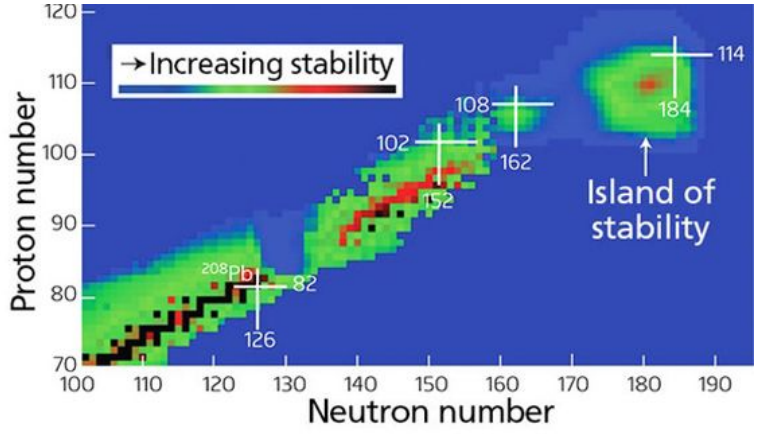
Analysis of Alpha-Decay Chains of Elements $Z = 119$ and $Z = 120$ in the Two-Center Shell Model: Competition Between Allowed and Forbidden Transitions

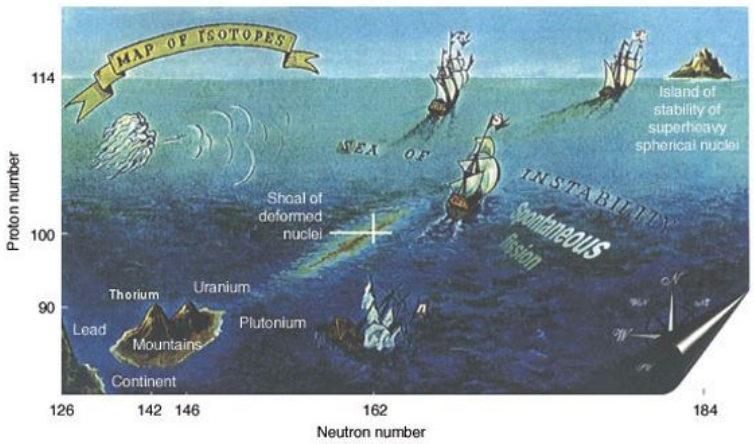
Anna Bezbakh, G.G.,Adamian, N.V.Antonenko

Joint Institute for Nuclear Research, Dubna

Nanjing, China
19 October 2026

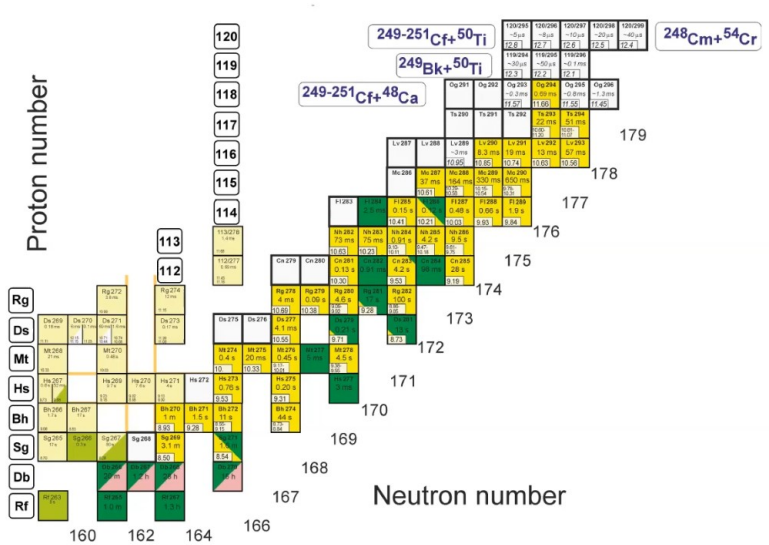
Introduction: Superheavy Nuclei and the "Island of Stability"





Key points:

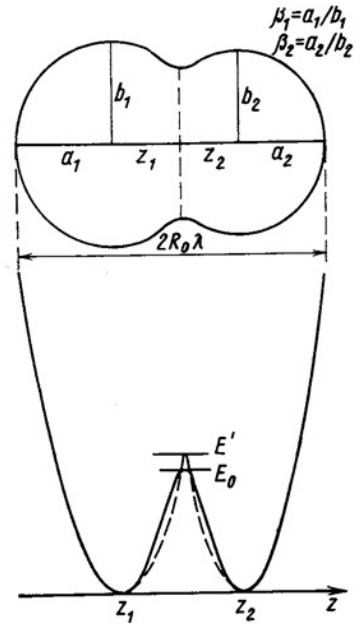
- SHN synthesis up to $Z = 118$ (Og) via hot fusion ^{48}Ca + actinides
- ^{48}Ca reactions exhausted — heavier beams needed: ^{50}Ti, ^{51}V, ^{54}Cr, ^{58}Fe
- Cross-sections drop to ∼10–30 fb
- Key question: next proton shell closure? $Z = 114$ or $Z \geq 120$?
- Our approach: $Z = 120$ is the next magic number



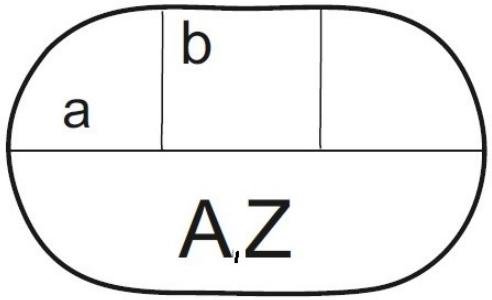
Model. Adiabatic two-center model of the nucleus (TCSM[1])

Hamiltonian of the model:

$$H = (-\hbar^2/2m)\nabla^2 + V(\rho, z) + V_{ls}(\vec{r}, \vec{p}, \vec{s}) + V_{l^2}(\vec{r}, \vec{l})$$



- $\lambda = L/2R_0$
- η_A
- η_Z
- $\varepsilon = E_0/E'$
- $\beta_i = a_i/b_i$ $(i = 1, 2)$



- ★ λ
- ★ $\beta_1 = \beta_2$
- ★ $\eta_A = \eta_Z = 0$

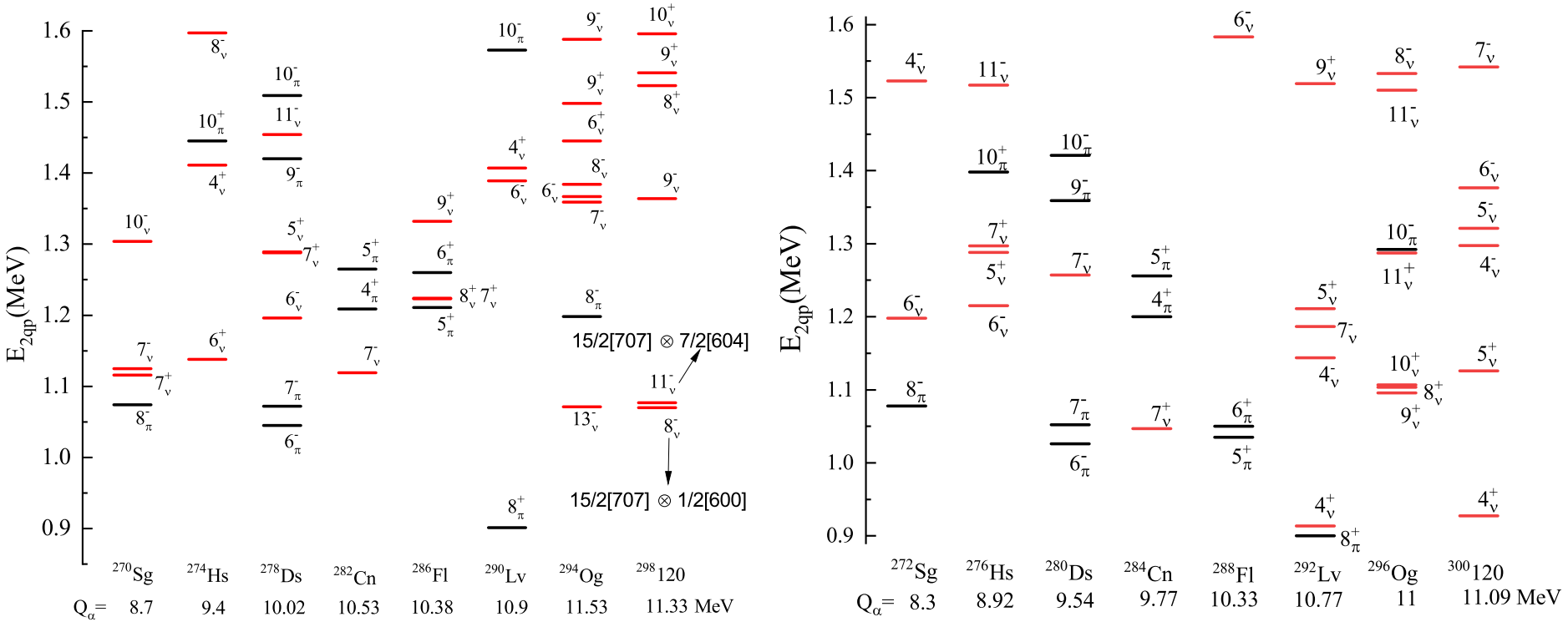
[1] J. Maruhn, W. Greiner W. , Z. Physik., **2**51, 431 (1972)

Model

- Microscopic–macroscopic approach based on modified TCSM
- Parameters fitted to known actinides
- Pairing: BCS approximation, monopole-type strength
- $E_\mu = \sqrt{(e_\mu - e_F)^2 + \Delta^2} - \sqrt{(e'_\mu - e_F)^2 + \Delta^2}$
- $E_{2qp} = \sqrt{(e_\mu - e_F)^2 + \Delta^2} + \sqrt{(e'_\mu - e_F)^2 + \Delta^2}$
- T_α: phenomenological formula[2]
  $\log_{10} T_\alpha = 1.5372\, Z\, (Q_\alpha - E_\mu)^{-1/2} - 0.1607\, Z - 36.573$
- Hindered α-decays ($I > 0$) can be faster than unhindered ones due to large Q_α: suppression $\sim 4^I$

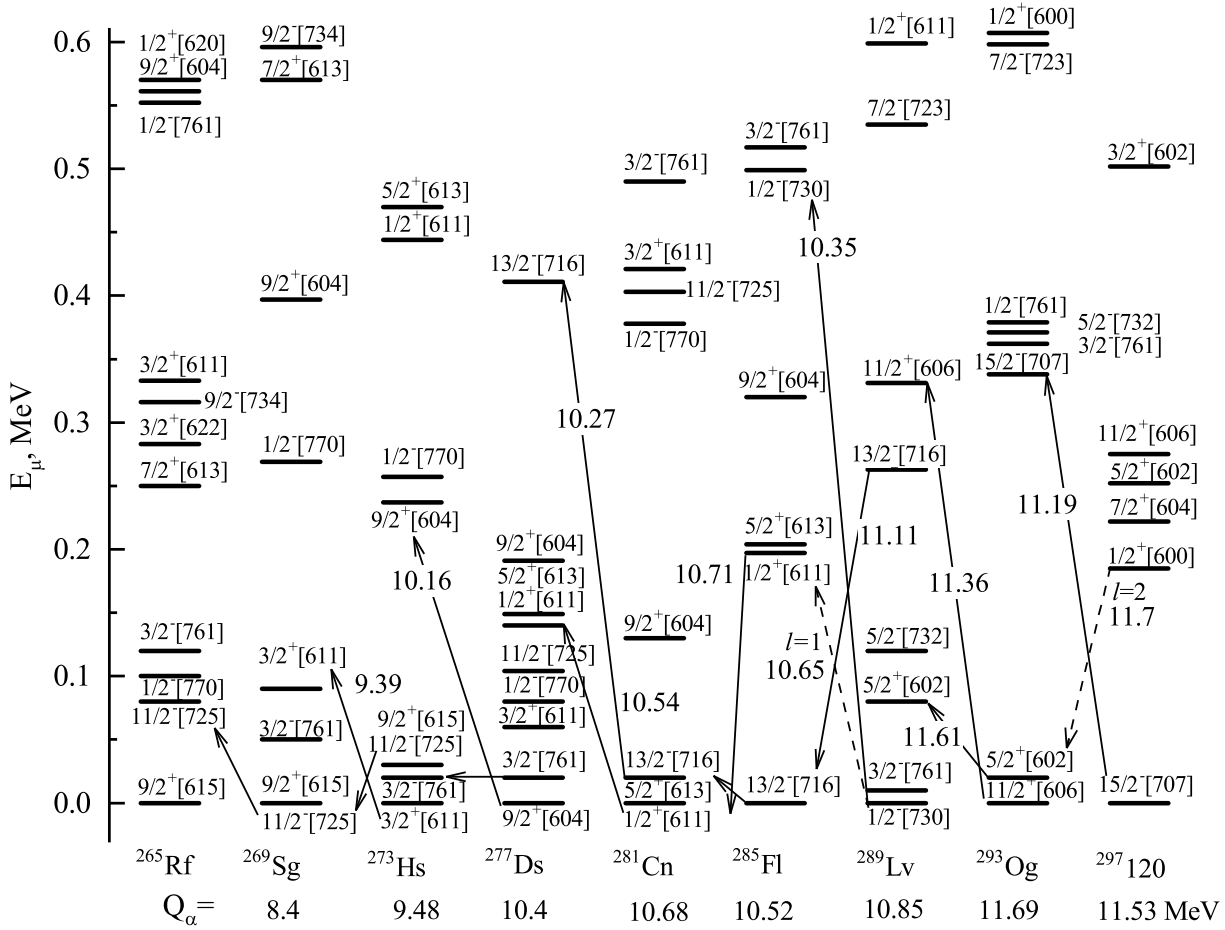
[2] A. Parkhomenko and A. Sobiczewski, Acta Phys. Pol. **B** 36, 3095 (2005)

Shell effects $Z = 120$ and E_{2qp}



- State is isomeric if $\Delta K > 3$ and close in energy to GS
- "K"-isomers are "protected" from γ-decay dua to large K values
- Proton gap increases $\Rightarrow$ shell effect strengthens

α-decay Chain of $^{297}120$

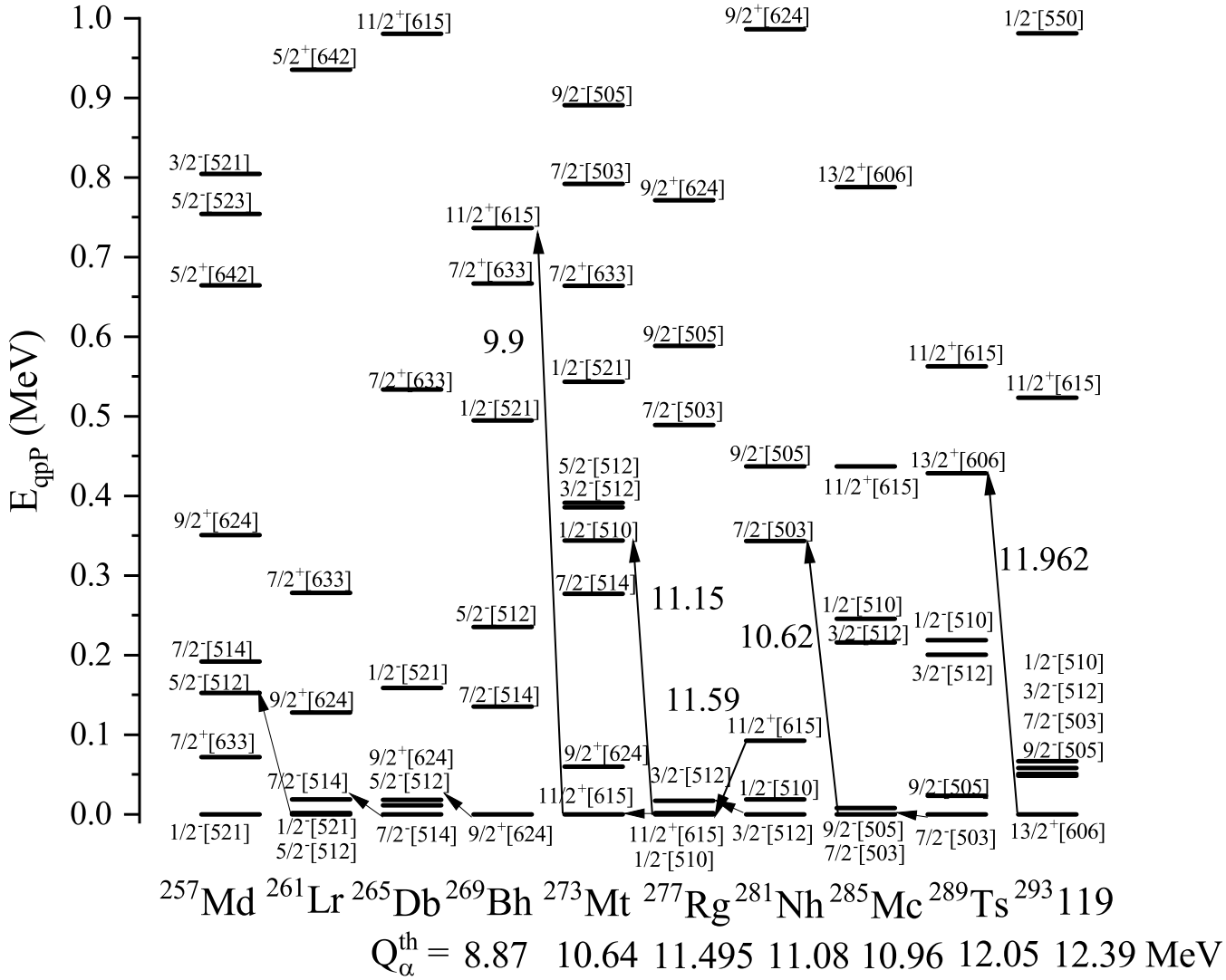


- Large $K \Rightarrow T_{1/2} > 50$ ms $\Rightarrow$ possible α-decays from isomers $\Rightarrow$ branching of α-decay chains from GS and isomers
- ^{273}Hs: $T_{\alpha}^{\mathrm{th}} = 1.77$ s, $T_{1/2}^{\mathrm{exp}} = 0.68^{+0.30}_{-0.16}$ s
- Termination: SF in ^{269}Sg ($T_{1/2}^{\mathrm{exp}} = 12.7^{+7}_{-5}$ min)

α-decay Chains of $^{295,299,301}120$

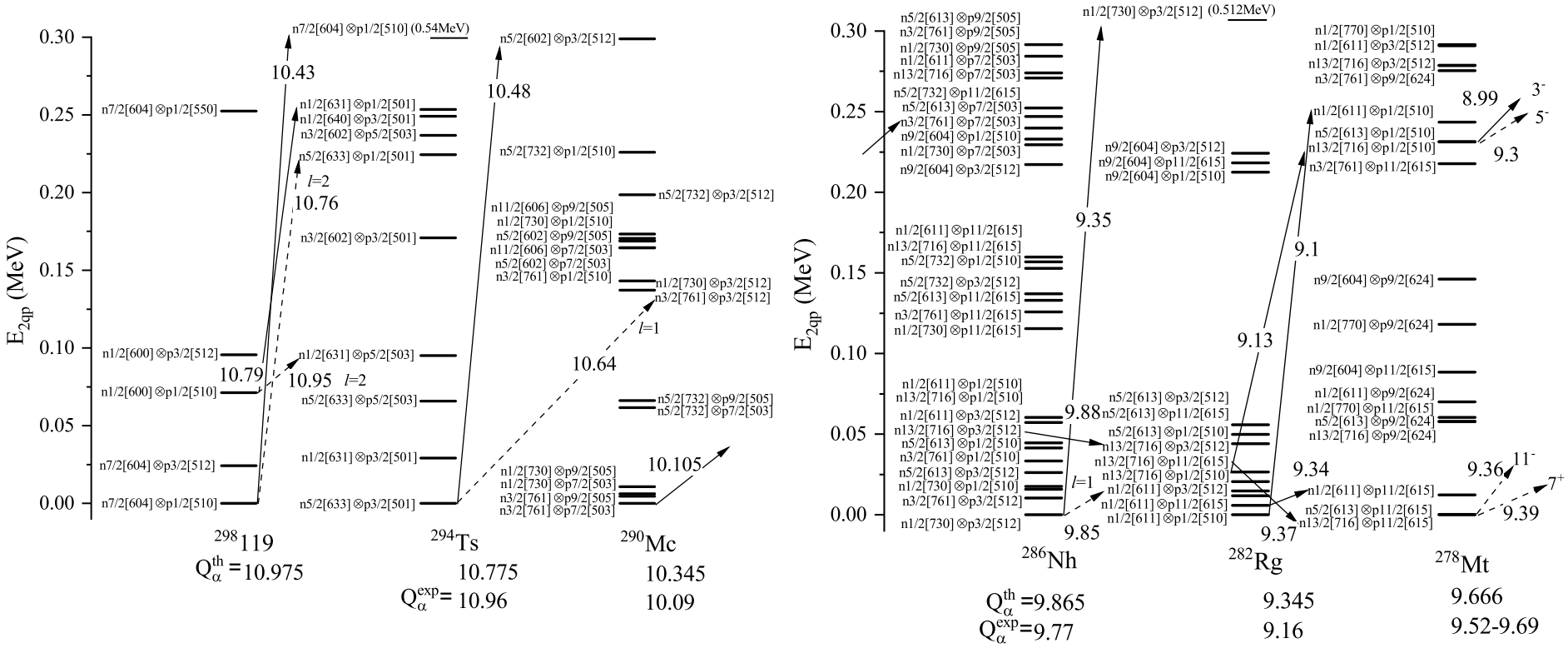
Isotope	Features	Termination
$^{295}120$	GS $11/2^+[606]$, isomer $5/2^+[613]$; hindered α-decays faster due to Q_α	SF ^{263}Rf
$^{299}120$	Three α-decay lines! GS $1/2^+[600]$, isomers $7/2^+[604]$, $15/2^-[707]$	SF ^{267}Rf
$^{301}120$	GS $1/2^+[600]$, isomer $7/2^+[604]$ $T_{\mathrm{SF}}^{\mathrm{exp}} = 3$ ms $\ll T_\alpha$	SF ^{277}Hs

α-decay Chain of $^{293}119$ (odd-even)



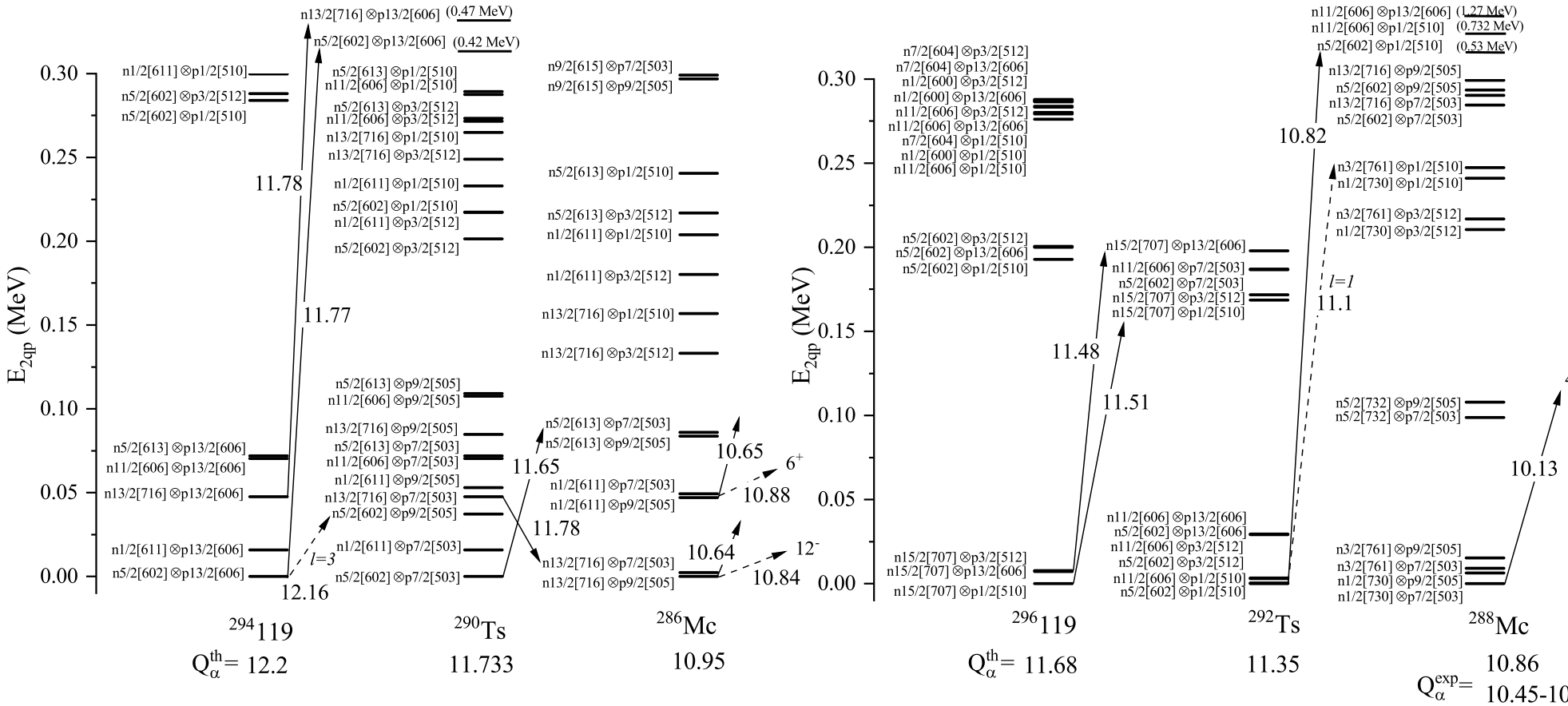
- Some isomers populated in direct production may not appear in α-chain
- Termination: SF ^{273}Mt

$Z = 119$ and E_{2qp} (odd-odd)



- Termination: SF/α ^{270}Db ($T_\alpha > 1$ h)
- Q_α^{th} vs Q_α^{exp}: agreement within uncertainty

α-decay Chains of $^{294}119$ and $^{296}119$



- Termination: SF ^{266}Db and SF ^{268}Db

Main Conclusions[3]

1. $Z = 120$ is the next proton magic number
2. Isomeric states in α-decay chains of $Z = 119, 120$ produce additional α-lines
3. $^{299}120$ - three α-decay lines (unique prediction)
4. Hindered α-decays ($l > 0$) can be faster than unhindered ones due to large Q_α
5. Terminations: $Z = 120 \rightarrow$ Sg/Hs/Rf; odd-odd $Z = 119 \rightarrow$ Db; odd-even $\rightarrow$ Mt
6. Large K values in GS or isomers delay SF, allowing α-decay to proceed
7. Calculated values of T_α are in good agreement with experimental data where available.

[3] A.N.B., G.G. Adamian, and N.V. Antonenko, PRC **114**, 024316 (2026)

xièxie



Thank you

Modification of TCSM

$$H = (-\hbar^2/2m)\nabla^2 + V(\rho, z) + V_{ls}(\vec{r}, \vec{p}, \vec{s}) + V_{l^2}(\vec{r}, \vec{l})$$

$$V_{ls} = -\frac{2\hbar\kappa}{m\omega_0'}(\nabla V \times \mathbf{p})\,\mathbf{s}$$

$$V_{l^2} = -\kappa\mu\hbar\omega_0' l^2 + \kappa\mu\hbar\omega_0' \frac{N(N+3)}{2}\delta_{if}$$

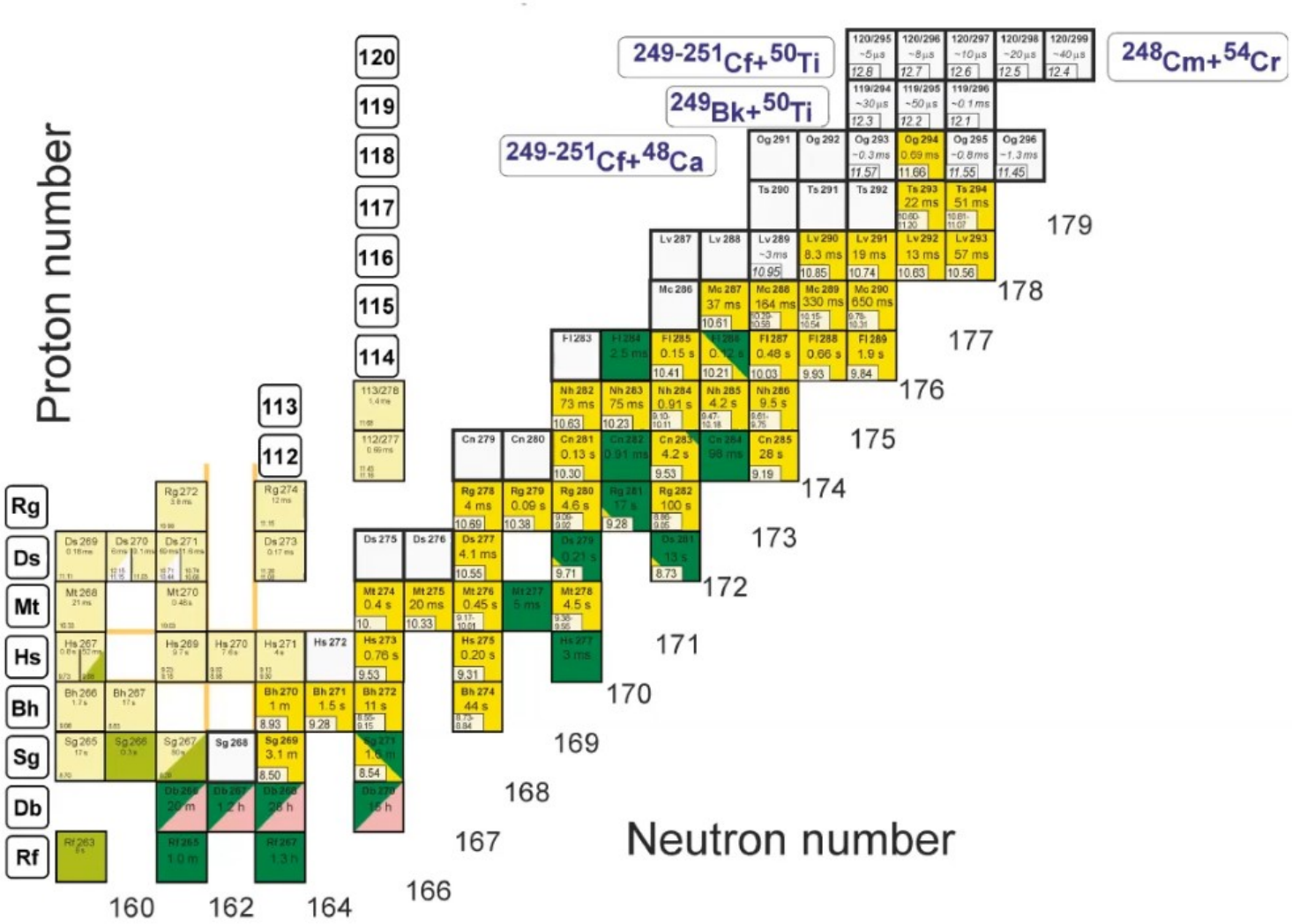
In order to improve the description of the nuclear spins and parities the weak dependence on $(N-Z)$ in V_{ls} and V_{l^2} [4] was introduced.

Parameters:

$$\kappa_n = 0.076 + 0.0058(N-Z) - 6.53\times10^{-5}(N-Z)^2 + 0.002A^{1/3}$$
$$\mu_n = 1.598 - 0.0295(N-Z) + 3.036\times10^{-4}(N-Z)^2 - 0.095A^{1/3}$$
$$\kappa_p = 0.0383 + 0.00137(N-Z) - 1.22\times10^{-5}(N-Z)^2 - 0.003A^{1/3}$$
$$\mu_p = 0.335 + 0.01(N-Z) - 9.367\times10^{-5}(N-Z)^2 + 0.003A^{1/3}$$

[4] G.G. A., N.V. A., and W. Scheid, PRC **81**, 024320 (2010)

Production of SHN



No experimental data in the SHE region → Good theoretical predictions are needed.