ADVANCES IN NUCLEAR STRUCTURE FROM PHOTONUCLEAR REACTIONS

Norbert Pietralla
IKP, TU Darmstadt

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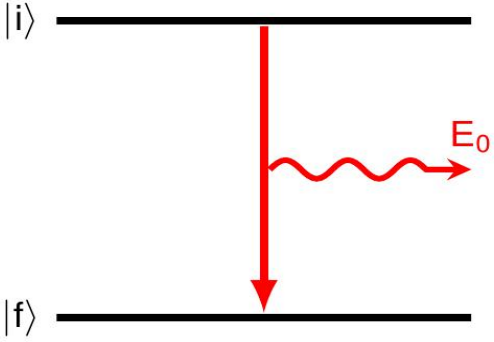
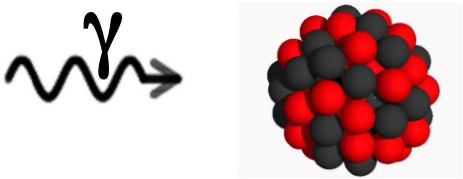
γ-decay

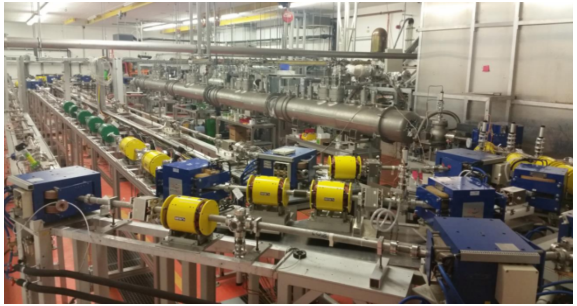


photoexcitation



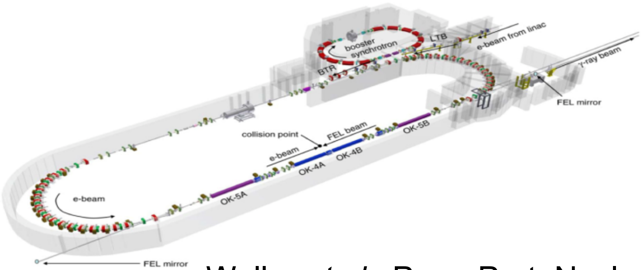
Situation with γ facilities

S-DALINAC, TU Darmstadt



1.1.2016 – 31.12.2019
A.Schwenk et al.

ELI-NP, Bucharest, 2018-



HIγS,
Duke Univ.,
2001-

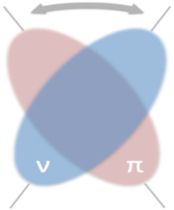
Weller *et al.*, Prog. Part. Nucl. Phys. 62 (2009) 257

Outline

- **Recent Advances on Nuclear Dipole Modes**
  - E1 Pygmy Dipole Resonance
    - Is the PDR a valence-neutron mode?

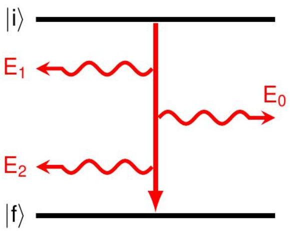
H.Pai, P.Ries, U.Gayer, V.Werner

  - M1 Scissors Mode
    - What is the E2-collectivity of the Sc.M.?



T.Beck, V.Werner

- **Recent Advances on Nuclear γ-Decay**
  - γγ/γ, Competitive Double-Gamma Decay

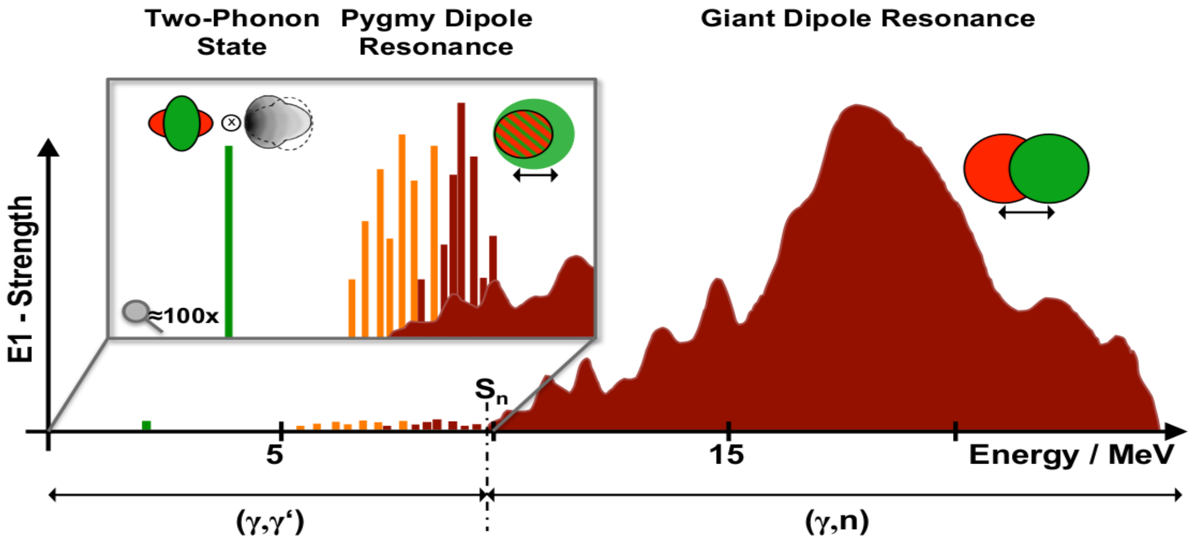


EPS PhD Award 2014

C.Walz, H.Scheit, T.Aumann, V.Ponomarev, R.Lefol

- **Outlook and Summary**

1. E1 Strength and Pygmy Dipole Resonance



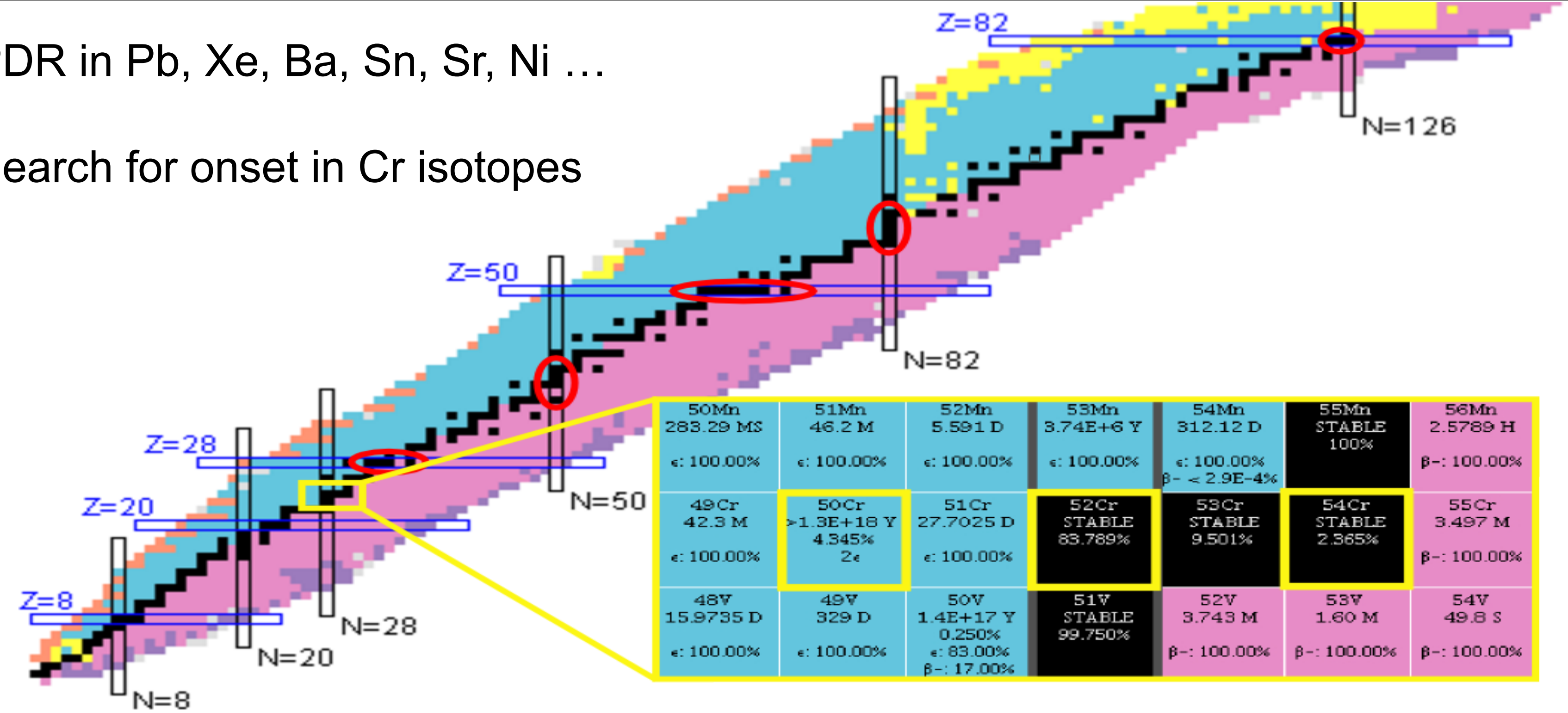
initial Fig. design by A.Zilges

PDR = “Enhanced electric dipole strength below and around neutron separation threshold”

Pygmy Dipole Resonance - Overview

PDR in Pb, Xe, Ba, Sn, Sr, Ni …

Search for onset in Cr isotopes



Darmstadt High Intensity Photon Setup

K.Sonnabend et al., NIM A 640, 6 (2011).

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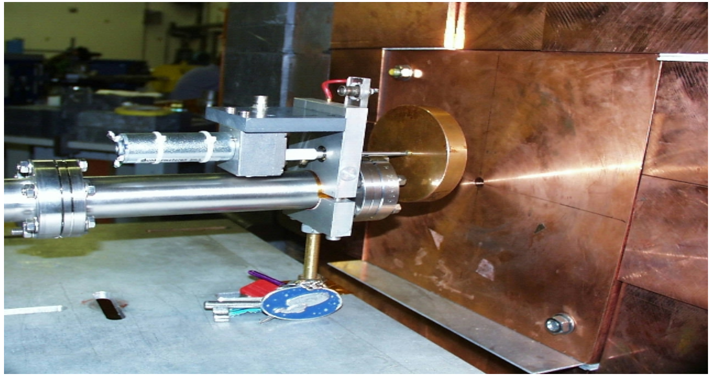
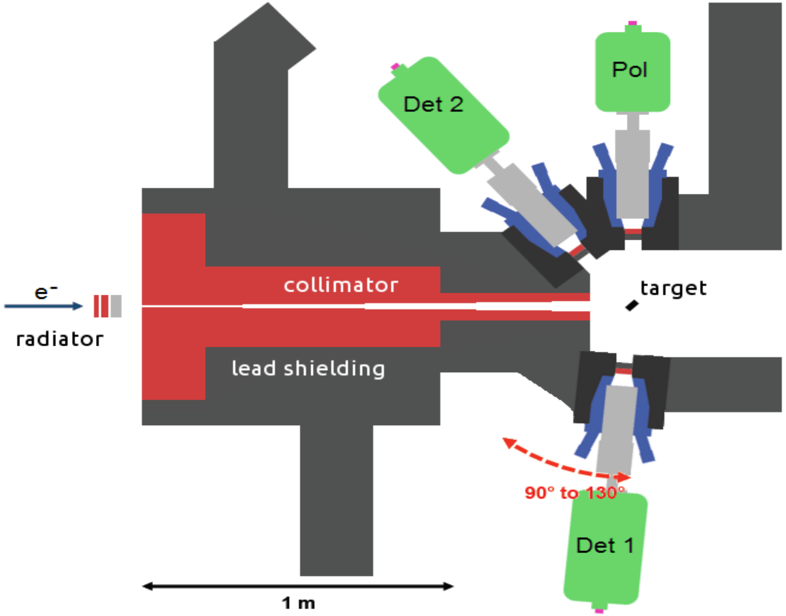
Bremsstrahlung γ spectrum provided by S-DALINAC

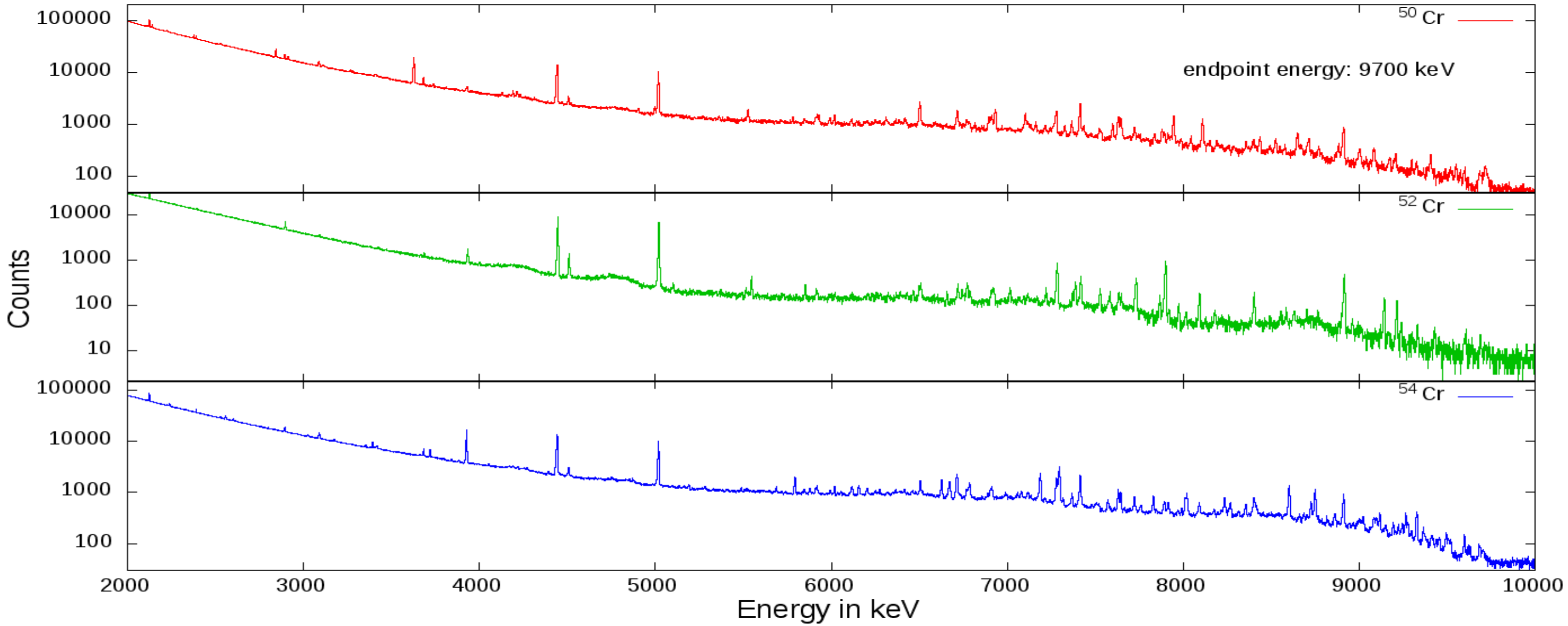


Order of multipole from angular distribution



C. Romig PhD thesis, TU Darmstadt, 2015 (modified)

Chromium Isotopes - Spectra @ DHIPS

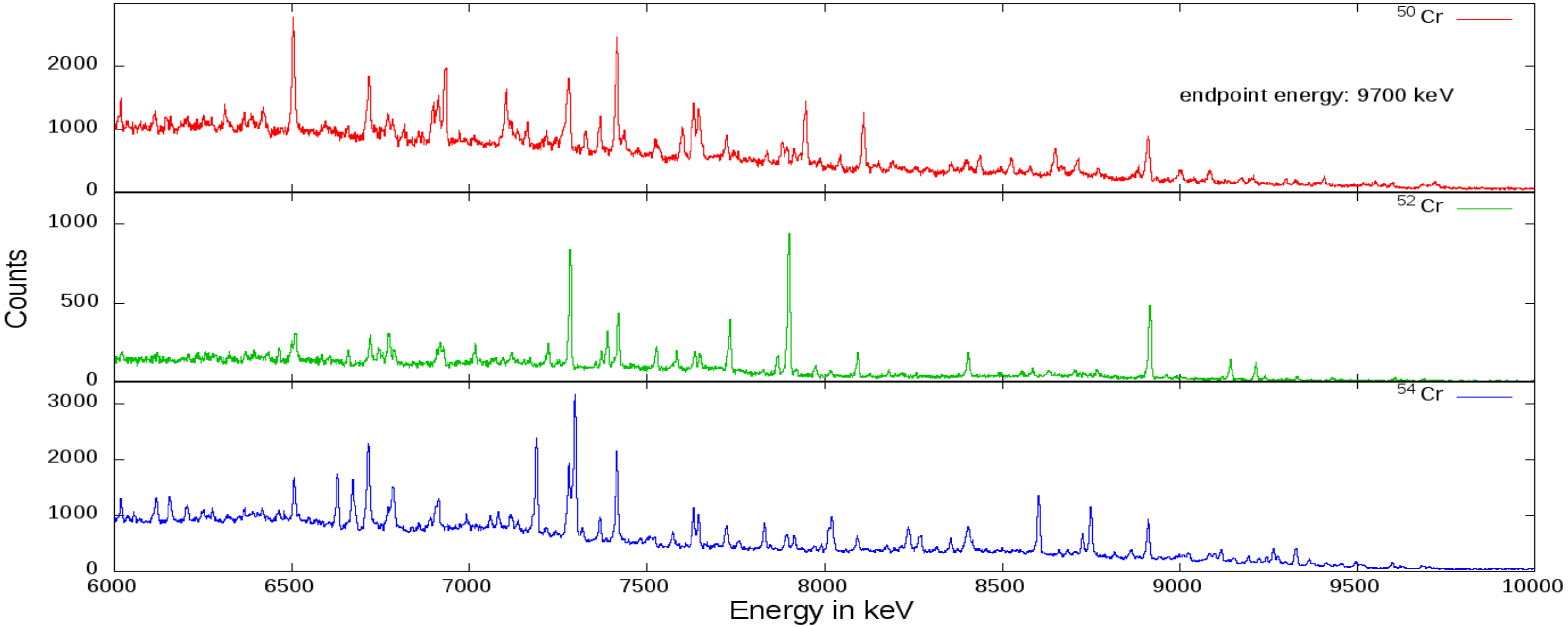


^{50}Cr

^{52}Cr

^{54}Cr

Chromium Isotopes - High Energy

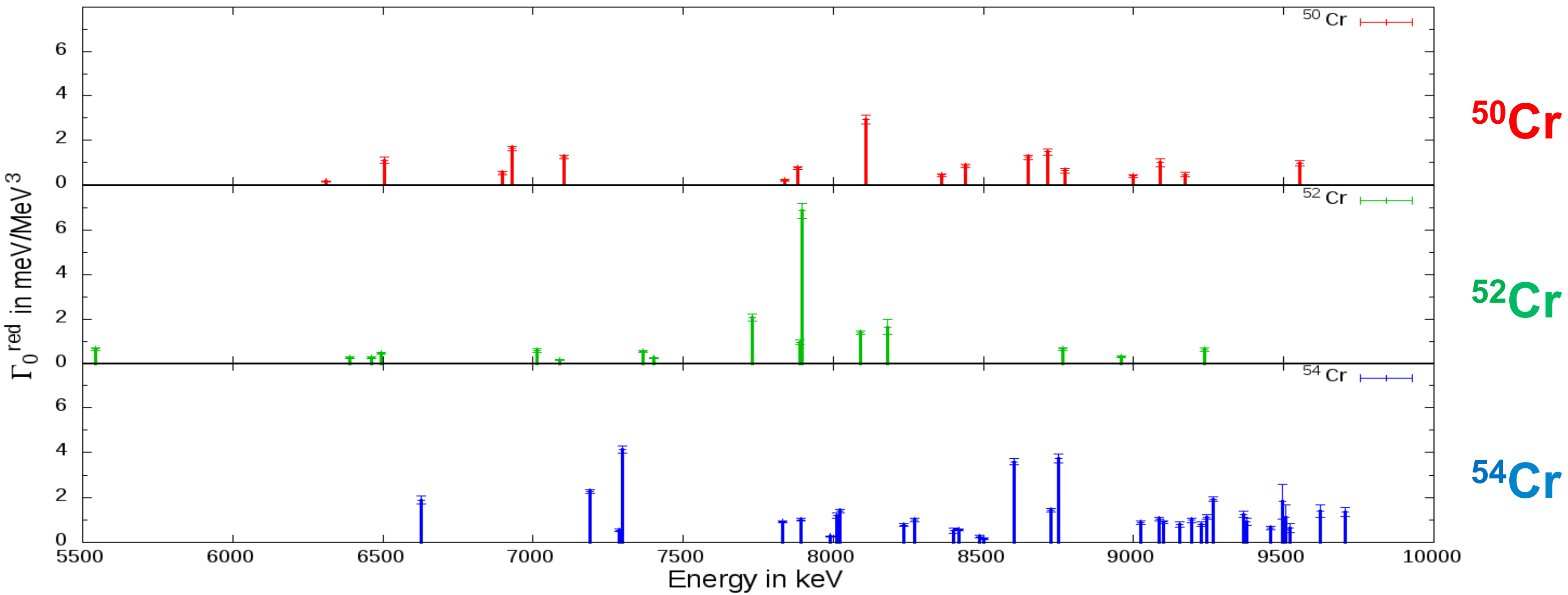


^{50}Cr

^{52}Cr

^{54}Cr

Reduced Transition Strength



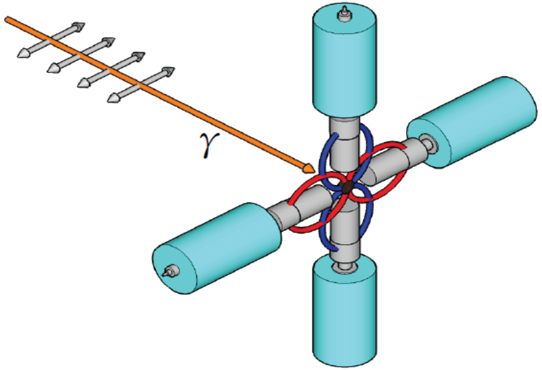
$$\Gamma_0^{red} = \Gamma_0 / E_\gamma^3$$

Parity Measurement @ HIγS

parity from asymmetry ε of count rate between detector plains

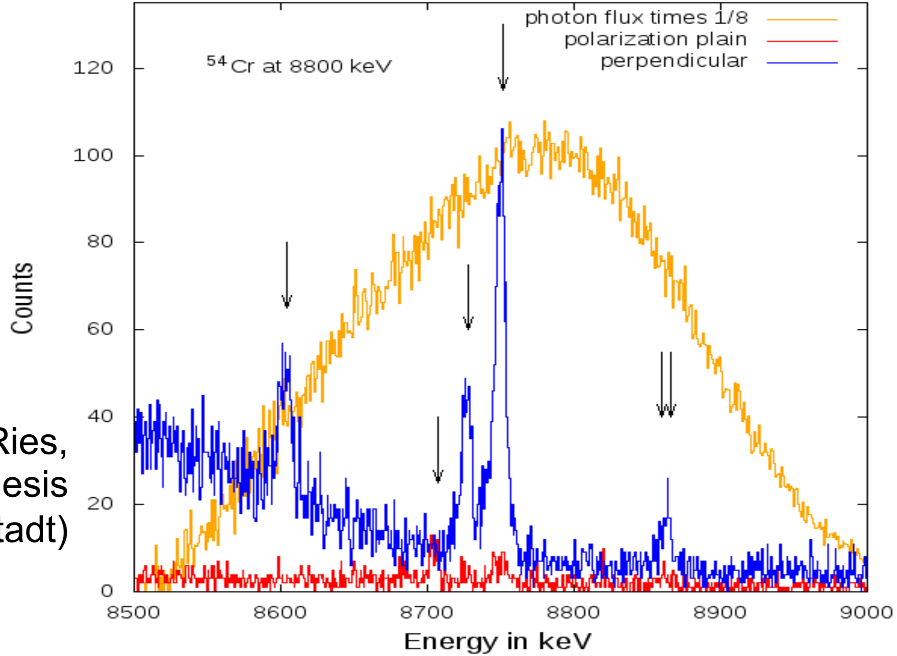
$$\varepsilon = \frac{N_{\parallel} - N_{\perp}}{N_{\parallel} + N_{\perp}}$$

N. Pietralla *et al.*
Phys. Rev. Lett.
88 012502 (2002)

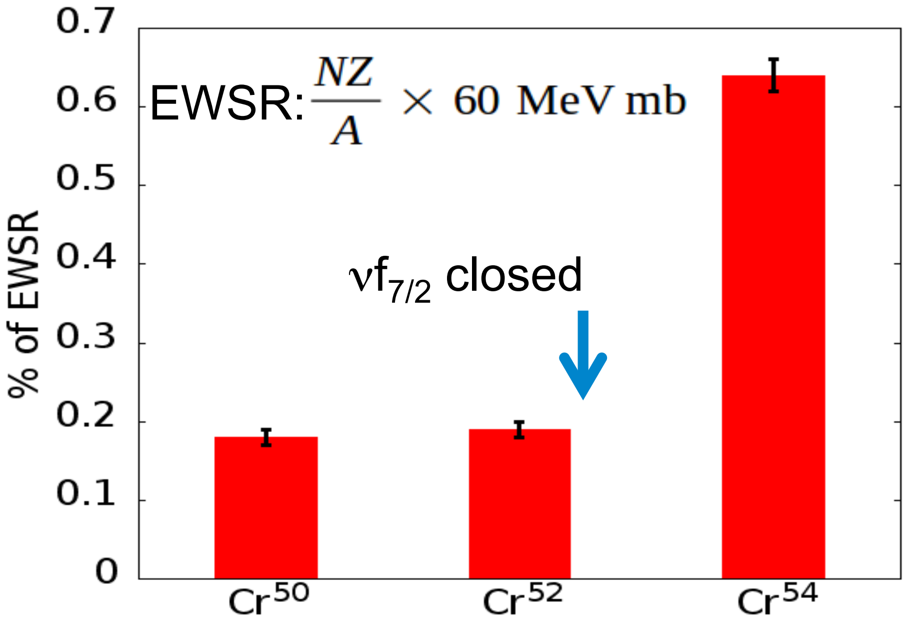


N.Pietralla et al., NIM A483, 556 (2002)

P.Ries,
M.Sc. thesis
(TU Darmstadt)

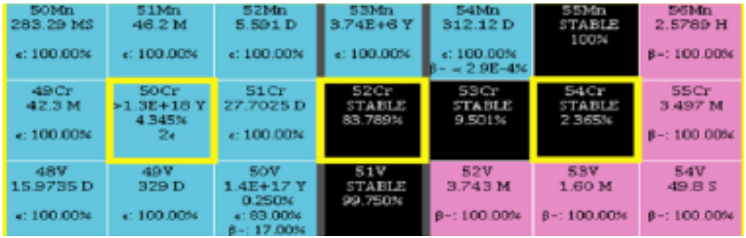


Effect of *pf*-valence neutrons

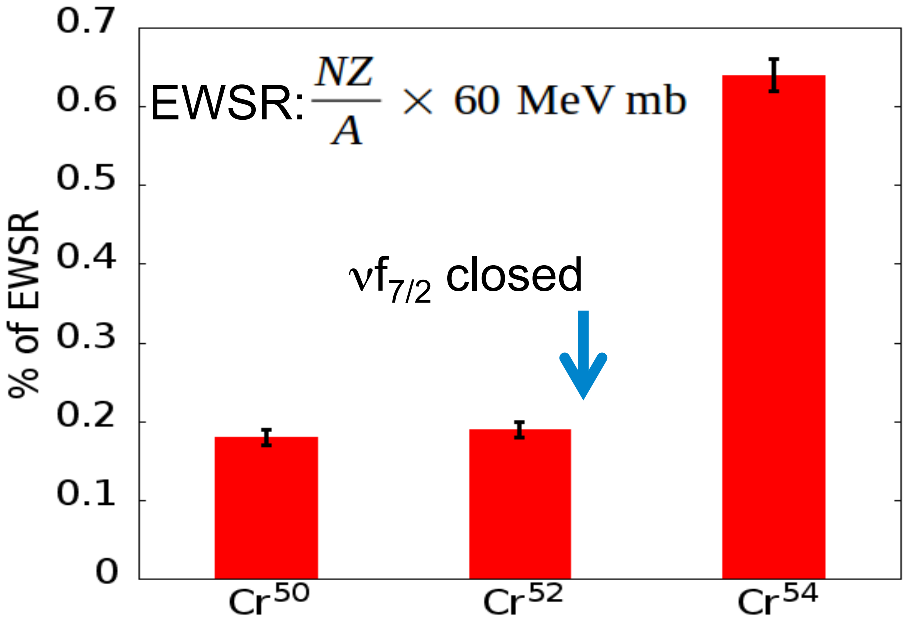


Significant increase of transition strength beyond shell-closure

Evidence for valence-neutron character of PDR (?)



Effect of *pf*-valence neutrons



Significant increase of transition strength beyond shell-closure

Evidence for valence-neutron character of PDR (?)

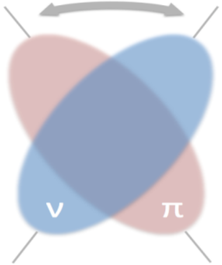
→ contributes to dipole polarizability

$$a_D \propto \sum_n \frac{\langle 0^+_{gs} || \mathbf{E1} || 1^-_n \rangle \langle 1^-_n || \mathbf{E1} || 0^+_{gs} \rangle}{E_n}$$

→ Correlation to density dependence of symmetry energy in nuclear EoS

→ Radius of Neutron Stars

2. Collectivity of the *M1* scissors mode



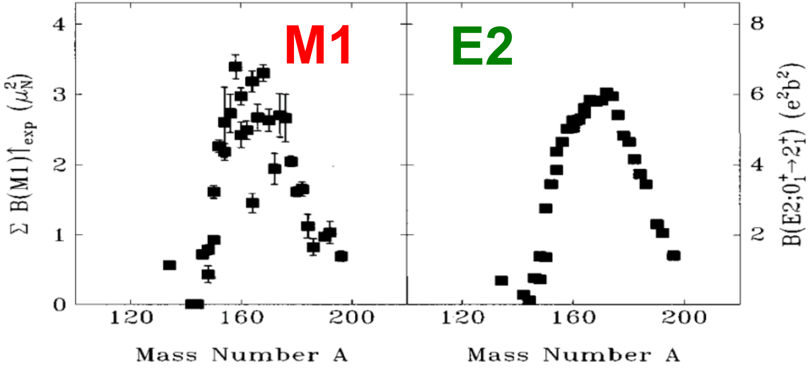
Prediction: 1978 in **TRM** by Lo Iudice and Palumbo
1981 in **IBM-2** by Iachello

Observation: 1983 by Richter *et al.* in (e,e') at the DALINAC
1984 by Berg *et al.* in (γ,γ') at Stuttgart Dynamitron

Systematics:

$$E_{\mathrm{sc}} \propto \delta A^{-1/3}$$

$$\sum B(M1;0_1^+ \rightarrow 1_{\mathrm{sc}}^+) \propto \delta^2$$



Pietralla *et al.*, Phys. Rev. C 58 (1998) 184

High Statistics NRF experiment on ^{156}Gd at HIγS

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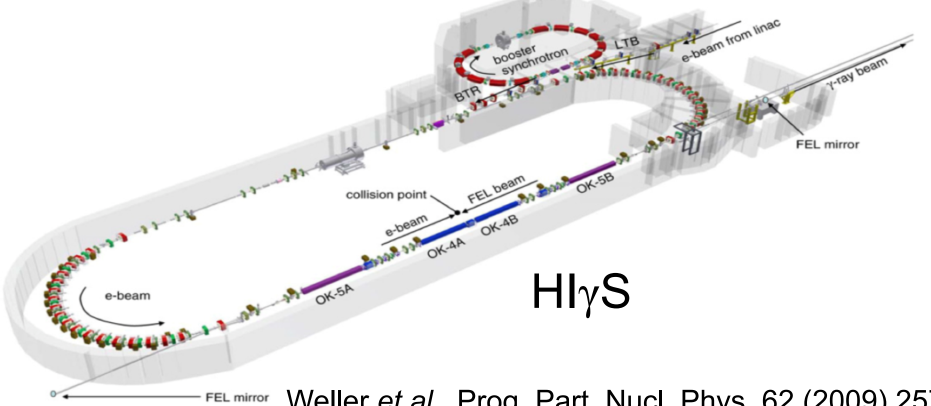
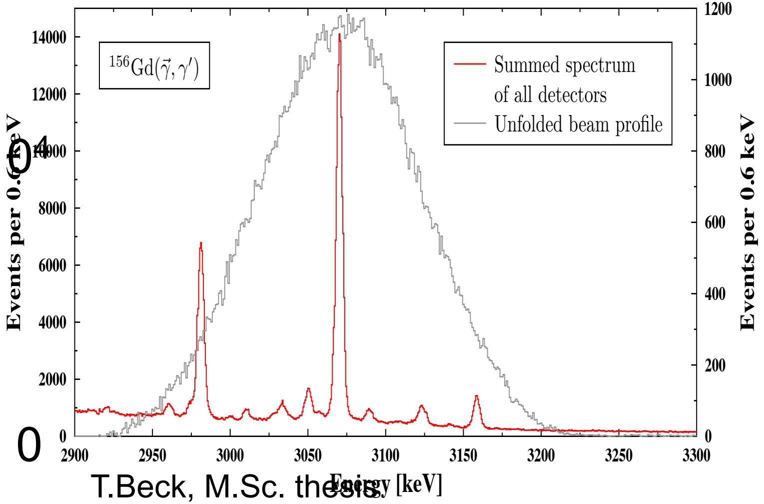


HIγS

Weller *et al.*, Prog. Part. Nucl. Phys. 62 (2009) 257

^{156}Gd($\vec{\gamma}$,γ')



T.Beck, M.Sc. thesis (TU Darmstadt, 2016)

<u>Target:</u> $^{156}Gd_2O_3$ with 10 g of ^{156}Gd, enrichment of 93.79 %

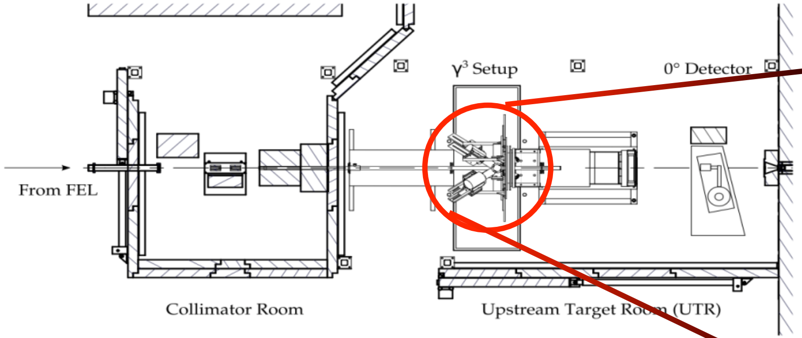
<u>Beam:</u>

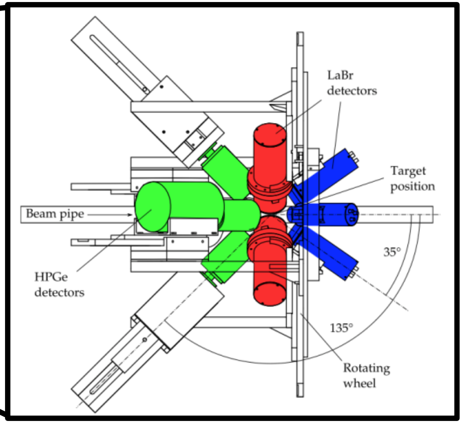
Energy: 3.07(7) MeV,

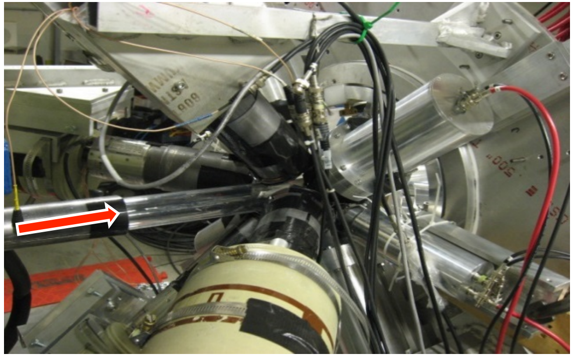
Duration: ≈ 52.8 h

γ^3 @ HIγS

B.Löher et al, NIM A 723, 136 (2013).





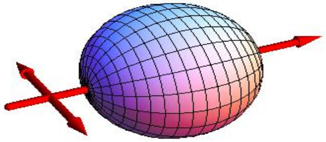


- 4 HPGe & 8 LaBr detectors
- close geometry
- high flexibility due to interchangeability

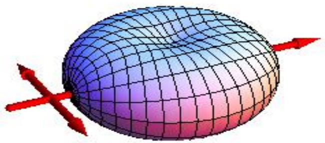
E2/M1 multipole mixing ratio of ScM Decay

Angular distribution of $1^+_{sc} \rightarrow 2^+_1$

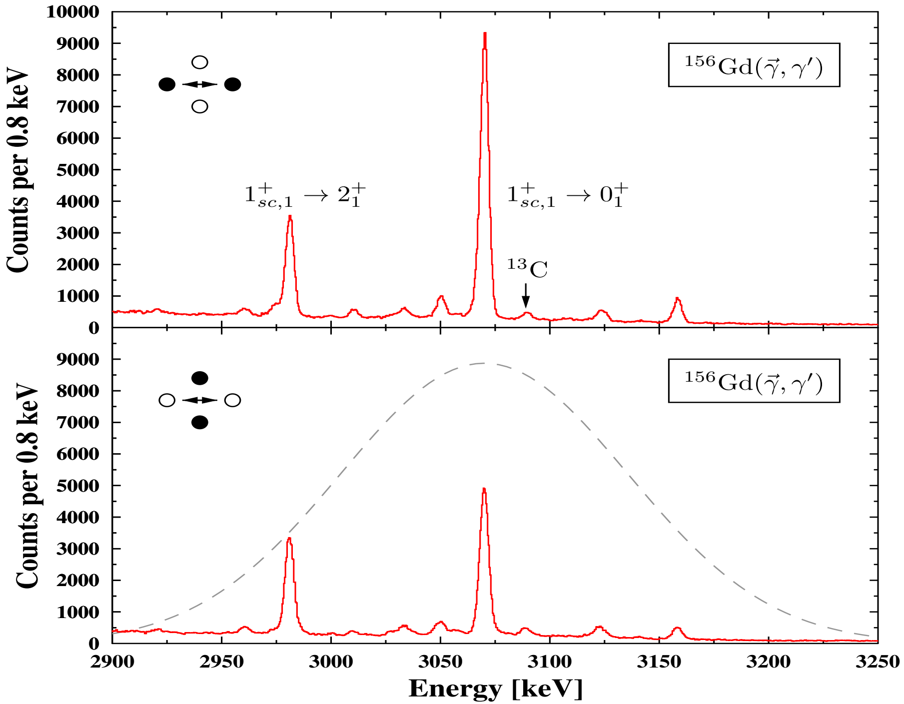
at $\theta = 135^o$



$$0^+ \xrightarrow{\vec{\gamma}} 1^+_{\rm sc} \xrightarrow{\rm M1} 2^+_1$$

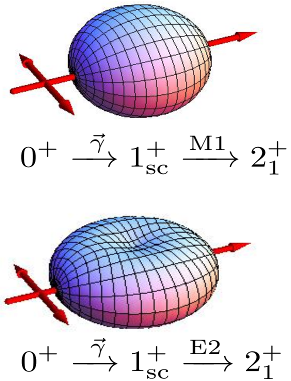


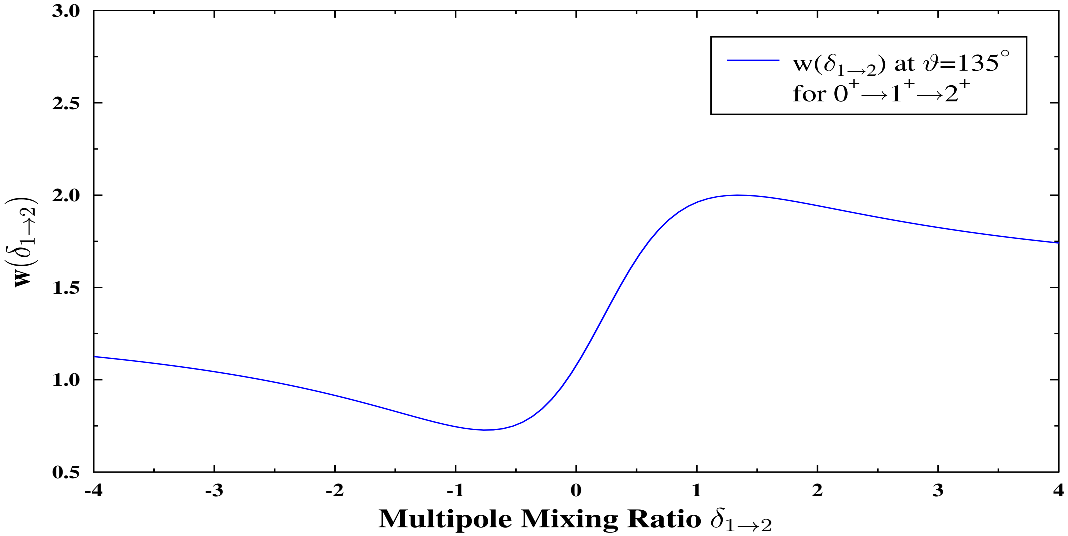
$$0^+ \xrightarrow{\vec{\gamma}} 1^+_{\rm sc} \xrightarrow{\rm E2} 2^+_1$$



Determination of the multipole mixing ratio

$$w(\delta_{1\to 2}) = \frac{W_{\parallel}(\delta_{1\to 2})}{W_{\perp}(\delta_{1\to 2})} \stackrel{!}{=} \frac{A_{\parallel}(1^+_{\mathrm{sc}} \to 2^+_1)/\epsilon_{\parallel}}{A_{\perp}(1^+_{\mathrm{sc}} \to 2^+_1)/\epsilon_{\perp}}$$

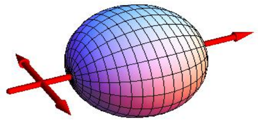




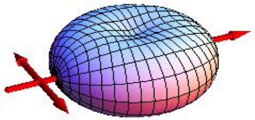
Determination of the multipole mixing ratio

$$\delta_{1\to 2} = \frac{\sqrt{3}}{10}\frac{E_\gamma}{\hbar c}\frac{\langle 2_1^+ \| \hat{T}(E2) \| 1_{sc}^+ \rangle}{\langle 2_1^+ \| \hat{T}(M1) \| 1_{sc}^+ \rangle}$$

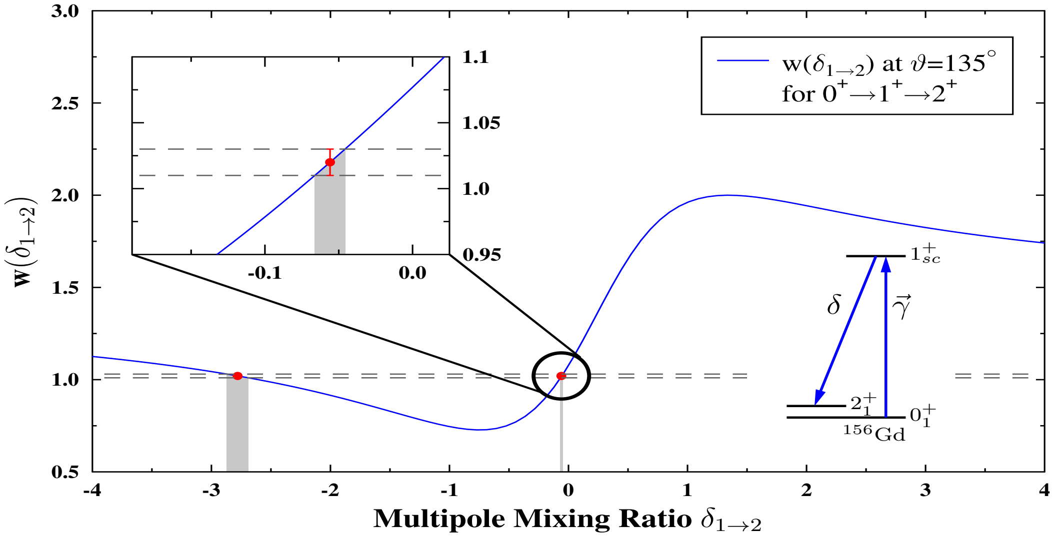
$$\boxed{\delta_{1\to 2} = -0.06(1)}$$



$0^+ \xrightarrow{\vec{\gamma}} 1^+_{\mathrm{sc}} \xrightarrow{\mathrm{M1}} 2^+_1$



$0^+ \xrightarrow{\vec{\gamma}} 1^+_{\mathrm{sc}} \xrightarrow{\mathrm{E2}} 2^+_1$



Effective boson charges from *F*-vector *E*2 transitions in a deformed nucleus

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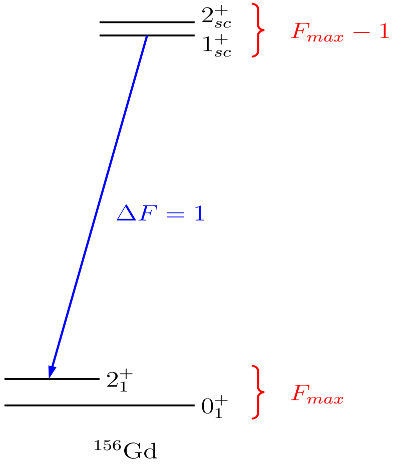
^{156}Gd

Multipole mixing ratio determines F-vector E2 transition strength

$$\longrightarrow \quad B(E2; 1^+_{\mathrm{sc}} \to 2^+_1) = 0.027(11)\ \mathrm{W.u.}$$



First information on an *F*-vector *E*2 transition in an axially-deformed nucleus!

Enables the determination of local values of the effective boson charges e_π and e_ν for *E*2 transitions in the IBM-2.

<u>*E*2 transition operator:</u> $$T(E2) = e_\pi Q_\pi^{\chi_\pi} + e_\nu Q_\nu^{\chi_\nu}$$

Effective boson charges from *F*-vector *E*2 transitions

Relation to E2 boson charges in the *F*-spin limit of the IBM-2 SU(3) d.s.l.

$$B(E2;1^+_{\mathrm{sc}} \to 2^+_1) = (e_\nu - e_\pi)^2 \cdot f(N_\nu, N_\pi)$$

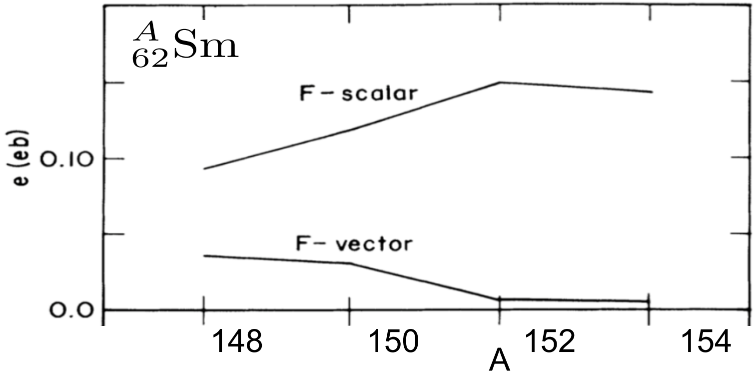
$$B(E2;2^+_1 \to 0^+_1) = (e_\nu N_\nu + e_\pi N_\pi)^2 \cdot g(N)$$

van Isacker *et al.*, Ann. Phys. 171 (1986) 253

→ Local values for effective boson charges:

$$e_\pi = 0.126(1)\ eb$$

$$e_\nu = 0.113(2)\ eb$$

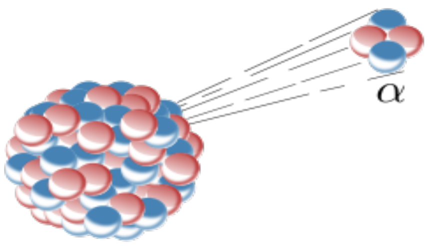


Otsuka and Ginocchio, Phys. Rev. Lett. 54 (1985) 777

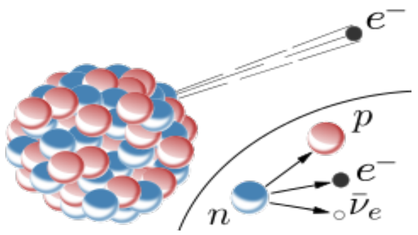
3. Double-Gamma Decay

First order radioactive decay processes:

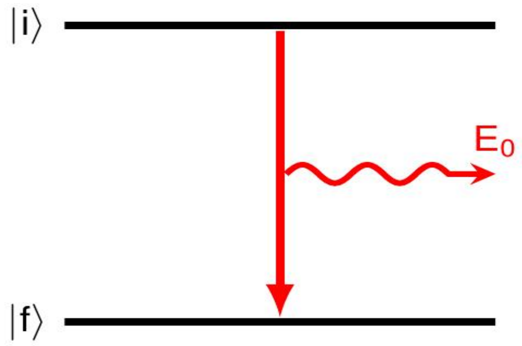
α-decay



β-decay



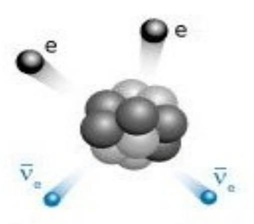
γ-decay

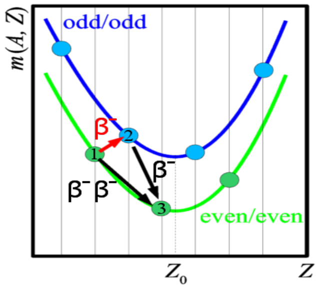


~ 1900: Henri Becquerel, Marie Curie,
Ernest Rutherford, Paul U. Villard, ...

Radioactive decay: Second order

double β-decay $2\nu\beta\beta$ ($0\nu\beta\beta$)

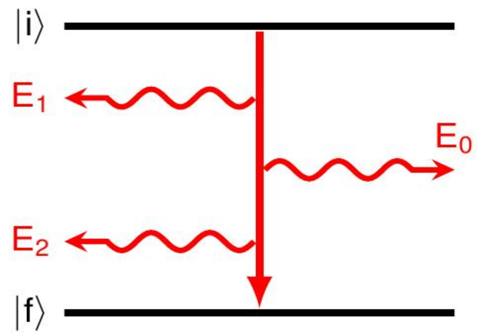




first evidence in the laboratory:

*S. Elliot, A. Hahn, and M. Moe, PRL **59**, 2020 (1987)*

competitive double γ-decay $\gamma\gamma/\gamma$



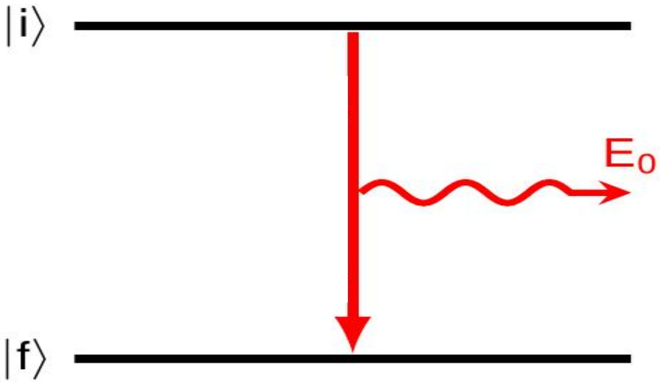
competitive double-gamma decay has not been observed until 2014

$$\text{M.E.} = \langle f|\hat{O}(2)\hat{O}(1)|i\rangle = \sum \langle f|\hat{O}(2)|n\rangle\langle n|\hat{O}(1)|i\rangle$$

The double-gamma decay

First discussed by Maria Göppert-Mayer in her doctoral thesis in 1930

M. Göppert-Mayer, Über Elementarakte mit zwei Quantensprüngen (1930)



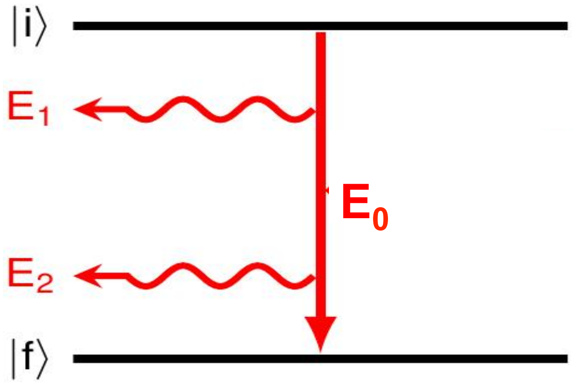
The double-gamma decay

First discussed by Maria Göppert-Mayer in her doctoral thesis in 1930

M. Göppert-Mayer, Über Elementarakte mit zwei Quantensprüngen (1930)

Second order process (10^{-6} weaker)

- $E_0 = E_1 + E_2$
- E_1, E_2 are continuous



well studied in atomic physics

- *M. Lipes et al., PRL 15, 690 (1965)*
- *P.H. Mokler et al., Phys. Scr. 69, C1 (2004)*
- *K. Ilakovac et al., Rad. Phys. Chem. 75, 1451 (2006)*

The double-gamma decay in nuclear physics

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$\gamma\gamma$-decay only known in a special case:
$0^+ \rightarrow 0^+$ (^{90}Zr, ^{40}Ca, ^{16}O)

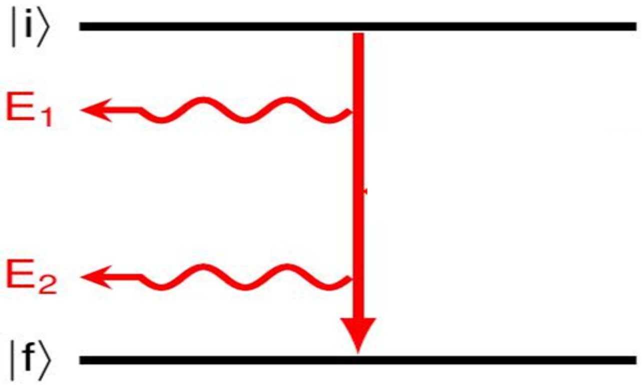
- *J. Schirmer et al., PRL 53, 1897 (1984)*
- *J. Kramp et al., NPA 474, 412 (1987)*

never observed in competition to allowed single γ-transition

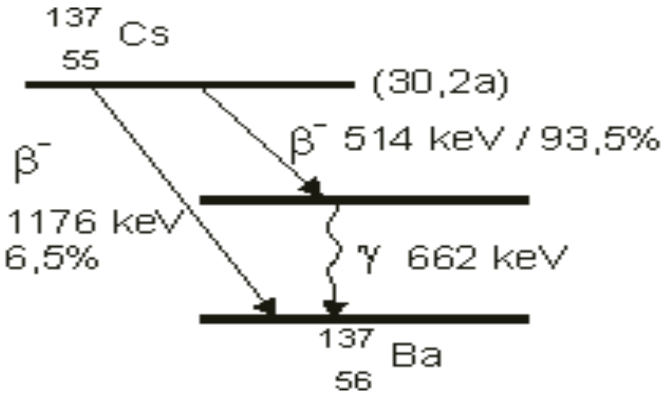
- *W. Beusch et al., Helv Phys. Acta 33, 363 (1960)*
- *J. Kramp et al., NPA 474, 412 (1987)*
- *V.K. Basenko et al., Bull. Russ. Acad. 56, 94 (1992)*
- *C.J. Lister et al., Bull. Am. Phys. Soc. 58(13), DNP.CE. 3 (2013)*

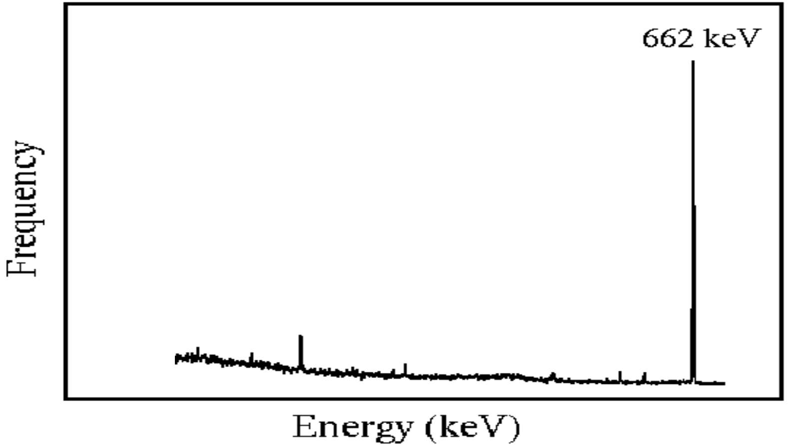
main experimental obstacle:

- presence of the one-photon decay



Search for $\gamma\gamma/\gamma$ - decay in ^{137}Cs γ - standard

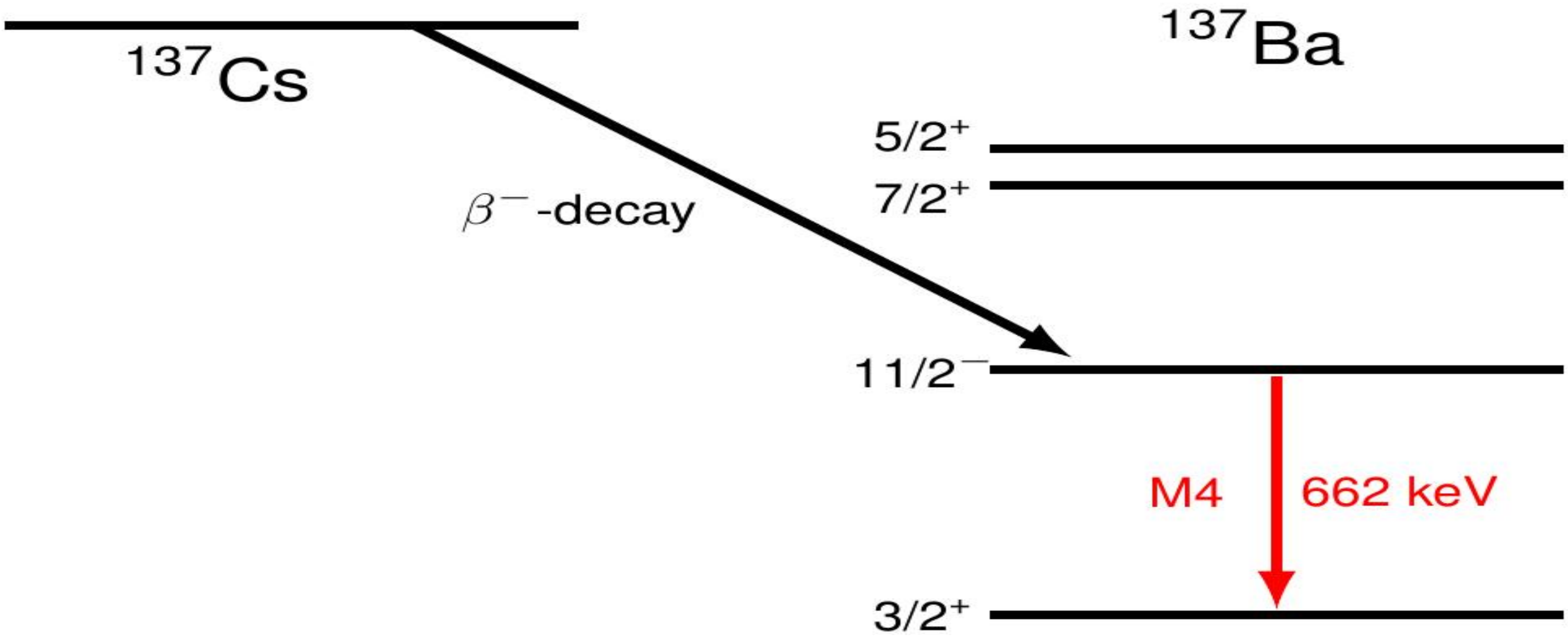




- Study 662-keV transition in ^{137}Ba
- use radioactive ^{137}Cs -source

Decay scheme of ^{137}Cs

- Activity of ^{137}Cs -source: 16.3(5)µCi

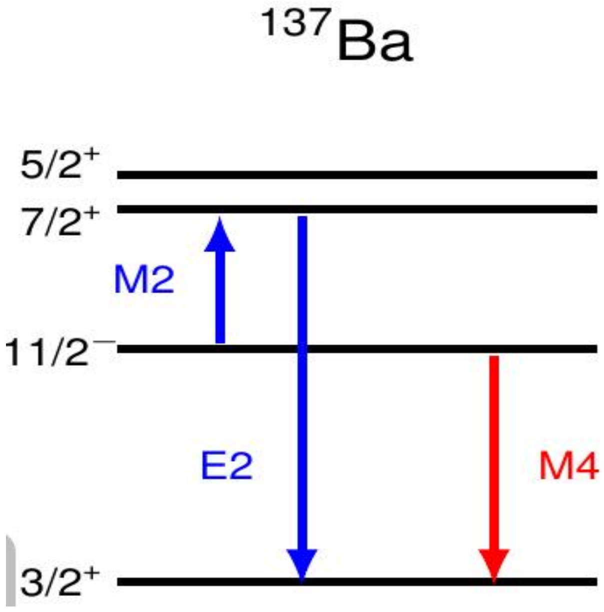


Matrix element of the double-gamma decay

$$\frac{\mathrm{d}\Gamma^2_{\gamma\gamma}}{\mathrm{d}\omega\mathrm{d}\cos\theta}(\alpha_{OO'}, \ldots)$$

$$\alpha_{OO'} = \sum_n \frac{\langle f||\mathbf{O}||n\rangle \cdot \langle n||\mathbf{O}'||i\rangle}{E_n}$$

$$\alpha_{M2E2} = \frac{\langle 3/2^+||\mathbf{E2}||7/2^+\rangle \cdot \langle 7/2^+||\mathbf{M2}||11/2^-\rangle}{E_{7/2^+}} + \ldots$$

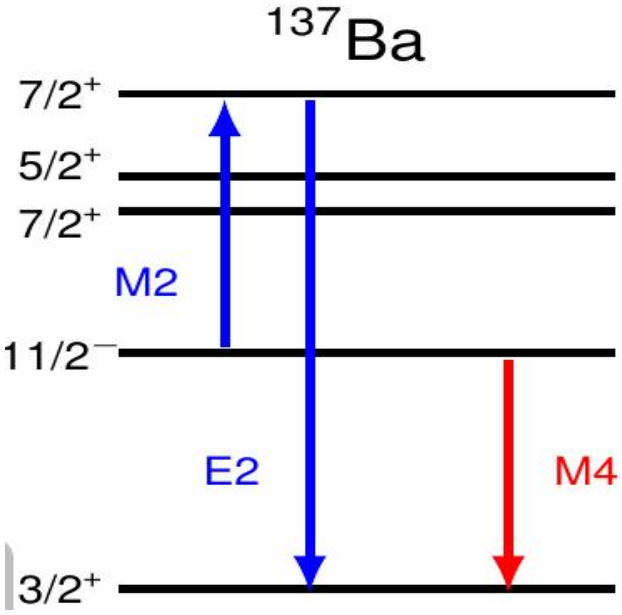


Matrix element of the double-gamma decay

$$\frac{d\Gamma^2_{\gamma\gamma}}{d\omega d\cos\theta}(\alpha_{OO'}, \ldots)$$

$$\alpha_{OO'} = \sum_n \frac{\langle f||\mathbf{O}||n\rangle \cdot \langle n||\mathbf{O}'||i\rangle}{E_n}$$

$$\alpha_{M2E2} = \frac{\langle 3/2^+||\mathbf{E2}||7/2^+\rangle \cdot \langle 7/2^+||\mathbf{M2}||11/2^-\rangle}{E_{7/2^+}} + \ldots$$

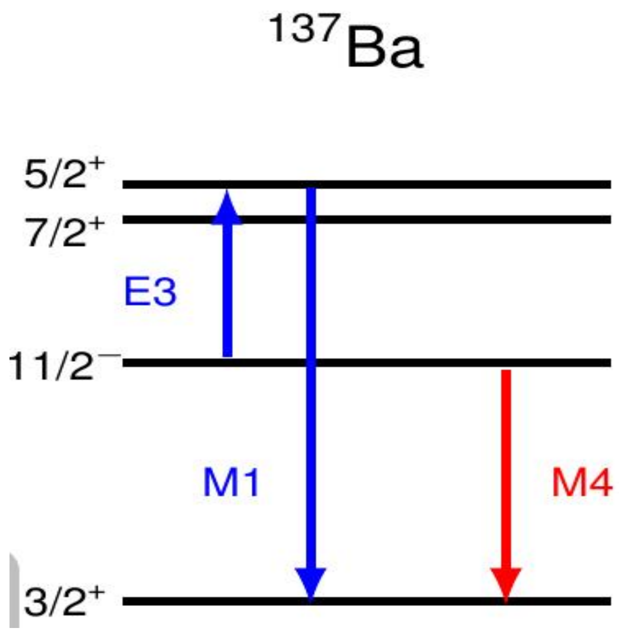


Matrix element of the double-gamma decay

$$\frac{\mathrm{d}\Gamma^2_{\gamma\gamma}}{\mathrm{d}\omega \mathrm{d}\cos\theta}(\alpha_{OO'}, \ldots)$$

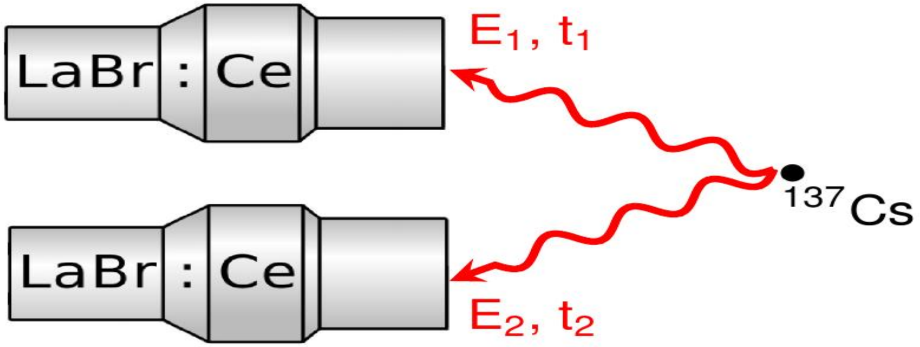
$$\alpha_{OO'} = \sum_n \frac{\langle f||\mathbf{O}||n\rangle \cdot \langle n||\mathbf{O}'||i\rangle}{E_n}$$

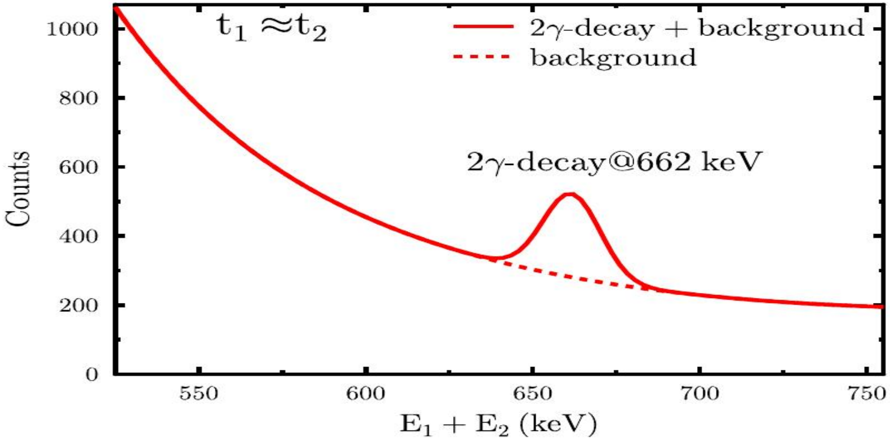
$$\alpha_{E3M1} = \frac{\langle 3/2^+||\mathbf{M1}||5/2^+\rangle \cdot \langle 5/2^+||\mathbf{E3}||11/2^-\rangle}{E_{5/2^+}} + \ldots$$



Basic principle of the experiment

•use radioative ^{137}Cs -source: 16.3(5)µCi





- background ↔ small decay probability (~1 event per day)
  - direct Compton scattering
  - random coincidences
  - cosmic rays, sequential Compton scattering, internal radioactivity

The experimental setup & direct Compton scattering

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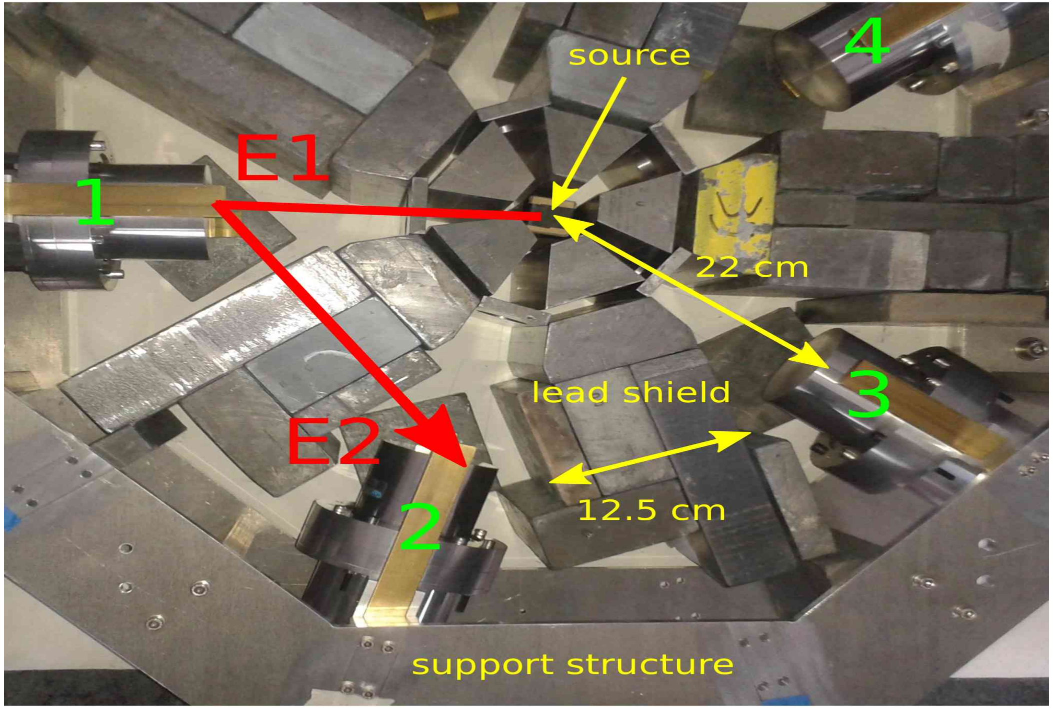
- 72°: 5 detector pairs
- 144°: 5 detector pairs

- $E_1 + E_2 = 662$ keV
- Compton scattering

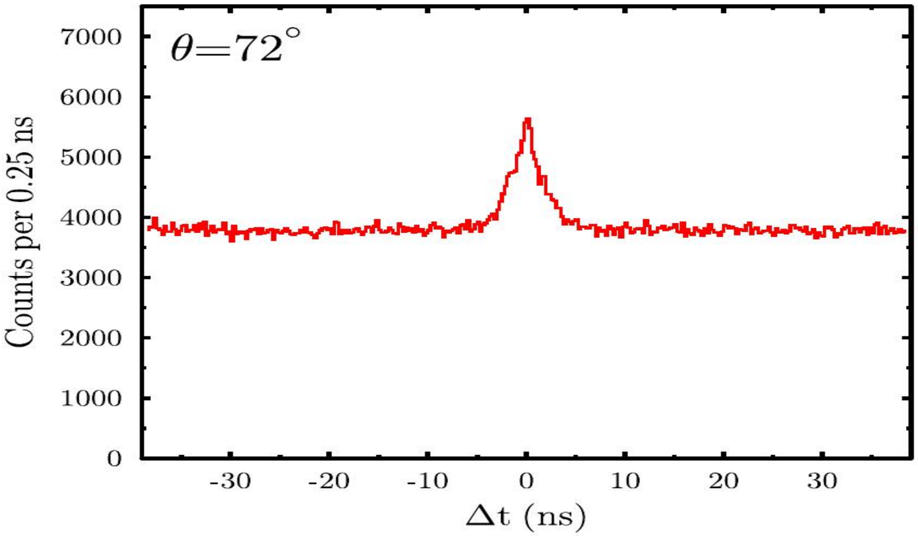
  $\Longleftrightarrow$

  double-gamma decay

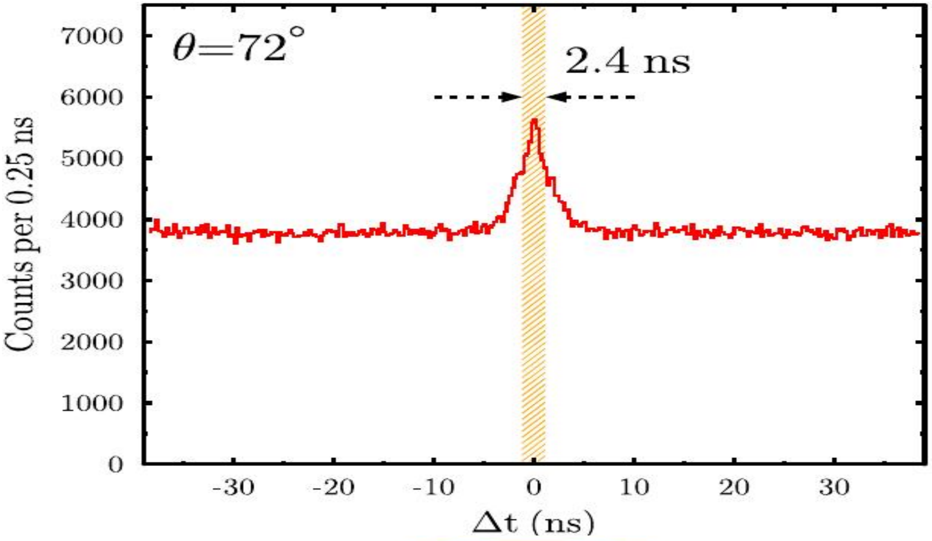
- $\epsilon_{abs} = 1.50(5)\%$
- measurement time: 1273 h

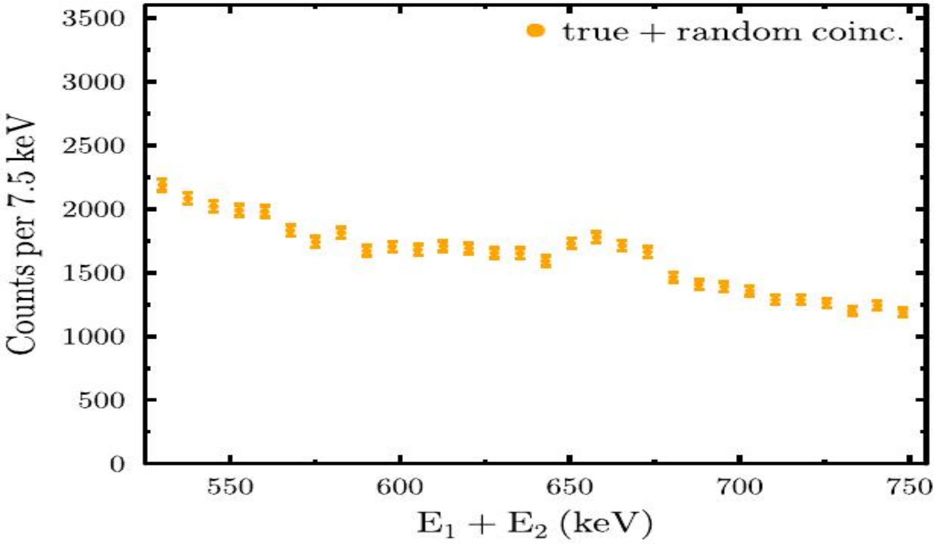


Time spectrum & random coincidences



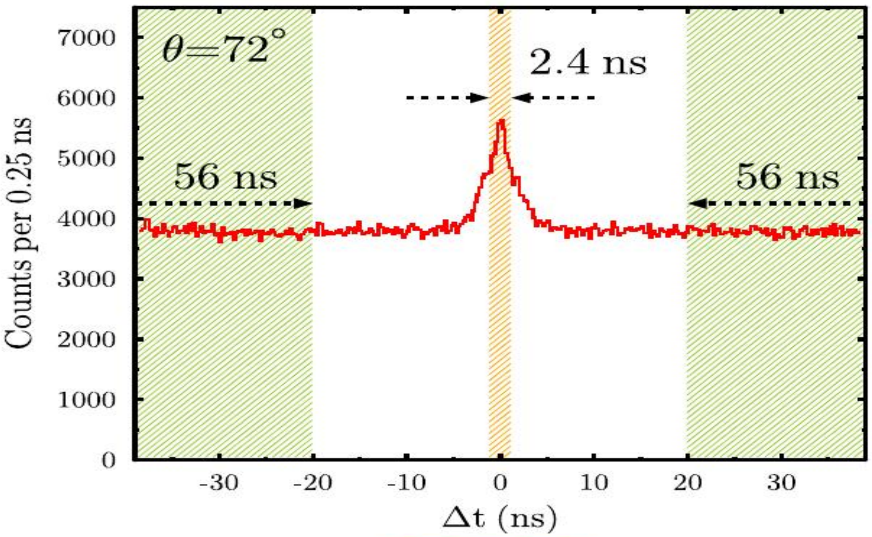
Time spectrum & random coincidences

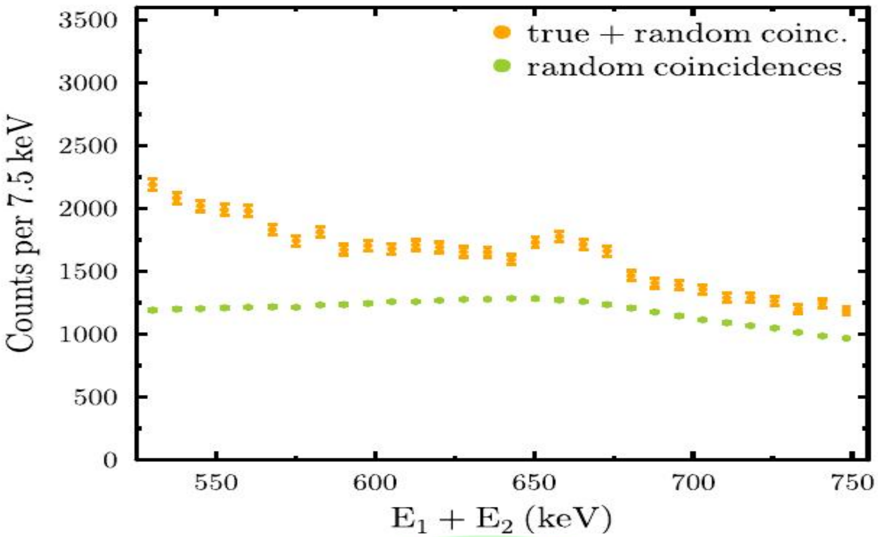




use excellent time resolution of the $LaBr_3$-detectors

Time spectrum & random coincidences





use excellent time resolution of the $LaBr_3$-detectors

random coinci-dences determine uncertainty

Results

LETTER nature

doi:10.1038/nature15543

Observation of the competitive double-gamma nuclear decay

Oct. 15th, 2015

C. Walz[1], H. Scheit[1], N. Pietralla[1], T. Aumann[1], R. Lefol[1,2] & V. Yu. Ponomarev[1]

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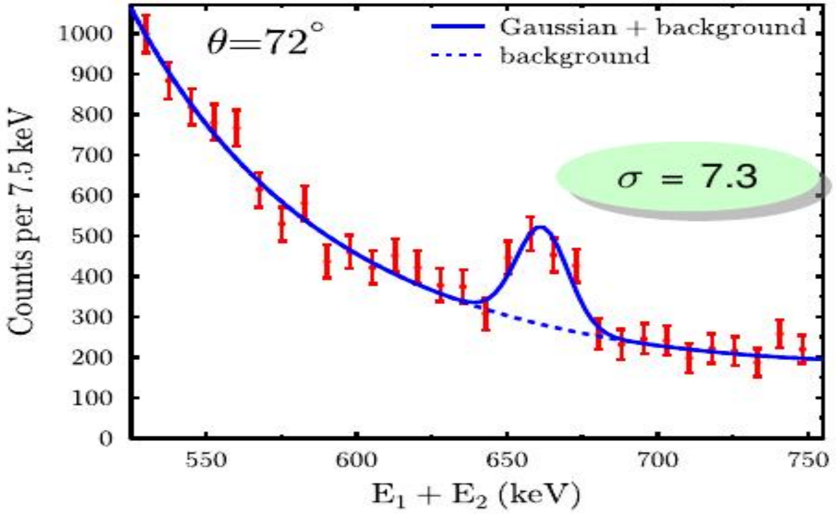
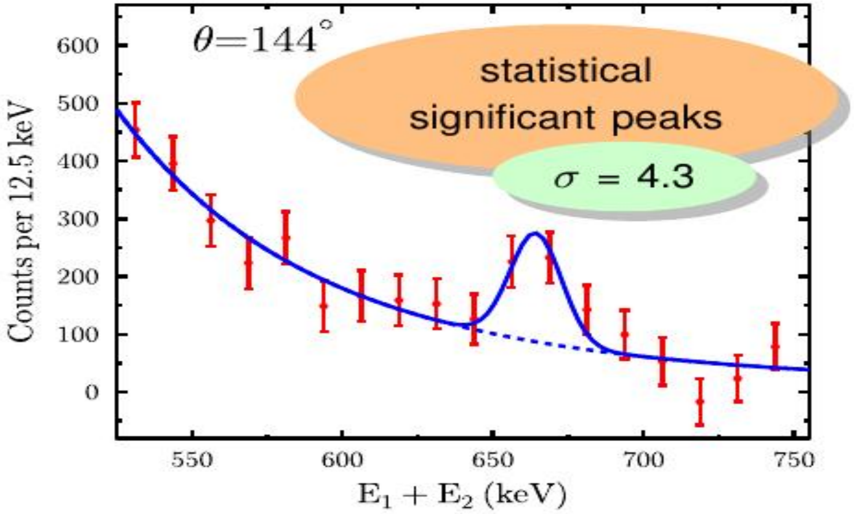


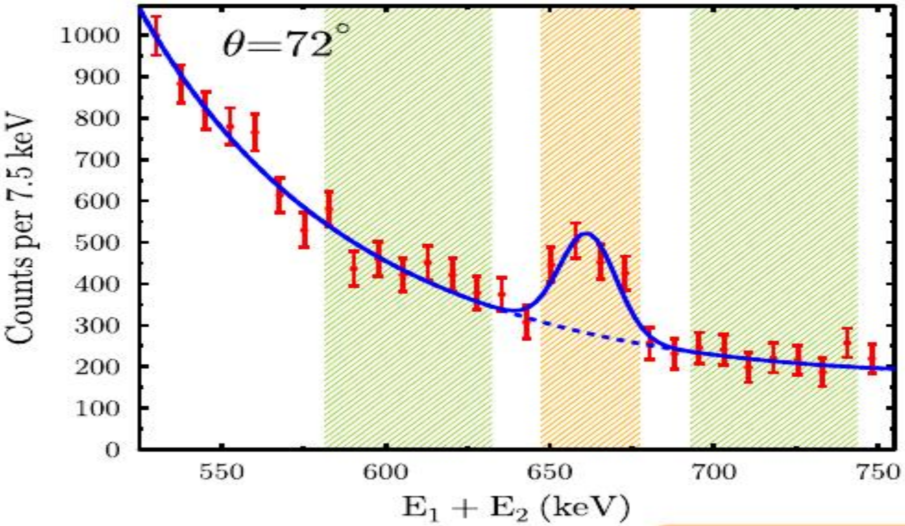


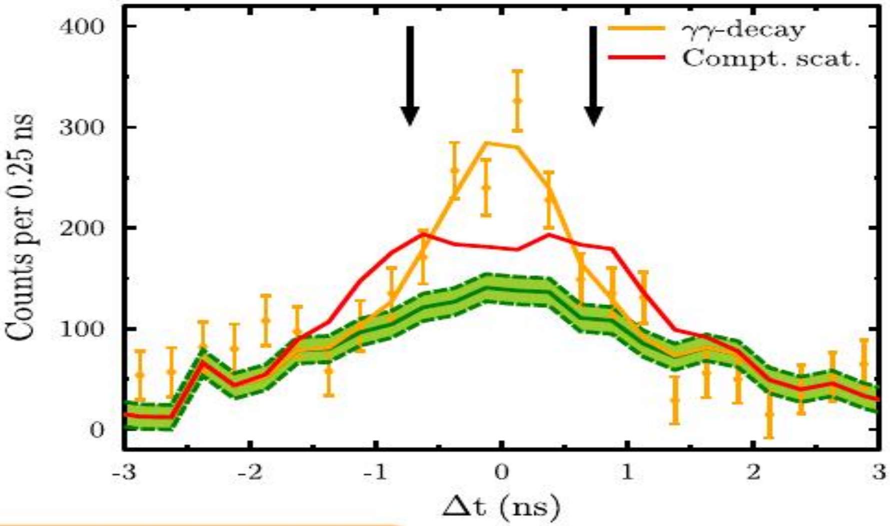
$A_{2\gamma}(72^\circ)$ = 693(95) counts
$\Gamma_{\gamma\gamma}/\Gamma_{\gamma}(72^\circ) = 1.56(23)\cdot 10^{-6}$

$A_{2\gamma}(144^\circ)$ = 325(76) counts
$\Gamma_{\gamma\gamma}/\Gamma_{\gamma}(144^\circ) = 0.70(18)\cdot 10^{-6}$

- Result: Successful observation of the competitive double-gamma decay

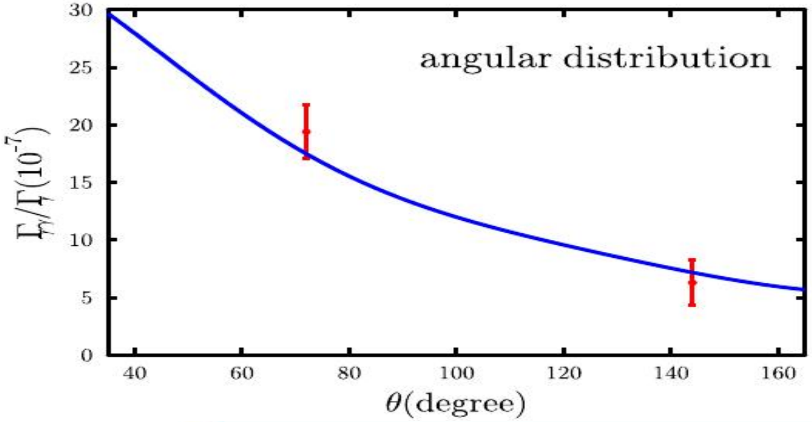
Timing analysis

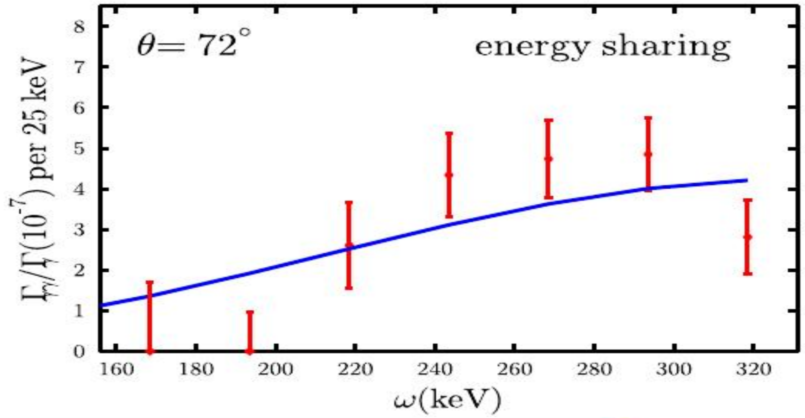




Shape of the time spectrum proofs that Compton scattering is not the origin of the peak at 662 keV

Results





$$\frac{d\Gamma^2_{\gamma\gamma}}{d\omega\, d\cos\theta} = A_{qq}(\alpha^2_{M2E2}) + A_{od}(\alpha^2_{E3M1}) + A_x(\alpha_{M2E2} \cdot \alpha_{E3M1})$$

- Assumption: Only α_{M2E2} and α_{E3M1} co
- A_{qq}, A_{od} and A_x exhibit characteristic
- fit both distributions simultaneously to determine α_{M2E2} and α_{E3M1}

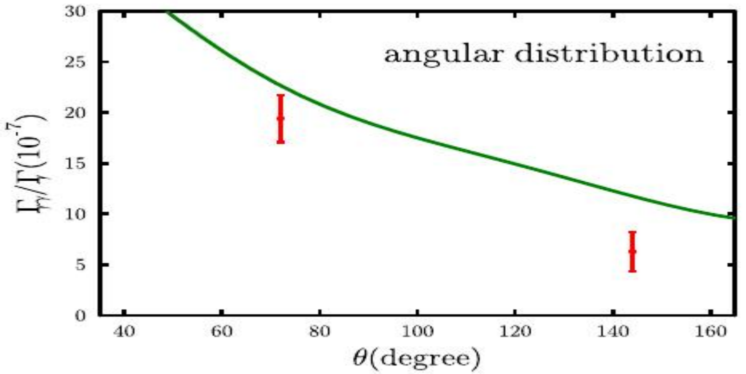
$\alpha_{M2E2} = +38.2(36)$ $e^2 fm^4 / MeV$
$\alpha_{E3M1} = +7.4(38)$ $e^2 fm^4 / MeV$

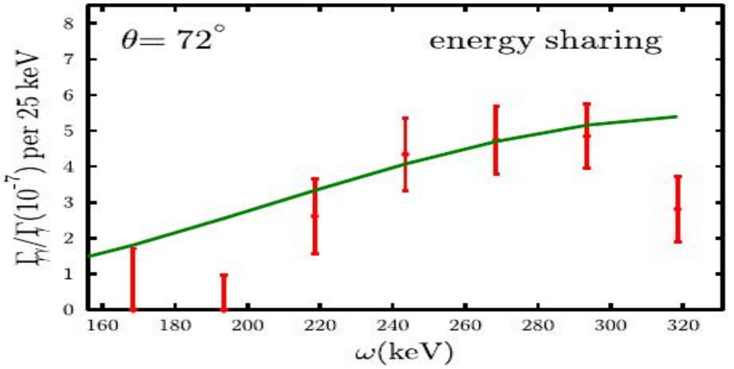
Results & comparison to QPM

	exp	QPM
$\Gamma_{\gamma\gamma}/\Gamma_{\gamma}(10^{-6})$	2.1(3)	2.69
$\alpha_{M2E2}(\frac{e^2 fm^4}{MeV})$	+38.2(36)	+42.6
$\alpha_{E3M1}(\frac{e^2 fm^4}{MeV})$	+7.4(38)	+9.5

γγ/γ - branching ratio: ~ 10^{-6}

- α_{M2E2} dominates
- relative sign between α_{M2E2} and α_{E3M1} is positive
- good description in the framework of the QPM





Electric dipole polarizability $\leftrightarrow$ matrix element of the double-gamma decay

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Electric dipole polarizability:

$$a_D \propto \sum_n \frac{\langle 0^+_{\mathrm{gs}} || \mathbf{E1} || 1^-_{\mathrm{n}} \rangle \langle 1^-_{\mathrm{n}} || \mathbf{E1} || 0^+_{\mathrm{gs}} \rangle}{E_n}$$

Matrix element of the double-gamma decay ($\mathrm{J}_i^+ = 0^+, 2^+$):

$$\alpha_{E1E1} \propto \sum_n \frac{\langle 0^+_{\mathrm{gs}} || \mathbf{E1} || 1^-_{\mathrm{n}} \rangle \langle 1^-_{\mathrm{n}} || \mathbf{E1} || J_i^+ \rangle}{E_n}$$

- similar structure of a_D and α_{E1E1}
- α_{E1E1} alternative quantity?
- a_D requires measurement of $E1$-strengths over wide energy range (difficult)
  $\Longleftrightarrow$ α_{E1E1} accessible through one electromagnetic transition

Summary

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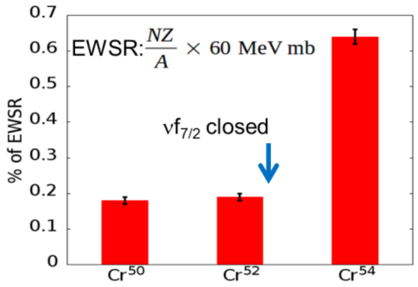
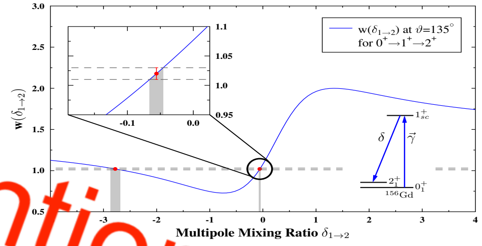
Photonuclear reactions classical, yet timely, field



H.Pai, P.Ries

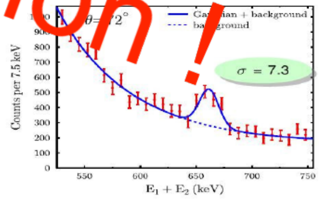
PDR strength doubles beyond $\nu f_{7/2}$ closure



T.Beck

Sc.M. → gsb transition E2 „collectivity“ measured

Thank you for attention !



C.Walz, H.Scheit

Competitive double-gamma decay ($\gamma\gamma/\gamma$) observed

C.Walz et al., Nature 526, 406 (2015).

Complementary Information

Darmstadt High Intensity Photon Setup

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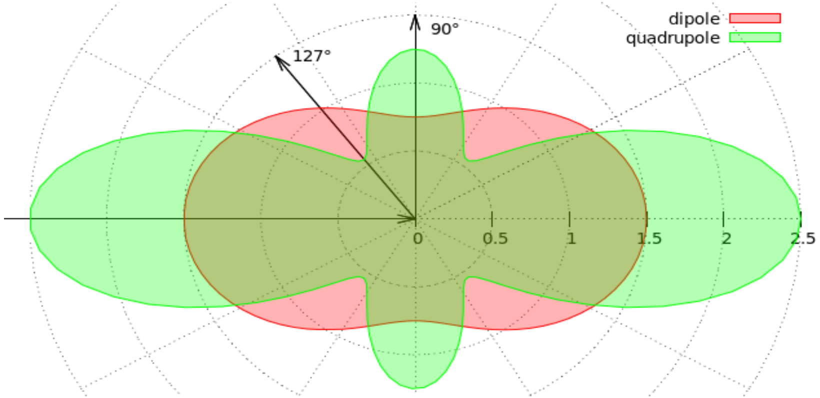
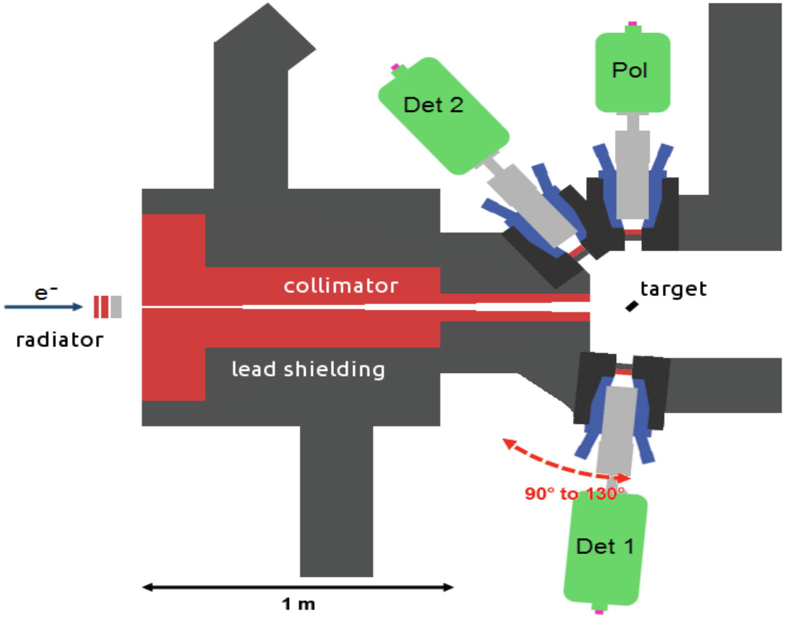
Bremsstrahlung γ spectrum provided by S-DALINAC

Order of multipole from



P. Ries master these, TU Darmstadt, 2015



C. Romig PhD these, TU Darmstadt, 2015 (modified)

The *F*-spin quantum number in the IBM-2

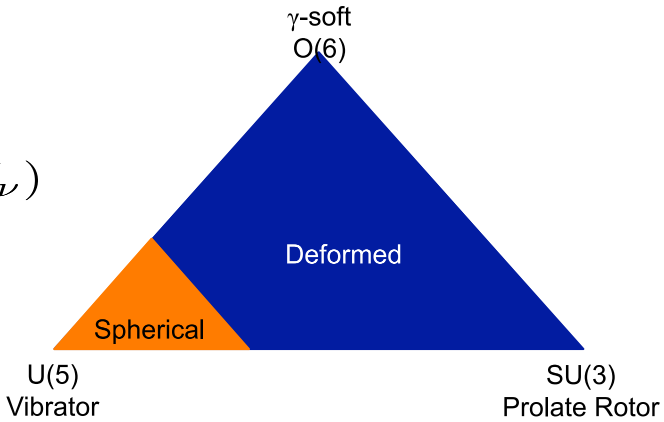
Mixed Symmetry States (MSSs) need the distinction of neutron and proton degrees of freedom! → sd-IBM-2

Classification of πν-symmetry: *F*-spin quantum number

Arima *et al.*, Phys. Lett. B 66 (1977) 205
Otsuka *et al.*, Nucl. Phys. A 309 (1978) 1
Iachello, Phys. Rev. Lett. 53 (1984) 1427
van Isacker *et al.*, Ann. Phys. 171 (1986) 253

fully symmetric $$F = F_{max} = \frac{1}{2}(N_\pi + N_\nu)$$

mixed symmetric $$F = F_{max} - 1$$



Candidate for the $2^+_{\mathrm{sc}} \rightarrow 2^+_1$ transition

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Asymmetry: $$\epsilon(\vartheta) = \frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + I_{\perp}}$$

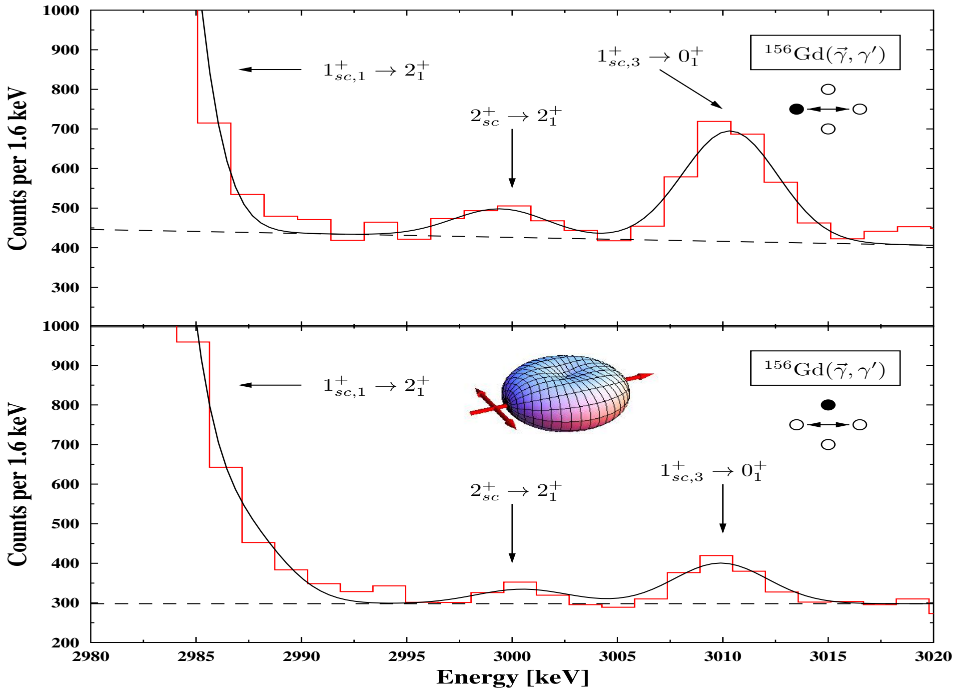
Theory: 0.176

Experiment: 0.20(11)

Observable		Experiment	Alaga estimate
$B(M1; 1^+_{\mathrm{sc},1} \rightarrow 0^+_1)$	$[\mu_N^2]$	0.451(39)	
$B(M1; 1^+_{\mathrm{sc},1} \rightarrow 2^+_1)$	$[\mu_N^2]$	0.232(49)	
$B(M1; 2^+_{\mathrm{sc}} \rightarrow 2^+_1)$	$[\mu_N^2]$		0.70(15)
$B(M1; 3^+_{\mathrm{sc}} \rightarrow 2^+_1)$	$[\mu_N^2]$		0.40(8)
$B(M1; 3^+_{\mathrm{sc}} \rightarrow 4^+_1)$	$[\mu_N^2]$		0.30(6)
$B(E2; 1^+_{\mathrm{sc},1} \rightarrow 2^+_1)$	[W.u.]	0.027(11)	
$B(E2; 2^+_{\mathrm{sc}} \rightarrow 0^+_1)$	[W.u.]		0.011(4)
$B(E2; 2^+_{\mathrm{sc}} \rightarrow 2^+_1)$	[W.u.]		0.004(2)
$B(E2; 2^+_{\mathrm{sc}} \rightarrow 4^+_1)$	[W.u.]		0.012(5)
$B(E2; 3^+_{\mathrm{sc}} \rightarrow 2^+_1)$	[W.u.]		0.008(3)
$B(E2; 3^+_{\mathrm{sc}} \rightarrow 4^+_1)$	[W.u.]		0.019(8)

Transition strength:

$$B(E2; 2^+_{\mathrm{sc}} \rightarrow 0^+_1) = 0.052(7)\ \mathrm{W.u.}$$

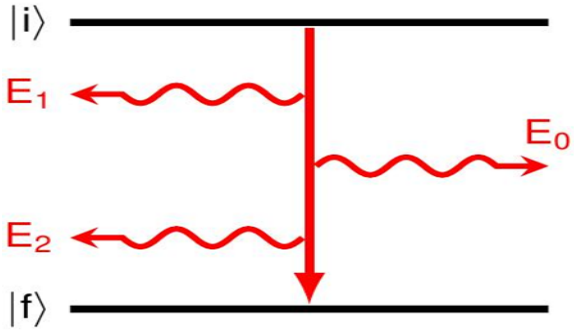


Objectives

- Observation of the „competitive double-gamma decay” ($\gamma\gamma/\gamma$)

- Measurement of the energy distribution and $\gamma\gamma$-angular correlation

- Determination of the multipole order and radiation character

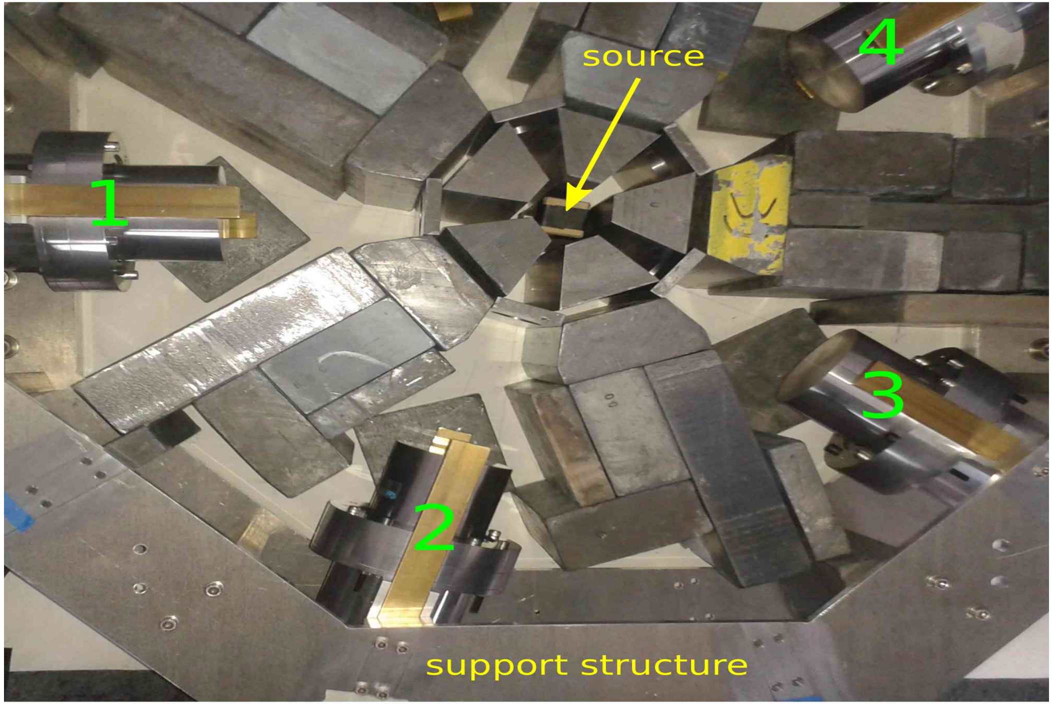


•Determination of $\gamma\gamma/\gamma$ - branching ratio $\Gamma_{\gamma\gamma}/\Gamma_{\gamma}$:

$$\Gamma_{\gamma\gamma}/\Gamma_{\gamma}(\theta) = \Gamma_{\gamma\gamma}/\Gamma_{\gamma} \cdot W(\theta)$$

The experimental setup & direct Comption scattering

- 72°: 5 detector pairs
- 144°: 5 detector pairs



The experimental setup & direct Comption scattering

- 72°: 5 detector pairs
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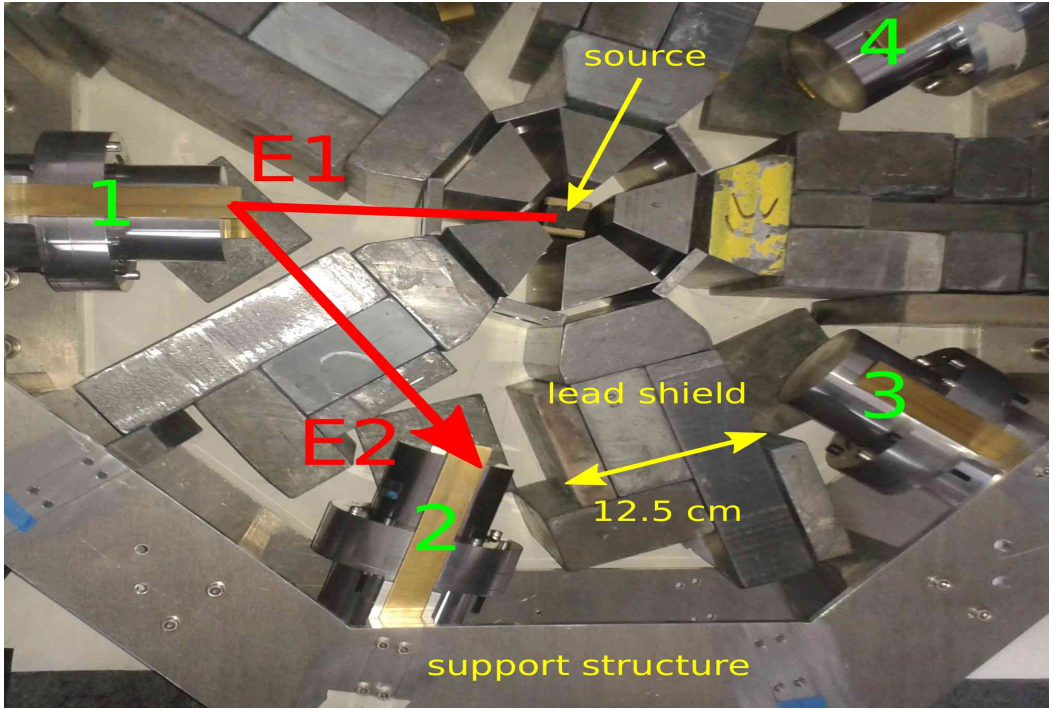
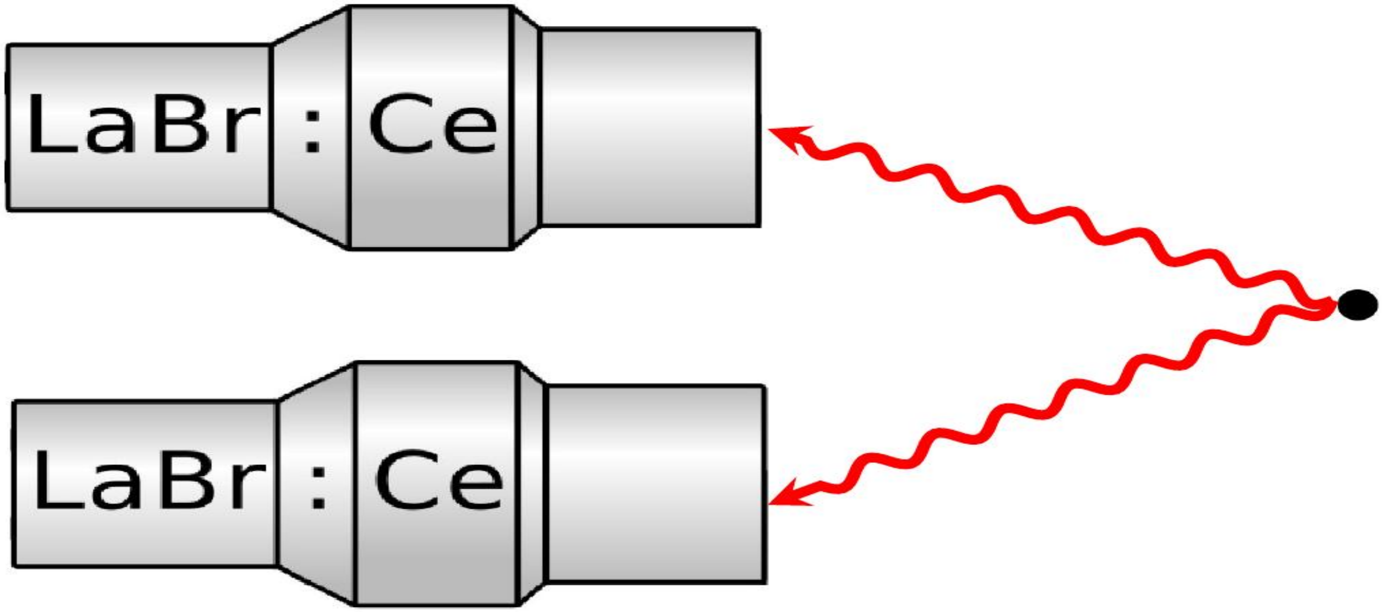
- $E_1 + E_2 = 662$ keV
- Compton scattering
  $\Longleftrightarrow$
  double-gamma decay



Timing spectrum & random coincidences



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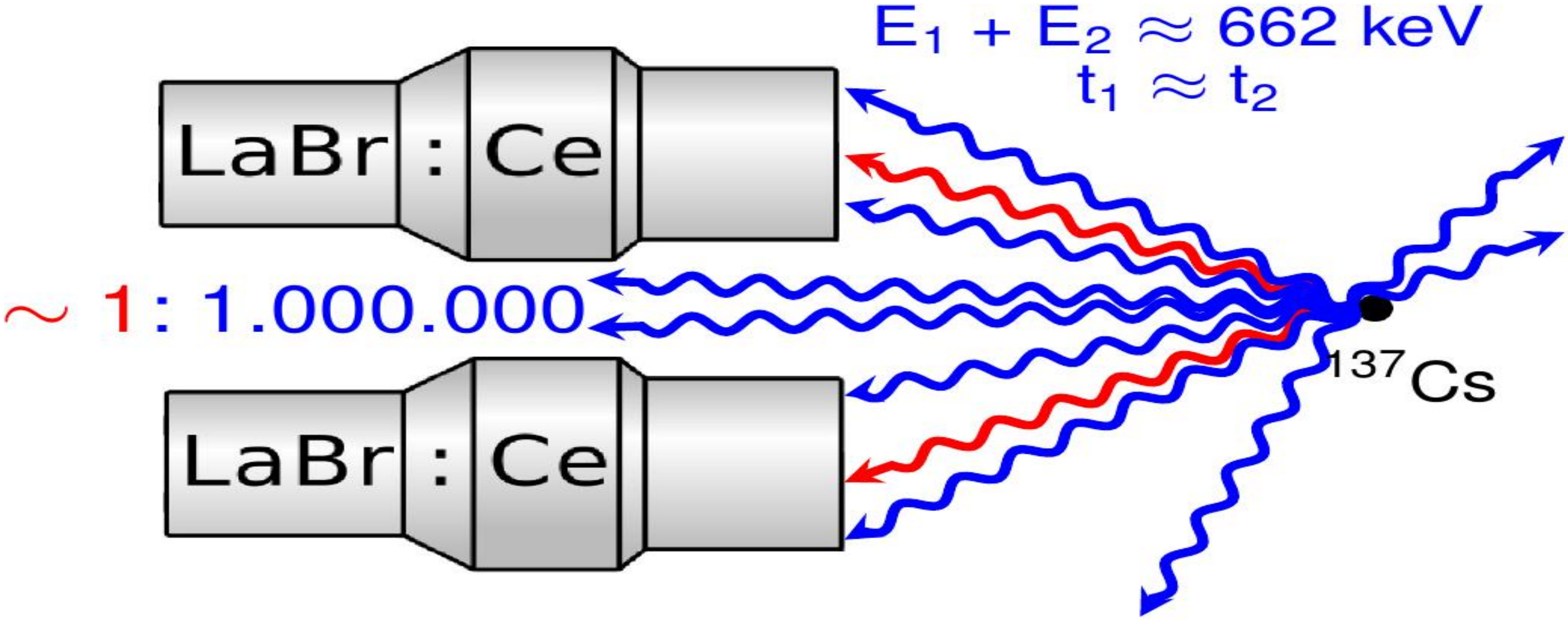
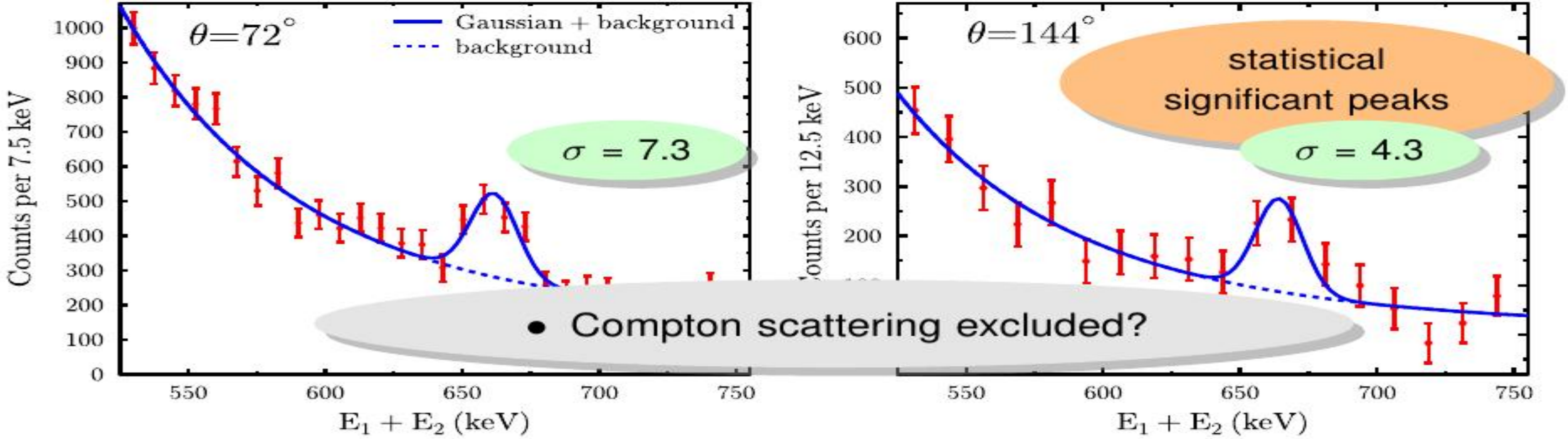


Results



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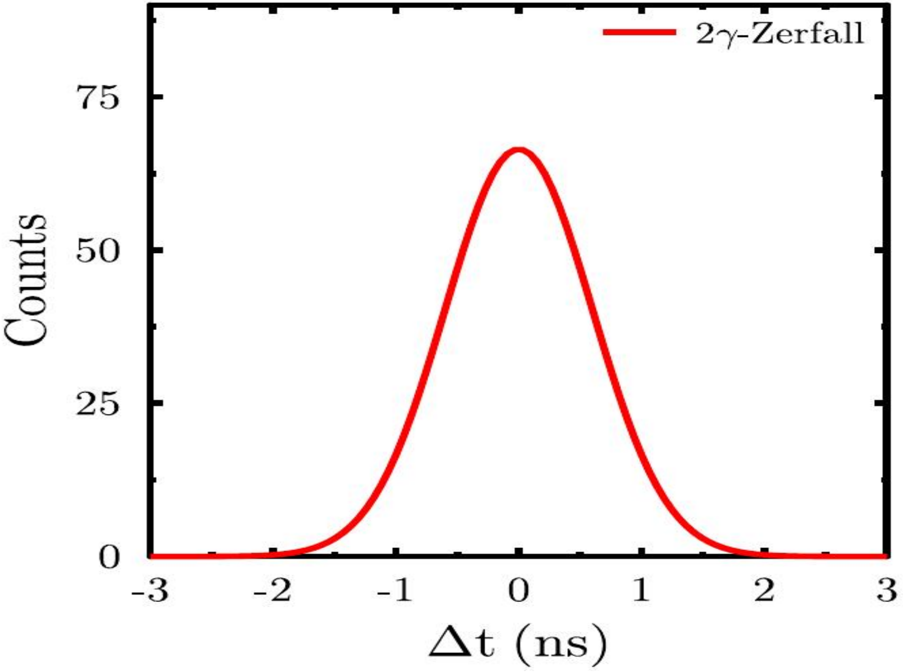
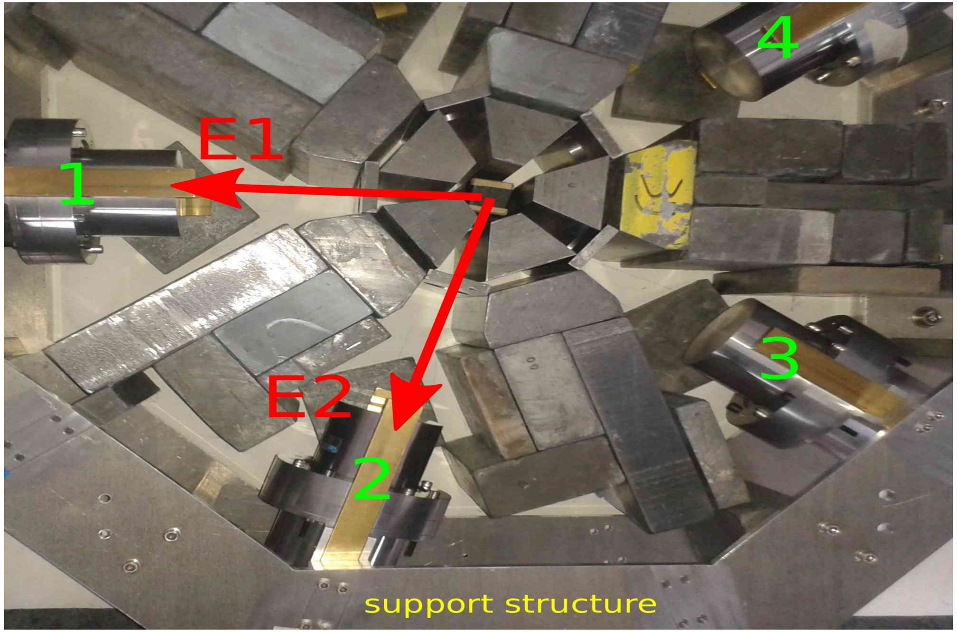
► Result: Successful observation of the competitive double-gamma decay

Critical analysis (1)





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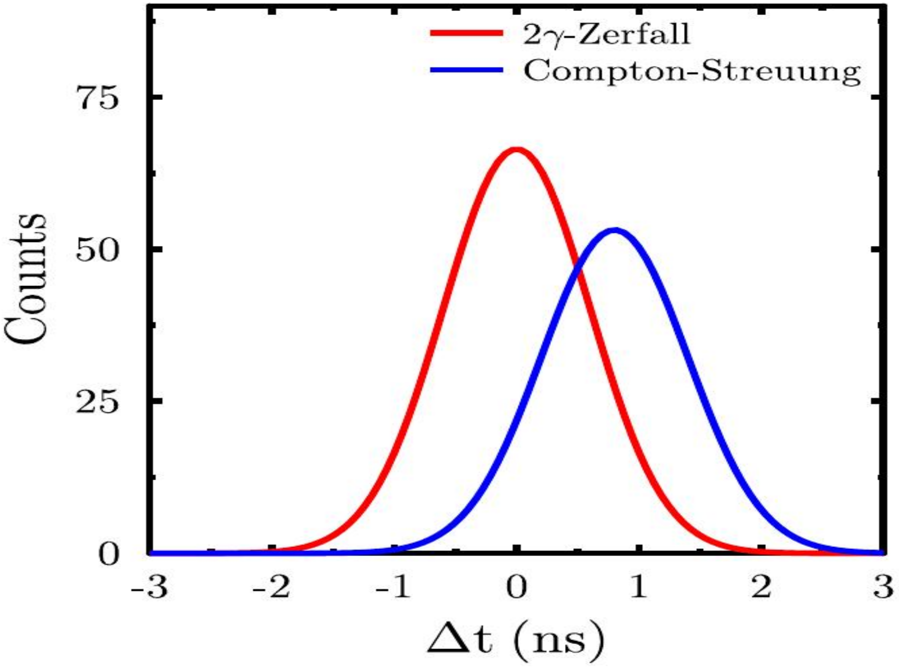

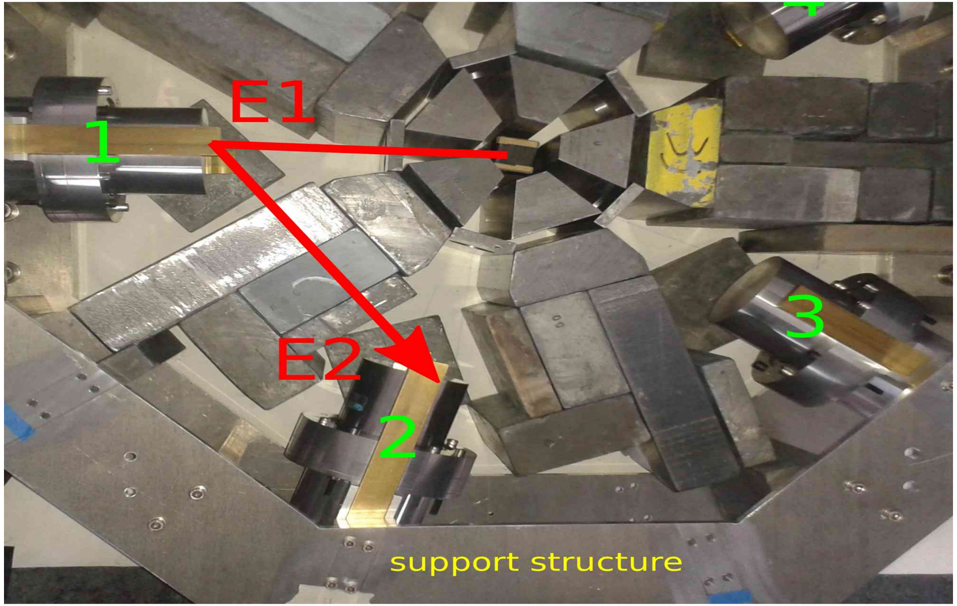

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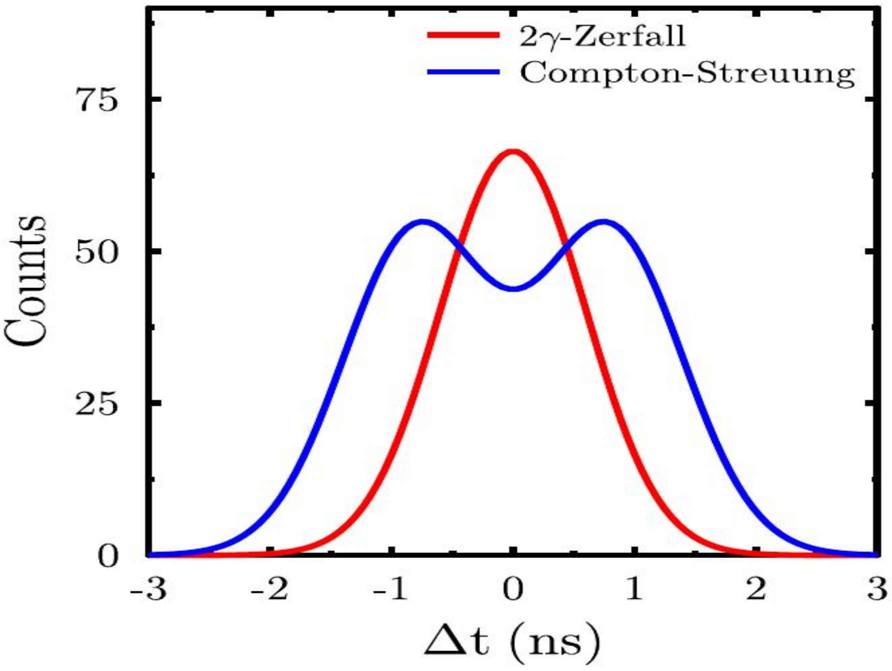
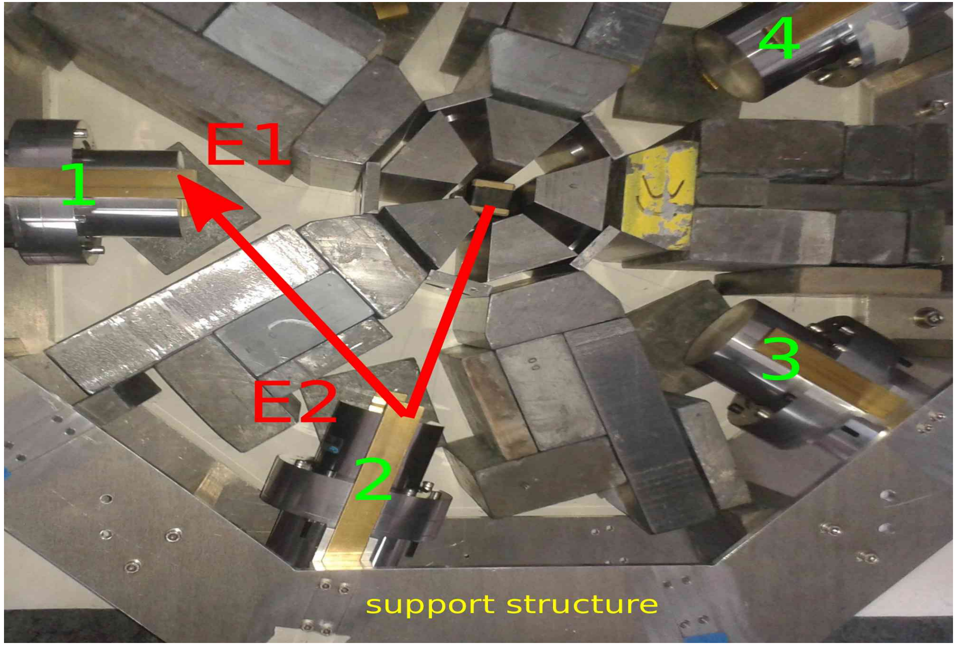
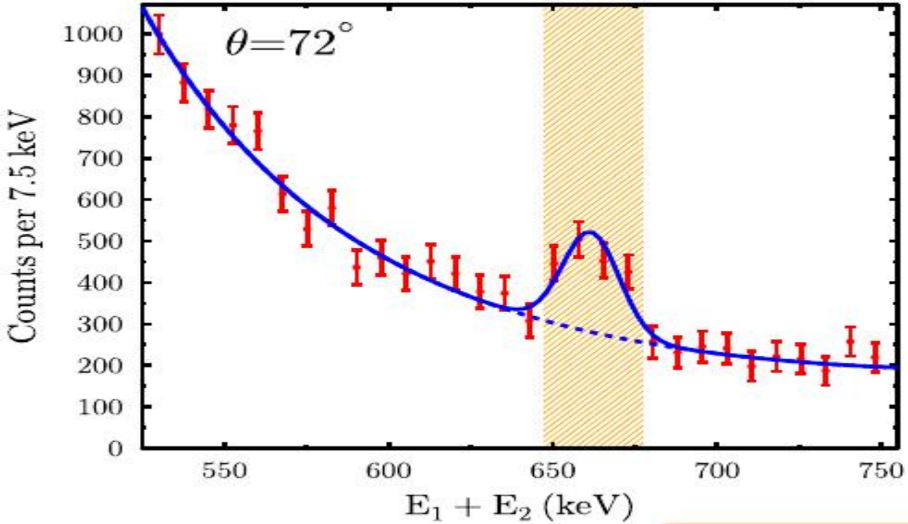
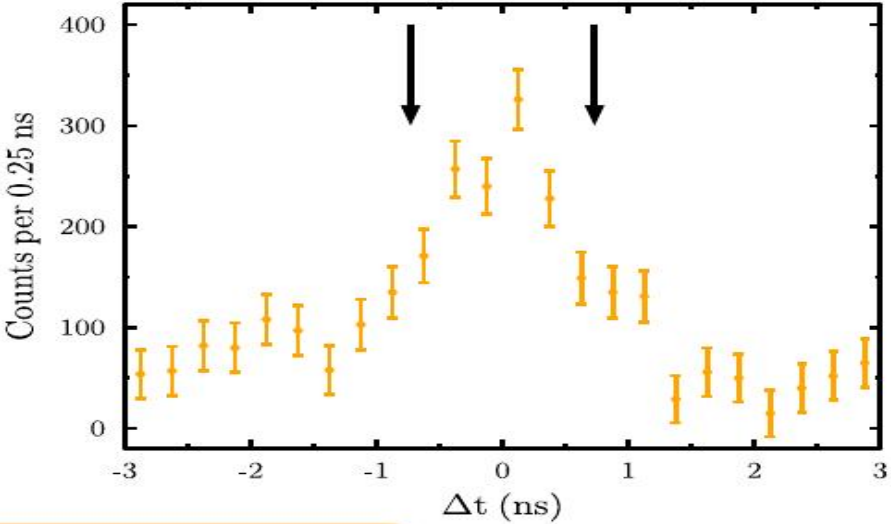




Critical analysis (2)





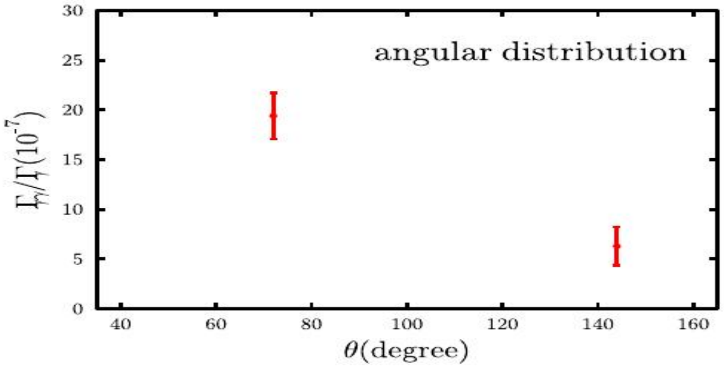
Shape of the time spectrum proofs that Compton scattering is not the origin of the peak at 662 keV

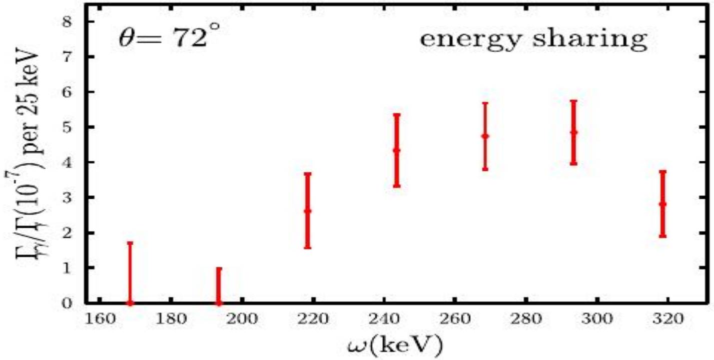
Outline

- Double-gamma - decay
- Experiment
- Data analysis & results
  - First $\gamma\gamma/\gamma$ - branching ratio
  - **Multipole analysis**
- Summary

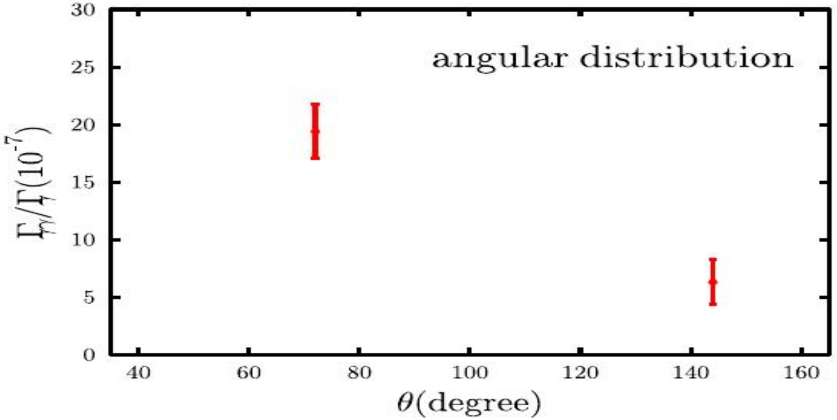
Objectives

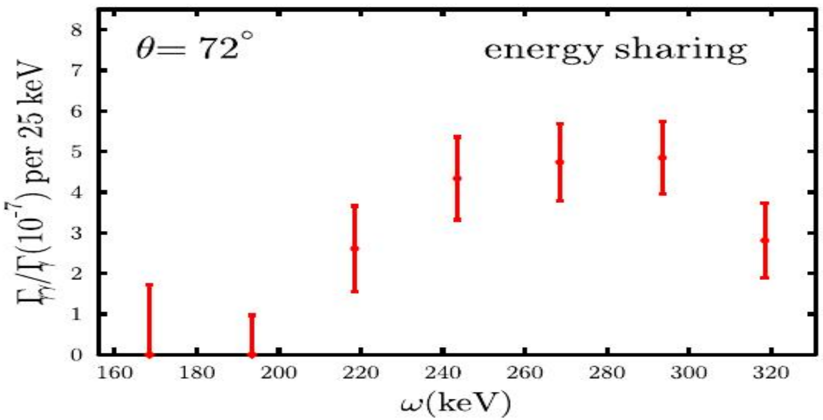
- Observation of the "competitive double-gamma decay" ✓
- Measurement of the energy sharing and angular distributions ✓
- Determination of the multipole order and radiation character
- Determination of $\Gamma_{\gamma\gamma}/\Gamma_\gamma$:
  $\Gamma_{\gamma\gamma}/\Gamma_\gamma(\theta) = \Gamma_{\gamma\gamma}/\Gamma_\gamma \cdot W(\theta)$





Results





$$\frac{d\Gamma^2_{\gamma\gamma}}{d\omega d\cos\theta} = A_{qq}(\alpha^2_{M2E2}) + A_{od}(\alpha^2_{E3M1}) + A_x(\alpha_{M2E2} \cdot \alpha_{E3M1})$$

- Assumption: Only α_{M2E2} and α_{E3M1} contribute
- A_{qq}, A_{od} and A_x exhibit characteristic dependence on ω and θ
- fit both distributions simultaneously to determine α_{M2E2} and α_{E3M1}

Summary

- Observation of the competetive double-gamma decay
- Measurement of the energy sharing and angular distributions

- Branching ratio: $\Gamma_{\gamma\gamma}/\Gamma_{\gamma} = 2.1(3) \cdot 10^{-6}$ (in ^{137}Ba)
- Determination of the matrix elements a_{E2M2} and a_{E3M1}
- M2E2-decay paths through $7/2^{+}$ states dominate

- Formally similar to E1 polarizability / $0\nu\beta\beta$ - NME
- Related to Symmetry Parameter of Nuclear EoS ?
- Access to aspects of NME for $0\nu\beta\beta$ - decay ?