On the way to the synthesis of new elements: 119 and 120

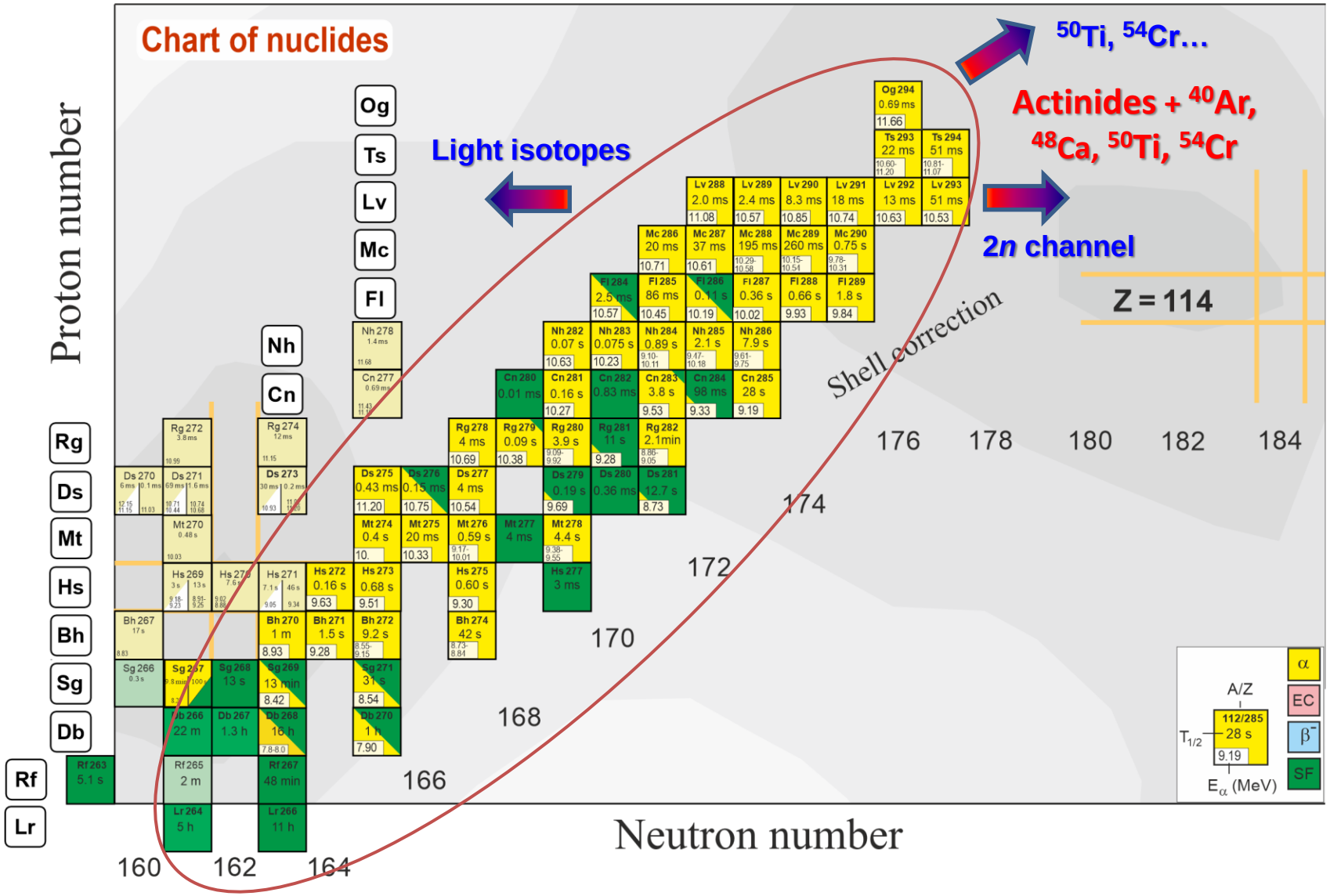
N.D.Kovrizhnykh

Flerov Laboratory of Nuclear Reactions JINR

21th Workshop on Recoil Separator for Superheavy Element Chemistry & Physics

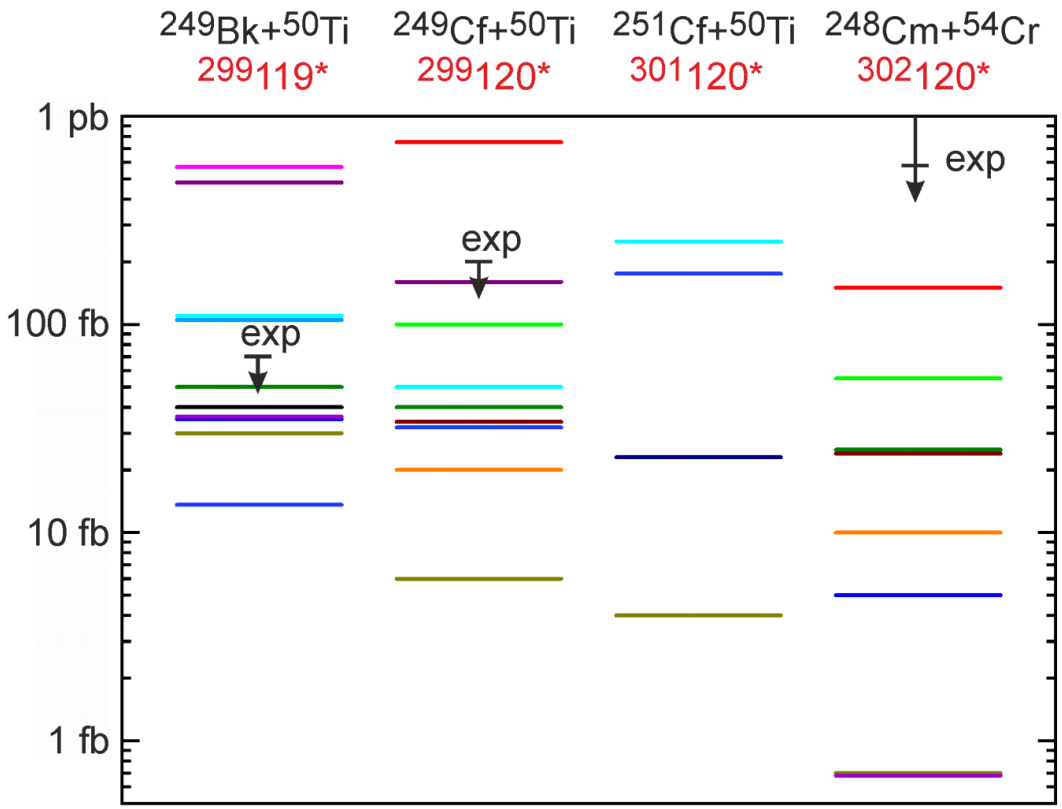
Area of known superheavy isotopes

Production of new isotopes and synthesis of new elements 119, 120…



Predictions of production cross-sections of element 119 and 120 isotopes in $^{249}Bk+^{50}Ti$, $^{249-251}Cf+^{50}Ti$, $^{248}Cm+^{54}Cr$ reactions

(*difference by 2-3 orders of magnitude*)



V.I. Zagrebaev *et al.*, Phys. Rev. C **78**, 034610 (2008)
K. Siwek-Wilczynska *et al.*, Int. J. Mod. Phys. E **19**, 500 (2010).
A.K. Nasirov *et al.*, Phys. Rev. C **84**, 044612 (2011).
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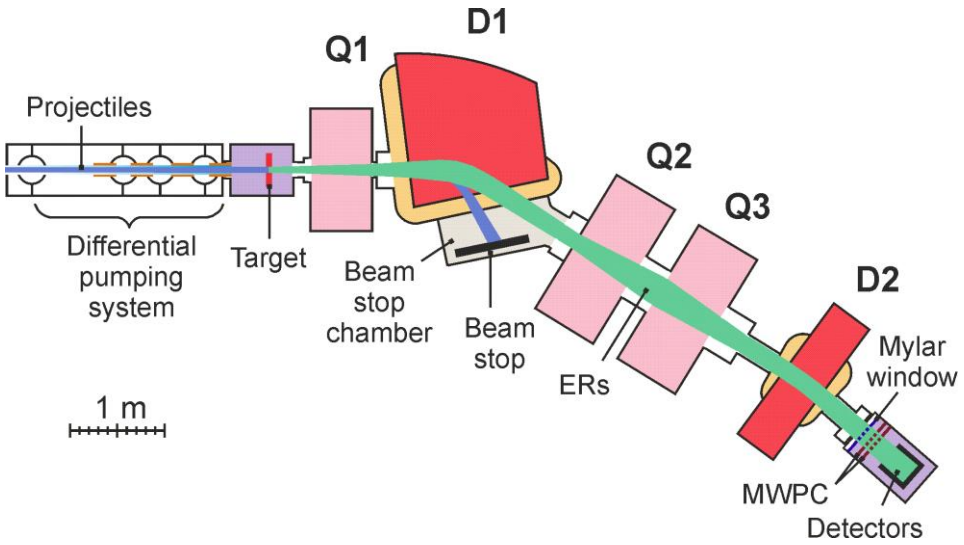
Z.H. Liu *et al.*, Phys. Rev. C **84**, 031602(R) (2011).
K. Siwek-Wilczynska *et al.*, Phys. Rev. C **99**, 054603 (2019).
K.P. Santhosh *et al.*, Phys. Rev. C **96**, 034610 (2017).
K. Siwek-Wilczynska *et al.*, Phys. Rev. C **86**, 014611 (2012).
A.N. Kuzmina *et al.*, Phys. Rev. C **85**, 014319 (2012).
Jinjuan Zhang *et al.*, Nucl. Phys. A **909**, 36 (2013).
Z.H. Liu, J.D. Bao, Phys. Rev. C **87**, 034616 (2013).
V.I. Zagrebaev, W. Greiner, Nucl. Phys. A **944**, 257 (2015).
G. G. Adamian *et al.*, Phys. Part. Nucl. **47**, 387 (2016).
A. Ansari *et al.*, Int. J. Mod. Phys. E **26**, 1750050 (2017).

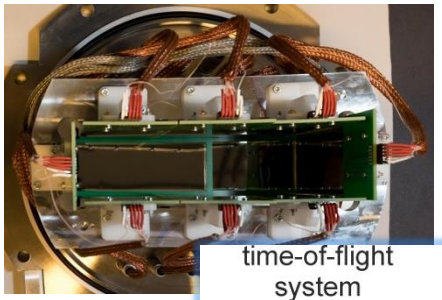
SHE Factory

Dubna Gas-Filled Recoil Separator DGFRS-2



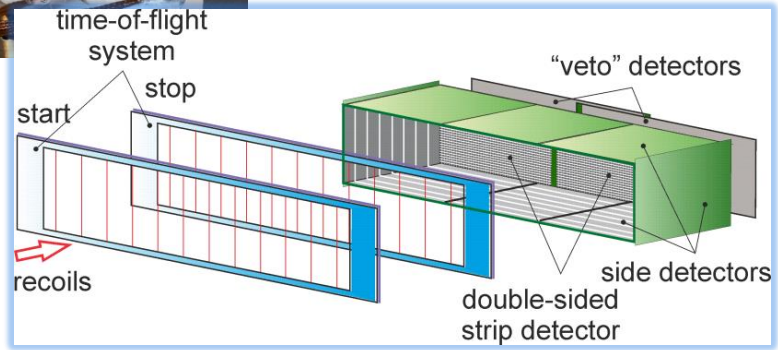
24-sm target, 12 sectors

Rotating target, magnets (Q1, D1, Q2, Q3, D2), beamstopper, detector chamber.

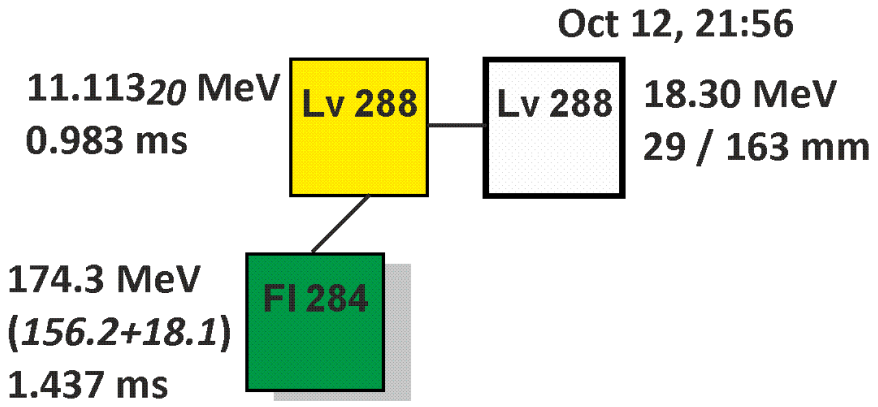


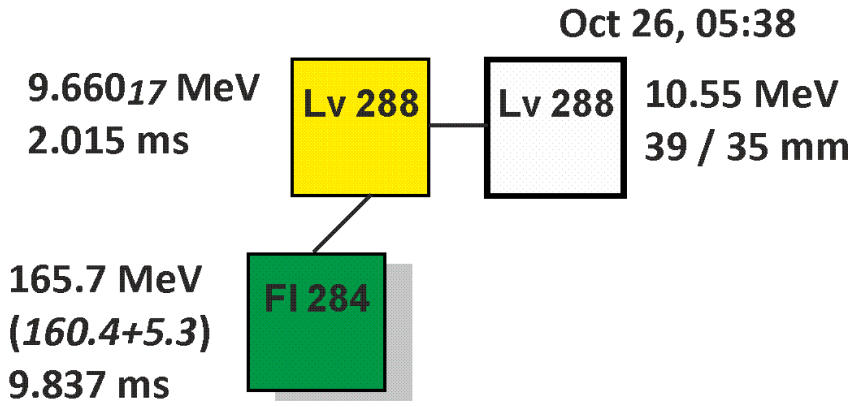
48×220 DSSD & 60×120 SSSD

Digital and analog electronics



Experiment $^{238}U + ^{54}Cr$





Target ^{238}U: 0.72 mg/cm^2

Dose: 7.2 x 10^{19}

Excitation energy: 42 MeV

Cross-section ~36 *(12-82)* fb

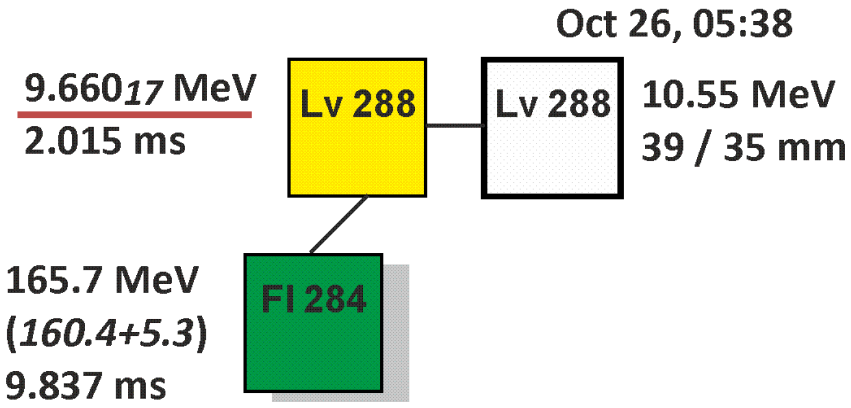
For the first time:

Actinide + ^{54}Cr

New isotope ^{288}Lv

Confirmation of ^{284}Fl

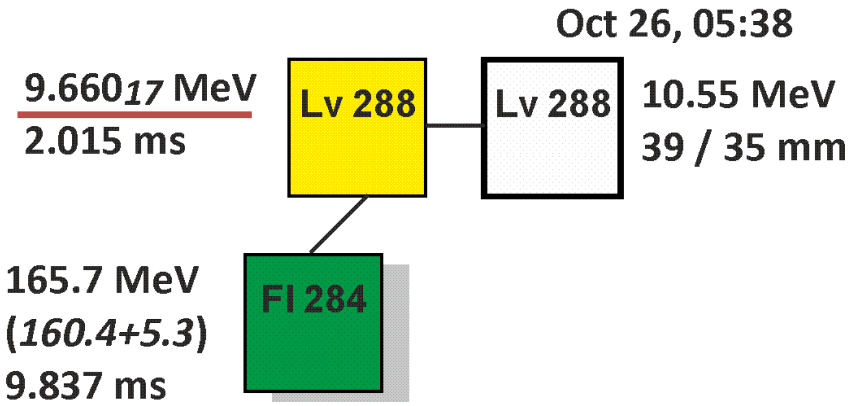
Experiment $^{238}U + ^{54}Cr$



Possible reasons:

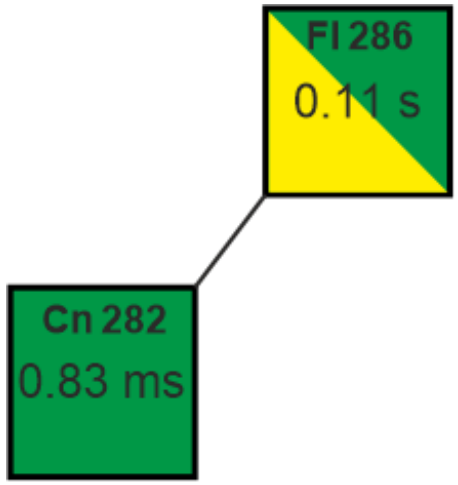
1. Temporary change in the gain of the recording equipment - could not be confirmed or refuted.
2. α-particle deposited energy only in focal detector and escaped from it at the small angle.
3. Decay to excited state of ^{284}Fl – seems very unlikely during large differences between α-decay energies and close decay times.

Experiment $^{238}U + ^{54}Cr$



Possible reasons:

4. It's product of αxn-channel of $^{238}U + ^{54}Cr$ reaction:

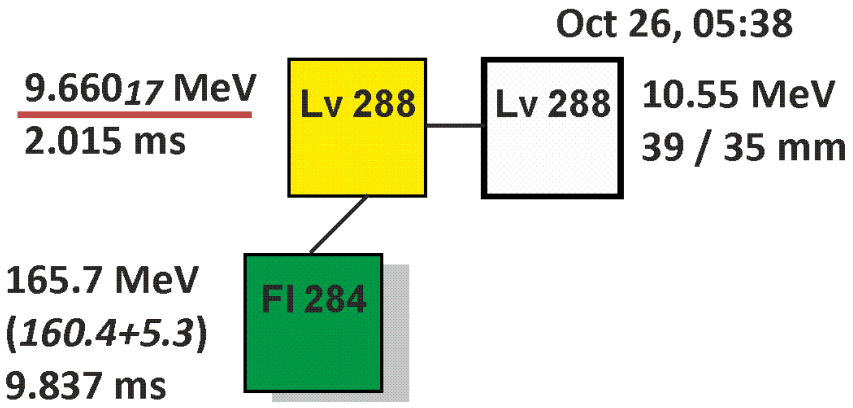


9.60 MeV
A. Såmark-Roth *et al.*
PRL 126, 032503 (2021)

$$^{286}\mathrm{Fl}: \mathrm{T}_{1/2} = 105^{+17}_{-13}\, ms \Rightarrow P(2.015\, ms) \sim 10^{-2}$$

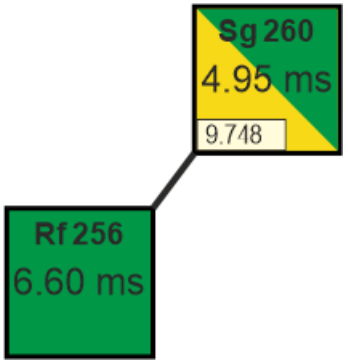
$$^{282}\mathrm{Cn}: \mathrm{T}_{1/2} = 0.83^{+0.18}_{-0.13}\, ms \Rightarrow P(9.837\, ms) \sim 3 * 10^{-4}$$

Experiment $^{238}U + ^{54}Cr$

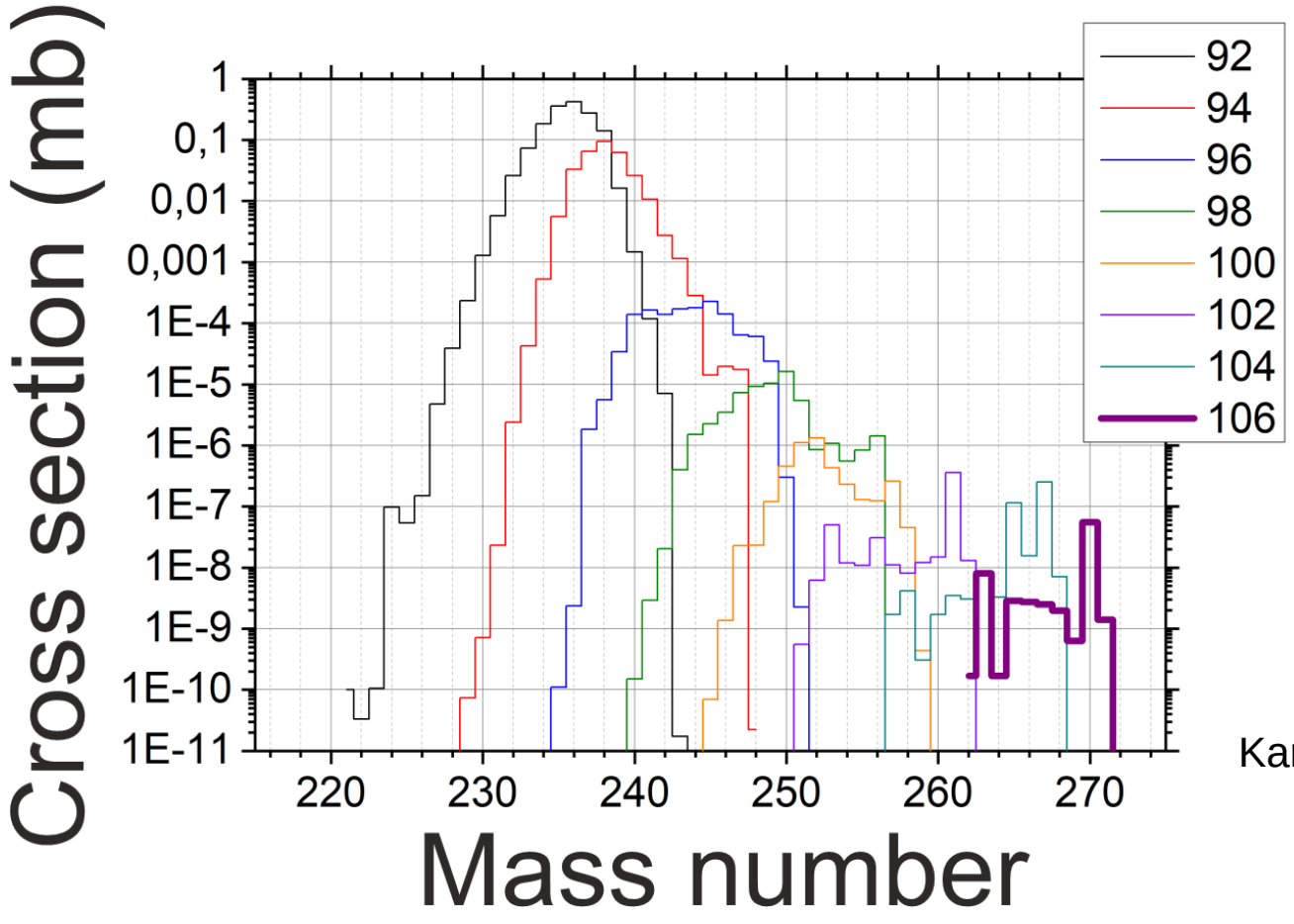


Possible reasons:

5. It's product of multinucleon transfer reactions:



Yields for multi-nucleons transfer reaction products



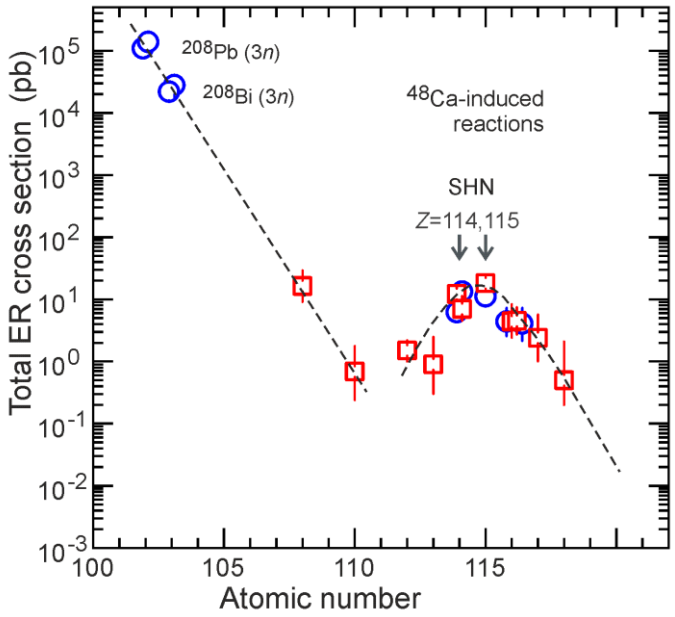
Karpov, Saiko

Y (^{260}Sg / ^{262,264,266,268,270}Sg) < 1/500

We tentatively attributed the second decay chain to the isotope ^{288}Lv

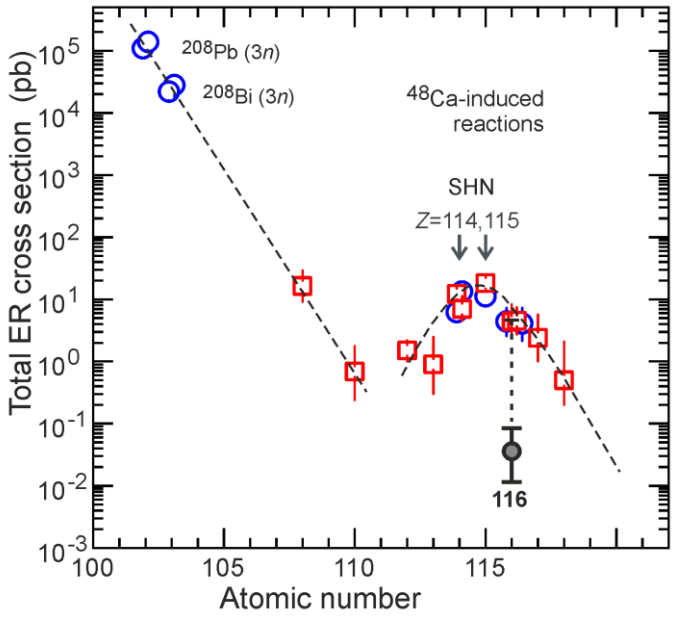
Next stage

Synthesis of new elements 119 and 120



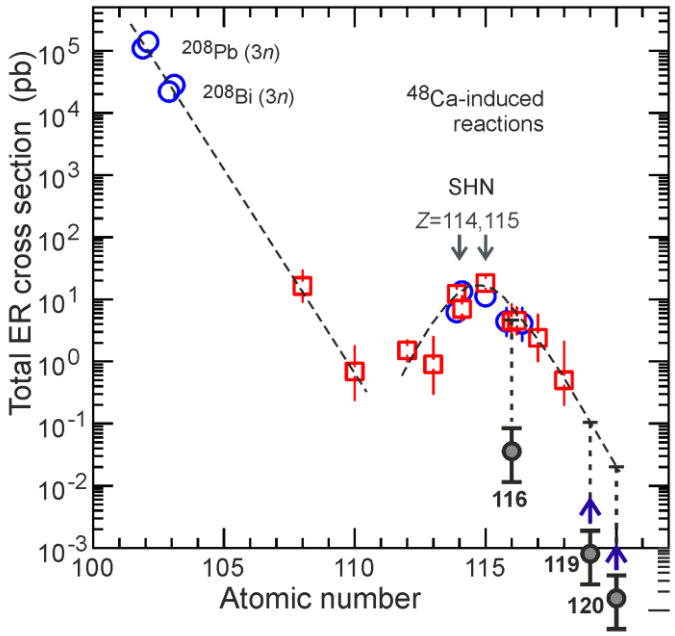
Next stage

Synthesis of new elements 119 and 120



Next stage

Synthesis of new elements 119 and 120



σ=**1** fb, h_t=**0.7** mg/cm^2, I_{beam}=**4** pμA $\rightarrow$ **$\approx$1 / 3 year**

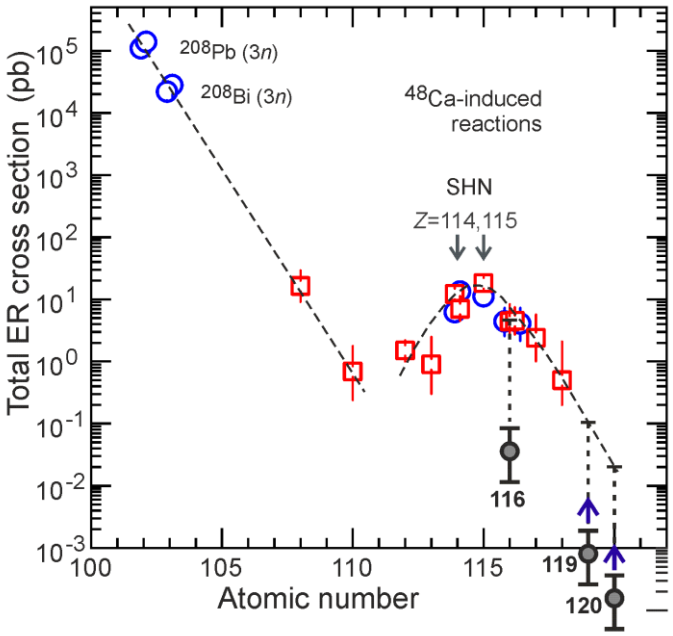
Z_{mag} = 120 – 126?

119:

Cross section ~1 fb

Next stage

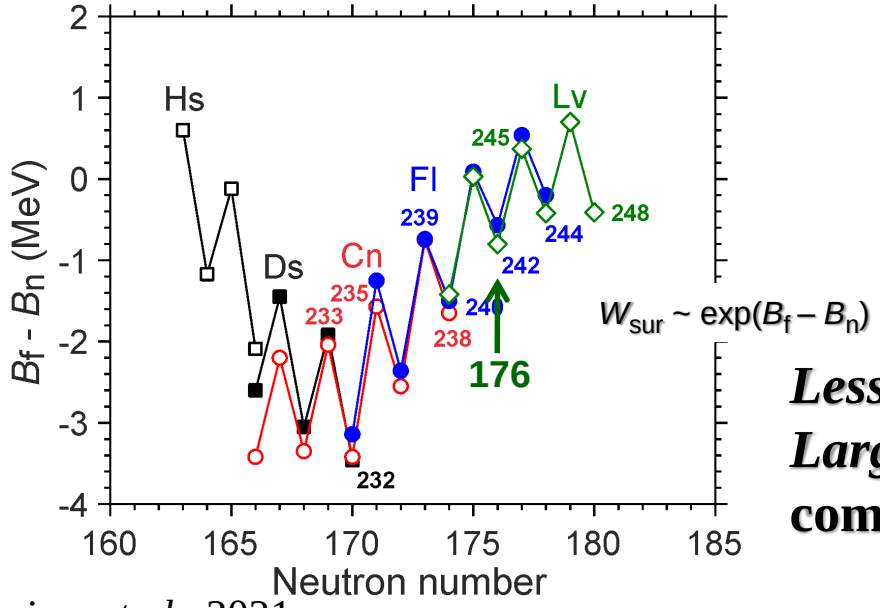
Synthesis of new elements 119 and 120



σ=**1** fb, h_t=**0.7** mg/cm^2, I_{beam}=**4** pμA → ≈**1 / 3 year**

119:
Cross section ~1 fb

Estimation accuracy:
experiment



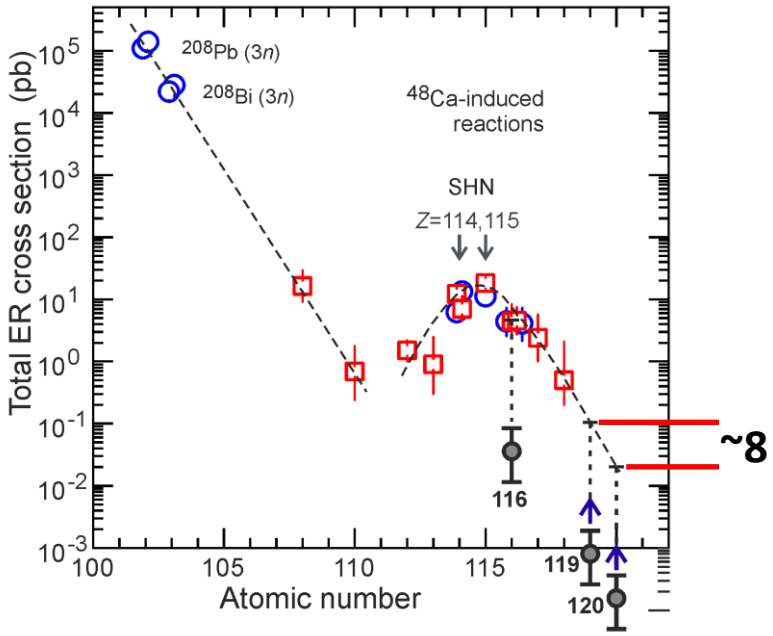
^{248}Cm + ^{48}Ca → ^{296}Lv (*N*=180)
^{245}Cm + ^{48}Ca → ^{293}Lv (*N*=177)
^{238}U + ^{54}Cr → ^{292}Lv (*N*=176)

***Less* survivability –**
***Larger* formation probability of compound nucleus**

P. Jachimowicz *et al.*, 2021

Next stage

Synthesis of new elements 119 and 120

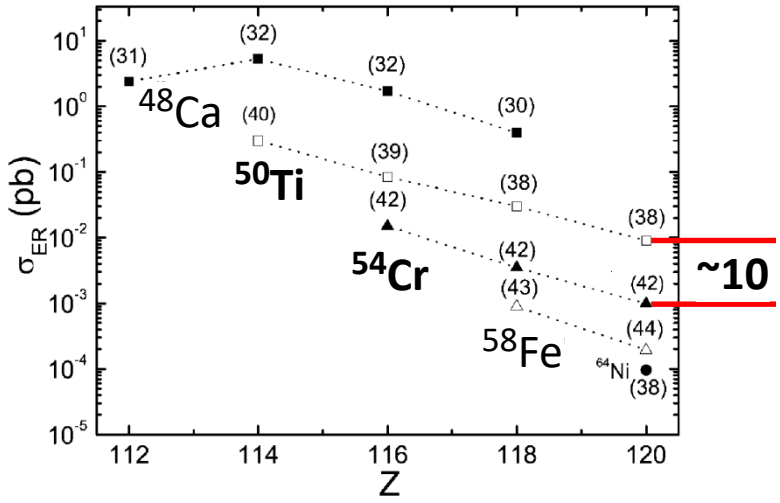


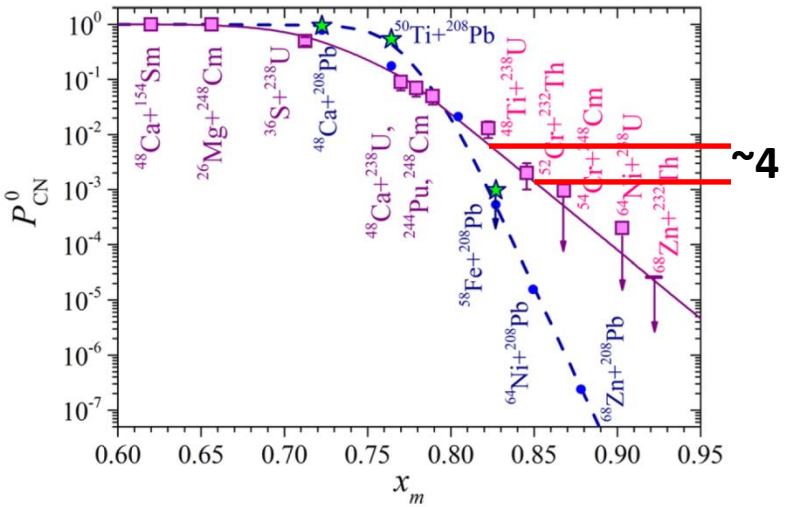
$^{48}Ca \rightarrow {}^{50}Ti \rightarrow {}^{54}Cr$

$^{245}Cm + {}^{48}Ca \rightarrow {}^{293}Lv^*$

$^{242}Pu + {}^{50}Ti \rightarrow {}^{292}Lv^*$

$^{238}U + {}^{54}Cr \rightarrow {}^{292}Lv^*$

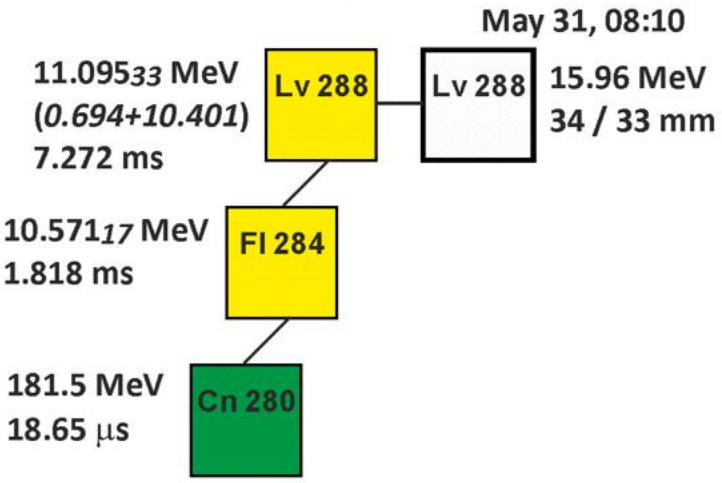


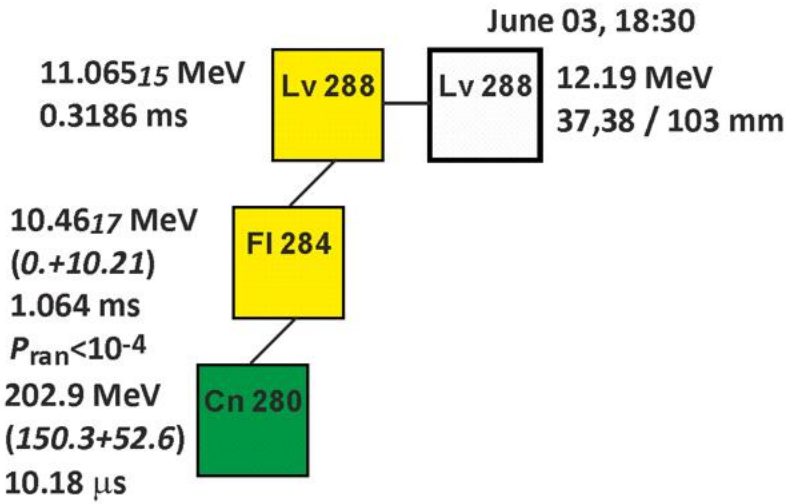


G.G. Adamian *et al.*, PRC 101, 034301 (2020)

M.G. Itkis *et al.*, EPJ A 58, 178 (2022)

Experiment ^{242}Pu + ^{50}Ti





Target ^{242}Pu: 0.72 mg/cm^2

Beam dose: 1.5 x 10^{19}

Excitation energy: 41 MeV

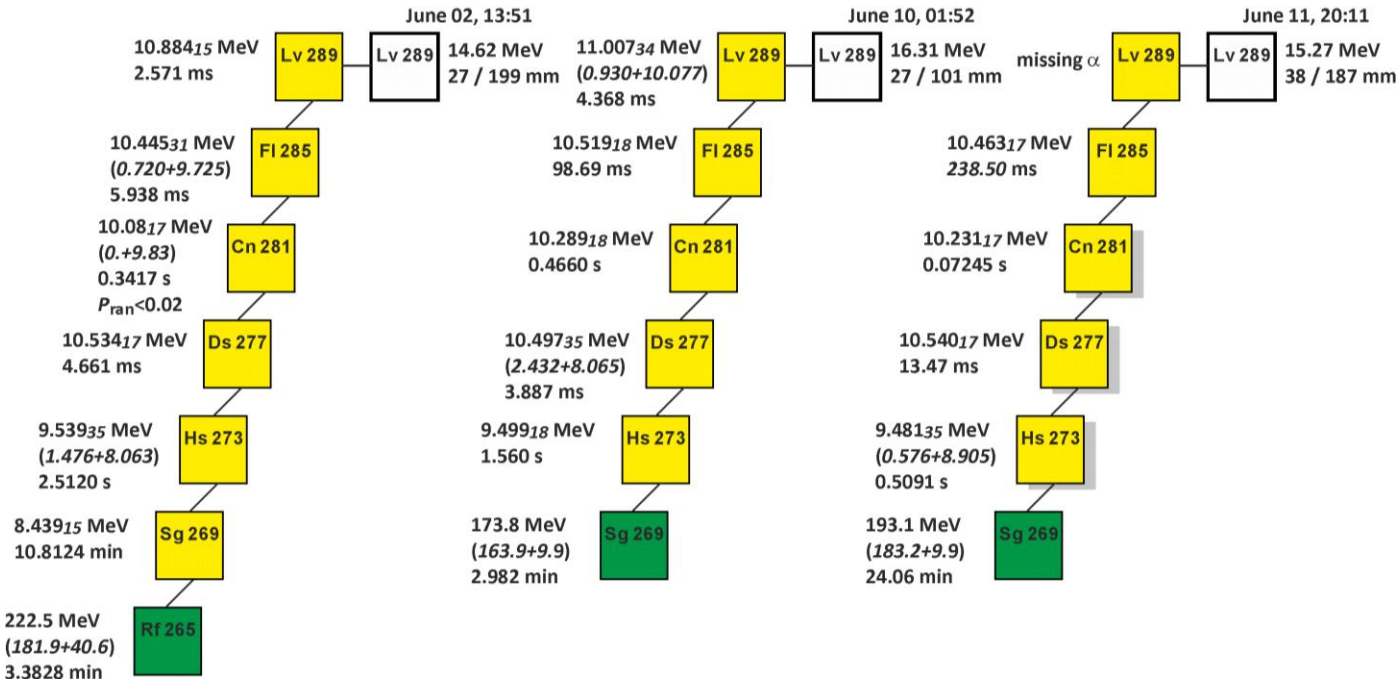
Cross-section ~220 *(70-490)* fb

For the first time:

New isotope ^{280}Cn

α-decay of ^{284}Fl

Experiment ^{242}Pu + ^{50}Ti



Target ^{242}Pu: 0.72 mg/cm^2

Beam dose: 1.5 x 10^{19}

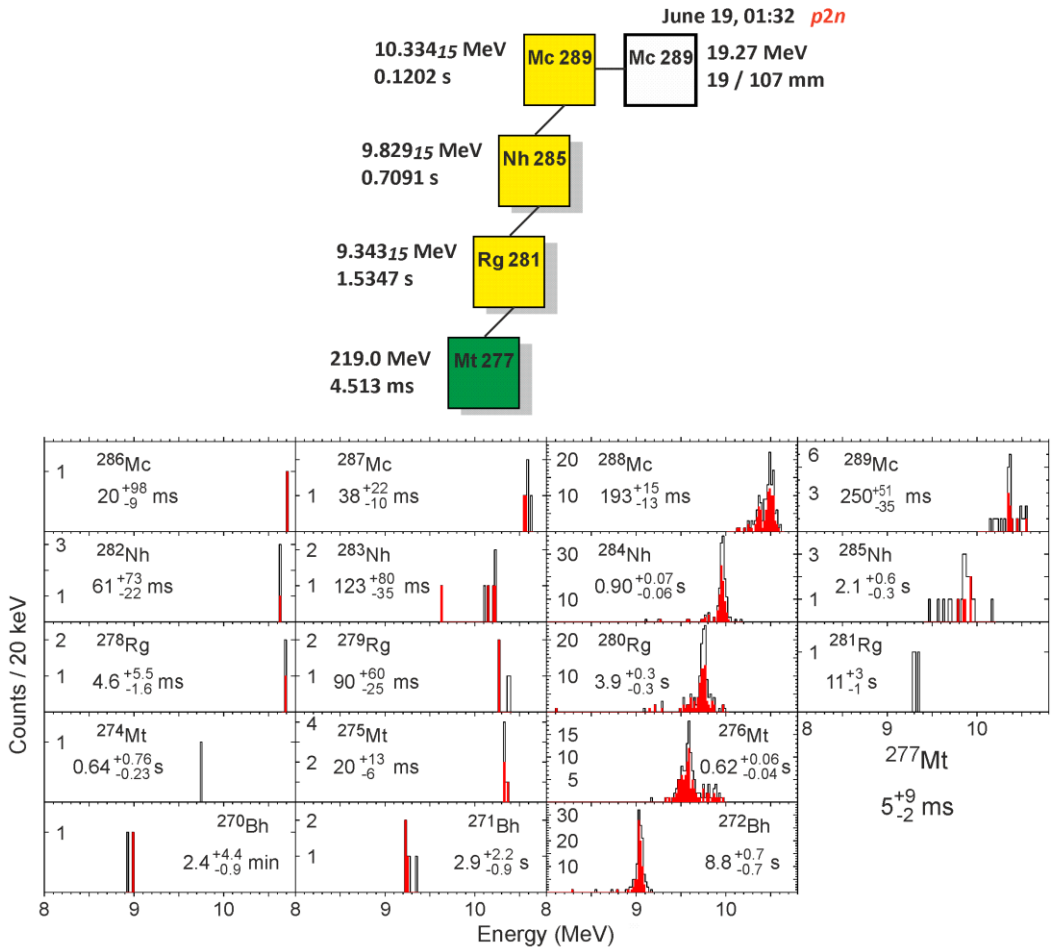
Excitation energy: 41 MeV

Cross-section ~320 *(140-660)* fb

For the first time:

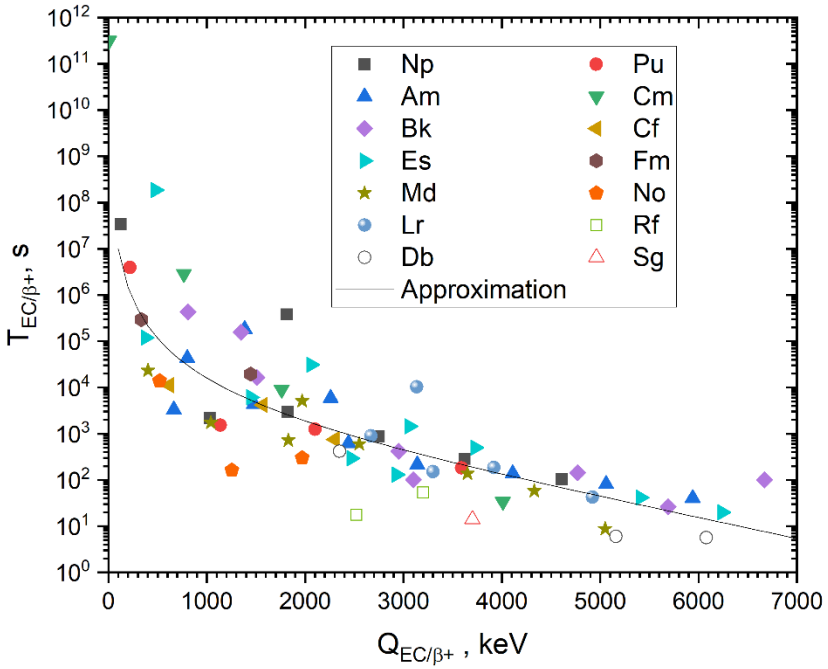
New isotope ^{289}Lv

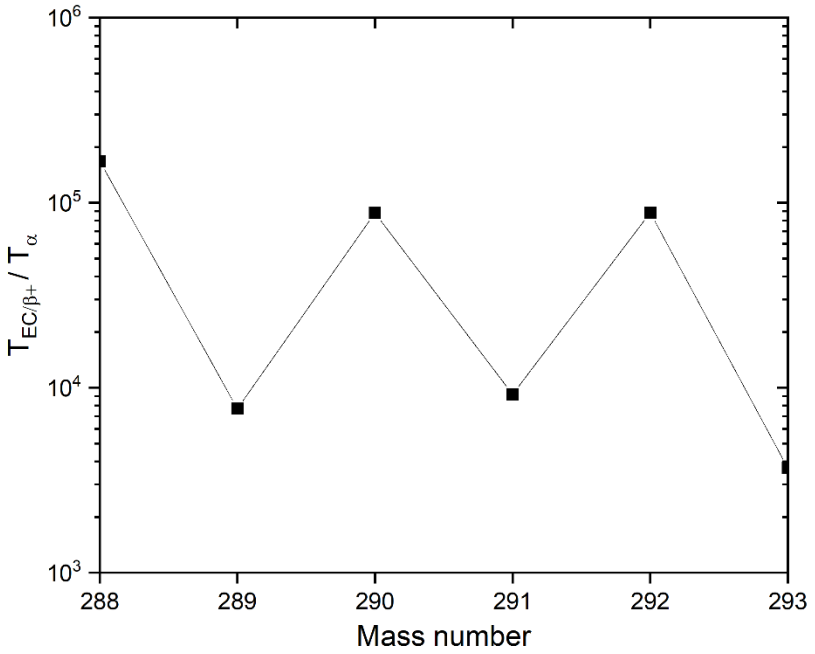
Experiment ^{242}Pu + ^{50}Ti



Experiment ^{242}Pu + ^{50}Ti

pxn-channel or EC/β^+?

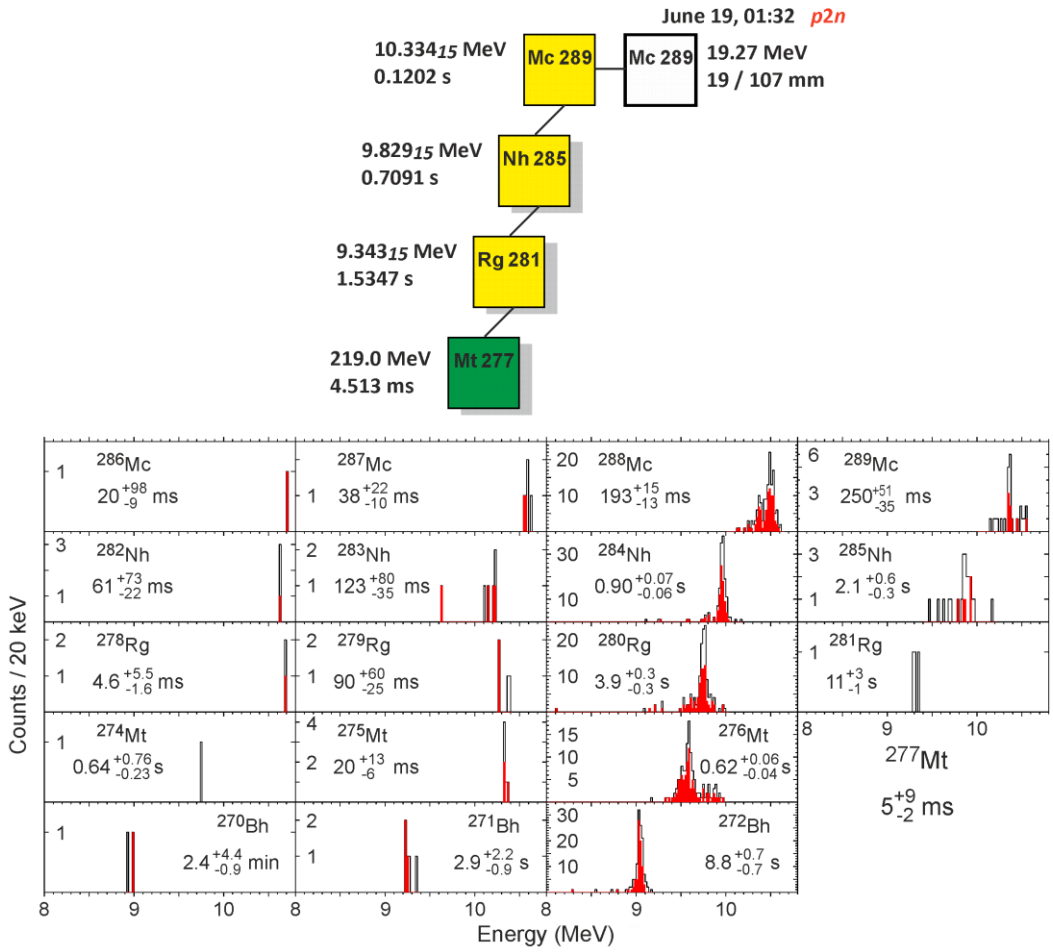




F. G. Kondev, M. Wang, W. J. Huang, S. Naimi, and G. Audi, Chin. Phys. C 45, 030001 (2021).

Observation of *pxn*-channel more probable, than EC/β^+-decay

Experiment ^{242}Pu + ^{50}Ti



Target ^{242}Pu: 0.72 mg/cm^2

Beam dose: 1.5 x 10^{19}

Excitation energy: 41 MeV

Cross-section ~0.11 *(0.02-0.37)* pb

For the first time:

***pxn* channel**

Actinide + ^{48}Ca, ^{50}Ti, ^{54}Cr

Decay properties of observed isotopes

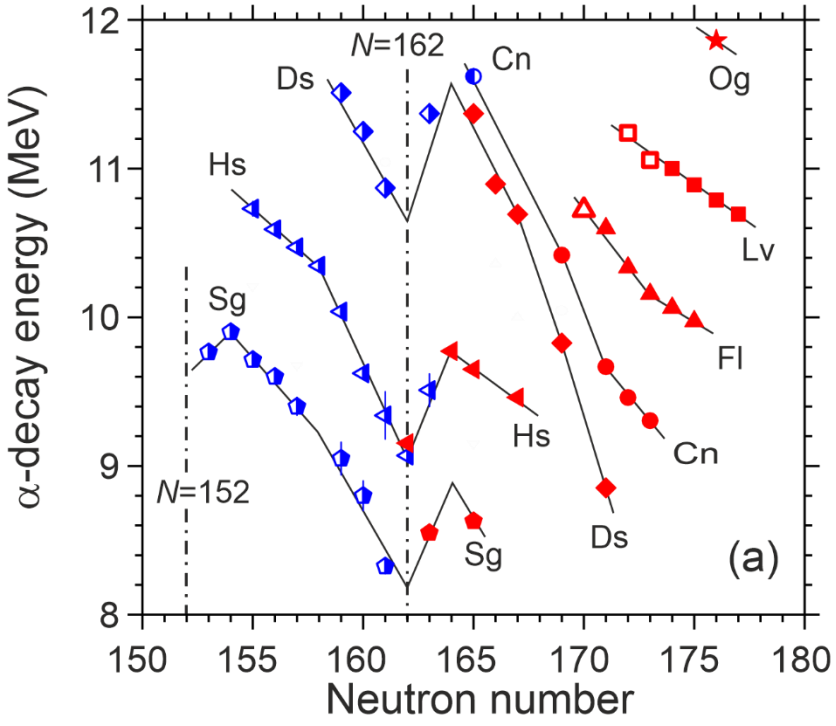
Nucleus	Decay mode, branch (%) [a,b]	Half-life [b]	E_a (MeV) [c]	Q_a (MeV) [c]	T_α [b]	T_{SF} [b]
^{288}Lv	α	$2.0^{+2.3}_{-0.7}$ ms	11.084(15)	11.240(15)		
^{284}Fl	SF: 76^{+9}_{-19}	$2.5^{+1.2}_{-0.6}$ ms	10.570(17)	10.721(17)	$10.4^{+8.4}_{-5.4}$ ms	$3.2^{+2.0}_{-0.9}$ ms
^{280}Cn	SF	10^{+18}_{-4} μs				
^{289}Lv	α	$2.4^{+4.4}_{-0.9}$ ms	10.904(15)	11.057(15)		
^{285}Fl	α	86^{+43}_{-21} ms	10.450(17)	10.600(17)		
^{281}Cn	α	$0.16^{+0.08}_{-0.04}$ s	10.270(17)	10.418(17)		
^{277}Ds	α	$4.0^{+1.8}_{-1.0}$ ms	10.538(17)	10.692(17)		
^{273}Hs	α	$0.68^{+0.30}_{-0.16}$ s	9.509(17)	9.650(17)		
^{269}Sg	α: 87^{+6}_{-23}	13^{+6}_{-4} min	8.423(15)	8.550(15)	14^{+9}_{-3} min	$1.6^{+1.9}_{-1.1}$ h
^{265}Rf	SF	$1.3^{+0.8}_{-0.3}$ min				

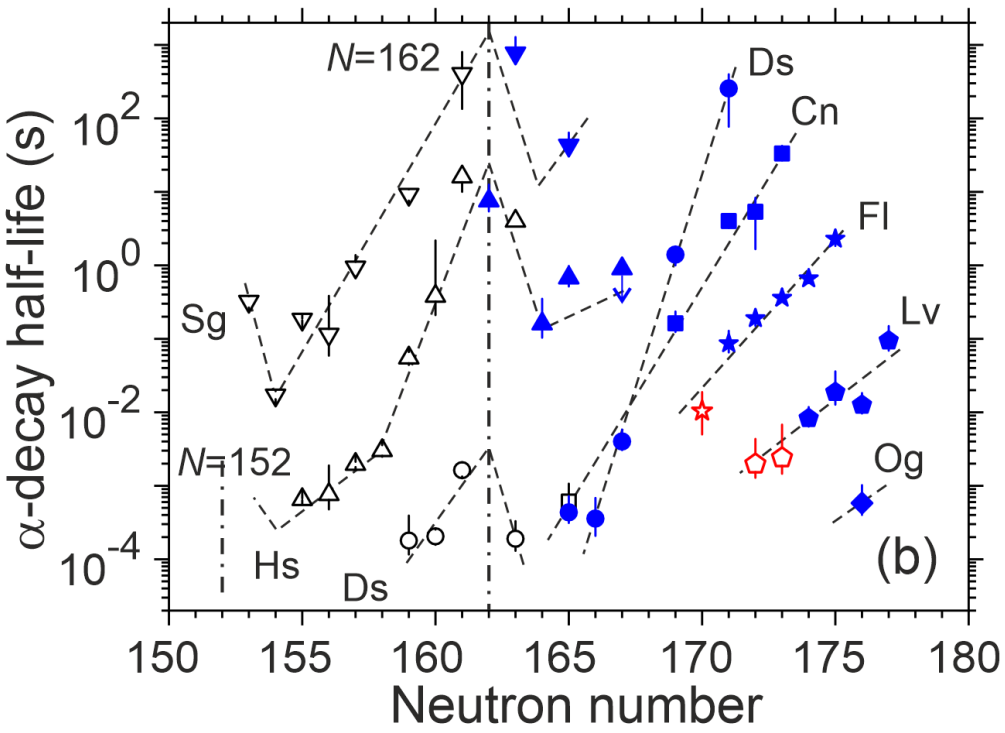
[a] Branch is given for the most probable decay mode (a or SF). The branching ratio is not listed when only one decay mode was observed.

[b] Error bars correspond to 68%-confidence level.

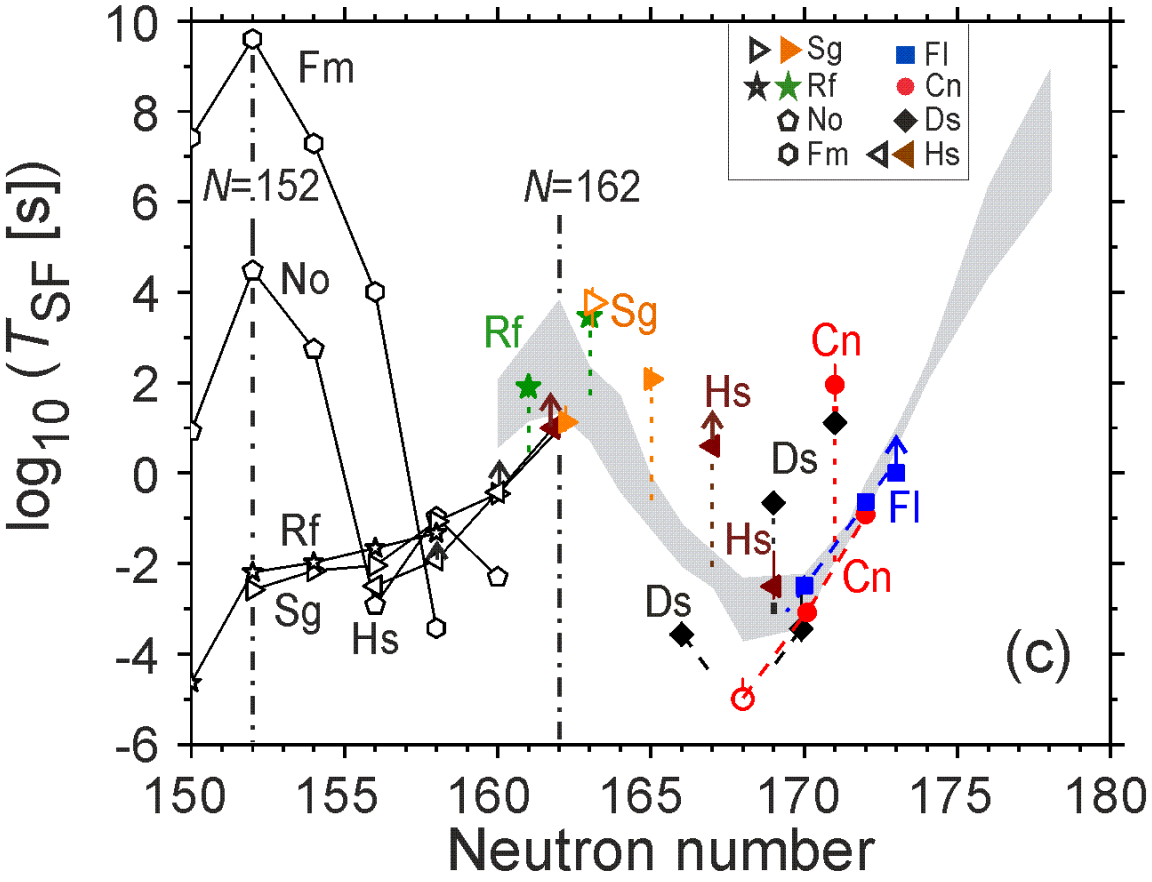
[c] Energy uncertainties (standard deviations) given in parentheses correspond to the data with the best energy resolution.

Decay properties of observed isotopes

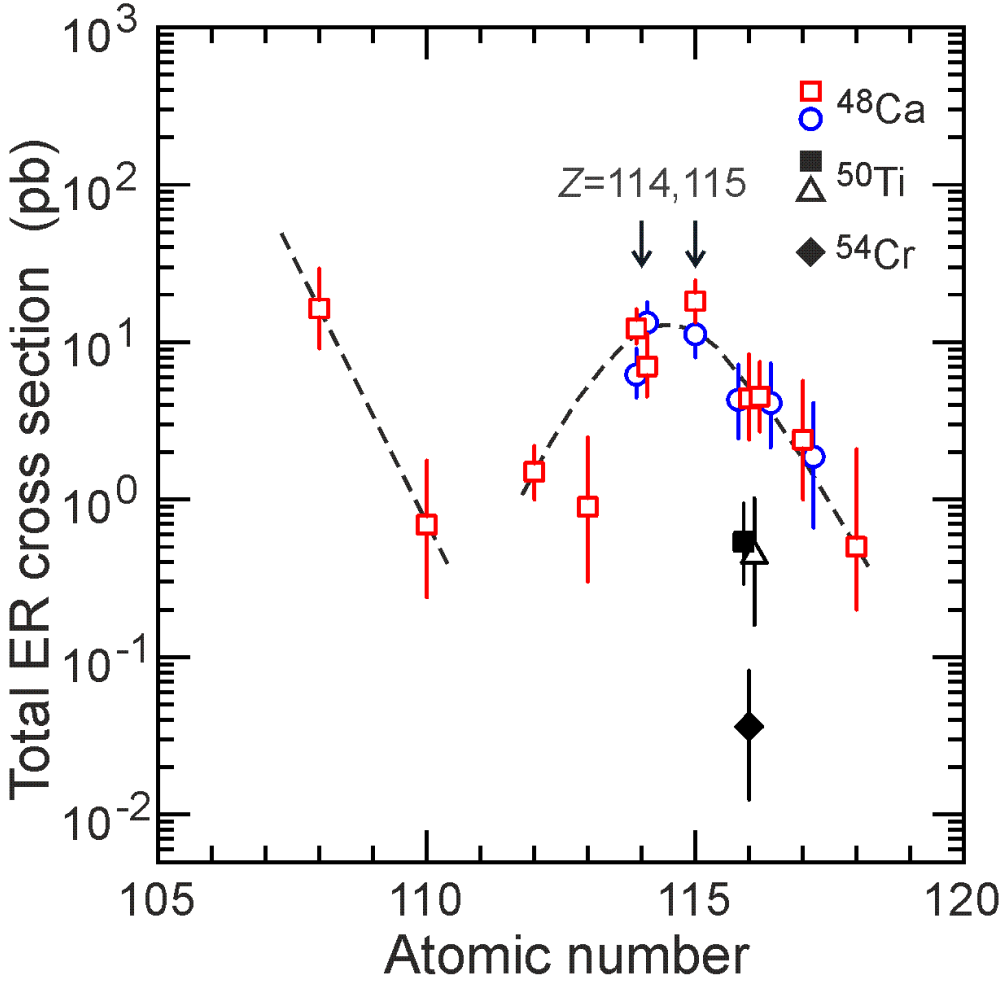




Decay properties of observed isotopes

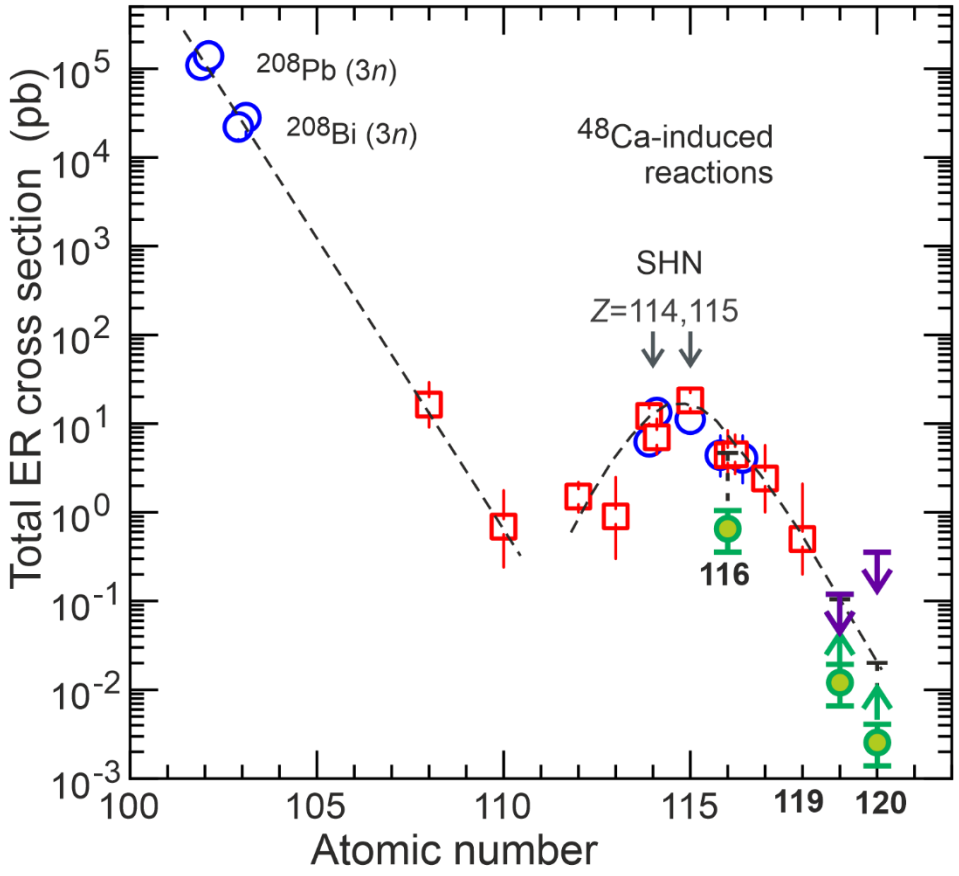


Production cross-sections of superheavy elements



^{50}Ti + ^{244}Pu
J.M. Gates *et al*.
PRL 133, 172502 (2024)

Production cross-sections of superheavy elements



119: ~10 fb
120: ~2.5 fb

Gates 2024: 25-50 fb Z=120
Khuyagbaatar 2024: 20 fb Z=119
6 fb Z=120

DGFRS-2: Results of experiments

$^{238}U+^{54}Cr$

Cross section of the actinide + ^{54}Cr reaction (decrease by ~150)
Synthesis of new isotope ^{288}Lv
Confirmation of ^{284}Fl

$^{242}Pu+^{50}Ti$

Cross section of reaction (decrease by ~10)
Synthesis of new isotopes ^{289}Lv and ^{280}Cn
α-decay of ^{284}Fl
First observation of *pxn*-evaporation channel

Cross section of the reaction with ^{50}Ti is ~15 times larger than with ^{54}Cr

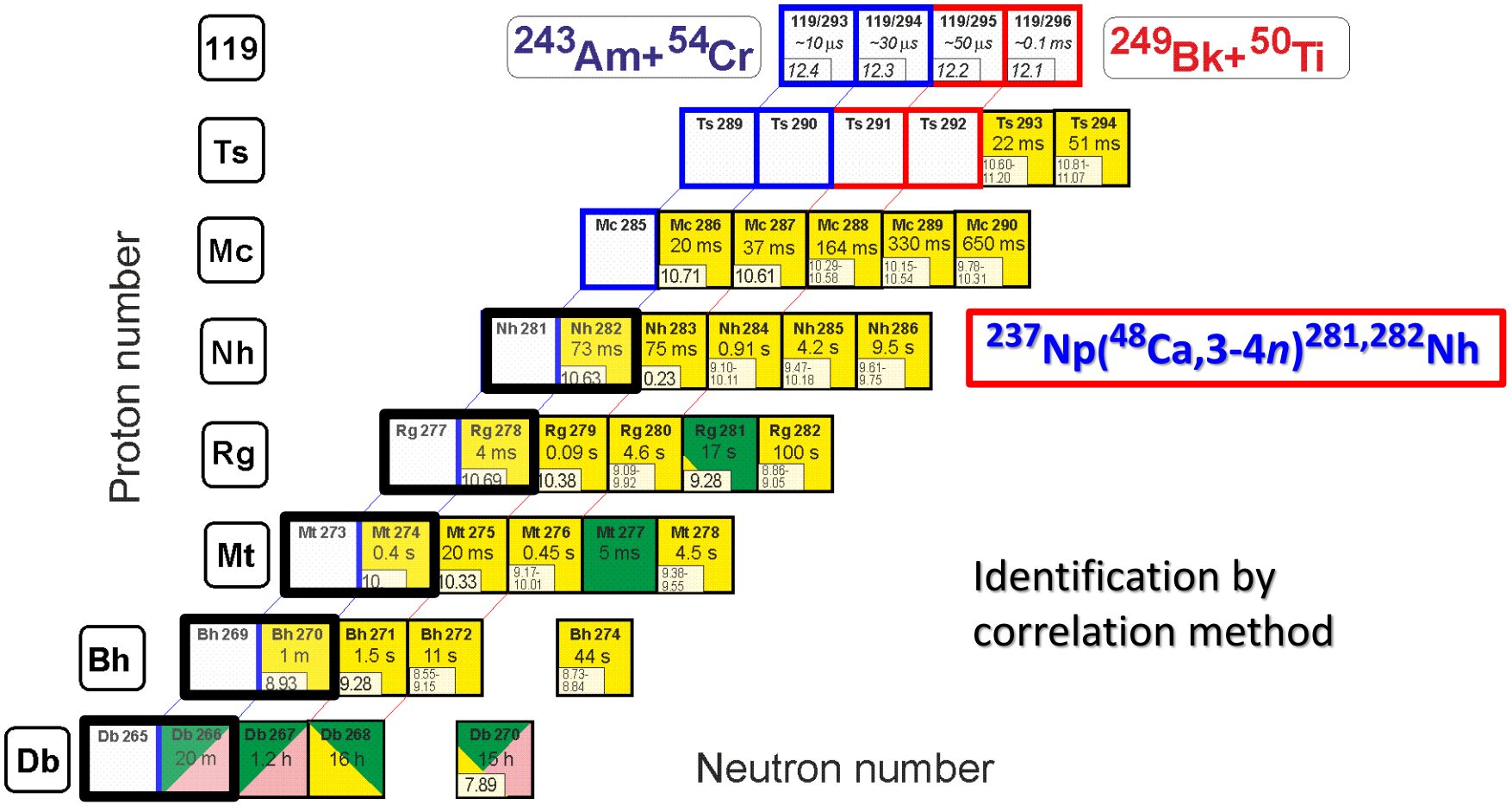
Discovery of new SHE 119 and 120 is within experimental reach!

Thank you for attention!

Perspectives

Synthesis of new element 119

$^{243}Am(^{54}Cr,3\text{-}4n)^{293,294}119$ $^{249}Bk(^{50}Ti,3\text{-}4n)^{295,296}119$



Identification by correlation method

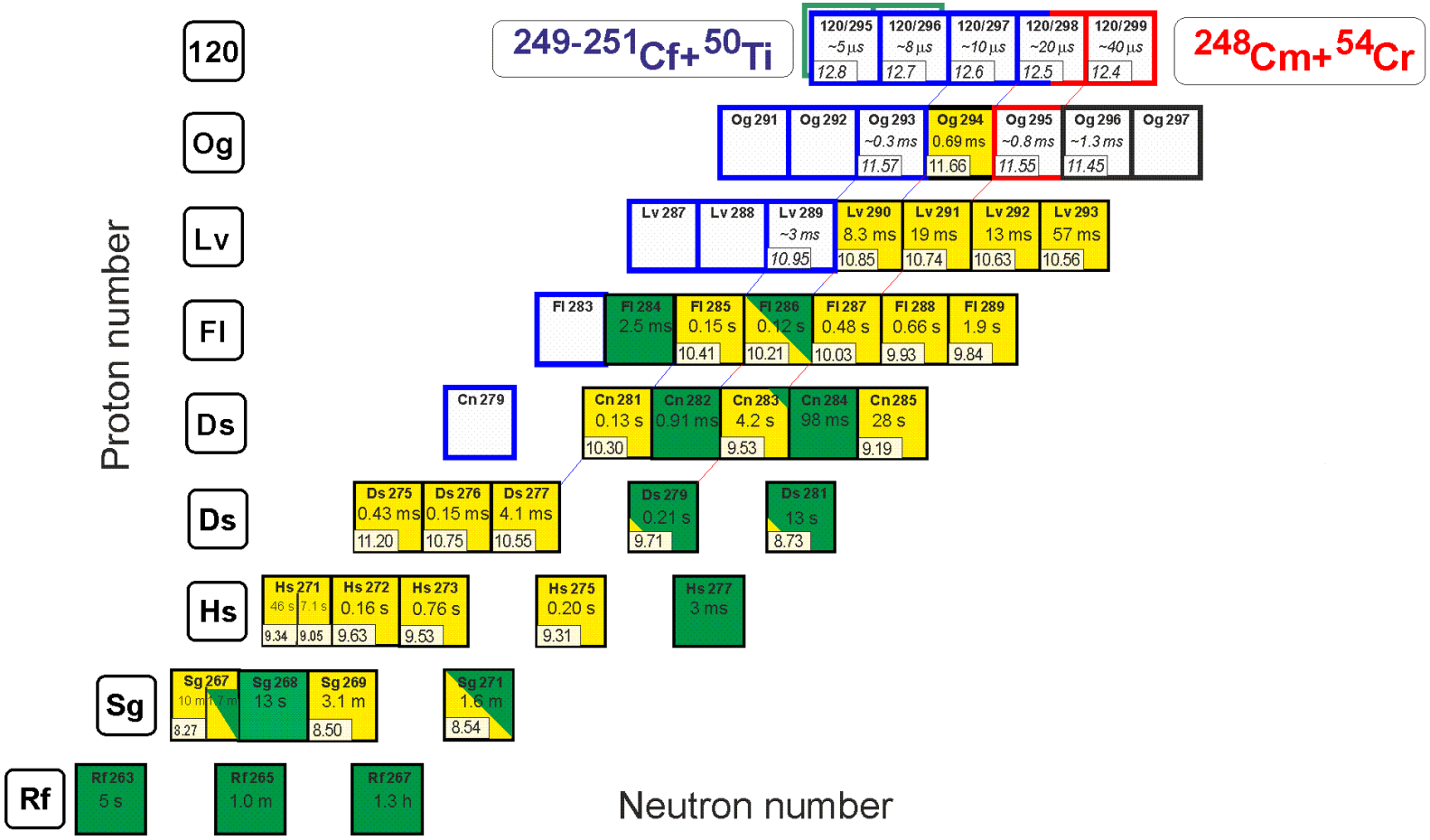
Perspectives

Synthesis of new element 120

$^{249\text{-}251}Cf(^{50}Ti,3\text{-}4n)^{295\text{-}298}120$

$^{248}Cm(^{54}Cr,3\text{-}4n)^{298,299}120$

$^{245}Cm(^{54}Cr,3\text{-}4n)^{295,296}120$



Known decay properties