

Međuigra stanja jednočestičnog
karaktera i kolektivnih pobuđenja
izotopa olova
pobuđenih reakcijama prijenosa
neutrona

Kristijan Gorički

Mentor: dr.sc. Suzana Szilner



Sudar
neutronskih
zvijezda

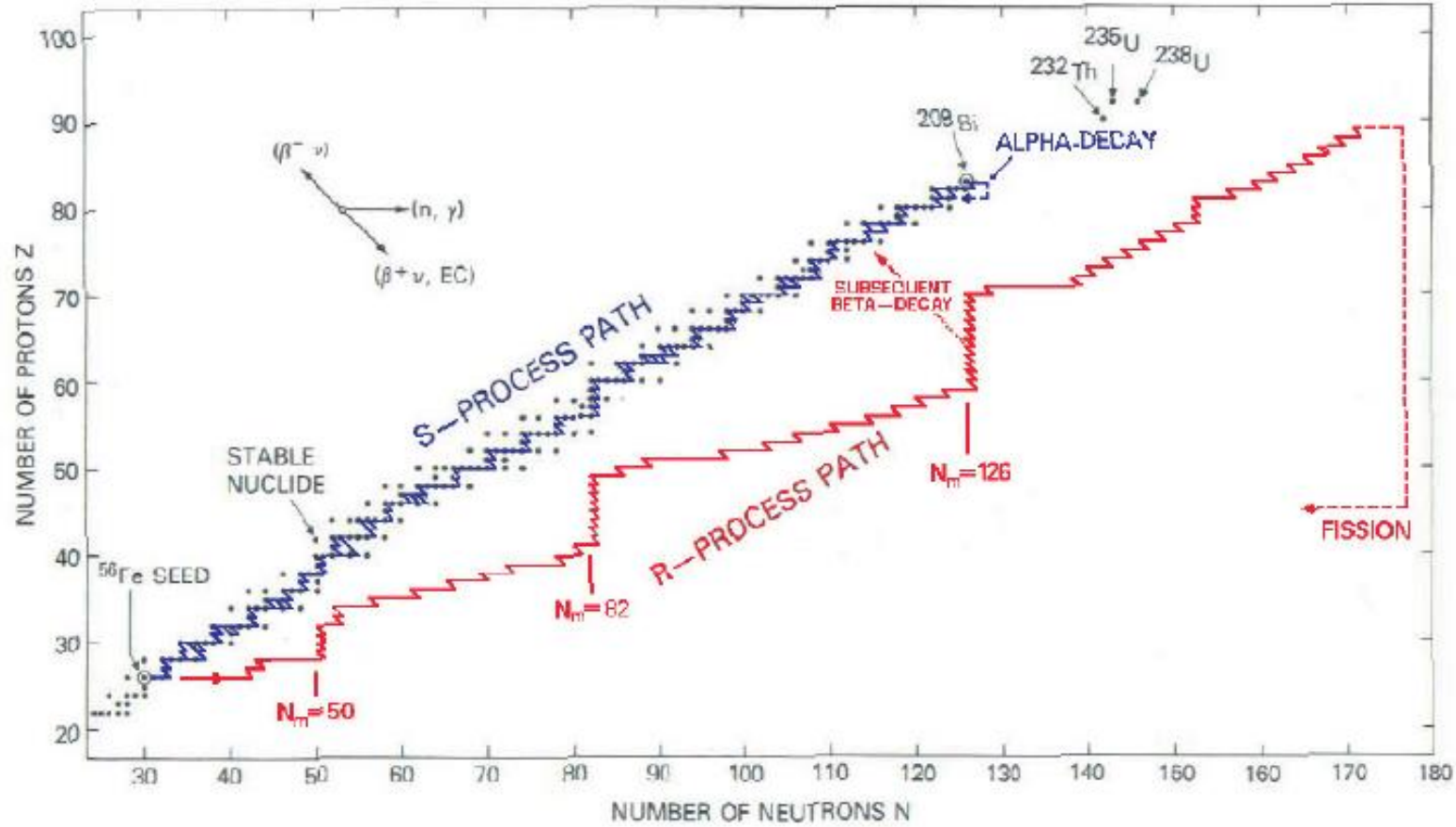
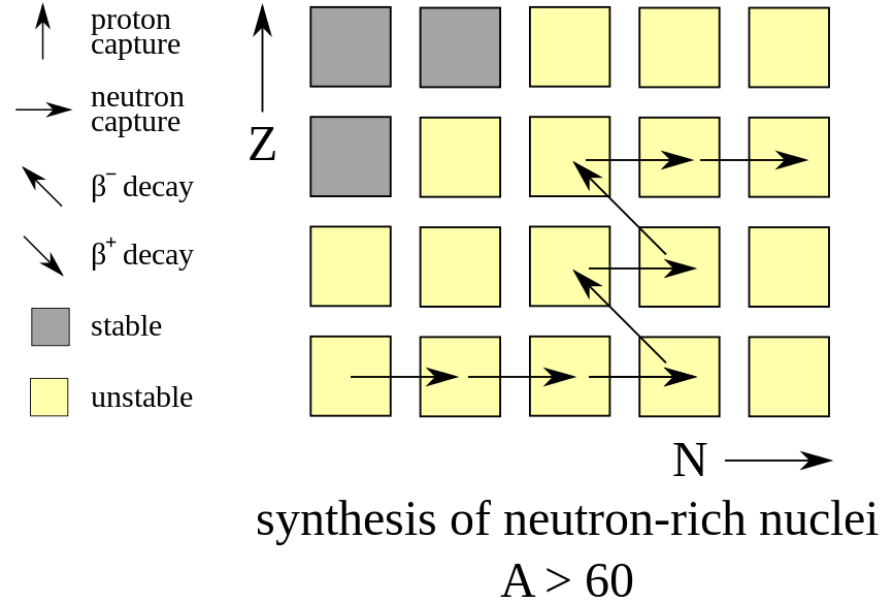
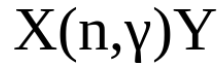
NGC 4993, Hydra, 2017.

Dark Energy Camera / CTIO
i-band
Time Relative to 2017 August 17

+0.5 days

Credit: P. S. Cowperthwaite / E. Berger
Harvard-Smithsonian Center for Astrophysics

r-process rapid neutron captures

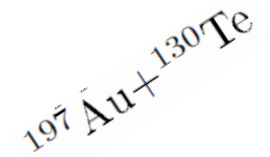
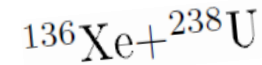
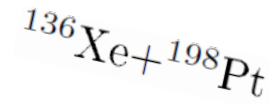
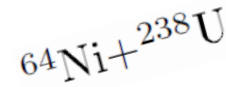
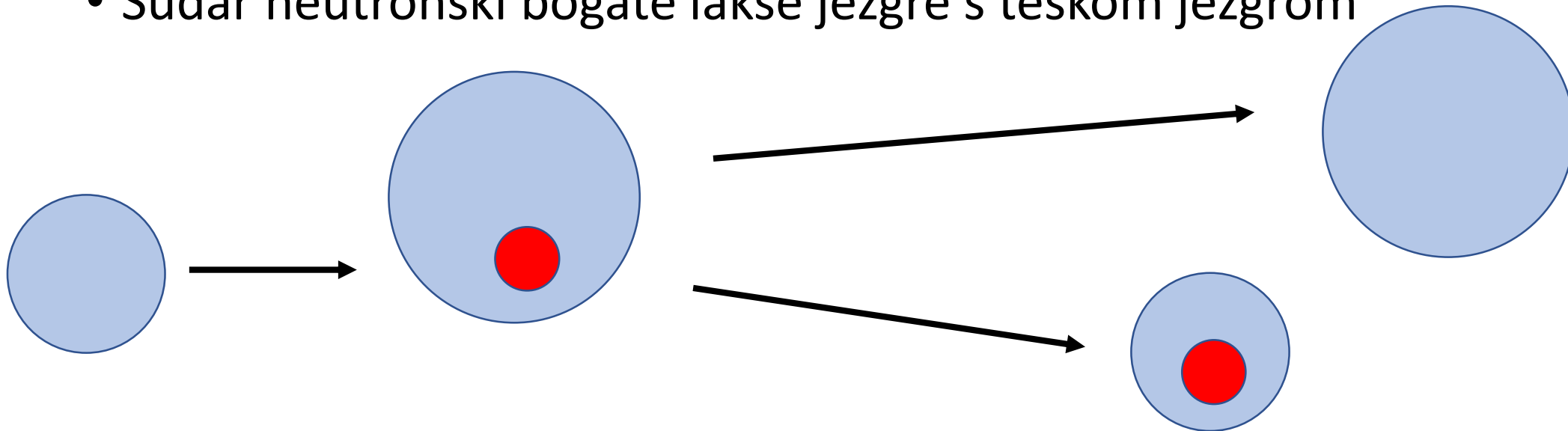


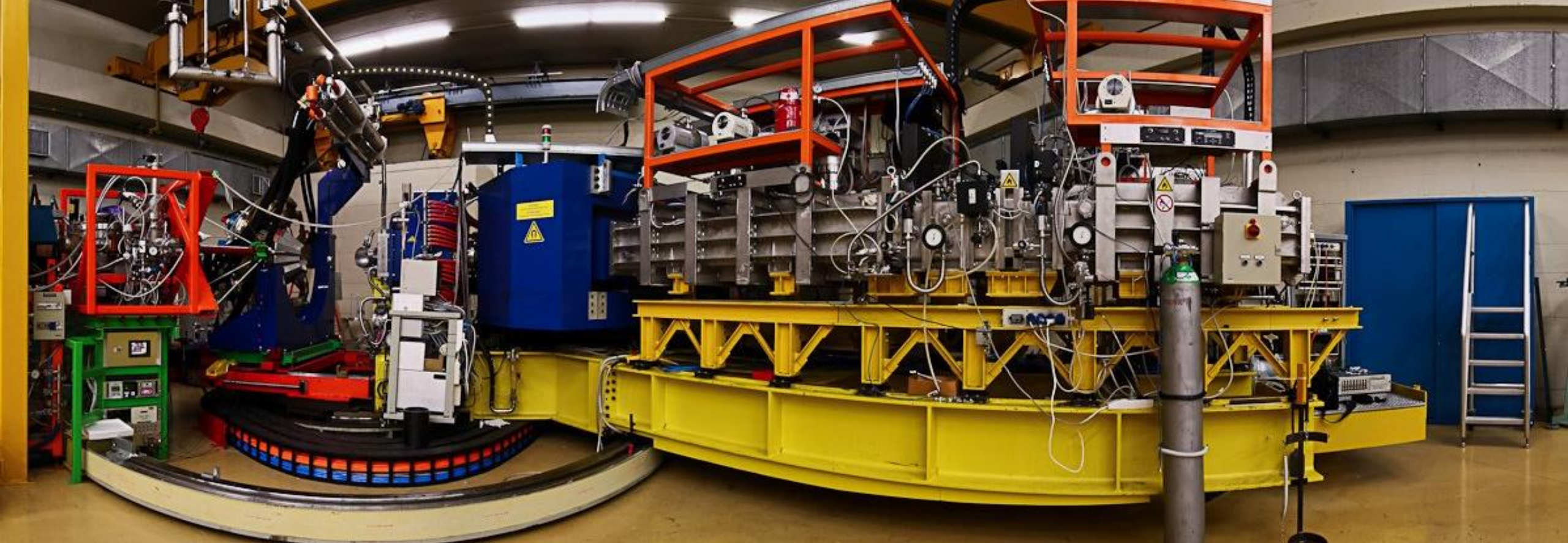
r-proces

- rapid neutron capture
- Međugra uhvata neutrona I fotodezintegracije
- Produkti – neutronski bogate jezgre

Sinteza na Zemlji

- Reakcije fuzije uz upotrebu snopova neutronske bogatih radioaktivnih snopova
- Reakcije uhvata neutrona (potreban vrlo visoki tok)
- Reakcije prijenosa nukleona – pobiranje (*pick up*) i ogoljavanje (*stripping*)
- Sudar neutronske bogate lakše jezgre s teškom jezgrom



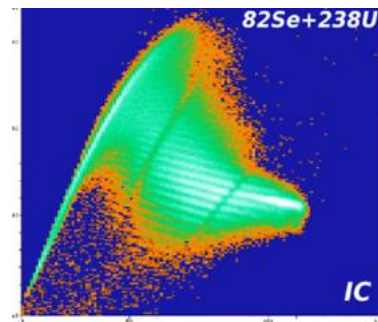
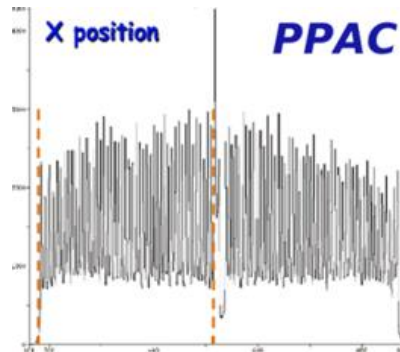
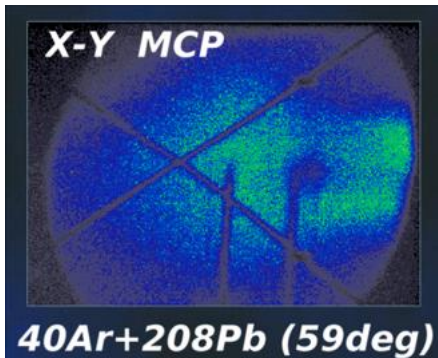
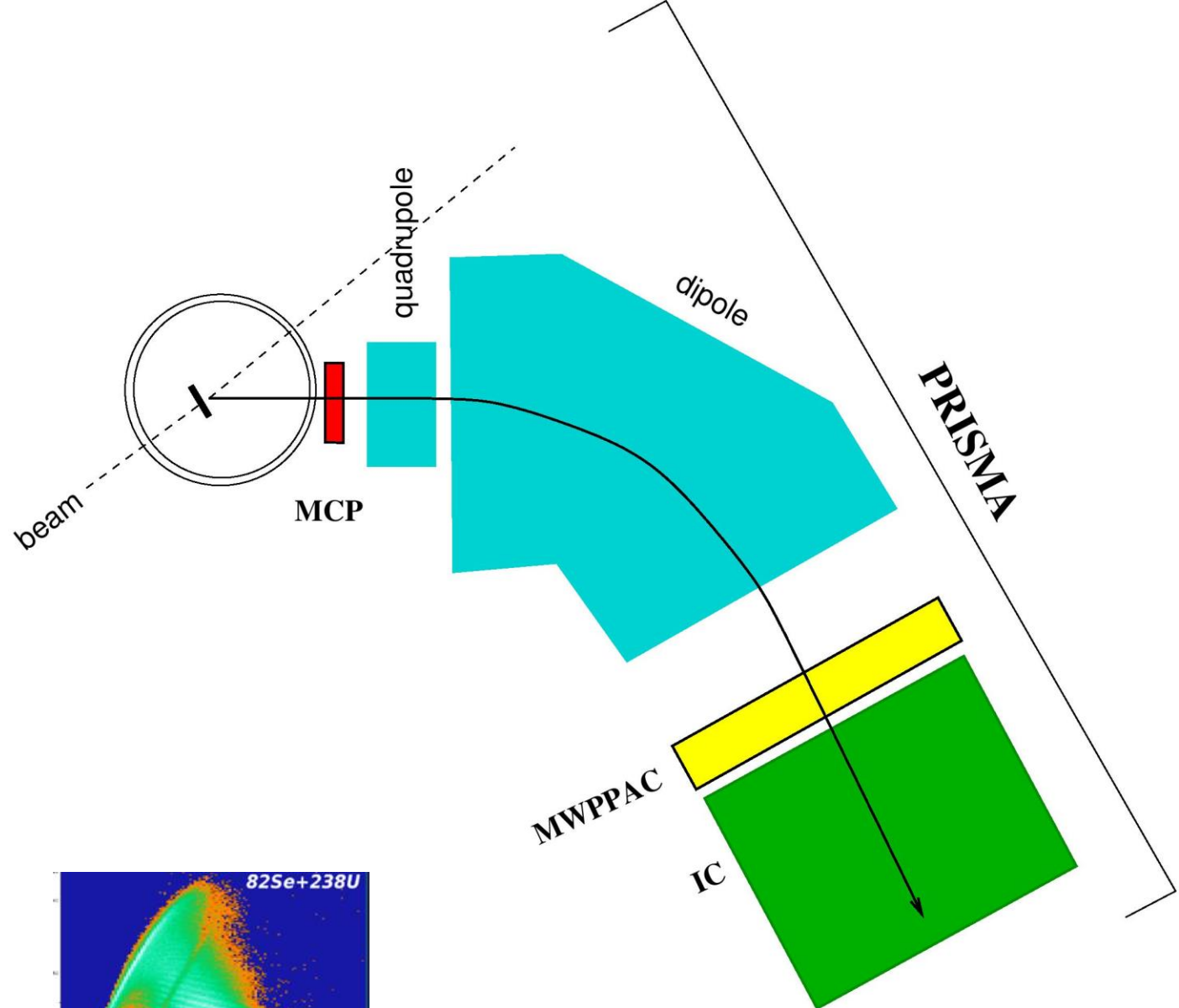


Mjerni postav

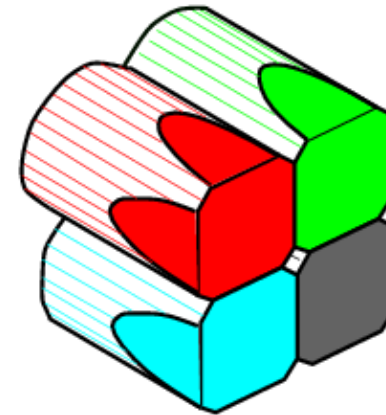
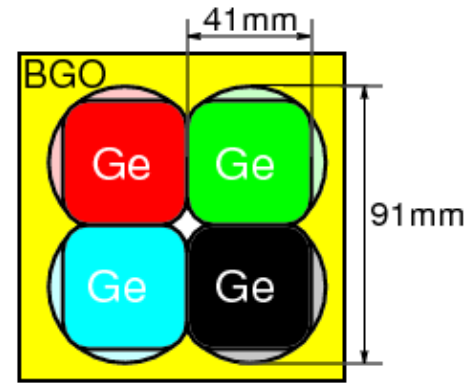
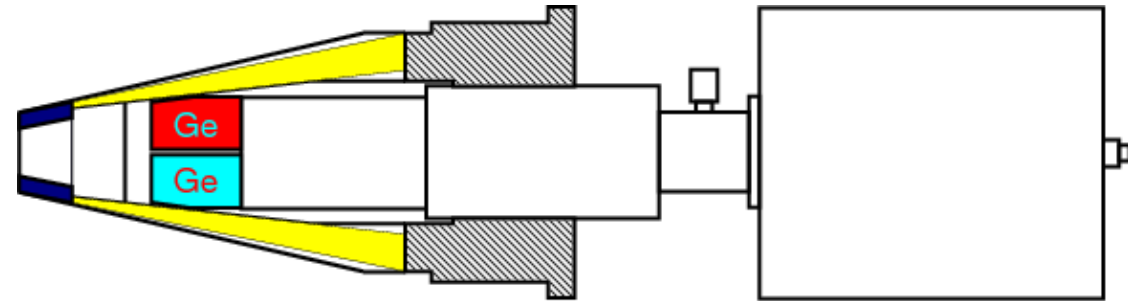
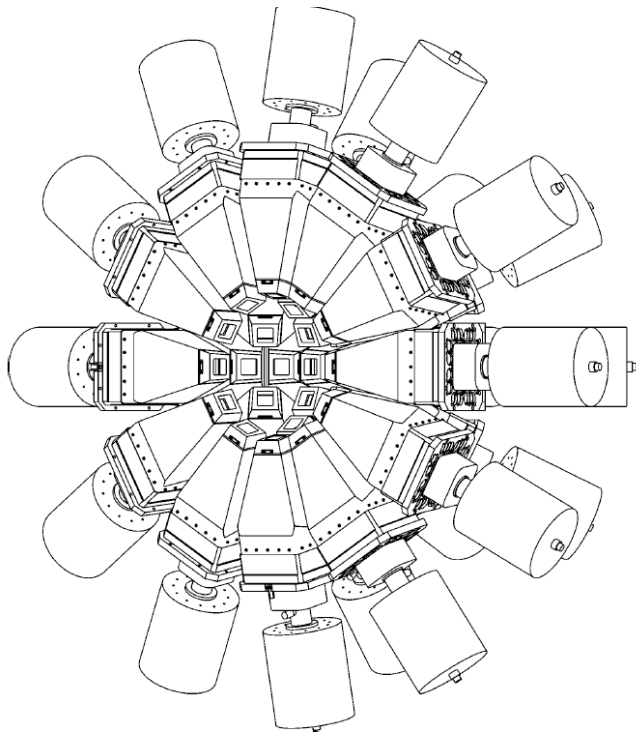
- Nacionalni laboratorij Legnaro
- PRISMA
- CLARA
- Snop ^{40}Ar ubrzan do 255 MeV
- Meta - pločica ^{208}Pb debljine $300\mu\text{g}/\text{cm}^3$

PRISMA

- magnetski spektrometar
- *Micro channel plate* (x,y,t)
- Kvadropolni I dipolni magnet
- *Multi wire parallel plate avalanche counter*(x,y,t)
- *Ionisation chamber*(E, ΔE)



S. Szilner et al; Phys. Rev. C 76, 024604 (2007)
G. Montagnoli et al; Nucl. Instr. and Meth. in Phys. Res. A 547, 455 (2005)
S. Beghini et al; Nucl. Instr. and Meth. in Phys. Res. A 551, 364 (2005)



CLARA

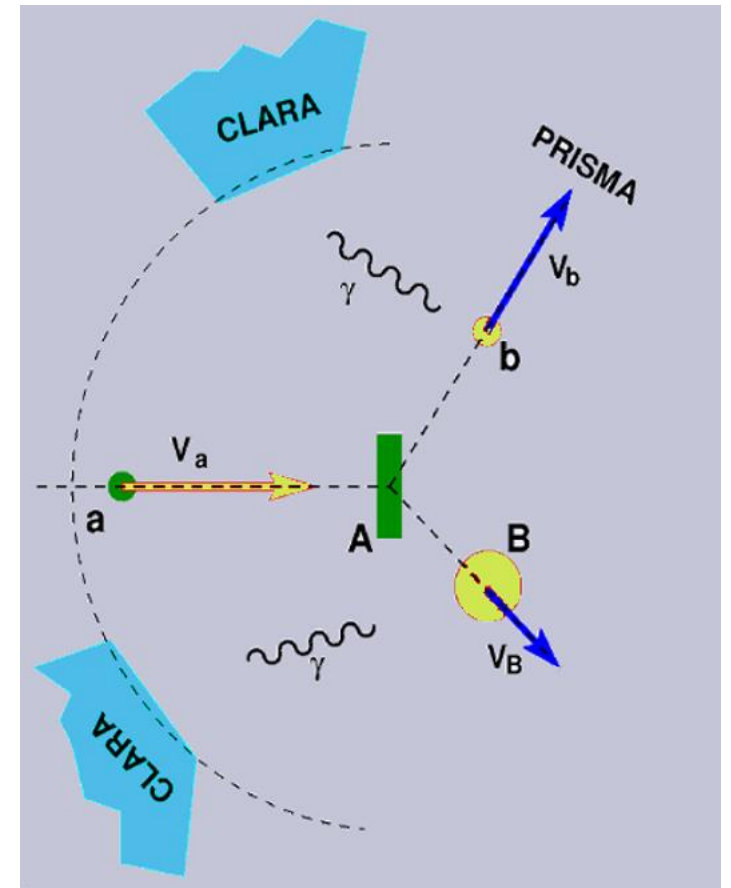
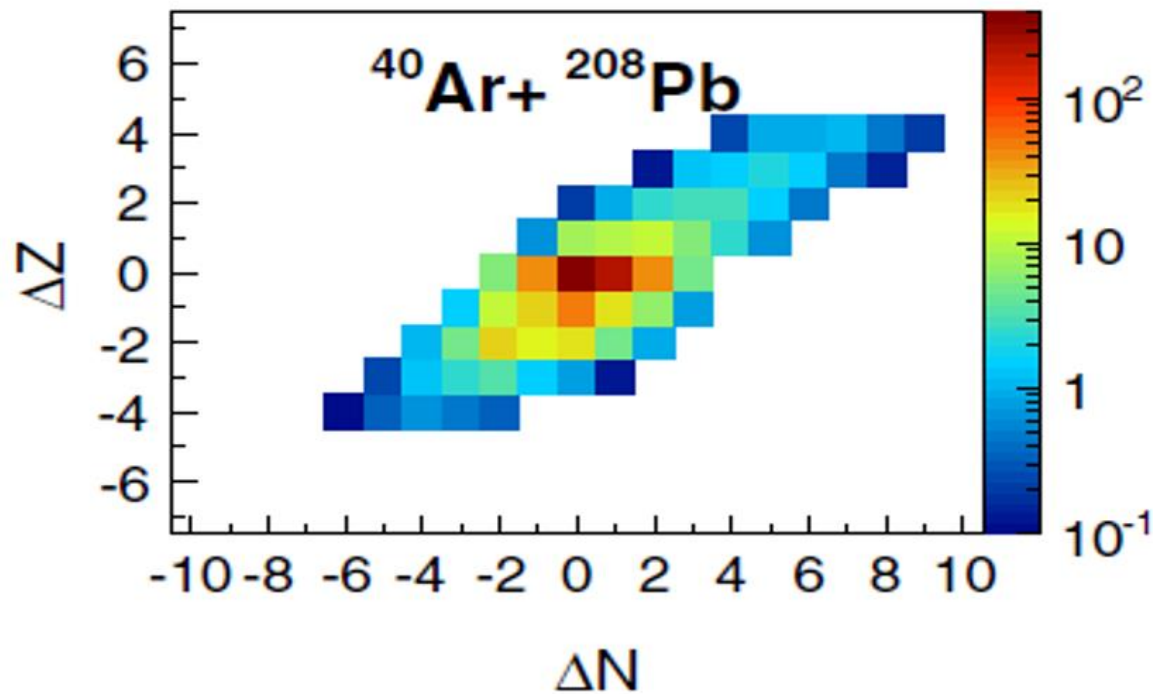
- Detektor elektromagnetskog zračenja
- 24 germanijska Clover detektora uronjenih u kriostat (tekući dušik)
- Clover – 4 germanijska kristala visoke čistoće oklopljeni BGO (*Bismuth germanate*) antikomptonkim štitom

Obrada podataka

- Mjerimo:
 - MCP – x , y položaj i vremenski signal(start)
 - MWPPAC – x , y položaj i vremenski signal(stop)
 - IC – ukupna energija E i gubitak energije ΔE
 - CLARA – energija elektromagnetkog zračenja
- Rekonstrukcija putanje događaj po događaj
- Dobivamo:
 - Atomi broj A i broj protona Z
 - Naboj iona Q
 - Vektor brzine lakog partnera
 - Doppler korigirani E_γ

Obrada podataka

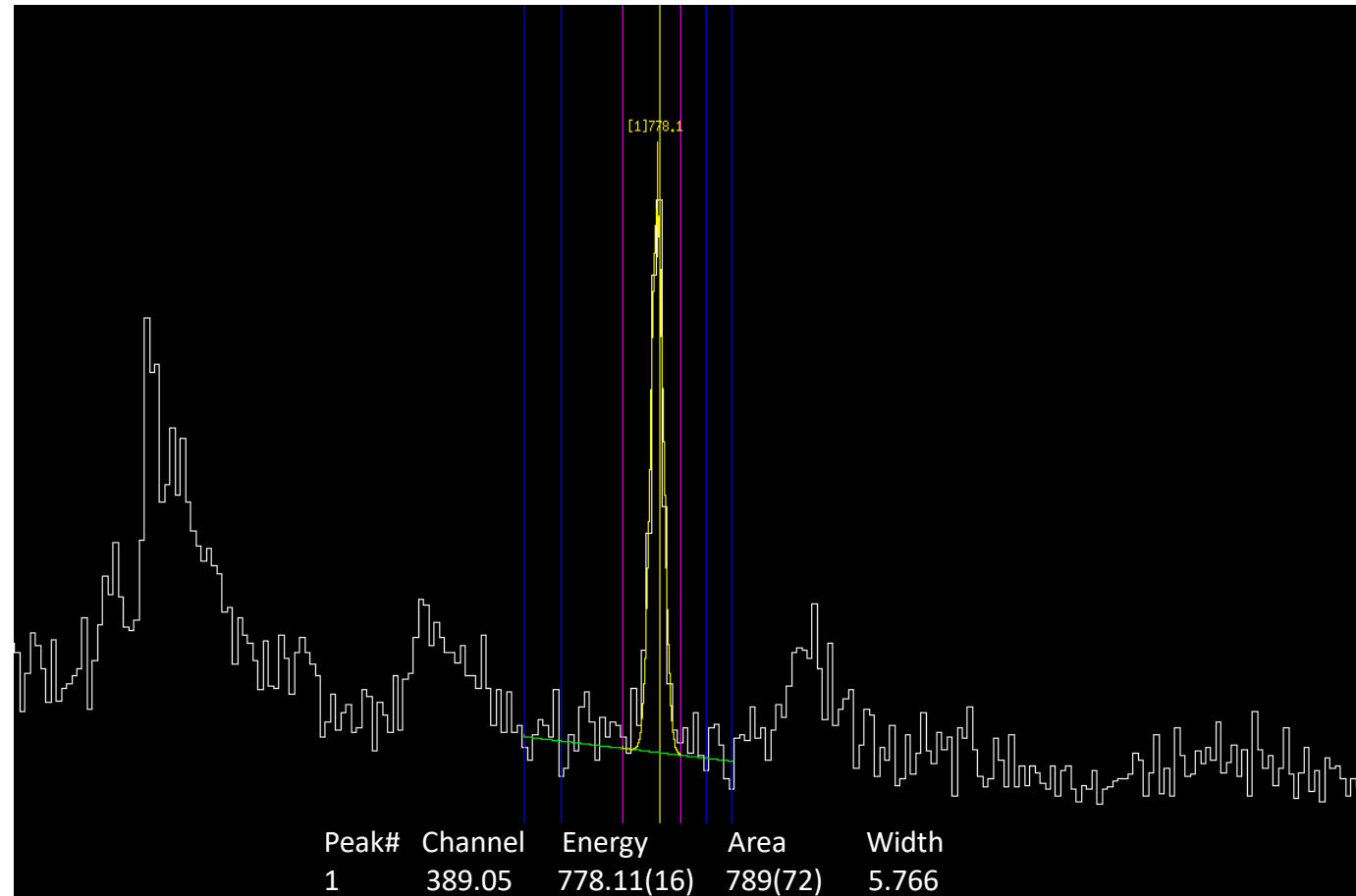
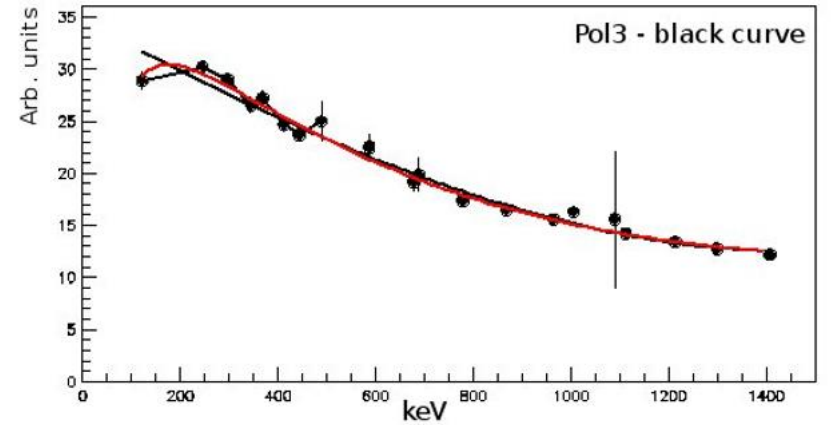
- Vektor brzine lakog partnera + zakoni očuvanja \rightarrow vektor brzine teškog partnera



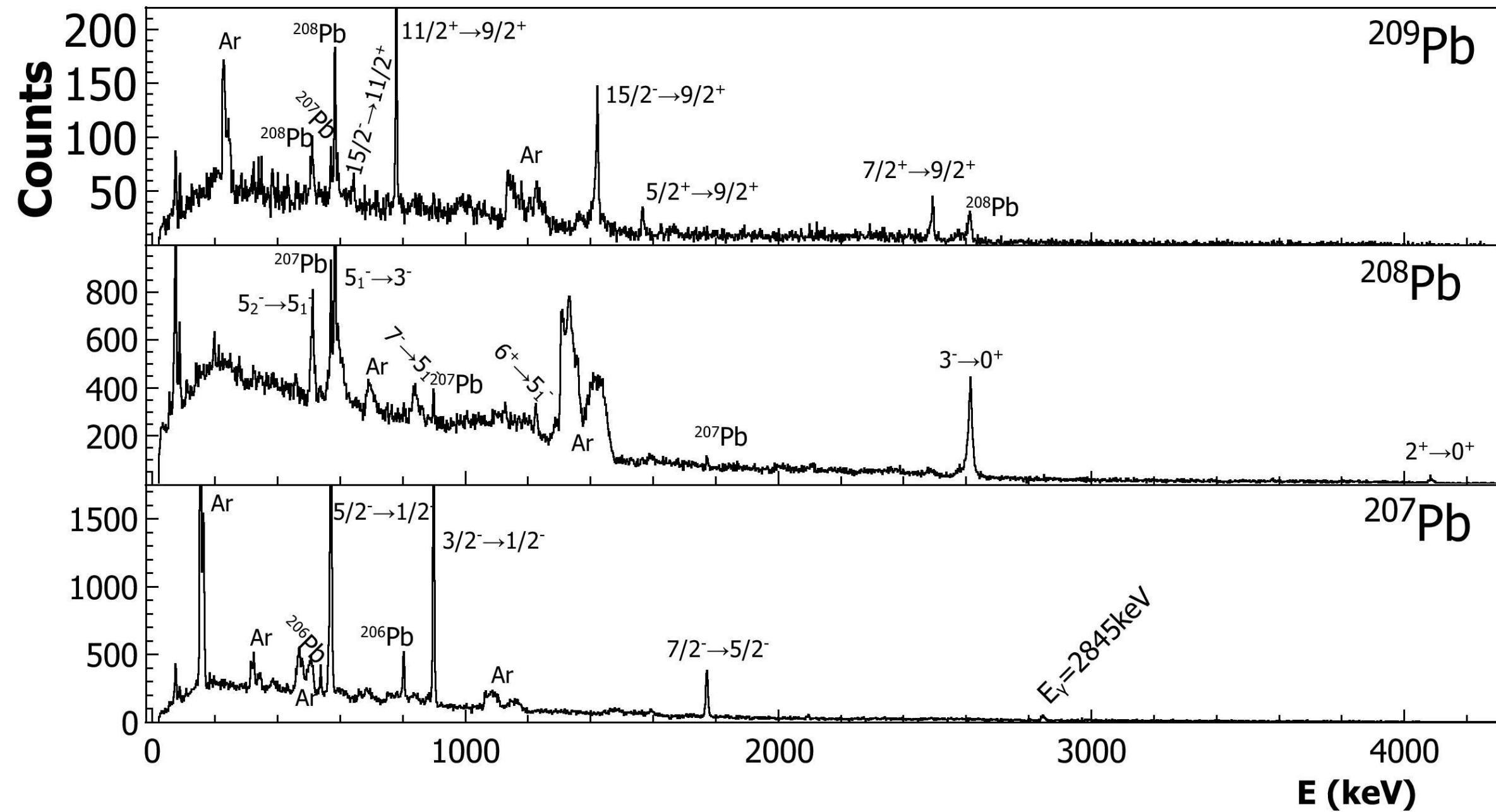
Obrada podataka

- Kalibracija efikasnosti CLARA detektora
- Doppler korekcija
- gamma spektar
- prilagodba Gauss krivulje
 - Širina, položaj(energija), jačina vrha
- NNDC

CLARA eff fit (152Eu source)

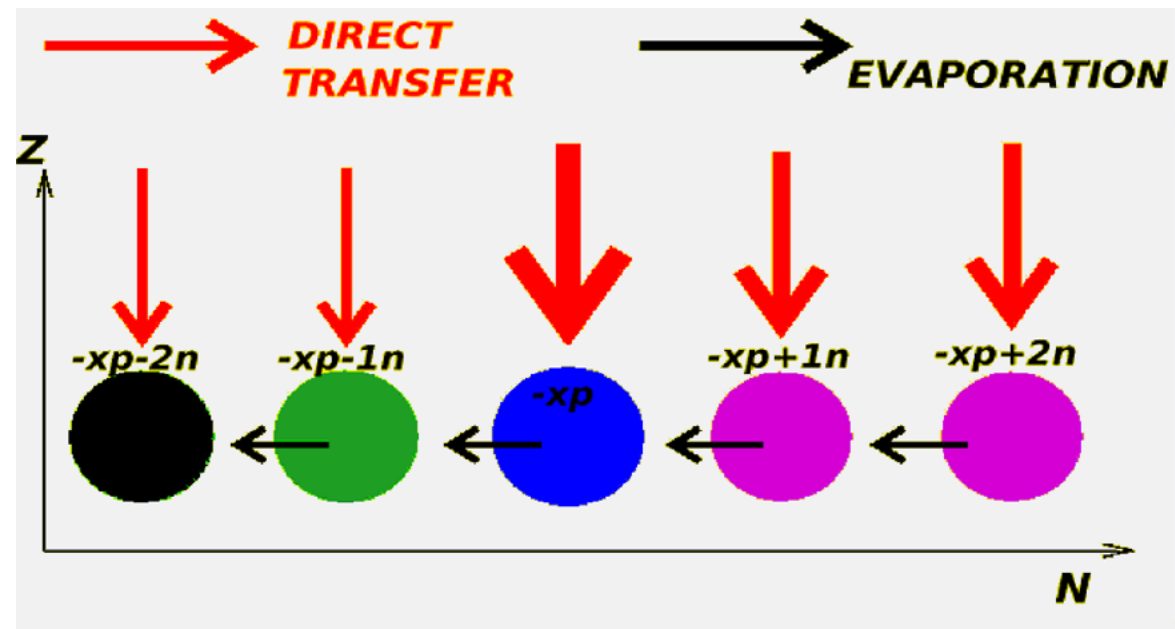


$^{40}\text{Ar} + ^{208}\text{Pb}$



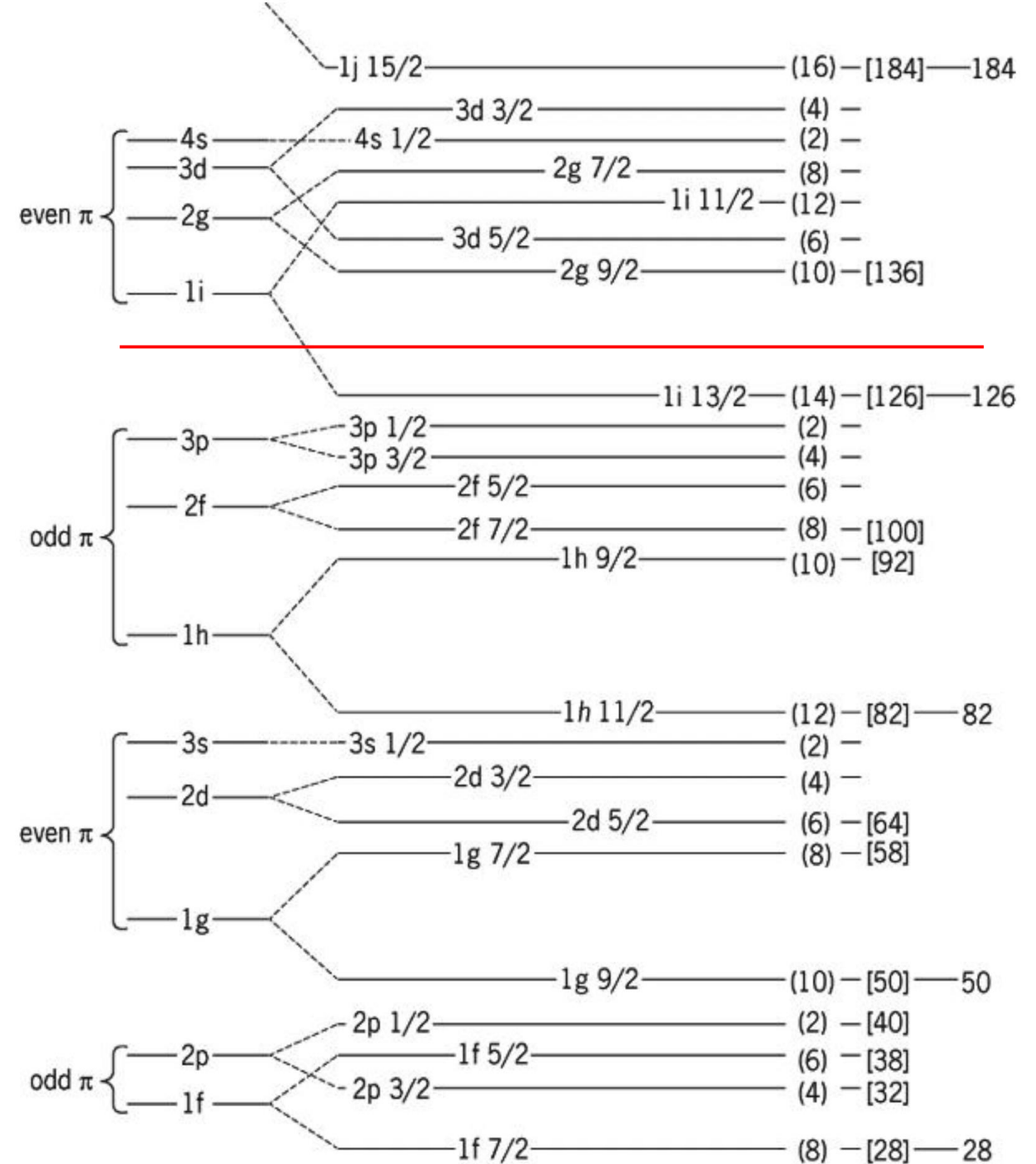
Gamma spektar

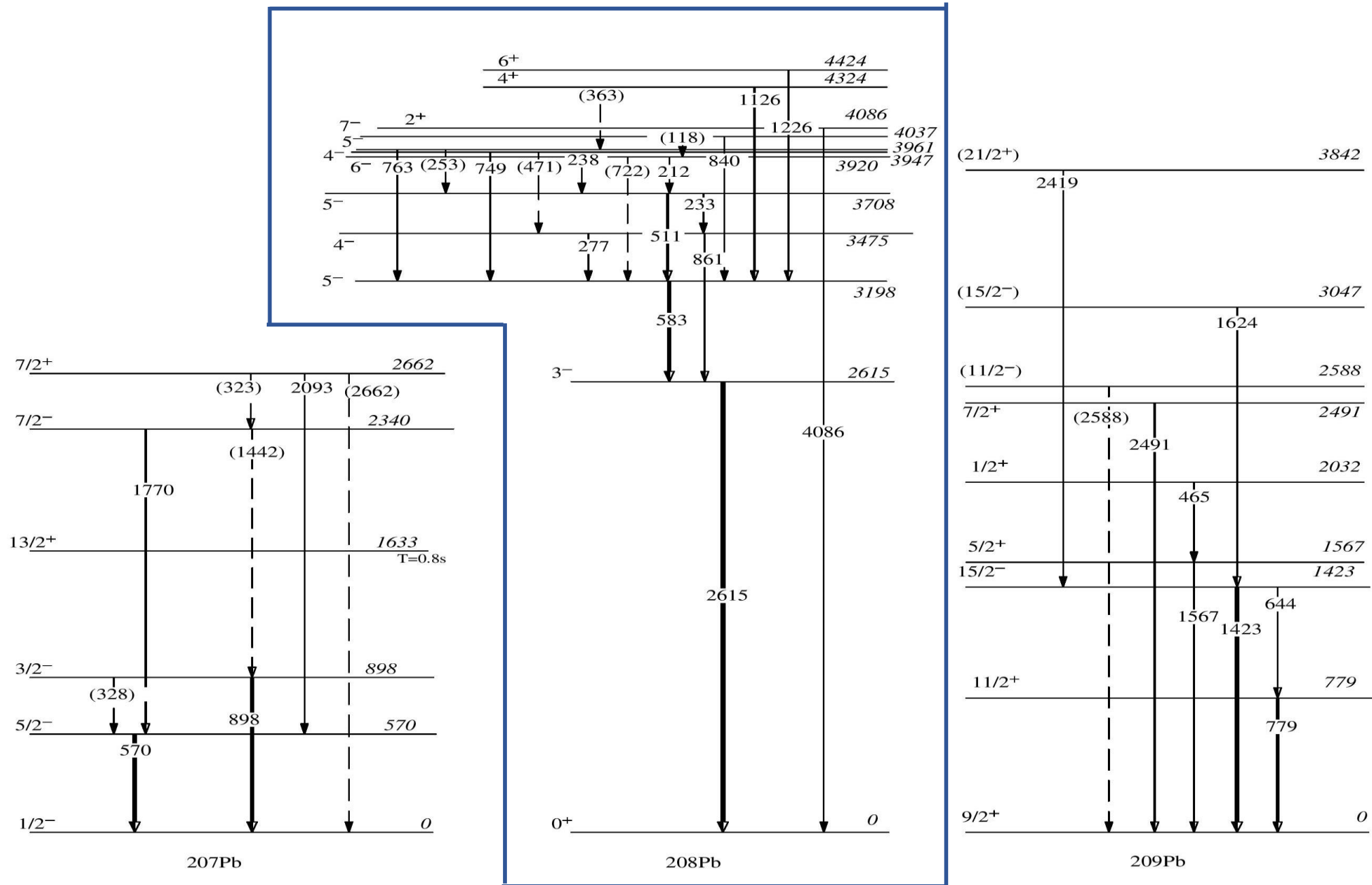
- Kandidati za gamma vrhove – karakteristike: uski, visoki vrhovi koji se dobro ističu od pozadine
- Rengensko zračenje atomskih orbitala
- Pogrešno Doppler korigirani vrhovi lakog binarnog partnera
- Evaporacija neutrona



^{208}Pb

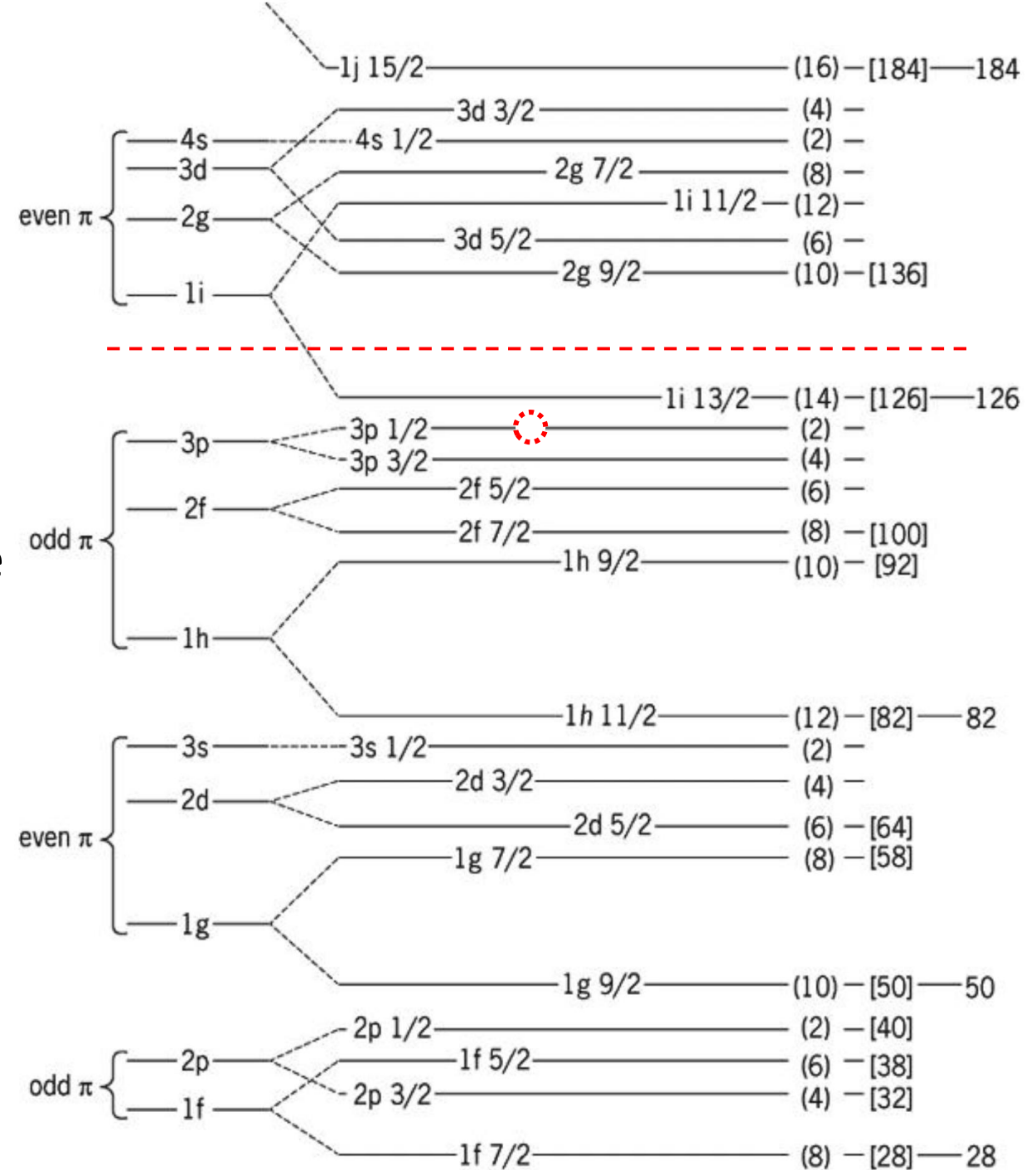
- Dvostruko magična jezgra ($Z=82$ i $N=126$)
- Prvo pobuđeno stanje 3^- na 2615 keV
- 3^- stanje oktopolnog karaktera s $B(E3: 3^- \rightarrow 0^+) = 34 \text{ W.u.}$
- Kolektivnost negativnih stanja
- Stanja pozitivnog pariteta visoke energije

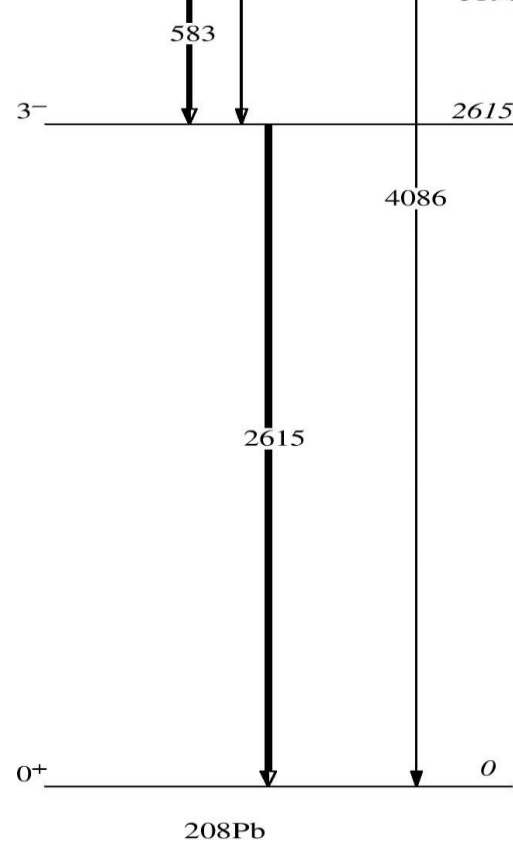
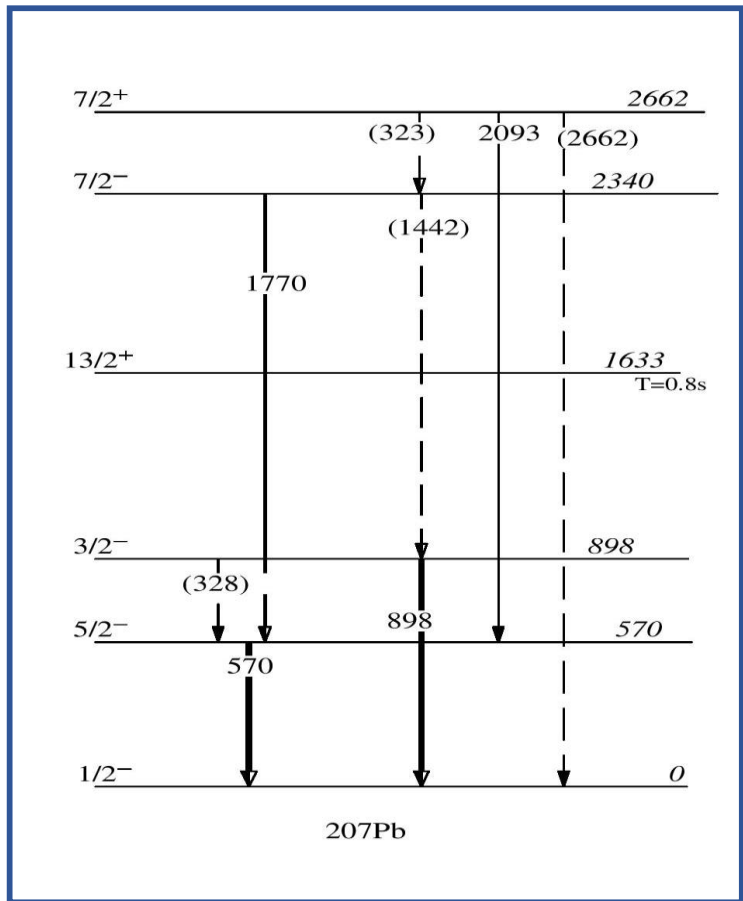
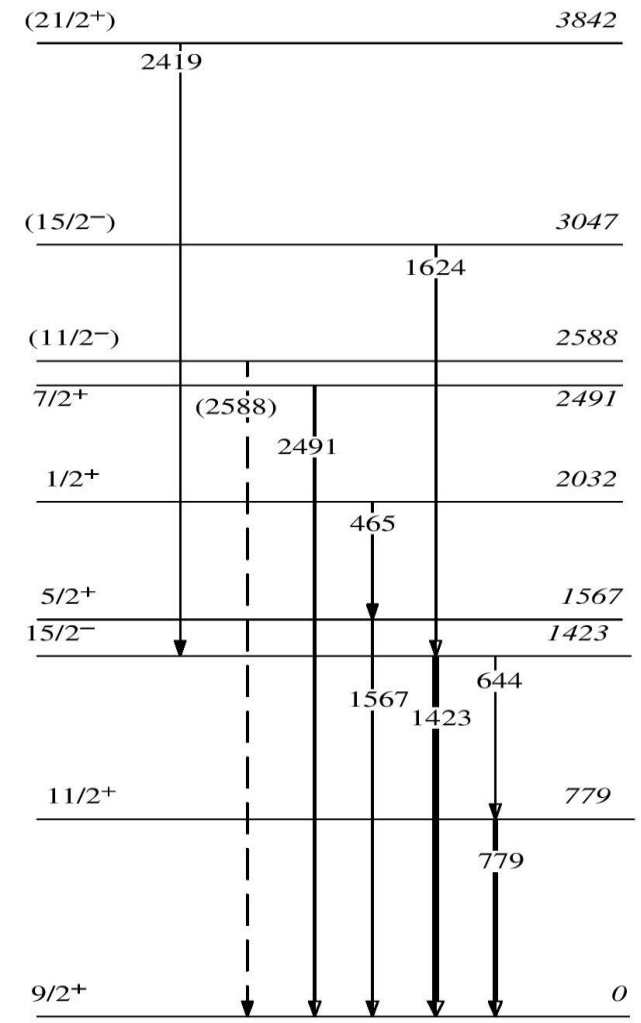
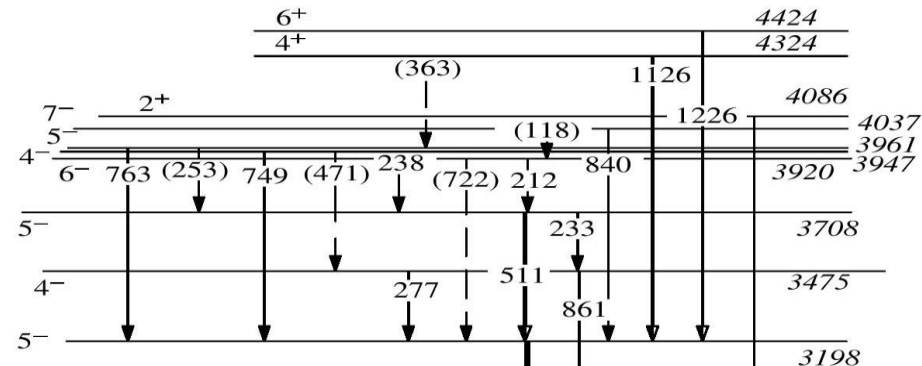




^{207}Pb

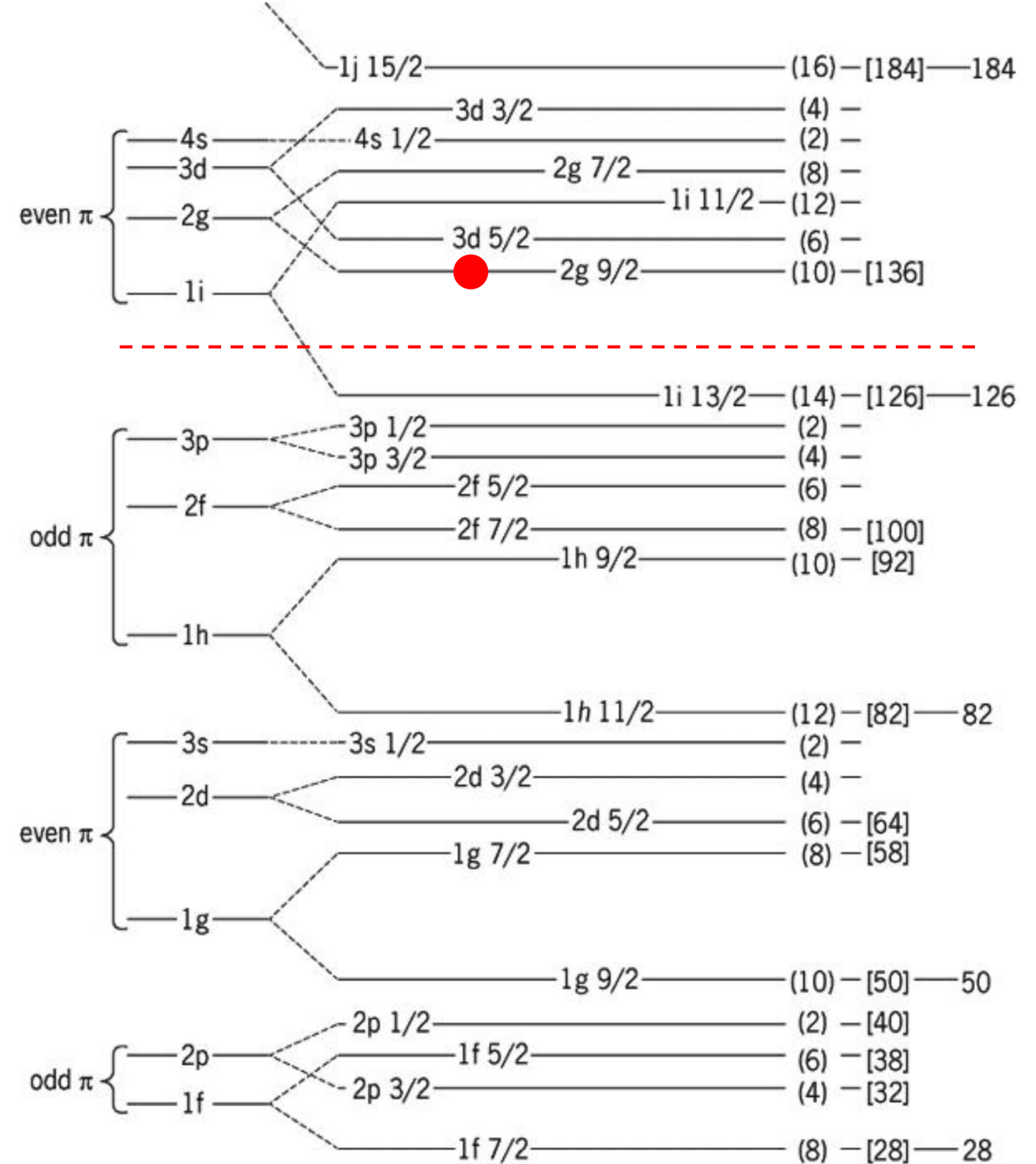
- Šupljina na ^{208}Pb sredici
- Jednočestična stanja - detektirana sva osim $9/2^-$ i $13/2^+$
- $T_{1/2}(13/2^+) = 0.8\text{s} \gg$ vremenske skale uređaja (μs)
- $7/2^+$ vezano stanje osnovnog stanja ^{207}Pb na 3^- stanje ^{208}Pb
- Novi prijelaz:
 $[4479](?) \rightarrow 13/2^+ [1633]$
 $E_\gamma = 2845\text{ keV}$

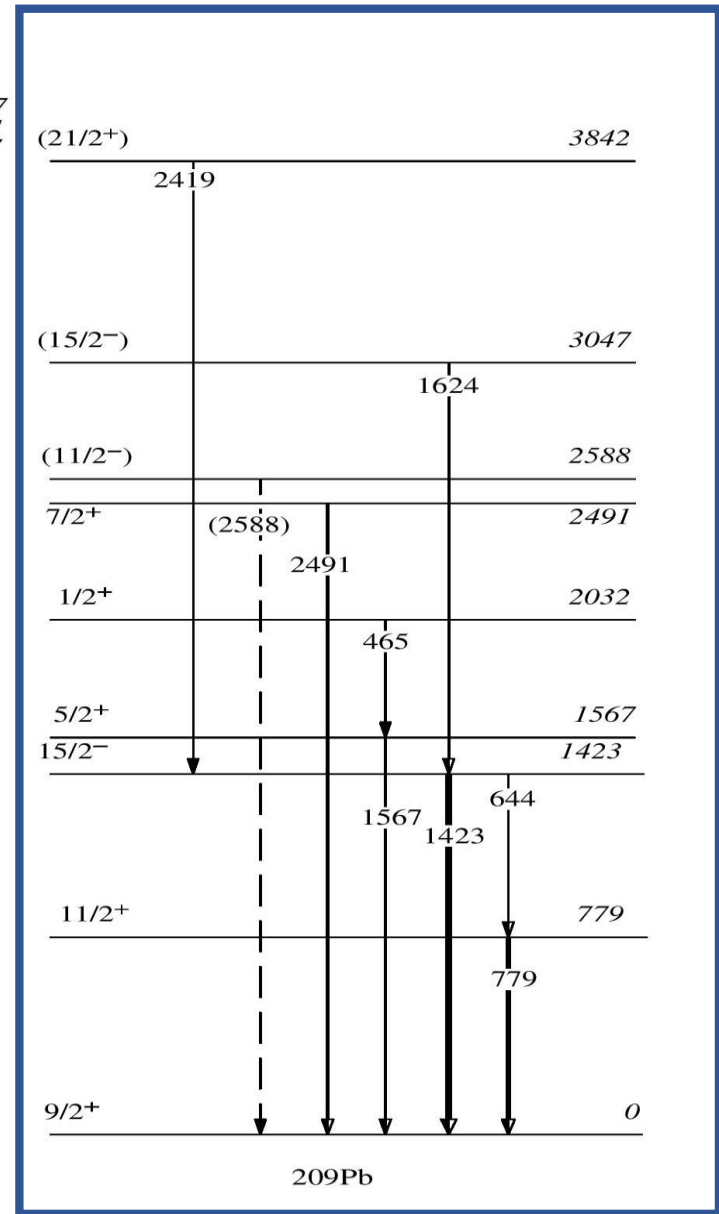
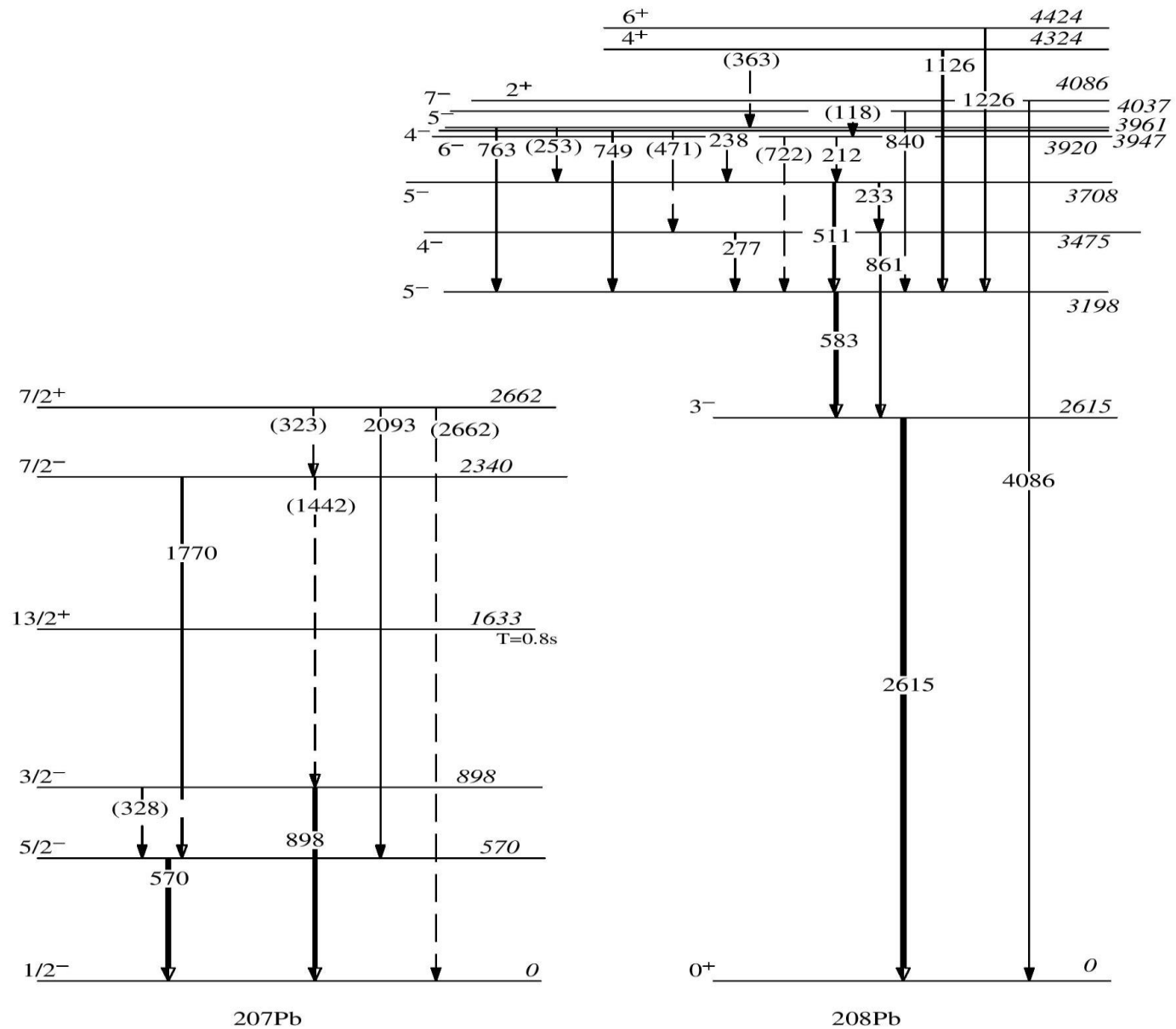




^{209}Pb

- Neutron na ^{208}Pb sredici
- Jednočestična stanja – detektirana su pobuđenja sva osim $3/2^+$
- Vezanje stanja jednočestičnih karaktera ^{209}Pb na 3^- stanje ^{208}Pb
- Nova stanja visokih spinova $11/2^-$, $15/2_2^-$ i $21/2^+$





Zaključak

- Detektirana su nova stanja kod jezgara ^{207}Pb i ^{209}Pb
- Najveća nastanjenost:
 - ^{208}Pb – oktopolno 3^- stanje
 - ^{207}Pb i ^{209}Pb – jednočestična stanja (vezanje šupljine na ^{208}Pb sredicu)
- Veza oktopolnog 3^- sa pripadnim vezanim stanjima izotopa oko ^{208}Pb
- Energijska sistematika nije dovoljna
- Mjerenje jačine elektromagnetskih prijelaza
- Udarni presjeci za reakcije prijenosa neutrona
- Usporedba rezultata sa sličnim reakcijama

Literatura

- <https://www.npr.org/sections/thetwo-way/2017/10/16/557557544/astronomers-strike-gravitational-gold-in-colliding-neutron-stars?t=1580314415912>
- https://www.researchgate.net/figure/Paths-of-the-s-and-r-processes-in-the-N-Z-plan-Both-processes-start-with-the-nuclides_fig2_224831125
- <https://sites.google.com/site/rachelfreedastronomy/fusion-in-the-sun/life-cycle-of-stars/r-process>
- <http://inspirehep.net/record/850577/plots#0>
- M. Rejmund, K. H. Maier, R. Broda, B. Fornal, M. Lach, J. Wrzesinski, J. Blomqvist, A. Gadea, J. Gerl, M. Gorska, H. Grawe, M. Kaspar, H. Schaner, Ch. Schlegel, R. Schubart, and H. J. Wollersheim, Eur. Phys. J. A 8 , 161 (2000) and references therein.
- L. Corradi, G. Pollarolo and S. Szilner, J. of Phys. G 36, 113101 (2009), and references therein.