Lifetime measurements using DSAM with the MINIBALL set-up

Michael Thürauf

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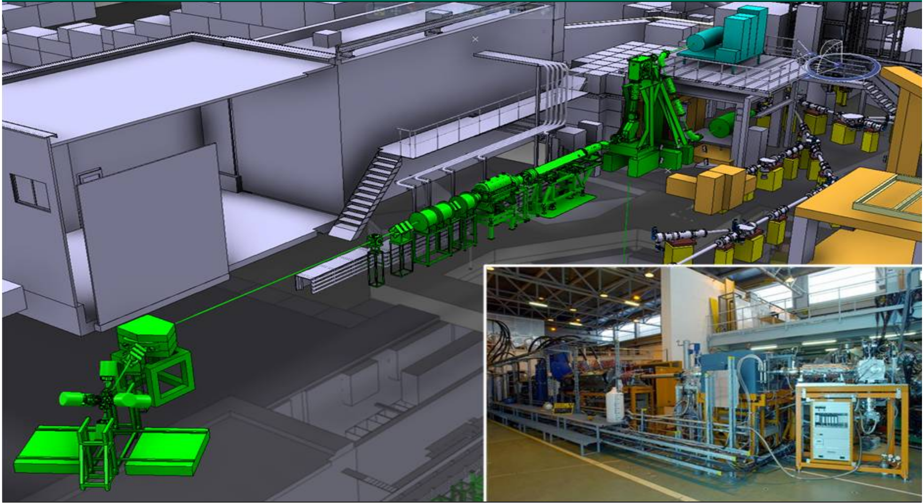

Outline

Outline

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Introduction

DSAM – Doppler-Shift Attenuation Method

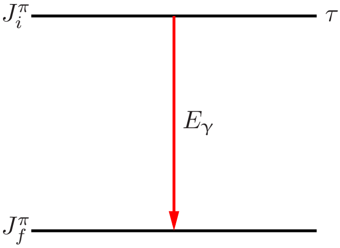
MINIBALL set-up

Analysis of ^{140}Ba and ^{126}Cd

Conclusion and Outlook

Introduction

Motivation



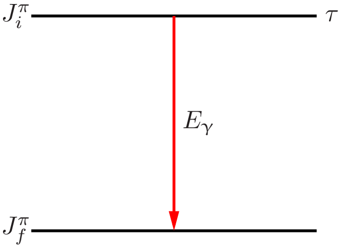
The lifetime of a nuclear state is

- directly measurable

$$\frac{1}{\tau} = \frac{\ln 2}{T_{1/2}} = C(\sigma l)\; E_\gamma^{2l+1}\; B(\sigma l; J_i \to J_f) \;\propto\; \left|\langle f \| M(\sigma l) \| i\rangle\right|^2 \; .$$

Introduction

Motivation



The lifetime of a nuclear state is

- directly measurable
- model independent

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Introduction

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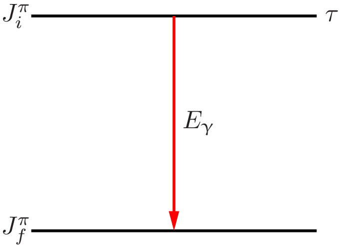

The lifetime of a nuclear state is

- directly measurable
- model independent
- inverse proportional to the transition strength

$$\frac{1}{\tau} = \frac{\ln 2}{T_{1/2}} = C\,(\sigma l)\;E_\gamma^{2l+1}\;B\,(\sigma l; J_i \rightarrow J_f) \propto \left|\langle f \,\|\, M\,(\sigma l) \,\|\, i\rangle\right|^2 \; .$$

Introduction

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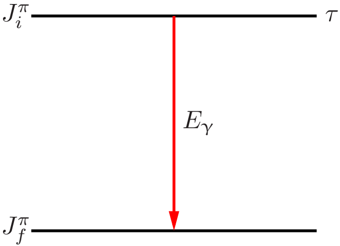


The lifetime of a nuclear state is

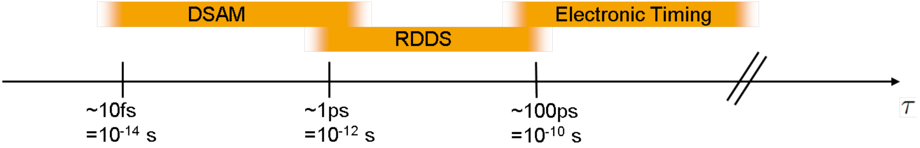
- directly measurable
- model independent
- inverse proportional to the transition strength
- a testcase for the nuclear wave functions

$$\frac{1}{\tau} = \frac{\ln 2}{T_{1/2}} = C(\sigma l)\ E_\gamma^{2l+1}\ B(\sigma l; J_i \rightarrow J_f) \propto \left|\langle f \,\|\, M(\sigma l) \,\|\, i \rangle\right|^2 .$$

Introduction

Methods to measure lifetimes

The choice of your method is depending on the scale of the lifetime!



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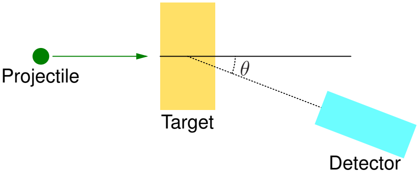
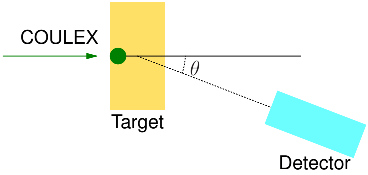
DSAM – Doppler-Shift Attenuation Method



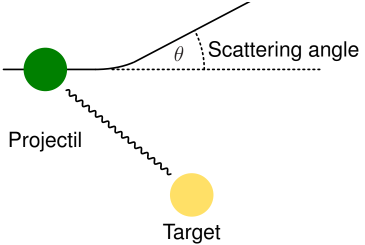
- Projectile is shot on a thick target

DSAM – Doppler-Shift Attenuation Method



- Projectile is shot on a thick target
- COULEX: Coulomb excitation

DSAM – Doppler-Shift Attenuation Method



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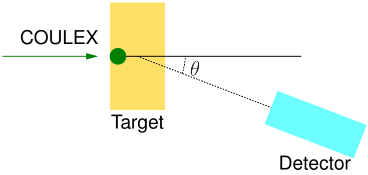

- Projectile is shot on a thick target
- COULEX: Coulomb excitation
- Projectile is slowed down

DSAM – Doppler-Shift Attenuation Method

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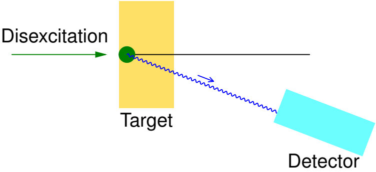

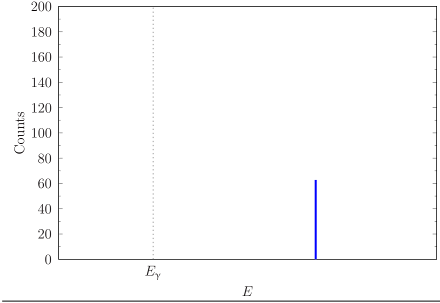

- Projectile is shot on a thick target
- COULEX: Coulomb excitation
- Projectile is slowed down
- Emission of doppler-shifted photons

$$E'_\gamma = E_\gamma \left(1 + \beta(t) \cos\theta\right)$$

DSAM – Doppler-Shift Attenuation Method

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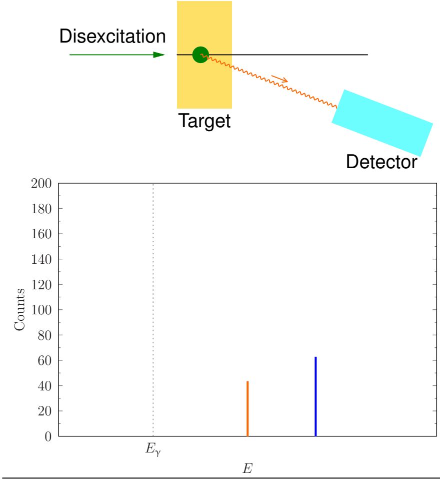

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DSAM – Doppler-Shift Attenuation Method

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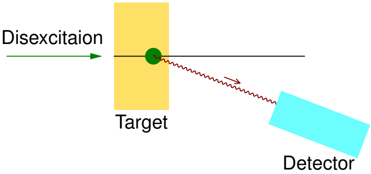

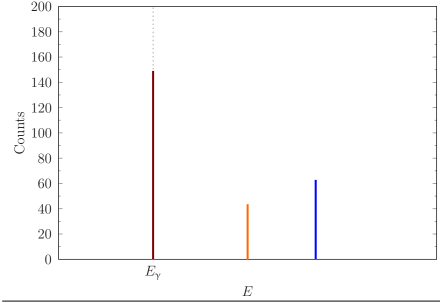

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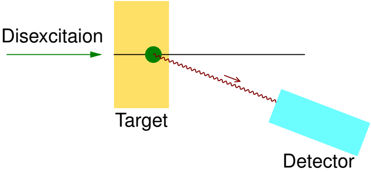

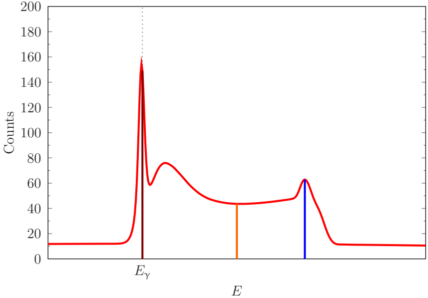

- Projectile is shot on a thick target
- COULEX: Coulomb excitation
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- Emission of doppler-shifted photons

$$E'_\gamma = E_\gamma \left(1 + \beta\,(t) \cos\theta\right)$$

- Lineshape

DSAM – Doppler-Shift Attenuation Method

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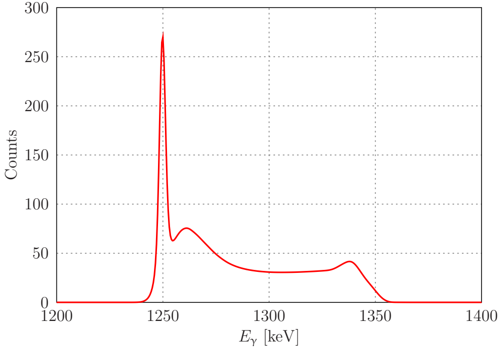
The lineshape is sensitive to the lifetime



^{nat}Cu(^{114}Sn, ^{114}Sn)^{nat}Cu

$E_{beam} = 3.8\,\mathrm{MeV/u}$

$E_\gamma = 1250\,\mathrm{keV}$

$\theta = 10^\circ$

$\tau = 1.0\,\mathrm{ps}$

DSAM – Doppler-Shift Attenuation Method

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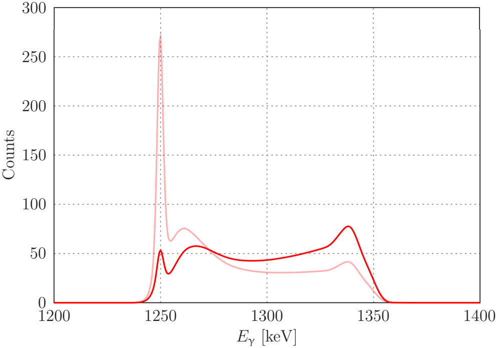

$^{nat}Cu(^{114}Sn, ^{114}Sn)^{nat}Cu$

$E_{beam} = 3.8\,MeV/u$

$E_\gamma = 1250\,keV$

$\theta = 10^\circ$

$\tau = 0.5\,ps$

DSAM – Doppler-Shift Attenuation Method

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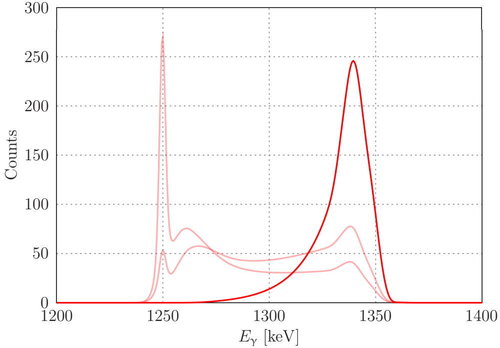
The lineshape is sensitive to the lifetime



$^{nat}Cu(^{114}Sn, ^{114}Sn)^{nat}Cu$

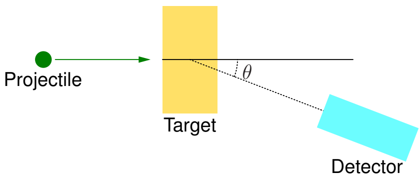
E_{beam} = 3.8 MeV/u

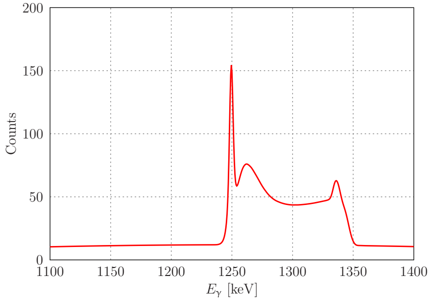
E_γ = 1250 keV

θ = 10°

τ = 0.1 ps

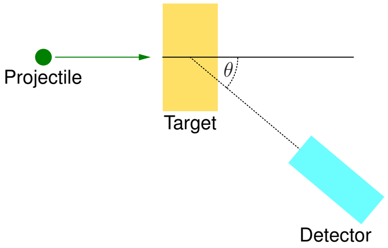
The lineshape depends on the angle θ

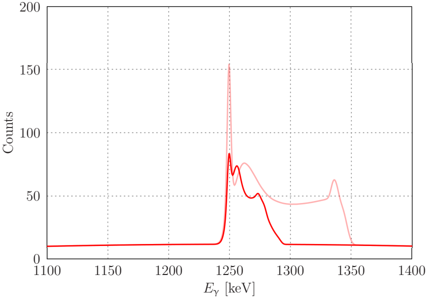




$$E'_\gamma = E_\gamma \left(1 + \beta(t) \cos\theta\right)$$

The lineshape depends on the angle θ





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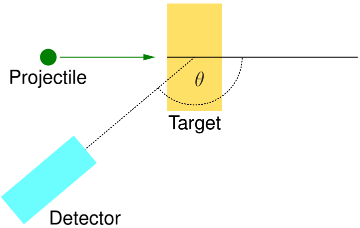

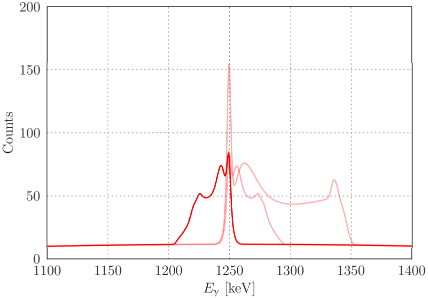

$$E'_{\gamma} = E_{\gamma}\left(1 + \beta(t)\cos\theta\right)$$

DSAM – Doppler-Shift Attenuation Method

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Determination of the lifetime

- Monte-Carlo simulation of Coulomb Excitation and deceleration process on the basis of GEANT4

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Determination of the lifetime

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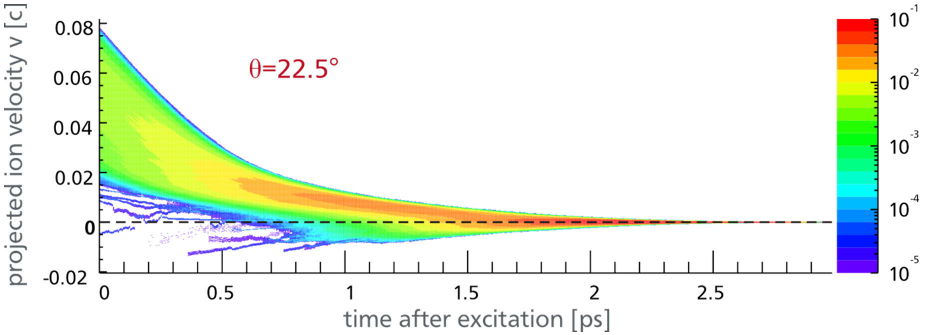
- Monte-Carlo simulation of Coulomb Excitation and deceleration process on the basis of GEANT4

Stopping-Matrix



DSAM – Doppler-Shift Attenuation Method

Determination of the lifetime

- Monte-Carlo simulation of Coulomb Excitation and deceleration process on the basis of GEANT4
- Calculate theoretical lineshape
  - Depending on the angle and the slowing-down history
  - Lifetime is a free parameter

DSAM – Doppler-Shift Attenuation Method

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DSAM – Doppler-Shift Attenuation Method

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DSAM – Doppler-Shift Attenuation Method

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- Used software: APCAD – Analysis Program for Continuous-Angle DSAM (C. Stahl; IKP TU Darmstadt; M.Sc.-Thesis 2011)

DSAM – Doppler-Shift Attenuation Method

Determination of the lifetime

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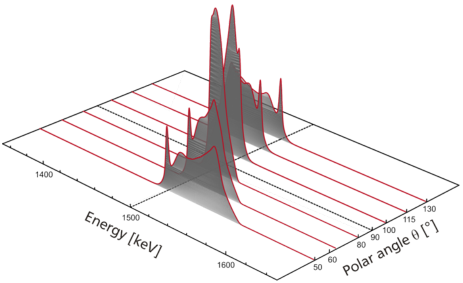
Simultaneous fit of all spectra



xcitation and deceleration process on

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NESHAPE (J.C. Wells, N.R. Johnson;

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DSAM – Doppler-Shift Attenuation Method

Determination of the lifetime

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Simultaneous fit of all spectra

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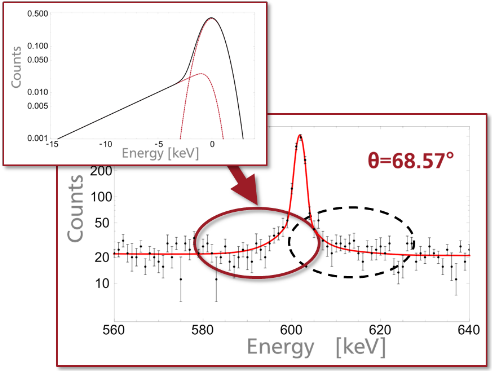
C. Wells, N.R. Johnson;

tinuous-Angle DSAM

Detector response



DSAM – Doppler-Shift Attenuation Method

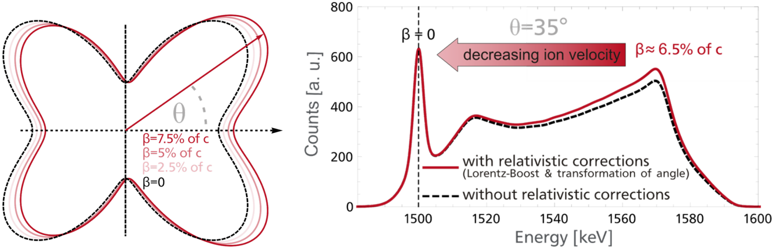
Determination of the lifetime

Simultaneous fit of all spectra

citation and deceleration process on

Detector response

Relativistic angular distribution



560 580 600 620 640

Energy [keV]

Outline

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MINIBALL set-up

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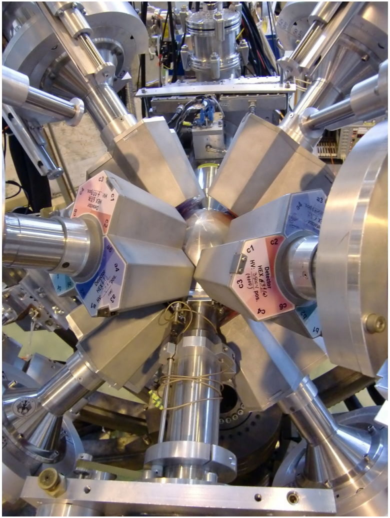

- Germanium detector array

MINIBALL set-up

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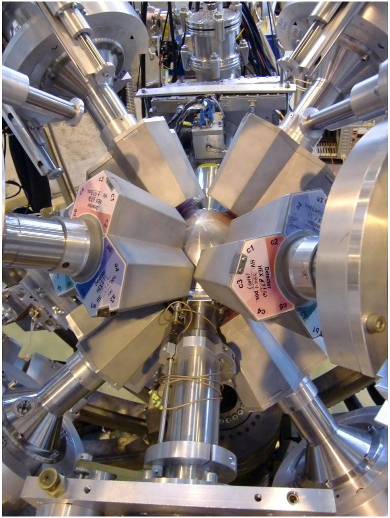

- Germanium detector array
- 60 % solid angle coverage

MINIBALL set-up

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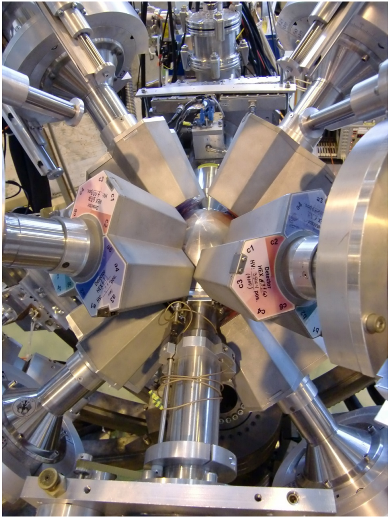

- Germanium detector array
- 60 % solid angle coverage
- 8 triple cluster

MINIBALL set-up

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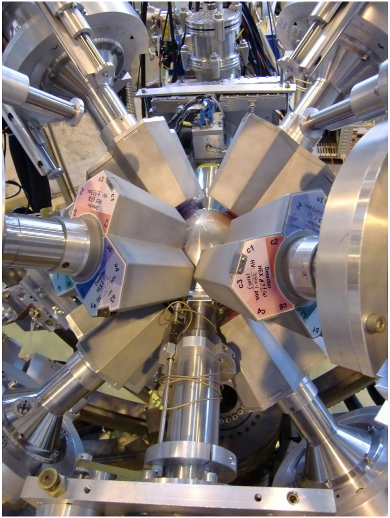
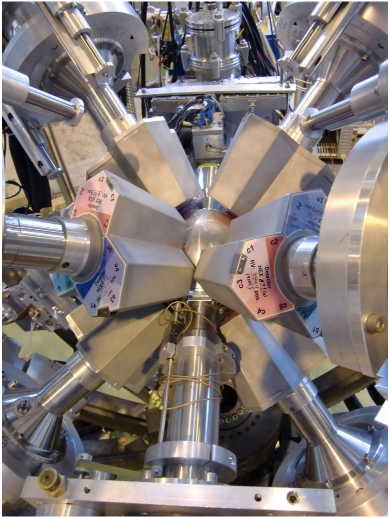


- Germanium detector array
- 60 % solid angle coverage
- 8 triple cluster
- 24 HPGe detectors

MINIBALL set-up



- Germanium detector array
- 60 % solid angle coverage
- 8 triple cluster
- 24 HPGe detectors
- For DSAM: Thick target

Outline

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Analysis of ^{140}Ba and ^{126}Cd

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Z \ N	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
57	La 125	La 126	La 127	La 128	La 129	La 130	La 131	La 132	La 133	La 134	La 135	La 136	La 137	La 138	La 139	La 140	La 141	La 142	La 143
56	Ba 124	Ba 125	Ba 126	Ba 127	Ba 128	Ba 129	Ba 130	Ba 131	Ba 132	Ba 133	Ba 134	Ba 135	Ba 136	Ba 137	Ba 138	Ba 139	Ba 140	Ba 141	Ba 142
55	Cs 123	Cs 124	Cs 125	Cs 126	Cs 127	Cs 128	Cs 129	Cs 130	Cs 131	Cs 132	Cs 133	Cs 134	Cs 135	Cs 136	Cs 137	Cs 138	Cs 139	Cs 140	Cs 141
54	Xe 122	Xe 123	Xe 124	Xe 125	Xe 126	Xe 127	Xe 128	Xe 129	Xe 130	Xe 131	Xe 132	Xe 133	Xe 134	Xe 135	Xe 136	Xe 137	Xe 138	Xe 139	Xe 140
53	I 121	I 122	I 123	I 124	I 125	I 126	I 127	I 128	I 129	I 130	I 131	I 132	I 133	I 134	I 135	I 136	I 137	I 138	I 139
52	Te 120	Te 121	Te 122	Te 123	Te 124	Te 125	Te 126	Te 127	Te 128	Te 129	Te 130	Te 131	Te 132	Te 133	Te 134	Te 135	Te 136	Te 137	Te 138
51	Sb 119	Sb 120	Sb 121	Sb 122	Sb 123	Sb 124	Sb 125	Sb 126	Sb 127	Sb 128	Sb 129	Sb 130	Sb 131	Sb 132	Sb 133	Sb 134	Sb 135	Sb 136	Sb 137
50	Sn 118	Sn 119	Sn 120	Sn 121	Sn 122	Sn 123	Sn 124	Sn 125	Sn 126	Sn 127	Sn 128	Sn 129	Sn 130	Sn 131	Sn 132	Sn 133	Sn 134	Sn 135	Sn 136
49	In 117	In 118	In 119	In 120	In 121	In 122	In 123	In 124	In 125	In 126	In 127	In 128	In 129	In 130	In 131	In 132	In 133	In 134	In 135
48	Cd 116	Cd 117	Cd 118	Cd 119	Cd 120	Cd 121	Cd 122	Cd 123	Cd 124	Cd 125	Cd 126	Cd 127	Cd 128	Cd 129	Cd 130	Cd 131	Cd 132	Cd 133	
47	Ag 115	Ag 116	Ag 117	Ag 118	Ag 119	Ag 120	Ag 121	Ag 122	Ag 123	Ag 124	Ag 125	Ag 126	Ag 127	Ag 128	Ag 129	Ag 130			

Analysis of ^{140}Ba and ^{126}Cd

^{140}Ba

Experiment

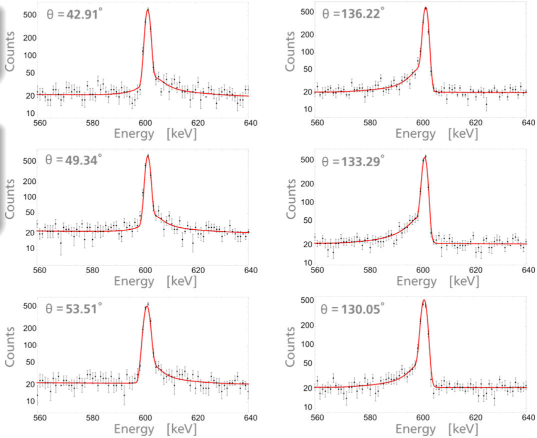
IS411 in Aug. 2007

Beam

^{140}Ba at 2.85 MeV/u stopped in a thick $^{nat.}$Cu target

Simultaneous use of all spectra for the fitting procedure.

The spectra are connected by the angular distribution (also fitted).

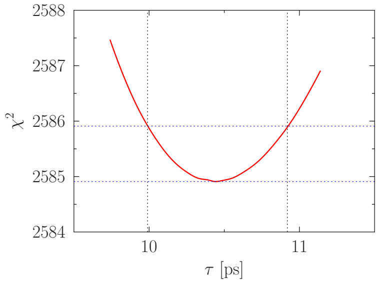


12 more angles used for the fit

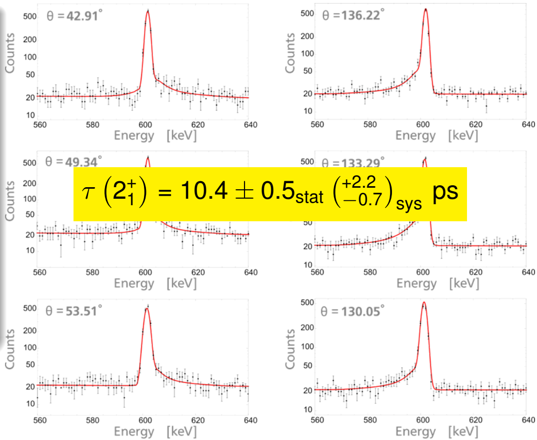
Analysis of ^{140}Ba and ^{126}Cd

^{140}Ba

χ^2 distribution



C. Bauer et al. PRC **86**, 034310 (2012)



$$\tau\left(2_1^+\right) = 10.4 \pm 0.5_{\text{stat}} \left({}^{+2.2}_{-0.7}\right)_{\text{sys}} \text{ ps}$$

12 more angles used for the fit

Analysis of ^{140}Ba and ^{126}Cd

^{126}Cd

Experiment

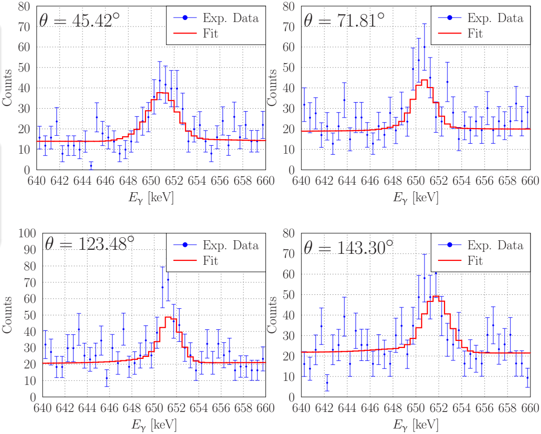
IS477 in Aug. 2011

Beam

^{126}Cd at 2.85 MeV/u stopped in a thick ^{64}Zn target

Simultaneous use of all spectra for the fitting procedure.

The spectra are connected by the angular distribution (also fitted).

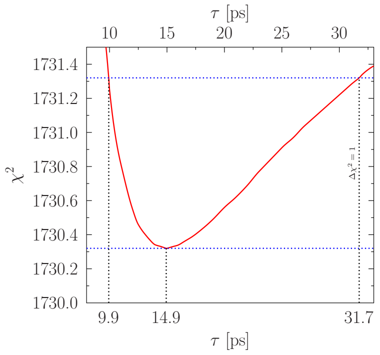


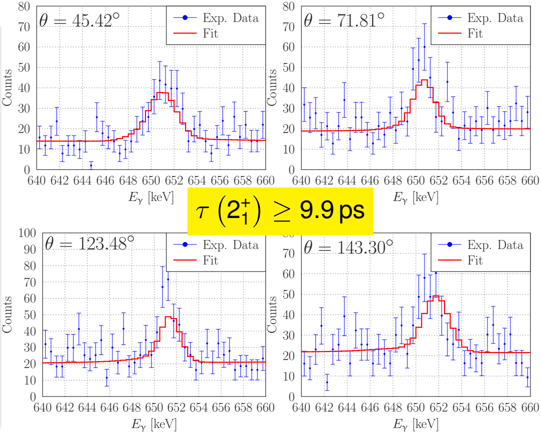
16 more angles used for the fit

Analysis of ^{140}Ba and ^{126}Cd

^{126}Cd

χ^2 distribution





$\tau\left(2_1^+\right) \geq 9.9$ ps

16 more angles used for the fit

Outline

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Conclusion and Outlook

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Conclusion

- $B(E2)$ and Q_s together with COULEX-data in ^{140}Ba

$$B\left(E2; 0_1^+ \rightarrow 2_1^+\right) = 0.696^{+0.027}_{-0.073}\,\mathrm{e^2b^2} \qquad Q_S\left(2_1^+\right) = -0.52(34)\,\mathrm{eb}$$

- Transistion strength in ^{126}Cd

$$B\left(E2; 0_1^+ \rightarrow 2_1^+\right) \leq 0.346\,\mathrm{e^2b^2}$$

Conclusion and Outlook

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Conclusion

- $B(E$ ... 34) eb
- Tran

$$B\left(E2;0_1^+\rightarrow 2_1^+\right)\leq 0.346\,e^2b^2$$

Preliminary COULEX result ^{126}Cd

$$B\left(E2;0_1^+\rightarrow 2_1^+\right)=0.224(15)\,e^2b^2$$

S. Ilieva et al., in preparation

Conclusion and Outlook

Conclusion

- $B(E2)$ and Q_s together with COULEX-data in ^{140}Ba

$$B\left(E2; 0_1^+ \rightarrow 2_1^+\right) = 0.696^{+0.027}_{-0.073}\,\mathrm{e^2b^2} \qquad Q_S\left(2_1^+\right) = -0.52(34)\,\mathrm{eb}$$

- Transistion strength in ^{126}Cd

$$B\left(E2; 0_1^+ \rightarrow 2_1^+\right) \leq 0.346\,\mathrm{e^2b^2}$$

Outlook

- Differential DSAM (τ in the order of ns, no contamination in chamber)
- Planned DSAM with ^{80}Zn
- Plunger measurements (Sotirios Harissopoulos; Demokritos, Athens, Greece)

Conclusion and Outlook

Thank you for your attention!

3D fit function

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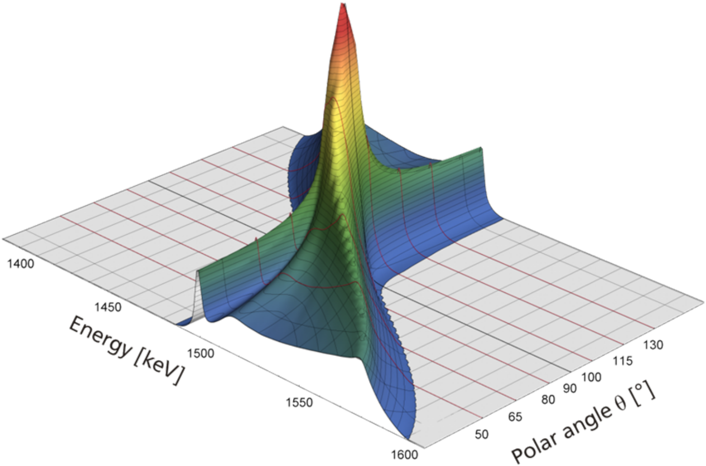

B(E2) ^{126}Cd

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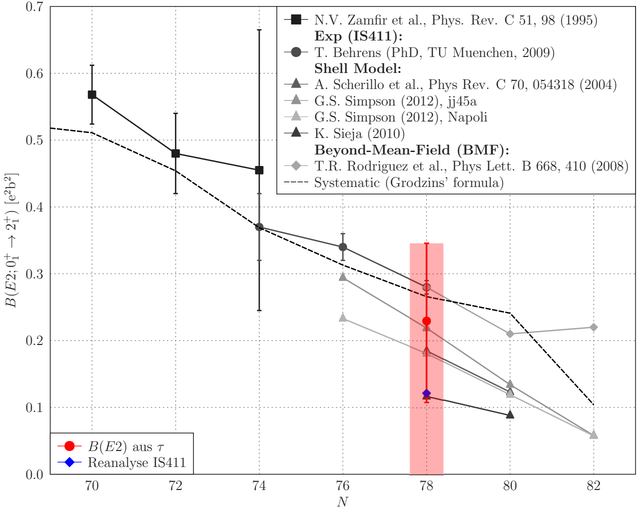
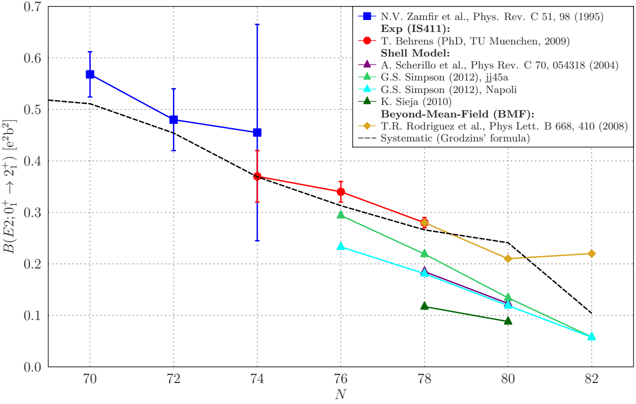


B(E2) ^{126}Cd



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Exp (IS411):
T. Behrens (PhD, TU Muenchen, 2009)
Shell Model:
A. Scherillo et al., Phys Rev. C 70, 054318 (2004)
G.S. Simpson (2012), jj45a
G.S. Simpson (2012), Napoli
K. Sieja (2010)
Beyond-Mean-Field (BMF):
T.R. Rodriguez et al., Phys Lett. B 668, 410 (2008)
Systematic (Grodzins' formula)
$B(E2; 0_1^+ \rightarrow 2_1^+)$ [e^2b^2]
N
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
70
72
74
76
78
80
82

B(E2) ^{140}Ba

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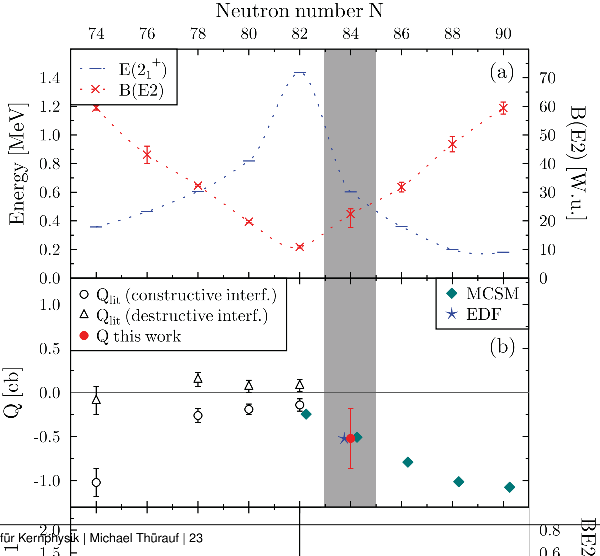

B(E2) ^{140}Ba

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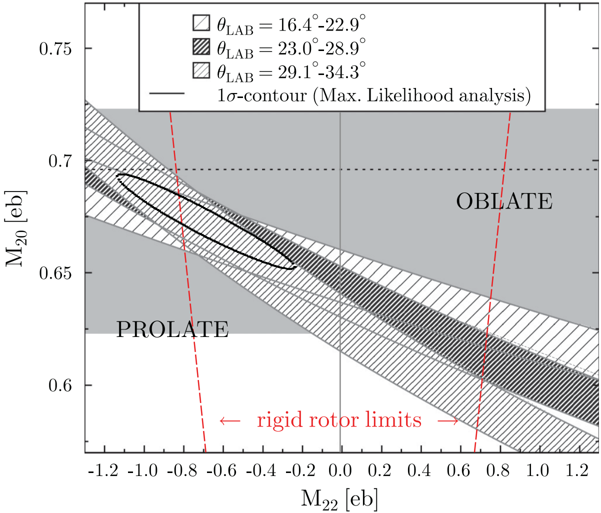

Differential DSAM

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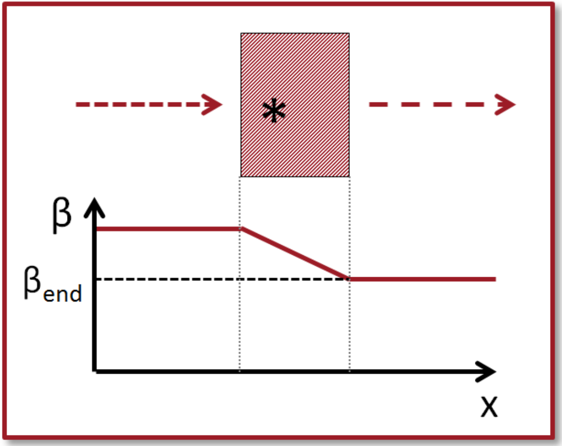

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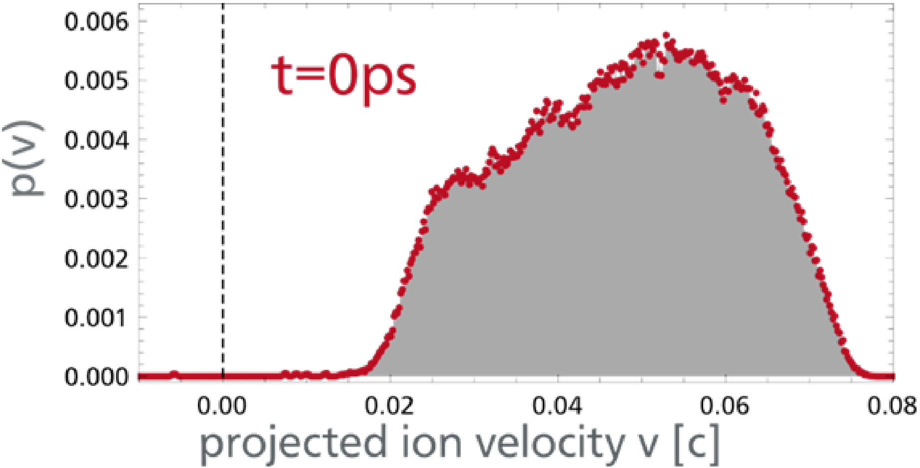

Stopping

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