Incoherent Photoproduction of η Mesons from the Deuteron near Threshold

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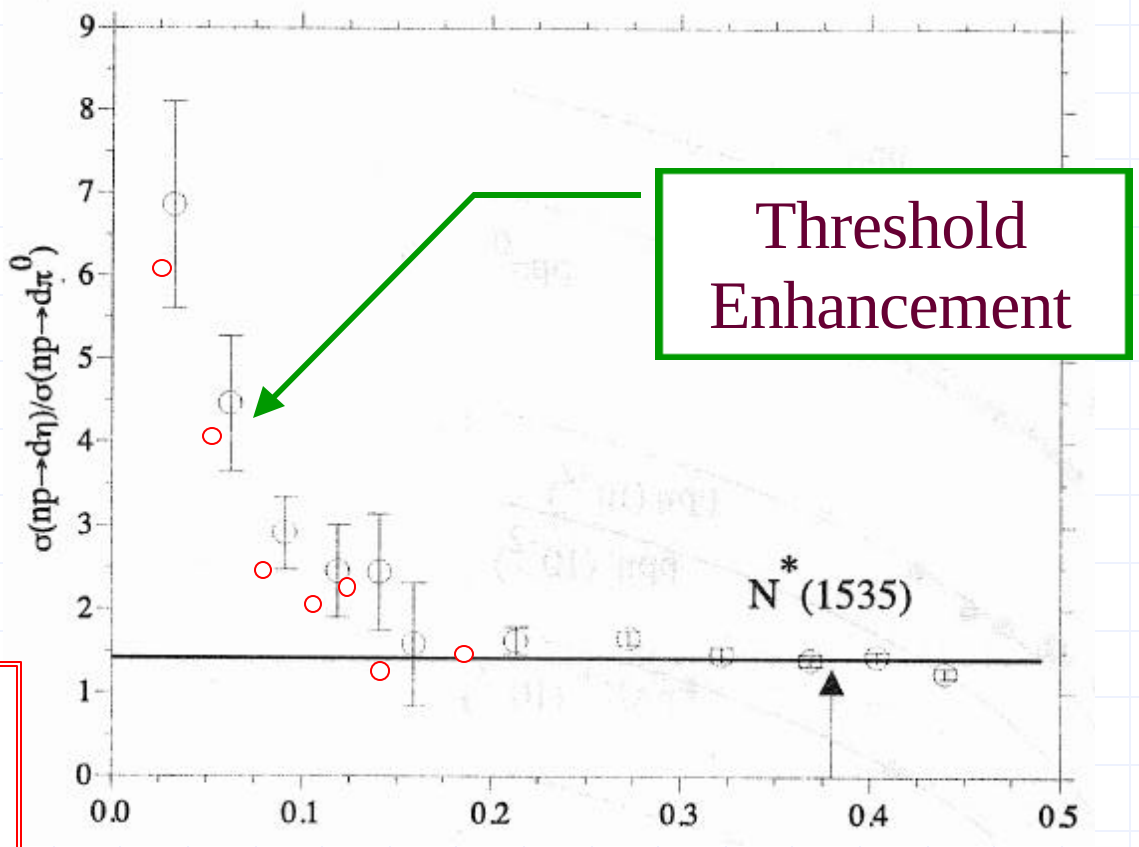
Observation:

$$\frac{s\,(np \to dh)}{s\,(np \to dp^{0})} > 1$$



Conjecture:

ηN interaction >

πN interaction

at low energy

⇒ maybe η almost bound

⇒ eta mesic nuclei

$\varepsilon = p_{meson}/mass_{meson}$

Threshold Reactions

- **Study ηN interaction in a threshold reaction**
- Observed: enhancement in $pp \to pp\,\eta$
  - lots of theoretical work, but likely inconclusive so far
- Possible final states:
  - $p\,p\,\eta$ and $n\,p\,\eta$
- Possible initial states:
  - $p\,p$ ..... $n\,p$ .... ^2H = deuteron

$$p\,p \to p\,p\,\eta$$

$$p\,n \to p\,n\,\eta$$

incoherent

$$\gamma\ d \to p\,n\,\eta$$

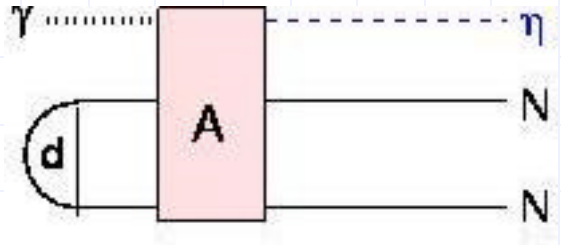
photons

$$\gamma\ d \to d\,\eta$$

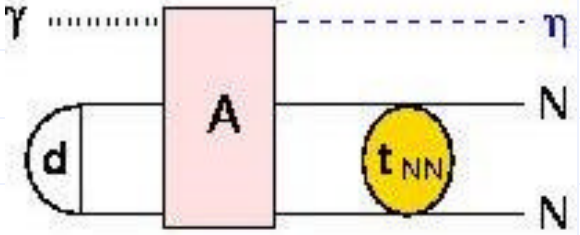
coherent

Incoherent η-photoproduction from deuterium

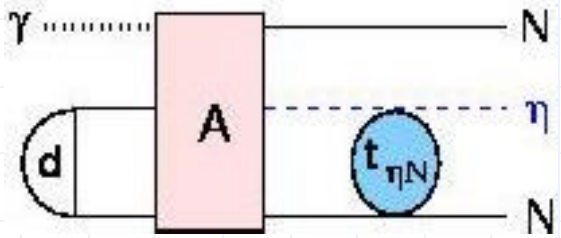
$$\left\langle k_g j_d \left| \mathrm{A} \right| \Psi_{NNh} \right\rangle$$



Impulse Approximation (IA)



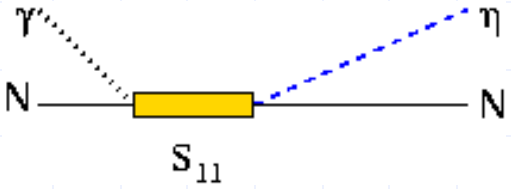
NN FSI (final state interaction)



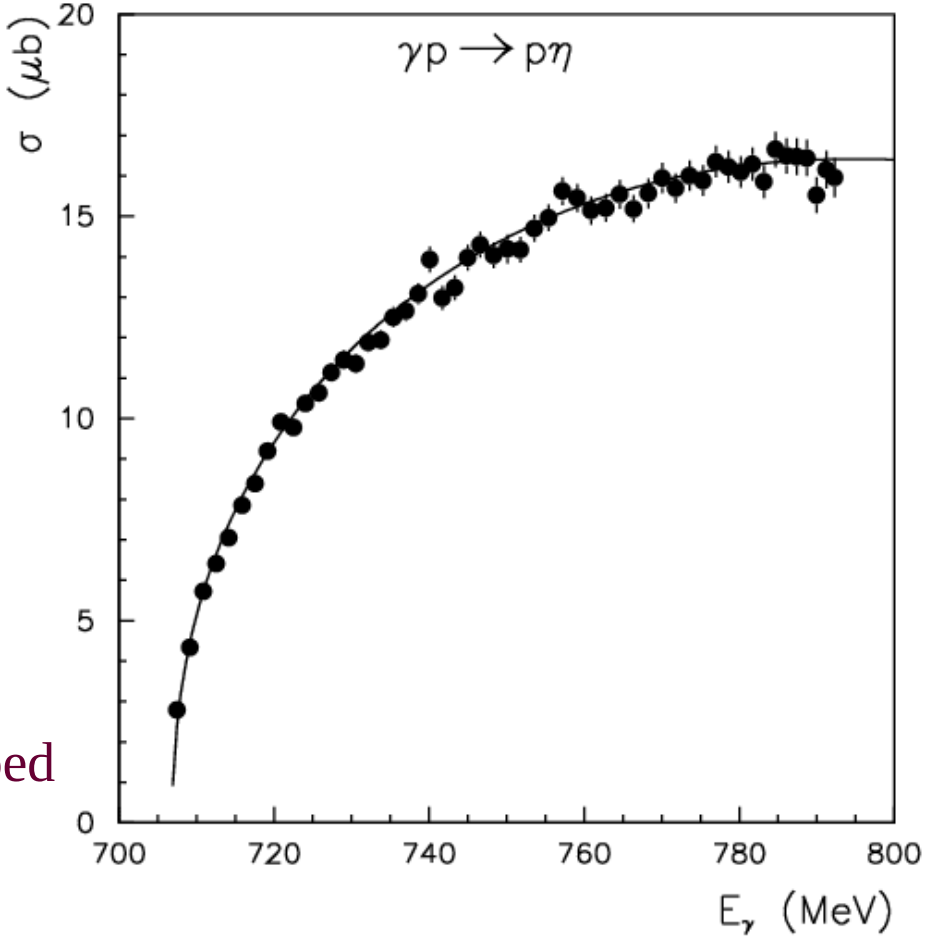
ηN FSI

Total cross section for $\gamma p \rightarrow p\eta$

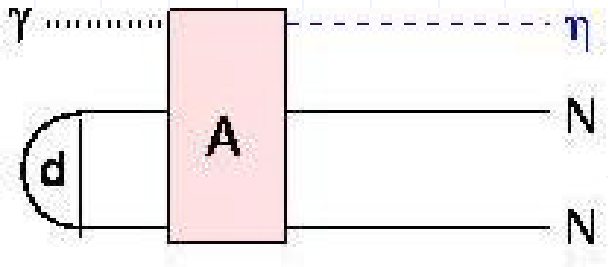
N* (1535) = S_{11}
dominant mechanism



take parameter from literature
check if experiment ($\gamma p \rightarrow p\eta$) is described



Total cross section for γd→npη (IA)



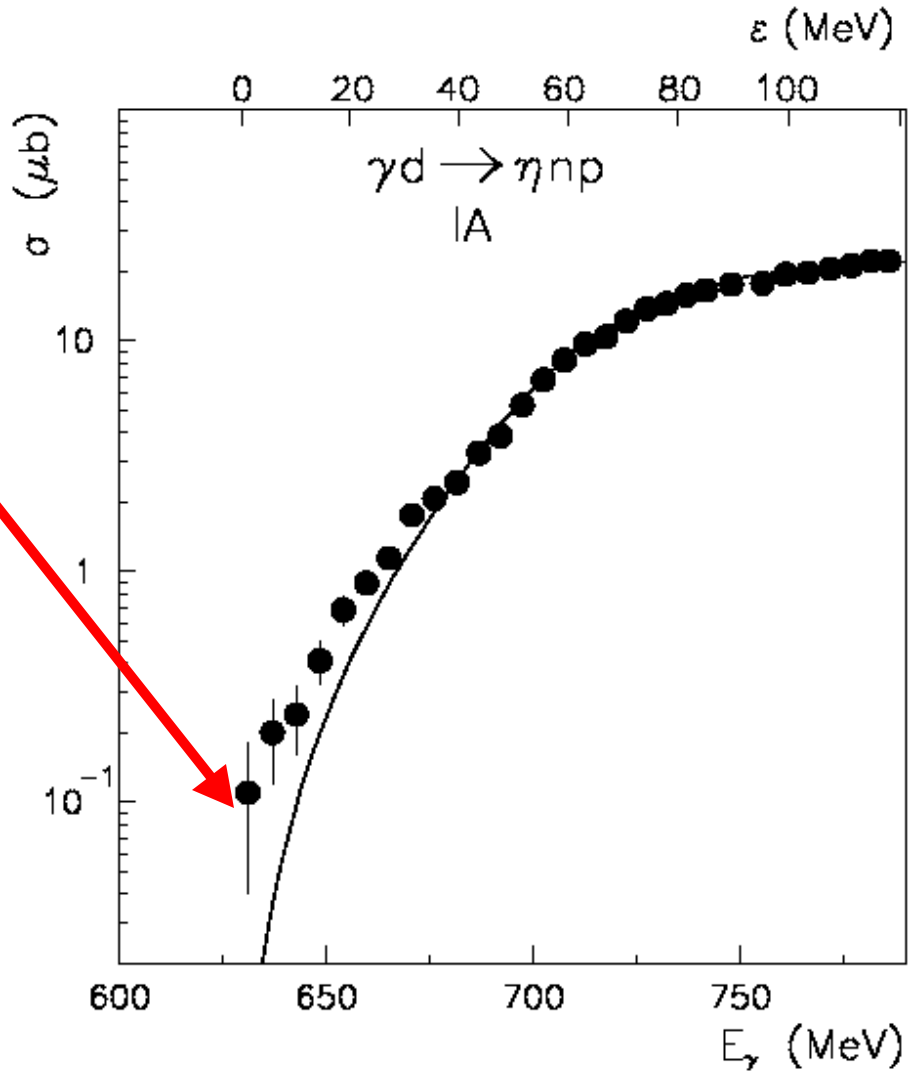
Threshold enhancement

excess energy:

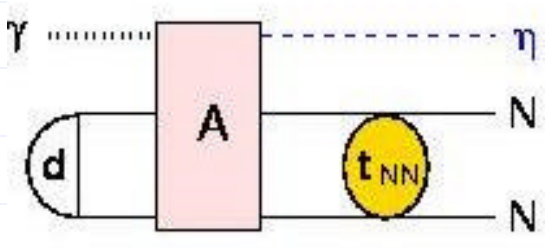
$$e = \sqrt{s} - m_p - m_n - m_h$$

invariant mass:

$$s = m_d^2 + 2m_d E_g$$



Consider NN FSI

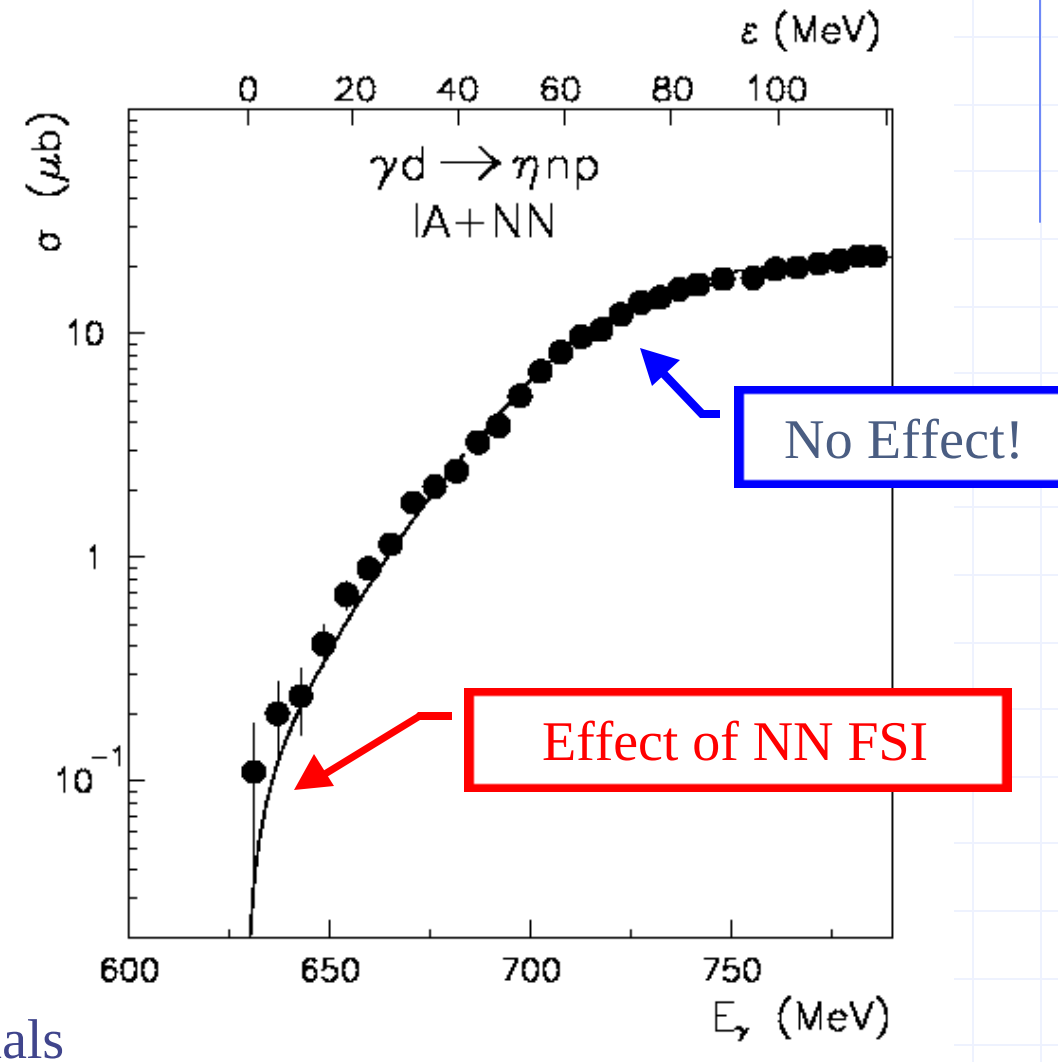


t_{NN} and ϕ_d

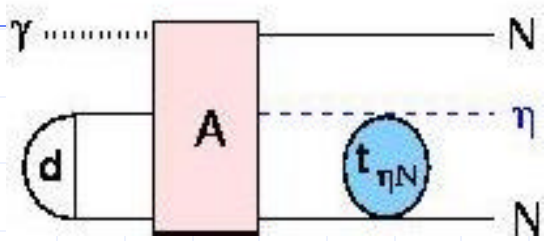
from CD-Bonn potential

Calculation does **not** depend on the NN potential employed

Integration over ϕ_d suppresses off-shell differences of NN potentials

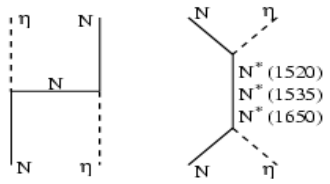


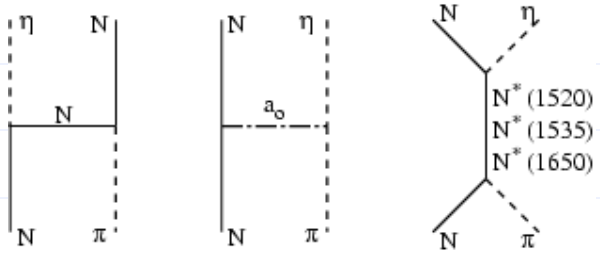
Consider ηN FSI

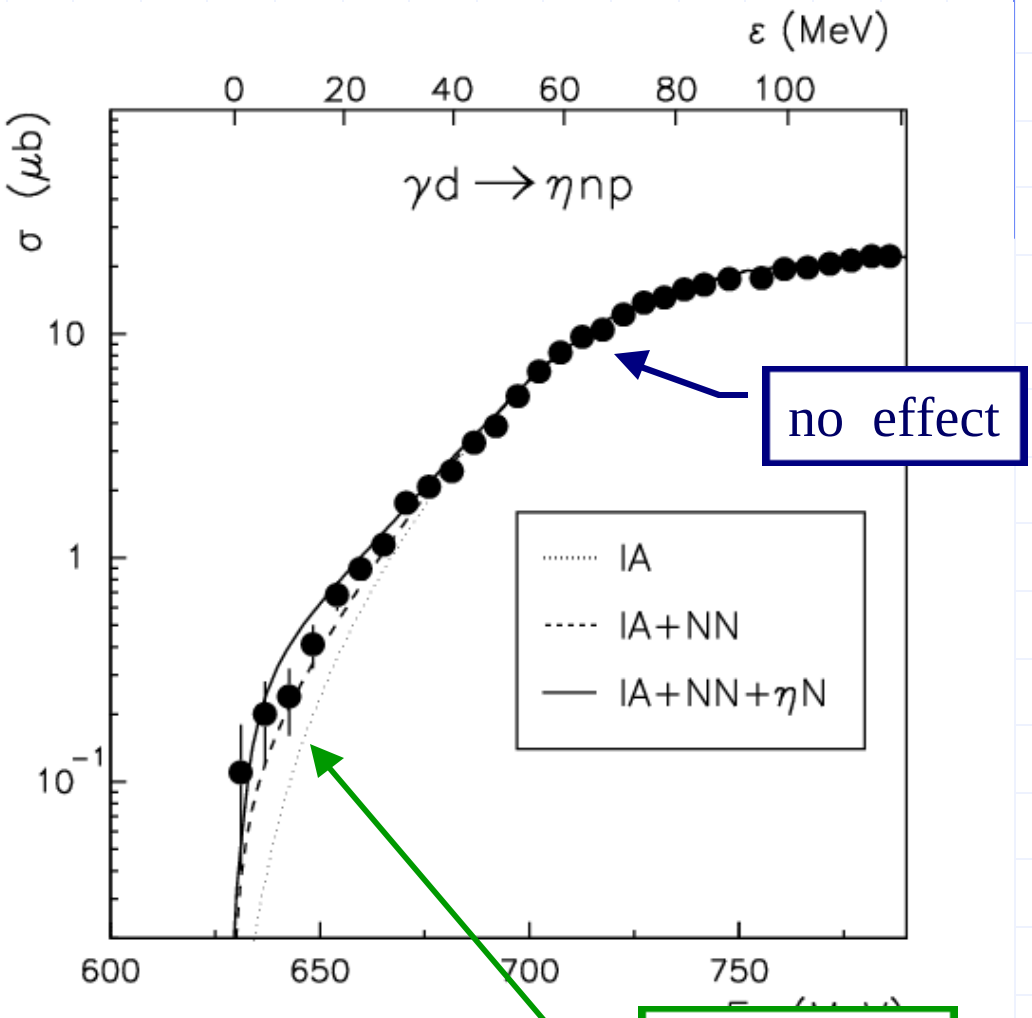


extract t_{hN} from a pN model
(here Jülich Meson-Baryon model)

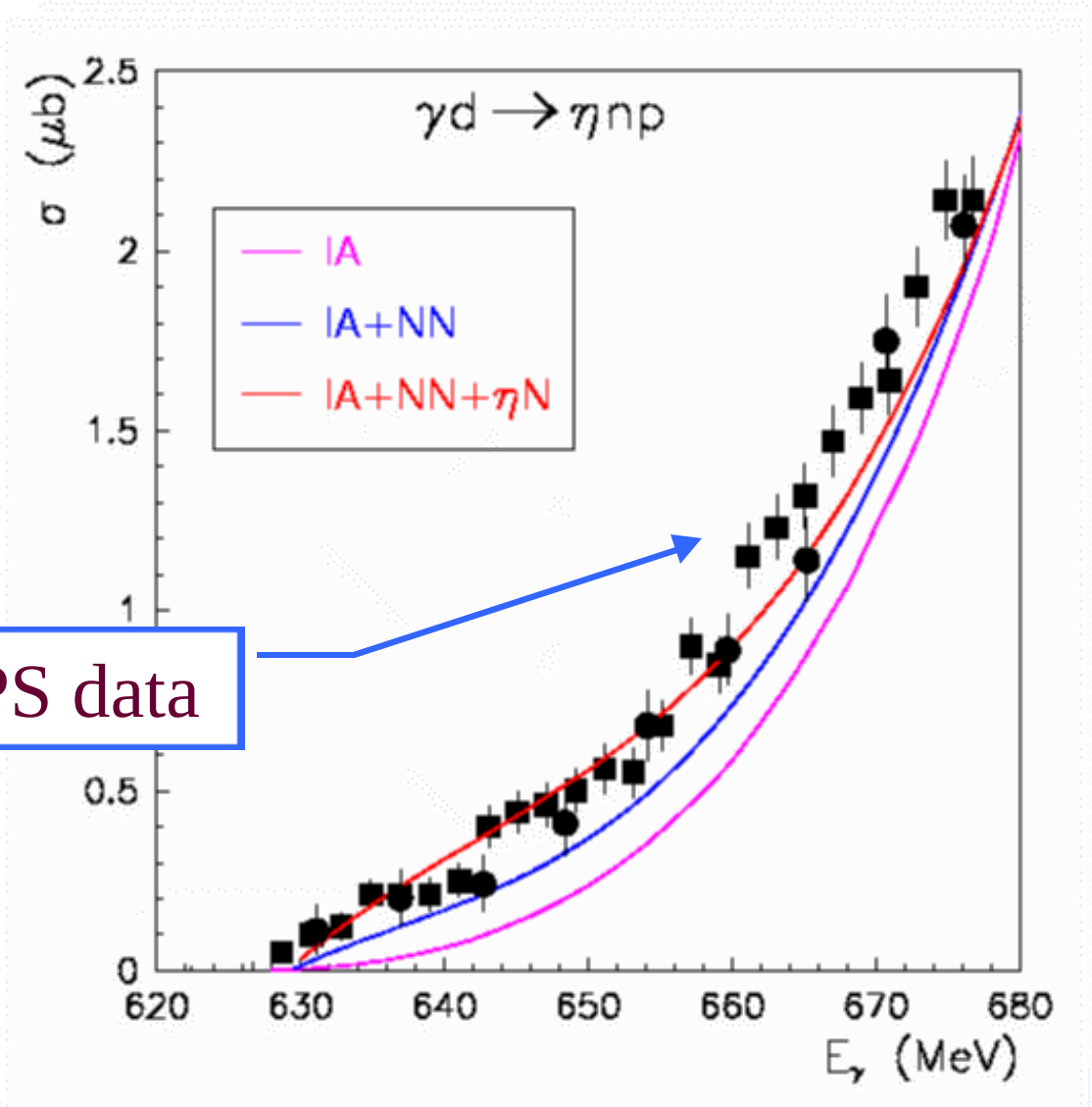
leading order diagrams for ηN





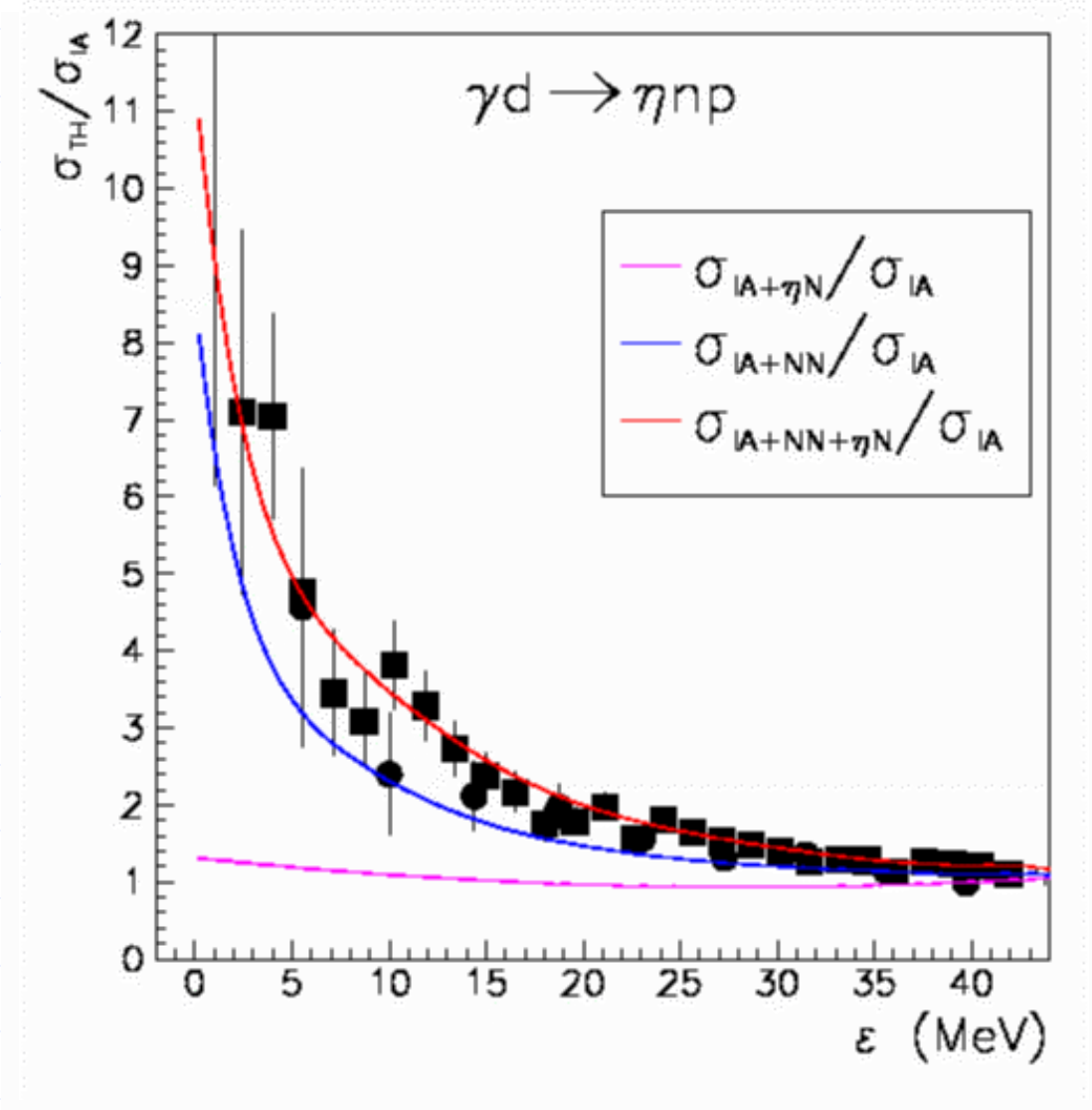


Total Cross Section γd→ηnp



new TAPS data

Size of FSIs:


$\gamma d \rightarrow \eta np$
σ_{TH}/σ_{IA}
$\sigma_{IA+\eta N}/\sigma_{IA}$
$\sigma_{IA+NN}/\sigma_{IA}$
$\sigma_{IA+NN+\eta N}/\sigma_{IA}$
0 1 2 3 4 5 6 7 8 9 10 11 12
0 5 10 15 20 25 30 35 40
ε (MeV)

t-matrix $t_{\eta N}(q,k)$

- ηN t-matrix derived from model for πN scattering
- extract scattering length: $a_{\eta N} = \lim_{q \to 0} f(q)$
  - effective range expansion

$$f(q) = \left[\frac{1}{a_{hN}} + \frac{r_{hN} q^2}{2} - iq \right]^{-1} = -p \, \frac{\sqrt{q^2 + m_N^2}\,\sqrt{q^2 + m_h^2}}{\sqrt{q^2 + m_N^2} + \sqrt{q^2 + m_h^2}} \, t_{hN}(q,q)$$

$$a_{hN} = 0.42 + i0.34 \text{ fm}$$

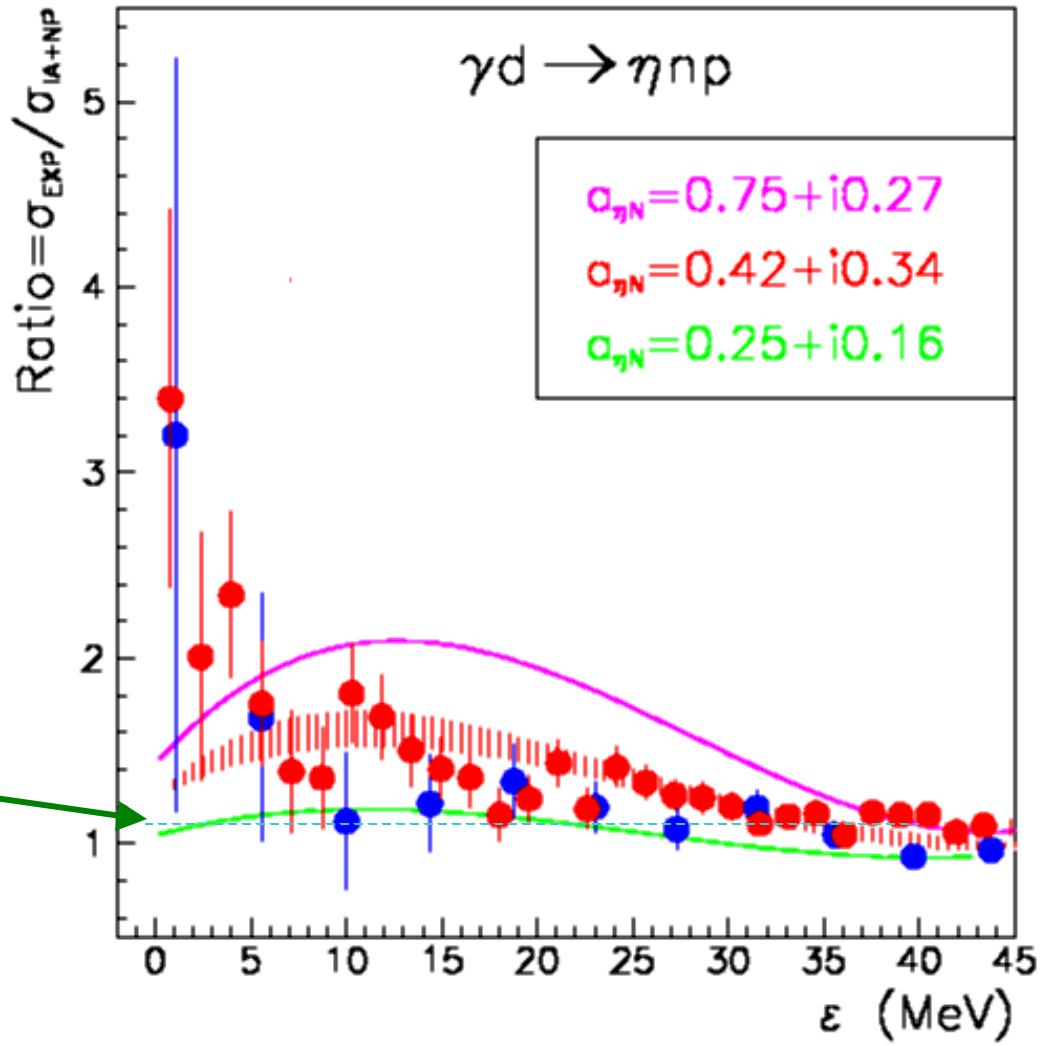
$$r_{hN} = -2.0 + i0.8 \text{ fm}$$

ηN FSI with **exact t-matrix** and effective range expansion give numerically the SAME result

we can test a_{hN}

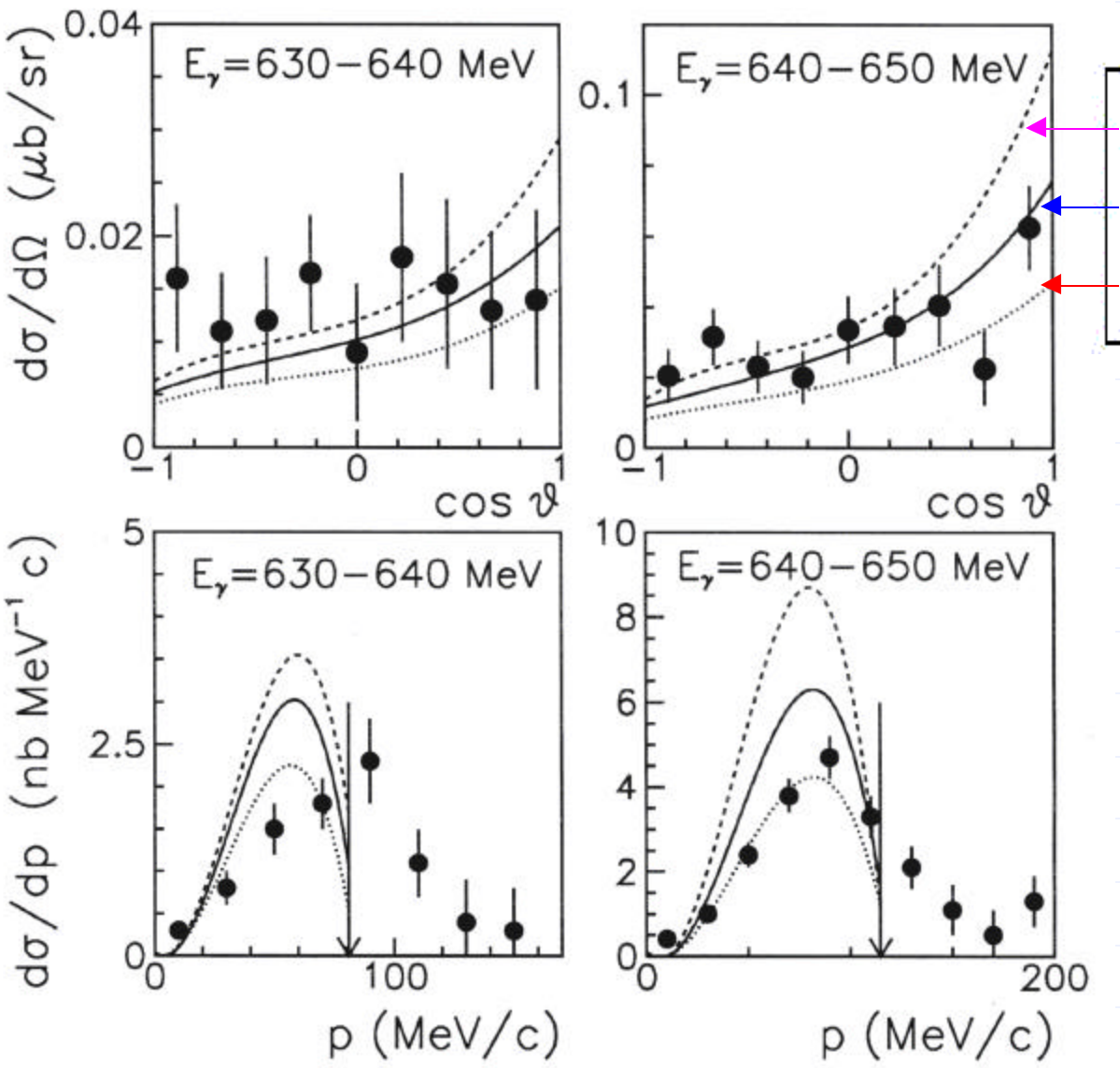
Linear Scale for ηN Enhancement

- Divide data through our calculation IA+NN-FSI



calculation
IA+NN-FSI

Angular and Momentum Spectra of the η



Incoherent η Photoproduction from the Deuteron near Threshold

favors moderate scattering length $a_{\eta N}$

a (fm)	Reference	Year	Model
0.27 + i0.22	Bhalero	1985	RM
0.25 + i0.16	Bennhold	1991	RM
~~0.98 + i0.37~~	Arima	1992	T
0.55 + i0.37	Wilkin	1993	FSI
0.51 + i0.21	Sauermann	1995	K
0.68 + i0.24	Kaiser	1995	EL
~~0.888+i0.279~~	Batinic	1995	T
0.476+i0.279	Faeldt	1995	RM
0.621+i0.306	Abaev	1996	T
0.51 +i0.21	Sauermann	1997	K
~~0.74 + i0.27~~	Green	1997	K
~~0.717+i0.263~~	Batinic	1998	T
~~0.87 + i0.27~~	Green	1999	K
~~1.05 + i0.27~~	Green	1999	K
0.32 + i0.25	Caro Ramon	2000	EL
~~0.772+i0.217~~	Nieves	2001	EL
0.54 + i0.49	Krippa	2001	EL
0.42 + i0.34	Juelich	2001	T

Punchlines: $\gamma d \rightarrow np\eta$

- Calculation of neutron-proton FSI does **NOT** depend on nuclear potential model
- Effective range expansion for ηN FSI gives numerically the same result as a sophisticated model
- Model independent test of ηN scattering length $a_{\eta N}$
- Our studies prefer $a_{\eta N}$ to be on the smaller side

Publications in:

- Sibirtsev, Schneider, Elster, Haidenbauer, Krewald, Speth
  - Phys.Rev.C65:067002,2002; http://xxx.lanl.gov/abs/nucl-th/0203039
  - Phys.Rev.C65:044007,2002; http://xxx.lanl.gov/abs/nucl-th/0111086
  - Phys.Rev.C64:024006,2001; http://xxx.lanl.gov/abs/nucl-th/0104011
- Elster, Sibirtsev, Schneider, Haidenbauer, Krewald, Speth
  - 7th International Workshop on Meson Production, Properties and Interaction, May 24-28, 2002,Krakow, Poland
    http://xxx.lanl.gov/abs/nucl-th/0207052