Exotic neutron rich nuclei in the ^{132}Sn region

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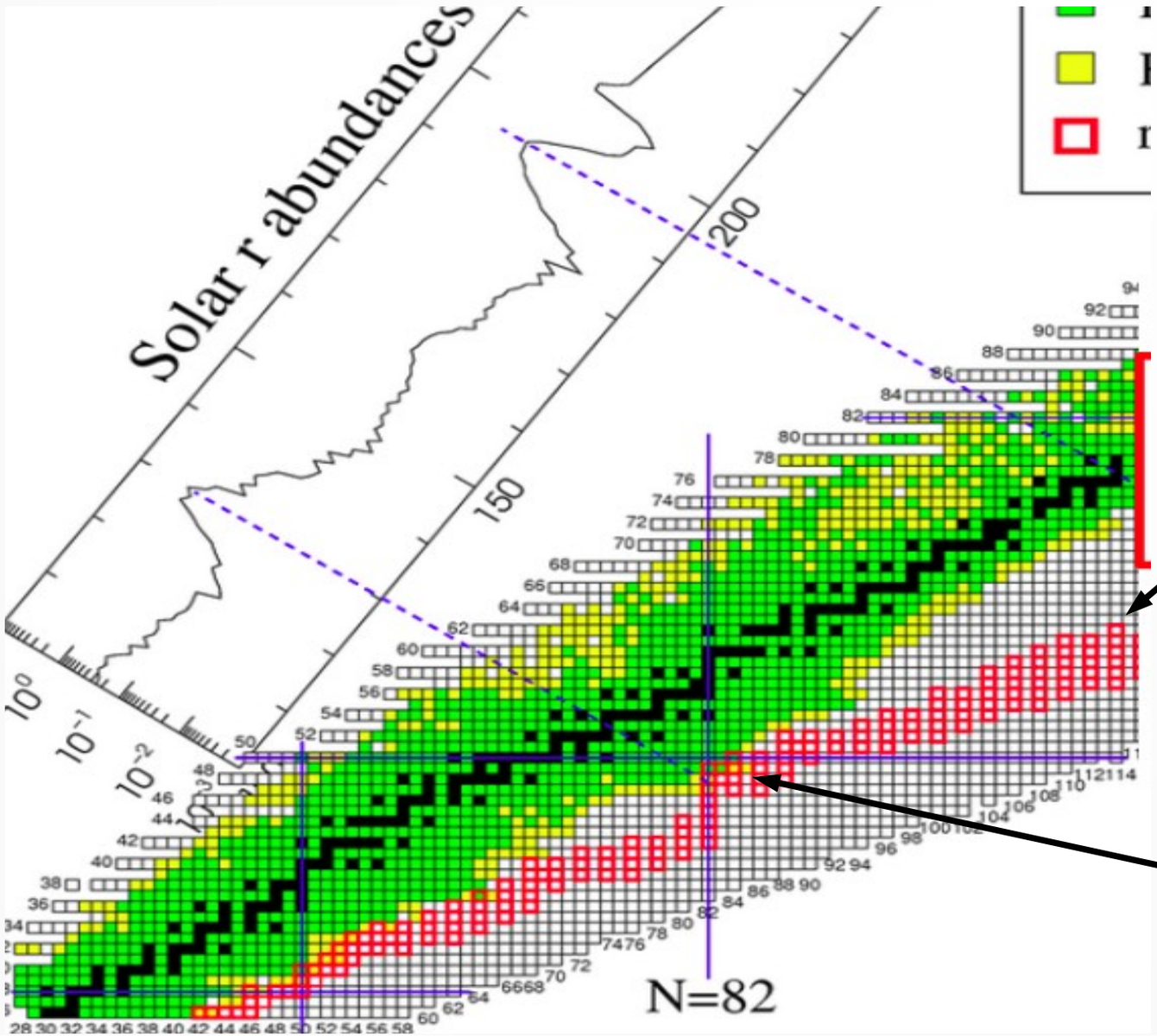
R Process



Responsible for about 50% of all nuclei above iron.

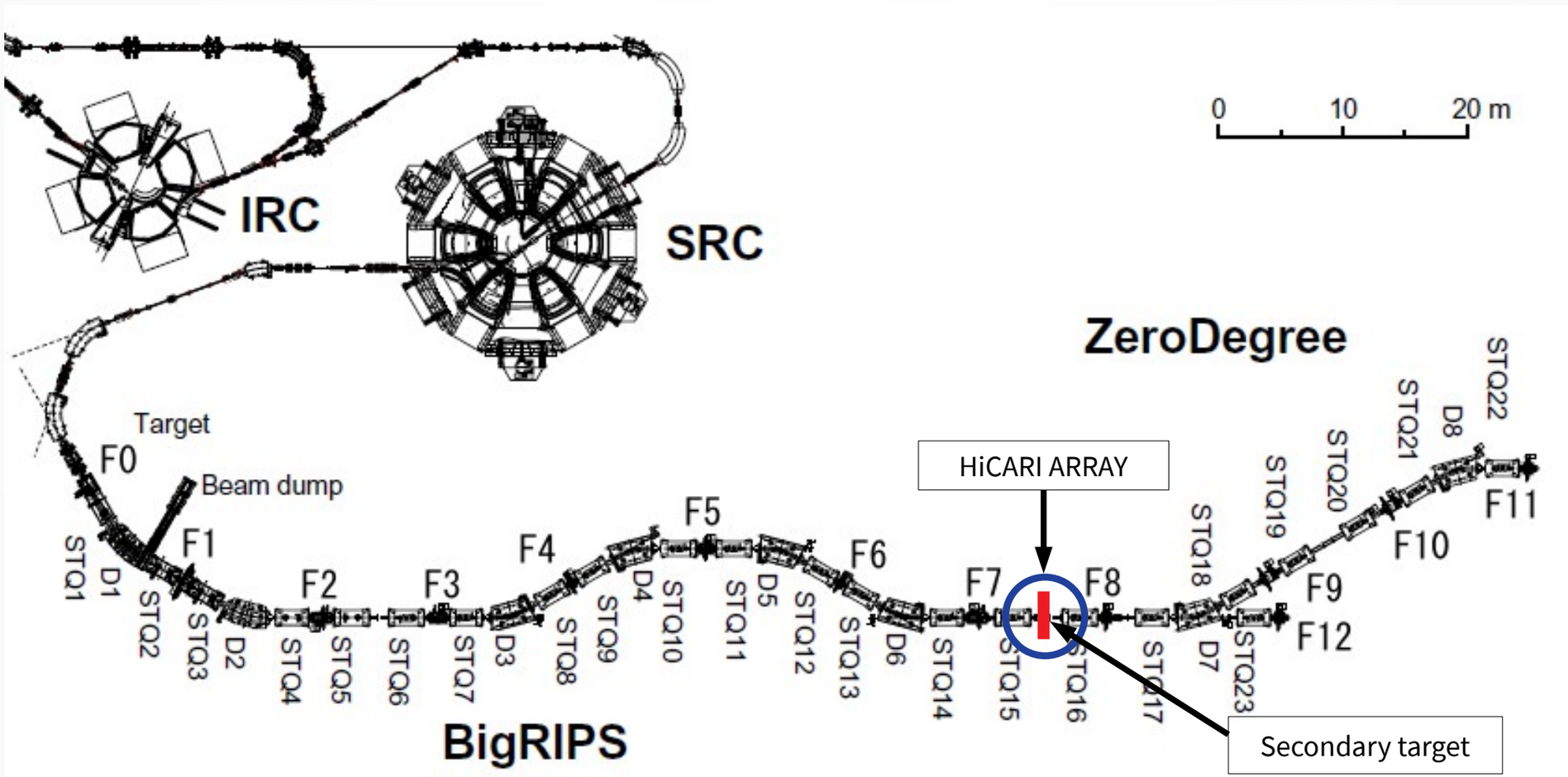
Extremely high neutron flux environments are required.

Grey region isotopes have no data available

N=82,Z=50,A~130 Region of interest

- *Grawe H. et al 2007 Rep. Prog. Phys. 70 1525*

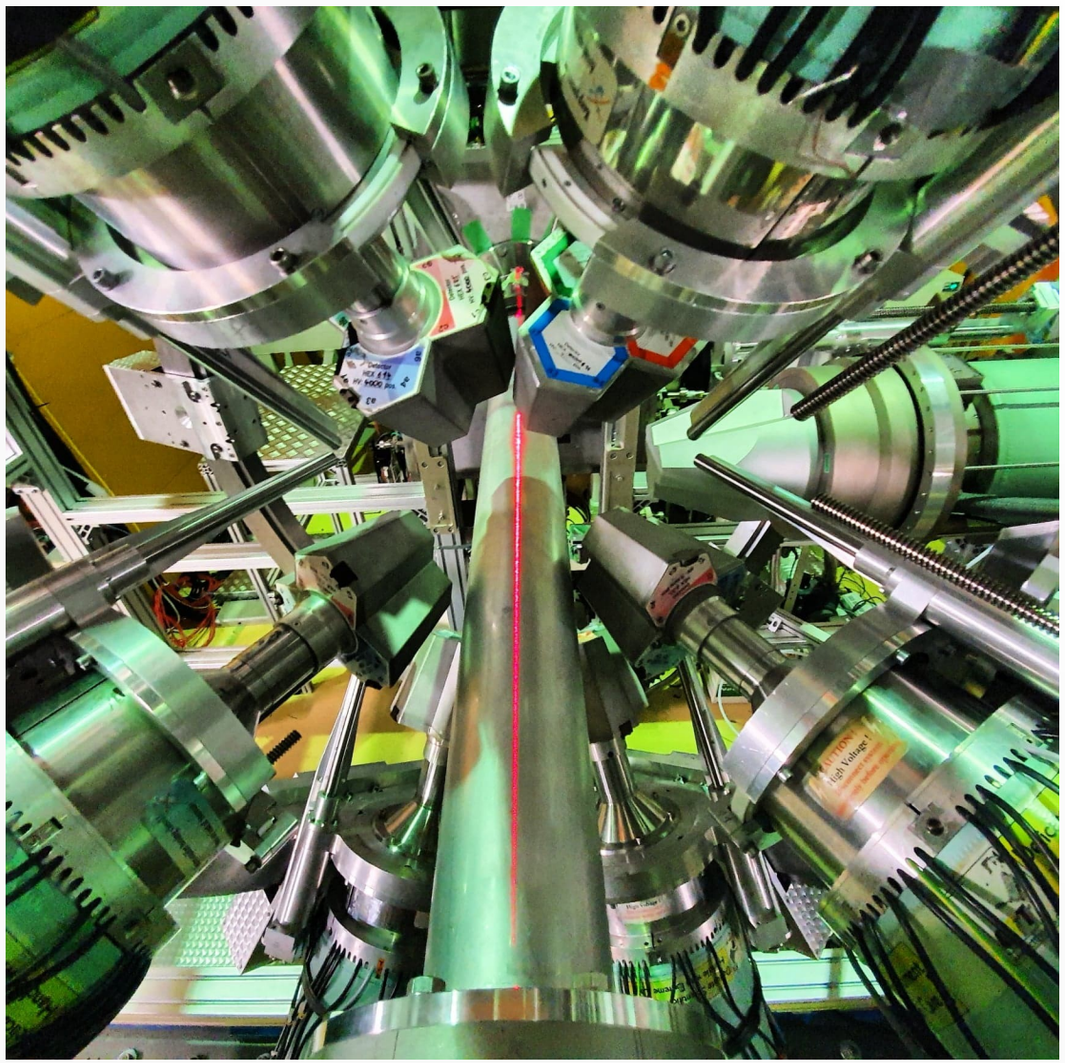
BigRIPS and Zero Degree Fragment Separators



Primary Beam of ^{238}U at 345 MeV/u, beam intensity of 60pnA.
BigRIPS tuned for ^{130}Cd with a measured beam rate of about 50pps.
ZeroDegree tuned for ^{129}Ag.

- *Kubo T. et al, BigRIPS separator and ZeroDegree spectrometer at RIKEN RI Beam Factory, Prog. Theor. Exp. Phys.2012, 03C003*

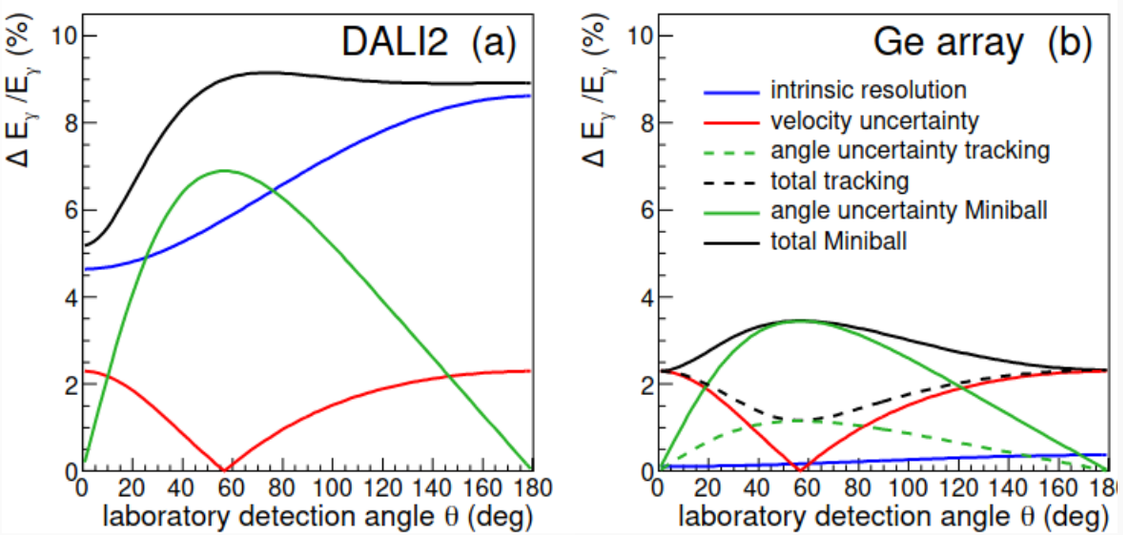
HiCARI - 光



HiCARI part way through construction

Why HiCARI?

- Temporary, high resolution detection system at RIKEN
- Combines multiple types of HPGe detectors of different designs
- Replaces DALI2 of NaI type



- *Proposal for construction of HiCARI, https://www.nishina.riken.jp/collaboration/SUNFLOWER/devices/hrarray/ConstructionProposal.pdf*

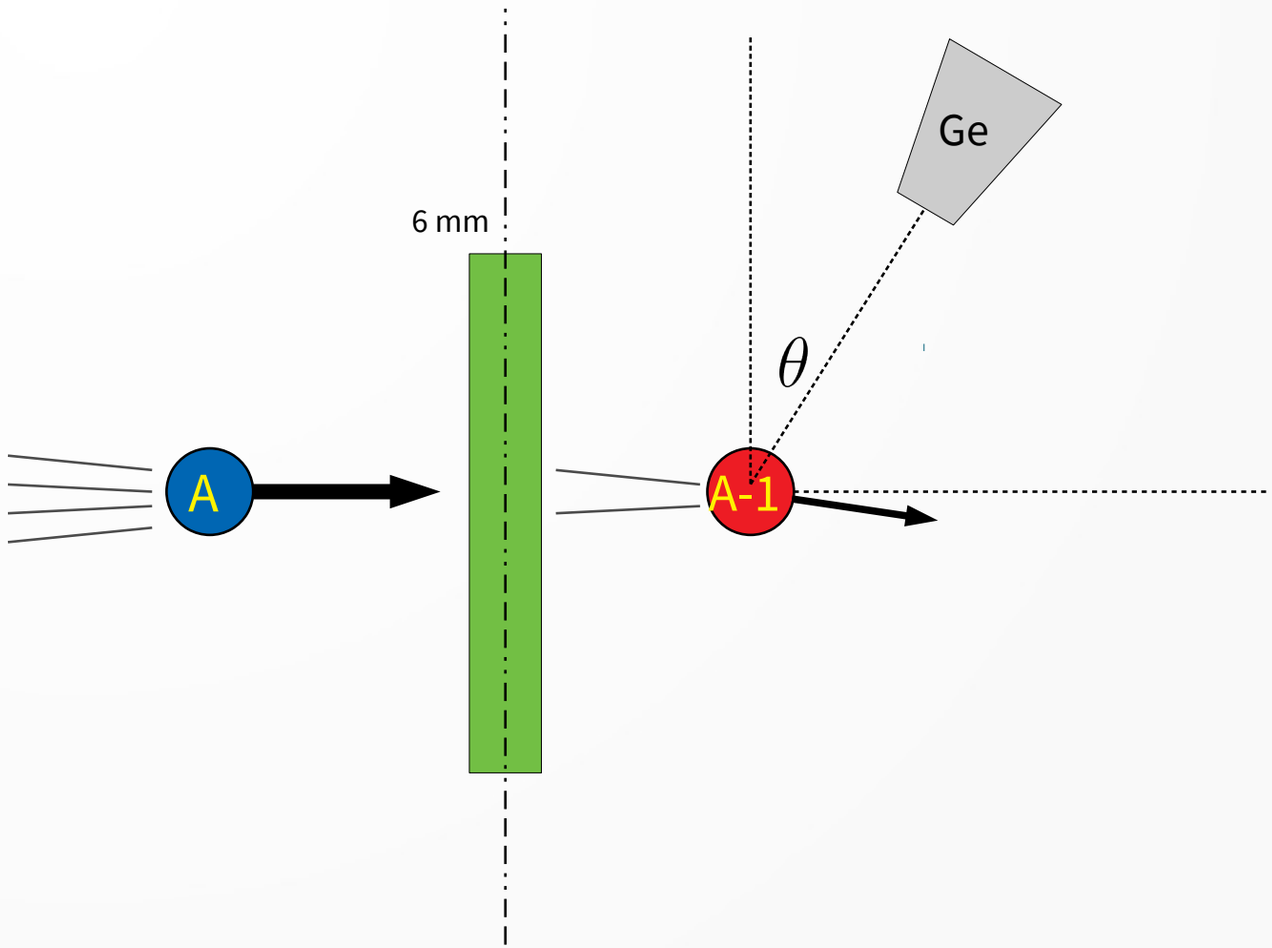
High velocity Doppler correction

~150 MeV/u , v~0.5 v/c

Thick 6mm secondary target

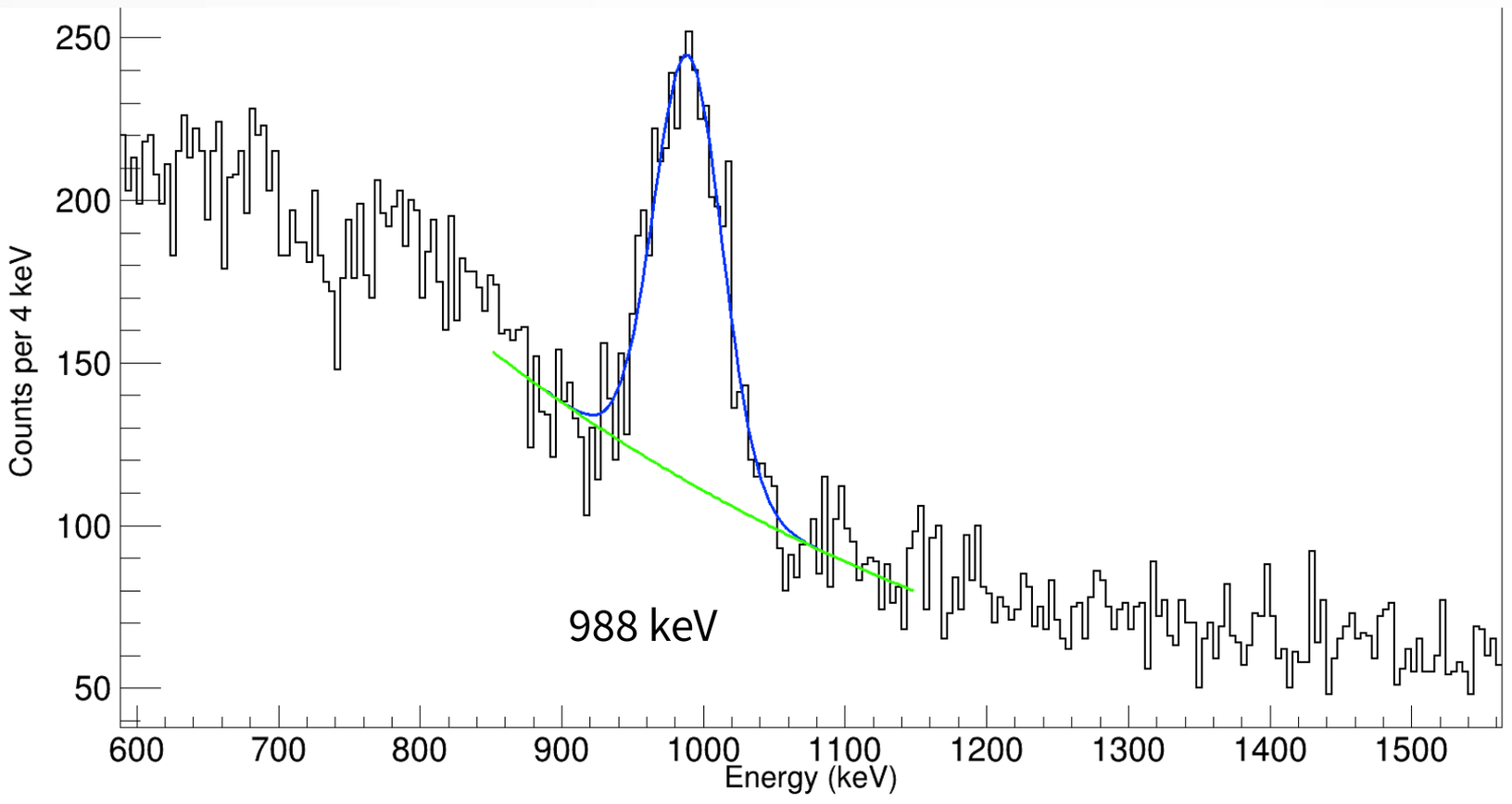
$$E'_\gamma = E_\gamma \frac{1 - \beta \cos\theta}{\sqrt{1 - \beta^2}}$$

Accurate beta and positions needed



Mid target (t=0)

^{9}Be(^{132}Sn,^{131}In) Test case



Known single particle proton structure. Populated directly

M1 988 keV Transition

$\pi\, p^{3}/_{2} \rightarrow \pi\, p^{1}/_{2}$

Short life time resulting in prompt transition

Gives information on ideal signal response from HiCARI

Nature of thick target broadens the peak even at such short lifetimes

Shell Model

NuShellX

Model Space :
Z: 28~50
N: 50~82

jj45pna interaction

Single particle energies from experiments ^{131}In,^{131}Sn

Doesn't work well near ^{132}Sn
e.g ^{130}Cd

jj45pna was modified

Proton-proton interaction from Cenxi Yuan et al, Phys.Lett.B 762 (2016) 237

Works well for region

Reaction theory

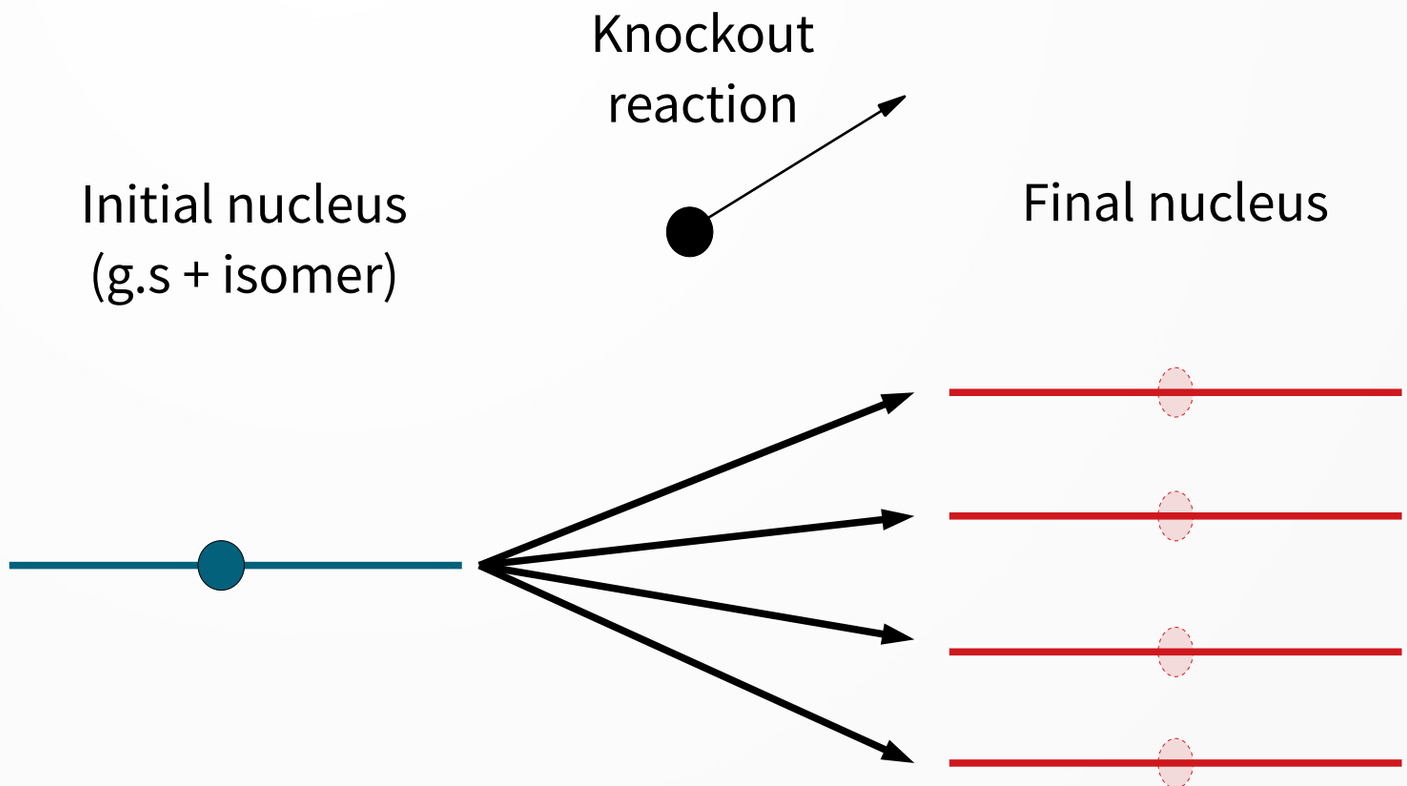
Shell Model: Excited states and wave functions

↓

Wave functions gives spectroscopic factors

↓

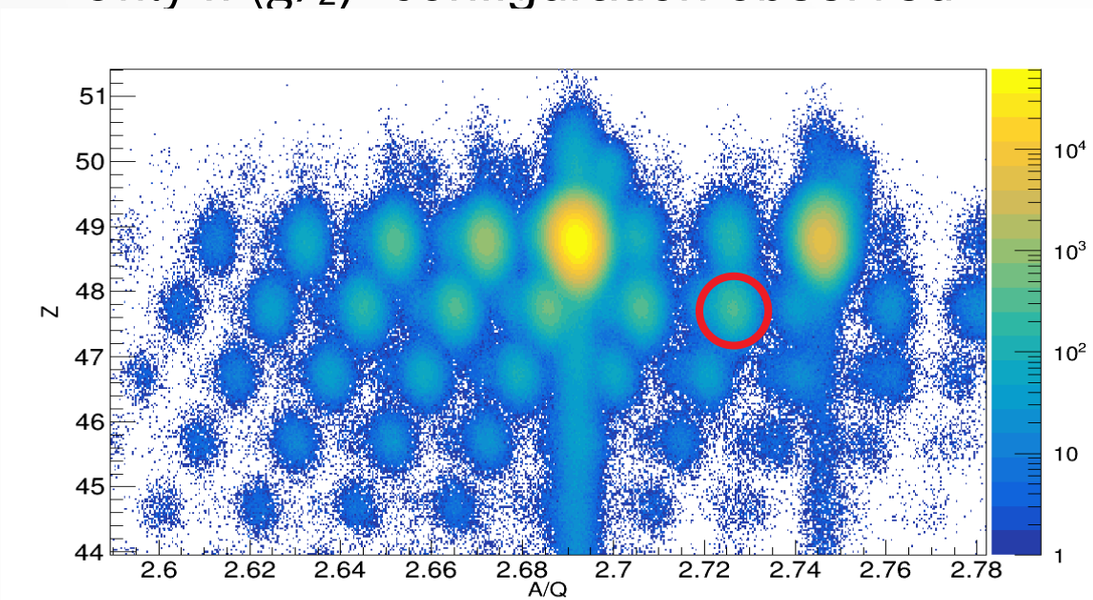
Spectroscopic factors to get reaction cross section on a <u>state by state basis</u>



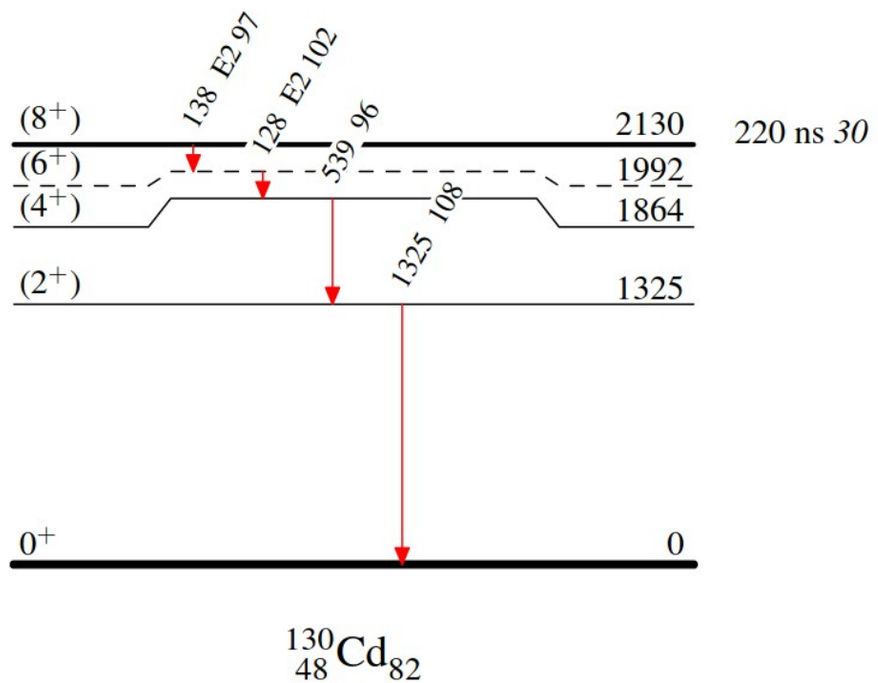
J. A. Tostevin, Nucl. Phys. A 682, 320 (2001).
P. G. Hansen and J. A. Tostevin, Annu. Rev. Nucl. Part. Sci. 53,219 (2003)

^{130}Cd proton-proton interaction

- Z=48
- N= 82
- Only delayed yrast transitions observed at GSI and RIKEN
- Only π $(g_{9/2})^2$ configuration observed



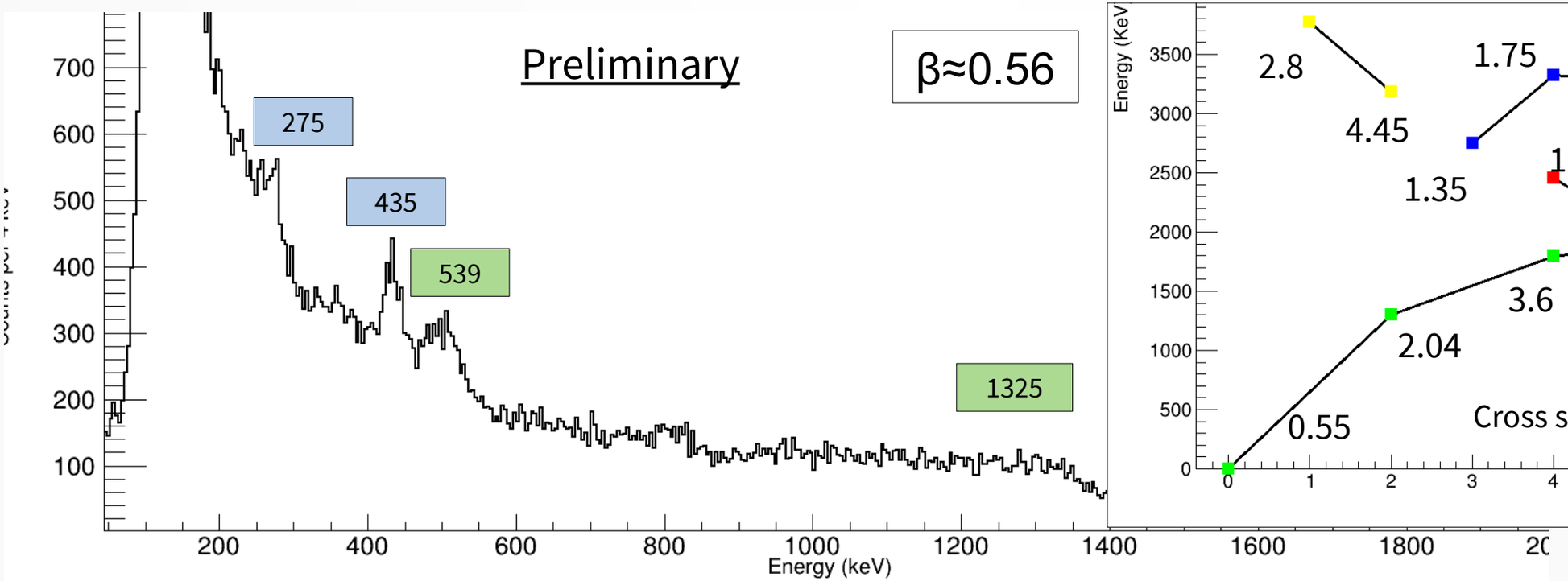
Zero degree Particle identification plot gated on ^{131}In in Bigrips. ^{130}Cd highlighted



Gives information on proton-proton interaction

Ideal to test shell model calculations

$^{9}Be(^{131}In,^{130}Cd)$

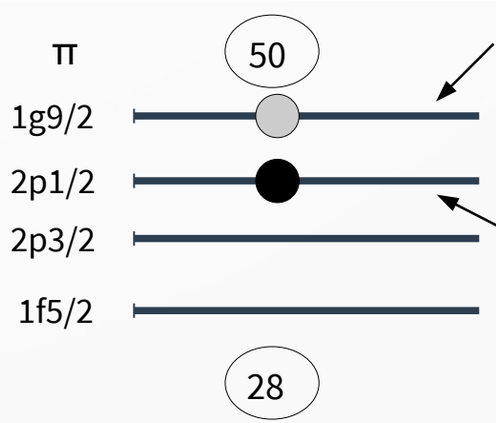


Known transitions

New transition

$4^{+} \rightarrow 2^{+}$

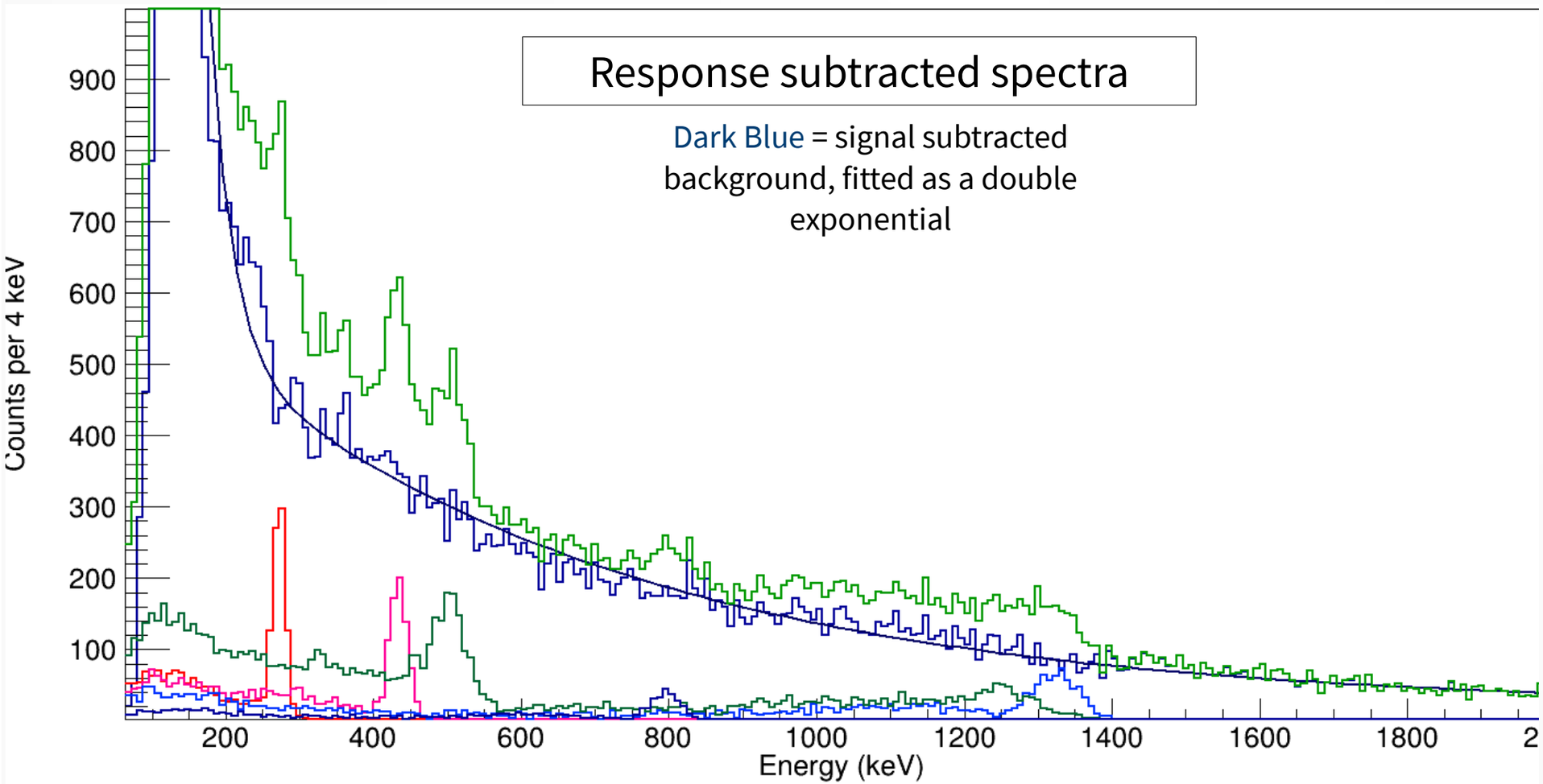
$2^{+} \rightarrow 0^{+}$

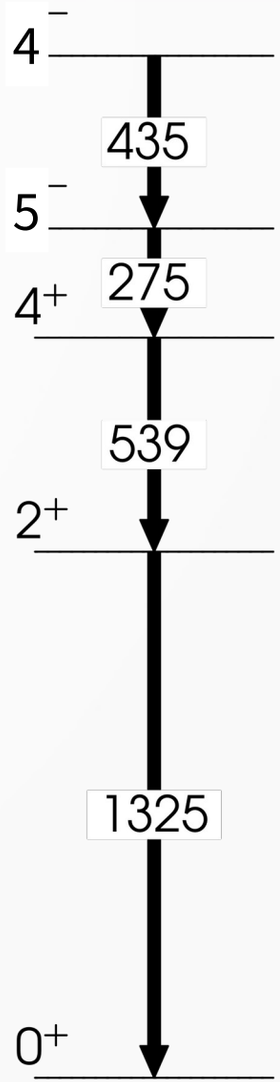


^{131}In g.s configuration

^{131}In isomer configuration

^{130}Cd Interpretation





Use Geant4 Simulation to generate response signal from HiCARI

Outlook

Still work to be done on shown isotopes, final fitting and improved simulations

Developing level schemes of other nuclei

^{130}In ^{132}In ^{129}In

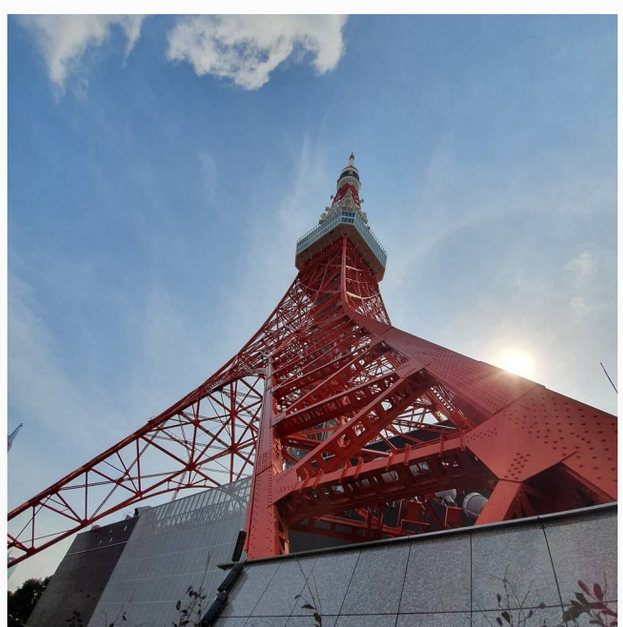
Other work being carried out in parrallel by Michael Armstrong at GSI

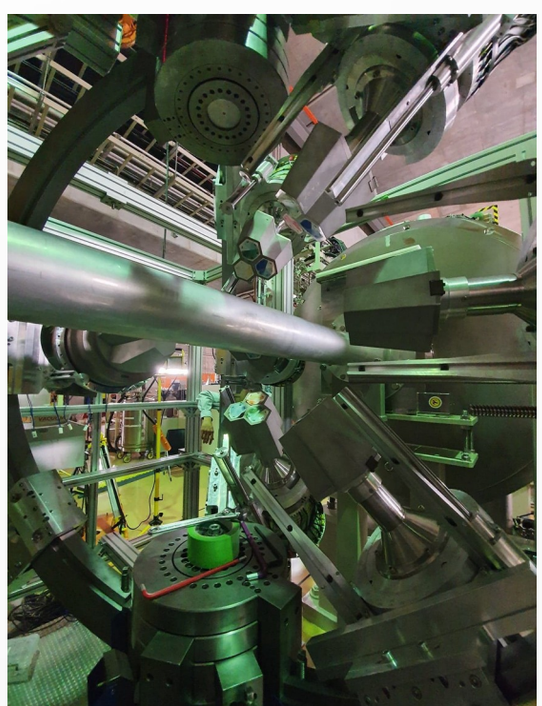
Life time analysis of yrast states in ^{128}Cd

^{129}Ag proving to be challenging, low statistic with high background supressing gammas

Summary

- Wide variety of nuclei in the ^{132}Sn region in data set
- Preliminary decay scheme for ^{130}Cd determined
- Provides Information on proton-proton interaction





Collaborators

T Parry[1], M Armstrong[2], Zs Podolyák[1], M Górska[2], J Acosta[3], Z Q Chen[1], A Jungclaus[3], K Wimmer[3,4], P Doornenbal[4], N Aoi[5], H Baba[4], G Bartram[1], F Browne[4], C Campbell[6], H Crawford[6], H De Witte[7], C Fransen[8], H Hess[8], S Iwazaki[5], J Kim[4], A Kohda[5], T Koiwai[9,4], B Mauss[4], B Moon[4], P Reiter[8], D Suzuki[4], R Taniuchi[10,4], S Thiel[8], J A Tostevin[1], Y Yamamoto[5], A Yaneva[2] and C Yuan[11]

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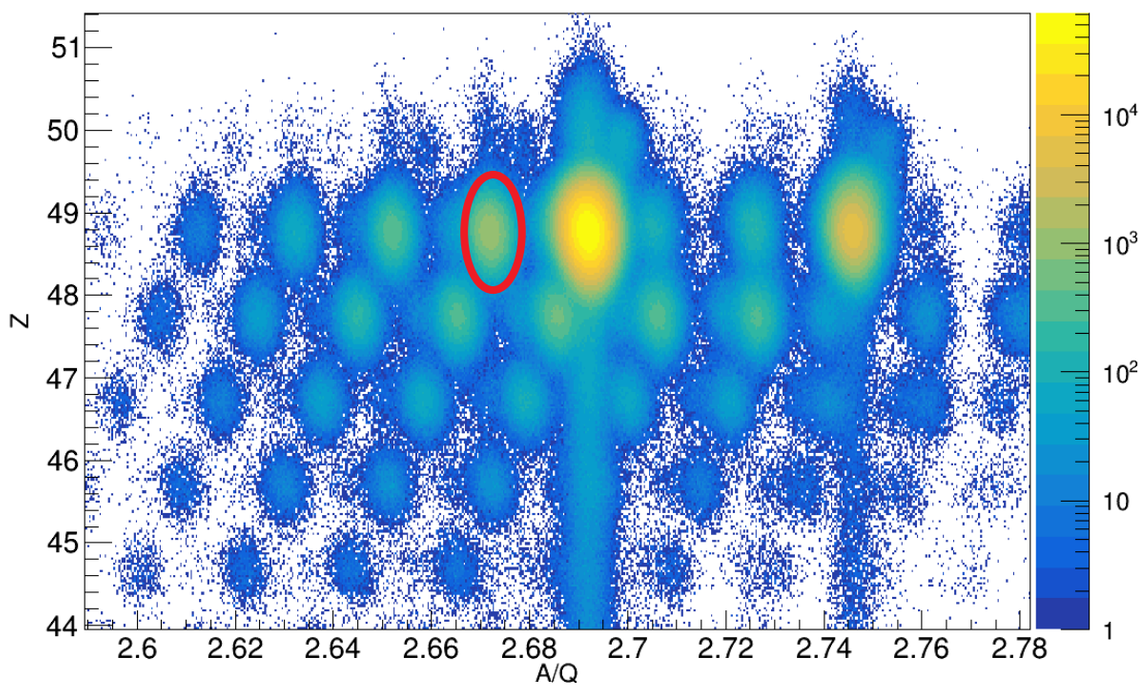
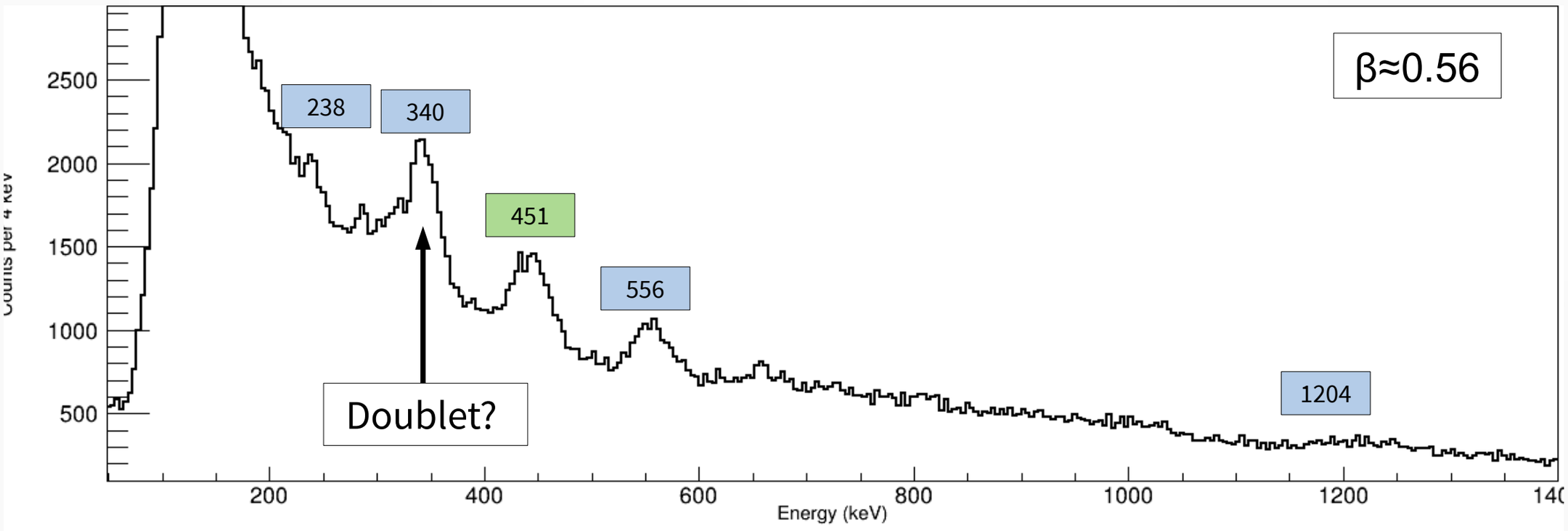
^{130}In proton-neutron interaction

- Z=49 , N=81
- Gives information on proton neutron interaction below ^{132}Sn
- Relativey high production rate
- Studied in beta decay, low spin states populated ^{130}Cd→^{130}In



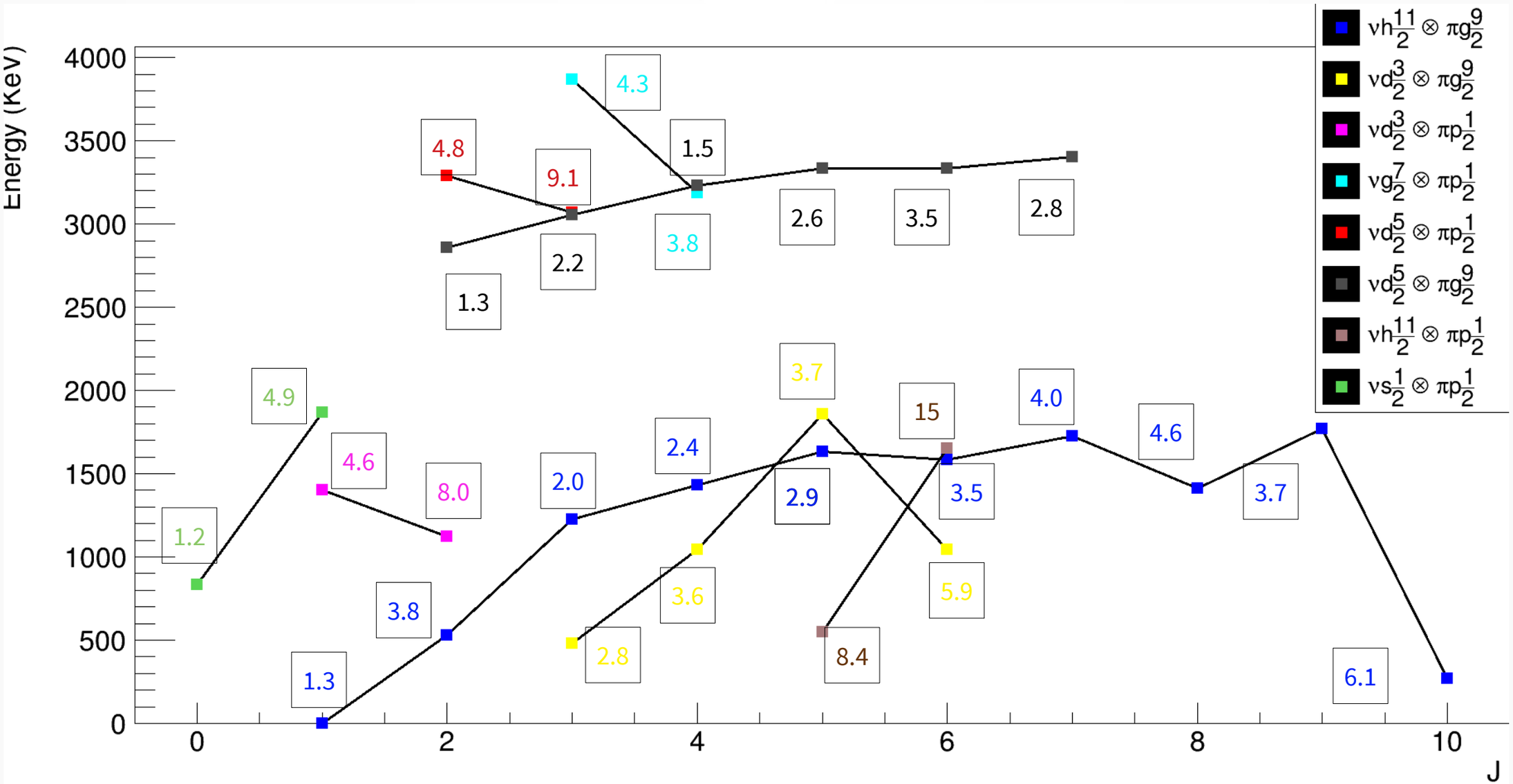
Zero degree Particle idtentification plot gated on ^{131}In in Bigrips. ^{130}In highlighted

$^{9}Be(^{131}In,^{130}In)$



Again due to being populated by ^{131}In likely to have π $g_{9/2}$ and π $p_{1/2}$ configurations

^{130}In


Energy (KeV)
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
J
4.3
4.8
9.1
1.5
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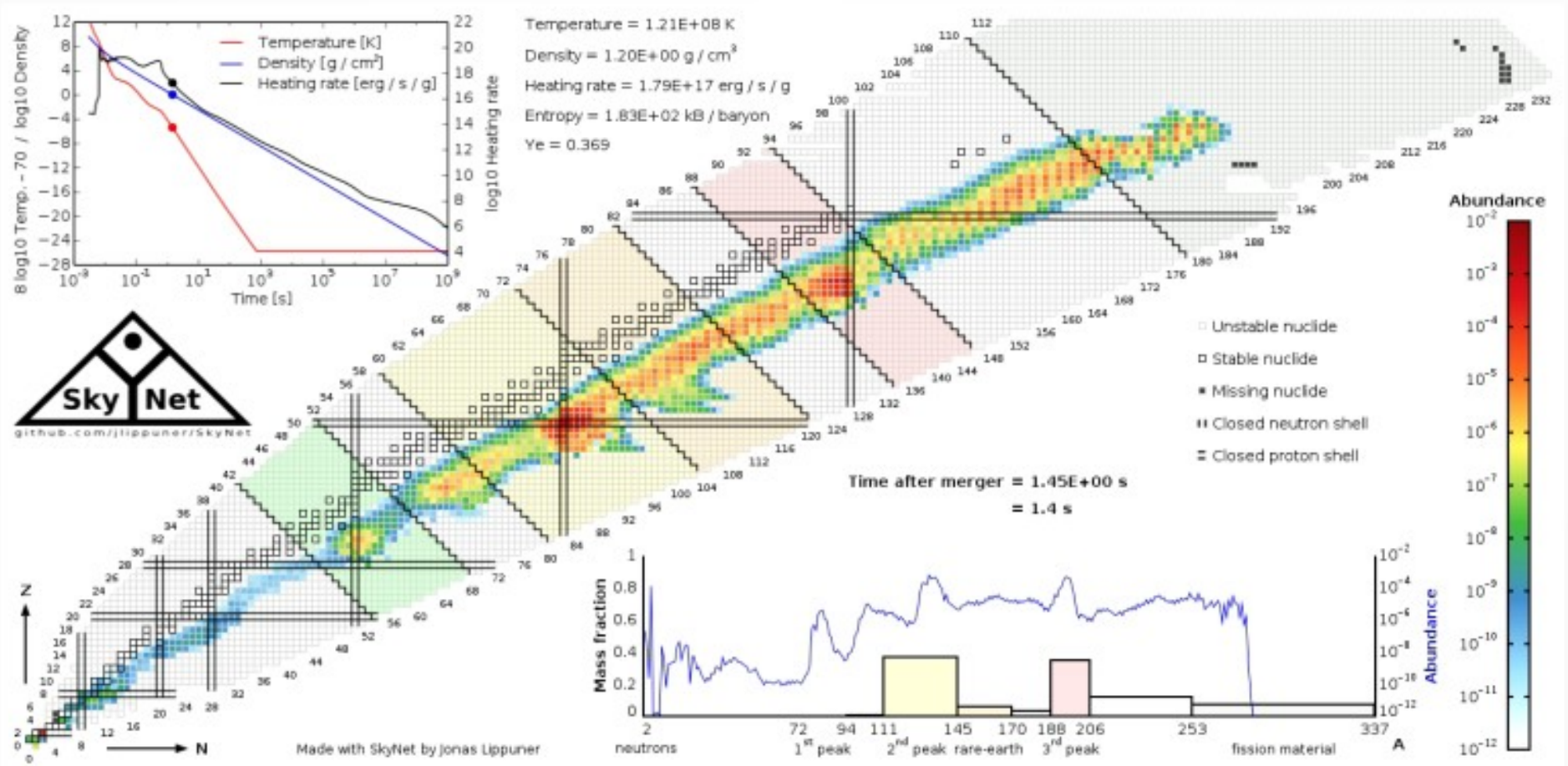
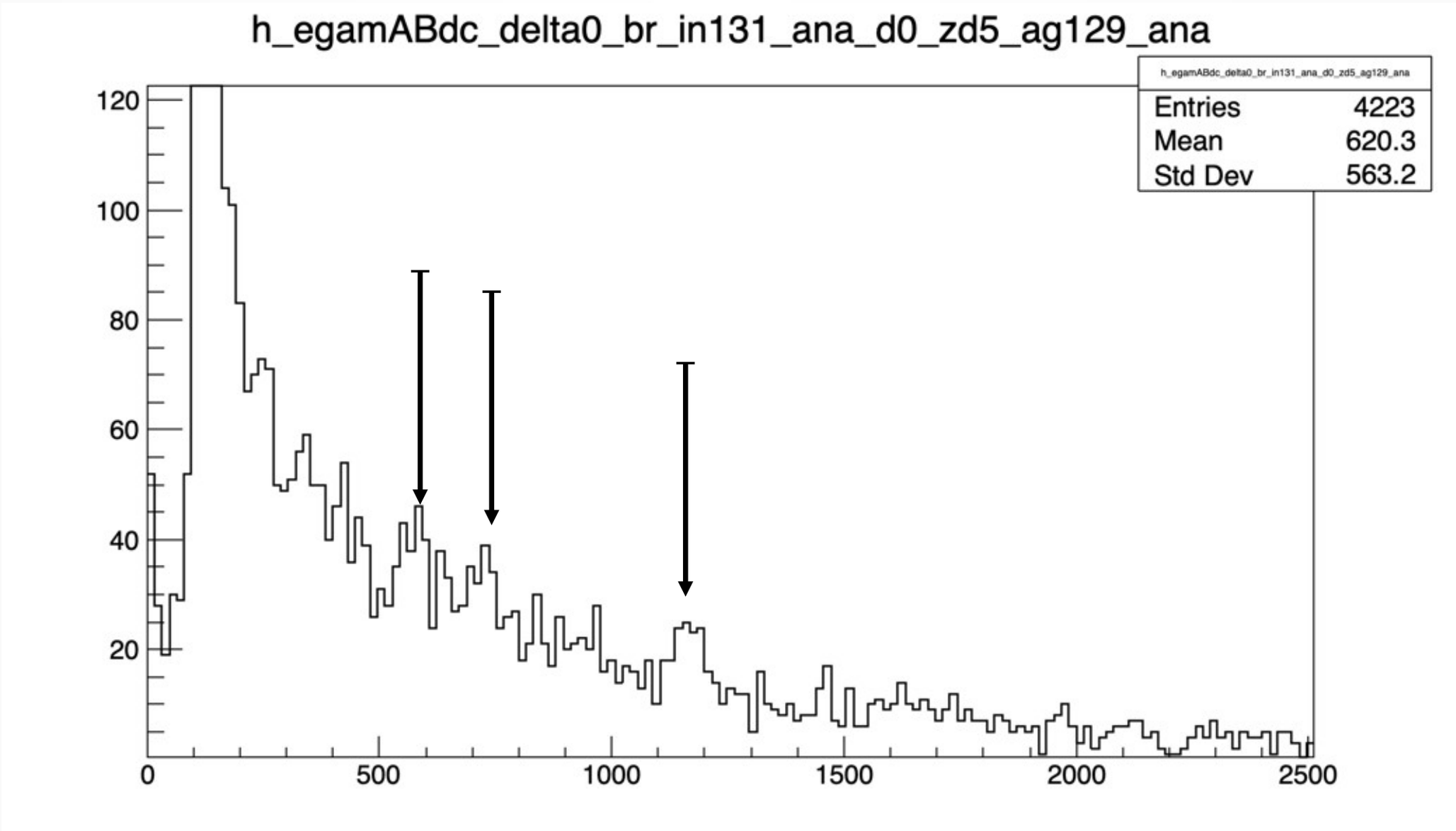
3.5
2.8
3.8
2.2
1.3
4.9
4.6
8.0
1.2
2.4
2.0
3.7
15
4.0
4.6
2.9
3.5
3.7
3.8
3.6
5.9
2.8
8.4
1.3
6.1
$\nu h_{\frac{11}{2}} \otimes \pi g_{\frac{9}{2}}$
$\nu d_{\frac{3}{2}} \otimes \pi g_{\frac{9}{2}}$
$\nu d_{\frac{3}{2}} \otimes \pi p_{\frac{1}{2}}$
$\nu g_{\frac{7}{2}} \otimes \pi p_{\frac{1}{2}}$
$\nu d_{\frac{5}{2}} \otimes \pi p_{\frac{1}{2}}$
$\nu d_{\frac{5}{2}} \otimes \pi g_{\frac{9}{2}}$
$\nu h_{\frac{11}{2}} \otimes \pi p_{\frac{1}{2}}$
$\nu s_{\frac{1}{2}} \otimes \pi p_{\frac{1}{2}}$

The R Process



- *SkyNet Animation, Jonas Lippuner,https://jonaslippuner.com/research/skynet/*

^{129}Ag?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Mean 620.3
Std Dev 563.2
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80
60
40
20
0
500
1000
1500
2000
2500