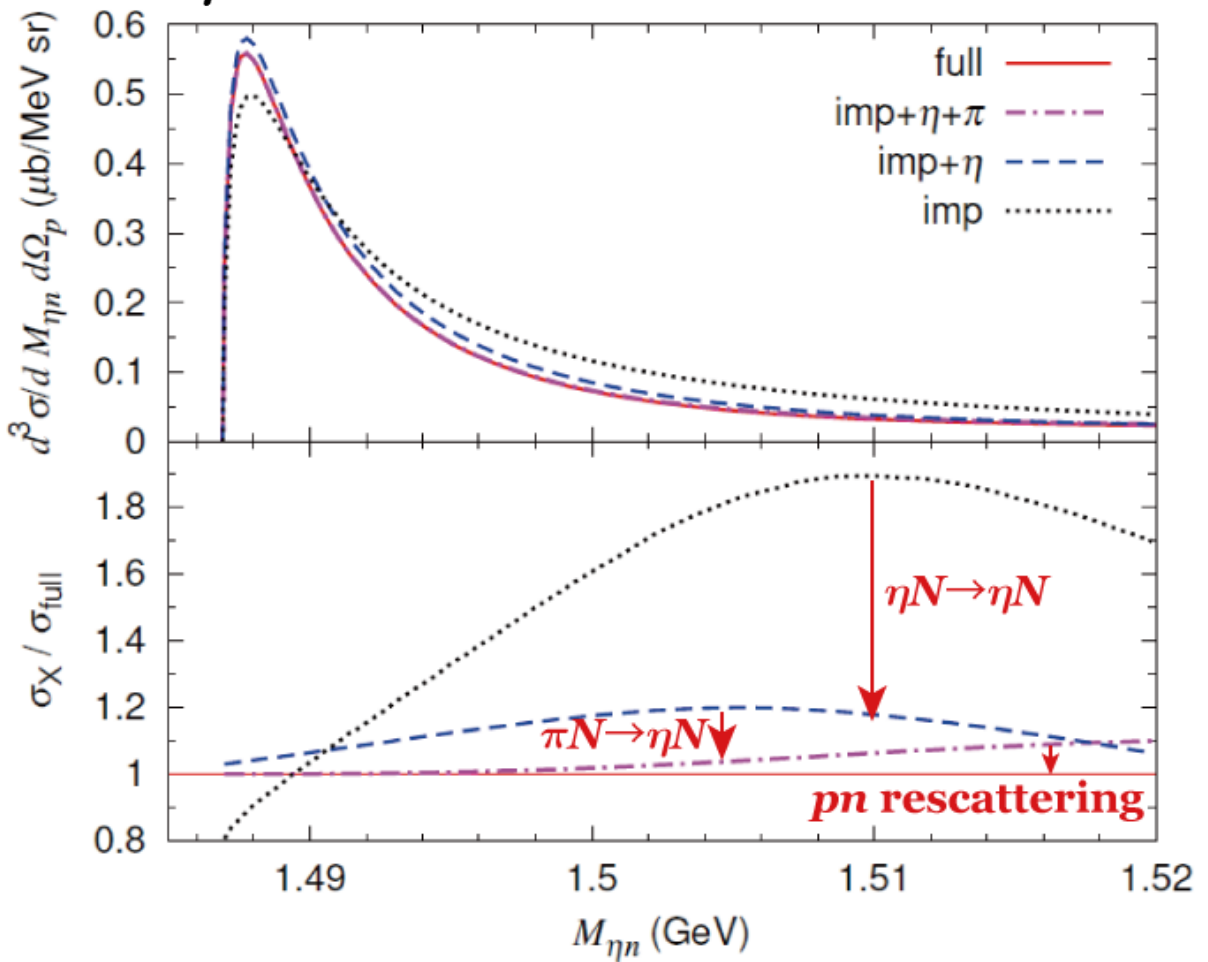
proposed kinematics for $a_{\eta N}$ determination using $\gamma d \rightarrow \eta pn$



ηN scattering length

differential cross section for for $\gamma d \to \eta pn$ as a function of ηn invariant mass

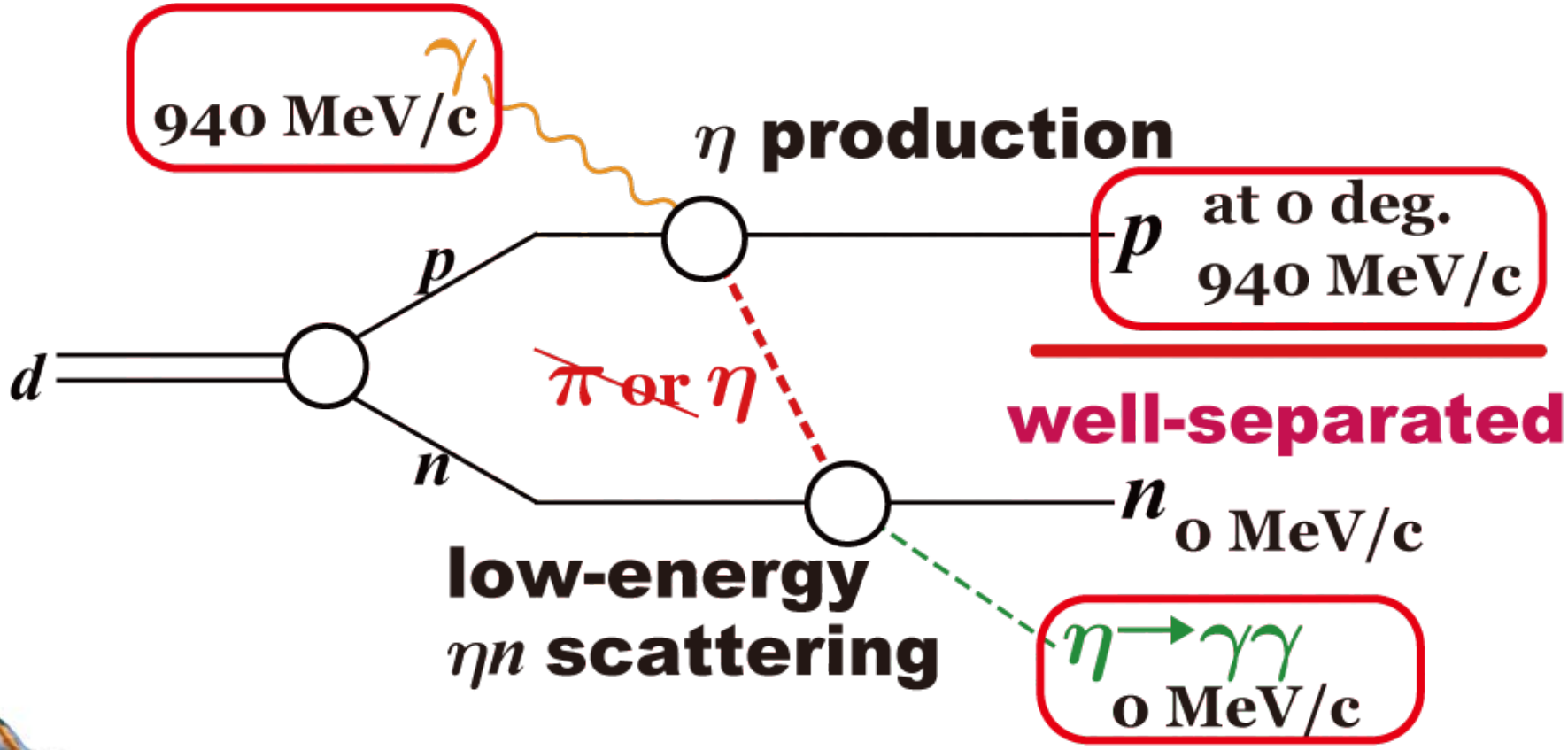




S.X. Nakamura, H. Kamano, T. Ishikawa, Phys. Rev. C 96, 042201 (R) (2017).

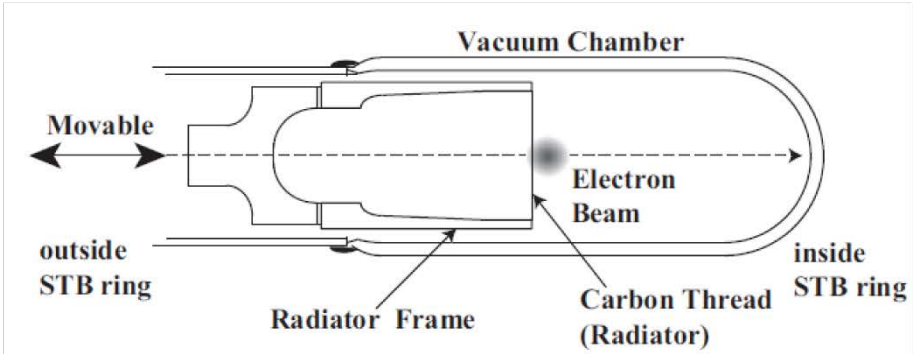
experiments

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



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

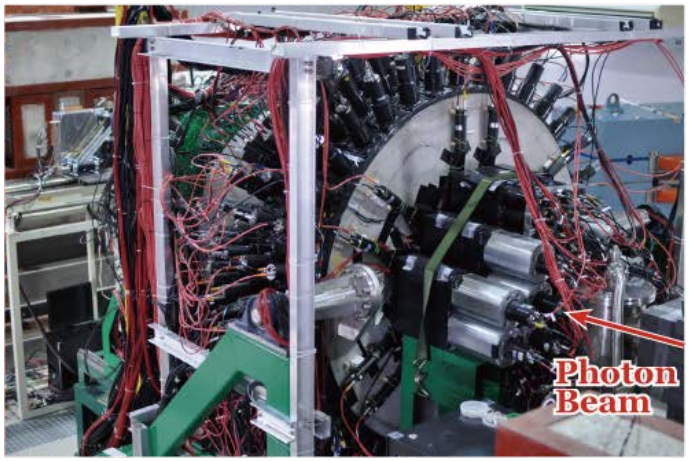
$$E_\gamma = 0.80 \sim 1.25\ \mathrm{GeV}$$

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).

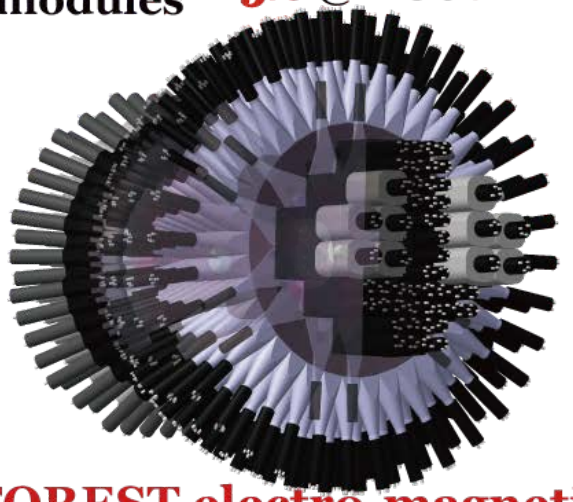
experiments

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

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



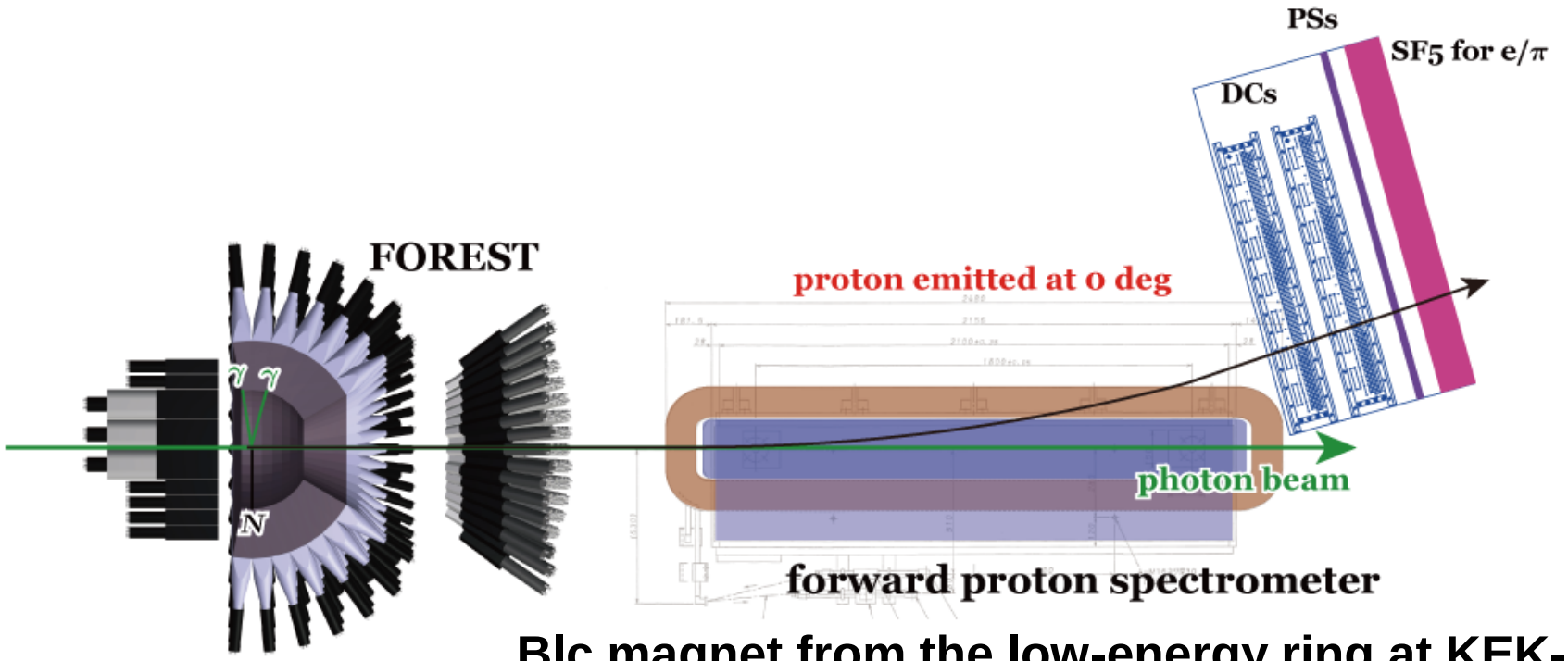
Target: 45 mm thick LH2 & LD2
T. Ishikawa



FOREST electro-magnetic calorimeter

experiments

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

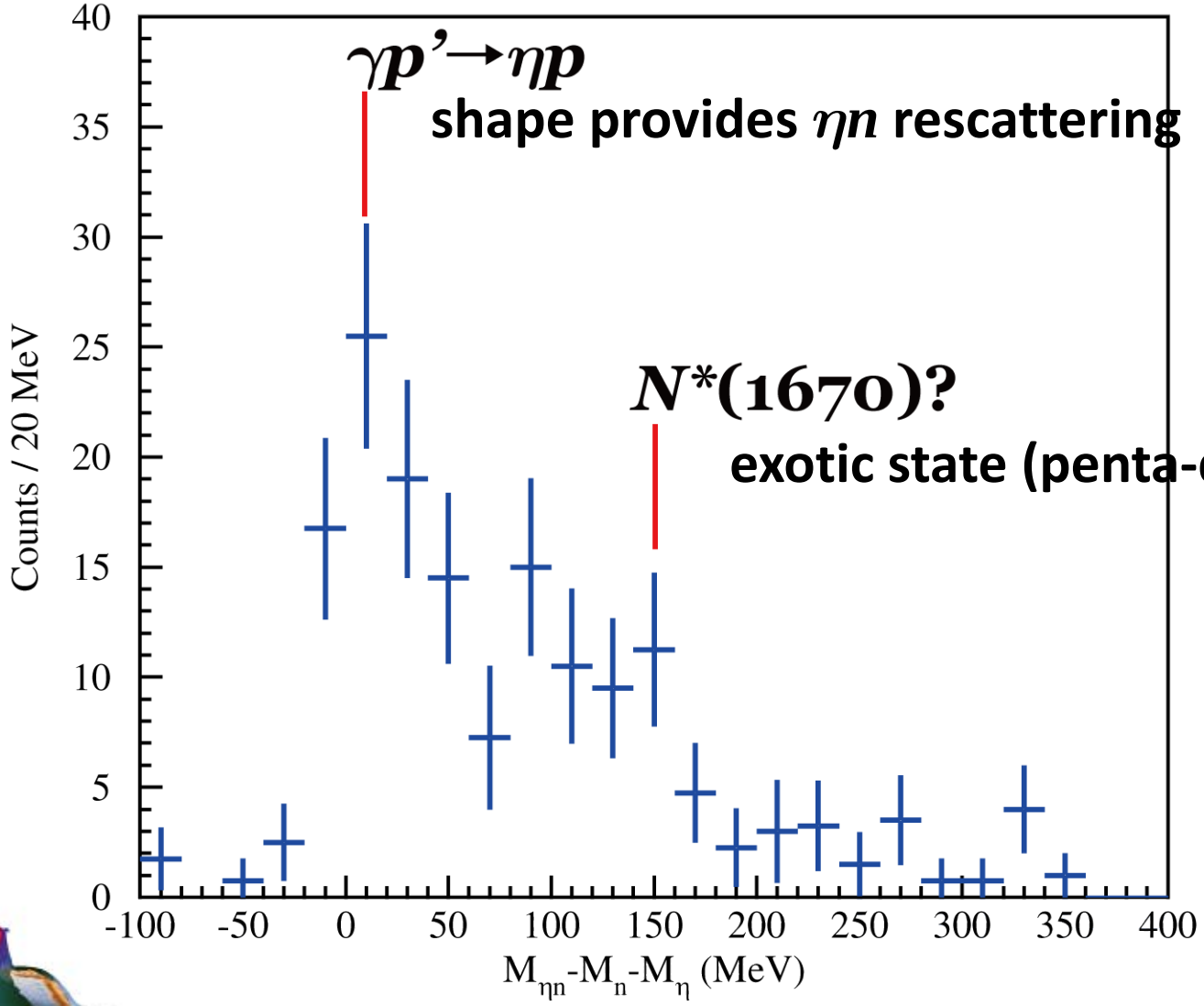
data acquired
two particles in FOREST

	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~	> 0.77 G	> 2.58 G	> 0.08 G

current statistics: ~½ of the original plan

current status

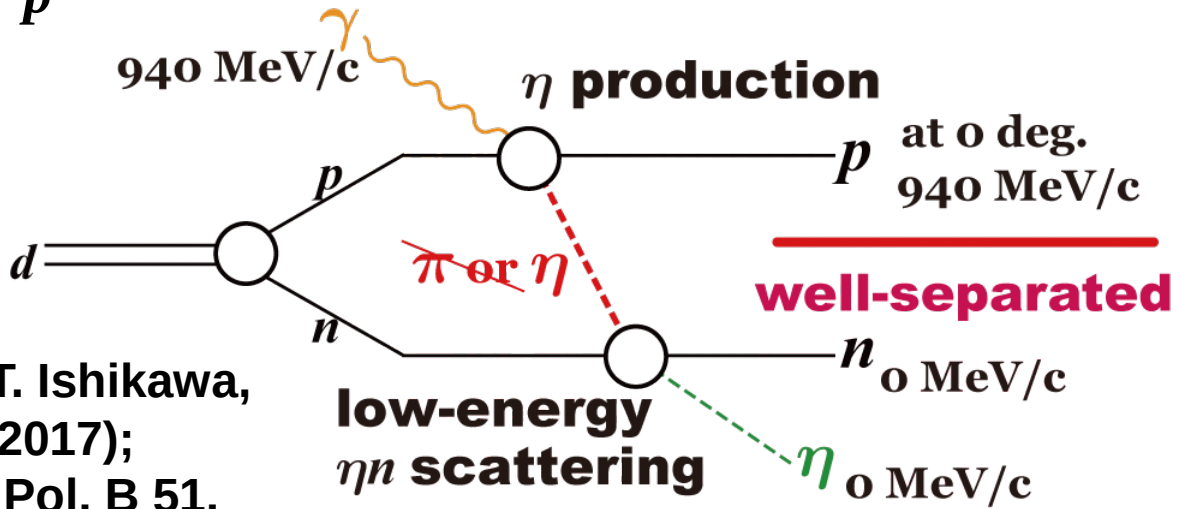
ηn invariant mass distribution



summary

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: ~½
analysis is on-going

FOREST/BLC collaboration

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