

MAGISOL decay experiments in 2015

A tale of two studies of β -delayed p -emission

Jacob G. Johansen

on behalf of the IS507 and IS541 collaborations

Aarhus University

December 4th 2015



The two experiments

IS507

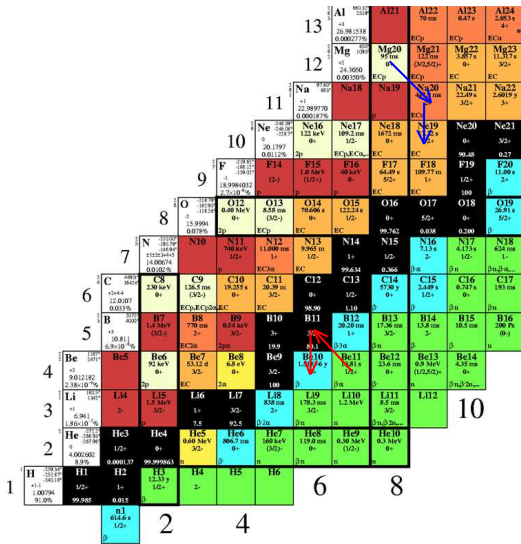


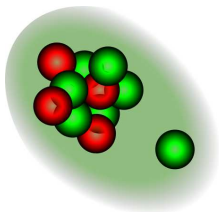
- Performed April 2015
- Second part of IS507
- * Morten V. Lund

IS541

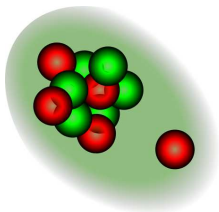


- Performed May 2015
- Second part of IS541
- * Karsten V. Riisager

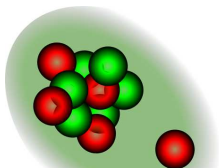




		C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
6	C	2.30 keV 0+	136.5 ms (3/2-)	19.255 s 0+	20.39 m 3/2-	0+	1/2-	57.90 y 0+	2.649 s 1/2+	0.747 s 0+	193 ms 0+
		EC, β^+ , EC, β^+ , EC	EC	EC	EC	98.90	1.10	β	β	β , n	β , n
5	B	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
		1.4 MeV (3/2-)	770 ms 2+	6.54 keV 3/2-	3-	3+	20.50 ms 1+	17.50 ms 3/2-	13.4 ms 2+	10.5 ms β	200 fs (0-)
		EC, β^+	EC, β^+	EC, β^+	EC, β^+	EC, β^+	EC, β^+	EC, β^+	EC, β^+	EC, β^+	EC, β^+
4	Be	Be5	Be6	Be7	Be8	Be9	Be10	Be11	Be12	Be13	Be14
		92 keV 0+	53.12 d 0+	6.8 eV 0+	3/2-	3/2-	1.57 s 1/2+	10.81 s 1/2+	23.6 ms 0+	0.9 MeV (1/2, 5/2)+	4.35 ms 0+
		EC	EC	EC	EC	EC	EC	EC	EC	EC	EC
3	Li	L4	L5	L6	L7	L8	L9	L10	L11	L12	
		2-	1.5 MeV 3/2-	1+	3/2-	2+	3/2-	1.2 MeV 3/2-	8.5 ms 3/2-	β , n, β , 2n...	
		EC	EC	EC	EC	EC	EC	EC	EC	EC	
2	He	He3	He4	He5	He6	He7	He8	He9	He10		
		1/2+	0+	0.69 MeV 3/2-	806.7 ms 3/2-	160 keV (3/2)	119.8 ms 0+	0.39 MeV (1/2-)	0.3 MeV 0+		
		EC	EC	EC	EC	EC	EC	EC	EC		
1	H	H1	H2	H3	H4	H5	H6				
		1/2+	1-	12.33 y 1/2+	2-						
		EC	EC	EC	EC	EC	EC	EC	EC		
			n1 614.6 s 1/2+								
			β								

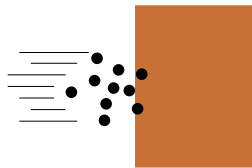


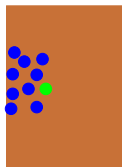
	C	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
6	4803 28410 +544 12.0107 0.033%	230 keV 0+	136.5 ms (3/2-)	19.255 s 0+	20.39 m 3/2-	0+	1/2-	5730 y 0+	2.649 s 1/2+	0.747 s 0+	193 ms 0+
		EC, β^+ , EC, β^+ , EC	EC	EC	98.90	1.10	β^-	β^-	β^-	β^-	β^-
5	B	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
	3705 4002 +3 10.811 5.9 $\times 10^{-8}\%$	1.4 MeV (3/2-)	770 ms 2+	6.54 keV 3/2-	3-	8.11 1.5 $\times 10^{-6}$ y 3+	20.50 ms 1+	17.50 ms 3/2-	13.4 ms 2-	10.5 ms β^-	200 fs (0-)
		EC, β^+ , EC, β^+ , EC	EC, β^+ , EC, β^+ , EC	EC, β^+ , EC, β^+ , EC	EC, β^+ , EC, β^+ , EC	β^-	β^-	β^-	β^-	β^-	β^-
4	Be	Be5	Be6	Be7	Be8	Be9	B10	Be11	Be12	Be13	Be14
	1500 3471 +2 9.012182 2.38 $\times 10^{-7}\%$	92 keV 0+	53.12 d 3/2-	6.8 eV 0+	3/2-	100	1.5 $\times 10^{-6}$ y 3+	10.81 s 1/2+	23.4 ms 0+	0.9 MeV (1/2, 5/2)+	4.35 ms 0+
		β^-	β^-	β^-	β^-	β^-	β^-	β^-	β^-	β^-	β^-
3	Li	L4	L5	L6	L7	L8	L9	L10	L11	L12	
	1875 3547 +3 6.941 1.80 $\times 10^{-9}\%$	2-	1.5 MeV 3/2-	1+	3/2-	858 ms 2+	178.3 ms 3/2-	1.2 MeV 3/2-	8.5 ms 3/2-	β^- , β^- , β^-	
		β^-	β^-	β^-	β^-	β^-	β^-	β^-	β^-	β^-	
2	He	He3	He4	He5	He6	He7	He8	He9	He10		
	710 3498 +2 4.002602 8.9%	0.00137	99.999863	0.69 MeV 3/2-	806.7 ms 3/2-	160 keV (3/2)	119.8 ms 0+	0.39 MeV (1/2-)	0.3 MeV 0+		
		β^-	β^-	β^-	β^-	β^-	β^-	β^-	β^-		
1	H	H1	H2	H3	H4	H5	H6				
	1008 1836 +1 1.00794 91.0%	1/2+	1-	12.33 y 1/2+	2-						
		β^-	β^-	β^-	β^-						
			n1 614.6 s 1/2+								



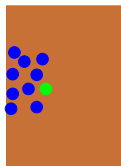
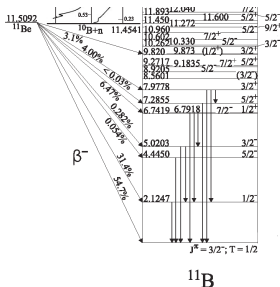
		C8		C9	C10	C11	C12	C13	C14	C15	C16	C17		
6		C	4803 28410	230 keV 0+	126.5 ms (3/2-)	19.255 s 0+	20.39 m 3/2-	0+	1/2-	5730 y 0+	2.649 s 1/2+	0.747 s 0+	193 ms 0+	
		ECp, EC, EC		EC	EC	98.90								
5		B	3205 4002	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	
			1.4 MeV (3/2-)	770 ms 2-	6.54 keV 3/2-	19.9 1/2+	3-	20.30 ms 1+	17.36 ms 3/2-	13.4 ms 2	10.3 ms 0+	10.3 ms 0+	200 fs (0-)	
		EC, 2n		2p	2p	2p								
4		Be	1201 3471	Be5	Be6	Be7	Be8	Be9	B10	Be11	Be12	Be13	Be14	
			9.012182 2.38x10 ⁻⁸ %	92 keV 0+	53.12 d 0+	6.8 eV 0+	6.8 eV 0+	3/2-	100	1.5 MeV 1/2+	10.81 s 1/2+	23.6 ms 0+	0.9 MeV (1/2, 5/2)+	4.35 ms 0+
		EC		2n	2n									
3		Li	1603 1307	L4	L5	L6	L7	L8	L9	L10	L11	L12		
			6.941 1.80x10 ⁻⁸ %	2-	1.5 MeV 3/2-	1+	3/2-	858 ms 2+	178.3 ms 3/2-	1.2 MeV 0+	8.5 ms 3/2-			
		n												
2		He	713 3453	He3	He4	He5	He6	He7	He8	He9	He10			
			4.002602 8.0%	1/2+	0+	0.69 MeV 3/2-	806.7 ms 3/2-	160 keV (3/2)	119.8 ms 0+	0.30 MeV (1/2-)	0.3 MeV 0+			
		0.000137		99.999863										
1		H	1008 1008	H1	H2	H3	H4	H5	H6					
			1.00784 91.0%	1/2+	1-	12.33 y 1/2+	2-							
		0.015												
				n1										
				614.6 s 1/2+										

- BR(Theoretical) = $3.0 \cdot 10^{-8}$ - D. Baye and E.M. Tursonov, Phys Lett B696 (2011) 464
- BR(Experimental) = $8.3(9) \cdot 10^{-6}$ - K. Riisager et al, Phys Lett B732 (2014) 305
- $E_p = 50 - 240$ keV - Hard to detect.

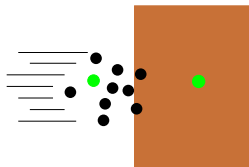
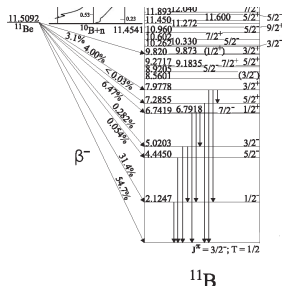




- $BR = \frac{N_{10\text{Be}}}{N_{11\text{Be}}}$
- $N_{10\text{Be}}$ measured using AMS at VERA, Vienna.
 - Beginning of next year by O. Forstner.
- $N_{11\text{Be}} = \frac{N_{2125\text{keV}}}{BR \epsilon (1-\tau)}$ 1xGe and 4xCsI.

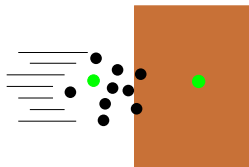
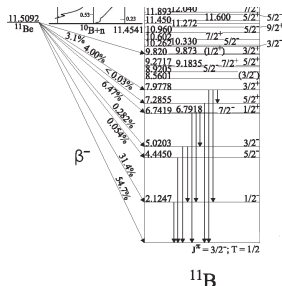


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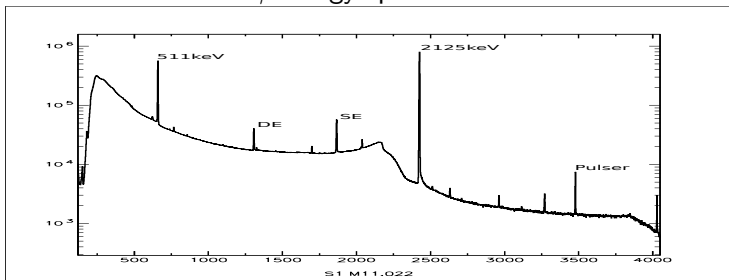


- Control of contaminations extremely important!! ($BR \sim 10^{-6}$)

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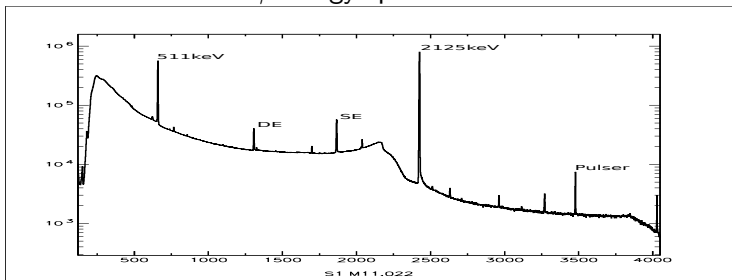


- Control of contaminations extremely important!! ($BR \sim 10^{-6}$)

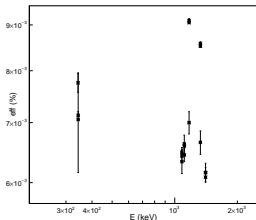
γ -energy spectrum:

Uncertainties:

$$\bullet \frac{\Delta N_{2125\text{keV}}}{N_{2125\text{keV}}} \approx 0.06\%$$

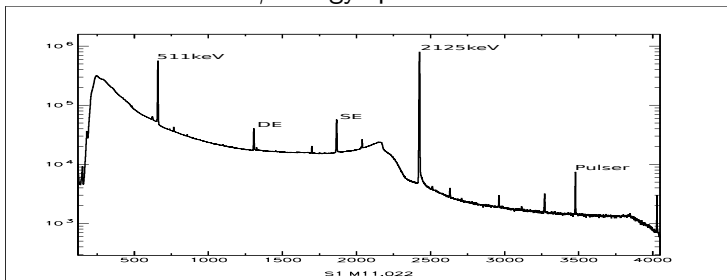
γ -energy spectrum:

Efficiency:

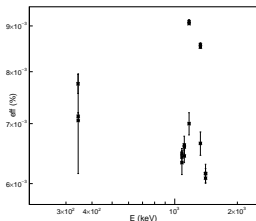


Uncertainties:

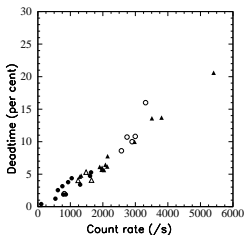
- $\frac{\Delta N_{2125\text{keV}}}{N_{2125\text{keV}}} \approx 0.06\%$
- $\frac{\Delta \epsilon}{\epsilon} \approx 3.7\%$

γ -energy spectrum:

Efficiency:



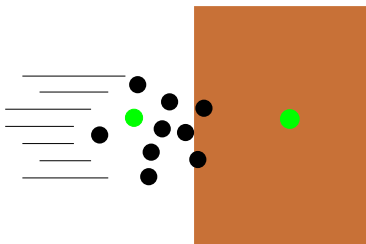
Deadtime:



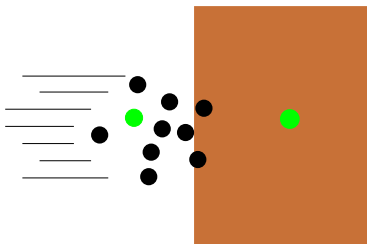
Uncertainties:

- $\frac{\Delta N_{2125\text{keV}}}{N_{2125\text{keV}}} \approx 0.06\%$
- $\frac{\Delta \epsilon}{\epsilon} \approx 3.7\%$
- $\frac{\Delta \tau}{\tau} \approx 3.5\%$
- $\frac{\Delta N_{11\text{Be}}}{N_{11\text{Be}}} \approx 6.5\%$

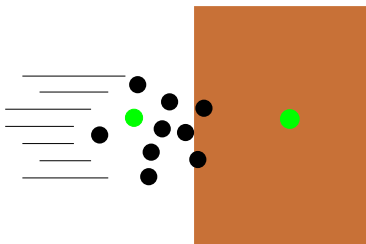
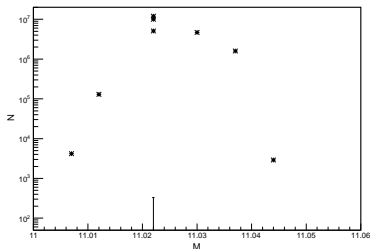
- ^{10}Be in the plate:
 - Pure copperplate
 - Blank sample
- Possible sources in beam:
 - $^{11}\text{Li}(\beta n)$ ($M = 11.044$)
 - ^{10}BeH ($M = 11.021$)
 - ^{10}Be ($M = 10.014$)



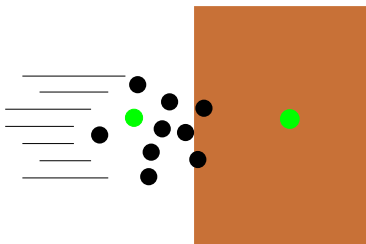
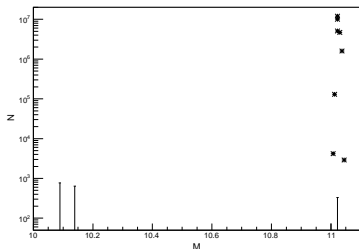
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 - ^{10}Be ($M = 10.014$)
- Measures to reduce inbeam sources
 - Slits - Lower all offmasses
 - RILIS - Destroys ^{10}BeH
 - Timedelay - ^{11}Li decay before transfer

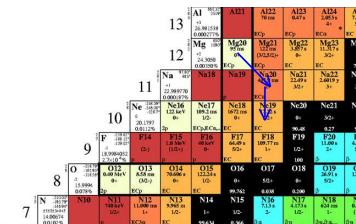
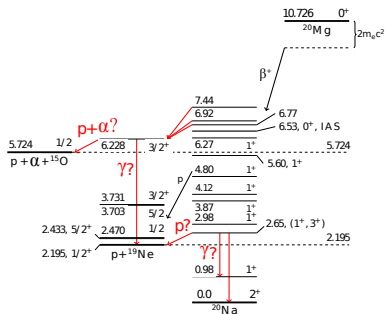


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 - Timedelay - ^{11}Li decay before transfer
 - Samples at different masses

Mass scan. $N_{11\text{Be}}$:

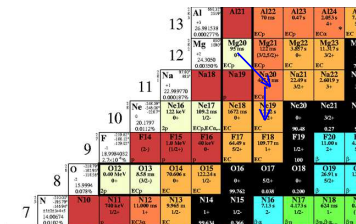
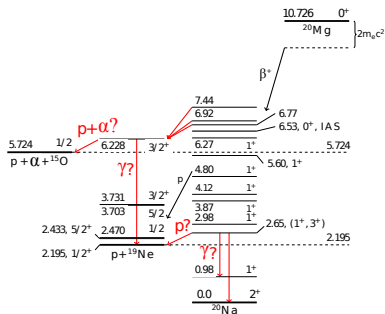
- ^{10}Be in the plate:
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Mass scan. $N_{11\text{Be}}$:



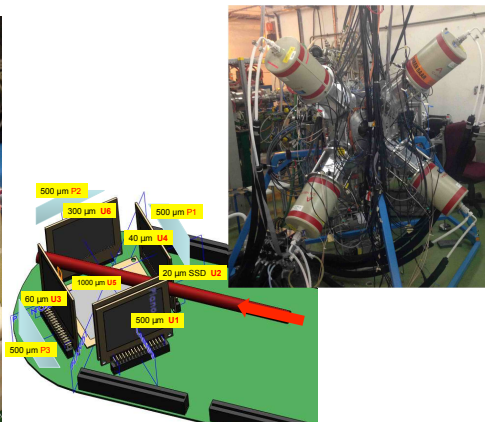
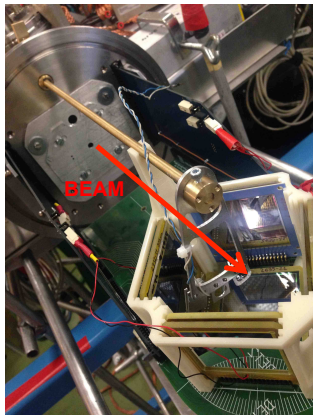
Hot CNO breakout: $^{15}\text{O}(\alpha, \gamma)^{19}\text{Ne}(p, \gamma)^{20}\text{Na}$

- $^{20}\text{Mg}(\beta\gamma)^{20}\text{Na}$
- $^{20}\text{Mg}(\beta p\gamma)^{19}\text{Ne}$
- $^{20}\text{Mg}(\beta p\alpha)^{15}\text{O}$
- $^{20}\text{Mg}(\beta\alpha p)^{15}\text{O}$



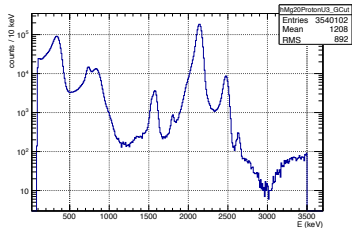
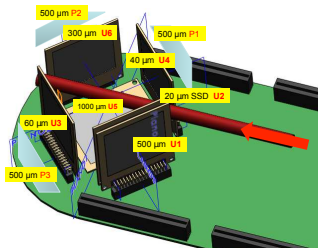
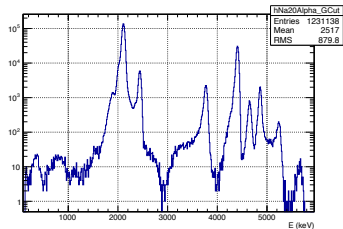
Hot CNO breakout: $^{15}\text{O}(\alpha, \gamma)^{19}\text{Ne}(p, \gamma)^{20}\text{Na}$

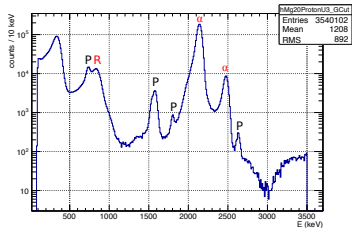
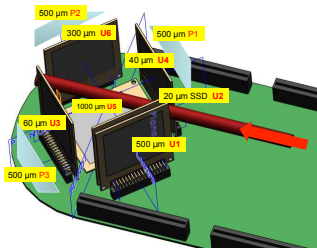
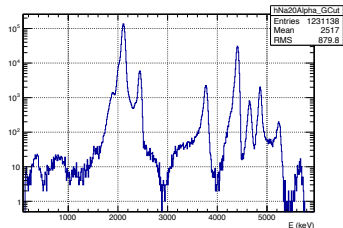
- $^{20}\text{Mg}(\beta\gamma)^{20}\text{Na}$ - Absolute normalisation
- $^{20}\text{Mg}(\beta p\gamma)^{19}\text{Ne}$
- $^{20}\text{Mg}(\beta p\alpha)^{15}\text{O}$
- $^{20}\text{Mg}(\beta\alpha p)^{15}\text{O}$

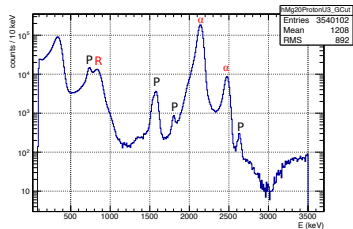
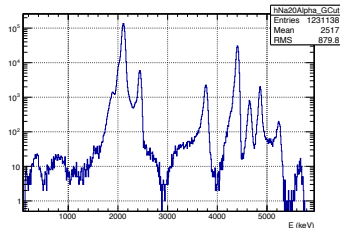
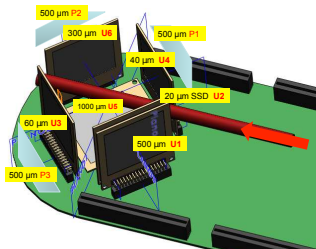
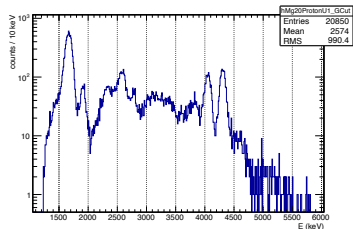


Beam @ target (70% transmission):

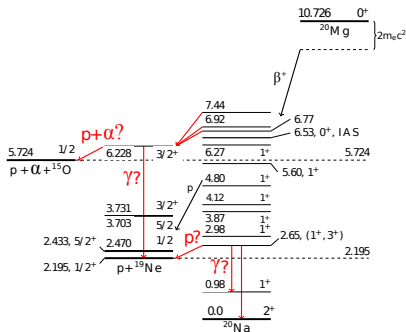
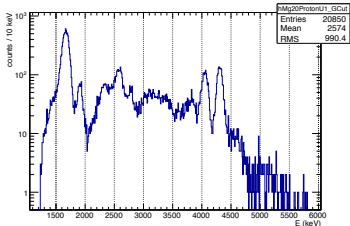
- ^{20}Mg : $I = 60 \text{ Hz}$ (p 's from $^{20}\text{Mg}(\beta p)$)
- ^{20}Na : $I = 500 \text{ Hz}$ (α 's from $^{20}\text{Na}(\beta\alpha)$)

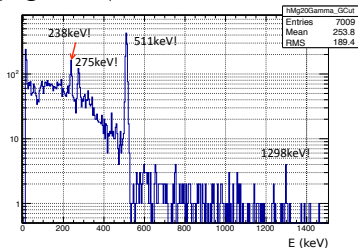
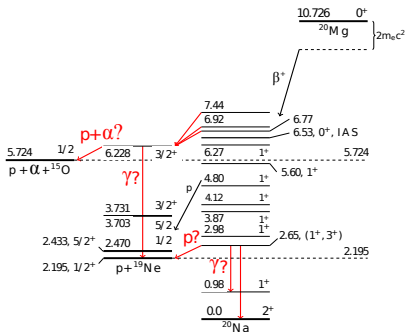
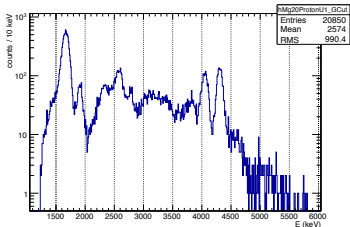
ΔE : ΔE (Coincidence with ^{16}O):

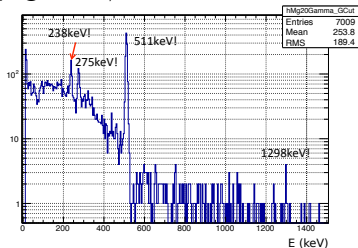
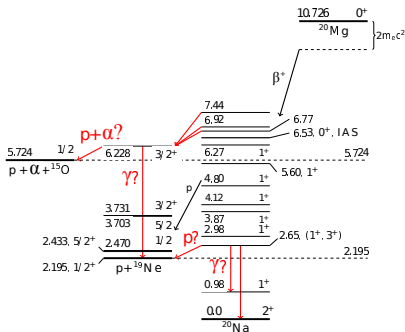
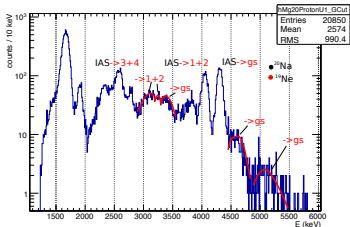
ΔE : ΔE (Coincidence with ¹⁶O):

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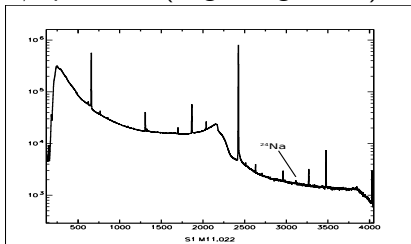
p -gated γ : $\Delta E + E$ for $E > 0$ (p):

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One more isotope for the coffee

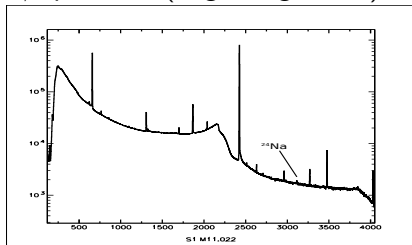
One more isotope for the coffee - ^{24}Na

γ -spectrum (beginning IS541):

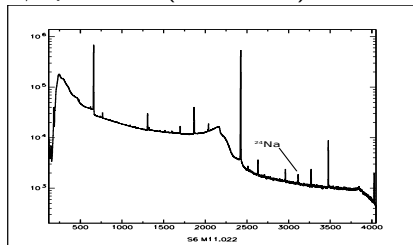


One more isotope for the coffee - ^{24}Na

γ -spectrum (beginning IS541):

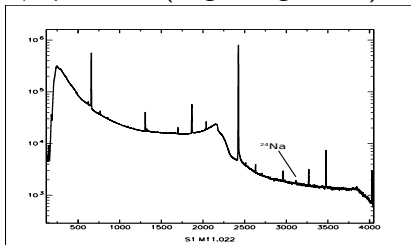


γ -spectrum (end IS541):

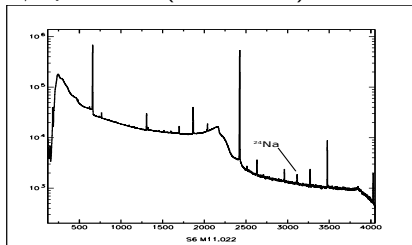


One more isotope for the coffee - ^{24}Na ($T_{1/2} = 15\text{h}$)

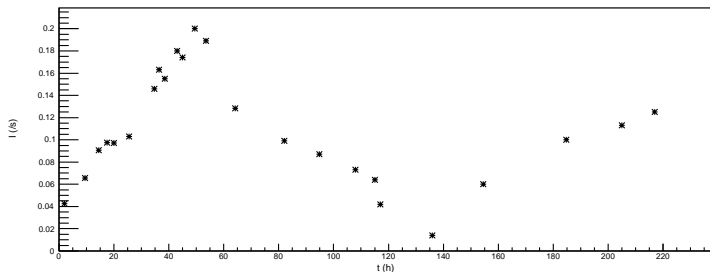
γ -spectrum (beginning IS541):



γ -spectrum (end IS541):



$I_{2754\text{keV}}$ ($I_{^{24}\text{Na}}$) throughout and after the experiment:



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- $N_{11\text{Be}}$ determined
- Mass scan around $M = 11.022$
- Efficiency and deadtime determined

IS507:

- States in ^{20}Na identified
- Two new states discovered
- $\log ft$ -values determined

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Thank you:

Karsten Riisager, Morten Vinther Lund
and the IS541 and IS507 collaborations

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Thank you for your attention