

A gyenge r -folyamat vizsgálata az Atomkiban



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XVII. Magyar Magfizikus Találkozó
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Reakció hálózatok

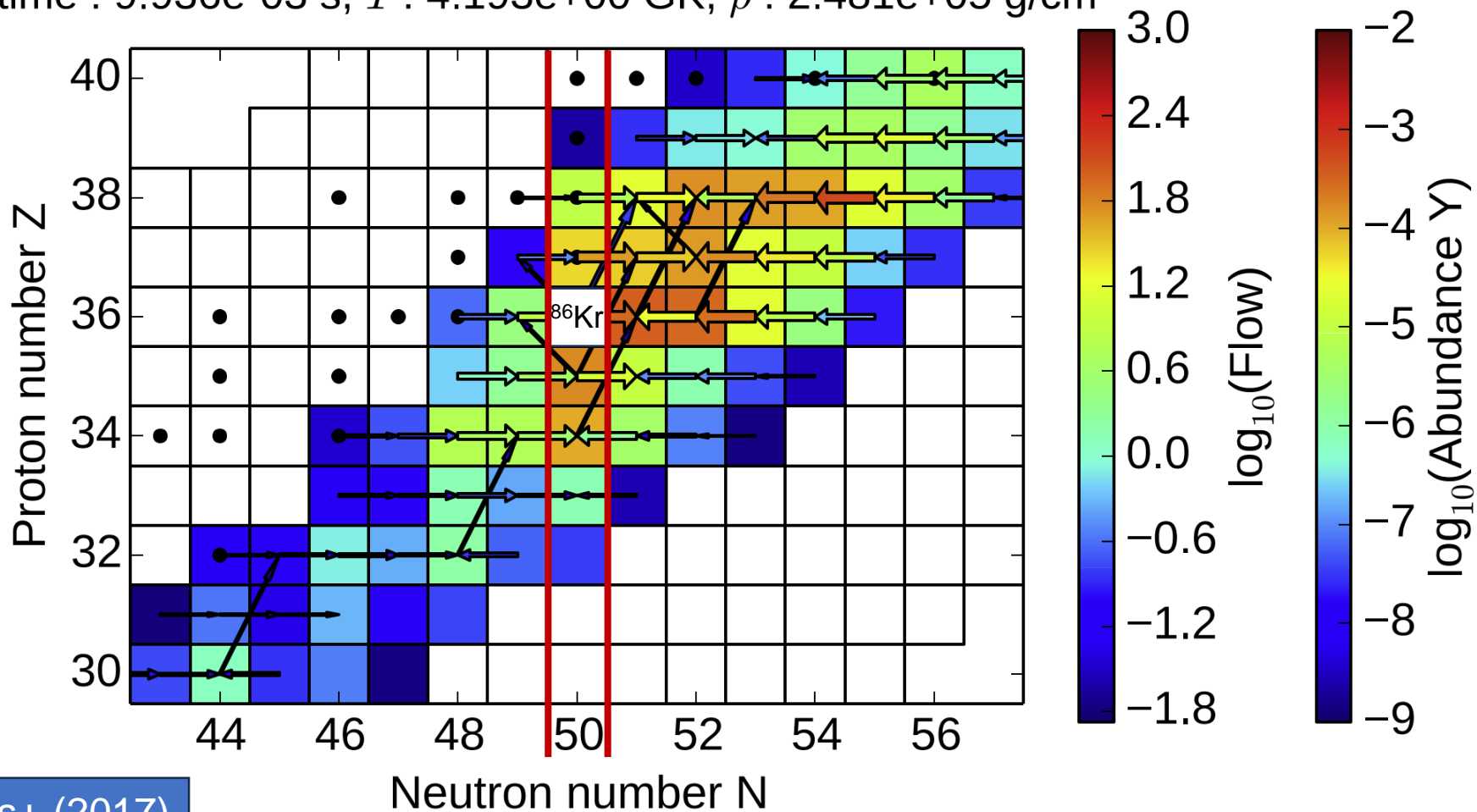
Gyenge r-folyamat: $Y_n/Y_{seed} \leq 10^{-2}$ →

Stabilitás völgyéhez közel

(α, γ) , (α, n) , (p, γ) , (p, n) reakciók segítségével halad magasabb Z felé

↓
lassú β -bomlás

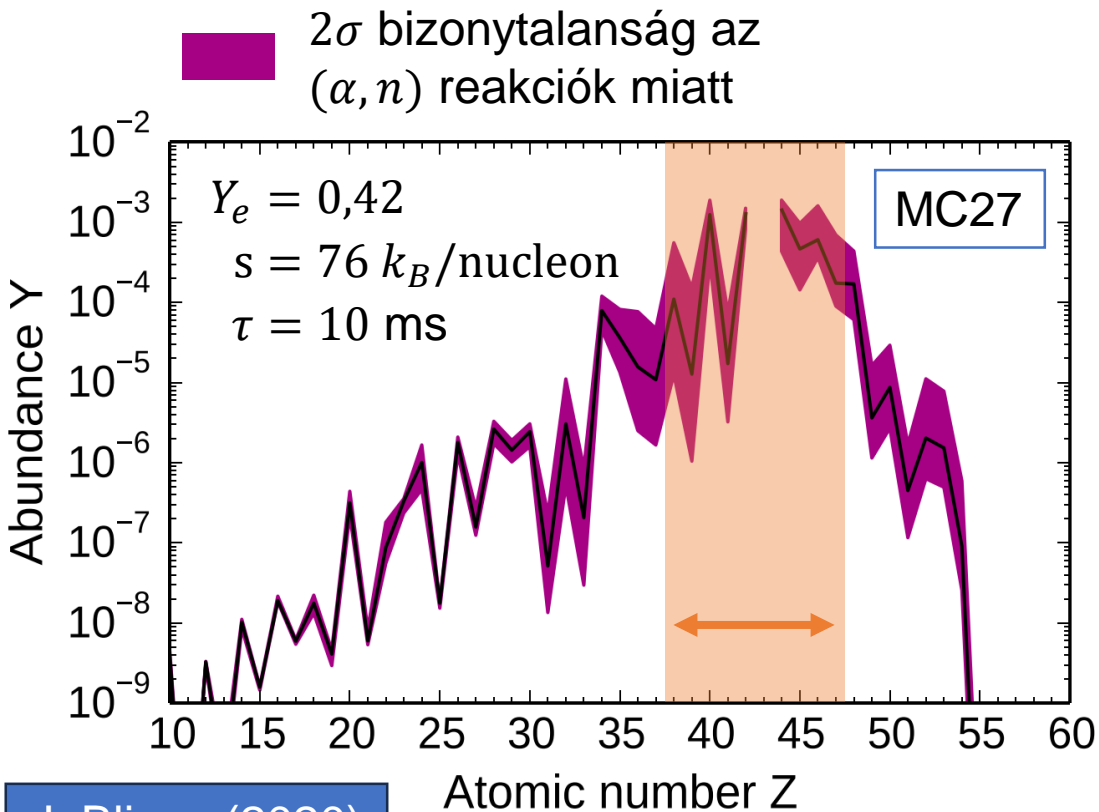
time : 9.936e-03 s, T : 4.193e+00 GK, ρ : 2.481e+05 g/cm³



Az (α, n) reakciók jelentősége

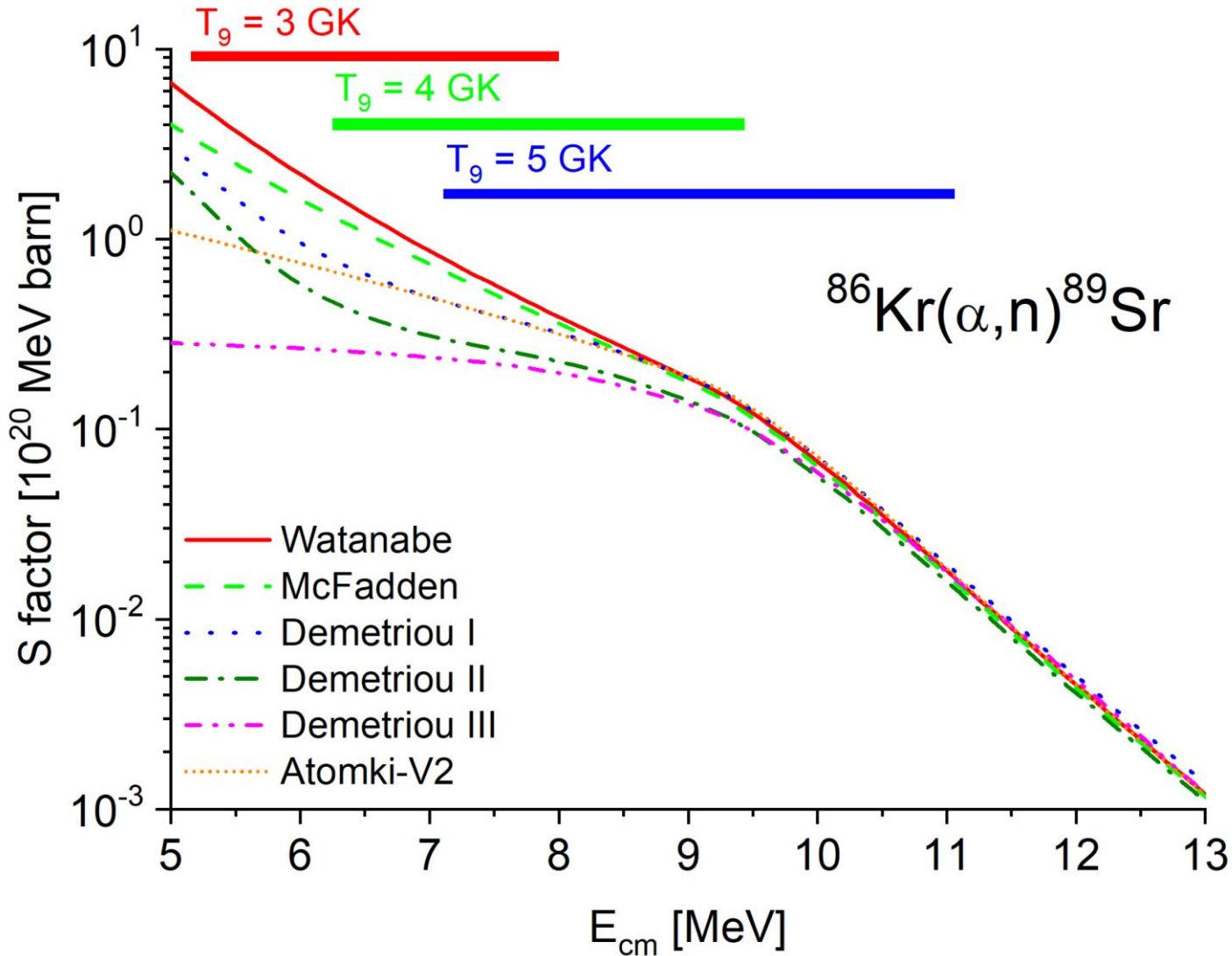


Z	Trajektóriák
38-42, 44, 45, 47	4, 5, 7, 8, 13, 14, 15, 16, 20, 24, 25, 33, 34, 35



Trajectory	Y_e	Entropy k_B/nuc	Expansion time ms
MC1	0.42	129	11.7
MC2	0.45	113	11.9
MC3	0.45	122	10.3
MC4	0.44	66	19.2
MC5	0.43	66	34.3
MC6	0.4	56	63.8
MC7	0.47	96	11.6
MC8	0.43	78	35
MC9	0.40	73	28.1
MC10	0.40	54	31
MC11	0.44	104	13.2
MC12	0.48	85	9.7
MC13	0.43	64	35.9
MC14	0.45	46	14.4
MC15	0.48	103	20.4
MC16	0.49	126	15.4
MC17	0.46	132	12.4
MC18	0.45	131	21.4
MC19	0.41	75	9.8
MC20	0.41	42	59.3
MC21	0.41	31	22.2
MC22	0.40	40	46.7
MC23	0.41	48	37.5
MC24	0.43	56	16.2
MC25	0.46	96	20.9
MC26	0.40	84	36.2
MC27	0.42	76	10
MC28	0.46	113	11.9
MC29	0.41	66	41.4
MC30	0.43	79	26.3
MC31	0.43	71	11.4
MC32	0.42	103	12.7
MC33	0.49	175	14.2
MC34	0.40	34	58.7
MC35	0.44	48	13
MC36	0.40	32	63.4

Probléma az asztrofizikailag releváns energiákon

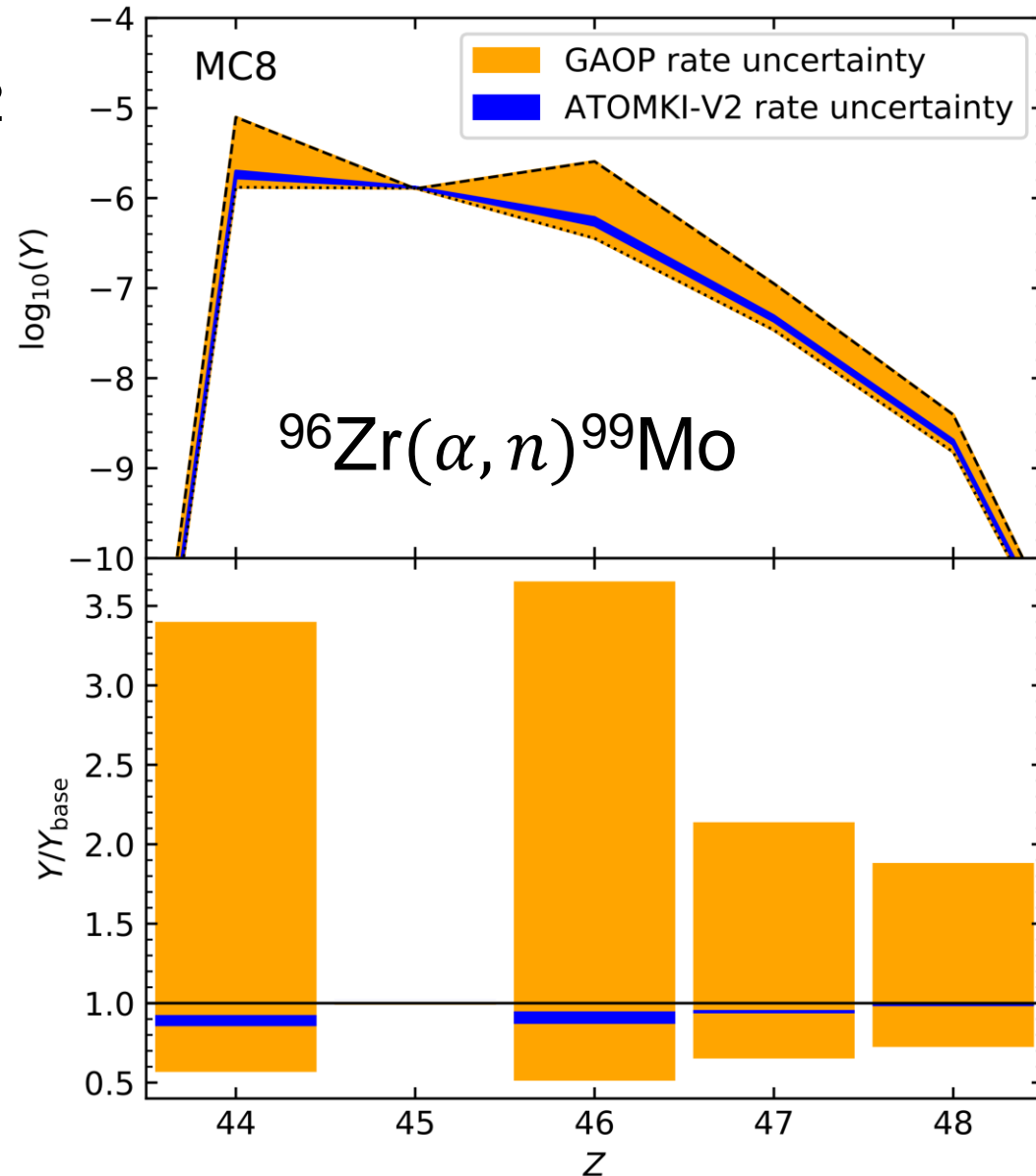


Kísérleti megoldás?

$^{96}\text{Zr}(\alpha, n)^{99}\text{Mo}$ mérések → ATOMKI-V2 potenciál

Minél több mérés szükséges:

- releváns **energiákon**
- releváns **izotópokon**



Releváns izotópok

Reaction	Z	MC tracers
$^{59}\text{Fe}(\alpha, n)^{62}\text{Ni}$	39 – 42, 45	34, 36
$^{68}\text{Fe}(\alpha, n)^{71}\text{Ni}$	36, 37	3
$^{63}\text{Co}(\alpha, n)^{66}\text{Cu}$	39–42, 45	20, 34, 36
$^{71}\text{Co}(\alpha, n)^{74}\text{Cu}$	36, 37	3
$^{74}\text{Ni}(\alpha, n)^{77}\text{Zn}$	36–42	2, 3, 17, 18, 32
$^{76}\text{Ni}(\alpha, n)^{79}\text{Zn}$	36–42	2, 3, 18, 32
$^{67}\text{Cu}(\alpha, n)^{70}\text{Ga}$	47	35
$^{77}\text{Cu}(\alpha, n)^{80}\text{Ga}$	37	3
$^{72}\text{Zn}(\alpha, n)^{75}\text{Ge}$	39–42	36
$^{76}\text{Zn}(\alpha, n)^{79}\text{Ge}$	36, 37–42	2, 3, 17, 18, 32
$^{78}\text{Zn}(\alpha, n)^{81}\text{Ge}$	36, 37–42	2, 3, 17, 18, 32
$^{79}\text{Zn}(\alpha, n)^{82}\text{Ge}$	36, 37–42	2, 3, 18, 32
$^{80}\text{Zn}(\alpha, n)^{83}\text{Ge}$	36, 37, 39–42	2, 3, 18, 32
$^{81}\text{Ga}(\alpha, n)^{84}\text{As}$	36, 38, 39, 41	17, 32
$^{78}\text{Ge}(\alpha, n)^{81}\text{Se}$	39–42	36
$^{80}\text{Ge}(\alpha, n)^{83}\text{Se}$	36–39, 42	28, 33, 36
$^{82}\text{Ge}(\alpha, n)^{85}\text{Se}$	36–39, 41	11, 17, 19, 27, 28, 33
$^{83}\text{As}(\alpha, n)^{86}\text{Br}$	36, 37, 41	11, 26, 27, 28, 33
$^{84}\text{Se}(\alpha, n)^{87}\text{Kr}$	36–42, 44, 45	2, 6, 7, 8, 9, 10, 11, 18, 19, 20, 22, 23, 24, 26, 27, 28, 29, 30, 31, 33, 34, 36
$^{85}\text{Se}(\alpha, n)^{88}\text{Kr}$	36–42, 44, 45	2, 6, 7, 8, 9, 10, 11, 18, 19, 22, 23, 24, 26, 27, 28, 29, 30, 31
$^{85}\text{Br}(\alpha, n)^{88}\text{Rb}$	37–39	6, 7, 8, 9, 10, 22, 23, 24, 26, 28, 29, 30, 31
$^{87}\text{Br}(\alpha, n)^{90}\text{Rb}$	37, 39	6, 9, 10, 29, 31
$^{88}\text{Br}(\alpha, n)^{91}\text{Rb}$	39	26
$^{86}\text{Kr}(\alpha, n)^{89}\text{Sr}$	38–42, 44, 45, 47	4, 5, 7, 8, 13, 14, 15, 16, 20, 24, 25, 33, 34, 35
$^{87}\text{Kr}(\alpha, n)^{90}\text{Sr}$	38–42, 45	4, 5, 7, 8, 13, 16, 20, 24, 25, 28, 30, 33, 34
$^{88}\text{Kr}(\alpha, n)^{91}\text{Sr}$	37–42, 44, 45	2, 4, 5, 6, 7, 8, 9, 11, 13, 16, 17, 18, 19, 20, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34
$^{89}\text{Kr}(\alpha, n)^{92}\text{Sr}$	39, 40, 42, 44, 45	2, 6, 11, 17, 18, 19, 26, 27, 28, 29, 30, 32
$^{90}\text{Kr}(\alpha, n)^{93}\text{Sr}$	37–42, 44–46	2, 3, 6, 9, 10, 11, 17, 18, 19, 22, 26, 27, 28, 29, 30, 31, 32
$^{87}\text{Rb}(\alpha, n)^{90}\text{Y}$	41, 45	14, 15
$^{89}\text{Rb}(\alpha, n)^{92}\text{Y}$	41, 42	5, 7, 13, 20, 34
$^{88}\text{Sr}(\alpha, n)^{91}\text{Zr}$	42, 44	14, 15
$^{89}\text{Sr}(\alpha, n)^{92}\text{Zr}$	42	14, 15
$^{90}\text{Sr}(\alpha, n)^{93}\text{Zr}$	42, 44–47	4, 5, 12, 13, 14, 15, 16, 20, 35
$^{91}\text{Sr}(\alpha, n)^{94}\text{Zr}$	44, 45	5, 12, 13, 16
$^{92}\text{Sr}(\alpha, n)^{95}\text{Zr}$	38, 42, 44–47	4, 5, 6, 7, 8, 11, 12, 13, 16, 20, 21, 22, 23, 24, 25, 28, 29, 30, 31, 34
$^{93}\text{Sr}(\alpha, n)^{96}\text{Zr}$	42, 44 – 47	6, 7, 9, 10, 11, 22, 26, 27, 28, 29, 30, 31
$^{94}\text{Sr}(\alpha, n)^{97}\text{Zr}$	37–42, 44–47	2, 6, 7, 8, 9, 10, 11, 18, 19, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32
$^{94}\text{Y}(\alpha, n)^{97}\text{Nb}$	45	4, 8, 16, 21, 23, 24, 25
$^{95}\text{Y}(\alpha, n)^{98}\text{Nb}$	45, 46	8, 23, 24, 25, 30
$^{94}\text{Zr}(\alpha, n)^{97}\text{Mo}$	44, 45	14, 15, 35
$^{95}\text{Zr}(\alpha, n)^{98}\text{Mo}$	45–47	5, 12, 13, 35
$^{96}\text{Zr}(\alpha, n)^{99}\text{Mo}$	44–47	4, 5, 6, 7, 8, 12, 13, 16, 20, 21, 22, 23, 24, 25, 29, 30, 35
$^{97}\text{Zr}(\alpha, n)^{100}\text{Mo}$	44, 46, 47	4, 5, 6, 7, 8, 21, 22, 23, 24, 25, 29, 30
$^{98}\text{Zr}(\alpha, n)^{101}\text{Mo}$	44, 46, 47	6, 7, 8, 22, 23, 24, 25, 29, 30
$^{97}\text{Nb}(\alpha, n)^{100}\text{Tc}$	45, 46, 47	12, 13, 14, 15, 35

Kísérleti megoldás?

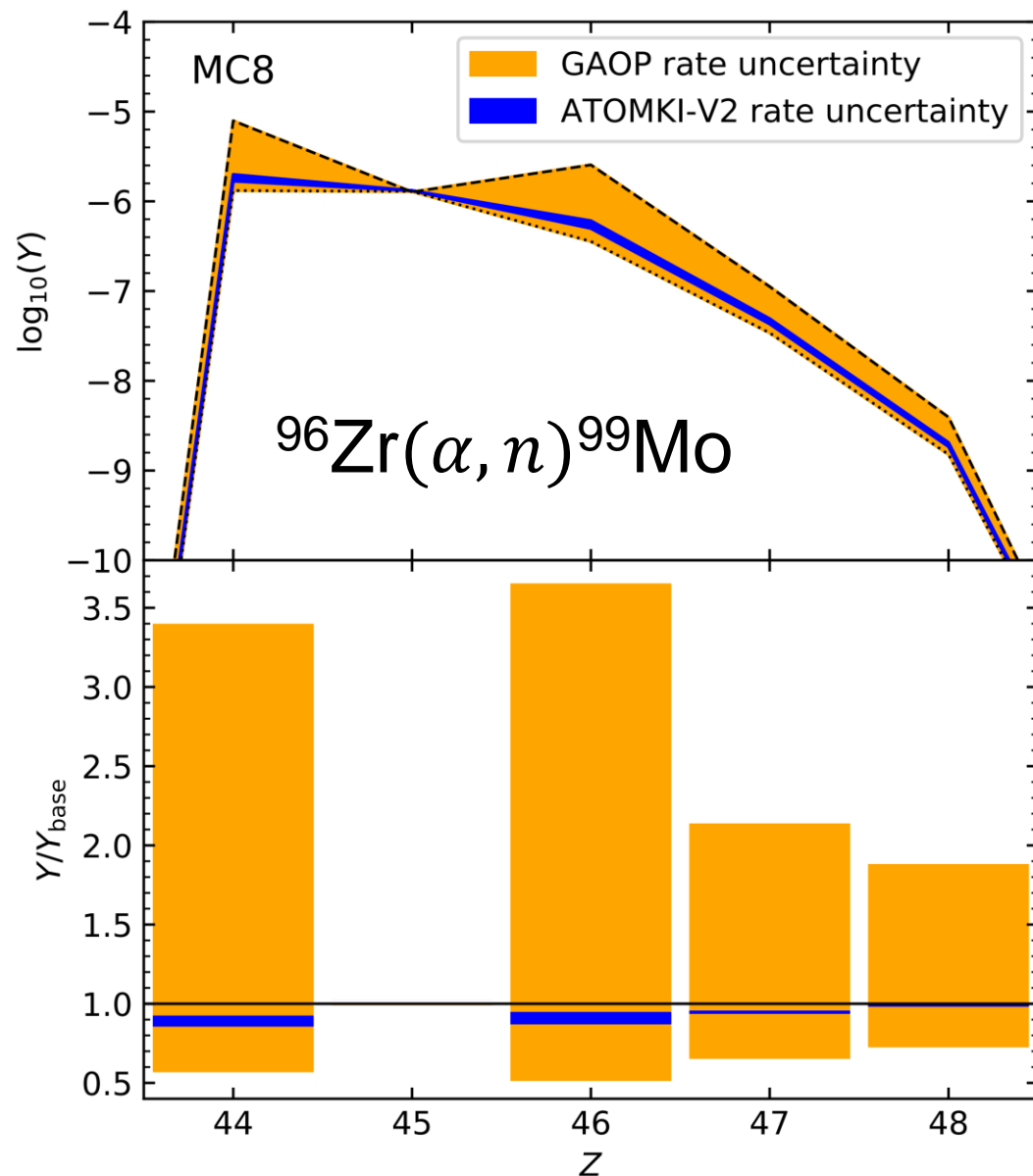
$^{96}\text{Zr}(\alpha, n)^{99}\text{Mo}$ mérések → ATOMKI-V2 potenciál

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- releváns **izotópokon**

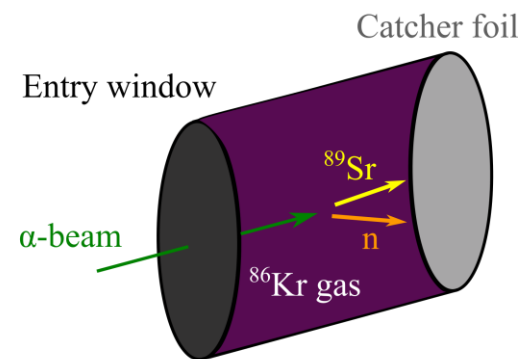
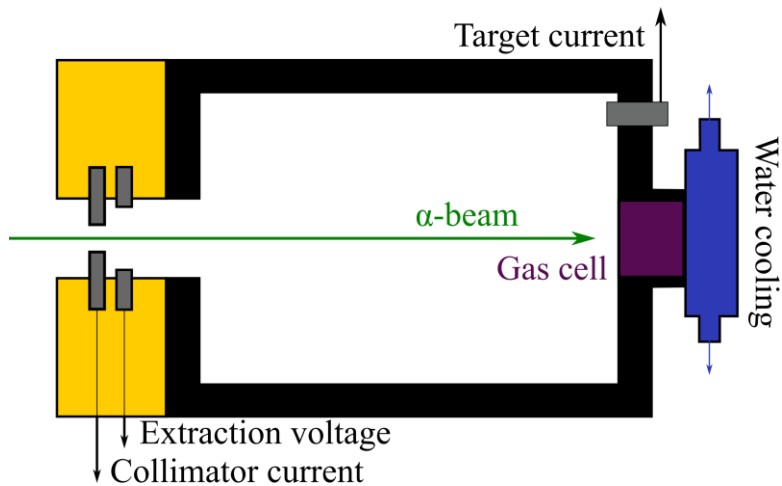
Folyamatban lévő mérések:

- NSCL
- ANL
- Triumph
- ATOMKI



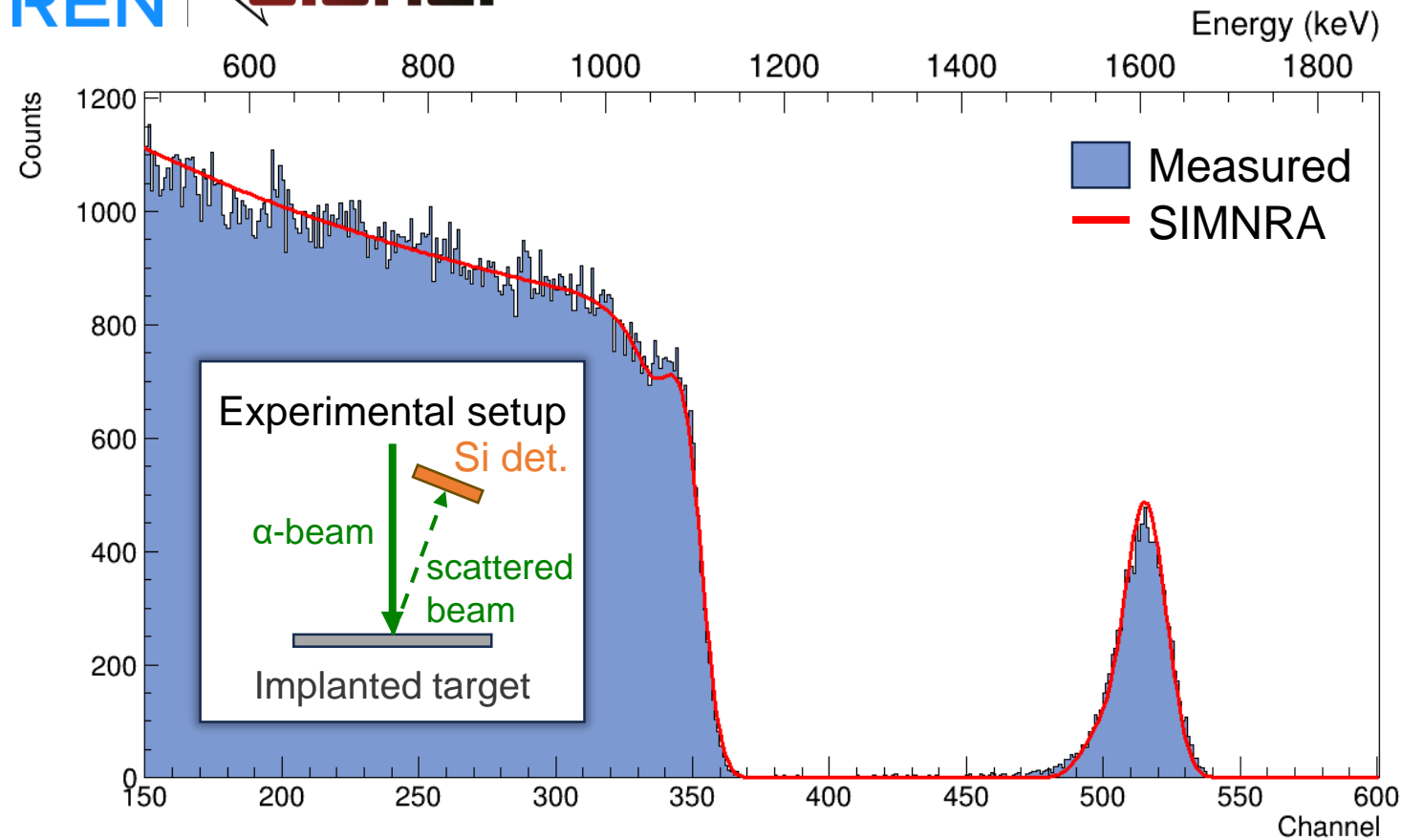
Besugárzás

MGC-20
cyclotron

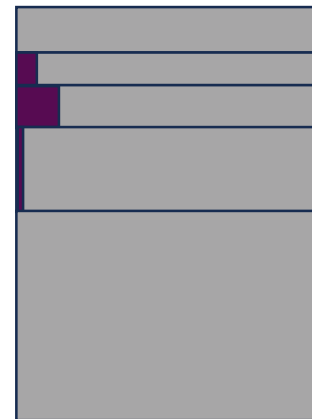


HUN
REN

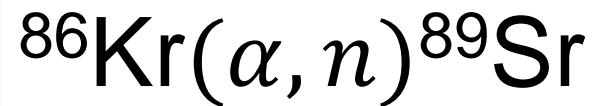
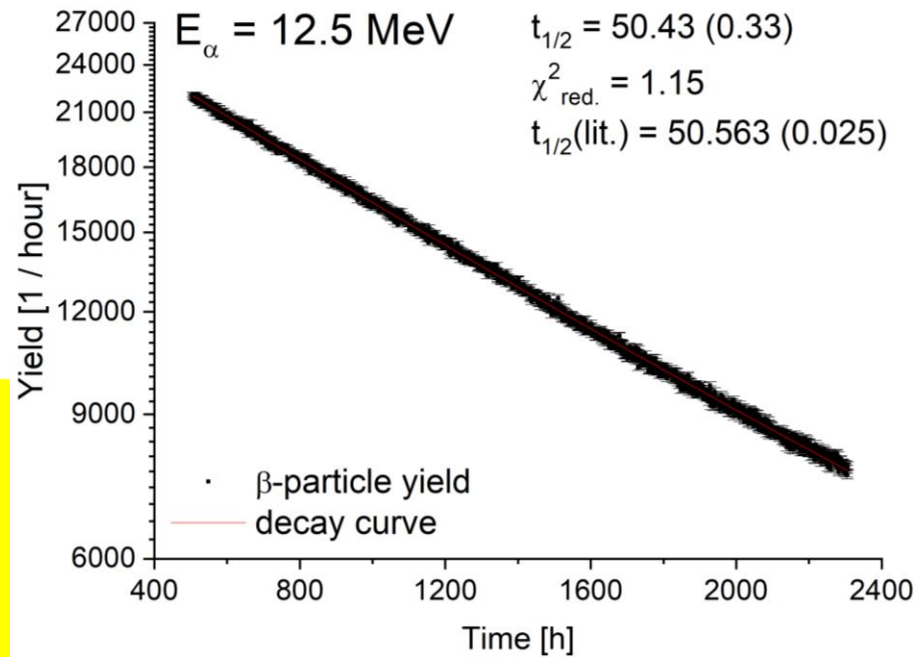
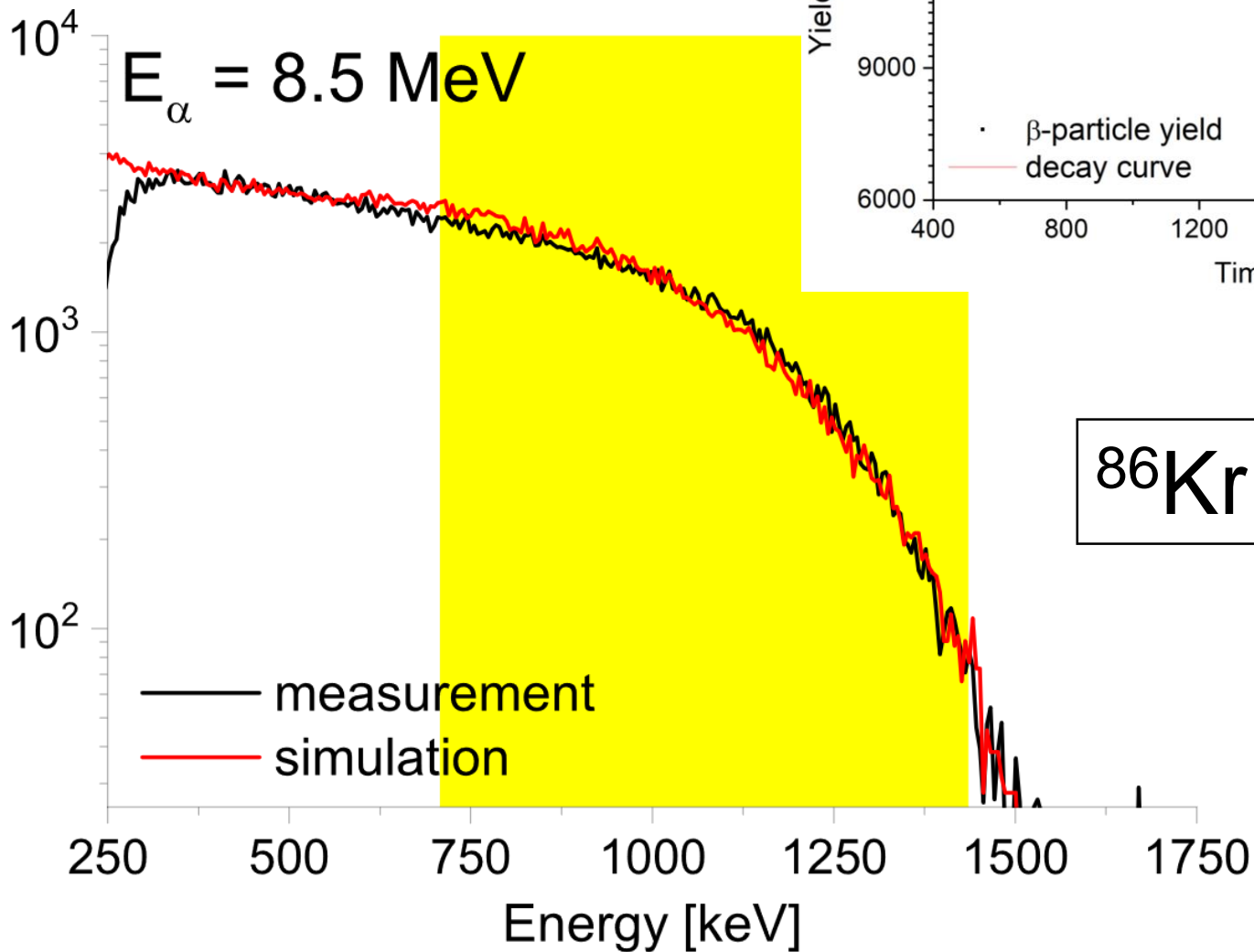
WIGNER



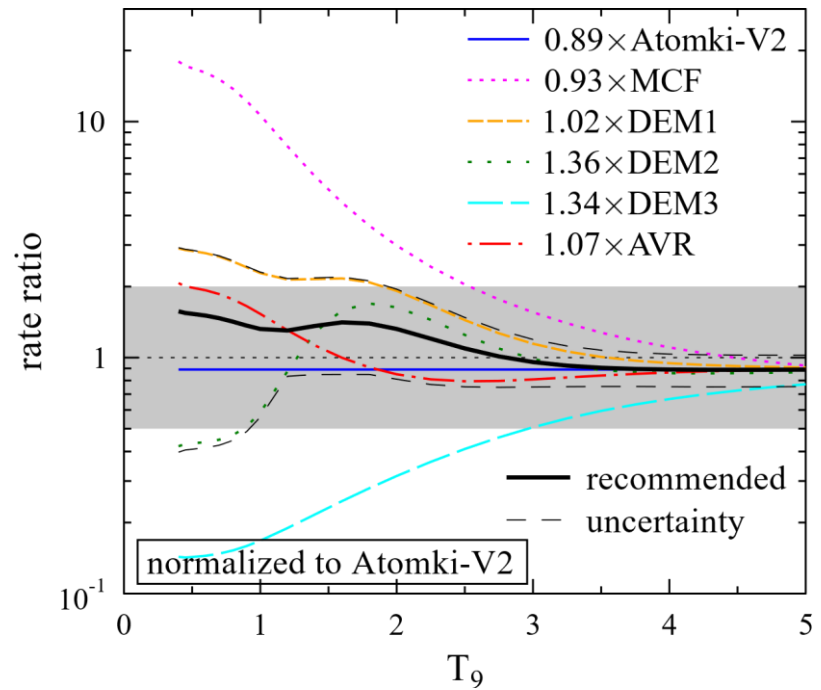
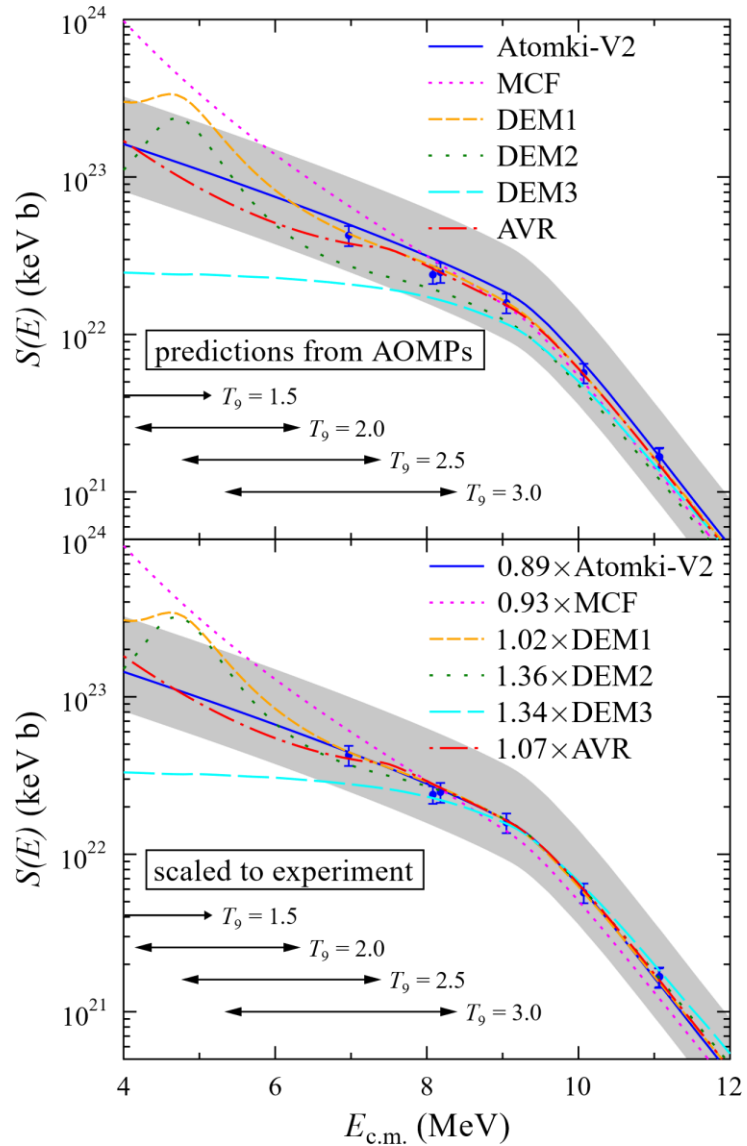
Alternatíva:
implantált céltárgy



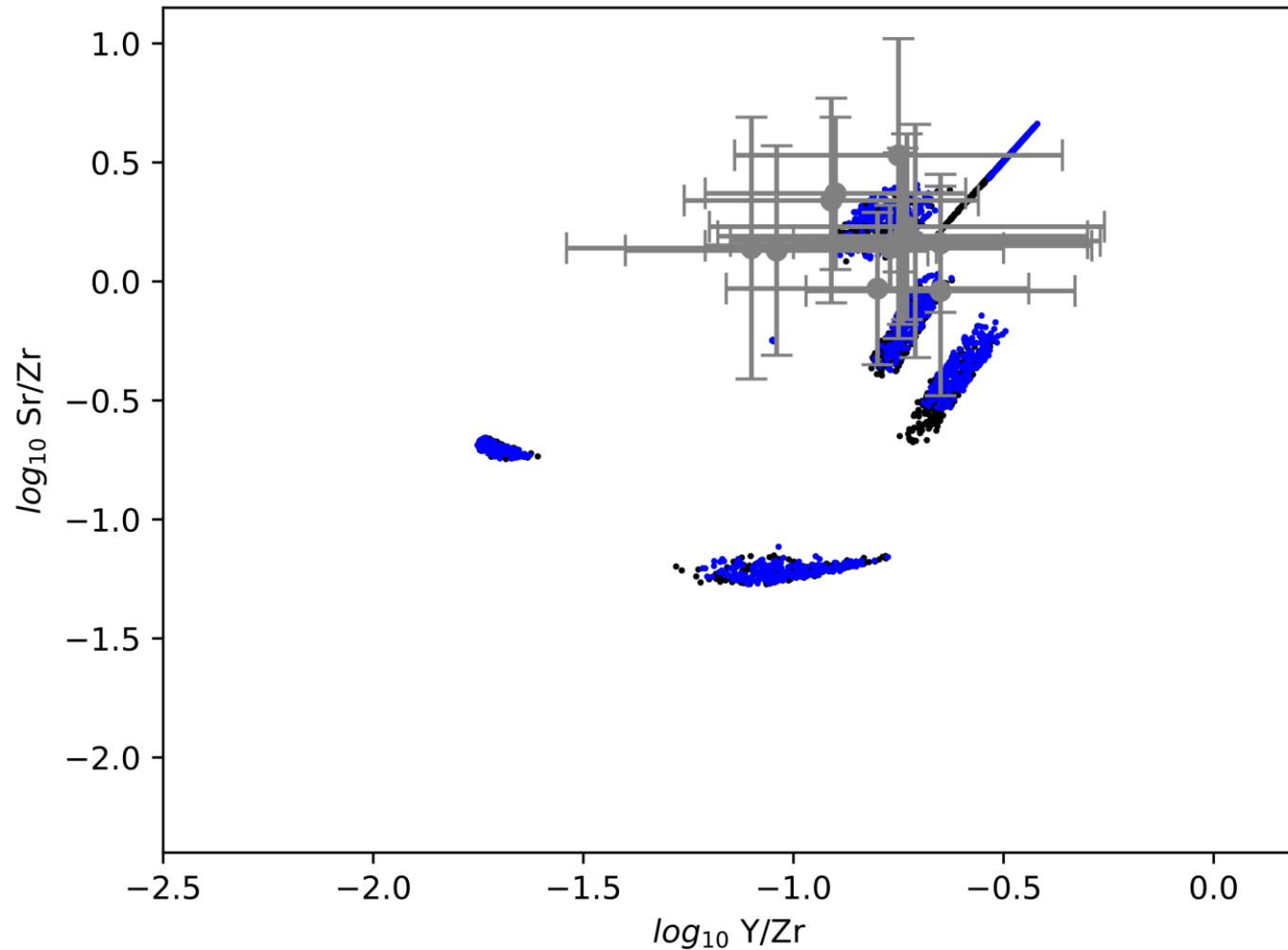
Aktivitás mérés



Eredmények



Asztrofizika következmények



Gyenge r-folyamat

- Töltött részecske befogás (α, n) , (p, n) , (α, γ) , (p, γ)
- $^{86}\text{Kr}(\alpha, n)$ kulcsreakció \longleftrightarrow Hatáskeresztmetszet számítások bizonytalanok

Aktivációs módszer:

- Gáz céltárgy
 - Implantált céltárgy
 - Áram mérés
 - β -bomlás
- $\} \longrightarrow ^{86}\text{Kr}(\alpha, n)^{89}\text{Sr}$
-

Eredmények és asztrofizikai következmények:

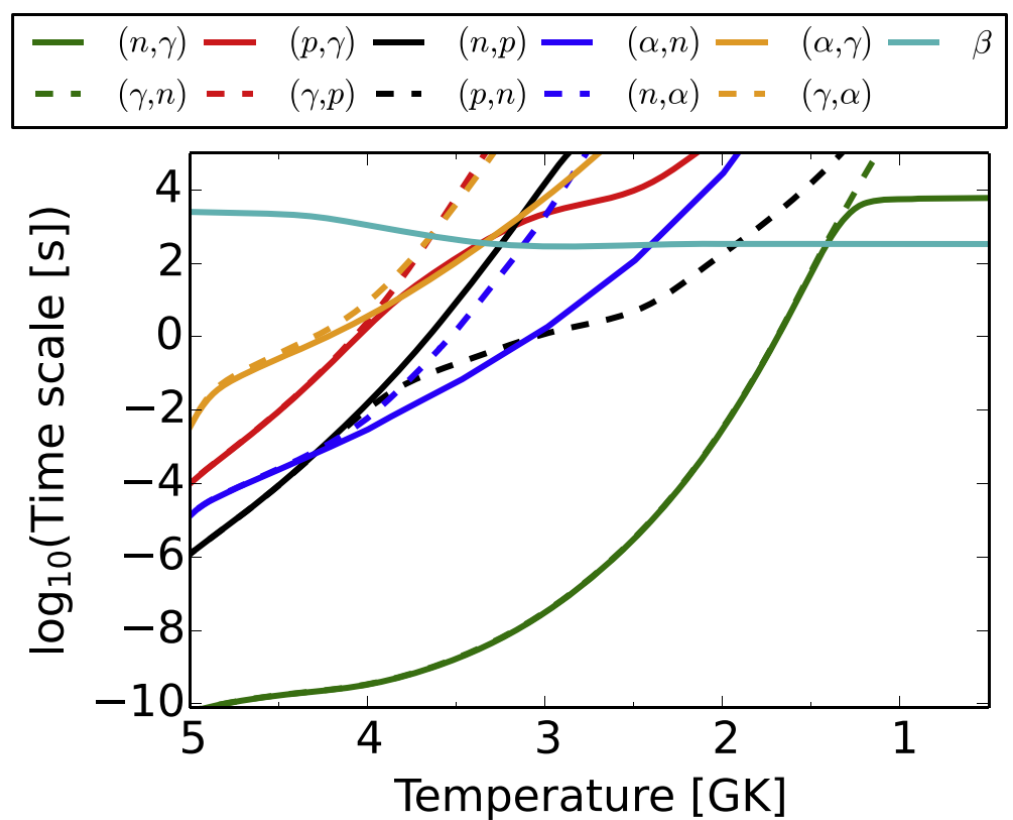
10-es faktor
bizonytalanság elméletből



bizonytalanság
megszorítása

Kitekintés

- Alacsony hőmérsékleten, korai szakaszban (p, n) reakció dominál
- Új $^{86}\text{Kr}(p, n)^{86}\text{Rb}$ mérések Tandetron laboratóriumban
- β - és γ -bomlás mérések



Köszönöm a figyelmet!

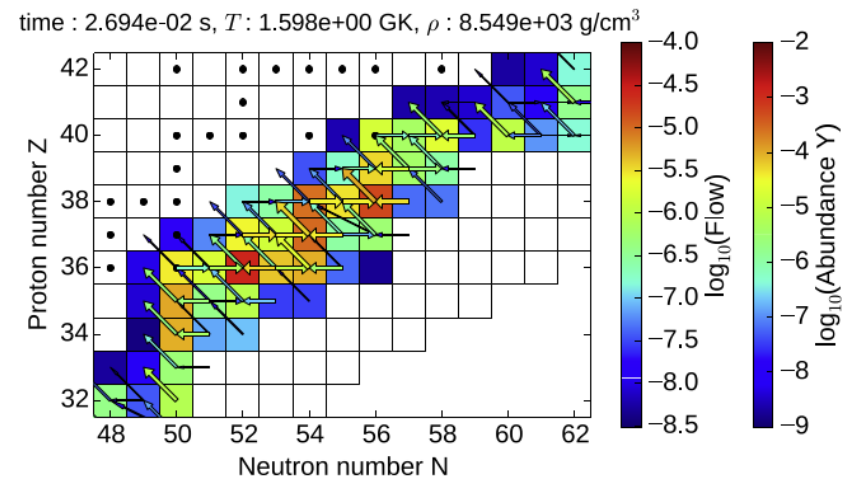
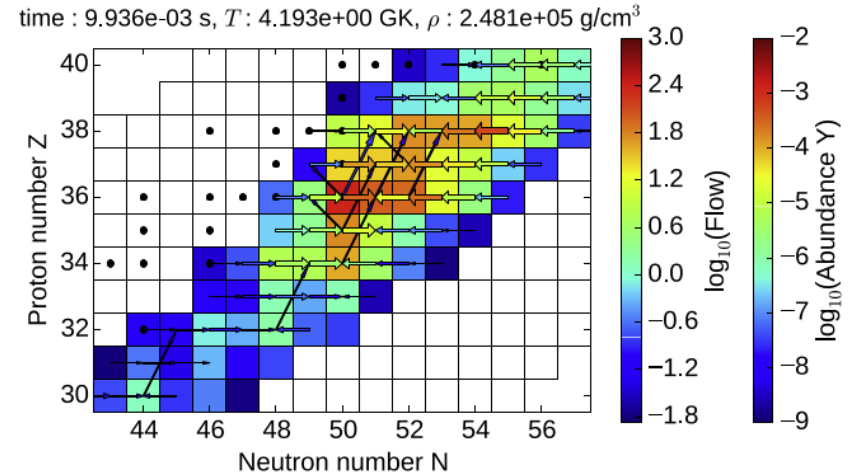
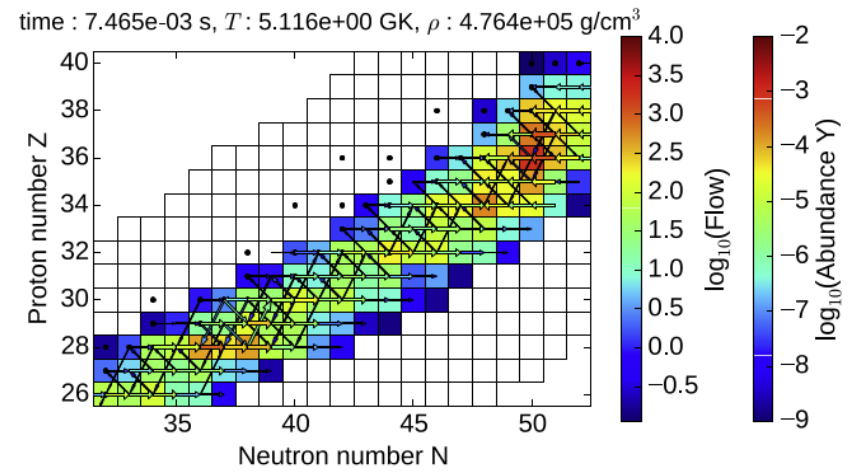
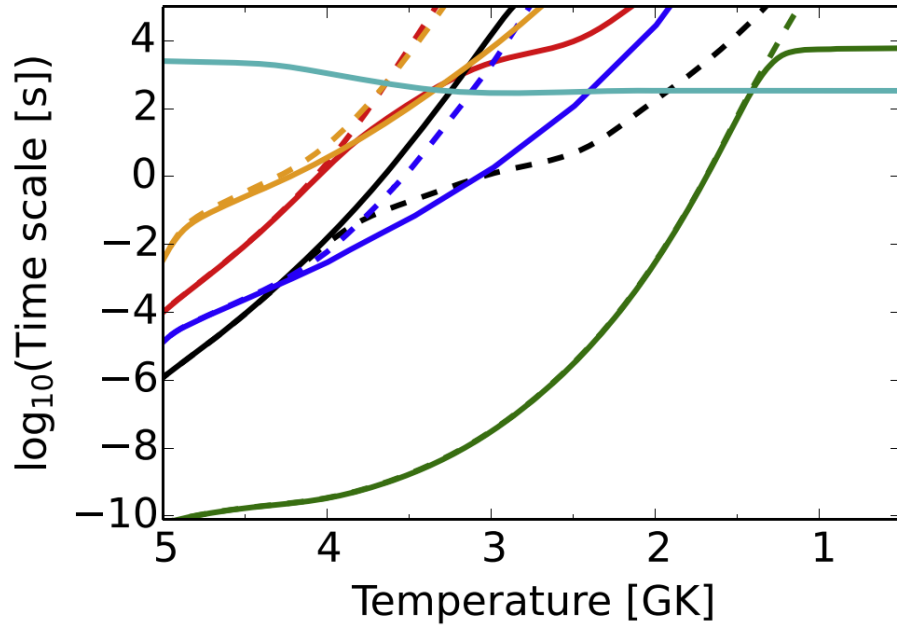
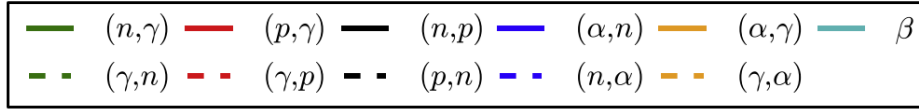
J. Bliss et. al, J. Phys. G: Nucl. Part. Phys. **44** (2017) 054003

J. Bliss et. al, PRC **101**, (2020) 055807

G. G. Kiss et. al, APJ **908**, (2021) 202



Hőmérséklet függés



Különböző reakciócsatornák

