

Superheavy Element Search Campaign at TASCA

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for the **TASCA** and **TASISpec** collaboration

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“Nuclear Fission and Decay of Exotic Nuclei”
JAEA, TOKAI, Japan
March 21-22, 2013

The *TASCA* Collaboration



LBL/UCB Berkeley (USA)
LLNL Livermore (USA)
Vanderbilt U (USA)
ORNL Oak Ridge (USA)
U Liverpool (UK)
U Surrey (UK)
U Lund (Sweden)
JAEA Tokai (Japan)

U Jyväskylä (Finland)
U Oslo (Norway)
Chalmers U Gothenburg (Sweden)
PSI Villigen/U Berne (Switzerland)
ITE Warschau (Poland)
SINP Kolkata (India)
IMP Lanzhou (China)
ANU Canberra (Australia)

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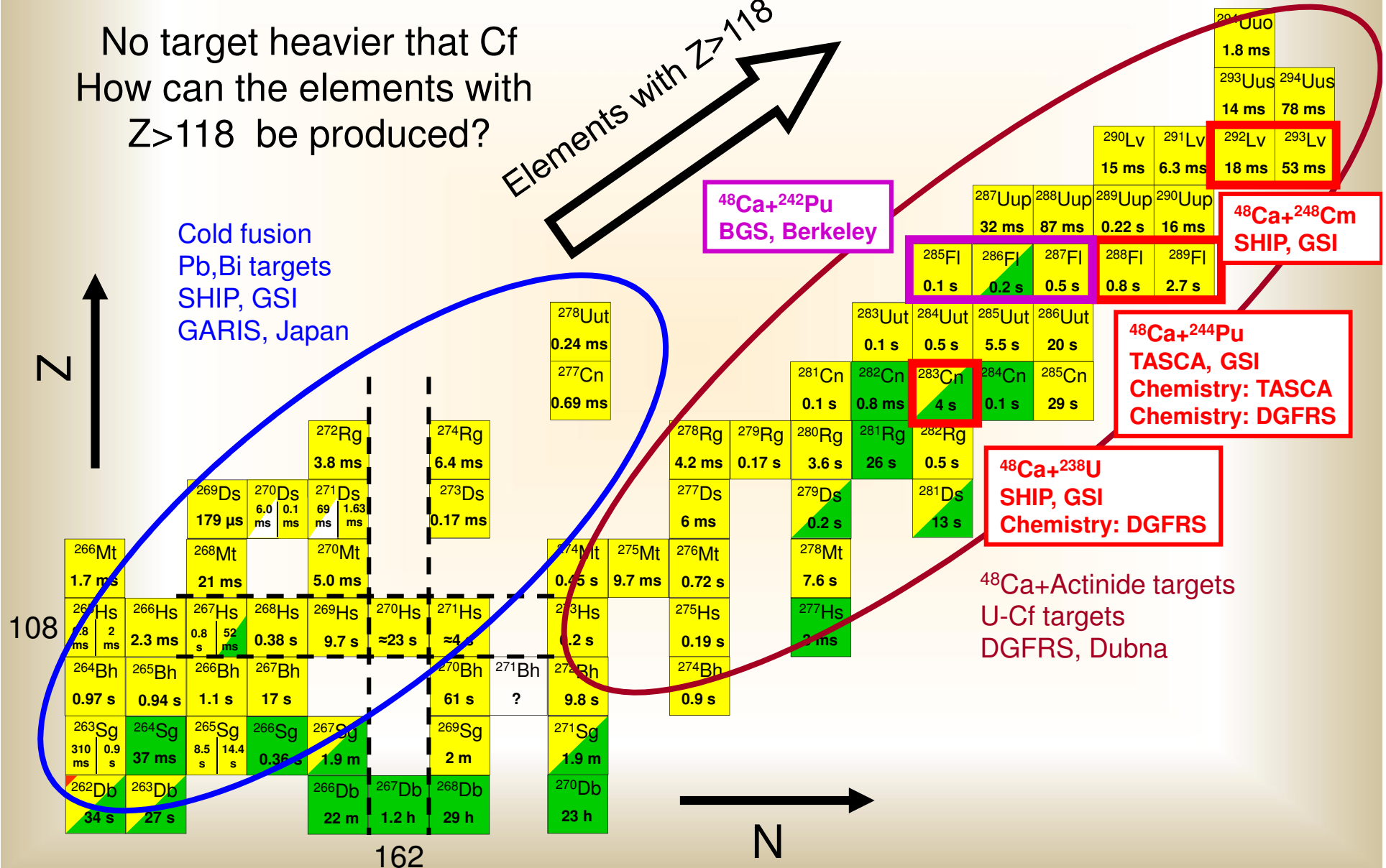
Present status on SHE

Theory: Spherical nuclei
 $N=184$ and $Z=114, 120, 126$?

No target heavier than Cf
 How can the elements with $Z > 118$ be produced?

Elements with $Z > 118$

Cold fusion
 Pb, Bi targets
 SHIP, GSI
 GARIS, Japan



Reactions for formation of element 119/120

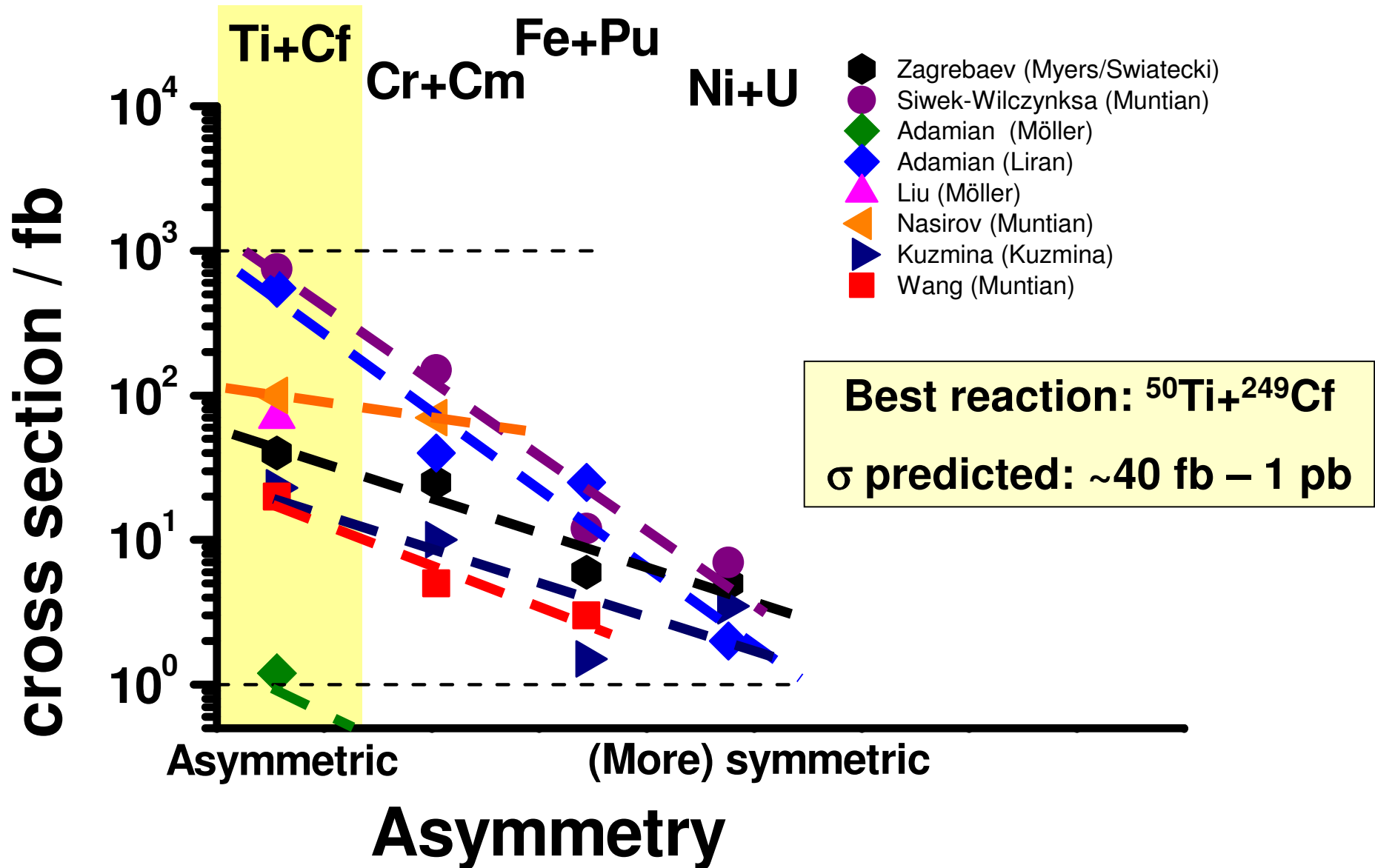
Element 119

Z_{Beam}	Beam	Target	$E^* @ B_{\text{Bass}}$
21	^{45}Sc	^{249}Cf	41.7
22	^{50}Ti	^{249}Bk	32.4
23	^{51}V	^{248}Cm	36.8
24	^{54}Cr	^{243}Am	31.5
25	^{55}Mn	^{244}Pu	37.7
26	^{58}Fe	^{237}Np	29.9
27	^{59}Co	^{238}U	36.7

Element 120

Z_{Beam}	Beam	Target	$E^* @ B_{\text{Bass}}$
21			
22	^{50}Ti	^{249}Cf	31.7
23	^{51}V	^{249}Bk	35.9
24	^{54}Cr	^{248}Cm	33.0
25	^{55}Mn	^{243}Am	34.5
26	^{58}Fe	^{244}Pu	33.9
27	^{59}Co	^{237}Np	32.9
28	^{64}Ni	^{238}U	27.3

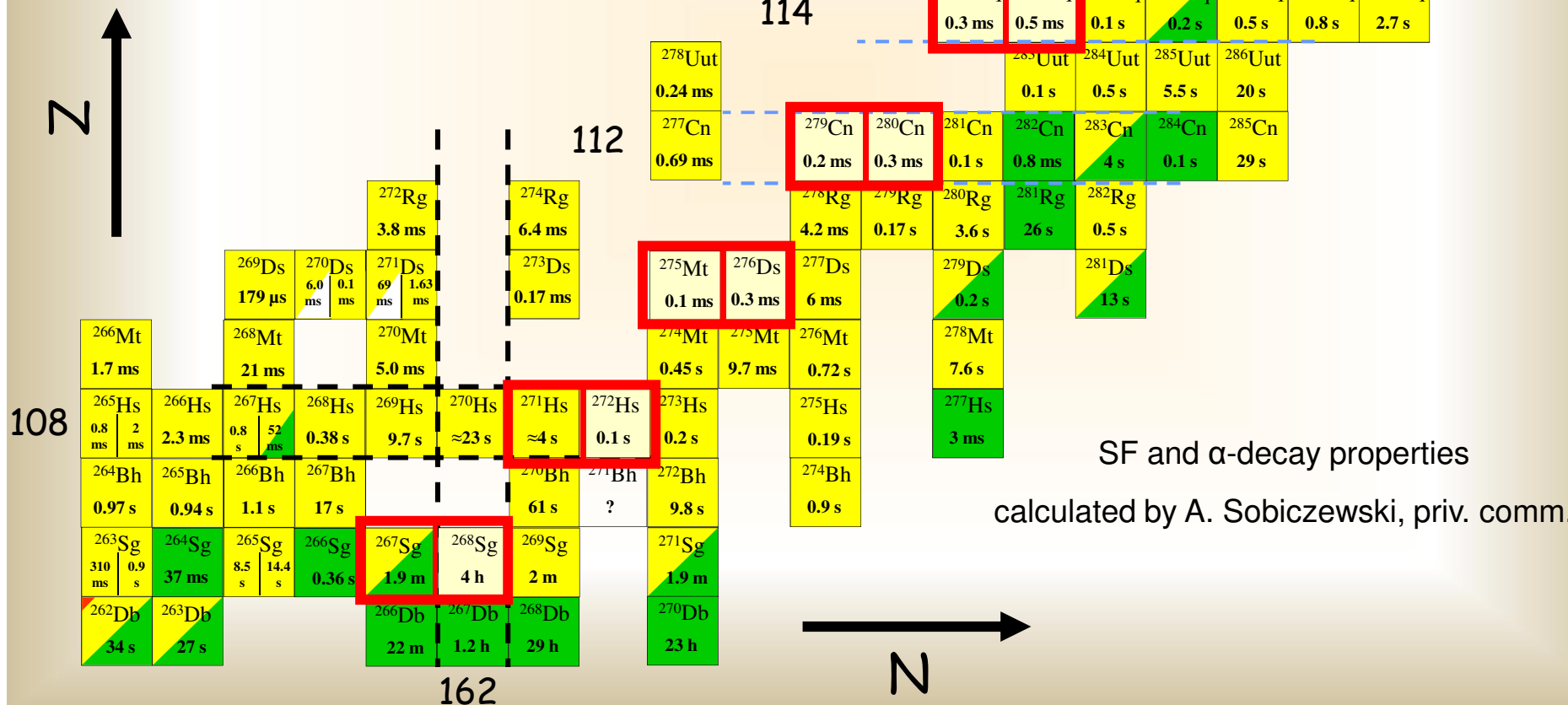
The reactions for production of the element 120



Expected decay chains from $^{295}_{120}$ and $^{296}_{120}$

Z=120

Half-life: order of μs

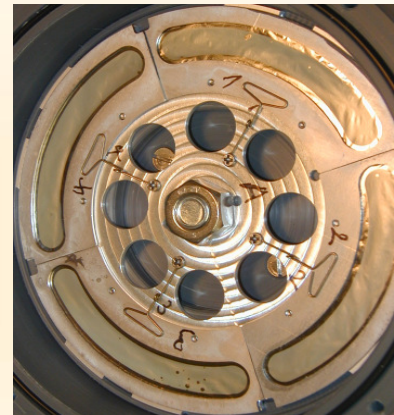
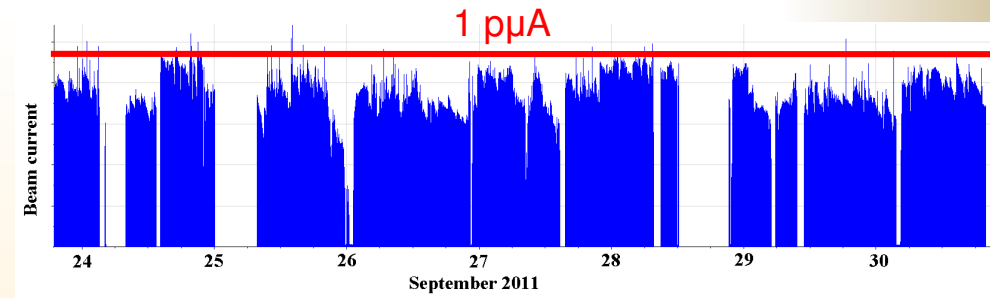


SF and α -decay properties
calculated by A. Sobczewski, priv. comm.

Experimental setup

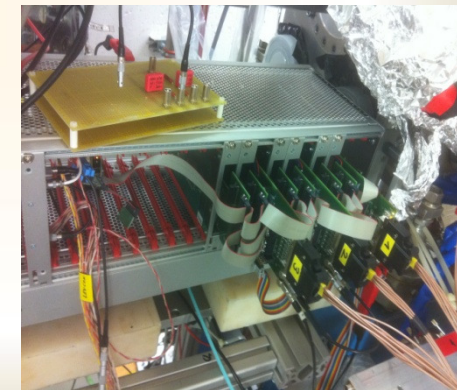
Experimental challenges

- ✓ 1) Stable and reliable ^{50}Ti beam
Ion source + UNILAC groups, Target lab
GSI + HIM
- ✓ 2) New target wheel for high intensity beam
TASCA, GSI experimental electronics
- ✓ 3) Production of ^{249}Cf and ^{249}Bk targets
LBNL, Berkeley; ORNL, Oak Ridge;
Inst. Nuclear Chemistry Uni Mainz; GSI target lab
- ✓ 4) New „fast“ electronics for μs -activities
GSI experimental electronics, Univ. Lund, Sweden, HIM
- ✓ 5) Improved background suppression and charge state predictions of heavy ions at **TASCA**
TASCA, GSI and LBNL, Berkeley, USA



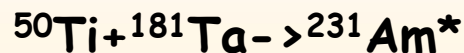
Ø Target Wheel: 100 mm
Ø Beam Spot: 8 mm

Tested with ^{40}Ar up to
2500 particle-nA on $^{\text{nat}}\text{Gd}$



Preparatory experiments

Preparatory experiments

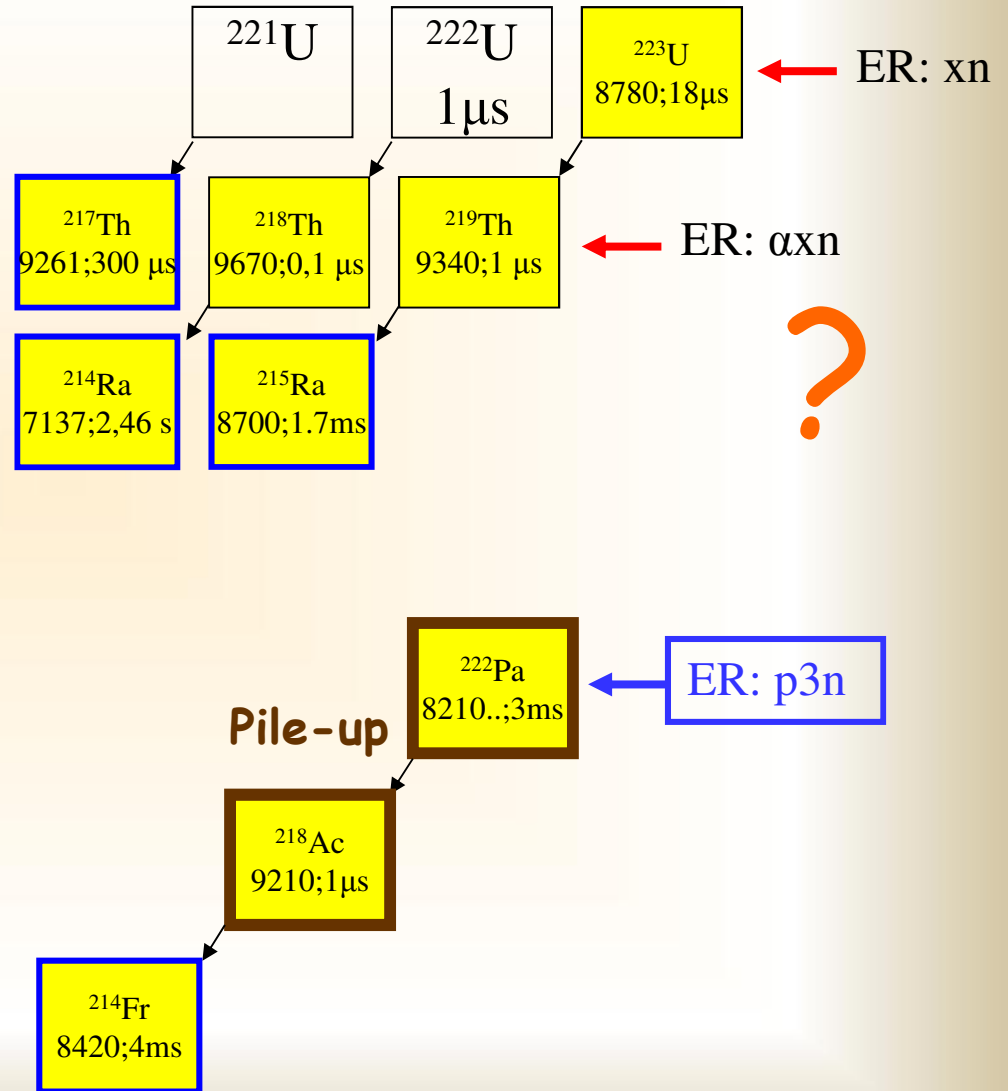
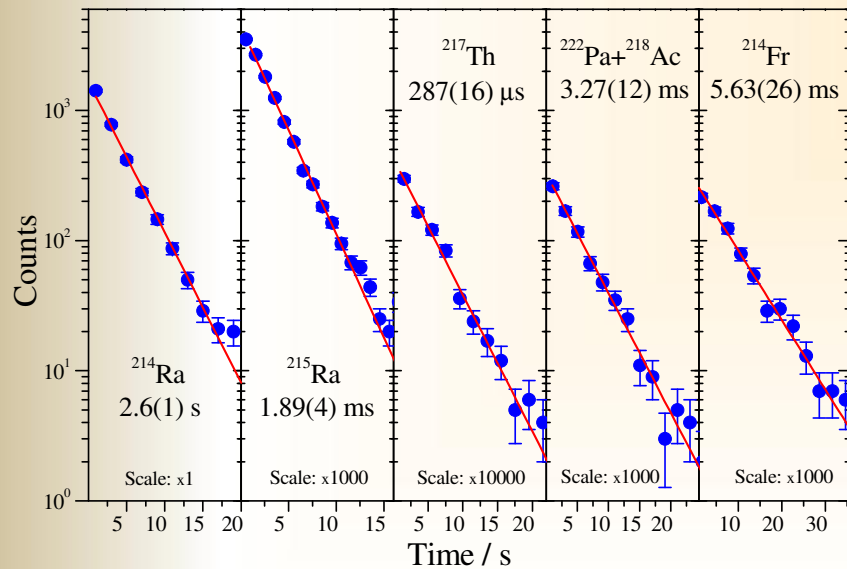
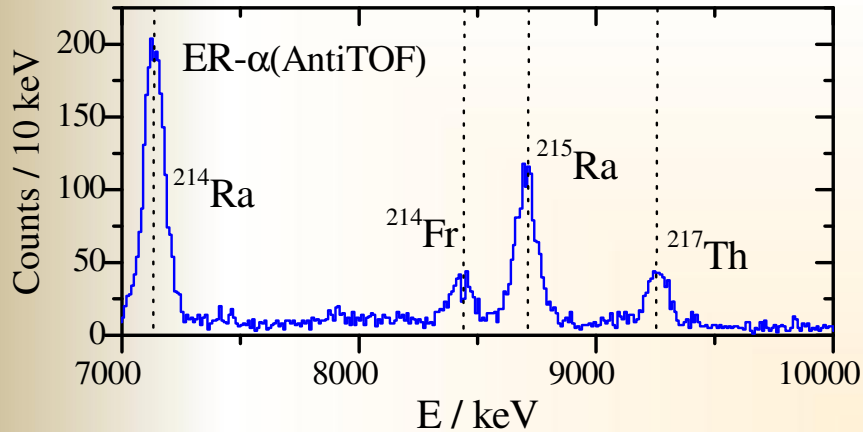


		U		5n		4n		Compound nucleus									
		92		U 218		U 219		U 222		U 223		U 224		U 225		U 226	
		0.56m 0.51m		80 μs		1 μs		0.7 ms		59 ms		281 ms					
		α 10.678; α 8.612		α 9.77		α		α 8.47		α 7.86; 7.83;		α 7.56; 7.37;					
Pa 214	Pa 215	Pa 216	Pa 217	Pa 218	Pa 219	Pa 220	Pa 221	Pa 222	Pa 223	Pa 224	Pa 225	Pa 226	Pa 227	Pa 228	Pa 229	Pa 230	Pa 231
17 ms	14 ms	200 ms	1.5 ms 3.4 ms	0.78 μs	5.9 μs	4.3 ms	4 μs	0.95 s	0.8 s								
α 8.12	α 8.09	α 7.87; 7.81...; γ	α 10.16; 9.55...; α 8.33	α 9.61; 9.54; γ	α 9.90	α 9.65	α 9.08; g	α 8.21; 8.54...	α 8.01; 8.20	α 7.555; 7.460	α 7.5; 7.20						
Th 213	Th 214	Th 215	Th 216	Th 217	Th 218	Th 219	Th 220	Th 221	Th 222	Th 223	Th 224	Th 225	Th 226	Th 227	Th 228	Th 229	Th 230
1.7 μs	0.14 s	1.24 μs	80 ms	1.2 s	0.18 ms 28 ms	247 μs	0.1 μs	1.05 μs	1.05 μs	1.05 μs	1.05 μs	1.05 μs	1.05 μs	1.05 μs	1.05 μs	1.05 μs	1.05 μs
lγ 799; 382	α 7.69	lγ 623; 639; 830; α 7.68	α 7.52; 7.39;	lγ α 9.91	α 7.92; 7.30; γ	α 9.27; 8.73;	α 9.67	α 9.34	α 8.79	α 8.15; 8.47...	α 7.98; 7.60	α 7.324; 7.285...; γ 177; 152; 114...	α 7.17; 7.00; γ 177...; e ⁻				
Ac 212	Ac 213	Ac 214	Ac 215	Ac 216	Ac 217	Ac 218	Ac 219	Ac 220	Ac 221	Ac 222	Ac 223	Ac 224	Ac 225	Ac 226	Ac 227	Ac 228	Ac 229
880 ms	731 ms	8.2 s	0.17 s	43 μs 440 μs	0.18 28 ms	1.1 μs	11.8 μs	26 ms	52 ms	63 s	5.0 s	2.10 m					
α 7.37	α 7.36	α 7.21; 7.08...; γ	α 7.60; 7.21...; γ	9.11...; α 9.05	lγ 660; α 10.54	α 9.65	α 9.205	8.664	α 7.85...; γ	α 7.65; 7.44...	α 6.81...; α 7.01...; lγ ?; e ⁻ ; g	α 6.647; 6.662...; e ⁻ ; γ (99, 191...)					
Ra 211	Ra 212	Ra 213	Ra 214	Ra 215	Ra 216	Ra 217	Ra 218	Ra 219	Ra 220	Ra 221	Ra 222	Ra 223	Ra 224	Ra 225	Ra 226	Ra 227	Ra 228
4.0 μs	13 s	10.5	13.0	2.1 ms 164.4 s	67 μs 2.46 s	0.6 μs 1.6 ms	0.19 μs 1.6 μs	25.6 μs	10 ms	18 ms	28 s	38 s					
lγ α 6.911...; γ; e ⁻ ?	lγ α 6.90; 6.27; γ; e ⁻ ?	lγ α 8.08...; e ⁻ ; γ	lγ α 7.14; 6.51; e ⁻ ; γ	α 8.9...; γ	α 9.35	α 8.99	α 8.39; g	α 7.679; 7.989...; γ 316, 214...	α 7.45; 7.39	α 6.613; 6.761...; γ 149...; C-14	α 6.559; 6.237...; γ 324...; C-14						

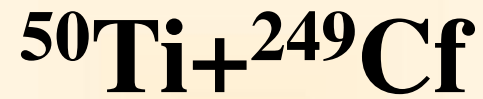
N=126

The reaction $^{50}\text{Ti} + ^{176}\text{Yb}$: Analog part of data

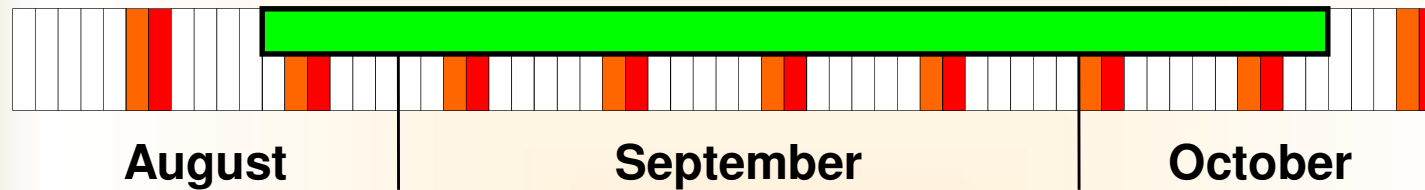
Correlation analysis: Analog electronics



Search for element 120

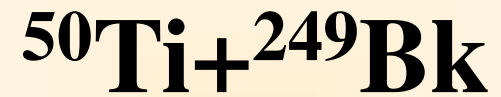


Search for element 120 (2011)

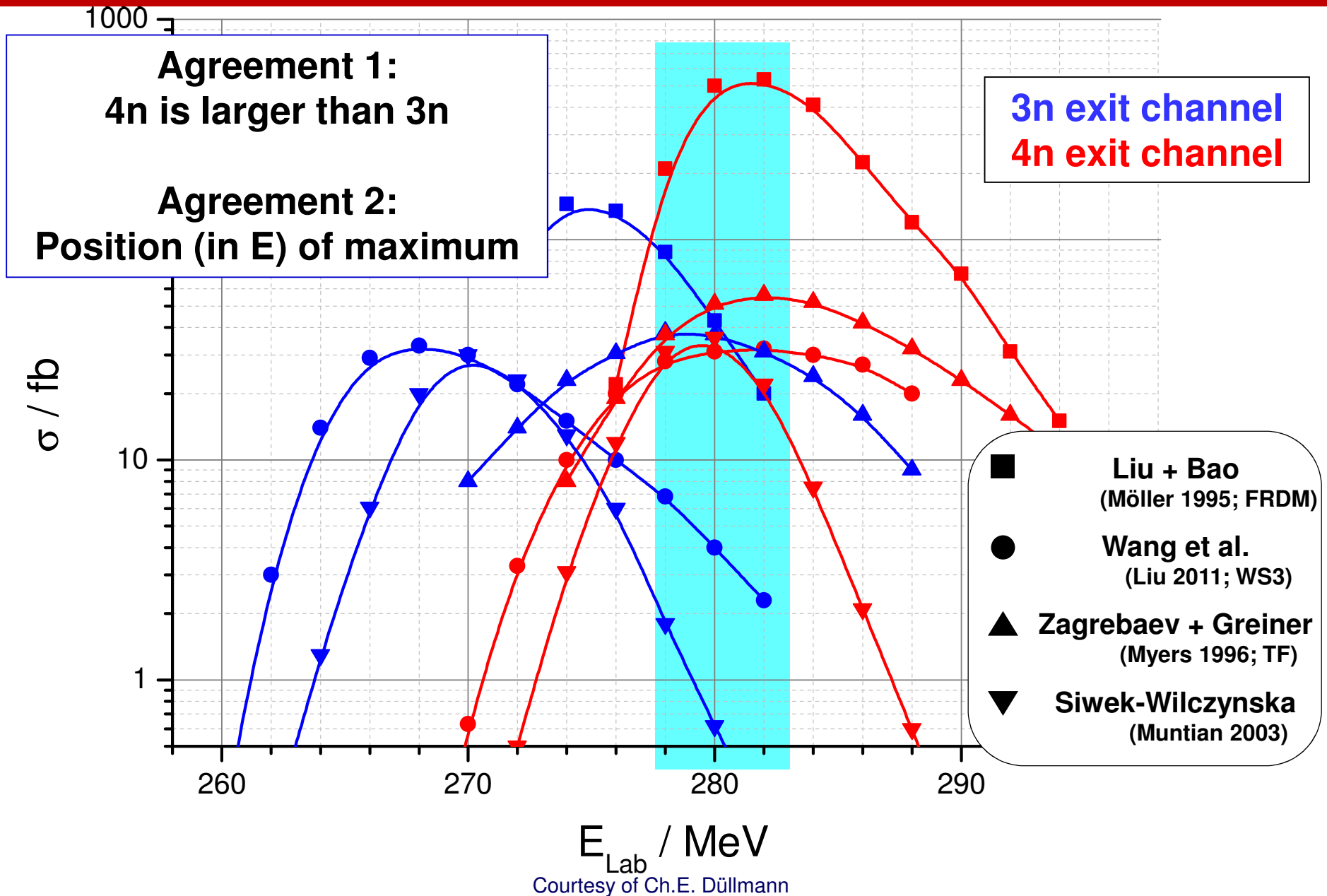


UNILAC operational for Cf ~39 days

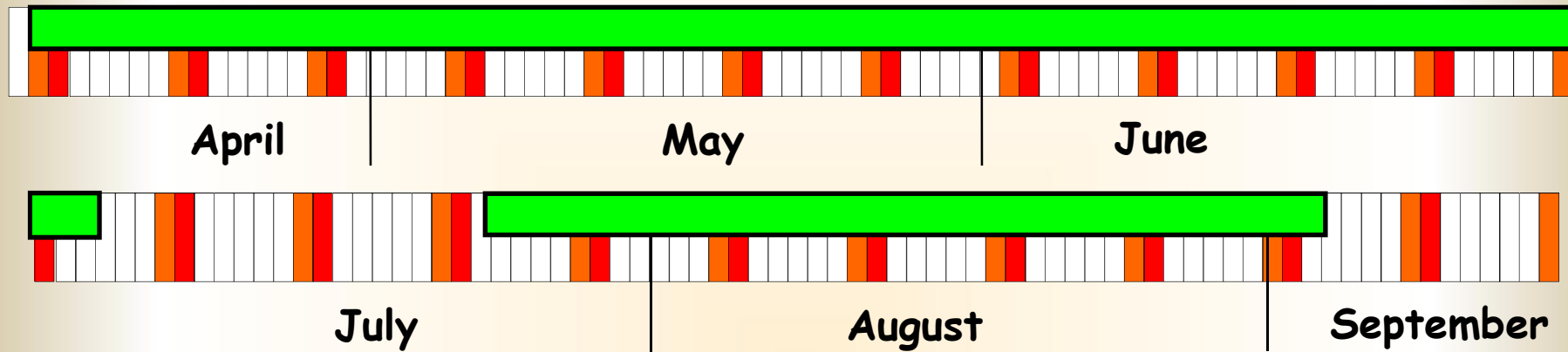
Search for element 119



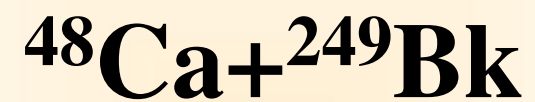
$^{50}\text{Ti} + ^{249}\text{Bk}$ Excitation Function



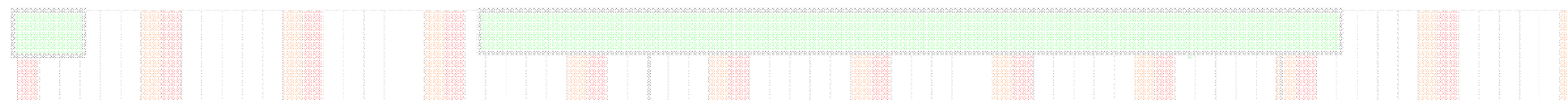
Search for element 119 (2012)



Production of element 117



Production of element 117



July

August

September



X-ray spectroscopy of element 115
 $^{48}\text{Ca}+^{243}\text{Am}$

TASiSpec

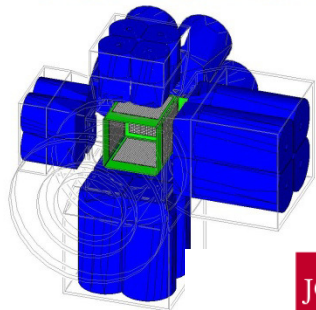
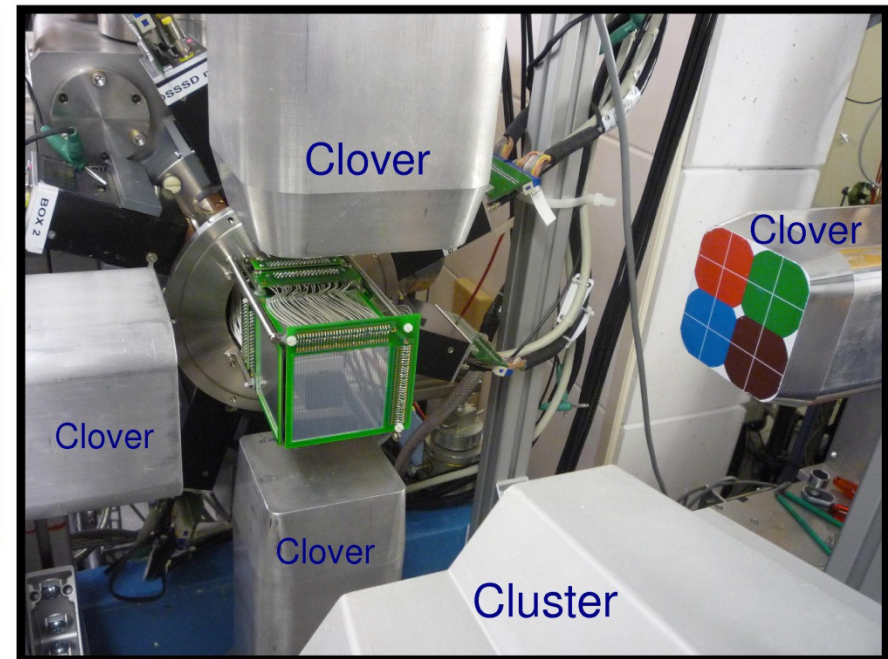
Highly efficient multi-coincidence spectroscopy set-up
for TASCAs very compact focal plane image

1 Implantation DSSSD (1024 pixels)
4 box-DSSSDs (1024 pixels)
=> ~80% α -detection efficiency

4 Ge Clover (4*4 crystals)
1 Ge Cluster (7 crystals)
=> ~40% γ -detection eff. at 150 keV

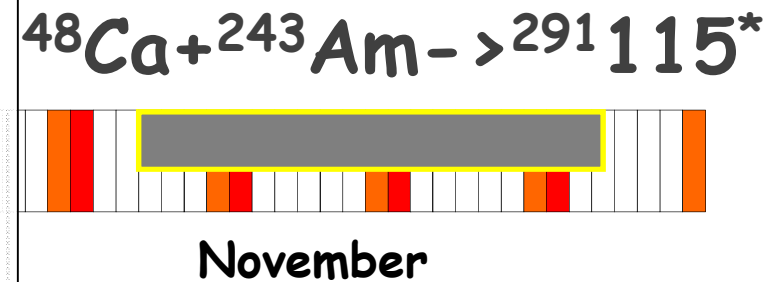
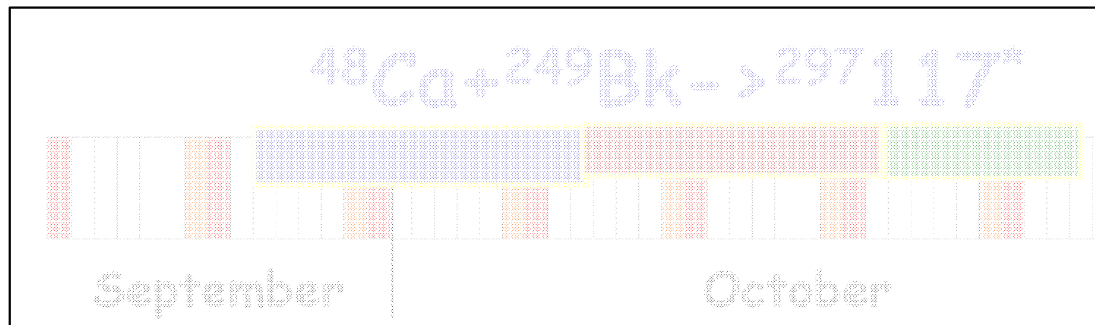
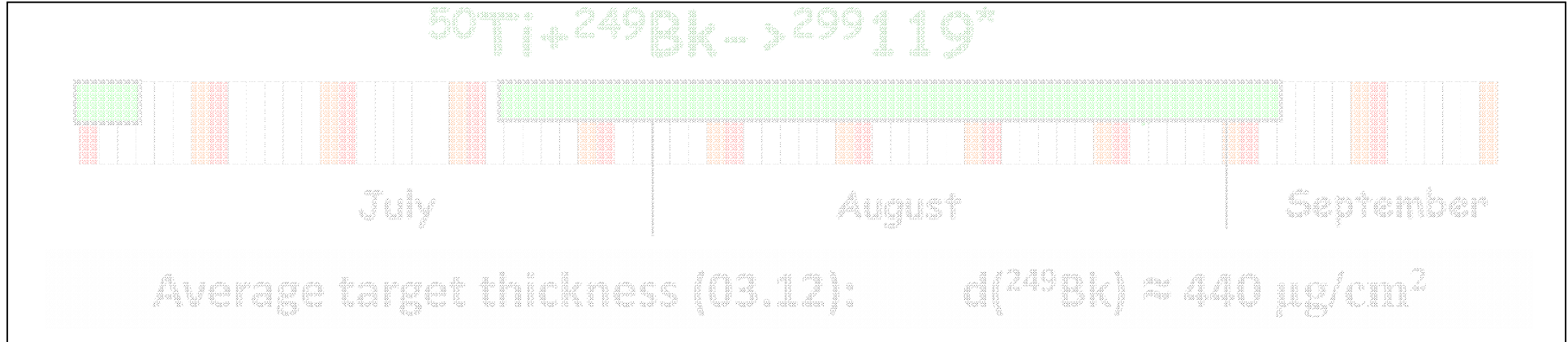
L-L Andersson et al., NIM A 622, 164 (2010)

L.G. Sarmiento et al., NIM A 667, 26 (2011)



Virtually constructed with GEANT4 simulation package

Production of the element 115



Summary and Outlook

- **Superheavy** experiments 2011/12:
 - focus: **search for elements 119 / 120** in ^{50}Ti induced reactions
 - check **element 117**
 - direct **Z measurement of $^{48}\text{Ca}+^{243}\text{Am}$ chains** (TASISpec)