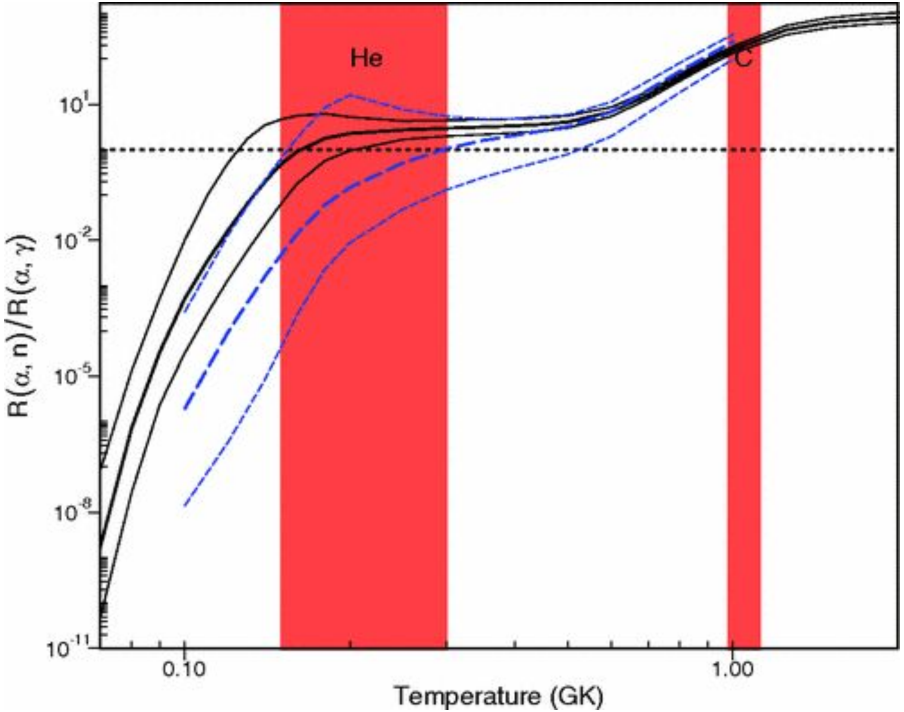
Re-evaluation of the ^{22}Ne+α reaction rates

Phil Adsley - padsley@tamu.edu

Background

Previous evaluation based on then-current nuclear data by Longland, Iliadis + Karakas, 2012

Since then multiple new experiments (I will discuss) with potential changes to the rates



R. Longland, C. Iliadis, and A. I. Karakas
Phys. Rev. C 85, 065809

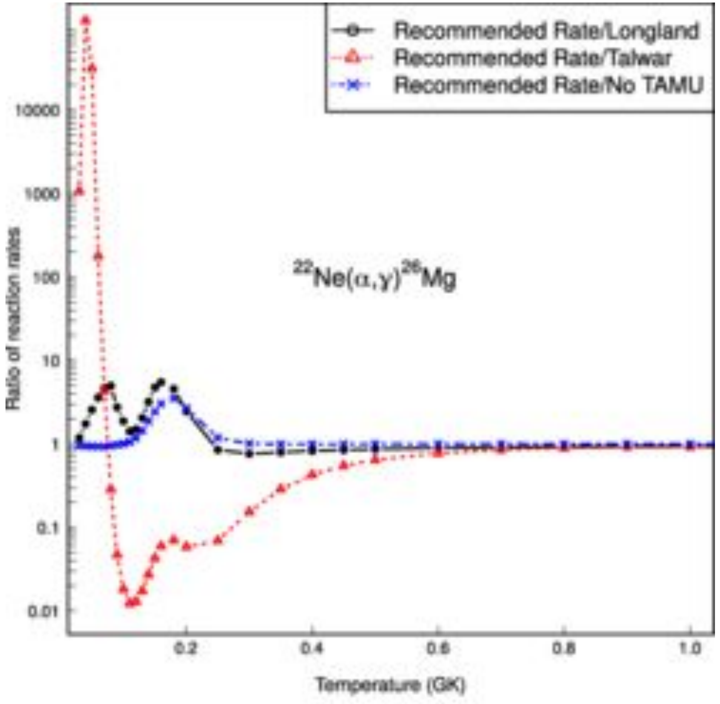
Methodology

Deliberate choice to base on Longland++ evaluation

Using the same Monte Carlo code (RatesMC)

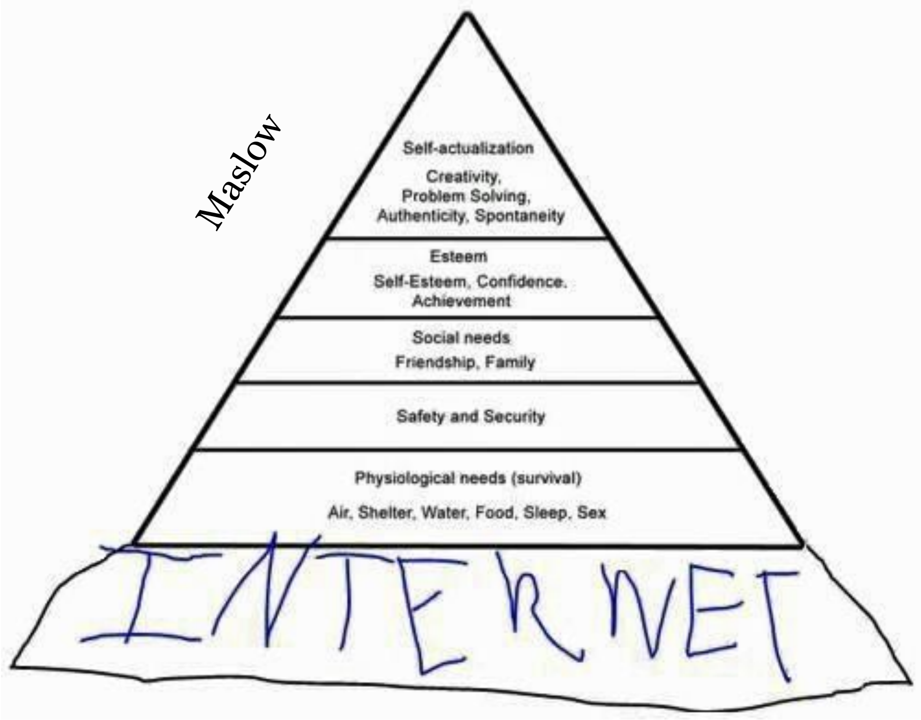
Minimise methodological changes, just concentrate on nuclear data

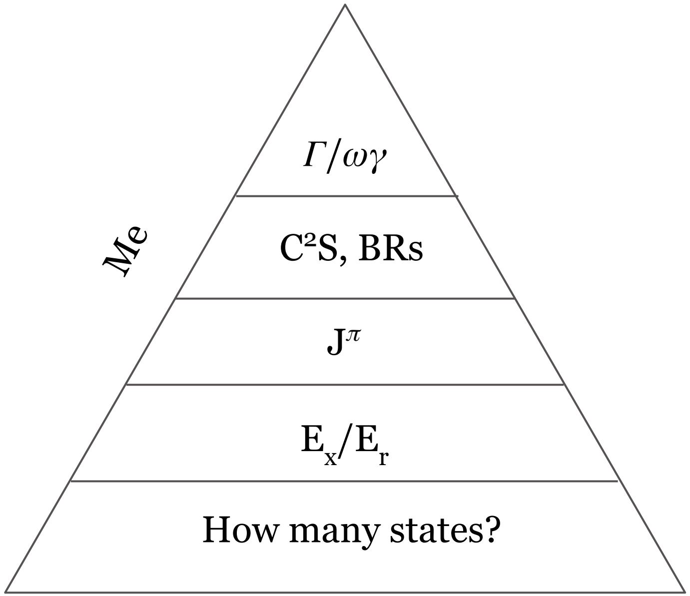
One important change - where we have clear connection between ^{22}Ne(α,γ) and ^{22}Ne(α,n) resonances, treat them as the same resonance not independently



So based on that the ^{22}Ne(α,γ) rate didn't really change, and we have the same mistake for one of the higher-energy resonances

The Hierarchy Of Needs



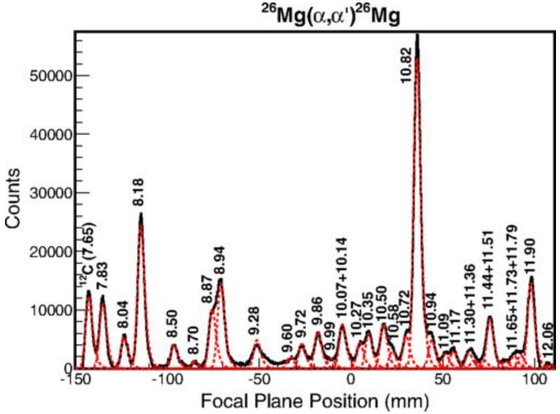


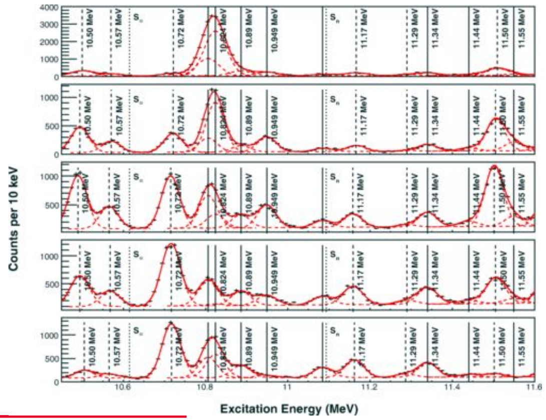
^{26}Mg(α,α')

Two datasets at the same energy - Talwar++ and PA++

Discrepant interpretations - I suggested 0^+ for a state at 10.8 MeV, Talwar suggested 1^- linked to ^{26}Mg(γ,γ')

No impact for ^{22}Ne(α,n) since below neutron threshold but impact on ^{22}Ne(α,γ)



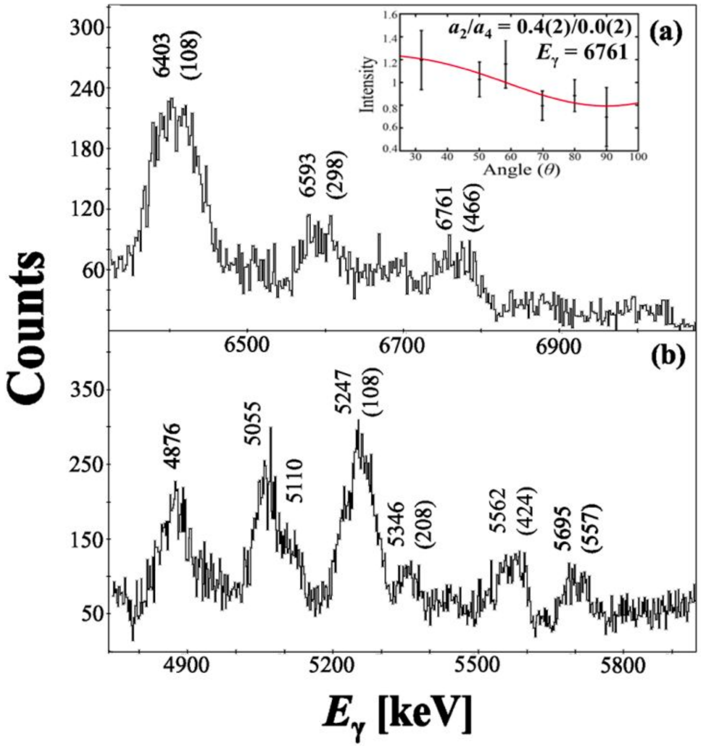


Fusion-evaporation γ spec

Gammasphere using the $^{11}B(^{16}O,p)$ reaction

Yet another state at 10.8 MeV! But fusion-evaporation too high spin (J>1) to be the states in $^{26}Mg(\gamma,\gamma')$ or $^{26}Mg(\alpha,\alpha')$

Assigned to be $J^{\pi}=2^{+}$



Lotay++ EPJA 55 109 (2019)

^{26}Mg(p,p')

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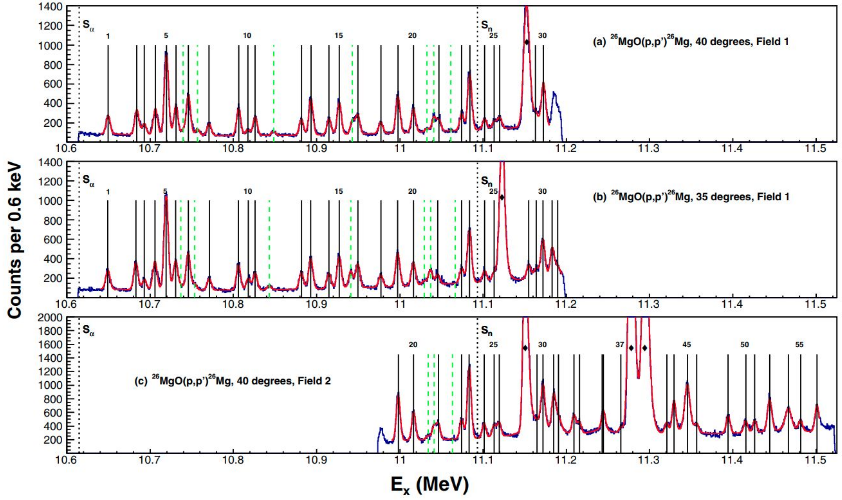
To resolve, used ^{26}Mg(p,p') with high resolution at Munich

Quite a low beam energy = weak selectivity to structure

Find three states, replace Talwar assignment and accept the Gammasphere, PA and ^{26}Mg(γ,γ') assignments



Vertical lines denote states - black are ^{26}Mg, green are ^{24}Mg
PA++ PRC 97 045807

Neutron Resonance Scattering

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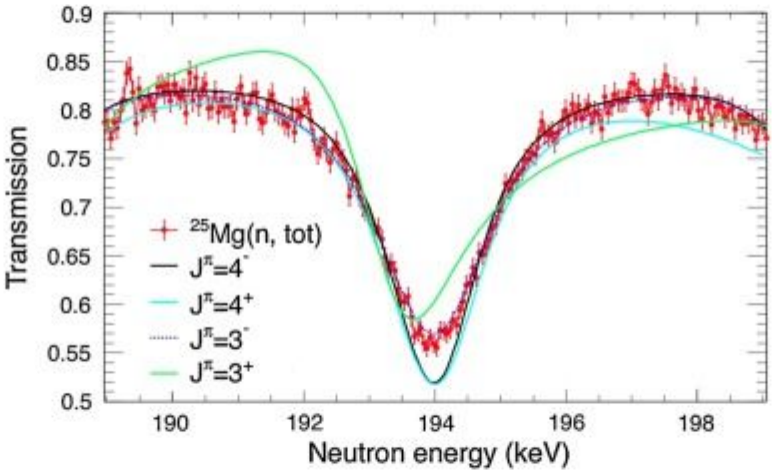
^{25}Mg+n data at nTOF

Get both neutron and γ width information

Really good energy data

Only above the neutron threshold



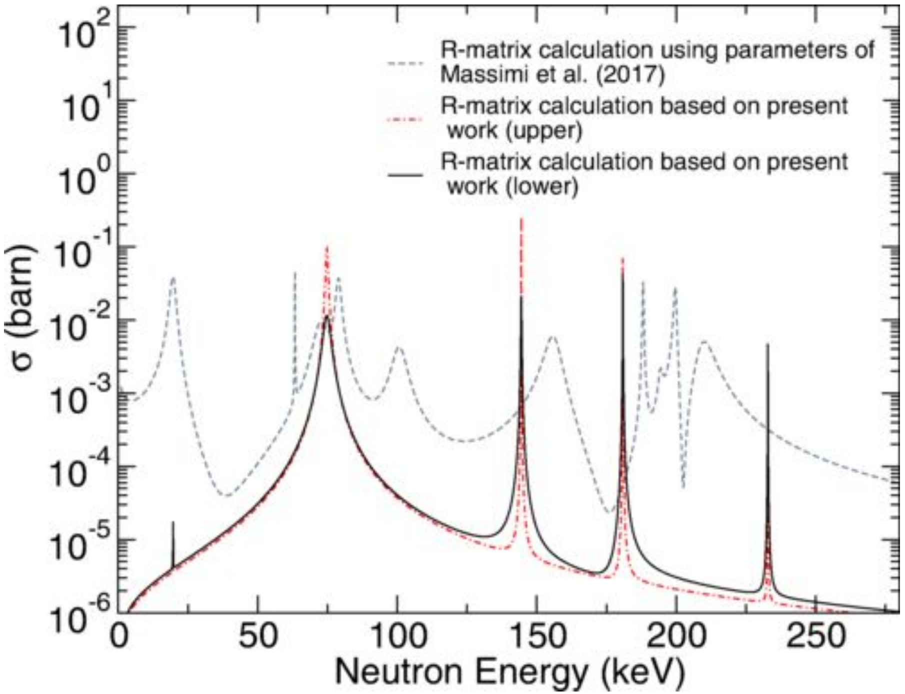
Massimi C. et al., PLB 768, 1-6 (2017)

$^{25}Mg(d,p)$

Study with Grand Raiden, not included in the 2021 evaluation (sadly! I really like this experiment)

Some level assignments or additional data which should make it into the next evaluation

Interesting point here that it showed that it's actually hard to get (n,γ) from (d,p) which manifested something I hadn't previously understood

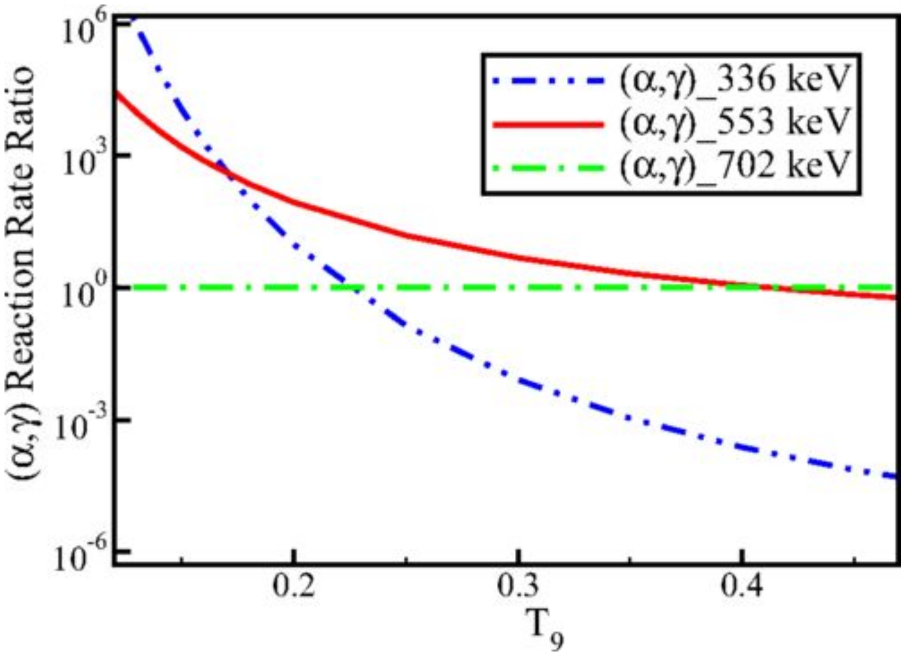


Talwar $^{22}Ne(^{6}Li,d)$

Also at Grand Raiden

^{22}Ne gas cell, ^{6}Li beam

Find a new strong, previously unobserved resonance at 553-keV which enhances the $^{22}Ne(\alpha,\gamma)$ reaction rate considerably



TAMU Measurements*

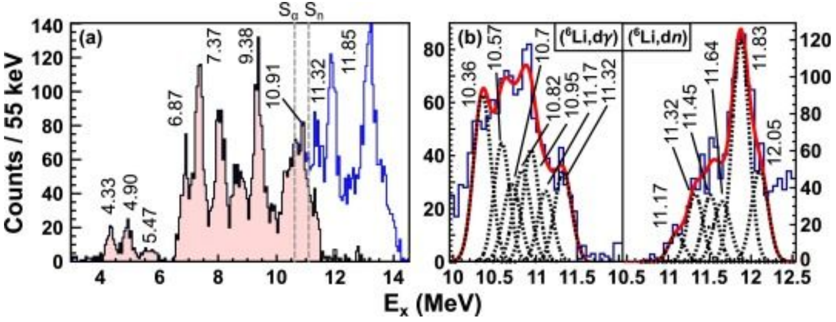
Two measurements

-Shuya's ^{22}Ne(^{6}Li,d) with branching ratio of decays

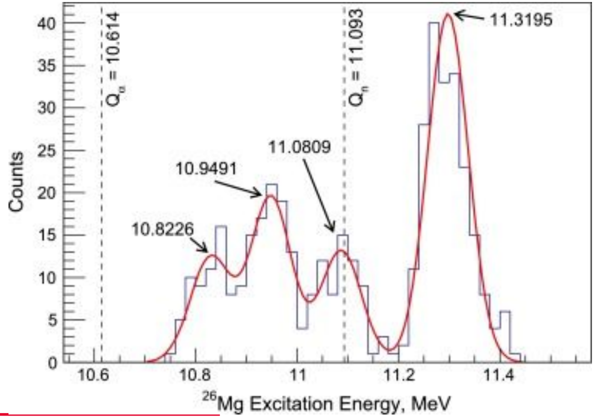
-Heshani's sub-Coulomb ^{22}Ne(^{6}Li,d) transfer measurement for "model-independent" α-particle widths

-Both suggest revising down the ^{22}Ne(α,n) resonance strength

*both predate my time at TAMU



Ota++, PLB 802 135256 and Jayatissa++ PLB 802 135267

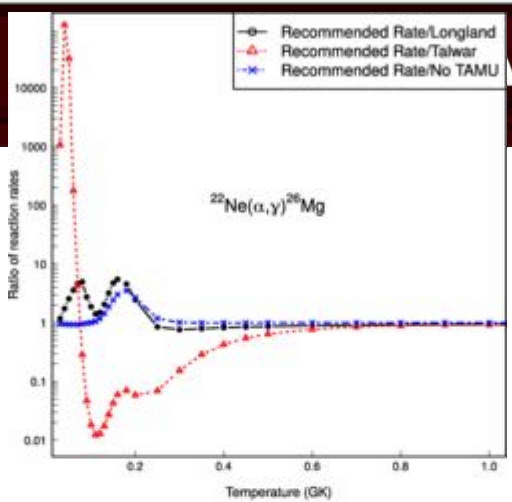


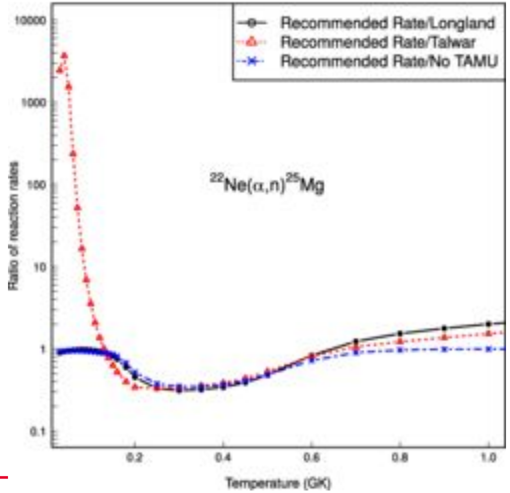
Results of the evaluation

Basic result is:

Small possible bumps for $^{22}Ne(\alpha,\gamma)$ at low temperature due to new resonances with new spins

$^{22}Ne(\alpha$,n) has a decrease in the recommended rate due to new TAMU results from the branching ratios and the sub-Coulomb transfer data





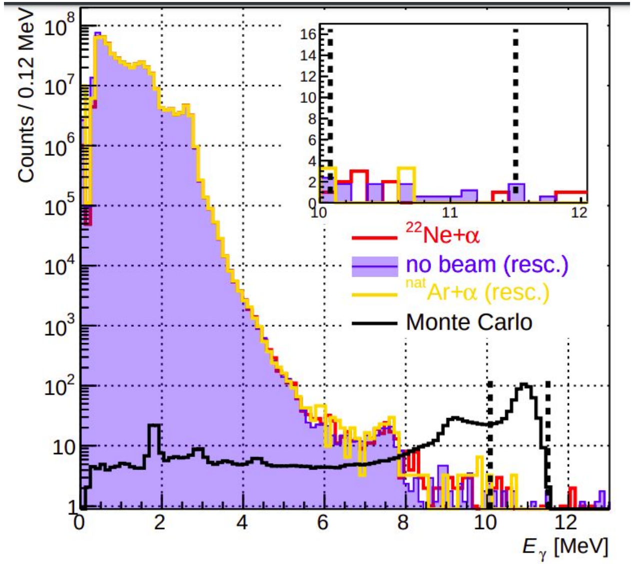
What's happened since then?

New direct measurements at LUNA for E_r = 334-keV resonance (upper limit) - little change to $^{22}Ne(\alpha,\gamma)$ rate but it's a good sign for future LUNA measurements

CASPAR for 706-keV resonance and "Talwar" resonance

DRAGON also did some (as yet unpublished?) measurements

$^{25}Mg(d,p)$ with Grand Raiden



Piatti++ Eur. Phys. J. A 58, 194 (2022)

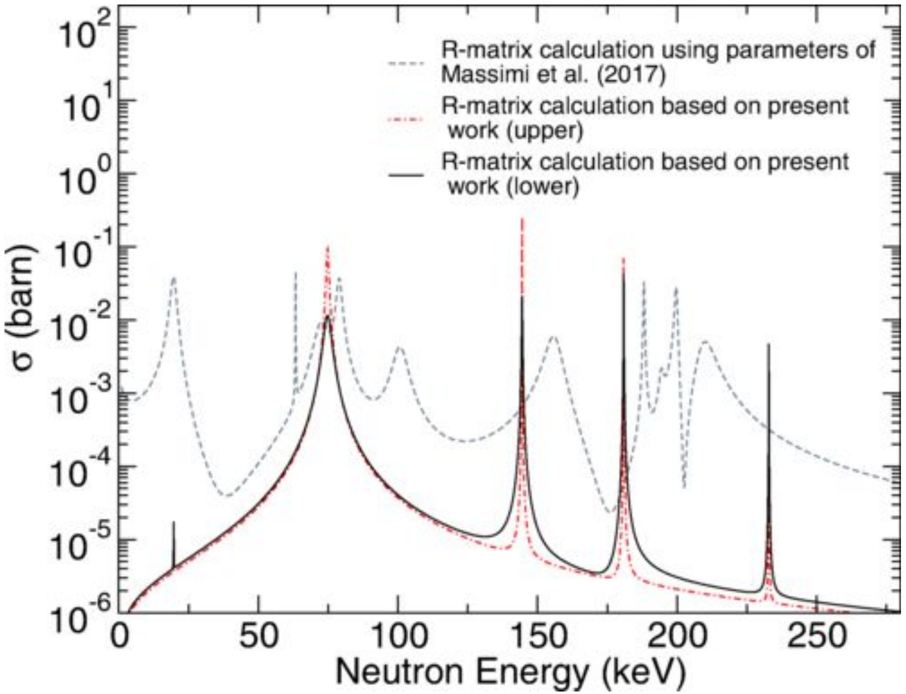
Black curve shows the simulated spectrum using the previous upper limit on wg

$^{25}Mg(d,p)$

Study with Grand Raiden, not included in the 2021 evaluation (sadly! I really like this experiment)

Some level assignments or additional data which should make it into the next evaluation

Interesting point here that it showed that it's actually hard to get (n,γ) from (d,p) which manifested something I hadn't previously understood



Big Open Questions

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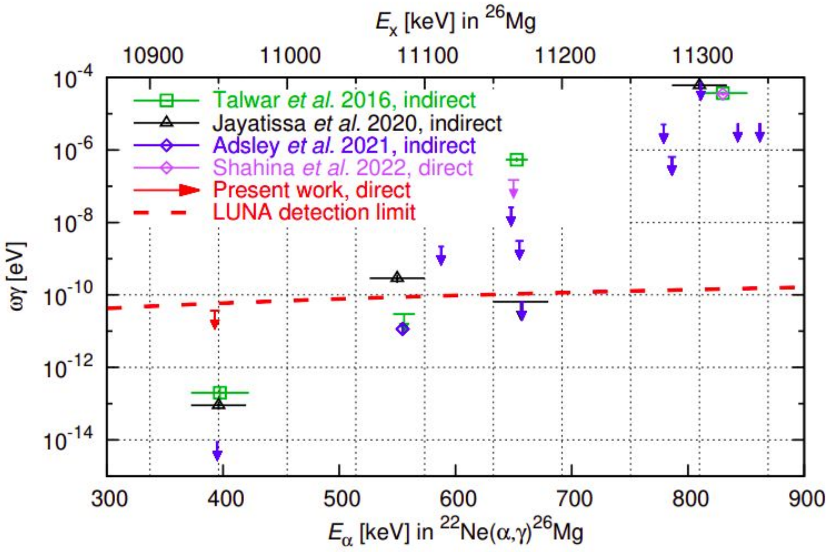
1. The neutron/γ branching of the 706-keV resonance
2. Is there a lower-energy resonance? How can the results of Talwar++ be understood in the context of other experiments?

706-keV resonance

We seem to have a decent agreement on the $^{22}Ne(\alpha,\gamma)$ reaction



CASPAR

LENA

Wolke

DRAGON?

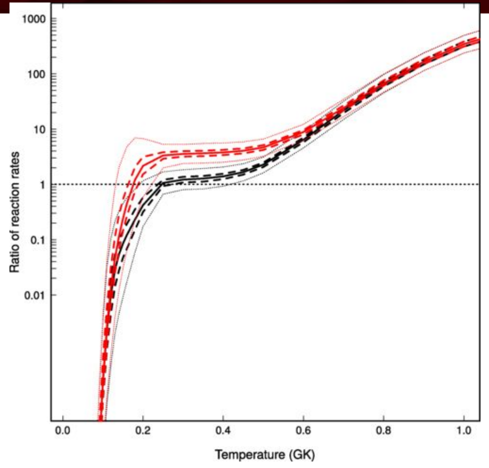
LUNA-MV?

706-keV resonance

We seem to have a poor agreement on the ^{22}Ne(α,n) reaction

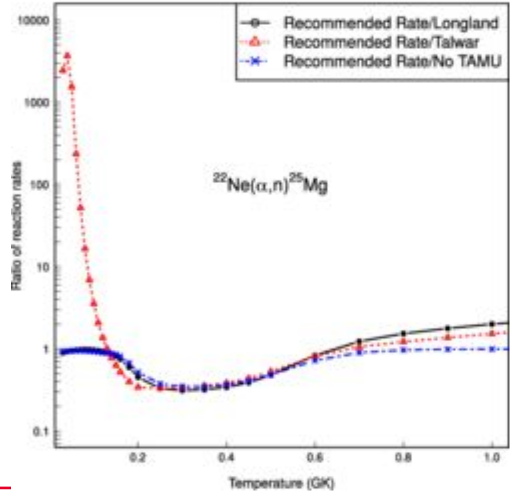
Jaeger and CASPAR (to be published?) vs TAMU[2]

This is, to my mind, the most urgent nuclear-data need for this reaction



From 2021 evaluation

"Recommended" here is with the TAMU results - all of the difference in (a,n) is due to those

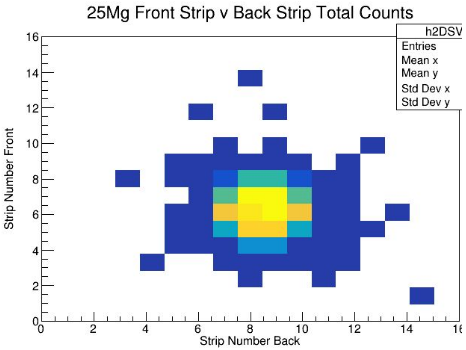


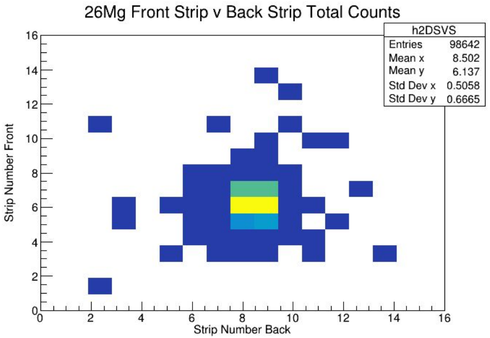
E.g. trying to remeasure the BR

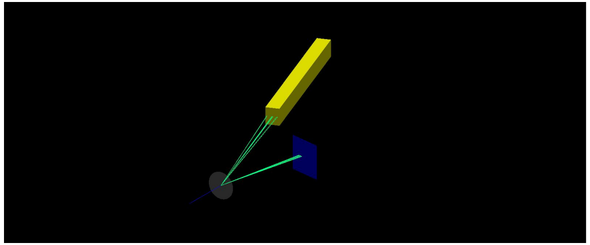
My student and I are working on a plan to try to remeasure the γ/n BR using the MDM but with better resolution

Currently considering trying to detect the heavy ^{26}Mg and ^{25}Mg recoils in the chamber and look at how spread out they are but this looks “challenging” depending on the reaction

Should be a target for future experiments - relative determination of resonance strength as sanity check





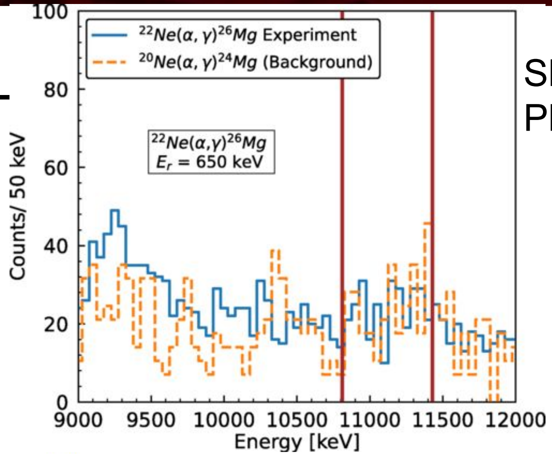


“Talwar” resonance

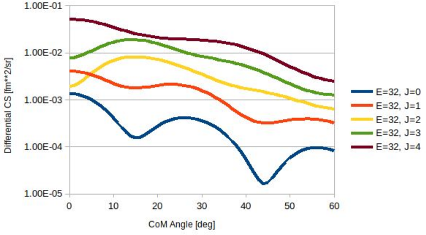
The 557-keV resonance from Talwar - not seen in direct measurements underground (CASPAR)

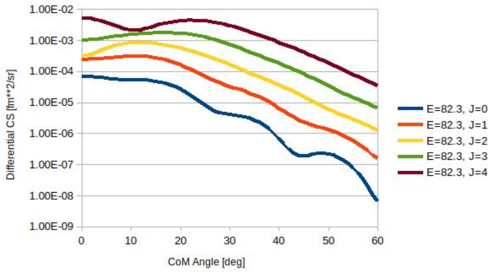
Interpretation given is that it could be a high-spin resonance with different populations due to beam energy changes

I can’t reproduce this with DWBA for J<5 but I also didn’t try that hard



Shahina++
Phys. Rev. C 106, 025805





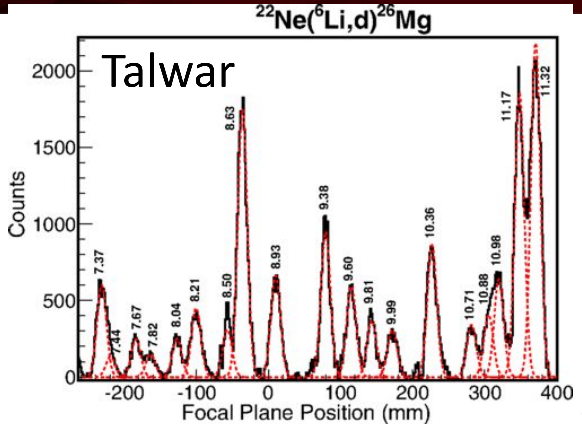
"Talwar" resonance

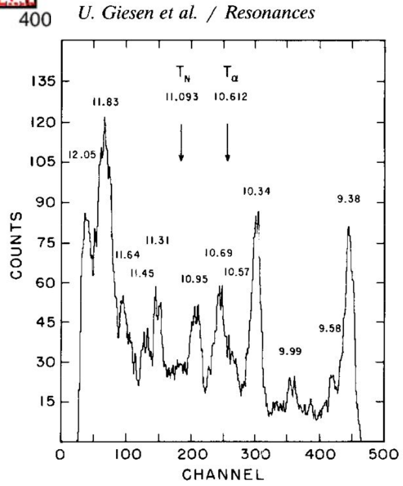
Open question that needs answering: are the resonances in Giesen++ and Talwar++ the same?

Energies are different around 11.2-11.4 MeV but otherwise the double-peak structure is similar

Can we get the other states to agree? They don't really! Some E_X in both but not as many as we'd like

Reanalysis would be beneficial (if someone has the Giesen data!)





SplitPole Measurement @ Orsay

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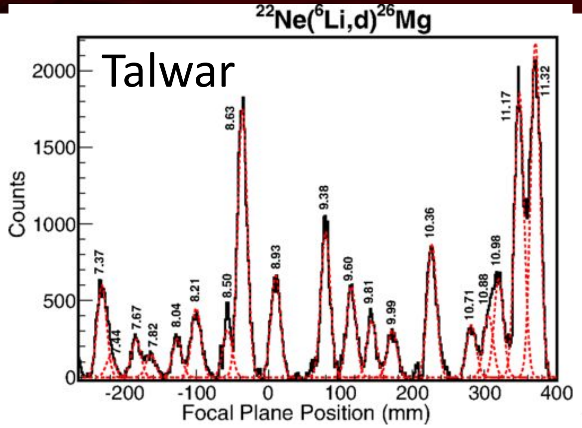
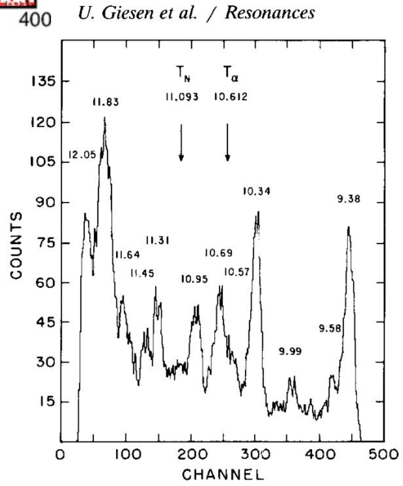
Fairouz Hammache has a proposal to measure $^{22}Ne(^{7}Li,t)$ with the gas cell and the SplitPole

A high-resolution dataset at a different energy:

-Can check Talwar vs Giesen energies

-Can hopefully also check the spin as an explanation for the differences





So what?

I think we’re in a good place! (Not just Napoli, you know what I mean)

We’ve got good spectroscopy, we’ve probably identified most of the levels, have good information on spins/parities, spectroscopic factors

Two big problems, one is maybe not important (but it would be nice to understand why!) and the other is being approached by multiple groups and is susceptible to many different experimental approaches

Re-evaluation of the $^{22}Ne(\alpha,\gamma)^{26}Mg$ and $^{22}Ne(\alpha,n)^{25}Mg$ reaction rates

Philip Adsley,[1,2,3,*] Umberto Battino,[4,5] Andreas Best,[6,7] Antonio Caciolli,[8,9] Alessandra Guglielmetti,[10] Gianluca Imbriani,[6,7] Heshani Jayatissa,[11] Marco La Cognata,[12] Livio Lamia,[13,12,14] Eliana Masha,[10] Cristian Massimi,[15,16] Sara Palmerini,[17,18] Ashley Tattersall,[4,5] and Raphael Hirschi[19,5,20]

[1] *Institut Physique Nucléaire d'Orsay, UMR8608, CNRS-IN2P3, Université Paris Sud 11, 91406 Orsay, France*
[2] *iThemba Laboratory for Accelerator Based Sciences, Somerset West 7129, South Africa*
[3] *School of Physics, University of the Witwatersrand, Johannesburg 2050, South Africa*
[4] *School of Physics and Astronomy, University of Edinburgh, EH9 3FD, UK*
[5] *The NuGrid Collaboration, http://www.nugridstars.org*
[6] *University of Naples "Federico II" Corso Umberto I, 40, 80138 Napoli NA, Italy*
[7] *Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, Strada Comunale Cinthia, 80126 Napoli NA, Italy*
[8] *Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, Via F. Marzolo 8, 35131 Padova, Italy*
[9] *Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Via F. Marzolo 8, 35131 Padova, Italy*
[10] *Università degli Studi di Milano and INFN Milano, Via Celoria 16, I-20133 Milano*
[11] *Physics division, Argonne National Laboratory, Argonne IL 60439, USA*
[12] *Laboratori Nazionali del Sud - Istituto Nazionale di Fisica Nucleare, Via Santa Sofia 62, 95123 Catania, Italy*
[13] *Università degli Studi di Catania, Dipartimento di Fisica e Astronomia "E. Majorana", via Santa Sofia 64, Italy*
[14] *CSFNSM-Centro Siciliano di Fisica Nucleare e Struttura della Materia, Via Santa Sofia 64, 95123 Catania, Italy*
[15] *Istituto Nazionale di Fisica Nucleare, Sezione di Bologna, Bologna, Italy*
[16] *Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
[17] *Dipartimento di Fisica e Geologia, Università degli Studi di Perugia, Perugia, Italy*
[18] *Istituto Nazionale di Fisica Nucleare, Sezione di Perugia, Perugia, Italy*
[19] *School of Chemical and Physical Sciences, Keele University, Keele ST5 5BG, UK*
[20] *Kavli IPMU (WPI), University of Tokyo, Kashiwa 277-8583, Japan*

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