Statistical analysis of decay chains of the heaviest elements

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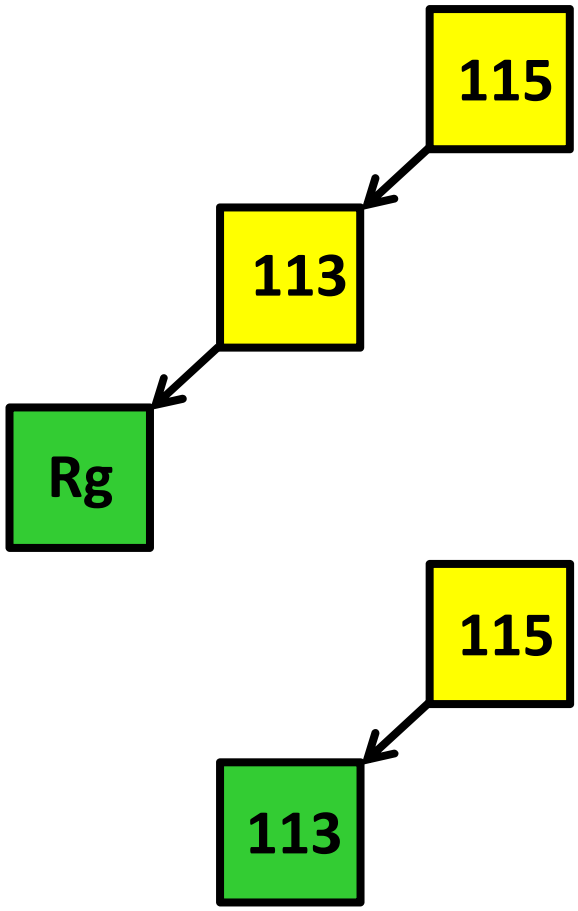
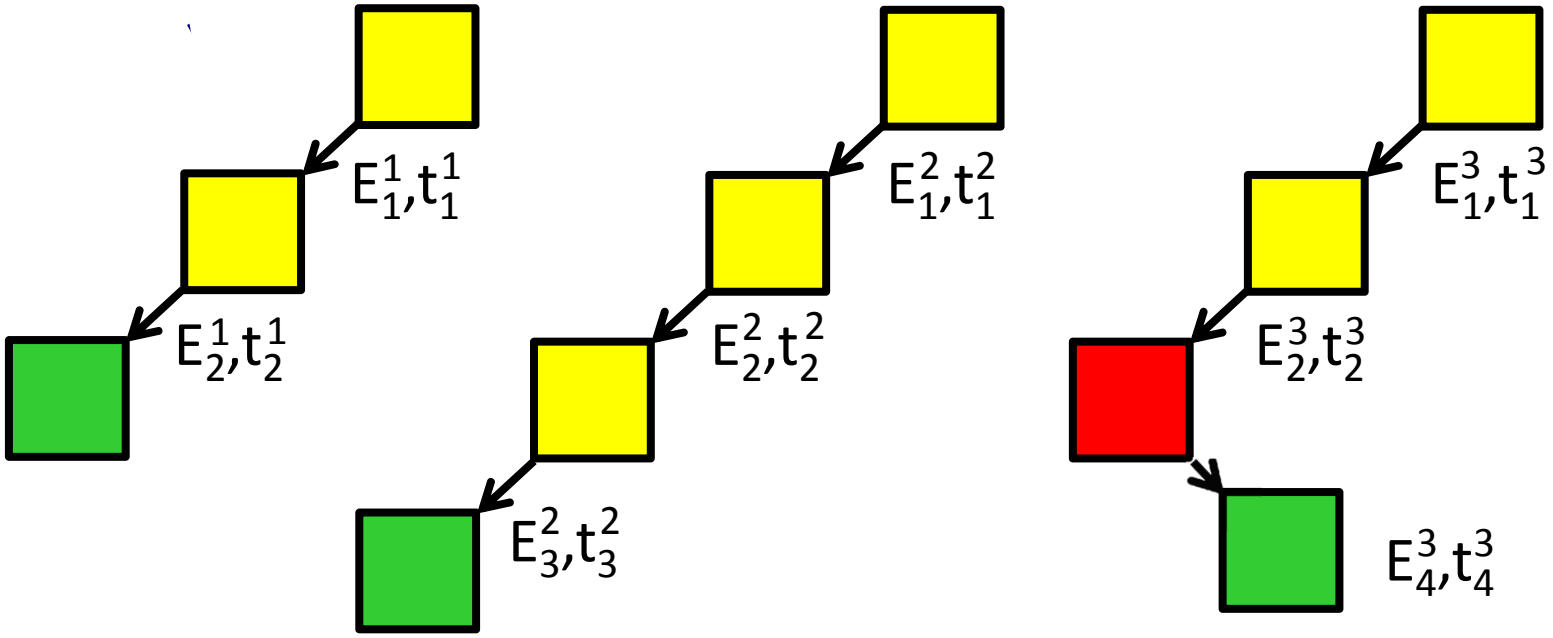
Outline

- Difficulties with characterising decay chains
- New low-number statistical method
- Applications to E115 & E117



Characteristics

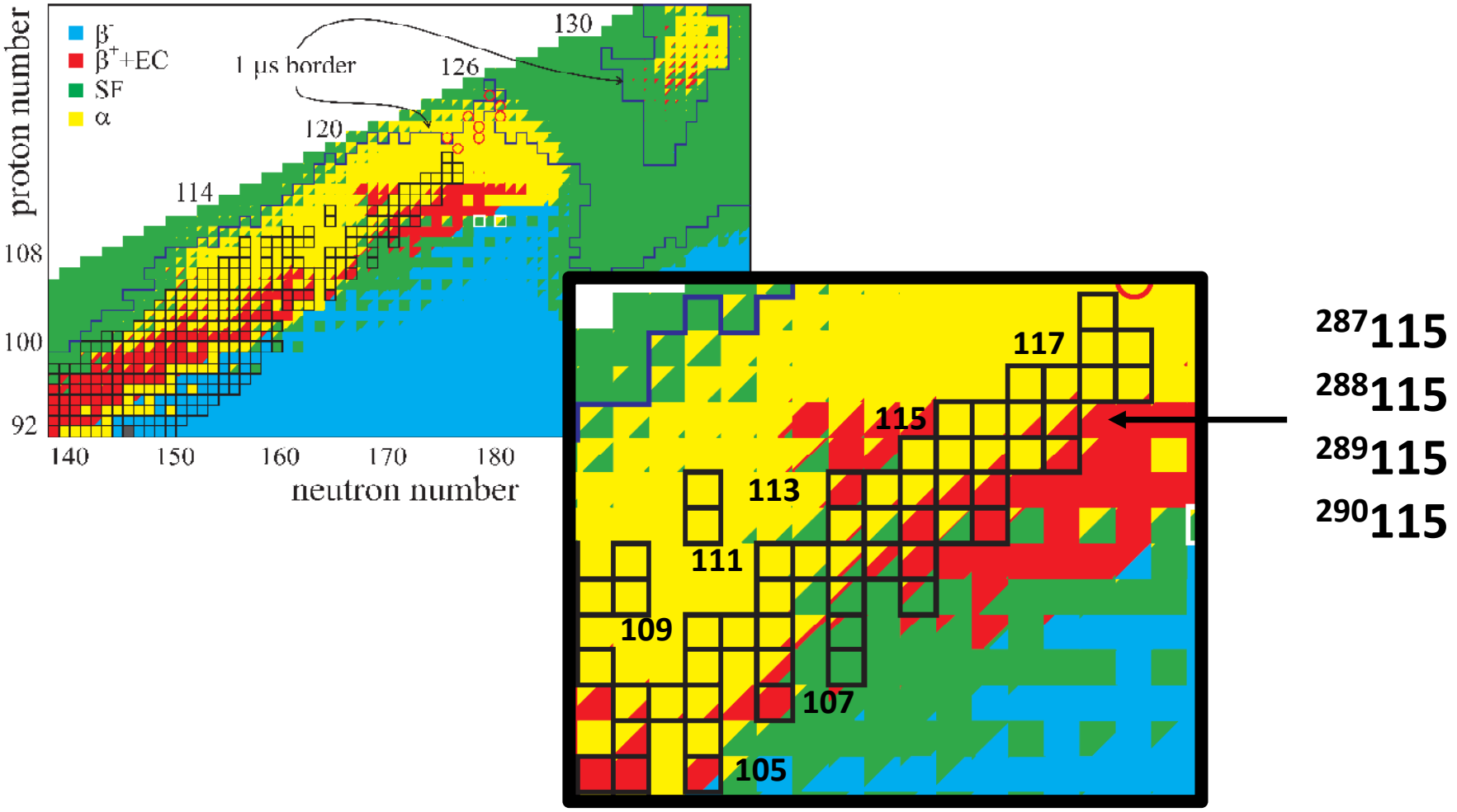


Decay Mode – α/SF/electron capture (EC)

Energies – often excited (and isomeric) states

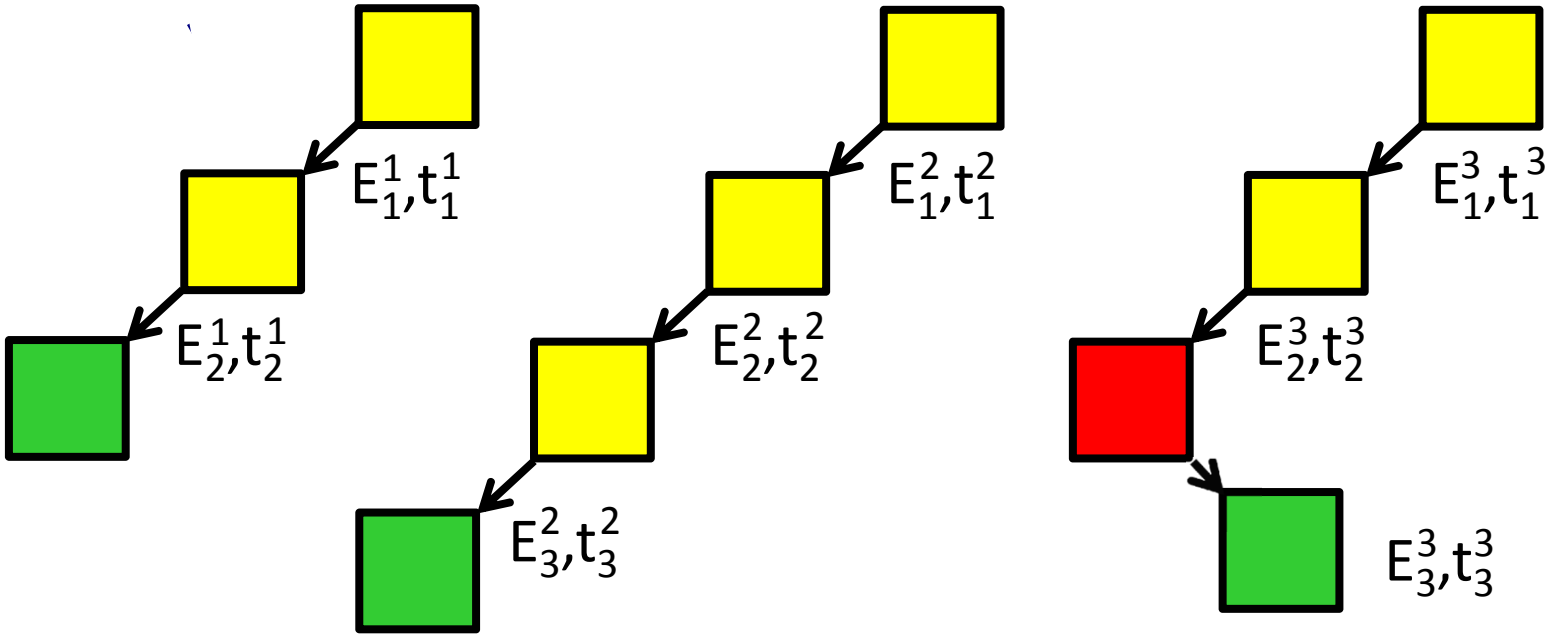
Times – exponential decay

Characteristics



A. Karpov *et al.*, Int. J. Mod. Phys. **E** (2012)

Characteristics



Decay Mode – α/SF/electron capture (EC)

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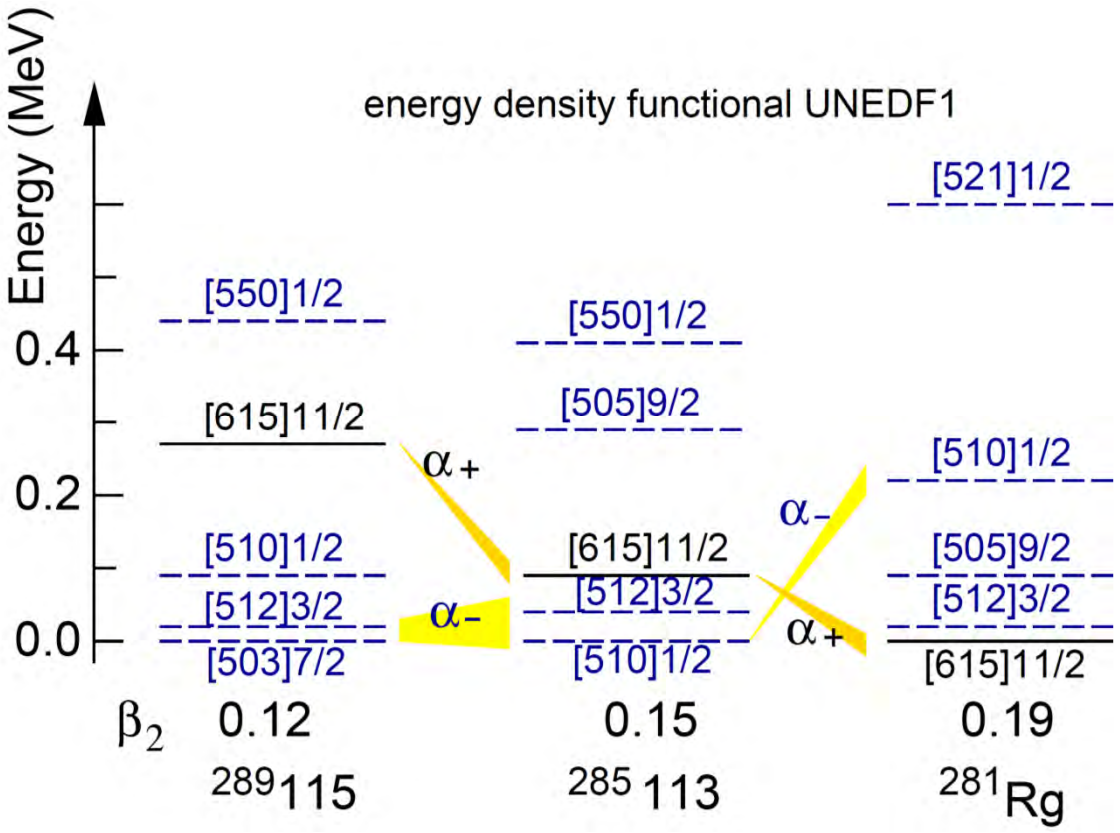
Characteristics

α decays in odd nuclei:



often to excited states → decay energies can vary

sometimes isomeric → different decay paths possible

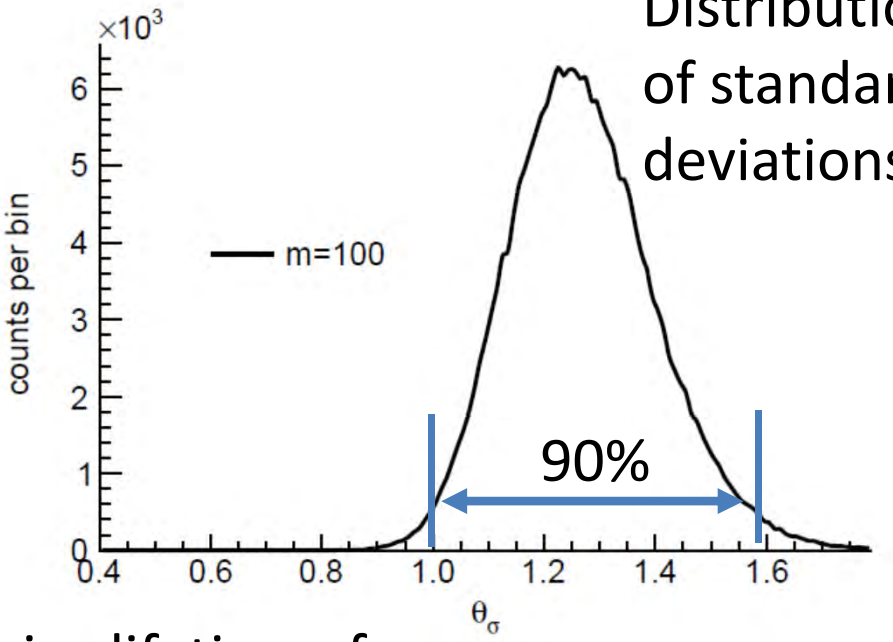
Schmidt's test

Standard deviation of ln(t) in a set.

Karl-Heinz Schmidt, Eur. Phys. J. A 8: 141 (2000)

$$\sigma_\theta = \sqrt{\frac{\sum_{i=1}^{n}(\theta_i - \bar{\theta})^2}{n}}$$

$$\theta = ln(t)$$

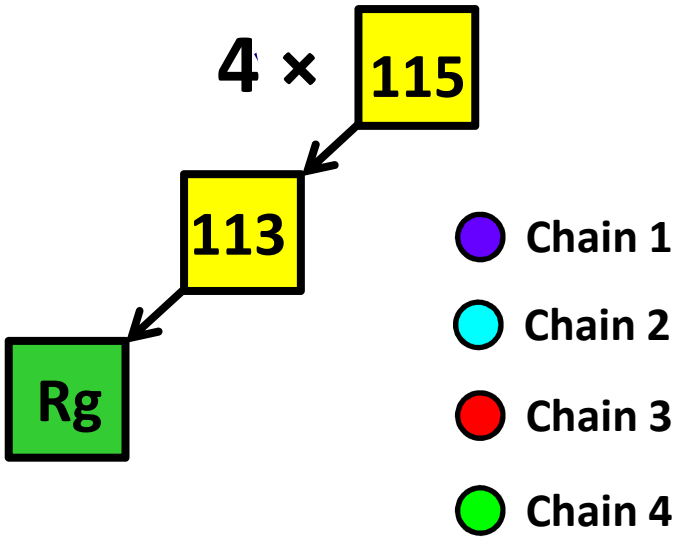


Too high: The data set contains lifetimes from more than one radioactive species

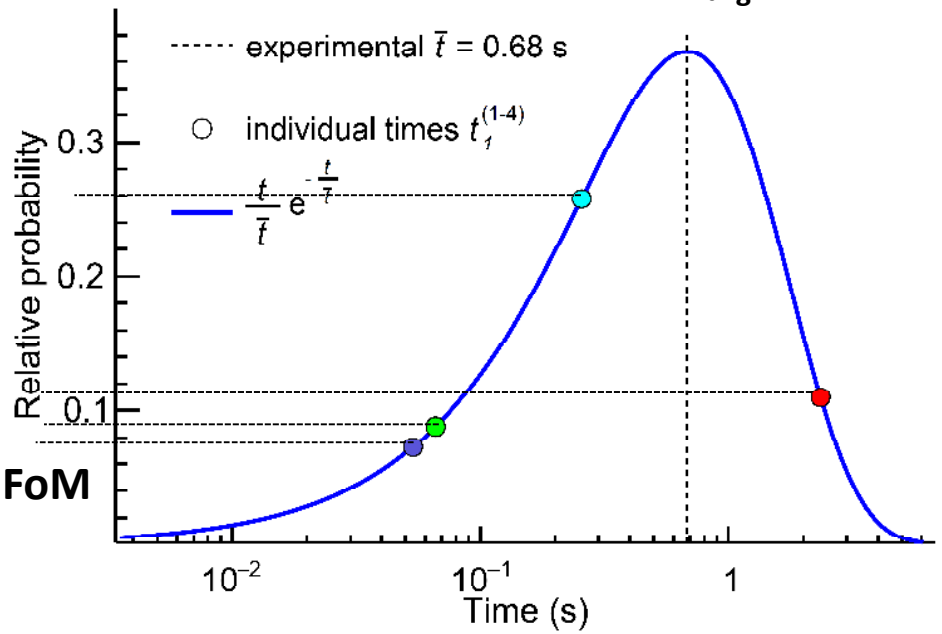
Too low: Measurement not sensitive to all decay times

OR the data set is somehow "pruned".

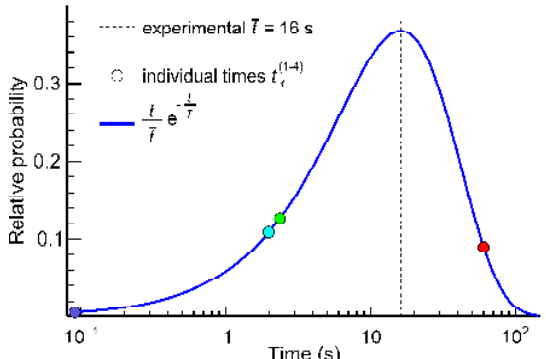
Extended test



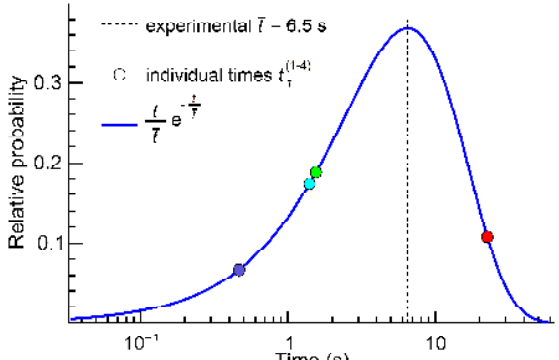
Decay step 1, probability density function for times, if τ is estimated as t_{avg}



Decay step 2

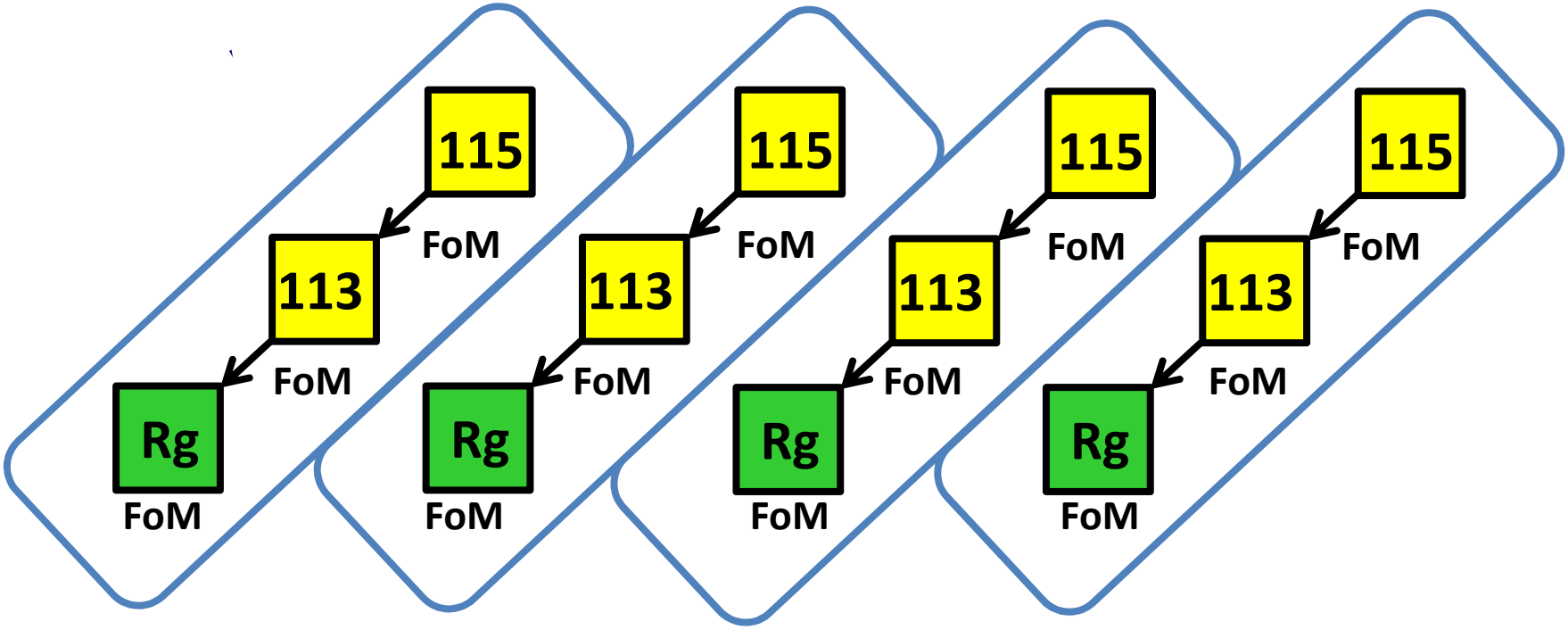


Decay step 3



U. Forsberg *et al.*, NPA (2016)

Extended test



FoM for chain = geom. avg.

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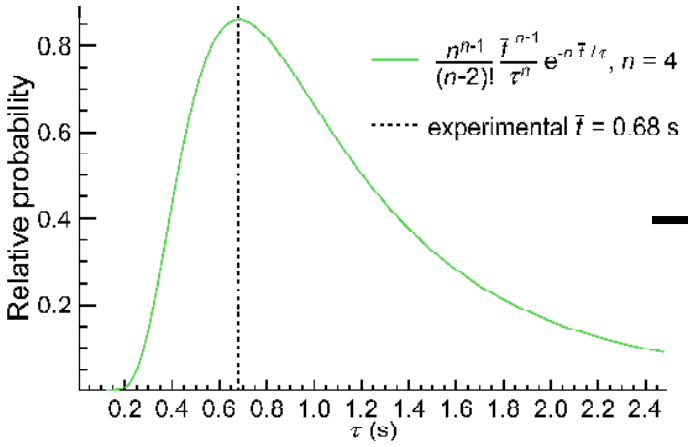
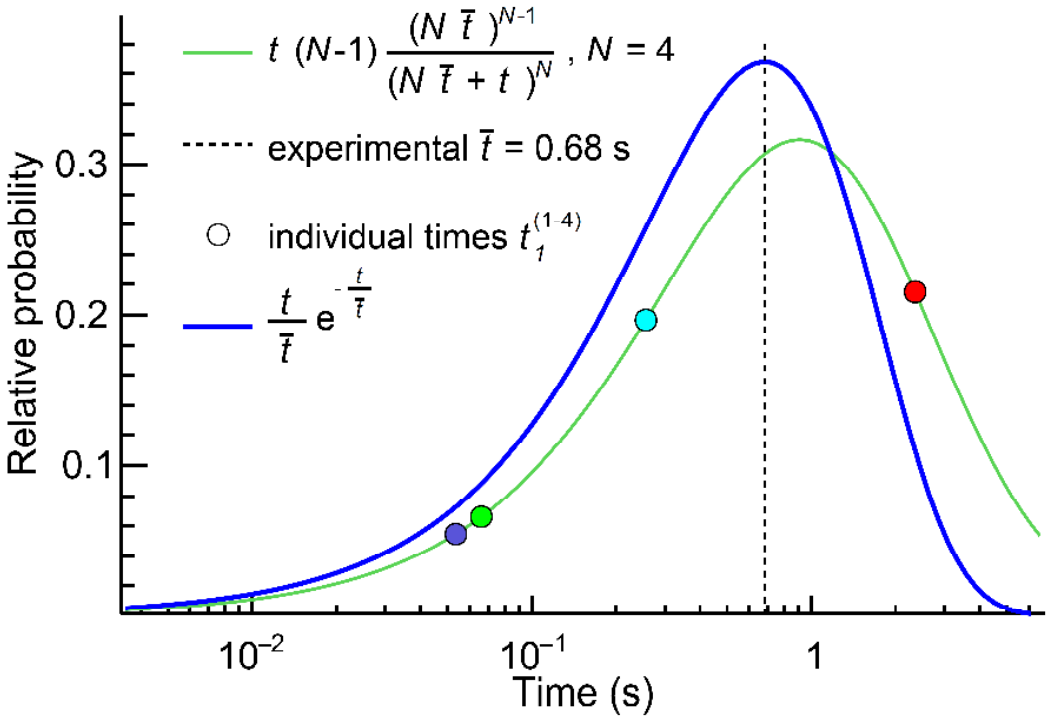
FoM for set = arithmetic average over all chains

Extended test

τ uncertainty also taken into account!

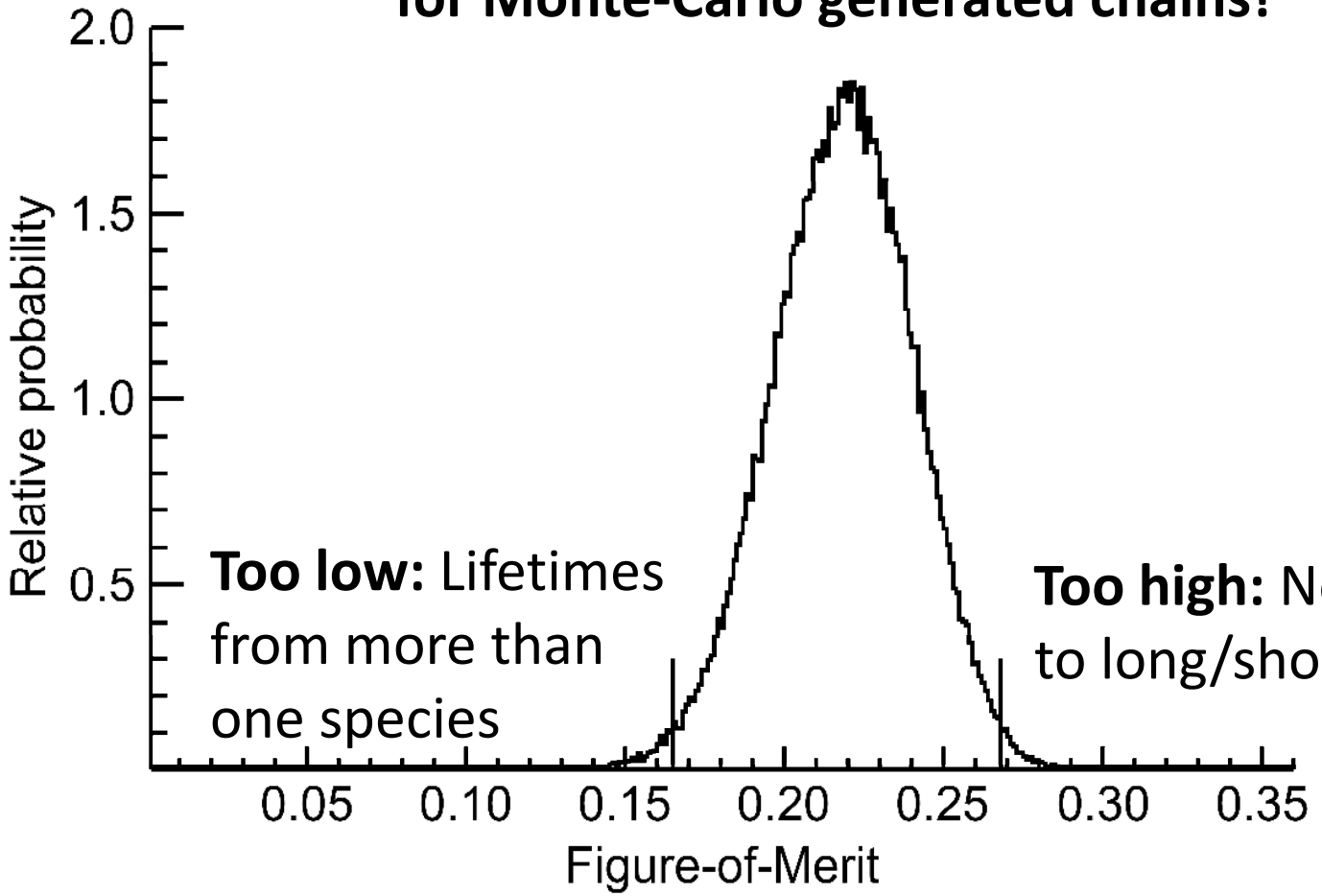
Likelihood function for τ
(N = 4, t_{avg}= 0.68 s)





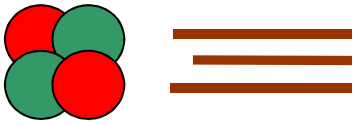
Extended test

Compare with distribution of FoM for Monte-Carlo generated chains!



Too low: Lifetimes from more than one species

Too high: Not sensitive to long/short times OR ”pruned”

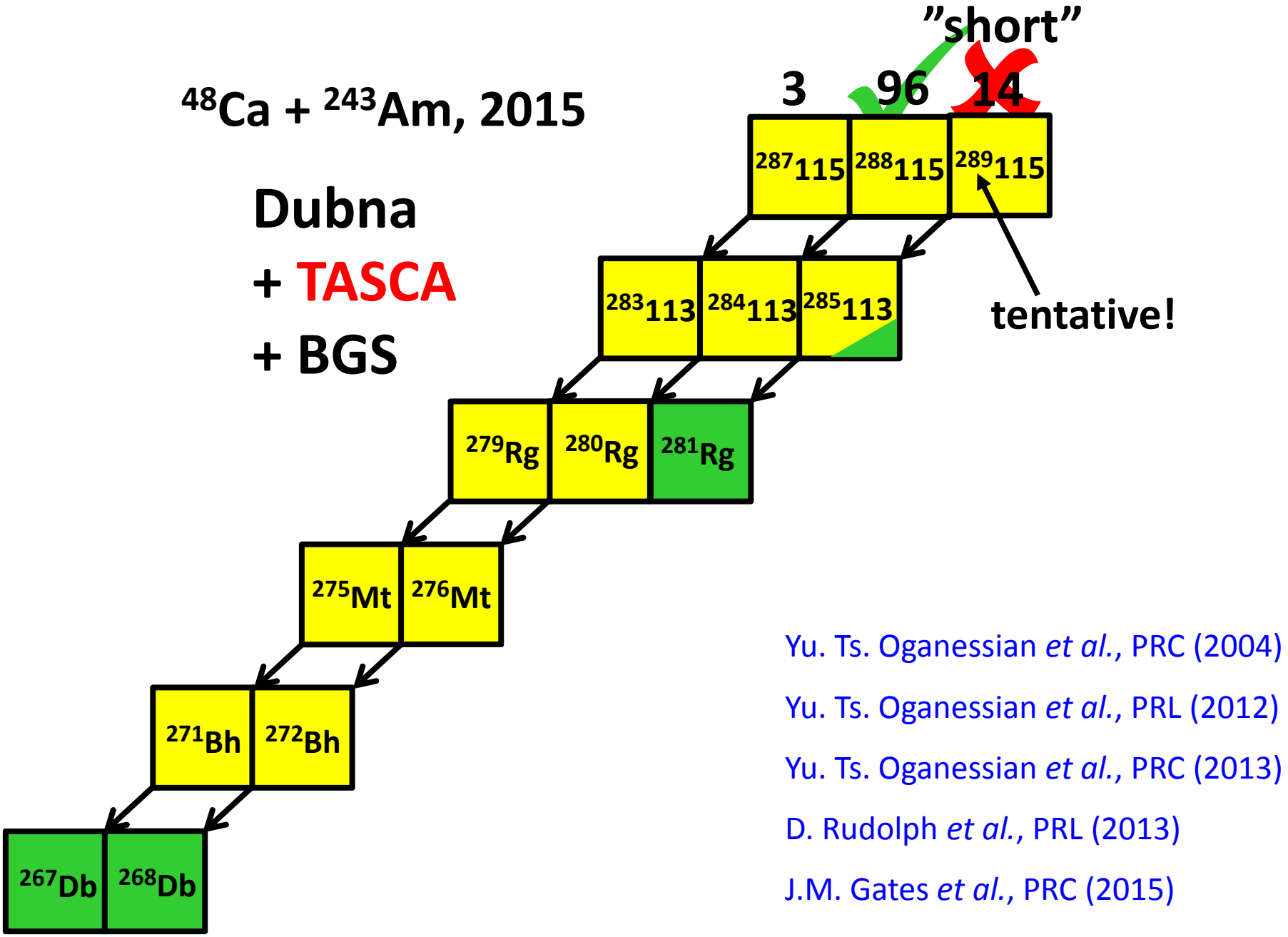


Extended test

Calculate experimental FoM –
Compare with MC-generated chains

Geometric over each chain –
Arithmetic over sets of chains

Uses information from entire chains
Chains with missing members can be included



Yu. Ts. Oganessian *et al.*, PRC (2004)

Yu. Ts. Oganessian *et al.*, PRL (2012)

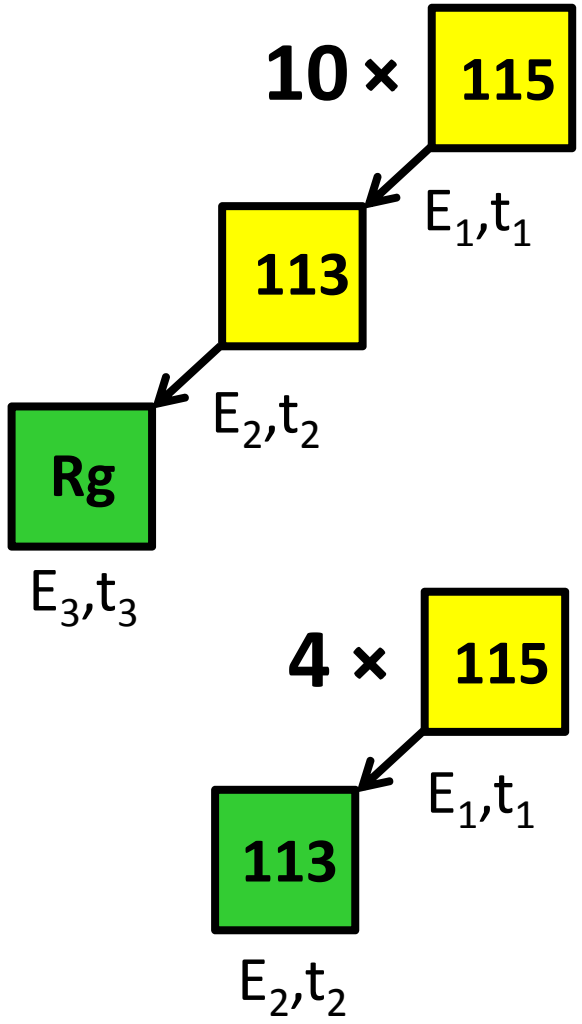
Yu. Ts. Oganessian *et al.*, PRC (2013)

D. Rudolph *et al.*, PRL (2013)

J.M. Gates *et al.*, PRC (2015)

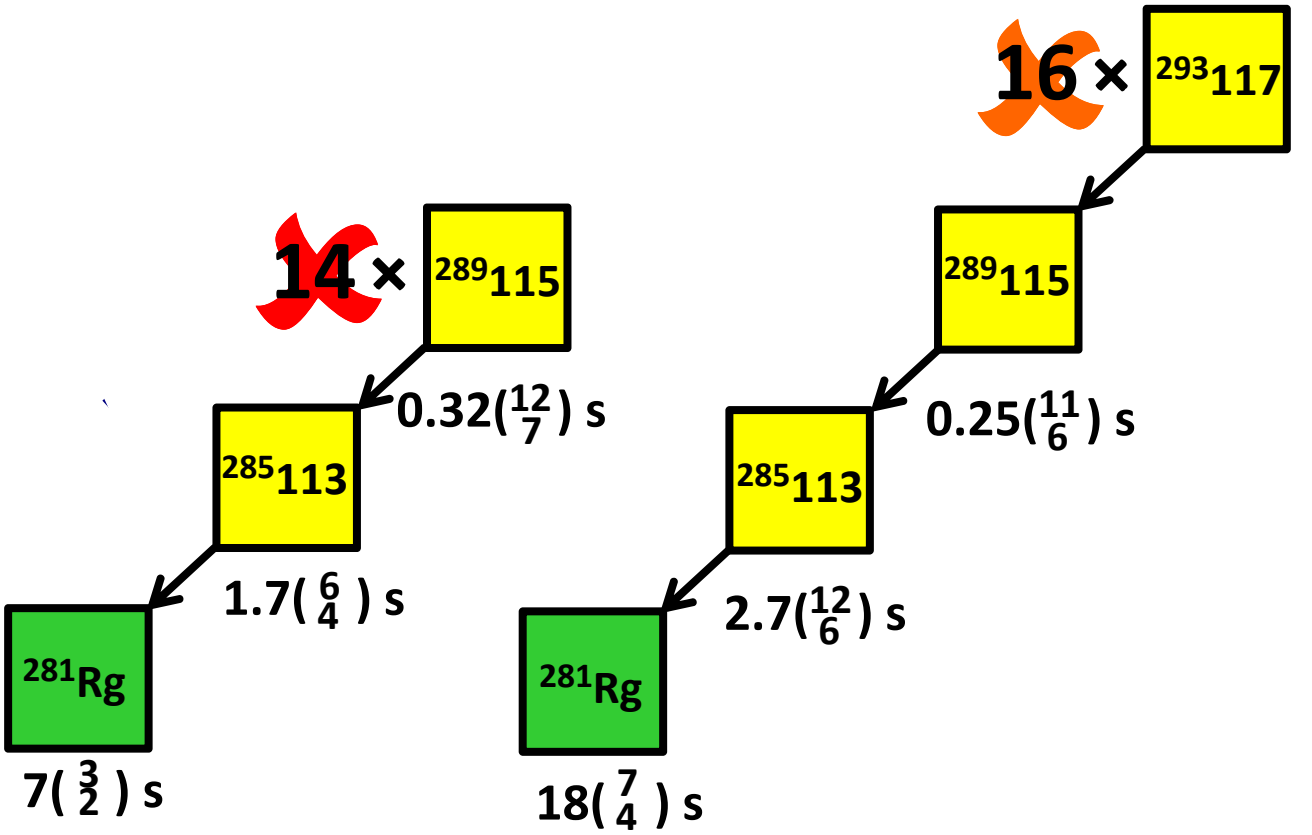
World data set of short E115 chains

	No.	E_1 (MeV) Δt_1 (s)	E_2 (MeV) Δt_2 (s)	E_3 (MeV) Δt_3 (s)
TASCA	T1	**10.51(1)**	**242**^{a}	
		0.227	**0.378**	
	T2	**1.45(1)**^{b}	**211**	
		0.0645	**0.366**	
	T3	10.54(4)^c	**9.95(5)**^{c}	**196**
		0.261	**1.15**	**0.343**
	T4	10.34(1)	**9.89(1)**	**218**^{a}
		1.46	**0.0262**	**0.432**
	T5	**10.49(4)**^{c}	**9.97(1)**	**135**
		0.345	**0.369**	**14.4**
	T6	**10.53(1)**	**9.89(5)**^{c}	**230**^{a}
		0.210	**1.05**	**8.27**
	T7	**0.541(3)**^{b}	3.12(1)^b	**230**^{a}
		0.815	2.33	**2.89**
Dubna	D1	10.377(62)	**9.886(62)**	**215.7**
		0.2562	**1.4027**	**1.9775**
	D2	10.540(123)^c	9.916(72)	**214.9**^{a}
		0.0661	1.5500	**2.3638**
	D3	10.373(50)	9.579(50)	141.1
		2.3507	22.5822	60.1855
	D4	10.292(170)^c	10.178(55)	**182.2**^{a}
		0.0536	0.4671	**0.0908**
BGS	B1	10.49(5)	9.82(2)	**107**
		0.214	1.54	**7.57**
	B2	10.49(2)	**187**^{a}	
		0.0591	**0.824**	
	B3	10.22(2)	**128**	
		0.0455	**0.0142**	

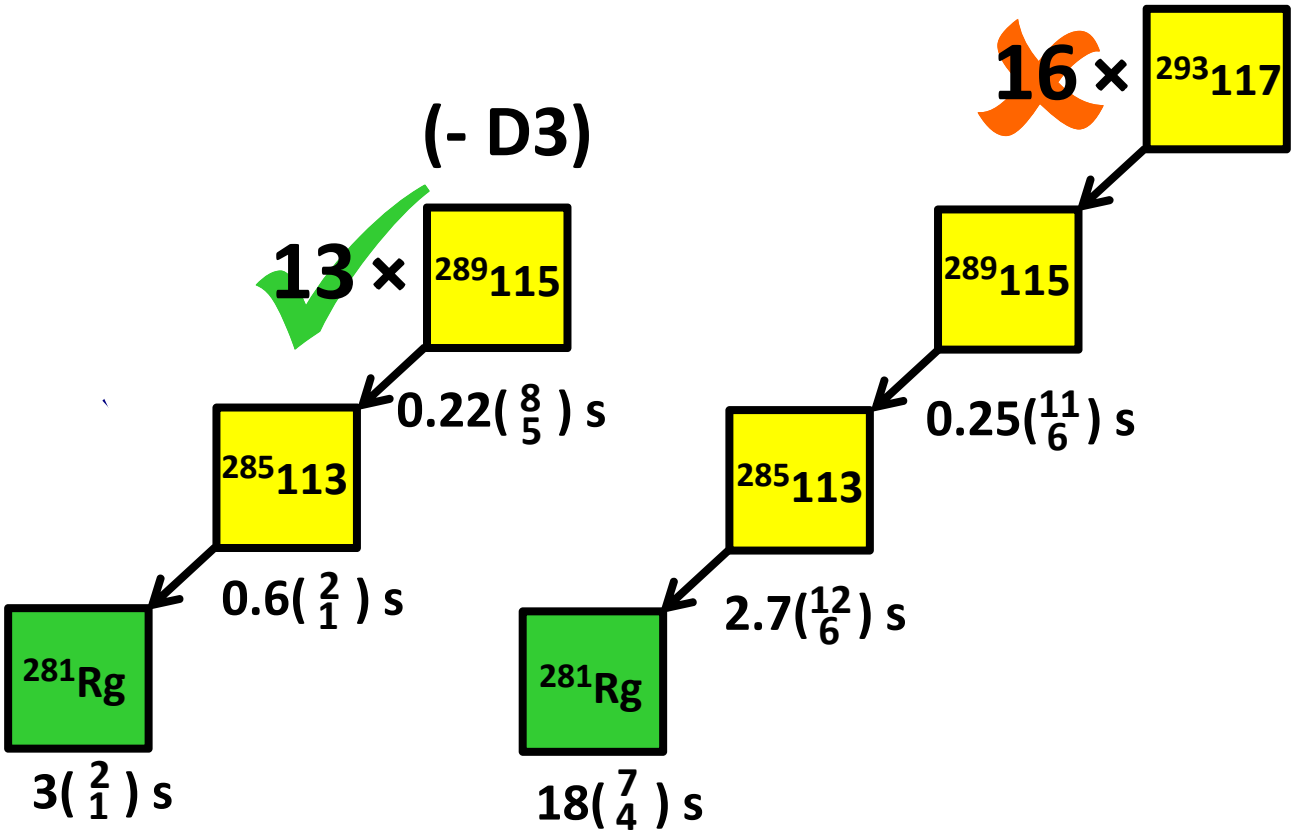


NOT a set of chains following the same decay path! (<1% error risk)

E115-E117 link

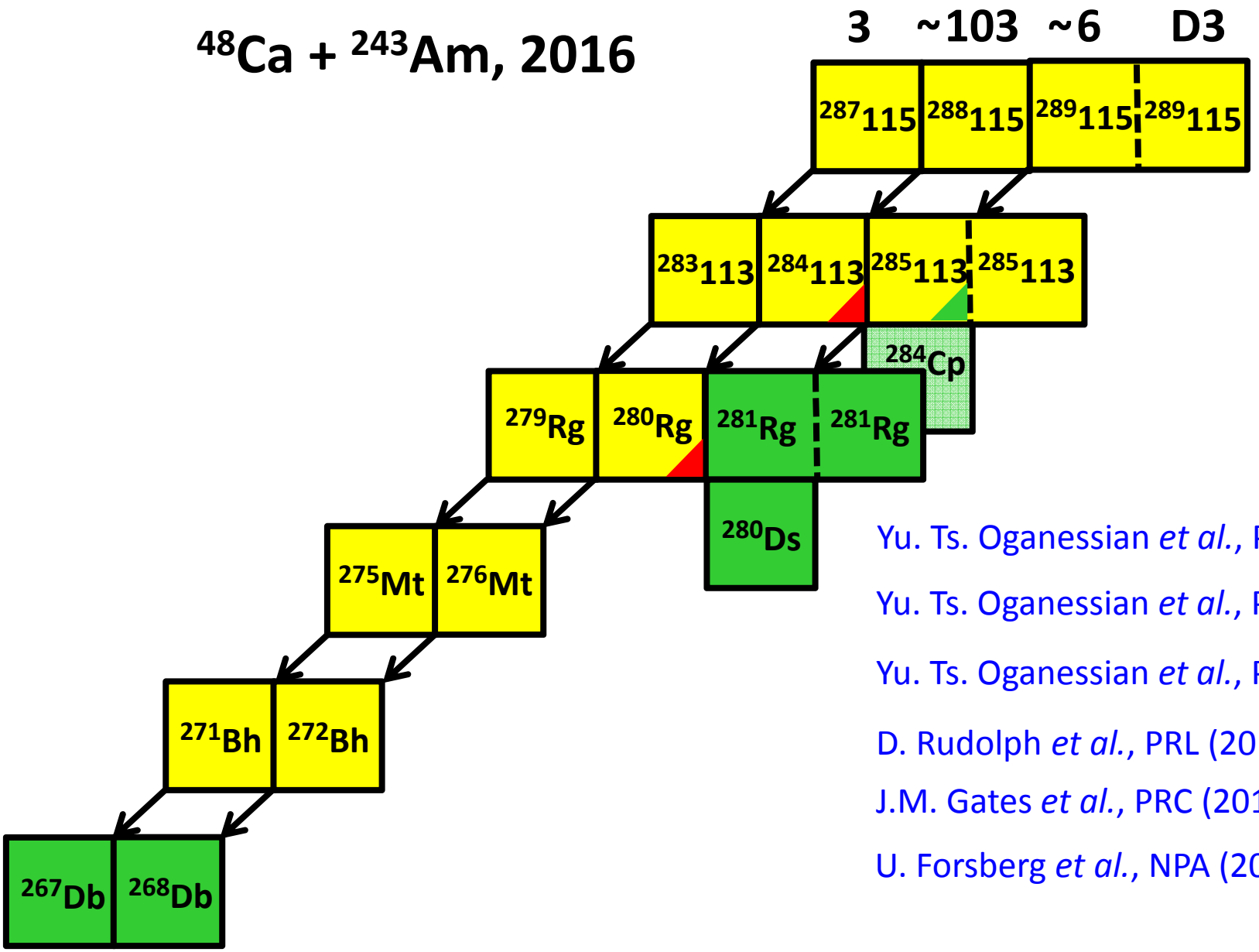


E115-E117 link



What are the short E115 chains?
Is there a link between E115 and E117?

P.J Karol *et al.*, Pure. Appl. Chem. (2016)



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J.M. Gates *et al.*, PRC (2015)

U. Forsberg *et al.*, NPA (2016)

Summary

Different decay modes, decays to excited (+ isomeric) states = complicated!

Low-statistics method developed to check congruence within sets of chains

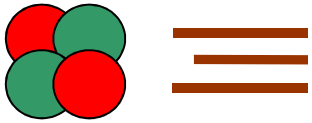
U. Forsberg et al., NPA (2016), U. Forsberg, PhD thesis (2016)

The proposed link between E115 and E117 is, most likely, missing

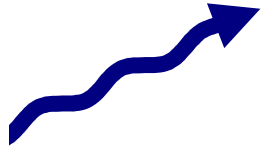
U. Forsberg et al., PLB (2016)

Re-interpretation of E115 short chains necessary

U. Forsberg et al., NPA (2016)



Outlook



Useful with a general congruence tester?

Alternative ideas? Can other chain features be included?