Single proton-hole states in N=126 nucleus ^{205}Au

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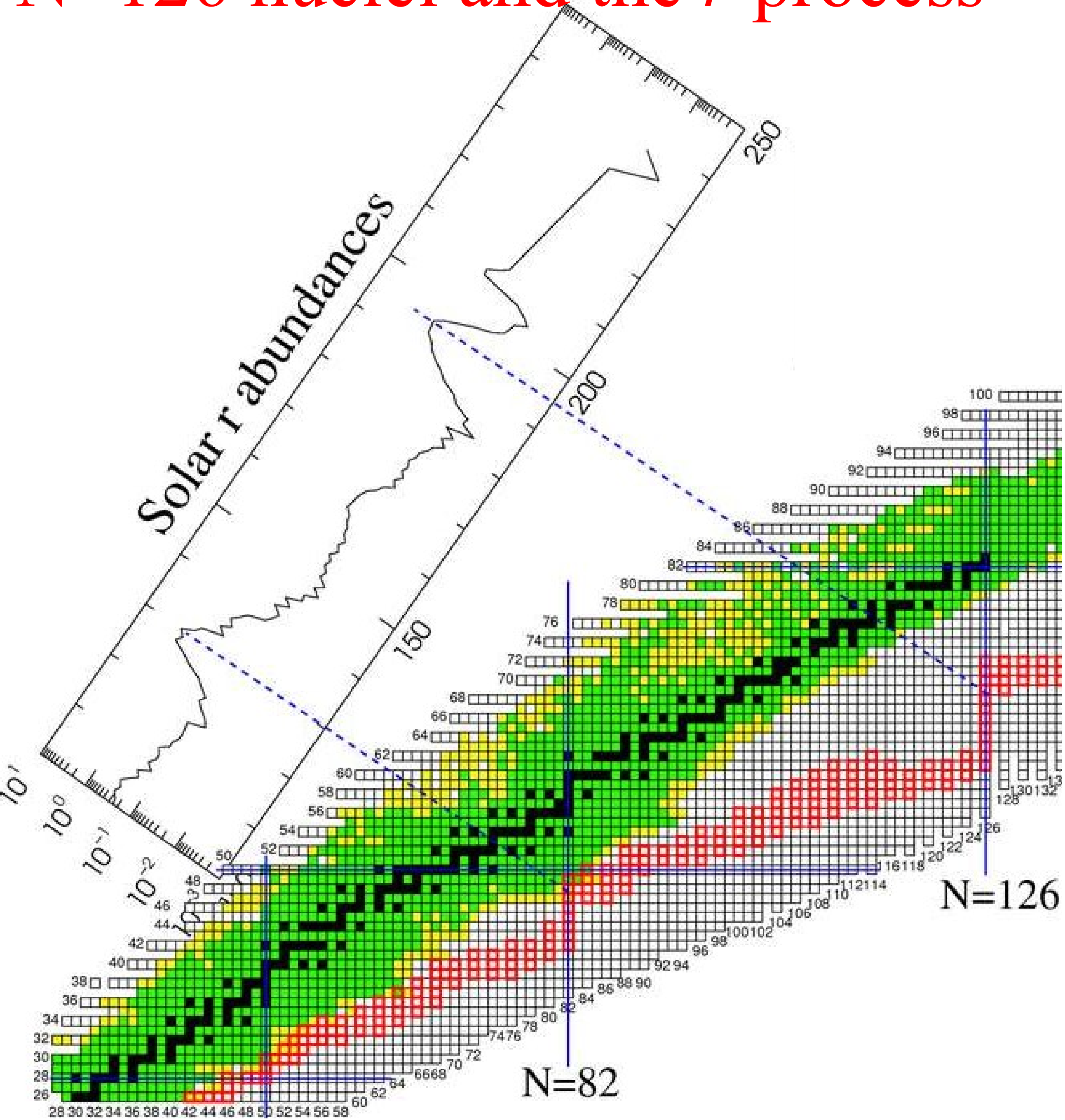
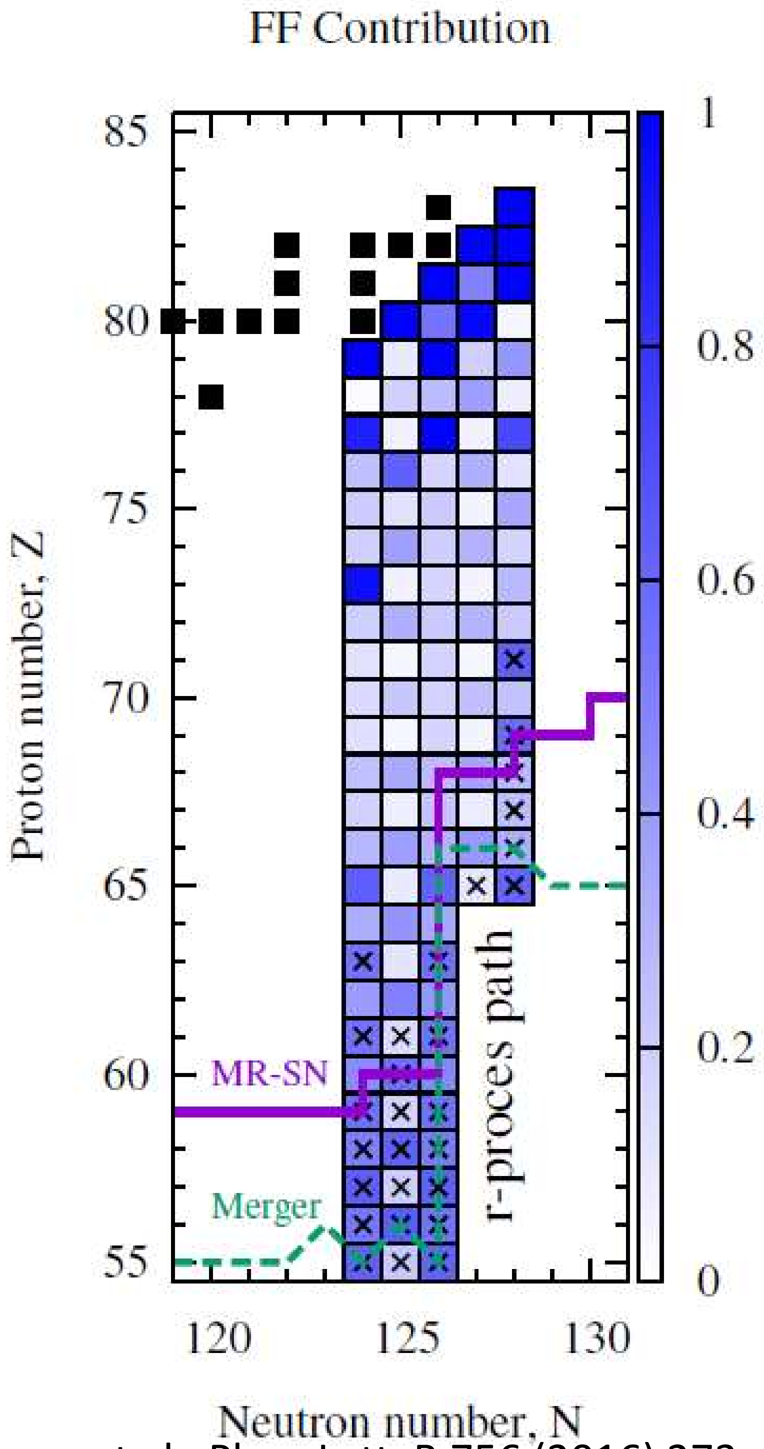
N=126 nuclei and the *r* process

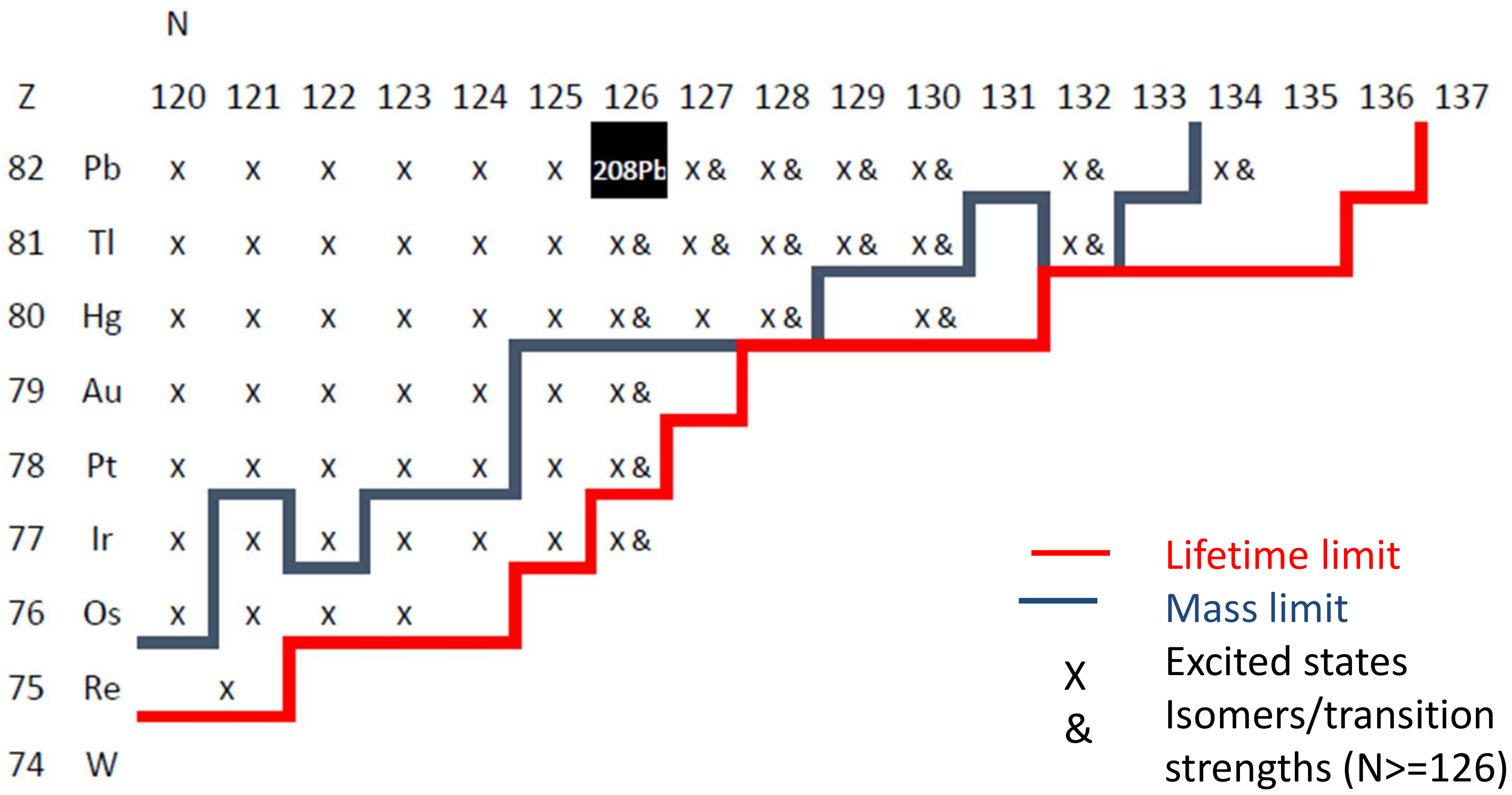




N. Nishimura et al., Phys. Lett. B 756 (2016) 273

D.-L. Fang et al., Phys. Rev. C88 (2013) 034304

Neutron-rich N~126 region



N

Z		120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137
82	Pb	x	x	x	x	x	x	208Pb	x &	x &	x &	x &		x &		x &			
81	Tl	x	x	x	x	x	x	x &	x &	x &	x &	x &		x &					
80	Hg	x	x	x	x	x	x	x &	x	x &		x &							
79	Au	x	x	x	x	x	x	x &											
78	Pt	x	x	x	x	x	x	x &											
77	Ir	x	x	x	x	x	x	x &											
76	Os	x	x	x	x														
75	Re		x																
74	W																		

— Lifetime limit

— Mass limit

X Excited states

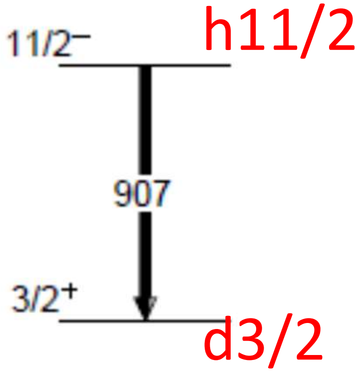
& Isomers/transition strengths (N>=126)

Experimental single proton-states below ^{208}Pb

^{207}Tl (Z=81)

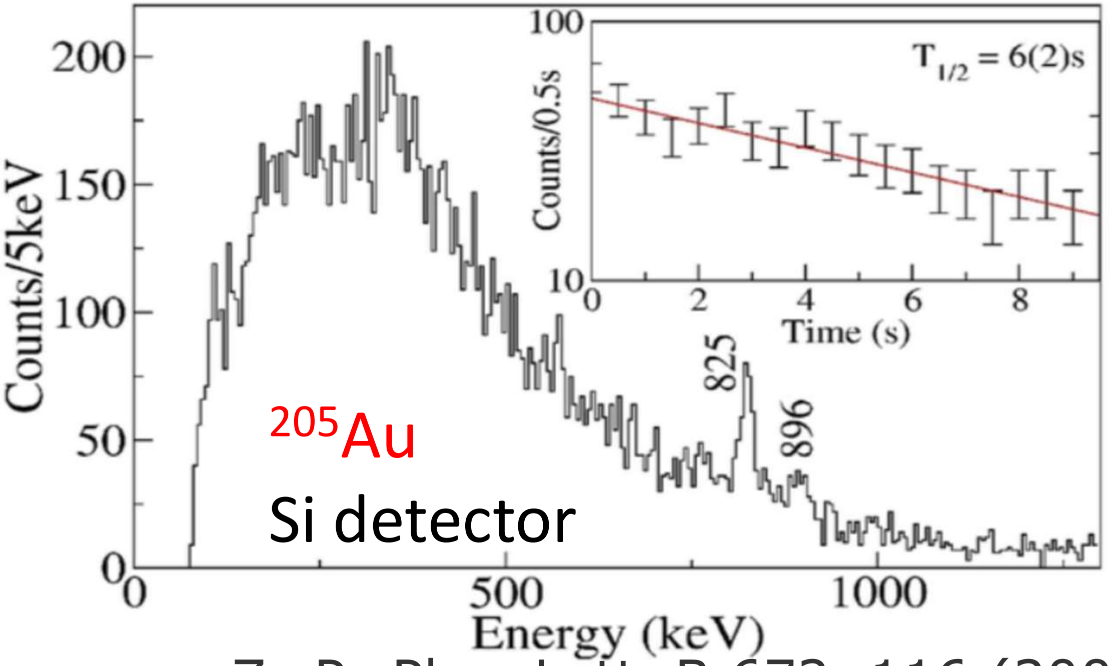
3473	7/2+	g7/2
1683	5/2+	d5/2
1348	11/2-	h11/2
351	3/2+	d3/2
0	1/2+	s1/2

^{205}Au (Z=79)



h11/2

d3/2



^{205}Au

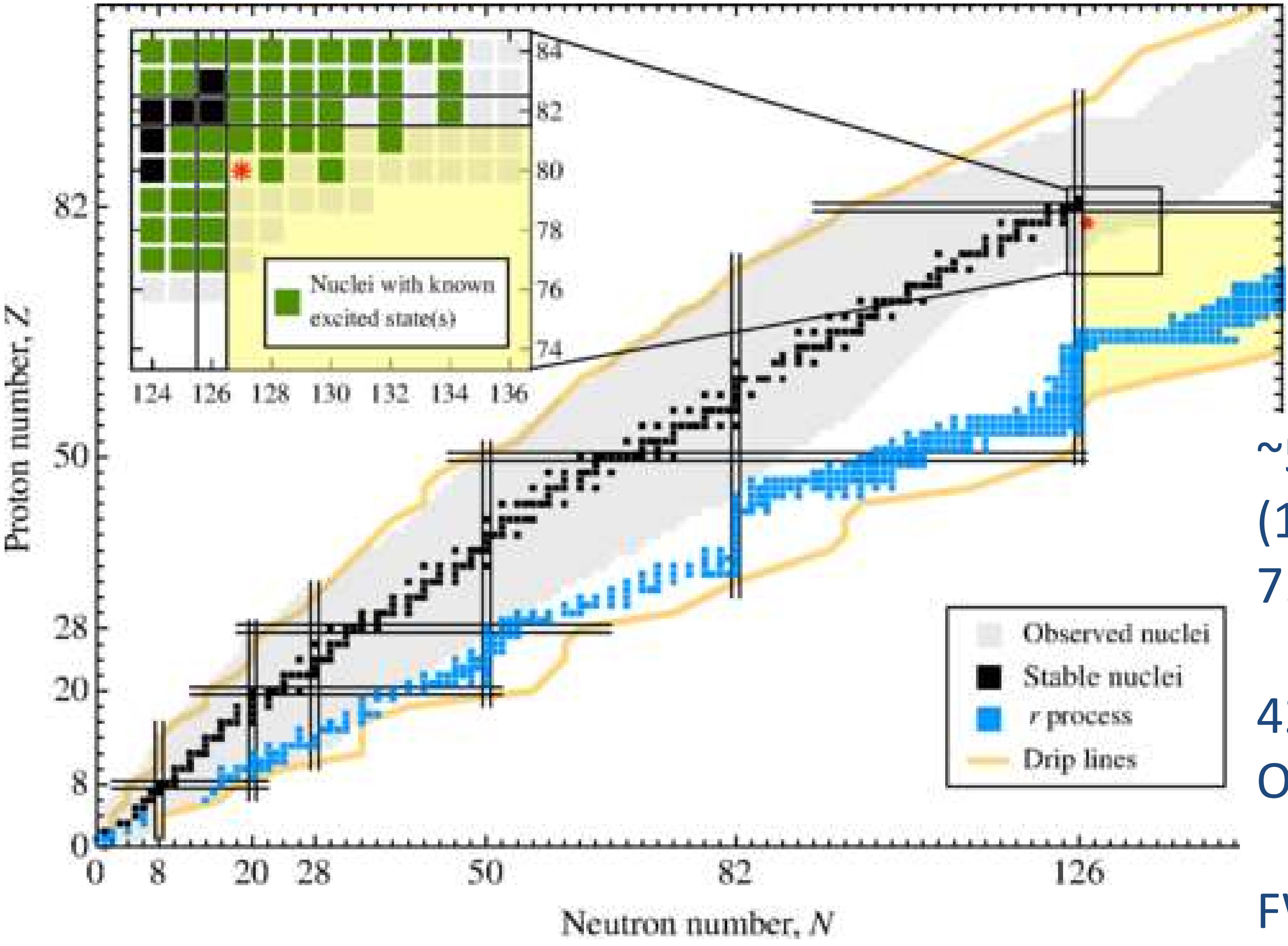
Si detector

Zs.P., Phys.Lett. B 672, 116 (2009

d(^{206}Hg,p)^{207}Hg => Neutron N>126 orbitals

First Exploration of Neutron Shell Structure below Lead and beyond N=126

T. L. Tang et al. Phys. Rev. Lett. 124, 062502 (2020)



~5x10^{5} ^{206}Hg/s

(1.5x10^{11} total)

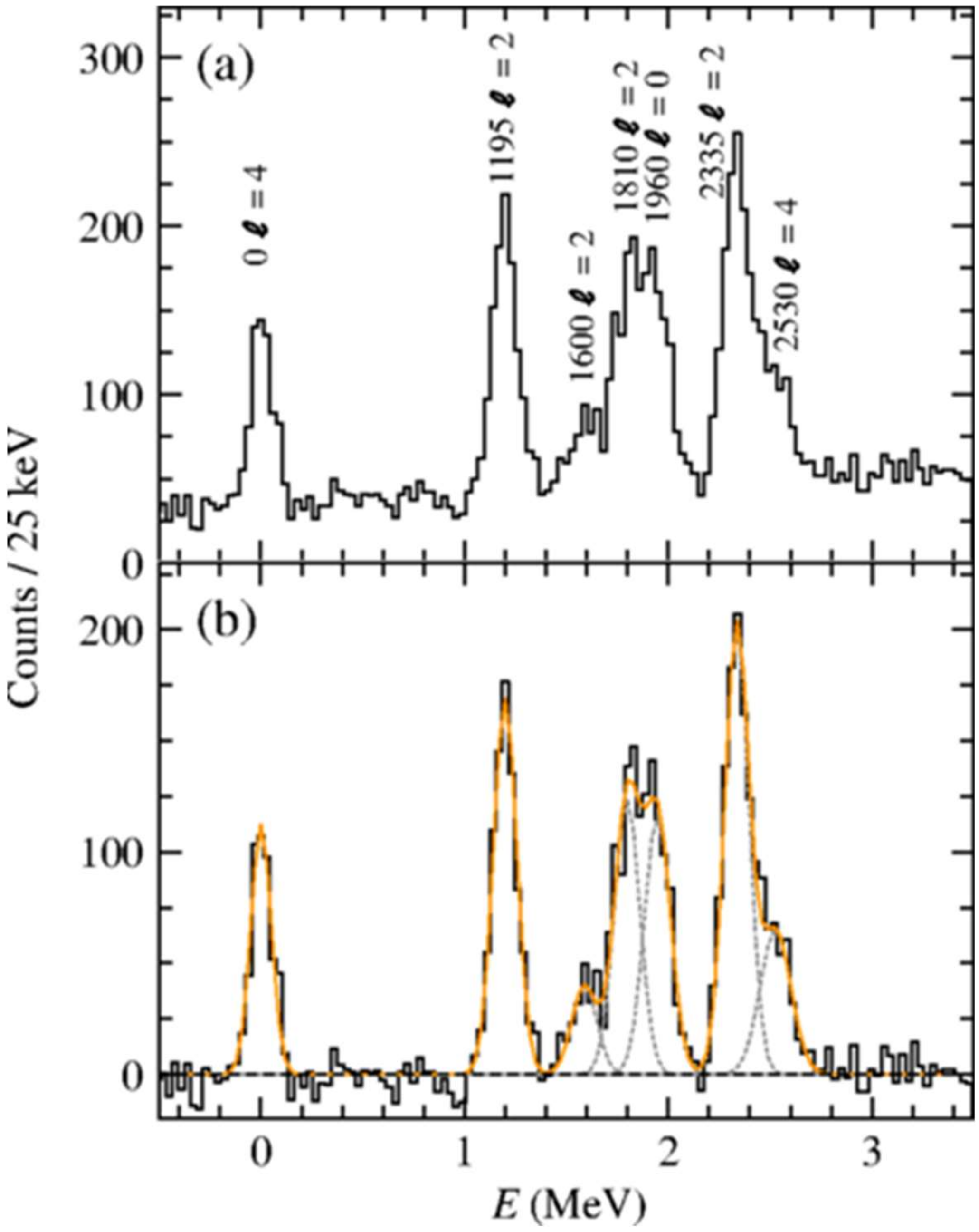
7.38 MeV/u

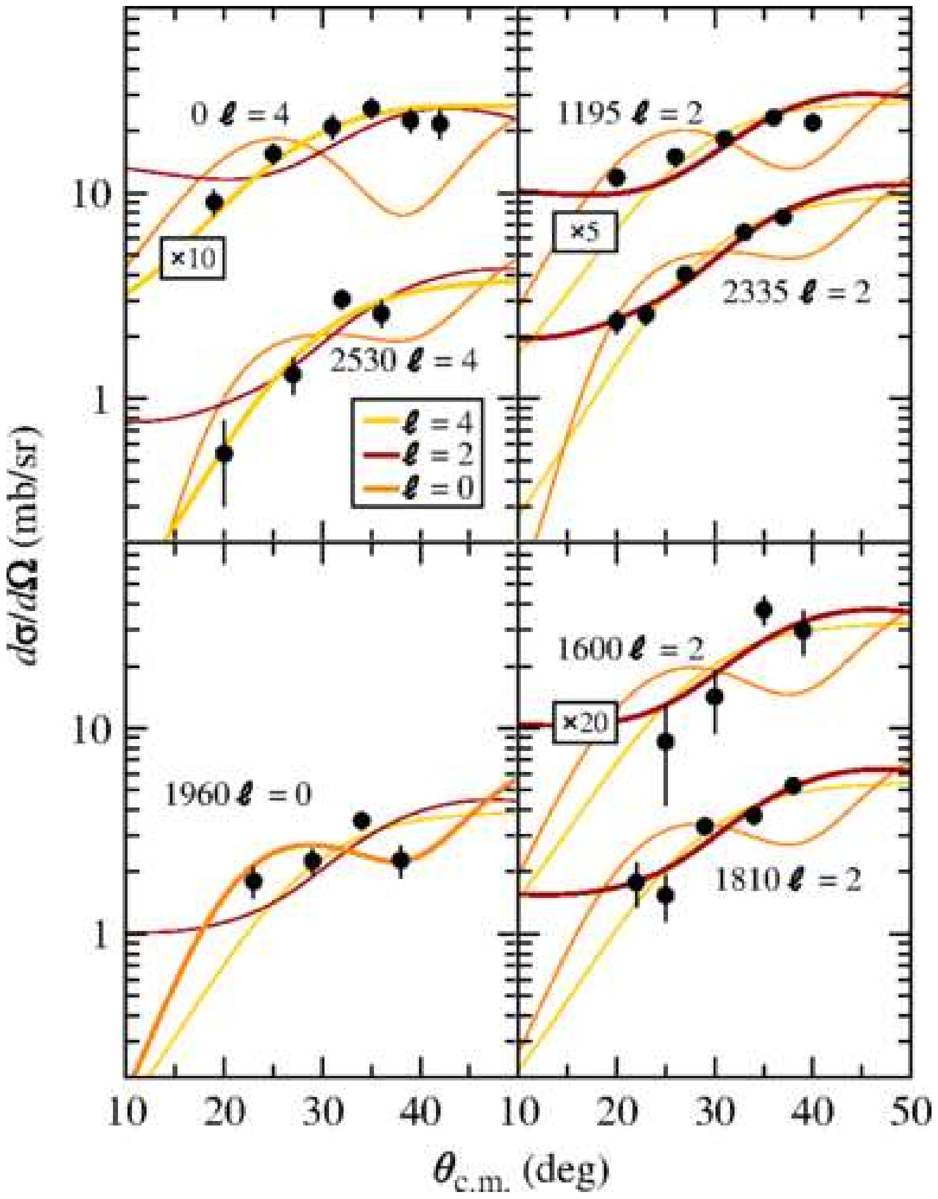
42 μg/cm^{2} D

Out of 165

FWHM~140 keV

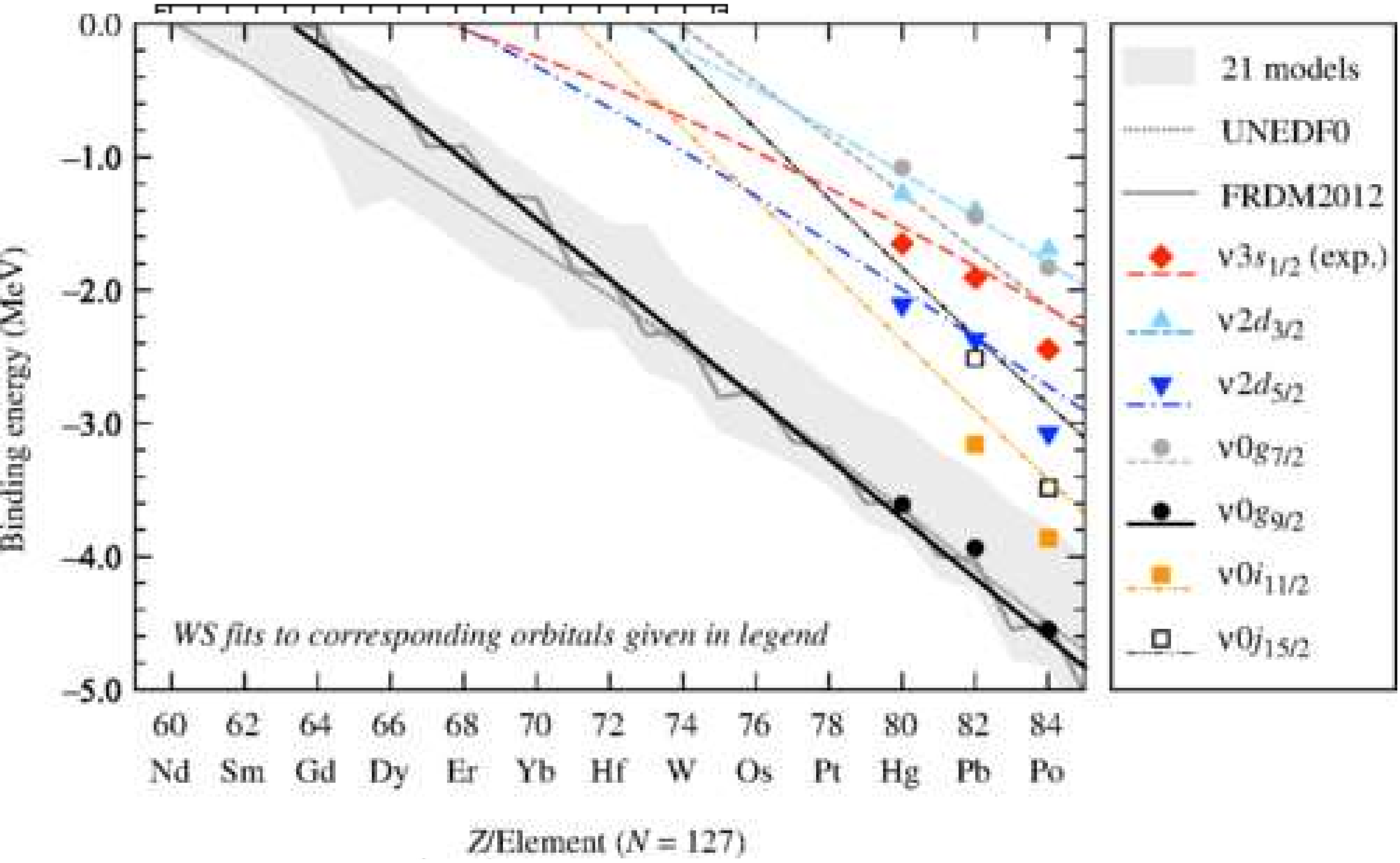
$(^{206}Hg,p)^{207}Hg$gd





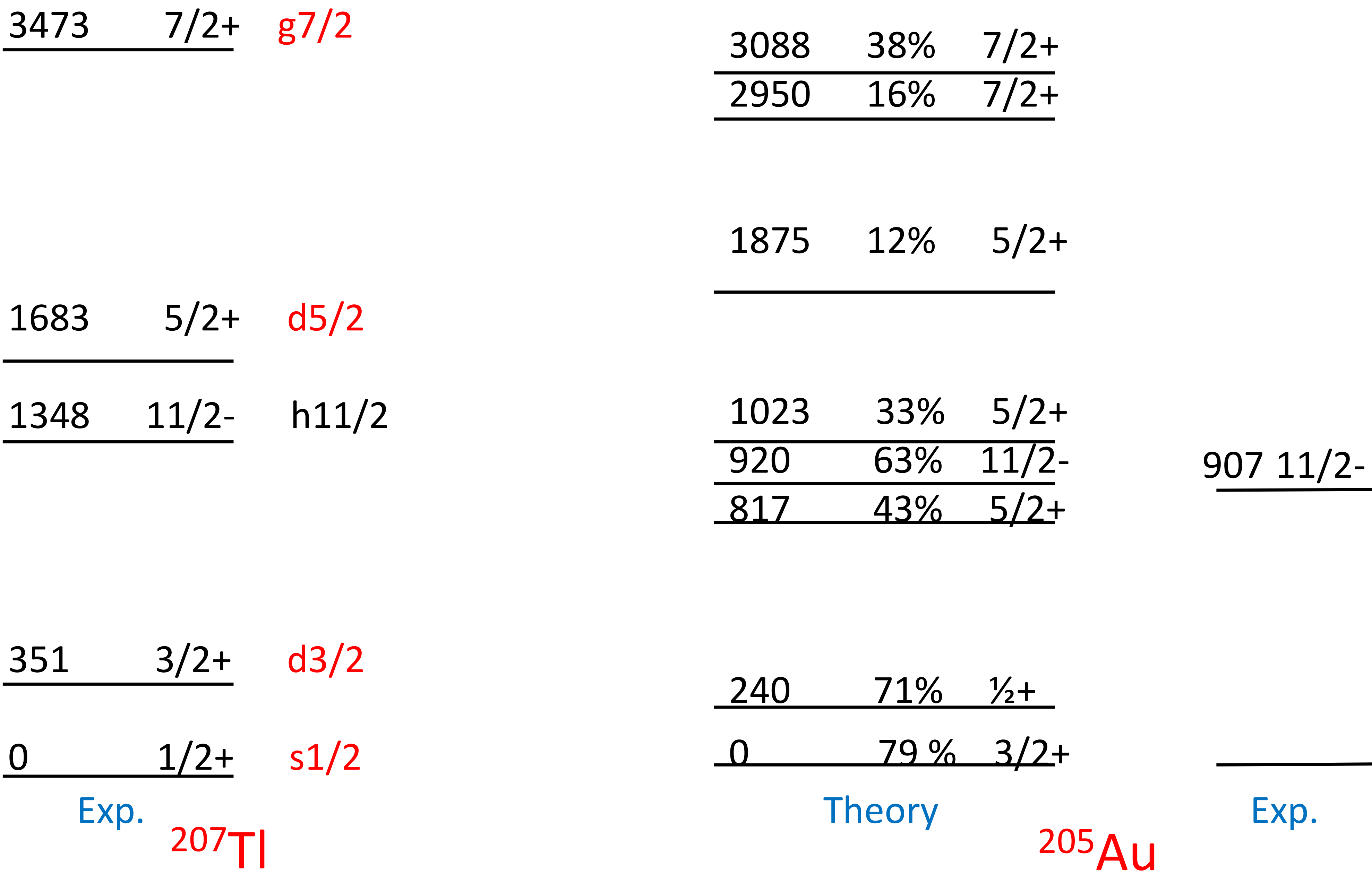
T. L. Tang et al. Phys. Rev. Lett. 124, 062502 (2020)

^{206}Hg(d,p)^{207}Hg



T. L. Tang et al. Phys. Rev. Lett. 124, 062502 (2020)

Aim of exp.: find $s_{1/2}$, $d_{5/2}$ and $g_{7/2}$ states in ^{205}Au



3473 7/2+ g7/2

1683 5/2+ d5/2

1348 11/2- h11/2

351 3/2+ d3/2

0 1/2+ s1/2

Exp.

^{207}Tl

3088 38% 7/2+

2950 16% 7/2+

1875 12% 5/2+

1023 33% 5/2+

920 63% 11/2-

817 43% 5/2+

240 71% ½+

0 79 % 3/2+

Theory

907 11/2-

Exp.

^{205}Au

Aim of exp.: find $s_{1/2}$, $d_{5/2}$ and $g_{7/2}$ states in ^{205}Au

3473 7/2+ g7/2

1683 5/2+ d5/2

1348 11/2- h11/2

351 3/2+ d3/2

0 1/2+ s1/2

Exp.

^{207}Tl

	C^2S	
3088	5.22	7/2+
2950	1.46	7/2+
1875	0.057	5/2+
1023	3.17	5/2+
920	11.43	11/2-
817	2.55	5/2+
240	1.38	½+
0	3.56	3/2+

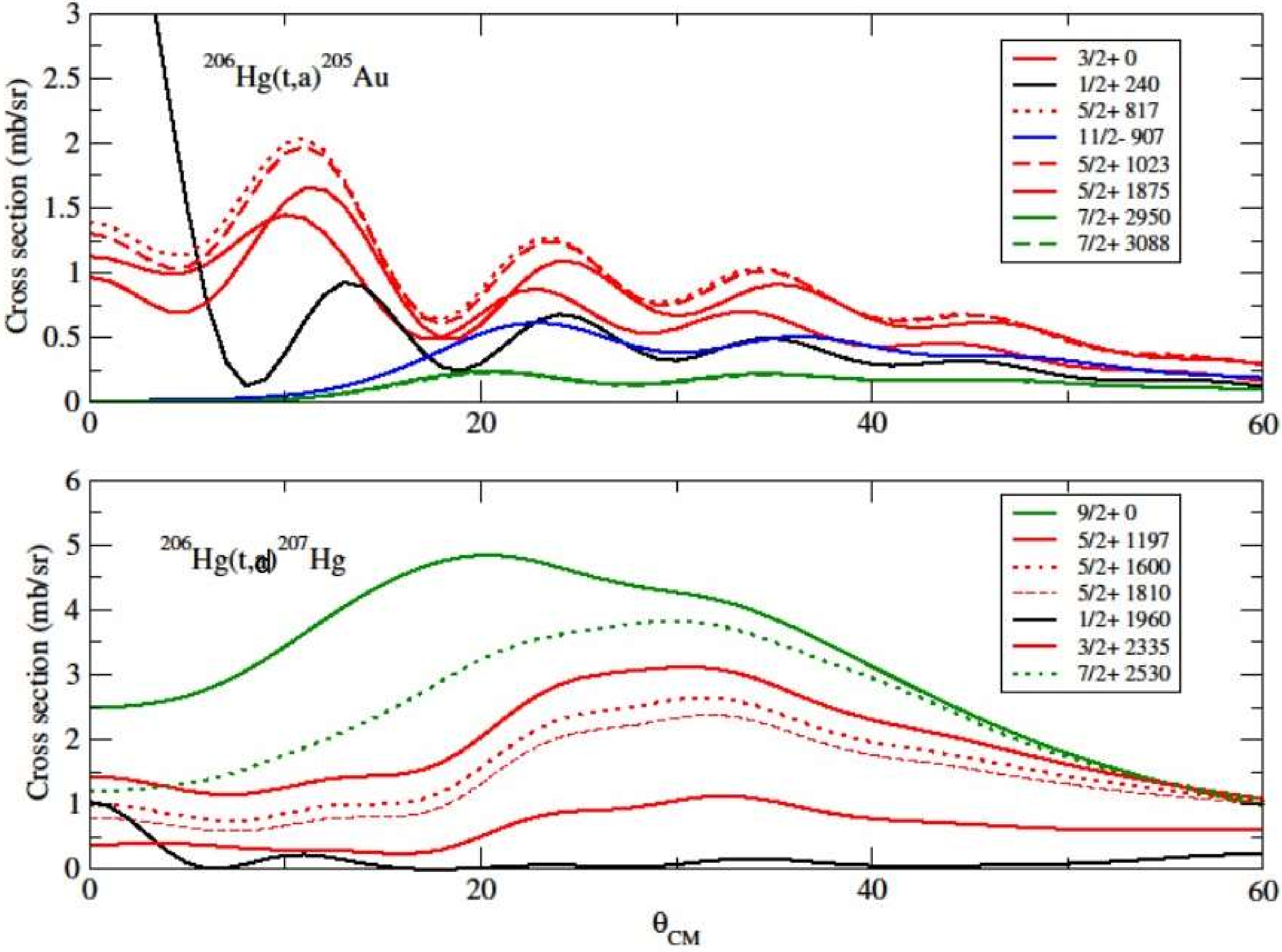
Theory

^{205}Au

907 11/2-

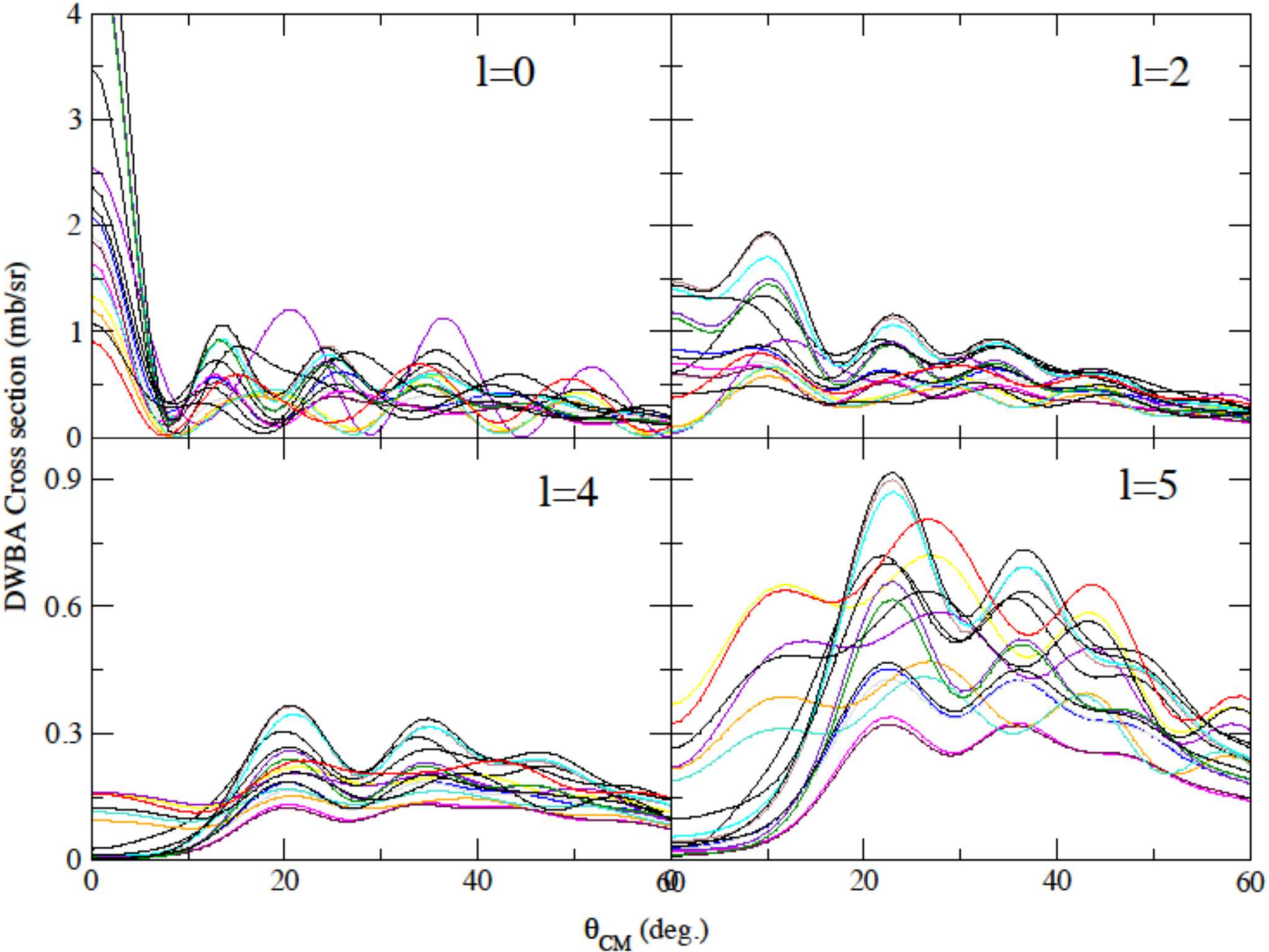
Exp.

Cross sections



Spectroscopic factors not considered

$^{3}H(^{206}Hg,^{4}He)^{205}Au$



Different optical potentials (7 for ^{3}H, 3 for ^{4}He): Spread: ~3

DWBA calculations using different optical potentials. The references for the ones I used are:
Alphas
http://dx.doi/org/10.1142/S0218301315500925
http://dx.doi.org/10.1103/PhysRevC.49.2136
http://dx.doi.org/10.1103/PhysRevC.49.2136
Tritons
http://dx.doi.org/10.1007/s11433-011-4488-5
http://dx.doi.org/10.1088/0954-3899/36/8/085104
http://dx.doi.org/10.1088/0954-3899/36/8/085104
http://dx.doi.org/10.1016/j.nuclphysa.2007.03.004
http://dx.doi.org/10.1016/0375-9474(87)90551-3
http://dx.doi.org/10.1016/0375-9474(80)90013-5
BECCHETTI AND GREENLEES, POL. PHEN.. IN NUCL. REAC. 1971, P682

So, there are 21 different combinations of incoming and outgoing potential. The spread in absolute numbers is around a factor of 3. Which is large. I guess because global studies of He and t potentials are less extensive than d and p.

The references for the potentials used are :
For tritons D. Y. Pang, P. Roussel-Chomaz, H. Savajols, R. L. Varner, and R. Wolski, PRC 79, 024615 (2009)
http://dx.doi.org/10.1103/PhysRevC.79.024615
For alpha partiles: Bassani and Picard, Nucl Phys A 131 (1969) http://dx.doi.org/10.1016/0375-9474(69)90601-0. This is a fixed potential that was used in (a,t) studies by John Schiffer, Ben Kay and Sean on Sn isotopes quite successfully.
These combinations of potentials were also used in a systematic study of quenching of transfer cross sections across the nuclear chart which produced consistent results
https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.111.042502.

David Sharp (he has made the calculations) have had a quick look at various other potentials, there are changes in the shape and so depending on the coverage then can discount some sets based on the distributions, but they all peak at roughly the same place – though the absolute magnitude varies significantly – by orders by around a factor of 3 for l=2 for example, relative numbers vary by much less though usually.

In terms of the range and angular step: the simulations indicate that we can use Z>350 mm (up to 600 mm) for all states in 205Au. The useful range increases, lower Z limit can be used, as the energy of the excited state deccreases. The pitch on the silicon array is 0.95mm. We have the flexibility to divide the rang, based on the level of statistics in to however many angular bins are optimum.

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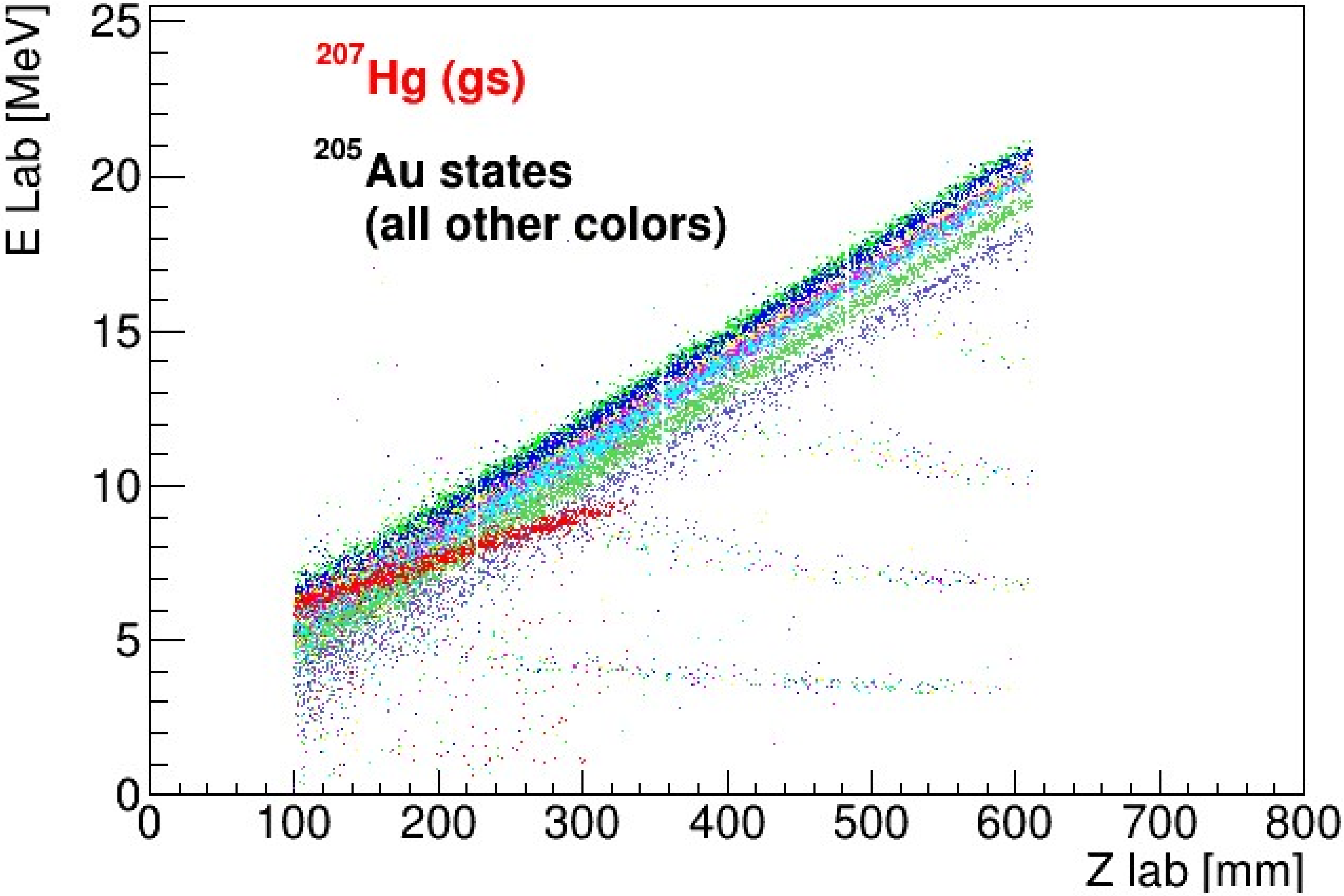
The triplet at ~1 MeV will be difficult, but it depends on the exact energy values and statistics. As a minimum we should be able to get the total l=2 and 5 yields.

Apologies for the confusion regarding spectroscopic factors and the contribution of the single-proton orbitals to the wave functions. The latter ones are indicated on figure 1. The spectroscopic factors, calculated for the overlap of the 206Hg ground-state and the 205Au states are not given in the proposal.
The values are:

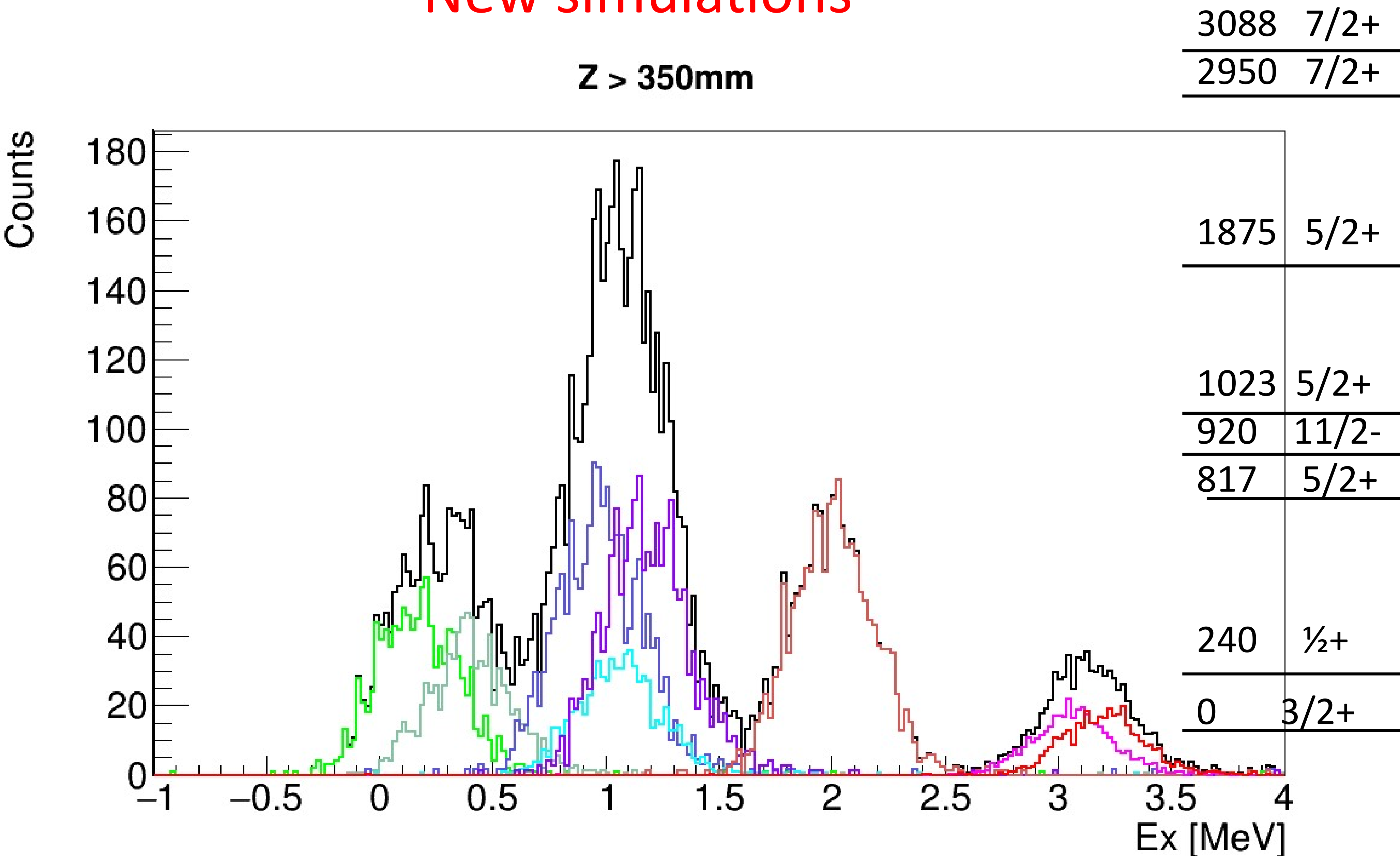
Energy,	C^2*S,	single-proton contributions
0	3.557	79%
240	1.384	71%
817	2.553	42%
920	11.434	63%
1023	3.170	33%
1875	0.058	12%
2950	1.457	16%
3088	5.227	38%

For the simulations the spectroscopic factors were used. As you pointed out, figure 4 was not correct, we realised this while checking the numbers. The new simulations, new figure 4, is attached. (but the cross sections shown in figure 2 does not include the spectroscopic factors).

$^{3}H(^{206}Hg,^{4}He)^{205}Au$ and $^{3}H(^{206}Hg,d)^{207}Hg$



New simulations



σ=290 keV Z=0 – 600 mm

σ=180 keV with Z >350mm

TAC comments

<table>
<tr><th colspan="6">Single-proton-hole orbitals in the N=126 nucleus ^{205}Au</th></tr>
<tr><th>CDS#</th><th>Proposal #</th><th>IS #</th><th>Setup</th><th>Shifts</th><th>Isotopes</th></tr>
<tr><td>CERN-INTC-2024-001</td><td>INTC-P-684</td><td></td><td>ISS</td><td>16</td><td>206Hg</td></tr>
<tr><td>Beam intensity/purity, targets-ion sources</td><td colspan="5">Required rate 5E5 pps.at experiment (inconsistency between text and table) -> No problems foreseen.

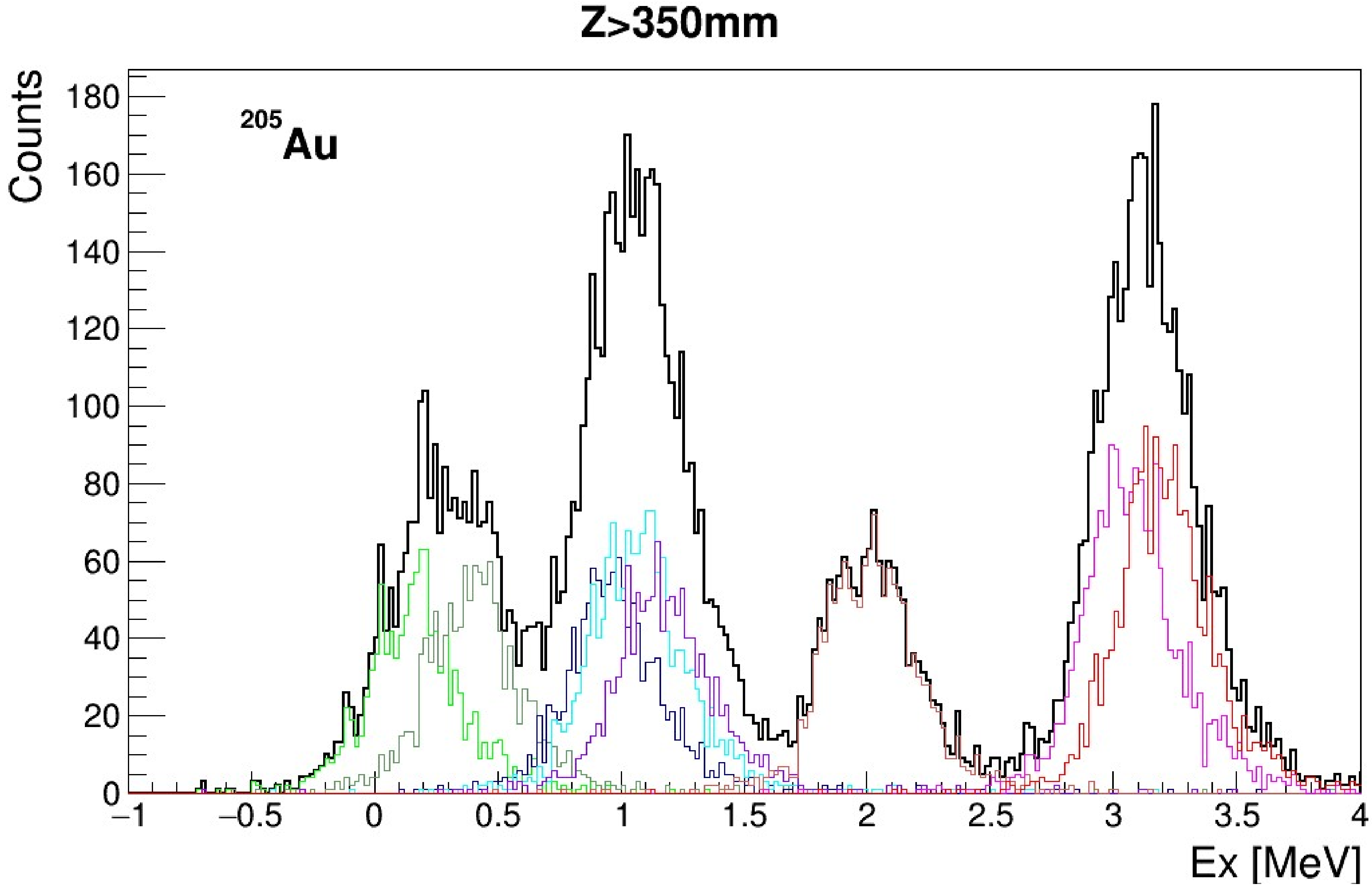
Technical info for future reference:
• Previously produced:
○ #619: 206Hg 7.6E6/uC (https://logbook.cern.ch/elogbook-server/GET/showEventInLogbook/3124758)
○ https://logbook.cern.ch/elogbook-server/GET/showEventInLogbook/3128235 :
• Liquid lead target, VADLIS mode requested.
• Standard VD5 or biasable extraction plates? -> Biasable extraction should improve the yield of laser ions but this is still in development so should be tested beforehand to make sure that the isolators last.</td></tr>
<tr><td>General implantation and setup</td><td colspan="5"></td></tr>
<tr><td>HIE-ISOLDE</td><td colspan="5">The energy is at the edge of feasibility limits, considering the current (degraded) state of the machine -> Would it be possible to run with lower energies, if necessary?

Technical info for future reference:
• 206Hg, 7.5 MeV/u, 5E5 pps at ISS, 16 shifts, delivered before https://isoldeop.web.cern.ch/elements/mercury /fred
• Charge state 46+ mentioned in proposal, probably need to go to 51+ now. -> A/Q = 4.04 is probably ok, repetition rate 2-3 Hz is feasible with new gun._

-</td></tr>
<tr><td>General Comments</td><td colspan="5">Should not be scheduled together with collection on GLM/GHM based on previous experience (changing between VADLIS and plasma ion source is time consuming.)</td></tr>
<tr><td>Safety</td><td colspan="5">Using ISS installation with no modifications (no additional hazards).
ISIEC at EDMS 1869840 and Safety Clearance at EDMS 2616581. In any case, a new Safety Clearance 2024 is to be sent after general and electrical inspections.

Tritium targets have been used in the past, however, tritium is volatile and difficult to monitor. Before the experiment can run, the necessary discussions with RP should be foreseen. Additionally, a safety form for the use of external sources will be required.</td></tr>
<tr><td>TAC recommendation</td><td colspan="5">The TAC does not see any particular issues with this proposal, unless the HIE ISOLDE energy degrades further.</td></tr>
</table>

OLD and wrong (spectroscopic factors)



Summary

Abstract: Single-proton states in the N=126 closed neutron shell nucleus ^{205}Au will be identified via the (t,^{4}He) reaction in inverse kinematics at the ISOLDE Solenoid Spectrometer. Excited states dominated by a proton-hole in the **$s_{1/2}$, $d_{5/2}$ and $g_{7/2}$** orbitals and their spectroscopic factors will be established. The understanding of the evolution of proton states in neutron-rich N=126 nuclei is key for the prediction of the properties of the r-process path nuclei.

Summary of requested shifts: 16 shifts (15 shifts measurement + 1 shift tuning and debugging)

^{3}H(^{206}Hg,^{4}He)^{205}Au at ISS (Si at forward angles)

^{206}Hg from liquid lead target 5x10^{5} pps at 7.5 MeV/u

^{3}H:Ti target