# Level scheme and level half lives of <sup>30</sup>AI

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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Introdu	ction				

- Data analysis of experiment IS414
- Study of the region known as Island of Inversion around <sup>32</sup>Na
- $\beta$ -decay chains of  $^{30,31,32,33}$ Na
- Use of the fast timing technique  $\mathsf{ATD}\beta\gamma\gamma(t)$
- This analisys focuses on <sup>30</sup>Al level scheme and excited levels half lives

Introduction	Motivation ●○○○	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Theory					
Island c	of Inversion	on			



### Island of Inversion

Possible inversion of the  $f_{7/2}$  and  $d_{3/2}$  orbits in the Z = 10 - 12and N = 20 - 22 region

Introduction	Motivation ○●○○	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Theory					

$$^{32}$$
Mg  $N = 20 Z = 12$ 

- Far more bound than predicted
- First 2<sup>+</sup> at very low energy (885 keV)
- Indicates deformation properties
- Presence of intruder estates



Introduction	Motivation ○○●○	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Goals of the expe	riment				

## Experiment on <sup>32</sup>Mg and decay chain

- Measurement of the half life of the first 2<sup>+</sup> state (885 keV)
- Precission of about 1.5 ps





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## Experiment on <sup>30,31</sup>Mg and decay chain

- Characterization of level schemes
- Search for intruder states
- Candidate for  $0^+$  in  ${}^{30}Mg$
- One of the decay products is <sup>30</sup>Al

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## Experiment on <sup>32</sup>Mg and decay chain

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### Experiment on <sup>30,31</sup>Mg and decay chain

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## <sup>30</sup>AI

• The nucleus <sup>30</sup>Al can provide information on the evolution from the Valley of Stability towards the Island of Inversion.

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Previous works					

## Previous level schemes



### Détraz et al. 1979

"Beta decay of 27-32Na and their descendants", by C. Détraz *et al.* Phys. Rev. C 19, 164176 (1979)



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## Previous level schemes



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#### Hinners et al. 2008

"Complementary studies of T =  $2^{30}$ Al and the systematics of intruder states" by T. A. Hinners *et al.* Phys. Rev. C 77, (2008)

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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions

## Advance Time Delayed $\beta\gamma\gamma(t)$

### Outline

- The technique is based in triple coincidence  $\beta\gamma\gamma(t)$
- The level scheme is determined by coincidences between two HPGe
- $\bullet\,$  The timing is done with a TAC between the  $\beta$  and  ${\rm BaF_2}$  detector
- The half-life of the excited levels is measured by the slope of the time response ( $T_{1/2} > 60ps$ ) or the displacement of the centroid from the prompt calibration curve ( $T_{1/2} < 60ps$ )
- The method relies on precise calibration of the time response of the fast detectors
- Half-lives down to the picoseconds can be measured

Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions





Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions



$\gamma_1$	in	Ge	and	$\gamma_2$	in	the	fast	timing
$t_1 =$	=	$\tau_0$ –	- τ <sub>2</sub>					
	7			6		1		
$\gamma_2$	in	Ge	and	$\gamma_1$	in	the	fast	timing
t <sub>2</sub> =	_	$\tau_0$ +	$- au_1$	$+\tau$	2			



Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions





$$\tau_1 = t_2 - t_1$$



Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Convel					

- Convolution technique
  - Convolution technique may be used if  $T_{1/2} > 60 ps$
  - Fit of the timing distribution to a prompt transition plus a exponential decay
  - Prompt part may be approximated to a gaussian distribution
  - $F(t_j) = \gamma \int_A^{+\infty} e^{-\delta(t_j-t)} e^{-\lambda(t-A)} dt$



Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment ●○○○	Experimental results	Conclusions
Experiment run					



Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment ○●○○	Experimental results	Conclusions
Experimental setu	цр				

#### Detectors

- 1 X NE111A:  $\beta$ -detector 3 mm width
- 2 X *BaF*<sub>2</sub>: timing (1.5" base, 1" top, 1" height)
- 2 X HPGe: energy resolution and selection of decay branches



Introduc	stion
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Motivation

 $\mathsf{ATD}eta\gamma\gamma(t)$  technique

Experiment

Experimental results

Conclusions

#### Experimental setup

### Data were acquired with 2 systems simultaneously

- DMP Analog
- XIA (PIXIE 4) Digital

### Analog system

- ADC-0: Starter logical signal
- ADC-1: β-detector energy
- ADC-2: Fast TAC-1
- ADC-3: BaF<sub>2</sub>-1 energy
- ADC-4: Fast TAC-2
- ADC-5: BaF<sub>2</sub>-2 energy
- ADC-6: HPGe-1 energy
- ADC-7: HPGe-2 energy

#### Digital system

- Card 1-0: PSBooster proton impacts
- Card 1-1: HPGe-1 energy
- Card 1-2: HPGe-2 energy
- Card 2-0: Fast TAC-1
- Card 2-1: BaF<sub>2</sub>-1 energy
- Card 3-0: Fast TAC-2
- Card 3-1: BaF<sub>2</sub>-2 energy
- Card 4-0:  $\beta$ -detector energy

Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment ○○○●	Experimental results	Conclusions
Experimental se	tup				
$\beta^-$ -dec	ay chain				

Z	e 100.00% cp: 1.3E-3%	e: 100.00%	e 100.00%	100%	A 100.00%	∦ = 100.00%	β-: 100.00%	\$-100.00%	β~: 100.00%
14	4.16 S c 100.00N	STABLE 92.230%	57ABLE 4.683%	STABLE 3.087%	157-3 M 8- 100.00%	150 Y 150 Y	6.11.5 β-: 100.00%	2.77.5 p- 100.004	0.70 S
13	26A1 7.17E+5 Y & 100.00%	27A1 STABLE 100%	28A1 2.2414 M β-100.00%	29A1 6.56 M β- 100.00%	30A1 3.60 S β-100.00%	31A1 644 MS β-: 100.00%	32A1 33.0 MS β- 100.00% β-n 0.70%	33A1 41.7 MS 6- 100.00% 8-8.850N	34A1 42 MS β-: 100.00% β-m 27.00%
12	25Mg STABLE 10.00%	26Mg STABLE 11.01%	27Mg 9.450 M # 100.00N	28Mg 203915 H #~: 100.00W	29Mg 1.30 S 8+ 100.00%	30Mg 335 MS \$ 100.00%	31Mg 232 MS β-: 100.00N β-h: 1.70N	32Mg DG MS 8-: 100.00% 8-1: 5:50%	33Mg 90.5 MS β-: 100.00N β-h: 17.00N
11	24Na 14:007 H 8- 100:005	25Na 50 1 5 β 100.00%	26Ns 1.077/S β100.00%	27Na 301 MS β-: 100 00% β-а. 0.13%	28Na 30.5 MS β-: 100.00% β-n.0.58%	29Na 44.9 MS 8 100 00% 8-n 21 50N	30Ns 48 MS 6-: 100.00% 8-a: 30.00%	31Na 17 0 MS 8-100.00% 8-a: 37.00%	32Na 13.2 MS β-: 100.00% β-π.24.00%
	13	14	15	16	17	18	19	20	N

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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment ○○○●	Experimental results	Conclusions
Experimental se	tup				
$\beta^-$ -dec	ay chain				

	13	14	15	16	17	18	19	20	N
11	24Na 14.007 H §= 100.005	25Na 59.1 5 β 100.00%	26Ne 1.077.5 β100.00%	27Na 301 MS β-: 100 00% β-a: 0.13%	28Na 30.5 MS β 100.00% β-n.0.58%	29Na 44.9 MS 8 100 00% 8-n.21.50%	30Na 48 MS β-: 100.00% β-a: 30.00N	31Na 17 0 MS β - 100.00% β - a: 37.00%	32Na 13.2 MS β-: 100.00% β-π.24.00%
12	STABLE 10.00%	STABLE 11.01%	9.450 M J 100.00N	20.915 H F- 100.005	1.30 5 8- 100.00h	335 MS #-: 100.00%	21 β-, 100.00% β-h: 1.70%	9-100.00N 9-1:550N	β-: 100.00% β-h: 17.00%
13	26AI 7.17E+5.Y <100.00%	27AI STABLE 100%	28A1 2 2414 M β-100.00%	29A1 6.56 M β- 100.00%	3.60 S β-100.00%	S1AI 644 MS β-: 100.00%	<sup>33</sup> Τ <sub>1/2</sub> <sup>β-1</sup> Q(β	: 48 ms 3 <sup>.</sup> ): 17.3 2+	MeV
14	2751 4.16 5 c 100.00N	2851 STABLE 92,230%	2951 STABLE 4.683%	3051 STABLE 3.087%	815) 157-31M 8- 100.008	3251 155 Y 15:100.008	3351 6.21.9 8-: 100.00%	8451 2.77.5 8 100.00%	355) 0.78 S p-: 100.00%
z	20P 270 3 MS e 100 00% cp. 1 3E-3%	299 4 142 5 4 100.00%	30P 2:498 M +: 100:00%	31P STARLE 100%	329 14 362 D 8 100.004	32P 25.54.D #=100.005	94P 12 43 5 β-: 100.00%	35P 47.3 3 \$~100.00%	36P 5.6.2 β~ 100.00%

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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment ○○○●	Experimental results	Conclusions
Experimental se	tup				
$\beta^-$ -dec	ay chain				

z	20P 270 3 MS c 100 00% cp. 1 3E-3N	299 4 142 5 + 100 00%	30P 2:498 M 4:100.00%	J1P STABLE 100%	32P 14 262 D # 100.004	30P 25.54.0 ∦=100.005	D4P 12 43 5 β~ 100.00%	35P 47.3.3 β 100.00%	. ЭбР 5.6.5 6-: 100.00%
14	27 <u>5</u> 1 4_16 5 c 100.00N	2851 STABLE 92 230%	2951 STAULE 4.683%	3051 STABLE 3.087%	319 157.9 M 8- 100.008	T <sub>1/2</sub>	<sub>2</sub> : 335 m 3 <sup>-</sup> ): 6.96	ns 5 MeV	3551 0.70 5 0-: 100.00%
13	26A1 7 17E+5 Y 4:100.00%	27A1 STABLE 100%	28A1 2 2414 M β-: 100.00%	29A1 6.56 M β- 100.00%	30A1 3.60 S β-100.00%	s J∏. 64 β∹ 100.00%	0+ 8-100.00% 8-n.0.70%	β- 100.00% β-n.8.50%	34A1 42 MS β-: 100.00% β-π. 27.00%
12	25Mg STABLE 10.00%	26Mg STABLE 11.01%	27Mg 9:450 M # 100.00%	28Mg 20:915 H #-: 100:00N	29Mg 1.30 S \$+ 100.00%	30Mg 335 M5 \$ 100.00%	31Mg 232 MS β-: 100.00N β-h: 1.7004	32Mg 06 MS β-: 100.00N β-::::5504	33Mg 90.5 MS 8 100.00% 8-h: 17.00%
11	24Na 14.007 H β= 100.00h	25Na 59 1 5 β 100.00%	26Ne 1.077/5 β-100.00%	27Na 301 MS β-: 100 00% β-a: 0.13N	28Na 30.5 MS β-100.00% β-n.0.58%	29Na 44.9 MS 8 100 00% 8-n.21.50N	30Na 48 MS β-: 100.00% β-:n. 30.00N	31Na 17 0 MS 6 - 100.00% 8 - n. 37.00%	32Na 13.2 MS β-: 100.00% β-n.24.00%
	13	14	15	16	17	18	19	20	N

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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment ○○○●	Experimental results	Conclusions
Experimental se	tup				
$\beta^{-}$ -deca	ay chain				

z	20P 270 3 M3 c 100 00% cp: 1 3E-3%	29P 4 142 5 4 100 00%	30P 2 498 M +: 100.00%	31P STABLE 100%	<sup>343</sup> T <sub>1/</sub> Q(	<sub>2</sub> : 3.6 s β <sup>-</sup> ): 8.56	6 MeV	35P 47.3.5 \$-100.00%	06P 5.8.5 β- 100.00%
14	2751 4.16.5 c.100.009	2851 STABLE 92.230%	2951 STABLE 4.683%	30SI STABLE 3.087%	3. Jπ 157 8- 100.008	: 3+ + 100.0054	₽~: 100.00%	3451 2.77.5 8-, 100.00%	3551 0.78 5 β-: 100.00%
13	26A1 7 17E+5 Y & 100.00%	27A1 STABLE 100%	28A1 2.2414 M β-100.00%	29A1 6.56 M β- 100.00%	30A1 3.60 S β-100.00%	31A1 644 MS β-: 100.00%	32A1 33.0 MS β- 100.00% β-n.0.70%	33A1 41.7 MS β-100.00% β-π.8.50N	34A1 42 MS β-: 100.00% β-π. 27.00%
12	25Mg STABLE 10.00%	26Mg STABLE 11.01%	27Mg 9.450 M # 100.00%	28Mg 203915 H g- 10000N	29Mg 1 30 5 8- 100.00M	30Mg 335 MS \$ 100.00%	31Mg 232 MS β-: 100.00% β-h: 1.70%	32Mg DG MS \$100.00% \$-5.50%	33Mg 90.5 MS 8-: 100.00N 8-:: 17.00N
11	24Na 14.007 H 8- 100.00N	25Na 50 1 5 β 100.00%	26Na 1.077/5 β-:100.00%	27Na 301 MS β-: 100 00% β-a: 0.13%	28Na 30.5 MS β-: 100.00% β-n.0.58%	29Na 44.9 MS 8-: 100.00% 8-n.21.50N	30Ns 48 MS β~: 100.00% β-в. 30.00N	31Na 17 0 MS 8-: 100.00% 8-a: 37.00%	32Na 13.2 MS β-: 100.00% β-n.24.00%
	13	14	15	16	17	18	19	20	N

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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
<sup>30</sup> Al energy spe	ctra				
Peak id	entificati	on			

#### Peak identification

Digital system was used to set a 300-1200 ms time gate after the proton impact on the target to enhance the  ${}^{30}AI$  activity



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<sup>30</sup> A/ energy spect	ra				

## Coincidences HPGe-HPGe



B. Olaizola Level scheme and level half lives of <sup>30</sup>A/

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Level scheme					



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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Level scheme					



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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Timing calibratio	ns and corrections				

### Timing ADT

- There are three corrections in the technique:
  - $\beta$ -walk curve
  - 2 Compton-walk curve
  - Compton from different energies give different responses (2nd order)
- We need to calibrate the time response of each detector as a function of energy Prompt calibration curve
- These calibrations and corrections are common to every nucleus in the experiment
- Each BaF<sub>2</sub> produces an indepedent set of data

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B-walk	CUINA				



### Energy gate on the $\beta$ -detector

A common gate for both  $BaF_2$  was set in the 1000-4595 channel region to ensure a time constant response from the detector.

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Compto	on-walk c	curve			



### Time calibration

Comtpon walk curve from 1836 keV transition in <sup>88</sup>Sr

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B. Olaizola Level scheme and level half lives of <sup>30</sup>A/

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B. Olaizola Level scheme and level half lives of <sup>30</sup>A/

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Timing calibration	ns and corrections				

## Prompt-time calibration



### Time calibration

Relative time response curve for both crystals made with calibration sources  $^{24}\rm Na,~^{88}Rb$  and  $^{140}\rm Ba.$  The time calibration is 12 ps/chan.

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Half life	analysis				



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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Timing calibrati	ons and correction	5			
Half life	analysis				



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Timing calibrati	ons and correction	s			
Half life	analysis				



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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions
Timing calibrati	ons and correction	s			
Half life	analysis				



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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results ○○○○○○○○●	Conclusions
Timing calibration	ns and corrections				

Level (keV)	$\tau$ (BaF <sub>2</sub> -1)	au ( BaF <sub>2</sub> -2)	$T_{1/2}(ps)$
243.77 (3)	11.9 (4.3)	13.9 (5.8)	18.5 (5.0)
687.62 (6)	20.7 (9.2)	19.1 (8.2)	28.6 (8.8)

- 0			
$\gamma$ (keV)	Multi	B(GT) W.u.	N
243.77 (3)	M1	0.17 (5)	
443.77 (6)	M1	0.017 (6)	
687.8 (1)	E2	2.9 (9)	

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Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions

### Conclusions

- Level scheme with new levels and transitions
- Two candidates for a third 1+ state in this nucleus
- Half lifes of the first two excited estates

Introduction	Motivation	$ATDeta\gamma\gamma(t)$ technique	Experiment	Experimental results	Conclusions

# Thanks for your attention!

